Tracking Performances Studies for the Experimental Setup at the Electron-Ion Collider

Shyam Kumar[a,c]

Annalisa Mastroserio[b,c], Domenico Elia[c], Giacomo Volpe[a,c]

[a]Universita degli studi di Bari Aldo Moro, Italy, [b]Universita degli studi di Foggia, Italy, [c]INFN Bari, Italy.

Physics Motivations

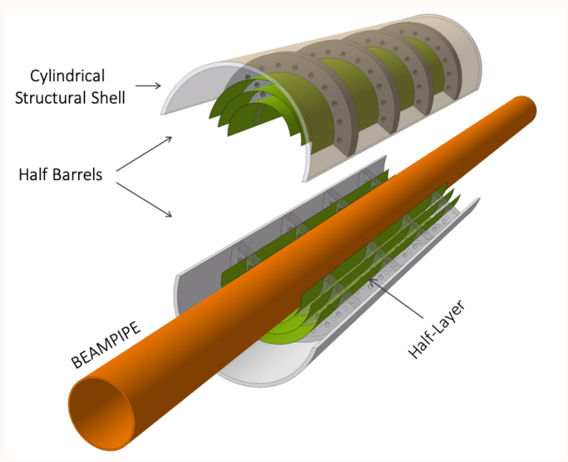
- The US **Electron-Ion Collider (EIC)** project will study the collisions of polarized electrons with polarized protons and ions to be built at BNL. EIC will provide the measurement to address the following open questions [1,2]:
  - How are sea quarks and gluons distributed in inside the nucleon?
  - What happens to the hadronic matter at extremely high gluon density (low-x regime)?
  - How do color-charged partons and colorless jets, interact with a nuclear medium?
  - How do the quark-gluon interactions creates nuclear binding?

ATHENA (A Totally Hermetic Electron-Nucleus Apparatus) is one of the detector designs provided as response to the Call for Detector Proposal issued by the EIC Project in 2021. It includes a tracking system with wide pseudorapidity (η) coverage, high granularity, and low material budget to achieve a good tracking and vertexing peformances [3].

ATHENA Tracker

- **Central Region:**

– 3 vertex (X/X_0=0.05%) and 2 barrel sagitta layers (X/X_0=0.55%) based on silicon MAPS in 65 nm CMOS technology currently being developed by ALICE ITS3, with expected spatial resolution $\sigma_{r\phi}=\sigma_z= 2.887\mu m$.



Layout of ALICE ITS3 detector (https://cds.cern.ch/record/2703140/);

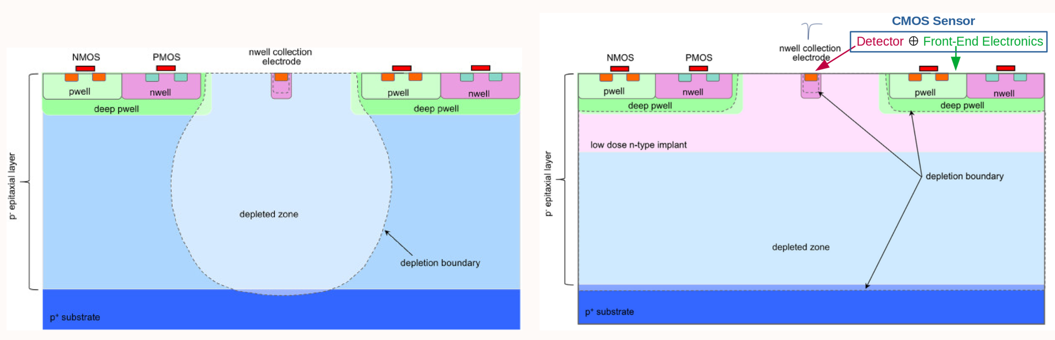


Figure 1: (Left) ALICE Run3 MAPS (**M**onolithic **A**ctive **P**ixel **S**ensor) sensor; and (Right) ALICE ITS3 MAPS Sensor [4];

– 4 micromegas layers with a resolution of $\sigma_{r\phi}=\sigma_z= 150\mu m$) and X/X_0=0.4% per layer.

- **Forward & Backward Region:**

– 6 forward and 5 backward silicon disks ($\sigma_r=\sigma_{r\phi}$=2.887 μm) with X/X_0=0.24% per layer.

– The two outer Si disks complemented by Gas Electron Multiplier (GEM) layers.

– One μRWELL layer in most forward region.

– Each GEM layer and μRWELL layer has X/X_0=0.4% and σ_r=250 μm, $\sigma_{r\phi}$=50 μm.

Simulation of ATHENA Tracker

- Negative pion are generated uniformly in pseudorapidity and momentum, propagated through the detector material using particle gun in GEANT4. This gives the true or Monte Carlo (MC) points on the detector planes. Digitization, hit reconstruction, tracking were performed at a later stage.
- Full simulation in Fun4All and Detector Description Toolkit for High Energy Physics (DD4HEP) framework are used to estimate the performance of tracking system.

