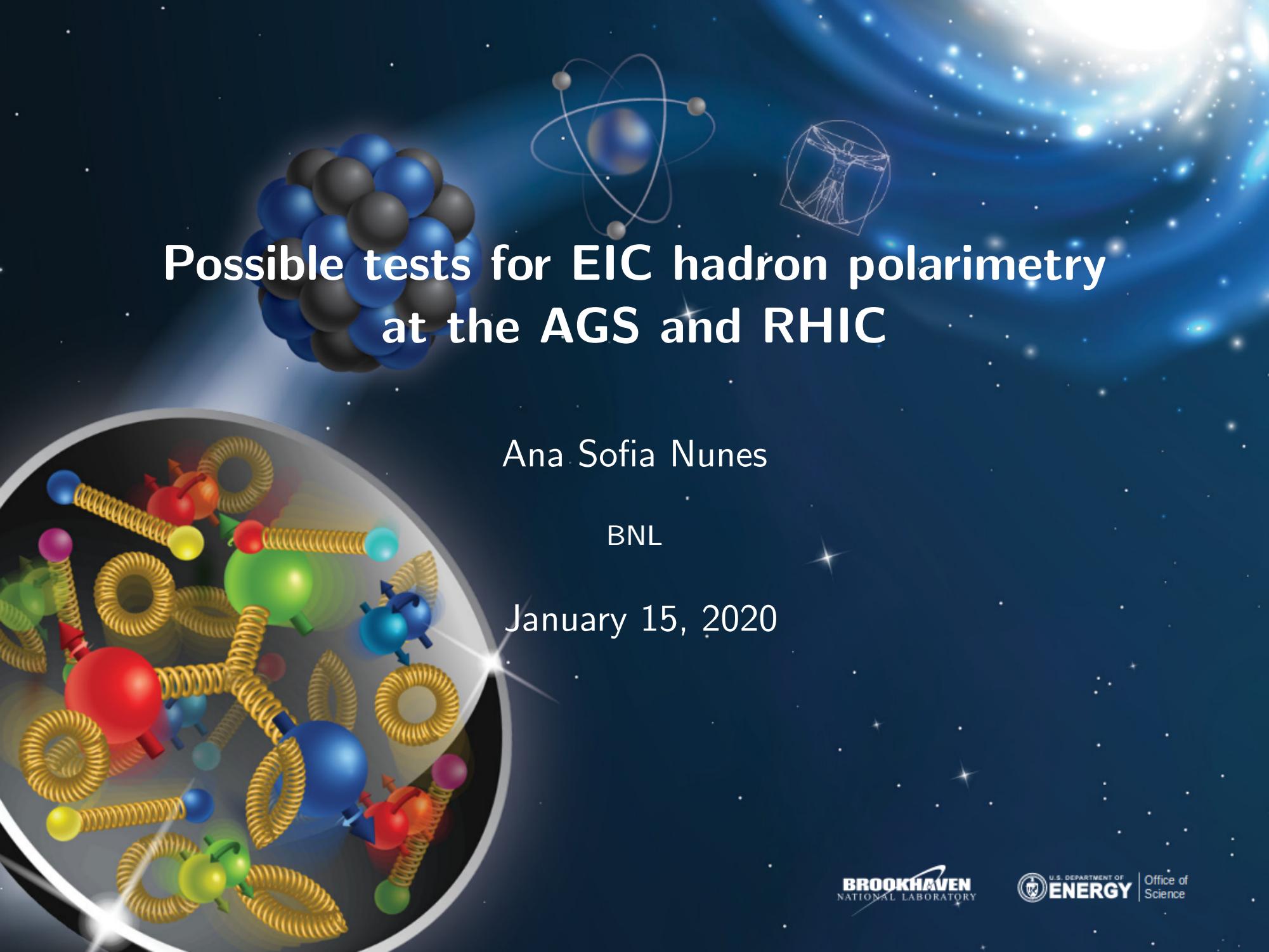

Possible tests for EIC hadron polarimetry at the AGS and RHIC

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January 15, 2020

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U.S. DEPARTMENT OF ENERGY | Office of Science

Introduction

- EIC@BNL announced by the DOE on 9/Jan/2020!!!
- "To make way for the new collider, the RHIC will shut down for good in 2024"
  [Paul Dabbar, DOE's undersecretary for science, https://www.sciencemag.org/news/2020/01/department-energy-picks-new-york-over-virginia-site-new-particle-collider]
- A test on the RHIC polarimeters, using a **second layer of silicon strips**, planned for 2021, to understand the feasibility of vetoing prompts
- Tests of *dd* **at the RHIC H-Jet** and of **polarized** *h* **on the AGS carbon polarimeters** can be done the next years to measure rates, analysing power A_N values and to evaluate the viability of *d* polarimetry at the EIC
- Other solid (e.g. gold) and gaseous (e.g. xenon) **target materials** should be considered
- Usage of other technologies, including better **timing resolution** and lower **electronics background**, should be considered

