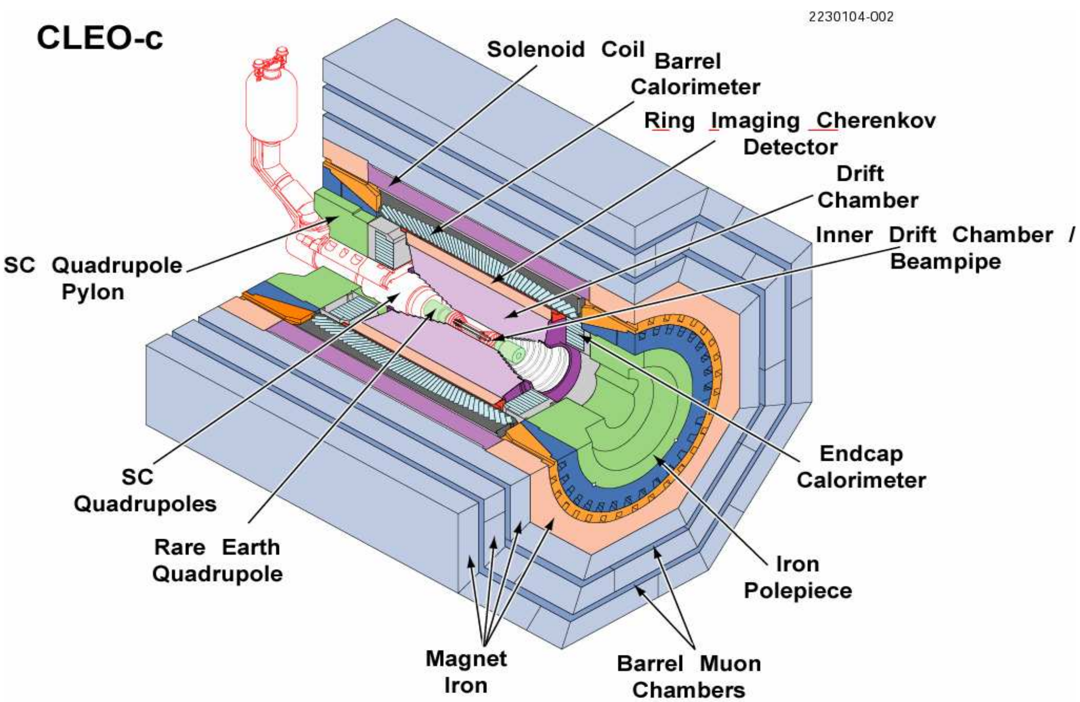
Charged Particle Tracking at Cornell: Gas Detectors and Event Reconstruction

Dan Peterson, Cornell University

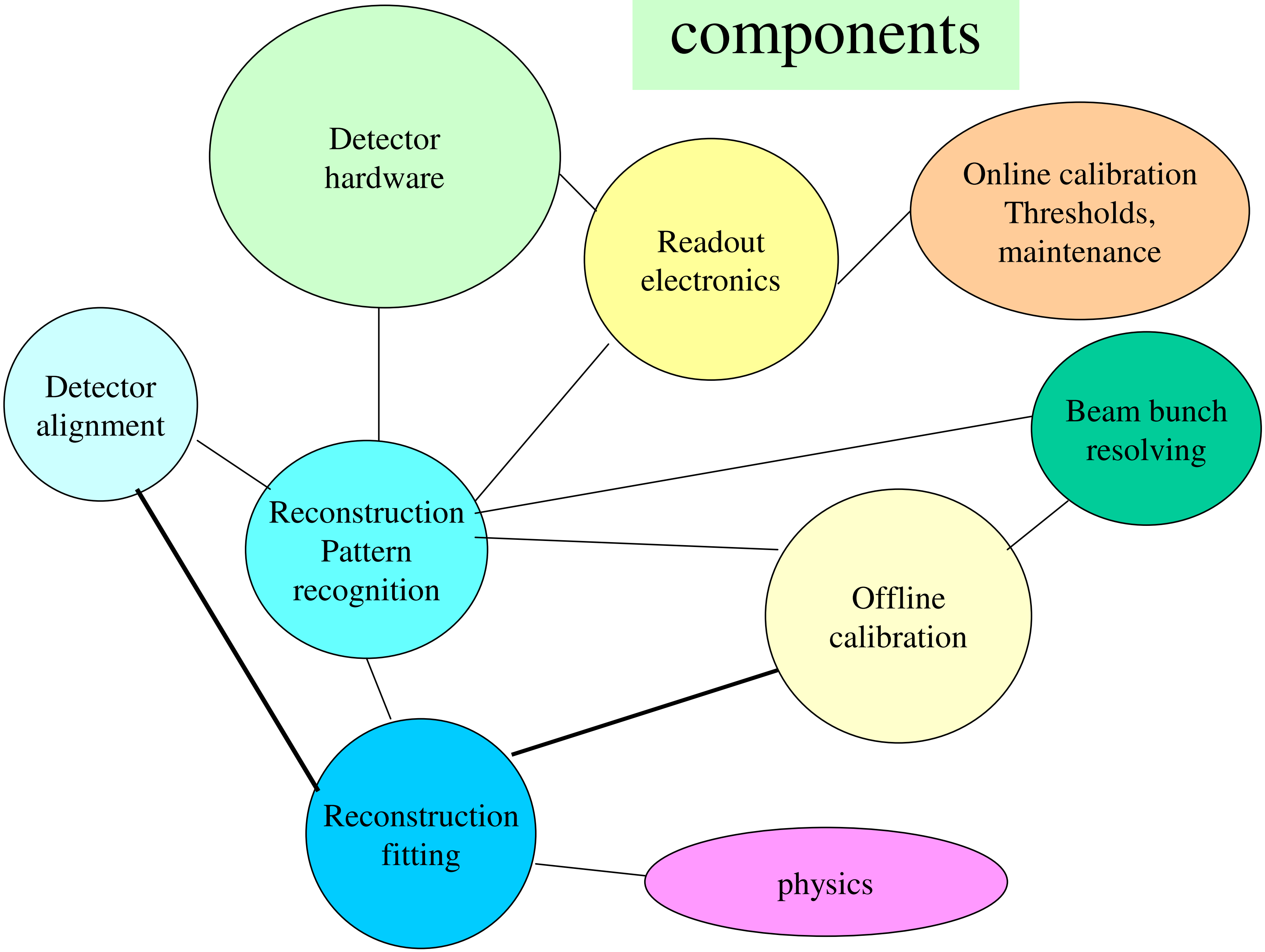


CLEO c

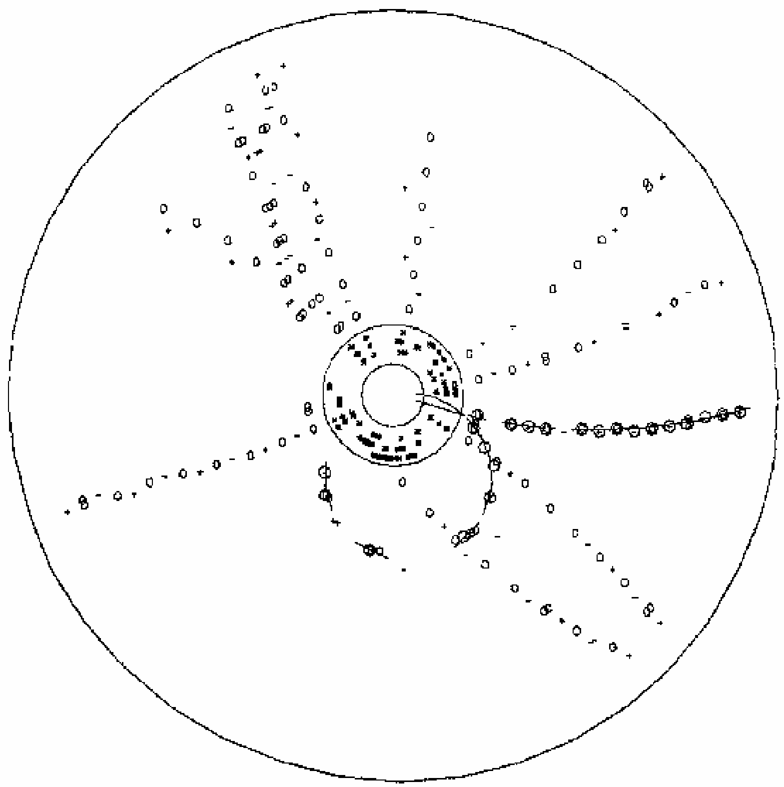
The Cornell group has constructed, operated and maintained the charged particle tracking detectors for CLEO since 1978.

