OLD DOMINION UNIVERSITY

The Machine-Detector Interface & Polarimetry

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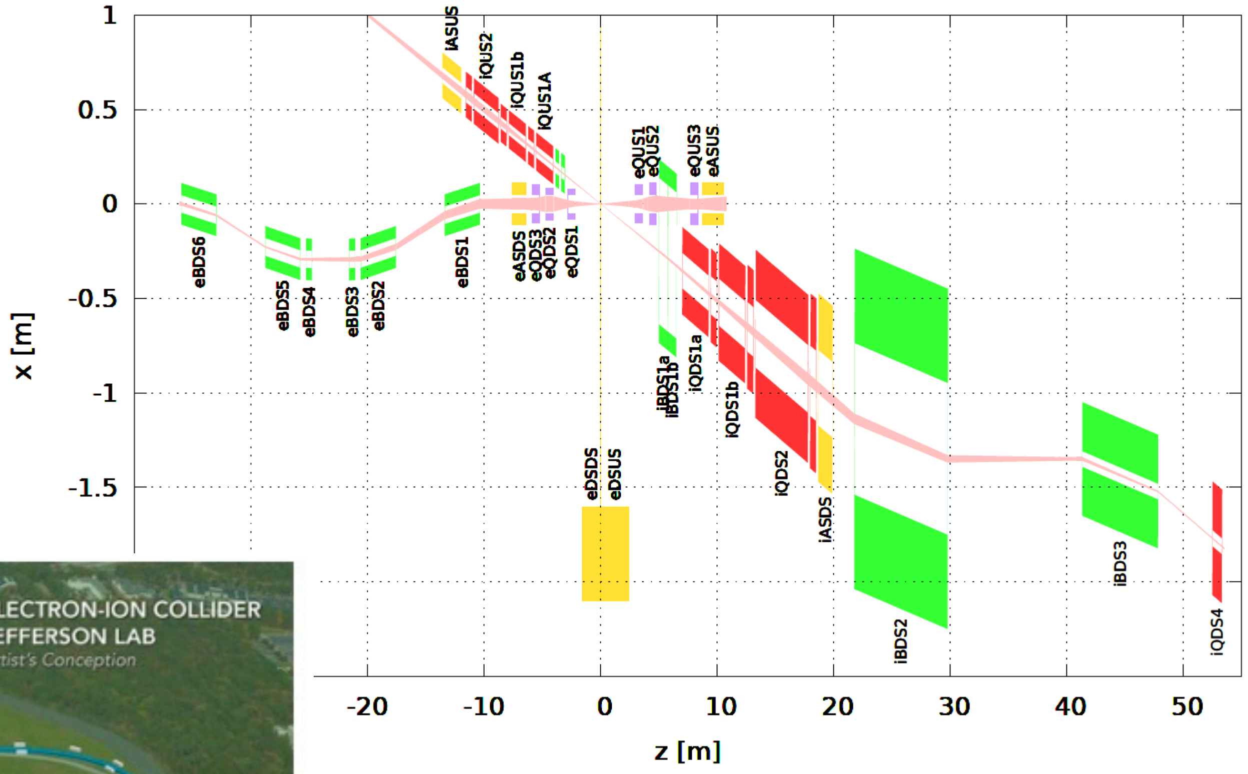
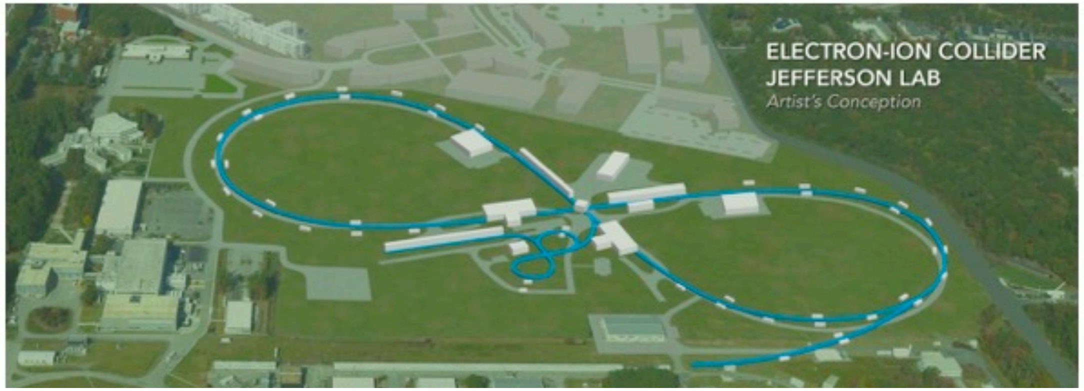
Interaction Region is the Whole Machine

