Tracking Software

Simon Taylor / JLab

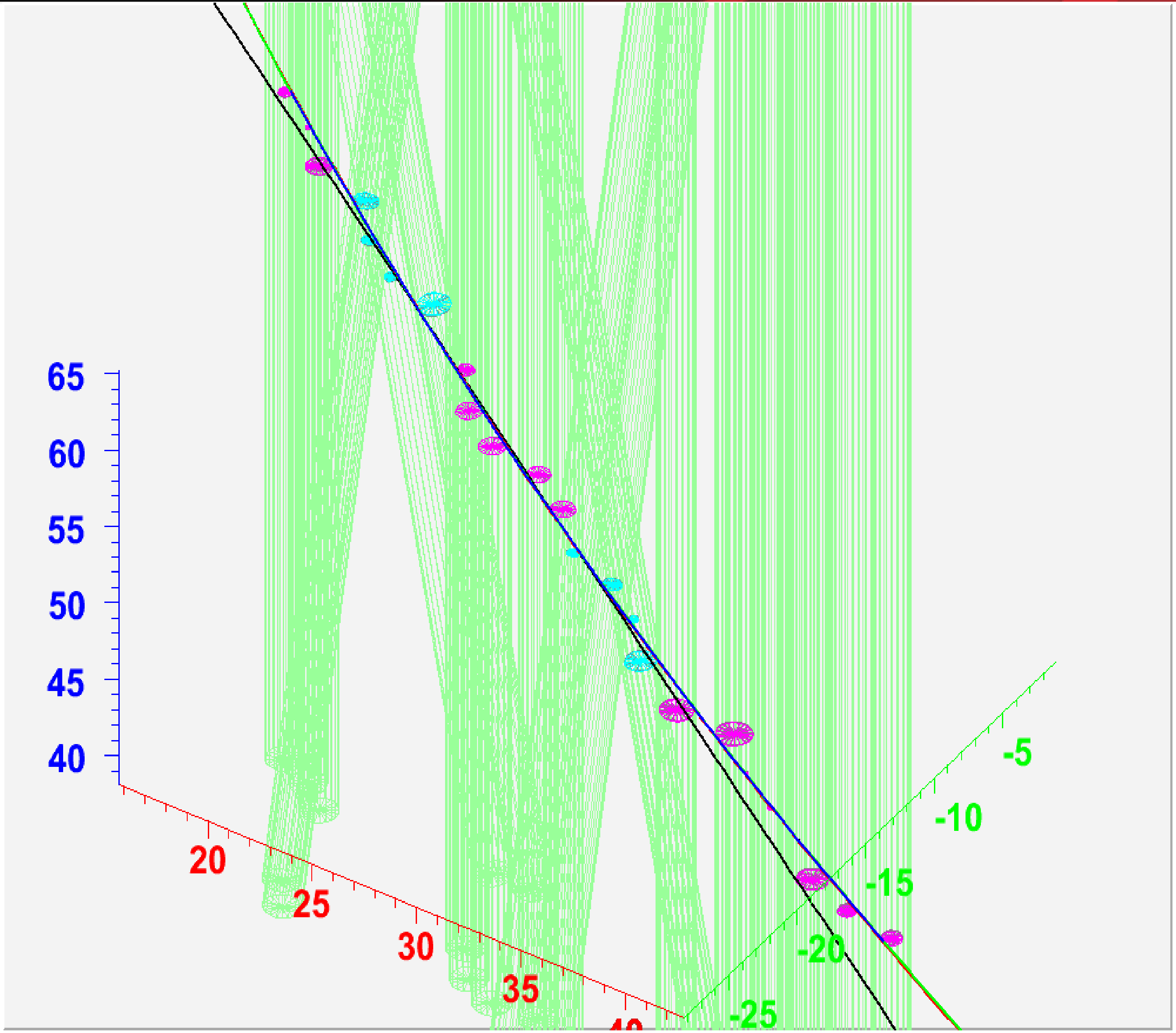
- Mark's Least-squares fitter
- Simon's Kalman Filter

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
  - Mangenta: axial
  - Cyan: stereo
  - Greyed-out: from SWTP track



3-D Display: good fit, top view

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- Red track = fit