Two talks will describe the chambers, electronics, calibration and reconstruction of charged particles in CLEO.

components


Detector hardware
Readout electronics
Online calibration Thresholds, maintenance
Detector alignment
Beam bunch resolving
Reconstruction Pattern recognition
Offline calibration
Reconstruction fitting
physics

CLEO I

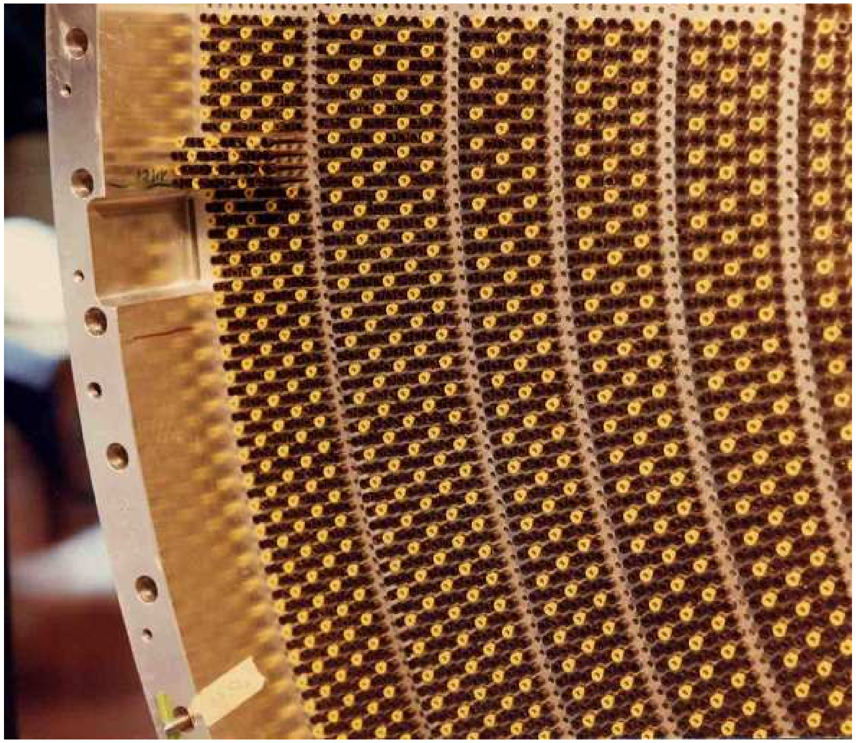


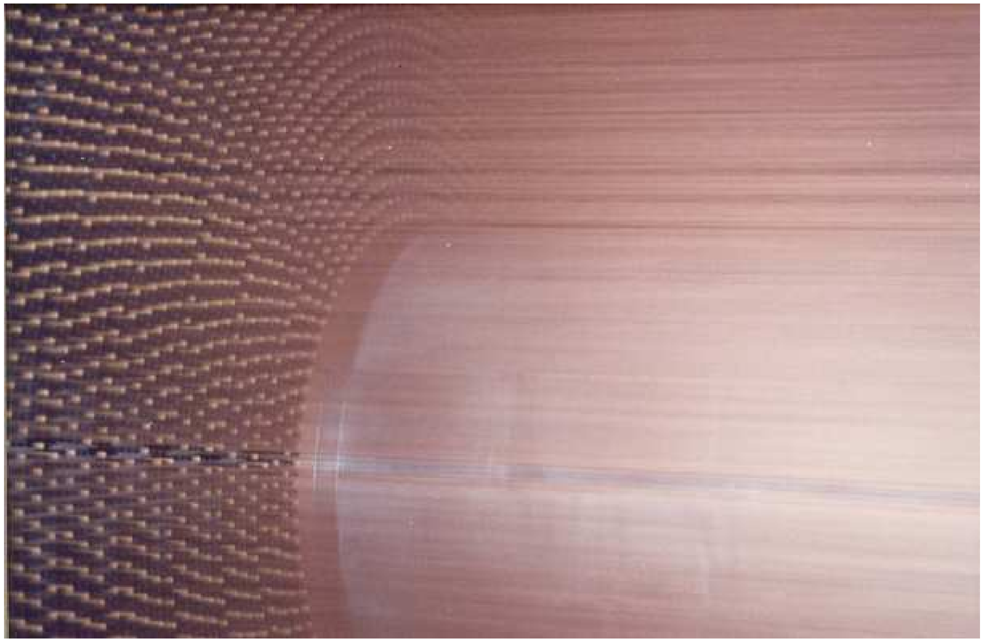
a sparse chamber (as seen in the event)
no local-ambiguity resolution
17 layers   [a u a v … a]

