Overview of DRD programmes and links to e-p/A collider projects

Synergy workshop between ep/eA and pp/pA/AA physic experiment

29 February 2024

P. Allport (Birmingham), D. Contardo (IP2I)

Outline

Reminder of DRD collaboration framework

General considerations on relation of strategic projects to DRD programmes

Highlights of DRD Work Packages related to e-p-A collider projects

Linking project concept needs to the DRD collaboration programmes

From ECFA Detector R&D Roadmap to DRD collaborations

2019 — ESPP update (HEP strategic projects) — 2021 — ECFA DRD proposals — 2024

Granada Symposium (WGs and Physics Briefing Book) — 2020 — ECFA detector R&D roadmap (TF & workshops community driven) — 2023 — DRD MoUs (collaborations active)

- establish strategic project performance requirements and their criticality to the physics program
- assess potential of technology options and studies needed to fulfil the requirements in due time
- recommend international coordination & organization and to establish long term strategic funding

➢ proposal to form DRD collaborations hosted at CERN was endorsed by CERN Council Sep. 2022

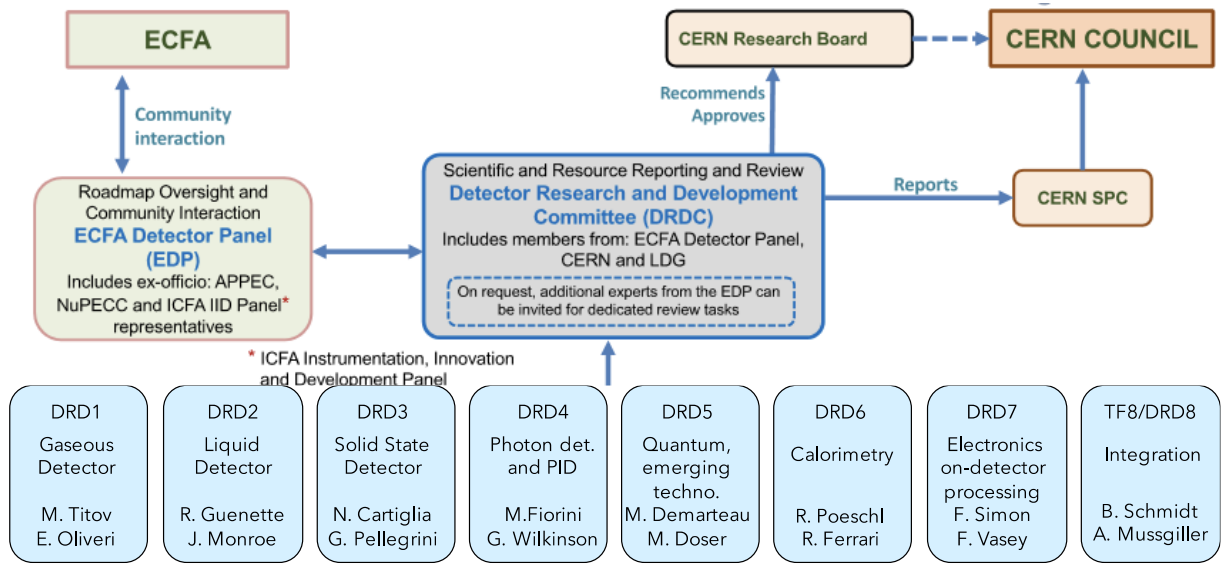
Framework for hosting DRD collaborations at CERN

general conditions for execution of experiments with Funding Agencies resource MoUs

ECFA Detector Pannel provides input on DRD proposals to the DRDC in terms of roadmap priorities
it follows-up evolution from project concept groups and achievements for update of the rodmap

ECFA Detector Panel (EDP):

- Co-chairs: ***Phil Allport*** *(Birmingham)*, ***Didier Contardo*** *(Lyon)*
- Scientific secretary: *Doris Eckstein (DESY)*
- Gaseous Detectors: *Silvia Dalla Torre (Torino)*
- Liquid Detectors: ***Inés Gil Botella*** *(CIEMAT)*
- Solid State Detectors: *Doris Eckstein, Phil Allport*
- PID & Photon Detectors: ***Roger Forty*** *(CERN)*
- Quantum and emerging Technologies.: *Steven Hoekstra (Groningen)*
- Calorimetry: ***Laurent Serin*** *(IJCLab)*
- Electronics: *Valerio Re (Bergamo)*
- Ex Officio: *ECFA Chair (Karl Jakobs), ICFA Detector Panel (Ian Shipsey), DRDC chair (**Thomas Bergauer**), APPEC & NuPECC observers*



Detector R&D Committee (DRDC):

- ***Thomas Bergauer*** (HEPHY Vienna)
- Scientific secretary: *Jan Troska* (CERN)
- *Stan Bentvelsen* (NIKHEF, **LDG**)
- *Shikma Bressler* (Weizmann)
- *Dimitry Budker* (Mainz)
- ***Roger Forty*** (CERN)
- *Claudia Gemme* (INFN and U. Genoa)
- ***Inés Gil Botella*** (CIEMAT)
- *Petra Merkel* (Fermilab, US)
- *Mark Pesaresi* (Imperial College)
- ***Laurent Serin*** (IJCLab)
- Ex-officio: ***P. Allport, D. Contardo*** (EDP)
- Ex-officio: CERN DRC, EP dep. head, KT head

names are current DRD collaboration link-persons to EDP and DRDC

DRD1, DRD2, DRD4, DRD6 have been approved by the CERN RB for a 3 years initial period
DRD3 has been approved up to the next RB for organization update
DRD7 and DRD5 aiming at approval at June CERN RB
Tracker community preparing a DRD8 collaboration LoI
Training (TF9) will be covered by newly created ECFA Training Panel

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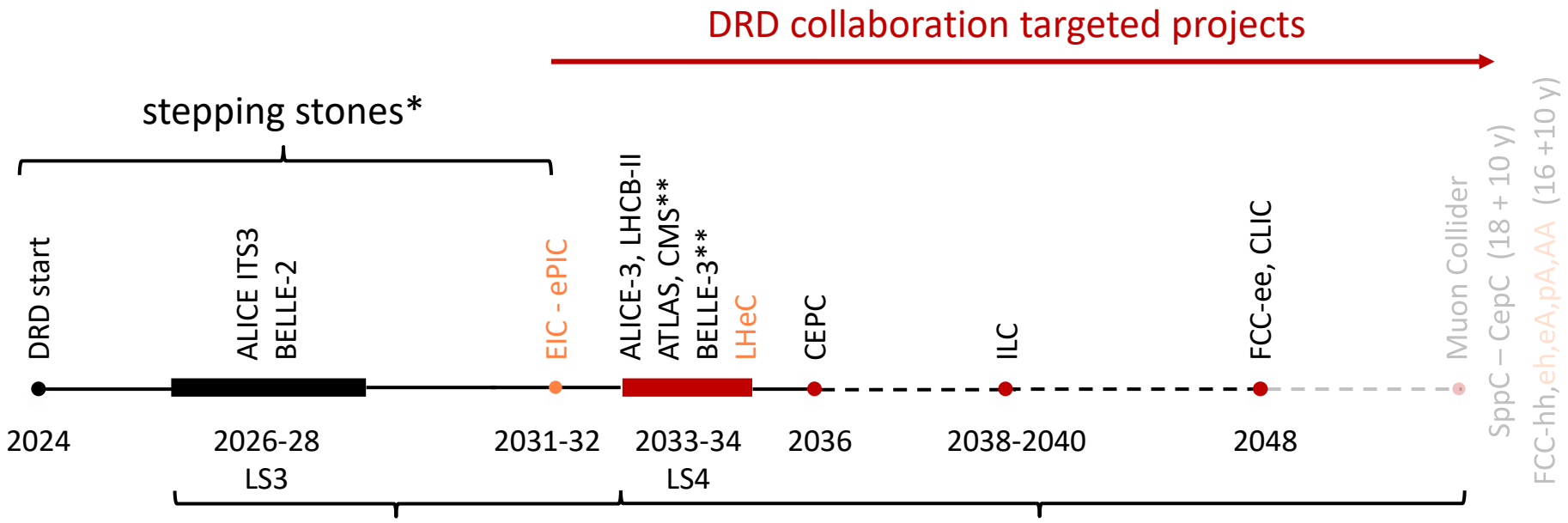
Collider project provisional timeline assumptions*



