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Local PROTON Polarimetry for EIC from Thick GEM in STAR

Proposal for Very Forward tracking in STAR

(up to eta=5)

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- **Local PROTON polarimetry in EIC**

  Might be done in a way similar to STAR and PHENIX, with ZDC and BBC

- **No other way is known at present**

- **But we don't know the physics adequately**

- **And we don't have appropriate detectors**

  either to study the physics in STAR

  or to work in EIC environment

- **Local Polarimetry of protons is needed to tune the spin rotation snakes in RHIC and EIC**
- **The ZDC polarimetry works in pp, but the best explanation, Diffraction Dissociation, is not universally accepted.**
- **We have a MC and documentation and presentations, but inadequate constraints due to detectors.**

- **We would like to understand it and be able to do something similar in ep local polarimetry for the proton**

- **Coulomb dissociation has almost identical kinematics, a known spin asymmetry, (FNAL E704, etc) but a smaller cross section in pp**
- **Coulomb dissociation spin asymmetry works with single photon exchange by interference of baryon resonances.**
- **Asymmetries in pion electroproduction appear to be consistent with this.**
- **We propose to develop rather simple detectors to investigate the physics in pp and to try to develop a system for eP.**

- **Coulomb Dissociation spin asymmetry (related to photoproduction) has physics and kinematics very similar to Diffraction Dissociation in pp. (Coulomb was Demonstrated in FNAL E704)**

- **In pp, the Coulomb Dissociation cross section is smaller than the Diffraction Dissociation cross section**

  Around 100 ub compared to around 3 mb in the pi p mass region of interest. (So we look at diffraction in STAR)

- **Many aspects of the Coulomb Dissociation are identical to electroproduction , and the spin analyzing power should be also**

- **We have not found a reference that precisely fits, probably because in this kinematic region the scattered electron goes extremely forward, and so data on electroproduction of pions on polarized targets is typically at somewhat higher Q^2**
- **We propose constraint on events from ZDC + pion tracking**

  without looking at e.

Primakoff process as a model for Diffraction Dissociation with spin analyzing power.

E704 - PRL 64 #4 p 357 (1990)

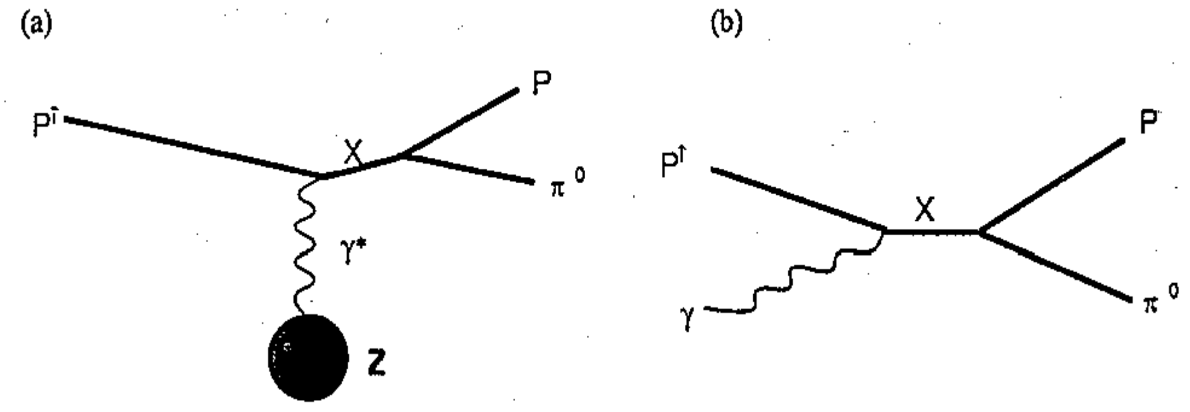


Fig. 1. (a) Primakoff Process, (b) Photoproduction

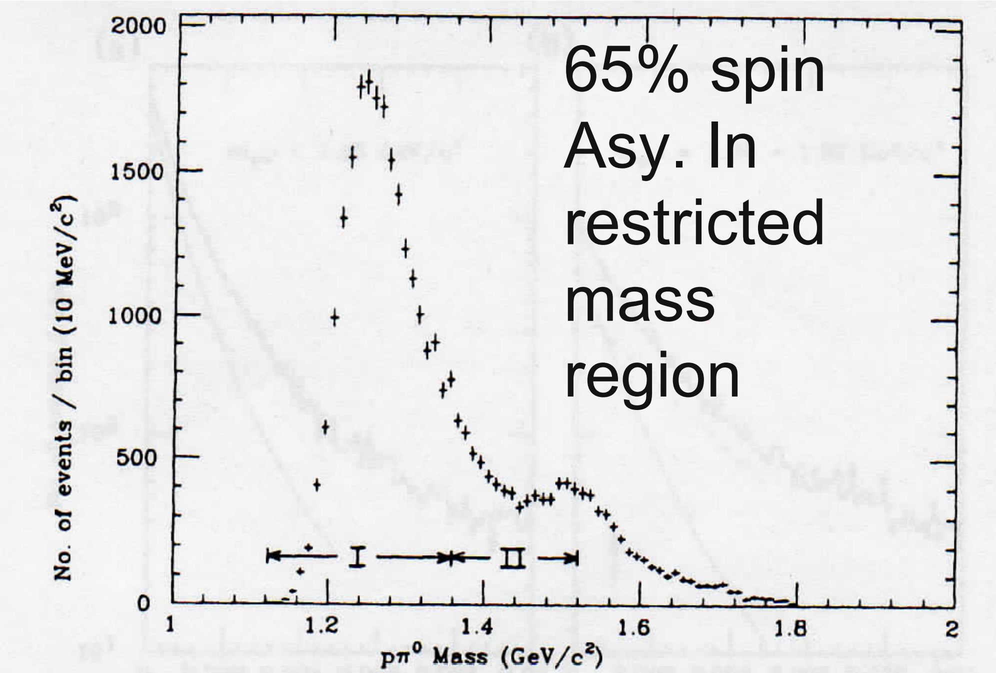
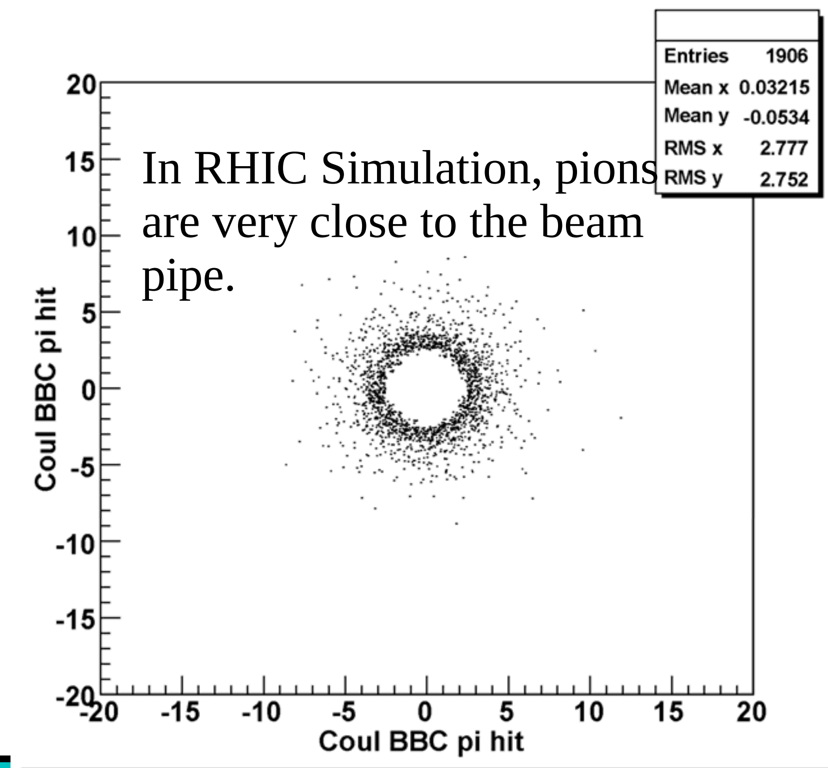


FIG. 2. The invariant-mass spectrum of the π^0-p system in $p+\mathrm{Pb}\rightarrow\pi^0+p+\mathrm{Pb}$ for $|t'|<1\times10^{-3}$ $(\mathrm{GeV}/c)^2$. Peaks due to the $\Delta^+(1232)$ and $N^*(1520)$ resonances are shown. Regions I and II are defined in the text.



