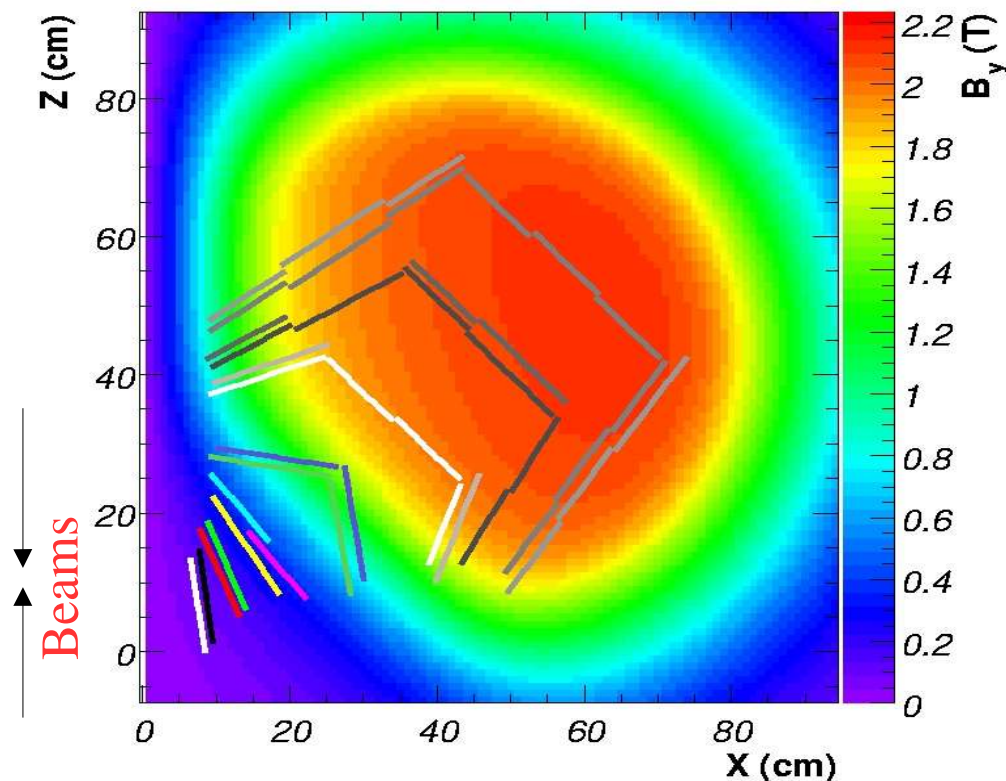


Novel String Banana Template Method of track reconstruction for high multiplicity events with significant multiple scattering

P. Kulinich (kulinich@mit.edu)

Outline:

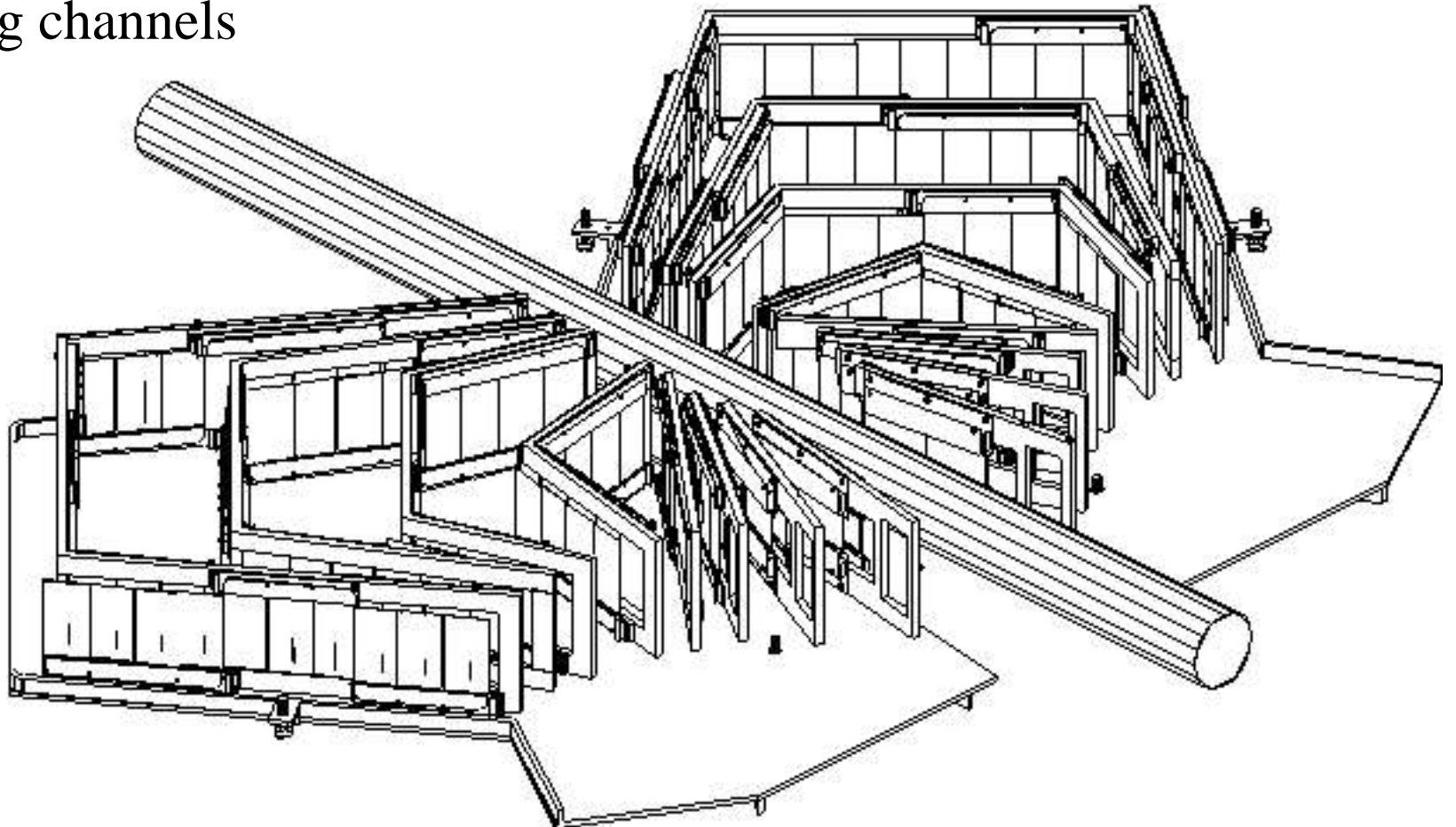
1. Method description.
2. Application for “toy” model and demonstration of capabilities.
3. Implementation for real spectrometer with complex geometry.



Goal : charged track reconstruction for "primary" particles in
~(6-:-20) “layers” Tracker with "externally given" Vertex
@ "low" momenta (MS up to ~(10-:-20) mrad per Si layer)
& high multiplicity events (combinatorial #)
& Horizontal granularity ~(0.44-:-1.0)mm @
& non-uniform magnetic field for ~2D Spectrometer
@ analog read-out (!!! @ limited granularity !)

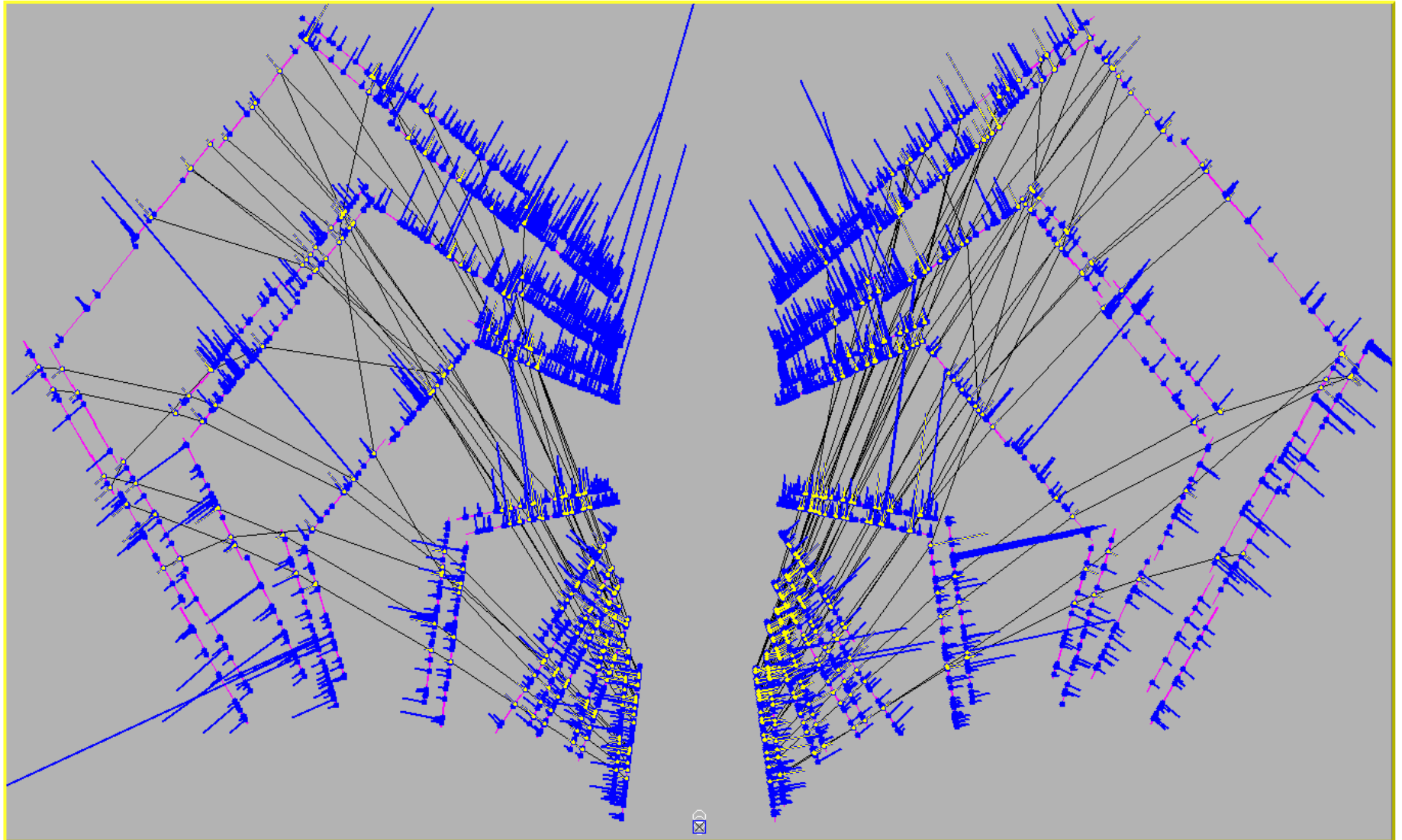
PHOBOS Si Spectrometer @RHIC @BNL

- * ~"2D" detector ($\phi \sim 100\text{mrad}$, $h \sim 80\text{mm}$)
- * alignment $\sim (50\text{--}100) \mu\text{m}$
- * $\langle \text{occupancy} \rangle \sim (2\text{--}3)\%$ HJ (*2 data)
- * 137 wafers $\sim (40 \times 80)\text{mm}^2$ overlapped
- * $\sim 108\text{k}$ analog channels

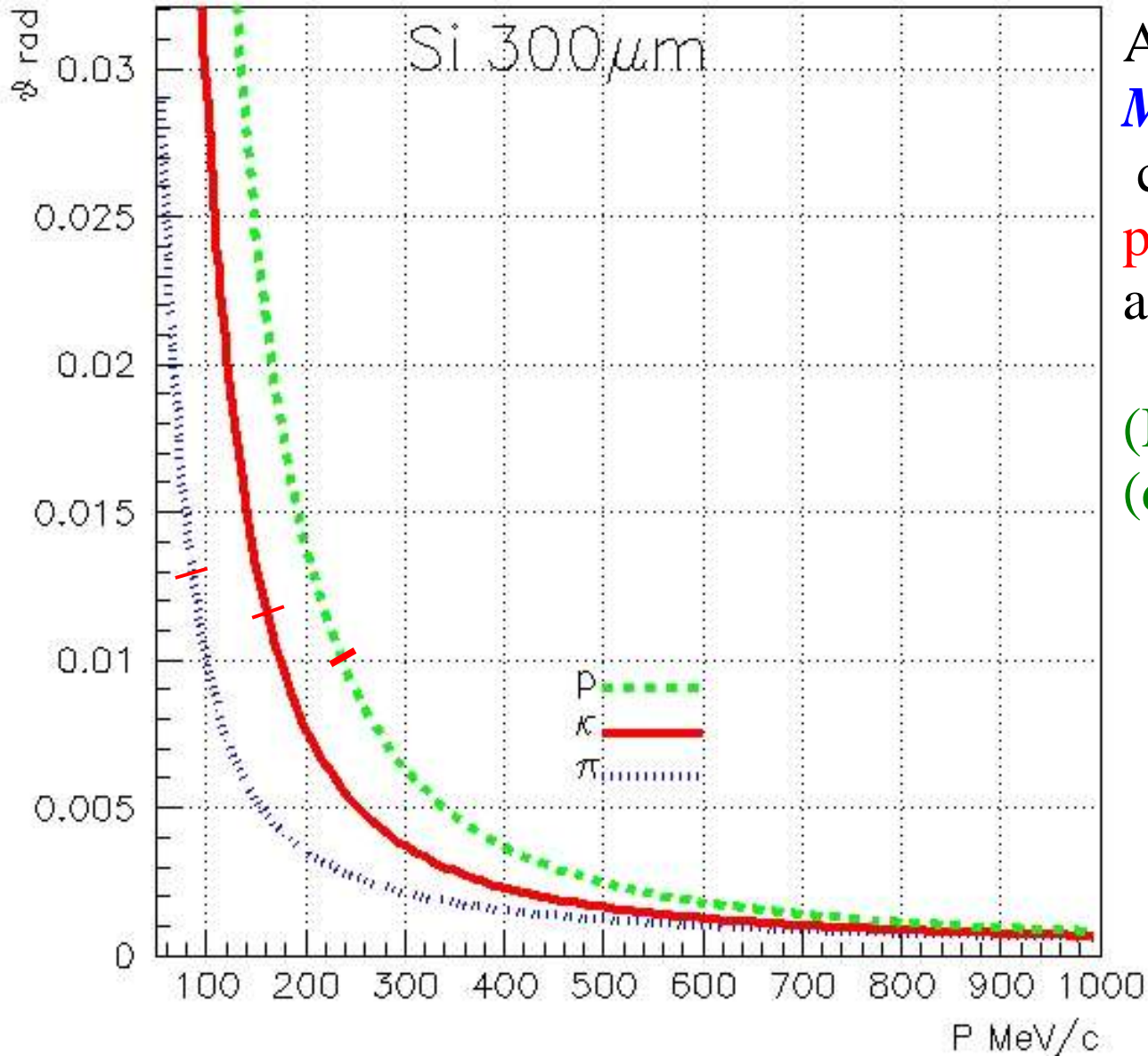


Au \leftrightarrow Au collision at $\sqrt{s_{NN}}=200$ GeV

For pattern recognition in high occupancy events more narrow search window is required – and for that one need “a priori” known momentum ...



