Jefferson Laboratory Users Group
07-09 June 2010

Summary of EIC Detector Workshop
4—5 June 2010
Talks on web
http://conferences.jlab.org/eic2010/

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Organizing Committee
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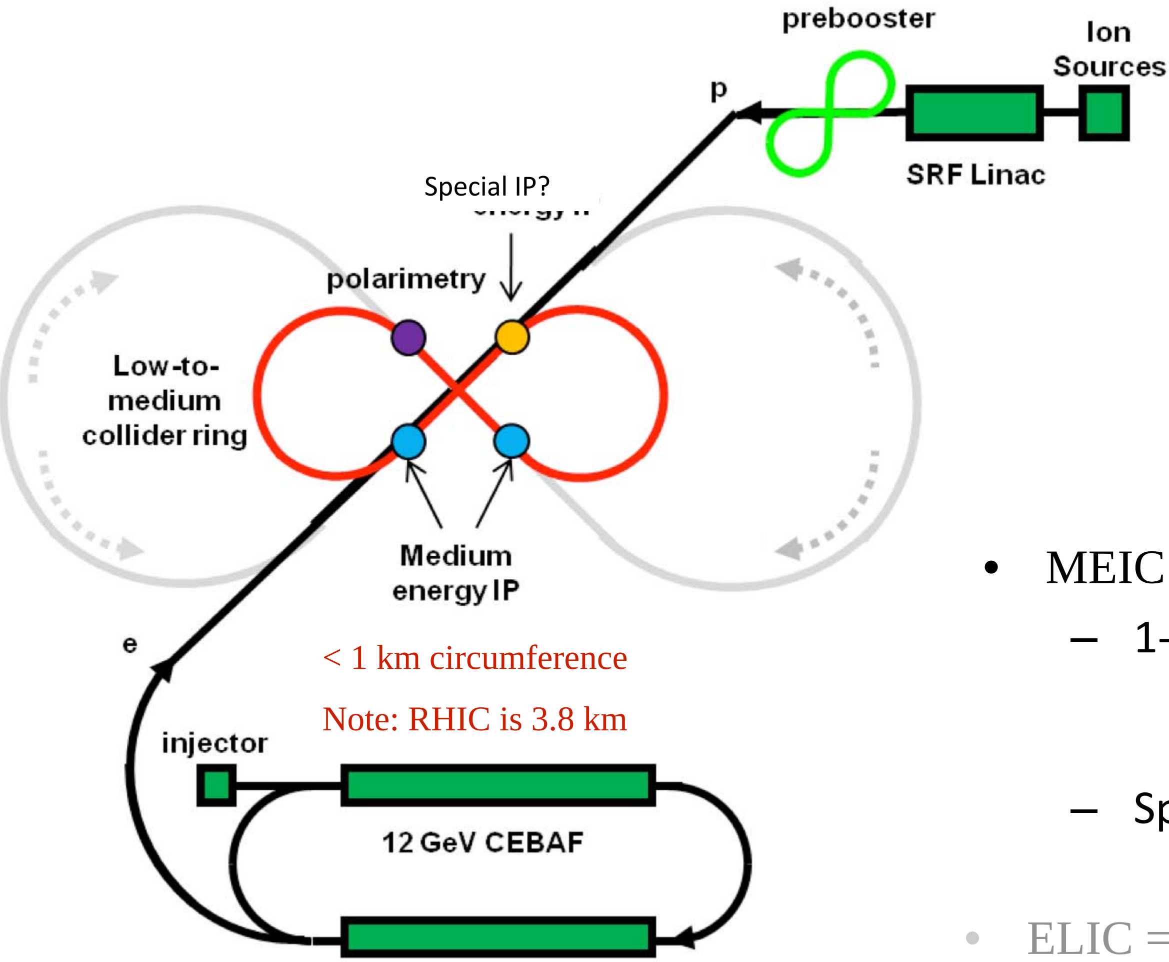
C.E.H.

EIC Detector

- Status of concept for a Collider Detector
  - Optimize for 6 GeV x 60 GeV
  - Range from 3x20 to 11x60
  - At least two detectors desired
- Review of critical detector technologies
  - Focus on particle ID
  - Tracking
- Integration of Detector, Interaction Point, Accelerator Lattice
  - Forward meson detection and far-forward baryon tagging.
  - Small angle and/or 0° electron tagging

MEIC@JLab – Detector Layout



< 1 km circumference

Note: RHIC is 3.8 km

1.4 km circumference

Electron energy: 3-11 GeV

Proton energy: 20-60 GeV

s = 250 - 2650 GeV^2

Can operate in parallel with fixed-target program

- MEIC = EIC@JLAB
  - 1-2 high-luminosity detectors
    - Luminosity ~ 10^{34} cm^{-2}s^{-1}
    - Low backgrounds
  - Special detector?
- ELIC = high-energy EIC@JLab
  - Phase-II upgrade?

