ePIC Collaboration Technical Coordinator Report

Silvia Dalla Torre

INFN TRIESTE

Electron-Ion Collider (EIC) Resource Review Board (RRB) Meeting
3rd EIC RRB meeting, Rome, May 6-7, 2024

TC supported by the TC-office

TC-office members

Prakhar Garg
(Yale)

Oskar Hartbrich
(ORNL)

Matt Posik
(Temple U.)

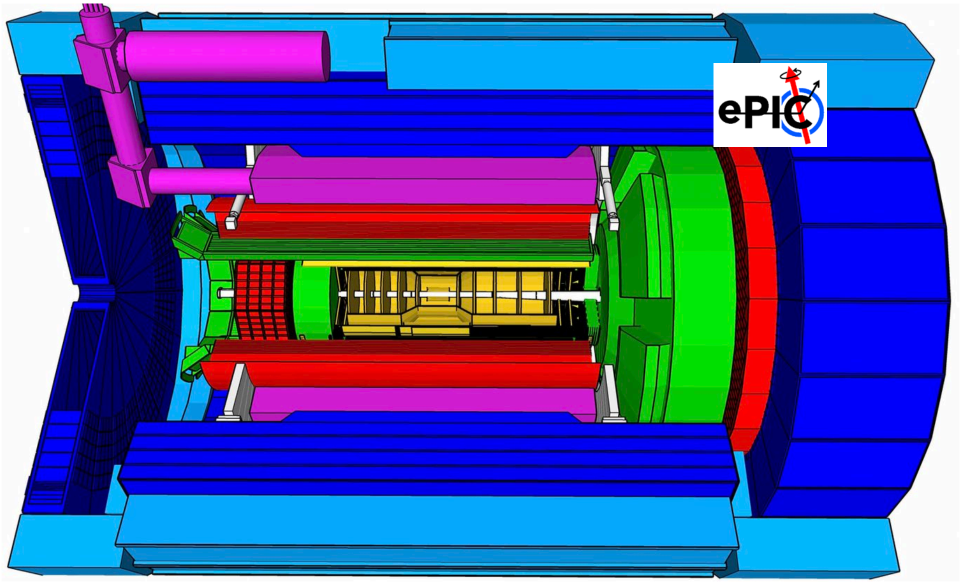
OUTLOOK

- ePIC as project detector and as ePIC Collaboration effort
- Technologies, expertise and institutions in ePIC
- The finalization of the ePIC detector design and the path to the TDR

The ePIC DETECTOR:

the combined EIC PROJECT and ePIC COLLABORATION efforts

ePIC (designed for IP6 at EIC) is the **Project Detector**



ePIC is the detector to which the **ePIC Collaboration** is dedicated

The community (Project and Collaboration) has turned the challenge arising from this dual nature of the ePIC detector into the opportunity for a highly coherent and effective effort.

There are **specific missions**:

- <u>Project</u>: ensure that all aspects related to the EIC project realization and completion are satisfied;
- <u>Collaboration</u>: optimize the physics reach of the detector and manage the Collaboration to make it functional, effectively operative and a professionally sound environment

Beyond these specificities, **Project and Collaboration are synergistically cooperating** across the two missions towards the common goal:
a detector matching the overall EIC physics scope.

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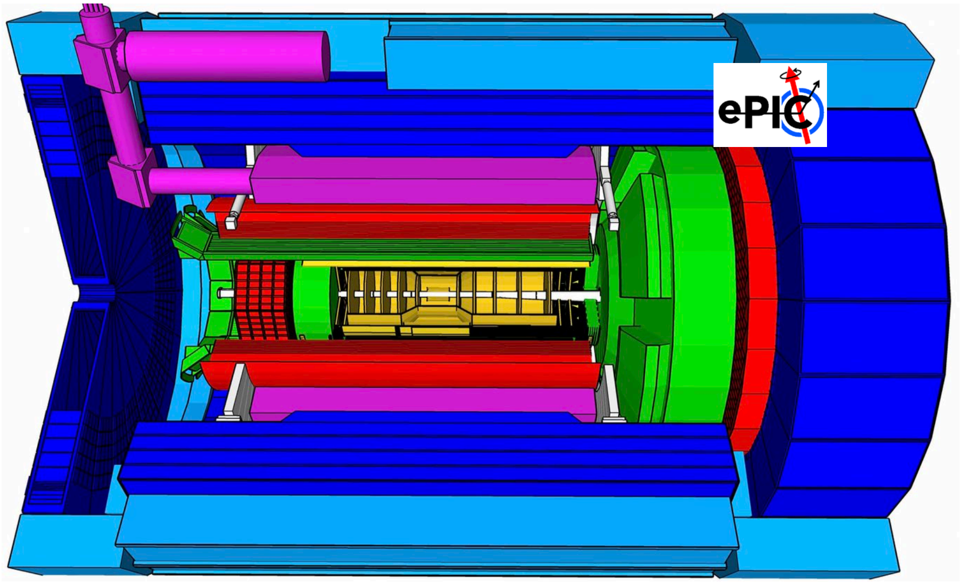

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Main topic in this report

Addressed in Spokesperson's report

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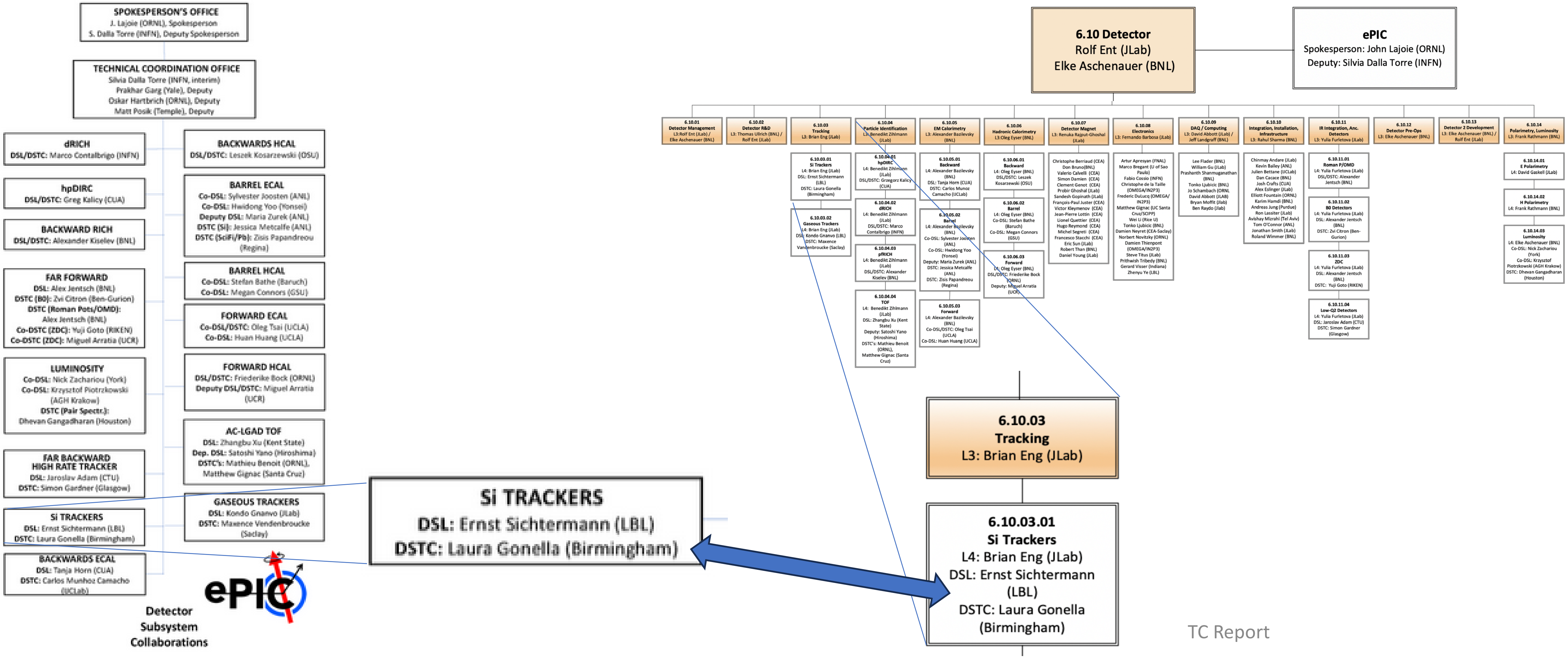
The combined EIC PROJECT and ePIC COLLABORATION efforts:

HOW?

Within ePIC, each subsystem is realized by a Detector Subsystem Collaboration, DSC (15 DSCs, in total) guided by a Leader assisted by Technical Contacts

In the Project organization, subsystems are under the responsibilty of CAMs and L4 managers – DSCs are co-responsible at L4 level



TC Report

The combined EIC PROJECT and ePIC COLLABORATION efforts:

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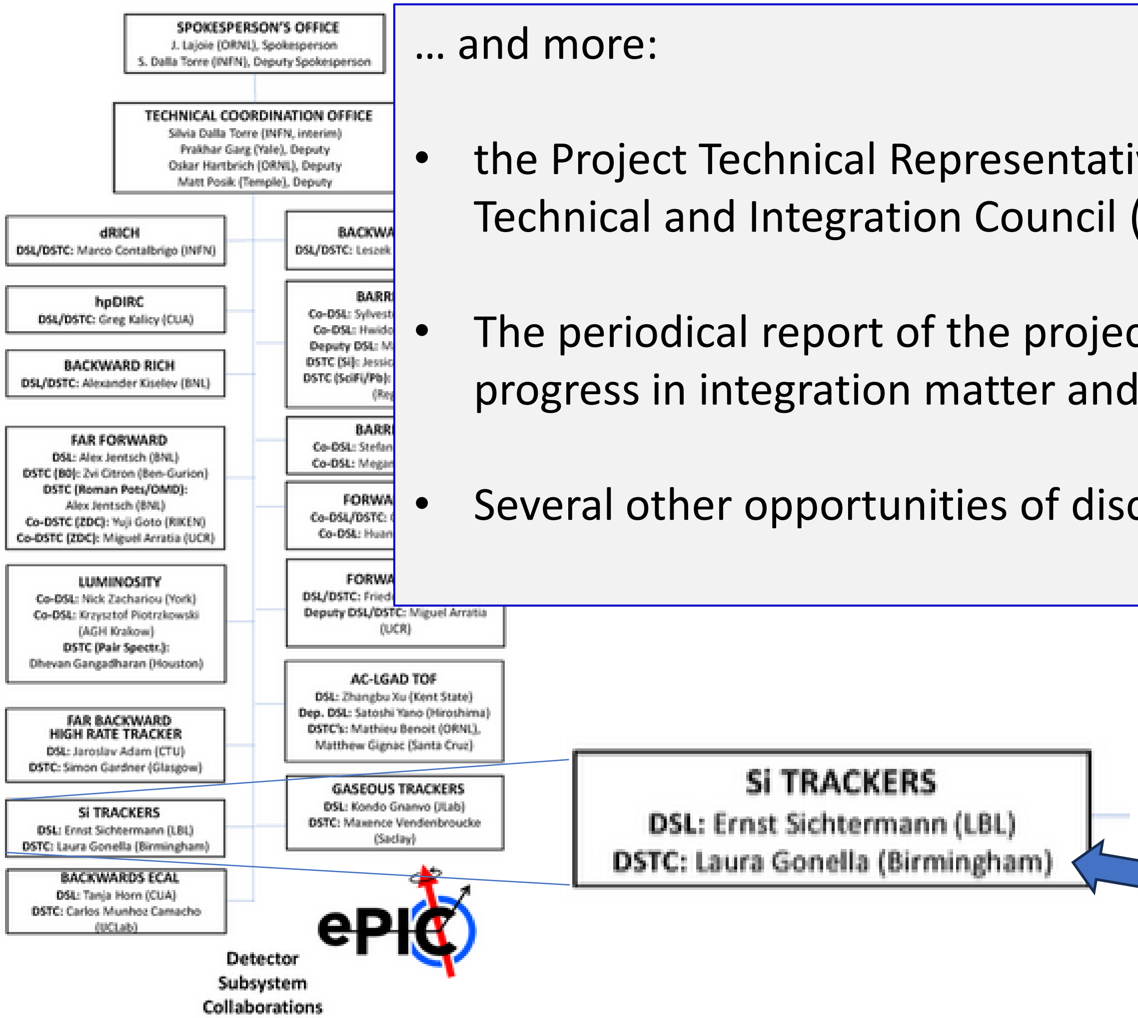
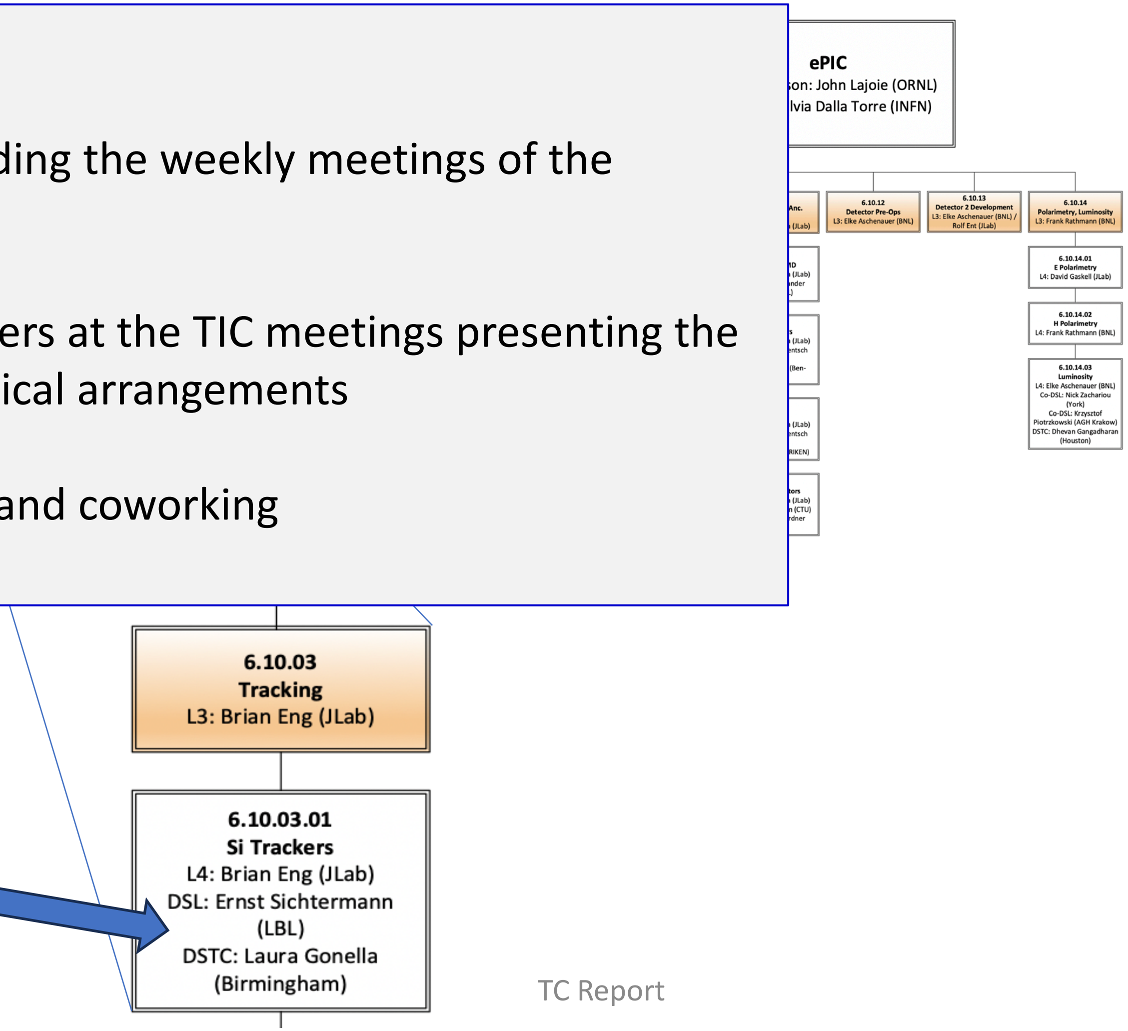


… and more:

- the Project Technical Representative attending the weekly meetings of the Technical and Integration Council (TIC)
- The periodical report of the project engineers at the TIC meetings presenting the progress in integration matter and mechanical arrangements
- Several other opportunities of discussions and coworking



OUTLOOK

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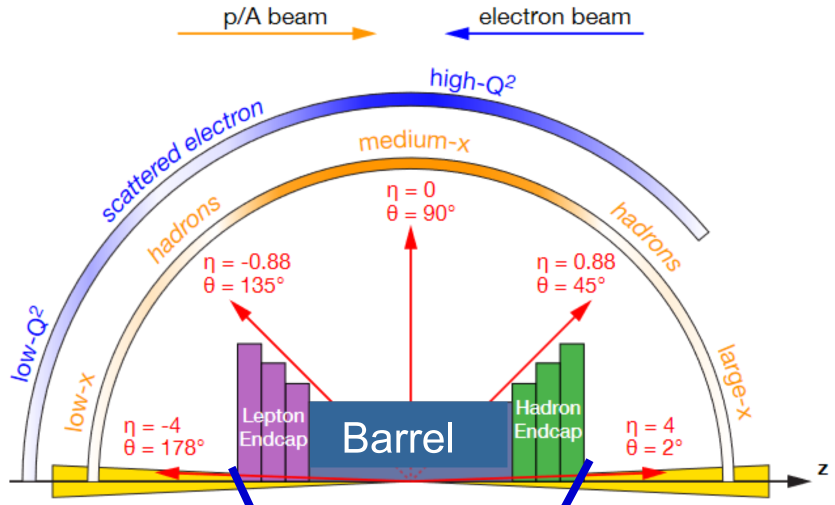
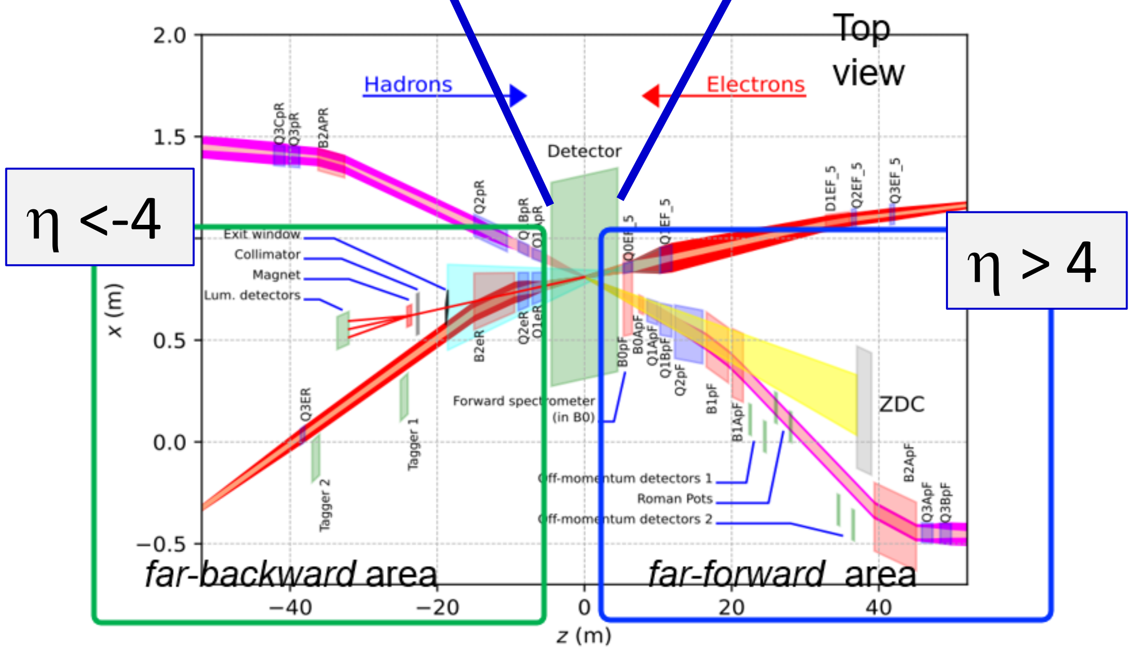
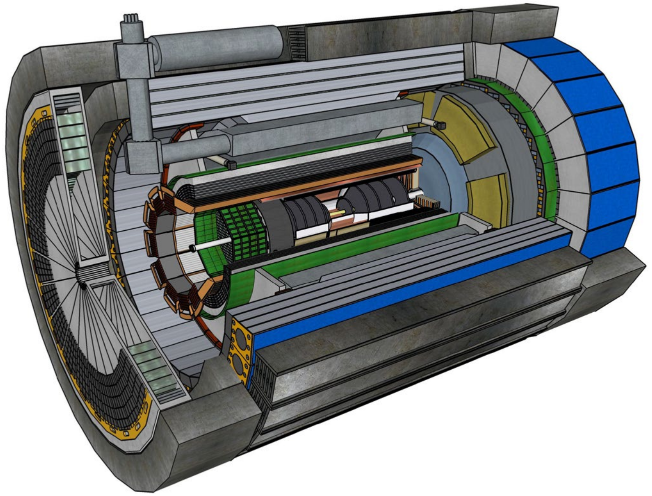
THE COMPLETE ePIC DETECTOR