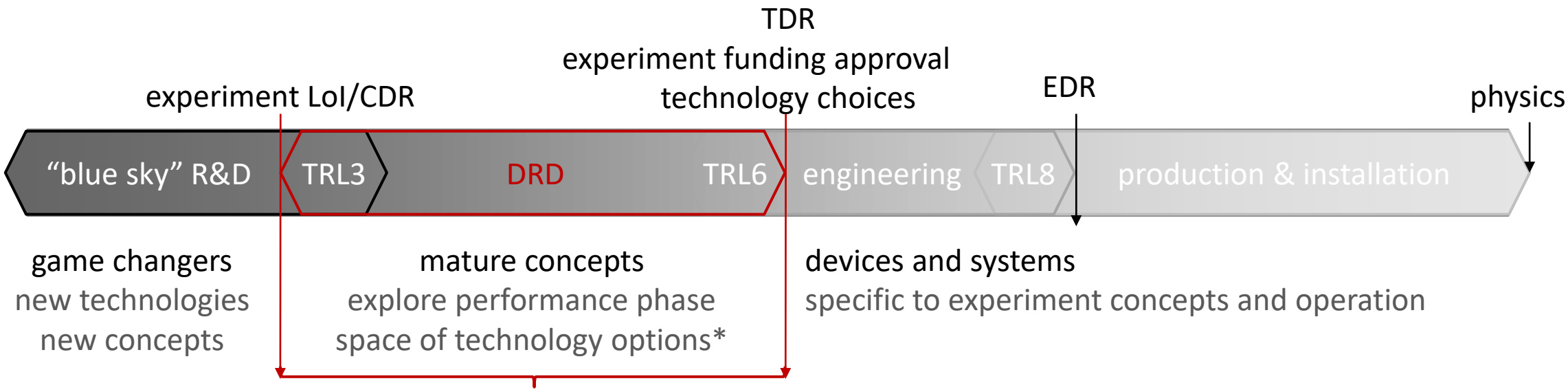
experiment entering engineering phase
SoA 1st implementation in experiments

not yet approved, planning constraint:

- ALICE-3, LHCB-II, FCC-ee - CLIC : HL-LHC planning
- LHeC : ERL and HL-LHC planning
- CEPC, ILC : approval decision
- MC : muon-beam R&D
- SppC, FCC-hh : accel. magnet R&D and e-e programme

** projects identified in ECFA detector roadmap with timelines for physics start (from ICFA/Desy seminar December 2023)*
some other short term programmes also enter stepping stones ex. FAIR, fixed target at SPS…
*** ATLAS/CMS could be replacement for radiation tolerance of the inner pixel and LGAD ToF layers in the forward region, BELLE-3 could be a further pixel upgrade for higher luminosity (these were not part of the ECFA detector roadmap but could benefit/enter the DRDs)*

Typical project technical and approval steps
DRD collaboration objective



DRD collaborations aim to ensure that R&D readiness is not a primary project schedule driver

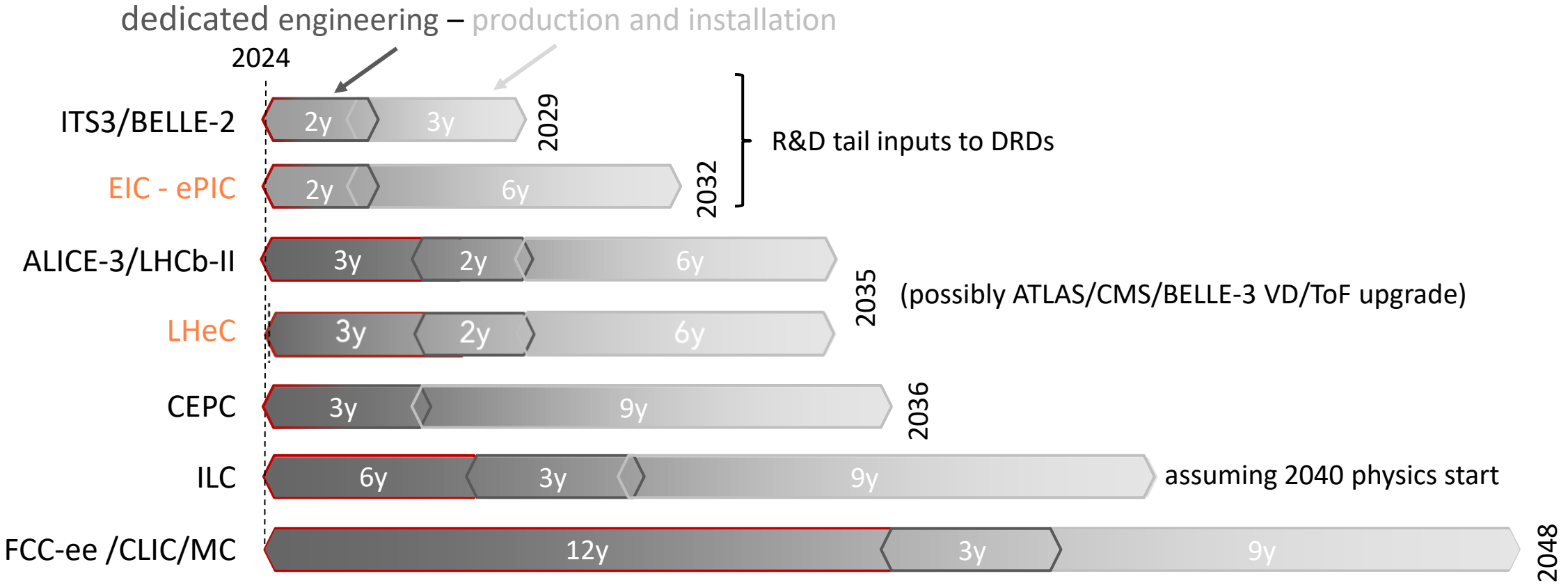
they allow proper coverage of project common technical development options with sustained resources

they can also provide a forum for some common “blue sky” activities

** generic systems and engineering aspects are also considered in DRDs*

Broad brush timelines for (generic) DRD collider projects*

thoughtful project planning needed to anticipate transition to the experiment specific stage



project simulations are crucial to cover the physics needs against specific beam conditions**

DRD collaborations need to consider parallelism of activities in transition periods

different project timelines can allow to envisage technology changes

** assuming similar typical timescales for specific experiment planning of same small/medium/large scale projects*

*** rates, irradiation levels and beam background*

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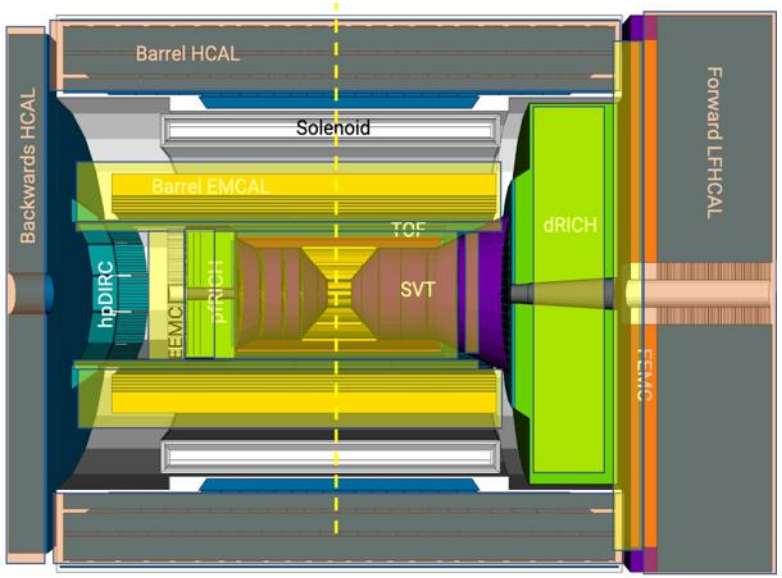
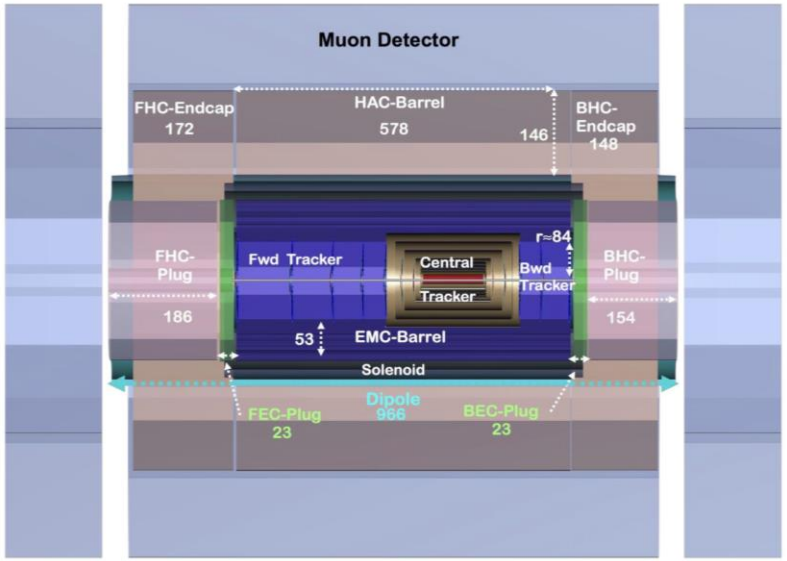
Detector concepts for ep/eA, pp/pA and AA

