MEIC detector design

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2nd Mini-Workshop on the MEIC Interaction Region

Jefferson Lab, November 2, 2012

Outline

Detection requirements and opportunties

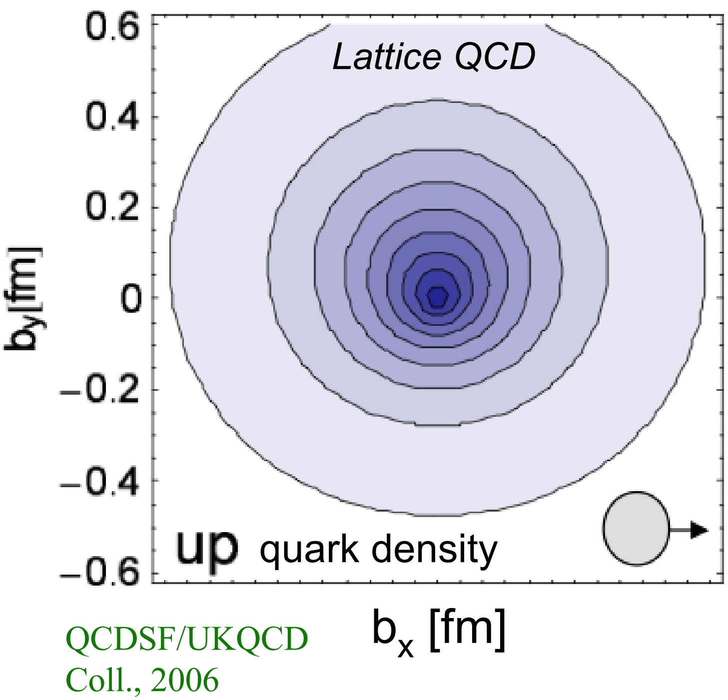
Full-acceptance detector (primary)

High-luminosity detector (secondary)

Imaging in coordinate and momentum space

<u>GPDs</u>

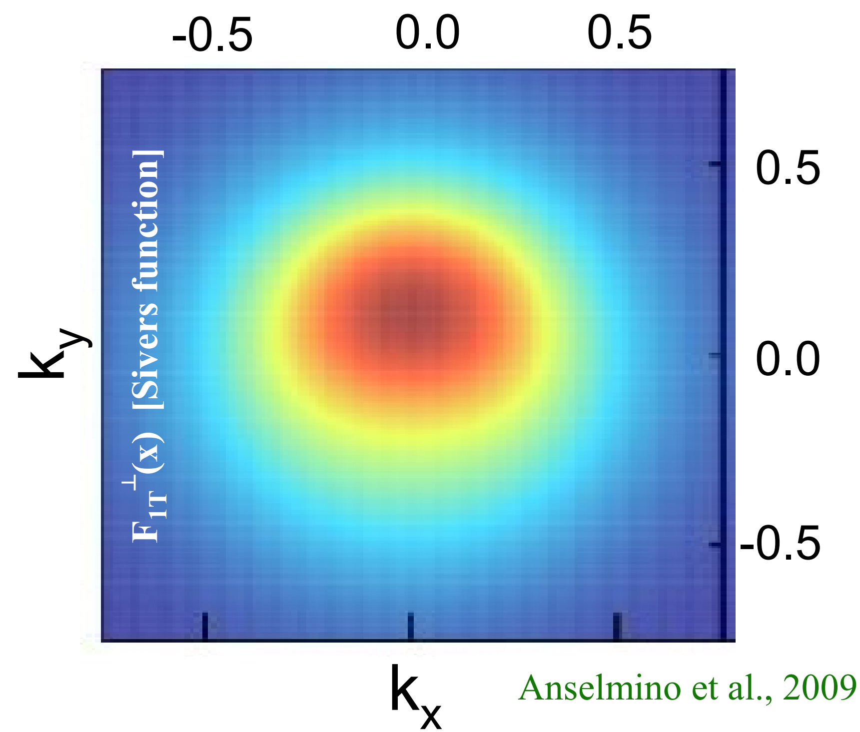
2+1 D picture in **impact-parameter space**



QCDSF/UKQCD Coll., 2006

<u>TMDs</u>

2+1 D picture in **momentum space**

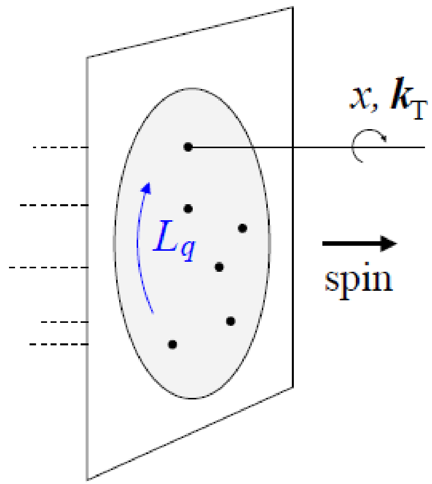


Anselmino et al., 2009

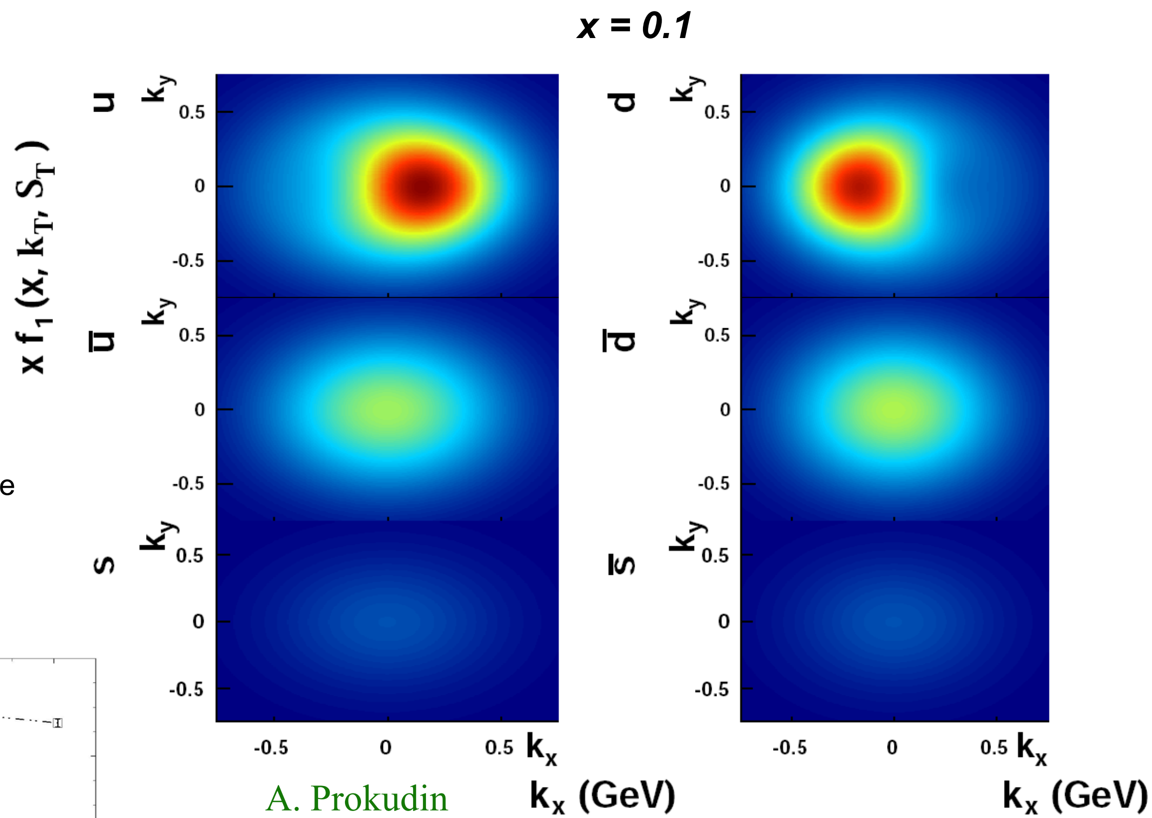
- Accessed through *exclusive* processes
- Image above for polarized nucleon
- Ji sum rule for nucleon spin

- Accessed through *Semi-Inclusive* DIS
- Requires transverse nuclon polarization
- OAM through spin-orbit correlations?

