Calorimetry - Toward DRD Calo

Roman Pöschl
Co-Coordinator Transition to DRD Calo

On behalf of DRD Calo Proposal Team

FCC France Meeting, November 2023, Strasbourg

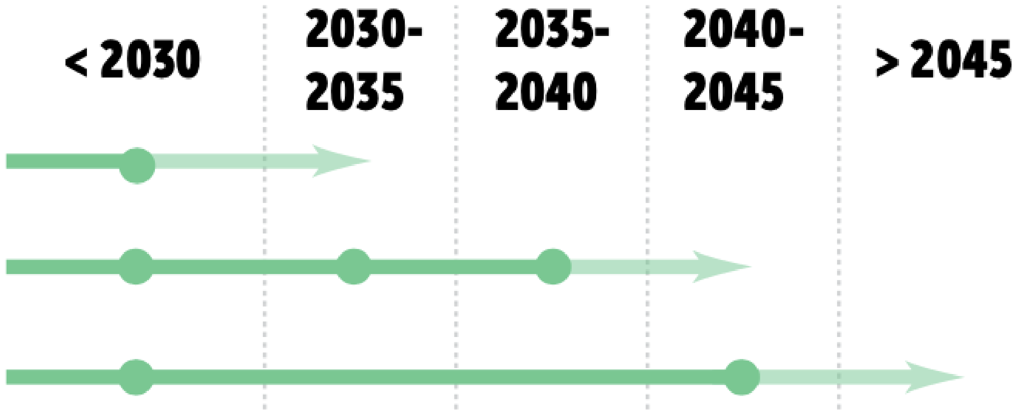
Future Facilities and DRDT for Calorimetry

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



- The Detector R&D Themes and the provisional time scale of facilities set high-level boundary conditions
  - See backup slides for detailed R&D tasks

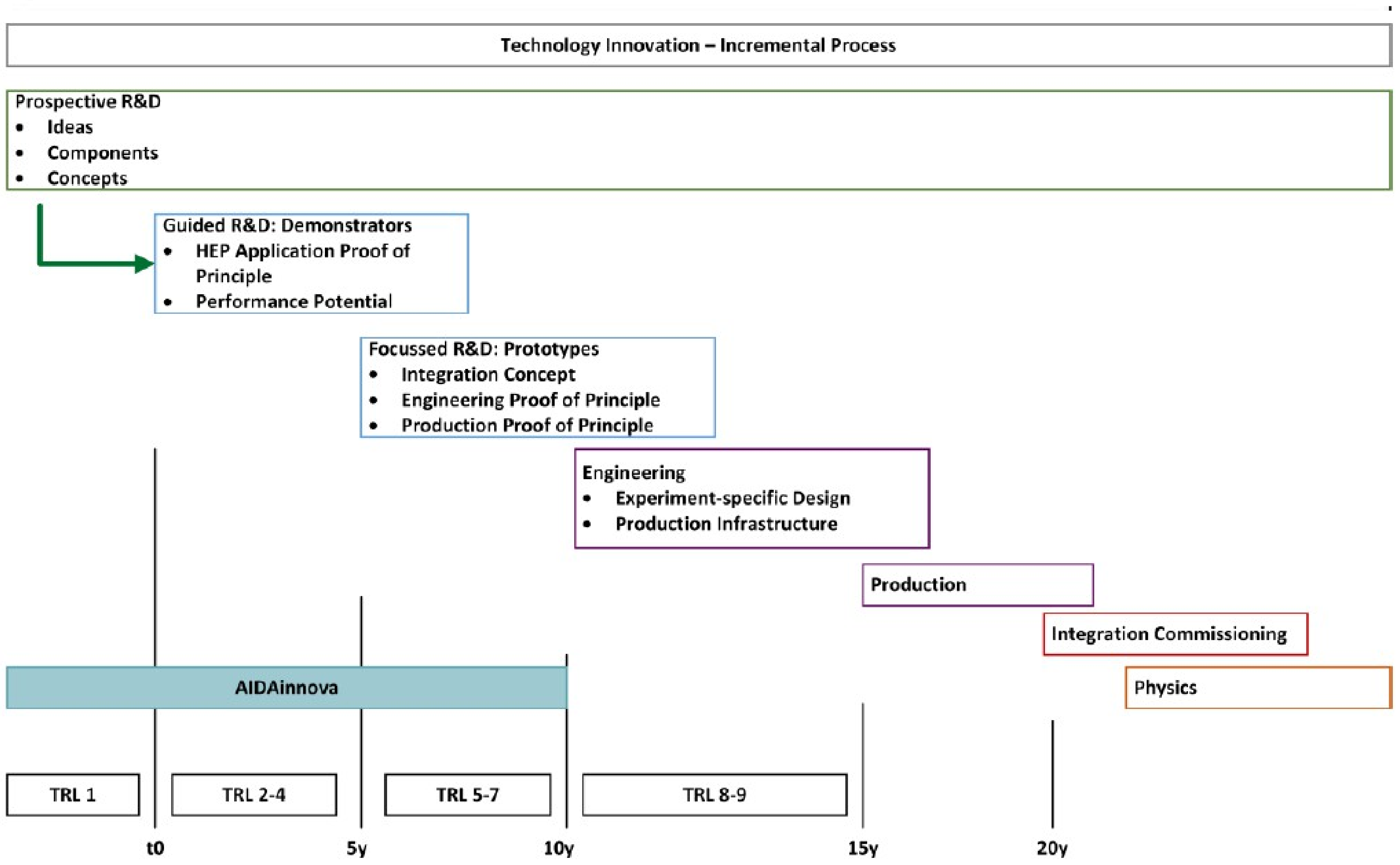
Categories of R&D

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, usually not yet covered within the projected budgets for the final deliverables)
3. "Blue-sky" R&D
   (competitive, short-term responsive grants, nationally organised)

vision

focus

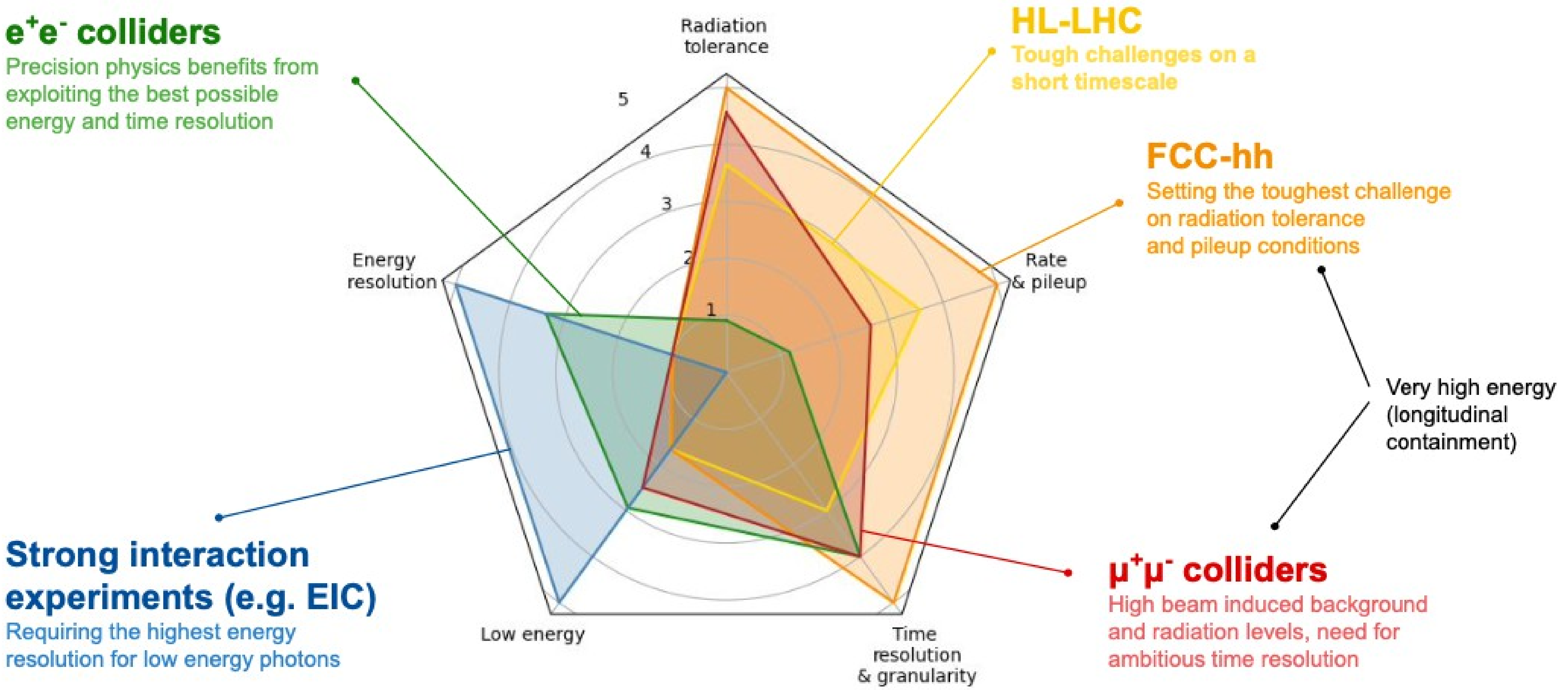
agility



Transitions Blue-sky → Strategic → Specific expected
Cross-fertilisation desired

F. Sefkow, CALICE Meeting and ECFA Higgs/top/EW Factory Meeting

Requirements for calorimetry at future colliders

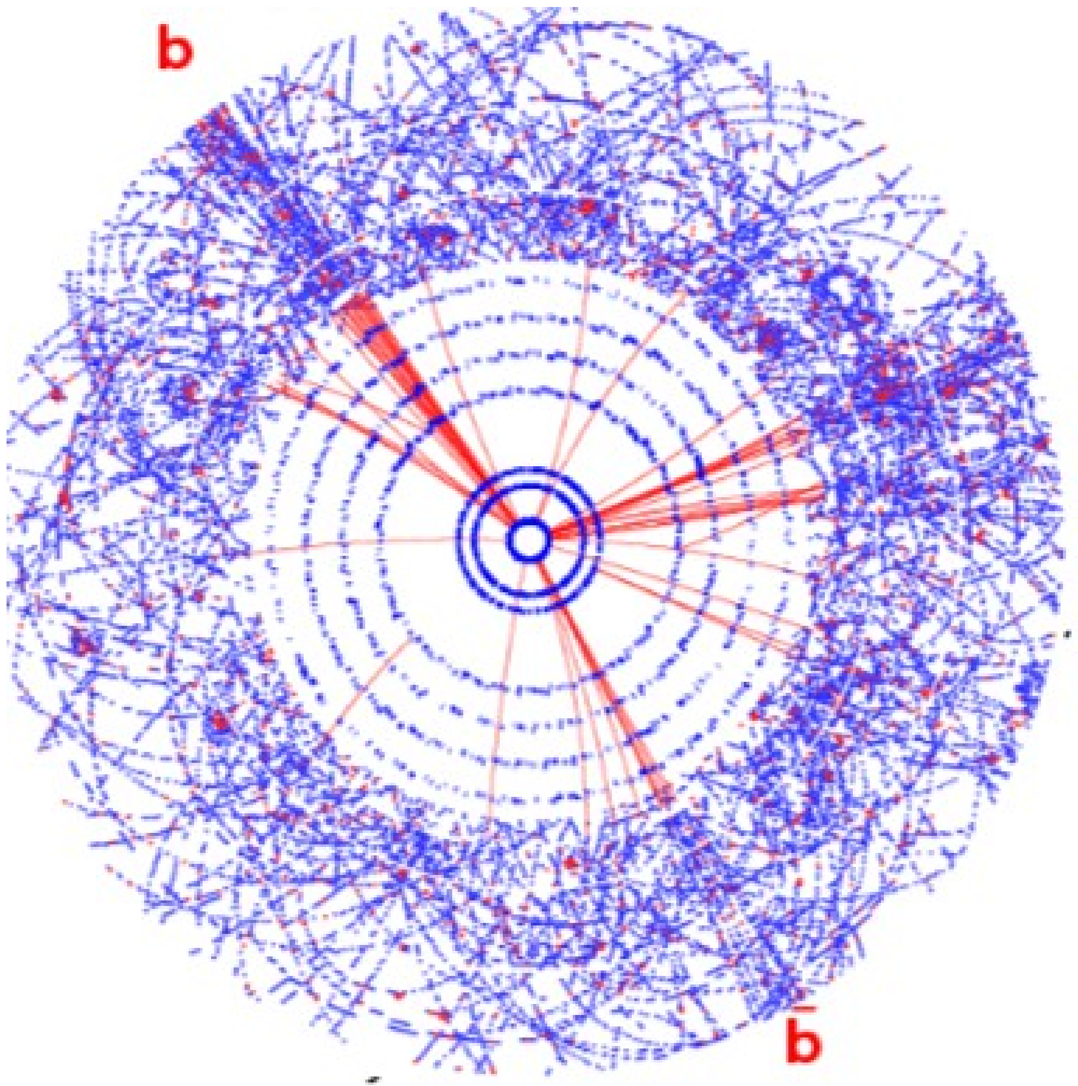


Inspired from [*https://indico.cern.ch/event/994685/*](https://indico.cern.ch/event/994685/)

M. T. Lucchini, 1st Calo Community Meeting

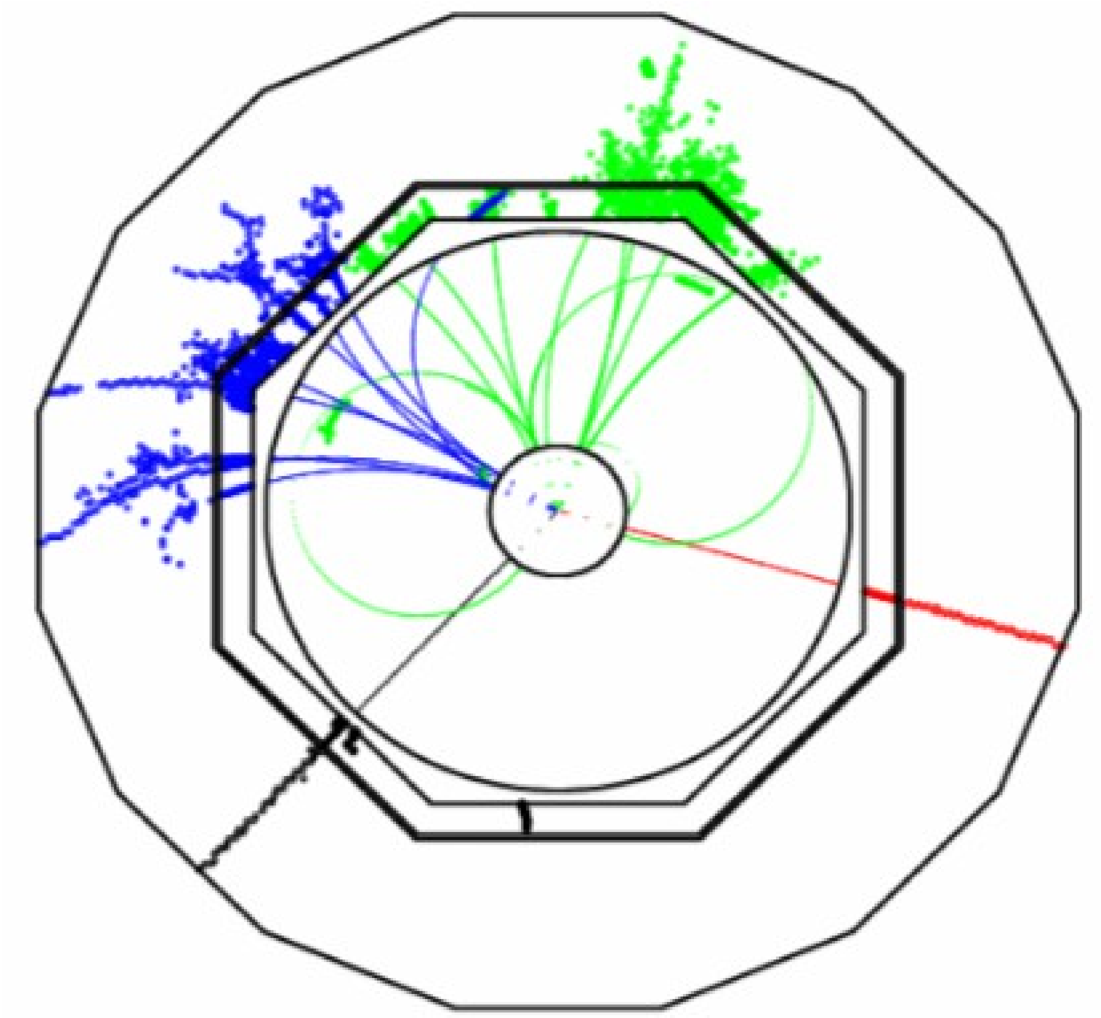
(Rough) Comparison – Hadron collisions ↔ e^+e^- collisions

Hadron-hadron collisions e.g. LHC



- Busy events
- Require hardware and software triggers
- High radiation levels

e^+e^--collisions



- Clean events
- No trigger **(??)**
- Full event reconstruction

Slide from Y. Sirois

Calorimetry = "Current Ecosystem"

- Proposals comes from pre-existing collaborations or working framework
- Consolidated modus-operandi and experience
- Need to pick up all the best and put into the DRD6 collaboration

G. Gaudio, 2nd Calo Community Meeting

DRD Calo - Proposal Team

ECFA

European Strategy Update

Coordinators: Roberto Ferrari, Gabriella Gaudio (INFN-Pavia), R.P.