A reminder





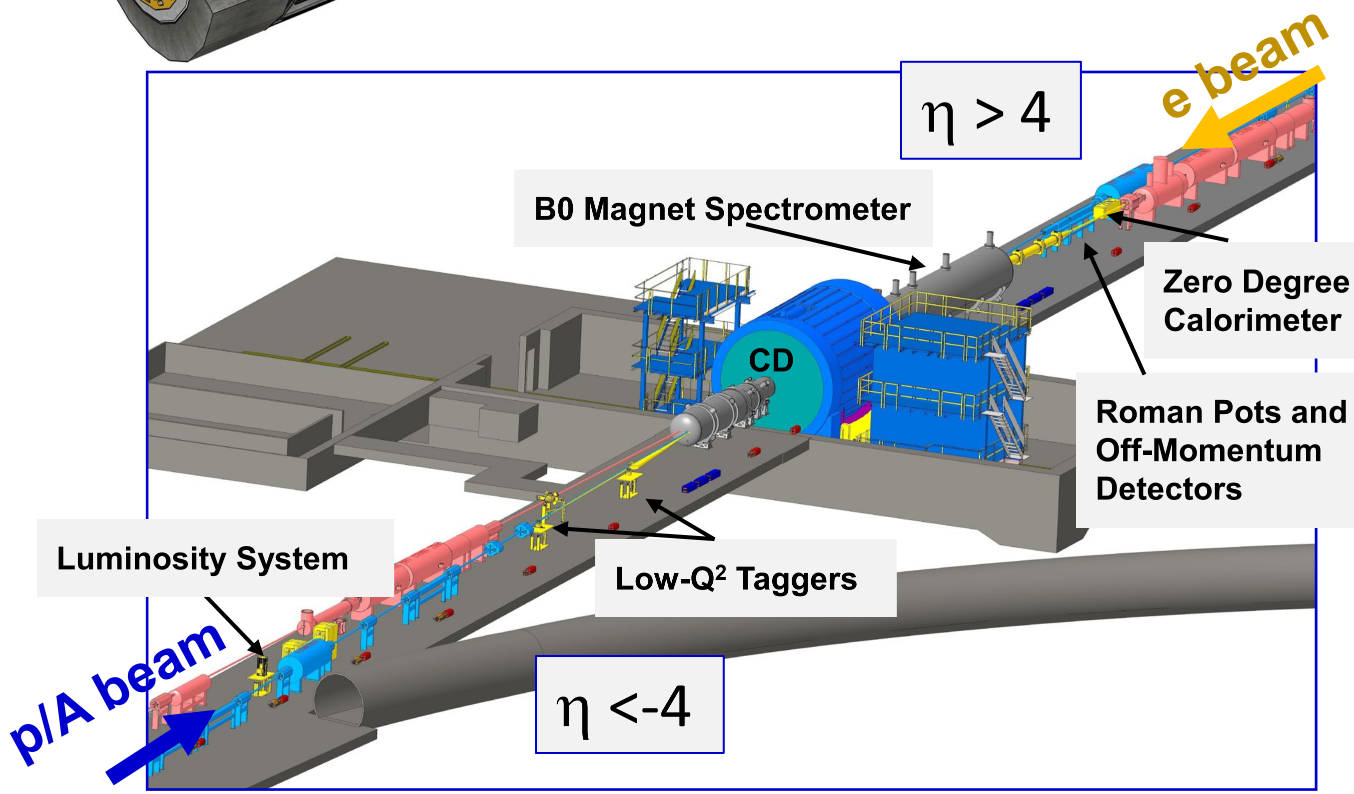


Central Detector (CD)

-4 < η < +4

Formed by:

- Backward endcap
- Barrel
- Forward endcap

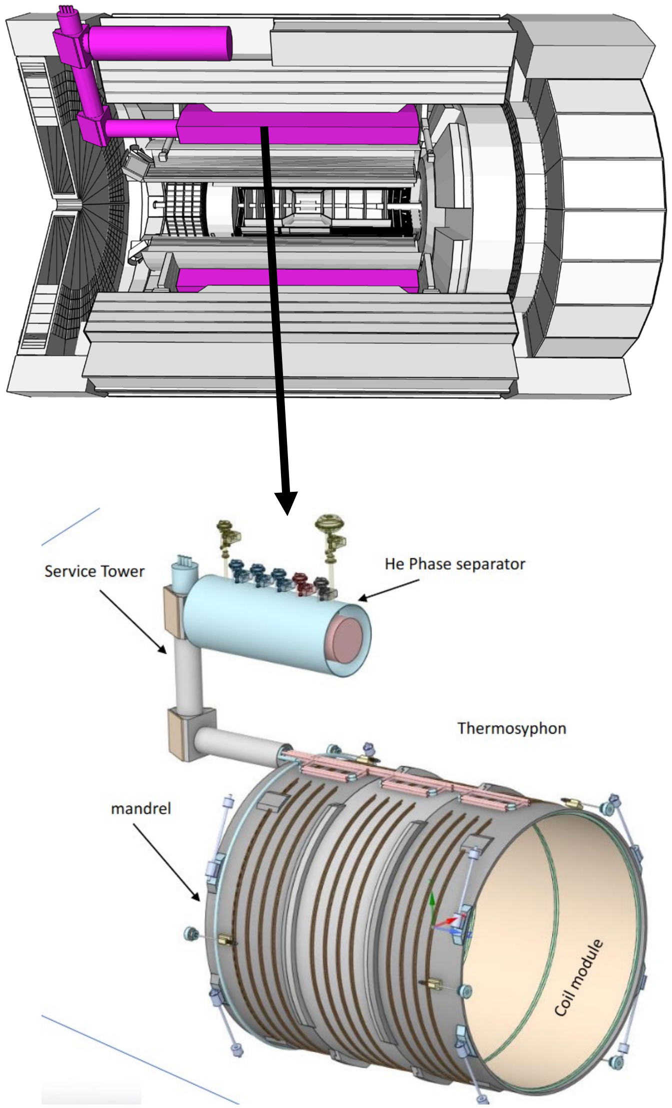


THE ePIC DETECTOR

In the following, the detector will be analyzed in term of technologies, required expertise and Institutions matching these needs

Collaborator contributions to detector subsystem efforts do not always imply established in-kind contributions

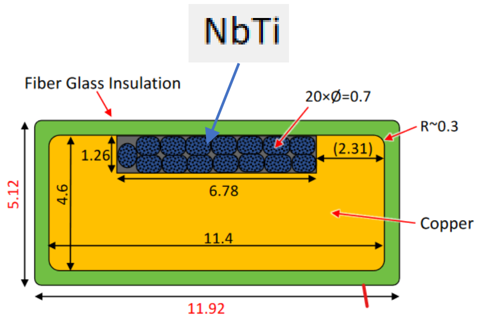
THE SOLENOID



Parameter	Value	Comment
Central Field B_0	2.0 T	
Lowest operating field	0.5 T	
Field Uniformity in FFA	12.5 % ± 100 cm around center 80 cm radius	Magnetic Field Properties
Projectivity in RICH Area	< 0.1 (mrad@30GeV/c) < 10 T/A/mm² From Z = 180 cm to 280 cm	

Reference field value: 1.7 T

Conductor Design



90% readiness review successfully passed in Fall 2023

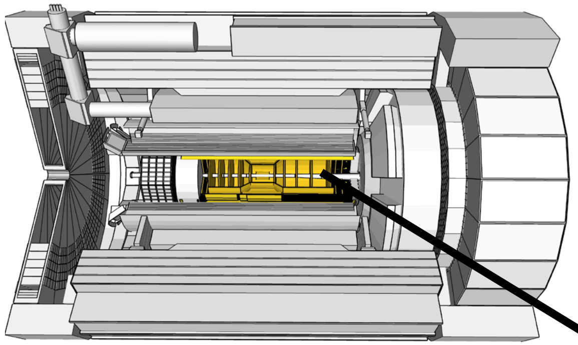
Solenoid design :

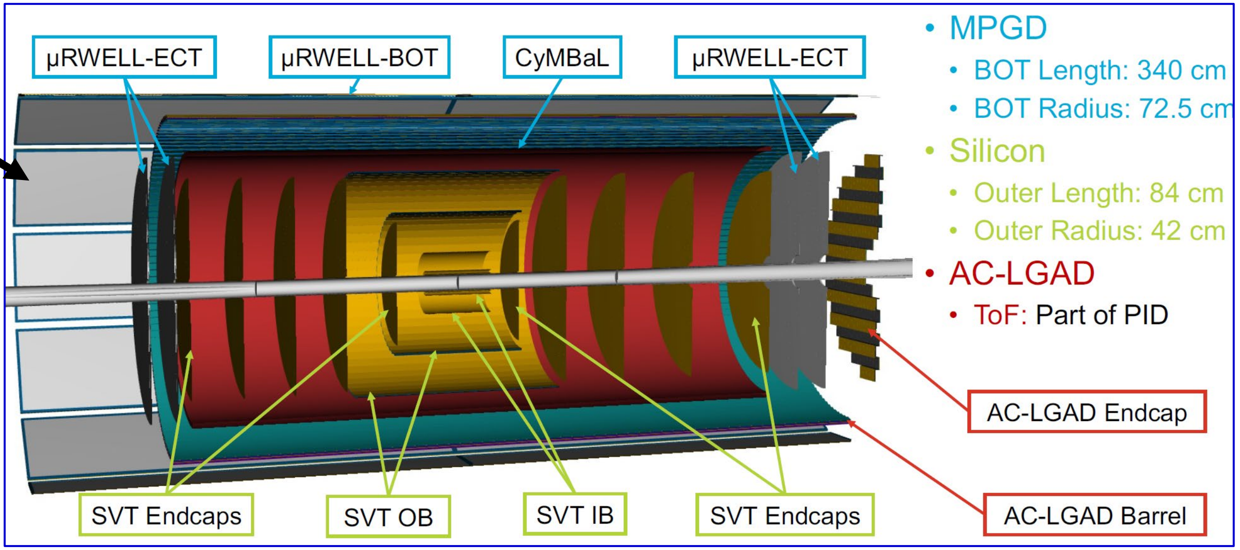
- **A combined effort Saclay – JLab – BNL**
- **groups with wide expertise in magnet design (magnets for accelerator/projects at CERN, Orsay, Jlab, BNL, …)**

Realization :

- **interest from Italy under investigation**
- **the considered Italian company realized the CMS solenoid and ~1/3 of the LHC dipoles**

TRACKING





ITS3 MAPS - NOVEL TECHNOLOGY

Co-developed by CERN and ePIC groups

- WIDE expertise in Si trackers:
- US groups: STAR, ALICE
- INFN: ALICE
- UK: ATLAS

