Tracking Software in MARLIN

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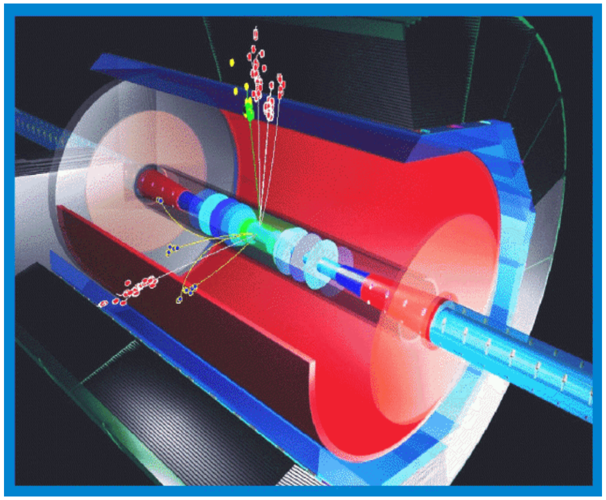
Simulation Workshop,
DESY
June 27, 2005

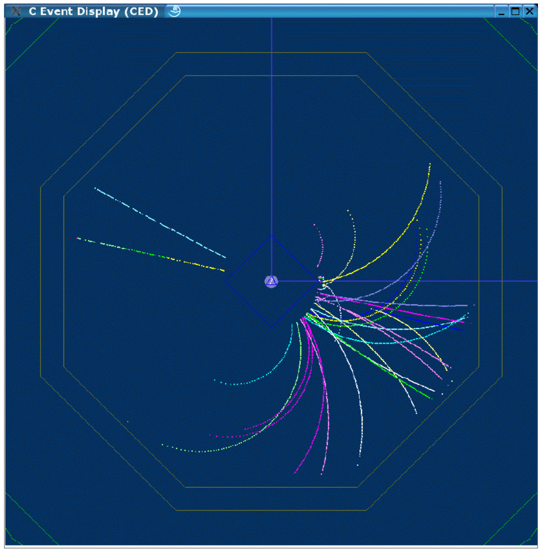
Outline

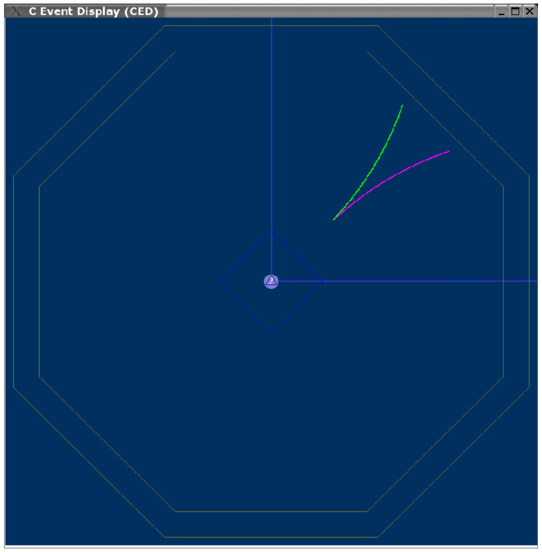
- Motivation
- Available Software
- MARLIN Implementation
- Some Preliminary Studies
- Future Plans
- Summary & Outlook



Tracking Performance Requirements

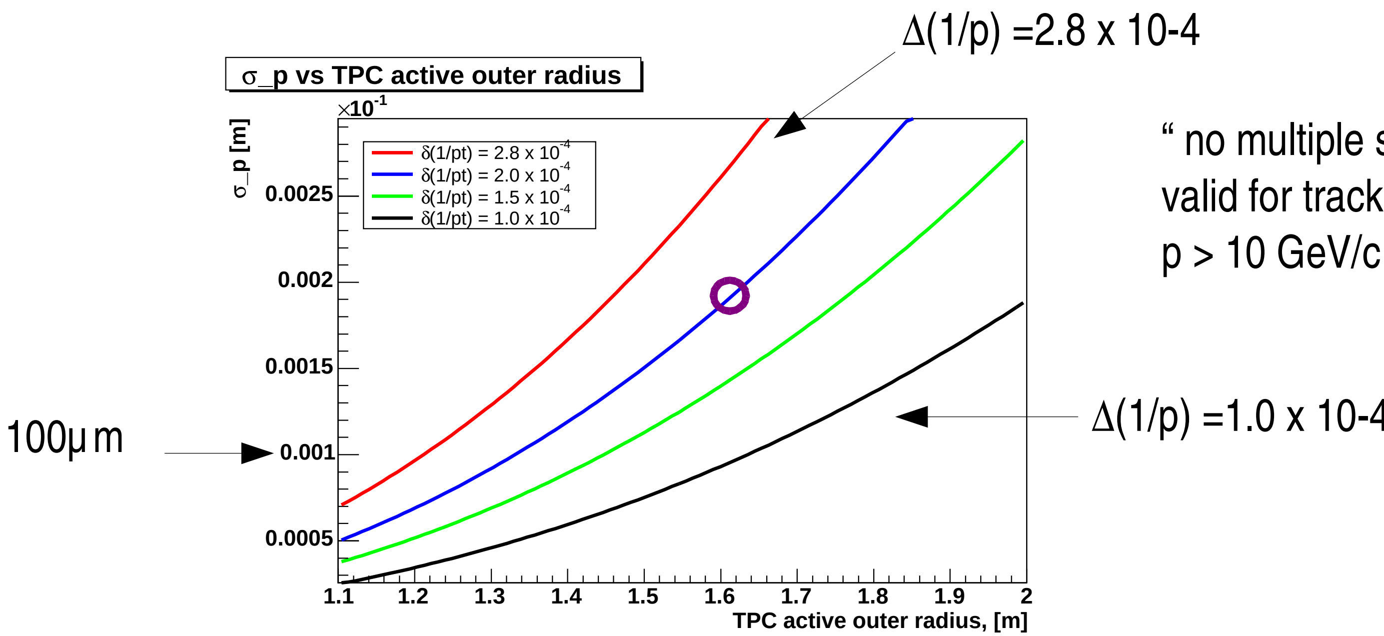
- $\Delta 1/p < 6x10^{-5} (GeV/c)^{-1}$: TPC only $< 2x10^{-4} (GeV/c)^{-1}$
  - Driven by recoil mass method for hZ -> XXmumu
- High efficiency means redundancy is needed
- Robust: able to efficiently reconstruct
  - curlers
  - kinks
  - V0





Motivation

- Momentum resolution of the TPC only, just use the Gluckstern Formula

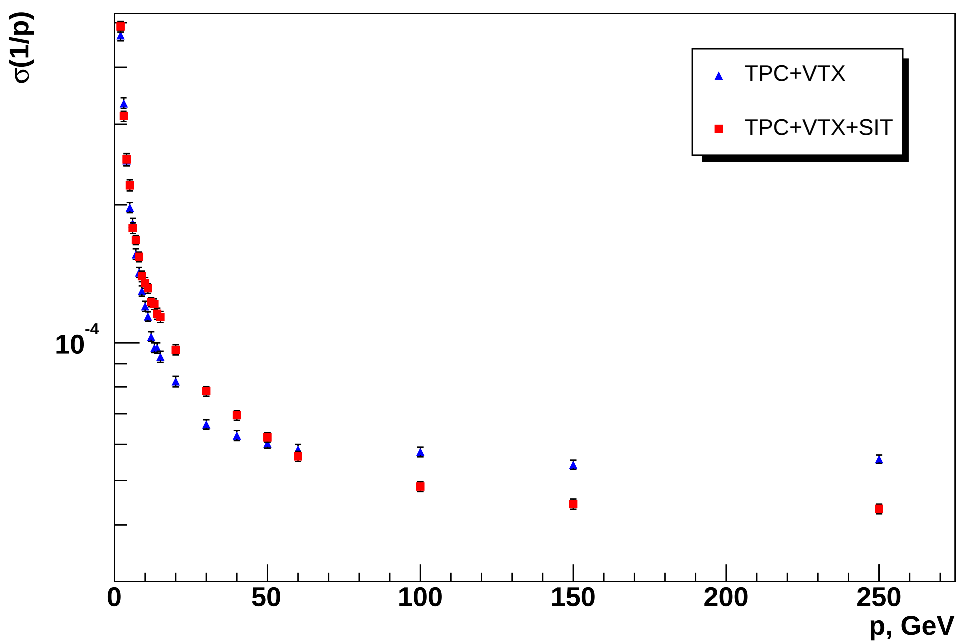


" no multiple scattering valid for tracks p > 10 GeV/c "

- Variation in point resolution limits analytical approach
- Background etc.

