ECFA

European Strategy Update

INFN
Istituto Nazionale di Fisica Nucleare
Sezione di Pavia

ECFA DRD6 overview

Roberto Ferrari
INFN Pavia

CEPC 2024 EU Workshop
Marseille, April 8, 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

Timescale of proposed future facilities

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

Timescale of proposed future facilities

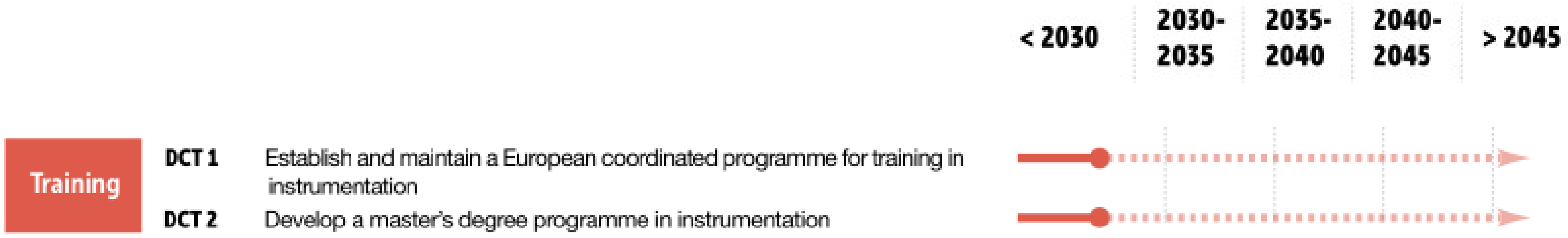
Timescale of projects as approved by European Lab Director Group (LDG)

guiding principle: project realisation must NOT be delayed by detectors

Detector R&D Themes

		< 2030 / 2030-2035 / 2035-2040 / 2040-2045 / > 2045
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



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

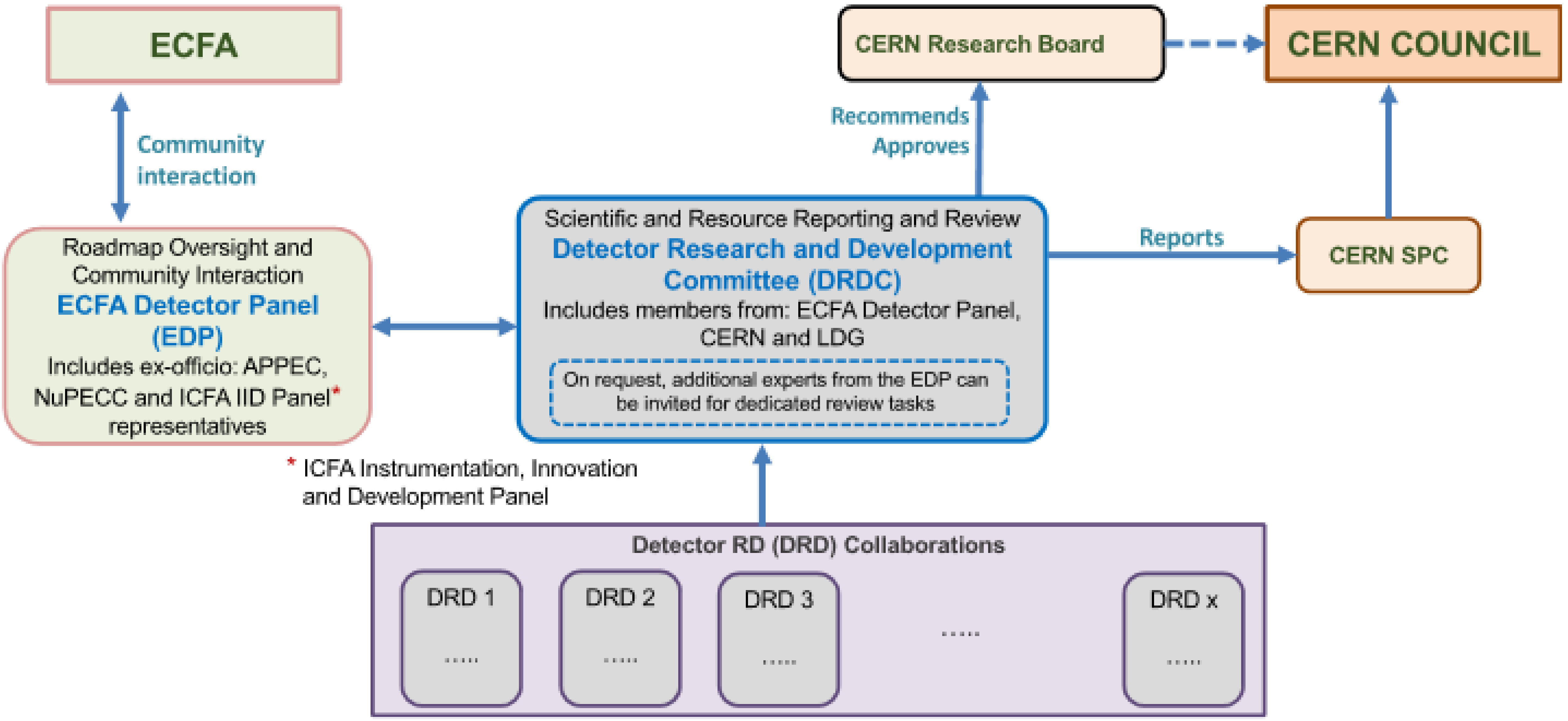
GSR7- Blue-sky R&D

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

GSR 9 - Industrial partnerships

GSR 10 - Open Science

Implementation



Detector R&D Collaborations

Fully Approved
- Gaseous Detectors (DRD1) [ex RD51]
- Liquid Detectors (DRD2)
- Photodetectors & Particle ID (DRD4)
- Calorimetry (DRD6)

Conditionally approved
- Semiconductor Detectors (DRD3) [ex RD50, RD42,..]

