Application of CLEO III Track Finding to a TPC

D. P. Peterson, R S. Galik, Cornell University, UCLC 30-June-2002

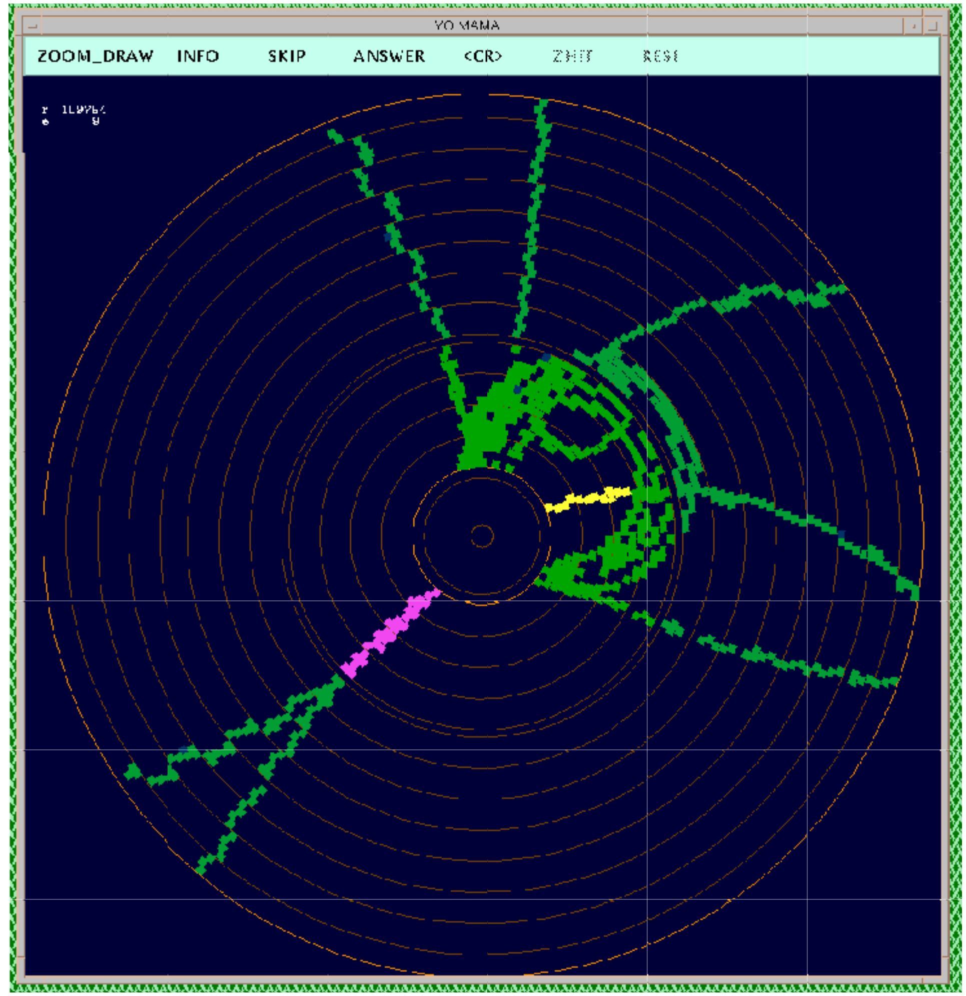
CLEO III track finding uses
cell level information in the initial phase,
does not depend on intrinsic device resolution,
is ideal for high (radial) density, low precision,
information.

CLEO III track finding was developed for a small-cell drift chamber but is applicable to any detector with similar cell-level information.

The goal of the initial phase is to find
segments that one would see by eye,
isolated anywhere in the chamber,
in contrast to algorithms seeded by arcs
defined by widely spaced (in radius) sets of hits.

A TPC is a 3-dimensional device. However, after clustering of the pad signals in r-ϕ, and assigning the cluster position to the closest pad center, projected TPC cell-level information is similar to that of a small-cell drift chamber.

This algorithm is readily applicable to a TPC.
(Course Z information can be used to reduce track and noise density that is projected onto the 2-D view.)



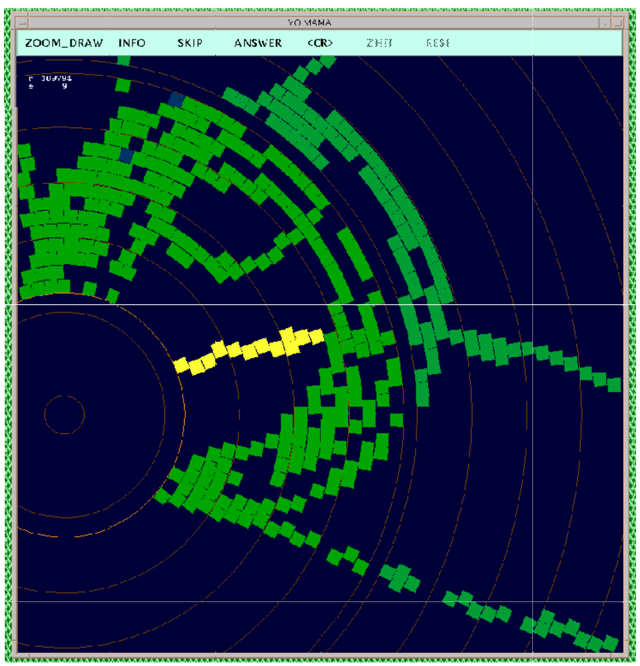
The found track **segmen**t. in yellow, is interrupted by the noise created by the looping track

CLEO III Track Finding.....Diagnostics, Graphics

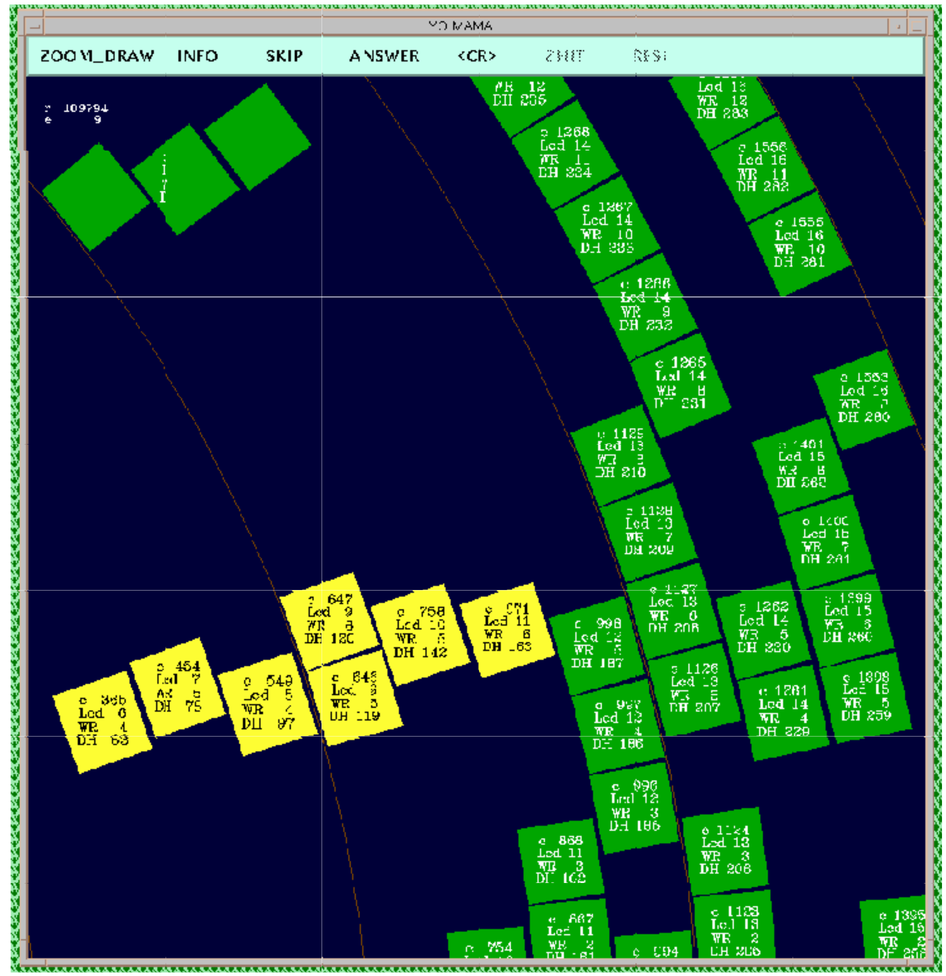
An important feature of CLEO III track finding is the **diagnostics package** providing information on the conditions encountered & decisions met in selecting track candidates at **intermediate steps** in the algorithm.

