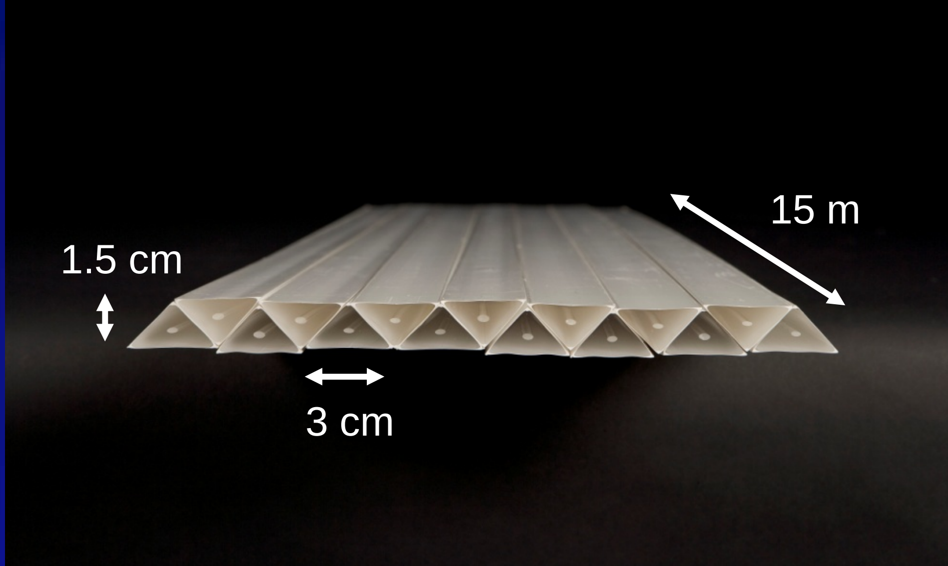
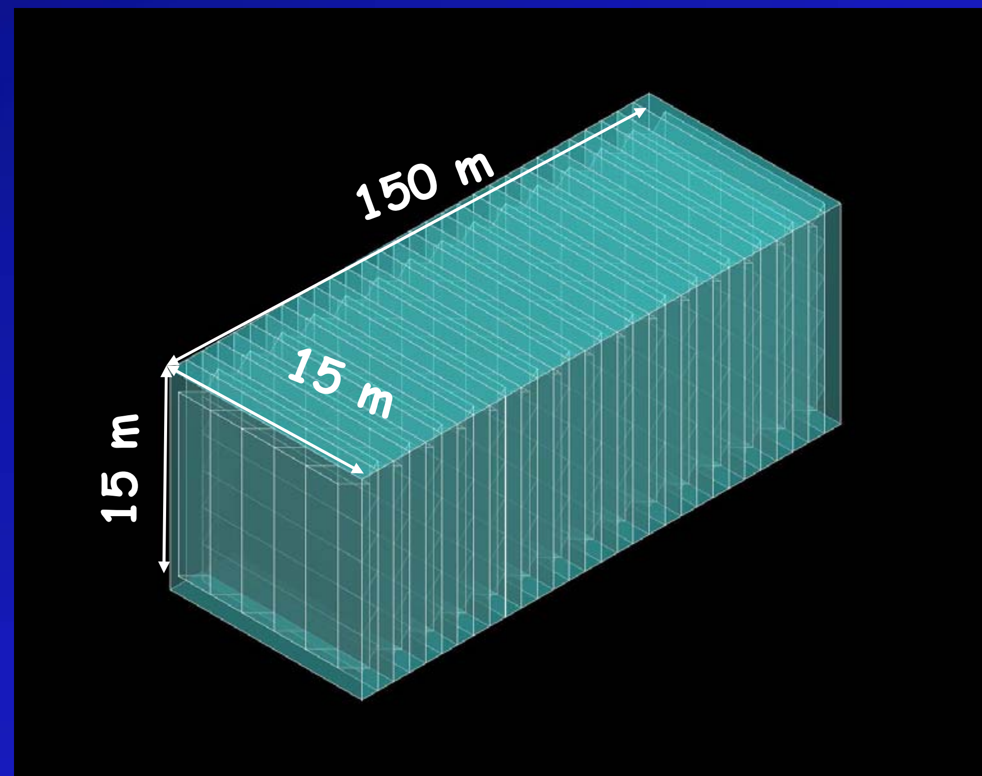
TASD Update

Fine-Resolution Totally Active Segmented Detector

Simulation of a Totally Active Scintillating Detector (TASD) using Nova and Minerva concepts with Geant4

- 35 kT (total mass)
- 10,000 Modules (X and Y plane)
- Each plane contains 1000 cells
- Total: 10M channels



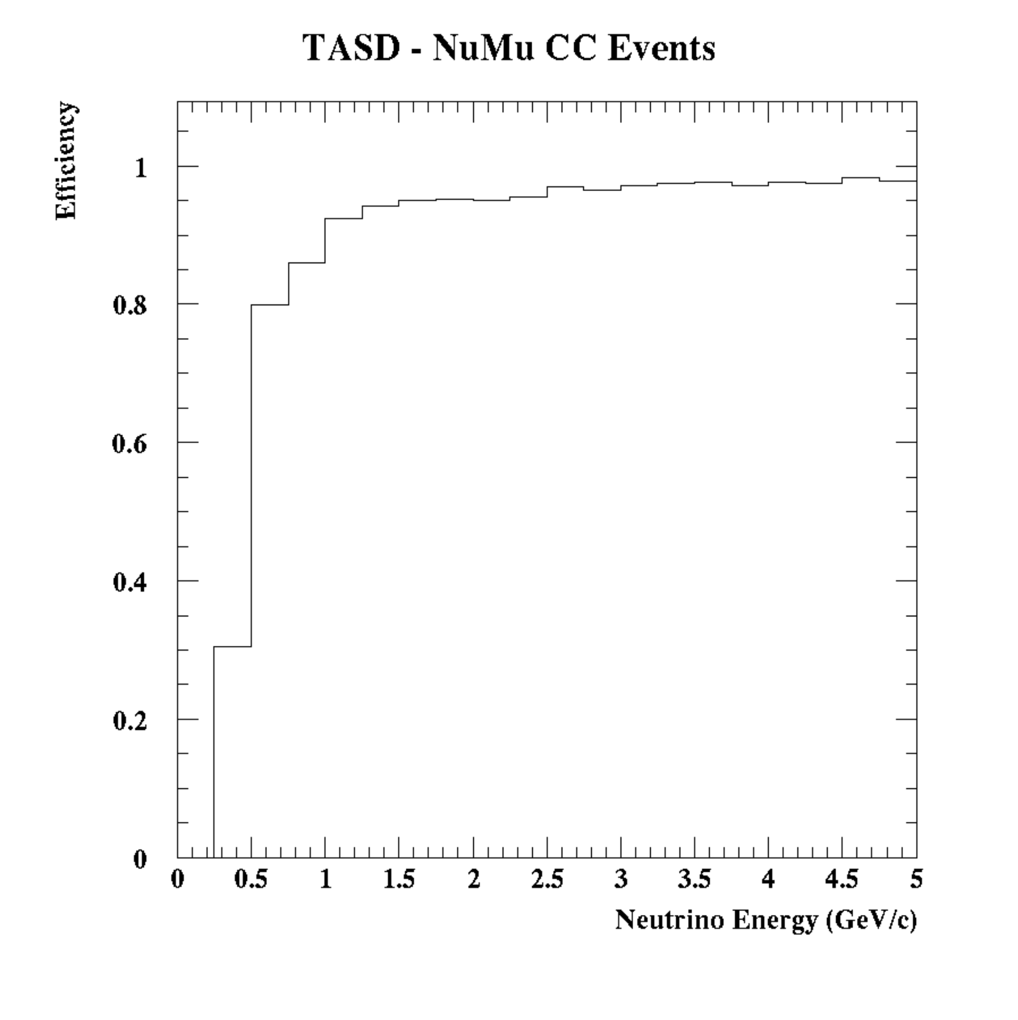


- Momenta between 100 MeV/c to 15 GeV/c
- Magnetic field considered: 0.5 T
- Reconstructed position resolution ~ 4.5 mm

