

## Novel pyrazolo[1,5-a]pyrimidines as translocator protein 18 kDa (TSPO) ligands: Synthesis, in vitro biological evaluation, [F]-labelling and in vivo neuroinflammation PET images.

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3 **Novel pyrazolo[1,5-a]pyrimidines as translocator protein 18 kDa (TSPO)**  
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6 **ligands: Synthesis, *in vitro* biological evaluation, [<sup>18</sup>F]-labelling and *in***  
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9 ***vivo* neuroinflammation PET images.**  
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35 **■ ABSTRACT**  
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38 A series of novel pyrazolo[1,5-a]pyrimidines, closely related to *N,N*-diethyl-2-(2-(4-(2-  
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40 fluoroethoxy)phenyl)-5,7-dimethylpyrazolo[1,5-a]pyrimidin-3-yl)acetamide (**2**, DPA-714), were  
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42 synthesised and biologically *in vitro* evaluated for their potential to bind the translocator protein 18  
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44 kDa (TSPO), a protein today recognized as an early biomarker of neuroinflammatory processes. This  
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46 series is composed of fluoroalkyl- and fluoroalkynyl- analogues, prepared from a common iodinated  
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48 intermediate *via* Sonogashira coupling reactions. All derivatives displayed subnanomolar affinity for  
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50 the TSPO (0.37 to 0.86 nM), comparable to that of **2** (0.91 nM). Two of them were radiolabelled with  
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52 fluorine-18 and their biodistribution was investigated by *in vitro* autoradiography and positron  
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54 emission tomography (PET) imaging on a rodent model of neuroinflammation. Brain uptake and  
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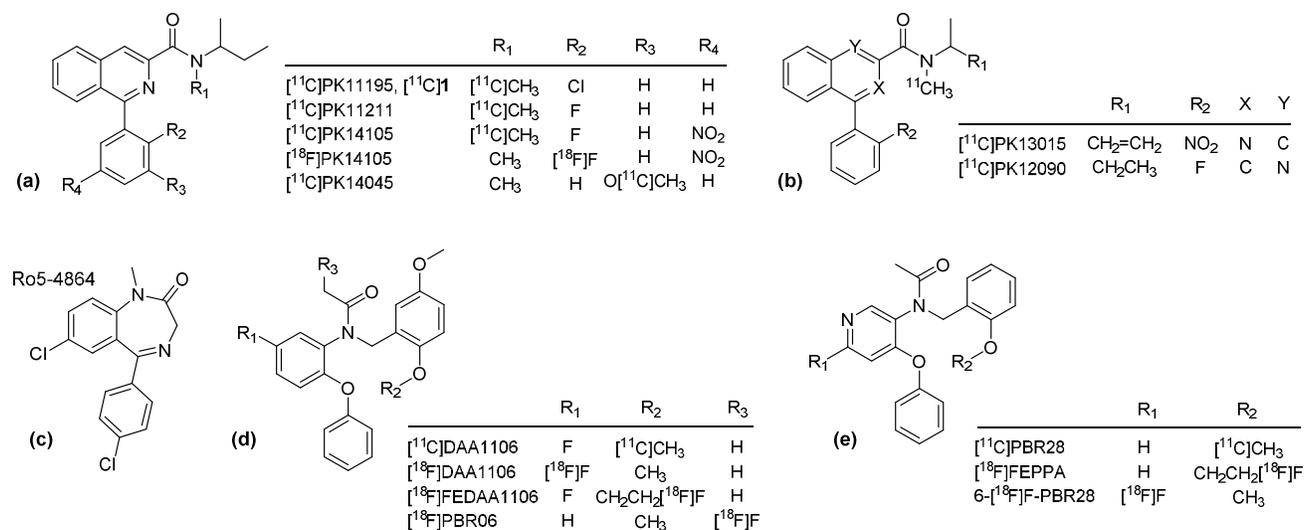
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3 local accumulation of both compounds in the AMPA-mediated lesion confirm their potential as *in*  
4 *vivo* PET-radiotracers. In particular, [<sup>18</sup>F]**23** exhibited a significantly higher ipsi- to contralateral ratio  
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6 at 60 minutes than the parent molecule [<sup>18</sup>F]**2** *in vivo*.  
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## 10 11 12 ■ INTRODUCTION

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14 Nearly all brain diseases reveal pronounced changes in the functional states of glial cells and most  
15 prominent is the presence of activated microglia in areas of progressive disease or tissue destruction.  
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17 Microglia activation is characterized by the overexpression of the translocator protein 18 kDa  
18 (TSPO) on the outer mitochondrial membranes, supporting for over two decades considerable efforts  
19 in the design of radioligands for the *in vivo* imaging of this pharmacological target by Positron  
20 Emission Tomography (PET).<sup>1</sup>  
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24 Today, the isoquinoline carboxamide [<sup>11</sup>C]**1** ([<sup>11</sup>C]PK11195<sup>1</sup>) is still the most widely used PET-  
25 radioligand to localise TSPO and visualise its expression level changes *in vivo*. Nevertheless the non-  
26 optimal profile of this radioligand, especially with regard to the high level of non-specific binding  
27 resulting in a poor signal to noise ratio obtained *in vivo* during PET studies, encourage the search for  
28 more adequate radioligands. Few analogues of **1** labelled with a short-lived isotope have been  
29 described so far, among which [<sup>11</sup>C]PK11211<sup>2</sup>, [<sup>11</sup>C]PK14105<sup>2</sup> and [<sup>18</sup>F]PK14105<sup>2</sup> or more recently  
30 [<sup>11</sup>C]PK13015<sup>3</sup>, [<sup>11</sup>C]PK12090<sup>3</sup> and [<sup>11</sup>C]PK14045<sup>3</sup> (Figure 1). SAR studies are still on-going to  
31 identify new lead TSPO ligands derived from **1** such as 4-phenylquinazoline-2-carboxamides<sup>4,5</sup> or  
32 derivatives featuring a 2-arylquinoline scaffold.<sup>6</sup> Besides these analogues of **1**, a number of new  
33 compounds, belonging to various chemical families, have also been prepared and investigated as  
34 TSPO ligands. Among them, some have been labelled (usually on the basis of their promising *in vitro*  
35 profiles) either with carbon-11 (T<sub>1/2</sub> = 20.4 min.) or with the longer half-life isotope fluorine-18 (T<sub>1/2</sub>  
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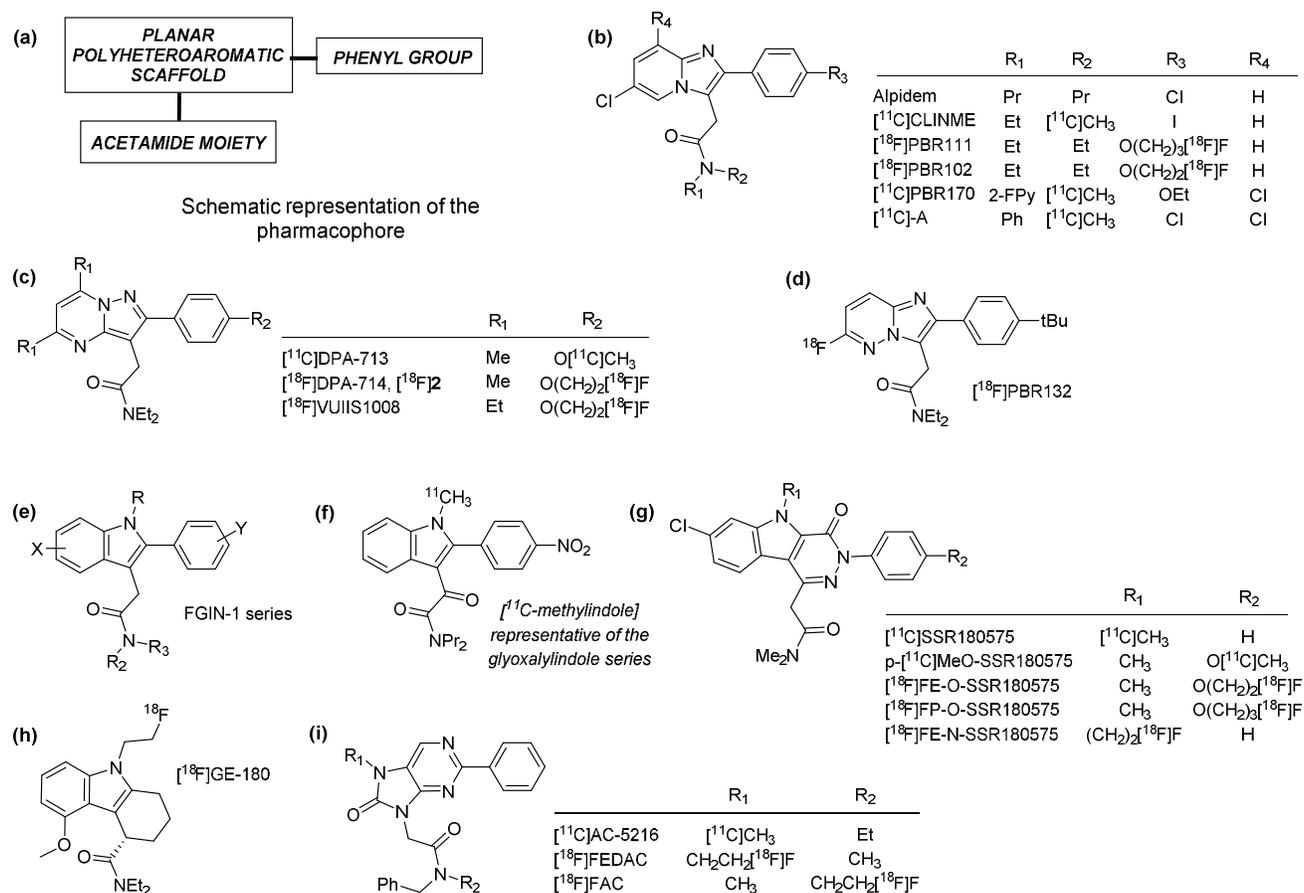
= 109.8 min.), and *in vivo* evaluated. The early discovery of the benzodiazepine Ro5-4864,<sup>7,8</sup> a chlorinated analogue of diazepam, as high affinity TSPO ligand and its carbon-11-labelling in 1984,<sup>9</sup> have encouraged the development of a series of compounds of which structures result from the cleavage of the diazepine ring, giving rise to the phenoxyarylacetamides family. [<sup>11</sup>C]DAA1106<sup>10-12</sup> was the first carbon-11-labelled representative of this series to emerge because of its subnanomolar binding affinity and selectivity for the TSPO. Its initial development was concomitant with the synthesis of two fluorine-18-analogues, [<sup>18</sup>F]FMDAA1106<sup>13</sup> and [<sup>18</sup>F]FEDAA1106,<sup>13</sup> which was rapidly followed by the preparation of [<sup>18</sup>F]PBR06<sup>14,15</sup> in 2005 and [<sup>18</sup>F]DAA1106<sup>16</sup> in 2007. So far, other closely related compounds have appeared in the literature for their high potential to *in vivo* PET-image the TSPO. For examples, [<sup>11</sup>C]PBR28,<sup>17,18</sup> a carbon-11-labelled phenoxyphenylacetamide, was proposed by Briard *et al.*, followed by two radiofluorinated analogues: [<sup>18</sup>F]FEPPA<sup>19</sup>, and more recently 6-[<sup>18</sup>F]F-PBR28.<sup>20</sup>



**Figure 1.** Representative examples of TSPO ligands belonging to the following families: (a) isoquinolines, including [<sup>11</sup>C]1, (b) other analogues of 1, (c) a benzodiazepine, (d) phenoxyphenylacetamides and (e) phenoxyphenylacetamides.

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3 Besides these derivatives inspired from **1** or benzodiazepines, TSPO PET imaging has encouraged  
4 the design of many other radioligands that share a number of common structural characteristics and  
5 can be grouped together around the schematic architectural representation proposed in Figure 2 (a).  
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8 Indeed, they exhibit a multicyclic heteroaromatic planar skeleton as central molecular core and have  
9 the particularity to commonly feature an acetamide function, linked to the heteroaromatic backbone,  
10 whose presence seems to be a requirement for efficient binding with the protein.<sup>21</sup> It is also  
11 interesting to note that most of these molecules display an aromatic ring directly attached to their  
12 planar scaffold. The first radiolabelled molecules of this kind were inspired from the structure of the  
13 imidazopyridine alpidem that binds both peripheral (TSPO) and central (CBR) benzodiazepine  
14 receptors. Within this series, [<sup>11</sup>C]CLINME<sup>22</sup>, [<sup>11</sup>C]PBR170<sup>23-26</sup> and [<sup>11</sup>C]-A<sup>27</sup> are carbon-11-labelled  
15 representative examples while [<sup>18</sup>F]PBR111<sup>28,29</sup> and [<sup>18</sup>F]PBR102<sup>28,29</sup> are fluorine-18-labelled  
16 specimens. Beside imidazopyridine acetamides, a number of bioisosteric structures have also been  
17 explored as potential scaffolds allowing specific and efficient binding to the TSPO, such as  
18 pyrazolopyrimidine or imidazopyridazine acetamides. The carbon-11-labelled compound [<sup>11</sup>C]DPA-  
19 713<sup>30-35</sup> and the fluorine-18 close analogues [<sup>18</sup>F]**2** ([<sup>18</sup>F]DPA-714)<sup>36-39</sup> and [<sup>18</sup>F]VUIIS1008<sup>40,41</sup> are  
20 illustrations of TSPO imaging agents belonging to the pyrazolopyrimidine acetamides family,  
21 whereas [<sup>18</sup>F]PBR132<sup>42</sup> is an example of imidazopyridazine acetamide radioligand. A number of 2-  
22 aryl-indole-3-acetamide derivatives, also known as FGIN-1 class compounds<sup>43</sup>, were screened  
23 against TSPO and were shown to display high affinity and selectivity. Recently, conformationally  
24 constrained versions of this series of molecules have been explored as novel TSPO ligands and one  
25 of them has been labelled at its methylindole moiety (Figure 2).<sup>44</sup> In this series, compounds feature a  
26 glyoxylamide moiety in replacement of the acetamide motif rendering the structures less flexible in  
27 hopes of increased affinity and selectivity toward the TSPO. Other closely related structures,  
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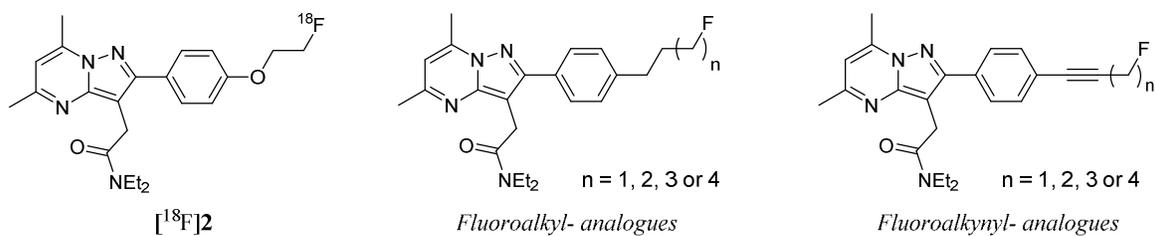
resulting from the fusion of the indole moiety with a pyridazine ring, have been proposed as potential probes to image TSPO expression. [ $^{11}\text{C}$ ]SSR180575<sup>45</sup> is a carbon-11-labelled illustration of this phenyl-pyridazinoindole acetamide family. Another indoleacetamide, [ $^{18}\text{F}$ ]GE-180<sup>46</sup>, bearing a labelling at the *N*-indole position has recently been reported. Unlike the other previously mentioned radioligands, it does not share the particularity of featuring a freely rotating aryl group linked to the main heteroaromatic core of the molecule and was conformationally constrained by cyclisation via an  $\alpha$ -branching of the acetamide part. Finally, a number of 2-aryl-8-oxodihydropurine acetamides have also been radiolabelled and evaluated for their potential to selectively image the TSPO expression. [ $^{11}\text{C}$ ]AC-5216,<sup>47</sup> [ $^{18}\text{F}$ ]FEDAC<sup>48</sup> and [ $^{18}\text{F}$ ]FAC<sup>48</sup> are representative examples belonging to the latter series.



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3 **Figure 2.** (a) Schematic representation of a number of TSPO ligands and some representative  
4 examples belonging to the following families: (b) 2-aryl-imidazo[1,2-a]pyridine-3-acetamides, (c) 2-  
5 aryl-pyrazolo[1,5-a]pyrimidine-3-acetamides, (d) 2-aryl-imidazo[1,2-b]pyridazine-3-acetamides, (e)  
6 aryl-pyrazolo[1,5-a]pyrimidine-3-acetamides, (d) 2-aryl-imidazo[1,2-b]pyridazine-3-acetamides, (e)  
7 2-aryl-indole-3-acetamides, (f) 2-aryl-indole-3-glyoxylamides, (g) 3-aryl-pyridazino[4,5-b]indole-5-  
8 acetamides, (h)  $\alpha$ -branched-indole acetamides and (i) 2-(8-oxo-2-aryl-dihydropurine) acetamides.  
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17 Among all these series of compounds, we have been particularly interested in the design of novel 3,5-  
18 dimethylpyrazolo[1,5-*a*]pyrimidin-3-ylacetamide (DPA) specimens, leading to the discovery of the  
19 fluoroethoxy derivative [ $^{18}\text{F}$ ]**2**,<sup>38-39</sup> today considered as a serious challenger of [ $^{11}\text{C}$ ]**1**. However,  
20 recent studies clearly demonstrate that this compound is rapidly and extensively *in vivo* metabolised  
21 in both rodents (rats) and non-human primates (baboons).<sup>49</sup> The major radiometabolites generated  
22 have been identified: they mainly result from oxidation at the sensitive methyl groups of the DPA  
23 scaffold or oxidation at the alpha-position of the nitrogen atom of the acetamide moiety leading to *N*-  
24 deethylated metabolites. These metabolites have been proved not to cross the human BBB.  
25 Nevertheless and in a lesser extent, the brain-penetrant radiometabolite [ $^{18}\text{F}$ ]fluoroacetate has also  
26 been shown to be liberated.<sup>49</sup> Indeed, [ $^{18}\text{F}$ ]**2** is also subjected to oxidation at the alpha-position of the  
27 oxygen bridging the fluorine-18 atom to the DPA scaffold (ether linkage). The presence of  
28 [ $^{18}\text{F}$ ]fluoroacetate as well as its further *in vivo* conversion to [ $^{18}\text{F}$ ]fluoride may reduce the PET image  
29 quality. Thus, within the present work, novel DPA analogues were designed by replacing the ether  
30 linkage of **2** with fragments preventing metabolic fluoroacetate release. Two sub-series of  
31 compounds were prepared: four fluoroalkyl- and four fluoroalkynyl- derivatives of **2**. Their TSPO  
32 binding and selectivity versus the CBR were evaluated *in vitro* as well as their lipophilicity. *In vitro*  
33 metabolism studies were also performed, using human, rat and mouse microsomes. Based on the *in*  
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*in vitro* data obtained, two representatives, one in each sub-class of analogues, were selected for radiolabelling with fluorine-18 to evaluate their potency as TSPO radiotracers in animal models.



