Status of ATHENA proposal

Pietro Antonioli - INFN Bologna

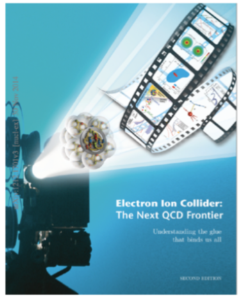
greatly indebted to the whole ATHENA (proto)-Collaboration

big credits to many EIC/ATHENA colleagues to build this presentation: S. Dalla Torre, E. Aschenauer, R. Preghenella, D. Elia, Y. Furletova, V. Berndikov, M. Contalbrigo, L. Gonnella, T. Hemmick, ..

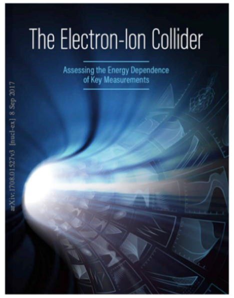
Outline

- a little bit of EIC generalities & physics with some emphasis on detector requirements
- ATHENA "status"
  - where we are in the process toward a real experiment
  - who we are: the (proto)-collaboration
  - our design choices
  - an overview of main sub-systems in ATHENA

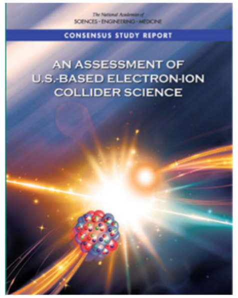
"Link effort" through this presentation: not a comprehensive, but it offers many links to people interested!
To start with, check last EICUG meeting (August 2021):
https://indico.bnl.gov/event/11463/



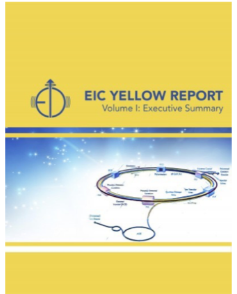
White Paper (2012)
Accardi et al,
arXiv:1212:1701



BNL Report (2017)
Aschenauer at el,
arXiv:1708.01527



NAS Study (2018)



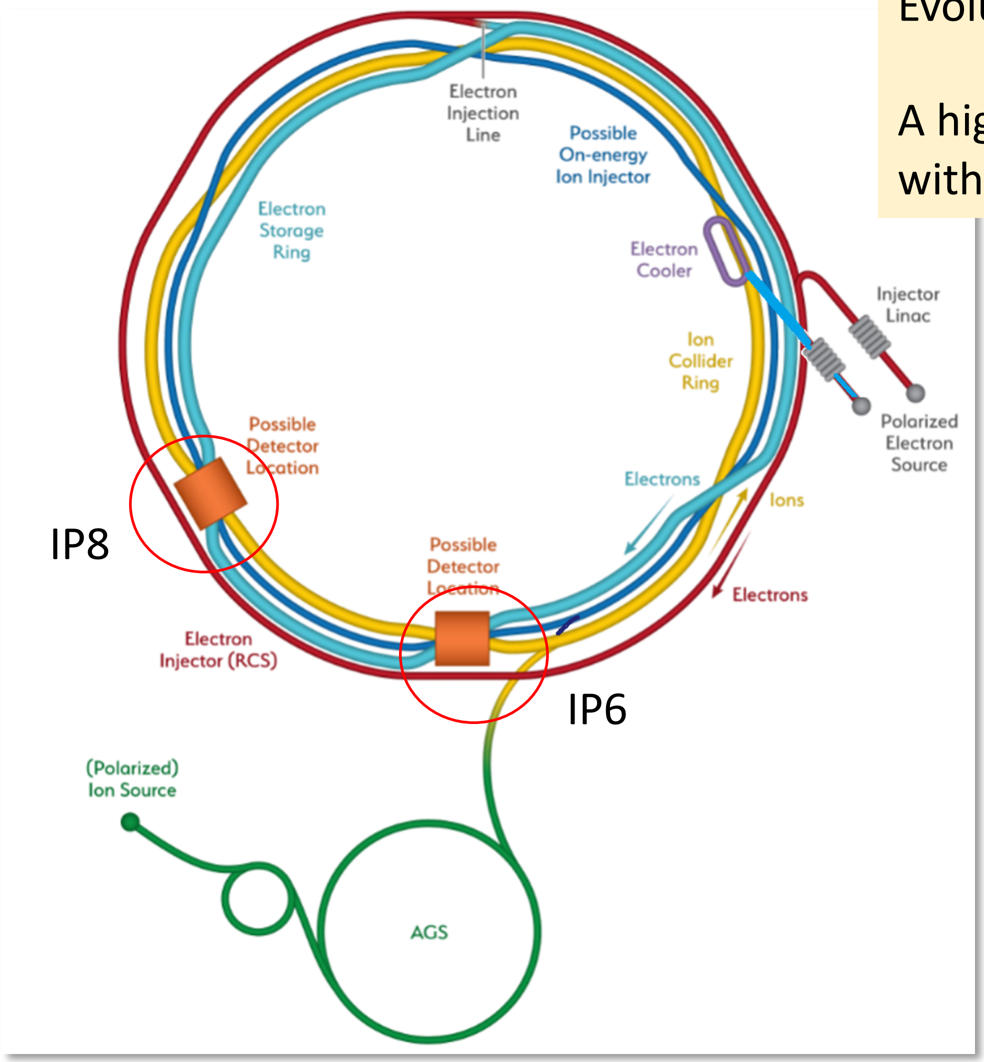
EIC Yellow Report (2021)
arXiv:2103.05419

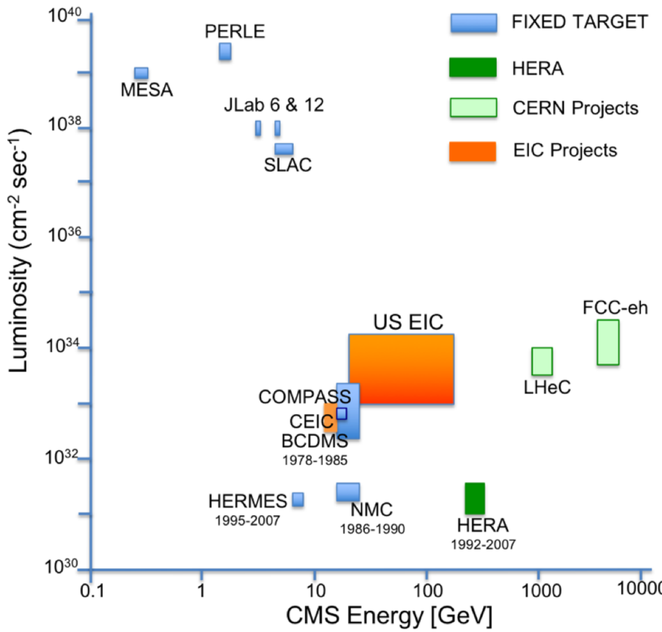
Yellow Paper (2016)
Accardi et al, Eur. Phys. J. A
(2016) 52: 268

EIC: an Electron-Ion collider at BNL

Evolution of RHIC (pp/pA/AA) facility at BNL → electron ring (E_e = 5-18 GeV)

A high luminosity ($10^{33} – 10^{34}$ $cm^{-2}s^{-1}$) polarized electron proton / ion collider with $\sqrt{s_{ep}}$ = 28 – 140 GeV





EIC key points

with respect to HERA:

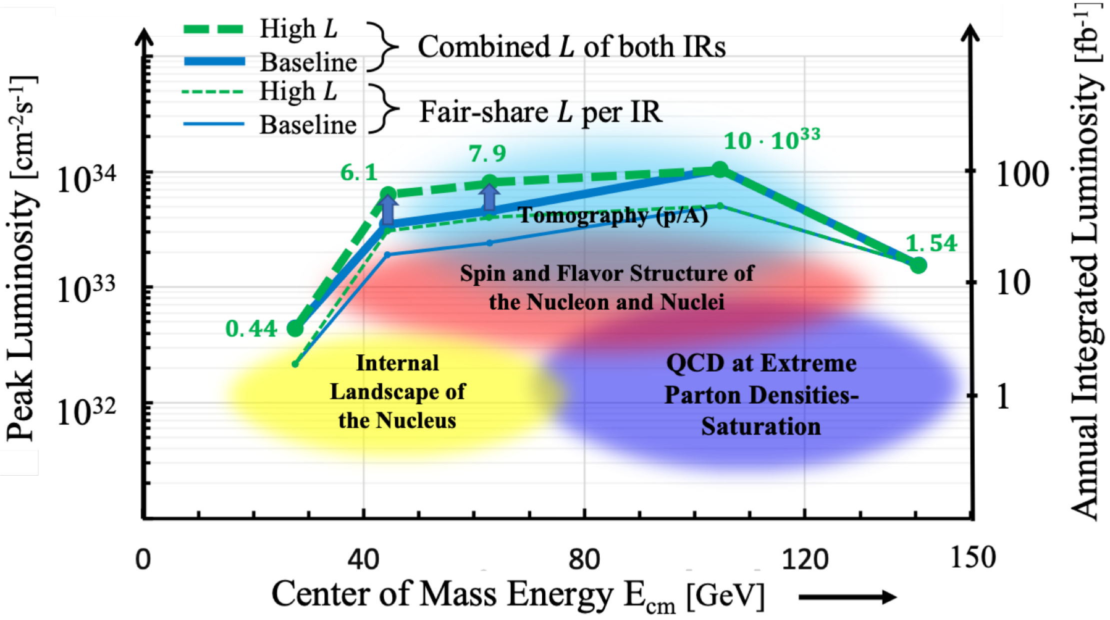
- luminosity x 100 to 1000 higher
- both (p, d, ^{3}He) and e polarized
- nuclear beams (d to U)

with respect to fixed target facilities

- more than 2 decades increase in kinematic coverage in x and Q^2

Currently DOE supports EIC project for one detector and one IR, but the facility might support two detectors/IRs (IP6/IP8)

EIC: physics reach & machine parameters

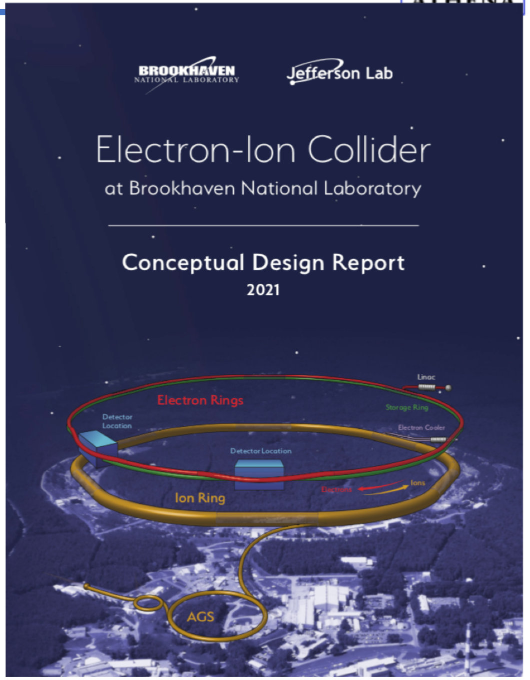


Hadron Storage Ring: 40 – 275 GeV
Electron Storage Ring: 5 – 18 GeV
25 mrad Crossing Angle

Machine Conceptual Design Report:
https://www.bnl.gov/ec/files/EIC_CDR_Final.pdf

Params at maximum lumi

Parameter	hadron	electron
Center-of-mass energy [GeV]	104.9	
Energy [GeV]	275	10
Number of bunches	1160	
Particles per bunch [10^{10}]	6.9	17.2
Beam current [A]	1.0	2.5
Horizontal emittance [nm]	11.3	20.0
Vertical emittance [nm]	1.0	1.3
Horizontal β-function at IP β^*_x [cm]	80	45
Vertical β-function at IP β^*_y [cm]	7.2	5.6
Horizontal/Vertical fractional betatron tunes	0.228/0.210	0.08/0.06
Horizontal divergence at IP $\sigma^*_{x'}$ [mrad]	0.119	0.211
Vertical divergence at IP $\sigma^*_{y'}$ [mrad]	0.119	0.152
Horizontal beam-beam parameter ξ_x	0.012	0.072
Vertical beam-beam parameter ξ_y	0.012	0.1
IBS growth time longitudinal/horizontal [hr]	2.9/2.0	-
Synchrotron radiation power [MW]	-	9.0
Bunch length [cm]	6	0.7
Hourglass and crab reduction factor [17]	0.94	
Luminosity [10^{34} cm^{-2}s^{-1}]	1.0	



If DIS is a pair of glasses to look inside the nucleon,
EIC is definetely a **new pair of glasses**!

Resolution is a few times smaller than target

Resolution 10's of times smaller than target

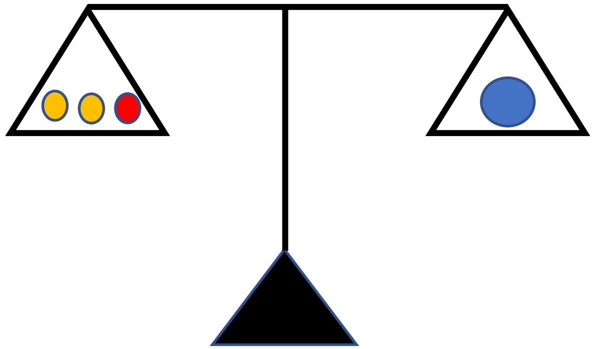
Resolution 100's of times smaller than target

Credit: Yulia Furletova

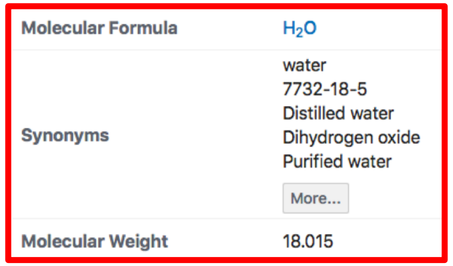
Why new glasses?

The way matter sums up is still quite a mistery!