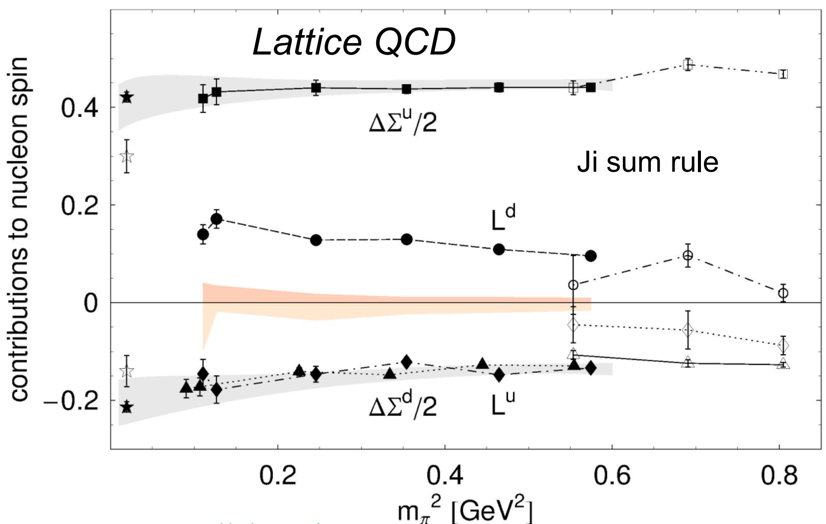
TMDs and Orbital Angular Momentum



Jaffe sum rule



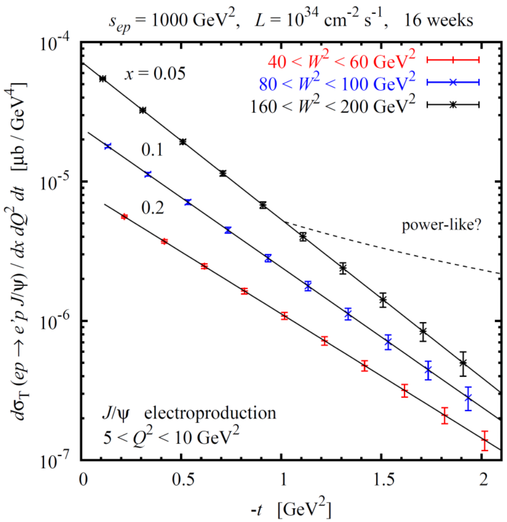
A. Prokudin

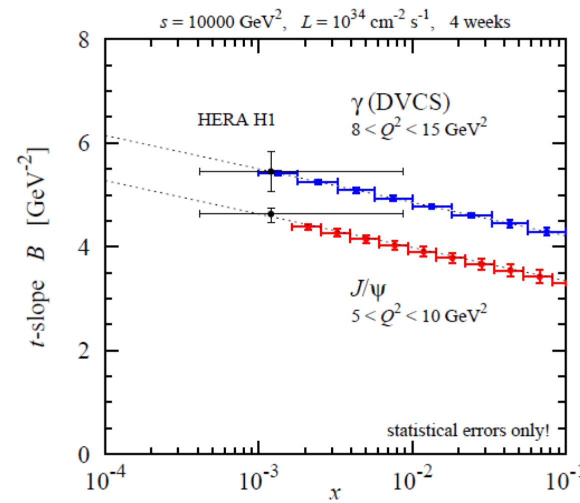


LHPC Collaboration

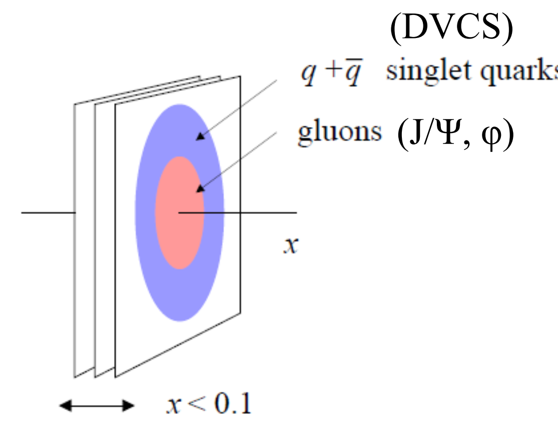
- Do up and down quarks orbit in opposite directions? How about other quarks?
- Need to detect hadron(s) from struck quark
- *How is this balanced by the fragmenting nucleon?*

Transverse spatial imaging of sea quarks and gluons

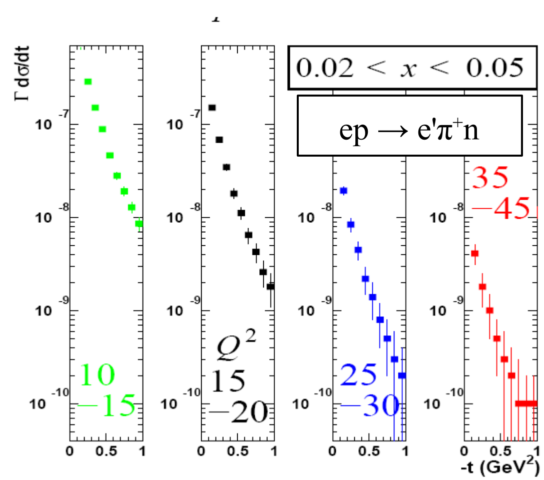


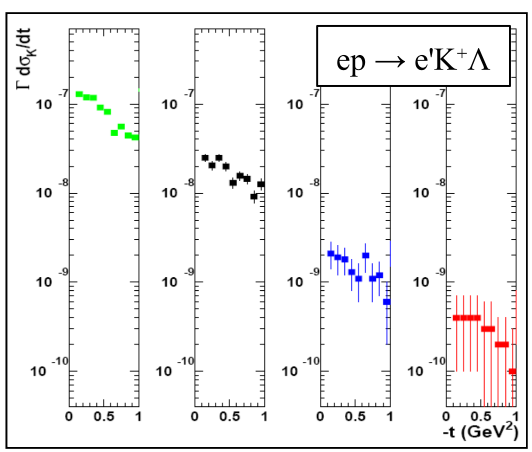


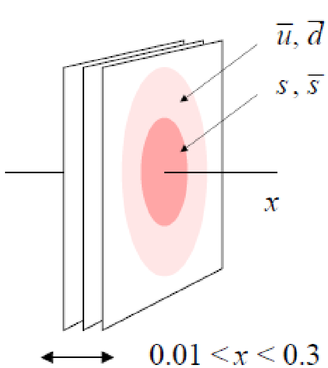
Weiss et al, INT 10-3



- Are the *radii* of quarks and gluons, or strange and light sea quarks, different at a given *x*?
- Full *image of the proton* can be obtained by **mapping *t*-distributions** for different processes.