CLEO I   drift chamber
1979 – 1986
Construction: 1977-1979

complex track overlap was a problem
limited dE/dX

CLEO II



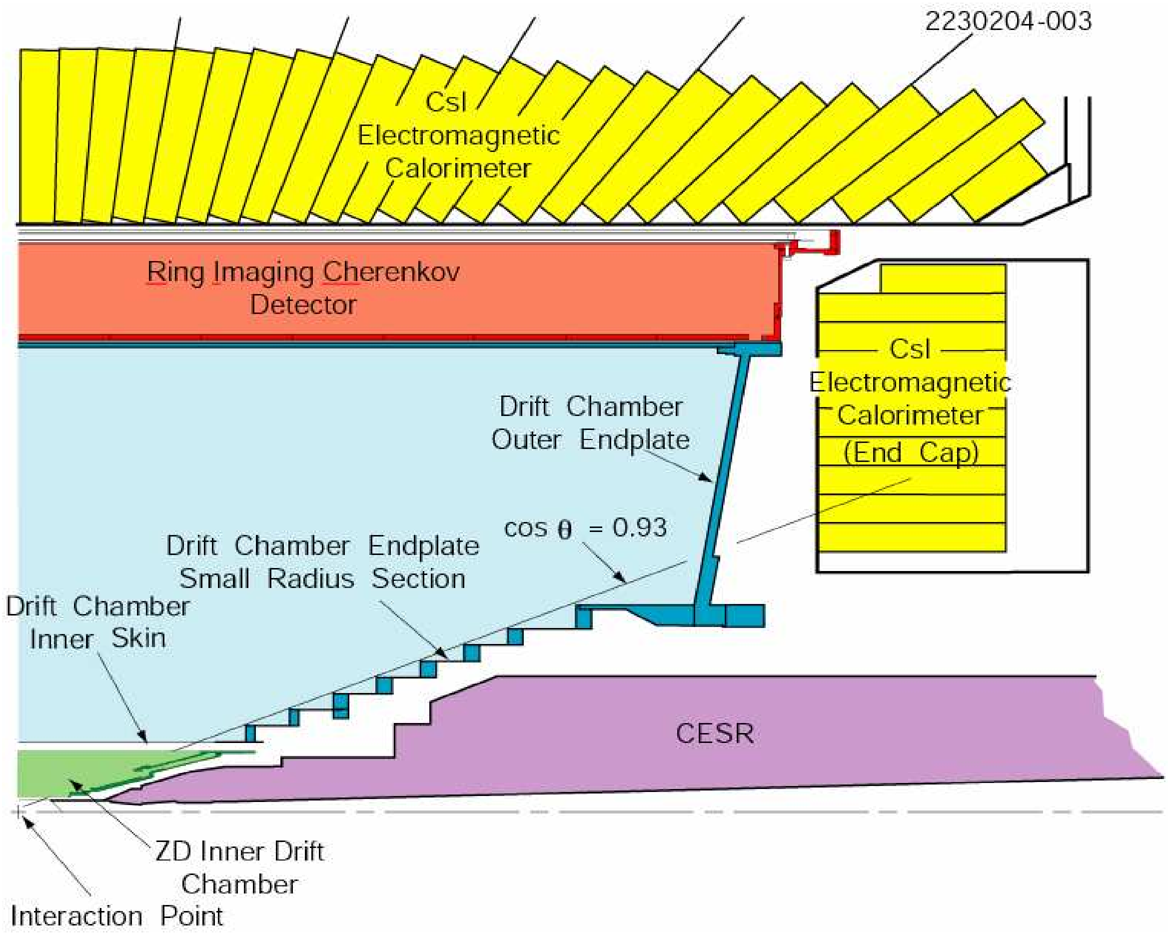


CLEO II drift chamber
1986 – 1998
Construction: 1983 - 1986

51 layers
dense cell design
axial superlayers (bushings shown in photo)
single stereo layers between the axial superlayers
inner and outer cathodes (inner shown in photo)
aluminum field wires
1.25 inch flat endplates (with 1 cm deformation)

The stereo layers were difficult to calibrate;
they were in a non-uniform field cage (vs Z).

CLEO III / CLEO c



integrated design:
space for new machine elements
space for new particle ID

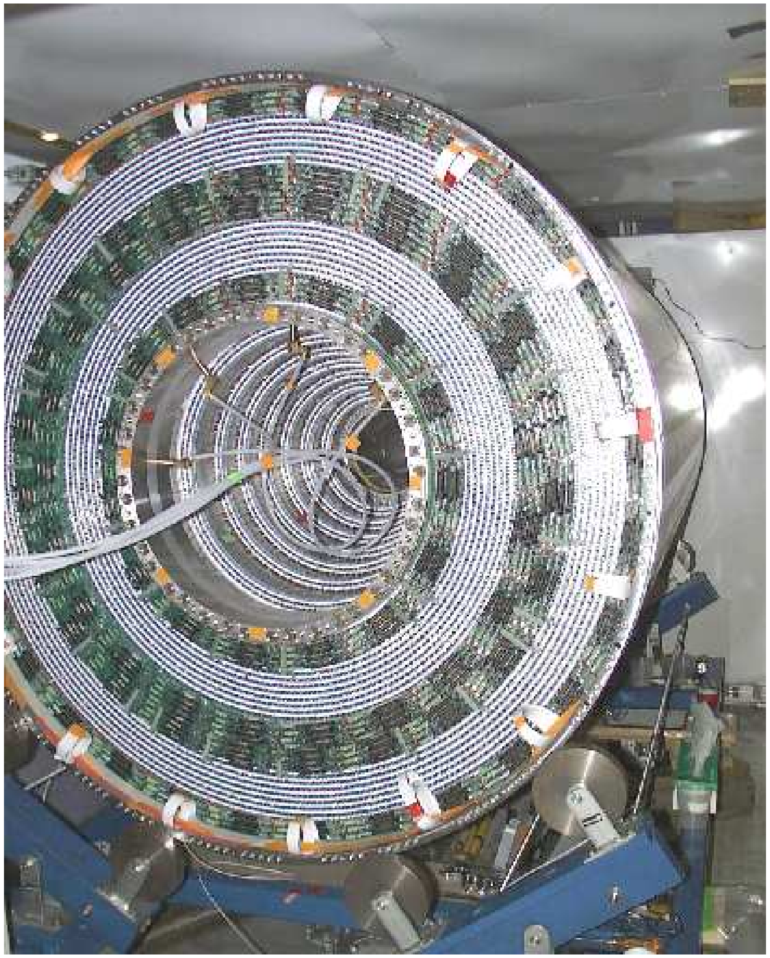
minimal radiating material:
particle ID
end cap CsI calorimeter

momentum resolution
as good at CLEO-II

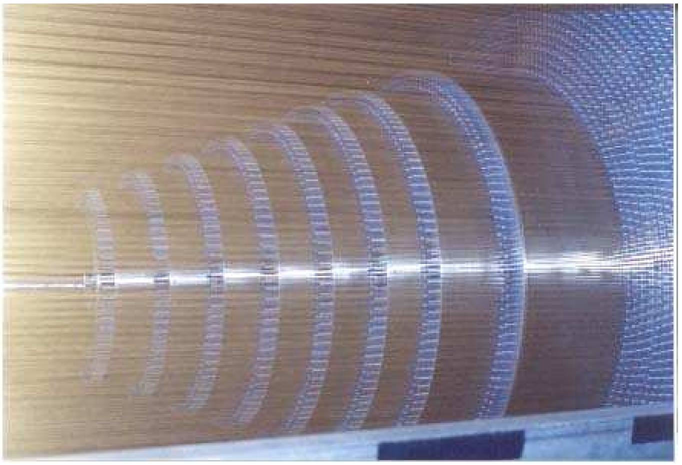
- uninterrupted tracking length
  0.12% X_0 inner wall

- improved spatial resolution
  cell improvements…

DR 3



CLEO III/c drift chamber
1999 – present
Design/Construction: 1992 - 1999

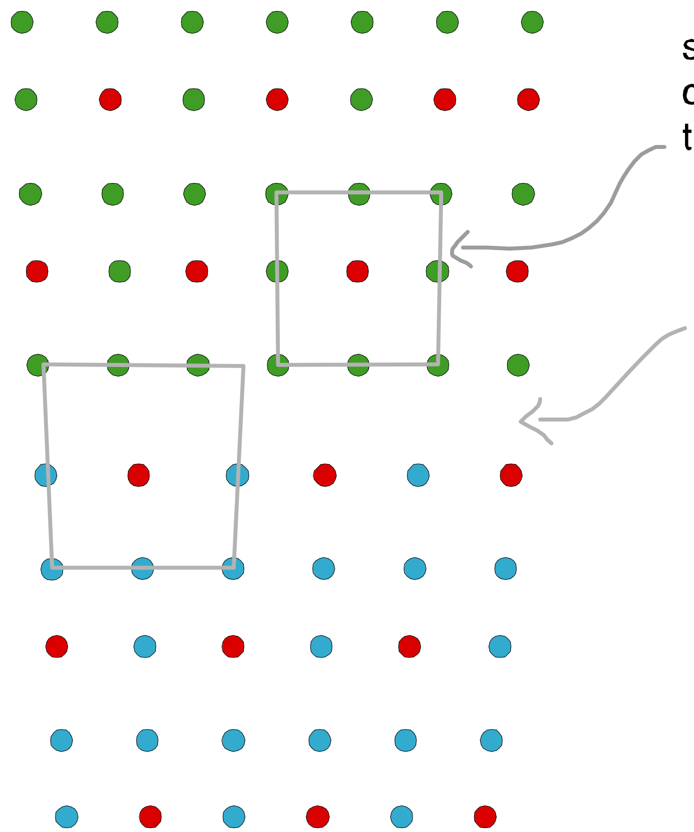


“wedding cake” structure; individual rings and bands

The conical “big” plate deforms < 1mm.

outer cathode

Cell Design



In a magnetic field,
a non-uniform up-down electric field would be rotated into a left-right asymmetry.

Adjust the sense wire position to compensate for non-uniform field wire density.
Drift cells are then electrically symmetric in the "r" direction (up-down) direction.

Left-right asymmetries are greatly reduced; calibration is simplified.
Field wire phase is not important.

