
# Highlights e discussione finale

INFN

POLITECNICO DI BARI

CAEN Tools for Discovery

FONDAZIONE BRUNO KESSLER

AIDA innova

# Domande per tematica tecnologica

1) quali sono i punti di forza della comunita' italiana?

2) quali sono le prospettive future a medio-lungo termine?

3) quali sono i punti critici che possono comportare rischi?

# Rivelatori a Stato Solido

Giovanni Ambrosi, Nicolò Cartiglia, Adriano Lai

1) quali sono i punti di forza della comunita' italiana?

- Storicamente:
  - Tradizione e know-how nella progettazione e realizzazione grandi tracciatori in HEP
  - Progettazione di **elettronica di readout** (per esempio RD53)
  - Forte presenza italiana per **tracciatori per lo spazio**

- R&D
  - Competenze scientifiche e tecnologiche su rivelatori **ibridi per timing** (LGAD/3D)
  - Pionieri della read-out **electronics a 28nm**

# IFD 22 – Solid States

## Highlights e Discussione Finale

2) quali sono le prospettive future a medio-lungo termine?

- l’aggiunta del **timing** sembra esser l’innovazione principale nei future detector per tracking. Prospettive di miglioramento delle tecnologie hybrid per 4D tracking (3D, RSD-LGAD, TI-LGAD,…)
- Serve uno **sviluppo dell'elettronica** in grado di sfruttare le proprieta' dei sensori gia raggiunti per le prospettive a medio termine
- **3D-Interconnesioni** per hybridi, ma anche monolitici, diventa essenziale per raggiungere specifiche richieste (risoluzione spazio-temporale e budget ridotto)
- Spazio: **esperimenti con piccoli satelliti** rappresentano una piattaforma ideale per qualificare tecnologie di rivelatori gia’ esistenti o in fase di sviluppo.
    - Potrebbero rappresentare un interessante ponte tra sviluppi per acceleratori pianificati in un futuro remoto e le tecnologie nello spazio

# IFD 22 – Solid States

## Highlights e Discussione Finale

3) quali sono i punti critici che possono comportare rischi?

- Lo sviluppo di elettronica e tecniche di integrazione avanzate sono molto costose e complesse:
  - Massa critica di persone e finanziamenti per affrontare le sfide piu' impegnative (esempio progetto IGNITE trasversale a sezioni INFN e competenze)
  - Individuare alcune tecnologie hardware specifiche per non rischiare di disperdere gli sforzi.
- Alcuni sviluppi sono a lungo temine (20+anni) e non ancora ben definiti (FCC, vs muon, vs …) Come si possono coinvolgere senior e junior su prospettive che non corrispondono alla vita lavorativa.
- Aspetti Tecnologici specifici
  - timing e low power (and low mass - high rad hardness) sono ad oggi requisiti ad oggi conciliabili.

# Rivelatori a fase liquida

Gioacchino Ranucci, Filippo Resnati,
Marco Selvi, Francesco Terranova

## Summary on Liquid Detectors - IFD2022

**Quali sono i punti di forza della comunità italiana?**

- Importanti legacies che hanno "forgiato" l'expertise dei gruppi italiani:
  - ICARUS e DS-50 per il LAr,
  - Borexino per lo scintillatore liquido, e le relative tecniche di purificazione
  - XENON per lo Xe-handling e il water Cherenkov (Gd-doped e non), utilizzato come mu e n veto
  - SK, Antares e KM3 per lo sviluppo di fotosensori utilizzati in HK
- I gruppi italiani sono in generale in posizioni chiave per quanto riguarda il design generale e lo sviluppo dei fotosensori dei rivelatori futuri.
- Gli R&D sono tutti svolti come attività mirate a esperimenti di punta nel contesto internazionale nei rispettivi ambiti. Questo spinge gli R&D a dover essere estremamente concreti e finalizzati.
- Ruolo del LNGS (almeno per DM e double-beta, dove parecchi degli schermi attivi sono "liquidi")

**Quali sono le prospettive future a medio-lungo termine?**

La strategia è chiara su tutte le linee, con grande e cruciale partecipazione italiana:

- DUNE e HK per i neutrini del GeV
- JUNO per i neutrini del MeV
- DARKSIDE-20k (Ar) e DARWIN (Xe) per la Dark Matter

**Quali sono i punti critici che possono comportare rischi?**

- readout di carica sul Vertical Drift di DUNE, miglioramento della light collection efficiency, e fast-readout per il ND
- verifica sul campo della adeguatezza delle specs di 20 kt di scintillatore liquido
- procurement di O(50t) di Xe o di Underground&Distilled Ar
- consolidare la tecnologia per l'utilizzo di O(10m2) SiPM criogenici o alternative per photodetectors
- consolidare supporto Neutrino Platform per le attività AstroParticle

# Foto-Rivelatori e PID

Fabio Gargano, Fulvio Tessarotto

1) quali sono i punti di forza della comunita' italiana?
Da quello che mi è emerso mi pare evidente che uno dei punti di forza sia il grande fermento sulle attività di R&D attorno ai SiPM. L'INFN dovrebbe continuare a lavorare, come già fa, a stretto contatto con FBK per testare nuove tipologie di SiPM prodotte ad hoc. Probabilmente FBK non è il partner ideale per grosse produzione, ma in quel caso una opzione potrebbe essere LFoundary.