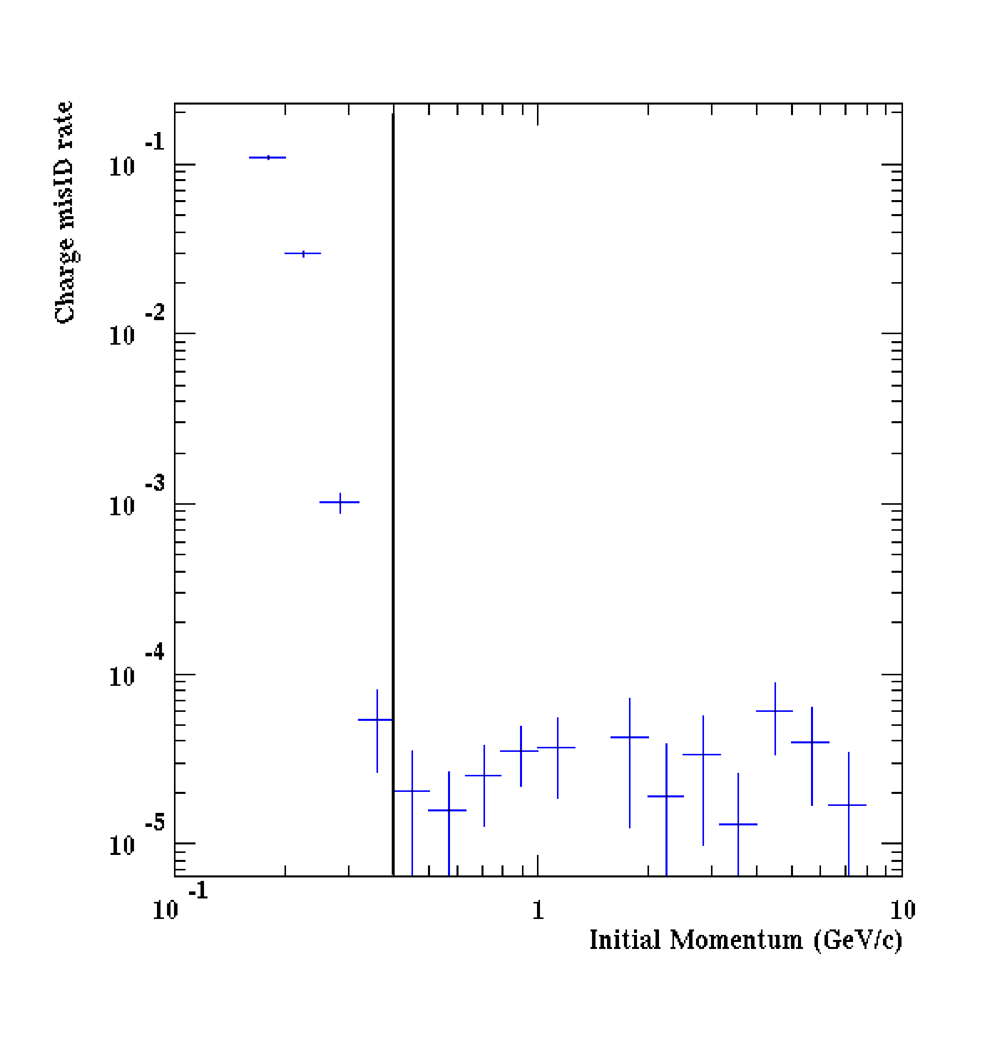
B = 0.5T

TASD Performance

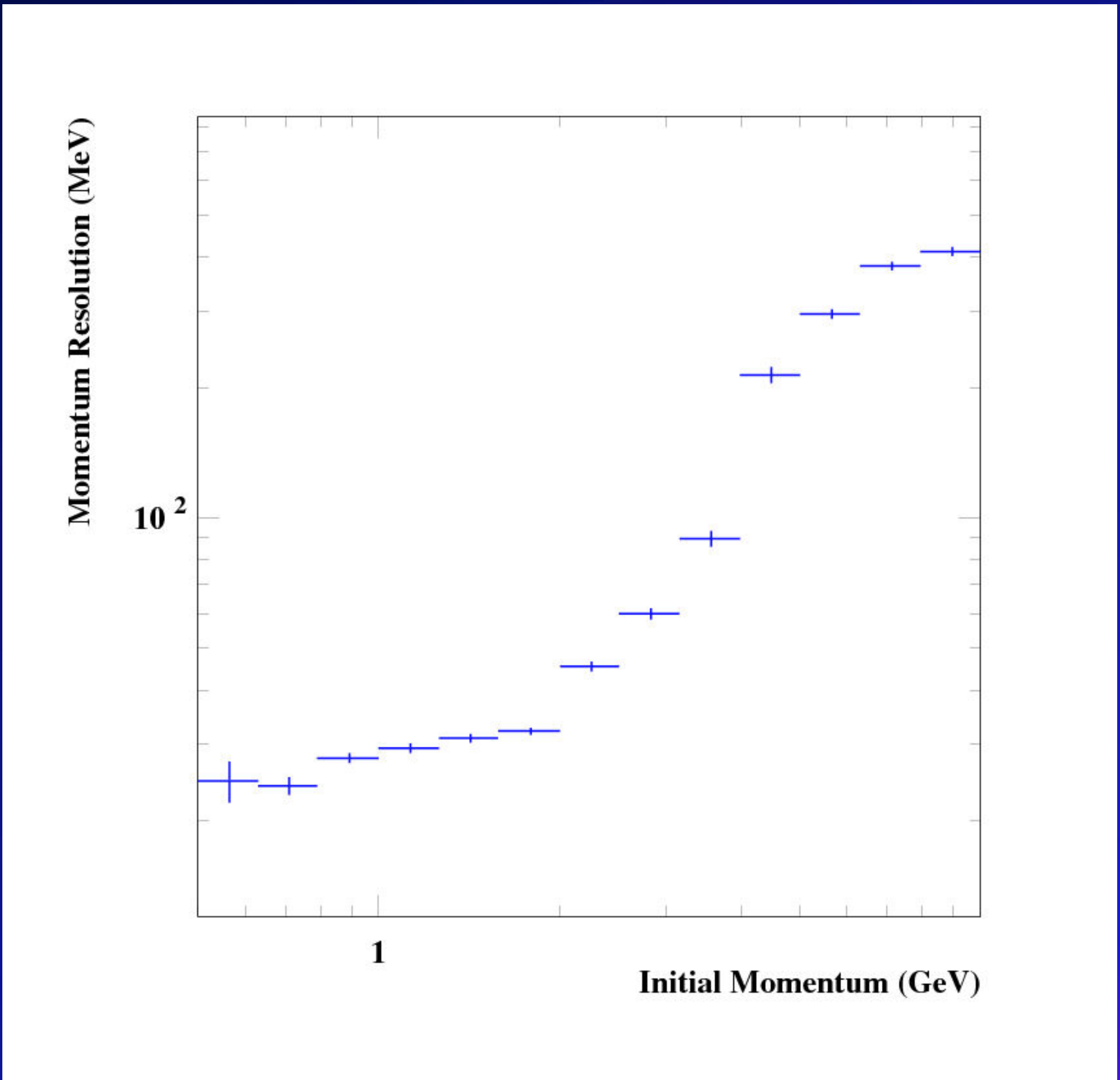
ν Event Reconstruction Efficiency



Muon charge mis-ID rate



TASD Performance II



- **Momentum resolution excellent**
  - Neutrino Event energy reconstruction from tracking
  - EM component from hit counting possibly
- **Simplifies electronics**
  - No calibration needed
  - Hit efficiency is only consideration
- **Expect**
  - $\sigma(E_{evt}) \approx$ 5-10% @ 2GeV
    - Based on extrapolations from Nova simulations

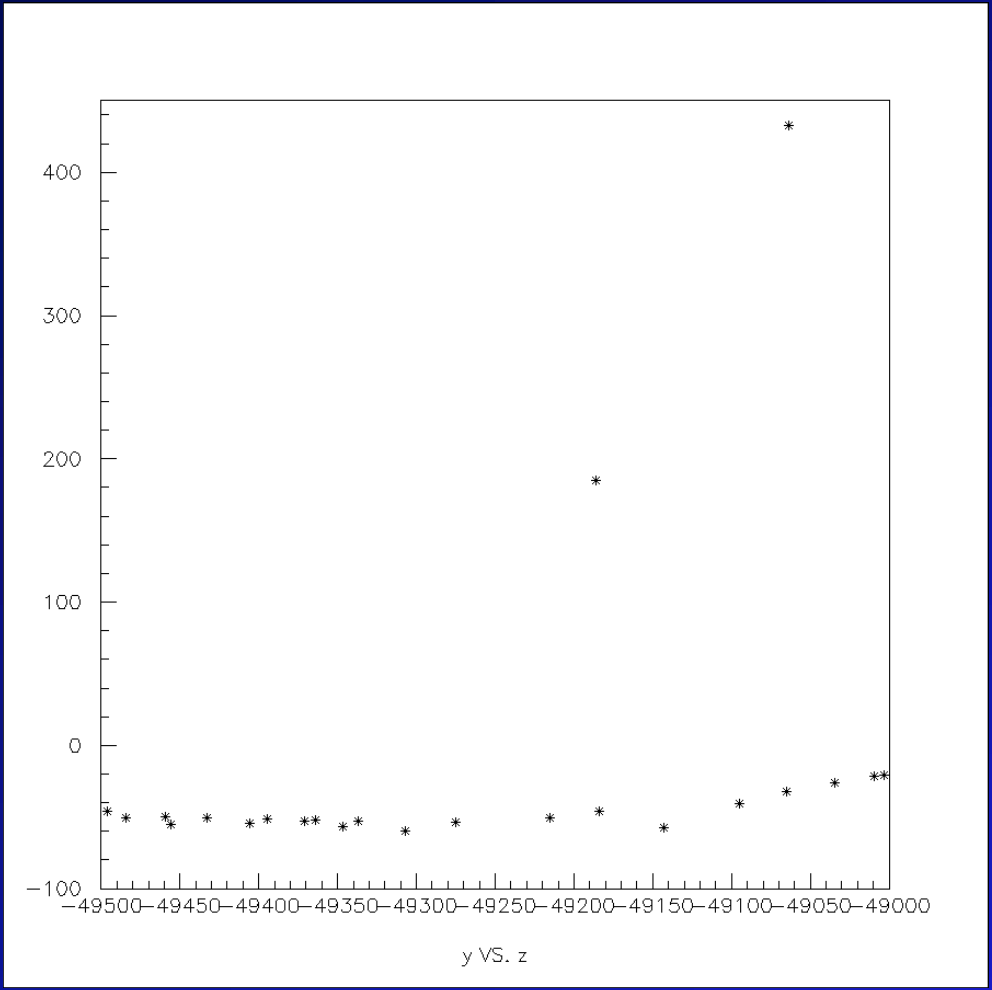
Initial Electron Charge ID Determination Exercise

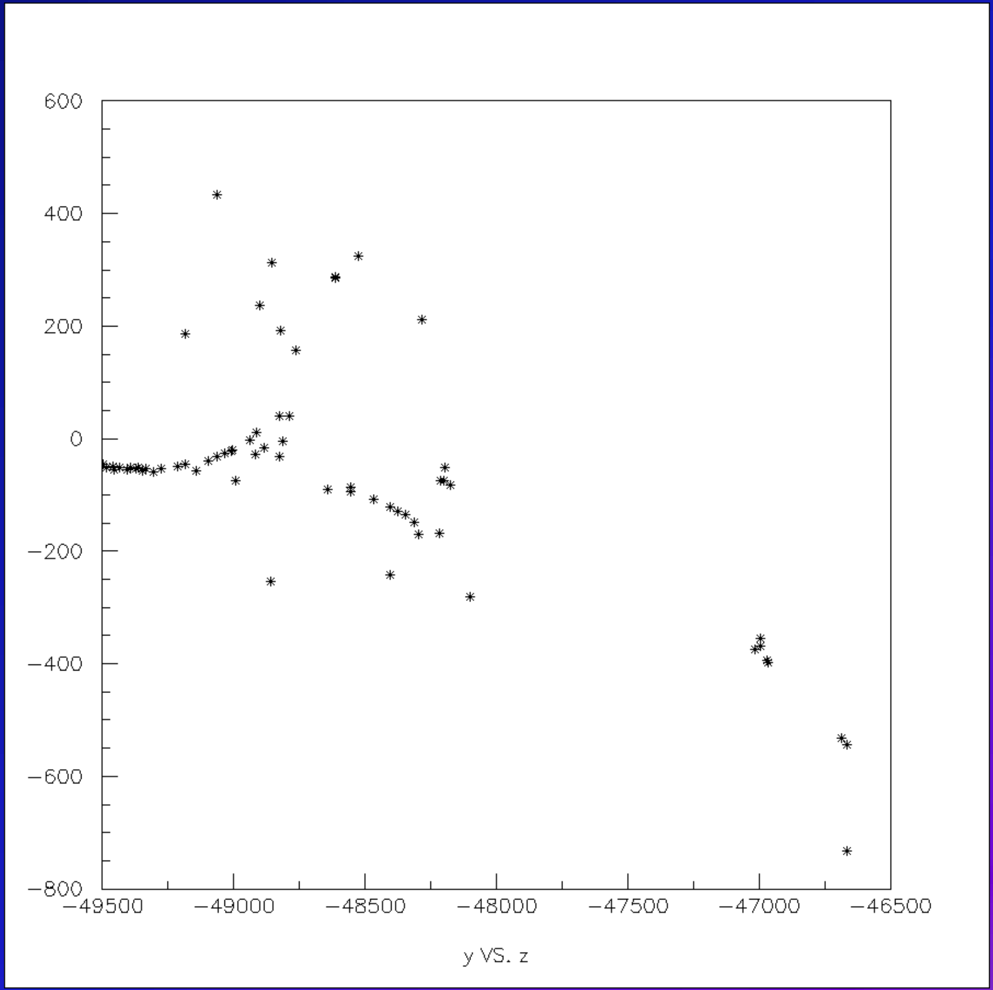
- As with the muons, start off with isolated positrons and attempt to reconstruct them first.
- If successful, we will then move to reconstructing ν_e CC events.
- First pass was made by simulating events and producing an "event display" which is reconstructed by eye by a few volunteers.

Data Sample

- Positrons were simulated in the TASD with the same dimensions, material, magnetic field, etc as in previous studies.
- 10 events each in momentum bins from 100 MeV/c to 4.9 GeV/c were simulated.
- The hit positions were smeared with hits removed at the correct rate to simulate position reconstruction efficiency.
- The remaining, smeared, positions were plotted.

