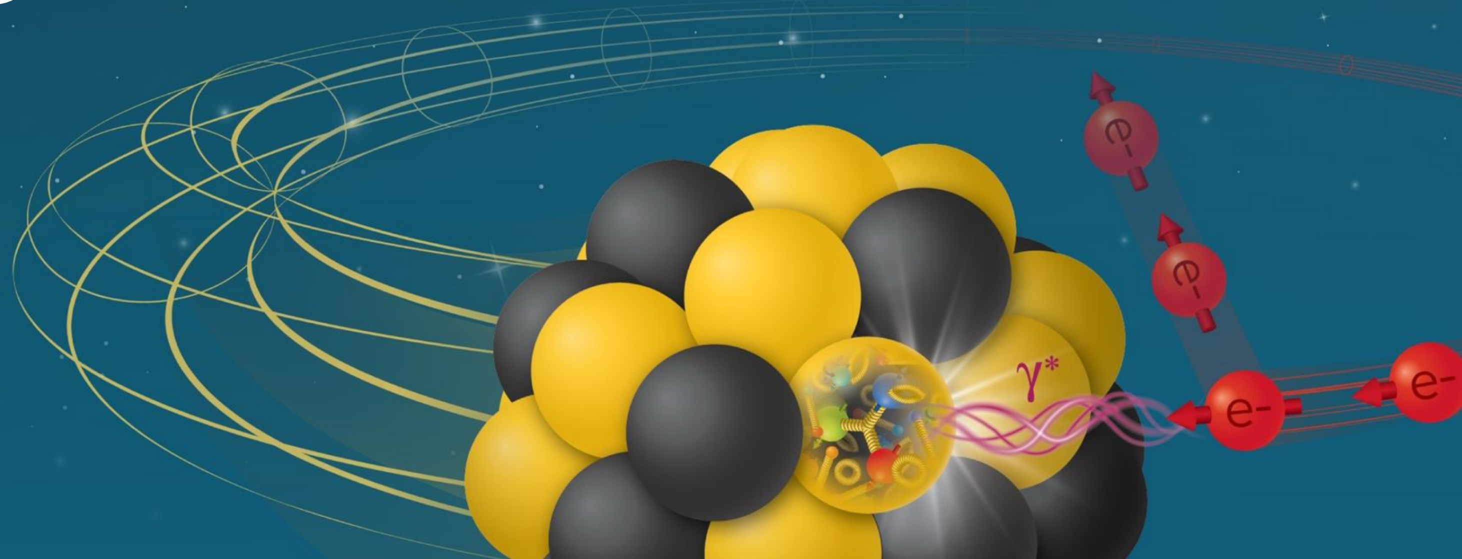
Status of HJET and *p*C Polarimeters

Prashanth

for the Polarimeter Group @ BNL

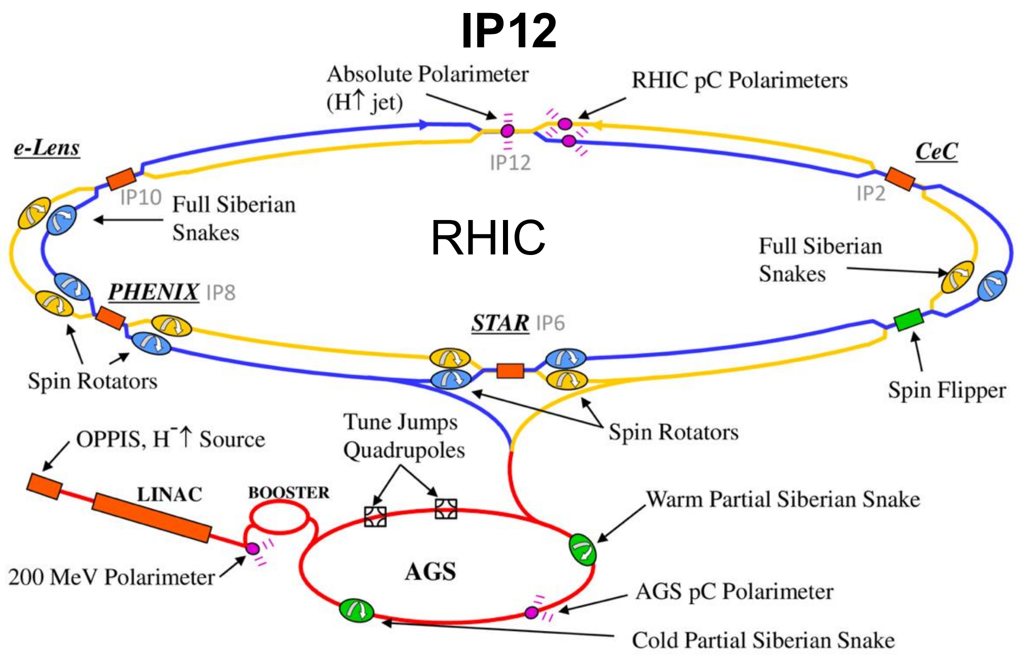


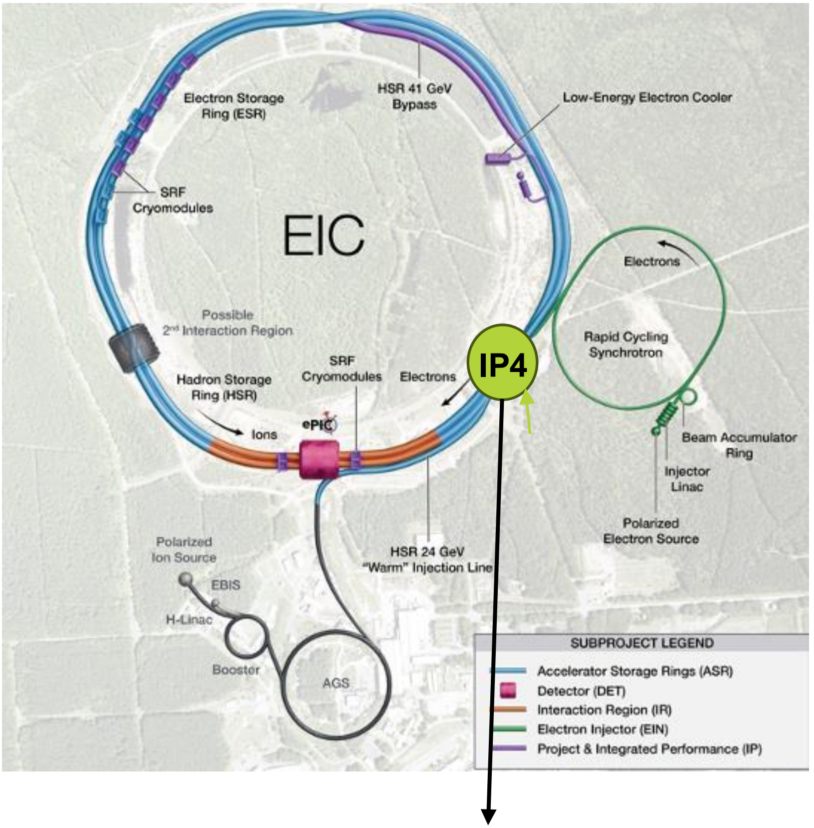
July 10-17th, 2026

