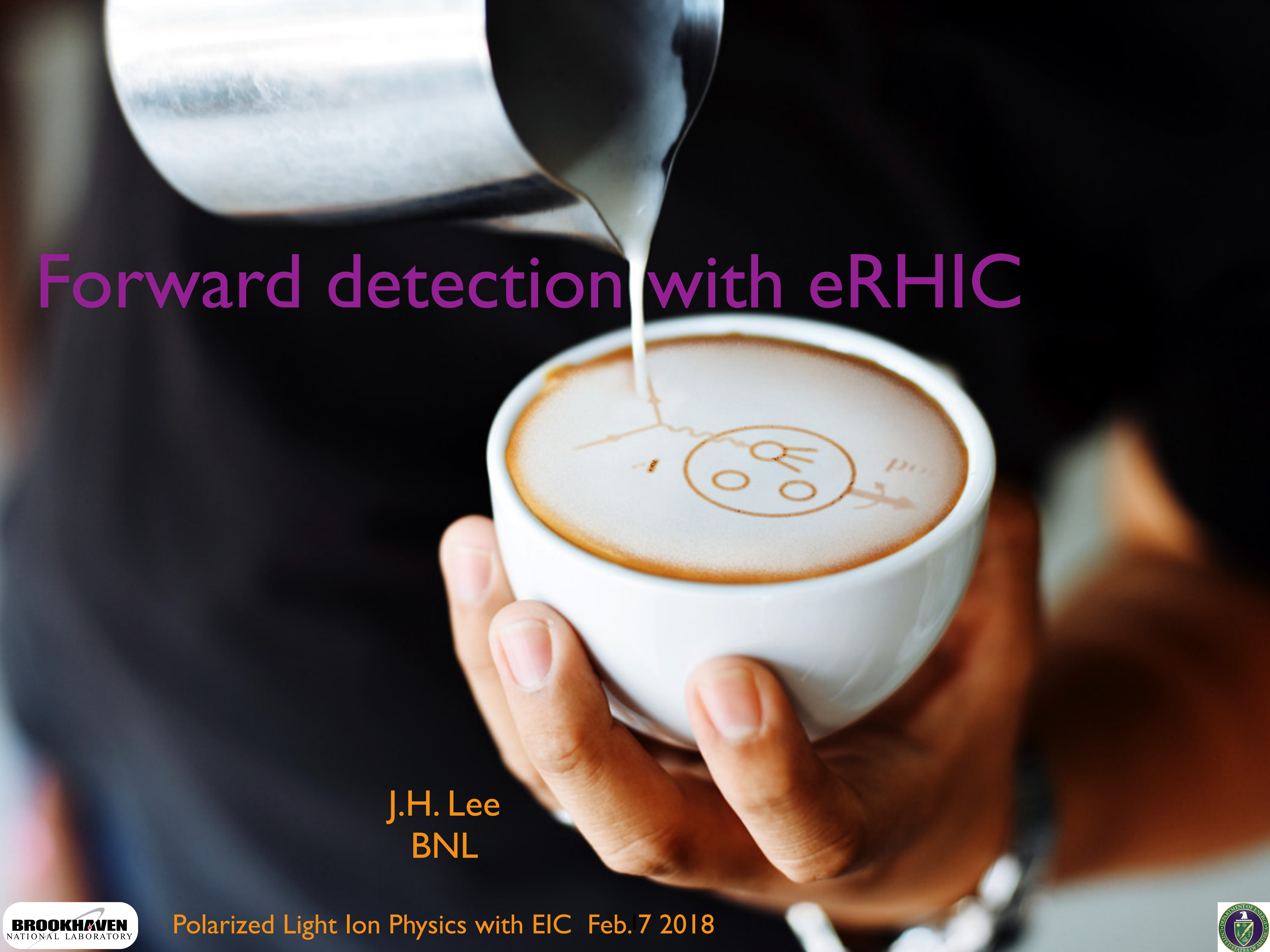


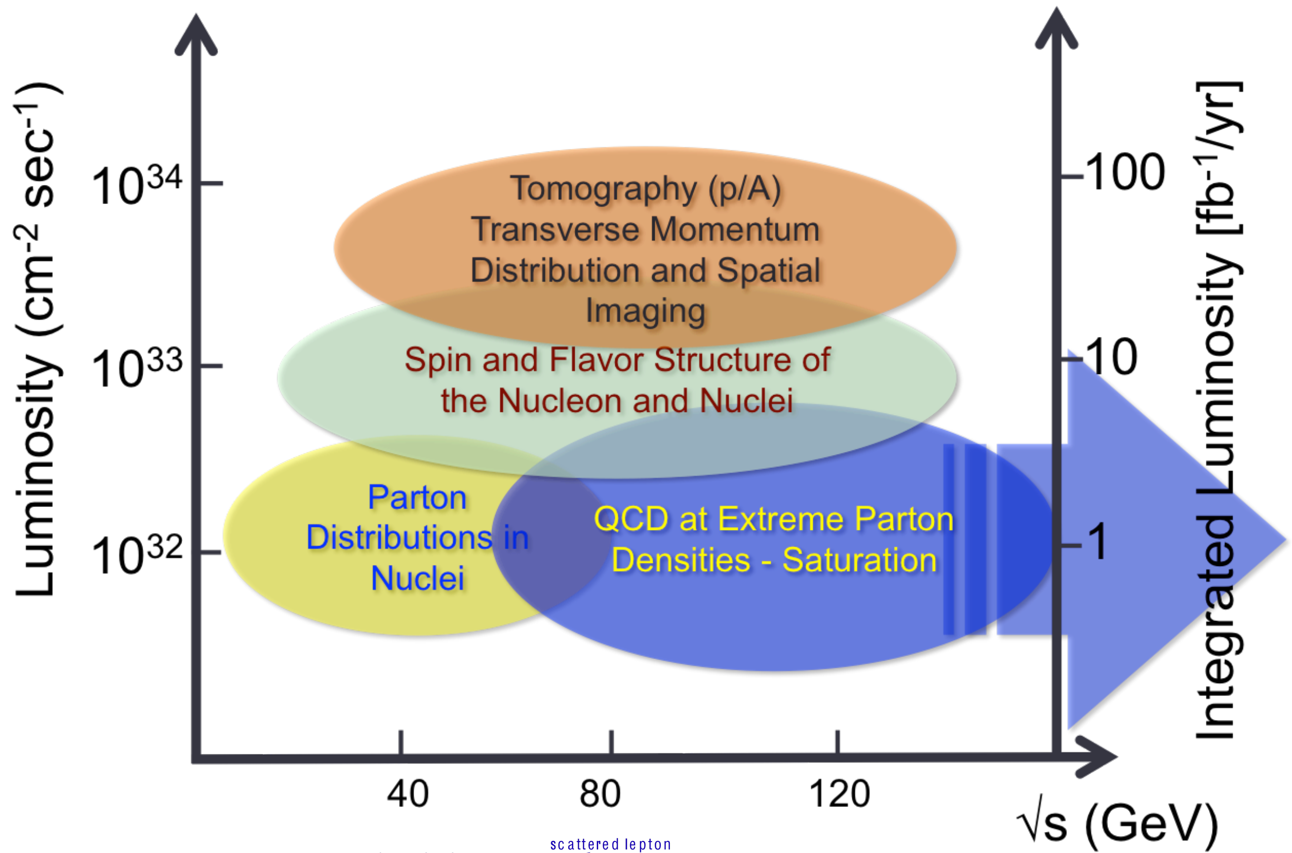
Forward detection with eRHIC

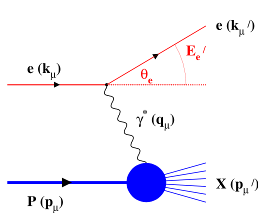
J.H. Lee
BNL

Outline

- EIC physics with (far-)forward tagging
- forward proton and spectator nucleon measurements in ep and eA: What's involved
- Interaction Region integration at eRHIC

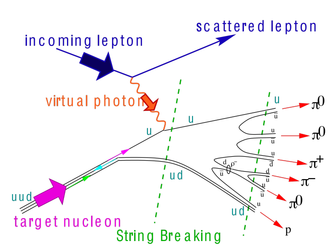
EIC physics and measurements





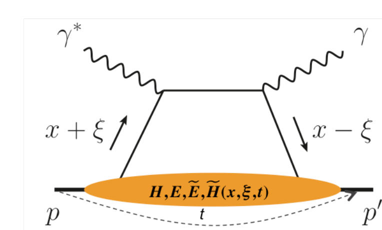
inclusive DIS

measure scattered electron with high precision



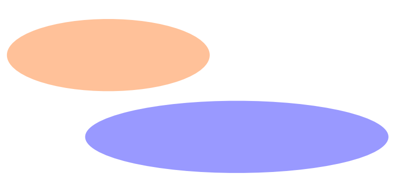
semi-inclusive DIS

detect the scattered lepton and final state (jets, hadrons, correlations in final state)



exclusive processes

all particles in the event identified



eRHIC main detector

-4<η<4: Tracking (TPC+GEM+MAPS) & E/M Calorimetry (hermetic coverage)

Hadron PID:

-1<η<1: proximity focusing RICH + TPC: dE/dx

1<η<3: Dual-radiator RICH

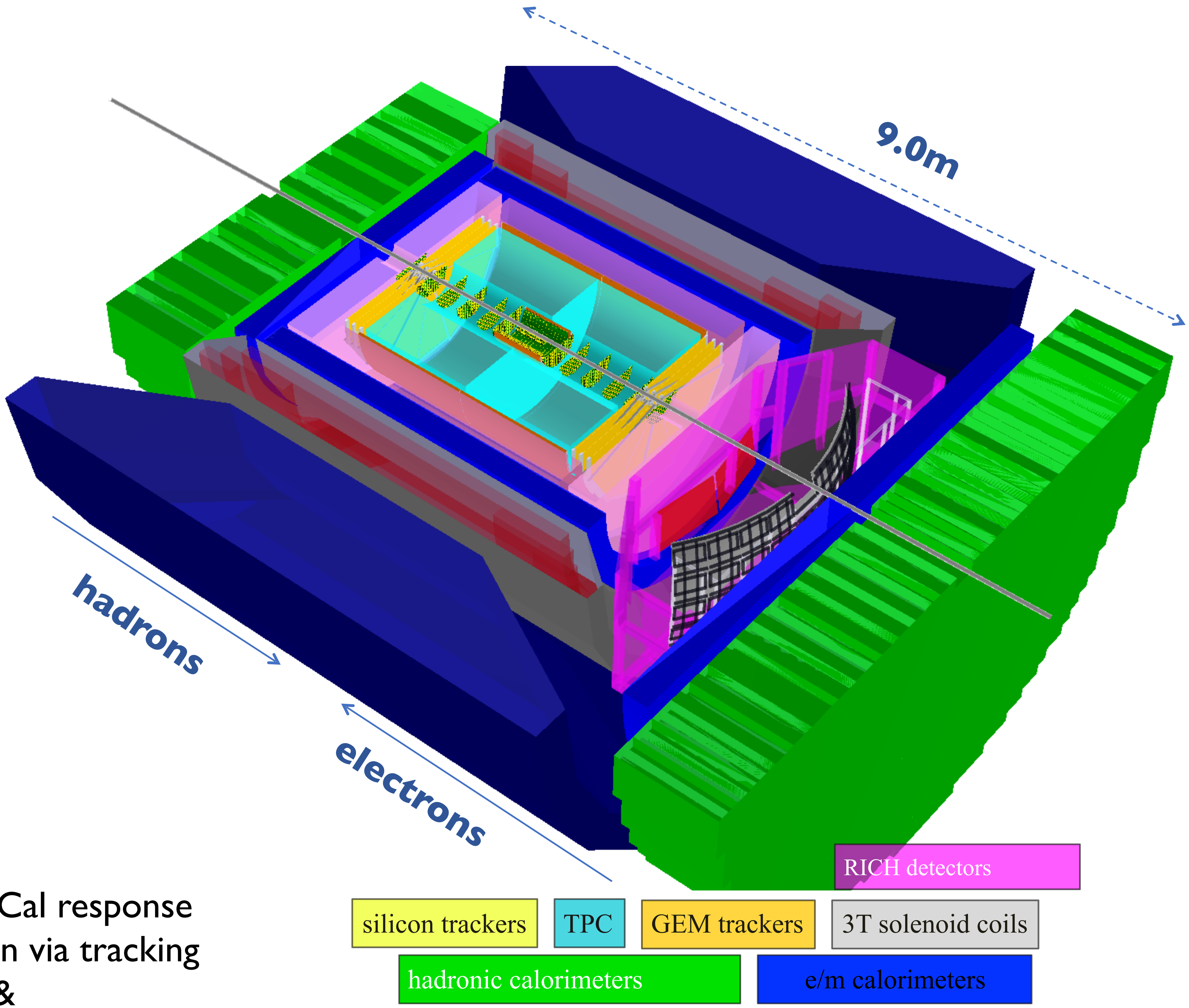
-1>η>-3: Aerogel RICH

Lepton PID:

-3 <η< 3: e/p

1<|η|<3: in addition HCal response & γ suppression via tracking

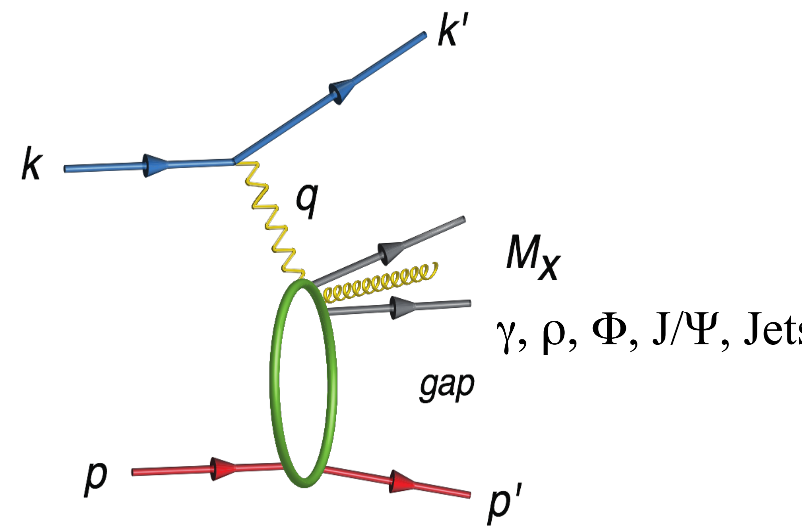
|η|>3: ECal+Hcal response & γ suppression via tracking

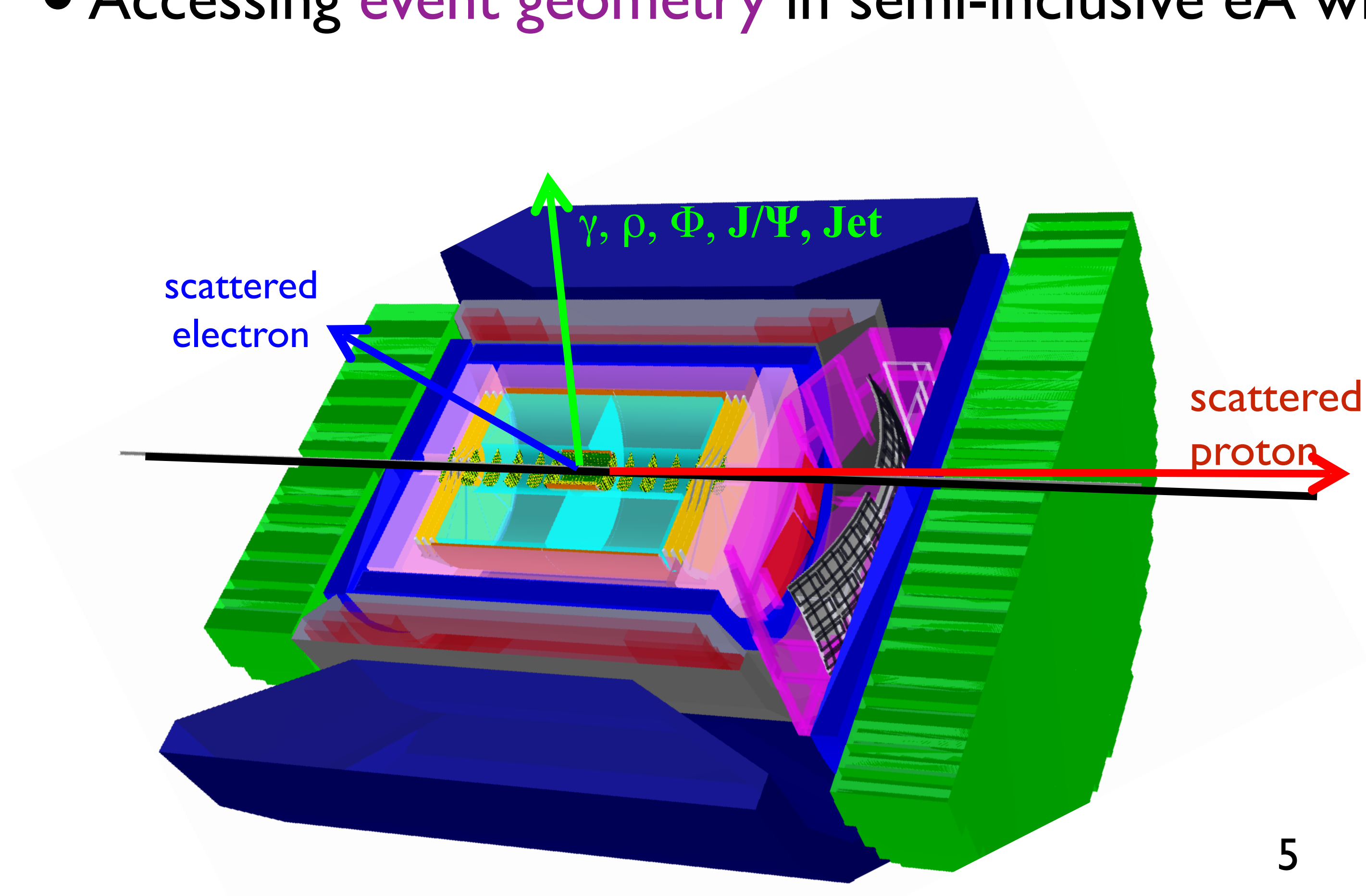


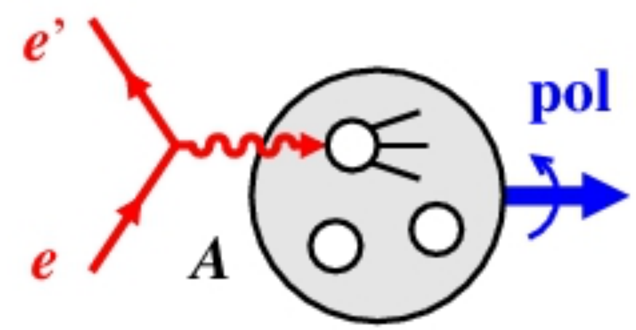
MAPS: CMOS Monolithic Active Pixel Sensors

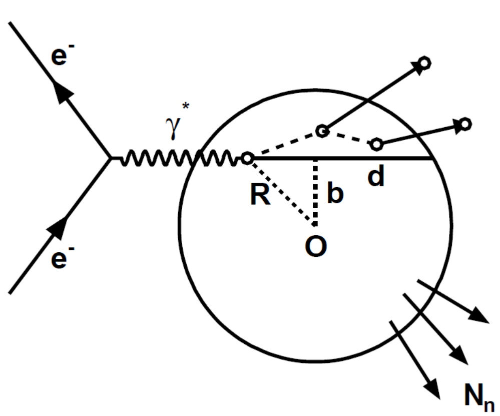
Physics with forward tagging

- Defining exclusive reactions in ep/eA:
  - ep: reconstruction of all particles in (diffractive) event including scattered proton with wide kinematics coverage
  - eA: identify with rapidity gap. need wide rapidity coverage [HCal for 1<η<4.5]
- Identifying coherence of nucleus in diffractive eA:
  - ~100% acceptance for neutrons from nucleus break-up
- Sampling target in e+^{3}He,d with spectator nucleons
- Accessing event geometry in semi-inclusive eA with evaporated nucleons