see presentations of P. Newman and P. Antonioli

ePIC ep/eA
8.5 m x 5.5 m

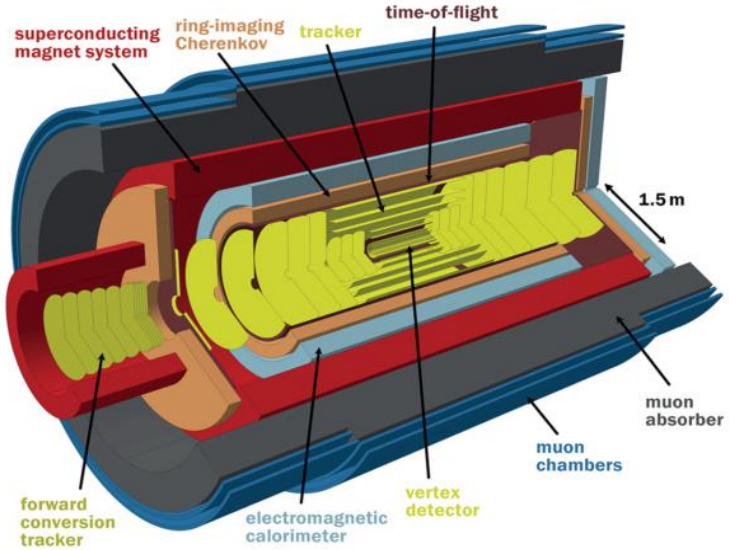


LHeC ep/eA
13 m x m 9 m

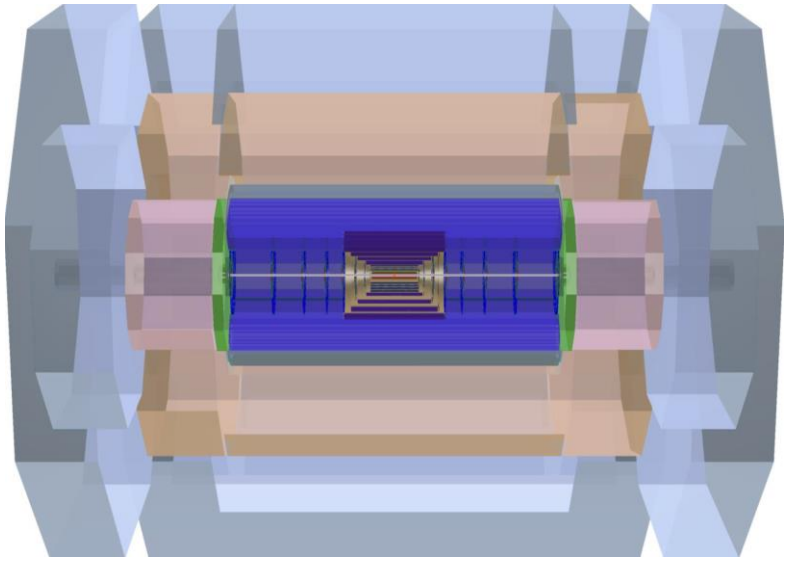


LHeC → FCC-ep
20 m x 14 m

ALICE-3 pp/AA



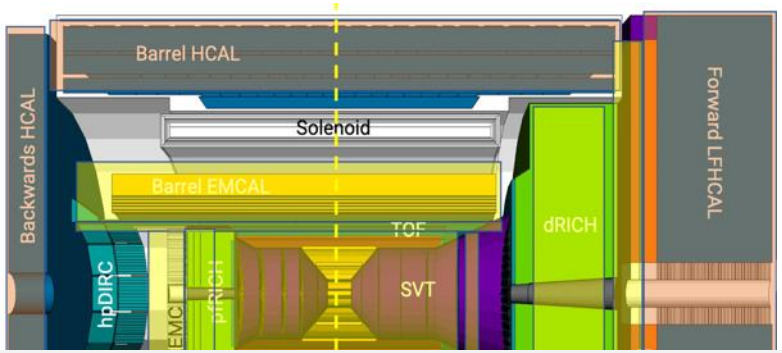
symetric detector
FCC-ep/eA/pp/AA



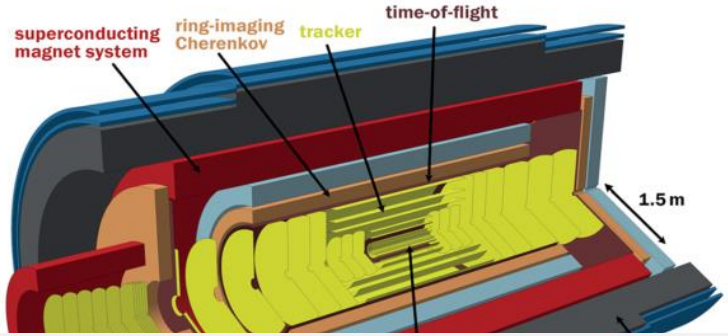
Detector concepts for ep/eA, pp/pA and AA in a nutshell

tonioli

C ep/eA
m x 5.5 m



E-3 pp/AA

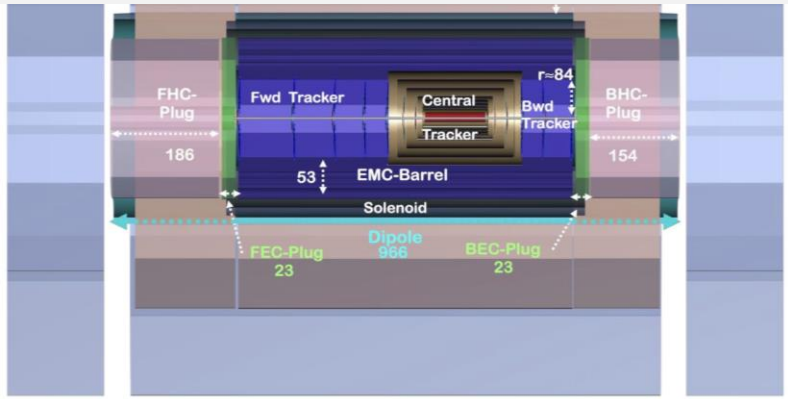


Highlight of detector requirements for the ECFA detector roadmap were presented by L. Musa at
https://indico.cern.ch/event/994685/contributions/4181740/attachments/2193327/3707745/MUSA_ECFA_IS_2021FEB.pdf

- considered mostly common, well covered by short timescale projects (ex. ALICE-ITS3) or SoA
- several technology proposed for 1st use in a large scale collider experiment in ePIC
- steps toward further incremental or new technology performance improvements for longer term e-e / e-h / h-h colliders project needs