- The mass spectra for Coulomb Dissociation and Diffraction Dissociation are somewhat different, and the spin asymmetries vs mass must be different.
- e.g. Δ 3/2 dominates in Coulomb, N* 1500 dominates in Diffraction
- We can only look for similar asymmetries in similar (pi n) mass ranges

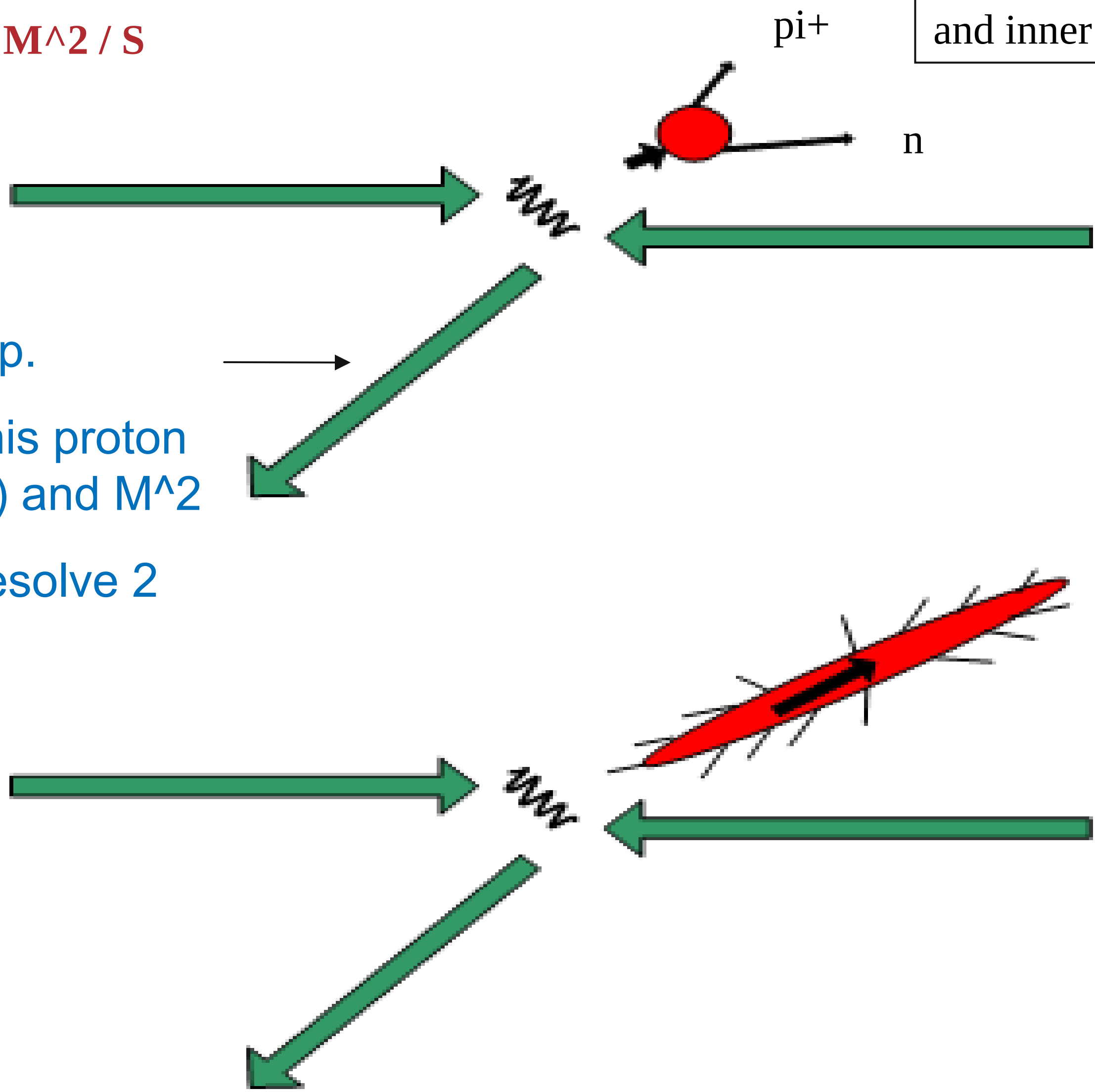
  As a model

Single Diffraction Dissociation

(1-x) = M^2 / S

The low-mass, 2-body events

Have the right kinematics to hit the ZDC and inner BBC



(1-x) = 0.0000001

(1-x) = 0.1

Collider Exp.

Measure this proton to find (1-x) and M^2

But can't resolve 2 body

Electroproduction

Mass spectrum at low Q^2

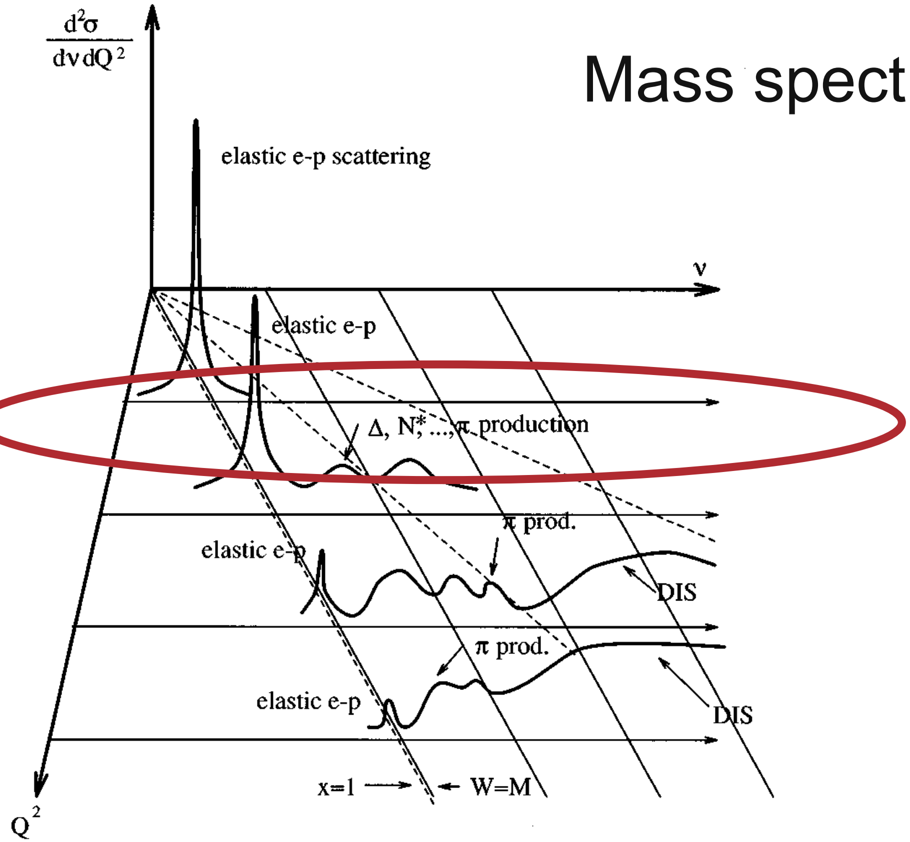
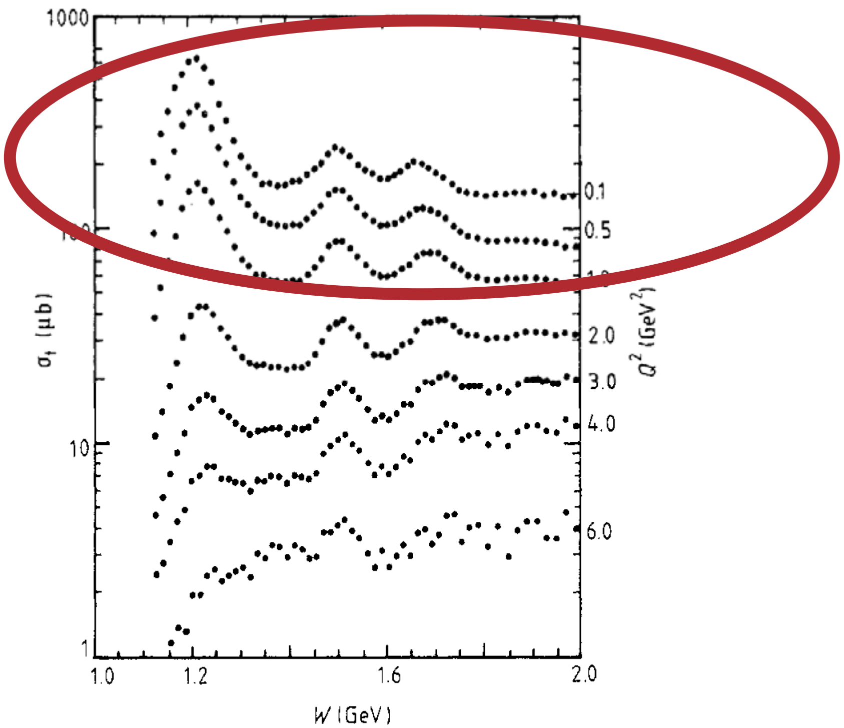


FIG. 1. Illustration of the continuity of physical processes: the double differential cross section for electron-proton inelastic scattering is sketched as a function of the energy transfer ν for different values of the resolution Q^2. Dashed and continuous lines correspond to constant values of x and W, respectively.



Total virtual photoproduction cross sections (from Brasse *et al* 1976).

