Status of beam test analysis

Joe S, July 2007

- Ran my analysis software for position 1-6 from 2006 run.
- Same data set shown by Jerry at Vienna but my own analysis code version.

- Still no treatment of charge sharing or crosstalk attempted, ADCs not used yet
- Using 25 ps/count for all Phillips TDCs (Matthieu's calibration will soon be included)

What's new/different?

- different analysis procedure compared to Jerry or Jose
- use "interpolated" pixel thetaC instead of raw Geant4 pixel thetaC
- latest calibration of time and thetaC "epsilons"
- chromatic correction procedure based on Geant4

(will attempt to use Jose's log-likelihood approach at some point)

Analysis Procedure

Measured quantities:

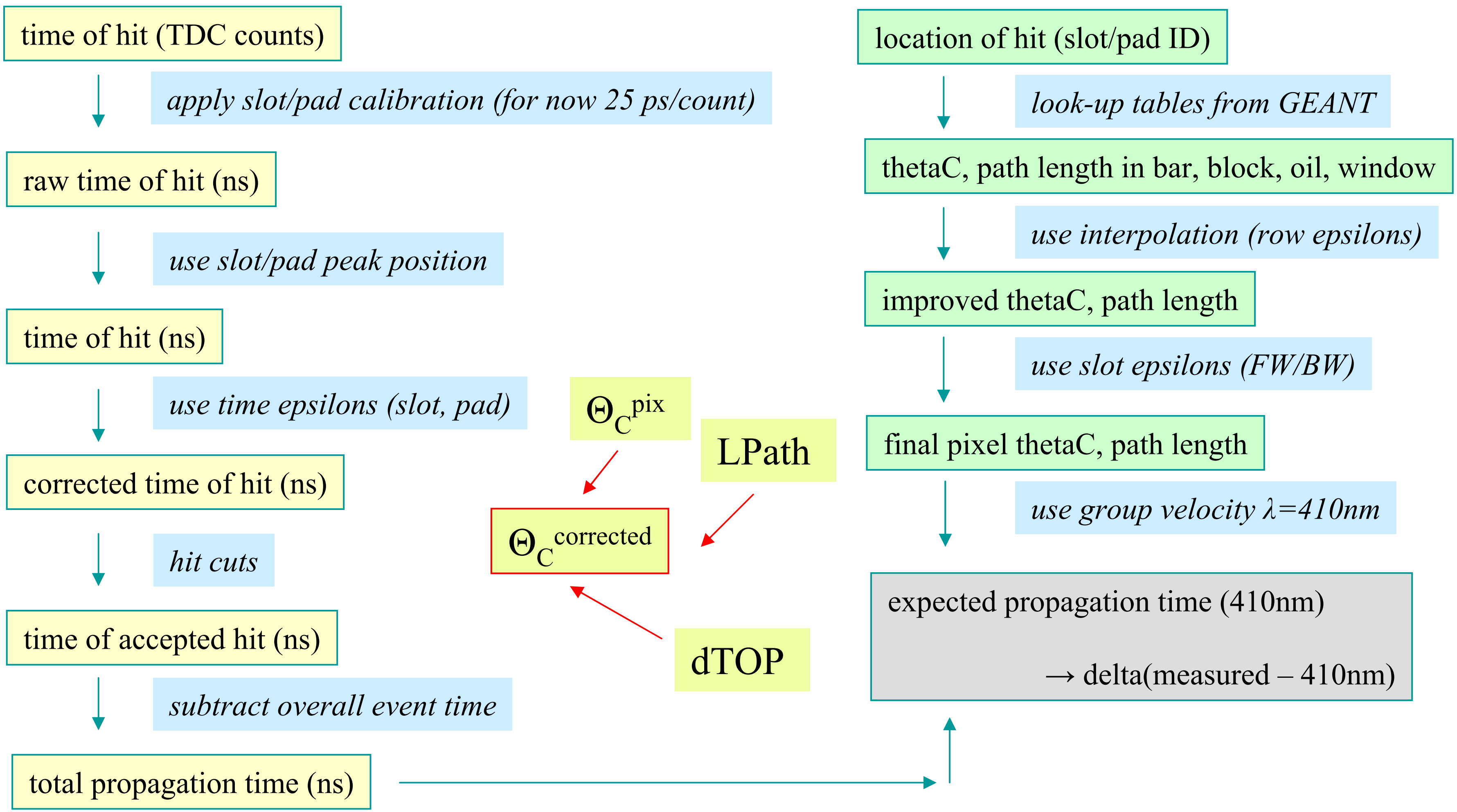
- time of hit (TDC counts)
- location of hit (slot/pad ID)
- charge of hit (not used yet)

Geant4 input:

- k_x, k_y of pad (fixed λ)
- photon propagation time (variable λ) [for time epsilons]

Want to know:

- thetaC of photon at production



Interpolated Pixel thetaC

Geant4 simulation was tuned to reproduce the occupancy in each slot reasonably well.
In stage 1 the mirror angle was tuned to match the ring location in data.
In stage 2 each slot offset was tuned to match the occupancy vs. row in each slot.

Fixed lambda G4 is used to calculate the average thetaC per pad.
If we neglect the effect of fringes this average thetaC is the same as the thetaC of the center of the pad.
However, we know that the center of the pad is not the most probable hit location for most pads.

In ESA beam test all tracks are at 90 degree angle, ring image in same location for each run.

This causes a problem: occupancy in any given pad biased for all tracks.

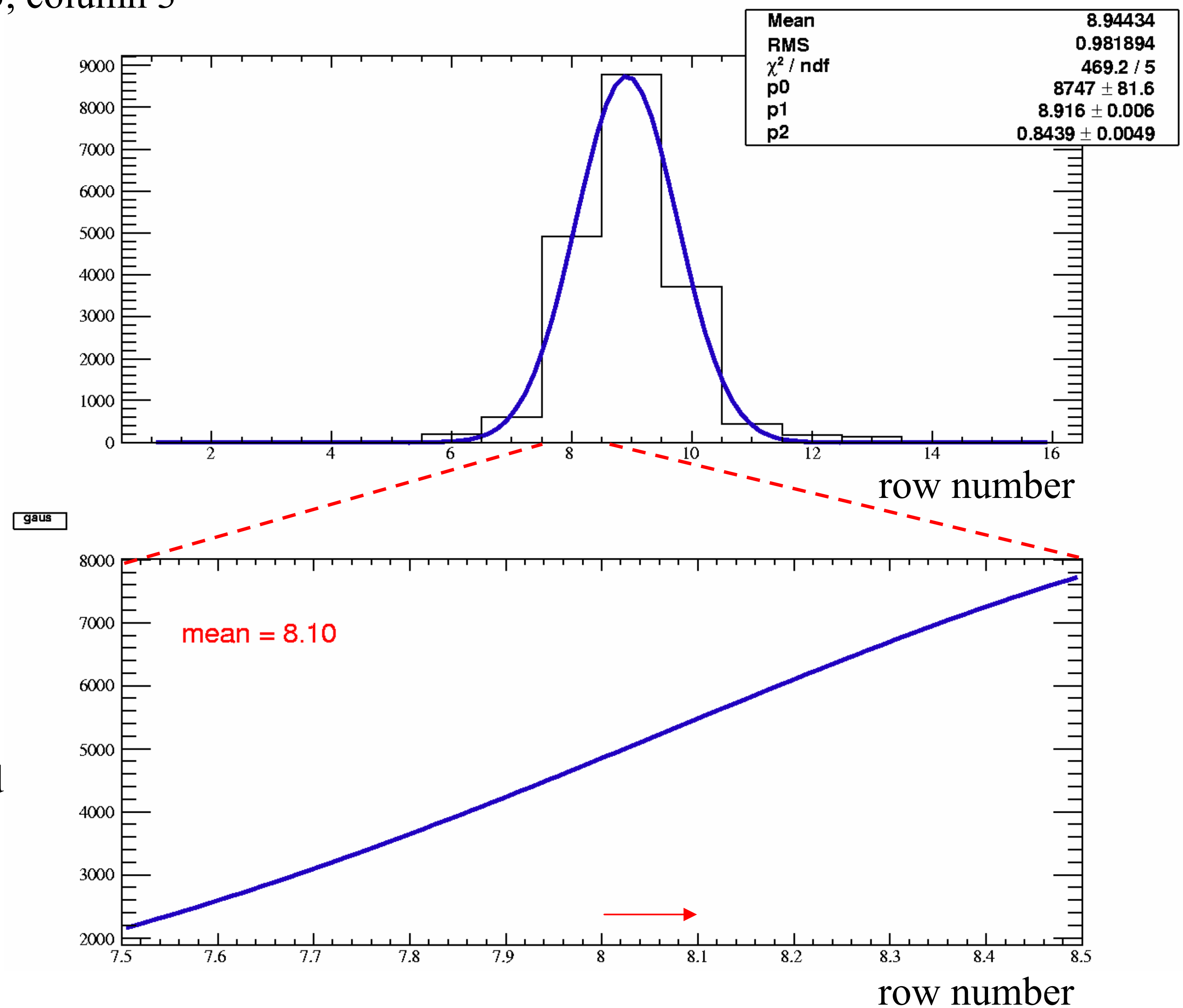
To correct this bias we can get a better approximation of the most probable hit location from the data itself: from the occupancy.

Each column of pads represents at good approximation a slice in thetaC space.

In each column of pads we expect a Gaussian shape (plus background) of the occupancy vs. row distribution (modified by the hit efficiency).