It is used for program development and provides the ability to **visually diagnose problems and pathologies**

Graphics features would translate well into JAVA.

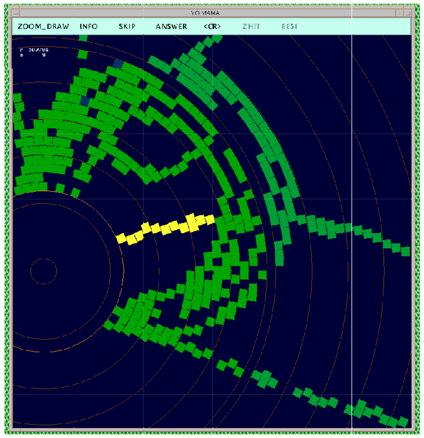


Zoom feature



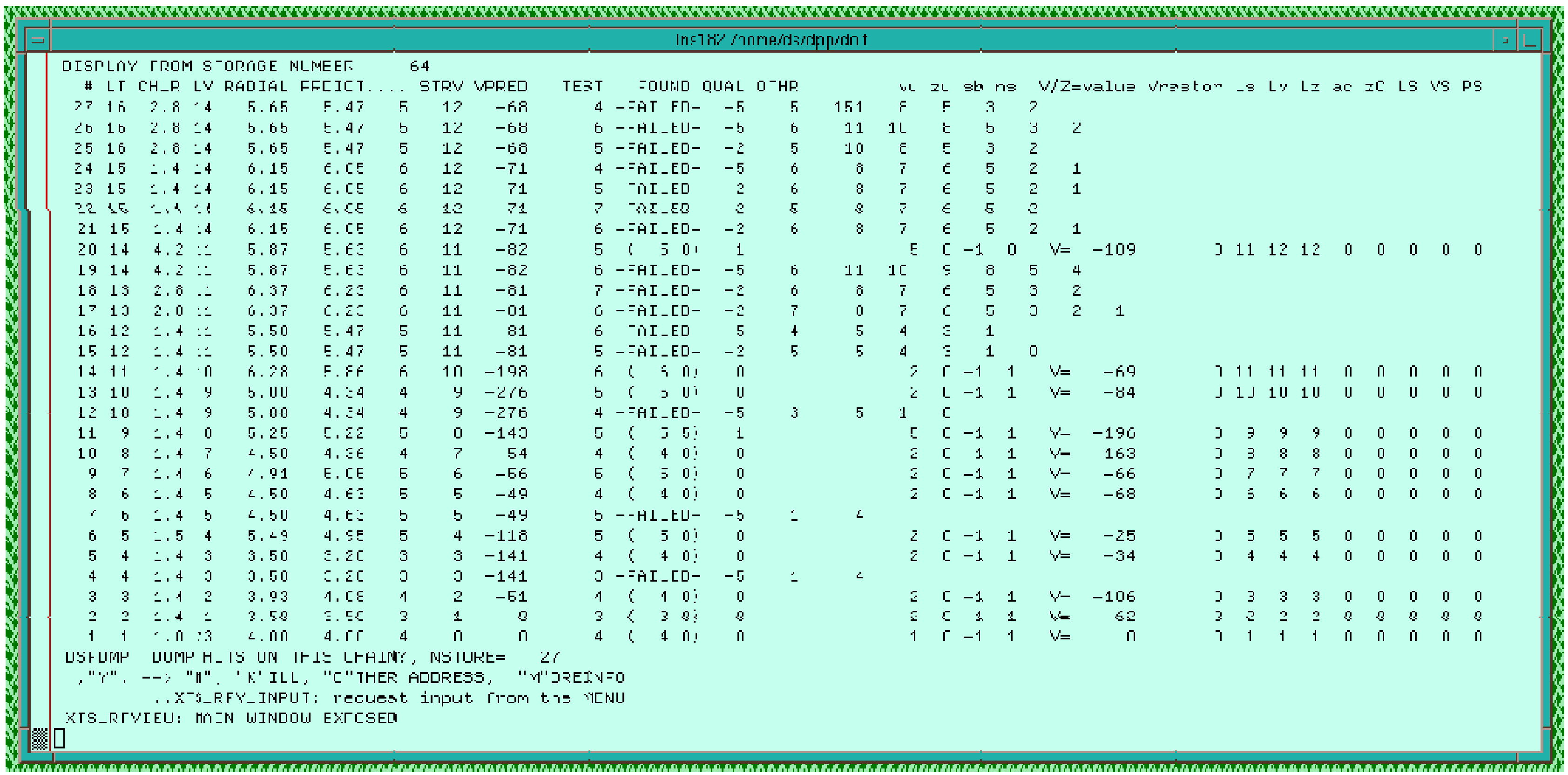
Cell information can be displayed for each cell. This can be device dependent.

CLEO III Track Finding…..Logging



The diagnostics package includes a logging feature that provides information on the successes and failures of the algorithm during the growth of a segment.

The chart below provides details on the conditions that lead to stopping the short segment.