- Hydrogen
- Oxygen

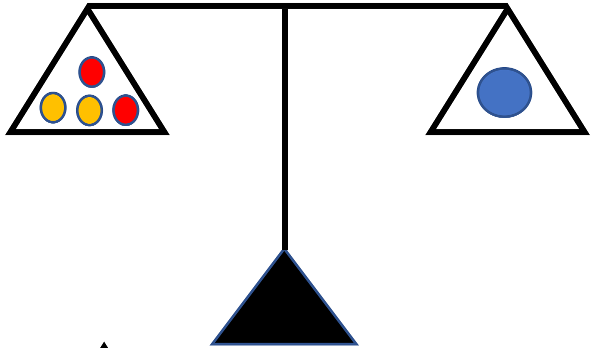


Water

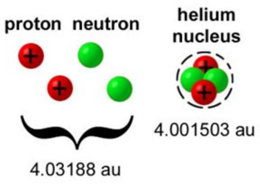


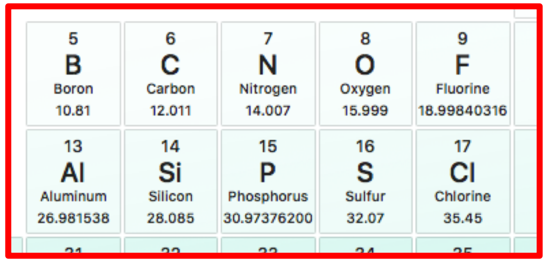
Molecular Formula	H_2O
Synonyms	water 7732-18-5 Distilled water Dihydrogen oxide Purified water More...
Molecular Weight	18.015

- Proton
- Neutron



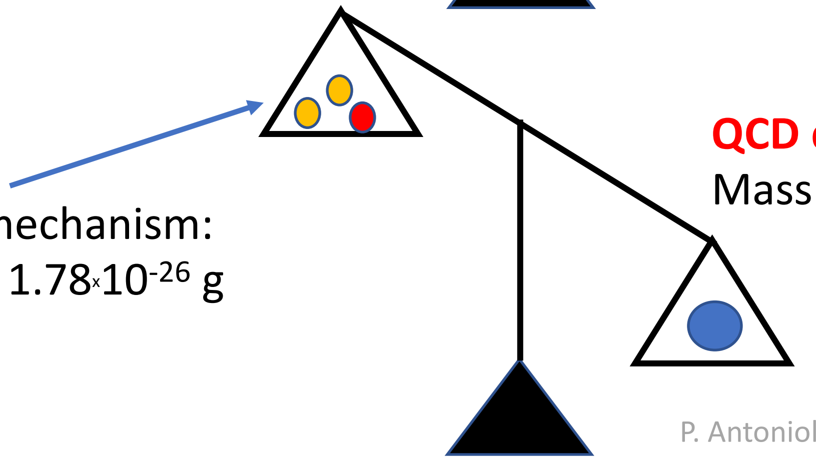
Helium





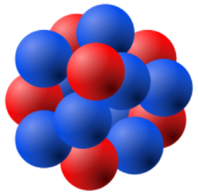
5 B Boron 10.81	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.99840316
13 Al Aluminum 26.981538	14 Si Silicon 28.085	15 P Phosphorus 30.97376200	16 S Sulfur 32.07	17 Cl Chlorine 35.45

- d quark
- u quark



Higgs mechanism:
Mass ≈ 1.78×10^{-26} g

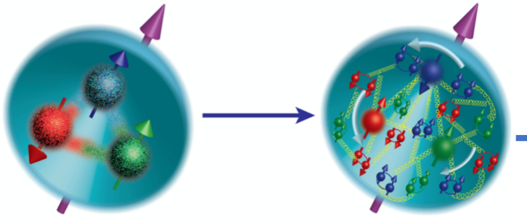
QCD dynamics makes 99% of proton mass!
Mass ≈ 168×10^{-26} g



proton

(and baryonic matter... is just 5% of the Universe....)

And for spin too…



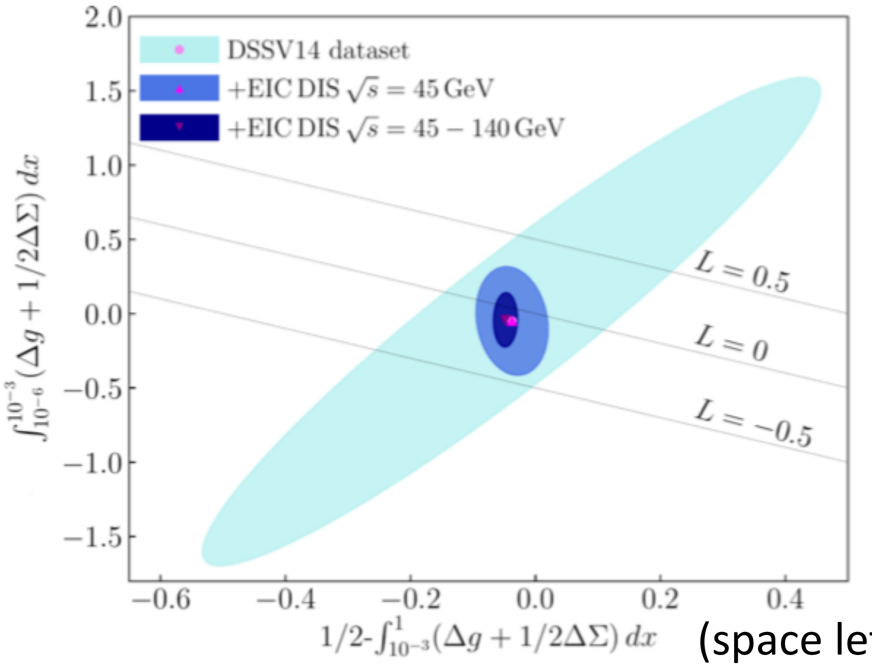
$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma(\mu) + \Delta G(\mu) + L_q(\mu) + L_g(\mu)$$

quark and gluon spin — orbital angular momentum

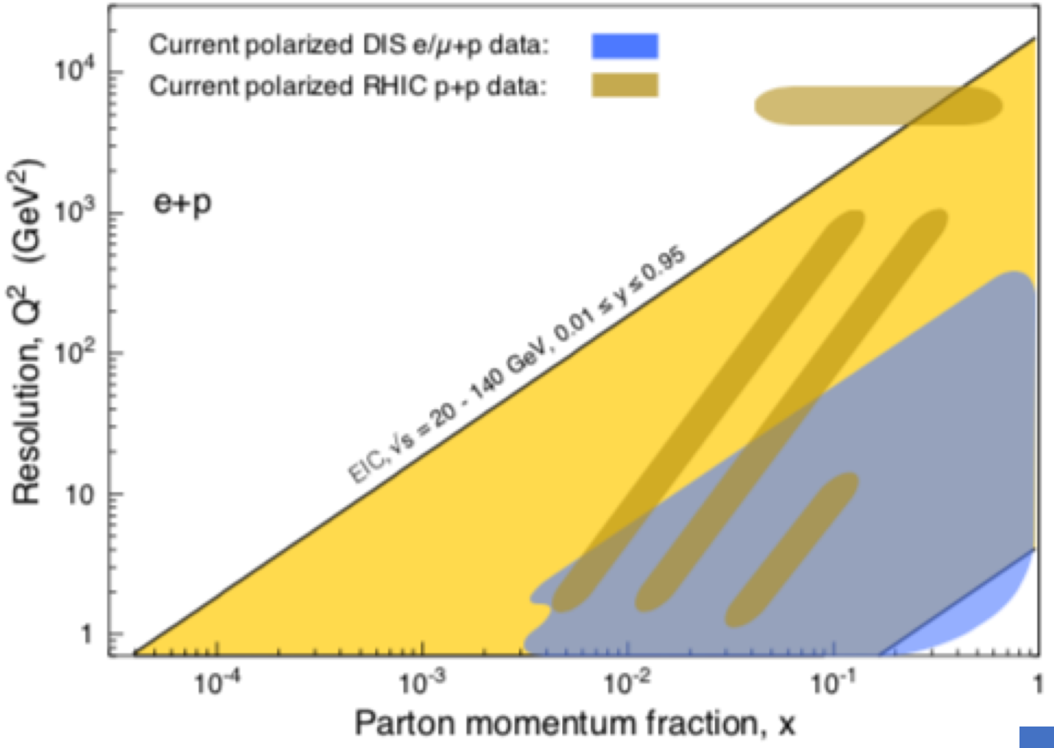
- the spin is the interplay between parton intrinsic properties & their interactions
- it is a dynamic not a static property!

- 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 x 10^{-3}

EIC will offer **polarized** beams in a largely unexplored x-Q^2 region!



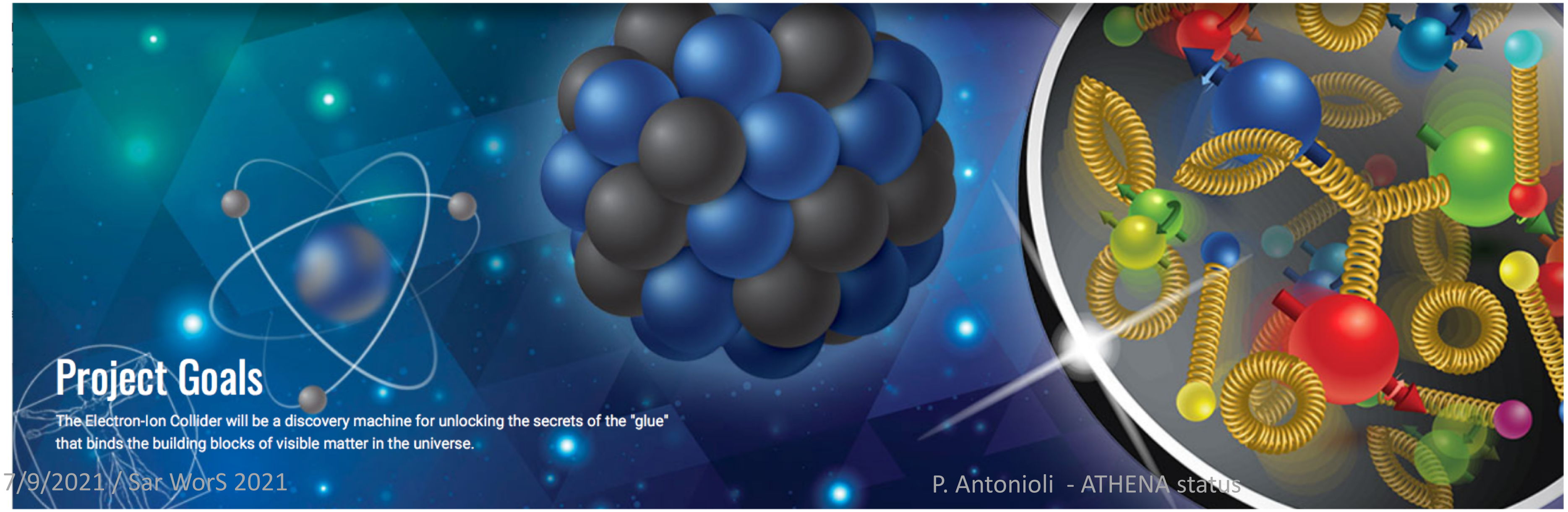
(space left for OAM!)



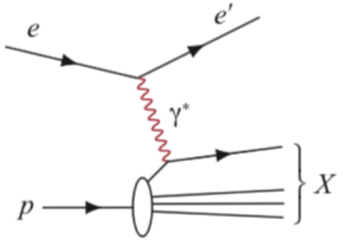
EIC can really resolve the spin components of the nucleon

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

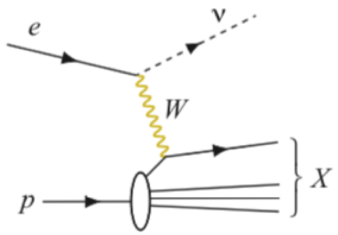
- How do the **nucleonic properties such as mass and spin emerge from partons** and their underlying interactions?
- **How are partons inside the nucleon distributed** in both momentum and position space?
- How do **color-charged quarks and gluons**, and jets, interact with a nuclear medium?
- How do the **confined hadronic states emerge** from these quarks and gluons?
- How do the **nuclear binding emerge** from quark-gluon interactions?
- How does a dense nuclear environment affect the dynamics of quarks and gluons, their correlations, and their interactions? **What happens to the gluon density in nuclei?** Does it saturate at high energy, giving rise to gluonic matter or a gluonic phase with universal properties in all nuclei and even in nucleons?