Representative from Coordination Team: Felix Sefkow

Track 1: Sandwich calorimeters with fully embedded Electronics – Main and forward calorimeters
Track conveners: Adrian Irles (IFIC, adrian.irles@ific.uv.es), Frank Simon (KIT, frank.simon@kit.edu), Jim Brau (University of Oregon, jimbrau@uoregon.edu), Wataru Ootani (University of Tokyo, wataru@icepp.s.u-tokyo.ac.jp), Imad Laktineh (I2PI, imad.laktineh@in2p3.fr)

Track 2: Liquified Noble Gas Calorimeters
Track Conveners: Martin Aleksa (CERN, martin.aleksa@cern.ch), Nicolas Morange (IJCLab, nicolas.morange@ijclab.in2p3.fr), Marc-Andre Pleier (mpleier@bnl.gov)

Track 3: Optical calorimeters: Scintillating based sampling and homogenous calorimeters
Track Conveners: Etiennette Auffray (CERN, etiennette.auffray@cern.ch),
Gabriella Gaudio (INFN-Pavia, gabriella.gaudio@pv.infn.it),
Macro Lucchini (University and INFN Milano-Bicocca, marco.toliman.lucchini@cern.ch),
Philipp Roloff (CERN, philipp.roloff@cern.ch), Sarah Eno (University of Maryland, eno@umd.edu),
Hwidong Yoo (Yonsei University, hdyoo@cern.ch)

Track 4: Transversal activities.
Christophe de la Taille (OMEGA, taille@in2p3.fr), Alberto Gola (FBK, gola@fbk.it)

Remark: Tracks in early proposal phase became Work Packages + Electronics

On the DRD Calo proposal ...

DRD 6: Calorimetry

Proposal Team for DRD-on-Calorimetry

November 20, 2023

Martin Aleksa[1], Etiennette Auffray[1], David Barney[1], James Brau[2], Sarah Eno[3], Roberto Ferrari[4], Gabriella Gaudio[4], Alberto Gola[5], Adrian Irles[6], Imad Laktineh[7], Marco Lucchini[8], Nicolas Morange[9], Wataru Ootani[10], Marc-André Pleier[11], Roman Pöschl[9], Philipp Roloff[1], Felix Sefkow[12], Frank Simon[13] Tommaso Tabarelli de Fatis[8], Christophe de la Taille[14], Hwidong Yoo[15] (**Editors**)

[1]CERN, Geneva, SWITZERLAND
[2]University of Oregon, Eugene, OR USA
[3]University of Maryland, College Park, MD USA
[4]INFN, Pavia, ITALY
[5]FBK, Povo, ITALY
[6]IFIC, CSIC-University of Valencia, Valencia, SPAIN
[7]IP2I Lyon, Villeurbanne, FRANCE
[8]University and INFN Milano-Bicocca, Milano, ITALY
[9]IJCLab, Université Paris-Saclay, Orsay FRANCE
[10]University of Tokyo, Tokyo, JAPAN
[11]Brookhaven National Laboratory, Upton, NY USA
[12]Deutsches Elektronen-Synchrotron DESY, GERMANY
[13]Karlsruhe Institute of Technology, Karlsruhe, GERMANY
[14]OMEGA, Palaiseau, FRANCE
[15]Yonsei University, Seoul, SOUTH-KOREA

Contents

1 Introduction 3

2 Organisation of the DRD-on-Calorimetry 3
2.1 Scientific organisation . . . 4
2.2 Governance . . . 5
2.2.1 Executive bodies . . . 6

3 Work Package 1: Sandwich calorimeters with fully embedded electronics 6
3.1 Description . . . 6
3.2 Activities and objectives . . . 7
3.2.1 Task 1.1: Highly pixelised electromagnetic section . . . 8
3.2.2 Task 1.2: Hadronic section with optical tiles . . . 9
3.2.3 Task 1.3: Hadronic section with gaseous readout . . . 10
3.3 Short-term applications . . . 13

4 Work Package 2: Liquified Noble Gas Calorimeters 13
4.1 Description . . . 13
4.2 Objectives . . . 13

5 Work Package 3: Optical calorimeters 14
5.1 Description . . . 14
5.2 Activities and objectives . . . 15
5.2.1 Task 3.1: Homogeneous and quasi-homogeneous EM calorimeters . . . 15
5.2.2 Task 3.2: Innovative sampling EM calorimeters . . . 16
5.2.3 Task 3.3: Hadronic sampling calorimeters . . . 17
5.2.4 Task 3.4: Materials . . . 17
5.3 Milestones and deliverables . . . 18
5.4 Short-term applications . . . 19

6 Work Package 4: Electronics and readout 19
6.1 Description . . . 19
6.2 Objectives . . . 19

7 Resources 21

8 Working Groups 21
8.1 Photodetectors . . . 21
8.2 Testbeam plans, facilities and infrastructure . . . 24
8.2.1 Thoughts on facilities and infrastructures . . . 25
8.3 Detector physics, simulations, algorithms and software tools . . . 26
8.3.1 Data models and data management . . . 26
8.3.2 DAQ software . . . 26
8.3.3 Simulation . . . 26
8.3.4 Particle flow algorithms . . . 27
8.3.5 Machine learning approach . . . 27
8.4 Industrial connection and technological transfer . . . 27
8.5 Mechanics and Integration . . . 27

9 Interconnections with other DRDs 27

10 Conclusion 28

A Institute list 28

B Contact persons to other DRDs 32

- **Final proposal submiited one week ago !!!!**
- 34 pages
- Based on world wide community input

- Short description of goals, projects and organisation
  - Organisational chart, see below
  - Example for table from Work Package 3 with short description

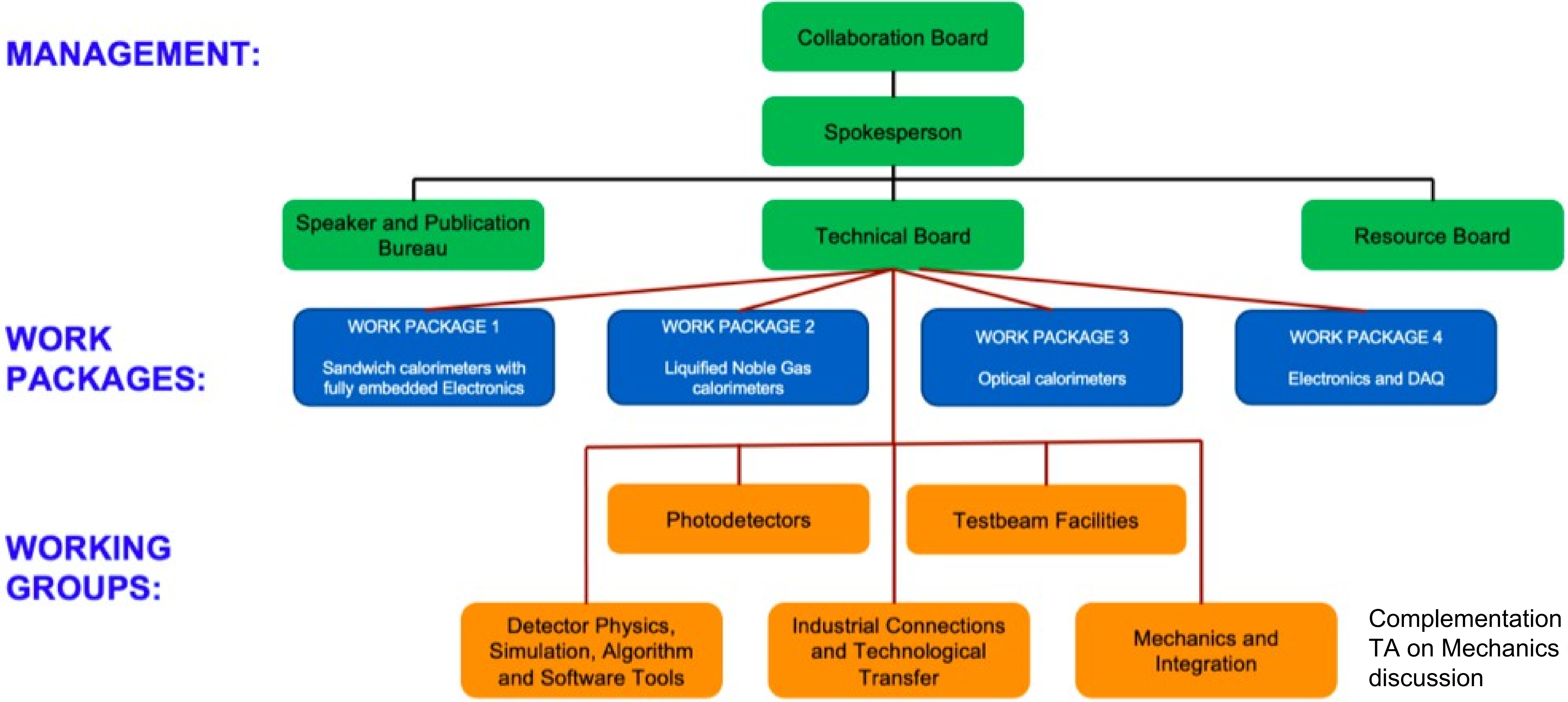
Table 2: Overview of R&D activities on optical calorimeter concepts.

Name	Calorimeter type	Application	Scintillator/WLS	Photodetector
HGCCAL	EM / Homogeneous	e^+e^- collider	BGO, LYSO	SiPMs
MAXICC	EM / Homogeneous	e^+e^- collider	PWO, BGO, BSO	SiPMs
CRILIN	EM / Quasi-Homog.	$\mu^+\mu^-$ collider	PbF_2, PWO-UF	SiPMs
GRAINITA	EM / Quasi-Homog.	e^+e^- collider	$ZnWO_4$, BGO	SiPMs
SPACAL	EM / Sampling	e^+e^-/hh collider	GAGG, organic	MCD-PMTs, SiPMs
RADICAL	EM / Sampling	hh collider	LYSO, LuAG	SiPMs
DRCAL	EM+HAD / Sampling	e^+e^- collider	PMMA, plastic	SiPMs, MCP
TILECAL	HAD / Sampling	e^+e^-/hh collider	PEN, PET	SiPMs

- Discussion in DRDC Meeting on December 4th

- Approval of DRD Calo by CERN Research Board on Dec. 6th

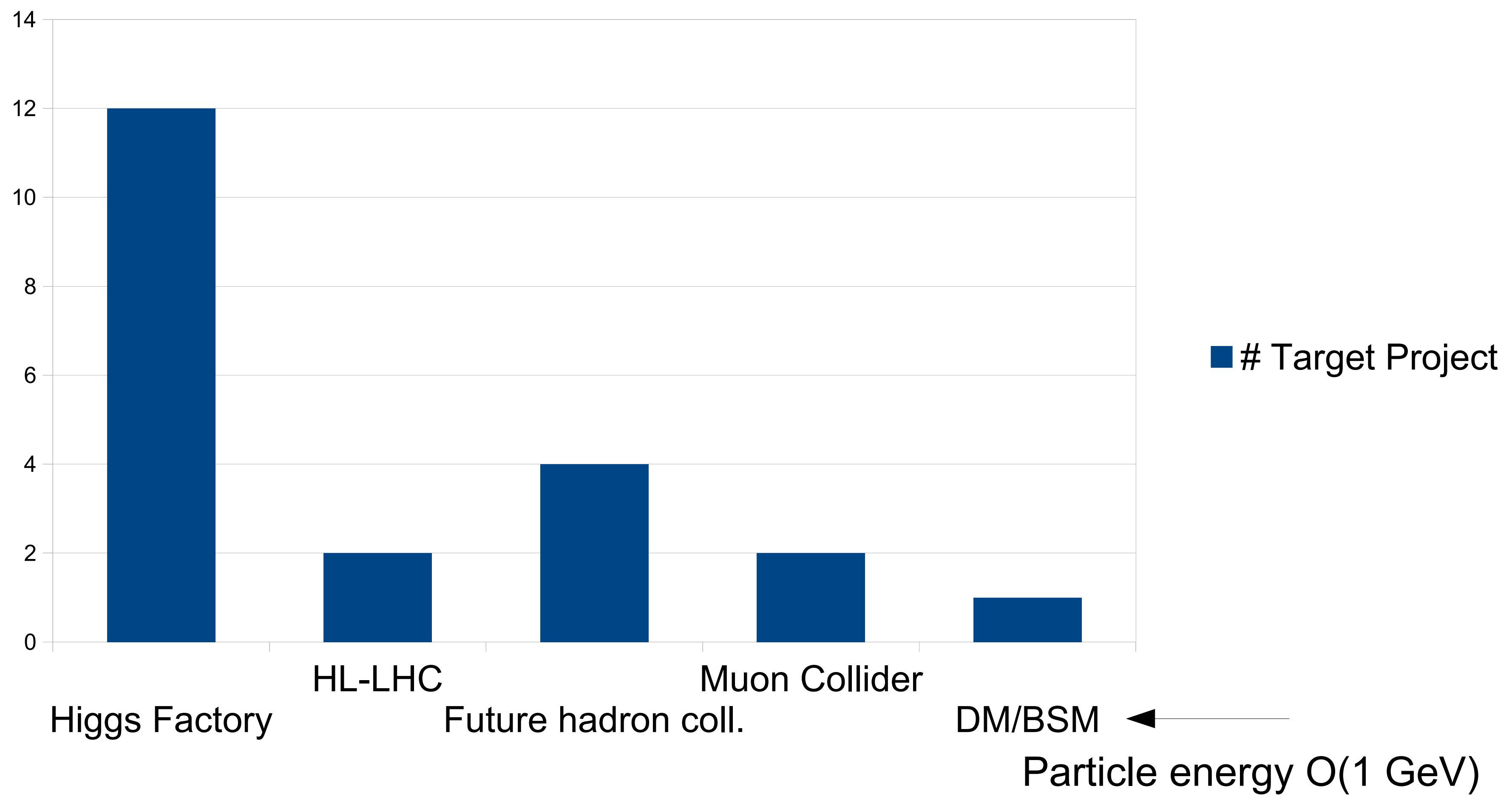
DRD Calo – Basic structure



Complementation with TA on Mechanics under discussion

Drawing: G. Gaudi

DRD Calo - Input proposals and target projects

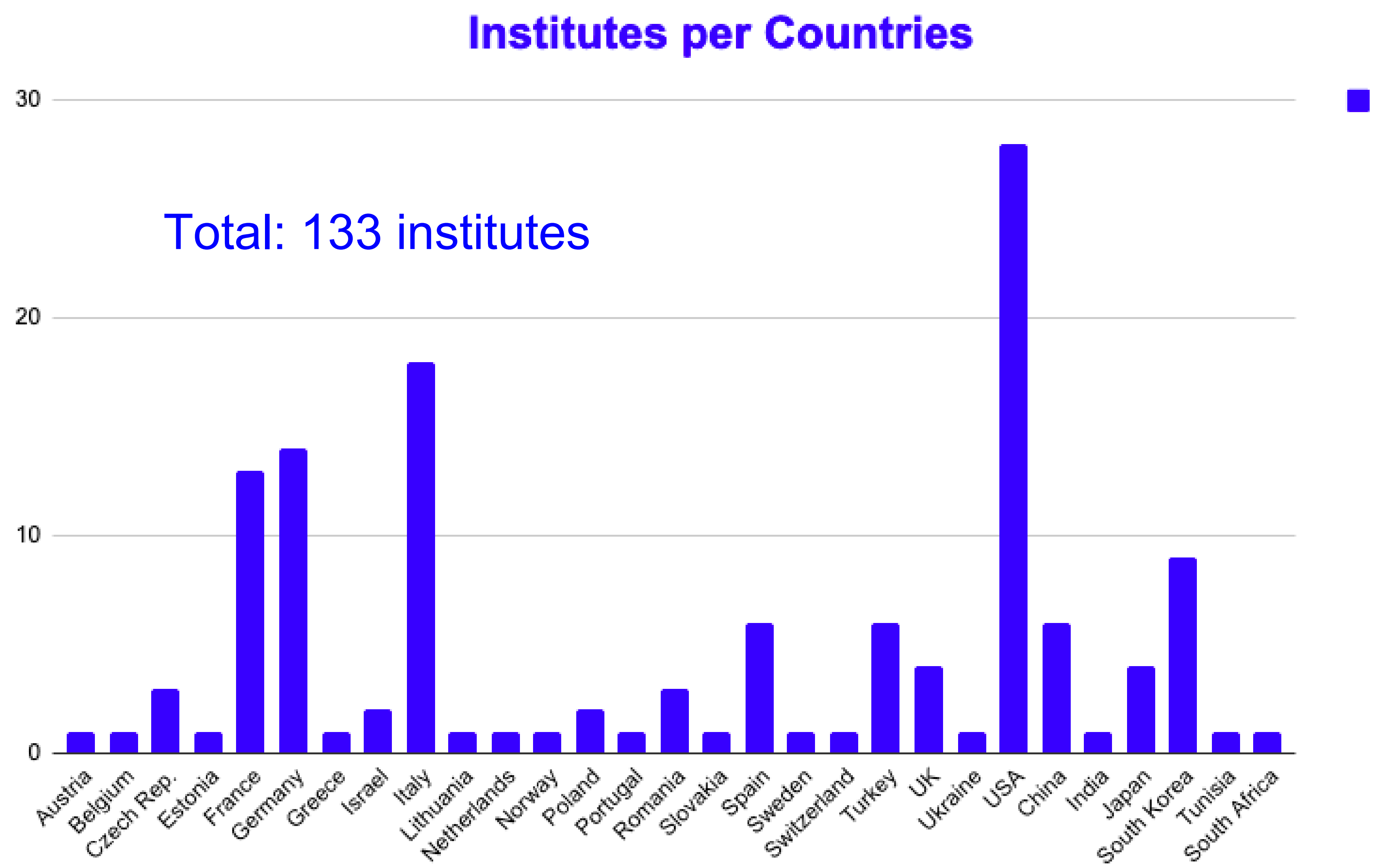


- Higgs factories dominate
  - HF includes heavy flavor that target superb elm. energy resolutions
- (Already now) orientation towards future hadron collider and muon collider