Possible tests for hadron polarimetry at the AGS and RHIC

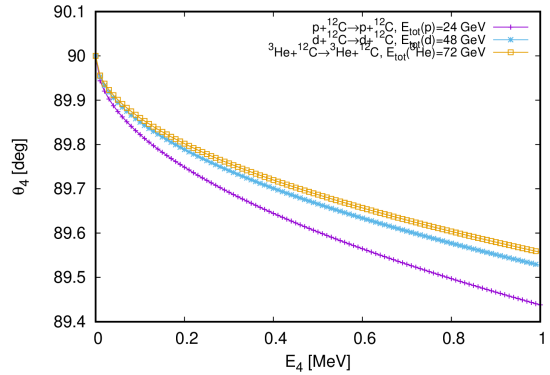
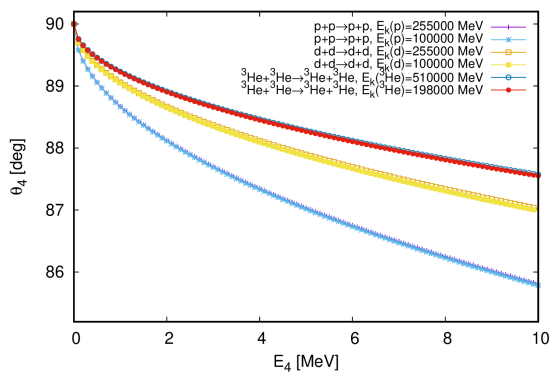
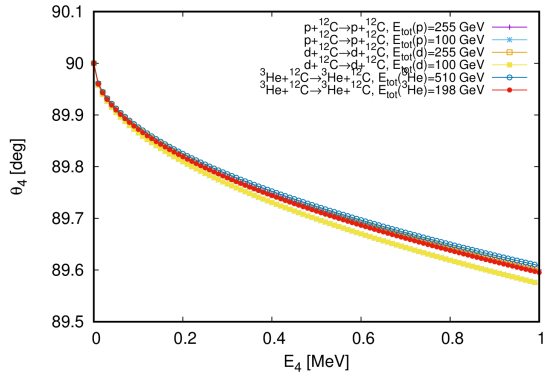
Tests at BNL for hadron polarimetry of EIC

Beam	Target	Ring/ Polarimeter	Energy/ nucleon	Comments
He-3	C	AGS/C	24 GeV	Was already done, useful to know rates (including background)
Polarized He-3	C	AGS/C	24 GeV	Useful to get the scaling factor of the A_N
He-3	He-3	RHIC/X	166 GeV	Useful to know rates (including background)
He-3	Polarized He-3	RHIC/X	166 GeV	Useful to get the scaling factor of the A_N
Polarized He-3	Polarized He-3	RHIC/X	166 GeV	Useful to get the A_N
He-3	C	RHIC/C	166 GeV	Useful to know rates (including background)
D	C	AGS/C	24 GeV	Useful to know rates (including background)
D	D	RHIC/Jet	100 GeV	Useful to know rates (including background)
D	Polarized D	RHIC/Jet	100 GeV	Useful to get the scaling factor of the A_N
D	C	RHIC/C	100 GeV	Useful to know rates (including background)

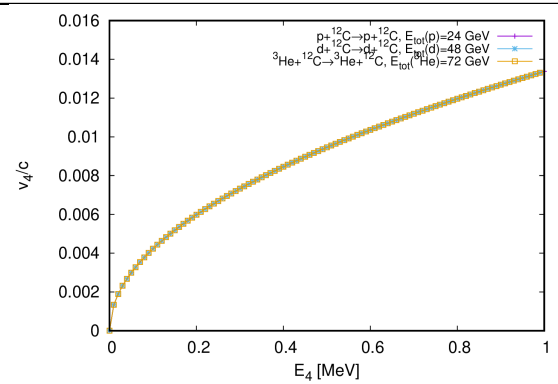
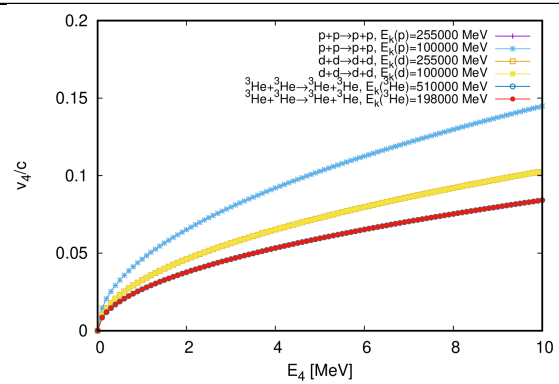
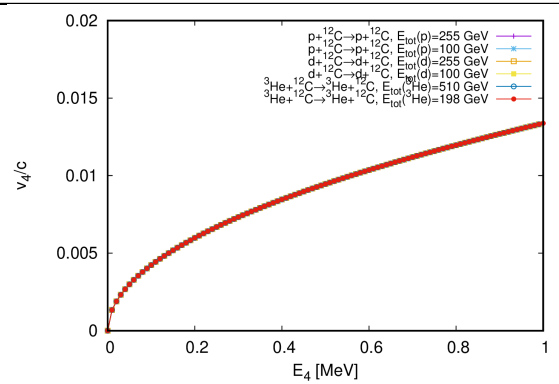
Maximum energies provide the smallest analysing powers, hence are better suited for tests.
X – dedicated setup attached to bottle with gas

