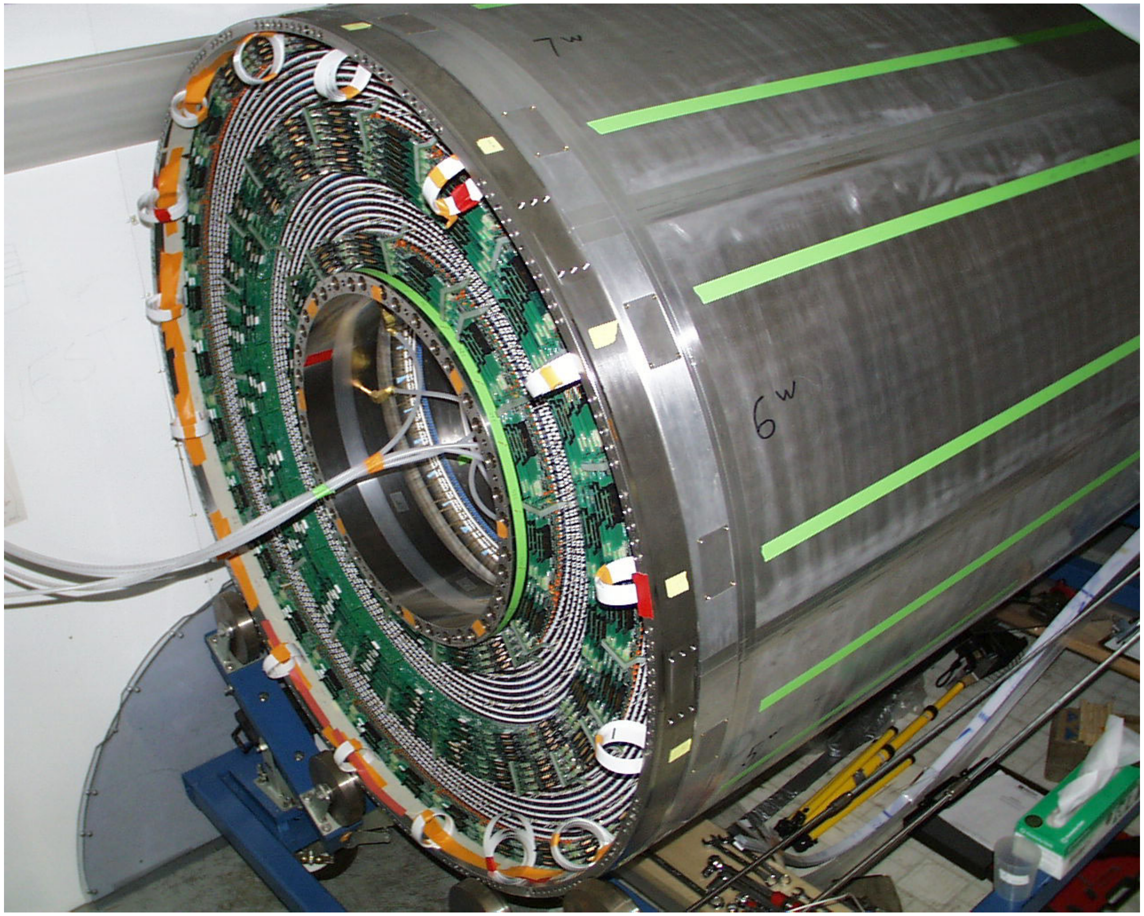
The CLEO-III Drift Chamber

Vienna Conference on Instrumentation, 19-February-2001

Daniel Peterson, Cornell University



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Motivation

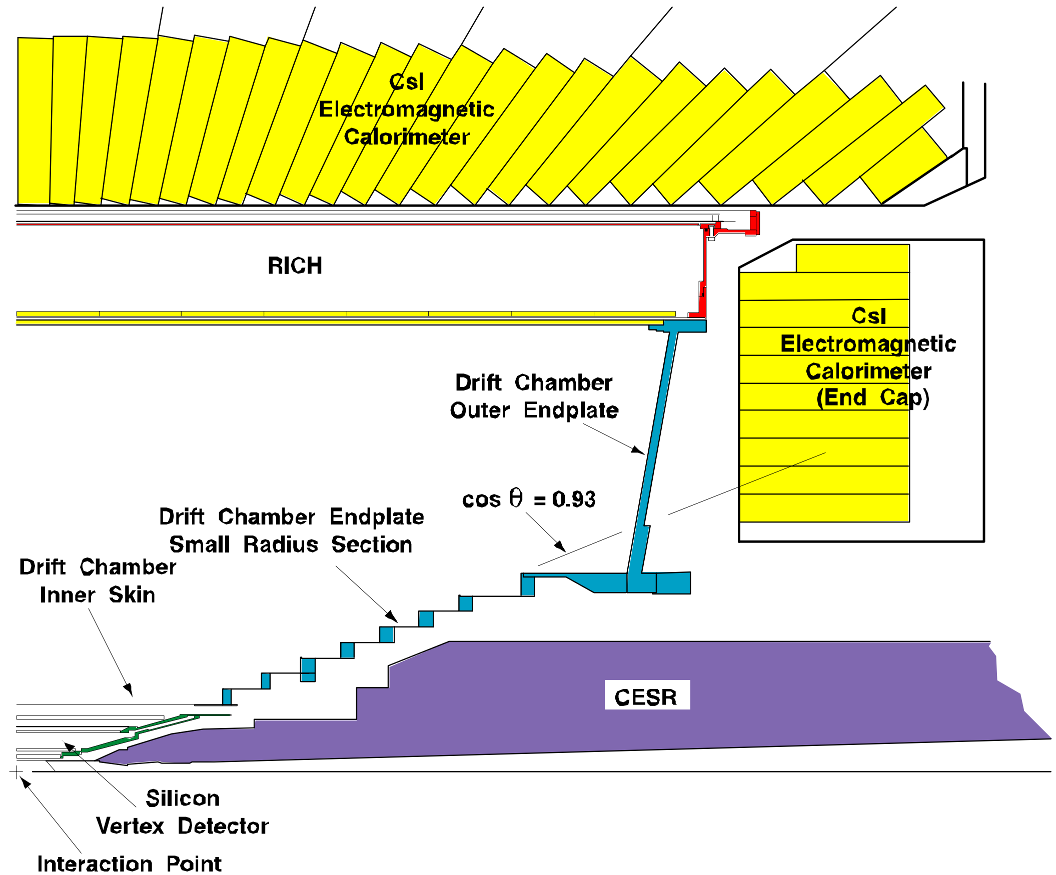
Upgrades of CLEO/CESR necessitate a new chamber.

Super-conducting focusing elements intrude into the detector.

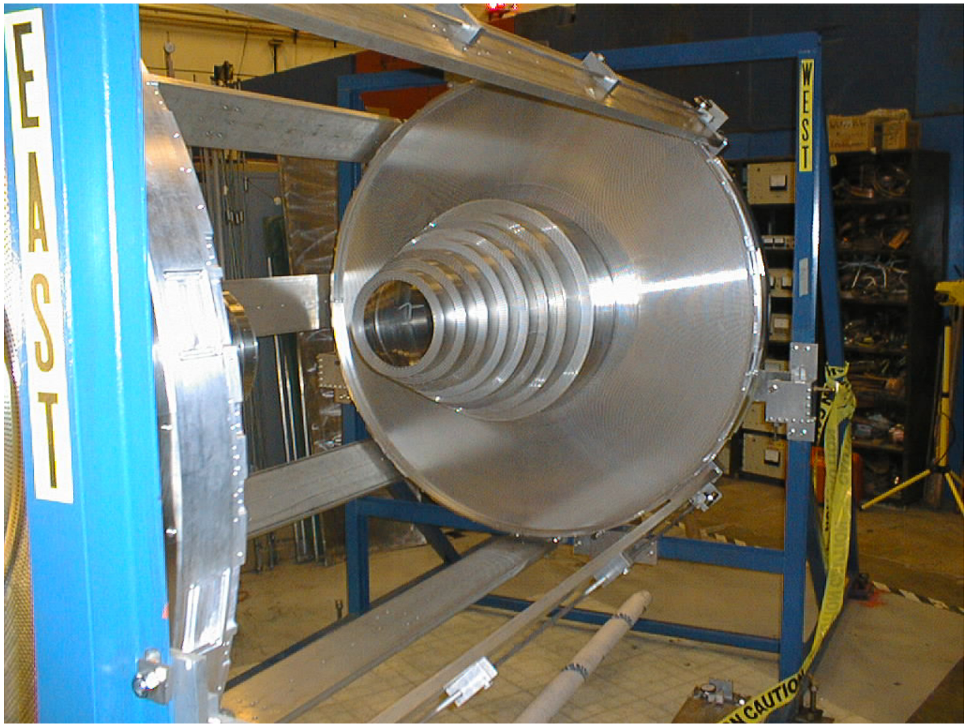
Outer radius reduced from
95cm to 82 cm
to allow installation of a
Ring Imaging Cherenkov detector.

