



中国科学院  
CHINESE ACADEMY OF SCIENCES



中国科学院近代物理研究所  
Institute of Modern Physics, Chinese Academy of Sciences

# Proton Beam Polarimetry for Spin Physics at HIAF and EicC

**Boxing Gou (勾伯兴)**  
**on behalf of the HIAF spin team**

Qingdao • April 20-22, 2026

The 1st Annual Conference on Electron-Ion Collider Physics in China

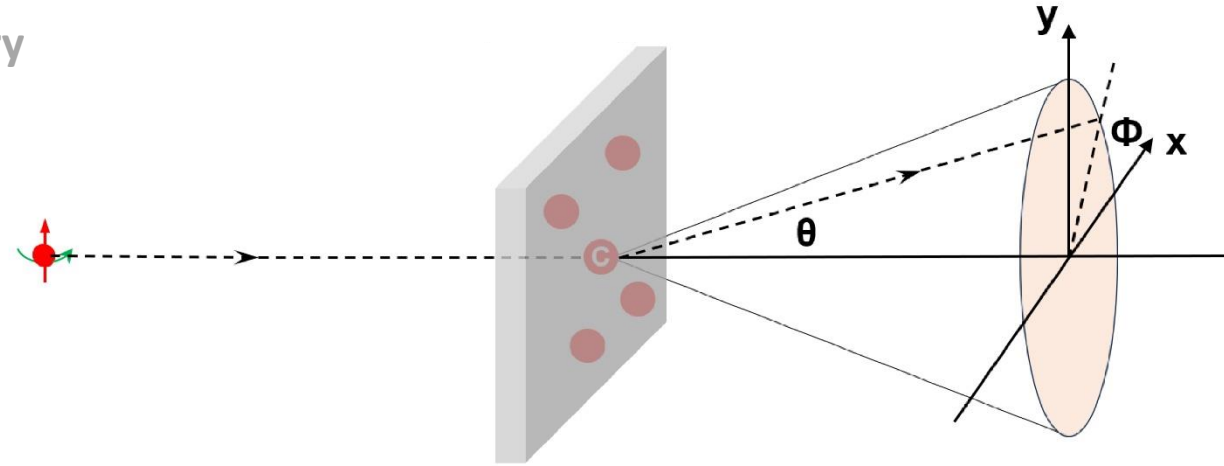
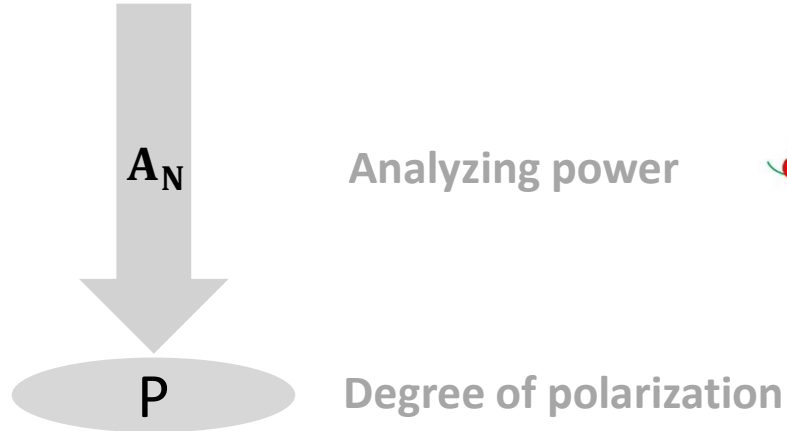
- Proton beam polarimeters for HIAF-EicC
  - Introduction
  - Absolute polarimeter
  - Relative polarimeter
  
- Efforts towards polarized beams/targets for HIAF
  - Polarized ion sources
  - Acceleration of polarized beams
  - Beam polarimetry and polarized targets

# General Principle of Polarimetry

## ➤ Reference reaction $\vec{p}X \rightarrow Y$

$$\frac{d^2\sigma}{d\theta d\phi} = \frac{1}{2\pi} \frac{d\sigma}{d\theta} \times [1 + A_N \cdot P \cdot \cos \phi]$$

Azimuthal asymmetry



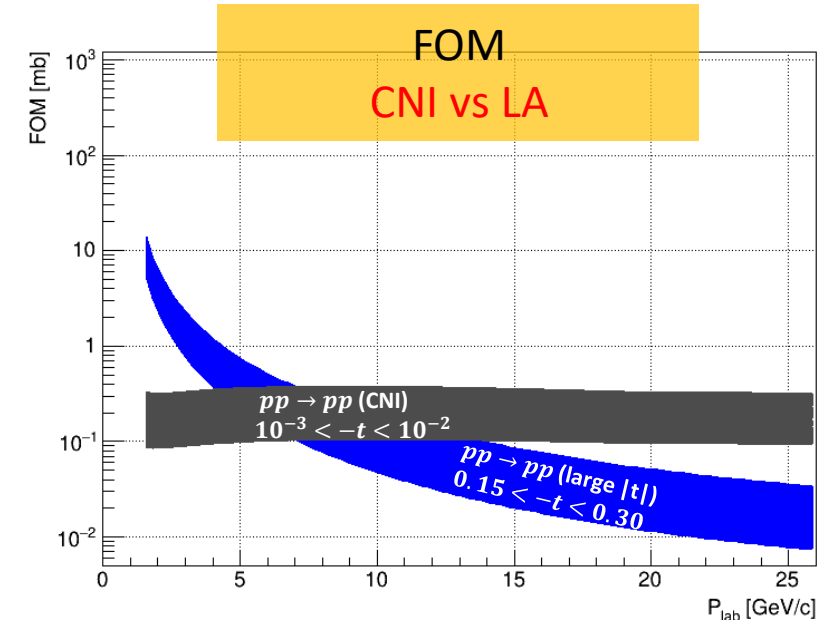
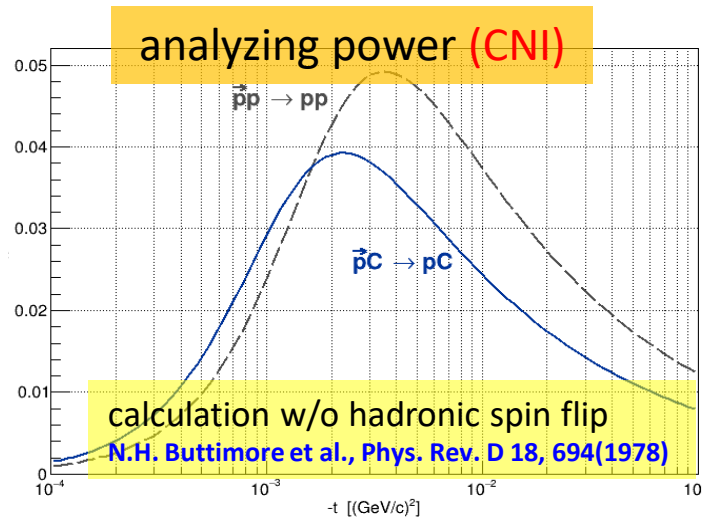
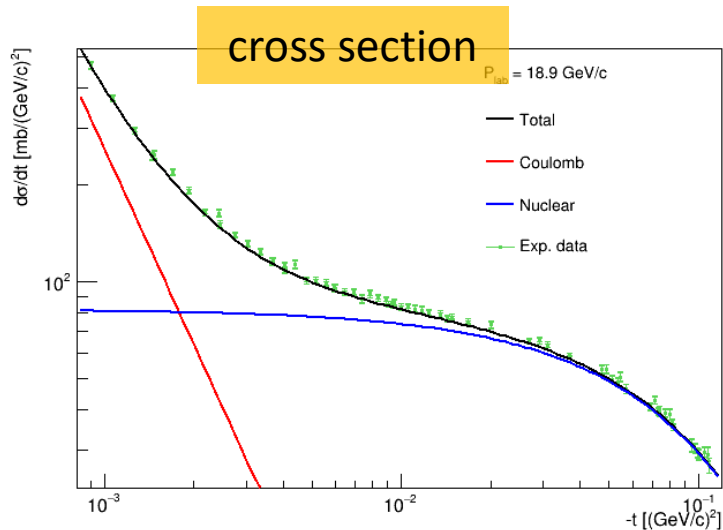
## ➤ Selection criteria

- $\sigma$  (cross section): **large**
- $A_N$  (analyzing power): **large** & **known**
  - ✓ measured
  - ✓ Calculable
- **Figure-of-merit:  $FOM = \sigma \cdot (A_N)^2$**

