

# ECFA Detector Panel Report

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The ECFA Detector Panel  
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The ECFA Detector Panel is a European Committee composed of detector physicists from a variety of experimental communities in particle and astro-particle physics. Its primary role is to review early stage detector R&D for programmes in these areas that are not yet linked to a host or leading laboratory with its own established review mechanisms. The role and composition of the panel make it well placed to provide an input on behalf of the European detector community for the ongoing update of the European Strategy for Particle Physics. To this end, a survey of this community was launched over the summer of 2018, with over 700 respondents representing 2900 FTEs at a variety of career stages in 37 countries. Perceptions of opportunities and challenges were investigated, along with attitudes to detector R&D activities within the wider community and associated issues with career opportunities. The survey was also able to identify the main areas of current detector R&D for particle and astro-particle physics in Europe as well as the community's views on the most promising future directions. This report outlines the main findings and the recommendations of the panel based on both the numerical data and the large number of highly informative comments provided by many of the respondents.

## Introduction

Detector technologies are essential for the progress in particle physics. Without advances in detector technologies there will not be progress in terms of experimental physics outcomes.

The development of advanced detector technologies requires high-level professional physics and engineering skills, original ideas, as well as dedicated effort typically spanning many years.

Detector technologies bring prominent importance and visibility to particle physics as a frontier domain for spin-off from basic research to applications of benefit to wider society.

The ECFA Detector Panel, a European committee to review the R&D effort for future projects, was created by ECFA in November 2011 and continued with an updated mandate in November 2016. The Detector Panel is aimed at providing advice on detector development efforts for projects at accelerator and non-accelerator experiments in particle and astro-particle physics in their preliminary and preparatory phases. It helps to create coherence of global detector R&D efforts by encouraging synergies between different activities and advising funding agencies if asked to do so.

Following the request from ECFA, this document aims at providing an overview of the status of detector R&D for particle physics and its interactions with related fields, and giving recommendations concerning future developments. In order to be able to complement and inform the Panel's views with those of the broader community, a survey was conducted during Summer 2018 to collect input from researchers involved in R&D activities in Europe. The full survey results are publicly available on the Panel web-page <http://ecfa-dp.desy.de/e279752/>. This document summarizes the survey statistics (section 1), findings and observations from the survey (section 2) and recommendations (section 3) and further ideas (section 4) of the panel.

### 1. Survey results

The survey consisted of 30 questions and collected 704 replies from people mainly working as Professor (28%), Physicist permanent (36%), Engineer permanent (8%) PostDoc in Physics (11%) or PhD student in Physics (8%) in their home institute.

87% of the respondents are involved in various R&D activities while the remaining 13% are not. The reasons for not working on R&D are other interests (58%), no time available (36%), not feeling competent (25%). Here, multiple answers were possible and the results are normalised to the number of replies.

296 team leaders reported about the number and degree of expertise of the FTEs working in their teams. Other 320 respondents indicated the percentage of time that they dedicate to R&D. All these values were taken into consideration for estimating the total number of FTEs represented by this survey. In obvious cases data were corrected for double counting, resulting in 2890 FTEs. The percentage of FTEs belonging to different categories of expertise is summarised in Tab. 1.

Categories	% of FTEs involved in R&D
Professors	2
Physicists (permanent position)	24
Engineers (permanent position)	18
PostDoc	13
PhD students	19
Other students	10
Technicians	13

**Table 1:** Percentage of 2890 FTEs belonging to different categories of expertise.

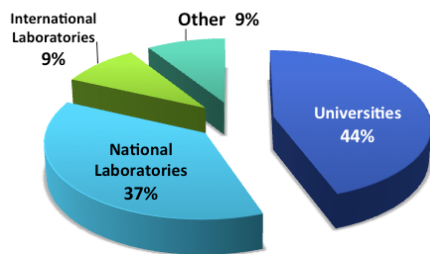
This survey represents the work of ~2900 FTEs from 37 countries, split according to CERN nomenclature into: 2368 from CERN member states, 52 from associate countries, 14 from associate pre-stage, 364 from observers and remaining 92 from other countries. The statistics include the contributions of FTEs from non-European countries but working on European projects.

