Hadron Polarimetry: tests @ RHIC

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EICUG mtg.
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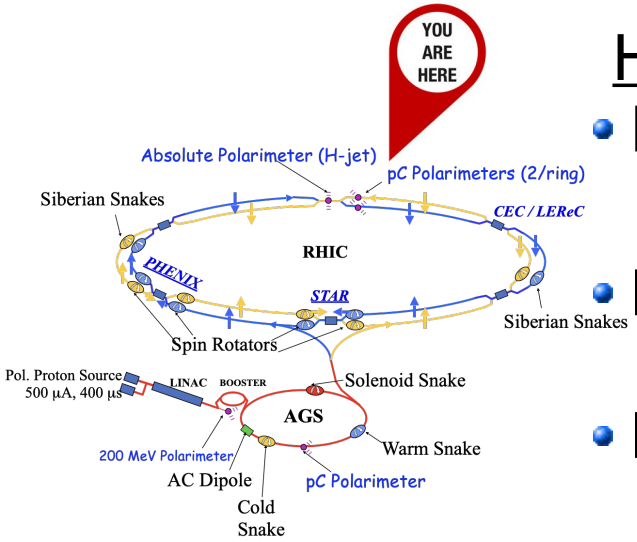
Polarimeters @ RHIC → EIC: challenges are expected

- Brief review*: RHIC polarimeters
  - polarized proton (Hjet) absolute polarimeter
  - proton-carbon (pC) relative polarimeter
- Expected challenges → tests @ RHIC
  1) Backgrounds to signal events → 2nd detector layer tests
  2) ^{3}He breakup → fragment tagging tests
  3) Carbon target lifetime → test new materials
- Timeline

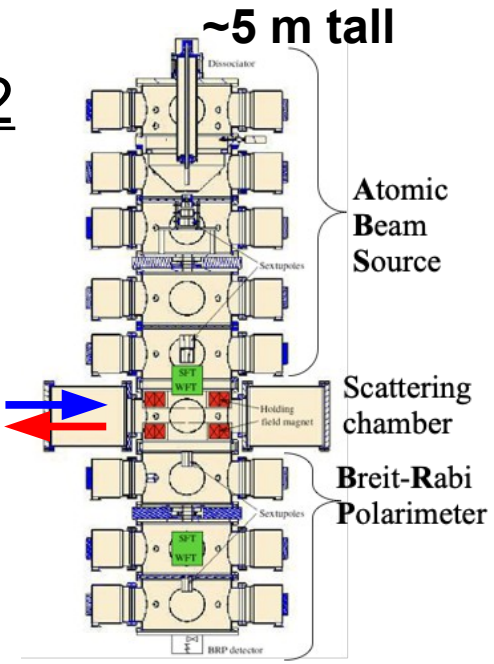
*more details RHIC & EIC polarimetry,
CFNS workshop "Beam Polarization and Polarimetry at EIC", June 2020:
https://indico.bnl.gov/event/7583/contributions/38670/attachments/29062/45020/EIC_Polar_Wrkshp_RHIC2EIC.pdf

RHIC polarimeters



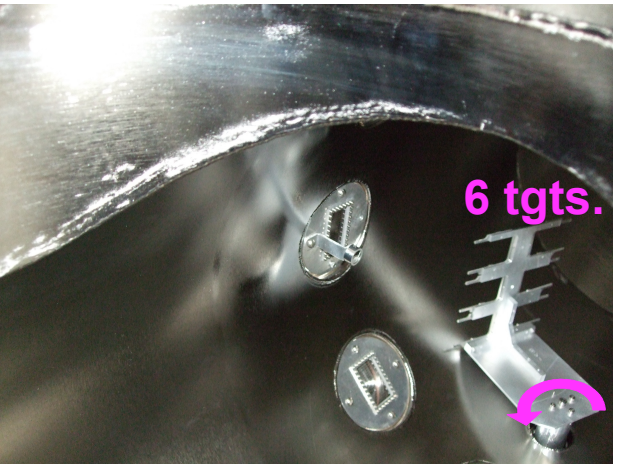
Hjet absolute polarim. @ RHIC IP12

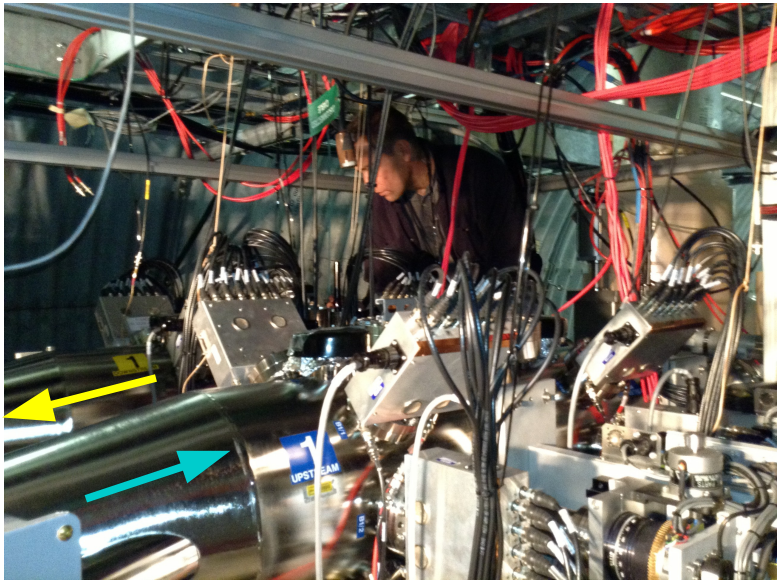
- Polarized atomic H source
  $P_{target} \approx 96\%$ (Breit-Rabi polarim.)
- Beams cross but don't collide inside target / scattering chamber
- Low rate:
  one absolute P_{beam} / RHIC fill