Full proposals submitted last week for review
- Quantum Sensors (DRD5)
- Electronics (DRD7)

Letter of Intent submitted
- Integration (DRD8)

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

MoU

MoU template yet to be provided by CERN legal service

- still waiting for → I.P. policy most sensitive issue

- Very light template

- MoU not supposed to be modified in future
  - Very hard process → should go again under full signature cycle
  - Does not provide any legal binding
  - Not required for membership

- Flexibility through "Annexes" (can change whenever necessary or useful):
  - Any change has to be just notified to CERN by providing new version
  - Instititute member list in Annex 1 → revise at least once every year
  - Funding agency list in Annex 2
  - ... Common fund contribute in Annex X (if any, can be zero)

Membership

At least 2 different ways to become member:

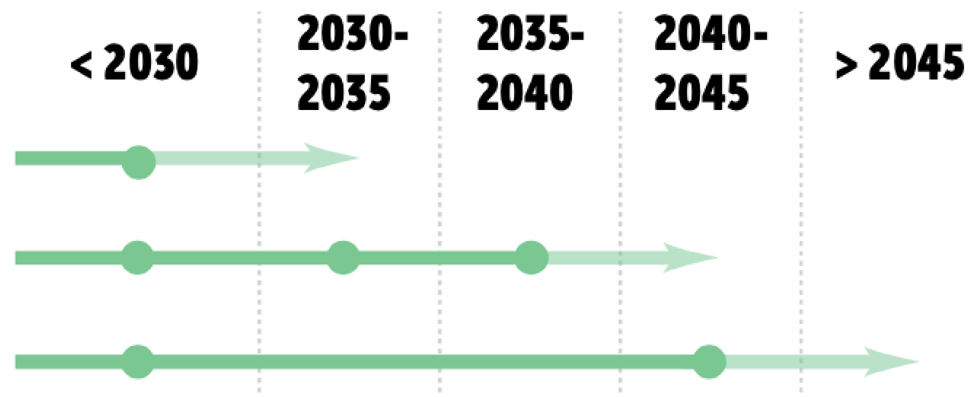
a) Signature of MoU or Annex 1
b) Letter by the Institute Director/Head stating the willing to participate and the contribute that will, in case, be brought in

- None provide legal binding → both closer to a “gentlemen agreement” than to a contract

DRD6 – Calorimetry

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

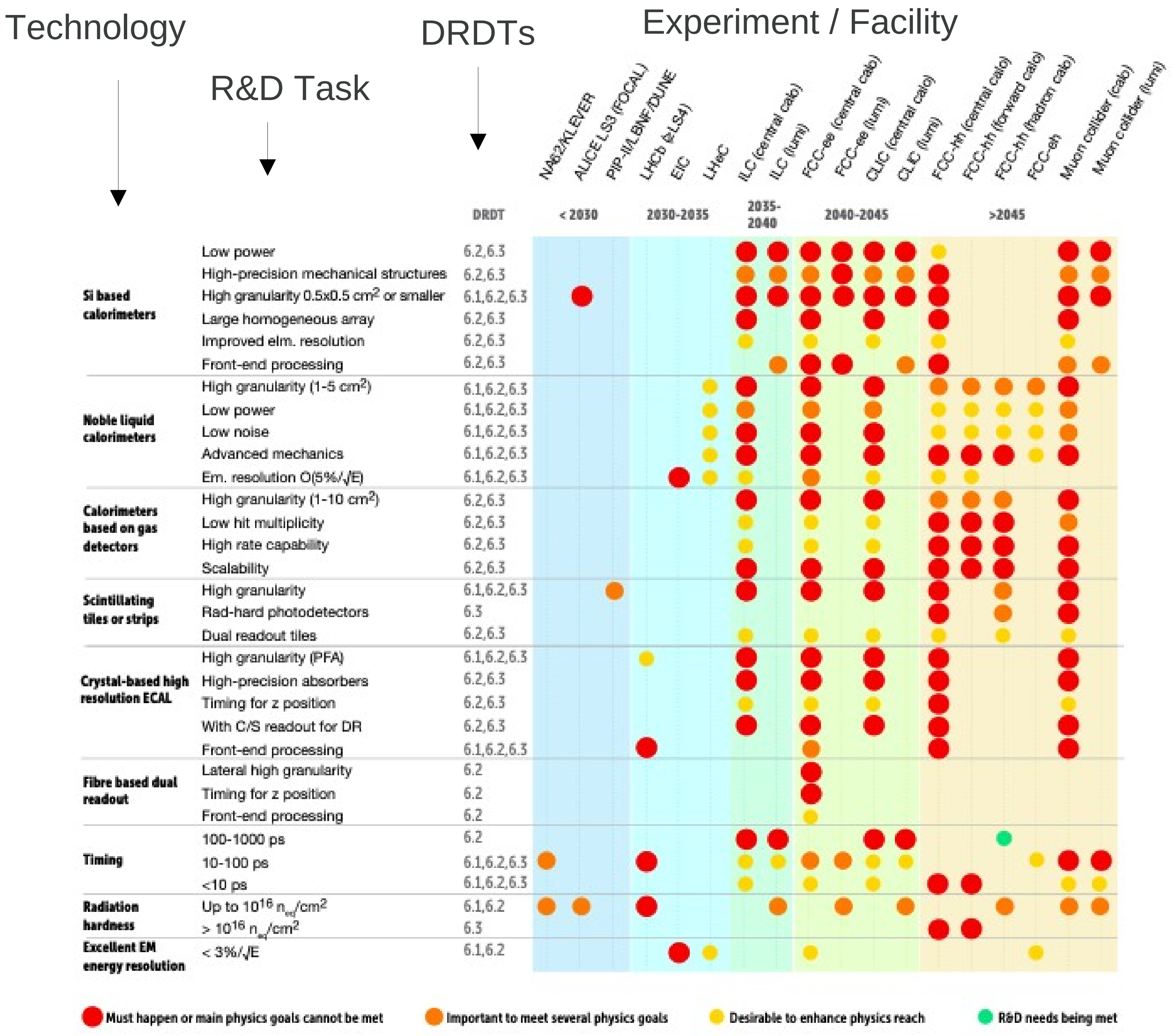
DRD6 – Calorimetry overview table

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



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, ...)

