Update on ePIC

10/17, 2022

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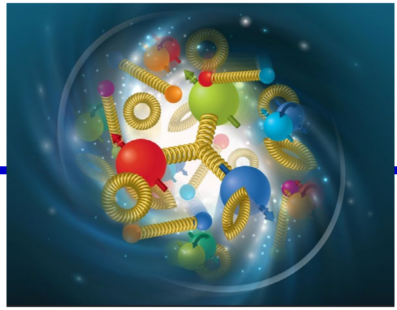
(ePIC interim Steering Committee, SC)

OUTLOOK

- INTRODUCTORY CONSIDERATIONS
- THE COLLABORATION
- THE DETECTOR

INTRODUCTORY NOTES

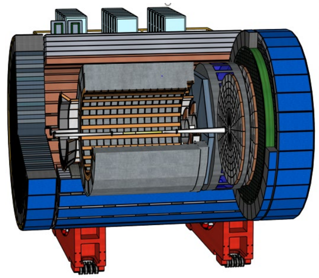


- **This talk is to update you about the ePIC detector**
  - **the ePIC detector is the reference frame for the EIC Project R&D proposals, which will be scrutinized during this meeting**

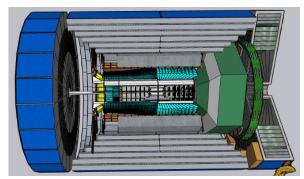
THE PATH TO DETECTOR-1

The Proposals

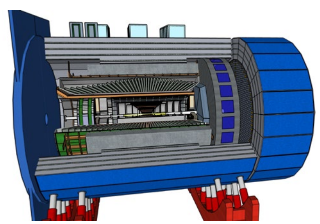
- **ATHENA**
  - A Totally Hermetic Electron-Nucleus Apparatus
  - Concept: General purpose detector inspired by the YR studies based on a new central magnet of up to 3T



- **CORE**
  - COmpact detectoR for the EIC
  - Concept: Nearly hermetic, general purpose compact detector, 2T baseline



- **ECCE**
  - EIC Comprehensive Chromodynamics Experiment
  - Concept: General purpose detector based on 1.5T BaBar magnet



Call for Collaboration Proposals for Detectors at the Electron-Ion Collider

Brookhaven National Laboratory (BNL) and the Thomas Jefferson National Ac... pleased to announce the Call for Collaboration Proposals for Detectors to b... Collider (EIC). The EIC will have the capacity to host two interaction regio... detector. It is expected that each of these two detectors would be repr...

Detector 1 is within the scope of the EIC project and should be b... the EIC User Group (EICUG) in the Yellow Report (YR) and inclu... This detector must satisfy the requirements of the EIC "mis... White Paper and the National Academies of Science (NA... support most but not all of the acquisition of Detector ... Point 6 (IP6) on the Relativistic Heavy-Ion Collider.

Detector 2 could be a complementary detector ... address science topics beyond those descri... (NAS) 2018 report. Detector 2 would resid... within the EIC project scope. Routes to ... explored.

Collaboration proposals made ... Proposals should consider th... welcome but proposals th... reference, proposals sh... as background infor...

The separate g... s follows:

- **Detector 1 Co**... : Experiments must address the EIC White Paper and NAS Report science case. The c... should propose a system that meets the performance requirements described in the EIC CD... EICUG YR. The design should be compatible with that of the accelerator and interaction region layout of the CDR. Completion of detector construction must be achieved by Critical Decision (CD)-4A, the start of EIC accelerator operations.

THE PATH TO DETECTOR-1

Following DPAP recommendation and Project decisions

the **ECCE and ATHENA proto-collaborations came together** to move forward towards:

- The formation of **a new scientific collaboration: ePIC**
- Consolidate and optimize, **evolving the reference detector to an advanced detector concept**

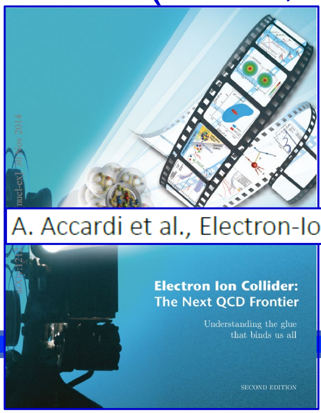
HOW?

- **Interim SC** from representatives in both proto-collaborations
- Forming **joint WGs**
- Organizing **detector consolidation and optimization**
- Steps for **establishing the new collaboration**

LEGACY FROM THE PREVIOUS ACTIVITY

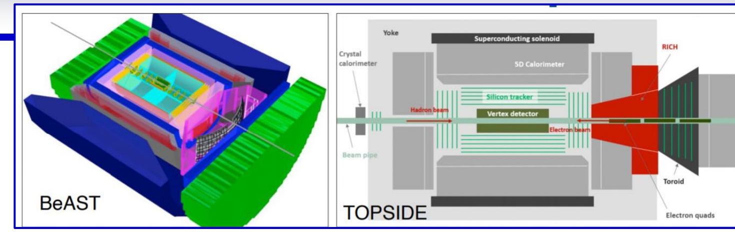
DETECTOR HISTORICAL BACKGROUND

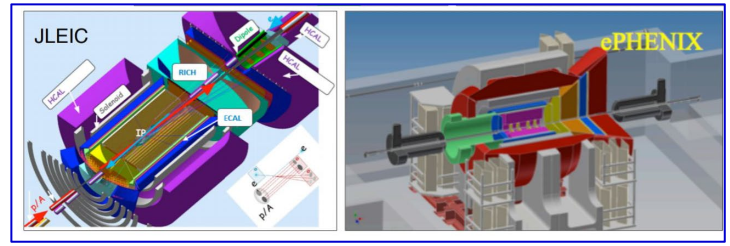
- **White paper** (2012, 2014)



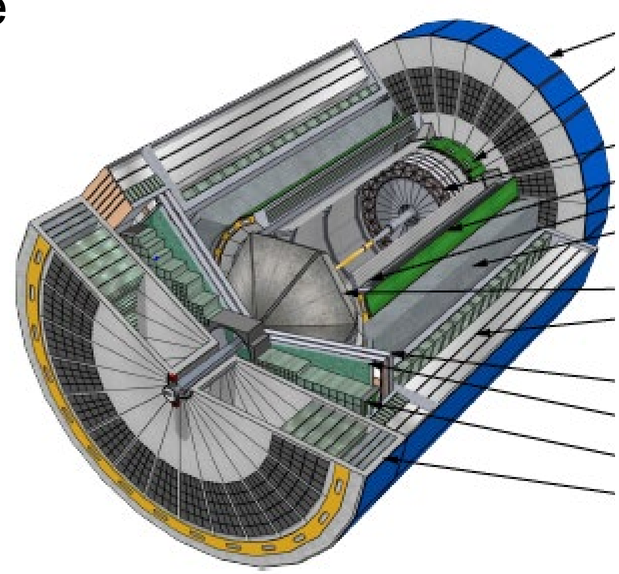
A. Accardi et al., Electron-Ion Collider: The next QCD frontier, Eur. Phys. J. A52 (2016) 268.

- **The initial concepts** in the 2010's





- The Yellow Report reference detector (2020)
  - ➢ A global effort of the EIC-User Group



LEGACY FROM THE PREVIOUS ACTIVITY

The program of Generic Detector R&D for EIC

- The development of detector technologies for the EIC detector(s) supported in years 2011-2021 by a robust R&D program with US and international participation
- An (incomplete) flavour:

Project	Topic
eRD1	WSciFi and SciGlass electromagnetic calorimetry
eRD3	MMG, GEM, and μRWell MPGD technologies
eRD6	Lightweight GEM tracker miniTPC* for PID in barrel through dE/dx MMG, GEM, and μRWell MPGD
eRD12	Auxiliary detectors: low-Q^2 tagger, far forward tracker (Roman Pots), luminosity measurement
eRD14	DIRC, dRICH, Photosensors, LAPPDs
eRD16	Forward and backward MAPS tracker disks

Tracking | PID | Calorimetry | Simulations | DAQ/Electronics

Project	Topic
eRD18	Barrel: main and vertex MAPS tracker
eRD22	TRD in forward region for enhanced e/h
eRD23	Streaming DAQ
eRD24	AC-LGAD sensors for Roman Pots and B0
eRD25	Merger of eRD16 and eRD18 covering Si tracker
eRD27	High Resolution ZDC
eRD29	AC-LGAD barrel ToF for enhanced PID

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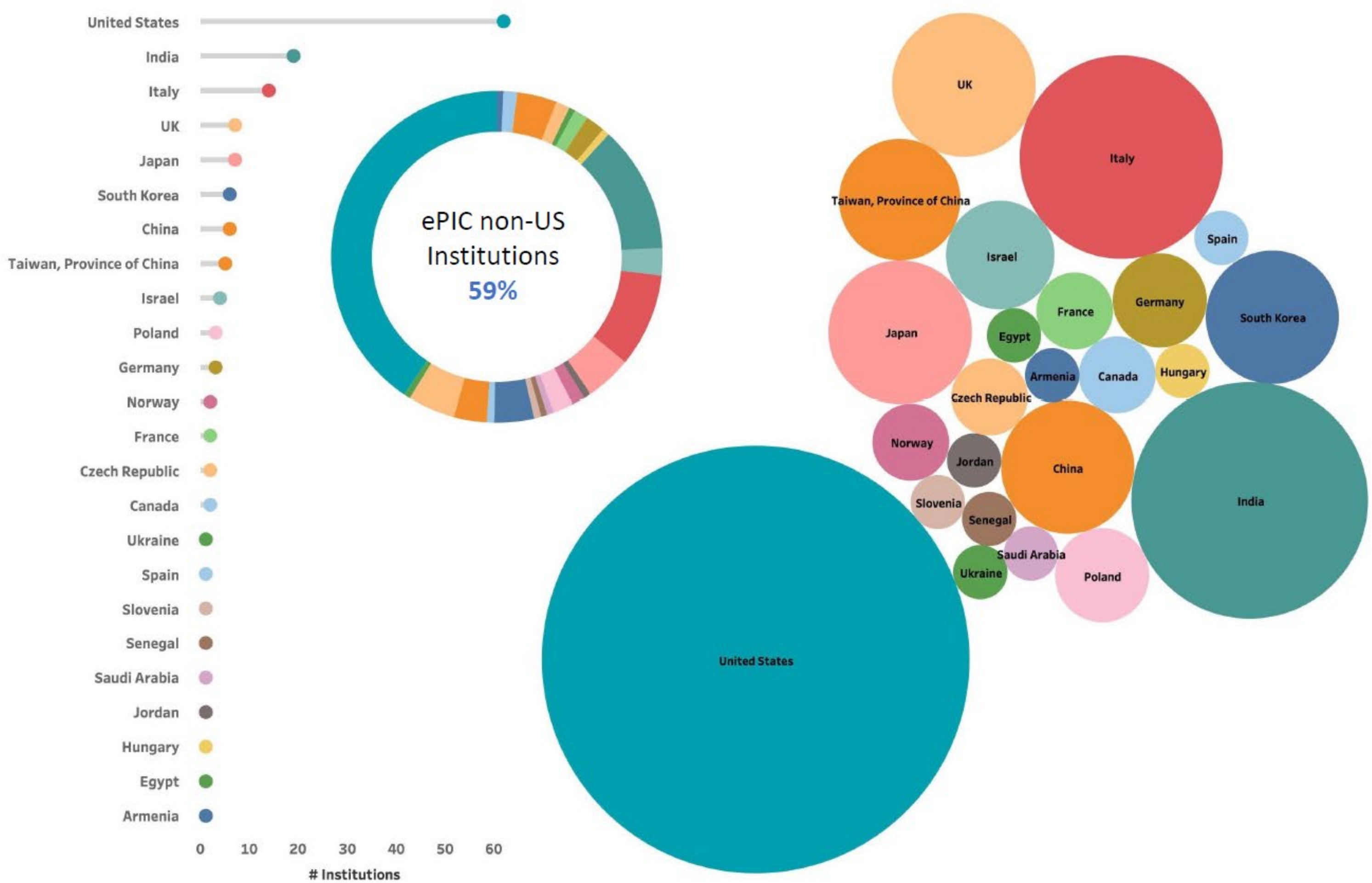
The ePIC Collaboration

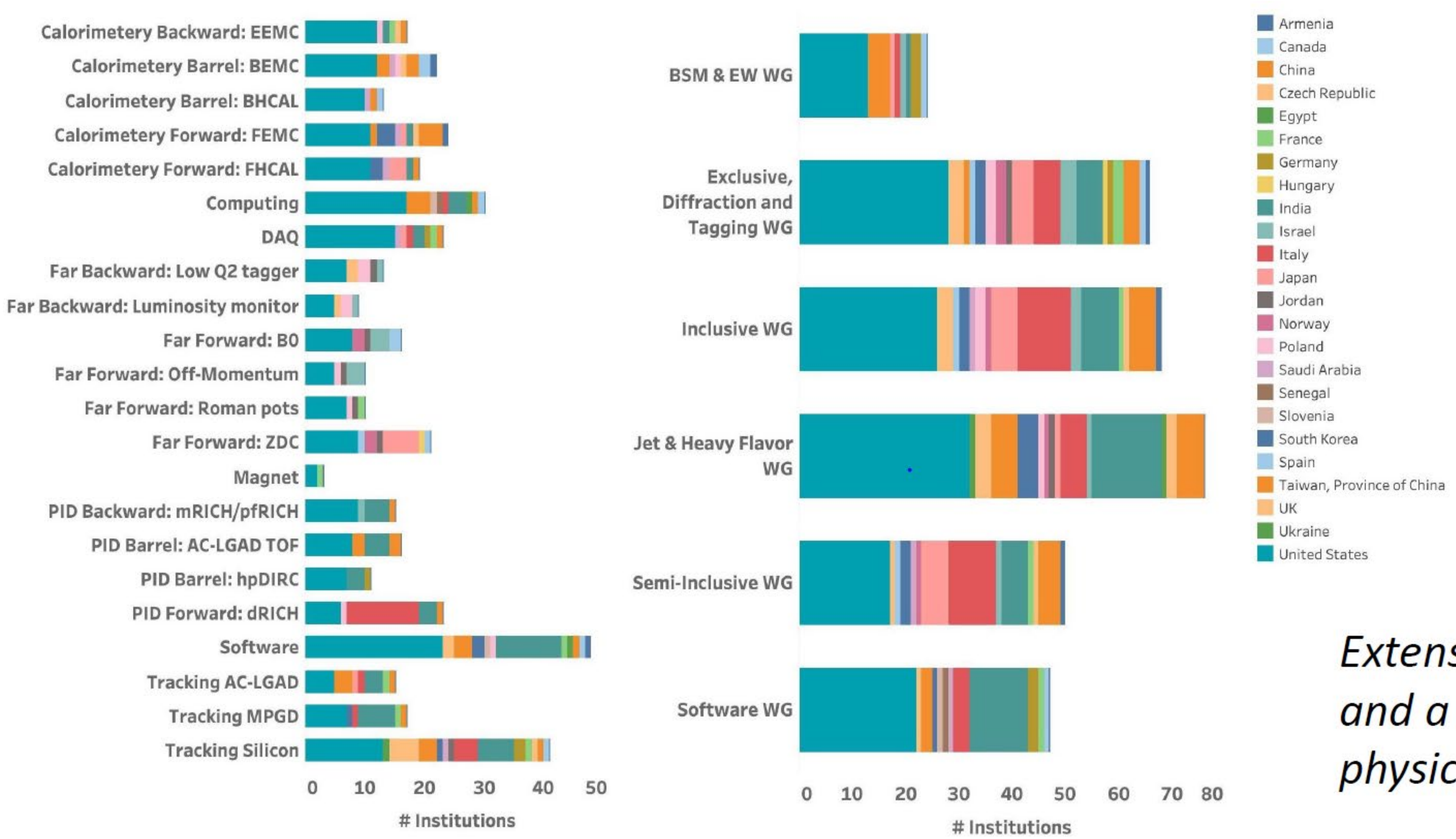


160+ institutions
24 countries

500+ participants

A truly global pursuit for a new experiment at the EIC!

