ECFA

European Strategy Update

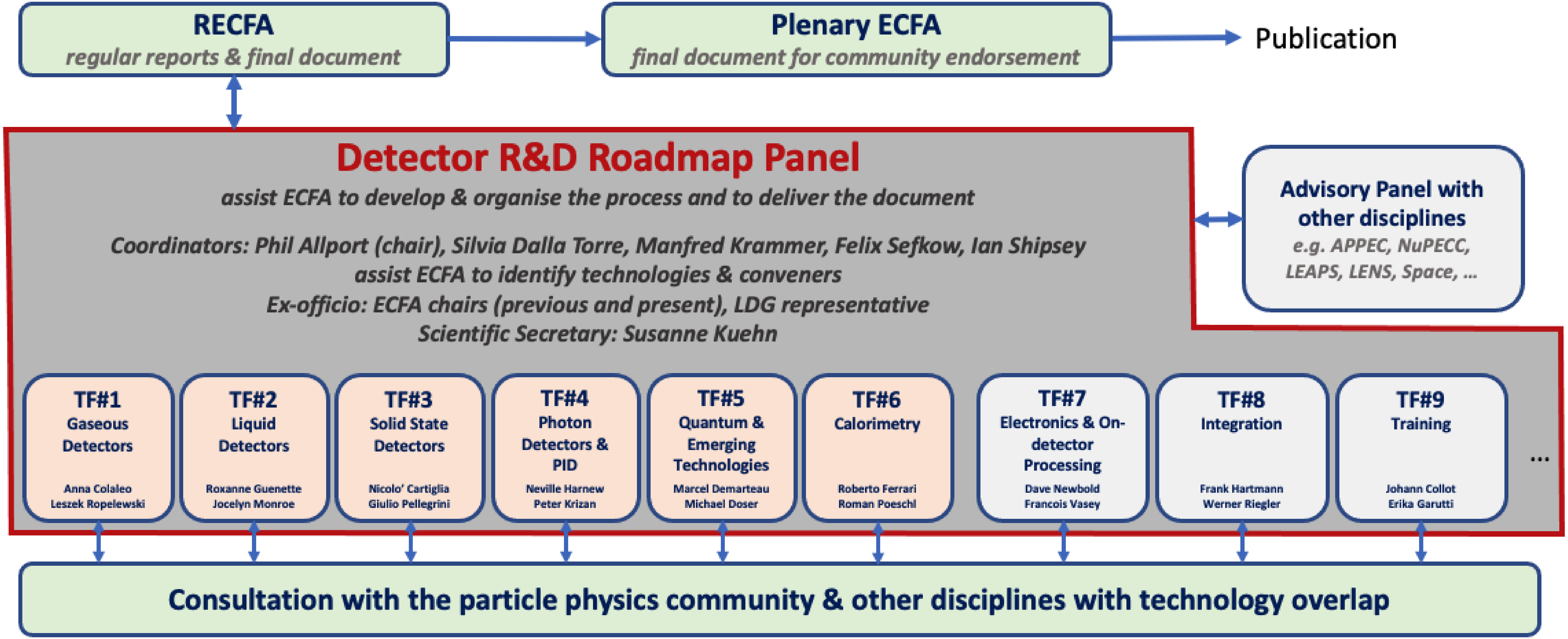
INFN
Istituto Nazionale di Fisica Nucleare
Sezione di Pavia

DRD6 Collaboration

Roberto Ferrari
INFN Pavia

CEPC 2024 Workshop
Hangzhou, October 23, 2024

Detector R&D Roadmap Panel



RECFA
regular reports & final document

Plenary ECFA
final document for community endorsement

Publication

Detector R&D Roadmap Panel

assist ECFA to develop & organise the process and to deliver the document

Coordinators: Phil Allport (chair), Silvia Dalla Torre, Manfred Krammer, Felix Sefkow, Ian Shipsey
assist ECFA to identify technologies & conveners
Ex-officio: ECFA chairs (previous and present), LDG representative
Scientific Secretary: Susanne Kuehn

Advisory Panel with other disciplines
e.g. APPEC, NuPECC, LEAPS, LENS, Space, …

TF#1 Gaseous Detectors
Anna Colaleo
Leszek Ropelewski

TF#2 Liquid Detectors
Roxanne Guenette
Jocelyn Monroe

TF#3 Solid State Detectors
Nicolo' Cartiglia
Giulio Pellegrini

TF#4 Photon Detectors & PID
Neville Harnew
Peter Krizan

TF#5 Quantum & Emerging Technologies
Marcel Demarteau
Michael Doser

TF#6 Calorimetry
Roberto Ferrari
Roman Poeschl

TF#7 Electronics & On-detector Processing
Dave Newbold
Francois Vasey

TF#8 Integration
Frank Hartmann
Werner Riegler

TF#9 Training
Johann Collot
Erika Garutti

…

Consultation with the particle physics community & other disciplines with technology overlap

Roadmap document(s)

- ECFA R&D Roadmap
  - CERN-ESU-017
  - 248 pages full text and 8 page synopsis

- Endorsed by ECFA and presented to CERN Council in December 2021

Roadmap identified:

  - General Strategic Recommendations (GSRs)
  - Detector R&D Themes (DRDTs) per task-force topic
  - Concrete R&D Tasks

THE 2021 ECFA DETECTOR
RESEARCH AND DEVELOPMENT ROADMAP

The European Committee for Future Accelerators
Detector R&D Roadmap Process Group

European Strategy Update | ECFA European Committee for Future Accelerators

Timescale of proposed future facilities

Timescale of projects as approved by European Lab Director Group (LDG)

< 2030	2030-2035	2035-2040	2040-2045	> 2045
SPS fixed target Other fixed target, FAIR (hep) Belle II ALICE LS3 PIP-II/LBNF/DUNE/Hyper-K	ALICE 3 LHCb (≥ LS4) EIC LHeC	ILC	FCC-ee CLIC	FCC-hh FCC-eh Muon Collider

Timescale of proposed future facilities

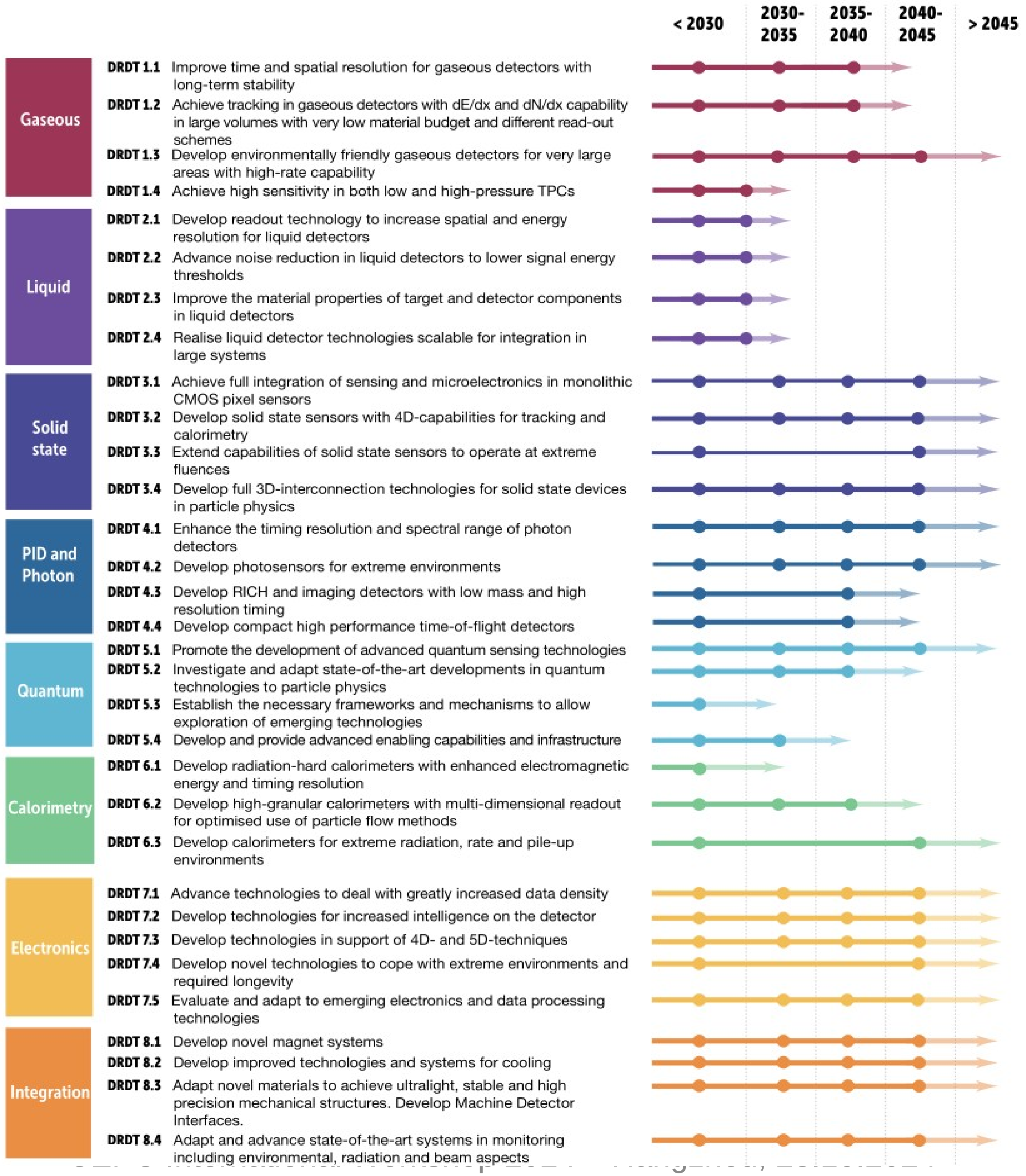
Timescale of projects as approved by European Lab Director Group (LDG)

Guiding principle for DRDs: any project realisation must *NOT* be delayed by detectors

→ main focus is strategic R&D

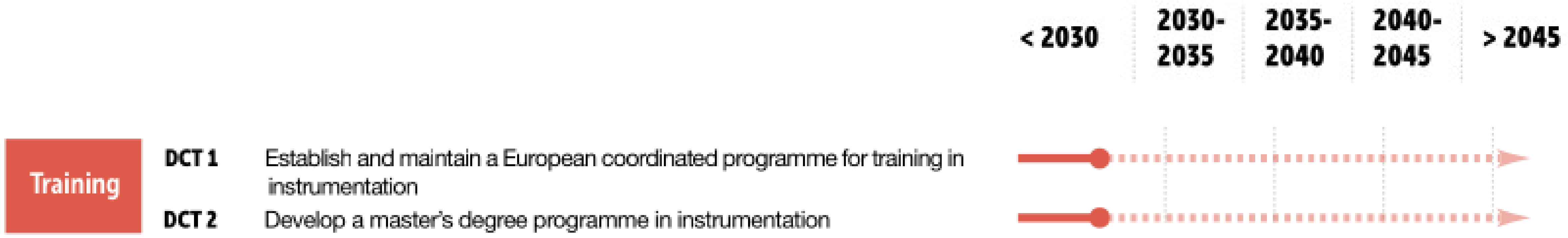
however also “blue-sky” R&D *MUST* be covered

