Thoughts on Polarimetry for ^{3}He Beams at RHIC

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Outline

- The New Order of two different polarized beams
- Requirements for the physics program and machine
- The Current set up
- Possible new concepts
- Other considerations
- Summary

Polarized ^{3}He Plans

- A polarized ^{3}He source is being constructed at MIT
- Delivery to BNL is expected within a year
- It will take a good portion of a year to install on EBIS and tune up
- A polarized ^{3}He beam will then be available in the AGS. No new equipment needed
- In RHIC polarized ^{3}He beam will require 6 snakes per beam. A longer time prospect
- Time to prepare for polarimetry

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^{3}He Beam Energies

H. Huang

Helion

	Energy	Momentum	γ
AGS Injection	5.05GeV	4.19GeV/c	1.79
AGS Extraction	33.30GeV	33.18GeV/c	11.83
RHIC Store	501GeV	501.14GeV/c	178.04

Proton

	Energy	Momentum	γ
AGS Injection	2.36GeV	2.16GeV/c	2.51
AGS Extraction	23.81GeV	23.79GeV/c	25.38
RHIC Store	250GeV	250.00GeV/c	266.45

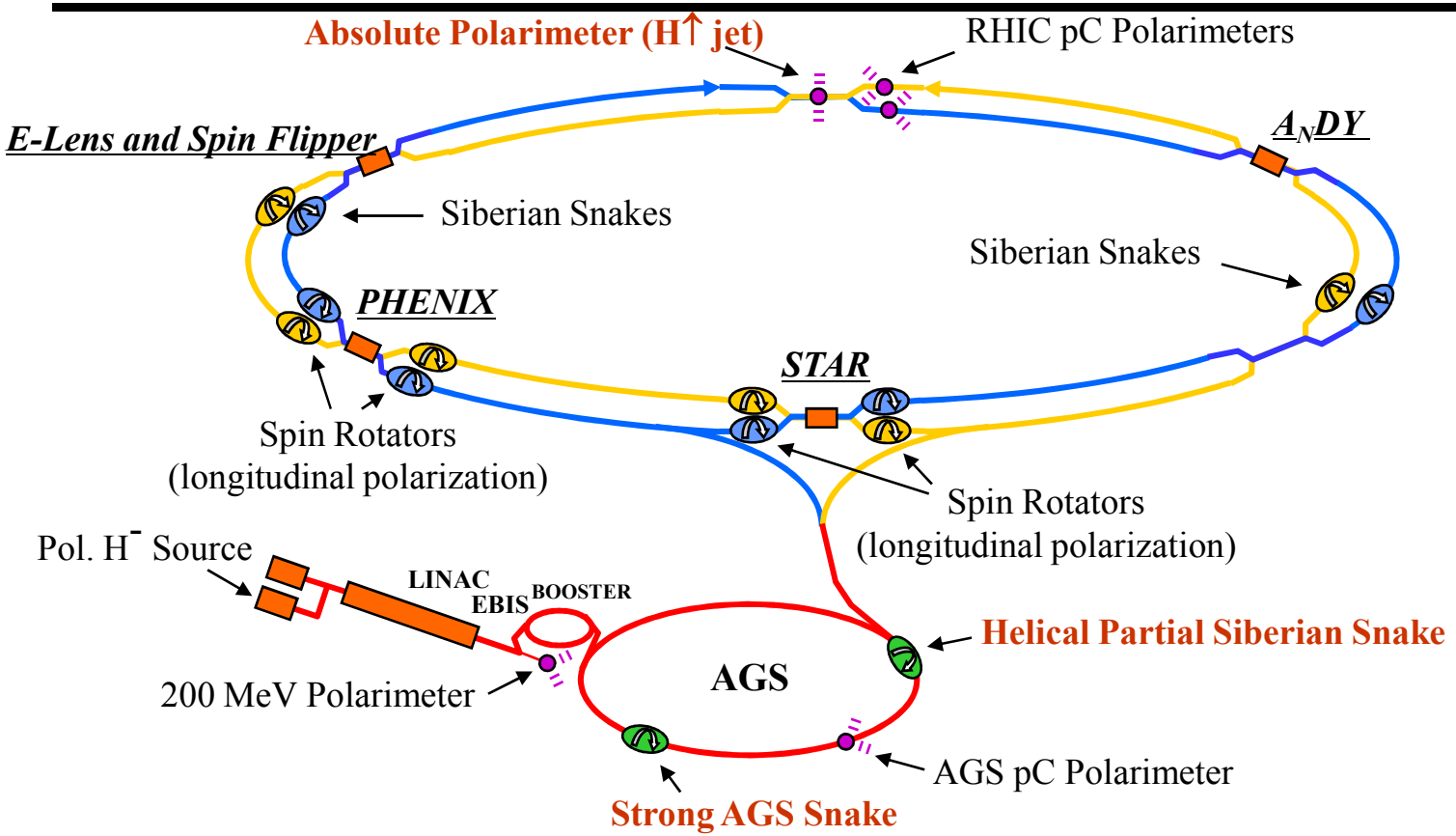
The Polarimetry Requirements for RHIC

- The polarimeters should operate over a very wide range
  Protons: 24 to 250 GeV, ^{3}He: 15 to 160 GeV
- The physics program requires precision polarimetry < 5%
- Polarimeter calibration is required at each energy
- Beam polarization profile(s)
- Polarization lifetime or decay during a store
- Polarization measurement on the ramp
- Bunch to bunch emittance measurements

The RHIC Polarimeters At A Glance

	H-Jet polarimeter	*p*-C polarimeter
Target	Polarized atomic hydrogen gas jet target	Ultra thin carbon ribbon
Event rate	~20 Hz 8% statistics in a 6-hr fill	~2M Hz 2-3% per measurement
operation	continuously	few minutes every few hours
A_N	Measured precisely BRP gives self-calibration	Requires calibration from the Jet data
Role	Absolute beam pol. measurement, Calibration for RHIC *p*C polarimeter	ONLINE monitor, Fill by Fill beam polarization Polarization Profiles Beam Emittance measurements