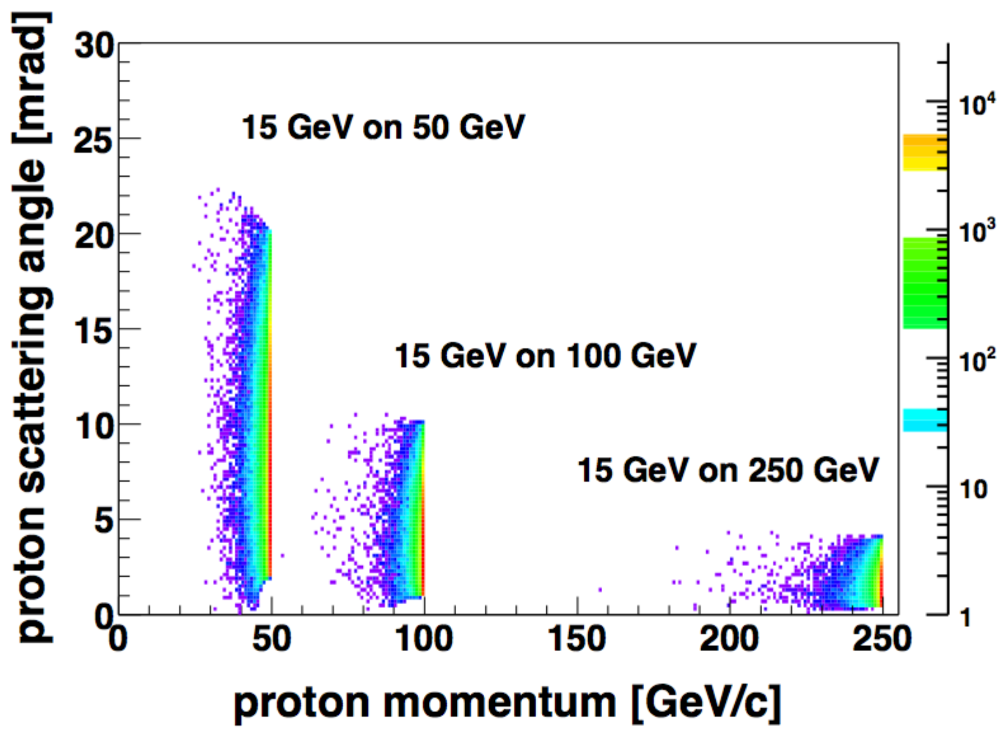


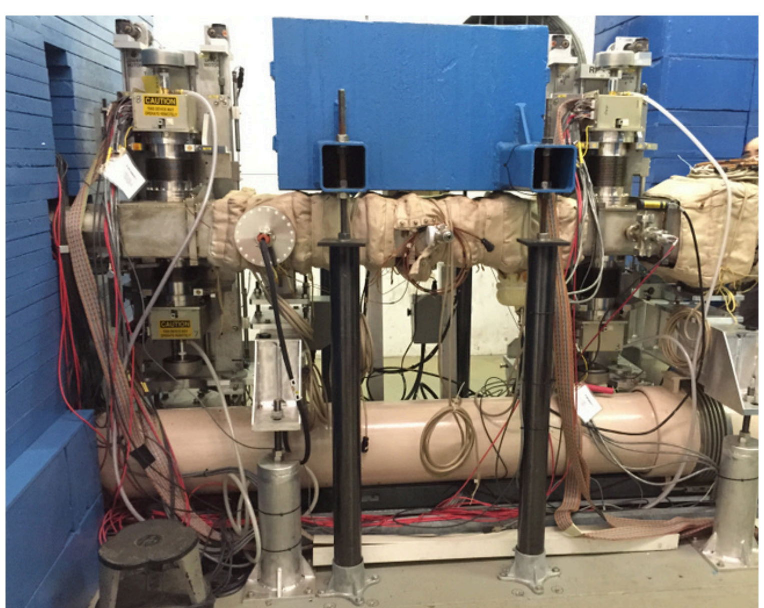






Forward protons in diffraction



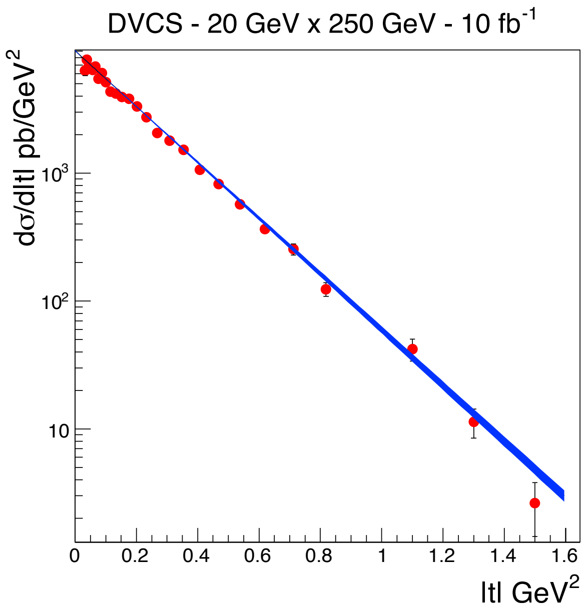


Roman Pots at STAR / RHIC

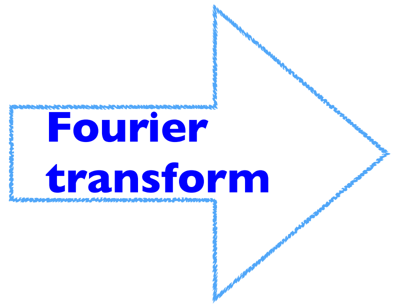
- Scattered with ~O(mrad): Need a detector close to the beam - Roman Pot to detect
- Large angle (high-t) acceptance mainly limited by magnet aperture [$t \sim p_T^2 \sim p^2\theta^2$]
- Small angle (low-t) acceptance limited by beam envelop (~<10σ)
- Reconstruction resolution limited by
  - beam angular divergence (~O(100μrad)), emittance
  - uncertainties in vertex reconstruction (x,y,z), beam offset, crossing, detector alignment, resolution
  - at RHIC
    - $\delta p/p \sim 0.005$
    - $\delta t/t \sim 0.03/\sqrt{t}$
  - in addition, effect of crab crossing (expected to be << beam divergence) need to be simulated

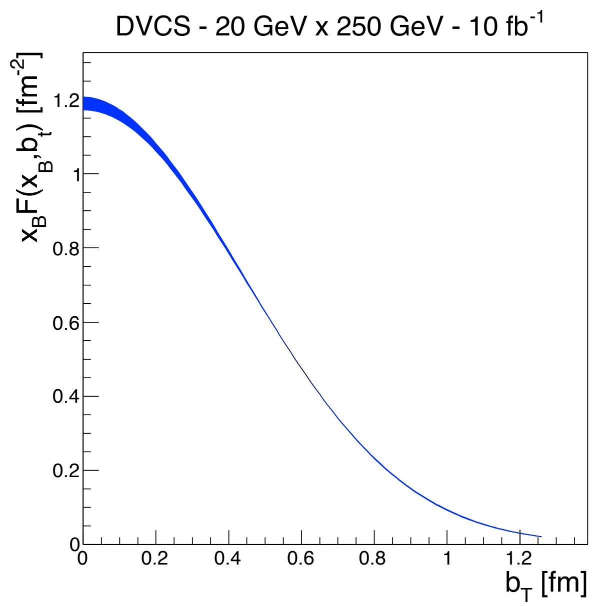
Impact of reduced proton acceptance

Measurement | **Physics observable** (cross-section vs impact parameter)



Plots from EIC White Paper:



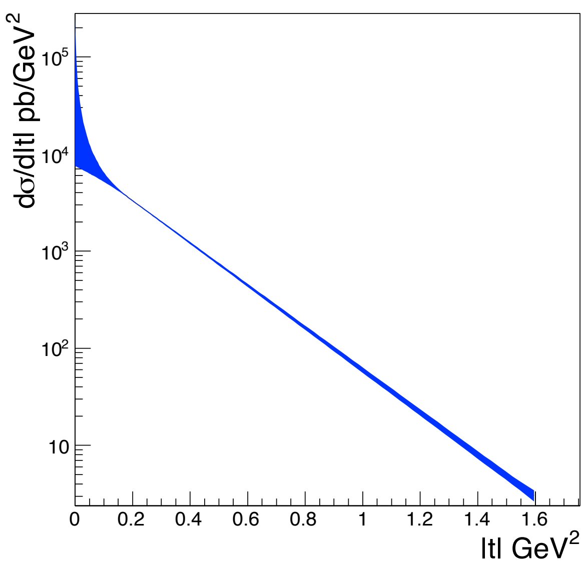


Requirement:

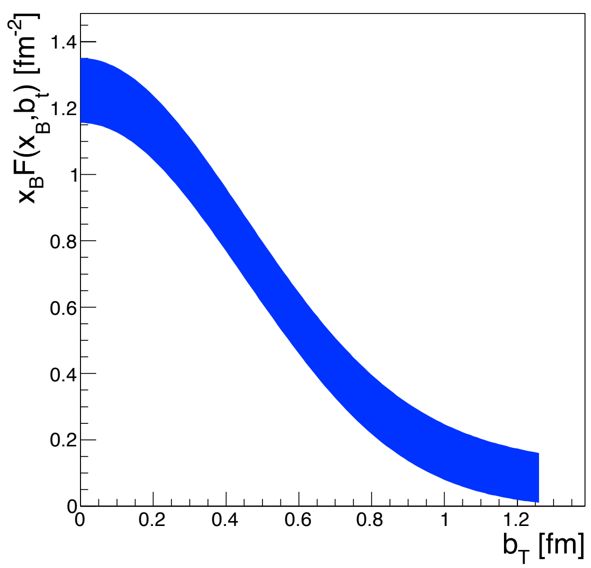
$\int L_{int} = 10 fb^{-1}$

$0.18 < p_t$ (GeV) < 1.3

$0.03 < |t|$ (GeV^2) < 1.6

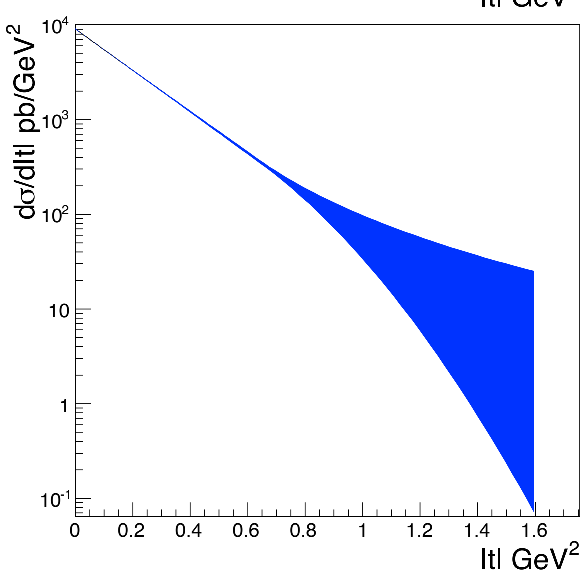


limited lower p_T-acceptance

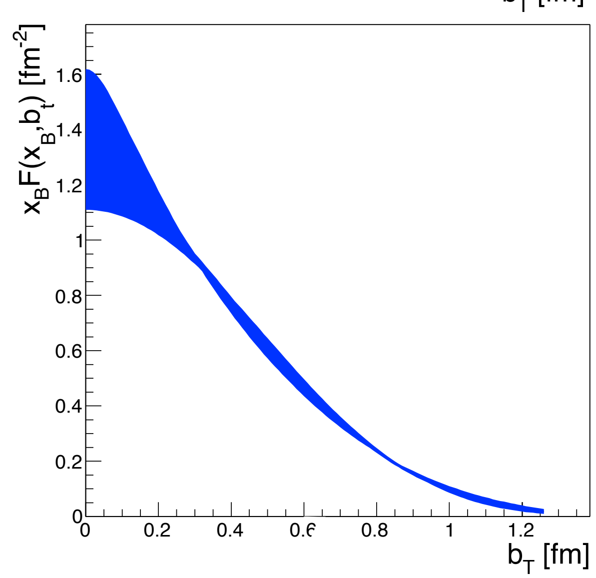


$\int L_{int} = 10 fb^{-1}$

$0.44 < p_T$(GeV) < 1.3



limited higher p_T-acceptance

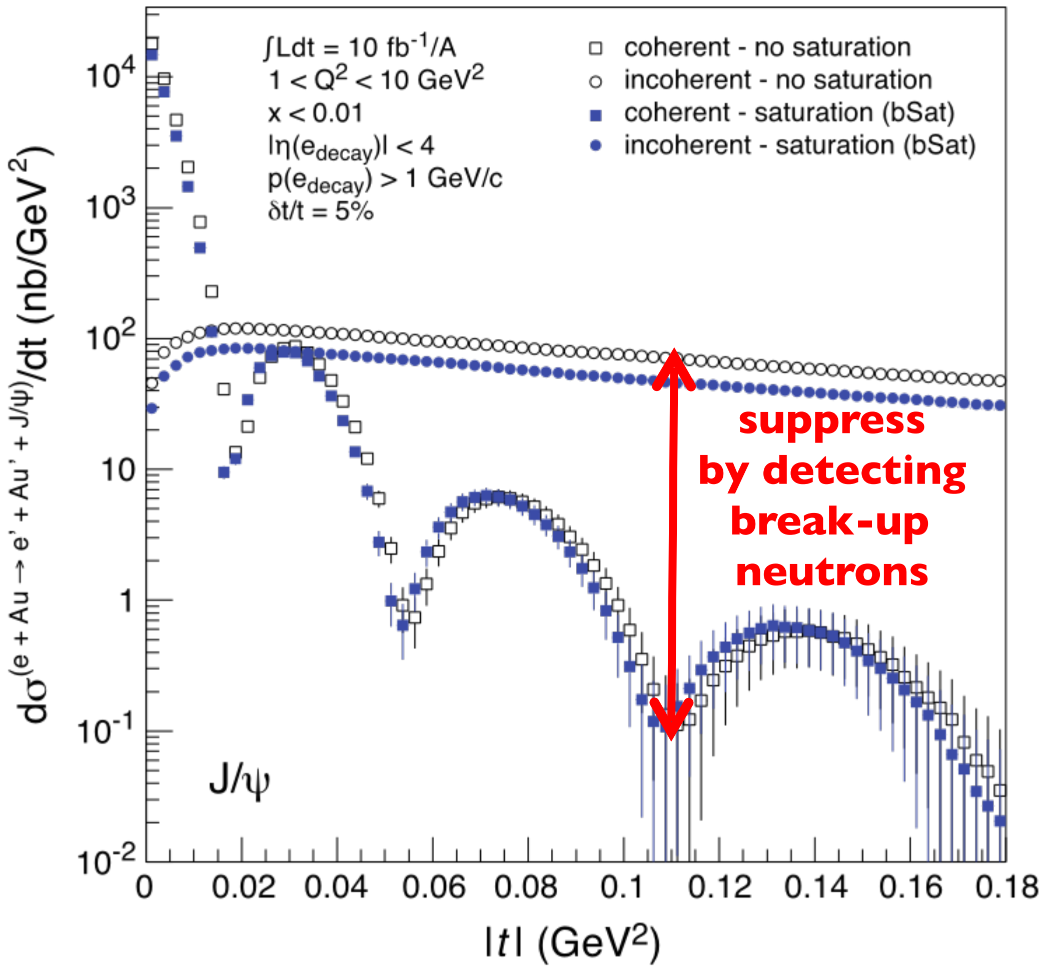


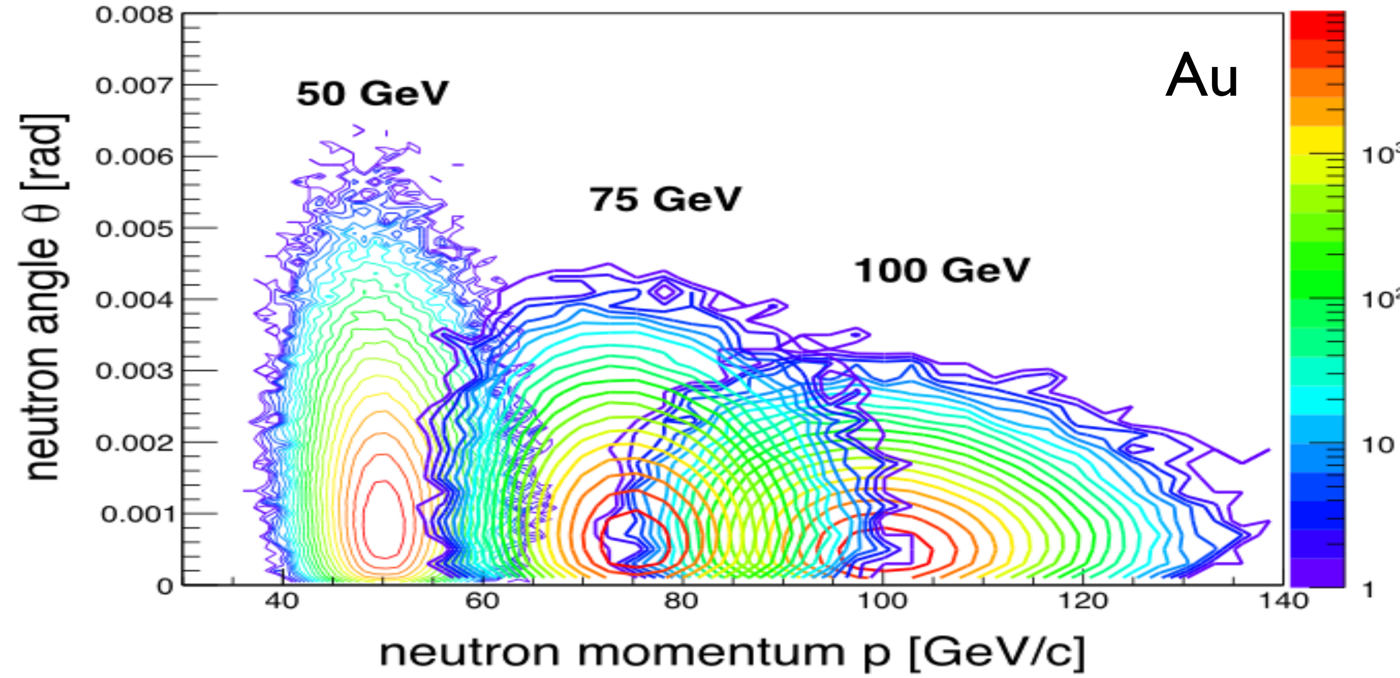
$\int L_{int} = 10 fb^{-1}$

$0.18 < p_T$ (GeV) < 0.8

Forward neutrons from nucleus break-up

Diffractive physics in eA
→ Measure spatial gluon distribution in nuclei
→ Reaction: $e + Au \rightarrow e' + Au' + J/\psi, \phi, \rho$