Example: run 22, slot 3, column 3

fit row distribution
with simple Gaussian

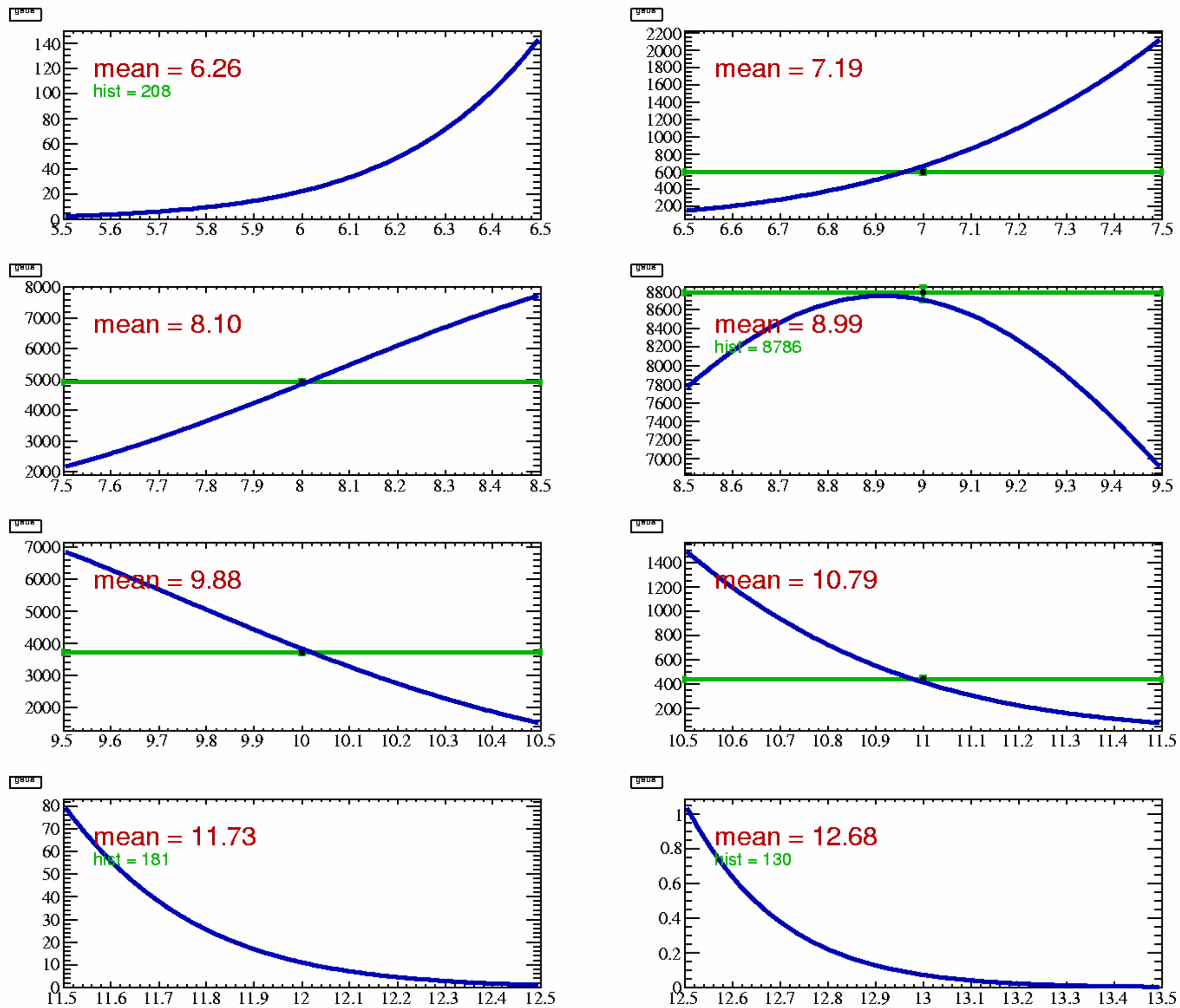


fit function
sampled within
row=8 bin

mean is slightly shifted
from center

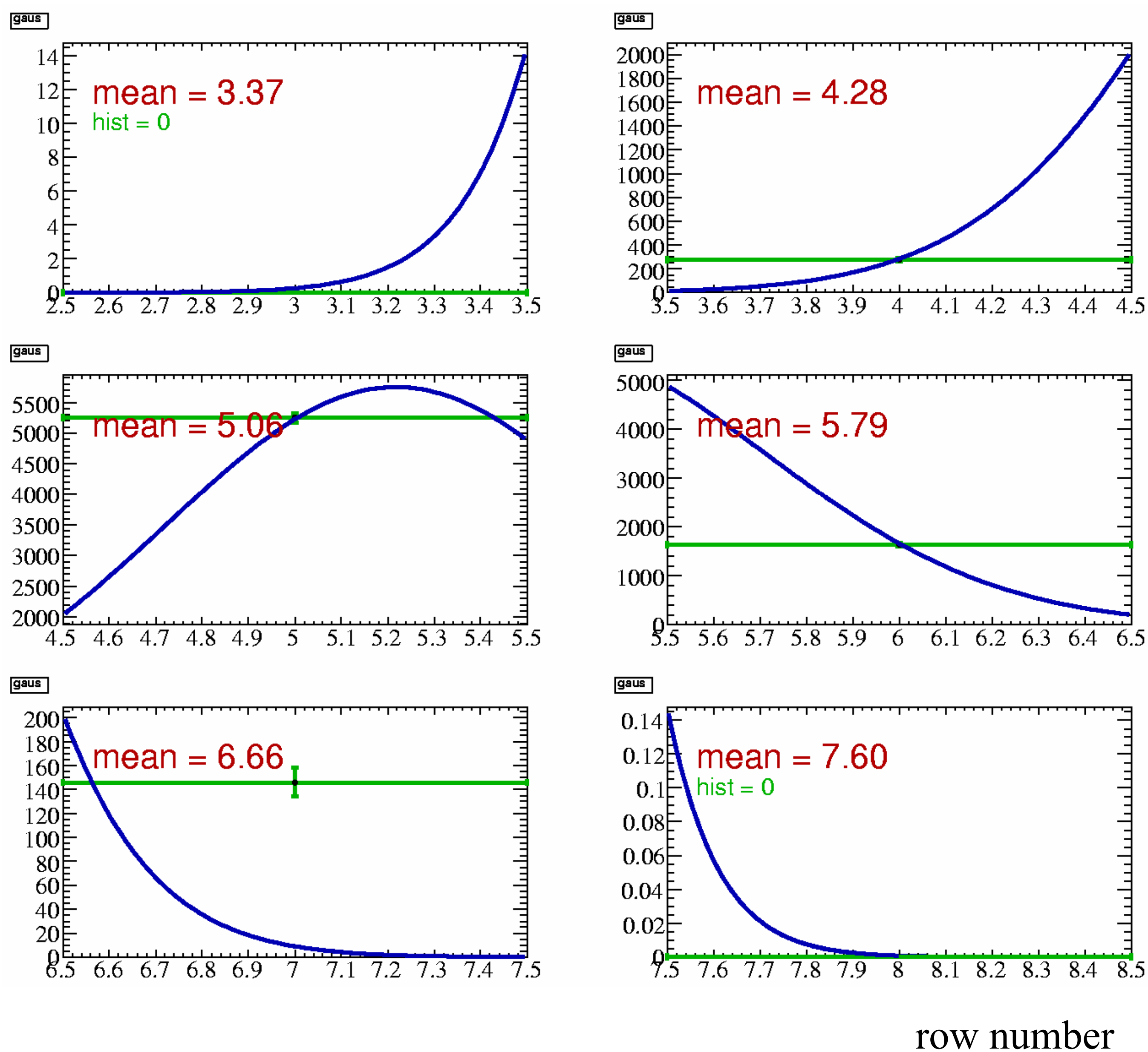
Example: run 22, slot 3, column 3 continued

For populated bins shifts up to ~10-20%



row number

Example: run 22, slot 4, column 1



Next step:

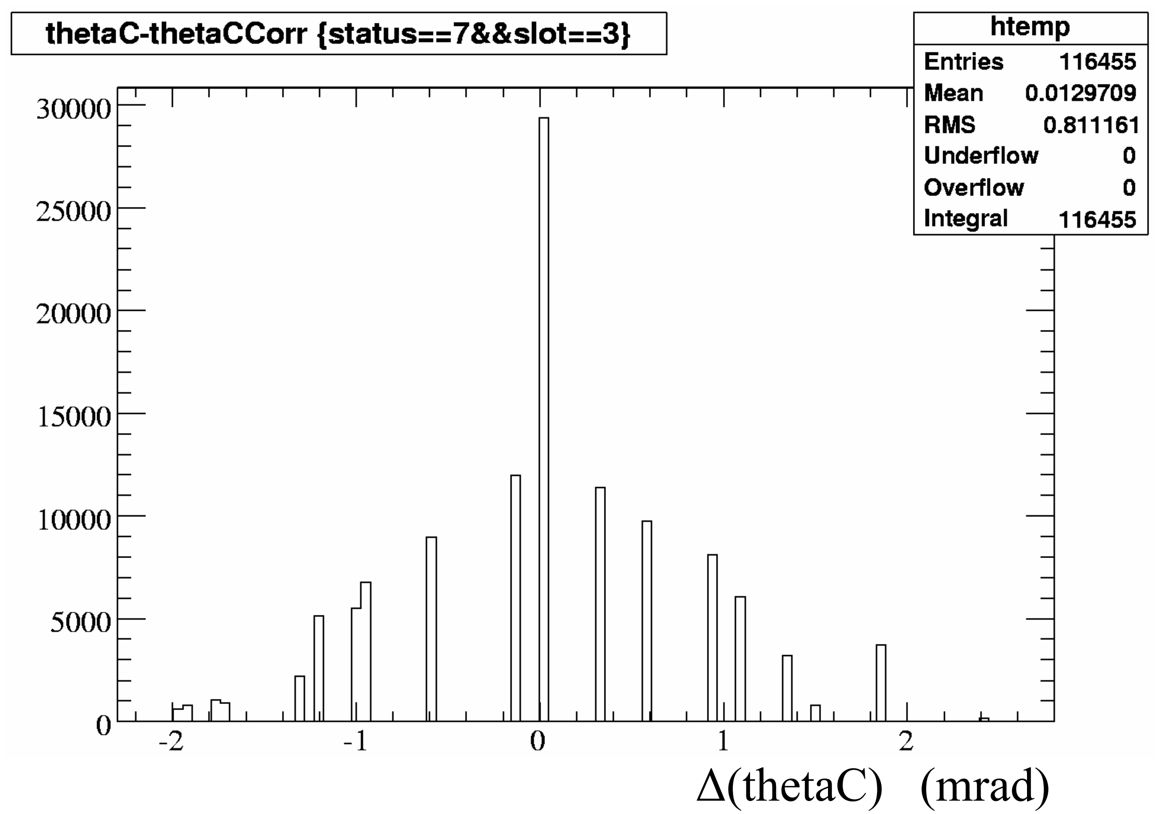
use these shifts to modify pad thetaC

Calculate new thetaC values as

Δ(row) = center of row bin from Gauss minus middle of row bin

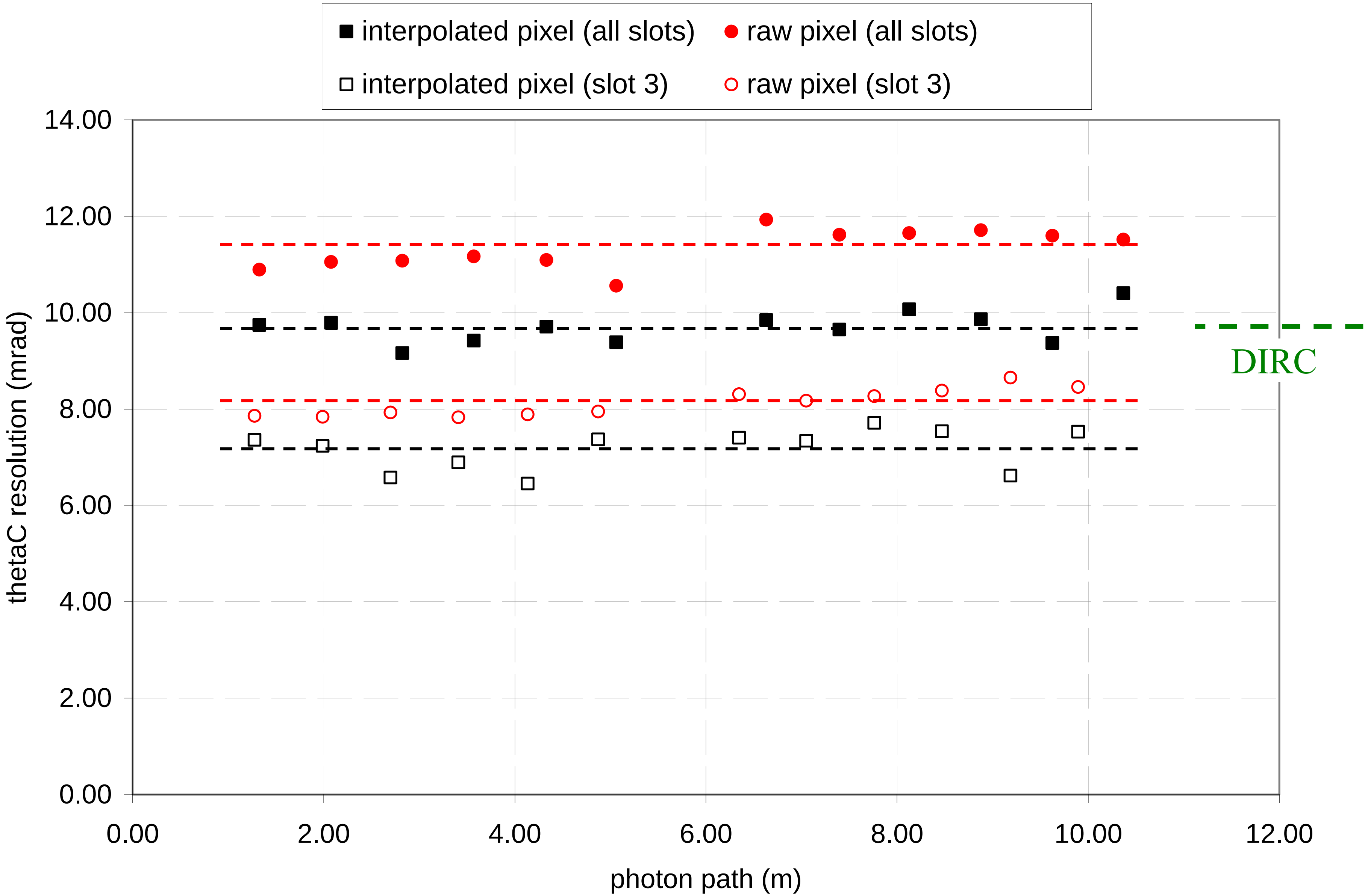
Δ(thetaC) = thetaC(fixed λ, pad) + Δ(row)*(thetaC(fixed λ, pad+1) – thetaC(fixed λ, pad))

Put Δ(thetaC) values (for slot 3, run 22 only) into conditions database, new
file Dirc_Row_Epsilon.txt



Raw vs. "interpolated" pixel thetaC for position 1-6 in 2.5 mrad bins.

→ interpolated pixel resolution close to expected resolution, close to DIRC



Calibration of “epsilons”

The analysis uses “epsilons” to account for unknown effects (ps/count, shift in x/y of pixel) causing differences between the average photon properties and the properties of a 410nm photon.

time epsilons: acts on deltaT

deltaT = difference between measured propagation time and time of average photon (variable λ analysis)

move deltaT fitted peak to zero for every pad, direct/indirect separate

finally move deltaT peak of each slot to zero (epsilon prime)

thetaC epsilons: acts on interpolated pixel thetaC

deltaThetaC = difference between mean thetaC and thetaC(λ =410nm) (separate for each slot)

move average fitted thetaC peak to 822nm, direct/indirect separate

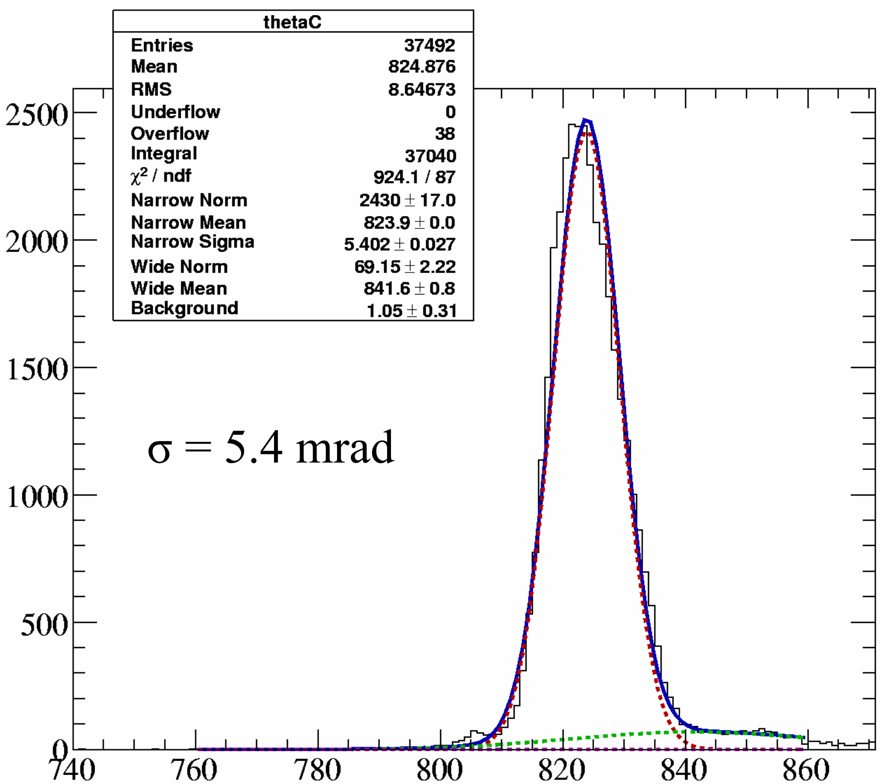
Those constants are currently in conditions DB (time) or hard-coded in my code (thetaC).

Choice of photon path definition

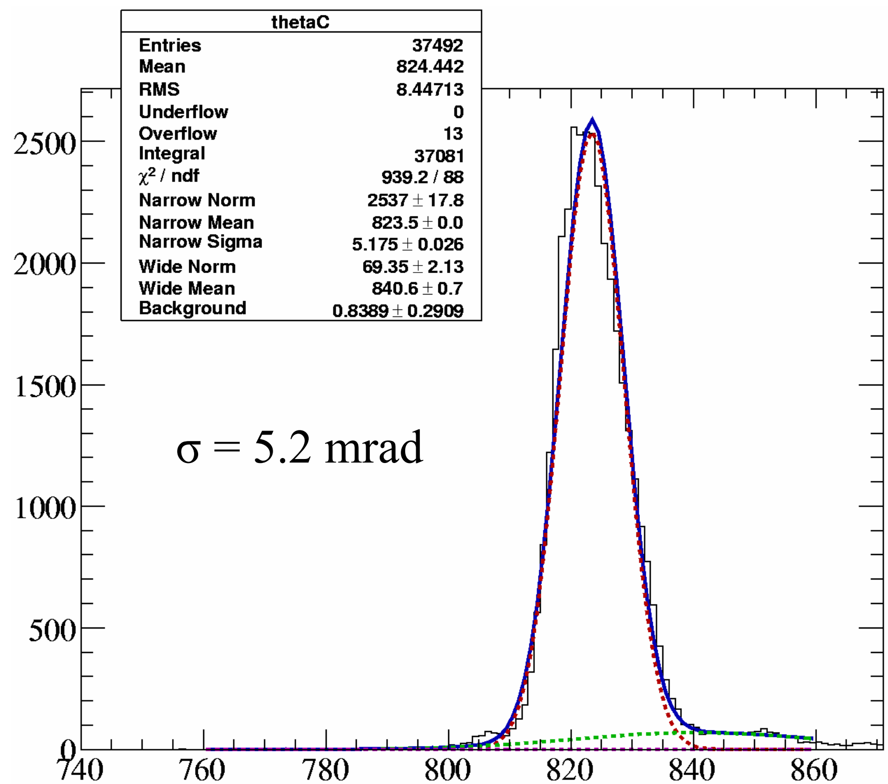
thetaC from TOP only, using beta=1
(cross-check only, not a PID method)

example: position 1 (run 22), all slots, indirect photons
double-Gauss, wide Gauss mean, width fixed

path in bar only

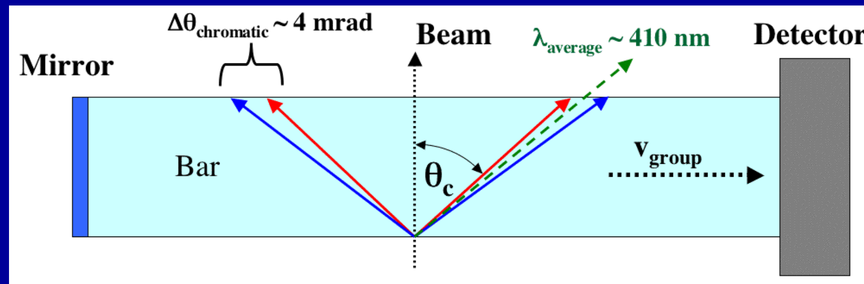


path in bar + block + oil + window

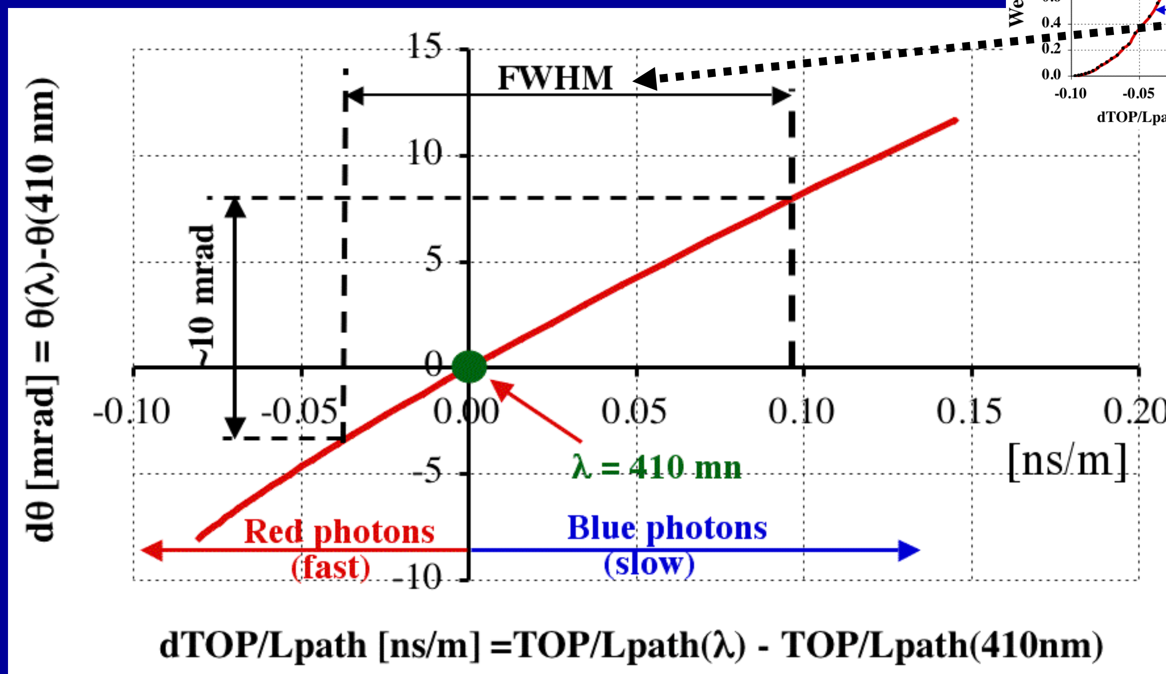


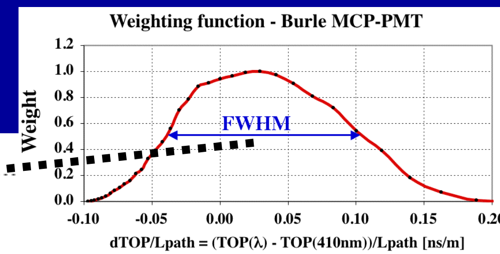
Cherenkov light: tagging color of photon by time