- Forward Tagging
- Spin Transport
- Polarimetry
- Luminosity Measurement



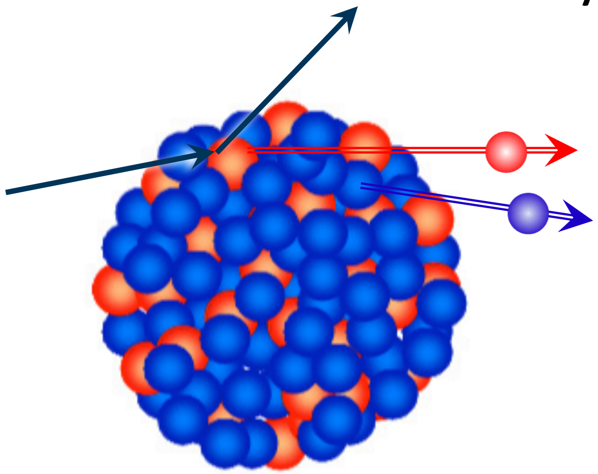


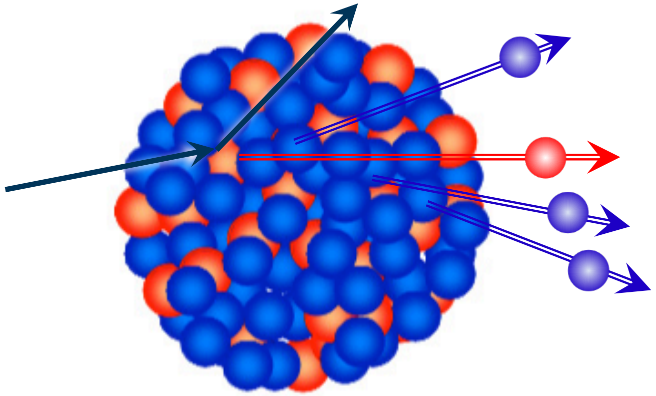
Ion Forward Detection: I.

- Spectator neutrons, protons in light nuclei
  - Rigidity K = momentum/charge
  - Proton in deuteron $(K_p - K_d)/K_d = -1/2$
  - Neutron in deuteron $\frac{\Delta K}{K_d} = \infty$
  - Proton in ^{3}He: $\left(K_p - K_{He}\right)/K_{He} = -1/3$
  - Deuteron in ^{3}He: $\left(K_d - K_{He}\right)/K_{He} = +1/3$
- Resolve the quark-gluon structure of a nearly free nucleon when spectator nucleon has momentum ZP_0/A
- Resolve interacting nucleons via large rigidity shift (+/– 10%)

Ion Forward Detection: II.

- Residual Nuclei in Heavy Nuclei
  - ^{207}Pb in ^{208}Pb : $\frac{\Delta K}{K} = -0.48\%$ at the limit of 10σ beam envelope
  - ^{207}Th in ^{208}Pb : $\frac{\Delta K}{K} = +0.75\%$
- Tag the eA impact parameter:
  - Tag on [top 3%] baryon multiplicity, smallest residual nucleus:
  - Boost the sensitivity (~x2) to gluon saturation