R&D activities are performed in the context of experiments belonging to the branches of physics as reported in Tab. 2. Multiple answers were possible.

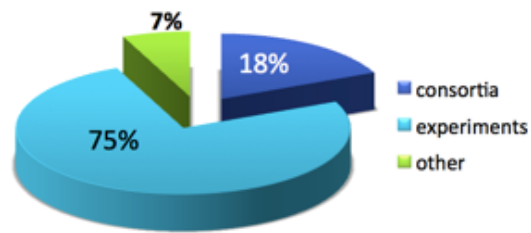
	% of replies
Astroparticle Physics	19
Neutrino Physics	17
Nuclear Physics	19
Particle Physics	72
Other branches of fundamental physics	12
Other	8
	>100

**Table 2:** Major branches of Physics in which detector R&D is performed normalised to the number of people who responded to the survey (*multiple answers possible*).

The affiliations of 2900 FTEs are distributed as in Fig. 2. The affiliation “other” mainly includes researchers working for national Institutes, public research centres and private companies.



**Fig. 2:** Affiliations of FTEs.



**Fig. 3:** Percentage of FTEs working within consortia, experiments or other.

Fig. 3 shows the FTEs involvement in research activities within consortia (AIDA, RD#,...), or in experiments (ATLAS, ALICE, ...) or in other organisations.

Only some 300 respondents out of the 616 who stated to be involved in R&D activities indicated the percentage of time that they invest in R&Ds. Results are reported in the Tab. 3.

<5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
4	38	45	51	18	55	15	23	29	7	12

**Table 3:** Number of researchers, with different expertise, who dedicate a certain percentage of time to R&D.

The survey offered the possibility to choose among several categories of detector R&D, technologies and electronics activities. The percentages of FTEs working in the different specializations are presented in Tab. 4 and Tab. 5.

<b>Detector categories</b>	<b>% of FTE</b>
Vertex detectors	15
Trackers	23
Detectors for Particle Identification	14
Calorimetry	15
Timing detectors	12
Highly specialized instrumentation for Neutrino searches	7
Highly specialized instrumentation for Astroparticle	7
Other ( <i>gamma spectrometry, neutron detection, dosimeter, beam monitors, gravitational waves.....</i> )	5

**Table 4:** Percentage of FTEs working in major detectors R&D categories.

<b>Detectors technologies</b>	<b>% of FTE</b>
Gaseous detectors	15
Semi-conductors	35
Scintillators and crystals	12
Photo-detectors	12
Cryogenic (liquid) detectors	3
Cerenkov detectors	3
Highly specialized mechanics	8
Detector specific software	10
Other ( <i>TES – RF related - bolometers, opto-mechanical sensors – MEMS, laser, photonics, magnets, quantum sensors ...</i> )	2

**Table 5:** Percentage of FTEs working in major detectors R&D technologies.

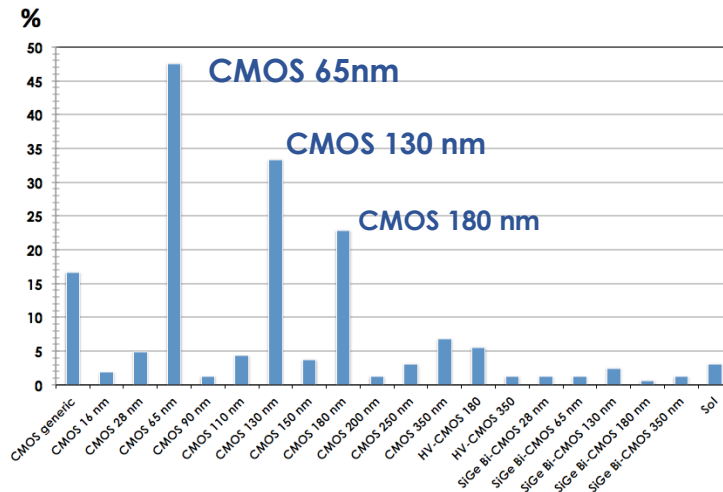
It appears, that a majority of people is involved in Vertex detectors and Trackers mostly based on semiconductors.

The survey investigated the interest in electronics R&D; multiple answers were allowed and are summarised in Tab. 6.