We are interested in the low mass (W) region, < 2.5 GeV

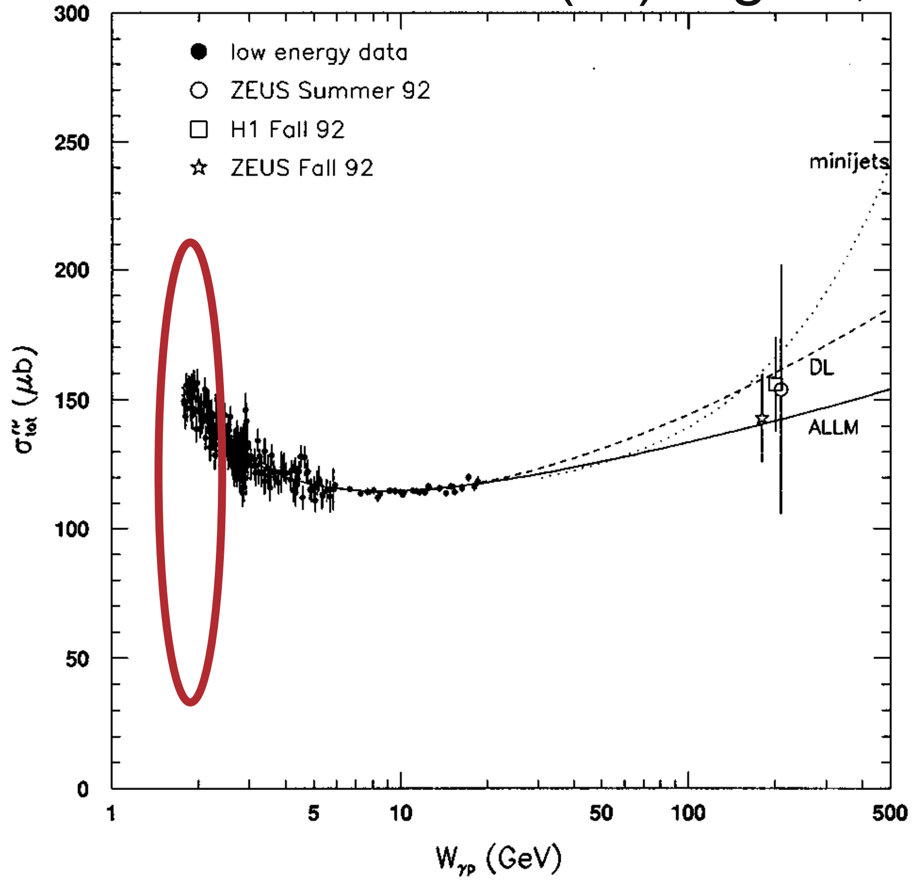
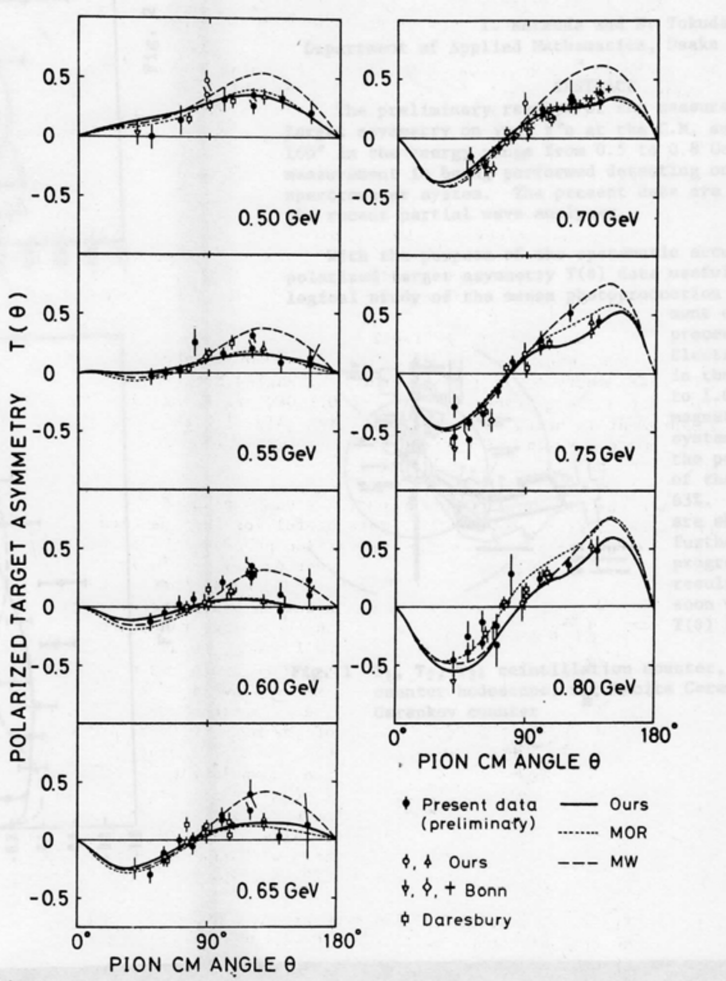


FIG. 3. Total photoproduction cross section as a function of the γp center-of-mass energy $W_{\gamma p}$. Low-energy data come from Alekhin *et al.* (1987), recent ZEUS Collaboration data from Derrick *et al.* (1994), and previous data from Derrick *et al.* (ZEUS Collaboration) (1992) and Ahmed *et al.* (H1 Collaboration) (1993). The curves are explained in the text. From Derrick *et al.* (ZEUS Collaboration) (1994).

Some Photoproduction examples showing large asymmetry.

$\gamma \; p \uparrow \; \rightarrow \; \pi^0 \; p$

$\gamma \; p \uparrow \; \rightarrow \; \pi^+ \; n$



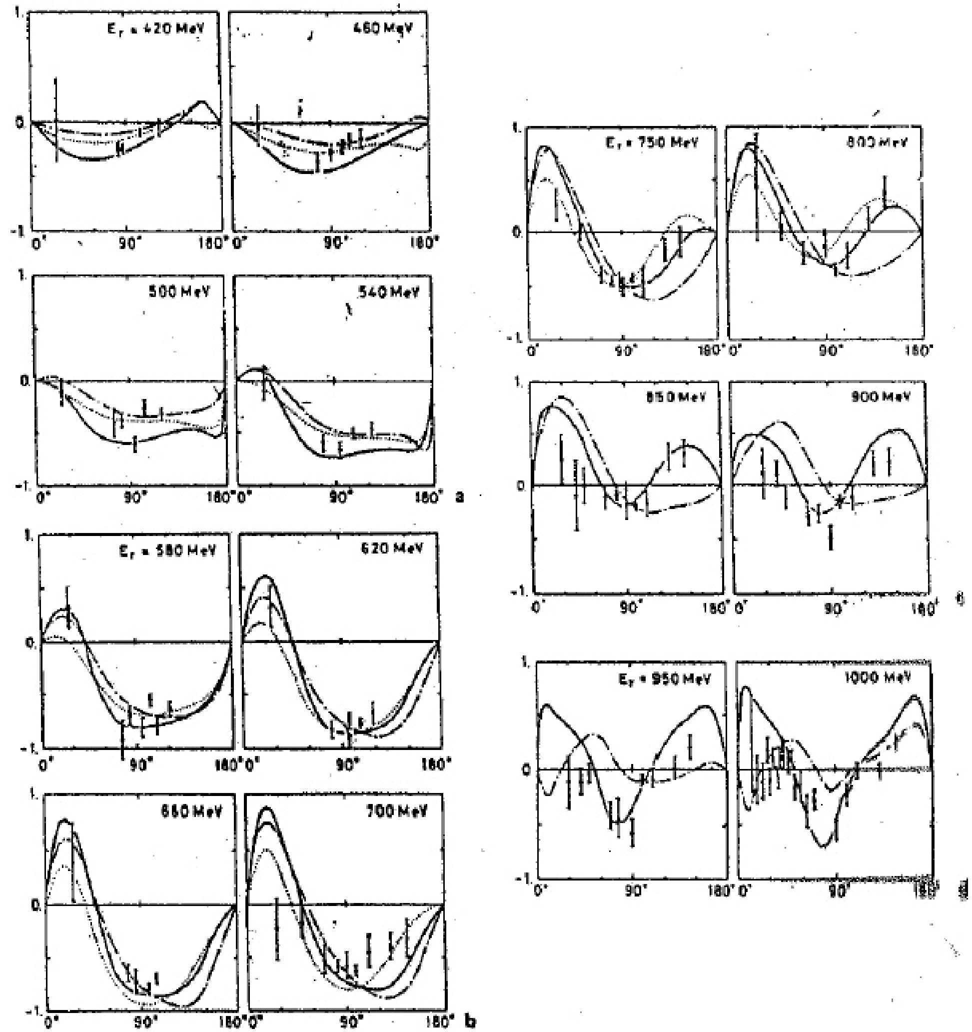


Fig.4 Polarized target asymmetry T(Θ) in $\gamma+p\uparrow\rightarrow\pi^0+p$ (Ref.11).