Multiple Scattering in 300 μm Si wafer



At high occupancy
 $MS*dL > pixel_size$
could affect
pattern recognition
and Momentum Resolution

(MS : MS angle)
(dL : inter-plane distance)

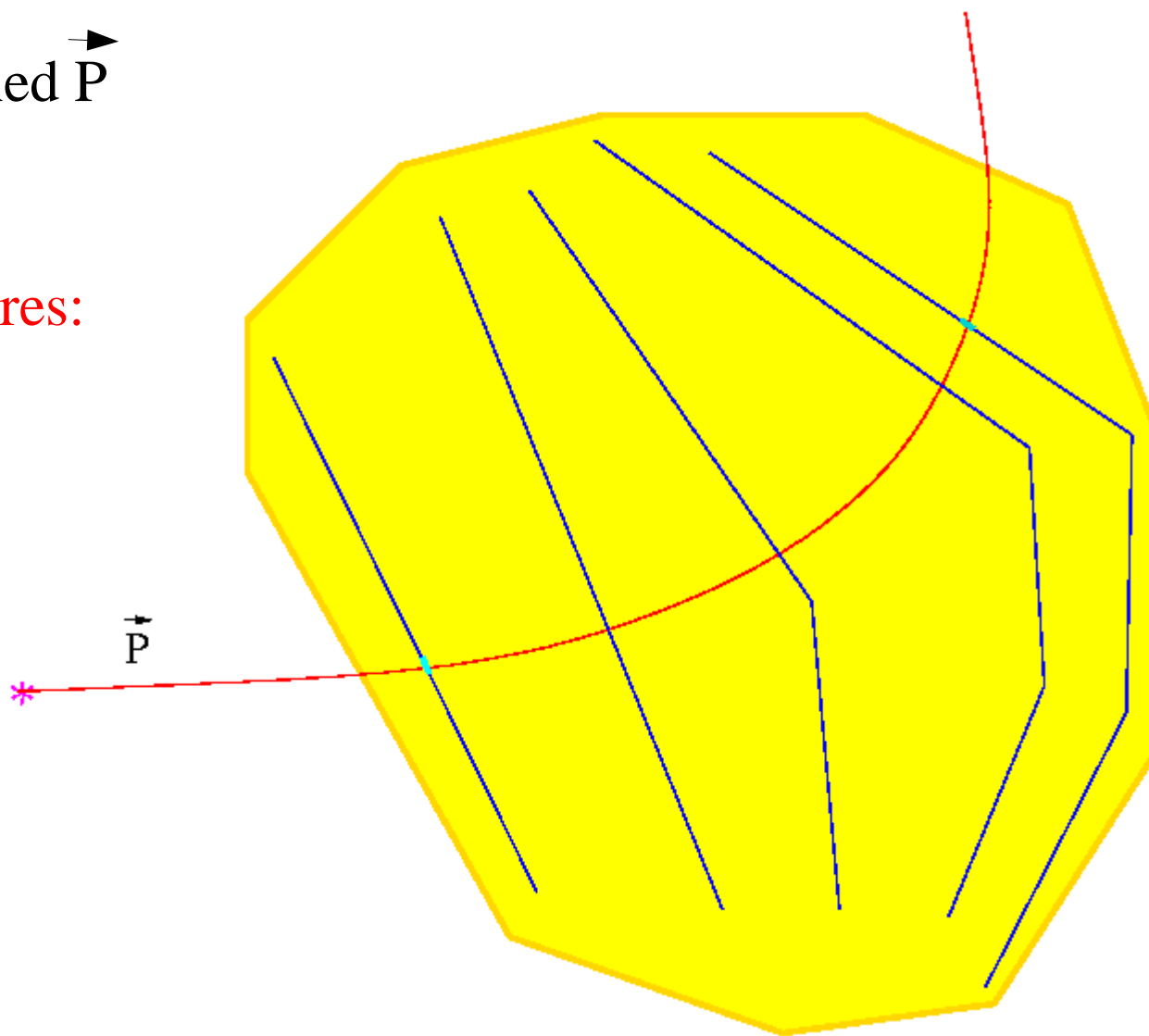
How particle is going ?

a) No MS, fixed \vec{P}

ensemble features:

$$\sigma_p=0;$$

$$\sigma_x=0$$



store hit positions for single track for given Vertex and \vec{P}

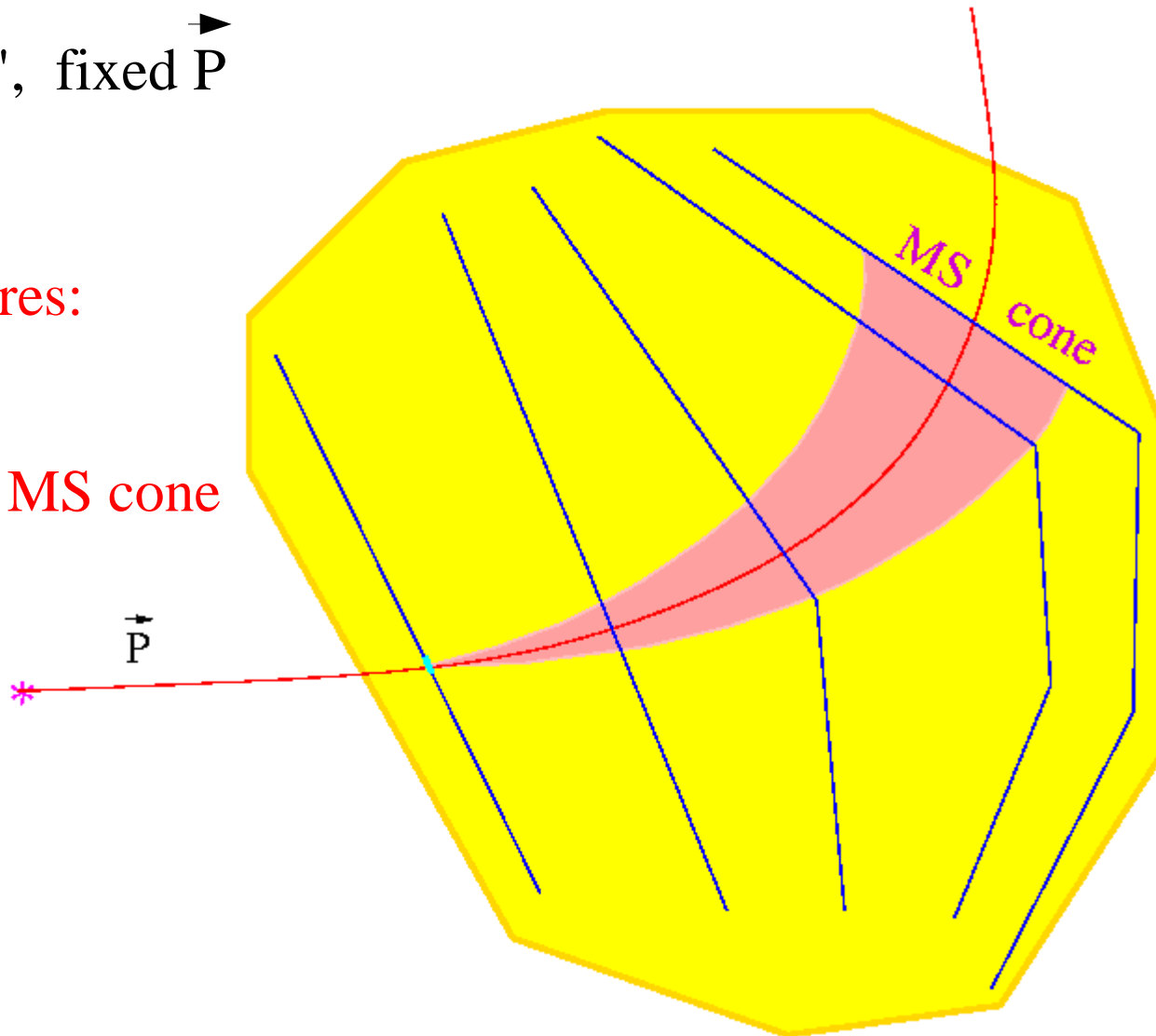
How particle is going ?

b) MS is "ON", fixed \vec{P}

ensemble features:

$\sigma_p=0$;

$\sigma_X > 0$: wide MS cone



calculate Covariance Matrix for MC tracks for given Vertex and \vec{P}

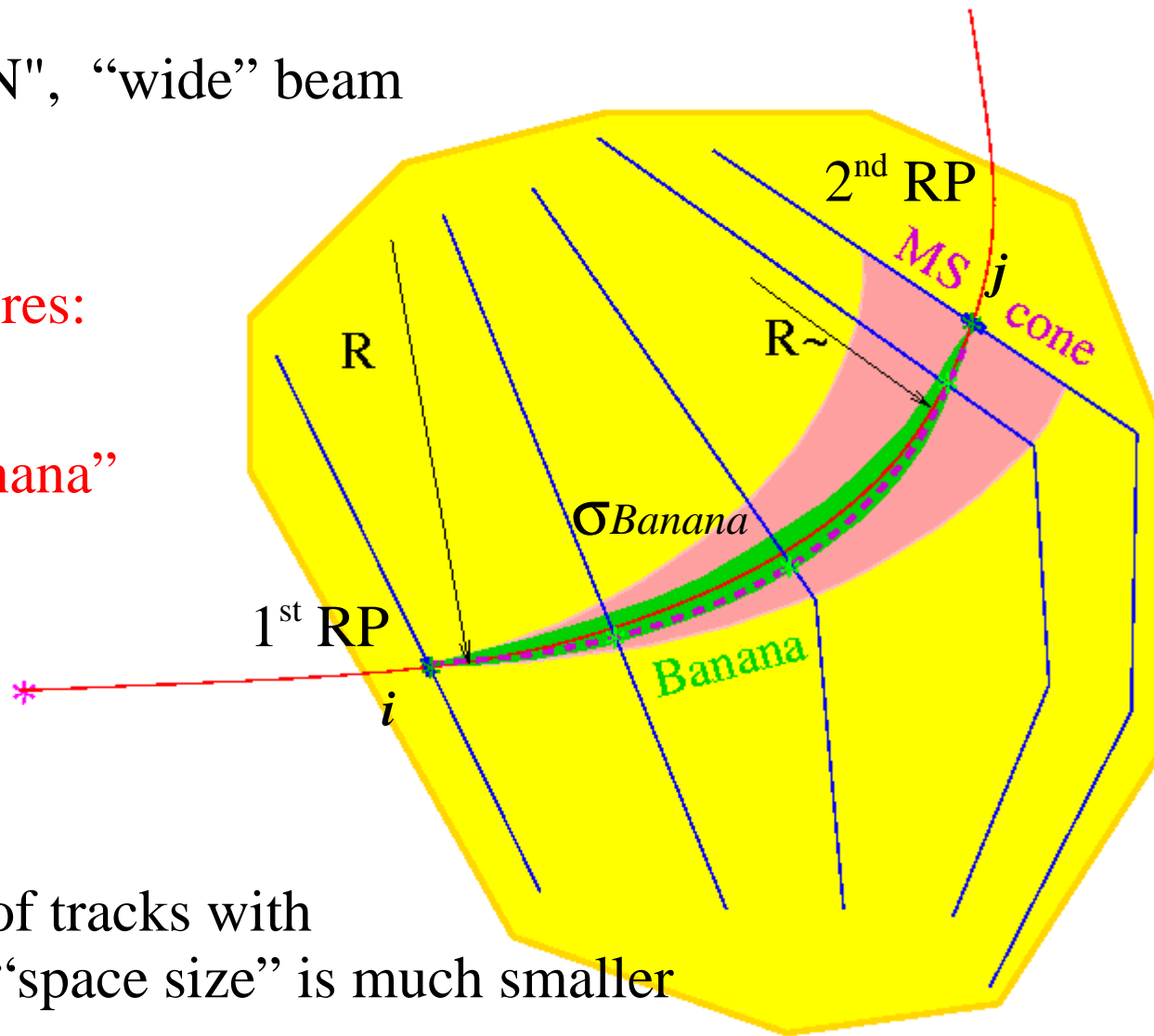
How particle is going ?

b~) MS is "ON", "wide" beam

ensemble features:

$\sigma_p \neq 0$;

narrower "Banana"



For ensemble of tracks with
3 fixed points "space size" is much smaller

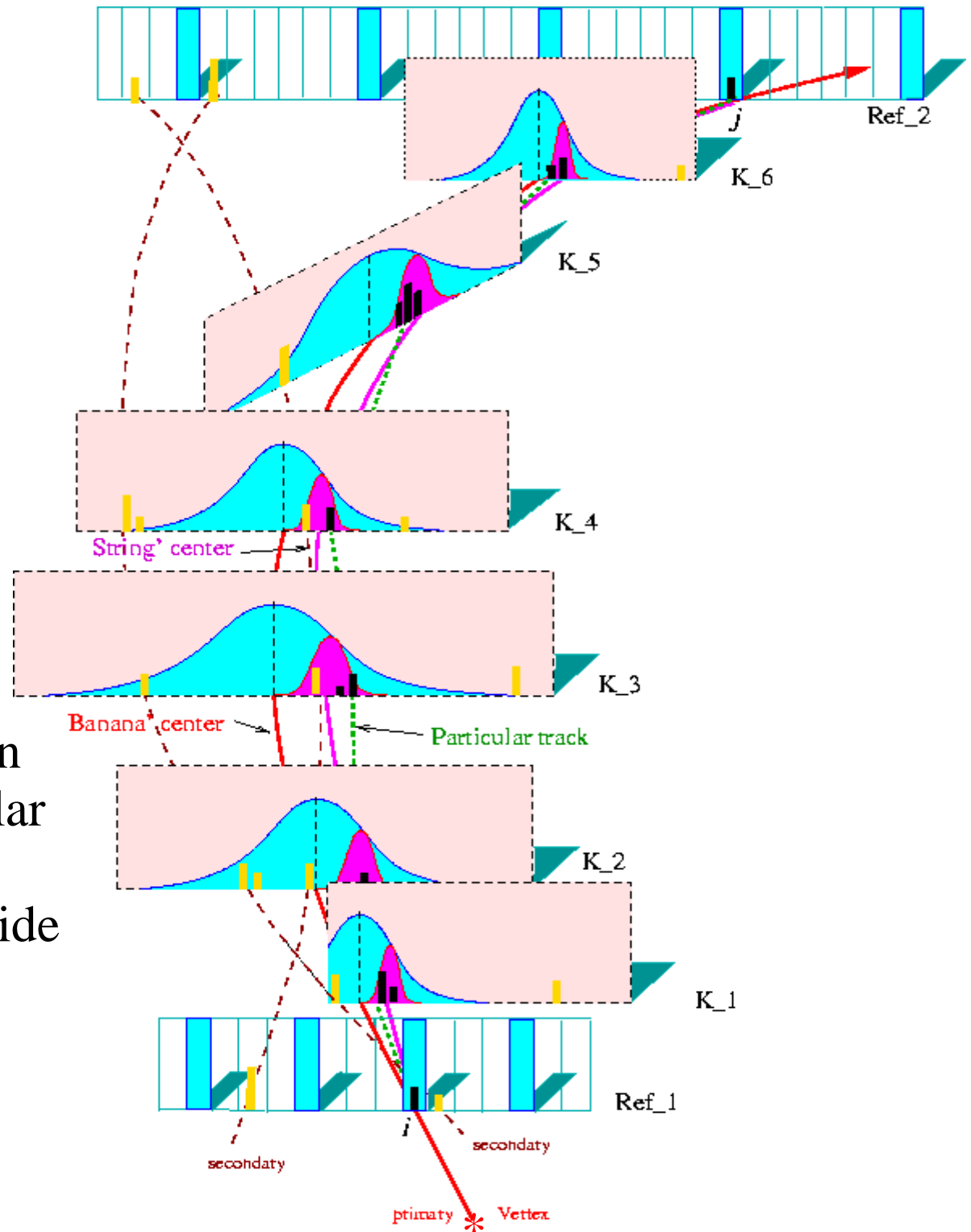
exploit **3points correlation** & calculate/measure σ_{Banana} , σ_P , σ_{String}
for given **Vertex** and **two pixels {i,j}** in 2 Reference Planes (RP)

How particle is going ?

