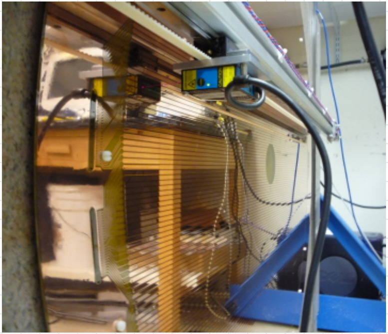
The Effects of Non-Flat Cathode Plane Surfaces in Drift Chambers of the GlueX Experiment



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November 22, 2010

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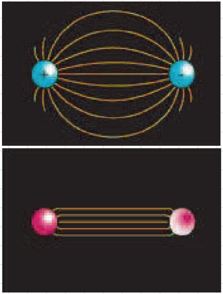
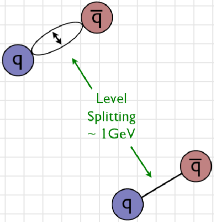
Exotic Hybrid Mesons





- Quarks must always be bound to at least one other (anti)quark by gluonic flux tubes
- Conventional mesons: quark-antiquark pair bound by a flux tube in the ground state
- Hybrid meson: flux tube is in an excited state, contributes to the angular momentum of the meson
- Exotic hybrid mesons: distinguishable from conventional mesons, exhibit J^{PC} which are unavailable to conventional mesons
- GlueX intends to map out the spectrum of exotic hybrid mesons, to aid in generalizing the naïve quark model

Exotic Quantum Numbers

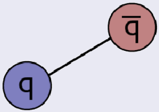
Spin: $|L-S| \leq J \leq L+S$

Parity: $P=(-1)^{L+1}$

Charge conjugation: $C=(-1)^{L+S}$

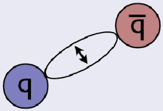
Identify J^{PC} experimentally by analyzing angular distributions of decay products.

Conventional Mesons



$$J^{PC} = 0^{-+}, 0^{++}, \\ 1^{++}, 1^{--}, 1^{+-}, \\ 2^{-+}, 2^{++}, \ldots$$

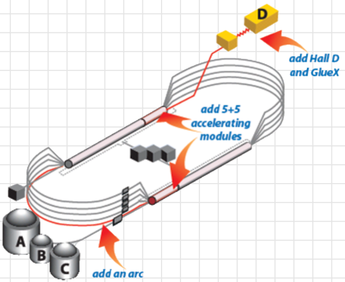
Hybrid Mesons



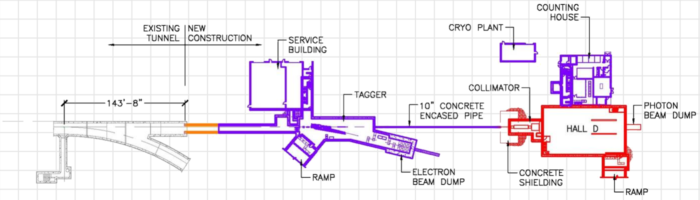
With an excited flux tube, exotic J^{PC} can be formed

$$J^{PC} = 0^{-+}, 0^{+-}, 0^{++}, \\ 1^{++}, 1^{--}, 1^{-+}, 1^{+-}, \\ 2^{-+}, 2^{+-}, 2^{++}, \ldots$$

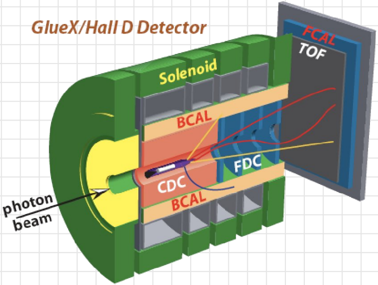
Jefferson Lab Upgrade



- Maximum energy of the electron beam will increased from 6 GeV to 12 GeV (to Hall D)
- Polarized electron beam will be incident on a diamond wafer, producing a linearly polarized photon beam via bremsstrahlung radiation
- Photon beam will travel to Hall D, where GlueX detectors will be housed



The GlueX Detectors



- Must detect charged and neutral particles
- Hermetic
- 2.2 T superconducting solenoidal magnet
- Fixed target ($\mathrm{LH_2}$)
- 10^8 tagged γ's per second

Charged Particle Tracking

- Central drift chamber (straw tube)
- Forward drift chamber (cathode strip)