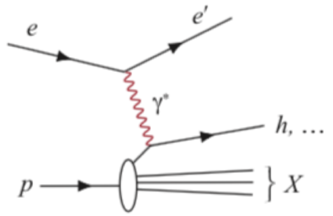
DIS processes → physics



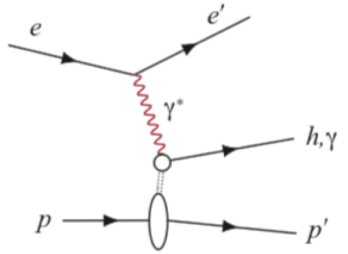
NC inclusive DIS
essential measurement: scattered electron



CC inclusive DIS
kinematics reconstructed via final state particles



Semi-Inclusive DIS
need to identify at least one hadron (+ HQ)



Exclusive DIS
full reconstruction → hermeticity

EIC extra-bonus: DIS in nuclei
- nPDF modifications
- gluon saturation (and its scale dependency from A) [jets]
- hadronisation in cold nuclear matter

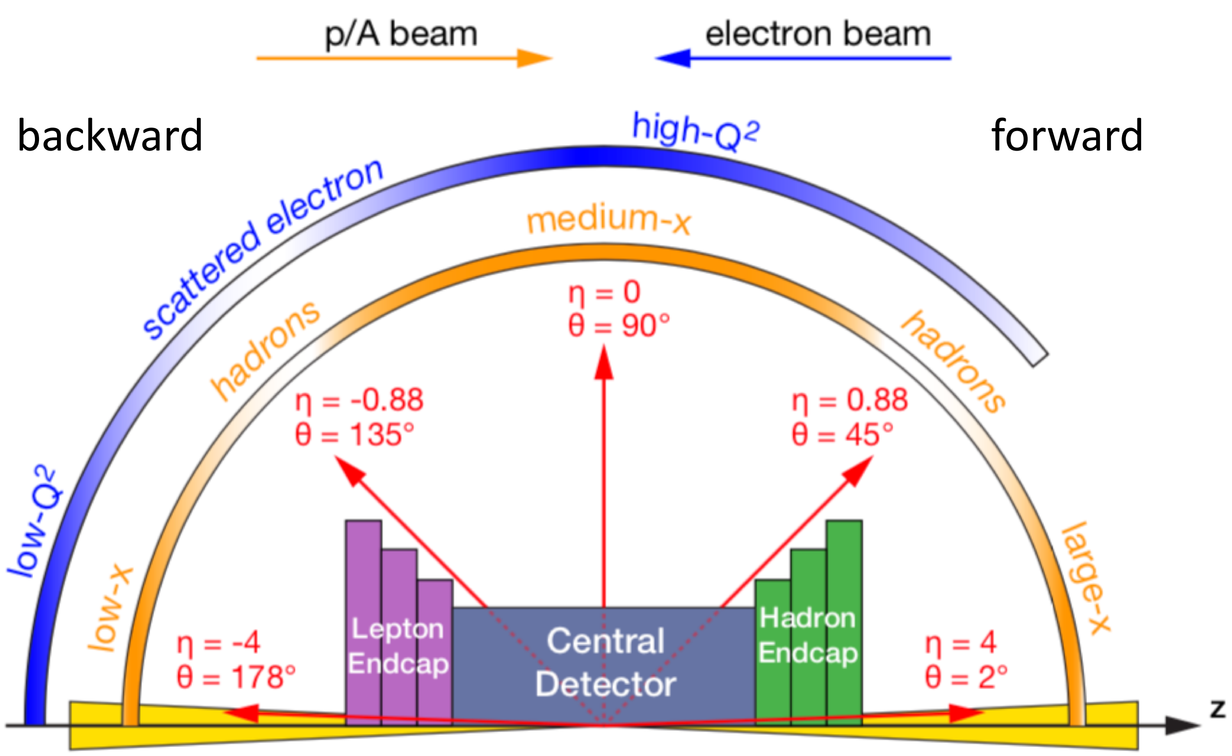
- di-hadron correlation for saturation studies
- transverse momentum distribution (TMD)

Multi-dimensional imaging of the nucleon

Deeply Virtual Compton Scattering (DVCS) and Deeply Virtual Meson Scattering
→ GPD

- detection of forward going proton scattered at small angle essential for several physics channel ($J/\psi - \Upsilon$ photoprodution |t| dependence, generalized parton distribution functions)
- diffractive cross sections proportional to gluon density → nuclear dependency?

Detector requirements (I)



- asymmetric beams → asymmetric detector
- hermetic detector
- moderate radiation hardness (w.r.t. to LHC)
- rapidity coverage for electrons and jets |η|<4
- large acceptance for diffraction

EM calorimetry requirements

backward $\sigma(E)/E \approx \frac{2\%}{\sqrt{E}} \otimes (1\text{-}3)\%$!

central $\sigma(E)/E \approx \frac{10\%}{\sqrt{E}} \otimes (1\text{-}3)\%$

critical for low x measurement → PDF mapping → spin

Excellent PID up to 50 GeV for π/K/p in the forward region, up to 10 GeV in barrel region !

critical for SIDIS measurement → transverse momentum distribution → 3D-imaging

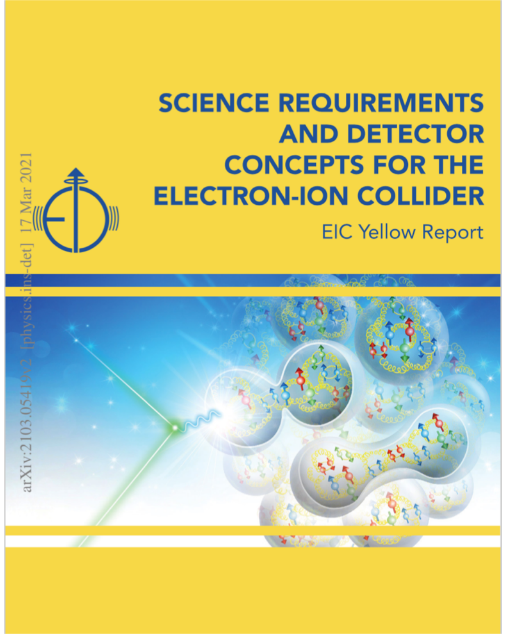
momentum resolution: !

central $\sigma(p_T)/p_T(\%) \approx 0.01 p_T \otimes 0.5$

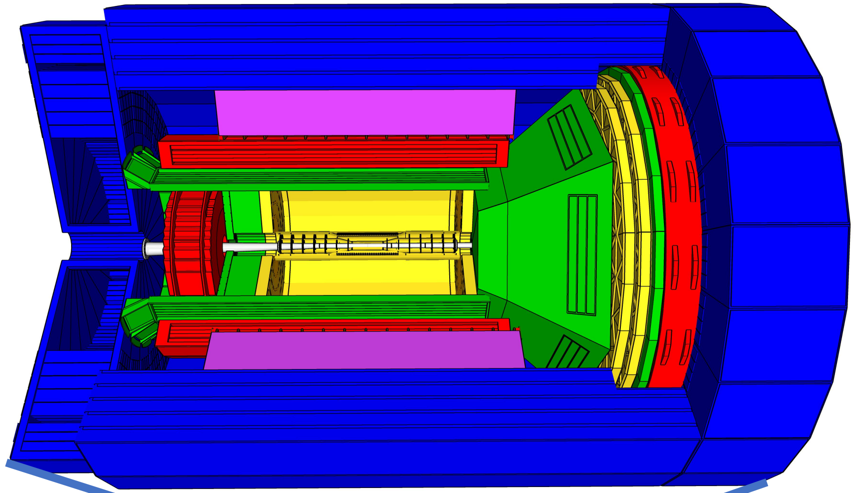
good hadronic resolution in the forward region

All this quantified by the community in the Yellow Report effort during 2020 (a collective pandemic remote effort)

A baseline detector for EIC (as per Yellow Report)



https://arxiv.org/abs/2103.05419



hadronic calorimeters

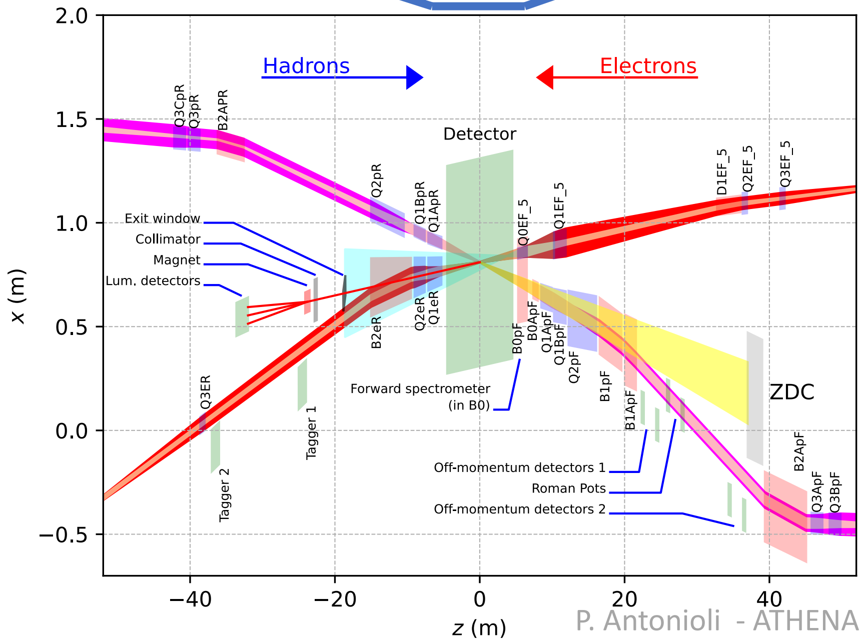
e/m calorimeters

PID: Tof, RICH and DIRC detectors

silicon tracker

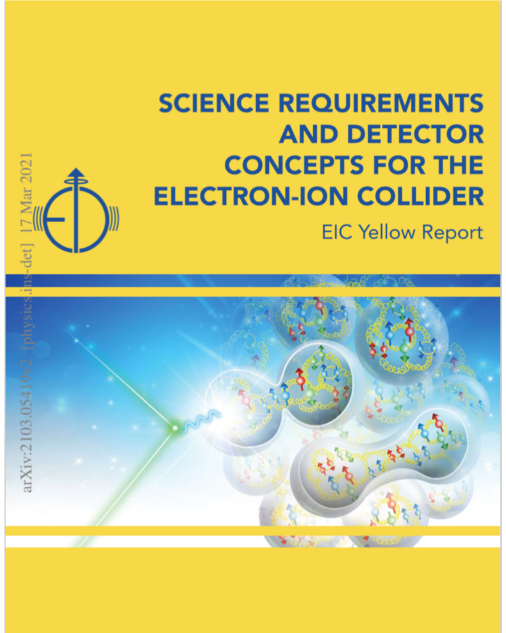
MPG tracker

magnet



Note need of larger acceptance for diffraction, neutron tagging for nuclear breakup, forward proton measurement at small angles: ZDC, Roman-Pots, low-Q^2 tagger

Detector requirements (II)



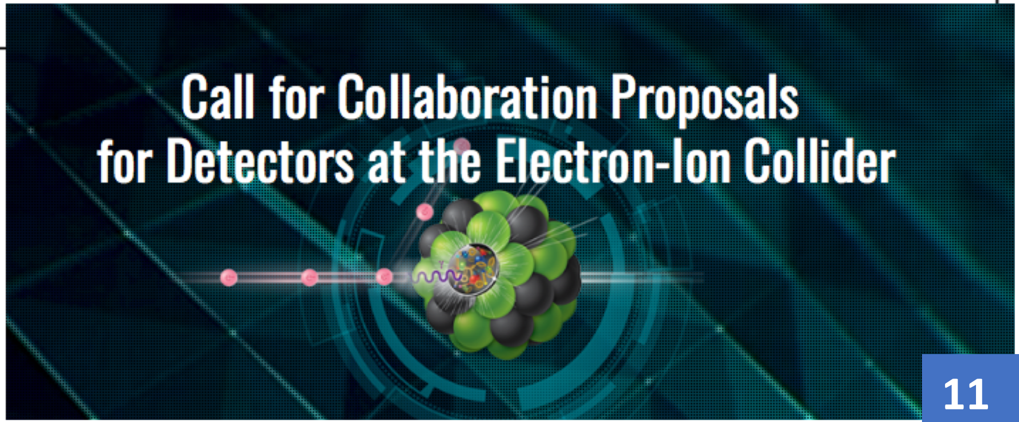
https://arxiv.org/abs/2103.05419

Nomenclature	Tracking						Electrons and Photons			$\pi/K/p$		HCAL		Muons
	Resolution	Relative Momentun	Allowed X/X_0	Minimum-p_T (MeV/c)	Transverse Pointing Res.	Longitudinal Pointing Res.	Resolution σ_E/E	PID	Min E Photon	p-Range	Separation	Resolution σ_E/E	Energy	
Low-Q2 tagger														
	Not Accessible													
		Reduced Performance												
Backward Detector		$\sigma_p/p \sim 0.1\% \times p \oplus 2\%$	~5% or less	150-300			$1\%/E \oplus 2.5\%/\sqrt{E} \oplus 1\%$	π suppression up to $1{:}10^{-4}$	20 MeV	$\leq$ 10 GeV/c	$\geq 3\sigma$	$50\%/\sqrt{E} \oplus 10\%$	~500MeV	Muons useful for background suppression and improved resolution
		$\sigma_p/p \sim 0.02\% \times p \oplus 1\%$			dca(xy) ~ $40/p_T$ µm $\oplus$ 10 µm	dca(z) ~ $100/p_T$ µm $\oplus$ 20 µm	$2\%/E \oplus (4\text{-}8)\%/\sqrt{E} \oplus 2\%$	π suppression up to $1{:}(10^{-3}\text{-}10^{-2})$	50 MeV					
Barrel		$\sigma_p/p \sim 0.02\% \times p \oplus 5\%$		400	dca(xy) ~ $30/p_T$ µm $\oplus$ 5 µm	dca(z) ~ $30/p_T$ µm $\oplus$ 5 µm	$2\%/E \oplus (12\text{-}14)\%/\sqrt{E} \oplus (2\text{-}3)\%$	π suppression up to $1{:}10^{-2}$	100 MeV	$\leq$6 GeV/c		$100\%/\sqrt{E} \oplus 10\%$		
Forward Detectors		$\sigma_p/p \sim 0.02\% \times p \oplus 1\%$		150-300	dca(xy) ~ $40/p_T$ µm $\oplus$ 10 µm	dca(z) ~ $100/p_T$ µm $\oplus$ 20 µm	$2\%/E \oplus (4^*\text{-}12)\%/\sqrt{E} \oplus 2\%$	3σ e/π up to 15 GeV/c	50 MeV	$\leq$ 50 GeV/c		$50\%/\sqrt{E} \oplus 10\%$		
		$\sigma_p/p \sim 0.1\% \times p \oplus 2\%$												
Instrumentation to separate charged particles from photons		Reduced Performance												
	Not Accessible													
Proton Spectrometer														
Zero Degree Neutral Detection														

