Performance Studies of the SD Muon Detector for the Linear Collider

C. Milstene -Arlington Workshop January 9-11,2003

- The major issues:
  - μ detection efficiency
  - μ π resolution
  - π punchthrough are analyzed from within Jas

- The data samples : sio files from SLAC

- The analysis: is based on R. Markeloff software

- A direct comparison in the main parameters with Piccolo for Tesla.

Plan

1) SD versus Tesla Detectors.

2) The choice of the energy points.

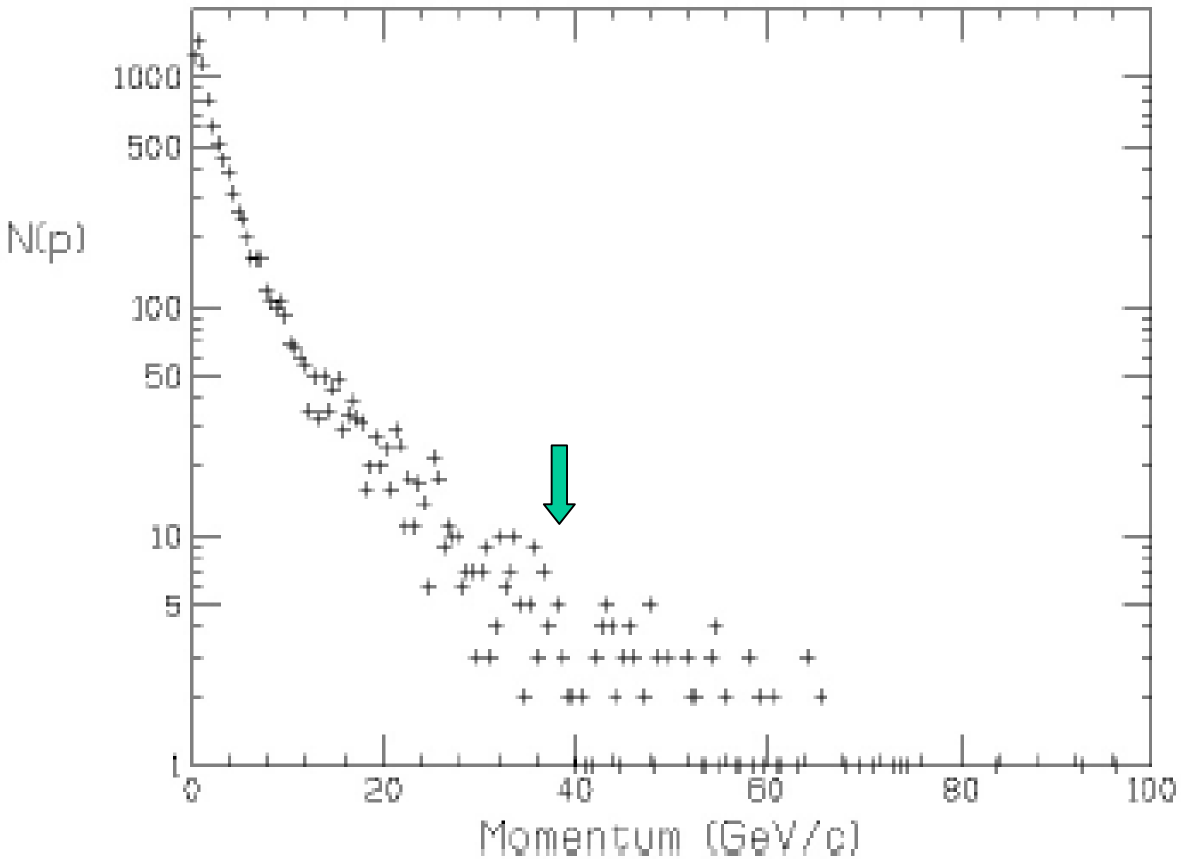
3) A set of typical and Non-typical π events and their μ counterpart.

4) Choice of the parameters for μ Detection:
   The μ detection efficiency stability upon changes of algorithms

5) The μ π resolution

6) The punchthrough π' s

The Choice of the Energy points



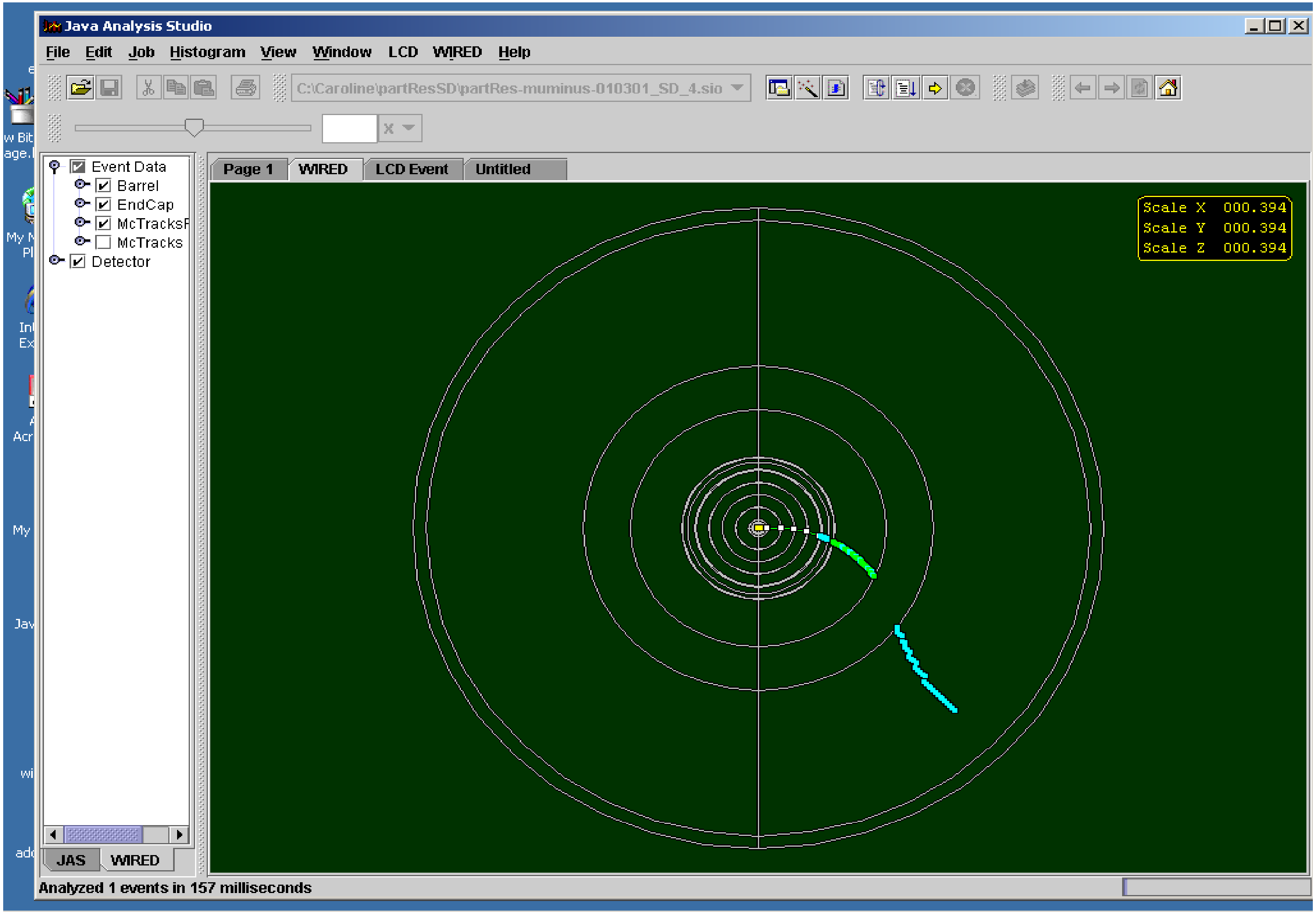
The majority of the particles are produced at energies below 30 GeV arrow.

μ at and above 4 GeV reach MuDet, Very few π of 5 GeV do.

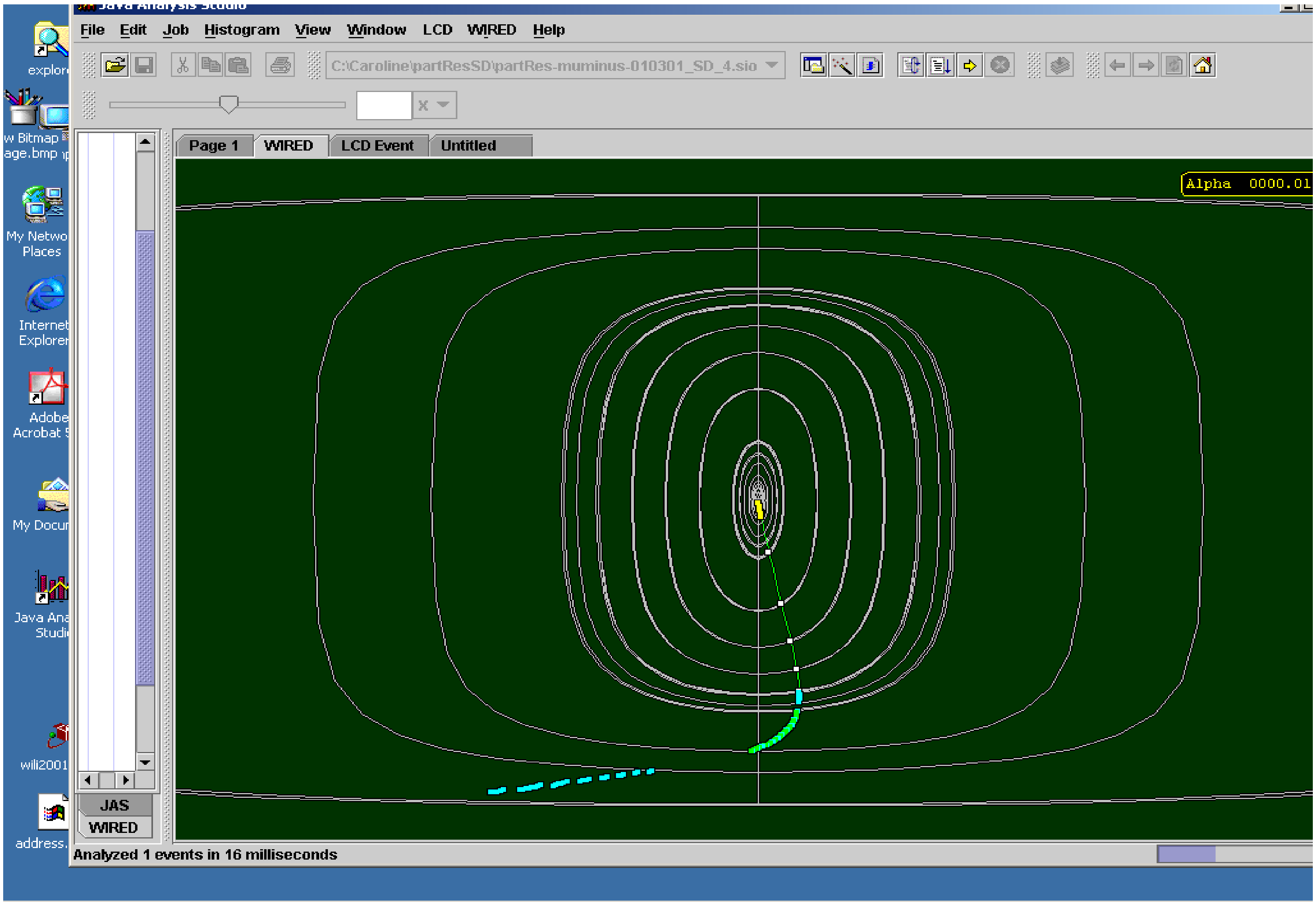
Part are curling back in the magnetic field.