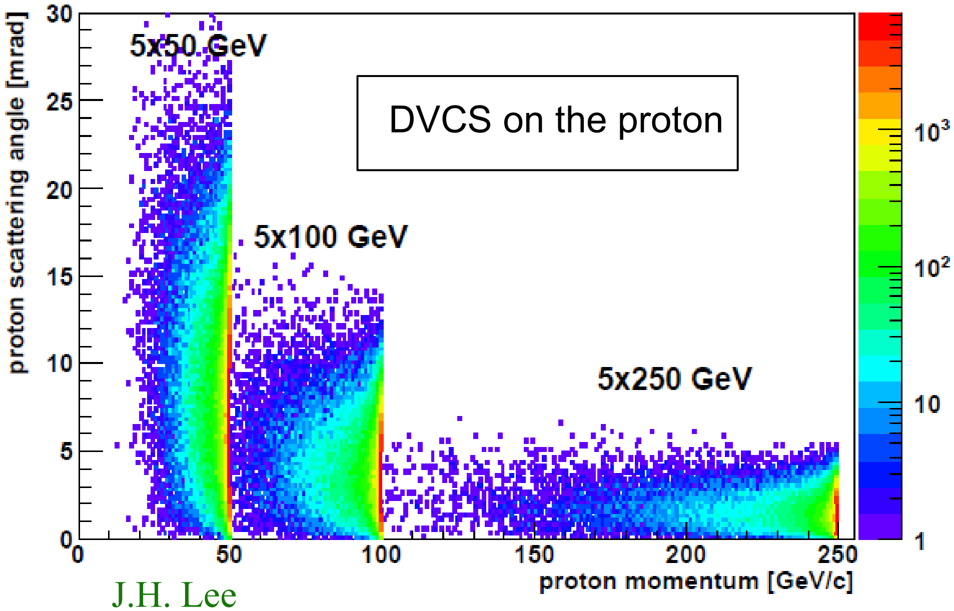


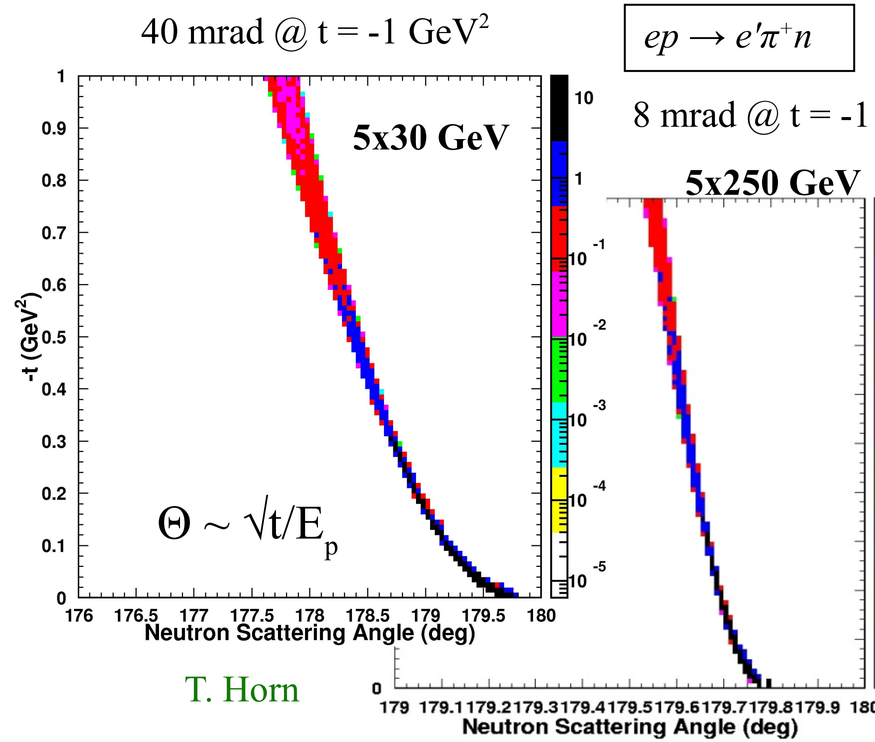




Horn et al. 08+, INT10-3

Recoil baryon detection

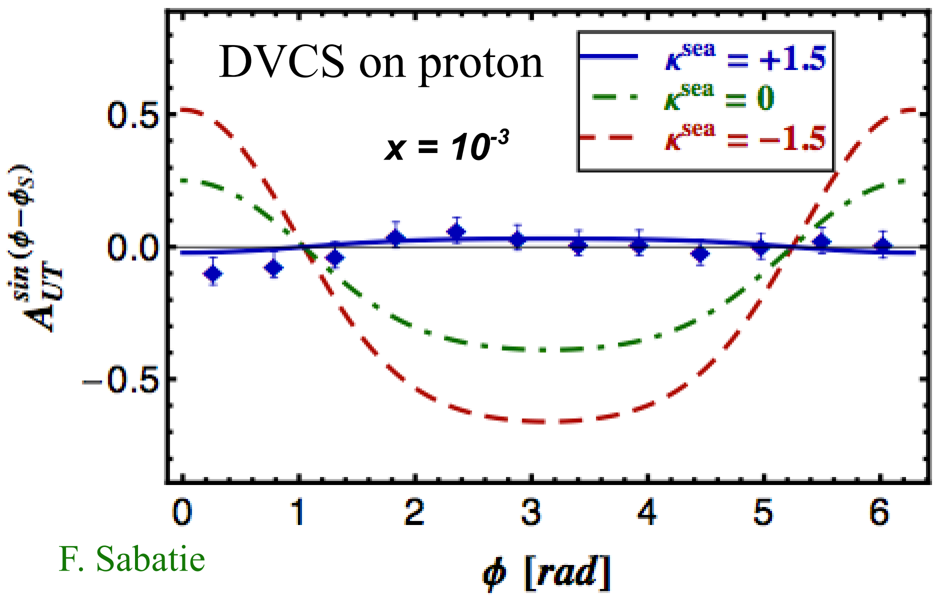




- At high proton energies, recoil baryons are scattered at small angles
  - Lower proton energies give better small-*t* acceptance and resolution in -*t*
  - Higher proton energies give better large-*t* acceptance for a given *maximum* ring energy
    - Lower maximum energy gives better acceptance at the *actual* running energy

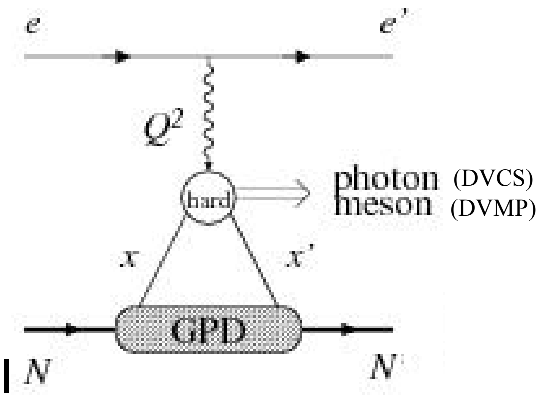
- Good recoil baryon detection requires
  - Wide range of proton (deuteron) energies
  - Small beam size to reach low -t

