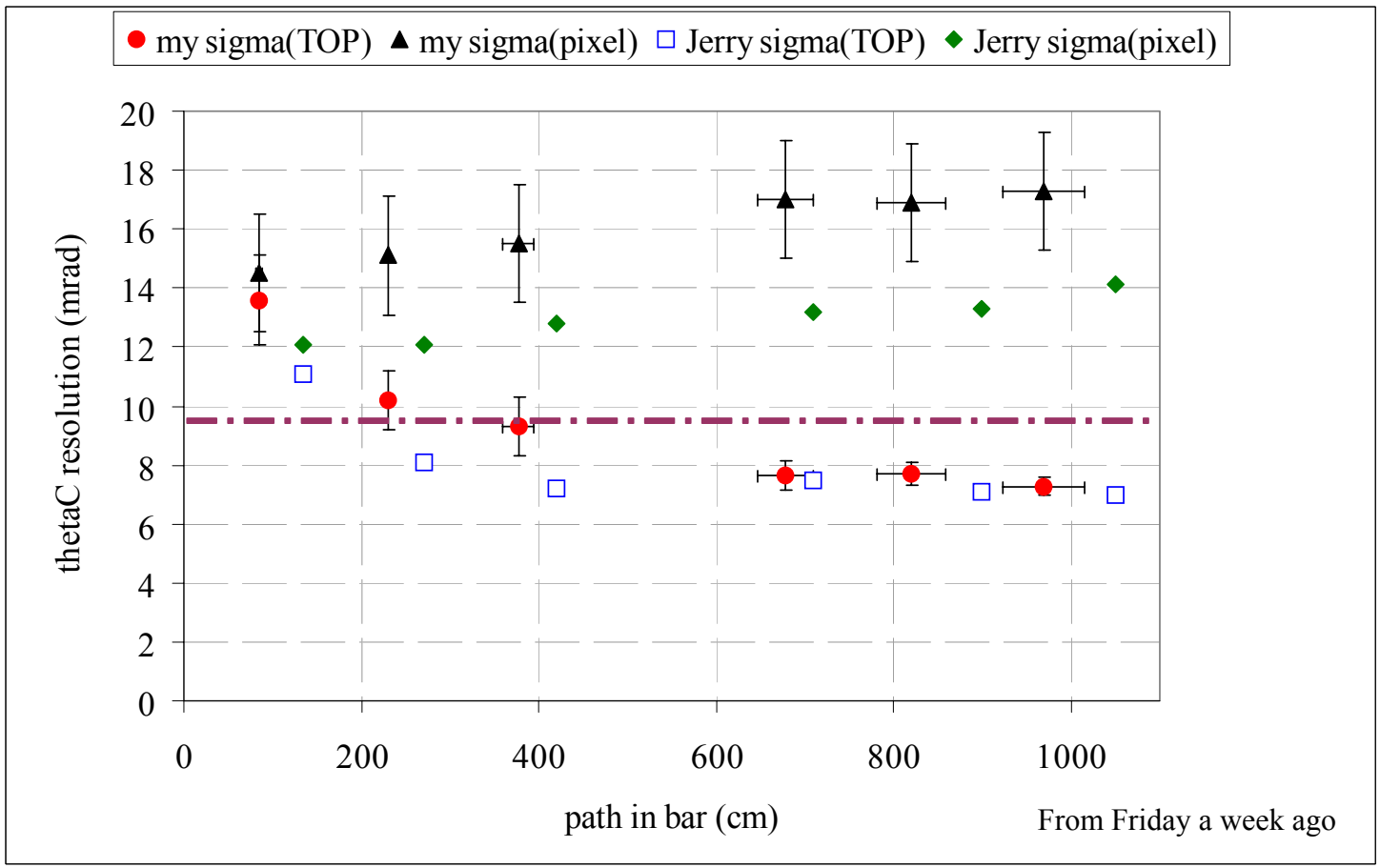
Worked this week on comparing my results to Jerry's and hunting for differences and bugs.

Main differences as of last week:

- pixel thetaC resolutions: mine were ~2mrad worse than Jerry's
- TOP thetaC resolutions agreed at long paths (7.0-7.5mrad) but mine were ~2mrad worse at short paths.

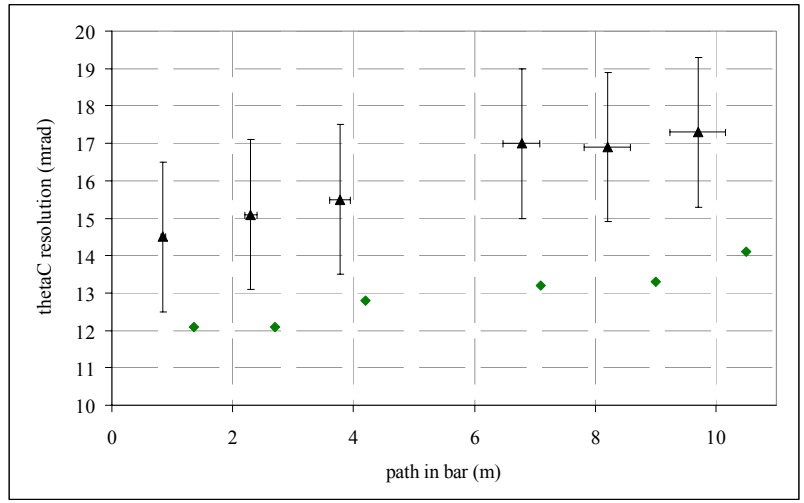
Also noticed after last week's meeting that Jose's pixel thetaC resolution is close to my values but his TOP thetaC resolution is better than Jerry's or mine: around 5-6mrad at longest path.