The RHIC Polarized Collider



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^{3}He Considerations

- Feels like 1996 when we started to look into proton polarimetery

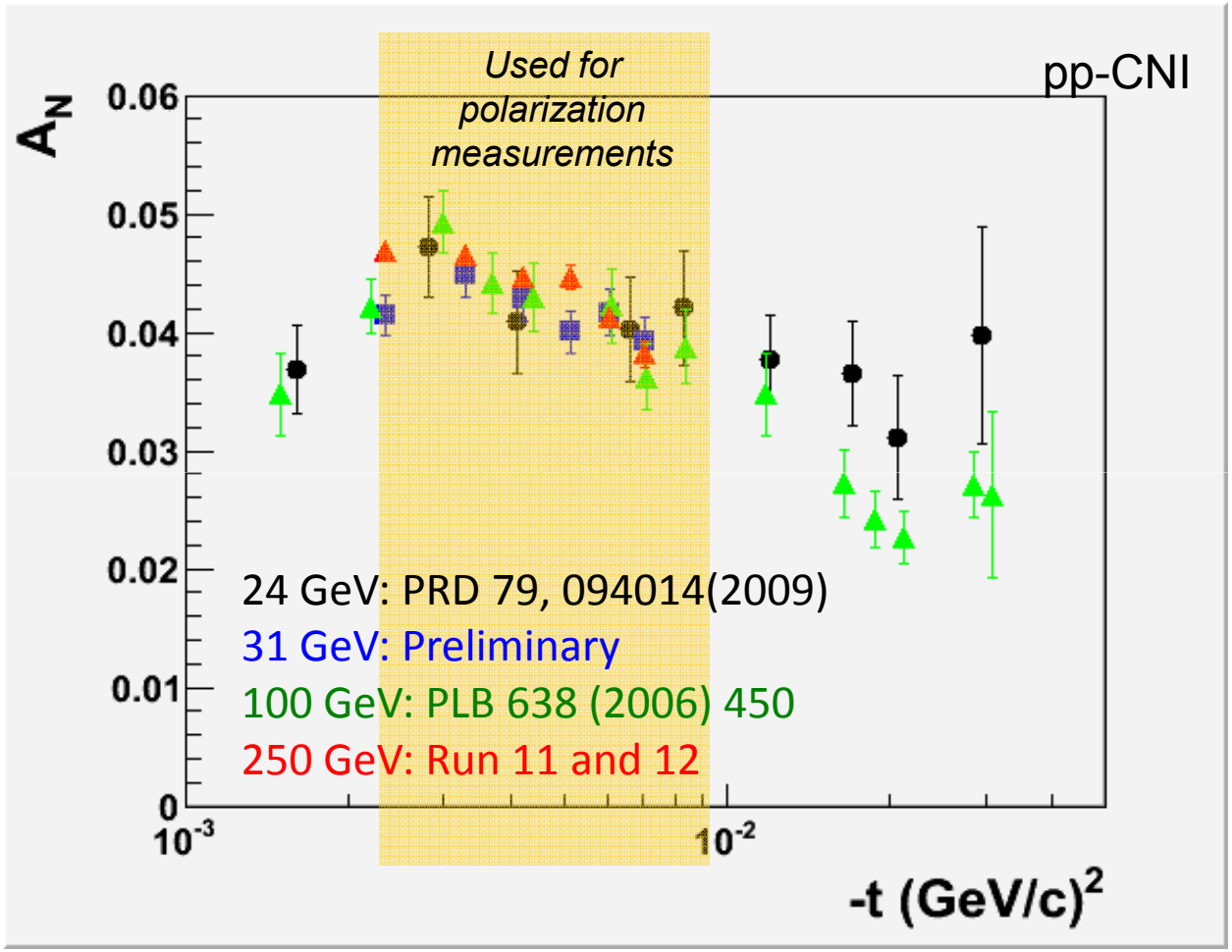
- We had a number of high energy spin physics reactions:
  - Inclusive Pion, Primakof Production, and CNI production

- Such is not the case with ^{3}He
  - The highest polarized helium beams 400 MeV

But

- What have we learned from our proton experience?
  - The answer is "CNI"

A_N in pp elastic scattering



Weak (if any) energy dependence ⇒
pp elastic scattering in CNI region is ideal for polarimetry in wide beam energy range

Possibly an unpolarized hydrogen Jet for higher intensity?

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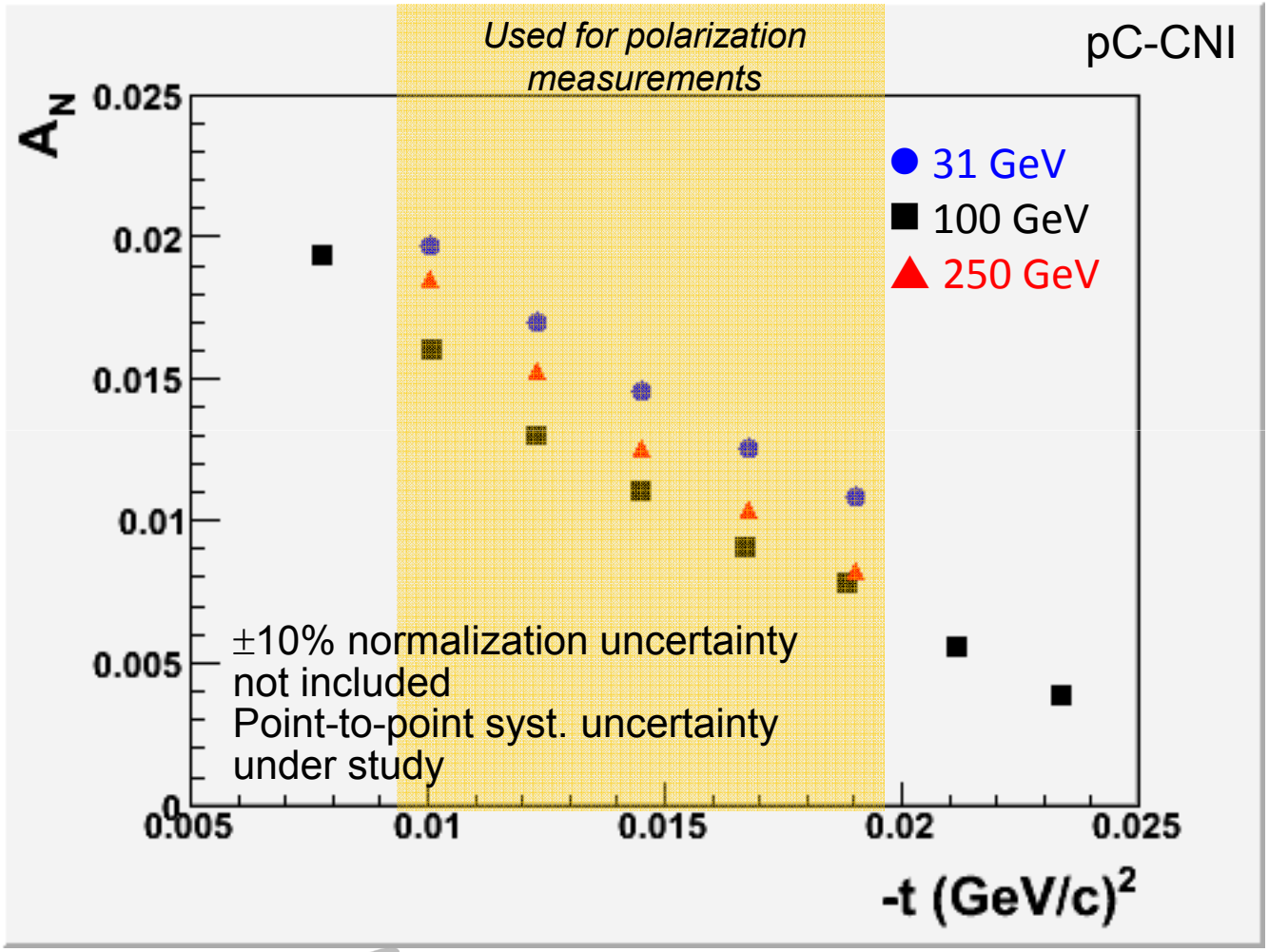
p-Carbon: A_N