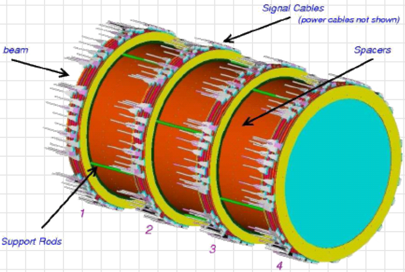
Calorimetry

- Barrel calorimeter (lead, fiber sandwich)
- Forward calorimeter (lead-glass blocks)

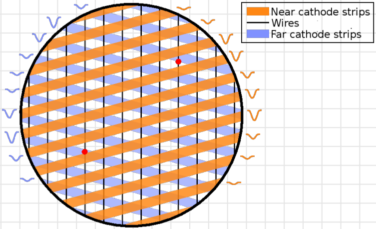
Particle Identification

- Time of flight wall (scintillators)
- Start counter
- Barrel calorimeter

The Forward Drift Chambers

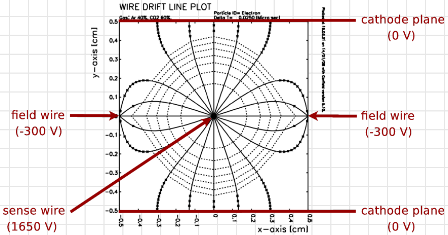


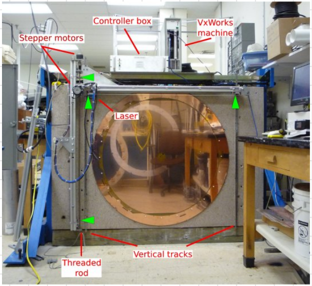
- 200 μm resolution
- Gas mixture is 40 % Ar, 60 % CO_2
- Four packages of 6 drift chambers



- Front cathode strips at 75°
- Wire plane at 0°
- Back cathode strips at -75°
- Signal read out from both cathode and wire planes

Cathode Plane Flatness

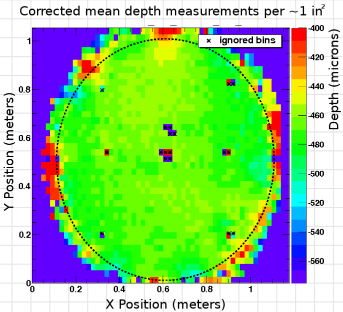




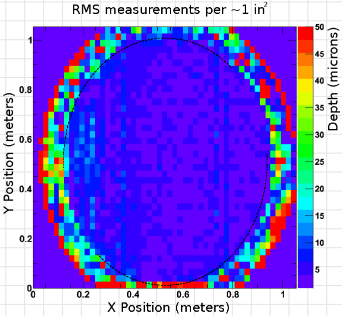
- Optimum field lines radiate away from the sense wire symmetrically
- Non-flat cathode planes break this symmetry

- Flatness measurement system scans a laser displacement sensor over the surface of a cathode plane
- Laser-to-cathode distances are recorded at regular intervals

Flatness Scan Results



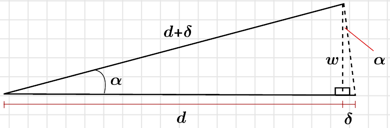
- Scan area is divided into 1×1 inch bins
- Average of the data within each bin is plotted
- Useful for detecting broad undulations



- RMS of 1×1 inch bins is plotted
- Useful for detecting local divots

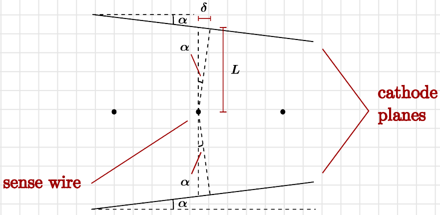
The difference between the highest peak and lowest pit of the surface profile is also recorded, for the entire surface and within each bin

Interpreting Flatness Statistics



$$\delta = \omega^2/d$$

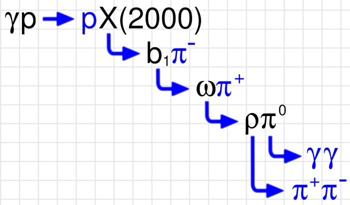
Bad case: $\omega = 70\,\mu\text{m}$, $d = 0.33\,\text{m}$
$\rightarrow \delta = 0.014\,\mu\text{m}$.