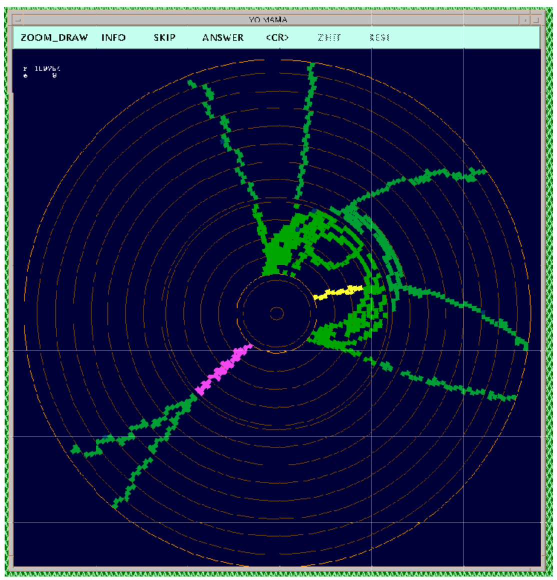
```
DISPLAY FROM STORAGE NUMBER      64
 # LT CH_R LV RADIAL PREDICT.... STRV VPRED   TEST  FOUND QUAL OTHR      vc zc sb ns  V/Z=value Vrestor Ls Lv Lz ac zC LS VS PS
27 16  2.8 14   5.65    5.47   5   12   -68    4 -FAILED-  -5    5  151   F   F    3    2
26 16  2.8 14   5.65    5.47   5   12   -68    6 --FAILED-  -5    6   11  10   6    5    3    2
25 16  2.8 14   5.65    5.47   5   12   -68    5 -FAILED-  -2    5   10   6   5    3    2
24 15  1.4 14   6.15    6.05   6   12   -71    4 -FAILED-  -5    6    8   7   6    5    2    1
23 15  1.4 14   6.15    6.05   6   12    71    5  FAILED    2    6    8   7   6    5    2    1
22 15  1.4 14   6.15    6.05   6   12    71    7  FAILED    2    5    8   7   6    5    2
21 15  1.4 14   6.15    6.05   6   12   -71    6 -FAILED-  -2    6    8   7   6    5    2    1
20 14  4.2 12   5.87    5.63   6   11   -82    5  (  5 0)   1             5   0  -1    0   V=  -109      0 11 12 12  0  0  0  0  0
19 14  4.2 12   5.87    5.63   6   11   -82    6 -FAILED-  -5    6   11  10   9    8    5    4
18 13  2.8 12   6.37    6.23   6   11   -81    7 -FAILED-  -2    6    8   7   6    5    3    2
17 13  2.0 12   6.37    6.23   6   11   -81    6 -FAILED-  -2    7    8   7   6    5    3    2    1
16 12  1.4 12   5.50    5.47   5   11    81    6  FAILED    5    4    5   4   3    1
15 12  1.4 12   5.50    5.47   5   11   -81    5 -FAILED-  -2    5    5   4   3    1    0
14 11  1.4 10   6.28    5.66   6   10  -198    6  (  5 0)   0             2   0  -1    1   V=   -69      0 11 11 11  0  0  0  0  0
13 10  1.4  9   5.00    4.34   4    9  -276    5  (  5 0)   0             2   0  -1    1   V=   -84      0 10 10 10  0  0  0  0  0
12 10  1.4  9   5.00    4.34   4    9  -276    4 -FAILED-  -5    3    5   1   0
11  9  1.4  0   5.25    5.22   5    0  -140    5  (  5 5)   1             5   0  -1    1   V=  -196      0  9  9  9  0  0  0  0  0
10  8  1.4  7   4.50    4.36   4    7    54    4  (  4 0)   0             2   0   1    1   V=   163      0  8  8  8  0  0  0  0  0
 9  7  1.4  6   4.91    5.05   5    6   -56    5  (  5 0)   0             2   0  -1    1   V=   -66      0  7  7  7  0  0  0  0  0
 8  6  1.4  5   4.50    4.63   5    5   -49    4  (  4 0)   0             2   0  -1    1   V=   -68      0  6  6  6  0  0  0  0  0
 7  6  1.4  5   4.50    4.63   5    5   -49    5 --FAILED-  -5    4    4
 6  5  1.5  4   5.49    4.95   5    4  -118    5  (  5 0)   0             2   0  -1    1   V=   -25      0  5  5  5  0  0  0  0  0
 5  4  1.4  3   3.50    3.20   3    3  -141    4  (  4 0)   0             2   0  -1    1   V=   -34      0  4  4  4  0  0  0  0  0
 4  4  1.4  3   3.50    3.20   3    3  -141    3 -FAILED-  -5    4    4
 3  3  1.4  2   3.93    4.08   4    2   -61    4  (  4 0)   0             2   0  -1    1   V=  -106      0  3  3  3  0  0  0  0  0
 2  2  1.4  1   3.58    3.50   3    1     0    3  (  3 0)   0             2   0   1    1   V=    62      0  2  2  2  0  0  0  0  0
 1  1  1.0 13   4.00    4.00   4    0     0    4  (  4 0)   0             1   0  -1    1   V=     0      0  1  1  1  0  0  0  0  0
DSFUMP  DUMP HITS ON THIS CHAIN?, NSTORE=   27
 ,"Y", --> "N", 'K'ILL, "O"THER ADDRESS,  "M"OREINFO
       ..XTS_RFY_INPUT: request input from the MENU
XTS_RFVIEW: MAIN WINDOW EXPOSED
```

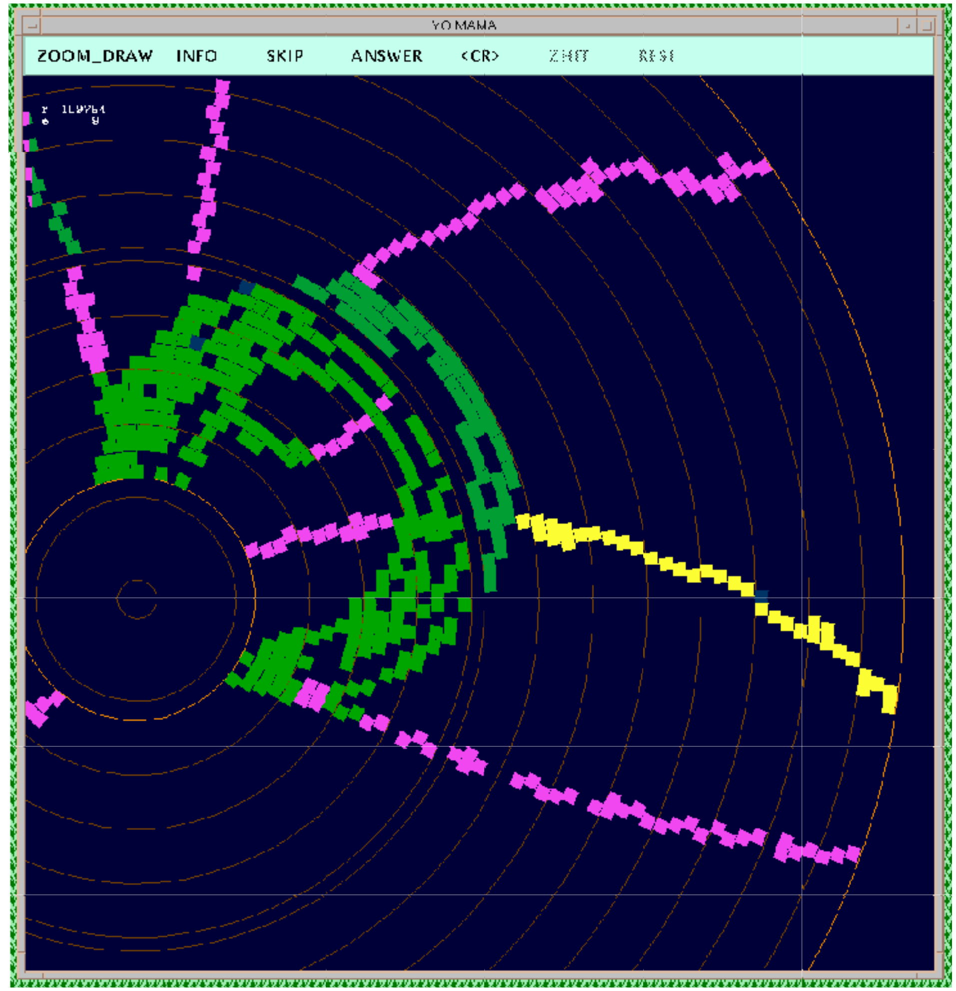
CLEO III Track Finding.....Segment Finding

I will describe some of the features of the algorithm before applying it to a TPC.

Segment-finding can start at any layer and run outward or inward.

It proceeds by adding cells satisfying tunable conditions of continuity and isolation.