**larger FOM → higher statistical precision**

# Polarimetric reaction search

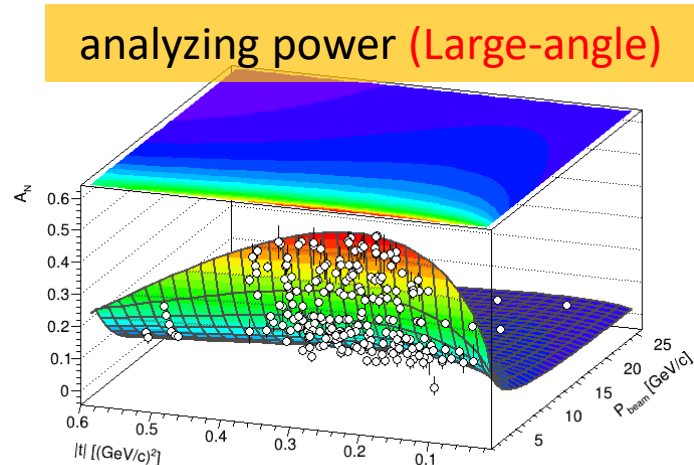
- **pp and pC elastic scatterings** have been widely used as polarimetric reactions
  - at almost all proton accelerators (PSI, TRIMUF, LAMPF, COSY, SATURNE, ZGS, KEK-PS, AGS, RHIC ...)
  - in a broad energy range from  $\sim 20$  MeV to 250 GeV



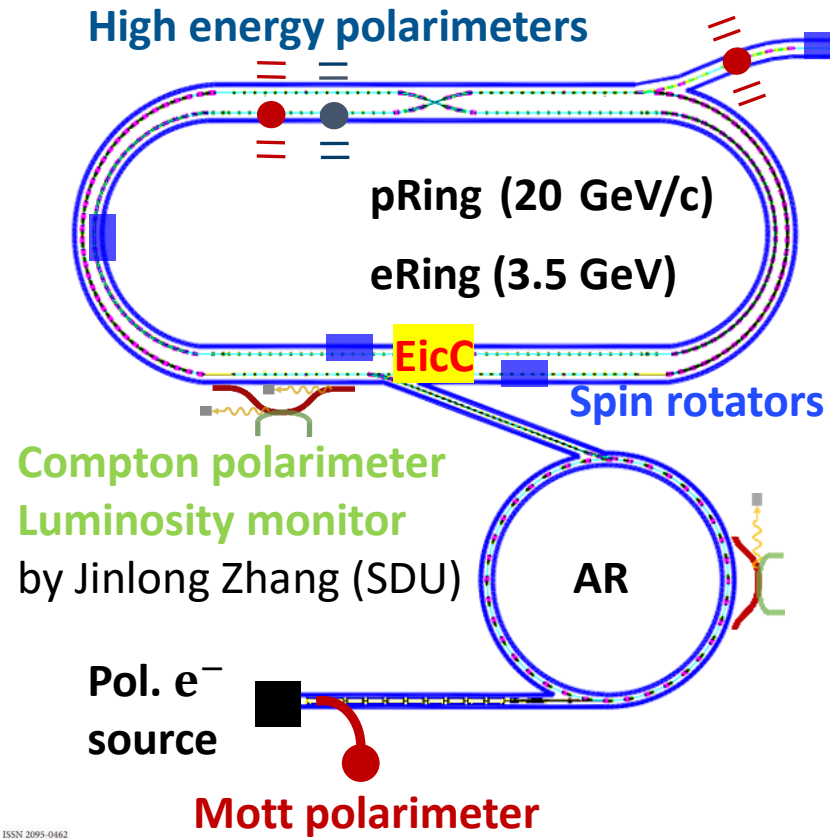
M.M. Block, R.N. Cahn, Rev. Mod. Phys. 57 (1985) 2

Xsc in terms of 3 parameters

- $\sigma_{tot}$ : Xsc of  $pp \rightarrow \text{anything}$
- $\rho$ :  $\text{Re}f_n(0)/\text{Im}f_n(0)$
- B: nuclear slope

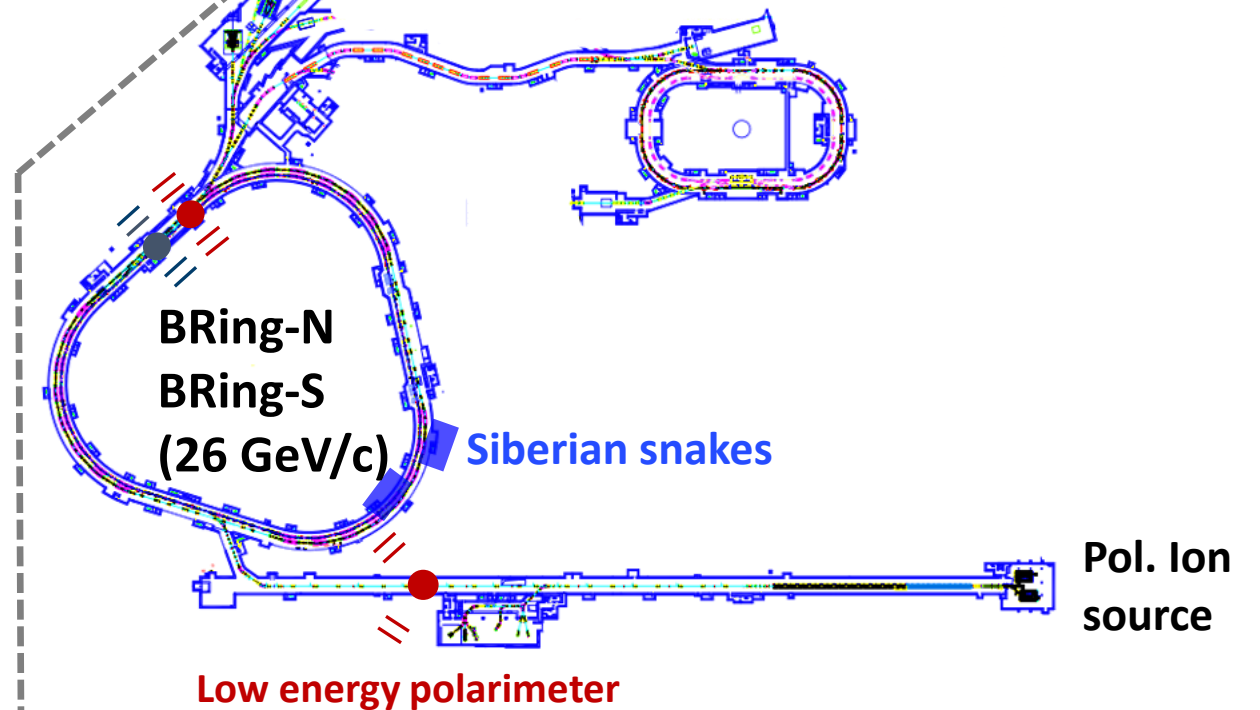


- Large-angle scattering at low energies
- CNI scattering at higher energies
  - sizable FOM
  - weak energy dependency



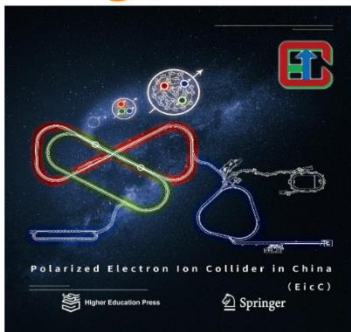
## ➤ Spin Physics at HIAF

The 2<sup>nd</sup> Workshop on Polarized Beam and Target - Physics and Applications (PBT2026)



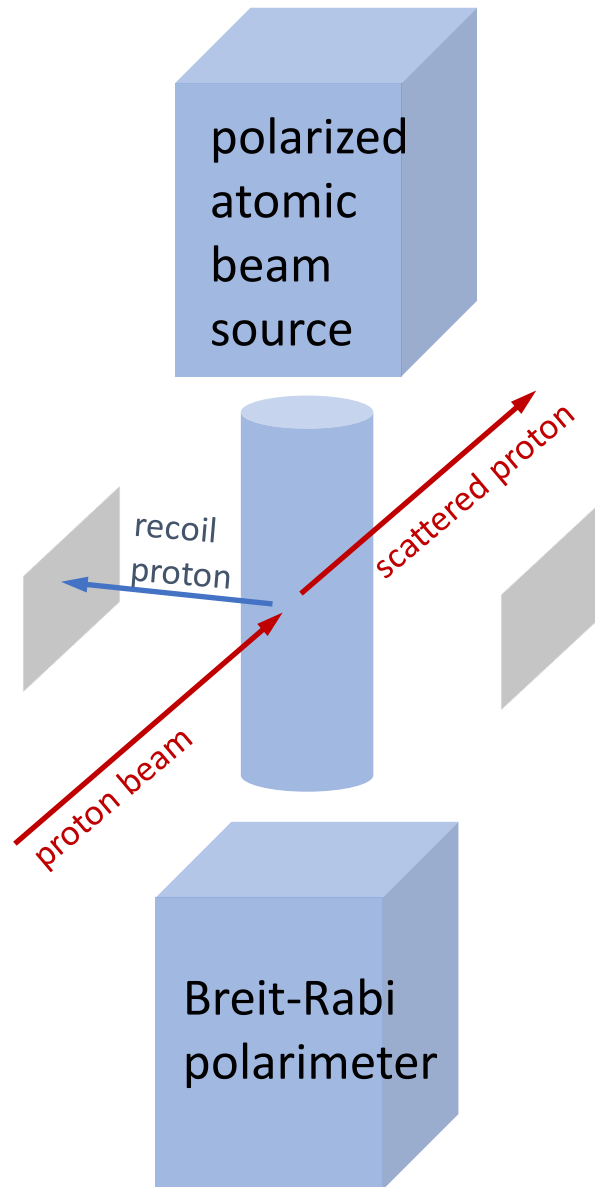
Frontiers of  
Physics

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Volume 16 Number 6  
December 2021



