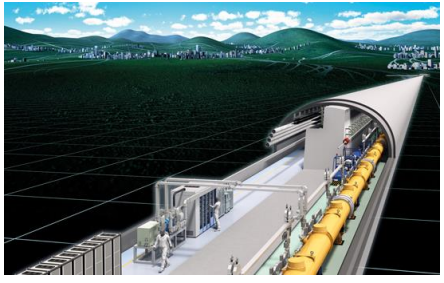
1. Physics, Experiments and Detectors at a Future Higgs/EW/Top Factory

Plenary ECFA statement (July 2020)

- *ECFA recognizes the need for the experimental and theoretical communities involved in physics studies, experiment designs and detector technologies at future Higgs factories to gather.* ***ECFA supports a series of workshops*** *with the aim to* ***share challenges and expertise, to explore synergies in their efforts*** *and to respond coherently to this priority in the European Strategy for Particle Physics (ESPP).*

Goal: bring the entire e^+e^- Higgs factory effort together, foster cooperation across various projects; collaborative research programmes are to emerge



- Study has been launched, **Working Groups** have started their activities, important **Topical Meeting** have been held / are upcoming

- The study is open to all interested physicists and a strong participation from the ILC, CLIC, FCC-ee and CEPC communities and beyond, e.g. (HL)-LHC, Belle, … are highly welcome;
  Also open for cooperation with other activities, e.g. Snowmass, …

ECFA Working Groups

WG 1: Physics Potential

Convener: Juan Alcaraz (CIEMAT - Madrid), Jenny List (DESY), Fabio Maltoni (UC Louvain / Bologna) and ~~James Wells (Univ. Michigan)~~ Jorge de Blas (Granada)

WG 2: Physics Analysis Methods

Convener: Patrizia Azzi (INFN-Padova / CERN), Fulvio Piccinini (INFN Pavia) and Dirk Zerwas (IJCLab / DMLab)

Kick-off meeting to start WG1 and WG2 activities took place on 18th June: https://indico.cern.ch/event/1033941/

WG 3: Detector R&D

Activities to be aligned with the ECFA Detector R&D Roadmap implementation

It may be possible that important detector R&D activities can be embedded in the defined Detector R&D Themes (DRDTs) of the ECFA Detector R&D Roadmap and in the emerging structures set up during the implementation process

Overall Goal: ECFA workshops in 2022 and 2023;
Final Report in 2024

2022 ECFA e^+e^- Workshop in Hamburg 5 – 7 October 2022

- Status of Working Group activities
- Discussion of future plans
- Interaction between theory and experiments
- …

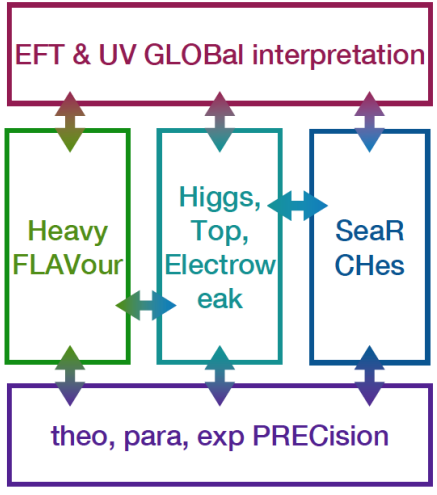
- An important **Outreach Event** is planned;

  Public Talk (kick-off for e^+e^- activities / next large collider in Europe)

Ongoing Activities of WG1 and WG2

Juan Alcaraz, Jorge de Blas, Jenny List, Fabio Maltoni

- **WG1**: Five sub-activities have been established:
  - **WG1-GLOB:** Global interpretation in (SM)EFT and UV complete models
  - **WG1-PREC:** Precision calculations and theoretical, parametric and experimental syst. uncertainties
  - **WG1-HTE:** Higgs, top and electroweak physics, incl. high-pT
  - **WG1-FLAV:** Flavour physics
  - **WG1-SRCH:** Direct discovery potential, incl. FIP



- **Seminar Series**
  (to be established, together with WG2)

https://indico.cern.ch/event/1044297/page/23971-wg1-group-activities

Ongoing Activities of WG1 and WG2

Patrizia Azzi, Fulvio Piccinini, Dirk Zerwas

- **WG2**: Has started to organise a series of important **Topical Meetings**:

  - ***First Topical Meeting on Generators*** on 9 -10th November 2021: https://indico.cern.ch/event/1078675/ (common workshop for WG1 and WG2)

  - ***Second Topical Meeting on Simulation*** on 1 -2nd February 2022: https://indico.cern.ch/event/1097819/

  - **Third Topical Meeting on Reconstruction** scheduled for 4 – 5th May 2022 (Agenda will develop here: https://indico.cern.ch/event/1124095/)

  → Follow-up in dedicated Focus Meetings

- Organisation in close interaction with **Software Ecosystem (KEY4HEP)** representatives of the various communities (Frank Gaede ILC, Gerardo Ganis FCC-ee, and André Sailer CLIC)

Access to Information, e-group

- Major entry portal to collect information on the ongoing activities:

  https://indico.cern.ch/event/1044297/ All upcoming events will be announced there!

- Registration of kick-off meeting has been used to define an e-group for further information

  ECFA-Workshop-Higgs-factory@cern.ch

  Subscription is still possible, please do so, if interested!

2. The 2021 ECFA Detector R&D Roadmap

- Approved by Plenary ECFA on 18 Nov 2021
- Released in December 2021, after presentation to CERN Council

Documents available:

https://cds.cern.ch/record/2784893

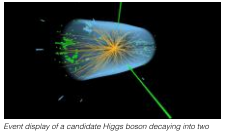
Synopsis Document

_Building the Foundations

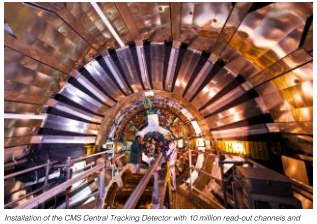
"Strong planning and appropriate investments in Research and Development (R&D) in relevant technologies are essential for the full potential, in terms of novel capabilities and discoveries, to be realised."

The field of particle physics builds on the major scientific revolutions of the 20th century, particularly on the experimental discoveries and theoretical developments which culminated in the Nobel Prize-winning discovery of the Higgs boson at CERN in 2012. The ambitions for the field going forward are set out from a European perspective in a global context in the European Strategy for Particle Physics (ESPP) which was updated in 2020. This strategy lays down a vision for the coming half-century, with a science programme which, in exploring matter and forces at the smallest scales and the Universe at earliest times, will continue to provide answers to questions once thought only to be amenable to philosophical speculation, and has the potential to reveal fundamentally new phenomena or forms of matter never observed before.

The ESPP recognises the huge advances in accelerator and detector technologies since the world's first hadron collider, the Intersecting Storage Rings, started operation at CERN 50 years ago. These advances have not only supported, and in turn benefited from, numerous other scientific disciplines but have spawned huge societal benefits through developments such as the World Wide Web, Magnetic Resonance Imaging, Positron Emission Tomography and 3D X-ray imaging.



Event display of a candidate Higgs boson decaying into two photons as recorded by the CMS experiment. (© CERN)



Installation of the CMS Central Tracking Detector with 10 million read-out channels and using silicon detectors covering an area of over 200 m². (© CERN)

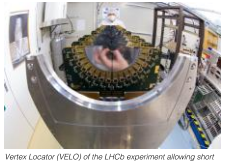
ATLAS gas detector based muon spectrometer, which covers a total area the size of a football field and measures the paths of the muons that pass through it to an accuracy of better than a tenth of a millimetre. (© CERN)

The far-reaching plans of the ESPP require similar progress over the coming decades in accelerator and detector capabilities to deliver its rich science programme. Strong planning and appropriate investments in Research and Development (R&D) on relevant technologies are essential for the full potential, in terms of novel capabilities and discoveries, to be realised.

The 2020 update of the ESPP called on the European Committee for Future Accelerators (ECFA) to develop a global Detector R&D Roadmap defining the backbone of detector R&D required to deploy the community's vision. This Roadmap aims to cover the needs of both the near-term and longer-term programme, working in synergy with neighbouring fields and with a view to potential industrial applications.

_Setting the Priorities

"To fully explore the properties of the Higgs boson and study many of the other deepest questions in physics necessitates the development of a roadmap for the required detector technologies."