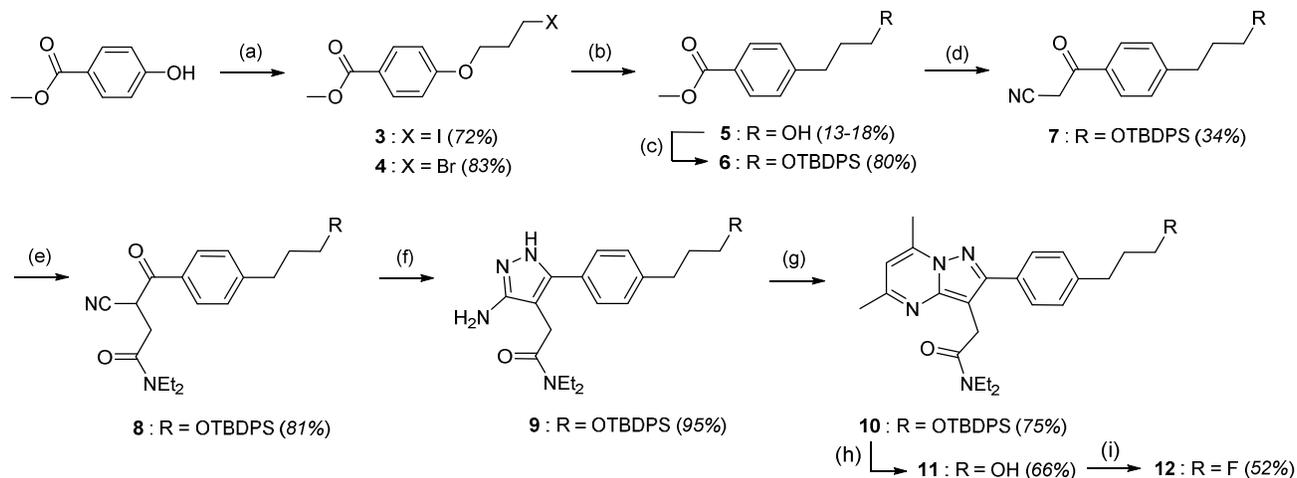
**Figure 3.** Structures of  $[^{18}\text{F}]\mathbf{2}$  and the investigated new fluoroalkyl- and fluoroalkynyl- analogues.

## ■ RESULTS AND DISCUSSION

**Chemistry.** Compound **12**, the structurally closest analogue of **2** in the fluoroalkyl series, featuring a methylene group in replacement of the oxygen atom, was the first candidate of the new series to be prepared. The initial synthetic route employed for its preparation is depicted on scheme 1. From commercially available methyl 4-hydroxybenzoate, the iodopropoxy or bromopropoxy derivatives **3** and **4** were obtained in good yields (72 and 83 % respectively) by *O*-alkylation with the appropriate 1,3-dihalopropane in presence of a base in acetone. They were subsequently converted to methyl 4-(3-hydroxypropyl)benzoate (**5**) *via* aryl translocation from oxygen to carbon using standard radical generating conditions (13-18 %).<sup>50</sup> The resulting alcohol **5** was subsequently protected with *tert*-butyldiphenylsilyl chloride (TBDPSCl) to give compound **6** (80 % yield). Reaction of **6** with sodium methoxide in refluxing acetonitrile yielded nitrile **7** which was alkylated with *N,N*-diethylchloroacetamide to afford amide **8** in sufficient amount (28 % over 2 steps). A first condensation reaction was conducted between **8** and hydrazine hydrochloride to afford the aminopyrazole **9** in excellent yield (95 %). The latter compound was subsequently submitted to a second condensation step using pentan-2,4-dione to achieve the construction of the DPA scaffold and generate the pyrazolo[1,5-*a*]pyrimidine **10** (75 % yield) to which hydroxyl group was subsequently

unprotected with tetrabutylammonium fluoride in THF to afford **11** (66 % yield). Finally, alcohol **11** was treated with the deoxofluorinating agent bis(2-methoxyethyl)aminosulfur trifluoride in toluene at room temperature to afford compound **12** in 52 % yield.

### Scheme 1. First synthetic pathway explored for the preparation of compound **12**<sup>a</sup>.

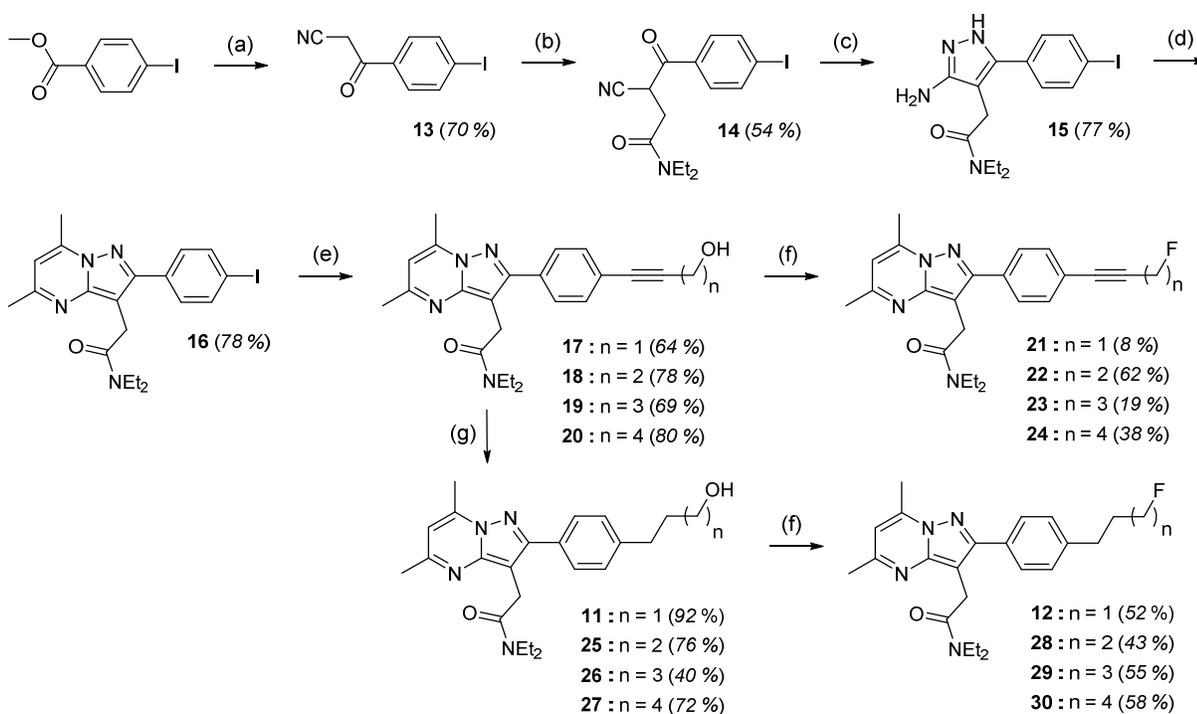


<sup>a</sup>Reaction conditions: (a) 1,3-diiodopropane or 1,3-dibromopropane,  $K_2CO_3$ , acetone, 50 °C, 16 h; (b)  $Bu_3SnH$ , AIBN, toluene, reflux, 12 h; (c) TBDPSCl, pyridine, r.t., 4 h; (d) NaOMe,  $CH_3CN$ , reflux, 4 h; (e) *N,N*-diethyl-chloroacetamide, NaOH, EtOH,  $H_2O$ , 75 °C, 12 h; (f)  $NH_2NH_2 \cdot H_2O$ , AcOH, EtOH, 60 °C, 3 h; (g) pentan-2,4-dione, EtOH, 60 °C, 16 h; (h) TBAF, THF, r.t., 8 h; (i) bis(2-methoxyethyl)aminosulfur trifluoride, toluene, r.t., 6 h.

Afterwards, a more general synthetic method was developed for the preparation of the fluoroalkyl- and fluoroalkynyl- analogues of **2**, *via* a common iodophenyl intermediate (compound **16**), as depicted in scheme 2. This alternative pathway was also reused for the preparation of **12** at a higher scale stimulated by the need to increase its global yield of production due to the very low yield of the translocation reaction (13 to 18 %). Thus, obtainment of cyanoketone **13** was achieved *via* formation of the lithium salt of acetonitrile by treatment with *n*-BuLi in THF at -60 °C followed by reaction

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3 with commercial methyl 4-iodobenzoate at -45 °C (70 % yield). Subsequent alkylation of **13** with  
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5 *N,N*-diethylchloroacetamide in presence of sodium hydroxide and sodium iodide in ethanol yielded  
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7 amide **14** (54 % yield) which, upon reaction with hydrazine monohydrate in refluxing ethanol with a  
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9 catalytic amount of acetic acid, afforded aminopyrazole **15** in 77 % yield. Pyrazolo[1,5-*a*]pyrimidine  
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11 **16** was efficiently obtained (78 % yield) by reacting **15** with pentan-2,4-dione in refluxing ethanol.  
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13 Sonogashira coupling of **16** with the appropriate alkynol using Pd(PPh<sub>3</sub>)<sub>2</sub>Cl<sub>2</sub> and CuI in triethylamine  
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15 afforded the expected hydroxyalkynylphenyl compounds **17**, **18**, **19** and **20** in good yields (64 %, 78  
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17 %, 69 % and 80 % respectively). Alcohols **17**, **18**, **19** and **20** were then reacted with bis(2-  
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19 methoxyethyl)aminosulfur trifluoride in dichloromethane to generate the corresponding fluorine  
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21 derivatives **21**, **22**, **23** and **24** (8 to 62 % yields). They were also hydrogenated in methanol in  
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23 presence of Pd/C for reduction of the triple bond to lead to their hydroxyalkylphenyl counterparts **11**,  
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25 **25**, **26** and **27** respectively (40 to 92% yields). It is worth noting that compound **21** was not easily  
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27 accessible using this strategy since reaction of bis(2-methoxyethyl)aminosulfur trifluoride with the  
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29 propargylic alcohol **17** led to side products difficult to separate from the expected fluoropropynyl  
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31 analogue **21**. Finally, in the alkyl- series, alcohols **11**, **25**, **26** and **27** were converted to their  
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33 fluorinated counterparts by deoxofluorination in dichloromethane to give fluoropropyl-compound **12**,  
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35 fluorobutyl-compound **28**, fluoropentyl-compound **29** and fluoroethyl-compound **30** in moderate  
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37 yields (43 to 58 %).  
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48 **Scheme 2. Synthetic preparation of fluoroalkynyl- (21-24) and fluoroalkyl- (12, 28-30)**  
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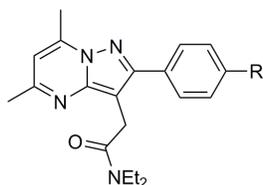


<sup>a</sup>Reaction conditions: (a) *n*-BuLi, CH<sub>3</sub>CN, THF, -65 °C, 30 min then methyl 4-iodobenzoate, -65 °C to -45 °C, 2 h; (b) NaOH, EtOH, r.t., 15 min then *N,N*-diethyl-chloroacetamide, NaI, r.t., 4 d.; (c) N<sub>2</sub>H<sub>4</sub>·H<sub>2</sub>O, AcOH, EtOH, 80 °C, 5-8 h; (d) acetylacetone, EtOH, 80 °C, 5 h; (e) alkynyl alcohol, CuI, Pd(PPh<sub>3</sub>)<sub>2</sub>Cl<sub>2</sub>, Et<sub>2</sub>NH, r.t., 24 h; (f) bis(2-methoxyethyl)aminosulfur trifluoride, CH<sub>2</sub>Cl<sub>2</sub>, r.t., 2-4 d.; (g) H<sub>2</sub>, Pd/C 10 %, CH<sub>2</sub>Cl<sub>2</sub>, r.t., 48 h.

***In vitro* binding assays.** The binding affinity for the TSPO of these novel analogues of **2** were measured by competition experiments against [<sup>3</sup>H]**1** in membrane homogenates of rat heart. The binding affinity of the newly synthesised compounds were also evaluated for the CBR by competitive binding assays against [<sup>3</sup>H]flunitrazepam using membrane homogenates of rat cerebral cortex. The inhibition constants (K<sub>i</sub><sub>TSPO</sub>) and percentage of inhibition at 1 μM (CBR) were determined for each ligand and are reported in Table 1. The lipophilicity parameter LogD<sub>7.4</sub> was also evaluated for this

new series of compounds on the basis of their HPLC retention times and the corresponding lipophilic efficiencies (LipE) were calculated.<sup>51</sup> Data are summarized in Table 1.

**Table 1. *In vitro* competitive binding assays, lipophilicity determination and LipE calculation.**

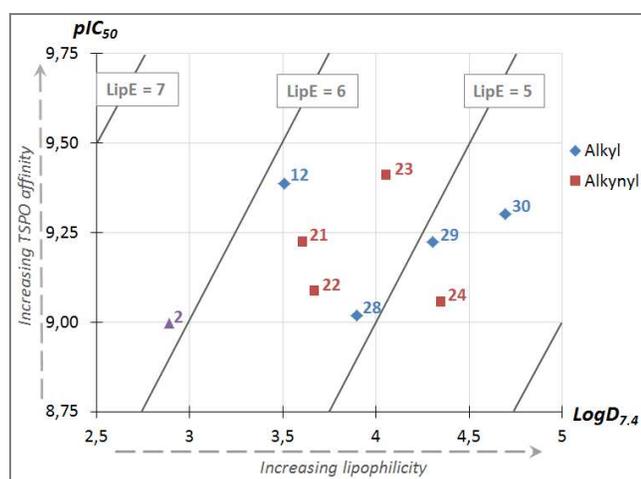


Series	Ligand	R	TSPO $K_i$ (nM) <sup>a,b</sup>	CBR % <i>inhib.</i> at 1 $\mu$ M <sup>c</sup>	LogD <sub>7.4</sub> <sup>d</sup>	TSPO pIC <sub>50</sub>	LipE <sup>e</sup>
	<b>2</b>	O-(CH <sub>2</sub> ) <sub>2</sub> -F	0.91 ± 0.08	0 %	2.89	9.00	6.11
Alkyl-	{ <b>12</b> <b>28</b> <b>29</b> <b>30</b>	(CH <sub>2</sub> ) <sub>3</sub> -F	0.37 ± 0.02	0 %	3.51	9.39	5.88
		(CH <sub>2</sub> ) <sub>4</sub> -F	0.86 ± 0.06	0 %	3.90	9.02	5.12
		(CH <sub>2</sub> ) <sub>5</sub> -F	0.54 ± 0.03	3 %	4.31	9.22	4.91
		(CH <sub>2</sub> ) <sub>6</sub> -F	0.45 ± 0.03	12 %	4.70	9.30	4.60
Alkynyl-	{ <b>21</b> <b>22</b> <b>23</b> <b>24</b>	C≡C-CH <sub>2</sub> -F	0.54 ± 0.04	0 %	3.61	9.22	5.61
		C≡C-(CH <sub>2</sub> ) <sub>2</sub> -F	0.74 ± 0.06	0 %	3.67	9.09	5.42
		C≡C-(CH <sub>2</sub> ) <sub>3</sub> -F	0.35 ± 0.04	0 %	4.06	9.41	5.35
		C≡C-(CH <sub>2</sub> ) <sub>4</sub> -F	0.79 ± 0.09	0 %	4.35	9.06	4.71

<sup>a</sup>TSPO  $K_i$  values were determined using membrane homogenates of rat heart and screened against [<sup>3</sup>H]**1** ( $K_d = 1.8$  nM,  $C = 0.2$  nM). <sup>b</sup>*In vitro* binding affinity values are the mean ± SE of duplicate measurements. <sup>c</sup>CBR binding affinity was evaluated using homogenates of rat cerebral cortex and expressed as % of inhibition at 1  $\mu$ M against [<sup>3</sup>H]flunitrazepam. <sup>d</sup>Retention time recorded for the tested compounds were converted into their logD<sub>7.4</sub> values using a validated, standardized HPLC method. <sup>e</sup>LipE values were calculated as follows : LipE = pIC<sub>50</sub> – LogD<sub>7.4</sub>.

All analogues displayed subnanomolar affinity for the TSPO (0.37 to 0.86 nM), comparable to **2** (0.91 nM). In the fluoroalkyl series, the lowest  $K_i$  value was obtained for compound **12** (0.37 nM) whereas in the alkynyl series, it was found for compound **23** (0.35 nM). Additionally, all compounds showed excellent selectivity towards TSPO, except compounds **29** and **30** that both exhibited a slight

binding affinity for the CBR (3 and 12 % at 1  $\mu$ M, respectively). The  $\text{LogD}_{7.4}$  values were all higher (3.51 – 4.70) than that of **2** (2.89), most likely due to the replacement of the oxygen atom attached to the phenyl ring, with alkyl- or alkynyl- fragments leading to less hydrophilic structures. These  $\text{LogD}_{7.4}$  values followed the expected trend of increase with the length of the carbonated side-chain in both series. Nevertheless, most of the  $\text{LogD}_{7.4}$  values keep in the range for expected good passive cerebral penetration of the ligands. Calculated LipE scores ranged from 4.60 (compound **30**) to 6.11 (compound **2**). The highest LipE score was obtained with **2** and is due to the combination of a subnanomolar affinity for the TSPO and a rather low  $\text{logD}_{7.4}$  value slightly inferior to 3. Compound **12** also displays a high LipE score of 5.88, while the lengthening of the side chain, especially in the fluoroalkyl- series, resulted in a drop of LipE values below 5 for compounds **29**, **30** and **24**. In the fluoroalkynyl- series, except for compound **24**, LipE values were all comparable (5.35 to 5.61). In particular, despite a  $\text{LogD}_{7.4}$  value above 4 (4.06), compound **23** exhibited a rather good LipE score (5.35) due to a high TSPO binding affinity. A LipE plot of the binding and lipophilicity data of the compounds is presented in Figure 4.



**Figure 4.** LipE plot of the newly synthesised compounds (**12**, **21–24**, **28–30**) and **2**:  $\text{pIC}_{50}$  vs  $\text{LogD}_{7.4}$ .

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6 ***In vitro* metabolism.** Oxidative metabolism of **2** and the newly synthesised compounds (**12**, **21-24**  
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8 and **28-30**) was investigated using hepatic microsomes from human, rat and mouse. The results,  
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10 expressed as the percentage of biotransformation obtained after 20 minutes of microsomal  
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12 incubation, are summarised in Table 2. All compounds are rapidly and extensively metabolised in  
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14 presence of rat and mouse microsomes, more than 90 % of biotransformation is generally observed  
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16 after 20 minutes. Biotransformation using human microsomes is more variable, with percentage  
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18 ranging from 31 % for **2** to 91 % for compound **29**. It can be noted that alkynyl derivatives are less  
19  
20 metabolised compared to their alkyl counterparts. These rather pronounced rates of biotransformation  
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22 are in line with what has already been observed with the parent molecule [<sup>18</sup>F]**2**:<sup>49</sup> indeed, it has been  
23  
24 shown that it is rapidly and extensively metabolised *in vitro* but also *in vivo* in both rodents (rats) and  
25  
26 non-human primates (baboons). Identification of the metabolites of **2** and [<sup>18</sup>F]**2**<sup>49</sup> notably revealed  
27  
28 that oxidation reactions occurred mainly (i) at the sensitive methyl positions of the pyrazolo[1,5-  
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30 *a*]pyrimidine core, (ii) at the alpha-position of the nitrogen atom of the acetamide function leading to  
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32 *N*-dealkylation and, in a lesser extent, (iii) at the alpha position of the oxygen atom of the  
33  
34 fluoroethoxy moiety of **2** leading to the release of fluoroacetate. These oxidative pathways generated  
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36 hydrophilic species, mainly non-brain penetrant except for [<sup>18</sup>F]fluoroacetate that cross the BBB and  
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38 might alter the PET image quality. Contrary to **2**, the newly synthesised compounds (**12**, **21-24** and  
39  
40 **28-30**) don't feature the sensitive ether linkage bridging the fluorine atom to the DPA scaffold and  
41  
42 therefore their metabolism may not lead to the unwanted liberation of fluoroacetate. Nevertheless,  
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44 they still feature the same DPA scaffold and may thus be subjected to a similar oxidative metabolic  
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46 pathway with regard to oxidation at the methyl positions and *N*-deethylation (or a combination of  
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48 both). Overall, this *in vitro* study suggests that **2**, **23** and **24** are the less sensitive compounds to  
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microsomal metabolism, especially with the human subcellular fractions (biotransformation at 20 min < 50 %). And, more specifically, in the fluoroalkyl series, **12** is the less metabolised compound using human microsomes with 79 % biotransformation at 20 minutes compared to 90 ± 1 % for **28**, **29** and **30**.