# Proton absolute polarimeter

# Pol. H-Jet polarimeter



$A_N$  can be self-calibrated with a pol. H target

	①	②	③	④
Beam	↑	↓	↑	↓
Target	↑	↑	↓	↓

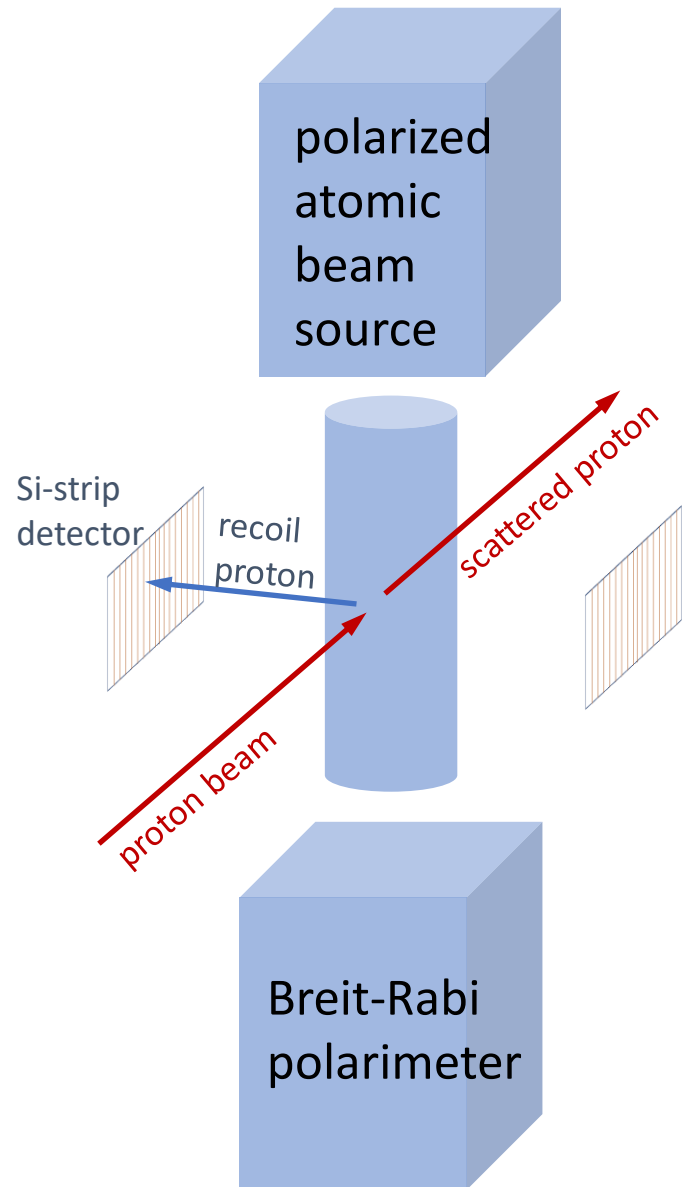
- Identical beam & target particles



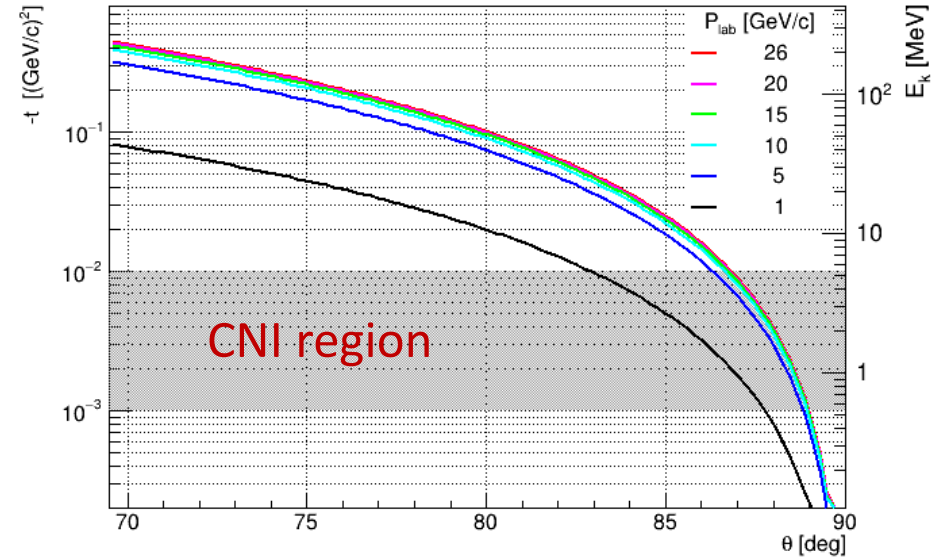
Same  $A_N$  for  $\begin{cases} \vec{p}p \rightarrow pp & \text{①} + \text{③} \text{ and } \text{②} + \text{④} \\ p\vec{p} \rightarrow pp & \text{①} + \text{②} \text{ and } \text{③} + \text{④} \end{cases}$

- $P_{\text{beam}} = \frac{\varepsilon_{\text{beam}}}{A_N} = -\frac{\varepsilon_{\text{beam}}}{\varepsilon_{\text{target}}} P_{\text{target}}$
- $P_{\text{target}}$  measured with Breit-Rabi polarimeter
- Left-right asymmetry:  $\varepsilon = \frac{N_L - N_R}{N_L + N_R}$  measured with **symmetrically placed detectors**

