# Performance of the nHCal for ePIC experiment based on Simulations


FACULTY OF NUCLEAR SCIENCES AND PHYSICAL ENGINEERING CTU IN PRAGUE

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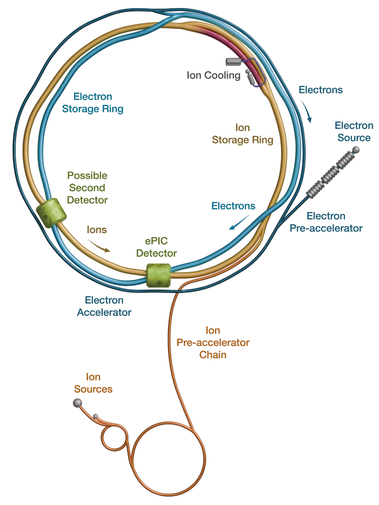
## Electron-Ion Collider

- Approved particle accelerator planned to be built in the next few years at Brookhaven National Laboratory
- Will repurpose a lot of infrastructure from the existing Relativistic Heavy Ion Collider (RHIC)
- First collider to have both colliding beams (electron and proton/ion) polarised
- Large range of center-of-mass energies:
  → from 20 GeV up to 140 GeV

**PHYSICS GOALS**

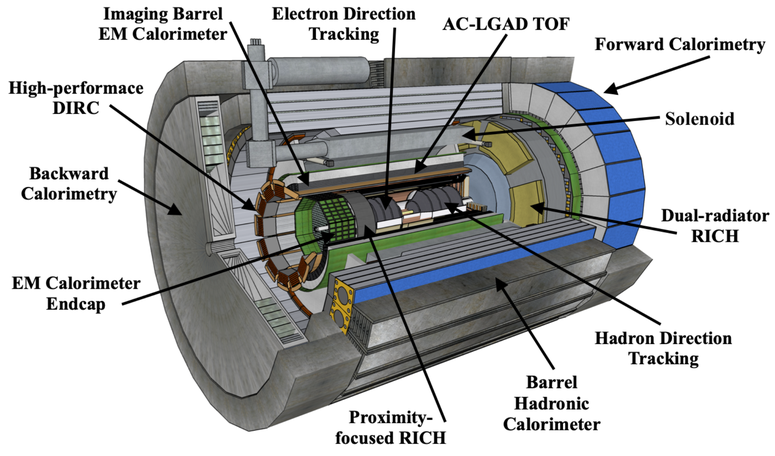
- Solve the proton spin puzzle
  - ▷ how the constituent quarks and gluons and their interactions contribute to the nucleon's spin
- Produce precise 3D images of protons and nuclei
  - ▷ extending simplistic models and broadening our understanding of gluon dynamics inside nucleons
- Study the dense nuclear medium
  - ▷ looking for a steady state of saturation called colour-glass-condensate




## ePIC detector

Designed to combine many subsystems for tracking and vertexing, particle identification, electromagnetic calorimetry and hadronic calorimetry

- Located at the Interaction Point 6, at the current location of the STAR detector
- Spanning a cylindrical volume with the length of $\sim 9.5$ m and radius of $\sim 2.67$ m
- Asymmetrical design to accommodate the difference in energies of the opposing colliding beams
- Large coverage in pseudorapidity - even more extended by the far detectors




## Negative Hadronic Calorimeter

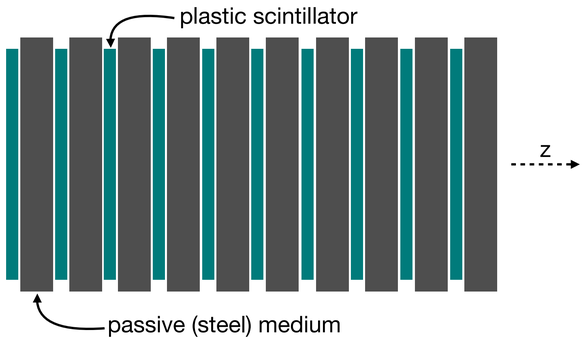
Sampling calorimeter located in the electron direction, serving as a tail catcher for the electromagnetic calorimeter in electron identification

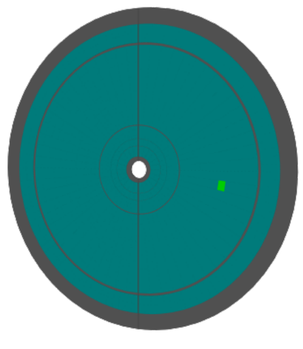
**ROLE**

- Distinguish charged and neutral hadronic showers coming from jets originating from fragmentation of low Bjorken $x$ partons
  - – high neutron efficiency and good shower separation required
- Identify muons from vector meson decays

**DESIGN**

- 10 alternating layers:
  - ▷ non-magnetic steel 4 cm (absorber)
  - ▷ plastic scintillator 4 mm (active medium) [segmented in 10×10 cm layers]
- Signal readout:
  - ▷ Scintillator light guided by wavelength-shifting fibers
  - ▷ Light collection managed by Silicon Photomultipliers (SiPM)



## Justification for the nHCal

Many low-$x$ physics topics through diffractive events require nHCAL and/or greatly benefit over other channels