From: Calorimetry
LC : Overview
Ray Frey, U. of Oregon
Chicago LCW, Jan 7, 2002

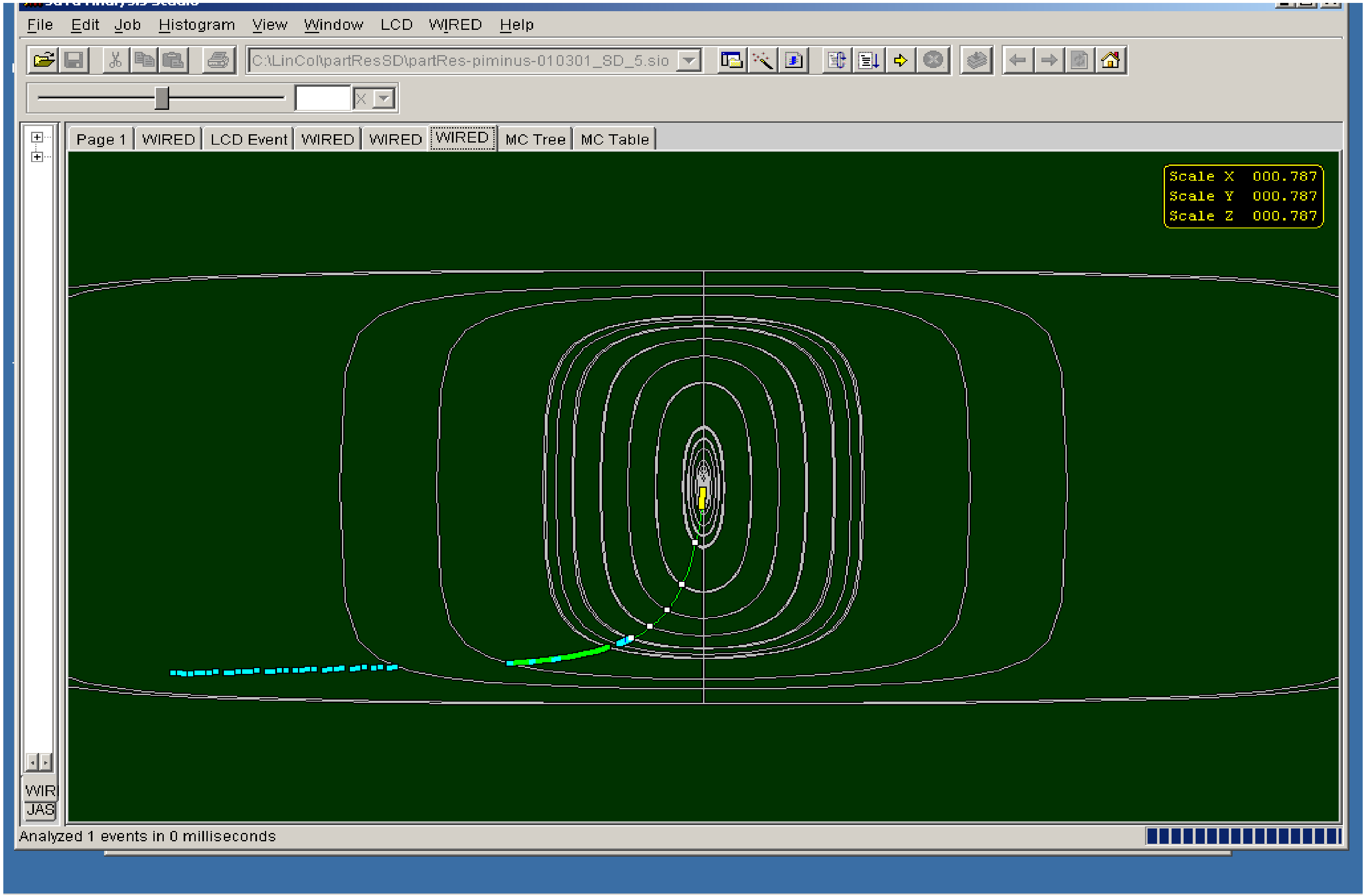
4 GeV Muon – Run 1 Event 2- 32 Hits in the Muon Barrel



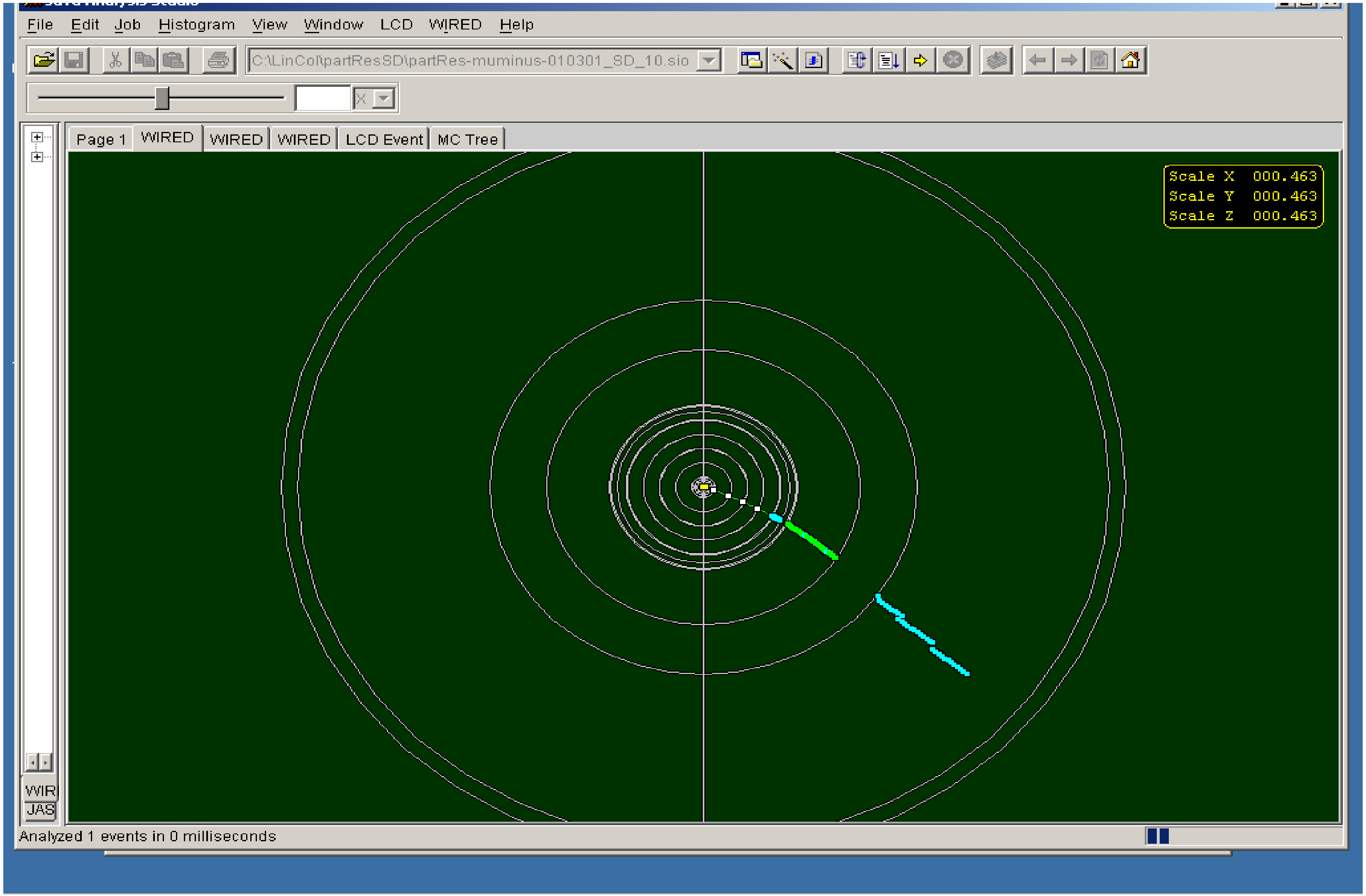
4 GeV Muon- Event 31 Run 1- Fish Eye View- 32 Hits in Muon Barrel



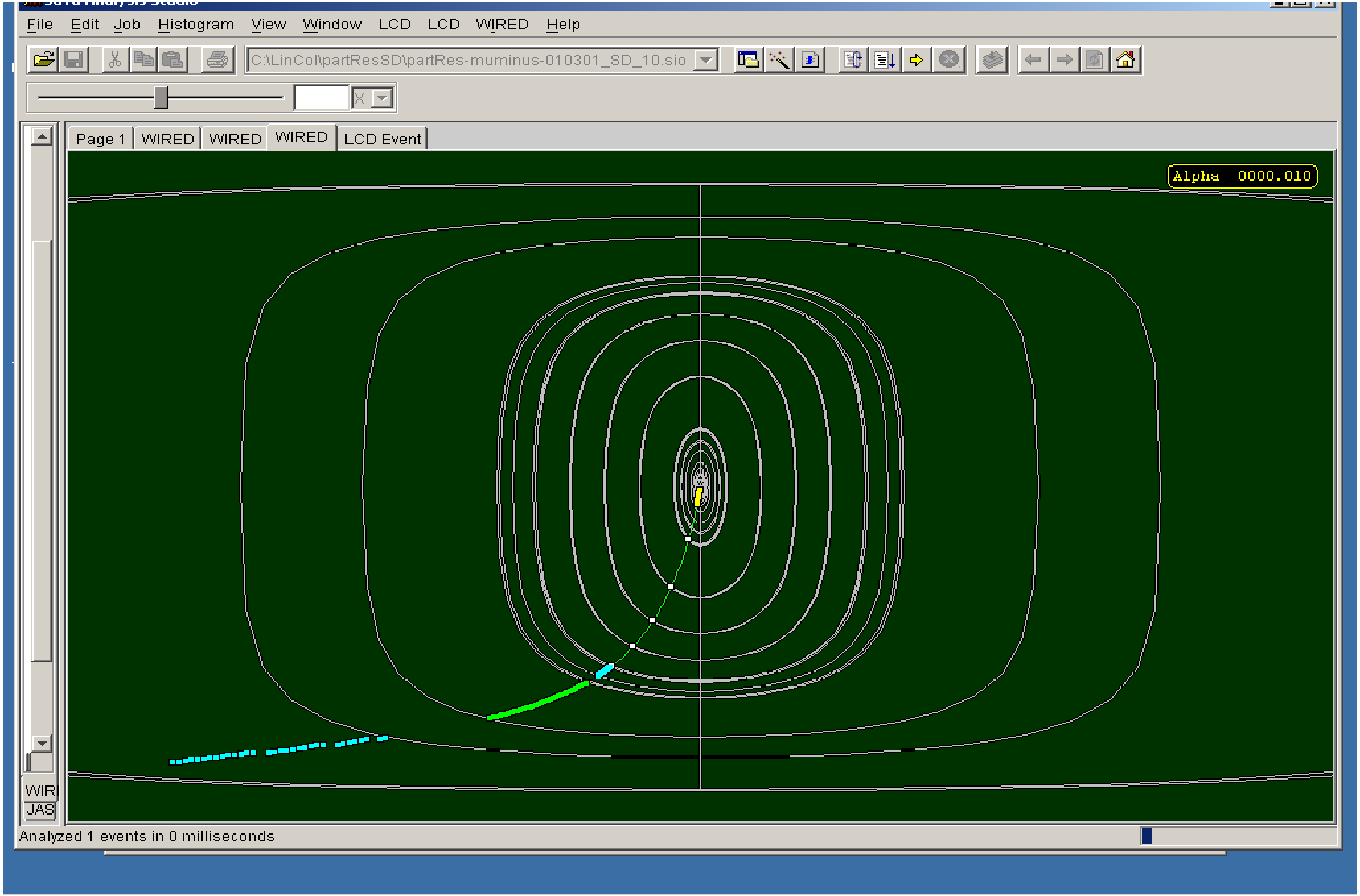
A 5 GeV π -> μ ν Decay – Event 206 Run 1-33 Hits MuDetector



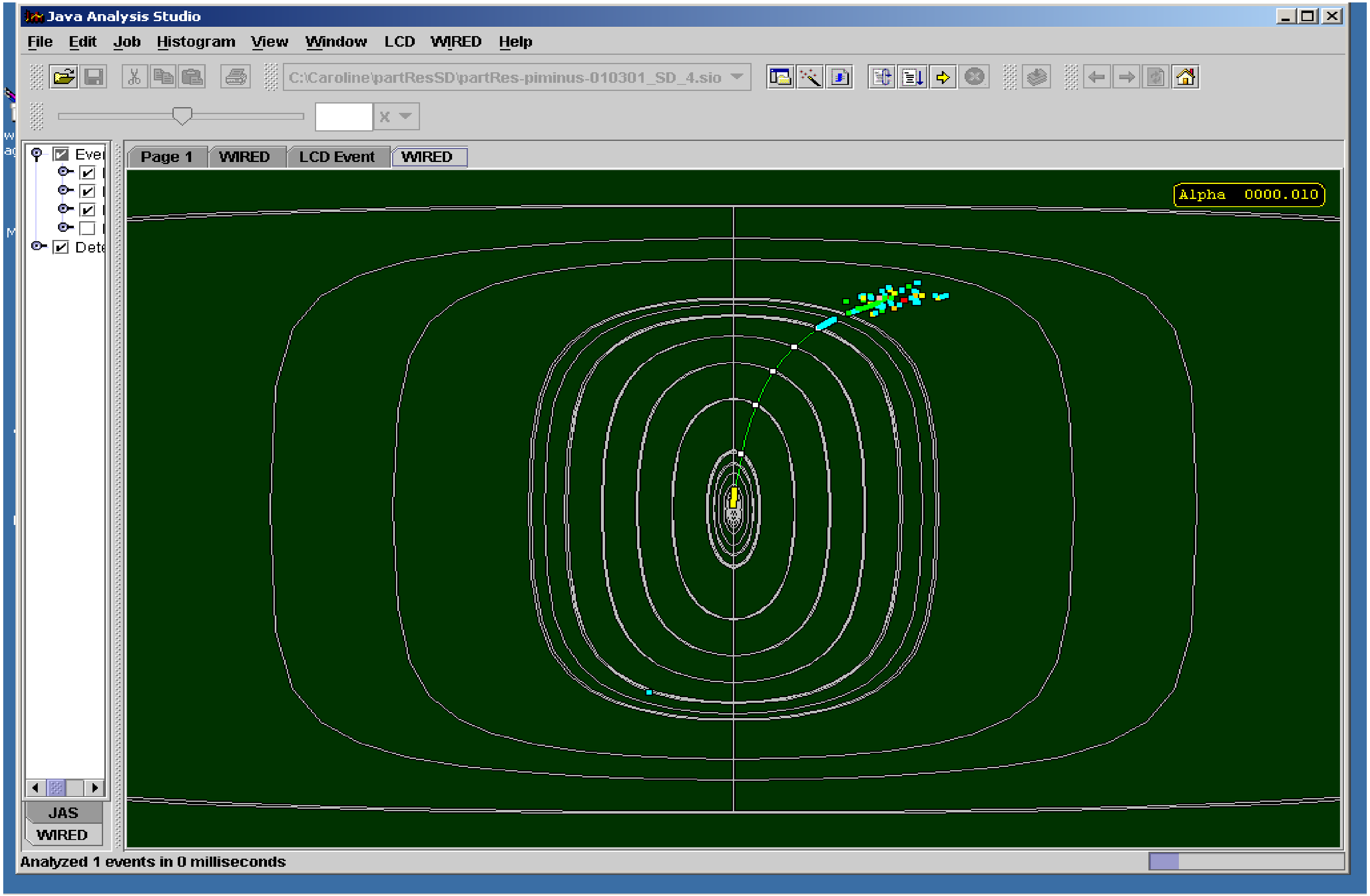
Typical 10 GeV μ –Event 9 Run 1-33 Hits in MuDetector



