MEIC Detector and Interaction Region

Lots of credit to Yuhong Zhang, Alex Bogacz, Slava Derbenev, Geoff Krafft, other CASA/Accelerator members, Tanja Horn, Charles Hyde, Pawel Nadel-Turonski for multiple accelerator and detector/interaction region ideas, plus slides stolen from Elke Aschenauer, Thomas Ullrich, and others at BNL

- EIC detector design is general, with some modifications
  Recent: some overlap with eRHIC interaction region design
- The EIC interaction region design & science optimizations
  - Intro to accelerator design: what to integrate with?
  - The interaction region design in simple terms
  - Optimizing the detector/interaction region design for detection of fragments in the ion direction.

Rolf Ent (Jefferson Lab) 05/18/2010

Quotes from EICAC Report on Accelerator R&D Priorities

Slide from Steve Vigdor

Highest priority:
- Design of JLab EIC
- High current (e.g. 50 mA) polarized electron gun
- Demonstration of high energy – high current recirculation ERL
- Beam-Beam simulations for EIC
- Polarized 3He production and acceleration
- Coherent electron cooling

High priority, but could wait until decision made:
- Compact loop magnets
- Electron cooling for JLab concepts
- Traveling focus scheme (it is not clear what the loss in performance would be if it doesn't work; it is not a show stopper if it doesn't)
- Development of eRHIC-type SRF cavities

Medium Priority:
- Crab cavities
- ERL technology development at JLAB

(M)EIC@JLab: Plan and Deliverables

Slide from Yuhong Zhang

- Accelerator Design "Contract"
  - Medium energy with scaled down parameters (ELIC version M.1)
  - "Contract" revision (end of 2010), after user workshops and the next EIC AC meeting
- "Design Manual"
  - A 20 to 30 page document, archived in web
  - Explanation of high level design choices
  - Main and secondary parameters, schemes
  - Major components, and interfaces between them
- Action items
  - Finish "action items/decision points" in about a week each
  - Work scope
    - Collecting information/references
    - Performing estimations/calculations if applicable
    - Formulate a solution/recommendation
    - Present in ELIC R&D meeting
    - Write a (minimum) half page on each item for the "design manual"
- *Similar Action Item: Detector/IR document*

Near-Term MEIC Design Parameters

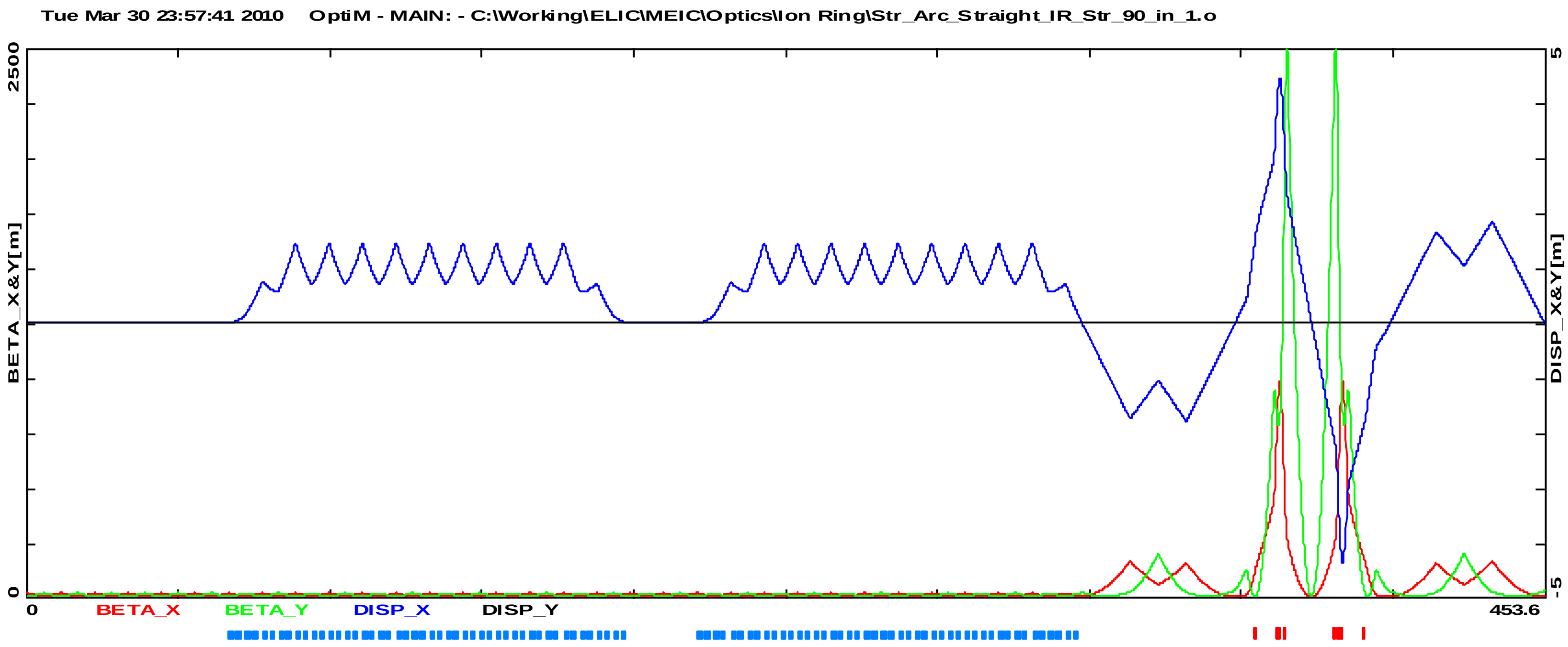
		Electron	Proton	
Collision energy	GeV	3 – 11	20 - 60	Ion booster 3–12 GeV, ring accepts 12 GeV injection
Max dipole field	T		6	Not too aggressive after LHC
Max SR power	kW/m	20		Factor two beyond best achieved?
Max current	A	2	1	~ max B-factory current, HOM in component HERA 0.15 A (?) RHIC 0.3 A
RF frequency	GHz	1.5	1.5	Use combination of gap (crossing angle) and RF shift to accommodate lower ion energies
Bunch length	mm	5	5	6 mm demonstrated in B-factory, 10 cm in RHIC (?)
IP to front face of 1st quad (l)	m	+/- 3 to 4	+/- 7	
Vertical β*	cm	2	2	Keep β_{max} below ~2 km, with $\beta_{max} = l^2/\beta^*$
Crossing angle	mrad	100		50 to 150 desired for detector advantages

Luminosity expected to be above 1×10^{34} e-nucleons/s/cm^2 around 60x5 GeV^2, and be well above 10^{33} at "s edges"

Figure-8 Ion Ring - Optics

Alex Bogacz

Uncompensated dispersion from arcs



Arc length C ~ 115 m + 20 m (for spin manipulation) + 115 m

(increased partly due to assumption of 60 GeV & 6 T max dipole fields)

Straight length L ~ 240 m (increased to accommodate spin rotator + SRF sections)

Total Ring Circumference would then be: 2 (L + C) = 980 m

Detector/IR in simple formulas

β_{max} ~ 2 km = l^2/β^* (l = distance IP to 1st quad)

Example: l = 7 m, β^* = 20 mm → β_{max} = 2.5 km

IP divergence angle ~ 1/sqrt(β^*)

Example: l = 7 m, β^* = 20 mm → angle ~ 0.3 mr
Example: 12 σ beam-stay-clear area
→ 12 x 0.3 mr = 3.6 mr ~ 0.2°

Making β^* too small complicates small-angle (0.5°?) detection before ion Final Focusing Quads, and would require too much focusing strength of these quads, preventing large apertures (up to 0.5°?)

Luminosity ~ 1/β^*

Interaction Region Optics (electrons)

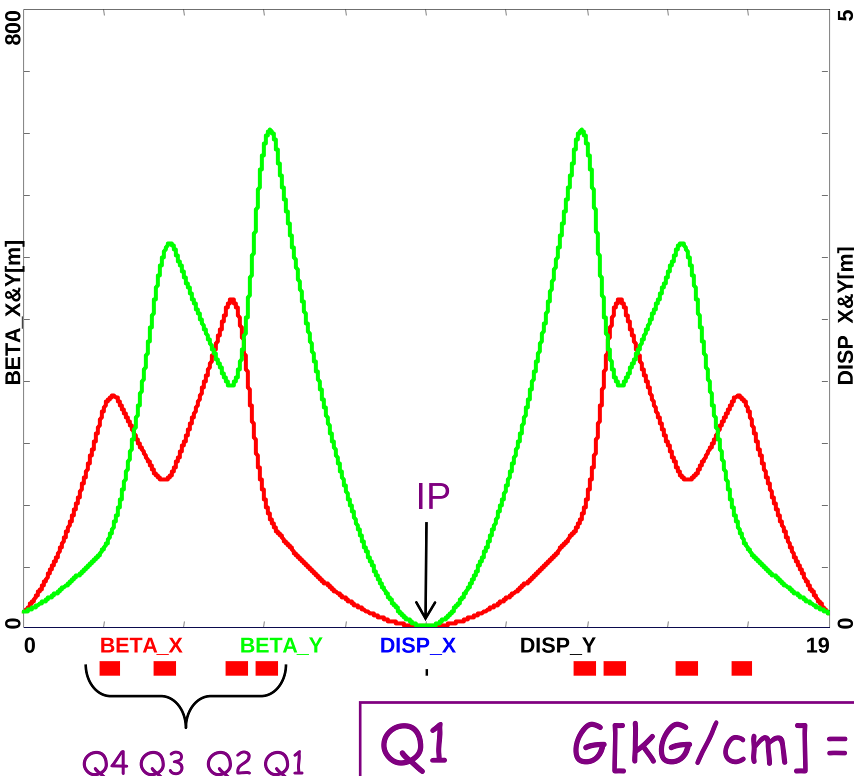
$\varepsilon_N^x = 22\times10^{-6} m$ $\beta_x^* = 10\, cm$

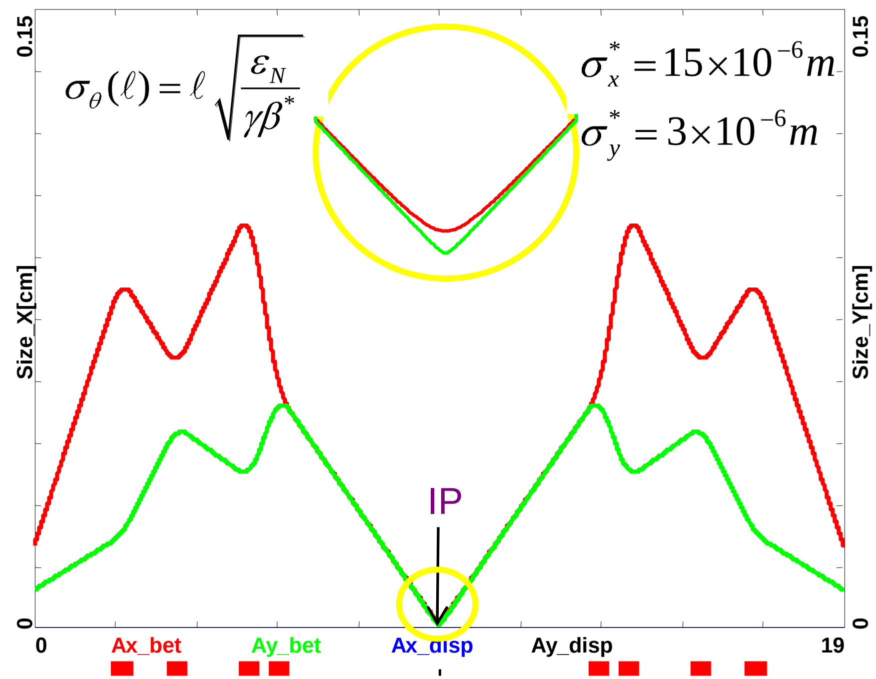
$\varepsilon_N^y = 4.4\times10^{-6} m$ $\beta_y^* = 2\, cm$

$$\zeta_{IR} \approx \frac{f^2}{\beta^*}\frac{1}{f} = \frac{f}{\beta^*}$$

Natural Chromaticity:

$\zeta_x = -47$ $\zeta_y = -66$

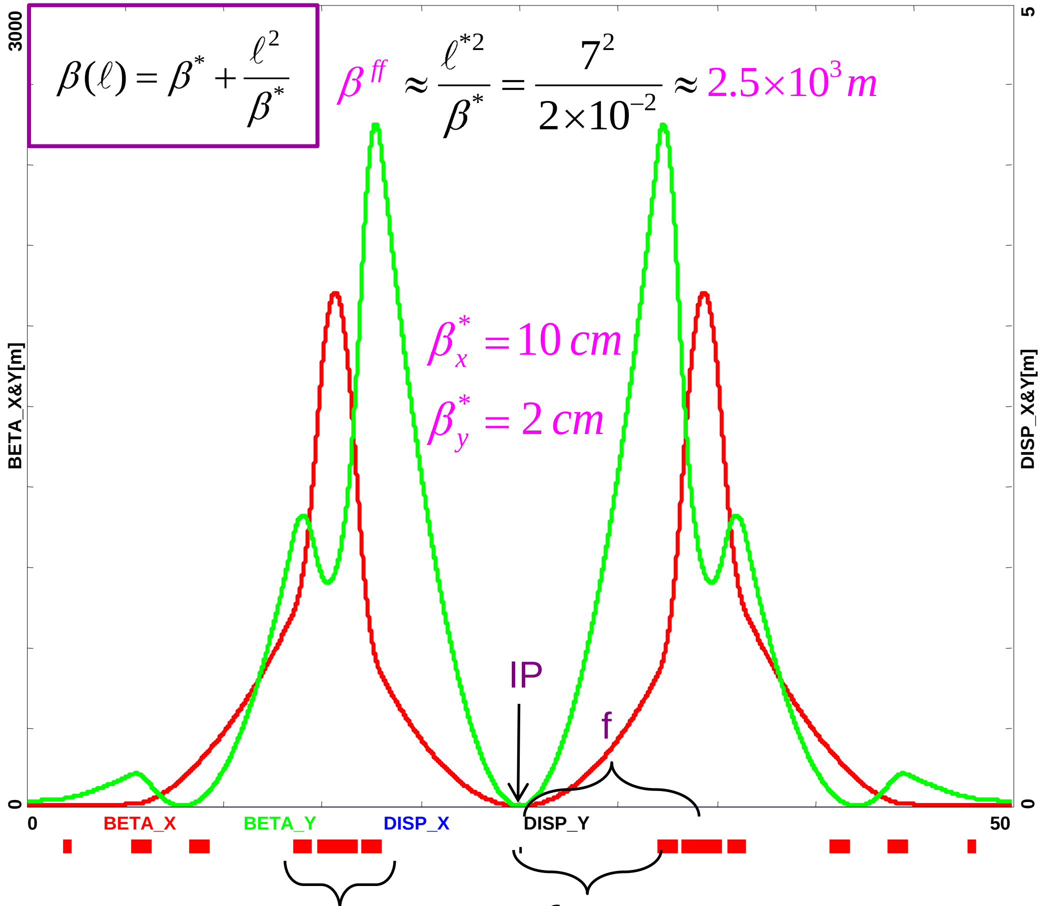




Q1	G[kG/cm] =	-2.8
Q2	G[kG/cm] =	3.1
Q3	G[kG/cm] =	-2.0
Q4	G[kG/cm] =	2.0

Q apertures small (~1.5 cm)
→ Peak fields ~ 0.5 T
→ "Baby-size" quads only

Interaction Region Optics (ions)



$$\beta(\ell) = \beta^* + \frac{\ell^2}{\beta^*}$$

$$\beta^{ff} \approx \frac{\ell^{*2}}{\beta^*} = \frac{7^2}{2\times10^{-2}} \approx 2.5\times10^3 m$$

$$\beta_x^* = 10\,cm$$

$$\beta_y^* = 2\,cm$$

$$\beta^{max} = \cancel{\beta^*} + \frac{\ell^{*2}}{\beta^*} \approx \frac{\ell^{*2}}{\beta^*} \approx \frac{f^2}{\beta^*}$$

$$f = \ell^* + {l_{FF}}/{2} \approx \ell^*$$

$$\zeta_1 := \frac{1}{4\pi}\int_0^l \beta_x\,(-g_0 + \eta_0\, g_1)\, ds;$$

$$\beta^{max} g_0^{FF}$$

$$\zeta_{IR} \approx \frac{f^2}{\beta *}\frac{1}{f} = \frac{f}{\beta *}$$

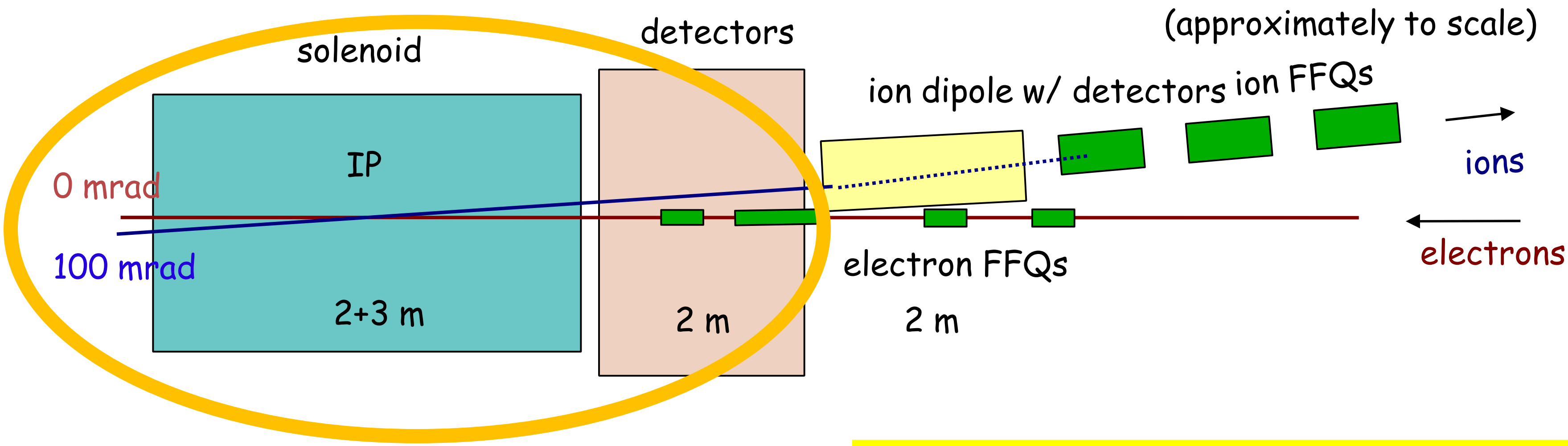
Natural Chromaticity: ζ_x = -88 ζ_y = -141

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

Q3 aperture 10 cm (@12 m) → 7T peak field
→ Particles < 0.5 degrees through FF quads

Detector/IR cartoon

Make use of a 100 mr crossing angle for ions!



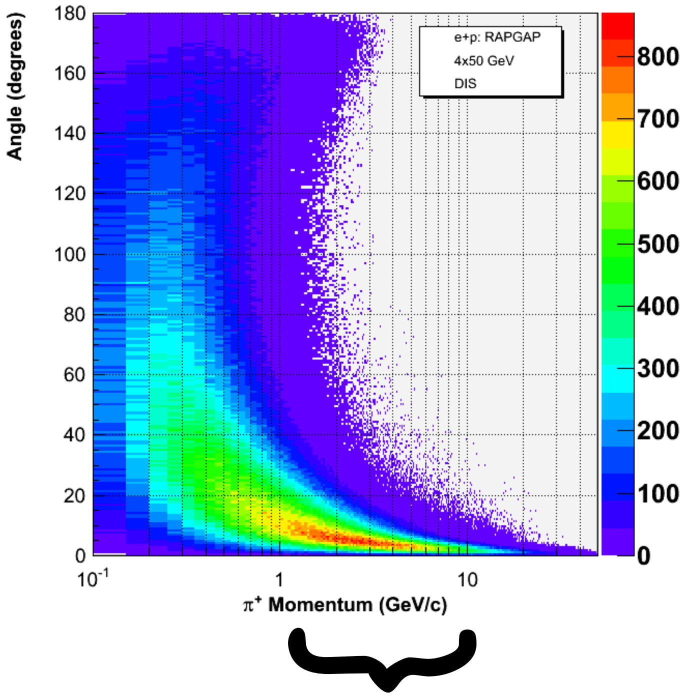
Central detector, more detection space in ion direction as particles have higher momenta

100 mr crossing angle
3.5 m distance IP – electron FFQs
→ Easy to squeeze baby-size electron FFQs in here

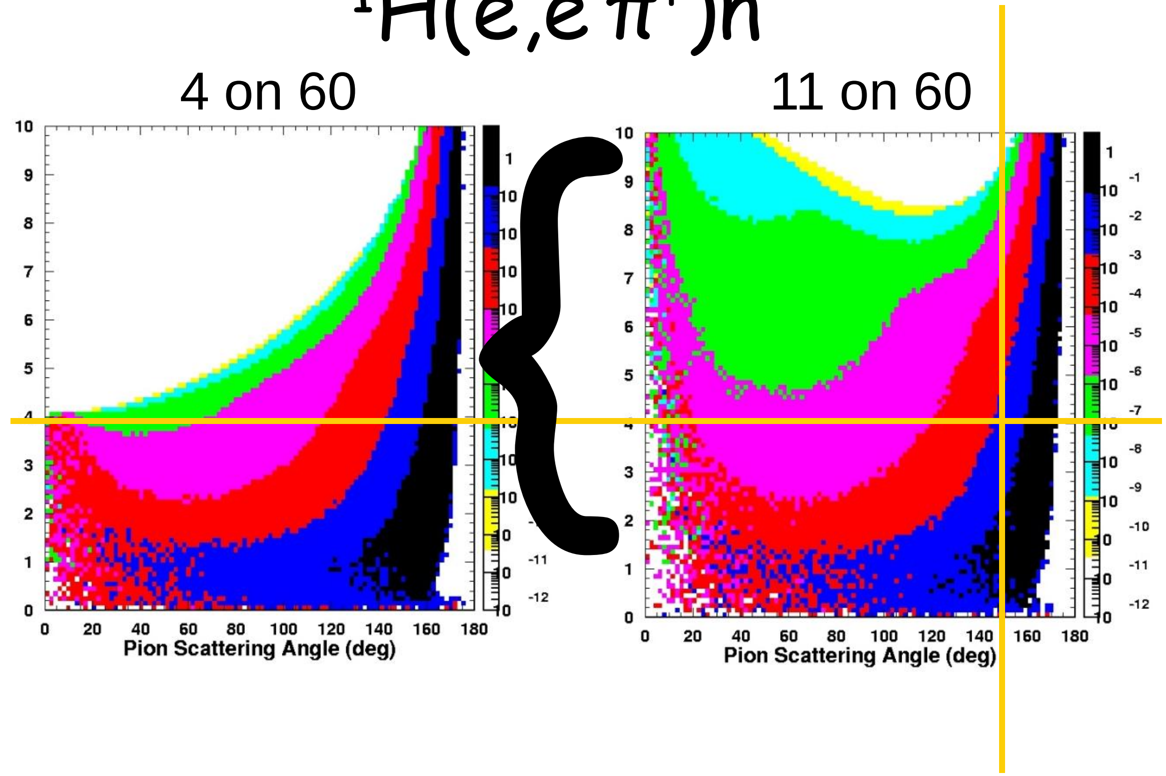
Distance IP - electron FFQs = 3.5 m
Distance IP - ion FFQs = 7.0 m