→ongoing DRD process must successfully integrate existing R&D activities

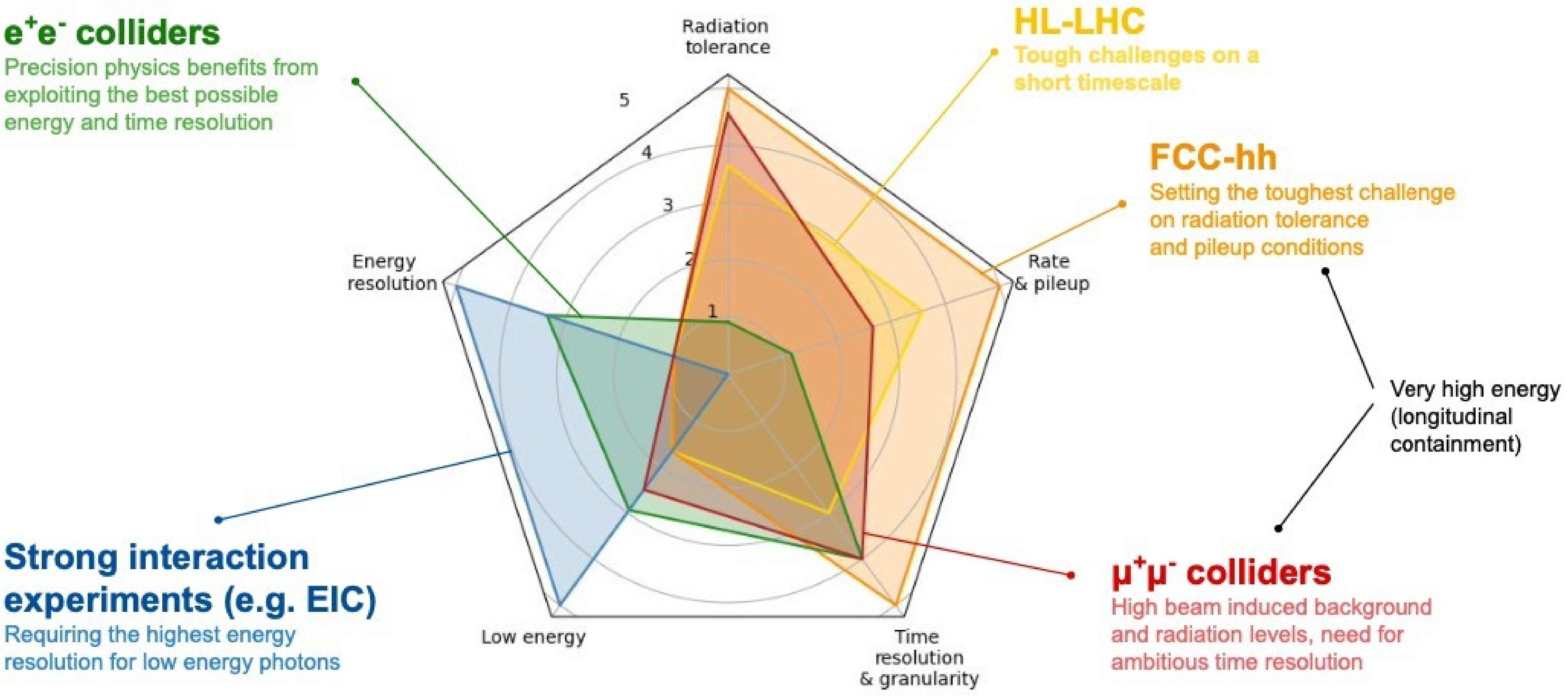
DRD6 – Few common keywords from input proposals

