Tracking Update

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- New magnetic field map
- Treatment of detector material
- Kalman Filter update

Fine-mesh Magnetic Field

- Magnetic field map calculated by ANSYS/POISSON
  - Coarse grid: 1 cm × 1 cm
  - Requires interpolation for positions in between grid points
  - Runge-Kutta: interpolation called 4 times per step in tracking code
- New *FineMesh* option: creates map with 1mm × 1 mm grid points in memory → interpolation not needed within magnet bore...

Reconstruction rates with 4 threads on ifarml6

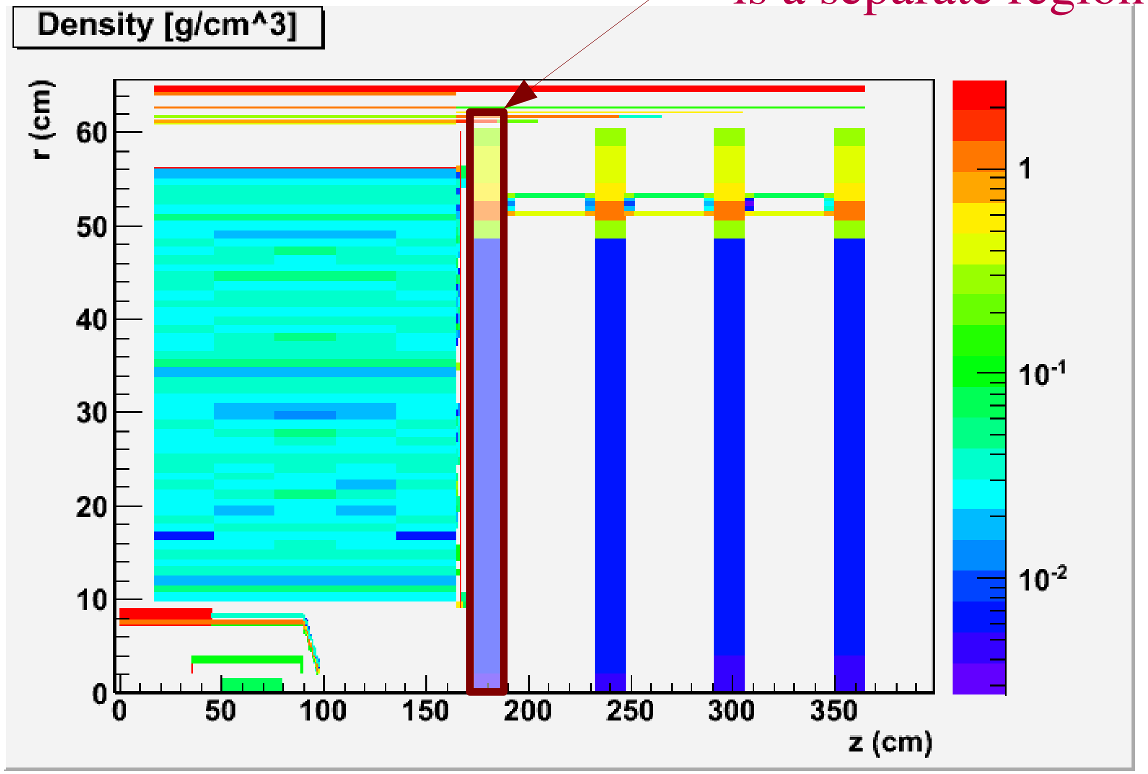
Particle	Algorithm	Interpolation(Hz)	FineMesh(Hz)
proton	Kalman	45.9	62.5
pion	Kalman	42.7	57.7

Using FineMesh has little effect on the ALT1 fitter...