Where do particles go - mesons

SIDIS π



$^1H(e,e'\pi^+)n$



Need Particle ID for p > 4 GeV in central region

→ DIRC won't work, add threshold Cherenkov or RICH

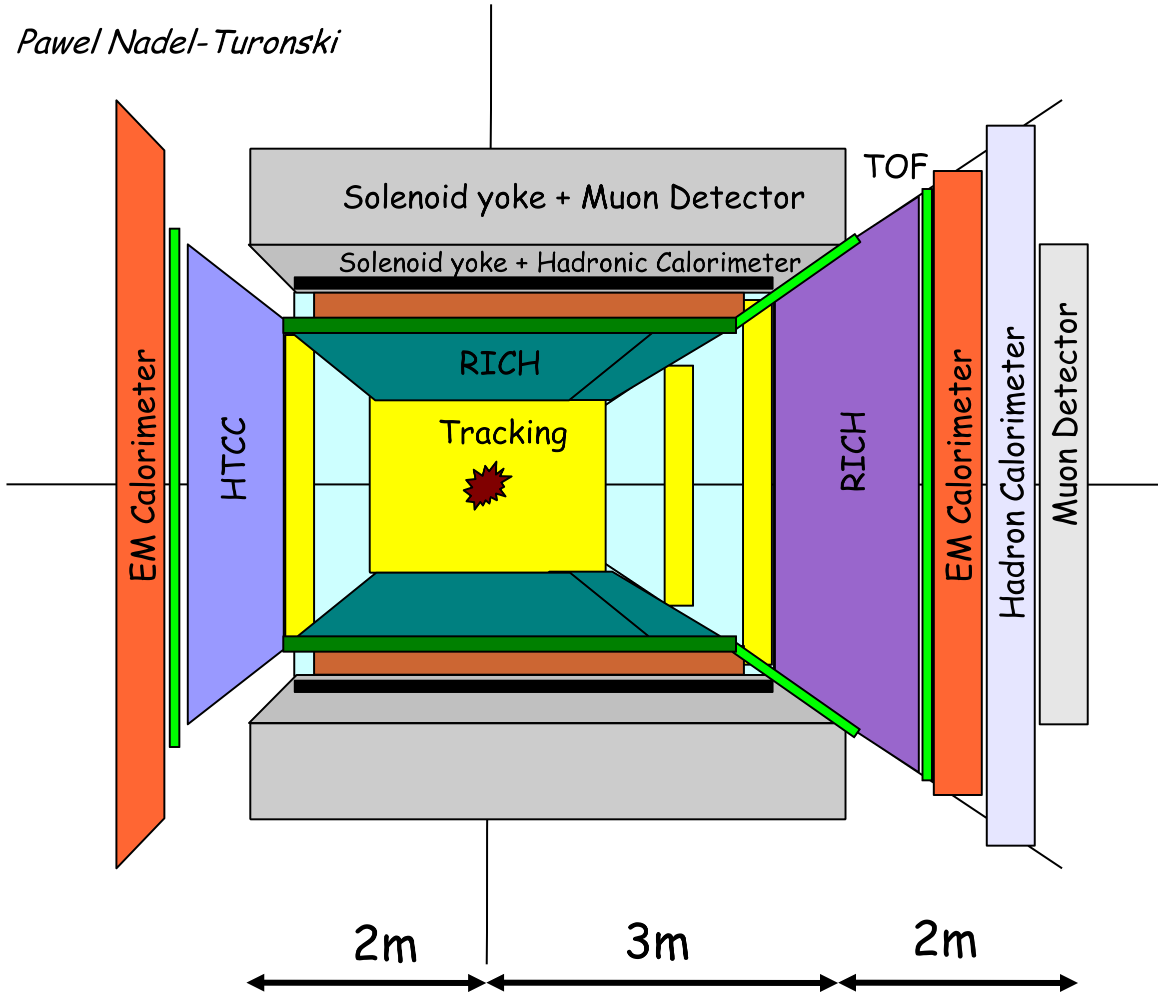
Need Particle ID for well above 4 GeV in forward region (< 30°?)

→ determines bore of solenoid

In general: Region of interest up to ~10 GeV/c mesons

Momentum ~ space needed for detection

Overview of Central Detector Layout

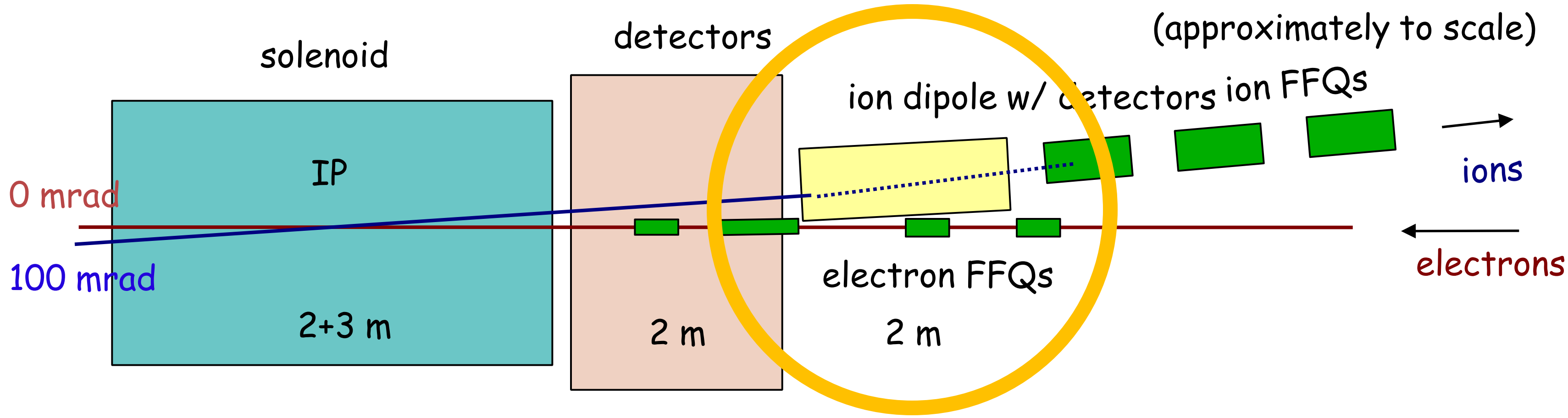


- EM Calorimeter (30-50 cm)
  - **Crystals**, small area
- TOF (5-10 cm)
- RICH (60-100 cm)
  - C_4F_8O + Aerogel
- **Or DIRC (10 cm) + LTCC (60-80 cm)**
  - **C_4F_8O gas**
  - **π/K: 4 - 9 GeV/c (threshold)**
  - **e/π: up to 2.7 GeV/c (LTCC)**
  - **K/p: up to 4 GeV/c (DIRC)**

- IP is shown shifted left by 0.5 meter here, can be shifted
  - Determined by desired bore angle and forward tracking resolution
  - Flexibility of shifting IP also helps accelerator design at lower energies (gap/path length difference induced by change in crossing angle)

Detector/IR cartoon

Make use of a 100 mr crossing angle for ions!



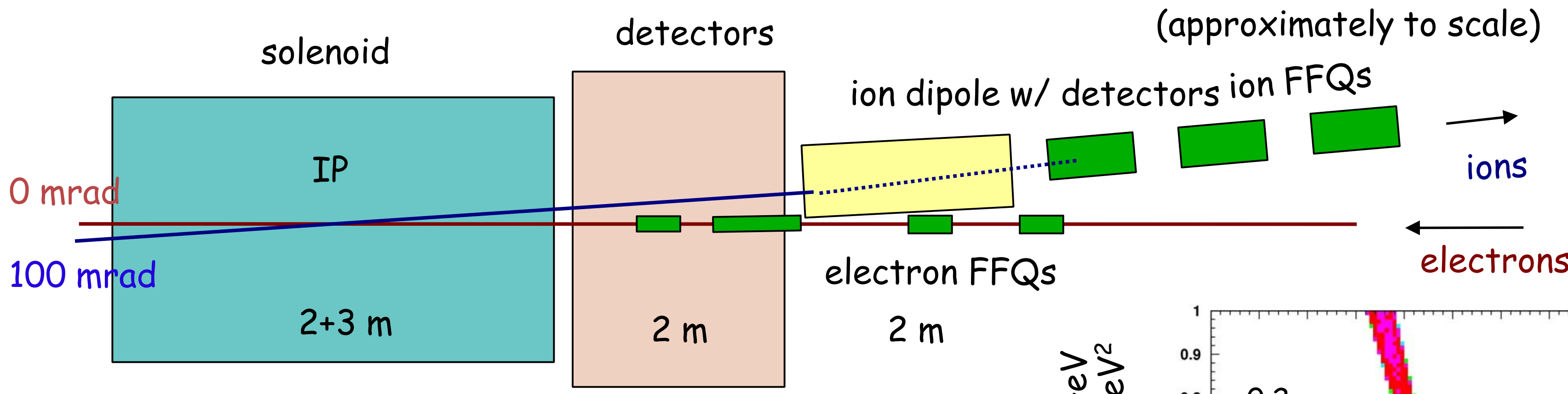
Detect particles with angles down to 0.5 deg.

Need up to 2 Tm dipole bend, but not too much!

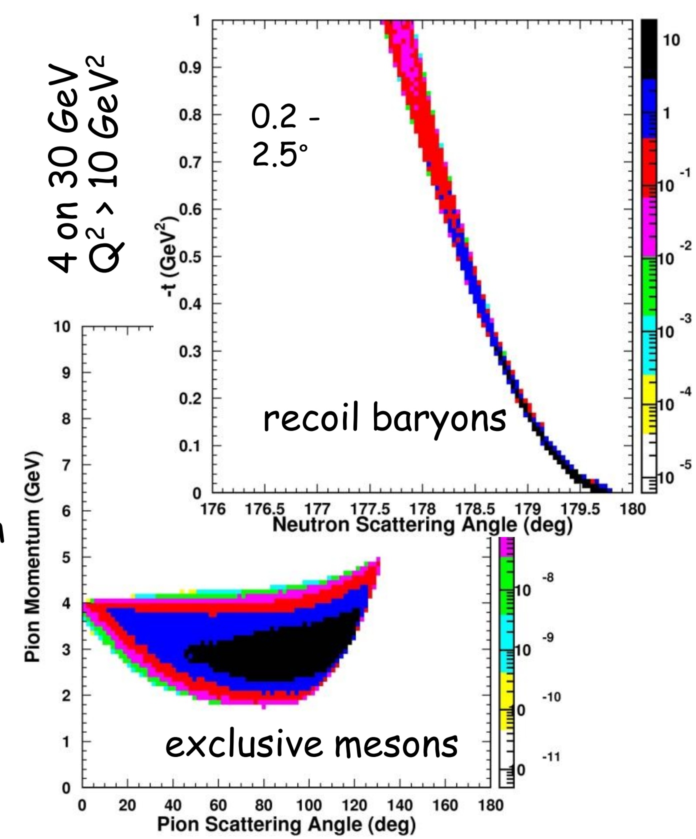
Detector/IR cartoon

Pawel Nadel-Turonski

Make use of a 100 mr crossing angle for ions!



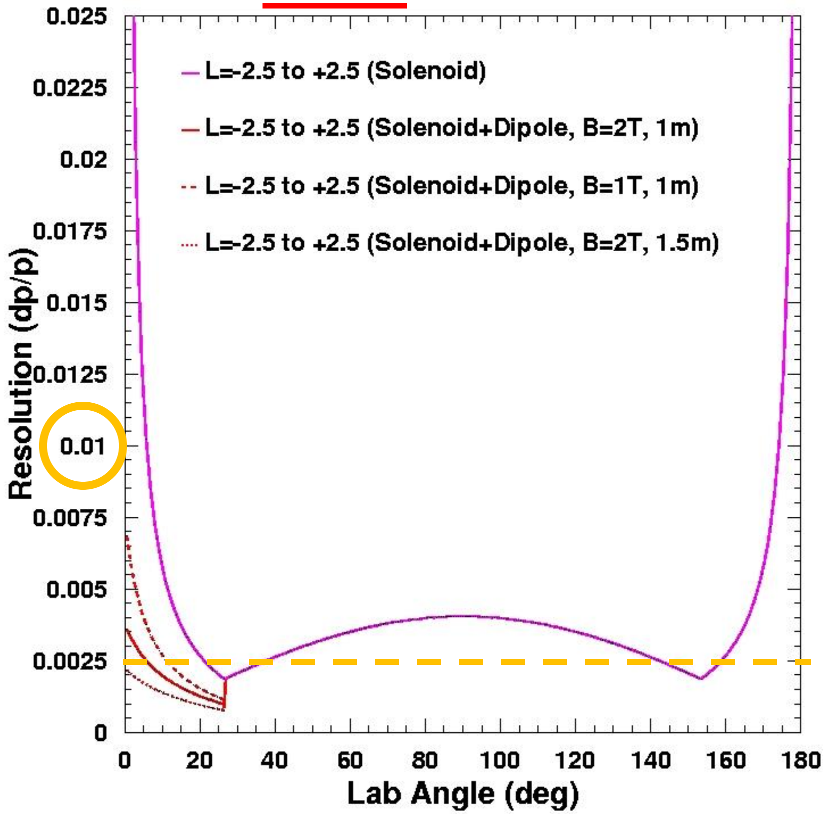
- Downstream dipole on ion beam line ONLY has several advantages
  - No synchrotron radiation
  - Electron quads can be placed close to IP
  - Dipole field not determined by electron energy
  - Positive particles are bent *away* from the electron beam
  - Long recoil baryon flight path gives access to low *-t*
  - Dipole does not interfere with RICH and forward calorimeters
    - Excellent acceptance (hermeticity)



