



EIC- Electron-Ion Collider and ePIC

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INFN - TRIESTE



OUTLOOK

- **The EIC Project**

- **ePIC – the project detector**



BREAKING NEWS, January 2020

Department of Energy

U.S. Department of Energy Selects Brookhaven National Laboratory to Host Major New Nuclear Physics Facility

JANUARY 9, 2020

The Electron Ion Collider (EIC), to be designed and constructed over ten years at an estimated cost between \$1.6 and \$2.6 billion, will smash electrons into protons and heavier atomic nuclei in an effort to penetrate the mysteries of the “strong force” that binds the atomic nucleus together.

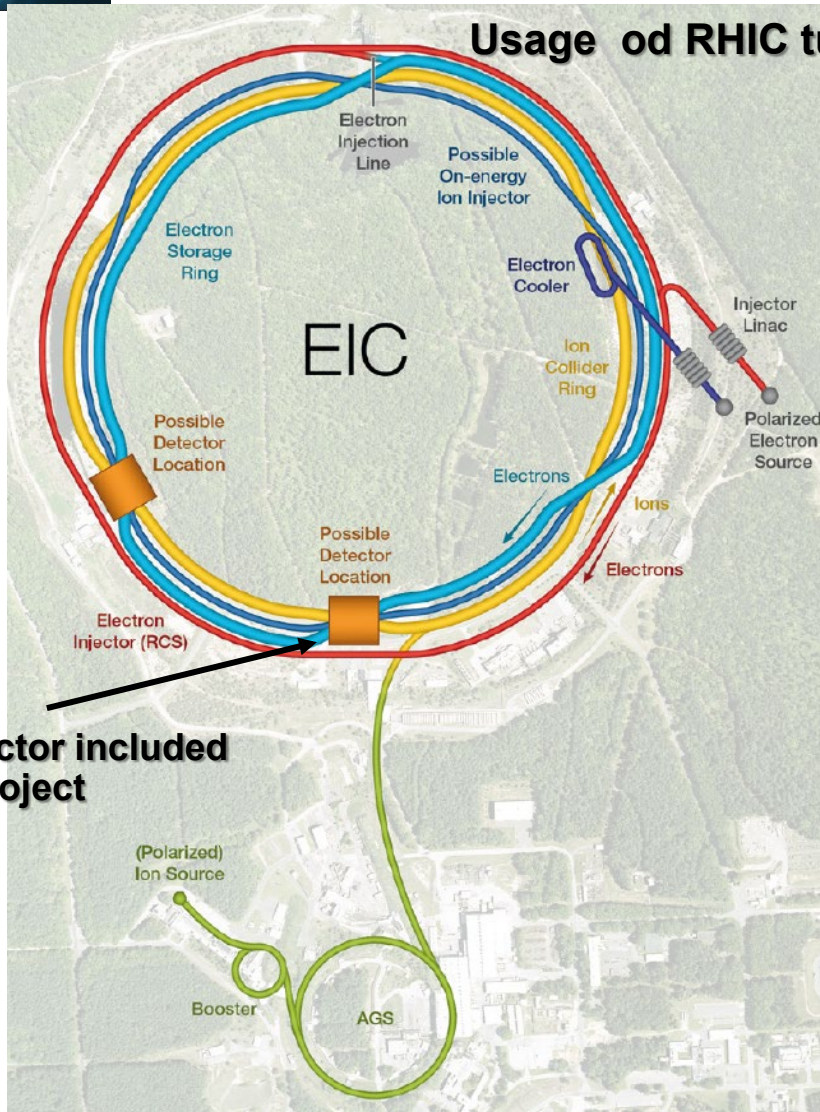
Secretary Brouillette approved Critical Decision-0, “Approve Mission Need,” for the EIC on December 19, 2019.

<https://www.energy.gov/articles/us-department-energy-selects-brookhaven-national-laboratory-host-major-new-nuclear-physics>