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- Blue track= “truth” hits
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  - Mangenta: axial
  - Cyan: stereo
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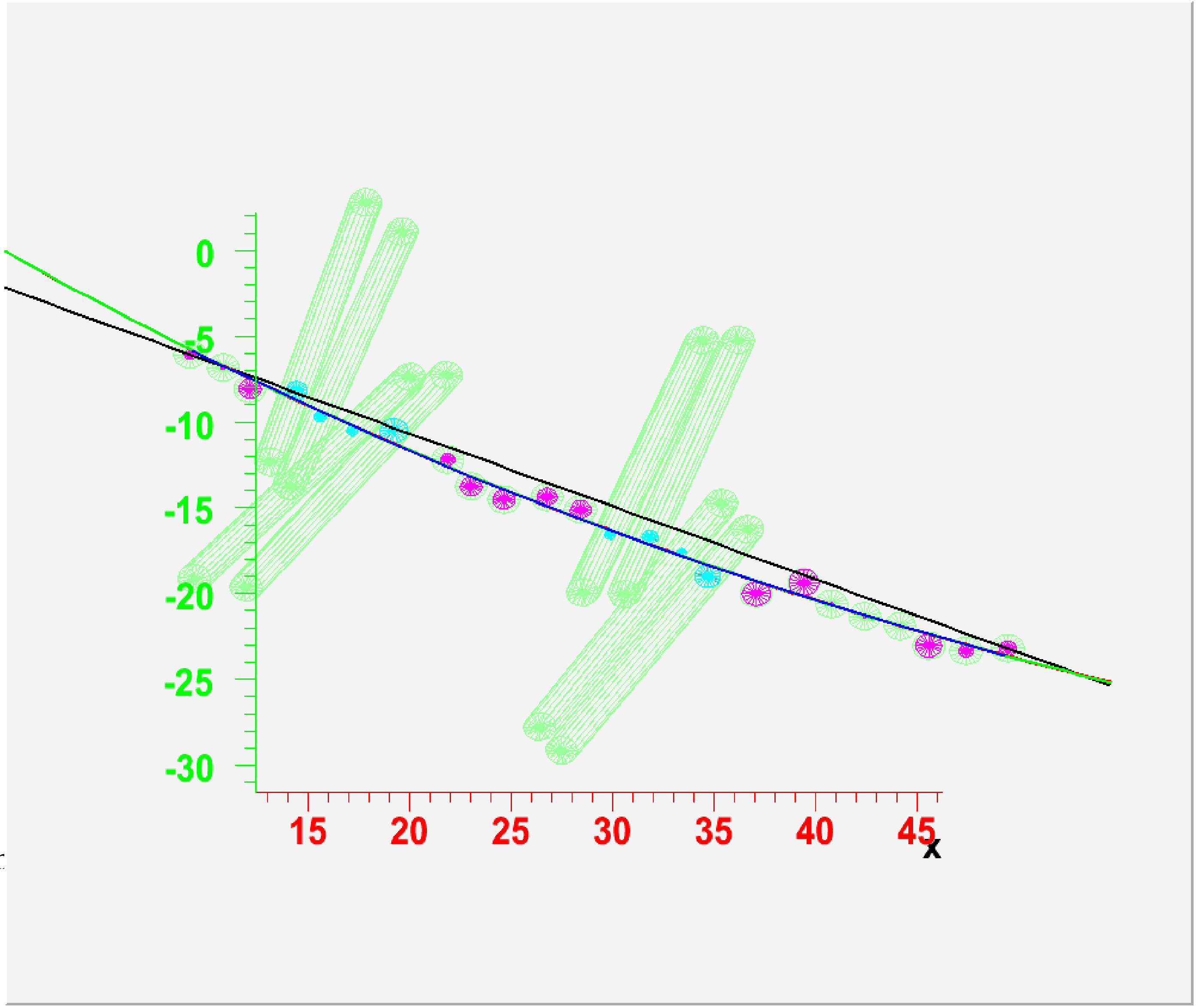

3-D Display: good fit, zoom