If the ZDC had very Good Energy Resolution :

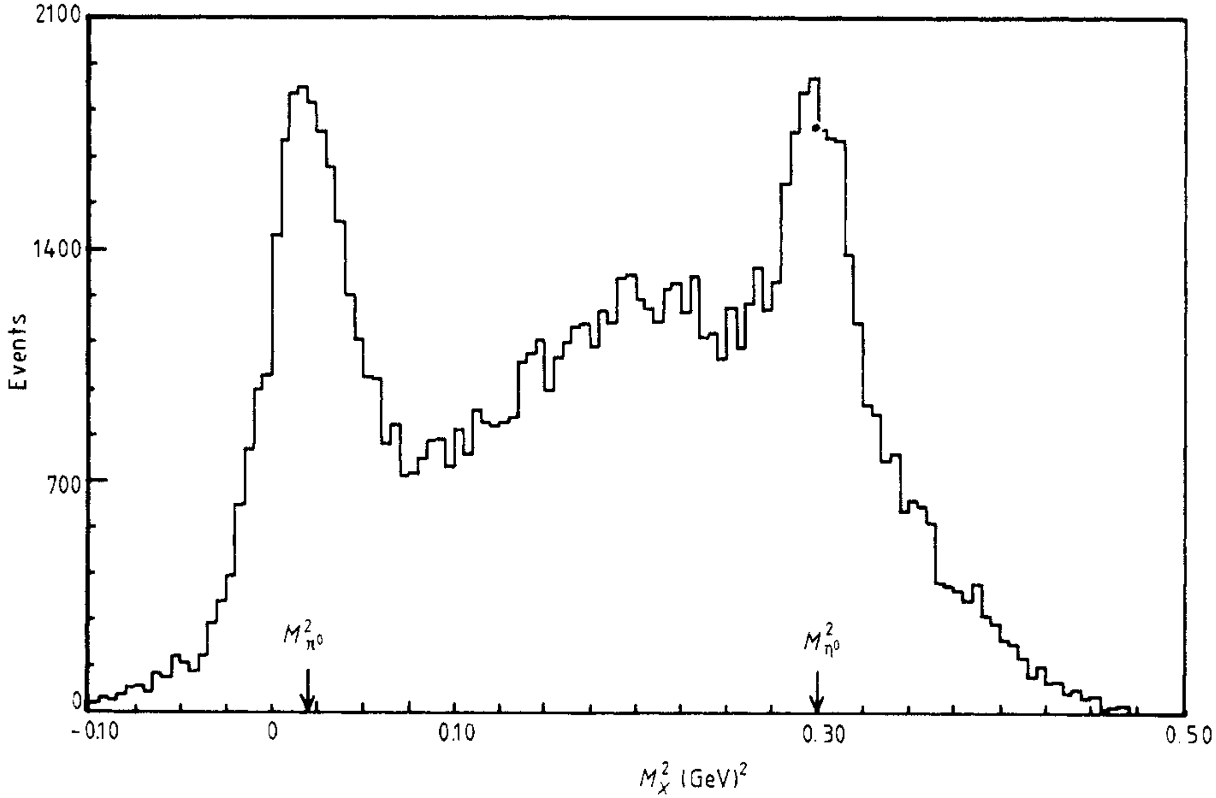


Figure 7. 'Missing mass squared' distribution for the process: $\gamma_v + p \rightarrow p + X$ (Latham *et al* 1979).

However, We have actually look for the pion by using tracking.

Triggering, resolution, etc

There is a problem in directly detecting e-p -> baryon resonance +e’

or triggering on it, because the e’ will be very far forward, basically in the beam or in the halo or near elastic e-p.

For pi+ n final state, we would be working with pion at an angle of > 10 mr anyway, in order to get outside the beampipe.

So two of these thick GEM detectors with 1 mm strips spaced 1 or 2 meters apart could find the vertex to within 10 or 20 cm, which (along with ZDC hit) would give the signature that the Pi+ n trigger was of interest.

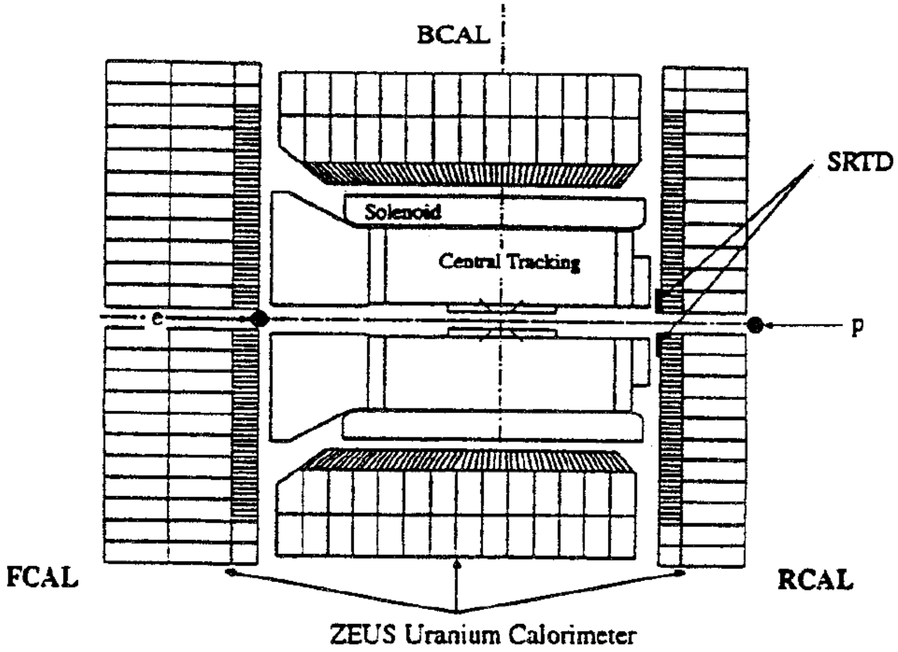
Possible Physics other than Polarimetry:

Tracking in front of calorimeter for small angle electrons

ZEUS results on the measurement and phenomenology of

F2 at low x and low Q^2

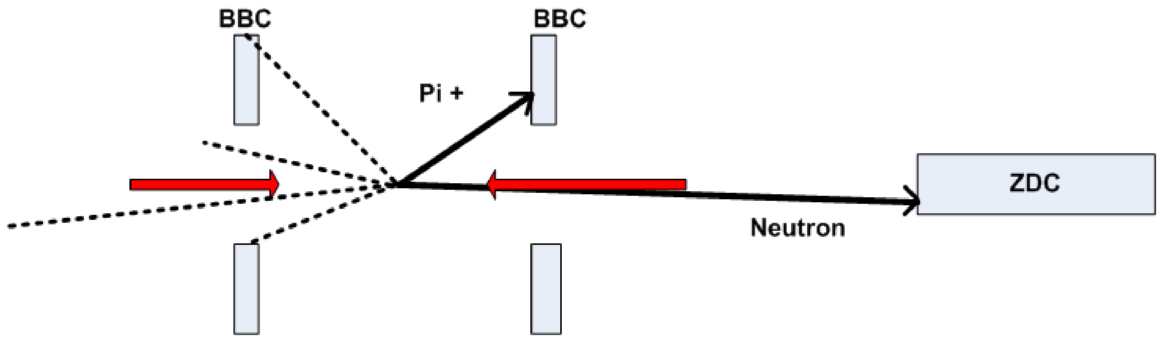
ZEUS Small Angle Rear
Tracking Detector - SRTD



The SRTD First Level Trigger at ZEUS, J.W.Dawson, et al,

A STAR Example

(Double Diffraction Dissociation)



Example of 2-body event with correlated hits in ZDC and BBC.

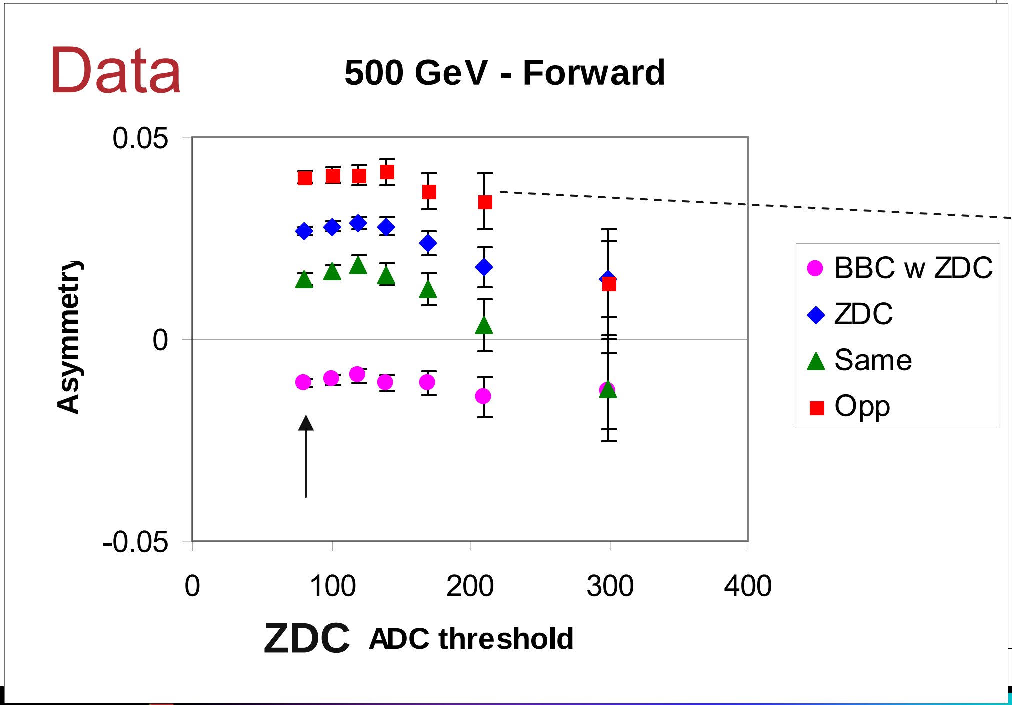
The innermost BBC counters are at approximately rapidity of 4 to 5 , and are around 9 cm wide.