$$d = \text{bin size} = 20\,\text{mm}$$
$$\sigma = \text{RMS statistic}$$
$$L = 5\,\text{mm}$$
$$\delta = \arcsin\left(\frac{\sqrt{12}\sigma}{d}\right) L$$

Bad RMS: $100\,\mu\text{m} \rightarrow \delta = 87\,\mu\text{m}$
Average RMS: $5\,\mu\text{m} \rightarrow \delta = 4\,\mu\text{m}$

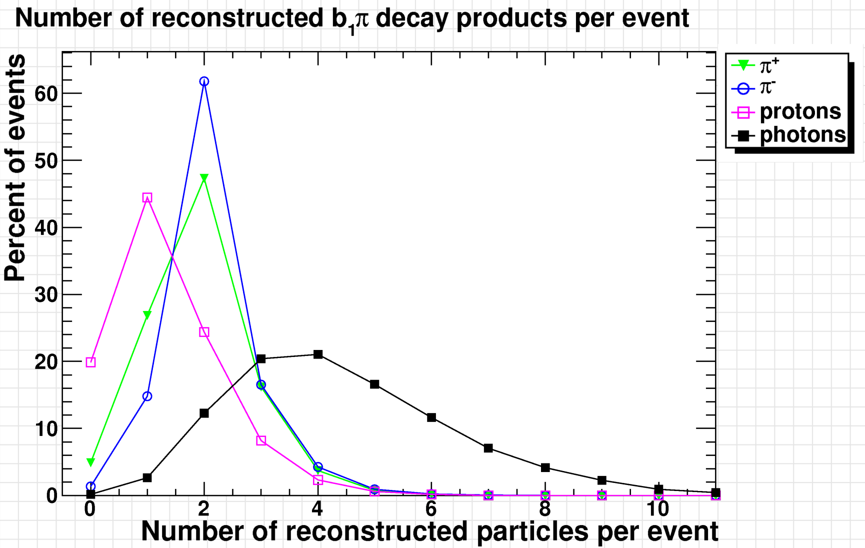
Track Reconstruction



- Curved paths are fit to measured particle positions from the FDC.
- Timing information from the start counter, FDC, and calorimeters are used to improve the fit.

- Particle type is calculated by measuring the particle's energy loss (amplitude of signal on wire, and amount of inward spiral), and rest mass (time of flight info gives velocity, and track radius gives momentum).
- Particle ID is improved by favoring particle types that are more likely to be found, and by applying momentum and energy conservation to events as a whole (not yet implemented).

Problems with Particle Tracking



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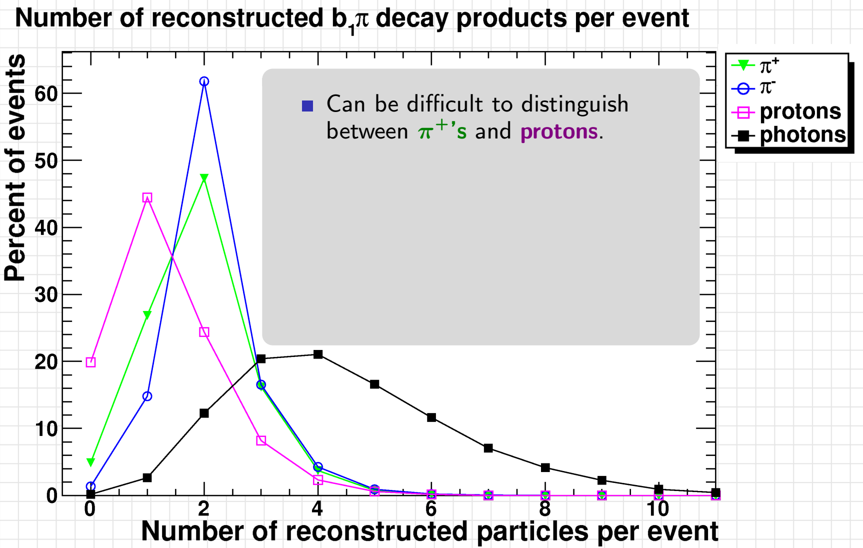
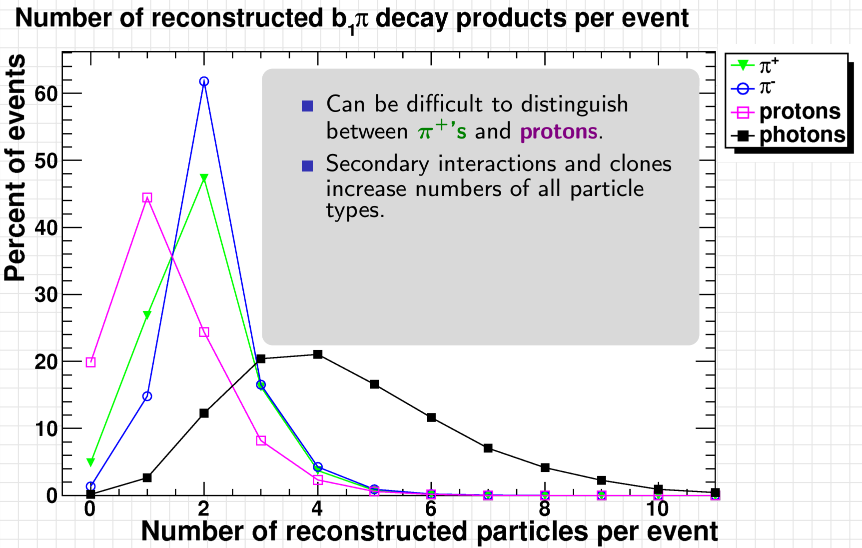