Detector/IR – Magnetic Fields

Tanja Horn

Pion momentum = 5 GeV/c,
4T **ideal** solenoid field



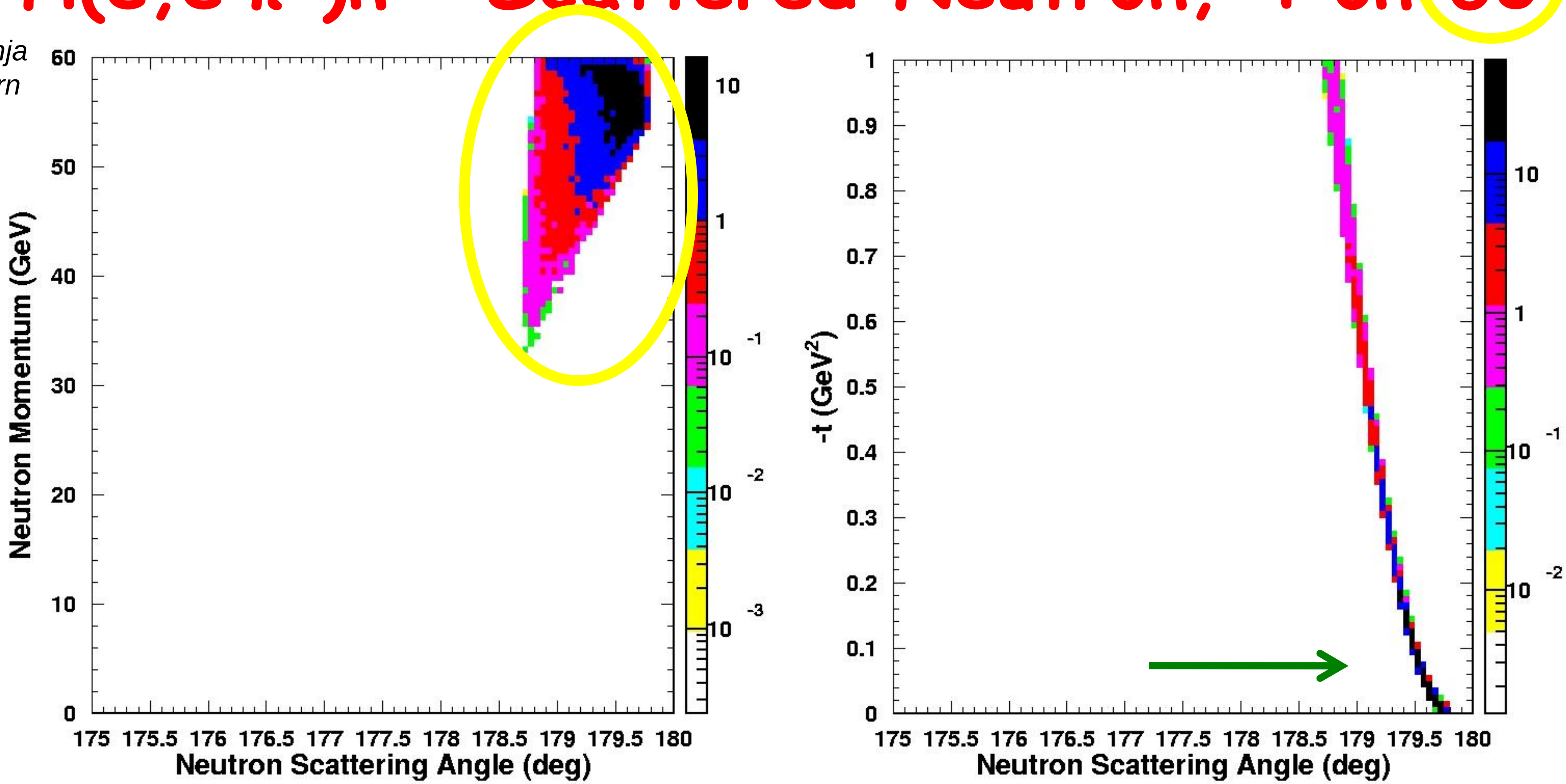
- Resolution dp/p (for pions) better than **1%** for **p < 10 GeV/c**
- obtain effective 1Tm field by having 100 mr crossing angle
- 200 mr ~ 12° gives effective 2Tm field

→ need to add 1-2Tm dipole field for small-angle pions (1°-6°) only

Add 2Tm transverse field component to get dp/p roughly constant vs. angle

$^{1}H(e,e'\pi^{+})n$ – Scattered Neutron, 4 on 60

Tanja Horn



- Low –t neutrons (or protons) are emitted at (very) forward angles
- Advantageous to have lower proton/ion energies: angle ~ $1/E_{p,ion}$
- Low-t recoil baryons have momenta close to the beam momenta
- For ion beams & coherent/diffractive/evaporation processes, situation can be even more forward-focused

Detector/IR – Forward Angles

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

Example: map t between t_{min} and 1 (2?) GeV
→ ~0.2 to 4.9 (9.8) degrees @ 12 GeV
→ ~0.2 to 3.0 (5.9) degrees @ 20 GeV
→ ~0.2 to 2.0 (3.9) degrees @ 30 GeV

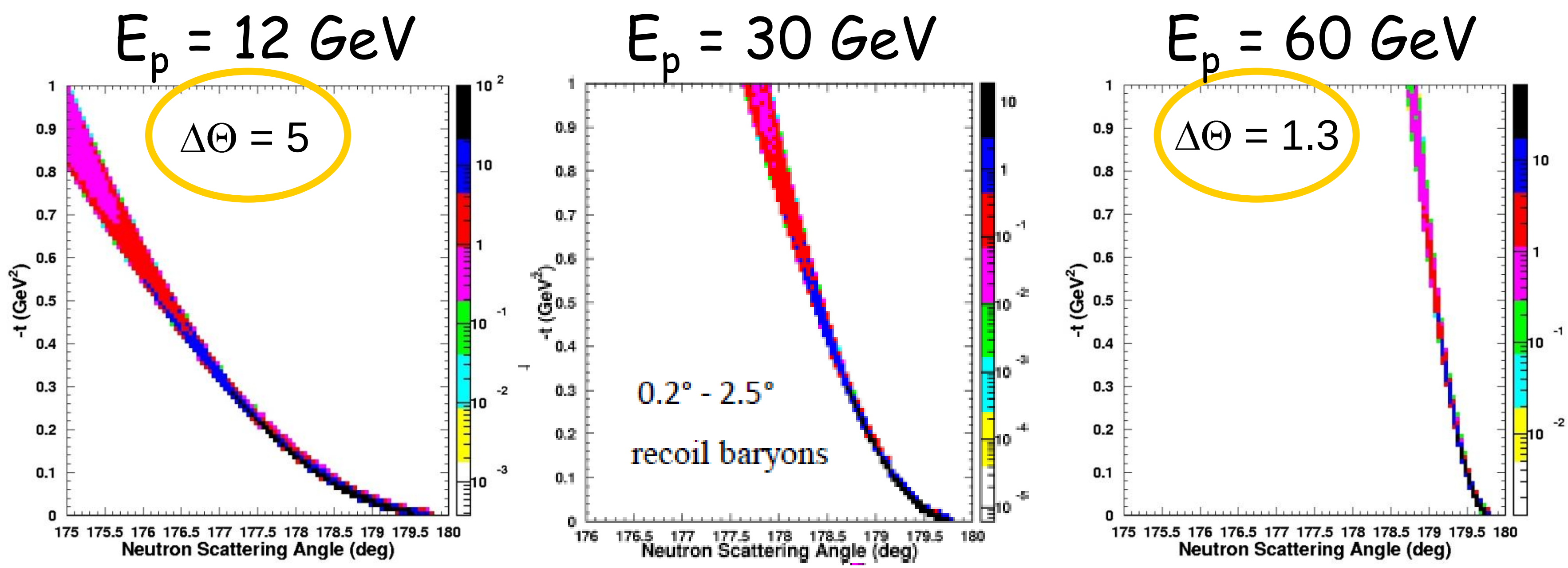
→ Cover between about 0.5 and 6 degrees?

Example I: *separation between 0.5° and 0.2°* (BSC)
~ 2.5 cm at 5 meter distance
May be enough for ~ 30 GeV protons
and neutrons from an O(1A) beam
(also need good angle (t) resolution!)

Example II: *6 degrees*
~ 0.5 meter radius cone at 5 meter

Detector/IR - Forward Angles

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

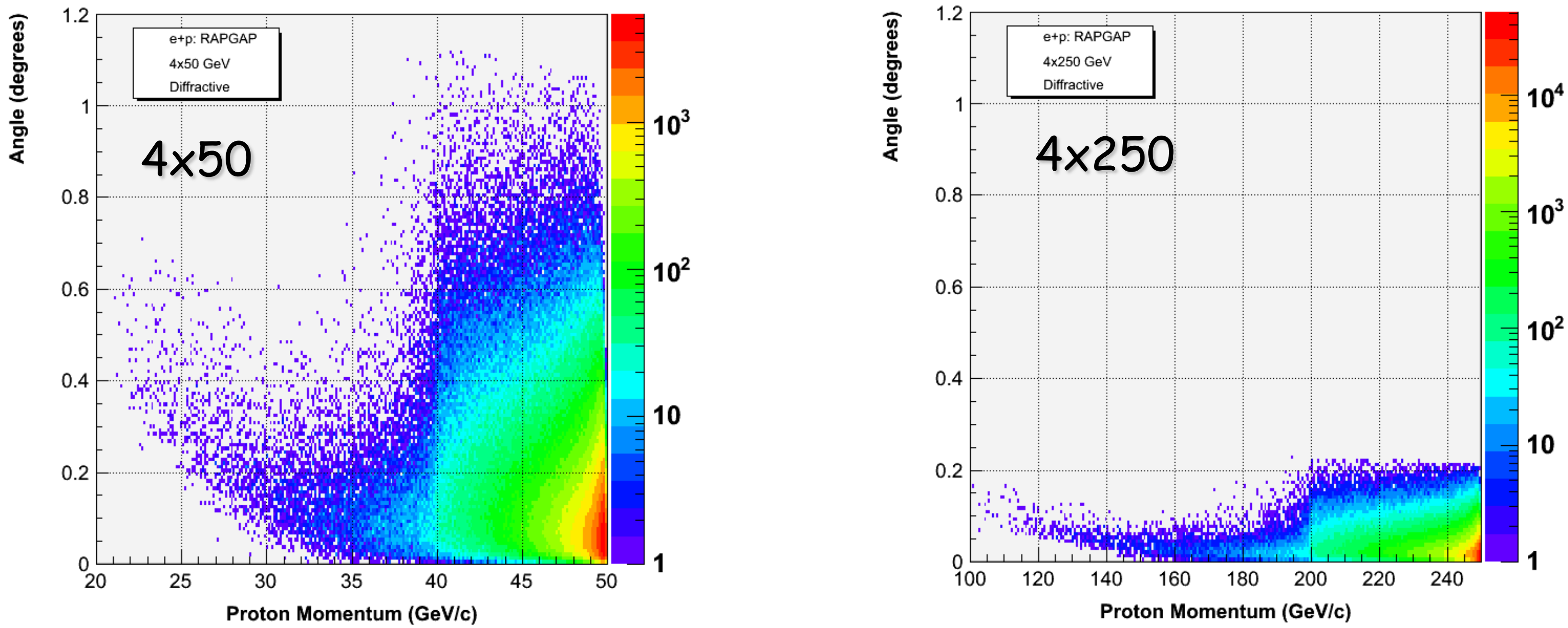


- → Must cover between 1 and 5 degrees
- → Should cover between 0.5 and 5 degrees
- → Like to cover between 0.2 and 7 degrees

Recoil Proton for Diffractive events

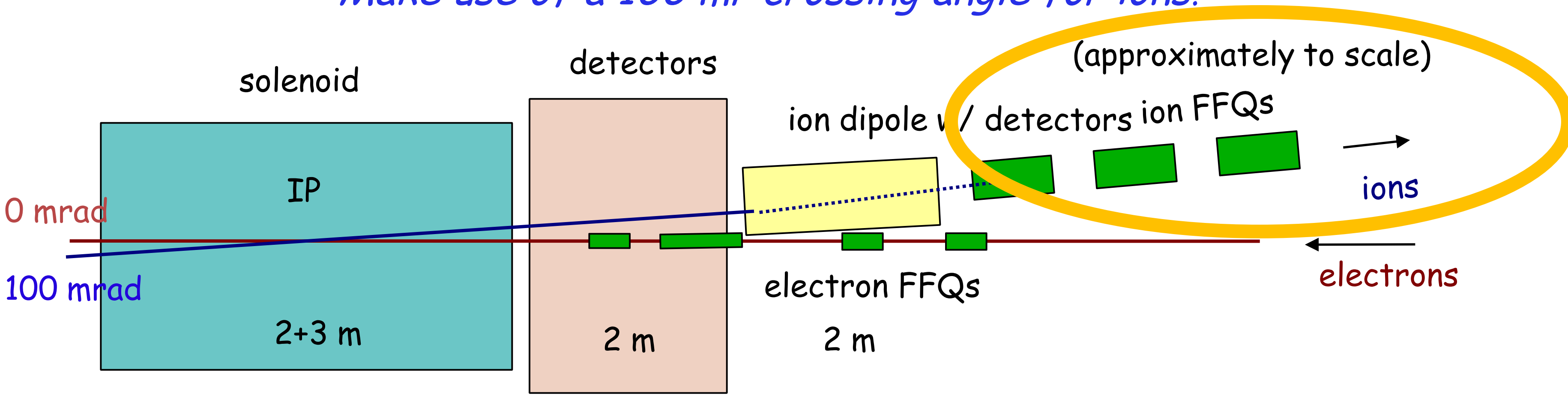
From BNL colleagues (Elke, Thomas)

Note that angular coverage here is not dissimilar from exclusive $^{1}H(e,e'\pi^{+})n$ reactions, but weight of distributions is shifted! → must detect particles below 0.5° too!