ECFA

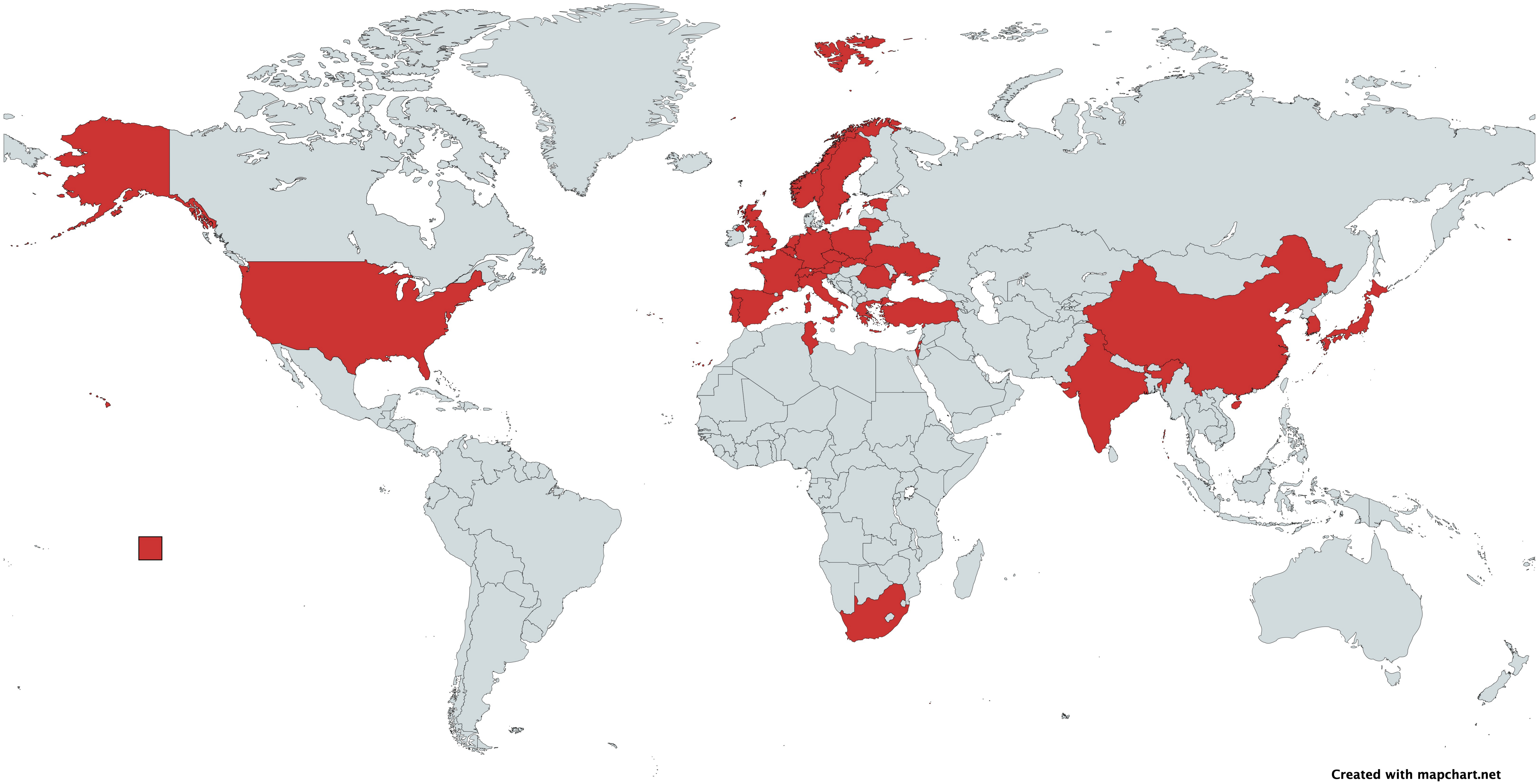
DRD Calo – Overall Interest

European Strategy Update

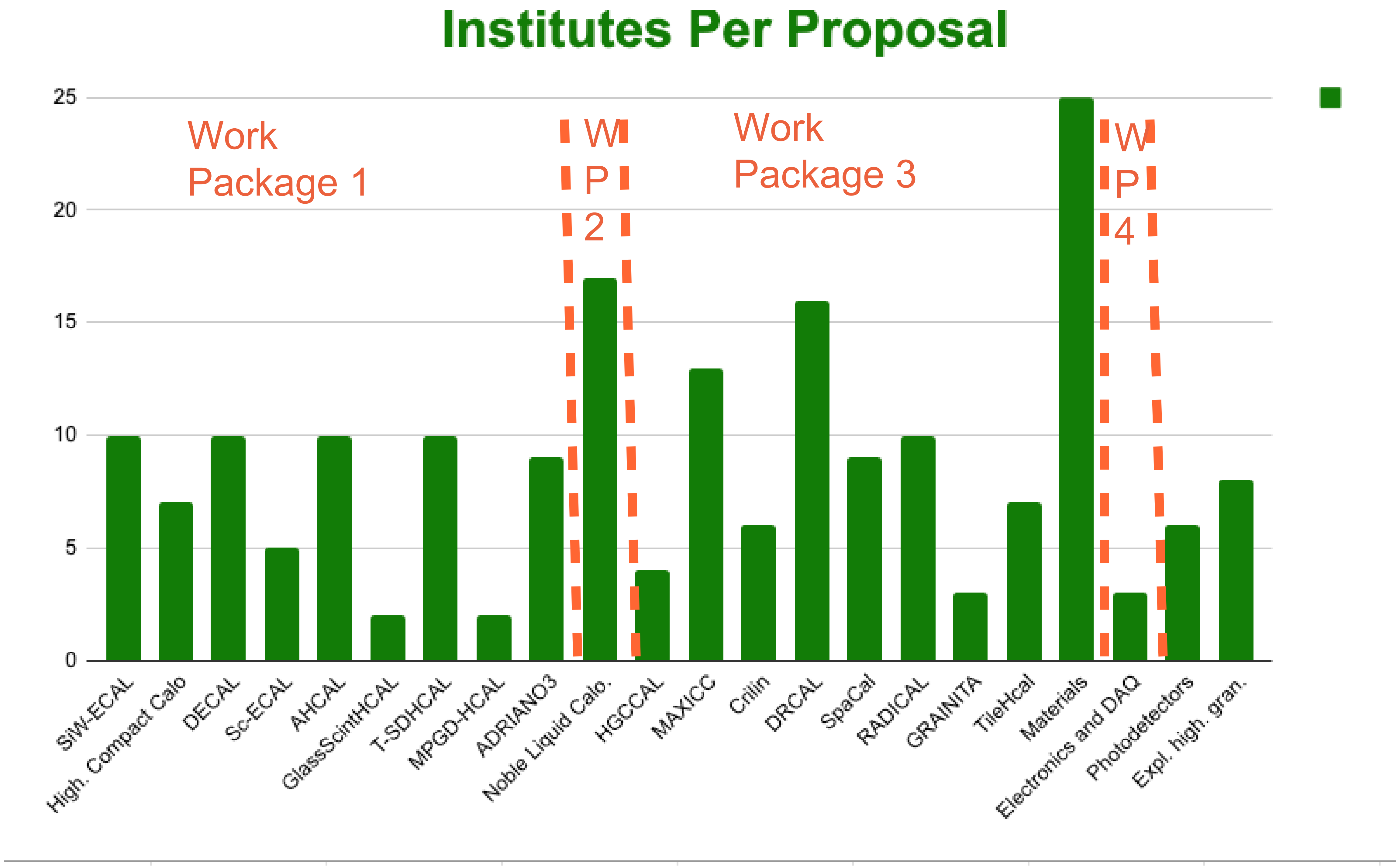


- Mainly European Groups but interest from all over the world (37%)
  - US biggest single participation -> close contact to emerging effort in US
  - Very visible Asian participation

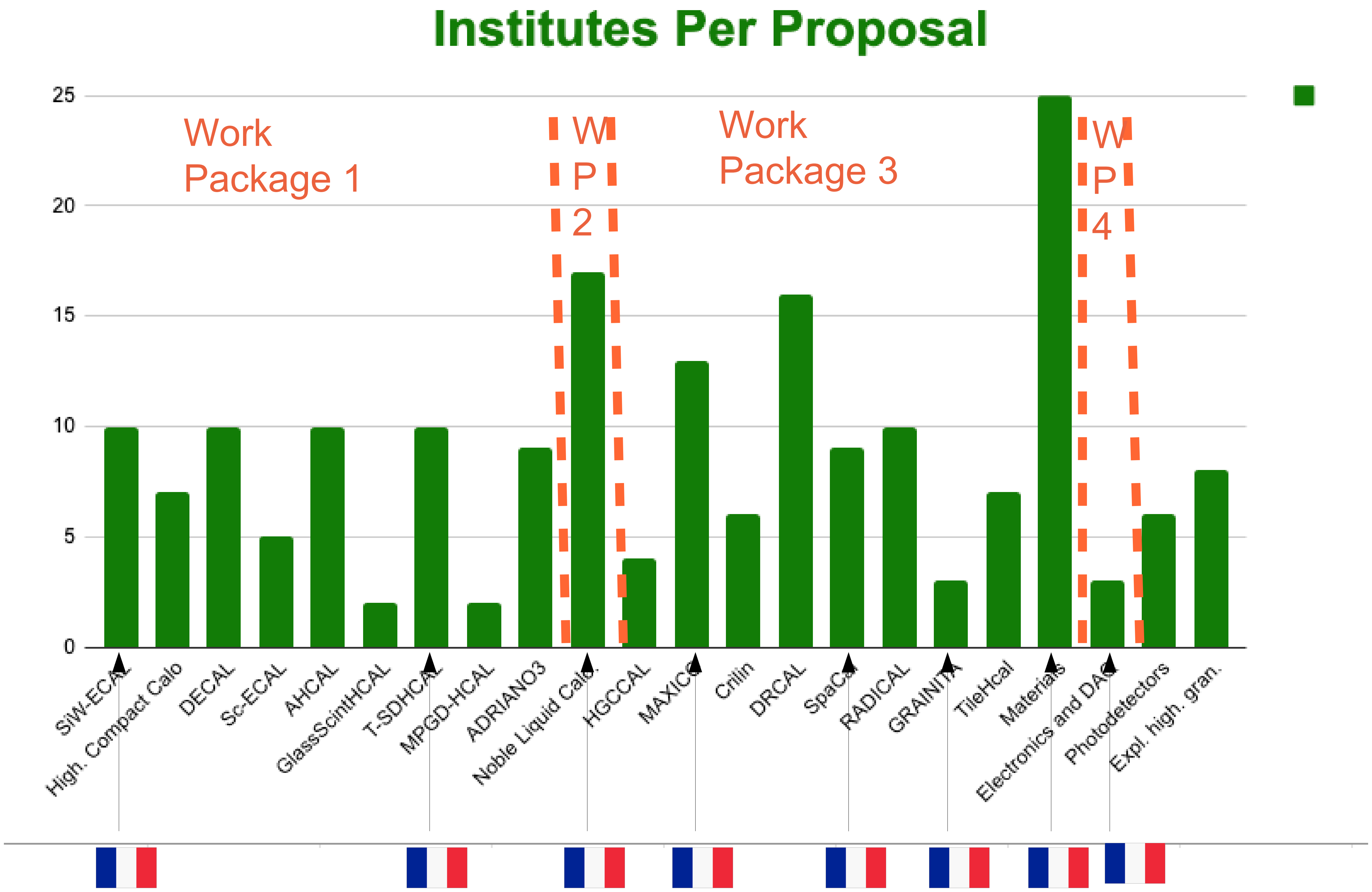
DRD Calo – Where?