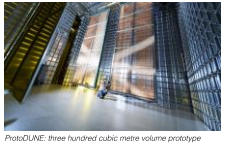


Vertex Locator (VELO) of the LHCb experiment allowing short lived particle lifetimes to be measured with precision of a twentieth of a picosecond. (© CERN)

The highest priority laid down by the updated ESPP is for a future Higgs factory to thoroughly explore the properties of this completely new type of particle, which is seen as a key to a much deeper understanding of how the Universe works. Until the discovery of the Higgs boson, every known particle was either a "matter" or a "force" particle, describing the world in terms of fundamental entities and their interactions without being able to accommodate the fact that particles also have mass. In the ESPP, the vision for the future facilities to fully explore the properties of the Higgs boson and study many of the other deepest questions in physics necessitates the development of a roadmap for the required detector technologies (in much the same way as the LHC and its upgrades significantly guided R&D planning for previous decades). The ECFA Detector R&D Roadmap addresses this need whilst highlighting synergies with other projects on nearer timescales and showing how they are also embedded in the longer-term context.

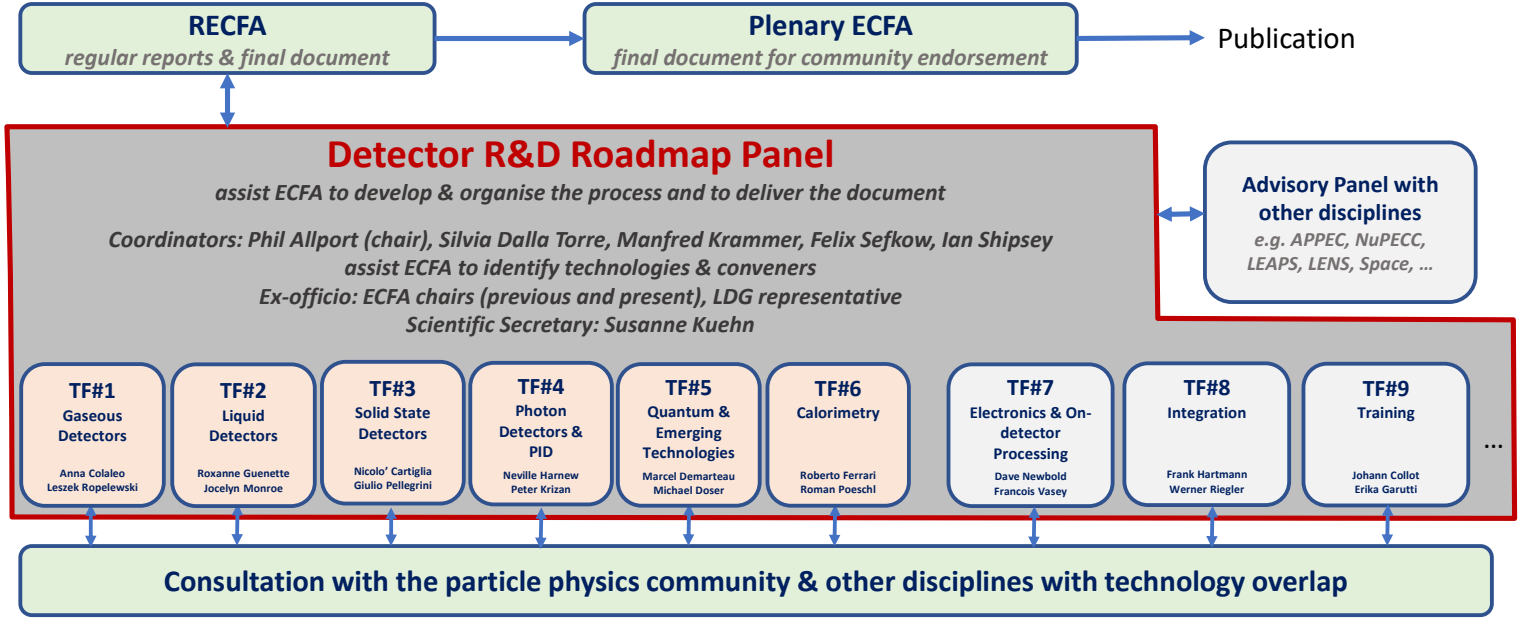
Insertion of lead-tungstate crystals (over three times the density of conventional glasses) into the high granularity electromagnetic calorimeter of the ALICE detector giving percent scale energy measurements. (© CERN)

In the area of detector development, it is vital to build on Europe's world-leading capabilities in sensor technologies for particle detection, using gas and liquid-based or solid-state detectors, as well as energy measurement and particle identification. Also required are cutting-edge developments in bespoke microelectronics solutions, real-time data processing and advanced engineering. Adequate resourcing for such technology developments represents a vital component for future progress in experimental particle physics. Talented and committed people are another absolutely core requirement. They need to be enthused, engaged, educated, empowered and employed. The ECFA Detector R&D Roadmap brings forward concrete proposals for nurturing the scientists, engineers and technicians who will build the future facilities and for incentivising them by offering appropriate and rewarding career opportunities.



