ePHENIX for eRHIC

A.Bazilevsky
For PHENIX Collaboration

March 28, 2012

XX International Workshop on
Deep-Inelastic Scattering and
Related Subjects

26-30 March 2012, University of Bonn

The Charge

eRHIC: one of the two options for Electron-Ion Collider (EIC)

- Add electron ring to RHIC:
  - Energy: E_e=5-30 GeV/c, E_p=50-250 GeV/c E_A=20-100 GeV
  - Polarization: 80% for e and 70% for p (^{3}He, d)
  - Species: All nuclei from p to U
  - Luminosity: $10^{33\text{-}34}$ $cm^{-2}sec^{-1}$
- The EIC physics goals: INT EIC report arXiv:1108.1713

eRHIC talk by V.Ptytsyn

ePHENIX:

- Electron beam bypass around PHENIX (and STAR) is costly
- Assuming its predecessor (PHENIX→sPHENIX) continues taking data in 2020+
- Clarify the physics goals of EIC feasible with ePHENIX

sPHENIX talk by K.Boyle

Staged Approach

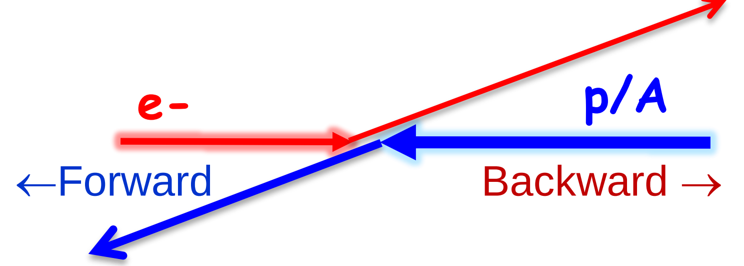
- Evolution from sPHENIX (pp and HI detector) to ePHENIX (DIS detector)
  - Make sPHENIX upgrade consistent with ePHENIX plans
- Anticipate new opportunities with the evolution of eRHIC towards higher lum. and beam energy
  - Start with 5 GeV electron beam on existing p/A beam
  - May be upgraded to electron beam 8-9 GeV in the first few years
  - Upgrade to electron beam energy to 20+ GeV and higher integrated lum.
- Funding from multiple resources
  - Initial DOE funding (sPHENIX)
  - Further funding from non-DOE and DOE sources
  - Possible funding from eRHIC related funds
- Attract new collaborators at different upgrade steps

Maximize physics impact via continuous evolution of detectors over time

INT EIC:
arXiv:1108.1713

Physics Goals

Under consideration/simulation



Spin and flavor structure of the nucleon

Understanding gluon and quark (total and flavor separated) helicity distribution

Inclusive and semi-inclusive measurements

Electron ID in backward and central rapidities, hadron PID in central and forward rapidities

Gluon and quark TMDs

Orbital motion, spin-orbit correlation, towards 3D imaging (momentum distribution in transverse plane)

Semi-inclusive measurements

Electron ID in backward and central rapidities, hadron PID in central and forward rapidities

GPDs

Spacial imaging of quarks and gluons, total angular momentum

Exclusive reactions: DVCS (exclusive production of mesons)

Electron ID in backward and central rapidities, Roman pots for forward proton, photon ID in backward and central rapidities (, hadron PID in wide acceptance)