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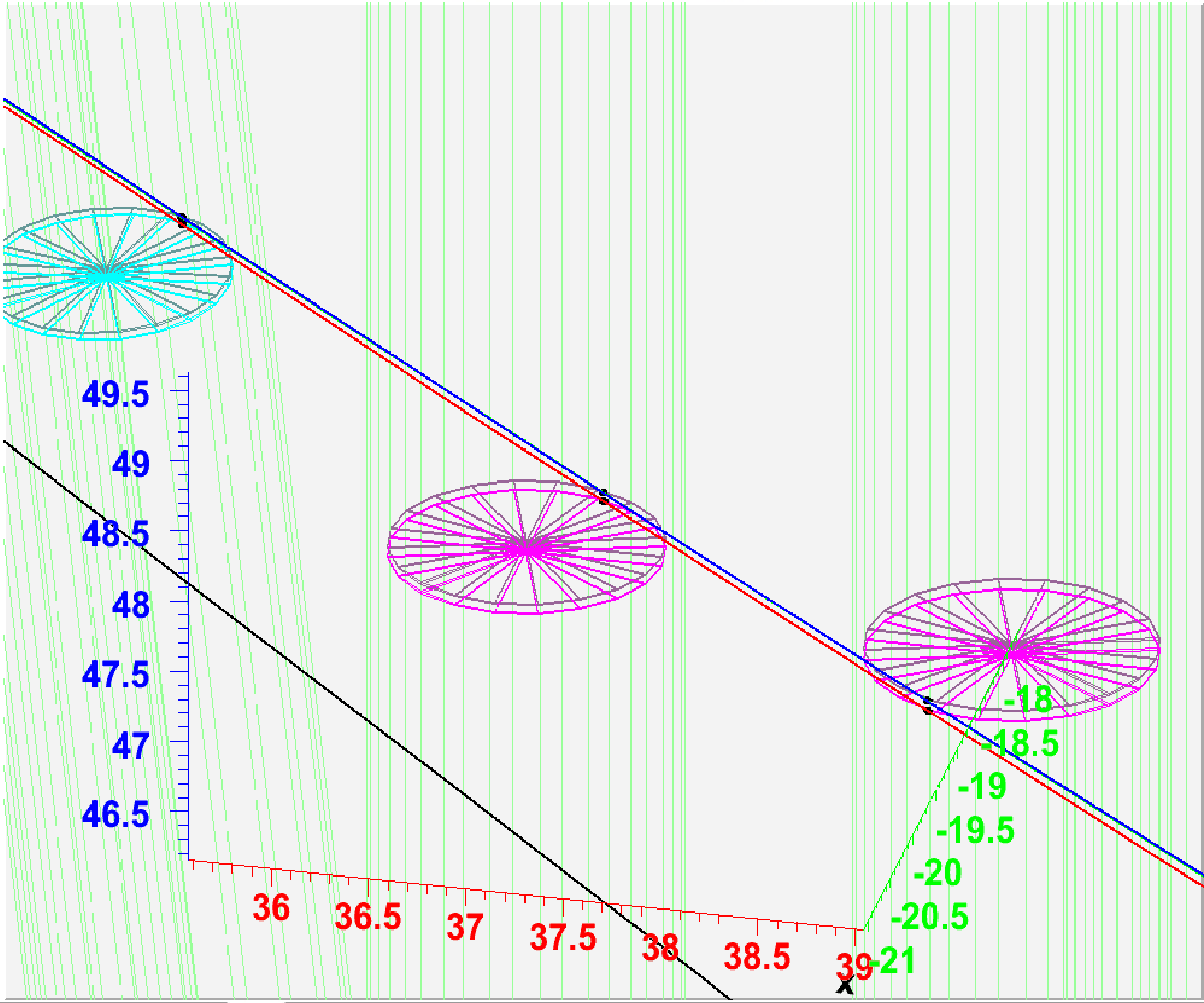

3-D Display: bad fit

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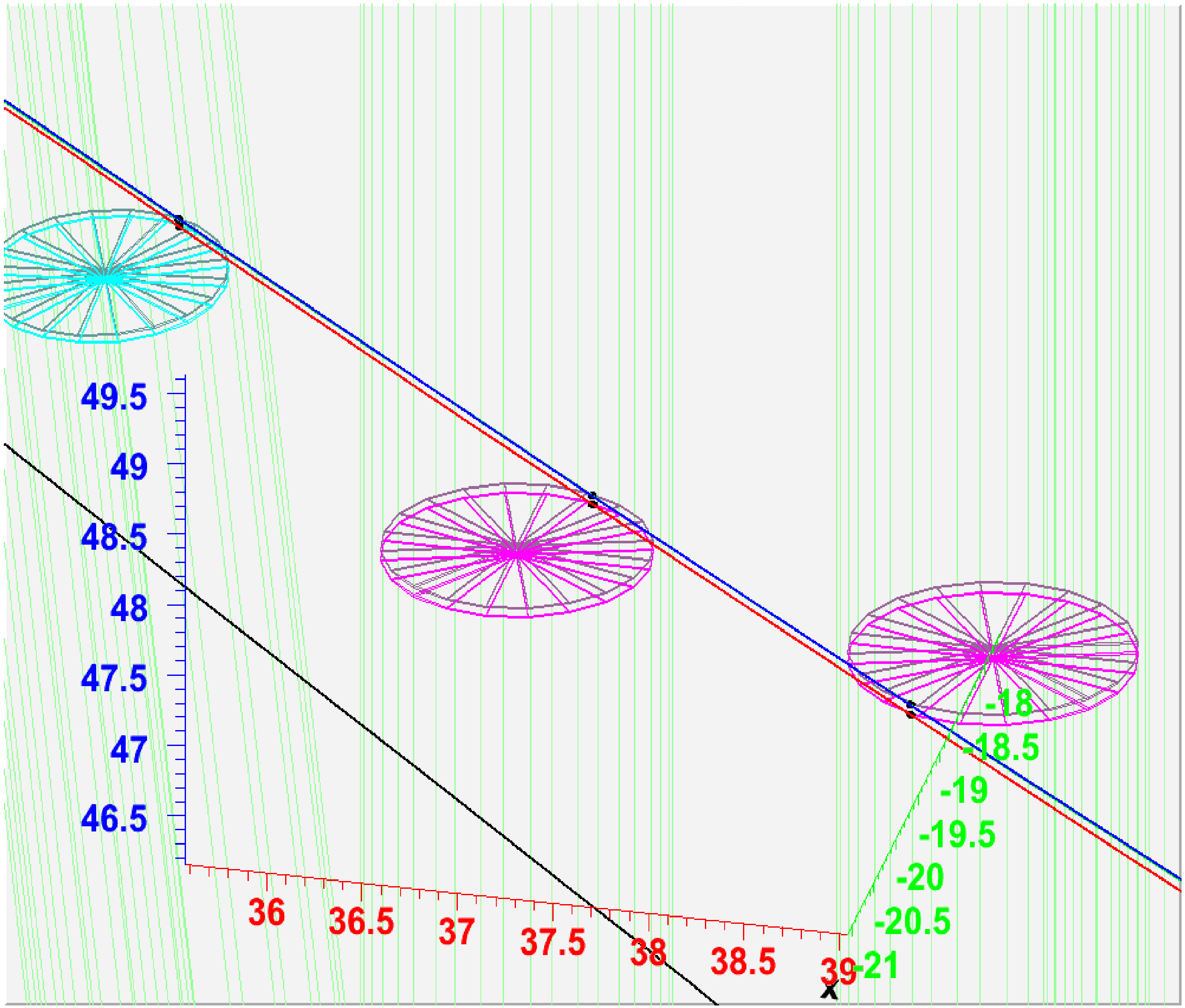

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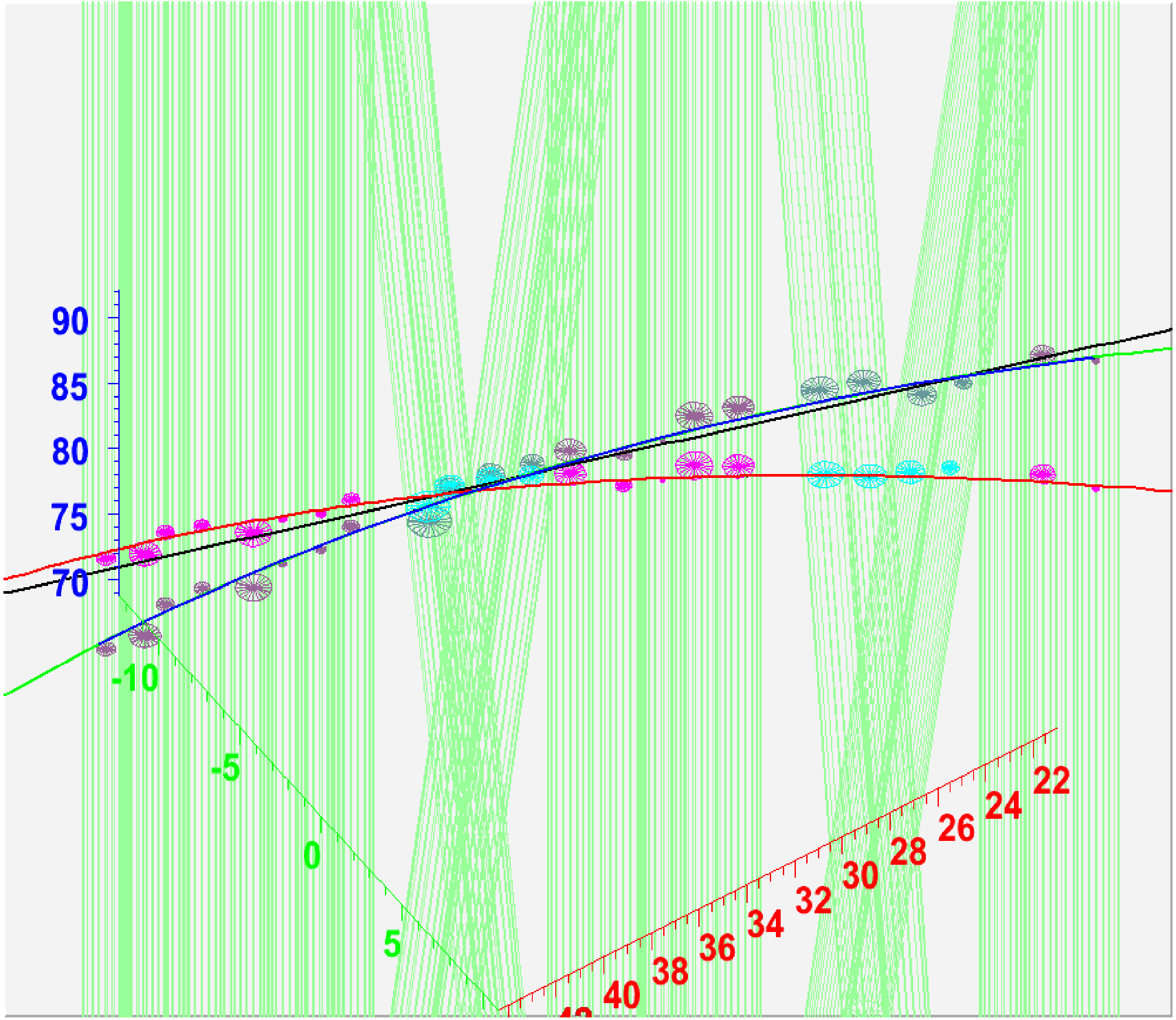
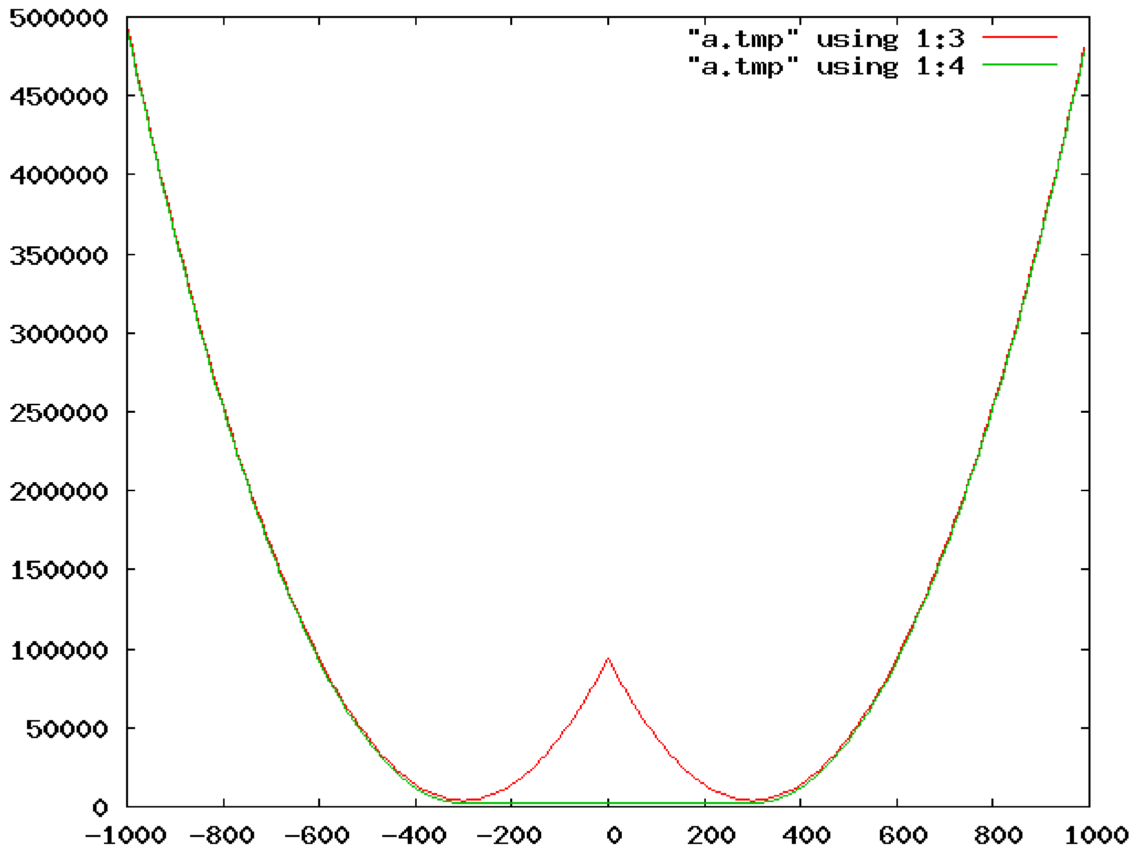