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

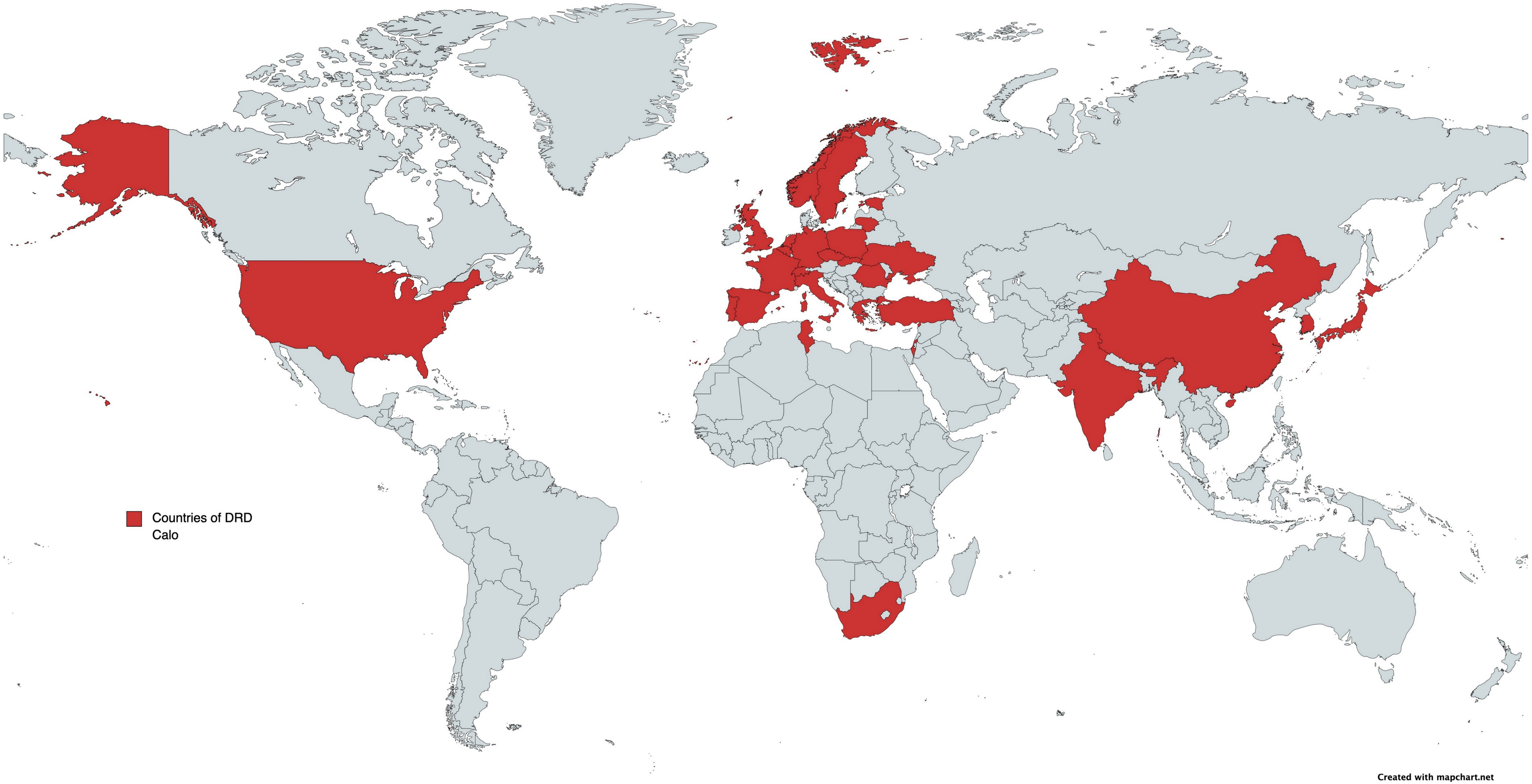


Inspired from https://indico.cern.ch/event/994685/

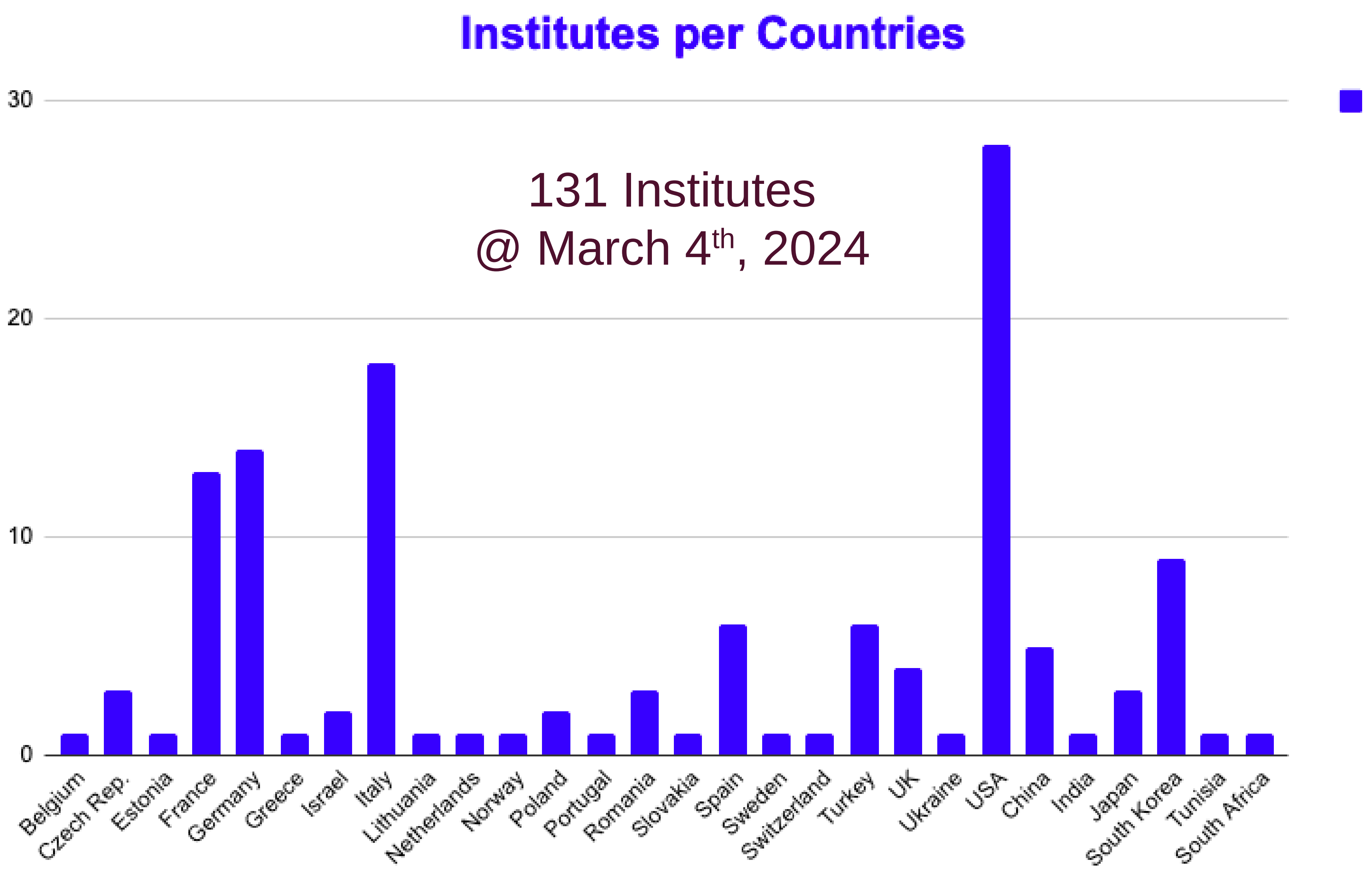
ECFA

DRD6 Collaboration

European Strategy Update

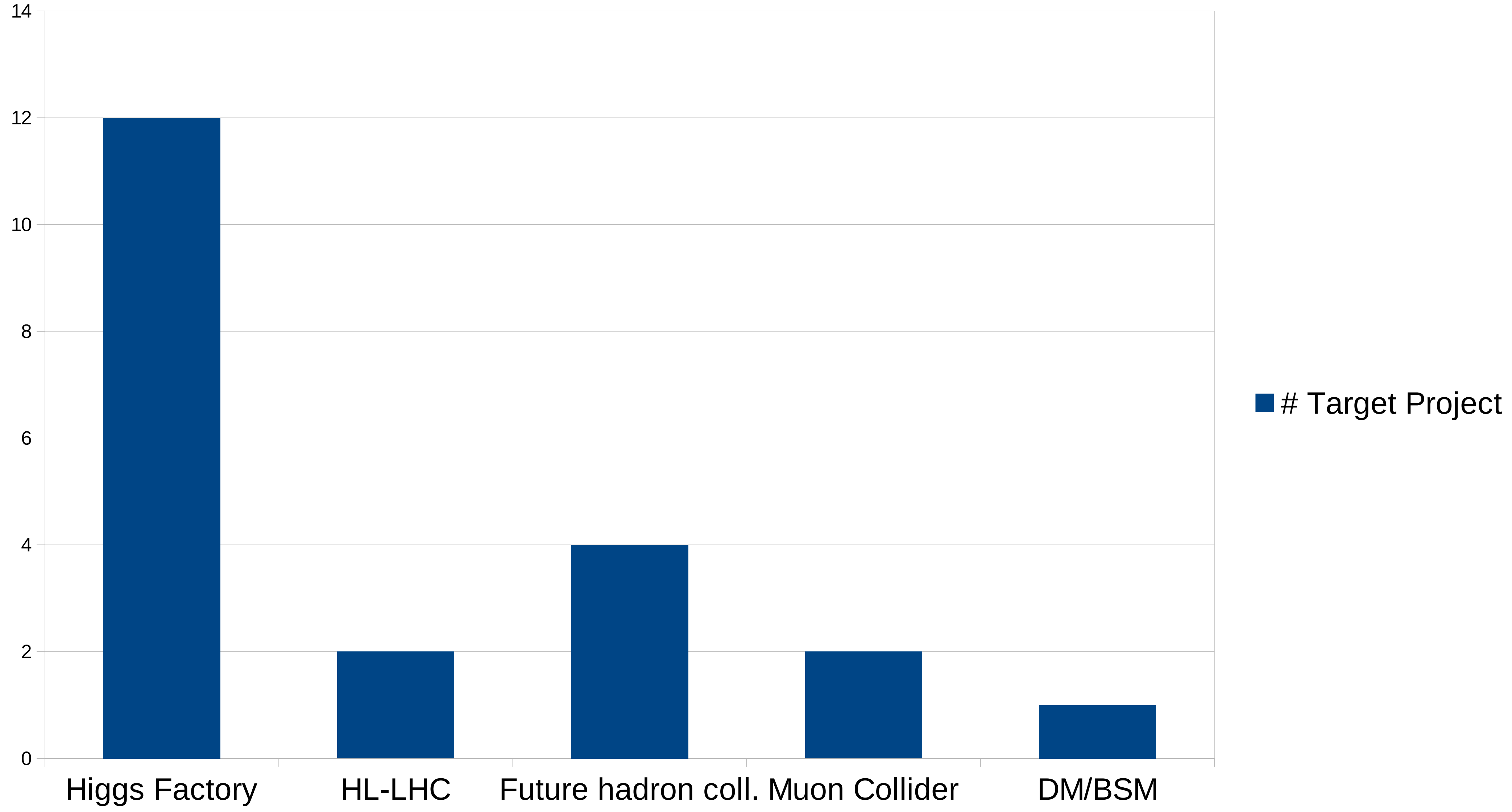


DRD6 Collaboration



- 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

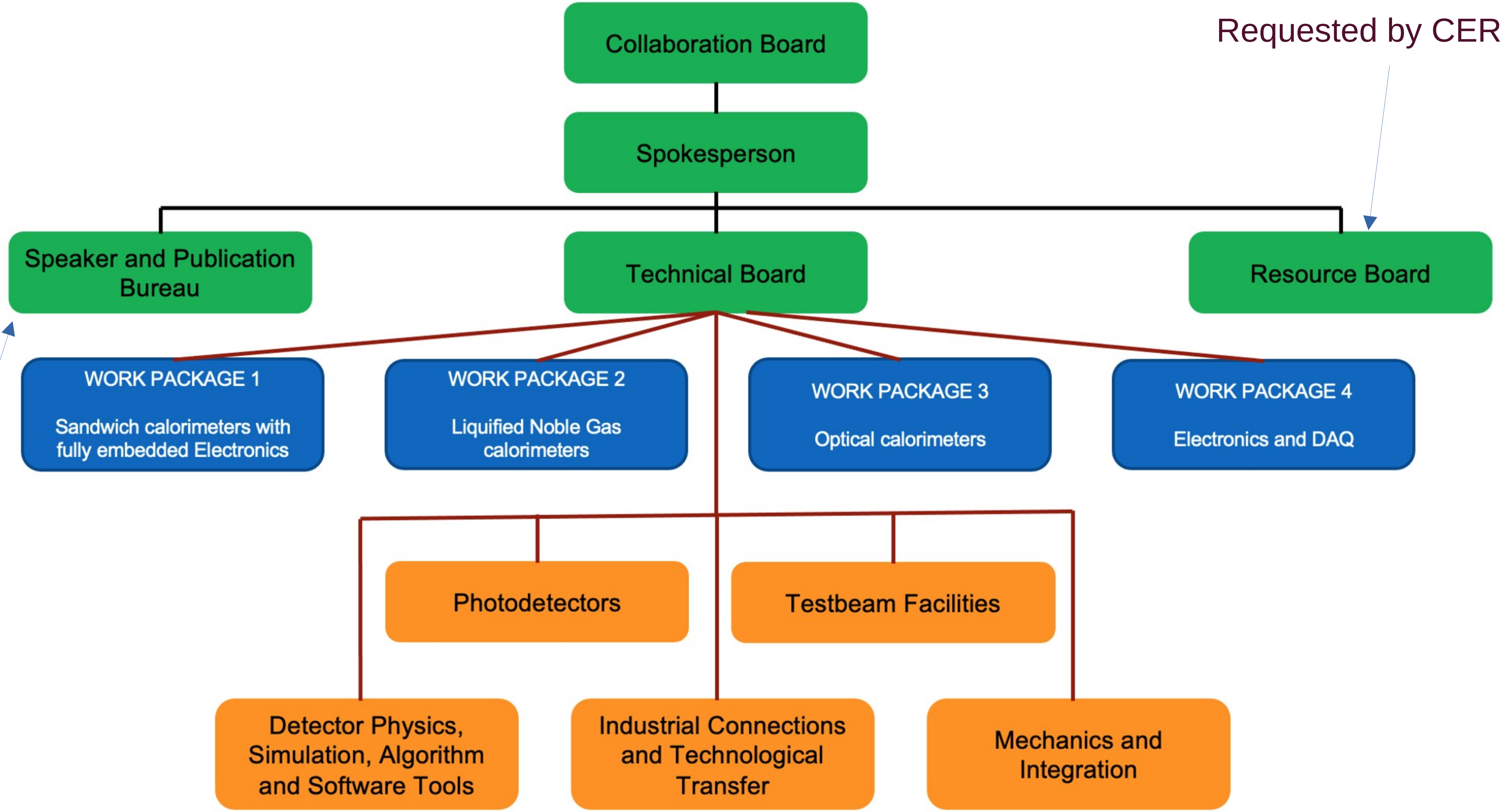