# Pol. H-Jet polarimeter in CNI Region

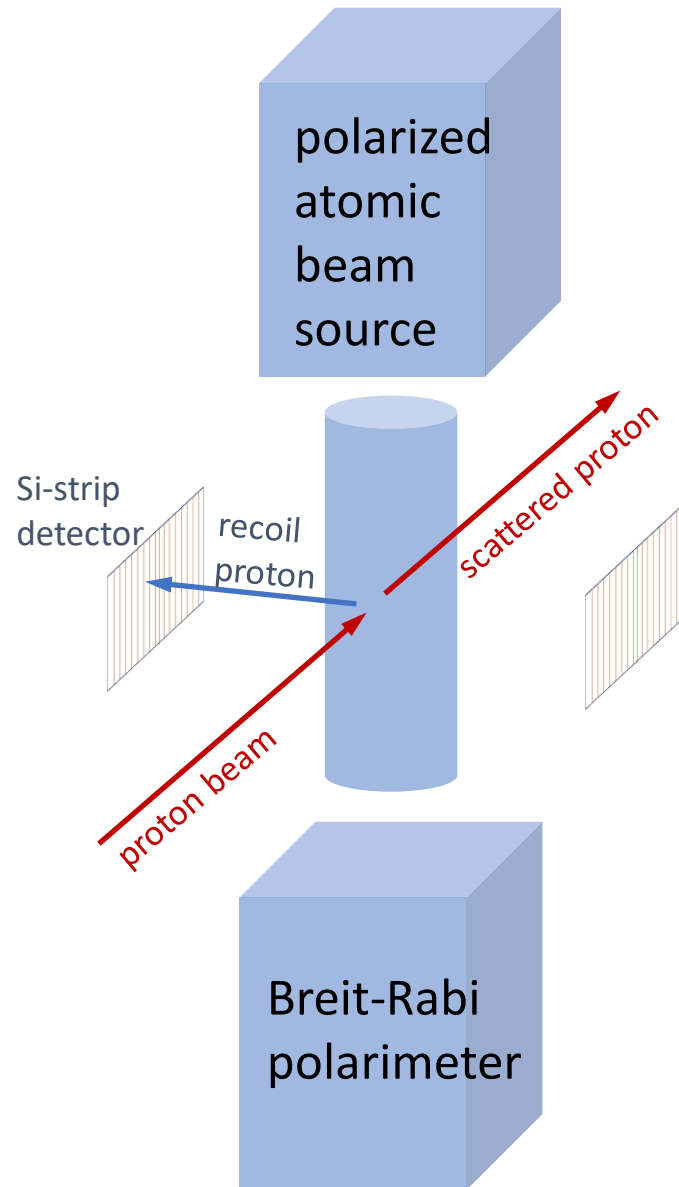


The polarimeter is energy independent in the CNI region



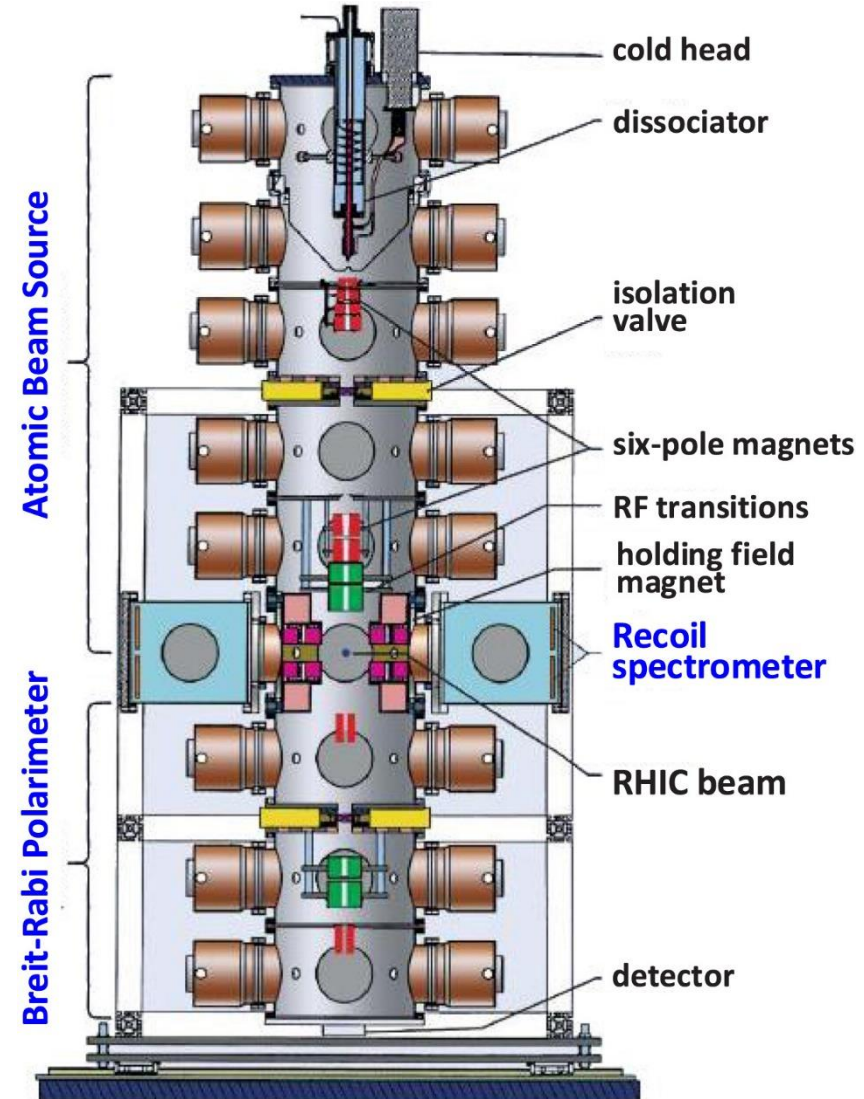
- CNI region:  $-t : 10^{-3} - 10^{-2} \text{ (GeV/c)}^2$
- Only detect recoil protons ( $E_K$ ): 0.6 – 5.3 MeV
- Two si-strip detectors covering  $\theta \lesssim 90^\circ$
- No need to change the hardware with energy