Detector R&D Themes



Gaseous	DRDT 1.1	Improve time and spatial resolution for gaseous detectors with long-term stability
	DRDT 1.2	Achieve tracking in gaseous detectors with dE/dx and dN/dx capability in large volumes with very low material budget and different read-out schemes
	DRDT 1.3	Develop environmentally friendly gaseous detectors for very large areas with high-rate capability
	DRDT 1.4	Achieve high sensitivity in both low and high-pressure TPCs
Liquid	DRDT 2.1	Develop readout technology to increase spatial and energy resolution for liquid detectors
	DRDT 2.2	Advance noise reduction in liquid detectors to lower signal energy thresholds
	DRDT 2.3	Improve the material properties of target and detector components in liquid detectors
	DRDT 2.4	Realise liquid detector technologies scalable for integration in large systems
Solid state	DRDT 3.1	Achieve full integration of sensing and microelectronics in monolithic CMOS pixel sensors
	DRDT 3.2	Develop solid state sensors with 4D-capabilities for tracking and calorimetry
	DRDT 3.3	Extend capabilities of solid state sensors to operate at extreme fluences
	DRDT 3.4	Develop full 3D-interconnection technologies for solid state devices in particle physics
PID and Photon	DRDT 4.1	Enhance the timing resolution and spectral range of photon detectors
	DRDT 4.2	Develop photosensors for extreme environments
	DRDT 4.3	Develop RICH and imaging detectors with low mass and high resolution timing
	DRDT 4.4	Develop compact high performance time-of-flight detectors
Quantum	DRDT 5.1	Promote the development of advanced quantum sensing technologies
	DRDT 5.2	Investigate and adapt state-of-the-art developments in quantum technologies to particle physics
	DRDT 5.3	Establish the necessary frameworks and mechanisms to allow exploration of emerging technologies
	DRDT 5.4	Develop and provide advanced enabling capabilities and infrastructure
Calorimetry	DRDT 6.1	Develop radiation-hard calorimeters with enhanced electromagnetic energy and timing resolution
	DRDT 6.2	Develop high-granular calorimeters with multi-dimensional readout for optimised use of particle flow methods
	DRDT 6.3	Develop calorimeters for extreme radiation, rate and pile-up environments
Electronics	DRDT 7.1	Advance technologies to deal with greatly increased data density
	DRDT 7.2	Develop technologies for increased intelligence on the detector
	DRDT 7.3	Develop technologies in support of 4D- and 5D-techniques
	DRDT 7.4	Develop novel technologies to cope with extreme environments and required longevity
	DRDT 7.5	Evaluate and adapt to emerging electronics and data processing technologies
Integration	DRDT 8.1	Develop novel magnet systems
	DRDT 8.2	Develop improved technologies and systems for cooling
	DRDT 8.3	Adapt novel materials to achieve ultralight, stable and high precision mechanical structures. Develop Machine Detector Interfaces.
	DRDT 8.4	Adapt and advance state-of-the-art systems in monitoring including environmental, radiation and beam aspects

Detector Community Themes



Training

DCT 1 Establish and maintain a European coordinated programme for training in instrumentation

DCT 2 Develop a master's degree programme in instrumentation

w/ key focus on inclusivity and diversity

Generic Strategic Recommendations

GSR1- Supporting R&D facilities

GSR2- Engineering support for detector R&D

GSR3- Specific software for instrumentation

GSR4- International coordination and organisation of R&D activities

GSR5- Distributed R&D activities with centralised facilities

GSR6- Establish long-term strategic funding programmes

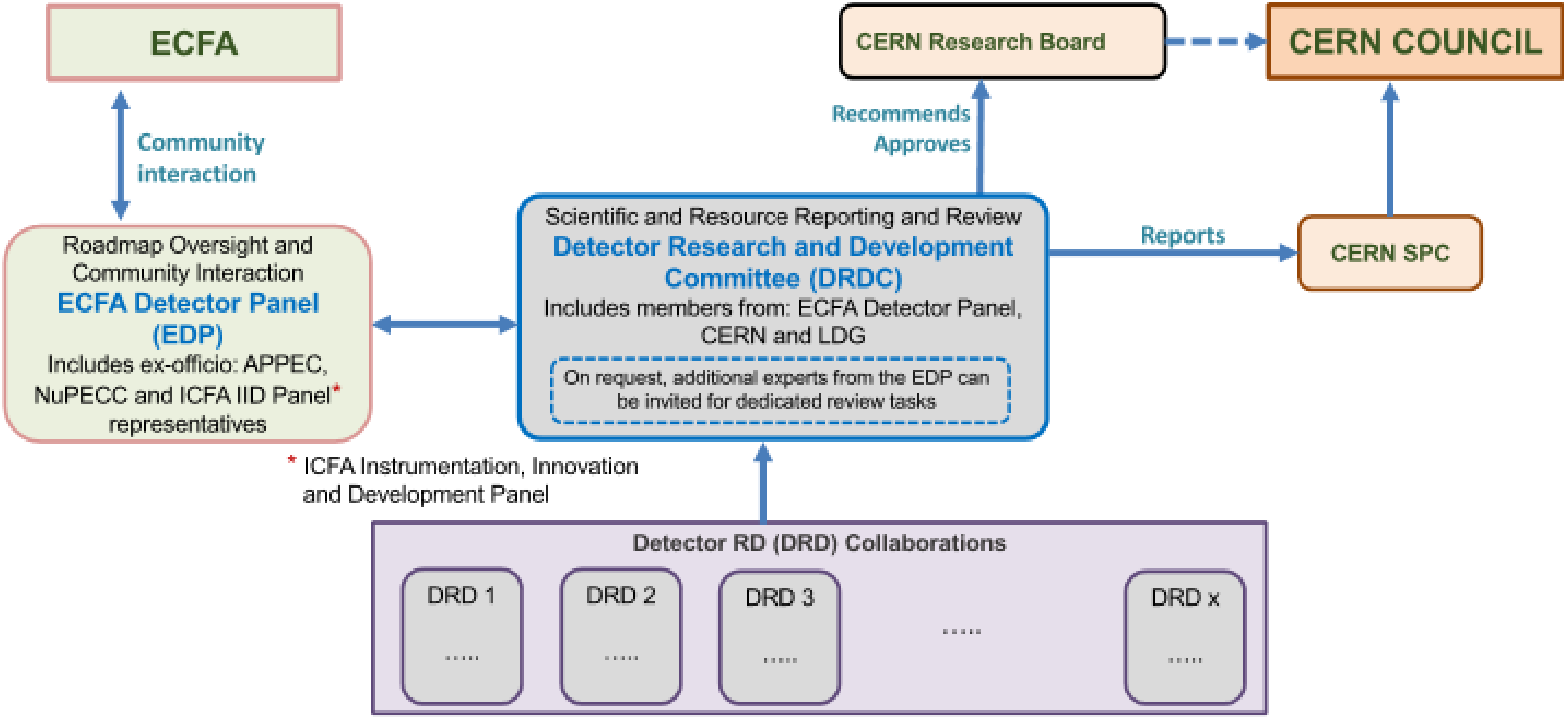
GSR7- Blue-sky R&D

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

GSR 9 - Industrial partnerships

GSR 10 - Open Science

Implementation



ECFA

Community interaction

Roadmap Oversight and Community Interaction
ECFA Detector Panel (EDP)
Includes ex-officio: APPEC, NuPECC and ICFA IID Panel* representatives

* ICFA Instrumentation, Innovation and Development Panel

CERN Research Board

CERN COUNCIL

Recommends
Approves

Scientific and Resource Reporting and Review
Detector Research and Development Committee (DRDC)
Includes members from: ECFA Detector Panel, CERN and LDG

On request, additional experts from the EDP can be invited for dedicated review tasks

Reports

CERN SPC

Detector RD (DRD) Collaborations

DRD 1 ……

DRD 2 ……

DRD 3 ……

……

DRD x ……

Detector R&D Collaborations

- DRD1 : Gaseous Detectors [ex RD51]
- DRD2 : Liquid Detectors
- DRD3 : Semiconductor Detectors [ex RD50, RD42, ...]
- DRD4 : Photodetectors and Particle ID
- DRD5: Quantum Sensors
- DRD6: Calorimetry
- DRD7: Electronics
- DRD8: Integration

DRD Collaborations

- World-wide collaborations
- Built upon established detector R&D communities (RD50, RD51, Calice, Crystal Clear, ...) as well as (proto-)colloaborations for present or proposed facilities
- As inclusive as possible
- Identify and/or develop synergies → minimise duplications / optimise resource utilisation
- Try to assure that nothing was left or fell out ...
- Huge programme with short-term, middle-term, long-term targets

DRD Collaborations (2)

- Community-driven “resource-loaded” Work Packages (WPs) w/ dedicated (independent) funding lines
- Scientific organisation in Working Groups (Wgs): forum for sharing expertise and identifying joint projects
- Common projects (in case): short-term blue-sky R&D or common tool development

Each DRD independently formed & organised
→ community-driven process

Breakdown

Technology driven → gaseous detectors, liquid detectors, ... but calorimetry

→ calorimeters: big, complex systems with system issues

→ strong bidirectional relations with other DRDs

DRD6 – Calorimetry

DRD6 – Proposal Team

Coordinators: Roberto Ferrari, Gabriella Gaudio (INFN-Pavia), Roman Pöschl (IJCLab)

Representative from ECFA Detector R&D Panel: Felix Sefkow (DESY)

WP 1: Sandwich calorimeters with fully embedded electronics – Main and forward calorimeters

Conveners: Adrian Irles (IFIC), Frank Simon (KIT), Jim Brau (University of Oregon), Wataru Ootani (University of Tokyo), Imad Laktineh (I2PI), Lucia Masetti (J.G. Universität Mainz), Mary-Cruz Fouz (CIEMAT)

WP 2: Liquified noble gas calorimeters

Conveners: Martin Aleksa (CERN), Nicolas Morange (IJCLab), Marc-Andre Pleier (BNL)

WP 3: Optical calorimeters: Scintillating based sampling and homogenous calorimeters

Conveners: Etiennette Auffray (CERN), Macro Lucchini (University and INFN Milano-Bicocca), Philipp Roloff (CERN), Sarah Eno (University of Maryland), Hwidong Yoo (Yonsei University), Michaela Mlynarikova (CERN)

