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AIDAinnova

Advancement and Innovation for Detectors at Accelerators
Horizon 2020 Research Infrastructures project AIDAINNOVA

MILESTONE REPORT

ANALYSIS OF INNOVATIONS NEEDED IN MARKETS AND TECHNOLOGIES

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Abstract:

This report provides an overview of market-innovation trends of particle detectors, both by technology and by market application, as well as a summary of key policymaking initiatives that will impact the market. The methodology used in the first section is a combination of market research, patent database analysis, and market survey with AIDAinnova participants industry participants. The second part of the report summarises recent policymaking initiatives affecting the market, with a particular focus on semiconductors.

The Advancement and Innovation for Detectors at Accelerators (AIDAinnova) project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement no. 101004761. AIDAinnova began in April 2021 and will run for 4 years.

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1. INTRODUCTION

The quest for discoveries in particle physics continuously drives available or emerging technologies beyond their limits, and the almost industrial scale at which this happens, is one of the roots of its broader societal and economic impact. Developments in the particle detectors market are driven by the close collaboration between physicists, engineers and industrial partners.

The role of industry is rapidly increasing, due to the need of advanced technologies calling for highly specialised equipment, for example in microelectronics integration, and due to the scale of the installations, where thousands or millions of components require industrial-scale production and quality control infrastructure.

AIDAinnova advances the European detector development infrastructures through fostering an intensified co-innovation with industry. Knowledge transfer will be catalysed through co-innovative work in common detector projects, and it will strengthen the competence and competitiveness of the industrial partners in other markets [1].

With this in mind, the objective of this report is to first of all assess the technology trends of particle detectors, both by technology and by market application. The methodology used in this section is a combination of market research, patent database analysis, and market survey with AIDAinnova participants industry participants. The second part of the report then analyses recent policymaking initiatives affecting the market, with a particular focus on semiconductors. Overall the report aims at providing an insight into key market trends and drivers that will influence innovation potential in the particle detectors field.

1.1. METHODOLOGY

The data presented herein has been gathered from several sources to provide a quantitative picture of the market and innovation landscape in the field of particle detectors.

The analysis of the market was based on a contracted report by Verified Market Research [2]. Focusing on the market trends by product and by application, this study performed secondary and primary research, validated through the consulting of expert advice.

The initial secondary research focused on publicly available sources, from press releases and research papers, to industry magazines and governmental documents. Large databases, such as Reuters, Factiva, Bloomberg, One Source, and Hoovers, also provided meaningful qualitative and quantitative insight.
The following primary research was carried out through interviews given out by industry participants ranging from product managers to chief-level executives, who provided further data on the market and its trends.

In addition to analysing market data, this report aims at using a comparative approach to outline economical trends alongside innovation ones.

To gauge innovation within the field, an analysis of relevant patents offers the best approximation to an objective study, as these are, by definition, only granted to technologies or methods that prove to be inventive and novel. Therefore, the proposed methodology assumes a correlation between patents and innovative advancements in R&D, also known as a “Technology Landscape”.

This report relies on the International Patent Classification (IPC) system [3], which allocates patents to specific fields, applications, categories, etc., thus allowing for a comprehensive categorization and targeted patent searches. Within this system, one can search under the domain of Physics (G) to find the relevant class. The classification hierarchy is as follows:

- **G** – PHYSICS
  - **G01** – MEASURING; TESTING
    - **G01T** - MEASUREMENT OF NUCLEAR OR X-RADIATION (radiation analysis of materials, mass spectrometry G01N 23/00; tubes for determining the presence, intensity, density or energy of radiation or particles H01J 47/00);

Therefore, the data can be limited to patents and patent applications (i.e. the initial disclosures in patent prosecution) which have been allocated the G01T classification, as this class encompasses the field of particle detectors. The relevant records can be retrieved from the two main patent search databases, PATENSCOPE [4] and Espacenet [5]. These portals aggregate data from both international and national patent bureaus.

The resulting data pool consists of 154,807 patent records from 158 sources, pertaining to filings between 2003 and 2020. The compounded information was analysed in terms of distribution in time, country of origin, and prevalence of sub-category.

Another vital source of information can be found within the AIDAinnova consortium, given that it includes the participation of eight industrial participants. A short questionnaire was carried out with these industrial partners during the AIDAinnova Annual Meeting (March 2022) to gather information on the market, the technologies, and the applications of particle detectors. Please refer to Annex A for the full list of questions.

To conclude, this report takes an opportunity to outline a few examples of relevant policy-making initiatives that might bring about economic impact to the particle detectors' market in the next decade. More specifically two examples of recent legislative initiatives taken by the European Union and the United States of America are briefly drawn using primary sources as well as some government issued reports with a view to assess policymaking schemes in the area of semiconductors.