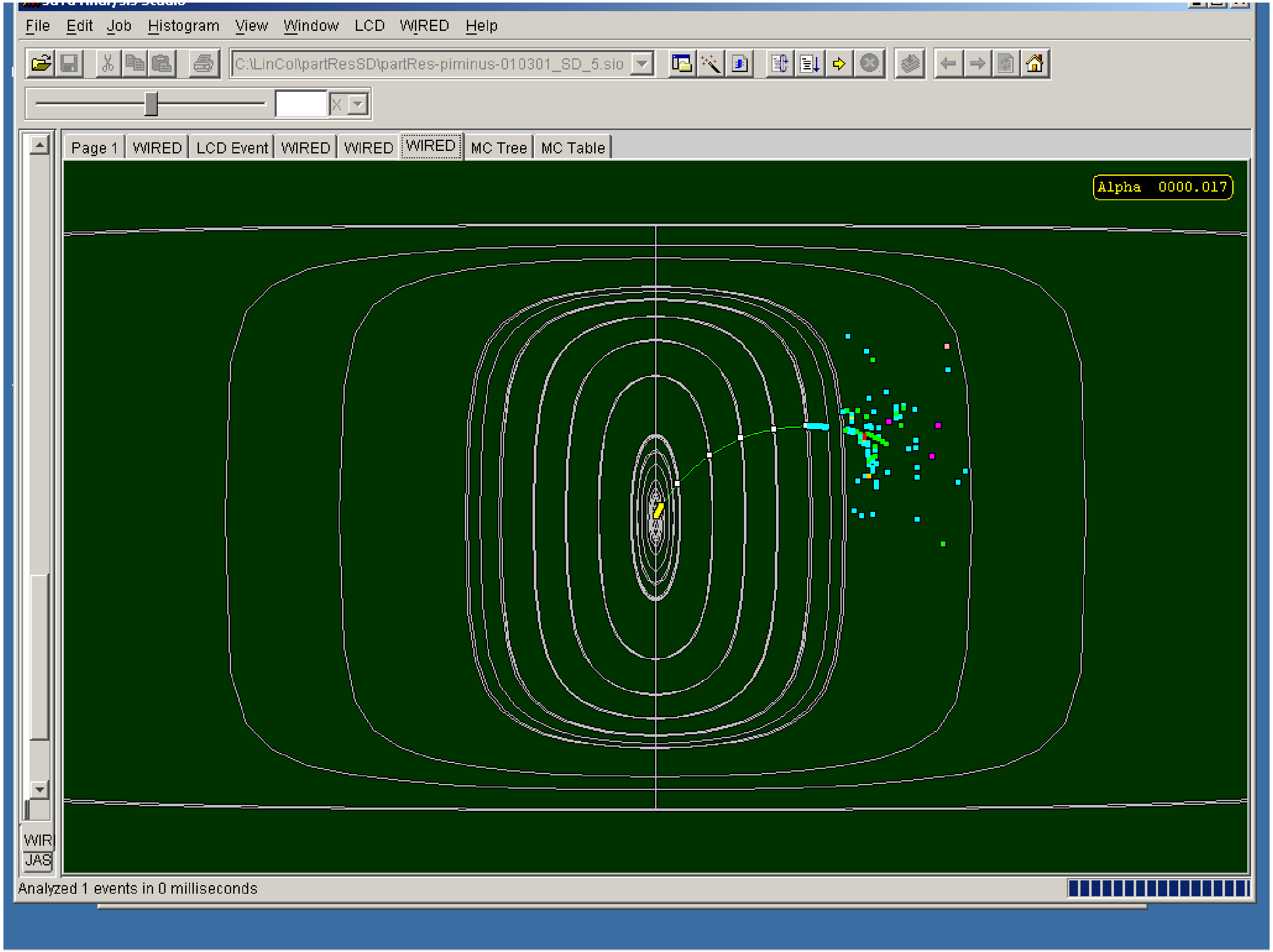
A Typical 10 GeV μ- Event 3 Run 1- With 33 Hits in MuDetector



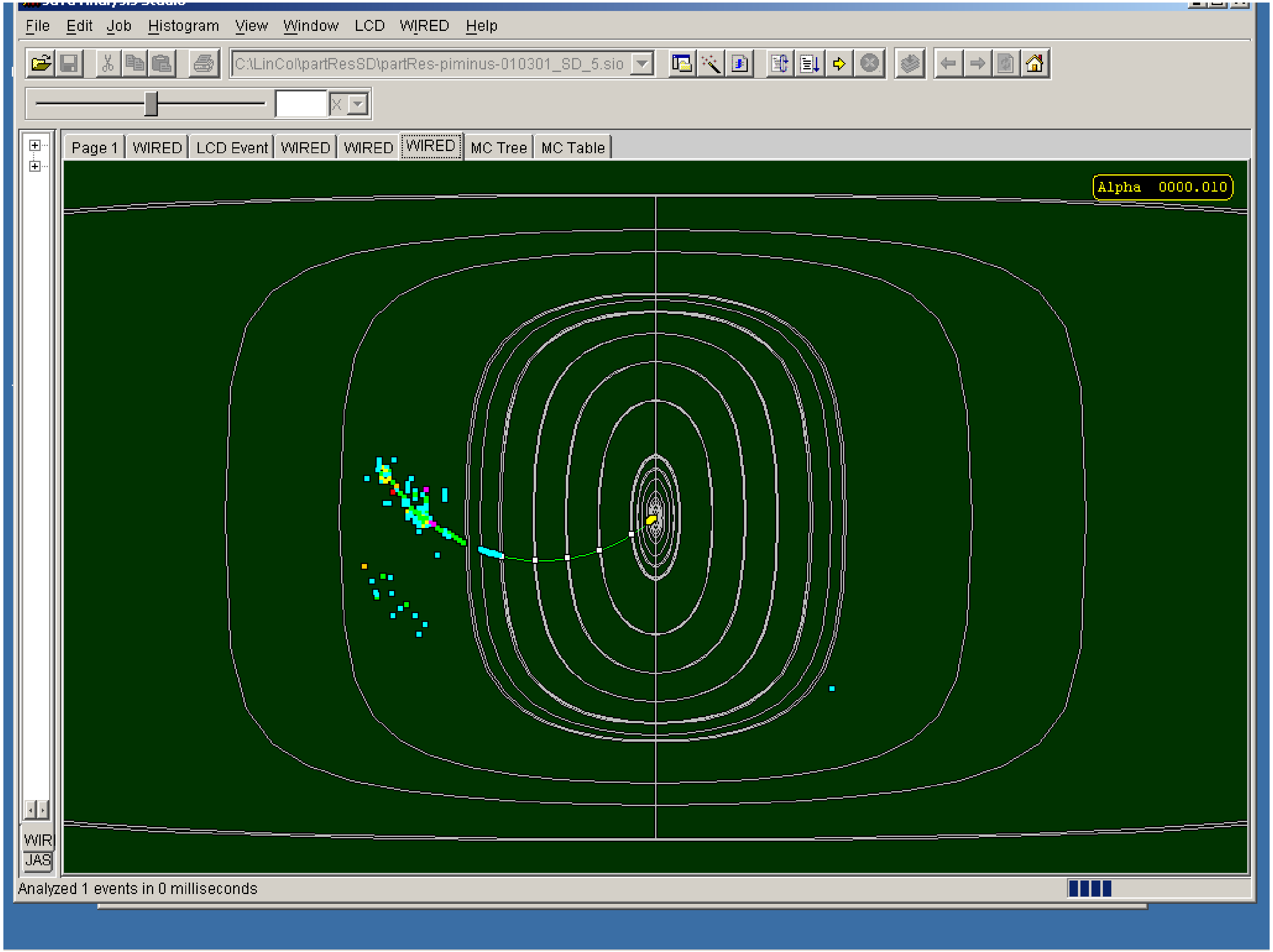
A Typical 4 GeV Pi- event 15 Run1 – y-Fish-Eye View no hits in Muon Detector



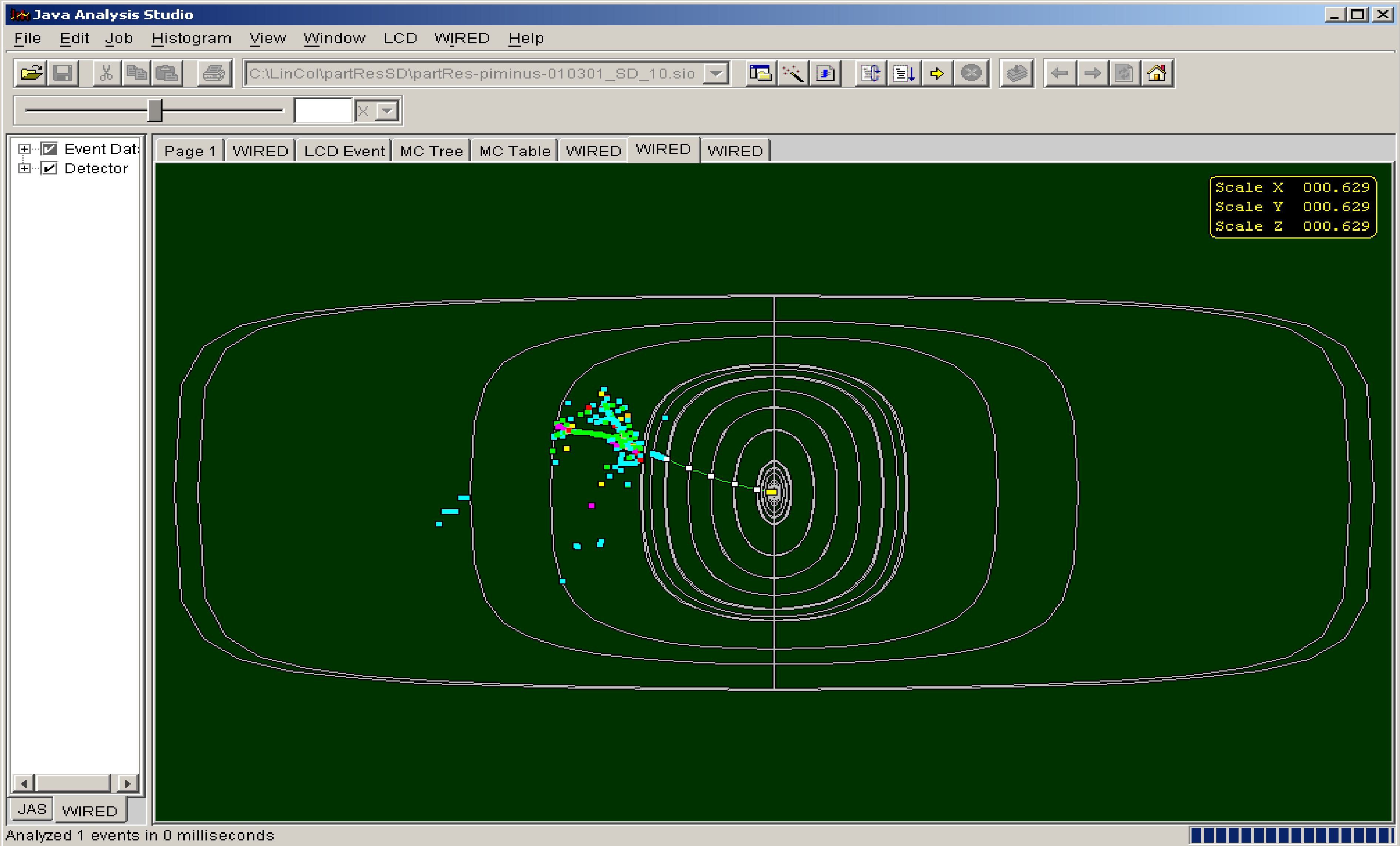
Typical 5 GeV pi-Event 142 Run 1- >100hits in HDCal- no Hits MuDetector