QCD matter in nuclei

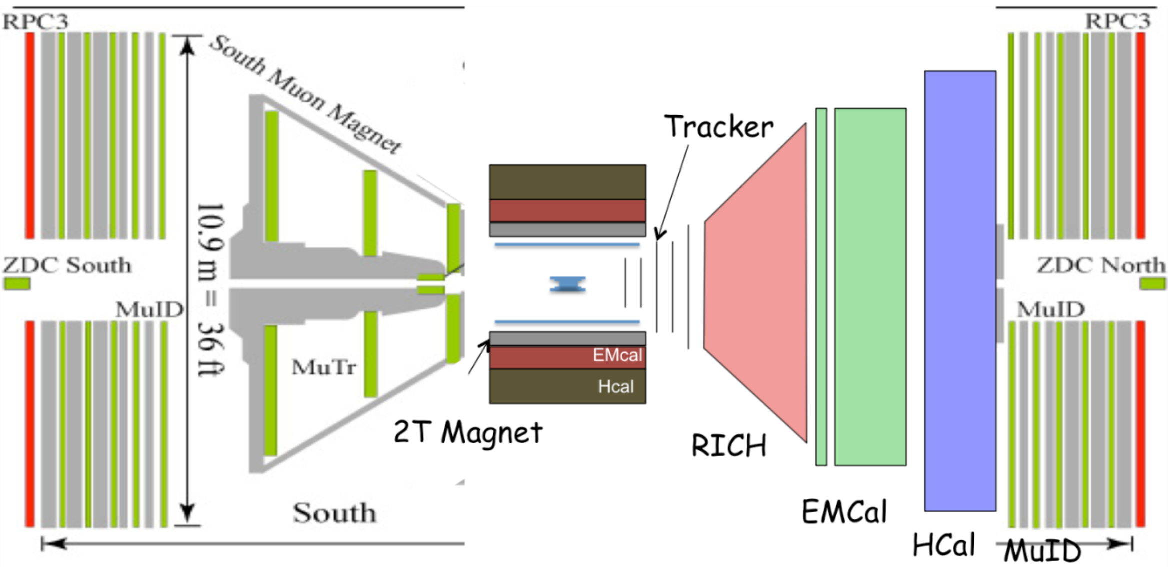
Structure of the nuclei, parton energy loss, start of low x physics

F_2, F_L (, di-hadrons, SIDIS, diffraction)

Electron ID in backward and central rapidities (, PID in wide acceptance)

Detector Concept: PHENIX → sPHENIX

sPHENIX talk
by K.Boyle



Replace central magnet with compact solenoid ($|\eta|<1$)

Tracking with enhanced VTX

Compact EMCal

Tungsten-scintillator

$\Delta\eta\times\Delta\varphi=0.02\times0.02$

Hadron Calorimeter

$\Delta\eta\times\Delta\varphi=0.1\times0.1$

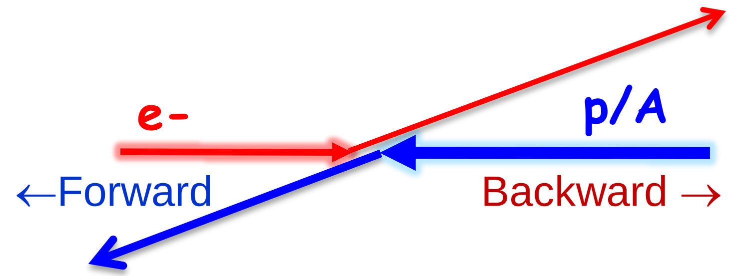
Being optimized for Jet measurements in pp and Heavy Ion collisions