# Pol. H-Jet polarimeter in CNI Region

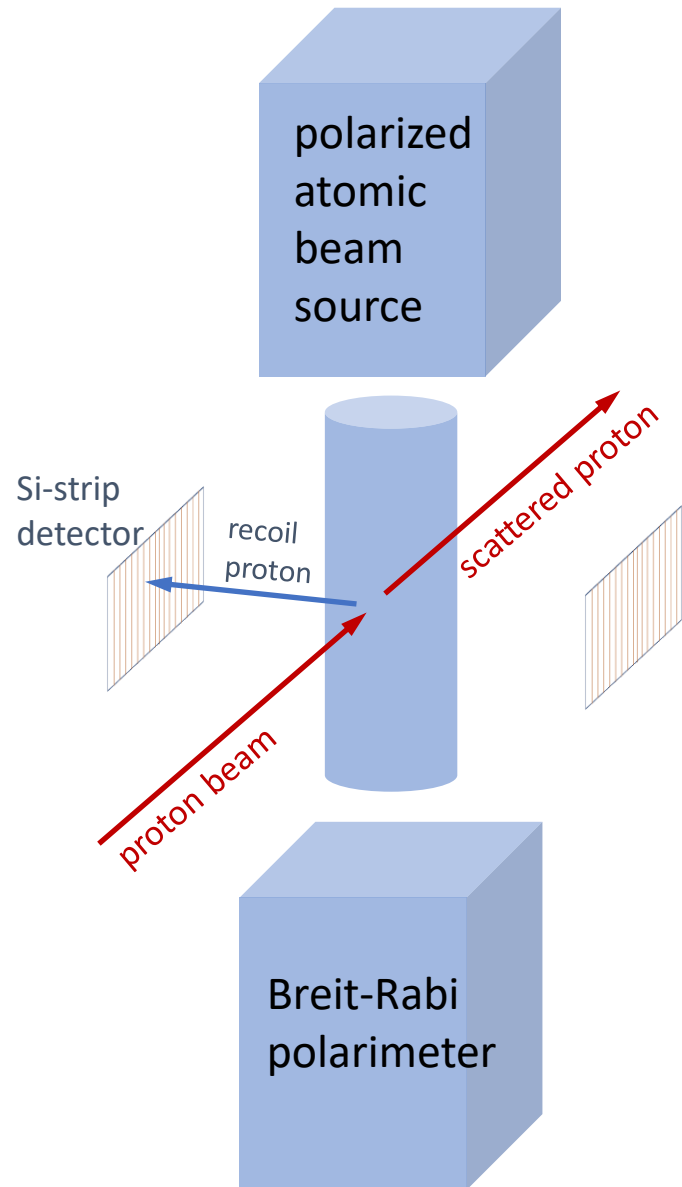


The H-Jet polarimeter at RHIC

Precision: 5% in 1 hour

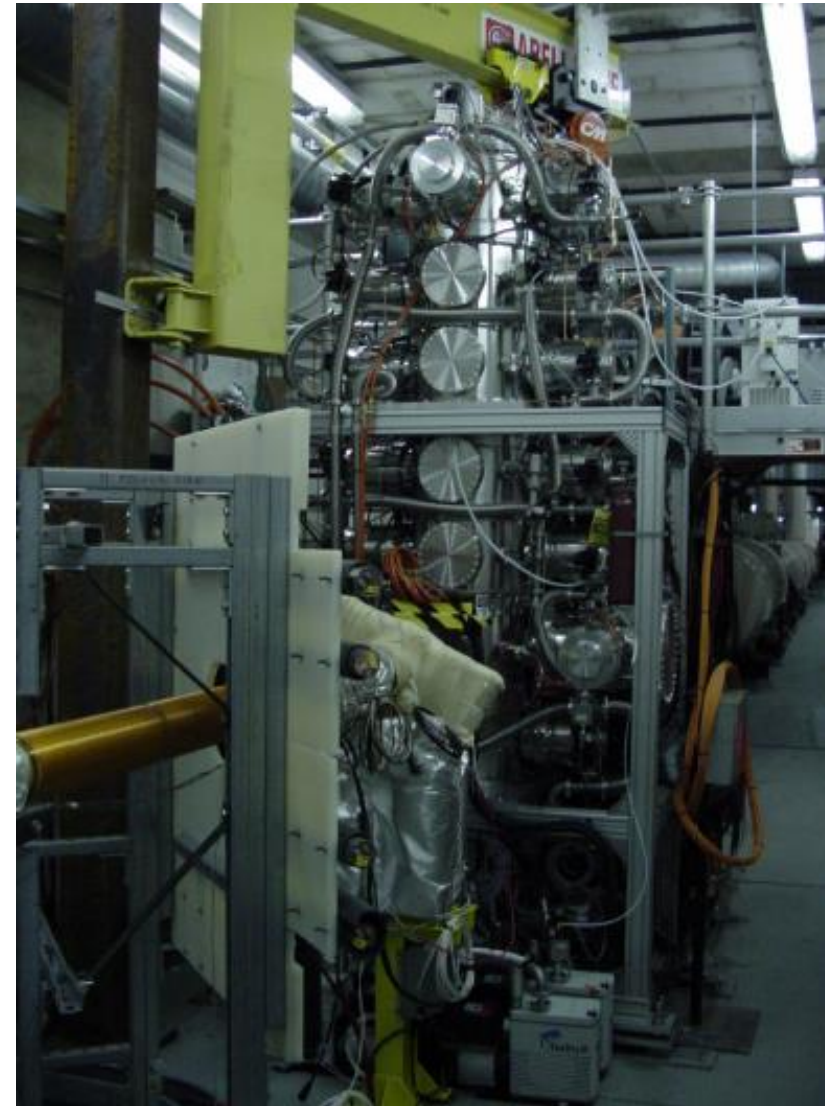


# Pol. H-Jet polarimeter in CNI region at RHIC



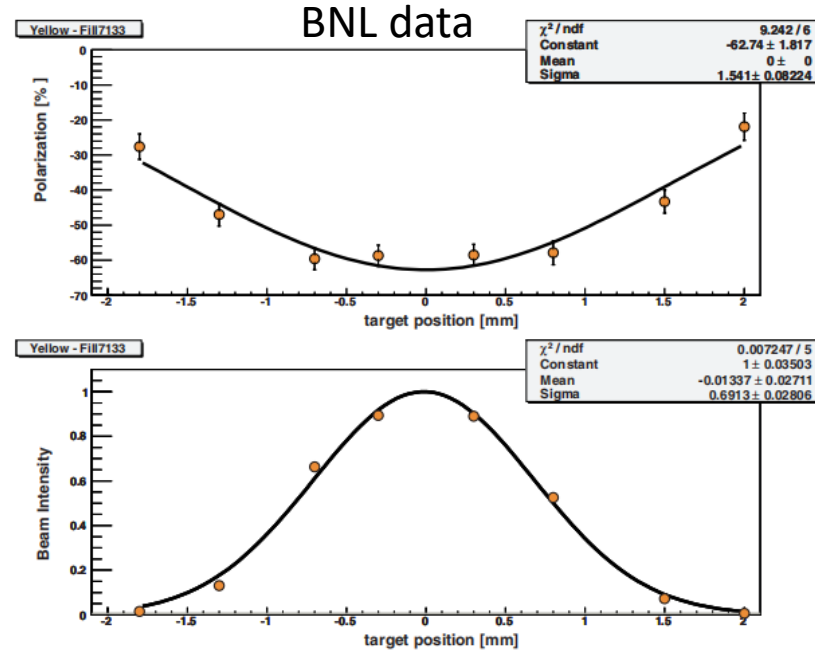
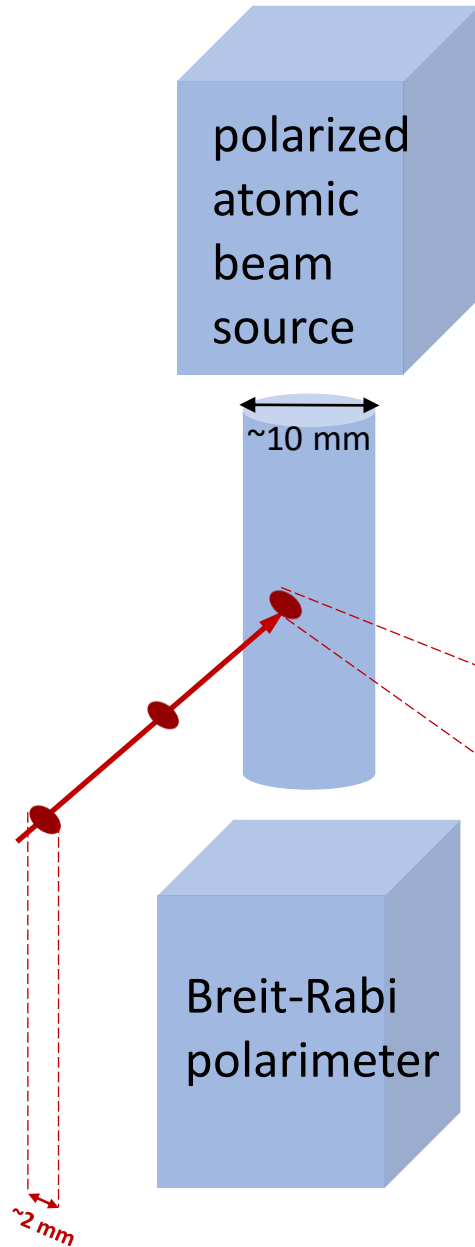
The H-Jet polarimeter at RHIC

Precision: 5% in 1 hour

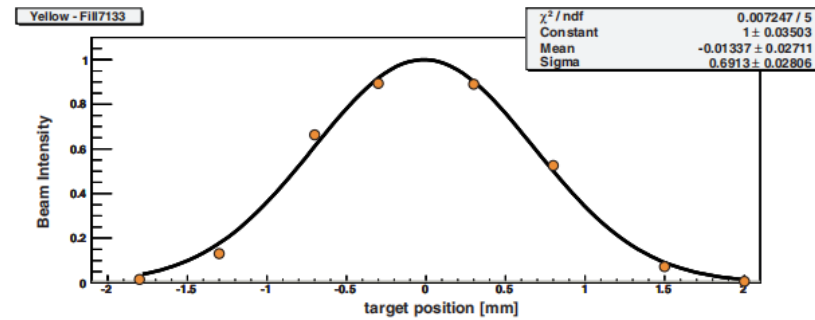
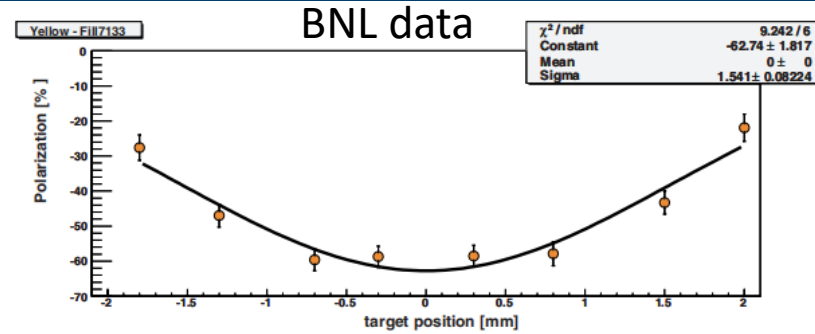
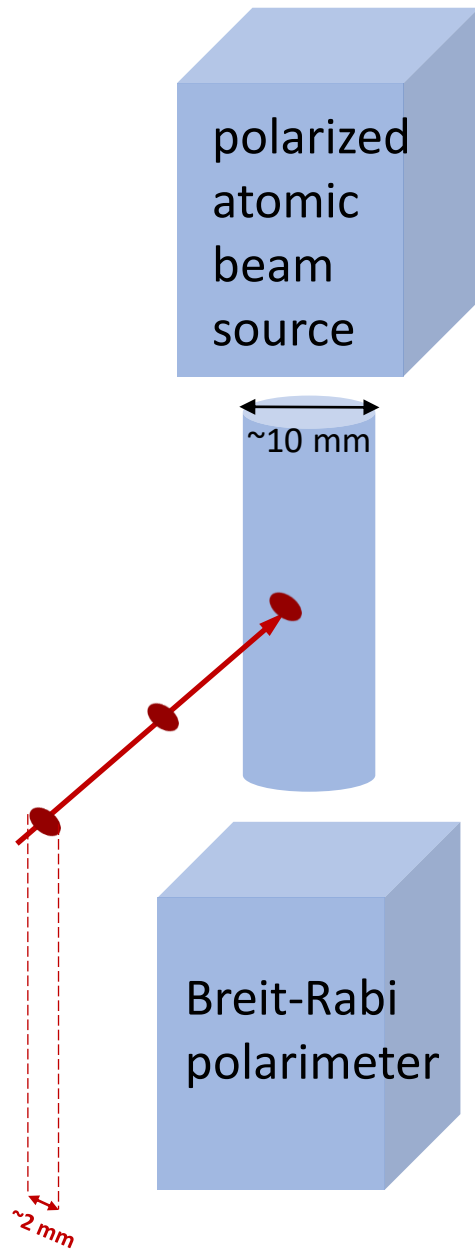