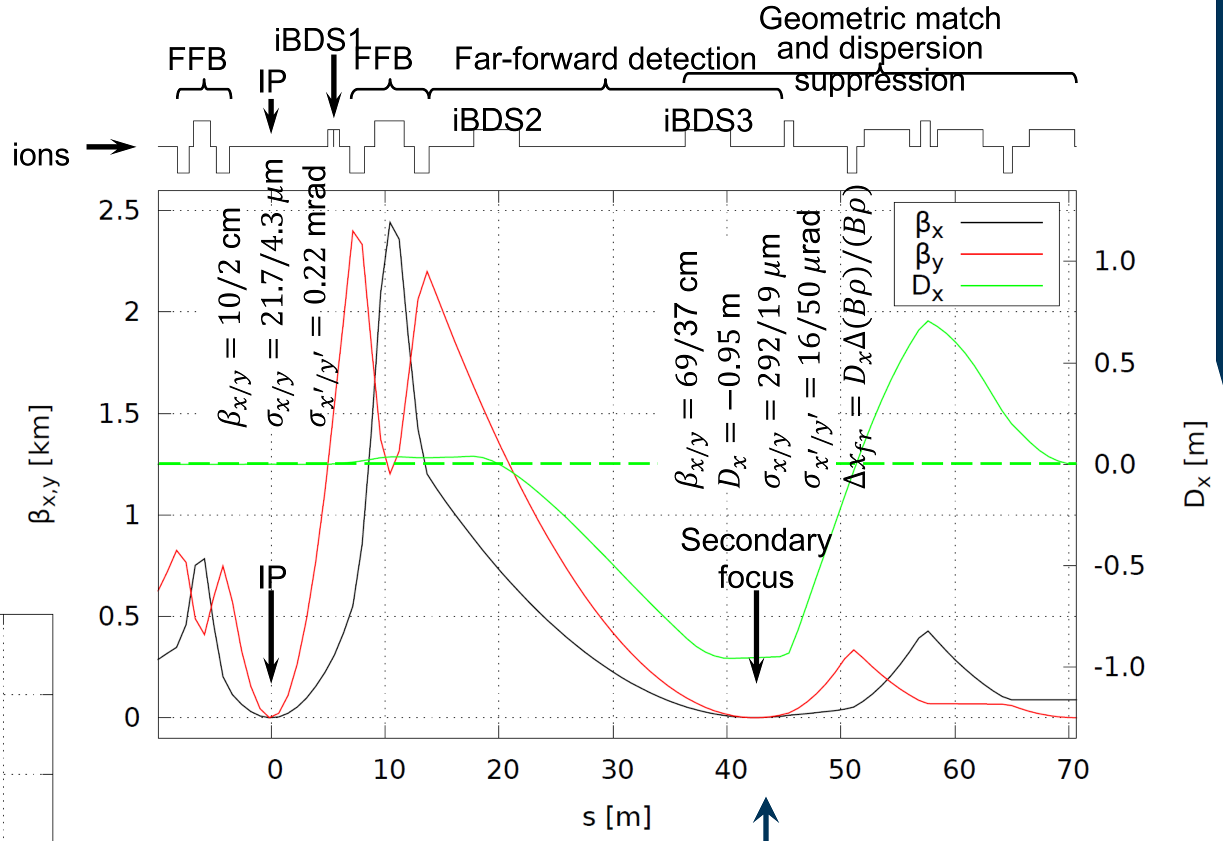


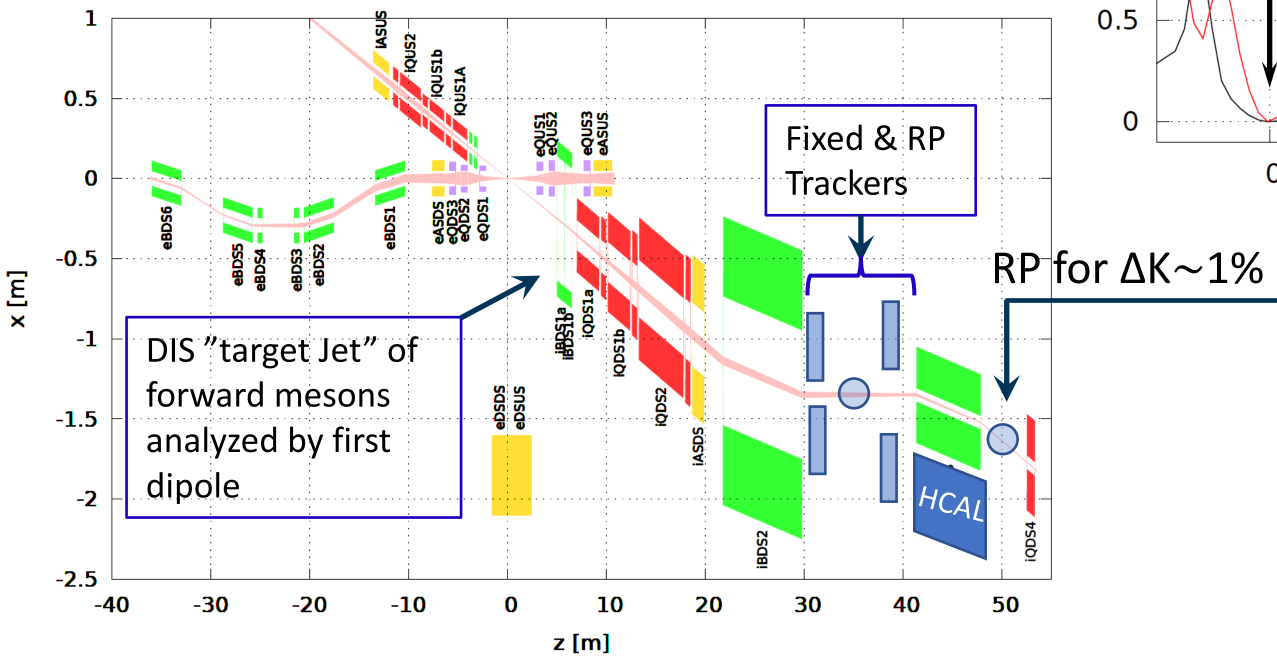
Ion Forward Detection: III.

- Femtography:
  - Deep Virtual Exclusive Reactions
  - $e + {}^{A}Z \rightarrow e + {}^{A}Z + V$, $V = \gamma$, $\boldsymbol{\rho}, \phi, \pi$, K, J/$\Psi$,…
  - ${}^{A}Z$ = p, d, He tag final state nucleus for $x_B > 0.005$
  - Medium to Heavy nuclei, veto on forward break-up
    - Detectors inside Dipole-3

Forward Tagging and target jet

Better, updated images of tracking detectors:
D. Romanov [Update on JLEIC Detector Design]
Morning Detector Session