The ePIC Collaboration



Extensive expertise and a wide array of physics interests.

STRUCTURING THE COLLABORATION

- April: Formation of joint working groups and start of technological consolidation process
- June: Collaboration roster established via institutional survey
- July:
  - Name selection via members vote,
  - Collaboration council establishment and interim chairs appointment,
  - Collaboration formation meeting @ Stony Brook University (July 26th-28th).
- August: Formation of charter committee
- October:
  - 6th: Draft bylaws sent to collaboration,
  - 14th: Collaboration council meeting to discuss draft bylaws,

now

- Late October – Early November:
  - Comments and feedback collection of draft bylaws,
  - Final bylaws circulated to collaboration members,
  - Vote and adoption of collaboration bylaws.
- Late November: Collaboration leadership election and appointment of formal roles as defined by bylaws.

INTERIM STRUCTURE

- The Steering Committee (author of this talk)

- The Collaboration Council, an Institution Representative per Institution

  - Interim co-chairs:
  - Victoria Greene (Vanderbilt U.) and Franck Sabatié (CEA/Saclay)

  - The Charter Committee:
  - Pietro Antonioli , Olga Evdokimov (co-chair), Douglas Higinbotham (co-chair), Barbara Jacak, Zein-Eddine Meziani, Rosi Reed, Ralf Seidl and Peter Steinberg

- The Working Groups, physics and detector aspects

Working Groups

WGs have a key role in the consolidation/optimization process

GD/I WG: Recently enlarged to enhance coordination effort
(new members: Carlos Munoz Camacho, Joe Osborn)

	WG	Conveners			
Transversal WGs	Global Detector Optimization	Richard Milner	Jin Huang	Thomas Ullrich	Silvia Dalla Torre
	Simulation production and QA	Joe Osborn	Wenliang (Bill) Li	Zhoudunming (Kong) Tu	Wouter Deconinck
	Computing and Software	Cristiano Fanelli	David Lawrence	Sylvester Joosten	Andrea Bressan
	DAQ / Electronics / Readout	Chris Cuevas	Jo Schambach	Alexandre Camsonne	Landgraf Jeff
Detector WGs	Tracking	Xuan Li	Kondo Gnanvo	Laura Gonella	Francesco Bossu
	Calorimetry	Friederike Bock	Carlos Munoz Camacho	Oleg Tsai	Paul Reimer
	PID Cherenkov	Xiaochun He	Grzegorz Kalicy	Tom Hemmick	Roberto Preghenella
	PID ToF	Wei Li	Constantin Loizides	Franck Geurts	Zhenyu Ye
	Far Forward	Michael Murray	Yuji Goto	Jentsch Alex	John Arrington
	Far Backward	Igor Korover	Nick Zachariou	Krzyzstof Piotrzkowski	Adam Jaroslav
Physics WGs	Inclusive Physics	Tyler Kutz	Claire Gwenlan	Barak Schmookler	Paul Newman
	Jets and Heavy Flavor	Cheuk-Ping Wong	Wangmei Zha	Miguel Arratia	Page Brian
	Exclusive, Diffraction, & Tagging	Axel Schmidt	Rachel Montgomery	Spencer Klein	Daria Sokhan
	Semi-Inclusive Physics	Ralf Seidl	Charlotte Van Hulse	Anselm Vossen	Marco Radici
	BSM & precision EW	Xiaochao Zheng	Sonny Mantry	Furletova Yulia	Ciprian Gal

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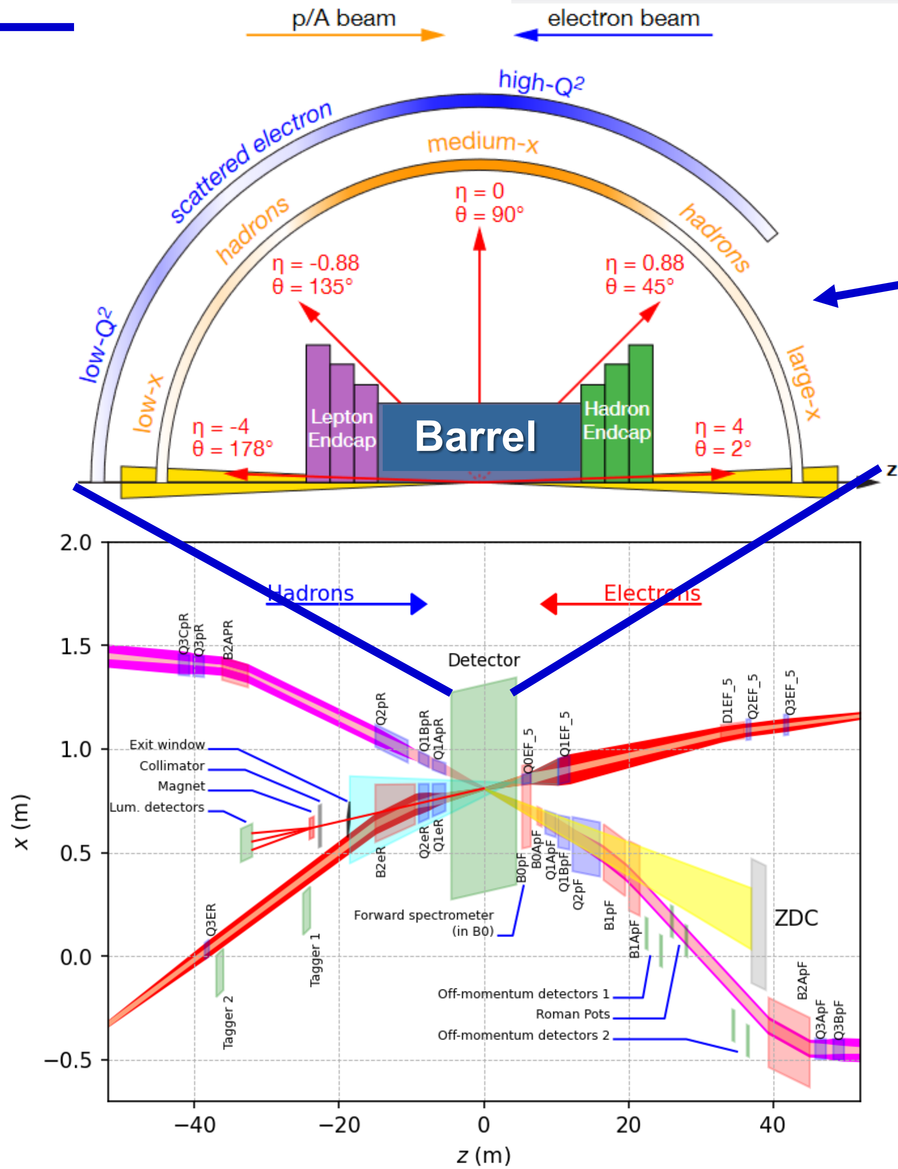
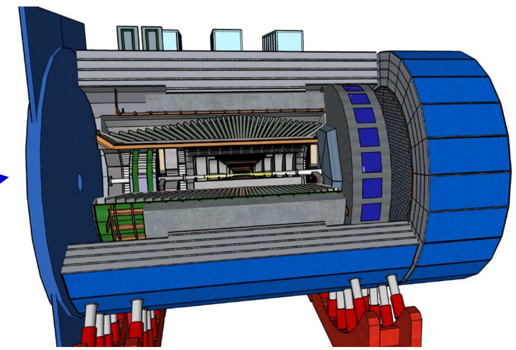
THE COMPLETE DETECTOR





Central Detector (CD)

Total size detector: ~75m
Central detector: ~10m
Backward electron detection: ~35m
Forward hadron spectrometer: ~40m

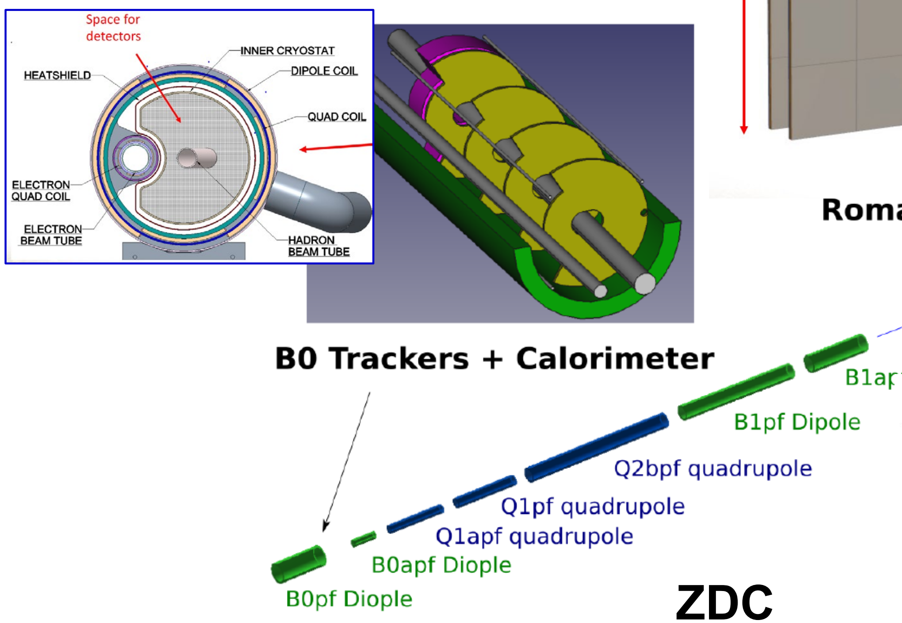
Auxiliary detectors needed to tag particles with very small scattering angles both in the outgoing lepton and hadron beam direction (B0-Taggers, Off-momentum taggers, Roman Pots, Zero-degree Calorimeter and low Q2-tagger).

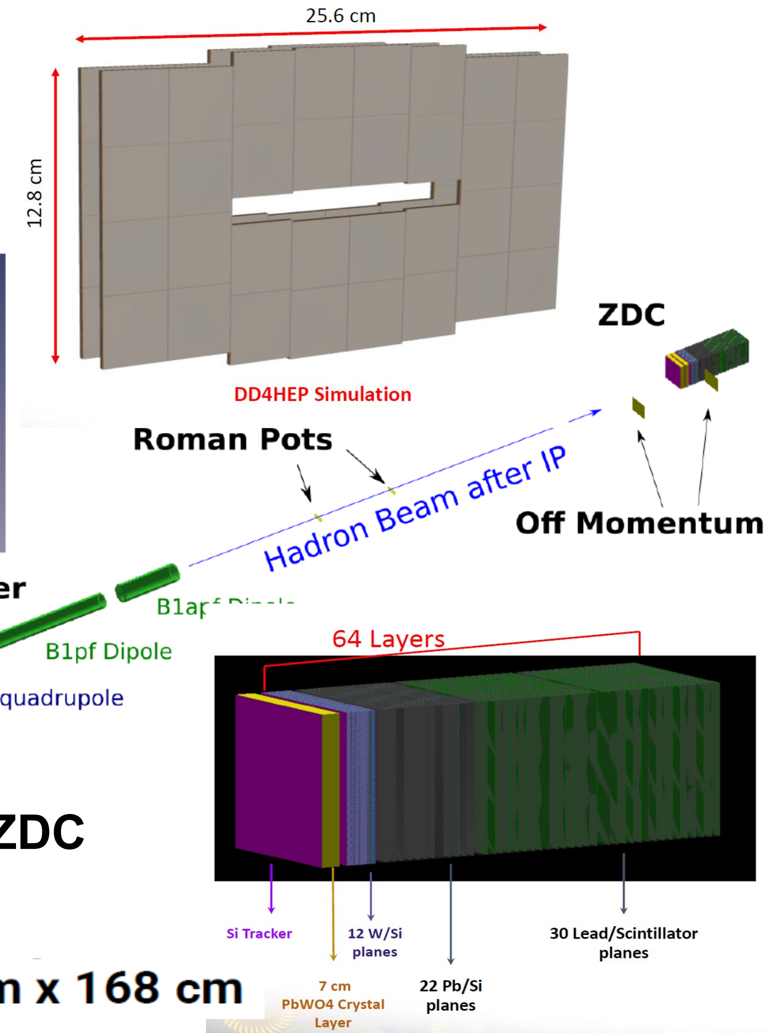
Far Forward

- **Instrumentation in the B0 magnet**
- **Roman Pots and Off Momentum detectors**
- **Zero degree Calorimeter**

TECHNOLOGIES (including alternatives)

- **$PbWO_4$ Cal**
- **W/Si sensors**
- **Pixelated AC-LGADs**
- **MAPS**
- **W/SciFi**
- **Pb/Sci**