From Jerry's Vienna talk



Principle chromatic correction by timing:





TOP = time of propagation of photon in the bar

TOP/Lpath = $1/v_{group}(\lambda)$

Cherenkov angle production controlled by n_{phase} ($\cos\theta_c = 1/(n_{phase}\beta)$):

Propagation of photons is controlled by n_{group} ($v_{group} = c_0/n_{group} = c_0/[n_{phase} - \lambda \, dn_{phase}/d\lambda]$):

θ_c (red) < θ_c (blue)

v_{group}(red) > v_{group} (blue)

Chromatic correction using Geant 4

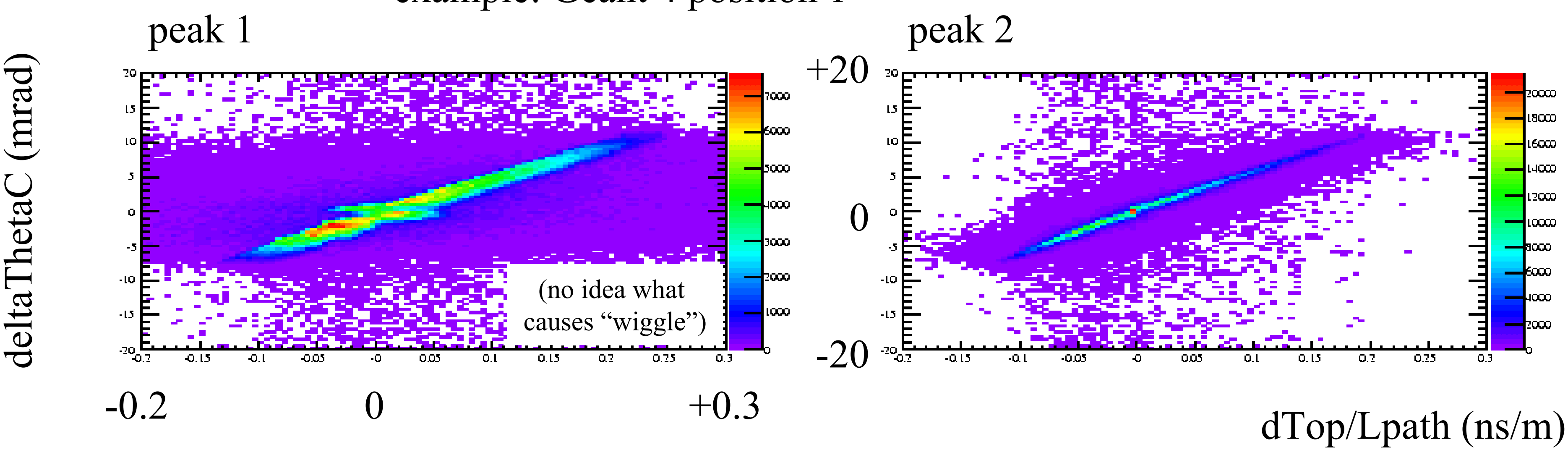
G4 contains “theoretical” correlation between delta(thetaC) and dTOP/LPath

The slope of delta(thetaC) vs. dTOP/LPath gets modified by timing resolution, pixelization of path and thetaC, and is a function of pathlength (→ see next slide)

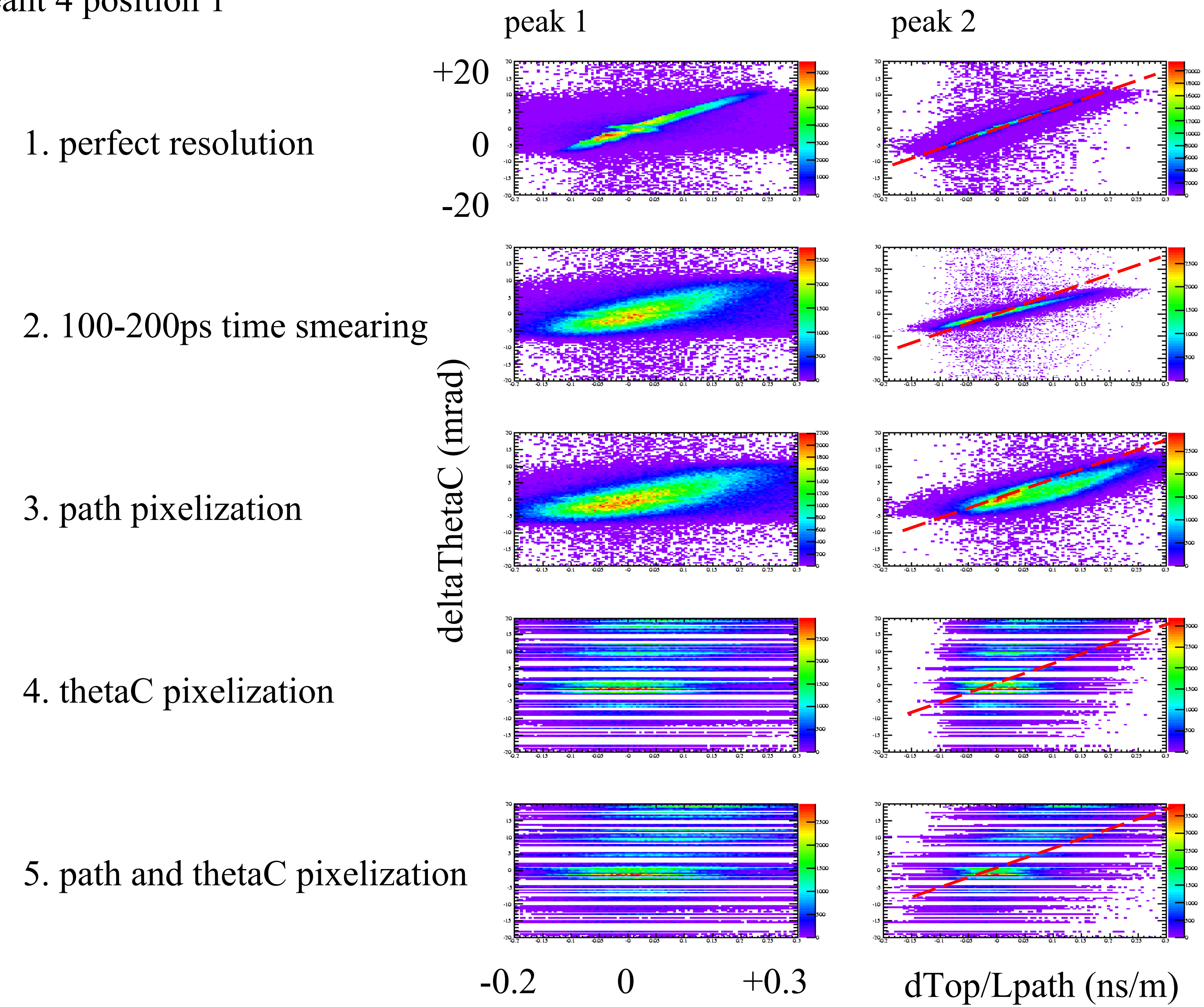
Want to correct “only” chromatic effect, not combined effect

→ use the slope for a perfect unsmeared, unpixelated detector

example: Geant 4 position 1



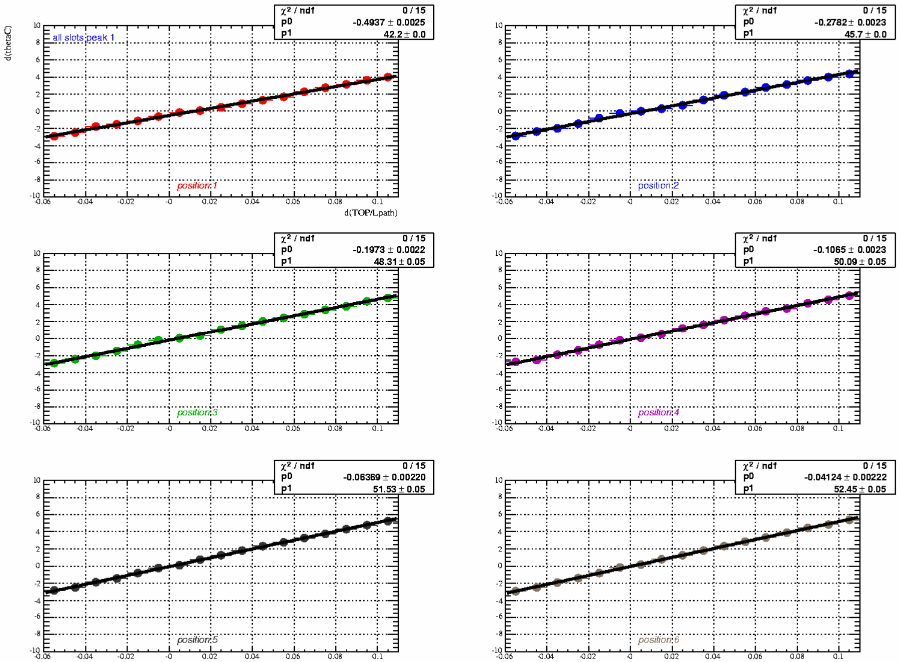
example: Geant 4 position 1



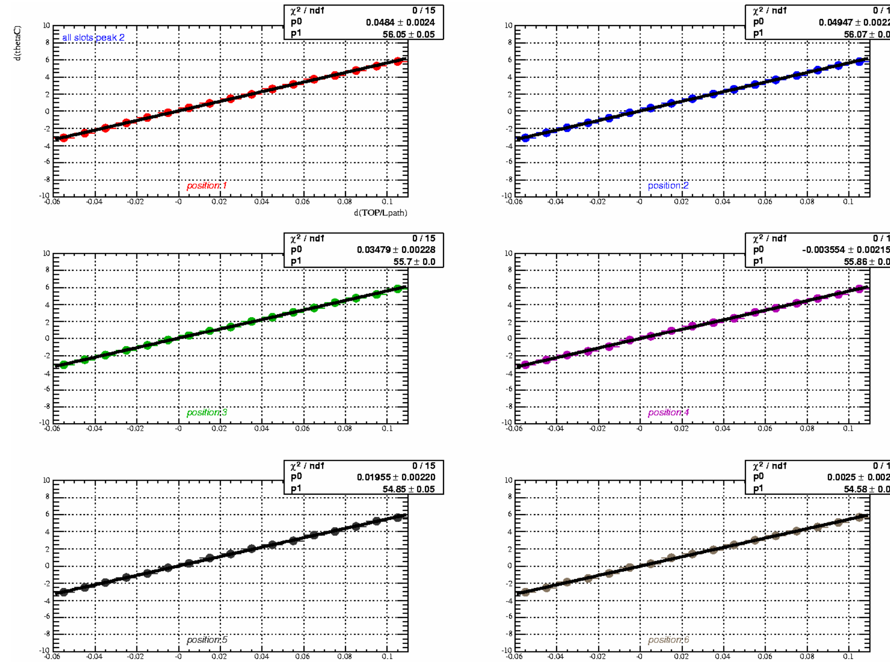
Chromatic correction in Geant 4

profile plot fitted with line to extract intercept and slope
for positions 1-6, use parameters in reco code