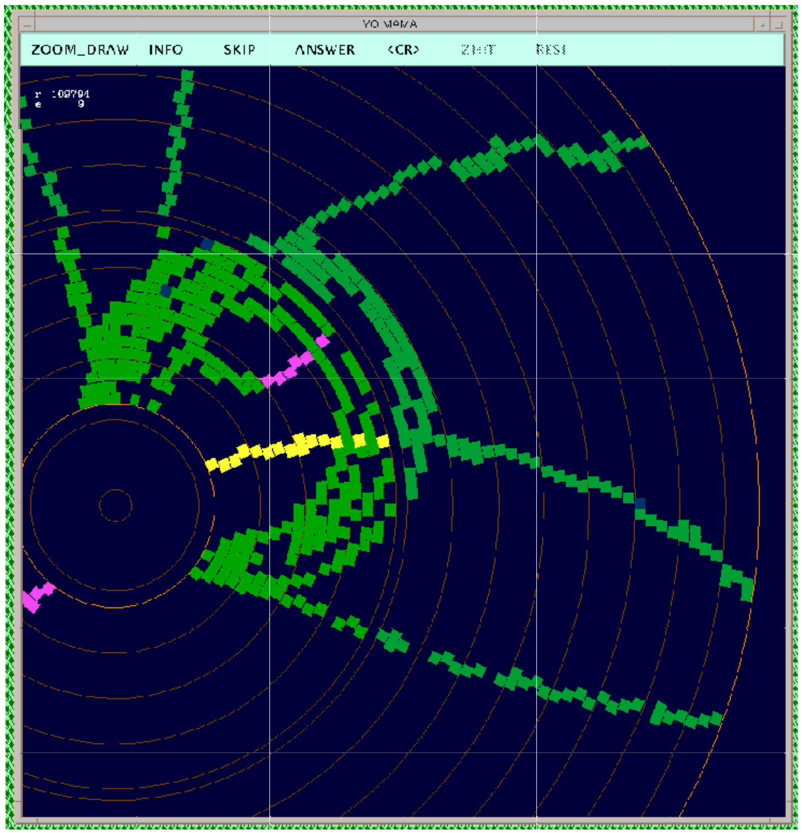




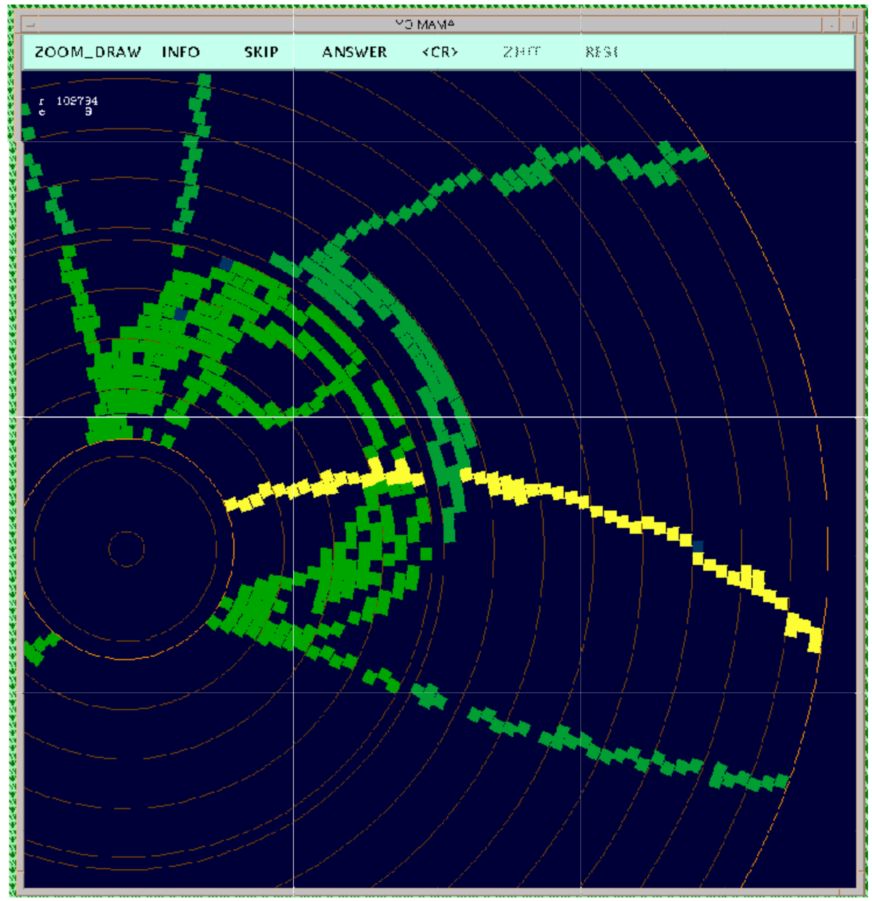
Here, the latter half of the track is found as a second segment.

CLEO III Track Finding.....Overcoming Noise "extend" and "merge"

After all clean segments are found *(within the z-projection road for a TPC application),* well established segments can be **extended** into noisier regions.



Two segments can be **merged** into another segment.
Merge provides compensation for the tight hit selection requirements used in initial segment-finding.



Application of CLEO III Track Finding to a TPC
.....Segment Selection

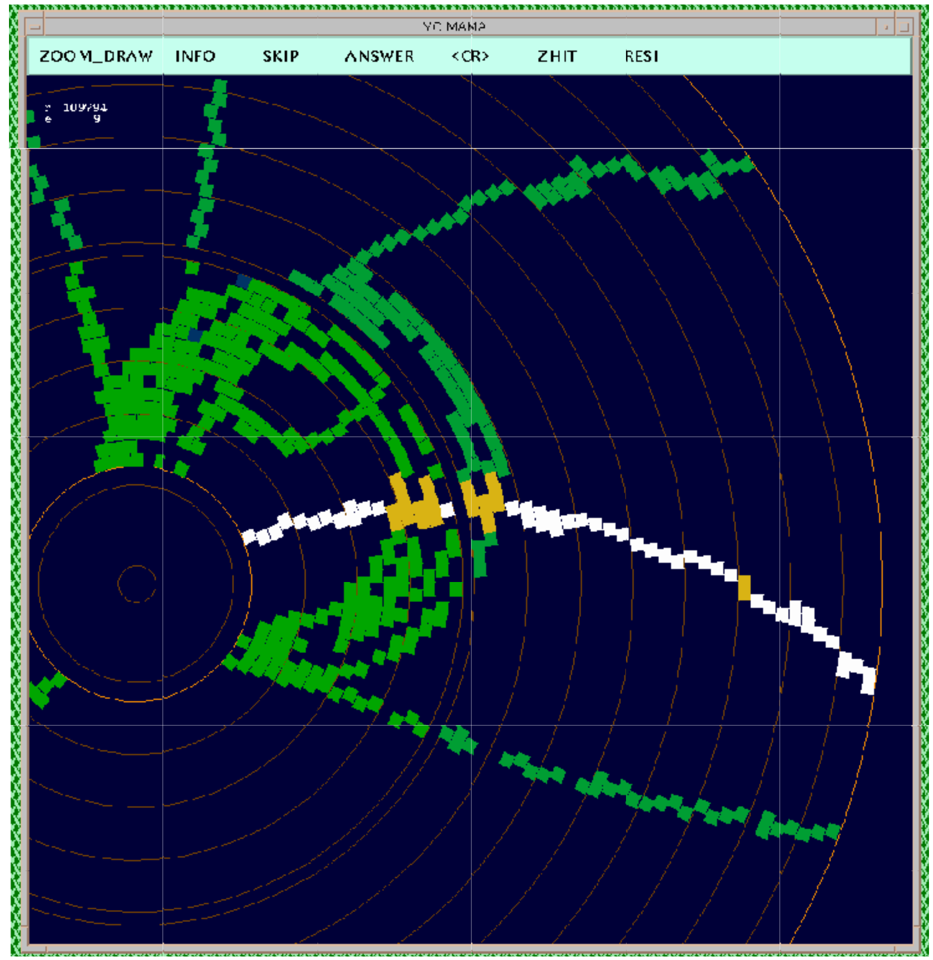
Segments are be selected, by order of quality,
for **further processing**.