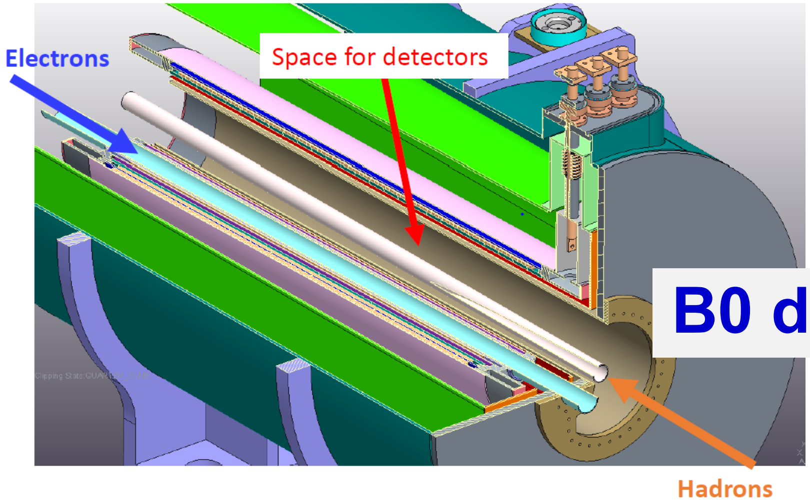


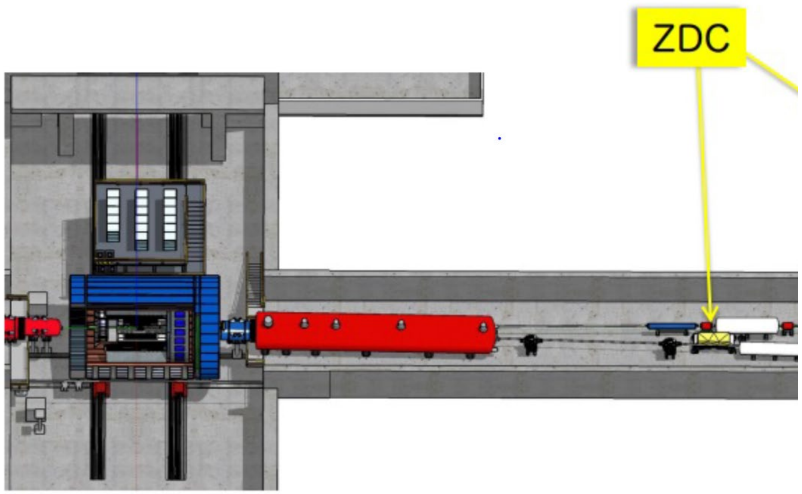


Dimension: 60 cm x 60 cm x 168 cm

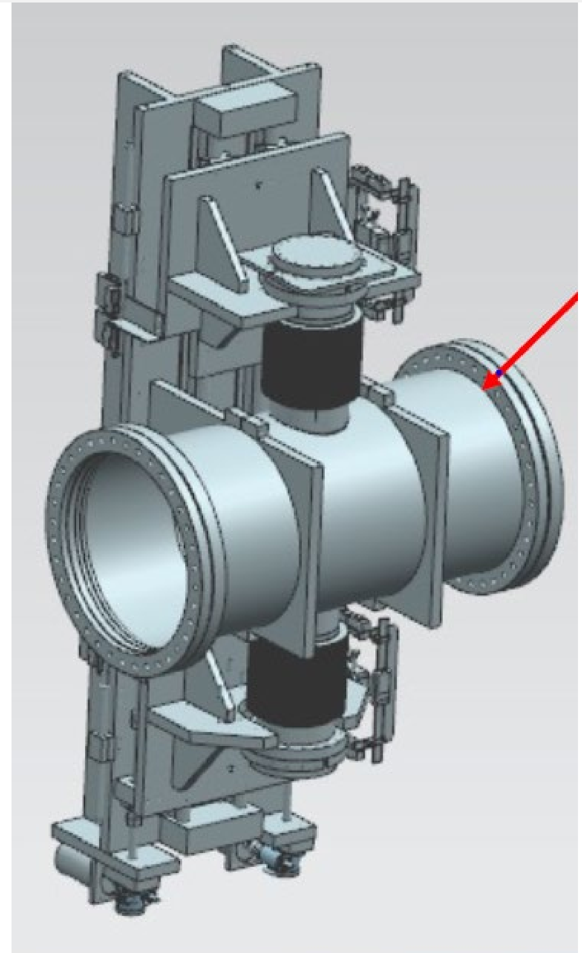
Specific of far forward: high level of integration with the machine

B0 detectors





RPs and off-momentum detectors



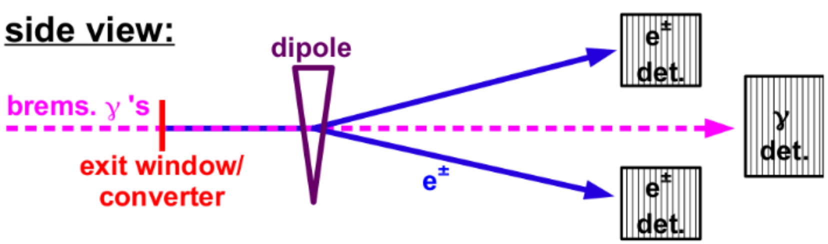
Far Backward

- Luminosity monitor (electron-ion bremsstrahlung)
- Low-Q2 tagger

TECHNOLOGIES (including alternatives)

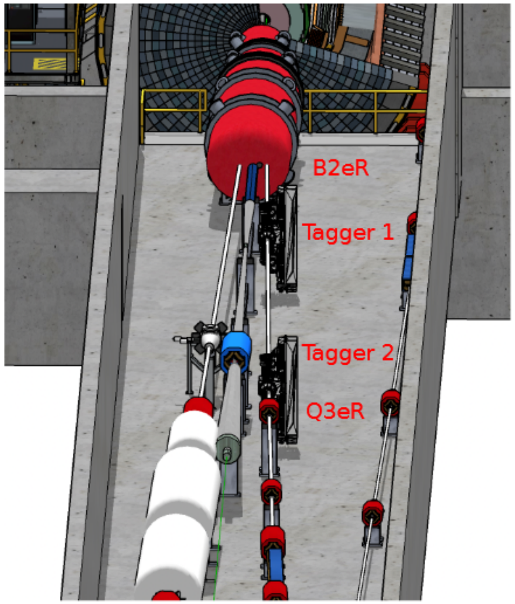
- <u>AC-LGAD</u>
- <u>$PbWO_4$ Cal</u>
- <u>Spaghetti W-calorimeter</u> with radiation-hard scintillating fiber
- <u>Cherenkov-radiating quartz fibers</u> read out by SiPMs

Figure: Luminosity detector

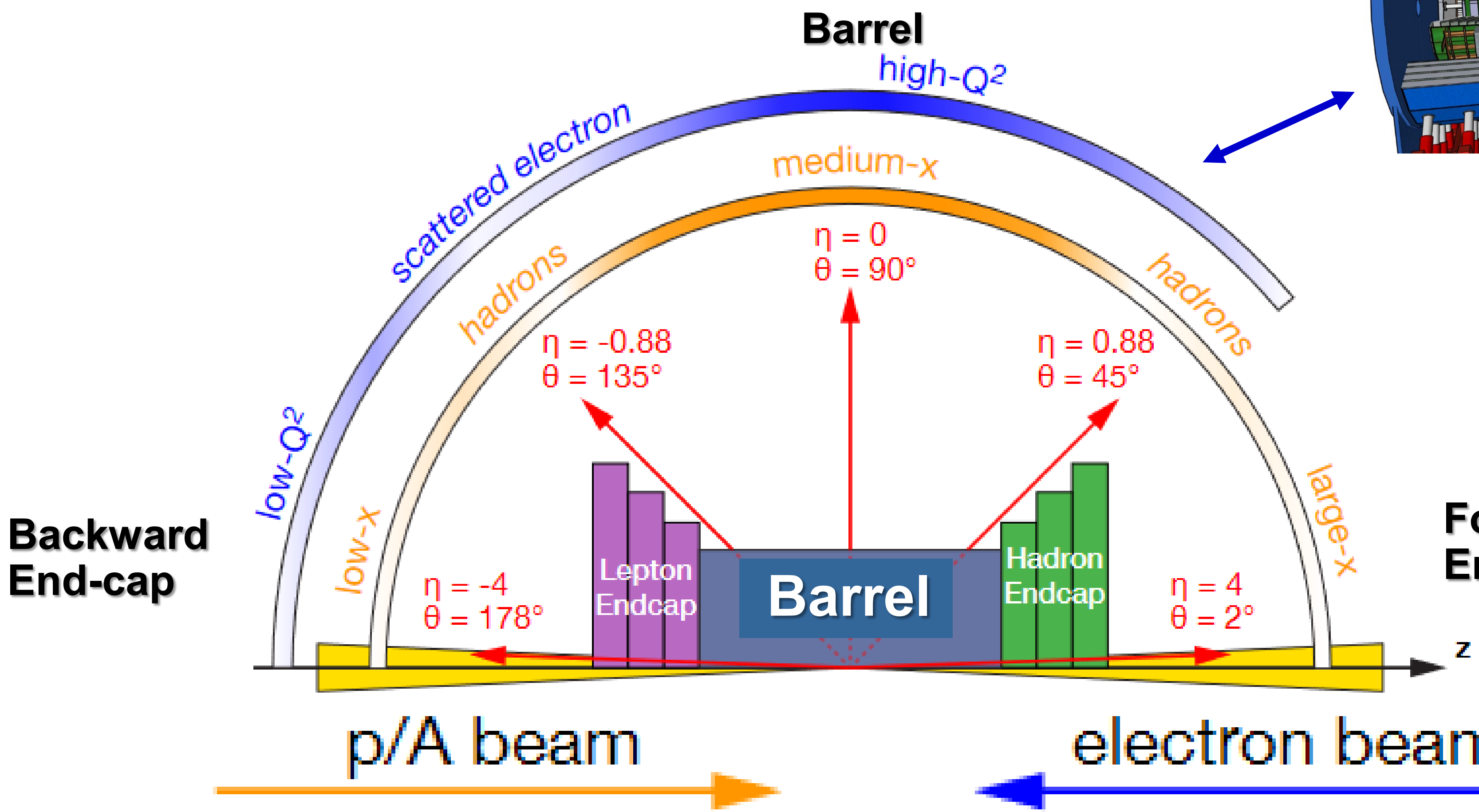


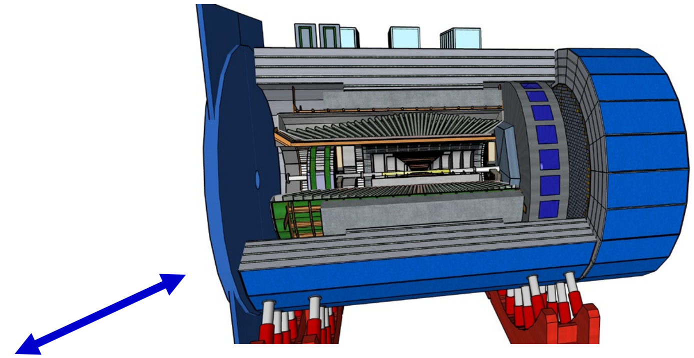
Overall challenge:

- High ebvent rates up to O(100 mHz) in calorimeter for luminosity measurements

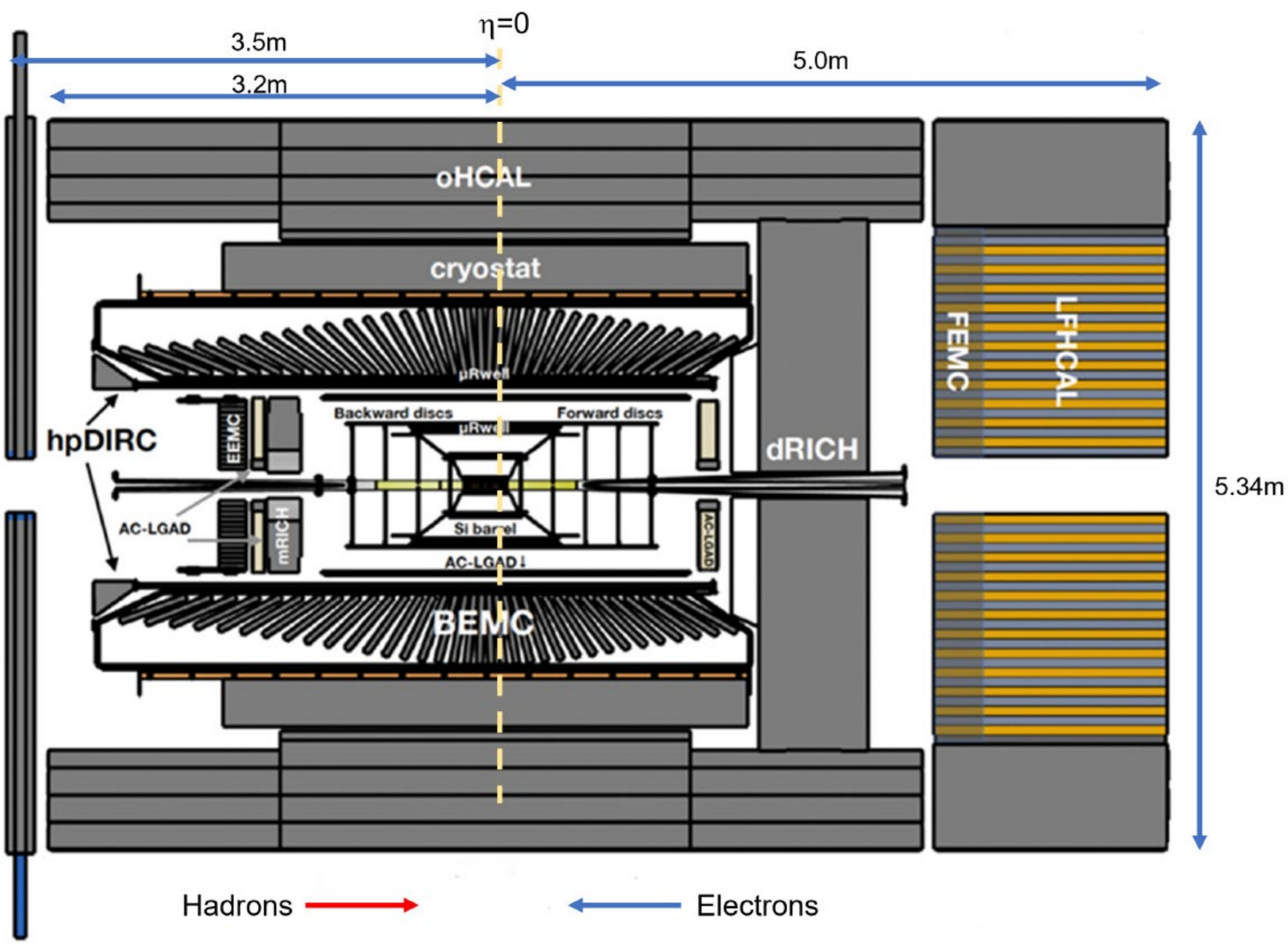


THE CENTRAL DETECTOR





Current ePIC DESIGN



Tracking:

- New 1.7T solenoid
- Si MAPS Tracker
- MPGDs (μRWELL/μMegas)

PID:

- hpDIRC
- mRICH/pfRICH
- dRICH
- AC-LGAD (~30ps TOF)

Calorimetry:

- SciGlass/Imaging Barrel EMCal
- PbWO4 EMCal in backward direction
- Finely segmented EMCal +HCal in forward direction
- Outer HCal (sPHENIX re-use)