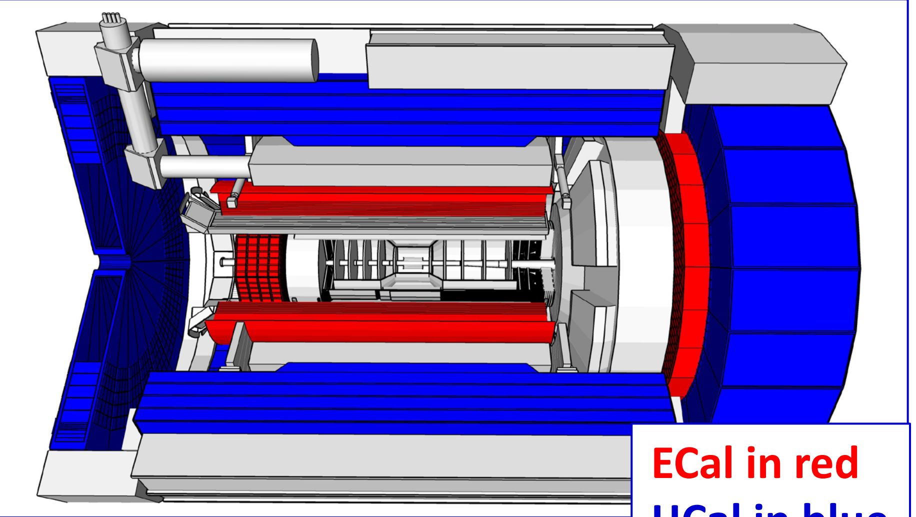
μR-WELL with GEM pre-amplification - NOVEL TECHNOLOGY

- Wide experience in MPGD thanks to several realization for experiments at Jlab, for STAR and the novel CMS Muon System
- invention of μR-WELL by INFN-Frascati assisting the INFN participants

Cylindrical MICROMEGAS CONSOLIDATED TECHNOLOGY

- realized for CLAS12 by the same CEA-SACLAY group

SENSORS for ePIC CALORIMETRY



ECal in red
HCal in blue

SiPM sensors for all Calorimeters

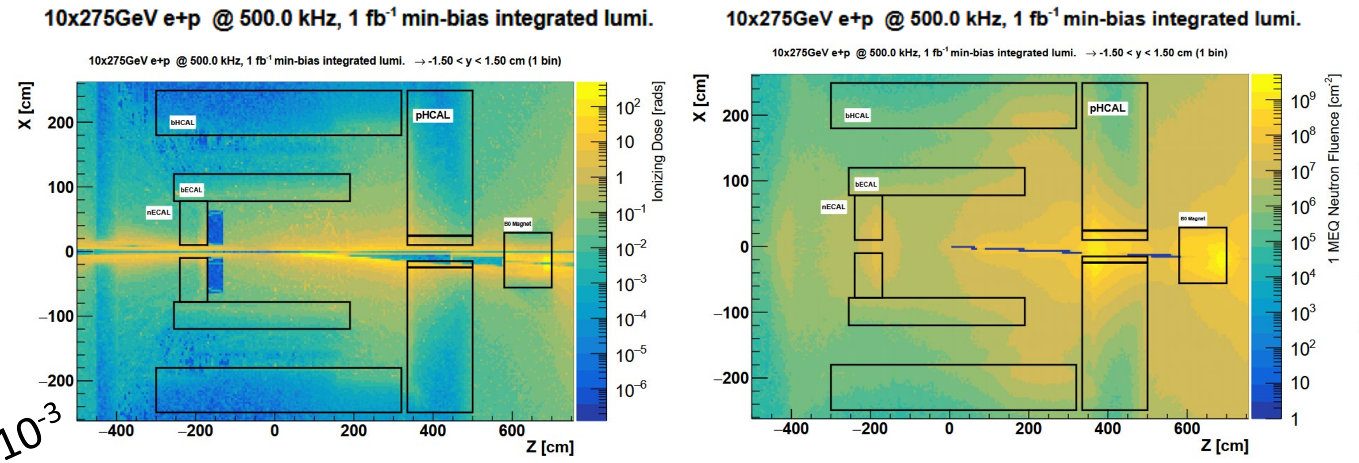
- SENSORS RECENTLY INTRODUCED IN CALORIMETRY

- direct experience is coming from the applications in GlueX, STAR and sPHENIX
- These colleagues now at work for ePIC calorimetry

SiPM features relevant for calorimetry in ePIC

- Operation in magnetic field
- Wide dynamic range
- Low noise
- Effect of the radiation
  - Not new, already addressed for STAR and sPHENIX
  - Further irradiation campaign on-going

Rad Dose and Neutron Flux

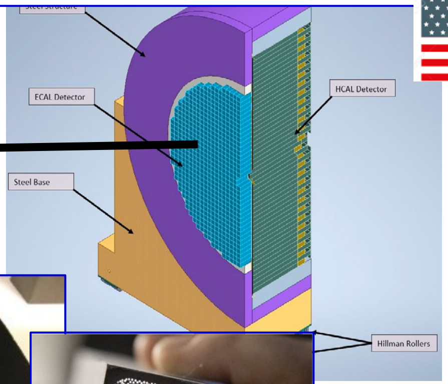


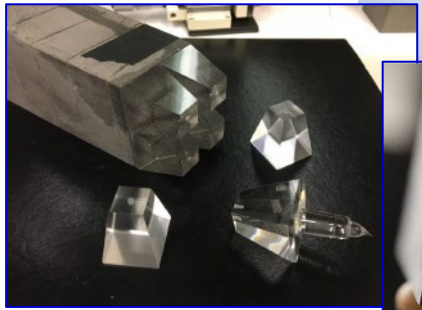
Doses and fluxes ~ 10^{-3} compared to HL-LHC

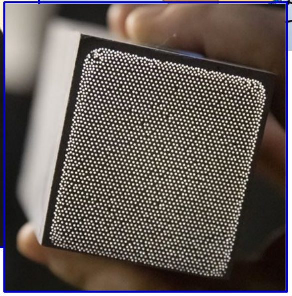
ELECTROMAGNETIC CALORIMETRY

SciFi/W - NOVEL TECHNOLOGY MOVING TOWARDS COINSOLIDATION

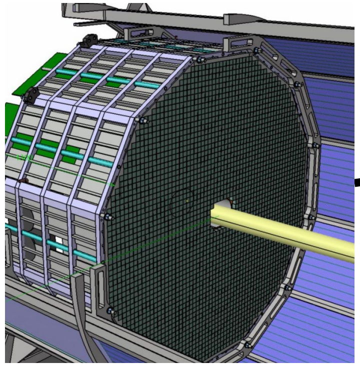
- Pioneered for EIC and already used for sPHENIX

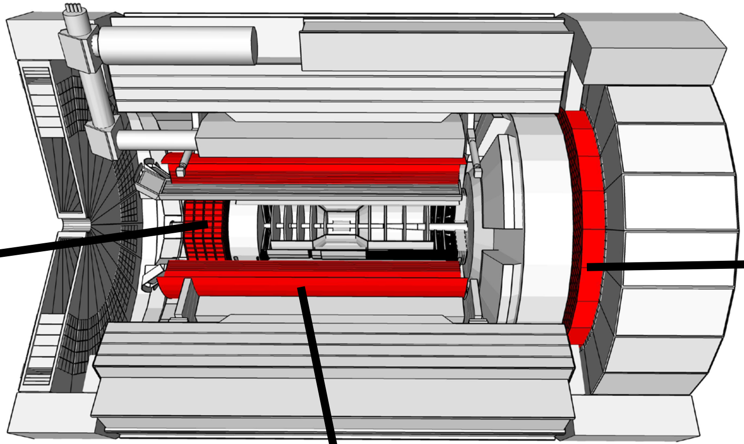


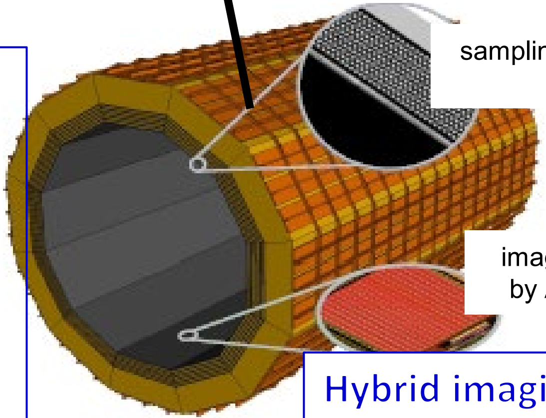




Backwards EMCal
PbW04 crystals, fine granularity







$PbWO_4$ crystals - WIDELY CONSOLIDATED TECHNOLOGY

- *Adopted for NPS, FCAL, CMS, PANDA*
- <u>Novel challenge</u>: preserving the exceptional resolution adopting SiPM sensors
- Effort by a strong collaboration with calorimeter expertise including US institutions, CNRS, groups from Czech R. and Armenia

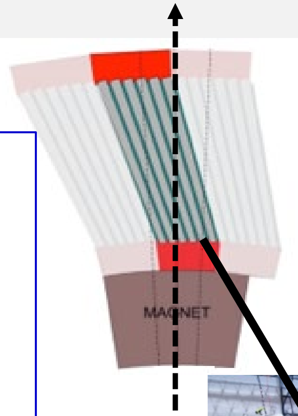
Hybrid imaging calorimetry - INNOVATIVE ARCHITECTURE BY CONSOLIDATED INGREDIENTS

- imaging calorimetry developed at CERN
- Imaging by ASTROPIX MAPS (for NASA AMEGO-X mission, NASA collaborators), following ATLASPIX
- Pb/SciFi sampling calorimetry established at GlueX
- Strong collaboration including complementary competences by US, Canada, Korea and Germany groups

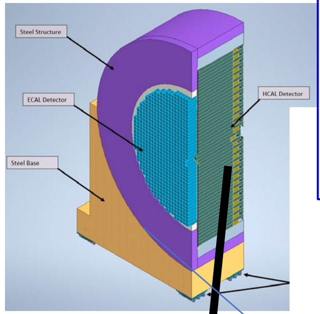
HADRONIC CALORIMETRY

Steel/scintillator sampling calorimetry - CONSOLIDATED TECHNOLOGY –

- Identification of neutral hadron jets, especially at low x
- Tail catcher for e/m calorimeter
- μ identification

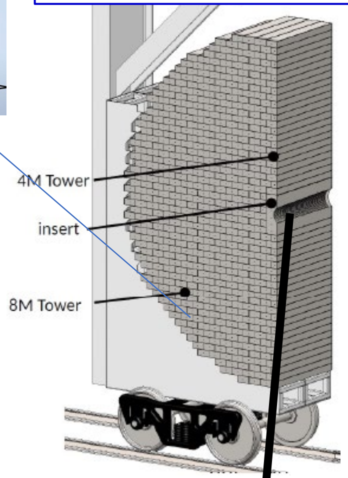


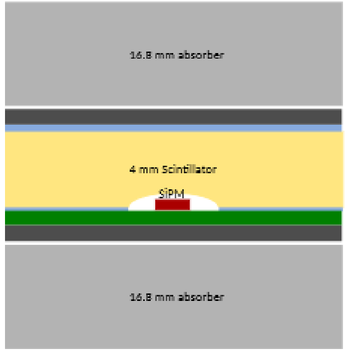
Barrel Hcal
(re-use from sPHENIX)