peak 1



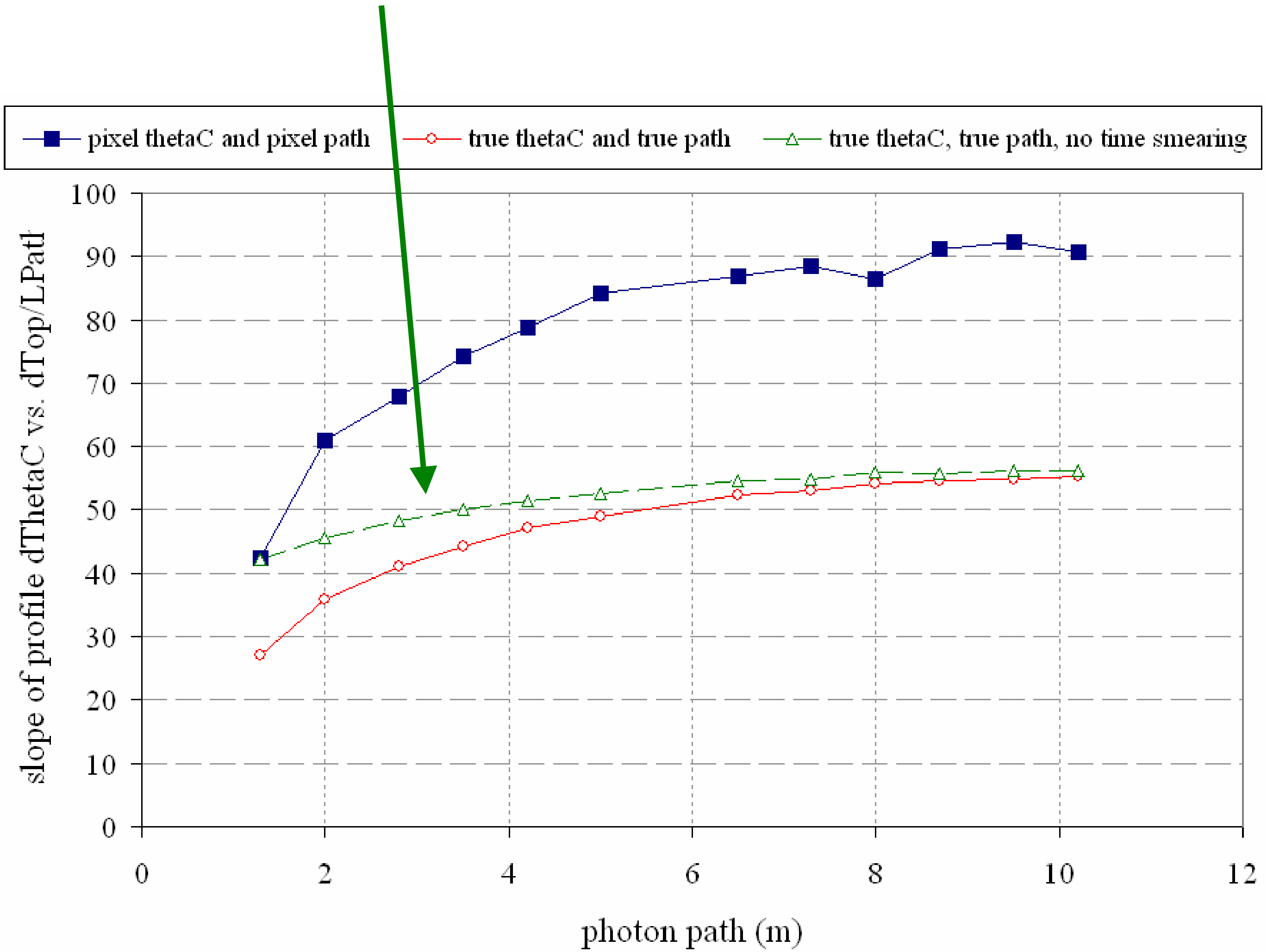
peak 2



Chromatic correction in Geant 4

intercept and slope as function of position used in analysis code

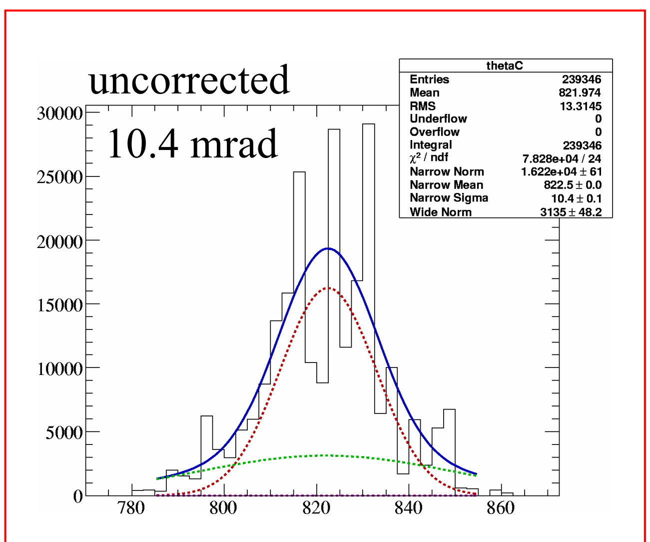
we are using “true” G4 prediction without pixelization or smearing

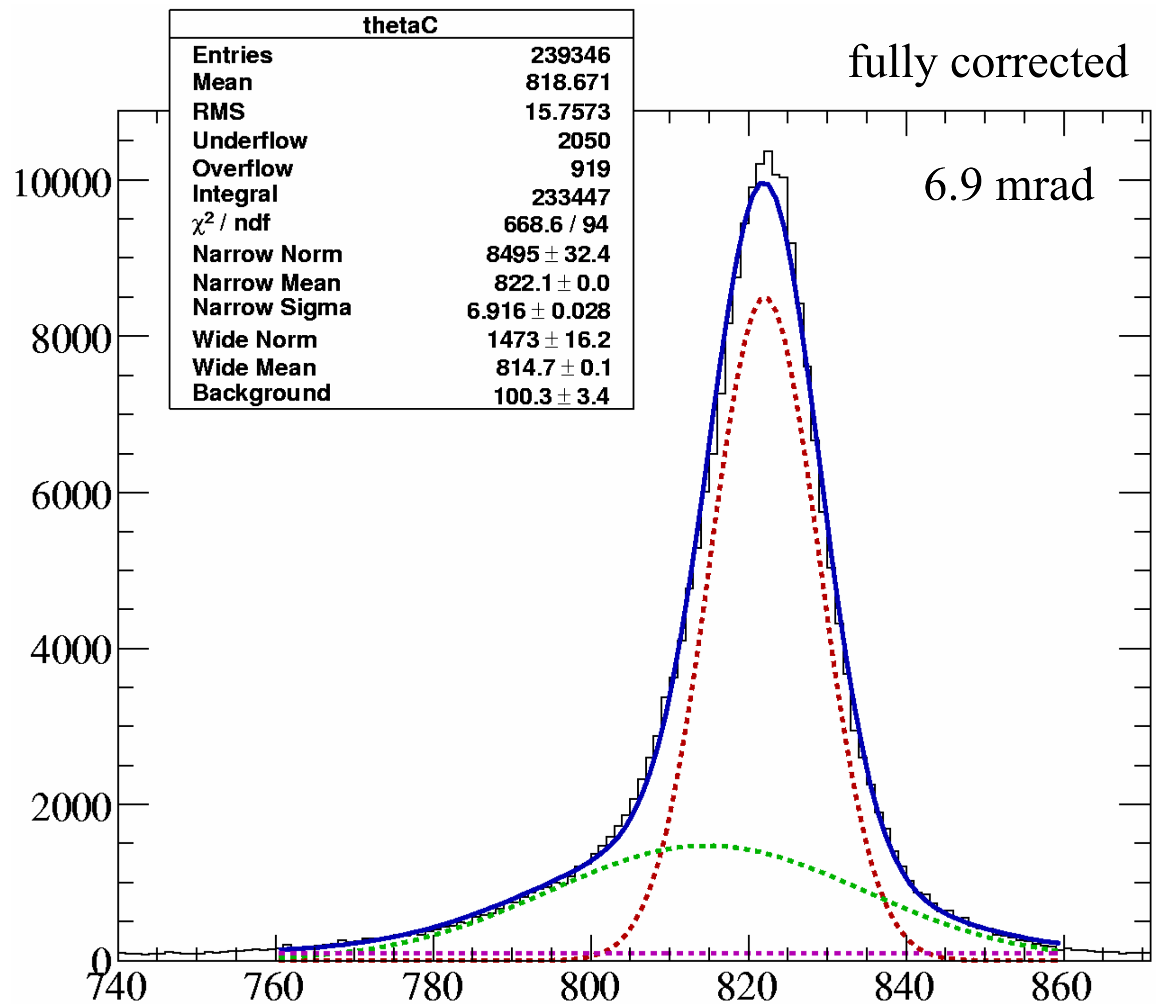


fully corrected thetaC

example: position 1 (run 22), all slots, indirect photons
double-Gauss plus constant