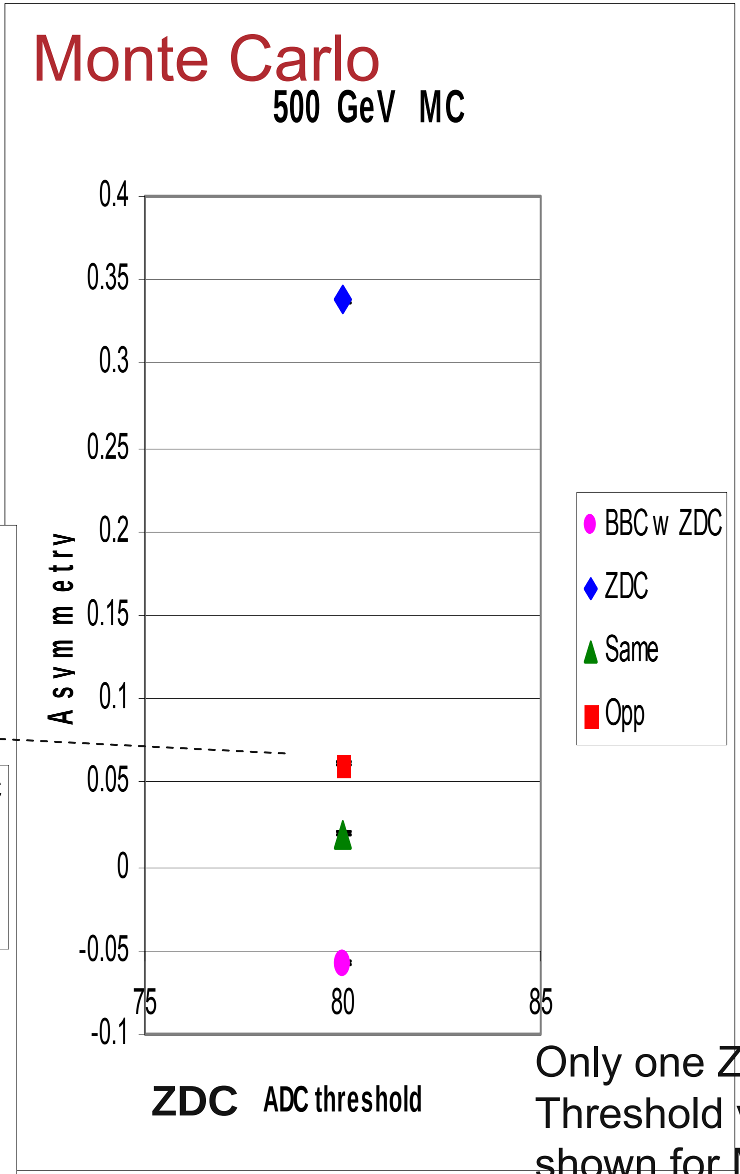
The effective (n pi+) mass resolution with this BBC-size position resolution on the pion is several GeV/c^2.

A resolution of around 2 mm at the BBC would be commensurate with the 1 cm resolution on particles in the ZDC which is further away

Star Spin Asymmetry

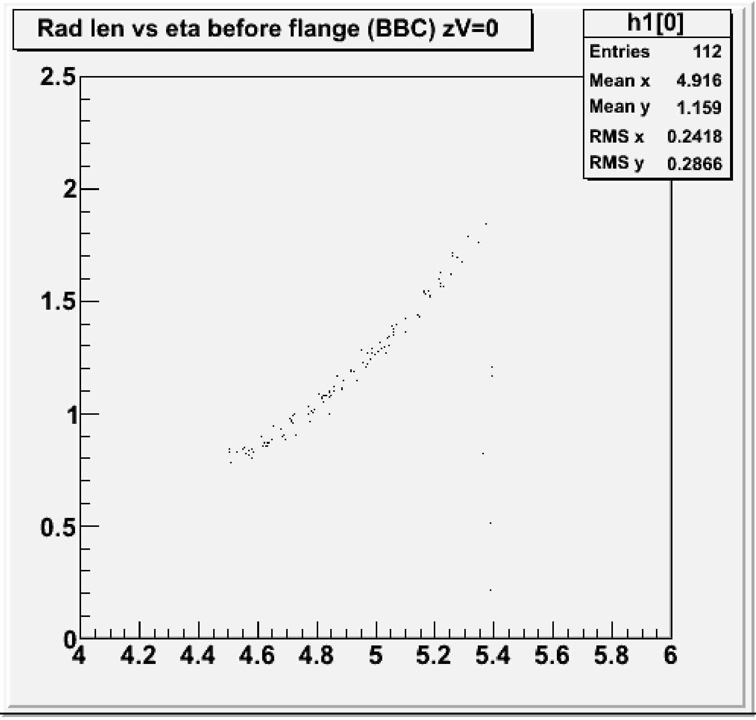
Data compared to a simple MC with kinematics and geometry and approximate CDF DD cross section and multiplicity

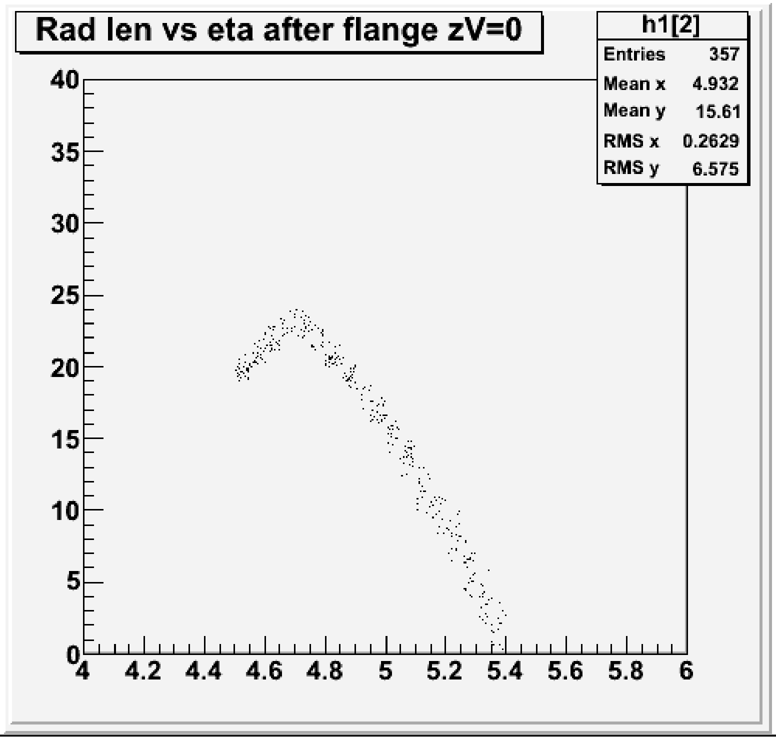




Only one ZDEC Threshold value shown for MC

Reason for location, size, type of detector, etc to test:

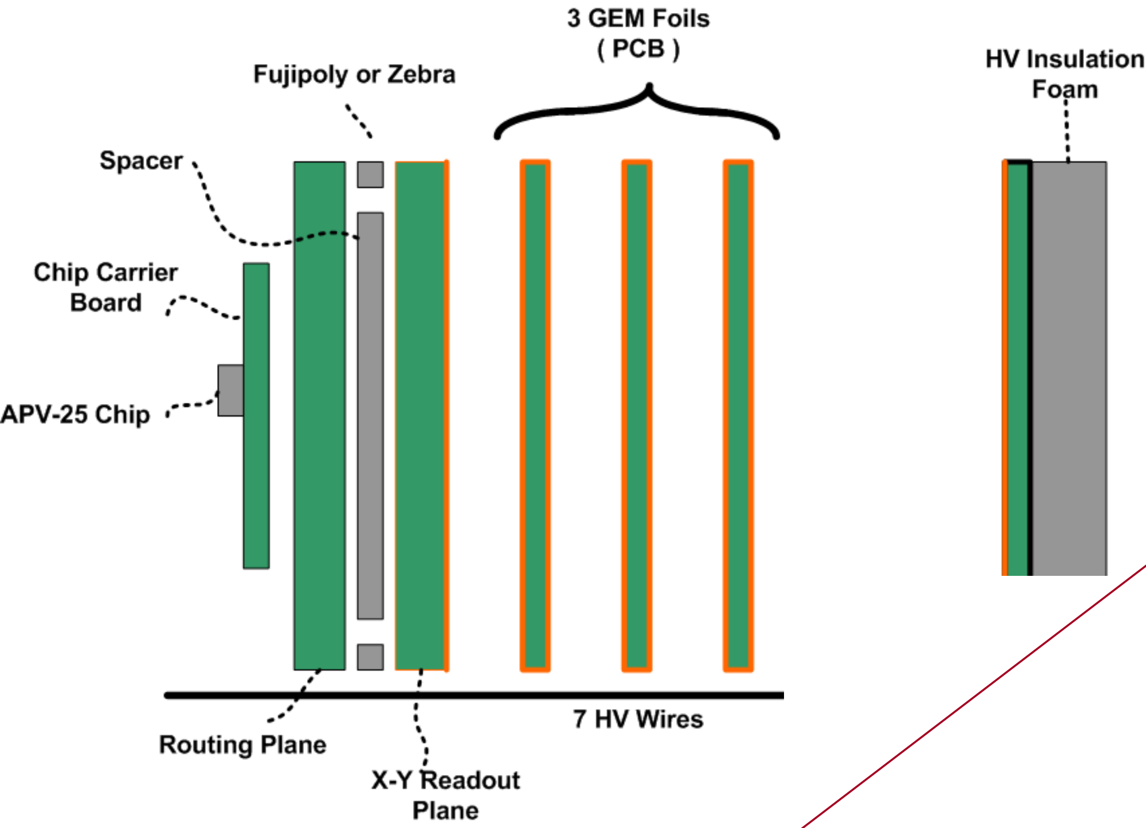


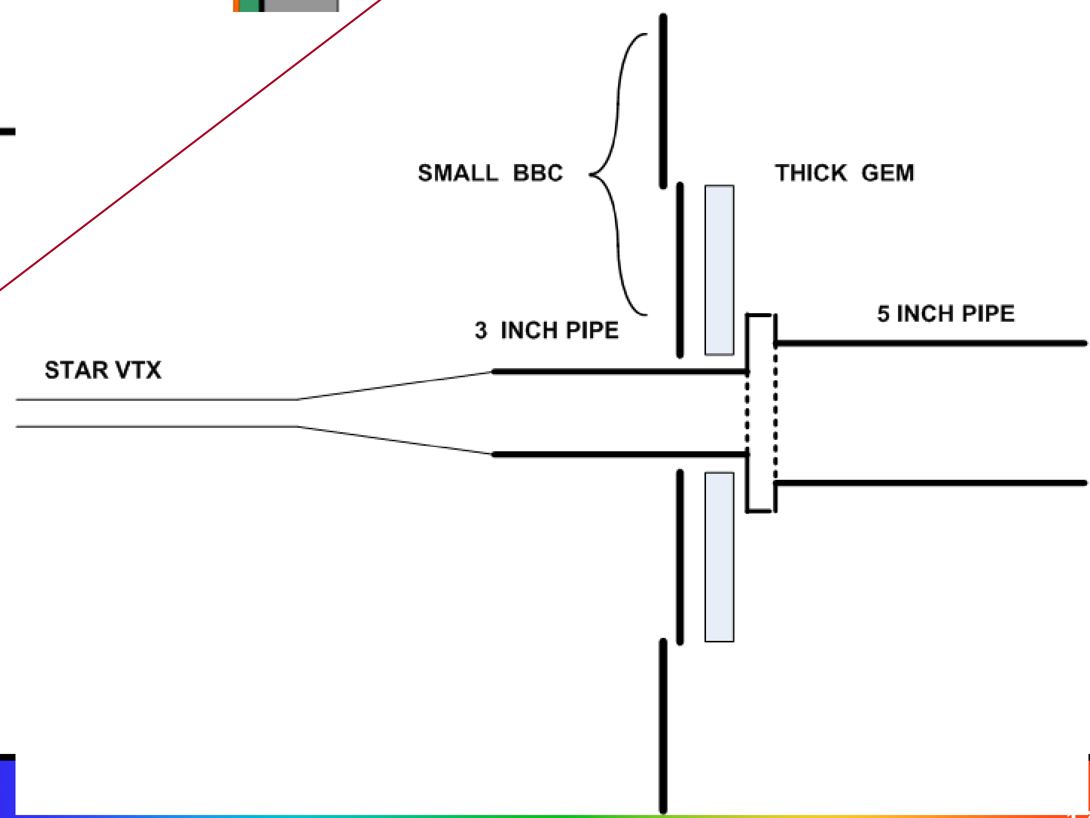


Radiation length before (a) and after (b) the vacuum flange between 3 inch and 5 inch pipes just downstream If the BBC.

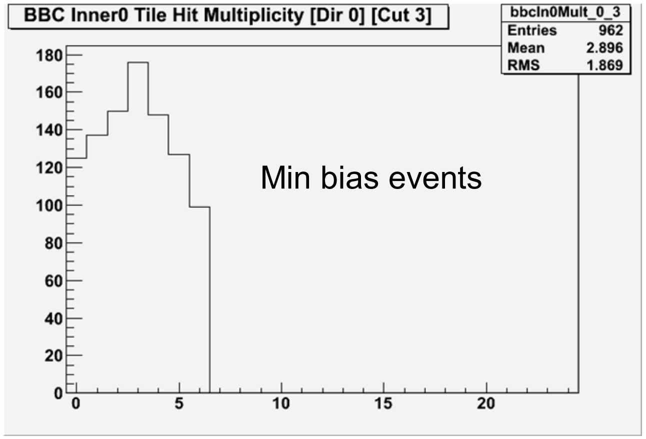
The flange is half aluminum and half stainless steel, explosion welded.

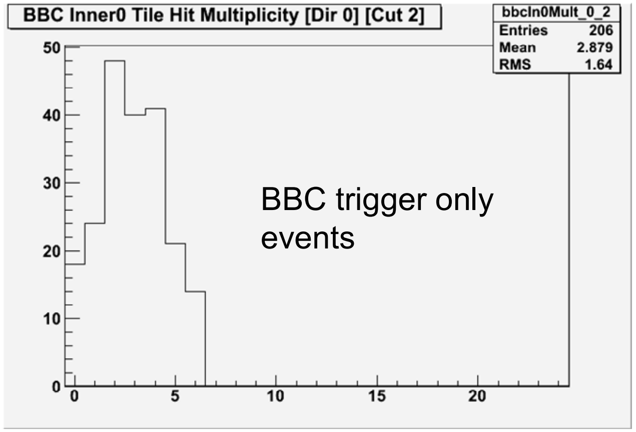
At Small Angles there would be a lot of material in front of any larger downstream detector in STAR.


3 GEM Foils
(PCB)
Fujipoly or Zebra
HV Insulation
Foam
Spacer
Chip Carrier
Board
APV-25 Chip
7 HV Wires
Routing Plane
X-Y Readout
Plane

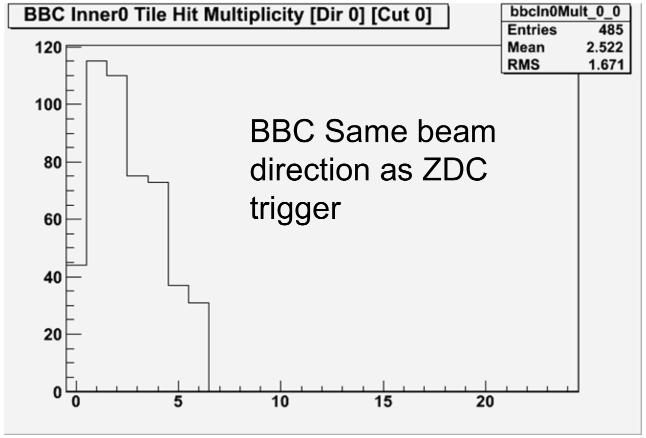

SMALL BBC
THICK GEM
3 INCH PIPE
5 INCH PIPE
STAR VTX

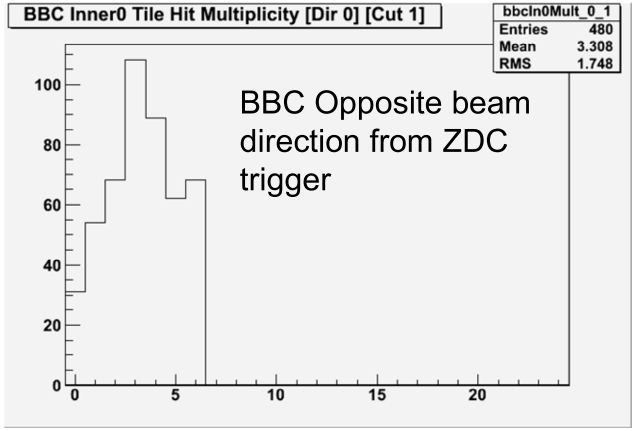
Multiplicity and reconstruction ambiguities – typical 3 hits in 6 BBC counters so average in one counter is not high, but we can investigate further.