# Proton fast (relative) polarimeter

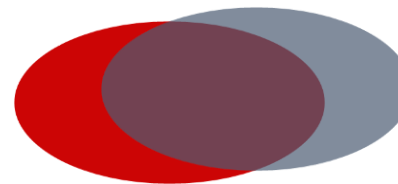
# Polarization profile



# Polarization profile

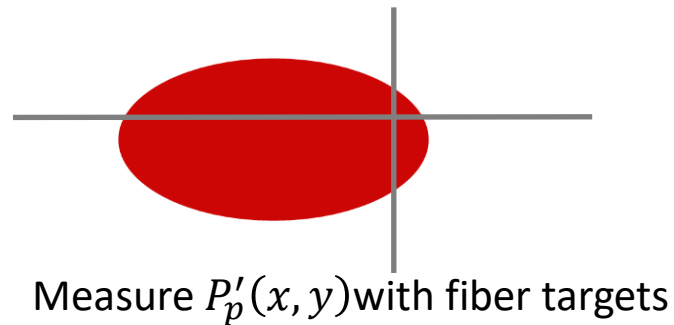
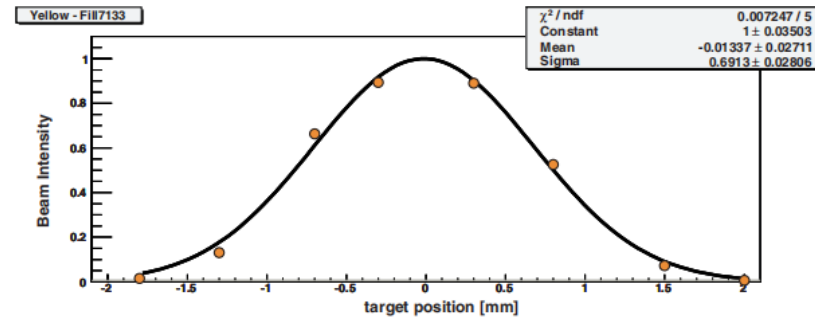
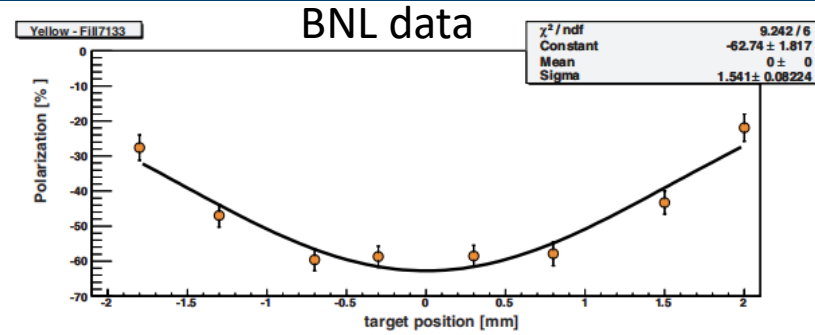
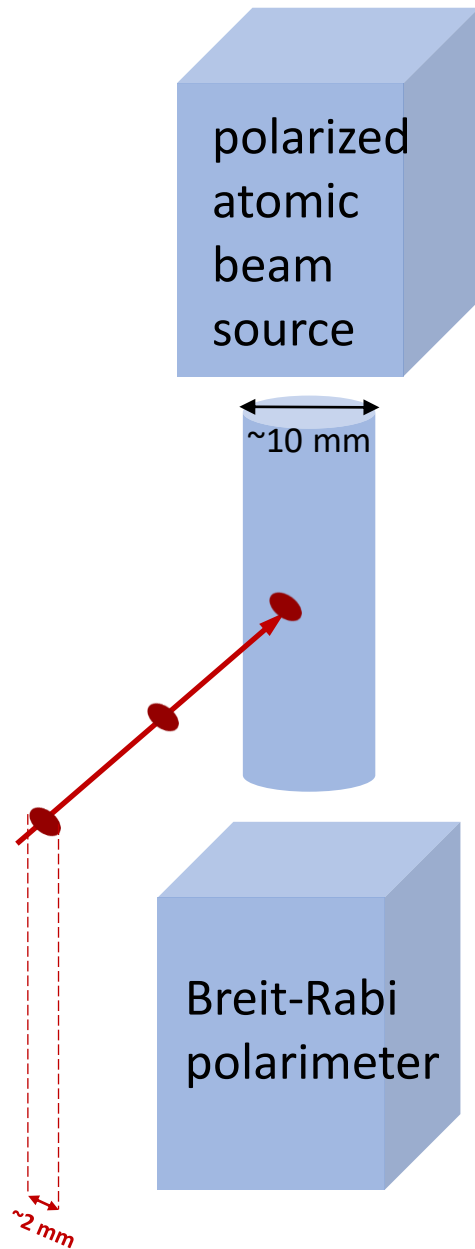


Beam-beam overlap at collider



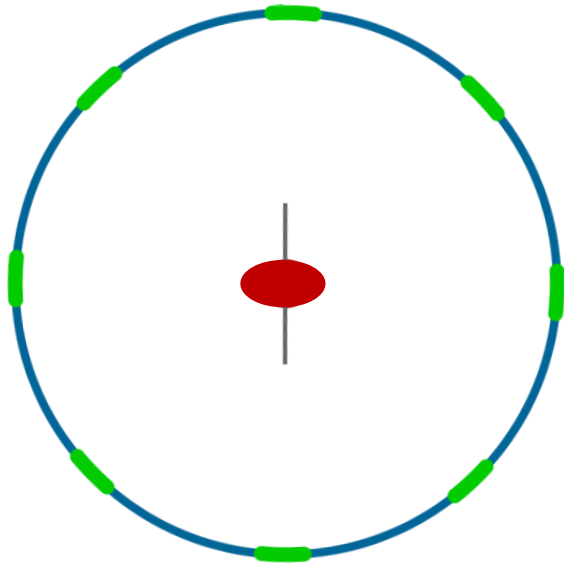
$$\langle P_p \rangle = P_p(x, y) \otimes I_p(x, y) \otimes I_e(x, y)$$

# Polarization profile



# p-C polarimeter

## p-Carbon CNI Polarimetry in the AGS and RHIC

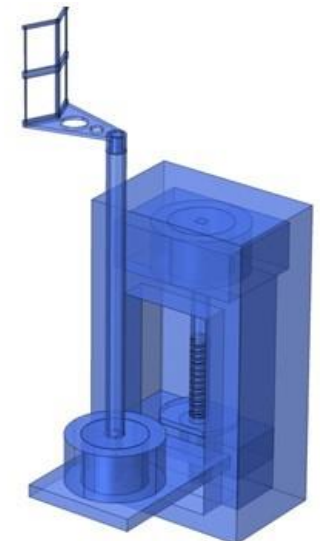
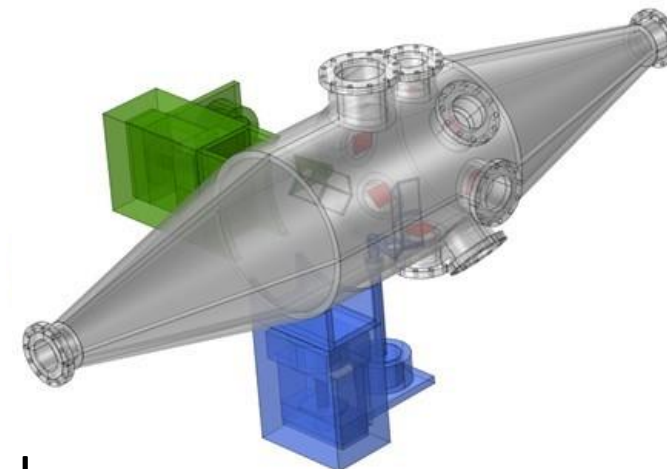
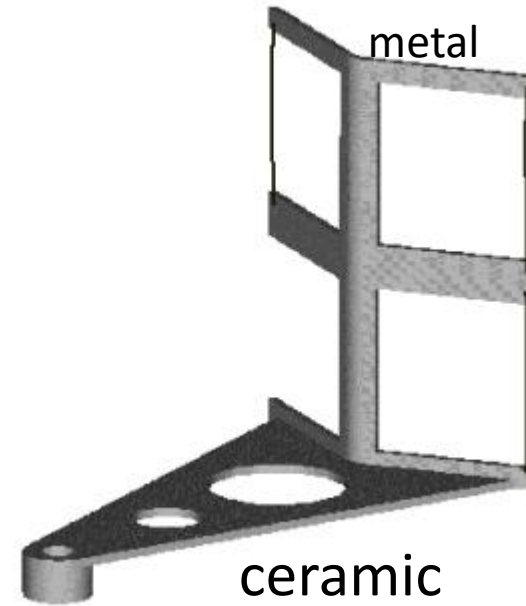


### Target box

- Radius: 16 cm

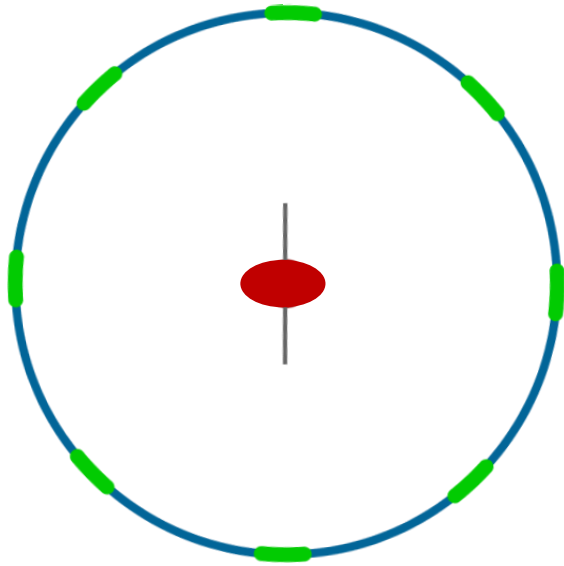
### Target frame

- ceramic v plate
- metal holders
- 4 holders (3 carbon + 1 empty)
- 1 left empty for background check