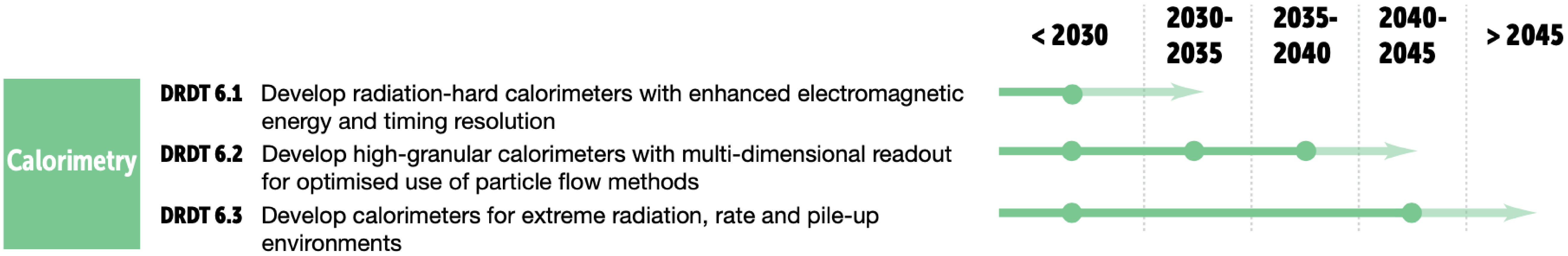
WP 4: Electronics and DAQ

Christophe de la Taille (OMEGA)

Transversal Activitiies

Photodetectors: Alberto Gola (FBK)

DRD6 – Future facilities and DRDTs for calorimetry



Calorimetry

DRDT 6.1 Develop radiation-hard calorimeters with enhanced electromagnetic energy and timing resolution

DRDT 6.2 Develop high-granular calorimeters with multi-dimensional readout for optimised use of particle flow methods

DRDT 6.3 Develop calorimeters for extreme radiation, rate and pile-up environments

- DRDTs and (provisional) time scale of facilities set high-level boundary conditions
- Both as well as GSRs should be taken into account when formulating R&D proposals

few details in next slides

DRD6 – Calorimetry overview table

Project	~Earliest Start of data taking	Current Calorimeter options					
		Solid state	Scintilling tiles/strips	Crystals	Fibre based r/o (including DR)	Gaseous	Liquid Noble Gas
HL-LHC (>LS4)	2030			✔	✔		
SuperKEKb (>2030)	2030			✔			
ILC	2035	✔	✔			✔	
CLIC	2045	✔	✔				
CEPC	2035	✔	✔	✔	✔	✔	✔
FCC-ee	2045	✔	✔	✔	✔	✔	✔
EiC	2030		✔	✔	✔		
FCC-hh (eh)	>2050	✔	✔				✔
Muon Collider	> 2050	✔	✔	✔	✔	✔	
Fixed target	“continous”		✔	✔	✔		✔
Neutrino Exp.	2030		✔				(✔)

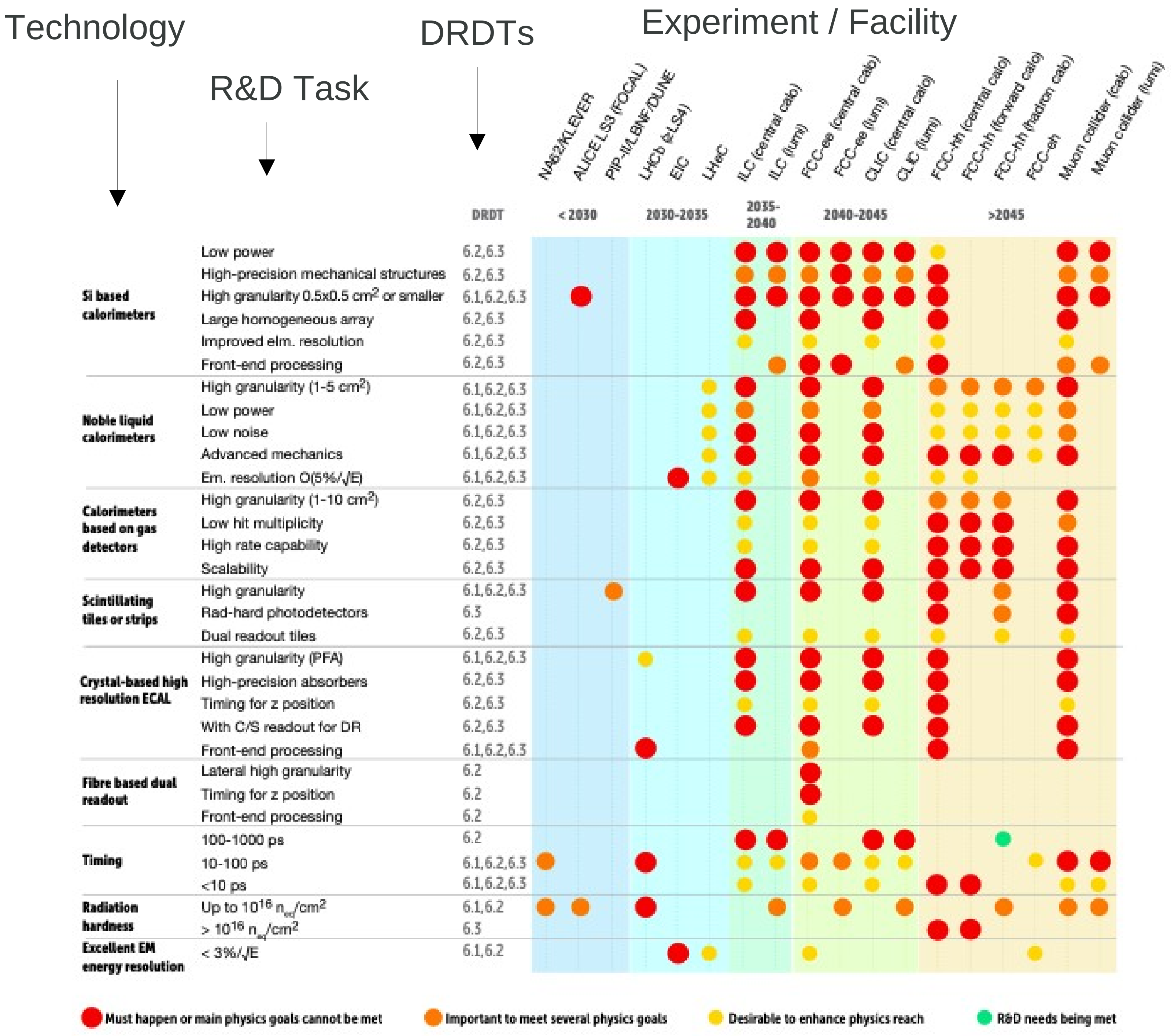
in most cases, final choices still to be made

DRD6 – Identified key technologies and R&D tasks

- Key technologies and requirements identified in roadmap
  - Si based calorimeters
  - Liquid Noble Gas calorimeters
  - Calorimeters based on gas detectors
  - Scintillating tiles and strips
  - Crystal based high-resolution ECal.s
  - Fibre-based dual readout

- R&D should in particular enable
  - Precision timing
  - Radiation hardness
  - High granularity

- R&D Tasks grouped into
  - Must happen
  - Important
  - Desirable
  - Already met



Technology	R&D Task	DRDT	< 2030			2030-2035			2035-2040		2040-2045				>2045					
			NA62/KLEVER	ALICE LS3 (FOCAL)	PIP-II/LBNF/DUNE	LHCb (≥LS4)	EIC	LHeC	ILC (central calo)	ILC (lumi)	FCC-ee (central calo)	FCC-ee (lumi)	CLIC (central calo)	CLIC (lumi)	FCC-hh (central calo)	FCC-hh (forward calo)	FCC-hh (hadron calo)	FCC-eh	Muon collider (calo)	Muon collider (lumi)
Si based calorimeters	Low power	6.2,6.3							🔴	🔴	🔴	🔴	🔴	🔴	🟡				🔴	🔴
	High-precision mechanical structures	6.2,6.3							🟠	🟠	🟠	🔴	🟠	🟠	🔴				🟠	🟠
	High granularity 0.5x0.5 cm^2 or smaller	6.1,6.2,6.3		🔴					🔴	🔴	🔴	🔴	🔴	🔴	🔴				🔴	🔴
	Large homogeneous array	6.2,6.3							🔴		🔴		🔴		🔴				🔴	
	Improved elm. resolution	6.2,6.3							🟡		🟡		🟡		🟡				🟡	
	Front-end processing	6.2,6.3								🟠	🔴	🔴		🟠	🔴				🟠	🟠
Noble liquid calorimeters	High granularity (1-5 cm^2)	6.1,6.2,6.3						🟡	🔴		🔴		🔴		🟠	🟠	🟠	🟠	🔴	
	Low power	6.1,6.2,6.3						🟡	🟠		🟠		🟠		🟡	🟡	🟡	🟡	🟠	
	Low noise	6.1,6.2,6.3						🟡	🔴		🔴		🔴		🟡	🟡	🟡	🟡	🟠	
	Advanced mechanics	6.1,6.2,6.3						🟡	🔴		🔴		🔴		🔴	🔴	🔴	🟡	🔴	
	Em. resolution $O(5\%/\sqrt{E})$	6.1,6.2,6.3					🔴	🟡	🟡		🟠		🟡		🟡	🟡				
Calorimeters based on gas detectors	High granularity (1-10 cm^2)	6.2,6.3							🔴		🔴		🔴		🟠	🟠	🟠		🔴	
	Low hit multiplicity	6.2,6.3							🟡		🟡		🟡		🔴	🔴	🔴		🟠	
	High rate capability	6.2,6.3							🟡		🟡		🟡		🔴	🔴	🔴		🔴	
	Scalability	6.2,6.3							🔴		🔴		🔴		🔴	🔴	🔴		🔴	
Scintillating tiles or strips	High granularity	6.1,6.2,6.3			🟠				🔴		🔴		🔴		🔴		🟠		🔴	
	Rad-hard photodetectors	6.3													🔴		🟠		🔴	
	Dual readout tiles	6.2,6.3							🟡		🟡		🟡		🟡		🟡		🟡	
Crystal-based high resolution ECAL	High granularity (PFA)	6.1,6.2,6.3				🟡			🔴		🔴		🔴		🔴				🔴	
	High-precision absorbers	6.2,6.3							🔴		🔴		🔴		🔴				🔴	
	Timing for z position	6.2,6.3							🟡		🟡		🟡		🔴				🟡	
	With C/S readout for DR	6.2,6.3							🔴		🔴		🔴		🔴				🔴	
	Front-end processing	6.1,6.2,6.3				🔴					🟠				🔴				🔴	
Fibre based dual readout	Lateral high granularity	6.2									🔴									
	Timing for z position	6.2									🔴									
	Front-end processing	6.2									🟡									
Timing	100-1000 ps	6.2							🔴	🔴			🔴	🔴			🟢			
	10-100 ps	6.1,6.2,6.3	🟠			🔴			🟡	🟡	🟠	🟠	🟡	🟡				🟡	🔴	🔴
	<10 ps	6.1,6.2,6.3							🟡		🟡		🟡		🔴	🔴			🟡	🟡
Radiation hardness	Up to 10^{16} n$_{eq}$/cm^2	6.1,6.2	🟠	🟠		🔴				🟠		🟠		🟠			🟠		🟠	🟠
	> 10^{16} n$_{eq}$/cm^2	6.3													🔴	🔴				
Excellent EM energy resolution	$< 3\%/\sqrt{E}$	6.1,6.2					🔴	🟡			🟡							🟡		

🔴 Must happen or main physics goals cannot be met
🟠 Important to meet several physics goals
🟡 Desirable to enhance physics reach
🟢 R&D needs being met

DRD6 – Reminder on today's "ecosystem" for calorimetry

- European projects such as AIDAinnova and EURO-Labs
- CERN EP-Programme
- Existing collaborations (LHC Experiments, Belle II, DUNE, NA62, KLEVER, ...)
- R&D Collaborations and communities (CALICE, FCAL, Crystal Clear, GranuLAr, CalVision, ...)
- Proto collaborations (ILD, SiD, CLICdp, FCC Detector with LAr, IDEA, EpIC, ...)