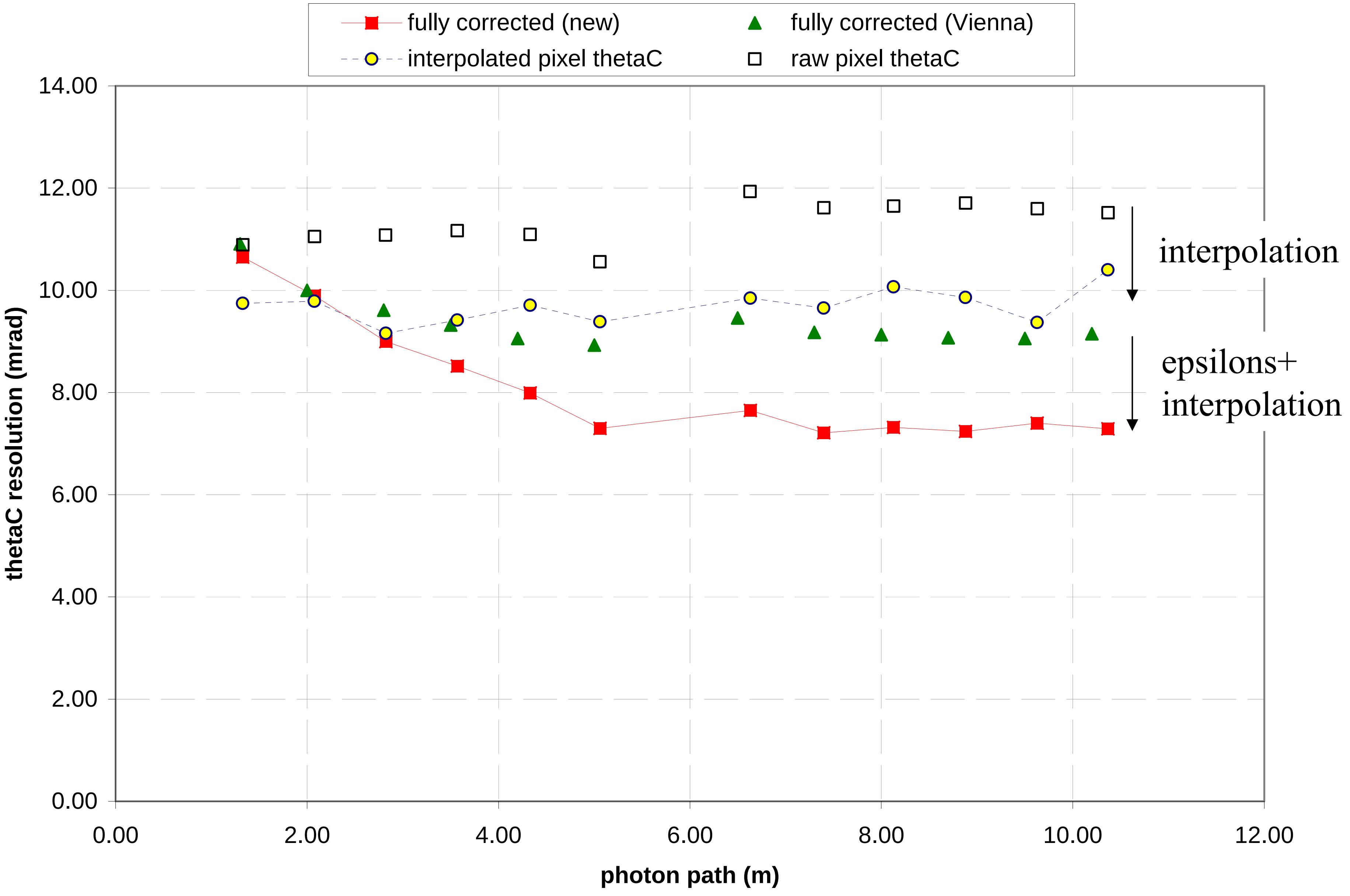
quote sigma of
narrow core Gaussian





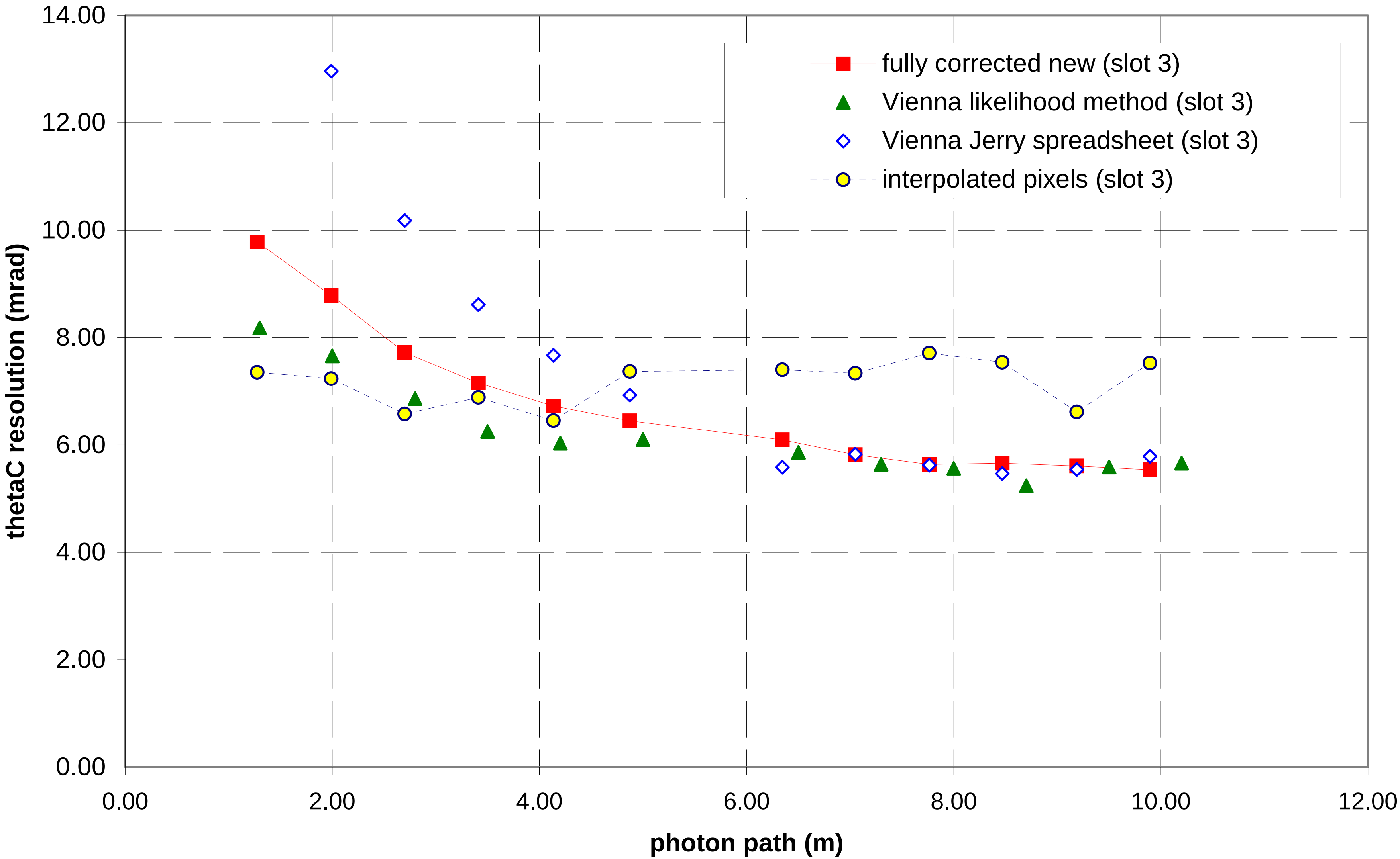
Comparison of thetaC as function of photon path for all slots combined

→ chromatic correction effective for path longer than 2-3 m.



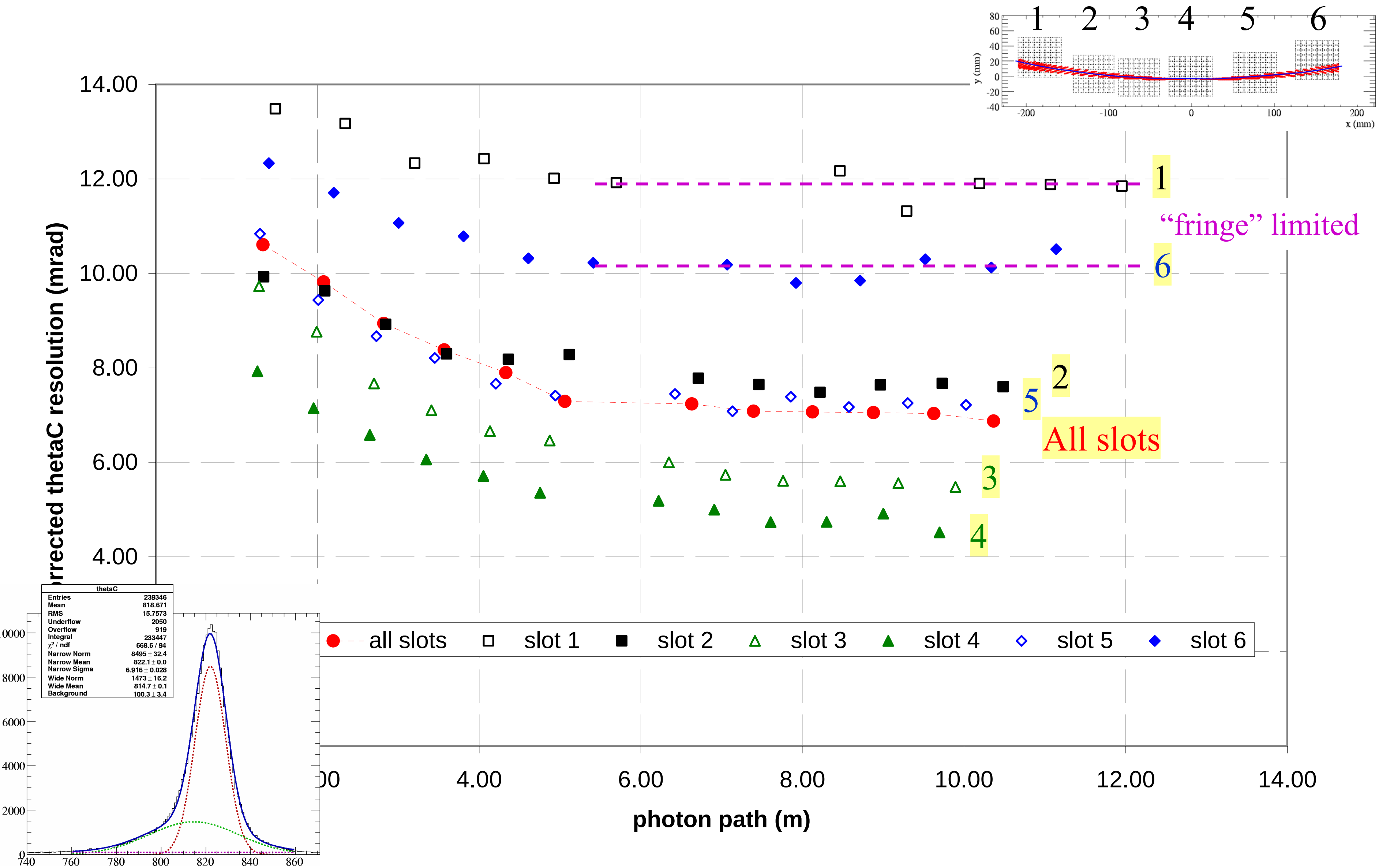
Comparison of thetaC as function of photon path for slot 3 only