Detector requirements

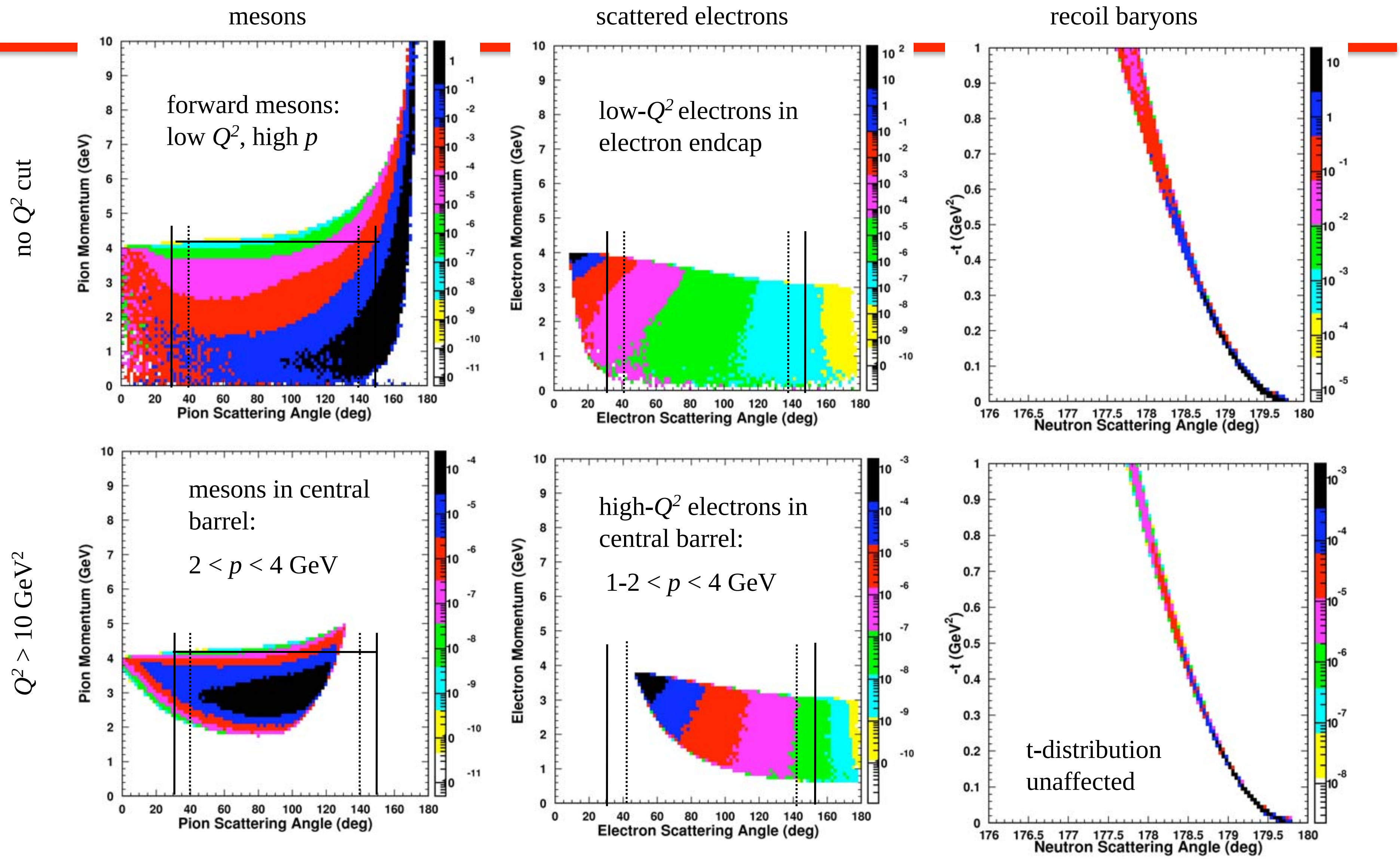
1. Mainly driven by exclusive physics

- Hermeticity (also for hadronic reconstruction methods in DIS)
- Particle identification (also SIDIS)
- Momentum resolution (kinematic fitting to ensure exclusivity)
- Forward detection of recoil baryons (also baryons from nuclei)
- Muon detection (J/Ψ)
- Photon detection (DVCS)

2. But not only …

- Very forward detection (spectator tagging, diffractive, coherent nuclear, etc)
- Vertex resolution (charm, strangeness)
- Hadronic calorimetry (jet reconstruction)

Low Q^2 (J/Ψ) vs high Q^2 (light mesons) – 4 on 30 GeV, (x_B<0.1)



Particle ID:

- PMT based RICH counter
  - HERMES dual RICH (Aerogel+CF4) E. Cisbani (INFN)
- DIRC: Jochen Schwiening (GSI)
  - "images" of Cerenkov cone propagated by total internal reflection in solid fused Silica
  - BABAR + proposals for PANDA, Super-B etc.
  - π/K/p separation up to 5 GeV/c
- dEdX / TOF / RICH N. Smirnov (Yale)
  - ALICE high momentum RICH R&D (p>10 GeV) :
    Cs or CsI photo-cathode evaporated onto micro-pattern amplifier/readout
- EM Calorimetry ($e/\gamma/\pi$) S. Stepanyan
  - $PbWO_4$ Crystals
  - Sampling : Pb-Scin, W-Si, Shashlyk
- Hadronic Calorimeter : S. While (BNL)
  - Zero Degree Neutron Detection

The DIRC in BABAR

DIRC thickness:

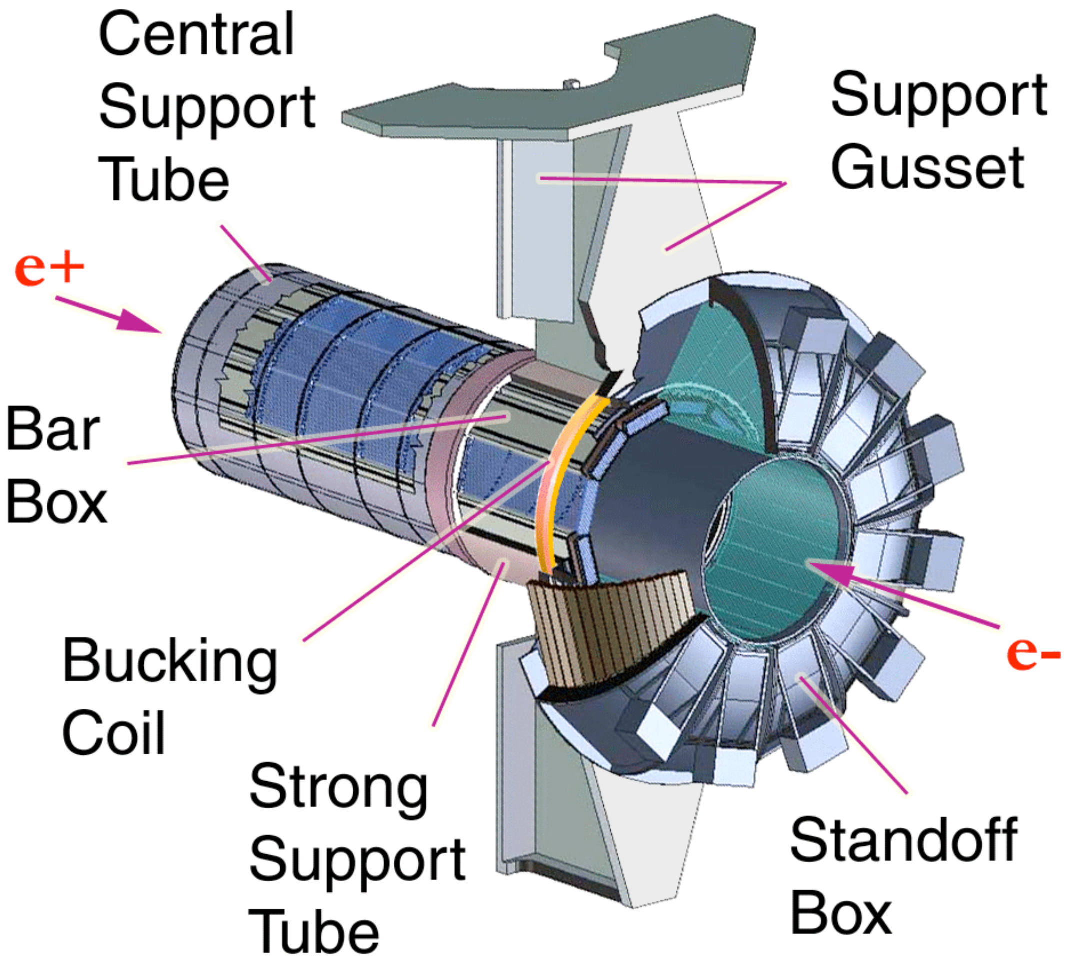
8 cm radial incl. supports

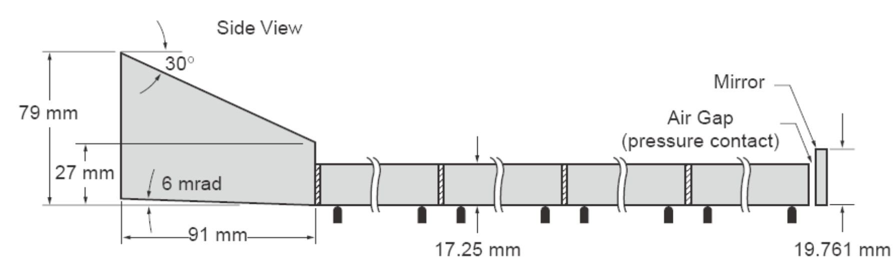
19% radiation length

at normal incidence

DIRC photon detection array:

10,752 PMTs ETL 9125





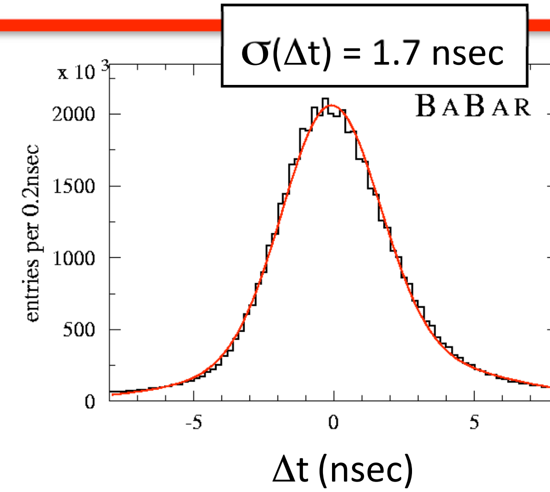
DIRC RECONSTRUCTION: (x,y,t)

For BABAR DIRC time information provided powerful tool to reject accelerator and event related background.

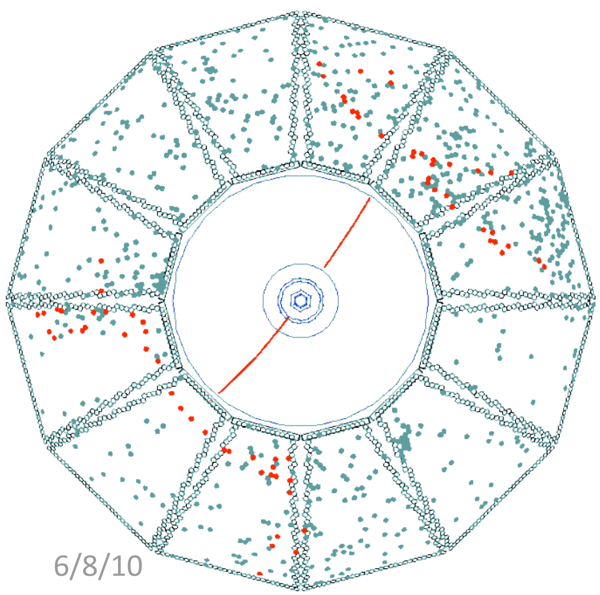
Calculate expected arrival time of Cherenkov photon based on

- track TOF
- photon propagation in radiator bar and in water

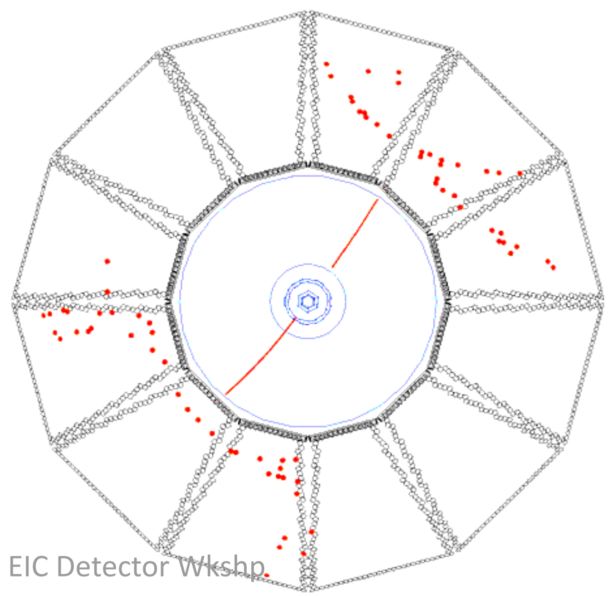
Δt: difference between measured and expected arrival time



± 300 nsec trigger window (~500-1300 background hits/event) → ± 8 nsec Δt window (1-2 background hits/sector/event)



→

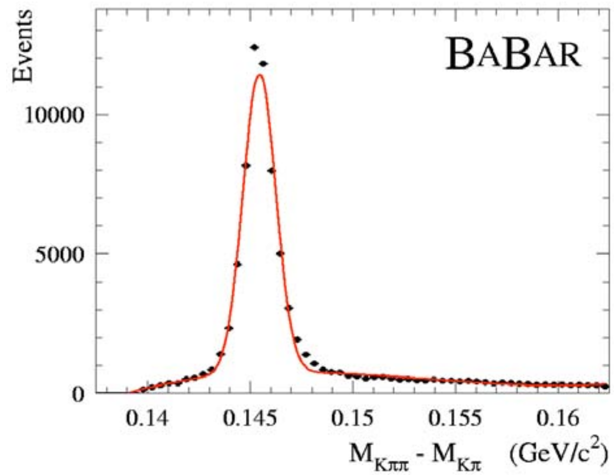


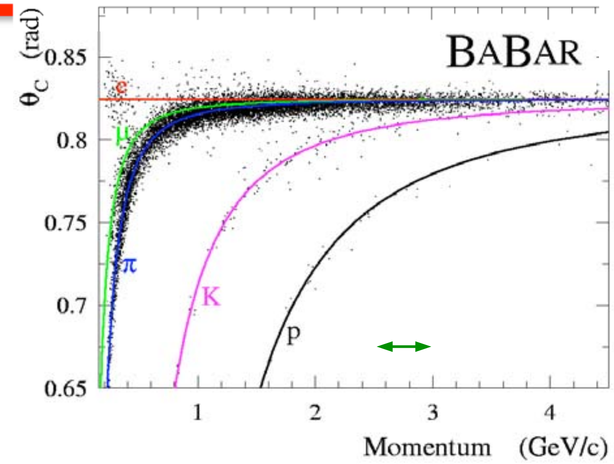
Δt also used to determine event time for "self-triggering" of DIRC.