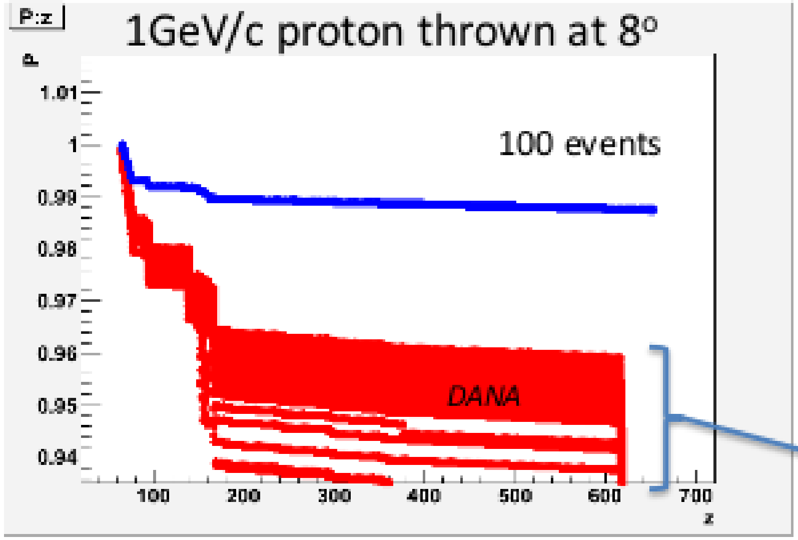
New Material Maps

- Active part of detector divided into material map regions
  - Increased the number of regions (match to detector structures)
  - Increase the number of sampling points within regions

For example, each FDC package is a separate region



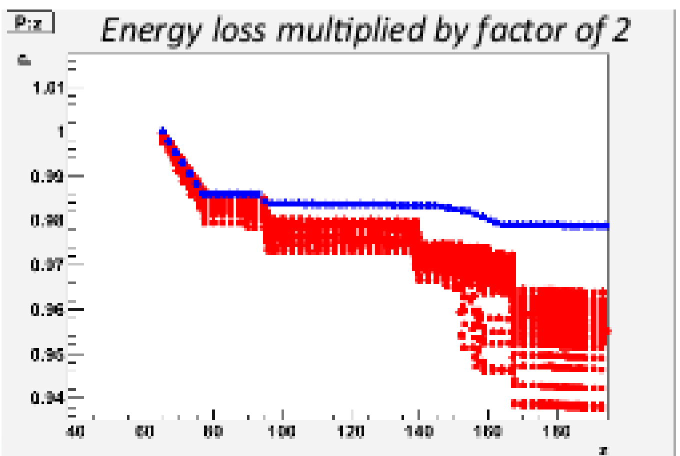
Energy loss due to material



Spread due to explicit δ-ray production.

GEANT

- Reconstructing protons with systematically low momentum
- Pions exhibit much less (if any) such shift
- Energy loss due to material not being properly accounted for



- Slope in P vs. Z is off by factor of 2 in LH2 target
- An empirical factor of 2 was added to the dP/dx calculation to account for this
- The problem turned out to be a bug in these plots where P^2 was being plotted rather than P