Layer Design

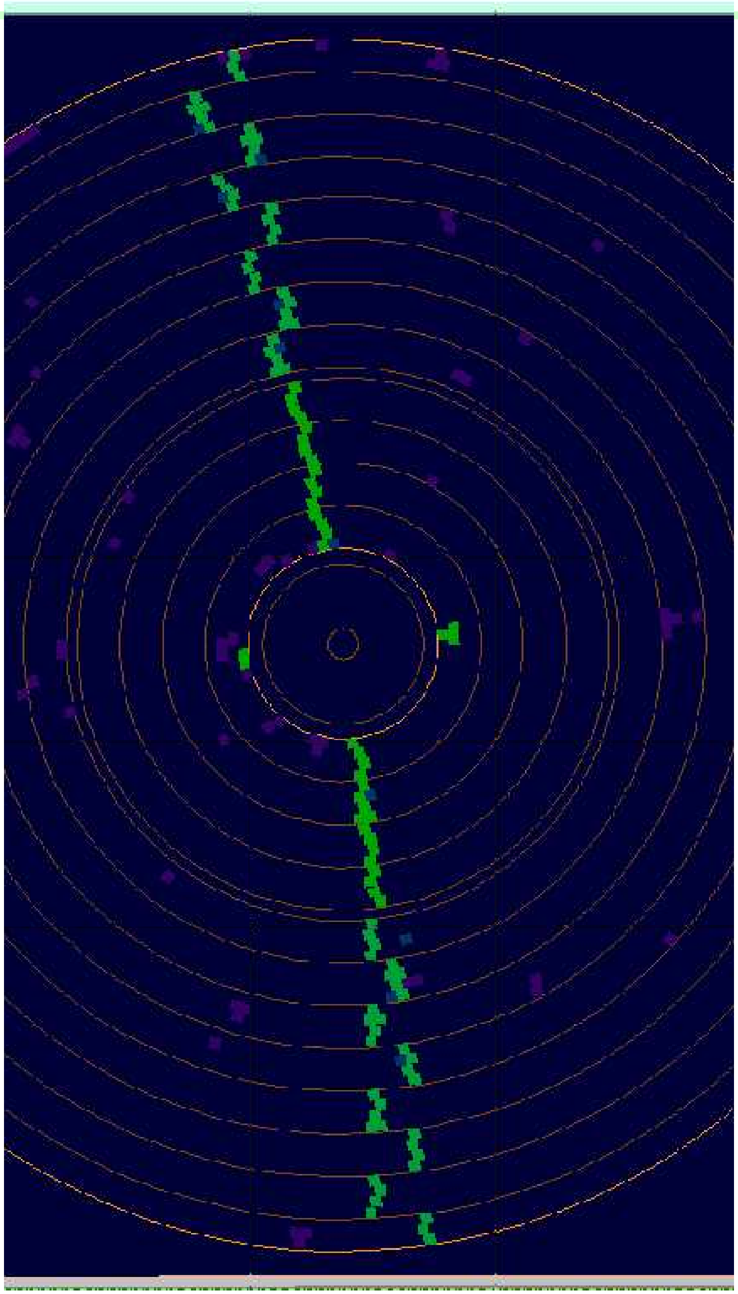
Maximize number of measurements:
AXIAL-STEREO interfaces, which require separate field layers or create distorted cell geometry, are limited by grouping stereo layers together.

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,
  - **nearly constant hyperbolic sag**

cell shape constant over the length of the chamber



Spatial Resolution

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

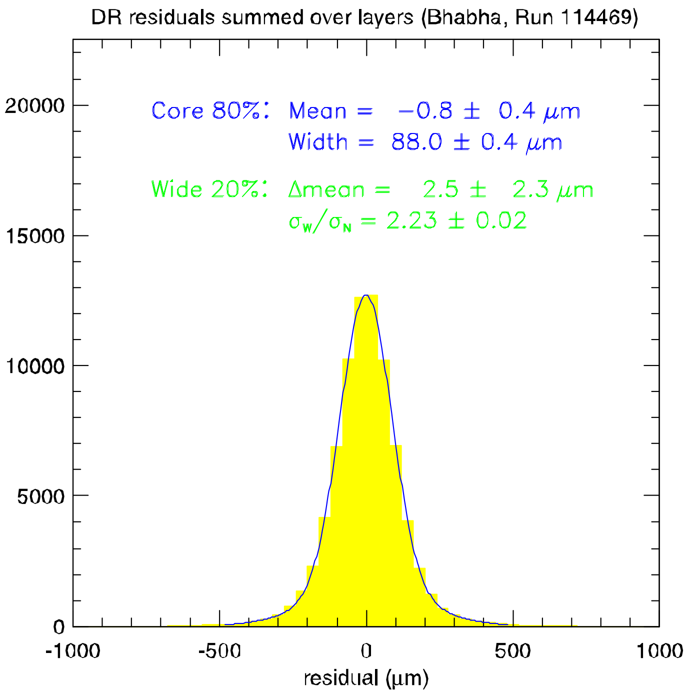
Parameterized as double gaussian with fixed 80% fraction in narrow component.

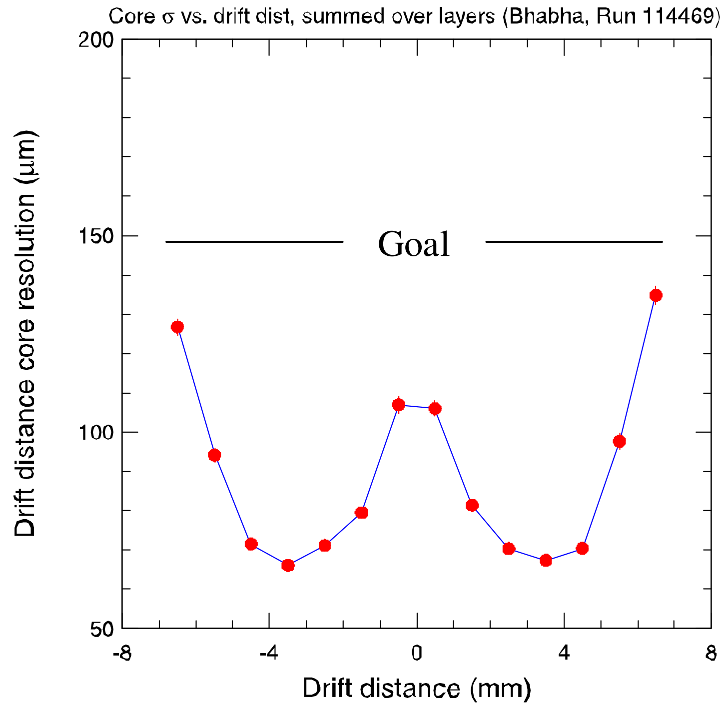
Narrow component:

σ=88 μm (average over entire cell)

wide component: 200 μm

average : 110 μm (Goal: 150 μm)