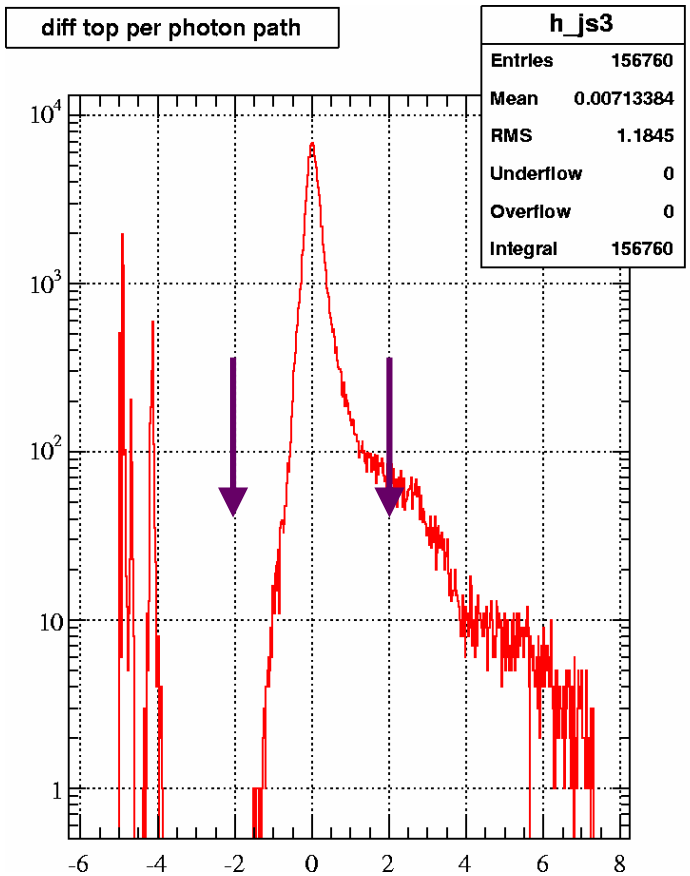


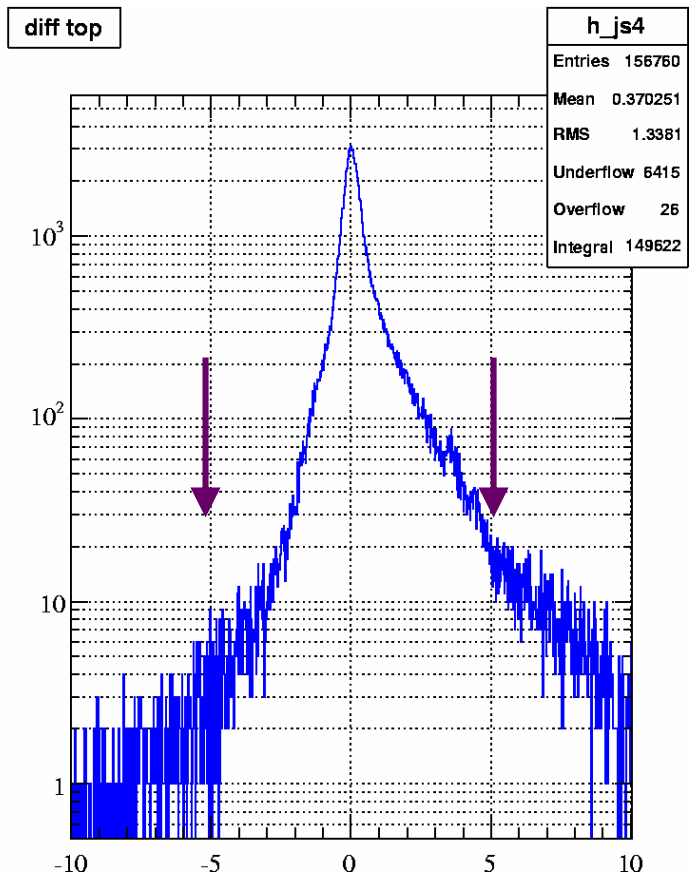
Investigated the cause of the differences in the pixel thetaC resolutions that Jerry and I see.

Went through Jerry's code on /u4/jjv/pos1_run12b
Jerry uses cuts on time differences for each pad:

- abs of (meas-exp TOP)/path <2 ns/m
- abs of meas-exp TOP < 5ns







The time cuts only remove ~10% of the hits
but they have a big influence on the
thetaC pixel resolution

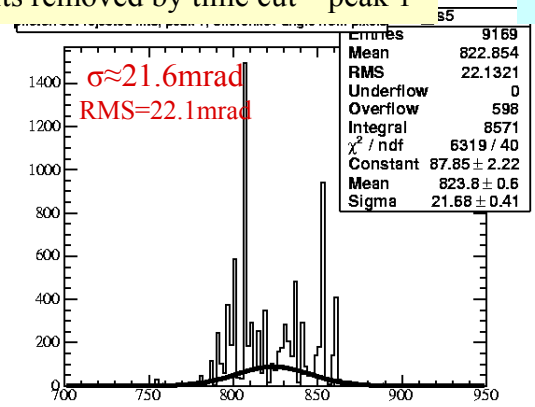
But those 10% are mostly off-ring (the time cut filters
efficiently) and therefore influence a
single-Gaussian fit strongly

Once this cut is removed, Jerry and I agree on the
pixel thetaC resolutions

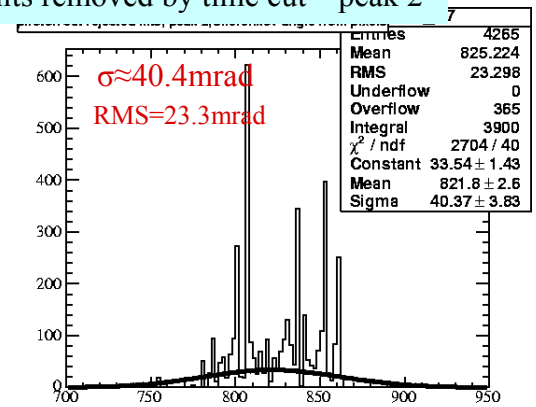
That does not mean that this cut is bad – we just need to be
aware of it, study, tune, and understand it better.

For now I don't use any cut on either quantity.