Motivation

- Also the TPC forms part of the overall tracking system, with which the final performance goals must be met
- This brings matching into play
- The final performance of the TPC will also be determined by the tracking system it encloses



- Full simulation required
- Flexibility and Performance do not make happy bed fellows

Available Software

- Break LEP tracking out of Brahms and reuse it within a MARLIN Processor
- The LEP tracking within Brahms provides the following:
  - Track finding
  - Track fitting
  - Ambiguity resolver
  - Full matching between subsystems

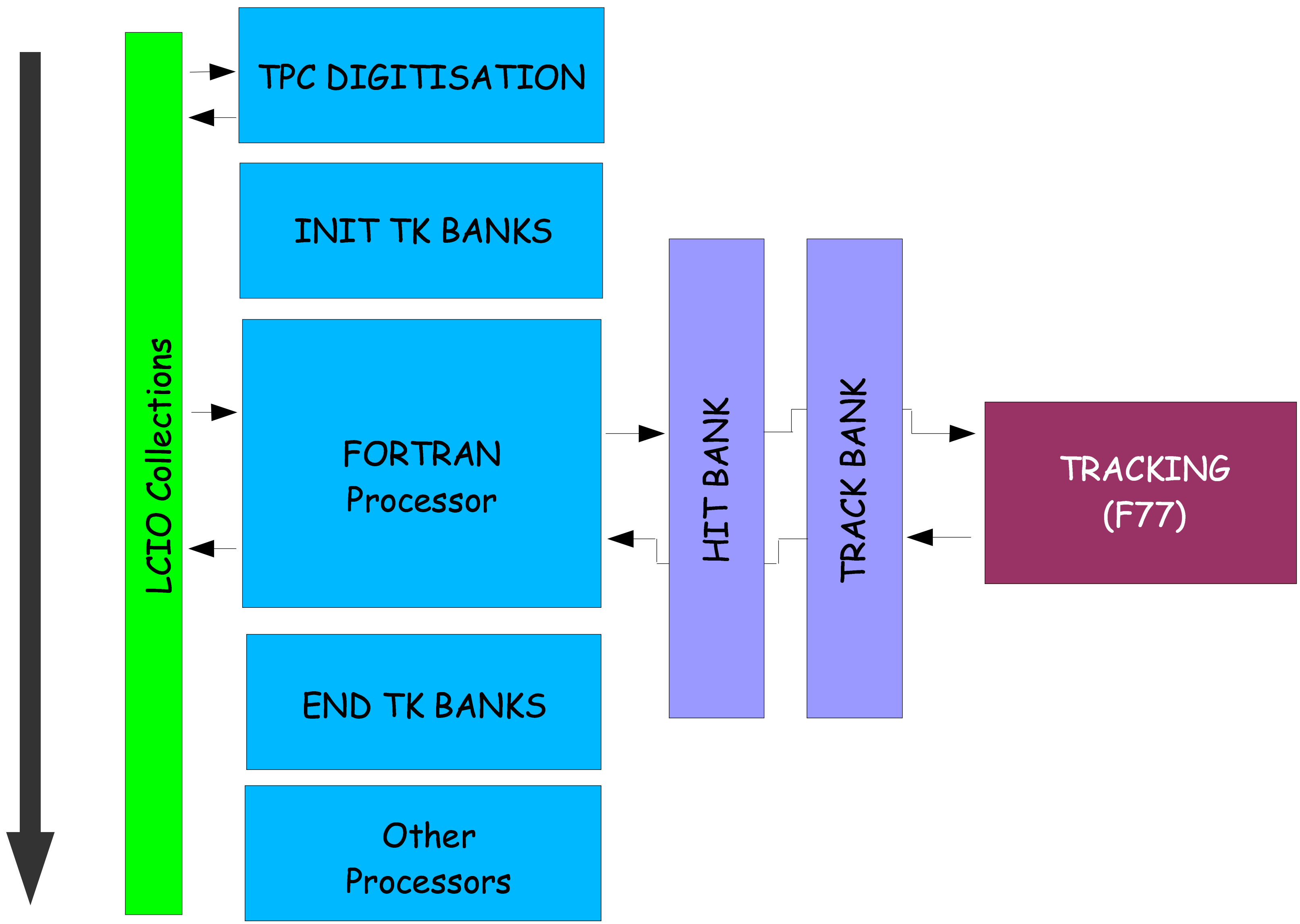
Brahms -> MARLIN

- MARLIN offers modularity, whilst the C++ STL offers robust variable size containers with dynamic memory allocation
- Tracking code fairly entrenched within BRAHMS (F77) and makes extensive use of GEANT geomtery banks and ZEBRA which is prone to unrecoverable errors
- Wrapping the F77 tracking code required an interface either to the ZEBRA banks or some alternative data storage

Implementation

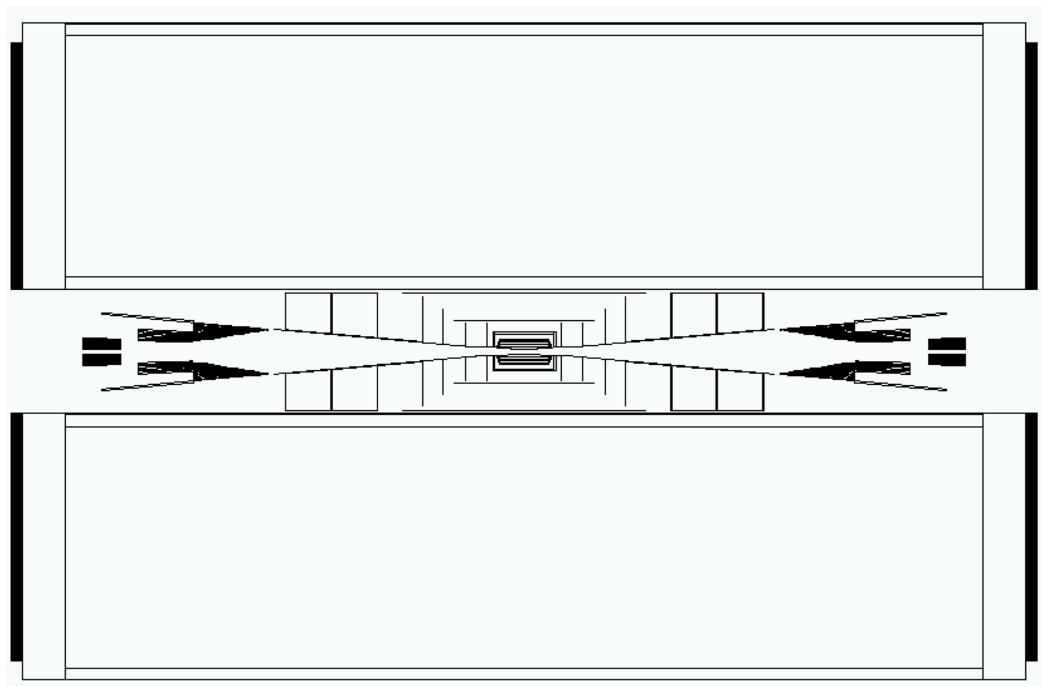
- A C++ Class is defined that describes an STL vector of structures which mimic the ZEBRA banks
- The Class also provides gets() and sets() to access the data
- In F77 statement functions are used to call C++ functions
- cfortan.h is used to facilitate these calls in a machine independent way
- Within MARLIN one processor instantiates the bank structures and another is responsible for deleting them
- Between these processors a global pointer is used to give access to the banks

Tracking Schematic



The TPC

- For tracking within the TPC the following must be defined:
  - outer active radius
  - inner active radius
  - max drift length
  - R Phi resolution
  - Z resolution
  - double track resolution
  - pad geometry
  - Gas parameters