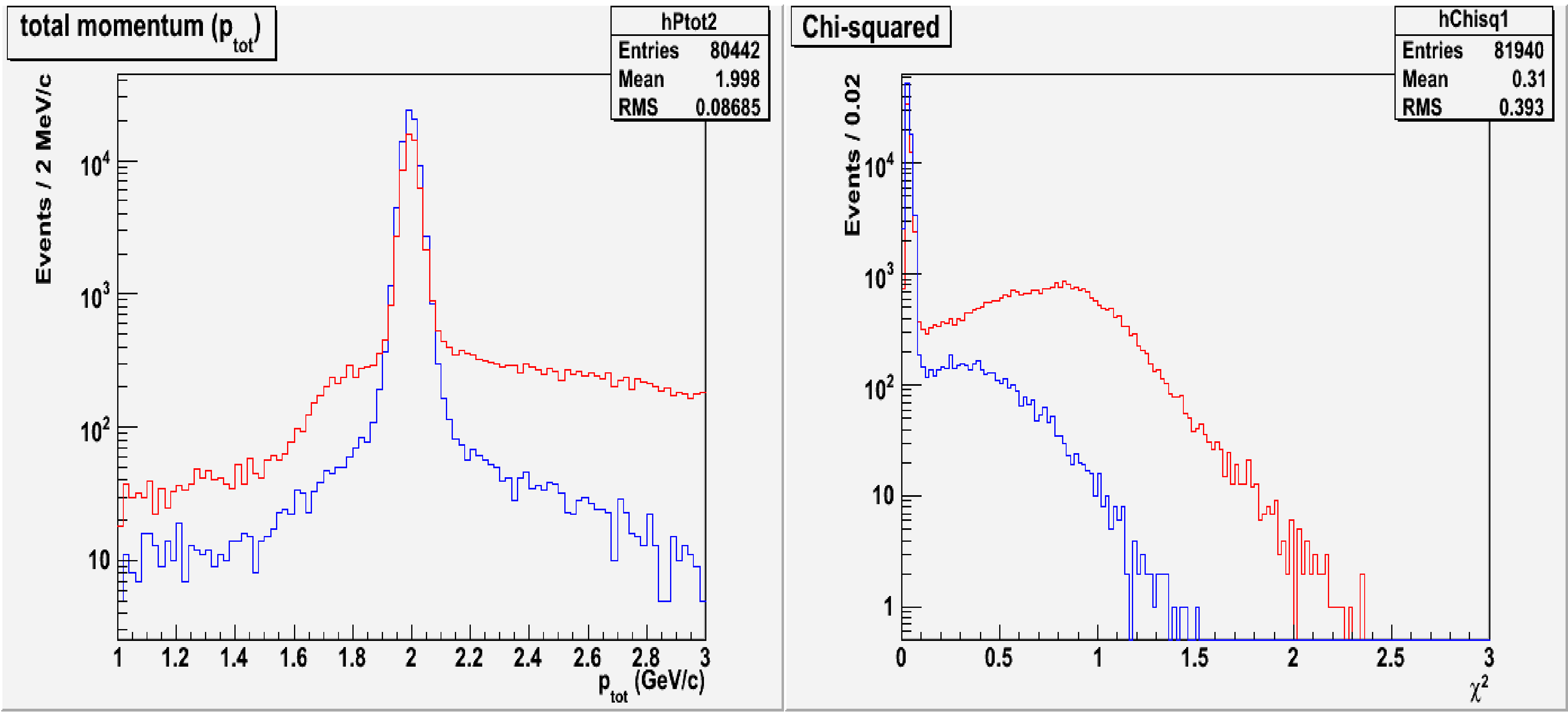


2-Pass Fitting: addressing left-right problem

- 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

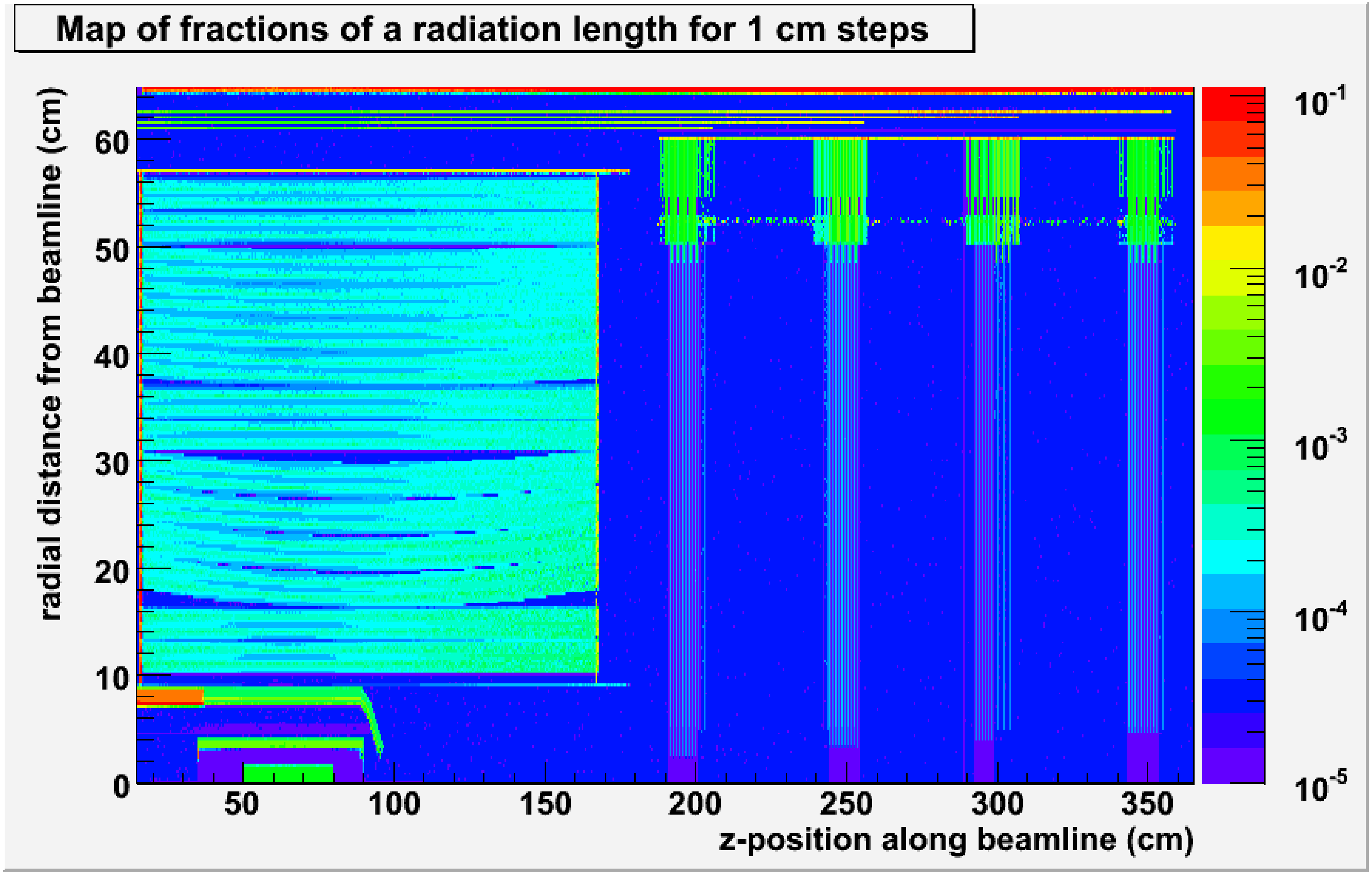
HDDM template for fitter output

```xml
<?xml version="1.0"?>
<HDDM class="fitter" version="1.0" xmlns="http://www.gluex.org/hddm">