Sample Events

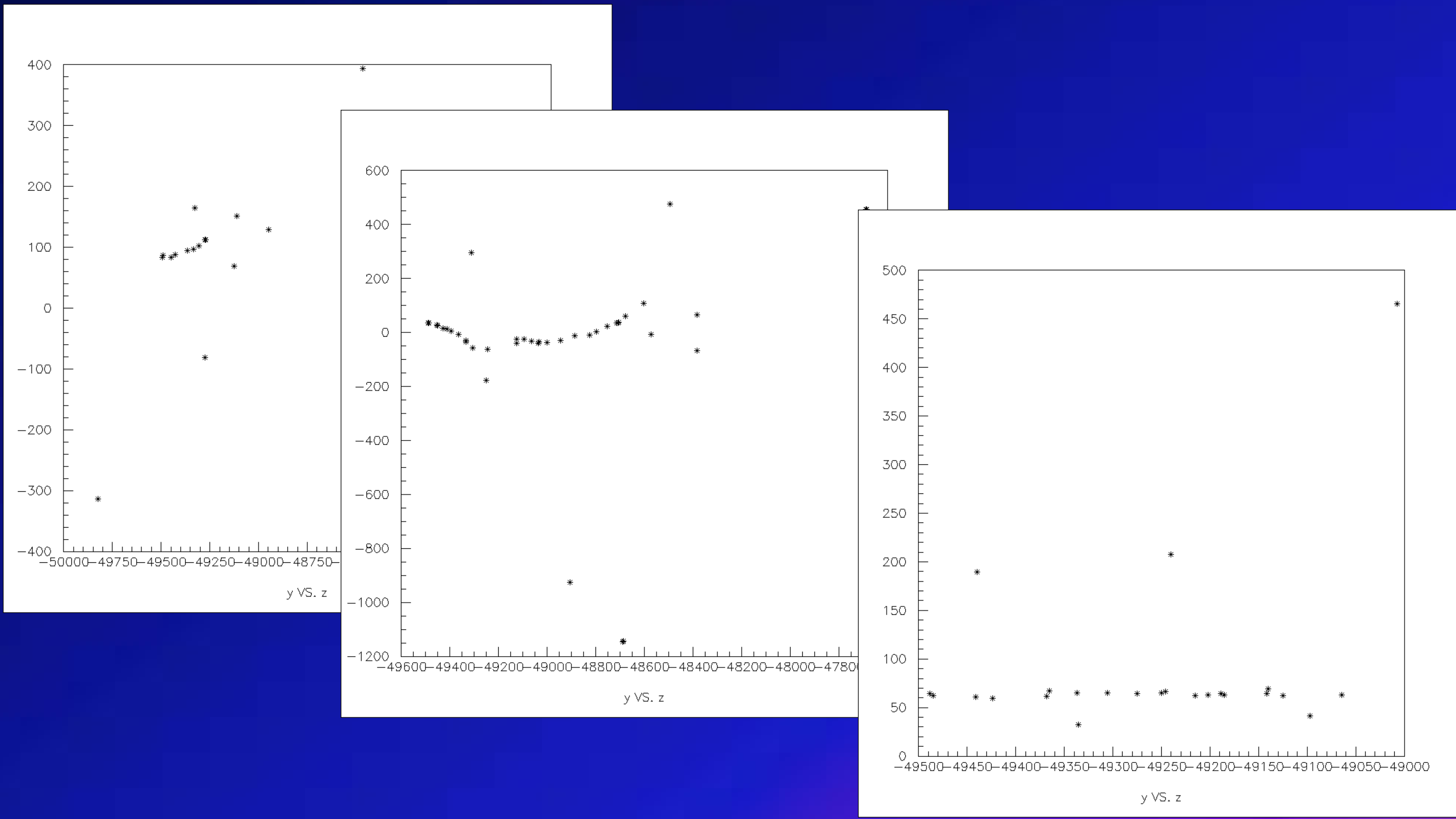




Analysis Technique

- Before the plots were generated, the raw data files were passed through a "blinder" program which assigned a random event number to the file and chose whether or not to flip the Y axis when making the display.
- In this way there was no way of knowing if a given event display was of a positive or negative track from a low, medium or high momentum particle before trying to do the "reconstruction".
- Each person attempted to determine the track curved up or down.

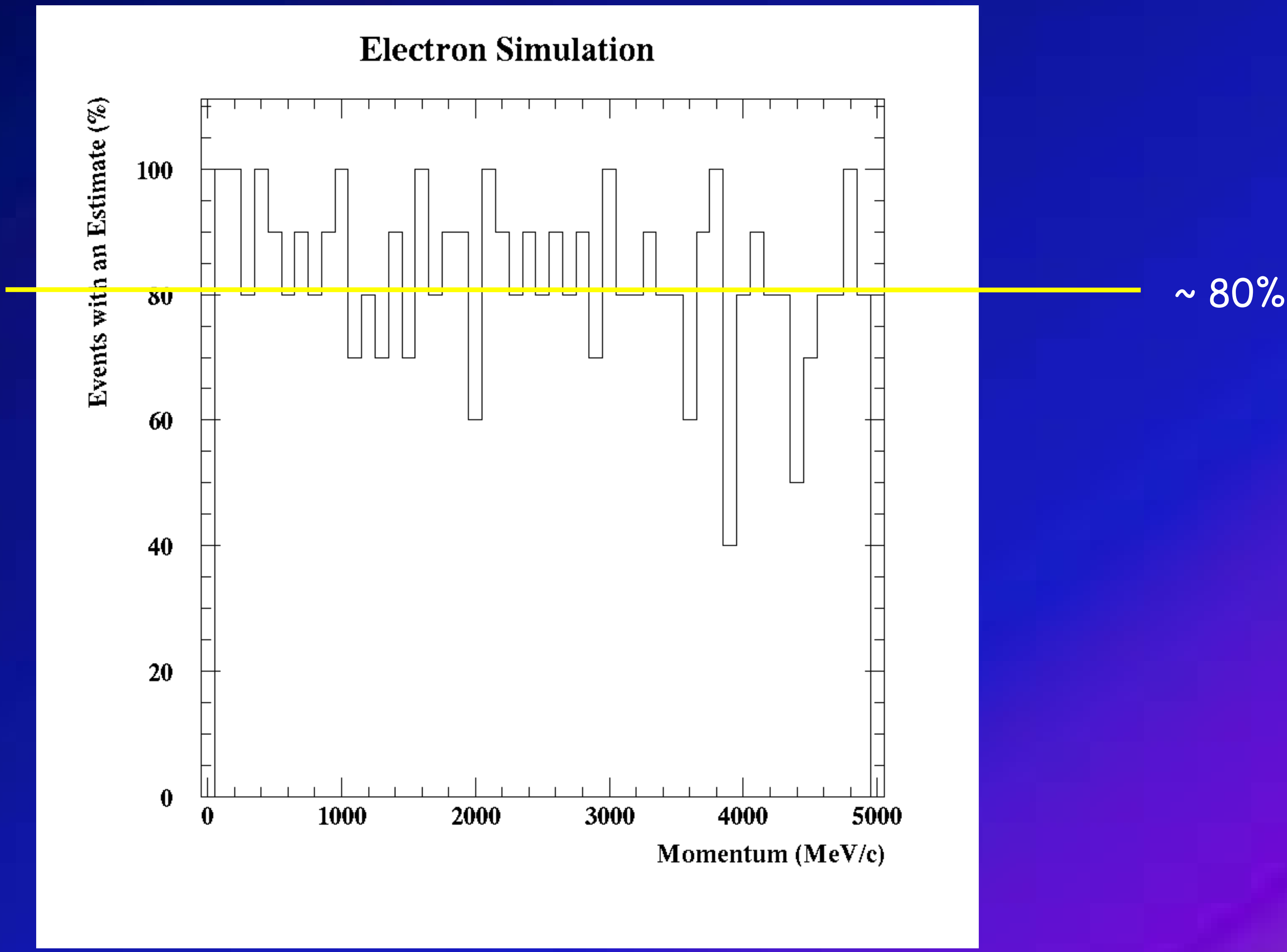
Curving Up or Down?



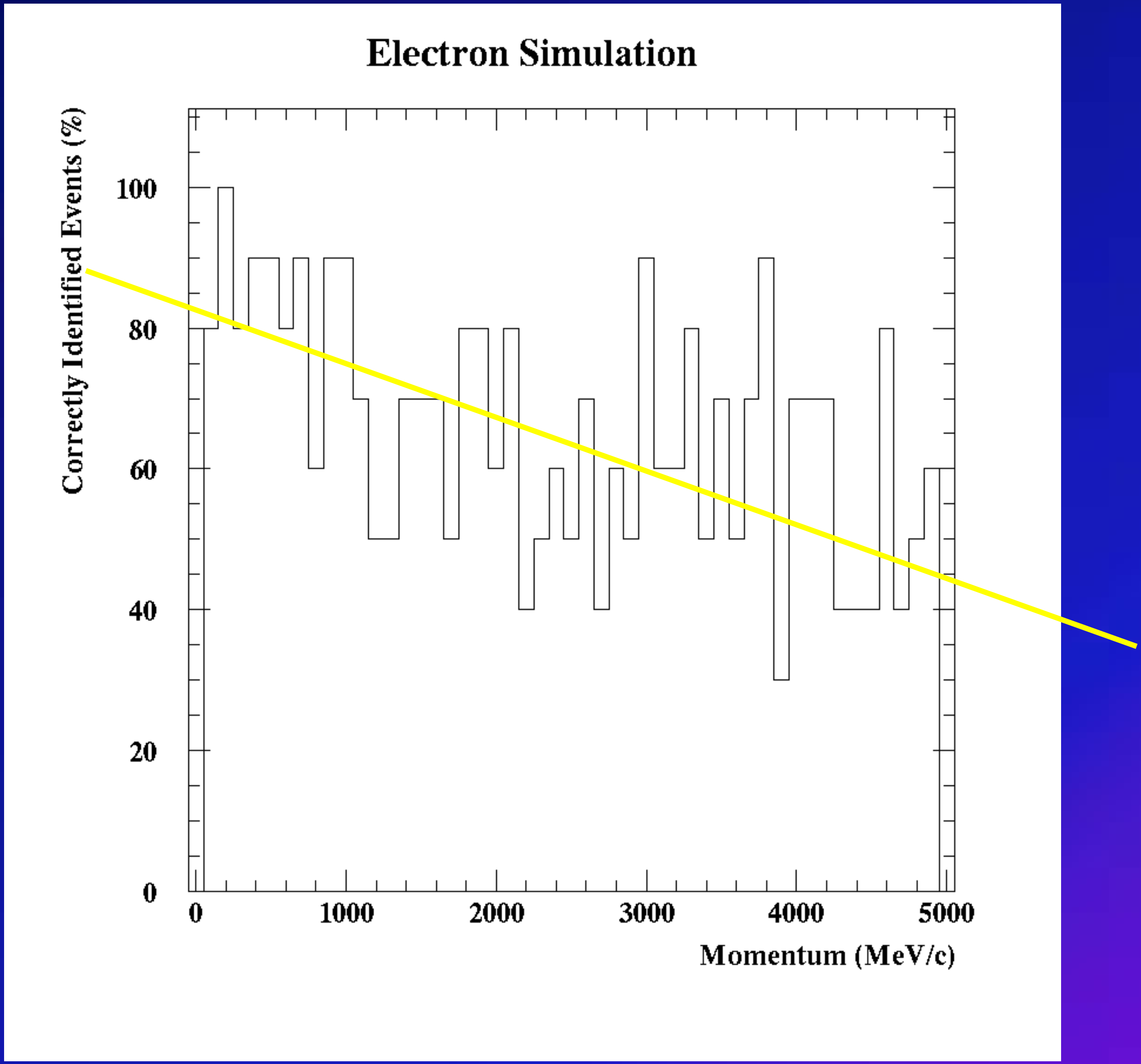
Event Scanners

- Events were scanned by Malcolm Ellis, Paul Kyberd, Olga Mena and AB.
- In the vast majority of cases, we agreed on the assignment of an event into one of three categories:
  - Bends Up, Bends Down, Can't Tell
- When there was disagreement, the assignment that was most common was taken (this usually meant excluding one person's measurement).