In further future: replace one of the muon arms by forward spectrometer

Tracker, RICH, EMCal, Hcal

To measure hadrons, electrons, photons, jets

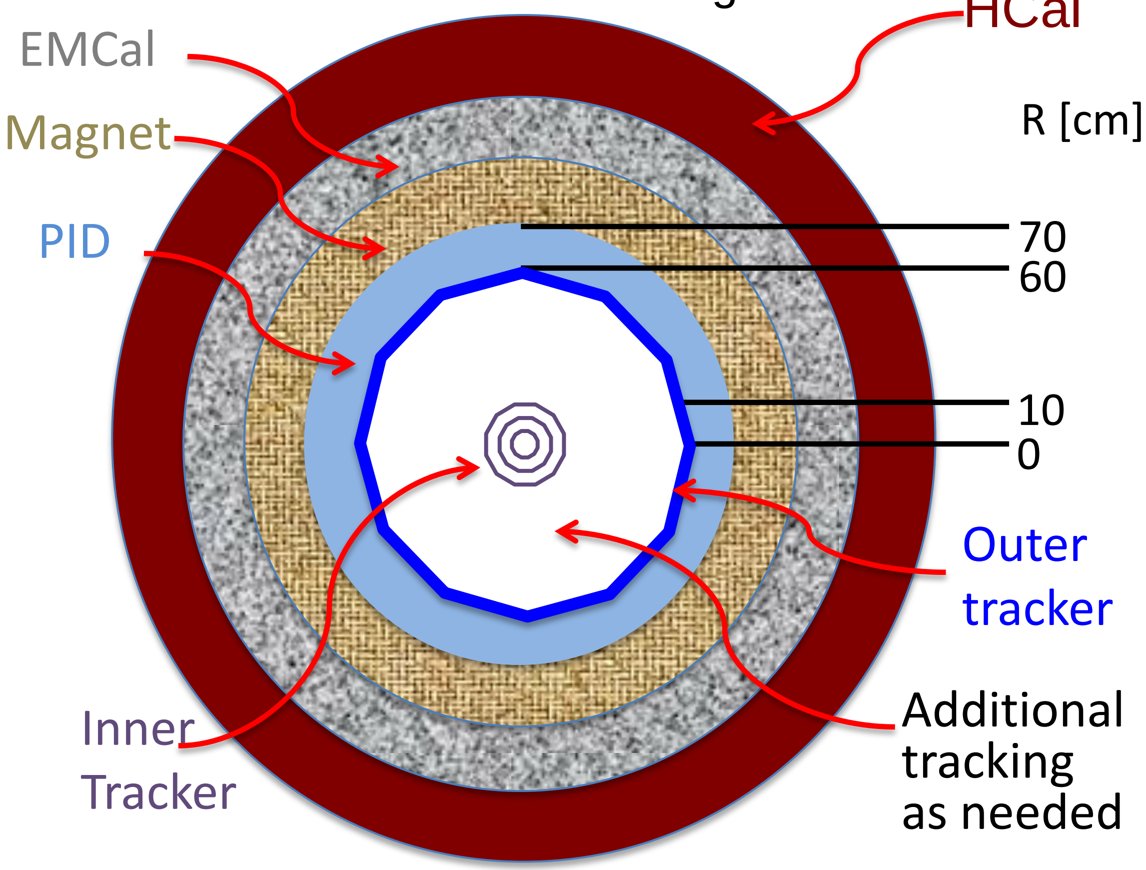
Detector Concept: sPHENIX → ePHENIX



Minimal configuration/requirements:

- Backward: electrons, photons
- Barrel: electron, photons, hadrons
- Forward: hadrons
- Roman Pots for forward protons

Barrel cross section diagram



Immediate focus:

Make sure sPHENIX concept of barrel consistent with upgrade plans for ePHENIX physics

sPHENIX central arm proposal (CD0) to be submitted on Jul 1, 2012

Is EMCal resolutions good enough?

Enough space for PID?