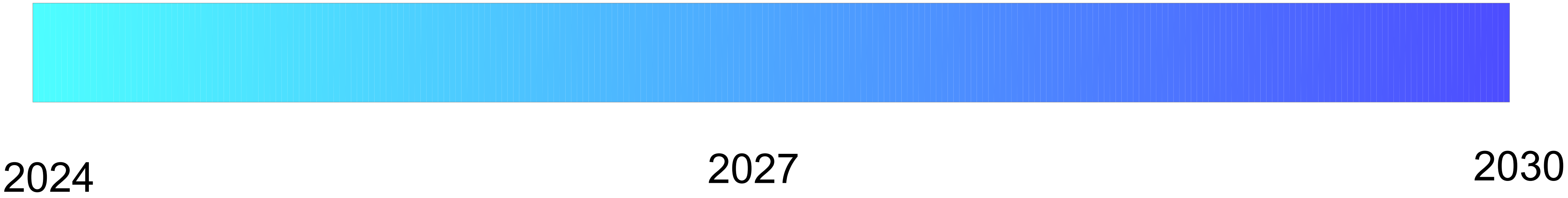
DRD Calo – Basic structure



DRD Calo – Basic structure



Ramp up of activities – Rough View

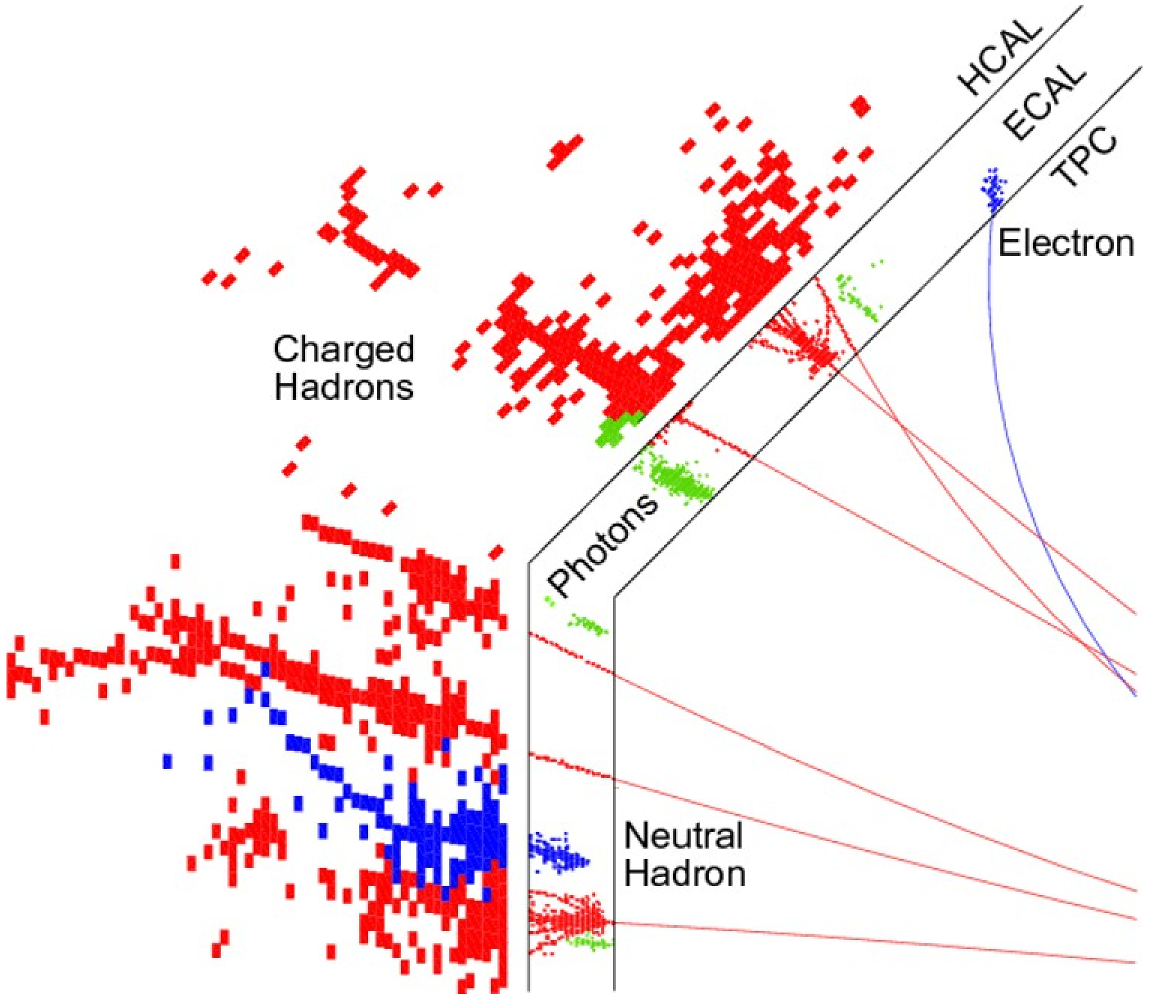


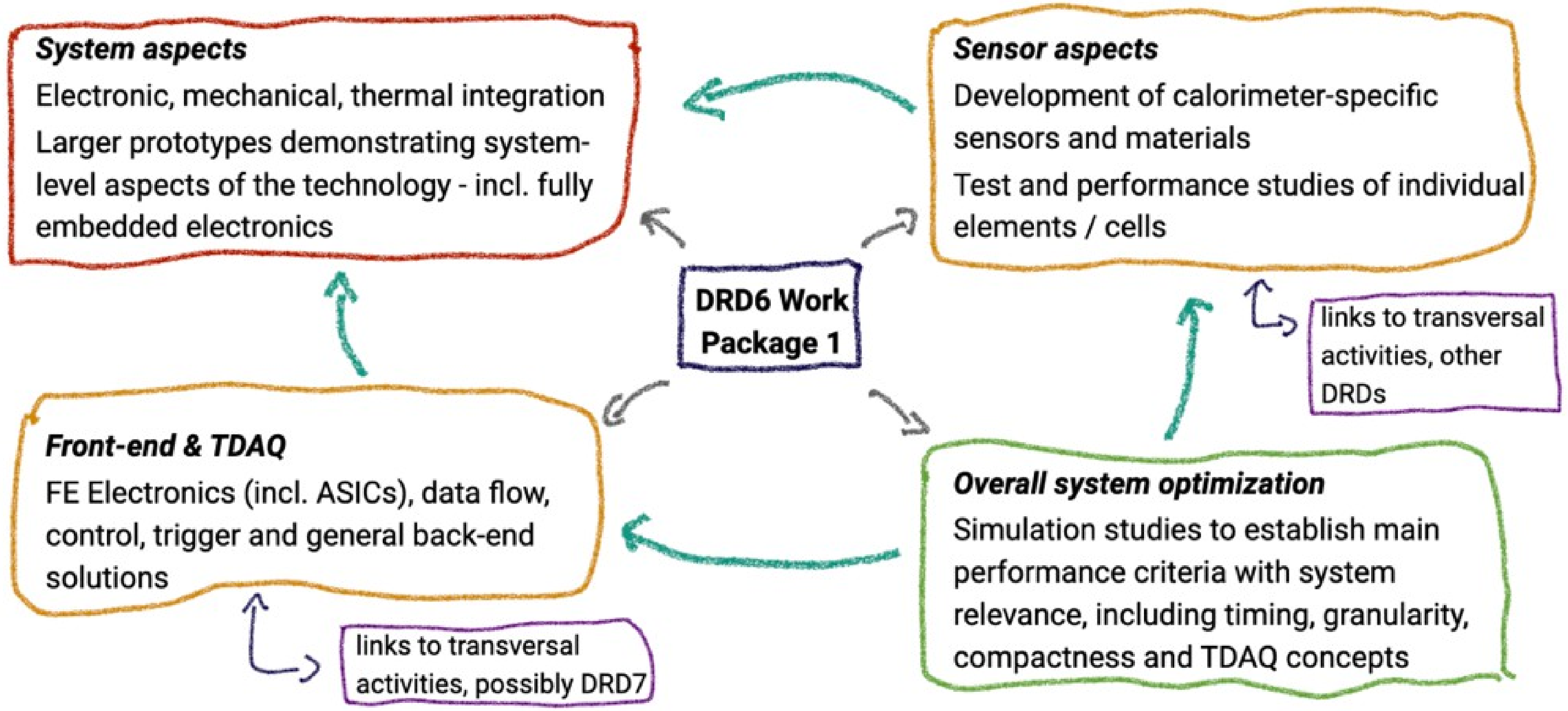
- Input-proposals reveal little (extra) need at the beginning (2024-2026)
  - Start with prototypes that are either existing or currently under construction
  - (Mainly) benefitting from existing funding at national level of international level (i.e. AIDAinnova, EUROLABS in Europe or CalVision, RADICAL in the US [plus maybe others])
  - Specification studies, concept proof – Would require fresh funding

- Relatively high density of beam tests with new (large scale) prototypes after 2026
  - Several large scale prototypes demonstrate ambition of R&D programme

- Execution of program requires <u>availability and support</u> of beam test facilities
  - See also later

Work Package 1 – Imaging calorimeters





Imaging calorimeters live on the high separation power for Particle Flow

- Challenges:
  - High pixelisation, 4pi hermetic -> little room for services
    - Detector integration plays a crucial role
- New strategic R&D issues
  - Detector module integration
  - Timing
  - High rate e+e- collider (such as FCCee)

Work Package 2 – Liquid Noble Gas Calorimeters

- Develop the calo design
  - Study design solutions for endcaps
  - Study general performance in simulation, in combination with some HCAL concept
  - Optimize granularity
- Build a first prototype and measure performance in testbeam
  - Need to design and optimize electrodes, absorbers
  - Readout electronics
  - Can then be refined to test further developments / new ideas

4 Work Areas

1. General design and expected performance
2. Readout electrodes
3. Readout electronics
4. Mechanical studies and prototype

Work Package 3 - Optical calorimeters

- More than e.g. Imaging calorimeters optical calorimeters put emphasis on the electromagnetic energy resolution
  - (Liquid Noble) interpolates a bit between these two cases
- Elm. resolutions down to 1-2%/√E are envisaged
  - Advantageous for Higgs Factory, indispensable for Heavy Flavour

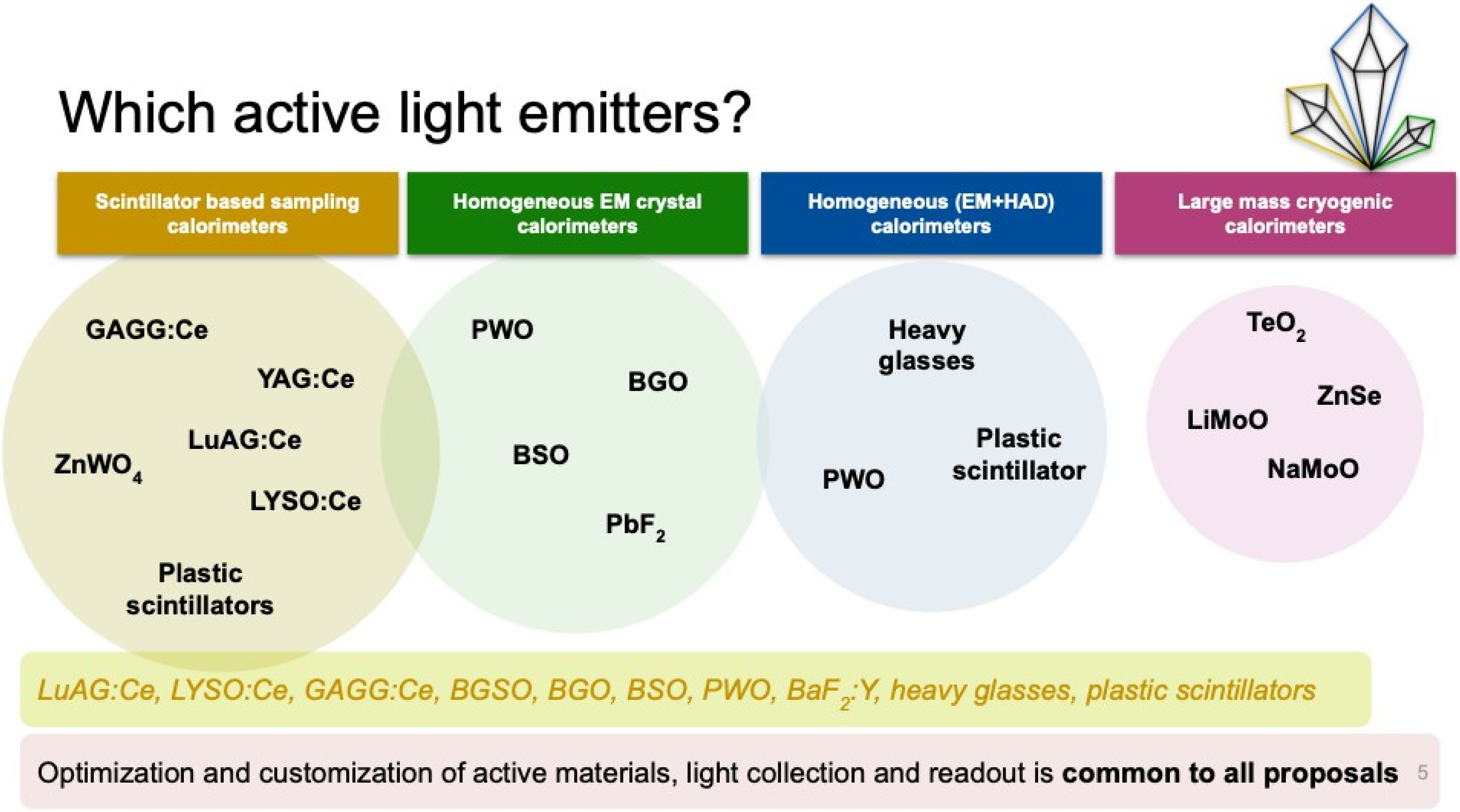
Table 2: Overview of R&D activities on optical calorimeter concepts.

Name	Calorimeter type	Application	Scintillator/WLS	Photodetector
HGCCAL	EM / Homogeneous	e^+e^- collider	BGO, LYSO	SiPMs
MAXICC	EM / Homogeneous	e^+e^- collider	PWO, BGO, BSO	SiPMs
CRILIN	EM / Quasi-Homog.	$\mu^+\mu^-$ collider	PbF_2, PWO-UF	SiPMs
GRAINITA	EM / Quasi-Homog.	e^+e^- collider	$ZnWO_4$, BGO	SiPMs
SPACAL	EM / Sampling	e^+e^-/hh collider	GAGG, organic	MCD-PMTs, SiPMs
RADICAL	EM / Sampling	hh collider	LYSO, LuAG	SiPMs
DRCAL	EM+HAD / Sampling	e^+e^- collider	PMMA, plastic	SiPMs, MCP
TILECAL	HAD / Sampling	e^+e^-/hh collider	PEN, PET	SiPMs

- Main challenges
  - Find the good optical material
  - Find the adequate photosensor
  - Move from table top to system
    - First project to fully make this step is SpaCal (LHCb)

Materials for optical calorimeters

P. Roloff, M. Lucchini
2nd Calo Community Meeting



- R&D will have to break down the plethora of materials to few on which the R&D will focus on
- Definition of criteria needed!

DRD Calo - The “readout landscape”

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

Trends:

- On-detector embedded elx.
  - Challenges: #channels, Low power digital noise, data reduction
- Off-detector electronics: Fibre/crystal readout
  - Challenges:
  - Low power, data reduction
- Digital calorimetry:
  - Challenges:
  - (extreme) #channels, low power, data reduction

Different calorimeter types but similar challenges

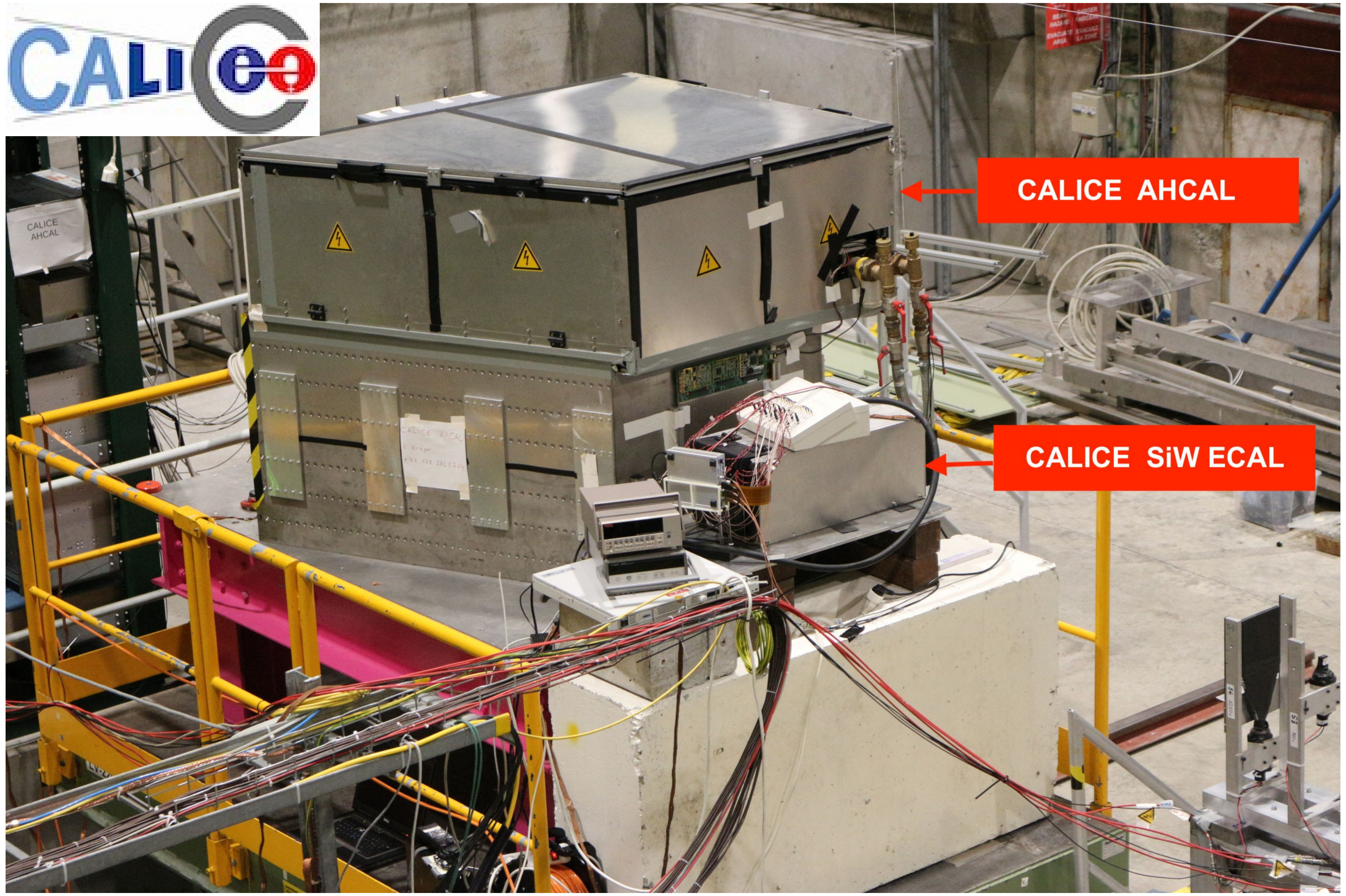
Work Package 4 – Electronics and DAQ

- The main goal will be to avoid parallel developments
  - Take CALICE as example
- ASICs needed for prototypes > 2025/26 should be produced in a common MPW run that serve many projects within DRD Calo
  - ASICs for prototype that should take data in ~2027 have to be available latest around one year earlier
- => Common ASICs production will be one overarching goal of the 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 DRD
- Requires close communication with DRD 3 and DRD 7

Quick Summary

- WP1: 16 Milestones and 16 Deliverables
- WP2: 2 Milestones and 1 Deliverable
- WP3: 21 Milestones and 17 Deliverables
- WP4: 1 Milestone and 1 Deliverable

Dedicated Calorimeter Beamline?



