DE LA RECHERCHE À L'INDUSTRIE

Irfu - CEA Saclay
Institut de recherche sur les lois fondamentales de l'Univers

The Very-Near-Site at Chooz

a New Experimental Hall to Study CEνNS

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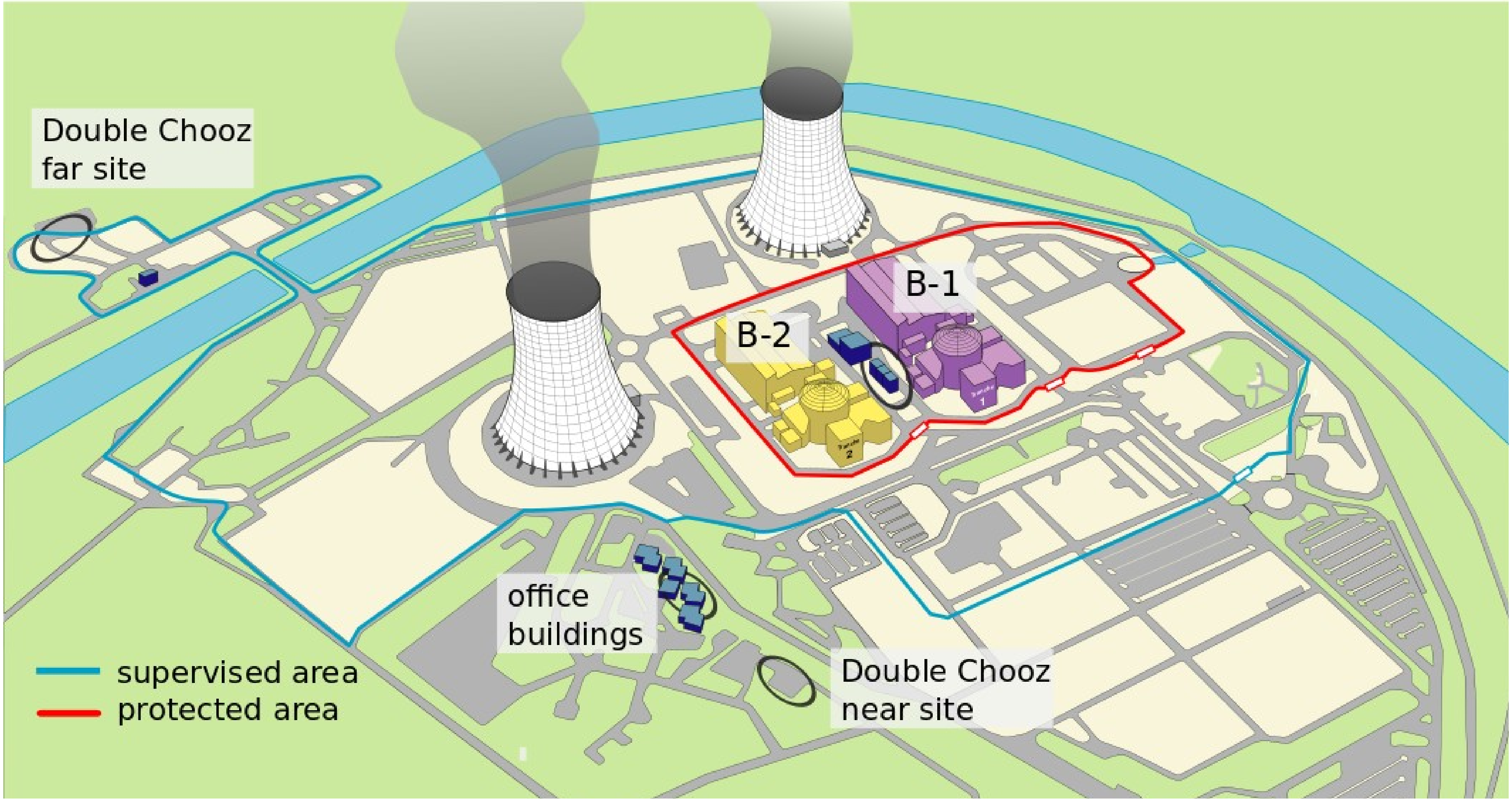
Magnificent CEvNS workshop, Nov 2nd-3rd 2018, Chicago