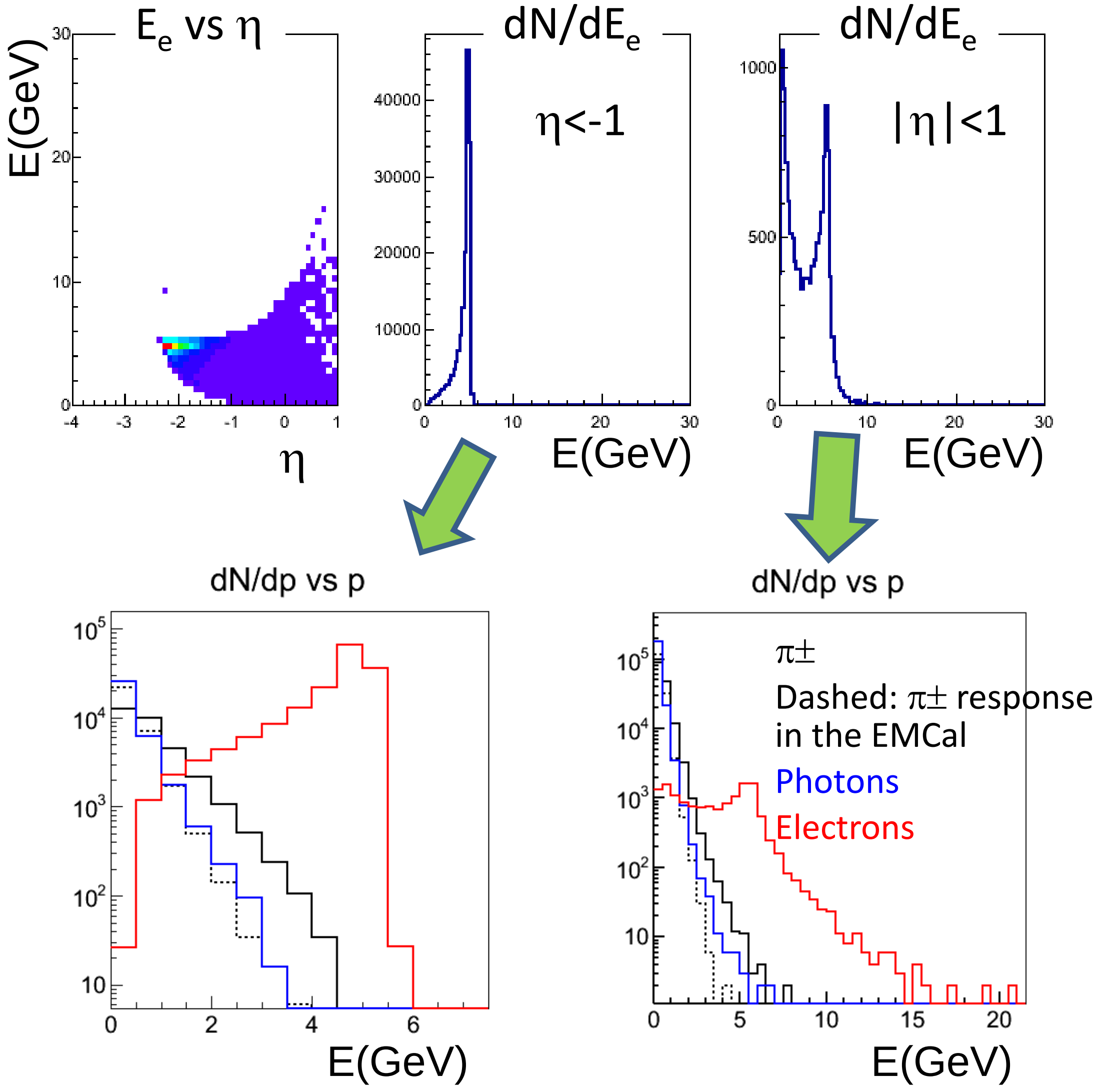
Momentum range for PID

Material budget limitation for tracking

PYTHIA generator

Inclusive DIS kinematics

5 GeV (e) × 100 GeV (p)



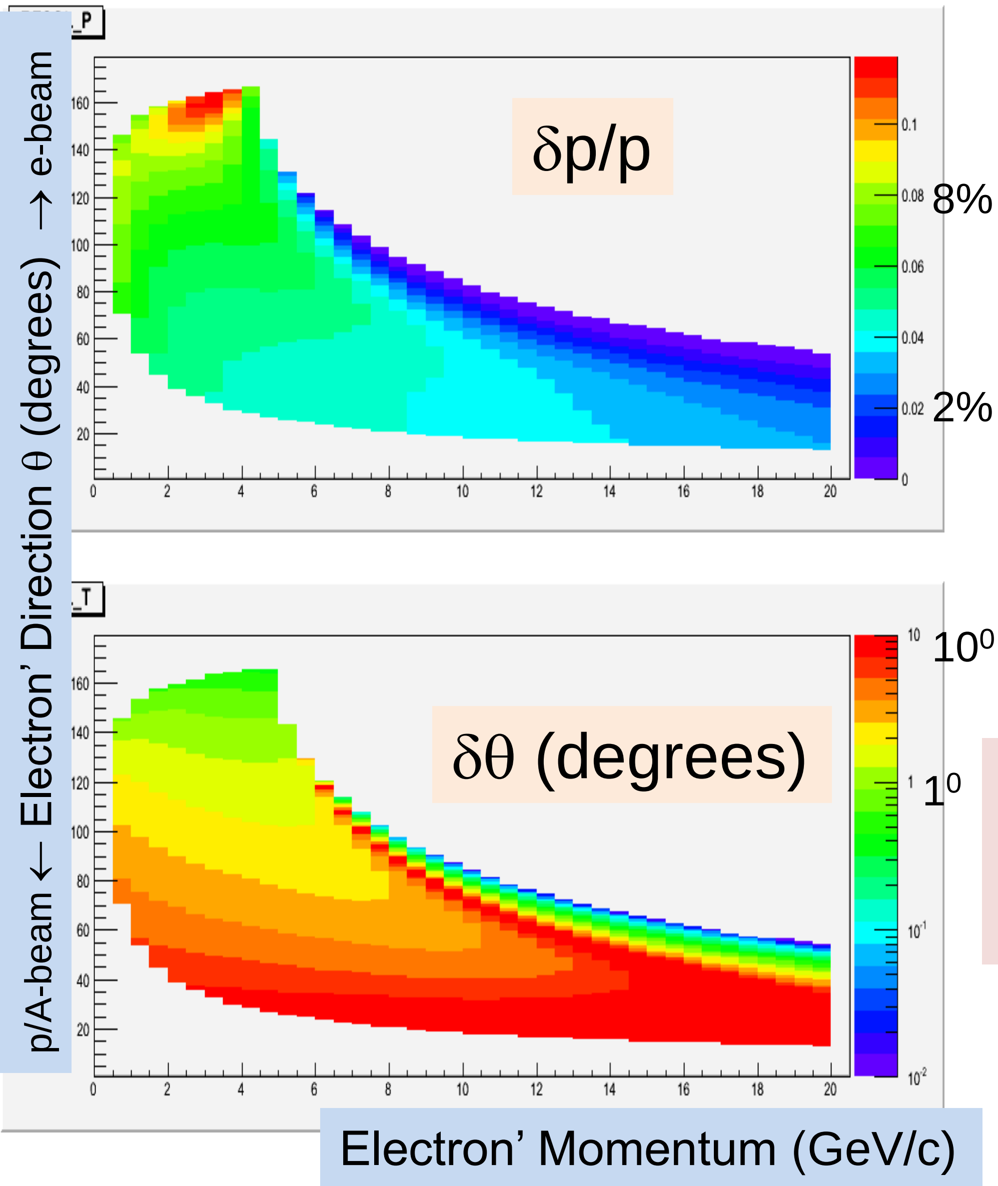
Scattered electron energy ranges from 0 to the electron beam energy, and higher in central and forward rapidities