**Table 2. *In vitro* oxidative metabolism.**

Series	Ligand	% biotransformation at 20 min <sup>a</sup>		
		Human	Rat	Mouse
Alkyl-	<b>2</b>	31 %	100 %	90 %
	<b>12</b>	79 %	100 %	99 %
	<b>28</b>	89 %	99 %	100 %
	<b>29</b>	91 %	99 %	100 %
	<b>30</b>	89 %	97 %	96 %
Alkynyl-	<b>21</b>	55 %	99 %	100 %
	<b>22</b>	60 %	98 %	100 %
	<b>23</b>	47 %	91 %	98 %
	<b>24</b>	39 %	96 %	78 %

<sup>a</sup>hepatic microsomal (male CD1 mouse, male Sprague-Dawley rat or humans (BD pool)) incubation, followed by analysis of the supernatant using HPLC/ESI-MS/MS.

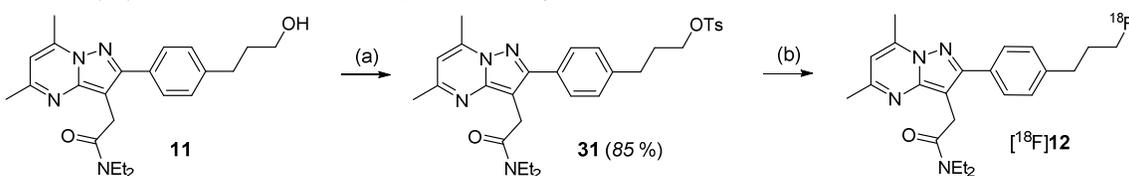
On the basis of the *in vitro* preliminary results (affinity, lipophilicity and metabolism) of the newly synthesised compounds: **12**, in the fluoroalkyl series, and **23**, in the fluoroalkynyl series, were chosen for radiolabelling with fluorine-18 to further investigate their *in vivo* PET properties as TSPO radiotracers.

**Radiochemistry.** Fluorine-18-labelling of compounds **12** and **23** was performed using a TRACERLab FX-FN synthesiser (GEMS) by nucleophilic aliphatic substitution on their corresponding tosylates **31** and **32** (precursors for labelling) with [<sup>18</sup>F]fluoride (Scheme 3).

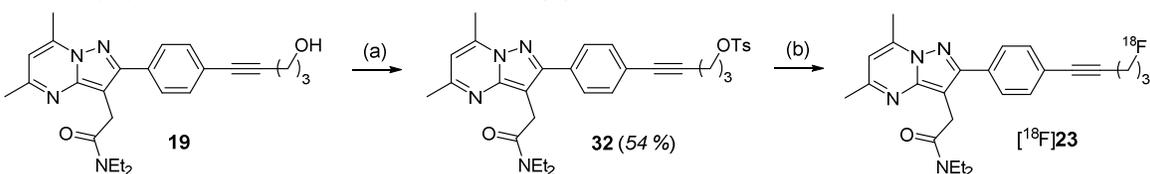
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3 Compounds **31** and **32** were synthesised from the corresponding alcohols **11** and **19** by reaction of *p*-  
4 toluenesulfonylchloride or *p*-toluenesulfonylanhydride in dichloromethane in presence of  
5 triethylamine as depicted in Scheme 3 (85 and 45 % yield, respectively). The efficiency of  
6 incorporation of fluorine-18 was first investigated with compound **12** in various reaction conditions  
7 and the optimized conditions were then used for the labelling of compound **23** (Table 2). Briefly, the  
8 no-carrier-added dried K[<sup>18</sup>F]F-[2.2.2]-cryptand complex was first prepared from cyclotron-produced  
9 [<sup>18</sup>F]fluoride, potassium carbonate and [2.2.2]-cryptand. An acetonitrile or DMSO solution of the  
10 tosylate **31** (or **32**) was then added to the reaction vessel containing K[<sup>18</sup>F]F-[2.2.2]-cryptand and the  
11 resulting mixture was heated at various temperature and for variable duration. The resulting mixture  
12 was then diluted with the HPLC mobile phase, pre-purified on a SepPak<sup>®</sup> Alumina N<sup>™</sup> cartridge and  
13 purified on an HPLC semi-preparative X-Terra<sup>™</sup> RP18 column. Identity of the collected radioactive  
14 product was confirmed by co-elution with reference compound **12** (or **23**, respectively) on an  
15 analytical HPLC system. Formulated solutions of [<sup>18</sup>F]**12** (or [<sup>18</sup>F]**23**), ready for use, were typically  
16 obtained after a synthesis time of 50 ± 5 min from end of bombardment (EOB). Average batch  
17 product activities, radiochemical yields (RCY) and specific radioactivities (SRA) obtained from the  
18 various [<sup>18</sup>F]**12** radiosynthesis trials are compiled in Table 3.  
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**Scheme 3. Preparation of tosylates 31 and 32, and labelling of [<sup>18</sup>F]12 and [<sup>18</sup>F]23<sup>a</sup>.**

Precursor preparation and fluorine-18-labelling of **12** in the alkyl- series



Precursor preparation and fluorine-18-labelling of **23** in the alkynyl- series



<sup>a</sup>Reaction conditions: (a) TsCl or Ts<sub>2</sub>O, TEA, CH<sub>2</sub>Cl<sub>2</sub>, 0°C to r.t., 5 to 16 h; (b) K[<sup>18</sup>F]F-[2.2.2]-cryptand, K<sub>2</sub>CO<sub>3</sub>, solvent, T (°C), time (min) [see Table 3 for details].

**Table 3. Labelling conditions and results of radiosynthesis trials for [<sup>18</sup>F]12 and [<sup>18</sup>F]23 preparation.**

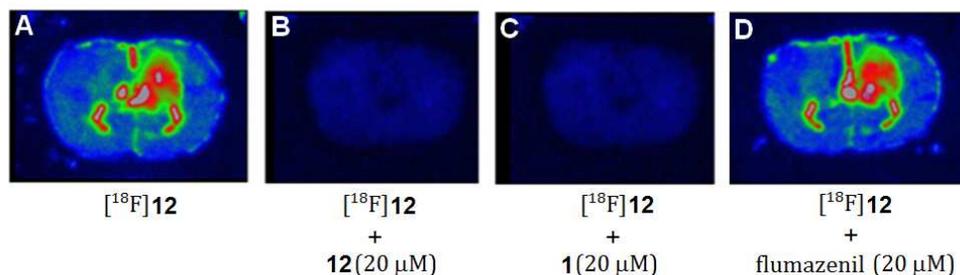
Precursor	Solvent	Temperature (°C)	Reaction time (min)	RCY <sup>a</sup> (d.c.)	SRA <sup>a</sup> (GBq/μmol)	Product
<b>31</b>	DMSO	165	5	38 ± 6	110 ± 5	[ <sup>18</sup> F]12
<b>31</b>	CH <sub>3</sub> CN	100	10	50 ± 11	75 ± 15	[ <sup>18</sup> F]12
<b>31</b>	CH <sub>3</sub> CN	100	5	37 ± 10	78 ± 14	[ <sup>18</sup> F]12
<b>32</b>	CH <sub>3</sub> CN	100	10	24 ± 7	83 ± 9	[ <sup>18</sup> F]23

<sup>a</sup>Values are the mean ± SD of at least 3 independent radiosyntheses

Typically, starting from 33–52 GBq of [<sup>18</sup>F]fluoride, 9–17 GBq of [<sup>18</sup>F]12 were obtained, within 50 ± 5 min, with moderate SRA ranging from 60 to 115 GBq/μmol at end of synthesis (EOS). [<sup>18</sup>F]Fluorination of **12** proved to be the most efficient in acetonitrile when heating the reaction mixture at 100°C for 10 minutes with an average decay-corrected (d.c.) RCY of 50 ± 11%. Attempts to reduce reaction time to 5 min or increase reaction temperature to 165°C in DMSO, led to a lower labelling efficacy with d.c. RCY below 40%. [<sup>18</sup>F]Fluoride incorporation for the preparation of [<sup>18</sup>F]23 was satisfactory using acetonitrile as solvent at 100°C for 10 min and these labelling

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3 conditions were used for the preparation of ready-to-inject [ $^{18}\text{F}$ ]**23** batches for *in vivo* studies. Quality  
4 controls were performed on aliquots of formulated radioligands [ $^{18}\text{F}$ ]**12** and [ $^{18}\text{F}$ ]**23**. The radiotracers  
5 preparations were clear solutions with a measured pH between 5 and 7. As demonstrated by  
6 analytical HPLC analysis, radiochemical and chemical purities were greater than 95 % and the  
7 preparations were chemically and radiochemically stable for four hours at ambient temperature on  
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20 **Autoradiography.** The high binding affinity and selectivity for TSPO of **12** and **23** were confirmed  
21 by *in vitro* autoradiography studies of their corresponding radiofluorinated-versions in sections of rat  
22 brain with acute local neuroinflammation. Rat brain slices were generated from our in-house model,  
23 seven days after an excitotoxic AMPA injection in the right striatum of Wistar rats.<sup>23,34,52</sup> In a first set  
24 of experiments, the radioligand was incubated alone and accumulation of the tracer was observed in  
25 the lesioned area (right-hand side) when compared to the control side (left-hand side) as seen on  
26 Figure 5A for [ $^{18}\text{F}$ ]**12**. In a second and third set of experiments the radioligand was incubated  
27 together with an excess of either its non-labelled version (**12** or **23**) or the TSPO ligand of reference  
28 **1**. Images obtained either with [ $^{18}\text{F}$ ]**12** (Figure 5B and 5C) or [ $^{18}\text{F}$ ]**23** (not shown here) proved the  
29 absence of non-specific binding of the ligands and the specificity for the TSPO target, the binding  
30 being fully inhibited in the lesioned area in both cases. Finally, in a fourth set of experiments, the  
31 evaluated radioligand was incubated with an excess of flumazenil, a CBR-specific ligand, to confirm  
32 its absence of affinity for this target. As shown on Figure 5D and as expected from the previous *in*  
33 *vitro* competition assays with [ $^3\text{H}$ ]flunitrazepam (another CBR-specific ligand), the binding of  
34 [ $^{18}\text{F}$ ]**12** was not affected by the presence of an excess of flumazenil, proving again its selectivity for  
35 the TSPO.  
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**Figure 5.** Autoradiography *in vitro* of [ $^{18}\text{F}$ ]12 (5-10 nM) on rat AMPA-lesioned brain sections : (A) alone, (B) with non-labelled 12 (20  $\mu\text{M}$ ), (C) with 1 (20  $\mu\text{M}$ ) and (D) with flumazenil (20  $\mu\text{M}$ ).

Autoradiographic images, obtained with [ $^{18}\text{F}$ ]23 as radioligand, were comparable to the one presented for [ $^{18}\text{F}$ ]12: [ $^{18}\text{F}$ ]23 accumulates in the lesioned area, and the use of 1 or non-labelled 23 fully inhibited the binding of [ $^{18}\text{F}$ ]23 while flumazenil did not. The target to background ratio (TBR), calculated as the bound radiotracer in the lesion versus the bound radiotracer in the contralateral side, was determined after incubation of the radiotracer alone and values obtained for [ $^{18}\text{F}$ ]12 and [ $^{18}\text{F}$ ]23 are presented in Table 4 for comparison to [ $^{18}\text{F}$ ]2. The TBR of [ $^{18}\text{F}$ ]12 ( $2.4 \pm 0.3$ ) and [ $^{18}\text{F}$ ]23 ( $1.9 \pm 0.3$ ) were surprisingly more than 50 % lower than the one of [ $^{18}\text{F}$ ]2 ( $5.4 \pm 2.0$ ).

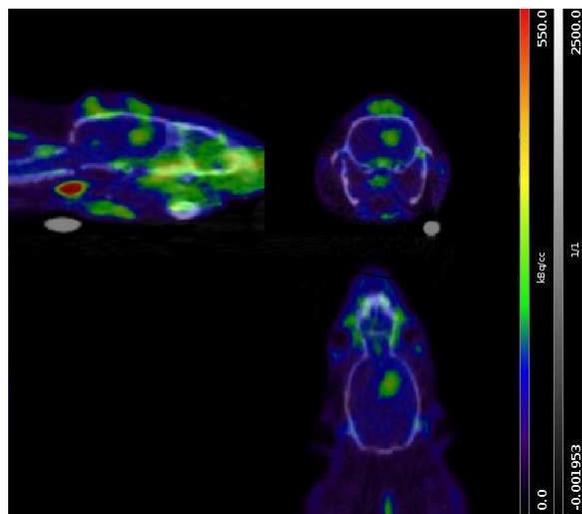
**Table 4.** TBR calculated from *in vitro* autoradiographies of [ $^{18}\text{F}$ ]2, [ $^{18}\text{F}$ ]12 and [ $^{18}\text{F}$ ]23.

[ $^{18}\text{F}$ ]-tracer	TBR <sup>a</sup>
[ $^{18}\text{F}$ ]12	$2.4 \pm 0.3$
[ $^{18}\text{F}$ ]23	$1.9 \pm 0.3$
[ $^{18}\text{F}$ ]2	$5.4 \pm 2.0$

<sup>a</sup>TBR values are the mean  $\pm$  SD of at least 3 independent experiments

**Small animal PET studies.** PET imaging was performed with [ $^{18}\text{F}$ ]12 and [ $^{18}\text{F}$ ]23 on anaesthetised Wistar rats seven days after AMPA-induced brain lesion in the right striatum.<sup>23,34,52</sup> As representative

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3 examples, Figure 6 shows summed coronal, sagittal and axial images of rat brain from 5 to 60  
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5 minutes after injection of [ $^{18}\text{F}$ ]**12**. Similar images were obtained after injection of [ $^{18}\text{F}$ ]**23**.  
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28 **Figure 6.** microPET images acquired as summed data from 5 to 60 minutes after intravenous  
29 injection of [ $^{18}\text{F}$ ]**12** to AMPA-induced brain lesioned rat.  
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35 Data reported in Table 5 show that both [ $^{18}\text{F}$ ]**12** and [ $^{18}\text{F}$ ]**23** rapidly enter the brain with initial uptake  
36 values, 2 minutes p.i., in the lesioned striatum of 0.43 and 0.39 percentages of injected dose per  
37 milliliter (% ID/mL) respectively. These uptakes were lower 60 minutes p.i. but still relatively high  
38 (0.33% for [ $^{18}\text{F}$ ]**12** and 0.24% for [ $^{18}\text{F}$ ]**23**), suggesting that the radiotracers still bound their target. In  
39 contrast, uptake in the contralateral side decreased along the study and was rather low 60 minutes p.i.  
40 with values of 0.09 and 0.05 % ID/mL for [ $^{18}\text{F}$ ]**12** and [ $^{18}\text{F}$ ]**23**, respectively. A marked contrast  
41 between the lesioned area and the corresponding area in the intact contralateral hemisphere of the rat  
42 brain was thus obtained for [ $^{18}\text{F}$ ]**12** after 60 minutes, with a calculated ipsilateral-to-contralateral  
43 ratio of  $3.57 \pm 0.48$  (n=4) that reflects a high *in vivo* specific binding for the TSPO and is comparable  
44 to that measured for [ $^{18}\text{F}$ ]**2** ( $3.71 \pm 0.39$ ). Analogously, the calculated ratio for [ $^{18}\text{F}$ ]**23** reached a  
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value of  $4.62 \pm 0.44$  ( $n=4$ ) which is greater than that of [ $^{18}\text{F}$ ]2. Noteworthy, these ratios increased along the study and may even be higher using extended imaging protocols. The better contrast obtained with [ $^{18}\text{F}$ ]23 mainly results from the quicker wash out of the radiotracer in the non-lesioned area. Table 5 compiles the uptake values obtained in the lesioned and non-lesioned area over a period of 60 minutes, as well as the corresponding calculated ipsi/contra ratios for radioligands [ $^{18}\text{F}$ ]12, [ $^{18}\text{F}$ ]23 and [ $^{18}\text{F}$ ]2.

**Table 5. [ $^{18}\text{F}$ ]12, [ $^{18}\text{F}$ ]23 and [ $^{18}\text{F}$ ]2 uptake values in the lesioned and non-lesioned rat brain areas over a period of 60 minutes post-injection, and the corresponding calculated ipsi/contra ratios.**

Time (min)	Ipsi uptake (% ID/mL)			Contra uptake (% ID/mL)			Ipsi/contra ratio		
	[ $^{18}\text{F}$ ]12	[ $^{18}\text{F}$ ]23	[ $^{18}\text{F}$ ]2	[ $^{18}\text{F}$ ]12	[ $^{18}\text{F}$ ]23	[ $^{18}\text{F}$ ]2	[ $^{18}\text{F}$ ]12	[ $^{18}\text{F}$ ]23	[ $^{18}\text{F}$ ]2
2	$0.43 \pm 0.20$	$0.39 \pm 0.07$	$0.40 \pm 0.02$	$0.28 \pm 0.13$	$0.23 \pm 0.04$	$0.24 \pm 0.02$	$1.53 \pm 0.16$	$1.70 \pm 0.12$	$1.63 \pm 0.12$
5	$0.40 \pm 0.17$	$0.38 \pm 0.05$	$0.36 \pm 0.01$	$0.23 \pm 0.11$	$0.16 \pm 0.03$	$0.19 \pm 0.01$	$1.72 \pm 0.35$	$2.43 \pm 0.32$	$1.91 \pm 0.20$
15	$0.37 \pm 0.16$	$0.30 \pm 0.05$	$0.34 \pm 0.03$	$0.16 \pm 0.08$	$0.09 \pm 0.02$	$0.12 \pm 0.02$	$2.15 \pm 0.33$	$3.38 \pm 0.31$	$2.76 \pm 0.14$
40	$0.32 \pm 0.14$	$0.25 \pm 0.06$	$0.31 \pm 0.05$	$0.10 \pm 0.05$	$0.06 \pm 0.01$	$0.08 \pm 0.02$	$3.05 \pm 0.51$	$4.01 \pm 1.05$	$3.71 \pm 0.49$
60	$0.33 \pm 0.15$	$0.24 \pm 0.04$	$0.30 \pm 0.05$	$0.09 \pm 0.04$	$0.05 \pm 0.01$	$0.08 \pm 0.01$	$3.57 \pm 0.48$	$4.62 \pm 0.44$	$3.71 \pm 0.39$

## ■ CONCLUSION

A novel series of 5,7-dimethylpyrazolo[1,5-a]pyrimidin-3-ylacetamides modified at the 4-position of the phenyl ring were synthesised and *in vitro* evaluated for their potential to bind the TSPO. All newly synthesised compounds showed comparable or higher affinity for the TSPO than the parent molecule **2**, with  $K_i$  values in the subnanomolar range. The TSPO/CBR selectivity was also assessed for all compounds and was proved to be conserved. Determination of their  $\text{LogD}_{7.4}$  demonstrated moderately increased lipophilicity compared to **2**, however most of the values were in the range for

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3 suitable blood brain barrier passive penetration. Preliminary metabolism studies were also conducted  
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5 for the title compounds. Among them, two candidates were radiolabelled with fluorine-18 and  
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7 evaluated *in vitro* and *in vivo* for their specific binding to the TSPO and their potential as PET probes  
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9 on a rat model of acute neuroinflammation. The data obtained revealed that the newly developed  
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11 radioligands, [<sup>18</sup>F]12 and [<sup>18</sup>F]23, are well suited for imaging neuroinflammation *in vivo*. The  
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13 potential of these promising PET radiotracers will be further investigated, in particular with regard to  
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15 their metabolic profiling *in vivo*.  
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## 20 21 22 23 24 ■ EXPERIMENTAL SECTION