Events that we could ID

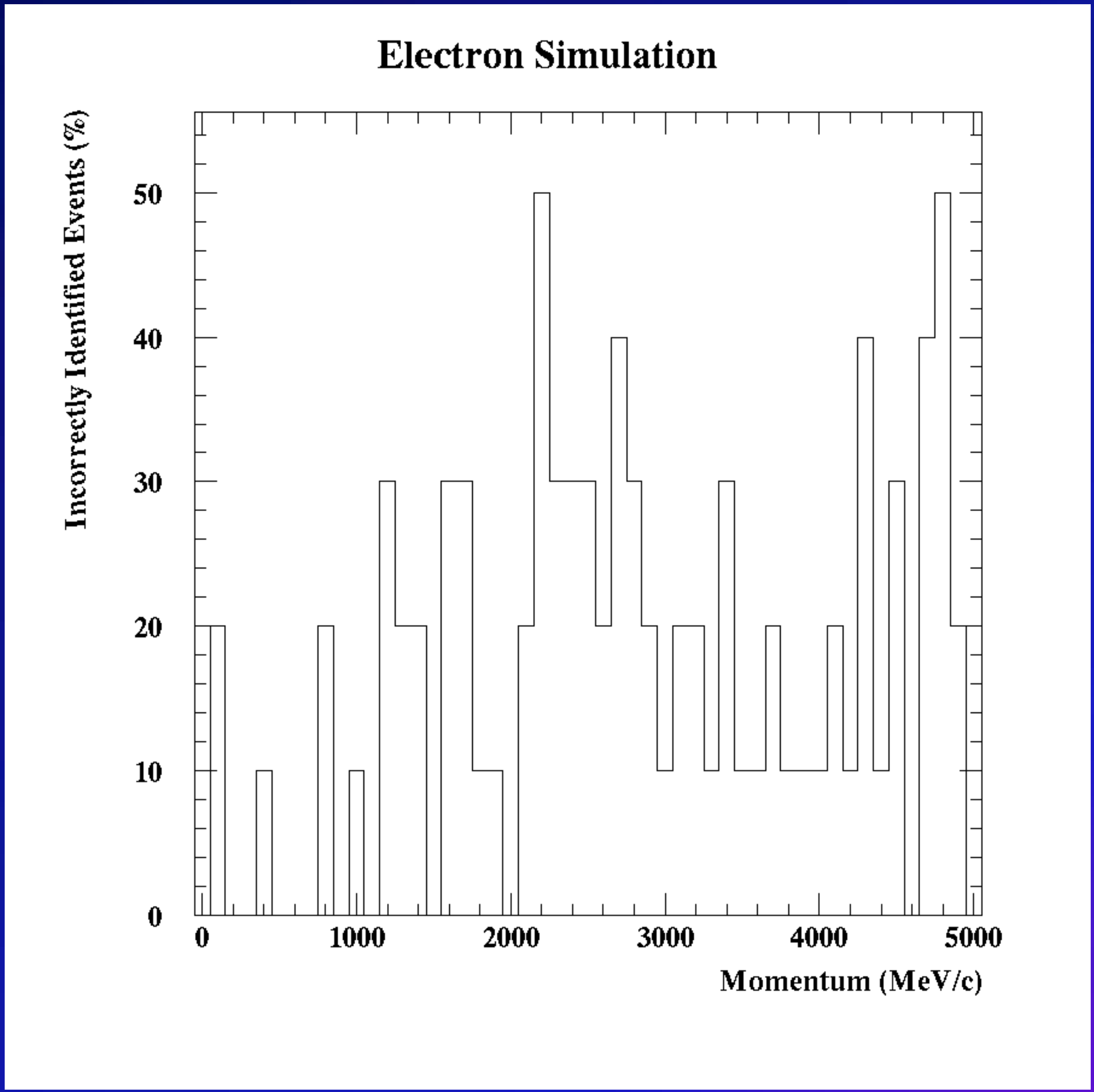


Correctly Identified Events

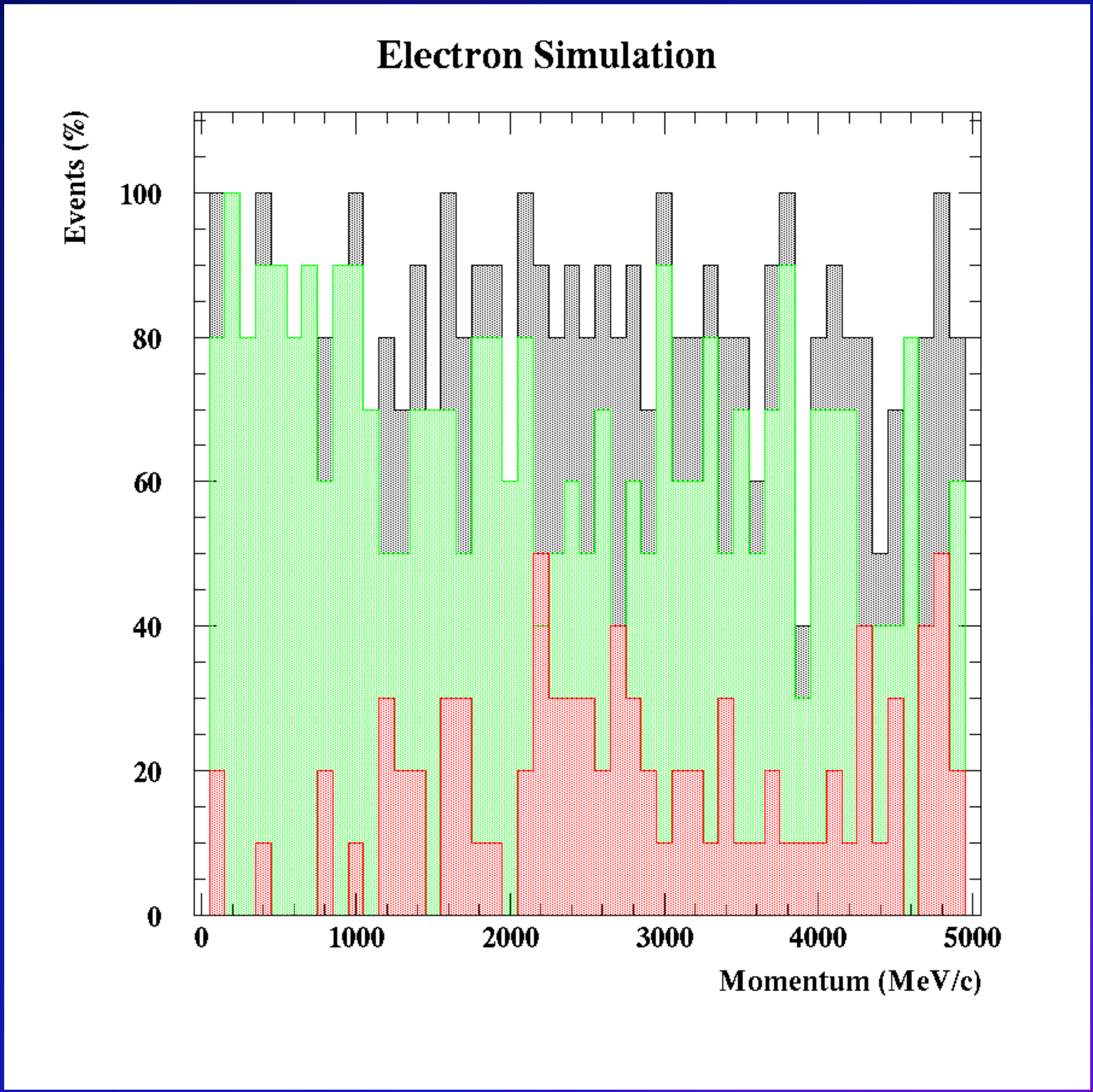


~ 50 - 80%

Events We Got Wrong



Summary of Previous Plots



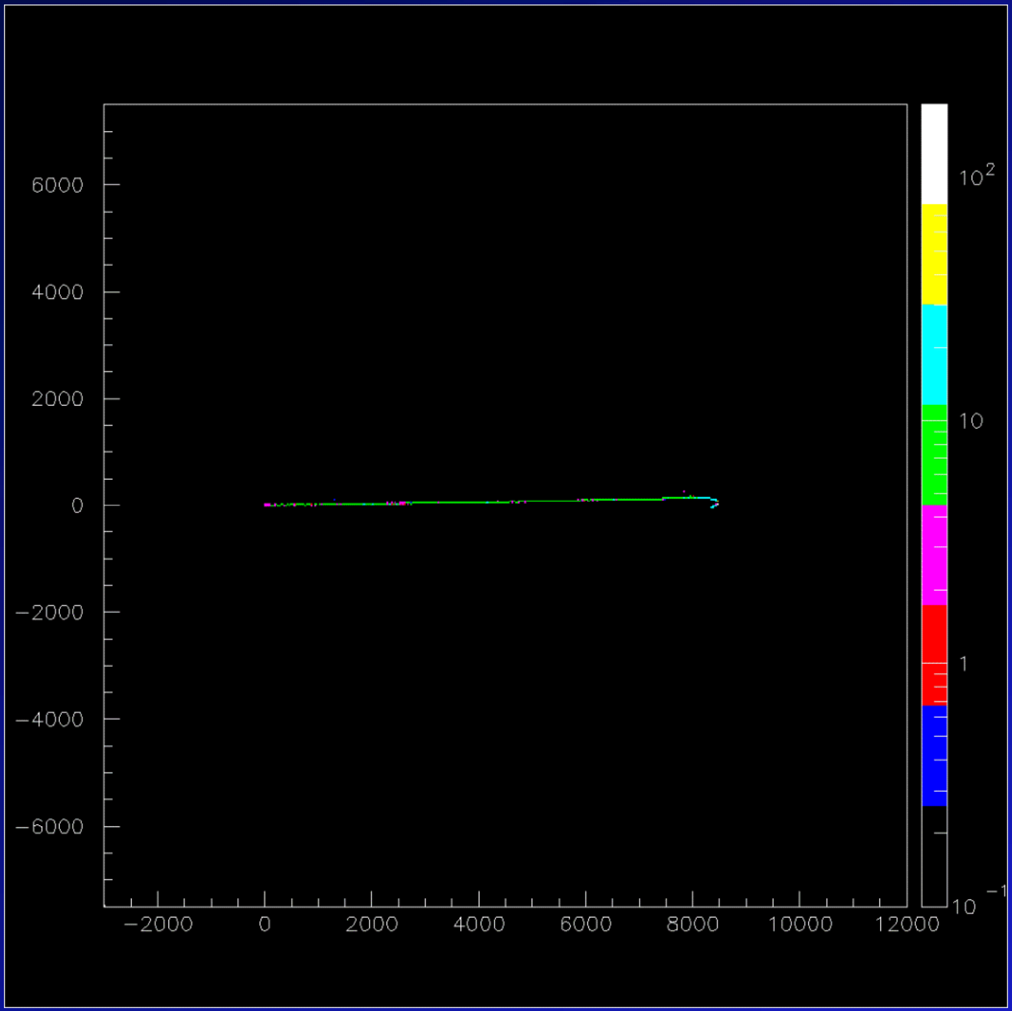
Summary

- A very simple "by eye" reconstruction seems to be able to find a curved stub before the electron showers in ~ 80% of events.
- The charge is correctly identified almost all the time at low momentum and even at 3 GeV/c only 30% of events are given the wrong sign.
- This should hopefully be improved by the use of a proper fit!

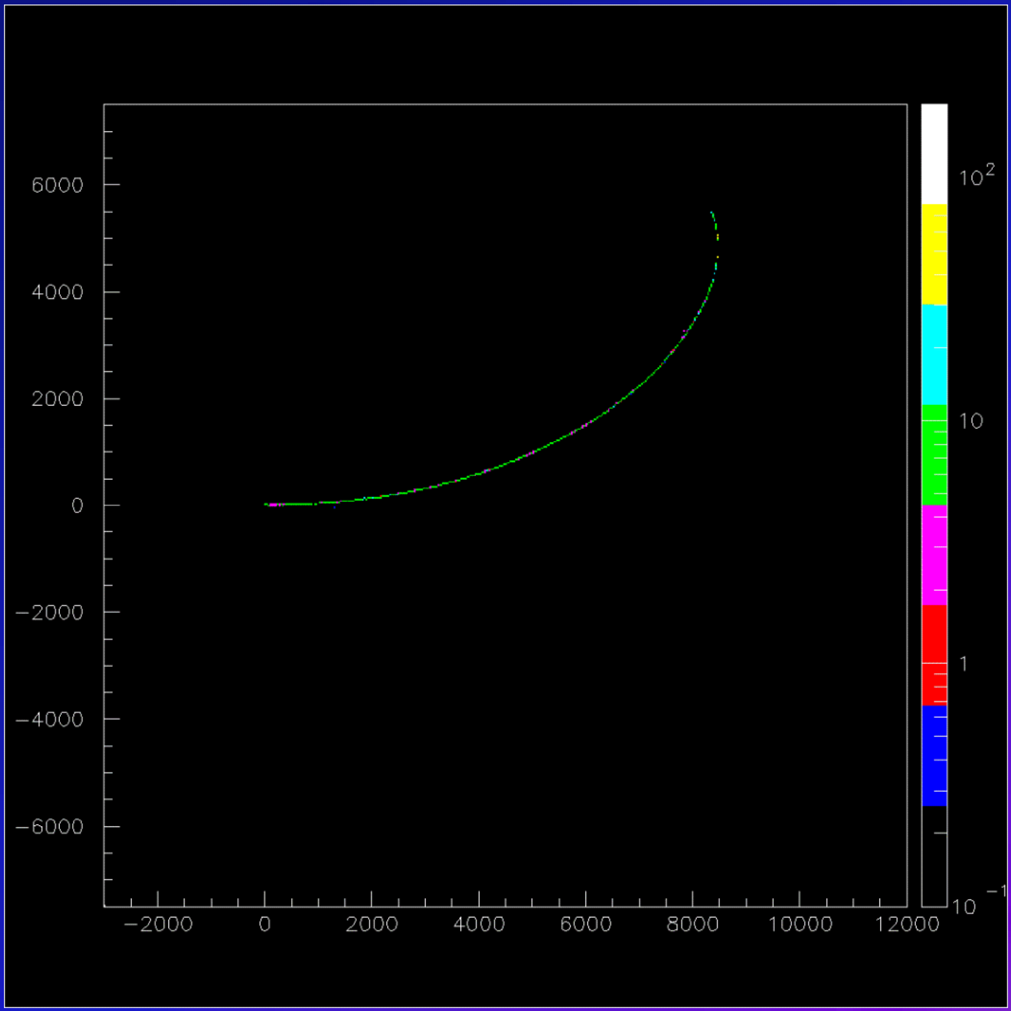
Next Steps

- **Electron reconstruction:**
  - Decide on a clear analysis criteria and repeat "eye reconstruction" on a new set of events.
    - Also look at B=1T
  - If this produces a similar result then we will move to a proper track fit and analysis.
- **Pion / hadronic background:**
  - MIND group (Valencia + Glasgow) has been making progress in this area.
  - Need to find time to continue integration of MIND/TASD software as previously discussed.
- **Now it will get Harder**