2) quali sono le prospettive future a medio-lungo termine?
Su questo mi pare che il documento ECFA sia abbastanza chiaro, nel medio termine vanno portate avanti tutte le tecnologie di photodetection, ma tenendo presente che il futuro a lungo termine ( a meno di game changer inaspettati) prevede un uso massiccio di SiPM. Come detto ieri la tecnologia tuttavia non ha ancora fatto una vera prova sul campo in grossi esperimenti e per lunghi periodi di operatività, quindi il futuro non è perfettamente chiaro e l'R&D è ancora determinante

# Foto-Rivelatori e PID

Fabio Gargano, Fulvio Tessarotto

3) quali sono i punti critici che possono comportare rischi? La criticità principale che vedo è l'eterogeneità della comunità di riferimento. Non ripeto quanto detto ieri, ma la PID è argomento trasversale a tutte le comunità e a tutte le tecnologie di rilevazione di particelle. Anche la photodetection non si limita a sole applicazioni di PID ma spazia su campi ampi.

Altro punto critico da sottolineare è il disaccoppiamento fra sensore ed elettronica. Se non è ben gestito potrebbe portare a non trascurabili problemi di convergenza di tempi ed intenti.

# Rivelatori a gas

Davide Boscherini, Paolo Iengo, Davide Pinci

1. Punti di forza della comunita' italiana

Diversity: gruppi attivi su tante differenti tecnologie;
Vitalità delle attività di R&D in corso: comunità ancora nutrita con molti giovani; Competenze derivanti da lunga tradizione;

2. Prospettive future medio e lungo termine

**Medio Termine**: lavori di sviluppo su tecnologie di frontiera per le applicazioni non solo ai grandi progetti LHC, ma anche in altri campi che vanno dalla fisica astroparticellare alla fisica nucleare ed alle applicazioni medicali.

**Lungo Termine**: sono state presentate proposte per FCC, Muon Collider e più in generale proposte per nuove tecnologie e materiali che potranno essere sviluppati per progetti futuri.

3. Punti critici che possono comportare rischi

In diversi momenti è stato evidenziato come gli sviluppi dell'elettronica di front-end non sempre seguono di pari passo gli avanzamenti e le necessità delle nuove tecnologie di rivelatori.
Rischi e riduzioni della disponibilità dei gas di uso consolidato. Questo comporta la necessità di continuare ad esplorare nuove soluzioni con risultati e tempi non garantiti estendendolo a tutte le tecnologie di rivelatori.

# Ulteriori Considerazioni

Le sessioni e le successive discussioni sono state senz'altro utili ed interessanti. Riteniamo quindi che questi workshop ed altre occasioni per tenere unita ed aggiornata la comunità di chi si occupa di sviluppo e realizzazione di rivelatori siano cruciali e possano aiutare anche a stimolare possibili scambi tra i vari gruppi e per questo andrebbero programmate con regolarità.

La chiusura del gruppo RD51 e l'evoluzione verso la nuova struttura DRD apre una fase incerta che desta preoccupazione. Riteniamo fondamentale che non venga persa l'esperienza positiva di RD51 pur riconoscendo la necessità di allargarsi a tutte le tecnologie. Una discussione aperta sulle nuove linee sarà perciò necessaria affinché l'INFN possa utilmente seguire ed indirizzare la transizione.

21. Introduzione Gas Detectors
Davide Boscherini (Istituto Nazionale di..., Davide Pinci (Istituto Nazionale di..., Paolo Iengo (Istituto Nazionale di...
18/10/2022, 16:30

22. The IDEA drift chamber at FCC-ee and CEPC and related elx
Brunella D'Anzi (INFN - Bari)
18/10/2022, 16:50

91. RPC with Gallium Arsenide electrodes, a solution for medium sized high-rate detectors
Alessandro Rocchi (Istituto Nazionale di...
18/10/2022, 17:00

93. The Resistive Cylindrical Chamber, a new detector based on the generalization of the RPC detectors to the quasi-planar field
Alessandro Rocchi (Istituto Nazionale di...
18/10/2022, 17:10

94. Greening Resistive Plate Chamber detectors for HEP applications.
Alessandra Pastore (Istituto Nazionale di...
18/10/2022, 17:20

95. Fast Timing MPGD
Piet Omer J Verwilligen (Istituto Nazionale di...
18/10/2022, 17:30

96. Picosec Micromegas: a fast-timing gaseous detector for MIPs
Davide Fiorina (INFN & UNiversità P..., Davide Fiorina (Istituto Nazionale di..., Davide Fiorina (Università & INFN P...
18/10/2022, 17:40

97. The micro-RWELL: from the R&D to the technology transfer towards Industry
Giovanni Bencivenni (LNF)
18/10/2022, 17:50

98. New Resistive Micromegas structures for future detectors
M Teresa Camerlingo, Maria Teresa Camerlingo (Istituto Nazionale di...
18/10/2022, 18:00

92. TPC gassose a lettura ottica per eventi di bassa energia
Flaminia Di Giambattista (Istituto Nazionale di...
18/10/2022, 18:10