Detector/IR cartoon

Make use of a 100 mr crossing angle for ions!



Want to detect particles with angles up to 0.5° before ion FFQs, but how about particles with angles below 0.5°?

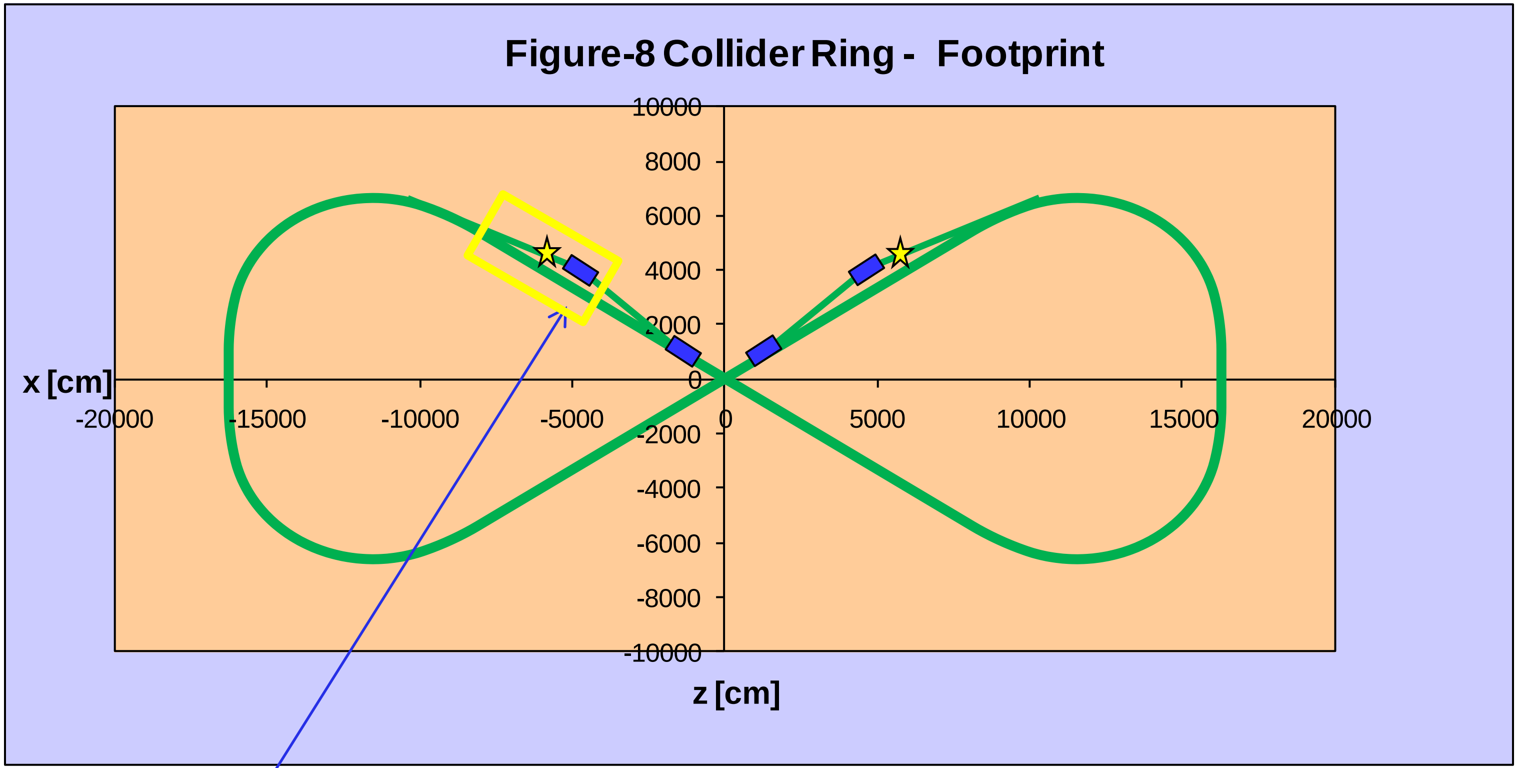
Distance IP - ion FFQs = 7.0 m

(Driven by push to 0.5 degrees detection before FFQs)

Figure-8 Collider Rings

(Reminder: MEIC/ELIC scheme uses 100 mr crab crossing)

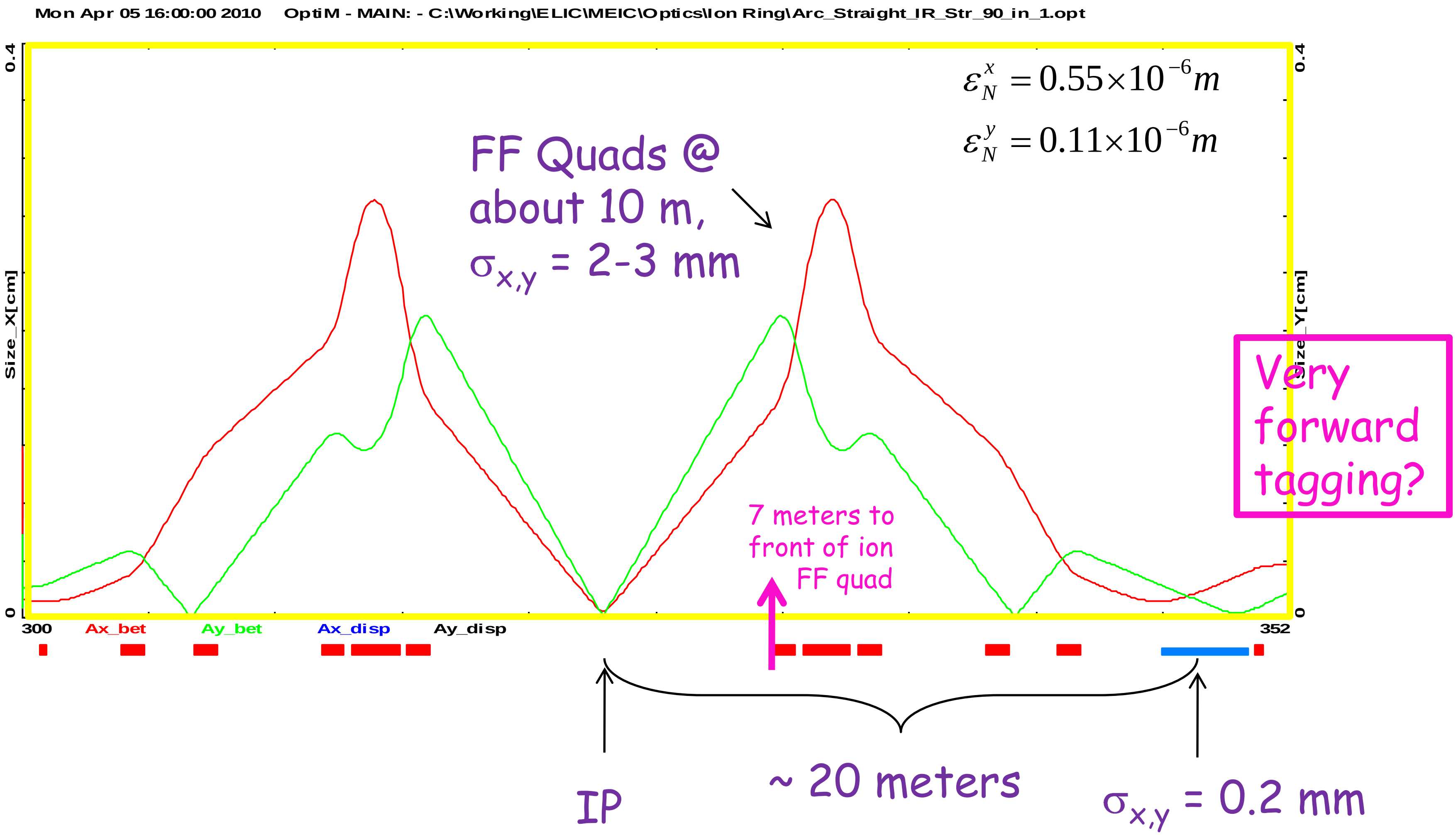
Present thinking: ion beam has 100 mr horizontal crossing angle
Renders good advantages for **very-forward particle detection**



200 mr bend would need 40 Tm dipole @ ~20 m from IP

total ring circumference: ~970 m
~60 degrees arc/straight crossing angle

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

Detector/IR - Very Forward

- Ion Final Focusing Quads (FFQs) at 7 meter, allowing ion detection down to 0.5° *before* the FFQs (BSC area only 0.2°)

- Use large-aperture (10 cm radius) FFQs to detect particles between 0.3 and 0.5° (or so) in few meters after ion FFQ triplet

  σ_{x-y} @ 12 meters from IP = 2 mm
  12 σ beam-stay-clear → 2.5 cm
  0.3° (0.5°) after 12 meter is 6 (10) cm
  → enough space for Roman Pots & "Zero"-Degree Calorimeters

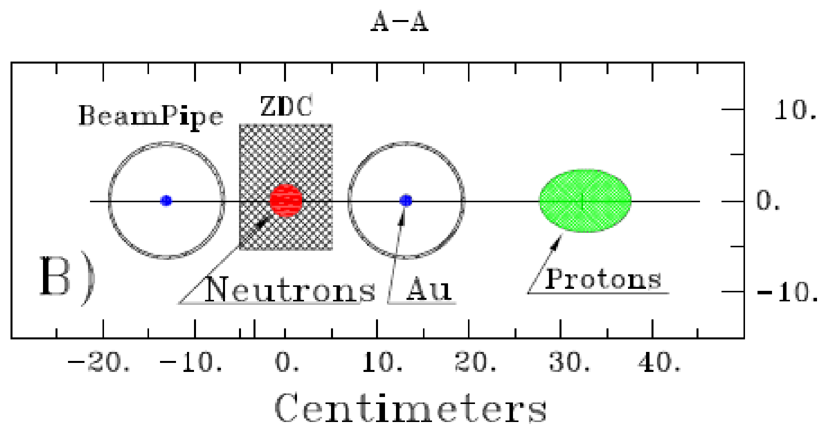
- Large dipole bend @ 20 meter from IP (to correct the 100 mr ion horizontal crossing angle) allows for very-small angle detection (< 0.3°)

  σ_{x-y} @ 20 meters from IP = 0.2 mm
  10 σ beam-stay-clear → 2 mm
  2 mm at 20 meter is only 0.1 mr…
  Δ(bend) of 29.9 and 30 GeV spectators is 1.3 mr = 5 mm @ 4 m
  Situation for zero-angle n detection very similar as at RHIC!

Forward Neutron Detection Thoughts – A Zero Degree Calorimeter

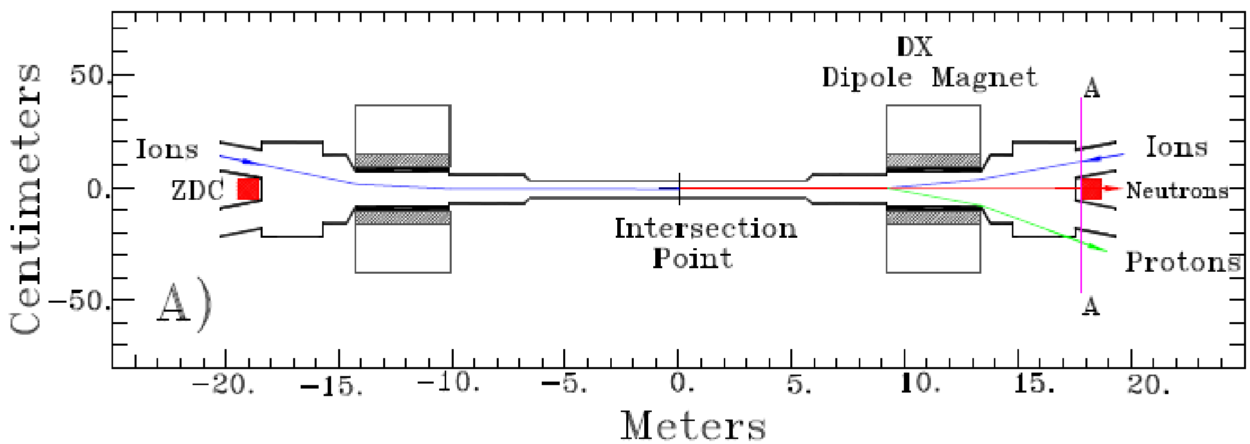
The RHIC Zero Degree Colorimeters *arXiv:nucl-ex/0008005v1*

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)
(& 40 cm thick)



Have good efficiency and only 1 cm "dead-edge" (albeit not very good ΔE resolution).