2. MARKET LANDSCAPE FOR PARTICLE DETECTORS

The global particle detector market is estimated to reach USD 3,838.53 million by 2028 from USD 2,302.30 million in 2020. From an economic point of view, the trend reflects that North America holds the largest market share of 41.06% (2020), followed by European markets led by the UK (8.2%), Germany (7.9%), and France (5.8%). On the other hand, both Figure 1 and recent market data suggest that Asia-Pacific is the fastest growing region [6].

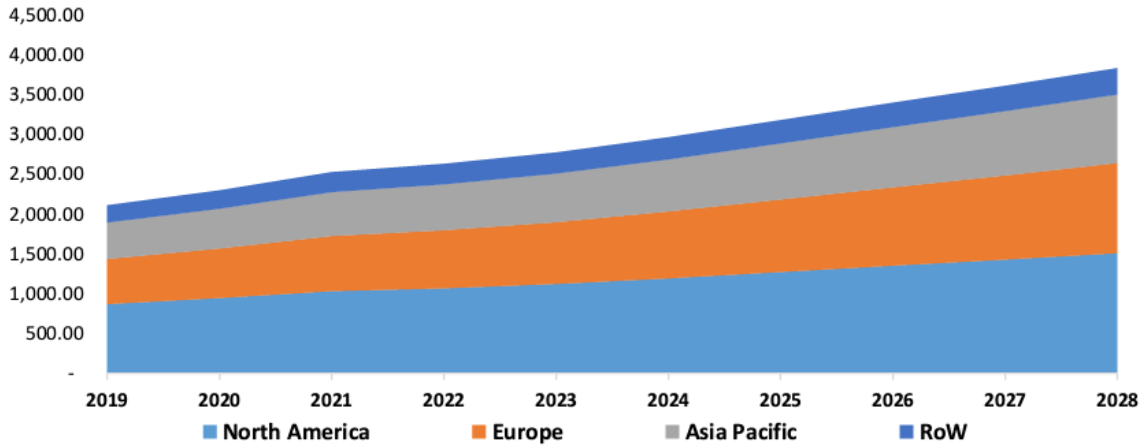
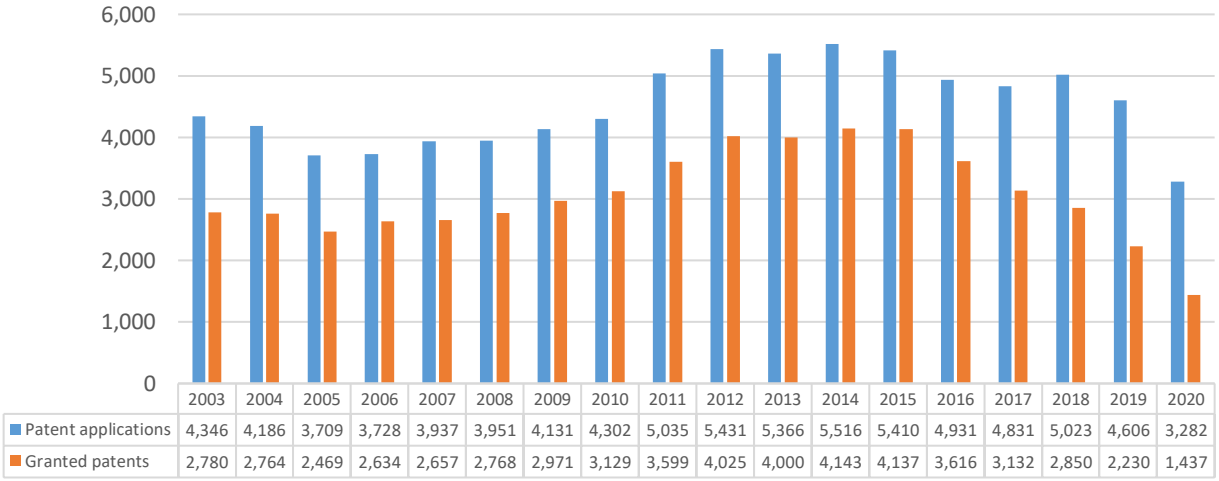


Fig. 1 – Global particle detectors market, by geography (2021-2028)

The innovation trends in field of particle detectors are analysed through reviewing the patent records allocated with the class G01T, as mentioned before. Figure 2 shows the evolution in number of patent records throughout the years.