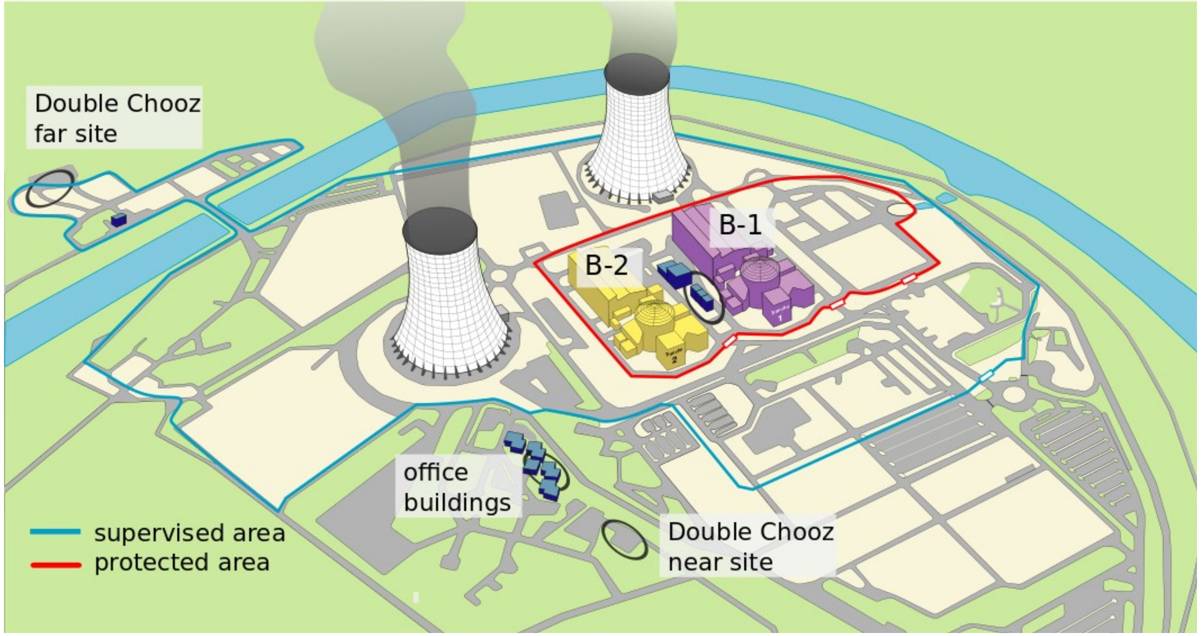
Outline

- The Chooz Nuclear Power Plant
- The Very-Near Site (VNS) @ Chooz
- NU-CLEUS @ VNS
- The BASKET Project – a possible synergy with NU-CLEUS

The Chooz Nuclear Power Plant



The Chooz Nuclear Power Plant



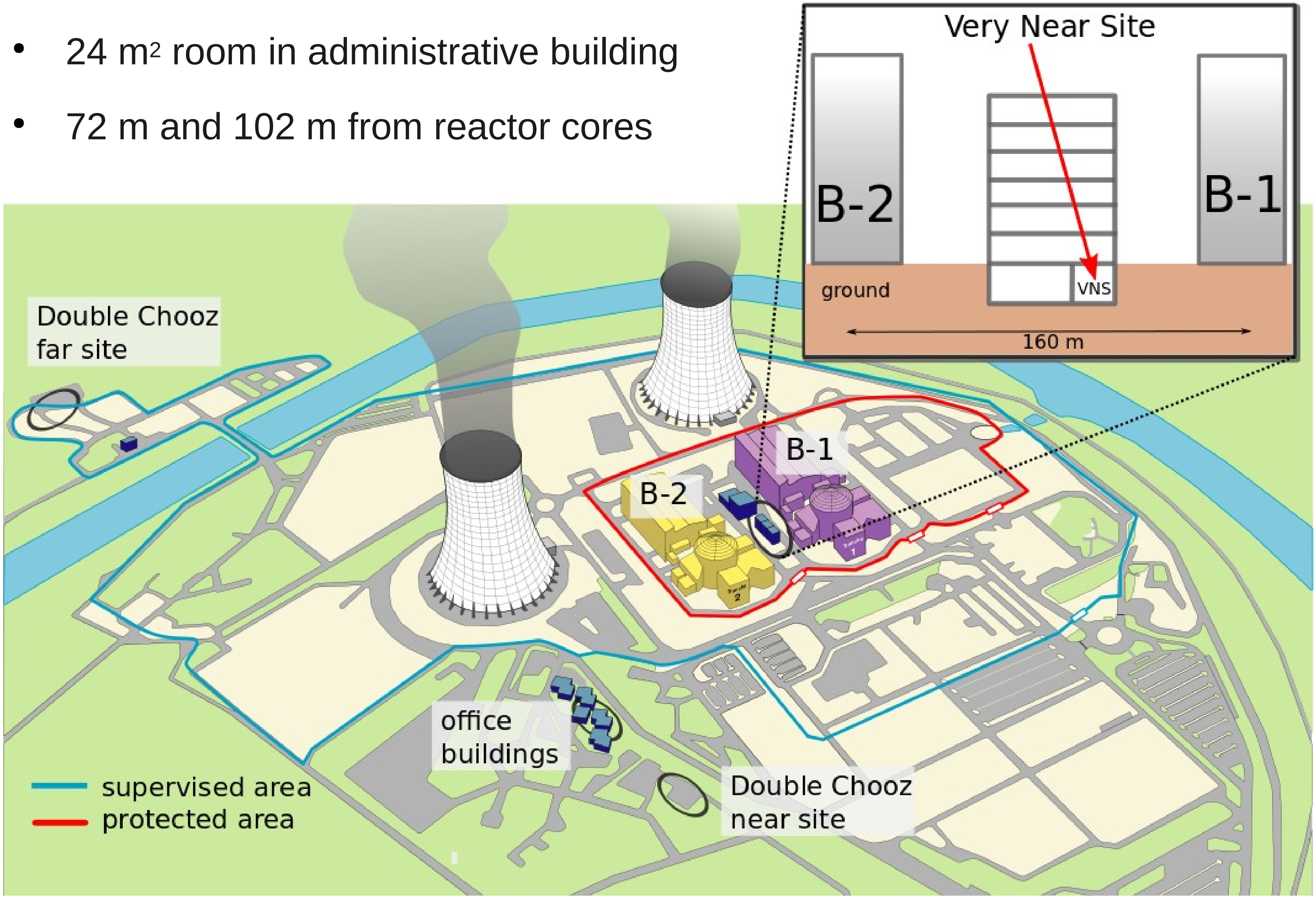
- Operated by Electricité de France (EdF) in the Ardennes region (northern France)
- 2 reactor cores, each with max. thermal power of **4.25 GW$_{th}$**
- Long history of ν-experiments :
  - 1996-1999 host of the Chooz experiment and
  - 2003-2018 of the Double Chooz experiment

→ **existing infrastructure with office buildings**

- Agreement between CEA and EdF drafted to establish experimental site for NU-CLEUS