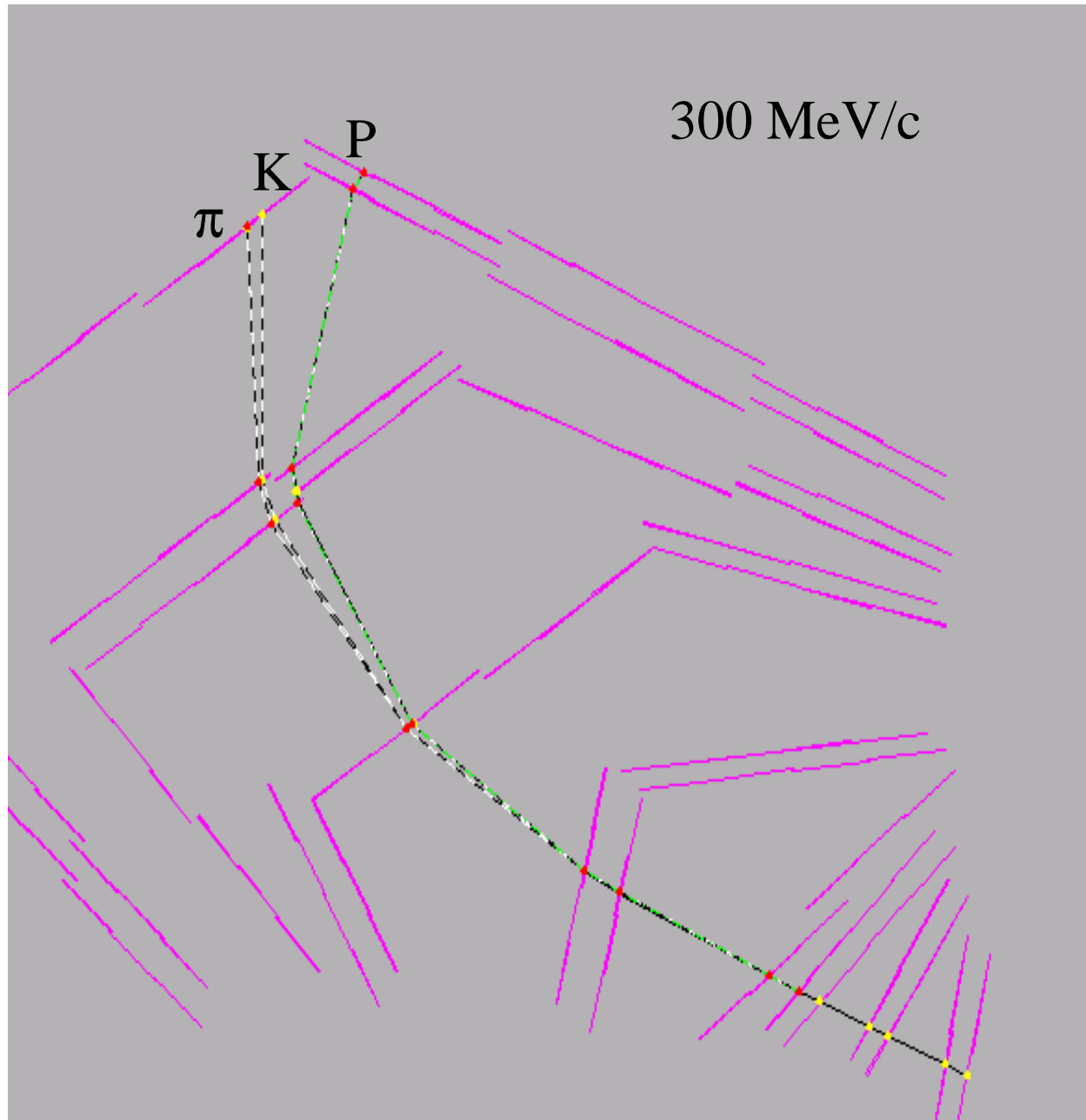
b~) MS is "ON"

Banana width for ensemble of all tracks passed through 3 "fixed" points

String width : "uncertainty" in the hit positions for a particular event based on **1 parameter** model – relative position inside the Banana (~4-6 time more narrow than Banana)



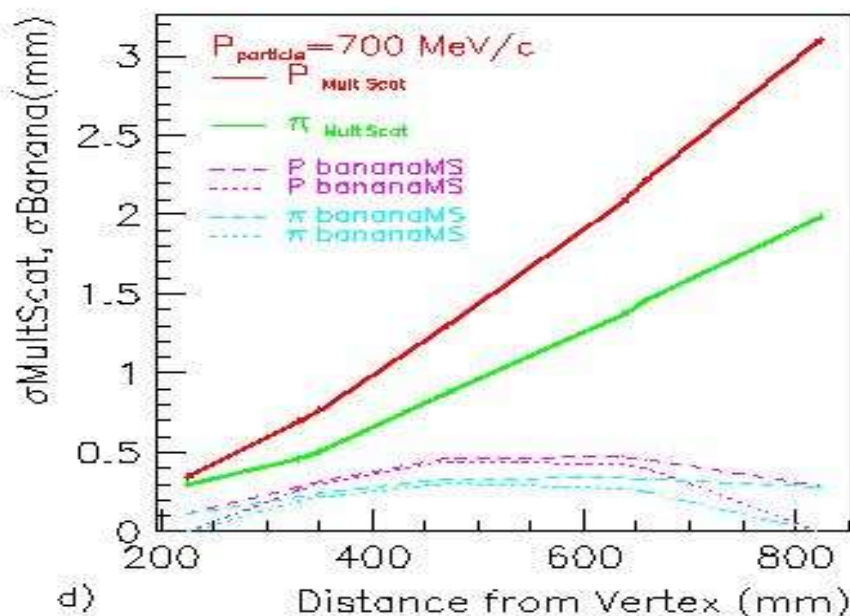
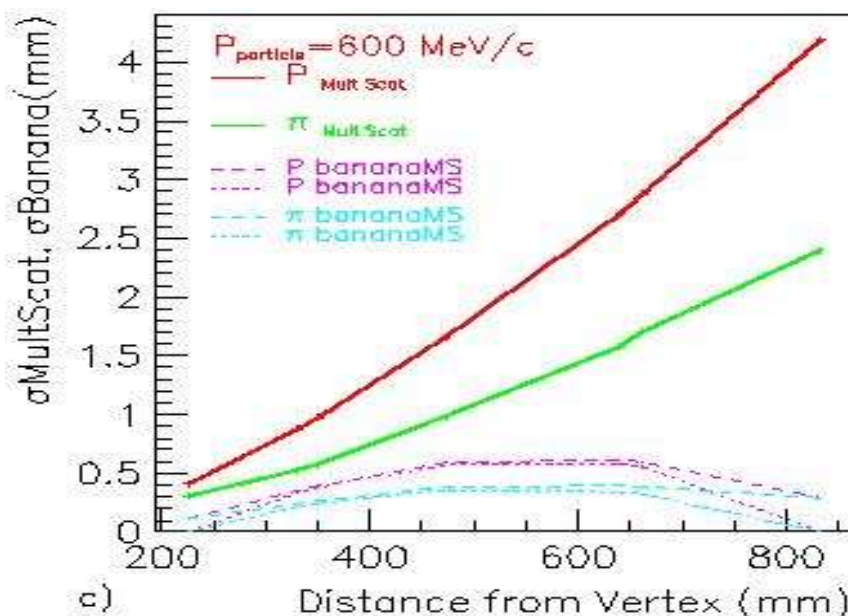
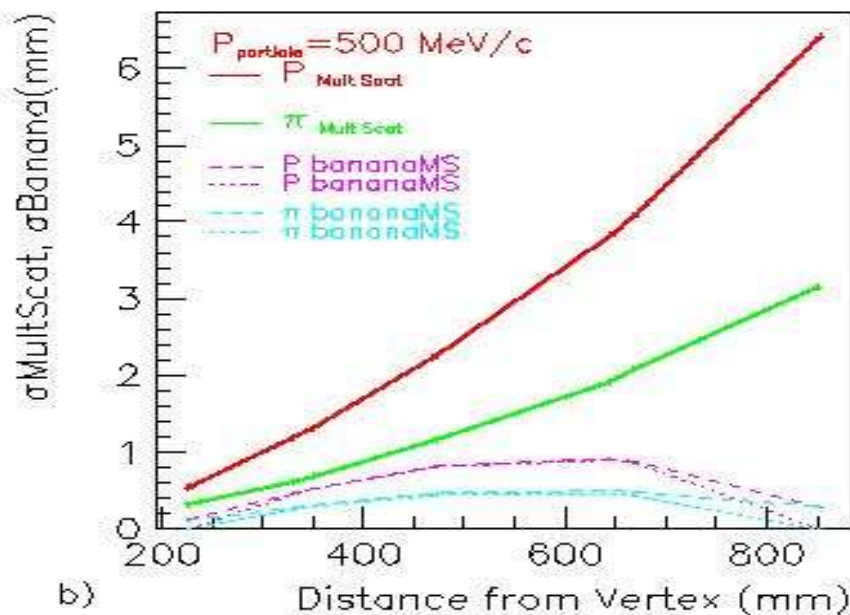
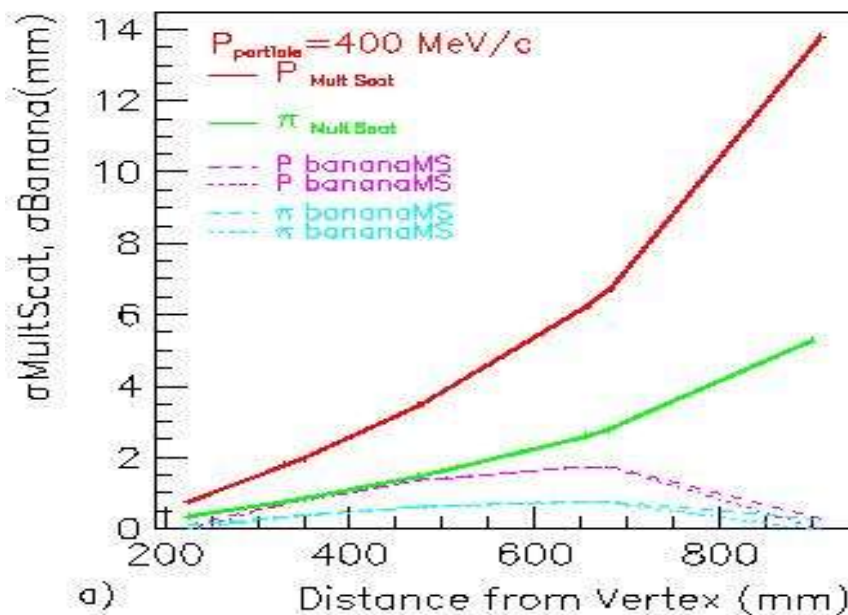
How particles are going ?



