EIC-JLab Detector Workshop
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Jefferson Laboratory

Forward and Far-Forward Detection at ELIC

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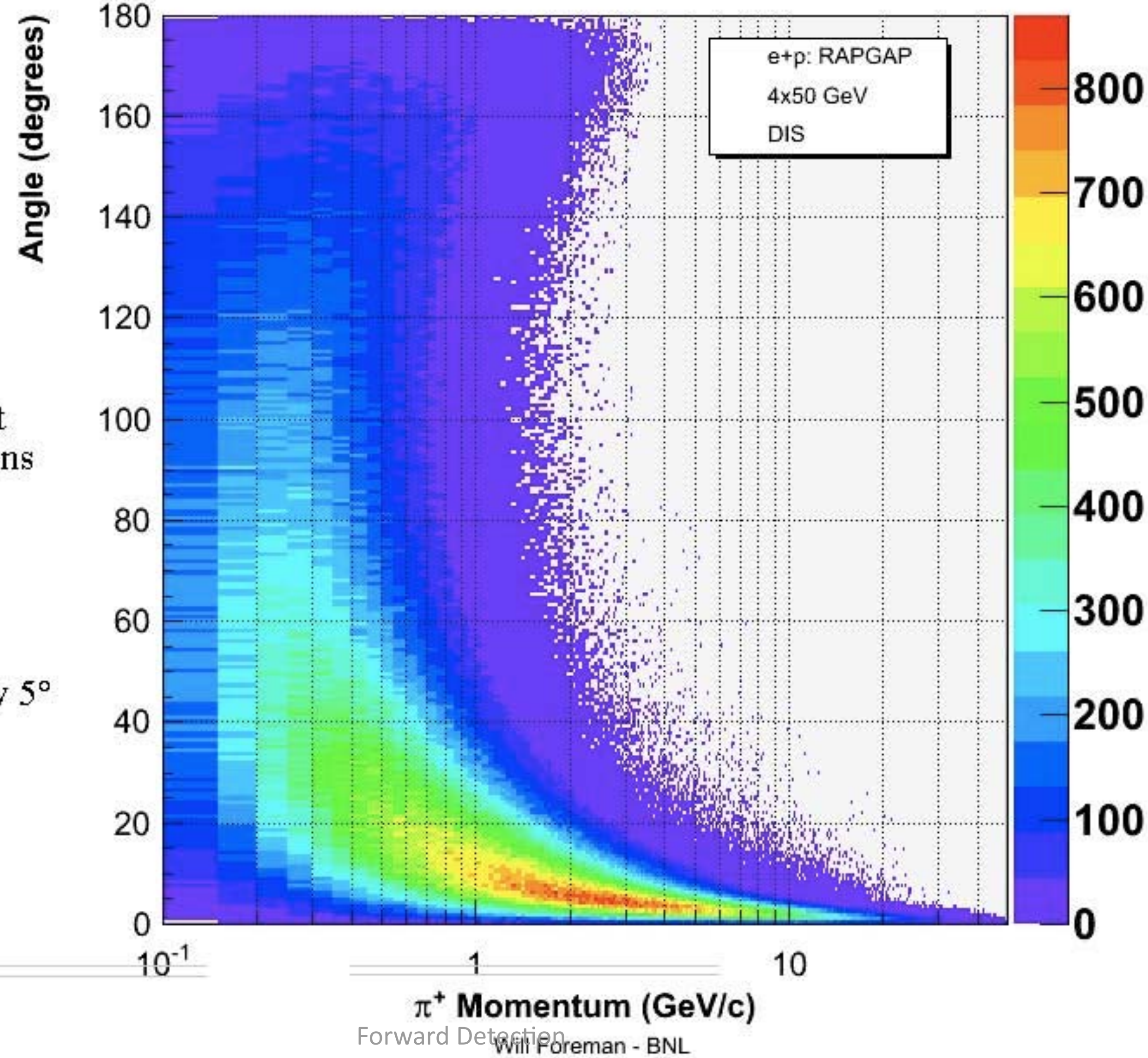
Forward Particles of a 6x60 GeV collider

- "Forward" is defined relative to ion beam
  - Important issues also for low Q2 tagging on electron side, not addressed here.
- SIDIS and exclusive processes produce "jet" fragmentation particles (γ, π, *K*, etc).
  - These particles fill the full 4π laboratory detector space,
- Exclusive, DIS, Rapidity gap events produce ultra forward baryons, and forward mesons from dissociation.
  - Exclusive: ep → epγ
  - SIDIS or RapGap: ep → e'K…Λ…
  - Deep Exclusive or SIDIS production of forward Δ, Λ will produce forward mesons and nucleons
    - mesons: momenta ~(m/M)P ~8 GeV/c θ ~ (0.2 GeV/c) / (8 GeV/c) ~25 mrad
    - nucleons: P~50 GeV/c, θ ~4 mrad
- Photoproduction can produce forward mesons [nearly] up to beam momentum

(Semi-) inclusive meson production kinematics

- Essential to detect and identify mesons at *all* angles
- Detection most challenging below 5°