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27 **General.** Chemicals were purchased from Aldrich France and were used without further purification.  
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29 Flash chromatographies were conducted on silica gel or alumina gel (0.63-0.200 mm, VWR)  
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31 columns. TLCs were run on pre-coated plates of silica gel 60F<sub>254</sub> (VWR, France). The compounds  
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33 were localized at 254 nm using a UV-lamp and by dipping the TLC-plates in a 1% ethanolic  
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35 ninhydrin solution or a basic potassium permanganate aqueous solution and heating on a hot plate.  
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39 <sup>1</sup>H and <sup>13</sup>C NMR spectra were recorded on a Bruker (Wissembourg, France) Avance 400 MHz  
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41 apparatus and chemical shifts were referenced to the hydrogenated residue of the deuterated solvent  
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43 (δ[CD<sub>2</sub>HCN] = 1.94 ppm, δ[CD<sub>2</sub>HOD] = 3.31 ppm, δ[CDHCl<sub>2</sub>] = 5.32 ppm, δ[CHCl<sub>3</sub>] = 7.24 ppm)  
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45 for <sup>1</sup>H NMR and to the deuterated solvent (δ[CD<sub>3</sub>CN] = 118.7 ppm, δ[CD<sub>3</sub>OD] = 49.2 ppm,  
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47 δ[CD<sub>2</sub>Cl<sub>2</sub>] = 54.0 ppm and δ[CDCl<sub>3</sub>] = 77.2 ppm) for <sup>13</sup>C NMR experiments. The standard  
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49 concentration of the analysed samples was 20 mg/mL. The chemical shifts are reported in ppm,  
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51 downfield from TMS (s, d, t, q, m and b for singlet, doublet, triplet, quadruplet, multiplet and broad,  
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53 respectively). The low-resolution mass spectra (MS) were measured on a Thermo Electron (Les Ulis,  
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3 France) Ion Trap LCQ Deca XP1 spectrometer (positive electrospray ionization (ESI)). The high-  
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5 resolution mass spectrometry (HRMS) analyses were performed by Imagif (ICSN-CNRS, Gif-sur-  
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7 Yvette, France) by electrospray with positive (ESI+) or negative (ESI-) ionization mode. Purity of the  
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9 synthesised compounds was determined using analytical HPLC (HPLC A) and was found to be more  
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11 than 95 %. HPLC A: UPLC/SQD Acquity Waters, Acquity BEH C18 (2.1 x 50 mm) column, 1.7  $\mu$ m,  
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13 mobile phase: H<sub>2</sub>O (A), CH<sub>3</sub>CN + 0.1 % formic acid (B), linear gradient from 2 to 100 % (B) in 3  
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15 min with a flow rate of 1.0 mL/min. LogD<sub>7.4</sub> values were determined based on a validated and  
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17 standardized HPLC method (HPLC B): Alliance 2695 - PDA Waters, X-Terra MS C18 (4.6 x 20  
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19 mm, 3.5  $\mu$ m) column, mobile phase: 5 mM MOPS/(CH<sub>3</sub>)<sub>4</sub>NOH pH 7.4 (A), 5 % MOPS/(CH<sub>3</sub>)<sub>4</sub>NOH  
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21 (100 mM, pH 7.4) / 95 % CH<sub>3</sub>CN (B), gradient (A / B): 98:2 (0.5 min), 0:100 (4.8 min), 98:2 (1.6  
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23 min), with a flow rate of 1.2 mL/min, 25 °C, detection at 254 nm.  
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29 **Chemistry. Methyl 4-(3-iodopropoxy)benzoate (3).** To a suspension of 18.7 g of potassium  
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31 carbonate (136 mmol) in acetone (1 L) was added diiodopropane (22.4 mL, 195 mmol). The mixture  
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33 was stirred at ambient temperature under argon before addition of a solution of 10.0 g of methyl 4-  
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35 hydroxybenzoate (65.8 mmol) in acetone (100 mL). The reaction mixture was then heated to 50 °C  
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37 and stirring was prolonged for 16 h. The resulting mixture was filtered to remove insoluble potassium  
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39 carbonate and the filtrate was evaporated under reduced pressure. The crude product was purified by  
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41 silica gel column chromatography using heptane/EtOAc (5/1, v/v) as eluent to yield compound **3**  
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43 (15.2 g, 47.6 mmol, 72 % yield) as light yellow crystals. R<sub>f</sub> (heptane/EtOAc: 2/1 v/v): 0.48. <sup>1</sup>H NMR  
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45 (CDCl<sub>3</sub>)  $\delta$  7.97 (d, J = 8.8 Hz, 2H), 6.91 (d, J = 8.8 Hz, 2H), 4.07 (t, J = 6.2 Hz, 2H), 3.87 (s, 3H),  
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47 3.36 (t, J = 6.2 Hz, 2H), 2.28 (q, J = 6.2 Hz, 2H). <sup>13</sup>C NMR (CDCl<sub>3</sub>)  $\delta$  166.9 [C], 162.4 [C], 131.7  
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49 [2 $\times$ CH], 122.8 [C], 114.1 [2 $\times$ CH], 67.4 [CH<sub>2</sub>], 51.9 [CH<sub>3</sub>], 32.8 [CH<sub>2</sub>], 2.2 [CH<sub>2</sub>I]. Mp: 47-48°C.  
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51 ESI(+)-MS: m/z 321 [M+H]<sup>+</sup>.  
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3 **Methyl 4-(3-bromopropoxy)benzoate (4).** For the preparation of methyl 4-(3-  
4 bromopropoxy)benzoate **4**, the procedure described above with methyl 4-hydroxybenzoate **2** was  
5 reproduced with dibromopropane instead of diiodopropane as alkylating agent. Starting from 10.0 g  
6 of **2** (65.8 mmol), 14.9 g of compound **4** (54.7 mmol, 83 % yield) could be obtained as a white solid  
7 after silica gel column chromatography using pure toluene as eluent.  $R_f$  (toluene 100 %): 0.32.  $^1\text{H}$   
8 NMR ( $\text{CDCl}_3$ )  $\delta$  7.98 (d,  $J = 8.8$  Hz, 2H), 6.92 (d,  $J = 8.8$  Hz, 2H), 4.16 (t,  $J = 6.0$  Hz, 2H), 3.88 (s,  
9 3H), 3.60 (t,  $J = 6.4$  Hz, 2H), 2.34 (m, 2H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  166.9 [C], 162.5 [C], 131.7 [2 $\times$ CH],  
10 122.9 [C], 114.2 [2 $\times$ CH], 65.6 [ $\text{CH}_2$ ], 51.9 [ $\text{CH}_3$ ], 32.2 [ $\text{CH}_2$ ], 29.7 [ $\text{CH}_2$ ]. ESI(+)-MS:  $m/z$ , not seen.  
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22 **Methyl 4-(3-hydroxypropyl)benzoate (5).** *Starting from methyl 4-(3-bromopropoxy)benzoate*  
23 *(4):* 12.73 g of **4** (46.6 mmol) were dissolved in dry toluene (1 L) and the solution was stirred under  
24 argon and heated to 100 °C. A solution containing azobisisobutyronitrile (AIBN, 1.54 g, 9.4 mmol)  
25 and tributyltin hydride (15 mL, 55.9 mmol) in dry toluene (100 mL) was slowly added to the solution  
26 of **4** over a period of 1 h and stirring was prolonged at 100 °C overnight. Full conversion of the  
27 starting material was confirmed by TLC and the reaction mixture was then concentrated under  
28 reduced pressure. The residue was purified by silica gel column chromatography using  
29 heptane/EtOAc (2/1, v/v) as eluent to yield compound **5** (1.61 g, 8.30 mmol, 18 % yield) as a light  
30 yellow oil.  
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43 *Starting from methyl 4-(3-iodopropoxy)benzoate (3):* 15.2 g of **3** were subjected to the procedure  
44 described above. Purification of the crude product afforded compound **5** (1.13 g, 5.82 mmol, 13 %  
45 yield).  $R_f$  (heptane/EtOAc: 2/1 v/v): 0.14.  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  7.95 (d,  $J = 8.4$  Hz, 2H), 7.26 (d,  $J =$   
46 8.4 Hz, 2H), 3.90 (s, 3H), 3.67 (t,  $J = 6.4$  Hz, 2H), 2.76 (t,  $J = 7.6$  Hz, 2H), 1.90 (m, 2H).  $^{13}\text{C}$  NMR  
47 ( $\text{CDCl}_3$ )  $\delta$  167.4 [C], 147.6 [C], 129.9 [2 $\times$ CH], 128.7 [2 $\times$ CH], 128.1 [C], 62.2 [ $\text{CH}_2$ ], 52.2 [ $\text{CH}_3$ ],  
48 34.0 [ $\text{CH}_2$ ], 32.3 [ $\text{CH}_2$ ]. ESI(+)-MS:  $m/z$ , not seen.  
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3 **Methyl 4-(3-((*tert*-butyldiphenylsilyl)oxy)propyl)benzoate (6).** To 1.31 g of **5** (6.75 mmol)  
4 dissolved in dry pyridine (25 mL) was added *tert*-butyl-diphenylsilyl chloride (2.11 mL, 8.10 mmol)  
5 and the reaction mixture was stirred for 4 h at ambient temperature. After addition of ethyl acetate  
6 (200 mL) the solution was washed twice with a 1.0 M aqueous hydrochloric acid solution (2 x 300  
7 mL) and once with brine (250 mL). The organic layer was then dried over sodium sulfate before  
8 being filtered and evaporated to dryness. The resulting residue was purified by silica gel column  
9 chromatography using toluene/heptane (2/1, v/v) as eluent to yield compound **6** (2.34 g, 5.40 mmol,  
10 80% yield) as a colorless oil.  $R_f$  (toluene 100 %): 0.36.  $^1\text{H NMR}$  ( $\text{CDCl}_3$ )  $\delta$  7.93 (d,  $J = 8.0$  Hz, 2H),  
11 7.66 (d,  $J = 6.4$  Hz, 4H), 7.43-7.38 (m, 6H), 7.22 (d,  $J = 8.0$  Hz, 2H), 3.91 (s, 3H), 3.68 (t,  $J = 6.4$  Hz,  
12 2H), 2.79 (t,  $J = 7.6$  Hz, 2H), 1.88 (m, 2H), 1.07 (s, 9H).  $^{13}\text{C NMR}$  ( $\text{CDCl}_3$ )  $\delta$  167.2 [C], 147.8 [C],  
13 135.6 [4 $\times$ CH], 133.9 [2 $\times$ C], 129.7 [2 $\times$ CH], 129.6 [2 $\times$ CH], 128.5 [2 $\times$ CH], 127.7 [C], 127.6 [4 $\times$ CH],  
14 62.9 [CH<sub>2</sub>], 52.0 [CH<sub>3</sub>], 33.8 [CH<sub>2</sub>], 32.2 [CH<sub>2</sub>], 26.9 [3 $\times$ CH<sub>3</sub>], 19.3 [C]. ESI(+)-MS:  $m/z$  433  
15 [M+H]<sup>+</sup>.  
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34 **3-(4-(3-((*tert*-Butyldiphenylsilyl)oxy)propyl)phenyl)-3-oxopropanenitrile (7).** Sodium  
35 methoxide (250 mg, 4.62 mmol), **6** (2.00 g, 4.62 mmol) and dry acetonitrile (25 mL) were mixed at  
36 ambient temperature and the resulting reaction mixture was stirred and heated to reflux until the  
37 reaction was complete (1-2 days, TLC monitoring). Addition of water (5 mL) and diethyl ether (5  
38 mL) to the mixture allowed extraction in the organic layer of unreacted starting material. The  
39 aqueous phase was collected and acidified to pH 6 with 20% aqueous sulfuric acid solution to  
40 precipitate the desired compound **7** that was filtered off and dried under vacuum. Compound **7** (695  
41 mg, 1.57 mmol, 34% yield) was obtained as a white powder in a sufficient pure form to be used in  
42 the next step without further purification.  $R_f$  (toluene/AcOEt 95/5, v/v): 0.33.  $^1\text{H NMR}$  ( $\text{CDCl}_3$ )  $\delta$   
43 7.81 (d,  $J = 8.0$  Hz, 2H), 7.65 (m, 4H), 7.46-7.36 (m, 6H), 7.30 (d,  $J = 8.0$  Hz, 2H), 4.05 (s, 2H), 3.68  
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(t, J = 6.0 Hz, 2H), 2.81 (t, J = 7.6 Hz, 2H), 1.88 (m, 2H), 1.07 (s, 9H). <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 186.5 [C], 150.2 [C], 135.5 [4×CH], 133.7 [2×C], 132.0 [C], 129.6 [2×CH], 129.2 [2×CH], 128.5 [2×CH], 127.6 [4×CH], 113.8 [C], 62.6 [CH<sub>2</sub>], 33.5 [CH<sub>2</sub>], 32.2 [CH<sub>2</sub>], 29.2 [CH<sub>2</sub>], 26.8 [3×CH<sub>3</sub>], 19.2 [C]. ESI(-)-MS: m/z 440 [M-H]<sup>-</sup>. HR-ESI(+)-MS m/z calcd for C<sub>28</sub>H<sub>30</sub>NO<sub>2</sub>Si: 440.2046 [M+H]<sup>+</sup>, found 440.2042.

**4-(4-(3-((*tert*-Butyldiphenylsilyl)oxy)propyl)phenyl)-3-cyano-*N,N*-diethyl-4-oxobutanamide**

**(8).** To 16.3 mL of a 0.125 M solution (2.04 mmol) of sodium hydroxide in a 8/2 mixture of ethanol and water, were successively added **7** (750 mg, 1.70 mmol), sodium iodide (765 mg, 5.10 mmol) and *N,N*-diethylchloroacetamide (256 μL, 1.87 mmol). The resulting mixture was stirred at 75 °C for 12 h, diluted then with a 0.1 M aqueous hydrochloric acid solution (100 mL) and extracted with ethyl acetate (100 mL). The organic layer was separated, washed with brine, dried over sodium sulfate before being filtered and evaporated to dryness. The resulting residue was purified by silica gel column chromatography using toluene/EtOAc (95/5, v/v) as eluent to yield compound **8** (764 mg, 1.38 mmol, 81 % yield) as an orange oil. R<sub>f</sub> (toluene/AcOEt 9/1, v/v): 0.29. <sup>1</sup>H NMR (CD<sub>2</sub>Cl<sub>2</sub>) δ 7.97 (d, J = 8.0 Hz, 2H), 7.70 (m, 4H), 7.45-7.35 (m, 8H), 7.25 (m, 1H), 7.19 (m, 1H), 5.00 (dd, J = 8.8, J = 4.8 Hz, 1H), 3.73 (t, J = 6.0 Hz, 2H), 3.40-3.23 (m, 5H), 2.93 (dd, J = 16.0, J = 4.8 Hz, 1H), 2.86 (t, J = 7.6 Hz, 2H), 1.92 (m, 2H), 1.25 (t, J = 7.2 Hz, 3H), 1.08 (m, 12H). <sup>13</sup>C NMR (CD<sub>2</sub>Cl<sub>2</sub>) δ 189.5 [C], 166.8 [C], 149.9 [C], 135.4 [4×CH], 133.8 [2×C], 132.0 [C], 129.5 [2×CH], 129.1 [2×CH], 128.9 [2×CH], 127.6 [4×CH], 117.4 [C], 62.7 [CH<sub>2</sub>], 41.8 [CH<sub>2</sub>], 40.4 [CH<sub>2</sub>], 34.0 [CH], 33.6 [CH<sub>2</sub>], 32.9 [CH<sub>2</sub>], 32.1 [CH<sub>2</sub>], 26.5 [3×CH<sub>3</sub>], 19.0 [C], 13.8 [CH<sub>3</sub>], 12.6 [CH<sub>3</sub>]. ESI(+)-MS: m/z 555 [M+H]<sup>+</sup>, 577 [M+Na]<sup>+</sup>, 593 [M+K]<sup>+</sup>. HR-ESI(+)-MS m/z calcd for C<sub>34</sub>H<sub>43</sub>N<sub>2</sub>O<sub>3</sub>Si: 555.3043 [M+H]<sup>+</sup>, found 555.3036.

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**2-(3-Amino-5-(4-(3-((*tert*-butyldiphenylsilyl)oxy)propyl)phenyl)-1*H*-pyrazol-4-yl)-*N,N*-diethylacetamide (9).** To 750 mg of **8** (1.35 mmol) dissolved in ethanol (6.8 mL) were added glacial acetic acid (140  $\mu$ L) and hydrazine monohydrate (100  $\mu$ L, 2.03 mmol). The resulting reaction mixture was stirred at 60 °C for 3 h, cooled down to room temperature and diluted with ethyl acetate (100 mL). The organic layer was successively washed with a saturated aqueous ammonium chloride solution, brine and dried over sodium sulfate before being filtered and evaporated to dryness. The resulting residue was purified by silica gel column chromatography using CH<sub>2</sub>Cl<sub>2</sub>/MeOH (9/1, v/v) as eluent to yield compound **9** (734 mg, 1.29 mmol, 95 % yield) as a light pink oil. R<sub>f</sub> (CH<sub>2</sub>Cl<sub>2</sub>/MeOH 95/5, v/v): 0.15. <sup>1</sup>H NMR (CD<sub>2</sub>Cl<sub>2</sub>)  $\delta$  7.68 (m, 4H), 7.46-7.38 (m, 6H), 7.32-7.26 (m, 4H), 3.72 (t, J = 6.0 Hz, 2H), 3.49 (s, 2H), 3.32 (q, J = 7.2 Hz, 2H), 3.07 (q, J = 7.2 Hz, 2H), 2.80 (t, J = 7.6 Hz, 2H), 1.91 (m, 2H), 1.09 (m, 12H), 0.90 (t, J = 7.2 Hz, 3H). <sup>13</sup>C NMR (CD<sub>2</sub>Cl<sub>2</sub>)  $\delta$  170.0 [C], 153.5 [C], 142.9 [C], 142.8 [C], 135.4 [4 $\times$ CH], 134.0 [C], 133.9 [2 $\times$ C], 129.5 [2 $\times$ CH], 129.0 [2 $\times$ CH], 127.6 [4 $\times$ CH], 127.5 [2 $\times$ CH], 98.0 [C], 62.9 [CH<sub>2</sub>], 42.2 [CH<sub>2</sub>], 40.3 [CH<sub>2</sub>], 34.0 [CH<sub>2</sub>], 31.7 [CH<sub>2</sub>], 28.2 [CH<sub>2</sub>], 26.5 [3 $\times$ CH<sub>3</sub>], 19.0 [C], 13.8 [CH<sub>3</sub>], 12.7 [CH<sub>3</sub>]. ESI(+)-MS: m/z 569 [M+H]<sup>+</sup>, 591 [M+Na]<sup>+</sup>, 607 [M+K]<sup>+</sup>.