Processing starts by fitting the **cell locations**
to a hypothesis function (helix).

Here, only the isolated cells (in white) are
included in the fit.

The orange cells are in a road but not yet in the fit.

At this level,
TPC data could be treated
much like drift chamber data.



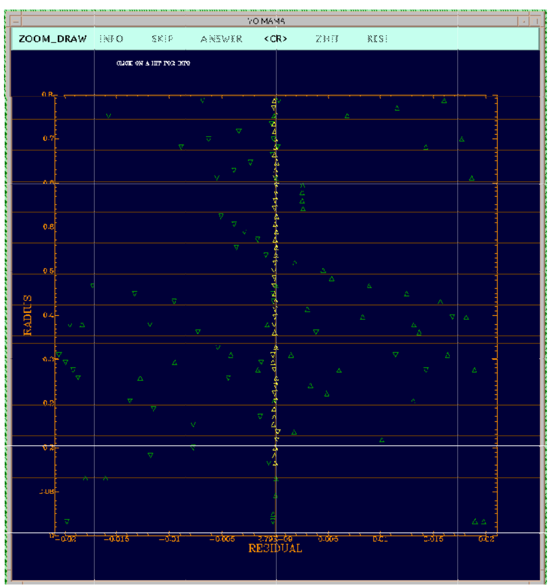
CLEO III Track Finding .....second phase

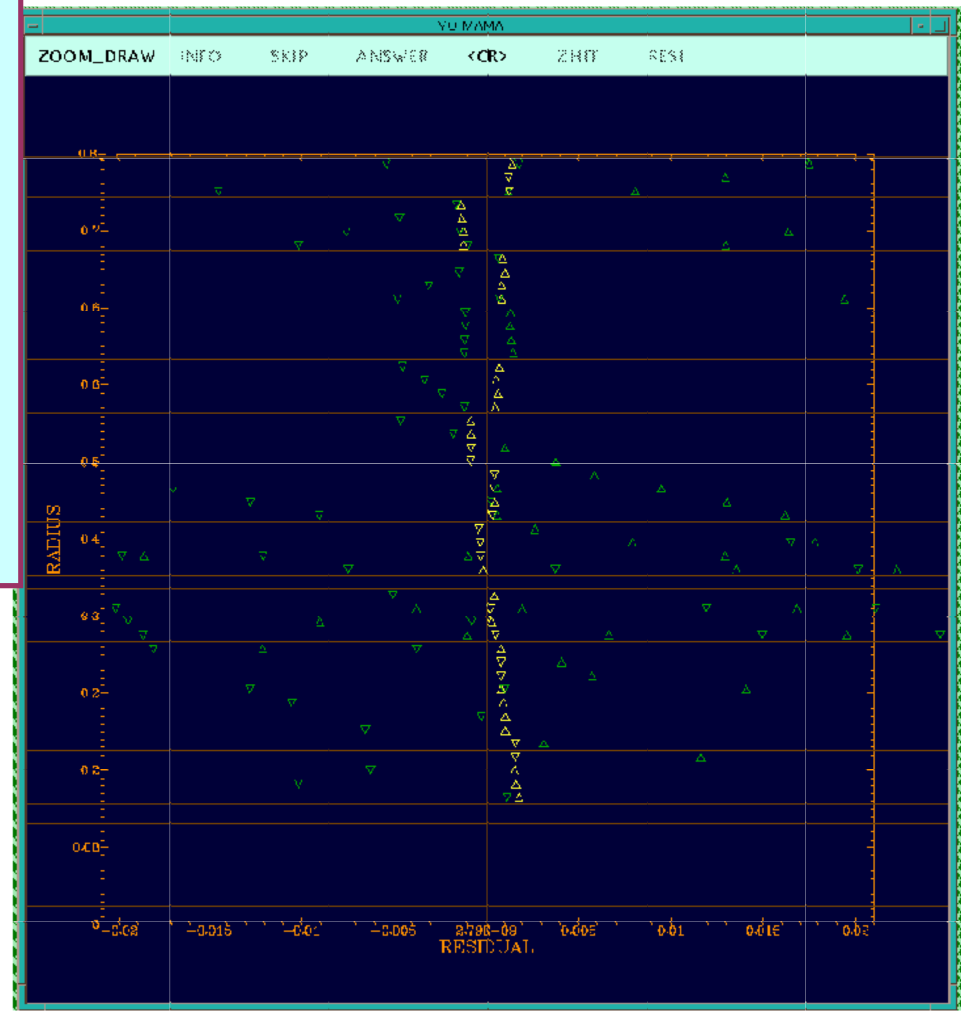
Processing continues using in the second phase using preliminary corrected position measurements.

Final corrected cluster position measurements (e.g. including correction for track angle) would not be required because the track is well-defined at the cell information level.

Local ambiguity resolution is used to determine the drift sign (not applicable to a TPC).

Track segments defined in super-layers are matched to form a track meeting continuity requirements. (This is directly applicable to a TPC.)





The **residual display** is used for diagnostics and development of the latter phases.

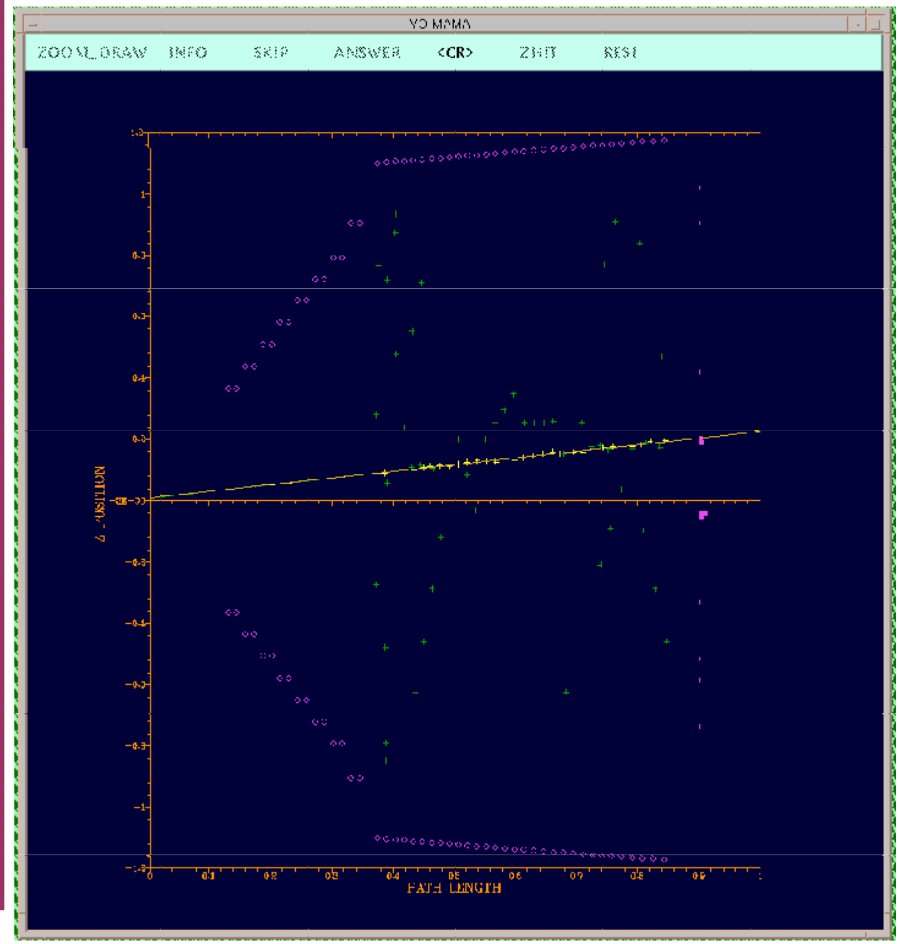
Application of CLEO III Track Finding to a TPC
.....differences in the second phase

A **small-cell drift chamber** has
time information for precise r-ϕ measurements,
a drift distance **sign ambiguity**, and
pulse height information.
Stereo layers provide the z information.