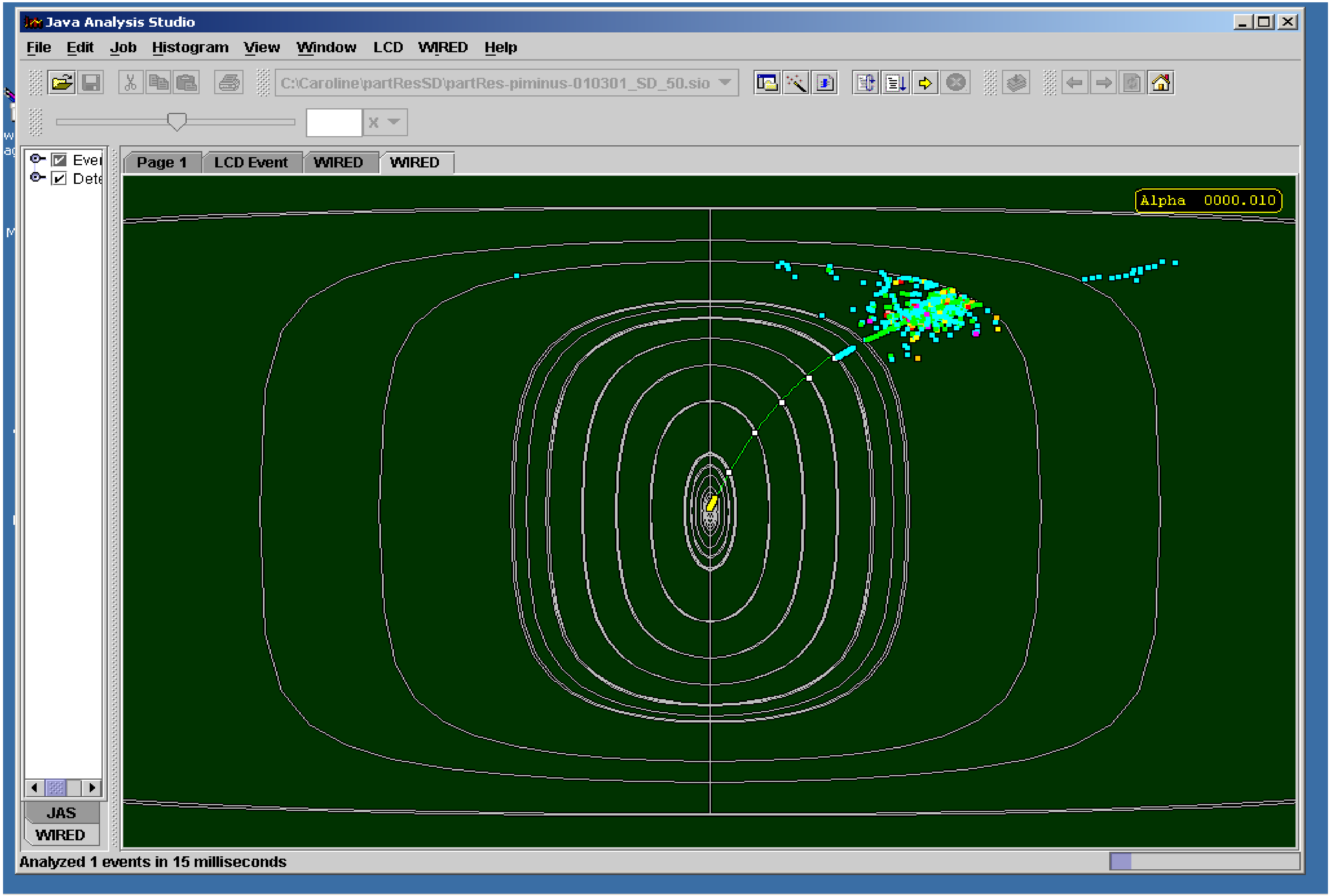
Typical 5 GeV pi- Event 21 Run 1-Curling Back Effect of B=5T



Typical 10 GeV punchthrough π-event 118-Run1- 6 hits MuDet



Punch Through 50 GeV pi- event 11 run 0- y-EyeFish View-18 hits in Muon Detector



The SD and TESLA Muon Detectors

Comparison of the relevant parameters:

	SD	TESLA
Outer_thick_plate (Tesla only)		645cm
Outer_Radius	660.5cm	585cm
Inner_Radius	348.5cm	445cm
	---------	--------
	312 cm	140cm

The Unit:

	SD	TESLA
	Fe 5cm	Fe 10cm
	Gap 1.5cm RPC/gap	Gap 4cm
	48 Layers	10 Layers
	80cm Fe=16 planes	80cm Fe=10planes
#Inter. Length Prior to MuDet	SD(EM+HAD)= 3.9 Lambda(Si+W)	Tesla 5.4 Lambda

The Algorithm

$\underline{\mu}$

$\mu_{candidate}$

$\underline{\max\Phi_{bins}(\text{Tk-HDCal})}=4$

$\underline{\max\ \theta_{bins}(\text{Tk-HDCal})}\ =2$

Minimum

HDNHits = 0

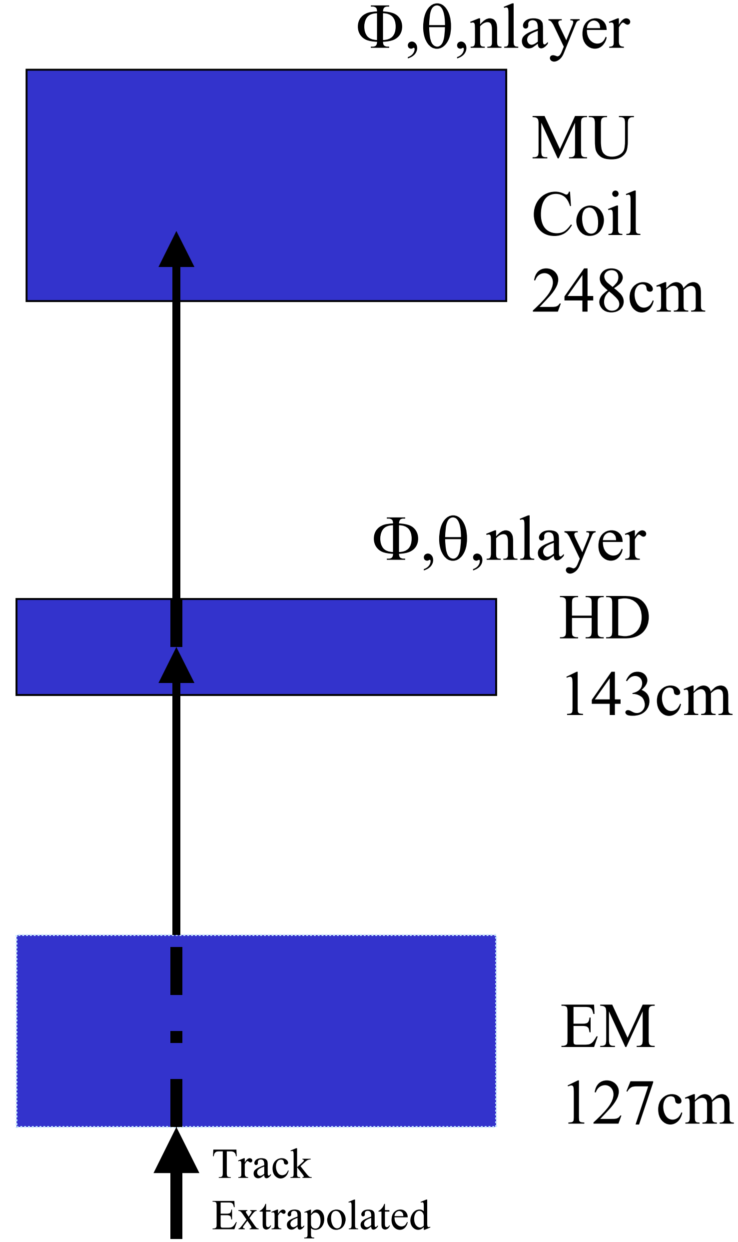
MUNHits =12

Track
HDNLayers
HDNHits
HDHits
MUNLayers
MUNHits
MUHits

$\underline{\max\Phi_{bins}(\text{Tk-HDCal})}=3$

μ list

$\underline{\max\ \theta_{bins}(\text{Tk-HDCal})}\ =1$

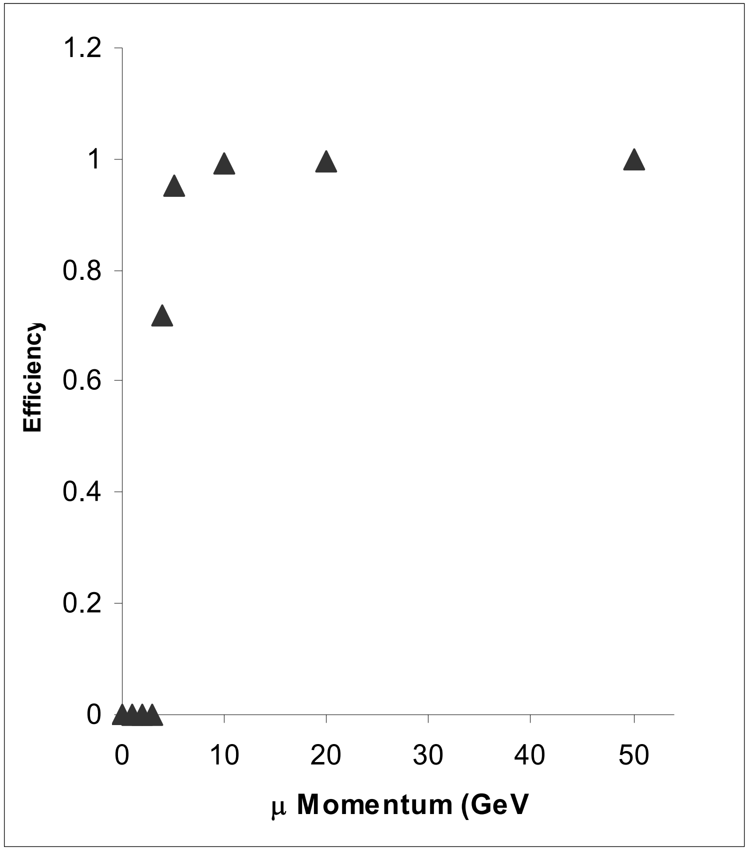


SD Detector

Muon Package of R. Markeloff

Single Muon Efficiency = F(Particle Momentum)

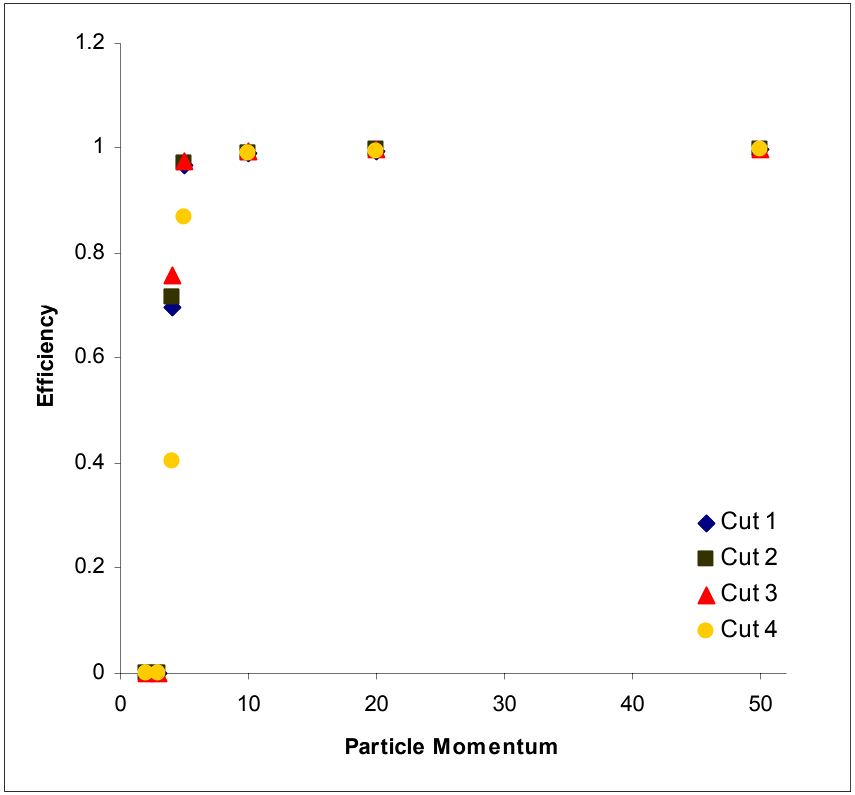
The Algorithm chosen are based upon the μ properties of penetration in correlation with the lack of interactions and the track continuity. The decays have been subtracted following the procedure used in the source code of MCPseudoParticle by M.Ronan/T. Johnson.