Kinematics

θ_4 (angle of recoil particle with respect to beam direction) vs its energy

pC AGS	H-Jet	pC RHIC
		

v_4/c (relative velocity of recoil particle) vs its energy

pC AGS	H-Jet	pC RHIC
		

[From: https://skisickness.com/2010/04/relativistic-kinematics-calculator/]

Polarized Light Ion Beams

- **Similar kinematics** of light ions and pp
- **Breakup of light ions** has to be taken into account
- Simplest model:

$$A_N = \frac{\sqrt{x}}{x^2+3} \cdot A_N^{\text{opt}} = \frac{\sqrt{x}}{x^2+3} \cdot \frac{k}{4m_p}\sqrt{-3t_e}$$

with $x = \frac{t}{t_e}$, $t_e = -\frac{\sqrt{3}ZZ'}{\sigma_{\text{tot}}}$

$k_p = 1.793,\ k_{^3He} = -1.398,\ k_D = -0.143$

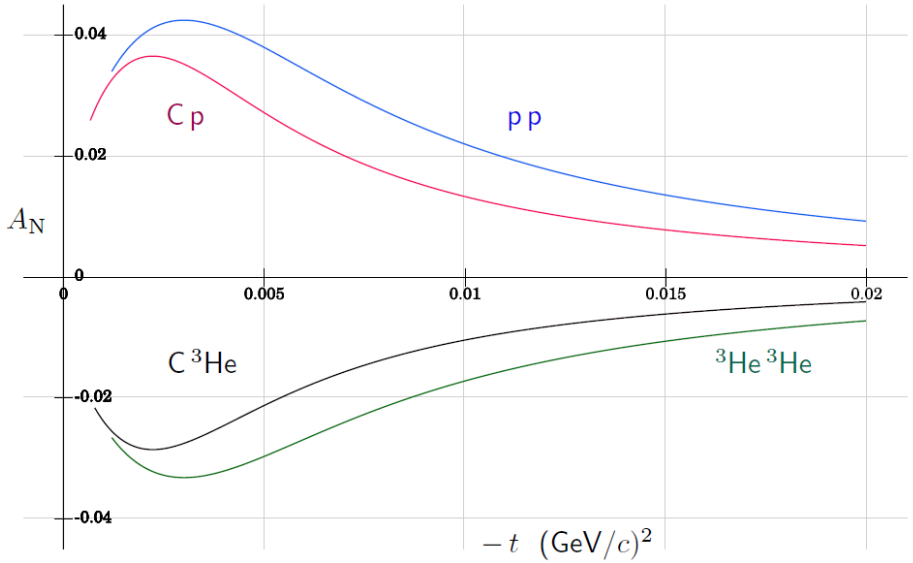


Figure 1: Analyzing power A_N versus invariant momentum transfer (-t) in (GeV/c)^2 for (1) p p and p h scattering, (2) C p scattering, (3) C h scattering, (4) h h and p h scattering

[N. Buttimore]

- Commonly used in heavy ions field:

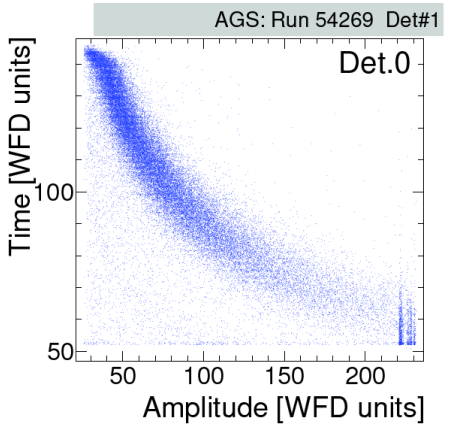
$$\sigma_{tot,A_1+A_2} = \pi \cdot (R_1 + R_2)^2 = \pi \cdot \left[1.22 \cdot A_1^{1/3} + 1.22 \cdot A_2^{1/3}\right]^2 \text{ with } R_p = 0.5 \text{ fm}$$

- Polarimetry using elastic scattering in the CNI region in D-D or D-C **very difficult**
- A **test with a jet of polarized deuterons with known polarization** can be done in the next few years **at the H-Jet**

Helium-3 Beams

- Gas of **polarized helium-3** nuclei (helion) was used as **fixed target** at HERMES [Nucl. Instr. & Methods A367 1995 9699], JLab and Jülich
- A helium-3 beam was **tested sucessfully at the AGS C polarimeters**
- "Event rate gain for helion due to elastic cross section is estimated to be $A^{2/3} = 3^{2/3} = 2.08$. The actual observed gain is about 2."