ProtoDUNE: three hundred cubic metre volume prototype Liquid Argon Neutrino Detector being constructed at CERN. (© CERN)

The Detector R&D Roadmap Process

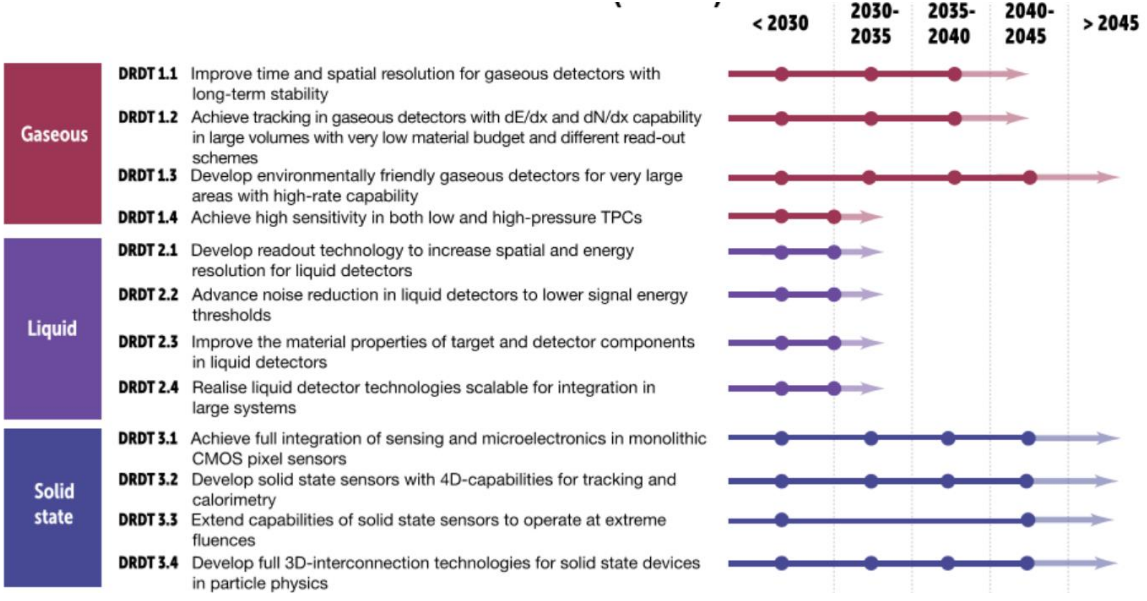


- ***Task forces*** *were composed of experts from the community covering key sub-topics in the relevant technology areas, including* ***two conveners*** *(who are part of the Roadmap Panel)*

- *Progress with emerging technologies in adjacent fields is provided through an* ***Advisory Panel with Other Disciplines*** *(→ expert contacts by Task Forces area)*

