TestFitter performance and new options

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Introduction

Motivation

Distances between planes $\sim 0(100\ mm)$ + scattering angles $\sim 0(0.1\ mrad)$

$\Rightarrow$ track displacement due to scattering $\sim 0(10\ \mu m)$ (for beam energy of few GeV)

Effect comparable with position resolution $(1 - 2\ \mu m)$!

$\Rightarrow$ significantly influences the measurement, straight line fit is not sufficient...

Analytical approach

Describes the performance of the telescope including multiple scattering (!)

Simplifying assumptions:

- sensors (and all other material eg. windows) are very thin layers
- small scattering angles (Gaussian approximation)
- Gaussian position measurement errors
- perfect alignment

Analytical approach: track fitting by solving matrix equation

$\Rightarrow$ error on the position reconstructed at DUT given by telescope geometry only

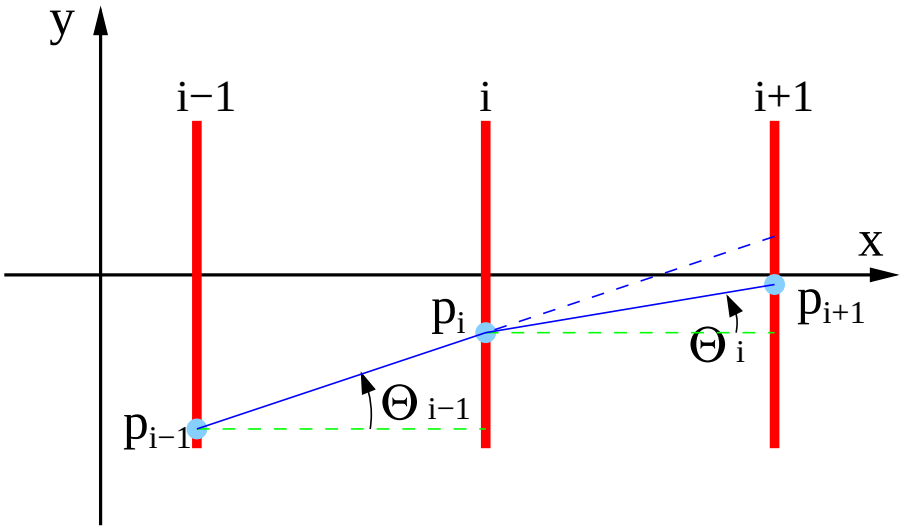
Introduction

Analytical approach

We can determine track position in each plane (including DUT), i.e. N parameters $(p_i,\, i = 1 \ldots N)$, from $M < N$ measured positions in telescope planes.

We use constraints on multiple scattering!

Contribution of plane i to χ^2 of the fit



position measurement — multiple scattering

$$\Delta\chi_i^2 = \left(\frac{y_i - p_i}{\sigma_i}\right)^2 + \left(\frac{\Theta_i - \Theta_{i-1}}{\Delta\Theta_i}\right)^2$$

where: $\Theta_i = \dfrac{p_{i+1} - p_i}{x_{i+1} - x_i}$

Both terms present for planes $i \neq 1, i_{DUT}, N$,
first term missing for DUT, second for first and last plane

Constraint from the beam direction also taken into account.

χ^2 minimum can be found by solving the matrix equation - fast!

Introduction

Optimization

The chosen approach is to check all possible hit combinations.

Without optimization this would be very CPU time consuming ($t \sim (N_{hit})^{N_{plane}}$)

$\Rightarrow$ 3 hit (or 2 hit when using beam constraint) combinations checked first
If χ^2 too large, all combinations including these hits can be skiped ($t \sim (N_{hit})^3$)

Other options improving performance:

- UseNominalResolution: same matrix used for all events (no missing hits)
- UseBeamConstraint: χ^2 can be calculated already for 2 hits ($t \sim (N_{hit})^2$)
- AllowAmbiguousHits: only one loop over all fit possibilities (no missing hits allowed)

Unfortunatly, performance very poor for recent data.