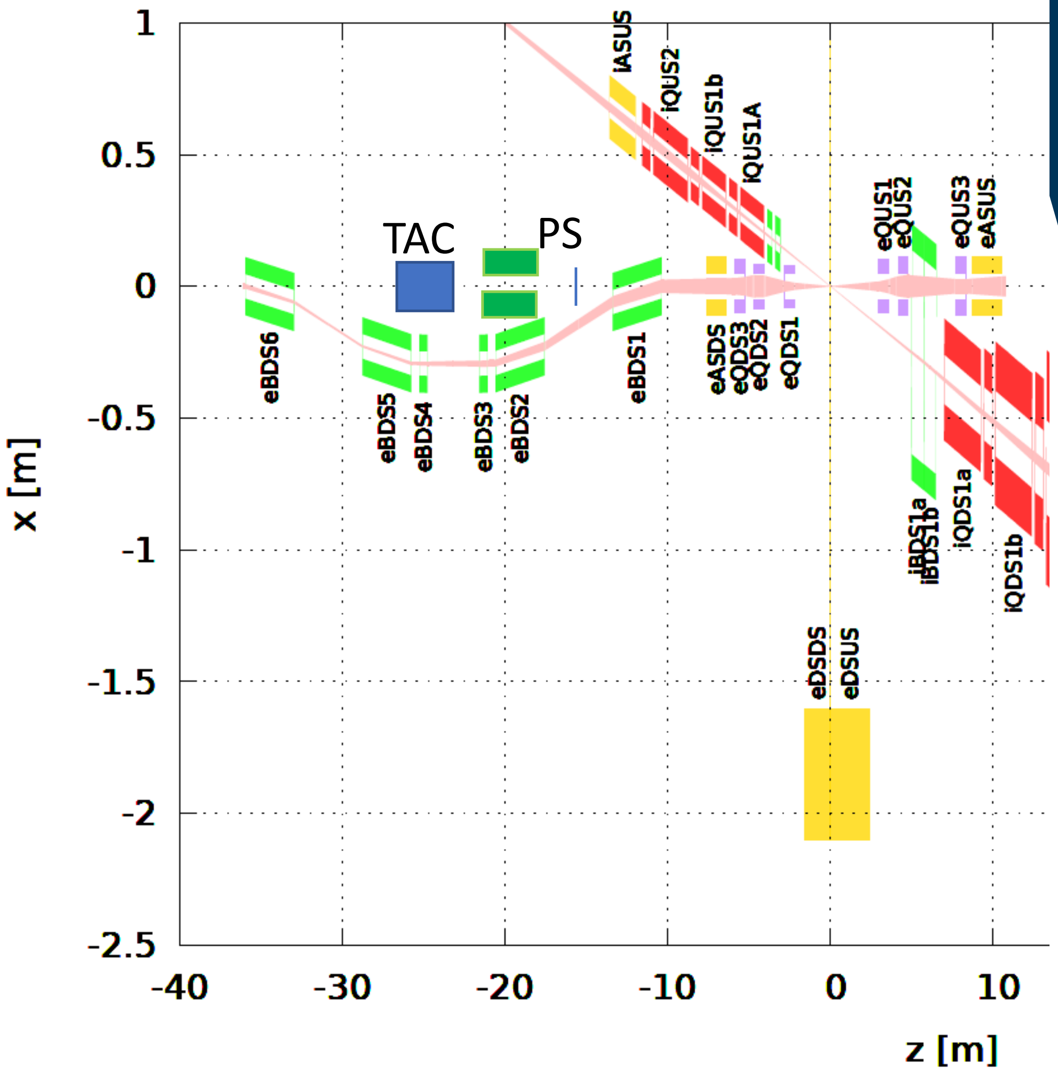


Electron Beamline

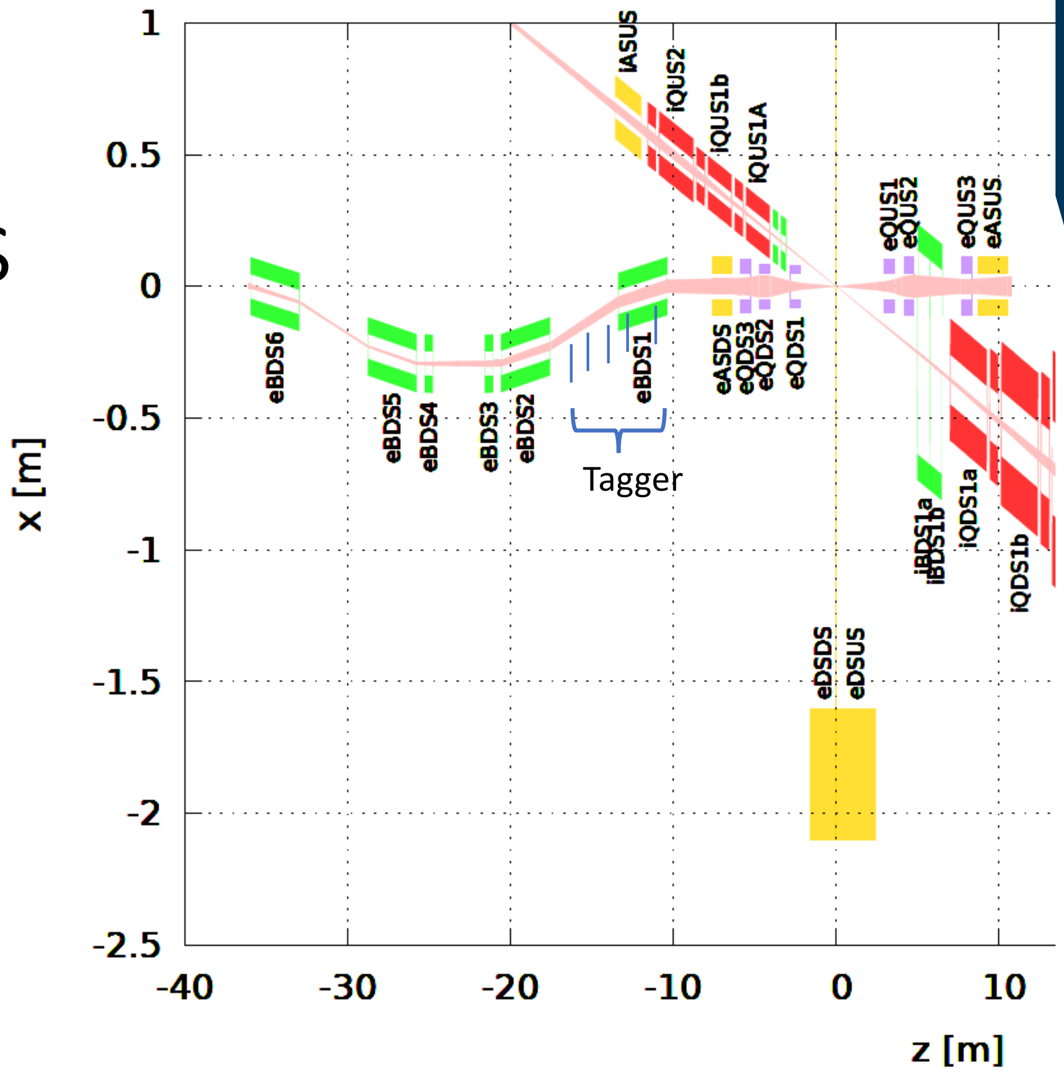
- Several kilowatts of synchrotron radiation in Interaction Region from upstream electron quads.
  - Mostly from beam halo
  - 1 cm radius cooled collimator 1m upstream of IP
  - 3 cm radius central beam chamber
    - PEP-II: 2 layer Be beam pipe with water cooling middle layer
      30 μm gold inner coating to absorb soft X-rays
    - eRD21 R&D study in progress of vertex tracker occupancy
- Downstream Chicane
  - Electron Compton Polarimeter
  - Post-vertex tagging of quasi-real photo-production
  - 0° Beamline for luminosity monitor (photons)

Luminosity Monitor

- 0° line in eBDS1
  - Vacuum line to TAC
- Bremsstrahlung flux into TAC
  5 GeV/bunch @ L=10^{34}/cm^2/sec
  - Total Absorption Calorimeter (TAC) technology is challenging
    Liquid Ar ionization?
    Quartz W sandwich sampling?
- Space is cramped for vertical bend Pair-Spectrometer (PS)
- ECal in front of eQDS1 is 3rd technology for Luminosity Monitor