Lista dei contributi (rapid talk) della sessione dei gaseous detectors

# Calorimetri

Francesca Cavallari, Ivano Sarra, Monica Sisti, Gabriella Gaudio

IFD - Bari 17-19 Ottobre 2022

## Outlook and Experience operating calorimeters for discussion

### Crystal calorimeters

- achieve optimal e.m. energy resolution
- require hard work to monitor and calibrate
- Good calibration is needed also for trigger rate stability
- Data streaming off-detector allows more flexibility and future trigger upgrades
- Can achieve precision timing

### Higly segmented / Particle Flow calorimeters

- Are optimal for particle flow techniques combined with good tracker
- Must measure the neutral hadrons and photons well
- Are intrinsically redundant
- Produce a lot of data
- Require a dedicated, sophisticated and fast software
- require some triggering logic on the front-end (today)
- Full data streaming is not possible today (perhaps in the future?)
- require detailed simulation effort to describe shower containment and especially for calibration
- Can be equipped with a precision timing layer

### Dual readout technique

- Allows best resolution for hadrons through measurement of e/h fraction
- Can be combined with a crystal e.m. calorimeter in front through Scintillation/Cerenkov light separation
- Could be made granular
- Can be equipped with precision timing measurement

# Quantum sensors “primer”

Caterina Braggio, Mirko Lobino

1) quali sono i punti di forza della comunita' italiana?

2) quali sono le prospettive future a medio-lungo termine?

3) quali sono i punti critici che possono comportare rischi?

# Trasferimento Tecnologico

1) quali sono i punti di forza della comunita' italiana?

2) quali sono le prospettive future a medio-lungo termine?

3) quali sono i punti critici che possono comportare rischi?

# Training

1) quali sono i punti di forza della comunita' italiana?

2) quali sono le prospettive future a medio-lungo termine?

3) quali sono i punti critici che possono comportare rischi?

# Discussione

- Abbiamo incluso tutte le attività e le comunità sperimentali
- Ci confrontiamo con diverse realtà internazionali non solo le facilities, ma anche gli ambienti under(ground-water-ice) e spazio …..
- Al CERN è in corso l'implementazione della Raodmap affidata a ECFA
- La Strategia per la Fisica delle Particelle in US si chiude nel 2023 con P5
- APPEC e NUPPEC hanno partecipato alla roadmap ECFA e stanno elaborando un piano

# ECFA Detector R&D Roadmap – Targeted facilities

- Full exploitation of the **HL-LHC** (R&D still needed for LS3 upgrades and for experiment upgrades beyond then) including studies of flavour physics and quark-gluon plasma (where the latter topic also interfaces with nuclear physics)
- R&D for **long baseline neutrino physics** detectors (including aspects targeting astro-particle physics measurements) and supporting experiments such as at those at the CERN Neutrino Platform
- Technology developments needed for detectors at **e+e- EW-Higgs-Top factories** in all possible accelerator manifestations including instantaneous luminosities at 91.2 GeV of up to $5\times10^{36}$ $cm^{-2}s^{-1}$.
- The long-term R&D programme for detectors at a **future 100 TeV hadron collider** with integrated luminosities targeted up to 30 $ab^{-1}$ and 1000 pile-up for 25 ns BCO
- Specific long-term detector technology R&D requirements of a **muon collider operating at 10 TeV** and with a luminosity of the order of $10^{35}$ $cm^{-2}$ $s^{-1}$
- Accelerator-based studies of **rare processes, DM candidates and high precision measurements** (including strong interaction physics) at both storage rings and fixed target facilities, interfacing also with atomic and nuclear physics.
- R&D for optimal exploitation of **dedicated collider experiments** studying the **partonic structure of the proton and nuclei** as well as interface areas with nuclear physics
- Very broad detector R&D areas for **non-accelerator-based experiments**, including dark matter searches (including axion searches), reactor neutrino experiments, rare decay processes, neutrino observatories and other interface areas with astro-particle physics.

# 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

*Aim: * Propose mechanisms to achieve a greater coherence across Europe to better streamline the local and national activities and make these more effective.*

** Give the area greater visibility and voice at a European level to make the case for the additional resources needed for Europe to maintain a leading role in particle physics with all the associated scientific and societal benefits that will flow from this.*

# Proposte

- Preparazione del documento breve per la GE ==> draft entro fine ottobre
- Come ottimizziamo il networking?

- Sarebbe bello avere l'elenco completo di chi ha partecipato, interessi etc ==> prepariamo questionario?? mailing list?