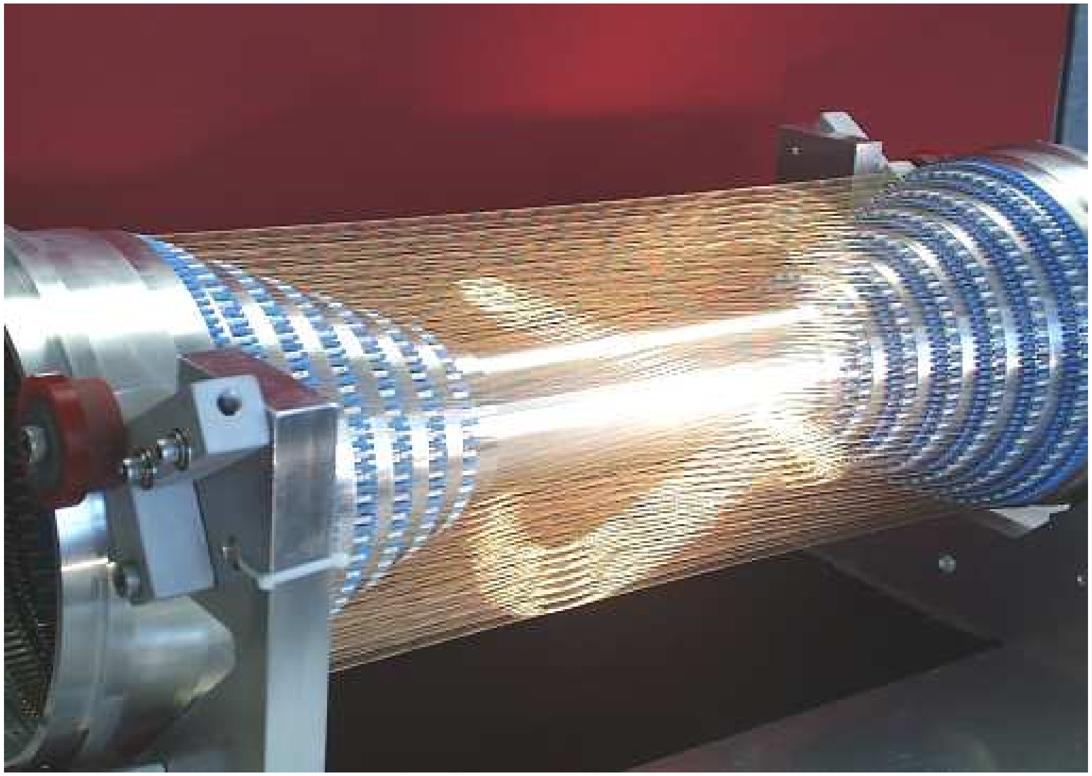


Narrow component of resolution w.r.t drift distance

65 μm minimum: due to calibration (next talk)

135 μm at cell edge: due to cell improvements

ZD



CLEO c   inner drift chamber
2003 – present
Design/Construction: 2001 - 2003

Goals:

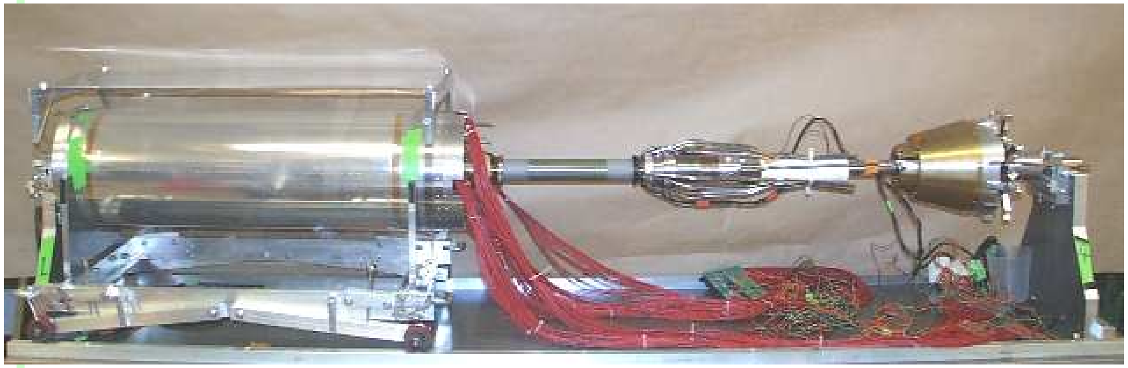
momentum resolution, σ_p/p, $p < 1$ GeV,   equivalent to that of DR3 + silicon
0.33% at 1 GeV

Z_0 resolution consistent with charm physics near threshold: 0.7 mm

Features:

very large stereo angle: $d(r\phi)/dz = 0.1$
0.01 % X_0 outer wall (0.12 % in DR3 inner wall) provides continuous volume

ZD installation



an integrated assembly involving
tracking and vacuum groups

The interaction vacuum chamber (2 layer beryllium, fluid cooled) was originally designed for installation with the clam-shelled Si-3 detector.

The vacuum chamber was retrofitted into the ZD chamber retaining all
- cooling,
- radiation monitoring, and
- tungsten masking.

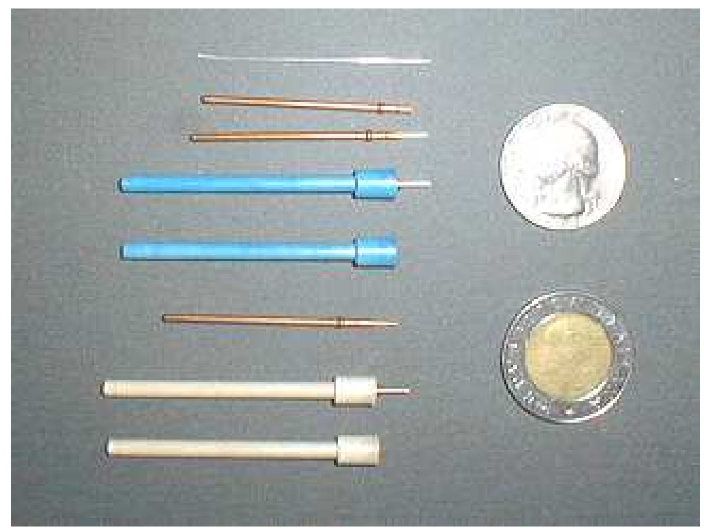
A boat-in-a-bottle problem.

Working with our **drafting dept.,** down-time was reduced by 3-D modeling the installation steps.

Cornell Influence

ZEUS:
- drift chamber design: influenced by CLEOII
- crimp pins: copied design and (Swiss) vendor

BaBar:
- general advice:
- endplate manufacture:
  - *Cornell is aggressive in pursuing vendors and working with vendors to develop processes to meet our requirements.*
  - BaBar had their drift chamber endplate fabricated at the commercial machine shop trained by Cornell.
  - (Photo shows DPP measuring the BaBar endplate at the commercial machine shop.)

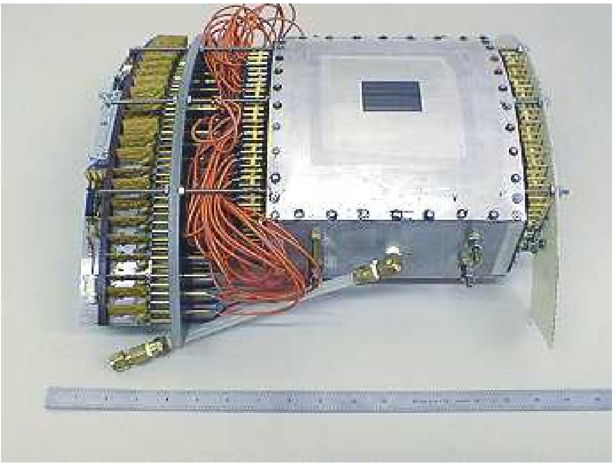


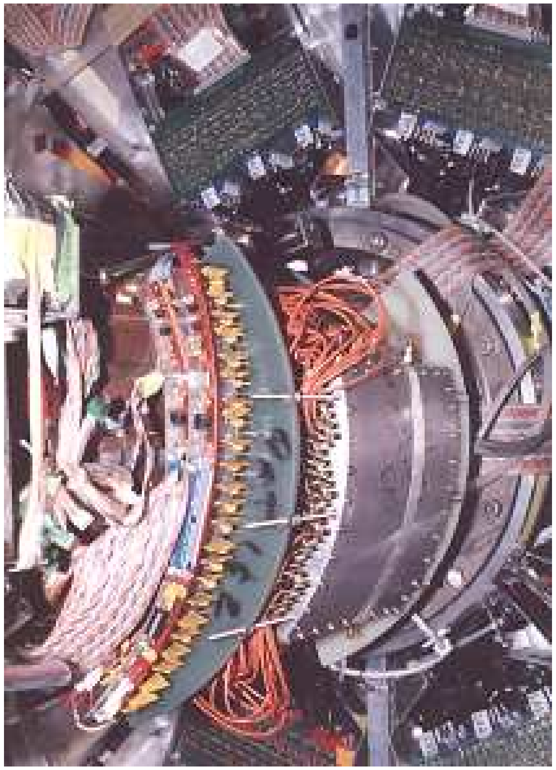
BESIII:
- design of inner endplate cone
- crimp pins: copied design and (US) vendor