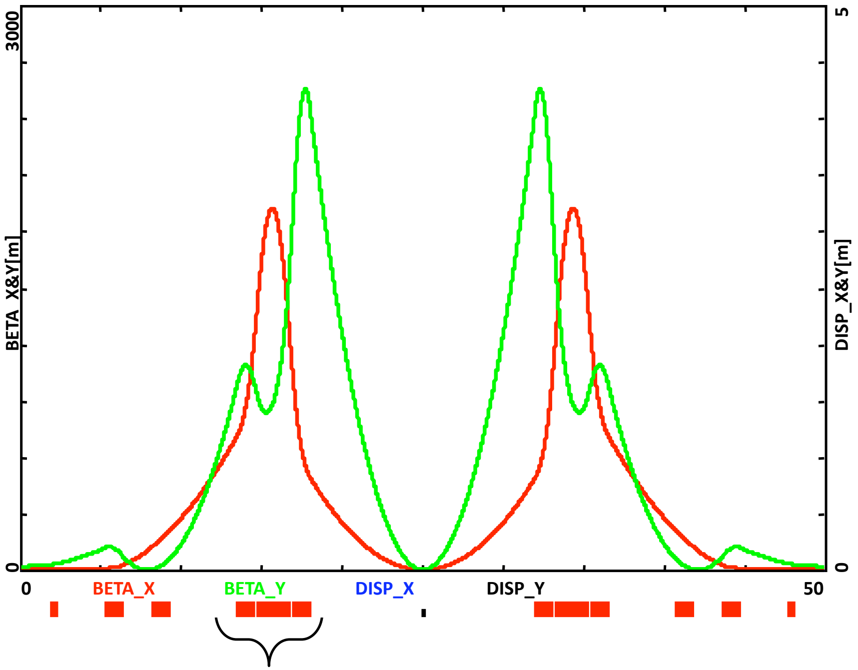
IR Optics (ions) at 60 GeV

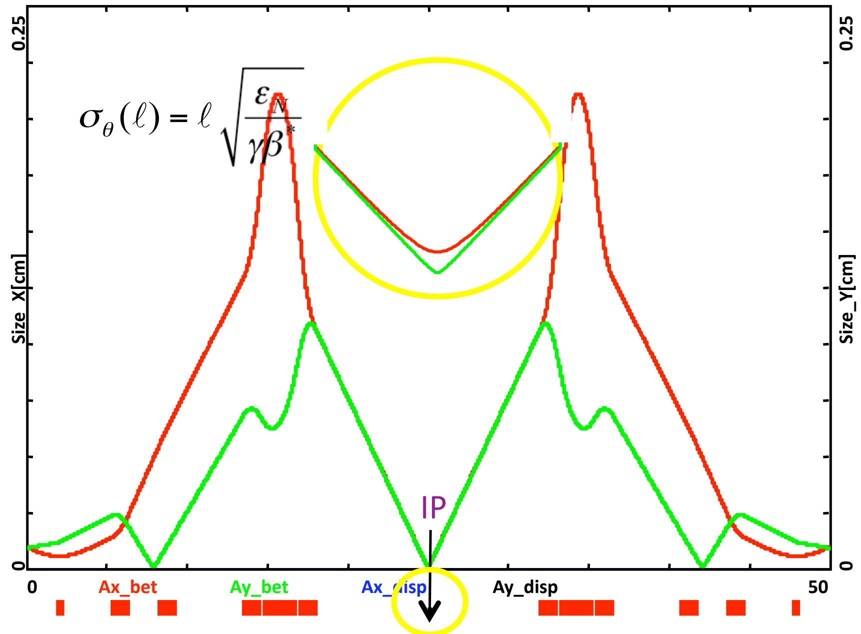
$\varepsilon_N^x = 0.15\times10^{-6} m$ $\beta_x^* = 10\, cm$

$\varepsilon_N^y = 0.03\times10^{-6} m$ $\beta_y^* = 2\, cm$

$\sigma_x^* = 15\times10^{-6} m$

$\sigma_y^* = 3\times10^{-6} m$





FF triplet : Q3 Q2 Q1

Q1	G[kG/cm] = -9.7
Q2	G[kG/cm] = 6.9
Q3	G[kG/cm] = -6.8

Q1 aperture = 7 cm (@ 7m)