While radial space is limited, momentum resolution must not be compromised.

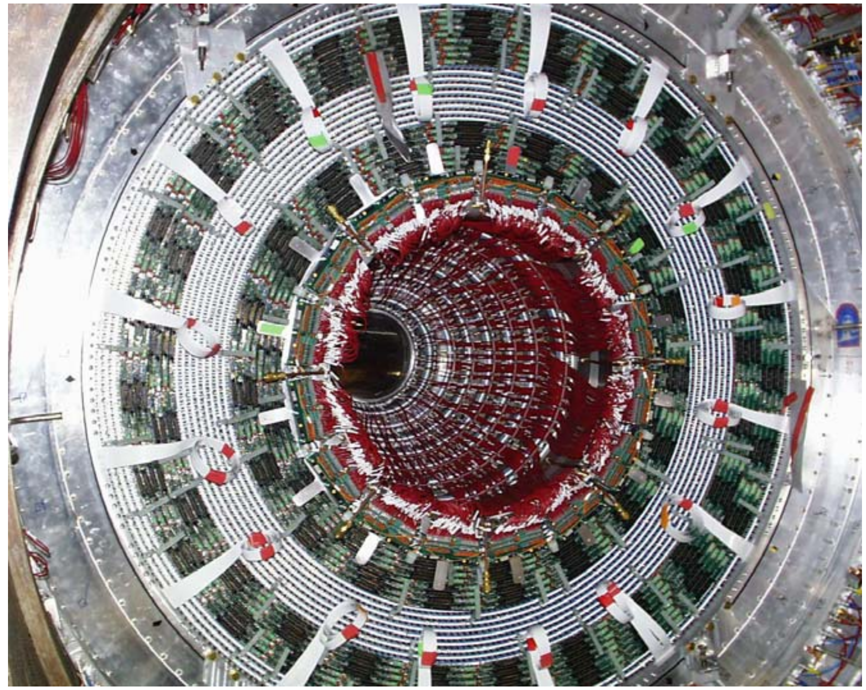
- maximize measurements; minimum unused volume
- resolution <150 μm in all layers (including stereo)
- gas RL > 330 m
- < 0.0015 RL distorting extrapolation to silicon



Endplate Assembly



June 1997



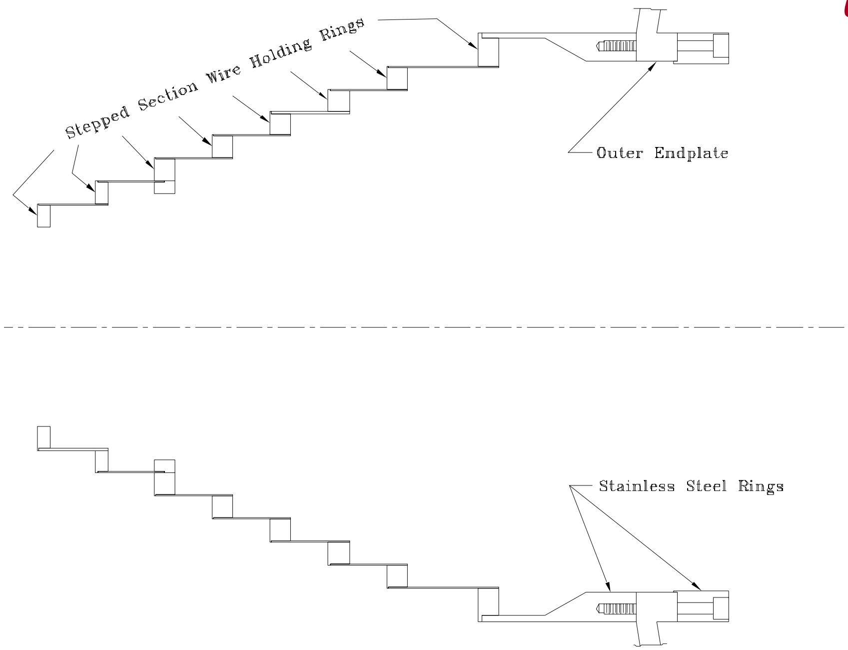
August 1999

Multi-component endplate
allows space for focusing magnets

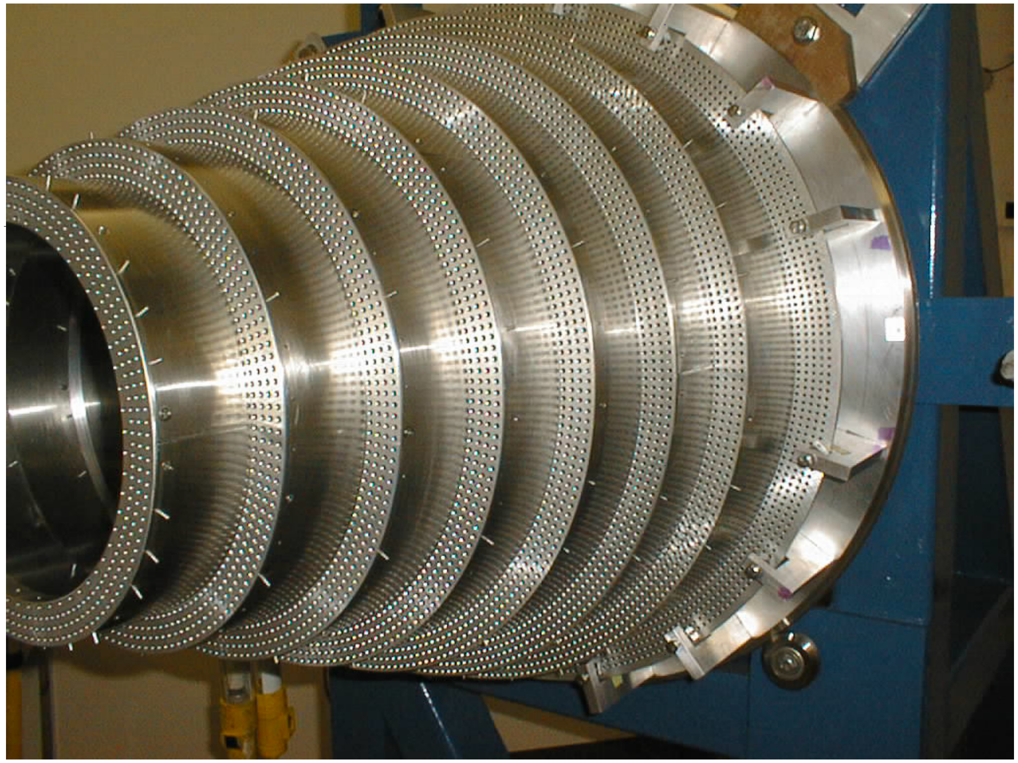
half-Length: 124.5 cm
outer radius: 82 cm
inner radius: 12.5 cm
47 anode layers, 9796 cells
outer cathode, 8 x192 strips

Note: endplate mounted pre-amps
inner section cables
ground network
cathode cables