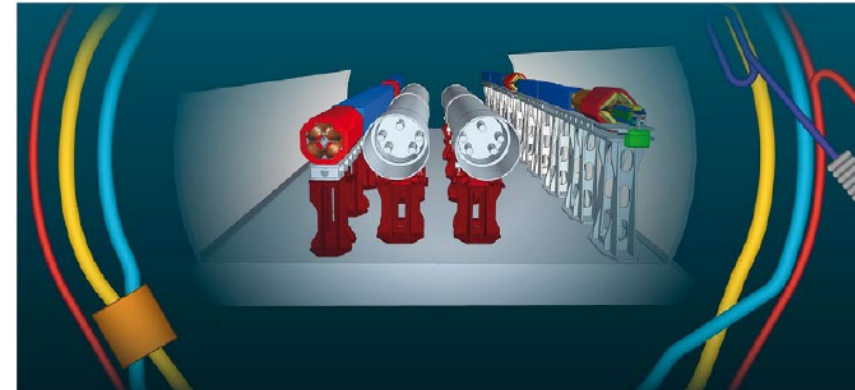
The EIC project



Usage of RHIC tunnel and RHIC p/ion complex



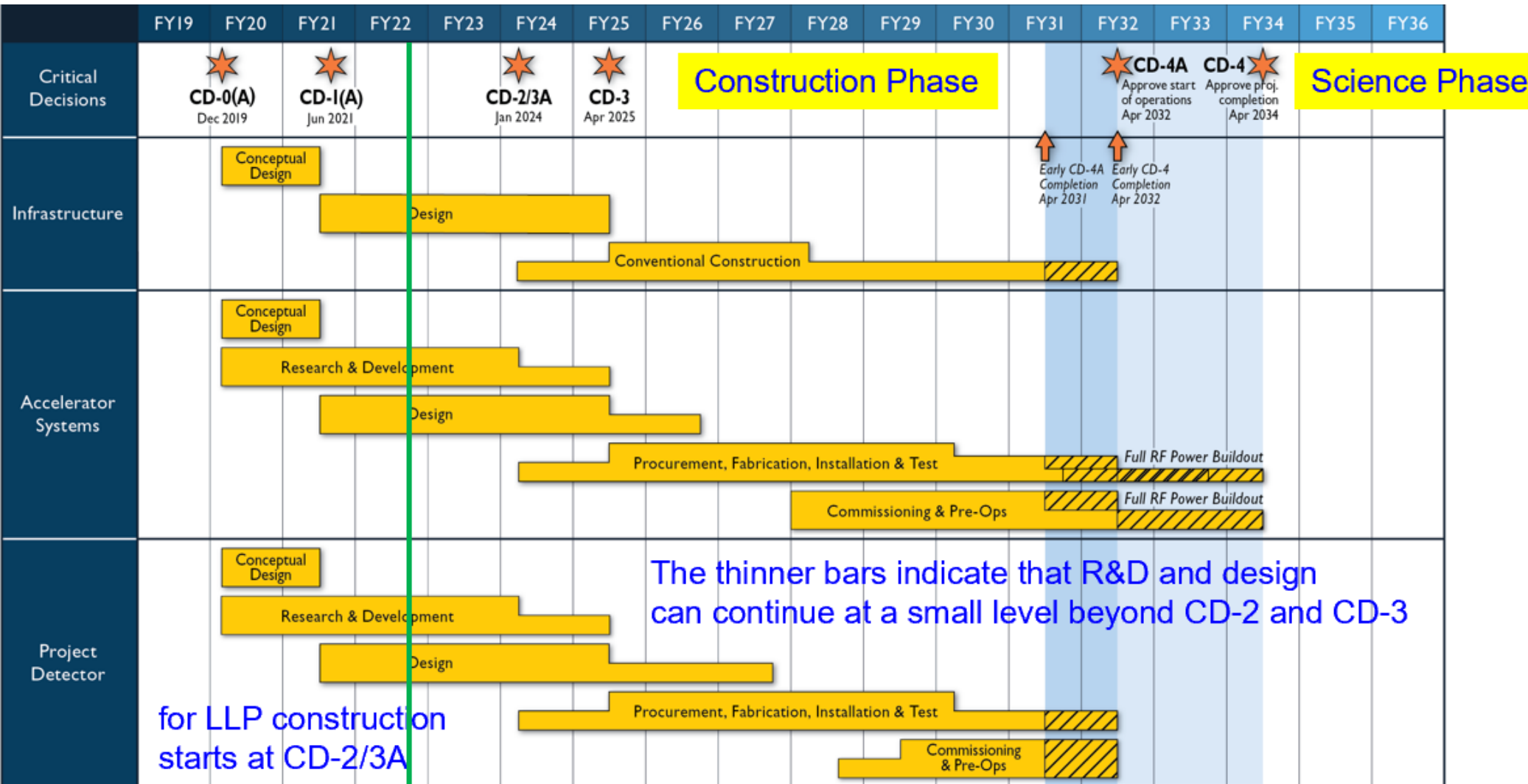
IP6 detector included in the project



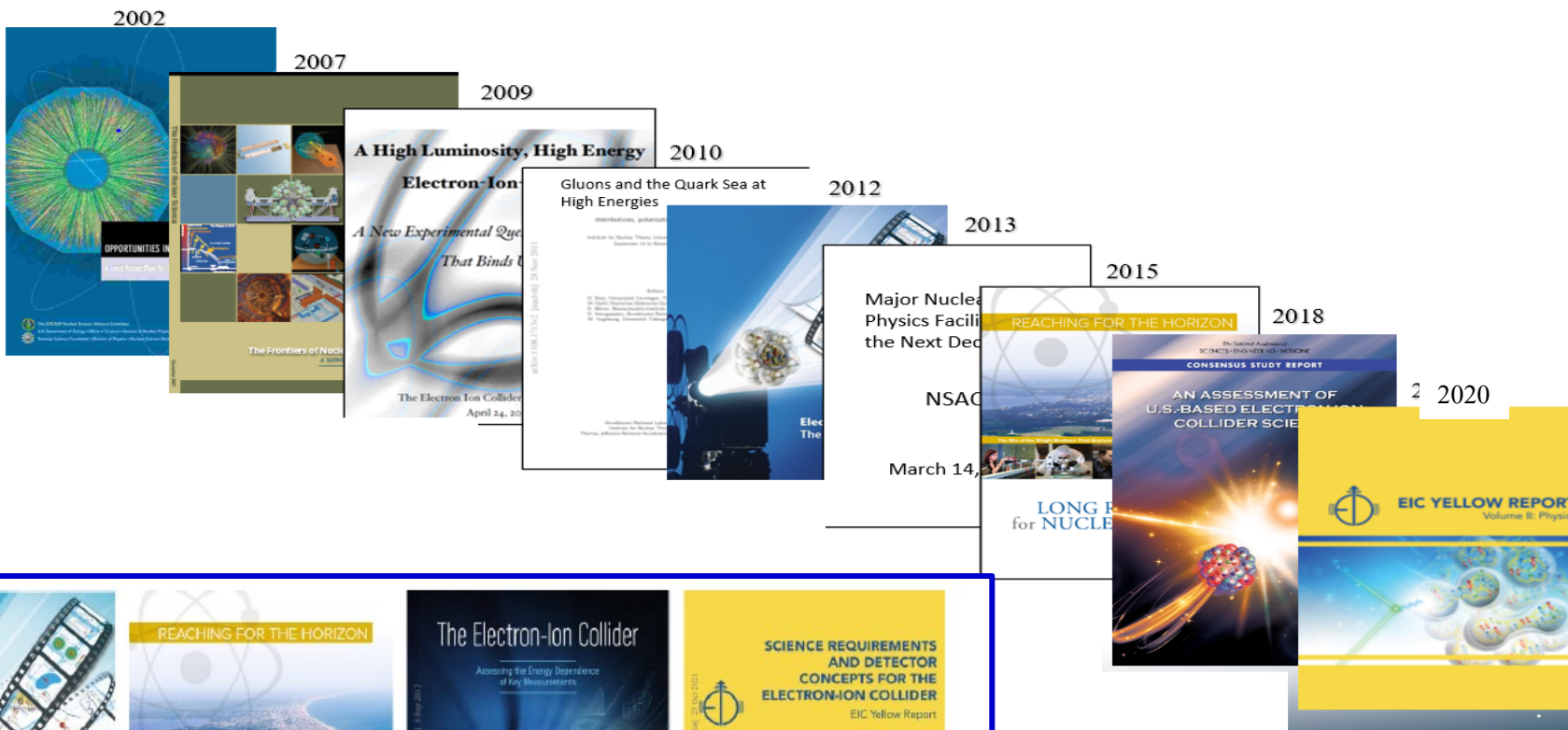
- spanning a wide kinematical range
 - ECM: 20 – 141 GeV
- High luminosity
 - up to $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$
- highly polarized e ($\sim 70\%$) beams
- highly polarized light A ($\sim 70\%$) beams
- wide variety of ions: from H to U
- Number of interaction regions: up to 2



The EIC timelines



THE PATH TO THE EIC PROJECT



NAS report
EIC project is compelling, fundamental and timely

THE INTERNATIONAL COMMUNITY

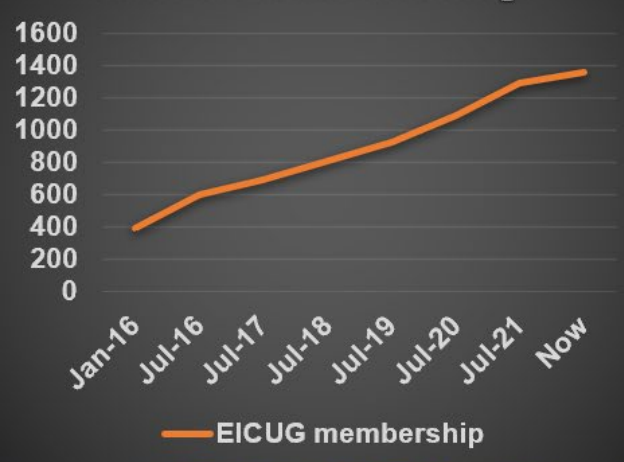
The EIC User Group:
<https://eicug.github.io/>

Formed 2016 –

- 1361 collaborators,
- 36 countries,
- 267 institutions as of September 20, 2022.

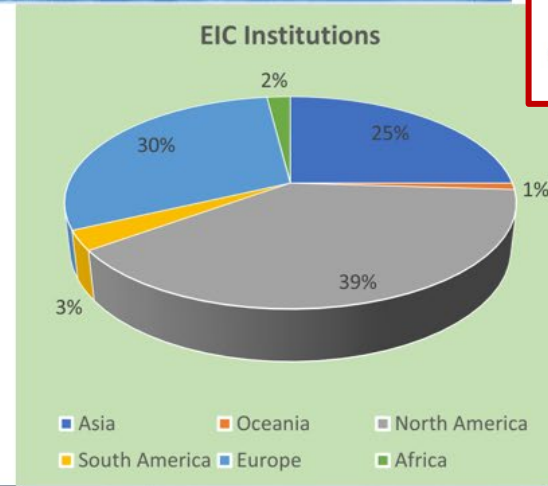
Strong and Growing International Participation.