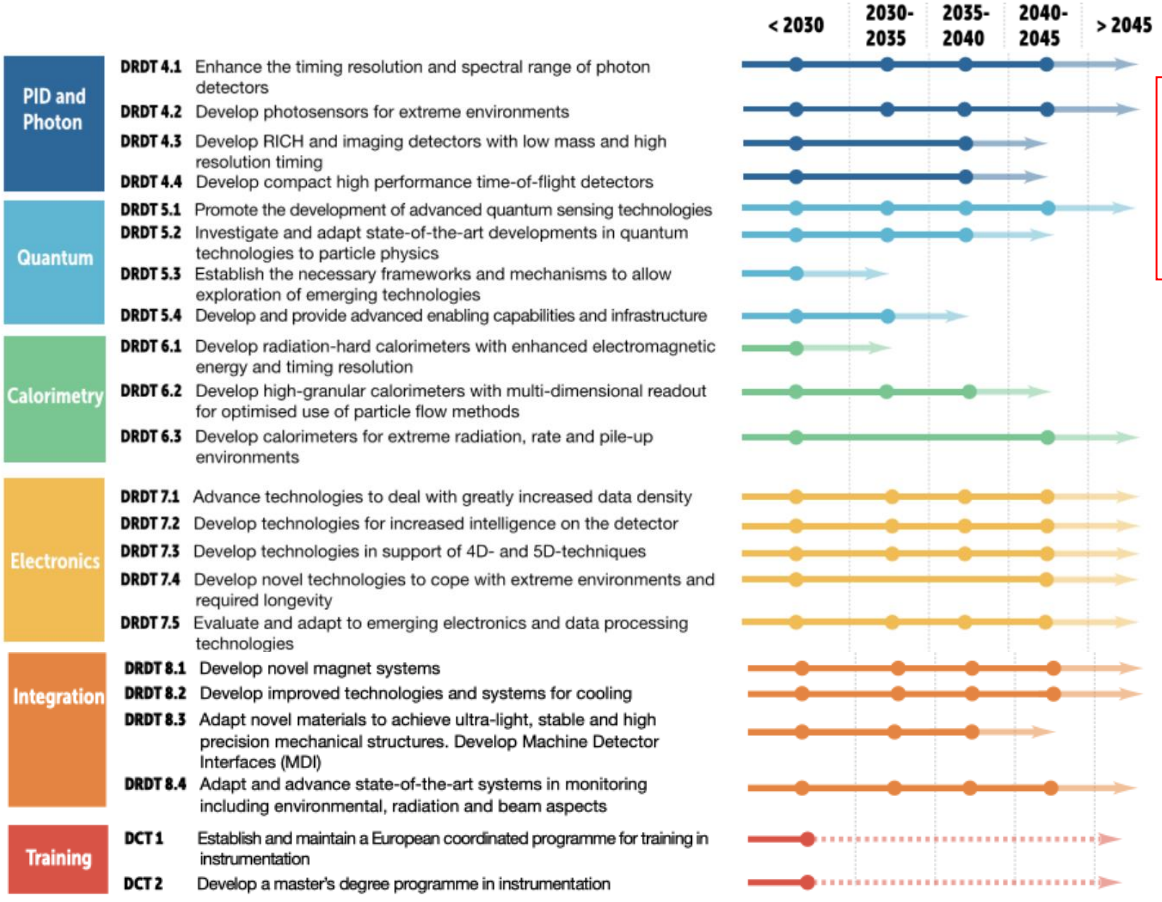
Information on the full process: [ECFA Detector R&D Roadmap]

Detector R&D Roadmap: Detector R&D Themes (DRDTs)



- Stepping stones are shown to represent the R&D needs of facilities intermediate in time.
- The faded region acknowledges the typical time needed between the completion of the R&D phase and the readiness of an experiment at a given facility**.**
- Future beyond the end of the arrows is simply not yet defined, not that there is an expectation that R&D for the further future beyond that point will not be needed.

Detector R&D Roadmap: Detector R&D Themes (DRDTs)



Detector R&D Roadmap: General Strategic Recommendations

GSR 1 - Supporting R&D facilities

GSR 2 - Engineering support for detector R&D

GSR 3 - Specific software for instrumentation

GSR 4 - International coordination and organisation of R&D activities

GSR 5 - Distributed R&D activities with centralised facilities

GSR 6 - Establish long-term strategic funding programmes

GSR 7 - Blue-sky R&D

GSR 8 - Attract, nurture, recognise and sustain the careers of R&D experts

GSR 9 - Industrial partnerships

GSR 10 - Open Science

More details in backup slides

Next Steps: Implementation Plan

- ECFA Roadmap Coordination group has been entrusted to work out the implementation plan

  Coordination Group: Phil Allport, Silvia Dalla Torre, Jorgen D'Hondt, Karl Jakobs, Manfred Krammer, Susanne Kühn, Felix Sefkow and Ian Shipsey

- To be iterated with Restricted ECFA

- Discussions with Funding Agencies are planned (together with LDG) before March Council week

- First presentation and discussion in March Council

Backup Slides

Detector R&D Roadmap: General Strategic Recommendations

GSR 1 - Supporting R&D facilities

It is recommended that the structures to provide **Europe-wide coordinated infrastructure in the areas of: test beams, large scale generic prototyping and irradiation be consolidated and enhanced to meet the needs of next generation experiments** with adequate centralised investment to avoid less cost-effective, more widely distributed, solutions, and to maintain a network structure for existing distributed facilities, e.g. for irradiation

GSR 2 - Engineering support for detector R&D

In response to ever more integrated detector concepts, requiring holistic design approaches and large component counts, the R&D should be supported with **adequate mechanical and electronics engineering resources**, to bring in expertise in state-of-the-art microelectronics as well as advanced materials and manufacturing techniques, to tackle generic integration challenges, and to maintain scalability of production and quality control from the earliest stages.