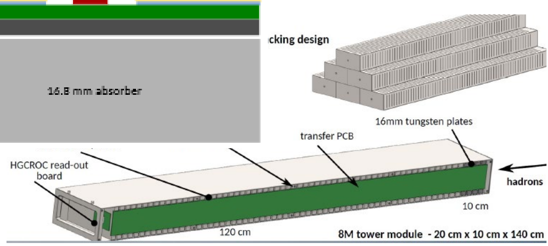
INNOVATIVE ORIGINAL DESIGN

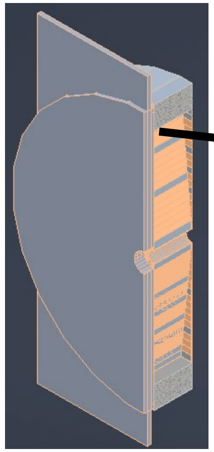
- inspired by CALICE developments adopted by ePIC by a strong US collaboration
- A Hungarian group with wide expertise in QA of large SiPM sets

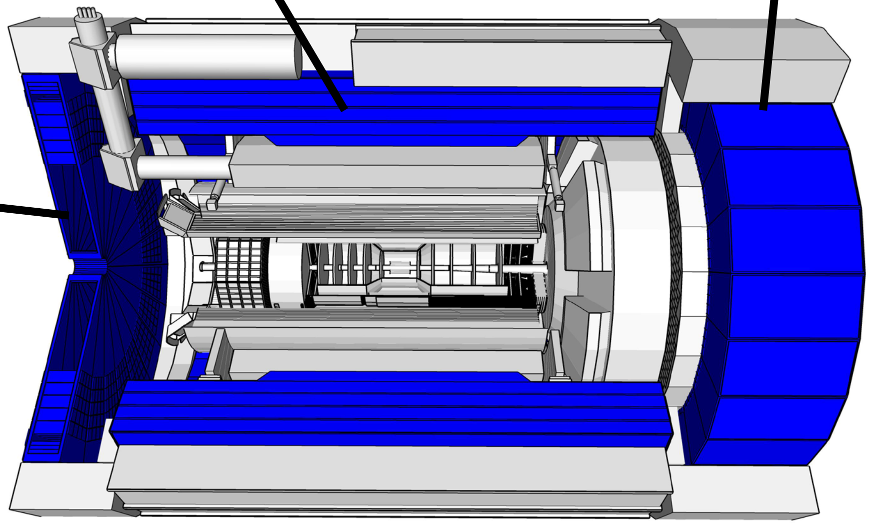




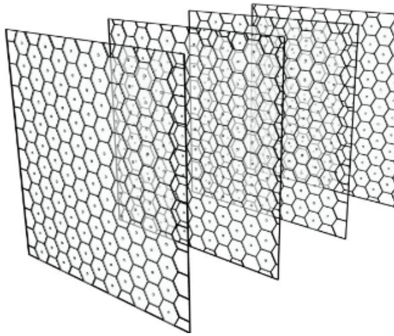
Forward Hcal
SiPM on tile



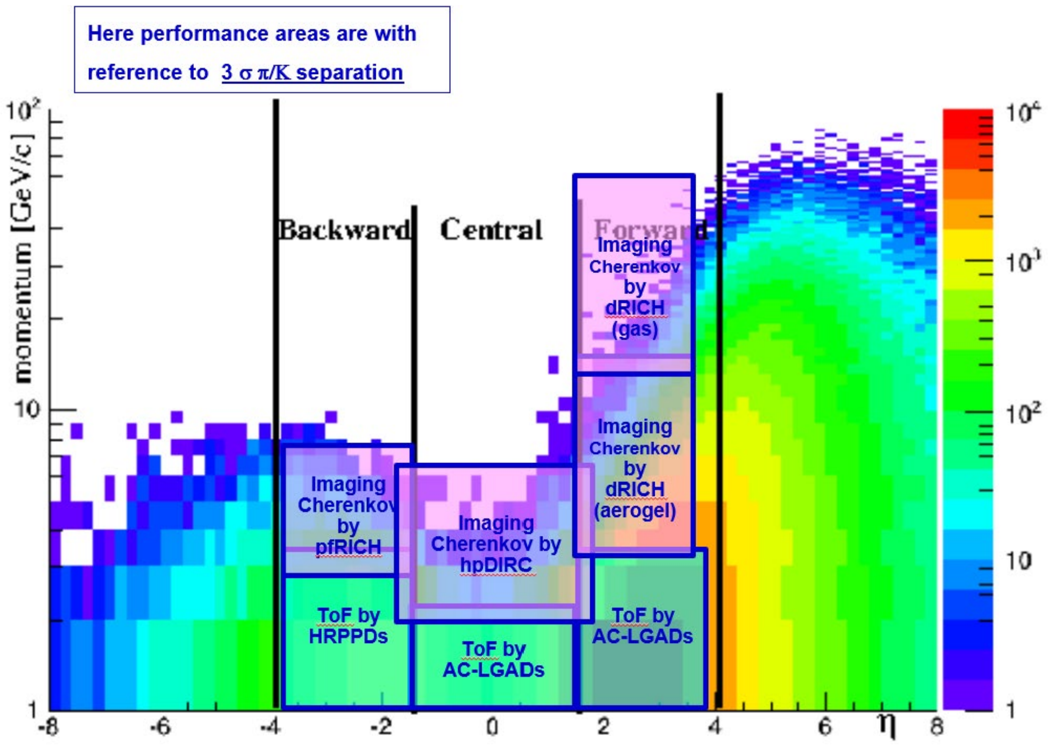


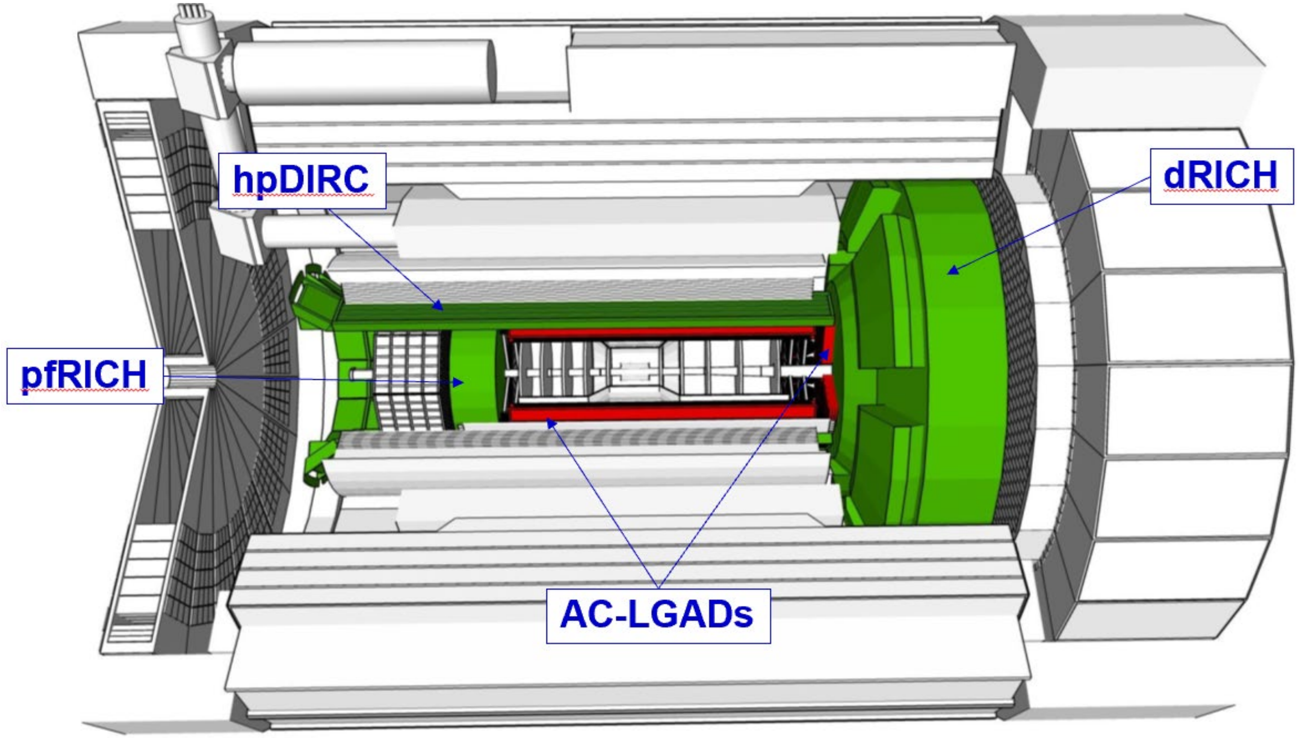


INSERT by the same technology with finer granularity at high η



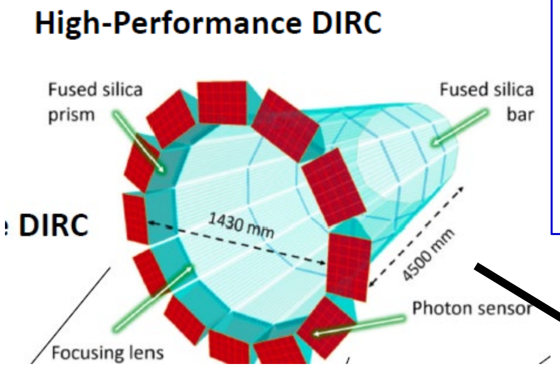
PARTICLE IDENTIFICATION - by Cherenkov imaging





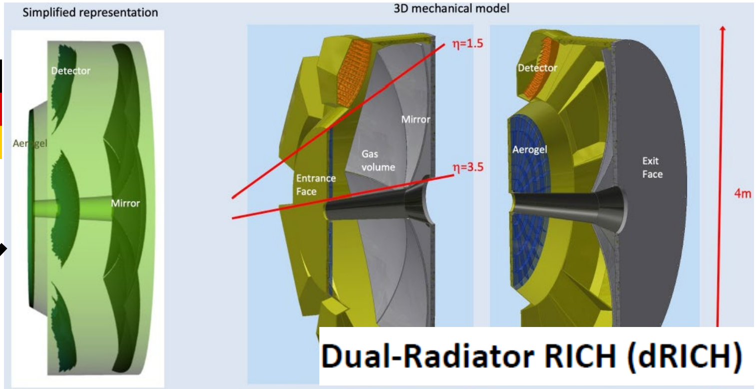
PARTICLE IDENTIFICATION - Cherenkov Imaging