Signal/Background high

- ✓ Should not be a problem to identify scattered electron, except when its energy is very low
- ✓ Decay photon background only at lowest energy ⇒ photon conversion should not be a problem for reasonably thin tracking
- ✓ Need to simulate Bremsstrahlung

Momentum and angle resolution

5 GeV (e) × 100 GeV (p)



Inclusive measurements:

$$\sigma_{red} = F_2(x, Q^2) - \frac{y^2}{Y_+} F_L(x, Q^2)$$

$$(x, Q^2) \rightarrow (p, \theta)_{e'}$$

Resolution → Systematics → Unfolding

Assume: σ_{syst}~1/5 of systematics

0.1×0.1 binning in $\log_{10}(x) \times \log_{10}(Q^2)$

Require: 1% uncertainty in each bin

"Reasonable" resolutions may be enough:

$\delta p/p$ ~ 2-8%

$\delta\theta$ ~ 1 degree

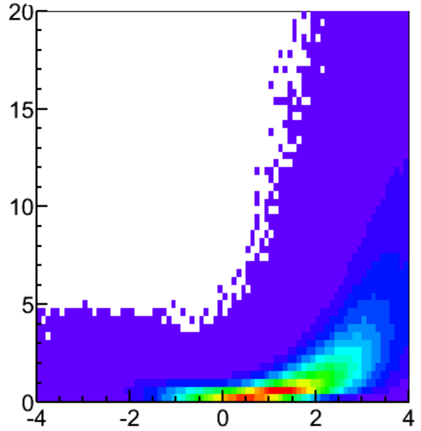
PYTHIA generator

5 GeV (e) × 100 GeV (p)

Hadron PID: kinematics

Semi-Inclusive measurements

p (GeV/c) vs η



Hadron are going preferably in p-beam direction

But still a lot (with smaller p) in barrel (|η|<1)

Barrel:

Don't lose in (x,Q^2) space if no identification for hadrons at >4 GeV/c

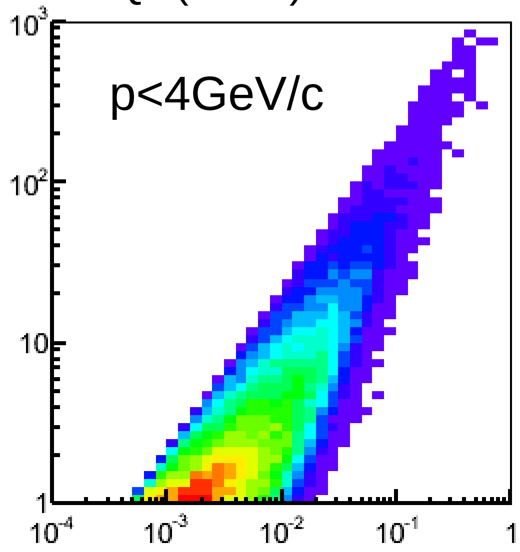
Forward:

Need higher mom PID

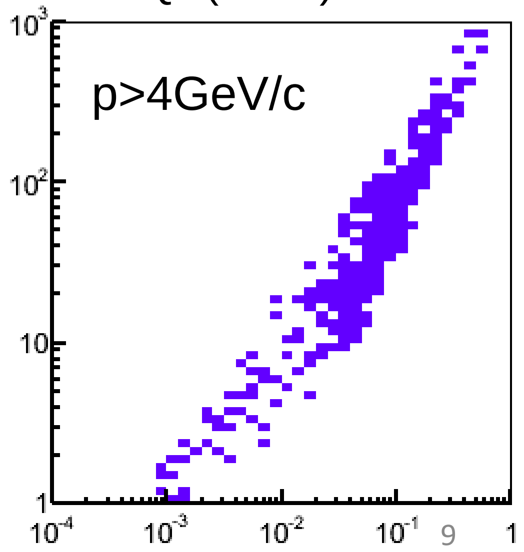
See talk by T.Barton with similar conclusion from on gluon Sivers with D-mesons

|η|<1

Q^2 (GeV^2) vs x

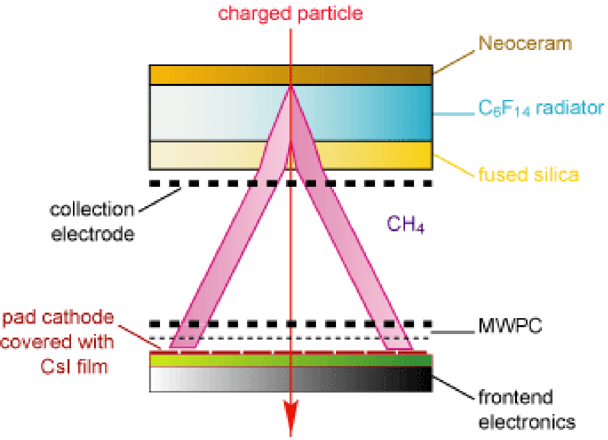


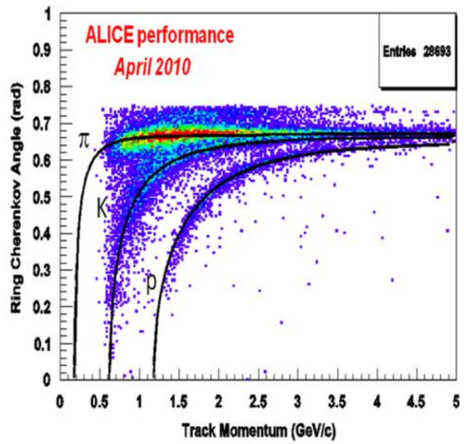
Q^2 (GeV^2) vs x



Hadron PID: detection

Barrel: would like to have π/K separation out to ~4 GeV/c



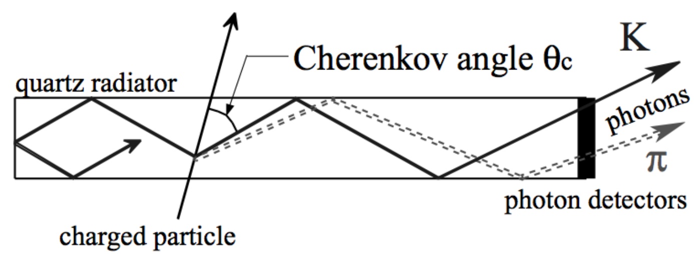


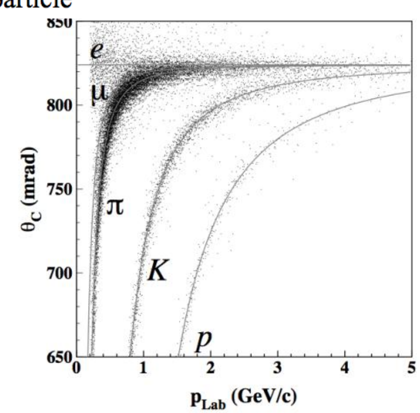
Proximity Focused RICH (ALICE)

- Thin radiator followed by expansion volume.
- Discussions ongoing for how to push this PID to higher momentum.