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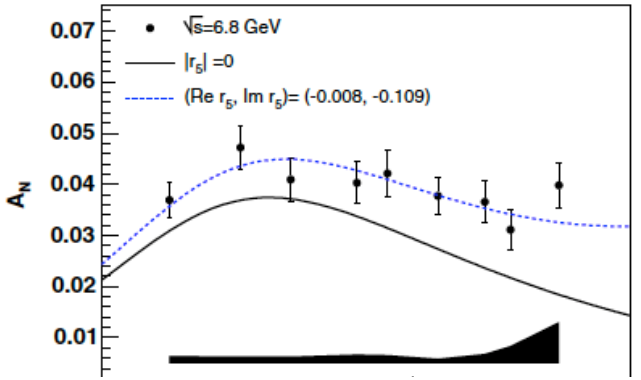
Weak energy dependence ⇒ *pC* elastic scattering in CNI region is good in wide beam energy range

Hadronic Single Spin Flip

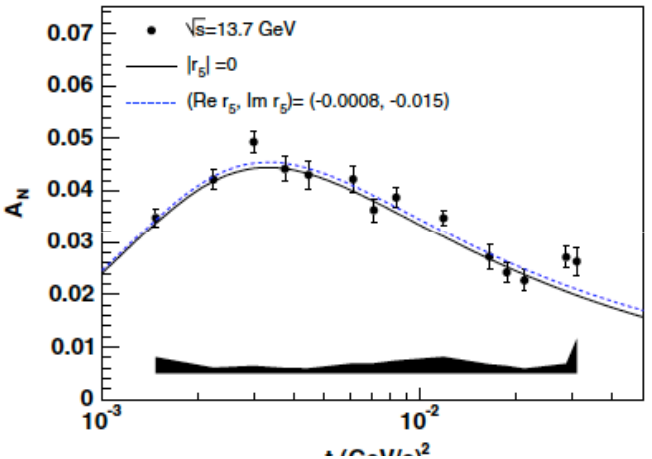
24 GeV fixed target

Alekseev et al. Phys. Rev D 79, 094014 (2009)



100 Gev Fixed target

H. Okada et al., Phys. Lett. B638, 450 (2006)

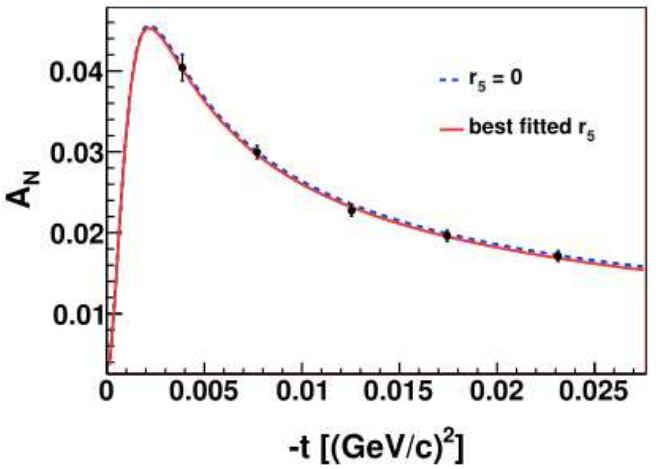


√S=200 GeV

L. Adamczyk et al., arXiv:126.1928 [nucl-ex]

Submitted to PLB

Spin Flip Amplitude significant at low energies but is approximately zero at 100 GeV



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The Options

- ^{3}He-Carbon CNI
  - We will use current polarimeters at the AGS and RHIC
  - We should be able to see the CNI banana
  - What about beam breakup or excited states
  - What analyzing power?
- ^{3}He – p elastic scattering
  - Use the polarized RHIC hydrogen Jet
  - Analyzing power?
- ^{3}He-^{3}He elastic scattering
  - Requires a new jet target

p-^{3}He CNI

L. Trueman arXiv:0710.3380v1 [hep-ph]

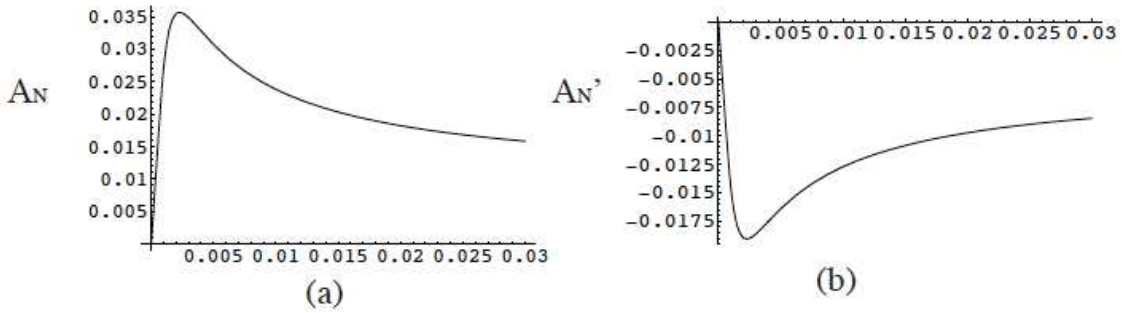


FIG. 2: Analyzing powers A_N and A'_N at $p_L = 100 GeV/c$ with zero hadronic spin-flip factor