Endplate Inner Section



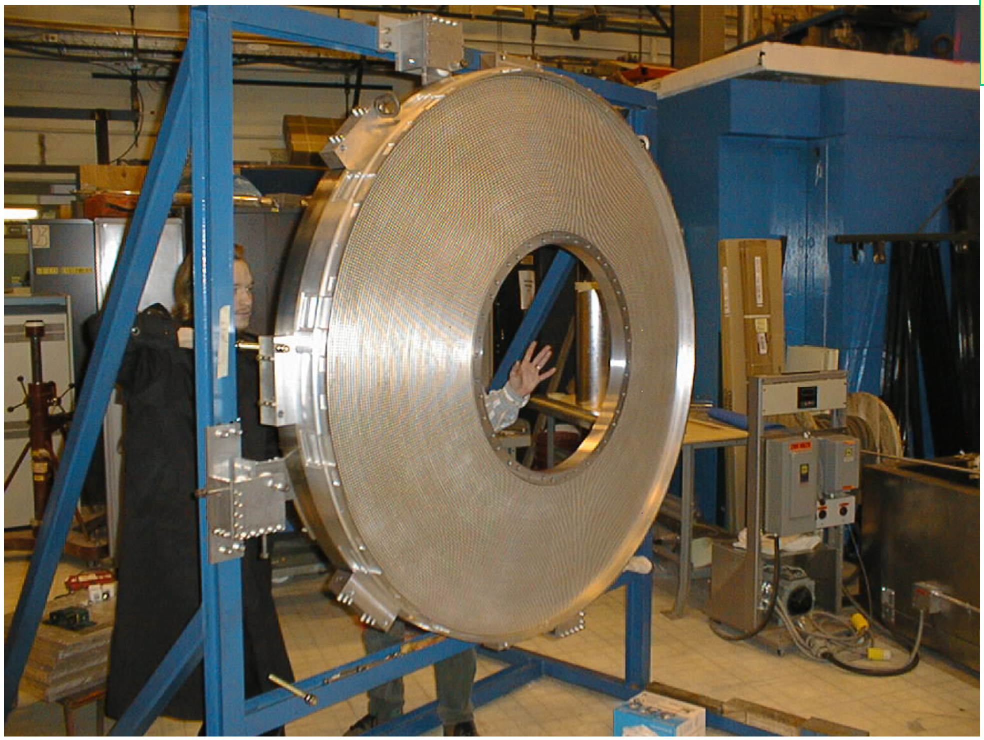
- constructed of 8 precision drilled rings
- located with 1.3 mm thick stainless steel bands
- secured with radial screws and dowel pins fitting between the wire holes
- Layer spacing is uninterrupted between rings.
- defines 93% solid angle coverage

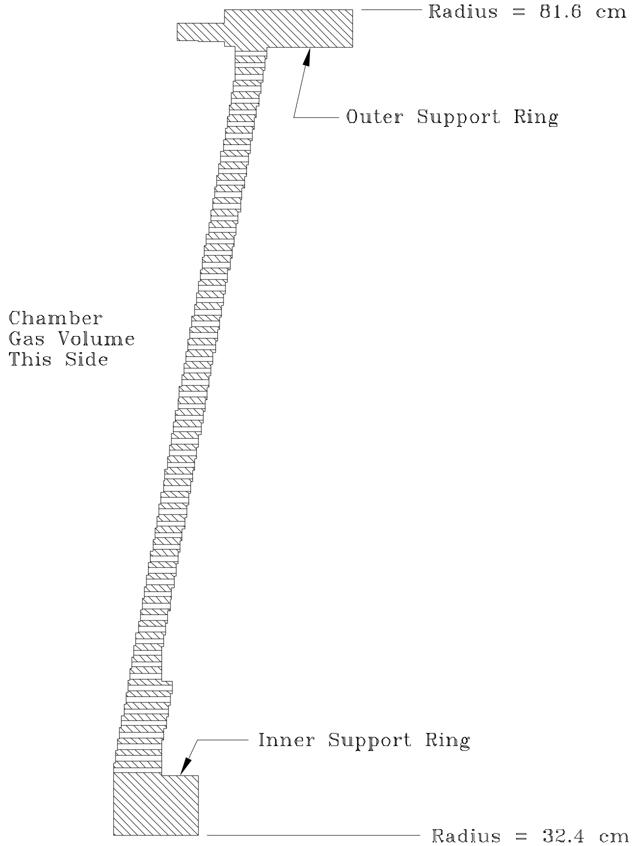


February 1997

Each of the 8 rings contains 2 anode layers and and associated field wire layers at smaller radius. There are the same number of anode cells per layer, with half-cell-stagger, in the anode layers on each ring.

Endplate Outer Section





- machined from 16.5 cm thick plate
- Finished thickness is 1.52 cm shadowing the end cap calorimeter
- Terraced surface follows slope of 0.178 ; the “z” difference is 7.4 cm over radial change.
- Inner/Outer support rings add stiffness; deflection from 4500 kg wire load: 0.6mm.

The outer section supports 31 anode layers and associated field wire layers.
Layers are grouped in 8 stereo super-layers with equal number of cells per layer and half-cell-stagger.

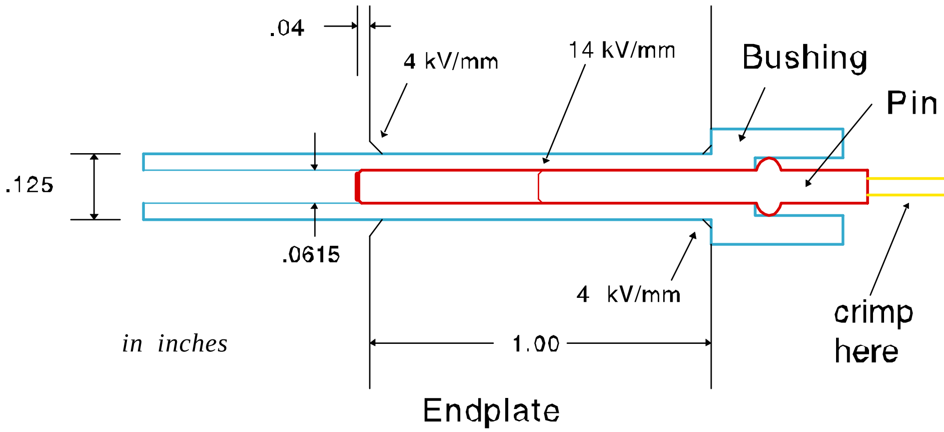
Inner gas/RF seal

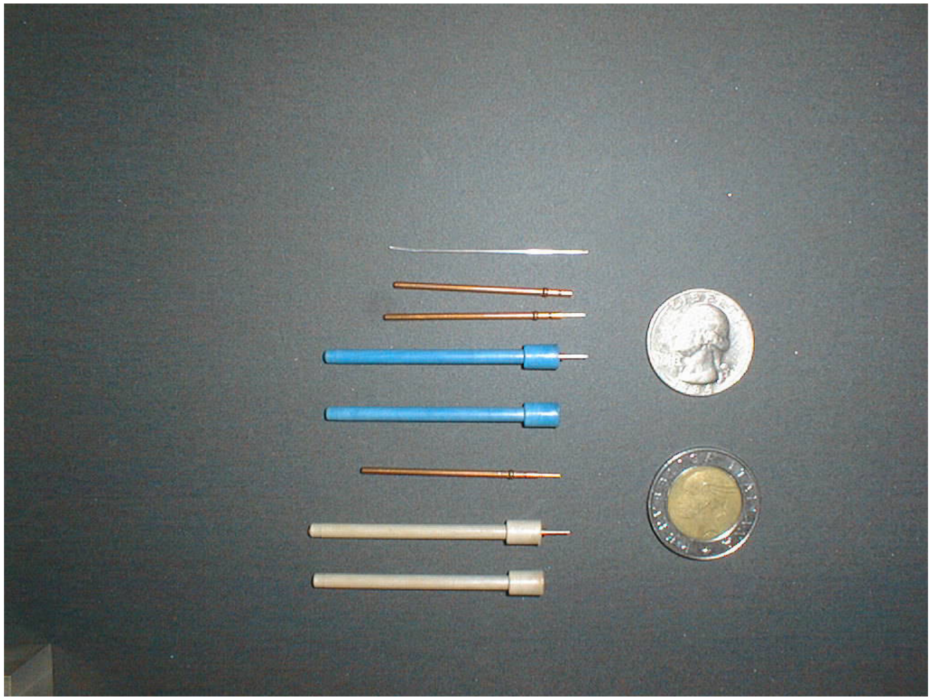
- Scattering material < 0.15% RL required to allow use of the outer silicon layer in momentum measurement at all momenta.
- Radial distortion tolerance < 250 μm for electric field uniformity in first layer.
- Beryllium tube fails specifications.

- Inner cylinder is 0.12% RL composite:
  - 2 layers or 20 μm aluminum
  - 2.0 mm Rohacell® foam

- Strain limit: 0.8 mm
  - Requires rigid endplates
  - Limit on motion of endplates after installing inner cylinder
  - Requires detailed understanding of creep of the aluminum field wires throughout the life of the chamber.