New option introduced: UseSlope gave large improvement, but only for “full tracks”

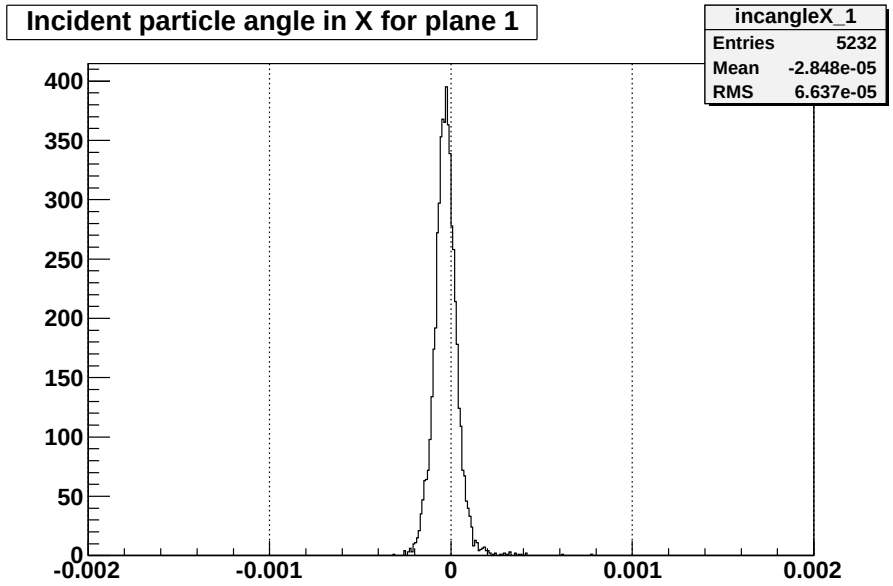
Performance

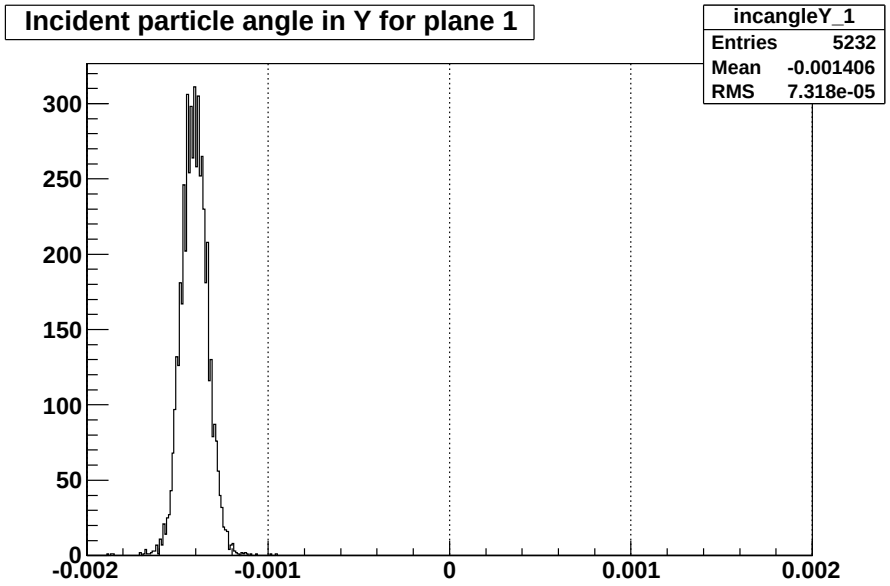
Reasons for poor performance studied for run 10233 (6 digital sensor planes)

UseBeamConstraint

One of the main assumptions of the analytical approach was that the beam was exactly perpendicular to the sensor plane.

This is not the case in the new data:





Fit is still OK. But UseBeamConstraint option could not be used

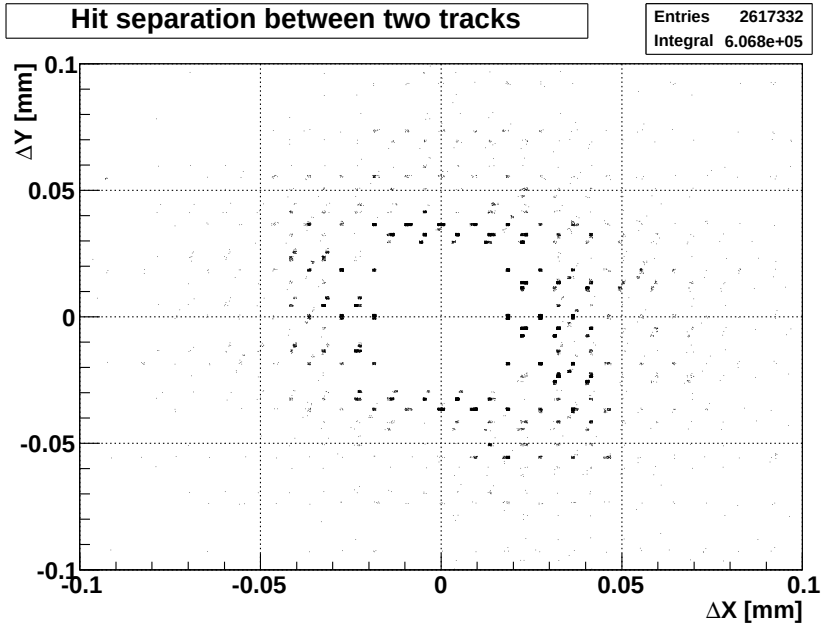
Performance

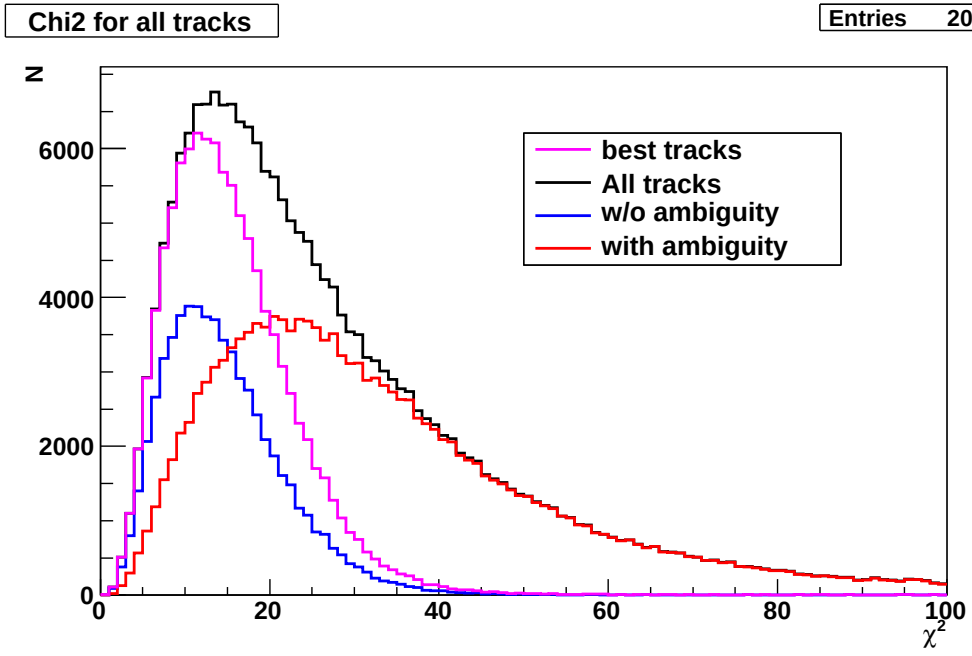
AllowAmbiguousHits

All hit combinations passing χ^2 cut were stored (given hit could be used more than once).

In the new data number of fitted tracks more than doubled with this option!

Correlated hit pairs ("ghosts" ?) $\Rightarrow$ some track candidates differ by one or two hits only.