EICUG membership @ time of EICUG Meetings



Annual EICUG meeting

- 2016 UC Berkeley, CA
- 2016 Argonne, IL
- 2017 Trieste, Italy
- 2018 CUA, Washington, DC
- 2019 Paris, France
- 2020 Miami, FL
- 2021 VUU, VA & UCR, CA
- 2022 Stony Brook U, NY
- 2023 Warsaw, Poland



Among the main Achievements:
The Yellow Report



THE SCIENTIFIC SCOPE

Towards non perturbative QCD

→ EIC will answer to these hot questions: a machine to study nucleon glue

- **q, g distributions (momentum, space, spin) within the nucleon?**
- **nucleon properties (MASS !) from q, g and QCD?**
- **q, g distributions in the dense nuclear matter ?**
- **Gluon density in nuclei, does it saturate at small x-values?**
- **interaction of coloured q and g and colourless particles with the nuclear matter**
- **how confined hadron states emerge**
- **And more:**
 - Heavy (and light) q spectroscopy
 - 'initial state' states in HI collisions
 - ...

The way matter sums up is still quite a mystery!

● Hydrogen
 ● Oxygen
 ● Proton
 ● Neutron
 ● d quark
 ● u quark

● Water
 ● Helium
 ● proton
 ● neutron

Higgs mechanism:
 Mass $\approx 1.78 \cdot 10^{-26}$ g
 QCD dynamics makes 99% of proton mass!
 Mass $\approx 168 \cdot 10^{-26}$ g
 (and baryonic matter... is just 5% of the Universe...)

Molecular Formula: H_2O
 water
 7732-88-8
 Distilled water
 Dihydrogen oxide
 Purified water
 Synonyms: ...
 Molecular Weight: 18.015

Periodic Table snippet:
 5 B 6 C 7 N 8 O 9 F
 Boron Carbon Nitrogen Oxygen Fluorine
 10 Ne 11 Na 12 Mg 13 Al 14 Si 15 P 16 S 17 Cl 18 Ar
 Neon Sodium Magnesium Aluminum Silicon Phosphorus Sulfur Chlorine Argon

7/9/2023 / Sar WorS 2023 P. Antonioli - ATHENA status 5

$$\frac{1}{2} = \frac{1}{2} \Delta\Sigma(\mu) + \Delta G(\mu) + L_q(\mu) + L_g(\mu)$$

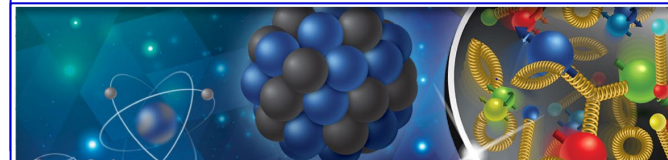
quark and gluon spin orbital angular momentum

- since late '80s we know $\Delta\Sigma$ is not the dominant term
- only 25% comes from quarks/anti-quarks – gluon contr. at 30%
- big uncertainties! → no data on $\Delta\Sigma$ and ΔG for $x < 5 \times 10^{-3}$

EIC will offer **polarized** beams in a largely unexplored x-Q² region!

EIC can really resolve the spin components of the nucleon P. Antonioli - ATHENA status 6

EIC physics: a machine to study the nucleon "glue"

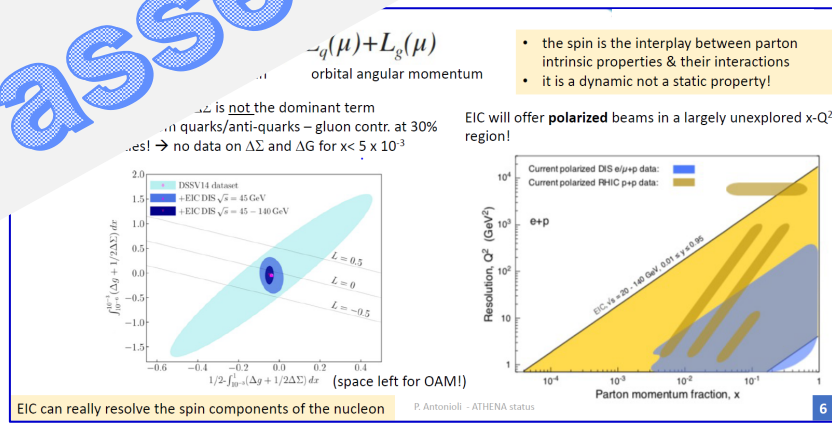
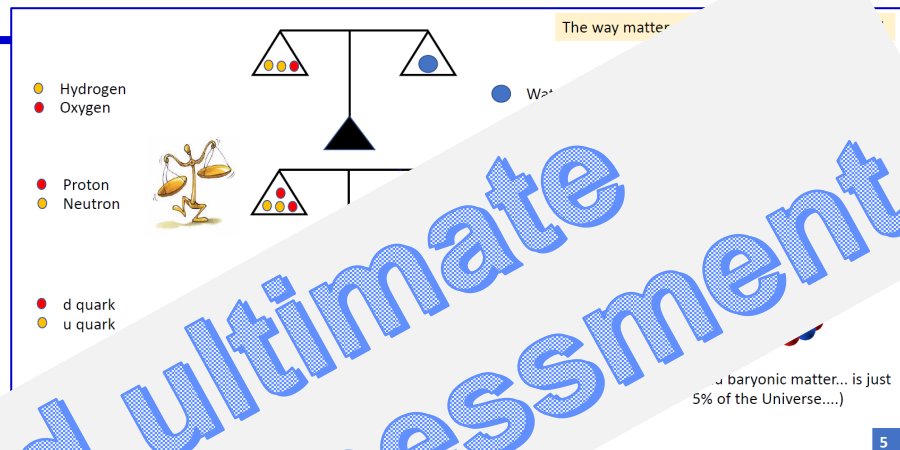


THE SCIENTIFIC SCOPE

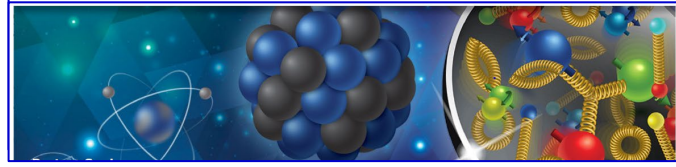
Towards non perturbative QCD

→ EIC will answer to these hot questions: a machine to study nucleon glue

- **q, g distributions (momentum, space, spin) within the nucleon?**
- **nucleon properties (MASS !) from q, g and QCD?**
- **q, g distributions in the dense matter ?**
- **Gluon density in dense matter at small x-values**
- **interactions in dense matter**
- **states emerge**
- **(and light) q spectroscopy**
- **'initial state' states in HI collisions**



EIC physics: a machine to study the nucleon "glue"