ePIC/EICUG Meeting

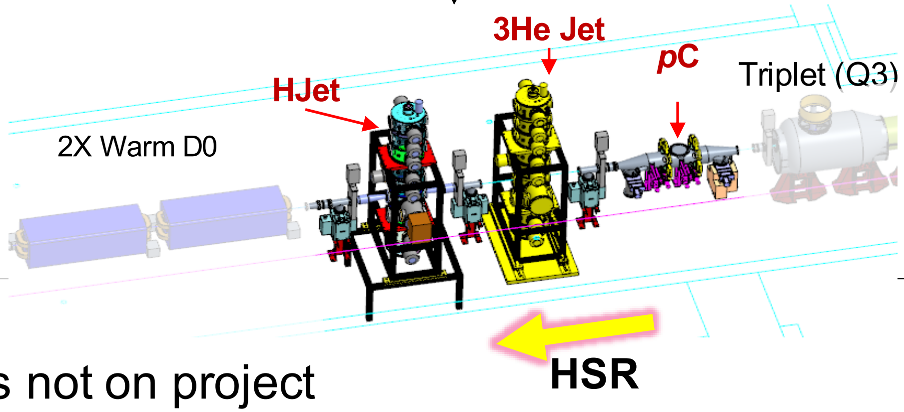
Electron-Ion Collider

HJET & *p*C from RHIC to EIC



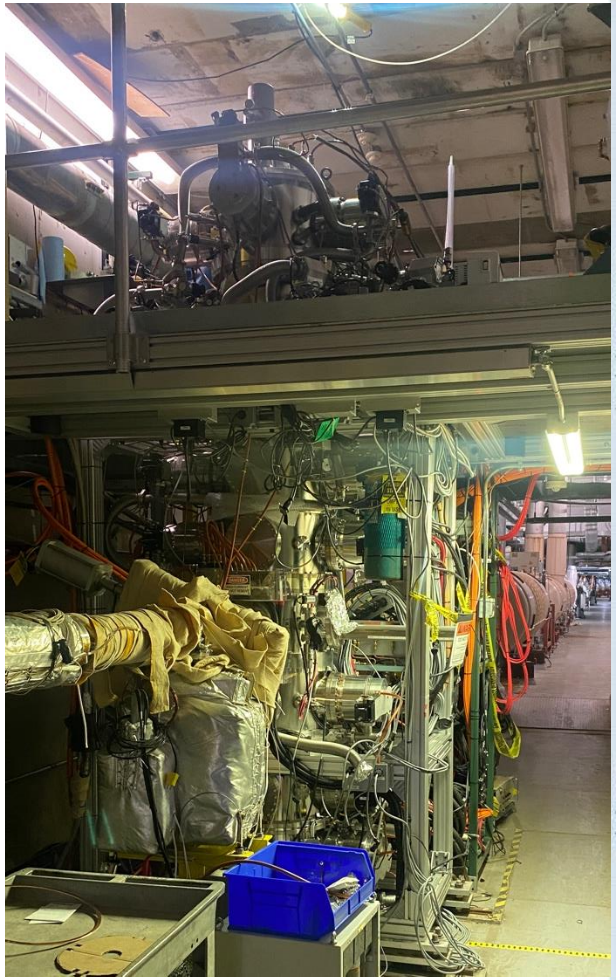


HJET and *p*C polarimeters will be refurbished and upgraded for EIC use!

