FOCAL
a Forward Calorimeter for PHENIX

Richard Seto
University of California, Riverside
Workshop on Saturation, the Color Glass Condensate and Glasma:
What Have we Learned from RHIC?
BNL - May 12, 2010

Why the FOCAL

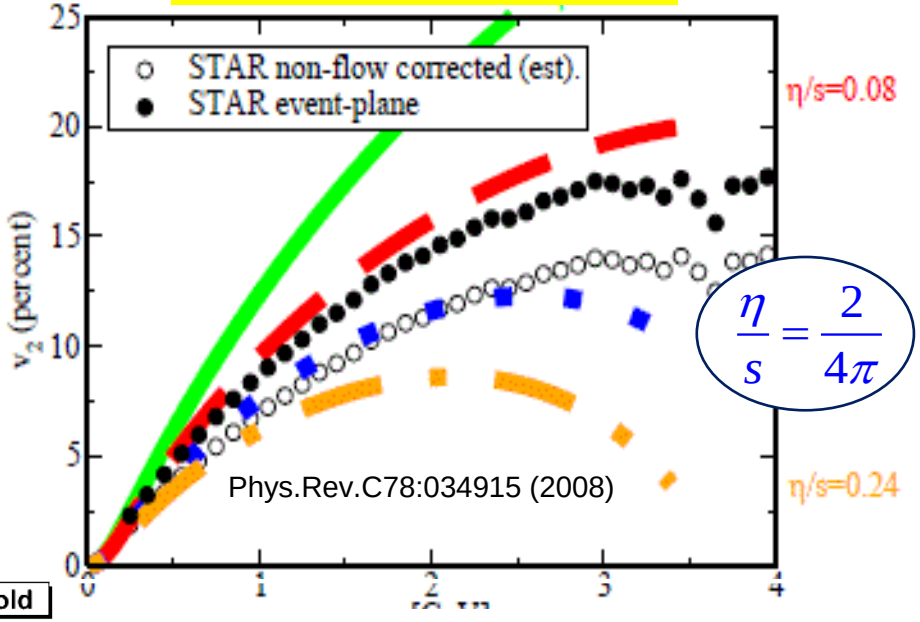
- To understand cold nuclear matter
  - Color Glass? Something else?
- To understand heavy ion collisions
  - The confluence of experimental data and theory has given us the possibility of an unprecedented understanding of the sQGP
    - Hydro gives a good description of the system
    - Techniques for strongly coupled and/or dense systems
    - Lattice QCD

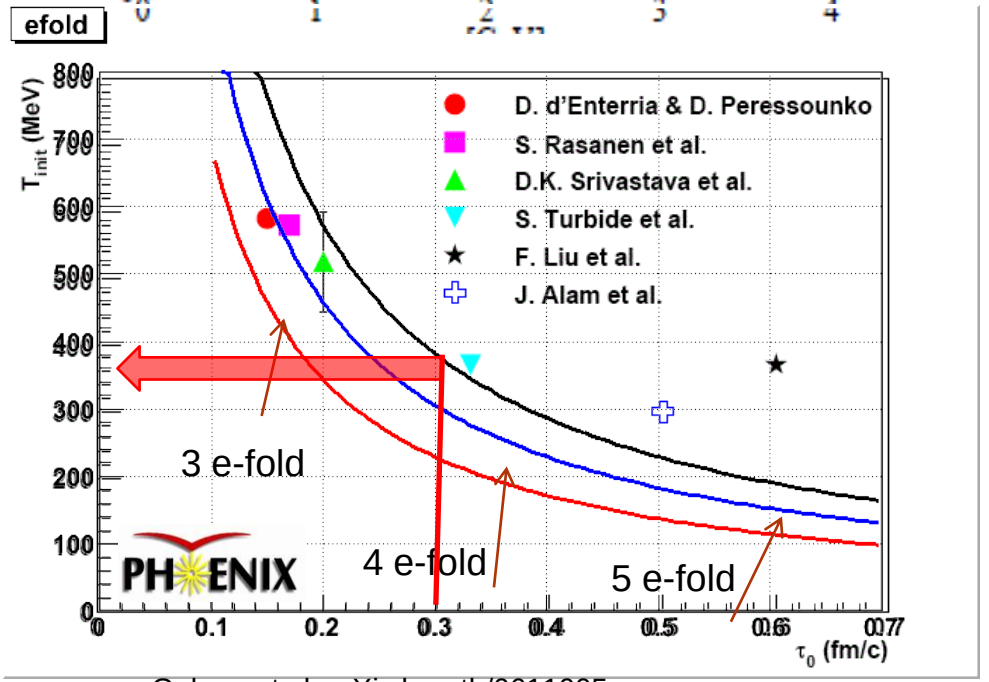
➔Now we need the initial state.