Helion-carbon scattering at C polarimeters of the AGS:



[H. Huang *et. al.*, Proceedings of IPAC2014, Dresden, Germany, doi:10.18429/JACoW-IPAC2014-WEPRO071]

- "The beam intensity during our June 2012 test was fairly low, about 3×10^9. The rate would depend on what target size we use. At the time, when I used the data taking gate width as 700 ms, the event rate was 20k during that 700 ms. In future EIC operation, we expect beam intensity to be $(1-2) \times 10^{11}$." (Haixin Huang, email 14/Jan/2020)
- Source of polarized ^{3}He is available; a **test with polarized ^{3}He in C polarimeters of the AGS** can be envisioned

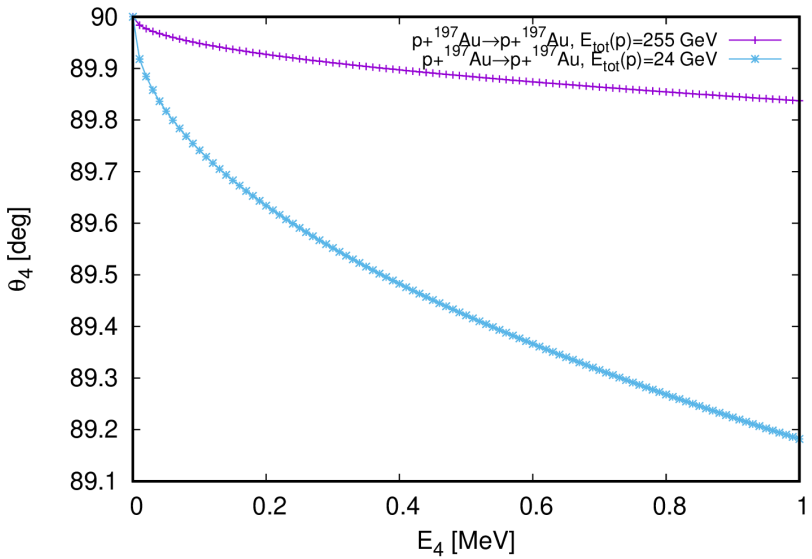
Gold as a substitute for carbon in pC polarimeters?

- Leeds University has found a way of making a gold sheet just two atoms thick so that there should be few multiple scattering events were the sheet (or sheets) whisked by to avoid depletion. The recoil angle may then act as a constraint. (Nigel Buttimore) ["Scientists create the world's thinnest gold",]

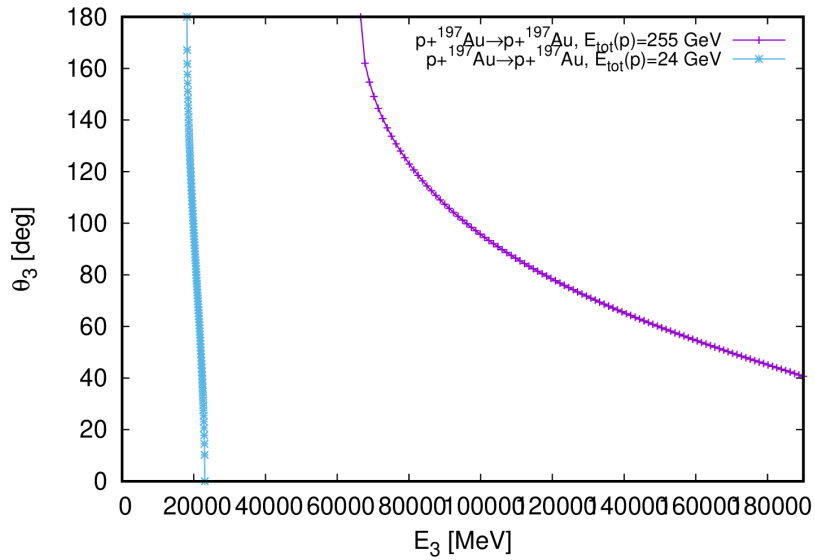
- "I had alerted Andrei Poblaguev to the possibility of a gold polarimeter. As you may know, he pointed out that, most likely, inelastic $pAu \rightarrow pAu^*$ scattering rather than elastic $pAu \rightarrow pAu$ had been measured. For a gold target polarimeter one would have to theoretically understand the difference between detecting recoil protons and recoil Gold. Also, the desirable recoil Gold energy of 8 keV may be too small by comparison with the HJET electronic noise of about 20 keV. I suppose that electrostatic acceleration of the recoiling Au (to increase energy and lower time-of-flight) is not possible."