BABAR DIRC PERFORMANCE EXAMPLE

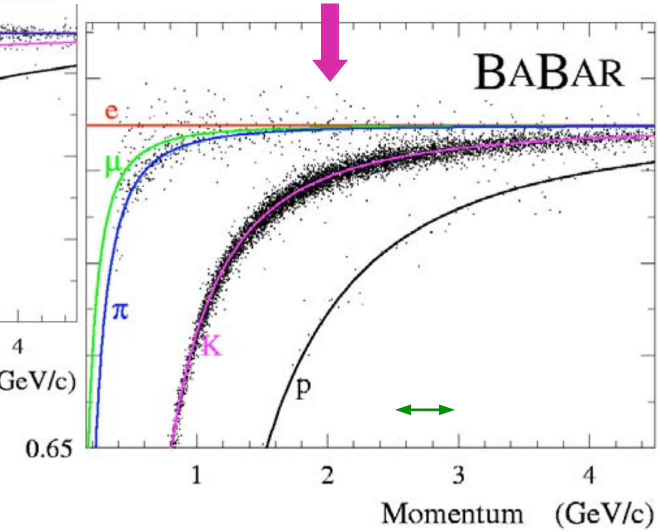
$D^{*-} \rightarrow D^0 \pi^-$

$\quad \hookrightarrow K^- \pi^+$

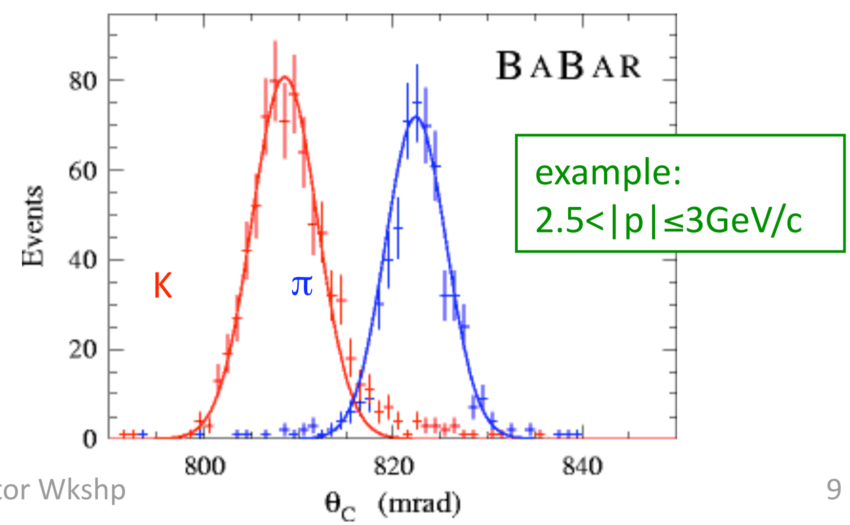




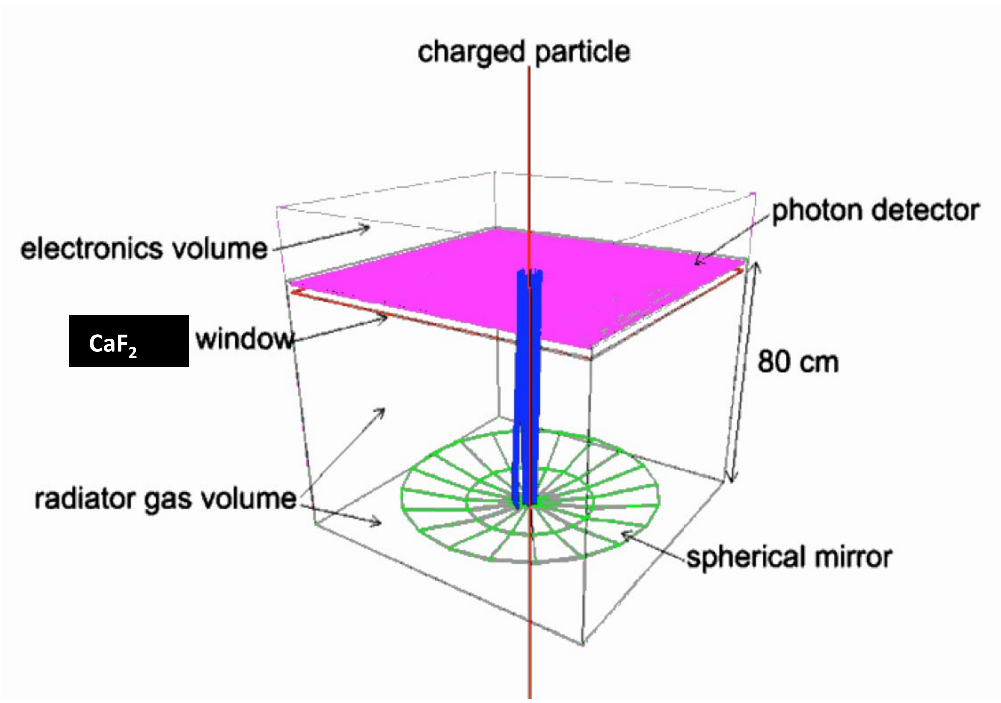
kinematically identified
π and K



- Select D^0 candidate control sample with mass cut (±0.5 MeV/c²)
- π and K are kinematically identified
- calculate selection efficiency and mis-id
- Correct for combinatorial background (avg. 6%) with sideband method.



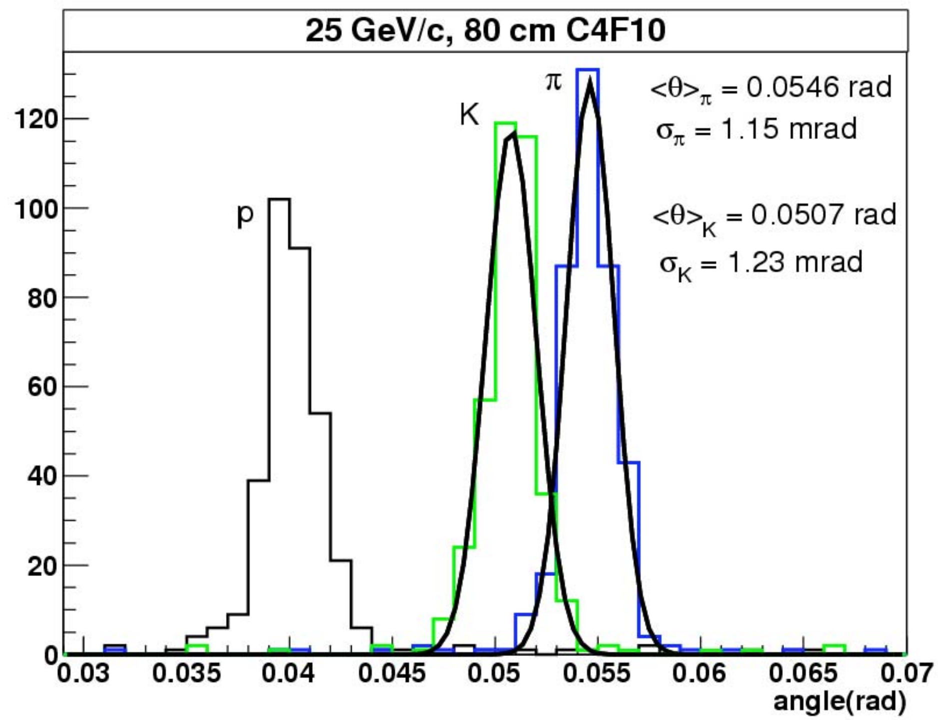
ALICE HMPID R&D



- Focusing RICH, C_4F_{10} gas radiator L~ 80 cm
- Photon detector *a la* HMPID, baseline option: MWPC with CsI pad (8x8 mm) segmented photocathode; alternative: CsI-TGEM or GEM
- Spherical (or parabolic) mirror, composite substrate, Al/MgF2 coating
- FEE based on HMPID Gassiplex chip, analogue readout for localization via centroid measurement