Muons: 0.3 to 3 GeV

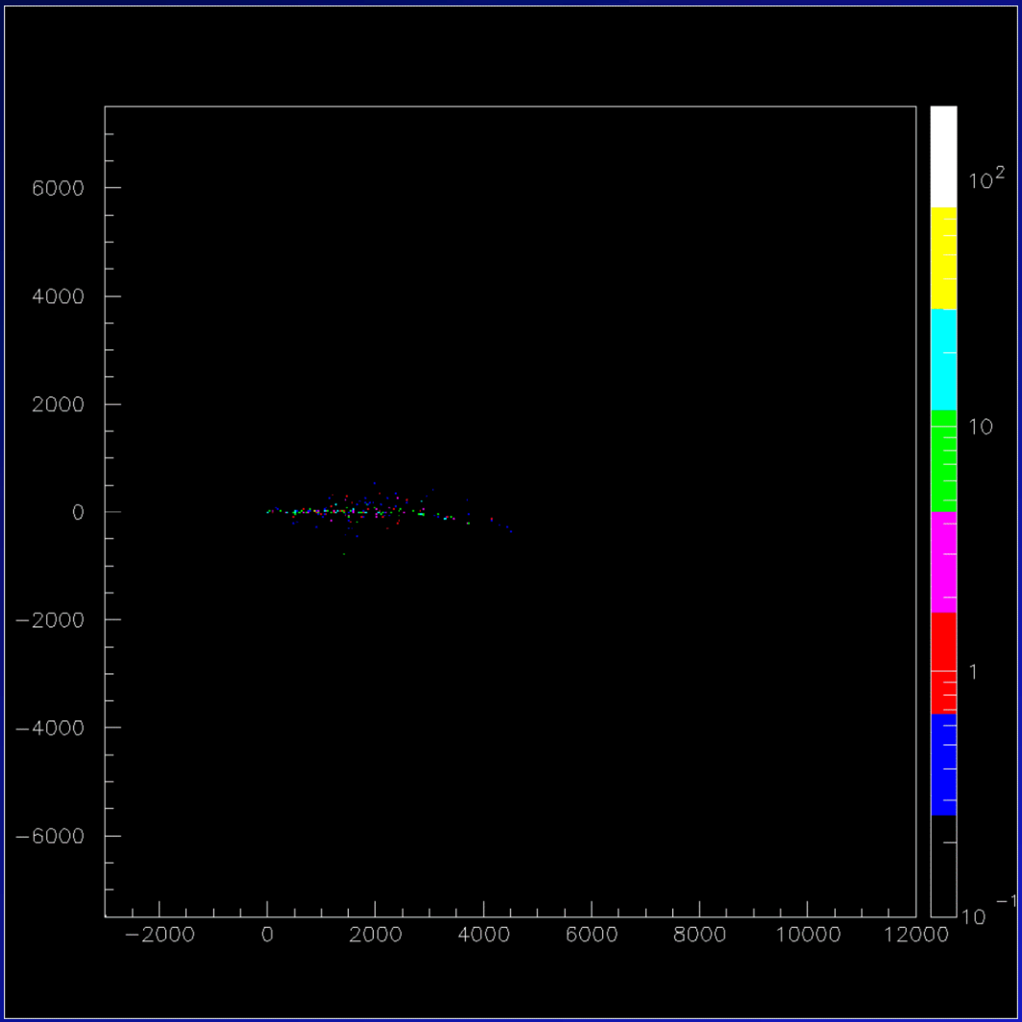


Non Bend Plane



Bend Plane

Electrons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10^2
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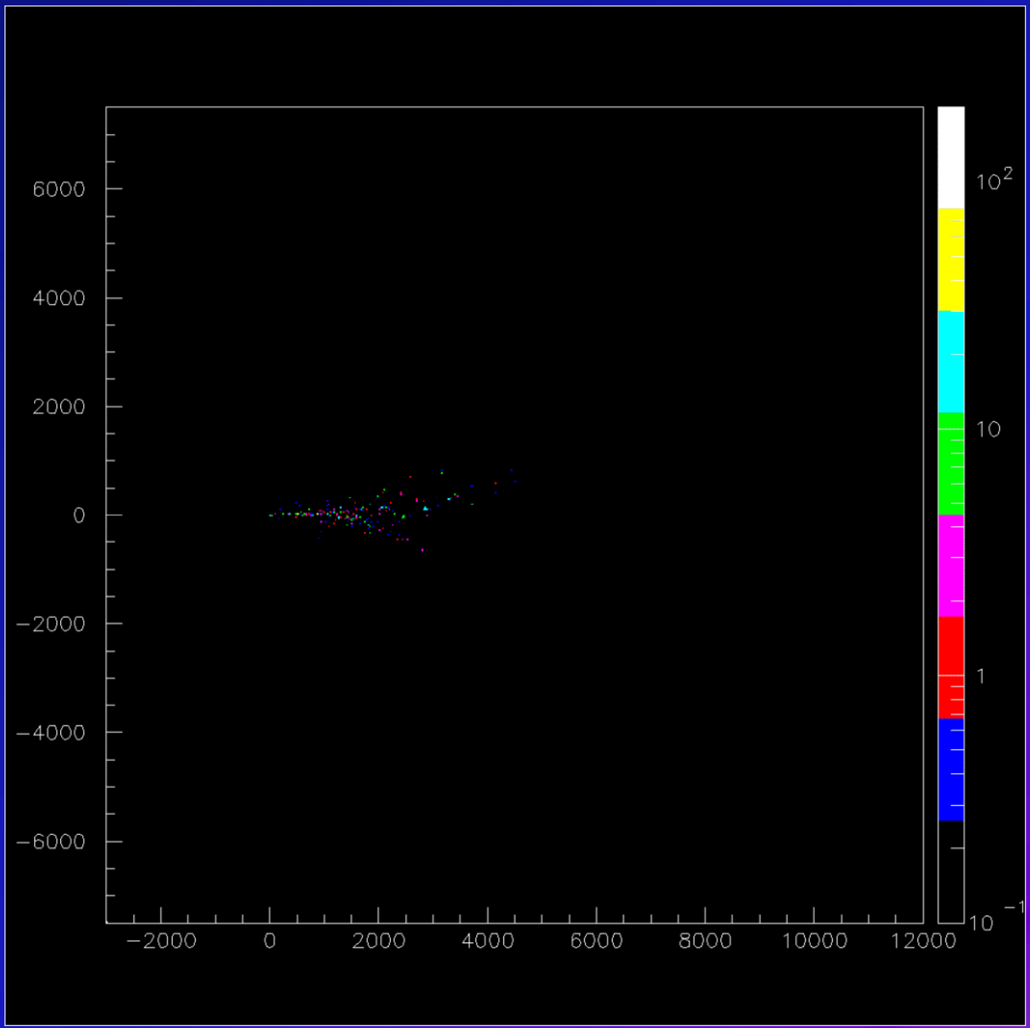
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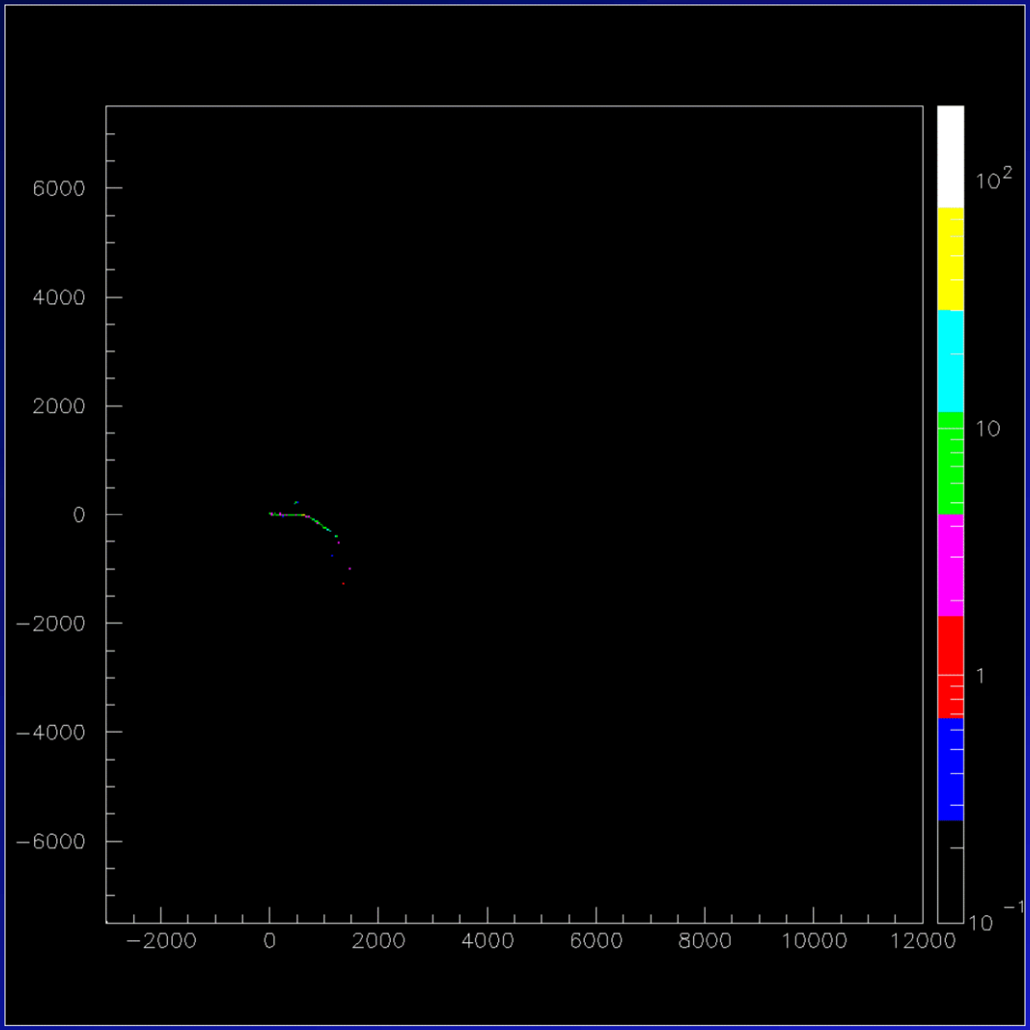
Pions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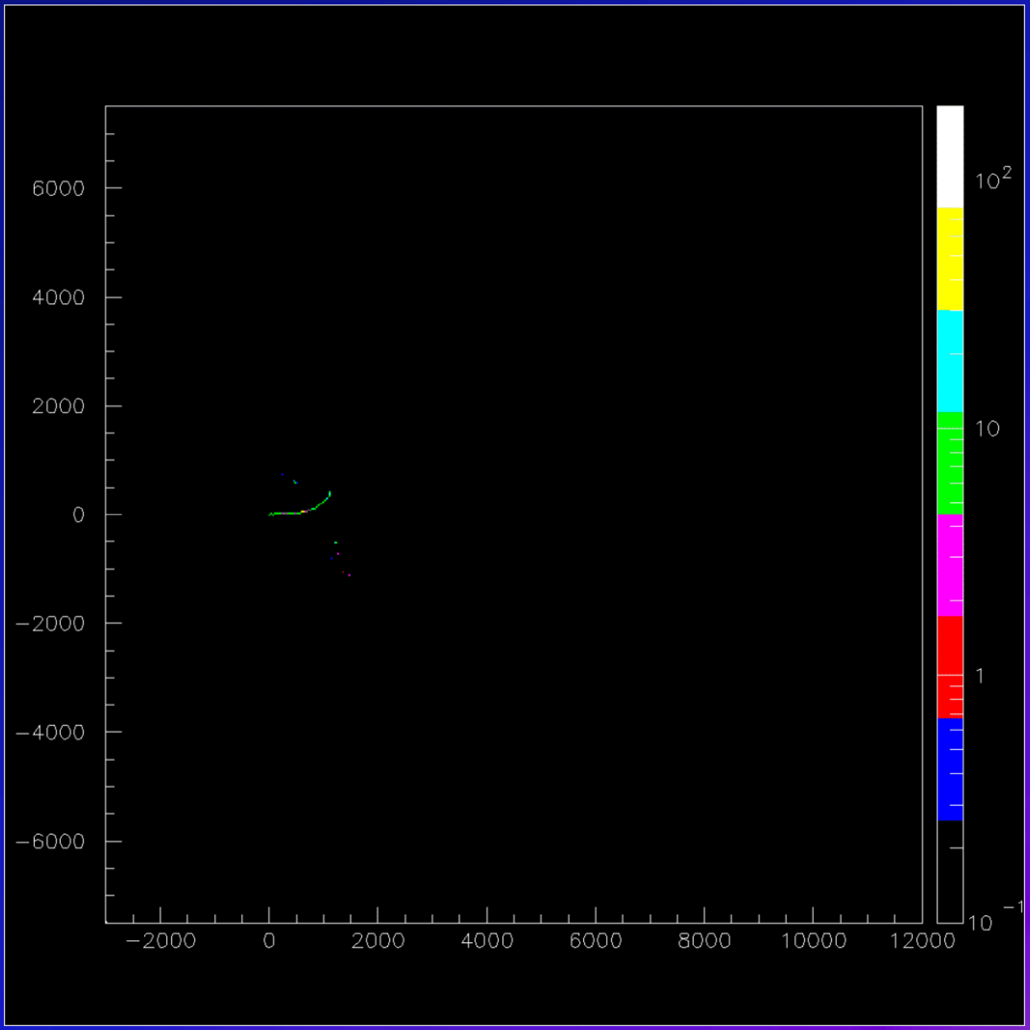
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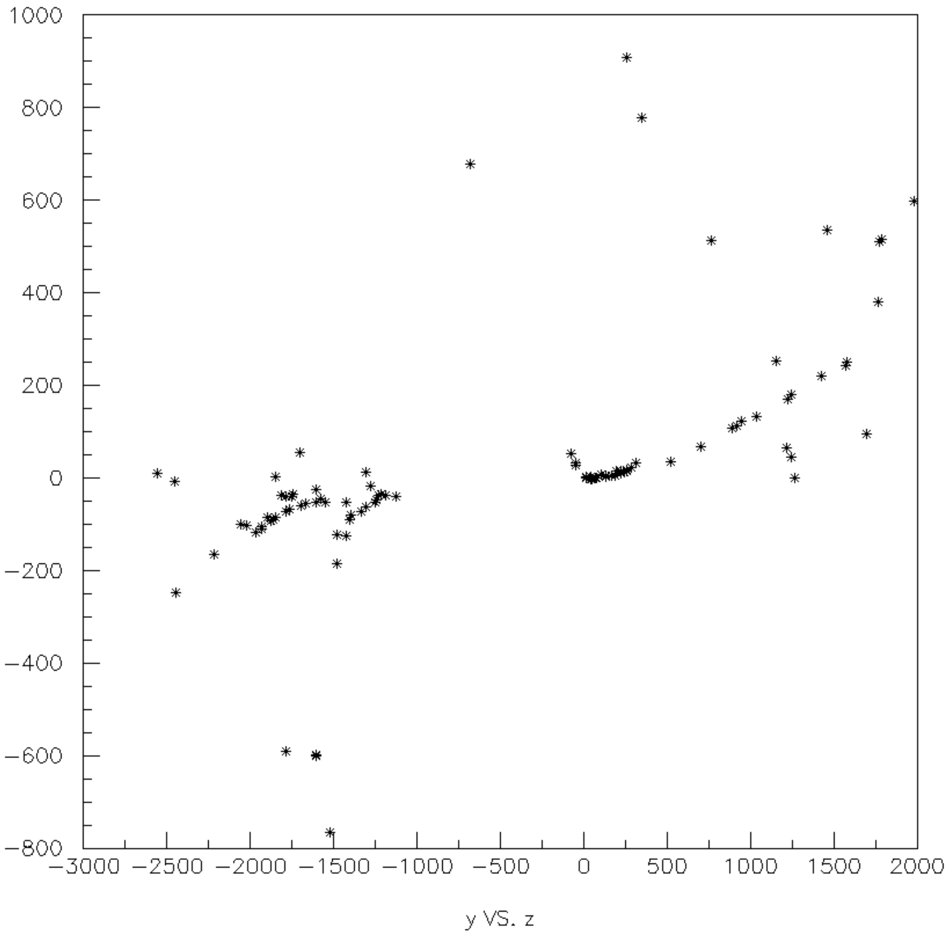
10^{-1}