A **TPC** has
time information for precise z measurements
and pulse height and shape information.

r-ϕ –z hit information in **both** applications.

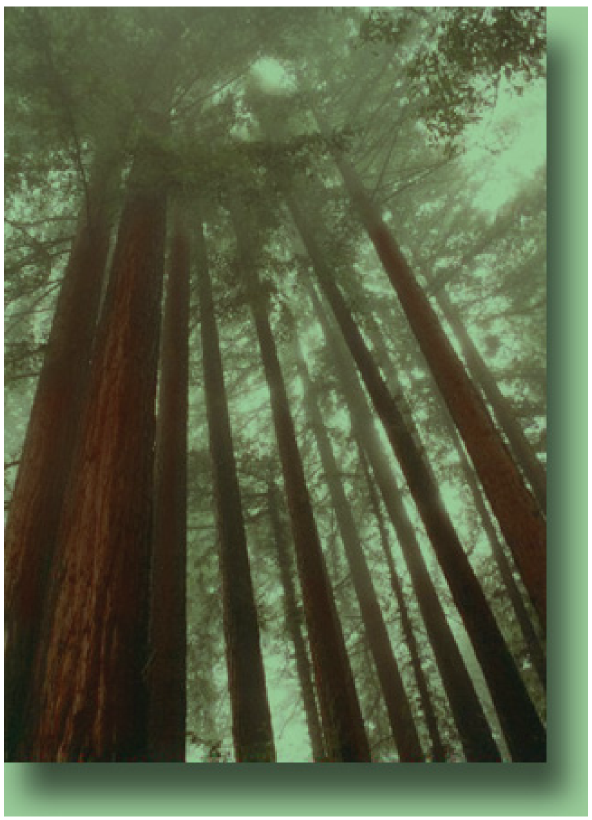
In a **TPC**,
the **z projection is not coupled** with r-ϕ
because there is no sign ambiguity.
Second phase hit selection is less complicated.

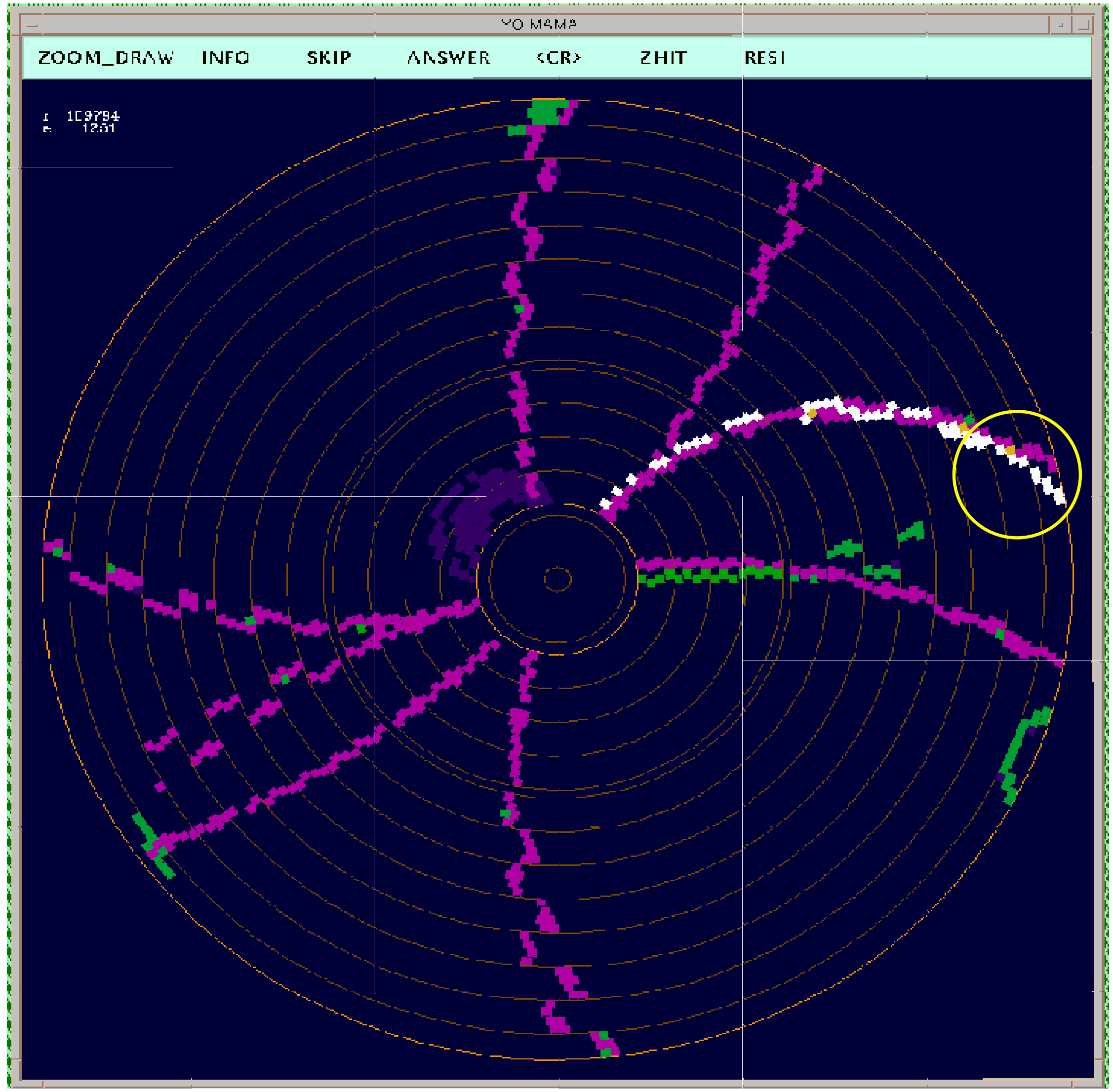


The Z-projection. Both applications use a z fit to discriminate against bad initial-phase segments

track extension in the second phase

CLEO III track finding,
using fitted track segments
in **self selected isolated regions,**
is highly successful in extending
tracks into complicated noisy regions.





You see into the crowns of the trees because the trunks tell you where to look.