Kinematics of *p*Au final state particles for AGS and RHIC energies

Au



p

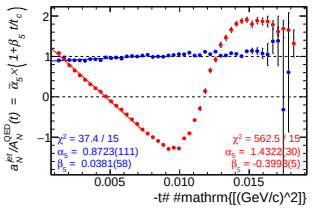


[From: https://skisickness.com/2010/04/relativistic-kinematics-calculator/]

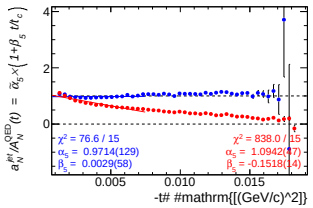
Tests (parasitic measurements) at the H-Jet since 2015

[Andrei Poblaguev, mail 7/Jan/2020]

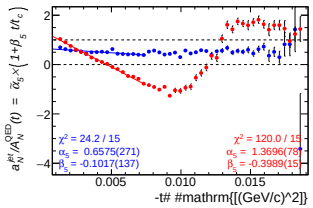
pAu_100



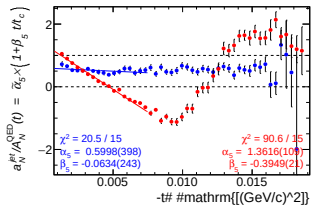
pAl_100



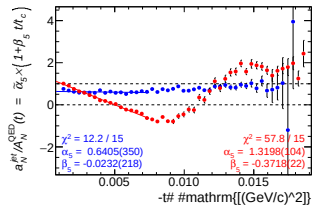
dAu_30



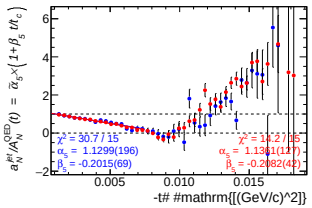
dAu_20



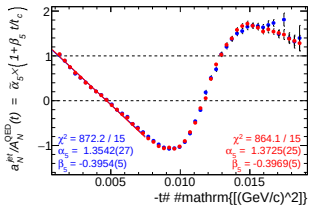
dAu_10



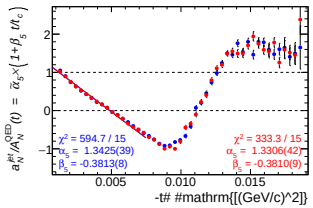
dAu_100



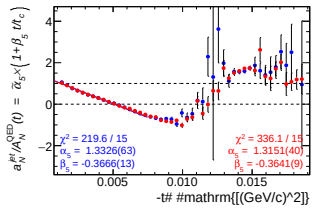
AuAu_7.4



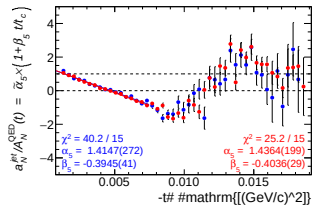
AuAu_3.85



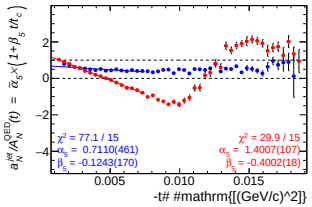
AuAu_27



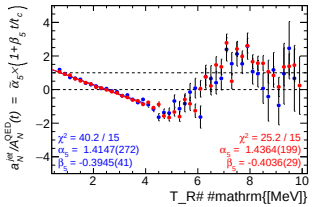
AuAu_13



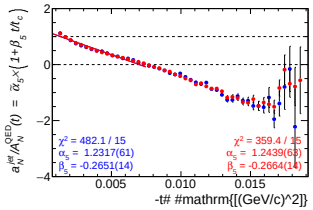
AuAu_10



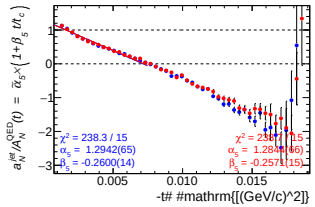
AuAu_100



ZrZr_100



RuRu_100

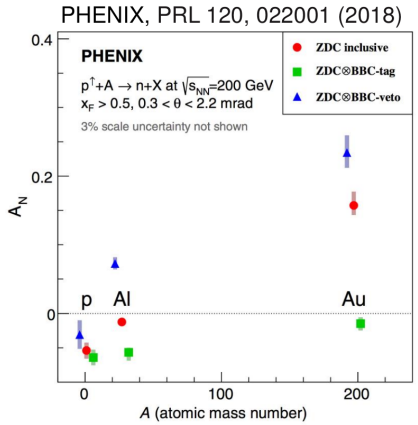


- pAu(100) single spin asymmetry changes sign, depends on beam energy

Alternative Approach

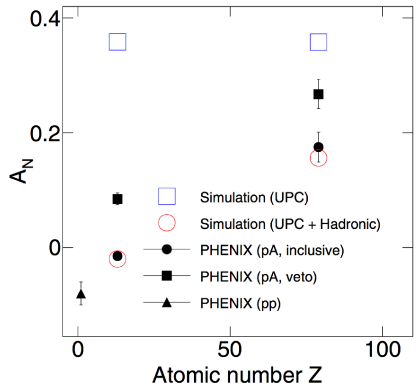
- A **large asymmetry** was measured by PHENIX in **forward neutrons from $\vec{p}$ on nuclei** (Al and Au)
- γ from high Z nucleus scatters on $\vec{p}$ target; parameterizations of $\gamma + \vec{p} \rightarrow n + \pi^+$ (MAID**) and photon flux (STARlight*) describe PHENIX results:

Data:

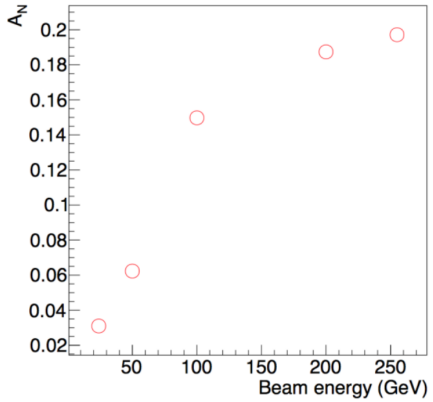


Model vs data

[G. Mitsuka, PRC 95, 044908 (2017)]



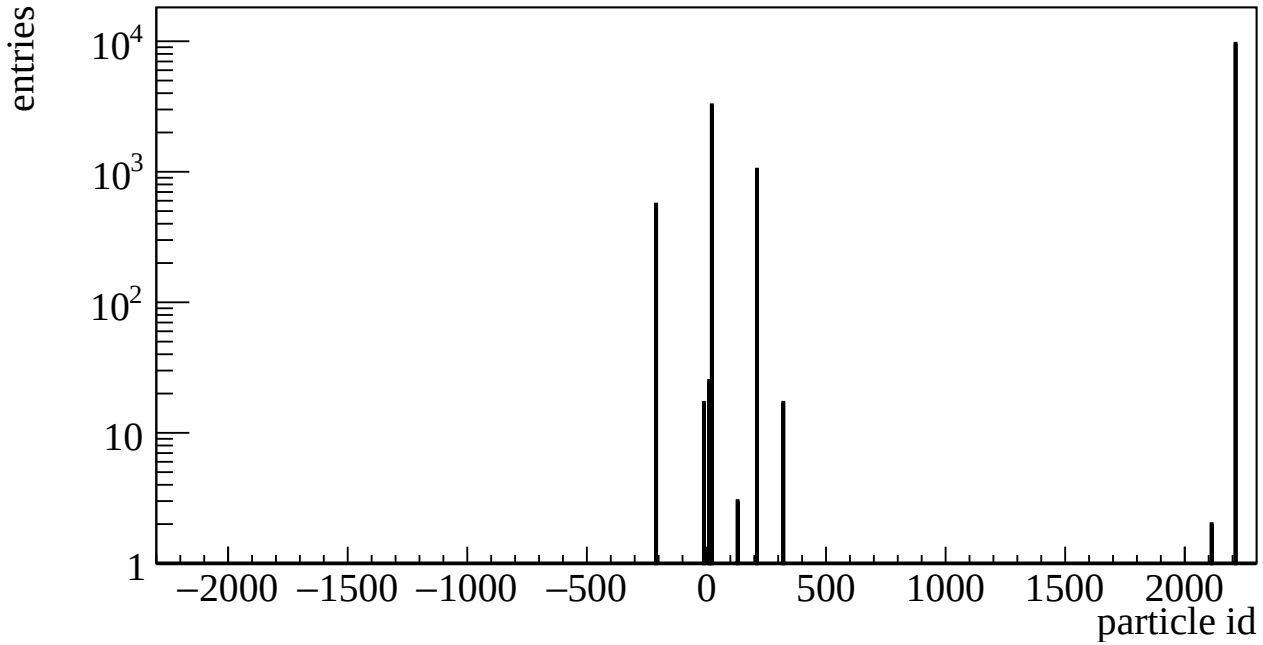
Simulation (pAu):



- **Polarimeter: high Z target (*e.g.* Xe gas jet) in $\vec{p}$ beam**
- Would require a calorimeter to detect neutrons at low angles
- Open questions: can a thin jet ($\sim$ 100 μm) of Xe gas be produced and allow enough statistics for lifetime of P and profile measurements?

(*) Klein et al., Comput. Phys. Comm. 212 (2017) 258 (**) Drechsel et al., Eur. Phys. J. A 34 (2007) 69

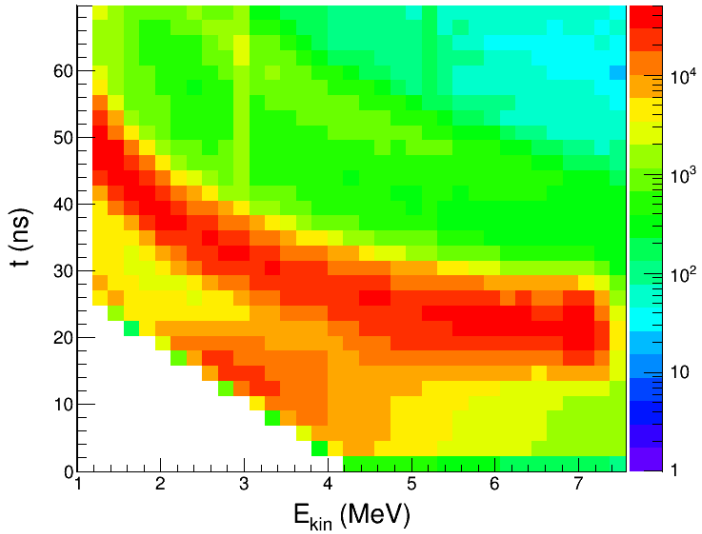
Pythia simulations of the present RHIC H-Jet polarimeter