Quasi-Real Photons, Zero-Degree Electrons



- eBDS1 (& matched eBDS6) are C-magnets with open aperture for photon tagging
- Tagged $\boldsymbol{\gamma}$p luminosity
  - $dL_{\gamma p} \approx t^V L_{ep} \frac{dk_\gamma}{k_\gamma}$
  - $t^V = (\cdots)\alpha_{QED} \approx 0.02$
  - $L_{\gamma p} \approx t^V L_{ep}$ for $k_\gamma > k_e/3$

Electron Polarimetry: Laser Compton Backscattering

- eBDS1 (& matched eBDS6) are C-magnets with open aperture for photon tagging
- Tagged γp luminosity
  - $dL_{\gamma p} \approx t^V L_{ep} \frac{dk_\gamma}{k_\gamma}$
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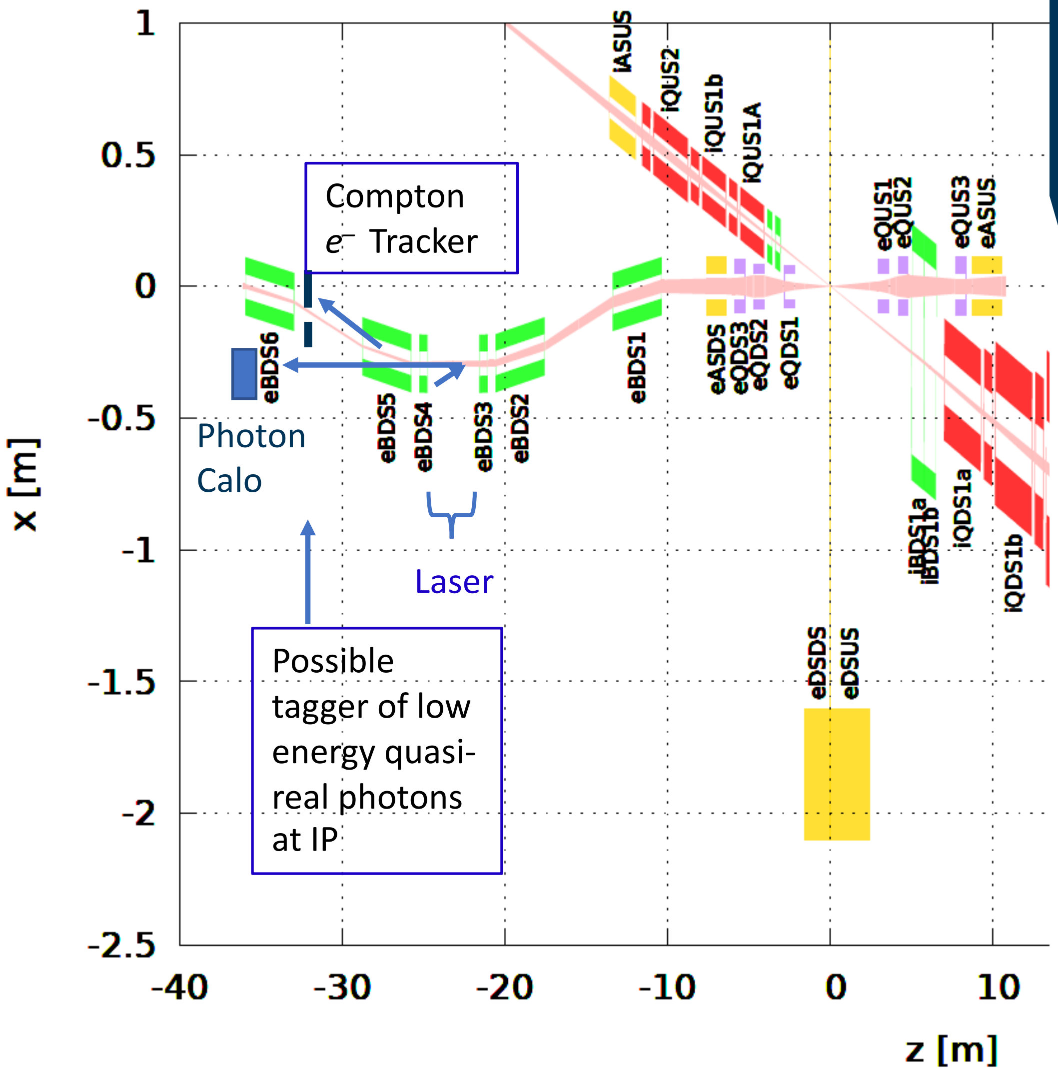
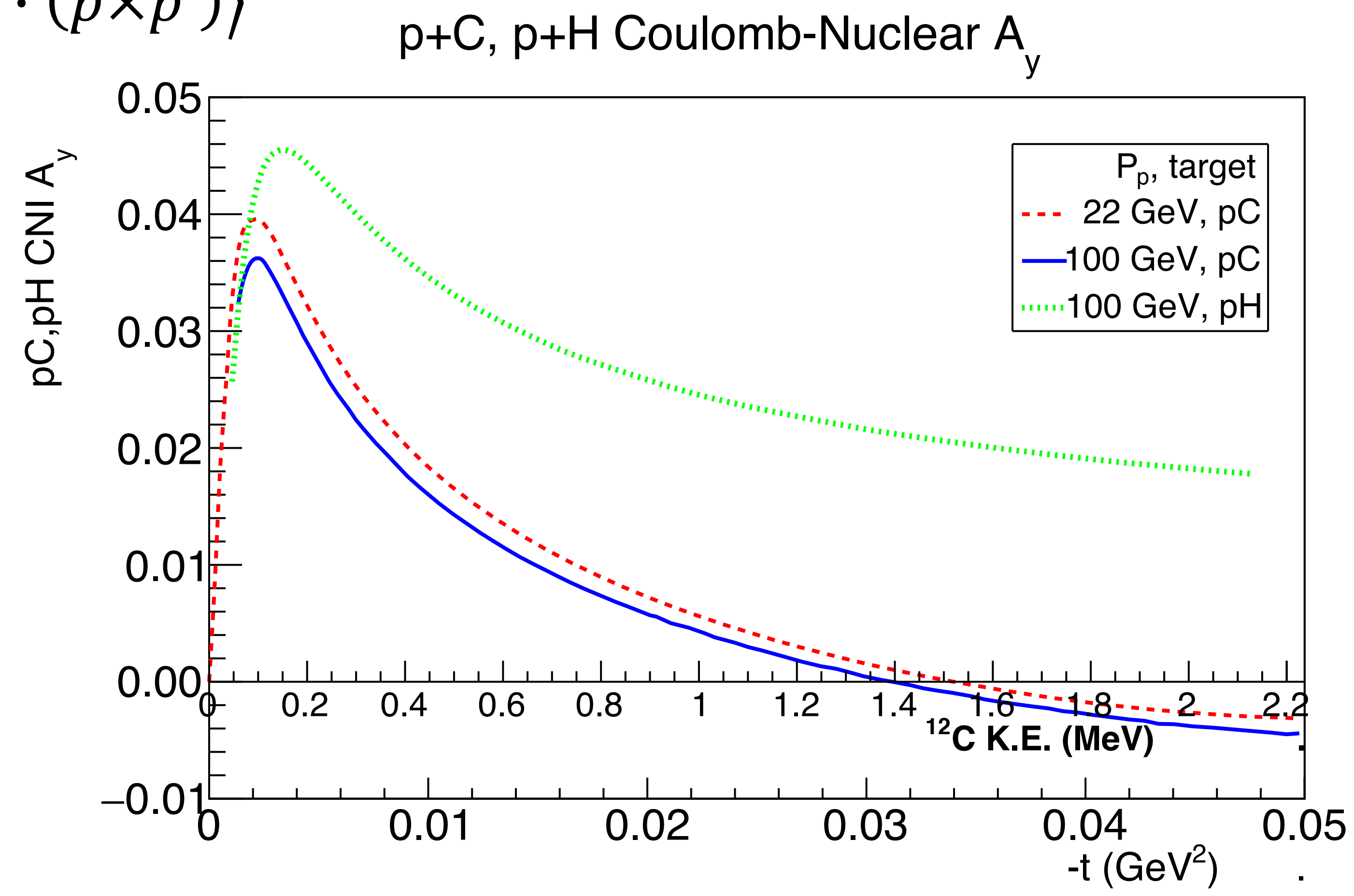