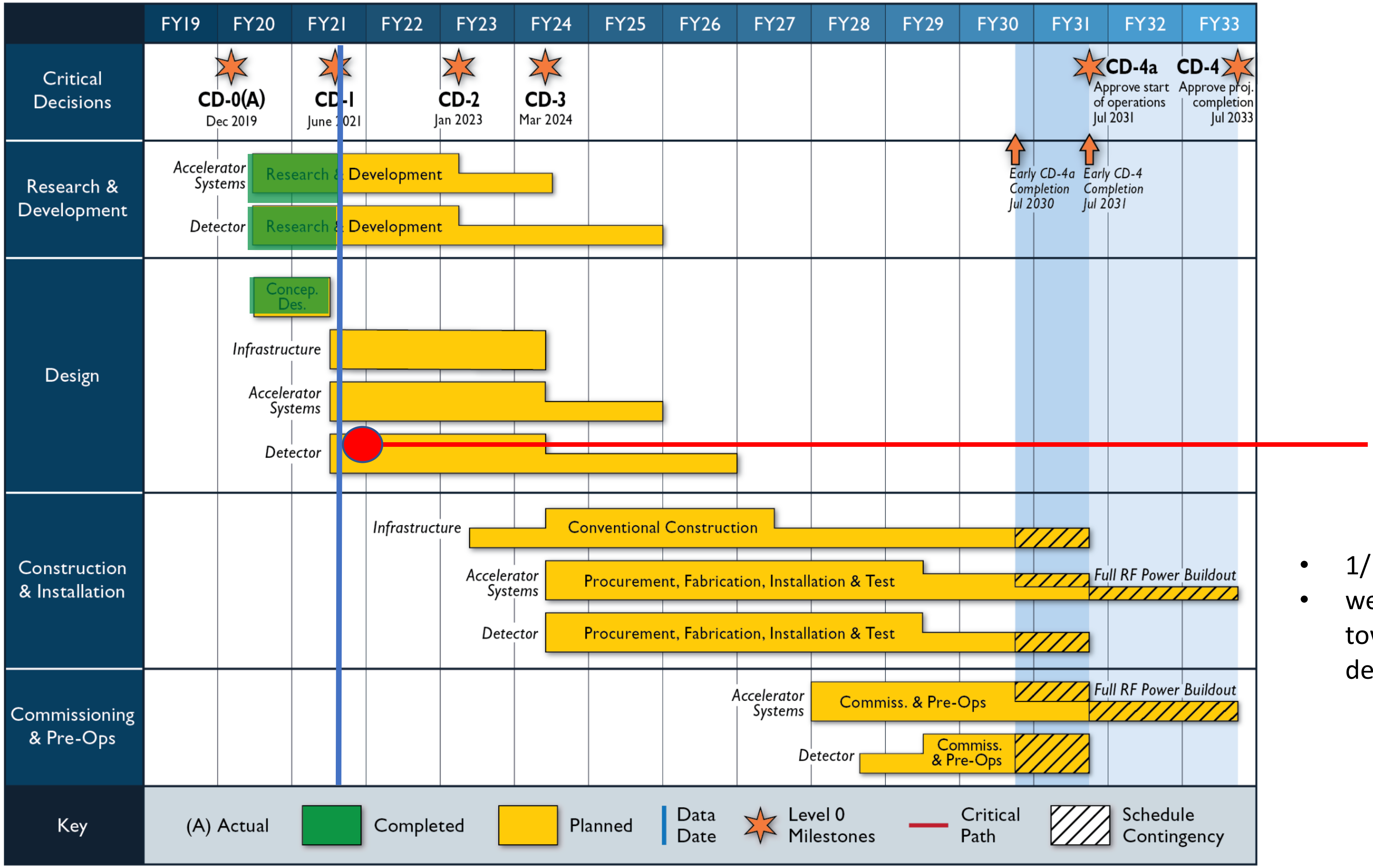
Following release of Yellow Report, issued a call for detector proposals

- https://www.bnl.gov/eic/CFC.php

deadline 1st/December/2021



EIC timeline and experiment selection



1/Dec/2021: Detector proposals (proto-collaborations)

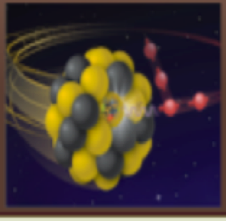
- 1/Mar/2022 report from Advisory Panel
- we expect Jan-Jun 2022 intense period toward detector & final collaborations definition!

ATHENA status: when all started…

Kick-off meeting for EIC@IP6

https://indico.bnl.gov/event/10825/

Kick-off Meeting for an EIC Detector at IP6 (EIC@IP6)



12-13 March 2021

US/Eastern timezone

- Overview
- Timetable
- Remote Login Instructions
- Contribution List
- My Conference
  - My Contributions
- Registration
- Participant List

Following the site selection for construction of the U.S. Electron-Ion Collider research facility by the U.S. Department of Energy (DOE) in early 2020, the EIC Users Group led a year-long Yellow Report initiative to define the detector design criteria needed to realize the EIC physics described in the EIC White Paper, supported by the National Academy of Sciences. Using the Yellow Report as input, a Reference Detector concept was presented at the recently held DOE Critical Decision-1 review of the EIC.

A Call for EIC Detector Proposals has been issued by DOE & BNL/JLab on March 6, 2021 with an expected proposal submission deadline on December 1st, 2021. The EICUG community's strong preference for two detectors has led to multiple exciting detector initiatives. We invite all interested groups and consortia to come together to plan for a detector inspired by the Yellow Report detector concept based on a new central detector magnet up to 3T, which could evolve into a concrete proposal and collaboration formation for IP6.

with 292 register participants,

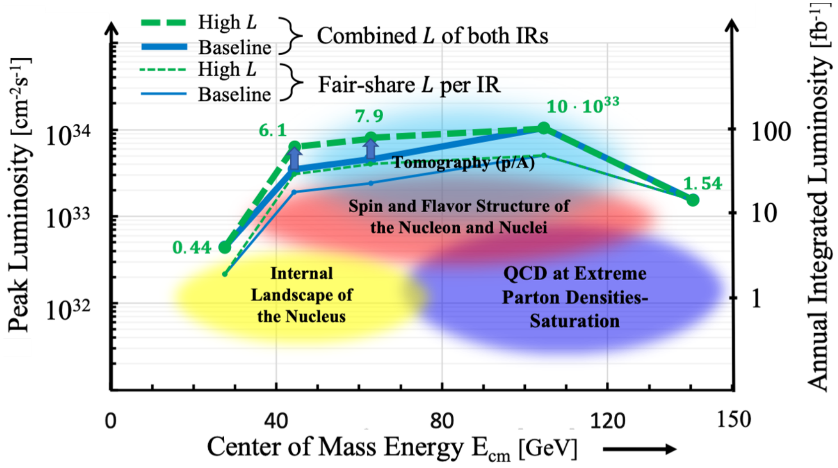
attendance peak at 197,

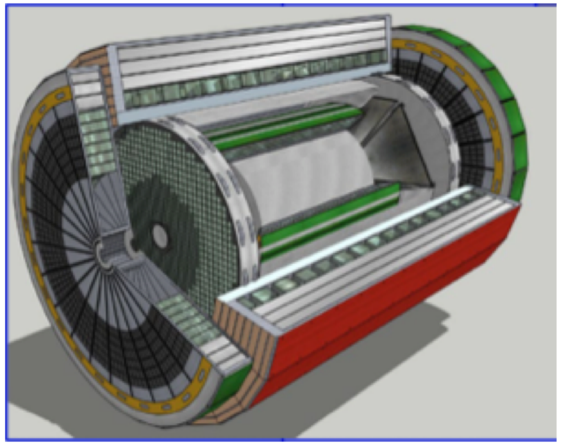
no session with less than 130 participants

key points from the beginning:
- 3T magnet
- @IP6

ATHENA key points

- We want to cover the whole EIC physics program
- Build a proposal inspired by YR and CDR: use YR studies as starting point (and evaluate variants to "baseline detector" if useful/possible)
- Design the detector with a **new 3 T solenoid magnet** to better exploit EIC potential
- **IP6 choice** due to the advantages of the larger experimental hall
  - new solenoid with large bore diameter maximise IP6 potentialities
  - in July it was confirmed IP6 has 0.5 m extra space (very useful for forward region!)
- New detector components to exploit state-of-the art technology

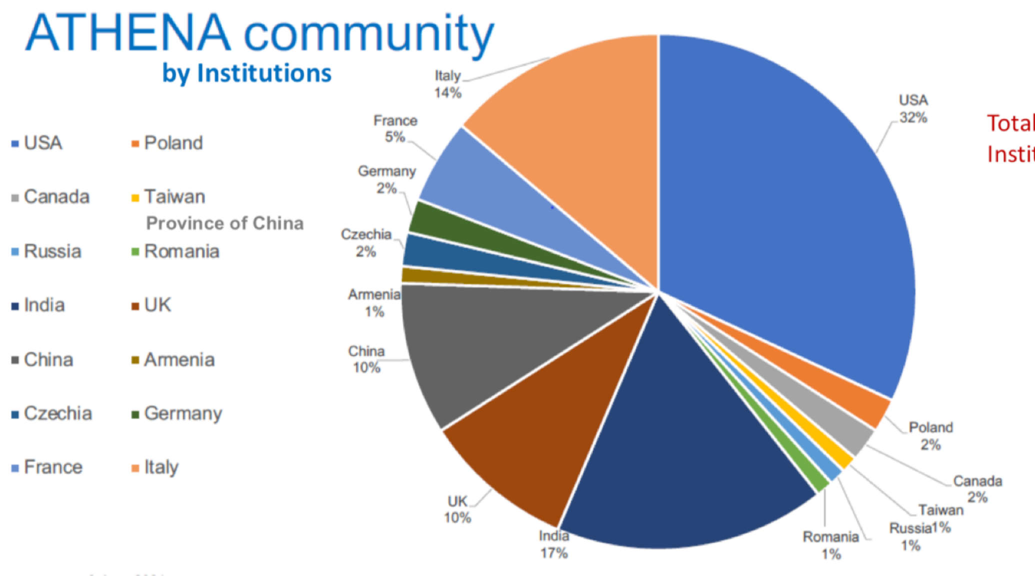




and ATHENA challenges (partly common to many proto-collaborations)

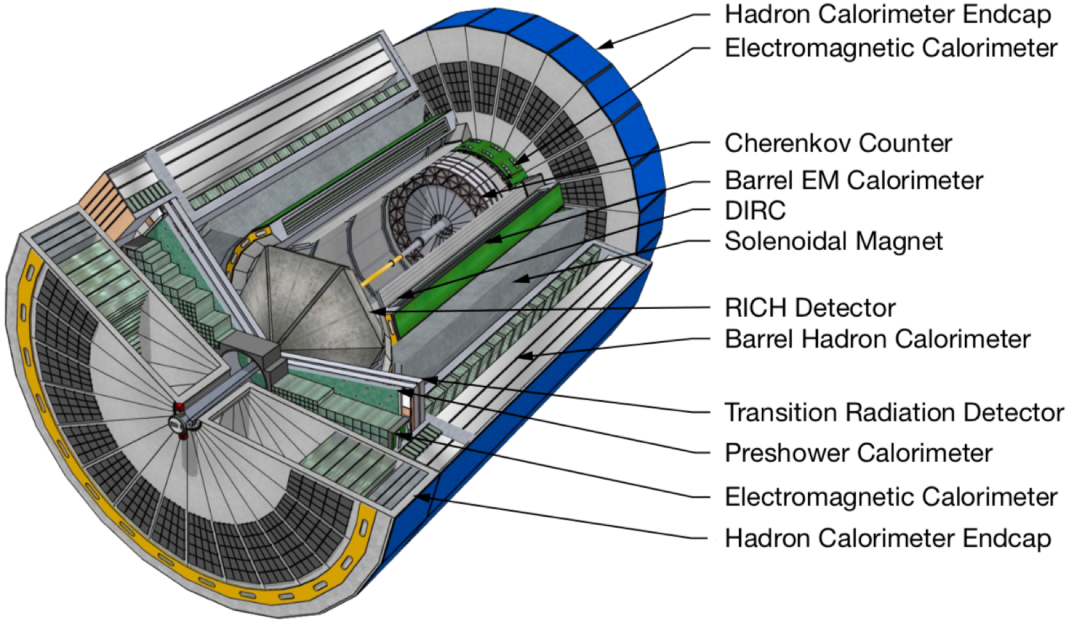
- No solenoid specifications fixed → we contribute to its design (but it takes time and additional resources)
- Choice of promoting new future-oriented simulation and reconstruction framework (investment for the Technical Design phase)
- Several technologies options proposed for different sub-systems in the YR → a selection will be needed
- Build the community (currently largely diversified!)
  - https://athena-eic.org
  - bi-weekly meetings (15 meetings so far)
  - structure, charter, working groups etc.

  under COVID-19 restrictions

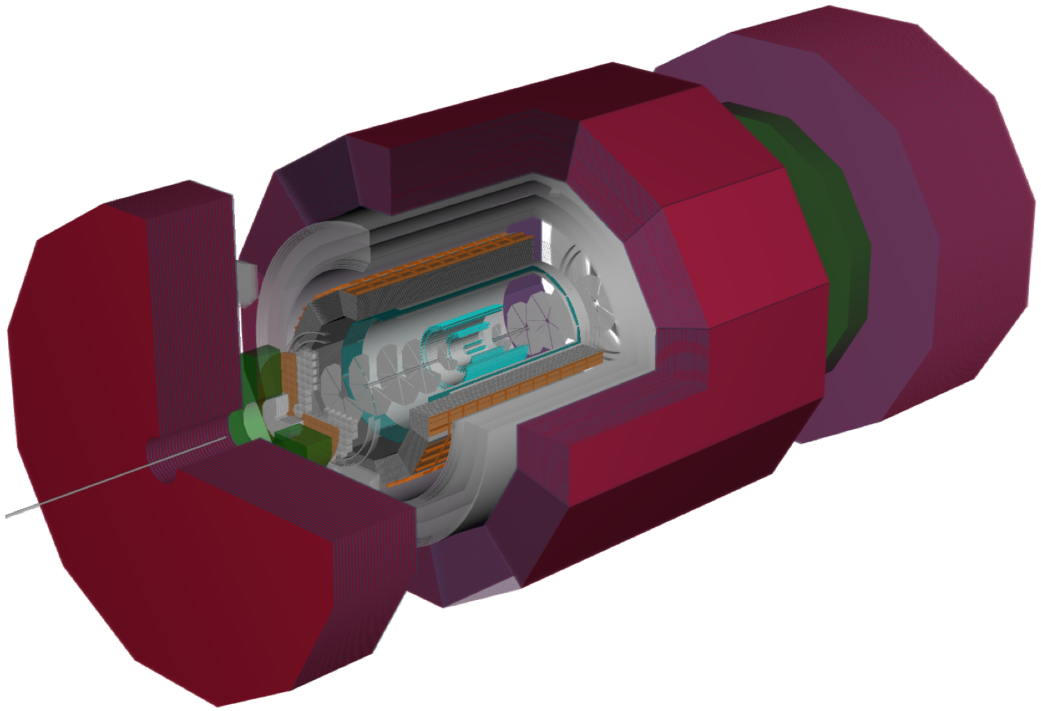


Total: 95 Institutions

Toward detector design (and simulation effort)