Implication: do not make earlier ion bend dipole strong < 2 TM!

Forward Neutron Detection Thoughts – A Zero Degree Calorimeter

- EIC@JLab case: 40 Tm bend magnet at 20 meters from IP
  → very comparable to present RHIC case!
- 40 Tm bends 60 GeV protons with 2 times 100 mr

→ deflection @ a distance of about 4 meters = 80 cm (protons)
→ no problem to insert Zero Degree Calorimeter in this design

Zero Degree Calorimeter properties:

- Example: for 30 GeV neutrons get about 25% energy resolution

(large constant term due to unequal response to electrons and photons relative to hadrons)

→ Should be studied, sufficient for an EIC?

- Timing resolution ~ 200 ps
- Very radiation hard (as measured at reactor)
- Angle resolution?

→ Position resolution ~ 1 cm, distance of 5(10+) m
→ order of magnitude 2 (<1) mr or so
→ at 30 GeV proton energy: $\delta t \sim 0.04$

Spectator Proton Tagging

Assume electron-deuteron collisions, with 30 GeV/nucleon deuteron beam

100 mr horizontal crossing angle for ion beam would require a very large 40 Tm magnet at 20 meter from the IP. In the end, exact crossing angle will be an optimization between

- crab cavity performance
- detector needs
- 40 Tm vs. 20 Tm (or so) bend magnet

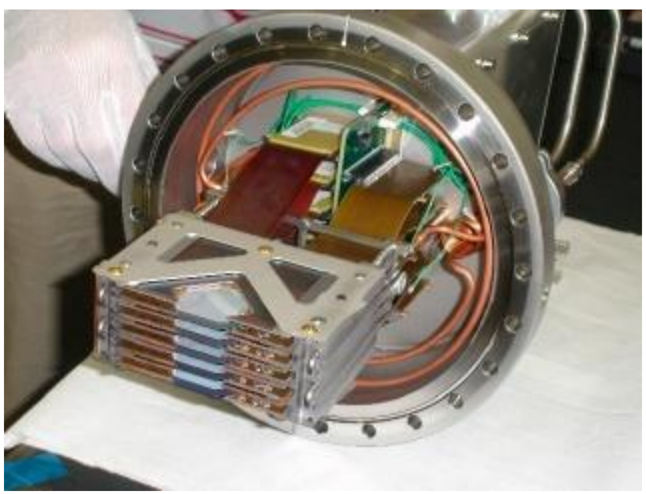
Can use this large magnet field for spectator proton tagging

- deuteron beam (30 GeV/nucleon) gets bend by 200 mr
- Δ(bend) 30 GeV spectator proton w.r.t. deuteron beam = 200 mr
  → at 4 meter some 80 cm separation from main beam
- Pm = 0 ~ 30 GeV spectator proton, p_m = 100 MeV/c ~ 29.9 GeV
- Δ(bend) 30 GeV vs. 29.9 GeV = 1.3 mr
- If detectors are positioned 4 m after 40 Tm magnet → 5 mm bend
- 1% (300 MeV/c) would become 16 mm bend (4 mr) = **LARGE!!!**
- **Piece of cake to distinguish, even for 10 Tm magnet**
  → ***need to fold in intrinsic beam spread to check resolutions***
- No need for roman pots due to large separation from main beam

Very-Forward Ion Tagging

100 mr horizontal crossing angle for ion beam would require large 40Tm magnet at 20 meter from the IP. If so, can use this for spectator proton tagging.

→ Proton tagging concept looks doable, even if the horizontal crossing angle was reduced by a factor of two or three.



Roman pots (photos at CDF (top) and LHC (bottom), …) ~ 1 mm from beam achieve proton detection with < 100μ resolution

→ Need to use this for coherent processes like DVCS(p,^{4}He) where recoil nucleus energy = beam energy minus a small t correction. *Work in progress.*
$\Delta p/p \sim 3 \times 10^{-4}$ now → in ballpark

MEIC Overview - Summary

- Near-term design concentrates on parameters that are within state-of-the-art (exception: small bunch length & small vertical β^* for proton/ion beams)
- Detector/IR design has concentrated on *maximizing acceptance* for deep exclusive processes and processes associated with very-forward going particles
- Exact energy/luminosity profile still a work in progress
- Summer 2010: MEIC design review followed by internal cost review (and finalizing input from user workshops)
- Many parameters related to the detector/IR design seem to be well matched now (crossing angles, magnet apertures/gradients/peak fields, field requirements), such that we do not end up with large "blind spots".

Electron-Ion Collider – JLab User Meetings Roadmap

- March 12 + 13 — @Rutgers: Electron-Nucleon Exclusive Reactions
- March 14 + 15 — @Duke: Partonic Transverse Momentum in Hadrons: Quark Spin-Orbit Correlations and Quark-Gluon Interactions
- April 07, 08, 09 — @ANL: Nuclear Chromo-Dynamic Studies
- May 17 +18 — @W&M: Electroweak Studies
- June 04 + 05 — @JLab: MEIC Detector Workshop

- June 07,08,09 — 2010 JLab Users Group Meeting
  (with session dedicated to a summary of users workshops, held in Spring 2010, that explored physics motivations of an Electron-Ion Collider, entitled "Beyond the 12 GeV Upgrade: an EIC at JLab?")

Personal Note: Energy-Luminosity profiles **will** change
→Assume base luminosity, say 10^{33} or 10^{34} e-ions/cm^2/s
→ show what you need for 5 on 20, 5 on 50, 5 on 100, 5 on 250
→ show what you need for 10 on 20, 10 on 50, 10 on 100, 10 on 250
→ think what the implications are for the acceptance

Electron-Ion Collider – Roadmap

- EIC (eRHIC/ELIC) webpage: http://web.mit.edu/eicc/

- Last meeting: January 10-12, 2010 @ Stony Brook
- **Next meeting: July 29-31, 2010**
  @ Catholic University, DC

CUA

- Long INT10-03 program @ Institute for Nuclear Theory, Seattle,
  centered around spin, small-x, imaging, electroweak
  September 10 – November 19, 2010

- Weekly meetings at both BNL and JLab
- Wiki pages at http://eic.jlab.org/ &
  https://wiki.bnl.gov/eic

Backup

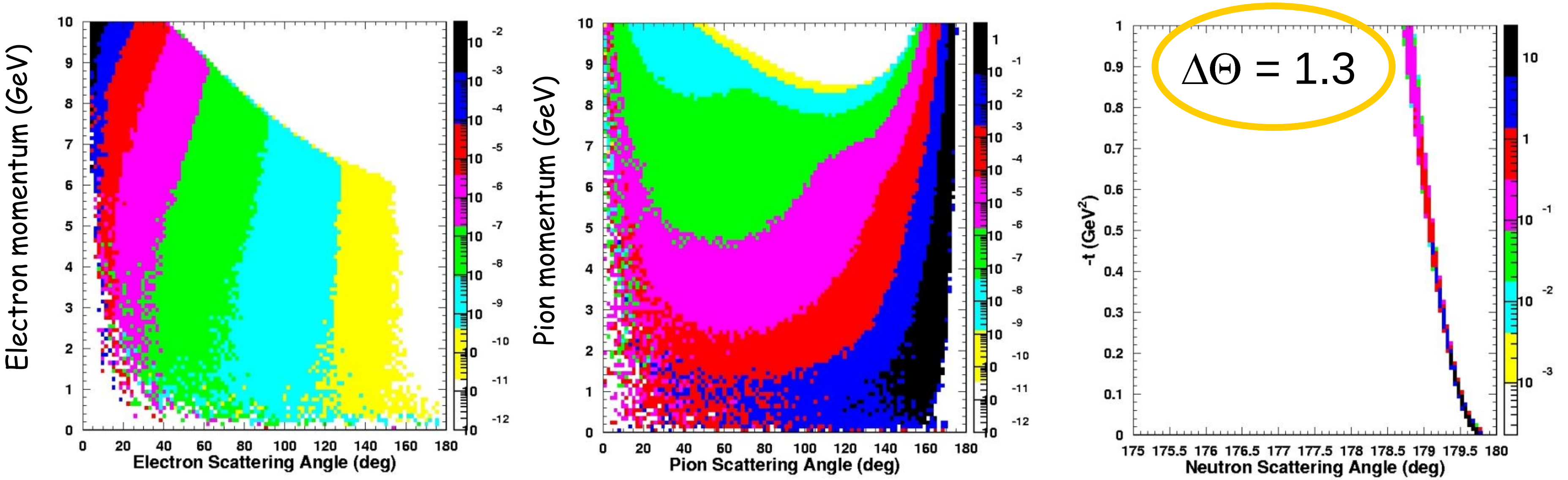
DIRC + C4F8O Threshold Cherenkov:
+ Full particle Identification up to p = 4 GeV/c
+ Pion identification above p = 4 GeV/c
+ π/e separation to "help" EM calorimeter up to p = 2.7 GeV/c

- No p/K separation above p = 4 GeV/c
  is this a problem?
  What are the proton of interest above 4 GeV
  in the central detector region?
  Should check both e-p and e-A case

In forward region want HERMES-like dual-type RICH, or threshold imaging RICH, to allow for full π/K/p particle identification up to p ~ 8 GeVc or higher: assumed 2 meter space need for this. Always want C4F8O to help π/e?

Why a collider with lower & ~symmetric energies?

Example: e + p → e′ + π^+ + n, 11 GeV electrons, 60 GeV protons

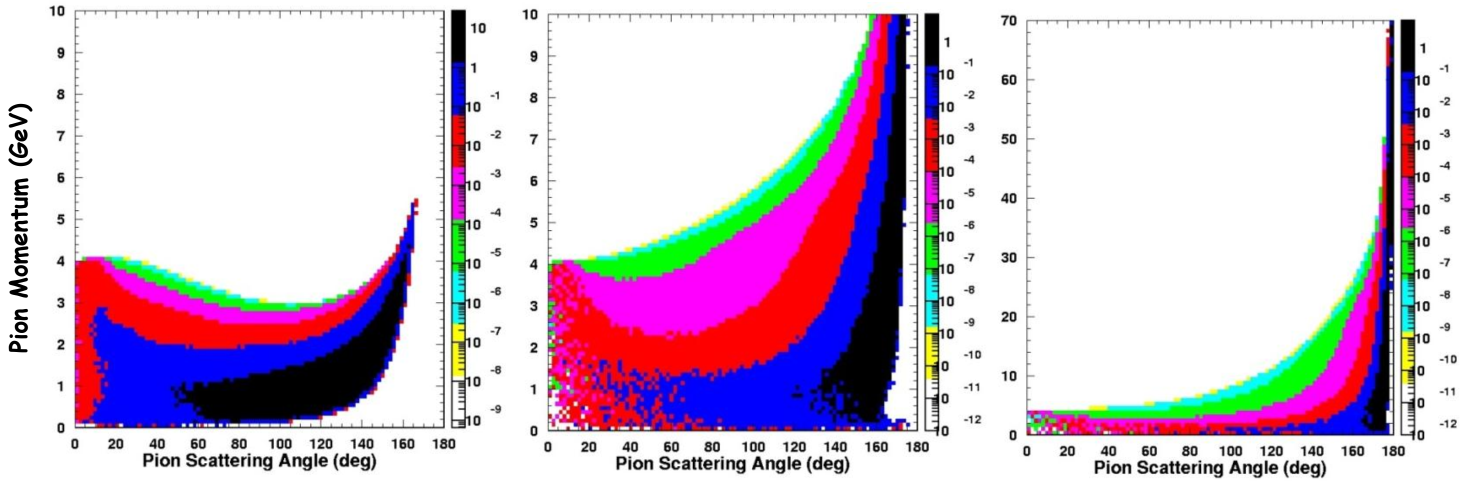


- lower-energy, more symmetric collider
  - → electron momentum up to 11 GeV (photoproduction)
  - → wider π^+ angular distribution
  - → electron and pion momentum similar to optimize ΔM^2
  - → momenta in range where particle identification well proven
  - → wider recoil n distribution
  - → t resolution better: $\delta t/t \sim t/E_p$