Different templates for different species at low momentum

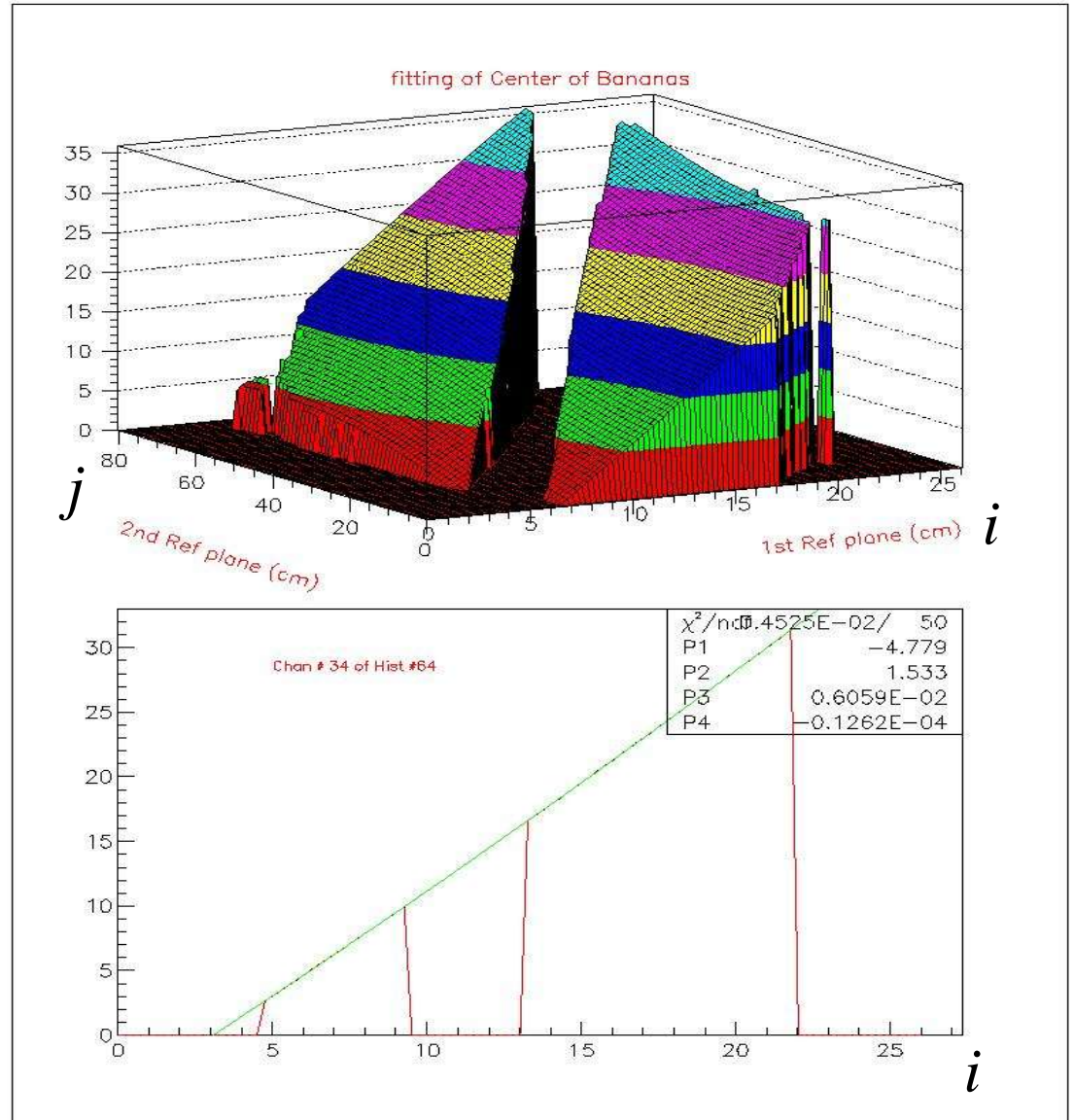
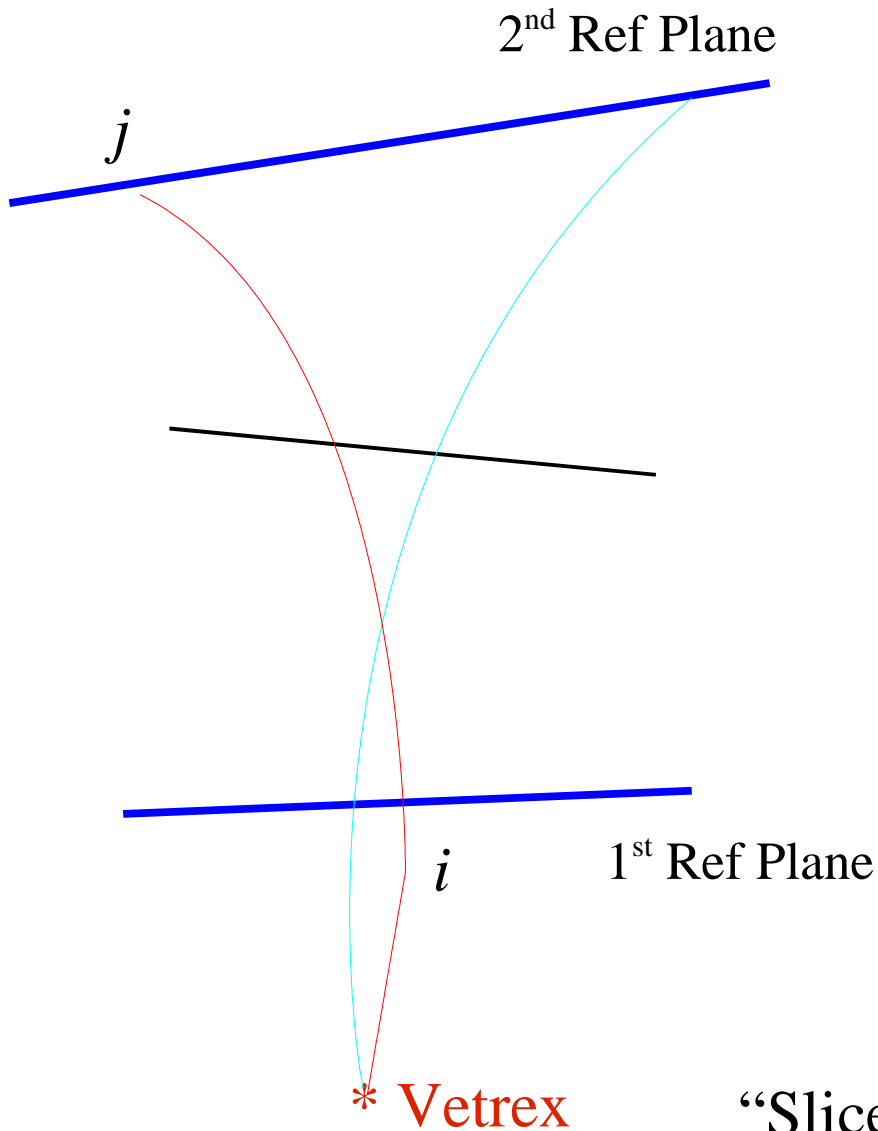
MS - Banana

Width of MS and Banana-road in MS with 2 fixed pixels (first and last planes)



Templates and their fitting/parametrization ("large plane" case)

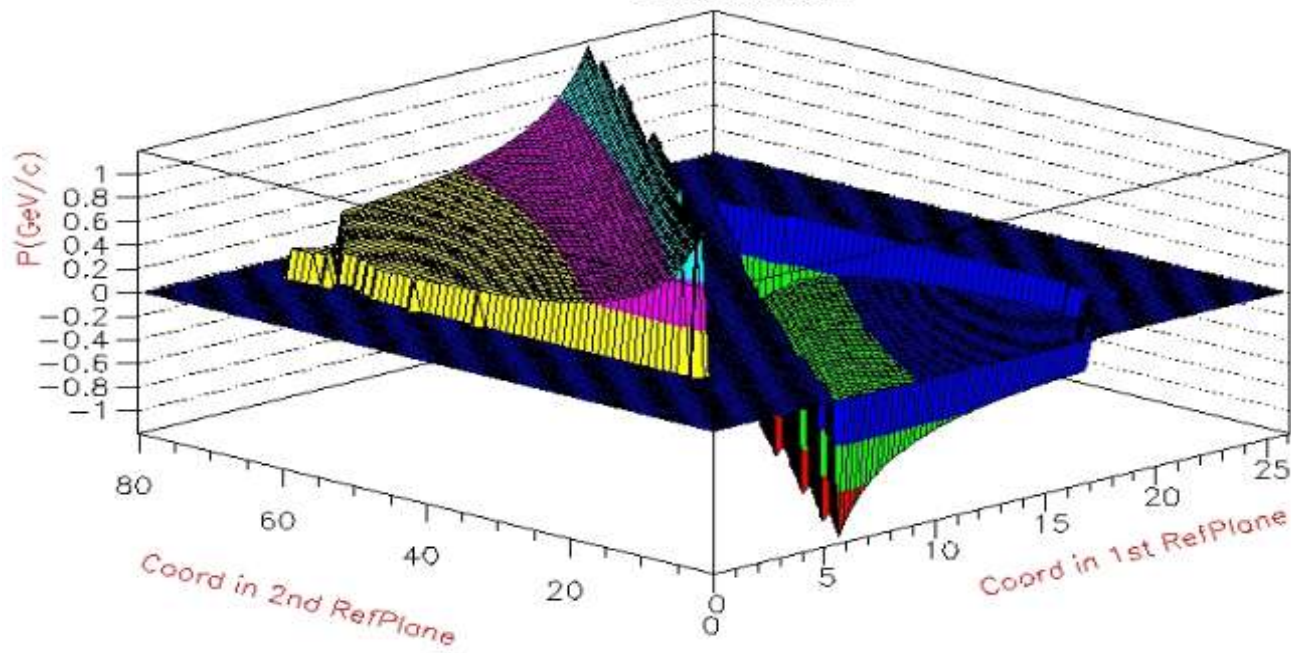
Center of Banana for internal plane vs. $\{i,j\}$



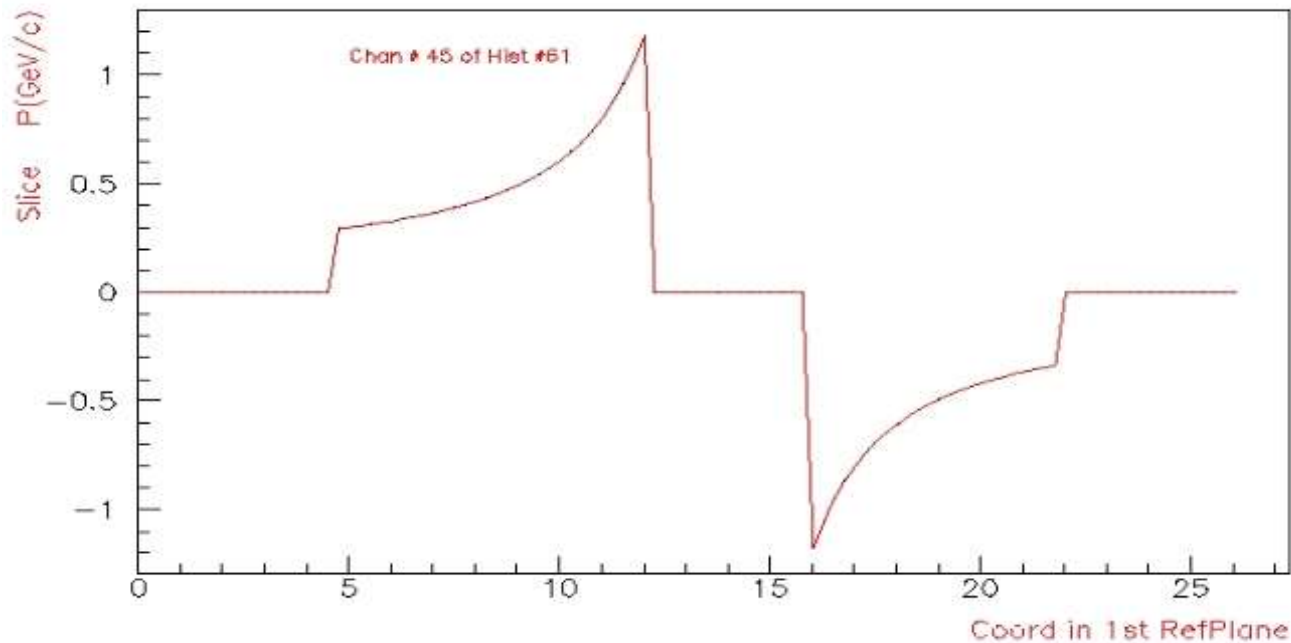
“Slice” parametrization for decreasing of data size

Templates and their fitting/parametrization ("large plane" case)

Momenta

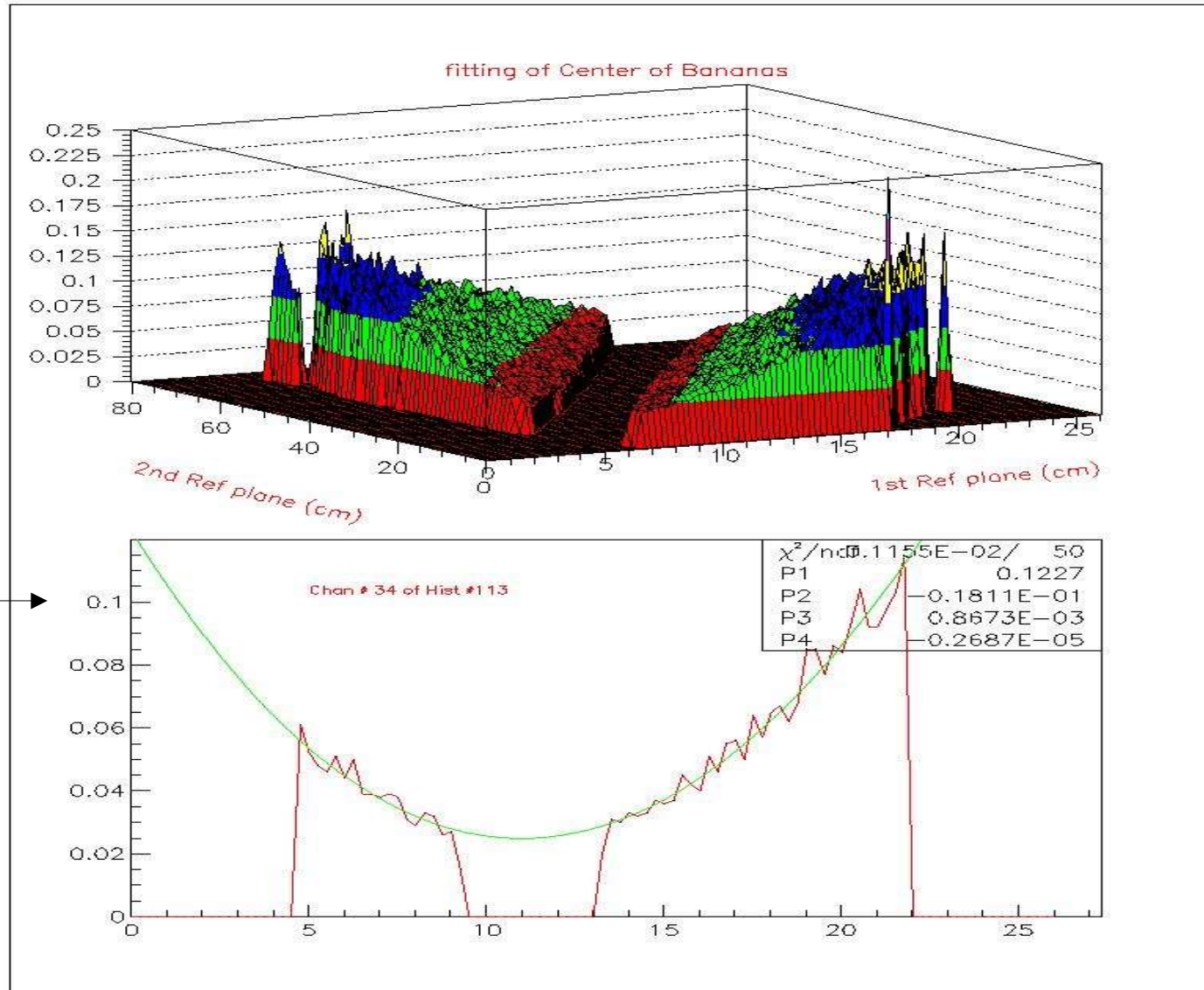


for "1/P" it's
"more flat"

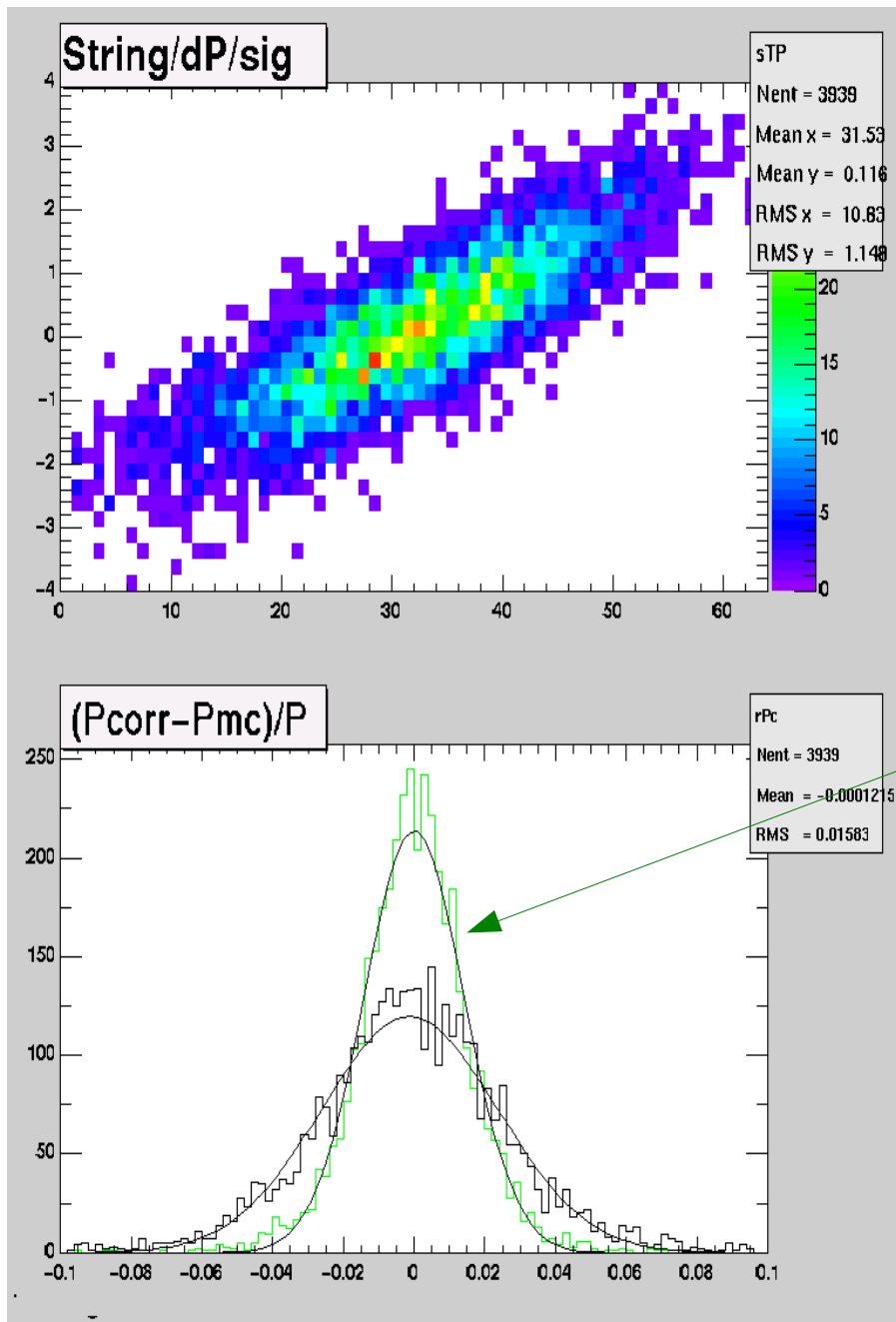


Templates and their fitting/parametrization ("large plane" case)

Sigma of Banana for internal plane vs. {i,j}



Momentum Resolution



SBTM has an **additional parameter** :
Relative String deflection,
which correlates with
Momentum “deflection”
from average of Banana.