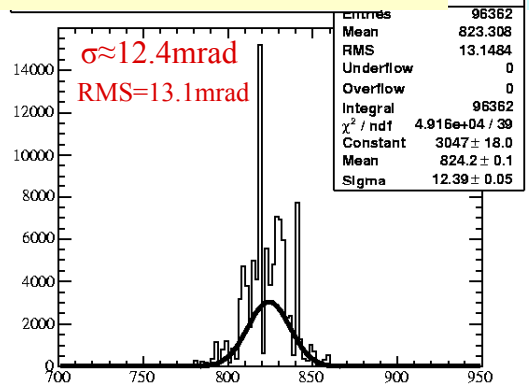
hits removed by time cut – peak 1



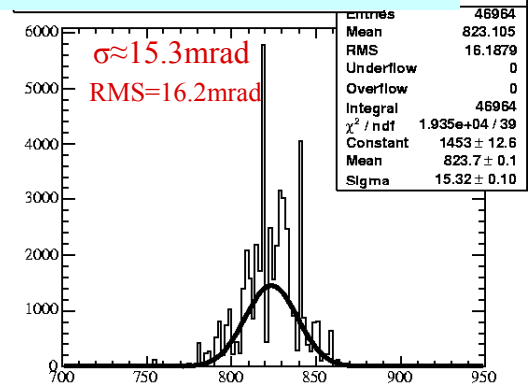
hits removed by time cut – peak 2



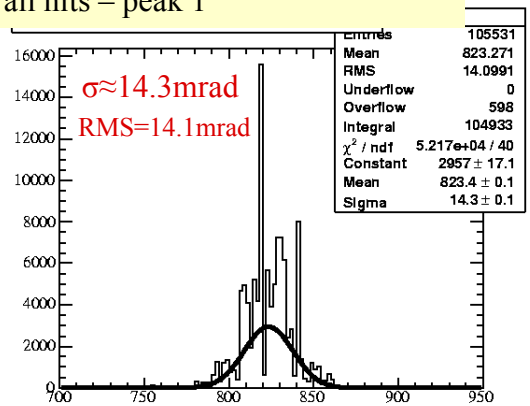
hits selected by time cut – peak 1



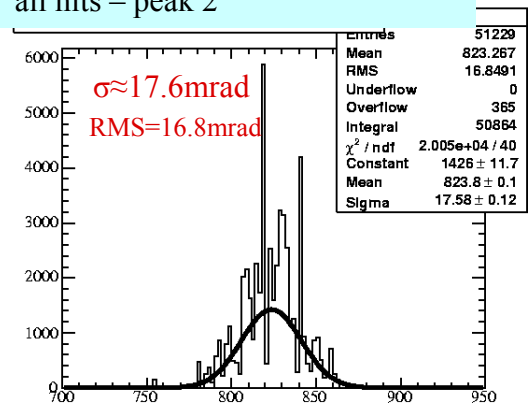
hits selected by time cut – peak 2



all hits – peak 1

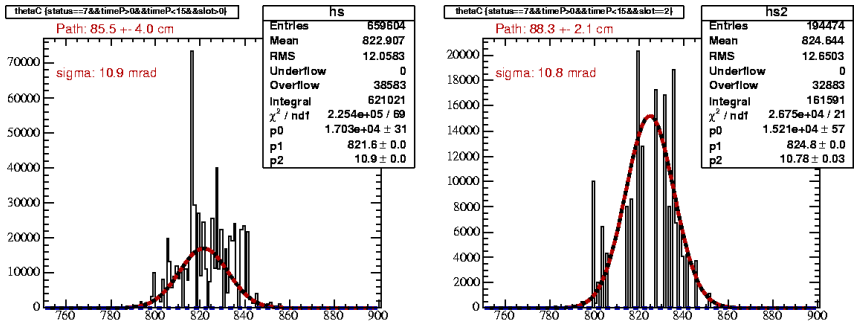


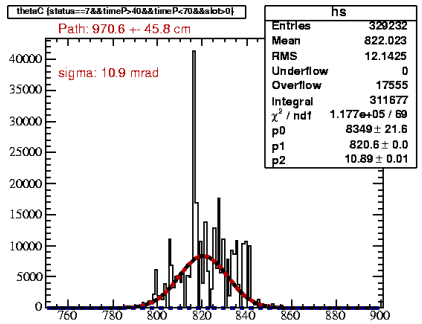
all hits – peak 2

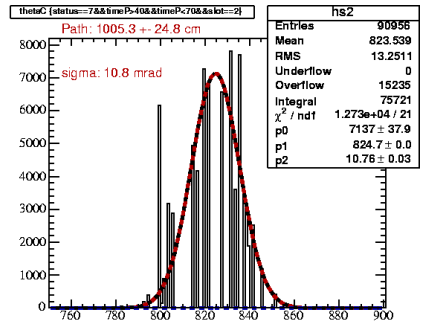


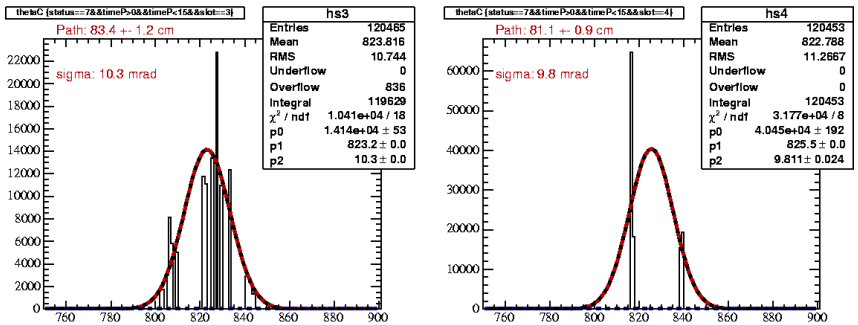
Fits to pixel thetaC for each slot in GEANT4 and in all data runs

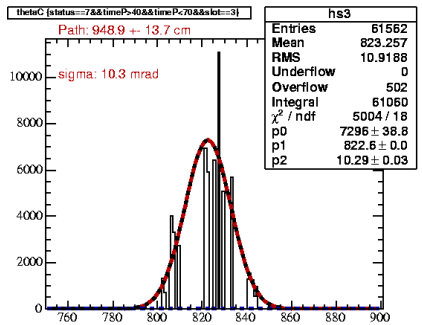
GEANT 4 peak 1 and peak 2, Gauss plus constant fitted.