TPC Geometry

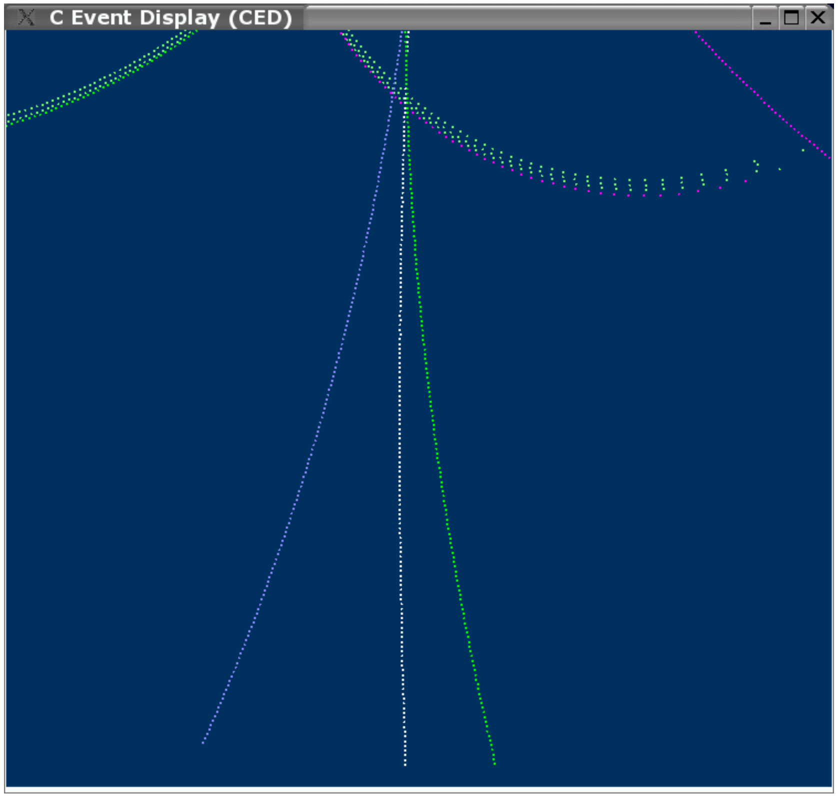
- In MARLIN the geometry is handled in a similar way to the bank structure
  - a TPC Class is defined which uses STL vectors to act as pad rings
  - header files provide the hard geometric numbers
  - The TPC object is instantiated and deleted by MARLIN processors GeomInitProcessor and GeomEndProcessor
  - Between these processors access is given via a global pointer

Digitisation

- TPCDigiProcessor provides Gaussian smearing according to the specified rphi and z resolutions
- Care is taken to minimize disturbance by limited double hit resolution
- Hits which would produce merged readout signals are flagged
- This follows a geometric approach
- At present these hits are removed from the sample
- We need to reconsider Hit production in simulation for non radial tracks

Track Finding

- TPC Pat-Rec modified ALEPH code
- Hits sorted by radius and phi
- Chains created from Out -> In
- Search stops at half TPC radius
- Circle Fit used to fit chains, taking multiple scattering within the TPC gas into account
- Discovered chains are then moved in picking up hits towards the inside of the TPC



Tracking Kalman Filter

- Chains which survive are passed to a Kalman filter for final fitting
- Kalman Filter developed for DELPHI
- Fast recursive algorithm implemented using the weight matrix formalism
- Taylor expansion around reference trajectory, provided by Circle fit, used as starting point to obtain a linear system
- Takes into account multiple scattering and energy loss in the material described as a sequence of surfaces
- Outlier logic, able to remove measurements depending on a χ^2 probability cut

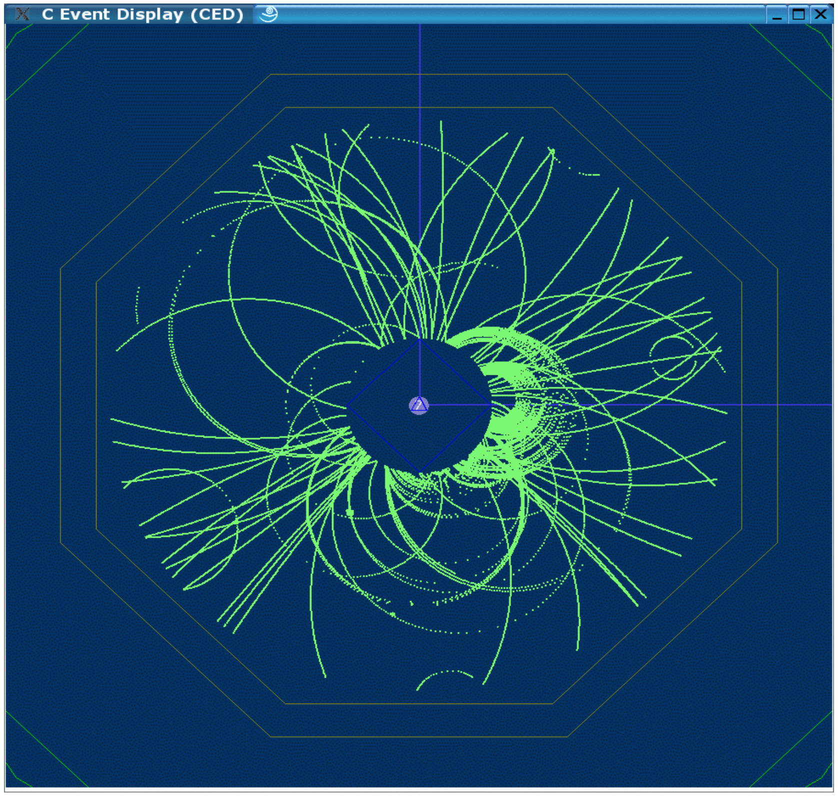
Track Model

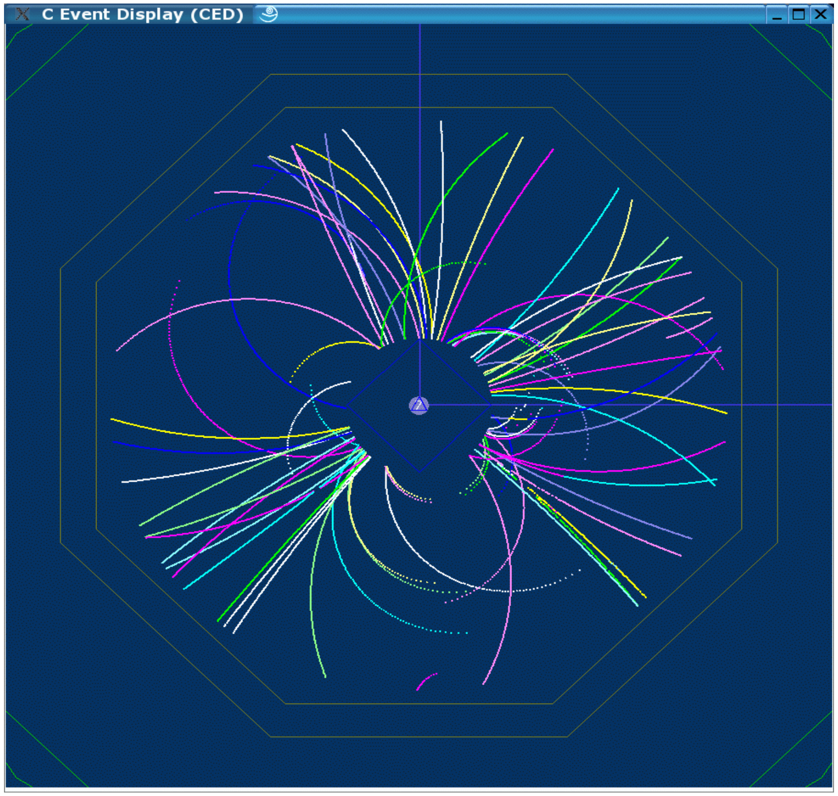
- Helix Hypothesis

- Ω – curvature signed with charge
- d0 – distance of closest approach signed
- z0 – z co-ordinate of point of closest approach
- ϕ – azimuthal angle of the momentum
- tan λ – slope in the Sz plane dz/dS