After correction Momentum
Resolution becomes better.

Track reconstruction steps:

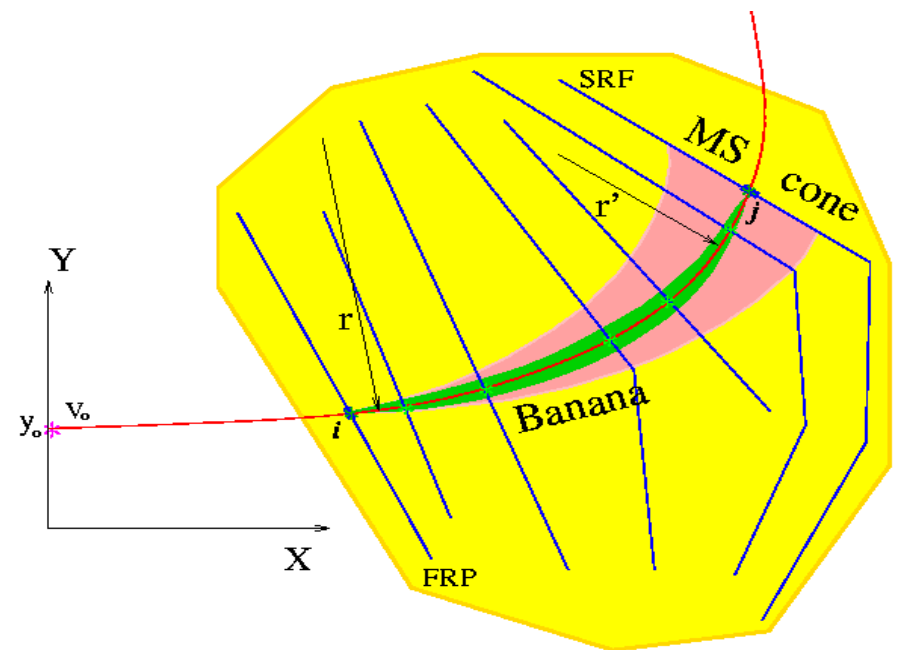
$$\{Y\} \Rightarrow \{F\} \Rightarrow \{C\}$$

Where $\{Y\}$ is an N -dimensional *pattern* space of vectors \vec{y} with real coordinates $\{y_k, 1 \leq k \leq N\}$ of tracks in all related planes. $\{F\}$ is an n -dimensional ($n \leq N$) *feature* or *model* space given by some transformation which permits us to simplify the task without losing tracking capabilities. $\{C\}$ is an m -dimensional ($m \leq n$) *classification* space which describes real track parameters. For a spectrometer with non uniform magnetic field and complex geometry a numerically calculated track model is natural choice.

SBTM has few more model parameters
(usually $m=5$,
 $n=7$ for “toy” model below)

Track reconstruction Steps:

1. Find Banana with hits for all $\{i,j\}$
2. Check if hits are inside the “String”
3. Correct Momentum

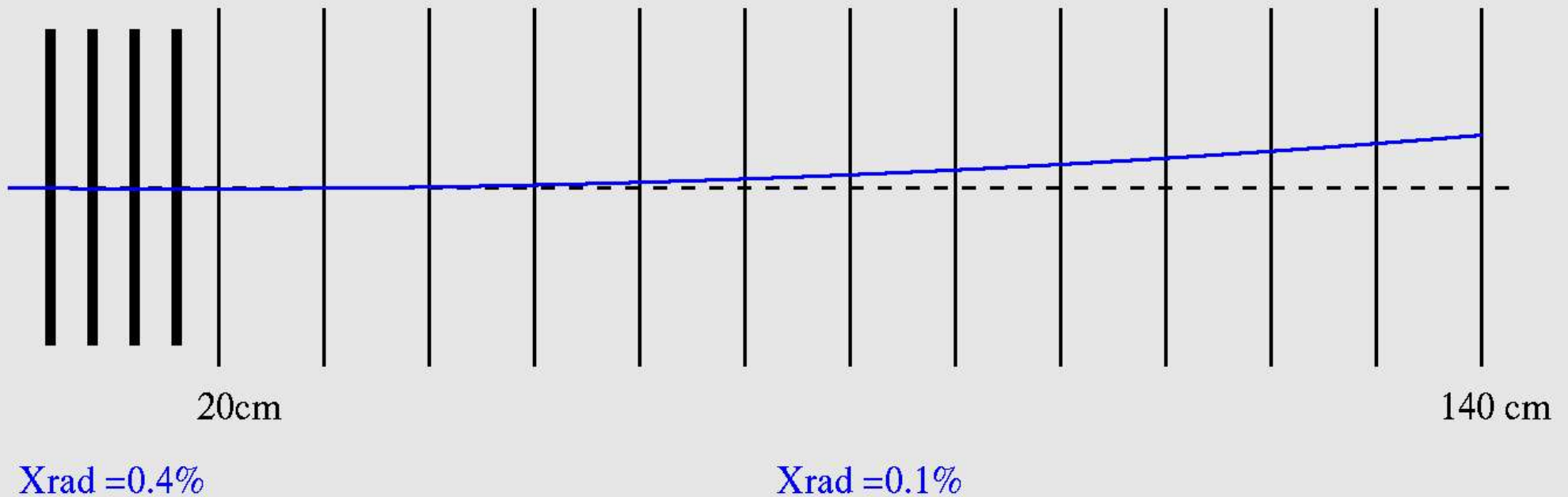


Comparison to Optimal Track Fitting (OTF) which reproduces the results of the global LSM fit