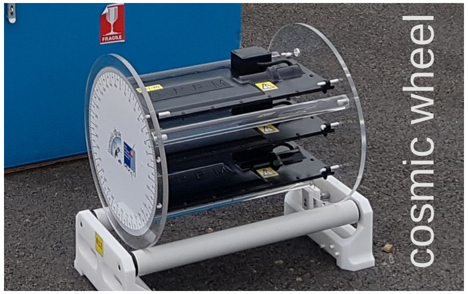
The Very-Near-Site (VNS) @ Chooz

- 24 m^2 room in administrative building
- 72 m and 102 m from reactor cores



Background Characterization Measurements

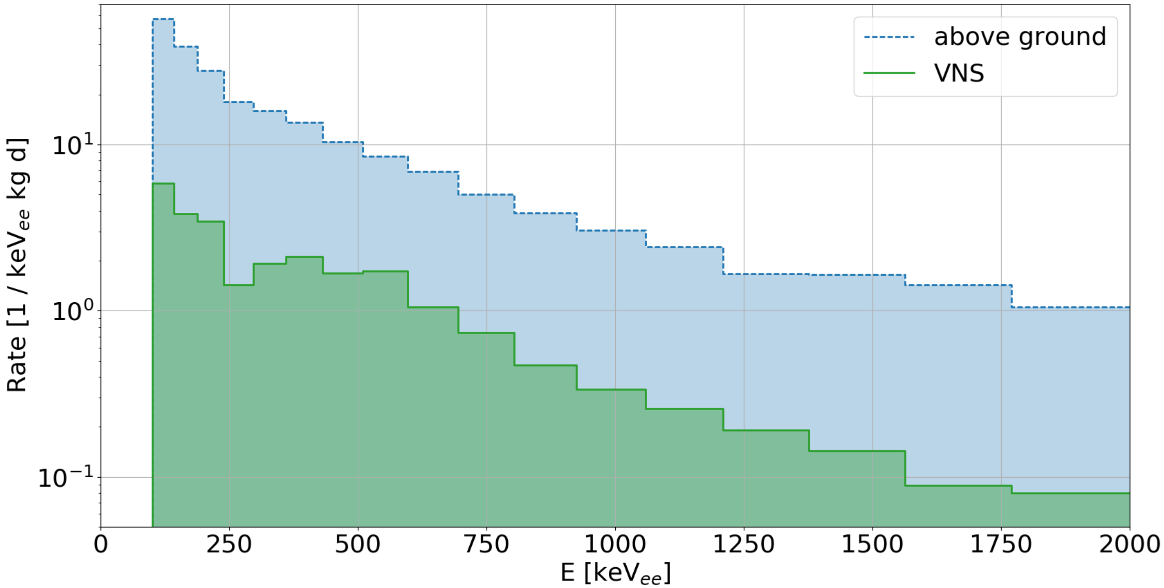
- Campaign to characterize background at VNS started
- First measurements perfomed at surface and VNS to determine **neutron and muon attenuation** factors, further measurements planned
- Results will be used to optimize the design of a compact shielding and evaluate expected backgrounds in target detectors
- **Vibration measurements** planned for end of 2018



Neutron Attenuation

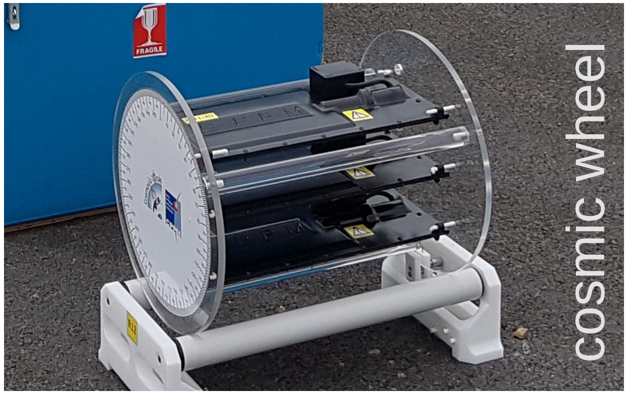
- Neutrons are expected to be a challenging background
- No neutrons from reactor cores expected
- Liquid scintillator cells from TUM with PSD capabilities to disciminate electronic from nuclear recoils

- Preliminary results give a neutron attenuation factor of 8
- Spectral shapes at VNS compatible with that at surface



Muon Attenuation

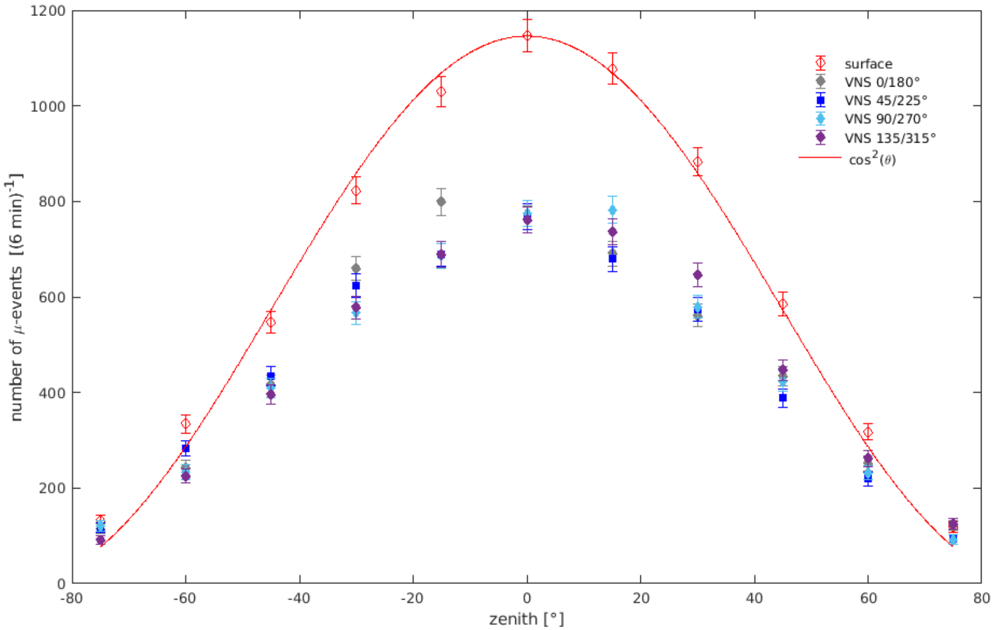
- Cosmic wheel from « science à l'école » outreach programm, developed by CPPM Marseille