Some First Results

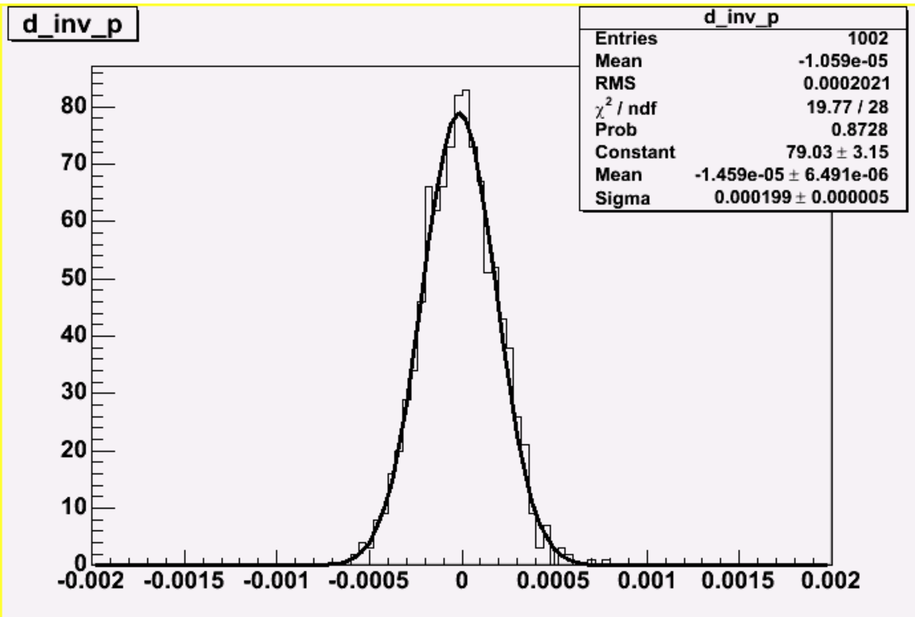
- A nice ttbar event

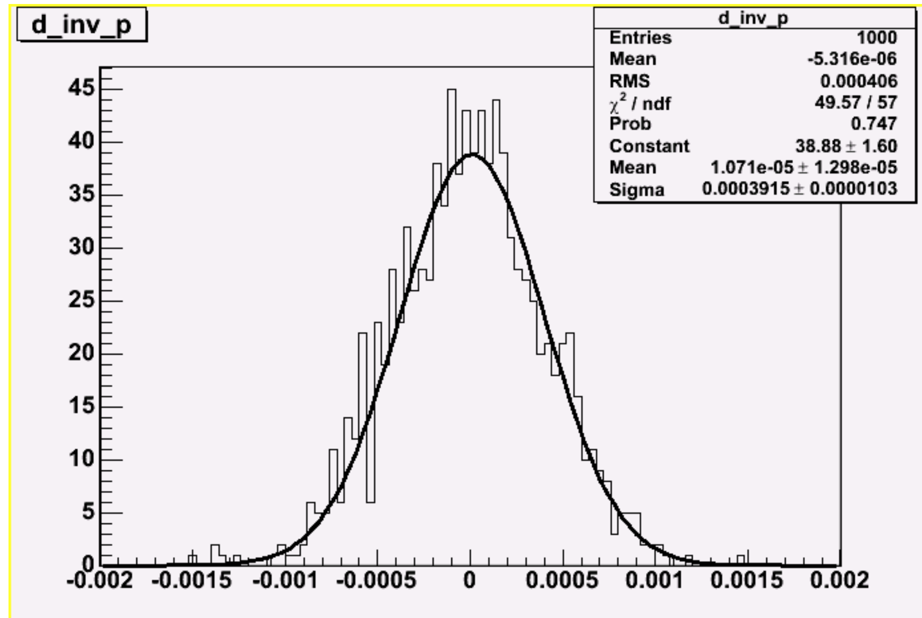




Single Particle Studies

- 30GeV muons – multiple scattering negligible





TPC R_{outer} = 169cm , 200 pad rows

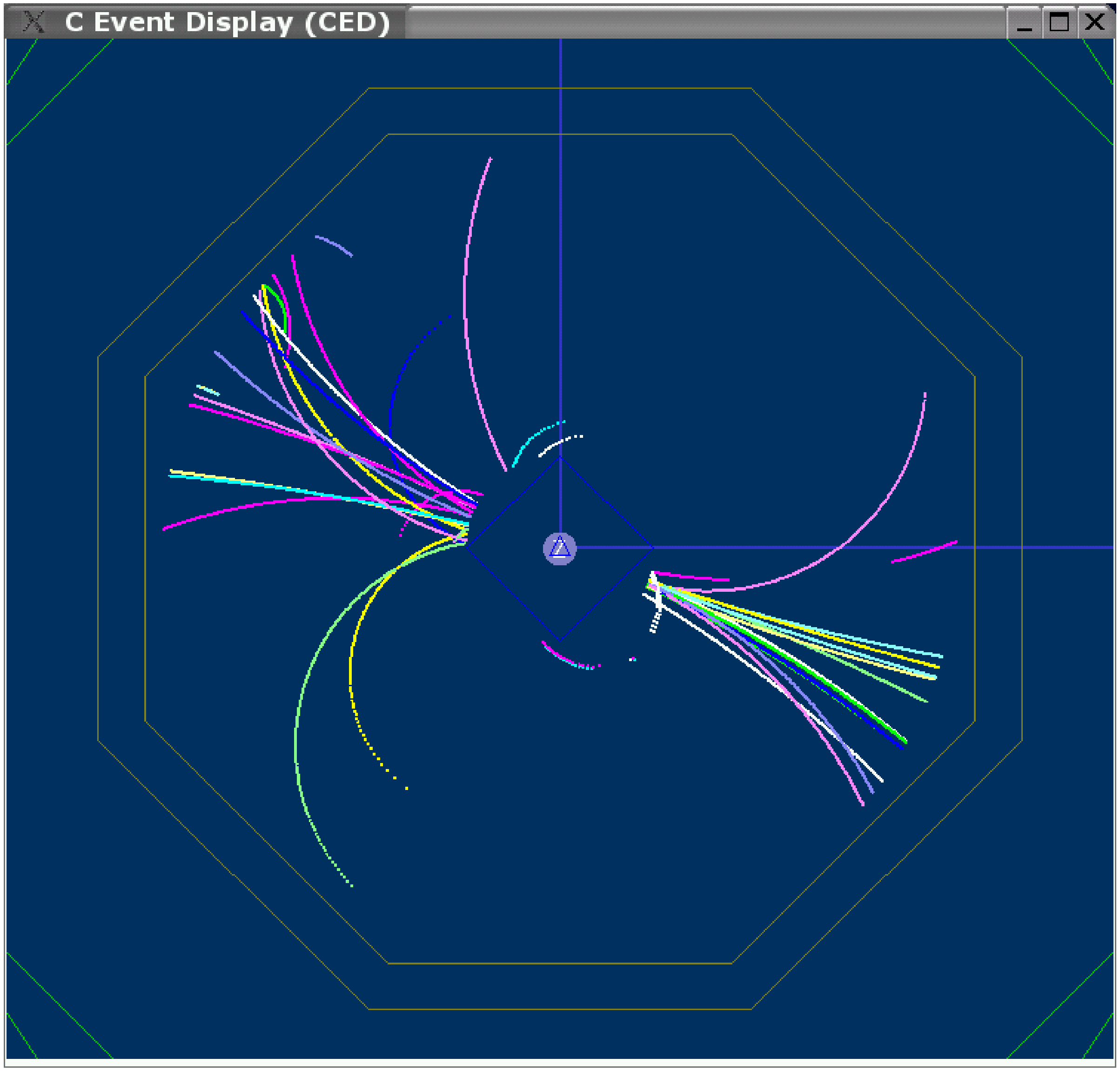
$\delta(1/p) \sim 2 \times 10^{-4}$

TPC R_{outer} = 131cm , 150 pad rows

$\delta(1/p) \sim 4 \times 10^{-4}$

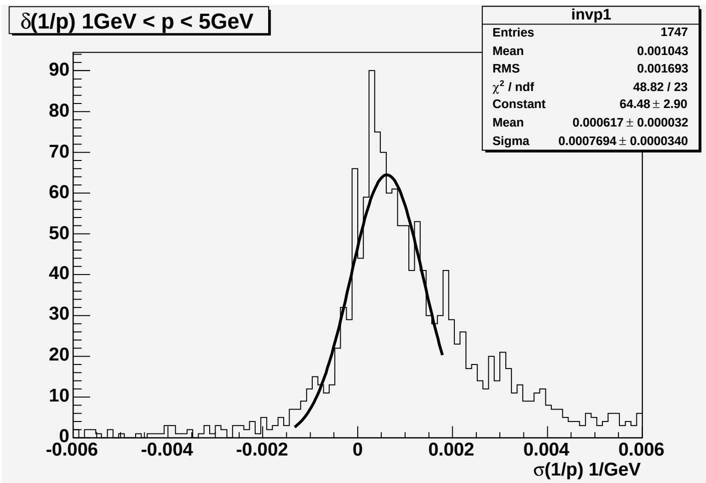
ddbar events @500 GeV

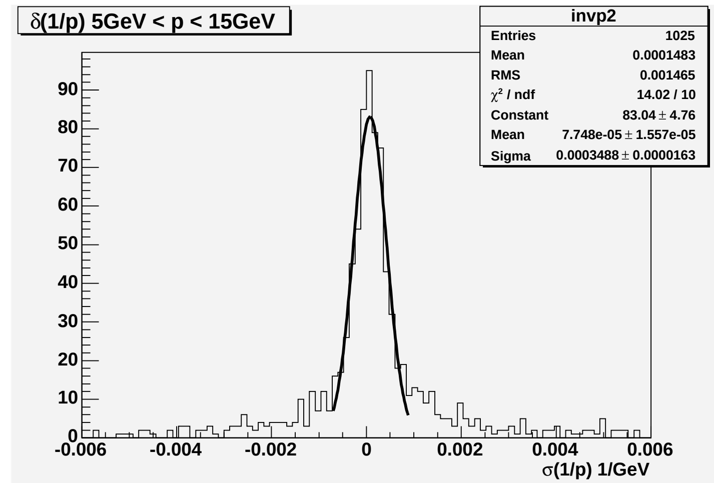
- Are a not very interesting ... but a bit tricky when it comes to tracking
- Narrow dense jets
- Many low energy curlers
- For intial studies
  - In HEPEvt
  - No daughters in TPC
  - At least 3 hits in detector
  - p > 1 GeV