Windowless designs also use C_4F_{10} or CF_4 as both Cerenkov and amplifier medium.

PID performance: ID range



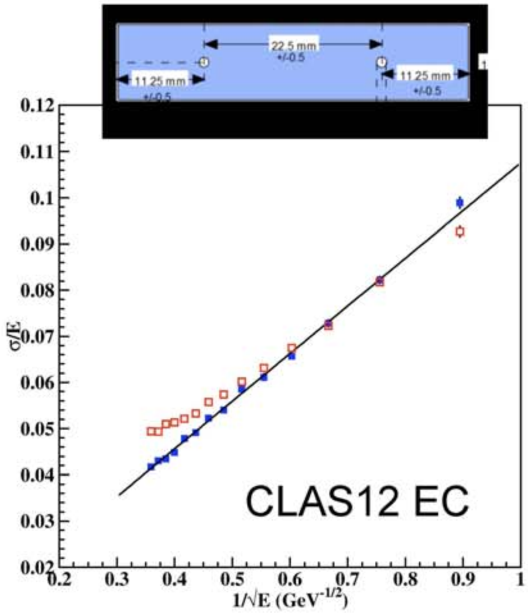
	Signal (GeV/c)	Absence of signal (GeV/c)
π	4-24	
K	11-24	
p	18-38	11-18

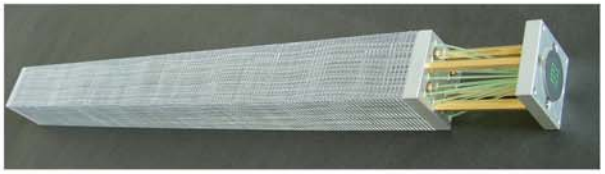
Lower limit: Cherenkov threshold
Upper limit: 3σ separation

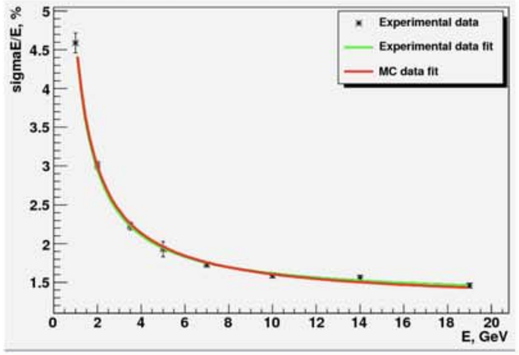
TestBeam and AliROOT simulation

EFEC

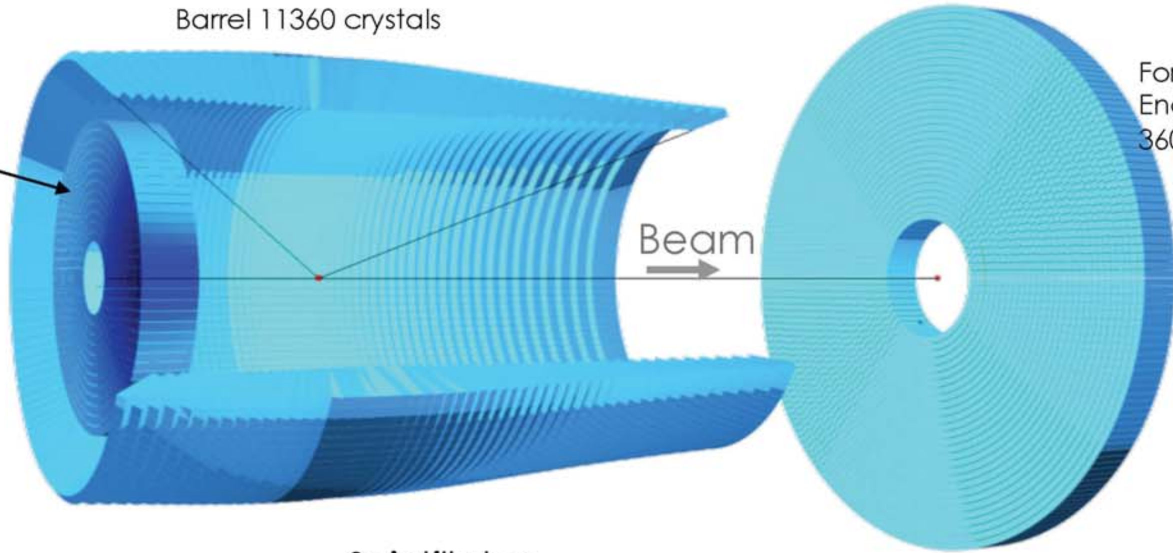
- Area to cover - ~40 m² (similar to CLAS)
- The most economical solution - lead-scintillator sandwich
  - Extruded scintillators with WS fiber readout (CLAS12 PCAL)
  - Will provide required hermeticity and needed granularity
  - Expected energy resolution $\sigma/E=10\%/\sqrt{E}$
- Somewhat better resolution can be achieved with "shashlyk" type configuration, used in ALICE, LHCb (LHC), HERA-B (DESY), PHENIX (RHIC), PANDA (GSI)







2-The electromagnetic calorimeter in the target spectrometer



15552 crystals

Compact geometry
Nearly 4 π coverage
High rate capabilities
→
<u>Scintillator</u>
Small Radiation length
Small Moliere radius
Fast response
→
Lead tungstate ($PbWO_4$)

Magnetic field 2T → Photo sensors APD (Barrel)
VPT (Endcap)

Energy from 10 MeV to 15 GeV

Tracking/ Triggering / Simulations

- Tracking: F. Klein (CUA)
  - Pattern recognition
  - Technologies:
    - Si
    - Drift Chambers
    - Micro Pattern Detectors (GEM, MicroMegas)
    - TPC
- Triggering : B. Raydo (JLab)
  - Challenge of asynchronous triggering with 1.5 GHz beam structure
  - JLab 6 GeV : analog
  - Pipeline DAQ/Triggering
    - CLAS12, HallD
- Simulations: T. Horn (CUA)
  - Event Generators
  - GEANT based framework for simulations