# p-C polarimeter

## p-Carbon CNI Polarimetry in the AGS and RHIC

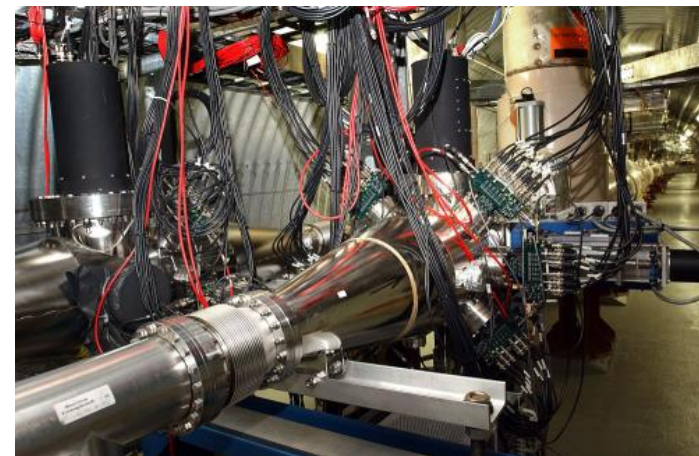
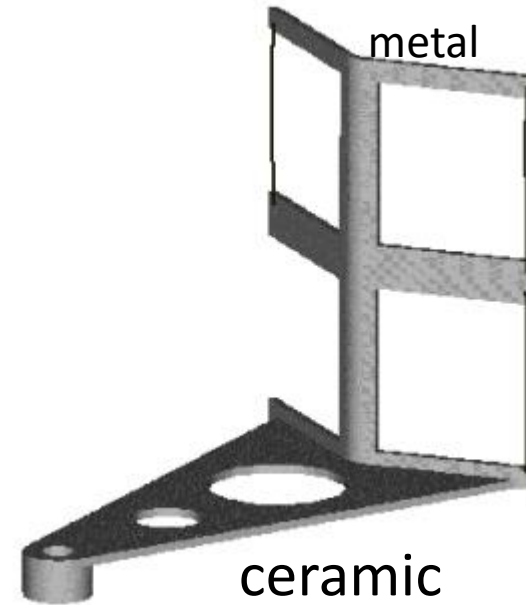


### Target box

- Radius: 16 cm

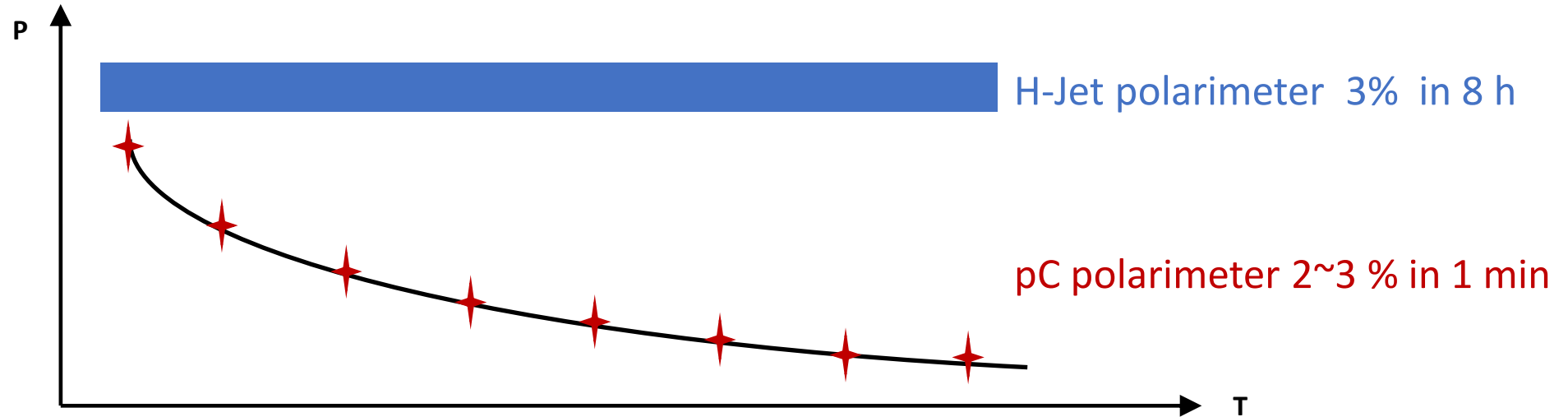
### Target frame

- ceramic v plate
- metal holders
- 4 holders (3 carbon + 1 empty)
- 1 left empty for background check



# Polarimetry at RHIC

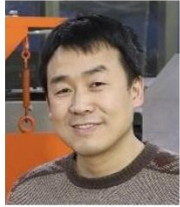
The RHIC experience will be adopted for EicC



	H-Jet polarimeter	pC polarimeter
Target	Polarized H gas jet	Carbon fiber
Target thickness	$\sim 10^{12} \text{ atoms/cm}^2$	$\sim 10^{16} \text{ atoms/cm}^2$
Event rate	$\sim 60 \text{ Hz}$	$\sim 2 \text{ MHz}$
Operation	continuously	$\sim 1 \text{ min/h}$
Analyzing power	self-calibrated	unknown
Role	Absolute, slow Noninvasive	Fast, relative Polarization profile Feedback for machine tuning

# Efforts towards polarized beams/targets at HIAF

- A team for **polarized ion source**, **polarized beam acceleration** and **polarized target**
- International collaborations