A unique and ultimate collider for QCD assessment



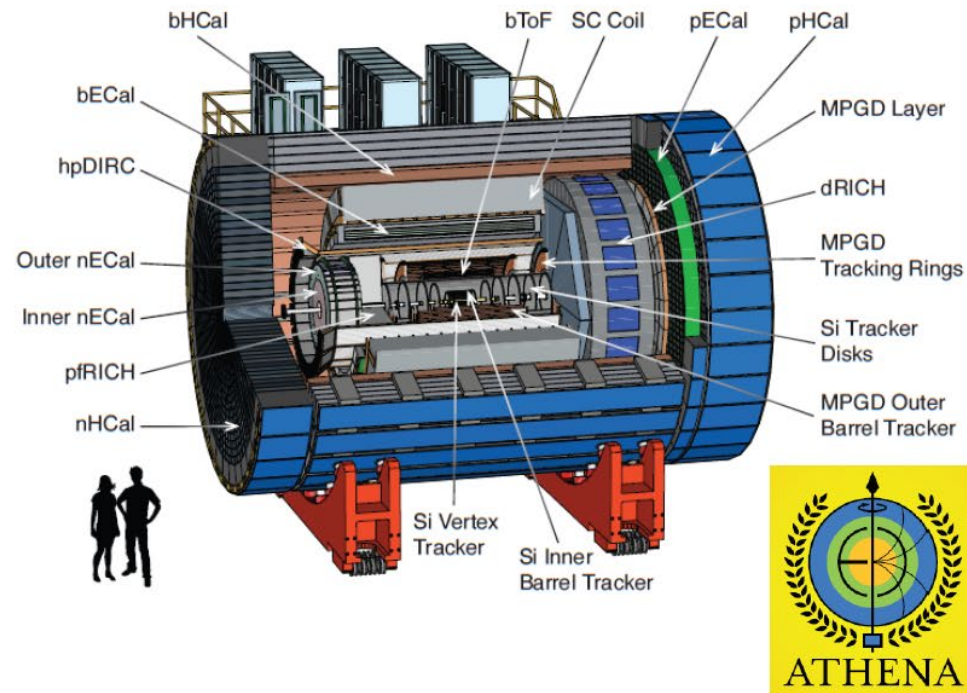
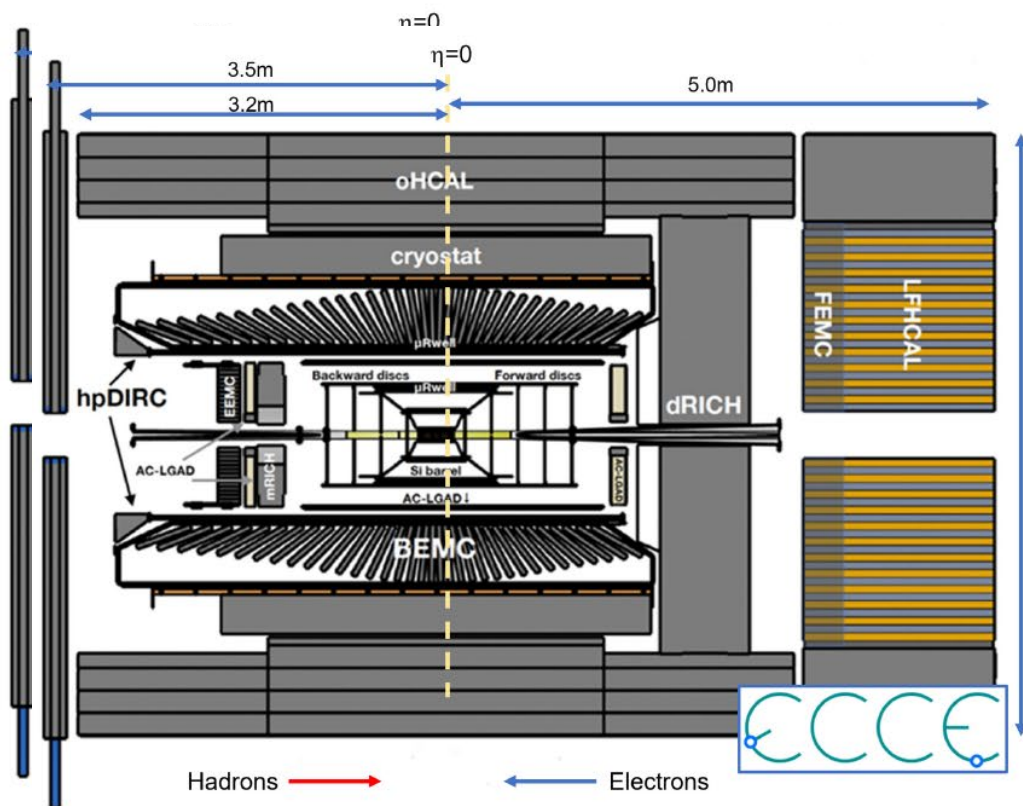
OUTLOOK

- **The EIC Project**

- **ePIC – the project detector**



ECCE and ATHENA



Key conceptual differences – bore size and magnetic field!



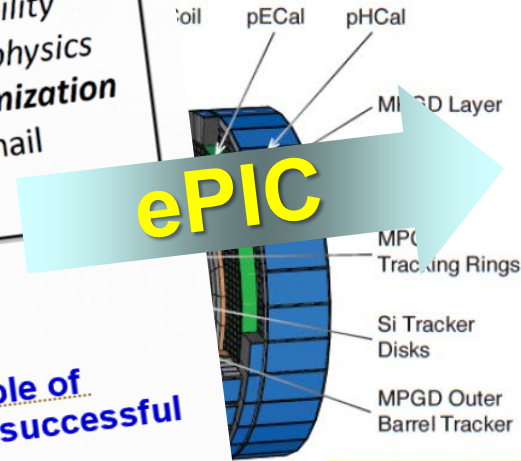
ECCE and ATHENA

Project – assumed the DPAP recommendations:

“The EIC Project recognizes that the panel recommended ECCE as the Project Detector. As described in the panel report, we will urge the proto-collaboration to: **(1) integrate new collaborators** in a manner that enables them to make contributions that impact the capabilities and success of the experiment in significant ways, including new collaborating individuals and groups into positions of responsibility and leadership; and **(2) integrate new experimental concepts** and technologies that improve physics capabilities without introducing inappropriate risk. **ECCE is the reference design for this optimization and consolidation so that the Project Detector can advance to CD2/3a in a timely way**” – email communication from the EIC Project Team on 13 March 2022.

In this context, some statements in the DPAP report are key:

- “The managements and collaborations of both ATHENA and ECCE are capable of becoming a solid basis for the full development and implementation of a successful Detector 1.
- ... the proto-collaborations are not yet at the strength necessary to prepare a detector for Day 1 of the EIC.”