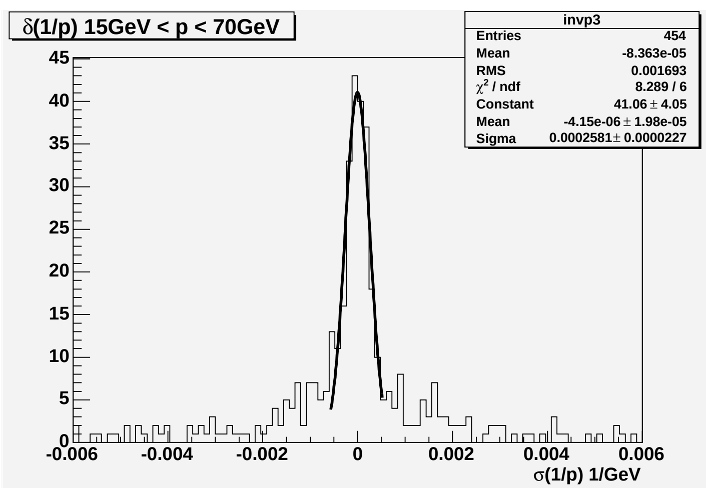


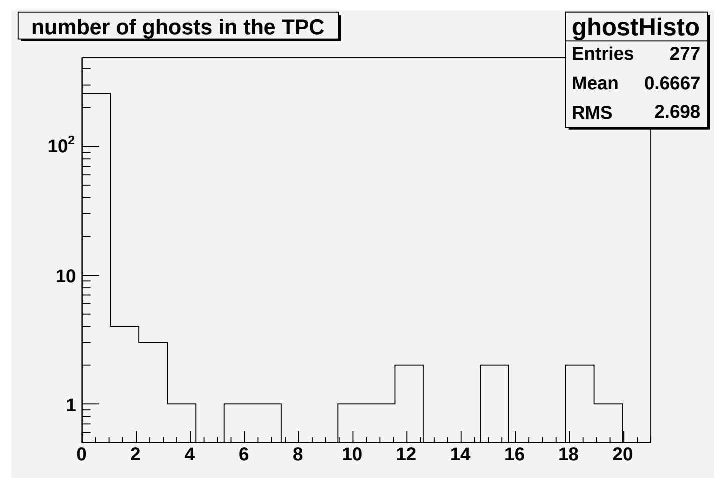
ddbar momentum resolution

- Approaching $2x10^{-4}$ but with large tails



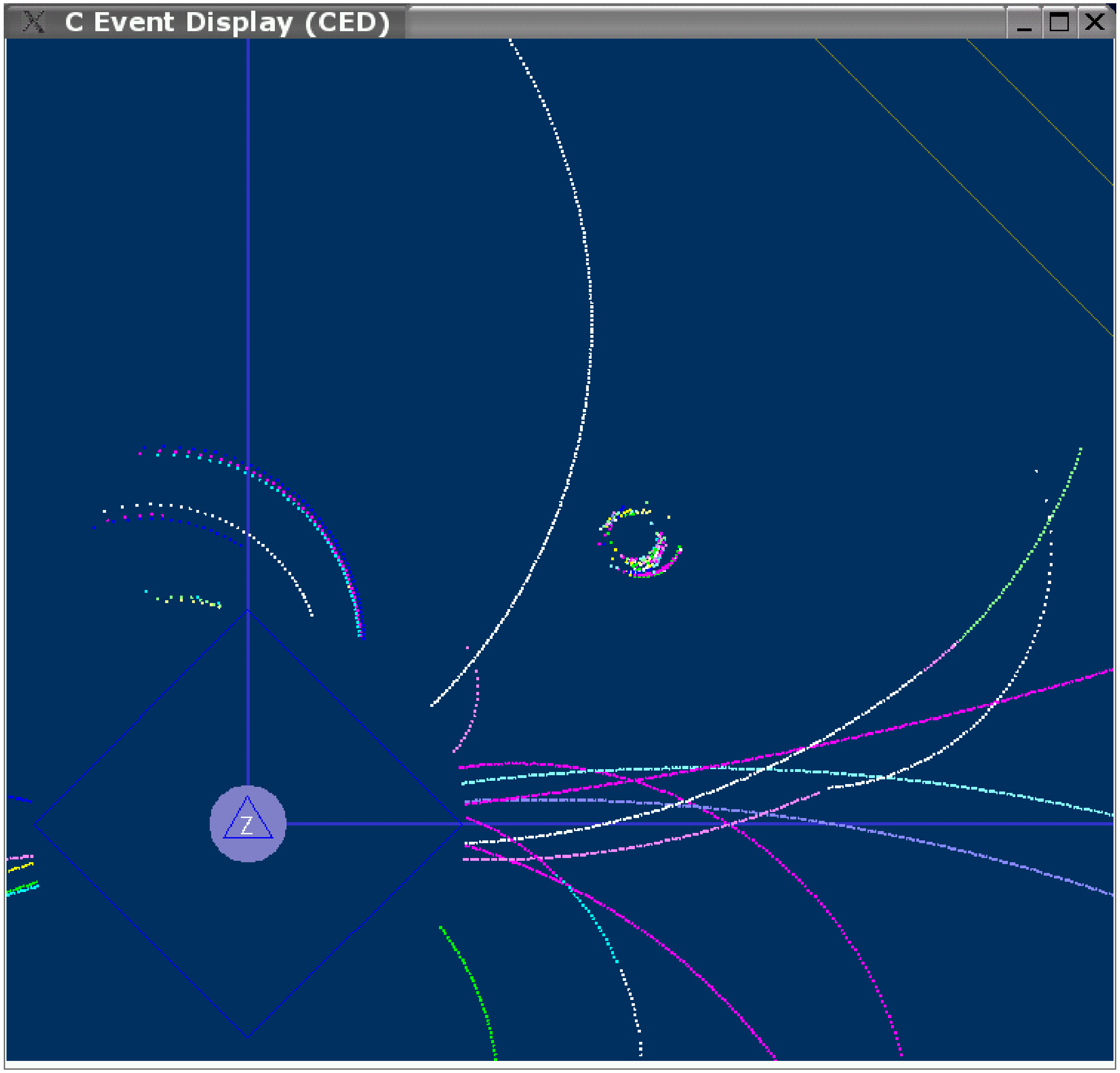






Potential Problems

- Correct kink finding is imperative for PFlow concept