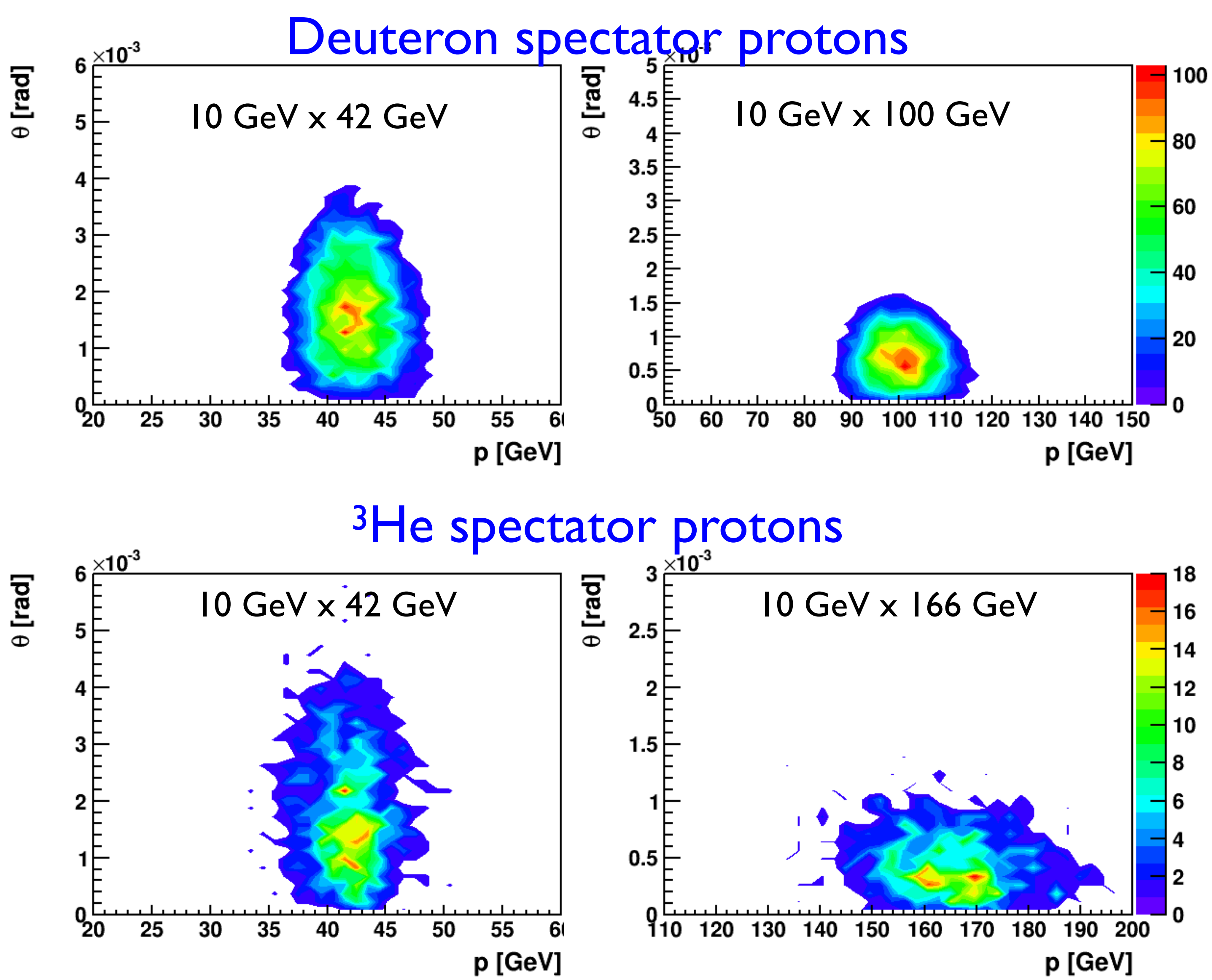


Physics requires forward scattered nucleus needs to stay intact
→ Veto incoherent diffraction with break-up (evaporated) neutron detection

Requirements

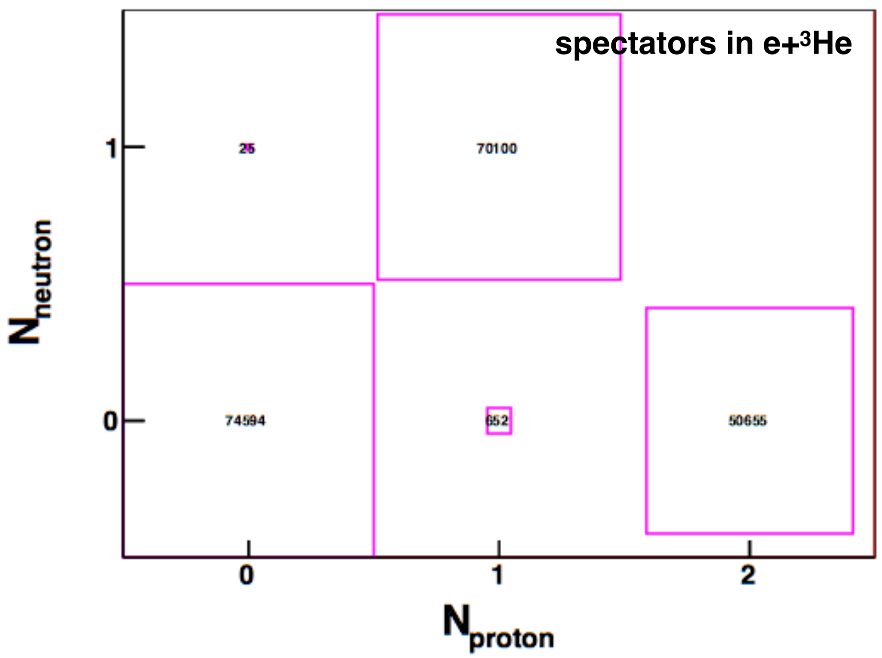
- Need at +/- 4 mrad beam element free region before the zero degree calorimeter for 100% acceptance to detect the break-up neutrons at 100 GeV
- Neutrons are also crucial to reconstruct collisions geometry
  ➔ precision neutron energy with good reconstruction resolution with complete coverage

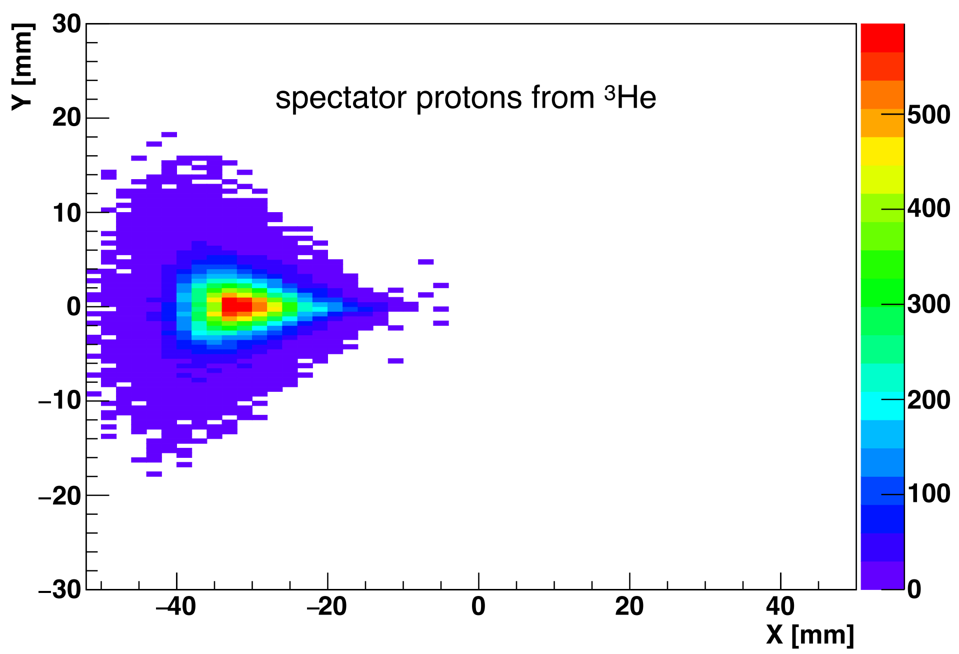
Spectator protons in ^{3}He, d



- Crucial for identifying processes with a neutron “target” [e(p)+n] in light ions - d, ^{3}He
  - Spectator neutron (<~4 mrad) can be identified by a calorimeter at beam rapidity (zero degree calorimeter)
  - Tagging spectator protons from d, ^{3}He
    - Relying on separation from magnetic rigidity (B_r) changes
      ^{3}He: p = 3/2:1
    - Momentum spread mainly due to Fermi motion + Lorentz boost