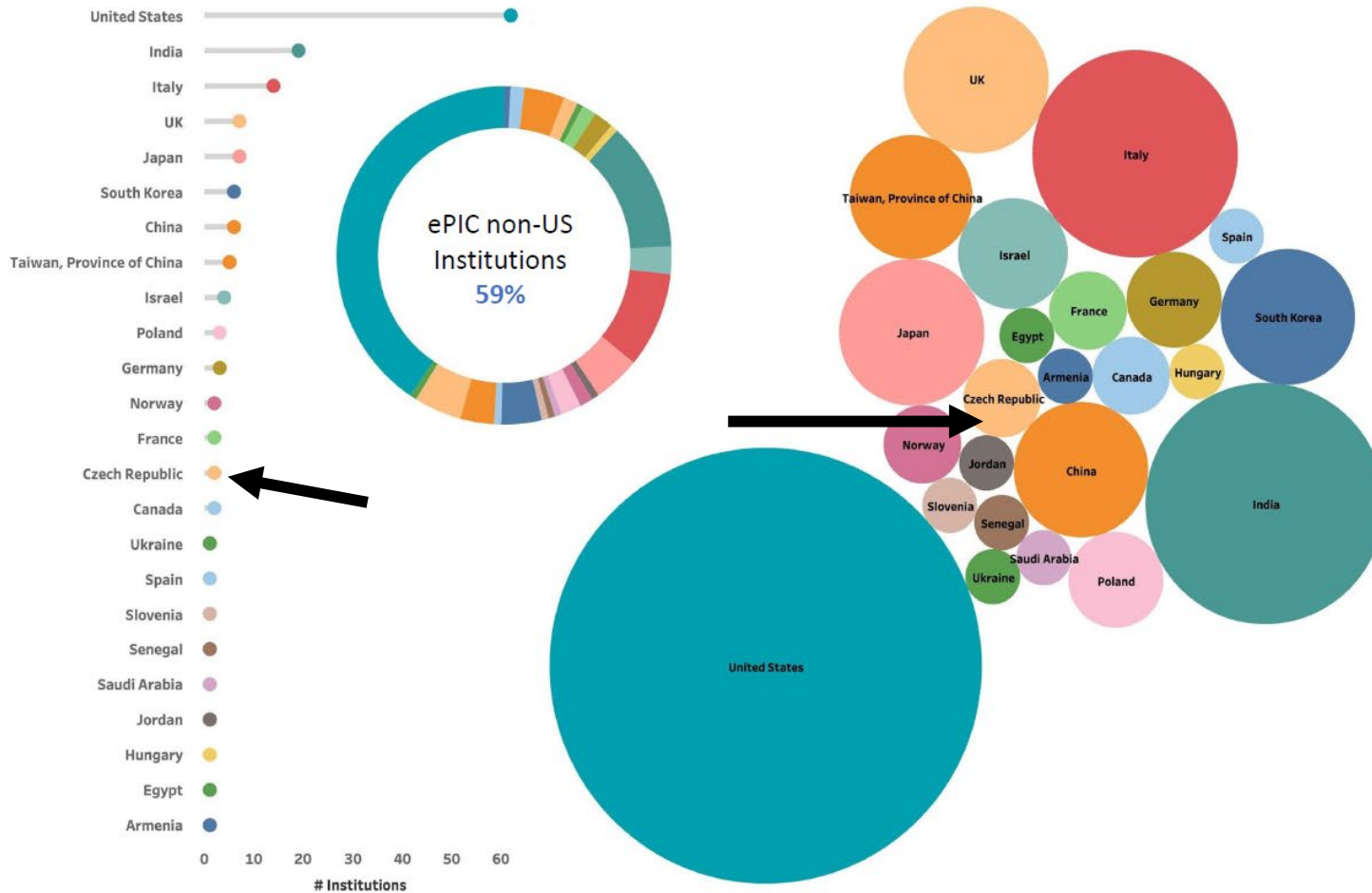
Barrel Tracker



Key conceptual differences – bore size and magnetic field!



The ePIC Collaboration

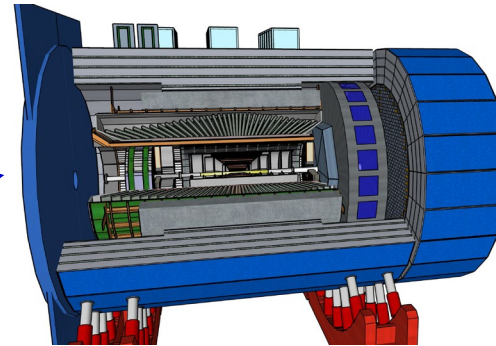
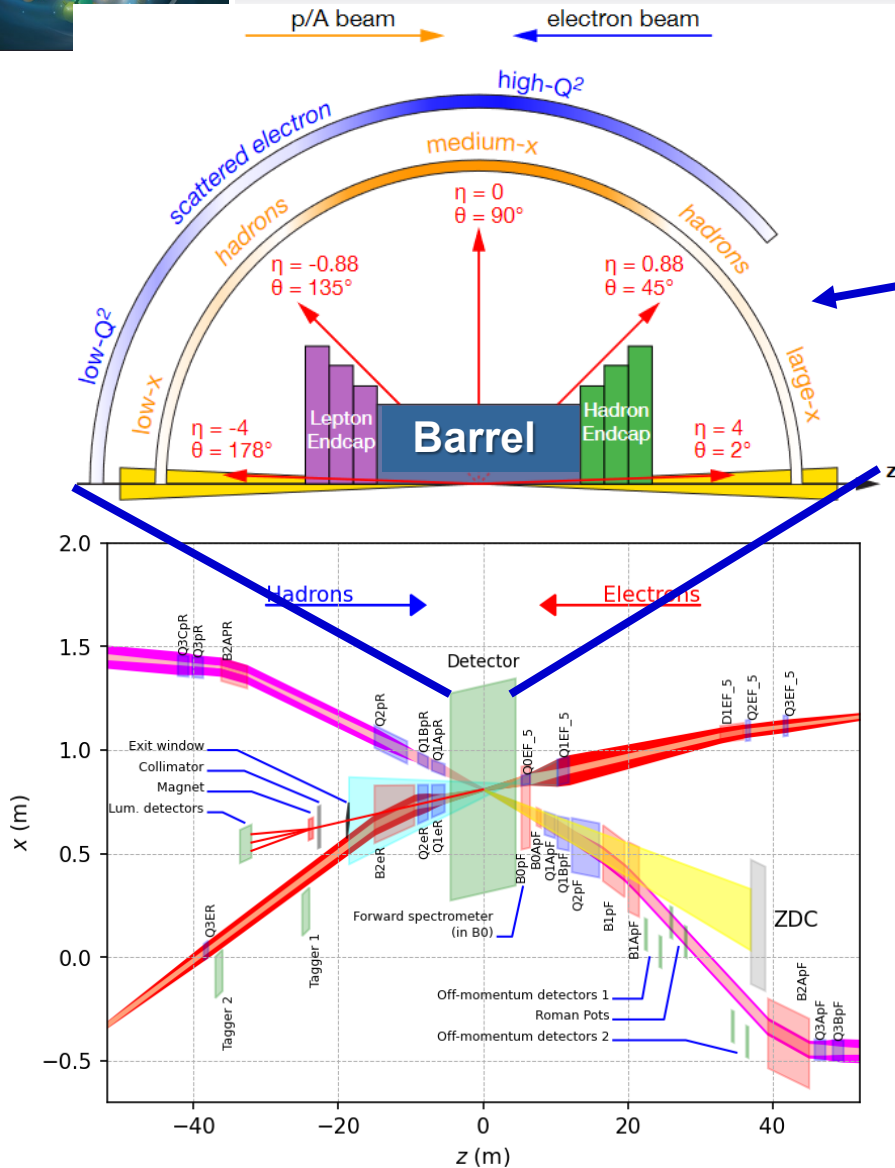


*160+ institutions
24 countries*

500+ participants

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

THE COMPLETE ePIC DETECTOR

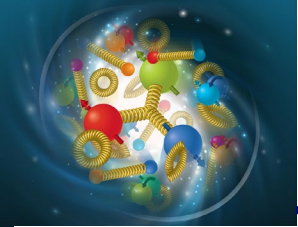


Central Detector (CD)

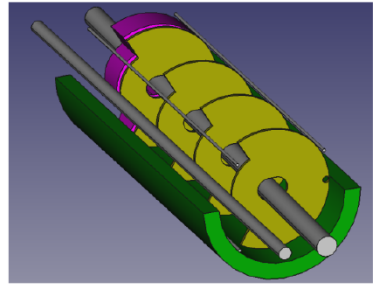
Total size detector: ~75m
 Central detector: ~10m
 Backward electron detection: ~35m
 Forward hadron spectrometer: ~40m