team leader



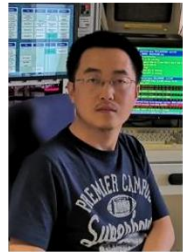
pol.  $^3\text{He}$



engineering  
vacuum



pol. H/D source



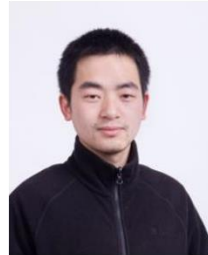
polarimeter  
pol. H/D target



pol. ion source  
pol. H/D target



magnet



beam diagnostic



polarimeter  
pol. H/D target



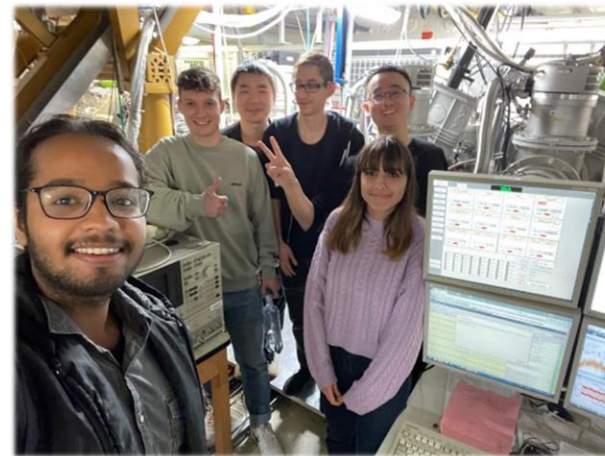
pol. beam acc.  
spin manipulation



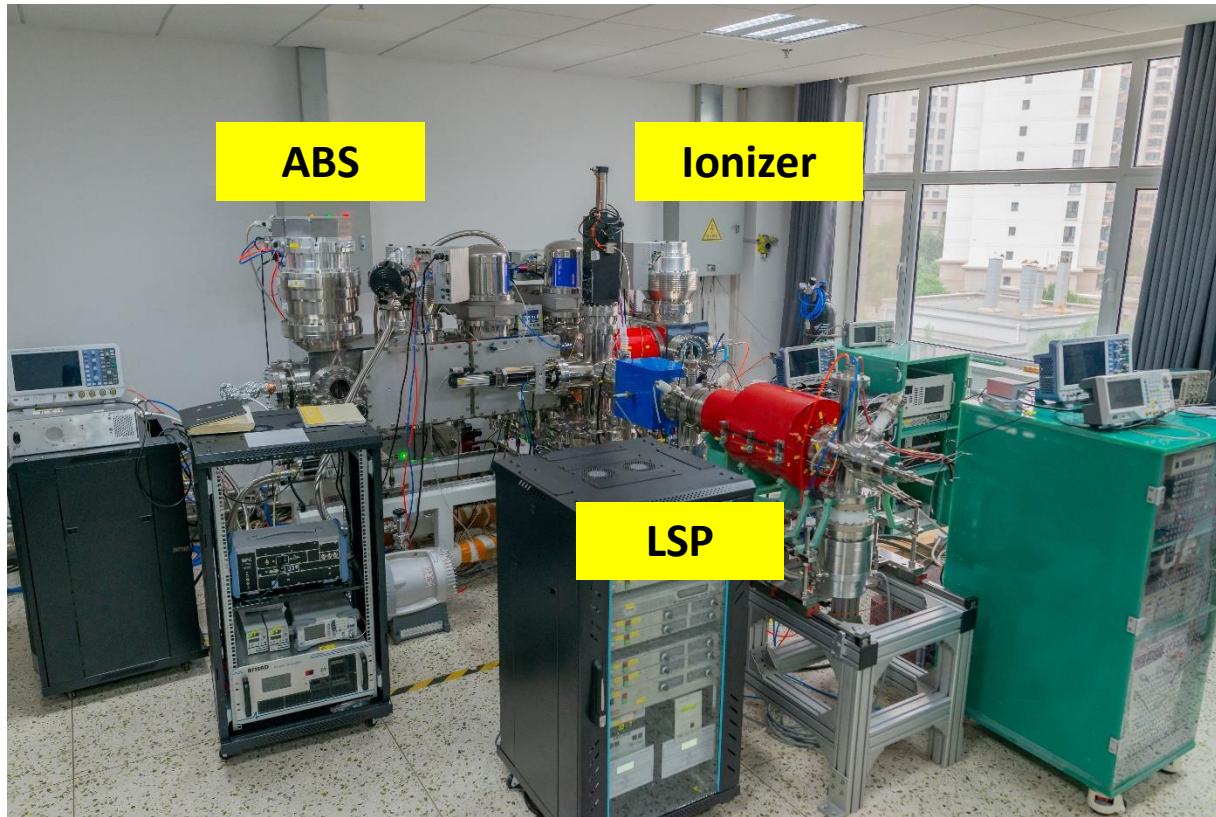
ionizer  
Lamb-Shift  
polarimeter



control system  
pol. atomic beam



# Efforts towards polarized beams/targets at HIAF



A polarized  $H^+/D^+$  source already built at IMP

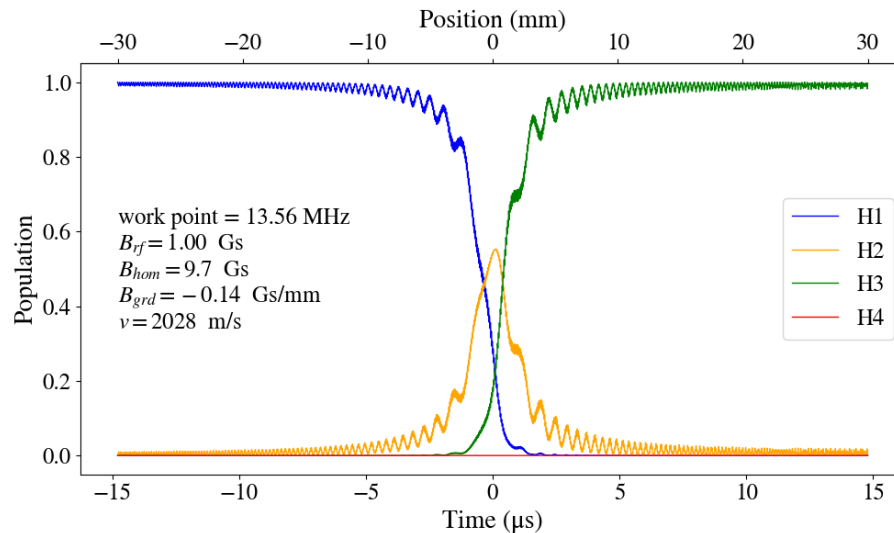
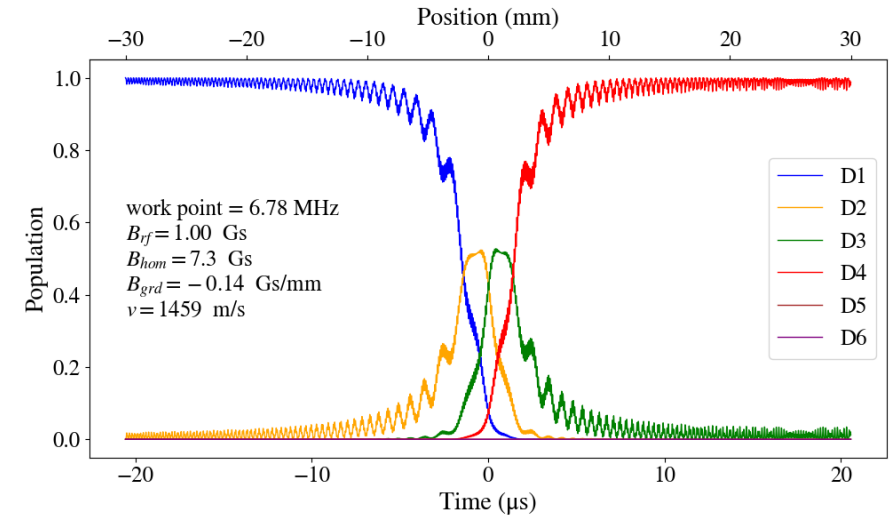
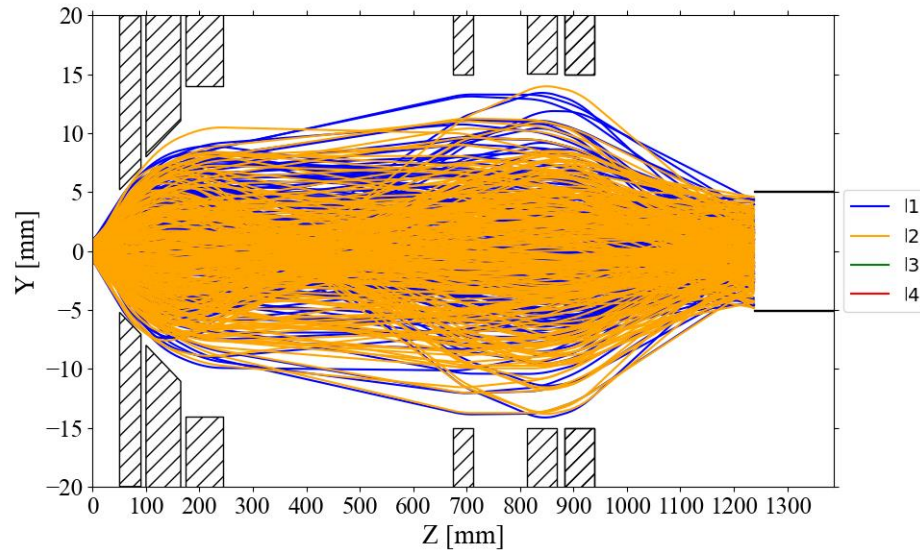
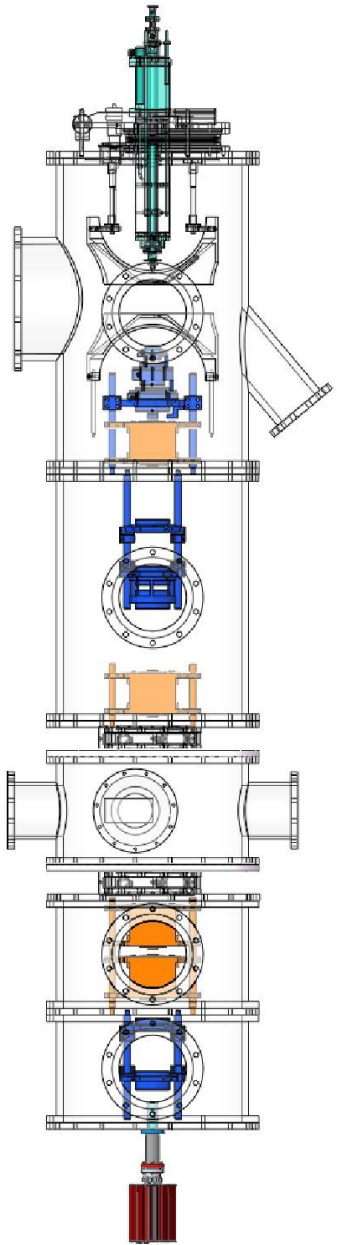
- Intensity:  $> 1$  mA
- Polarization:  $> 80\%$
- Repetition frequency: 2-5 Hz
- Pulse width:  $> 100$  us

see [talk by Yaojie Zhai at PBT2026](#)

**Polarized beam acceleration at HIAF investigated by Minxiang Li et al.**

- constant field solenoid Siberian snake: [NIMA 1031, 166405 \(2022\)](#)
- tensor-polarized deuteron beam: [Phys. Rev. Accel. Beams 28, 094002](#)

# PIT design in progress



## PIT design in progress

- ✓ Preliminary mechanical design
- ✓ Atomic tracking in sextuple magnet
- ✓ Zeeman transition in RF units

💰 Financial support received from CAS 😊

# Summary

- Tools for spin physics being developed
  - Polarized ion source (**built**)
  - Polarized beam acceleration (**investigated**)
  - Beam polarimetry and pol. gas target (**just funded**)
- Spin physics at HIAF -- a necessary step toward EicC
  - Instrument (Siberian Snakes ...)
  - Expertise and team

***Thank you!***