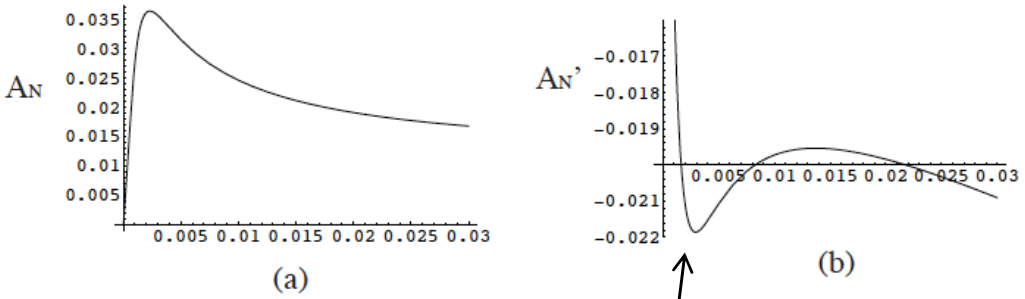


FIG. 3: Analyzing powers A_N and A'_N at $p_L = 100\,GeV/c$ using the non-zero hadronic spin-flip factors in text.

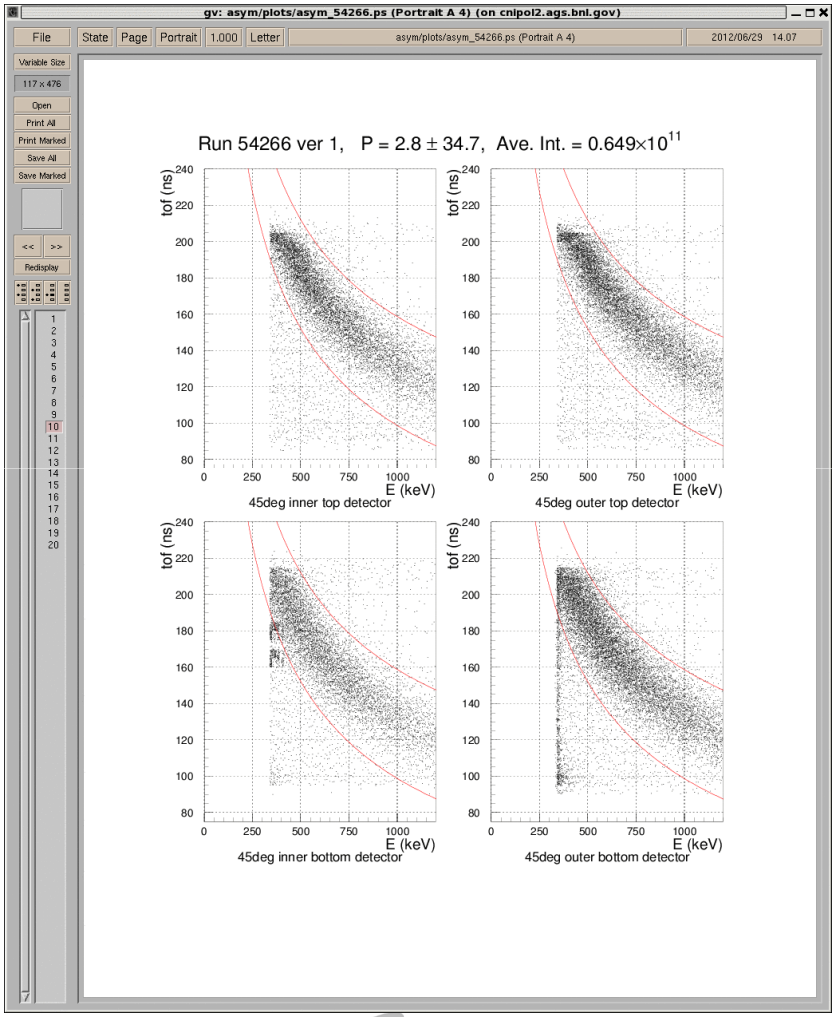
A little difficult as the asymmetry is at low t

^{3}He AGS Test (6/28)

H. Huang

- Test the beam optics and dynamics with ^{3}He from the booster into the AGS and possible problems with the cold snake on.
  - With a ^{3}He beam test the CNI polarimeter in the AGS. We need to confirm that the polarimeter Si detectors can detect recoil carbons.
- Three days alloted for tests (starting on June 28th):
  - First day: get beam through Booster and possible in the AGS without snakes.
  - Second day: get beam through AGS with cold snake on but low tune; polarimeter setup followed.
  - Third day: get beam in the AGS with high vertical tune and cold-snake-on.

Carbon Bananas Observed!



- Rate estimate: gain due to elastic cross section: $A^{2/3} = 3^{3/2} = 2.08$.
- Actual observed: ~2.
- A_N: estimated as 78% of the p-carbon one (from Nigel Buttimore)

$$-0.780\sqrt{\frac{2\,\sigma_{\mathrm{tot}}^{\mathrm{p}}}{\sigma_{\mathrm{tot}}^{\mathrm{h}}}}$$

- The kinematics only tells us these are slow carbons. But are they coming from elastic scattering?