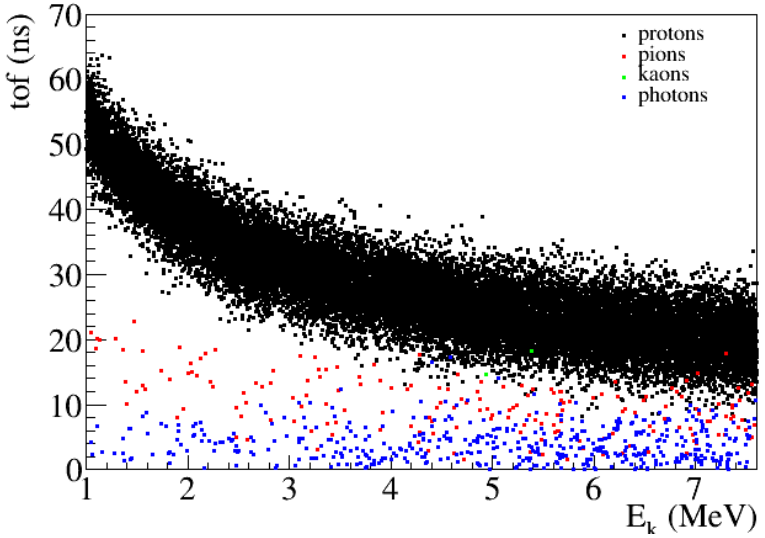
- phythiaRHIC (Phythia6), $E_1 = 255$ GeV, $E2 = 0.00001$ GeV; 5×10^6 events, acceptance of the H-Jet silicon detectors
- MSEL=0
  MSUB(91)=1 ! Elastic
  MSUB(92)=1 ! Singly diffractive (XB)
  MSUB(93)=1 ! Singly diffractive (AX)
  MSUB(94)=1 ! Double diffractive
  MSUB(95)=1 ! Low-pT scattering

  MSUB(96)=1 ! Semihard QCD $2 \rightarrow 2$
- Most common particles in the final state: protons, pions, photons, kaons

Pythia simulations of the present RHIC H-Jet polarimeter



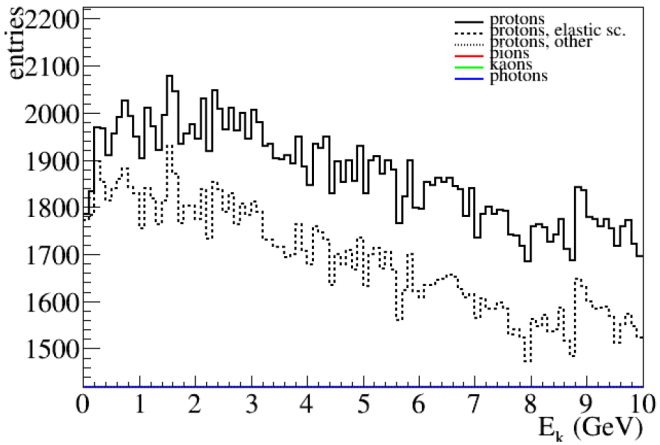
2017 H-Jet data

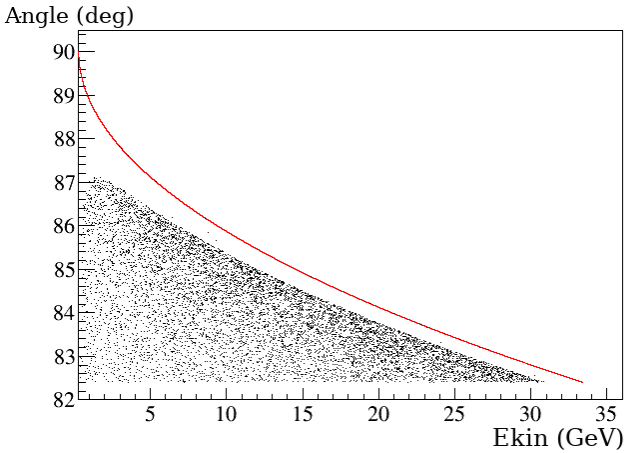


Pythia pp simulations

- Bunch length of 3.7 s used to produce the smearing
- "Banana" plot is reproduced