Common setup at CERN June 2022

- Calorimeters are typically large objects
  - A beam test is similar to a small experiment
- Difficult for facility managers to schedule calorimeter beam tests
  - No concurring running with other devices possible
- Takes lots of expertise to carry out a successful beam test campaign
  - Implies use of infrastructure
- A dedicated beam line maybe with dedicated slots during a year may help curing these issues
  - Would need sustained expertise on the beamline
- R&D programme has to cope with facility schedules
  - e.g. CERN-SPS essentially closed 2026-2028

Further activities and resources

- Photodetectors
  - Many optical systems need in particular novel SiPM --> Overlap with DRD 4

- Data analysis
  - Calorimeter data have a high scientific value beyond the actual hardware tests
    - GEANT4 comparison including the inclusion into the geant4-val suite
    - Playground for algorithms (there was a dedicated input proposal on that)
  - The full exploitation of data requires the development of data models and the availability of CPU and storage resources

- Human and financial resources are needed to ensure the service tasks

DRD Calo – Next Steps

- 17th Nov. 2023 – Submission of DRD Calo proposal

- Now - Winter 2023/24

  - Consolidation of organisation
    - Formation of a proto-collaboration board
    - Management structure
    - Formulation of governance rules
- Organisation will benefit from experience by existing R&D Collaborations

- 1st January 2024 – DRD on Calorimetry in place
  - Kick-off Meeting Spring 2024

Conclusions

- DRD on Calorimetry will pursue strategic R&D for calorimeters for future colliders
  - Partially new efforts, partially capitalizing on existing activities

- Programme will cover wide area of calorimeters that are suited to meet the DRDT
  - Programme compiled based on Community consultation
  - A worldwide effort with pure European, European/non-European, pure non-European projects

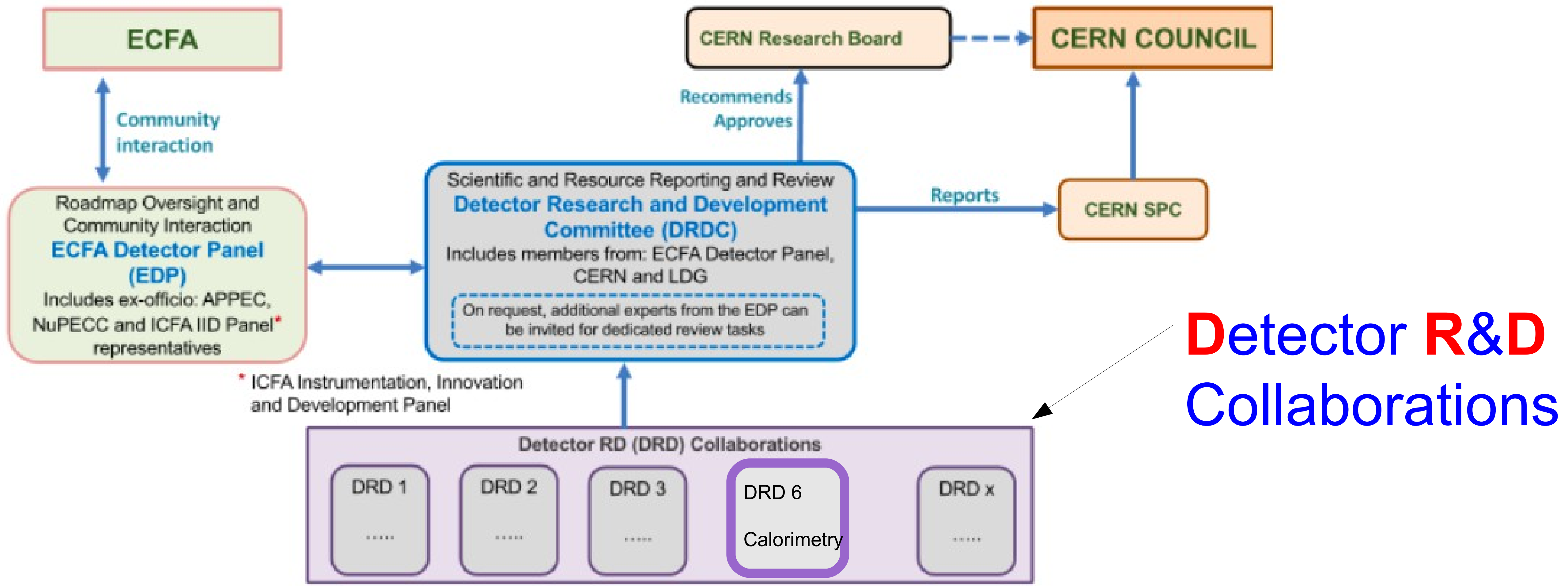
- Separation in four work packages and several working groups
  - Transversal activities ensure synergies within DRD Calo and with other DRDs
  - Strong links to other DRDs

- **Goal is to have the DRD Calo in place on January 1st 2024**

- Discussion to (concretely) set up the DRD are making progress in proposal team
  - Soon formation of proto-Collaboration Board.
  - Scheduling of first collaboration meeting imminent

Backup

Future Organisation of Detector R&D (in Europe)



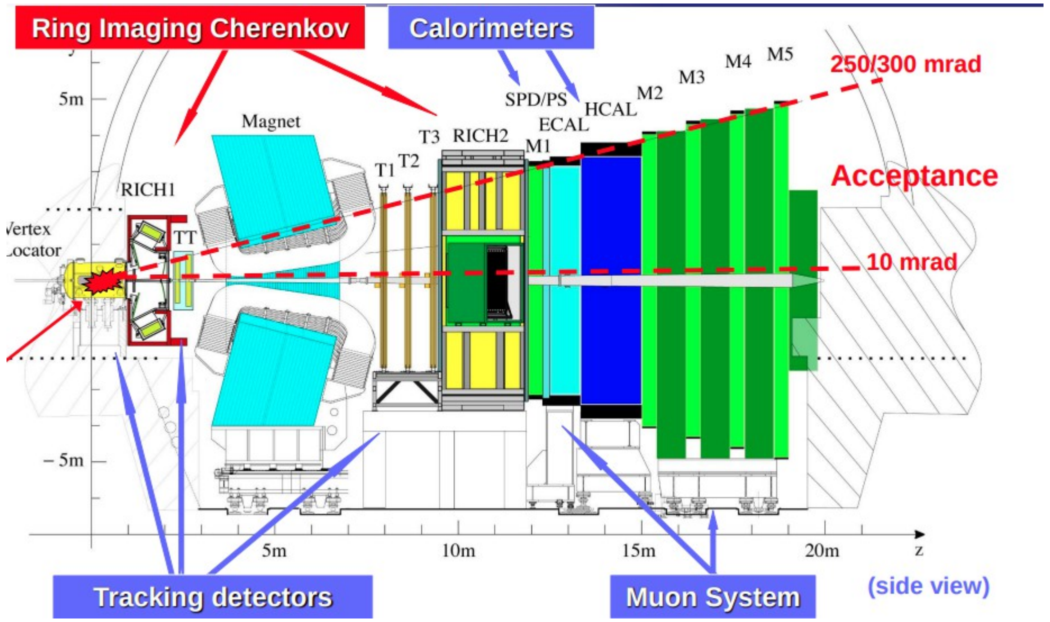
- Current model: DRD will be hosted by CERN and therefore become legally CERN collaborations
  - Significant participations by non-European groups is explicitly welcome and needed
  - World wide collaborations!
- The progress and the R&D will be overseen by a DRDC that is assisted by ECFA
  - https://committees.web.cern.ch/drdc
  - Thomas Bergauer of ÖAW/Austria appointed as DRDC-Chair
- The funding will come from national resources (plus eventually supranational projects)

ECFA

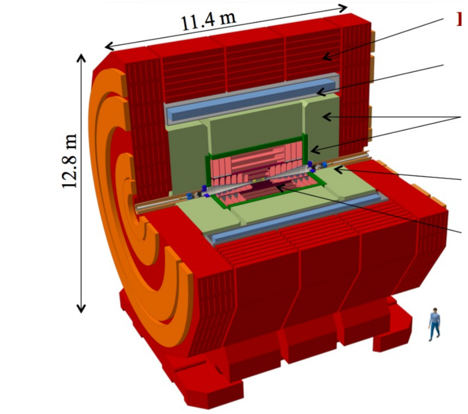
(Main) Target Projects of Detector R&D

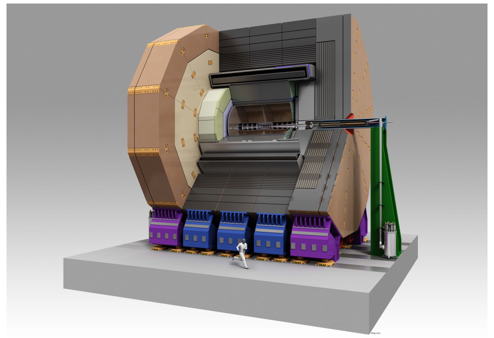
European Strategy Update

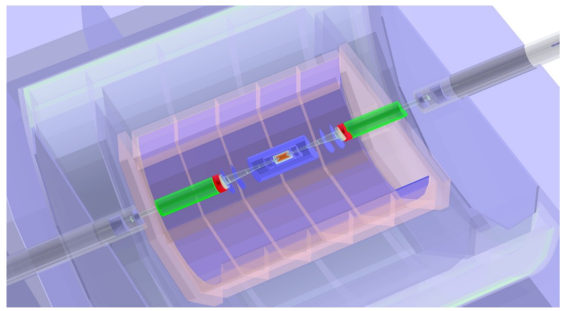
HL-LHC after LS4

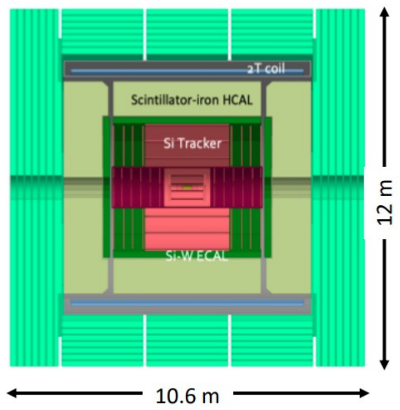


Higgs Factories

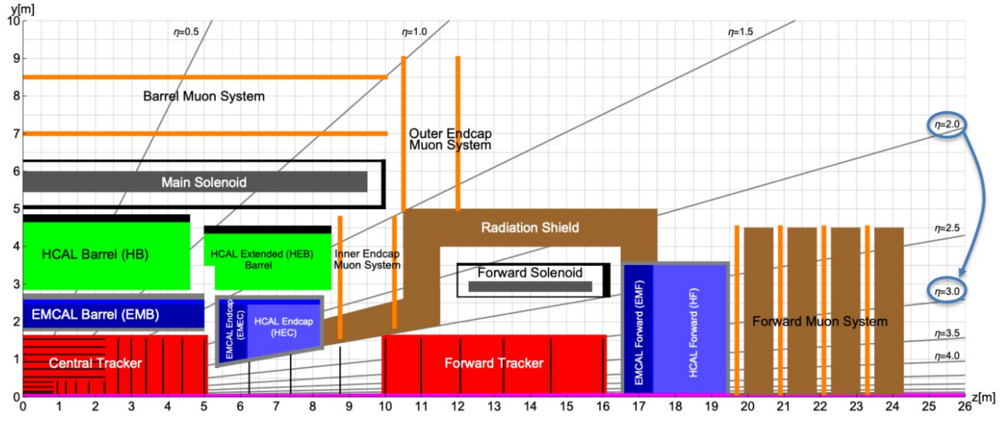




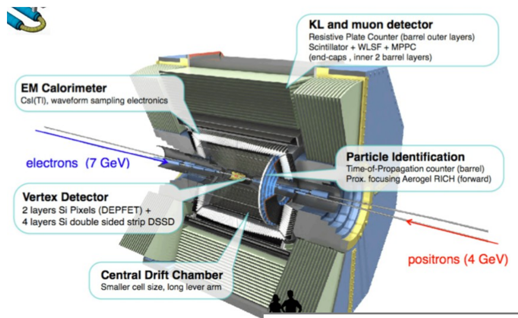


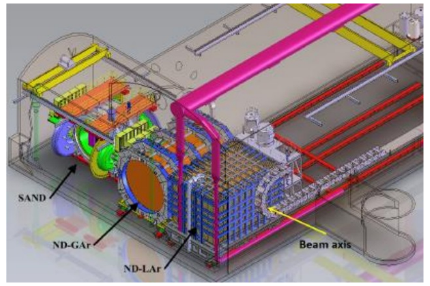


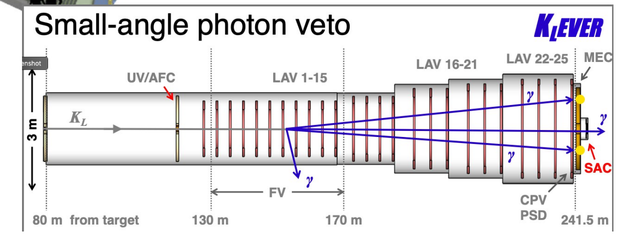
Future hadron colliders (including eh colliders)



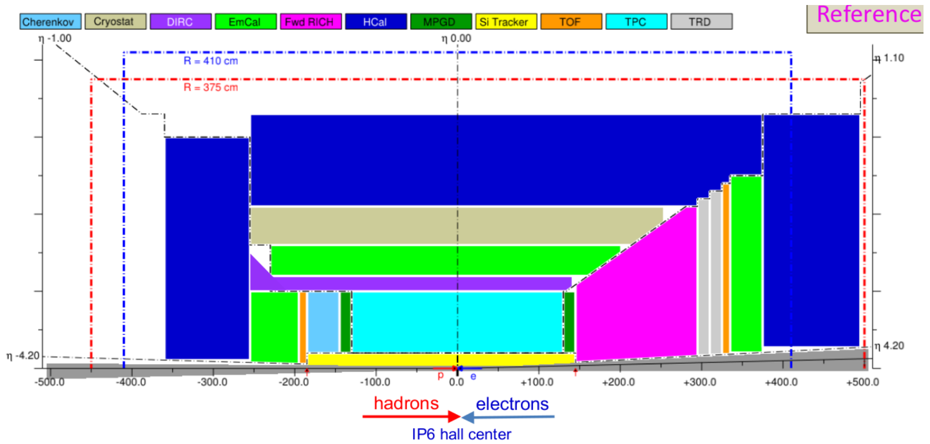
SuperKEKB, DUNE ND and Fixed Target



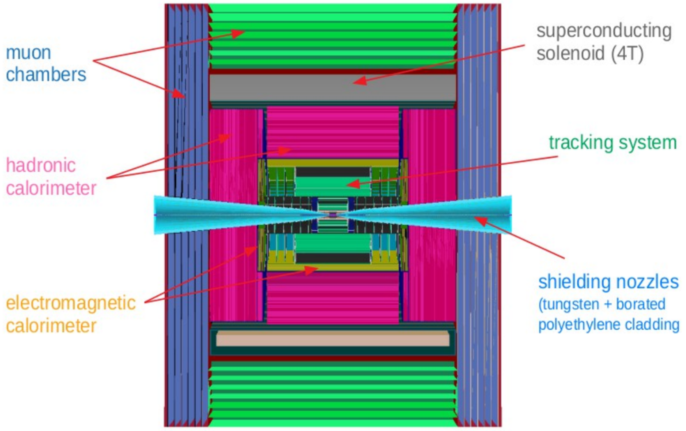




EiC



Muon Collider



ECFA

The roadmap document(s)

European Strategy Update

- ECFA R&D Roadmap
  - CERN-ESU-017 https://cds.cern.ch/record/2784893
  - 248 pages full text and 8 page synopsis

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

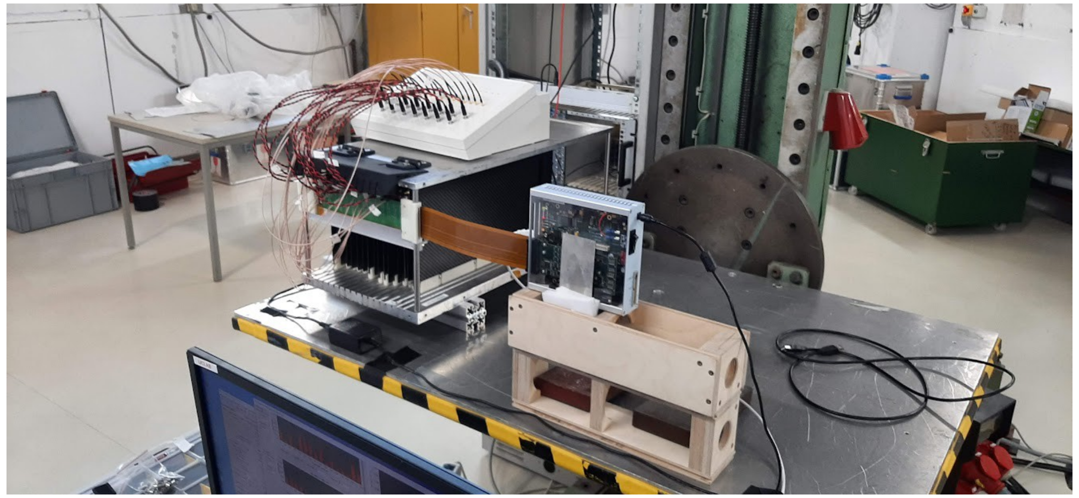
The Roadmap has identified
  - General Strategic Recommendations (GSR)
  - Detector R&D Themes (DRDT) for each of the taskforce topics
  - Concrete R&D Tasks

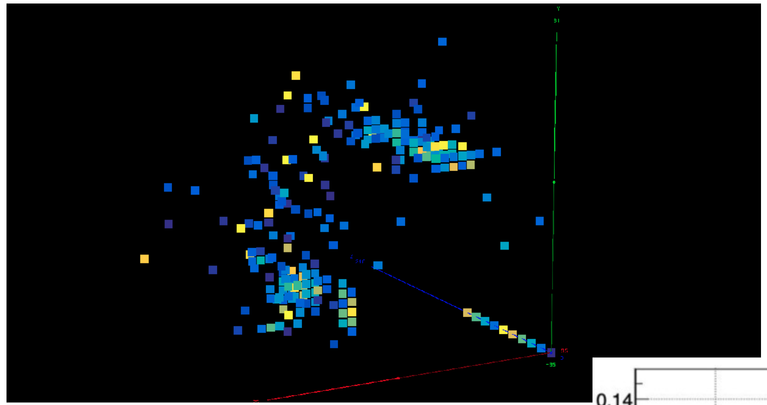
- Timescale of projects as approved by European Lab Director Group (LDG)