After input-proposal collection and feedback from CERN and DRDC:

Requested by CERN

MANAGEMENT:

WORK PACKAGES:

WORKING GROUPS:



*SPB also in charge for dissemination

DRD6 – Proposed structure → started filling up

1) CB-Chair : R.F., elected about one moth ago

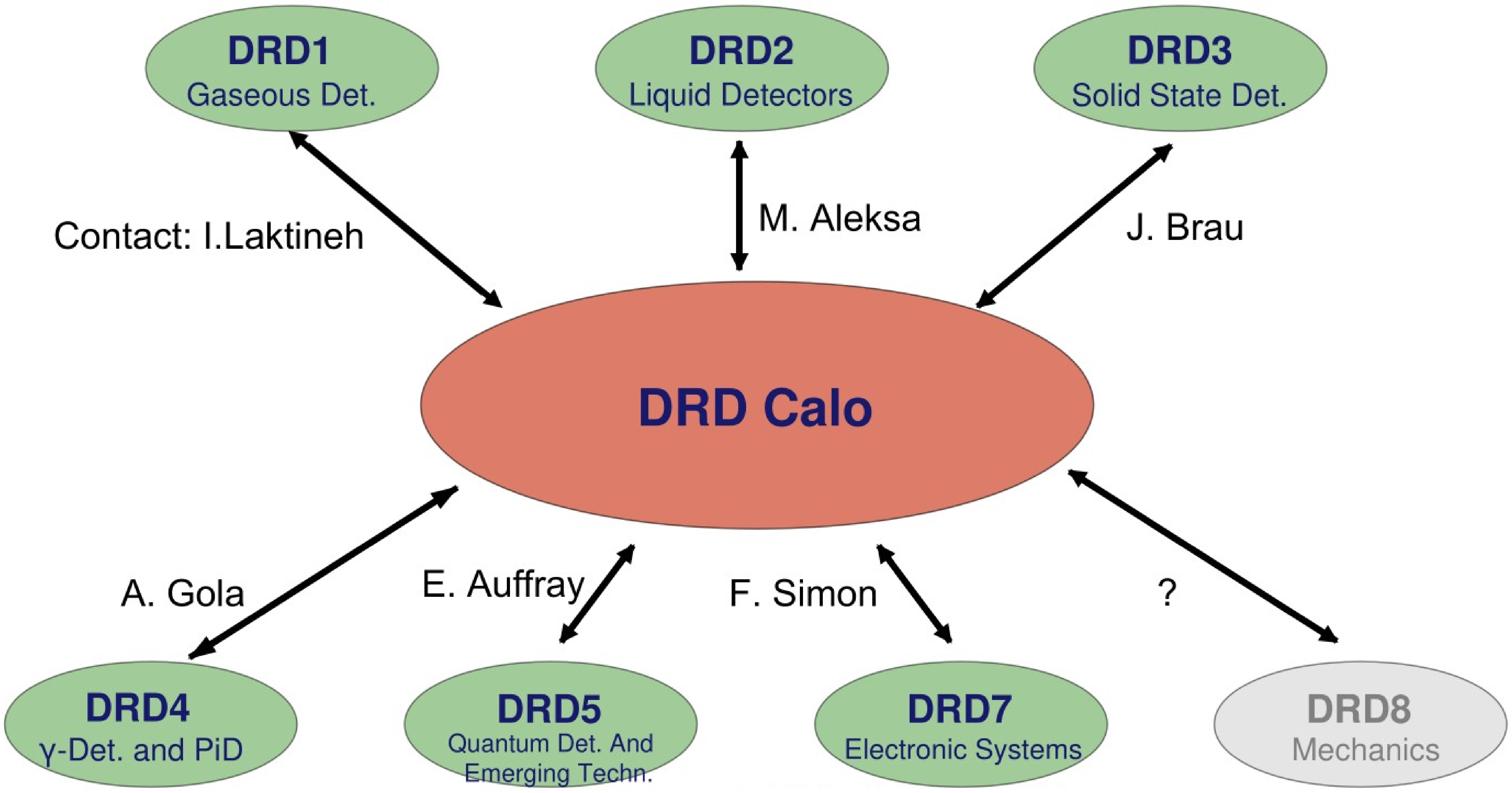
2) S.P. : to be elected in next 10-15 days (Roman Poeschl, only candidate)