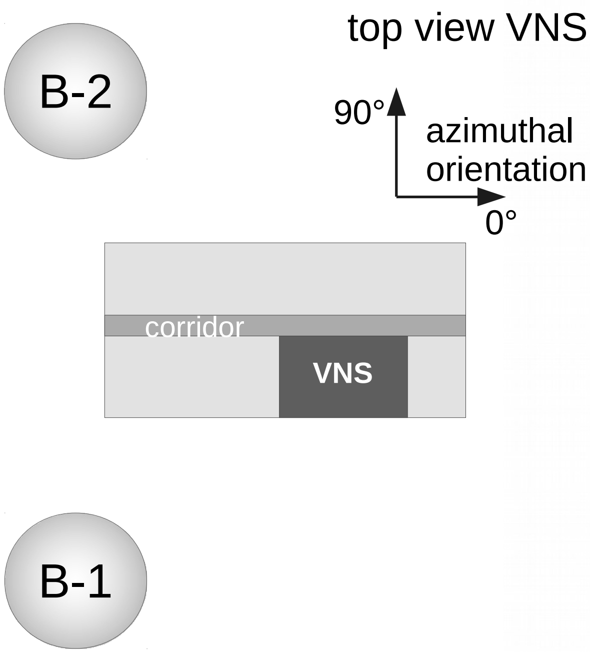
- Preliminary results give a muon attenuation factor of 1.4
- Use muon attenuation to estimate overburden m_0 :