GPDs with transversely polarized “targets“



F. Sabatie

Model

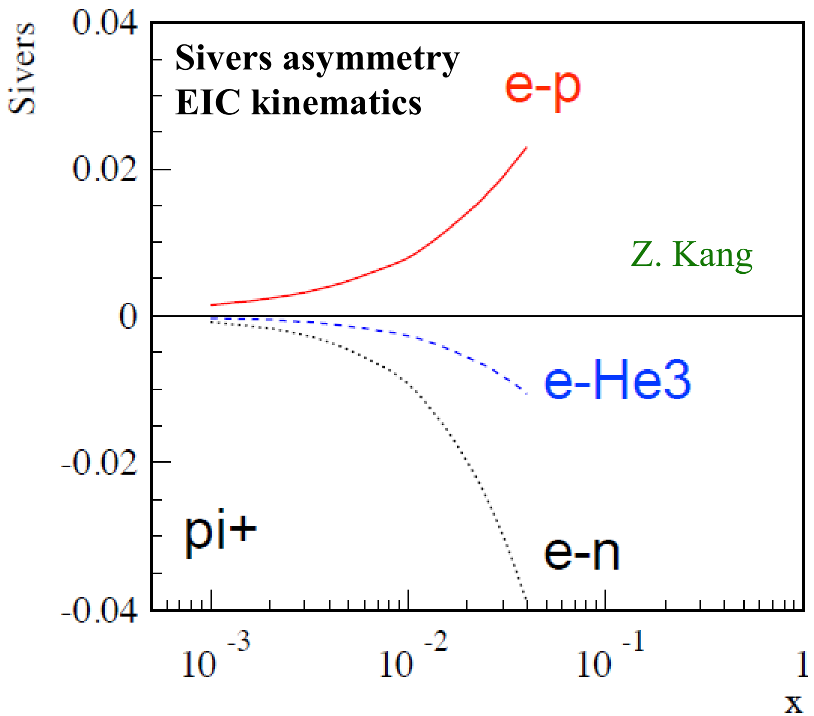


$$E^i(x, \xi, t) = \kappa^i(t)\, H^i(x, \xi, t)$$

Error bars shown only for $\kappa^{sea} = +1.5$

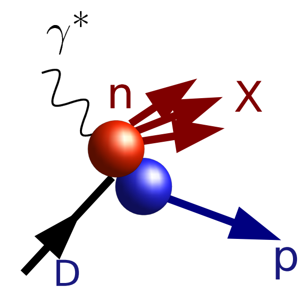
- DVCS on a transversely polarized target is sensitive to the ***GPD E***
  - GPD H can be measured through the beam spin asymmetry
- Meson production is more selective: J/Ψ sensitive to corresponding ***gluon GPDs***
- *GPD program requires good resolution and acceptance in -t, but also transversly polarized proton and **neutron targets***

Spectator tagging with polarized deuterium



„If one could tag neutron, it typically leads to larger asymmetries“

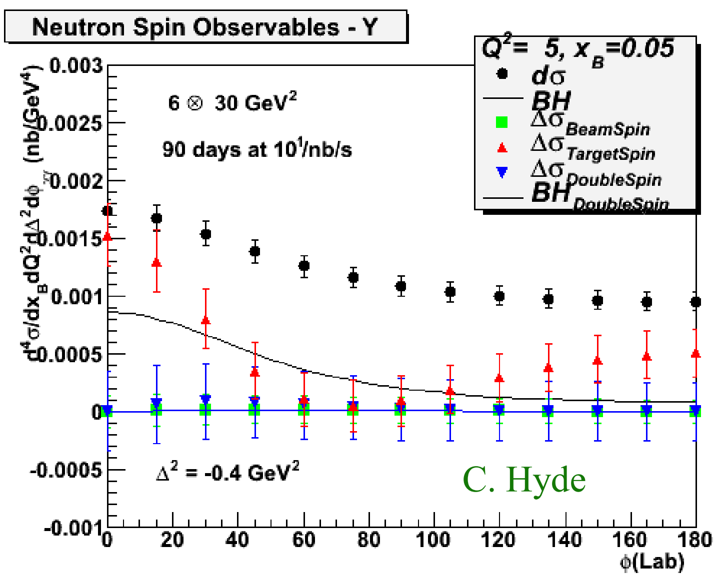
Z. Kang



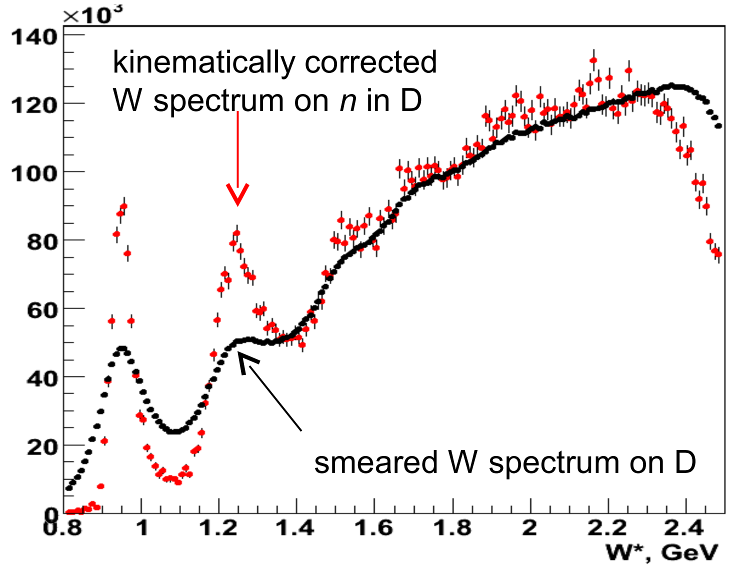
- Polarized neutrons are important for probing d-quarks through SIDIS