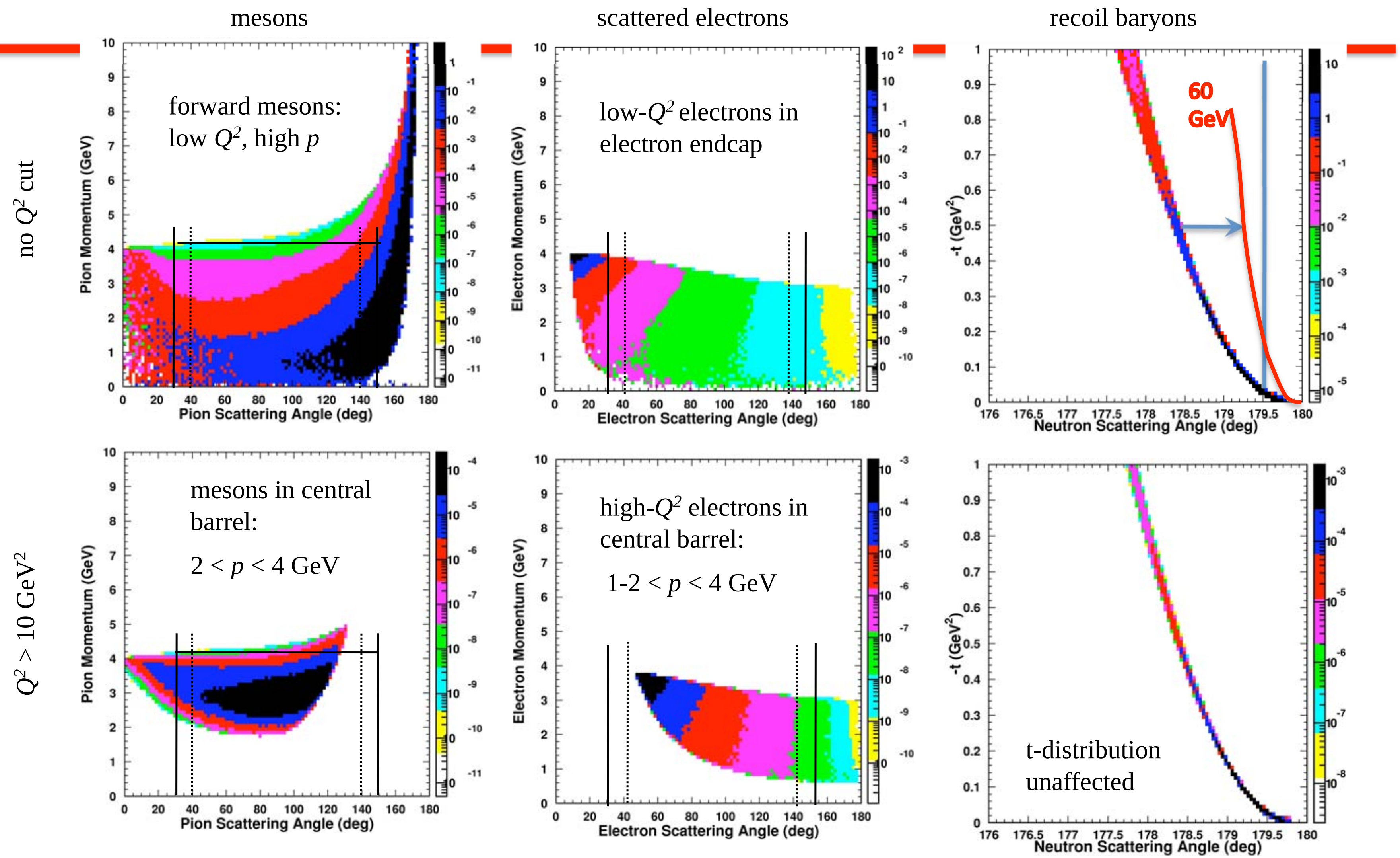
Q3 aperture =10 cm (@12 m)