Ion Polarimetry

- RHIC
  - Coulomb Nuclear Interference: tag slow recoils near 90° from “fixed target”
  - $\vec{p} + \vec{H}(atomic\ jet) \rightarrow p(90°) + X$
    - Absolute polarization, but slow ~ 1/fill
  - $\vec{p} + C(foil) \rightarrow C(90°) + X$
    - Fast, but relative polarization only
- Deuterium, ^{3}He
  - Need dedicated polarized atomic jets
  - For deuterium, coherent n and p approximately cancel
    - Resolve n, p scattering by tagging scattering angle of downstream “beam” proton
    - $\vec{d} + C(foil) \rightarrow C(90°) + p(> 0.5 mrad) + X$
    - Diffractively scattered proton from beam has half the momentum of the deuteron

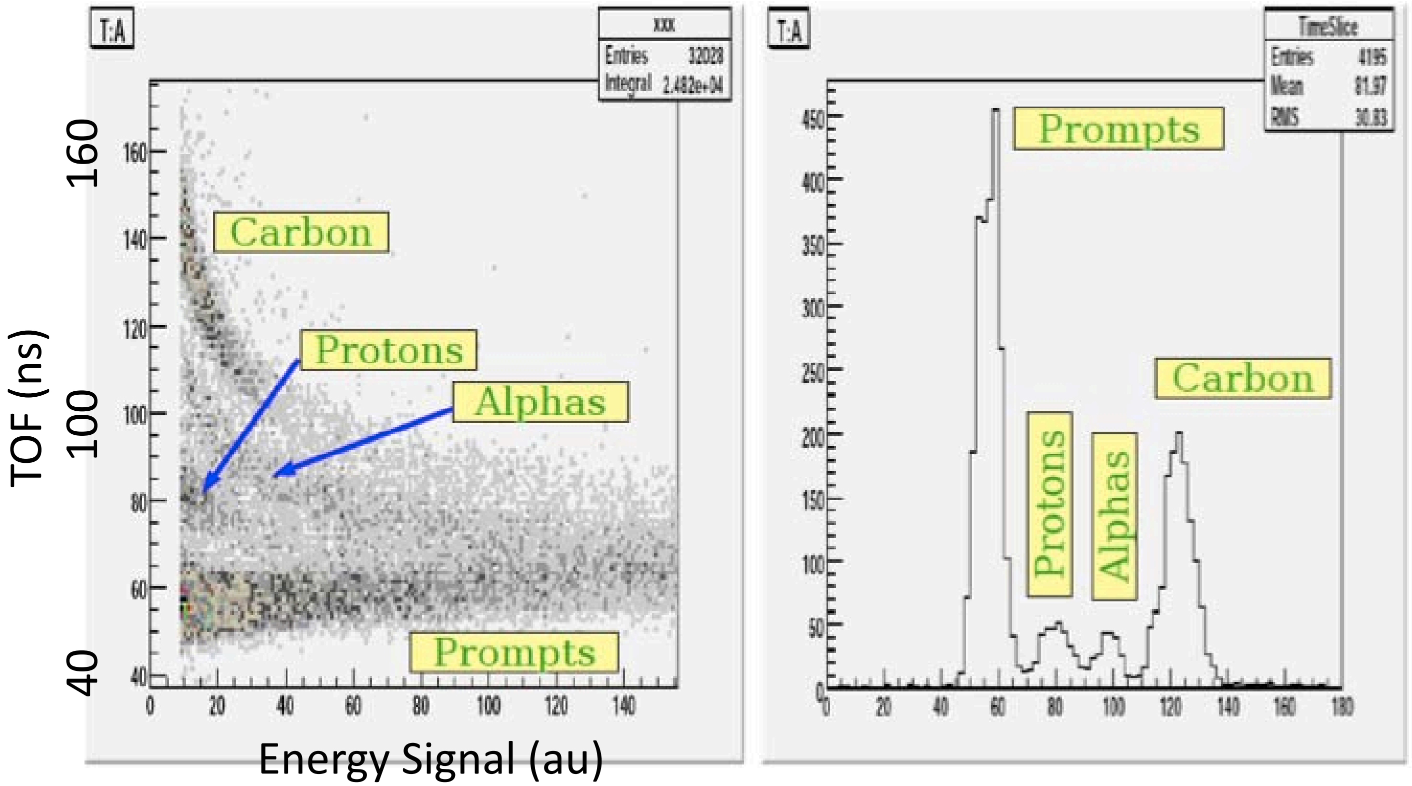
Coulomb-Nuclear Interference: pC and pH Scattering