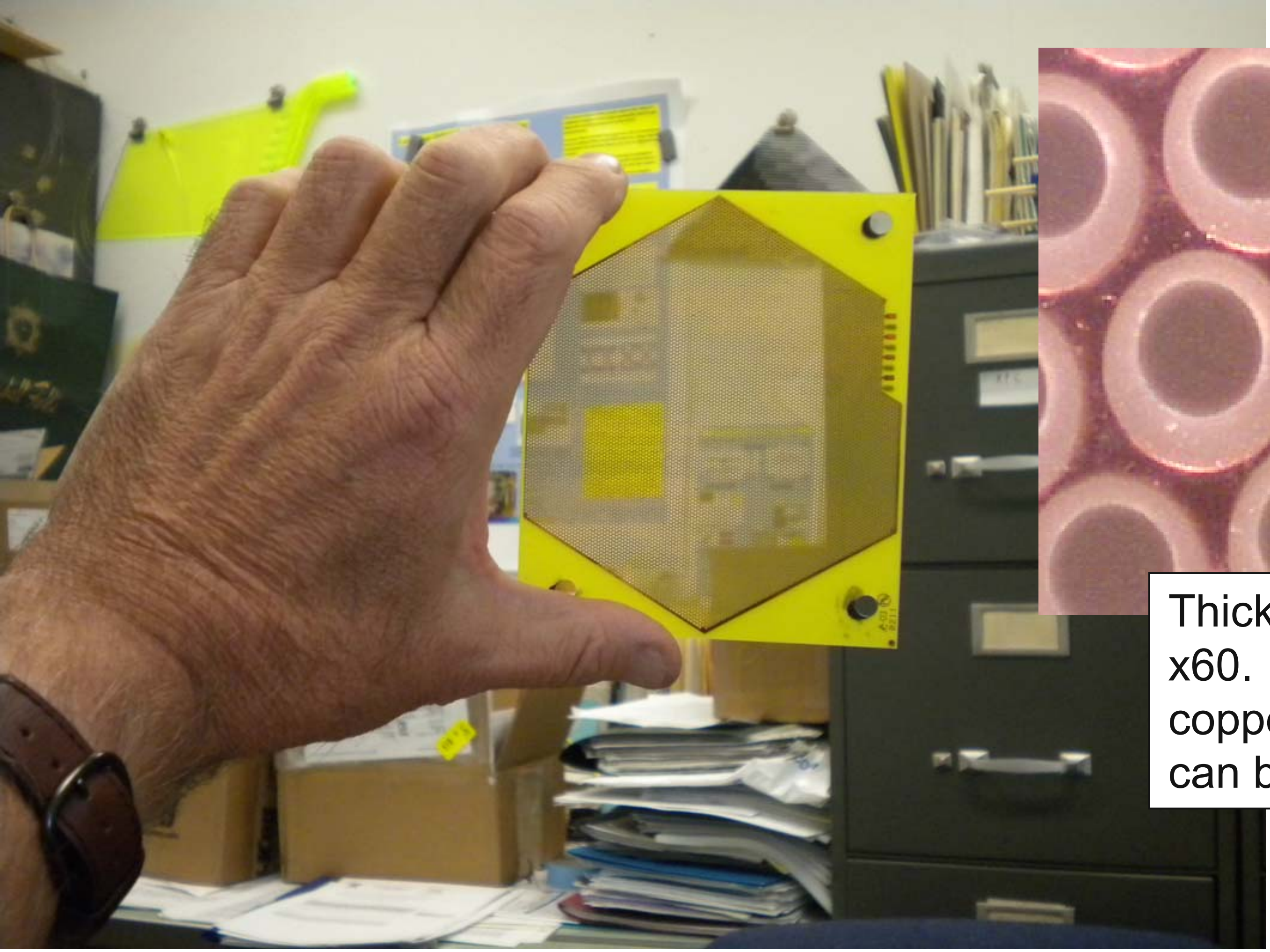


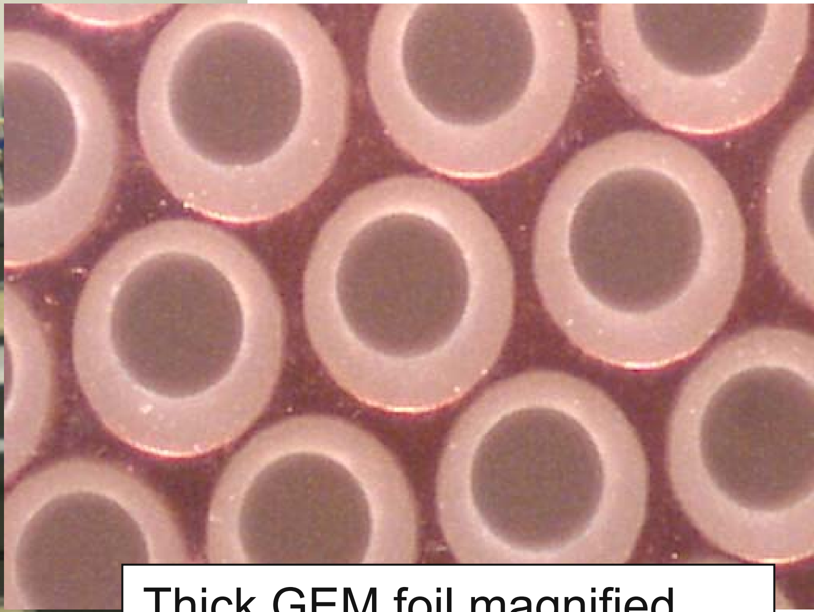


Inner 6 BBC Counters





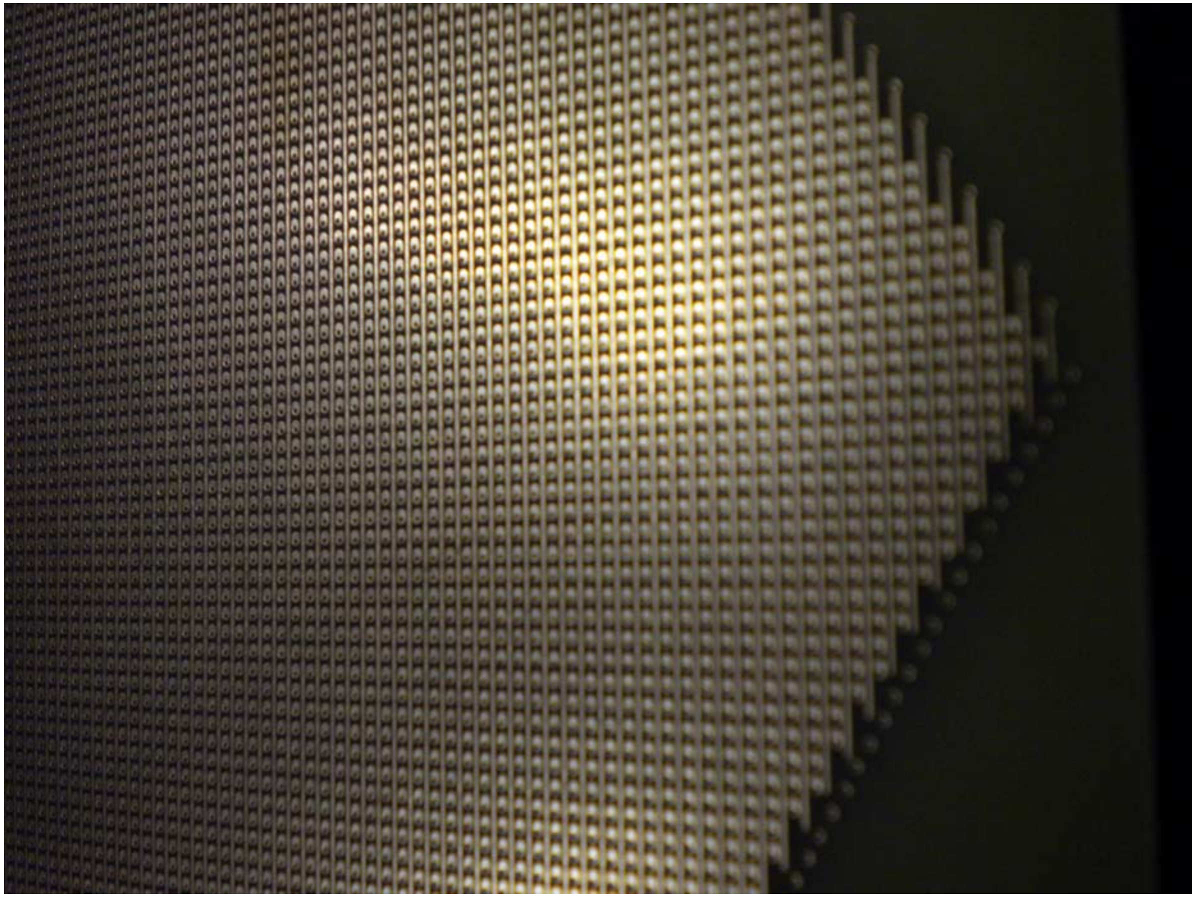




Thick GEM foil magnified x60. The recess of the copper around each hole can be seen.

Thick GEM foil to match small BBC counter size.

Holes are on 1 mm centers, almost equilateral triangular mesh.



Front of readout plane, which is a 2D board, showing pad and strip structure. The strips are 1 mm apart. The pads are on 1 mm centers and are elliptical. The pads in each row are connected on the back of the board. The signals are routed on the back to pads around the edges for readout connections.

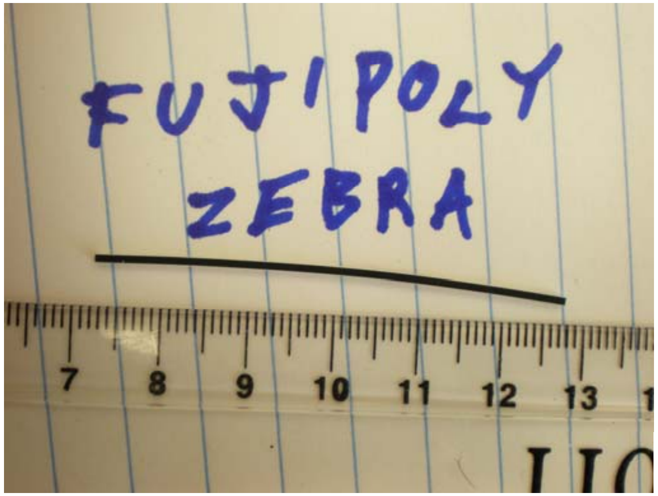
Thus we have X and Y readout simultaneously. We need to test charge sharing.

Back of routing plane, showing APV chip and connector.

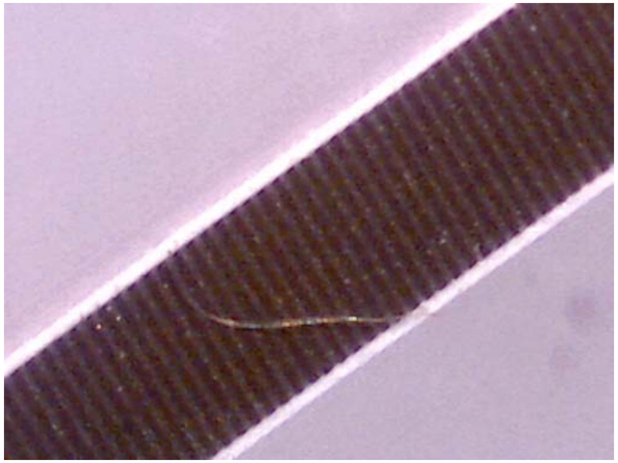
Also, one can see that readout sensor rows are ganged together, typically in groups of 3. This will make the prototype resolution only 3 mm/ root(12) but allows the use of only 1 APV chip per detector patch.