# ECFA Detector R&D Roadmap – processo 2021

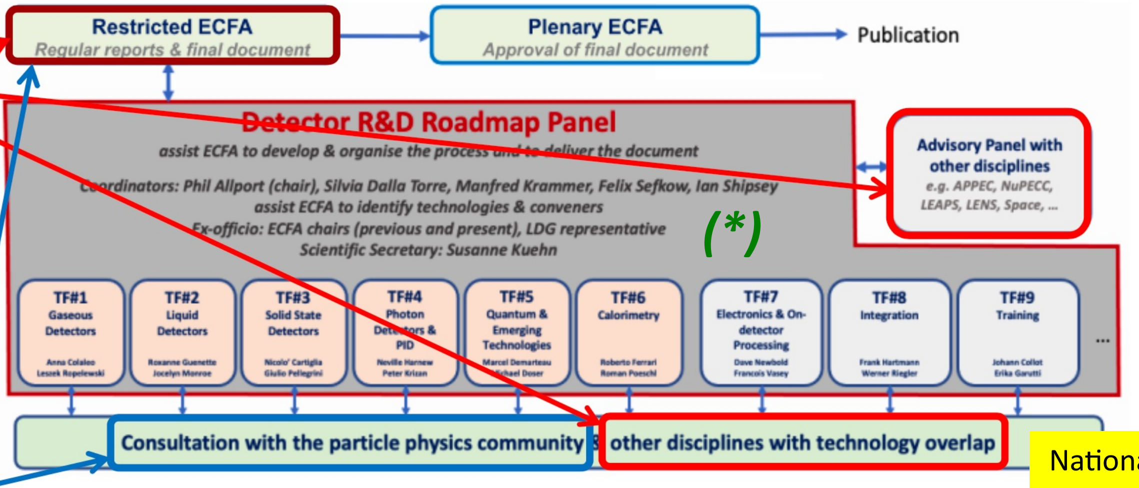

Document released in December 2021 after presentation to CERN Council: https://cds.cern.ch/record/2784893

**ECFA** European Committee for Future Accelerators

## Roadmap Organisation

***"Organised by ECFA, a roadmap should be developed by the community to balance the detector R&D efforts in Europe, taking into account progress with emerging technologies in adjacent fields"* ***

***"The community should define a global detector R&D roadmap that should be used to support proposals at the European and national levels"* ***




**ECFA Detector R&D Roadmap Panel web pages at:**
**https://indico.cern.ch/e/ECFADetectorRDRoadmap**

*** 2020 European Particle Physics Strategy Update**
**https://europeanstrategyupdate.web.cern.ch/**

*(*) Phil Allport, Silvia Dalla Torre, Jorgen D'Hondt, Karl Jakobs, Manfred Krammer, Susanne Kuehn, Felix Sefkow, Ian Shipsey*

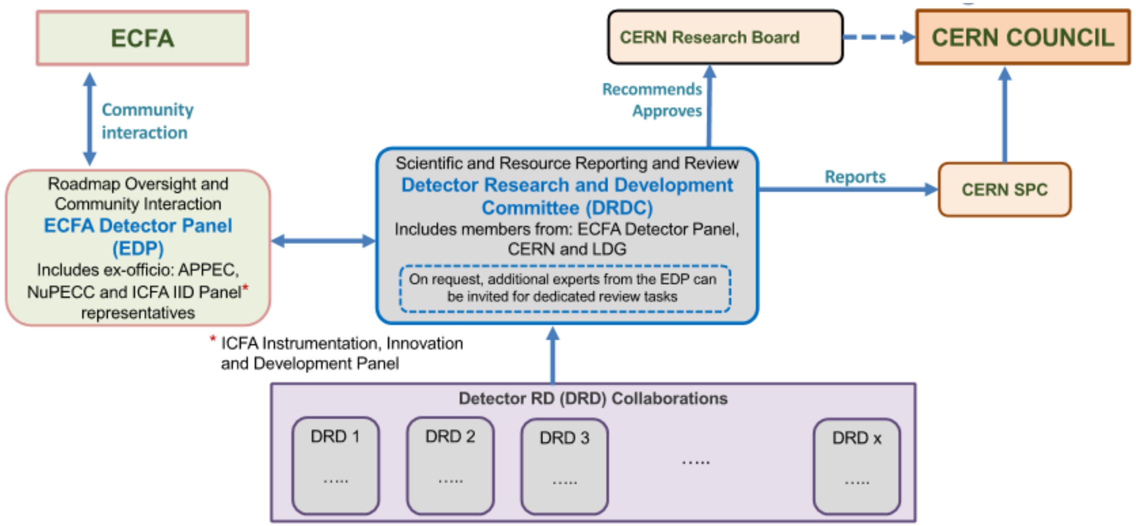
# ECFA Detector R&D Roadmap – piani

- CERN Council has mandated ECFA to work out a detailed implementation plan
  *(in close collaboration with the SPC, the funding agencies and the relevant research organisations in Europe and beyond)*
- ECFA **Roadmap Coordination Group*** worked out a proposal to organise long-term R&D efforts into:
  **newly established Detector R&D (DRD) Collaborations anchored at CERN**

**Three areas of Detector R&D:**

1. Strategic R&D via DRD Collaborations (long-term strategic R&D lines)
(address the high-priority items defined in the Roadmap via the DRDTs)
2. Experiment-specific R&D (with very well defined detector specifications)
(funded outside of DRD programme, via experiments)
3. ”Blue-sky” R&D
(competitive, short-term responsive grants, nationally organised)

**The aim is to start projects by the beginning of 2024 with a gradual ramp-up of resources in 2024/2025 to reach a steady state in 2026**



# Preparazione di un documento

- Prendiamo l’occasione per un documento che copra in modo più completo le attività INFN
- Non includendo esplicitamente elettronica e infrastruttura perché li consideriamo inclusi del resto
- Siamo nella fase in cui si discute l’implementazine della roadmap
- → e quindi è importante in questo momento discuterne tra di noi, in un modo che permetta a tutti di dare il loro contributo
- Ci sarà un prossimo plenary ECFA a Novembre e dobbiamo arrivarci preparati
- P-ECFA 17-18 Nov +varie CSN sempre a Novembre → scadenza per il documento (Bozza fine ottobre)