→DRD 6 process successfully built integrating existing R&D activities

DRD6 – Common issues – lot of room for collaboration

New active materials:

- Fast, high-density, low-cost, scintillating materials
- Fast and rad-hard WLS fibres

Sensors + FE elx:

- Low x-talk, low-noise, low-power budget
- High granularity → high integration → embedded FE elx
- High-precision timing → from O(100) ps down to O(10) ps
- Radiation hardness
- Si/GaAs sensors: high integration, very-front-end integration, sensor bonding
- CMOS sensors: MAPS, digital SiPMs
- Photosensor architecture: MCP-PMTs, SiPMs, LGADs, ...,
- Photosensor performance: dynamic range, light yield, timing, UV sensitivity, ...
- ASICs: architecture, timing performance
- Components / connectors reliability
- High data rate → on-chip processing (DNN) for data selection and compression

DRD6 – Common issues – lot of room for collaboration (2)

Mechanics / production issues:

- Low-material budget
- High mechanical precision
- Industrialisation, engineering, scalability → relation w/ industry
- High-density absorber (e.g. W) production → (e.g.) 3D-printing

Services:

- Cooling
- Powering and control
- Clock distribution for O(10) ps timing

Others:

- Beam test infrastructure, setup & DAQ software (EUDAQ)
- Beam line features + common beam requests
- MC samples → common benchmarks
- Software tools (DD4hep, EDM4hep, Key4hep, ...), event-data format (?)
- Test benches, but also ... PFA and dual readout

add transversal package to cover overarching topics?

DRD6 – External synergies

With respect to other DRDs:

- Gaseous Detectors (TF1) for hadron calorimetry
- Solid State Detectors (TF3) for CMOS sensors
- PID and Photon Detectors (TF4) for all optical readout calorimetry
- Electronics and On-detector Processing (TF7)
- Integration (TF8) for cooling

Other fields: above all, medical imaging

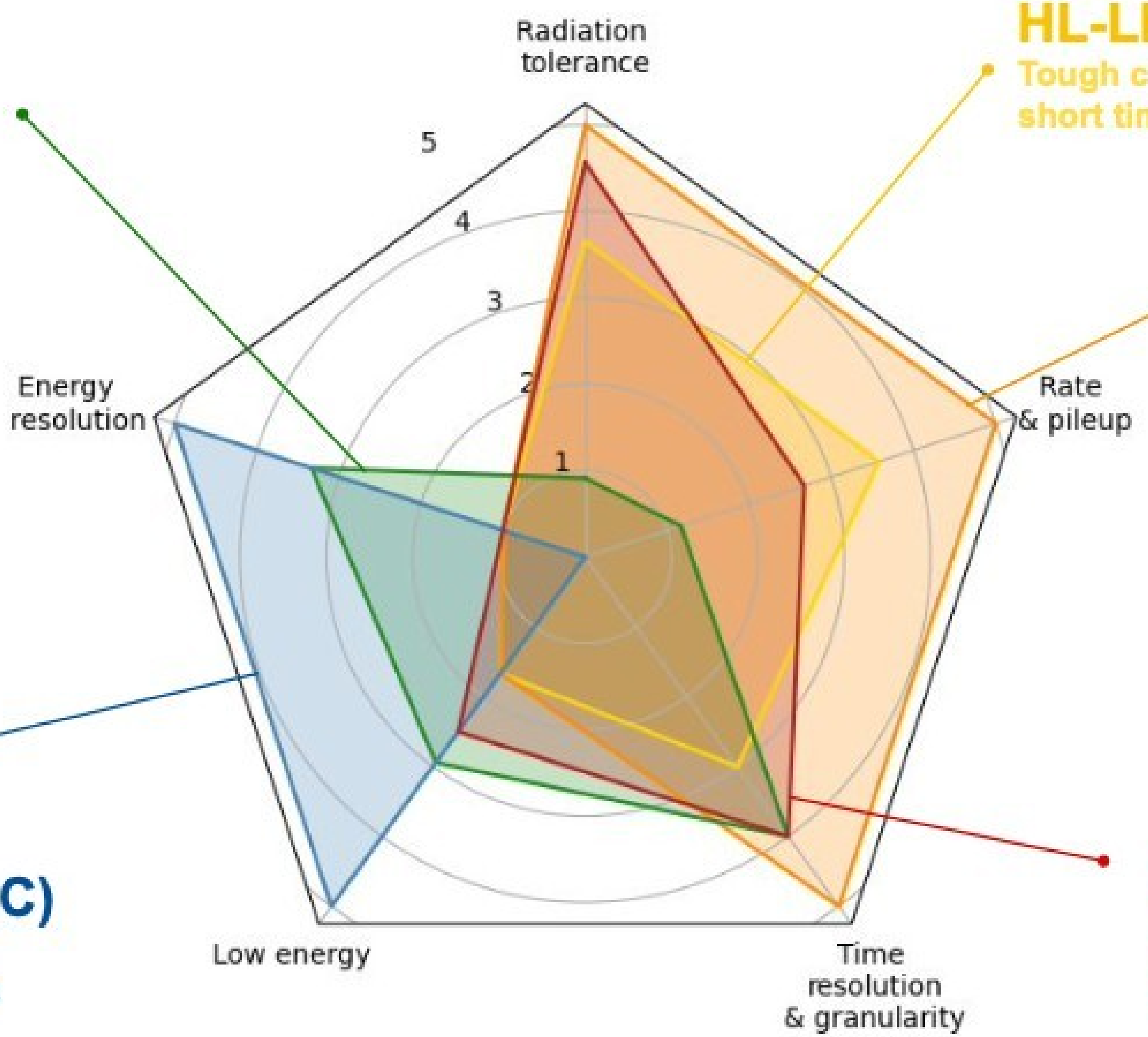
DRD6 – Few common keywords from input proposals

High granularity → critical for PFA (but not only)

Timing resolution → critical for hadron colliders (but not only)

Hadronic energy resolution → critical for lepton colliders

DRD6 – Requirements for calorimetry at future colliders



e^+e^- colliders

Precision physics benefits from exploiting the best possible energy and time resolution

HL-LHC

Tough challenges on a short timescale

FCC-hh

Setting the toughest challenge on radiation tolerance and pileup conditions

Very high energy (longitudinal containment)

Strong interaction experiments (e.g. EIC)

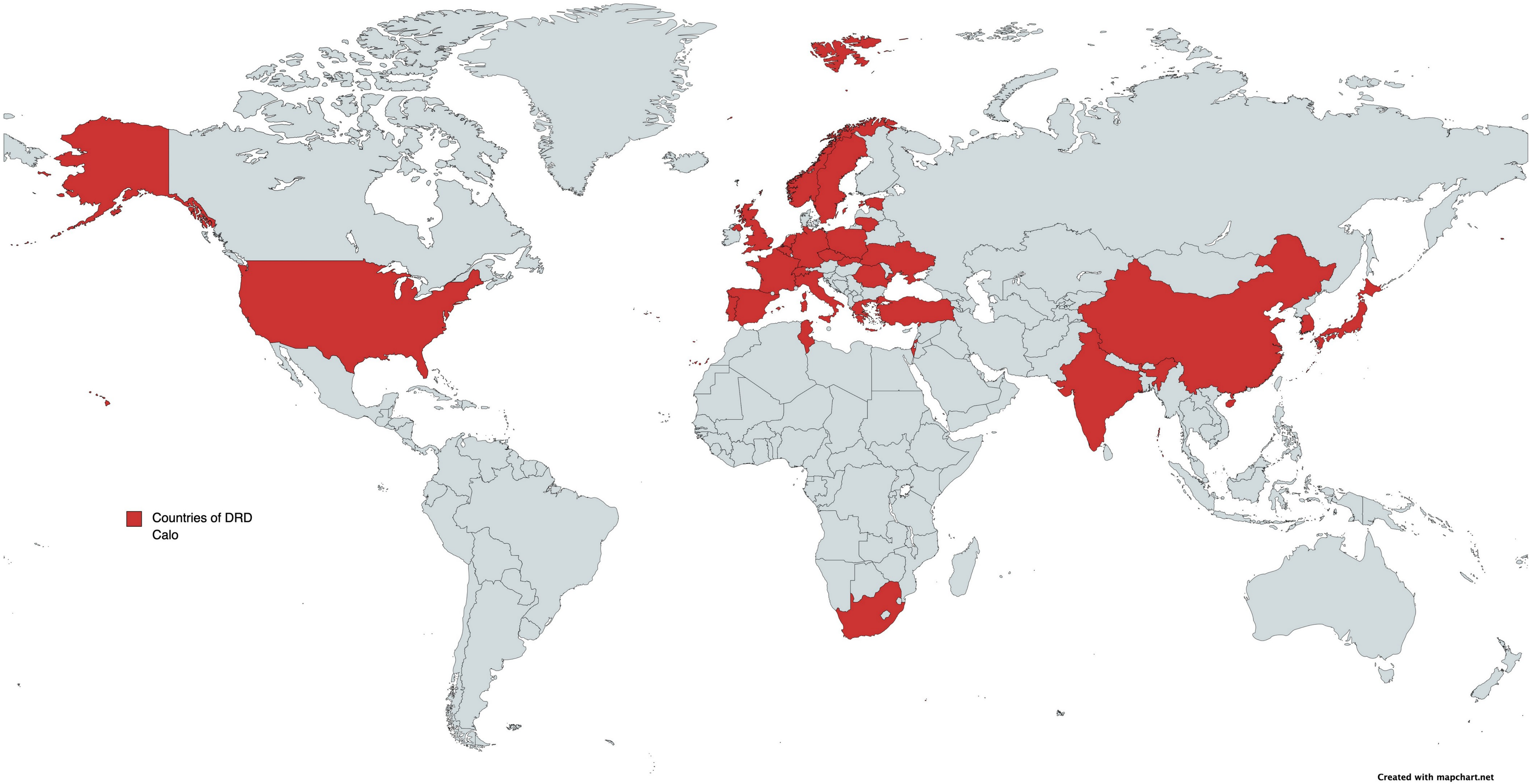
Requiring the highest energy resolution for low energy photons