pC relative polarim. ~70 m from RHIC IP12

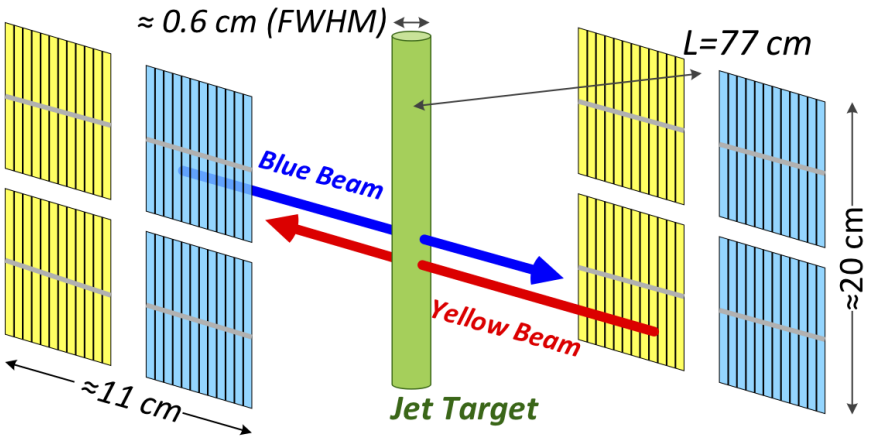
- High rate: several P_{beam} / RHIC fill $\Rightarrow$ dP/dt
- C target passed across beam
  $\Rightarrow$ transverse polar. profile P(x,y)
- P scale calibrated pC/Hjet normalization



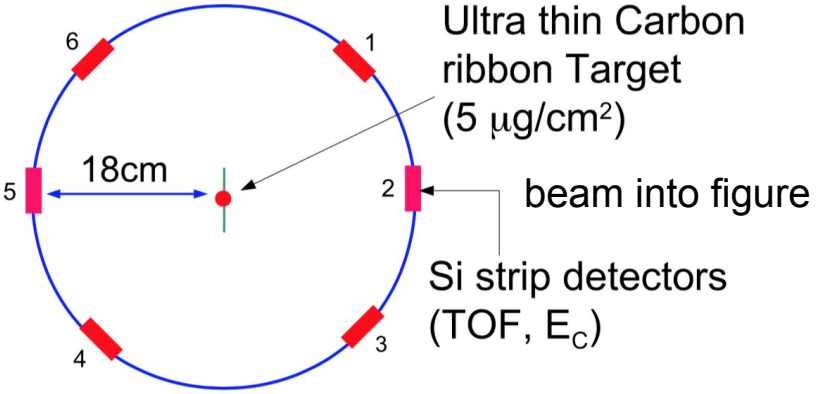


RHIC polarimeter detectors, PID

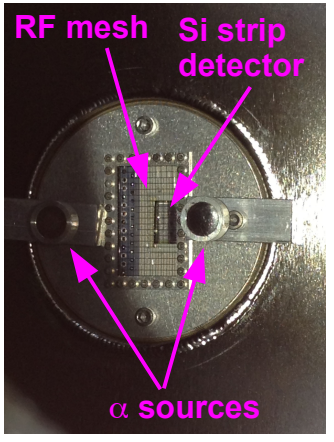
- Polarimetry via Single Spin azimuthal Asymmetry:
  $dN/d\phi \propto 1 + P \cdot A_N \cdot \sin(\phi)$

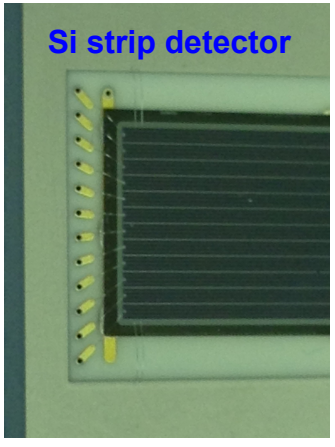


Hjet: elastic pp→pp
- Si strip detectors L/R beams
- Measure: ADC → kinetic E
  TDC → TOF
- Strip # ∝ scattering angle



proton-Carbon: elastic C→pC
- 6 Si strip detectors around beam
- Measure: ADC → kinetic E
  TDC → TOF





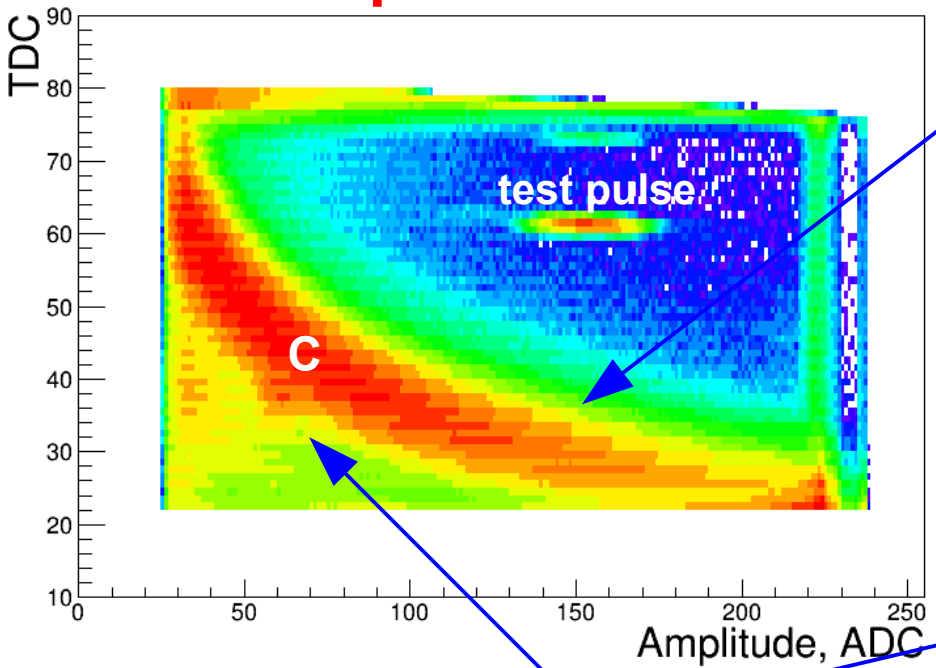
Particle ID
- Via non-relativistic TOF $\propto 1/\sqrt{E_{kin}}$
- Hjet: select protons from pp→pp
- pC: select carbons from pC→pC