Activities of the Simulation Working Group

- Event Generators (standardized format)
  - Rate predictions including simulations of the detector restrictions
  - Input for detector design
    - Momentum and angular distributions for various particles

- Fast MC
  - Input: resolution function

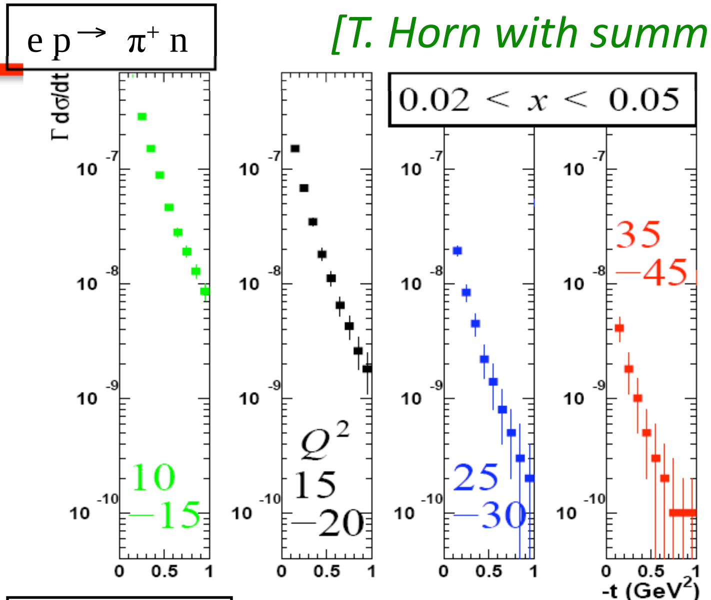
- GEANT MC
  - Based on the CLAS12 simulation package GEMC

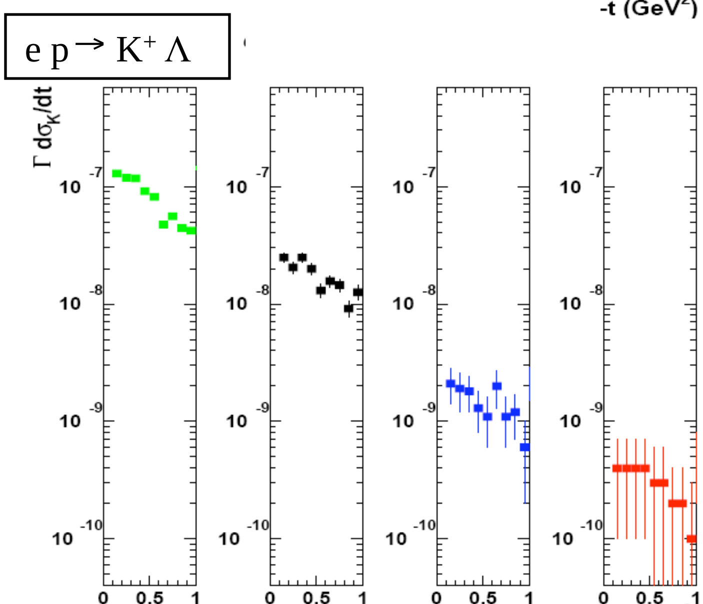
- Event Reconstruction/Tracking (for GEANT data)

- Semi weekly meetings with Physics+Accelerator EIC group

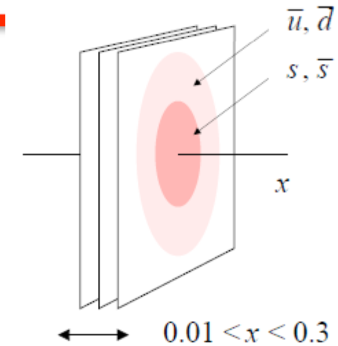
Exclusive Generators: π^+/K^+

[T. Horn with summer student: D. Cooper '08]





- Do strange and non-strange sea quarks have the same spatial distribution?



- Simulation for charged π^+ production, assuming 100 days at a luminosity of 10^{34}, with 5 on 50 GeV (s = 1000)
- Pion cross section models:
  - –Ch. Weiss: Regge model
  - –T. Horn: π^+ empirical parameterization
- Kaon cross section model:
  - –T. Horn: K^+ empirical parameterization based on DESY, Cornell, JLab data

Pushes for high luminosity ~10^{34} and lower and more symmetric energies

Summary - main detector challenges (P. Nadel-Turonski)

1. Central Detector

- Particle ID (e/π/K/p)
- Momentum resolution (tracker radius / layout)
- Electron beam on Solenoid Axis
- Ion beam crossing angle 50 – 100 mrad.

2. Forward hadron detection

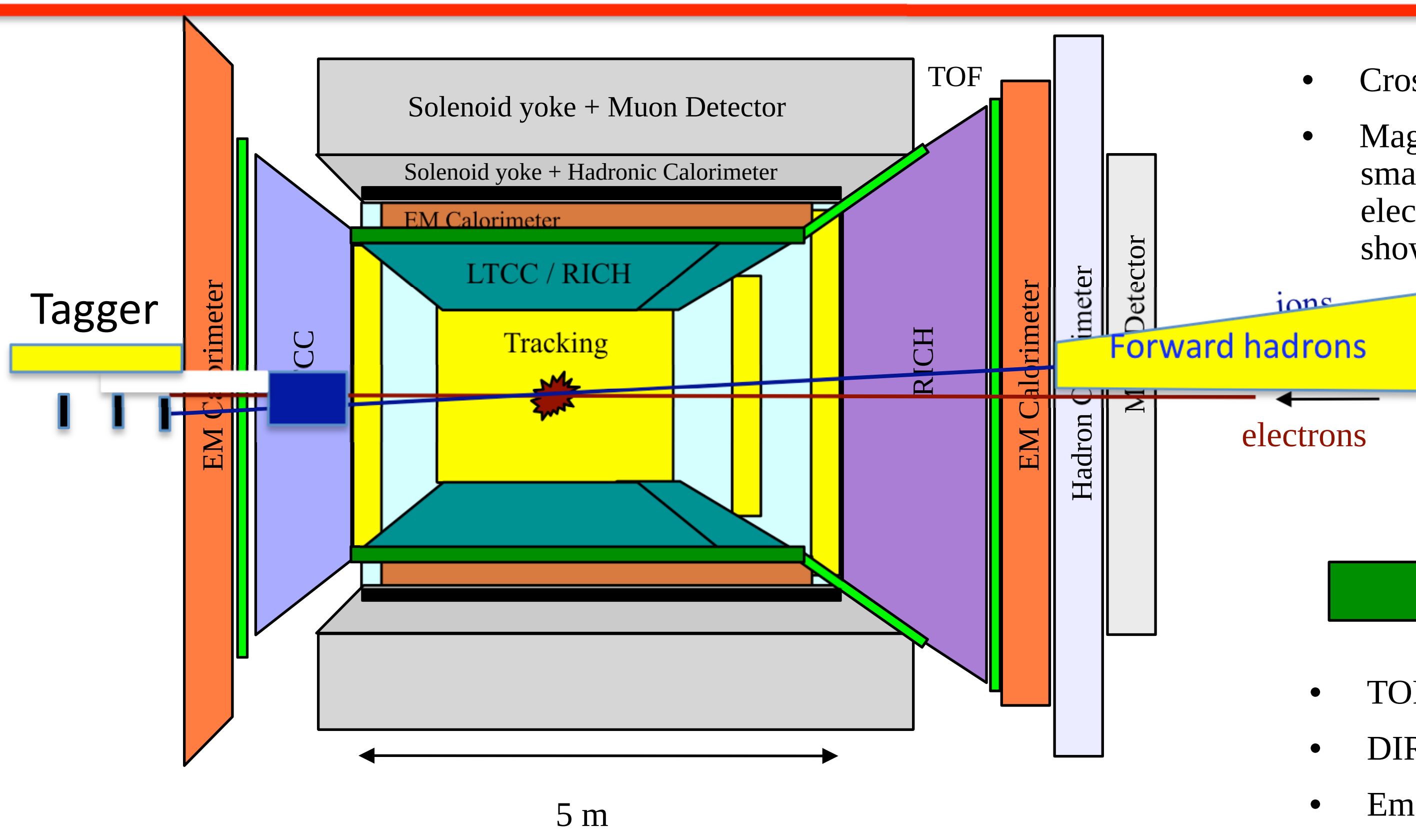
- Acceptance (3 stages needed)
- Momentum resolution at intermediate angles (0.5-5°)