**2-(2-(4-(3-((*tert*-Butyldiphenylsilyl)oxy)propyl)phenyl)-5,7-dimethylpyrazolo[1,5-*a*]pyrimidin-3-yl)-*N,N*-diethylacetamide (10).** To 720 mg of **9** (1.27 mmol) dissolved in ethanol (16 mL) was added pentan-2,4-dione (143  $\mu$ L, 1.39 mmol) and the resulting mixture stirred overnight at 60 °C. Evaporation of the reaction solvent afforded a crude product that was purified by silica gel column chromatography using pure ethyl acetate as eluent to yield compound **10** (600 mg, 0.95 mmol, 75% yield) as a beige powder. R<sub>f</sub> (EtOAc 100 %): 0.18. <sup>1</sup>H NMR (CD<sub>2</sub>Cl<sub>2</sub>)  $\delta$  7.70 (m, 6H), 7.46-7.38 (m, 6H), 7.29 (d, J = 8.4 Hz, 2H), 6.58 (s, 1H), 3.91 (s, 2H), 3.75 (t, J = 6.0 Hz, 2H), 3.50 (q, J = 7.2 Hz, 2H), 3.40 (q, J = 7.2 Hz, 2H), 2.80 (t, J = 7.6 Hz, 2H), 2.76 (s, 3H), 2.57 (s, 3H), 1.94

(m, 2H), 1.23 (t, J = 7.2 Hz, 3H), 1.12 (t, J = 7.2 Hz, 3H), 1.09 (s, 9H).  $^{13}\text{C}$  NMR ( $\text{CD}_2\text{Cl}_2$ )  $\delta$  169.6 [C], 157.6 [C], 154.5 [C], 147.6 [C], 144.8 [C], 142.5 [C], 135.5 [4 $\times$ CH], 133.9 [2 $\times$ C], 131.3 [C], 129.5 [2 $\times$ CH], 128.5 [2 $\times$ CH], 128.2 [2 $\times$ CH], 127.5 [4 $\times$ CH], 108.2 [CH], 100.9 [C], 63.0 [CH<sub>2</sub>], 42.1 [CH<sub>2</sub>], 40.4 [CH<sub>2</sub>], 34.1 [CH<sub>2</sub>], 31.7 [CH<sub>2</sub>], 27.9 [CH<sub>2</sub>], 26.6 [3 $\times$ CH<sub>3</sub>], 24.3 [CH<sub>3</sub>], 19.0 [C], 16.6 [CH<sub>3</sub>], 13.9 [CH<sub>3</sub>], 12.8 [CH<sub>3</sub>]. ESI(+)-MS: m/z 633 [M+H]<sup>+</sup>, 655 [M+Na]<sup>+</sup>, 671 [M+K]<sup>+</sup>. HR-ESI(+)-MS m/z calcd for C<sub>39</sub>H<sub>49</sub>N<sub>4</sub>O<sub>2</sub>Si: 633.3625 [M+H]<sup>+</sup>, found 633.3607.

***N,N*-Diethyl-2-(2-(4-(3-hydroxypropyl)phenyl)-5,7-dimethylpyrazolo[1,5-a]pyrimidin-3-yl)acetamide (11).** *From 10:* To 585 mg of **10** (0.93 mmol) dissolved in tetrahydrofuran (5 mL), was added tetrabutylammonium fluoride (TBAF, 1.0 M in tetrahydrofuran, 1.85 mL, 1.85 mmol) and the resulting reaction mixture stirred at ambient temperature overnight. The mixture was then diluted with ethyl acetate and successively washed with a saturated aqueous ammonium chloride solution and brine. The organic layer was dried over sodium sulfate, filtered and evaporated to dryness. The resulting residue was purified by silica gel column chromatography using CH<sub>2</sub>Cl<sub>2</sub>/MeOH (97/3, v/v) as eluent to yield compound **11** (240 mg, 0.61 mmol, 66 % yield) as a white powder.

*From 17:* To a solution of 209 mg of *N,N*-diethyl-2-(2-(4-(4-hydroxyprop-1-yn-1-yl)phenyl)-5,7-dimethylpyrazolo[1,5-a]pyrimidin-3-yl)acetamide **17** (0.536 mmol) in dichloromethane (4-5 mL) was added 10 % palladium on charcoal (5 mol %). The reaction flask was degassed under vacuum and filled with hydrogen at 1 atm. and the reaction mixture was stirred at ambient temperature for 24 h. The mixture was then filtered on a silica pad and washed with a mixture of CH<sub>2</sub>Cl<sub>2</sub>/MeOH (8/2, v/v). The filtrate was concentrated to dryness and the residue was purified by silica gel column chromatography using CH<sub>2</sub>Cl<sub>2</sub>/MeOH (99/1 to 95/5, v/v) as eluent to afford compound **11** (194 mg, 0.492 mmol, 92 % yield) as a white solid. R<sub>f</sub> (CH<sub>2</sub>Cl<sub>2</sub>/MeOH 95/5, v/v): 0.17.  $^1\text{H}$  NMR ( $\text{CD}_2\text{Cl}_2$ )  $\delta$  7.70 (d, J = 8.0 Hz, 2H), 7.29 (d, J = 8.0 Hz, 2H), 6.56 (s, 1H), 3.89 (s, 2H), 3.63 (t, J = 6.4 Hz, 2H),

3.49 (q,  $J = 7.2$  Hz, 2H), 3.39 (q,  $J = 7.2$  Hz, 2H), 2.73 (m, 5H), 2.53 (s, 3H), 1.87 (m, 2H), 1.70 (bs, 1H), 1.22 (t,  $J = 7.2$  Hz, 3H), 1.10 (t,  $J = 7.2$  Hz, 3H).  $^{13}\text{C}$  NMR ( $\text{CD}_2\text{Cl}_2$ )  $\delta$  169.6 [C], 157.6 [C], 154.5 [C], 147.6 [C], 144.8 [C], 142.3 [C], 131.4 [C], 128.5 [2 $\times$ CH], 128.3 [2 $\times$ CH], 108.2 [CH], 100.9 [C], 61.9 [CH<sub>2</sub>], 42.1 [CH<sub>2</sub>], 40.4 [CH<sub>2</sub>], 34.3 [CH<sub>2</sub>], 31.8 [CH<sub>2</sub>], 27.9 [CH<sub>2</sub>], 24.3 [CH<sub>3</sub>], 16.6 [CH<sub>3</sub>], 14.0 [CH<sub>3</sub>], 12.8 [CH<sub>3</sub>]. ESI(+)-MS:  $m/z$  395 [M+H]<sup>+</sup>, 417 [M+Na]<sup>+</sup>, 433 [M+K]<sup>+</sup>. HR-ESI(+)-MS  $m/z$  calcd for  $\text{C}_{23}\text{H}_{31}\text{N}_4\text{O}_2$ : 395.2447 [M+H]<sup>+</sup>, found 395.2447.

***N,N*-Diethyl-2-(2-(4-(3-fluoropropyl)phenyl)-5,7-dimethylpyrazolo[1,5-a]pyrimidin-3-yl)acetamide (12).** 168 mg (0.43 mmol) of *N,N*-diethyl-2-(2-(4-(3-hydroxypropyl)phenyl)-5,7-dimethylpyrazolo[1,5-a]pyrimidin-3-yl)acetamide **11**, were reacted with bis(2-methoxyethyl) aminosulfur trifluoride (Deoxo-Fluor<sup>®</sup>, 50% solution in toluene, 0.28 mL, 1.07 mmol) in toluene (2.5 mL) at room temperature for 6 h. The reaction mixture was then evaporated to dryness and the residue purified by silica gel column chromatography using  $\text{CH}_2\text{Cl}_2/\text{MeOH}$  (99/1, v/v) as eluent to give compound **1** (88 mg, 0.22 mmol, 52 % yield) as a beige solid.  $R_f$  ( $\text{CH}_2\text{Cl}_2/\text{MeOH}$  98/2 v/v): 0.50.  $t_R$  (HPLC A) = 1.18 min.  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  7.74 (d,  $J = 8.0$  Hz, 2H), 7.28 (d,  $J = 8.0$  Hz, 2H), 6.52 (s, 1H), 4.46 (dt,  $J_{\text{H-F}}^2 = 46.8$  Hz,  $J_{\text{H-H}}^3 = 6.0$  Hz, 2H), 3.93 (s, 2H), 3.49 (q,  $J = 7.2$  Hz, 2H), 3.40 (q,  $J = 7.2$  Hz, 2H), 2.79 (t,  $J = 7.2$  Hz, 2H), 2.74 (s, 3H), 2.54 (s, 3H), 2.10-1.96 (m, 2H), 1.20 (t,  $J = 7.2$  Hz, 3H), 1.10 (t,  $J = 7.2$  Hz, 3H).  $^{13}\text{C}$  NMR ( $\text{CD}_2\text{Cl}_2$ )  $\delta$  169.6 [C], 157.6 [C], 154.4 [C], 147.6 [C], 144.8 [C], 141.4 [C], 131.7 [C], 128.5 [2 $\times$ CH], 128.4 [2 $\times$ CH], 108.2 [CH], 101.0 [C], 83.2 [d,  $J_{\text{C-F}}^1 = 163.0$  Hz,  $\text{CH}_2\text{F}$ ], 42.1 [CH<sub>2</sub>], 40.4 [CH<sub>2</sub>], 31.9 [d,  $J_{\text{C-F}}^2 = 20.0$  Hz,  $\text{CH}_2$ ], 31.0 [d,  $J_{\text{C-F}}^3 = 6.0$  Hz,  $\text{CH}_2$ ], 27.9 [CH<sub>2</sub>], 24.3 [CH<sub>3</sub>], 16.5 [CH<sub>3</sub>], 14.0 [CH<sub>3</sub>], 12.8 [CH<sub>3</sub>]. ESI(+)-MS:  $m/z$  397 [M+H]<sup>+</sup>, 419 [M+Na]<sup>+</sup>. HR-ESI(+)-MS  $m/z$  calcd for  $\text{C}_{23}\text{H}_{30}\text{FN}_4\text{O}$ : 397.2404 [M+H]<sup>+</sup>, found 397.2411.

**3-(4-Iodophenyl)-3-oxopropanenitrile (13).** To 50 mL of anhydrous tetrahydrofuran cooled at -60 °C was added first a 1.6 M *n*-butyllithium solution in hexanes (62.5 mL, 100 mmol) and then,

cautiously, a solution of acetonitrile (5.2 mL, 100 mmol) in anhydrous tetrahydrofuran (50 mL) over a period of 15-20 min while maintaining the temperature below -50 °C. The mixture was then stirred for 30 min at -60 °C. 12.0 g of methyl 4-iodobenzoate (45.8 mmol) dissolved in anhydrous tetrahydrofuran (70 mL) was then cautiously channeled to the mixture over 20 min while maintaining the temperature below -50 °C. Once the addition finished, the reaction mixture was stirred for 1 h at -60 °C and 2 h at -45 °C. Once completed (TLC-monitoring), the reaction was quenched at -40 °C with addition of water (200 mL) under vigorous stirring. Then, a 37 % aqueous hydrochloric acid solution was added to acidify the aqueous layer to pH 2. A white inorganic precipitate was filtered off and the filtrate was extracted twice with ethyl acetate (2 x 200 mL). The combined organic layers were washed with water (2 x 100 mL) and brine (100 mL), dried over sodium sulfate, filtered and concentrated to dryness to afford pure compound **13** (8.64g, 31.9 mmol, 70 % yield) as a beige solid.  $R_f$  (heptane/acetone 3/1, v/v): 0.28.  $^1\text{H}$  NMR ( $\text{CD}_3\text{CN}$ )  $\delta$  7.95 (d,  $J = 8.4$  Hz, 2H), 7.64 (d,  $J = 8.4$  Hz, 2H), 4.29 (s, 2H).  $^{13}\text{C}$  NMR ( $\text{CD}_3\text{CN}$ )  $\delta$  188.5 [C], 138.2 [2xCH], 134.1 [C], 129.7 [2xCH], 114.6 [C], 101.8 [C], 29.7 [ $\text{CH}_2$ ]. ESI(-)-MS:  $m/z$  270 [ $\text{M-H}$ ] $^-$ . HR-ESI(-)-MS  $m/z$  calcd for  $\text{C}_9\text{H}_5\text{NOI}$ : 269.9416 [ $\text{M-H}$ ] $^-$ , found 269.9421.

**3-Cyano-*N,N*-diethyl-4-(4-iodophenyl)-4-oxobutanamide (14).** To a solution containing 8.64 g of **13** (31.9 mmol) in a mixture of ethanol (170 mL) and water (30 mL) was added portionwise and under vigorous stirring sodium hydroxide (1.40 g, 35.0 mmol). The reaction mixture was stirred for 15 min at ambient temperature and then sodium iodide (9.60 g, 64.0 mmol) was added in one portion, followed by the dropwise addition of *N,N*-diethylchloroacetamide (4.40 mL, 32.1 mmol). The reaction mixture was stirred for 4 days at ambient temperature. Once the reaction completed (TLC-monitoring), the suspension was filtered to remove inorganic salt and the filtrate was concentrated to dryness. The residue was purified by silica gel column chromatography using  $\text{CH}_2\text{Cl}_2/\text{MeOH}$  (100/0 to 98/2, v/v) as eluent to yield compound **14** (6.61 g, 17.2 mmol, 54 % yield) as a beige

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3 powder.  $R_f$  (heptane/EtOAc 2/1, v/v): 0.26.  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  7.76 (d,  $J = 8.0$  Hz, 2H), 7.60 (d,  $J =$   
4 8.0 Hz, 2H), 4.95 (dd,  $J = 9.6$  Hz,  $J = 4.0$  Hz, 1H), 3.50-3.25 (m, 5H), 2.88 (dd,  $J = 12.0$  Hz,  $J = 4.0$   
5 Hz, 1H), 1.27 (t,  $J = 7.0$  Hz, 3H), 1.10 (t,  $J = 7.0$  Hz, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  189.1 [C], 166.8 [C],  
6 138.4 [2xCH], 133.6 [C], 130.1 [2xCH], 116.7 [C], 102.8 [C], 42.0 [ $\text{CH}_2$ ], 40.6 [ $\text{CH}_2$ ], 33.7 [CH],  
7 32.7 [ $\text{CH}_2$ ], 14.0 [ $\text{CH}_3$ ], 12.9 [ $\text{CH}_3$ ]. ESI(-)-MS:  $m/z$  383 [M-H]. HR-(ESI+)-MS  $m/z$  calcd for  
8  $\text{C}_{15}\text{H}_{18}\text{IN}_2\text{O}_2$ : 385.0413 [M+H] $^+$ , found 385.0428.

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18 **2-(3-Amino-5-(4-iodophenyl)-1H-pyrazol-4-yl)-N,N-diethylacetamide (15).** To 2.25 g of **14**  
19 (5.86 mmol) dissolved in ethanol (30 mL) was added monohydrated hydrazine (802  $\mu\text{L}$ , 16.4 mmol)  
20 and glacial acetic acid (586  $\mu\text{L}$ , 10.2 mmol). The reaction mixture was heated at 80  $^\circ\text{C}$  for 3 h and  
21 then concentrated to dryness. The residue was partitioned between water (50 mL), which was  
22 basified at pH 10 with a 3.0 M sodium hydroxide aqueous solution, and ethyl acetate (50 mL). The  
23 organic layer was separated, washed with water (2 x 50 mL) and brine (50 mL), dried over sodium  
24 sulfate, filtered and concentrated to dryness. The residue was triturated in cold diethyl ether (10 mL)  
25 to give a solid which was collected, washed with cold diethyl ether (2 x 5 mL) and suck-dried to  
26 afford pure compound **15** (1.80 g, 4.52 mmol, 77 % yield) as a beige powder.  $R_f$  ( $\text{CH}_2\text{Cl}_2/\text{MeOH}$   
27 93/7, v/v): 0.20.  $^1\text{H}$  NMR ( $\text{CD}_3\text{OD}$ )  $\delta$  7.78 (d,  $J = 8.4$  Hz, 2H), 7.22 (d,  $J = 8.4$  Hz, 2H), 3.54 (s, 2H),  
28 3.31 (q,  $J = 7.2$  Hz, 2H), 3.24 (q,  $J = 7.2$  Hz, 2H), 1.06 (t,  $J = 7.2$  Hz, 3H), 1.00 (t,  $J = 7.2$  Hz, 3H).  
29  $^{13}\text{C}$  NMR ( $\text{CD}_3\text{OD}$ )  $\delta$  170.9 [C], 152.5 [C], 143.0 [C], 137.6 [2xCH], 131.0 [C], 129.2 [2xCH], 97.0  
30 [C], 93.0 [C], 42.1 [ $\text{CH}_2$ ], 40.4 [ $\text{CH}_2$ ], 27.8 [ $\text{CH}_2$ ], 12.7 [ $\text{CH}_3$ ], 11.7 [ $\text{CH}_3$ ]. ESI(+)-MS:  $m/z$  399  
31 [M+H] $^+$ . HR-(ESI+)-MS  $m/z$  calcd for  $\text{C}_{15}\text{H}_{20}\text{IN}_4\text{O}$ : 399.0682 [M+H] $^+$ , found 399.0674.

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51 **N,N-Diethyl-2-(2-(4-iodophenyl)-5,7-dimethylpyrazolo[1,5-a]pyrimidin-3-yl)acetamide (16).**  
52 To a solution of 7.0 g of **15** (17.6 mmol) in ethanol (140 mL) was added acetylacetone (2.9 mL, 28.2  
53 mmol). The reaction mixture was heated to reflux for 5 h and was left cooled down to ambient  
54 temperature without stirring overnight allowing the product to crystallize spontaneously. The crystals  
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3 were filtered, washed with cold ethanol (2 x 20 mL) and suck-dried under vacuum to afford pure  
4 compound **16** (6.4 g, 13.8 mmol, 78 % yield) as white needles.  $R_f$  ( $\text{CH}_2\text{Cl}_2$ /acetone 8/2, v/v): 0.48.  $^1\text{H}$   
5 NMR ( $\text{CDCl}_3$ )  $\delta$  7.77 (d,  $J = 8.4$  Hz, 2H), 7.60 (d,  $J = 8.4$  Hz, 2H), 6.54 (s, 1H), 3.95 (s, 2H), 3.52 (q,  
6  $J = 7.2$  Hz, 2H), 3.40 (q,  $J = 7.2$  Hz, 2H), 2.74 (s, 3H), 2.57 (s, 3H), 1.23 (t,  $J = 7.2$  Hz, 3H), 1.11 (t,  $J$   
7 = 7.2 Hz, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  169.8 [C], 157.7 [C], 154.0 [C], 147.6 [C], 144.7 [C], 137.5  
8 [2xCH], 133.3 [C], 130.4 [2xCH], 108.5 [CH], 101.2 [C], 94.4 [C], 42.3 [ $\text{CH}_2$ ], 40.6 [ $\text{CH}_2$ ], 27.9  
9 [ $\text{CH}_2$ ], 24.6 [ $\text{CH}_3$ ], 16.8 [ $\text{CH}_3$ ], 14.3 [ $\text{CH}_3$ ], 13.0 [ $\text{CH}_3$ ]. HR-(ESI+)-MS  $m/z$  calcd for  $\text{C}_{20}\text{H}_{24}\text{N}_4\text{O}$ :  
10 463.0995 [ $\text{M}+\text{H}$ ] $^+$ , found 463.1011.  
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22 **General procedure for the synthesis of *N,N*-diethyl-2-(2-(4-(*n*-hydroxyalk-1-yn-1-yl)phenyl)-**  
23 **5,7-dimethylpyrazolo[1,5-*a*]pyrimidin-3-yl)acetamide (17-20).** To 200 mg of **16** (0.432 mmol)  
24 dissolved in triethylamine (4 mL) was added, under argon, the appropriate alkynol (1.2 eq), followed  
25 by palladium bis(triphenylphosphine)dichloride (2 mg, 0.5 mol %) and copper iodide (1 mg, 0.01 eq).  
26 The reaction mixture was stirred at ambient temperature for 48 h and concentrated to dryness. The  
27 resulting residue was partitioned between ethyl acetate (20 mL) and water (20 mL). The organic layer  
28 was collected and the aqueous layer was extracted once again with ethyl acetate (20 mL). The  
29 organic layers were combined, washed with brine (30 mL), dried over sodium sulfate, filtered and  
30 concentrated to dryness. The residue was purified by silica gel column chromatography using  
31  $\text{CH}_2\text{Cl}_2$ /MeOH (99/1 to 95/5, v/v) as eluent to afford the title compounds.  
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46 ***N,N*-Diethyl-2-(2-(4-(4-hydroxyprop-1-yn-1-yl)phenyl)-5,7-dimethylpyrazolo[1,5-**  
47 **a]pyrimidin-3-yl)acetamide (17).** The procedure described above was used with prop-2-yn-1-ol (29  
48 mg, 518 mmol) to give compound **17** (108 mg, 0.277 mmol, 64 % yield) as a beige powder.  $R_f$   
49 ( $\text{CH}_2\text{Cl}_2$ /MeOH 93/7, v/v): 0.29.  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  7.79 (d,  $J = 8.0$  Hz, 2H), 7.50 (d,  $J = 8.0$  Hz,  
50 2H), 6.55 (s, 1H), 4.48 (s, 2H), 3.98 (s, 2H), 3.52 (q,  $J = 7.2$  Hz, 2H), 3.40 (q,  $J = 7.2$  Hz, 2H), 2.76  
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(s, 3H), 2.59 (s, 3H), 1.23 (t, J = 7.2 Hz, 3H), 1.11 (t, J = 7.2 Hz, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  169.9 [C], 157.7 [C], 154.2 [C], 147.5 [C], 144.8 [C], 133.8 [C], 131.7 [2xCH], 128.4 [2xCH], 122.4 [C], 108.5 [CH], 101.3 [C], 88.1 [C], 85.4 [C], 51.4 [CH<sub>2</sub>], 42.3 [CH<sub>2</sub>], 40.6 [CH<sub>2</sub>], 27.9 [CH<sub>2</sub>], 24.5 [CH<sub>3</sub>], 16.8 [CH<sub>3</sub>], 14.3 [CH<sub>3</sub>], 13.0 [CH<sub>3</sub>]. HR-(ESI<sup>+</sup>)-MS  $m/z$  calcd for  $\text{C}_{23}\text{H}_{27}\text{N}_4\text{O}_2$ : 391.2134 [M+H]<sup>+</sup>, found 391.2137.