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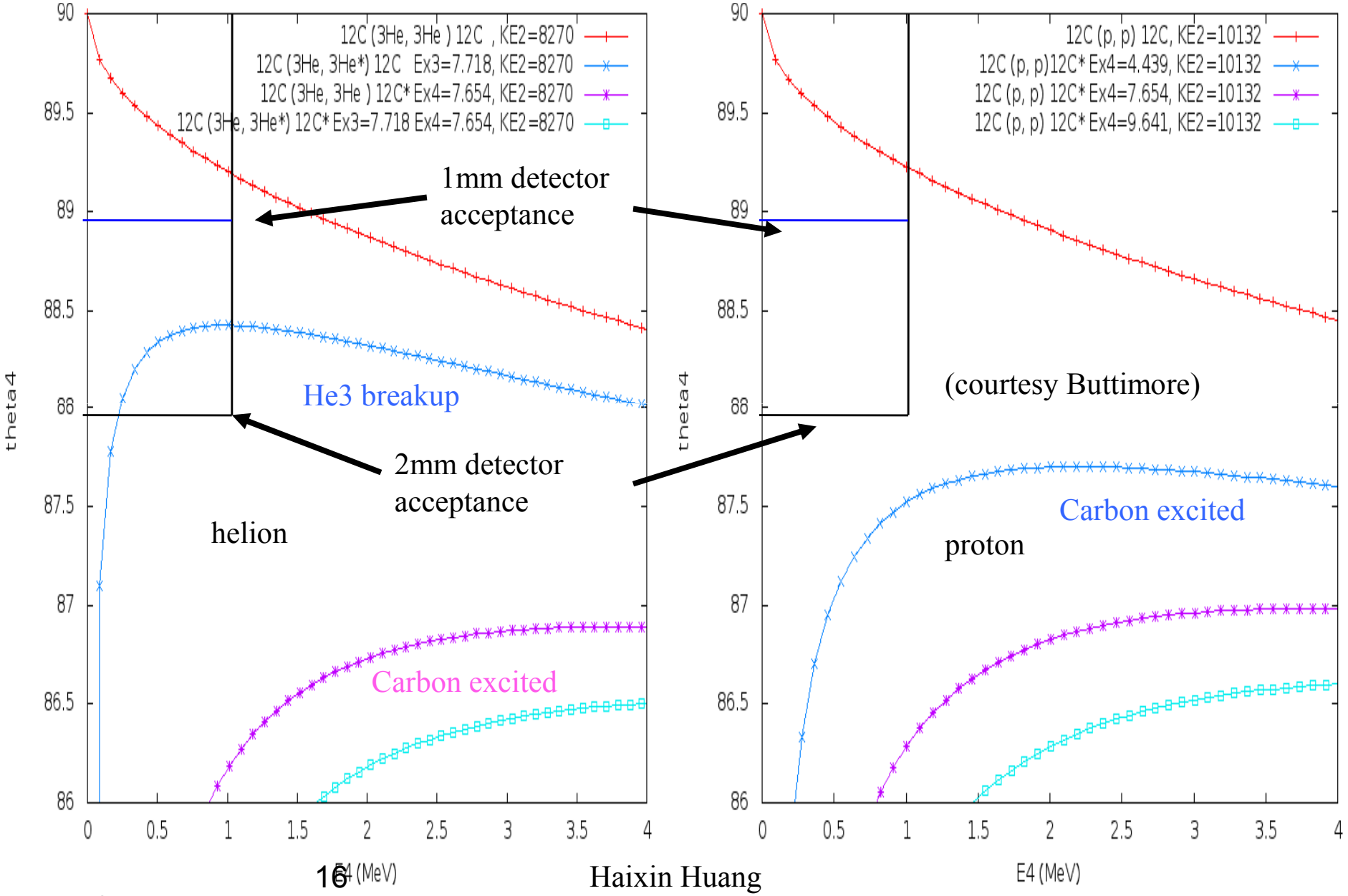
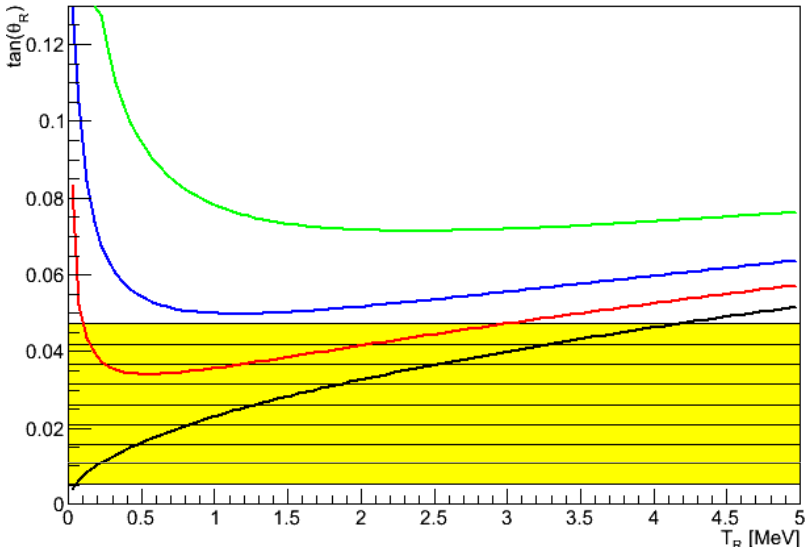
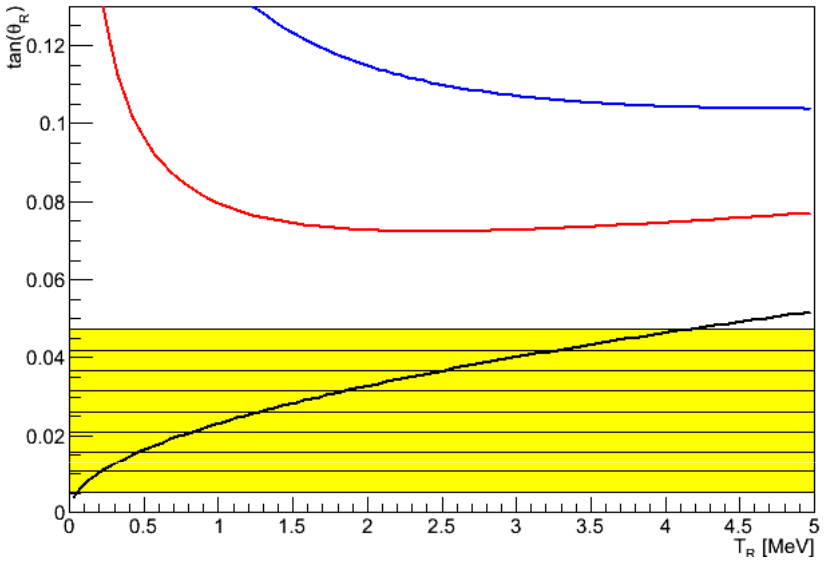
Carbons inside the Detector Acceptance



Kinematics for CNI scattering at RHIC



p-p at 250 GeV



^{3}He-p at 160 GeV

Elastic

Elastic+m_π

Elastic+2m_π

The Yellow strips are the Jet silicon Detector acceptance

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We need a system for calibration

- Use a polarized Helium 3 target the polarization of which is measured through a different process to

- Use the polarized proton beam to measure A_N vs t in p-^{3}He elastic scattering

- If we measure Analyzing power in ^{3}He – ^{3}He elastic scattering
  - No breakup as the CNI process with momentum transfer < 1 MeV well below the nuclear binding energy

- Use a polarized ^{3}He Jet and utilize the identical "entities" principle in elastic scattering.
  - Simultaneously measured A_N using the Jet polarization and then turn around and measure the beam polarization.

A ^{3}He Jet Target?