<event run="int" number="int" maxOccurs="unbounded">
  <fdcdata minOccurs="0" maxOccurs="1">
    <fdchit id="int" x="double" y="double" z="double" minOccurs="1"
            maxOccurs="unbounded" />
  </fdcdata>
  <cdcdata minOccurs="0" maxOccurs="1">
    <cdchit id="int" x="double" y="double" z="double" theta="double"
            phi="double" dist="double" minOccurs="0" maxOccurs="unbounded" />
  </cdcdata>
  <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

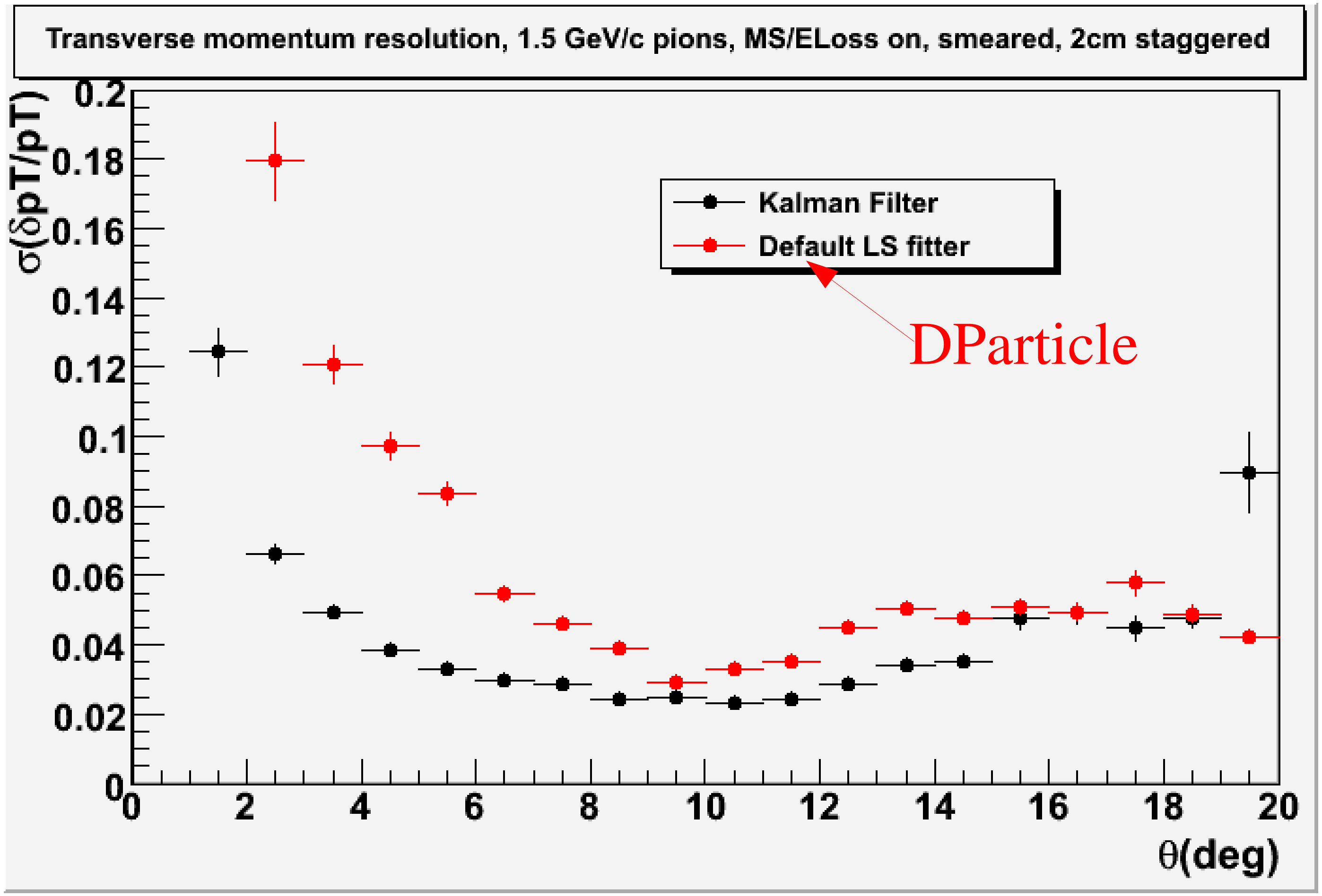
Radiation Length Map



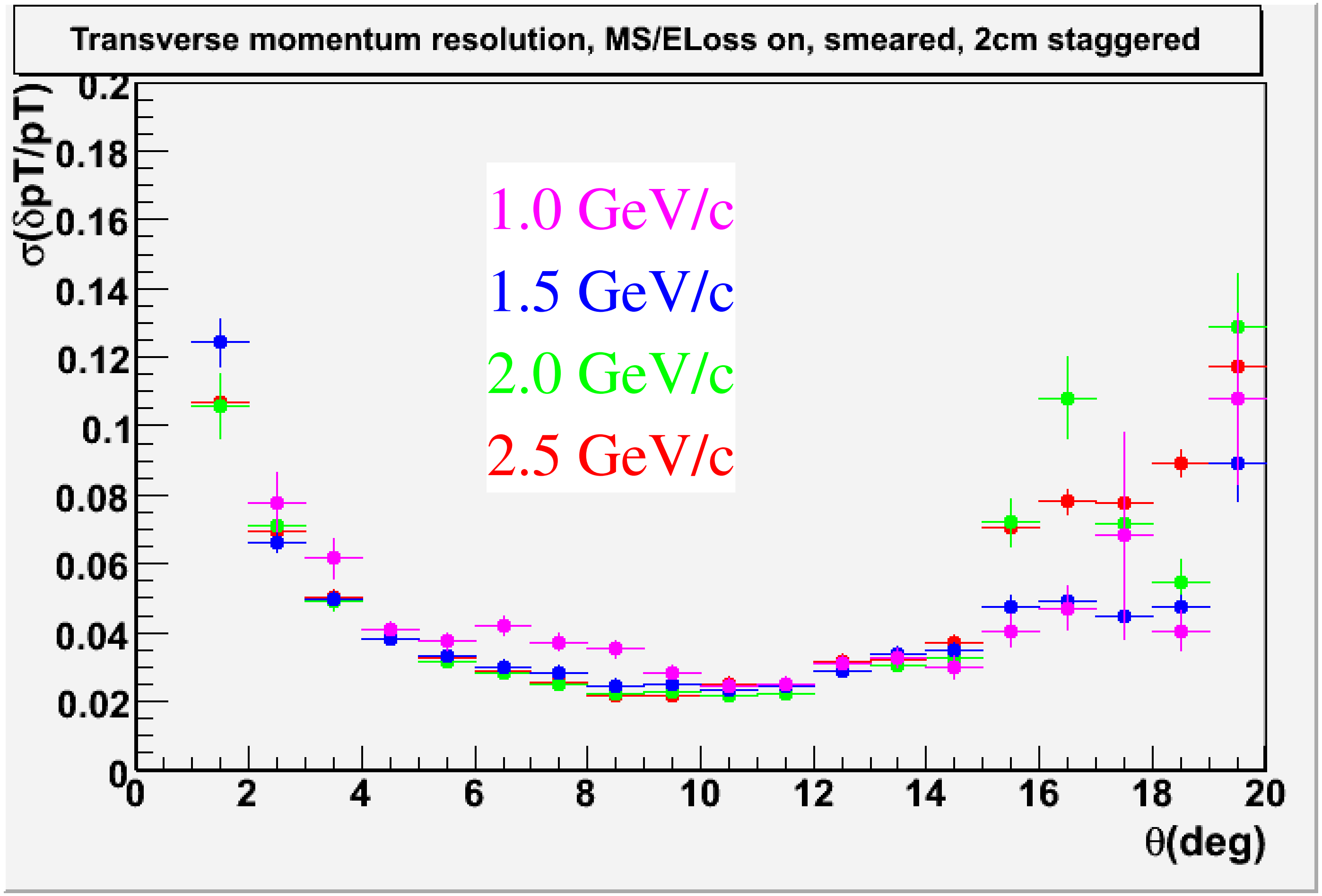
Tracking Resolution Studies

- 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, σ=150 μm