- Deeply Virtual Compton Scattering (DVCS) on a neutron target

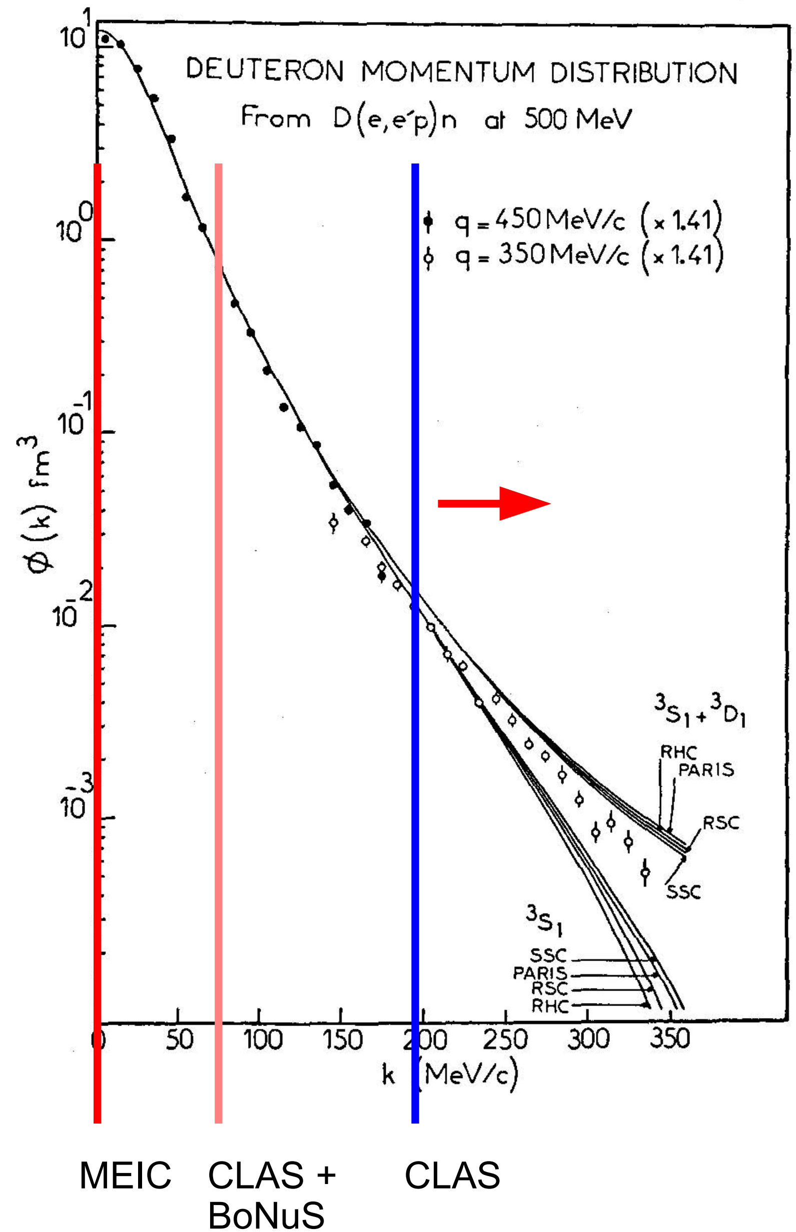
- Tagged, polarized *neutrons* are essential for the GPD program



Neutron structure through spectator tagging



CLAS BoNuS data with tagged spectators

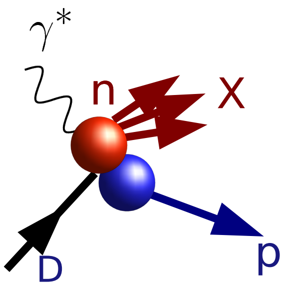


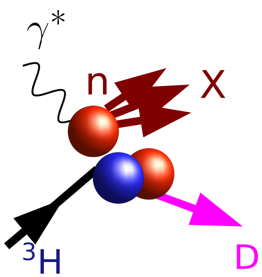
- In fixed-target experiments, scattering on *bound neutrons* is complicated
  - Fermi motion, nuclear effects
  - Low-momentum spectators
  - No polarization
- The MEIC is designed from the outset to tag spectators, and all nuclear fragments.

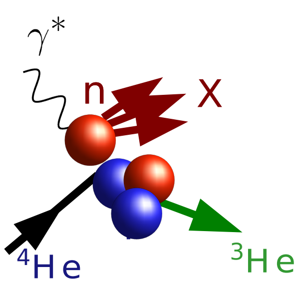
Spectator (and fragment) detection / tagging

Quasi-free neutron

target	spect.
D	p
^{3}H	D
^{4}He	^{3}He

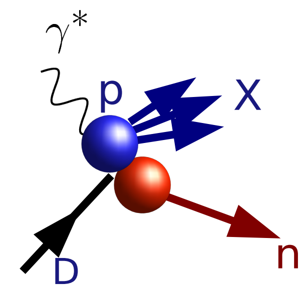


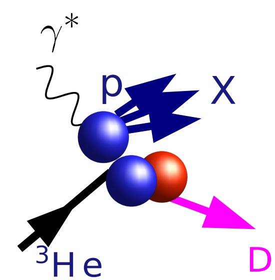


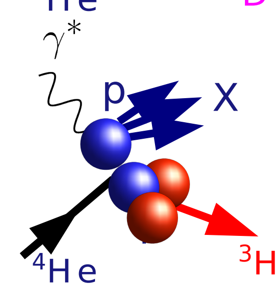


(Quasi)-free proton

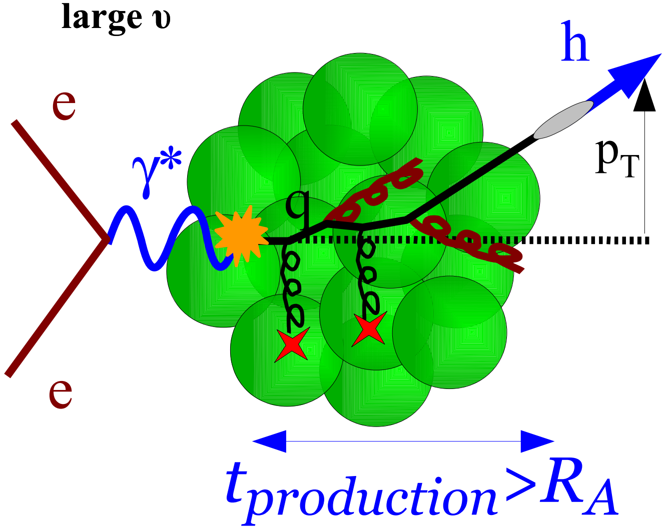
target	spect.
p	
D	n
^{3}He	D
^{4}He	^{3}H

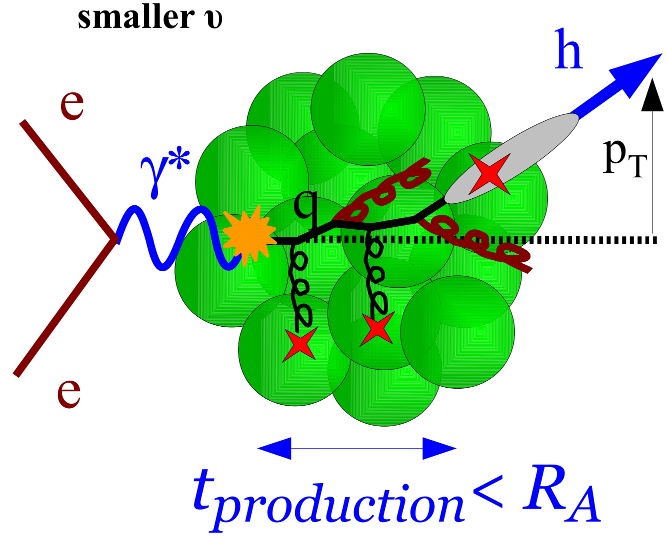




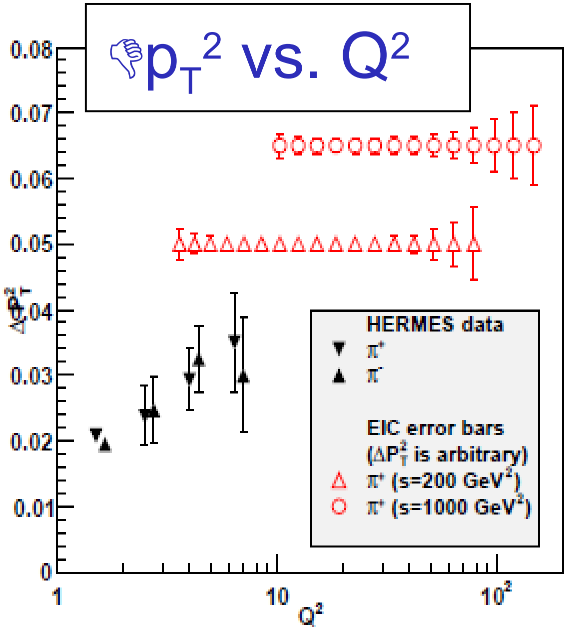


Quark propagation in matter (hadronization)