***N,N*-Diethyl-2-(2-(4-(4-hydroxybut-1-yn-1-yl)phenyl)-5,7-dimethylpyrazolo[1,5-*a*]pyrimidin-3-yl)acetamide (18).** The procedure described above was used with but-3-yn-1-ol (36 mg, 518  $\mu\text{mol}$ ) to give compound **18** (136 mg, 0.336 mmol, 78 % yield) as beige crystals.  $R_f$  ( $\text{CH}_2\text{Cl}_2/\text{MeOH}$  95/5, v/v): 0.22.  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  7.77 (d, J = 8.0 Hz, 2H), 7.48 (d, J = 8.0 Hz, 2H), 6.53 (s, 1H), 3.91 (s, 2H), 3.80 (t, J = 6.4 Hz, 2H), 3.50 (q, J = 7.2 Hz, 2H), 3.40 (q, J = 7.2 Hz, 2H), 2.73 (s, 3H), 2.69 (t, J = 6.4 Hz, 2H), 2.54 (s, 3H), 1.20 (t, J = 7.2 Hz, 3H), 1.10 (t, J = 7.2 Hz, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  169.9 [C], 157.7 [C], 154.3 [C], 147.7 [C], 144.7 [C], 133.3 [C], 131.7 [2xCH], 128.4 [2xCH], 123.2 [C], 108.5 [CH], 101.2 [C], 87.2 [C], 82.3 [C], 61.0 [CH<sub>2</sub>], 42.3 [CH<sub>2</sub>], 40.6 [CH<sub>2</sub>], 27.9 [CH<sub>2</sub>], 24.6 [CH<sub>3</sub>], 23.8 [CH<sub>2</sub>], 16.8 [CH<sub>3</sub>], 14.3 [CH<sub>3</sub>], 13.0 [CH<sub>3</sub>]. HR-(ESI<sup>+</sup>)-MS  $m/z$  calcd for  $\text{C}_{24}\text{H}_{29}\text{N}_4\text{O}_2$ : 405.2291 [M+H]<sup>+</sup>, found 405.2303.

***N,N*-Diethyl-2-(2-(4-(4-hydroxypent-1-yn-1-yl)phenyl)-5,7-dimethylpyrazolo[1,5-*a*]pyrimidin-3-yl)acetamide (19).** The procedure described above was used with pent-4-yn-1-ol (44 mg, 518  $\mu\text{mol}$ ) to give compound **19** (125 mg, 0.298 mmol, 69 % yield) as a white solid.  $R_f$  ( $\text{CH}_2\text{Cl}_2/\text{MeOH}$  94/6, v/v): 0.39.  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  7.74 (d, J = 8.0 Hz, 2H), 7.46 (d, J = 8.0 Hz, 2H), 6.54 (s, 1H), 3.93 (s, 2H), 3.81 (t, J = 6.4 Hz, 2H), 3.49 (q, J = 7.2 Hz, 2H), 3.40 (q, J = 7.2 Hz, 2H), 2.74 (s, 3H), 2.56 (s, 3H), 2.55 (t, J = 6.4 Hz, 2H), 1.86 (q<sup>5</sup>, J = 6.4 Hz, 2H), 1.22 (t, J = 7.2 Hz, 3H), 1.10 (t, J = 7.2 Hz, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  169.8 [C], 157.6 [C], 154.5 [C], 147.5 [C], 145.0 [C], 133.0 [C], 131.6 [2xCH], 128.4 [2xCH], 123.6 [C], 108.4 [CH], 101.3 [C], 90.2 [C], 81.1 [C],

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3 61.7 [CH<sub>2</sub>], 42.2 [CH<sub>2</sub>], 40.6 [CH<sub>2</sub>], 31.3 [CH<sub>2</sub>], 28.0 [CH<sub>2</sub>], 24.5 [CH<sub>3</sub>], 16.8 [CH<sub>3</sub>], 16.0 [CH<sub>2</sub>],  
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5 14.3 [CH<sub>3</sub>], 13.0 [CH<sub>3</sub>]. HR-(ESI<sup>+</sup>)-MS *m/z* calcd for C<sub>25</sub>H<sub>31</sub>N<sub>4</sub>O<sub>2</sub>: 419.2447 [M+H]<sup>+</sup>, found  
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10 ***N,N*-Diethyl-2-(2-(4-(4-hydroxyhex-1-yn-1-yl)phenyl)-5,7-dimethylpyrazolo[1,5-**  
11 **a]pyrimidin-3-yl)acetamide (20).** The procedure described above was used with hex-5-yn-1-ol (51  
12 mg, 518 μmol) to give compound **20** (149 mg, 0.346 mmol, 80 % yield) as beige crystals. R<sub>f</sub>  
13 (CH<sub>2</sub>Cl<sub>2</sub>/MeOH 95/5, v/v): 0.23. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.75 (d, J = 8.0 Hz, 2H), 7.46 (d, J = 8.0 Hz,  
14 2H), 6.52 (s, 1H), 3.94 (s, 2H), 3.69 (t, J = 4.0 Hz, 2H), 3.49 (q, J = 7.2 Hz, 2H), 3.40 (q, J = 7.2 Hz,  
15 2H), 2.74 (s, 3H), 2.55 (s, 3H), 2.46 (t, J = 6.8 Hz, 2H), 1.81-1.65 (m, 4H), 1.23 (t, J = 7.2 Hz, 3H),  
16 1.10 (t, J = 7.2 Hz, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 169.7 [C], 157.6 [C], 154.5 [C], 147.5 [C], 145.0 [C],  
17 132.8 [C], 131.6 [2xCH], 128.4 [2xCH], 123.8 [C], 108.4 [CH], 101.3 [C], 90.7 [C], 80.9 [C], 62.3  
18 [CH<sub>2</sub>], 42.2 [CH<sub>2</sub>], 40.6 [CH<sub>2</sub>], 31.8 [CH<sub>2</sub>], 28.0 [CH<sub>2</sub>], 24.9 [CH<sub>2</sub>], 24.3 [CH<sub>3</sub>], 19.2 [CH<sub>2</sub>], 16.9  
19 [CH<sub>3</sub>], 14.3 [CH<sub>3</sub>], 13.0 [CH<sub>3</sub>]. HR-(ESI<sup>+</sup>)-MS *m/z* calcd for C<sub>26</sub>H<sub>33</sub>N<sub>4</sub>O<sub>2</sub>: 433.2604 [M+H]<sup>+</sup>, found  
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36 **General procedure for the synthesis of *N,N*-diethyl-2-(2-(4-(*n*-fluoroalk-1-yn-1-yl)phenyl)-**  
37 **5,7-dimethylpyrazolo[1,5-*a*]pyrimidin-3-yl)acetamide (21-24).** To the appropriate *N,N*-diethyl-2-  
38 (2-(4-(*n*-hydroxyalk-1-yn-1-yl)phenyl)-5,7-dimethylpyrazolo[1,5-*a*]pyrimidin-3-yl)acetamide  
39 dissolved in toluene (2-4 mL) and dichloromethane (1.0-2.5 mL), were added 2-3 eq of a 50%  
40 Deoxo-Fluor<sup>®</sup> solution in toluene. The reaction mixture was stirred for 24 to 72 h at ambient  
41 temperature and additional Deoxo-Fluor<sup>®</sup> solution was added if required (TLC monitoring) to  
42 complete the conversion of the starting alcohol. The solvent was removed under vacuum and the  
43 resulting residue was dissolved in ethyl acetate (20 mL) and successively washed with water (20 mL)  
44 and brine (20 mL) before being dried over sodium sulfate, filtered and evaporated to dryness. The  
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3 crude material was purified by silica gel column chromatography using CH<sub>2</sub>Cl<sub>2</sub>/MeOH (99/1 to 95/5,  
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6 v/v) as eluent to yield the title compounds.

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8 ***N,N*-Diethyl-2-(2-(4-(3-fluoroprop-1-yn-1-yl)phenyl)-5,7-dimethylpyrazolo[1,5-a]pyrimidin-**  
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10 **3-yl)acetamide (21).** Starting from 210 mg (0.538 mmol) of **17** and using the general procedure  
11 described above, compound **21** (17 mg, 0.043 mmol, 8 % yield) was isolated as a white powder. R<sub>f</sub>  
12 (CH<sub>2</sub>Cl<sub>2</sub>/MeOH 95/5, v/v): 0.42. *t<sub>R</sub>* (HPLC A) = 1.19 min. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.83 (d, J = 8.0 Hz,  
13 2H), 7.55 (d, J = 8.0 Hz, 2H), 6.55 (s, 1H), 5.20 (d, J<sup>2</sup><sub>HF</sub> = 47.6 Hz, 2H), 3.95 (s, 2H), 3.52 (q, J = 7.2  
14 Hz, 2H), 3.40 (q, J = 7.2 Hz, 2H), 2.75 (s, 3H), 2.56 (s, 3H), 1.23 (t, J = 7.2 Hz, 3H), 1.11 (t, J = 7.2  
15 Hz, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 169.7 [C], 157.7 [C], 154.2 [C], 147.5 [C], 145.0 [C], 134.4 [C], 131.9  
16 [2xCH], 128.5 [2xCH], 121.5 [d, J<sup>4</sup><sub>CF</sub> = 4 Hz, C], 108.5 [CH], 101.4 [C], 89.5 [d, J<sup>3</sup><sub>CF</sub> = 12 Hz, C],  
17 83.2 [d, J<sup>2</sup><sub>CF</sub> = 22 Hz, C], 71.1 [d, J<sup>1</sup><sub>CF</sub> = 164 Hz, CH<sub>2</sub>], 42.3 [CH<sub>2</sub>], 40.6 [CH<sub>2</sub>], 27.9 [CH<sub>2</sub>], 24.4  
18 [CH<sub>3</sub>], 16.8 [CH<sub>3</sub>], 14.3 [CH<sub>3</sub>], 13.0 [CH<sub>3</sub>]. (ESI<sup>+</sup>)-MS: *m/z* 393 [M+H]<sup>+</sup>. HR-(ESI<sup>+</sup>)-MS *m/z* calcd  
19 for C<sub>23</sub>H<sub>26</sub>FN<sub>4</sub>O: 393.2090 [M+H]<sup>+</sup>, found 393.2084.

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22 ***N,N*-Diethyl-2-(2-(4-(4-fluorobut-1-yn-1-yl)phenyl)-5,7-dimethylpyrazolo[1,5-a]pyrimidin-3-**  
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24 **yl)acetamide (22).** Starting from 260 mg (0.643 mmol) of **18** and using the general procedure  
25 described above, compound **22** (162 mg, 0.399 mmol, 62 % yield) was isolated as a colorless oil. R<sub>f</sub>  
26 (CH<sub>2</sub>Cl<sub>2</sub>/MeOH 93/7, v/v): 0.48. *t<sub>R</sub>* (HPLC A) = 1.20 min. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.77 (d, J = 8.0 Hz,  
27 2H), 7.48 (d, J = 8.0 Hz, 2H), 6.52 (s, 1H), 4.60 (dt, J<sup>2</sup><sub>HF</sub> = 46.8 Hz, J<sup>3</sup><sub>HH</sub> = 6.8 Hz, 2H), 3.94 (s, 2H),  
28 3.50 (q, J = 7.2 Hz, 2H), 3.40 (q, J = 7.2 Hz, 2H), 2.86 (dt, J<sup>3</sup><sub>HF</sub> = 19.2 Hz, J<sup>3</sup><sub>HH</sub> = 6.8 Hz, 2H), 2.73  
29 (s, 3H), 2.55 (s, 3H), 1.24 (t, J = 7.2 Hz), 1.11 (t, J = 7.2 Hz, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 169.6 [C],  
30 157.6 [C], 154.0 [C], 147.5 [C], 145.1 [C], 133.2 [C], 131.7 [2xCH], 128.5 [2xCH], 123.1 [C], 108.3  
31 [CH], 101.3 [C], 89.4 [C], 85.1 [d, J<sup>3</sup><sub>CF</sub> = 6 Hz, C], 81.3 [d, J<sup>1</sup><sub>CF</sub> = 171 Hz, CH<sub>2</sub>], 42.2 [CH<sub>2</sub>], 40.6  
32 [CH<sub>2</sub>], 28.0 [CH<sub>2</sub>], 24.1 [CH<sub>3</sub>], 21.6 [d, J<sup>2</sup><sub>CF</sub> = 24 Hz, CH<sub>2</sub>], 16.9 [CH<sub>3</sub>], 14.3 [CH<sub>3</sub>], 13.0 [CH<sub>3</sub>].  
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(ESI<sup>+</sup>)-MS:  $m/z$  407 [M+H]<sup>+</sup>. HR-(ESI<sup>+</sup>)-MS  $m/z$  calcd for C<sub>24</sub>H<sub>28</sub>FN<sub>4</sub>O: 407.2247 [M+H]<sup>+</sup>, found 407.2248.

***N,N*-Diethyl-2-(2-(4-(5-fluoropent-1-yn-1-yl)phenyl)-5,7-dimethylpyrazolo[1,5-*a*]pyrimidin-3-yl)acetamide (23)**. Starting from 260 mg (0.622 mmol) of **19** and using the general procedure described above, compound **23** (50 mg, 0.118 mmol, 19 % yield) was isolated as a light yellow powder.  $R_f$  (CH<sub>2</sub>Cl<sub>2</sub>/MeOH 93/7, v/v): 0.54.  $t_R$  (HPLC A) = 1.30 min. <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  7.76 (d,  $J$  = 8.0 Hz, 2H), 7.47 (d,  $J$  = 8.0 Hz, 2H), 6.54 (s, 1H), 4.62 (dt,  $J^2_{HF}$  = 47.2 Hz,  $J^3_{HH}$  = 6.0 Hz, 2H), 3.97 (s, 2H), 3.50 (q,  $J$  = 7.2 Hz, 2H), 3.41 (q,  $J$  = 7.2 Hz, 2H), 2.76 (s, 3H), 2.59 (t,  $J$  = 7.2 Hz, 2H), 2.58 (s, 3H), 2.01 (dt,  $J^3_{HF}$  = 25.6 Hz,  $J^3_{HH}$  = 7.2 & 6.0 Hz, 2H), 1.23 (t,  $J$  = 7.2 Hz, 3H), 1.12 (t,  $J$  = 7.2 Hz, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>)  $\delta$  169.7 [C], 157.6 [C], 154.5 [C], 147.4 [C], 145.2 [C], 133.0 [C], 131.6 [2xCH], 128.4 [2xCH], 123.5 [C], 108.4 [CH], 101.3 [C], 89.3 [C], 82.5 [d,  $J^1_{CF}$  = 164 Hz, CH<sub>2</sub>], 81.2 [C], 42.2 [CH<sub>2</sub>], 40.6 [CH<sub>2</sub>], 29.5 [d,  $J^2_{CF}$  = 20 Hz, CH<sub>2</sub>], 28.0 [CH<sub>2</sub>], 24.3 [CH<sub>3</sub>], 16.9 [CH<sub>3</sub>], 15.4 [d,  $J^3_{CF}$  = 4 Hz, CH<sub>2</sub>], 14.3 [CH<sub>3</sub>], 13.0 [CH<sub>3</sub>]. (ESI<sup>+</sup>)-MS:  $m/z$  421 [M+H]<sup>+</sup>. HR-(ESI<sup>+</sup>)-MS  $m/z$  calcd for C<sub>25</sub>H<sub>30</sub>FN<sub>4</sub>O: 421.2404 [M+H]<sup>+</sup>, found 421.2404.

***N,N*-Diethyl-2-(2-(4-(6-fluorohex-1-yn-1-yl)phenyl)-5,7-dimethylpyrazolo[1,5-*a*]pyrimidin-3-yl)acetamide (24)**. Starting from 86 mg (0.199 mmol) of **20** and using the general procedure described above, compound **24** (33 mg, 0.076 mmol, 38 % yield) was isolated as a colorless oil.  $R_f$  (toluene/acetone 60/40, v/v): 0.52.  $t_R$  (HPLC A) = 1.33 min. <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  7.76 (d,  $J$  = 8.0 Hz, 2H), 7.46 (d,  $J$  = 8.0 Hz, 2H), 6.54 (s, 1H), 4.52 (dt,  $J^2_{HF}$  = 47.2 Hz,  $J^3_{HH}$  = 6.0 Hz, 2H), 3.96 (s, 2H), 3.50 (q,  $J$  = 7.2 Hz, 2H), 3.42 (q,  $J$  = 7.2 Hz, 2H), 2.75 (s, 3H), 2.58 (s, 3H), 2.50 (t,  $J$  = 7.2 Hz, 2H), 1.89 (dt,  $J^3_{HF}$  = 25.6 Hz,  $J^3_{HH}$  = 7.2 & 6.0 Hz, 2H), 1.75 (q<sup>5</sup>,  $J$  = 7.2 Hz, 2H), 1.20 (t,  $J$  = 7.2 Hz, 3H), 1.10 (t,  $J$  = 7.2 Hz, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>)  $\delta$  169.6 [C], 157.6 [C], 154.9 [C], 147.5 [C], 146.0 [C], 132.7 [C], 131.6 [2xCH], 128.4 [2xCH], 123.8 [C], 108.3 [CH], 101.3 [C], 90.3 [C], 83.6 [d,  $J^1_{CF}$  = 164 Hz, CH<sub>2</sub>], 81.1 [C], 42.2 [CH<sub>2</sub>], 40.6 [CH<sub>2</sub>], 29.5 [d,  $J^2_{CF}$  = 20 Hz, CH<sub>2</sub>], 28.0 [CH<sub>2</sub>], 24.4 [d,  $J^3_{CF}$