Test Chambers

several test chambers; this shows two

10 layer device for
measuring helium based gasses in the CLEO B-field
fitted in the endcap, strapped to the final quadrupole
3:1 square and 3:1 hexagon chamber were tested

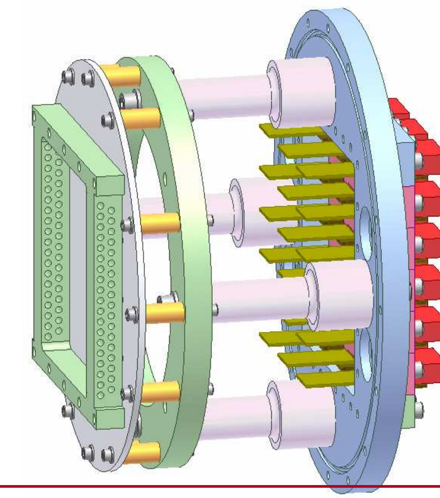




3 layer device to measure the ability
to control beam backgrounds at very low radius
inserted inside the, then, existing beam pipe

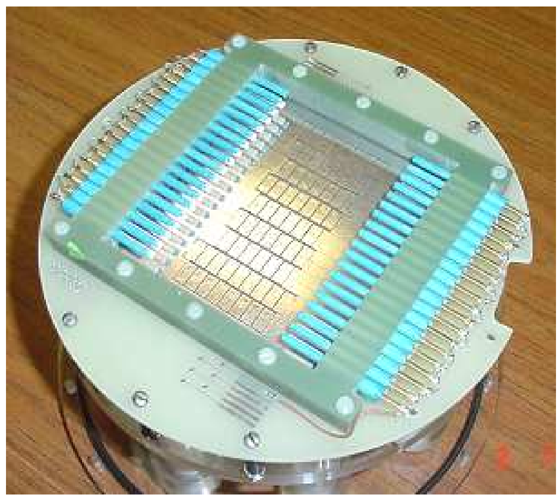
Linear Collider TPC R&D

TPC field cage, 64 cm, 20KV



readout end assembly, incl. feedthroughs

field cage termination, wire grid



wire avalanche stage, readout pads

TPC R&D is in collaboration with Ian Shipsey's group at Purdue who will provide the MPGD (GEM and MicroMegas) avalanche stages.

Pattern recognition

Various methods:

Some depend on intrinsic resolution, at some level requiring 3 points define circle (globally or locally).
This will probably be the case for the LHC pixel detectors; layer-layer spacing >> track separation.

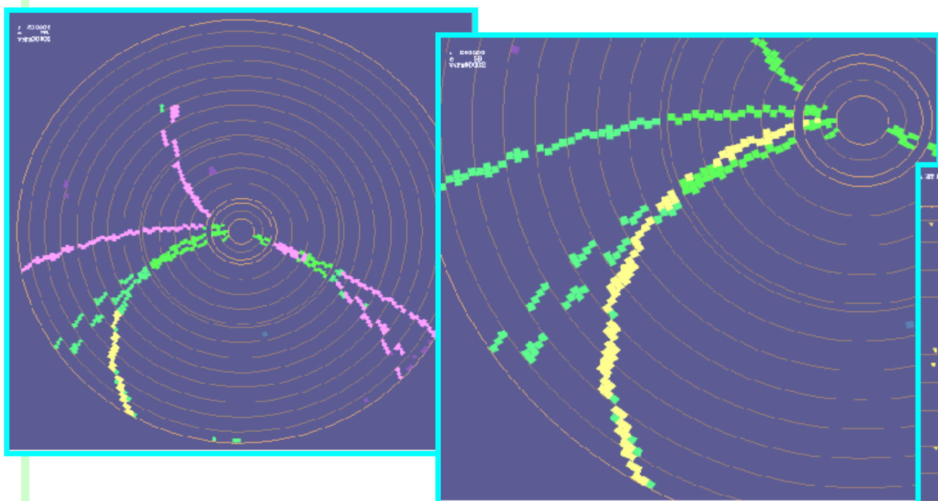
Our current method does not depend on intrinsic resolution to seed the track.

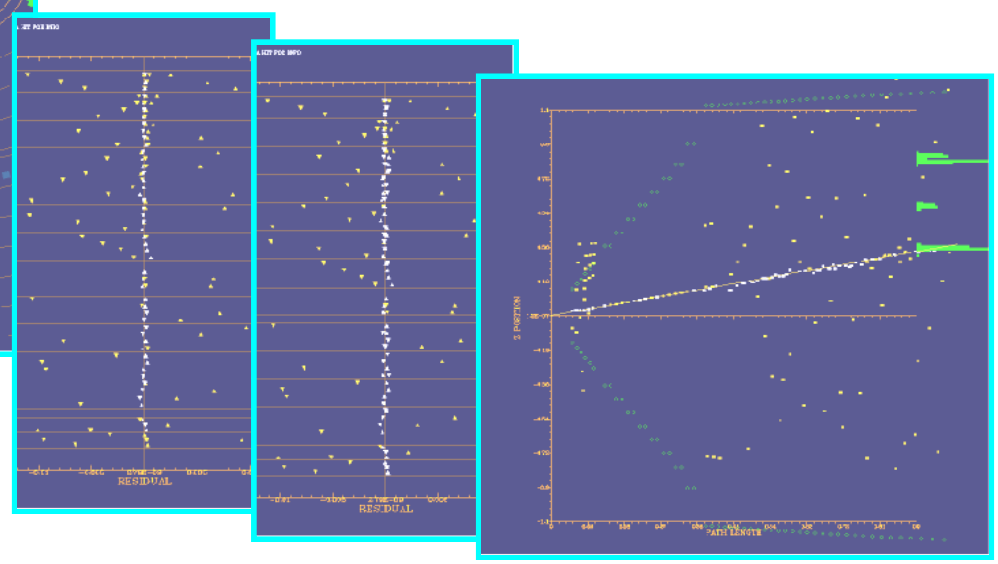
The method uses local chains of isolated hits at cell level,

extends into noisier regions,

then applies local-ambiguity-resolution using the precision information,

extends and adds still unidentified hits, now using precision information.

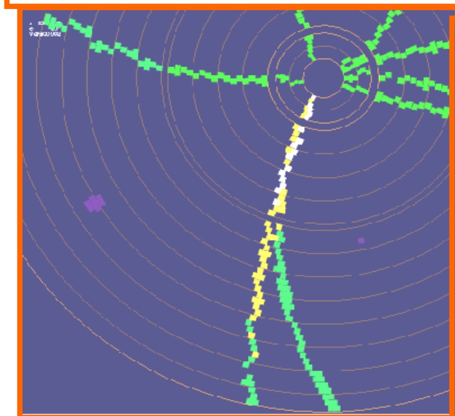


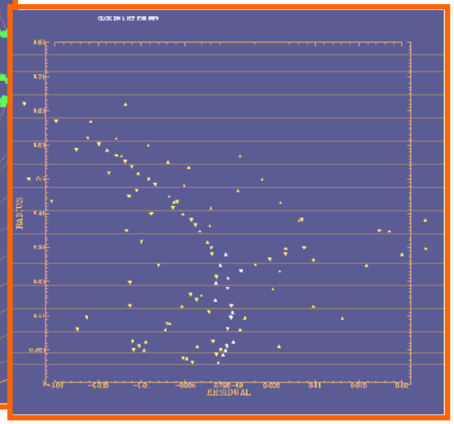


The algorithm has been optimized with the aid of the visual interface.