for: $P = 1 - \epsilon$

$$P^2 = (1-\epsilon)^2 \approx 1 - 2\epsilon$$

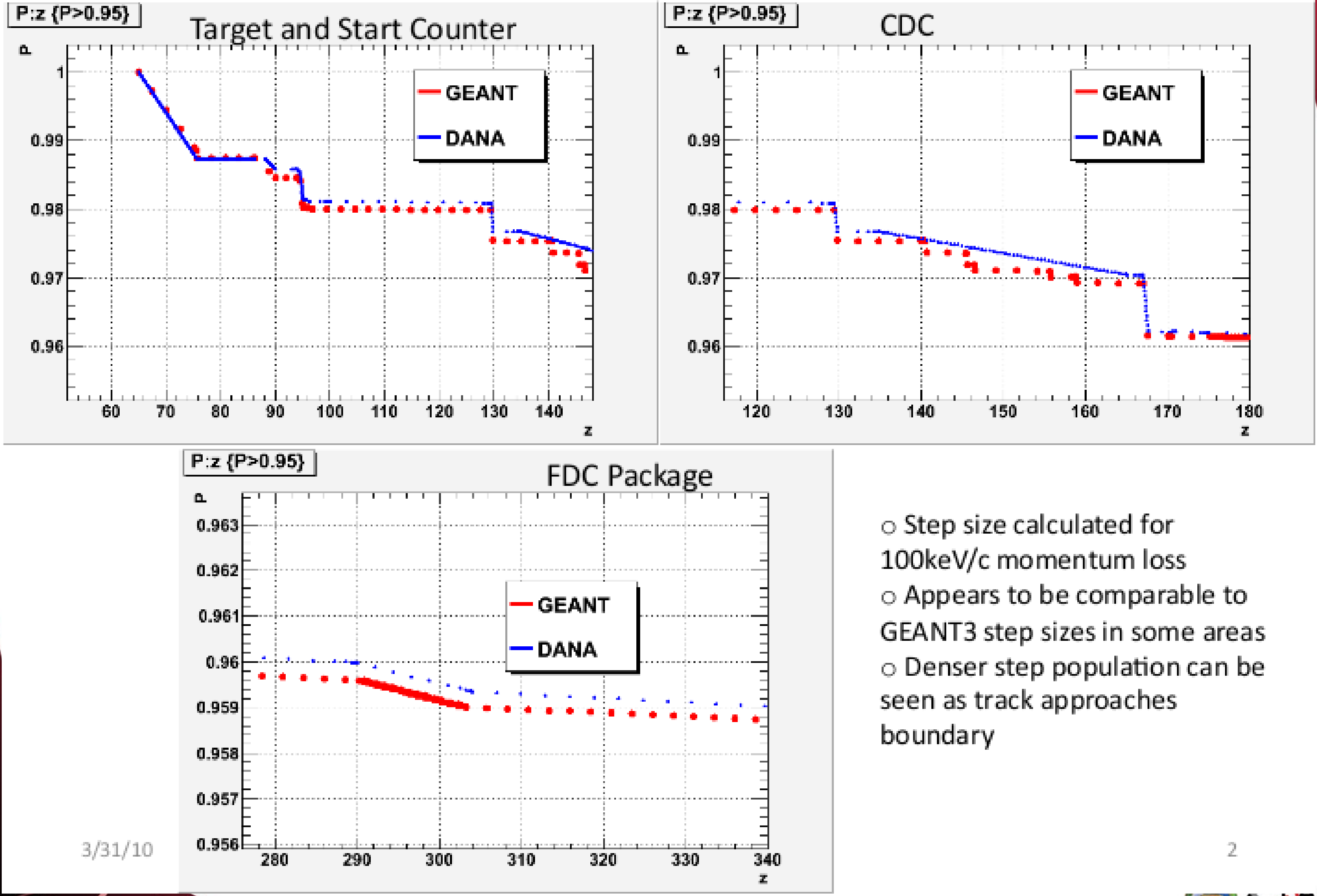
Adaptive Step Size

- Old algorithms relied on fixed step size $\rightarrow$ sometimes skipped over material $\rightarrow$ energy loss not correctly accounted for...
- New approach: adjust step size according to dE/dx in material at current position
  - Check for distance to nearest boundary enabled (not currently used by Kalman Filter)

$$\Delta s = \frac{100\text{keV}}{\left|\left\langle \frac{dE}{dx} \right\rangle\right|}$$

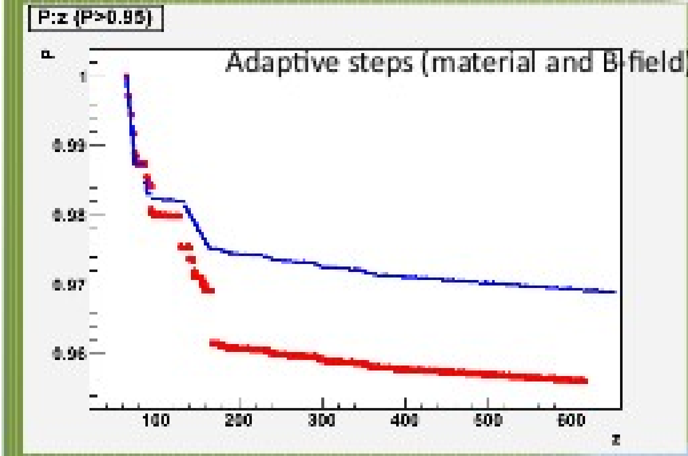
- Also adjust step size based on B-field gradient (not currently implemented in ALT1 fitter)