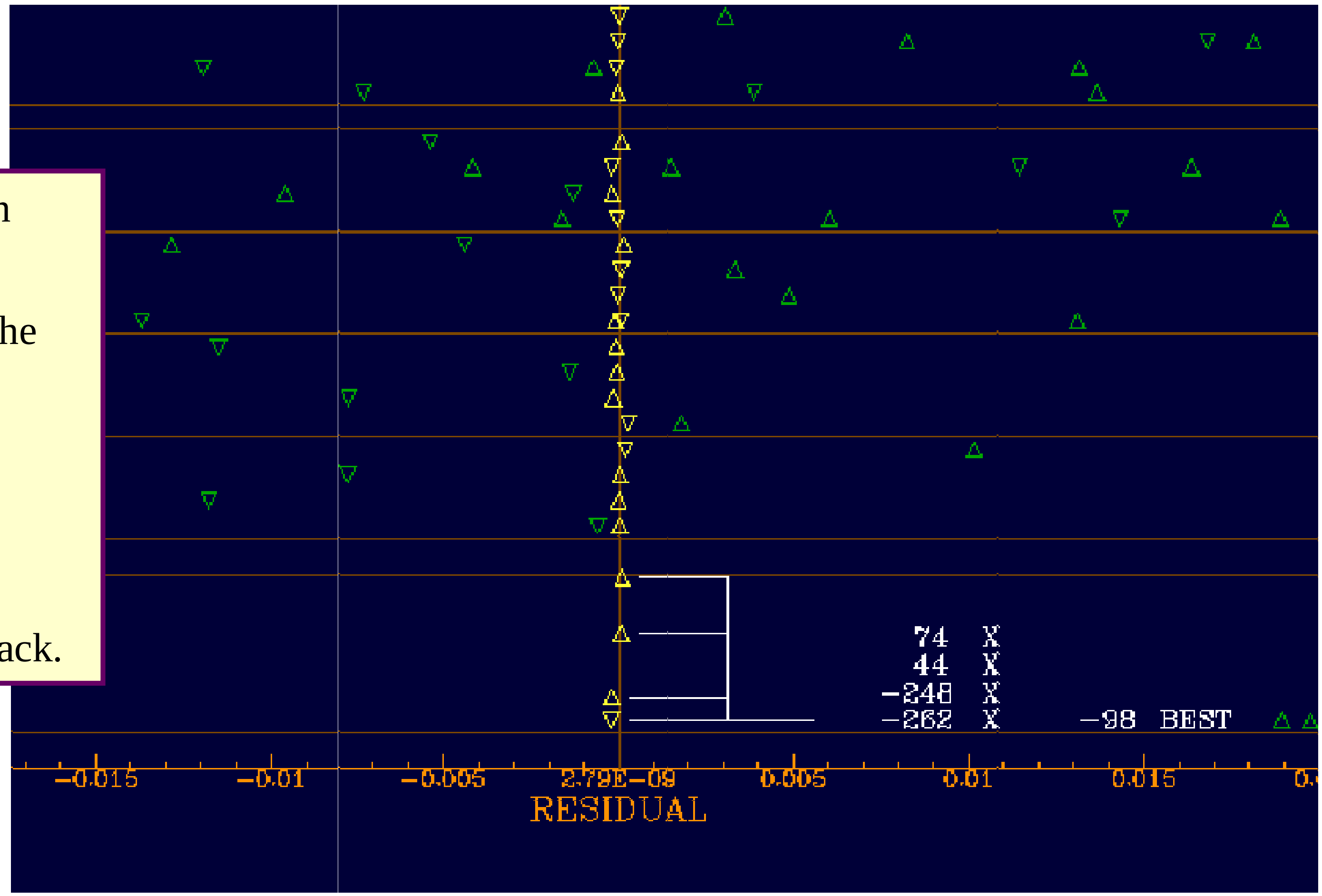
CLEO III Track Finding .....third phase

In a third phase, the track can be extended from the TPC into the silicon vertex detector.

The 4 silicon hits have been selected as a “group”

with the characteristic that the hits have a small residual spread within the group

but may have a larger average residual relative to the established track.



Silicon hits shown in the **residual display**

"TPC event"

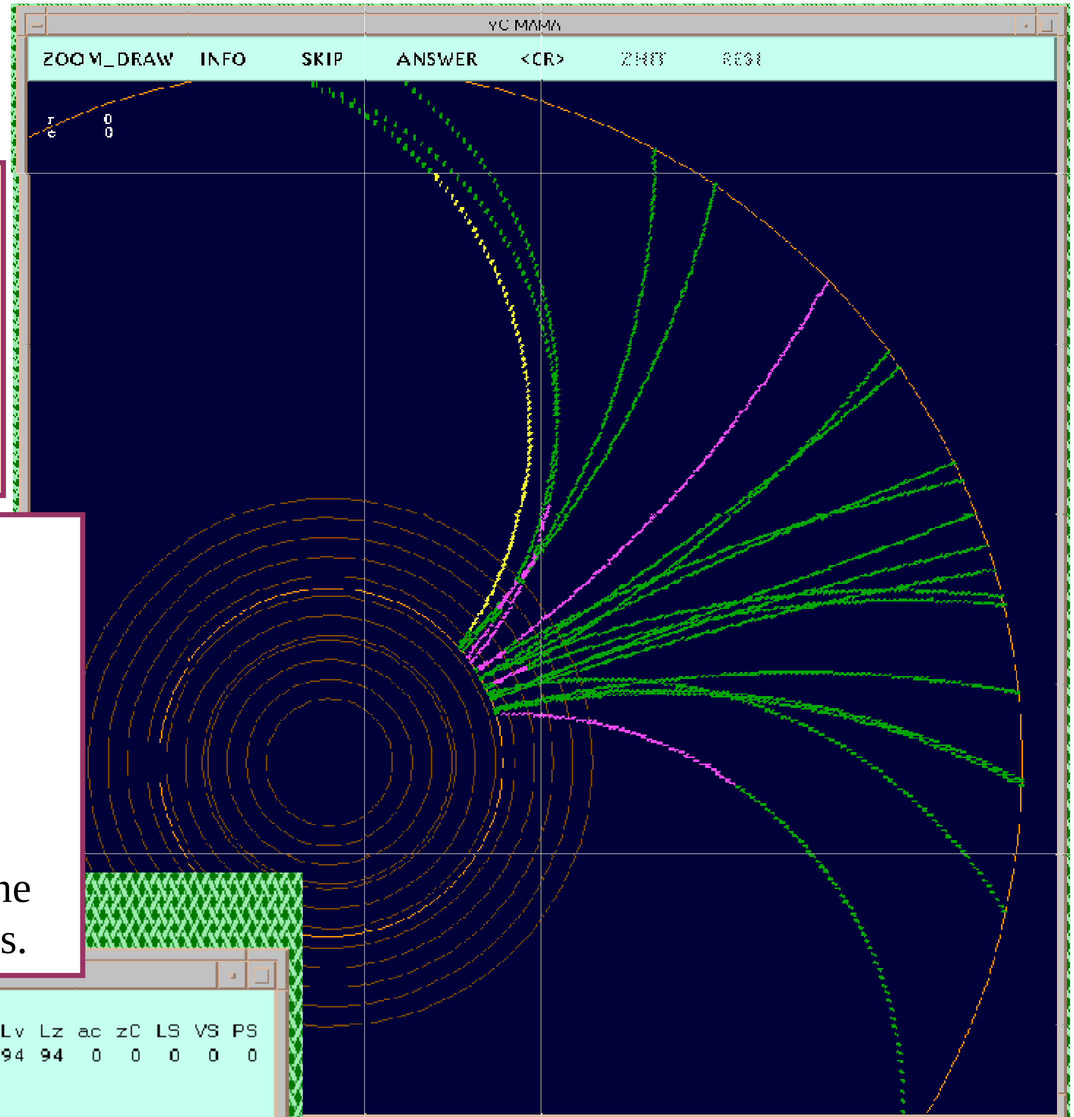
idealized detector, 100 layers, 2m o.r.
5mm x 15mm cells
single pad "hits", no clustering, no noise,
no Z clustering, only 1 hit/cell

20 tracks in the jet, +/- .3 in ϕ, +/- .3 in $\cot\theta$

Tracks are found, but
there are many short segments.
Yellow indicates current track,
Pink, a previous track,
Green, valid hits for pattern recognition.