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 and backward



Far Forward



Roman Pots

Hadron Beam after IP

ZDC

Off Momentum

ZDC

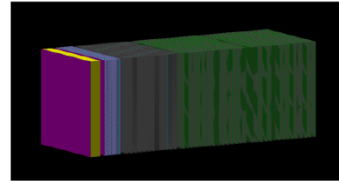


Figure: Low- Q^2 taggers

Far Backward

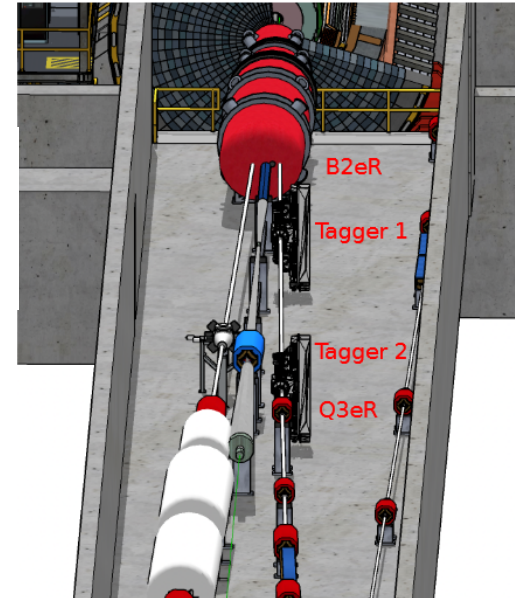
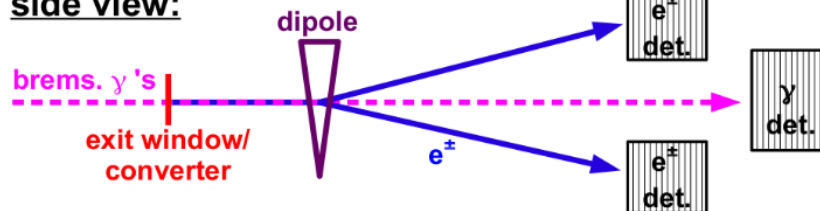


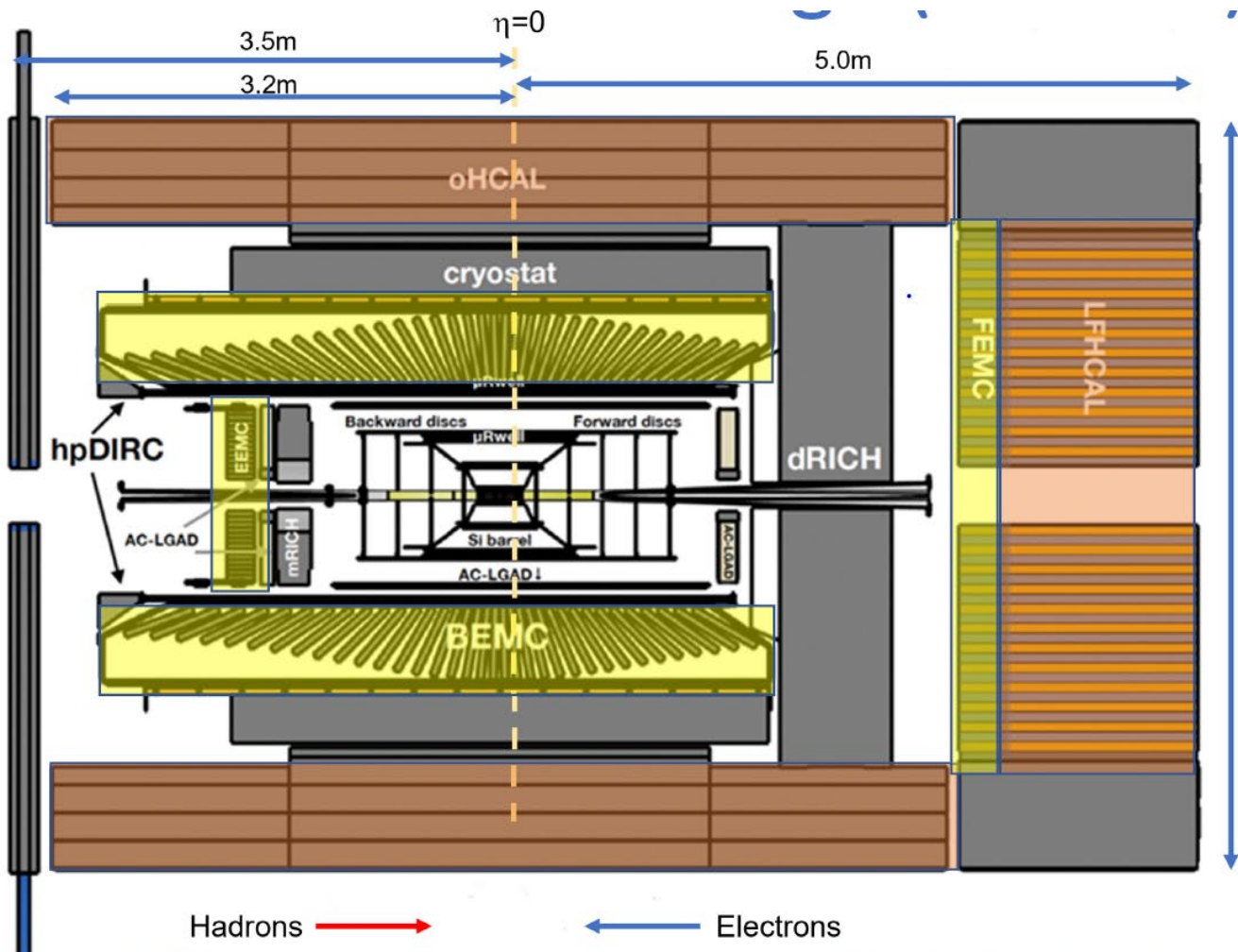
Figure: Luminosity detector

side view:





ePIC CENTRAL DETECTOR



Tracking:

- New 1.7T solenoid
- Si MAPS Tracker
- MPGDs (μ RWELL/ μ Megas)

PID:

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

Calorimetry:

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

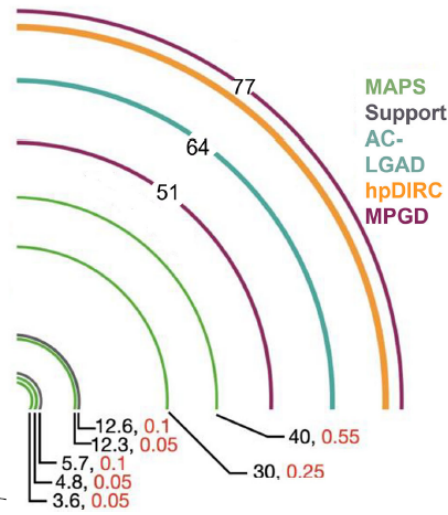
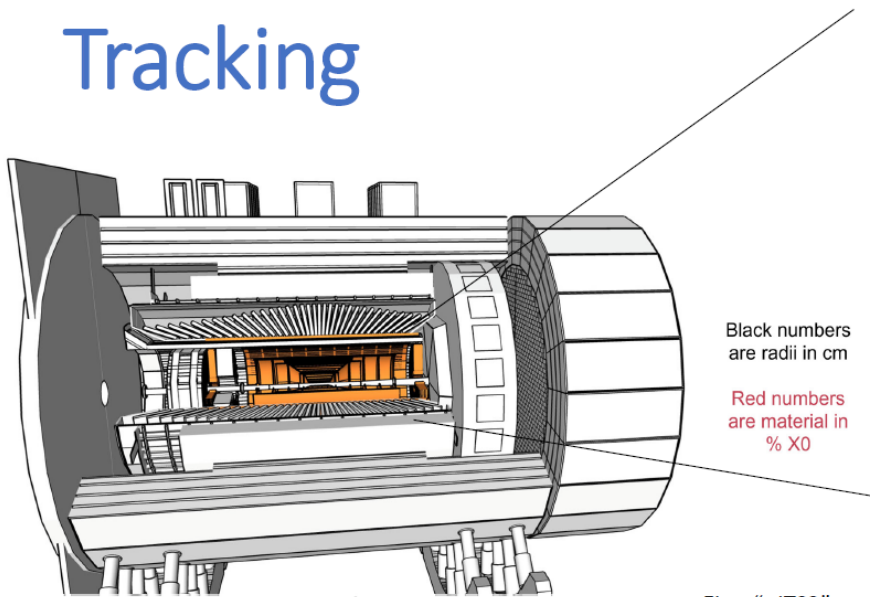
9/23/2022

