



Tracking Software

Simon Taylor / JLab

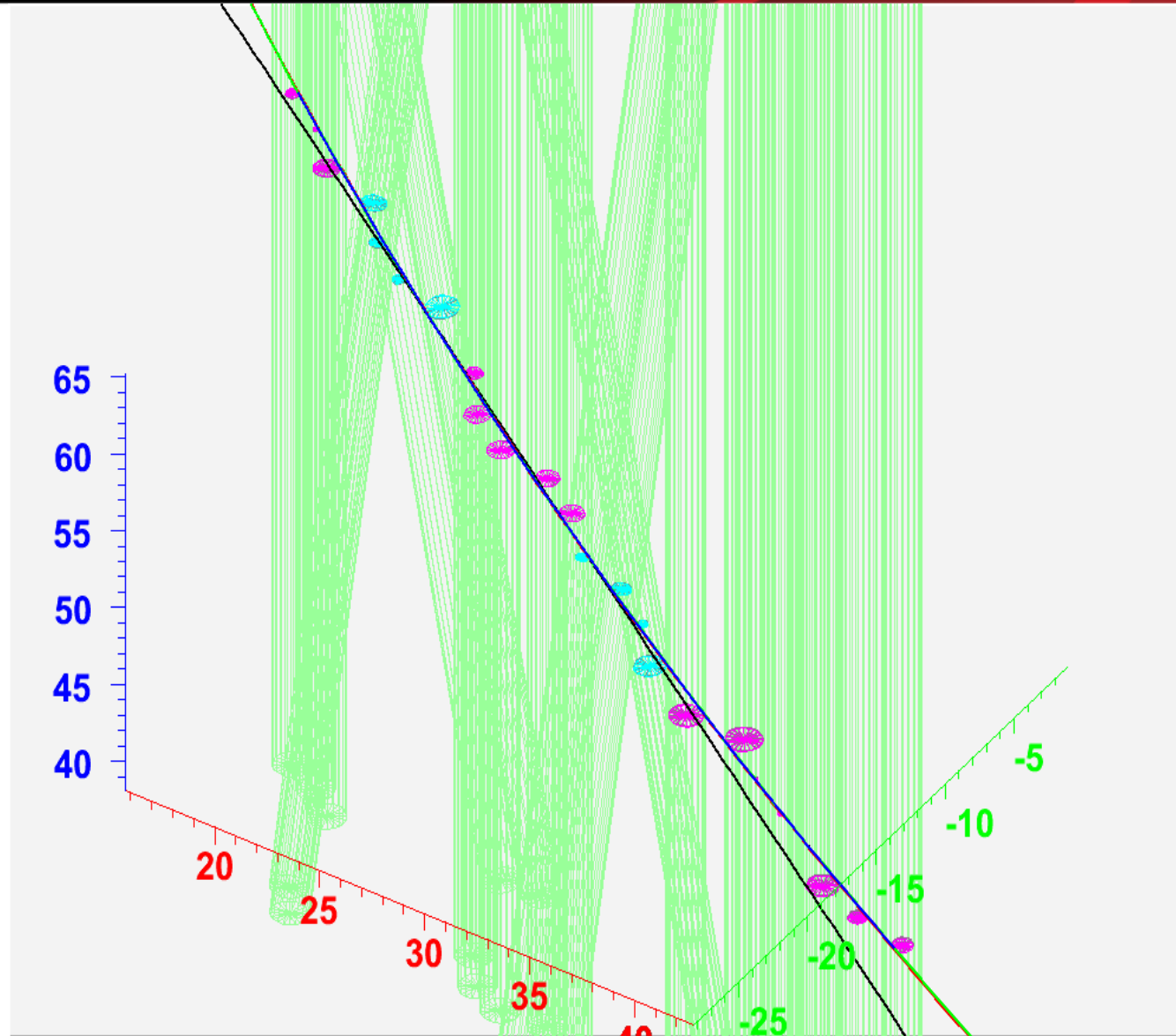
- Mark's Least-squares fitter
- Simon's Kalman Filter

Mark's Least-Squares Track Fitter

- Uses Levenberg-Marquardt algorithm from GNU Scientific Library (in turn, taken from MINPACK)
- Works with FDC hits, CDC hits, or any combination
- Track parameters:
 - Total inverse momentum: $1/p_T$
 - Polar angle: θ
 - Azimuthal angle: ϕ
 - Transverse distance of point of closest approach to beamline: x'_0
 - Z of point of closest approach to beamline: z_0