Guiding principle: Project realisation must not be delayed by detectors

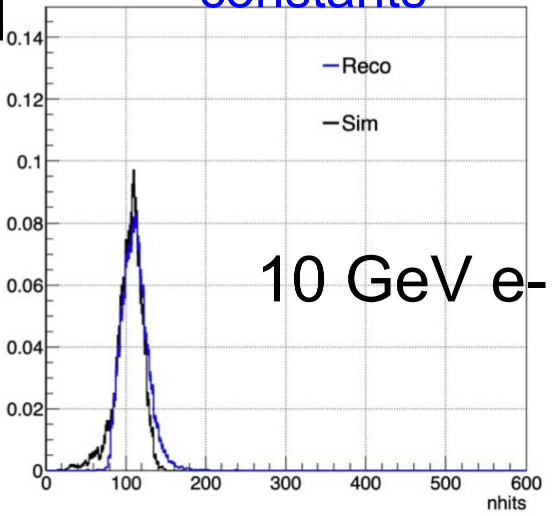
Imaging calorimeters – Testbeams 2022/23

Silicon tungsten (SiW) Ecal





- 15 layers
- 15000 cells 5x 5mm^2
- **Analogue** r/o
- 450000 calib constants

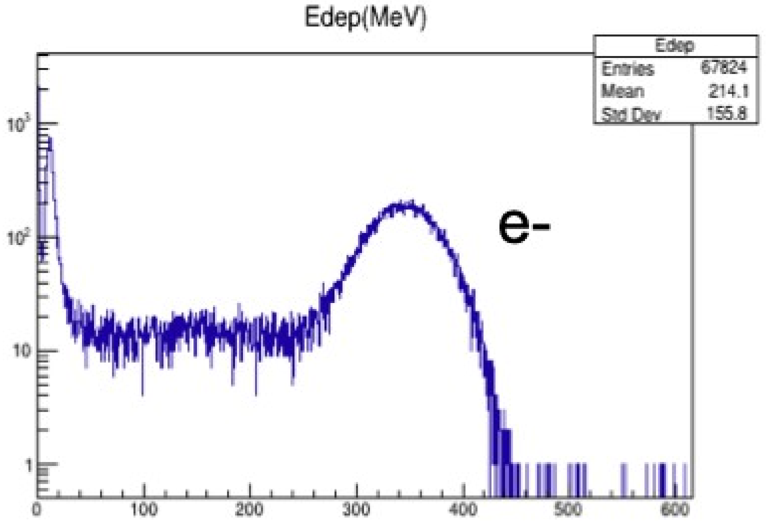


Getting control

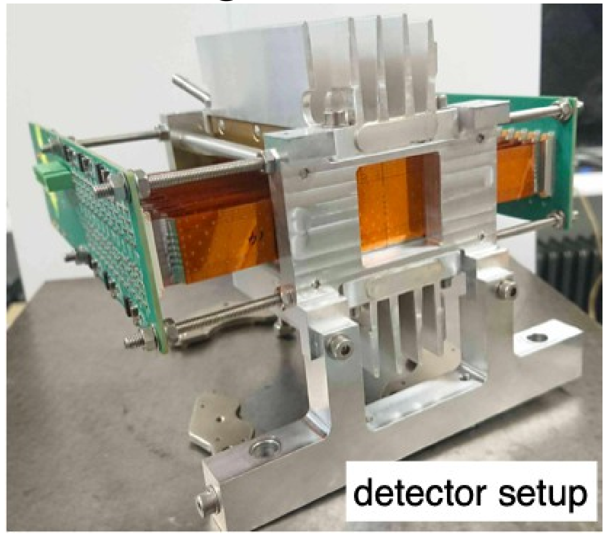
Scintillator Tungsten ScEcal

- 16 layers
- 7000 strips 5x45 mm^2
- Analogue r/o

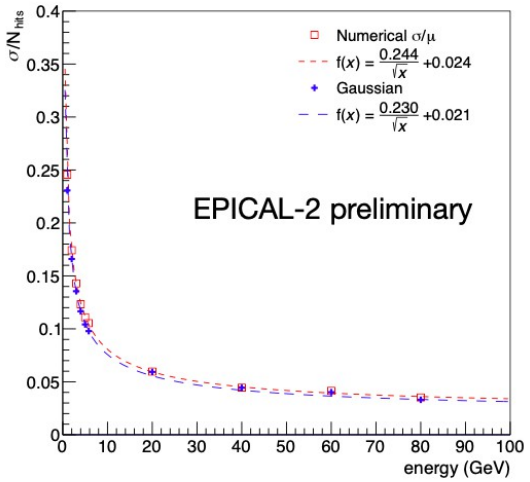
10 GeV/c



Digital ECAL



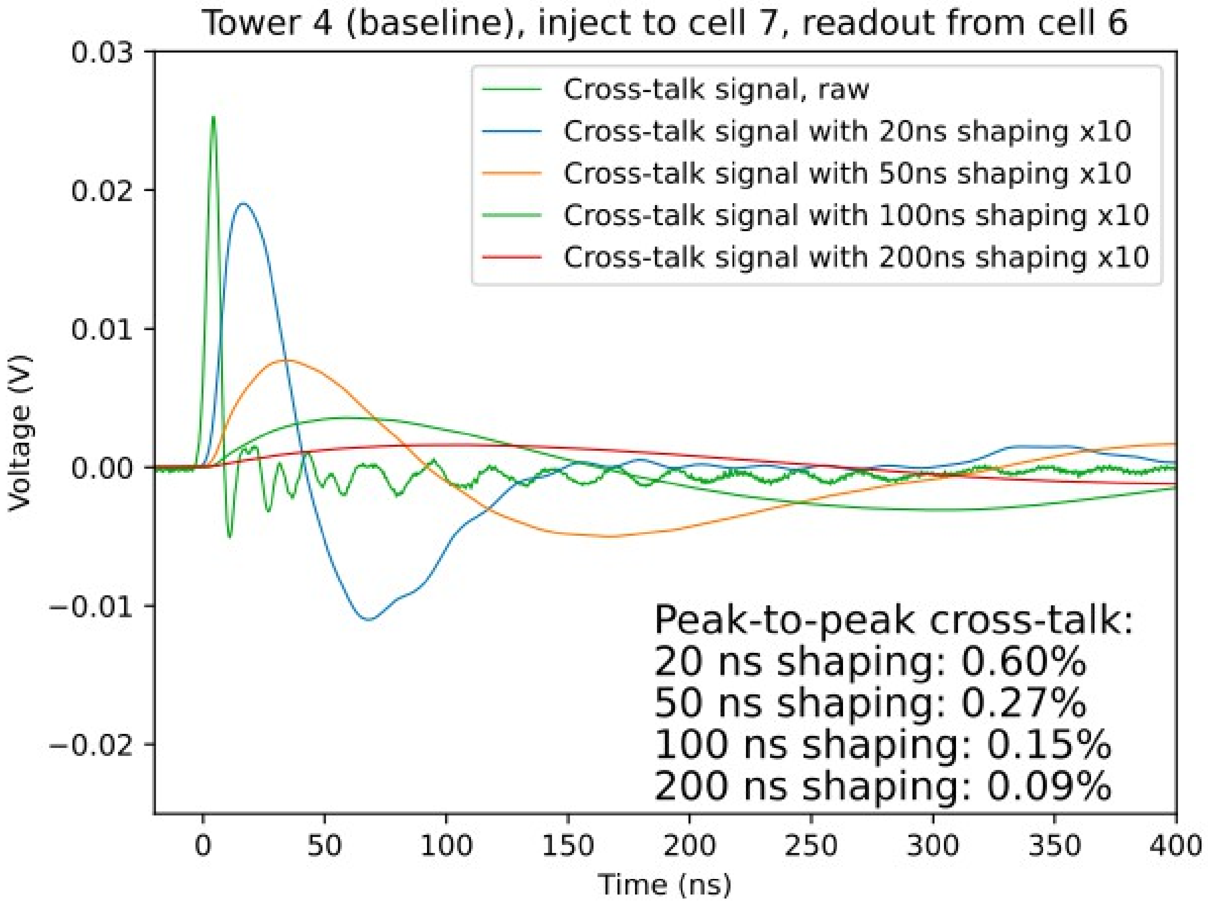
- 24 layers with each
  - •3mm tungsten absorber
  - •2 Alpide CMOS Sensors (NIM A 845:583-587, 2017)
  - •Ultra thin flex cables
- 29.24x26.88 μm2 pixel size
  - •Active surface 3x3 cm2



R&D for Liquid Noble Gas Calorimeters

Highly segmented -> highly dense PCB

"Greatest enemy": Cross talk



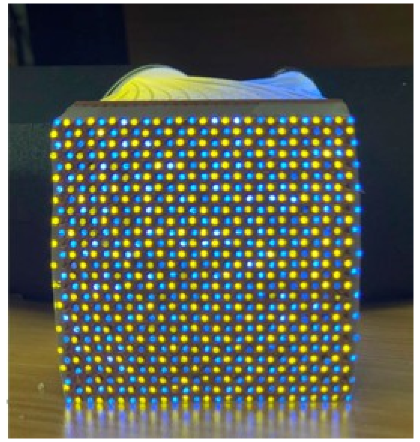
Long shaping time helps

N. Morange, 2nd Calo Community Meeting

Dual readout calorimetry – Building Blocks

Fast signals

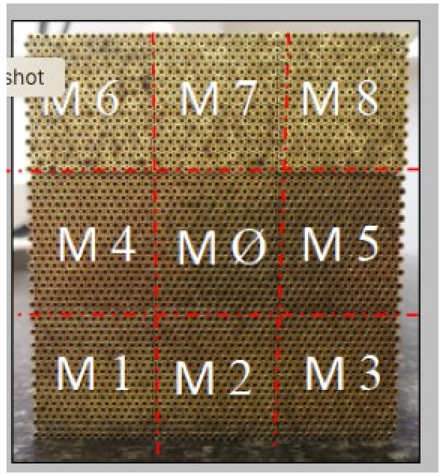
Slow signals



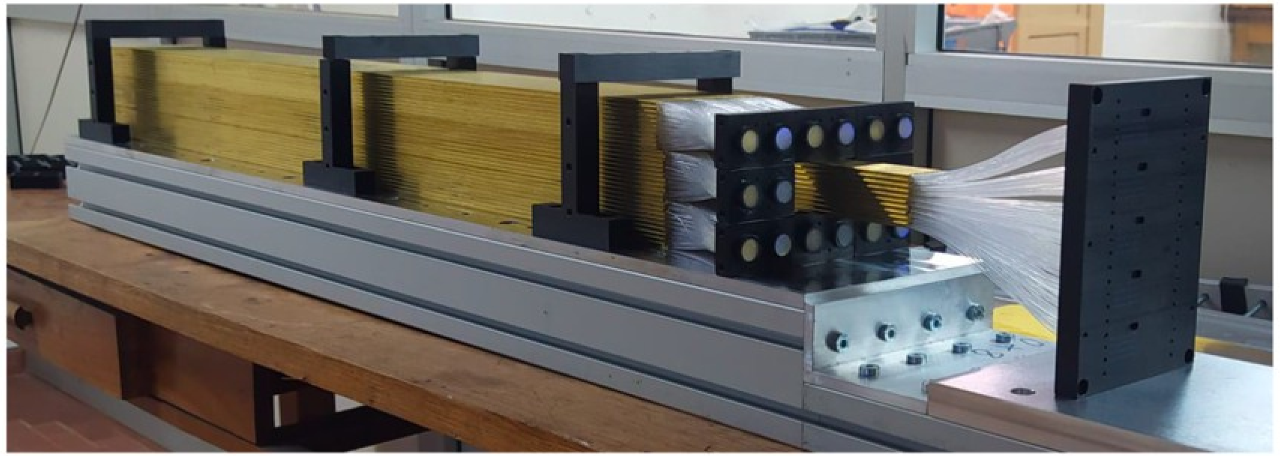
Dual readout to capture Electromagnetic and hadronic components of shower

Prototype development

- First step "electromagnetic prototype" 10x10x100cm^3
  - Qualification of
    - Assembly procedure
    - Readout systems



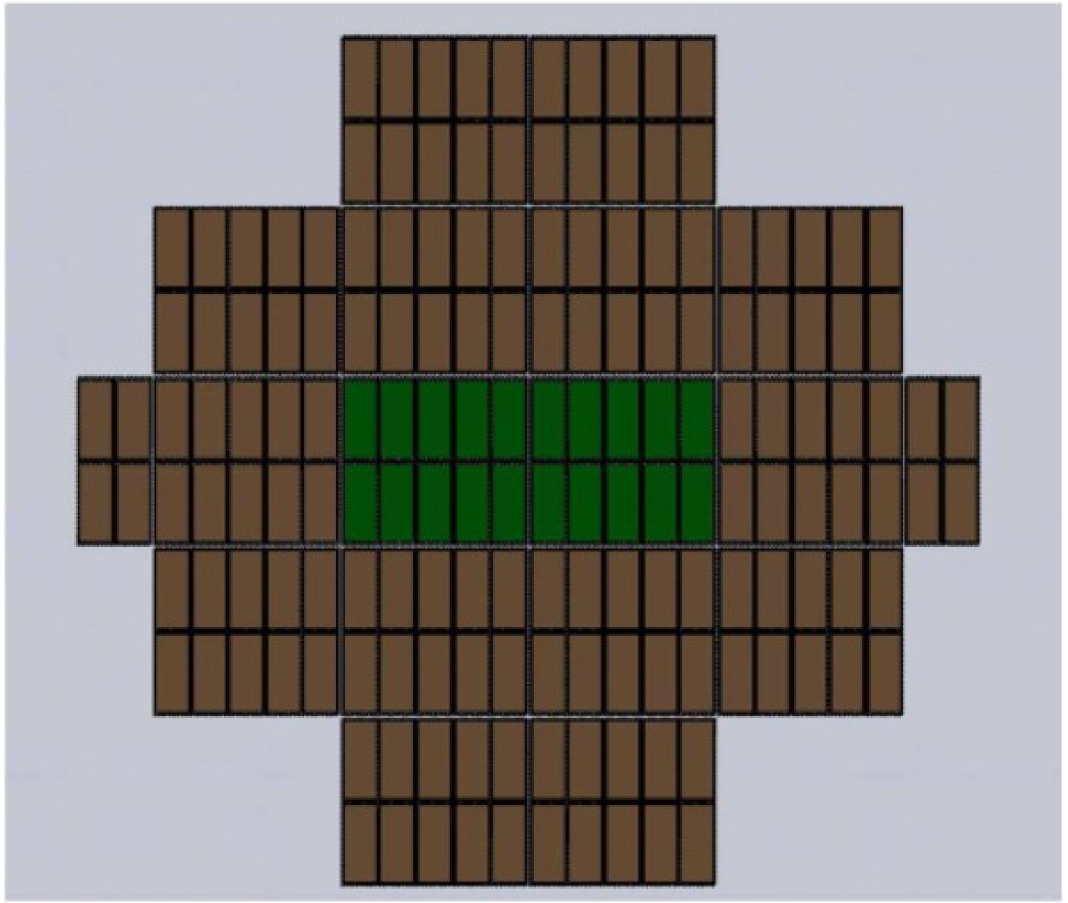
Stack of capillaries



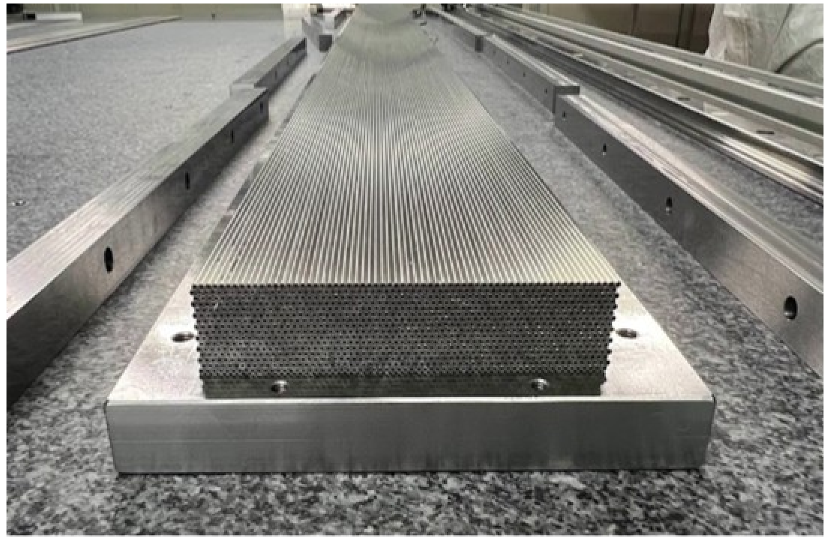
Outgoing fibres guided to readout plane

Dual readout calorimetry – Towards large prototype

Prototype with hadronic containment

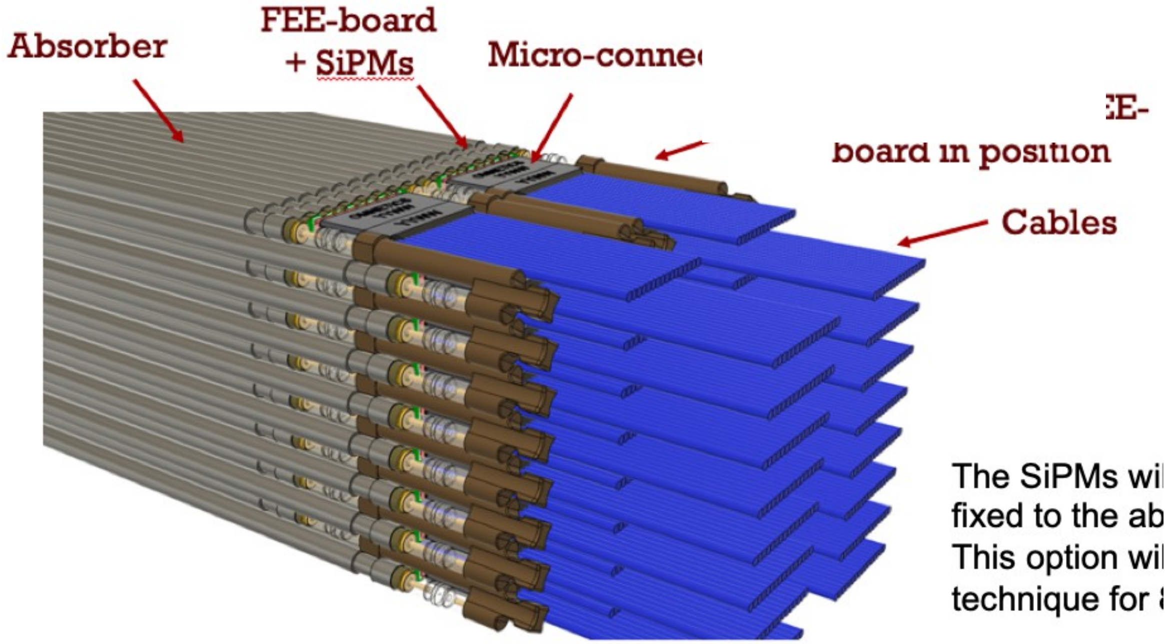


- 65x65x200 cm^3
- 17 modules in total
- 2 central modules equipped with SiPMs
- 15 modules equipped with PMTs