Need for the initial state of the sQGP (examples)

- η/s
  - Reminder: AdS/CFT $\frac{\eta}{s} = \frac{1}{4\pi}$
    - Conjectured bound
  - Theoretical Progress Romatchke – viscous hydro
  - Conclusion depends in initial conditions!
- Temperature
  - Make a measure of low p_T photons (black body radiation)
  - Use a model of time dependence and fit data
  - Initial T Depends on knowing τ_0 the initial thermalization time
  - Kovchegov & Taliotis find τ_0~ 0.3 fm/c matching ***initial conditions*** similar to a CGC using strong coupling methods (arXiv:0705.1234)

Initial condition:CGC

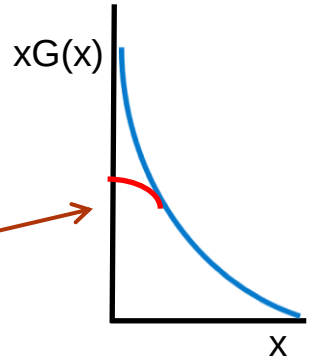


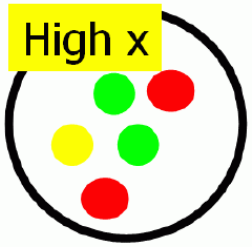


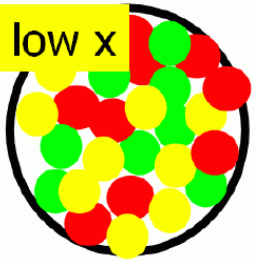
Gubser et al: arXiv:hep-th/0611005

What does the initial state look like?

- Gluons at Low-x
  - Not well understood
  - Growth must be "tamed" at low-x
  - Saturation and the CGC
    - describe low-x gluons in terms of classical fields (Color Glass Condensate)
    - (p)d+A collisions - nuclear "oomph" factor ~$A^{1/3}$
      - Enhances gluon density compared to nucleons

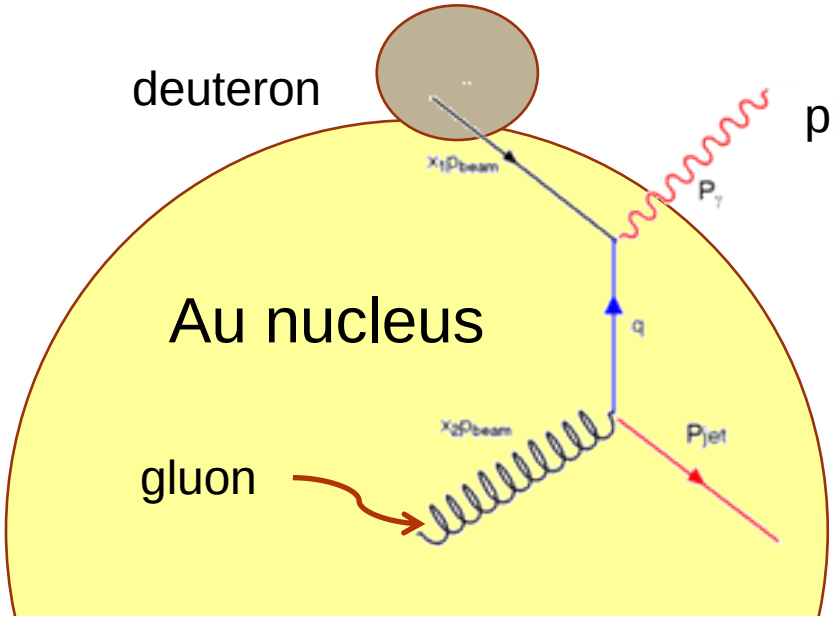






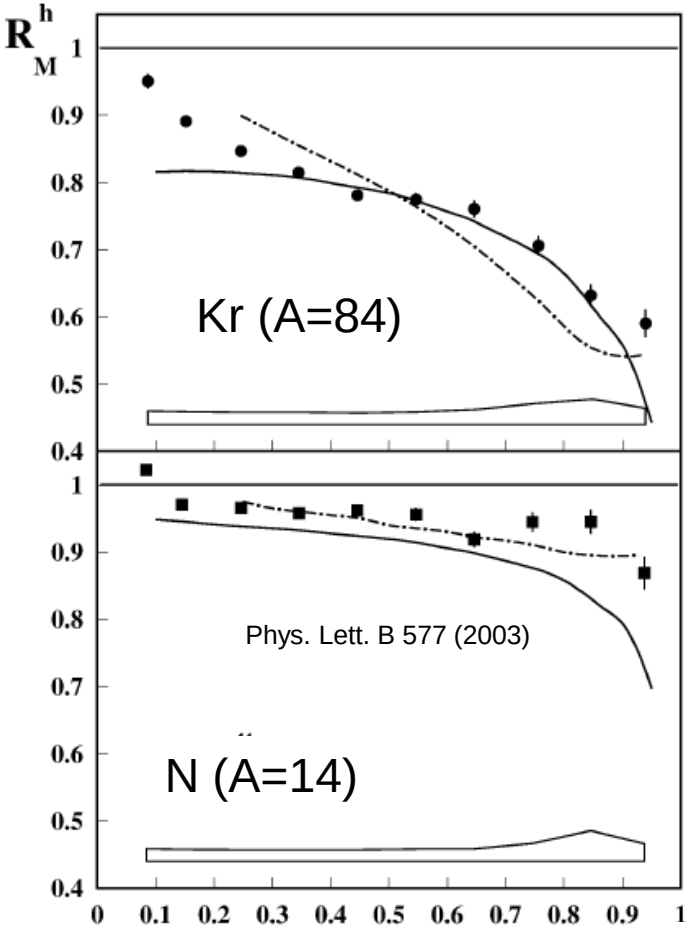
- Other explanations and effects (implemented in a variety of ways)
  - Coherence
  - Shadowing
  - Higher twist effects
  - Initial state energy loss
- Measurements that involve scattering off low-x gluons can probe this physics