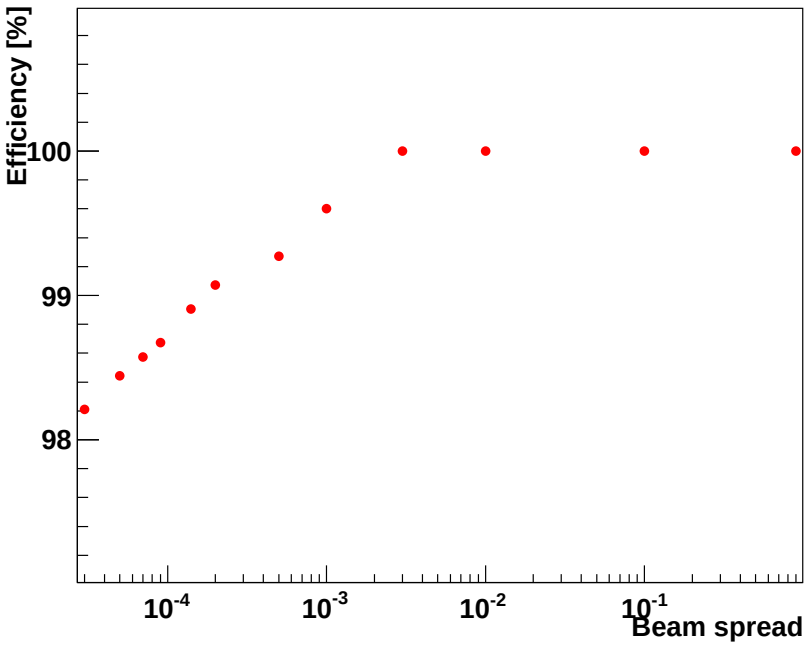
New development

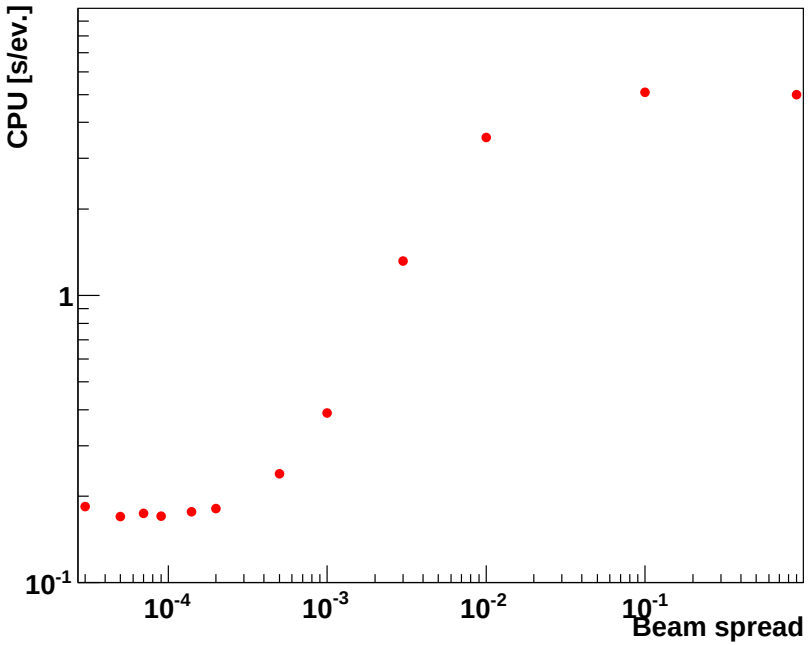
UseBeamConstraint

Fitting algorithm was modified to take into account possible beam tilt.

Two new control cards: BeamSlopeX and BeamSlopeY

Results for “worst case” - fit to 4-6 planes (AllowMissingHits = 2):





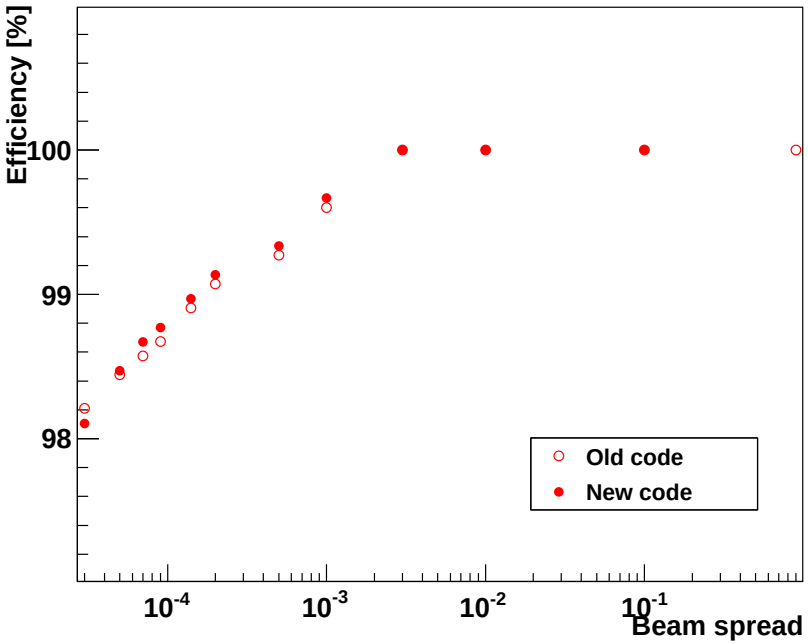
Performance restored $\Rightarrow$ improvement by factor ~ 20 Very high efficiency (safe)!