Another possibility for TASD?

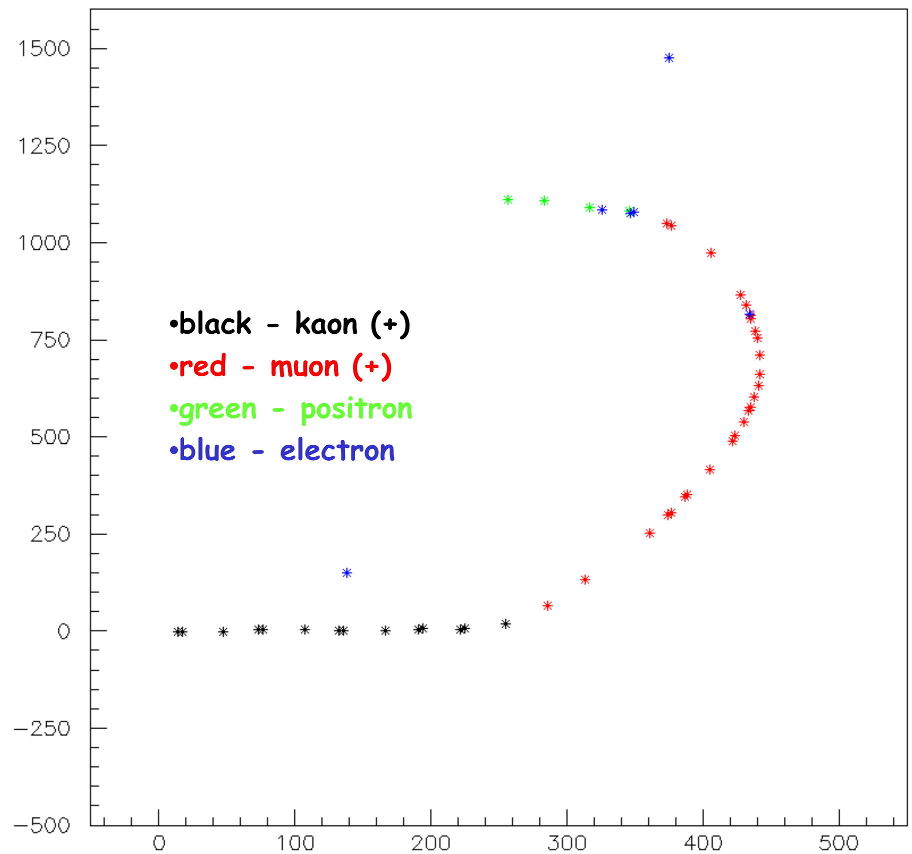
- Large neutrino detectors are often considered for nucleon decay experiments as well.
- Could the TASD be used for such searches?
  - How Large is Large Enough?
    - Dare we say 100 kT?
- Nothing serious done so far, but a couple of quick simulations seem to indicate that this is worth pursuing.

Proton Decay

$P \to \pi^+ \pi^0$



$P \to K^+ \nu$



Detector R&D Issues

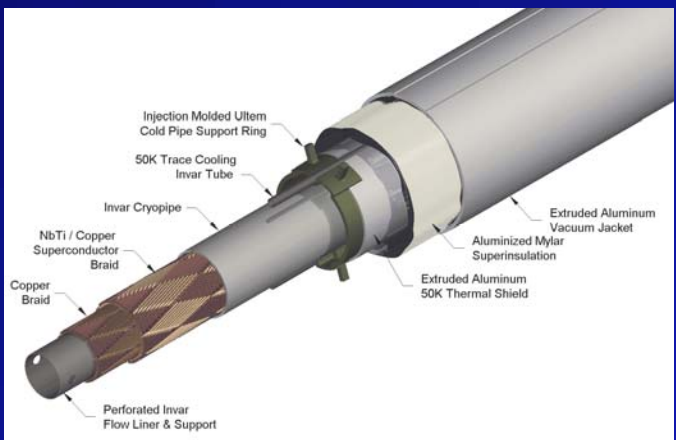
Detector R&D

There are 3 components to this detector and their respective R&D

- Magnet
- Scintillator Production
- Photo-detector and electronics

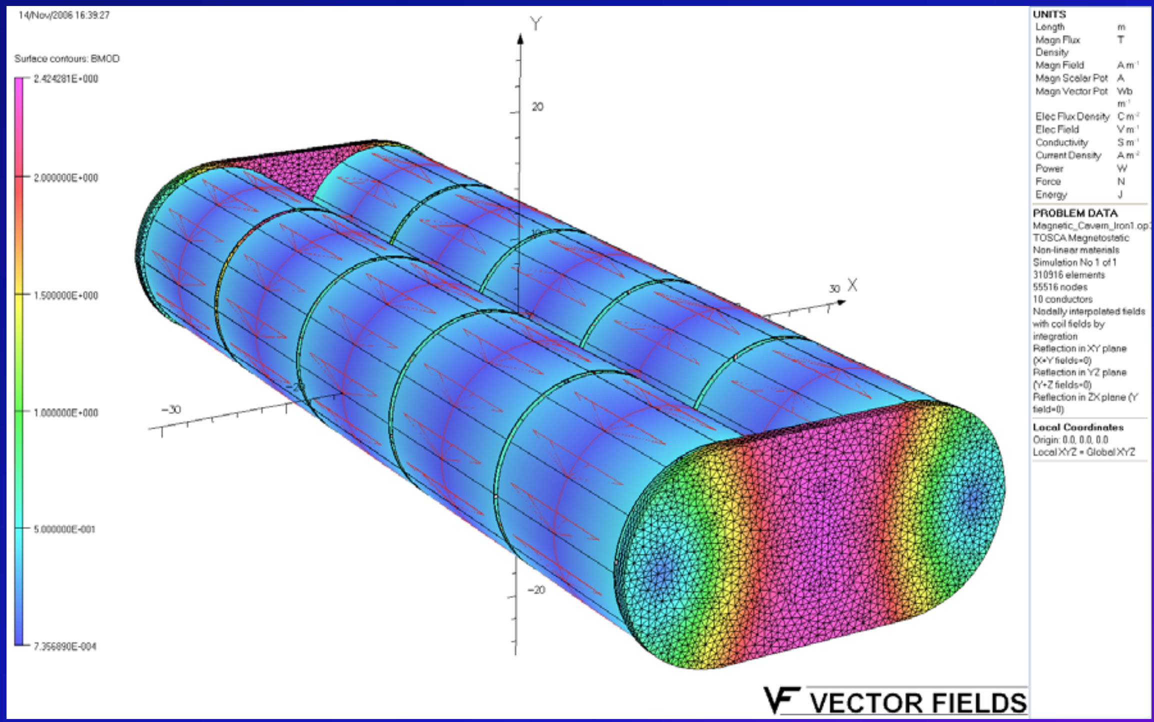
Very-Large-Magnetic Volume R&D

- Production of very large magnetic volumes – expensive using conventional technology
  - For SC magnets – cost driven by cryostat
  - Use VLHC SC Transmission Line Concept
    - Wind around mandrel
    - Carries its own cryostat
    - No large vacuum loads



- Scaling Factor:
  - Cost $\propto$ r ?