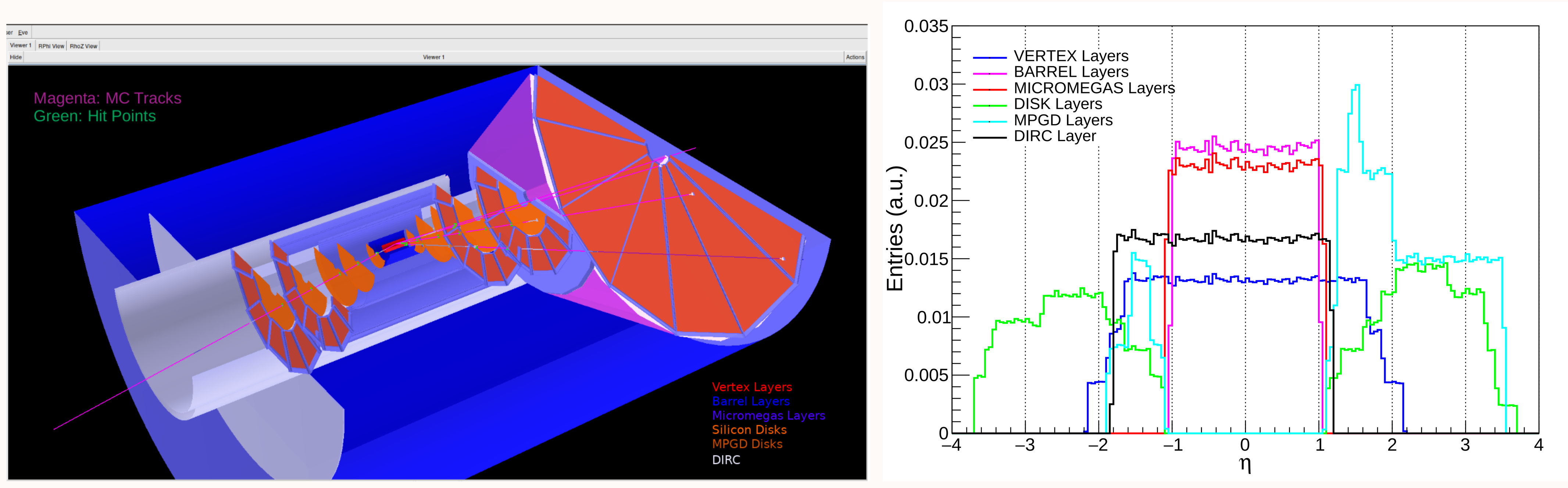


Figure 2: (Left) Event Display of ATHENA showing the detector volumes with embedded π^- MC tracks (magenta) and hits (green) using Fun4All simulation framework; and (Right) pseudorapidity coverage of each detector from the hit positions;

ATHENA Tracking Performance

- Expected performances met the physics requirements as stated in the Yellow Report (YR), except for the most backward pseudorapidities (-3.5< η < -2.5) and momenta below 2 GeV, respectively.

  – Further technology R&D to reduce material, combined with sophisticated analysis techniques and further overall detector layout optimizations needed to fully achieve physics goals.

  – The EIC community is currently working in a join "Detector 1" Collaboration with the aim of combining the ATHENA and ECCE (EIC Comprehensive Chromodynamics Experiment) designs and prepare a baseline detector configuration in view of the TDR activities in 2023.

Acceptance	Momentum resolution σ(p)/p		Transverse pointing resolution $\sigma(DCA_T)$	
	Performance	Requirements	Performance	Requirements
$-3.5 < \eta < -2.5$	$\sim 0.04\% \times p \oplus 1.5\%$	$\sim 0.1\% \times p \oplus 0.5\%$	$\sim 80/p_T \oplus 10\mu m$	$\sim 30/p_T \oplus 50\mu m$
$-2.5 < \eta < -1.0$	$\sim 0.01\% \times p \oplus 0.5\%$	$\sim 0.05\% \times p \oplus 0.5\%$	$\sim 50/p_T \oplus 5\mu m$	$\sim 30/p_T \oplus 20\mu m$
$-1.0 < \eta < 1.0$	$\sim 0.05\% \times p \oplus 0.4\%$	$\sim 0.05\% \times p \oplus 0.5\%$	$\sim 30/p_T \oplus 5\mu m$	$\sim 20/p_T \oplus 5\mu m$
$1.0 < \eta < 2.5$	$\sim 0.01\% \times p \oplus 0.5\%$	$\sim 0.05\% \times p \oplus 1.0\%$	$\sim 50/p_T \oplus 5\mu m$	$\sim 30/p_T \oplus 20\mu m$
$2.5 < \eta < 3.5$	$\sim 0.02\% \times p \oplus 1.5\%$	$\sim 0.1\% \times p \oplus 2.0\%$	$\sim 80/p_T \oplus 10\mu m$	$\sim 30/p_T \oplus 50\mu m$