Pins, Bushings, Wire





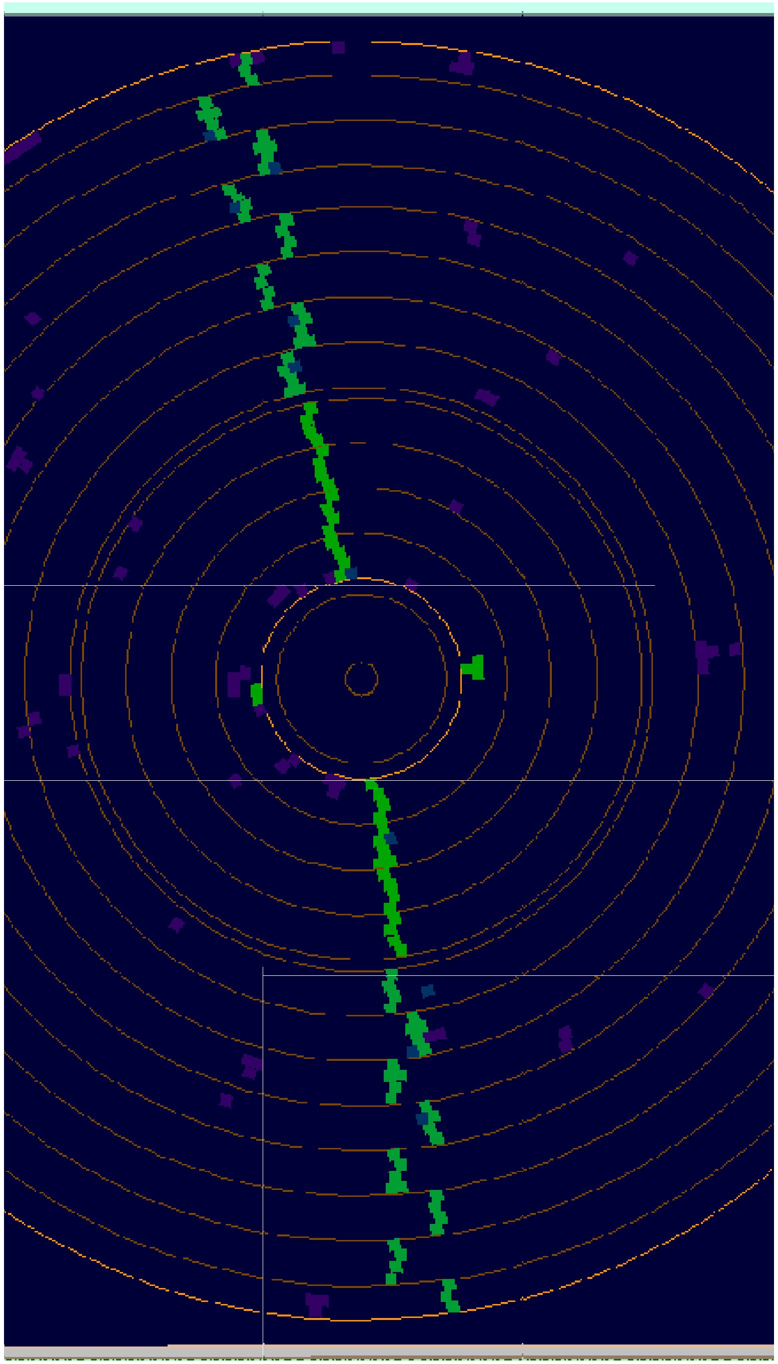
- Pins are 2 component coaxial
  - Extends beyond endplate to reduce electric field
  - copper outer part .0615 inch OD
  - aluminum-6051 core for aluminum field wire
  - copper core for tungsten sense wire, .0067 inch ID
- Bushings are Hoechst Celanese VECTRA® A130
  - chosen for mold shrinkage 0.2% (ULTEM® 0.7%)
  - water absorption 0.02% (ULTEM 1.25 %)
  - dielectric strength 38 kV/mm (ULTEM 33 kV/mm)

Field wire: California Fine Wire
110 μm Al 5056
.75 μm Au, Ni flash
"ultra-finish"
Sense wire: 20 μm W
3% Re, Au plated

Layer Design

Maximize number of measurements:
AXIAL-STEREO interfaces, which
require separate field layers or
create distorted cell geometry, are
limited by grouping stereo layers together.

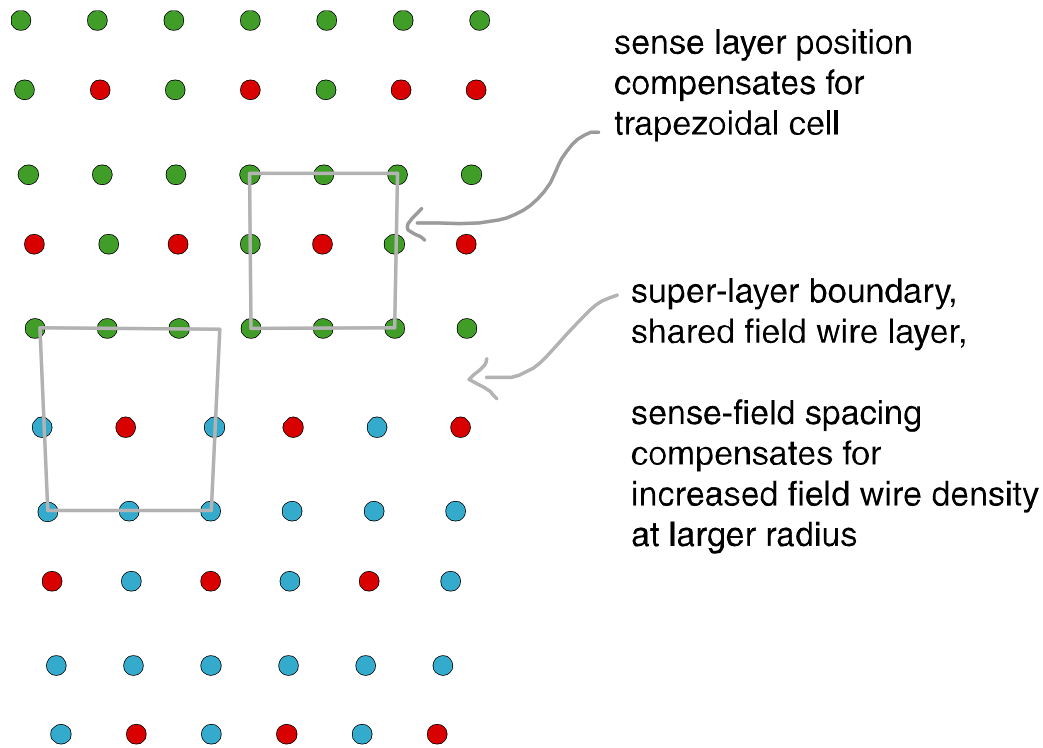
- 47 layers
- 16 axial layers in stepped section
  arranged in 8 groups of 2 layers,
  constant number of cells,
  half-cell-stagger
- 31 stereo layers in outer section
  arranged in 8 super-layers,
  constant number of cells,
  half-cell-stagger
  $d(r\phi)/dz \simeq 0.02 - 0.03$, alternating sign,
  cell shape constant over length of chamber
  nearly constant hyperbolic sag