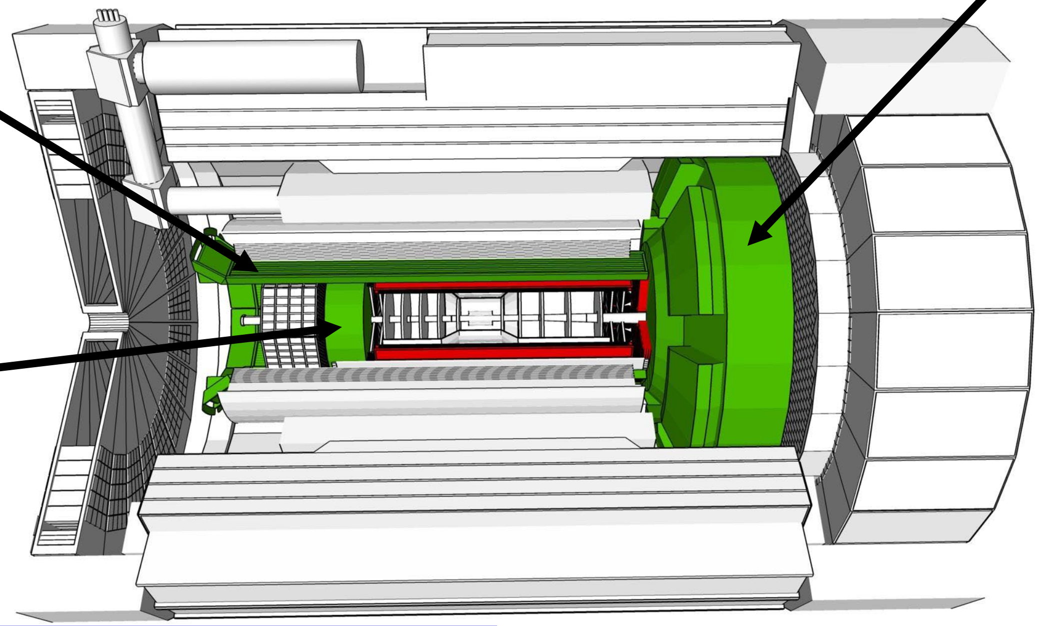
Single photon sensors: SiPMs

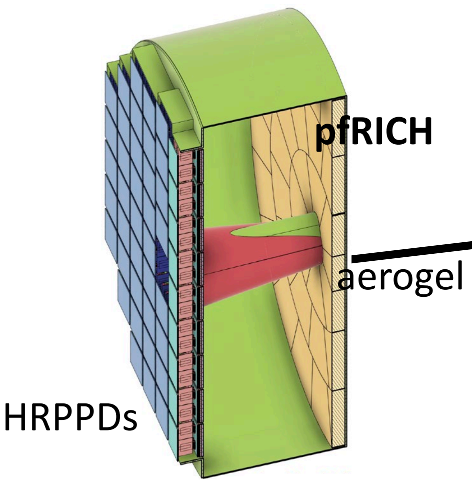


hpDIRC – EVOLUTION OF A CONSOLIDTED TECHNOLOGY

- Constant evolution of the BaBar DIRC concept: focusing DIRC (J. Va'vra), PANDA DIRC, BELLE II TOP
- US and German Collaborators (from BaBar and PANDA experience); JLab support







Dual radiator RICH - CONSOLIDATED TECHNOLOGY

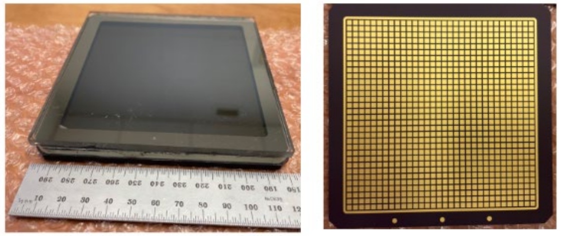
- 3rd world-wide example of dual radiator RICH by ePIC (following HERMES, LHCb)
- developed over more than 10y by 10 INFN groups with wide experience in RICHes (ALICE, COMPASS, HERMES, CLAS12), recent addition of US and India institutions

Proximity focusing RICH - CONSOLIDATED TECHNOLOGY

- Several preceding examples (ALICE, CLAS12, BELLE II)
- Longer proximitry gap for increased resolution
- by ePIC groups in US, Italy and Japan

SINGLE PHOTON SENSORS FOR CHERENKOV IMAGING at ePIC

HRPPDs: Large-size MCP-PMTs by INCOM for the pfRICH



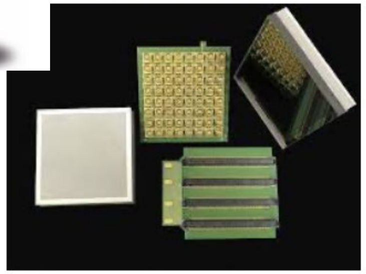
DC-coupled HRPPDs by Incom Inc.

HRPPDs: Large-size MCP-PMTs by INCOM – NOVEL TECHNOLOGY

- Engineering contribution by ePIC
- Establishing LAPPDs/HRPPDs as devices for RICHes
- Establishing LAPPDs/HRPPDs adequate for ToF measurement
- cooperating with industry
- by US (wide detector experience) and Italy (specific single photon detection experience) groups

PHOTONIS XP85122-S

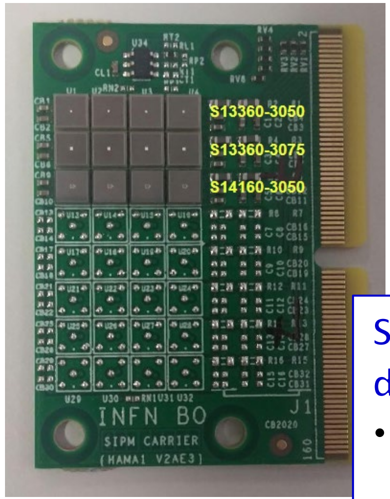
Photek MAPMT 253



Commercial MCP-PMTs (Photonis/Photek) for the hpDIRC

Commercial MCP-PMTs – NOVEL APPROCH

- So far, commercial MCP-PMTs (by Hamamatsu) only used in BELLE II TOP
  - Performance in coupling with sensors from different companies to be established

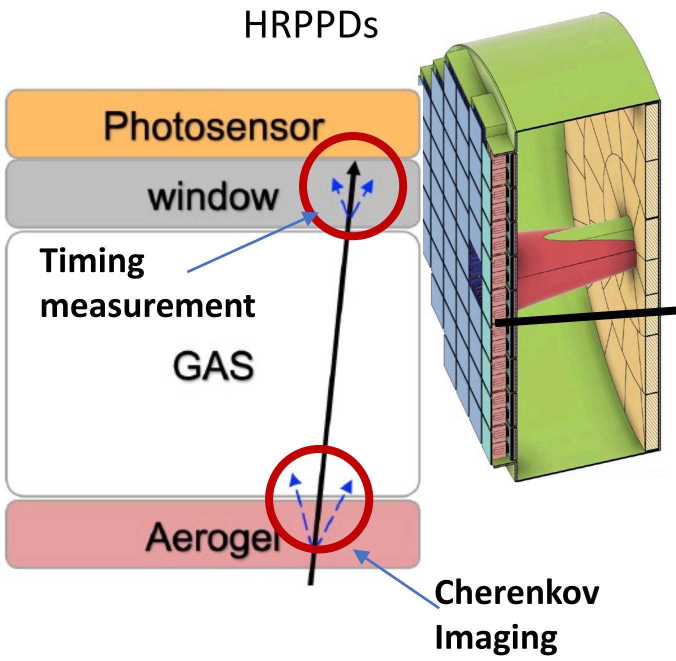


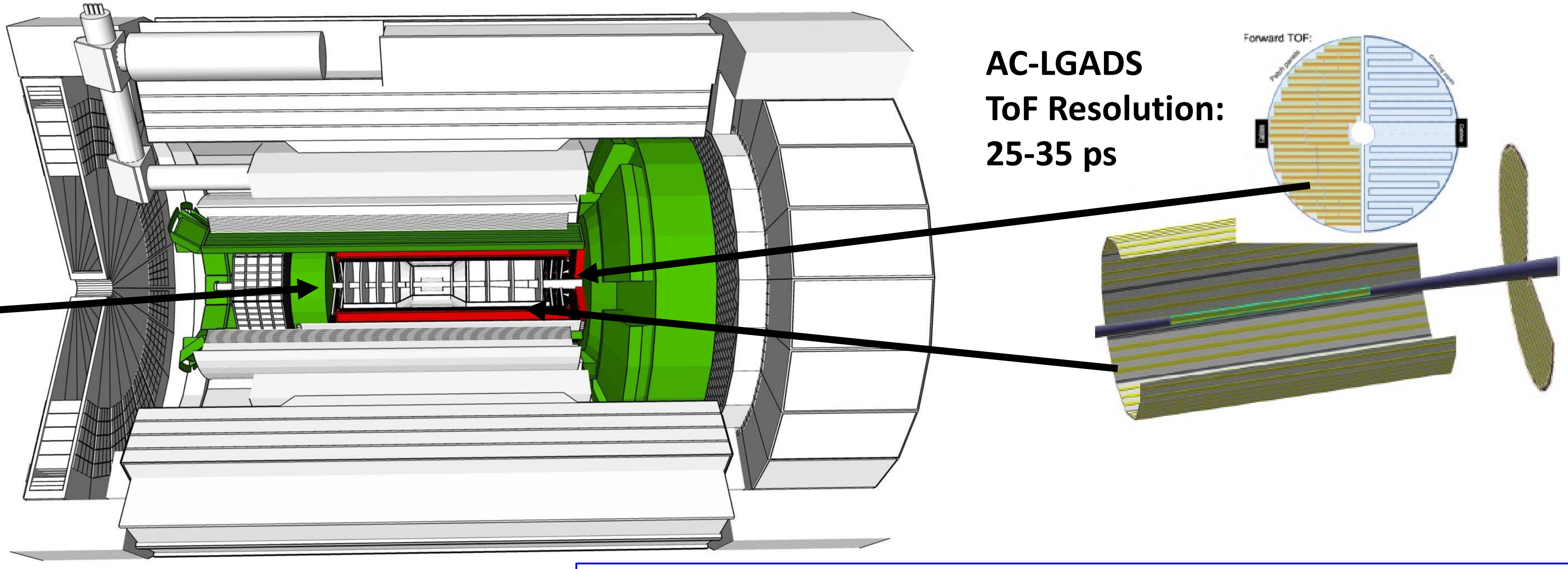
SiPMs as single photon detectors for the dRICH