  - FDC hits smeared, $\sigma\approx$200 μm

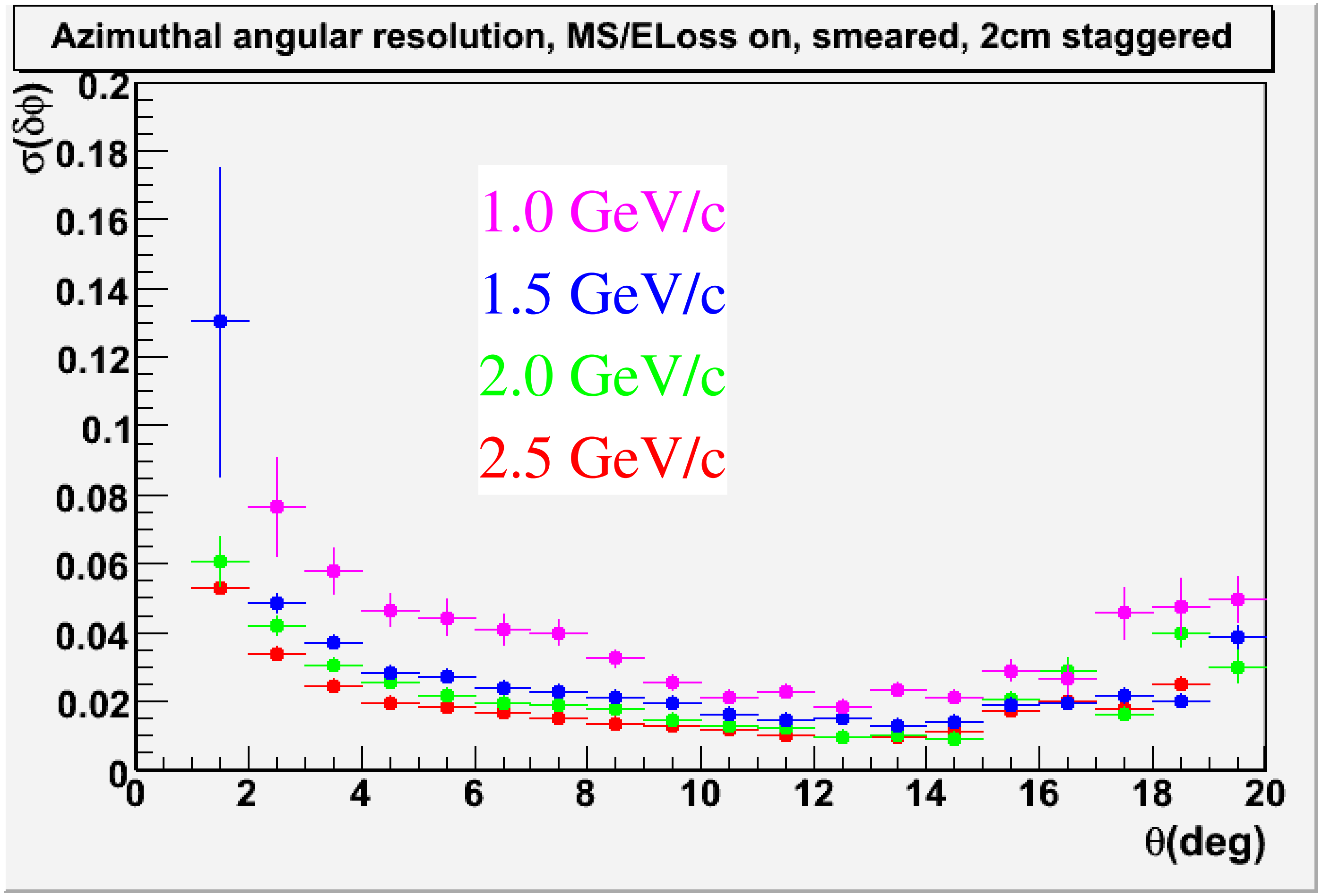
Transverse Momentum Resolution



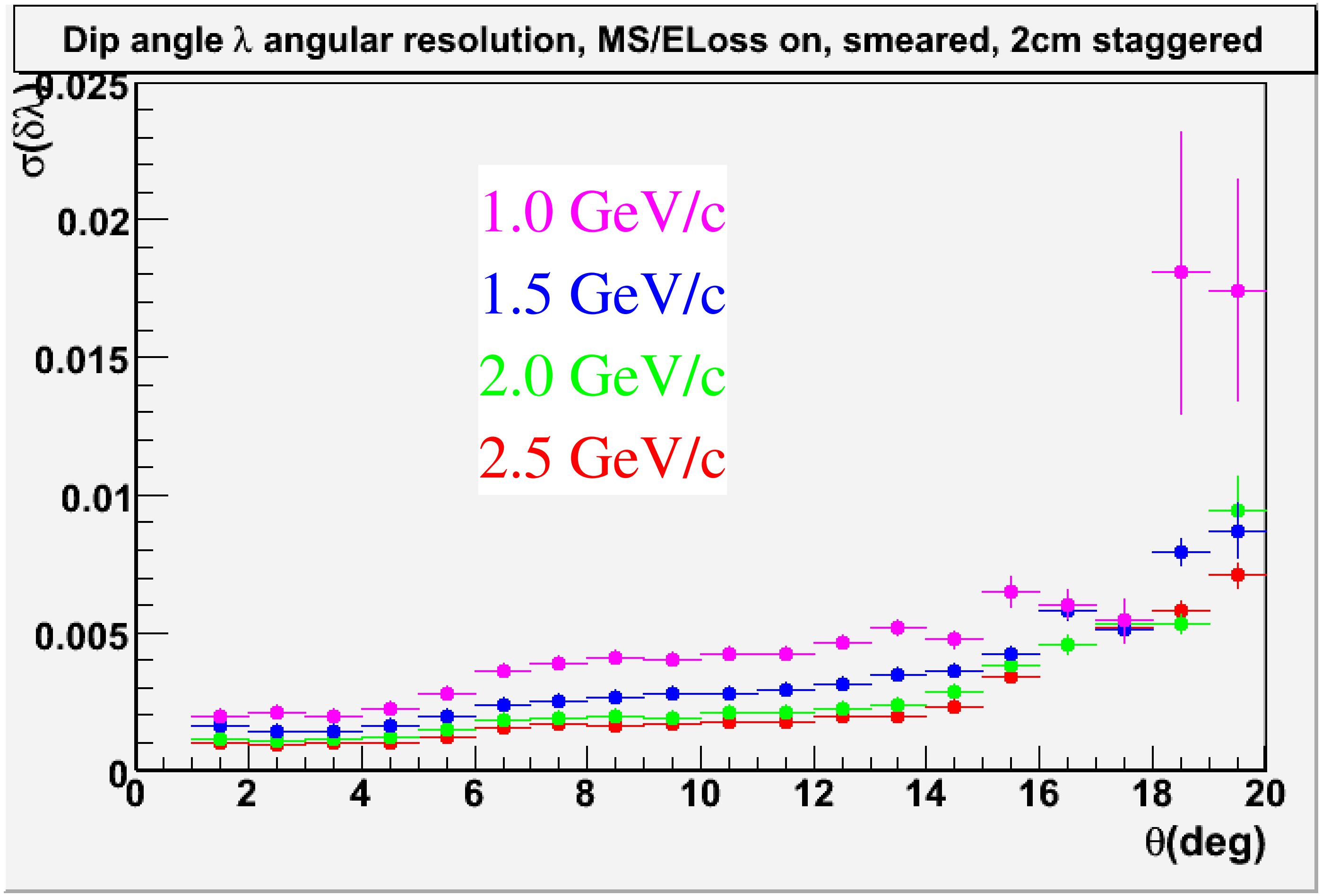
Momentum Resolution



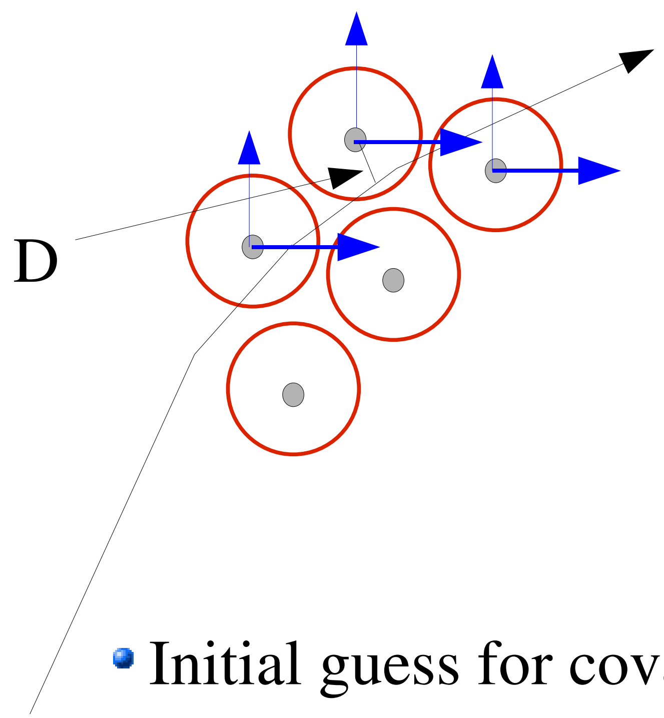
Azimuthal Angular Resolution



Dip Angle Resolution



Kalman Filter for Central Tracks



- Use central parameters:

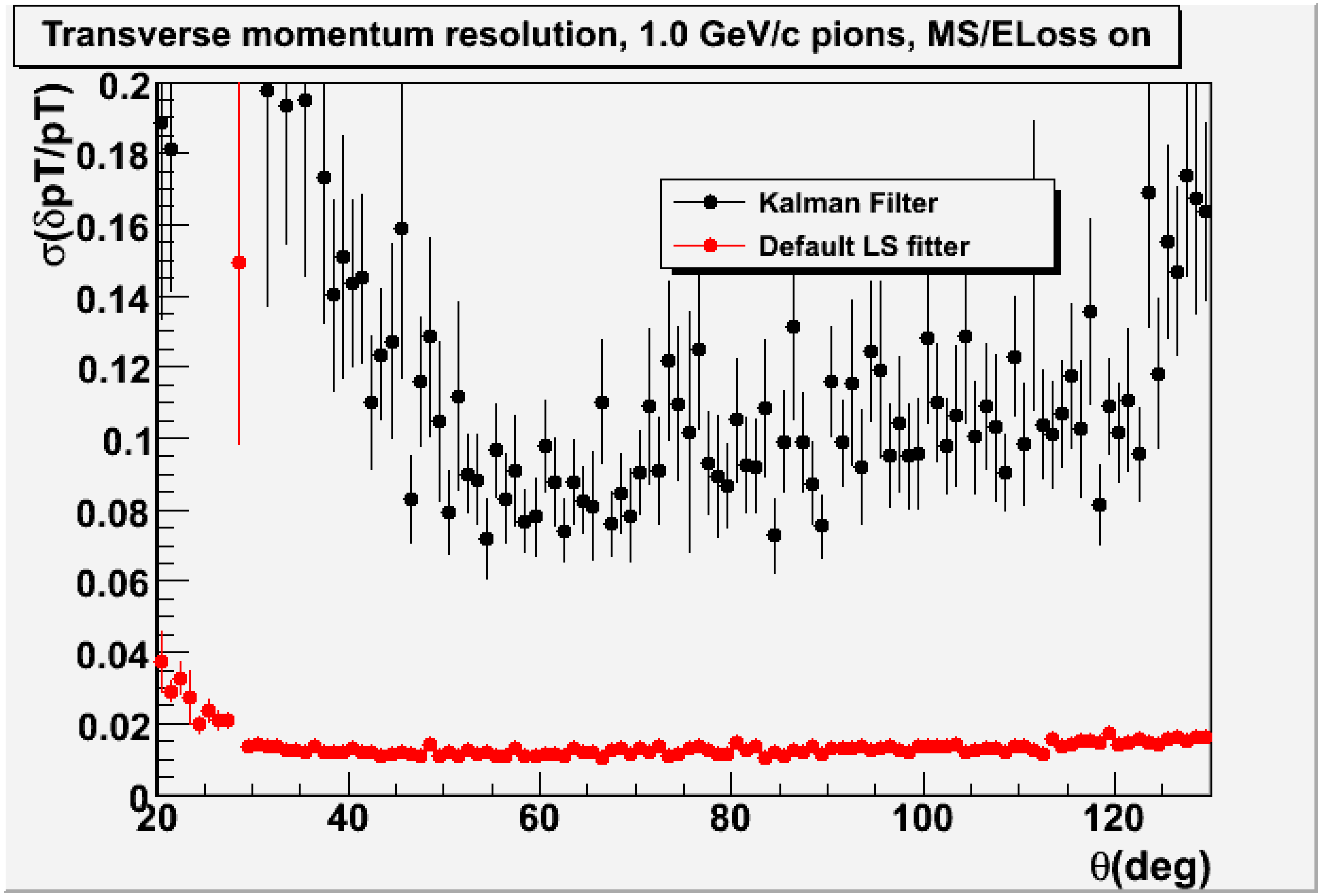
  $\{q/p_T, \phi, \tan\lambda, D, z\}$

  - 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)

$\sigma(\Delta p_T/p_T) = 4\%$, σ_D=1 mm, σ_z = 1 mm, σ_ϕ=25 mrad, σ_λ=40 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 $\theta \sim 10°$ 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