<b>Activities on electronic domains</b>	<b>% Normalised to number of respondents (311)</b>
Monolithic integrated silicon detectors	27
FPGA firmware	38
FE ASICs for several detector types	79
On-detector & optoelectronics	45
Off-detector & Trigger	29
Off-detector & processing	26
Powering	19
Other ( <i>RF data transmission, services &amp; integration,....</i> )	2

**Table 6:** Involvement in R&D on different electronics domains (*multiple answers possible*).

25% of respondents are involved in R&D on the Front End electronics technologies listed in Fig. 4. Multiple entries were possible for this question; data are normalised to the respondents to the question.



**Fig. 4:** Main technologies pursued on Front End electronics by 25% of respondents.

88% of respondents are, as well, involved in characterization, integration and performance optimization studies. The activities are reported in the Tab. 7.

Activities	% normalised to number of respondents (537)
Beam tests	66
Ageing studies	21
Radiation hardness tests	44
Quality control / Quality assurance	42
Cooling	19
Services and integration	34
Software development for detector simulations	37
Software development for detector performance assessment	38
Other ( <i>design, Integration, production, trigger optimization, DAQ, alignment, radiopurity checks, development with industries</i> )	5
	>100

**Table 7:** Sub-activities in which researchers are involved (*multiple answers possible*).

78% of respondents perceive that their R&D activities are suited also for applications outside fundamental physics. Mentioned in this context were the fields of medicine (65%), dosimetry (26%), civil security (18%), cultural heritage (10%), nuclear control (25%) and others such as photon science, geophysics, volcanology, industry, magnet related activities, muon & large tomography, data handling, space, agriculture, optics, precision metrology, marine biology, environmental, high-tech engineering, telecommunications (18%) (*multiple answers possible*).

However, with this variety of possible applications, it is puzzling to see that only in 30% of cases, exploitation or technology transfer strategies are embedded in the programmes. And, it is also surprising to learn that, when a technology transfer strategy is possible, almost 70% of the groups feel that they do not get enough support to solve financial, manpower, technical and legal issues.

Roughly 50% of detector R&D activities are carried out in partnership with industry. Here, in 50% of the cases the collaboration with industries is restricted to the R&D phase while in 34% of the cases industries are exploited only for the mass production. In the remaining 16% of the cases, the collaboration with industries covers both the R&D and production phases.

R&D programmes are mostly reviewed by national agencies (68%) and the associated experiments or collaborations (48%), followed by international agencies (29%). Note, that multiple answers were possible. The funding agencies involved are reported in the Tab. 8.

Agency	% Respondents
International funding program	13
EU funding program	32
National funding agency	71
Home Institute	52
Not aware	5
Other ( <i>Mainly private or industry</i> )	1
	>100

**Table 8:** Agencies funding the R&D projects (*multiple answers possible, data normalized to number of respondents*).

It is worth noting that still a very large majority of funding sources are the home institutes or the national funding agency, even if the funds from the EU programmes play a non-negligible role.

Other forms of support were investigated, namely: support in terms of manpower, funds, access to common infrastructure and irradiation facilities. The results as described in Tab. 9 being: excellent infrastructure available for testing; manpower perceived as not being sufficient; there is a reasonable availability of funds.

Manpower (550 entries)		Funds (550 entries)		Access to test beam (430 entries)		Test beam infrastructures (415 entries)		Irradiation facilities (355 entries)	
YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
35 %	65 %	55 %	45 %	92 %	8 %	88 %	12 %	89 %	11 %

**Table 9:** Available support to R&D for what concerns: manpower resources, funds, test beams access, test beam infrastructures and irradiation facilities.

According to this survey, the R&D in Europe is reasonably organized centrally (50% yes, 50% no), but it should be better coordinated among the fundamental physics communities (77% yes, 23% no).

The opportunities for PhD students and/or PostDocs to contribute to detector R&D was investigated. Normalised to the number of respondents, 65% of the people responding to the survey believe that there are enough opportunities and 35% replied negatively.

59% of the people responding to the survey claim that training in detector R&D is sufficiently available.

Concerning the perceived perspective for job/career opportunities for detector R&D experts in different domains, the respondents provided the results reported in Tab 10.