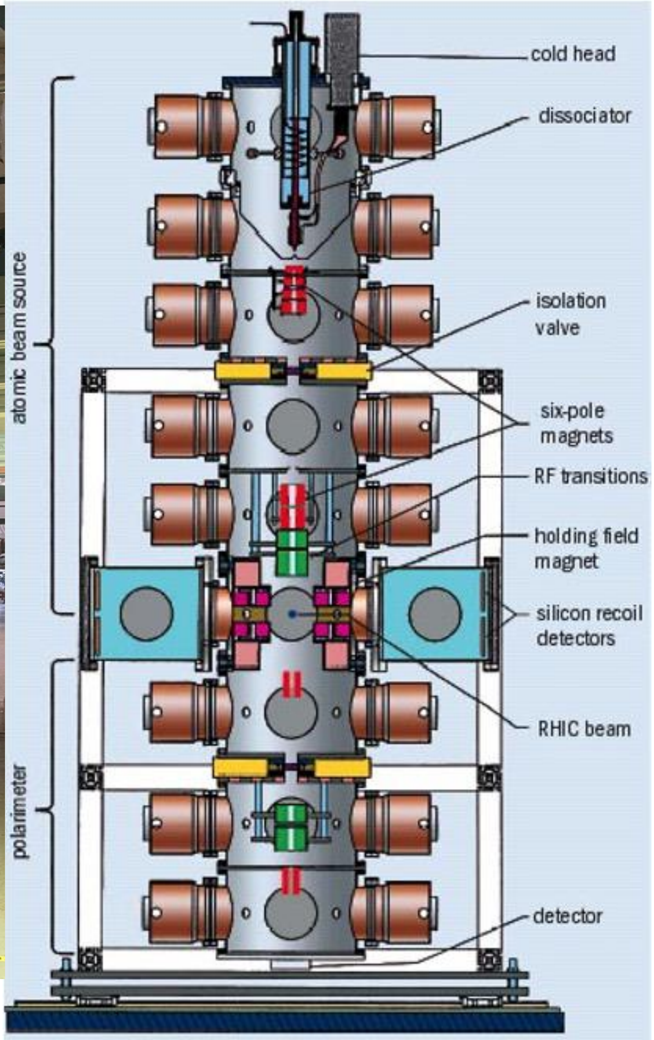


3He is not on project

RHIC - HJET

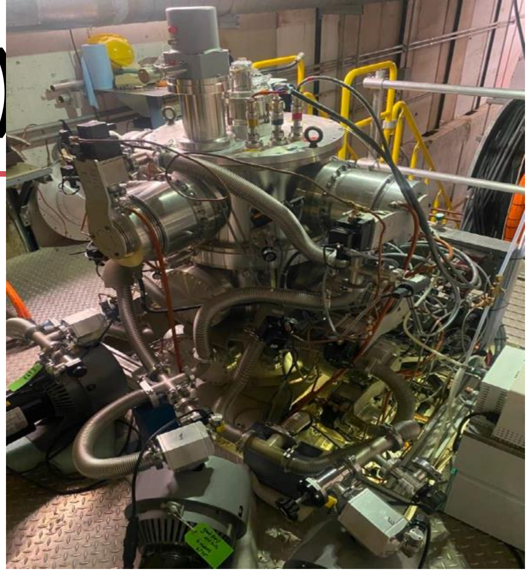


RHIC-HJET @ IP12

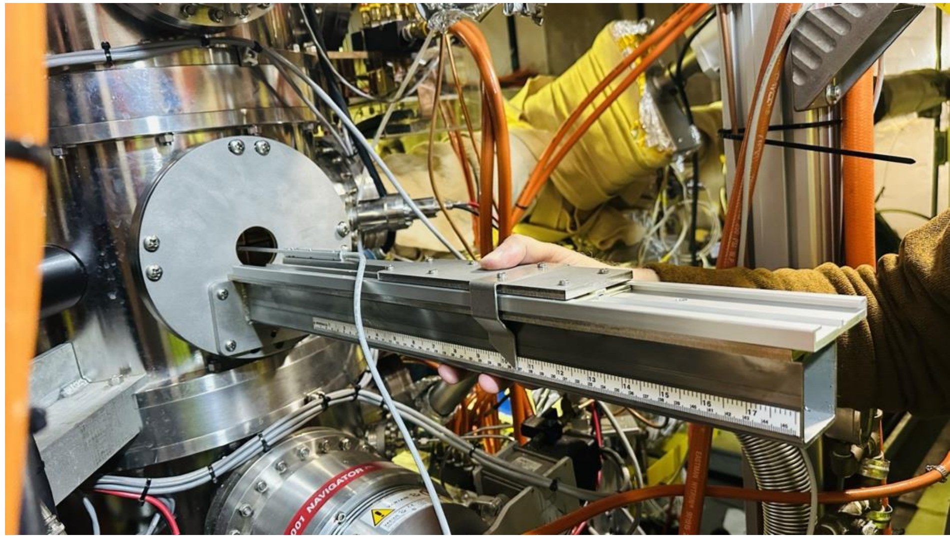


- Absolute beam polarimeter for RHIC polarized proton beams
- Uses a **polarized atomic hydrogen gas jet target** intersecting the circulating proton beam
- Relies on the precisely known polarization of the hydrogen target
- Measures **elastic proton–proton scattering** in the Coulomb-Nuclear Interference (CNI) region
- Achieves systematic uncertainties at the few-percent level
  - Historically around 3–5%
  - For EIC < 1% needed
- *p*C polarimeters are calibrated against H-Jet

Ongoing Activities (After RHIC Shutdown)