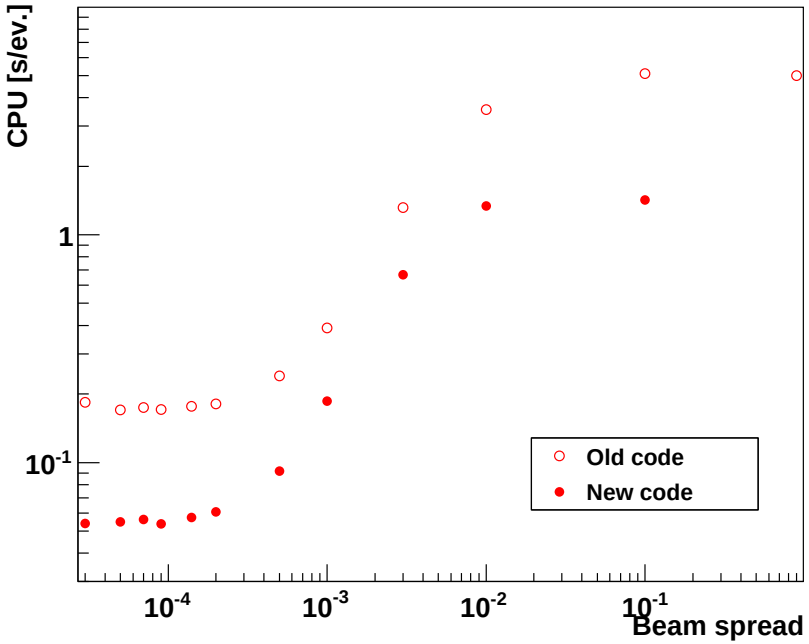
New development

AllowAmbiguousHits

New track selection algorithm logic. One loop over all track possibilities only.

Works in all cases, also when not all planes are hit (AllowMissingHits > 0) and independent on AllowAmbiguousHits flag. Improvement by factor $\langle N_{track} \rangle$