→ 7T peak fields

Particles < 0.5° = 10 mrad through FF quads

P⊥< 600 MeV/c

Low Q^2 (J/Ψ) vs high Q^2 (light mesons) – 4 on 30 GeV

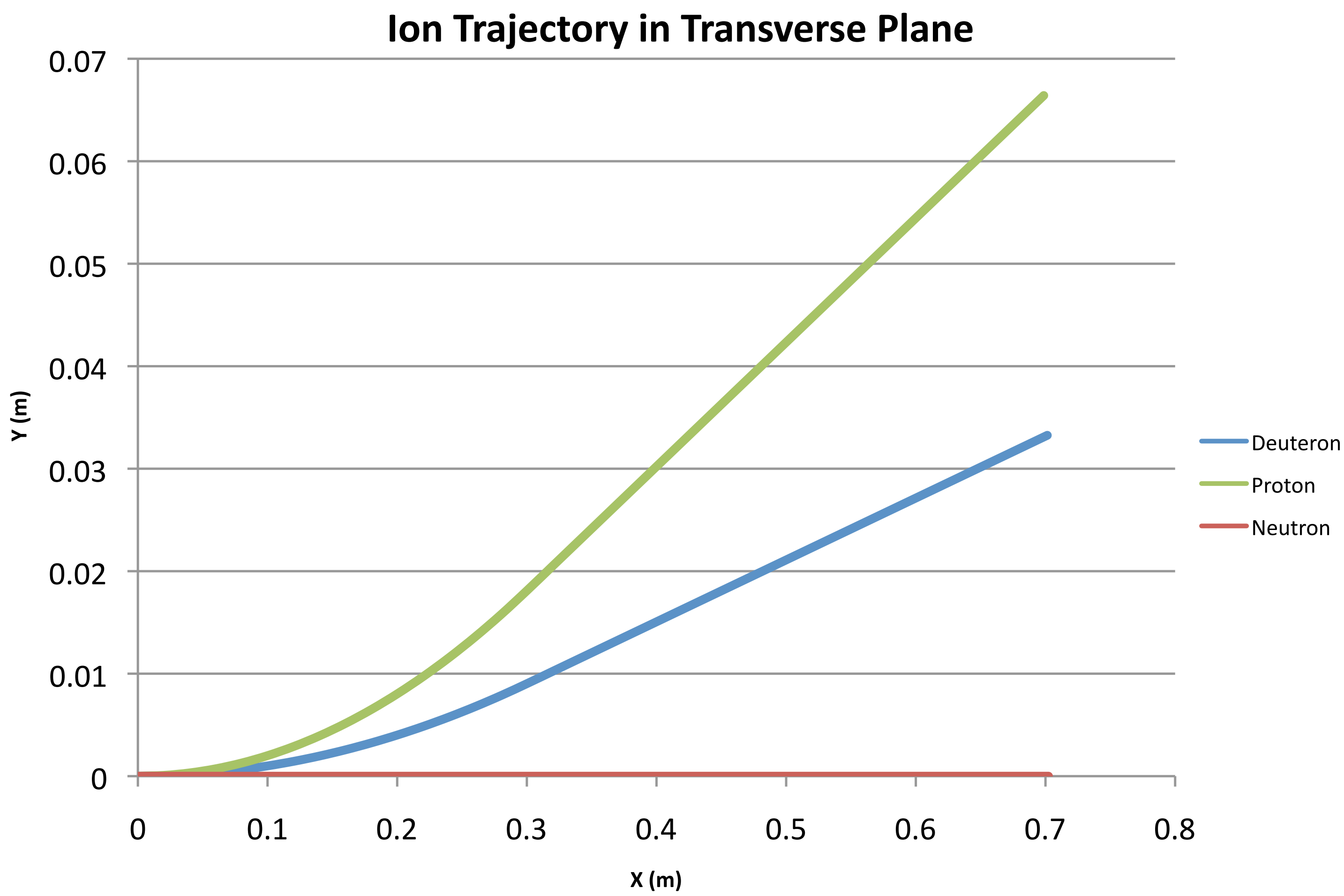


Neutral vs Charged Particle Detection

- Forward Spectrometer
  - Maximum available space on ion line is ~2m
    - After Endcap RICH, Before Final Focus Quads
- Dipole option
  - Maximum analysis of charged particles
- Off Axis trajectory through Solenoid + dipole bend of charged particle trajectories complicates detection of neutrons at 0° through FFQ1-Q3
  - No drift space between dipole and FFQ1 to separate beam from 0° neutrons
  - Instead use Dipole to cancel perpendicular field component of solenoid.
    - Neutrons now parallel to beam through quads

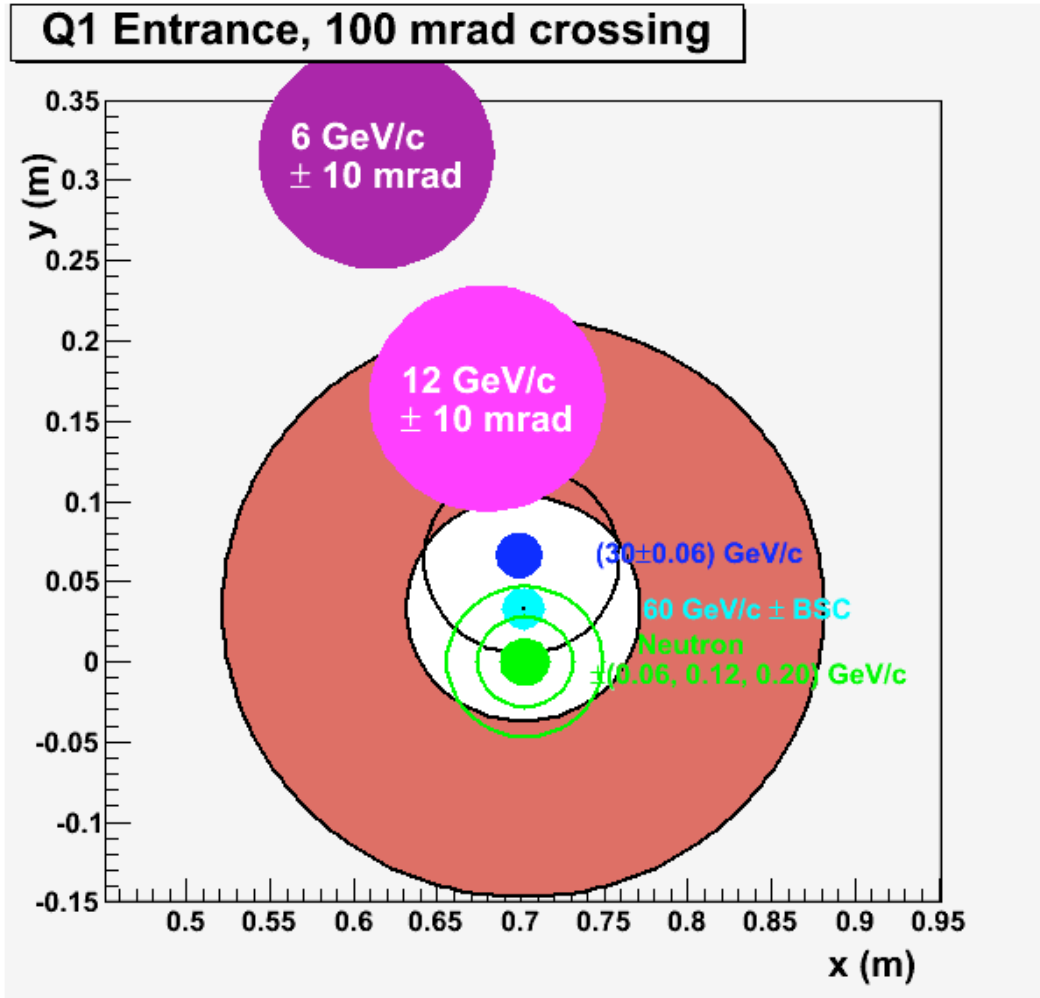
Precession of Trajectories in Solenoid

- 60 GeV/c Deuteron
- 100 mrad
- 4 Tesla Solenoid.