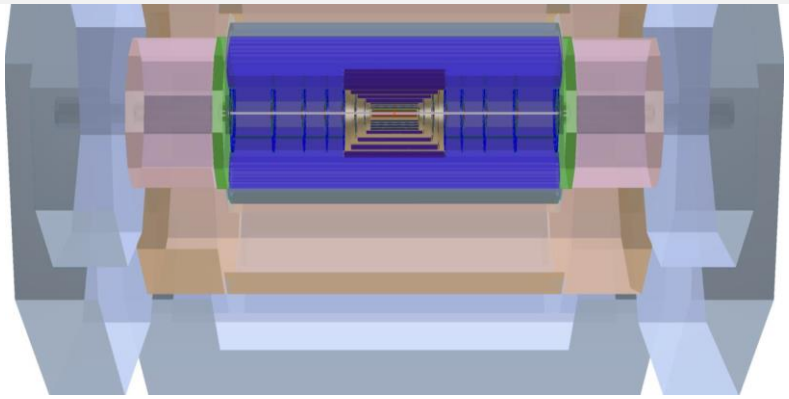
see presentations

LHeC ep/eA
13 m x m 9cm

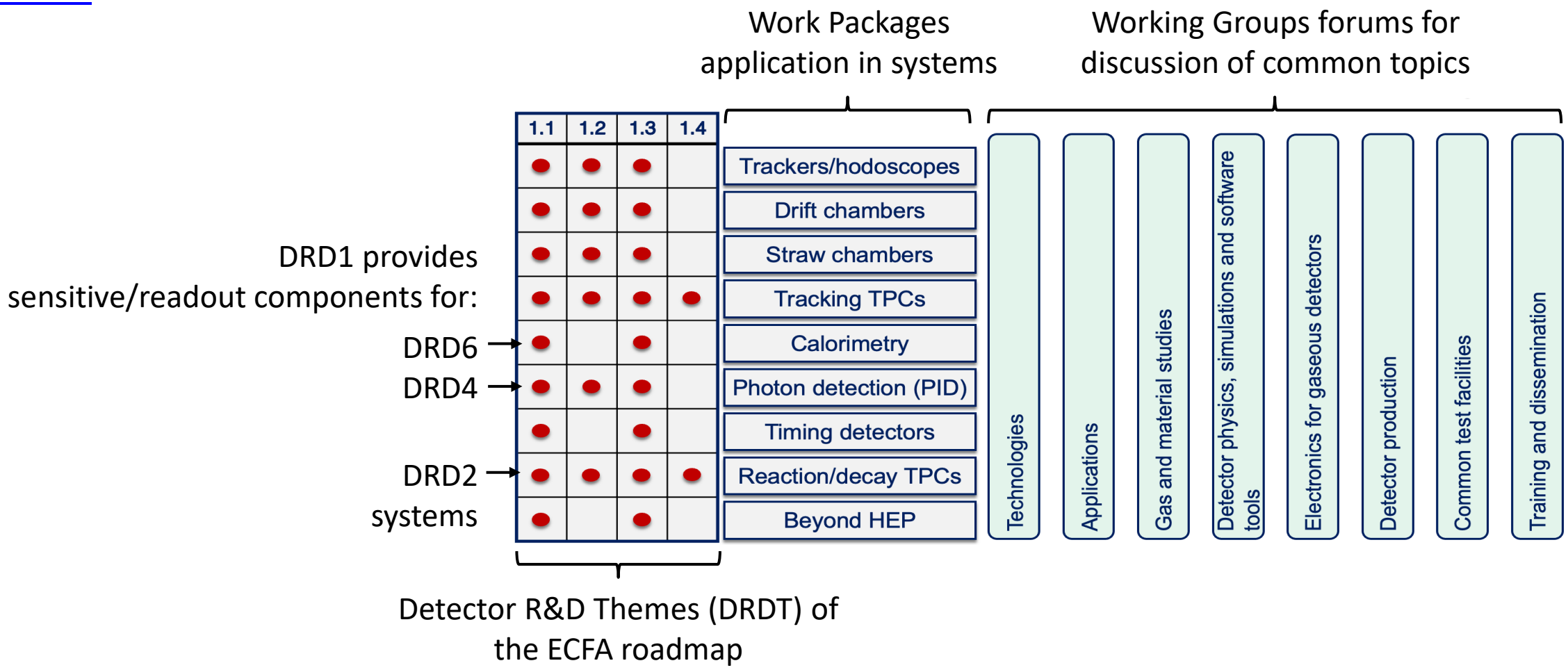


LHeC → FCC-
20 m x 14 m

symetric dete
FCC-ep/eA/pp/

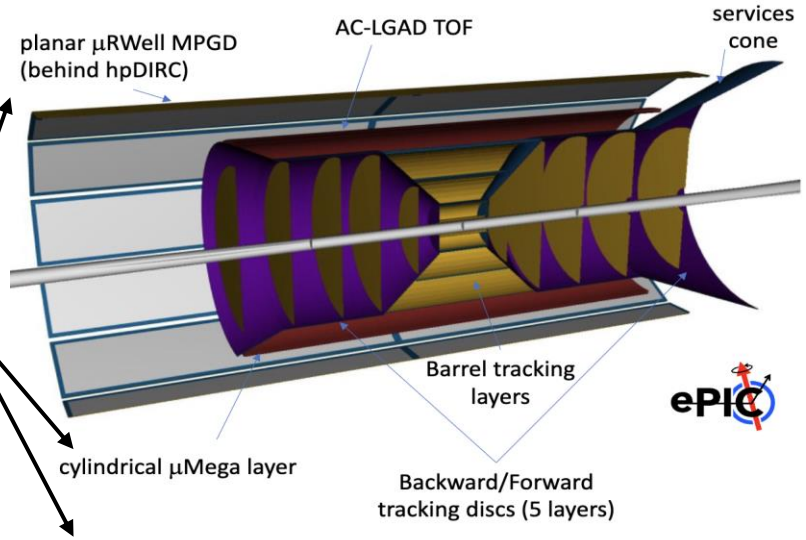


DRD1: Gaseous Detectors



DRD1: Gaseous Detectors

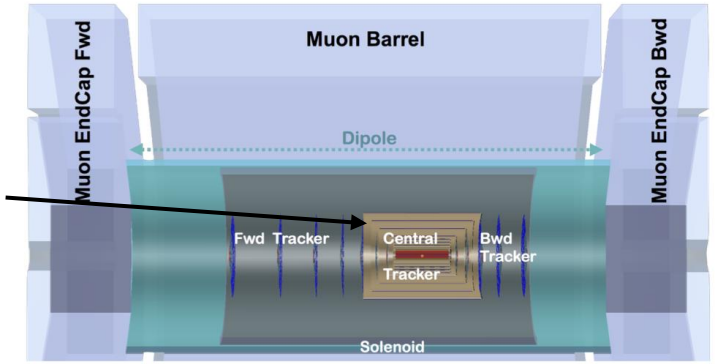
ePIC SoA first large scale use of new generation of MPGDs



Work Packages

time & spatial precision of MPGD, MWPC, RPC →	Trackers/hodoscopes
precise tracking in large volumes*,	Drift chambers
DCH and TPC with dE/dx - dN/dx high p_t PID,	Straw chambers
w/ low X/X_0, large #hits for tracking at e-e colliders →	Tracking TPCs
MPGD & RPC for High Granularity Calorimetry** →	Calorimetry
time & spatial precision of MPGD for gas RICH*** →	Photon detection (PID)
MPGD for ToF PID in Timing Layers at colliders**** →	Timing detectors
	Reaction/decay TPCs
	Beyond HEP

LHeC MDTs and Multigap-RPCs can consider precision timing



*DCH & TPC alternative for central traking (e-e collider concepts)