Unique to this proposal for Thick GEMs is the extreme simplification of the readout plane PC board (as 2 boards of 2 layers)

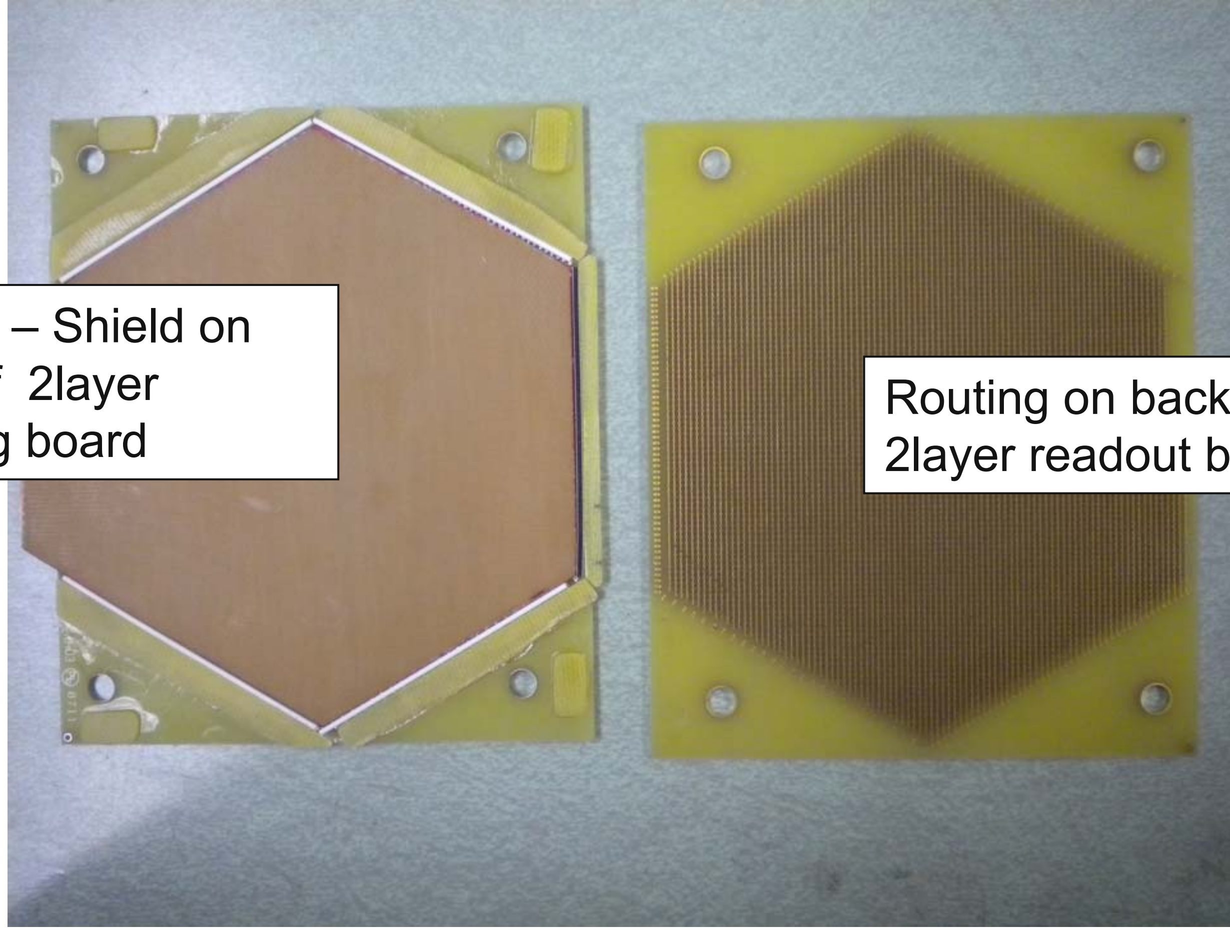
This is where a lot of the money is in regular GEMs.



Fujipoly Zebra conducts transverse to the long dimension. There are many isolated conduction paths per mm, so that there are no shorts in the long direction on the scale of interest.



Fujipoly ZEBRA rubber with directional conductivity. The carbon-laced conductive layers are seen. The strip is 1 mm wide and there are 240 layers per inch. (0.1 mm period)



Test of one ZEBRA connector.

The ZEBRA is the black stripe on the right edge of the left hexagon.

The electrical test of both conductivity and isolation of adjacent paths was successful after clamping with adequate pressure, as calculated from the ZEBRA specifications.

- We designed, and had produced, printed circuit boards for a prototype detector to use Thick GEMs for very forward particles in STAR (eta 4 to 5).
- These consisted of the 9 cm hexagonal GEM foil,(7000 holes), Fig[4], the readout plane with 150 pad rows and 150 stripes on 1 mm centers, Fig[5], Fig[6],
- and a coupling plane from the readout plane to the APV chip Fig. [7], Fig.[8] which would eliminate the expense of 4 layers with 7000 blind vias if the scheme of Zebra rubber connectors on the edge works. Fig[9], Fig[10] (figure # in proposal, not this slide show)
- A electrical test of one of the 5 ZEBRA strips on one edge of the boards was successful.
- These boards were designed and produced for minimum cost in small quantities, roughly $400 per board. These have not yet been tested further due to a lack of funding and effort.
- We are in the process of setting up a test stand.

Proposed Work, Costs, and Deliverables

- While we have been able to produce prototype PC boards of all the types needed for a detector, further work is needed in the following areas:
- A combination ZEBRA connector positioning, and compression system has been partially designed, but not produced. In current plans, this system will also be a ground plane between the readout board and the routing board.
- Testing of the GEM foils at High Voltage in Argon-CO2 gas is needed. The boards were designed and produced with the copper recessed away from the actual holes in the board, which tests in Israel and at CERN indicated was the correct approach to insure stability, but we have not tested it yet.
- A better High Voltage divider system is needed. Our current test chamber has some resistors on a PC board and rather long wires (10 to 15 cm) to each plane of the chamber.
- A way to control the shape of the electrostatic field at the edges of the chamber is needed in order to increase the efficiency near the edges. A study with an electrostatic simulation program would be a good project for a student.
- Beam tests to determine the maximum particle flux which can be tolerated are needed. We note that the TOTUM detector at the LHC has GEM foils operating in the very forward direction, and there are references quoting high rate capability in Thick Gems.

Proposed R&D development of single-plane detection

- We propose 4 stages
- 1) R+D to make 3 working prototype Thick GEM detectors
- this will require some iteration
- 2) Deploy 6 or 12 hexagonal planes over the inner BBC in STAR for single plane tracking, beam rate and multiplicity tests, and some level of pi+ n mass reconstruction to test the physics
- 3) Couple these detectors either with another plane downstream or another tracking detector to attempt tracking (with the beam pipe vacuum flange still a big issue)
- 4) Design two-plane geometry appropriate for EIC

Proposed R&D funding for at least 3 prototypes: of single-plane detection

■ Electronics (Extra ARC and ARM boards from FGT, cables,)	$12K
■ RORC and SIU	$ 4K
■ More APV carriers (including wire bonding)	$10K
■ M&S	$20K
(mechanical parts, backplane, electronic parts, second version of PC boards, Gas, HV cables, etc)	
■ Labor	$60K
■ (1/5 of postdoc, EE time for development, etc, Mech. tech)	
■ Travel to BNL	$18K
■	
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■ Sum R&D	$124K

Estimated Project construction cost (after R&D) (This looks low and needs contingency)

- To produce 24 chambers plus spares, to cover e.g. the 12 small BBC counters on each end of STAR with 1 layer of tracking.
-
- Fabricate 24 detectors
- PC boards $12K
- APV carriers $10K
- Gas and Cable $12K
- M&S $10K
- ANL Labor $40K
- BNL Labor $40K
- Travel $24K
-

- Sum Construction $148K

Physics References

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Hardware References

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“The RHIC Zero Degree Calorimeters”, C. Adler, A. Denisov, E. Garcia, M. Murray, H.Stroebele, S. White, arXiv:nucl-ex/0008005v1 8 Aug 2000

“Single Transverse Spin Asymmetry…..” PHENIX, PRL

“Measurements of the leading neutron production in polarized pp collision at rts=200 GeV”, Manabu Togawa, PHENIX Thesis, Kyoto, 2008

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Measurement Of The Analyzing Power In The Primakoff Process With A High-Energy Polarized Proton Beam.
By FERMILAB E-704 Collaboration, **Phys.Rev.Lett.64:357,1990**.

BACKUP

The HERMES paper in SPIN 2010 proceedings by Klaus Rith on inclusive pion asymmetries is written in terms of Collins effect, Sivers effect, twist 3,

But the kinematic region may be consistent with resonance production and interference seen in high energy fixed target experiments with the photons coming from heavy nuclei.

Asymmetry always peaks around pt of 0.75

Mass around (sqrt(.49)+ sqrt(.88+.49) = 1.87

Look in Rochester n A data for this mass

And find maximum x of pion for this mass