	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Patent applications	4,346	4,186	3,709	3,728	3,937	3,951	4,131	4,302	5,035	5,431	5,366	5,516	5,410	4,931	4,831	5,023	4,606	3,282
Granted patents	2,780	2,764	2,469	2,634	2,657	2,768	2,971	3,129	3,599	4,025	4,000	4,143	4,137	3,616	3,132	2,850	2,230	1,437

Fig. 2 – Number of patent applications and granted patents under IPC class G01T, worldwide, by year

The numbers reflect an increase in R&D efforts from 2005 to 2014, demonstrated by the rise in patent applications and granted patents. However, from 2015 onwards there was a decrease in patent records per year, alluding to a certain stagnation in innovation.

It should be noted that patent applications can take upwards of 5 years to be granted (if they are to be granted at all), which could explain the decrease in granted patents in more recent years. And this is

indeed reflected by the ratio of granted patents to patent applications, which was steadily between 65% and 75% until 2015, dropping to around 45 % in 2020.

However, there is no barrier that prohibits an entity from filing for patent protection at all. Thus, the decrease in patent applications in more recent years is a direct indicator that there are fewer innovative and novel inventions, therefore leading to the conclusion that innovation is starting to stale.

Patent records also provide knowledge on the geographical distribution of improvements in particle detectors. Figure 3 shows the proportion of patent applications originating from each of the world's major regions in this field.

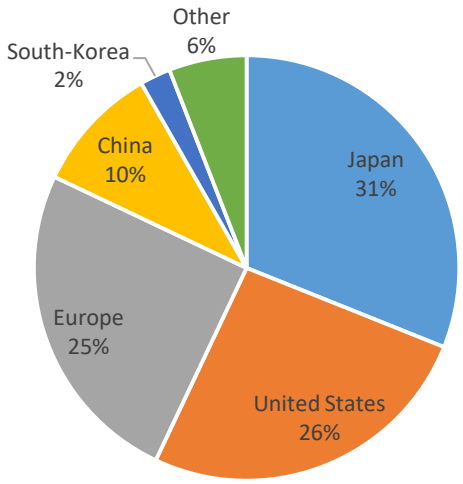


Fig. 3 – Geographical origin of patent applications under IPC class G01T, 2003-2020

The leading region is Japan, followed by the United States of America, with Europe in third place. China and South Korea close the top 5. More information could be extracted by looking at the distribution of patent records per geography area, by year, as shown in Figure 4.

It is therefore understood that, although Japan, the USA and Europe currently occupy the top 3 in terms of innovation, there are fewer and fewer patent applications being filed each year in these regions. With numbers for China seemingly on the rise, year on year, the trend is for the Asian powerhouse to gain prominence in the coming years, possibly aiming at disrupting the current *status quo*.

As such, it can be concluded that for Europe to remain relevant in the field of particle detectors, it is imperative it focuses on maximizing innovation in the technologies and the expertise. Funding attained for projects such as AIDAinnova guarantee the scientific and industrial communities in Europe remain competitive and independent.

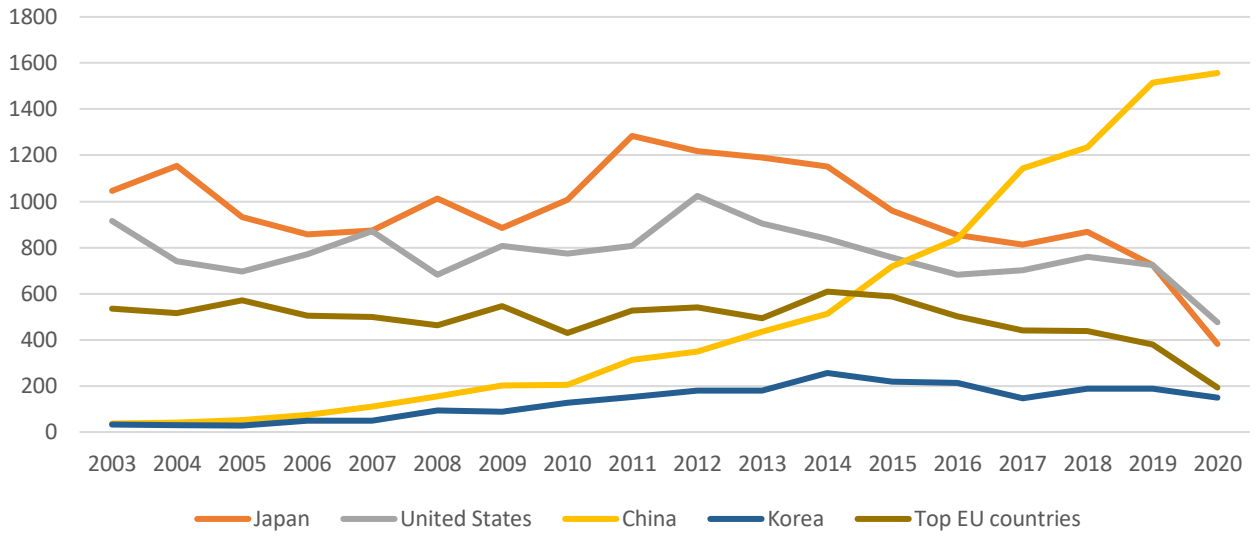


Fig. 4 - Number of patent applications under IPC Class G01T, per country of origin, by year