The μ Identification algorithm

- A charged track reconstructed
- Matching in HD within
  3Φ bins 1θbins
- Matching in MuCal within
  ΔΦ ~40mrd θ~20mrd
- More than 12 hits in Mucal

μ Efficiency Stability Against Algorithm Variations



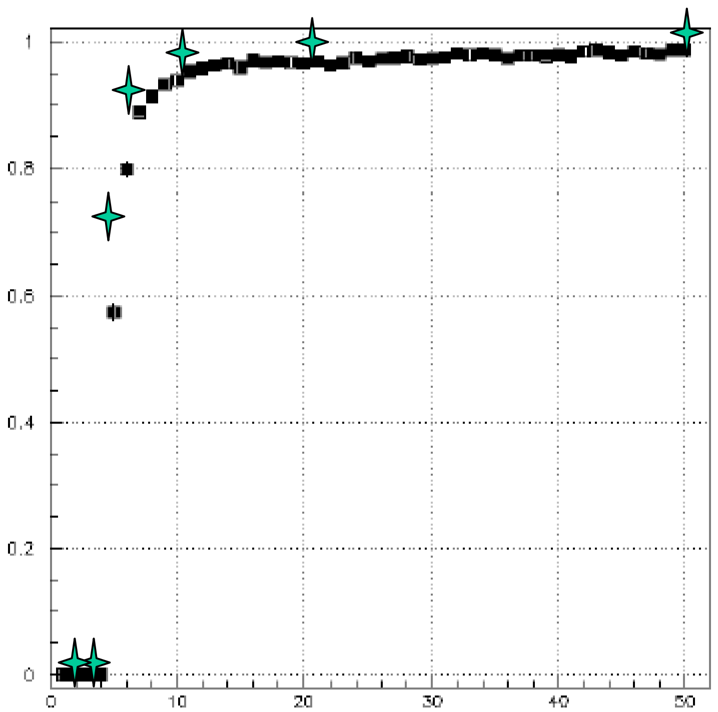
Cut1- ΔΦ ~40mrd Δθ~40mrd- cut at 16 planes(80cm of steel).

Cut2- ΔΦ ~40mrd Δθ~20mrd- cut at 12 planes.

Cut3- ΔΦ ~30mrd Δθ~10mrd- cut at 12 planes.

Cut4- ΔΦ ~30mrd Δθ~10mrd- cut at 8 planes.

Comparison With the μ Efficiency at Tesla



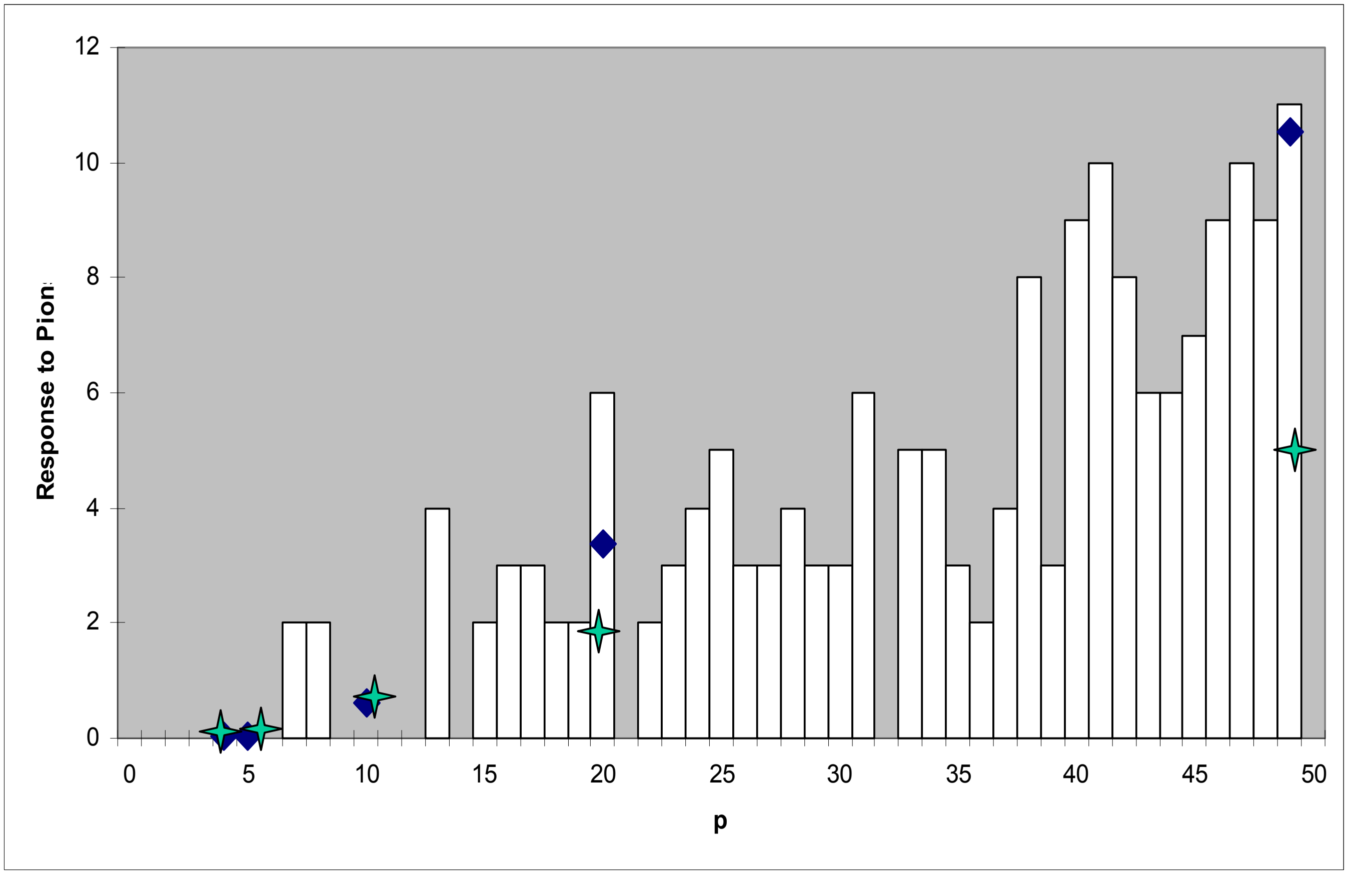
μ Efficiency for SD is represented on top of the plot of M.Piccolo for Tesla

The algorithm used by M. Piccolo:

- A μ stub crossing at least 8/11 planes (80cm of steel)
- A stub is defined by angular hits consistency in MuCal: The matching is within

$\Delta\Phi \sim 40$mrd $\Delta\theta \sim 40$mrd

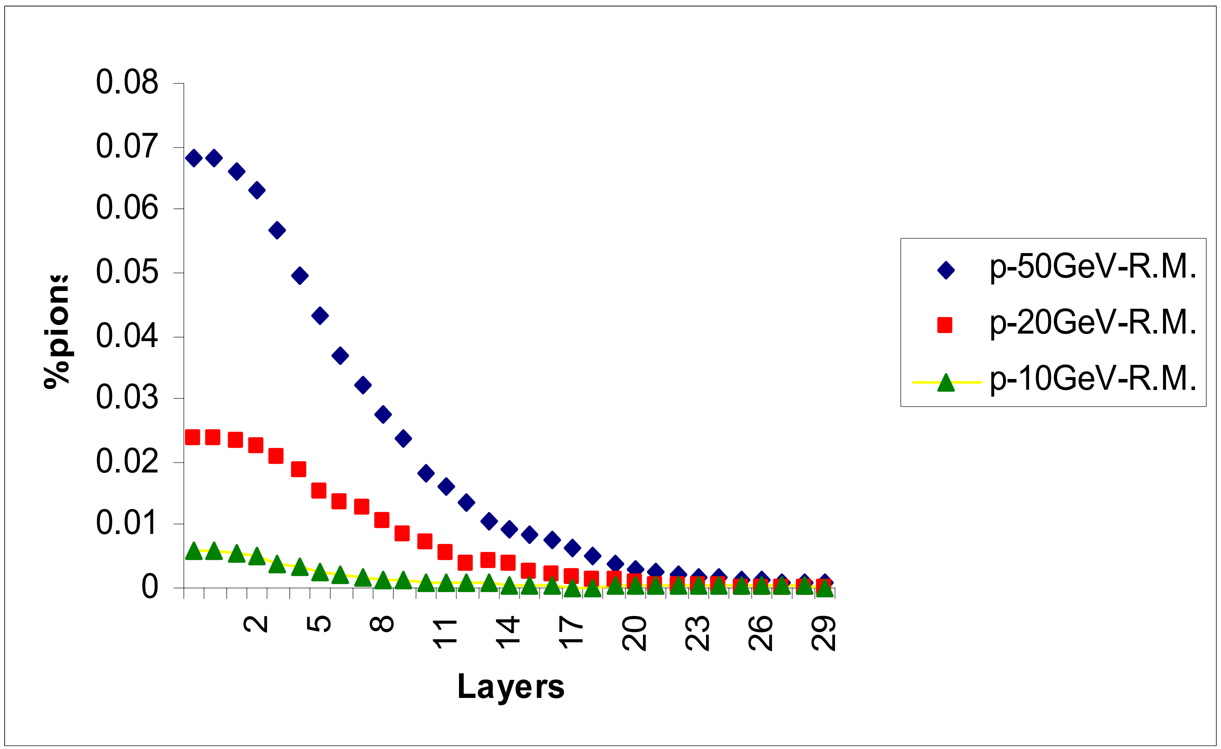
Pion Response of the Muon System



The response to π reported for 35000 events (Tesla) By M . Piccolo has been Reproduced **The** blue diamonds represent The SD points for π ***after normalization to account for the difference in interaction length and statistics.***

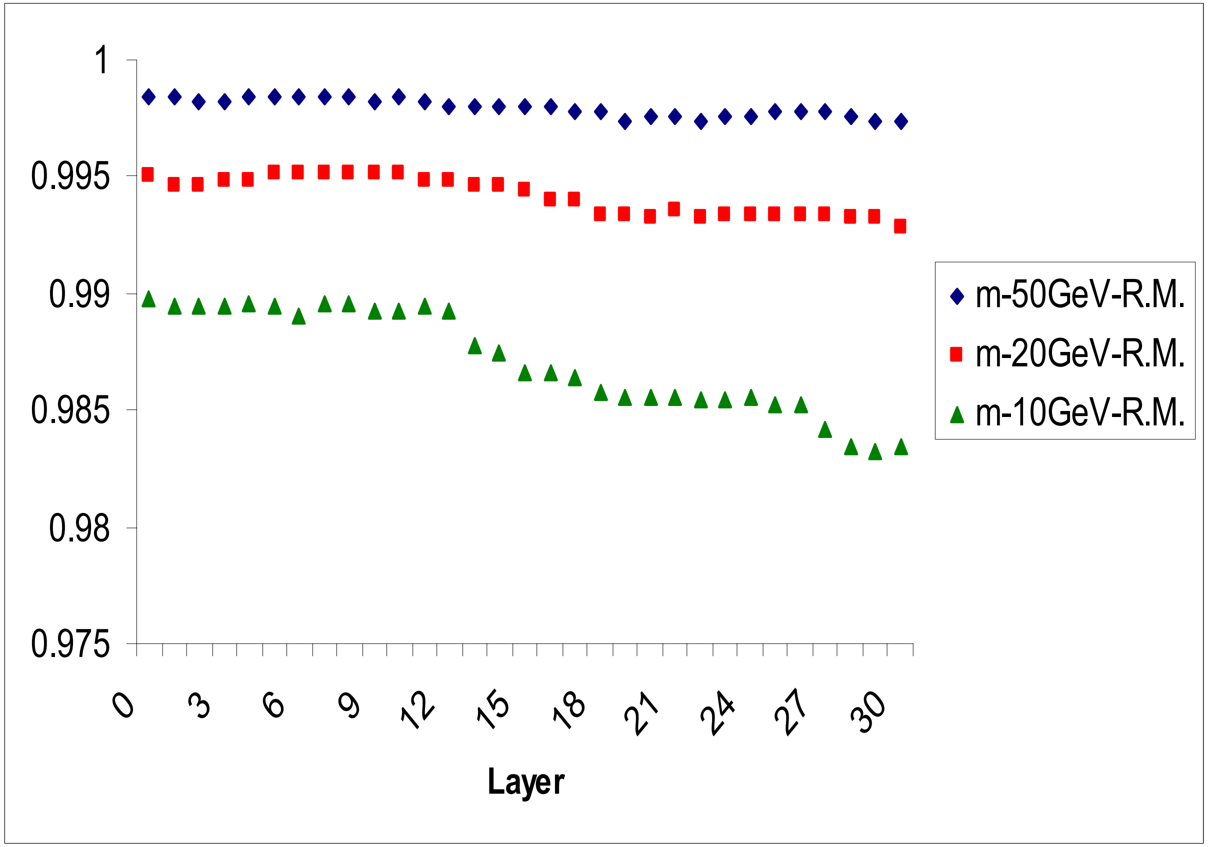
The Green stars Correspond to an extra cut: requiring 5 planes with >=2 hits.

Punch Through Per Layer



The π punch-through probability as a function of the layer number is shown for 3 points of energy using R. Markeloff SD cuts without applying any extra-cut .