$$\frac{R_{VNS}}{R_{surf}} = 10^{-1.32\log(1+m_0/10) - 0.26(\log(1+m_o/10))^2}$$

P. Theodorsson. Measurement of weak radioactivity. World Scientific, Singapore, 1996

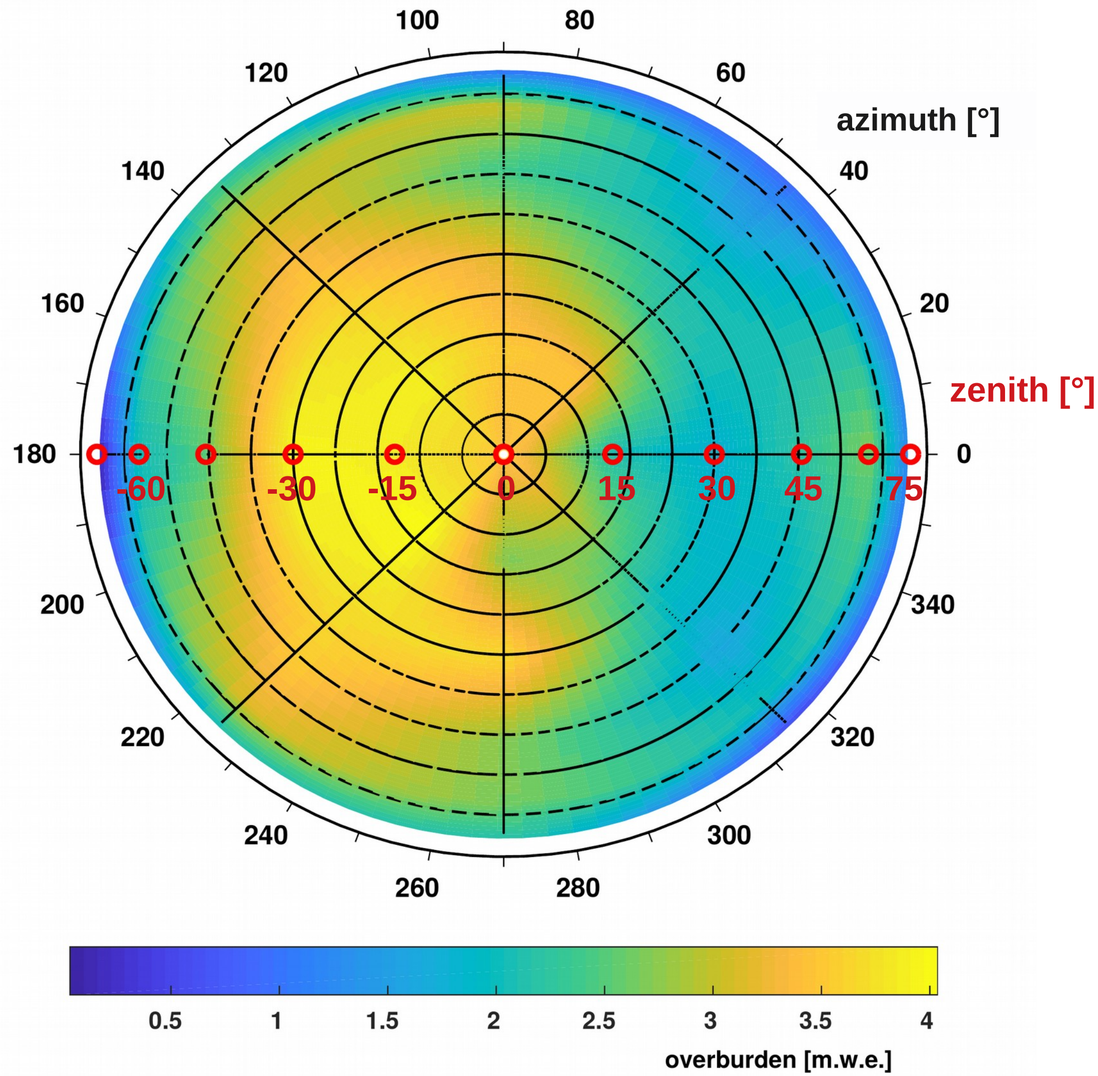


Overburden @ VNS



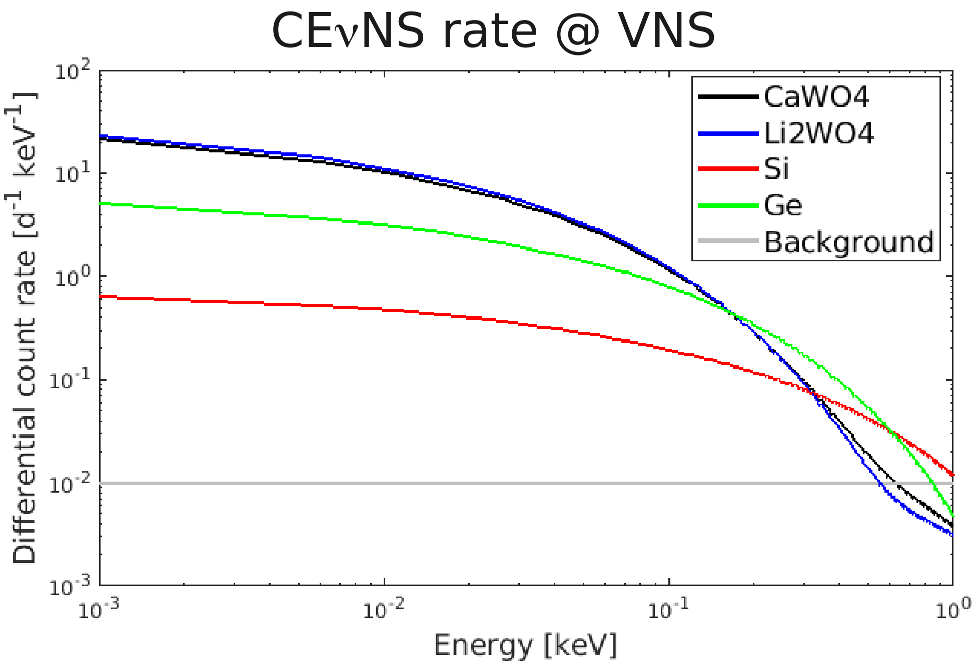
Overburden of

m_0 = (2.9 ± 0.1) m.w.e.



CEνNS Experiments @ VNS

- **Technical modifications** of VNS room
- Size of VNS: **24 m²**
  → compact setup (<10 t)
- Expected ν-flux: **10^{12} $\bar{\nu}_e$ /(s·cm²)**

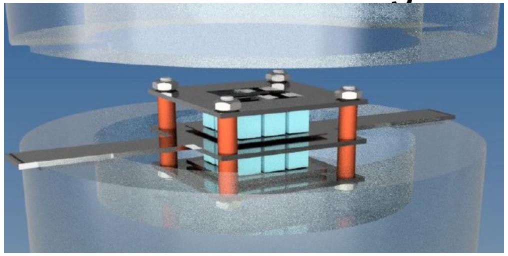


- Shallow overburden: **3 m.w.e.**
  → close to above ground conditions, high μ-rate
  → cosmic ray hadronic component largely suppressed
  → muon-induced background expected to be dominant

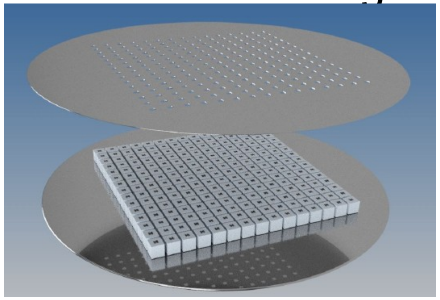
- NU-CLEUS detectors meet specification to run at VNS :
  - $CaWO_4$ crystals with energy threshold < **20 eV$_{nr}$** → **small target mass** to study CEνNS
  - demonstrated to run in **above ground** conditions

- On-going design and optimization of shielding
  - active muon-veto
  - passive shielding based on Pb and borated PE