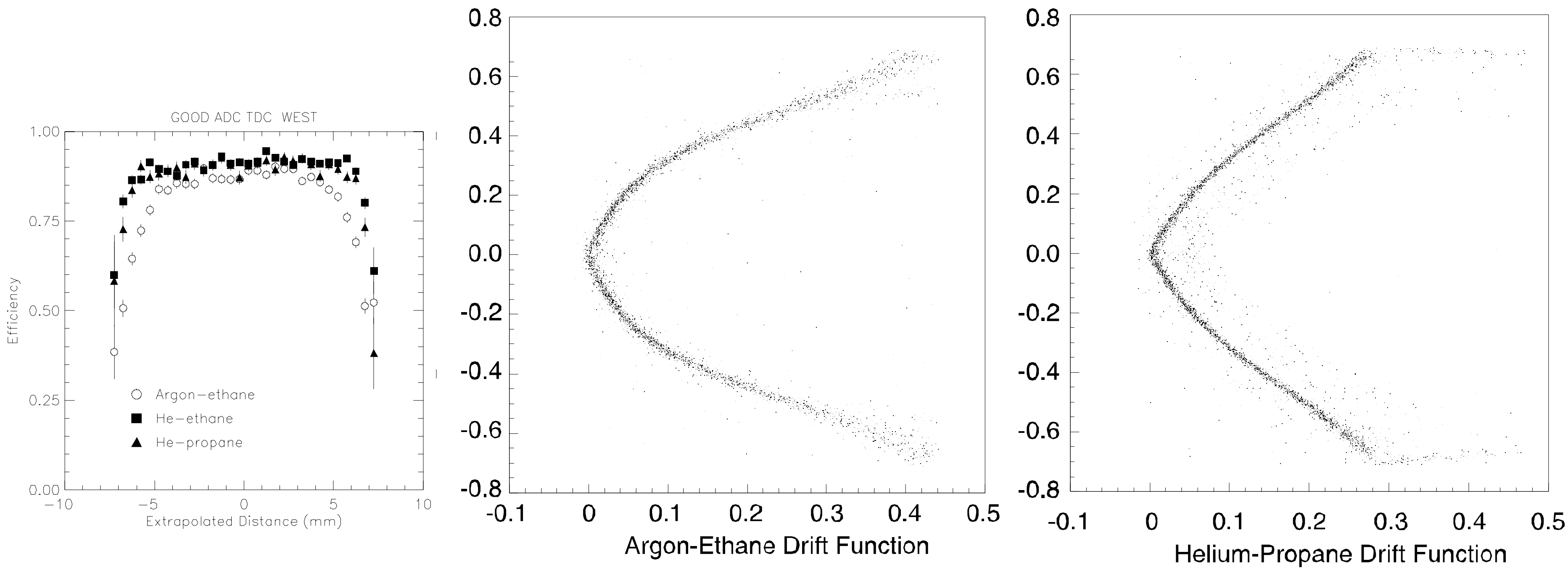
Cell Design

Require...
minimum dependence on L/R corrections
and no z-dependent corrections.

- Square cells, 3 field/sense
- 7mm (maximum drift distance)
- Field wire layer is shared at boundary between layer groups having differing number of cells and/or stereo angle sign.
  Random phase of wires above last layer in a super layer is unimportant.
  Radial spacing is held constant ; stereo sag differs < 80 μm.
- Radial spacing compensates for variations in field wire number density. (shown →)
  Compensation removes 1mm left-right asymmetries at maximum drift distance.
- Voltage applied to field wire layer inside of first anode layer compensates for field asymmetry introduced by inner skin.
- Voltage applied to segmented outer cathode strips compensates for z-dependent field asymmetry.

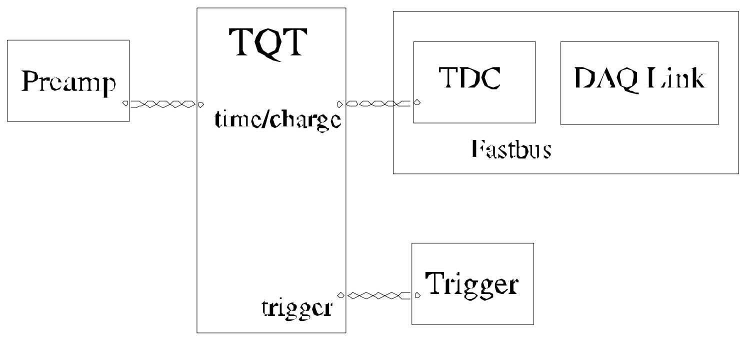


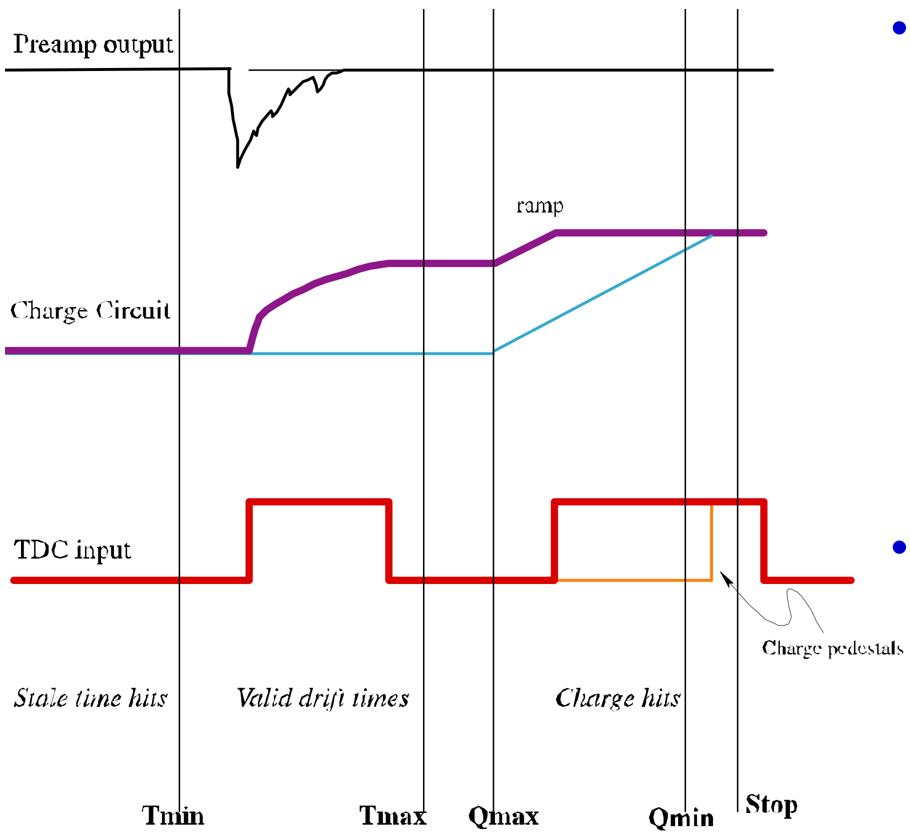
Chamber Gas



- CLEO had experience with Ar-C_2H_6 (50:50)
  - Efficiency loss at drift distance > 5mm
- Test chamber results: both He-C_2H_6 (50:50) and He-C_3H_8 (60:40) provide improved efficiency and reduced radiating material, RL=550m
- Ar-C_2H_6 (50:50) varies from (50 μm/ns) near the wire to (10 μm/ns) (note: split drift function)
- He-C_3H_8 (60:40) is a slower gas at 0 Tesla or close to the wire (30 μm/ns) but has a smaller Lorentz angle and consistent drift velocity in 1.5 Tesla.

Readout Electronics





- Multi-hit capability used to record noise history of cell for previous 32 μs.

- Preamp mounted on chamber (τ=8ns)
- TQT (time/charge->time)

  Threshold triggered time pulse

  Inhibit retrigger to 500 ns

  Charge converted to time pulse when valid event trigger initiates "ramp",

  or bleeds to reset if no trigger.

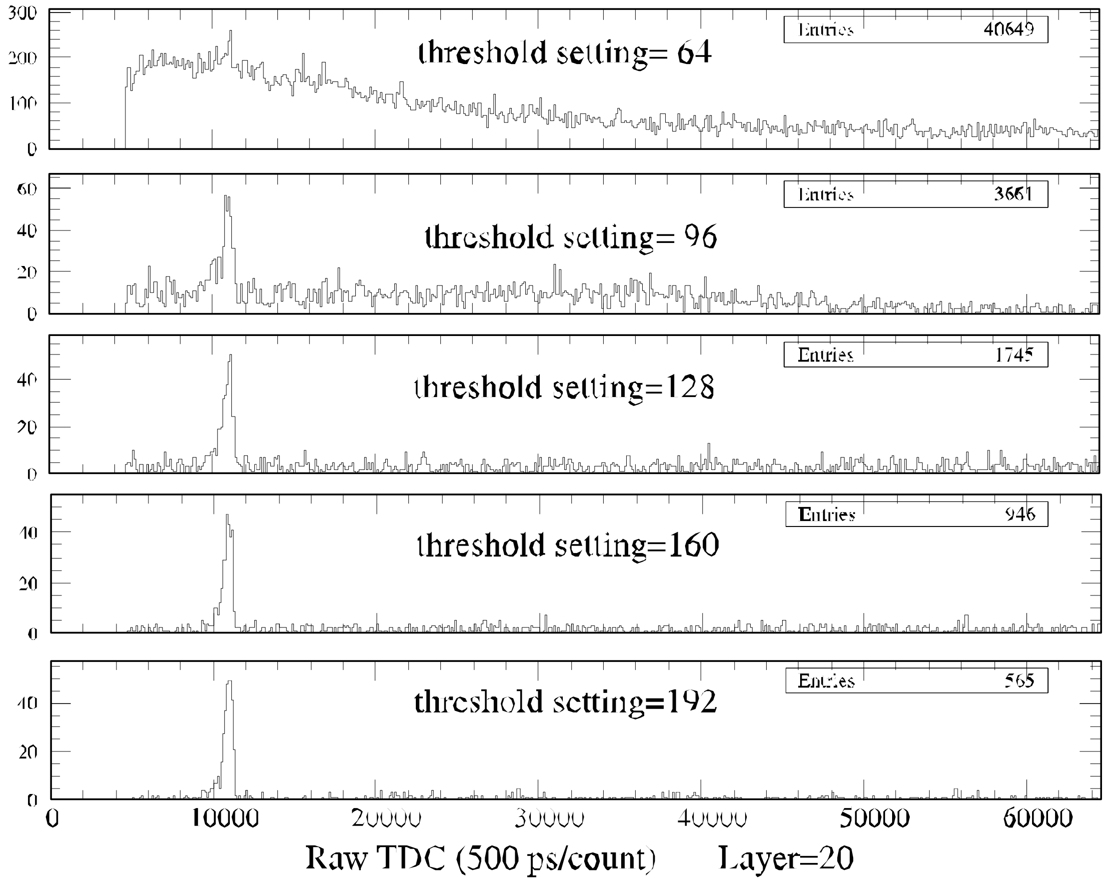
- LeCroy Fastbus TDC 1877s

  Multi-hit; logs time and charge as time hits.