Adaptive Step sizes in ALT1 fitter



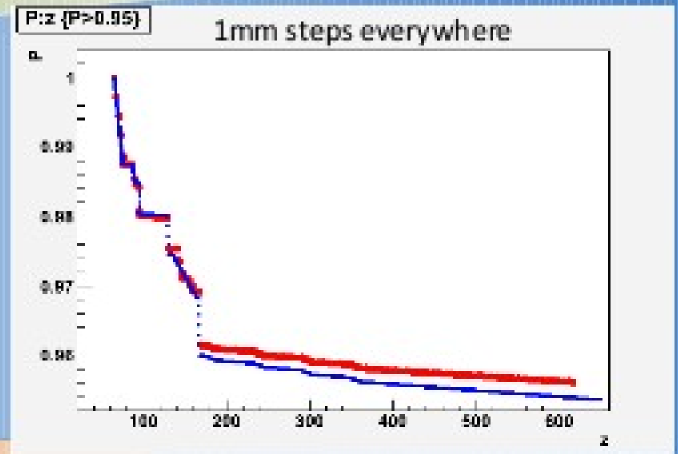
- Step size calculated for 100keV/c momentum loss
- Appears to be comparable to GEANT3 step sizes in some areas
- Denser step population can be seen as track approaches boundary

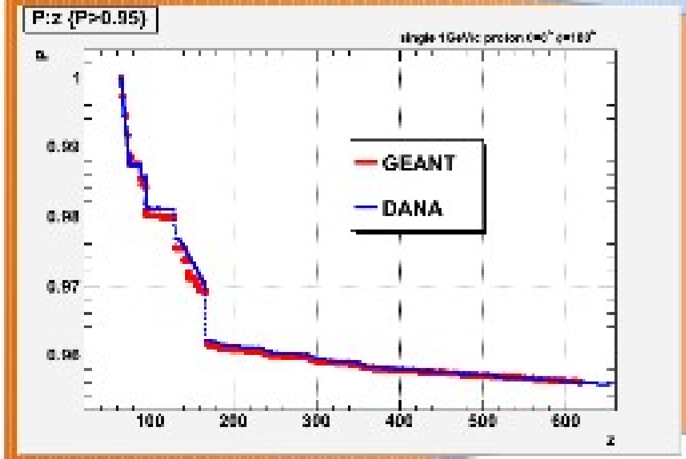
Getting Material Accounting Right



Slopes in large volumes correct, but large losses in small, dense volumes not being fully accounted for

Using 1mm steps everywhere does a better job accounting for material, but has huge performance cost