DRD1 provide sensitive elements to **DRD6 & ***DRD4 systems

****alternative to Solid State for precision timing

DRD3: Solid State Detectors

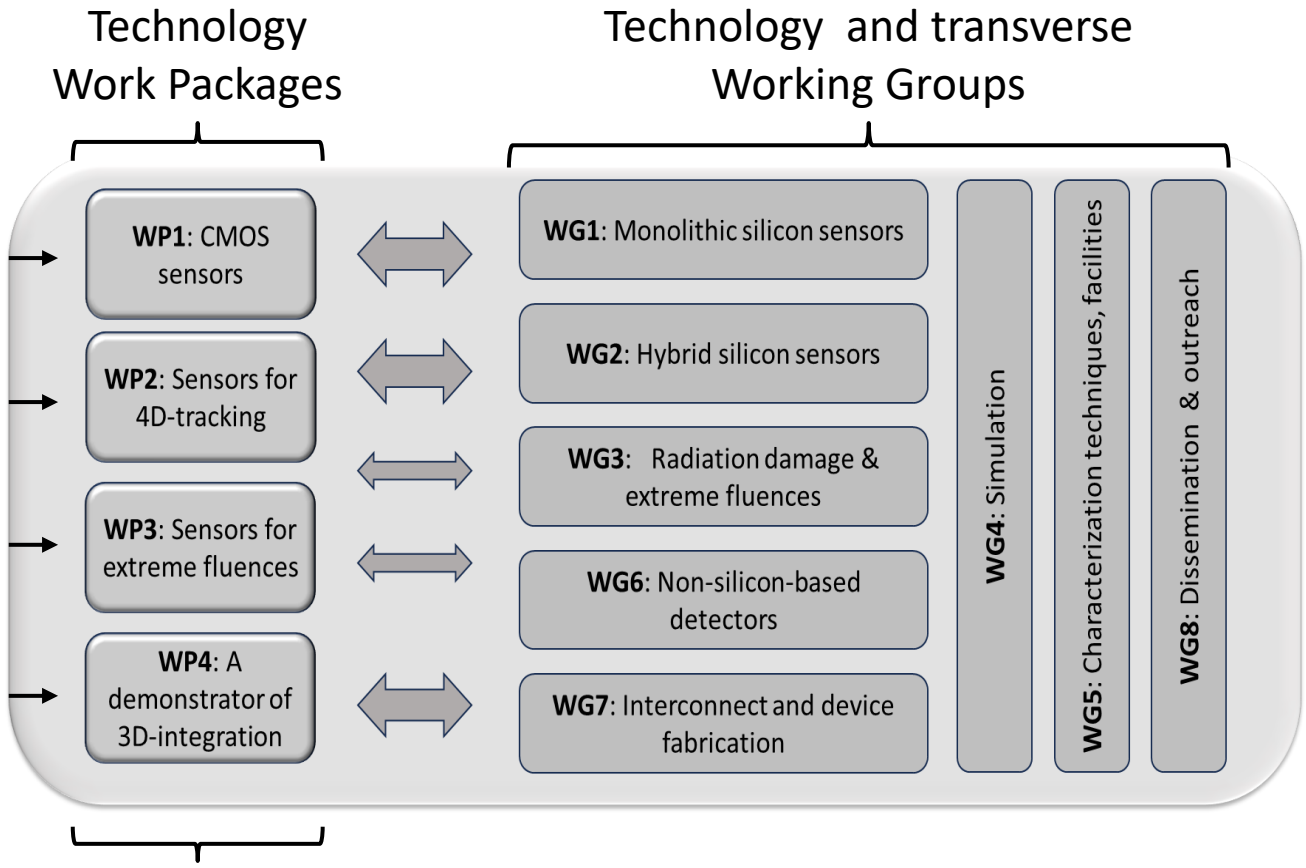
collapse propert ies

spatial resolution in thin large size sensors, Monolithic CMOS in several processes, extend from VD to CT/Calo., implement σ_t

high time and spatial resolution for 4D tracking & ToF PID layers, LGAD and 3D sensors

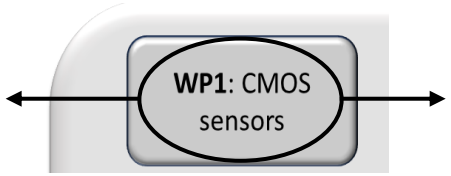
increase radiation tol., Silicon and WBG materials longer term projects

3D integration of electronics

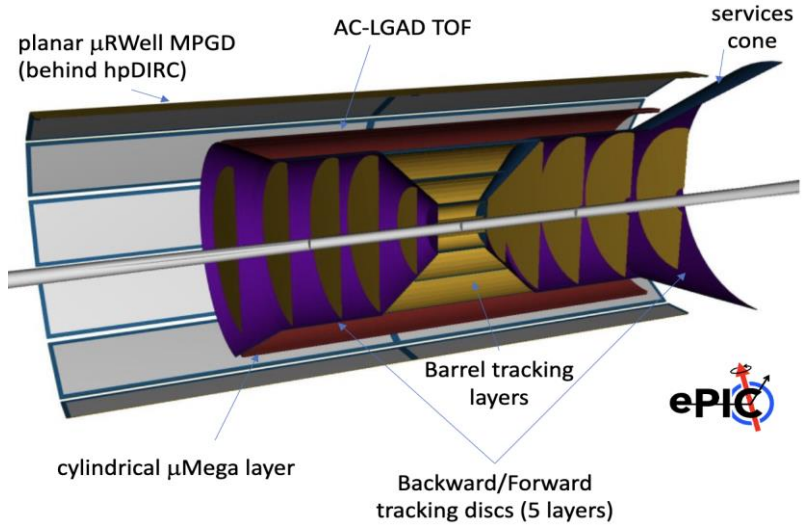


DRD3: Solid State Detectors

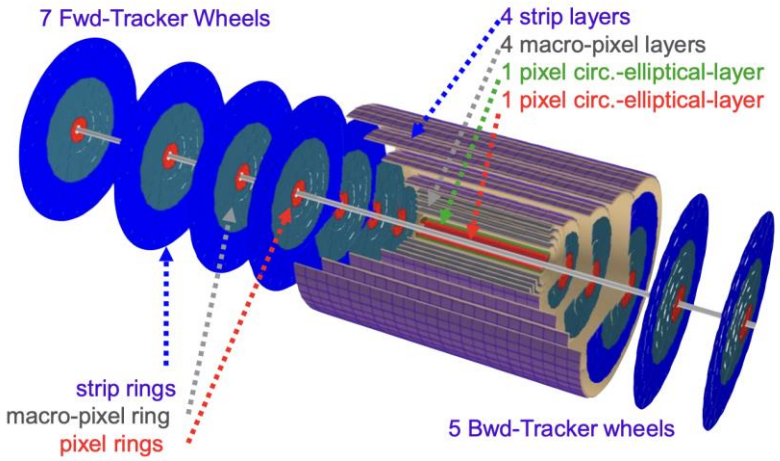
baseline for inner tracking layers TPSCo 65 nm
highest density/stitching/bending
today driven by ALICE ITS3 developments
(see W. Snoeys presentation)



ePIC 5 layers/disks O(10) m^2



LHeC larger scale O(30) m^2

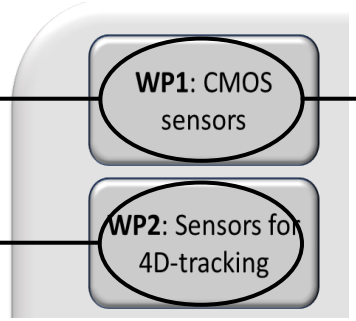


- different p-scale, but overall similar sensor requirements
- macro-pixels / strip designs not existing in TPSCo 65 nm synergies with ALICE-3 & LHCb-2…
  - alternative technologies (large electrodes)
- eliptical design for inner layers
- further improvements (e-e colliders…) increase chanel density and/or readout functionalities at constant power dissipation (spatial versus time precision (and $X>X_0$))

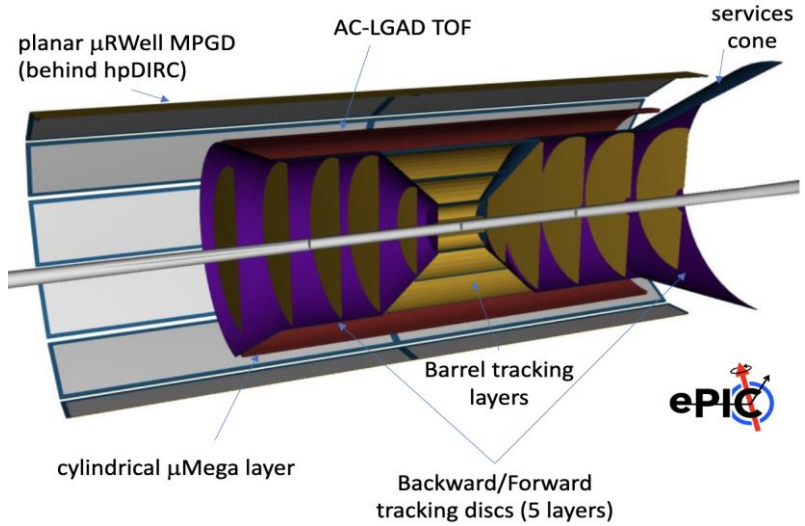
DRD3: Solid State Detectors

design for timing precision / implement gain layer
possibly different solution in different technologies
short term target O(30) ps