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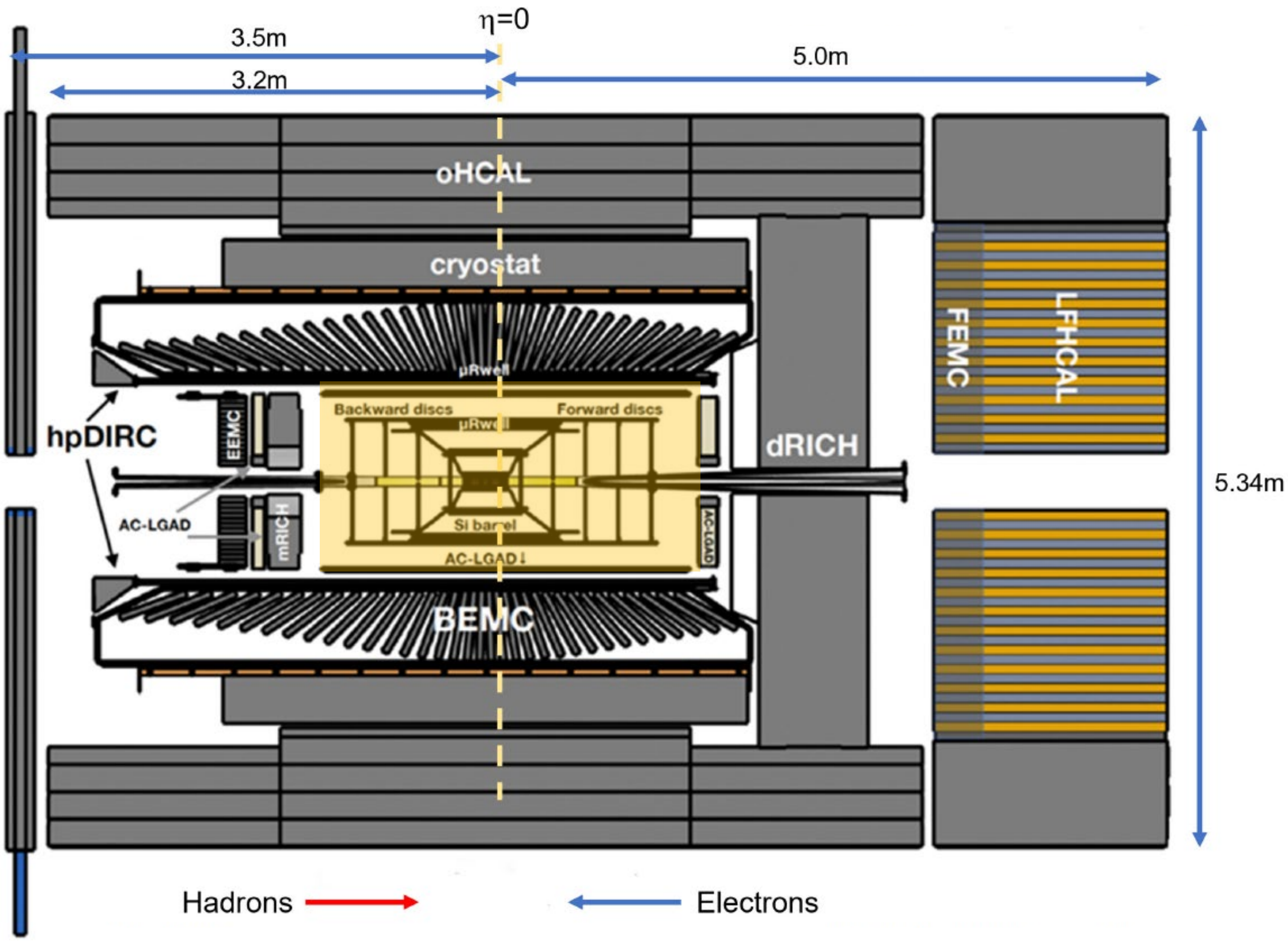

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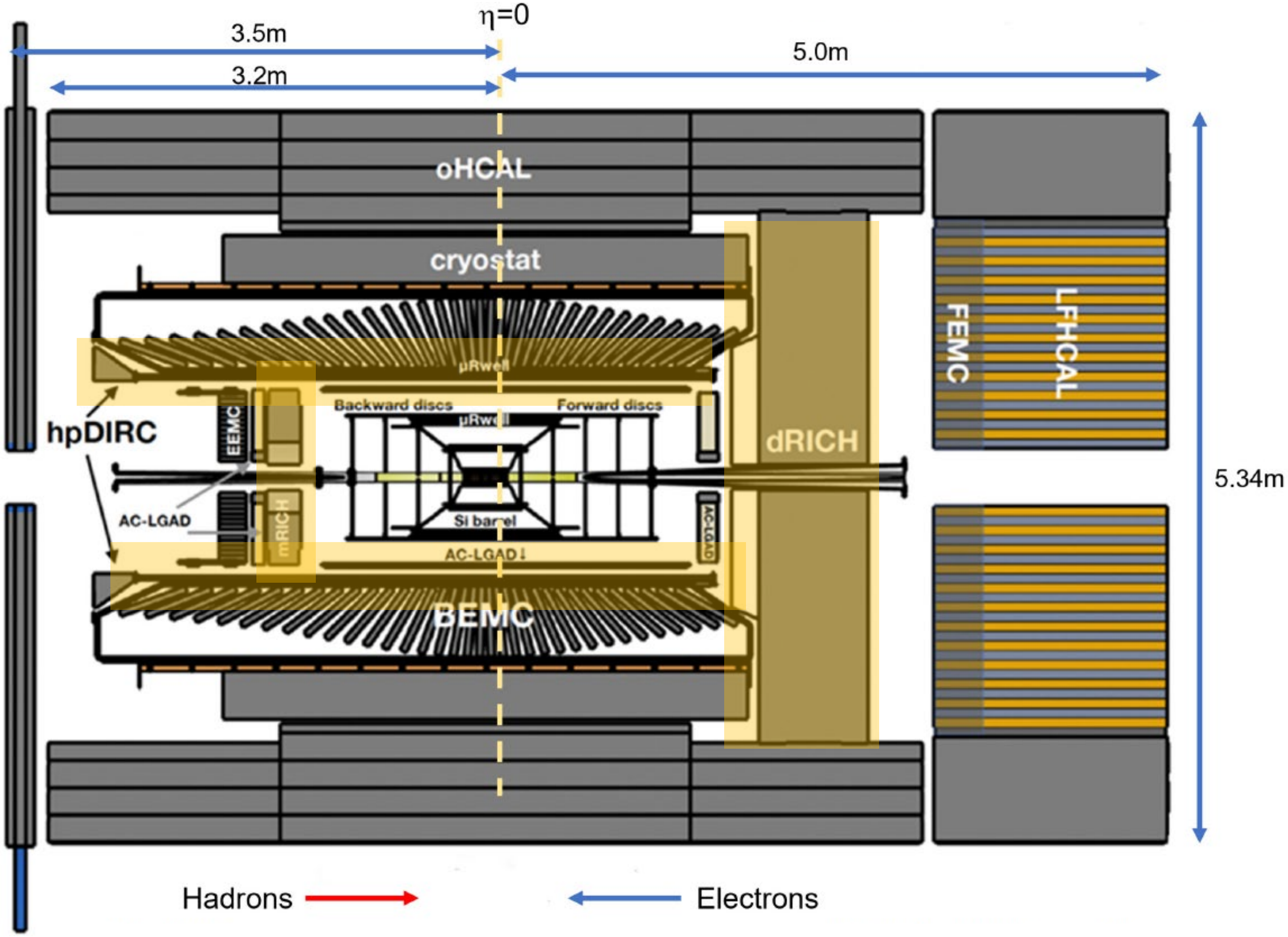

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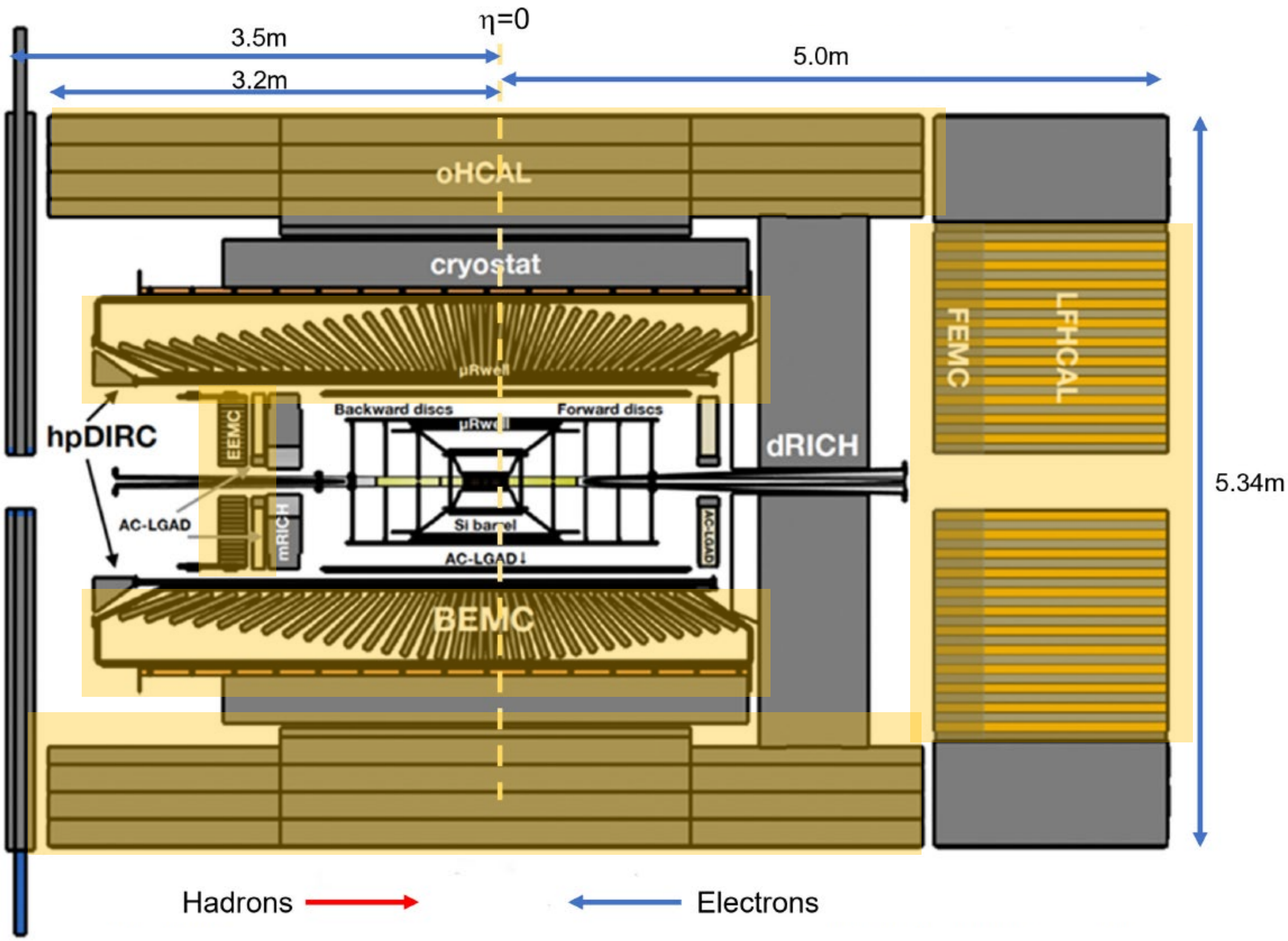

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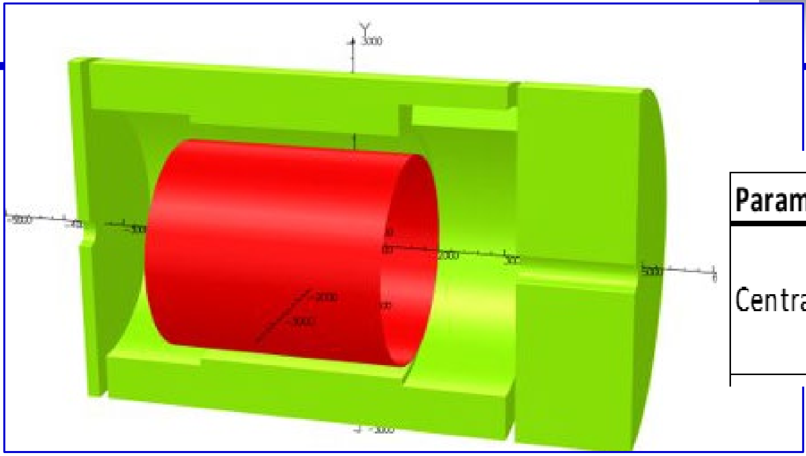
SOLENOID 1/2

Boundary conditions for a New Magnet

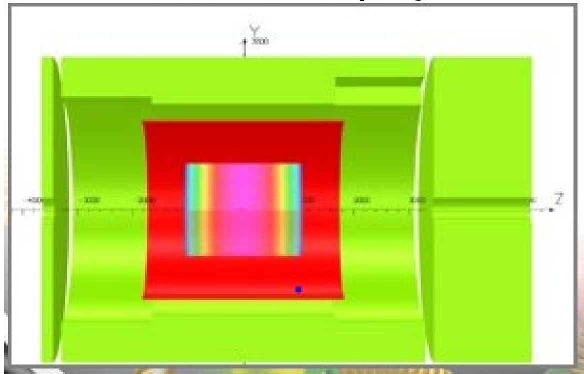
- Cost and Risk need to be manageable
  - Guideline: can we make a conservative magnet design that can reach a robust >1.5 Tesla but with the BaBar magnet geometry.
- Geometry needs to be consistent with BaBAR magnet
  - allows reuse of barrel hadron calorimeter
  - if geometry is changed BaBAR magnet cannot be realized as an opportunity (for example in case of issues with vendors for cladding Rutherford cable) as currently in the risk registry
  - allows space for fringe field mitigation

SOLENOID 2/2



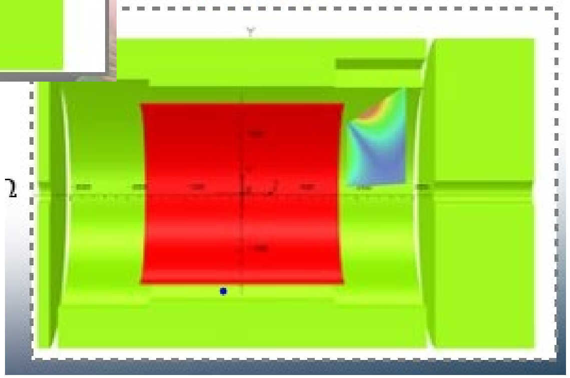
Parameter	Detector 1-Solenoid	Comments
Central Field (T)	1.5	Safe Operation
	1.7	Optimal
	2.0	Reachable

Flat Field Area (FFA)