- The Hermes Helium target used a storage cell (for a factor of 100 in density)
  - Is this possible at RHIC?
  - Can one use a variable storage cell concept to allow for injection and store as is being developed at COSY?

- With two electrons one cannot use magnetic focusing as we do with hydrogen. So the Jet has to be formed geometrically

- Huge pumping will be needed to keep an acceptable beam vacuum

The HERMES Target

- ^{3}He gas
- Polarized using metastabilty- exchange optical pumping
- Helium polarization in the cell measured at 54%
  - The Mainz target reached 90%
- Target thickness (cell) $1x10^{15}$ nucleons/ cm^2
- The target polarization was measured using the positron beam scattering. We need to find a different way
- Significant differential pumping was employed for beam vacuum

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A Jet Target

- At 10^{15} intensities a measurement can be very fast but not minutes.
- But the cell length defeats the energy angle correlation. A nice way to define elastic scattering
- If we cannot use a cell the intensity drops by a couple of orders of magnitude. This will be similar to the current situation, long measurements over a fill
- Can one use a polarized bottle system. These can hold several (4-5) Bar of pressure with long relaxation times. But this implies access to replenish

What Next?

- A theoretical estimate of the analyzing power of ^{3}He - ^{3}He elastic scattering in the CNI region
- Experimentally measure A_N in p-^{3}He and ^{3}He -^{3}He elastic scattering at various energies
  - The AGS is good start
- The selection of the recoil CNI particle is similar to what has been employed in our current systems
- If successful, then employ at RHIC
  - We need to find a suitable location if the polarized hydrogen jet is to remain in place.
- Lots of work ahead….

The Local Polarimeters

Needed for setting up the spin rotators

- The ZDCs measure a significant forward neutron asymmetry should we expect a similar analyzing power from Helium scattering?

- Do we need to measure the spectator proton?
- Roman Pots?

- We need theoretical guidance

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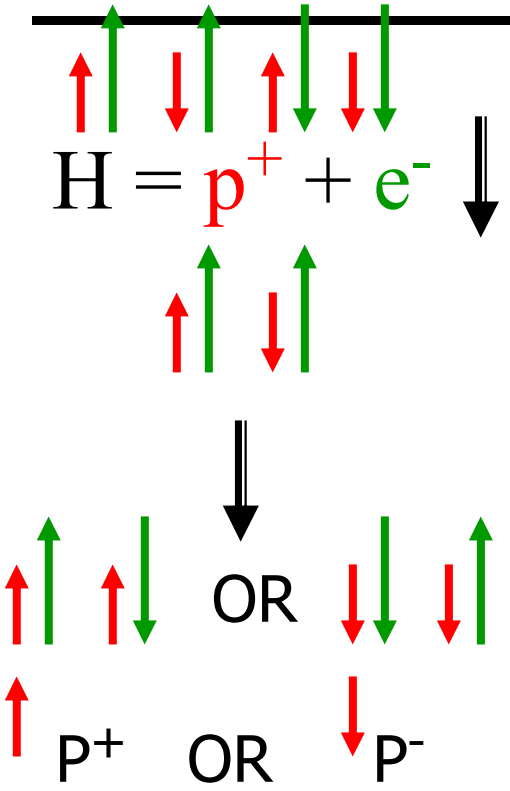
Summary

- ^{3}He-Carbon scattering has been observed at the AGS, the cross section a factor of 2 compared to p-Carbon.
- With polarized ^{3}He beams in the AGS we can simply tune up to maximize any observed asymmetry.
- We should be able to inject into RHIC and test ^{3}He-p (Jet) asymmetries
- One can study how high an energy can we preserve ^{3}He polarization with two snakes in RHIC.
- A polarized helium jet target allows beam calibration similar to what we did in pp