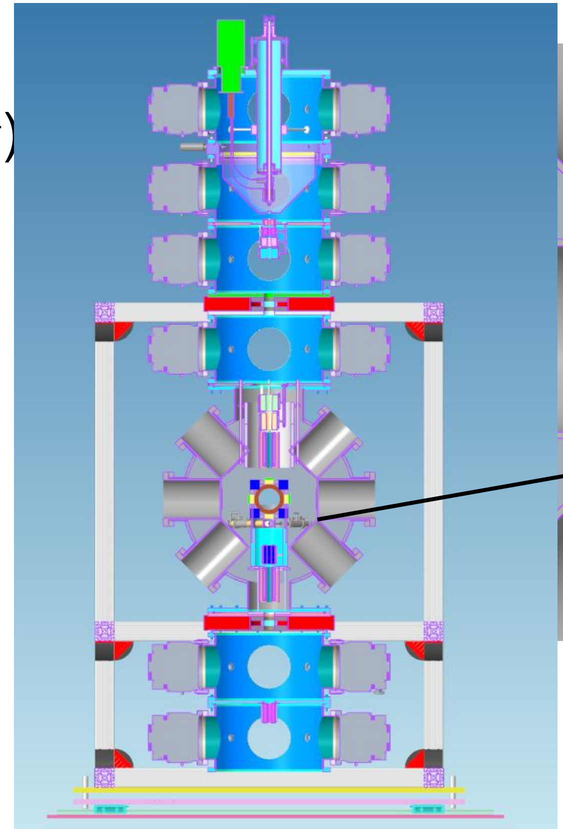


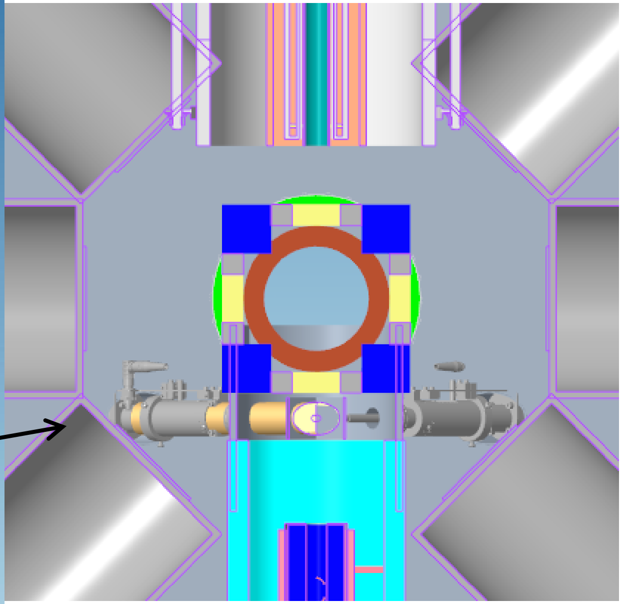
- Learn HJET operation and control systems from current experts
- Repair cold head **(Completed)**
- Perform magnetic field measurements of the HJET magnet system
- Characterize RF units **(Completed)**
- Electrical documentation and cable tracing **(Completed)**
- Replace Atomic Beam Source (ABS) and Breit–Rabi Polarimeter (BRP) power supplies
- Relocate HJET
  - RHIC Tunnel 1012 → Physics High Bay → EIC Tunnel 1004
- Upgrade High Bay
  - Electrical infrastructure upgrade to support HJET operation
  - Install mezzanine & soft-wall clean room



Planned Upgrades for the HJET

- **Detector System**
  - Measure full polarization vector, $\vec{P}=P_x,P_y$, (P_z)
  - Operate at **10× higher EIC bunch frequency**
- **Atomic Beam Source**
  - Upgrade 120mT to 400 mT holding field
  - New target chamber
- **BRP mass analyzer for improved H_2 background subtraction**
- **Controls**
  - Common EIC EPICS platform
  - Updated Safety PLC and motion controls

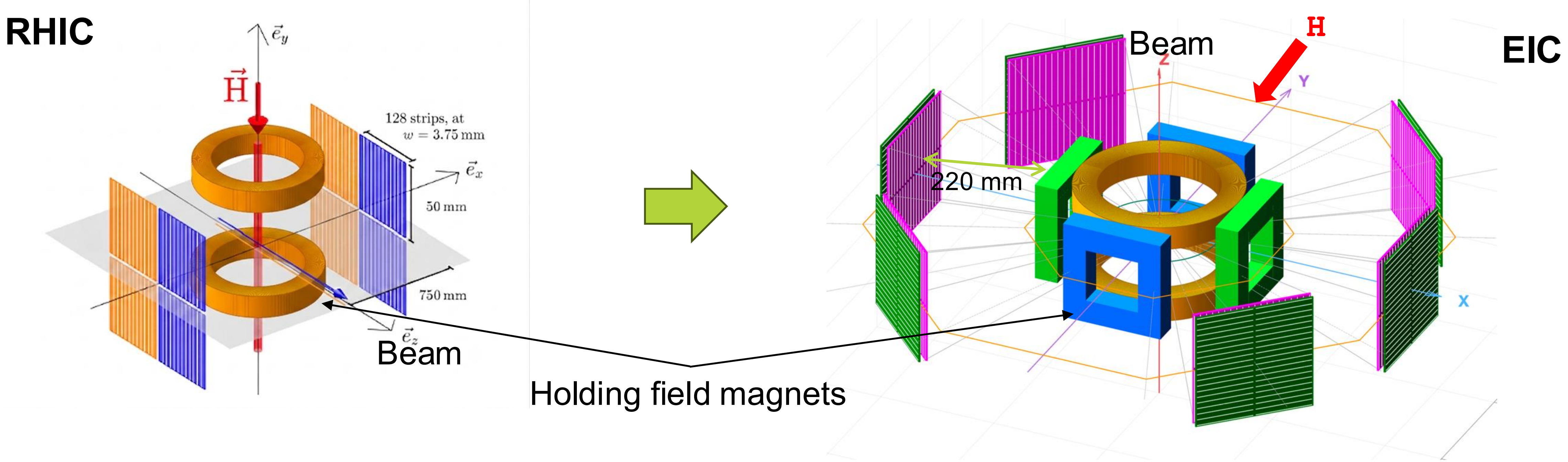




2D-QMA ports

Goals for the upgrades: Achieve **<1%** absolute polarization uncertainty for EIC