$\mu^+\mu^-$ colliders

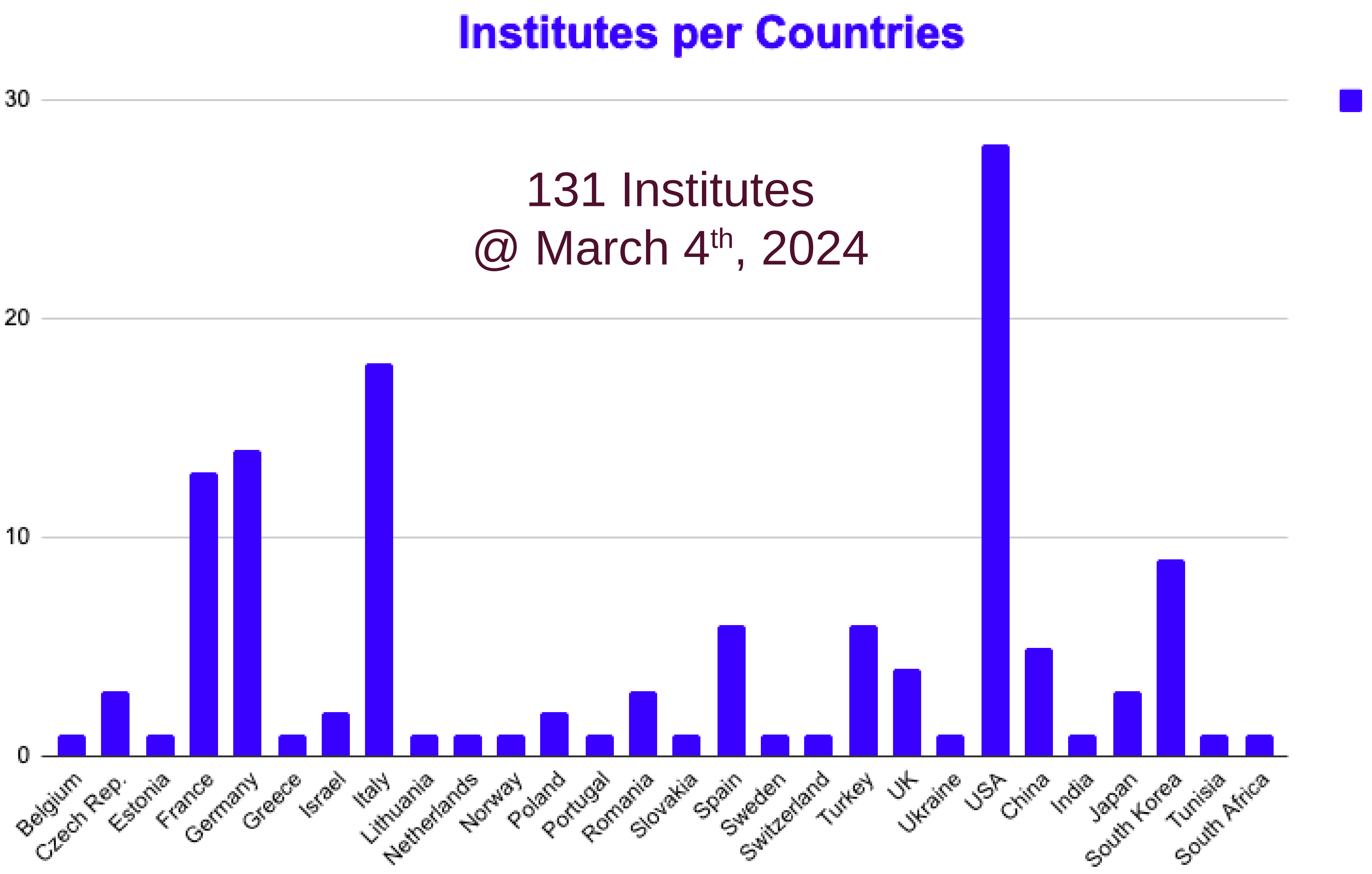
High beam induced background and radiation levels, need for ambitious time resolution

Inspired from https://indico.cern.ch/event/994685/

DRD6 Collaboration



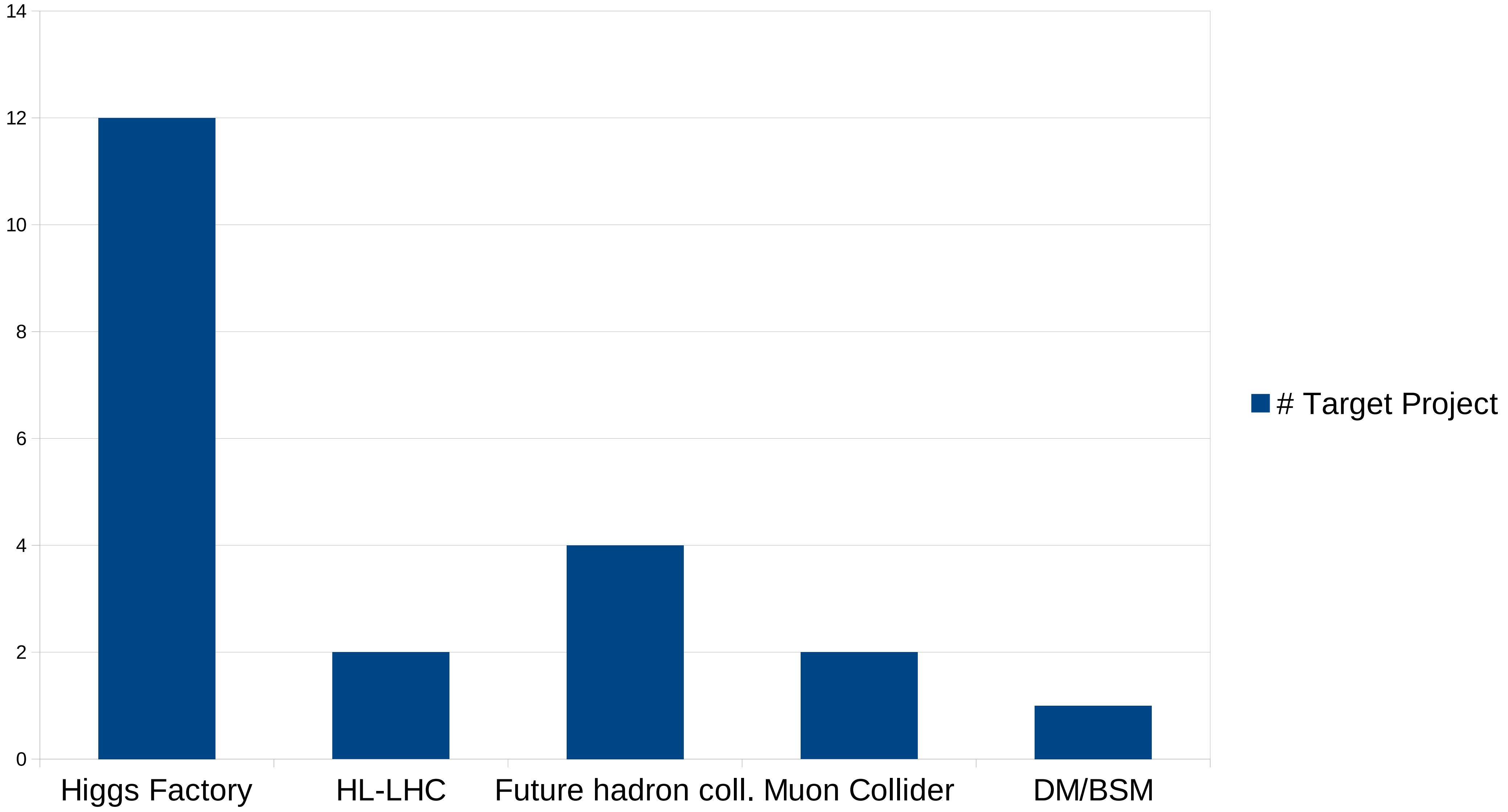
DRD6 Collaboration



131 Institutes
@ March 4th, 2024

- Mainly European Groups but interest from all over world (37%)
  - US biggest single participation → close contact to emerging effort in US
  - Very visible Asian participation

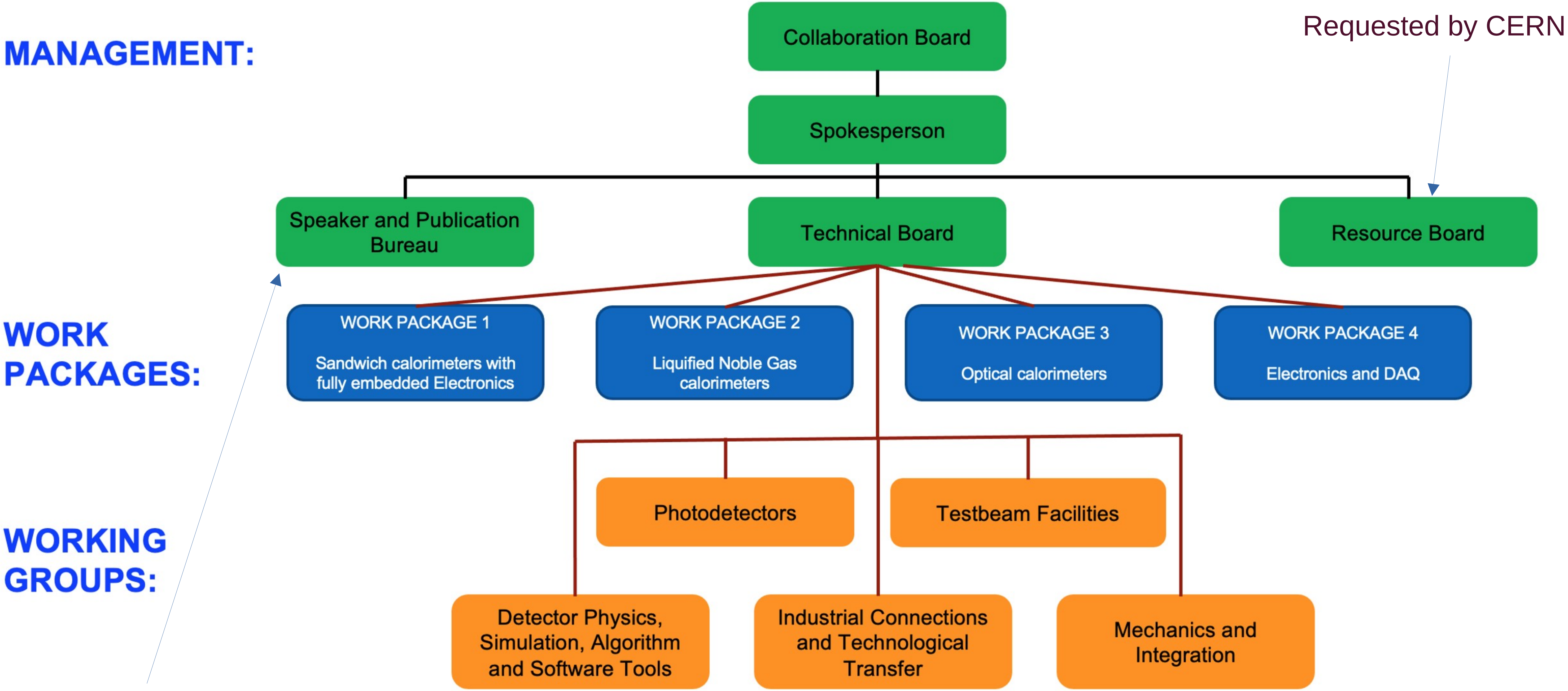
DRD6 – Target projects



- Higgs factories dominate → heavy-flavour physics programme often requires superb em energy resolutions
- Already now, orientation towards future hadron collider and muon collider