B=1 Tesla

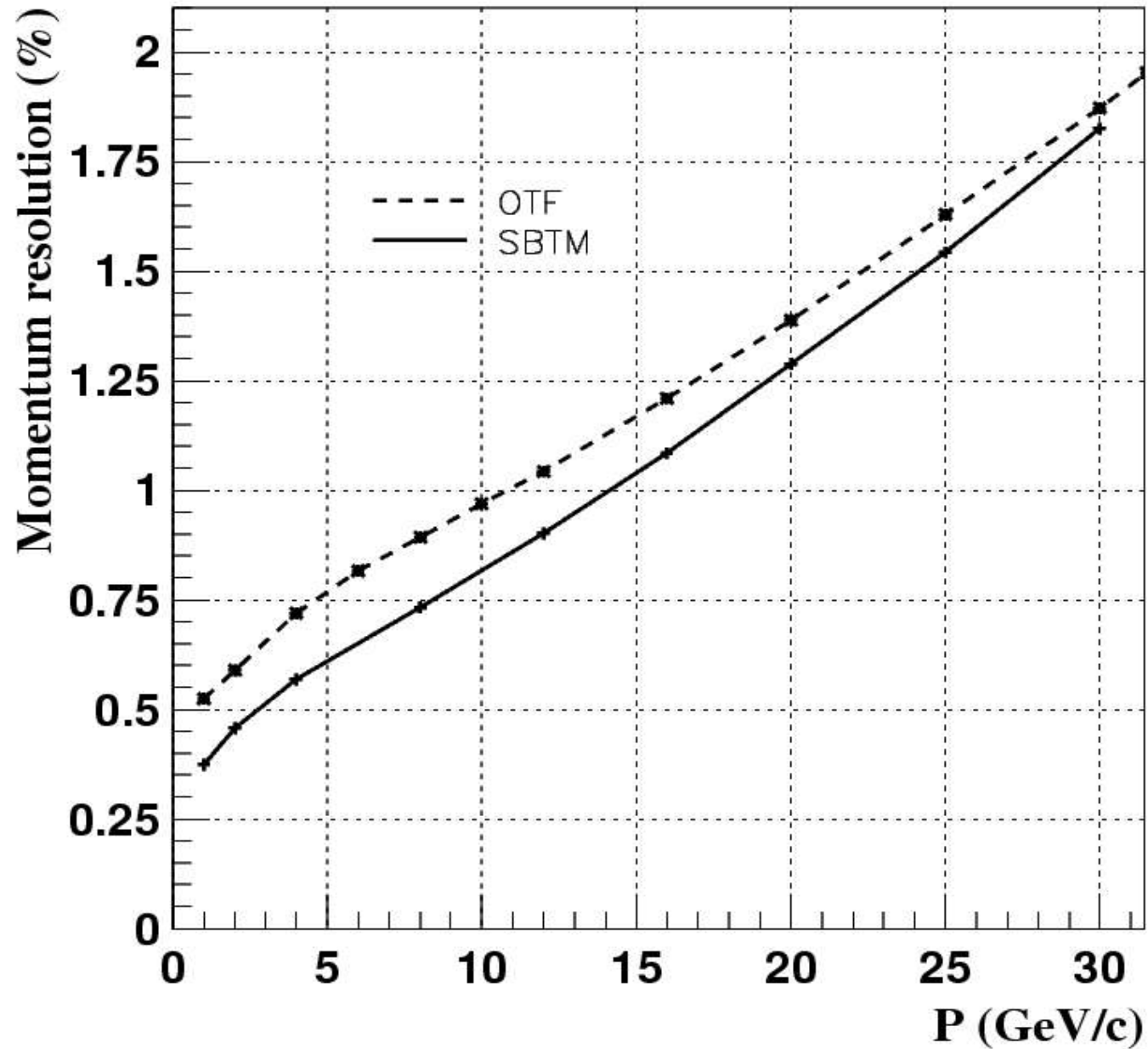
$\sigma_x = 5 \mu\text{m}$

$\sigma_x = 200 \mu\text{m}$

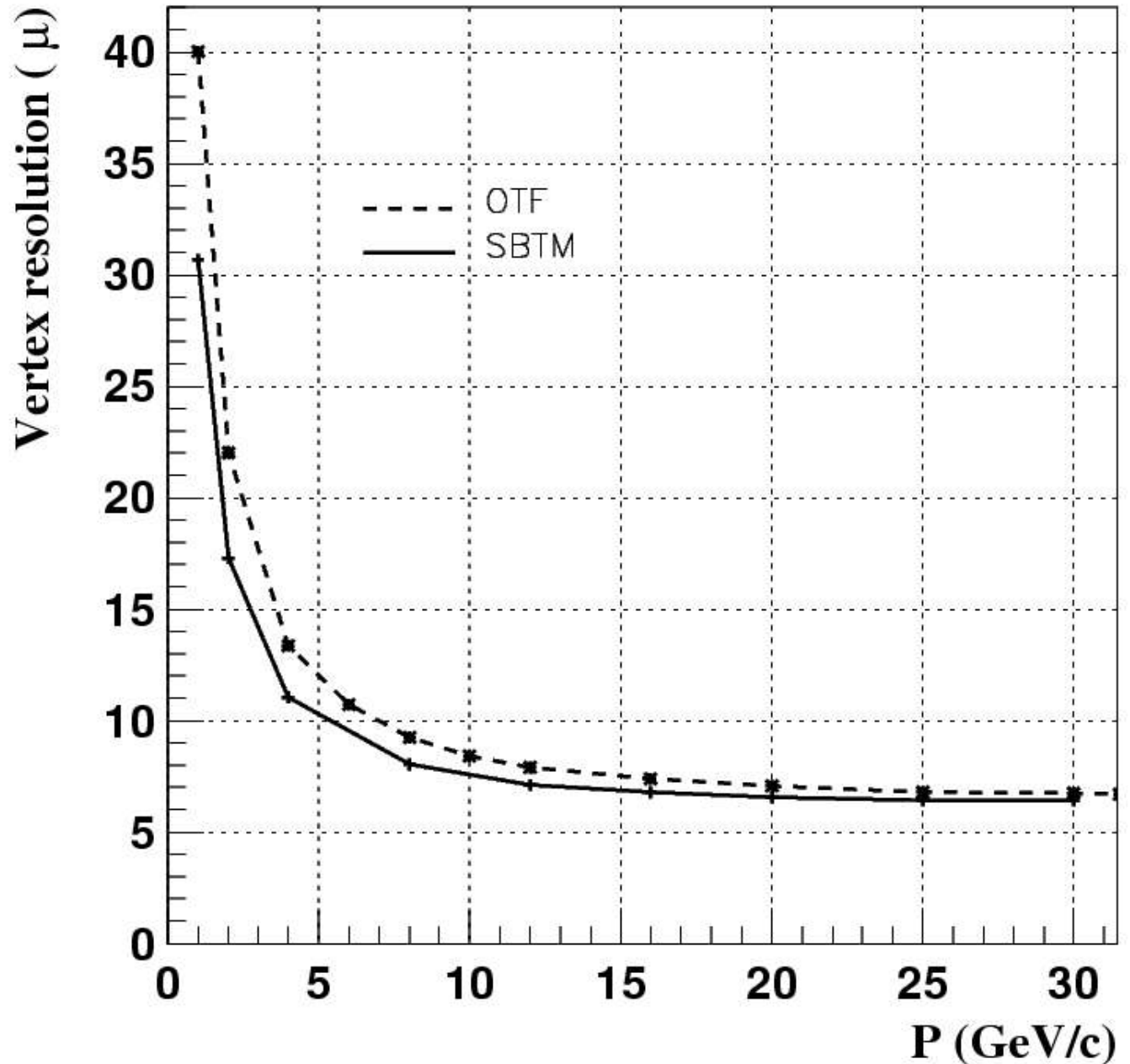


G. Lutz, “*Optimum track fitting in the presence of Multiple Scattering*”
NIM A273 (1988), 349-361

Momentum resolution for SBTM and OTF

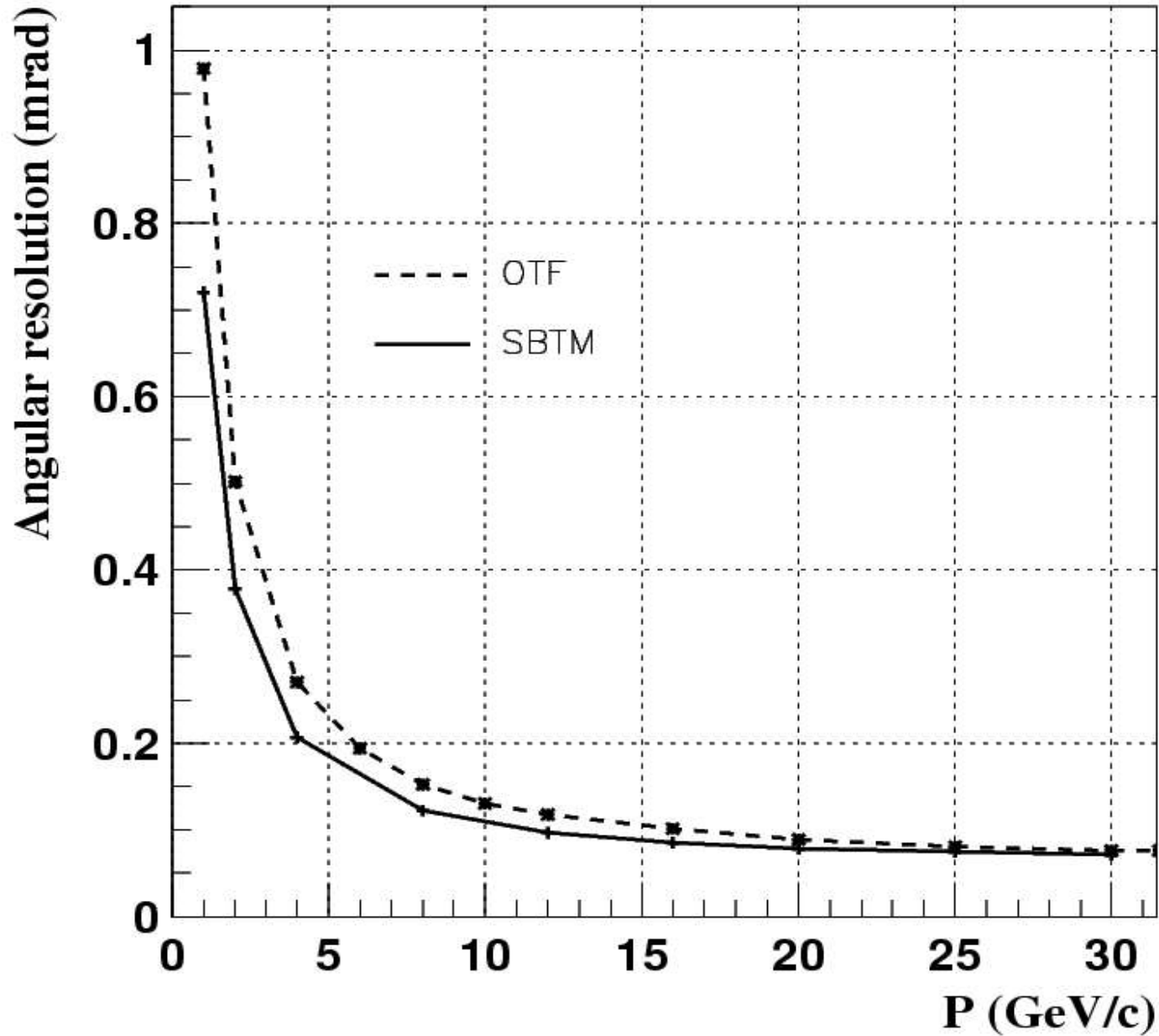


Vertex Resolution for SBTM and OTF

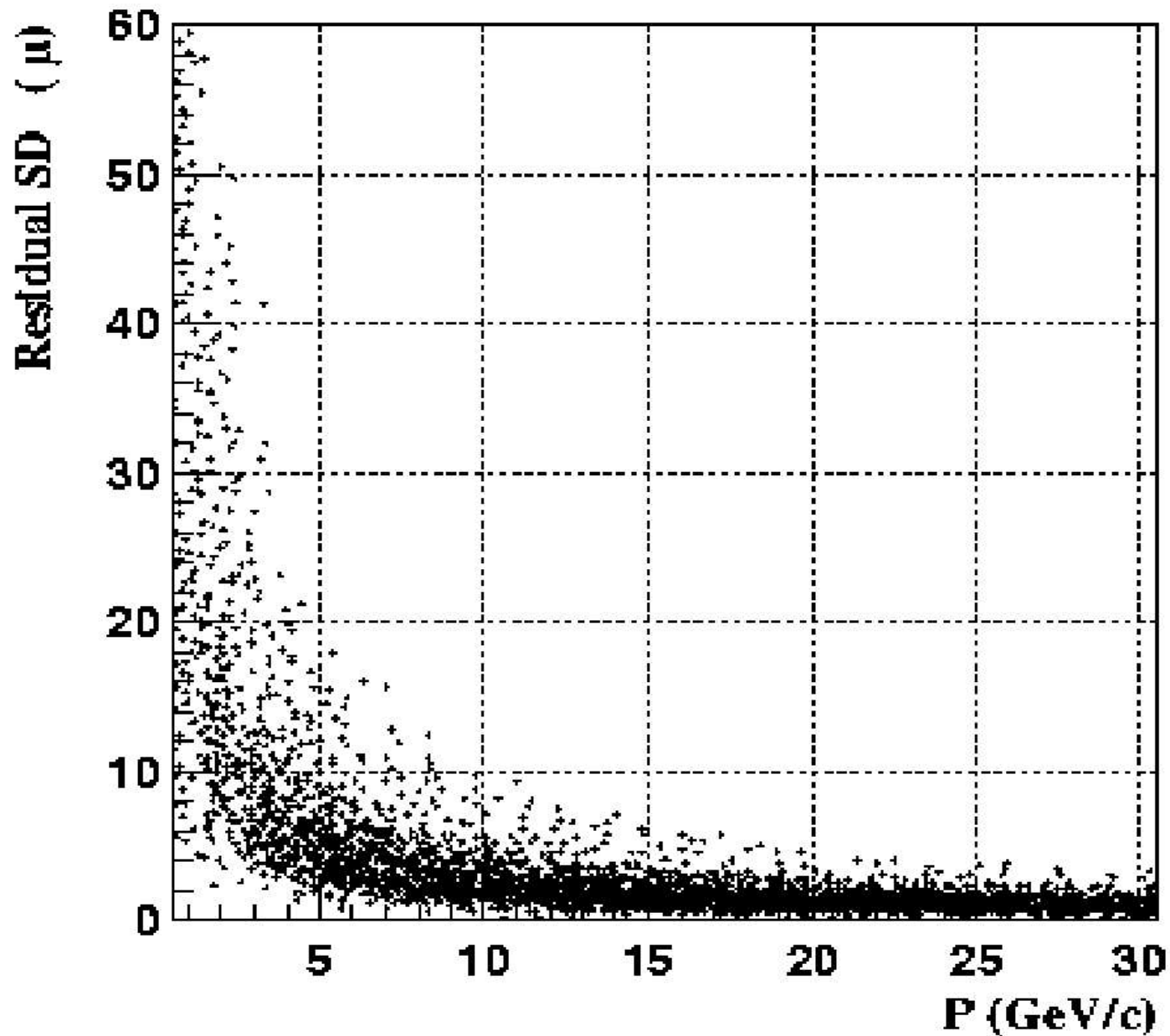


This method could be used to find Vertex; by increasing processing time few times

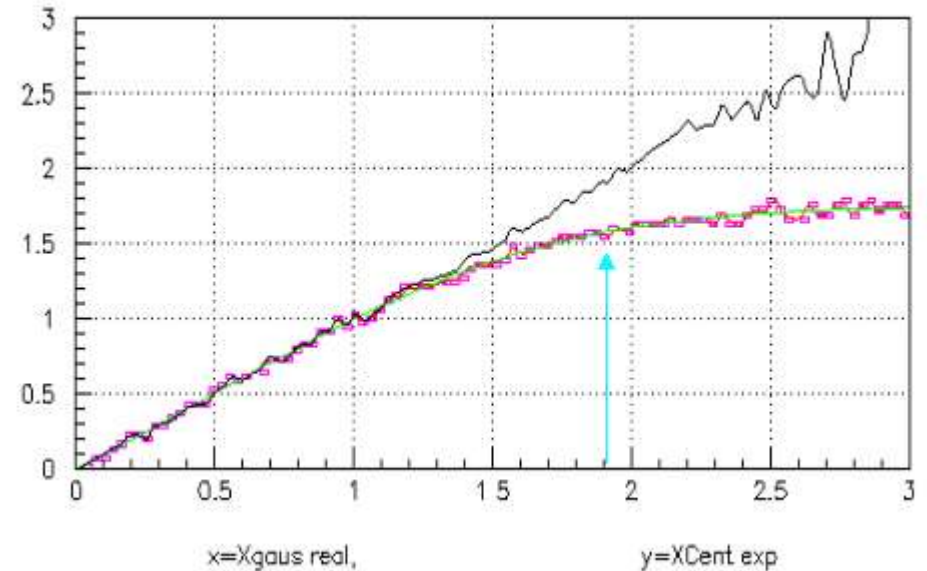
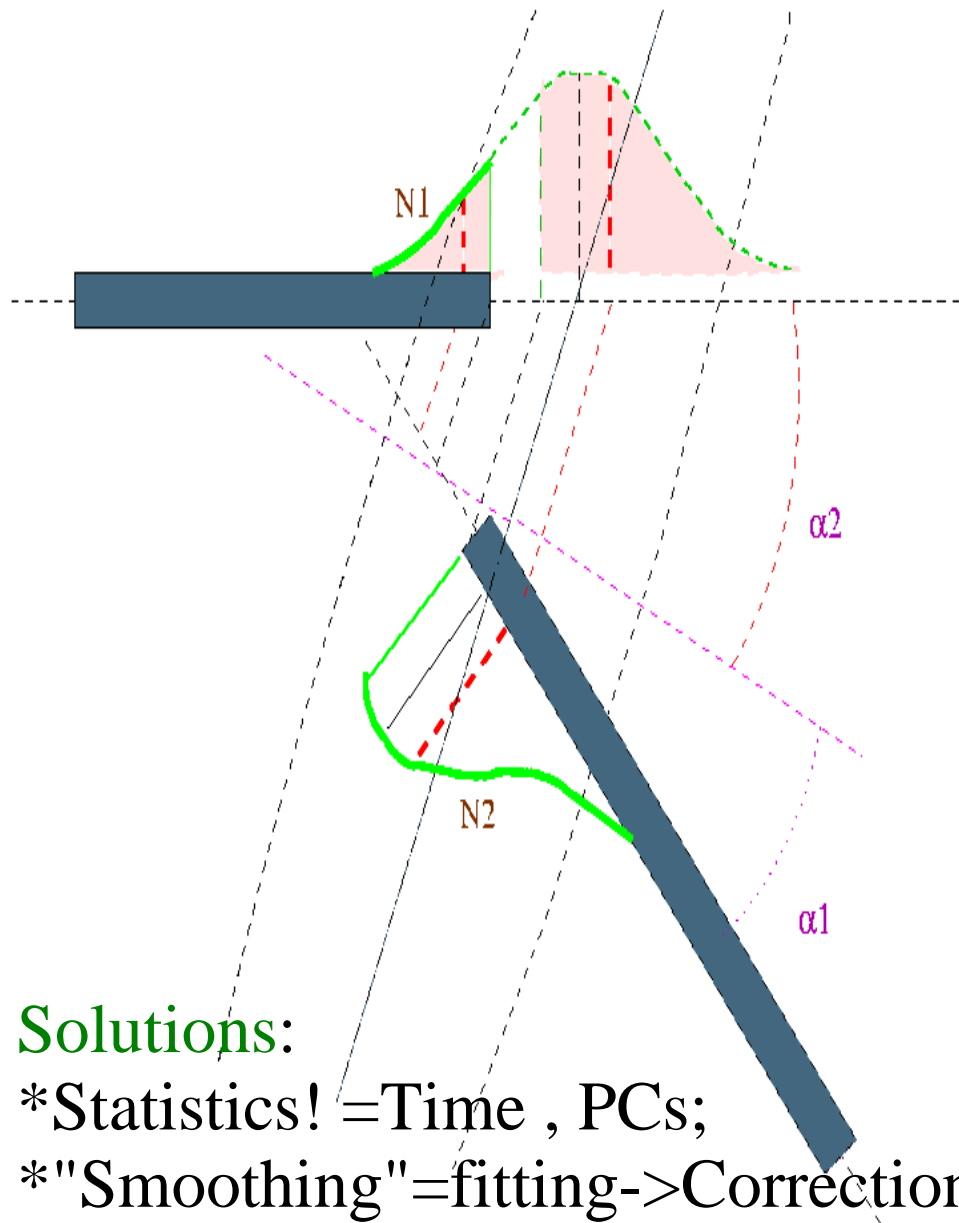
Angular Resolution for SBTM and OTF



Residuals for detector with “ideal” space resolution,
(how close is SBTM model to actual hits)



Problem #1 Edge correction...