# Comitato Scientifico e Locale

**SCIENTIFIC Organizing Committee**

Emilio Radicioni (INFN-Bari) Chair
Nadia Pastrone (INFN-Torino) Chair
Massimo Casarsa (INFN-Trieste)
Oliviero Cremonesi (INFN-MIB)
Corrado Gargiulo  (CERN)
Claudia Gemme (INFN-Genova)
Aldo Ianni (INFN-LNGS)
Stefano Levorato (INFN-Trieste)
Rosario Nania (INFN-Bologna)
Giovanni Paternoster (FBK-Trento)
Alberto Quaranta (UniTN-INFN-Trento)
Filippo Resnati (CERN)
Roberto Tenchini (INFN-Pisa)
Cristina Vaccarezza (INFN-LNF)

**LOCAL Organising Committee**

Emilio Radicioni (INFN-Bari) (Chair)
Nadia Pastrone (INFN-Torino)
Roberto Bellotti (Universita' degli studi di Bari)
Vincenzo Berardi (Politecnico di Bari)
Maria Gabriella Catanesi (INFN-Bari)
Fabio Gargano (INFN-Bari)
Flavio Loddo (INFN-Bari)
Lorenzo Magaletti (Politecnico di Bari)
Vito Manzari (INFN-Bari)
Salvatore My (Universita' degli studi di Bari)
Cosimo Pastore (INFN-Bari)
Vincenzo Spinoso (INFN-Bari)
Sonia Tangaro (Universita' degli studi di Bari)
Giacomo Volpe (Universita' degli studi di Bari)

**Technical and Administrative Support**

Francesca Assisi (INFN-Bari)
Alessandro Casale (INFN-Bari)
Enza D'Alba (INFN-Bari)
Antonio Silvestri (INFN-Bari)


# Buon lavoro a tutti !

*extras*

# ECFA Detector R&D Roadmap – processo 2021

**ECFA**
European Committee for Future Accelerators

## Roadmap Process

**Process involved: 67 authors; 12 expert Input Session speakers; ECFA National Contacts; respondents to the Task Force surveys; 121 Symposia presenters; 1359 Symposia attendees and 44 APOD TF topic specific contacts.**

*Task Force convenors, Task Force expert members and Panel members of the ECFA Detector R&D Roadmap Process*

**Task Force 1 Gaseous Detectors:** Anna Colaleo[1], Leszek Ropelewski[2] *(Conveners)* Klaus Dehmelt[3], Barbara Liberti[4], Maxim Titov[5], Joao Veloso[6] *(Expert Members)*

**Task Force 2 Liquid Detectors:** Roxanne Guenette[7], Jocelyn Monroe[8] *(Conveners)* Auke-Pieter Colijn[9], Antonio Ereditato[10,11], Ines Gil Botella[12], Manfred Lindner[13] *(Expert Members)*

**Task Force 3 Solid State Detectors:** Nicolo Cartiglia[14], Giulio Pellegrini[15] *(Conveners)* Daniela Bortoletto[16], Didier Contardo[17], Ingrid Gregor[18,19] Gregor Kramberger[20], Heinz Pernegger[2] *(Expert Members)*

**Task Force 4 Particle Identification and Photon Detectors:** Neville Harnew[16], Peter Krizan[20] *(Conveners)* Ichiro Adachi[21], Eugenio Nappi[1] Christian Joram[2], Christian Schultz-Coulon[22] *(Expert Members)*

**Task Force 5 Quantum and Emerging Technologies:** Marcel Demarteau[23], Michael Doser[2] *(Conveners)* Caterina Braggio[24], Andy Geraci[25], Peter Graham[26], Anna Grasselino[27], John March Russell[16], Stafford Withington[28] *(Expert Members)*

**Task Force 6 Calorimetry:** Roberto Ferrari[29], Roman Poeschl[30] *(Conveners)* Martin Aleksa[2], Dave Barney[2], Frank Simon[31], Tommaso Tabarelli de Fatis[32] *(Expert Members)*

**Task Force 7 Electronics:** Dave Newbold[33], Francois Vasey[2] *(Conveners)* Niko Neufeld[2], Valerio Re[29] Christophe de la Taille[34], Marc Weber[35] *(Expert Members)*

**Task Force 8 Integration:** Frank Hartmann[35], Werner Riegler[2] *(Conveners)* Corrado Gargiulo[2], Filippo Resnati[2], Herman Ten Kate[36], Bart Verlaat[2], Marcel Vos[37] *(Expert Members)*

**Task Force 9 Training:** Johann Collot[38], Erika Garutti[18,39] *(Conveners)* Richard Brenner[40], Niels van Bakel[9] Claire Gwenlan[16], Jeff Wiener[2], ex-officio Robert Appleby[41] *(Expert Members)*

https://indico.cern.ch/e/ECFADetectorRDRoadmap

*The Task Force Convenors join those listed below to compose the Detector R&D Roadmap Panel.*

**Panel coordinators:** Phil Allport[42] *(Chair)*, Silvia Dalla Torre[43], Manfred Krammer[2], Felix Sefkow[18], Ian Shipsey[16]

**Ex-officio Panel members:** Karl Jakobs[44] *(Current ECFA Chair)*, Jorgen D'Hondt[45] *(Previous ECFA Chair)*, Lenny Rivkin[46] *(LDG Representative)*