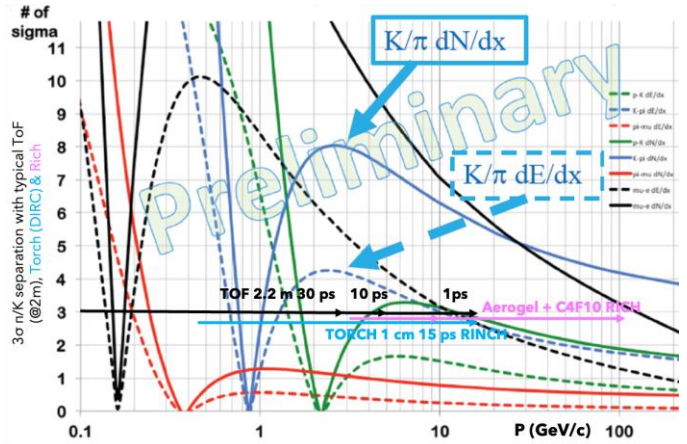
spatial resolution in LGADs
target precision ≲10 µm and ≲ 25 ps



ePIC



- no need of fine pitch in ToF layers at large radii (w/ low rates)
  - AC-LGAD option well suited today (MCMOS to be demonstrated)
- longer term reach O(<10) ps to increase momentum coverage
  - π/K & K/p dE/dx crossing in gas DCH and TPC covered with 30 ps
  - alternative with light sensors (DRD4)



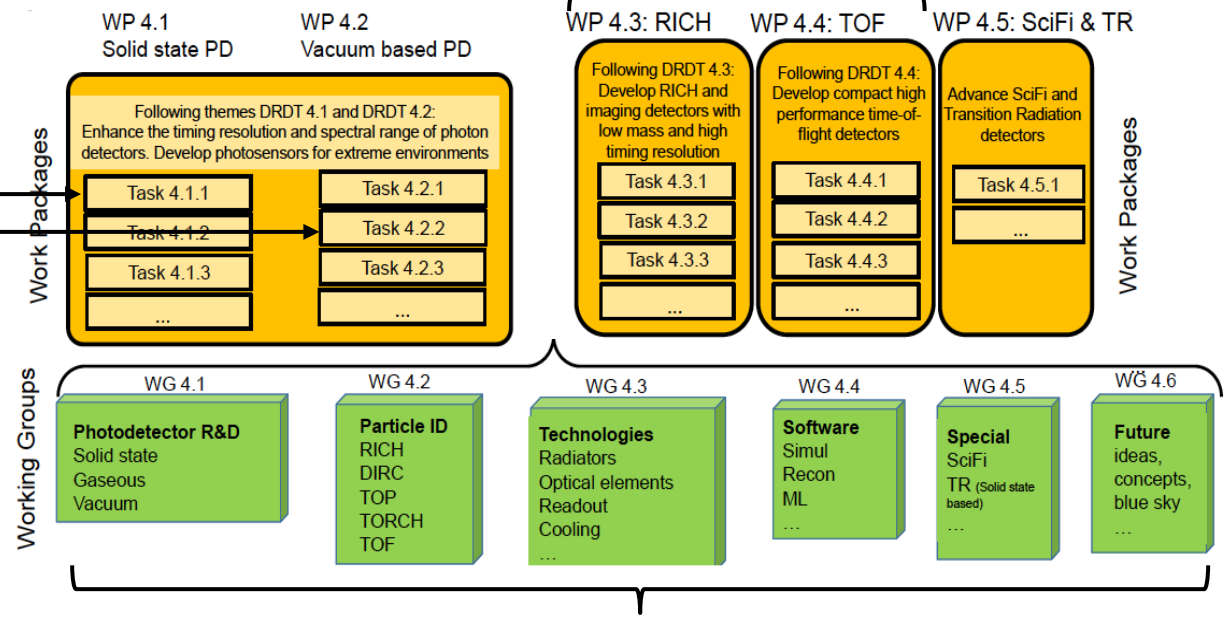
DCH PID w/ dE/dx and dN/dx + ToF layer at 2 m

DRD4: Photon detectors and PID

Work Packages are a mix of technology and systems matching the DRDTs of the ECFA roadmap

improve resolution and timing in RICH with new radiator materials, link to DRD1 for eco-friendly gas
new hetrogenous and light concepts for large momentum range
improve time resolution in ToF layers, link to DRD6 for scintillating materials

improve timing resolution, spectral range, and rad. tol. of
Photodetectors: solid state SiPM/SPADs
vacuum based MCP-PMT
link to DRD2 & DRD6 with focus on single/low #photons
gaseous PD in DRD1

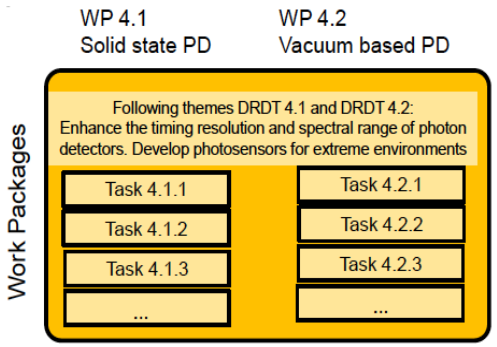


Working Groups are covering transverse/common aspect

DRD4: Photon detectors and PID

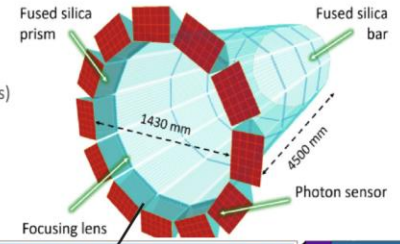
Heterogenous Dual Radiator Rich
synergy with thin ARC concept for e-e colliders

High-Performance DIRC synergy with LHCb-2

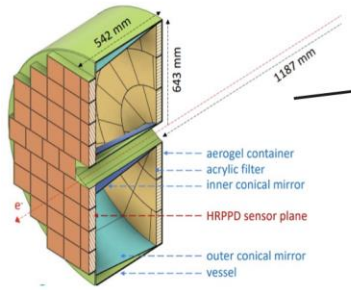


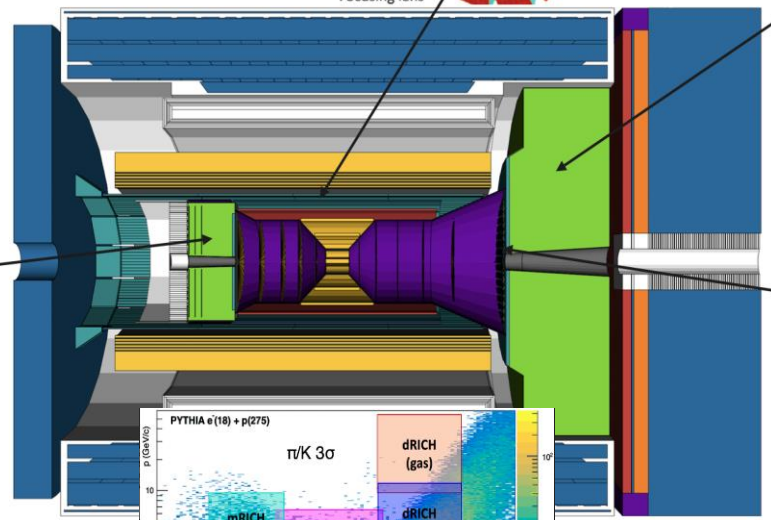
PhotoDetectors
sensitivity (UV)
and SPTR
to couple RICH
and ToF features

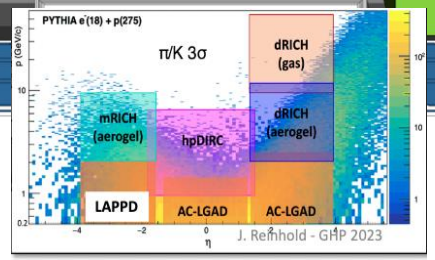
High-Performance DIRC
- Quartz bar radiator (BaBAR bars)
- light detection with MCP-PMTs
- Fully focused
- π/K 3σ separation at 6 GeV/c



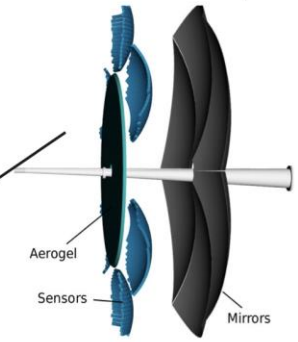
Proximity Focused (pfRICH)*
- Long proximity gap (~40 cm)
- Sensor: LAPPDs
- up to 9 GeV/c 3σ π/K sep.