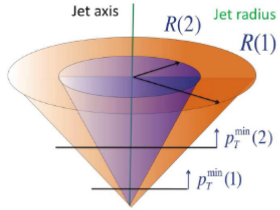




Accardi, Dupre



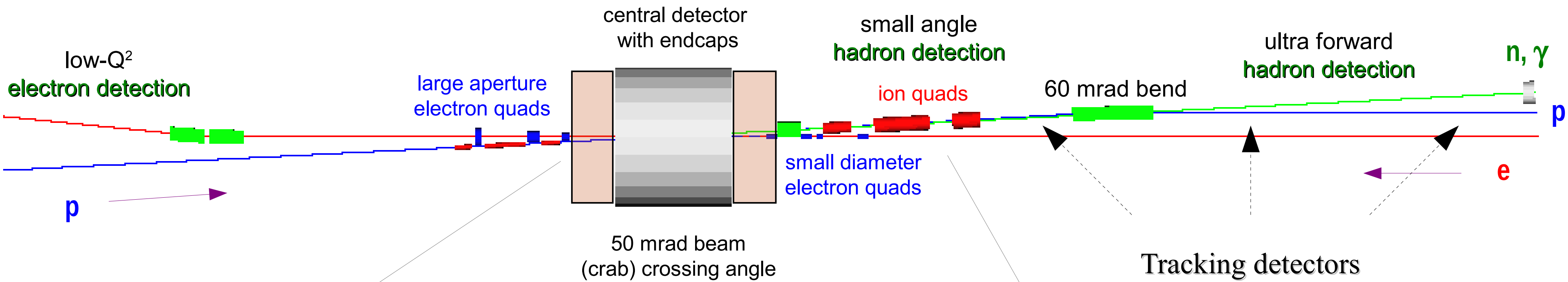
- Broadening of p_T distribution
- Heavy flavors: B, D mesons, J/Ψ …
- Hadron jets at s > 1000 GeV^2

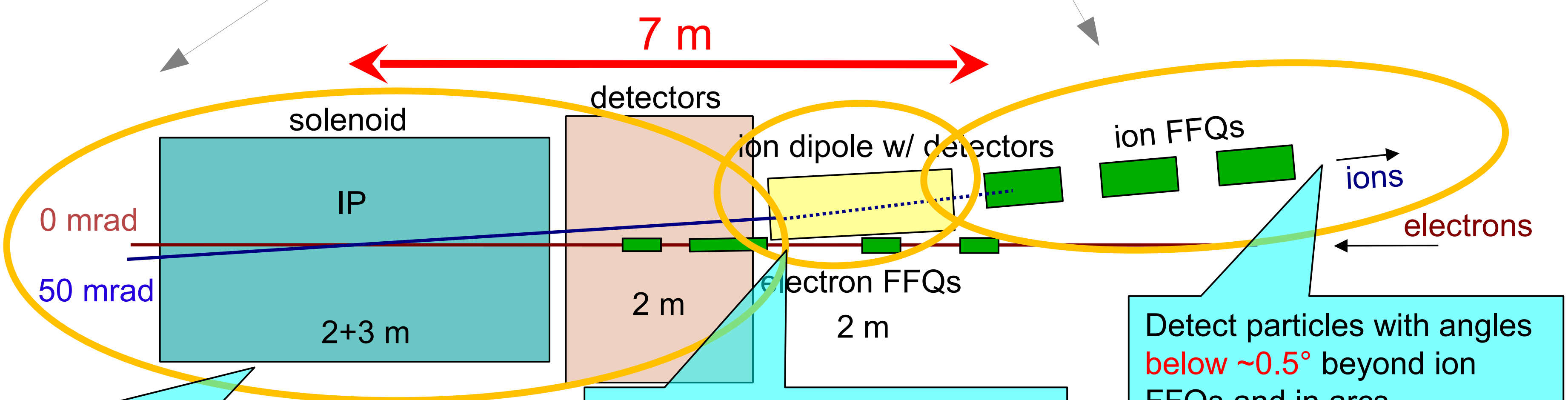


- *What happens to the nucleus?*
  - *Does it disintegrate to nucleons or fragments?*

Full-acceptance detector – strategy

No other magnets or apertures between IP and FP!





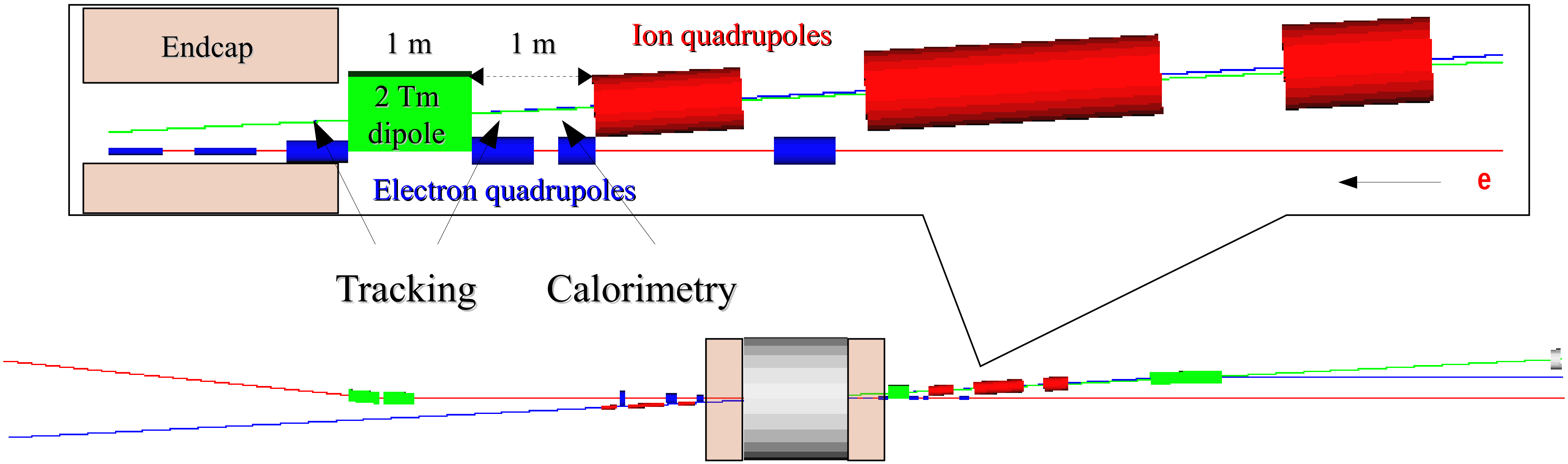
Central detector, more detection space in ion direction as particles have higher momenta

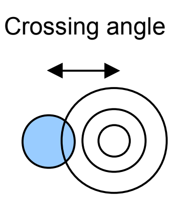
Detect particles with angles down to ~0.5° before ion FFQs. Need up to 2 Tm dipole in addition to central solenoid.