**Scientific Secretary:** Susanne Kuehn[2]

**ECFA**
European Committee for Future Accelerators

### Two Days of Input Sessions

Input Session speakers provided detailed specifications and continued giving support for the process

... particularly for checking if there were any unmet detector R&D needs for the ESPP identified programme which may have been overlooked in the symposia programmes.

| | Speaker | Presentation Topic |
|---|---|---|
| 1 | Chris Parkes | Detector R&D requirements for HL-LHC |
| 2 | Luciano Musa | Detector R&D requirements for strong interaction experiments at future colliders |
| 3 | Johannes Bernhard | Detector R&D requirements for strong interaction experiments at future colliders |
| 4 | Frank Simon | Detector R&D requirements for future linear high energy e+e- machines |
| 5 | Mogens Dam | Detector R&D requirements for future circular high energy e+e- machines |
| 6 | Martin Aleksa | Detector R&D requirements for future high-energy hadron colliders |
| 7 | Nadia Pastrone | Detector R&D requirements for muon colliders |
| 8 | Marzio Nessi | Detector R&D requirements for future short and long baseline neutrino experiments |
| 9 | Maarten De Jong | Detector R&D requirements for future astro-particle neutrino experiments |
| 10 | Laura Baudis | Detector R&D requirements for future dark matter experiments |
| 11 | Cristina Lazzeroni | Detector R&D requirements for future rare decay processes experiments |
| 12 | Alexandre Obertelli | Detector R&D requirements for future low energy experiments |

19th November 2021

### ECFA National Contacts

| Country | Name |
|---|---|
| Austria | Manfred Jeitler |
| Belgium | Gilles De Lentdecker |
| Bulgaria | Venelin Koshuharov |
| Croatia | Tome Anticic |
| Cyprus | Panos Razis |
| Czech Republic | Tomáš Davídek |
| Denmark | Mogens Dam |
| Finland | Panja Lukka |
| France | Didier Contardo |
| Germany | Lutz Feld |
| Greece | Dimitris Loukas |
| Hungary | Dezso Varga |
| Italy | Nadia Pastrone |
| Israel | Erez Etzion |
| Netherlands | Niels van Bakel |
| Norway | Gerald Eigen |
| Poland | Marek Idzik |
| Portugal | Paulo Fonte |
| Romania | Mihai Petrovici |
| Serbia | Lidija Zivkovic |
| Slovakia | Pavol Strizenec |
| Slovenia | Gregor Kramberger |
| Spain | Mary-Cruz Fouz |
| Sweden | Christian Ohm |
| Switzerland | Ben Kilminster |
| Turkey | Kerem Cankocak |
| United-Kingdom | Iacopo Vivarelli |
| Ukraine | Nikolai Shulga |
| CERN | Christian Joram |

**ECFA**
European Committee for Future Accelerators

### Full-day Public Symposia

Two days of Input Sessions covered all the future facilities and topic areas identified in the EPPSU (see back-up).

Following these were nine technology focussed full-day public symposia as the main fora to collect community input.

| Task Force | TF7 | TF8 | TF2 | TF5 | TF3 | TF1 | TF9 | TF4 | TF6 |
|---|---|---|---|---|---|---|---|---|---|
| Dates | 25/3/21 | 31/3/21 | 9/4/21 | 12/4/21 | 23/4/21 | 29/4/21 | 30/4/21 | 6/5/21 | 7/5/21 |
| Unique users | 369 + 123 (webcast) | 154 + 17 (webcast) | 197 + 5 (webcast) | 220 | 504 | 339 | 105 | 207 | 201 |
| Max. number of concurrent viewers | 230 + 123 (webcast) | 76 + 17 (webcast) | 130 + 5 (webcast) | 100 | 275 | 191 | 59 | 110 | 115 |

May 2021
- 07 May ECFA Detector R&D Roadmap Symposium of Task Force 6 Calorimetry
- 06 May ECFA Detector R&D Roadmap Symposium of Task Force 4 Photon Detectors and Particle Identification Detectors

April 2021
- 30 Apr ECFA Detector R&D Roadmap Symposium of Task Force 9 Training
- 29 Apr ECFA Detector R&D Roadmap Symposium of Task Force 1 Gaseous Detectors
- 23 Apr ECFA Detector R&D Roadmap Symposium of Task Force 3 Solid State Detectors
- 12 Apr ECFA Detector R&D Roadmap Symposium of Task Force 5 Quantum and Emerging Technologies
- 09 Apr ECFA Detector R&D Roadmap Symposium of Task Force 2 Liquid Detectors

March 2021
- 31 Mar ECFA Detector R&D Roadmap Symposium of Task Force 8 Integration
- 25 Mar ECFA Detector R&D Roadmap Symposium of Task Force 7 Electronics and On-detector Processing

Common registration for the symposia had logged 1359 participants by the end of the last one.

Received extensive feedback during symposia and after by email.

Surveys were also employed to receive direct inputs from individuals and via RECFA delegates or their National Contacts.

APOD appointed experts consulted where needed by Task Force convenors for advice on developments in their disciplines.