2022 Hot/Cold QCD Town Hall



TRACKING IN ePIC CD

Tracking

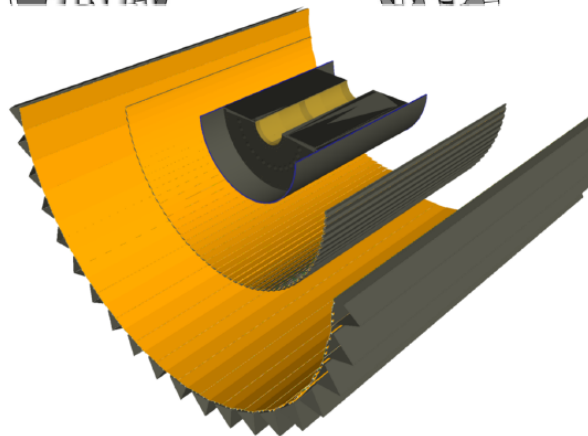


Si Tracker based on ALICE ITS3 65nm MAPS sensors.

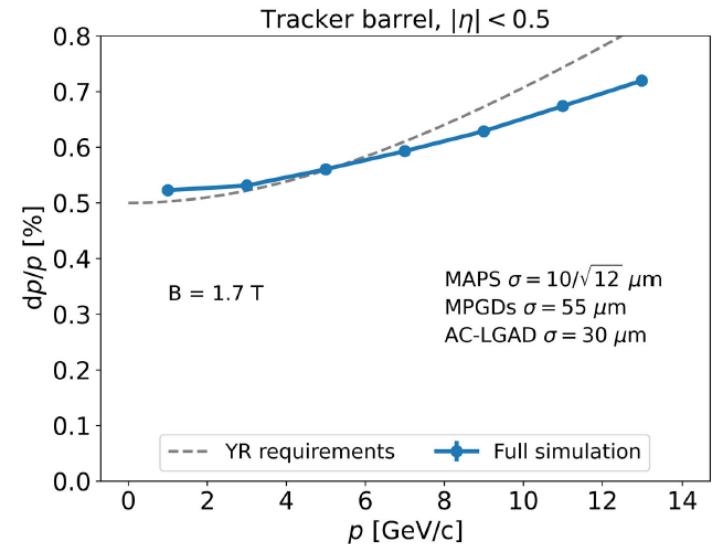
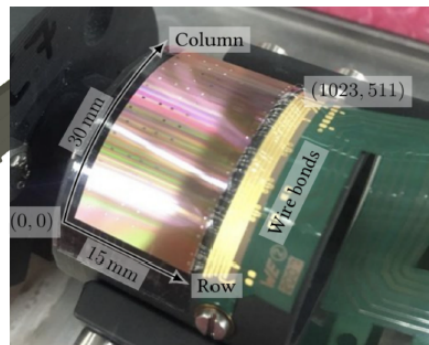
Five layers in barrel, supplemented by MPGDs for pattern recognition.

Five discs in forward/backward directions (+MPGD in forward)

Meets EICUG Yellow Report design requirements.



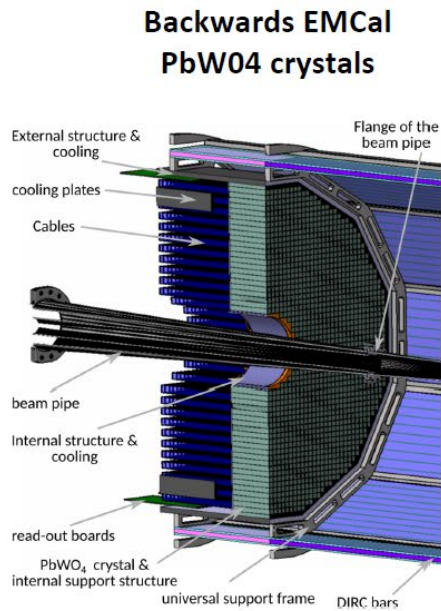
First "μITS3" assembly at CERN



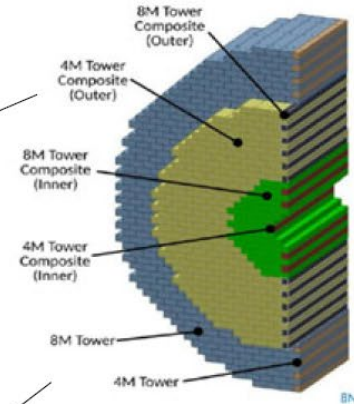
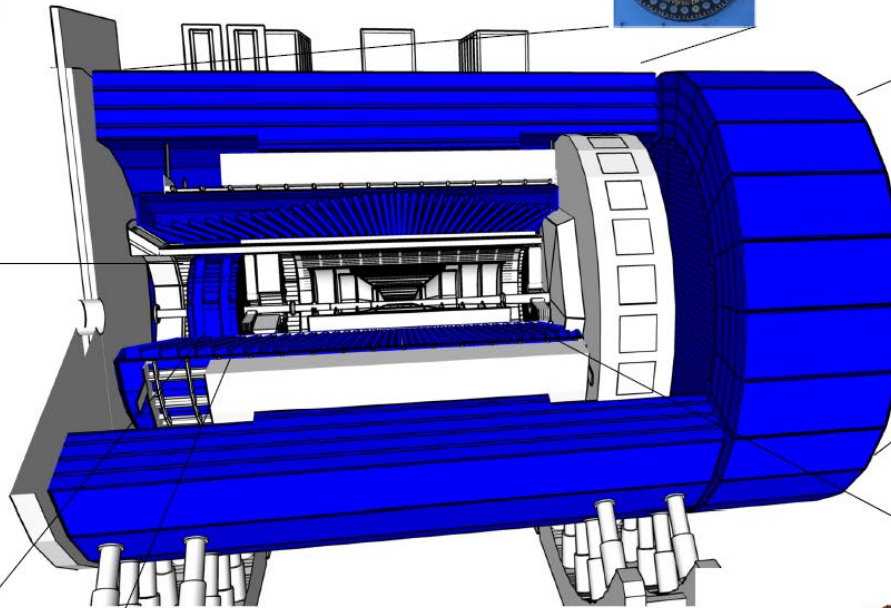