NU-CLEUS 10g

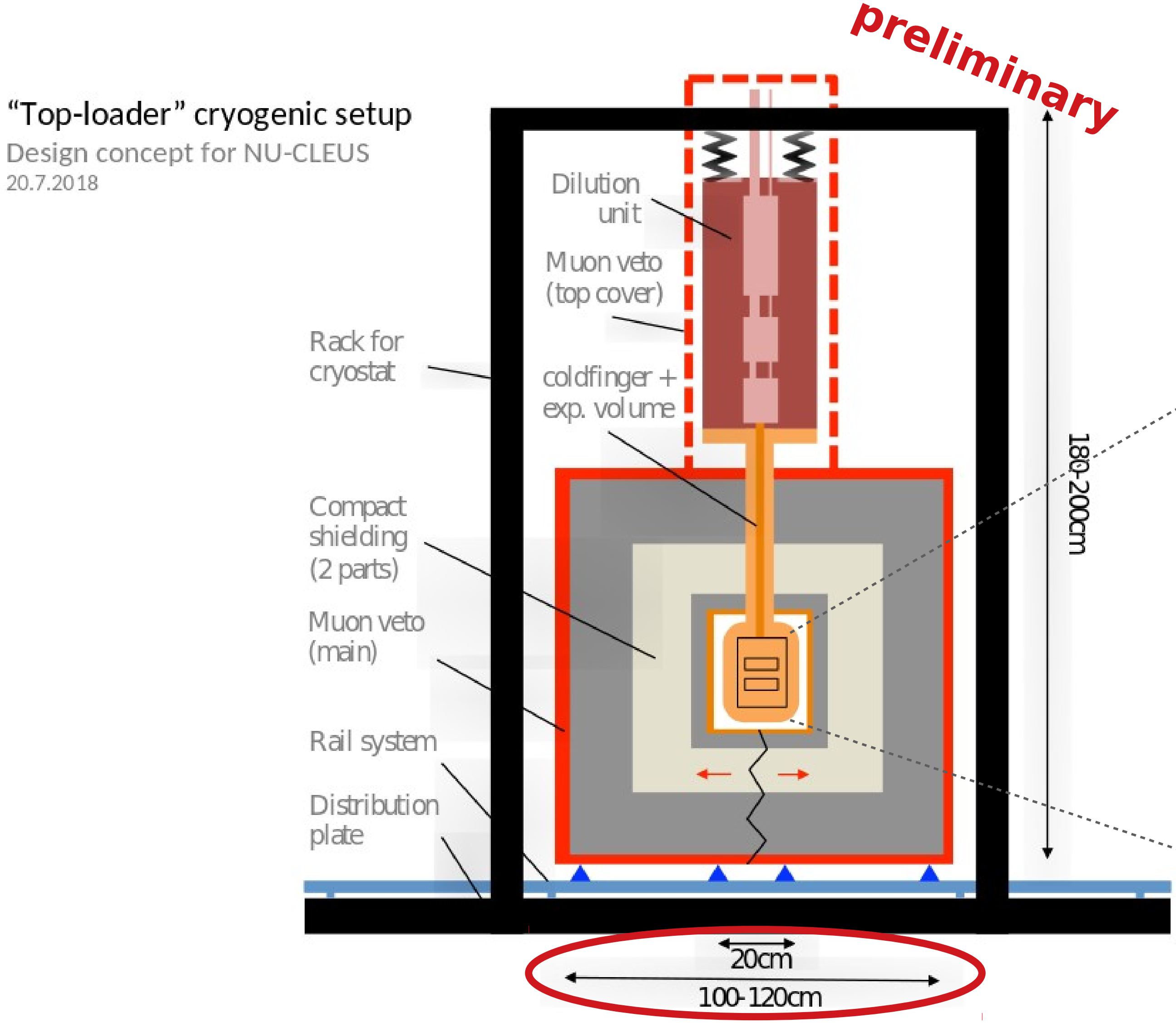


NU-CLEUS 1kg

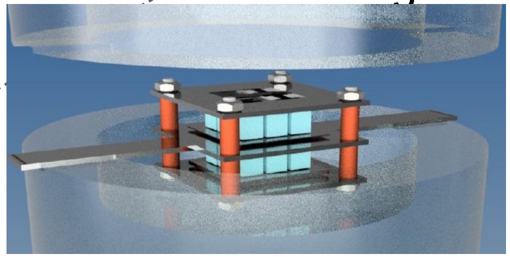


see talk by R. Strauss

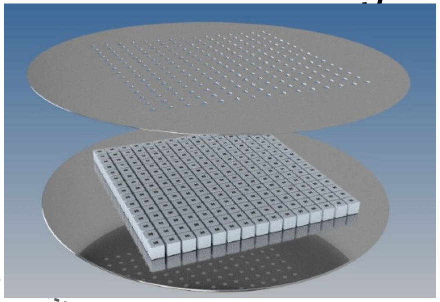
NU-CLEUS @ VNS