→ chromatic correction effective for path longer than 3 m
new G4 simple correction works better than Vienna version
Jose's log-likelihood method works best below 4m path
for indirect photons all methods give same result



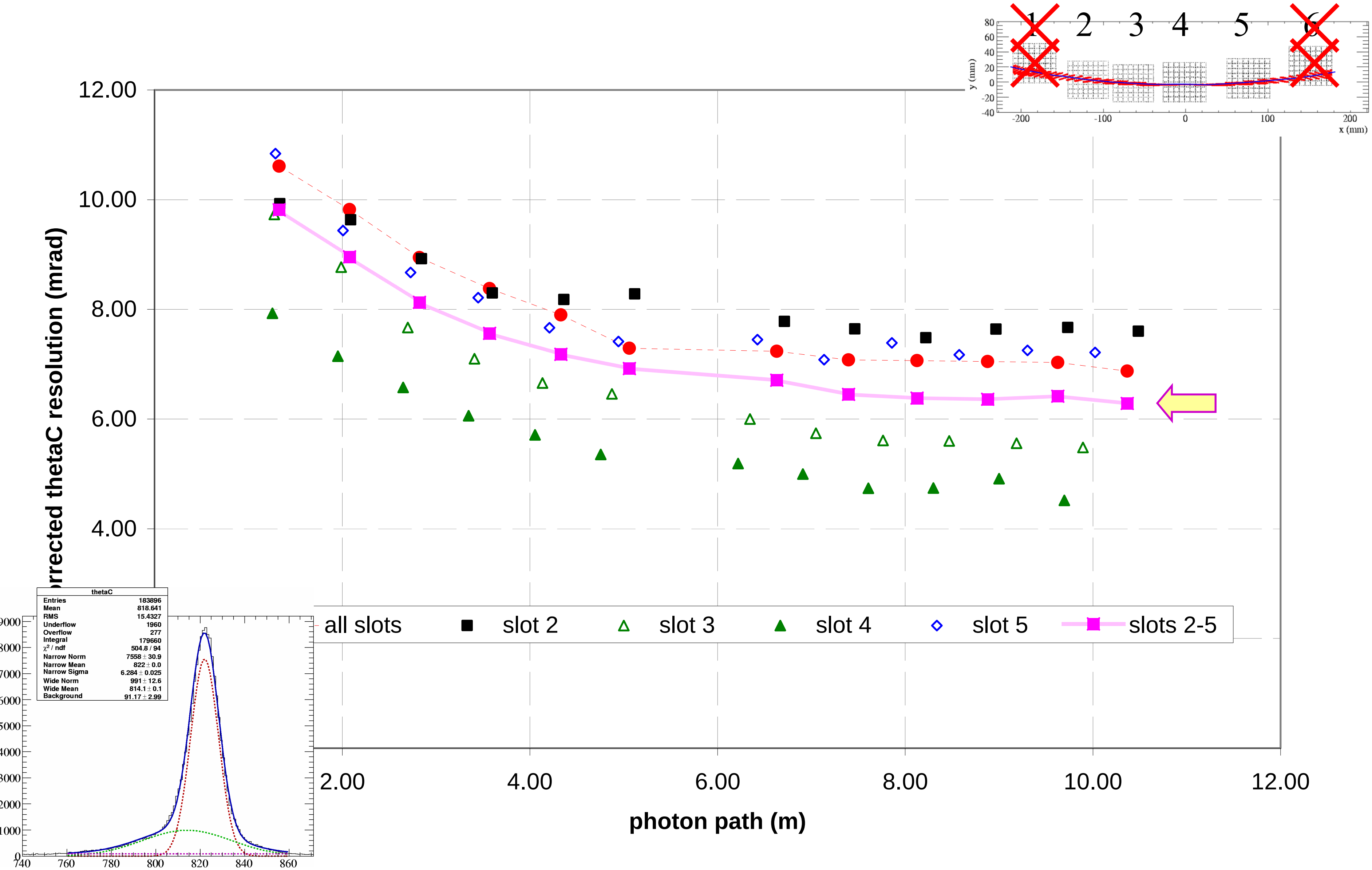
Fully corrected thetaC as function of photon path for each slot

→ if we get a handle on fringe issue we will improve overall resolution



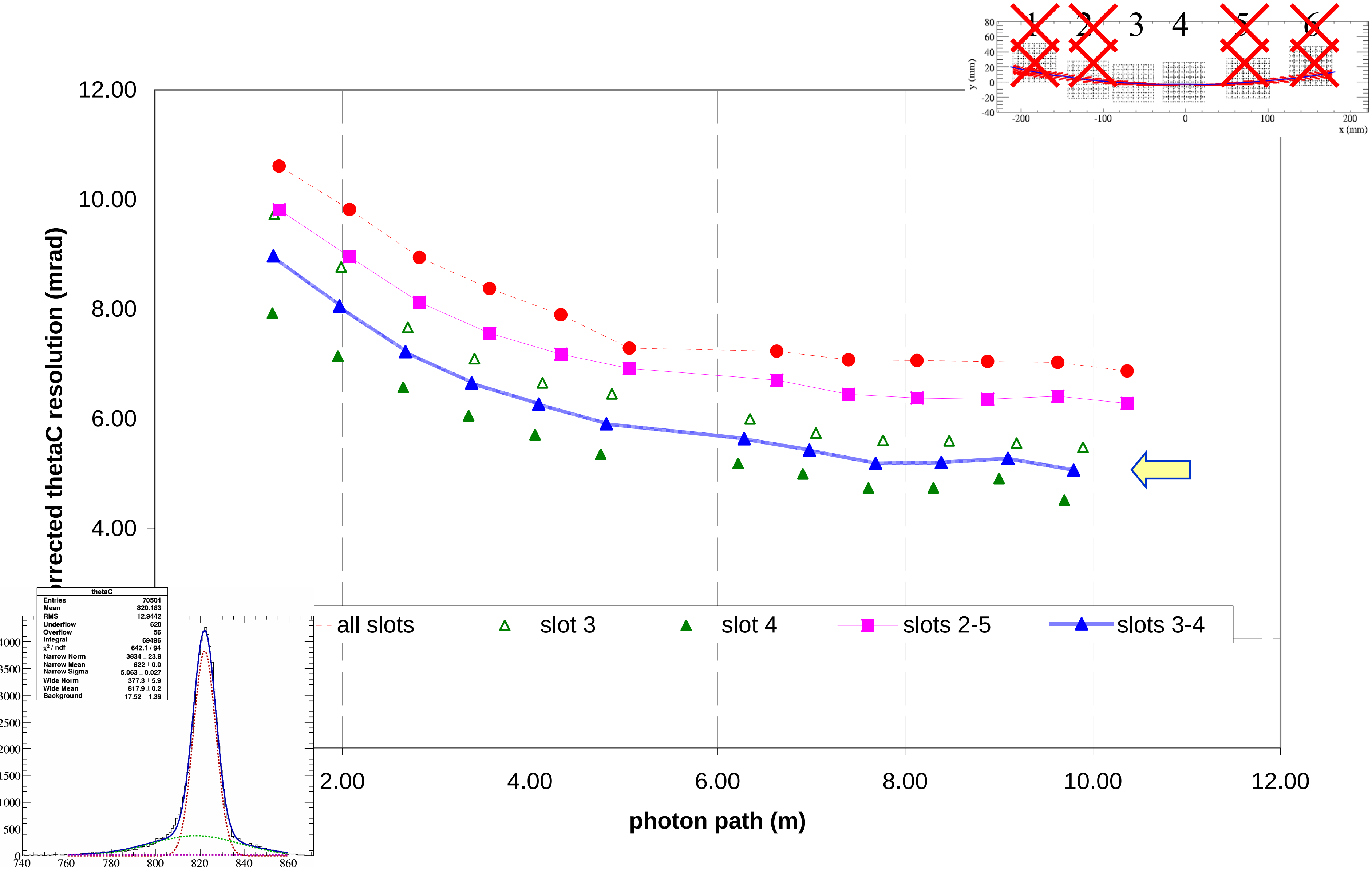
Fully corrected thetaC as function of photon path for each slot

→ approx. 1mrad improvement if we ignore slot 1 and 6
and reduced contribution from second Gaussian



Fully corrected thetaC as function of photon path for each slot

→ another 1-1.5mrad improvement if we use only slot 3 and 4
and further reduced contribution from second Gaussian



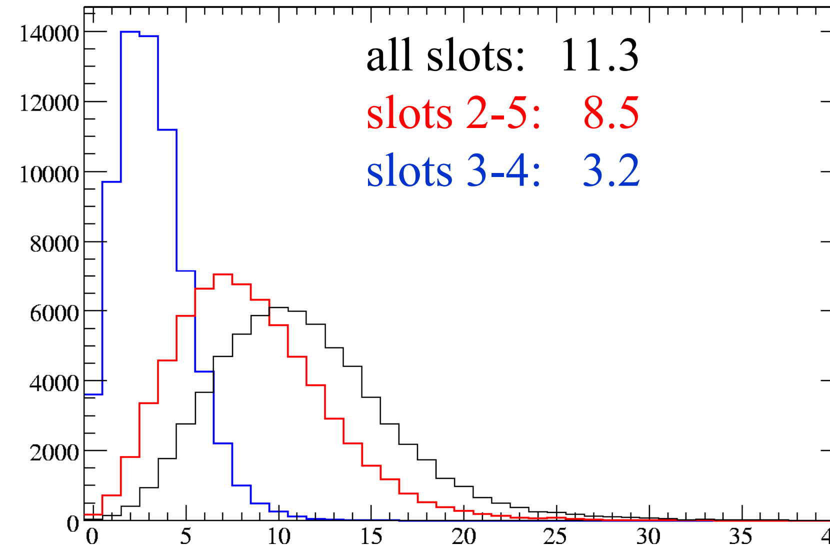
Photon statistics

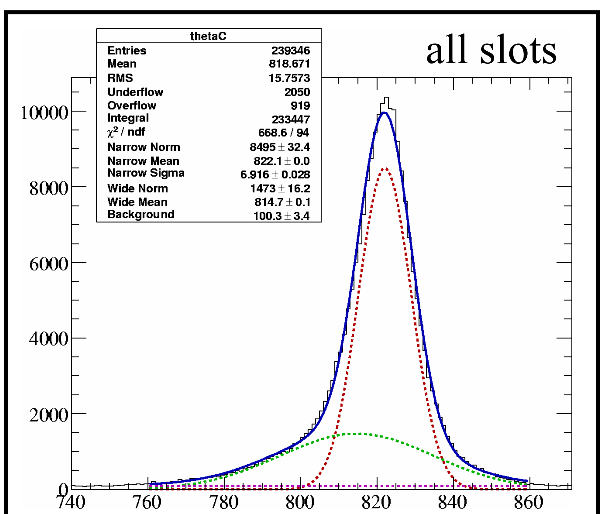
→ just for fun: if we restrict the acceptance to slots 2-5 (3-4) how many photons to we lose and what happens to the average resolution per event?