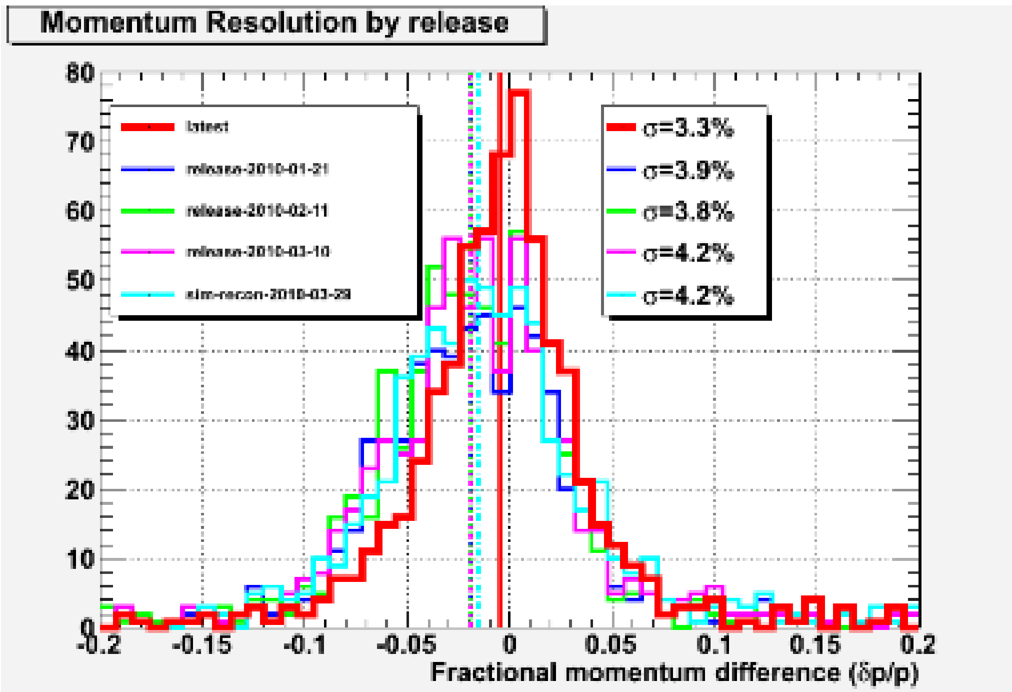




Added boundary checking of material maps to allow larger steps in areas far from boundaries, but small steps across boundaries

Reconstructed Protons in $\gamma p \rightarrow p\omega \rightarrow p\pi\pi\pi$

Numerous improvements to the tracking code and in particular to the material maps and how they are handled have led to improved proton reconstruction in the ALT1 fitter



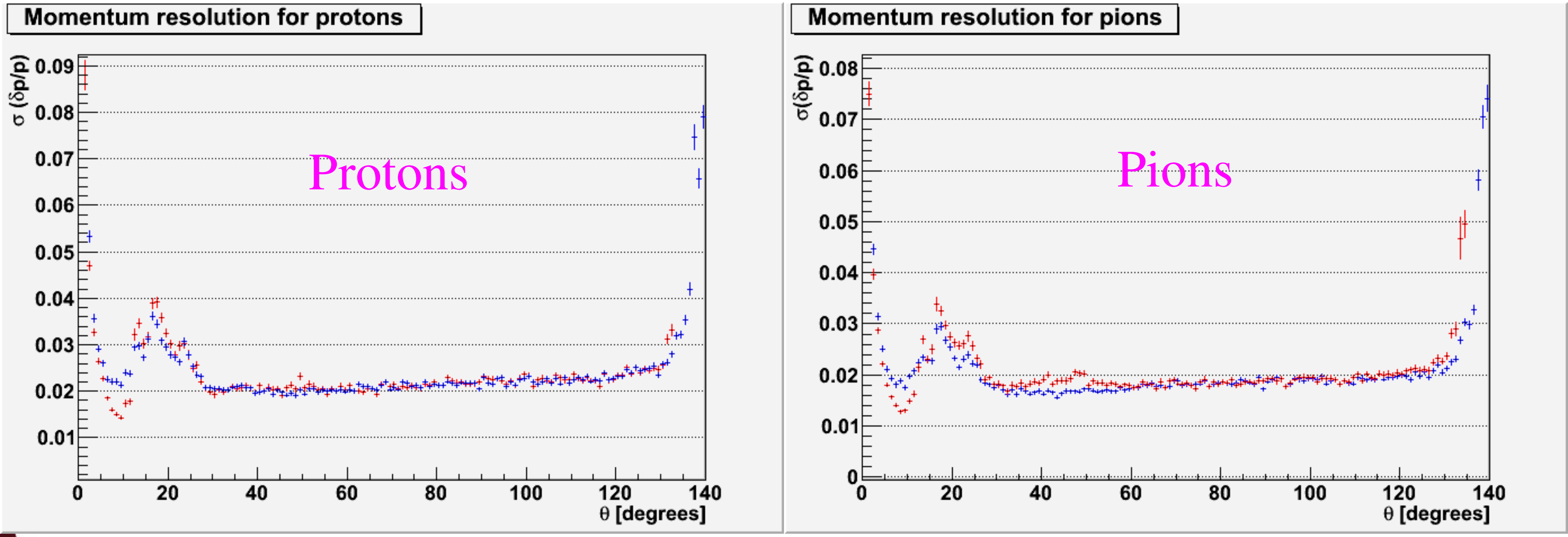
Release	Rate/core (ALT1)
latest	1.51 Hz
release-2010-01-21	1.42 Hz
release-2010-02-11	1.57 Hz
release-2010-03-10	1.09 Hz
sim-recon-2010-03-29	0.87 Hz