2.1. PARTICLE DETECTOR TECHNOLOGY TRENDS, BY R&D AREA

2.1.1. Market and innovation trends

Technological advancement in the area of particle detectors creates opportunities in the development of a range of innovations applied to the different types of detectors (gas-based, solid, scintillation-based etc.) as well as to their more specific R&D areas and components (e.g. patent subclasses).

From a detector product point of view, gas ionization detectors accounted for the largest market share of 42.03% in 2020, with a market valued of USD 967.58 million. These are followed by scintillation detectors (31.33%) valued at USD 721.38 million and by solid-state detectors with 17.95% in 2020 [7].

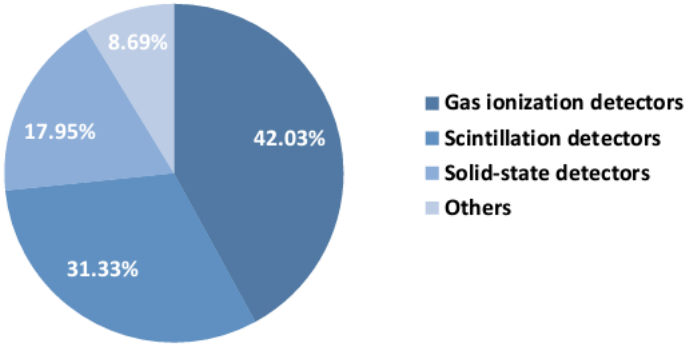


Fig. 5 – Market share by detector type, 2020

With regards to segmentation of innovation by R&D area, the IPC classification allows for the categorization of patent records in subclasses, helping further define the field, type of technology, application, etc. to which an invention is allocated. Thus, it is possible to review which subclasses are the most common for all patent records that have been filled under class G01T. Figure 6 breaks down these statistics.

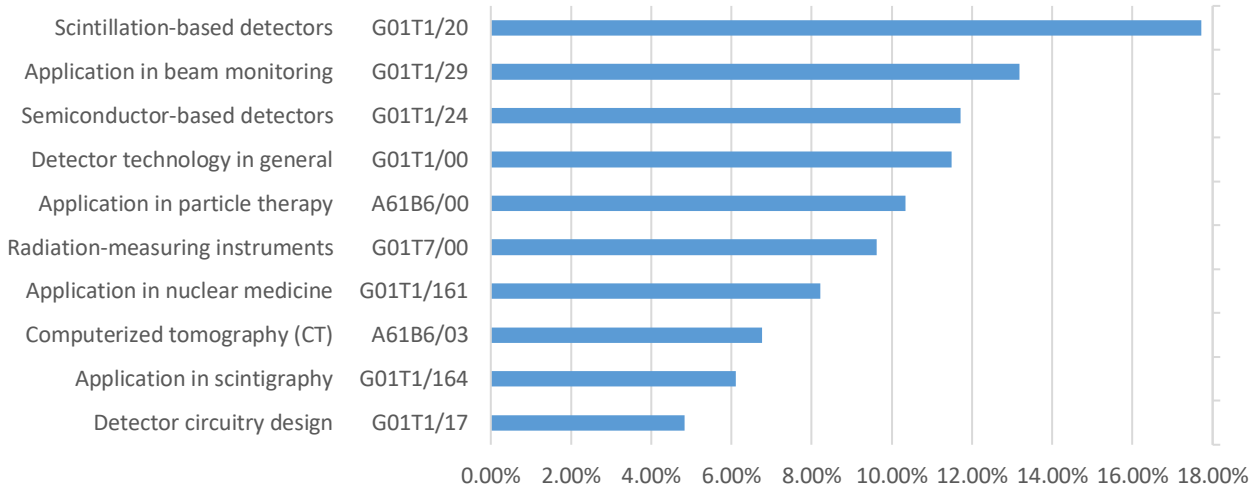


Fig. 6 – Proportion of granted patents per subclass, filed under IPC class G01T, 2003-2020

Figure 6 demonstrates the societal importance of innovation in particle detectors field, as a great part of the inventions in this space is cleared aimed at contributing to applications in medicine (application in nuclear medicine, computerized tomography, etc.). It is also noteworthy that the proportions of each of these R&D areas did not change dramatically up until now, thus maintaining the same relative order throughout time.