DIRC (BABAR)

- Very thin quartz radiator (radially detector ~10cm)
- Signal sent to large η for readout
- At BABAR, readout was huge fan out of PMTs at ends: Investigating smaller readout with SiPM
- At >3 GeV/c PID eff degrades: finer readout with SiPM may extend the range

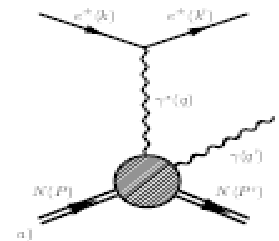




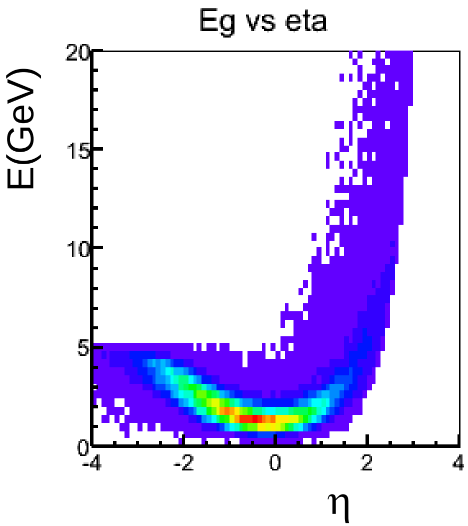
MILOU DVCS generator
E. Perez, L Schoeffel, L. Favart
arXiv:hep-ph/0411389

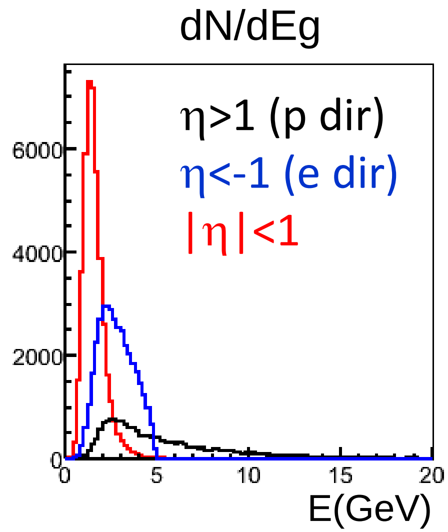
DVCS: kinematics

Exclusive measurements



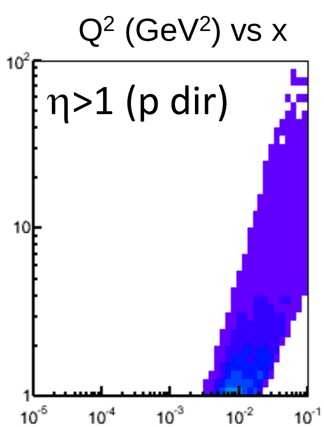
5 GeV (e) × 100 GeV (p)

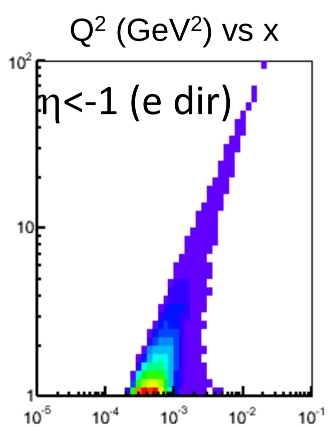


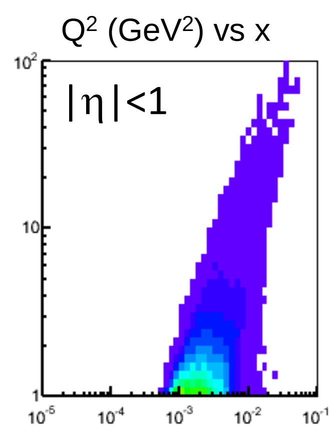


From 30% (for 20 GeV e-beam) to 45% (for 5 GeV e-beam) of DVCS photons are in central rapidity

Photon energy in central rapidity is in the range 1-3 GeV



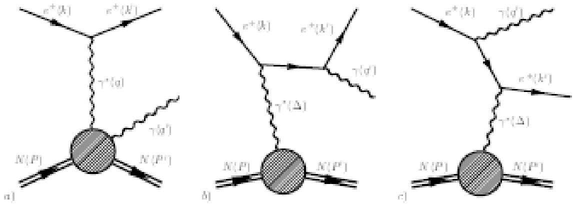




Central rapidity is important for DVCS photon reconstruction, as it covers its own kinematical area