  granularity: 0.5 ns

  stability: specification 0.3 ns

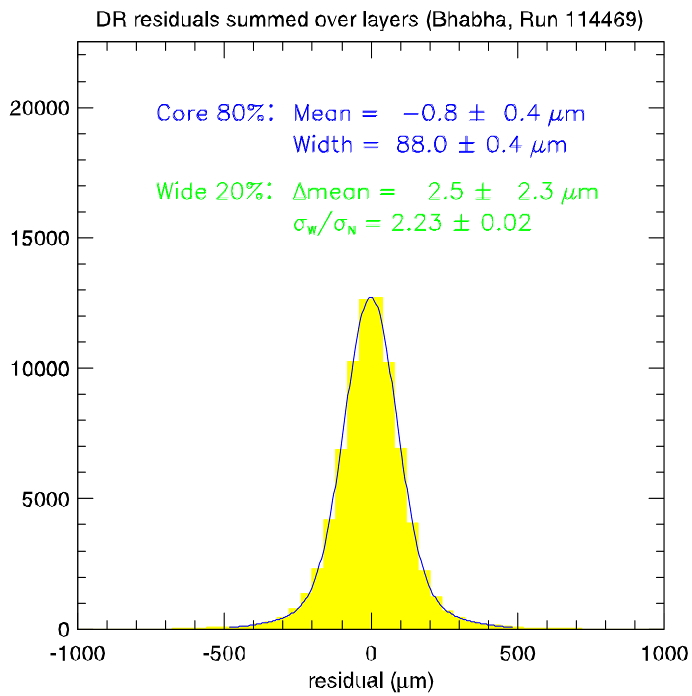
Discriminator Thresholds

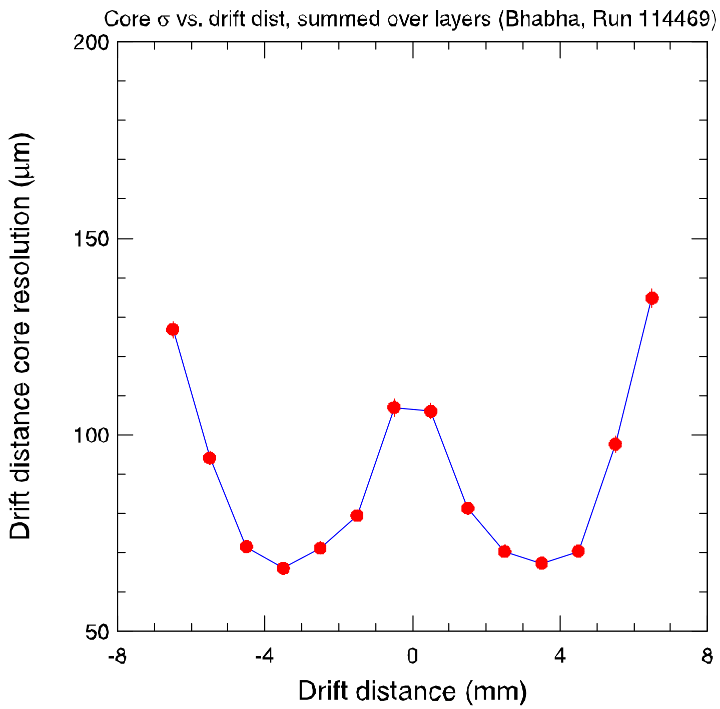


Threshold is set at 0.8 μA.
with a characteristic time of 8 ns
(amplifier rise time),
and gas gain ~ 10^5 ,
threshold is 0.4 primary ions .

- Thresholds can be set for each channel but, in practice, are set for each layer
- Scale: setting=255 ⇨1.3 μA
  (referred to the input)
- Low threshold causes a loss of efficiency because of the
  500 ns inhibit after each threshold crossing.
- High threshold may cause a loss of efficiency but would first cause a degradation of time resolution for tracks close to the wire (ion statistics).
- Select minimum threshold with manageable noise:
  noise rate ~ physical rate
- In this case, .8 μA

Spatial Resolution





Residuals: time-measured hit position are compared to the fitted position.

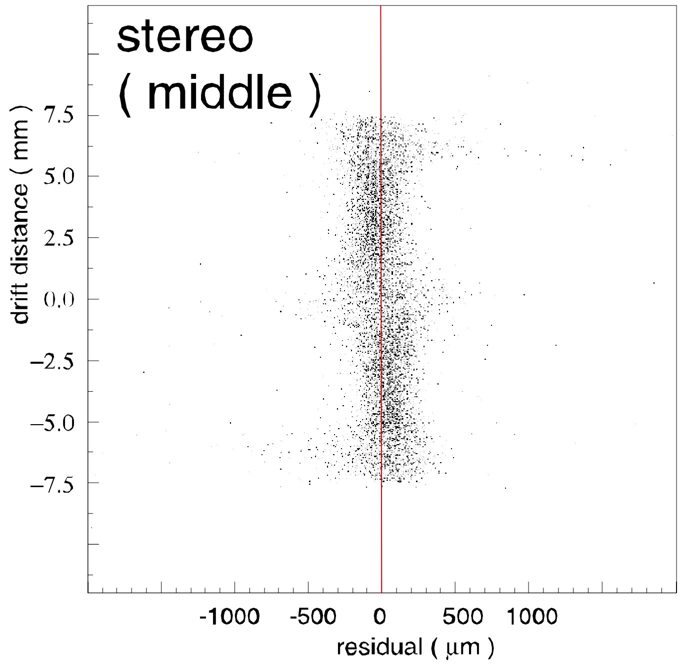
Parameterized as double gaussian with fixed 80% fraction in narrow component.

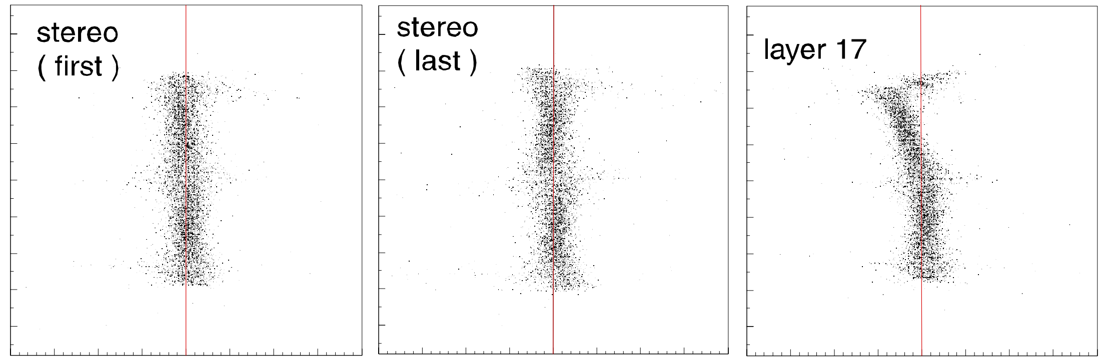
Narrow component: σ=88 μm (ave over cell)