3) W.P. coordinators: process started (WP2 coordinator to be endorsed by CB on next Wednesday)

4) Other management positions: S.P. will identify and propose candidates in next weeks (to be endorsed by CB)

DRD6 – Interplay with other DRDs

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



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

DRD6 – WP1 Tasks and Subtasks (→ Projects)

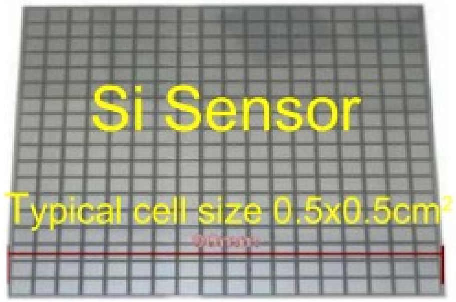
Elm. sections

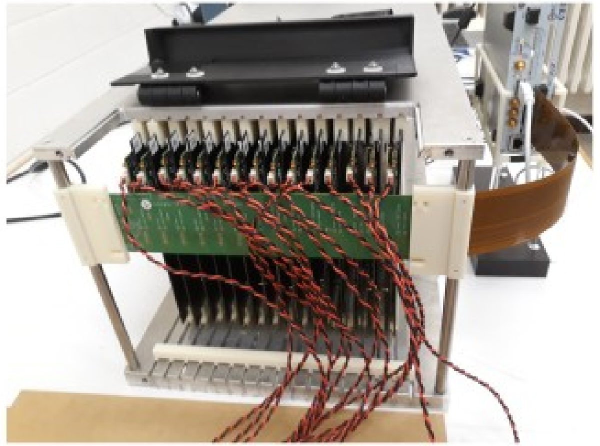
Hadronic sections

Task/Subtask	Sensitive Material/ Absorber	DRDT
Task 1.1: Highly pixelised electromagnetic section		
Subtask 1.1.1: SiW-ECAL	Silicon/ Tungsten	6.2
Subtask 1.1.2: Highly compact calo	Solid state (Si or GaAs)/Tungsten	6.2
Subtask 1.1.3: DECAL	CMOS MAPS/Tungsten	6.2, 6.3
Subtask 1.1.4: Sc-Ecal	Scintillating plastic strips/Tungsten	6.2
Task 1.2: Hadronic section with optical tiles		
Subtask 1.2.1: AHCAL	Scintillating plastic tiles/Steel	6.2
Subtask 1.2.2: ScintGlassHCAL	Heavy glass tiles/Steel	6.2
Task 1.3: Hadronic section with gaseous readout		
Subtask 1.3.1: T-SDHCAL	Resistive Plate Chambers/Steel	6.2
Subtask 1.3.2: MPGD-HCAL	Multipattern Gas Detectors/Steel	6.2, 6.3
Subtask 1.3.3: ADRIANO3	Resistive Plate Chambers+Scintillating plastic tiles/ Heavy Glass	6.1, 6.2, 6.3

DRD6 Task 1.1 - Highly pixelised e.m. section

Silicon W(olfram) ECAL

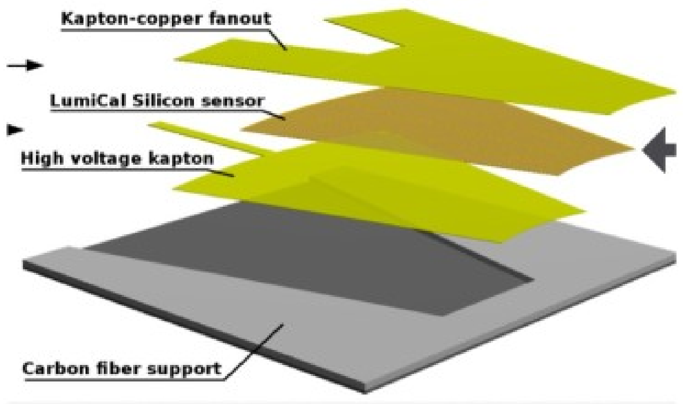




Main R&D Topics

- High level integration
- Power pulsing <-> continuous operation
- Reduction of power consumption;
- Cooling?
- Timing, if and how
- Real-size layers

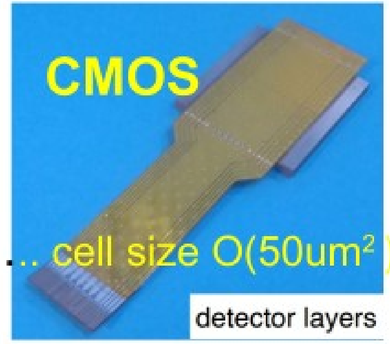
Compact Calo

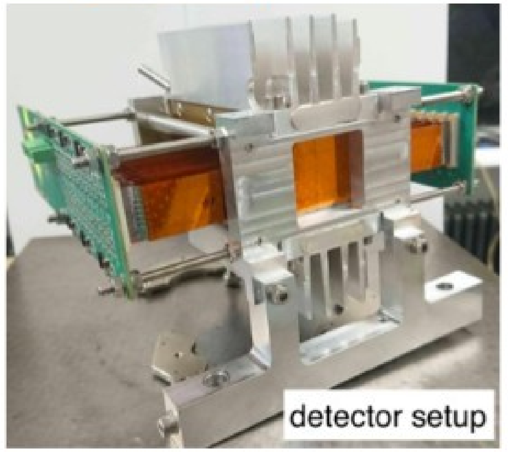


Main R&D Topics

- Testing of sensors with readout strips
- High level integration
- Study of conductive glue
- Wireless data transfer