Direct Photons – The Preferred Probe



- RHIC exps use <u>hadrons</u> to look at low-x gluons in Au
  - final state interactions complicate the theoretical interpretation
  - Direct photons -clean probe of initial state
  - Complementary to other efforts: FOCAL can make <u>both</u> measurements, extracting initial and final state effects

Hermes Collaboration



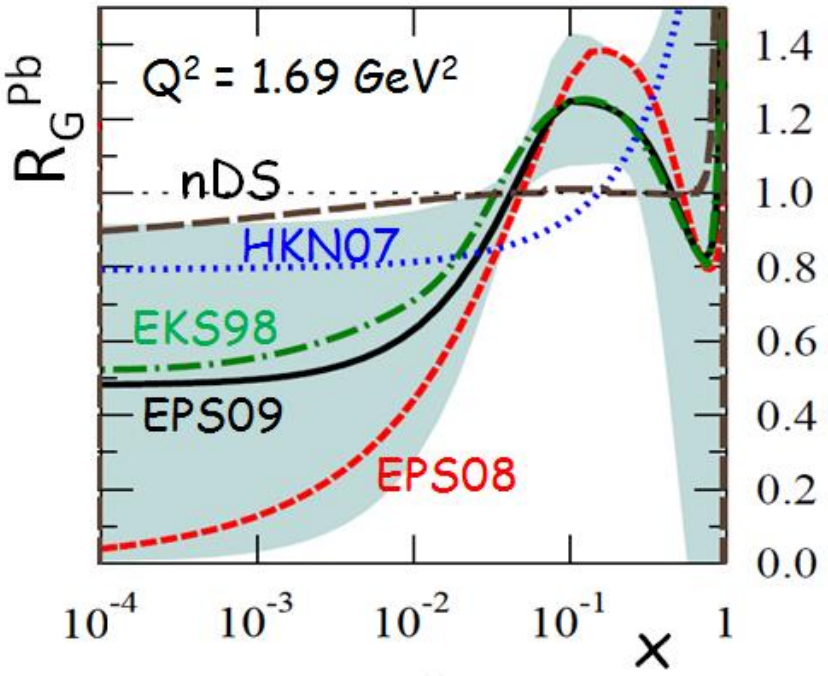
$$R_M^h(z, \nu, p_t^2, Q^2) = \frac{\frac{N_h(z,\nu,p_t^2,Q^2)}{N_e(\nu,Q^2)}\Big|_A}{\frac{N_h(z,\nu,p_t^2,Q^2)}{N_e(\nu,Q^2)}\Big|_D}$$

For the design of the FOCAL
Phenomenological fits to shadowing

- Well developed formalism
  - Theoretical curves available
- Fits to data for

$$R_G^{Pb}(x,Q^2) = \frac{xG_A(x,Q^2)}{AxG_p(x,Q^2)}$$

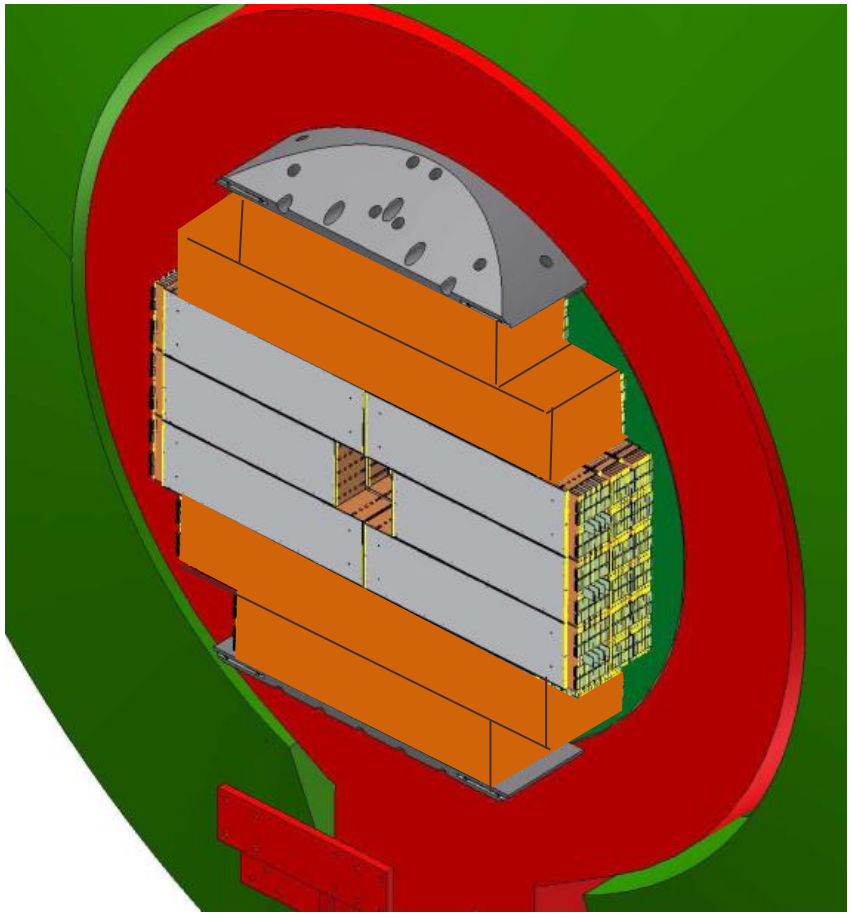
- Large Uncertainty at low-x (x<0.01)



Design Goal: Measure R using direct photons

What is the FOCAL?