DRD6 – Proposed structure

After input-proposal collection and feedback from CERN and DRDC:



*SPB also in charge for dissemination

DRD6: building steps

In 2023: Input from Community (and from DRDC)

November 17th, 2023 - Submission of DRD Calo Proposal
December 4th, 2023 - Discussion in DRDC Meeting
December 6th, 2023 - Approval of DRD Calo by CERN Research Board

January 2024: formation of Proto-Collaboration Board
~ beginning of March: election of CB Chair

April 10-12, 2024: 1st Collaboration Meeting
~ end of April: election of Spokesperson

October 30 - Nov 1, 2024: 2nd Collaboration Meeting

CB Members as of today: participation confirmed by 125 Institutes

Status: Management Positions

Spokesperson: Roman Poschl (IJCLAB)
Spokesperson Deputies: Mary-Cruz Fouz (CIEMAT), Marc-André Pleier (BNL)

Collaboration Board Chair: Roberto Ferrari (INFN Pavia)

Technical Board Chair (Technical Coordinator): Gabriella Gaudio (INFN Pavia)

Speaker and Publication Bureau Chair: Wataru Ootani (ICEPP, University of Tokyo)

Resource Board Chair (also Resource Coordinator): yet-to-be-identified (Resource Board on hold until full understanding of role)

WP1 Coordinator (yet-to-be-endorsed): Lucia Masetti (J. Gutenberg Universitaet Mainz)
Deputy: Adrian Irles (IFIC CSIC, UniversUV)

WP2 Coordinator: Nicolas Morange (IJCLAB)

WP3 Coordinator: Michaela Mlynarikova (CERN)
Deputy: Marco Lucchini (Università di Milano Bicocca)

WP4 Coordinator (yet-to-be-endorsed): Christophe de la Taille (OMEGA)

DRD6 – Work Packages and Tasks

WP 1: Sandwich calorimeters with fully embedded electronics
  - » Task 1.1: Highly pixelised electromagnetic section (4 sub-tasks)
  - » Task 1.2: Hadronic section with optical tiles (2 sub-tasks)
  - » Task 1.3: Hadronic section with gaseous readout (3 sub-tasks)

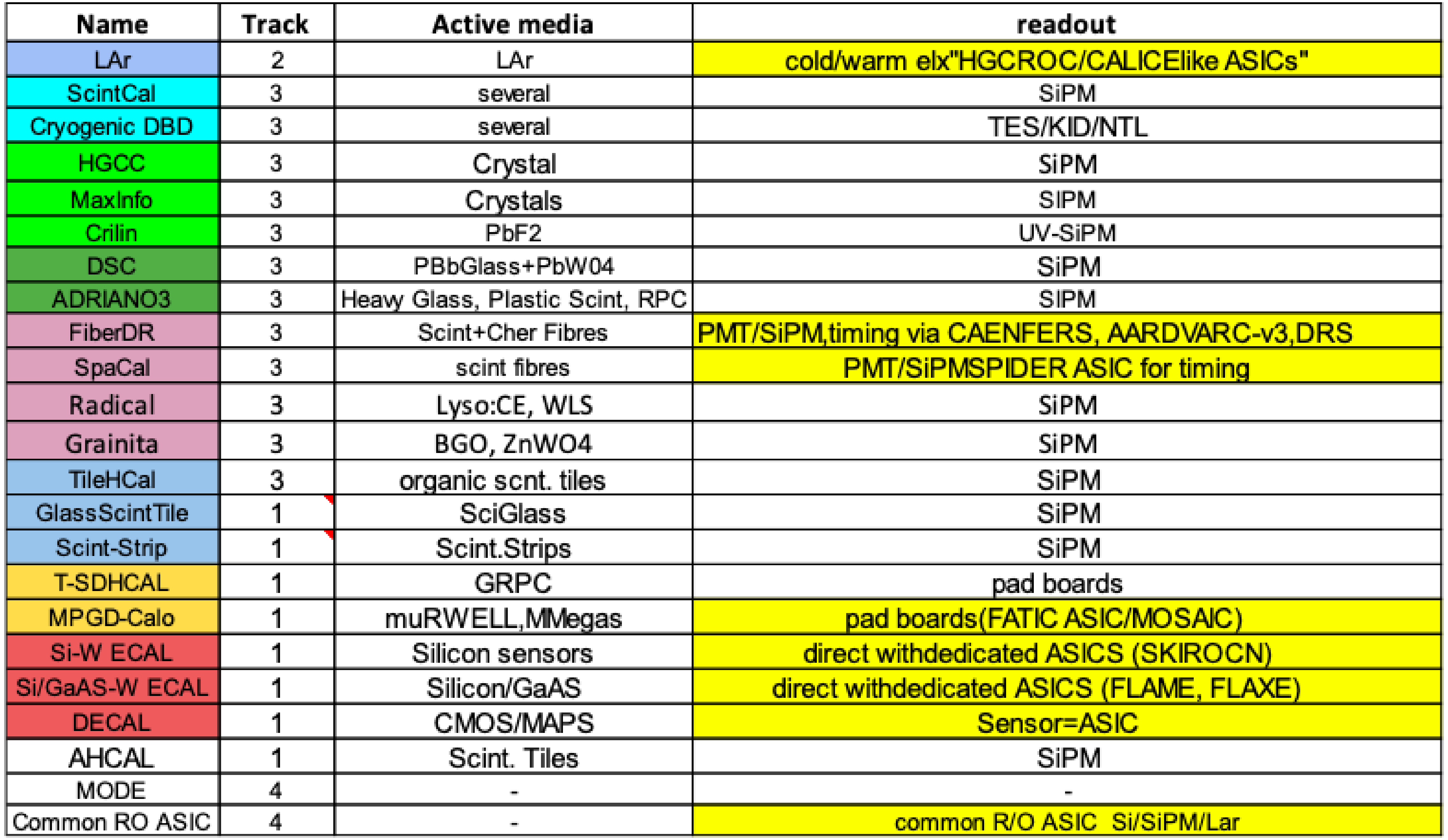
WP 2: Liquefied-noble-gas calorimeters

WP 3: Optical calorimeters: scintillating-based sampling and homogeneous calorimeters
  - » Task 3.1: Homogeneous and quasi-homogeneous EM calorimeters (3 sub-tasks)
  - » Task 3.2: Innovative sampling EM calorimeters (3 sub-tasks)
  - » Task 3.3: Hadronic sampling calorimeters (2 sub-tasks)
  - » Task 3.4: Materials (2 sub-tasks)

WP 4: Electronics and DAQ

Each sub-task is an independent working unit

DRD6 WP4 – Electronics and DAQ



Name	Track	Active media	readout
LAr	2	LAr	cold/warm elx"HGCROC/CALICElike ASICs"
ScintCal	3	several	SiPM
Cryogenic DBD	3	several	TES/KID/NTL
HGCC	3	Crystal	SiPM
MaxInfo	3	Crystals	SiPM
Crilin	3	PbF2	UV-SiPM
DSC	3	PBbGlass+PbW04	SiPM
ADRIANO3	3	Heavy Glass, Plastic Scint, RPC	SiPM
FiberDR	3	Scint+Cher Fibres	PMT/SiPM,timing via CAENFERS, AARDVARC-v3,DRS
SpaCal	3	scint fibres	PMT/SiPMSPIDER ASIC for timing
Radical	3	Lyso:CE, WLS	SiPM
Grainita	3	BGO, ZnWO4	SiPM
TileHCal	3	organic scnt. tiles	SiPM
GlassScintTile	1	SciGlass	SiPM
Scint-Strip	1	Scint.Strips	SiPM
T-SDHCAL	1	GRPC	pad boards
MPGD-Calo	1	muRWELL,MMegas	pad boards(FATIC ASIC/MOSAIC)
Si-W ECAL	1	Silicon sensors	direct withdedicated ASICS (SKIROCN)
Si/GaAS-W ECAL	1	Silicon/GaAS	direct withdedicated ASICS (FLAME, FLAXE)
DECAL	1	CMOS/MAPS	Sensor=ASIC
AHCAL	1	Scint. Tiles	SiPM
MODE	4	-	-
Common RO ASIC	4	-	common R/O ASIC Si/SiPM/Lar

Diffferent calorimeter technology but similar challenges:

- # channels,
- Power budget (cooling?)
- Noise
- Data reduction

DRD6 WP4 – Electronics and DAQ

- Avoid parallel developments
  - Take CALICE as example

- ASICs needed for prototypes >2025/26 possibly produced in common MPW run serving more projects
  - ASICs should be available ~ one year before data taking at latest

→ common ASIC production: overarching goal of DRD Calo

- Evoke possibility to hook onto production for other large projects (EiC?)
  - Agree on sharing among DRD Calo institutes and maybe with MPW runs in other DRDs

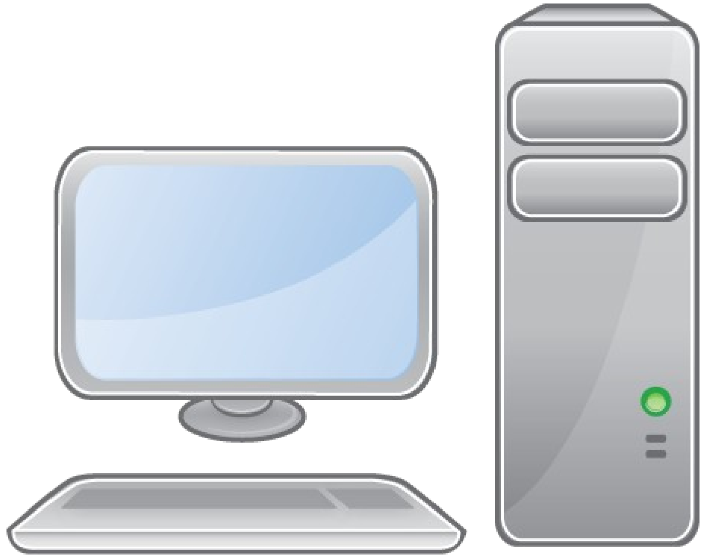
- Requires close communication with DRD3 and DRD7 (and maybe also DRD4)

DRD6 Working Groups – general scope

- Working Groups will address work that is common to all work packages in the DRD
- They thus ensure coherence and synergy of the scientific program of the DRD itself
- In general Working Groups ensure that scientific goals can be reached
  - Funds and personpower need to be included in the budget of the corresponding Work Packages
- Some Working Groups cover service tasks
  - Organisation and conduction of beam tests, if possible in a dedicated beam line for calorimetry
  - Software tools
  - The funding of these service tasks should be the subject of dedicated discussions in the course or shortly after the formation of the DRD
- The detailed organisation of the work within each working group is under the responsibility of dedicated coordinator(s) or directly under the responsibility of Technical Coordination