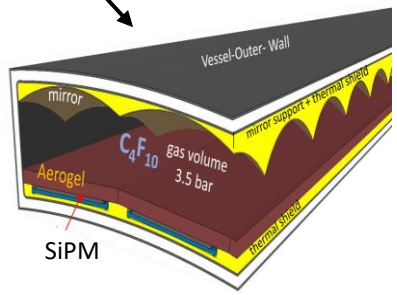




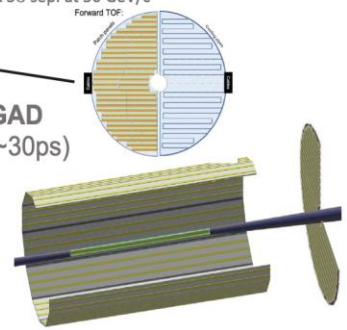
Dual-Radiator RICH(dRICH)



- C_2F_6 Gas Volume and Aerogel
- Sensors tiled on spheres (SiPMs)
- π/K 3σ sep. at 50 GeV/c



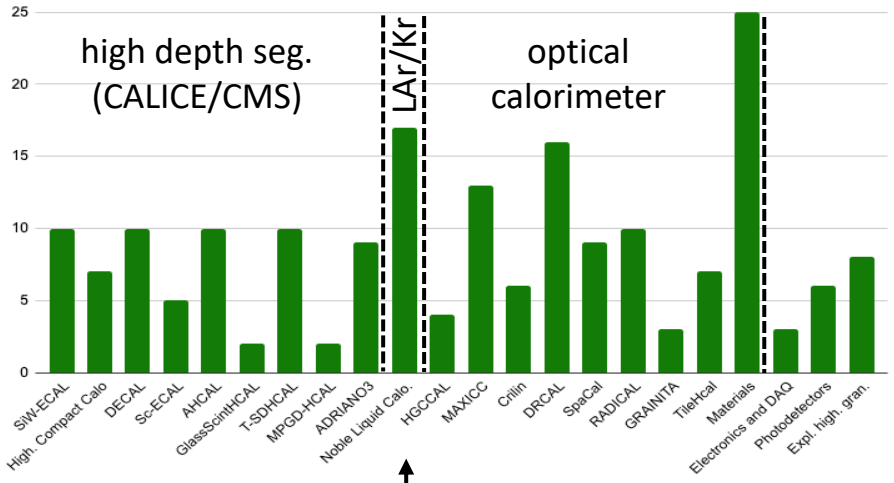
AC-LGAD TOF (~30ps)



https://indico.jlab.org/event/714/contributions/12568/attachments/9944/14673/The%20ePIC%20Experiment%20-%20JLUO%20Split.pdf

DRD6: Calorimetry

18 prototype projects to cover options
in configurations of electromagnetic and hadronic segments in all technology options



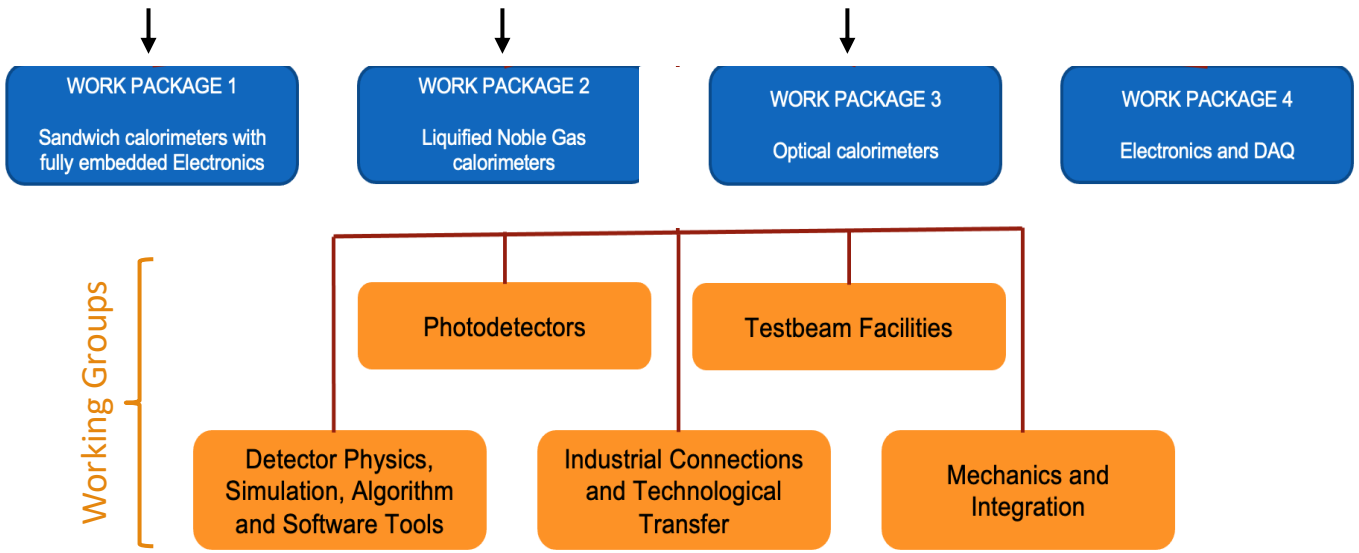
DRD1 MPGD, RPCs
DRD3 Si-sensors

new optical materials
RD18 – link to DRD5

DRD2 cold electronics

DRD2 and DRD4 PhotoDetectors

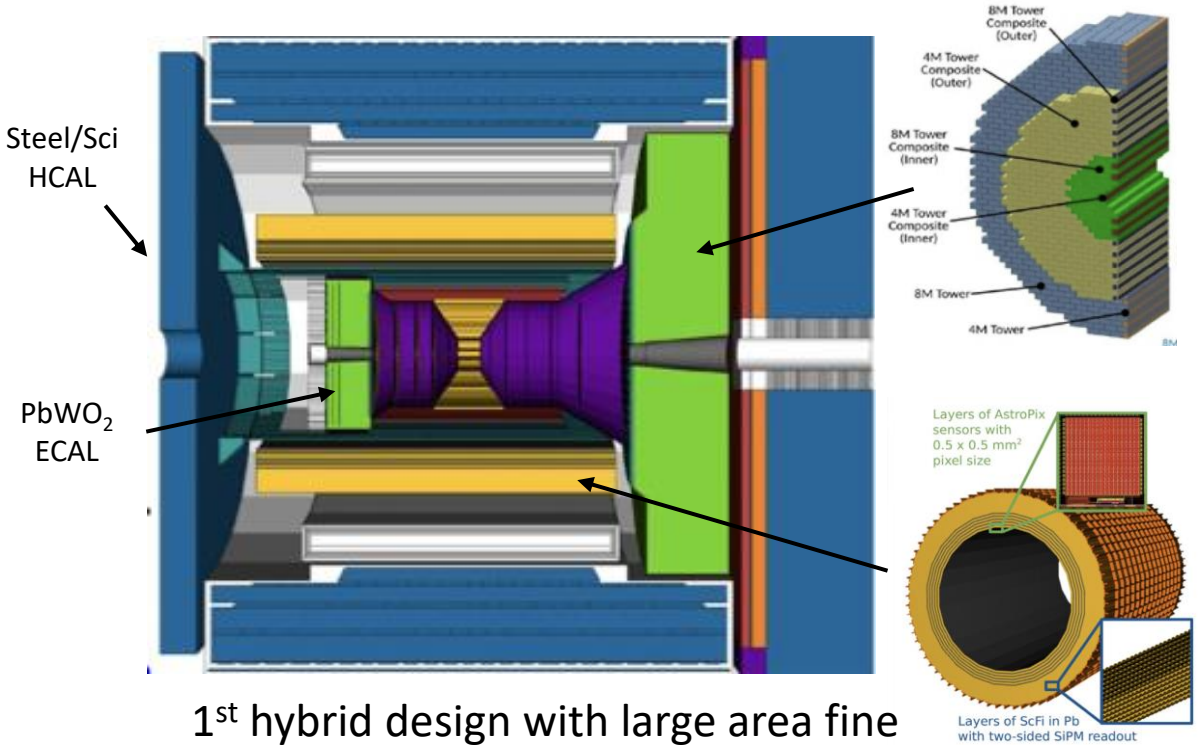
mostly driven by interest for future e-e colliders
particle flow in all concepts evolving to 5D
pre-existing communities in the 3 main class of calorimeters



new concepts digital MCMOS/RPC, opaque scint., depth seg. with prec. timing, homogenous HCAL, Quantum Dots