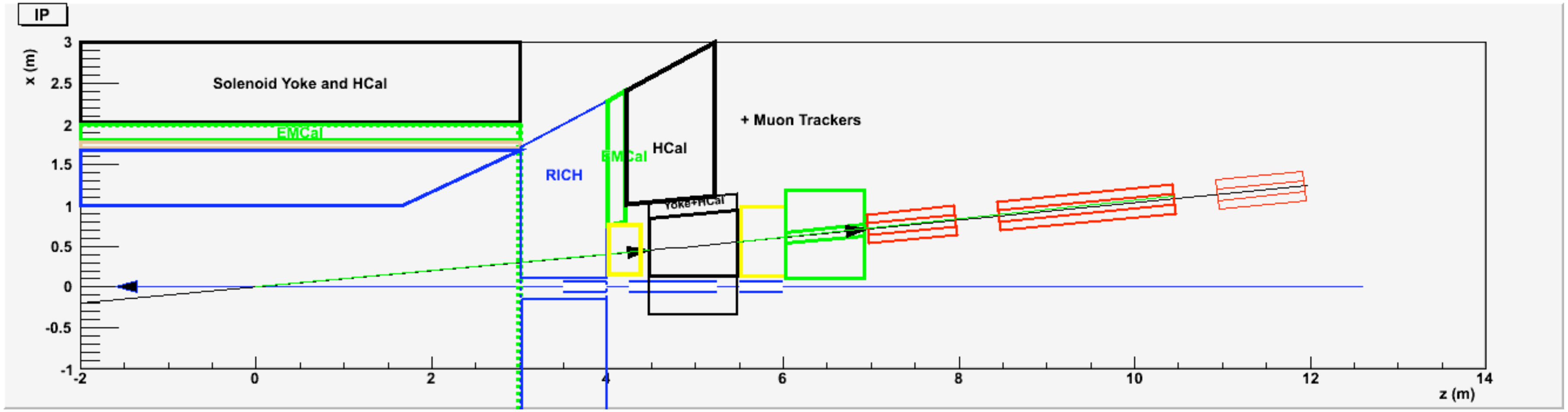


Precession of Trajectories in Solenoid

- 4 Tesla x 3m
  at 100 mrad
- G ~10 T/m
  - Oversized quad
    7 T max. field
- Primary N=Z beam, proton and neutron spectators in Q1 acceptance
- Need $B_x dl = -1.2$ Tm from Dipole to align charged and neutral trajectories through Q1-Q3
- Neutron cone larger at lower beam momenta?