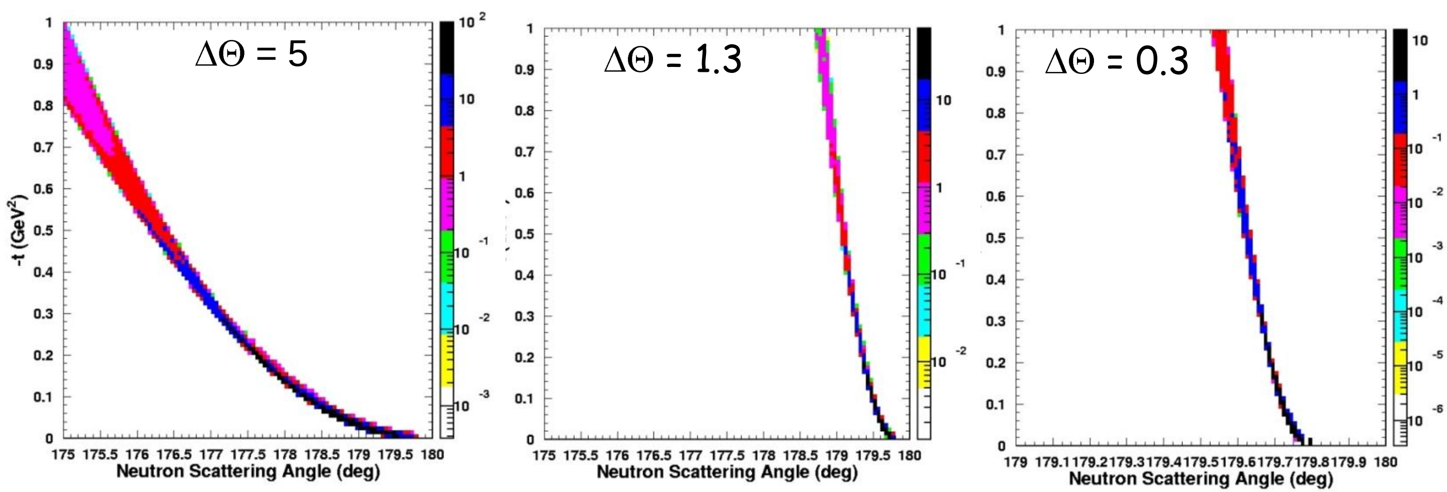
Why lower & more symmetric energies?

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

4 on 12 | 4 on 60 | 4 on 250



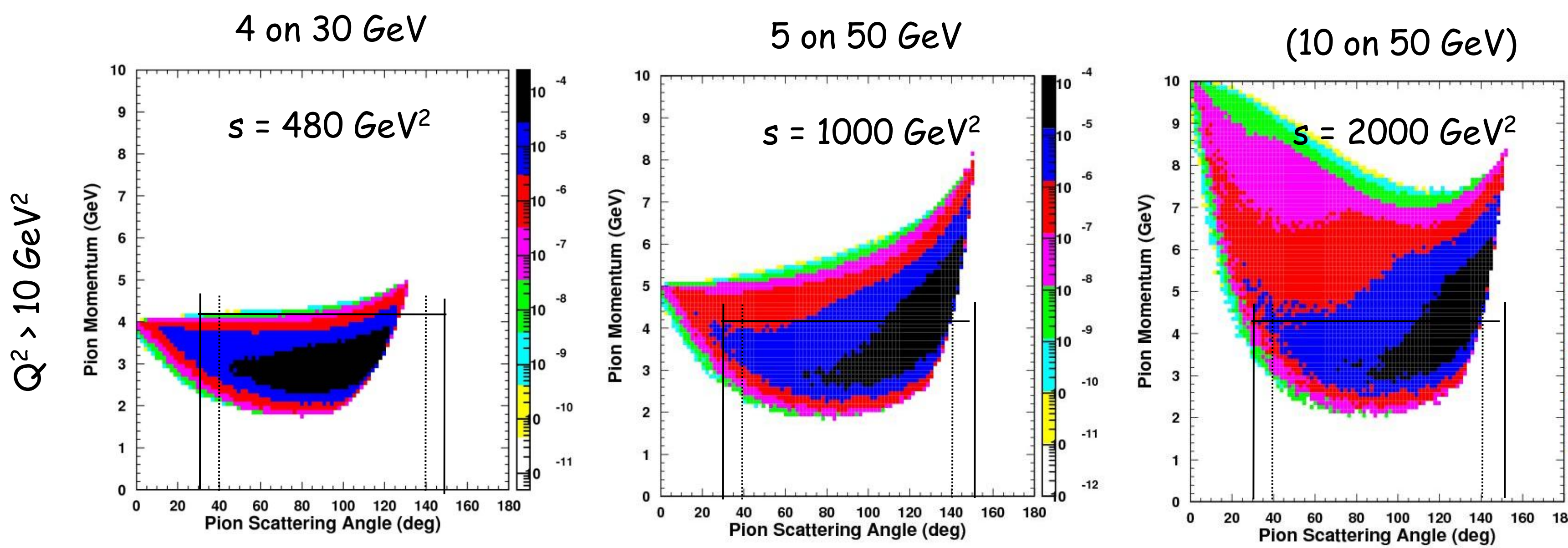
Example:
ep → e′π^+n
- momenta are smaller and wider at lower E_p
- easier for detector



Much improved t-resolution at lower E_p

Detector/IR - Kinematics

- Vertical lines at 30 (possibly up to 40) indicate transition from central barrel to endcaps
- Horizontal line indicates maximum meson momentum for π/K separation with a DIRC

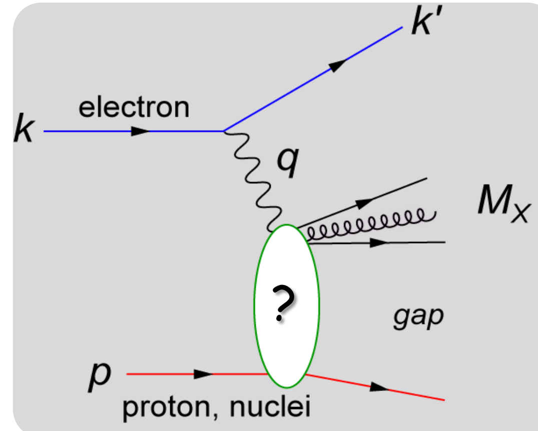


- With 12 GeV CEBAF, MEIC@JLab has the option of using higher electron energies
  - DIRC no longer sufficient for π/K separation
- RICH based on ALICE design might push the limit from 4 to 7 GeV
  - Requires a more detailed study – alternate idea is DIRC + LTCC
- RICH would extend the minimum diameter of solenoid from approximately 3 to 4 m
  - Main constraint since bore angle is not an issue in JLab kinematics

How to measure coherent diffraction in e+A ?

From Elke Aschenauer

- Beam angular divergence limits smallest outgoing Θ_{min} for p/A that can be measured
- Can measure the nucleus if it is separated from the beam in Si (Roman Pot) "beamline" detectors
  - $p_{Tmin} \sim pA\theta_{min}$
    - For beam energies = 60 GeV/n and θ_{min} = 100 μrad:
- These are large momentum kicks, much greater than the typical separation energy for heavy A



species (A)	p_{Tmin} (GeV/c)
d (2)	0.006
Si (28)	0.067
Cu (64)	0.154
In (115)	0.276
Au (197)	0.473
U (238)	0.571

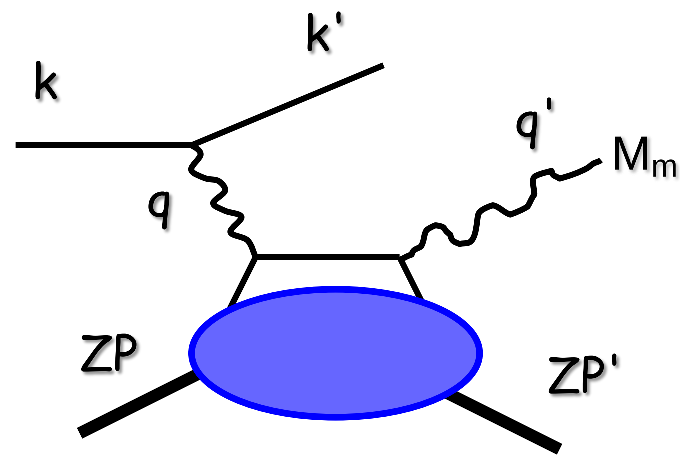
Recoil Tagging in Deeply Virtual Exclusive Reactions on Nuclei

$$e + {}^{A}Z \rightarrow e' + {}^{A}Z' + (\gamma,\rho,\omega,\phi,J/\Psi)$$

From Charles Hyde

Determining exclusivity requires tagging the nucleus in the final state. The typical scale of transverse momentum transfer is given by the rms nuclear radius.

$$P_{\perp} \approx \frac{\hbar c}{R_A} \approx 0.2\,\mathrm{GeV}\,A^{-1/3}$$



(for nuclei from ^{4}He to ^{20}Ne, this scale ranges from 125 MeV/c to 75 MeV/c)

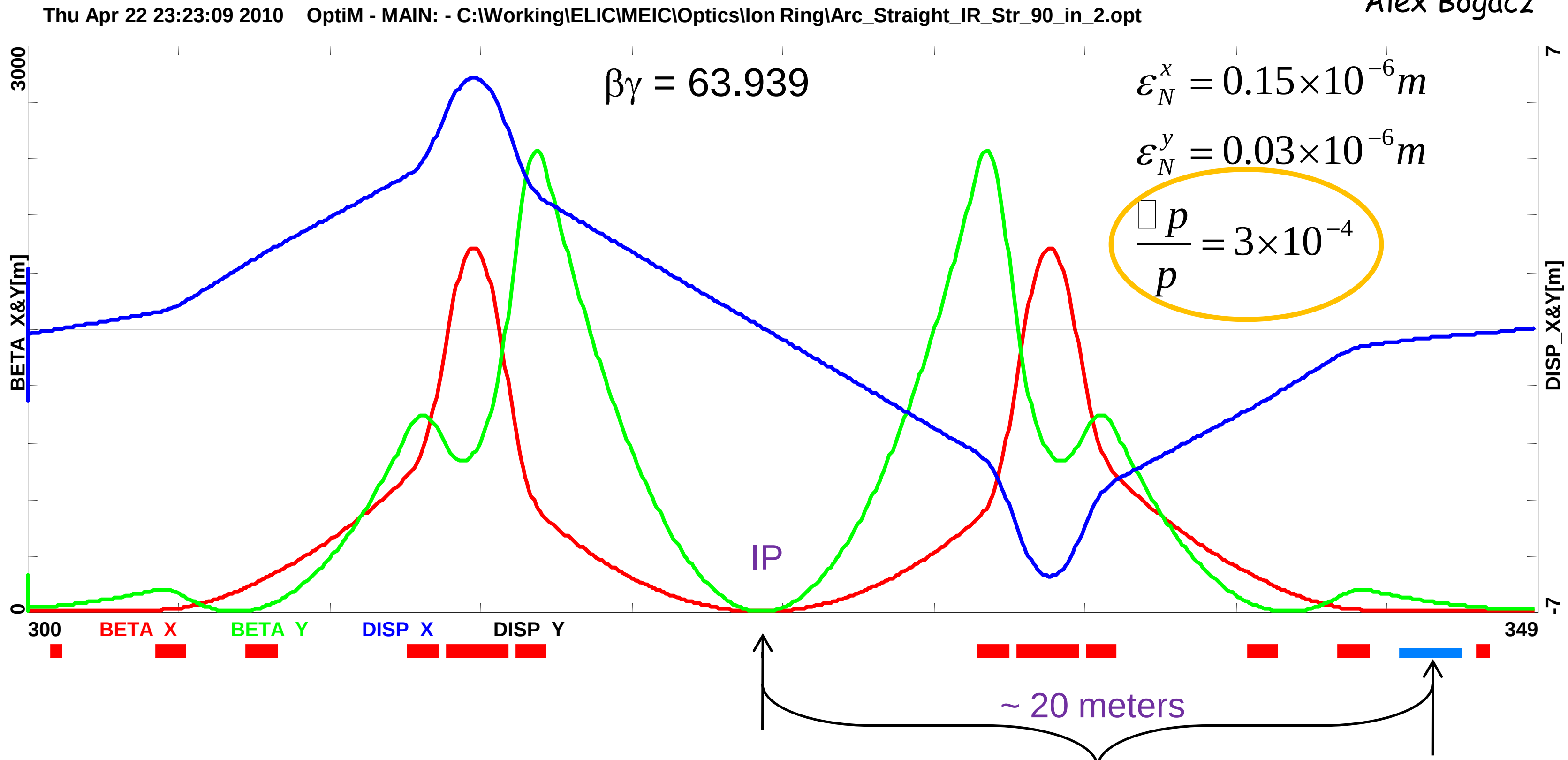
→ For Nuclei ≥ ^{4}He, the recoil nucleus is

- INSIDE the transverse admittance of the FF Quads
  - $\Theta_{ms} \approx 1$ mr → $P_{A,transverse} \approx Z\cdot(60$ MeV/c) *(for 60 GeV ion beam)*
  - Beam spread is larger than $1/R_A$ scale for nuclear imaging.
  - $Z\cdot(60$ MeV/c) > (0.2 GeV/c)/$A^{1/3}$ (≥75 MeV/c for $^{A}Z <$ ^{20}Ne)
- OUTSIDE the longitudinal admittance of the ring lattice!!!