2.1.2. AIDAinnova insights

The preliminary survey conducted during the AIDAinnova Annual Meeting provided insight into the industry participants' interpretation of the particle detectors' market and R&D efforts in the main technology areas. Figure 7 details the answers provided by the participants concerning which technology they find most relevant today and in ten-years time.

Fig. 7 – AIDAinnova survey responses for detectors market share

When asked about current market share, the majority of industry respondents evaluated both solid-state detectors (40%) and scintillation detectors (40%) as the leading detector technologies in 2022. However interestingly, when asked about the innovation trend in 10 years, 60% of respondents shifted their choice towards solid-state detectors.

2.2. PARTICLE DETECTOR TECHNOLOGY TRENDS, BY INDUSTRY APPLICATION

2.2.1. Market and innovation trends

Increasing demand for particle detectors from end-use industries ranging from healthcare to nuclear power plants is also a key driver for innovation in the market.

In 2020 Medical and Healthcare accounted for the largest market share of 34.76%, with a market value of USD 800.23 million, followed by Nuclear Power Plants (21.33%) with a market share value of 491.03 million and thirdly by Industrial Applications (19.3%) [8].

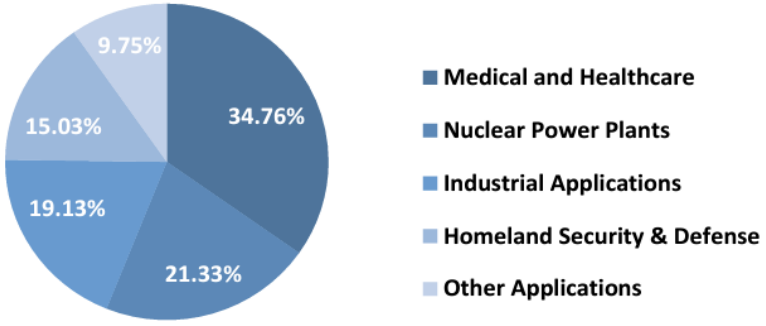


Fig. 8 – Market share by application, 2020

The same overall picture is reflected by the patent records tied to specific industries through IPC classification. Figure 9 shows the number of patent applications filed within the top 3 industries over the years.

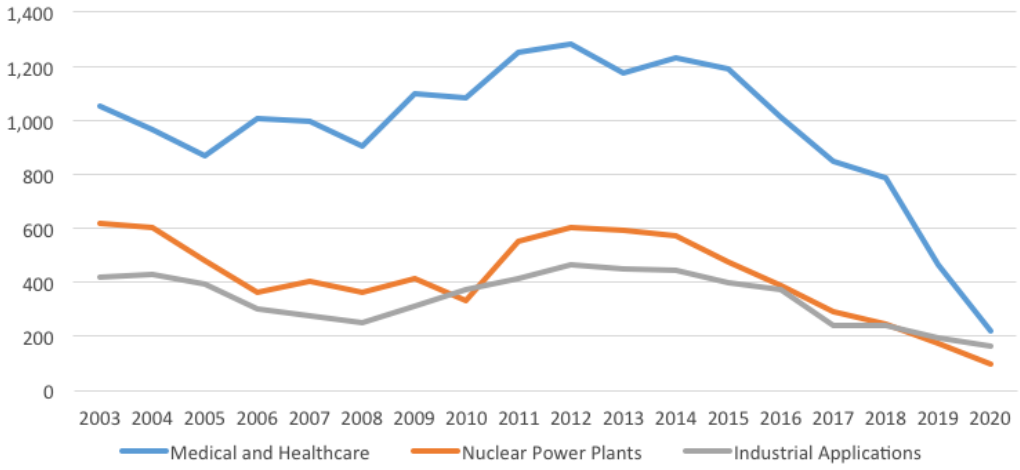


Fig. 9 – Number of patent applications under IPC Class G01T, by industry

It is understood that the relative proportion of patent applications by industry follows the same order as explained above, with Medical and Healthcare in first place, Nuclear Power Plants in second, and Industrial Applications close behind. Therefore, it is suggested that efforts in innovation are tied directly with market growth.

2.2.2. AIDAinnova insights

The short survey with AIDAinnova industrial participants also provided information on which industries they operate the most in. Figure 10 details the answers provided by the participants concerning their main customer segments.