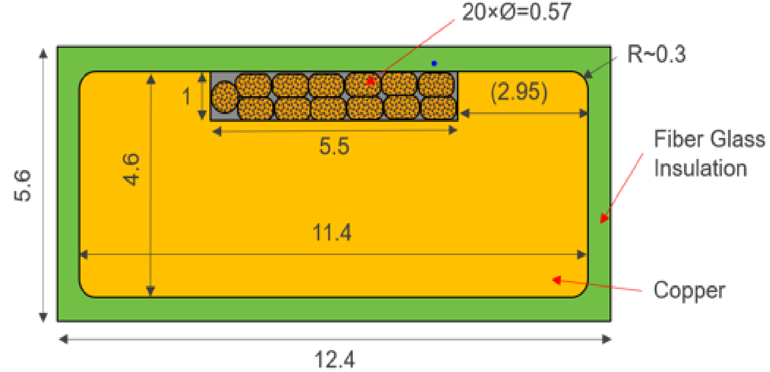


- Uniformity = 12.3% validated by the Physic Group
- Projectivity = 2.41 T/Amm²
- Coil dimensions within the specs

RICH Area



The cable



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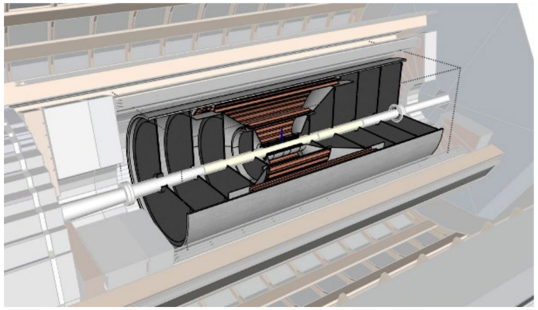
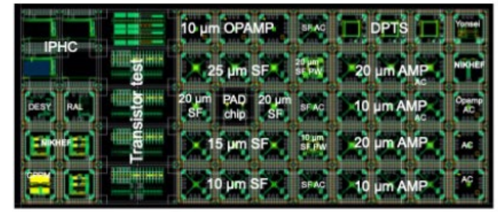
  - Central detector technologies

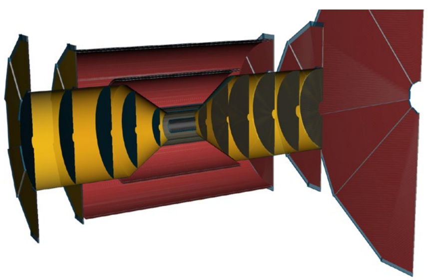
Si Tracking



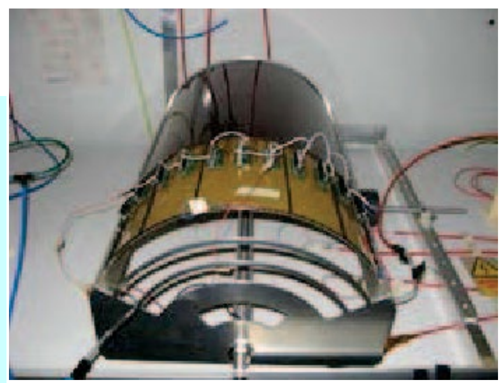
- **1 single technology:** 65-nm MAPS
  - O(10 μm) pitch, <20 mW/cm^2
  - Developed for ALICE ITS3
- **Silicon VERTEX (3 layers)**
  - First layer @ R ~ 4 cm
  - Material: 0.05% X/X_0 / layer
- **Silicon BARREL (2 layers)**
  - Material: 0.55% X/X_0 / layer
- **F & B Silicon DISKs (5 in Front and Back)**
  - Material: 0.24% X/X_0 / layer

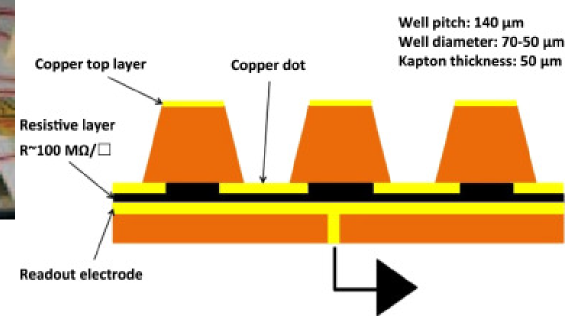


MPGDs



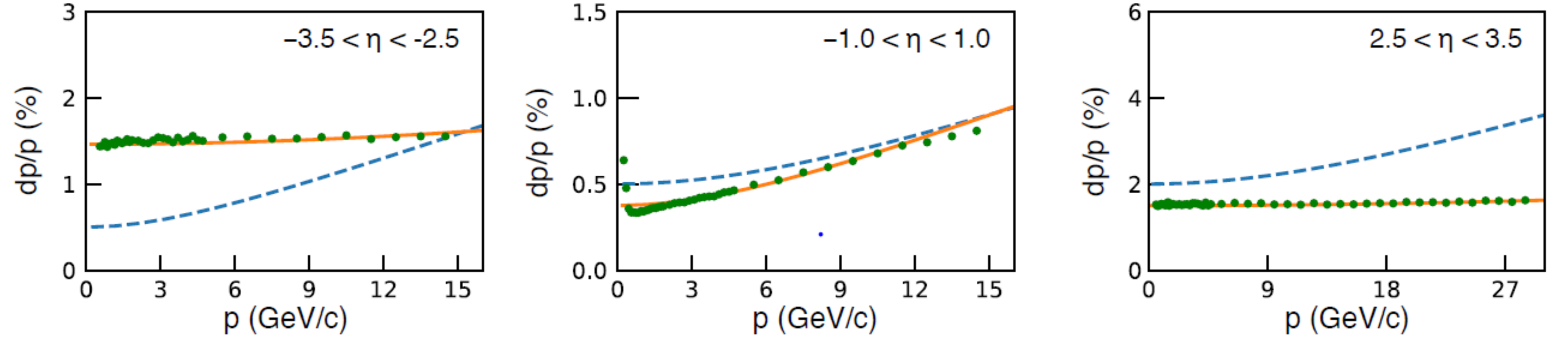
- Curved (cylindrical geometry) **MICROMEGAS / μRWell**
- Large-size **GEMs**
- **2-D read-out** needed



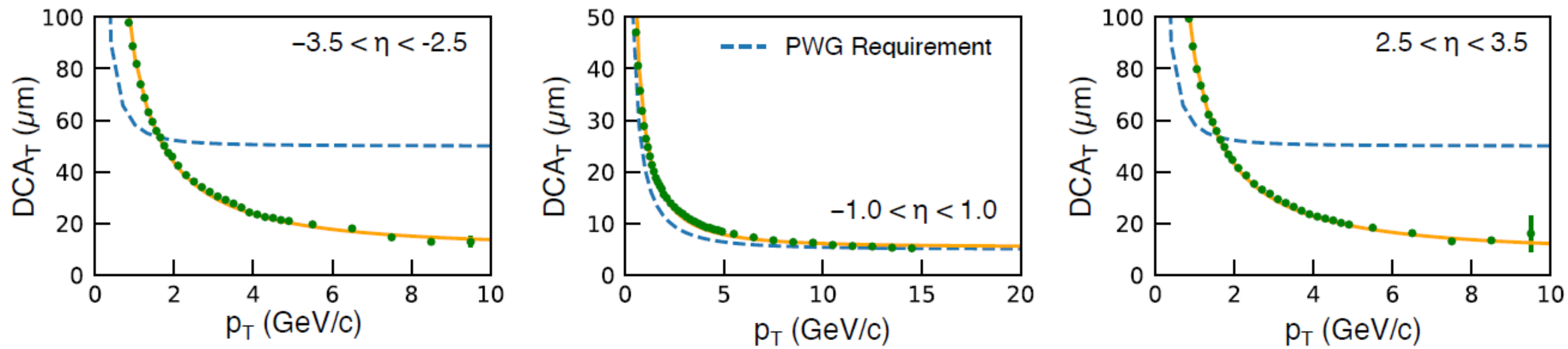


TRACKING GOALS

Momentum resolution vs p in 3 η-bins



Transfer **distance of closest approach** to the primary vertex vs p in 3 η-bins



Hot items in consolidation/optimization

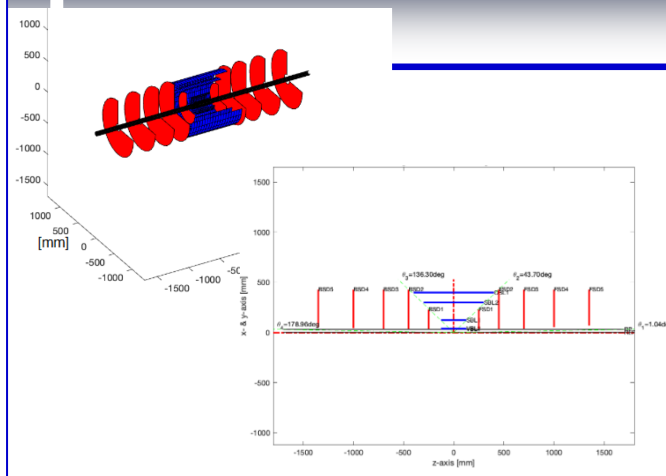
- ***Tracking***

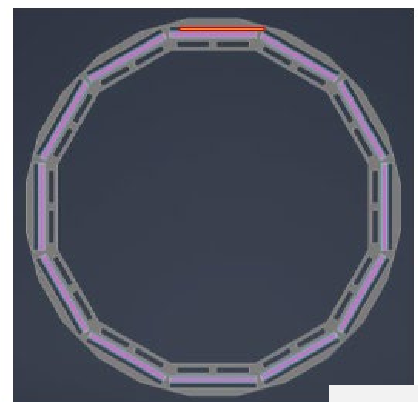
  - *The effort of configuration optimization including Si and gas trackers must continue*

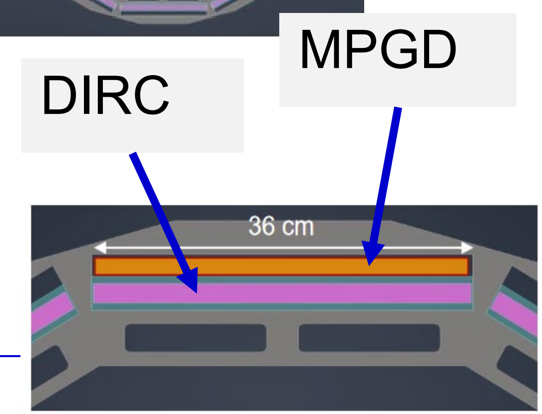
  - *Si Tracking: critical aspects are*
    - *the confirmation of the material budget (including cable routing)*
    - *the sizes and yields of the stitched sensors*

  - *The technology(ies) for the MPGD must be selected*
    - *The layer internal respect to the DIRC is cylindrical*
    - *The layer external to the DIRC (needed to improve DIRC resolution) approximates the cylinder by a set of flat trackers following the DIRC geometry*
    - *<u>Should cylindrical and flat detector adopt the same MPGD technology ?</u>*

  - *Large gaseous tracker behind the dRICH*
    - *Tension between dRICH resolution and space requested for the dRICH*



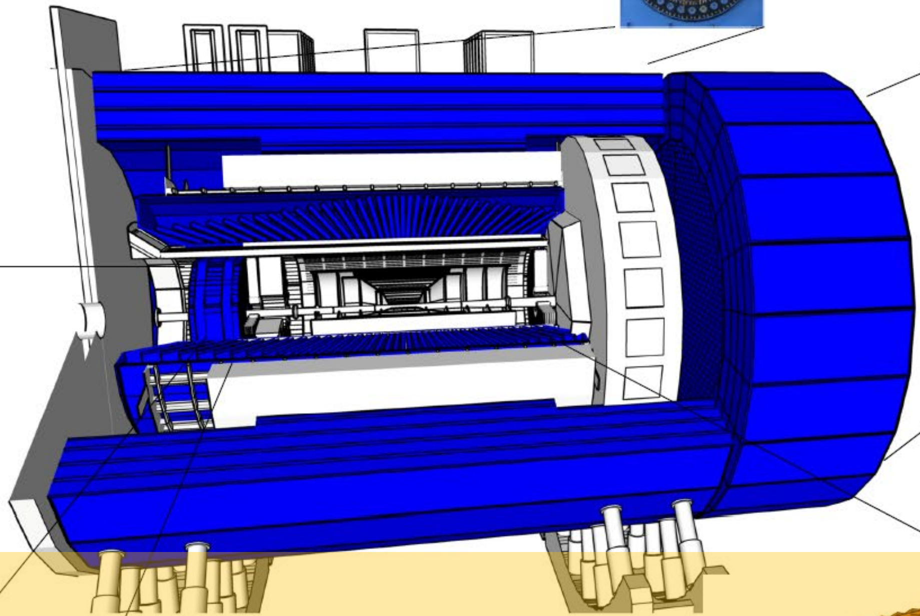




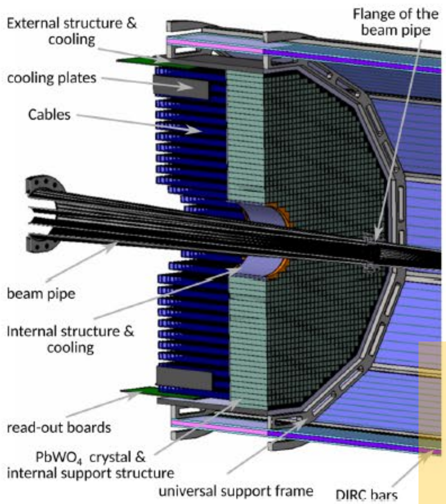
CALORIMETRY

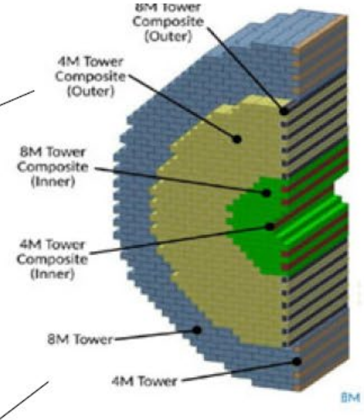
Consolidated design merging Technologies proposed by ECCE and ATHENA

Barrel HCAL
(sPHENIX re-use)



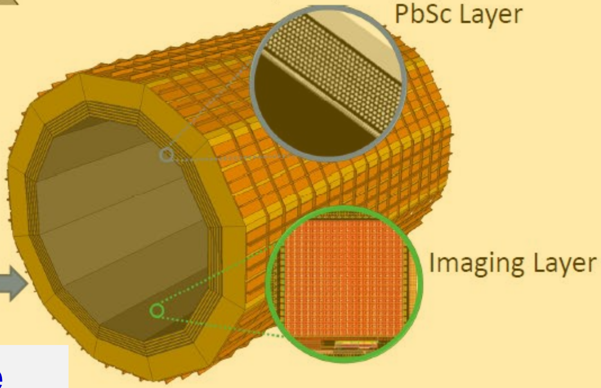
Backwards EMCal
PbW04 crystals





High granularity shashlik
W/SciFi EMCal
Longitudinally separated
HCAL with high-η insert