Upgrade to Detector and Holding Field Magnet

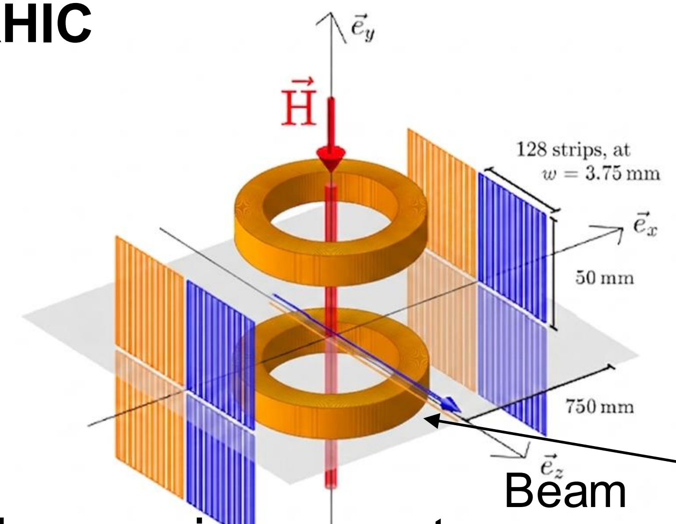


- EIC bunch frequency (~90 MHz) is ~10× higher than RHIC, at current holding field 120 mT, hydrogen hyperfine transitions overlap populated beam harmonics
  - Beam RF fields can drive resonant hyperfine transitions and depolarize the target
- Increasing the holding field to ~400 mT (100-400 mT tunable HTS)shifts all transitions away from populated EIC harmonics, providing a resonance-free operating region for HJET

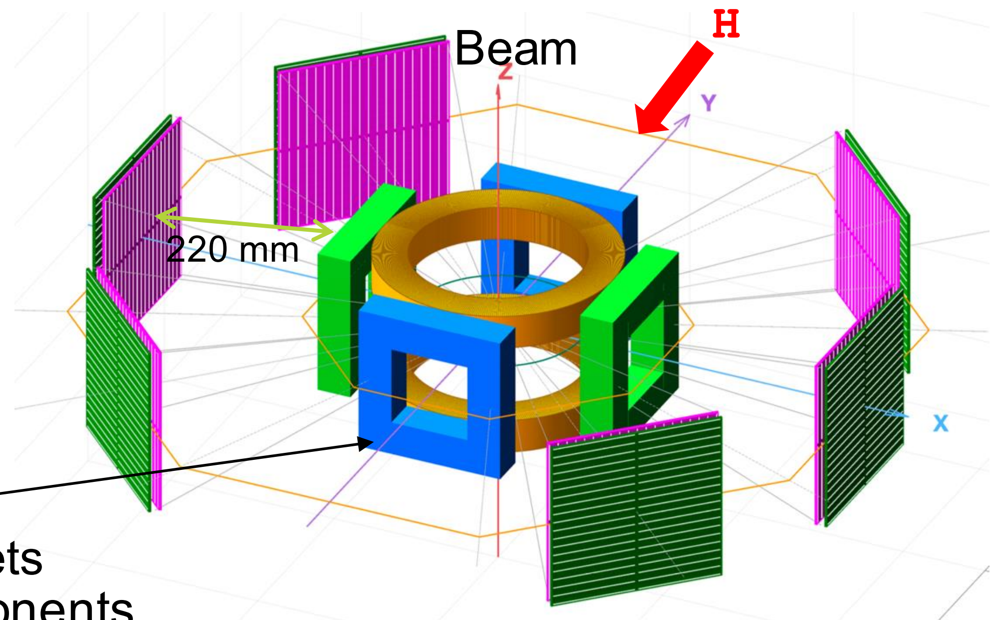
Ref: arXiv:2508.01366 [physics.acc-ph]