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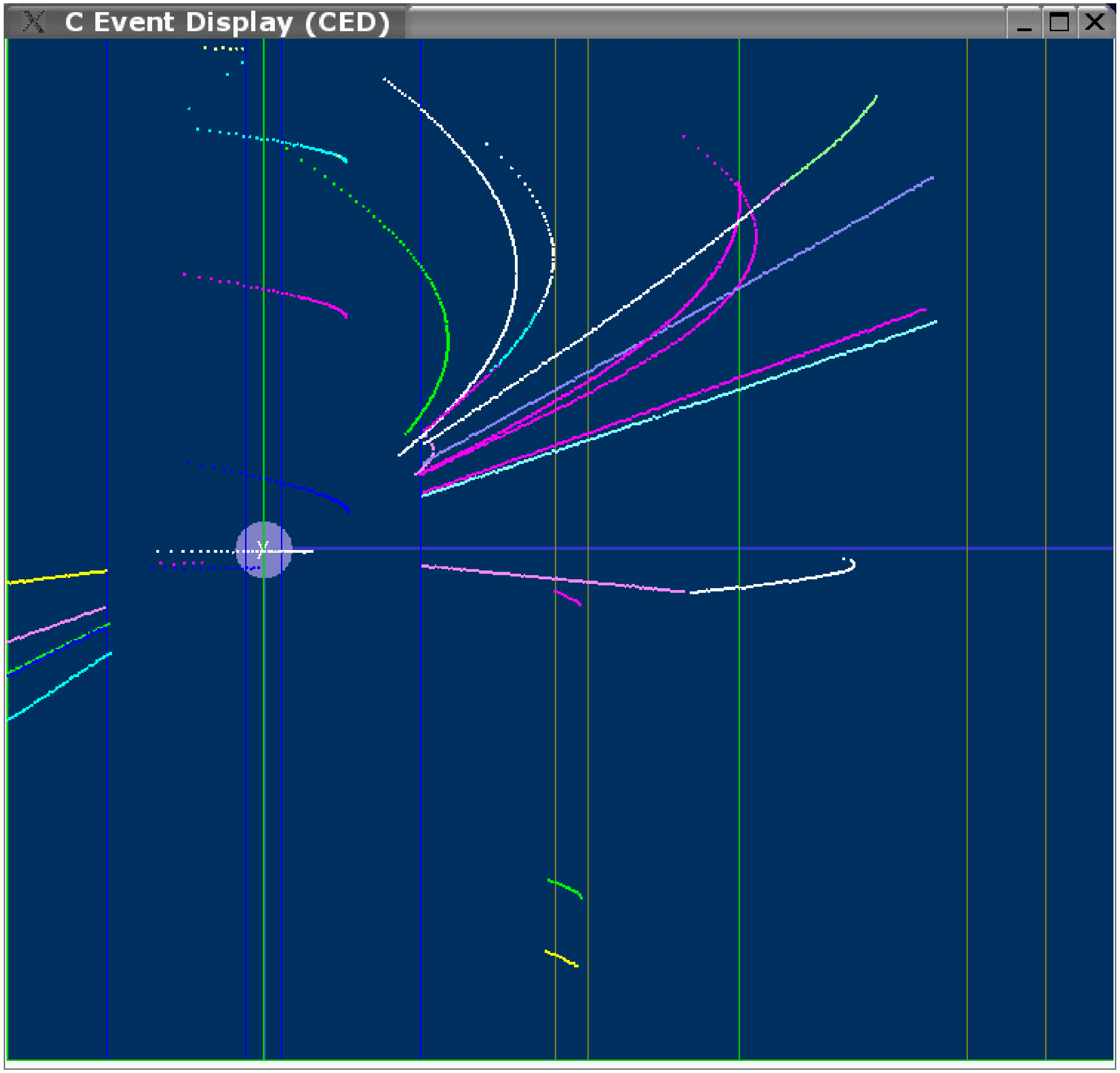
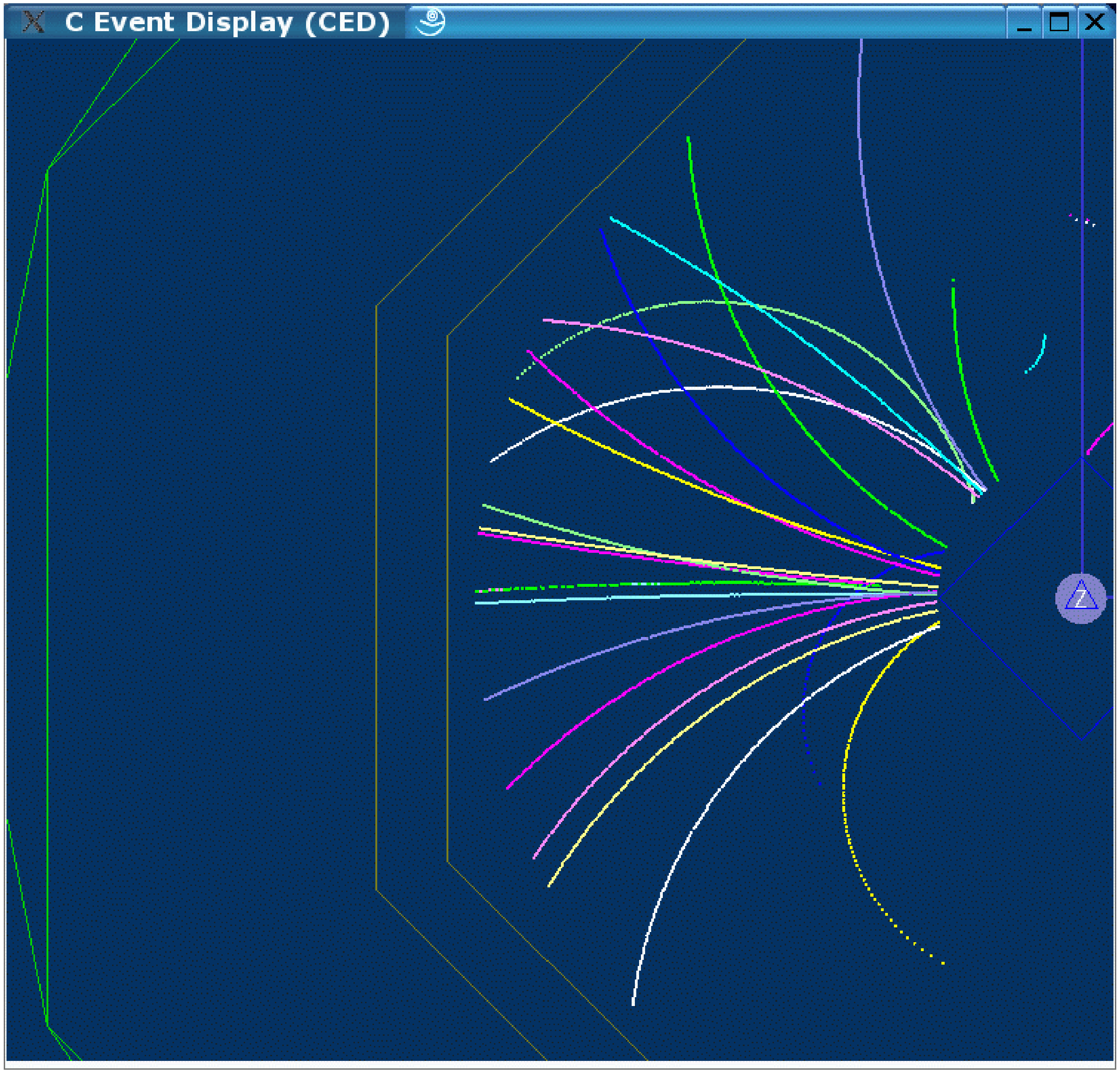


Potential Problems

- Kink Paranoia
- From time to time "perfectly healthy" tracks are being reconstructed in more than one piece.