New development

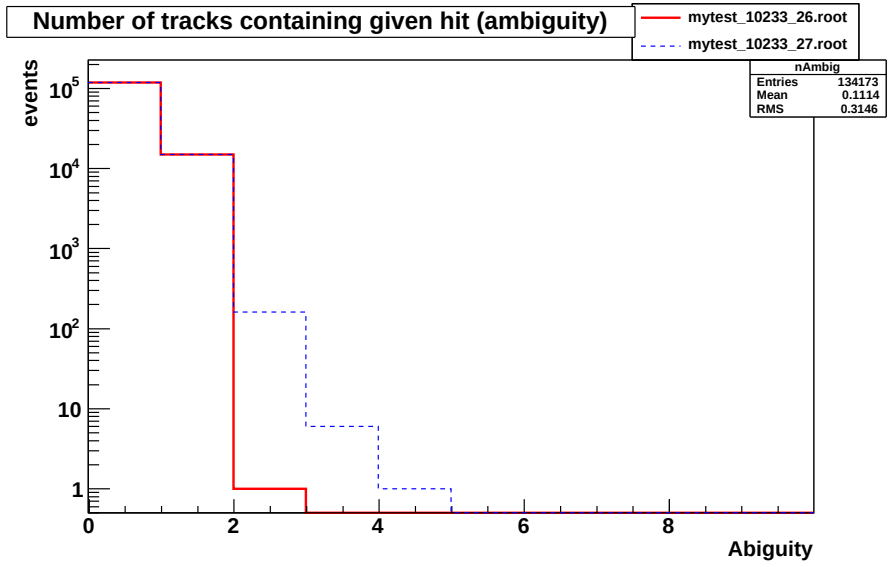
AllowAmbiguousHits

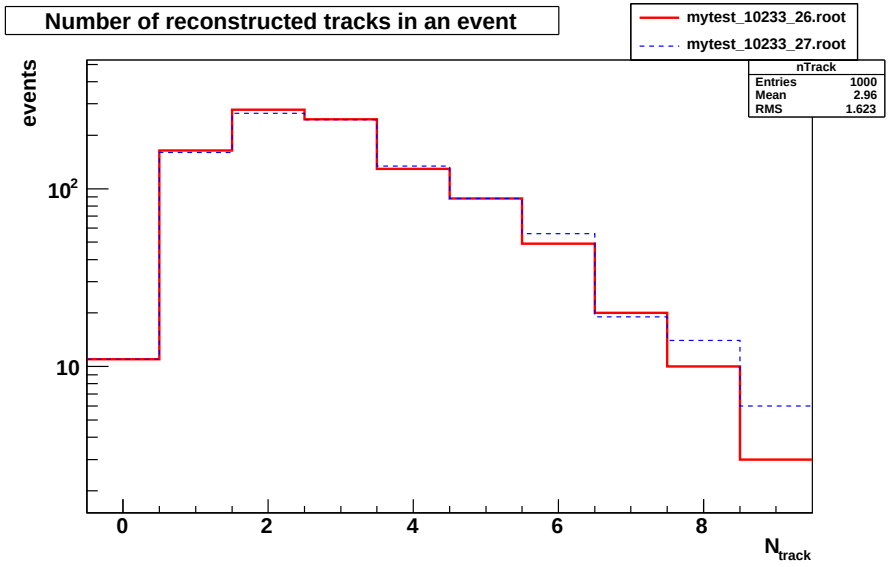
New option:

MaximumAmbiguousHits - maximum number of hits which can be shared by two tracks

For the considered run, MaximumAmbiguousHits=1 resulted only in 1 extra track in 1000 events (total of 2970 tracks) - safe.

Comparison of MaximumAmbiguousHits=1 and MaximumAmbiguousHits=2





For higher MaximumAmbiguousHits values “ghost” tracks apear... (2971 → 3052)

New development

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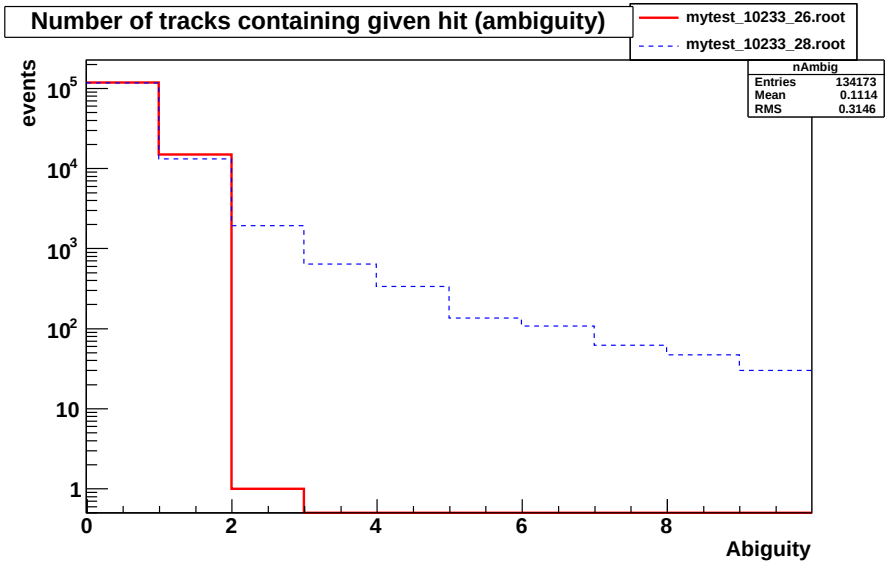
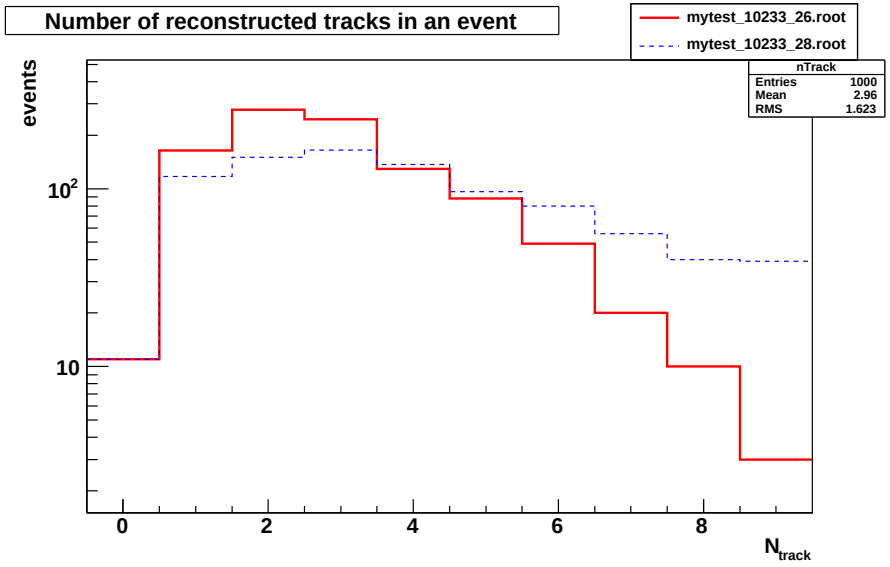
Comparison of MaximumAmbiguousHits=1 and MaximumAmbiguousHits=3