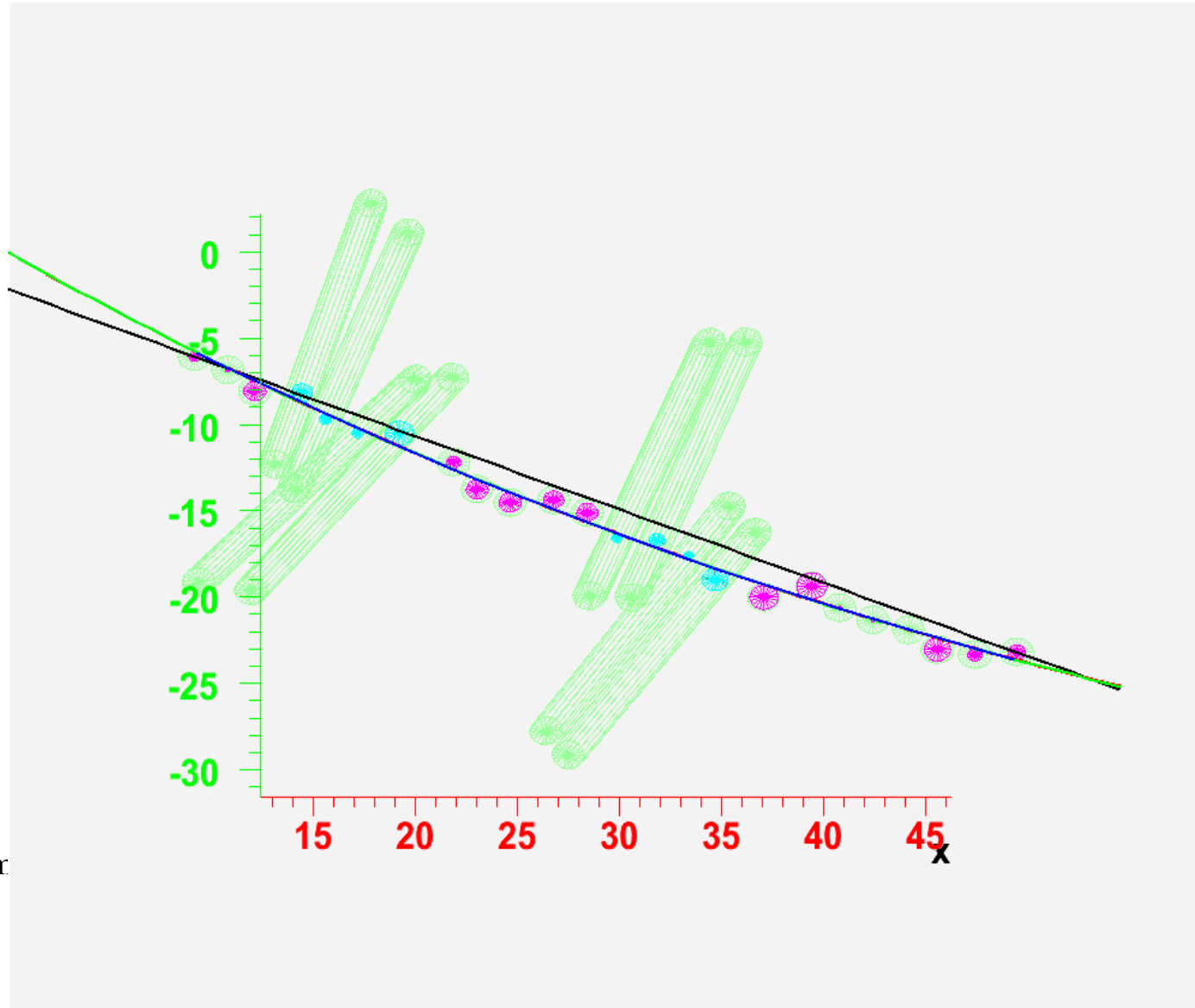
3-D Display: good fit

- Black track = initial guess
- Red track = fit
- Green track = swum with thrown parameters (SWTP)
- Blue track = “truth” hits
- Disks: isochrones at point of closest approach
 - Magenta: axial
 - Cyan: stereo
 - Greyed-out: from SWTP track



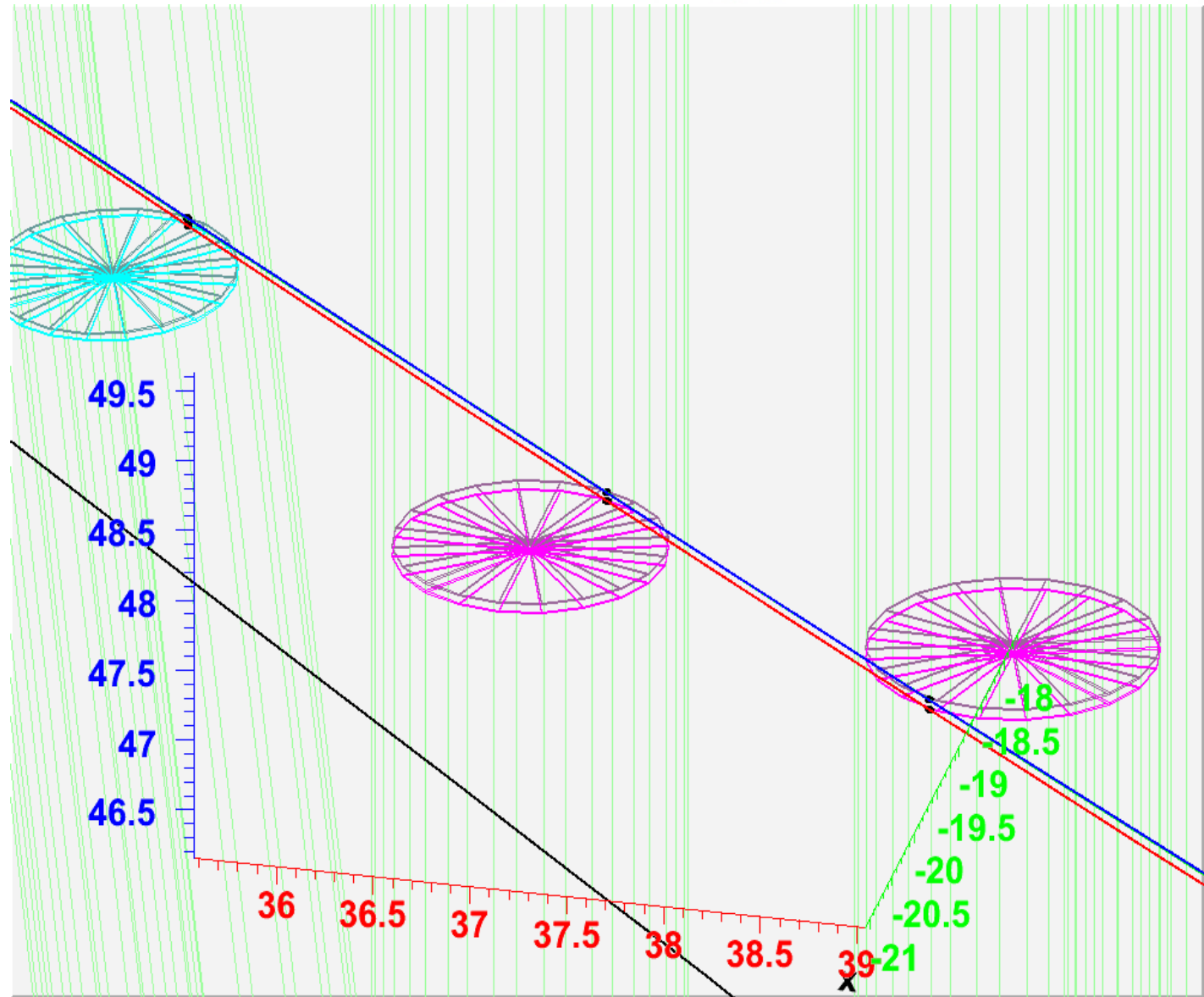
3-D Display: good fit, top view

- Black track = initial guess
- Red track = fit
- Green track = swum with thrown parameters (SWTP)
- Blue track = “truth” hits
- Disks: isochrones at point of closest approach
 - Magenta: axial
 - Cyan: stereo
 - Greyed-out: from SWTP track