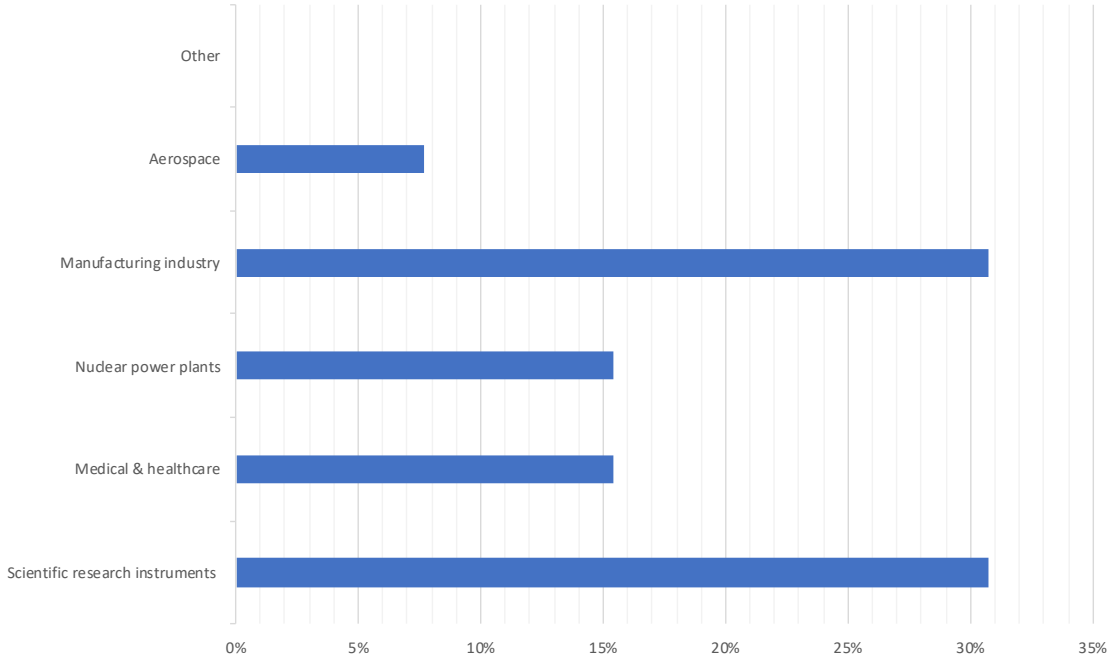


Fig. 10 – AIDAinnova industrial partners main customer segments

Key findings indicate that the majority of products commercialized by AIDAinnova industry partners are aimed at Scientific research instruments (31%) and the Manufacturing industry (31%), followed by Medical & healthcare (15%) and Nuclear power plants (15%), with only 10% remaining for Aerospace products.

3. RELEVANT POLICYMAKING INITIATIVES, FOCUS ON SEMICONDUCTORS

3.1. EUROPEAN UNION

3.1.1. Background

Europe currently holds leading research centres advancing developments of state-of-the-art semiconductor technologies, and it is very well positioned with diversified industrial end user sectors ranging from automotive to healthcare and agriculture. Despite these advantages, European Union (EU) accounted for an overall semiconductors market share of only 10% in 2019 [9].

Moreover, the recent global semiconductors shortages forced factory closures in a wide range of sectors from cars to healthcare devices. In the car sector, for example, production in some EU Member States decreased by one third in 2021 [10].