Forward Tracking

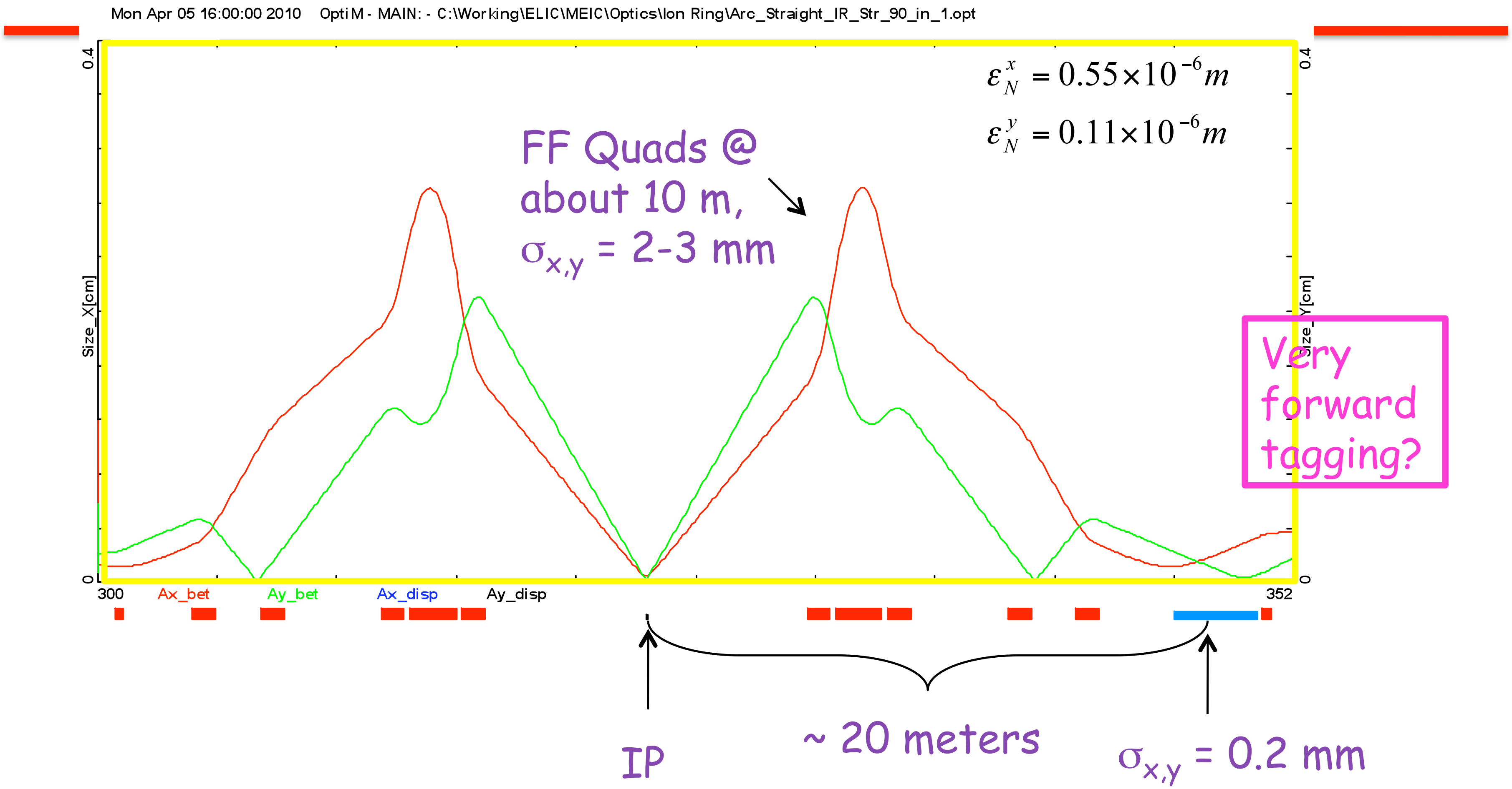


- 1.2 Tm vertical bend Dipole
  - Cancels ⊥ B-field of Solenoid
  - Tracking + EMCal + NeutronCal between dipole and Q1
    - Trajectories in shadow of Q1 are tracked
      - 12 GeV/c for < 10mr
    - Wide angle neutrons detected by annular HCal.
  - 0° neutrons and Charged particles aligned through Q1-Q3
    - Need 20 cm aperture of Quads Q4, Q5, Dipole at 15-20 m

Momentum Resolution of Forward Tracker

- Measure points to 100μ over 0.5 m length before and after dipole
  - δθ ~0.3 mrad.
- Dipole Bdl = -1.2 Tm
  - Bending angle
  - θ = (ecBdl)/(pc) = (0.3GeV)/(pc)
- Momentum Resolution
  - δp/p = δθ/θ = pc/(1000 GeV)
  - 1% at 10 GeV/c
  - 0.5% at 5 GeV/c

Ion Ring – Beam envelopes



Beam-stay-clear area near IP, before Q1: 10-12 σ → 2.5 cm @ 7 m = 0.2 deg
Beam-stay-clear area away from IP: 8-10 σ → 2 mm @ 20 m = 0.1 mr

Far Forward Tracking

- 20-40 Tm Dipole at 20m
  - Need 1-2 m drift space :
  - Dispersion ~ 1 m /100%
    - Not [anti-symmetric] Lattice dispersion: Dispersion of a 0° particle at IP
  - $\beta \sim D$
- Lattice Admittance $\Delta P/P$ ~0.003 = 10 $\delta P/P$
- "Recoil" ion with (P'-P)/P > 0.005
  - x> 5 mm
  - BSC ~ $10\,[\varepsilon\beta/\gamma]^{1/2}$ ~1 mm
  - $\delta x = 100\ \mu \rightarrow dp_{||}/p = 10^{-4} \rightarrow$ better than intrinsic beam spread
- Neutron Detection in ZDC
  - Neutron $P_{\perp}$<60 MeV/c cone is 20 mm radius
  - Separated from Beam by 200 mm after 2m drift
  - 10 mm resolution at 25 m $\rightarrow \delta\theta = 0.4$ mr $\rightarrow \delta p_{\perp} = 12$ MeV/c

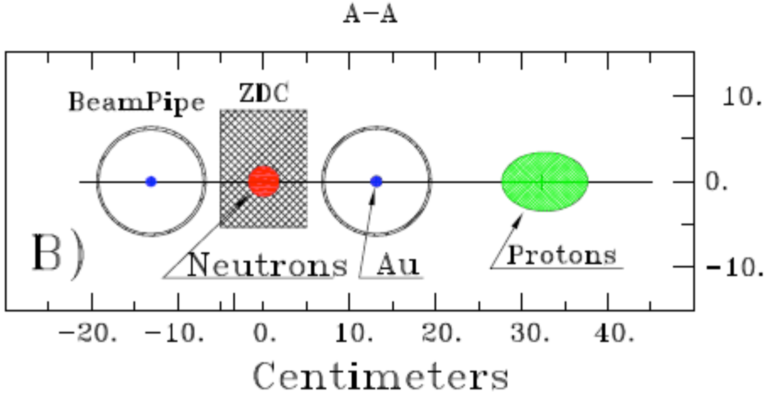
Conclusions

- Almost continuous (if not perfectly hermetic) detection is possible for forward and far-forward charged and neutral particles.
    - Modest dipole allows full tracking and PID, even in Quad shadow
    - Dipole Bdl = − Solenoid [Bdl $\tan\theta$]
        - Resolution will be degraded if Solenoid B-field or crossing angle is reduced
- Study 30m propagation through Beam Line optics for far forward exclusive protons, spectator protons, neutrons…
    - Coherent Nuclei?
    - Heavy fragments?
    - Neutron evaporation
- Start building a Monte Carlo!