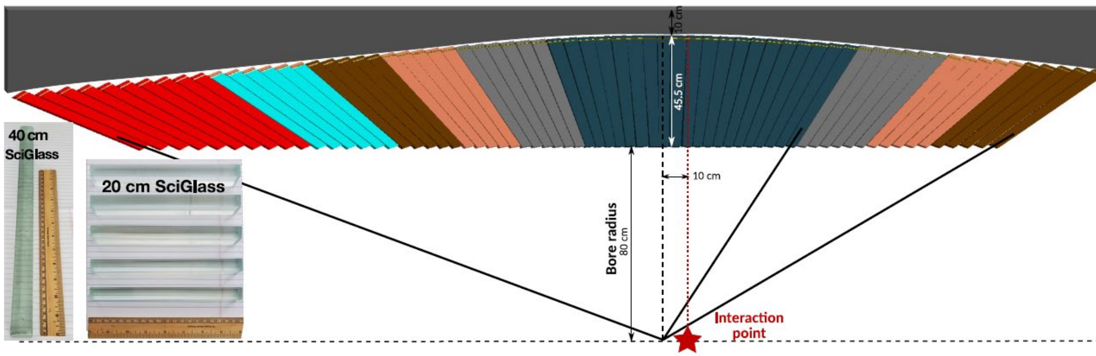
Complementary options for BECAL:
SciGlass or
Imaging Calorimeter

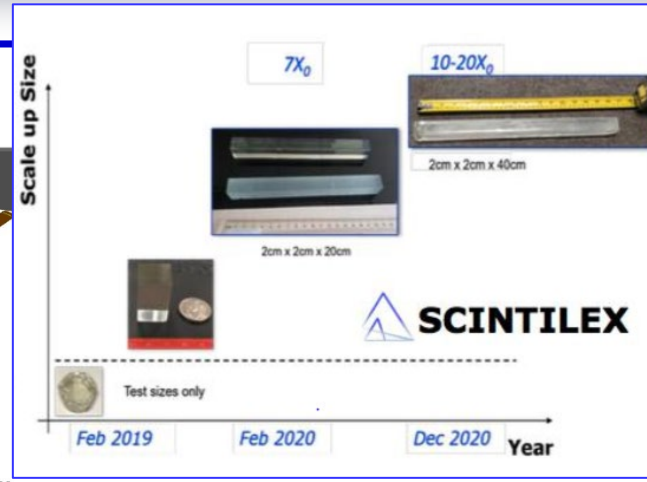


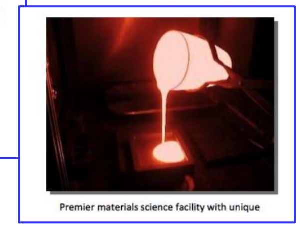
2 options for the barrel calorimetry

BARREL ECAL

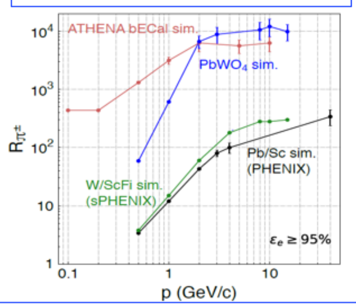
Barrel ECal with SciGlass blocks with projective geometry



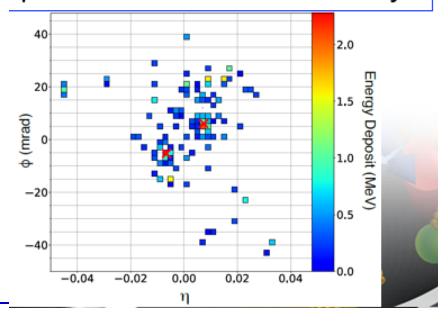




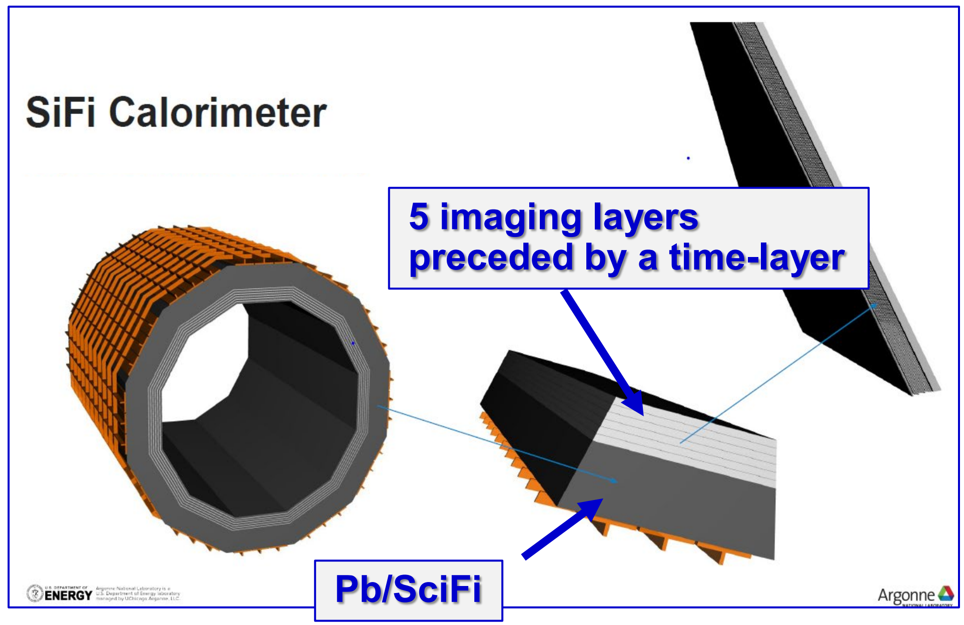
Separate e/π at low p



γ's from 15 GeV/c π^0 decay



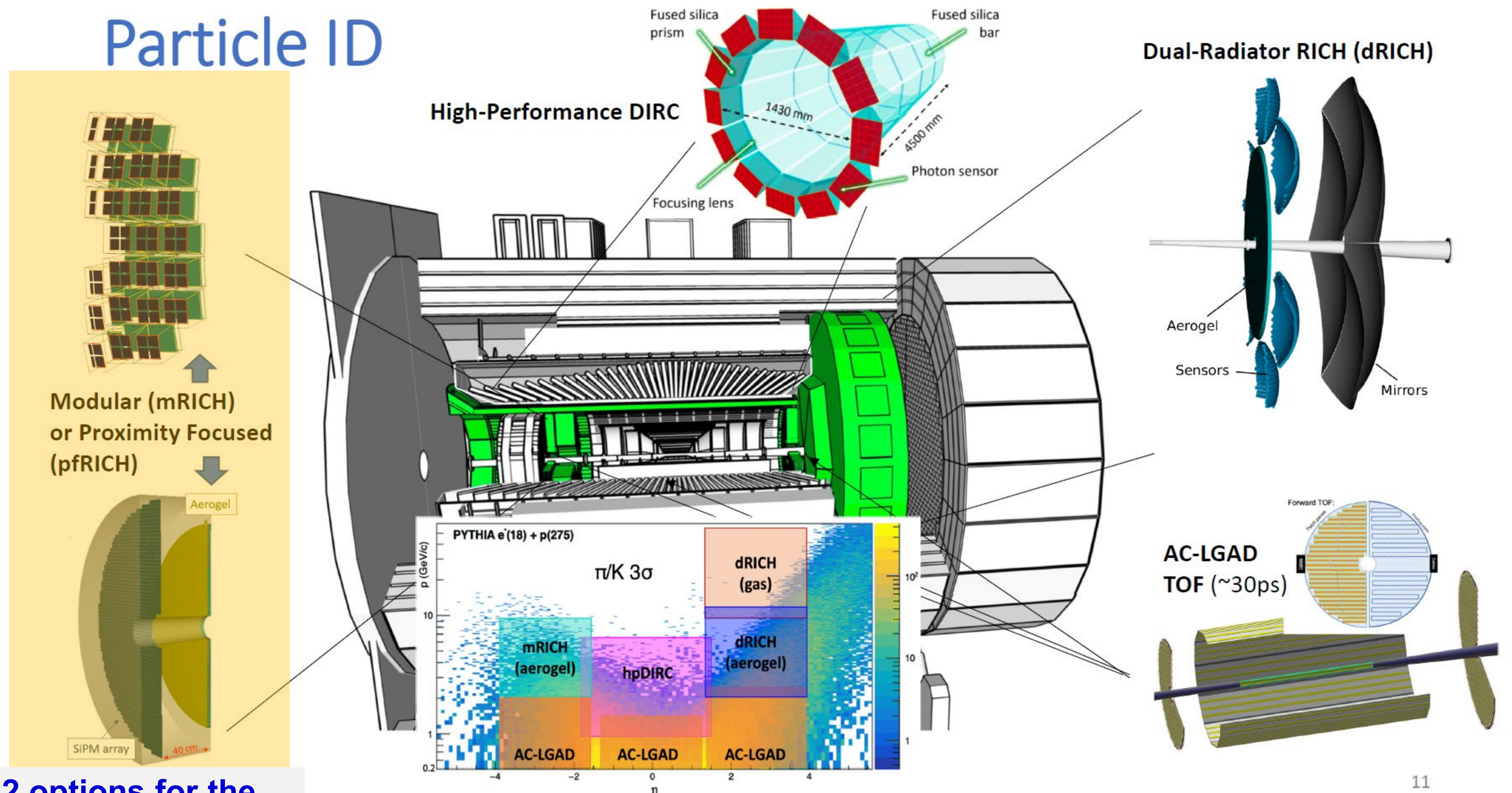
Barrel ECal with a <u>hybrid imaging calorimeter</u>



Hot items in consolidation/optimization

- ***Barrel ECal***
  - *Waiting for the results of*
    - *The simulation campaign*
    - *The test beams that should validate the parameters used in the simulations*
  - *Miscellanea of open questions*
    - *performances compared with requirements for physics;*
    - *integration features;*
    - *plans for electronics;*
    - *re-evaluate the costs for the ePIC geometry;*
    - *confirm the performance of the scintillating glass;*
    - *confirm the performance of the imaging approach*
- ***Backward Hcal***
  - *Requested by physics ?*
  - *Current reference: no backward HCal*

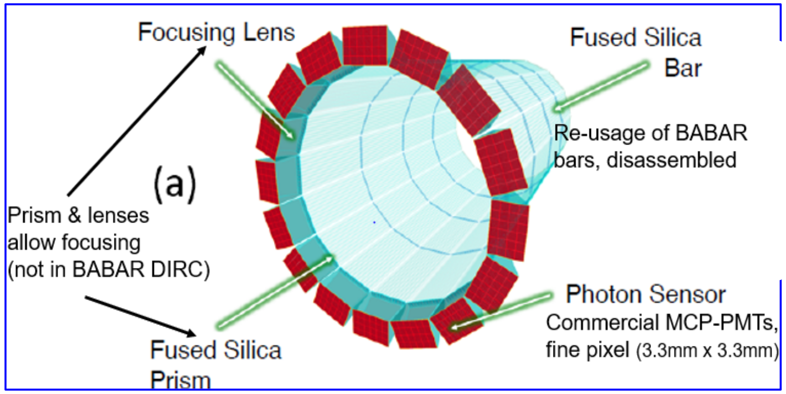
PID



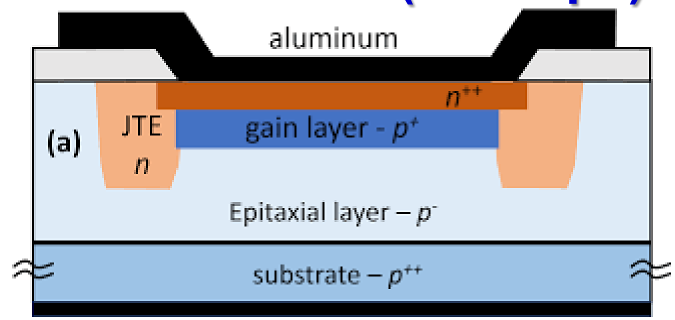
2 options for the backward RICH

PID, more

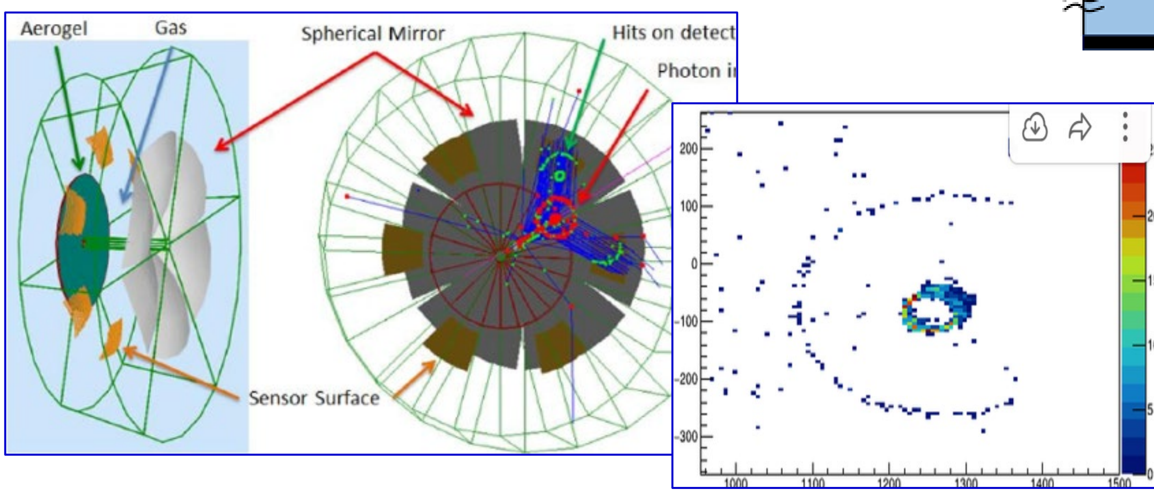
Focusing DIRC
with lenses (barrel)



ToF by AC-LGAD
(25-30 ps)



dRICH
2 radiators: Aerogel & gas
(forward)