Solutions:

- *Statistics! =Time , PCs;
- *"Smoothing"=fitting->Correction

This method was implemented for PHOBOS spectrometer
with complex geometry

ROOT (C++) V. Krylov , Dubna, Russia ; (see elsewhere)

Main features:

Templates :

π	(0.07-:-10.0) GeV/c
K	(0.16-:-10.0) GeV/c
P	(0.24-:-10.0) GeV/c

Banana Center, σ_{banana} , σ_{MScone} ,
P, σ_{P} , Length, angles

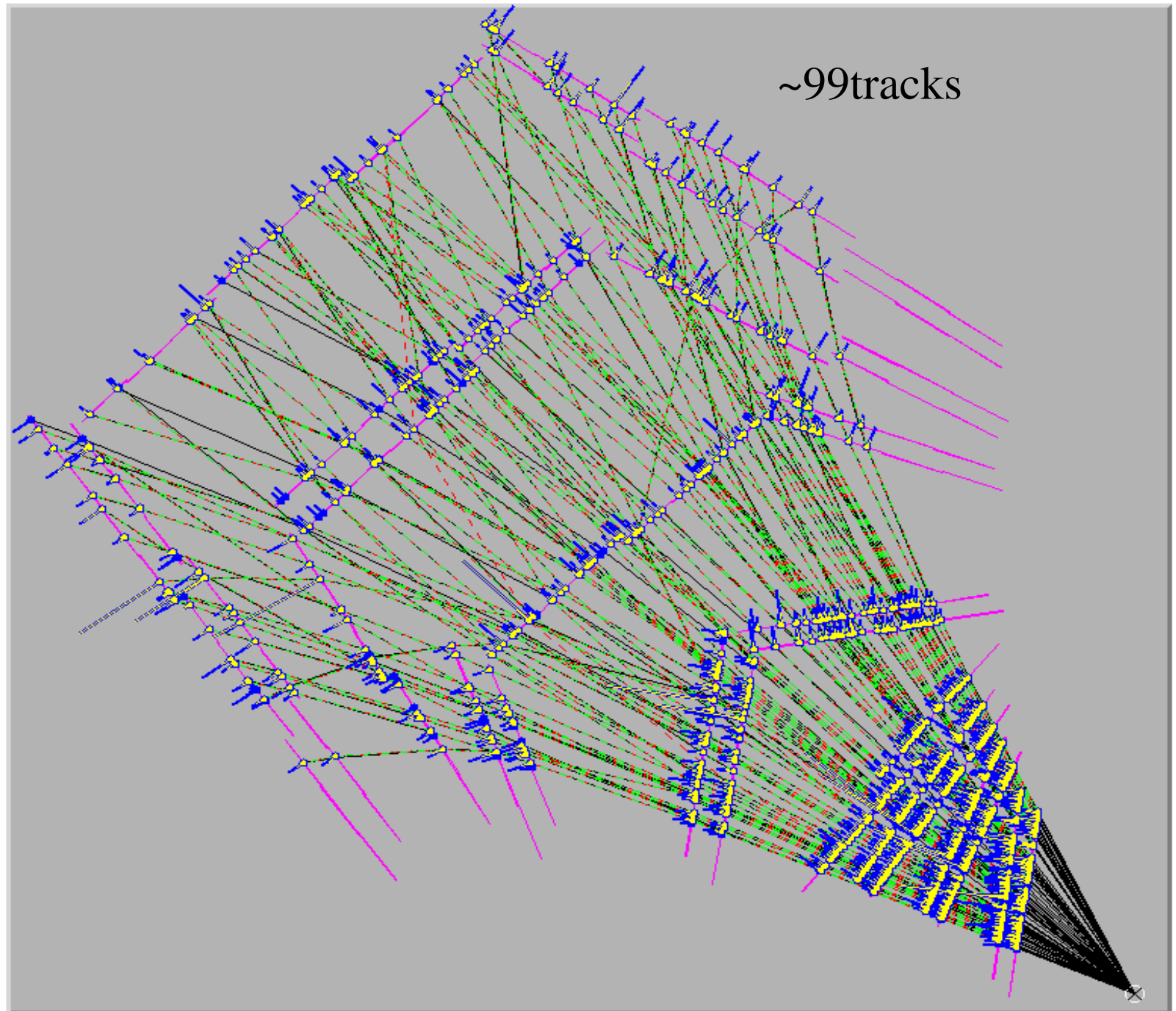
- In the PHOBOS case Templates are generated with $\sim 5\text{mm}$ step along beam pipe (Z) with interpolation between;
horizontal (X) shift of primary Vertex could be "corrected" using such linear set of Templates (along Z).

Test Sample for playing ...

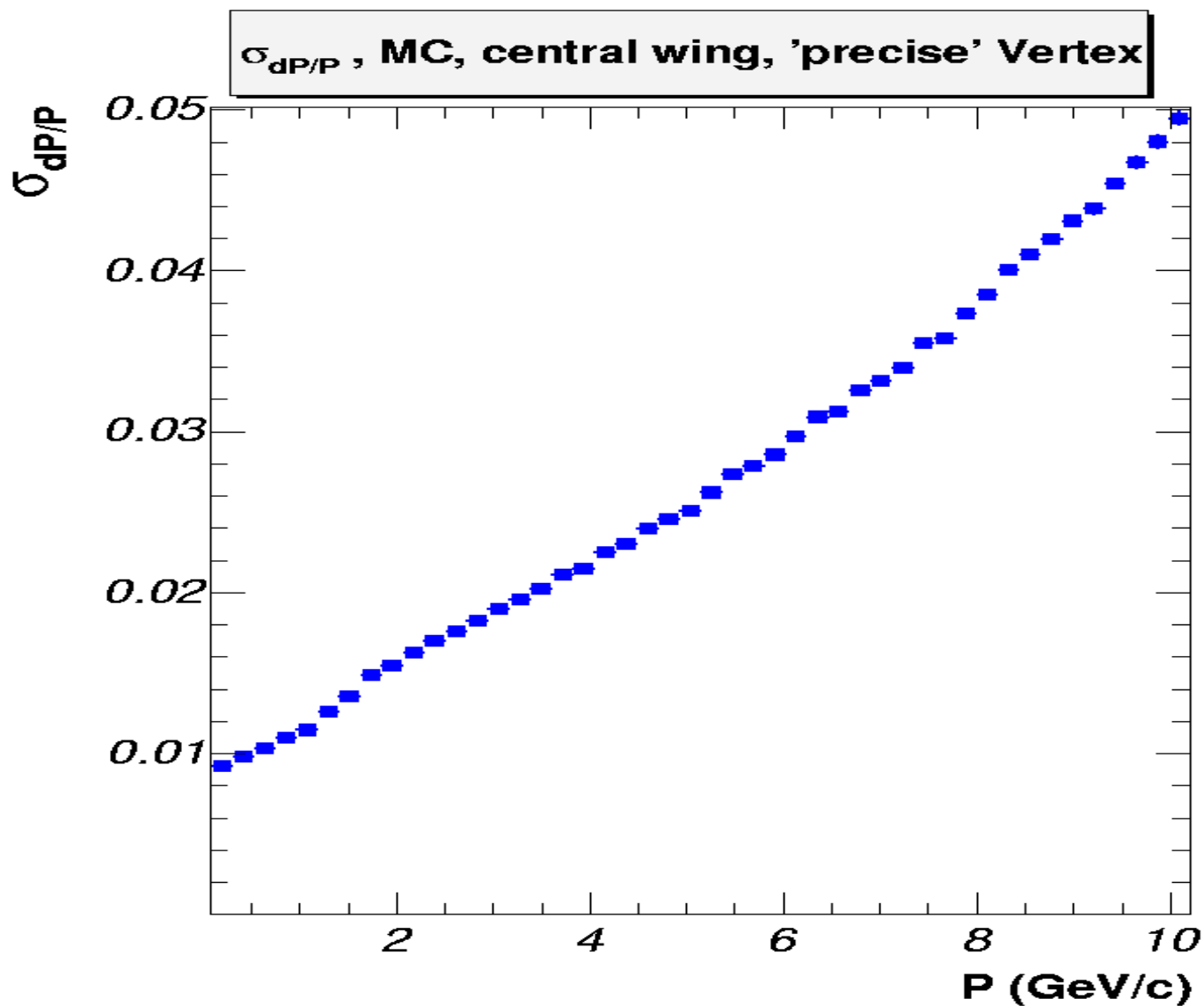
$\Delta\phi \sim 0.15$ rad

$\Delta\theta \sim 0.8$ rad

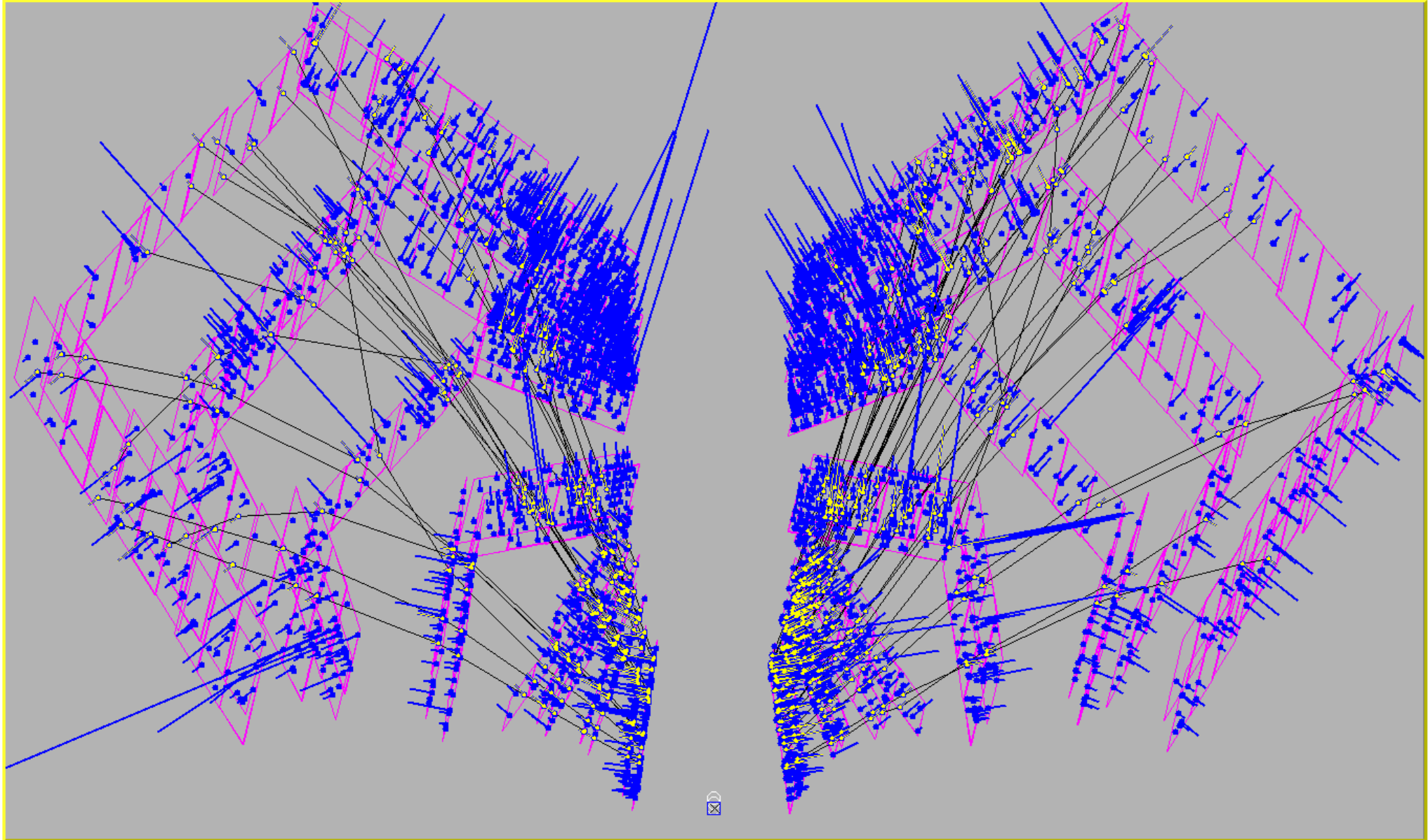
$\delta N/\Delta\eta \sim 5000$



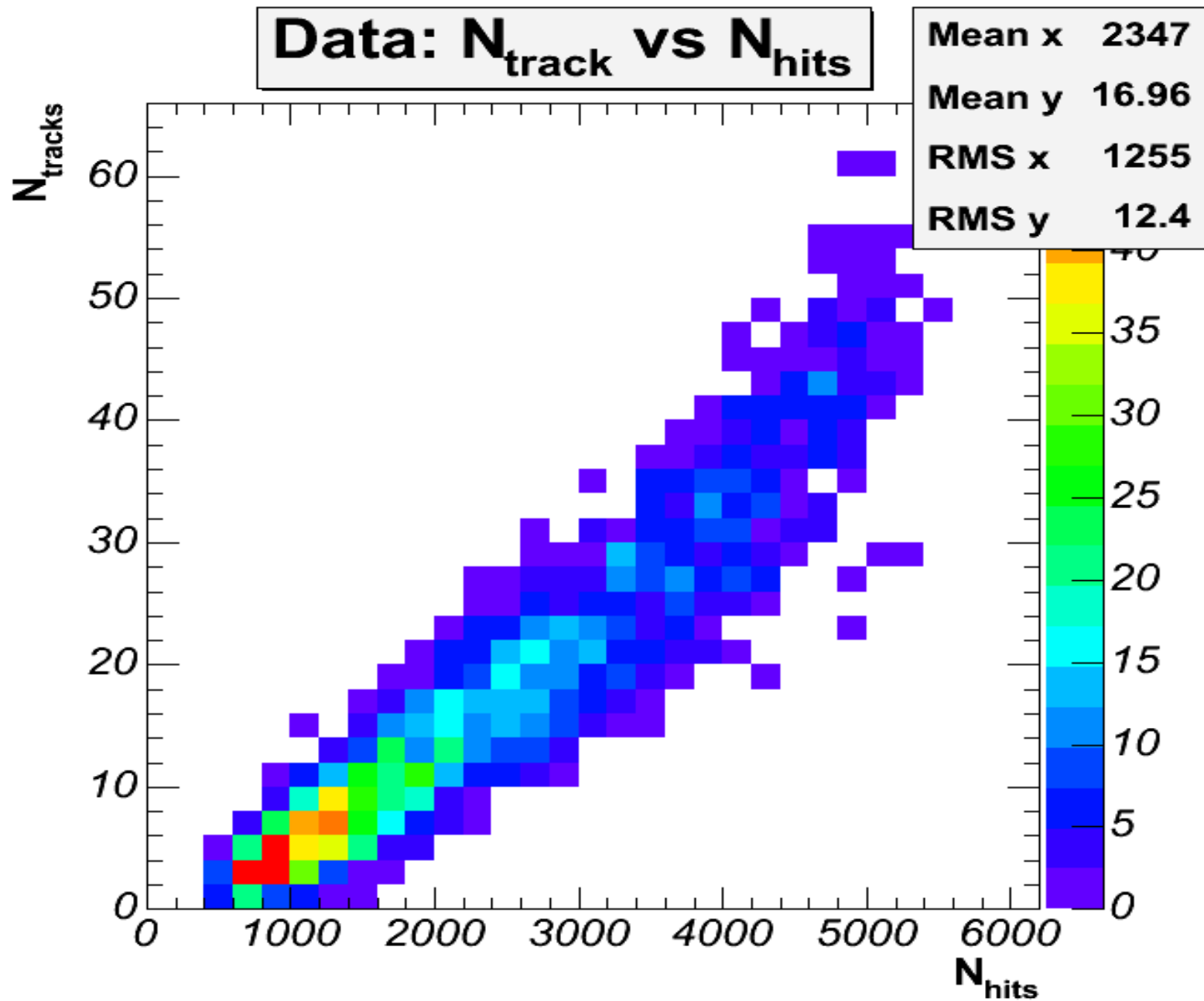
Momentum Resolution for MC (PHOBOS) with “exact” Vertex