3. Low-Q^2 electron tagging

- Endcap design (DIRC readout?)
- Common dipole for both beams?

4. Integration with accelerator

Central detector and End caps

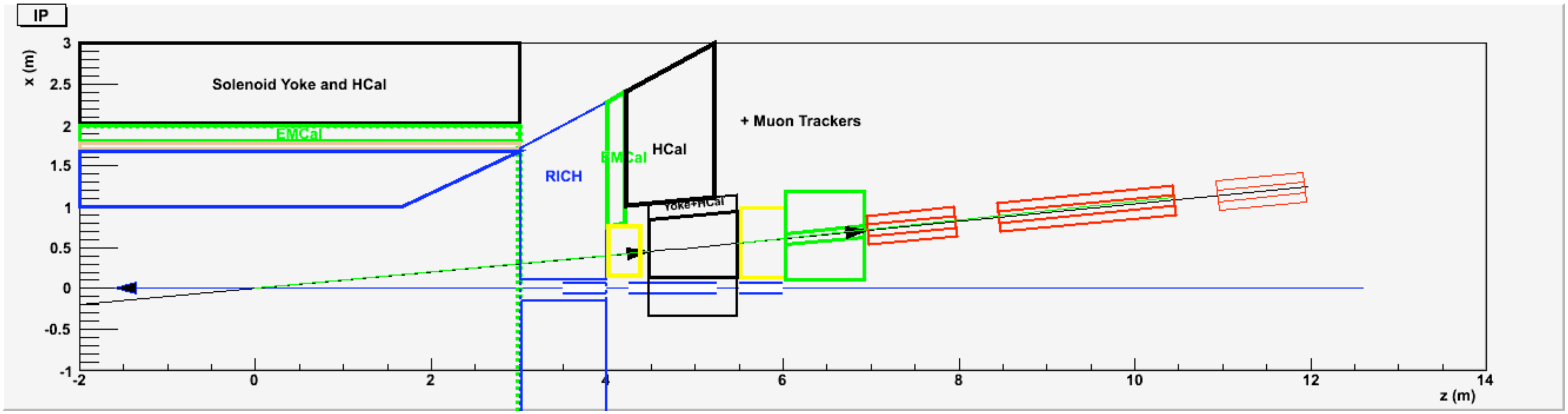


- Crossing angle: 3-5°
- Magnet apertures for small-angle ion and electron detection not shown

- TOF (5 cm)
- DIRC (10 cm)
- EmCal (20 cm)
- Low Threshold Cer 65cm

- The IP the IP is offset within the solenoid towards the electron endcap to provide more tracking space
- Barrel has ~1 m radial tracking + ~1 m [Cerenkov+DIRC+TOF+EMCal]
- Only active elements are shown. Detector can be "closed" magnetically