Upgrade to Detector and Holding Field Magnet

RHIC



EIC

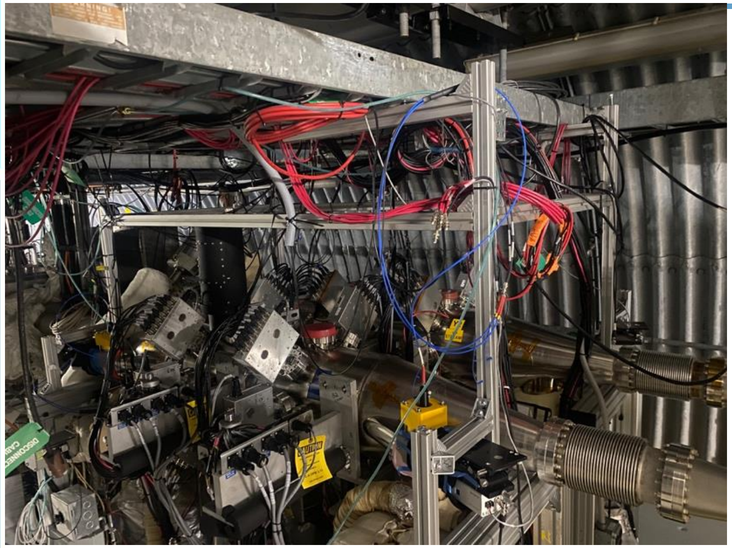


Holding field magnets

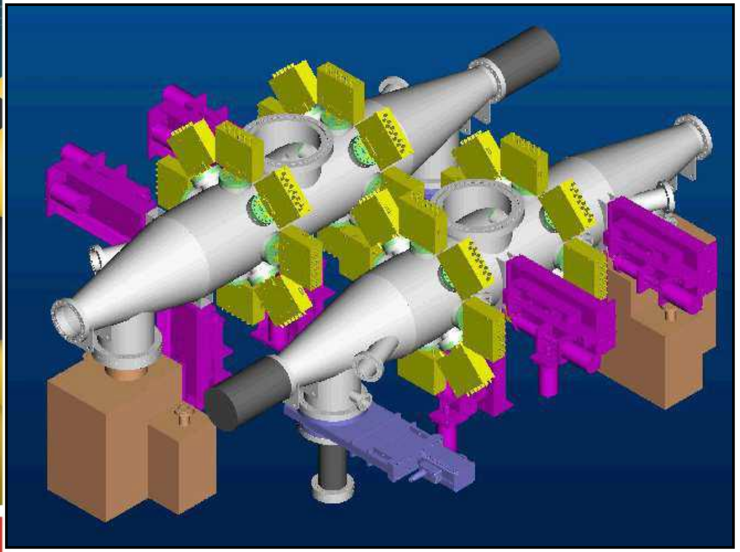
- Three-axis magnet:
  - Measurement of all the beam polarization components
    - RHIC only p_y
  - Better suppression of systematic errors through field reversal
    - Essential for achieving ΔP/P≈1%
  - Separation of hydrogen hyperfine-state contributions
    - HJET ABS typically injects: |1⟩+|4⟩ or |2⟩+|3⟩
    - Reversing the guide field allows these contributions to be disentangled experimentally
  - Full vector Px,Py, (Pz) polarimetry beyond the capabilities of the HJET
  - Detectors much closer->higher statistics in shorter time

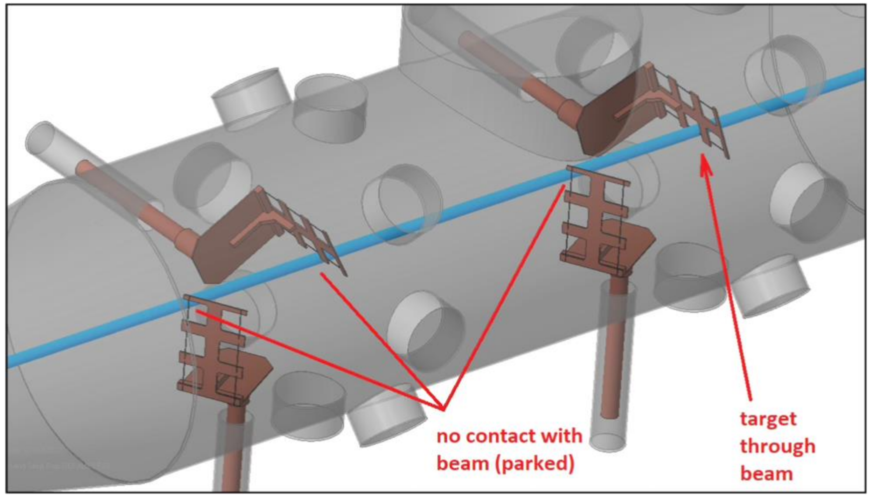
Improved Detector & Increased Beam Intensity → Measurement Time Reduced by ~20×

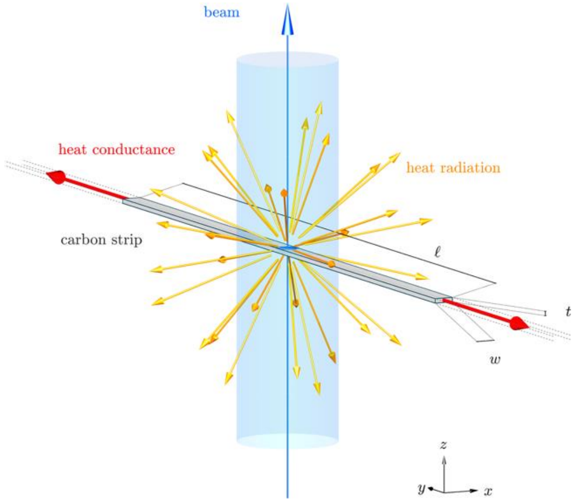
RHIC – pC Polarimeter



- Fast relative polarimeter for continuous beam polarization monitoring
- Calibrated by the HJET absolute polarimeter
- Uses proton–carbon elastic scattering from a thin carbon ribbon target in the CNI region
- Measures recoil carbon asymmetry with silicon detectors to determine beam polarization



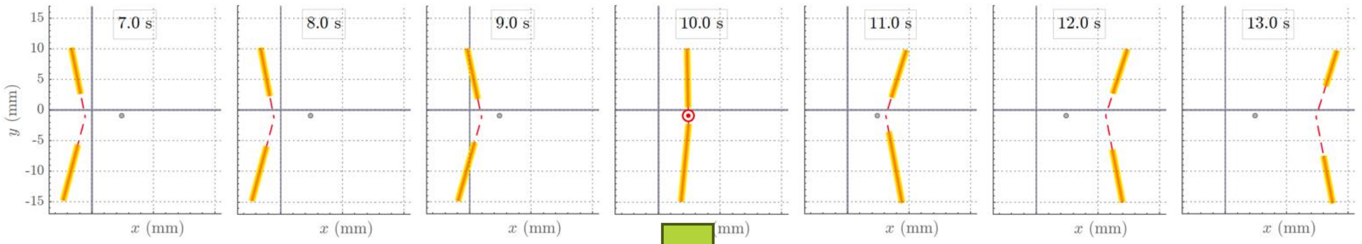




Thermal and Electromechanical Response of Ultra-Thin Carbon-Strip Targets

- RHIC observations indicated that target behavior cannot be explained by beam heating alone
- RF-induced strip-end heating and electromechanical effects also influence target lifetime
- The coupled model explains multiple RHIC observations:
  - Strip-end glow
  - Strip deformation
  - Target lifetime scale