	YES (%)	No (%)
In research field	39	61
In industry	66	34
In tertiary sector, requiring advanced software development skills	80	20

**Table 10:** Perceived perspective for job/careers for detector R&D experts.

380 respondents expressed their opinion on what they believe to be the most promising R&D areas for the next decade. The eleven most abundant results are reported in Tab. 11.

<b>Most promising future R&amp;Ds</b>	<b># answers (380 total)</b>
Precision timing	210
Precise position resolution	63
Precise energy measurements	25
Radiation Hardness	29
CMOS HV-MAPS monolithic	24
High granularity imaging calorimetry	21
Artificial intelligence / Machine Learning	16
Fast (tracker) triggers (online)	16
High rate capability	14
Low power consumption in detector systems/electronics,	14
4D tracking	14

**Table 11:** Perceived most promising future R&D topics (top-11).

The following items were frequently mentioned among the comments provided with the answers:

- The development towards detectors with multiple functionalities in a single detector device (e.g. precise position and time, precise position and energy, accurate measurement and particle identification, accurate measurement and fast trigger, etc)
- Detectors with embedded intelligence (advanced algorithms, self-calibration, real-time processing, machine learning / artificial intelligence);
- Detectors with fast readout (partially linked to the previous bullet), making use of fast algorithms, high-speed links, and handling of very large numbers of channels;
- Advances in engineering challenges, like low-mass services and interconnects, low power electronics and power distribution, detector cooling, large surfaces and scalability, reliability.

## 2. Findings and Observations

Several questions listed in the survey offered the option of entering additional feedback in free text form. In total some 2300 free text comments were received. These comments have been assigned to a few main subject categories, they have been analysed statistically for pertinent and recurring feedback and were put in direct relation with the statistical results presented in section 1. The main findings and observations resulting from this analysis are presented below. The resulting recommendations have been drawn up by the panel members and are presented in Section 3.

### Subject: Career opportunities:

As already stated, advanced detector technologies are essential for progress in experimental particle physics and this requires high-levels of professional physics and engineering skills, the ability to generate original ideas and dedicated effort over many years.

In terms of career perspectives, detector technology research is less well valued than physics data analysis and interpretation. This is already the case at PhD level, where a major focus on physics analysis is often a requirement for graduation. Subsequently there are fewer recruitment and career opportunities, in particular senior level grant support and long-term positions, for detector technology experts. This forces young talent to leave the field, despite their expertise being much needed by fundamental research and the future developments.

The imbalance between physics analysis experts and detector technology experts appears as a bias that perpetuates itself over the long term, given the dominance of physics analysis experts in decision-making positions.

#### Subject: Training opportunities

As mentioned in section 1, 59% of the persons responding to the survey claim that training in detector R&D is sufficiently available. Nonetheless, those who replied negatively underline the following main points:

For detector R&D it is important to have a broad view. Opportunities to gather experience on multiple detector technologies are limited.

Students and postdocs often lack basic knowledge in electronics, mechanics, software and instrumentation. University training is often insufficiently oriented towards these aspects.

In large experiments, there are very few and only narrow windows of opportunity for doing interesting detector R&D work; after the design era the R&D work becomes more specialised, industrialised, and less appropriate as a thesis topic.

#### Subject: Technology transfer from detector development to applications in wider society

Detector technologies bring prominent visibility and lend importance to particle physics as a frontier domain providing spin-off from basic research to applications in society.

Technology transfer from detector development to applications for wider society is embedded in one third of the detector R&D activities, though generally with insufficient support from the institutions involved.

#### Subject: Central coordination of R&D activities and coordination with other fields

Further coordination between detector development activities is often seen as very positive in terms of: networking, common workshops, exchange of information and ideas, reduction of duplication, exchange of methodologies, and sharing of effort, investments and infrastructure.

In view of the above, the networking R&D collaborations, such as RD50, RD51, RD53, CALICE and AIDA2020 are mentioned as positive examples. Further coordination efforts of this type (initiated through CERN or through new European funding programmes) would be welcomed.