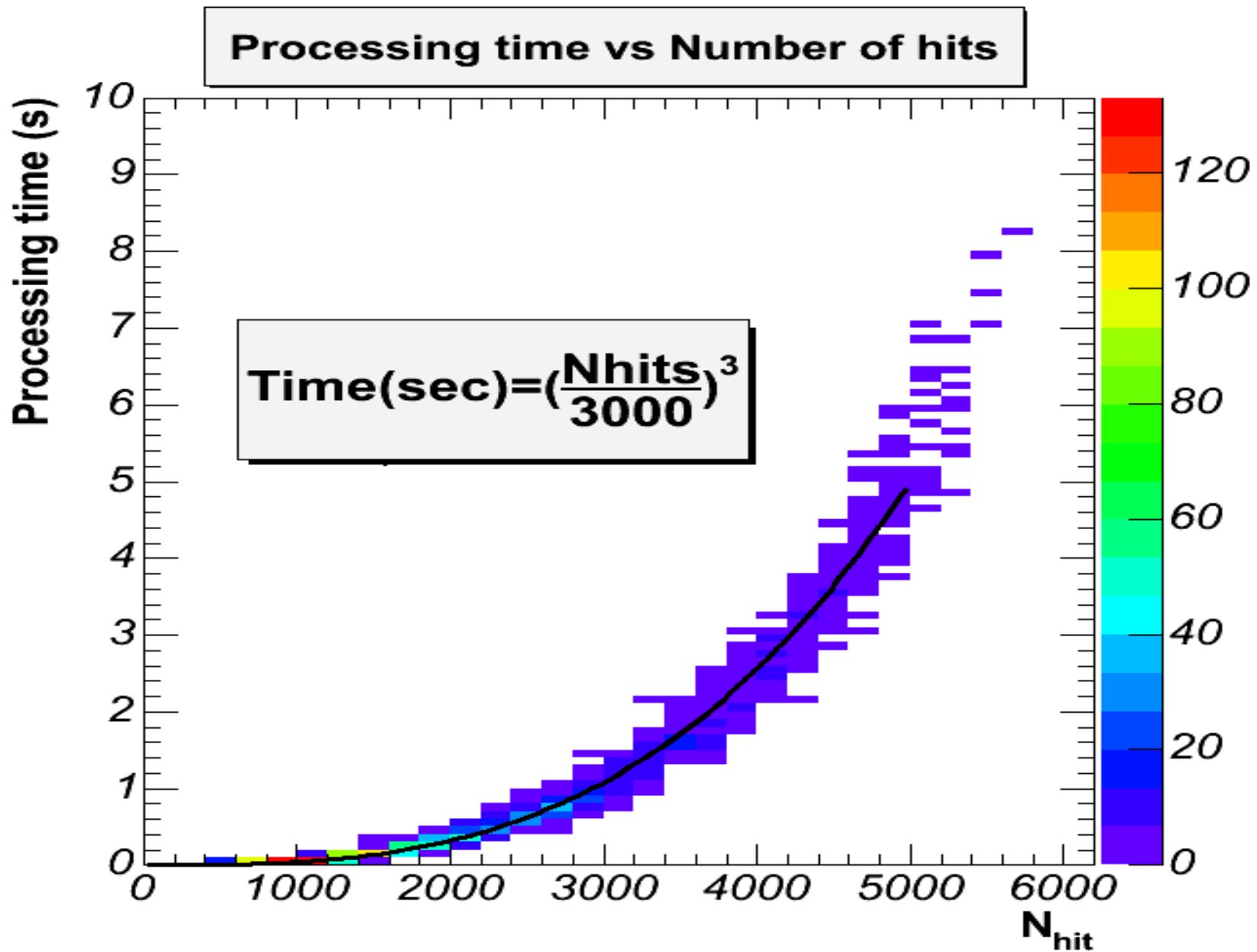
3D - event



N_{track} vs N_{hit} for AuAu 200G

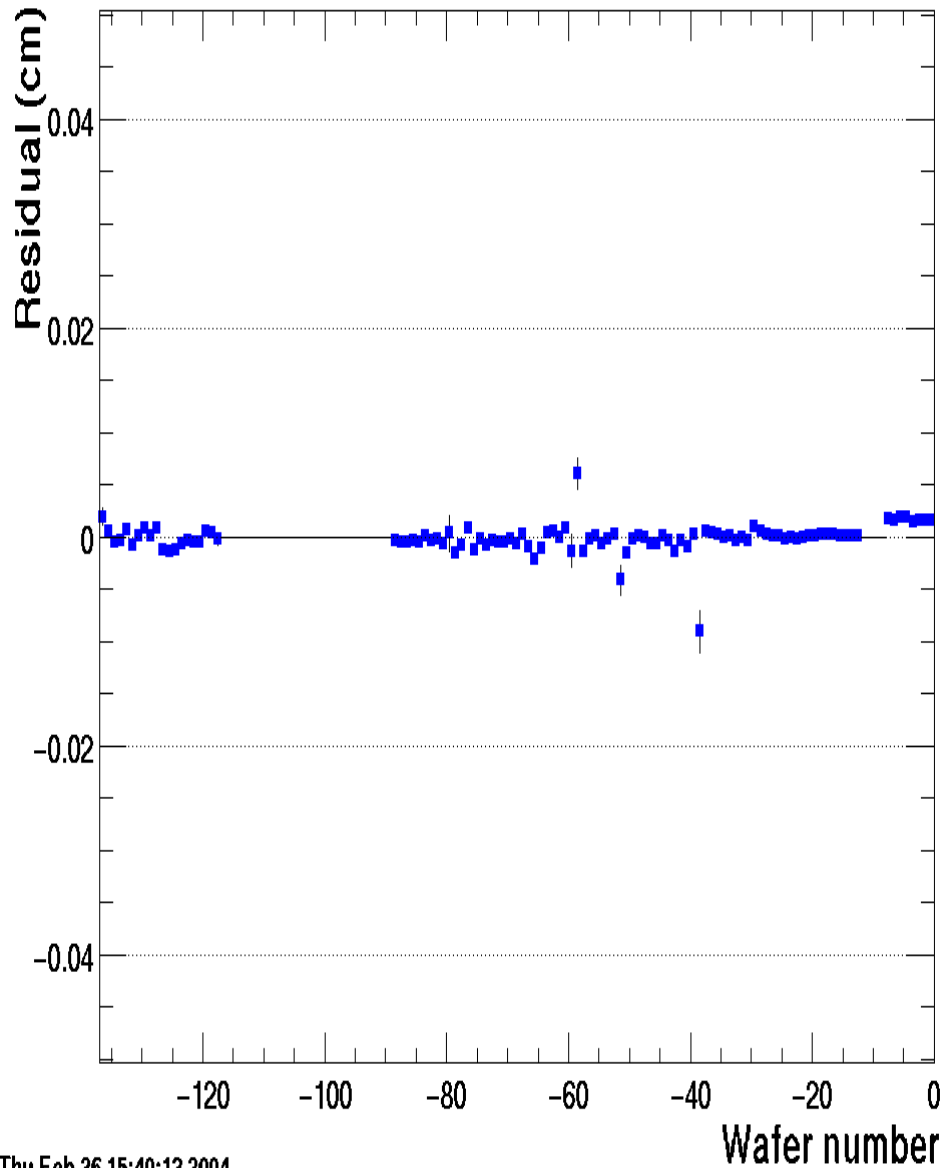


Computing time for reconstruction vs N_hits (Xeon 3GHz)



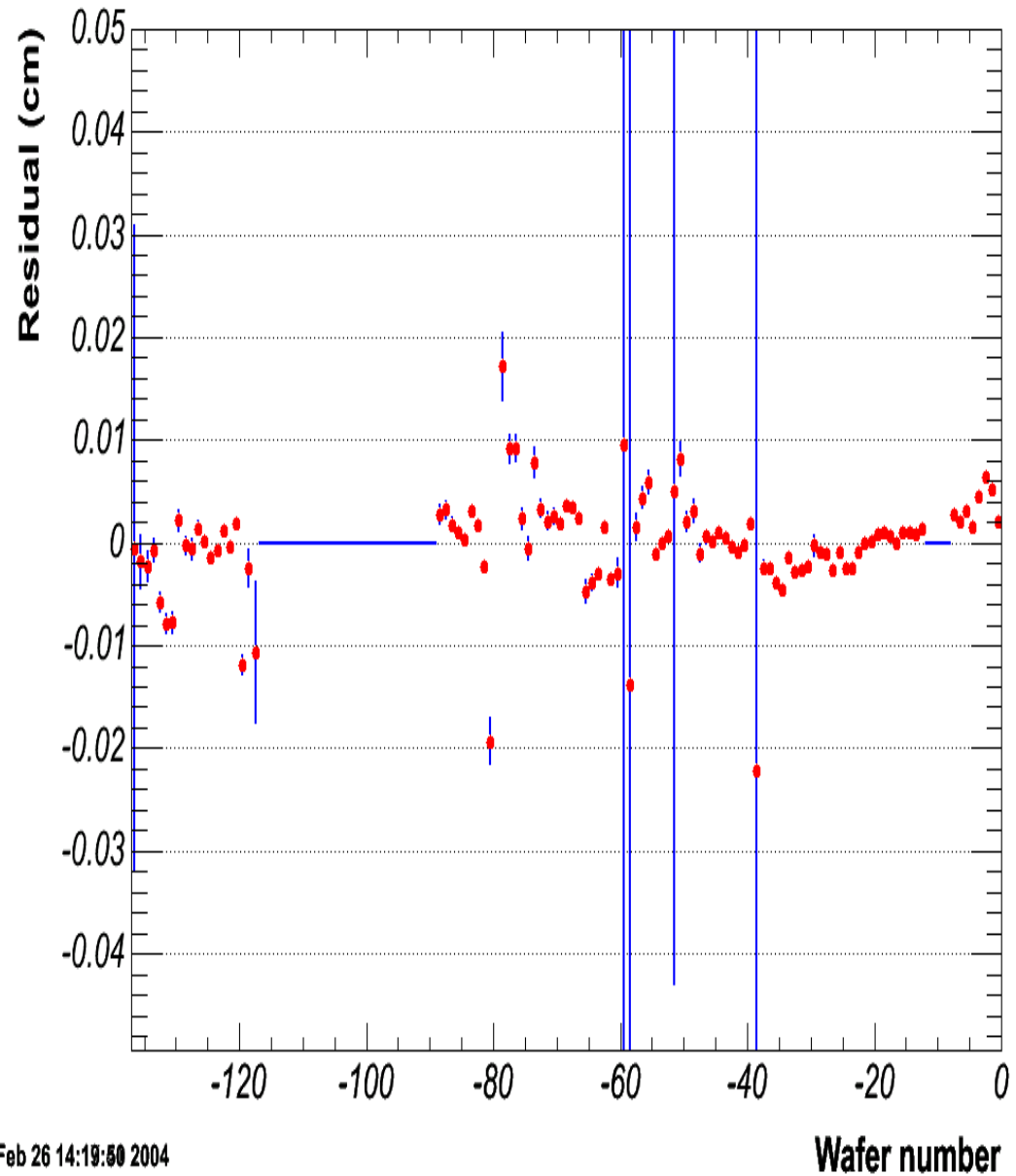
Residuals for MC and for Data

Residual for SpecN wafers in MC_55tracks



Thu Feb 26 15:40:12 2004

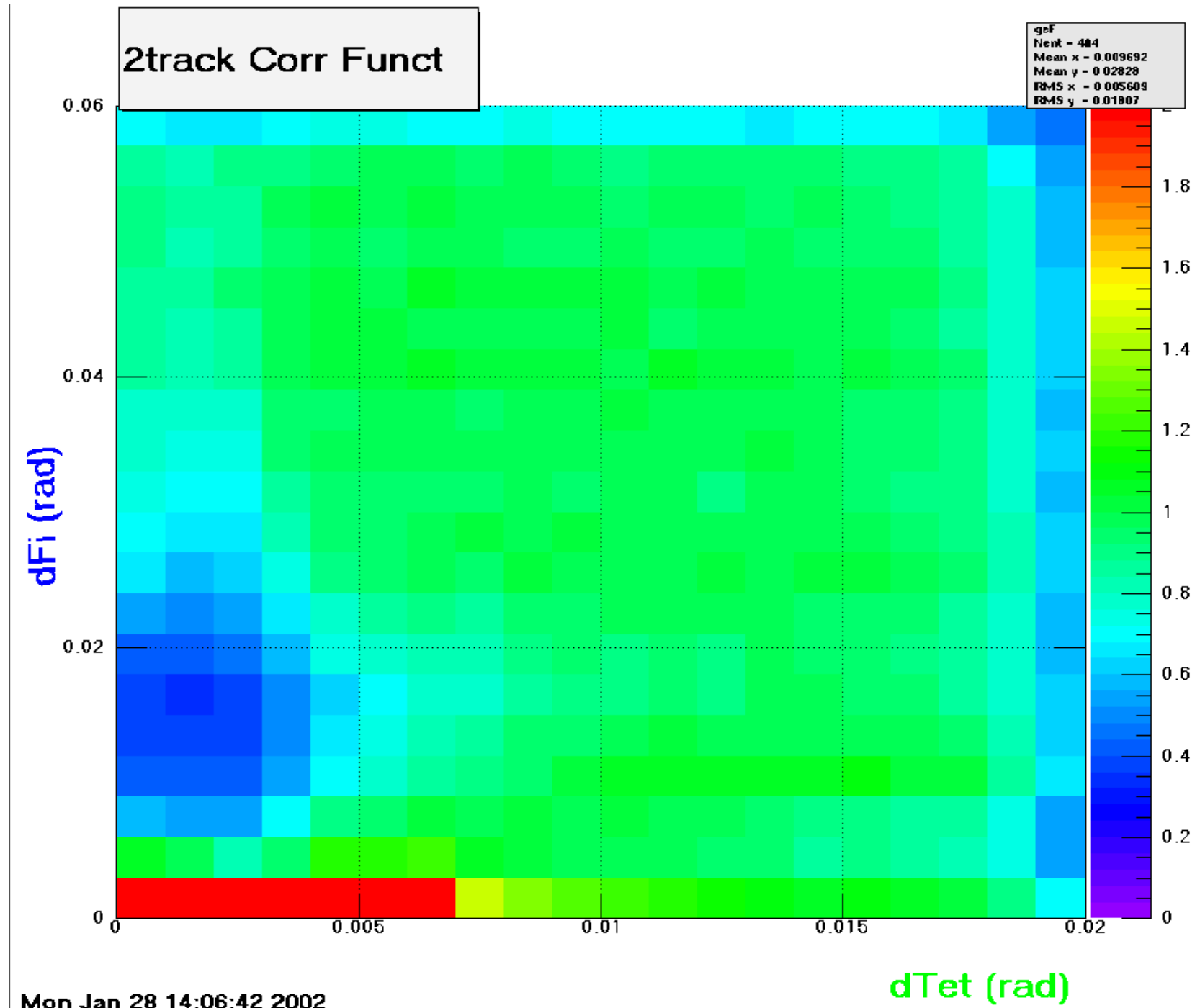
Residual for SpecN wafers



Thu Feb 26 14:19:50 2004

Wafer number

2 tracks correlation in $\Delta\theta$ & $\Delta\phi$



Conclusions

- “Global” method for primary track reconstruction with narrow search window for "given" Vertex with potentially better resolutions.
- MC/GEANT based accumulation of Templates (could be non-uniform B) (*Mean*, σ instead of Covariance Matrix, a priori to reconstruction)
- "Low momentum $\sim 80/160/240$ MeV/c" tracks could be reconstructed in high multiplicity events with MS ~ 10 mrad/layer.
- Acceptance is mainly determined by 2 "Reference Planes" (tracks in Magnet could be reconstructed without "Straight Region" planes)
- Occupancies up to $\sim 20\%$.
- Having Analog Read-out, one could survive in high occupancy case. Ghost cleaning algorithm based on Analog read-out allows many hits sharing ($N_{sh} < N_{pl} - 2 \dots 3$)
- Combinatorial $\{i, j\}$ sort out is shortened after $\sim (1-2)$ "lost planes" and because of narrow Banana, String-width.
- Powerful computers are required ...