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3 = 5 Hz, CH<sub>2</sub>], 23.9 [CH<sub>3</sub>], 19.1 [CH<sub>2</sub>], 16.9 [CH<sub>3</sub>], 14.2 [CH<sub>3</sub>], 13.0 [CH<sub>3</sub>]. (ESI<sup>+</sup>)-MS: *m/z* 435  
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5 [M+H]<sup>+</sup>. HR-(ESI<sup>+</sup>)-MS *m/z* calcd for C<sub>26</sub>H<sub>32</sub>FN<sub>4</sub>O: 435.2560 [M+H]<sup>+</sup>, found 435.2560.  
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8       **General procedure for the synthesis of *N,N*-diethyl-2-(2-(4-(*n*-hydroxyalkyl)phenyl)-5,7-**  
9 **dimethylpyrazolo[1,5-*a*]pyrimidin-3-yl)acetamide (25-27).** To a solution of the appropriate *N,N*-  
10 diethyl-2-(2-(4-(4-hydroxyalk-1-yn-1-yl)phenyl)-5,7-dimethylpyrazolo[1,5-*a*]pyrimidin-3-  
11 yl)acetamide (**18-20**) in dichloromethane (4-5 mL) was added 10 % palladium on charcoal (5 mol  
12 %). The reaction flask was degassed under vacuum and filled with hydrogen at 1 atm. and the  
13 reaction mixture was stirred at ambient temperature for 24 h. The mixture was then filtered on a silica  
14 pad and washed with a mixture of CH<sub>2</sub>Cl<sub>2</sub>/MeOH (8/2, v/v). The filtrate was concentrated to dryness  
15 and the residue was purified by silica gel column chromatography using CH<sub>2</sub>Cl<sub>2</sub>/MeOH (99/1 to 95/5  
16 v/v) as eluent to afford the title compounds.  
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29       ***N,N*-Diethyl-2-(2-(4-(4-hydroxybutyl)phenyl)-5,7-dimethylpyrazolo[1,5-*a*]pyrimidin-3-**  
30 **yl)acetamide (25).** Starting from 136 mg (0.302 mmol) of **18** and using the general procedure  
31 described above, compound **25** (94 mg, 0.230 mmol, 76 % yield) was isolated as a light yellow oil. R<sub>f</sub>  
32 (CH<sub>2</sub>Cl<sub>2</sub>/MeOH 93/7, v/v): 0.26. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.71 (d, J = 8.0 Hz, 2H), 7.25 (d, J = 8.0 Hz,  
33 2H), 6.50 (s, 1H), 3.91 (s, 2H), 3.63 (t, J = 6.4 Hz, 2H), 3.48 (q, J = 7.2 Hz, 2H), 3.40 (q, J = 7.2 Hz,  
34 2H), 2.73 (s, 3H), 2.67 (t, J = 6.4 Hz, 2H), 2.62 (s, 3H), 1.72 (q<sup>5</sup>, J = 6.4 Hz, 2H), 1.60 (q<sup>5</sup>, J = 6.4  
35 Hz, 2H), 1.19 (t, J = 7.2 Hz, 3H), 1.09 (t, J = 7.2 Hz, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 170.0 [C], 157.5 [C],  
36 155.1 [C], 147.6 [C], 144.7 [C], 142.5 [C], 131.1 [C], 128.6 [2xCH], 128.5 [2xCH], 108.2 [CH],  
37 100.9 [C], 62.6 [CH<sub>2</sub>], 42.2 [CH<sub>2</sub>], 40.5 [CH<sub>2</sub>], 35.4 [CH<sub>2</sub>], 32.2 [CH<sub>2</sub>], 28.0 [CH<sub>2</sub>], 27.4 [CH<sub>2</sub>], 24.6  
38 [CH<sub>3</sub>], 16.9 [CH<sub>3</sub>], 14.2 [CH<sub>3</sub>], 13.0 [CH<sub>3</sub>]. HR-(ESI<sup>+</sup>)-MS *m/z* calcd for C<sub>24</sub>H<sub>33</sub>N<sub>4</sub>O<sub>2</sub>: 409.2604  
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51 [M+H]<sup>+</sup>, found 409.2620.  
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***N,N*-Diethyl-2-(2-(4-(4-hydroxypentyl)phenyl)-5,7-dimethylpyrazolo[1,5-a]pyrimidin-3-yl)acetamide (26)**. Starting from 200 mg (0.478 mmol) of **19** and using the general procedure described above, compound **26** (80 mg, 0.189 mmol, 40 % yield) was isolated as a yellow oil.  $R_f$  (CH<sub>2</sub>Cl<sub>2</sub>/MeOH 9/1, v/v): 0.45. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.71 (d, J = 8.0 Hz, 2H), 7.26 (d, J = 8.0 Hz, 2H), 6.54 (s, 1H), 4.00 (s, 2H), 3.64 (t, J = 7.2 Hz, 2H), 3.50 (q, J = 7.2 Hz, 2H), 3.41 (q, J = 7.2 Hz, 2H), 2.77 (s, 3H), 2.67 (t, J = 8.0 Hz, 2H), 2.61 (s, 3H), 1.67 (q<sup>5</sup>, J = 7.2 Hz, 2H), 1.60 (q<sup>5</sup>, J = 7.2 Hz, 2H), 1.43 (m, 2H), 1.20 (t, J = 7.2 Hz, 3H), 1.10 (t, J = 7.2 Hz, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 169.9 [C], 157.4 [C], 154.8 [C], 147.8 [C], 145.0 [C], 142.7 [C], 131.0 [C], 128.6 [4xCH], 108.1 [CH], 101.0 [C], 62.9 [CH<sub>2</sub>], 42.2 [CH<sub>2</sub>], 40.5 [CH<sub>2</sub>], 35.6 [CH<sub>2</sub>], 32.6 [CH<sub>2</sub>], 31.1 [CH<sub>2</sub>], 28.1 [CH<sub>2</sub>], 25.2 [CH<sub>2</sub>], 24.5 [CH<sub>3</sub>], 16.9 [CH<sub>3</sub>], 14.2 [CH<sub>3</sub>], 13.0 [CH<sub>3</sub>]. HR-(ESI<sup>+</sup>)-MS  $m/z$  calcd for C<sub>25</sub>H<sub>35</sub>N<sub>4</sub>O<sub>2</sub>: 423.2760 [M+H]<sup>+</sup>, found 423.2751.

***N,N*-Diethyl-2-(2-(4-(4-hydroxyhexyl)phenyl)-5,7-dimethylpyrazolo[1,5-a]pyrimidin-3-yl)acetamide (27)**. Starting from 136 mg (0.314 mmol) of **20** and using the general procedure described above, compound **27** (99 mg, 0.226 mmol, 72 % yield) was isolated as a light yellow gum.  $R_f$  (CH<sub>2</sub>Cl<sub>2</sub>/MeOH 93/7, v/v): 0.30. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.71 (d, J = 8.0 Hz, 2H), 7.24 (d, J = 8.0 Hz, 2H), 6.51 (s, 1H), 3.92 (s, 2H), 3.61 (t, J = 6.8 Hz, 2H), 3.48 (q, J = 7.2 Hz, 2H), 3.40 (q, J = 7.2 Hz, 2H), 2.74 (s, 3H), 2.64 (t, J = 8.0 Hz, 2H), 2.54 (s, 3H), 1.64 (q<sup>5</sup>, J = 6.8 Hz, 2H), 1.54 (q<sup>5</sup>, J = 6.8 Hz, 2H), 1.34 (m, 4H), 1.18 (t, J = 7.2 Hz, 3H), 1.11 (t, J = 7.2 Hz, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 170.0 [C], 157.4 [C], 155.2 [C], 147.6 [C], 144.5 [C], 142.9 [C], 131.0 [C], 128.5 [4xCH], 108.2 [CH], 100.9 [C], 62.8 [CH<sub>2</sub>], 42.2 [CH<sub>2</sub>], 40.5 [CH<sub>2</sub>], 35.6 [CH<sub>2</sub>], 32.6 [CH<sub>2</sub>], 31.3 [CH<sub>2</sub>], 28.9 [CH<sub>2</sub>], 28.0 [CH<sub>2</sub>], 25.5 [CH<sub>2</sub>], 24.5 [CH<sub>3</sub>], 16.9 [CH<sub>3</sub>], 14.2 [CH<sub>3</sub>], 13.0 [CH<sub>3</sub>]. HR-(ESI<sup>+</sup>)-MS  $m/z$  calcd for C<sub>26</sub>H<sub>37</sub>N<sub>4</sub>O<sub>2</sub>: 437.2917 [M+H]<sup>+</sup>, found 437.2914.

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**General procedure for the synthesis of *N,N*-diethyl-2-(2-(4-(*n*-fluoroalkyl)phenyl)-5,7-dimethylpyrazolo[1,5-*a*]pyrimidin-3-yl)acetamide (28-30).** To the appropriate *N,N*-diethyl-2-(2-(4-(*n*-hydroxyalkyl)phenyl)-5,7-dimethylpyrazolo[1,5-*a*]pyrimidin-3-yl)acetamide (**25-27**) dissolved in toluene (2-4 mL) and dichloromethane (1.0-2.5 mL), were added 2-3 eq of a 50% Deoxo-Fluor<sup>®</sup> solution in toluene. The reaction mixture was stirred for 24 to 72 h at ambient temperature and additional Deoxo-Fluor<sup>®</sup> solution was added if required (TLC monitoring) to complete the conversion of the starting alcohol. The solvent was removed under vacuum and the resulting residue was dissolved in ethyl acetate (20 mL) and successively washed with water (20 mL) and brine (20 mL) before being dried over sodium sulfate, filtered and evaporated to dryness. The crude material was purified by silica gel column chromatography using CH<sub>2</sub>Cl<sub>2</sub>/MeOH (99/1 to 95/5, v/v) as eluent to yield the title compounds.

***N,N*-Diethyl-2-(2-(4-(4-fluorobutyl)phenyl)-5,7-dimethylpyrazolo[1,5-*a*]pyrimidin-3-yl)acetamide (28).** Starting from 140 mg (0.342 mmol) of **25** and using the general procedure described above, compound **28** (60 mg, 0.146 mmol, 43 % yield) was isolated as a yellow oil. *R*<sub>f</sub> (CH<sub>2</sub>Cl<sub>2</sub>/MeOH 93/7, v/v): 0.59. *t*<sub>r</sub> (HPLC A) = 1.25 min. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.73 (d, *J* = 8.0 Hz, 2H), 7.26 (d, *J* = 8.0 Hz, 2H), 6.52 (s, 1H), 4.46 (dt, *J*<sup>2</sup><sub>HF</sub> = 47.2 Hz, *J*<sup>3</sup><sub>HH</sub> = 5.6 Hz, 2H), 3.96 (s, 2H), 3.50 (q, *J* = 7.2 Hz, 2H), 3.41 (d, *J* = 7.2 Hz, 2H), 2.75 (s, 3H), 2.70 (t, *J* = 6.8 Hz, 2H), 2.57 (s, 3H), 1.80-1.70 (m, 4H), 1.23 (t, *J* = 7.2 Hz, 3H), 1.10 (t, *J* = 7.2 Hz, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 169.8 [C], 157.4 [C], 155.0 [C], 147.5 [C], 144.8 [C], 142.2 [C], 131.1 [C], 128.6 [2xCH], 128.5 [2xCH], 108.1 [CH], 101.0 [C], 83.9 [d, *J*<sup>1</sup><sub>CF</sub> = 163 Hz, CH<sub>2</sub>], 42.2 [CH<sub>2</sub>], 40.6 [CH<sub>2</sub>], 35.1 [CH<sub>2</sub>], 29.8 [d, *J*<sup>2</sup><sub>CF</sub> = 19 Hz, CH<sub>2</sub>], 28.1 [CH<sub>2</sub>], 26.8 [d, *J*<sup>3</sup><sub>CF</sub> = 5 Hz, CH<sub>2</sub>], 24.1 [CH<sub>3</sub>], 16.9 [CH<sub>3</sub>], 14.2 [CH<sub>3</sub>], 13.0 [CH<sub>3</sub>]. HR-ESI(+)-MS *m/z* calcd for C<sub>24</sub>H<sub>32</sub>FN<sub>4</sub>O: 411.2560 [M+H]<sup>+</sup>, found 411.2578.

***N,N*-Diethyl-2-(2-(4-(5-fluoropentyl)phenyl)-5,7-dimethylpyrazolo[1,5-a]pyrimidin-3-yl)acetamide (29)**. Starting from 160 mg (0.378 mmol) of **26** and using the general procedure described above, compound **29** (88 mg, 0.208 mmol, 55 % yield) was isolated as colorless oil.  $R_f$  (heptane/acetone 50/50, v/v): 0.39.  $t_R$  (HPLC A) = 1.35 min.  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  7.72 (d,  $J = 8.0$  Hz, 2H), 7.25 (d,  $J = 8.0$  Hz, 2H), 6.51 (s, 1H), 4.43 (dt,  $J_{\text{HF}}^2 = 47.6$  Hz,  $J_{\text{HH}}^3 = 6.0$  Hz, 2H), 3.95 (s, 2H), 3.49 (q,  $J = 7.2$  Hz, 2H), 3.41 (q,  $J = 7.2$  Hz, 2H), 2.74 (s, 3H), 2.67 (t,  $J = 7.6$  Hz, 2H), 2.56 (s, 3H), 1.80-1.65 (m, 4H), 1.46 (m, 2H), 1.20 (t,  $J = 7.2$  Hz, 3H), 1.10 (t,  $J = 7.2$  Hz, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  169.8 [C], 157.4 [C], 155.0 [C], 147.8 [C], 145.1 [C], 142.6 [C], 131.0 [C], 128.6 [2xCH], 128.5 [2xCH], 108.1 [CH], 101.0 [C], 84.0 [d,  $J_{\text{CF}}^1 = 163$  Hz,  $\text{CH}_2$ ], 42.2 [ $\text{CH}_2$ ], 40.5 [ $\text{CH}_2$ ], 35.5 [ $\text{CH}_2$ ], 30.9 [ $\text{CH}_2$ ], 30.2 [d,  $J_{\text{CF}}^2 = 19$  Hz,  $\text{CH}_2$ ], 28.1 [ $\text{CH}_2$ ], 24.7 [d,  $J_{\text{CF}}^3 = 6$  Hz,  $\text{CH}_2$ ], 24.2 [ $\text{CH}_3$ ], 16.9 [ $\text{CH}_3$ ], 14.2 [ $\text{CH}_3$ ], 13.0 [ $\text{CH}_3$ ]. HR-ESI(+)-MS  $m/z$  calcd for  $\text{C}_{25}\text{H}_{34}\text{FN}_4\text{O}$ : 425.2717 [ $\text{M}+\text{H}$ ] $^+$ , found 425.2718.

***N,N*-Diethyl-2-(2-(4-(6-fluorohexyl)phenyl)-5,7-dimethylpyrazolo[1,5-a]pyrimidin-3-yl)acetamide (30)**. Starting from 140 mg (0.320 mmol) of **27** and using the general procedure described above, compound **30** (82 mg, 0.186 mmol, 58 % yield) was isolated as an orange oil.  $R_f$  ( $\text{CH}_2\text{Cl}_2/\text{MeOH}$  93/7, v/v): 0.63.  $t_R$  (HPLC A) = 1.43 min.  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  7.72 (d,  $J = 8.0$  Hz, 2H), 7.25 (d,  $J = 8.0$  Hz, 2H), 6.51 (s, 1H), 4.43 (dt,  $J_{\text{HF}}^2 = 47.6$  Hz,  $J_{\text{HH}}^3 = 6.0$  Hz, 2H), 3.94 (s, 2H), 3.49 (q,  $J = 7.2$  Hz, 2H), 3.41 (q,  $J = 7.2$  Hz, 2H), 2.74 (s, 3H), 2.65 (t,  $J = 7.6$  Hz, 2H), 2.55 (s, 3H), 1.75-1.62 (m, 4H), 1.45-1.30 (m, 4H), 1.20 (t,  $J = 7.2$  Hz, 3H), 1.10 (t,  $J = 7.2$  Hz, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ )  $\delta$  169.9 [C], 157.4 [C], 155.5 [C], 147.3 [C], 145.0 [C], 142.8 [C], 130.9 [C], 128.5 [4xCH], 108.1 [CH], 101.0 [C], 84.1 [d,  $J_{\text{CF}}^1 = 163$  Hz,  $\text{CH}_2$ ], 42.2 [ $\text{CH}_2$ ], 40.5 [ $\text{CH}_2$ ], 35.6 [ $\text{CH}_2$ ], 31.2 [ $\text{CH}_2$ ], 30.3 [d,  $J_{\text{CF}}^2 = 19$  Hz,  $\text{CH}_2$ ], 28.7 [ $\text{CH}_2$ ], 28.1 [ $\text{CH}_2$ ], 25.0 [d,  $J_{\text{CF}}^3 = 5$  Hz,  $\text{CH}_2$ ], 24.2 [ $\text{CH}_3$ ], 16.9

[CH<sub>3</sub>], 14.2 [CH<sub>3</sub>], 13.0 [CH<sub>3</sub>]. HR-ESI(+)-MS *m/z* calcd for C<sub>26</sub>H<sub>36</sub>FN<sub>4</sub>O: 439.2873 [M+H]<sup>+</sup>, found 439.2889.

**3-(4-(3-(2-(Diethylamino)-2-oxoethyl)-5,7-dimethylpyrazolo[1,5-a]pyrimidin-2-yl)phenyl)propyl 4-methylbenzenesulfonate (31).** To 150 mg of *N,N*-diethyl-2-(2-(4-(3-hydroxypropyl)phenyl)-5,7-dimethylpyrazolo[1,5-a]pyrimidin-3-yl)acetamide **11** (0.381 mmol) dissolved in dichloromethane (5 mL), were added *p*-toluenesulfonyl chloride (87 mg, 0.457 mmol) and triethylamine (106 μL, 0.761 mmol). The reaction mixture was stirred at ambient temperature for 16 h and quenched with addition of a 1.0 M aqueous hydrochloric acid solution (30 mL). The product was extracted with ethyl acetate (20 mL) and the resulting organic layer washed with brine before being dried over sodium sulfate, filtered and evaporated to dryness. The resulting residue was purified by silica gel column chromatography using CH<sub>2</sub>Cl<sub>2</sub>/MeOH (98/2, v/v) as eluent to yield compound **31** (178 mg, 0.325 mmol, 85 % yield) as a light yellow oil. *R<sub>f</sub>* (CH<sub>2</sub>Cl<sub>2</sub>/MeOH 92/8, v/v): 0.35. <sup>1</sup>H NMR (CD<sub>2</sub>Cl<sub>2</sub>) δ 7.78 (d, *J* = 8.0 Hz, 2H), 7.67 (d, *J* = 8.0 Hz, 2H), 7.38 (d, *J* = 8.0 Hz, 2H), 7.17 (d, *J* = 8.0 Hz, 2H), 6.56 (s, 1H), 4.03 (t, *J* = 6.4 Hz, 2H), 3.88 (s, 2H), 3.49 (q, *J* = 7.2 Hz, 2H), 3.37 (q, *J* = 7.2 Hz, 2H), 2.73 (s, 3H), 2.69 (t, *J* = 7.6 Hz, 2H), 2.53 (s, 3H), 2.45 (s, 3H), 1.98 (m, 2H), 1.22 (t, *J* = 7.2 Hz, 3H), 1.09 (t, *J* = 7.2 Hz, 3H). <sup>13</sup>C NMR (CD<sub>2</sub>Cl<sub>2</sub>) δ 169.6 [C], 157.6 [C], 154.3 [C], 147.6 [C], 145.0 [C], 144.8 [C], 140.7 [C], 133.0 [C], 131.8 [C], 129.8 [2×CH], 128.5 [2×CH], 128.4 [2×CH], 127.7 [2×CH], 108.2 [CH], 101.0 [C], 69.7 [CH<sub>2</sub>], 42.1 [CH<sub>2</sub>], 40.4 [CH<sub>2</sub>], 31.1 [CH<sub>2</sub>], 30.3 [CH<sub>2</sub>], 27.9 [CH<sub>2</sub>], 24.3 [CH<sub>3</sub>], 21.3 [CH<sub>3</sub>], 16.5 [CH<sub>3</sub>], 14.0 [CH<sub>3</sub>], 12.8 [CH<sub>3</sub>]. ESI(+)-MS (*m/z*): 549 [M+H]<sup>+</sup>, 571 [M+Na]<sup>+</sup>, 587 [M+K]<sup>+</sup>. HR-ESI(+)-MS *m/z* calcd for C<sub>30</sub>H<sub>37</sub>N<sub>4</sub>O<sub>4</sub>S: 549.2536 [M+H]<sup>+</sup>, found 549.2541.