C-strip response through the beam, Reconstructed from video frames



Physics included in the model

Included effect	Why it matters
Beam heating	Deposits energy and raises target temperature
Secondary-e^{n} escape	Reduces the fraction of deposited energy retained as heat
RF end heating	Produces additional heating away from the beam spot
Electrostatic forces	Pull the strip toward the beam during operation
Mechanical deformation	Changes the strip geometry and affects heating and lifetime

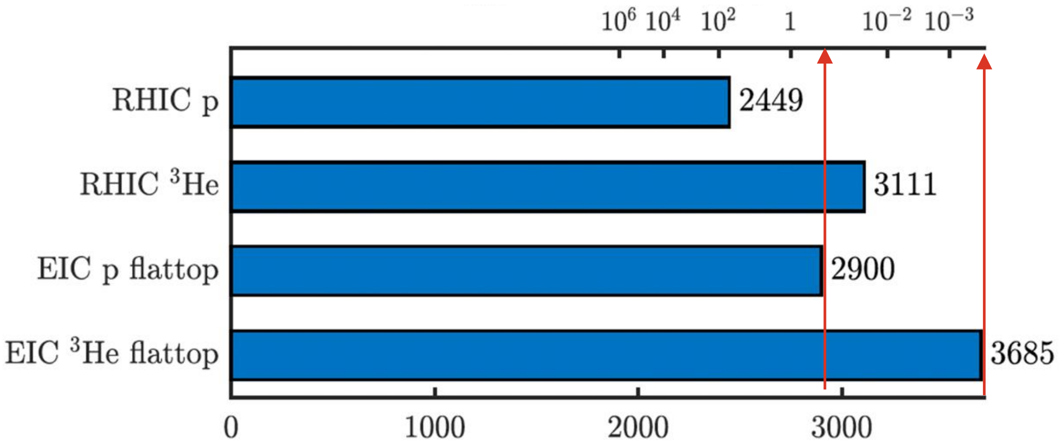
Reproduces the observed RHIC target-lifetime scale (15–120 predicted vs. 27–142 observed cycles)

Providing confidence for extrapolation to EIC beam conditions

Ref: arXiv:2606.29005 [physics.acc-ph]

Implications for EIC Carbon-Strip Targets

Estimated time to remove 50% of a 50nm strip



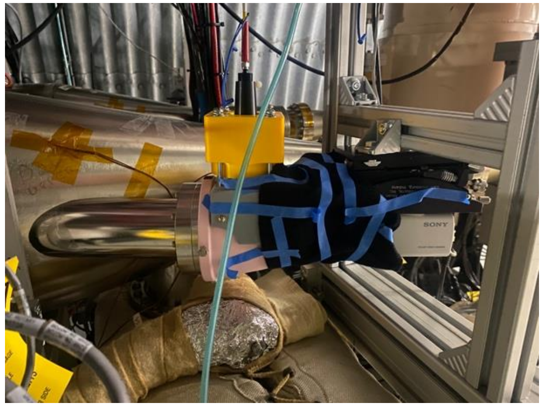
Predicted peak temperature of the moving carbon strip

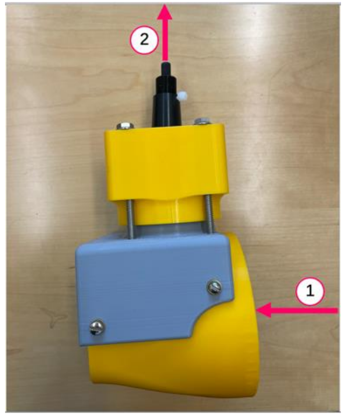
- Predicted peak target temperature increases from RHIC to EIC, reducing the allowable operating margin for carbon-strip targets
- Higher beam intensity and cooled-emittance beams increase the local thermal load on the C-strip
  - Motivates a re-evaluation of carbon-strip target survivability

Existing carbon-strip optimization	Future target concepts
• Faster scans • Improved detector acceptance • Optimized holder geometry • Beam optics	• Low-Z materials • Renewable targets • Moving ribbon/tapes • Pellet targets • Non-invasive polarimetry

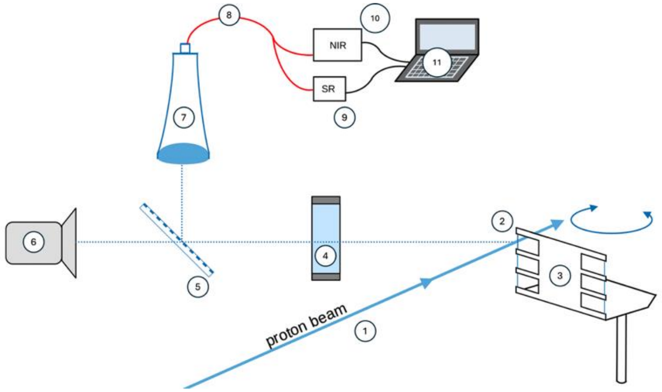
Ref: arXiv:2606.29005 [physics.acc-ph]

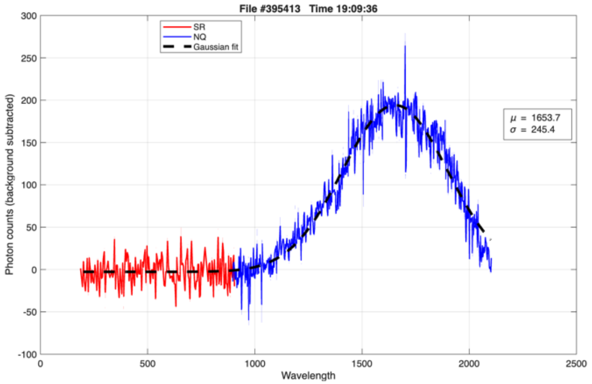
RHIC *p*C C-Strip Temperature Measurement