Reason for premature end of current track is
indicated in the log. (The track was found to the
last layer but the single hits look like stragglers.

```
TEST    FOUND  QUAL OTHR            vu zu sb ns  V/Z=value Vrestor Ls Lv Lz ac zC LS VS PS
 653  (653.0)    0                   2  0 -1  0   V=  1438         0 77 94 94  0  0  0  0  0
 650 -FAILED-   -5    1   653
 652 -FAILED-   -5    1   653
 651 -FAILED-   -5    1   653
 642 -FAILED-   -2    2   642 644
 640 -FAILED-   -5    2   642 644
 641 -FAILED-   -5    2   642 644
 630  (630.0)    0                   2  0 -1  0   V=  1352         0 77 93 93  0  0  0  0  0
 629 -FAILED-   -5    1   630
 621 -FAILED-   -5    2   619 617
 620 -FAILED-   -5    2   619 617
 619 -FAILED-   -2    2   619 617
 609  (609.0)    0                   2  0 -1  0   V=  1289         0 77 92 92  0  0  0  0  0
 608 -FAILED-   -5    2   609 605
 598  (598.0)    0                   2  0 -1  0   V=  1238         0 77 91 91  0  0  0  0  0
 588  (588.0)    0                   2  0 -1  0   V=  1217         0 77 90 90  0  0  0  0  0
```



No changes to the basic
pattern recognition.
No Z information is used, yet

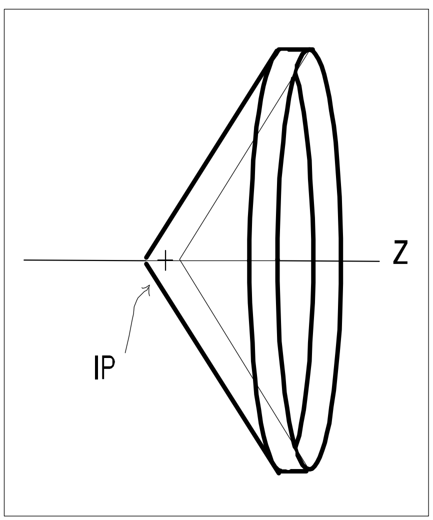
"TPC event", selected Z-projection road

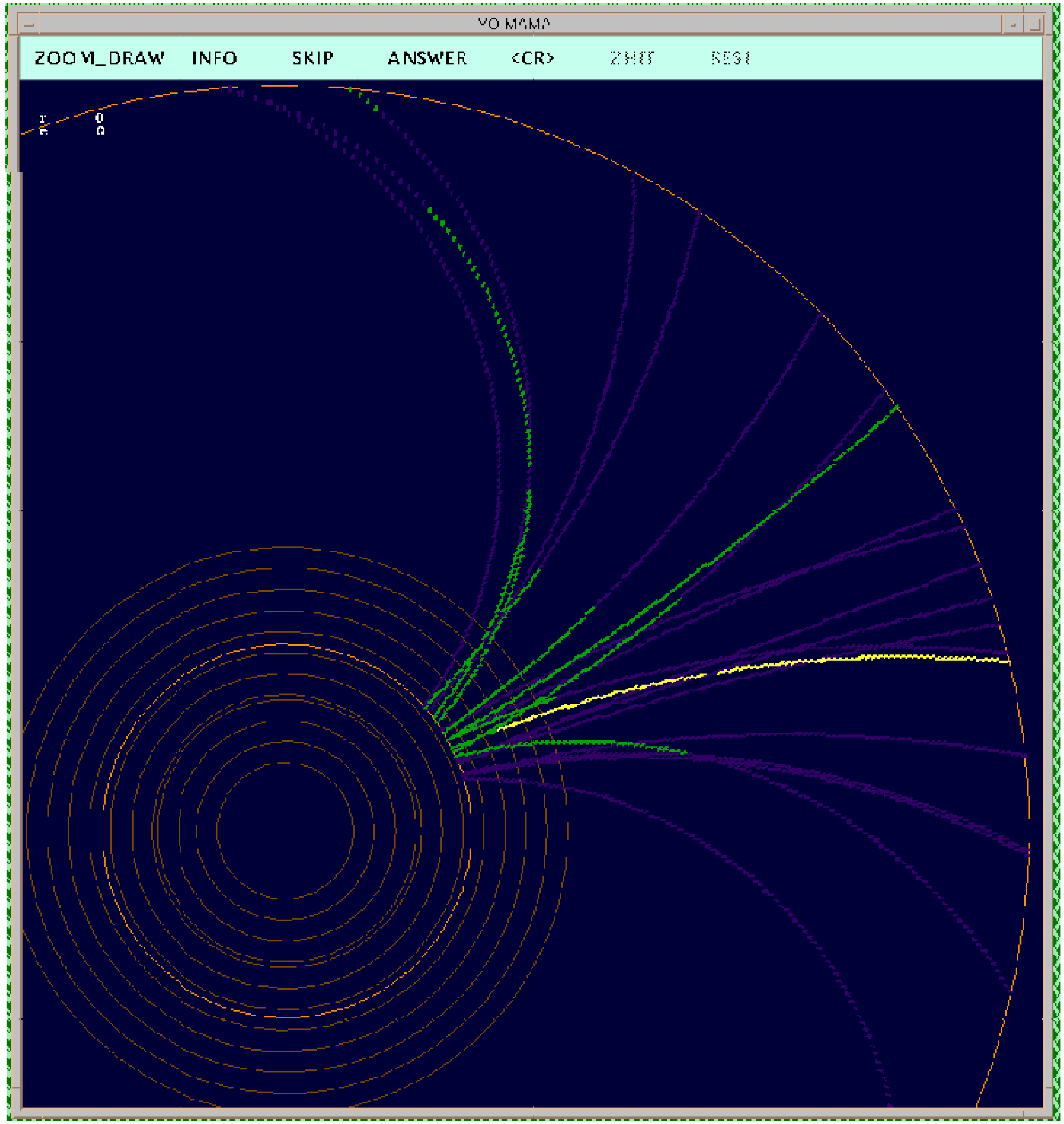
Hits are pre-selected to come from a z-projection cone.

Yellow indicates current track,
Green, valid hits for pattern rec.,
Purple, invalid, out-of-time.

Tracks are resolved.
Short segments may be ignored; they will be resolved in another projection.
Note: the curler falls out of the road.

Plan:
scan through the z projection roads.





Application of CLEO III Track Finding to a TPC, plan and costs

Convert to a format that is compatible with an **existing Linear Collider detector simulation**.

Optimize the method of selecting/scanning the **Z projection roads**.

Add **TPC detector specific information** to the 2^{nd} stage pattern recognition.

Add **clustering** in r-ϕ and Z. Add **noise**.

Add **read-out specific** (anode wire vs. GEM/MicroMegas) signal spreading characteristics.

Build **robustness** into the algorithm against signal pathologies through **tuning** with the aid of the graphical diagnostics,

Provide detailed, robust, analysis of track separation and pattern recognition efficiency (as a function of readout characteristics, segmentation (r-ϕ and Z), track density, and noise level) required to evaluate the (world) hardware development.

First year expenditures:	student support	$44,000
	computer	2,000
	travel	10,000
		$56,000