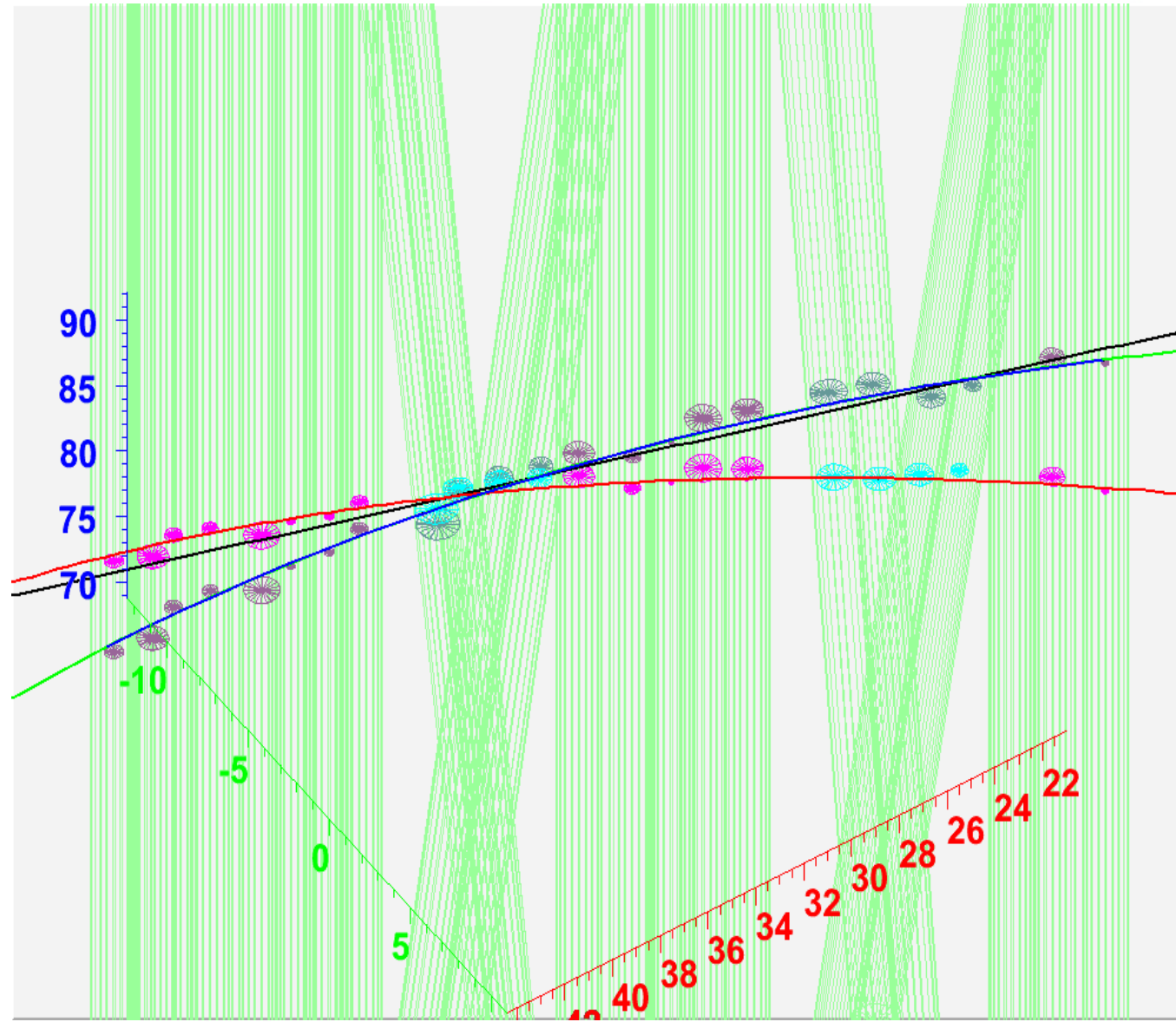
3-D Display: good fit, zoom

- Black track = initial guess
- Red track = fit
- Green track = swum with thrown parameters (SWTP)
- Blue track = “truth” hits
- Disks: isochrones at point of closest approach
 - Magenta: axial
 - Cyan: stereo
 - Greyed-out: from SWTP track



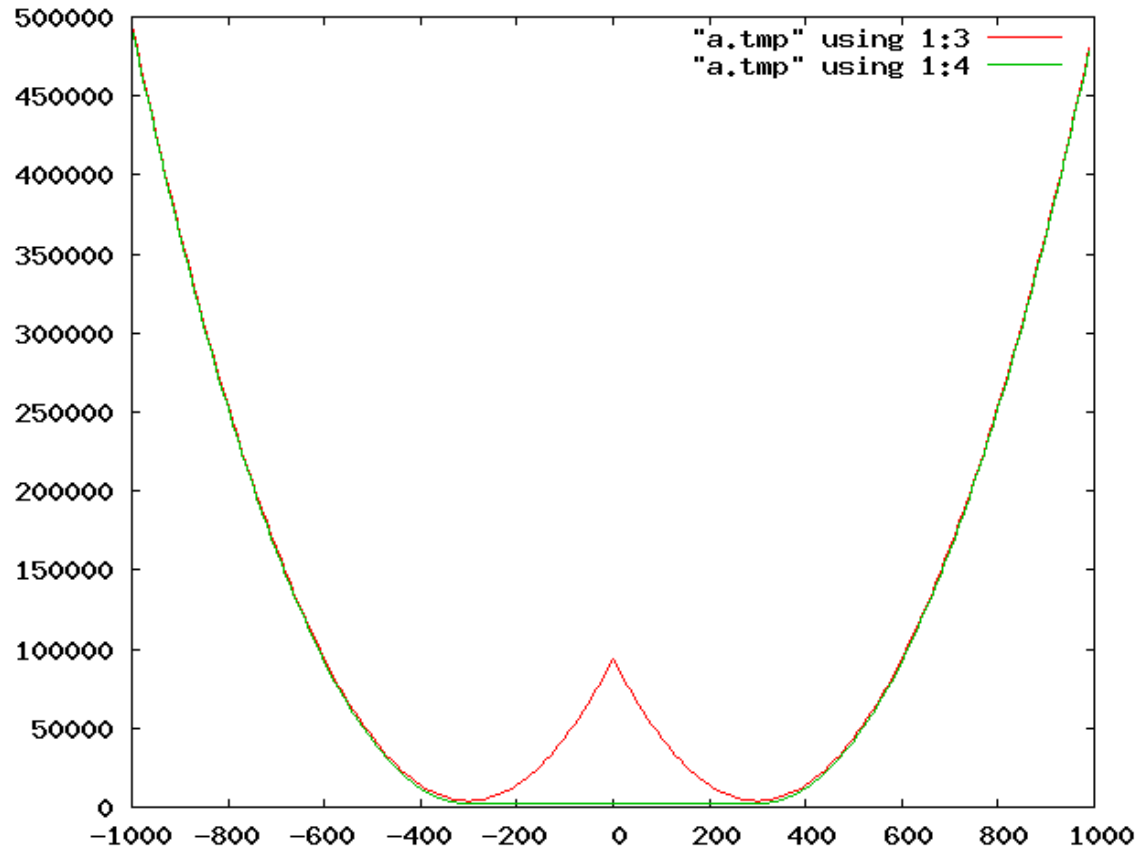
3-D Display: bad fit

- Black track = initial guess
- Red track = fit
- Green track = swum with thrown parameters (SWTP)
- Blue track = “truth” hits
- Disks: isochrones at point of closest approach
 - Magenta: axial
 - Cyan: stereo
 - Greyed-out: from SWTP track