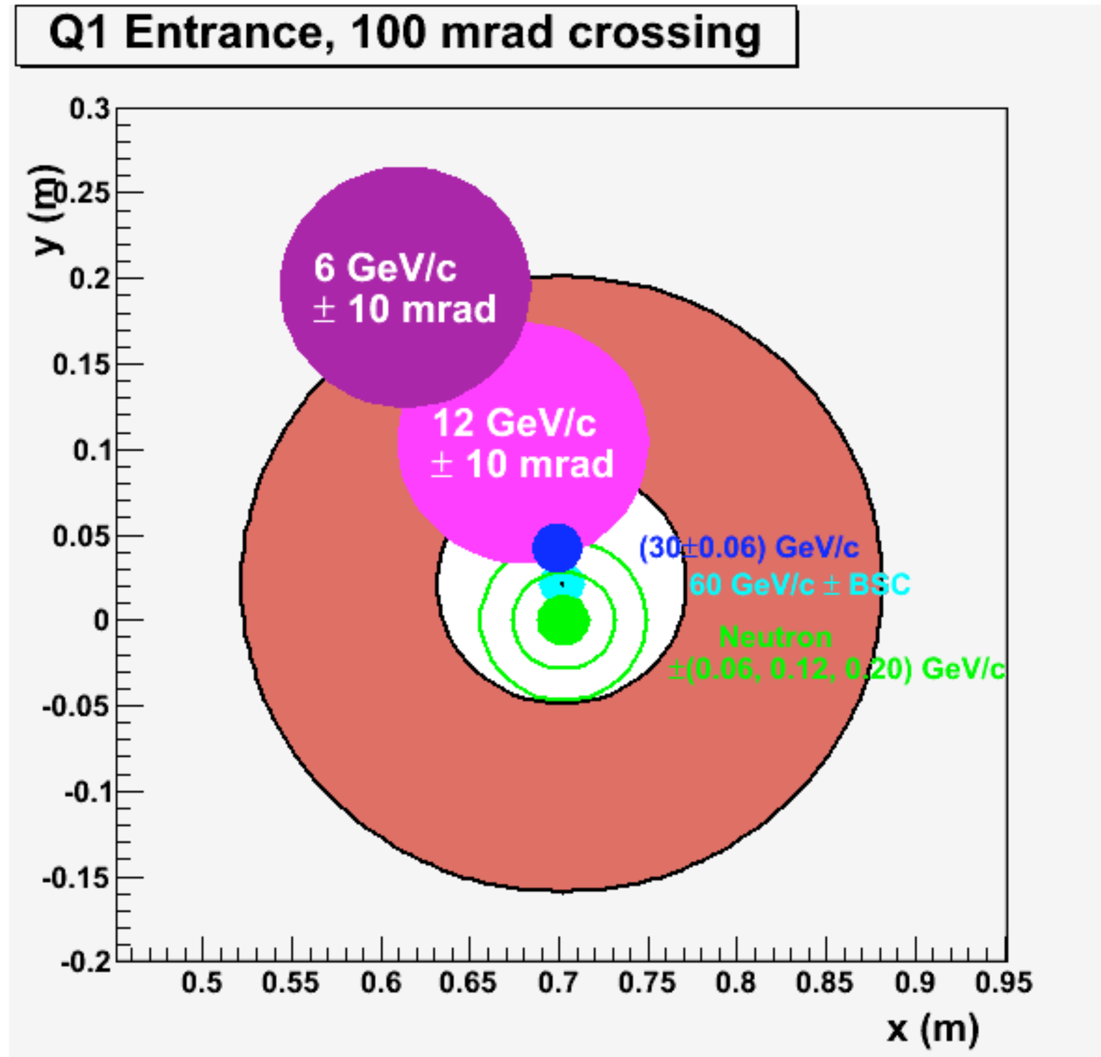
Forward Tracking



- 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-Q5
    - 20 Tm Dipole at 20 m : ZDC for neutrons, Tracking for P'<0.995P

Precession of Trajectories in Solenoid

- Solenoid
  - 4 Tesla x 3m at 100 mrad
- Q1-Q3
  - 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
- 10 GeV/c forward hadrons tracking dp/p ~1%
- Detect n,p Spectators after 20 Tm dipole at 20 m
  - Tracking acceptance P'<0.995 P
  - Resolution dP/P <3•10^{-4}.



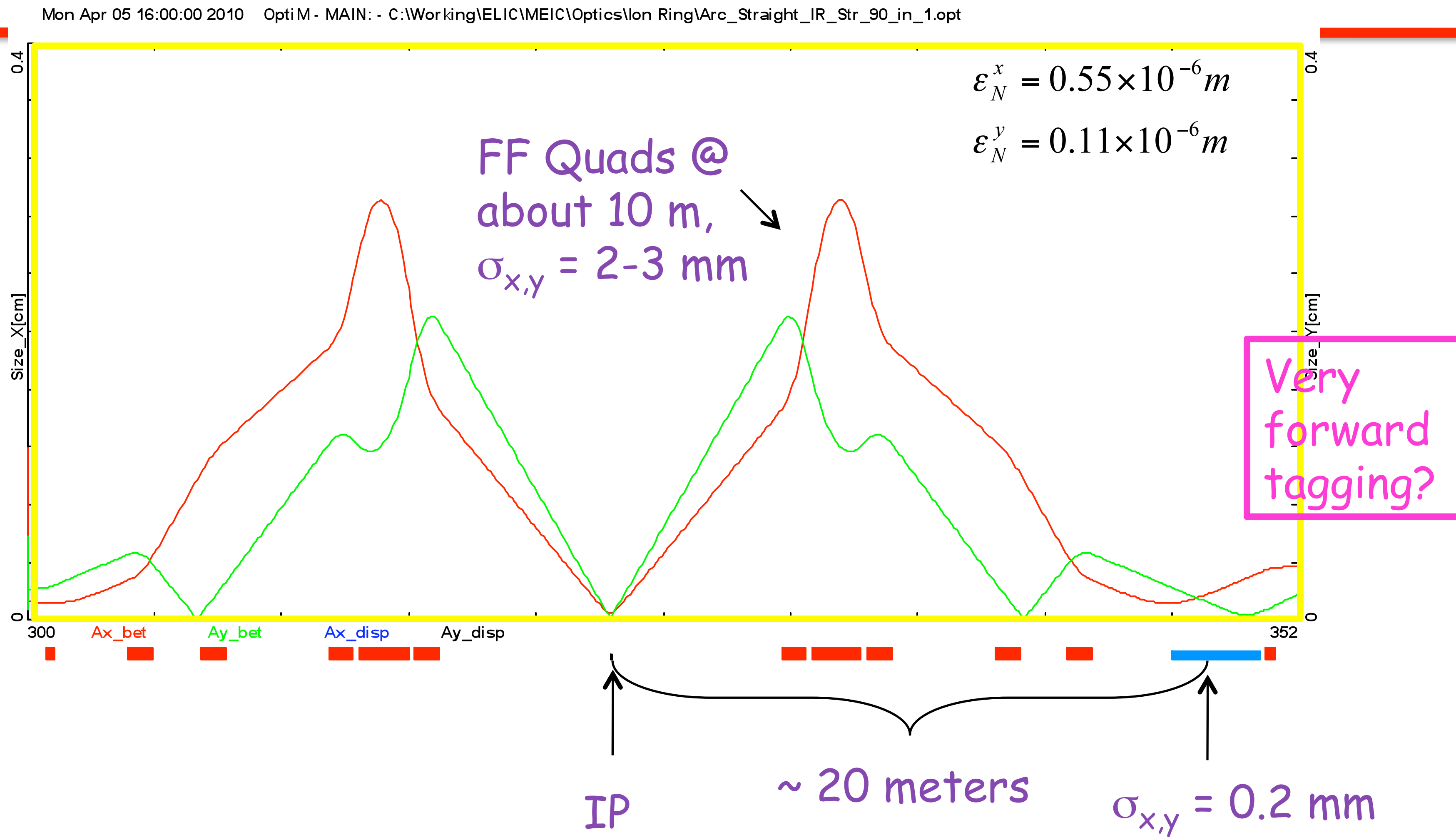
Conclusion

- Active detector design effort
  - Need lots of input from users on requirements for individual physics processes
  - Dynamic interaction with accelerator group
- Close to a "Zero Design Concept"
  - Next project, a "Fast Monte Carlo"
    - Analytic, not GEANT, easy to analyse output
- Happy to hear proposals for a more specialized second detector
- Join us !

Momentum Resolution of Forward Tracker

- Measure points to 100μ over 0.5 m length before and after dipole
  - $\delta\theta$ ~0.3 mrad.
- Dipole Bdl = -1.2 Tm
  - Bending angle
  - θ = (ecBdl)/(pc) = (0.3GeV)/(pc)
- Momentum Resolution
  - $\delta p/p = \delta\theta/\theta$ = 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

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 $\rightarrow$ epγ
  - SIDIS or RapGap: ep $\rightarrow$ 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

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
  - β ~ D
- Lattice Admittance $\Delta P/P \sim 0.003 = 10\ \delta P/P$
- "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