GSR 3 - Specific software for instrumentation

Across DRDTs and through adequate capital investments, the availability to the community of **state-of-the-art R&D-specific software packages must be maintained and continuously updated**. The expert development of these packages - for core software frameworks, but also for commonly used simulation and reconstruction tools - should continue to be highly recognised and valued and the community effort to support these needs to be organised at a European level.

GSR 4 - International coordination and organisation of R&D activities

With a view to creating a vibrant ecosystem for R&D, connecting and involving all partners, there is a **need to refresh the CERN RD programme structure and encourage new programmes for next generation detectors**, where CERN and the other national laboratories can assist as major catalysers for these. It is also recommended to revisit and streamline the process of creating and reviewing these programmes, with an extended framework to help share the associated load and increase involvement, while enhancing the visibility of the detector R&D community and easing communication with neighbouring disciplines, for example in cooperation with the ICFA Instrumentation Panel.

Detector R&D Roadmap: General Strategic Recommendations

GSR 5 - Distributed R&D activities with centralised facilities

Establish in the relevant R&D areas a distributed yet connected and supportive tier-ed system for R&D efforts across Europe. Keeping in mind the growing complexity, the specialisation required, the learning curve and the increased cost, consider more focused investment for those themes where leverage can be reached through centralisation at large institutions, while addressing the challenge that distributed resources remain accessible to researchers across Europe and through them also be available to help provide enhanced training opportunities.

GSR 6 - Establish long-term strategic funding programmes

Establish, additional to short-term funding programmes for the early proof of principle phase of R&D, also **long-term strategic funding programmes to sustain both research and development of the multi-decade DRDTs** in order for the technology to mature and to be able to deliver the experimental requirements. Beyond capital investments of single funding agencies, international collaboration and support at the EU level should be established. In general, the cost for R&D has increased, which further strengthens the vital need to make concerted investments.

GSR 7 – "Blue-sky" R&D

It is essential that **adequate resources be provided to support more speculative R&D** which can be riskier in terms of immediate benefits but can bring significant and potentially transformational returns if successful both to particle physics: unlocking new physics may only be possible by unlocking novel technologies in instrumentation, and to society. Innovative instrumentation research is one of the defining characteristics of the field of particle physics. "Blue-sky" developments in particle physics have often been of broader application and had immense societal benefit. Examples include: the development of the World Wide Web, Magnetic Resonance Imaging, Positron Emission Tomography and X-ray imaging for photon science.

Detector R&D Roadmap: General Strategic Recommendations

GSR 8 - Attract, nurture, recognise and sustain the careers of R&D experts

Innovation in instrumentation is essential to make progress in particle physics, and R&D experts are essential for innovation. It is recommended that ECFA, with the involvement and support of its Detector R&D Panel, continues the study of **recognition with a view to consolidate the route to an adequate number of positions with a sustained career in instrumentation R&D** to realise the strategic aspirations expressed in the EPPSU. It is suggested that ECFA should explore mechanisms to develop concrete proposals in this area and to find mechanisms to follow up on these in terms of their implementation. Consideration needs to be given to creating sufficiently attractive remuneration packages to retain those with key skills which typically command much higher salaries outside academic research. It should be emphasised that, in parallel, society benefits from the training particle physics provides because the knowledge and skills acquired are in high demand by industries in high-technology economies.

GSR 9 - Industrial partnerships

It is recommended to **identify promising areas for close collaboration between academic and industrial partners**, to create international frameworks for exchange on academic and industrial trends, drivers and needs, and to establish strategic and resources-loaded cooperation schemes on a European scale to intensify the collaboration with industry, in particular for developments in solid state sensors and micro-electronics.

GSR 10 – Open Science

It is recommended that the concept of **Open Science be explicitly supported in the context of instrumentation**, taking account of the constraints of commercial confidentiality where these apply due to partnerships with industry. Specifically, for publicly-funded research the default, wherever possible, should be open access publication of results and it is proposed that the Sponsoring Consortium for Open Access Publishing in Particle Physics (SCOAP^3) should explore ensuring similar access is available to instrumentation journals (including for conference proceedings) as to other particle physics publications.