While central coordination of R&D is mentioned as positive in terms of avoiding duplication of efforts and clustering of smaller activities, reservations are expressed in many of the responses. Central top-down organisation can be counterproductive as it may become too top down, may resist new ideas, may reduce freedom, may not deal well with conflicting constraints or requirements, and may increase overheads and bureaucracy.

There is a clear and largely shared call for improved exchange of information between fundamental physics fields and technology specialisations, to provide opportunities for better use of expertise available elsewhere and to facilitate multidisciplinary approaches (e.g. solid state physics, material science, nano-technologies, microelectronics, photonics, engineering institutions, industry).



### 3. Recommendations

In this section a number of recommendations are listed. They have been drawn up by the ECFA Detector Panel, principally motivated by statistical analysis of the feedback from the detector R&D survey discussed above.

The recommendations listed below overlap with recommendations already provided to the previous update of the European Strategy for Particle Physics in 2012. This holds in particular for the recommendations concerning career perspectives for detector scientists. Progress in this domain has been disappointing and more effective measures are needed.

#### Recommendations on: Career opportunities

In the interest of the field, detector research needs to be recognised correctly as a fundamental research activity bearing a large impact on the final physics results.

Detector development needs to be fully recognised as a research field leading to a PhD degree, while mixed PhD and postdoctoral positions in physics analysis combined with detector development need to be stimulated further.

Professional career opportunities for detector development experts need to be improved, for example through the creation of advanced research grants and long-term positions.

#### Recommendations on: Training opportunities

It would be profitable to enhance, already at the level of university training, the basic knowledge required for applied physics activities (e.g. electronics, mechanics, software and instrumentation).

Programmes that favour the exchange of students and young postdocs among different detector expert groups and in different institutions should be initiated and endorsed.

#### Recommendation on: Technology transfer from detector development to applications in the wider society

Enhanced support (financial, manpower, technical, legal) is needed from institutions to obtain adequate effectiveness in the technology transfer from particle detector development to applications relevant to the wider society. Effective technology transfer would bring fundamental research closer to the needs of the whole of society.

#### Recommendations on: Central coordination of R&D activities and coordination with other fields

Continued support is requested for detector development collaborations and consortia such as RD50, RD51, RD53, CALICE and AIDA2020, recognising enhanced productivity achieved through general networking, such as the exchange of information and methodologies, and the sharing of efforts, investments and infrastructures. Further initiatives towards similar R&D collaborations, initiated by CERN or through new European funding programmes, are recommended.

Initiatives towards enhanced exchange of information between physics fields and technology specialisations are recommended, in order to make better use of expertise available in other fields and improve on multidisciplinary approaches (e.g. solid state physics, material science, nano-technologies, microelectronics, photonics, engineering institutions, industry).

#### 4. Further Ideas

Based on the outcome of the survey, the ECFA panel has reflected on which role it can play in the process of implementing the derived recommendations, taking into account that the panel does not dispose of direct resources, but can make suggestions.

The panel is convinced that the major issues concerning visibility and perspective of detector scientist can only be addressed by changing attitudes, raising awareness and through distributed actions by many actors (in particular decision makers), within the particle physics community.

Examples of first ideas are listed below. These will be discussed with the parties involved and will be refined further. In addition to the points listed, the panel will explore other options beyond the examples listed below.

1. To offer patronage to some of the excellent instrumentation schools and see if they would award a small number of prizes for the best students attending.
  - 1.1. Possibilities for such prizes could include support to present their work at an appropriate conference or sponsorship in order to work for a fixed period with leading instrumentalists at one of the major international laboratories
  - 1.2. Another aspect of patronage for instrumentation schools could be to explore provision of a small number of scholarships to facilitate attendance by students who cannot be supported to come by their institutions.
2. Instrumentation schools could also be encouraged to offer some of their teaching materials (suitably acknowledged) through web pages set up by the ECFA-DP to improve teaching about detector technologies across European institutes. These actions should also help create more general interest in the schools themselves.
3. Greater appreciation of the vital role played by detector developments could be recognised by instigating a small number of ECFA-DP appointed positions as Detector Physics Ambassadors to appropriate experts in the field. These roles could include preparing a Webinar on the Detector Physics Ambassador's particular area of expertise and giving seminars at the relevant instrumentation schools.