Digital ECAL

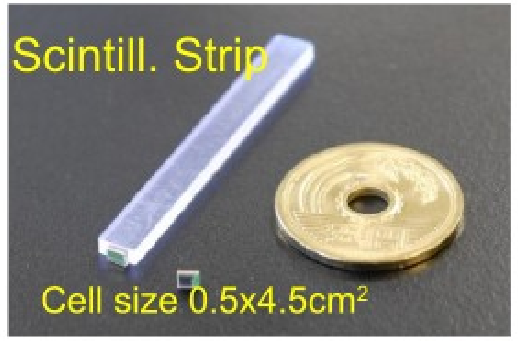




Main R&D Topics

- CMOS MAPS-based optimised for calorimetry
- Reduction of the power consumption to 1mW/cm²
- Stitching technologies for large surfaces

Scintillator ECAL



Main R&D Topics

- Power pulsing <-> continuous operations
- Reduction of power consumption
- Cooling?
- Timing, if and how
- Real-size layers

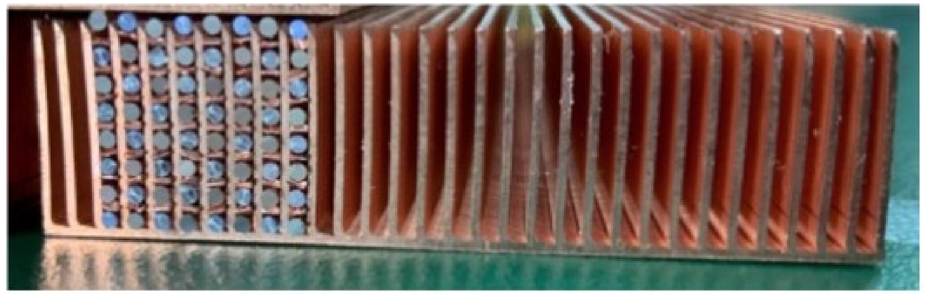
DRD6 – WP3 Tasks and Subtasks (→ Projects)

Project	Scintillator/WLS	Photodetector	DRDTs	Target
Task 3.1: Homogeneous and quasi-homogeneous EM calorimeters				
HGCCAL	BGO, LYSO	SiPMs	6.1, 6.2	e^+e^-
MAXICC	PWO, BGO, BSO	SiPMs	6.1, 6.2	e^+e^-
Crilin	PbF_2, PWO-UF	SiPMs	6.2, 6.3	$\mu^+\mu^-$
Task 3.2: Innovative Sampling EM calorimeters				
GRAiNITA	$ZnWO_4$, BGO	SiPMs	6.1, 6.2	e^+e^-
SpaCal	GAGG, organic	MCP-PMTs,SiPMs	6.1, 6.3	e^+e^-/hh
RADiCAL	LYSO, LuAG	SiPMs	6.1, 6.2, 6.3	e^+e^-/hh
Task 3.3: (EM+)Hadronic sampling calorimeters				
DRCal	PMMA, plastic	SiPMs, MCP	6.2	e^+e^-
TileCal	PEN, PET	SiPMs	6.2, 6.3	e^+e^-/hh
Task 3.4: Materials				
ScintCal	-	-	6.1, 6.2, 6.3	$e^+e^-/\mu^+\mu^-$/hh
CryoDBD Cal	TeO, ZnSe, LiMoO NaMoO, ZnMoO	n.a.	-	DBD experiments

Task 3.3: (EM+)Hadronic sampling calorimeters				
DRCal	PMMA, plastic	SiPMs, MCP	6.2	e^+e^-
TileCal	PEN, PET	SiPMs	6.2, 6.3	e^+e^-/hh

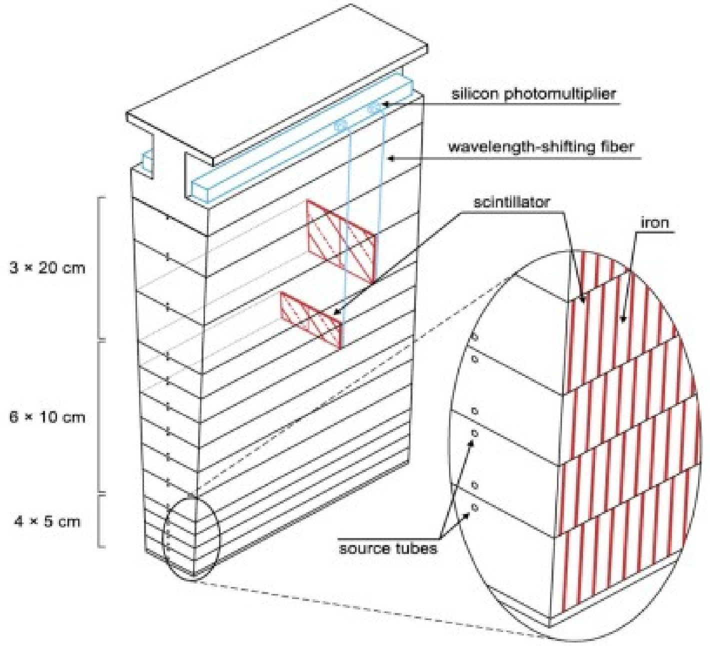
DRCal

- High resolution Electromagnetic and hadronic calorimeter based on Dual-Readout Technique
- Organic scintillating fibres in brass or steel absorber (different solutions under development).
- SiPM or MCP-PMT photon detectors integration of a large number of SiPMs



TileCal

- Hadron calorimeter with scintillating tiles and WLS fibre readout and SiPMs
- Cost-effective production of tiles, radiation hardness for FCC-hh
- Organic scintillating tiles, Steel (+Pb for FCC-hh) absorber