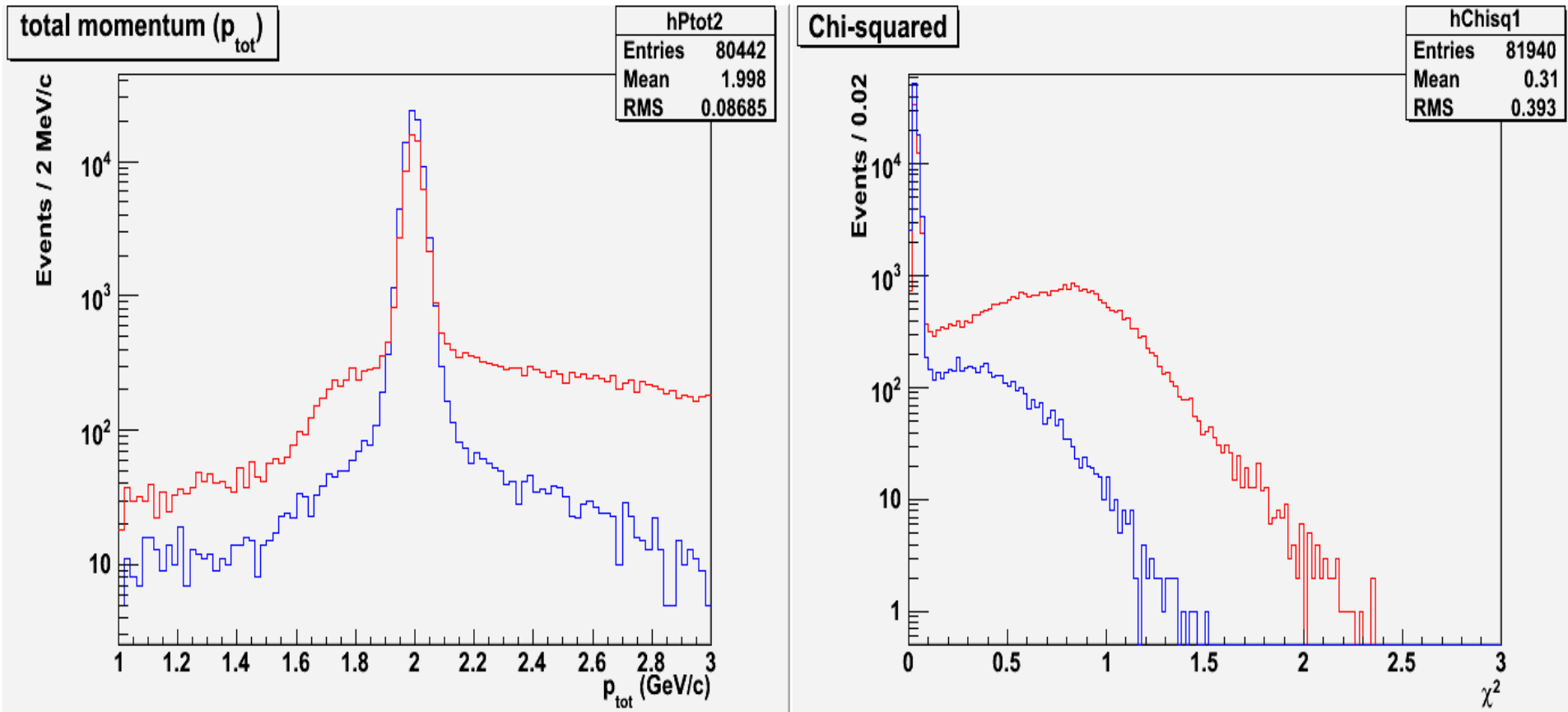


2-Pass Fitting: addressing left-right problem

- Problem: “potential barrier” prevents fitter from crossing from left to right.
- 1st pass: chi-squared term artificially set to 0 inside isochrone (green)
- 2nd pass: standard chi-squared term (red)



2-Pass Fitting: improvement in tails



- 2 GeV pions
- Red: traditional one-pass method -- Blue: two-pass method
- Reduction in tails in seen in momentum and in chi-squared

HDDM Output File Format

- Same concept as “hdgeant.hddm”
- Different HDDM template (next slide)
- Drives:
 - Event display
 - Root tree
- Current version stores details (verbose)
- Fit once, display many times
 - Adjusting root tree contents
 - Display engine independent of reconstruction engine

HDDM template for fitter output

```
<?xml version="1.0"?>
<HDDM class="fitter" version="1.0" xmlns="http://www.gluex.org/hddm">
<event run="int" number="int" maxOccurs="unbounded">
  <fdccdata minOccurs="0" maxOccurs="1">
    <fdchit id="int" x="double" y="double" z="double" minOccurs="1"
      maxOccurs="unbounded" />
  </fdccdata>
  <cdccdata minOccurs="0" maxOccurs="1">
    <cdchit id="int" x="double" y="double" z="double" theta="double"
      phi="double" dist="double" minOccurs="0" maxOccurs="unbounded" />
  </cdccdata>
  <track index="int" fitStatus="int" nFDC="int" nCDC="int" chisq="double"
    minOccurs="0" maxOccurs="unbounded">
    <trajectory index="int" chisq="double" minOccurs="0" maxOccurs="unbounded">
      <parameter label="int" value="double" minOccurs="0"
        maxOccurs="unbounded" />
      <point x="double" y="double" z="double" t="double" minOccurs="1"
        maxOccurs="unbounded" />
      <residual value="double" detector_index="int" minOccurs="0"
        maxOccurs="unbounded">
        <residInfoCdc id="int" xTraj="double" yTraj="double" zTraj="double"
          tTraj="double" xWire="double" yWire="double"
          zWire="double" dist="double" doca="double" minOccurs="0"
          maxOccurs="1"/>
        <residInfoFdc id="int" x="double" y="double" z="double" minOccurs="0"
          maxOccurs="1"/>
      </residual>
    </trajectory>
  </track>
</event>
</HDDM>
```