- Concept for 23 X 10^3 m^3

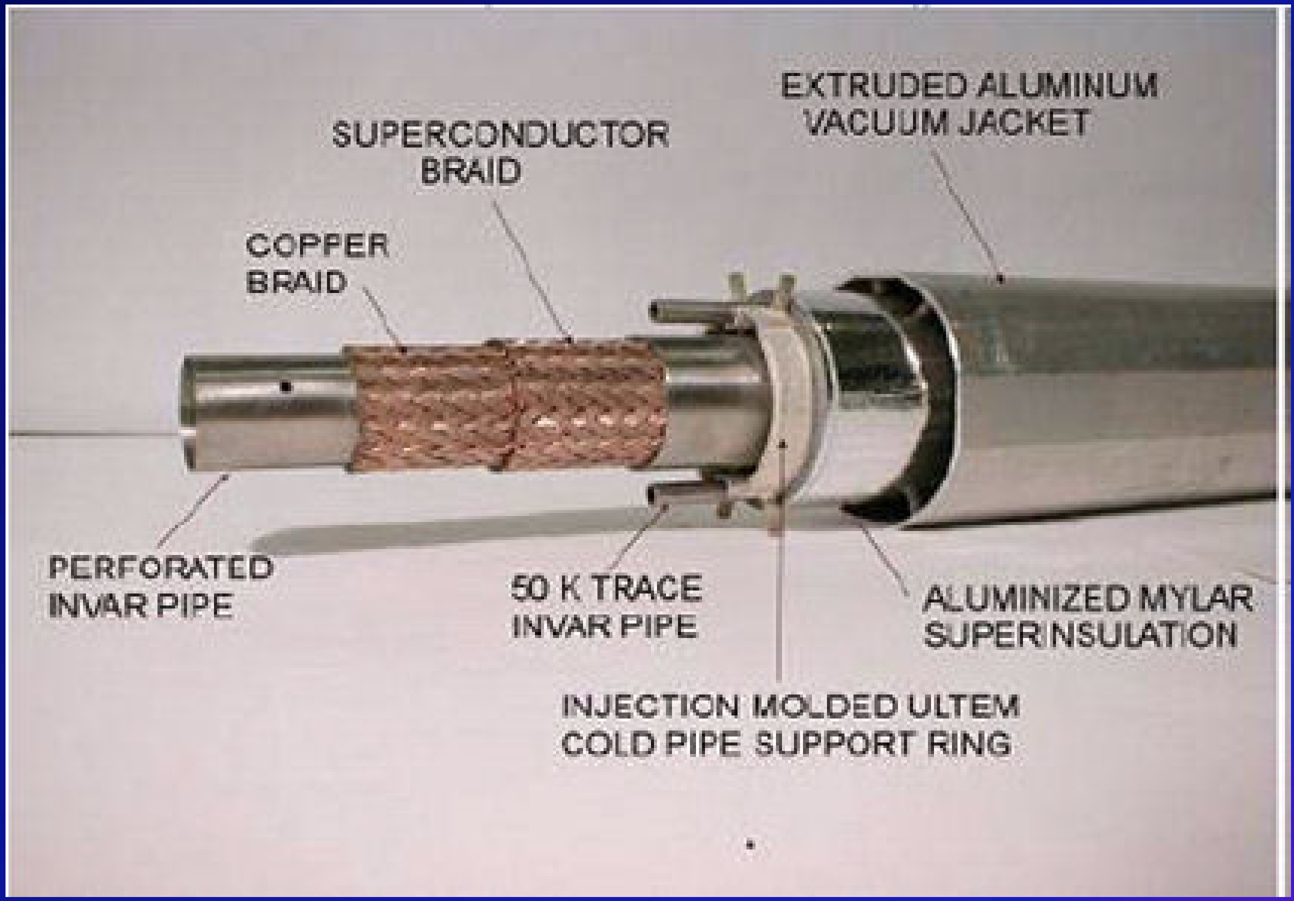


1 m iron wall thickness.

~2.4 T peak field in the iron.

Good field uniformity

Superconducting Transmission Line makes this concept possible *(affordable)*



- **SCTL not a "concept" – prototyped, tested and costed for the VLHC Project at Fermilab**

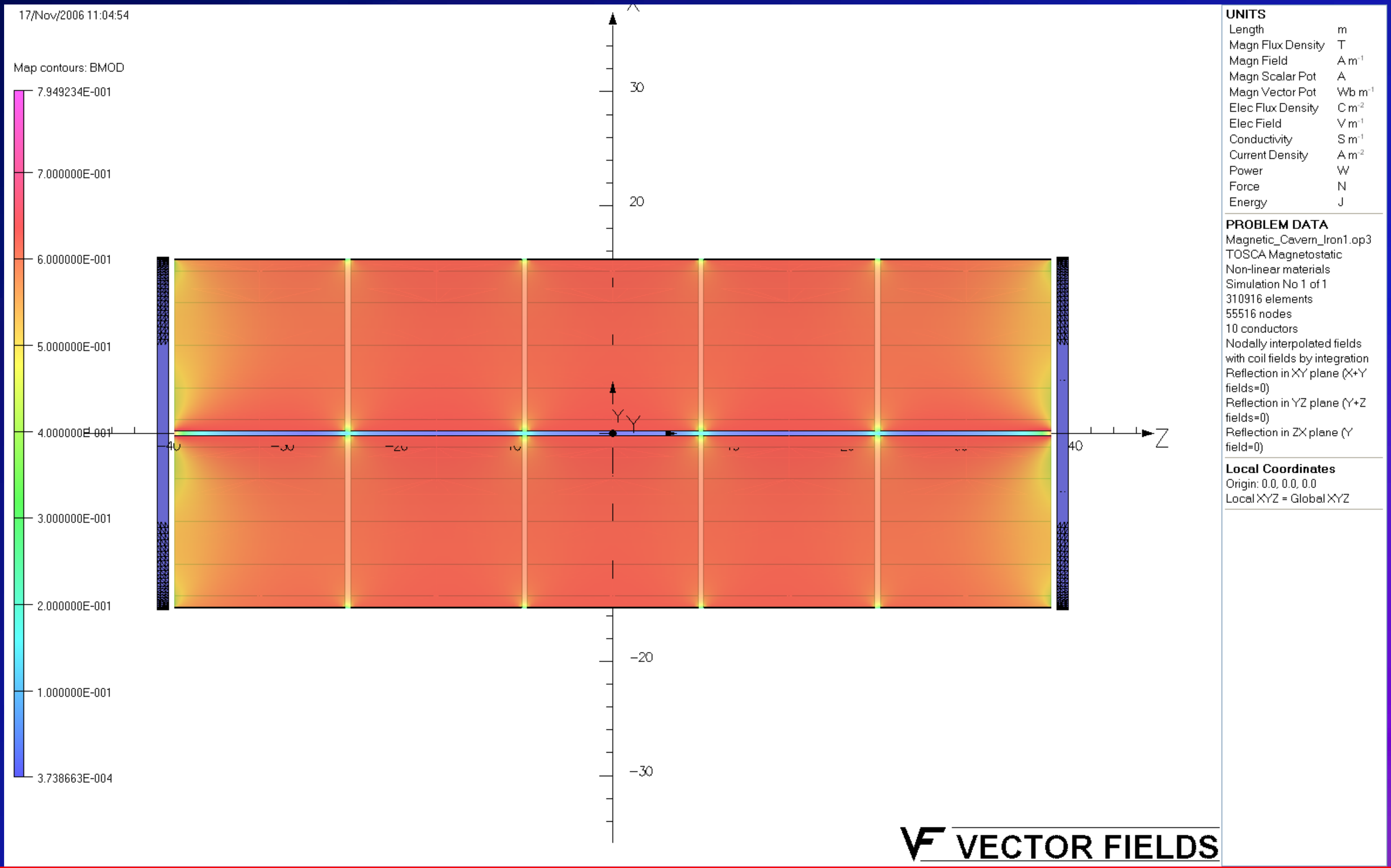
SCTL Parameters

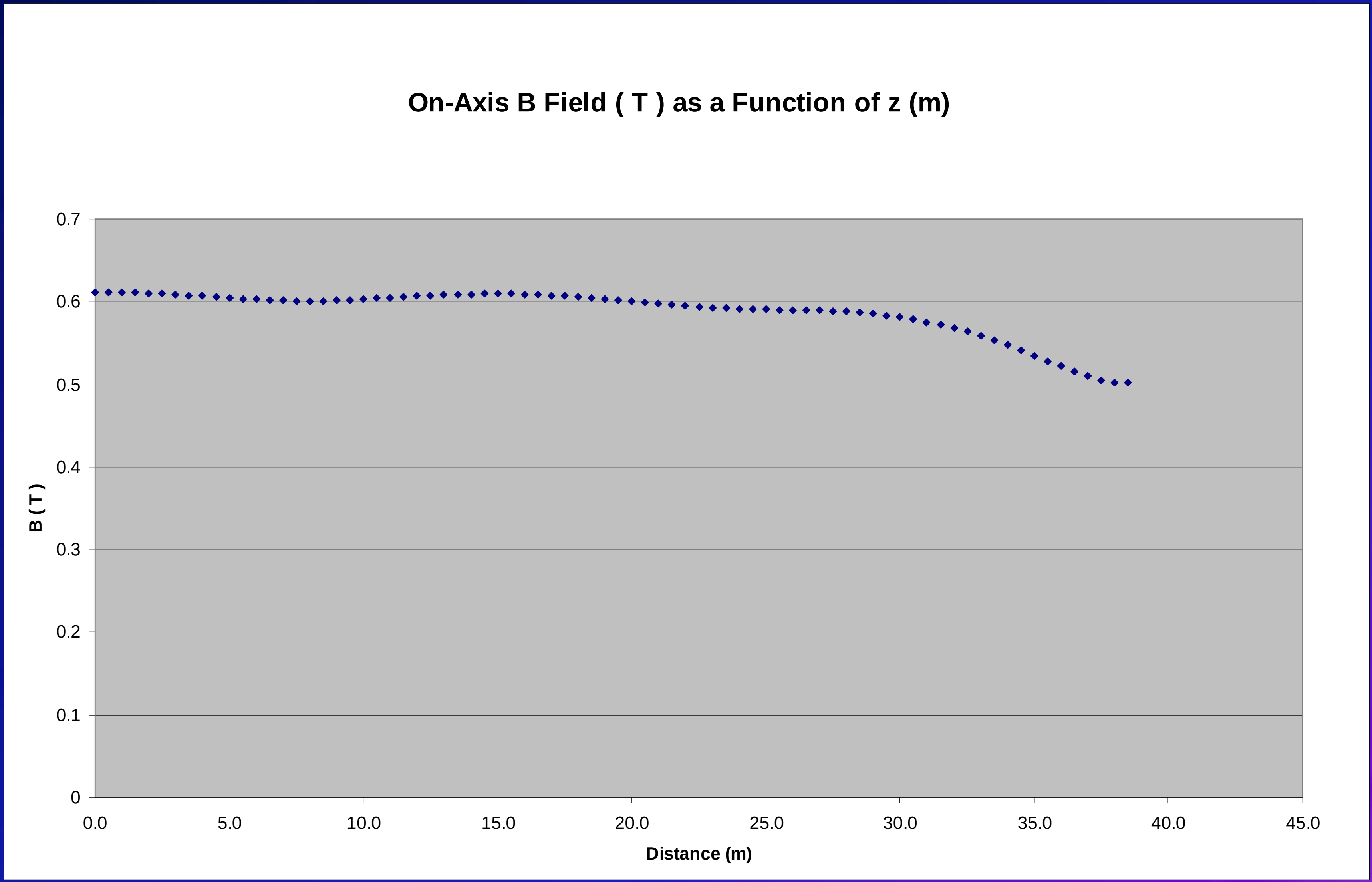
PARAMETER	UNIT	DESIGN	
		No iron	With iron
$I_{solenoid}$	MA	7.5	
N_{turns}/solenoid		150	
I_{turn}	kA	50	
$\|B\|_{average}$ in XZ	T	0.562	0.579
W_{total}	GJ	3.83	3.95
L_{total}	H	3.06	3.16
F_r maximum	kN/m	15.66	15.67
F_x maximum	kN/m	48.05	39.57