Detect particles with angles below ~0.5° beyond ion FFQs and in arcs.

Make use of the (50 mrad) crossing angle for ions!

Hadron detection prior to ion quadrupoles





- Large crossing angle (50 mrad)
  - Moves spot of poor resolution along solenoid axis into the periphery
  - Minimizes shadow from electron FFQs

- Large-acceptance dipole further improves resolution in the few-degree range

Ultra-forward hadron detection – requirements

1. **Good acceptance for ion fragments** (rigidity different from beam)

- Large downstream magnet apertures
- Small downstream magnet gradients (realistic peak fields)

2. **Good acceptance for recoil baryons** (rigidity similar to beam)

- Small beam size at second focus (to get close to the beam)
- Large dispersion (to separate scattered particles from the beam)

3. **Good momentum- and angular resolution**

- Large dispersion (*e.g.*, 60 mrad bending dipole)
- Long, instrumented magnet-free drift space

4. Sufficient separation between beam lines (~1 m)

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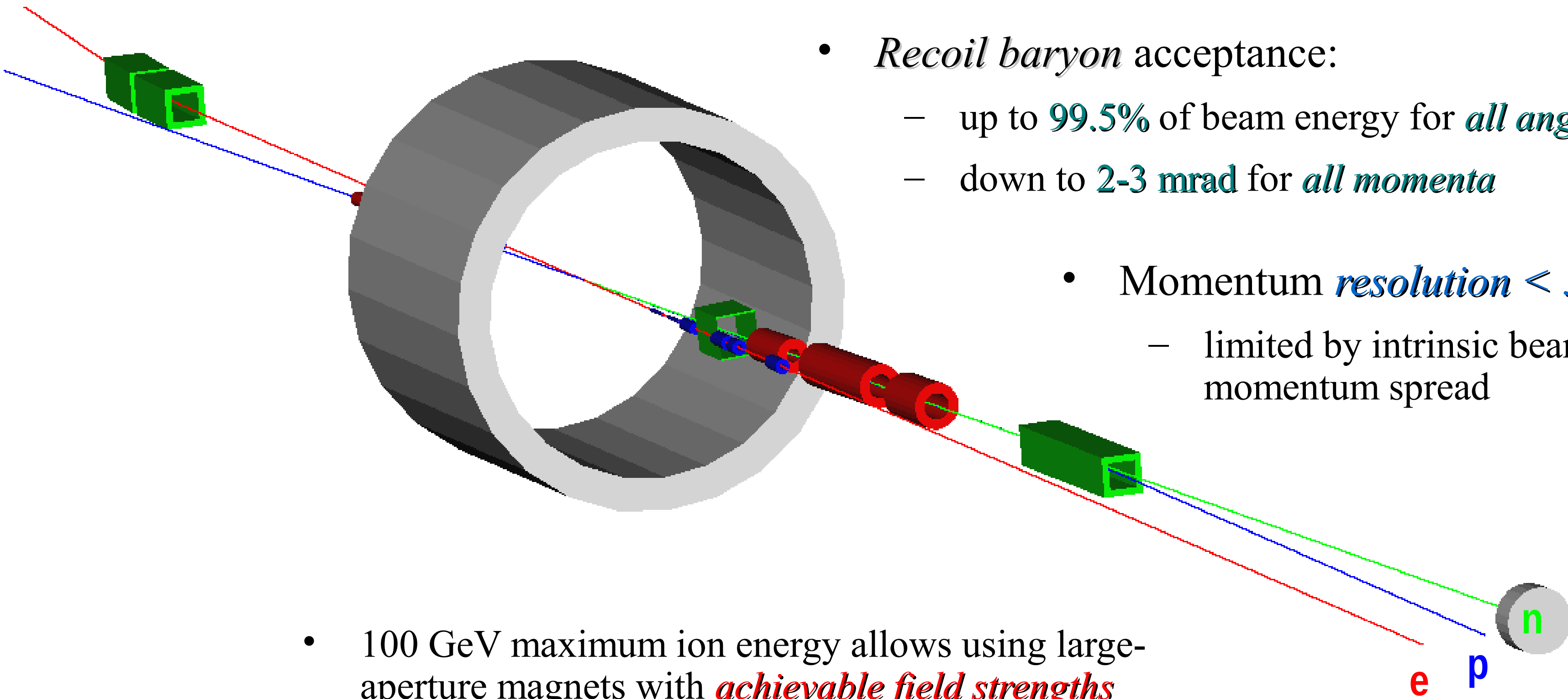
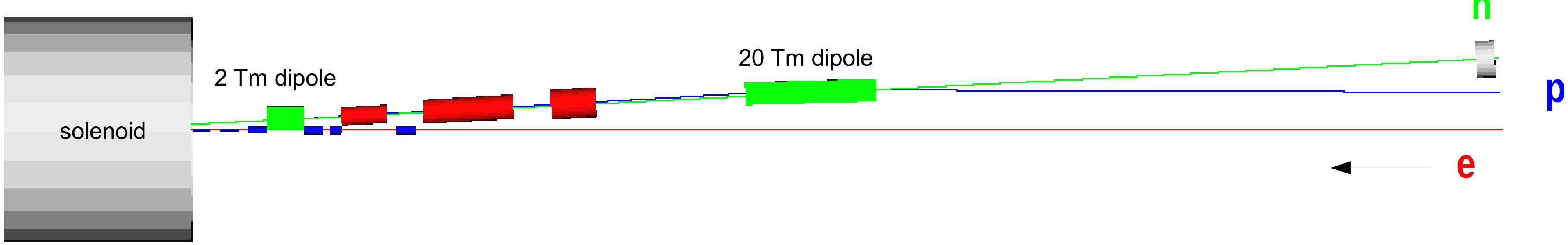
Ultra-forward hadron detection – summary

- *Neutron* detection in a 25 mrad cone ***down to zero degrees***
- Excellent acceptance for ***all ion fragments***



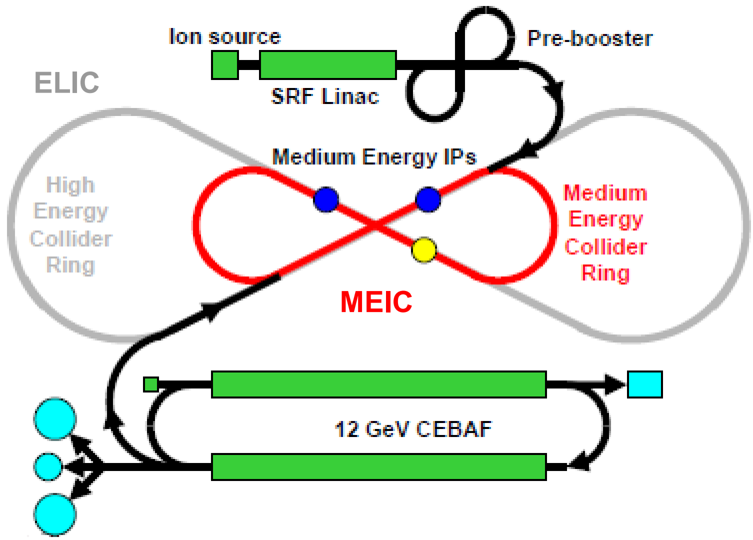
- *Recoil baryon* acceptance:
  - up to 99.5% of beam energy for ***all angles***
  - down to 2-3 mrad for ***all momenta***
- Momentum ***resolution < 3x10^-4***
  - limited by intrinsic beam momentum spread
- 100 GeV maximum ion energy allows using large-aperture magnets with ***achievable field strengths***