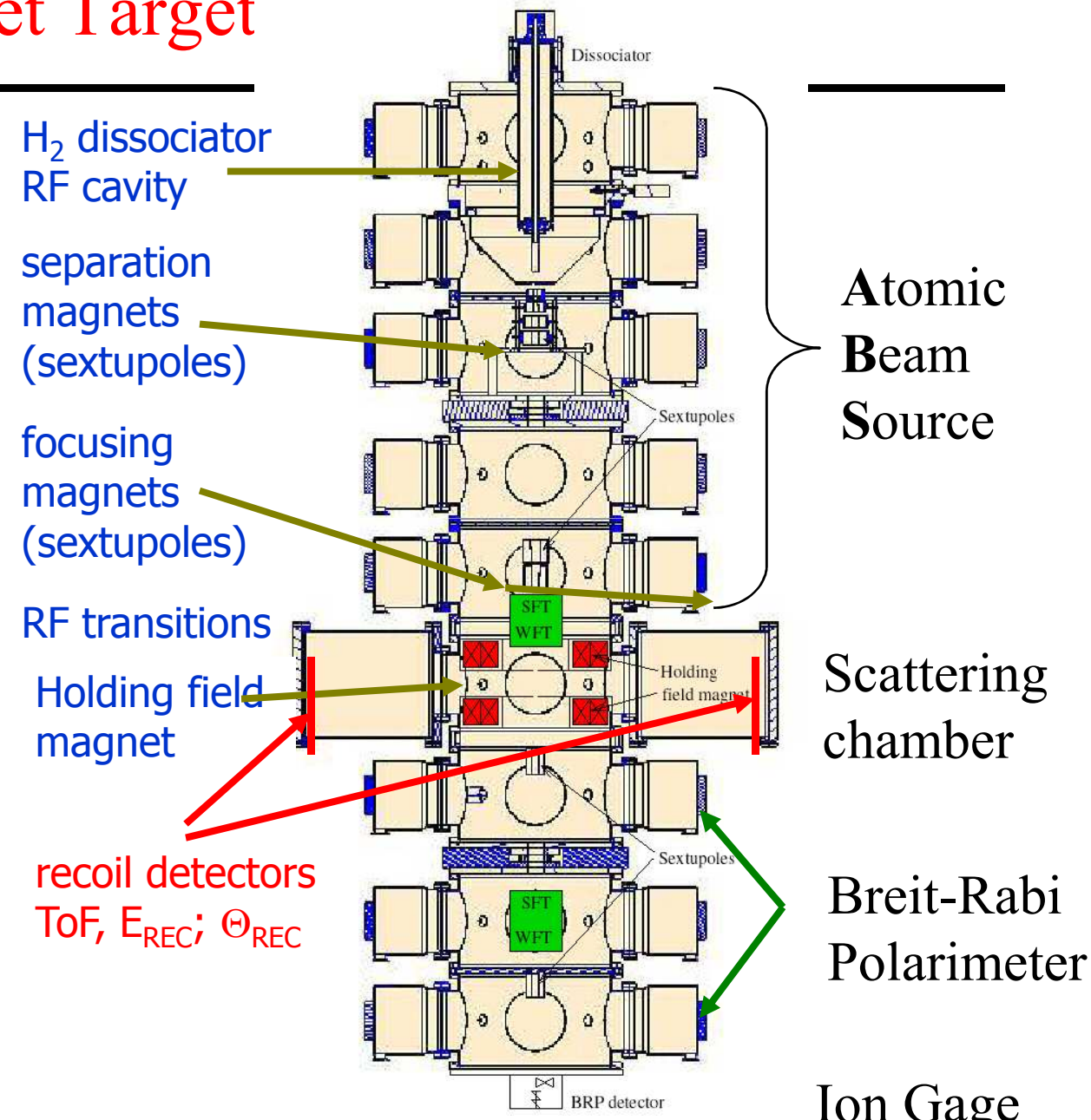
Backup

The Polarized H-Jet Target



record beam intensity
100% eff. RF transitions
focusing high intensity
B-R polarimeter

$P_{target} \sim 0.924 \pm 0.018$



The RHIC Carbon CNI polarimeters

- Can we use 3He – Carbon CNI?

  Pro:

    We can do polarization profiles

    Use an existing system

  Con:

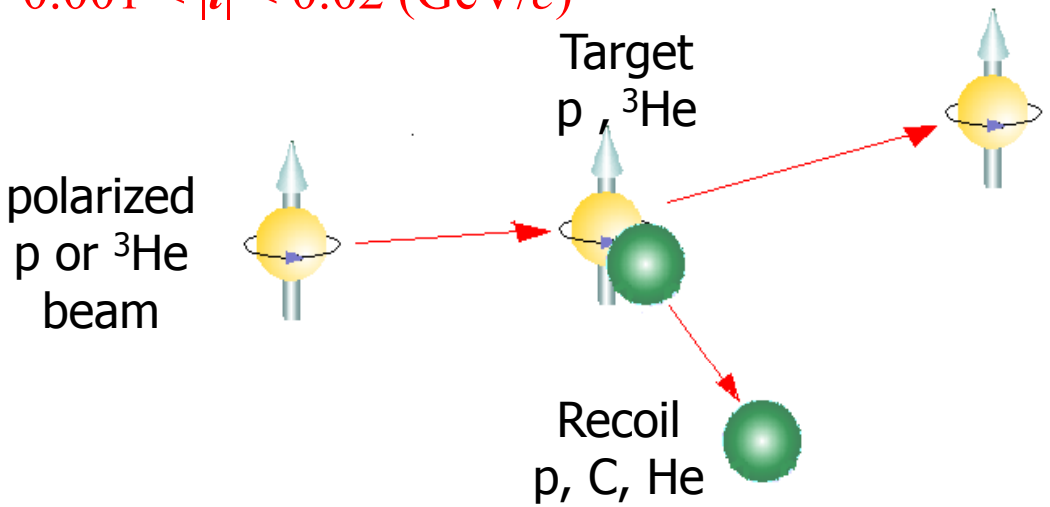
    Impact on the beam

    Will the helium breakup?

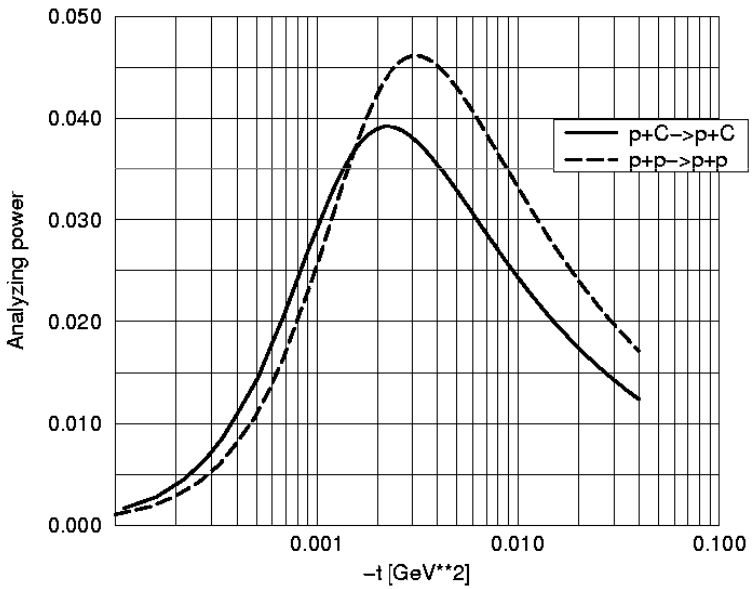
pp and p-Carbon and ^{3}He-3He Elastic Scattering

elastic kinematics are fully constrained by the recoils only !

$0.001 < |t| < 0.02$ (GeV/c)^2



Scattered
p , ^{3}He



For identical particles elastic scattering only:

$$\varepsilon = \frac{N_\uparrow - N_\downarrow}{N_\uparrow + N_\downarrow}$$

$$\varepsilon_{beam} = A_N \cdot P_{beam}$$

$$\varepsilon_{target} = -A_N \cdot P_{target}$$

$$P_{beam} = -\frac{\varepsilon_{beam}}{\varepsilon_{target}} \cdot P_{target}$$

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Needed measurements

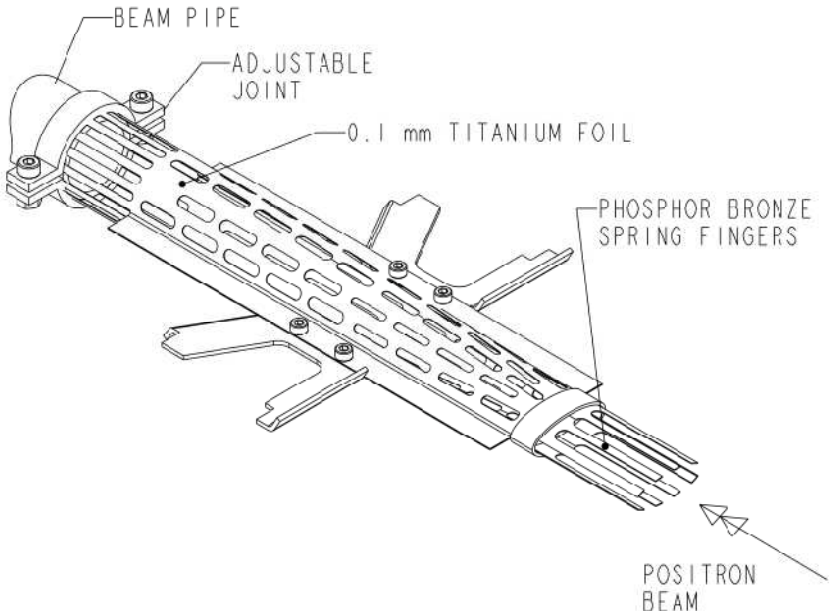
AGS

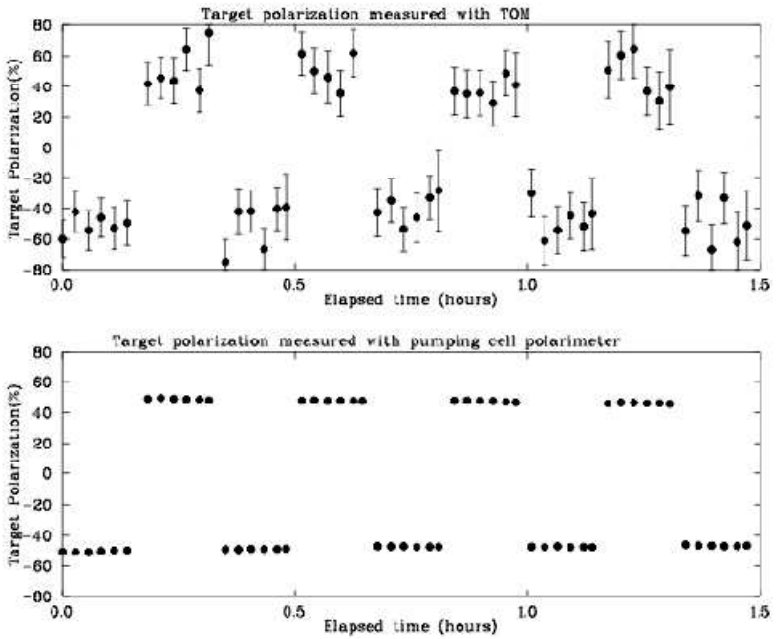
Do we need to measure beam polarization near injection?

- The CNI targets do not allow this
- Shall we employ a different process at low energy?

The CNI polarimeter is well poised for pol. 3He-Carbon measurements at AGS extraction energies

The HERMES Target





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The Local Polarimeters Cont'd

The BBC polarimeters

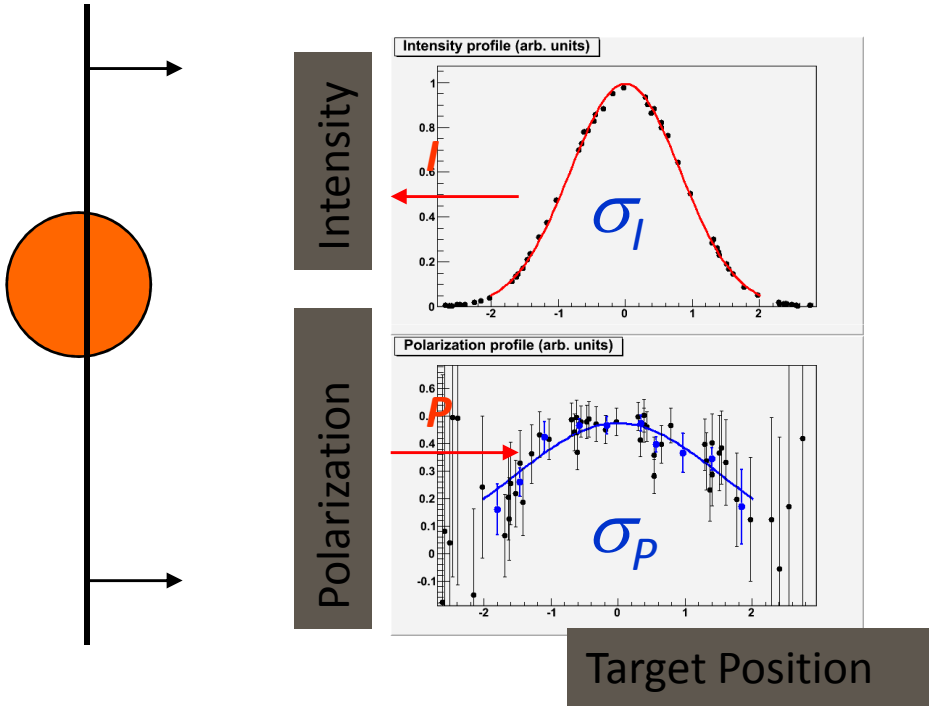
- Measure inclusive charged hadron production in the forward direction. A small analyzing power but with high rate. I suspect similar results from Helium scattering.

- We need theoretical guidance

- Should we think of some other schemes?

pC: Polarization Profile

pC Scan the Carbon target over the beam:

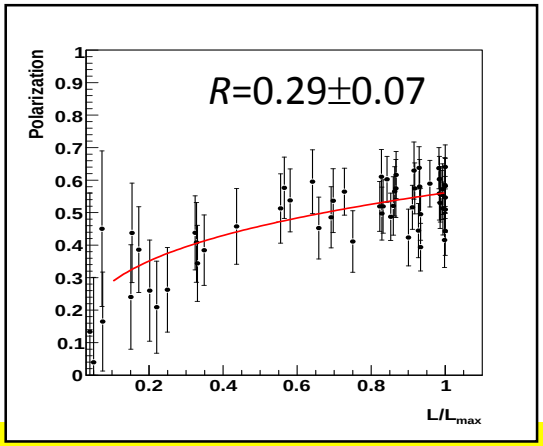


1. Directly measure σ_I and σ_P:

$$R = \frac{\sigma_I^2}{\sigma_P^2}$$

2. Obtain R directly from the $P(I)$ fit:

$$\left.\begin{aligned} P(x) &= P_{\max} \exp\left(-\frac{x^2}{2\sigma_P^2}\right) \\ I(x) &= I_{\max} \cdot \exp\left(-\frac{x^2}{2\sigma_I^2}\right) \end{aligned}\right\} \quad P = P_{\max} \cdot \left(\frac{L}{L_{\max}}\right)^R$$



Precise target positioning is NOT necessary

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$R \sim 0.1–0.3 \Rightarrow$ 5–15% difference in lower polarization seen by HJet compared to that observed by experiments