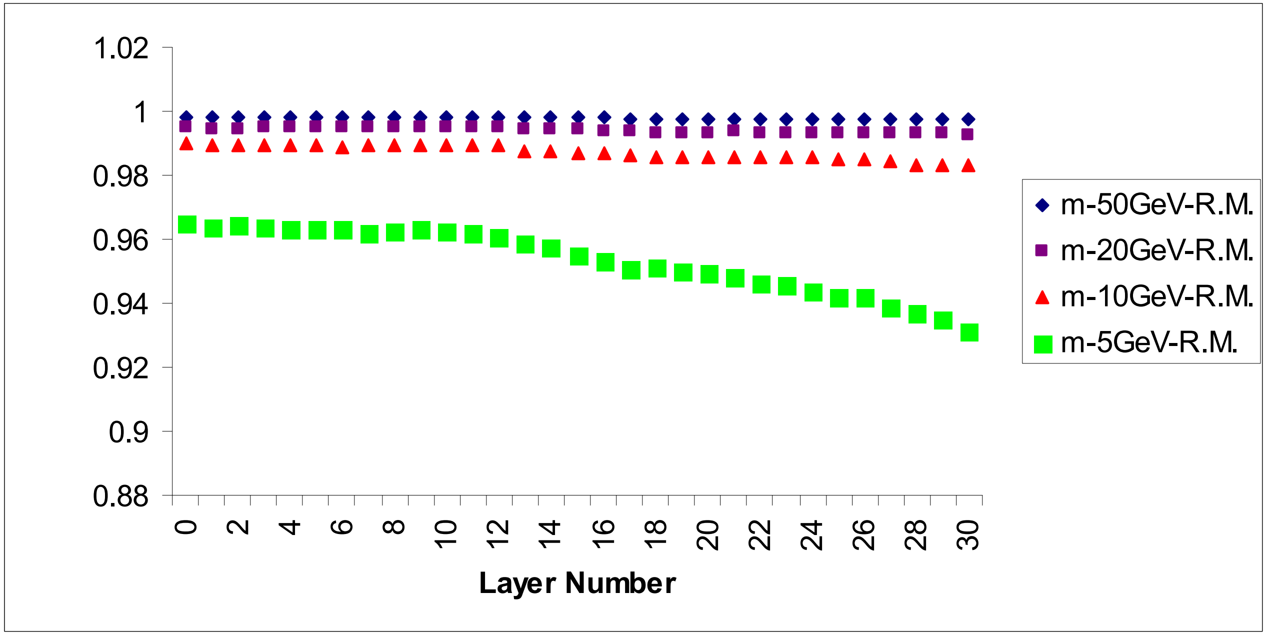
The layer hit pattern of the μ



The hit per layer probability as a function of the layer number is shown for the μ 's at 3 points of Energy as well.

The distribution is almost flat, especially at high energy, namely,almost all the μ 's leave at least a hit in each MuDet Layer. This difference with the π will be taken advantage of in our cuts.

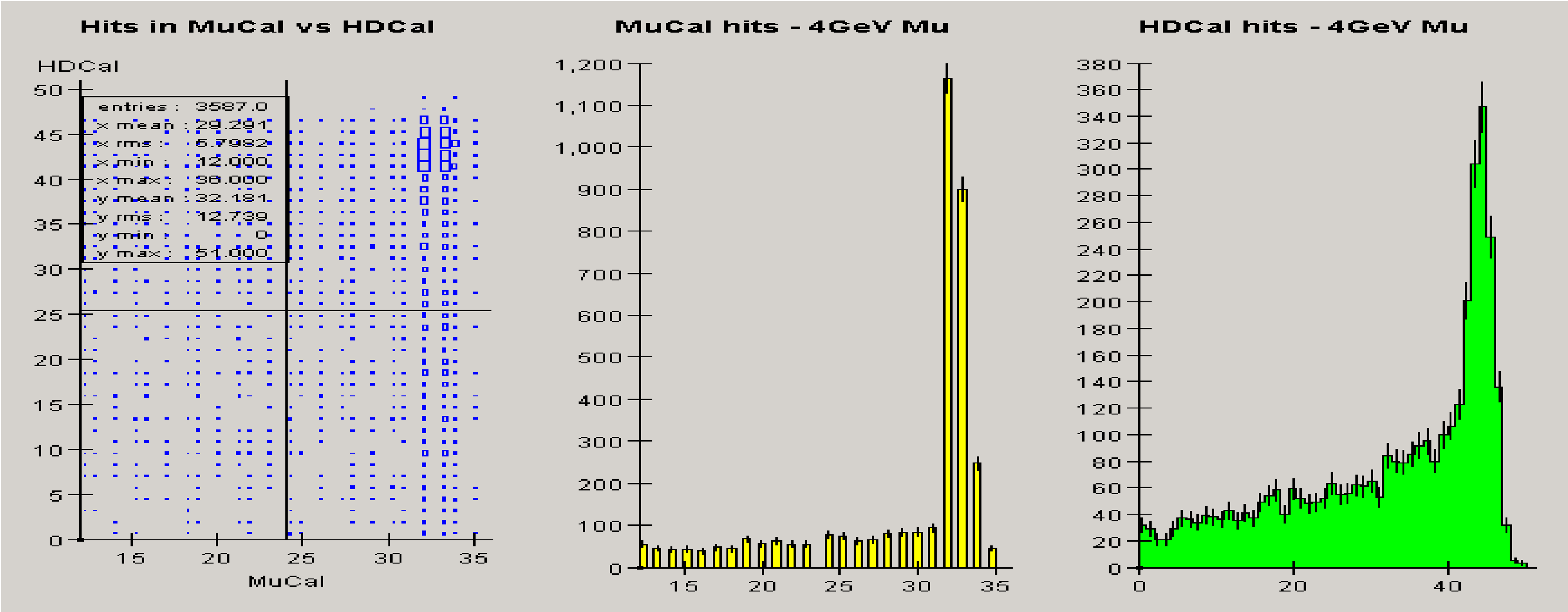
The layer hit pattern of the μ including momenta as low as 5 GeV



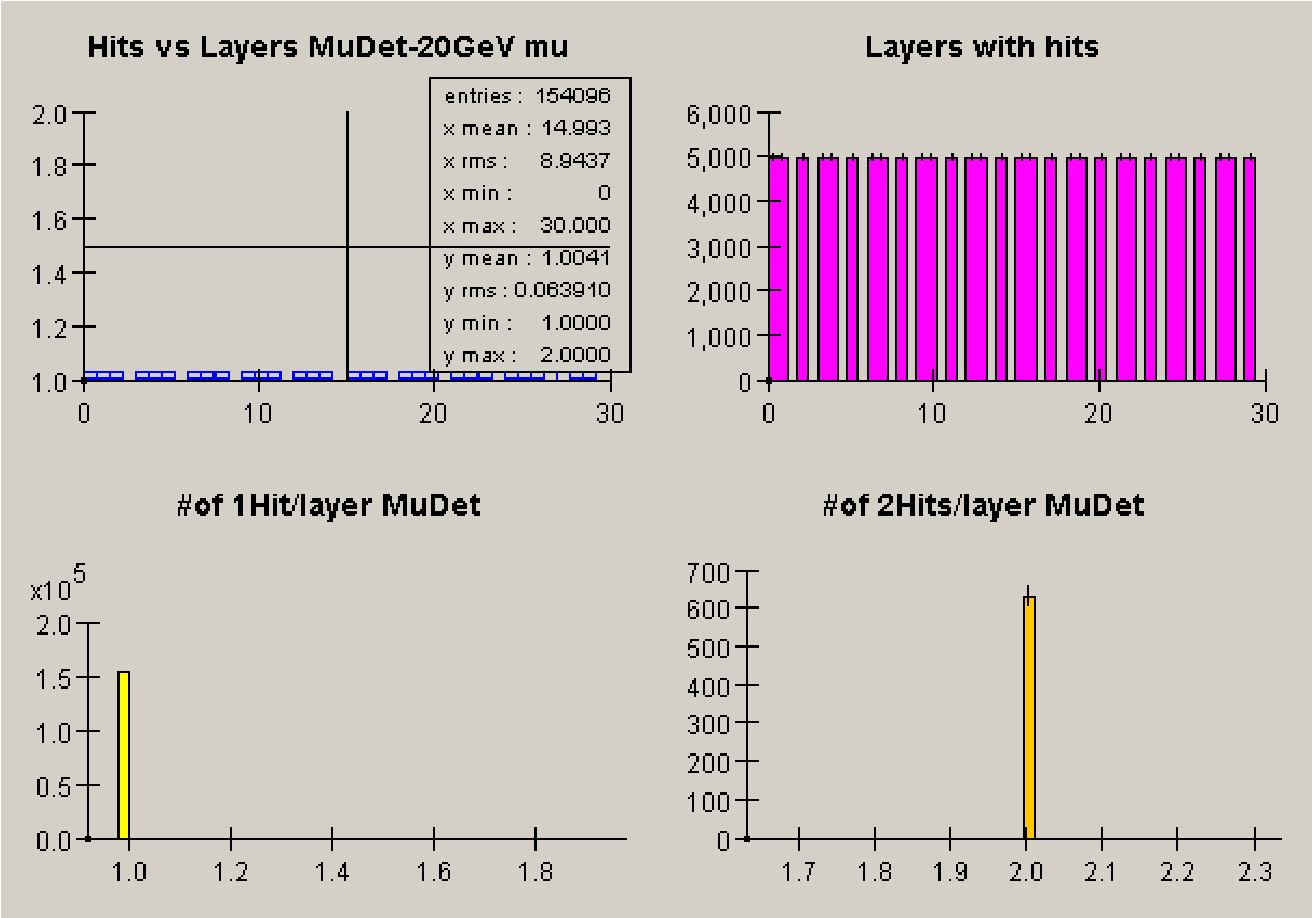
Even at 5 GeV, 95% of the Muons do leave Hits in the 22 first layers

A 4 GeV Muon with and without Minimum MUNHits cut

The distribution of hits in MuDet and HDCal shows that even At 4 GeV most of the μ leave around 30 hits in MuDet (2nd Figure).From the previous plots one gets that the hit distribution Per layer has hits in 30 layers, the μ leaves one hit per layer.



Hits/Layer left by a μ in the Mu Detector

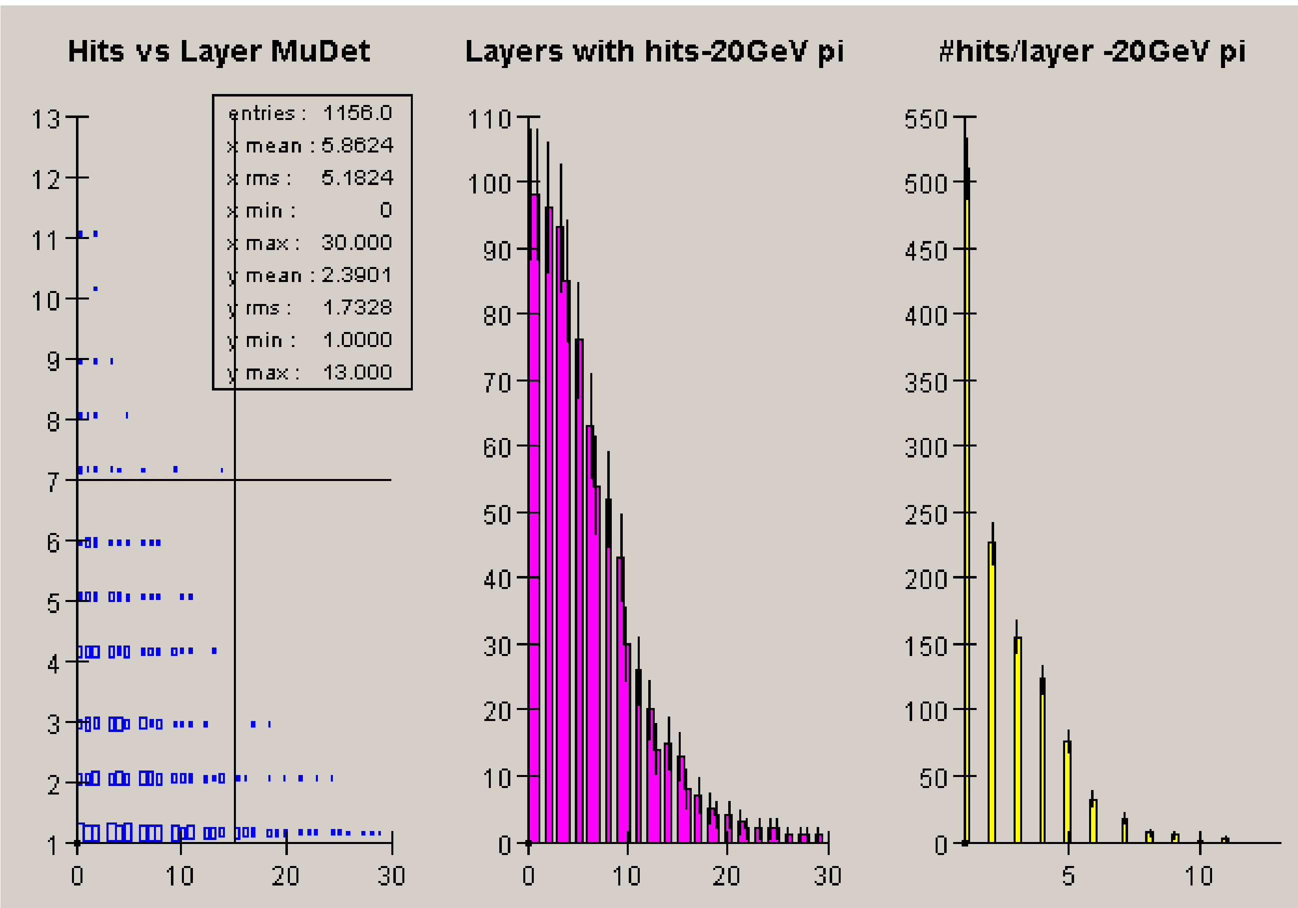


The muon leaves 1-2 hits in each of 30 layers of the Mu Detector.