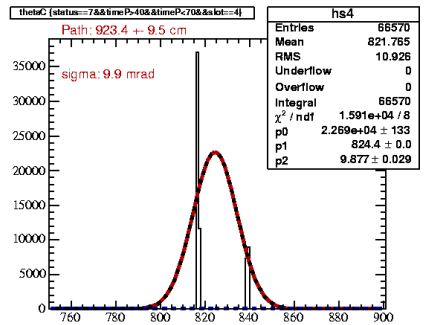


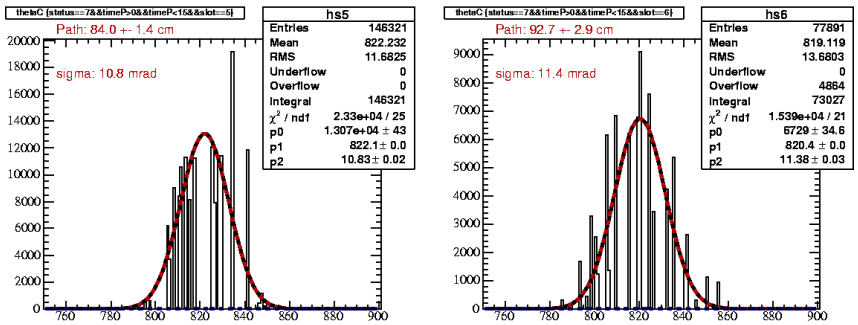




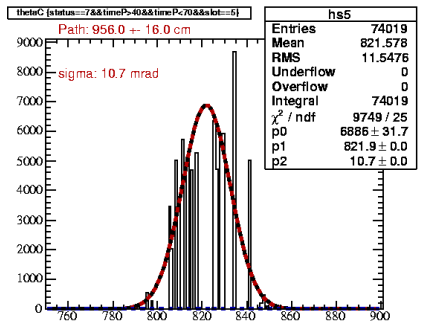


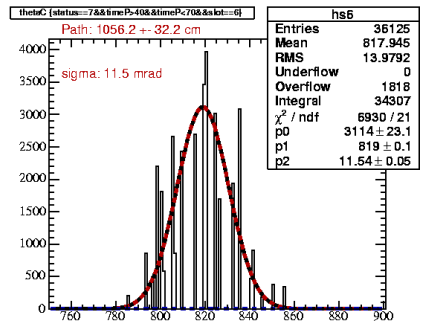






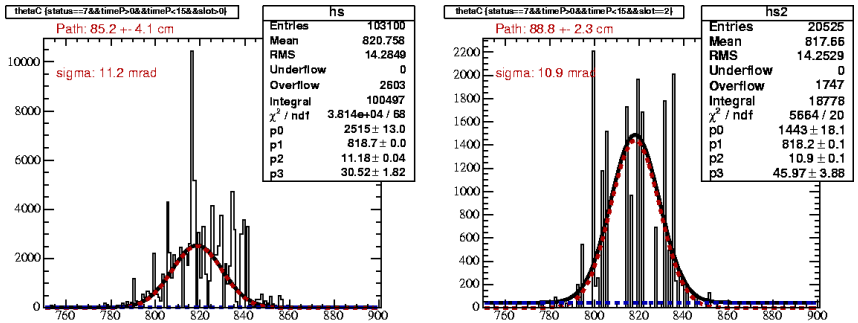
GEANT4 position 1, first peak

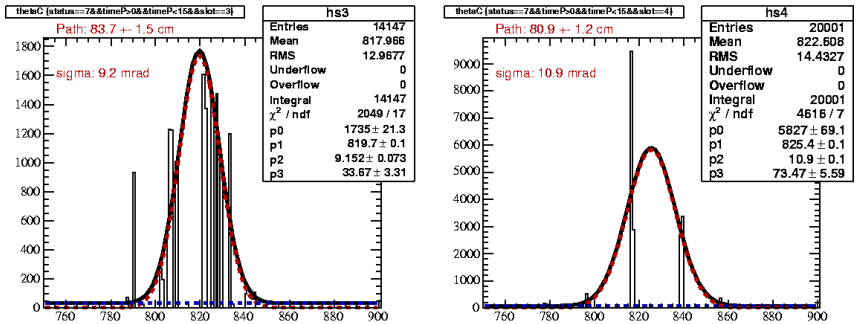


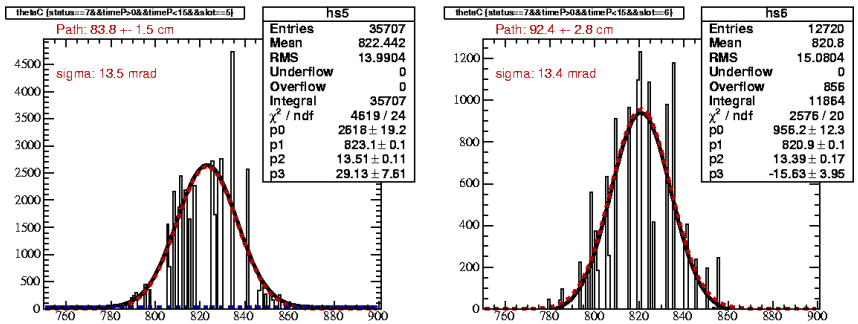


GEANT4 position 1, second peak

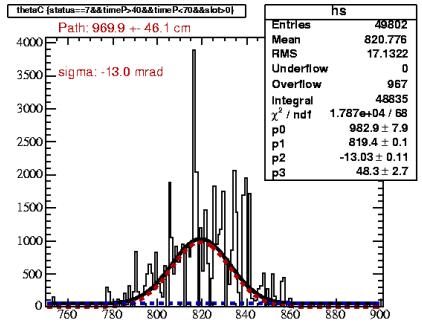
G+P0 fits to pixel thetaC for run 12b:

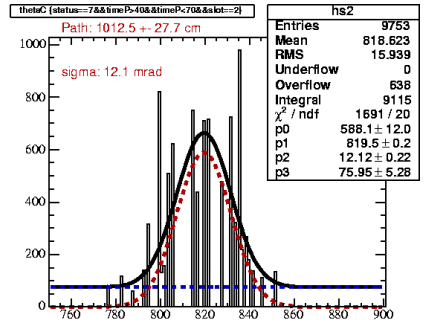


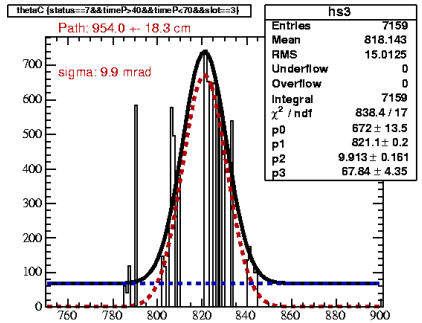


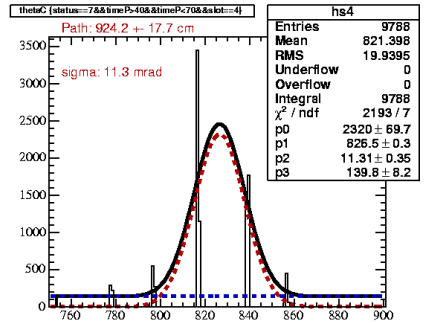


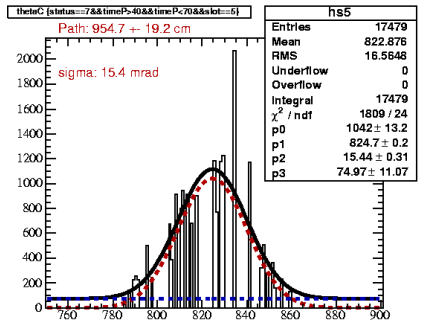
run 12b latest epsilons, first peak

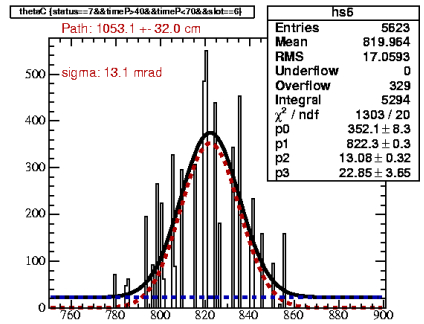






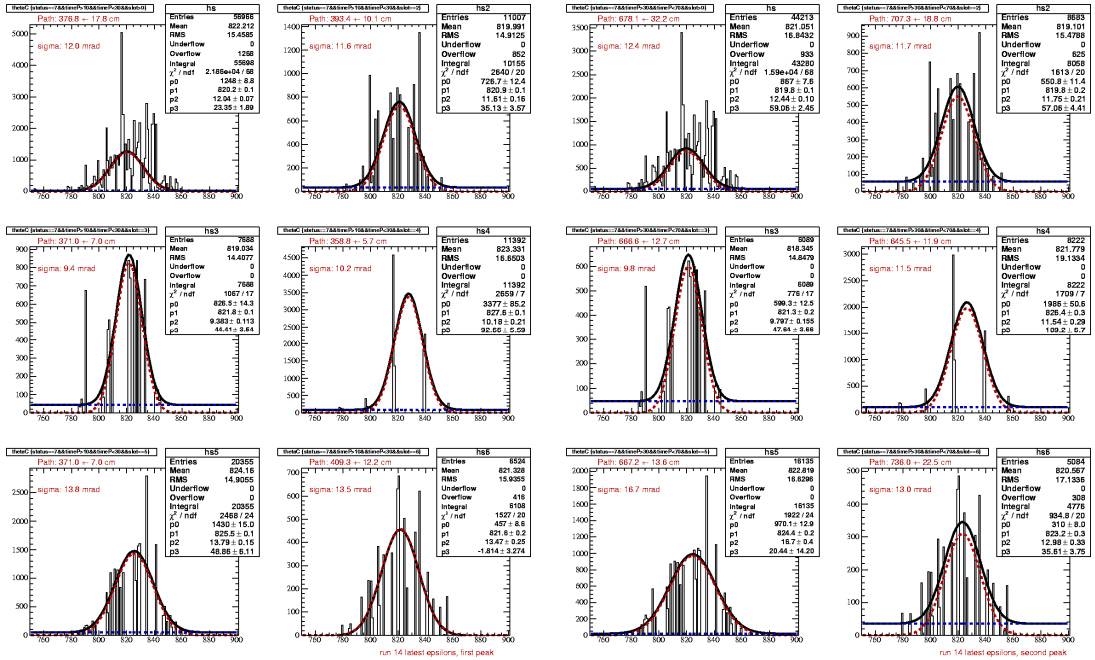






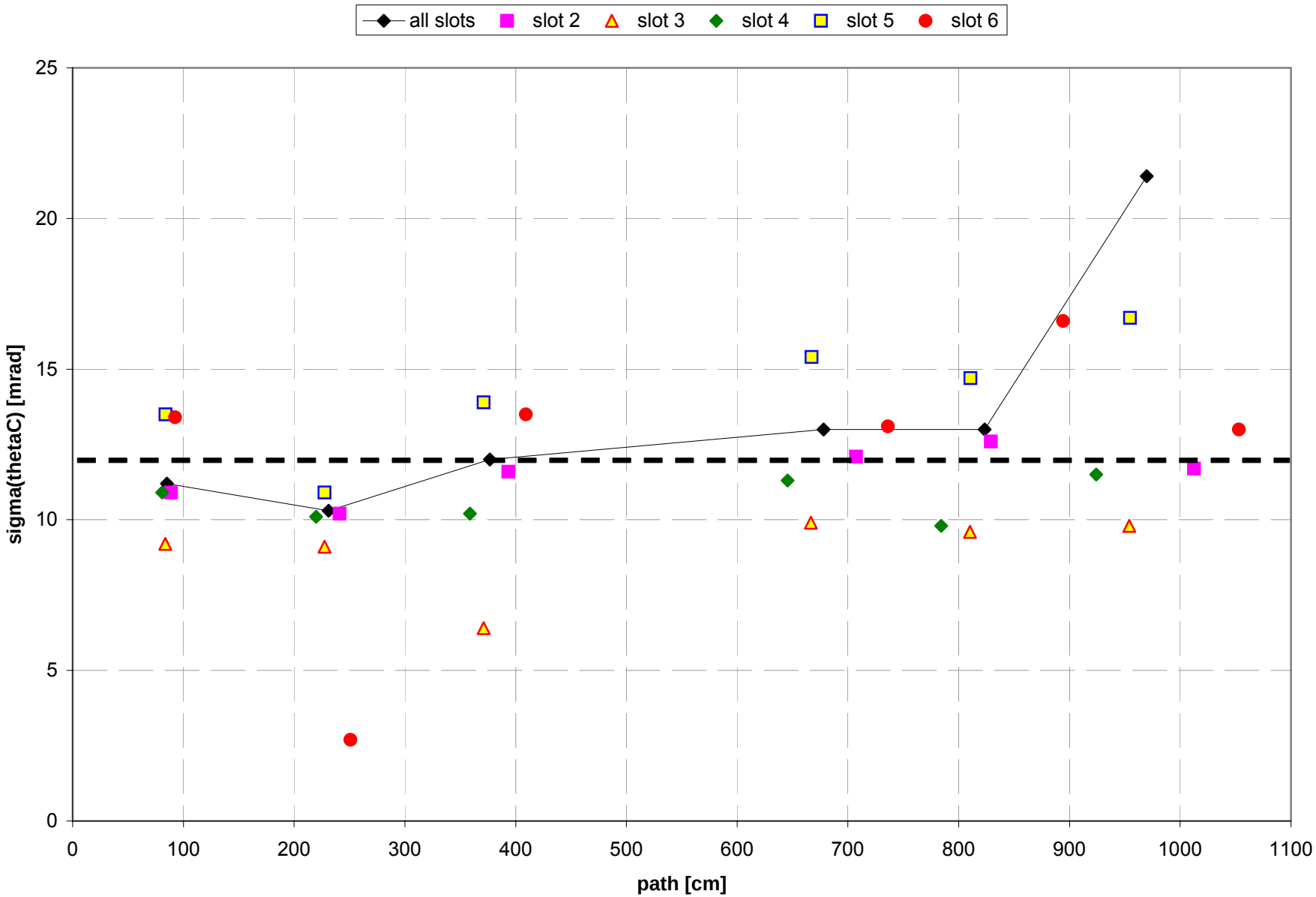
run 12b latest epsilons, second peak

G+P0 fits to pixel thetaC for run 14:



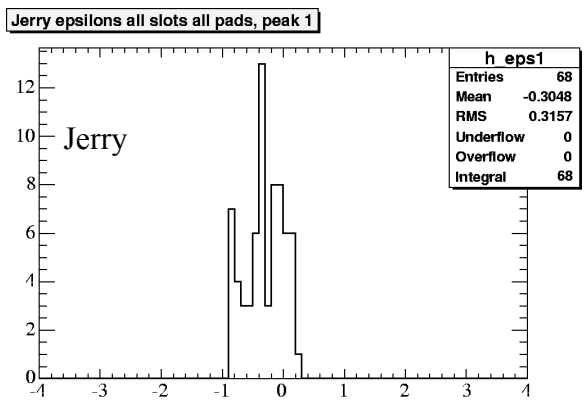
sigma (mrad)	peak1				peak2			
	run 12b	MC	run 13	run 14	latest	MC	run 13	run 14
slot 2	10.9	10.8	10.2	11.6	12.1	10.8	12.6	11.7
slot 3	9.2	10.3	9.1	9.4	9.9	10.3	9.6	9.8
slot 4	10.9	9.8	10.1	10.2	11.3	9.9	9.8	11.5
slot 5	13.5	10.8	10.9	13.8	15.4	10.7	14.7	16.7
slot 6	13.4	11.4	*2.7*	13.5	13.1	11.5	13.6	13