- Si-W calorimeter
  - 44cm from the interaction point
  - Replaces existing Cu nosecone
  - Modular Brick construction
- Prototype performance consistent with expectations
  - Detector is well understood

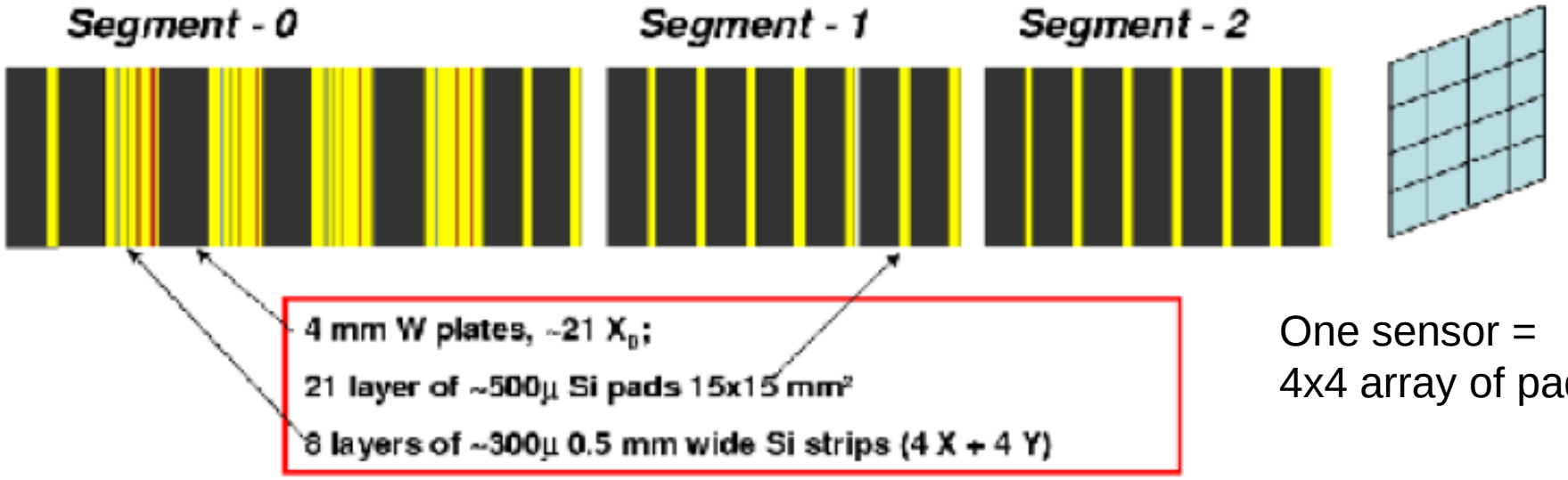


This is a very new type of detector!