MILOU DVCS generator
E. Perez, L Schoeffel, L. Favart
arXiv:hep-ph/0411389

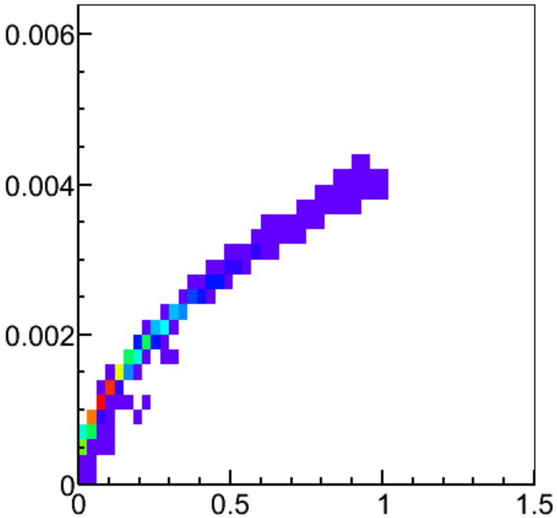
DVCS: reco



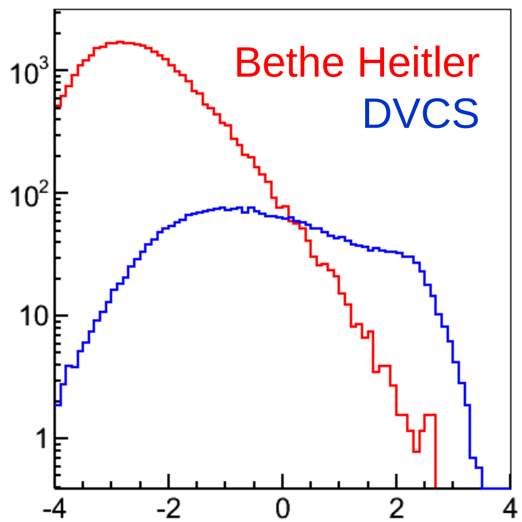
5 GeV (e) × 250 GeV (p)

Thanks to S.Fasio and E.Aschenauer for valuable discussions

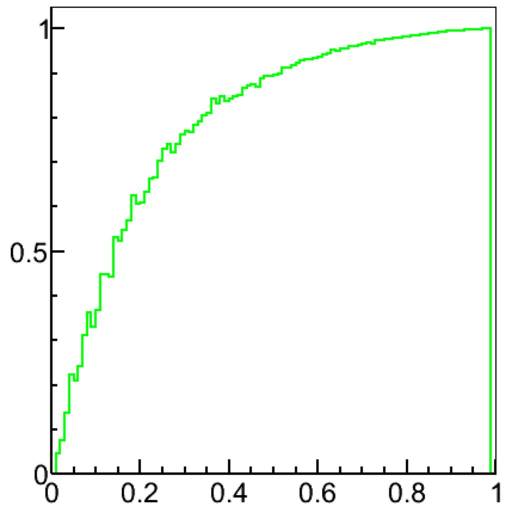
Proton θ vs $-t$ (GeV^2)



dN/deta



BH/(BH+DVCS) vs y



Roman Pots needed

BH is more backward than DVCS

Central and forward regions are cleaner for DVCS

DVCS dominates at low y

Summary and Plans

- The goal: to provide smooth transition sPHENIX $\rightarrow$ ePHENIX
  - Make sure sPHENIX upgrades consistent with ePHENIX physics
  - Immediate focus: central barrel, as the proposal for sPHENIX barrel to be submitted in July 2012
  - Working on forward/backward spectrometer design to satisfy both pp+HI and DIS physics
  - IR design influence and bunch spacing for DAQ/triggering to be considered
- Staged approach
  - Smooth transition sPHENIX $\rightarrow$ ePHENIX
  - New opportunities with eRHIC upgrading
  - Multiple source funding
  - Attract new collaborators at different upgrade steps
- Wide range of DIS physics tasks for ePHENIX under consideration/simulation
  - … Physicists usually are capable to do much more with given detector than originally anticipated

Thanks to BNL-EIC group for discussions and maintaining simulation packages

Backup

x-Q^2 coverage: for $\sqrt{s} = 45 - 140$ GeV

Wide and continuous coverage in Q^2 at fixed x at all Sqrt(s)

M. Stratmann