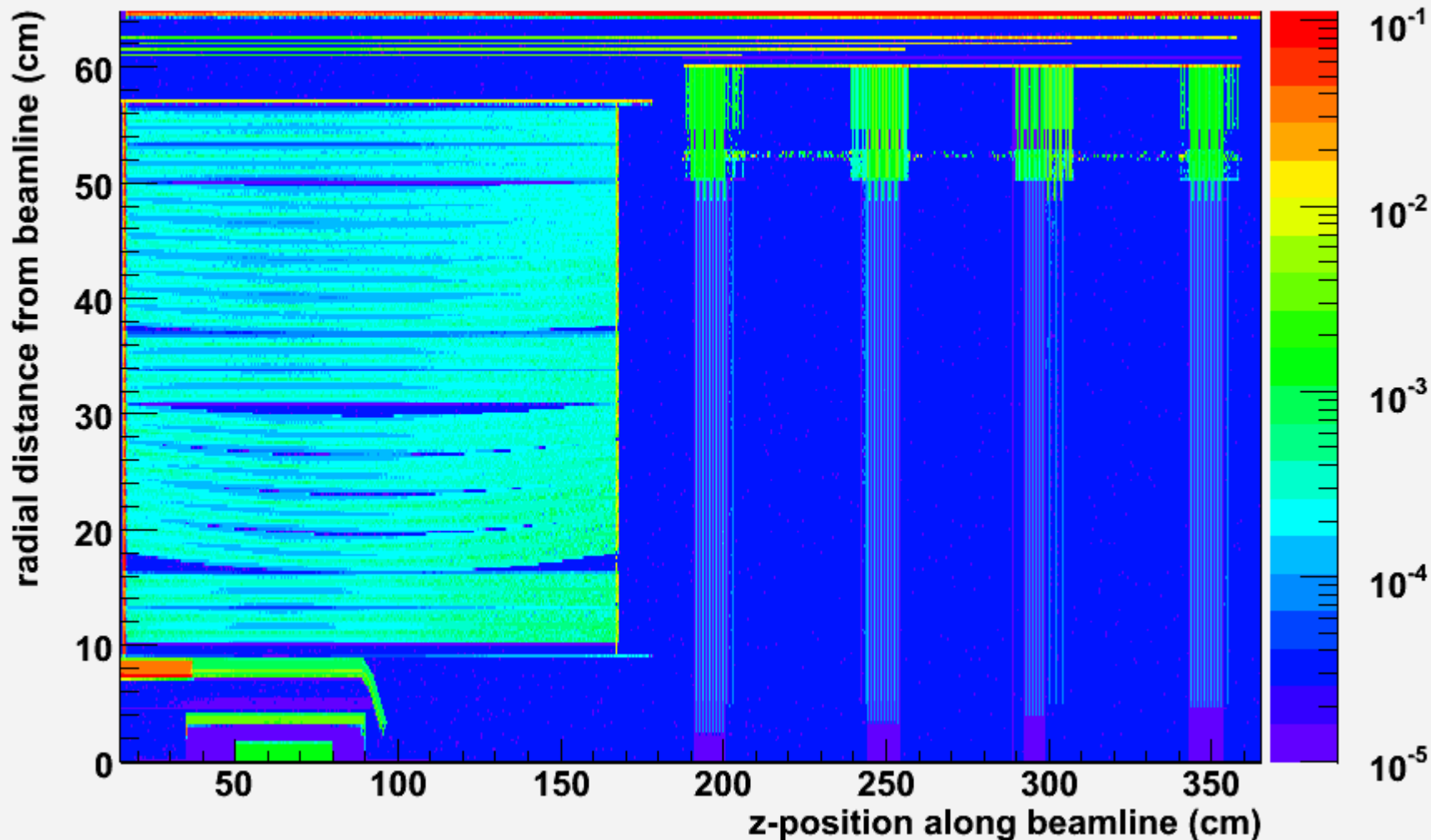


Kalman Filter for Forward Tracks

- Algorithm developed for tracks with hits in FDC, updated to include hits from CDC (no transformation of state vector!)
- State vector $\{x, y, t_x = dp_x / dp_z, t_y = dp_y / dp_z, q/p\}$
 - “Fitted” state vector considered as small perturbation relative to a **seed**
 - **Seed** determined from list of **track candidates** using helical model
- First step: create reference trajectory from seed, swimming from “vertex” to most downstream FDC hit
 - Take into account multiple scattering and energy loss when stepping through the field – *only do this for the reference trajectory...*
- Measurements added one by one, starting with most downstream hit
 - Iterate a few times – in practice only need 2 or 3 iterations for convergence

Radiation Length Map

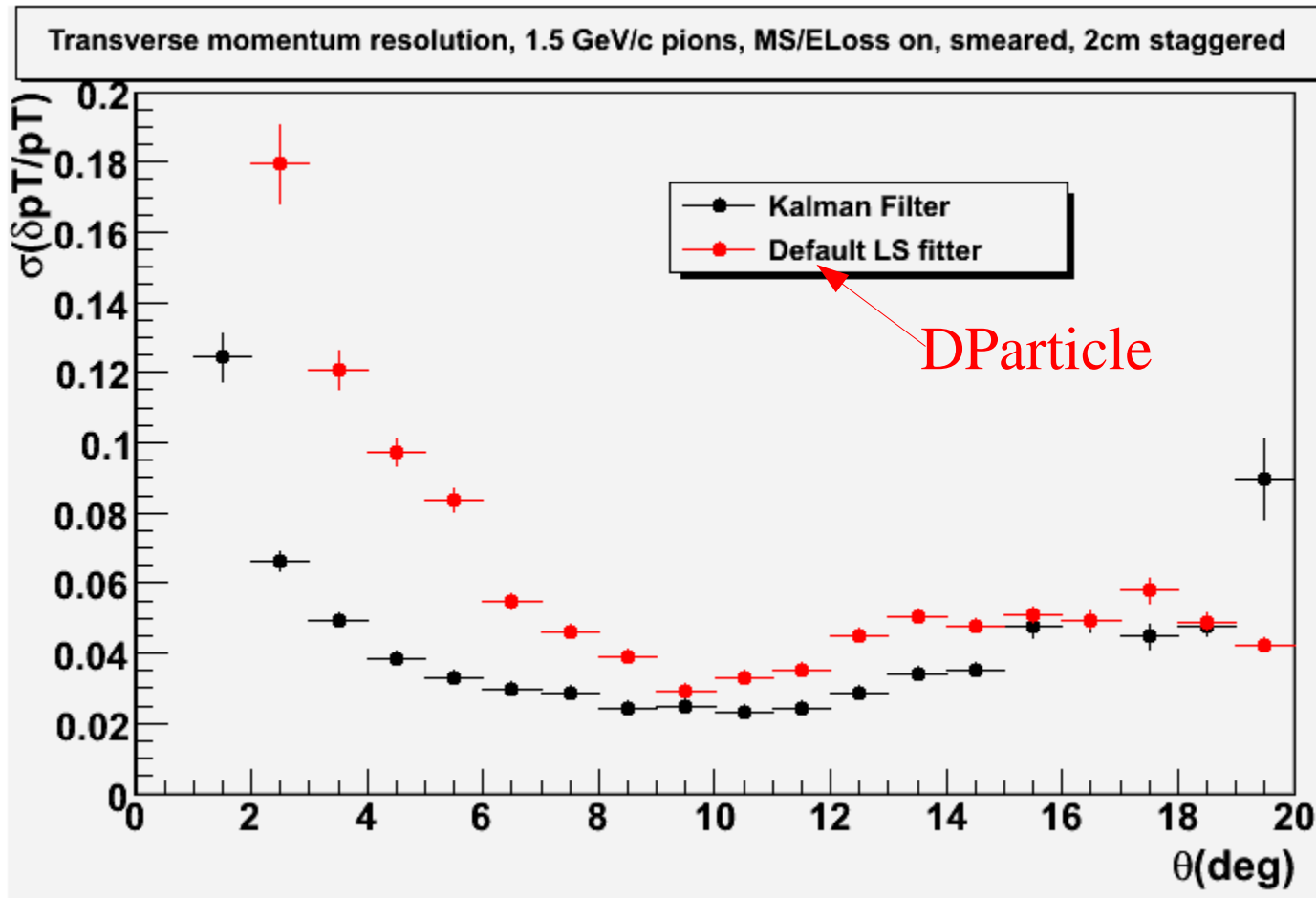
Map of fractions of a radiation length for 1 cm steps