Under construction as we speak

Major challenge
SiPM integration



Novel optical materials

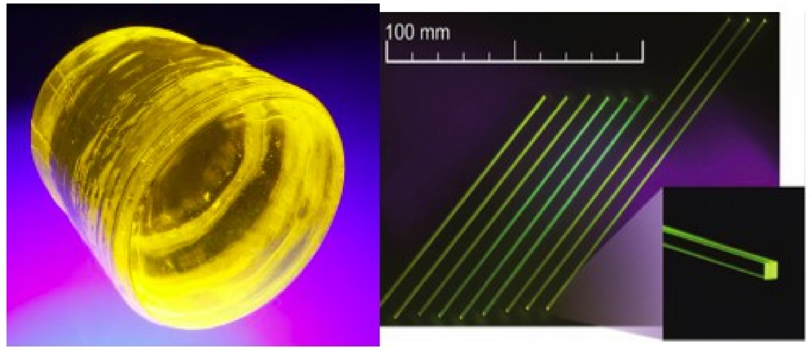
- Radiation hard optical materials with ultrafast timing response are required for new detectors in HEP, nuclear medicine and industry

- A time resolution below 30 ps or even in the sub ps domain requires a better understanding of the fast signal production mechanisms in detection materials

- Innovative test suites required for the combination of fast timing and radiation tolerance will be developed for the characterisation and classification of materials

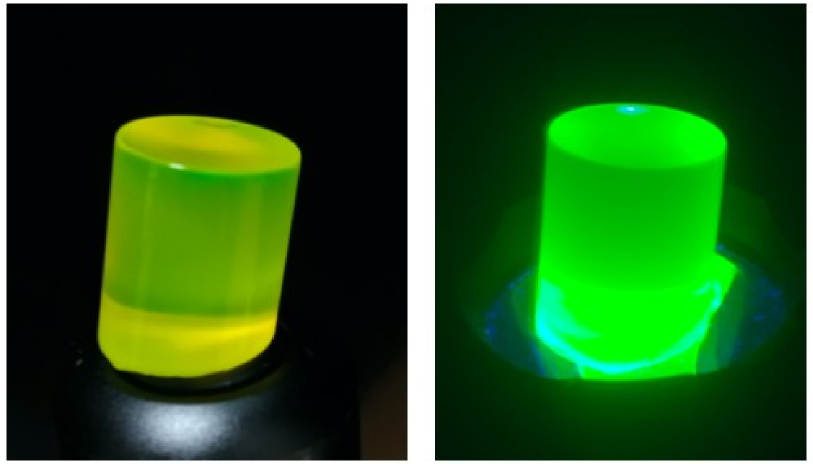
- Scalable and cost effective production techniques for the novel materials have to be explored together with the industrial partners

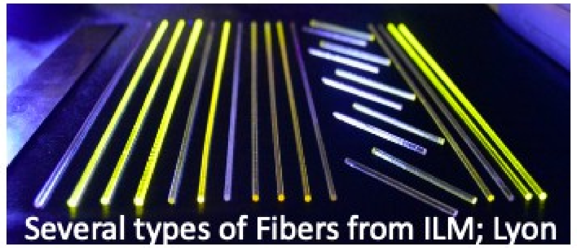
Crytur YAG ingots => fibers



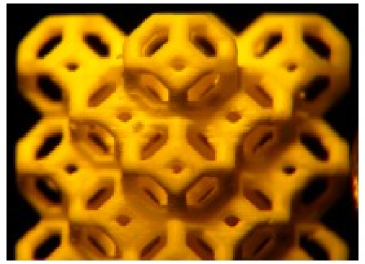
Crytur PWO crystals

GlasstoPower development on quantum materials





3 D printed garnet Crystals



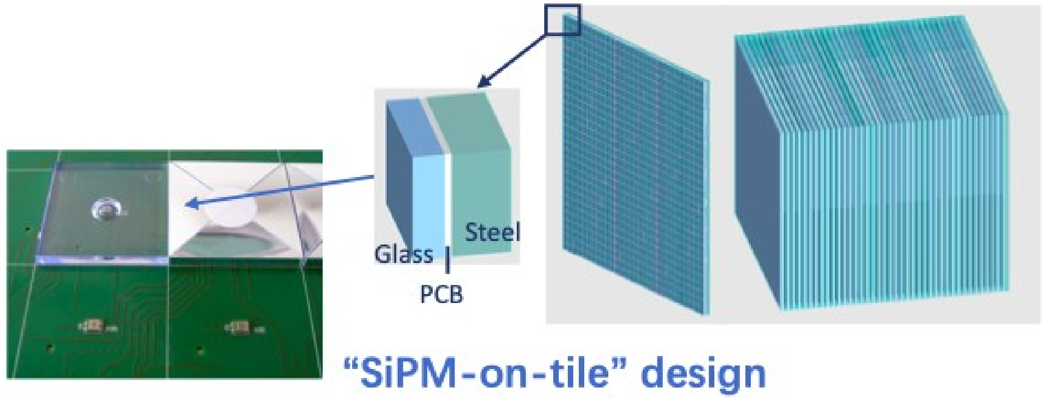
Courtesy G. Dosovitskyi, Kurchatov Institute

Glass Scintillators – The bright future?

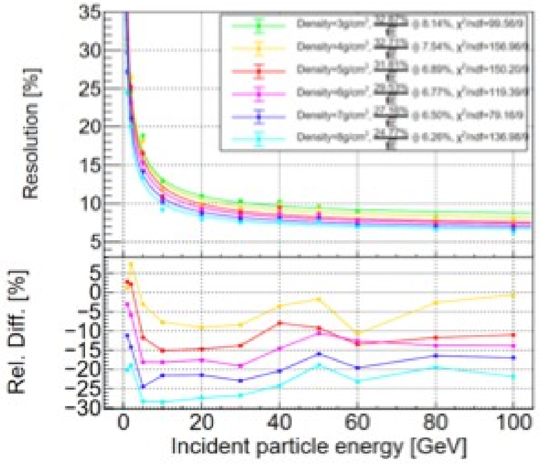
Glass scintillator HCAL

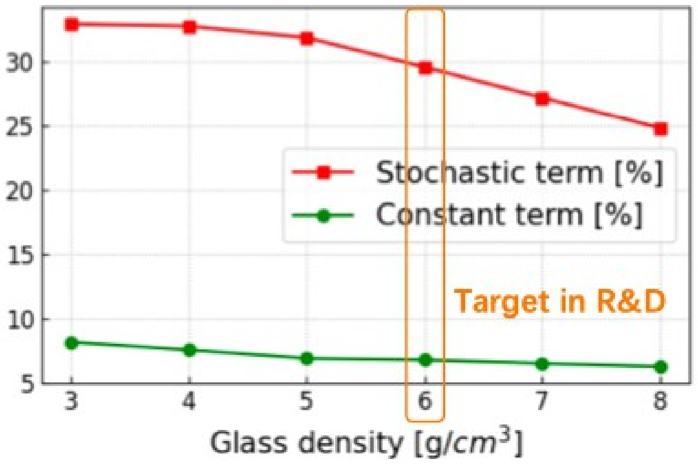
Sen & Dejing, TIPP 2023

- **Motivation: better energy resolution**
  - Higher density ➡ higher sampling fraction.
- **Validate with standalone simulation:**
  - λ_I = 23.83 cm, MIP response ~7 MeV/cm.
  - Standalone simulation of glass-steel:
    - 40 layers, total depth 5λ.



"SiPM-on-tile" design
AHCAL-like glass HCAL





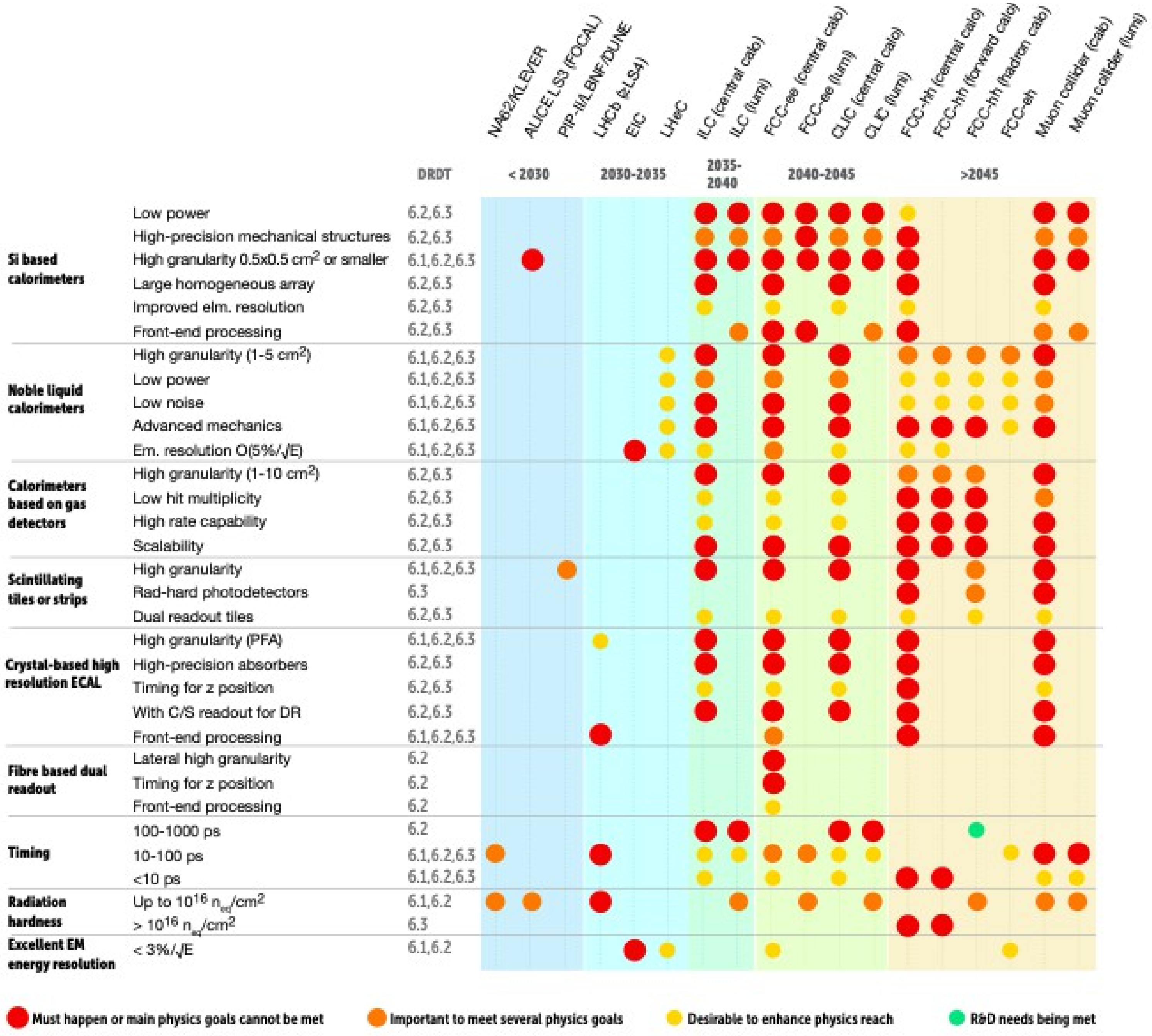
- HCAL resolution can be improved with higher density.
- Consider 6 g/cm^3 as glass scintillator R&D target (a balance with the light yield).

2023/10/11 Fangyi Guo | Second ECFA Workshop, 2023 16

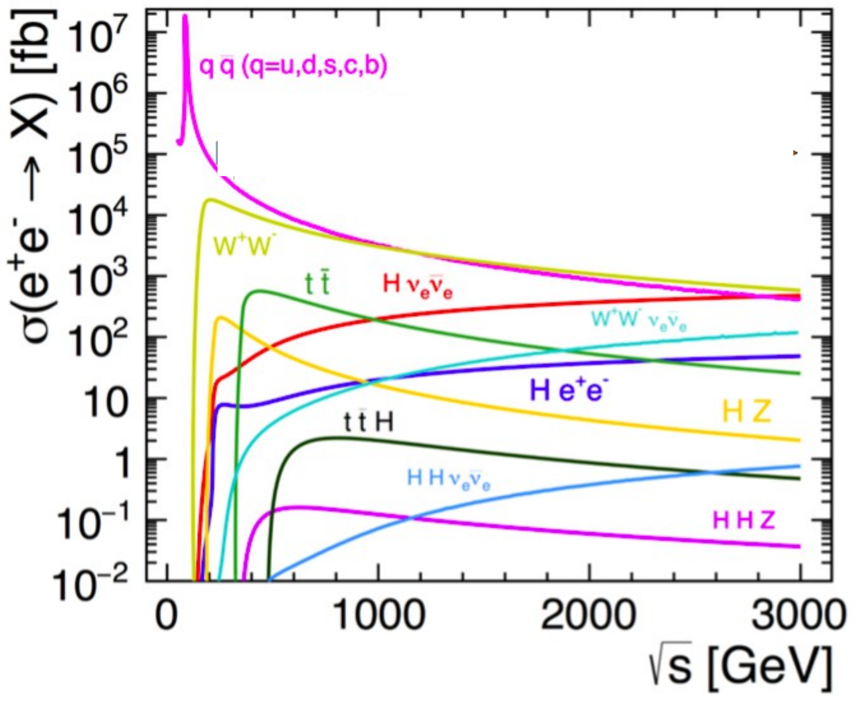
Two points to take home (my understanding):
- Would be relatively cheap
- Problem is optial diping to achieve transparency

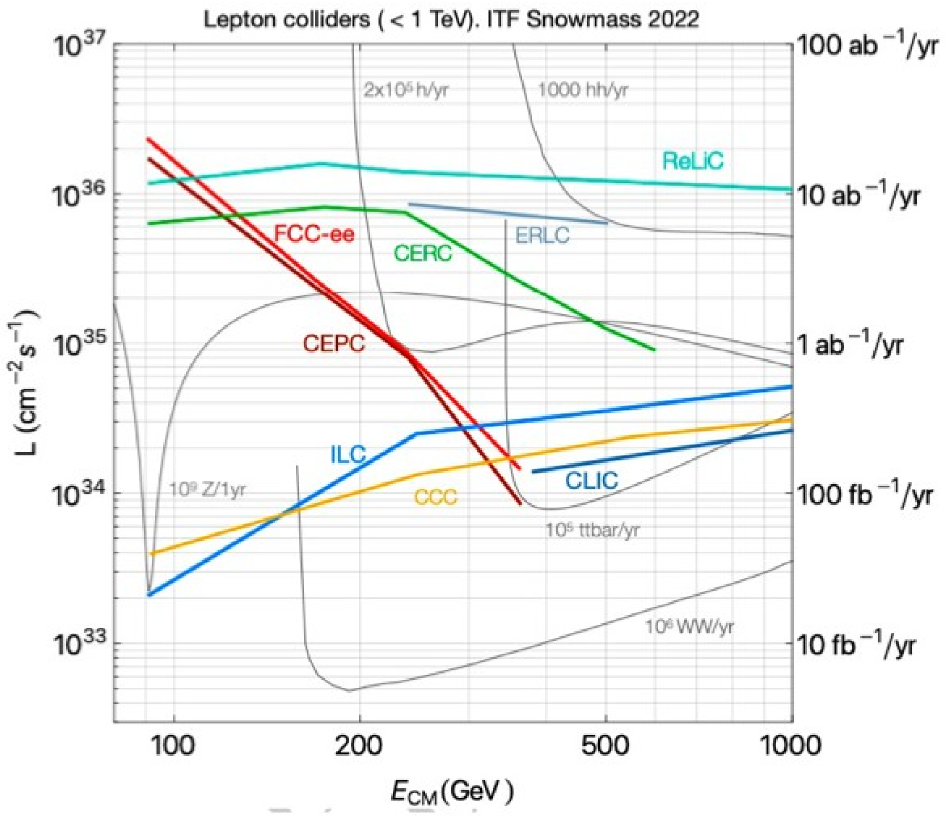
Calorimetry- Identified Key Technologies and R&D Tasks