- $A_y = \langle \sigma_p \cdot (p \times p') \rangle$



Energy-Time Correlation

RHIC pC



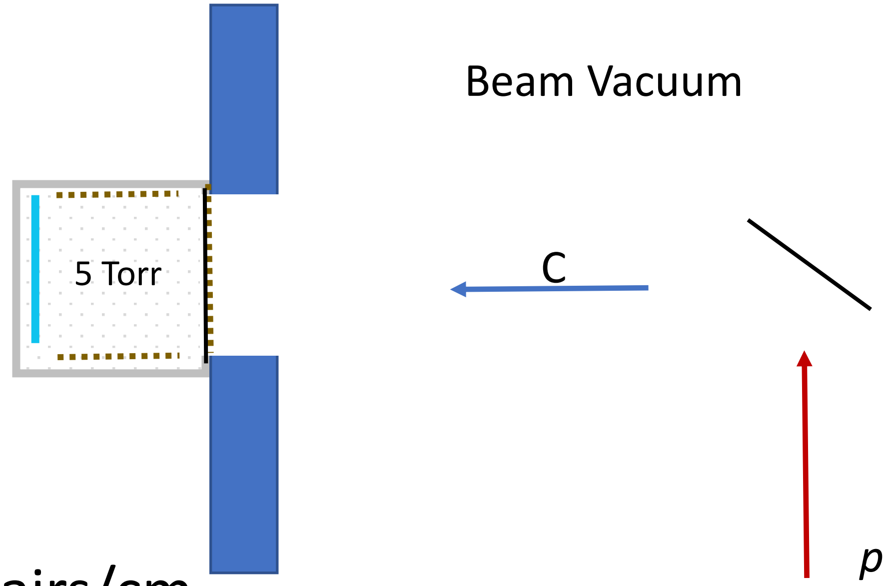
- Impossible to resolve C signal from p, α, π background with EIC bunch rep rate of 2 – 10 ns

Possible/Necessary Improvements for EIC
(relative to RHIC even for protons)

- Thinner C foil target
  - RHIC foils are 5 μg/cm^2
  - Graphene?
    - Resolve energy-angle correlation of scattering vertex
- Improved timing & energy resolution of Si sensor
  - Current energy resolution is >10x worse than statistical limit
  - Timing resolution of 10 ps 'advertised' for future LGAD sensors
  - Thinner Si sensor (50 μm) backed by punch-through detector
  - Thin gas counter (5 Torr, with ultrathin window) for ΔE detector
- Downstream spectrometer
  - High β at polarimeter target, resolve scattering angles > 0.5 m at secondary focus after first dipole

Thank you

- *p, α, C* PID from ΔE/E measurement
- Borrow concepts from low energy nuclear physics
- 5 Torr gas detector ~ 1 cm in front of Si-strip detector
  - Vacuum window must be as thin as target foil ($5\ \mu g/cm^2$). Support window with micro-mesh.



- C energy loss ≤ 0.1 MeV/cm in 5 Torr CO_2
- ≤ 3000 e^-ion pairs/cm

Polarimetry Conclusions

- R&D needed
  - Feasible with existing beams at RHIC, Jlab
- References

  - HOkada_*etal*_pp_AN_CNI_PhysLettB_6**38**(2006)450
  - YMakdisi Journal of Physics: Conference Series 295 (2011) 012130 doi:10.1088/1742-6596/295/1/012130
  - HHuang_RHIC_pC_IBIC2014_mopd01
  - H.Huang, IPAC 2015 Richmond VA, BNL-107425-2015-CP
  - B. Z. Kopeliovich, T. L. Trueman PHYSICAL REVIEW D, VOLUME 64, 034004
  - K. Shima, Phys Rev A **40** (1989) 3557
  - I.G. Alekseev, AIP Conf Proc **675**, 812 (2003); https://doi.org/10.1063/1.1607247
  - J. Tojo, *et al*, PRL **89** (2002) 052302-1
  - W.R. Lozowski, NIM **590** (2008) 157

Van der Meer Scans

- Absolute determination of Luminosity
  - Monitor a physics rate as the colliding beams are scanned across each other in 2D
  - Requires precision measurement of beam currents and collision centroid stability (3-D)
  - Does not require *a priori* knowledge of cross section.
- Interupts experimental data taking
  - Not a continuous monitor
- V. Balagura, NIM A **654** (2011) 634–638
  - RHIC: (IPAC'10, Kyoto Japan, May 2010 proceedings)
    - K.A. Drees, S.M. White, Vernier scan results from the first RHIC proton run at 250 GeV,
  - LHC:
    - M. Ferro-Luzzi, Determination of the luminosity at the LHC experiments, in: Proceedings of ICHEP'10, Paris, July 2010, published in PoS (ICHEP 2010) 010:
    - S.M. White, et al., First luminosity scans in the LHC, in: Proceedings of IPAC'10, Kyoto, Japan, May 2010.