SiPMs as single photon detectors for the dRICH - NOVEL APPROCH

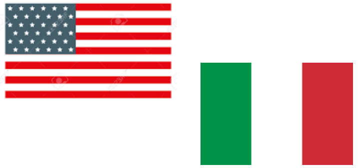
- Never used so far for RICHes in experiments (dark-count rate)
- Robust R&D with ePIC (5 INFN groups) including thermal annealing of radiation damage

PARTICLE IDENTIFICATION by ToF



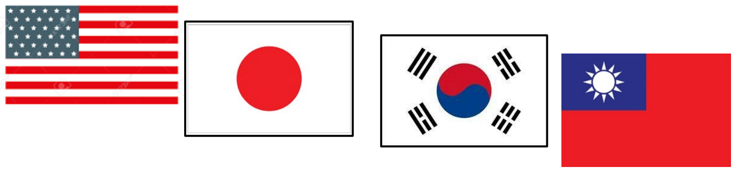


HRPPDs as timing device – NOVEL TECHNOLOGY



AC-LGADs – NOVEL TECHNOLOGY

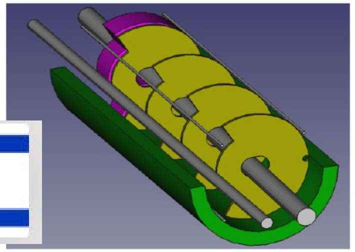
- LGADs well established
- A Si-based time-of-flight system from the joint effort of groups from US, Japan, Korea and Taiwan with major expertise in silicon sensors



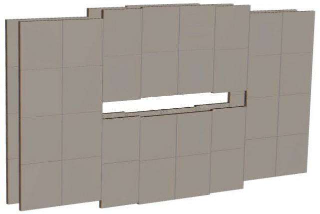
Far-forward

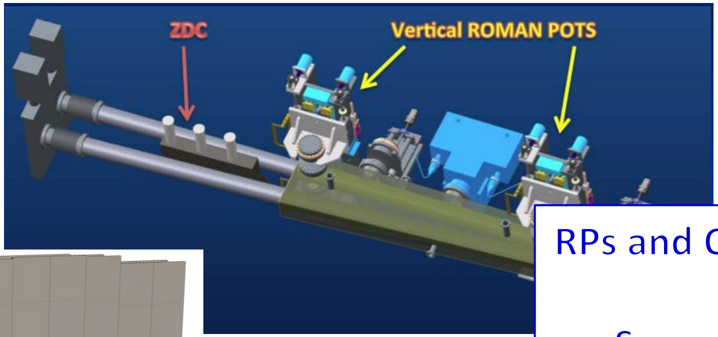
B0 trackers with AC-LGADS
B0 calorimetry by crystals

- TRACKING - Synergies with forward ToF
- CALORIMETRY - Synergy with backward ECal and ZDC



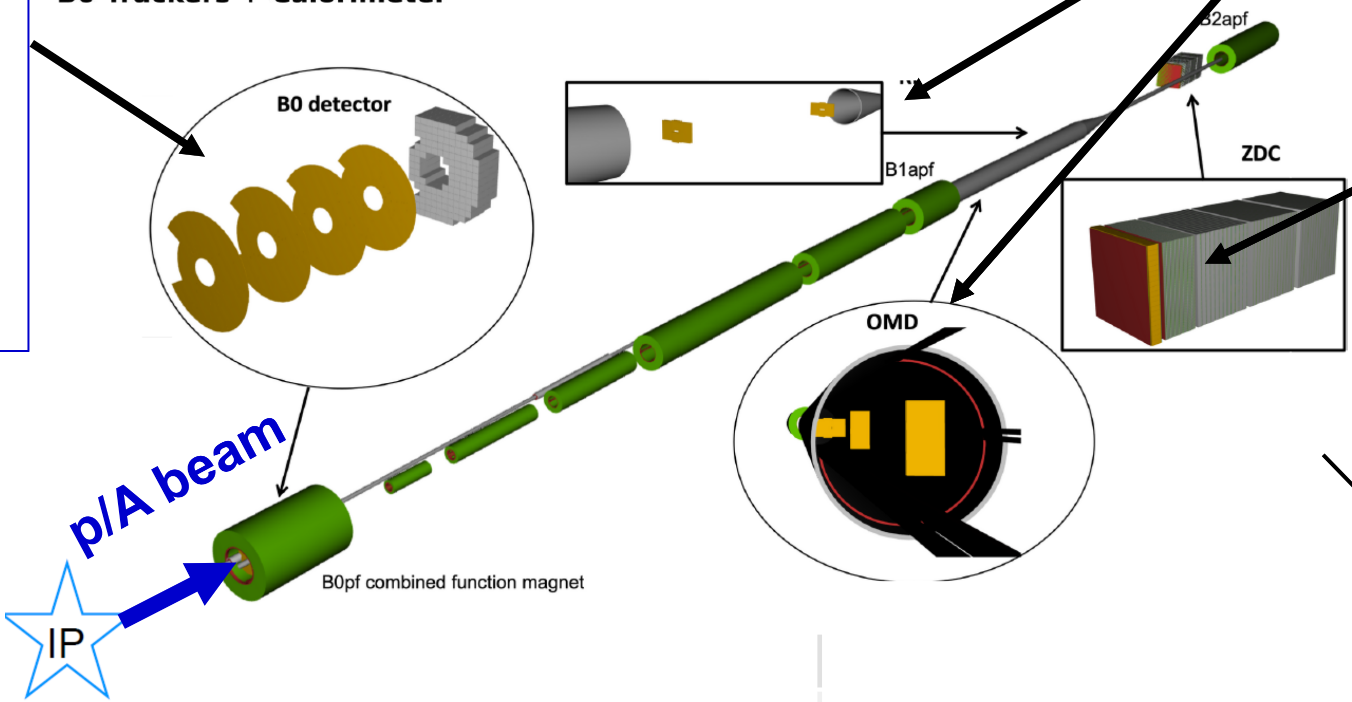
B0 Trackers + Calorimeter

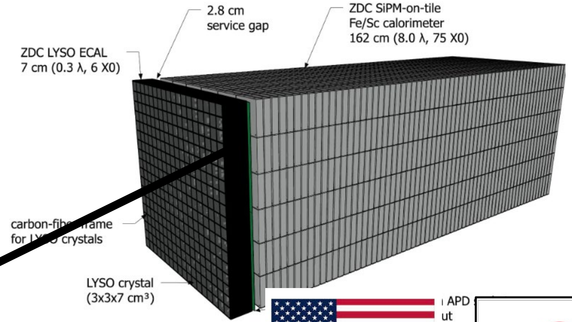




RPs and OMDs by pixelized AC-LGADs

- Synergies with forward ToF





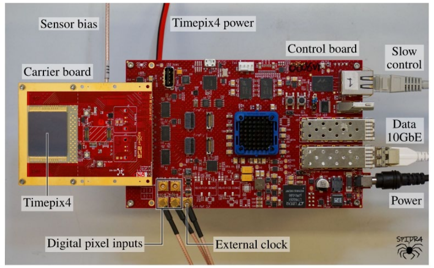
ZDC by crystals and SiPM-on-tile

- ECal - Synergy with backward ECal and B0 calorimetry
- HCal – Synergies with forward ECal insert

Far-backward

Low Q2 taggers
Tracking – Timepix4 Hybrid (ASIC+Si) – FRONTIER APPLICATION
Calorimetry – SciFi's

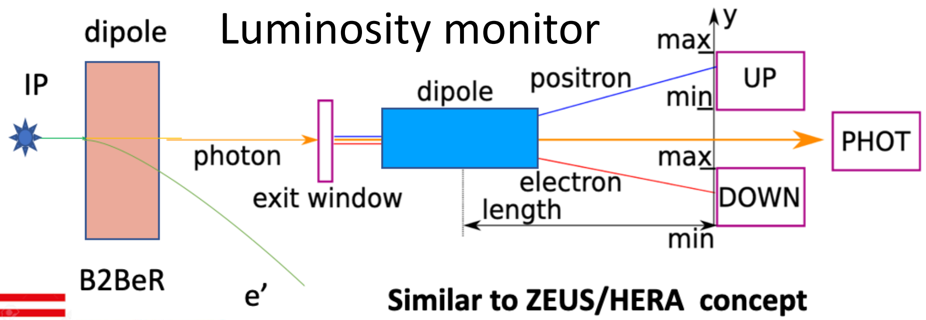
- Timepix4 – wide experience accumulated with the different timepix versions

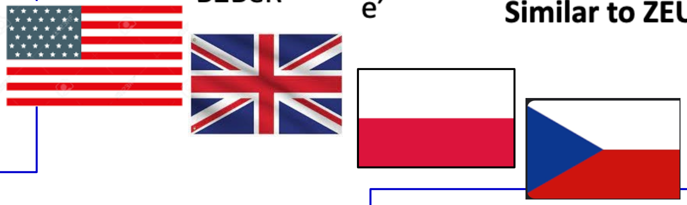


- CALORIMETRY - Synergy with forward ECal

Luminosity – high rate calorimeter – CONSOLIDATED TECHNOLOGIES

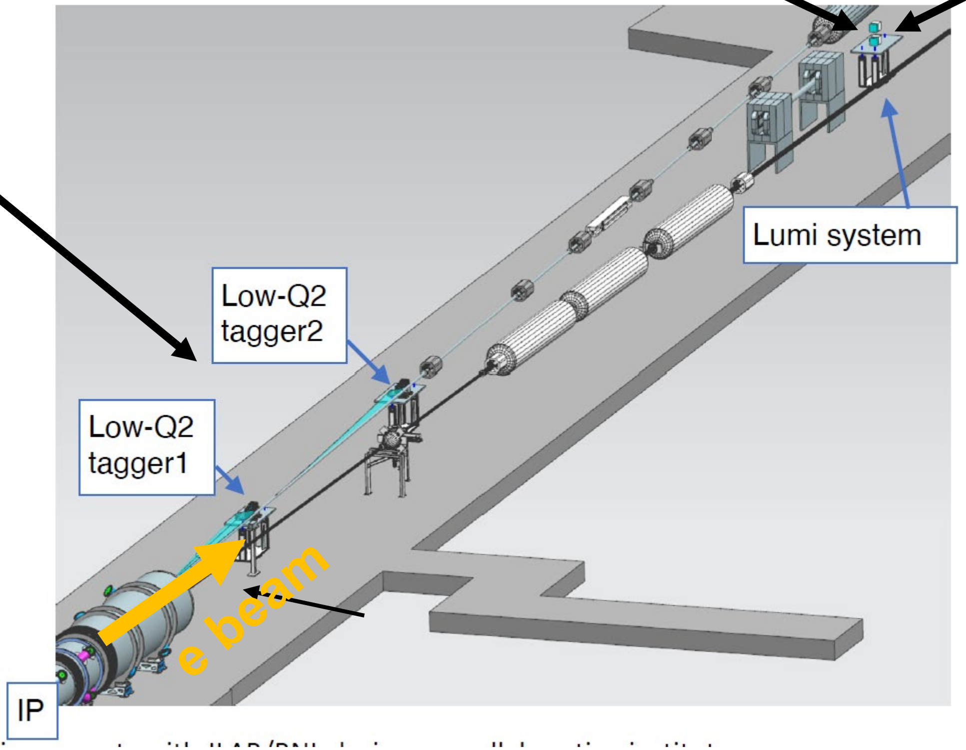
- W-SCiFi – synergies with forward ECal
- Cu-QFi