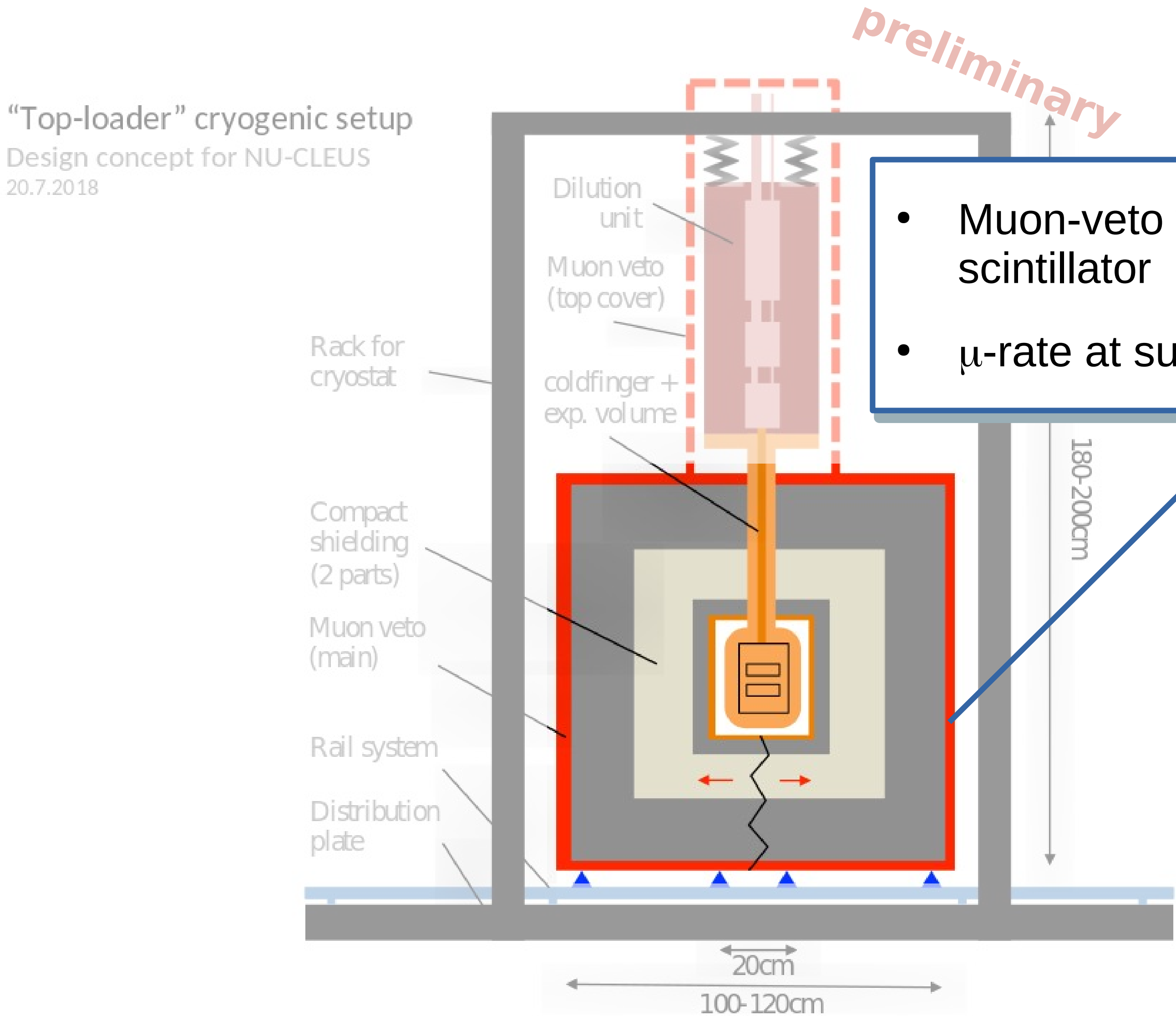
NU-CLEUS 10g



NU-CLEUS 1kg



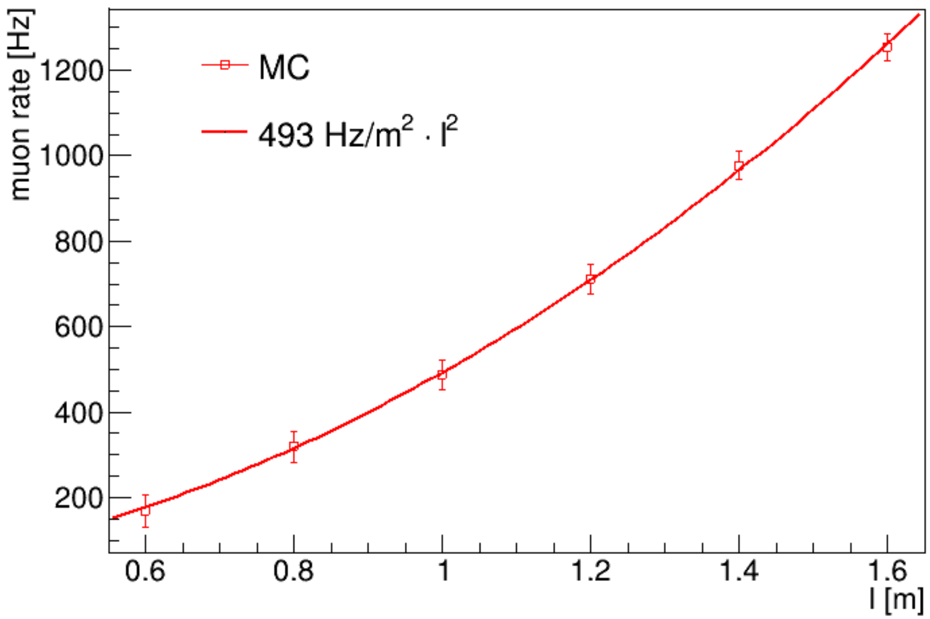
see talk by R. Strauss



- Muon-veto with 5 cm of plastic scintillator
- μ-rate at surface O(100 Hz/m²)