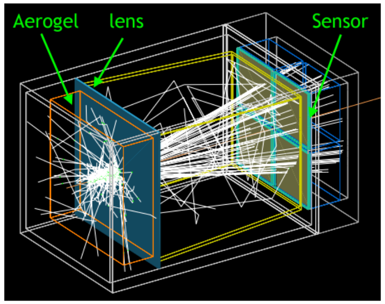
PID, more

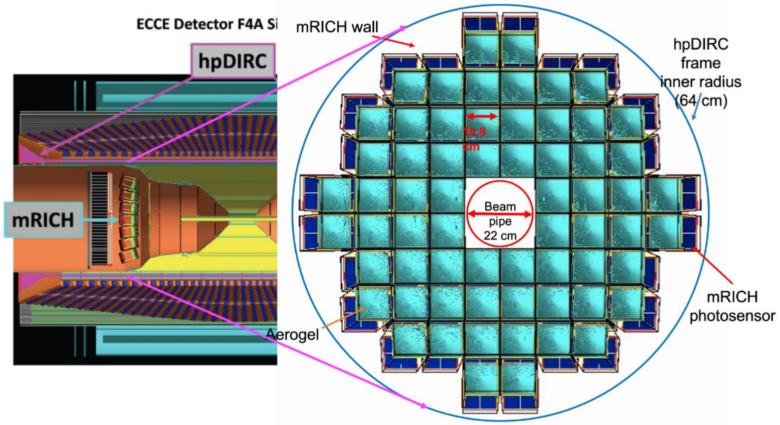
mRICH

Alternatives for Backward PID

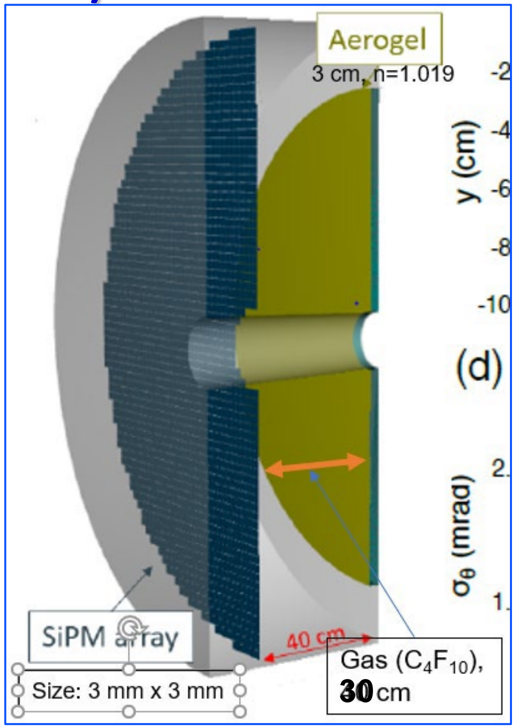
pfRICH

Modular proximity focusing aerogel RICH with focusing by Fresnel lenses





Single volume proximity focusing aerogel RICH with long proximity gap (~30 cm)



PHOTOSENSORS for CHERENKOV PID

Current reference and perspectives

- **commercial MCP by Photek or Photonis** — **hpDIRC**
  - **Cost !**

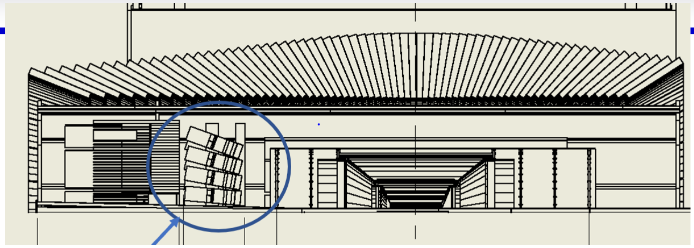
- **SiPM** — **dRICH and backw. RICH**
  - **Dark count rate and radiation damage mitigated with temperature**
  - **Performance recovery by thermal annealing (in situ ?)**
  - **Selection from different vendors**
  - **Robust and extended R&D ongoing**
  - **ALCOR FEE, modified for EIC application**

- **LAPPD** — **back-up SiPMs and alternative for hpDIRC**
  - **For backward RICH**
    - **Material budget (also cooling!)**
    - **Temperature gradient in front of crystal calorimeter**
    - **Possibility to offer also ToF information**
    - **LAPPD option more and more realistic per the backward RICH**

Hot items in consolidation/optimization

- ***PID***
  - *dRICH*
    - *Optimization of the detector configuration*
    - *Option of pressurized Ar instead of fluorocarbons*
  - *Backward RICH*
    - *Selection between the 2 options*
    - *Simulation*
  - *Validation of SiPMs as single photon detector*
    - *R&D*
    - *Simulation of the noise effect*
  - *LAPPD*
    - *Maturity*
    - *Performance for single photon and ToF*
    - *Production capabilities*

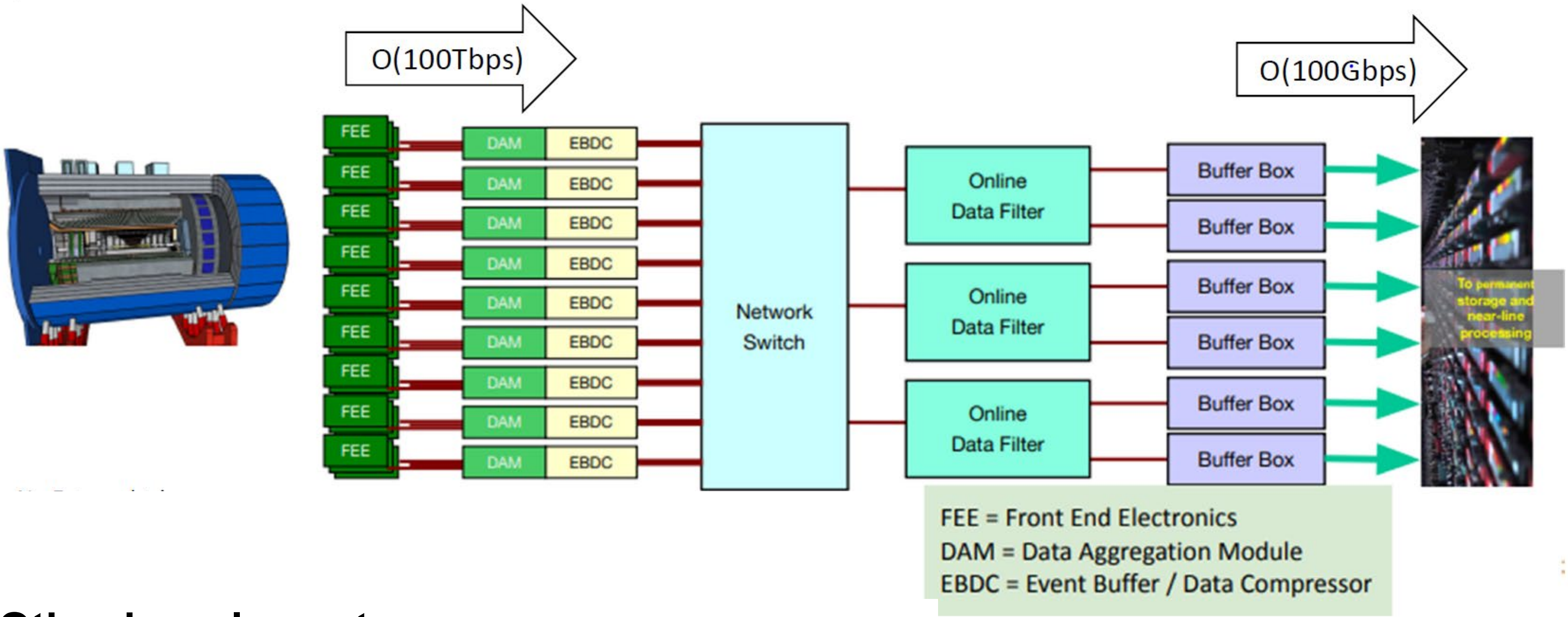
Hot items in consolidation/optimization



- ***The backward end-cap, in a holistic approach***
  - *Present reference includes (from inside to outside)*
    - *Backward RICH (mRICH/pfRICH) with SiPM photosensors operated at – 30-40°C*
    - *ToF layer by AC-LGAD (~ 7 kW power)*
    - *ECal by lead tungstate crystals*
  - *BUT:*
    - *ECal crystals require stable temperature ($|\Delta T|$ < 1°C)*
    - *Both AC-LGAD and SiPM are source of T field*
    - *The amount of material in front of ECal is, of course, a concern (ideally, when near to the ECal, max ~ 20% X_0)*
    - *An important cooling system is massive*
    - *There are space constrains for the detector integration*
  - *Options being considered:*
    - *Backward RICH (mRICH/pfRICH) with LAPPD*
      - *LAPPD can also provide ToF*
    - *NO ToF layer by AC-LGAD*
    - *ECal by lead tungstate crystals, no modifications respect to reference*

ePIC Streaming DAQ

Stored data volumes
~O(100Pb) per run



Other key elements:

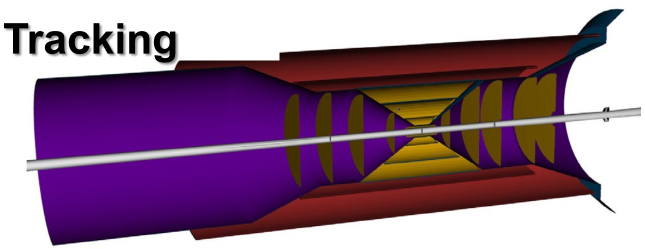
- **Timing system aiming at preserving ~10ps**
- **Slow and fast controls**

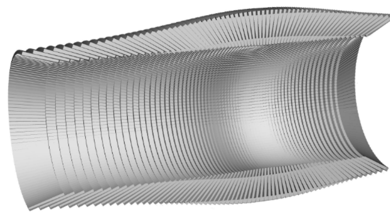
SIMULATION SOFTWARE

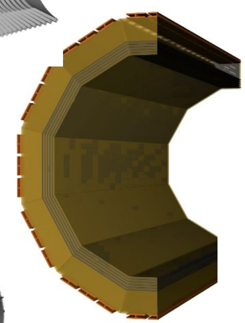
- **Merging of the community in term of common software tools**
  - **Process started in May and converged for the October simulation campaign**

- **October Simulation Campaign**
  - **First ambitious campaign after initial exercises in July**
  - **The geometry of all detector included**
  - **The reconstruction software not fully available: raw data saved as benchmark for reconstruction development and cross check**