RHIC – Zero Degree Calorimeter

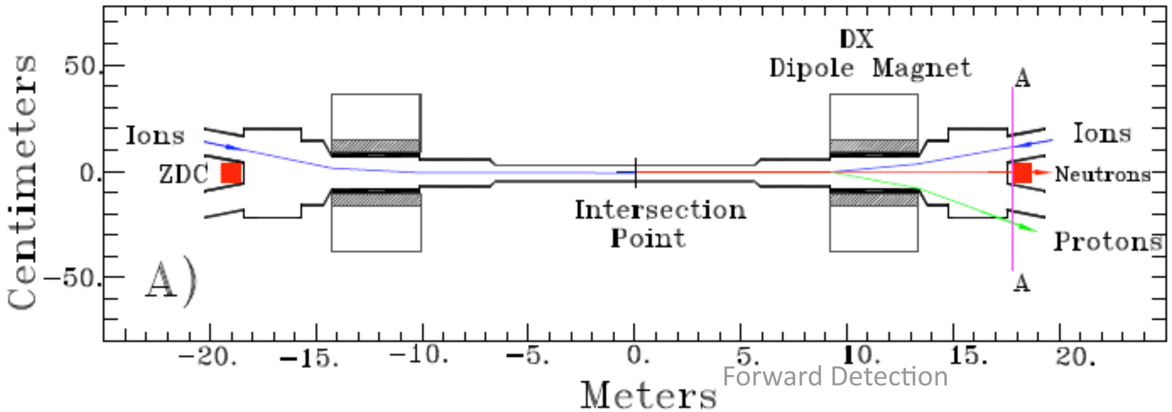
arXiv:nucl-ex/0008005v1

Context: The RHIC ZDC's are hadron calorimeters aimed to measure evaporation neutrons which diverge by less than 2 mr from the beam axis.



<2 mr at 18 meters from IP
→ neutron cone ~ 4 cm

ZDC = 10 cm (horizontal)
x 13 cm (vertical)