For higher MaximumAmbiguousHits values “ghost” tracks apear... (2971 → 5232)

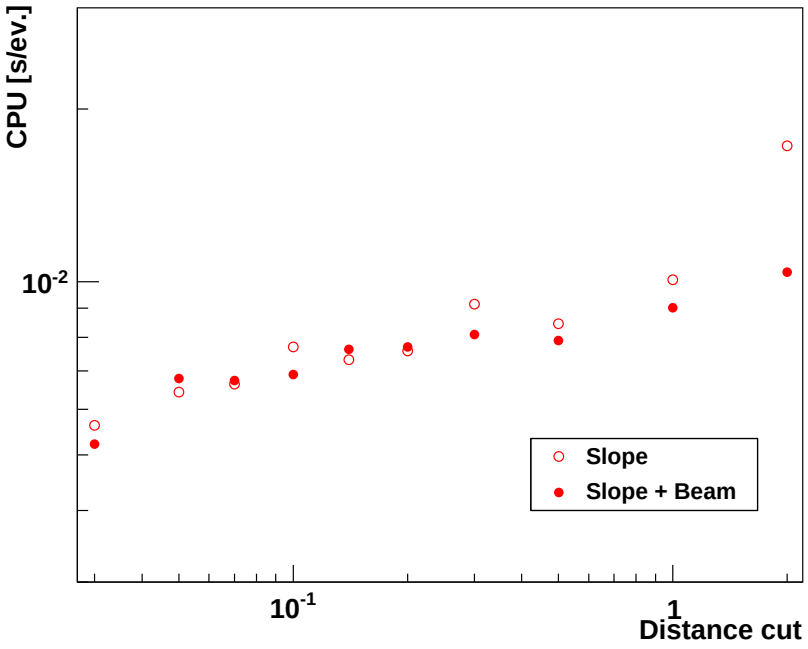
New development

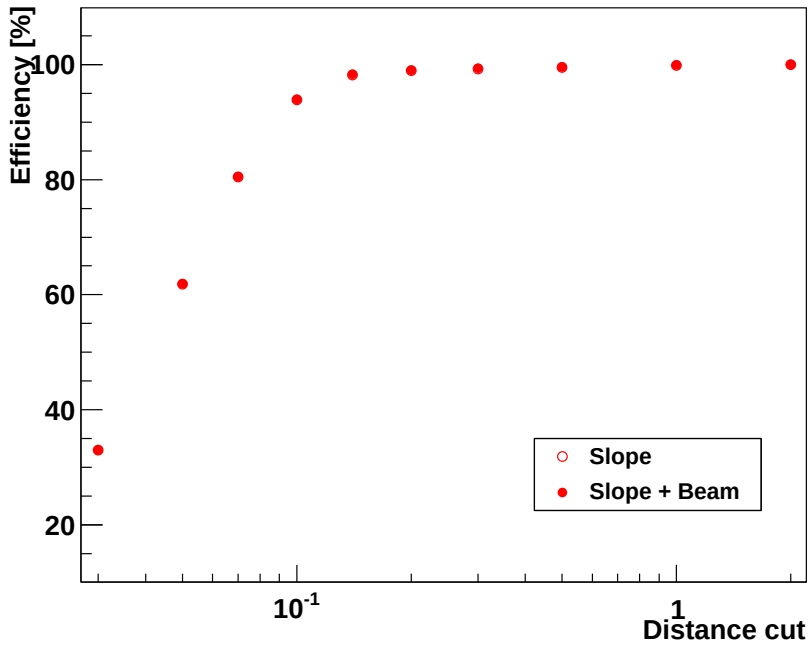
UseSlope

Number of considered track possibilities reduced by taking only hits within the assumed distance from the expected track (from the first hit position and the beam direction).

New version ! Now consistent with the rest of the code.