1) RHIC polarimeters: backgrounds

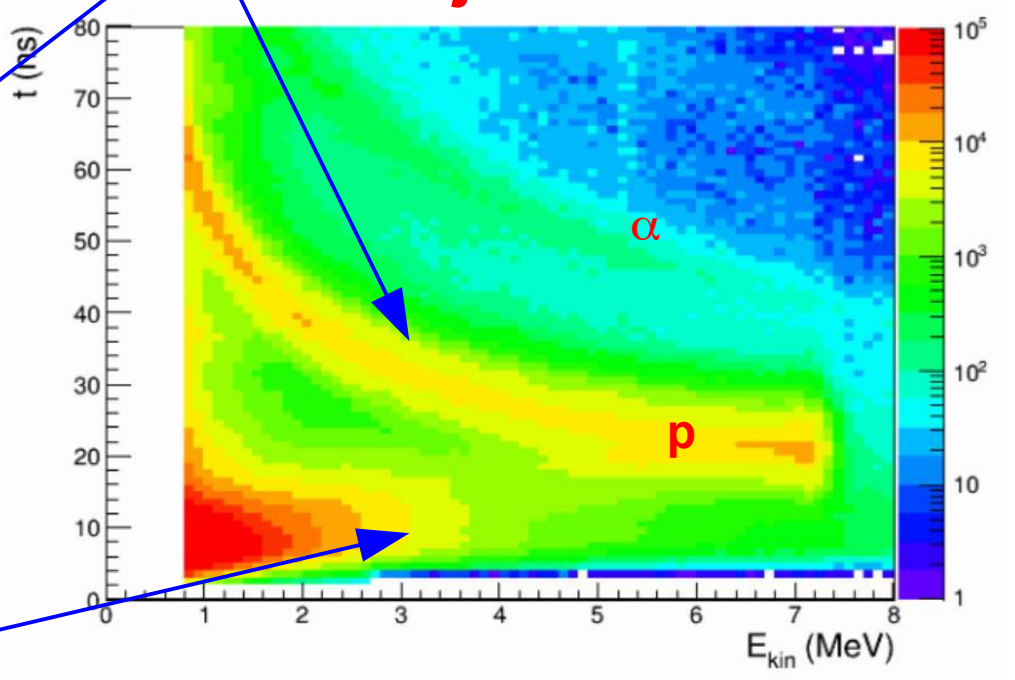
- TOF vs E_{kin}: signal in TOF $\propto 1/\sqrt{E_{kin}}$ "banana" curve:

Carbons in pC
Protons in Hjet

pC data



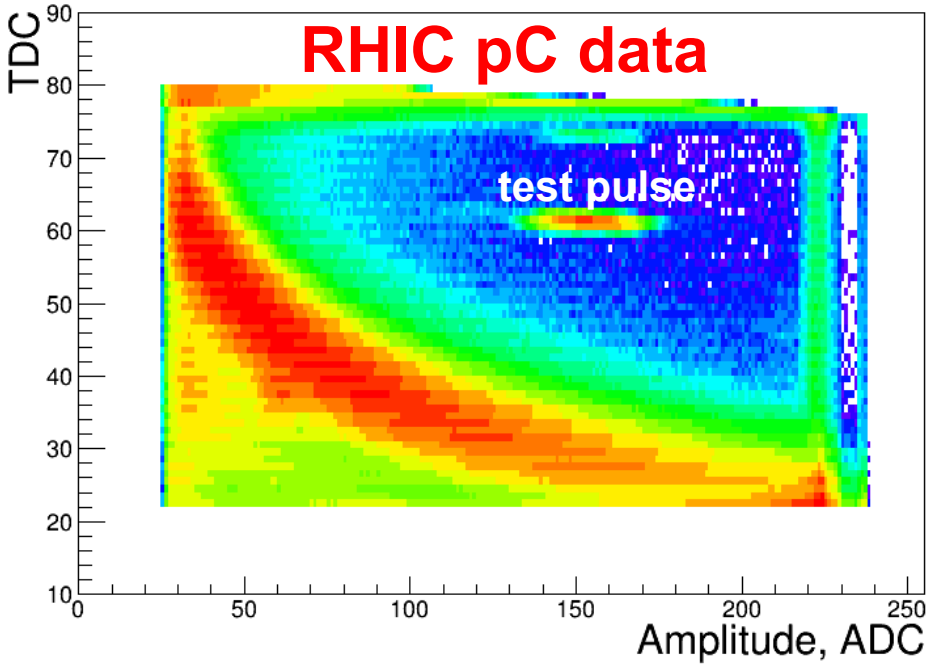
Hjet data

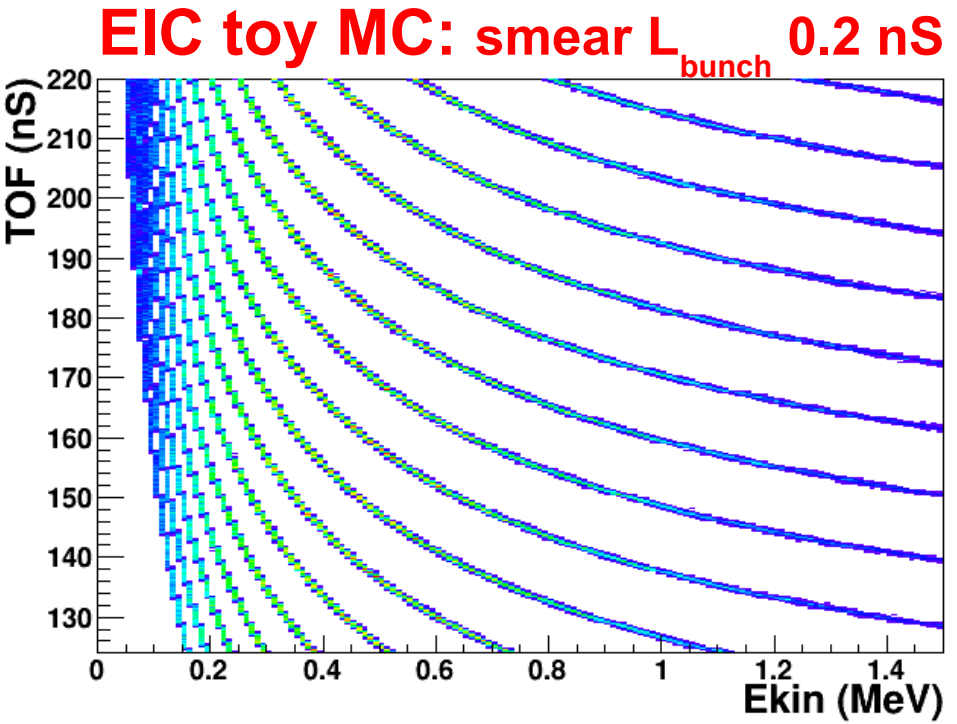


- Clear backgrounds below "banana" curves predominantly @ earlier TOFs
- Handled OK @ RHIC:
  - Hjet: from TOF, E_{kin} slices estimate bkg., subtract
  - pC: bkg. dilution calibrated in pC/Hjet normalization
- Problematic RHIC→EIC ↘

RHIC→EIC: 120→1160 bunches

- Signal p,C TOF ~20-90 nS; bunch spacing RHIC 106 nS → EIC 11 nS
- Particles from several bunch ×ings in system simultaneously:



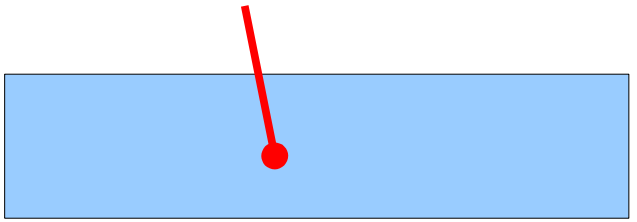


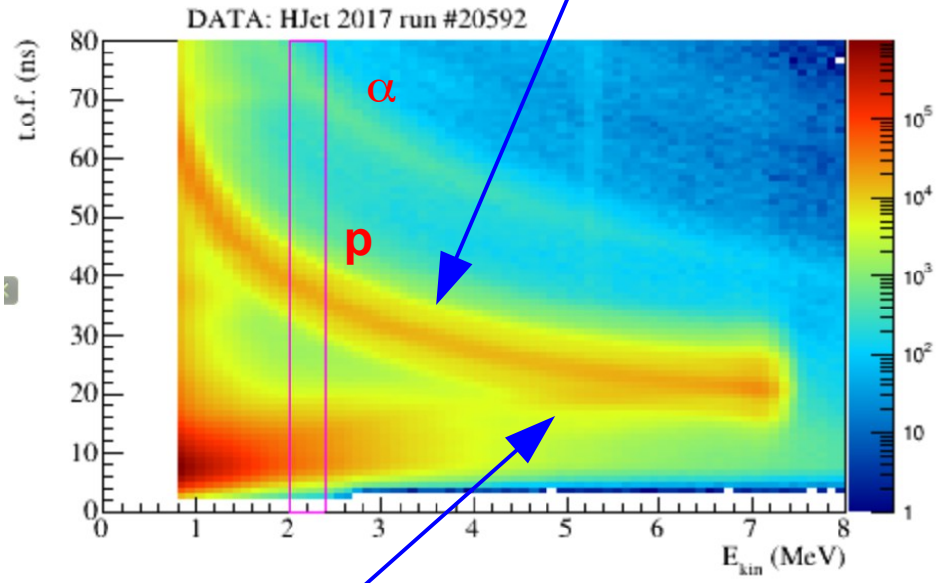
- Need to sort (Ekin,TOF) bands → bunch ×ings
- But for asymmetry measurements:
  - background: measured small but ≠0 asymmetry w.r.t. beam spin
  - overlaps w/ adjacent bunches
  - may be same/opposite +/- beam spin
  - dilute/enhance asymmetry
- A real mess; need way to minimize/eliminate backgrounds

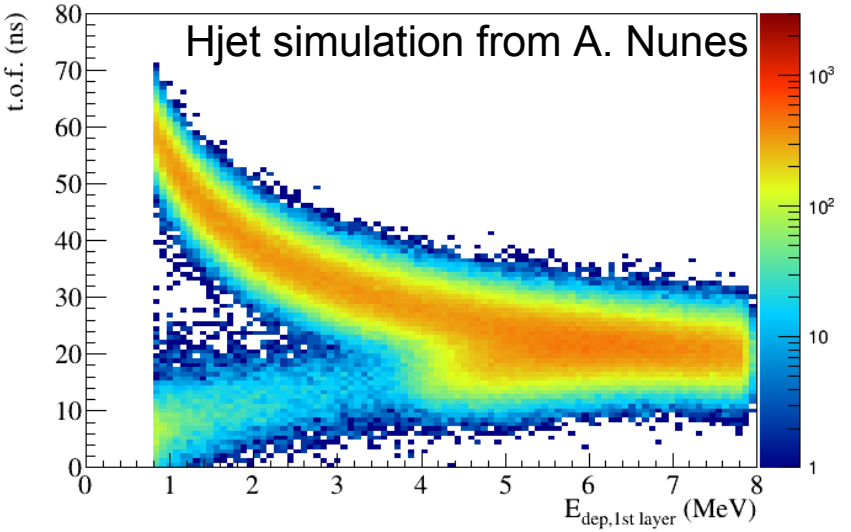
Background sources

Guided by simulations

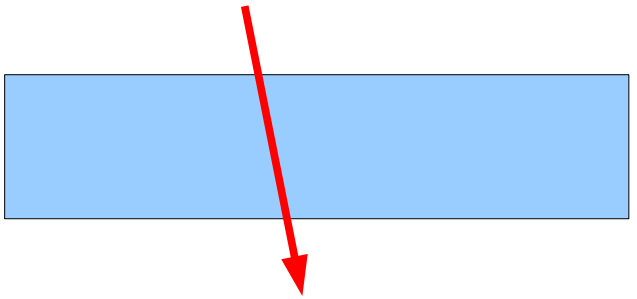
- "Banana" curve:
  - stop inside detector, E fully contained
  - follows TOF $\propto 1/\sqrt{E_{kin}}$ curve until cutoff 7-8 MeV