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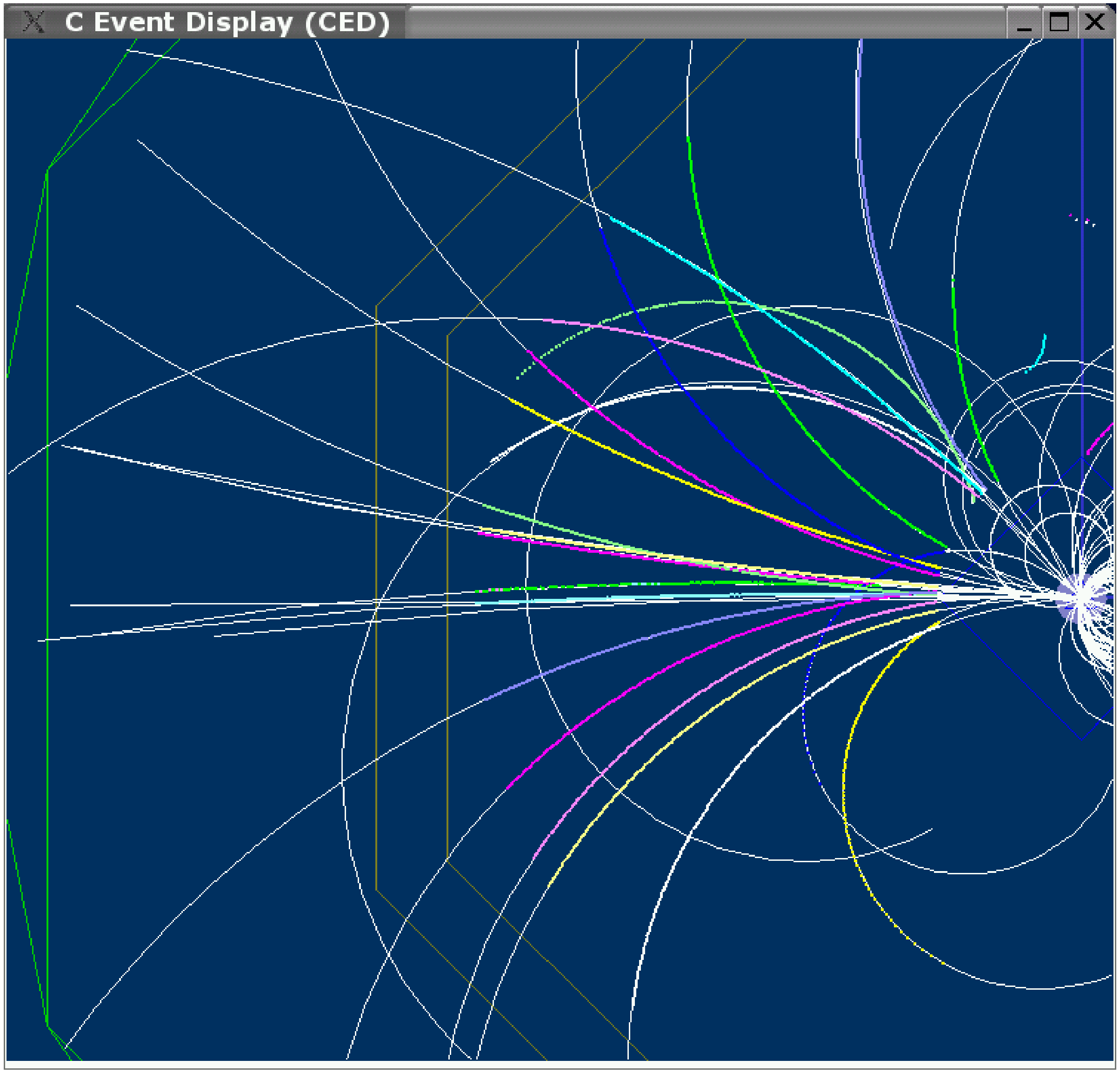
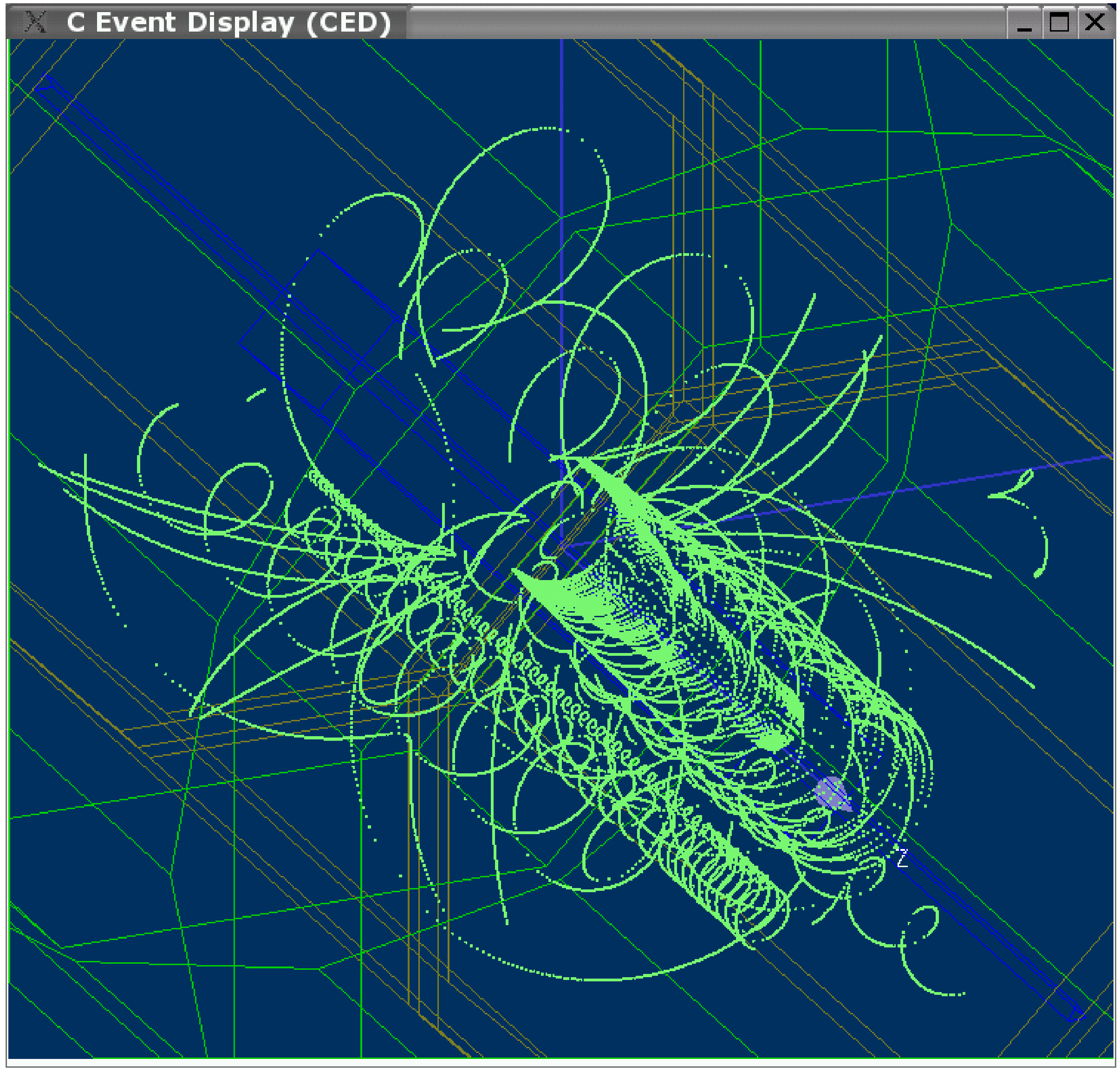


Potential Problems

- Curlers present a serious problem for the Pat-Rec
- Especially those around the inner radius
- Without care this event is likely to bring the Pat-Rec to its knees