19th November 2021 ECFA Detector R&

**ECFA**
European Committee for Future Accelerators

### Advisory Panel with Other Disciplines

| Organisation name | Contact name |
|---|---|
| APPEC | Andreas Haungs (Chair) |
| NuPECC | Marek Lewitowicz (Chair) |
| LEAPS | Caterina Biscari (Chair) |
| LENS | Helmut Schober (Chair) |
| ESA | Guenther Hasinger (Director of Science)<br>Franco Ongaro (Director of Technology, Engineering and Quality) |

APPEC: Astro-Particle Physics European Consortium
ESA: European Space Agency
LEAPS: League of European Accelerator-based Photon Sources
LENS: League of advanced European Neutron Sources
NuPECC: Nuclear Physics European Collaboration Committee

Named contacts for each TF where appropriate

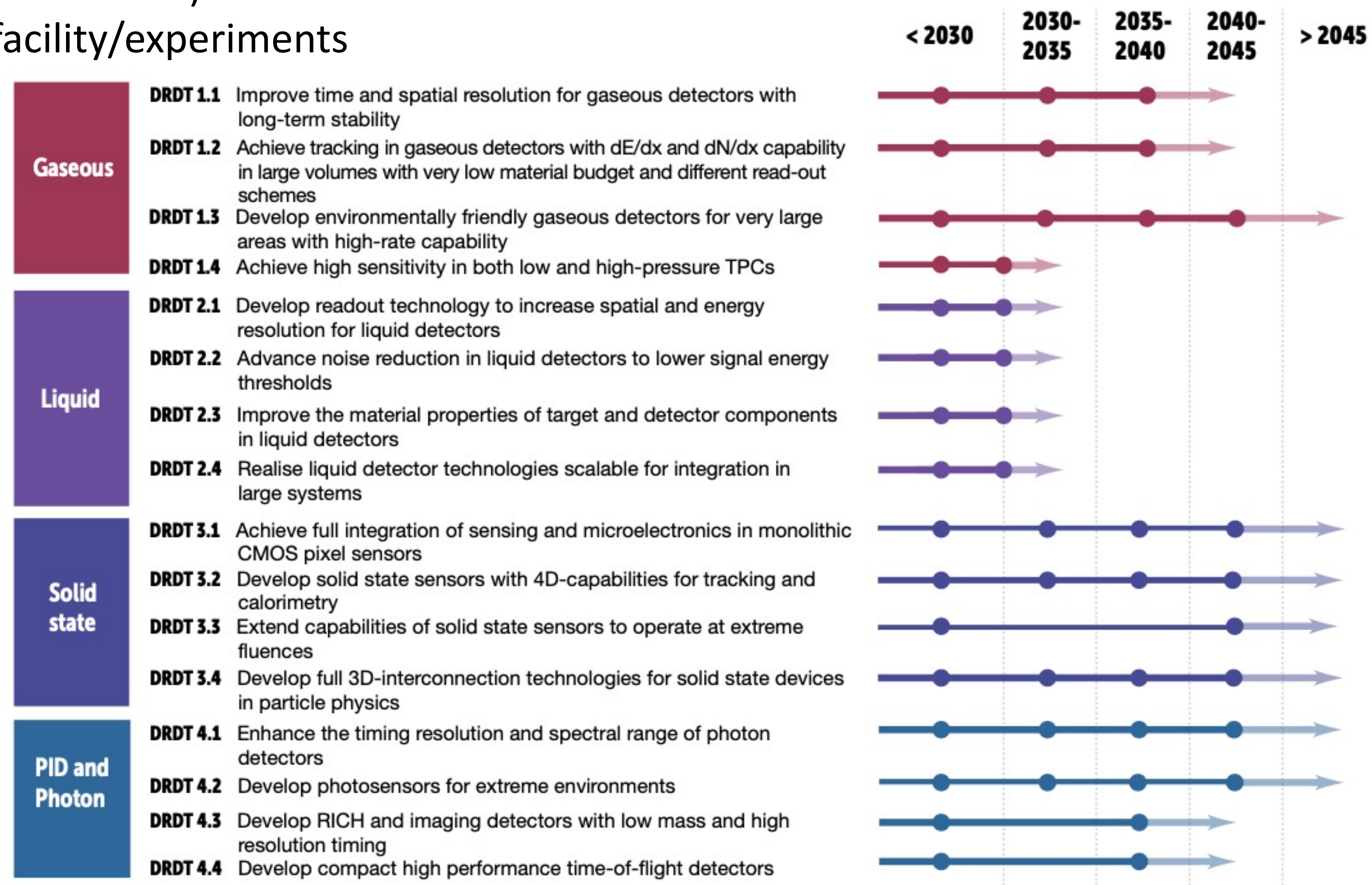
# ECFA Detector R&D Roadmap – Targeted facilities