YR baseline detector



ATHENA in DD4Hep

https://dd4hep.web.cern.ch/dd4hep/

https://gaudi-framework.readthedocs.io/en/latest/index.html

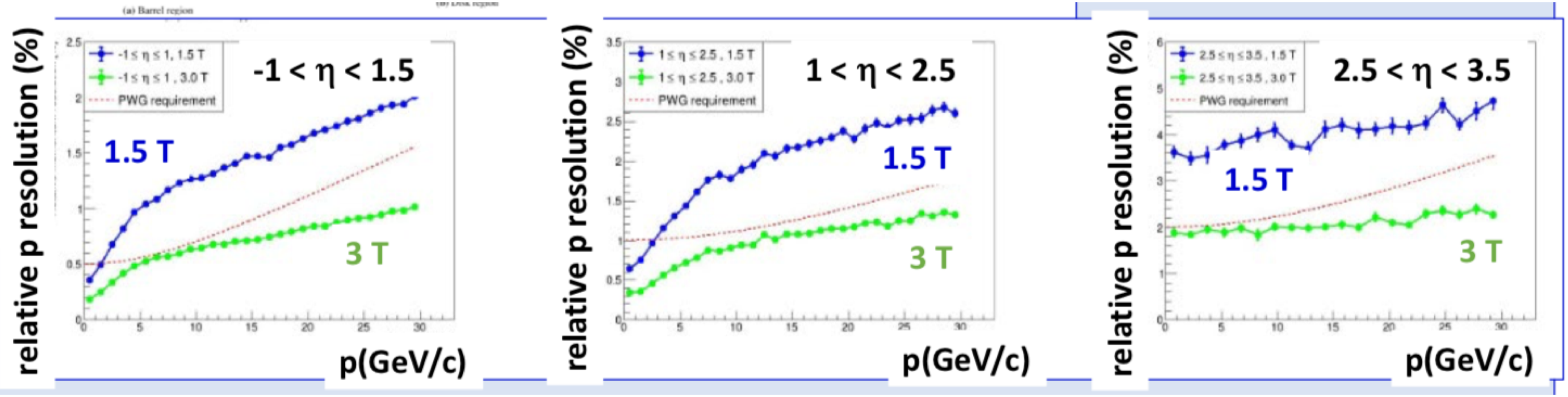
https://acts.readthedocs.io/en/latest/#

Integrated simulation tool selected within DD4hep framework (full suite includes DD4hep (geom/G4 interface), Gaudi (data-algorithm), ACTS (tracking/reco), Podio (output format)

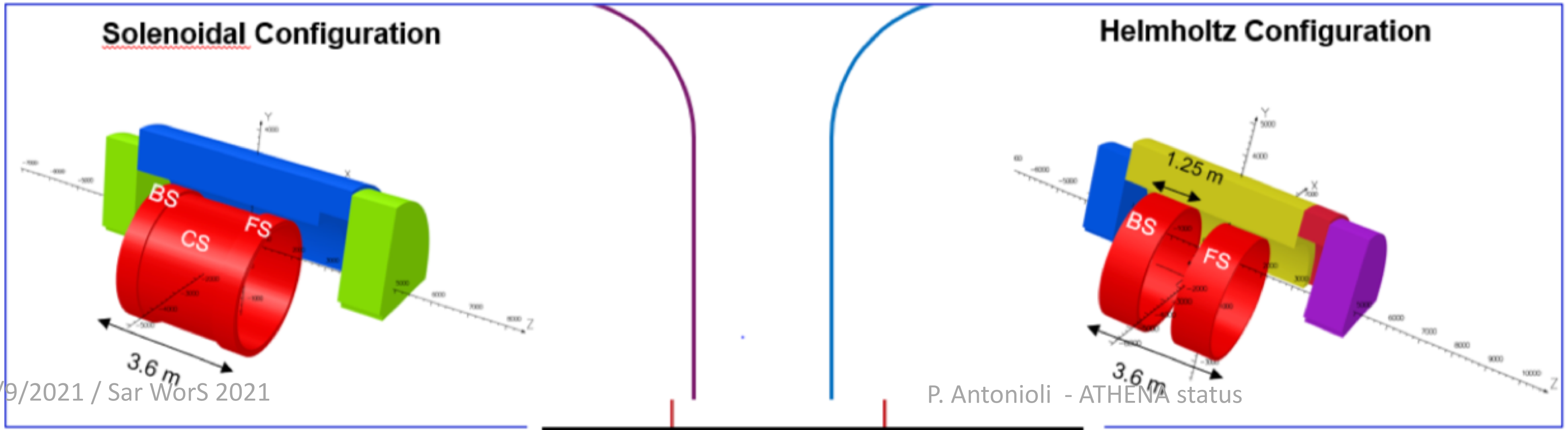
joint effort with ECCE toward unified(= fast/full) Simulation Toolkit: eAST

the choice and design of a 3T solenoid

Simulations by H. Wennlöf, Birmingham



- key gain on momentum resolution, as expected, and below PWG requirements
- low field devoted runs might be operated to collect low p_T data
- a large bore diameter (1.6 m) for the 3T solenoid brings additional space for central detectors

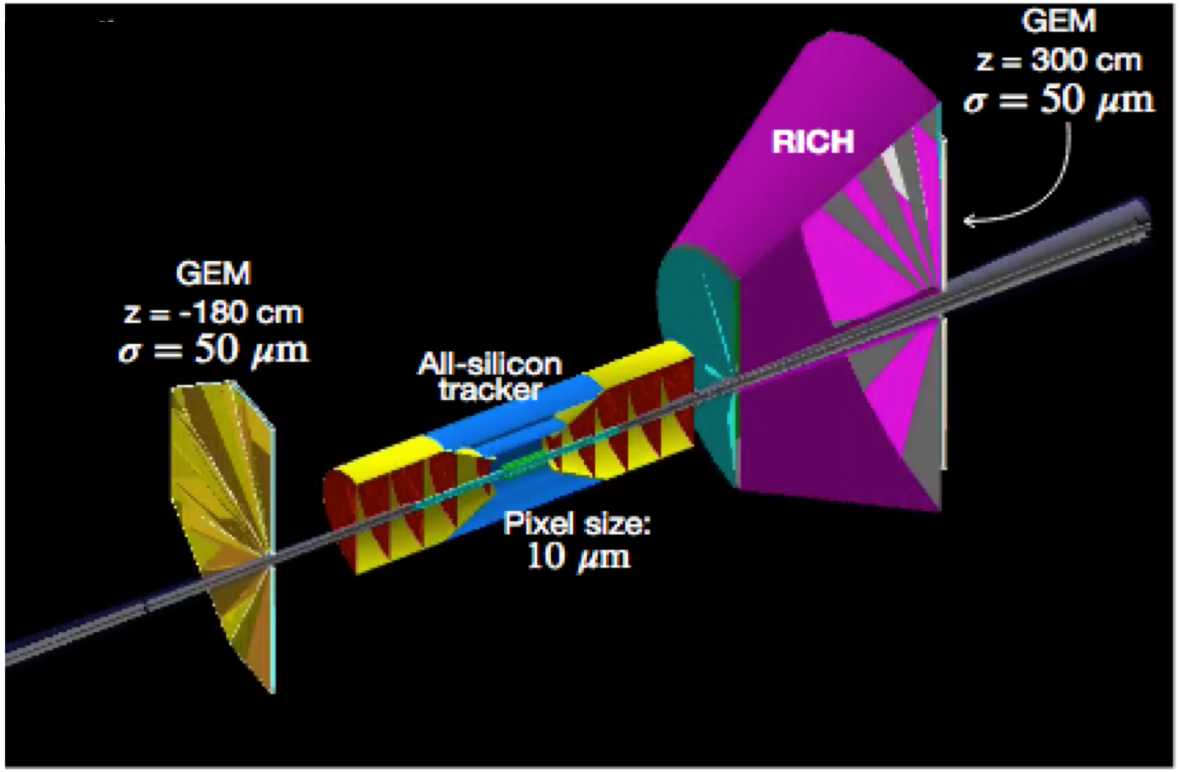


Different field configuration being tested

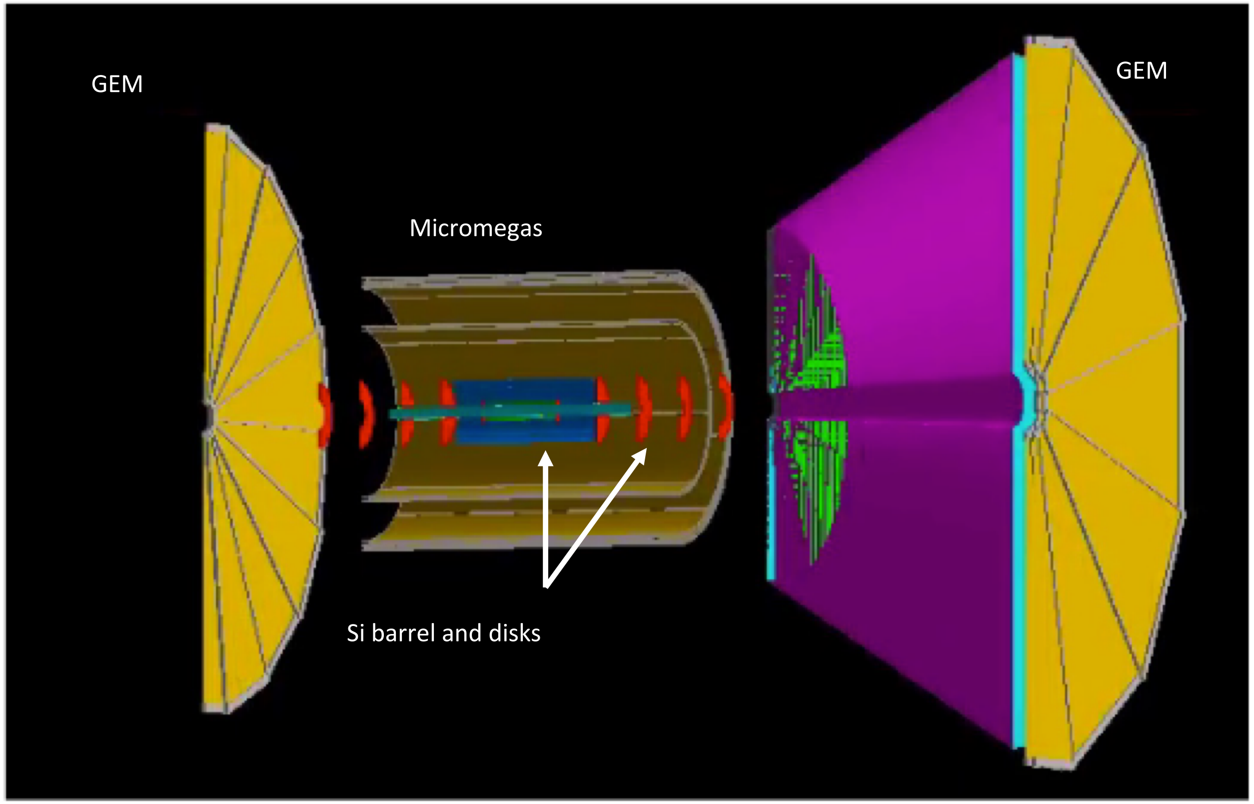
Parameter	Goal
B_{IP} (T)	3.00
Bore radius (mm)	1600
Coil length (mm)	360

ATHENA tracking (I)

all-silicon



hybrid



Same silicon and GEM technologies in both concepts, micromegas barrel layers in the hybrid concept; different layout configurations under test

- ALICE ITS3-derived Silicon Vertex and Tracking detector:

  10 um pixel pitch everywhere

  0.05% X/X0 vertex layers → 2 (3) vertex layers for all-silicon (hybrid)
  0.55% X/X0 barrel layers → 4 (2) barrel layers for all-silicon (hybrid)
  0.24% X/X0 disks → 5 + 5 disks for both configuration

- micromegas (hybrid baseline):

  ✓micromegas barrel layers to complement silicon tracking at central rapidity
  ✓**150 um** both in z and rphi
  ✓**0.4% X/X0** per layer → 6 barrel layers (hybrid)

more information: L. Gonnella https://indico.bnl.gov/event/11463/contributions/52587/attachments/36366/59762/20210804-ATHENA-tracking.pdf

ATHENA tracking

resolutions & material budget evaluated for different configurations

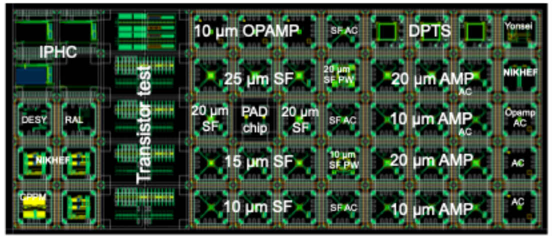
L. Gonnella @ EICUG meeting

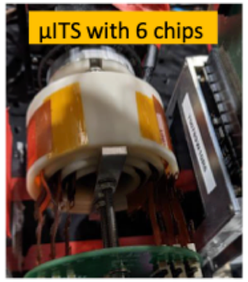
Technology choice: 65 nm MAPS

- Only technology that can satisfy the EIC requirements
- Significant benefits in exploiting synergies with ITS3

- ATHENA members actively participating to the EIC SC activities to develop technology and detector concept, and integrated into ITS3 WP