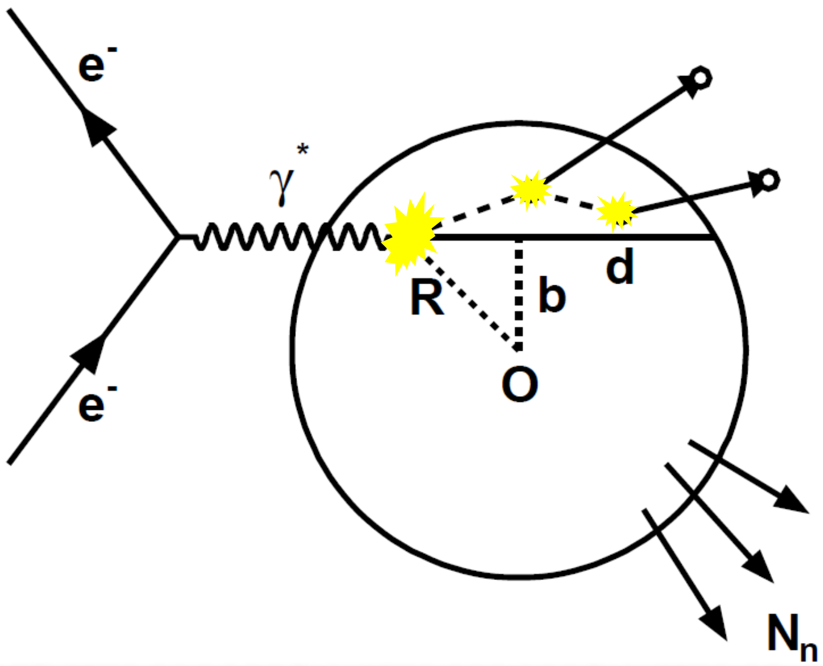
Spectator proton with Roman Pots





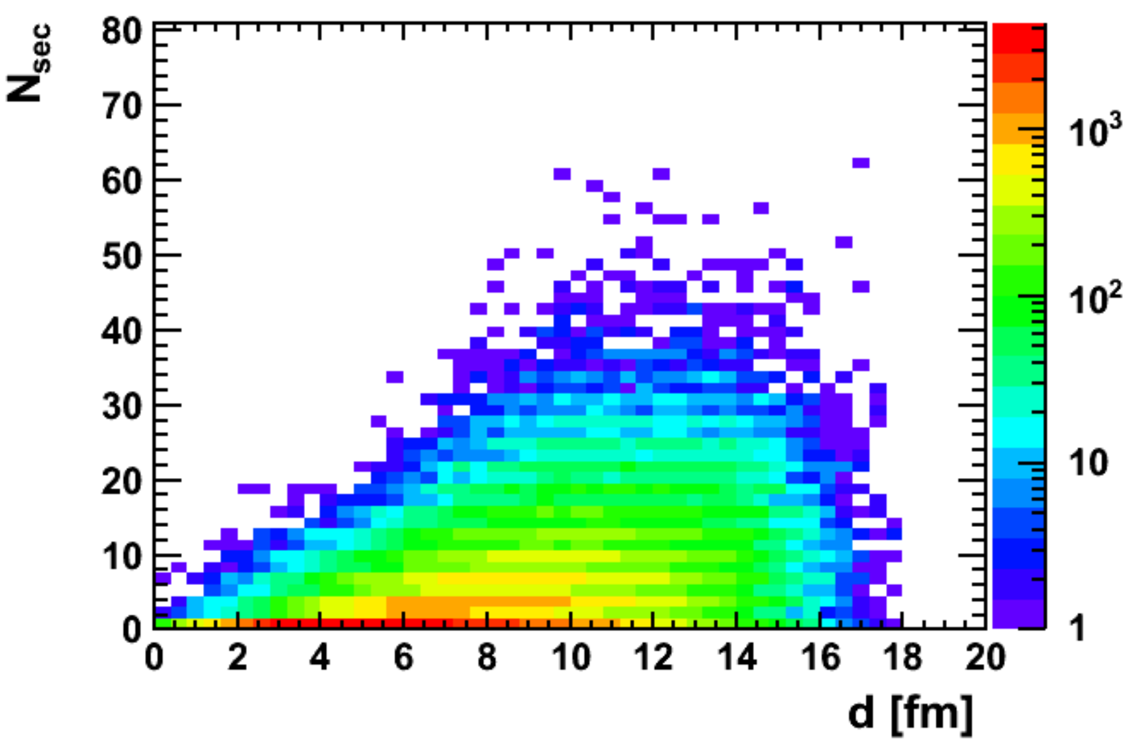
- Unambiguously identified e+p event vs e+n event in e+^{3}He 1p +1n vs 2p = 30% vs 22% (DPMJetIII)
- Common detector be utilized for tagging forward proton from diffraction and the spectator protons from ^{3}He?
- measurement can be done with RPs + forward detector + ZDC
- Shown example distribution at fixed locations at IR
- Detectors can be configured to optimize the acceptance

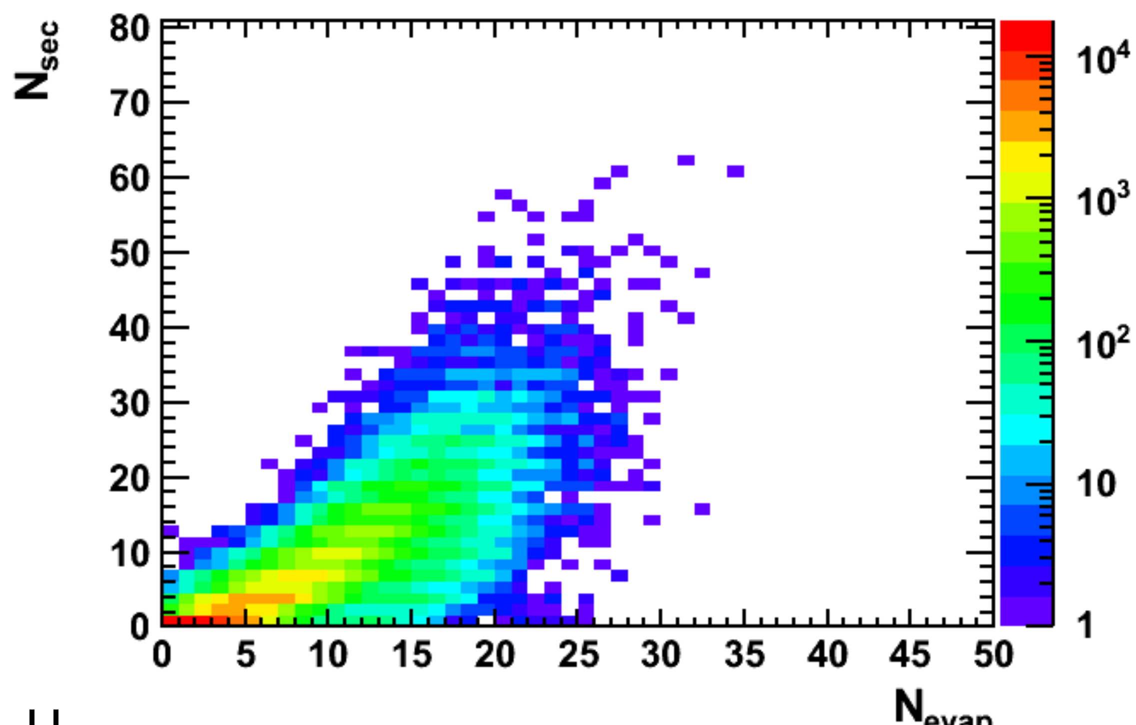
Controlling collision geometry in e-A?



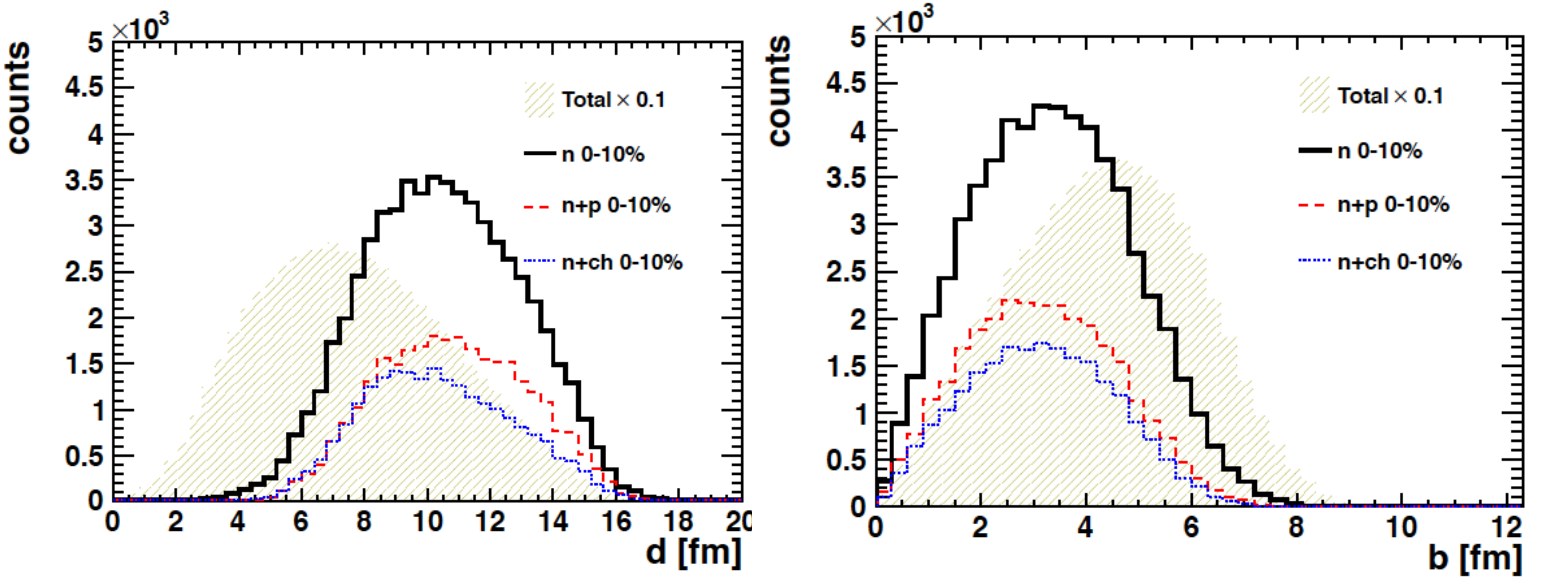
d : in medium traveling length
R : distance from involved nucleon to the center of nucleus
b : impact parameter
N_n: number of neutrons in forward region