CALORIMETRY IN ePIC CD

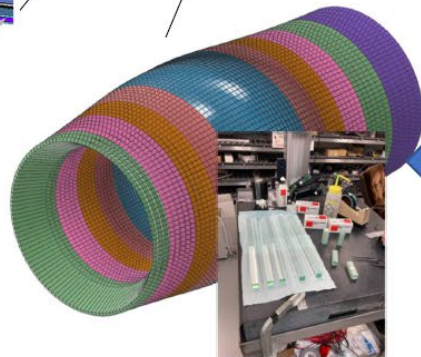
Calorimetry



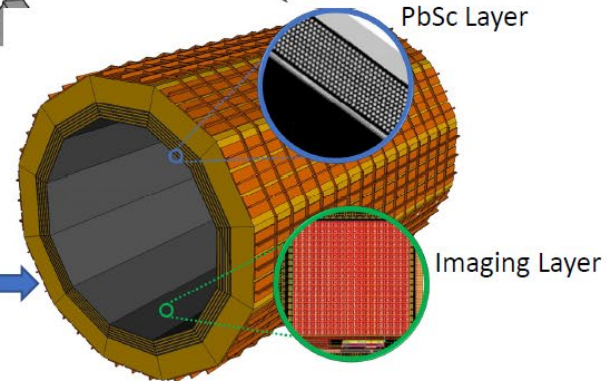
**Barrel HCAL
(sPHENIX re-use)**



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



**Complementary
options for BECAL:
SciGlass or
Imaging Calorimeter**

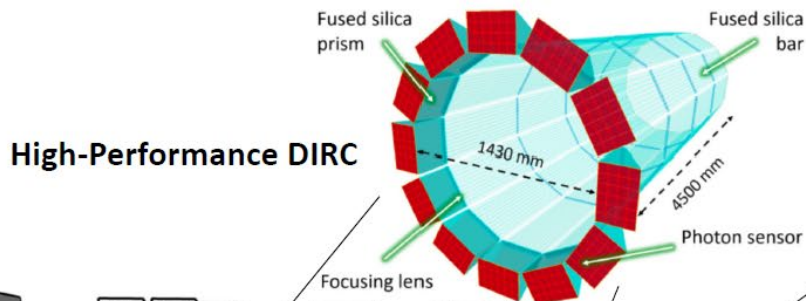
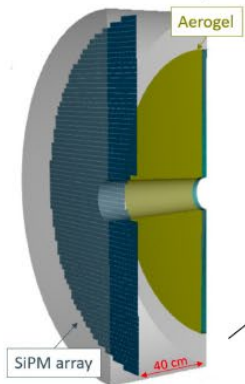




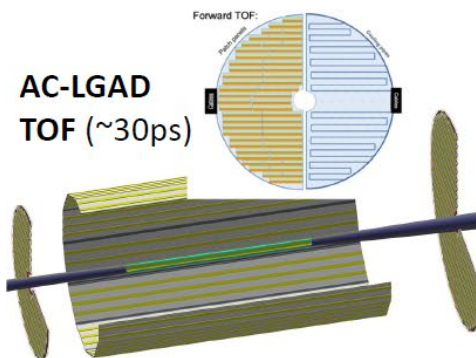
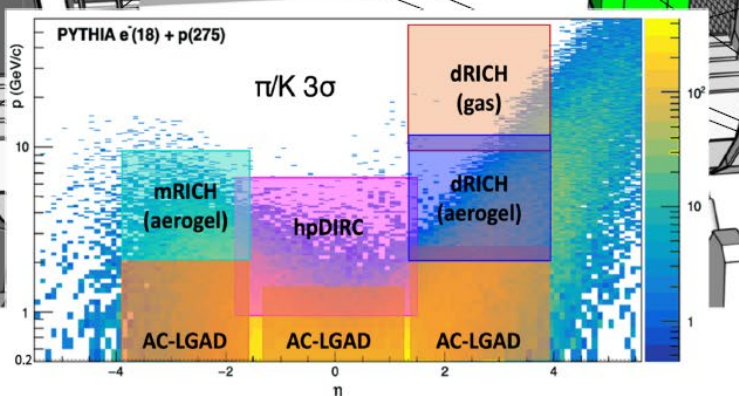
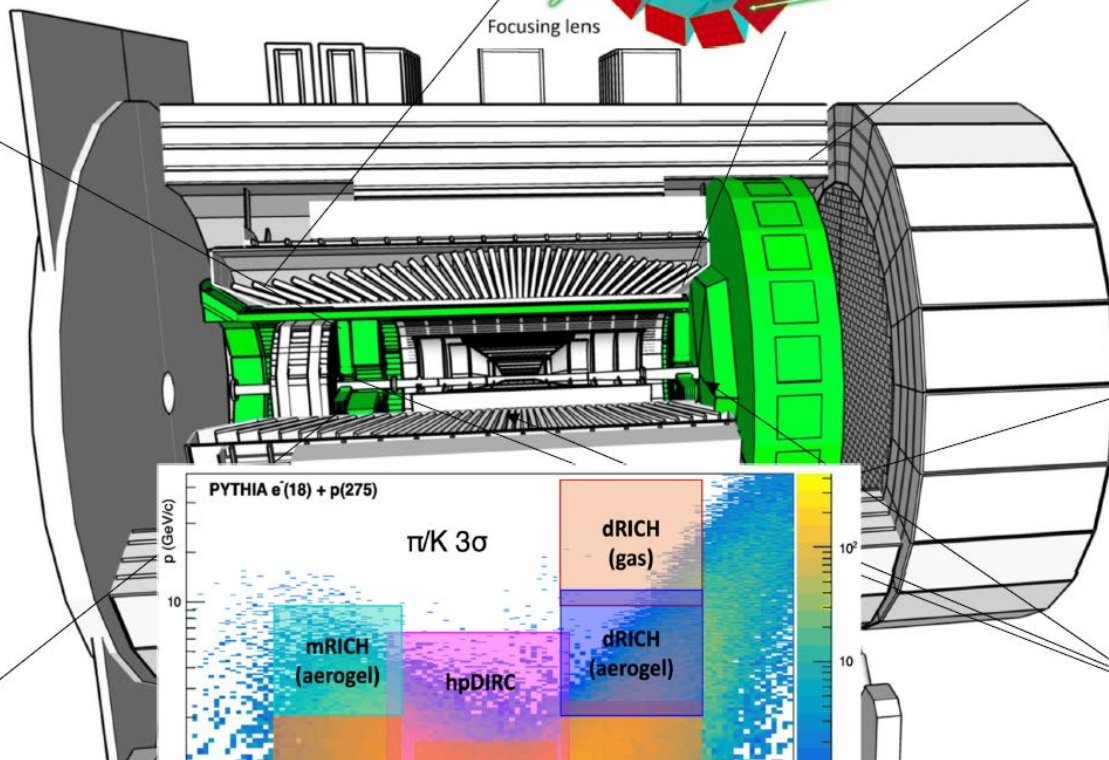
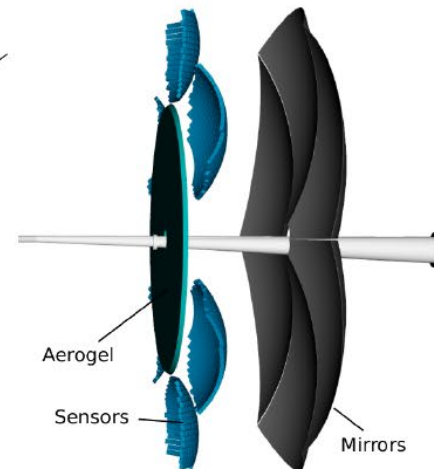
PID IN ePIC CD

Particle ID

Modular (mRICH)
or Proximity Focused
(pRICH)



Dual-Radiator RICH (dRICH)





CONCLUDING REMARKS

The EIC is a unique project, the only concrete one around the world for the ultimate understanding of **QCD**

- The EIC project is approved, financially well-supported and progressing according to schedule
- The ePIC Collaboration for the project detector effort has kicked-off

Ongoing detector activity: consolidation and developing pre-TDR (CD2) and TDR (CD3)

- EIC detector is an enormous undertaking that will require participation and expertise from both the RHIC and Jlab communities, the US academia as well as key international contributions!
- In parallel, the new Collaboration being formed and structured
- *It is NOW the right time to join the effort and get involved !*
- *Have exciting perspectives with us designing and building ePIC*