- Limb downward from right of "Banana" curve:
  - "punch-throughs" pass through detector
  - lower TOF → higher E_{kin} → smaller dE/dx
- Accumulation @ lowest E_{kin}, TOF:
  - pileup of very high E_{kin} p, π

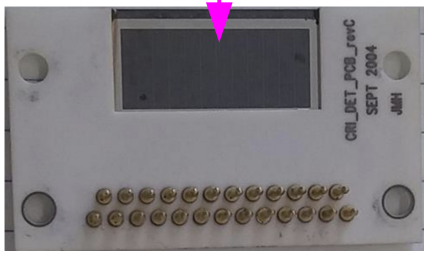


Test hypothesis: add 2nd detector layer, tag "punch-throughs"

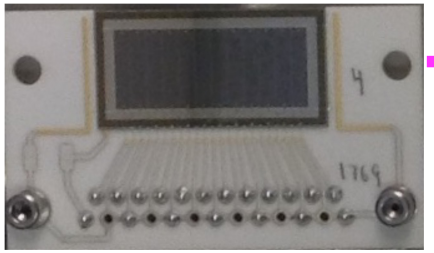
2nd detector layer tests: pC

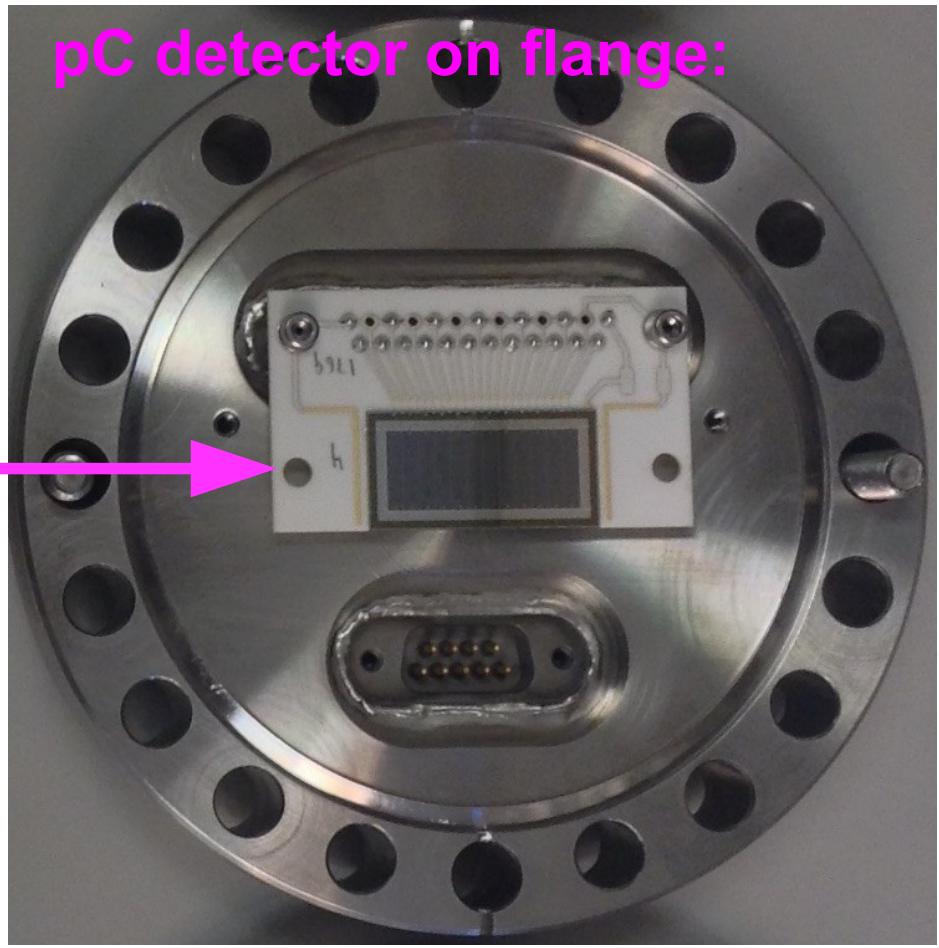
- Preliminary test w/ Hjet detector done already
  2 det. layers had ceramic board between, E loss; results inconclusive
- pC detectors have ceramic cutout:

bottom view:



top view:





Plan RHIC Run22:

- New feedthrough in flange
- Mount 2nd det. (rotated 180°) above 1st
- Readout in existing chain:
  electronics, DAQ, software, ...
- Try in 2 (of 24) pC detector ports
- Data coming: “punch-throughs” in pC, compare simulations …

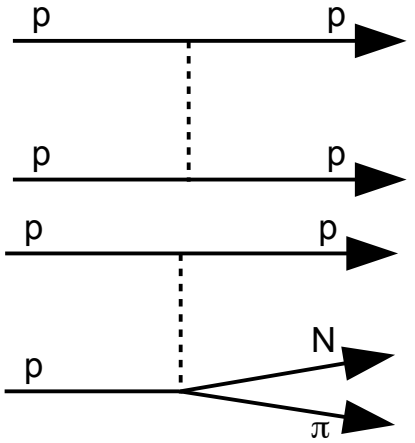
minimal new materials: new flanges/feedthroughs, preamp box mods.

2) Absolute polarim.: elastic scat.