- Ongoing R&D
  - **Sensor development** (with ITS3): MLR1 test structures received, testing about to start; design of ITS3 ER1 with stitched sensor ongoing
  - **Vertex layers** (with ITS3): thinning and bending studies proceeding with super ALPIDE structure; test beam of uITS with 6 bent ALPIDE chips
  - **Barrel layers & disks** (EIC specific): work has started within the EIC SC to define disk concept; work ongoing with EIC project engineers



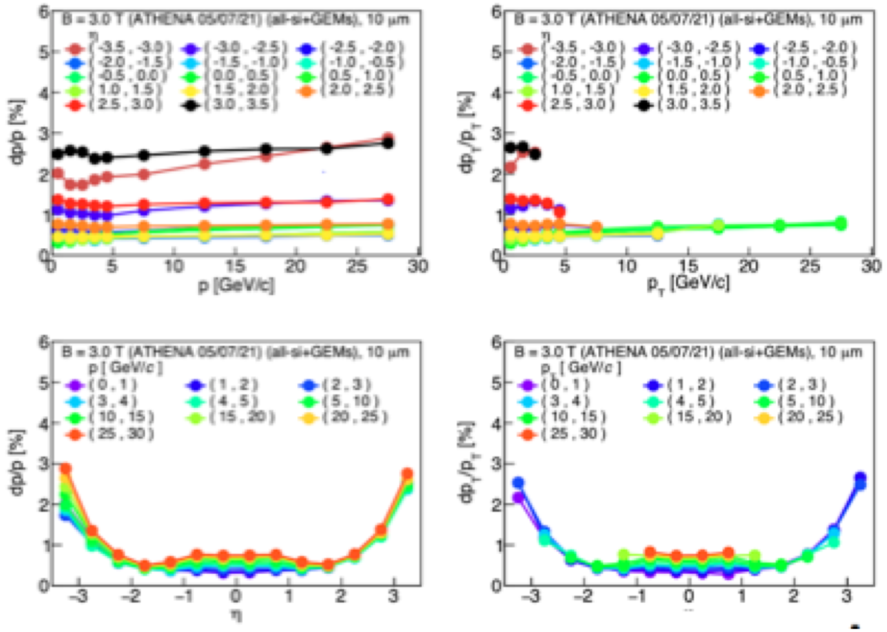


https://indico.bnl.gov/event/12512/contributions/52168/

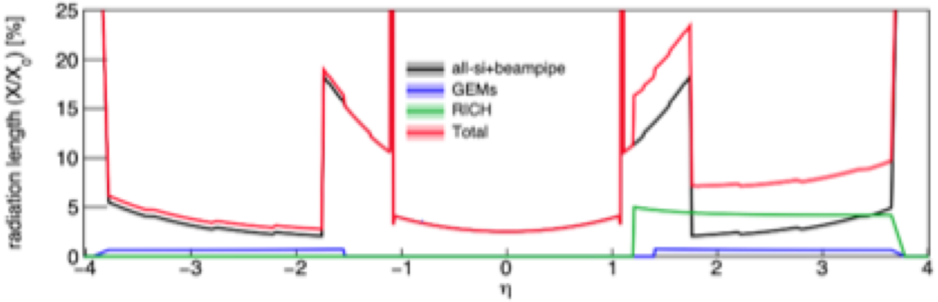
fallback solution on existing technology at 180 nm (ALICE ALPIDE)

all-silicon

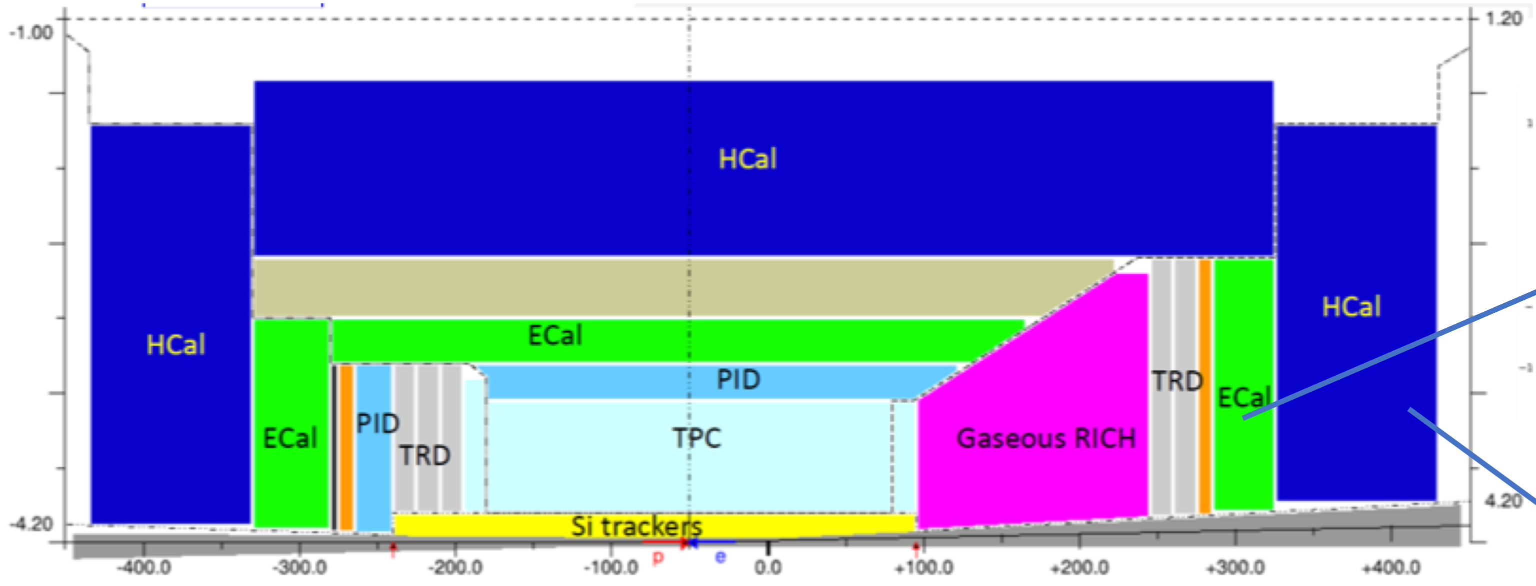
Momentum resolutions

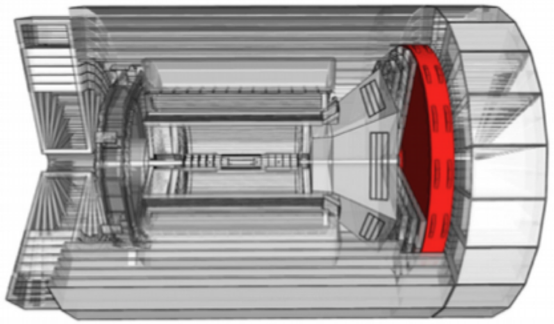


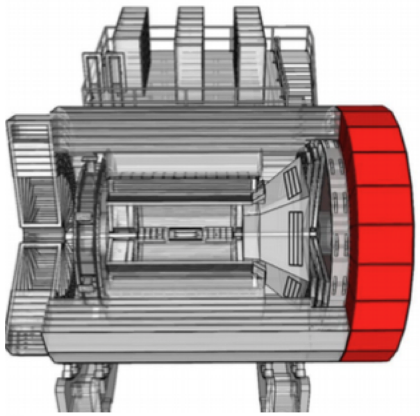
Detector Material Budget



ATHENA calorimeters (I)





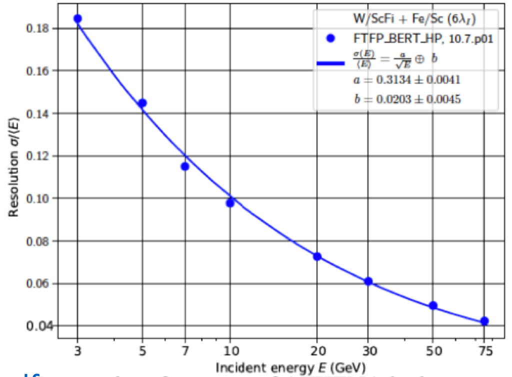


central detector: backward

- ECAL: hybrid: lead tungstate crystal ($PbWO_4$) insert and SciGlass outer ring
- HCAL: Iron/Scint sandwich + WLS fiber

central detector: forward

- ECAL: W-powder/SciFi: very compact with good EM resolution (+ sPHENIX exp.)
- HCAL: Iron/Scint sandwich + WLS fiber
  ongoing detector optimization (including total depth, layer thickness and granularity)

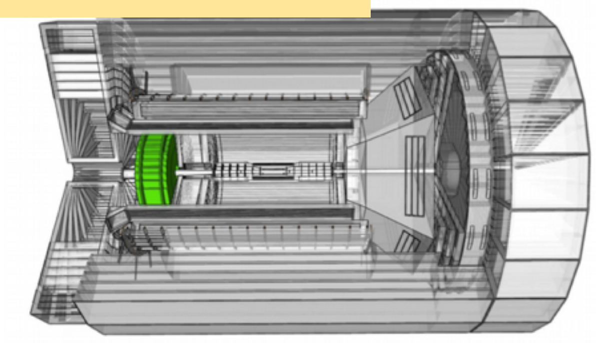


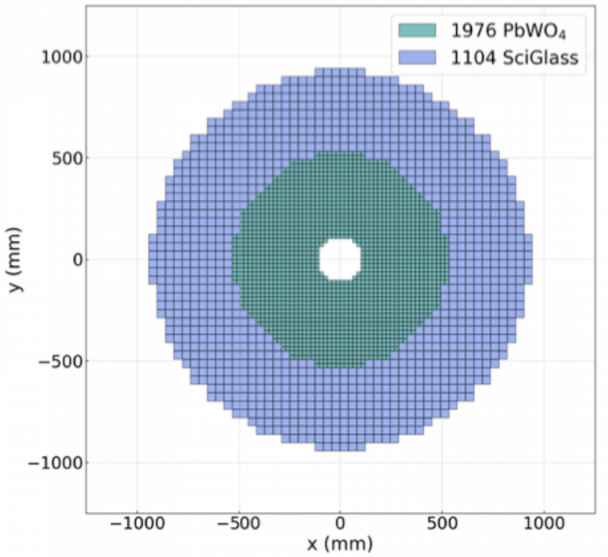
Expected performance of ATHENA hadron endcap (improved version of STAR FCS)

more info: V. Berdnikov https://indico.bnl.gov/event/11463/contributions/52549/attachments/36358/59733/Athena_calorimetry_Berdnikov.pdf

ATHENA calorimeters (II)

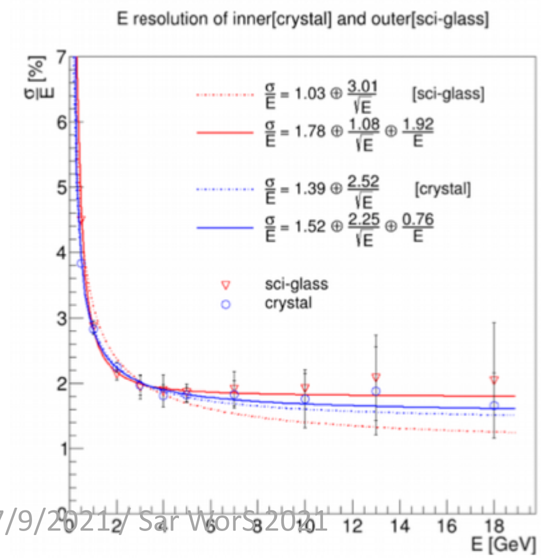
EMCAL backward

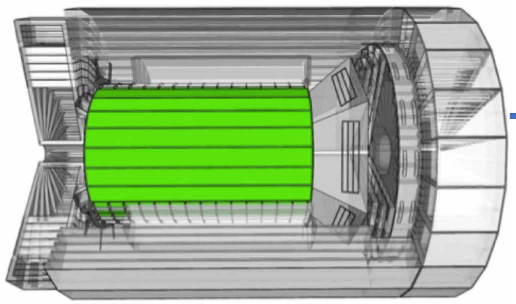




- sensors: SiPM
- production & cost

issue for PWO crystals

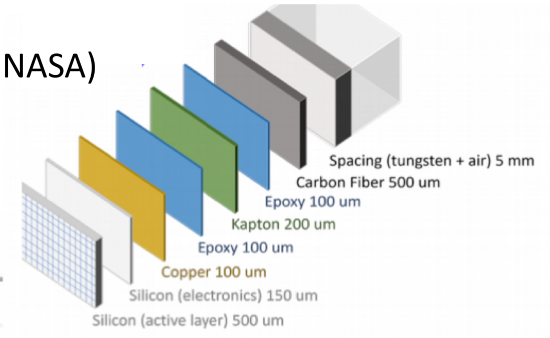


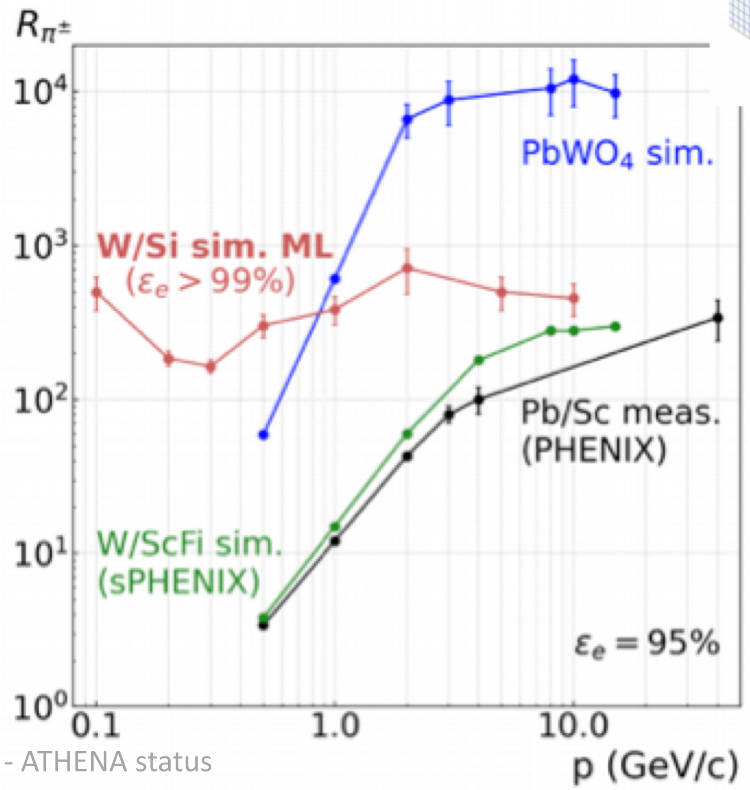


EMCAL barrel

innovative ATHENA
design for EMCAL (central):

- Absorber(W)/ScFiber calorimeter in combination with a Si-based tracking calorimeter
- Monolithic silicon sensor (AstroPix from NASA) [https://arxiv.org/abs/2101.02665]



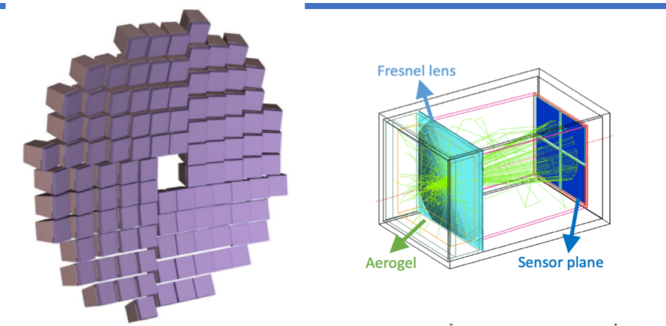


Provide better e/π separation at low energy!