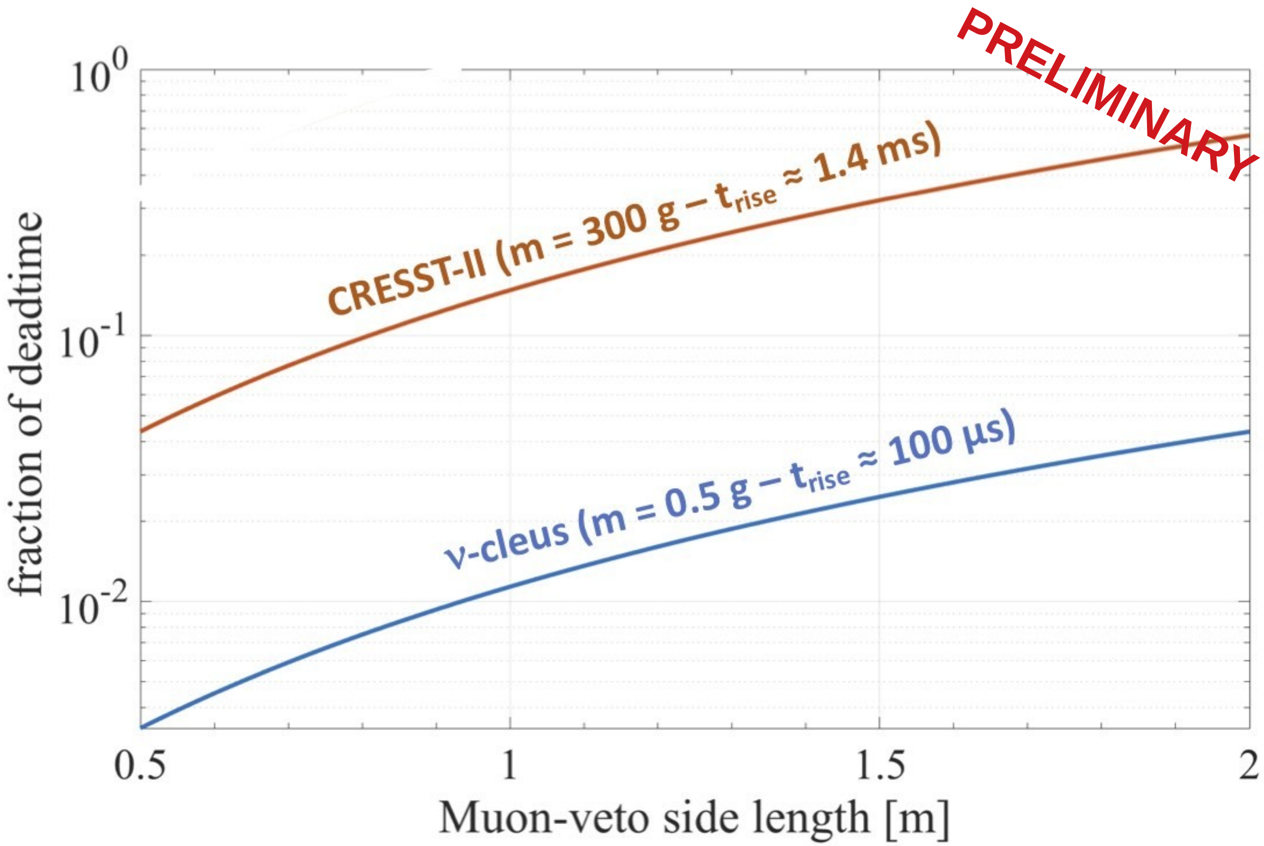
see talk by R. Strauss

Muon Trigger Rate



- Monte Carlo simulation of muon veto yield an expected muon-trigger rate < 500 Hz for a $1 m^3$ shielding
- MC validated with measured muon rate in the NUCIFER experiment

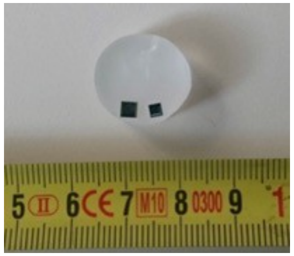
Muon-Induced Dead-Time



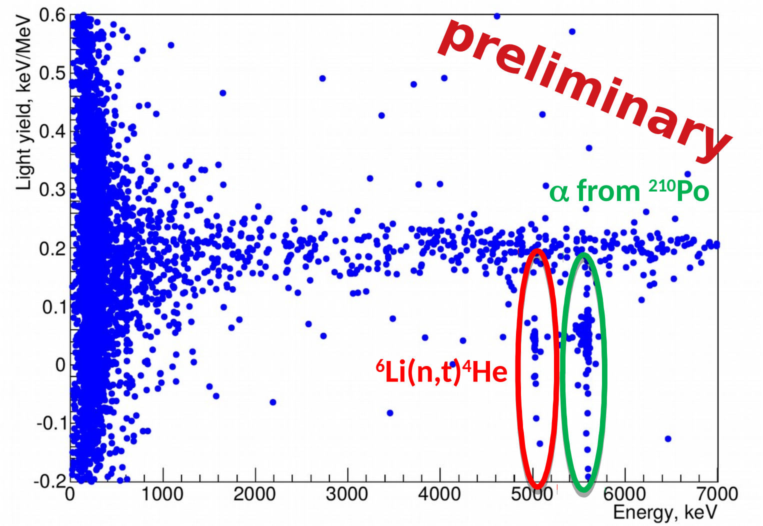
- Fast rise-time of NU-CLEUS detectors (100 µs) implies a dead-time of 1 % for a 1m³ shielding
- With NU-CLEUS a muon-veto up to (2m)³ is feasible

The BASKET Project

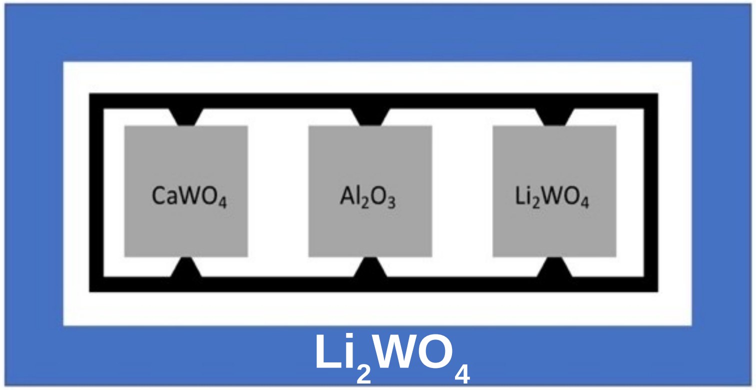
- R&D program to develop **Li_2WO_4** bolometers at CEA and CSNSM
- First prototype (11g) shows **good bolometeric and scintillation properties**
- Ongoing tests with 1g crystal and different phonon read-out to optimize energy threshold and time response
- Neutron capture on ^{6}Li can be used as **insitu neutron background characterization:**
  - $^{6}Li + n \rightarrow {}^{3}H + {}^{4}He$, with $E = 4.78$ MeV $+ E_n$
  - n-rate & fast neutron spectroscopy
- Investigate possibility to enrich and grow large sized Li_2WO_4 crystals



^{210}Po calibration source



The BASKET Project –
Possible Synergy with NU-CLEUS



- Li_2WO_4 target detectors:
  - similar CEνNS rate as $CaWO_4$ expected
  - additional target may yield supplementary information on background
- Li_2WO_4 outer veto (OV):
  - γ attenuation by W
  - Neutron identification via $^6Li(n,t)^4He$ $\rightarrow$ neutron rate and spectral information

Conclusion and Summary

- **Very-Near-Site (VNS) at Chooz** is a promising experimental site for future CEνNS experiments
- On-going background and simulation campaign to **fully characterize VNS**
- Strong support of the EdF power plant
- Plan to install **NU-CLEUS detectors at VNS** as first CEνNS experiment at Chooz **in 2020**:
  - low energy threshold of O(10 eV_{nr})
  - detector fiducialization for high background rejection
  - ~1% muon-induced dead-time thanks to fast rise time
- Consortium with Ricochet in preparation for further measurments