**5-(4-(3-(2-(Diethylamino)-2-oxoethyl)-5,7-dimethylpyrazolo[1,5-a]pyrimidin-2-yl)phenyl)pent-4-yn-1-yl 4-methylbenzenesulfonate (32).** To 200 mg of *N,N*-diethyl-2-(2-(4-(5-

hydroxypent-1-yn-1-yl)phenyl)-5,7-dimethylpyrazolo[1,5-a]pyrimidin-3-yl)acetamide **19** (0.478 mmol) dissolved in dichloromethane (8 mL), were added at 0°C, *p*-toluenesulfonic anhydride (170 mg, 0.520 mmol) and triethylamine (166 μL, 1.20 mmol). The reaction mixture was stirred at ambient temperature for 5 h and quenched with addition of a 1.0 M aqueous hydrochloric acid solution (50 mL). The product was extracted with ethyl acetate (50 mL) and the resulting organic layer washed with brine before being dried over sodium sulfate, filtered and evaporated to dryness. The resulting residue was purified by silica gel column chromatography using CH<sub>2</sub>Cl<sub>2</sub>/MeOH (98/2, v/v) as eluent to yield compound **32** (150 mg, 0.263 mmol, 55 % yield) as a white solid. *R*<sub>f</sub> (CH<sub>2</sub>Cl<sub>2</sub>/MeOH 95/5, v/v): 0.45. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.80 (d, *J* = 8.0 Hz, 2H), 7.76 (d, *J* = 8.0 Hz, 2H), 7.36 (d, *J* = 8.0 Hz, 2H), 7.31 (d, *J* = 8.0 Hz, 2H), 6.53 (s, 1H), 4.21 (t, *J* = 5.6 Hz, 2H), 3.94 (s, 2H), 3.51 (q, *J* = 7.2 Hz, 2H), 3.40 (q, *J* = 7.2 Hz, 2H), 2.74 (s, 3H), 2.55 (s, 3H), 2.49 (t, *J* = 6.8 Hz, 2H), 2.39 (s, 3H), 1.94 (m, 2H), 1.23 (t, *J* = 7.2 Hz, 3H), 1.11 (t, *J* = 7.2 Hz, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 169.7 [C], 157.6 [C], 154.4 [C], 147.0 [C], 145.0 [C], 144.8 [C], 133.1 [C], 132.8 [C], 131.6 [2×CH], 129.8 [2×CH], 128.4 [2×CH], 127.8 [2×CH], 123.3 [C], 108.4 [CH], 101.3 [C], 88.4 [C], 81.7 [C], 68.9 [CH<sub>2</sub>], 42.2 [CH<sub>2</sub>], 40.6 [CH<sub>2</sub>], 28.0 [CH<sub>2</sub>], 27.9 [CH<sub>2</sub>], 24.3 [CH<sub>3</sub>], 21.6 [CH<sub>3</sub>], 16.8 [CH<sub>3</sub>], 15.7 [CH<sub>2</sub>], 14.3 [CH<sub>3</sub>], 13.0 [CH<sub>3</sub>]. ESI(+)-MS (*m/z*): 573 [M+H]<sup>+</sup>. HR-ESI(+)-MS *m/z* calcd for C<sub>32</sub>H<sub>37</sub>N<sub>4</sub>O<sub>4</sub>S: 573.2536 [M+H]<sup>+</sup>, found 573.2524.

**Radiochemistry. Radioisotope production.** No-carrier-added fluorine-18 (half-life: 109.8 min) was produced via the [<sup>18</sup>O(*p,n*)<sup>18</sup>F] nuclear reaction by irradiation of a 2 mL [<sup>18</sup>O]water (> 97 % enriched, Rotem, CortecNet, Paris, France) target on an IBA Cyclone-18/9 (IBA, Belgium) cyclotron (18 MeV proton beam) and the aqueous radioactive solution was then transferred to the appropriate hot cell. Target hardware: Commercial, 2 mL, two-port, stainless steel target holder equipped with a domed-end niobium cylinder insert. **Target to hot cell liquid-transfer system.** 50 m PTFE line (0.8

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3 mm internal diameter ; 1/16 inch external diameter), 2.0 bar helium drive pressure, transfer time 2-3  
4 min. Typical production of [ $^{18}\text{F}$ ]fluoride at the end of bombardment for a 30-61 min (14.0 – 25.7  
5  $\mu\text{A}\cdot\text{h}$ ) irradiation: 26.6 – 48.0 GBq (720–1.30 mCi). **Radiosynthesis.** Radiofluorination were  
6 performed on a slightly modified TRACERLab FX-FN synthesiser<sup>53</sup> (GE Medical Systems,  
7 Germany) and the data were collected and processed by the TRACERLab FX software (GE  
8 Healthcare). HPLC purification at the semi-preparative scale was performed with the following  
9 equipment and conditions: System equipped with a Waters 515 pump, a UV detector K-2501  
10 (Knauer, Germany) and a radioactivity gamma detector (integrated in the synthesiser); column: semi-  
11 preparative X-Terra<sup>TM</sup> RP18, 300 $\times$ 7.8 mm, 7  $\mu\text{m}$  (Waters); eluent 0.1 M aqueous  $\text{NH}_4\text{OAc}$  (pH  
12 10)/ $\text{CH}_3\text{CN}$ : 60/40 (v:v); flow rate: 6 mL/min; temperature: rt; absorbance detection at  $\lambda = 254$  nm.  
13 The radiotracer is finally automatically formulated in a saline/ethanol 80:20 (v:v) solution. **Quality**  
14 **control.** The radiotracer preparations were visually inspected for clarity, absence of colour and  
15 particulates. An aliquot of the preparation was removed for determination of pH using standard pH-  
16 paper (Duotest<sup>®</sup>, Macherey-Nagel, pH 1-12, Hoerd, France). Chemical and radiochemical purities  
17 were also assessed on this aliquot by HPLC (analytical HPLC), with an authentic sample of tracer (**1**  
18 or **23**). The following equipment and conditions were used: Equipment: Waters (Guyancourt, France)  
19 Alliance 2965 equipped with a UV spectrophotometer (Photodiode Array Detector, Waters 2996) and  
20 a Berthold LB509 radioactivity detector; column: analytical Symmetry<sup>®</sup> C18, 50 $\times$ 4.6 mm, 3.5  $\mu\text{m}$   
21 (Waters); conditions: isocratic elution with solvA/solvB: 35/65 (v:v) (solvent A:  $\text{H}_2\text{O}$  containing  
22 Low-UV PIC<sup>®</sup> B7 reagent (20 mL for 1 L); solvent B:  $\text{H}_2\text{O}/\text{CH}_3\text{CN}$ : 30:70 (v:v) containing Low-UV  
23 PIC<sup>®</sup> B7 reagent (20 mL for 1 L)); flow rate: 2.0 mL/min; temperature: rt; absorbance detection at  $\lambda$   
24 = 254 nm. Particular attention was paid to the absence of non-radioactive precursor for labelling (**31**  
25 or **32**). Chemical and radiochemical stabilities of the entire preparation were tested by HPLC  
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(analytical HPLC) at regular 15 min intervals during 150 min. Specific radioactivity of the radiotracer was calculated from three consecutive HPLC (analytical HPLC) analyses (average) and determined as follows: the area of the UV absorbance peak corresponding to the radiolabelled product was measured (integrated) on the HPLC-chromatogram and compared with a standard curve relating mass to UV absorbance.

***N,N*-diethyl-2-(2-(4-(3-[<sup>18</sup>F]fluoropropyl)phenyl)-5,7-dimethylpyrazolo[1,5-a]pyrimidin-3-yl)acetamide ([<sup>18</sup>F]12).** The cyclotron produced irradiated water, once transferred to the module, was aspirated through a Sep-Pak<sup>®</sup> Light Accell<sup>™</sup> Plus QMA-cartridge (Waters) to fix [<sup>18</sup>F]fluoride anions and remove the [<sup>18</sup>O]enriched water. [<sup>18</sup>F]Fluoride (33-52 GBq) was then eluted with a solution of K<sub>222</sub> (12-15 mg) and K<sub>2</sub>CO<sub>3</sub> (1.5 mg) in water/acetonitrile (30/70 v/v, 1 mL) into the reaction vessel. The dried, no-carrier-added, K[<sup>18</sup>F]F-K<sub>222</sub> complex was prepared by evaporation of the solution with heating under vacuum (60 °C for 7 min followed by 120 °C for 5 min). [<sup>18</sup>F]12 was obtained by addition of a solution of the precursor for labelling **31** (4.0 to 4.5 mg) in the appropriate solvent (CH<sub>3</sub>CN or DMSO, 700 μL) to the dried K[<sup>18</sup>F]F-K<sub>222</sub> complex and fluorine-18 incorporation was evaluated in CH<sub>3</sub>CN by heating the reaction mixture at 100 °C either for 5 min or 10 min, or in DMSO by heating the reaction mixture for 5 min at 165 °C. After this period of heating, the reaction mixture was cooled to 50°C and diluted with HPLC solvent (2 mL) before being transferred under pressure through a Sep-Pak<sup>®</sup> Alumina N cartridge (Waters) and finally collected in a HPLC tube. The reaction vessel was rinsed with HPLC solvent (2 mL) and the resulting solution transferred to the HPLC tube *via* the Sep-Pak<sup>®</sup> Alumina N cartridge. The crude solution (4.7 mL) collected in the HPLC tube was injected onto reverse phase HPLC column (semi-preparative HPLC) and the product fraction of [<sup>18</sup>F]12 was collected, diluted with water (10 mL), passed through a Sep-Pak<sup>®</sup> Plus C18 cartridge (Waters) to fix the radiotracer and remove residual acetonitrile or salts by washing the

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3 cartridge with additional water (5 mL) before elution of the cartridge with ethanol (2 mL) and  
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5 dilution of the ethanolic solution of [<sup>18</sup>F]**12** with 0.9% aq. NaCl solution (8 mL) for *i.v.* injection.  
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8 **N,N-diethyl-2-(2-(4-(5-[<sup>18</sup>F]fluoropent-1-yn-1-yl)phenyl)-5,7-dimethylpyrazolo[1,5-**  
9 **a]pyrimidin-3-yl)acetamide ([<sup>18</sup>F]**23**).** The preparation of [<sup>18</sup>F]**23** was achieved using the same  
10 procedure as described above for the preparation of [<sup>18</sup>F]**12**, starting from the precursor for labelling  
11 **32**, and using a heating period of 10 min at 100 °C in CH<sub>3</sub>CN.  
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19 **In vitro competition assays (Table 1).** Binding affinities for the TSPO (K<sub>i</sub>) were determined  
20 using membrane homogenates from rat heart and screened against [<sup>3</sup>H]PK11195 (K<sub>d</sub> = 1.8 nM, C =  
21 0.2 nM). Affinities for the CBR were determined at a unique concentration (1 μM), using membrane  
22 homogenates from rat cerebral cortex and screened against [<sup>3</sup>H]flunitrazepam (K<sub>d</sub> = 2.1 nM, C = 0.4  
23 nM).  
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33 **Partition coefficient (log D<sub>7.4</sub>) and LipE calculation (Table 1).** LogD<sub>7.4</sub> (*n*-octanol/buffer pH  
34 7.4 partition coefficient) values were determined based on a validated and standardized HPLC  
35 method, by conversion of the recorded retention time for each compound (correlation between  
36 retention times and known logD values of similar compounds). HPLC conditions: Alliance 2695 -  
37 PDA Waters, X-Terra MS C18 (4.6 x 20 mm, 3.5 μm) column ; mobile phase 5 mM MOPS /  
38 (CH<sub>3</sub>)<sub>4</sub>NOH pH 7.4 (A), 5 % MOPS / (CH<sub>3</sub>)<sub>4</sub>NOH (100 mM, pH 7.4) / 95 % CH<sub>3</sub>CN (B) ; gradient  
39 (A / B): 98:2 (0.5 min), 0:100 (4.8 min), 98:2 (1.6 min) ; 1.2 mL/min ; 25 °C ; detection at 254 nm.  
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50 LipE was calculated as follows: LipE = pIC<sub>50</sub> – logD<sub>7.4</sub>.  
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55 **In vitro metabolism (Table 2).** Compounds were incubated with hepatic microsomal fractions  
56 (male CD1 mouse, male Sprague-Dawley rat or humans (BD pool)) using the following experimental  
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3 conditions throughout the study: microsomal proteins concentration = 1 mg/mL; bovine serum  
4 albumin (BSA) concentration = 1 mg/mL; substrate concentration = 5  $\mu$ M; cofactor (if used, see  
5 below): 1 mM aq. NADPH. For each compound to be tested, 2 samples were prepared: Sample A:  
6 microsomal incubation, 0 min, without cofactor; Sample B: microsomal incubation, 20 min, with  
7 cofactor. Enzyme activity was stopped with 1 volume of ACN, and proteins removed by  
8 centrifugation. The supernatant fluids were then analysed by HPLC/ESI-MS/MS with the mass  
9 spectrometer set in selected ion recording (SIR) in positive mode. The data were collected and  
10 processed using MassLynx 4.0 software from Waters-Micromass, leading to quantification of the  
11 unchanged tested compound. Analytical HPLC conditions: C18 (125 x 2.1 mm, 3  $\mu$ m) column;  
12 mobile phase: (A) H<sub>2</sub>O containing NH<sub>4</sub>OAc (0.25 g/L) and HCO<sub>2</sub>H (2 mL/L), (B) ACN / MeOH (80  
13 / 20) containing NH<sub>4</sub>OAc (0.15 g/L), HCO<sub>2</sub>H (2 mL/L) and H<sub>2</sub>O (10 mL/L) ; gradient (A/B): 90:10  
14 (0.75 min), 0:100 (3.25 min), 90:10 (2.0 min) ; 0.3 mL/min; injection volume: 10  $\mu$ L. The  
15 percentages of biotransformation, consisting in oxidative reactions as well as non-co-factor-  
16 dependent reactions such as ester bond hydrolysis, were calculated using the following formula and  
17 are reported in Table 2:  
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$$38 \quad [\% \text{ biotransformation}] = \left[ 1 - \left( \frac{\text{Peak Area corresponding to unchanged compound in Sample B}}{\text{Peak Area corresponding to unchanged compound in Sample A}} \right) \right] \times 100$$

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44 ***In vitro* autoradiographies and *in vivo* small animal PET studies. Acute neuroinflammatory**  
45 **animal model.** Striatal AMPA-mediated excitotoxicity and acute local neuroinflammation in the  
46 brain of Wistar rats was induced according to reported procedures.<sup>23,34,52</sup> The protocol used includes a  
47 stereotactic injection in the right striatum of 0.5  $\mu$ L of AMPA ((*R,S*)- $\alpha$ -amino-3-hydroxy-5-methyl-4-  
48 isoxazolopropionic acid, 15 mM in phosphate buffered saline (PBS) buffer) in anaesthetised and  
49 normothermally-controlled animals followed by a resting period of 7 days. ***In vitro* brain**  
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3 **autoradiographies.** Brain slices of unilaterally AMPA-lesioned animals were prepared according to  
4 reported procedures.<sup>23,34,52</sup> The protocol used includes decapitation of the animals under terminal  
5 anaesthesia, quick brain removal and freezing in cold (-80°C, dry-ice) isopentane followed by  
6 coronally, 10 µm-thick slicing of the brain at the level of the lesion. Then, adjacent brain slices (36  
7 slices from the center of the lesioned area) were taken and incubated for 20 min in Tris Buffer  
8 (TRIZMA pre-set Crystals, Sigma<sup>®</sup>, adjusted at pH 7.4 at 4°C, 50 mM with NaCl 120 mM)  
9 containing the radiotracer alone [<sup>18</sup>F]**12** or [<sup>18</sup>F]-**23**, 90-111 MBq, 500-600 MBq/L, 5-10 nM), or the  
10 radiotracer and PK11195 (20 µM), the radiotracer and its non-labelled version (20 µM) as well as  
11 the radiotracer and flumazenil (20 µM). Brain sections were then washed 2 times for 2 min and once  
12 for 10 sec with cold (4°C) buffer, then exposed on a Phosphor-Imager screen overnight.  
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Autoradiograms were scanned and then analysed using the ImageJ software (developed by the National Institutes of Health). A region of interest (ROI) was manually drawn around the core of the lesion, and an identical area was copy-pasted symmetrically into the contralateral hemisphere. Binding in the ROI was then expressed as the number of counts per surface unit. The target-to-background ratio (TBR) was calculated as the ratio of the binding in the lesioned versus the contralateral hemisphere. **Small animal PET studies.** Rats (n = 4, 355 ± 22.5 g) were imaged with the radiotracer ([<sup>18</sup>F]**12** or [<sup>18</sup>F]**23**) seven days after intrastriatal injection of AMPA (see above) using a commercially available, small-animal-dedicated, INVEON PET/CT or PET only tomograph (Siemens, Munich, Germany). Anaesthesia of animals was induced by a mixture of isoflurane and O<sub>2</sub> (3% / 97%). Animals were then placed in a home-made stereotaxic frame compatible with PET acquisition, maintained anaesthetised by using only a 1.5%-2.5% mixture of isoflurane in O<sub>2</sub> and maintained normothermic using a heating pad (Heater Pad Biovet<sup>®</sup>, m2m Imaging Corp., Cleveland, OH, USA). Animals were injected with the radiotracer (0.9-1.1 mCi, 3 to 20 nmoles, 350 to 500 µL))

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3 in the caudal lateral vein using a 24 gauge catheter. Imaging started at the time of injection of the  
4 radiotracer and lasted for 60 min. 3D-PET acquisitions were performed with the coincidence time  
5 window set to 3.432 nsec and the energy levels of discrimination set to 350 keV and 650 keV. The  
6 list mode file of the emission scans was histogrammed into 24 dynamic frames (3 x 30 sec, 5 x 60  
7 sec, 5 x 2 min, 3 x 3 min, 3x 3 min, 4 x 5 min and 1 x 10 min) with a maximum ring difference of 79  
8 and a span of 3. A 3D attenuation correction file was generated with correction factors either  
9 measured using an external cobalt-57 point source (PET only tomograph) or using the CT X-ray  
10 source (PET/CT tomograph). The emission sinograms (i.e., each frame) were then normalized and  
11 corrected for attenuation and radioactivity decay. 3D images were finally reconstructed with the  
12 Fourier rebinning (FORE) and ordered-subsets expectation-maximization, 2-dimensional (OSEM  
13 2D) algorithms (16 subsets and 4 iterations). Image analysis and quantification of radioactivity  
14 uptake in volumes of interest (VOIs) were performed using Brain-Visa / Anatomist version 3.1  
15 (developed in-house<sup>54</sup>). On the ipsilateral side, delineation of the lesion area was made by manual  
16 segmentation on the summed-frame images spanning the last 30 min of the PET acquisition. A region  
17 of interest (ROI) was drawn on each adjacent transaxial section containing the lesion and combined  
18 to define a volume of interest (VOI). On the contralateral side, an ovoid VOI (4 x 4 x 4 voxels, 22  
19 mm<sup>3</sup>) was manually positioned in the center of the striatum. These VOIs were then projected onto all  
20 dynamic frames and the resulting time activity curves were then normalized for the percentage of  
21 injected dose per milliliter (%ID/mL).  
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## 50 ASSOCIATED CONTENT

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53 **Supporting information availability:**  
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<sup>1</sup>H and <sup>13</sup>C NMR spectra as well as HRMS data of synthesised and tested compounds **12**, **21–24** and **28–32**.

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### Notes

The authors declare no competing financial interest.

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## ABBREVIATIONS USED

CBR, central benzodiazepine receptor; d.c., decay-corrected; DPA, 3,5-dimethylpyrazolo[1,5-a]pyrimidin-3-yl acetamide; EOB, end of bombardment; EOS, end of synthesis; LipE, lipophilic

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3 efficiency; PTFE, polytetrafluoroethylene; RCY, radiochemical yield; ROI, region of interest; SRA,  
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5 specific radioactivity; TBR, target-to-background ratio; TSPO, translocator protein 18 kDa (formerly  
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7 known as peripheral benzodiazepine receptor, PBR); VOI, volume of interest.  
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