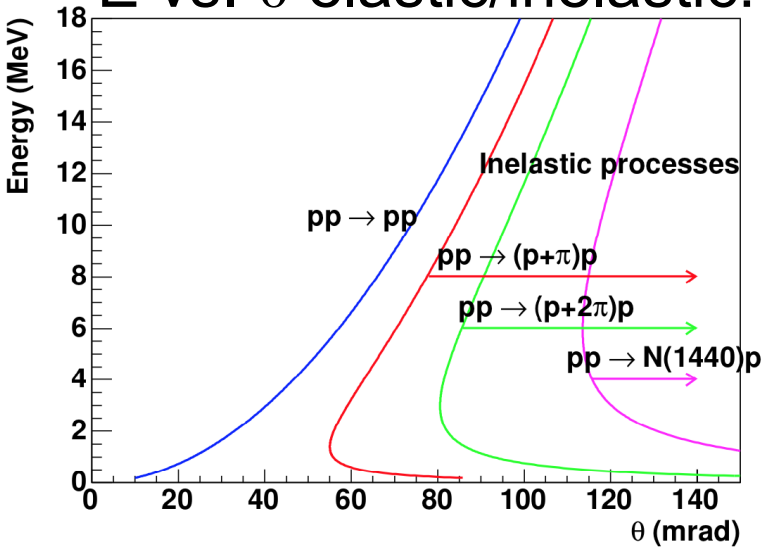
- Absolute polarimetry requires elastic scattering

  - Absolute proton polarimeter: pp→pp

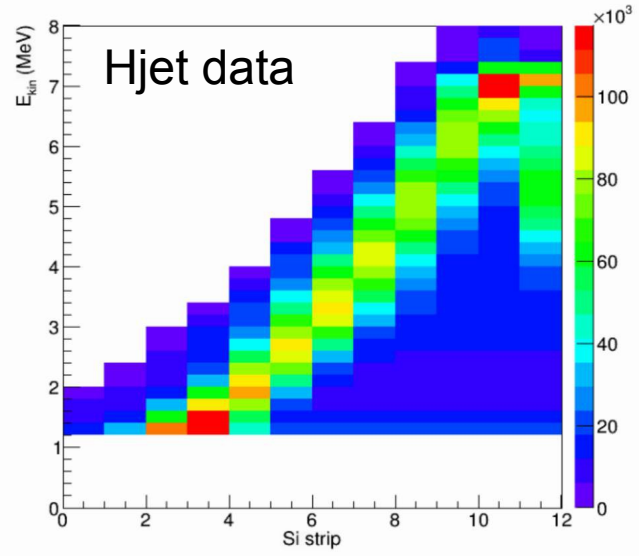
  - Lowest lying p breakup state is p→Nπ,
    $\Delta m = m_\pi \sim 140$ MeV



- E vs. θ elastic/inelastic:



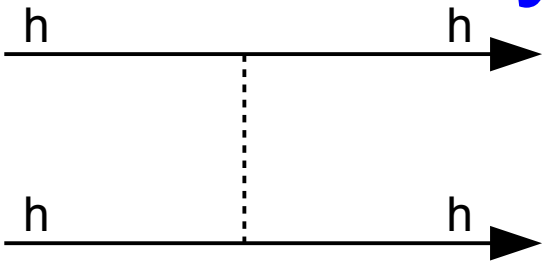
- Strip # ∝ scattering angle θ:
  (slide 3)



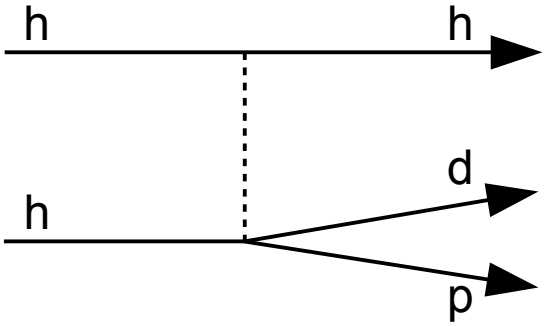
- Select E range / strip: reject inelastic pp → ppX
- Sufficient (E,θ) resolution in recoil detector
  to distinguish mass gap $\Delta m = m_\pi \sim 140$ MeV

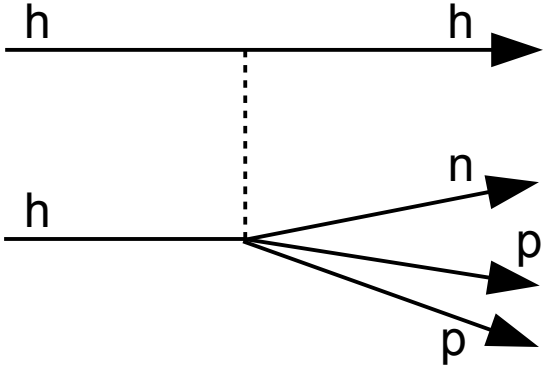
^{3}He absolute polarimetry

- Absolute ^{3}He≡h polarimeter: hh→hh



- Lowest lying h breakup state is h→dp, $\Delta m = m_d + m_p - m_h = 5.5$ MeV
- Next is h→npp, $\Delta m = m_n + 2m_p - m_h = 7.7$ MeV

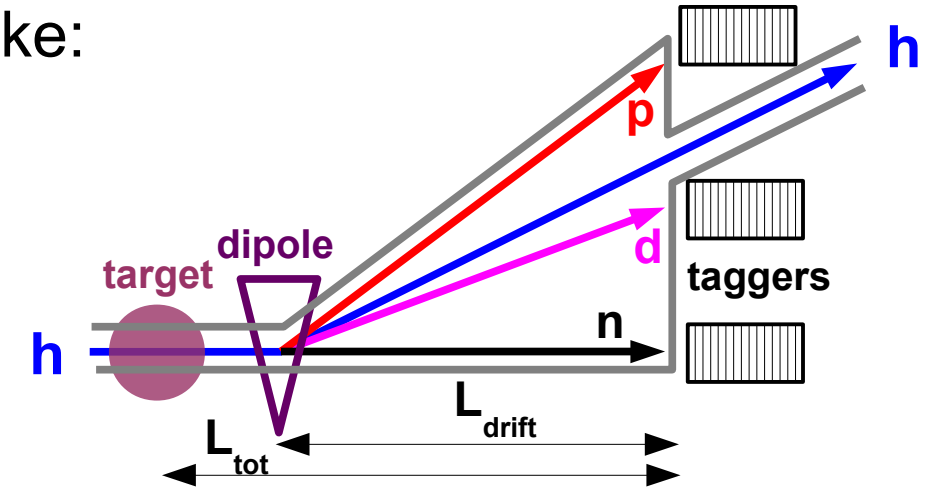




- If breakup vertex is target recoil: d,p,n may hit recoil detectors
  - rejected by energy-TOF PID h selection
- If breakup vertex is beam recoil: target h may hit polarim. detectors
  - recoil target h missing mass measurement needs ~MeV resolution to distinguish from elastic, very challenging
- Can we tag beam breakup downstream from target?