d → $N_{secondary}$ → $N_{evaporated\ neutron}$





collision geometry selected by forward neutrons



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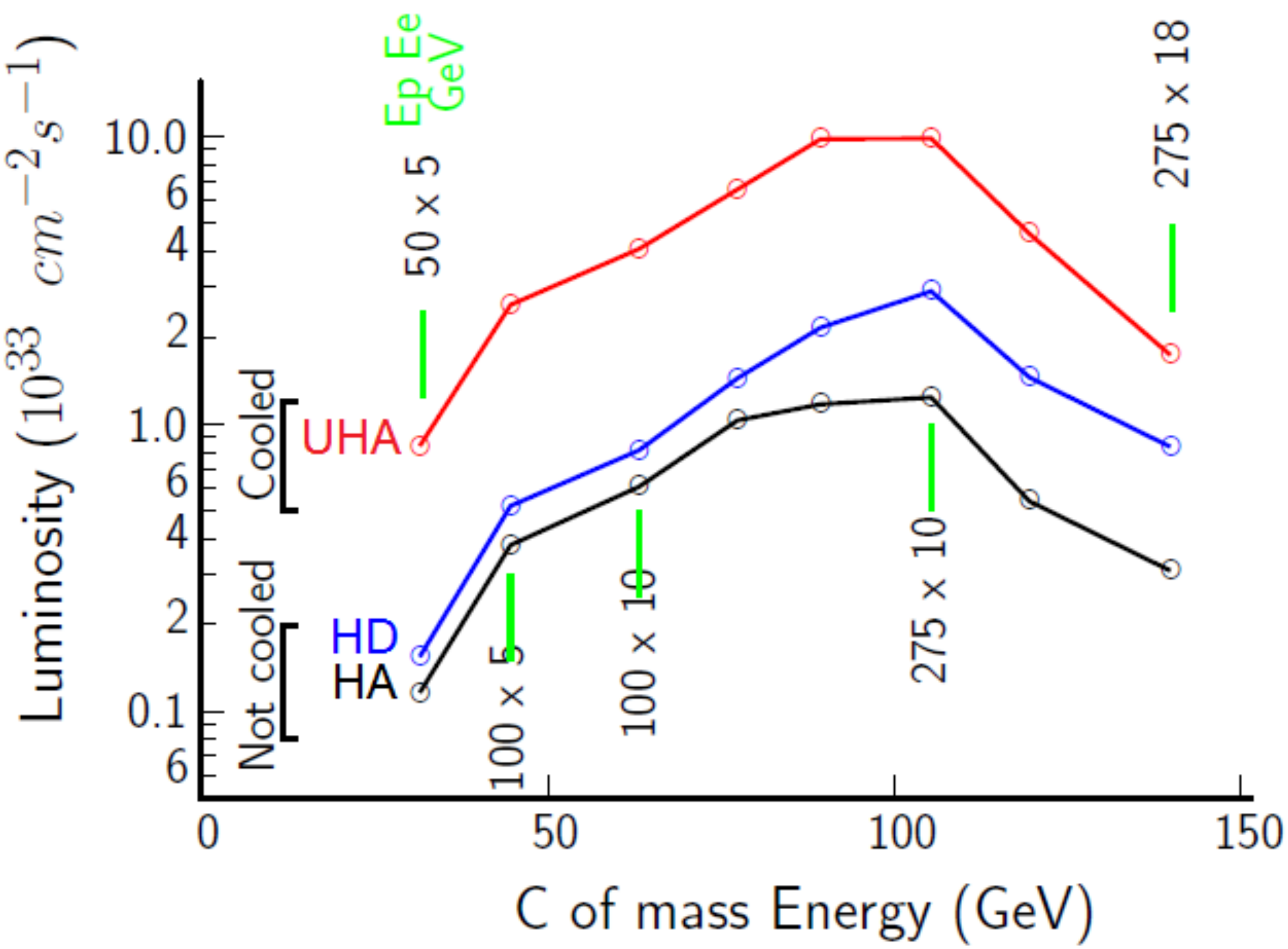
- Forward neutrons dominantly correlated with collision geometry
- Zero Degree Calorimeter (θ<~3mrad) can be used to count the forward neutrons
- More detailed study including unclear shadowing effect in progress

Interaction Region Requirements

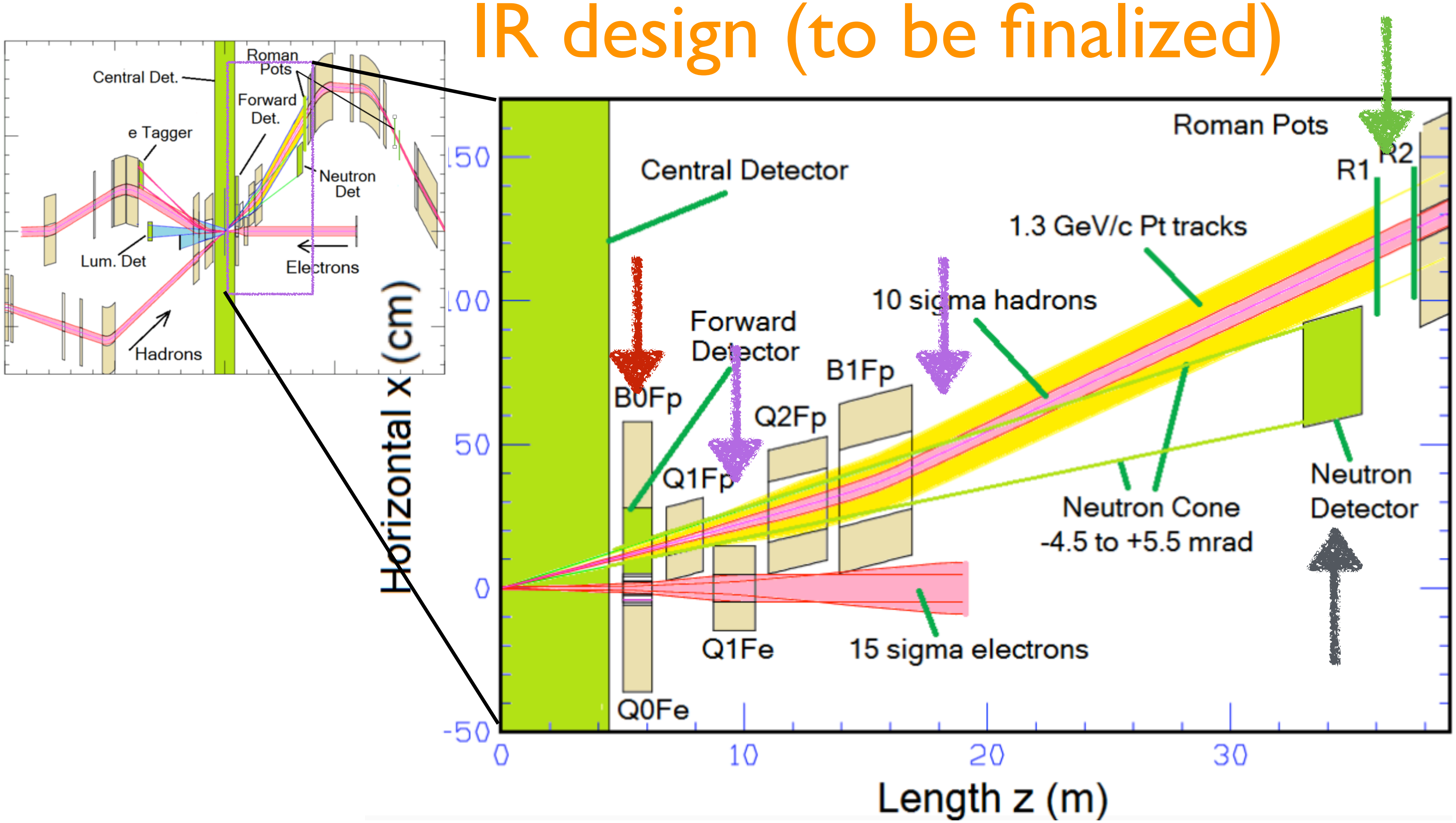
- Maximized Luminosity, Minimized background
- Buildable components
- Fit in experimental hall and tunnels
- **Acceptances and detectors for physics**
    - Luminosity monitor & e-tagger
    - +/- 4.5 m for Central detector
    - Widest possible angular coverage maximizing kinematic reach for forward proton
    - large and clear zero degree neutron acceptance
    - accommodate spectator nucleons with different rigidity

Luminosity vs. energy: eRHIC



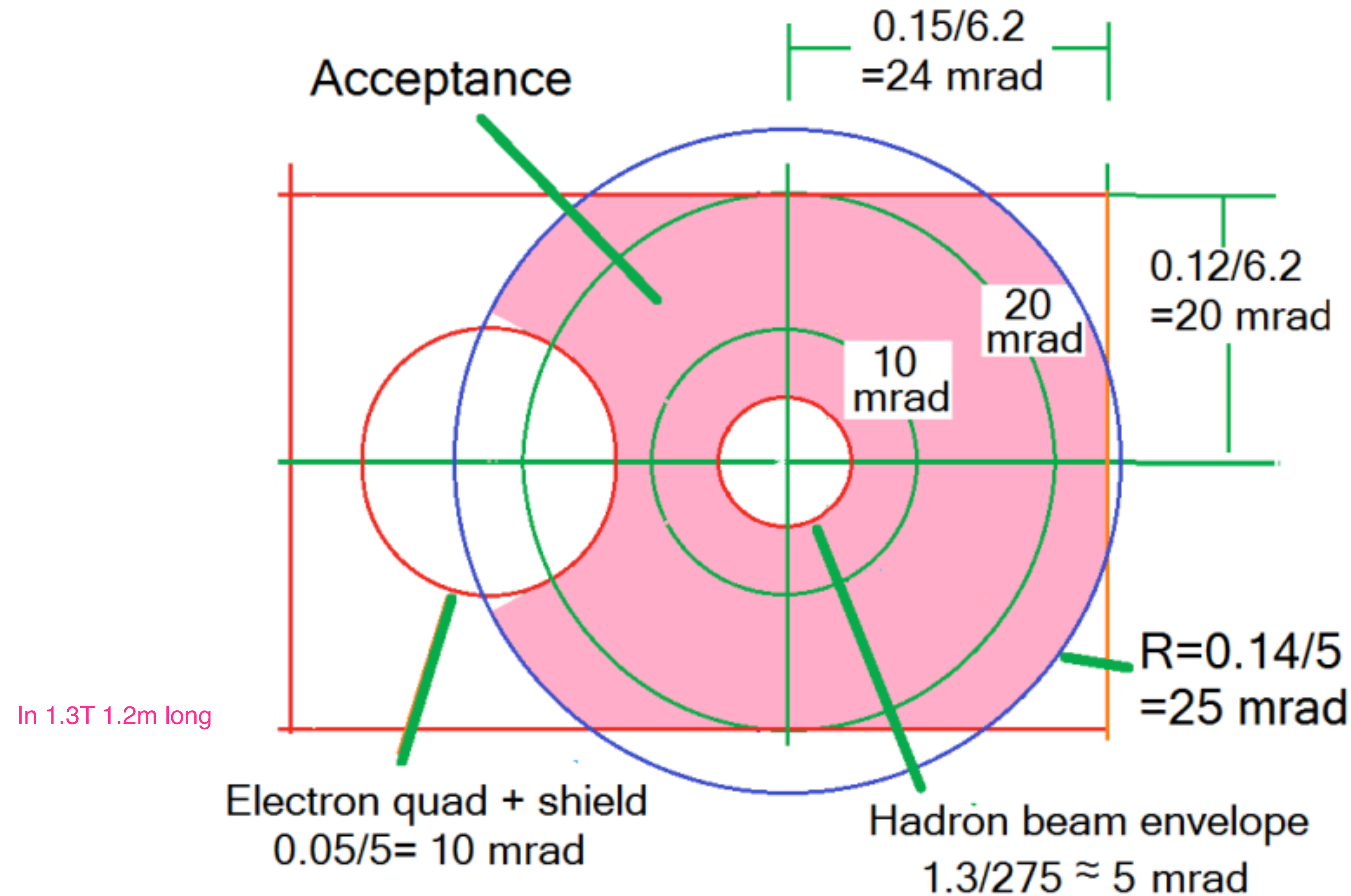
- Low divergence (High Acceptance) and High Luminosity (High Divergence) running mode for optimal physics running with physics program with forward protons
  - beam divergence 50 μrad - 300 μrad