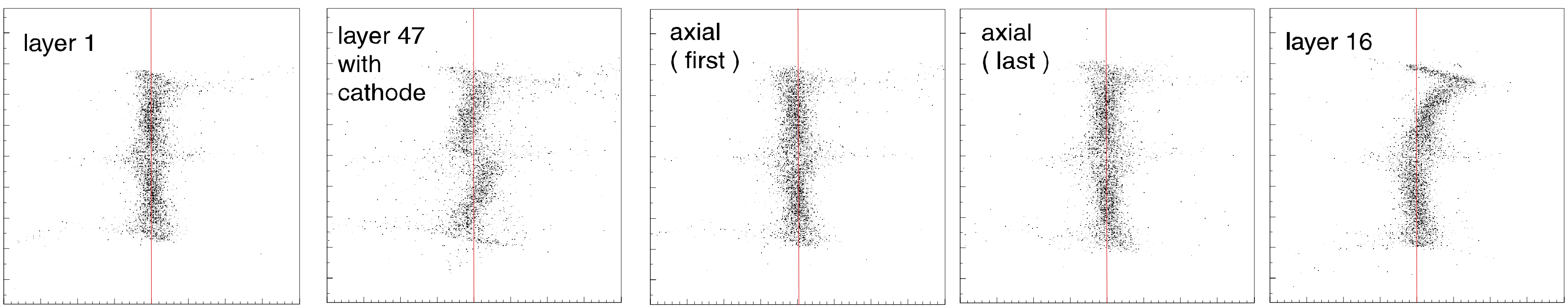
(wide component: 200 μm; ave:110; goal: 150)

Narrow component minimum: 65 μm

left-right asymmetries





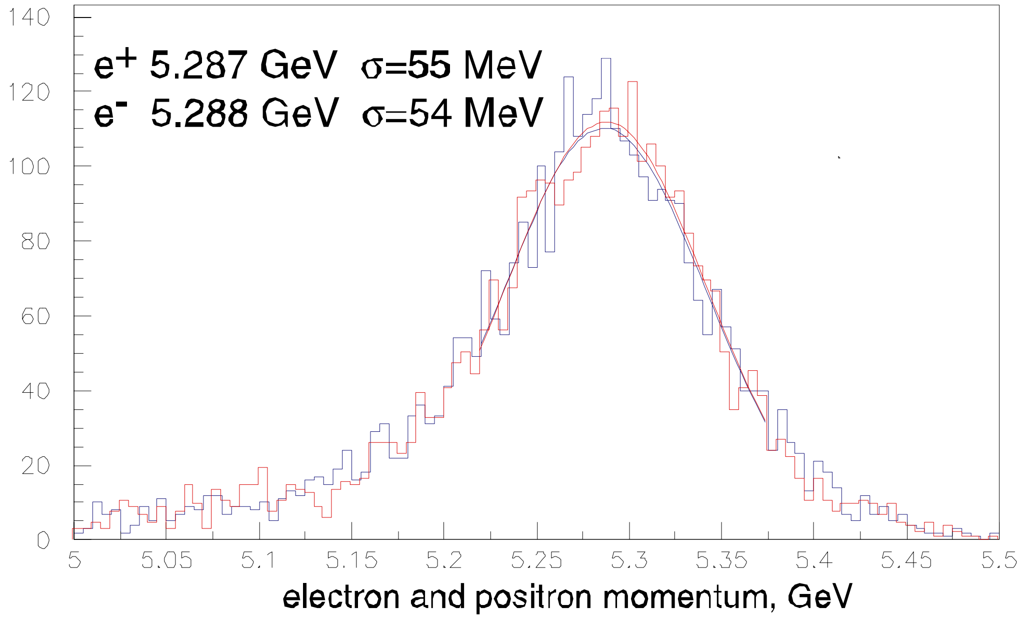


Left and Right residuals...

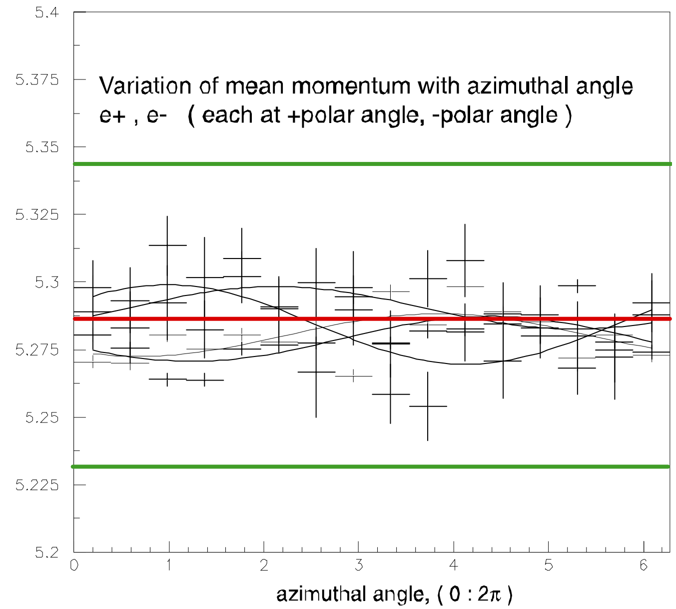
- relative to (-) side drift function
- deviation of (+) side indicates
  left–right asymmetry

Only layers 16 & 17 show asymmetry

{ for demonstration only;
real drift functions are 2 sided }



Momentum Resolution



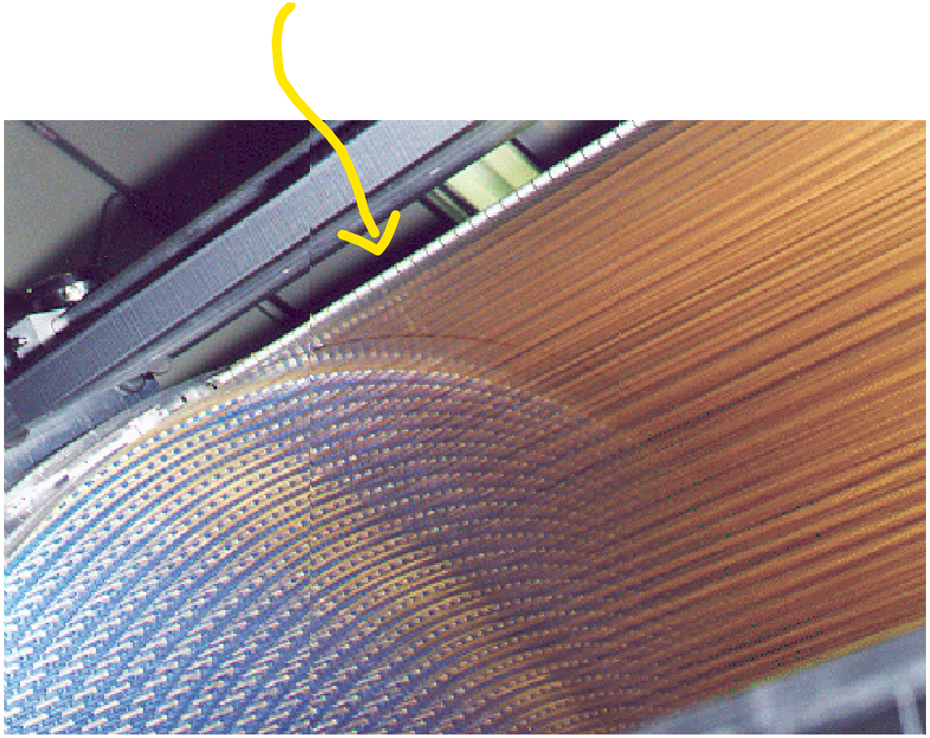
- Momentum measurement using only anodes; no cathode, no silicon.
- With a multi-component endplate, momentum is sensitive to misalignments of the endplate components.
  - Rotation of inner elements will cause charge splitting at one end.
  - Translation will cause charge splitting that oscillates in azimuth, at one end.
  - Intrinsic resolution is ~ 1%.
  - Sensitive to motions of order 50μm;

    (1% of sagita for P_t=5.28 GeV/c track).

Momentum variations for
- **{+/- charge} and**
- **{ +/- polar angle}**
- **as a function of azimuth**

are small compared to intrinsic resolution indicating sufficient alignment.

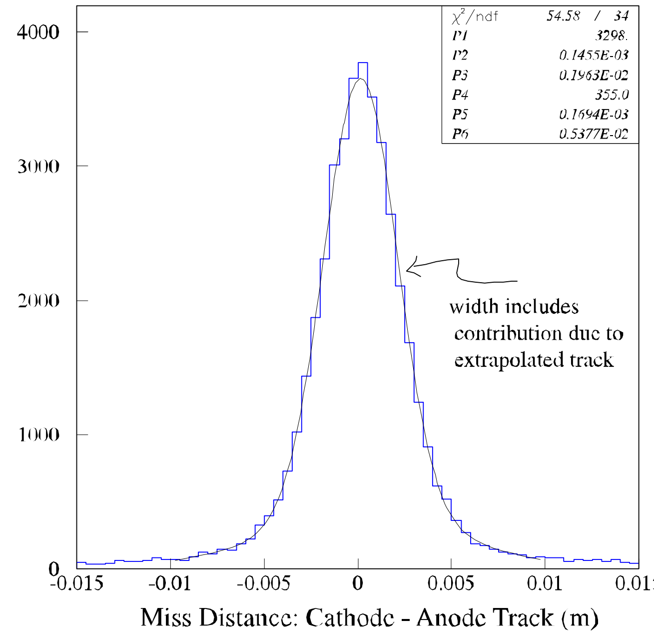
Outer Cathode



Segmented cathode forms the outer field cage for the outer (47th) layer.