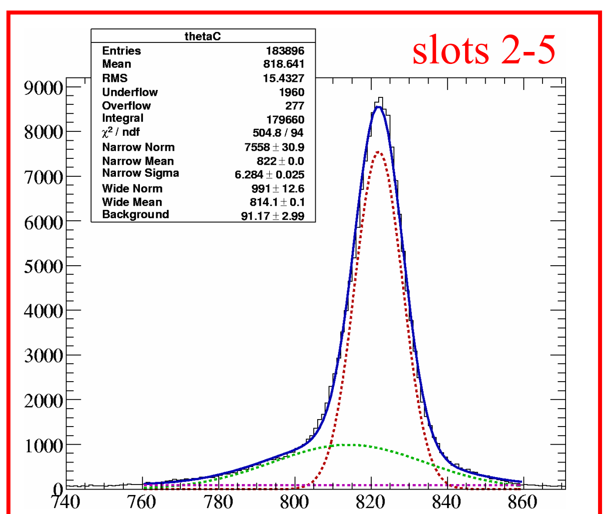
Example for position 1

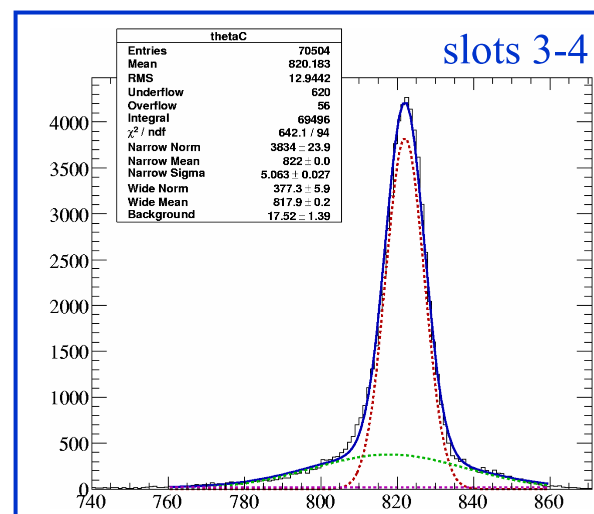
all slots: 7.3mrad/√11.3 = 2.17mrad
slots 2-5: 6.3mrad/ √8.5 = 2.16mrad
slots 3.4: 5.1mrad/ √3.2 = 2.85mrad

Many caveats: no charge-sharing accounting, I counted all hits, not just in time/thetaC window, no background correction, etc



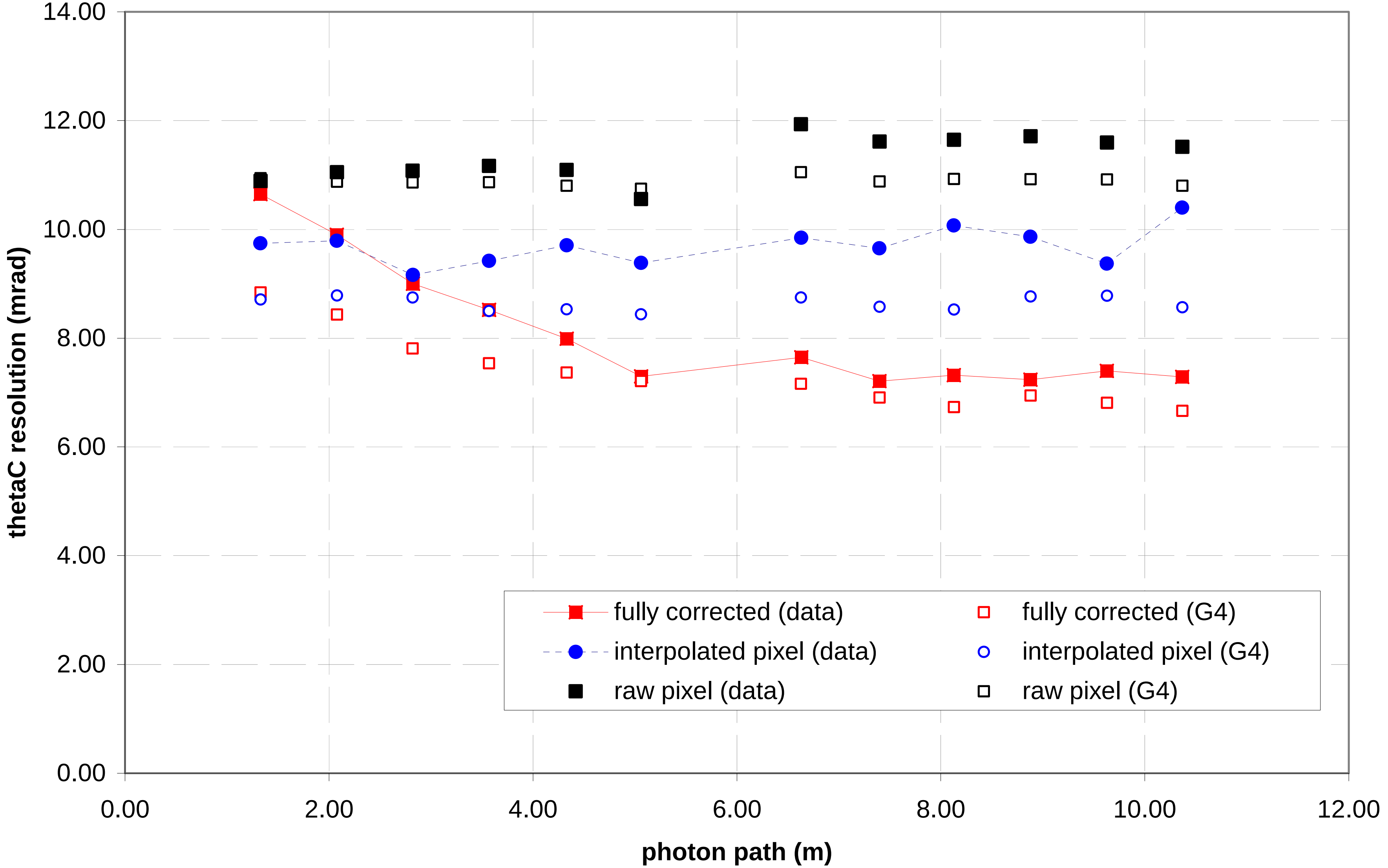






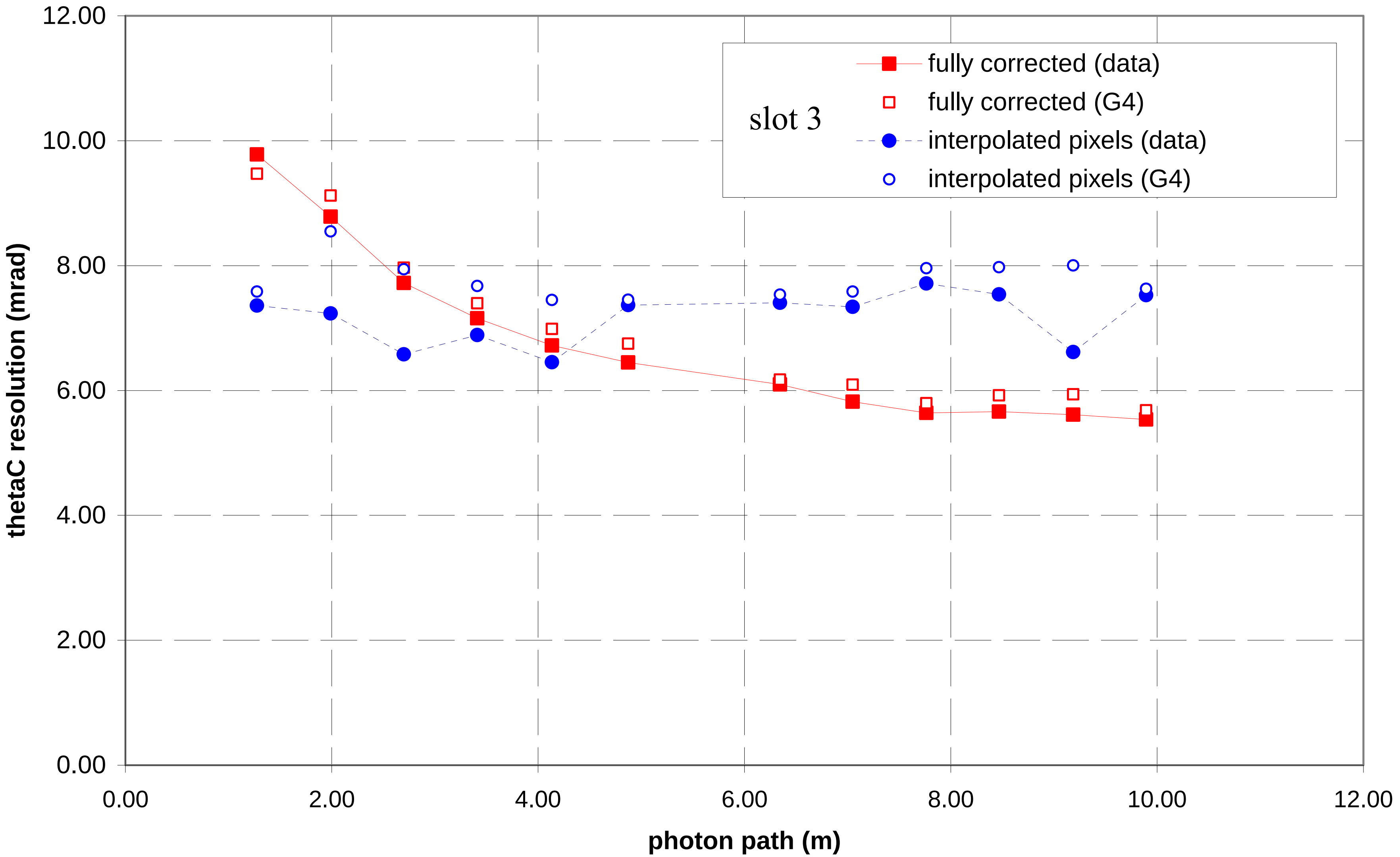
thetaC as function of photon path for all slots in data and Geant 4

→ good agreement for raw pixel and fully corrected thetaC values
do not understand why interpolated pixel results have bigger disagreement
than raw pixel results.



thetaC as function of photon path for slot 3 in data and Geant 4

→ good agreement



Summary

- interpolated pixel thetaC improve pixel results significantly, now close to expectation
- time and thetaC epsilons also make a difference
- reasonable agreement with Geant 4 analysis results

- results will improve further by using detailed ps/count calibration
- including Jose’s log-likelihood chromatic correction is technically challenging but probably worth the effort – will try to find the time
- charge-sharing treatment needed to help with resolution and N_0 measurement

- if an improved optics design can decrease contribution from fringes we can improve overall resolution