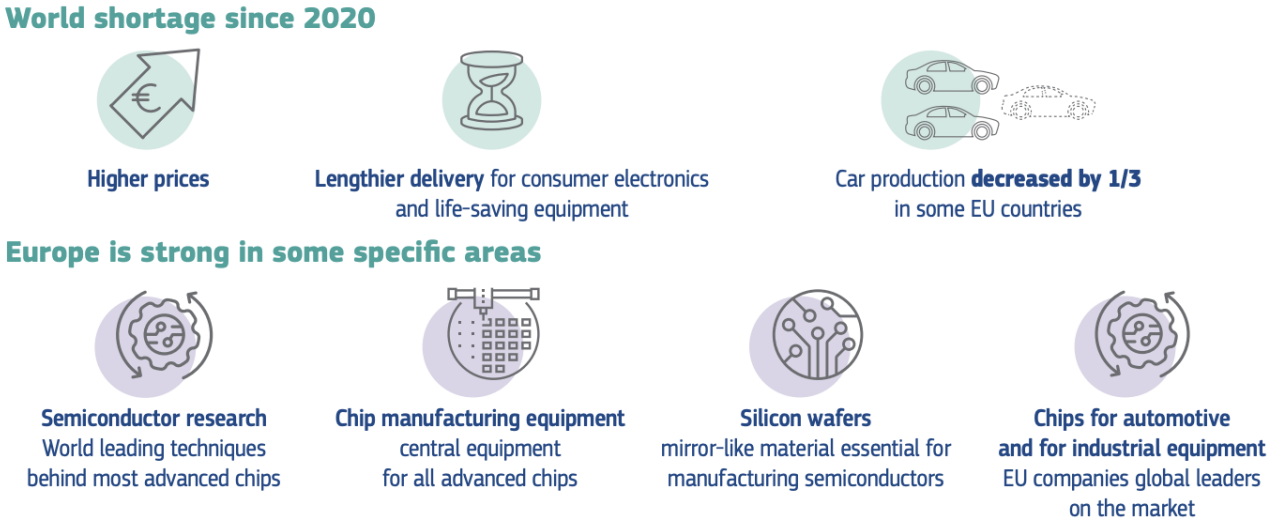


Fig. 11 – European semiconductors market, European Union, 2022

With a view to face these challenges and disruptions, on 15 September 2021 European Commission (EC) President Ursula von der Leyen announced an EU Chips Act in her State of the Union speech [11], which was subsequently included in the Communication adopted on 8th February 2022 proposing a Regulation on a European Chips Act.

The proposal contains a comprehensive set of measures to ensure the EU's security of supply and innovation in semiconductor technologies and applications. Its overall objective is to foster a thriving semiconductor sector from research to production as well as a resilient supply chain that will enable the EU to double its current market share to 20% in 2030 [12].

3.1.2. European Chips Act

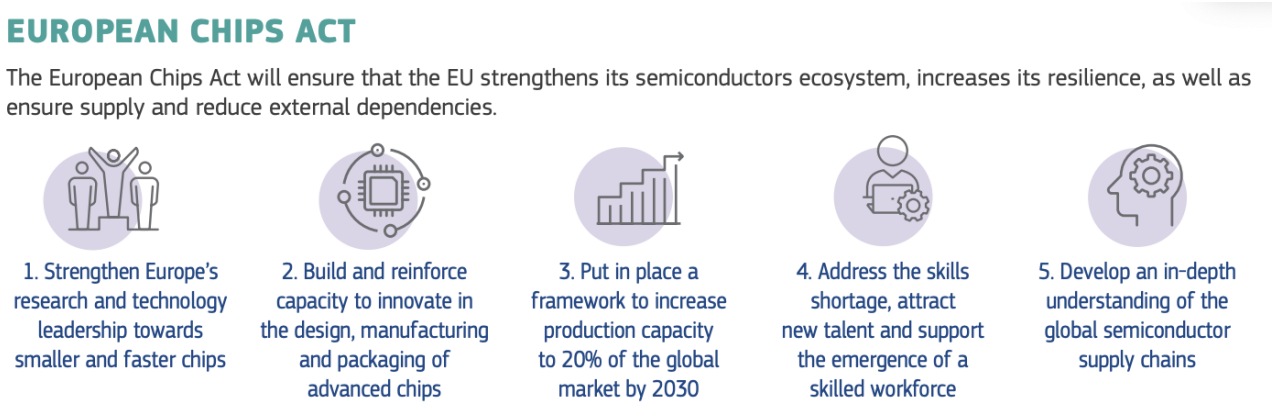


Fig. 12 – European Chips Act, European Union, 2022

More specifically, the European Chips Act entails a number of initiatives such as:

- The "Chips for Europe Initiative", which includes EUR 11 billion of public investment to finance technology leadership in research, design and manufacturing capacities up to 2030. This will also be complemented by a "Chips Fund", private equity funding for startups, scaleups and other companies in the supply chain, with a projected value of about EUR 2 billion.
- A new framework to ensure security of supply by attracting investments and enhanced production capacities, more specifically to set up new "first-of-a-kind" production facilities that will work on technologies that go beyond current state-of-the-art. The proposed regulation introduces two types of facilities:
    - **"**Open EU Foundries", dedicating manufacturing capacity to production for other industrial players;
    - "Integrated Production Facilities", designing and producing components serving their own markets.
- A coordination mechanism to monitor the supply of semiconductors, to estimate demand and anticipate shortages will be established between the Member States and the Commission. With this in mind, a "European Semiconductors Board" will be launched to enable efficient coordination on both permanent monitoring activities on demand/supply (preparedness) and on mitigation measures such as mandatory information gathering, prioritization of orders for critical sectors, and common purchasing schemes (crisis response) [13].