- 8 segments in azimuth
- 192 x 1.1 cm segmentation in “z”

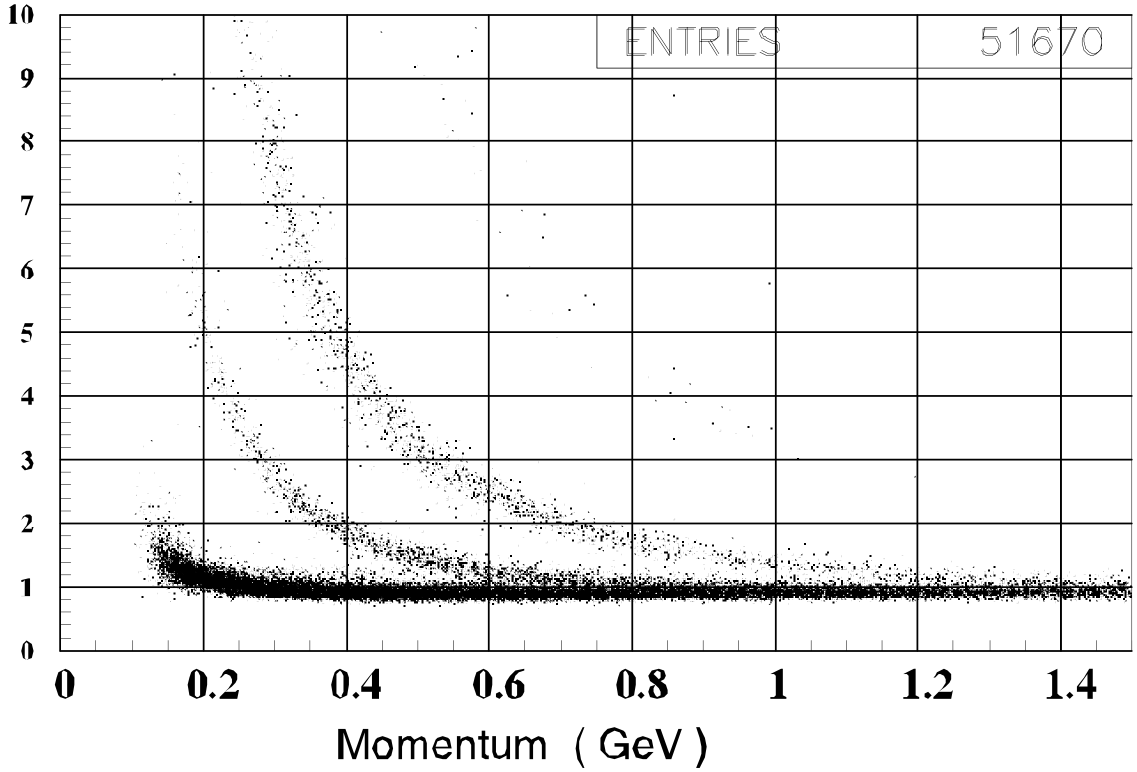
(Apply potential (+250 to 300 V) to create symmetric electric field around varying radius stereo anode wire.)



{cathode - “anode track” } resolution includes contribution of extrapolated track (~ 1.5 mm)

- derived cathode resolution: 1.2 mm
- 95% efficiency in 78% solid angle

Specific Ionization



dE/dX measurements for anode measurements

Bands observed for π,K,p,d

K/π separation to 700 MeV

Corrected for

- drift distance
- saturation at normal polar incidence
- (remove hits with multiple time hits)

Resolution for 5.28 GeV electrons: 5.0%

Conclusion

- installed, collecting data at 10.56 GeV, since July 2000
- hit resolution: 88 μm

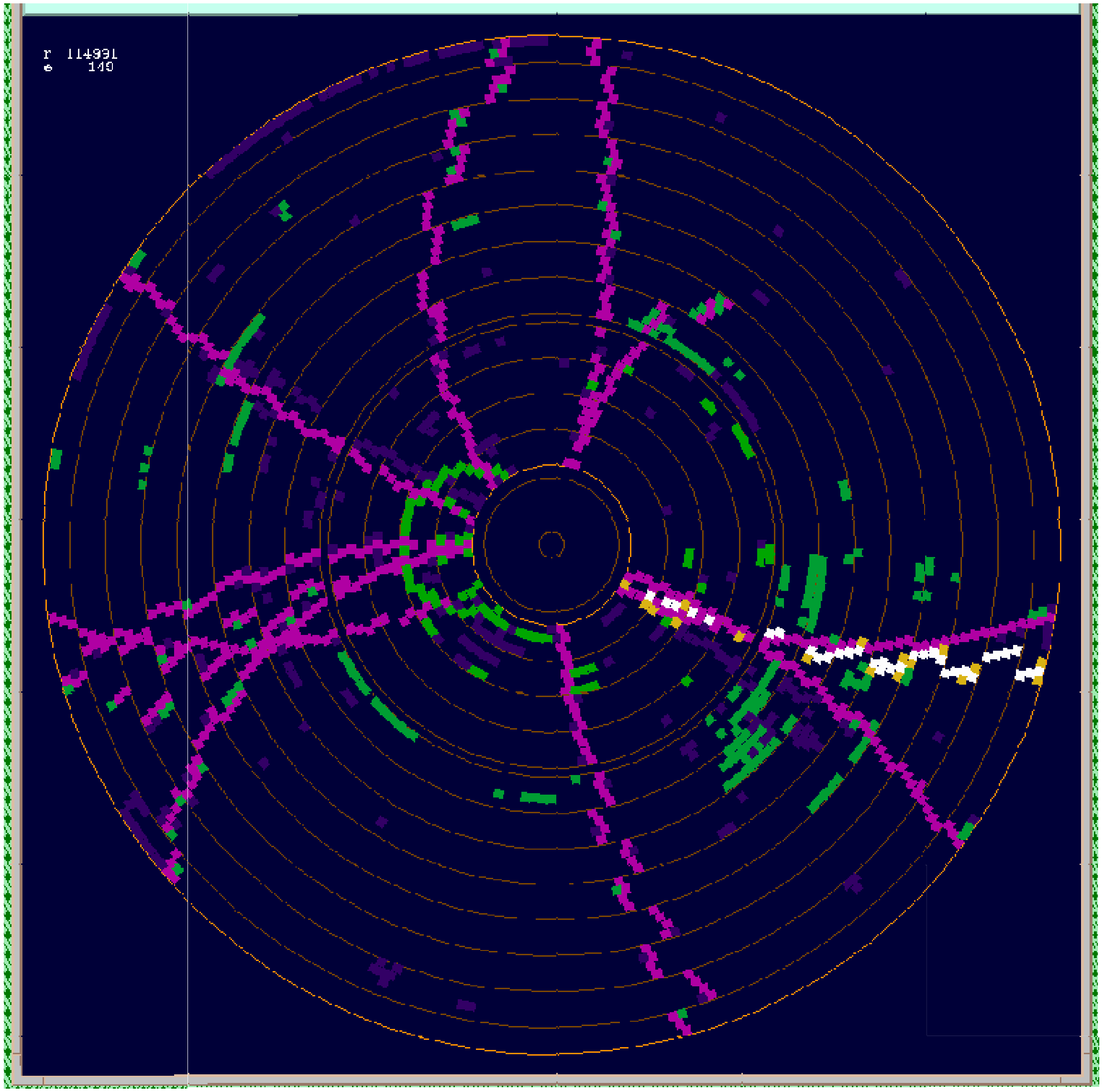
  (exceeding goals)
- Bhabha resolution at 5.28 GeV/c :

  54 Mev (chamber only)
- cathode resolution: 1.2 mm
- dE/dX resolution: 5%
- low electronic noise with high efficiency;

  sufficiently grounded
- beam debris noise is low

  even in a 32 μs window

  (note 2 early tracks)
- pattern recognition is efficient even for overlapping tracks.



■ found track ■ out-of-time ■ in-time/useable □ current track

What about……….

K0

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