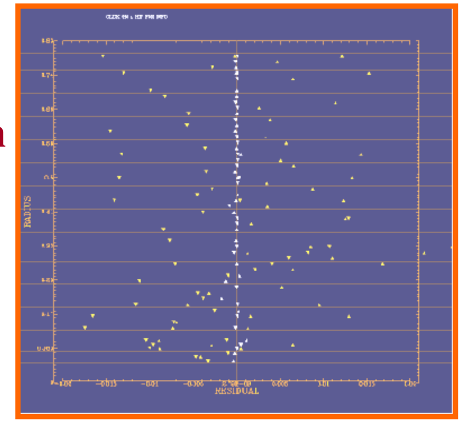
Pattern recognition pathologies

significant track overlap

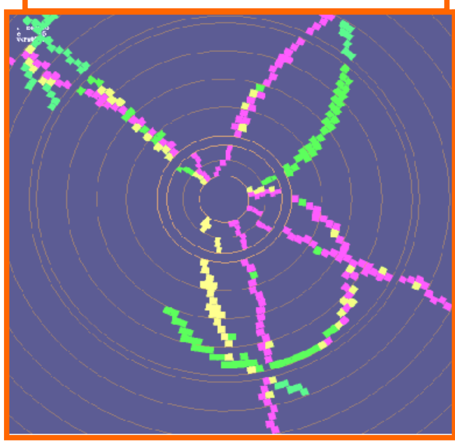


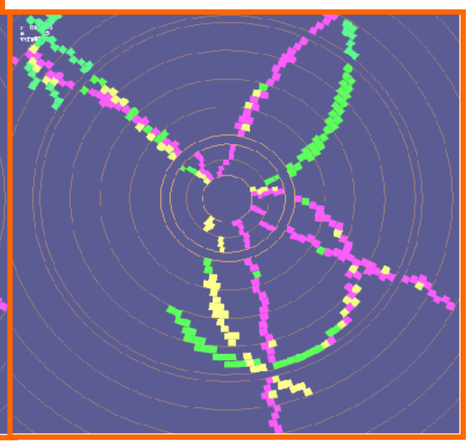


Loop:
initiate the **local-ambiguity-resolution** with a range of dZ hypotheses.

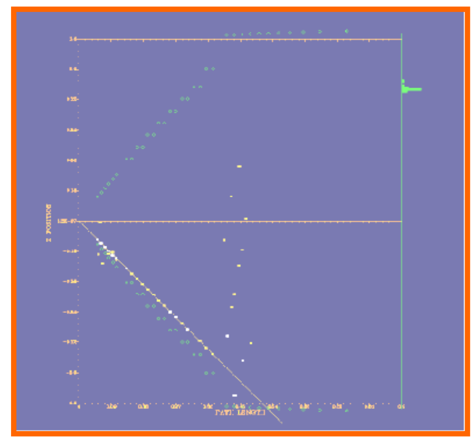


complexity in the ZD



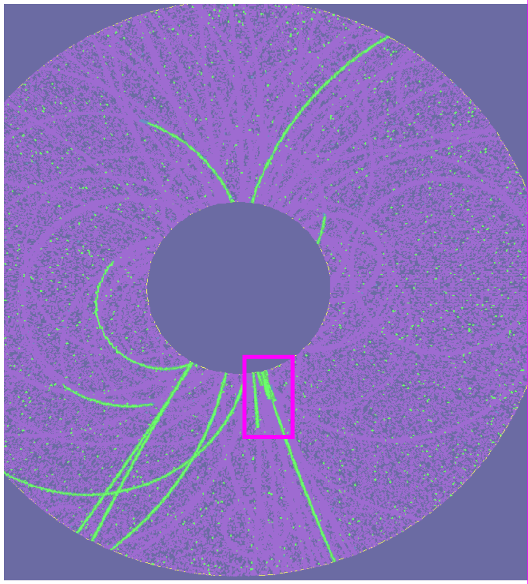


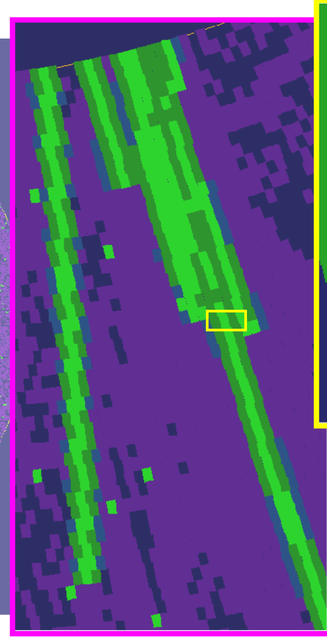
Loop:
initiate the **chain-finding** with a range of dZ hypotheses.

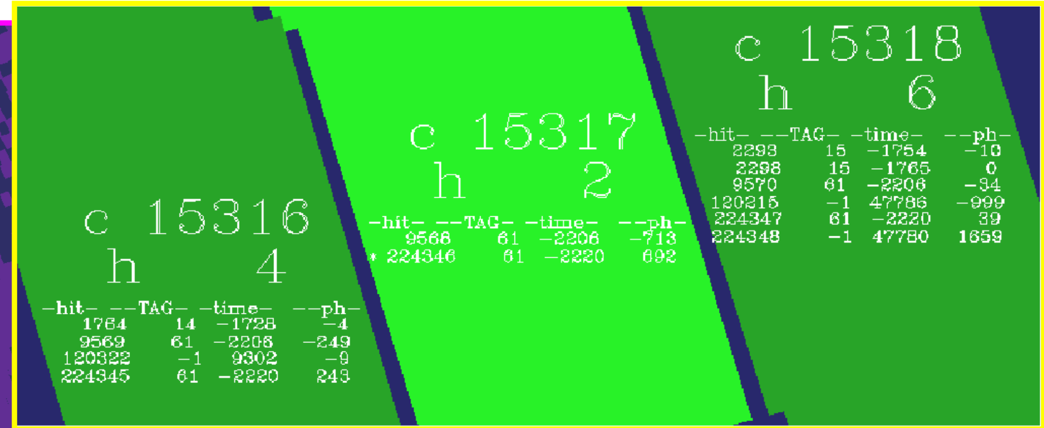


decays in flight: use tests with artificially shortened chamber radius, require decreased χ^2

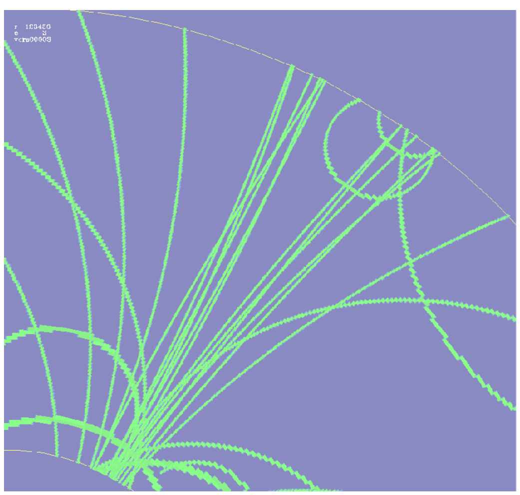
CLEO pattern recognition, application to a Linear Collider TPC





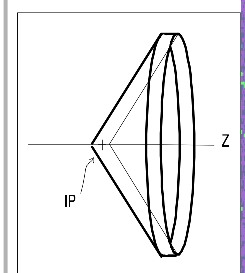


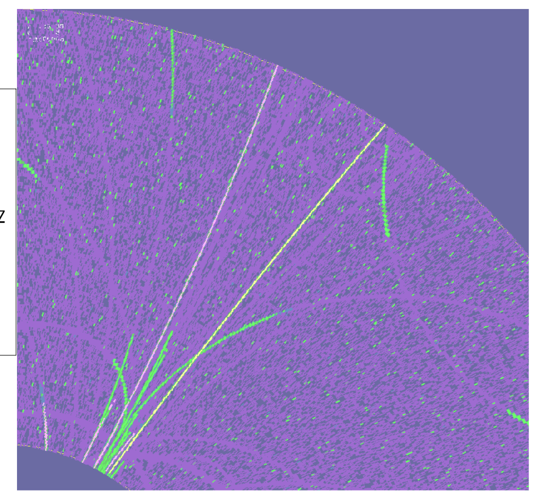
Cell count and track density are greatly increased.
Cells are multi-hit; time provides the z information.
At the cell level, pattern recognition is similar.
Only the means of extracting precision x,y,x information is different.