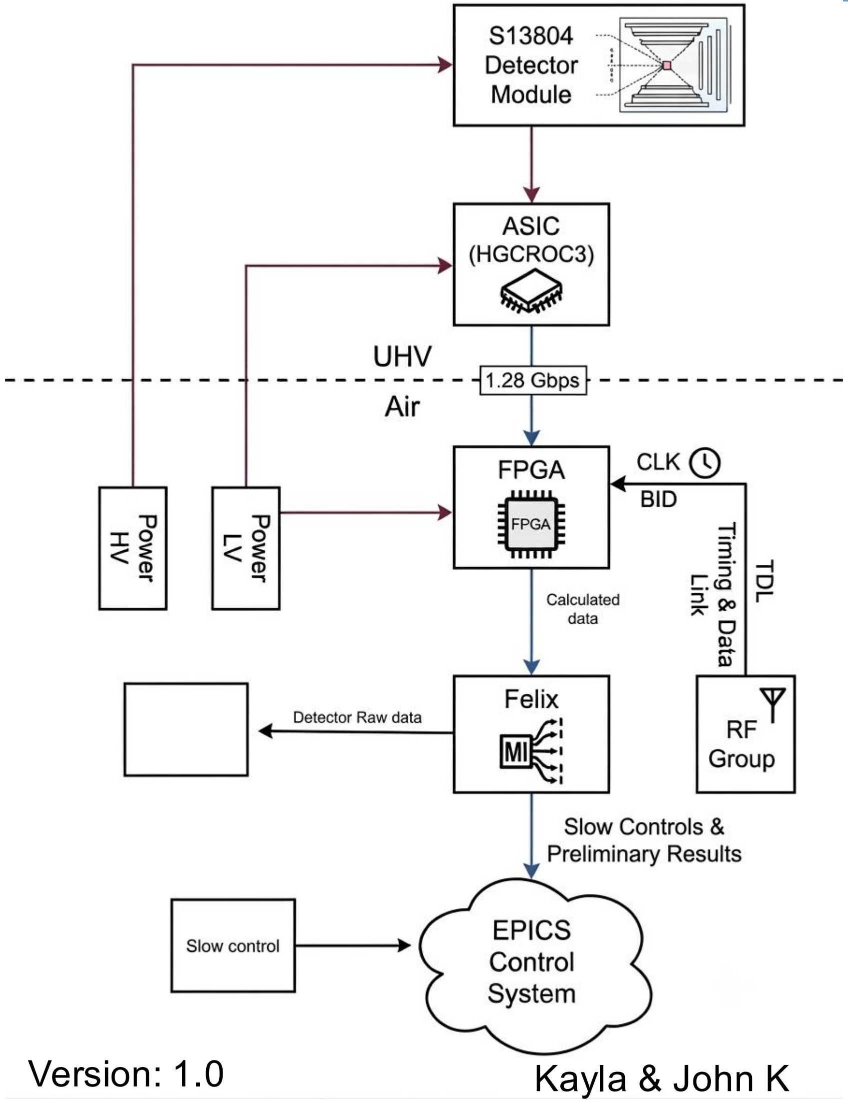
- Light emitted by the carbon target is collected through existing fused-silica viewports
- A semi-transparent (50/50) Polka-dot mirror directs half of the collected light to the existing camera and half to an optical collection system
- A collimating lens collects the emitted light and couples it into bifurcated optical fibers for transmission to the electronics room (~100 m away)
- The optical signal is split into visible and near-infrared spectrometers
  - Spectral coverage ~200 nm to ~2100 nm
- The measured light spectrum is compared with blackbody radiation spectra to estimate the temperature of the carbon target
- Data analysis and calibration are in progress





peak ~1650 nm
Preliminary estimate: **1760 K**
(calibration in progress)

Detector Systems and DAQ



- Hamamatsu S13804 is a large-area(97 × 97 mm²), single-sided silicon strip (Si width: 320 μm)detector with 1024 channels, providing high spatial resolution and fast readout for charged-particle detector
- Common silicon strip detector technology proposed for HJET and pC (and Booster), enabling shared front-end electronics, DAQ, and calibration while improving detector performance
- 8 strips grouped together to form 128 channel
- Two perpendicular detector planes provide the main position/energy measurement.
- 4-channel third layer acts as a veto layer to suppress punch-through and prompt background events
- ASIC: HGCROC3
- Custom FPGA board for signal conditioning, data handling & processing, clocking and synchronization

Control Systems (EPICS + PLC)

Mockup version of a common platform chassis

e.g.:AB GuardLogix

- **EIC control room** talks to polarimetry equipment
- Leverage the common platform developed by EIC Instrumentation for standardized controls, timing, networking
- Migrating to a common controls architecture based on EPICS 7
- Total number of process variables (PV) for HJET ~500 and pC ~200
- Most of these PVs are slow ~ 0.1 s
- All safety-critical and mission-critical functions will be implemented in Allen-Bradley Safety PLCs, ensuring reliable operation and independent protection from higher-level control systems
  - No Personal protection

Organization

- Project WBS 6.03.01.11
- L3 Manager for the Polarimetry: Frank Rathmann
- Members:
  - Frank Rathmann
  - Oleg Eyser
  - Vera Shmakova
  - Richard Porqueddu (ME)
  - Kayla Hernandez (EE)
  - Evgeny Shulga
  - Prashanth Shanmuganathan

If this project interests you, please consider joining us. Whether you're looking for a two-month summer project, a longer research stay, or a postdoctoral opportunity, we'd be excited to work with you