Changes to Kalman Filter Code

- Code no longer relies on scaling the measurement errors with an iteration-dependent schedule (asymptotically approaching no scaling)
  - This may be resurrected if we adopt the Deterministic Annealing Filter...
- Multiple-scattering formula due to Lynch and Dahl
  - More accurate than previously used formula (from PDG)
- Adaptive step size
- For fitting in the CDC, using linear approximations to the path through the field between steps to find DOCAs where feasible (otherwise fall back on slow iterative procedure)
- Started to implement part of the Kalman Smoother

Momentum Resolution

Particle gun, 250,000 events, 0.1-3.1 GeV/c



Kalman

Least Squares (ALT1)

Pull distributions

- Provide way to assess quality of errors in the fit and to look for biases
  - Expect mean=0, σ=1 if errors are correct and there is no bias

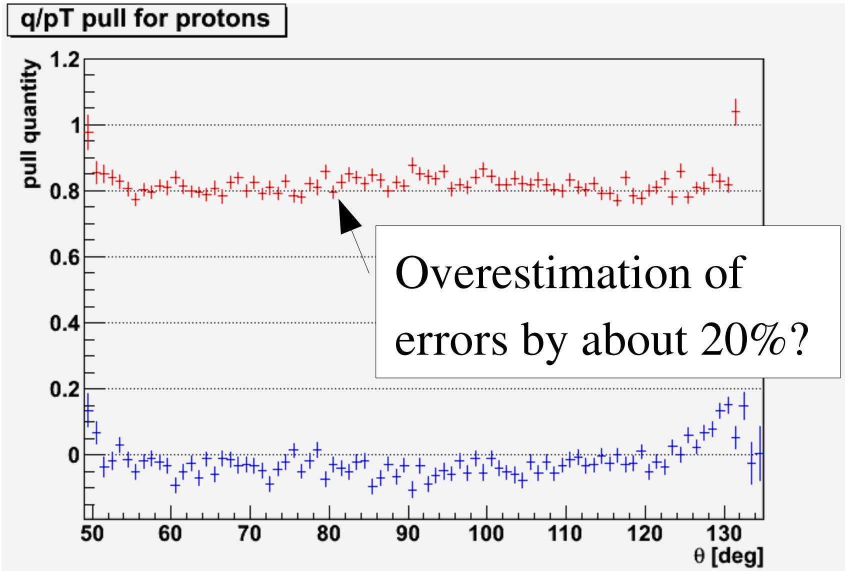
$$pull(\nu) \equiv \frac{\nu - \nu_{true}}{\sqrt{\sigma^2_{\nu\nu}}}$$

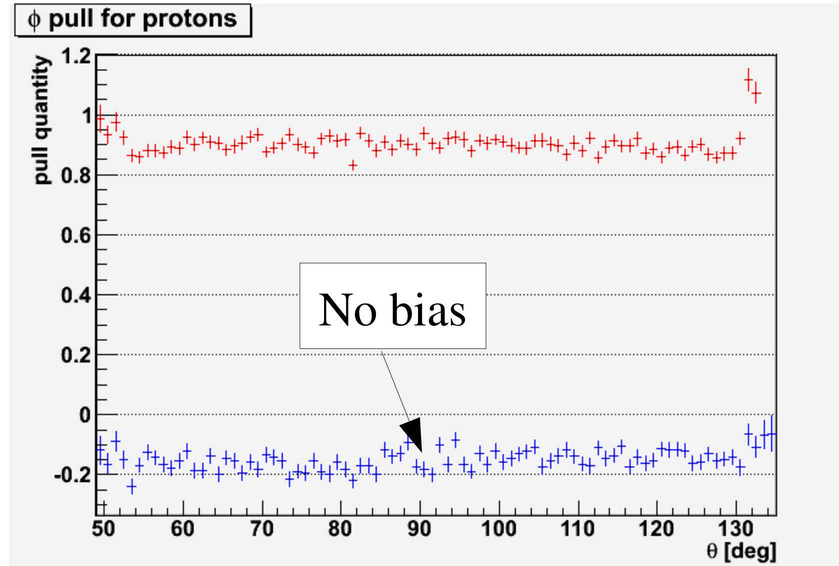
- Kalman filter parameters:
  - Forward parameters for θ <50° : $\{q/p,\ t_x=p_x/p_z,\ t_y=p_y/p_z,\ x,\ y\}$
  - Central parameters for θ>50° : $\{q/p_T,\ \tan\lambda,\ \phi,\ z,\ D\}$