LGAD to help PID optimization on-going!

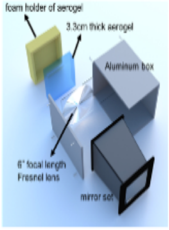
ATHENA: PID (I)

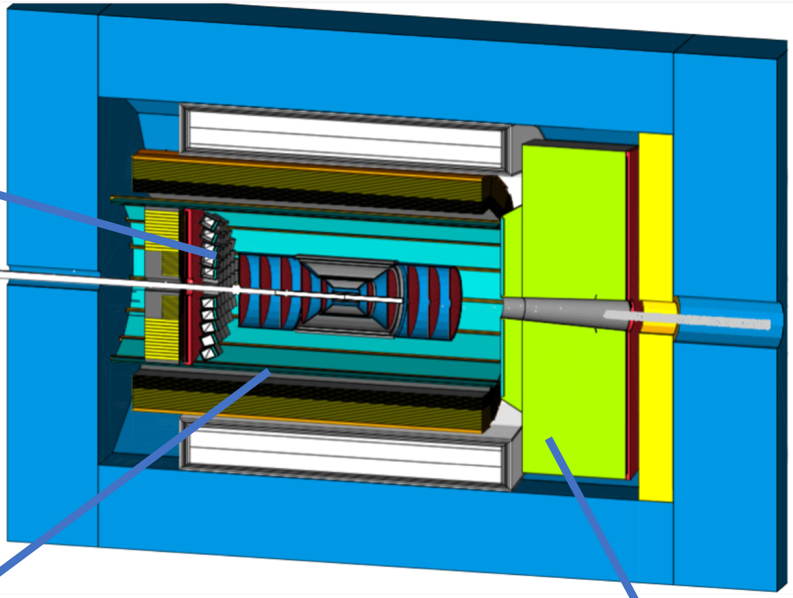
YR report baseline

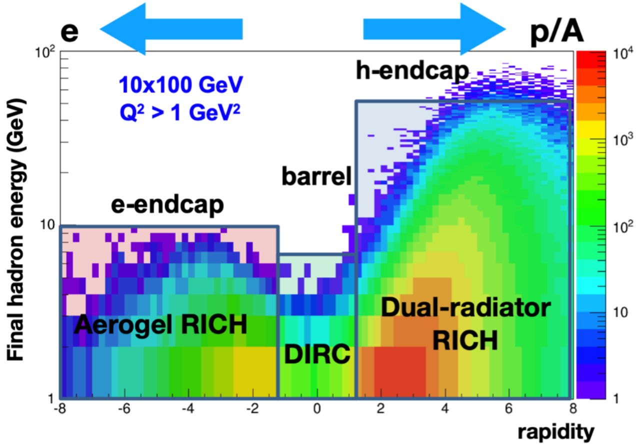


mRICH

Modular and compact ring imaging Cherenkov (mRICH) PID detector for EIC experiments







DIRC

HPDIRC: HIGH-PERFORMANCE DIRC FOR THE EIC DETECTOR

Greg Kalicy, Nilanga Wickramaarachchi (CUA) for the EIC PID Collaboration (eRD14)

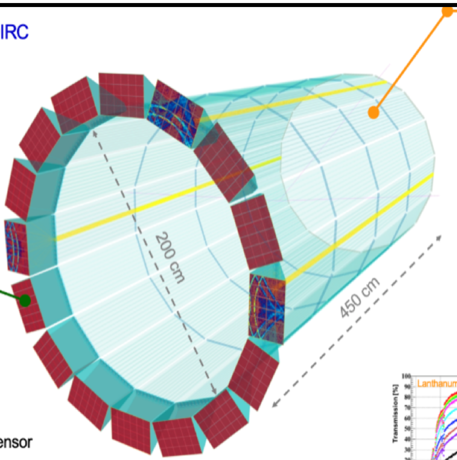
Initial design based on the PANDA Barrel DIRC
- narrow fused silica bars
- 3-layer spherical lens focusing
- fused silica prism expansion volume

Key improvements:
smaller pixels, faster photon timing,
radiation-hard lens, optimized algorithms

Photon detection

Efficient, fast single photon detection with
1 mm and 100 ps precision in high B-fields
→ latest generation lifetime-enhanced MCP-PMTs (commercial or LAPPD™) or SiPMs

Readout: efficient, fast, low-power, matched to sensor
→ waveform-sampling or FPGA-based electronics

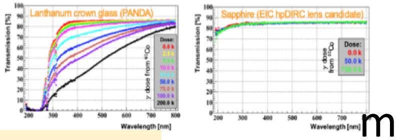


Optics

Synthetic fused silica bars or plates
- radiation hard, excellent transmission
- create Cherenkov light, guide to sensors

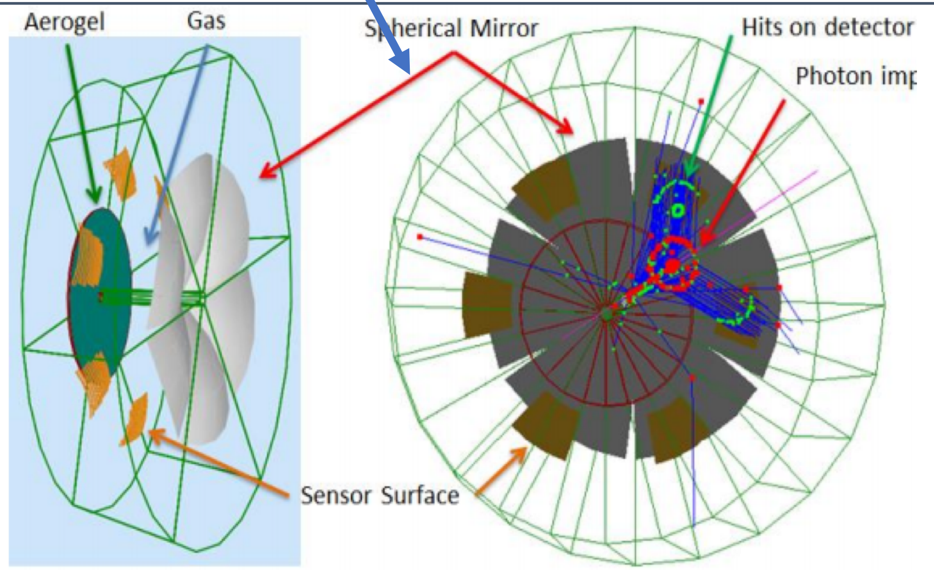
Fused silica prism as expansion volume
- compact, reduces size of sensor area

Novel multi-layer spherical lens
- reduces number of required DIRC bars
- low-loss focusing produces sharp ring images
- 3-layer design creates flat focal plane using high-refractive-index lens material
- identified radiation-hard materials for EIC



dRICH

dual-Radiator Ring Imaging Cherenkov (dRICH)

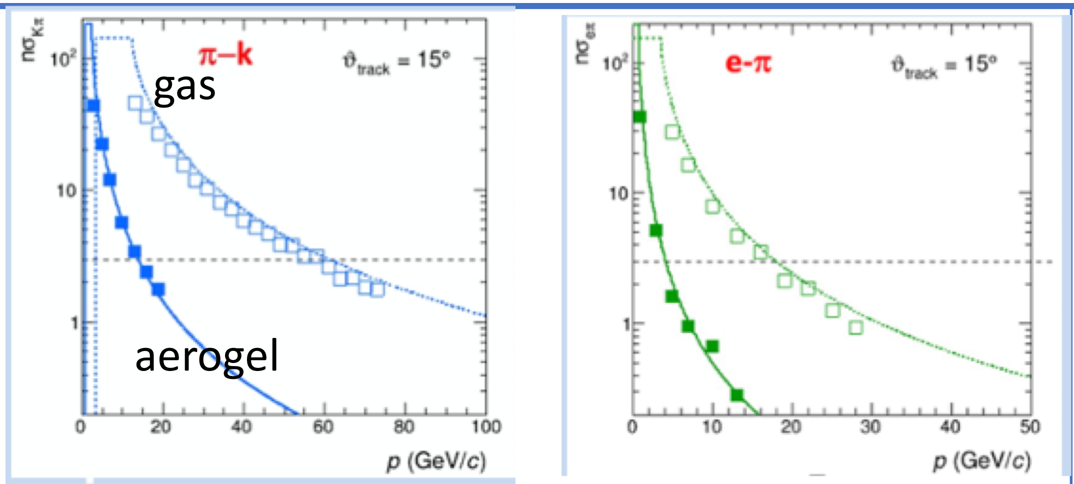


additional LGAD-based TOF and/or cluster-counting dE/dx under discussion

more info: T. Hemmick

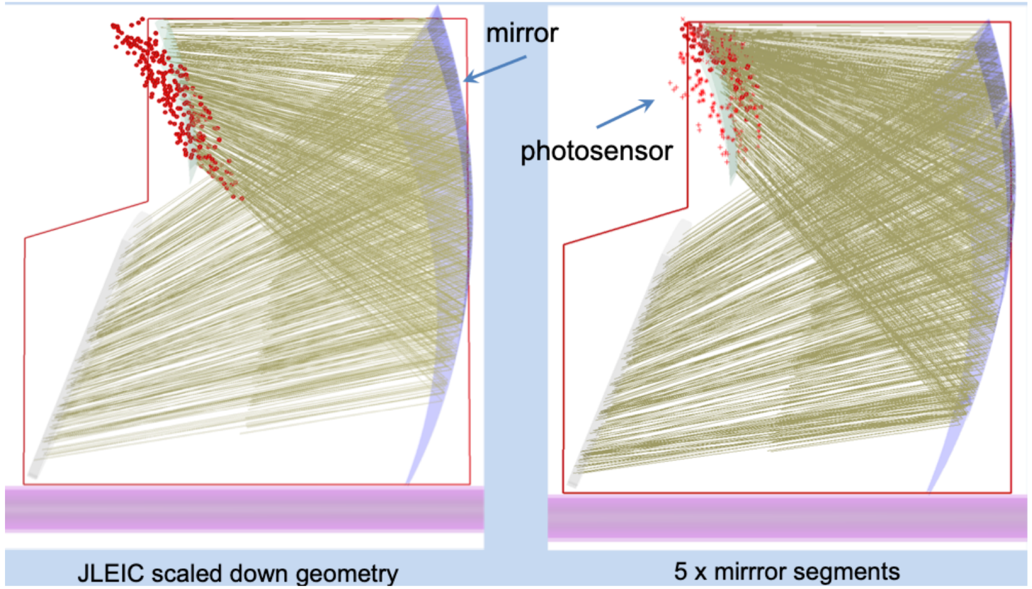
https://indico.bnl.gov/event/11463/contributions/52679/attachments/36354/59761/ATHENA-PID-v4.pptx

ATHENA PID (II) & photosensors



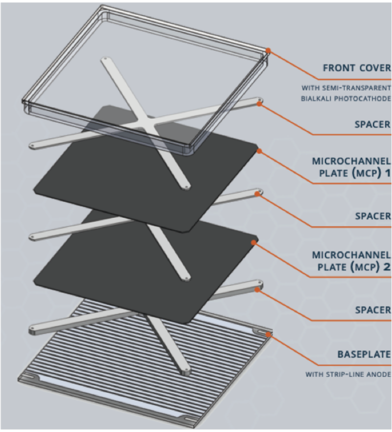
dRICH effective solution (YR baseline)

Radiators: aerogel, (n~1.02) and gas (nC2F6~1.0008)
Sensors outside acceptance
on-going careful geometry optimization