Works also with missing hits. Uses beam direction information (UseBeamConstraint=true)





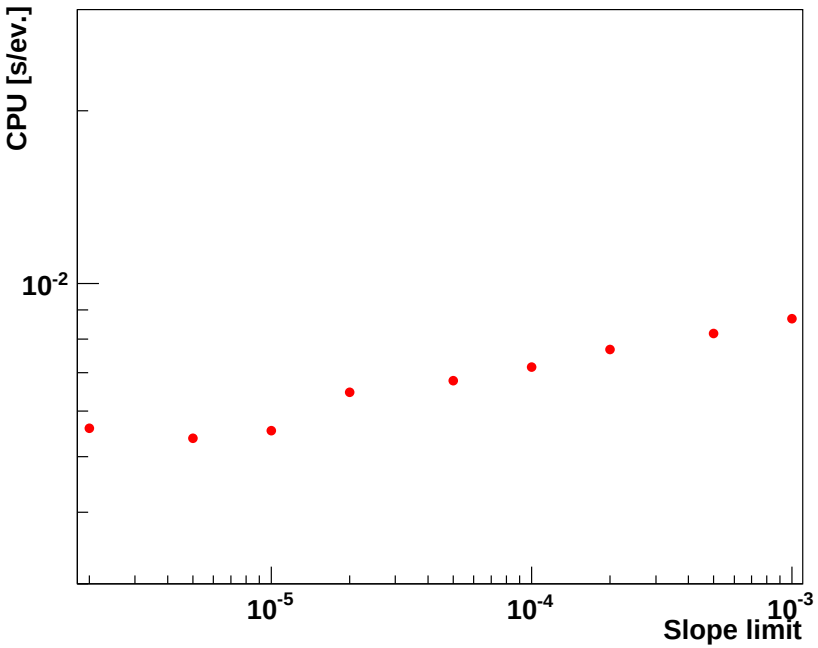
Be careful: significant efficiency losses if cut too tight!

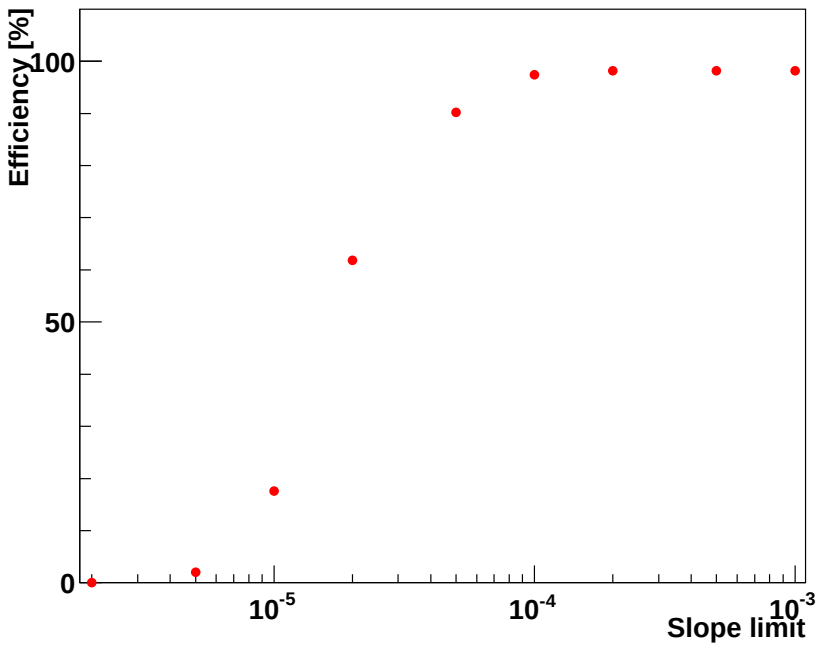
New development

UseSlope

Number of considered track possibilities can be also reduced by constraining scatering in subsequent planes (ie. slope changes; based on measured hit position).

Should be used with care, especially at low energies!





Significant efficiency losses if cut too tight!

Summary

Large parts of code rewritten.

Large performance improvemet, especially for tracks with missing hits

Measured CPU time per event (my laptop: 1.6GHz, 2GB RAM)
(run 10233, 20 hits per plane, 3 tracks per event; $\chi^2 < 100$)

setup	full tracks only	AllowSkipHits=2
Old version	0.38	5.0
New version	0.19	1.4
+ UseBeamConstraint	0.01	0.06
+ UseSlope	0.002	0.008

UseSlope should be used with care! Preselection only!
For well defined measurement χ^2 cut should decide about track selection.

New options to make it more flexible (beam slope, max. ambiguous hits)