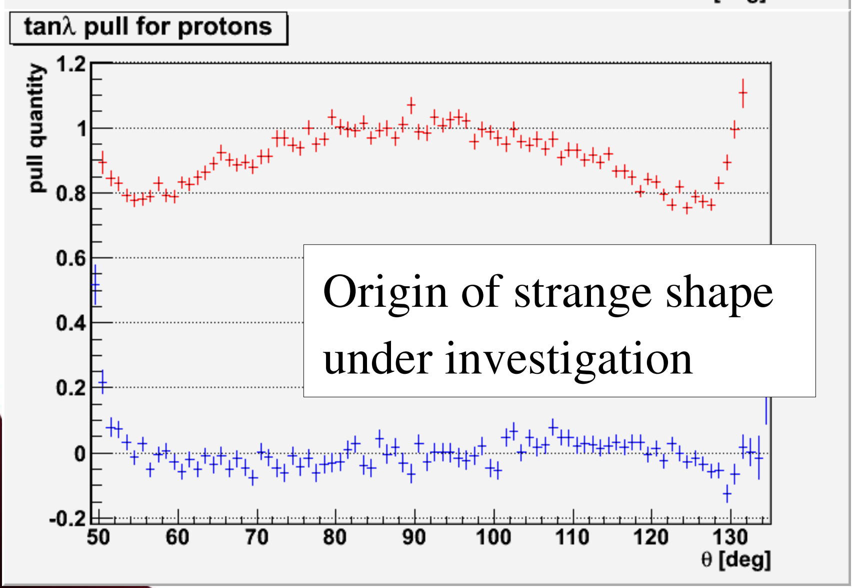
D=signed distance of closest approach to origin

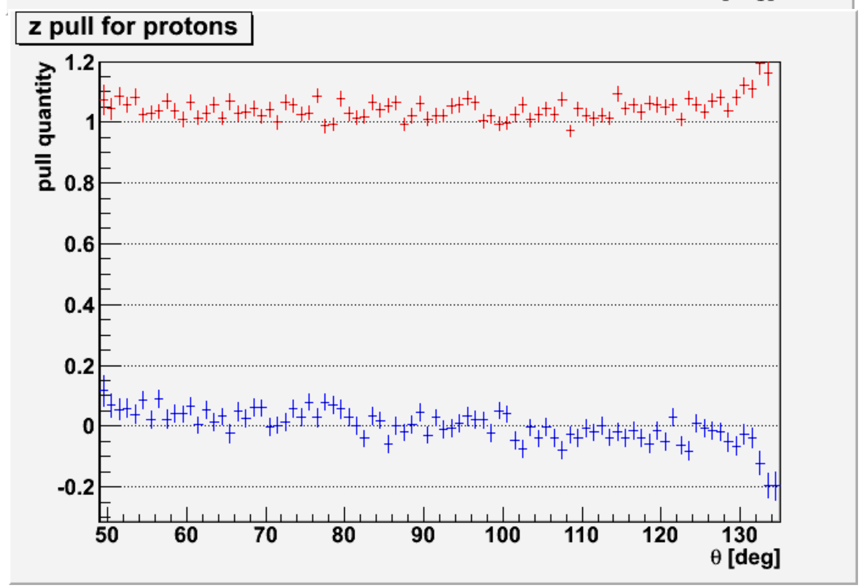
In following plots: blue symbols=mean, red symbols=σ