Other interaction regions

Space for 3 Interaction Points (IP)

- Main IPs located close to outgoing ion arc to reduce backgrounds



Full-acceptance detector (primary)

- 7 m from IP to ion final-focus quads

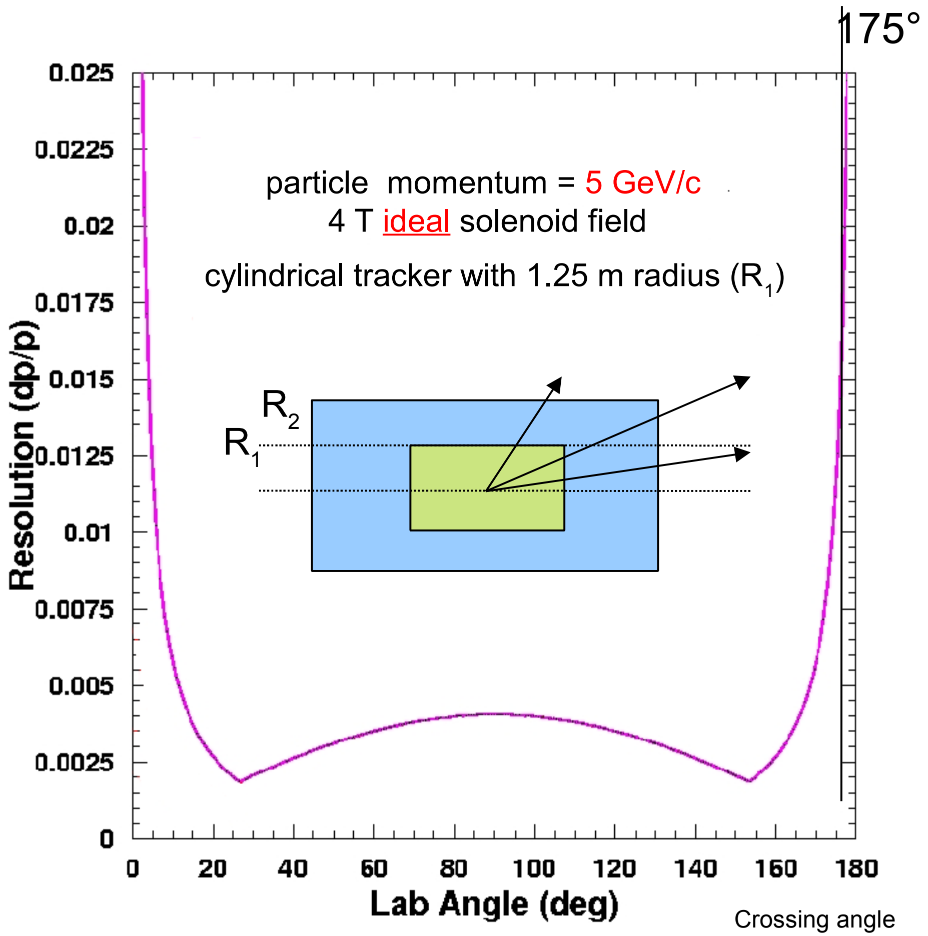
High-luminosity detector (secondary)

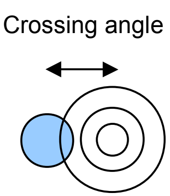
- 4.5 m from IP to ion final-focus quads

Special IP

- Space reserved for future needs

Momentum resolution at different rapidities

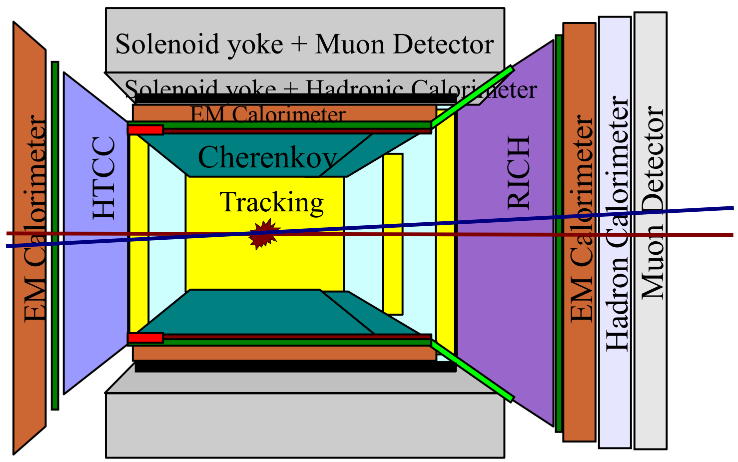


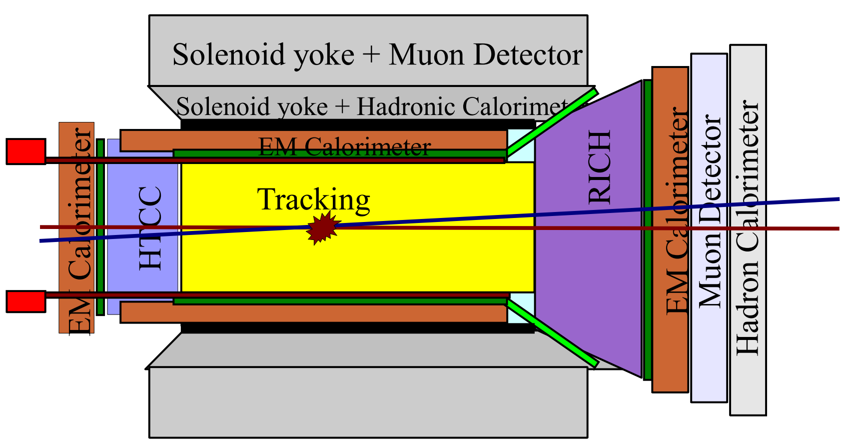


$\Delta p/p \sim \sigma p / BR^2$

- Tracker (not magnet!) radius R is important at central rapidities (*i.e.*, scattering angles)
- Only solenoid field B matters at forward rapidities
- Full-acceptance detector benefits from high field for uniform resolution
- High-luminosity detector solenoid could have a lower field and larger radius, focusing on transverse physics
- High-luminosity IP could give up the intermediate detection stage to save space, but keep the crossing angle and a simplified ultra-forward detection

Detector radius also useful for particle identificaton





- Small differences in the desired momentum range (p_{lab}) for π/K separation has a huge impact on detector layout
- If you need 8-9 GeV, the detector may look like on the left (1 m radial space for PID)
  - High luminosity detector?
- If 5-6 GeV is enough, the detector may look like this instead (0.1 m radial space for PID)
  - Full acceptance detector?

- TOF
- DIRC bar
- DIRC expansion volume