A hybrid between a calorimeter and a tracking detector

FOCAL Design

FOCAL Supertower

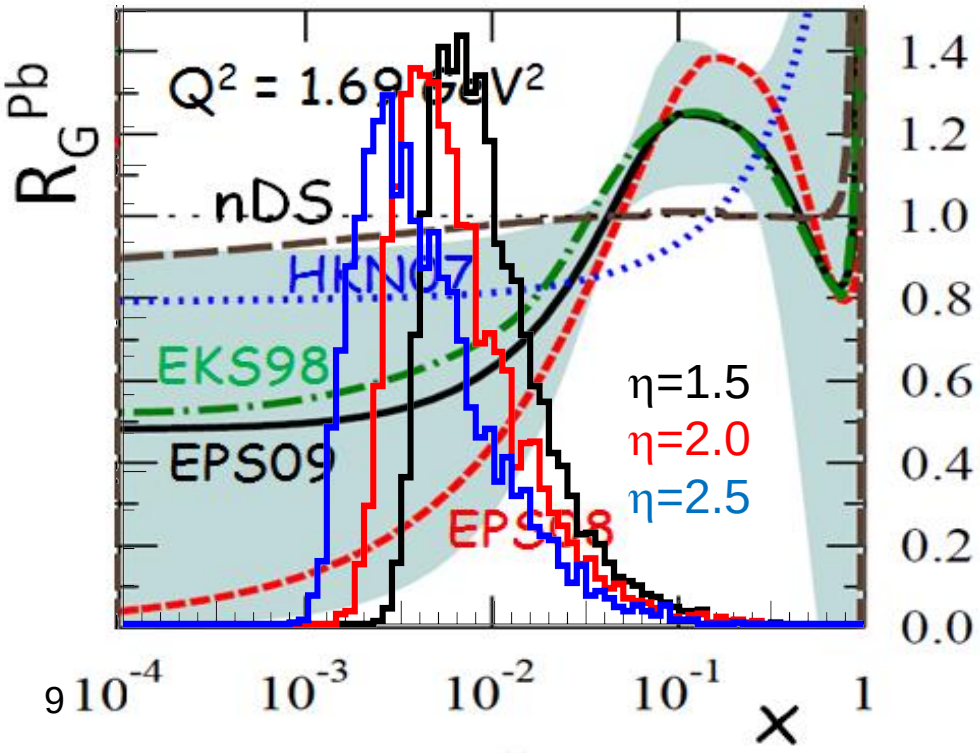


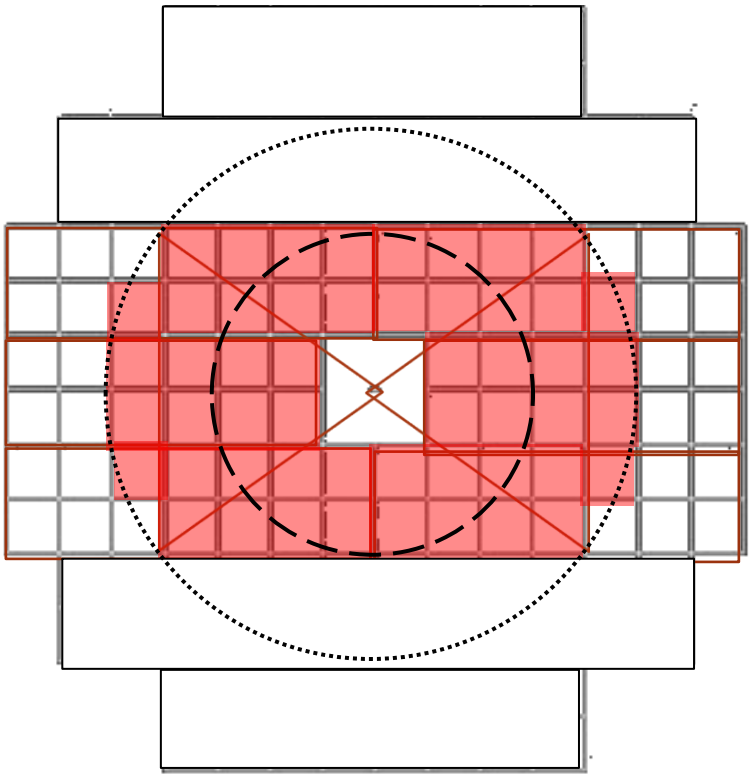
One sensor =
4x4 array of pads

- 4mm tungsten plates in three longitudinal segments
  - Detector is $24X_0$, $0.9L_{abs}$
- 15.5 mm^2 pads (matched to EM showers) for energy measurement
- 8 layers of 500μm Si strips in Segment 0 (4X layers, 4Y layers)
  - Positioned at $2X_0$, $3X_0$, $4X_0$, $5X_0$
  - π^0/γ separation for E<50GeV

Acceptance

- η = 1.6-2.7 (dashed circle)
  $\phi = 2\pi$
- η = 1.2-1.6 (dotted circle)
  $\phi = 0.27\ \pi$ (x 2)