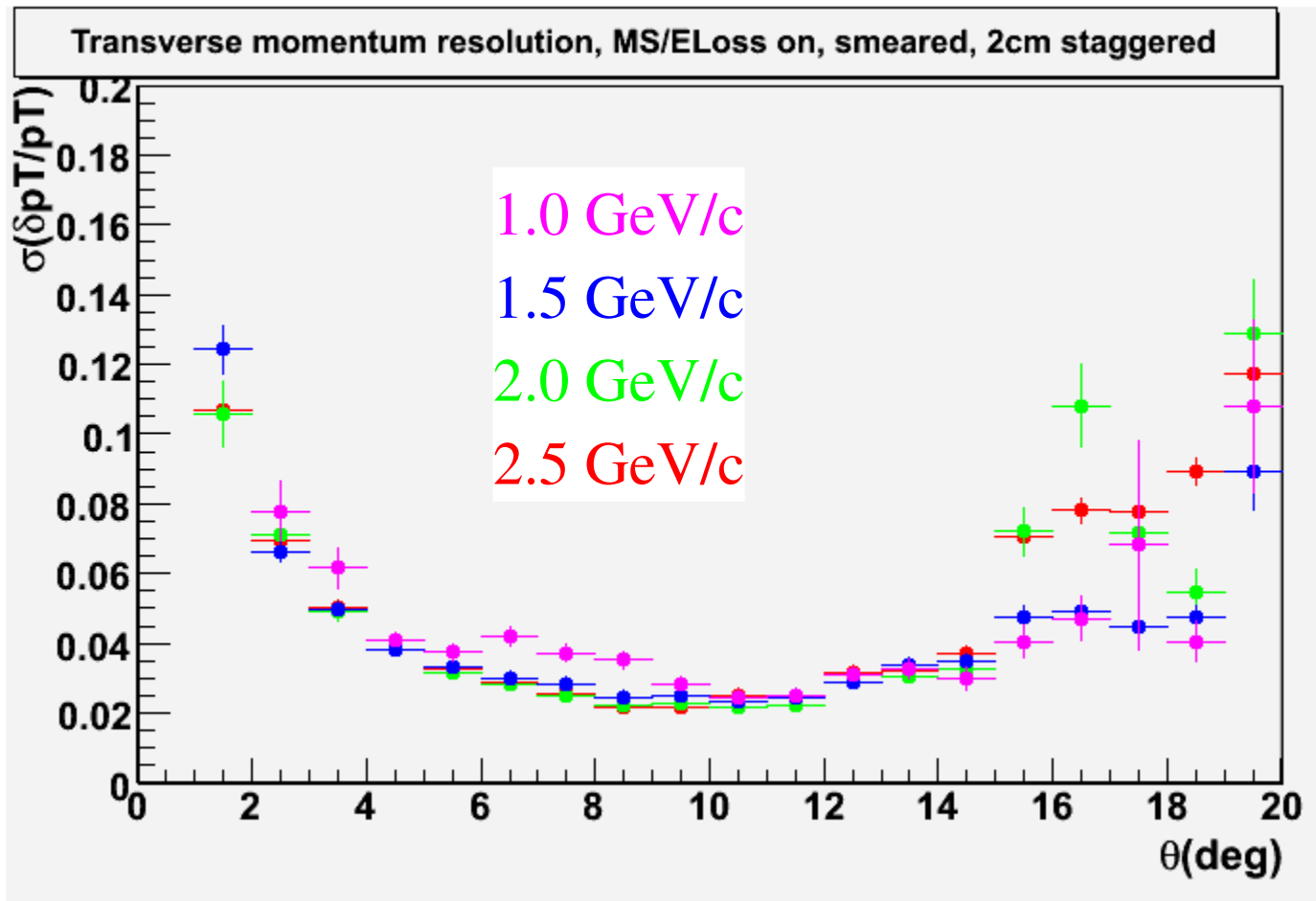
Tracking Resolution Studies

- Generated π^- tracks with discrete momenta (1.0, 1.5, 2.0, 2.5 GeV/c)
 - Vertex= uniform distribution in z within target (30 cm range)
 - Angular range= 1-20° for forward-track studies, to 140° for central-track studies
- Events simulated with HDGeant using GeomC
 - FDC wire plane spacing = 2 cm (repository has 3 cm spacing...)
 - Multiple scattering and energy loss turned on
 - CDC hits smeared, $\sigma=150 \mu\text{m}$
 - FDC hits smeared, $\sigma\approx 200 \mu\text{m}$