Pythia simulations of the present RHIC H-Jet polarimeter





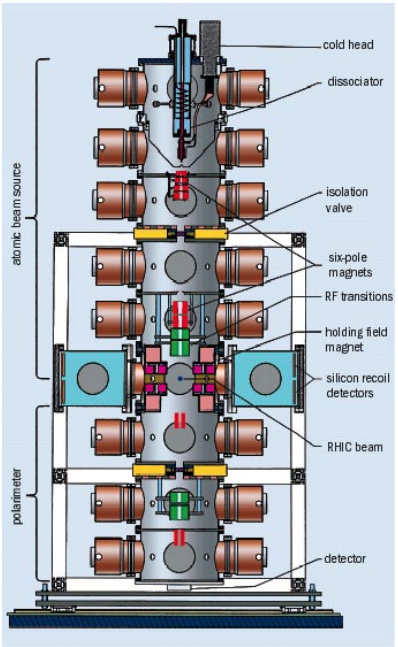
- High energy produced particles are protons
- It's possible to separate elastic and inelastic scattering protons based on angle and kinetic energy

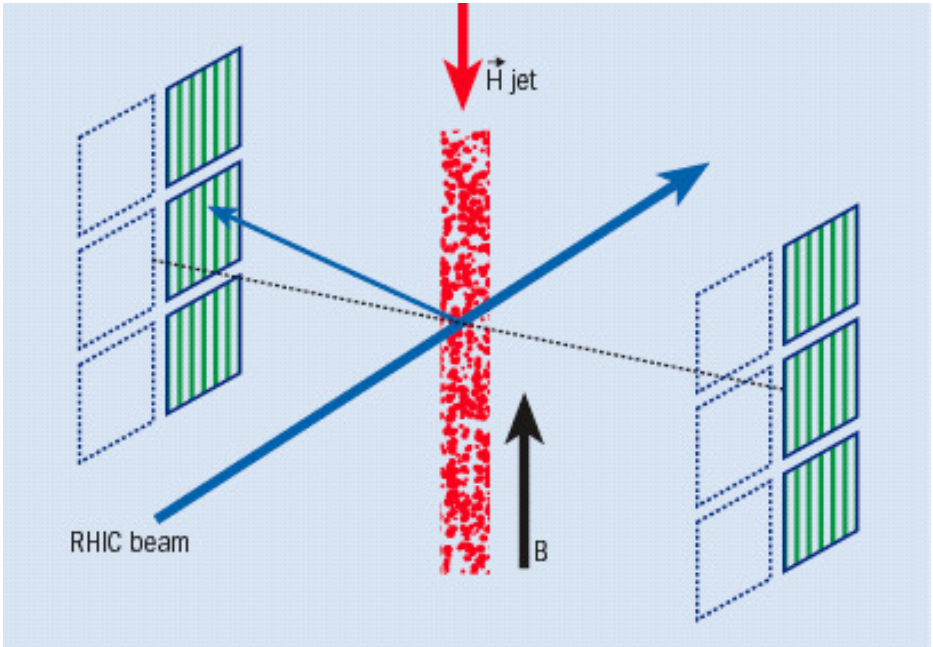
Summary

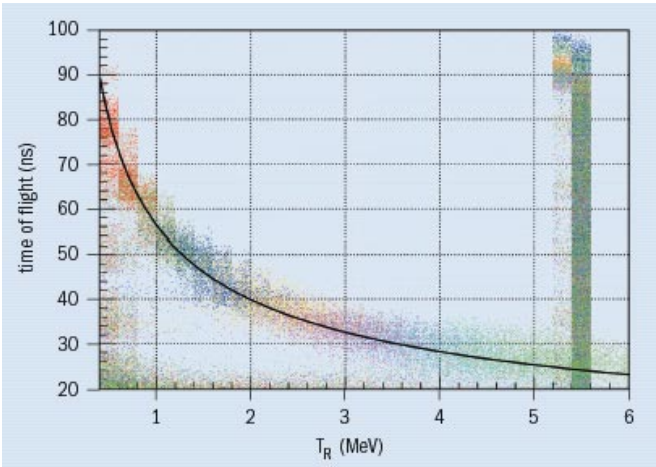
- We should make the best usage of the available unique conditions at AGS and RHIC until 2024
- APEX request being prepared, all input much appreciated!!!

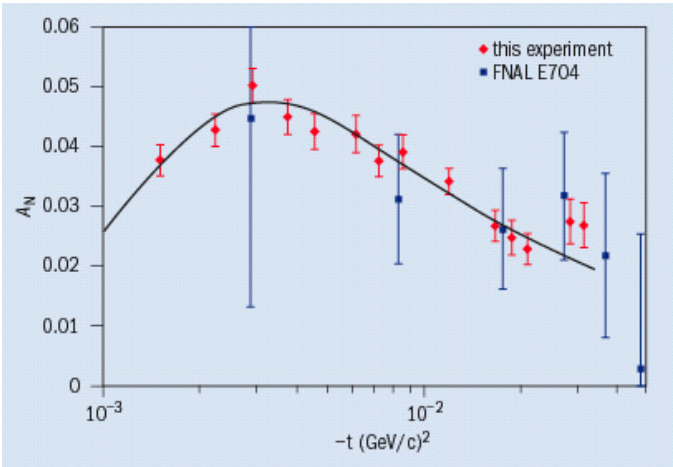
BACKUP

H-Jet









Source: https://cerncourier.com/a/h-jet-measures-beam-polarization-at-rhic/