Bremsstrahlung

- At $\mathcal{L} = 10^{33}$ */cm²/sec:*
  - Bremsstrahlung power ~ 0.04 Watt
  - Angular distribution dominated by *rms* angular spread of e^- beam: Photon *rms* ≈ 4 mm @ 20 m
  - Total Absorption ECal dose (10^7 sec exposure per year)
    - 0.4 MGray/year
    - Each photon absorbed in ~ 1 kg of high-Z material
    - Calorimeter options
      - Liquid Argon
      - Quantameter (SLAC 1960s): Alternating HV plates in vacuo
        - D. Yount, NIM **52** (1967) 1 –14
        - R. Anderson, NIM **65** (1968) 195–198
      - Calibrate with electron beam?
  - Pair Spectrometer (ZEUS method)
    - Rate is tunable (detector out of synchrotron and brem beam)

QED Compton: HERA experience

- Challenges:
  - acceptance, alignment, absolute precision
- E. Aaron (H1 collaboration) Eur. Phys. J. C (2012) **72**:2163
  - DOI 10.1140/epjc/s10052-012-2163-2
  - Erratum DOI 10.1140/epjc/s10052-014-2733-6
  - Electron gamma detection at 10° to 25° from e^{-} beam
- Theory:
  - A. Courau, P. Kessler, Phys Rev D 46 (1992) p. 117
  - K. Gaemers, M. van der Horst, Nuclear Physics B **316** (1989) 269-288: (Small angle theory, simulation)
- Compton22 Generator:
  - V. Lendermann, *et al.*, Eur. Phys. J. C **31**, 343 (2003). hep-ph/0307116

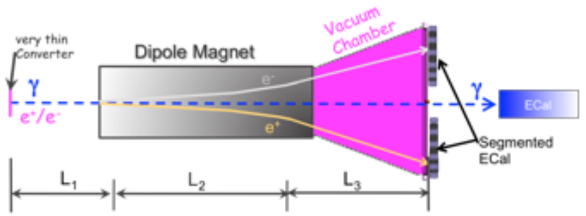
Luminosity Monitor: HERA Summary

Luminosity Detector

Concept:
Use Bremsstrahlung ep → epγ as reference cross section
- different methods:
- Bethe Heitler, QED Compton, Pair Production
- Hera: reached 1-2% systematic uncertainty

Goals for Luminosity Measurement:
- Integrated luminosity with precision $\delta L/L < 1\%$
- Measurement of relative luminosity: physics-asymmetry/10 → ~10^{-4} - 10^{-5}

EIC challenges:
- with 10^{33} cm^{-2}s^{-1} one gets on average 23 bremsstrahlungs photons/bunch for proton beam
  → A-beam Z^2-dependence
- Need more sophisticated solution
- BH photon cone < 0.03 mrad
  → acceptance completely dominated by lepton beam size

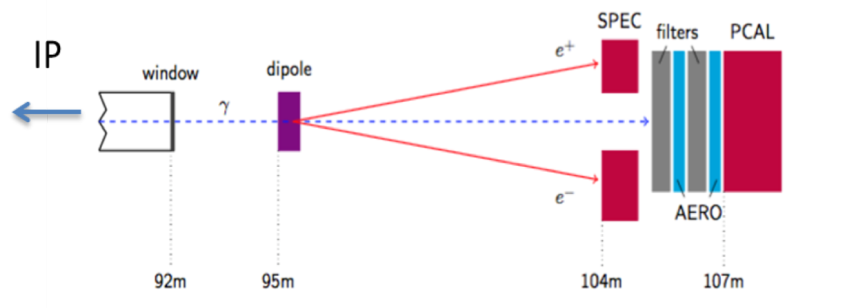


pair spectrometer
low rate
- High precision measurement for physics analysis
- The calorimeters are outside of the primary synchrotron radiation fan

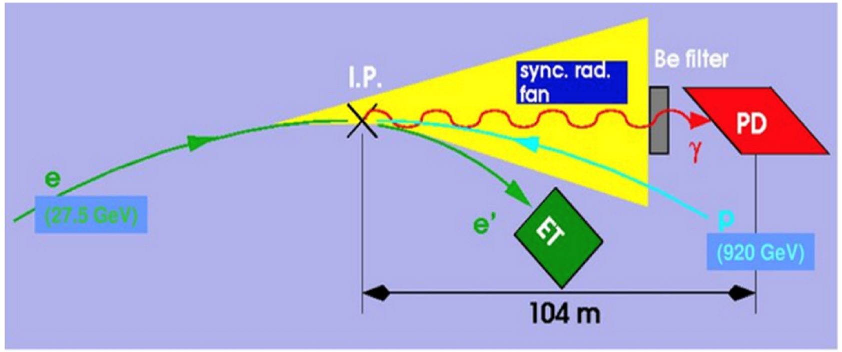
zero degree photon calorimeter
high rate
- Fast feedback for machine tuning
- measured energy proportional to # photons
- subject to synchrotron radiation

E.C. Aschenauer

Set up at ZEUS



At H1



R. Yoshida