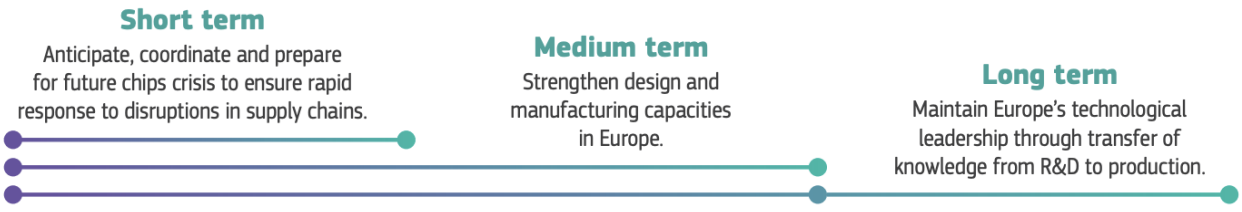


Fig. 13 – European Chips Act, European Union, 2022

3.2. UNITED STATES

3.2.1. Background

The United States of America share of global semiconductor fabrication capacity fell approximately from 40% in 1990 to around 12% in 2020, according to the Congressional Research Service (CRS) [14]. Many US policymakers see the semiconductor industry as vital to its economic and national security interests [15], and therefore address concerns of its declining share of market in both domestic production and in manufacturing know-how and capabilities.

3.2.2. US CHIPS ACT

In January 2021 US Congress passed the Creating Helpful Incentives to Produce Semiconductors (CHIPS) for America Act (S. 3933/H.R. 7178) as part of the National Defense Authorization Act (NDAA) for Fiscal Year 2021 [16]. The initiative promotes a number of programmes to both expand US semiconductor fabrication capacity and to support R&D of advanced microelectronics.

In terms of incentives, the Act provides financial assistance for the construction, expansion or modernization of a semiconductor fabrication plant in the US (Section 9902). Additionally, the Act establishes a Multilateral Semiconductors Security Fund, a collaborative funding mechanism for US and its international partners to promote the development of "secure semiconductors and secure microelectronic supply chains" (Section 9905).

Moreover, amongst other initiatives the act will:

- Establish a refundable investment tax credit for qualified semiconductor manufacturing equipment of manufacturing facilities located in the US;
- Establish a funding program of about USD 50 million for 2021-2025 to support R&D, material characterization, instrumentation, testing and manufacturing of semiconductors;
- Authorize USD 750 million for the establishment of a Multilateral Microelectronics Security Fund to support the development and adoption of secure microelectronics and secure microelectronics supply chains;
- Authorize USD 5.0 billion annually for 2021-2025 to:
    - establish and operate an Advanced Packaging National Manufacturing Institute within DOC to support U.S. leadership in advanced microelectronic packaging;
    - promote standards development;
    - foster public-private partnerships;
    - develop R&D programs to advance technology development relevant to such packaging;
    - establish an investment fund to support a startup domestic advanced microelectronic packaging ecosystem, accelerate technology transfer, ensure domestic supply chains; and
    - work with the Department of Labor to develop workforce training programs and apprenticeships in advanced microelectronic packaging capabilities.
- Authorize another USD 10 billion for national institutes and centres to conduct semiconductors' research [17].

In order to enable this initiative, the US Senate has passed the Innovation and Competition Act (USICA) on June 8th 2021 [18], which includes USD 52 billion in federal investments for both domestic semiconductor R&D and manufacturing provisions included in the CHIPS Act. Additionally, the US Congress has just passed, on February 4th 2022, the same level of funding to strengthen domestic semiconductor manufacturing and research as part of the America COMPETES Act of 2022 [19].

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ANNEX A: AIDAINNOVA PARTICIPANTS SURVEY

In order to gain more insight into market segmentation within AIDAinnova, a preliminary survey was conducted during the AIDAinnova Annual Meeting (March 2022) to assess industry participants' interpretation of the particle detectors' market and its innovation potential.

	Question
1.	Please describe to what industry field your main clients belong to: • Scientific research industries • Medical & healthcare • Nuclear power plants • Manufacturing industry • Aerospace • Other
2.	Where do your main clients operate primarely? • North America • Europe • Asia • Other
3.	What emerging technologies do you think will be most relevant to particle detectors?
4.	From your point of you, what kind of particle detector accounts for the biggest market share currently? • Gaseous ionization detectors • Solid-state radiation detectors • Scintillator-based detectors • Other
5.	From your point of you, what kind of particle detector accounts for the biggest market share in 10 years from now? • Gaseous ionization detectors • Solid-state radiation detectors • Scintillator-based detectors • Other
6.	Which is the primary WP(s) your company is interested in within the AIDAinnova project?