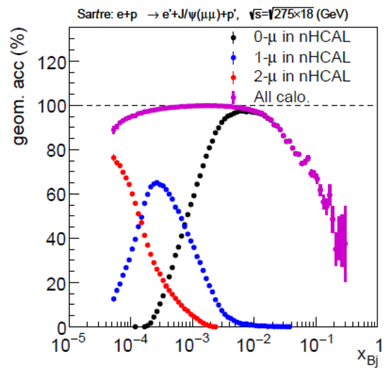
- Backed up by the H1 collaboration at HERA

→ they realised that the lack of backward HCal was detrimental for low-$x$ studies

- ▷ [Nucl.Instrum.Meth.A 386 (1997) 397-408]
- ▷ [Nucl.Phys.B 497 (1997) 3-30]

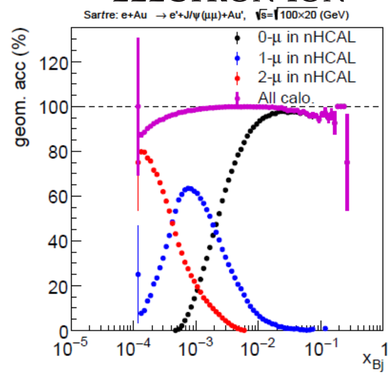
- Diffractive $J/\psi \to \mu^+\mu^-$ photoproduction is a crucial physics goal promised by ePIC
  - ▷ [Nucl.Phys.A 1026 (2022) 122447]

**ELECTRON-PROTON**




- nHCal crucial below $x = 10^{-3}$

**ELECTRON-ION**




- nHCal crucial below $x = 10^{-2}$

## Single Neutron Simulations

The following simulations were done to study the performance of nHCal measurements of neutrons in terms of detection efficiency and position resolution

**SETUP**

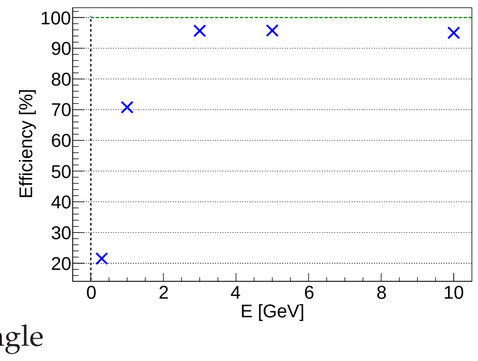
- single neutron shot in Hcal_only geometry
- neutron energies of 1, 3, 5, and 10 GeV with $\theta = 150°$ and $\phi = 45°$
- each configuration consisting of 100 000 events

**RECONSTRUCTION EFFICIENCY**

↑ The ratio of reconstructed to generated neutrons

- Generally improves with higher energies
- Reaches sufficient values ($\sim 95.8\%$) at 5 GeV

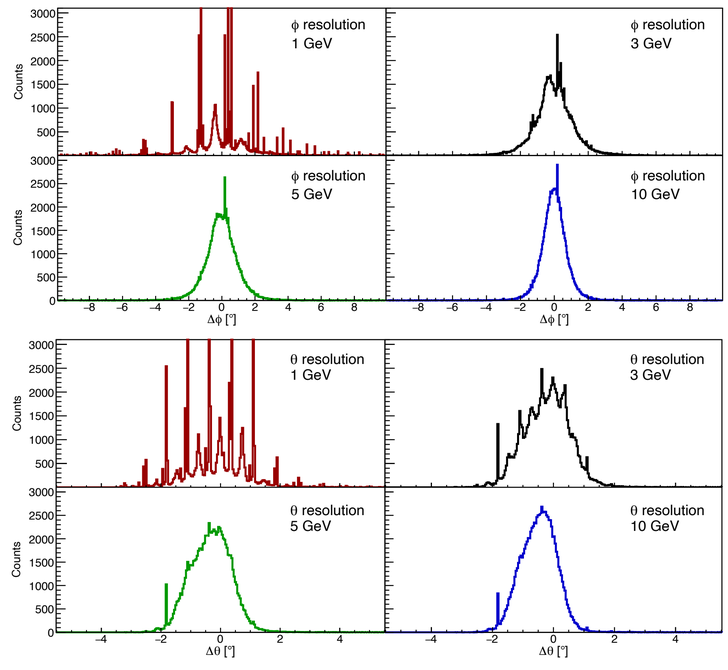
→ Chosen energy for the following plots




**ANGULAR RESOLUTIONS**

↑ The difference of reconstructed and Monte Carlo angle

- In ideal scenario the width of the distribution should approach zero
- Also generally improves with higher energies
- Sharp peaks (more prevalent at lower energies) appear when all energy is deposited in cluster with single tile




## Summary

- Obtained neutron detection performance from simulations:
  - ▷ efficiency $> 95\%$ for E $\geq$ 5 GeV
  - ▷ angular resolution improves with higher energies
- Negative Hadronic Calorimeter (nHCal) is critical for the ePIC detector as it enables precise studies at low-$x$
- Initial exclusion of such detector in the H1 experiment was later recognised as a significant limitation of physics output on key topics
- Baseline design is still being finalised in order to accommodate all physics requirements

## Acknowledgement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The ePIC Collaboration
https://www.epic-eic.org/