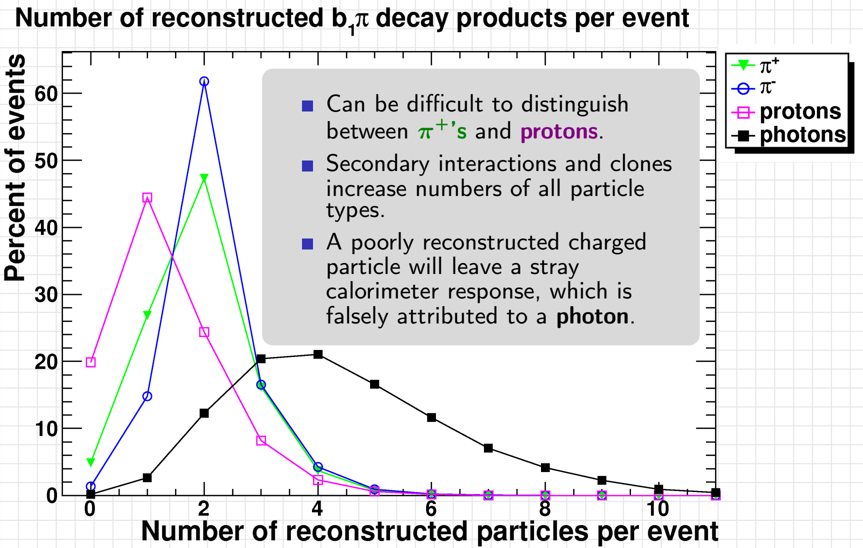
- Can be difficult to distinguish between π^+'s and **protons**.

Problems with Particle Tracking



- Can be difficult to distinguish between π^+'s and **protons**.
- Secondary interactions and clones increase numbers of all particle types.

Problems with Particle Tracking



Adding Error to Simulate Non-Flat Cathode Planes

Local Flatness Deviations

True particle positions and positions measured by the FDC's cathode planes are offset by values represented by a Gaussian function with nominal standard deviation of 150 μm. This standard deviation is increased to simulate a cathode plane covered in small dimples.

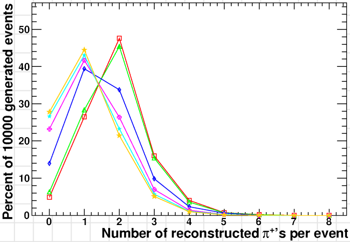
Broad Flatness Deviations

The radial coordinate (r) of position measurements taken by the FDC's cathode planes is systematically offset by $A\,(r/r_{\mathrm{max}})^2$, where A is used to amplify the offset. This roughly simulates a cathode plane which bulges like a dome.