ECFA

DRD6 WP3 – Milestones and deliverables

European Strategy Update

	Milestone	Deliverable	Description	Due date
HGCCAL	M3.1		Specifications of crystal, SiPM and electronics for highly granular EM crystal calorimeter prototype	2024
		D3.1	Development of 1-2 crystal EM modules to be exposed to beam tests	2024
	M3.2		Beam tests characterisation of a full containment highly granular EM crystal calorimeter prototype	2025
	M3.3		A first mechanical design for a final detector with crystal modules	2025
	M3.4		New reconstruction software for the long-bar design and updated PFA	2026
		D3.2	Large crystal module for hadronic performance, system integration studies and combined testbeam with HCAL	>2026
MAXICC	M3.5		Completion of qualification tests on components and selection of crystal, filter and SiPM candidates for prototype	2025
	M3.6		Report on the characterisation of crystal, SiPM and optical filter candidates and their combined performance for Cherenkov readout	2025
		D3.3	Full containment dual-readout crystal EM calorimeter prototype and testbeam characterisation	2026
	M3.7		Joint testbeam of EM module prototype with dual-readout fibre calorimeter prototype (DRCAL)	>2026
Crilin		D3.4	Acquisition and tests of crystals and SiPMs; design and production of electronics boards; design and production of the mechanical components	2024
		D3.5	Calorimeter fully assembled	2025
	M3.8		Beam test characterisation of a full containment EM calorimeter prototype	2025
	M3.9		Report on testbeam results	2026
GRAiNITA	M3.10		Characterisation of materials, wavelength shifters and SiPMs and identification of best technological choices	2024
		D3.6	Development of a GRAiNITA demonstrator as EM calorimeter prototype for e+e- collider (full shower containment)	2026
SpaCal		D3.7	Tungsten and lead absorbers for module-size prototypes	2024
	M3.11		Design of optimised light guides	2025
		D3.8	Set of crystal samples, SPIDER ASIC prototype	2026
	M3.12		Specification of photon detector and improved simulation framework available	2026
		D3.9	Module-size prototypes (significantly larger than EM showers) built and validated in beam tests	>2026
RADiCAL		D3.10	Single module with prototype scintillating crystals, SiPMs and front-end electronics cards built and tested.	2024
		D3.11	3x3 array of RADiCAL modules built and tested	2026
	M3.13		Paper on beam-test results for EM shower position, timing and energy	2026
	M3.14		Continue beam testing with alternative scintillation and wavelength shifting materials - for improved cost/performance.	>2026
DRCal		D3.12	Construction of full-scale dual readout module with hadronic shower containment	2025
	M3.15		Testbeam campaign to assess module performance: result paper	2026
	M3.16		Continue beam testing with alternative readout elx	>2026
TileCal	M3.17		Characterisation of PEN- and PET-based scintillating tiles including optimisation of readout with WLS fibres and SiPMs	2025
		D3.13	Construction of up to 3 prototypes of a sampling tile calorimeter module with WLS fibres and SiPM readout (for beam tests after 2026)	2026
	M3.18		Paper on beam test results	>2026
		D3.14	Full hadron-shower containment prototype built and tested	>2026
ScintCal	M3.19		Dataset of scintillation and radiation hardness properties of various scintillation materials studied	2026
		D3.15	Samples of a set of scintillators produced and characterised	2026
		D3.16	Samples of most promising glasses produced and characterised	>2026
	M3.20		Material selected for future detectors	>2029
CryoDBDCal	M3.21		Report crystals in terms of optimisation of growing/doping procedures	2024
		D3.17	Scintillating polymer for 3D-printing, with optimal mechanical and light-production properties, produced and tested	2025

3 Milestones and 4 deliverable in 2024

- **Milestones**
  - Task 3.1
    - HGCCAL: Specifications of crystal, SiPM and electronics for highly granular EM crystal calorimeter prototype
  - Task 3.2
    - GRAiNITA: Characterisation of materials, wavelength shifters and SiPMs and identification of best technological choices
  - Task 3.4
    - CryoDBDCal: Report crystals in terms of optimisation of growing/doping procedures
- **Deliverables**
  - Task 3.1
    - HCCCAL: Development of 1-2 crystal EM modules to be exposed to beam tests
    - Crilin: Acquisition and tests of crystals and SiPMs; design and production of electronics boards; design and production of the mechanical components
  - Task 3.2
    - SpaCal: Tungsten and lead absorbers for module-size prototypes
    - Radical: Single module with prototype scintillating crystals, SiPMs and front-end electronics cards built and tested

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

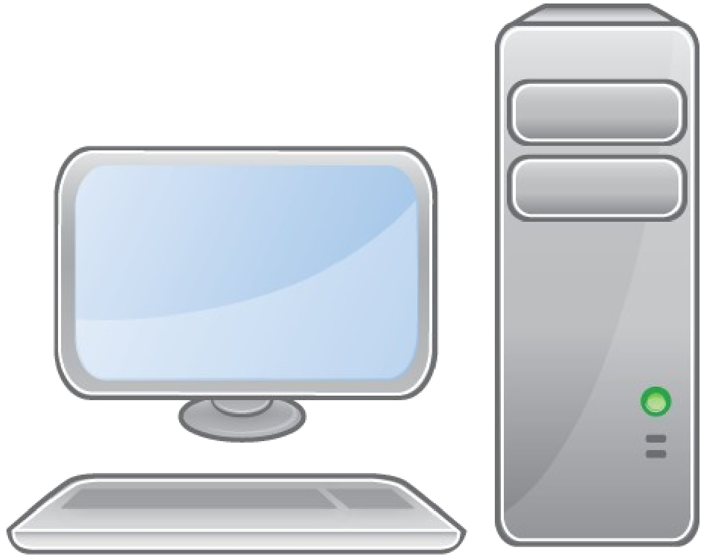
- Evoke possibility to hook onto production for other large projects (EiC?)
  - Agree on sharing among DRD Calo institutes and maybe with MPW runs in other DRDs
- Requires close communication with DRD3 and DRD7 (and maybe also DRD4)

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

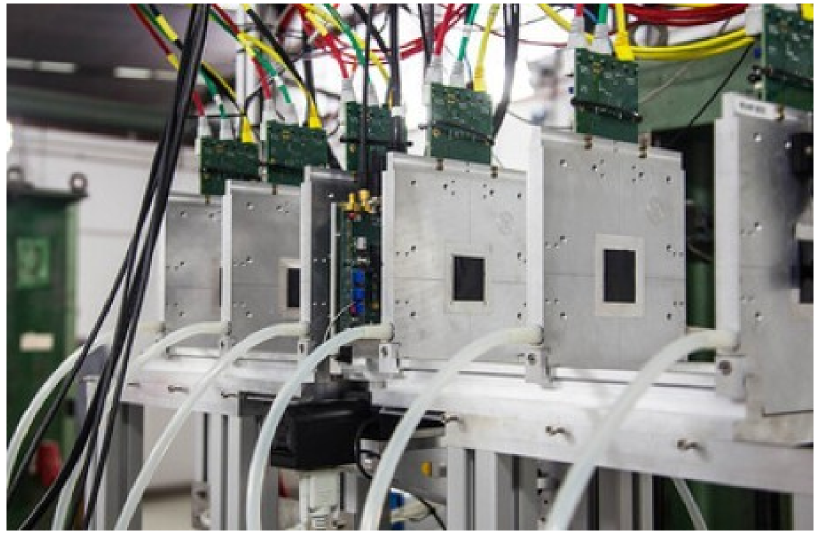
Generic equipment and tools



Overall planning

Your favorite
Calo Prototype(s)

Beam line infrastructure



Communication with operators

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

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

Conclusions

Following the EU particle physics strategy update and the ECFA detector R&D roadmap, 8 new collaborations have been formed:

- Bottom-up process with a worldwide participation
- Common basis
- Custom implementation (depending on community experience and story)
- Structure based on Work Packages (resource loaded) and Working Groups (NO resource load)
- All future facilities in the focus
- Setting up the collaboration NOW

Whoever willing/interested to join, is more than welcome!

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

ECFA — European Strategy Update

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 – 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 – 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)