- Key technologies and requirements are identified in ECFA Roadmap
  - Si based Calorimeters
  - Noble Liquid Calorimeters
  - Calorimeters based on gas detectors
  - Scintillating tiles and strips
  - Crystal based high-resolution Ecals
  - Fibre based dual readout
- R&D should in particular enable
  - Precision timing
  - Radiation hardness
- R&D Tasks are grouped into
  - Must happen
  - Important
  - Desirable
  - Already met



Future direction of R&D - Impact of event rates





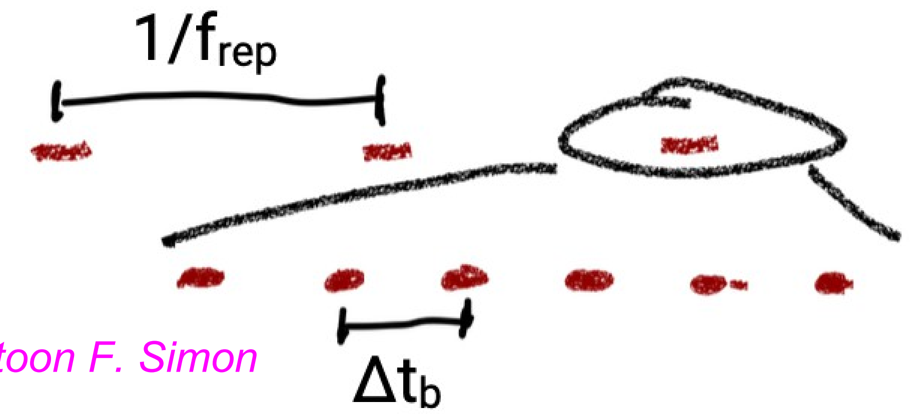
High energy e+e- colliders:

- Physics rate is governed by strong variation of cross section and instantaneous luminosity
- Ranges from 100 kHz at Z-Pole (FCC-ee) to few Hz above Z-Pole
- (Extreme) rates at pole may require other solutions than rates above pole

- Event and data rates have to looked at differentially
  - In terms of running scenarios and differential cross sections
  - Optimisation is more challenging for collider with strongly varying event rates
    - Z-pole running must not compromise precision Higgs physics

Operation mode- pulsed or continous

- Linear Colliders operate in bunch trains



Cartoon F. Simon

CLIC: Δt_b ~ 0.5ns, frep = 50Hz

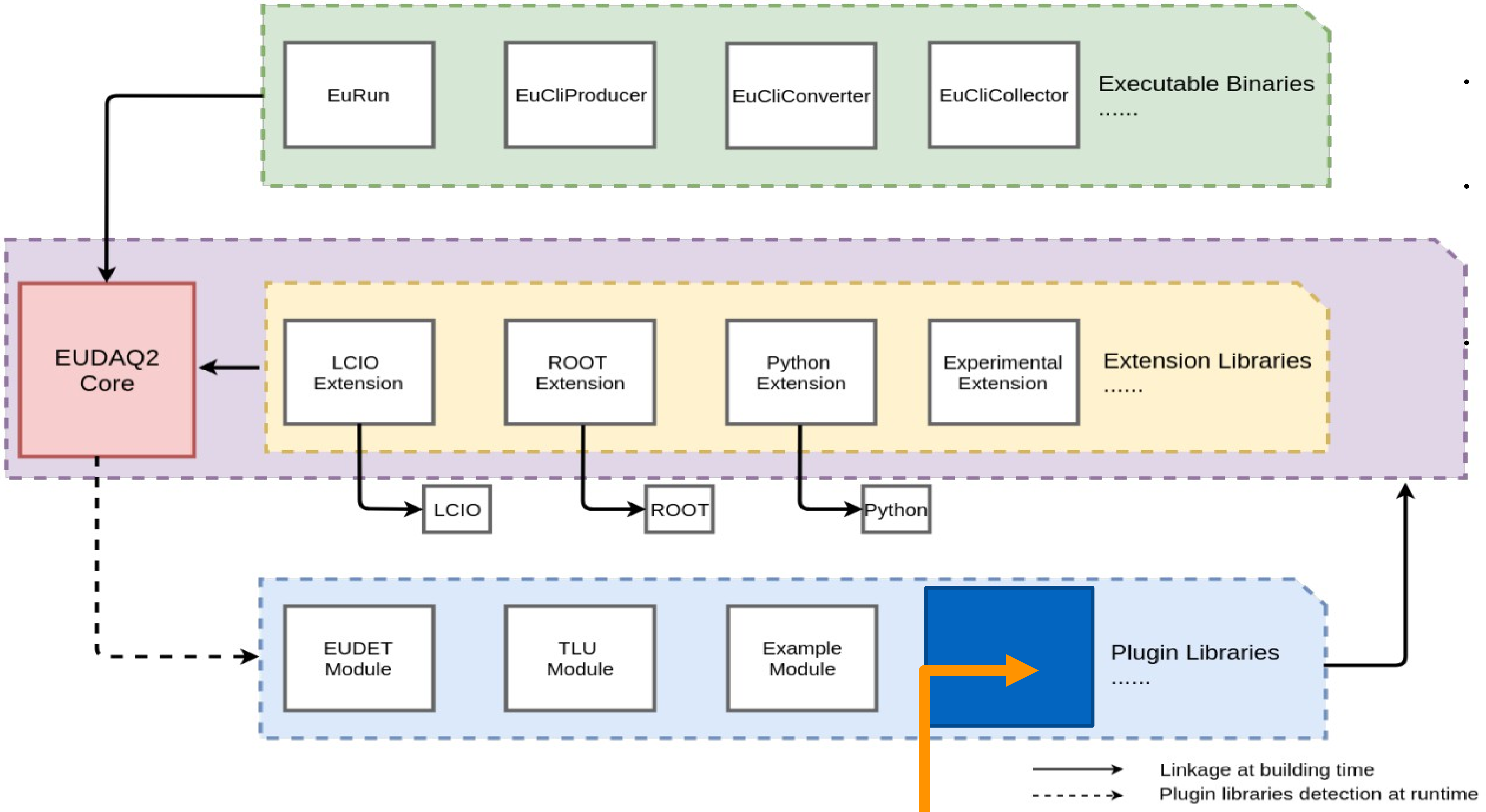
ILC: Δt_b ~550ns, frep = 5 Hz (base line)

- Power Pulsing reduces dramatically the power consumption of detectors
  - e.g. ILD SiECAL: Total average power consumption 20 kW for a calorimeter system with 10^8 cells
- Power Pulsing has considerable consequences for detector design
  - Little to no active cooling
  - => Supports compact and hermetic detector design

- Upshot: Pulsed detectors face other R&D challenges than those that will be operated in "continuous" mode
  - R&D Goal: Avoid/minimise active cooling also in continuous mode
  - Challenge differs depending on where the electronics will actually be located

Future Homogeneous Calorimeters

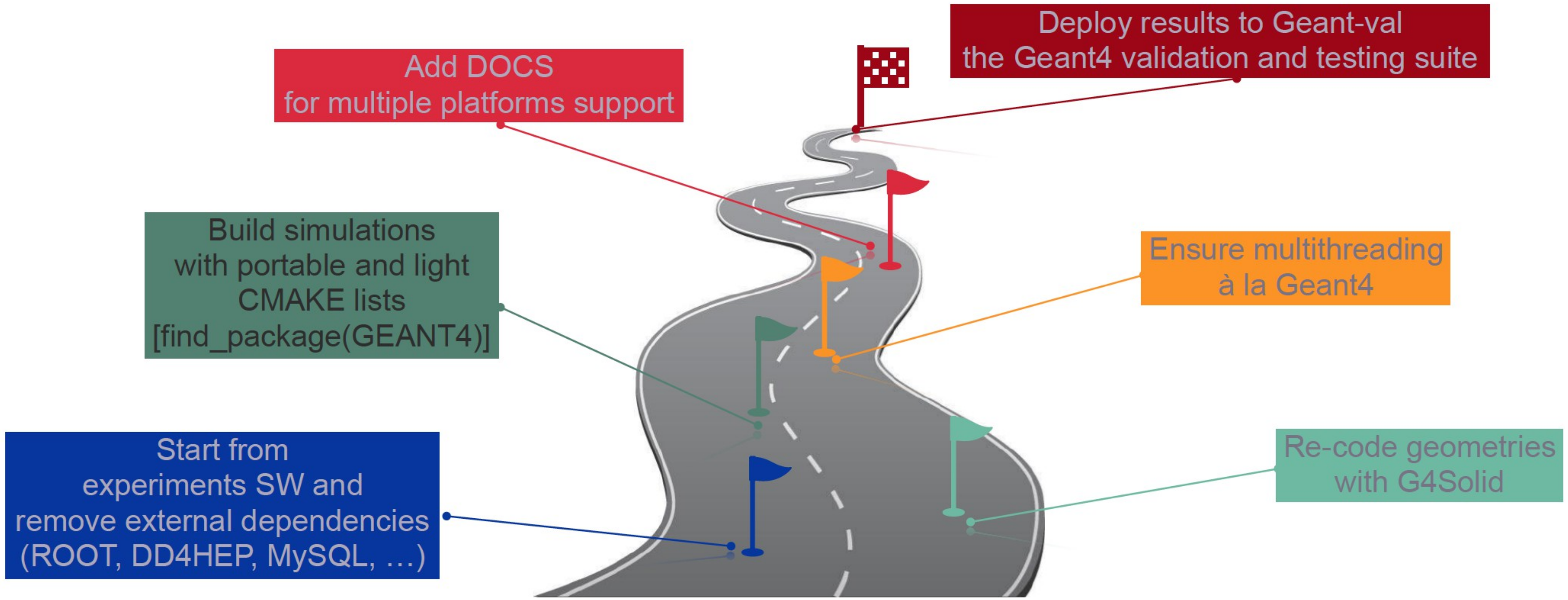
EUDAQ Data Acquisition Systems



PUT your calorimeter library here!

- Implementation of custom producers is rather simple
- easier integration with other eudaq producers (TLU, Telescopes)
- Already a long list of custom producers integrated:
  - CALICE SiWECAL,
  - CALICE AHCAL,
  - CALICE SiWECAL + AHCAL,
  - CMS HGCAL silicon prototype + CALICE AHCAL, ...

From experiments to geant-val, a winding road



geant-val.cern.ch

Geant-val is the Geant4 validation and testing suite.

For the Community, it allows to deploy results on a common data-base and fetch the information via a web-interface.

For the developers, it allows to Create multiple jobs over beam energies, particle types, physics lists

Better to involve G4 collaboration at the beginning of the testbeam. G4 collaboration available to help with the geant4-val inclusion

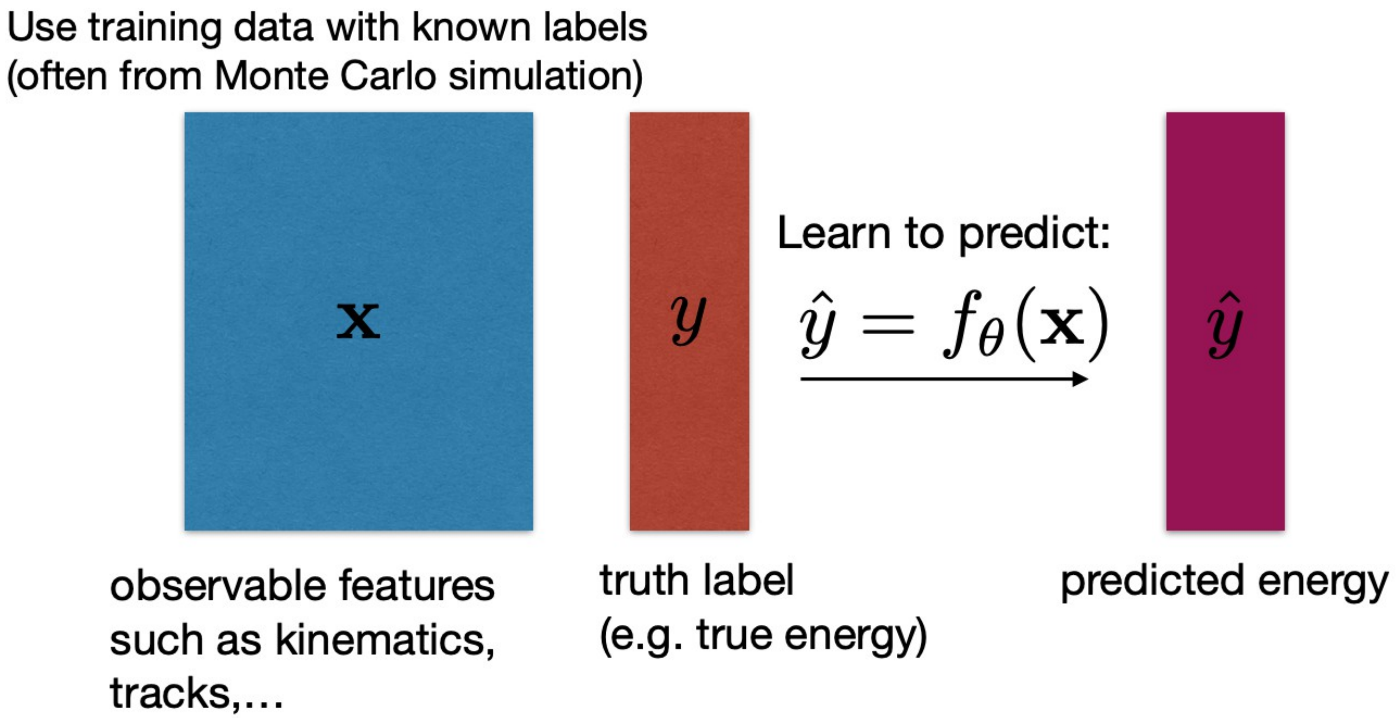
Tommaso Dorigo and MODE Collaboration

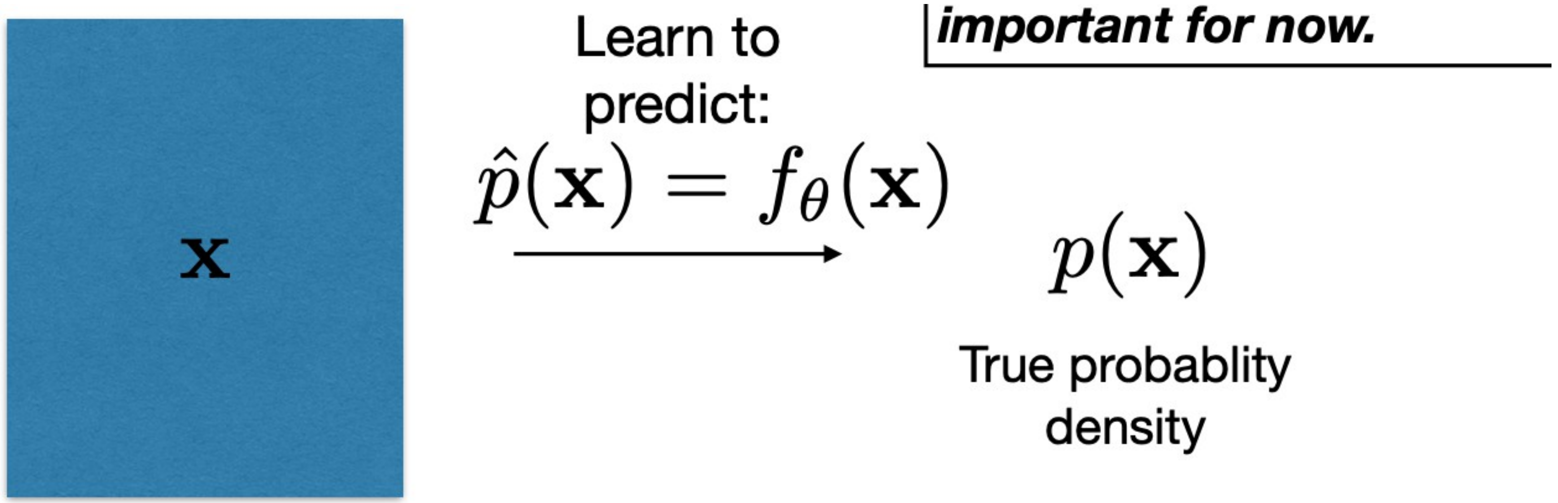
Machine Learning approach is gaining more and more importance in HEP and in calorimetry in particular

highly complex data with large number of detailed information

Simulation provides tagged data for supervised learning

Tracking, clustering, particle ID ...





CERN Schedule according to recent MTP