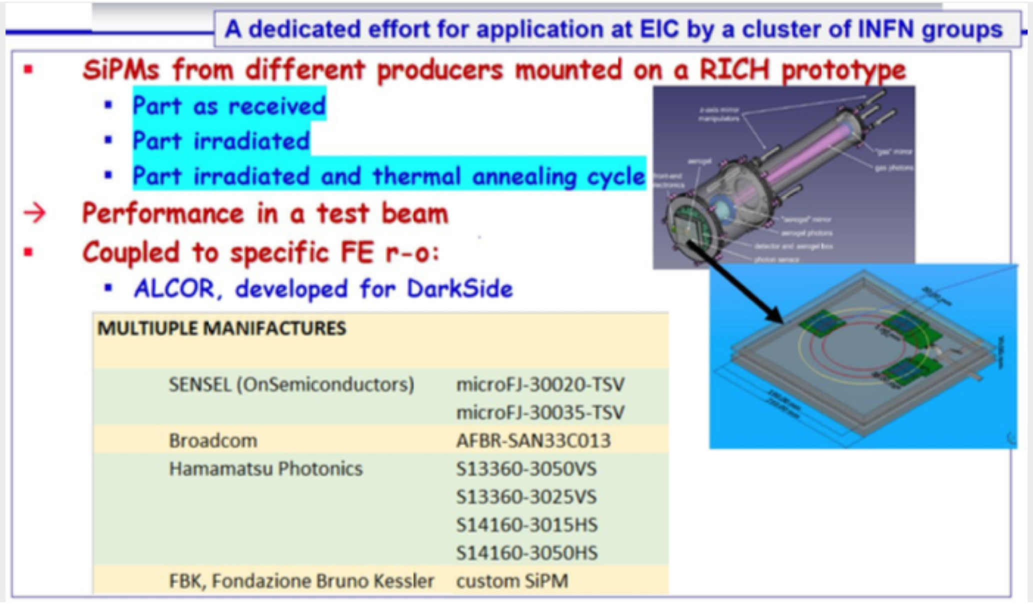
<u>the common challenges of photosensors' choice for PID detectors</u>

MCP-PMTs: commercially available (Photonis/Planacom)
costs & sensitive to B-field



LAPPD: Argonne + Incom www.incomusa.com
R&D effort to evaluate B-sensitivity

SIPM: "mature" technology – no sensitive to B field
<u>BUT:</u> radiation hardness
single-photon detection for RICH



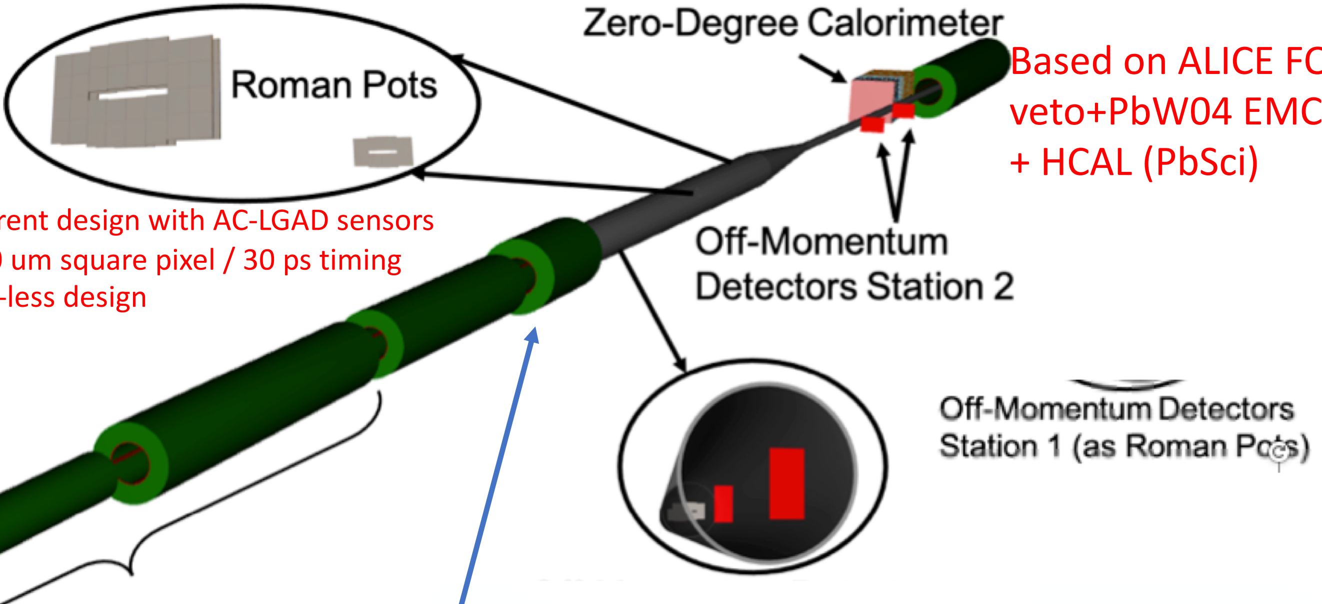
A dedicated effort for application at EIC by a cluster of INFN groups

- SiPMs from different producers mounted on a RICH prototype
  - Part as received
  - Part irradiated
  - Part irradiated and thermal annealing cycle
- → Performance in a test beam
- Coupled to specific FE r-o:
  - ALCOR, developed for DarkSide

MULTIUPLE MANIFACTURES	
SENSEL (OnSemiconductors)	microFJ-30020-TSV
	microFJ-30035-TSV
Broadcom	AFBR-SAN33C013
Hamamatsu Photonics	S13360-3050VS
	S13360-3025VS
	S14160-3015HS
	S14160-3050HS
FBK, Fondazione Bruno Kessler	custom SiPM

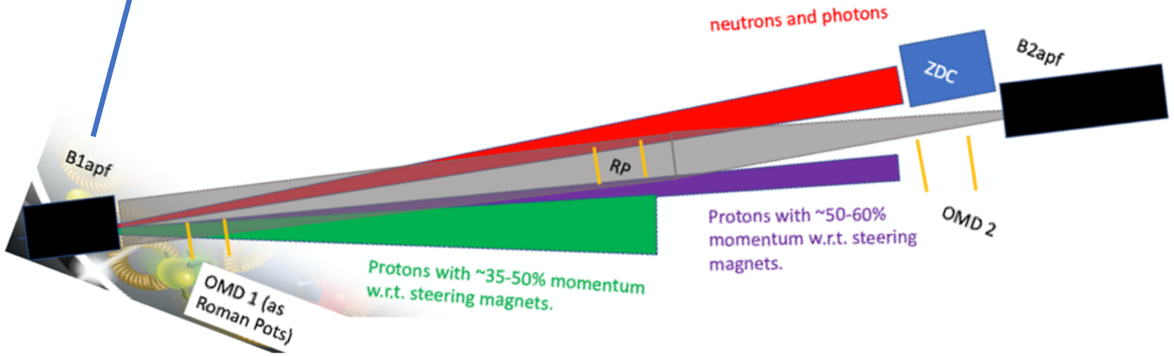
ATHENA far-forward detectors

Detector	Acceptance
Zero-Degree Calorimeter (ZDC)	$\theta < 5.5$ mrad ($\eta > 6$)
Roman Pots (2 stations)	0.0* < $\theta < 5.0$ mrad ($\eta > 6$)
Off-Momentum Detectors (2 stations)	$0.0 < \theta < 5.0$ mrad ($\eta > 6$)
B0 Detector	$5.5 < \theta < 20.0$ mrad ($4.6 < \eta < 5.9$)



Based on ALICE FOCAL design
veto+PbW04 EMCAL
+ HCAL (PbSci)

current design with AC-LGAD sensors
500 um square pixel / 30 ps timing
pot-less design



B0: charged particle reconstruction and photon tagging.

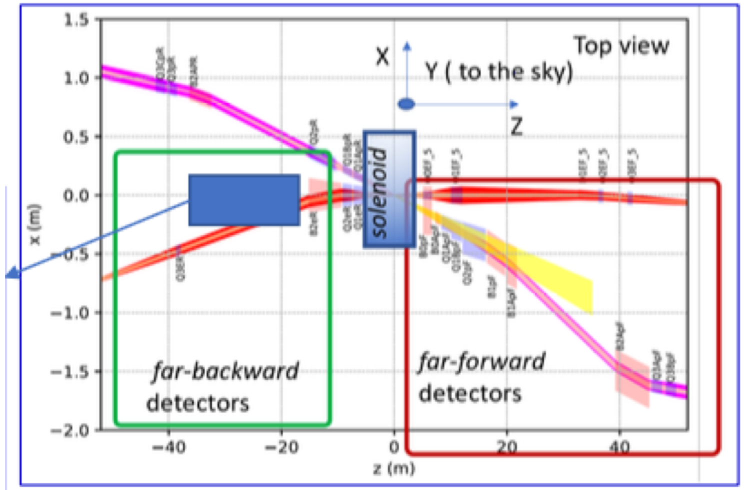
- Precise tracking -> need smaller pixels (20-50um) than for the RP
- Four tracking layers + silicon preshower with Pb converter for photon tagging.

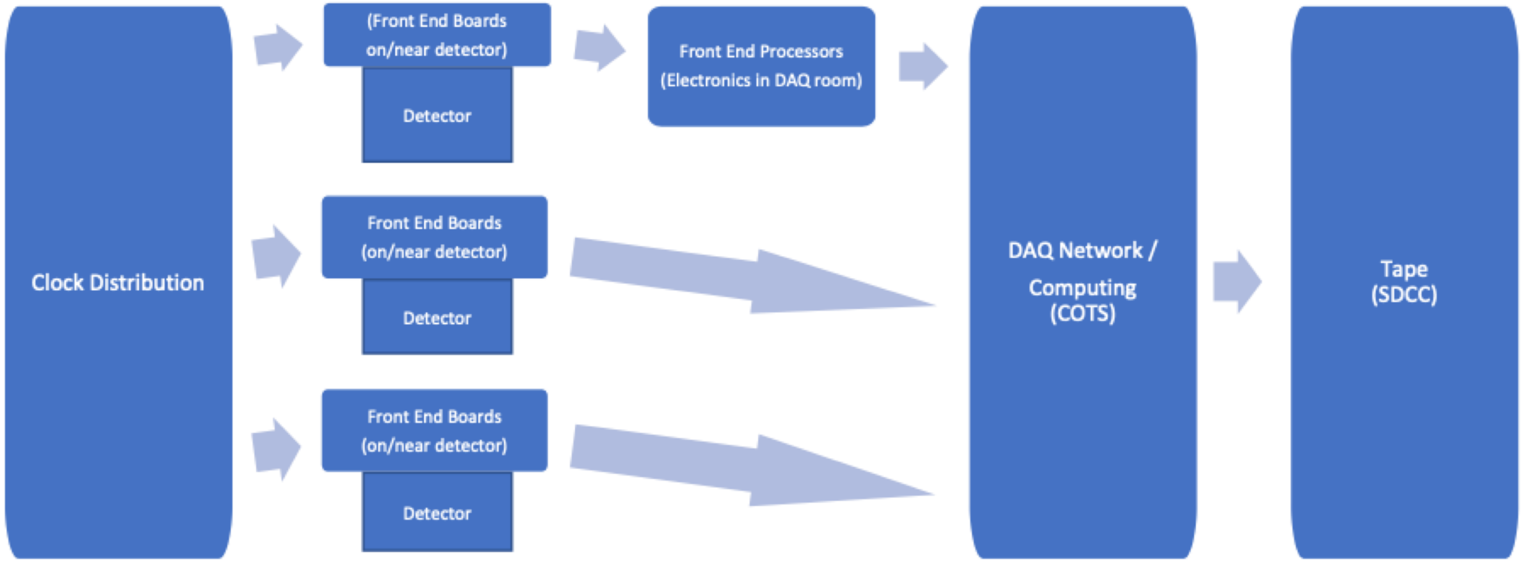
Off-momentum protons have different magnetic rigidity
Two stations allows more protons to be tagged before going through beam pipe material.

more: https://indico.bnl.gov/event/11463/contributions/52680/attachments/36353/59727/EICUG_ATHENA_FarForward_v4.pdf

Other sub-systems (not discussed here)

- far-backward detectors (luminometers, zerodegrees photon, low-Q2 tagging)
- polarimeters (joint EICUG effort)
- DAQ (triggerless streaming) in line with current trend (LHCb, ALICE, ...) and as per YR baseline → evaluation of system needs (& cost) based on ATHENA detectors





Summary & outlook

- ATHENA effort well on track through EIC timeline: from a baseline YR detector to an ATHENA-baseline
- building blocks: new **3T magnet** with large bore diameter, **state of the art detectors**, **modern software**
- <u>on-going MC production effort</u> → performance evaluation during coming weeks!
- on-going progresses towards new magnet
- *Starting from the YR with optimizations and novel elements*
  - Full Si or hybrid tracking
  - A novel approach considered for Calorimetry in the barrel
  - Grid-pix miniTPC proposed for PID & tracking
  - Important steps forward to establish SiPMs as sensors for Cherenkov imaging techniques
- *Large integration of activities within the whole EIC community* (Si consortium, Calorimeters, Far-fwd/far-bwd detectors, Polarimetry)

Sociological – scientific final comment:

- detector design / collaboration building is somehow a chaotic, lively and very intellectually stimulating environment in the life-cycle of an experiment
  → big opportunities
- COVID is making all this even more challenging, but what built in last two years (YR + proto-collaborations really remarkable!)

<u>contact us if interested!</u>

ATHENA at work: the WGs

WGs and Conveners

Software & Computing Working Group

CONVENERS: Sylvester Joosten, Dmitry Romanov, Whitney Armstrong, Andrea Bressan, Wouter Deconinck

PHYSICS VALIDATION WGs

- **Inclusive Working Group**
  CONVENERS: Barak Schmookler, Qinghua Xu, Paul Newman
- **Semi-Inclusive Working Group**
  CONVENERS: Marco Radici, Anselm Vossen
- **Jets/HF/EW-BSM Working Group**
  CONVENERS: Ernst Sichtermann, Stephen Sekula, Brian Page, Miguel Arratia
- **Exclusive/Tagging Working Group**
  CONVENERS: Salvatore Fazio, Spencer Klein, Daria Sokhan

SUB-DETECTOR WGs

- **Tracking Working Group**
  CONVENERS: Laura Gonella, Domenico Elia, Francesco Bossu, Matt Posik
- **PID Working Group**
  CONVENERS: Tom Hemmick, Roberto Preghenella, Franck Guerts
- **Calorimetry Working Group**
  CONVENERS: Oleg Tsai, Paul Reimer, Vladimir Berdnikov
- **Far Forward Working Group**
  CONVENERS: Alexander Jentsch, John Arrington
- **Far-Backward Working Group**
  CONVENERS: Krzyzstof Piotrzkowski, Jaroslaw Adam
- **Polarimetry Working Group**
  CONVENERS: Ciprian Gal, Oleg Eyser
- **DAQ Working Group**
  CONVENERS: Alexandre Camsonne, Jeffery Landgraf