DRD6 Working Groups – Testbeams

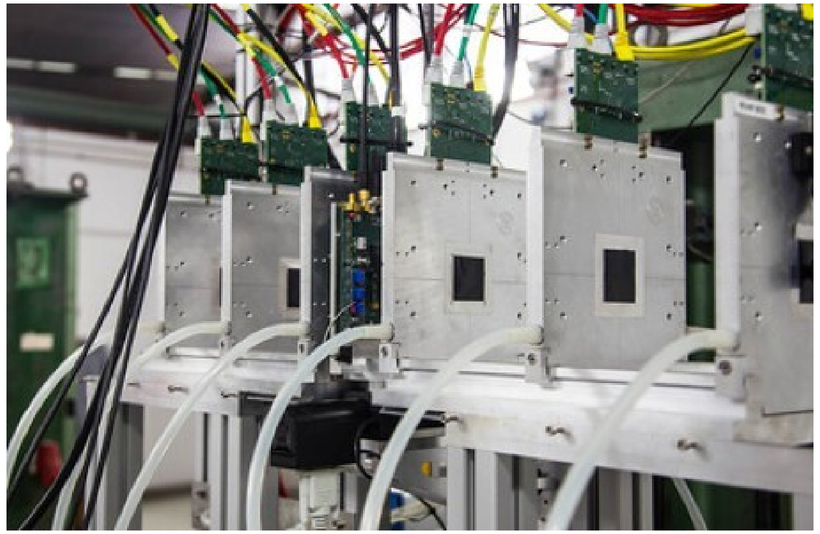
Generic equipment and tools



Overall planning

Your favorite
Calo Prototype(s)

Beam line infrastructure



- Many items are common to all projects
- Common coordination will streamline beam test programme

Communication with operators

DRD6 Working Groups – Testbeams

Calorimetric beam tests → small experiment, quite common requirements:

wide energy range
several kinds of beam particles
beam purity and energy
beam instrumentation for time, position and PID
big moving tables for big detectors
magnetic field

coordination of beam requests
coordination of and support for data taking

→ dedicated calorimetry beamline (in dedicated time slots) ?

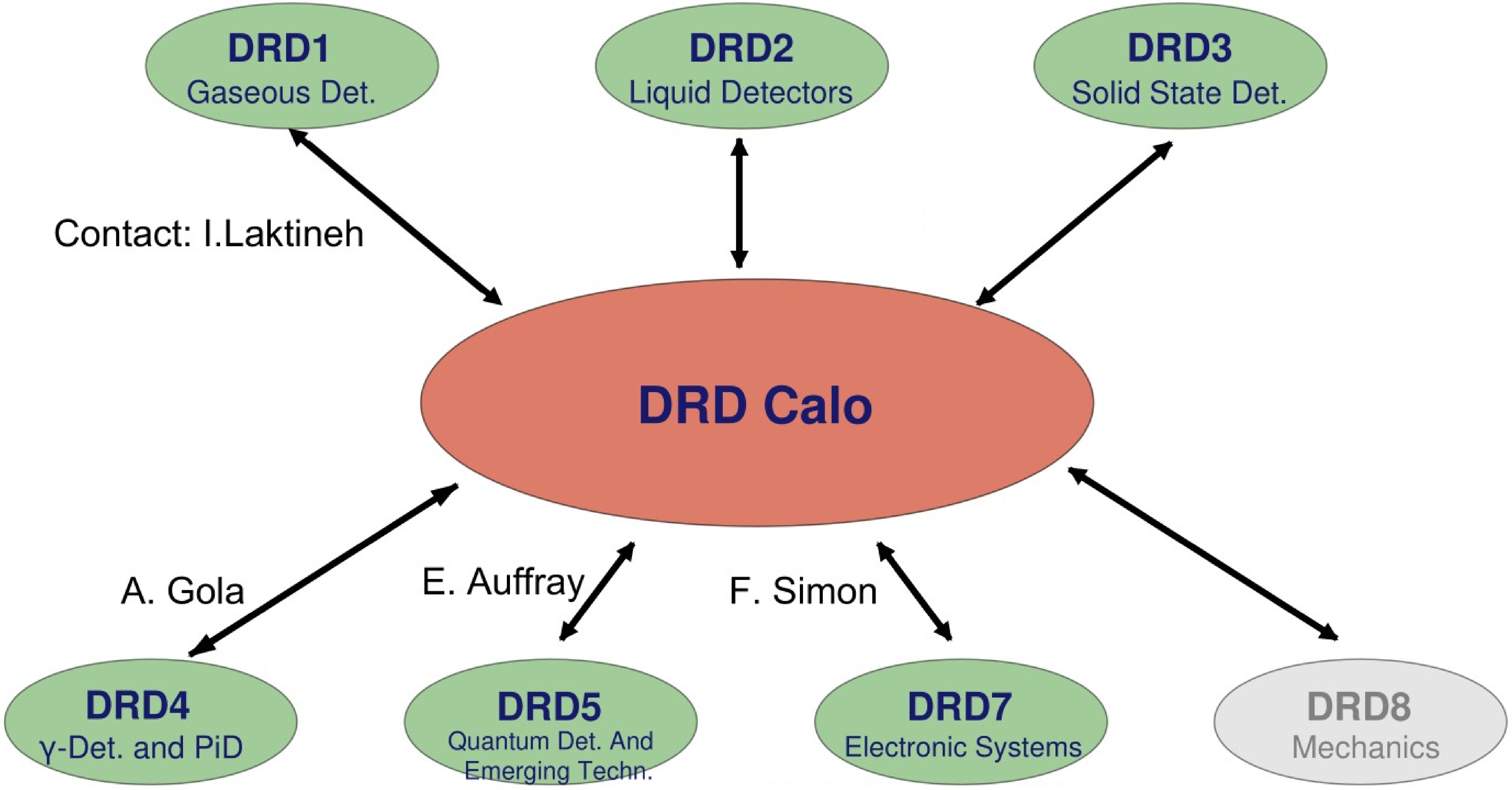
→ default facility: SPS

ECFA

DRD6 – Interplay with other DRDs

European Strategy Update

No R&D on primary elements (apart from scint. materials) but adaptation, tuning and integration



DRD1
Gaseous Det.

DRD2
Liquid Detectors

DRD3
Solid State Det.

Contact: I.Laktineh

DRD Calo

A. Gola

E. Auffray

F. Simon

DRD4
γ-Det. and PiD

DRD5
Quantum Det. And Emerging Techn.

DRD7
Electronic Systems

DRD8
Mechanics

MoU Status

- Must be very stable over time: any update will require new full signature cycle → very heavy process
- Anything subject to evolution must go in Annexes
- Strong requirement by CERN for uniformity over DRDs
  - However each DRD likely has specific issues (due to history, problematics, ...)
  - Some adaptation will be needed (in our opinion)
- Most controversial point: IP policy → many iterations between CERN Legal Service and CERN KT offices
- Resource Board needed
  - Responsible for common fund / common resources
  - Monitoring role over WP activities
  - Funding Agencies are represented in RB
  - MoU (Article 2): “A Funding Agency may be a Collaborating Institution or a body acting on behalf of one or more Collaborating Institutions in the conclusion of the MoU.”
  - FAs can be represented by link persons → RB could be subset of CB

MoU Annexes

- Should provide all needed flexibility
    - Revised once per year + updated any time is needed

- Annex 1: list of current Collaboration members

- Annex 2: essentially define Resource Board
    - Composition not fully crystal clear
        - Assembly of all FAs independently of commitments (i.e. including also FAs not yet committed to something) ?
    - In any case, members have to be agreed with corresponding FAs

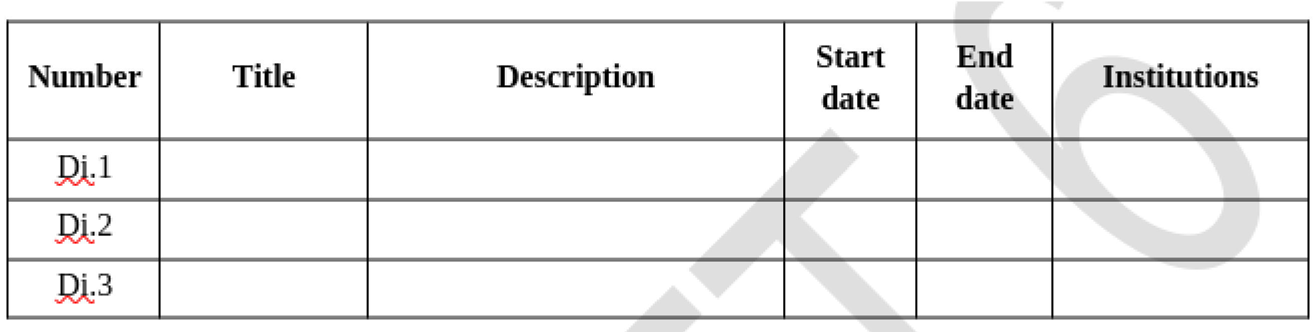
- Annex 7
    - All deliverables should go there or only those for which funding is assured ?
    - Tables require listing of resources and therefore commitments
    - Understand level of commitment any given FA is ready to make ?

    - May/should have first table entries by end of 2024

- How much are FAs aware of the "bureaucratic consequences" of the DRDs ?
    - There seem to be different levels of awareness - present draft has been sent to all major FAs

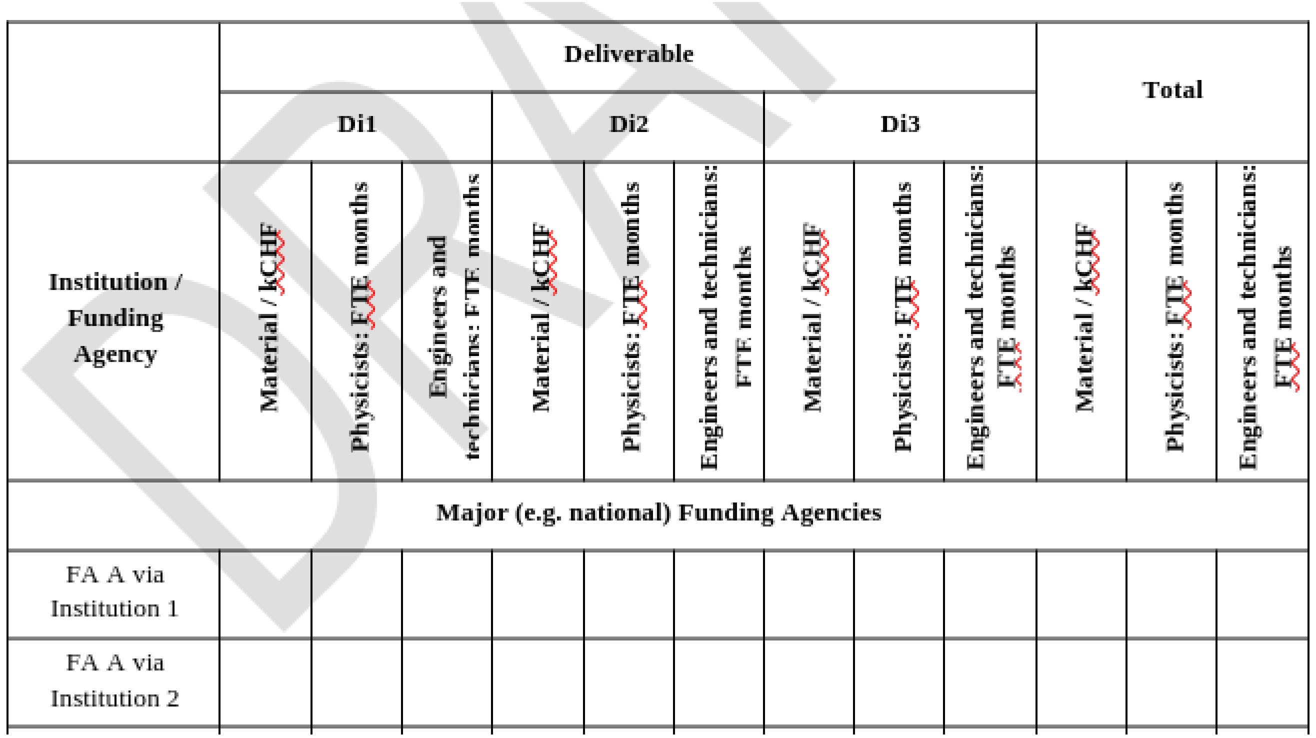
MoU Annex 7 – Work Packages

- Built around deliverables



Number	Title	Description	Start date	End date	Institutions
Di.1					
Di.2					
Di.3					