DRD6: Calorimetry

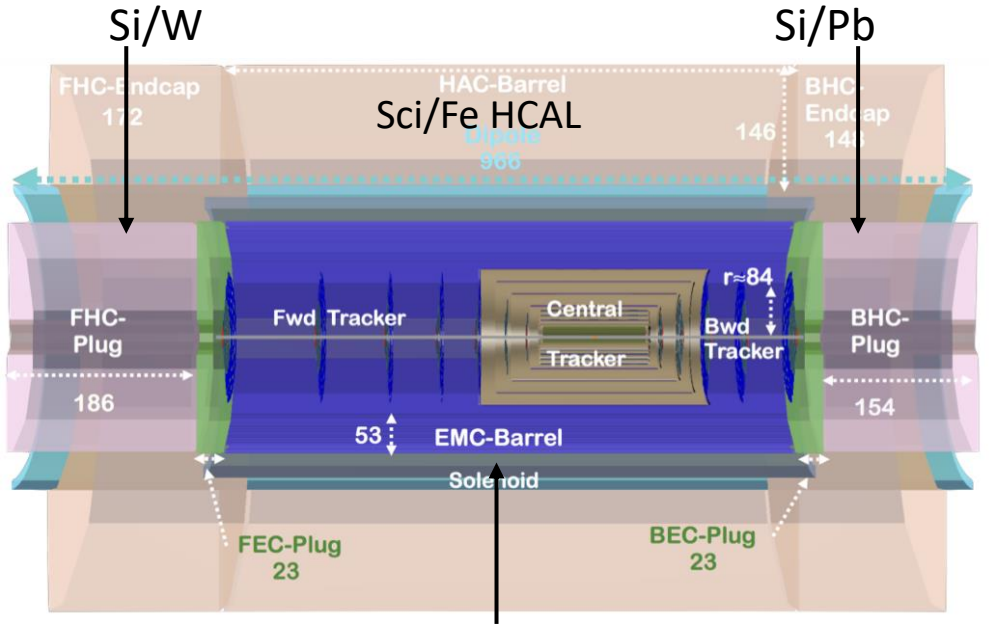
W/SciFi synergy with LHCb-2



1st hybrid design with large area fine pitch MCMOS & SciFi w/ both-end readout

https://indico.jlab.org/event/714/contributions/12568/attachments/9944/14673/The%20ePIC%20Experiment%20-%20JLUO%20Split.pdf

synergie with FCC-ee CLD concept and FCAL project for forward calorimetry (LUXE exp. in 2025-2026)



LAr EMCAL

synergy with FCC-ee ALLEGRO concept high segmentation geometry with multilayer-PCBs

LHeC

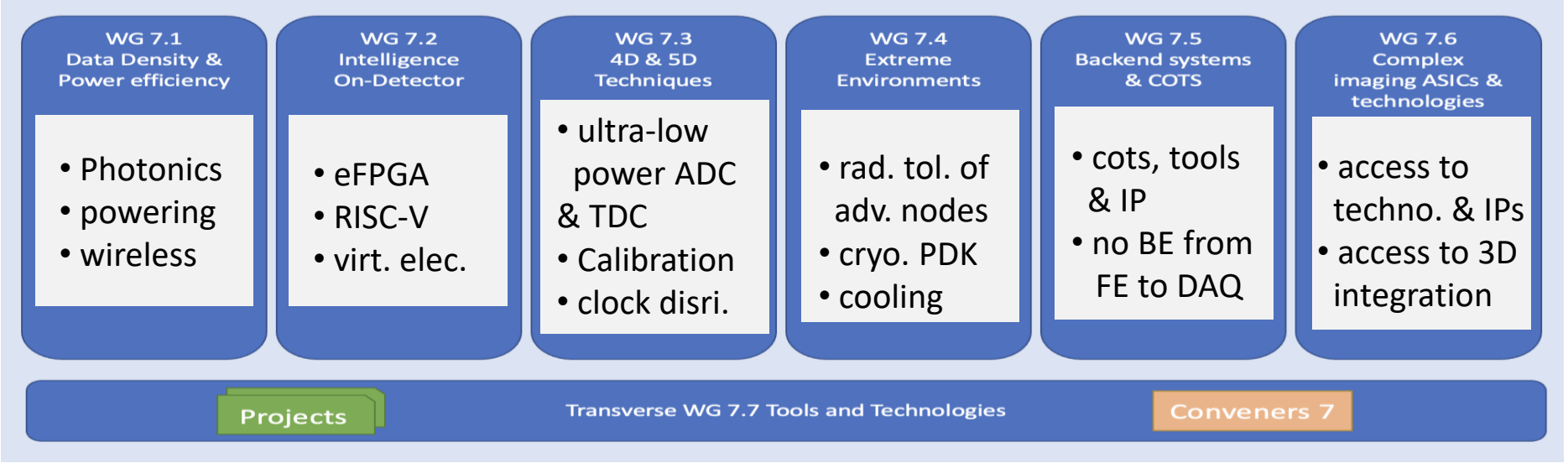
Also several developments for optical concepts with fibers/crystals implementing dual readout and/or precision timing in heterogenous or single material ex. IDEA concept for FCC-ee

DRD7 electronics systems

proposal submitted to DRDC targeting approval at June CERN RB

16 projects identified in WGs matching DRDTs of the ECFA roadmap

- advance the state-of-the-art in performance of electronics and data processing
- improve and develop further common standards, methodologies, and IP
- build expertise, increase efficiency and decrease duplication of effort
- provide facilities and tools for R&D in the community, with long-term continuity



major challenges to increasing at the same time channel density, speed for precision timing, on-detector treatment and data flow transmission at low power dissipation ultimately with high radiation tolerance

Outline

Reminder of DRD collaboration framework

General considerations on relation of strategic projects to DRD programmes

Highlights of DRD Work Packages related to e-p-A collider projects

Linking project concept needs to the DRD collaboration programmes

Linking project concept needs to the DRD collaboration programmes

- DRD contributions are through institutes
  - it is assumed that several institutes from Projects Concept Groups* are part of the DRDs
  - each institute has a representative in the DRD Collaboration Boards (decision body)
- Next step for DRDs is to prepare MoU planning of deliverable contributions & funding
  - PCGs can foster their contributions around WPs of interest (organized by DRDs to serve several projects)
- MoUs will be updated regularly (in cycles of 3-4 years)
  - based on R&D success reviewed by the DRDC and with the ECFA Detector Panel (EDP) providing input on the evolution of specifications and timelines from the Project Concept Groups
    - a first light iteration of the PCG inputs is foreseen on the timescale of initial MoUs
    - a second deeper update is foreseen for the next ESPP update (2026-2027), it can also serve to prepare the next cycle of the DRD programmes
- Simulation in PCGs are essential to identify their most critical performance parameters for R&D

The EDP will collate the PCG and community wide inputs on detector requirements
and update the specifications listed in the R&D Roadmap
The EDP is setting up a DRD managers forum to discuss common issues including theses updates

** concept groups can be collider project wide collaborations (LHeC/FCC-ee/CepC) or experiment proto-collaborations (ePIC, ILD/SiD)*

Thank you for your attention