Track Reconstruction with Local Dimples ($b_1\pi$)

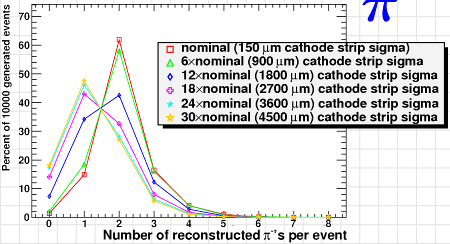
π^+

Number of reconstructed π^+'s per event



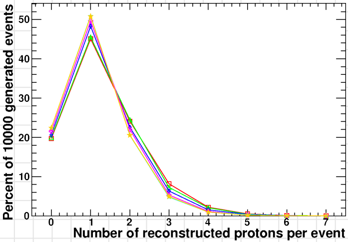
Number of reconstructed π^-'s per event

π^-

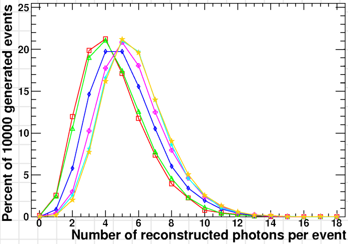


Number of reconstructed protons per event

p

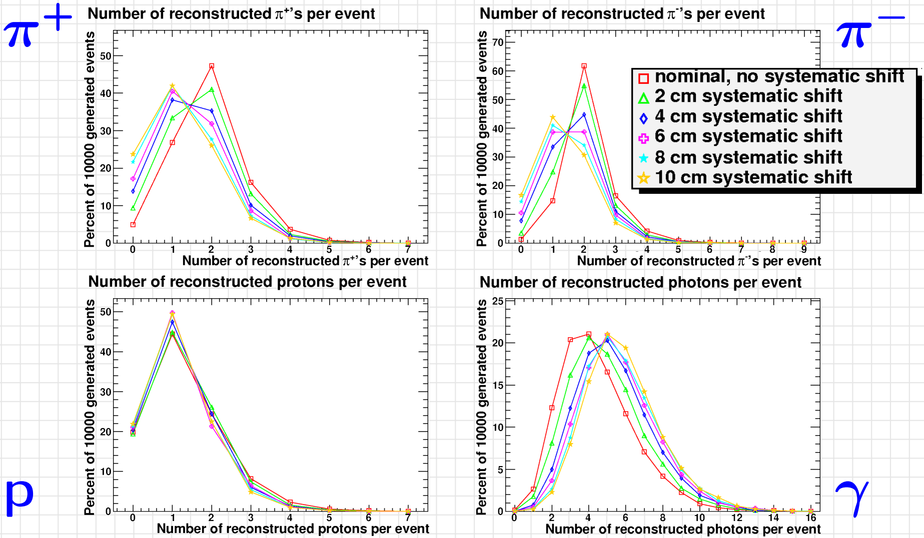


Number of reconstructed photons per event



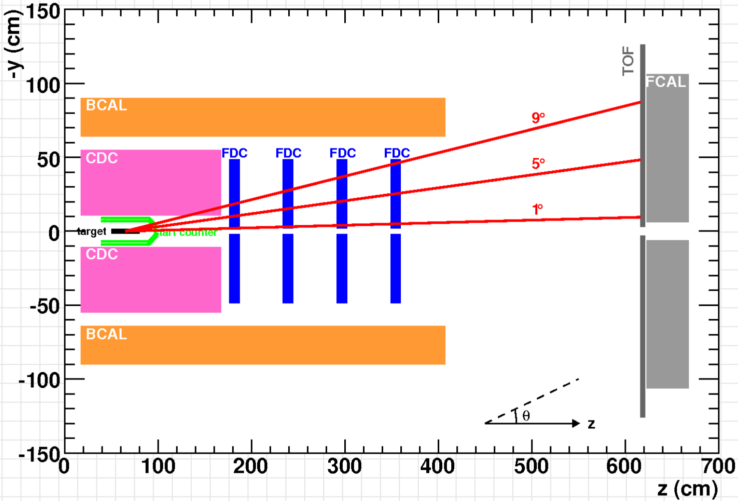
γ

Track Reconstruction with Broad Undulations ($b_1\pi$)