Tracking

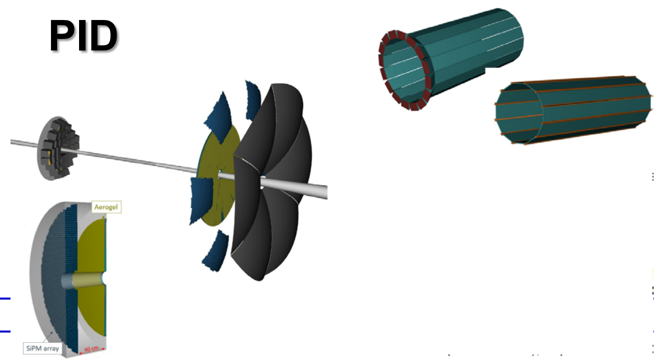




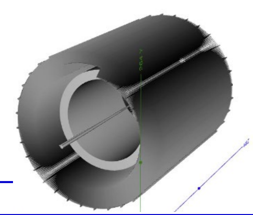


Encap calorimetry

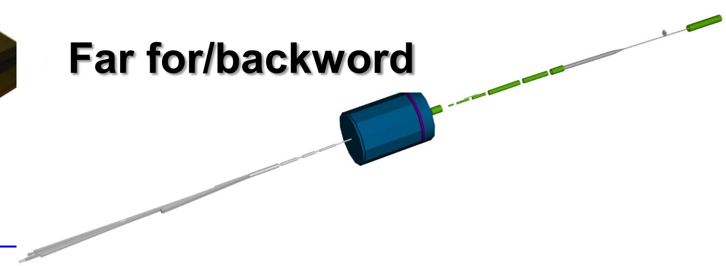
PID



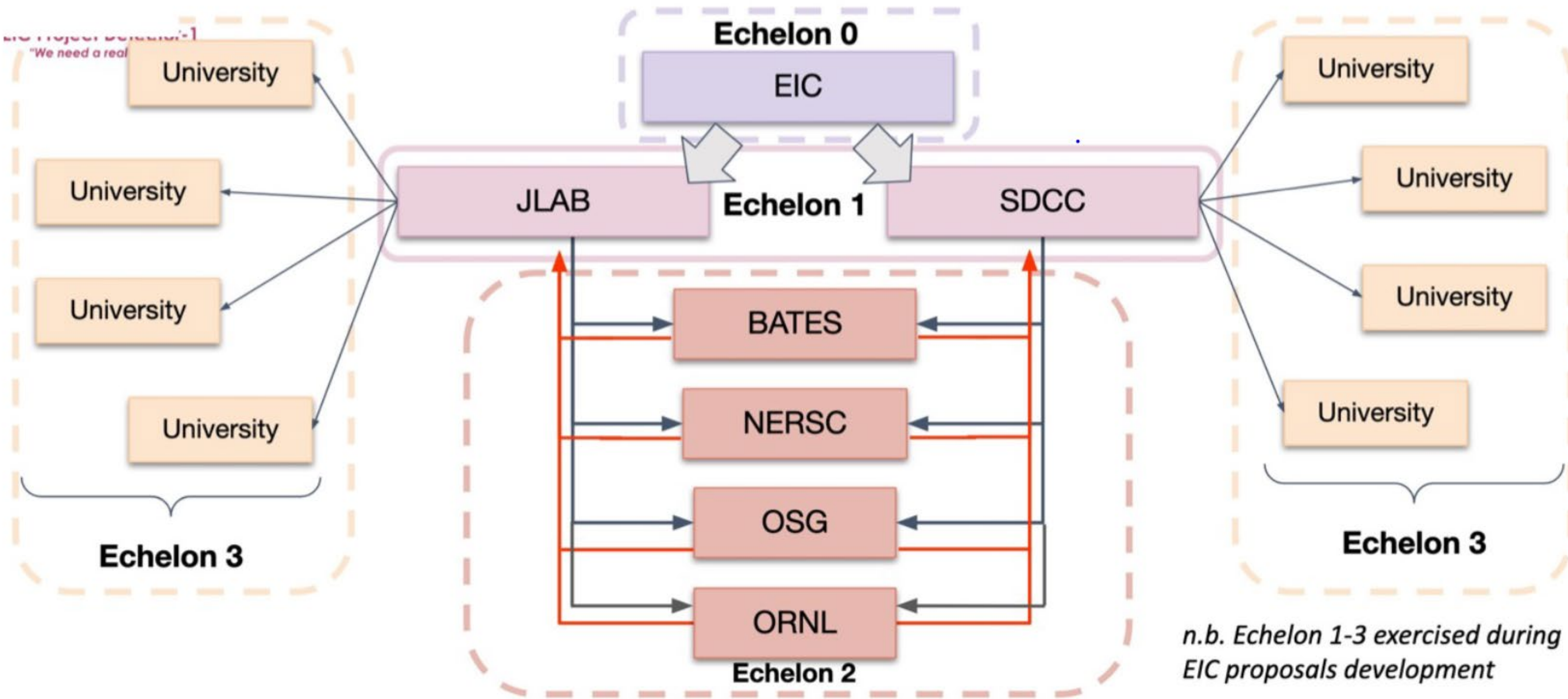
Barrel Ecal, both options



Far for/backword



Computing butterfly model

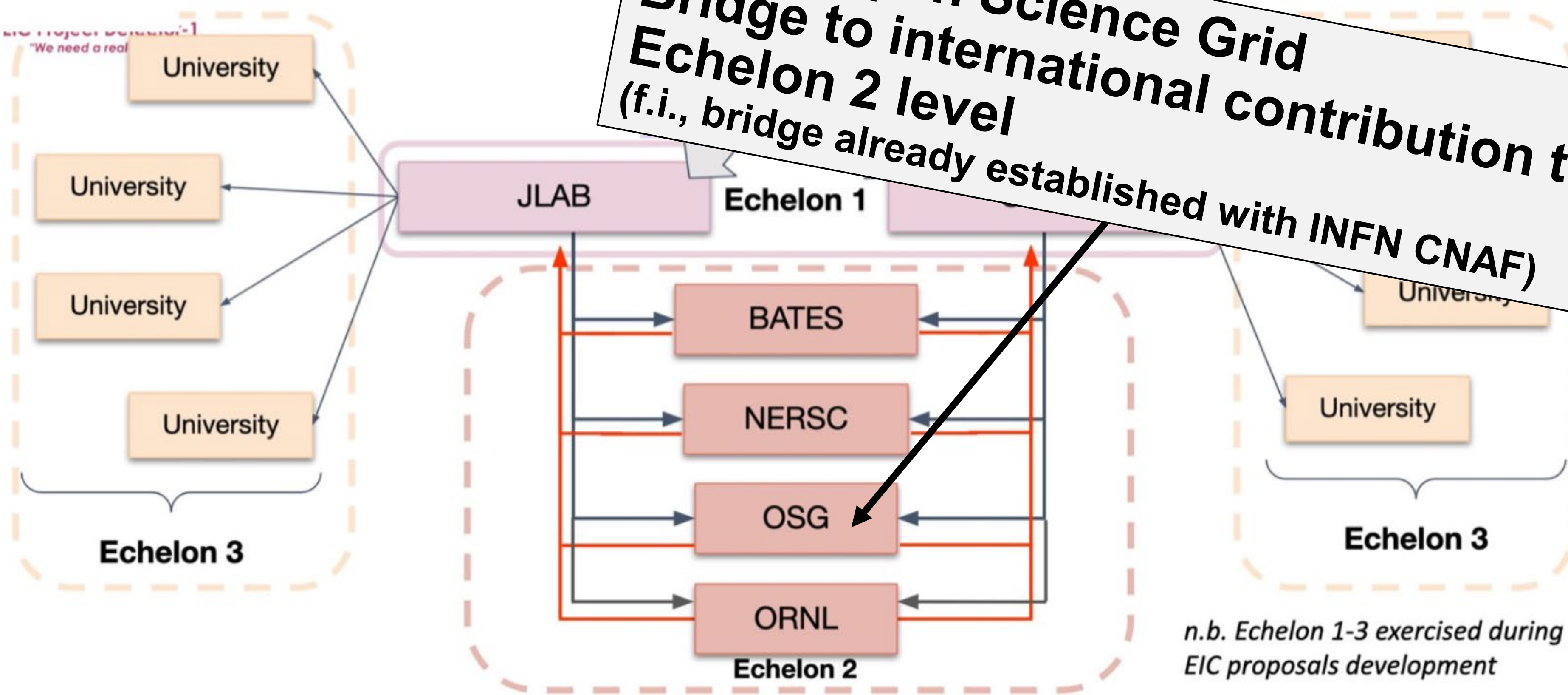


Nearly all storage (raw data, reconstructed data, simulated data) is stored across ***Echelon 1*** *sites*

COMPUTING INFRASTRUCTURE MODEL

Computing butterfly model

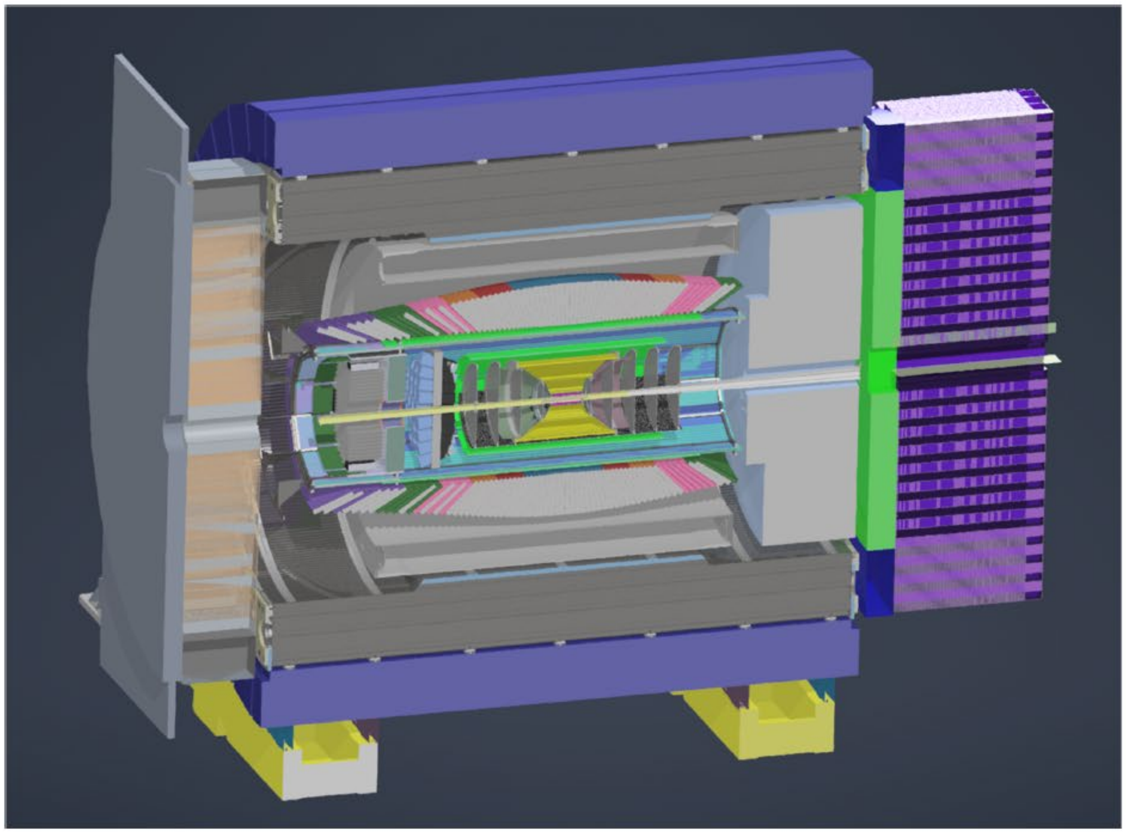
OSG – Open Science Grid
Bridge to international contribution to Echelon 2 level
(f.i., bridge already established with INFN CNAF)



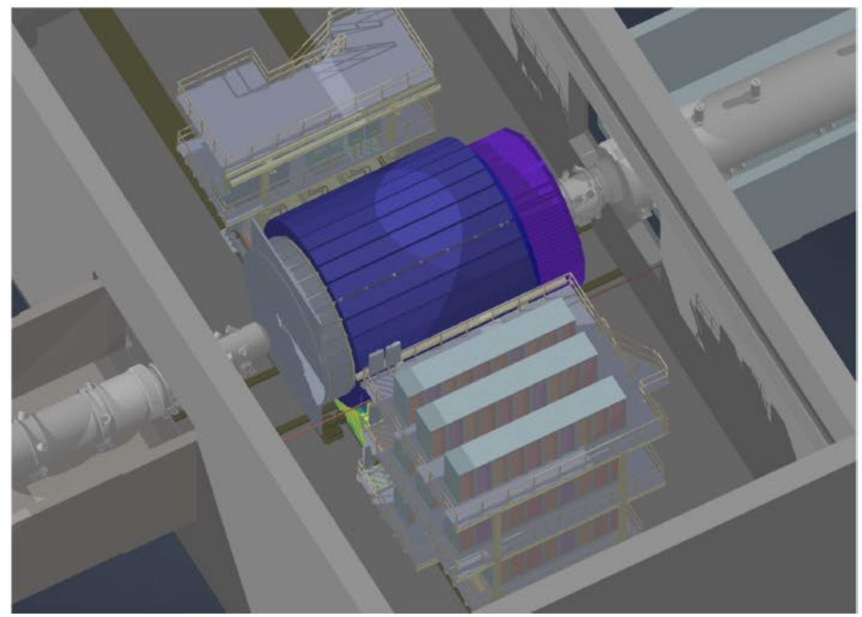
n.b. Echelon 1-3 exercised during EIC proposals development

*Nearly all storage (raw data, reconstructed data, simulated data) is stored across **Echelon 1** sites*

ENGINEERING DESIGN

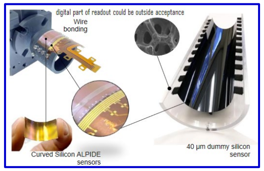


Full CAD design of ePIC ongoing to facilitate *realistic* detector integration.

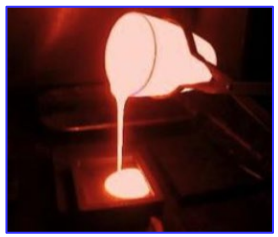


R&D NEEDS

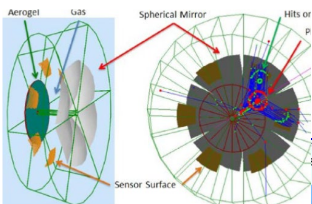
A SUMMARY

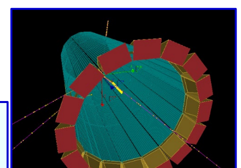


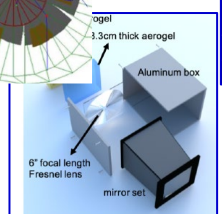
- MAPS
- 2-D read-out of MPGDs
- Cylindrical µRWELL



- SciGlass, large blocks
- Forward calorimetry







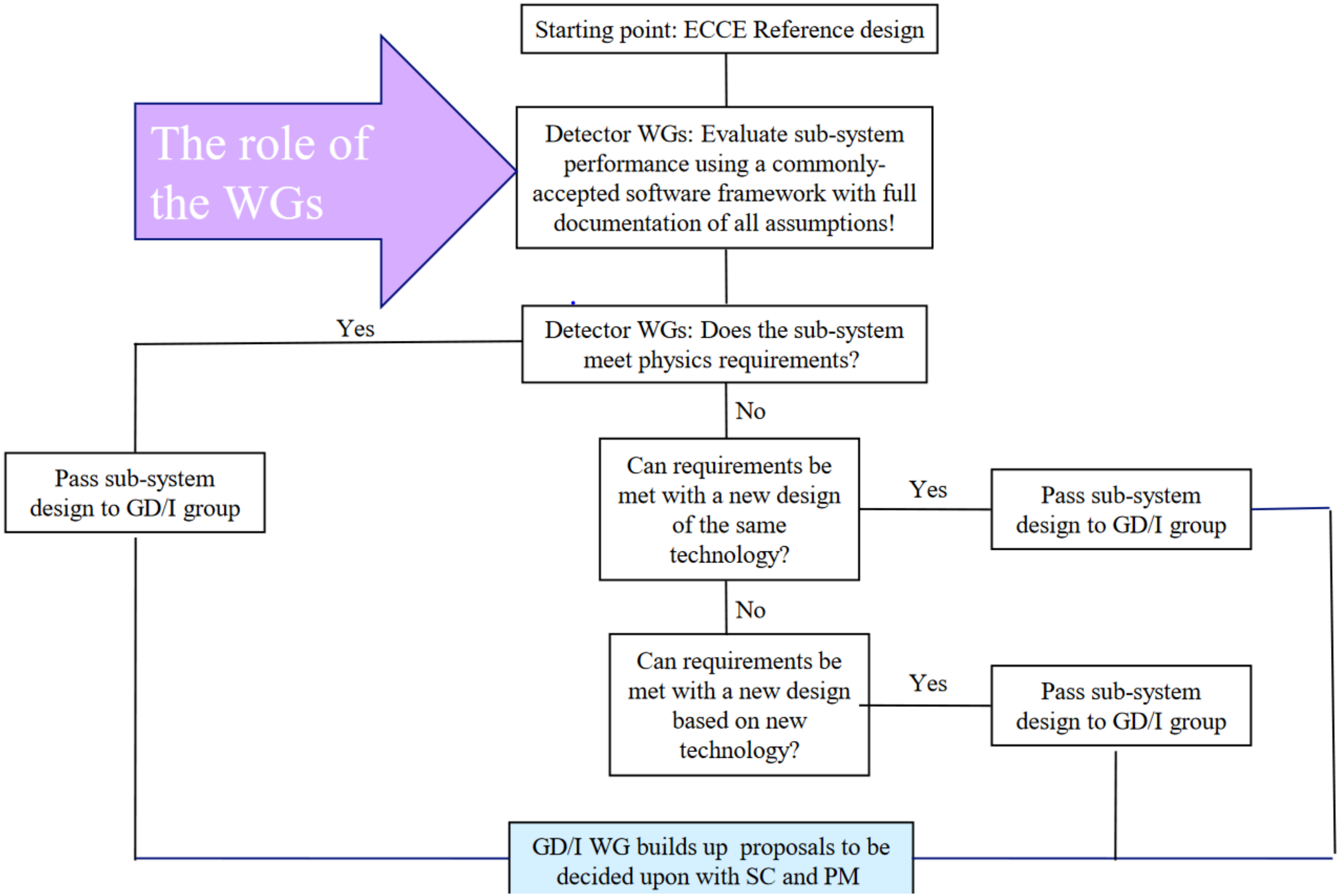
- dRICH
- mRICH
- hpDIRC

- SiPMs
- LAPPDs

The new EIC R&D focus on project detector (new since 2022)		
Sub-detector area	**ID**	**subject**
Tracking -Si	104	services - materail reduction
	111	configuration optimization
	113	sensor R&D - **NEW in 2023**
Tracking - gas	108	MPGDs
ToF/ Tracking	112	AC-LGAD
PID by Cherenkov	102	dRICH
	103	hpDIRC
	101	mRICH
Photosensors	110	SiPM, LAPPD, MCP
Calorimetry	106	forward Ecal
	107	Fowrad Hcal
	105	Scintillating Glass
Whole detector	109	ASICs

Decision process

Converging in consolidation/optimization



CONCLUSIVE MESSAGES

- **The ePIC Collaboration is running !**

  - **WG effort focused on consolidation and developing technical design for CD-2/3A (pre-TDR) and CD3 (TDR)**
  - **Increased coordination effort by the enlarged GD/I WG**
  - **Simulation activity: key to understand the single subdetectors and to get a holistic understanding of the detector as a whole**
  - **Non negligible consolidation and optimization items are still open**
  - **Of great support:**
    - **The constant dialog with the Project Management**
    - **The support of the project engineers for the integration**
  - **We count also on the suggestions from the DAC concerning technological matter**

THANK YOU