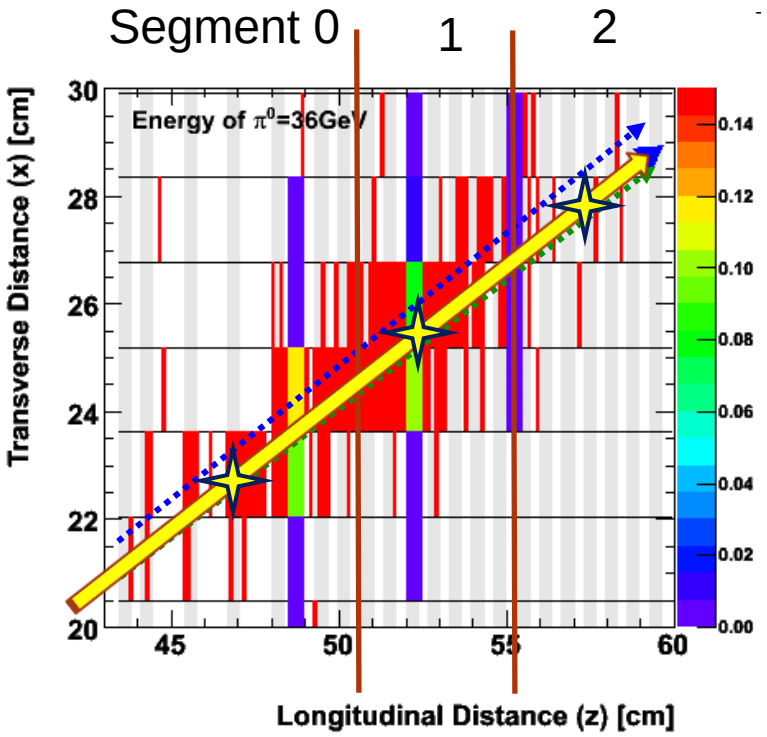




Coverage to x~10^{-3}
η_γ correlated with x

Key to measuring γ_{direct} ⇨Measuring the π^0

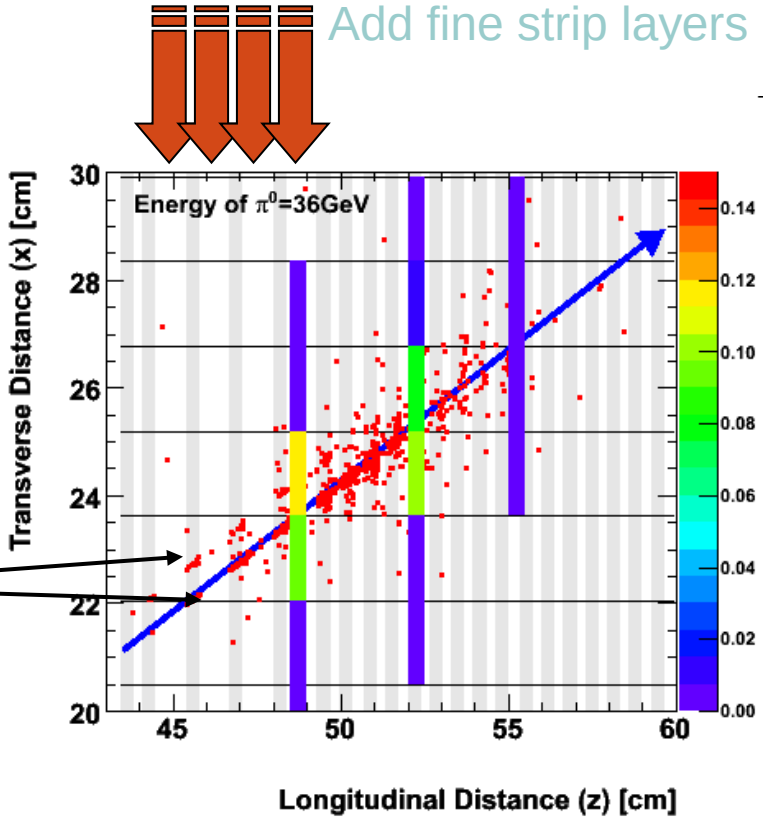
- A high energy π^0 shower as seen by the pads:
- Reconstruct "Track"
  - Find Center of gravity in each segment
  - NOTE: It's a tracking calorimeter with several planes
  - Found Center of Gravity but
  - Individual photon tracks not distinguishable



Look at GEANT Hits

Key to measuring γ_{direct} ⇨Measuring the π^0

- A high energy π^0 shower as seen by GEANT
  - Individual tracks clearly distinguishable
- STRIPS!…