Tagging ^{3}He (≡h) breakup @ EIC

- At breakup threshold, fragments travel colinearly with beam; fraction of beam rigidity R_h: $R_d = 4/3R_h$; $R_p = 2/3R_h$; $R_n = \infty$
- Dipole single bend approx., beam bent by θ_h: $\theta_d = ¾\theta_h$; $\theta_p = 3/2\theta_h$; $\theta_n = 0$
- Require: arrangement target → some dipole → drift space → taggers might look like:



- Require: drift space L_{drift} long enough to get fragments out of beampipe vacuum and into taggers
- Fragments from breakup @ threshold define 0° point in taggers; breakup above threshold spread around this point
- Require: total target→tagger distance L_{tot} as small as possible, maximize tagger angular acceptance

Tests @ RHIC next years

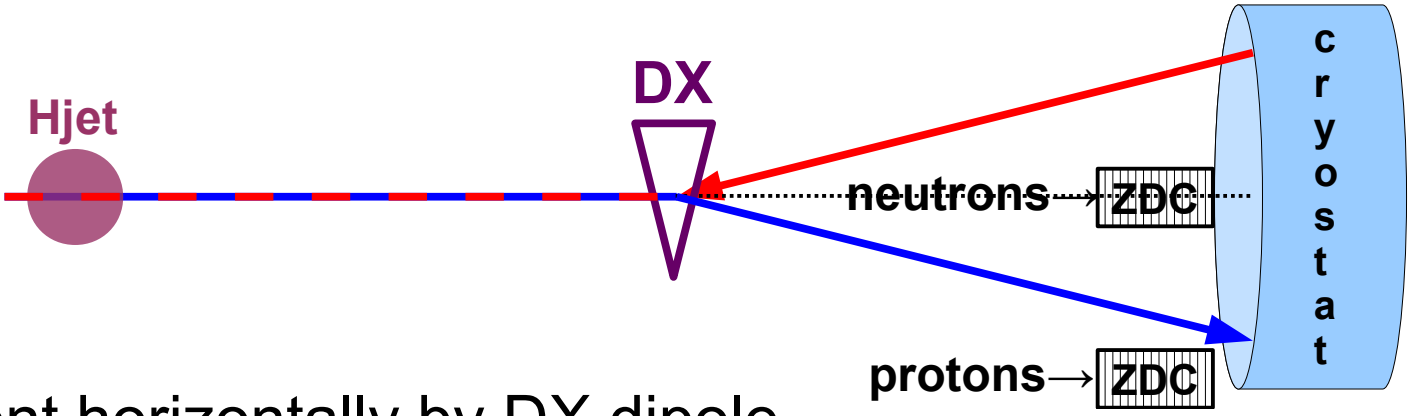
Can test h breakup with:

existing Hjet p target → p + p

h beam (APEX session) → h + n + p + p

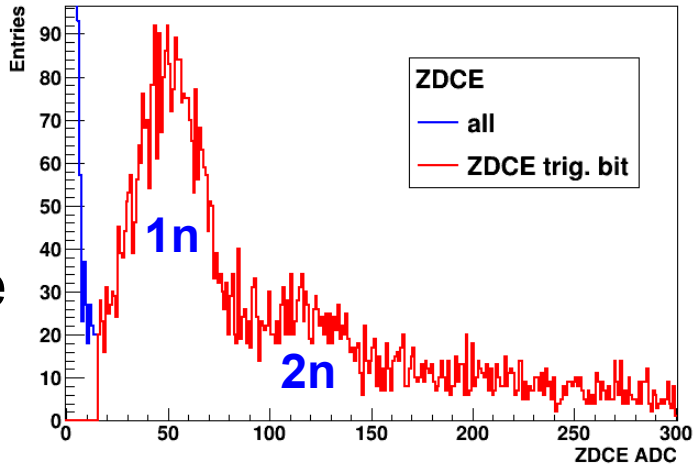
(APEX = Accelerator Physics EXperiments, in RHIC schedule)

- Downstream (Blue beam direction) from Hjet @ IP12:



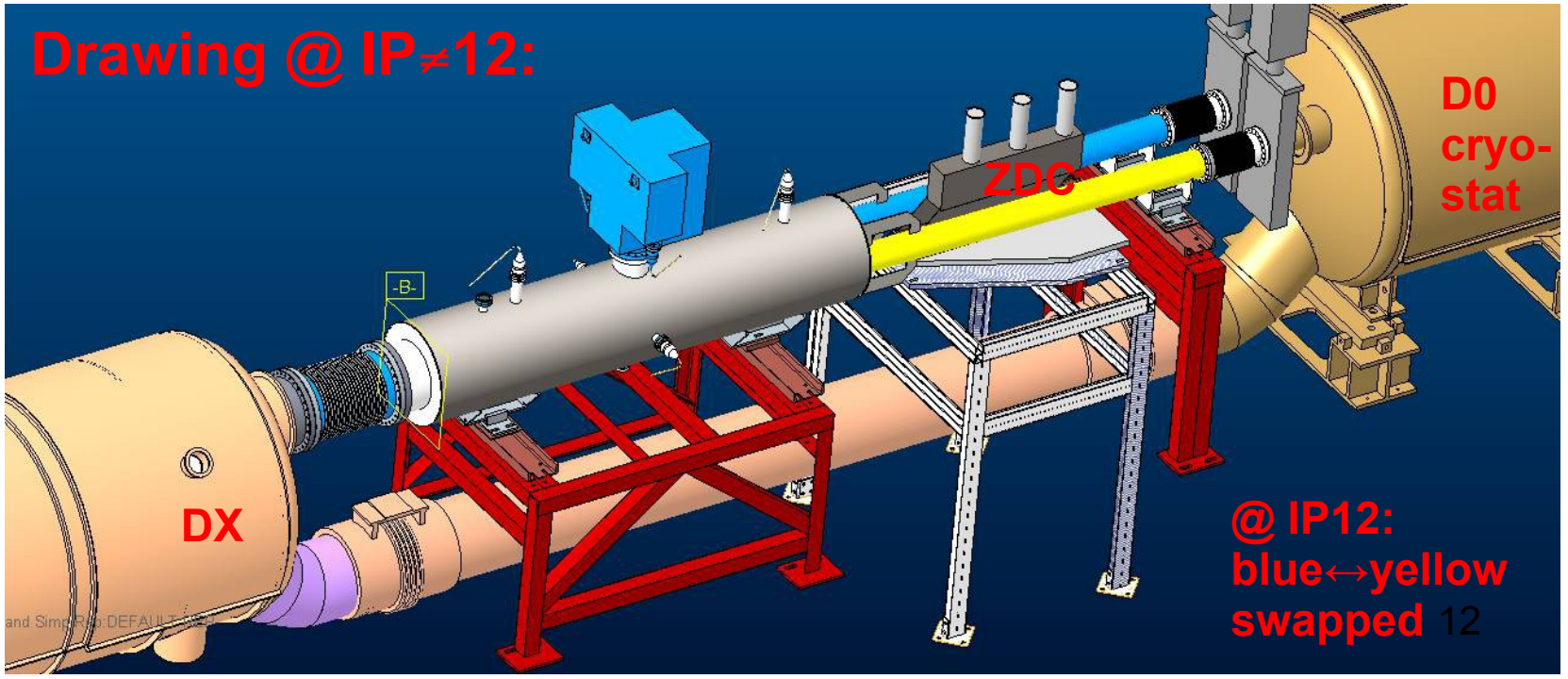
deuterons scrape beam pipe, no space for tagger

- Beams bent horizontally by DX dipole
- Space for taggers up to ~18 m, blocked beyond by cryostat
- 2 Zero Degree Calorimeters (ZDCs) from old Phobos experiment available
  - mediocre hadronic calorimeter
  - adequate for tagging



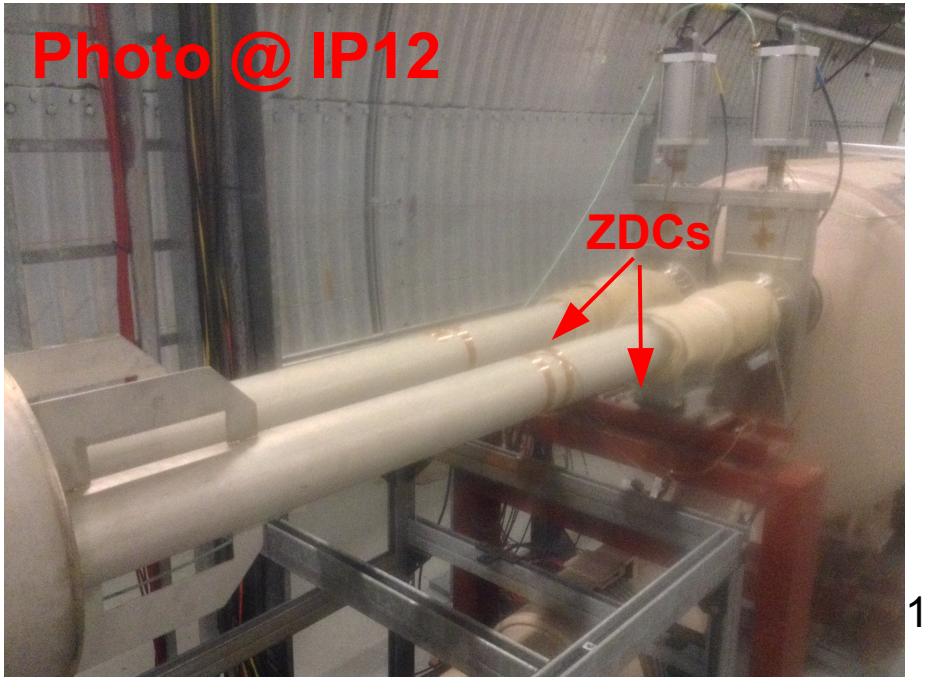
100 GeV neutrons

Tests @ RHIC next years



- Spare ZDCs between/outside beampipes after DX
- Readout into existing Hjet DAQ, correlate:
  target recoils ↔ ZDC hits
- Data coming: ^{3}He breakup tagging

minimal resources: install ZDCs,
~10 new signal/HV cables



3) C target lifetime

- Targets often happily sweeping across beam:

- But eventually:
  few sweeps ☹
  dozens sweeps 😐
  100's sweeps ☺
- Targets break

<u>@ RHIC</u>

- Simulation: target heating via beam dE/dx, RF
- Heated target sublimates away
- Correctly predicts best observed target lifetimes

<u>@ EIC</u>

- Higher: total beam current → dE/dx heating
  bunch frequency → RF heating
- Simulation predicts lifetime few seconds, sweeps; not viable

<u>Need alternative</u>

- Discussions w/ materials experts started (e.g. BNL CFN)
  no good options found yet
- Alternatives can be tested in RHIC pC polarimeters

Timeline

RHIC's final years

- Polarized proton runs 2022 (start Nov. 2021) & 2024
  - any tests with Hjet, pC polarimeters
    as discussed here, others we think of
- Heavy ion runs 2023 & 2025
  - AGS w/ polarized protons @ 24 Gev available behind RHIC fills
  - AGS has a pC polarimeter
    can do lower energy pC tests (2nd det. layer, targets. …)
- Will exploit opportunities @ RHIC → EIC polarimetry R&D