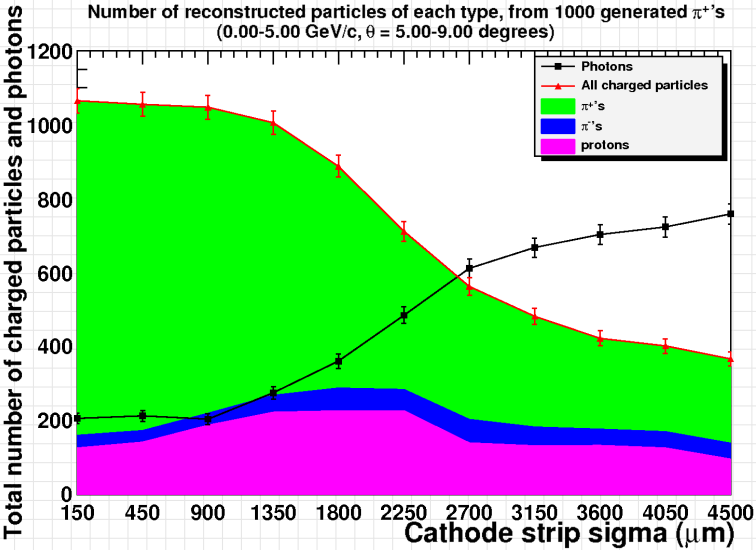


Detector Geometry

Straight tracks with 1, 5, and 9 degree inclines

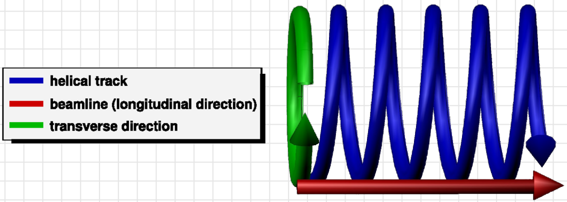


Track Reconstruction with Local Dimples (π^+)

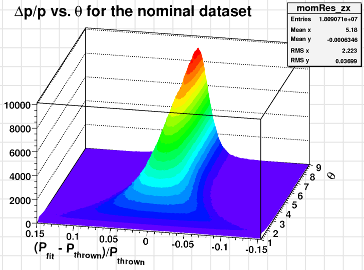


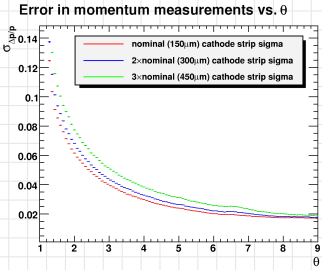
Measuring Momentum

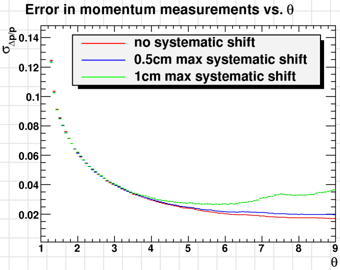
- Would like to compare true momentum to measured momentum in several flatness scenarios.
- Track curvature is directly related to transverse momentum — the component perpendicular to the magnetic field.
- Total momentum is related to transverse momentum by the inclination angle at which the particle exits the target.
- The accuracy of total momentum is limited by the accuracy of track curvature and initial inclination angle.



Momentum Resolution (π^+)

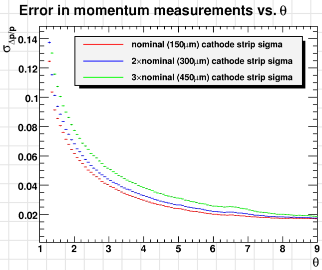


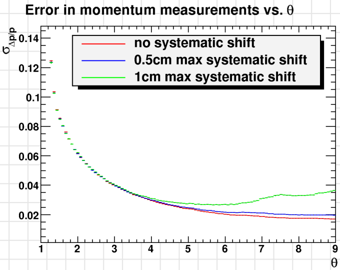




Momentum Resolution (π^+)

- At small angles:
  - When transverse momentum is small, track curveature is comparable to position resolution.
  - Initial inclination angles can not be measured as accurately.
- Humps correspond to angles at which tracks pass through more detector material.





Summary

- Flatness measurement system and methods for interpreting measurements are in place.
- From measurements of prototype cathode planes:
  - Offsets in position resolution due to local dimples are 5 μm.
  - Offsets in position resolution due to broad undulations are negligible.
- Noticeable effects on track reconstruction and particle resolution may not occur until statistical error approaches 150 μm, or systematic shifts approach a 0.5 cm maximum.