- Full exploitation of the **HL-LHC** (R&D still needed for LS3 upgrades and for experiment upgrades beyond then) including studies of flavour physics and quark-gluon plasma (where the latter topic also interfaces with nuclear physics)
- R&D for **long baseline neutrino physics** detectors (including aspects targeting astro-particle physics measurements) and supporting experiments such as at those at the CERN Neutrino Platform
- Technology developments needed for detectors at **e+e- EW-Higgs-Top factories** in all possible accelerator manifestations including instantaneous luminosities at 91.2 GeV of up to $5\times10^{36}$ $cm^{-2}s^{-1}$.
- The long-term R&D programme for detectors at a **future 100 TeV hadron collider** with integrated luminosities targeted up to 30 $ab^{-1}$ and 1000 pile-up for 25 ns BCO
- Specific long-term detector technology R&D requirements of a **muon collider operating at 10 TeV** and with a luminosity of the order of $10^{35}$ $cm^{-2}$ $s^{-1}$
- Accelerator-based studies of **rare processes, DM candidates and high precision measurements** (including strong interaction physics) at both storage rings and fixed target facilities, interfacing also with atomic and nuclear physics.
- R&D for optimal exploitation of **dedicated collider experiments** studying the **partonic structure of the proton and nuclei** as well as interface areas with nuclear physics
- Very broad detector R&D areas for **non-accelerator-based experiments**, including dark matter searches (including axion searches), reactor neutrino experiments, rare decay processes, neutrino observatories and other interface areas with astro-particle physics.

# Detector Research and Development Themes (1)

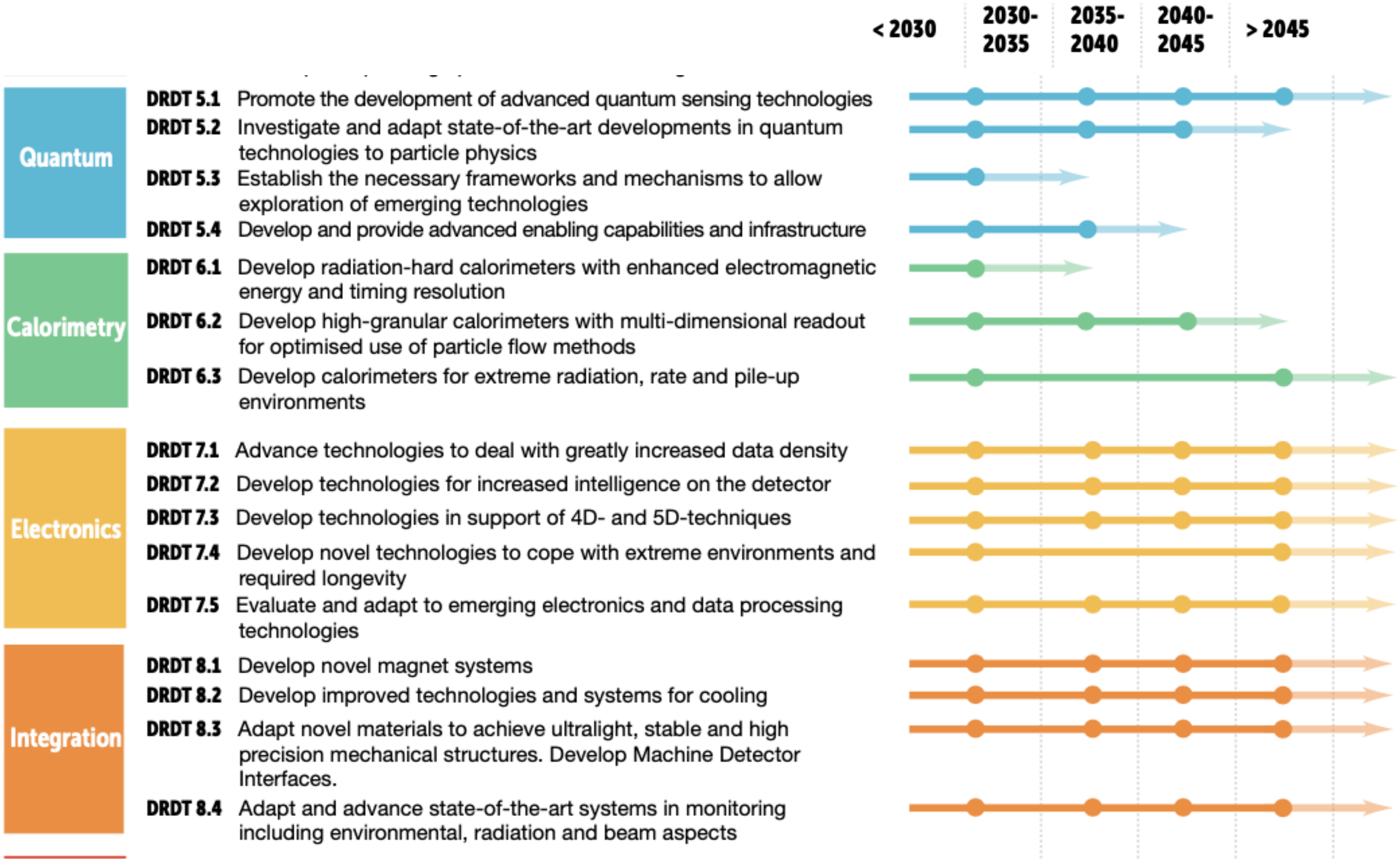
The summarizing timelines (in "Conclusions") are also based on the needs of the future facility/experiments

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




"short" timelines mainly correspond to science sectors where long-term planning is not needed/not possible

# *Detector Research and Development Themes (2)*



# 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

*Aim: * Propose mechanisms to achieve a greater coherence across Europe to better streamline the local and national activities and make these more effective.*

** Give the area greater visibility and voice at a European level to make the case for the additional resources needed for Europe to maintain a leading role in particle physics with all the associated scientific and societal benefits that will flow from this.*

# 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.