A lot more 1hit than 2 hits.

Next figure shows the hit pattern of a pion.

Hits/Layer left by a π in the Mu Detector



For the pion the hit pattern is different. The hits are not spread between all the layers. The 1st layers are the most populated.

The 1-2hits is in favor of 2 hits (the detail not shown).

There are up to 13 Hits per layer.

Further π μ Separation

Starting with the SD standard cut from R. Markeloff, further cuts have been added taking advantage of 2 characteristics of the μ:

- Penetration
- Low hit density (1-2 hits/layer)

-The minimum cut was based on the total number of hits. Requiring for the 12 hits to be in at least 8 layers will insure 1-2 hits/layer, this characterizes the μ ‘s.

-The cut at 8 layers should also take care of those π events which favors the 1st layers of the Mu Detector in the figure of punch through per layer against the flat distribution obtained for the penetrating μ’s.

-A cut in involving the density of hits within $\Delta\phi$ =40 , $\Delta\theta$=40 mrd has been added e.g. at least 4 layers with more than 3 hits or 5 layers with more than 2 hits .

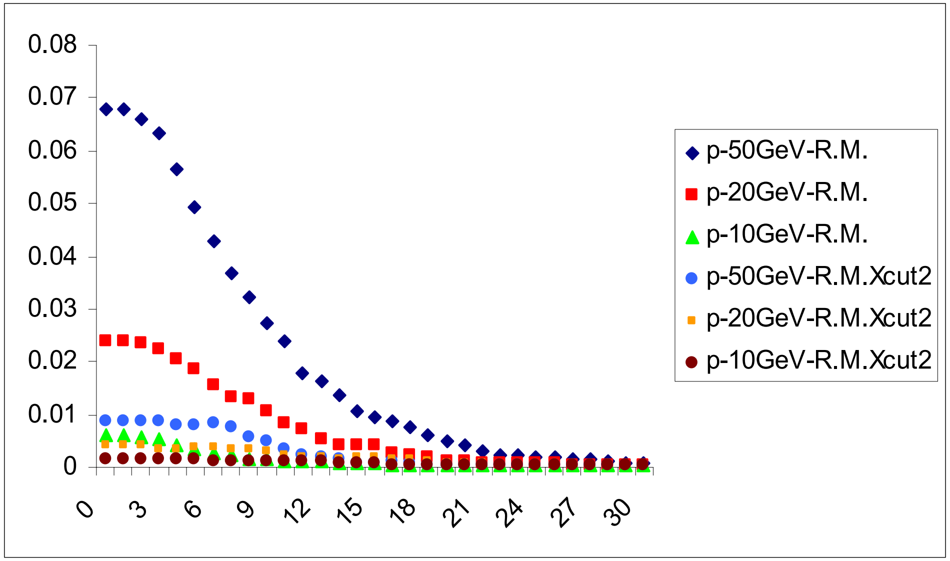
Tests of Extra Cuts

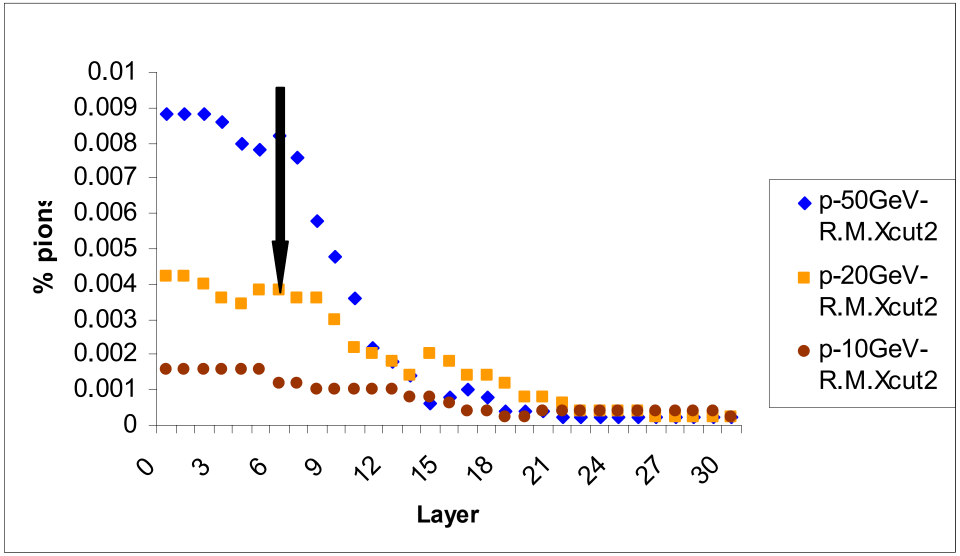
The previous cut

•Decreases the punch-through : left SD regular Cuts and (regular +extra) super-imposed , right SD (regular +extra) cuts only, in a bigger scale , The colors match in both figures.

The improvement is ~ 10% less punchthrough at 50 GeV, 18% less at 20 GeV, 30% at 10 GeV.

•The ultimate test is against physics, it should pass the test of jet events.





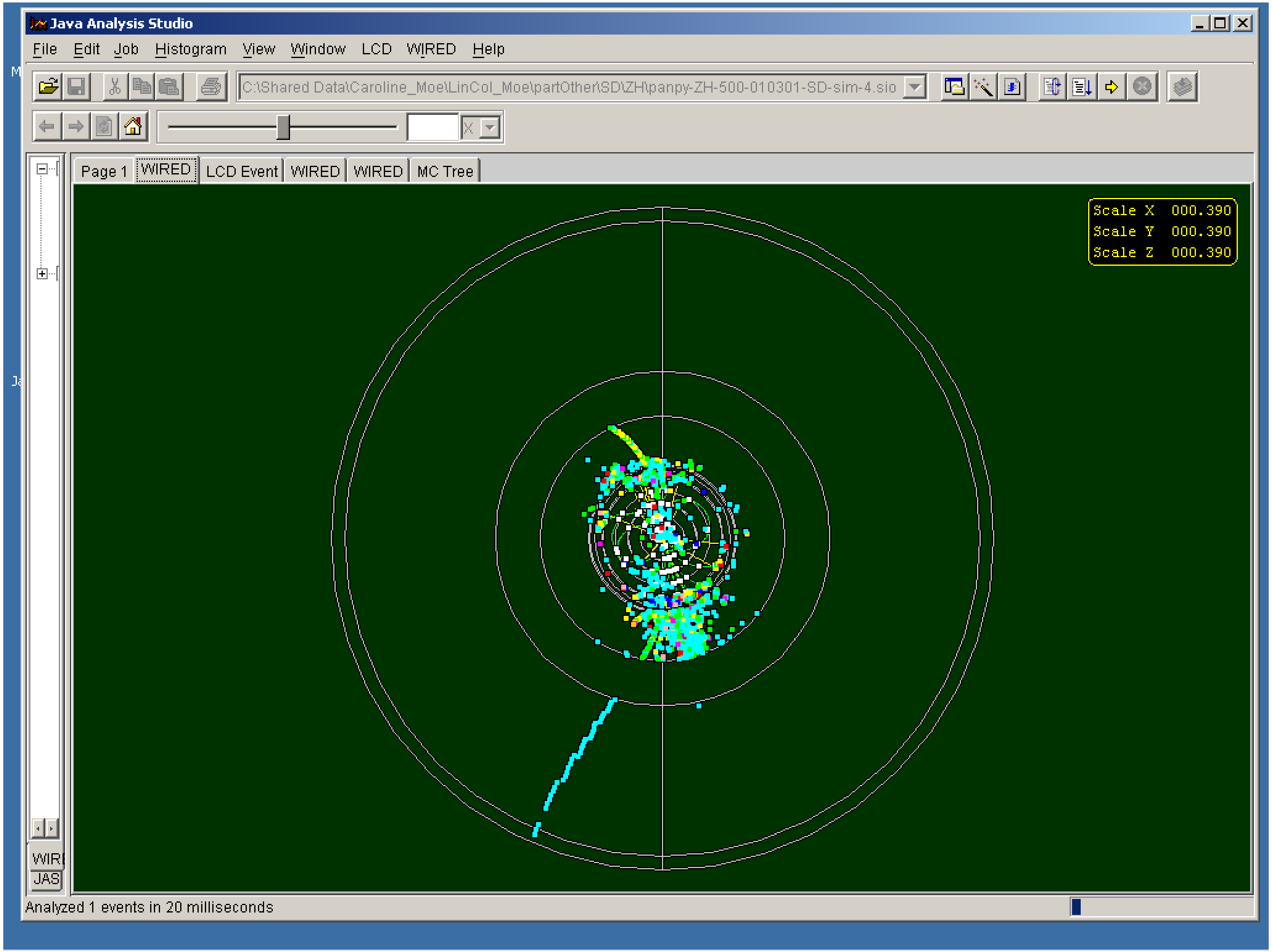
Tests of Extra Cuts(cont.)

Looking only at the cut on tracks having 5 layers with 2 or more hits within $\Delta\phi$ =40 , $\Delta\theta$=40 mrd was shown in the plot of the π response of the μ system on top of Tesla's results , with green stars.

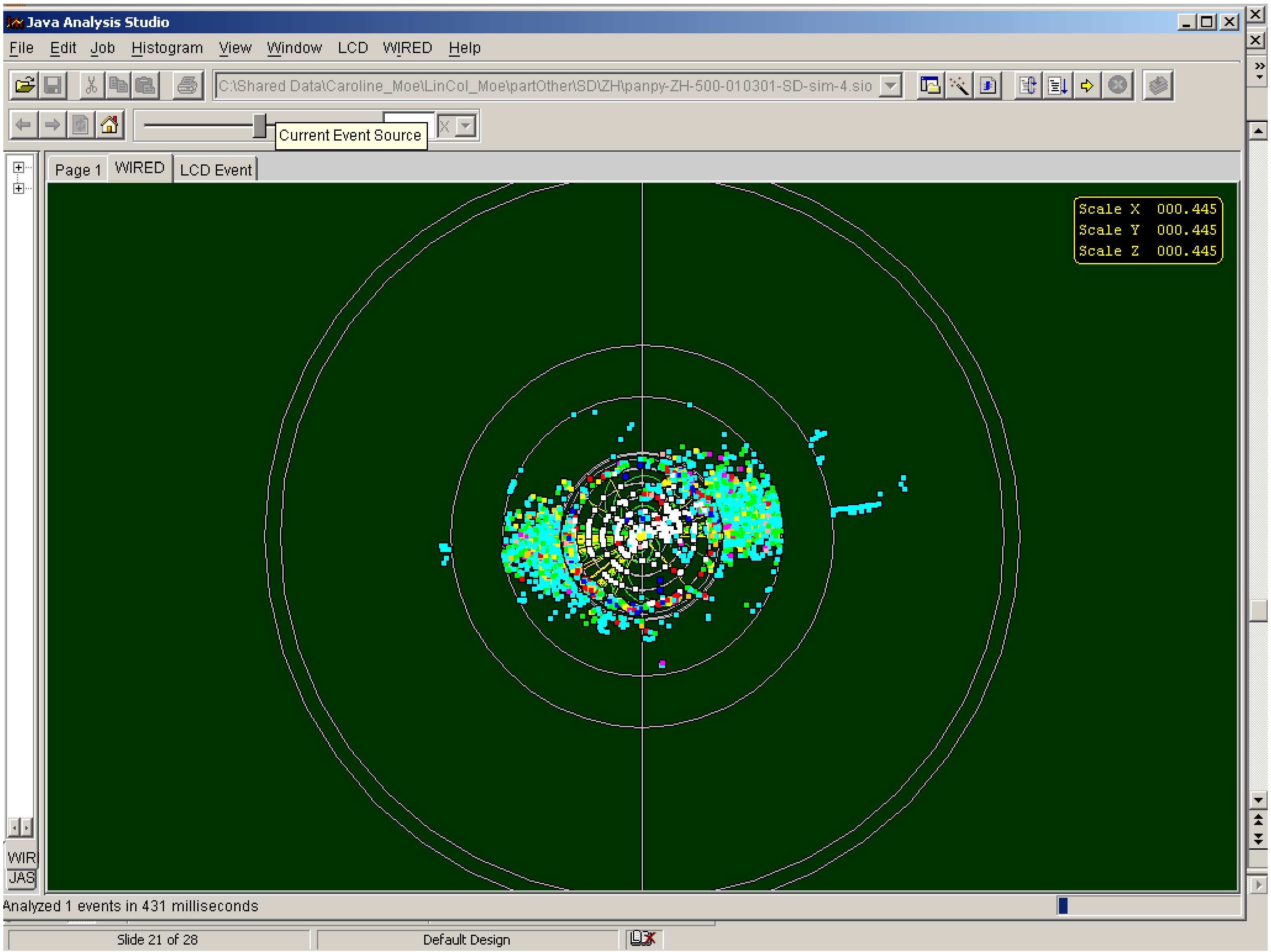
- It improved the separation π μ by a factor two at 50GeV and 20 GeV.
- Those cuts did barely affect the μ efficiency(within the error Bar), the μ range being of 1-2 hits per layer within the $\Delta\phi$,$\Delta\theta$ range.