IR design (to be finalized)



- Integrating requirements for hadron beam direction
  - Forward Detector (5 - 20 mrad)
  - Neutron detector ZDC (0 to 5 mrad)
  - Roman Pots (sensitive 1 to 5 mrad)
  - Possible "Spectator tagger"
- electron and hadron polarimetry at separate IR @ IP-12

Forward Detector - coverage (to be finalized)



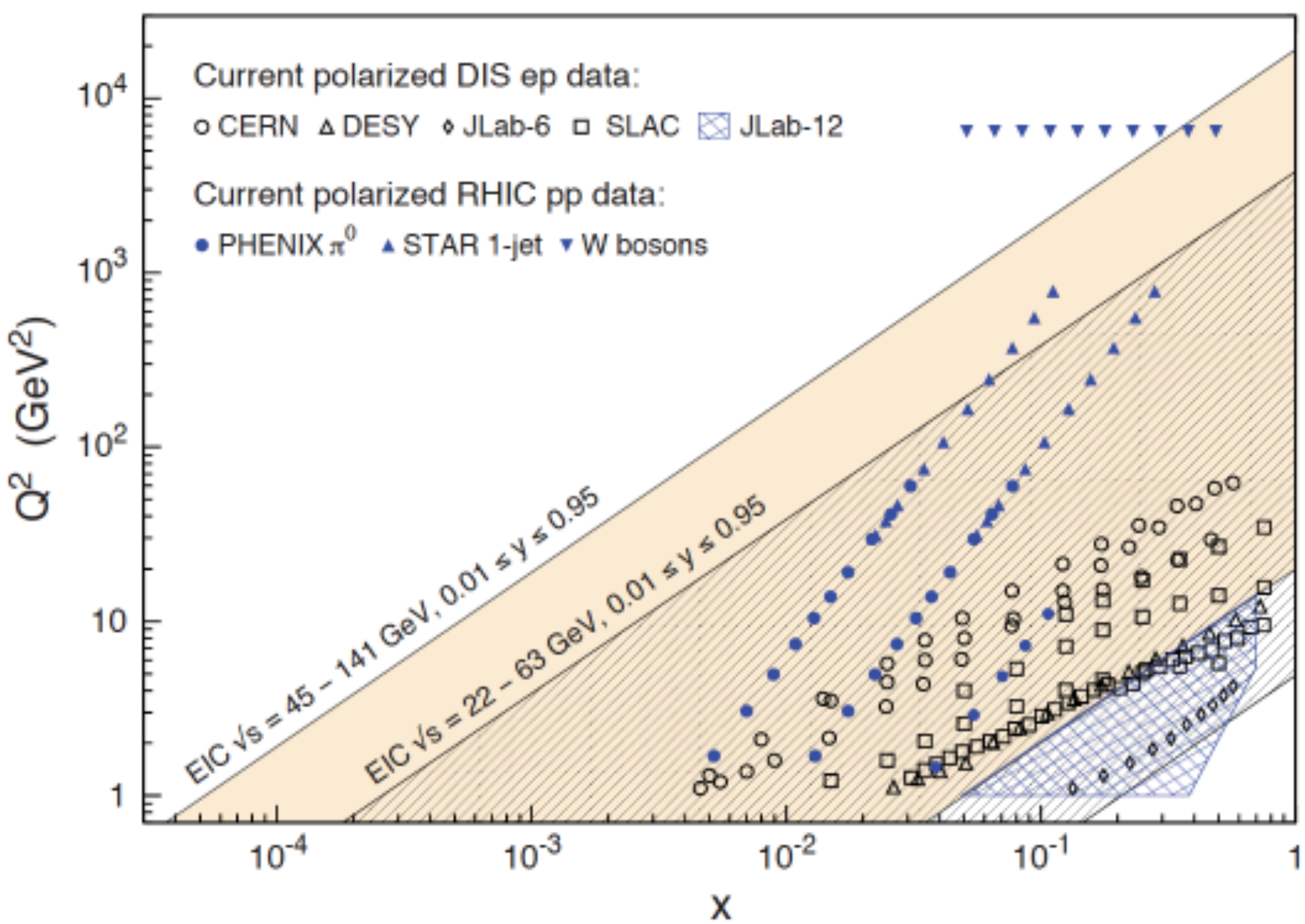
- Extending forward proton acceptance (5 - 20 mrad)
  - p_T-acceptance to ~1 GeV at proton beam energy 50 GeV
  - Design optimization in progress

Summary

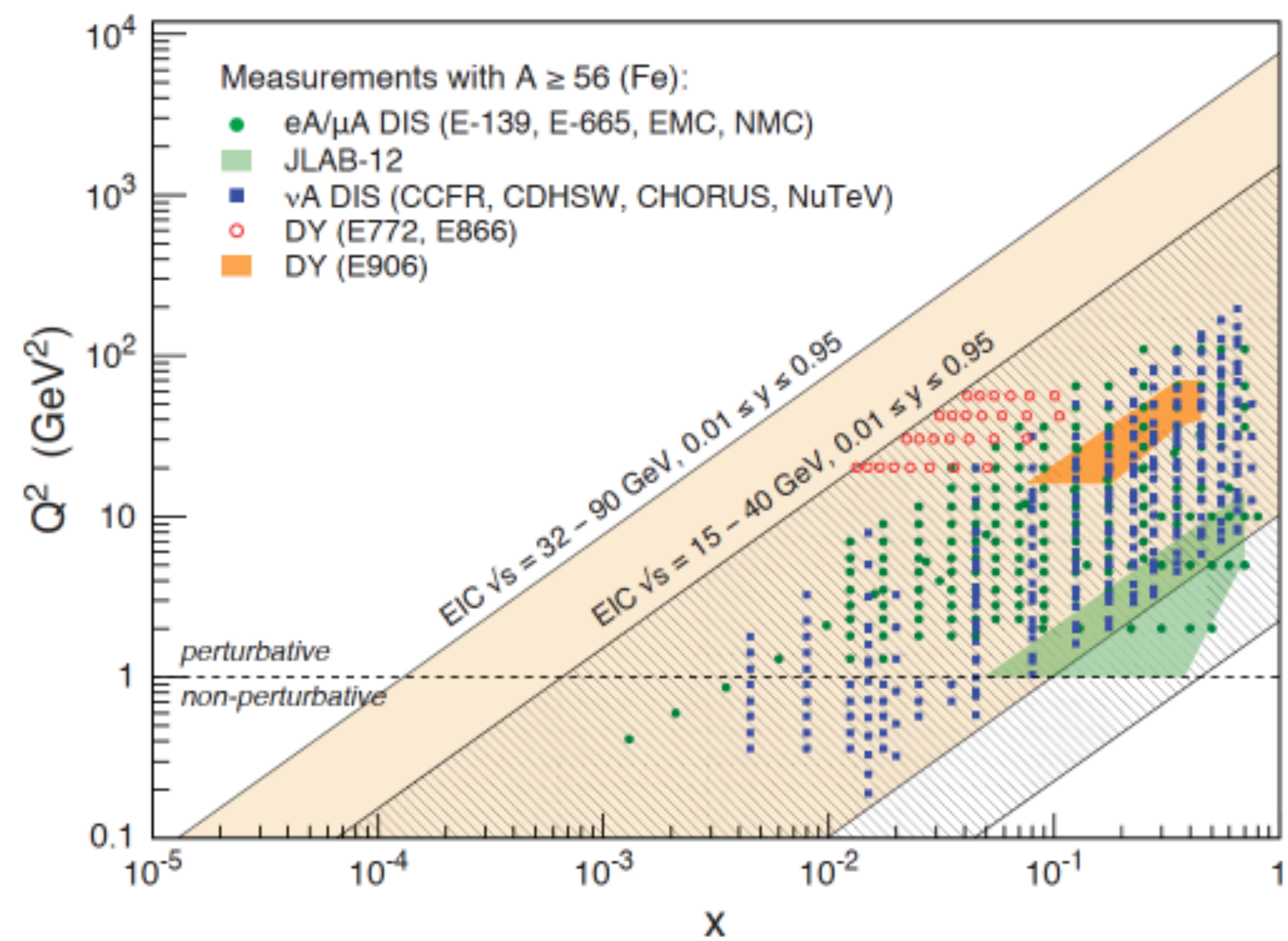
- Forward tagging crucial part of EIC physics
- Stringent requirement for forward detectors are integrated in the eRHIC IR design
- The IR with the forward detector system can cover physics needs for wide ranges of nucleon energies in ep and eA (50 - 275 GeV)
- More detailed study with further optimization underway

back-up

x-Q^2 range accessible at EIC



polarized e-p



e-A

x-Q² range for DVCS at EIC