100 kA op demonstrated

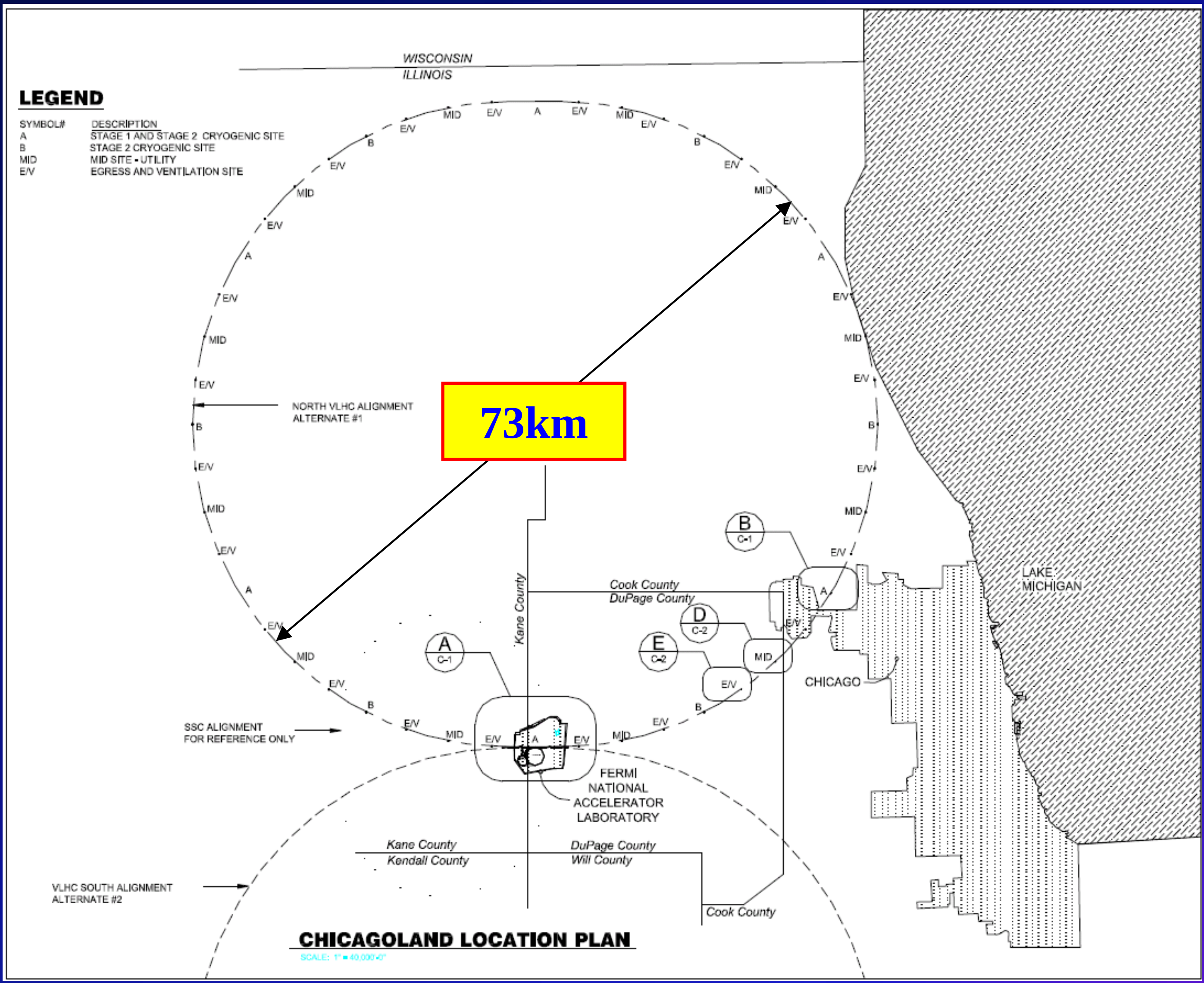
$1000/m ⇒ $50M

|B| in XZ cross-section



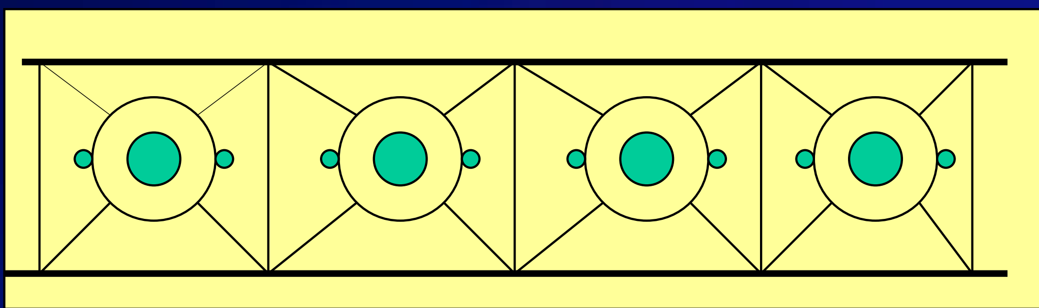

On-Axis B Field (T) as a Function of z (m)
B (T)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
Distance (m)

R&D - VLHC and cable design



- Pipetron type cable
  - Needs modification to provide long length (~5-7 km) and flexibility (bending diameter 15 m)
- Solenoid Strong-Back
- Assembly procedure

R&D – New SCTL Design for Solenoid Winding



Structure:

- Cable vacuum shell is now part of the solenoid support structure

LN shield is fabricated and installed independently:

- Two half-shells with LN pipes
- Super-insulation,
- Supports

Cable installed inside the LN shield:

- Thick LHe pipe with SC and Cu wires wound outside
- Thick Al or Cu tape (mechanical support and additional stabilizer) wrapped over SC/Cu wires
- Super-insulation
- Flexible (+/-2 mm dynamic range) supports
- R&D
  - Optimization of the SCTF for solenoid application
  - Build Full-Scale 3-turn prototype

We have a proposal written.
Trying to find appropriate funding source
$3M program (with manpower)

SCTL Approach to Large Solenoid – Conclusions

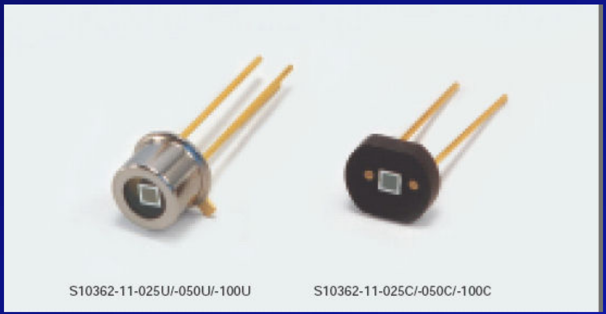
- The SCTL concept has been prototyped, tested and costed for the VLHC project
- Application for 15m diameter solenoids is different, however
  - Cost appears to be manageable (<$100-150M)
- R&D
  - Optimization of the SCTF for solenoid application
  - Engineering of fabrication process
  - Engineering of support structure

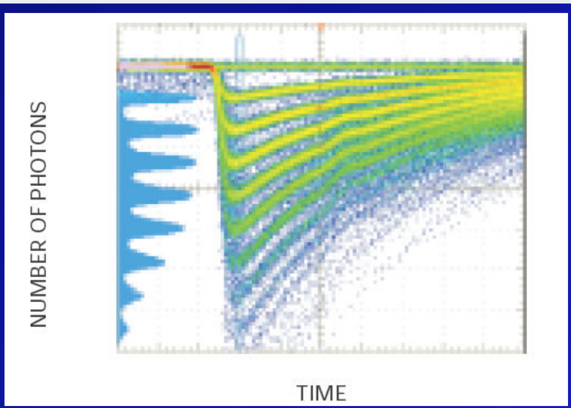
Scintillator

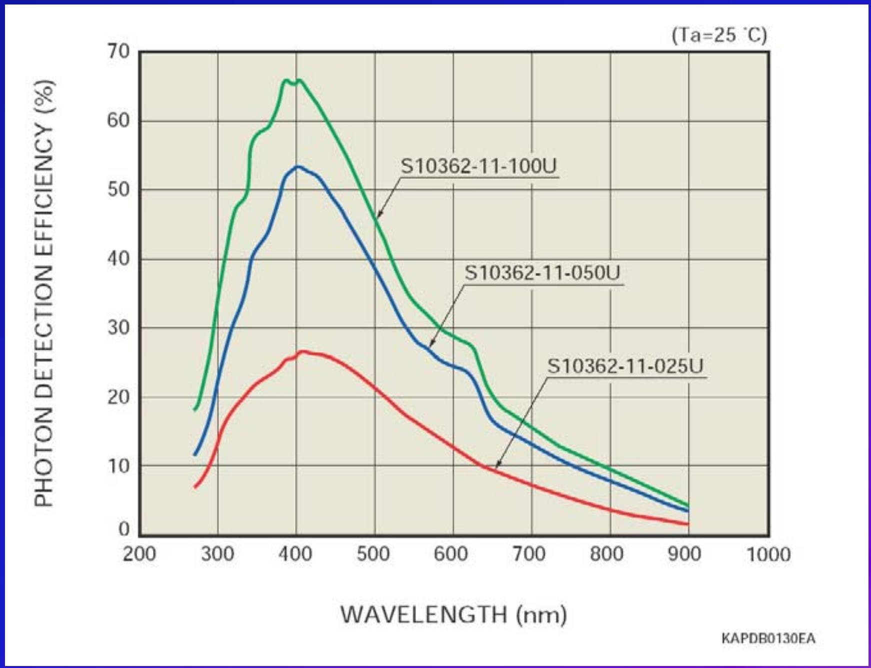
- There are really no technical show-stoppers here. It is just a matter of cost reduction
- Relatively small R&D Program ($250k)
  - Extrusion Die design to increase production through-put and efficiency
  - Extrusion Die Design to allow for co-extrusion of WLS fiber with scintillator profile
    - Has already been done successfully in tests on post-cladding Kuraray fiber with various polymers.
      - These were thin (100-300 μm), however

Photo-Detector and Electronics

- Here the R&D is already occurring all over the globe
- Silicon-PM, aka MPPD, aka MRSD
  - Hamamatsu, RMD & many others
  - Potential to lower the channel cost to <$10/ch (Target <$5)
  - Recent SiPM R&D program review at Fermilab
    - Fermilab ASIC group to begin develop of the sensor







Outlook

- A Low-Energy Neutrino Factory (coupled with the right detector) gives excellent capability in exploring the full neutrino mixing matrix and measure leptonic CP violation
- A finely segmented TASD is quite possible the right analysis tool for a Low-Energy NF
  - Much more simulation/study needs to be done, but the initial results are promising
  - Detector R&D program is well-defined
    - Magnet - $2-5M
    - Scintillator - $250k
    - Photo-detector – wait and see
- A Low-Energy Neutrino Factory (4 GeV) is certainly cheaper than a 20 GeV facility.
- Plus with proper planning a Low-Energy Neutrino Factory might be upgradeable to higher energy

Outlook II

- The performance of TASD looks to be very impressive
- Its power as a Nucleon decay experiment needs to be looked at in more detail
  - It may also be a powerful detector for Atmospheric neutrino detection, neutrinos from relic SN, etc.
- It might be interesting to speculate what a re-optimization of the NF might look like with two 50 kT TASD detectors.