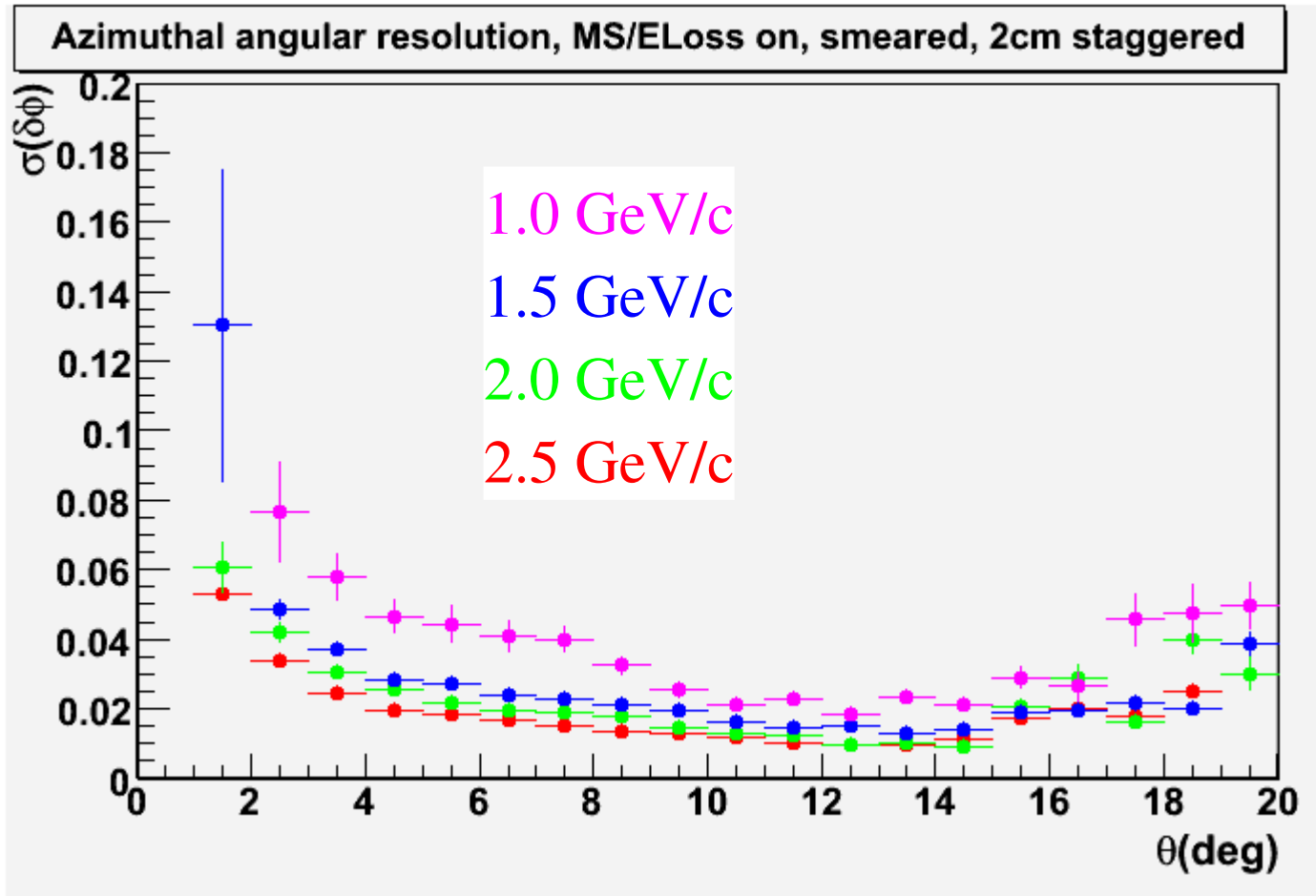
Transverse Momentum Resolution



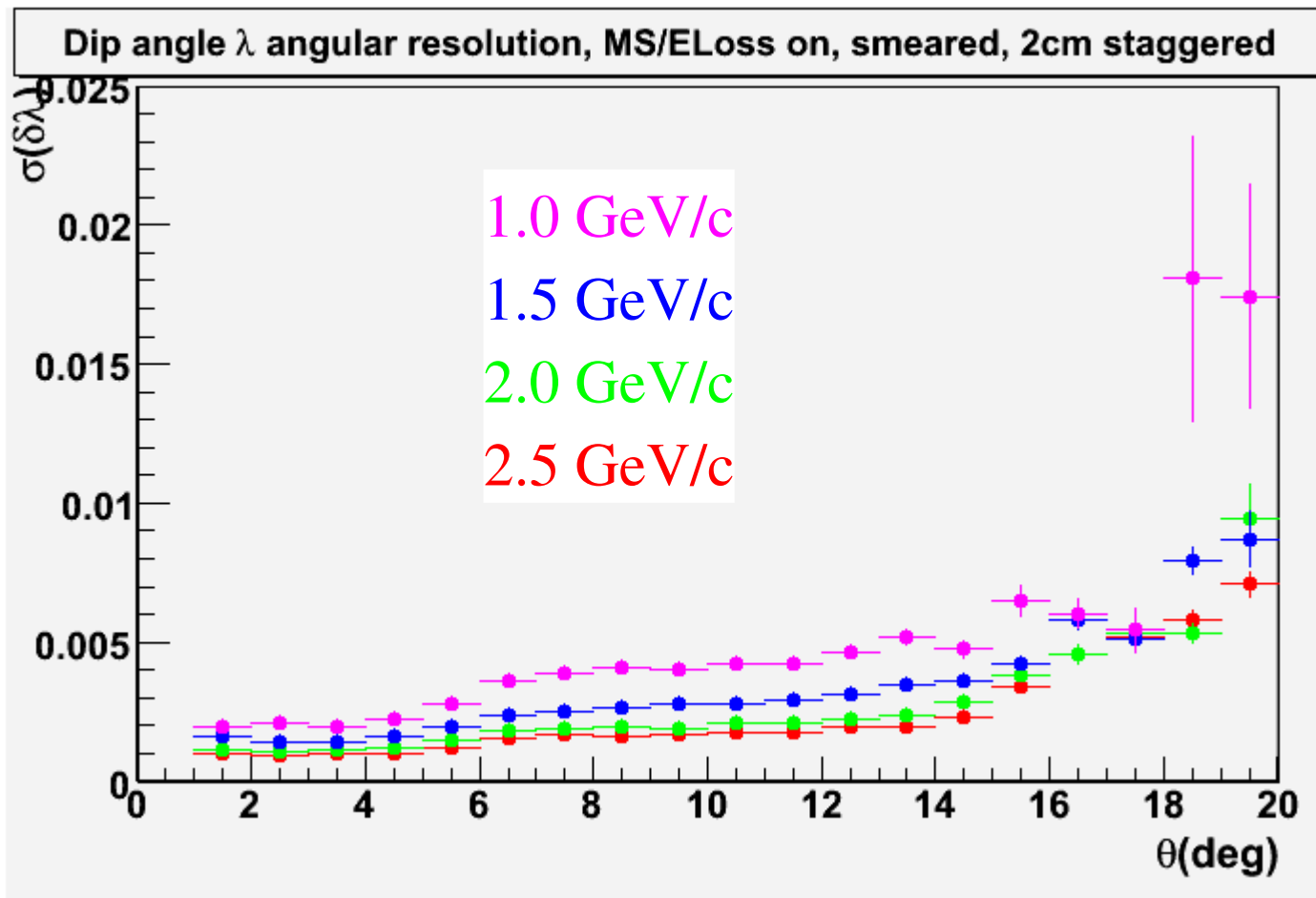
Momentum Resolution



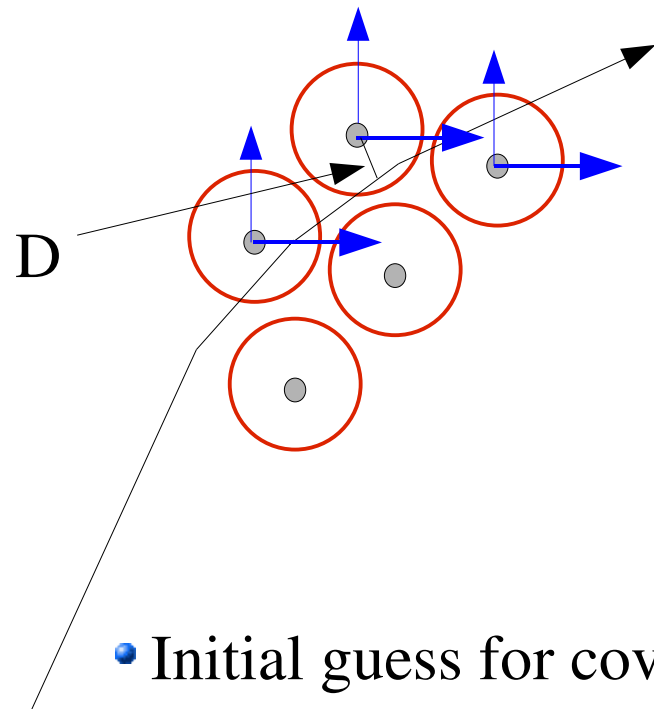
Azimuthal Angular Resolution



Dip Angle Resolution



Kalman Filter for Central Tracks



- Use central parameters:

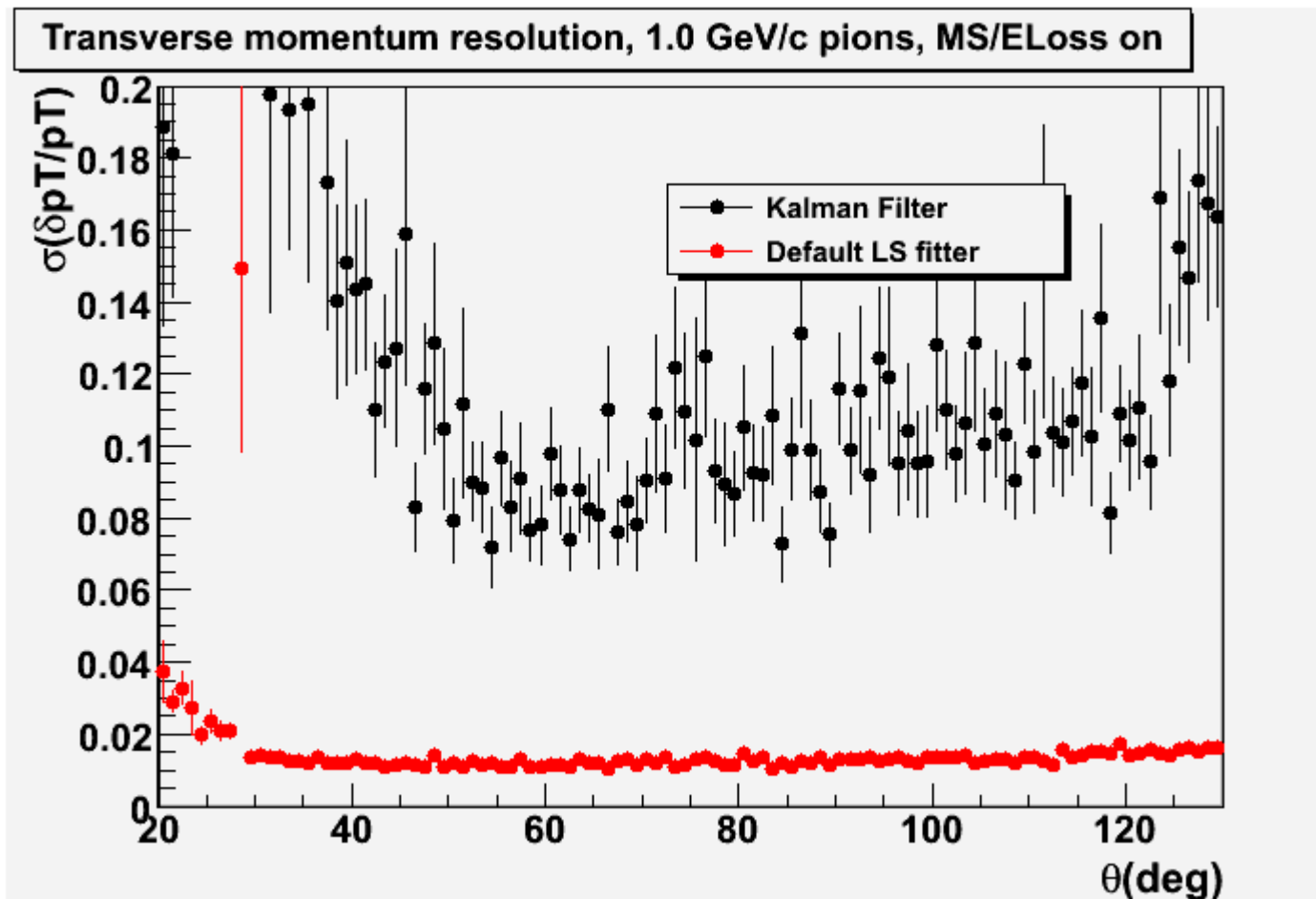
$$\{q/p_T, \phi, \tan \lambda, D, z\}$$

- D is distance of closest approach to the wire
 - Origin of coordinate system for D moves from wire position to wire position as hits are added

- Initial guess for covariance matrix (off-diagonal elements=0)

$$\sigma(\Delta p_T/p_T) = 4\%, \quad \sigma_D = 1 \text{ mm}, \quad \sigma_z = 1 \text{ mm}, \quad \sigma_\phi = 25 \text{ mrad}, \quad \sigma_\lambda = 40 \text{ mrad}$$

Momentum Resolution



Summary/Outlook for Kalman Filter

- Kalman filter working reasonably well for forward-going tracks
 - CDC hits included in more natural way (no transformation of state vector)
 - Works better for very forward tracks than current (1/12/09) version of DParticle for $p \geq 1$ GeV/c, good agreement in $\theta \sim 10^\circ$ region
 - Radiation Length map takes into account material as a function of position in detector without explicit checking of boundaries
- Making progress toward getting Kalman Filter to work with CDC-only tracks
- To do:
 - Make energy loss map, similar to radiation length map, using MC
 - Improve tracking resolution for CDC-only tracks