all slots	**11.2**	**10.9**	**10.9**	12	**13**	**10.9**	**13**	12.4

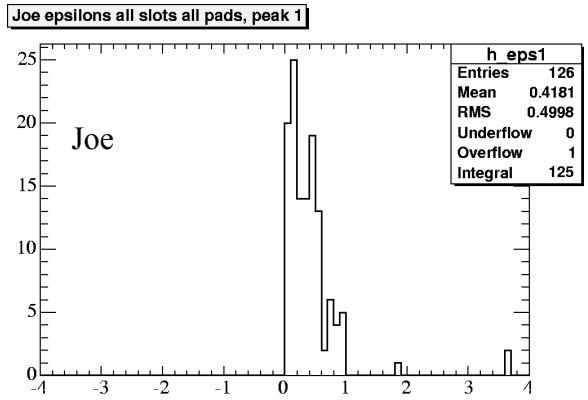
Comparison of latest thetaC(pixel) resolution in all slots

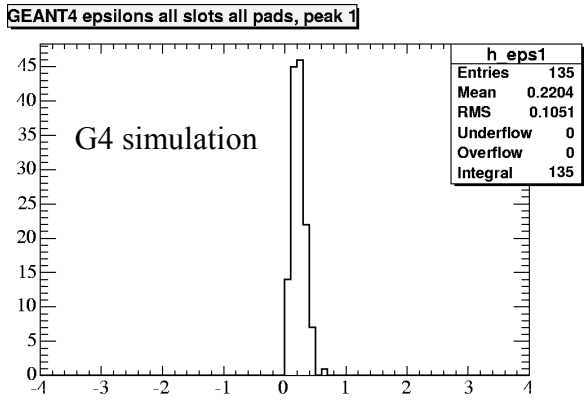


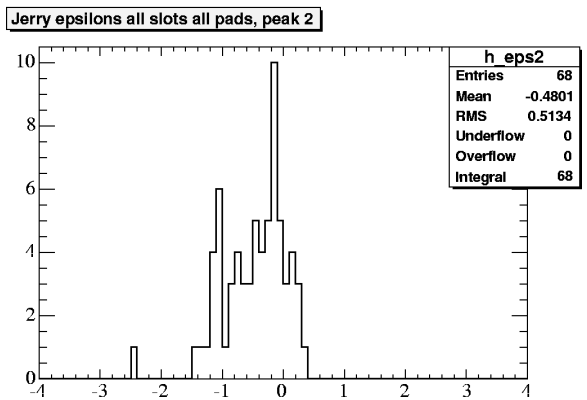
“epsilons” in G4 simulation

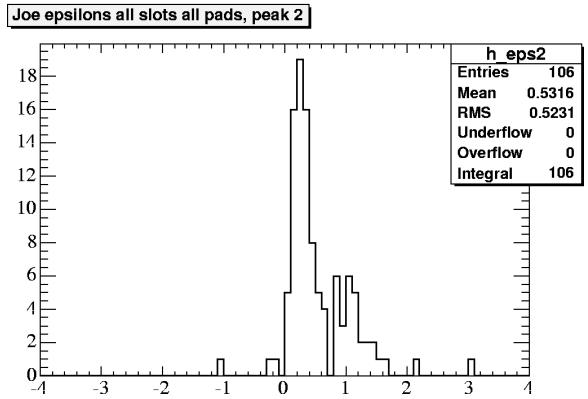
Looked at the latest G4 root file with charge sharing and ran with the variable lambda kBar angles. Then ran the usual peak 1/2 fits to determine my epsilons (using peak 1/2 kBar from variable lambda to determine $path_{exp}$ then assume λ=410nm to get TOP_{exp})
Clearly my G4 epsilons are not zero, in fact for peak 2 they are similar in size to data epsilons.
Conclude that my epsilons correct for wavelength dependence as well as the intended TDC calibration errors.