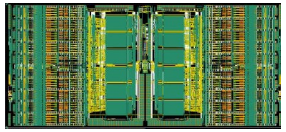
LUMINOSITY – pair spectrometers

- TRACKING – AC-LGAD strips
  Synergies with barrel ToF
- CALORIMETRY – W-SciFi -
  Synergy with farward ECal



FEE ASICs for the ePIC SENSORS

H2GCROC/CALOROC (IN2P3/OMEGA/IJCLAB, LLR, ORNL)

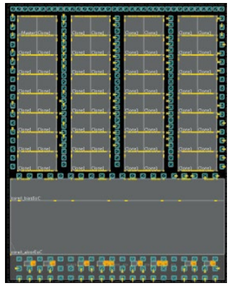


- For all calorimeter SiPMs in ePIC
  - Discreate component approach still under consideration for the backward ECal
- An option for the hpDIRC and the pfRICH (MCP-PMTs)

SALSA (U. of São Paulo, CEA/IRFU)

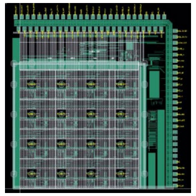
- Cylindrical MICROMEGAS
- μR-WELL

ALCOR (INFN-TORINO)



- dRICH SiPMs

EICROC (IN2P3/OMEGA/IJCLAB, BNL, CEA/IRFU)



- Pixelized AC-LGAD (RP, OMD, fToF)

FCFD (FNAL)

- Strip AC-LGAD (ToF, luminosity PS)
- Option for the hpDIRC and the pfRICH (MCP-PMTs)

OUTLOOK

- ePIC as project detector and as ePIC Collaboration effort
- Technologies, expertise and institutions in ePIC
- The finalization of the ePIC detector design and the path to the TDR

Technical Design Report (TDR) – Detector, the needs

From the Project Management talk, ePIC Meeting, Warsaw, July 2023

Chapter 2: Physics Goals and Requirements *(should be short, < 50 pages)*
- 2.1 EIC Context and History (like CDR 2.2 or YR section 1)
- 2.2 The Science Goals of the EIC and the Machine Parameters (like CDR 2.3)
- 2.3 The EIC Science (follow YR structure)
- 2.4 Scientific Requirements

Chapter 3: Interaction Region 6 Overview (Elke/Rolf contributing)

Chapter 8: Experimental Systems *(can be long such that we can use as standalone detector TDR)*
- 8.1 Experimental Equipment Requirements Summary (like CDR 8.2)
- 8.2 General Detector Considerations and Operations Challenges (YR 10, CDR 8.3)
- 8.3 EIC Detector
- 8.4 Detector R&D Summary
- 8.5 Detector Integration
- 8.6 Detector Commissioning and Pre-Operations

Chapter 11: Commissioning (Elke/Rolf contributing)

Appendix-B: Integration of a Second Experiment (mainly emphasizing feasibility, luminosity sharing, polarization with two experiments, and first-order checks of magnets/acceptance)

ePIC TDR engagement — Chapter structure

CHAPTER 2

2 Physics Goals and Requirements
- 2.1 EIC Context and History . . . .
- 2.2 The Science Goals of the EIC and the Machine Parameters. . . .
- 2.3 Scientific Requirements . . . .
  - 2.3.1 Systematic Uncertainties . . . .
  - 2.3.2 Radiative Corrections . . . .
- 2.4 The EIC Science (ePIC performance for key observables) . . . .
  - 2.4.1 Origin of Nucleon Mass . . . .
  - 2.4.2 Origin of Nucleon Spin . . . .
  - 2.4.3 Multi-Dimensional Imaging of the Nucleon . . . .
    - 2.4.3.1 Imaging in Momentum Space . . . .
    - 2.4.3.2 Imaging in Transverse Position Space . . . .
  - 2.4.4 Properties of Nuclear Matter . . . .
    - 2.4.4.1 Gluon Saturation . . . .
    - 2.4.4.2 Nuclear Modifications of Parton Distribution Functior
    - 2.4.4.3 Passage of Color Charge Through Cold QCD Matter .

CHAPTER 8

8 Experimental Systems
- 8.1 Experimental Equipment Requirements Summary . . . .
- 8.2 General Detector Considerations and Operations Challenges . . .
  - 8.2.1 General Design Considerations . . . .
  - 8.2.2 Backgrounds and Rates . . . .
  - 8.2.3 Radiation Level . . . .
- 8.3 The ePIC Detector . . . .
  - 8.3.1 Introduction . . . .
  - 8.3.2 Magnet . . . .
  - 8.3.3 Tracking . . . .
  - 8.3.4 Particle Identification . . . .
  - 8.3.5 Electromagnetic Calorimetry . . . .
  - 8.3.6 Hadron Calorimetry . . . .
  - 8.3.7 Particle Identification . . . .
  - 8.3.8 Far-Forward Detectors . . . .
  - 8.3.9 Far-Backwards Detectors . . . .
  - 8.3.10 Polarimetry . . . .
  - 8.3.11 Readout Electronics and Data Acquisition . . . .
  - 8.3.12 Software and Computing . . . .
- 8.4 Detector Integration . . . .
  - 8.4.1 Installation and Maintenance . . . .
- 8.5 Detector Commissioning and Pre-Operations . . . .

- ePIC responsibility
- Joint responsibility
- Project responsibility

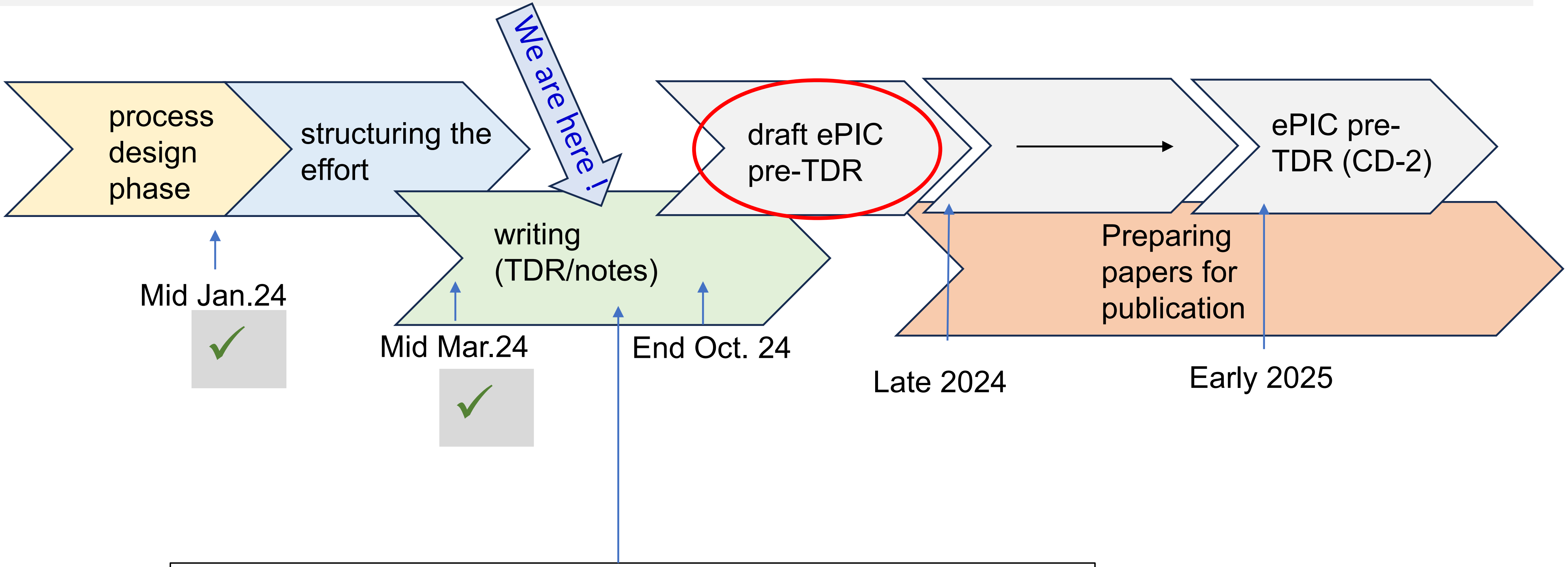
pre-TDR and TDR – the ePIC goals

- The ePIC contributions to the EIC pre-TDR and TDR (Chapters 2,8)
    - The EIC pre-TDR and TDR is the top priority
    - Precise timescale driven by EIC project requirements

- Scientific production/dissemination
  - *Derived from TDR Chapter 8 **"Experimental Systems"**:*
  - An extended version of the ePIC detector section from the EIC TDR with appropriate front matter, published in a scientific journal (such as NIMA, JINST, PRC, …)
    - *Detector Subsystem Collaborations and TC-office at work*
  - *Derived and expanded from TDR Chapter 2 **"Physics Goals and requirements"***
  - An ePIC Physics Performance long paper published in a scientific journal (such as NIMA, JINST, PRC, …)
    - *Analysis Coordinators and Physics Working Groups at work*

Software and computing Coordinators and Working Groups at work: infrastructure for all simulation studies

pre-TDR and TDR – the timelines



For the detector subsystems writing includes all the preparatory activity: lab and testbeam studies, prototyping, simulations

Detector Subsystem Collaborations have prepared their TDR effort planning periodically reviewed at the Technical and Integration Council (periodicity: ~ 6 weeks)

Summarizing

- The **ePIC detector** is fully profiting of the opportunity offered by being, at the same time,
  - The EIC Project Detector
  - The ePIC Collaboration Detector
- The **subsystems are progressing** thanks to the dedication and expertise of the ePIC Collaboration Institutions
  - Adequate qualified expertise is available for all the selected technologies (consolidated and novel ones)
  - The technology selection is functional to the required performance as resulting from the physics scope
- The **ePIC collaborative efforts towards the TDR:**
  - In full synergy with the EIC project
  - Effort design and structuring phases have been completed
  - The writing phase (which includes material production) is progressing
  - The dissemination goal via scientific publications is an integral element if this effort

Thank you