Kalman Filter pull distributions for protons

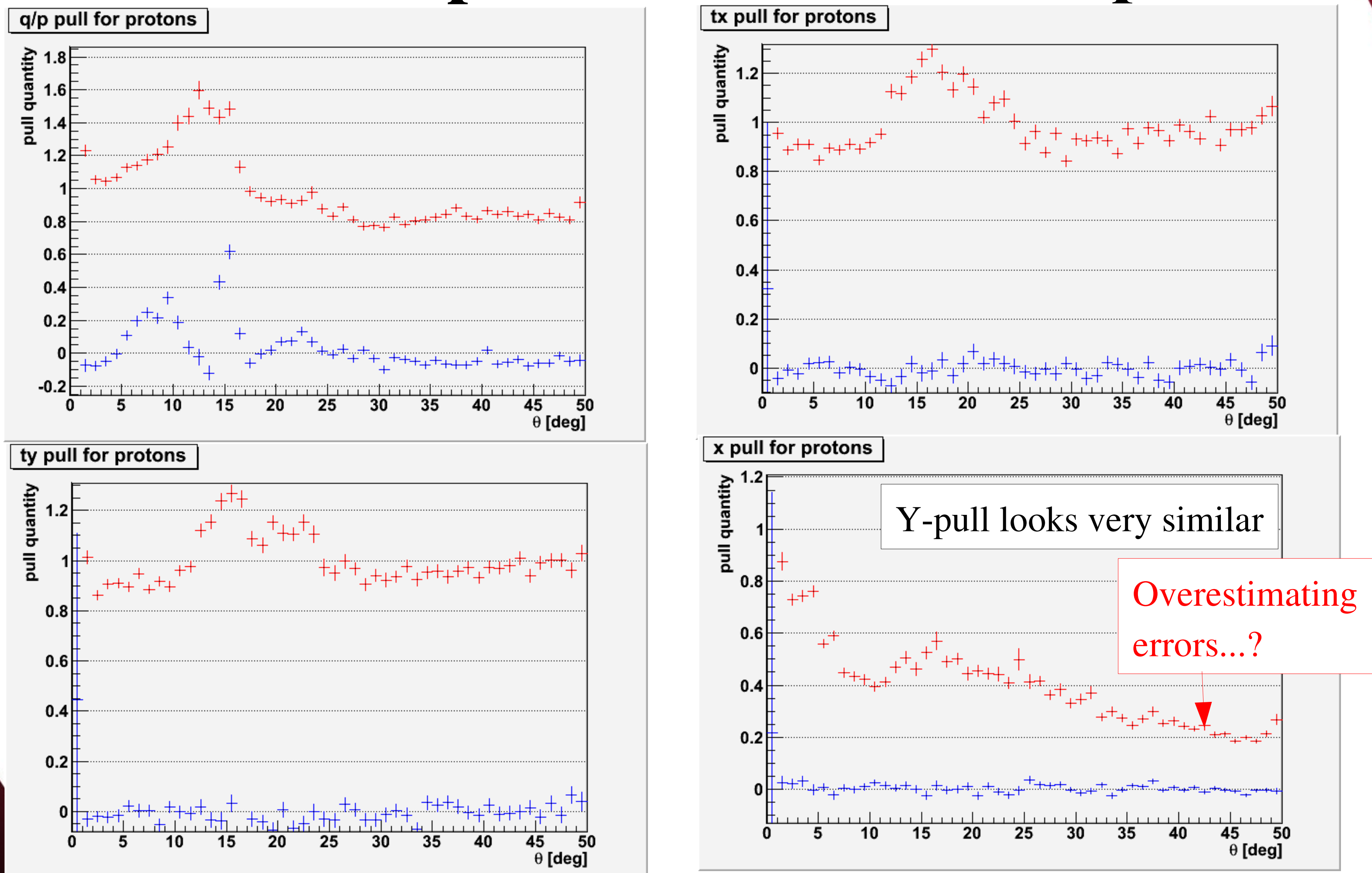








Kalman Filter pull distributions for protons



Summary

- Speed of both ALT1 and Kalman fitters has been improved
  - Working on further speed enhancements
    - Reduction of the number of iterations (without sacrificing resolution or efficiency...!)
    - Replacement of Root 3-vector routines with our own faster library
    - Replacement of Root Matrix routines with our own?
    - GPUs?
- Progress in understanding errors and biases
  - Energy loss in detector material treated in a better way
    - Adaptive step size with (optional) boundary checking
  - Looked at pull distributions of Kalman filter results
    - Biases minimal except for q/p in forward direction
    - Some errors still not very well understood...