  → The nuclei may be detectable at high resolution with far forward tracking in the lattice by having large dispersion → **dispersion increased!**

Transverse momentum at 60 GeV

Alex Bogacz



$$p_{x,y} = p\sigma_{x',y'}$$

$$\sigma_{x',y'} = \sqrt{\frac{1+\alpha_{x,y}^2}{\beta_{x,y}}\frac{\varepsilon_N^{x,y}}{\beta\gamma} + \left(D'_{x,y}\frac{\Delta p}{p}\right)^2}$$

$BetaX=10 cm
$BetaY=2 cm
$AlfaX=0
$AlfaY=0
$DispPrX=- 0.443902

$$\sigma_{x'} = 2.0\times10^{-4}$$
$$\sigma_{y'} = 1.5\times10^{-4}$$

$BetaX=446.8 cm
$BetaY=8293.5 cm
$AlfaX=1.51993
$AlfaY=15.6367
$DispPrX=0.1025

$$\sigma_{x'} = 5.2\times10^{-5}$$
$$\sigma_{y'} = 3.7\times10^{-5}$$

Far Forward Ion Tagging at (60 GeV/c) Z

From Charles Hyde

- Sample optics at token Roman Pot Telescope position
  - MEIC typical: Dispersion D = 1.5 m (3 m in IR)
    Beta function $\beta_{@ARC}$ = 15 m
  - MEIC typical: (x,Θ) = (250 μm, 125 μr) rms
  - Use a 8-10σ_x Beam Stay Clear (BSC) distance → 2.5 mm
  - Ions are detectable for $|dP_{A||}/P_A| > BSC/D = 1.5 \times 10^{-3}$

  Skewness 2ζ (~x/A) of DVCS = long. momentum fraction of a nucleon in projectile ion.
    - Skewness acceptance: $2\zeta >$ $(2.5\times10^{-3})A$ → 0.05 for 20Ne.
- Assumption: 1m drift with 100 μm spatial resolution
  - $d\Theta$ = 100 μr ➔ equal to beam Θ_{rms}.
  - P_A' Momentum Resolution = $\sigma_x/D = 2.5 \times 10^{-4}$.
    - $\Delta_{||} = (k-k'-q')_{||} = (P_A-P_A')_{||}$
    - $\sigma(\Delta_{||}) = (4 \times 10^{-4})(30\ GeV/c)\ A = (12\ MeV/c)\ A$
  - Exclusivity constraint $\Delta^2 = 2M_A\,(P_A'-P_A)$
- Using ELIC arc as spectrometer to a longitudinal momentum transfer resolution of 10^{-4} by increasing dispersion @ IR will be explored in more detail

Detector/IR in simple formulas

$\beta_{max} \sim 2$ km = l^2/β^* (l = distance IP to 1st quad)

Example: l = 7 m, β^* = 20 mm → β_{max} = 2.5 km

IP divergence angle ~ 1/sqrt(β^*)

Example: l = 7 m, β^* = 20 mm → angle ~ 0.3 mr
Example: 12 σ beam-stay-clear area
→ 12 x 0.3 mr = 3.6 mr ~ 0.2°

Making β^* too small complicates small-angle (0.5°?) detection before ion Final Focusing Quads, and would require too much focusing strength of these quads, preventing large apertures (up to 0.5°?)

Luminosity ~ 1/β^*

Detector/IR in simple formulas

$\beta_{max} \sim 2$ km $= l^2/\beta^*$ (l = distance IP to 1st quad)

Luminosity $\sim 1/\beta^*$

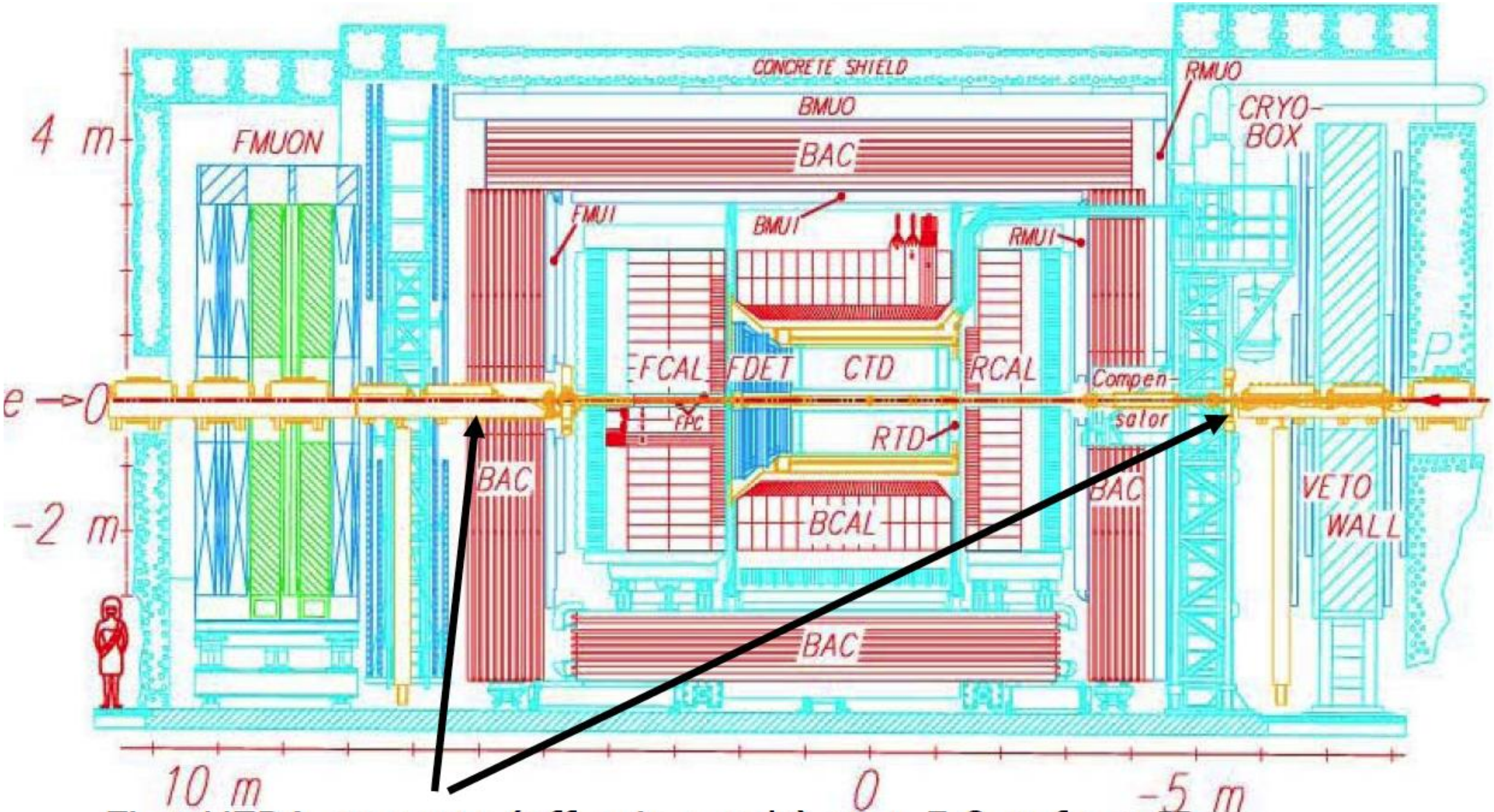
For EW studies, if it is not so important to have full acceptance at forward or backward angles, one could contemplate an interaction region with the Final-Focusing Quads moved in. E.g., for high-Q^2 electron scattering acceptance in the forward-ion region does not matter!

Move from l = 7 m to say l = 5 m → $\beta^* \sim 1$ cm (possible?)
→ luminosity * 2

Follow the precedent of next slides?
But, do NOT make the same mistake as HERA-II …
→ would require separate & dedicated IR!

Zeus @ HERA I

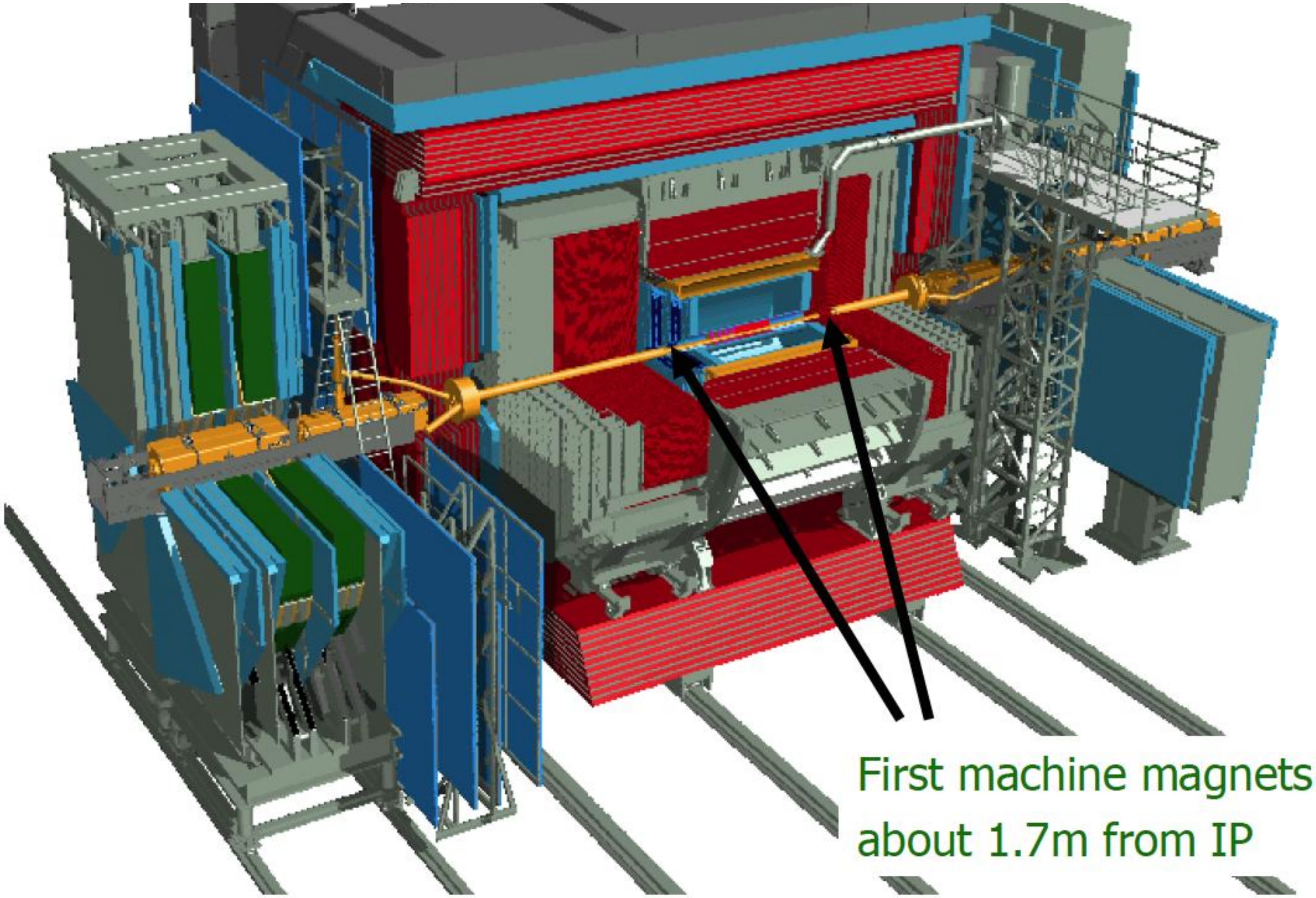
From Elke Aschenauer



First HERA magnets (off-axis quads) at ± 5.8 m from IP
Calorimeter covers >99.8% of full solid angle
Very small hole in FCAL (6.3 cm diameter), small vertical opening of RCAL

Zeus @ HERA II

From Elke Aschenauer



Focusing Quads close to IP
Problem for forward acceptance