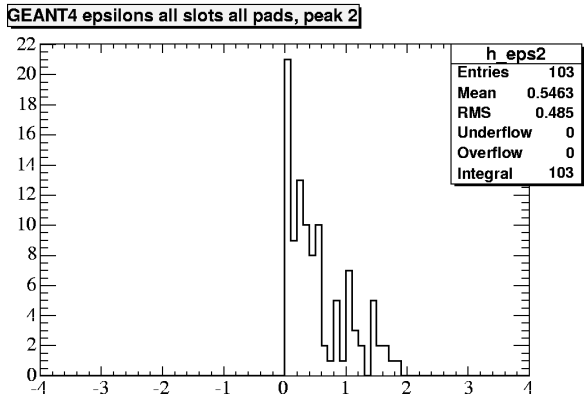












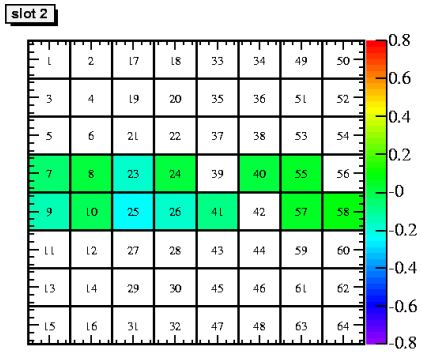
Projection of all epsilons, no offset applied.

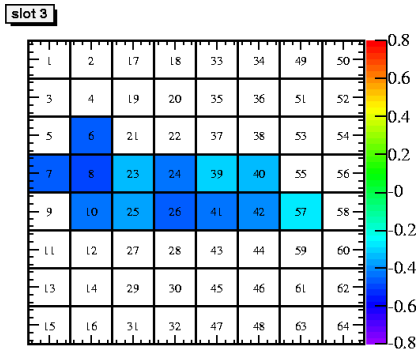
I tried a hybrid method for epsilons that combines my latest run 12b epsilons with the G4 epsilons.
The hope was that subtracting the G4 eps will eliminate the wavelength effects from the correction and reduce epsilons to a pure TDC calibration correction.

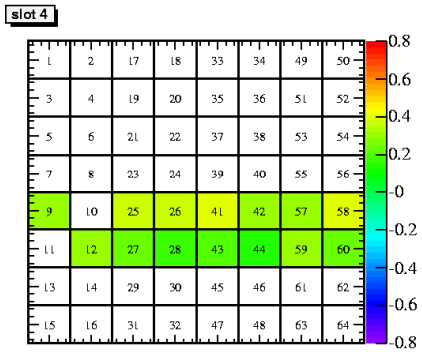
The deltaT and thetaC resolutions are clearly worse with such a hybrid method (not shown).

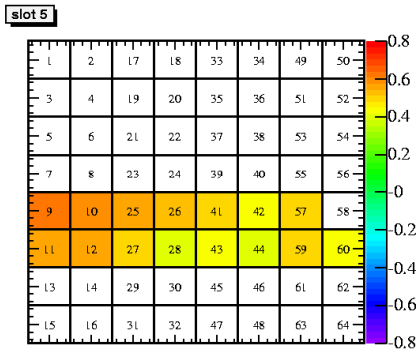
Another look at the epsilons.

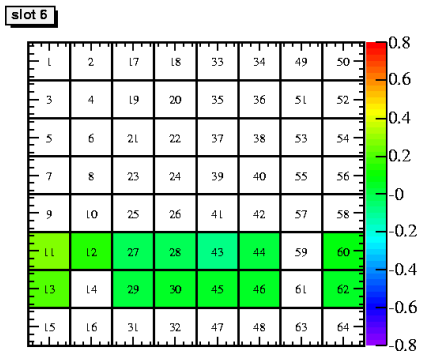
How do Jerry's run 12b values compare to mine and to GEANT4?





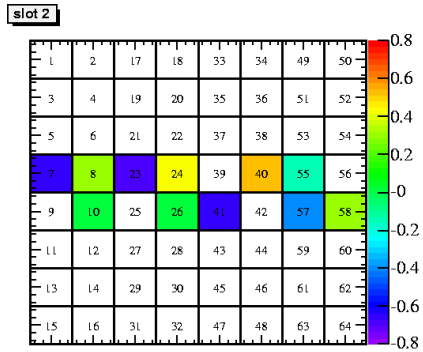


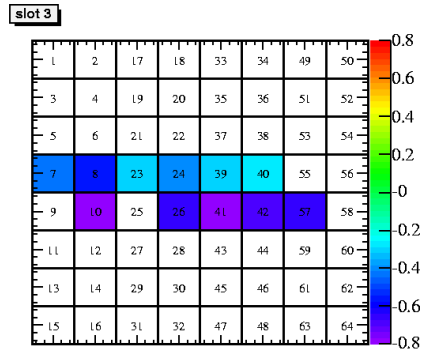


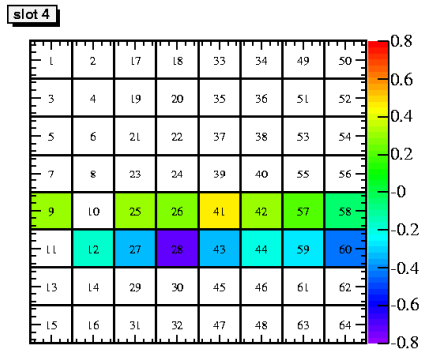


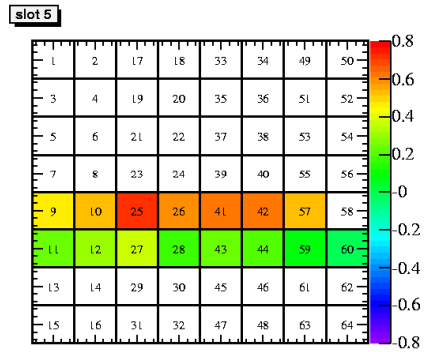
Jerry epsilons position 1

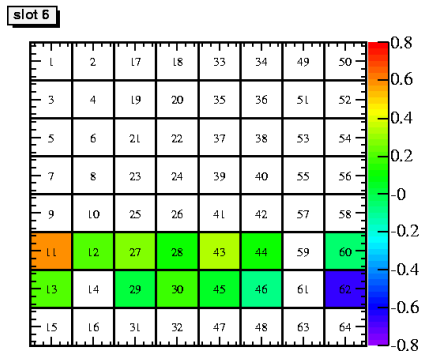
(peak 1: 0.4ns offset subtracted)