ZDC Dimensions

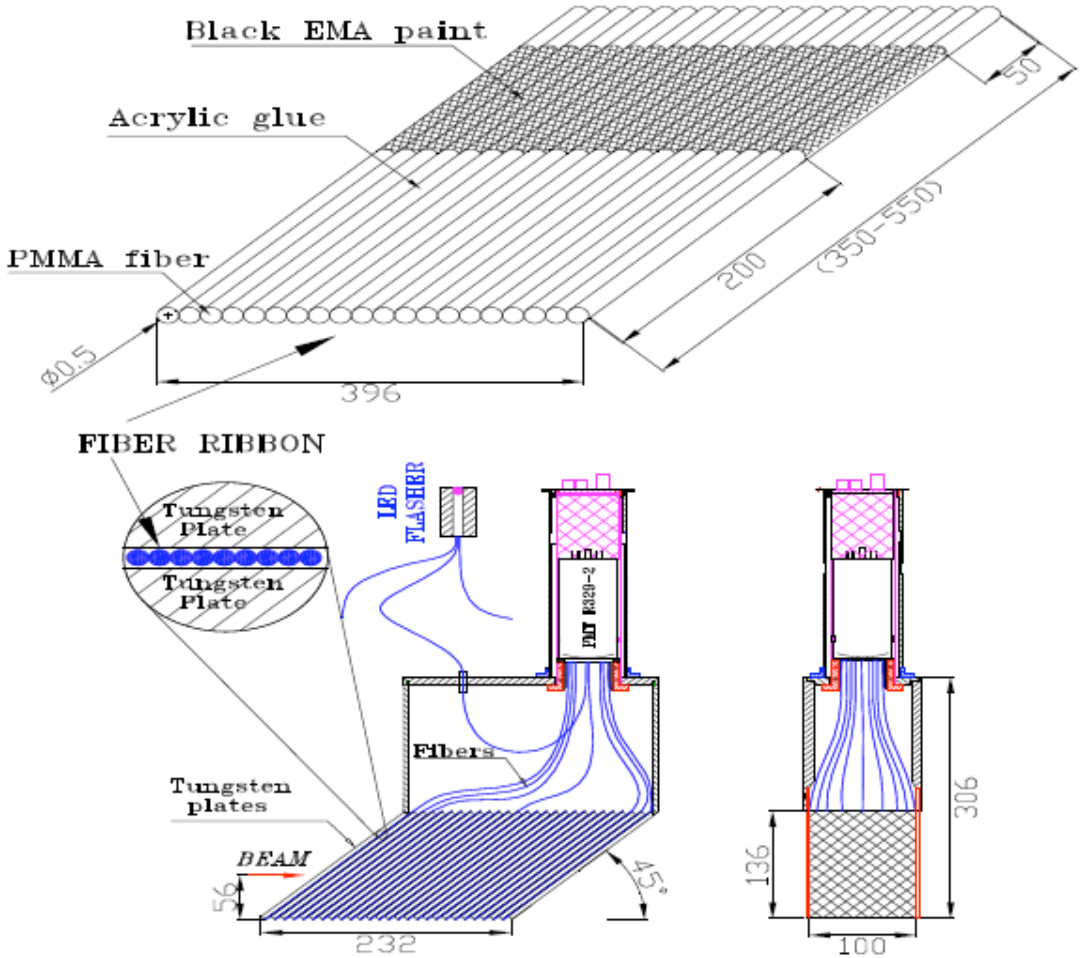


Table 1
Mechanical parameters of the ZDC's

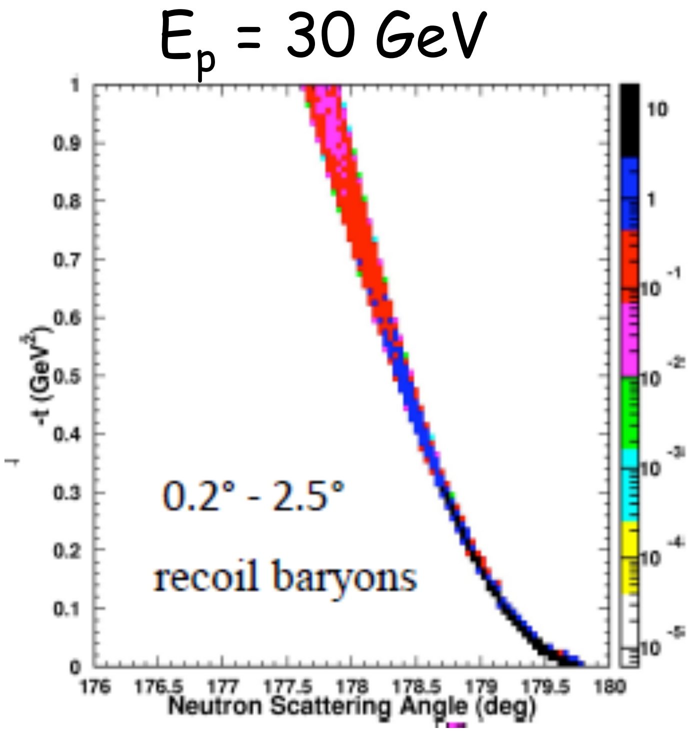
	Absorber	Space for fibers	Modules/Layers
Production ZDC	Tungsten alloy (100x187x5 mm^3)	1.4 mm	$3(5.1\lambda_I;149X_0)$ 27

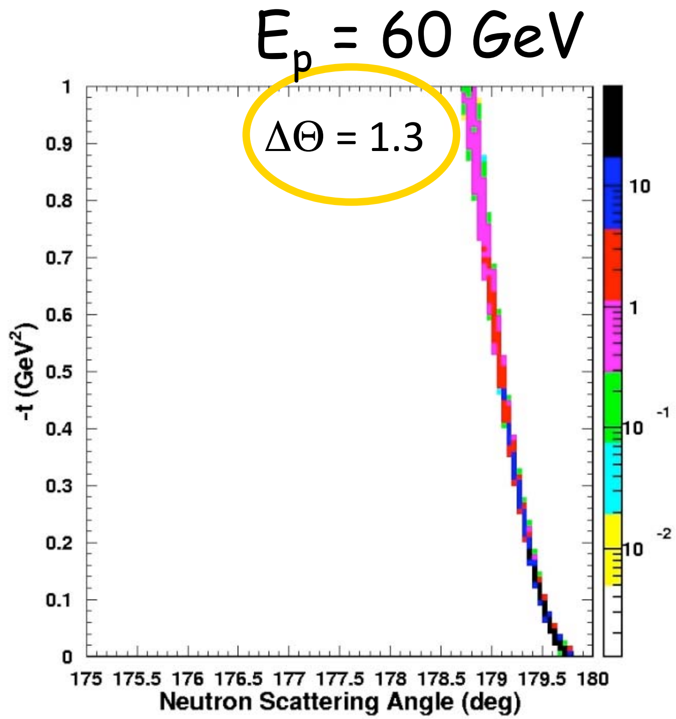
27 layers of 5 mm → 13.5 cm
3 modules → 40 cm thickness
60% Shower containment 1 cm from edge
$9\% + 8\%[GeV/E_n]^{1/2}$

Fig. 5. Mechanical design of the production Tungsten Modules.Dimensions shown are in mm.

Detector/IR in simple formulas

$t \sim E_p^2 \Theta^2 \rightarrow$ Angle recoil baryons = $t^{\frac{1}{2}}/E_p$





→ Must cover between 1 and 5 degrees (

→ Should cover between 0.5 and 5 degrees

→ Like to cover between 0.2 and 7 degrees

Deep exclusive kinematics: $ep \rightarrow e\pi^+n$

Tanja Horn