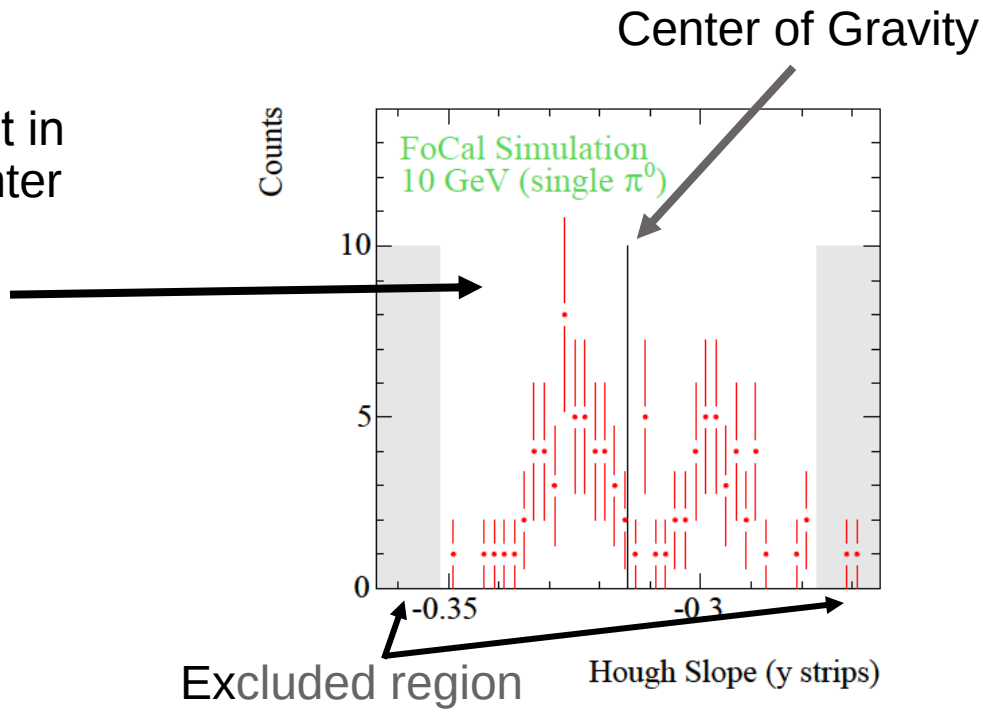


Identifying π^0 and γ – Strip tracking

Histogram slopes

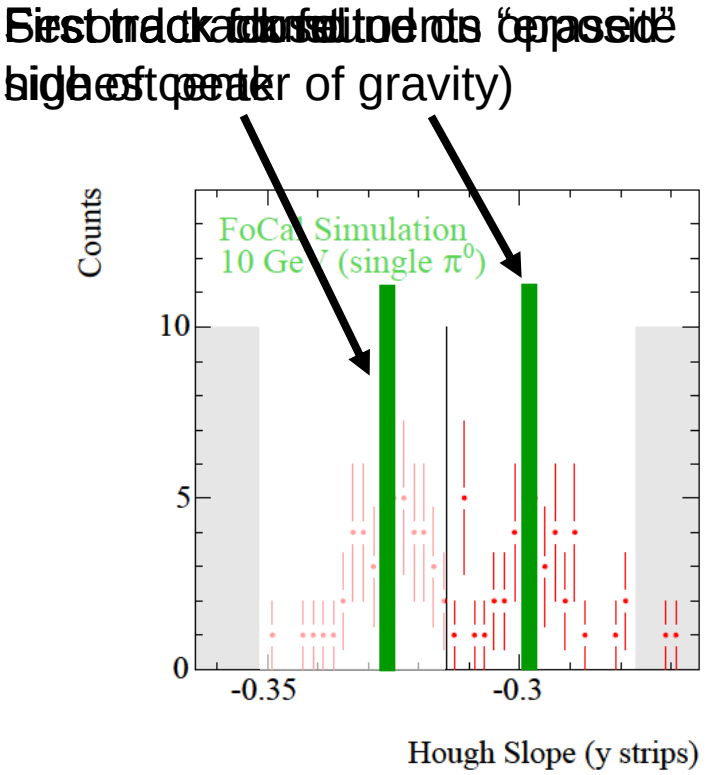
- Hough tracking in the strips
  - To track the particles during early shower development

- Construct a “slope” for each hit in a small region close to the center of gravity
  - Define “Region of Interest”
  - Histogram all hits, weight by energy



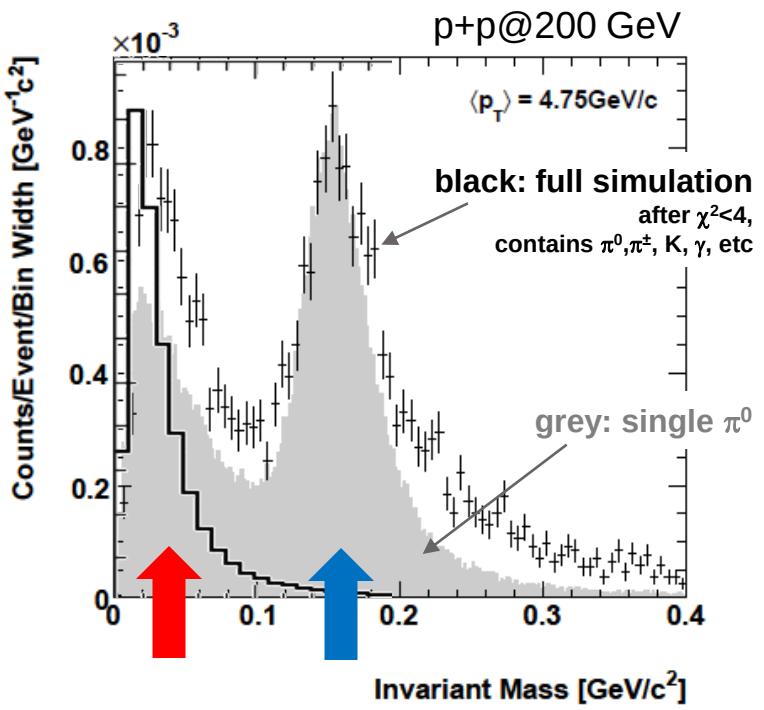
Identifying π^0 and γ – Strip tracking

- Hough tracking in the strips
  - To track the particles during early shower development
- Construct a “slope” for each hit in a small region close to the center of gravity
  - Define “Region of Interest”
  - Histogram all hits, weight by energy
  - Find first track
  - Find second track on opposite side of CG
  - Gives opening angle