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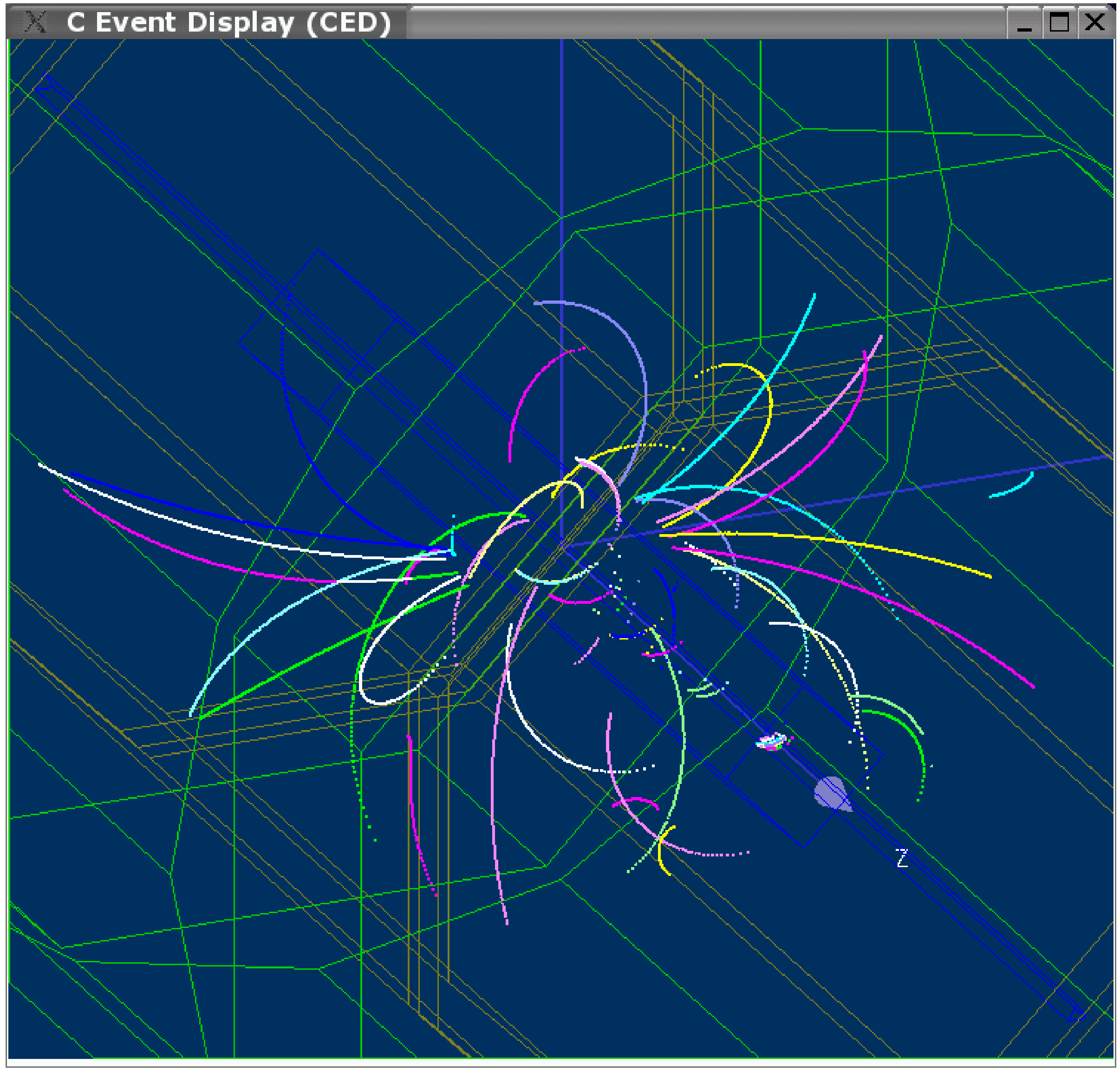
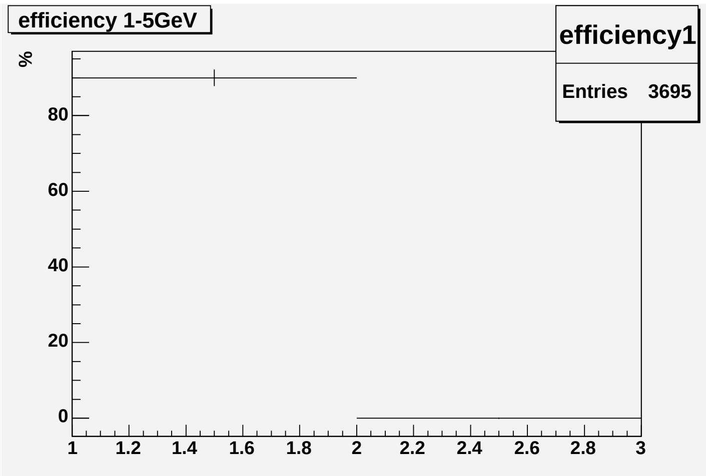
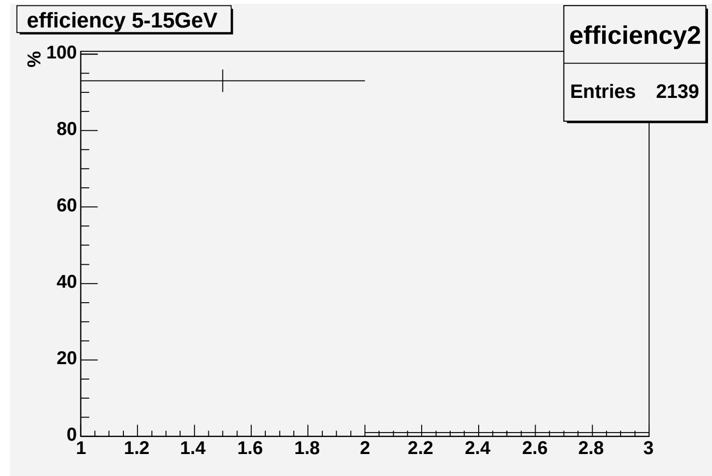
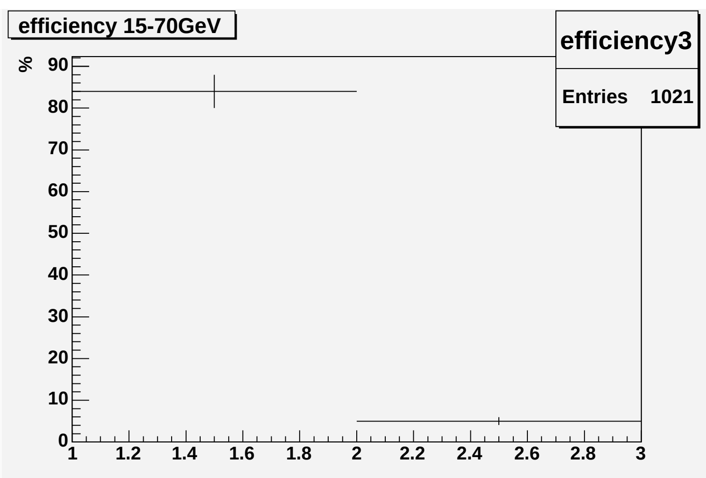


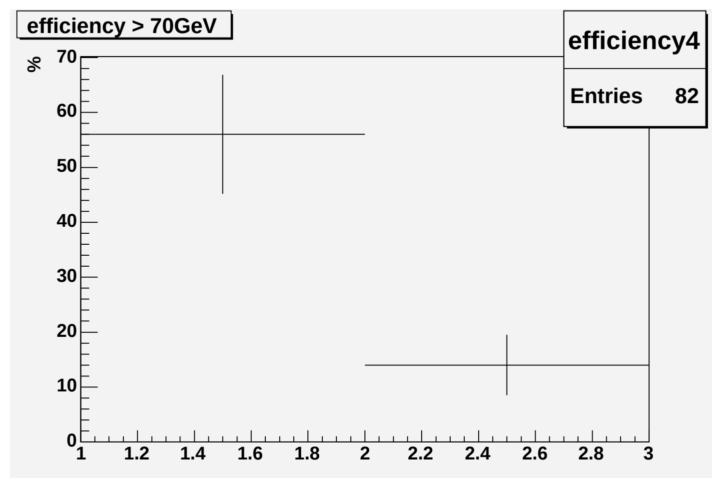
ddbar efficiency

- Seems robust but work needs to be done
- Bin 1: correctly reconstructed   Bin 2: reconstructed in more than one piece









Future Plans

- Currently most powerful approach is combinatorial Kalman filter (R. Mankel)
  - builds up a combinatorial tree of track candidates starting from a track seed
- Adaptive filters for track finding
- Studies are currently ongoing by R. Fruehwirth and A. Strandlie
  - Gaussian Sum Filter
    - Follows the same basic logic as the CKF
    - Global competition of all candidates and all hits including missing hits
  - Deterministic Annealing Filter
    - Iterated Kalman filter with annealing
  - Simulation in LHC environments show promising results
    - competitive speed and low fake rates

Summary & Outlook

- MARLIN processor which produces fitted LCIO track collections for the TPC from LCIO tracker hit collections
- Dimensional flexibility suitable for optimisation studies
- Plans to provide helper functions from parts of wrapped F77 code
  - e.g. fast helix fitter
- Improve Digitisation
- Include Ambiguity Processor
- Incorporate vertex hits into fit
- Bring code to release state
- Investigate Adaptive Filters
- To make any serious Optimisation and Physics Studies we need realistic tracking code.