Scanning of the Z assumption greatly reduces event complexity.

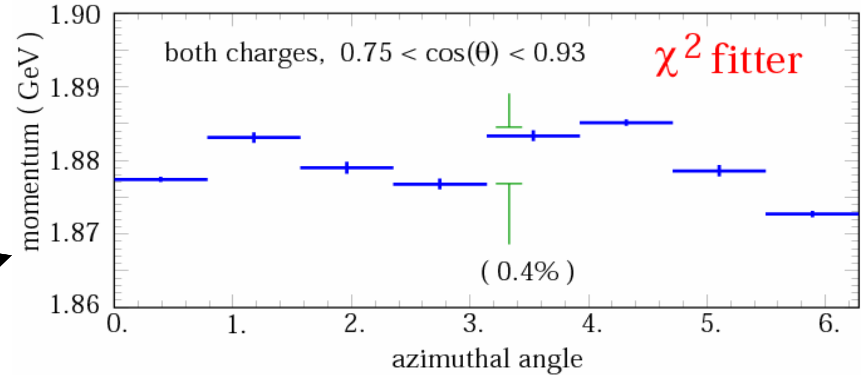
The program structure for the scan was first developed for the TPC, then applied to the ZD scan.





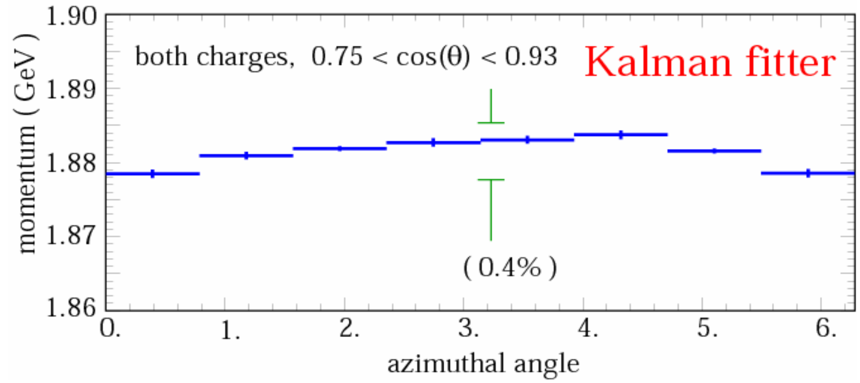
Kalman Fitting

The Kalman fit compensates for
 energy loss
 degradation of information due to scattering.



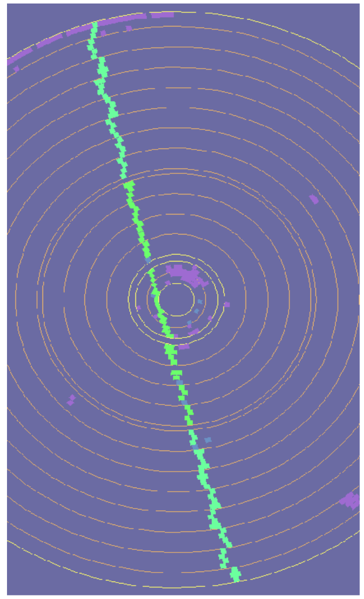
Transport method inherently allows
 application of a magnetic field map.

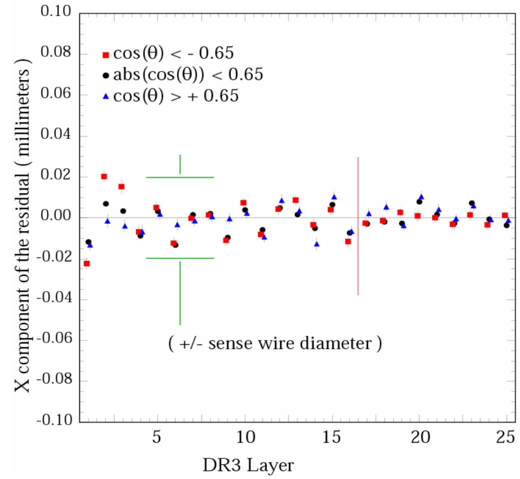
Our implementation also provides utilities to
 delete non-physical hits in a neutral decay hypothesis
 and refit.

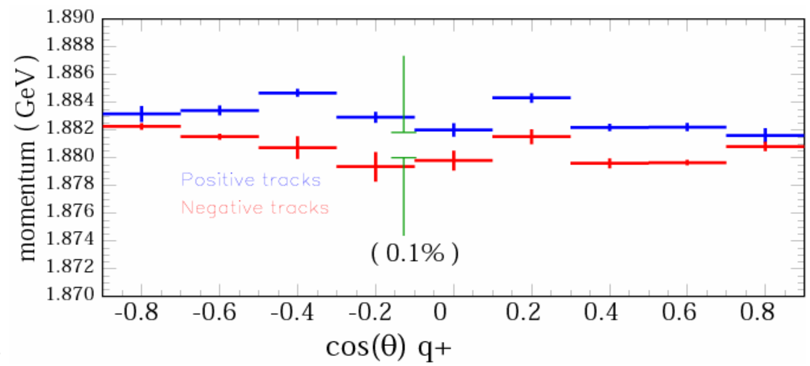


One of the authors of the original CLEO II program
 and the author of the CLEO III program
 are current members of the Cornell group.

alignment





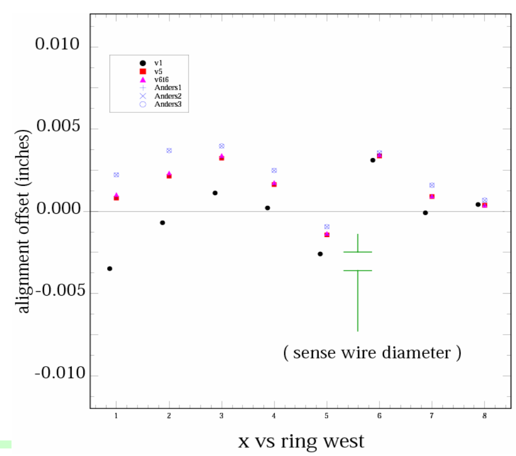


many parameter problem:
  2 ends - big plates, 8 small plates, ZD plates
  3 variables: δx, δy, $\delta\phi_z$

start with precision optical measurements before stringing
finish with clean data: Bhabha and mu pairs, cosmics.

sensible constraints: optical survey, mechanical tolerances
  for example: big-plate-to-big-plate twist ,
    the optical measure is superior to track measures

decoupled from calibration as much as possible;
  use symmetric drift region. (This is a large region due to cell.)



Last Slide !

Successful program in charged particle tracking

We are involved in every aspect of tracking.

Hardware designs are influenced by our calibration experience.
We approach calibrations and alignment with hardware experience.
It is the same people.

Track reconstruction is developed using a visual interface to quickly resolve pathologies.

We have benefited by working closely with the machine group for
 an integrated hardware design
 an understanding of backgrounds.

We have extensive technical support.
But, when a job is beyond our machine shops, we work **with** vendors.
 "Visit your vendors early and often."