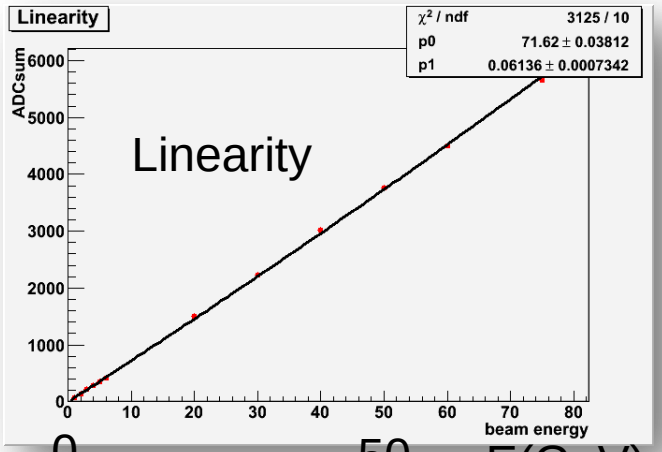


Invariant Mass Distribution
"Single track" π^0

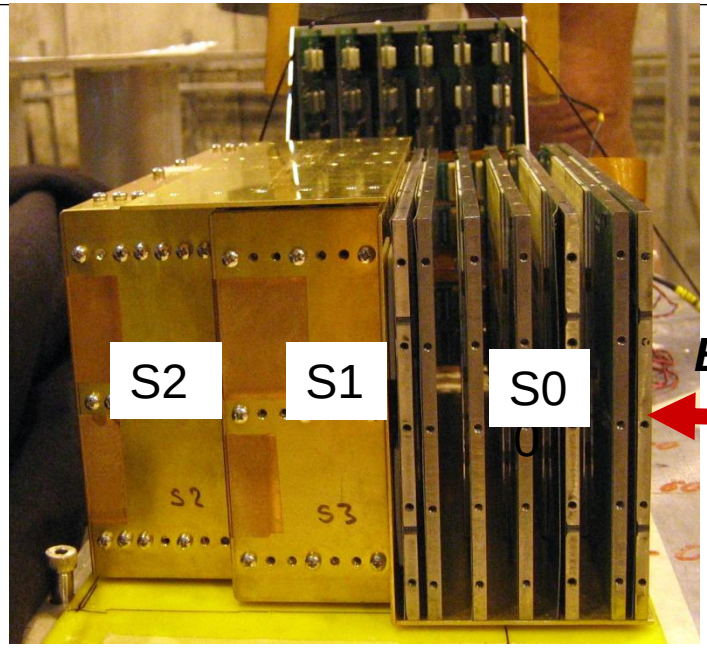
- Calculate invariant mass
  - Opening angle: derived only by strips
  - Photon energy: derived only by pads
    - Energy is assumed to be shared equally between each γ
  - photons reconstruct to small invariant mass
- Double-peak feature of the reconstruction:
  - Due to correctly reconstructed mass
  - 2nd photon is low energy or overlap too complete
  - Ratio can be gotten from test beam

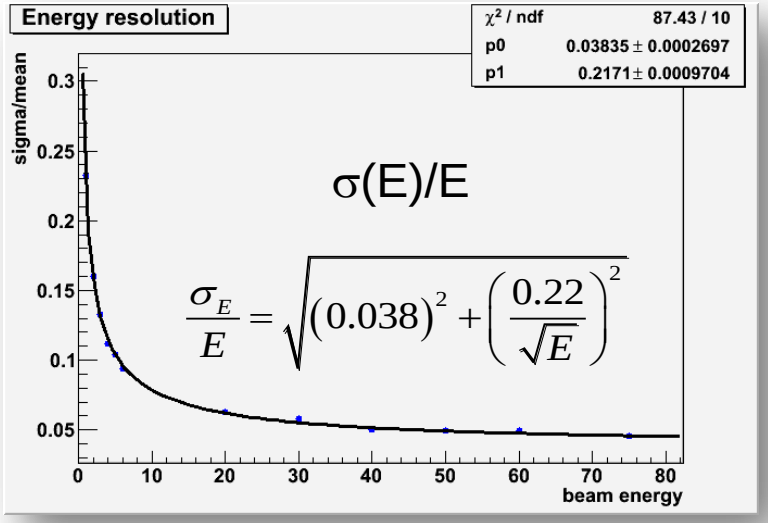


Test Beam CERN 2010



0. 50. E(GeV)





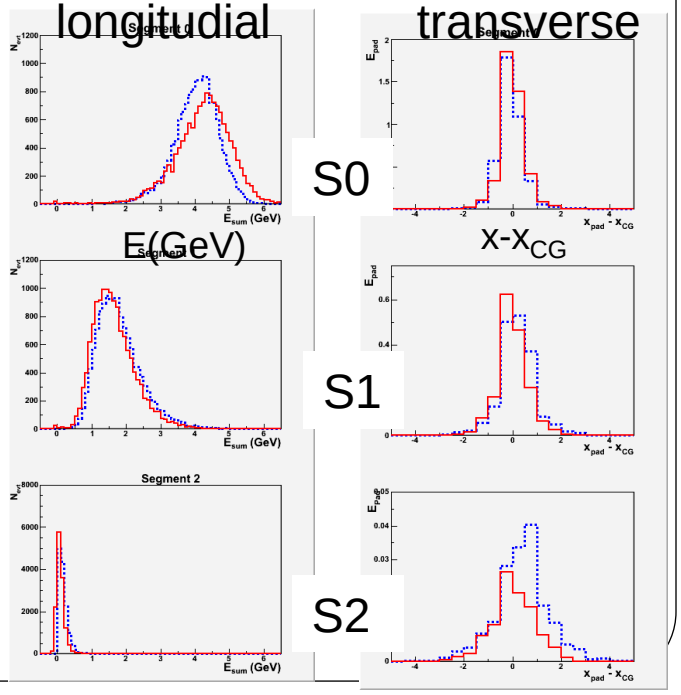
Simulation: 0.23/√E

(test beam- cable problem, HV?)

DATA

SIM

longitudinal and transverse profiles



Timescale and Summary

- **Timescale**
  - FOCAL could be on the floor for first data taking in Run-13 (2012-2013)
  - A reasonable timescale for the next d+Au run is probably Run-14
    - Runs 11-12 dominated by pp (*W* physics), AuAu
- **Summary**
  - **The FOCAL will make possible exciting new measurements of the gluon PDF at low-x**
    - Addresses saturation and CGC physics & the initial state of Heavy Ion Collisions
    - Main channel: Direct photon
      - direct probe of the gluon distribution making it simpler theoretically
      - complementary to existing efforts