The ultimate choice of the extra cuts and their tuning will be done using jets events as shown in the 2 next transparencies. In the 1st event the barrel μ does pass the cuts, whereas , in the 2nd event the signal in the Mu Detector is not detected. In the b-b$_{_bar}$ too the barrel μ pass the cuts.

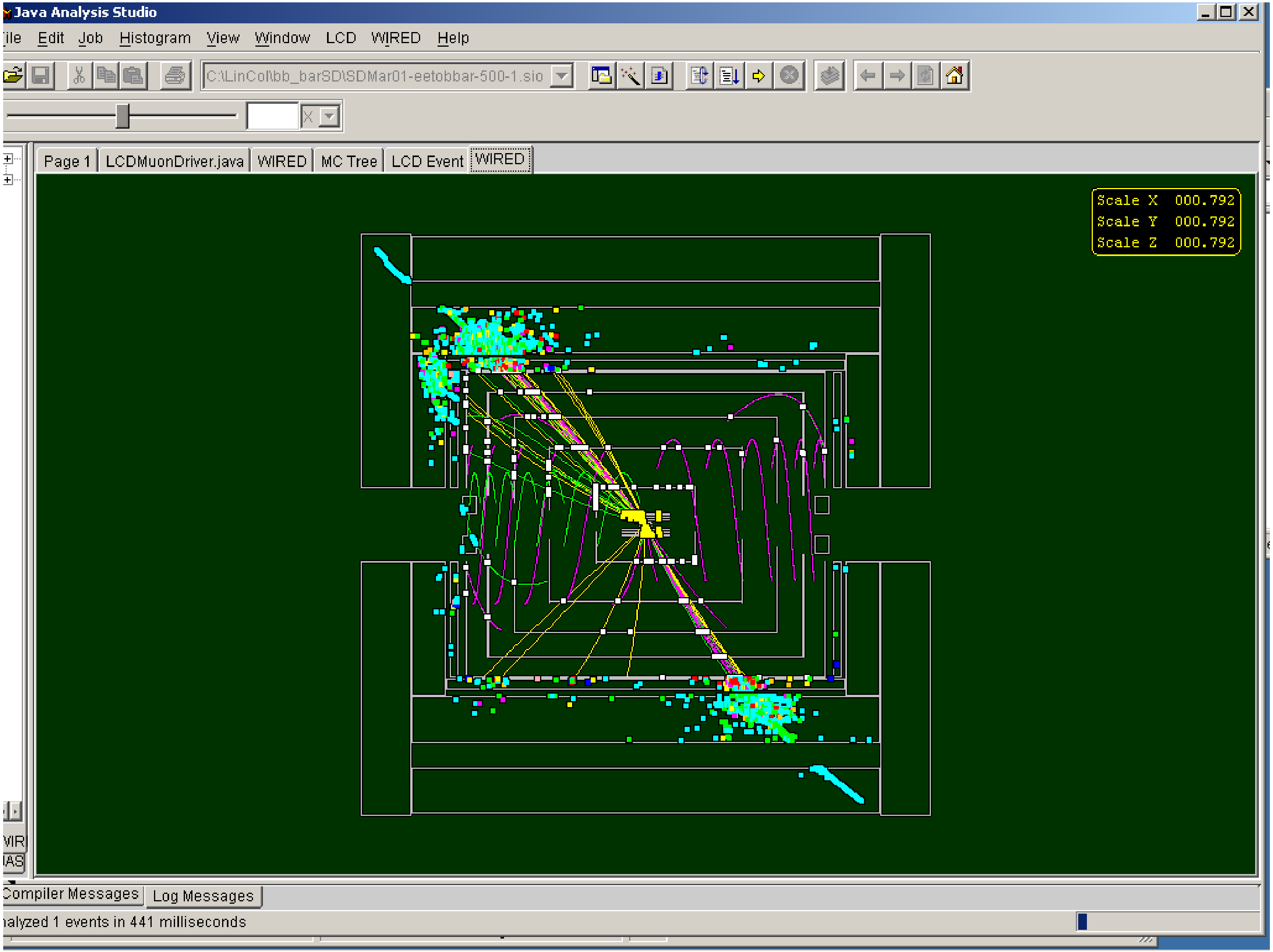
A 500 GeV ZH Event With a clear μ –Hits in MuBarrel & MuEndCap



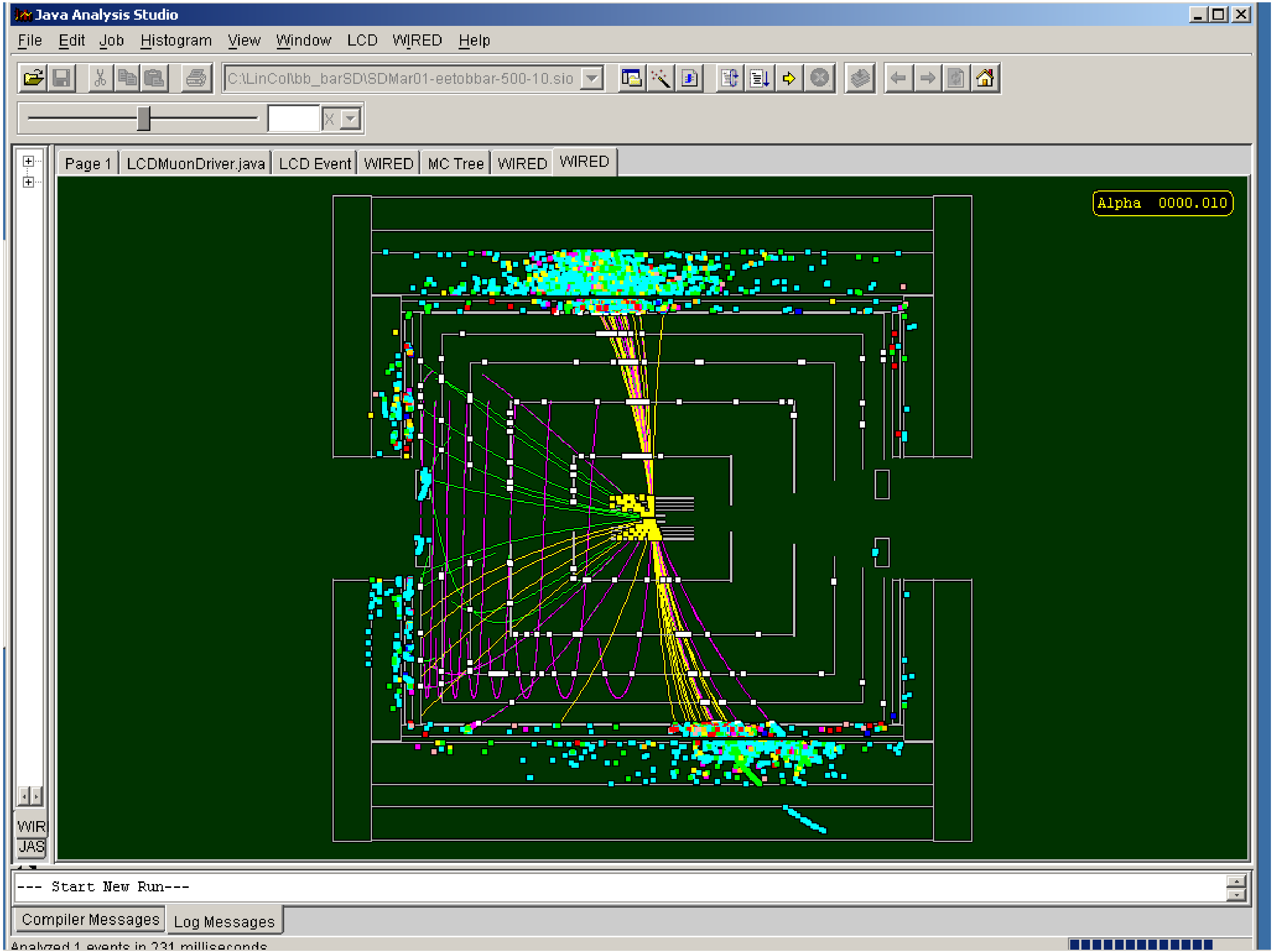
A 500 GeV ZH Event With a Mu Detector Signal Coming Not From a μ



A b-b$_{bar}$ Event With a clear μ –Hits in MuBarrel & MuEndCap



Another b-b$_{bar}$ With a m Detected in the Barrel with 28 Hits



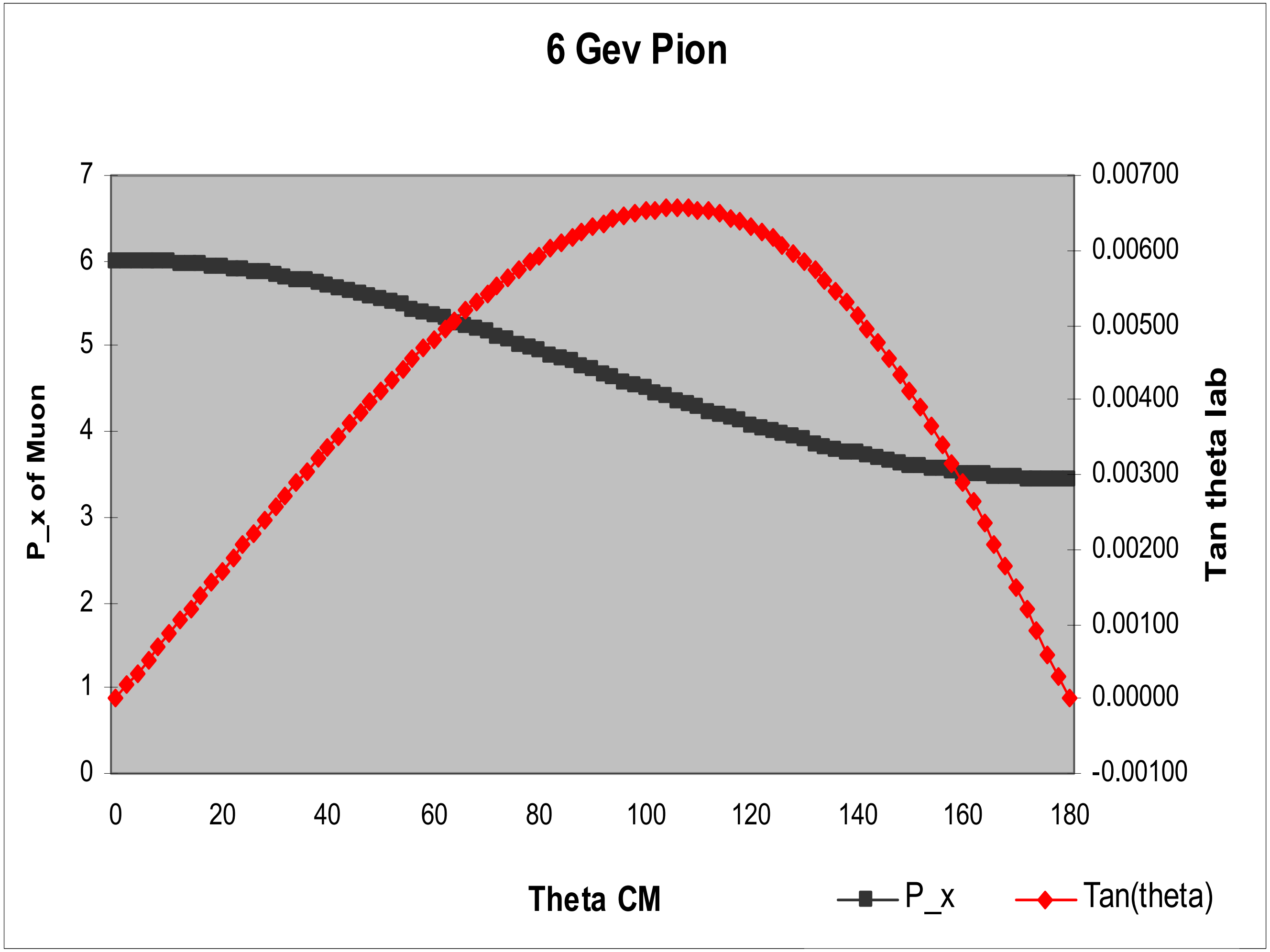
Conclusion

- The μ efficiency is stable through a large variety of algorithms and comparable in both detectors.

- The π response of the μ system is quite comparable as well.

- The π μ separation improves with cuts which take advantage of the μ penetration and on the multiplicity of hits per layer which is low (1-2 hits)for the μ but tend to be rather high for the π in part of the layers .

- The muon detector in Tesla has the advantage of having 5.4 Λ of material ahead (EM+HD), whereas, SD has only 3.9 Λ of material in (EM+HD). This increases the punch-through. In our Comparison it has been factored out. Improvements are anticipated by tuning the cuts and using calorimeter information.



From 6 GeV and up, the μ of the decay will be detected by MuDet being produced in the direction of the original π and with a p> 4GeV over almost the whole range.

(from G. Fisk)