- With detailed commitments of Fas



	Deliverable									Total		
	Di1			Di2			Di3					
Institution / Funding Agency	Material / kCHF	Physicists: FTE months	Engineers and technicians: FTF months	Material / kCHF	Physicists: FTE months	Engineers and technicians: FTF months	Material / kCHF	Physicists: FTE months	Engineers and technicians: FTE months	Material / kCHF	Physicists: FTE months	Engineers and technicians: FTE months
Major (e.g. national) Funding Agencies												
FA A via Institution 1												
FA A via Institution 2												

- What about activities not yet (or not fully) funded?

DRD6 Governance Rules

- Define collaboration structure + responsibilities and decisional processes
    - Membership
    - Voting procedures
    - Boards and their role
        - → Efficient operation without too much overhead
        - → WPs should be largely autonomous

- Not yet complete (Resource Board part still missing)

- Role of Speaker and Publication Bureau in WP-specific activities ?

- Living document -> may undergo changes, expecially in first phase
    - At least role of Resource Board has to be better understood

- Draft prepared by DRD6 Proposal Team ready to be discussed and voted by CB next week
    - Result of several iterations in Proposal Team
    - First feedback received by Institutes and action taken

- Should go in Annex 4 of MoU

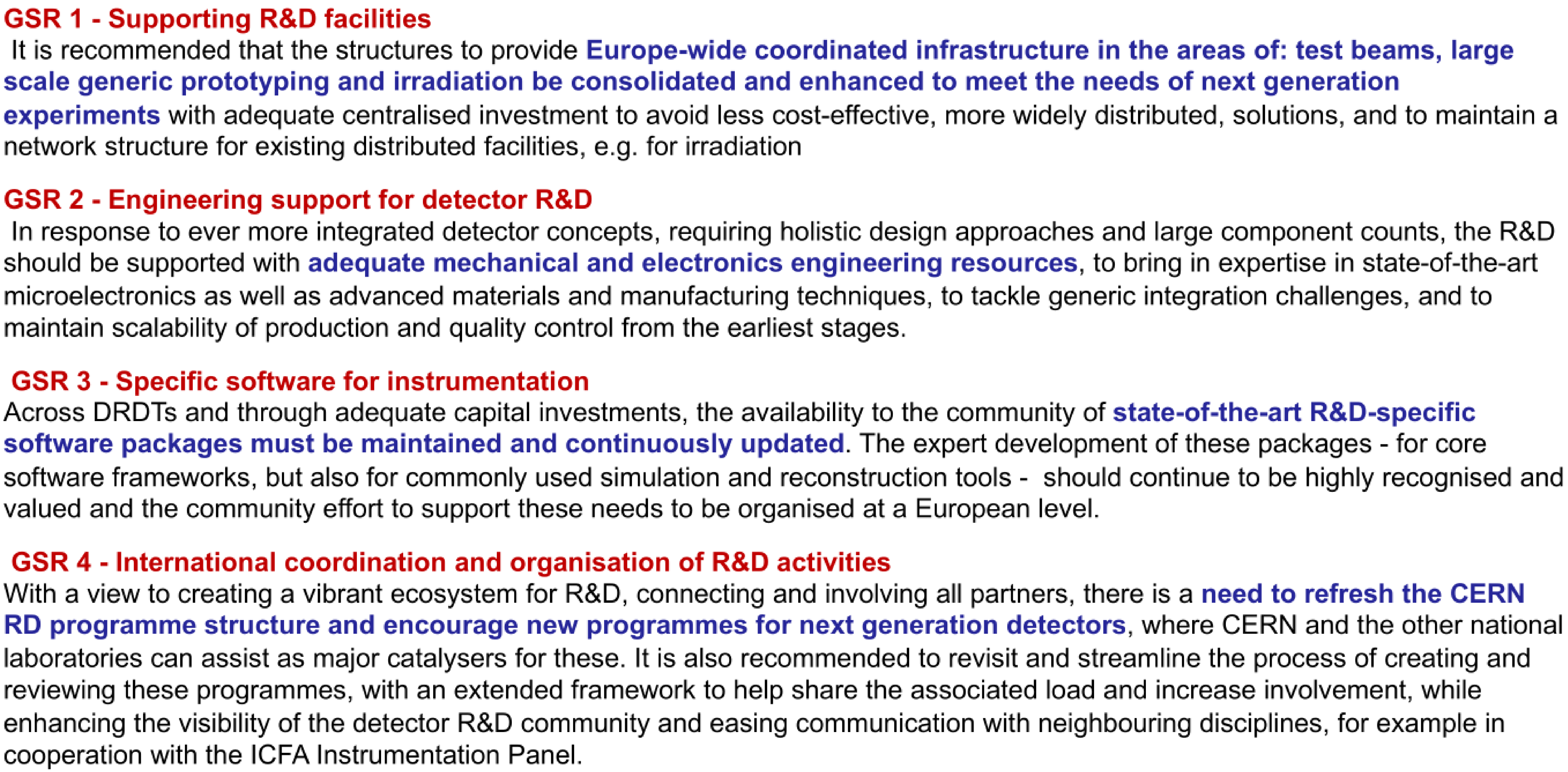
Conclusions

DRD6 is taking shape and momentum

- Already providing added value (e.g. time at CERN SPS beam lines)
- Should become a brand
- Above all, should allow sinergies and critical issues to be efficiently identified and tackled

Backup

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.

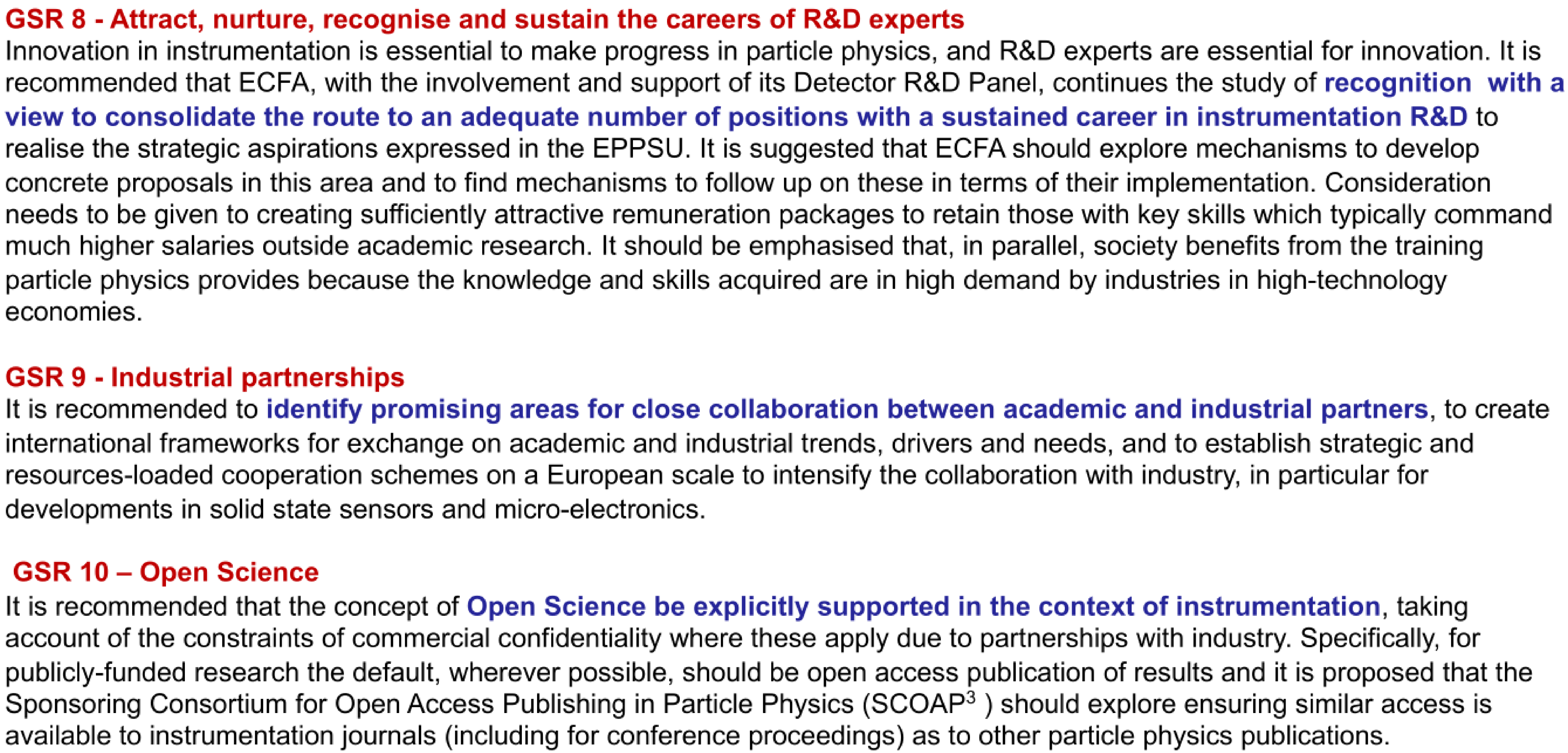
GSR 6 - Establish long-term strategic funding programmes

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.

DRD6 – Short-term applications

Several Phase-II and Phase-III HL-LHC upgrades:

CMS ECAL, LHCb ECal, ALICE FoCal

and also:

LUXE (XFEL), BELLE II ECal, EIC EEMCal

but ... all, except FoCal, EM calorimeters

DRD6 – Short-term applications (2)

High-performance hadron calorimetry only relevant for future Higgs/EWK factories?

Only rate capability and radiation hardness look to matter for hadron colliders (not surprising)