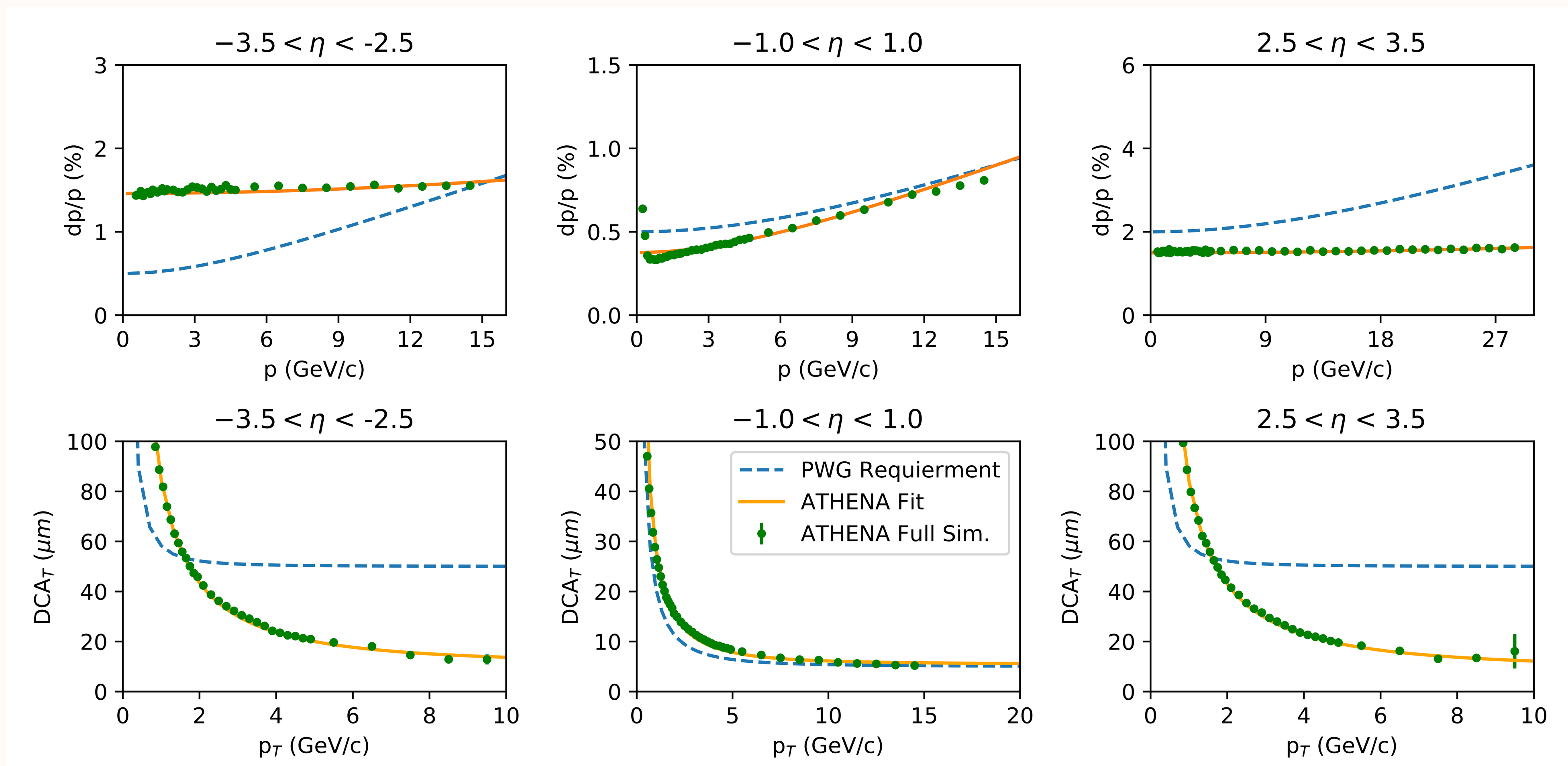


Figure 3: Tracking performances of ATHENA corresponding to simulated pions- uniform in η and momentum compared to the physics requirements in YR for selected η bins. (Top row) Momentum resolutions versus momentum and (Bottom row) Transverse DCA resolution versus transverse momentum [3];

References

1. R. Abdul Khalek, *et al.* "Science Requirements and Detector Concepts for the Electron-Ion Collider: EIC Yellow Report", [arXiv:2103.05419 [physics.ins-det]].
2. EIC, A machine that will unlock the secrets of the strongest force in Nature https://www.bnl.gov/eic/.
3. ATHENA, A new EIC experiment at IP6 at BNL https://sites.temple.edu/eicatip6/.
4. https://doi.org/10.1016/j.nima.2017.07.046

UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO

Università di Foggia

INFN Istituto Nazionale di Fisica Nucleare