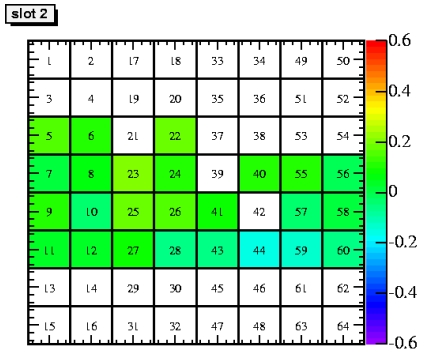


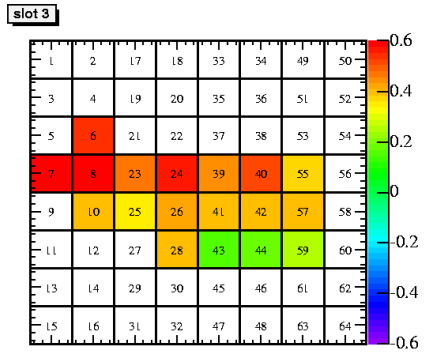


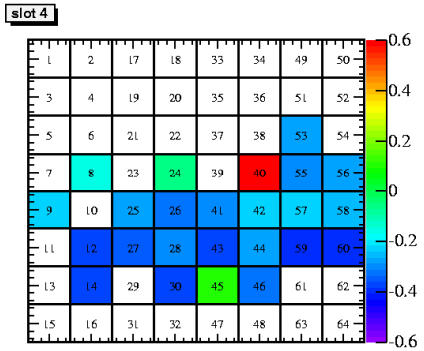


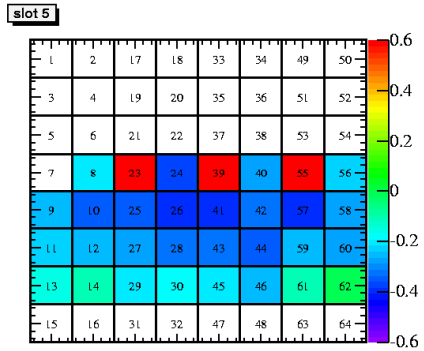
Jerry epsilons position 1

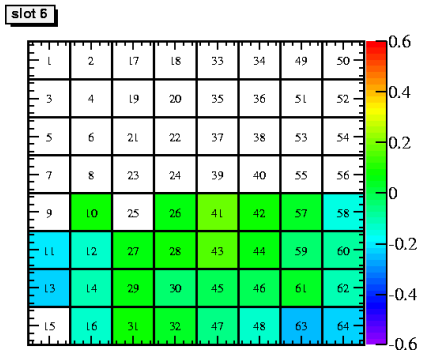
(peak 2: 0.4ns offset subtracted)





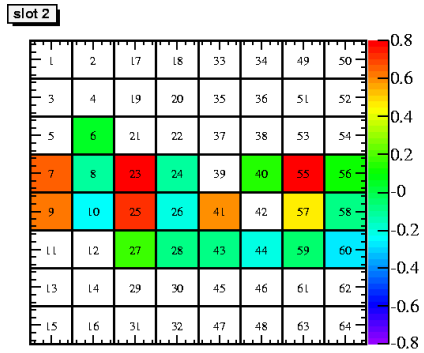


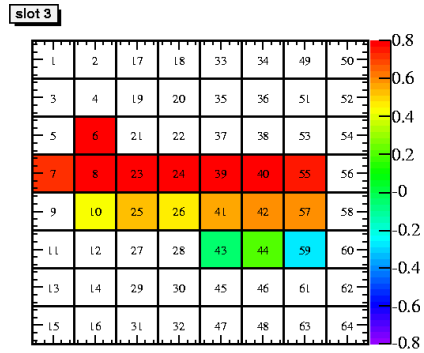


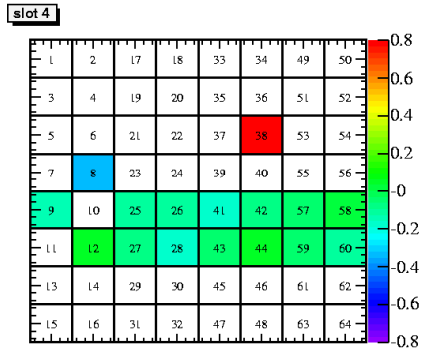


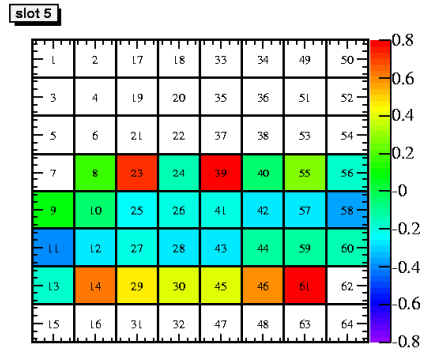
epsilons position 1

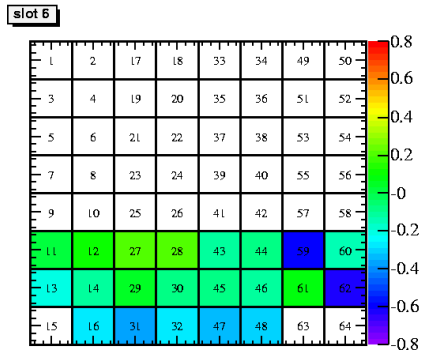
(peak 1: 0.4ns offset subtracted)





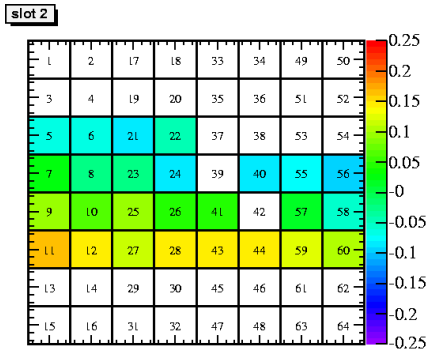


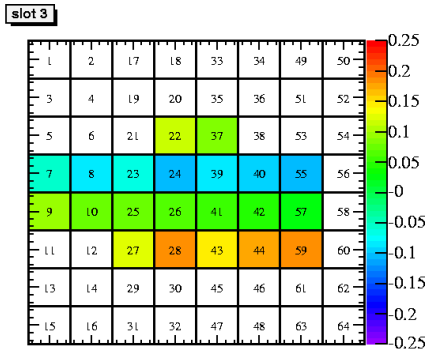


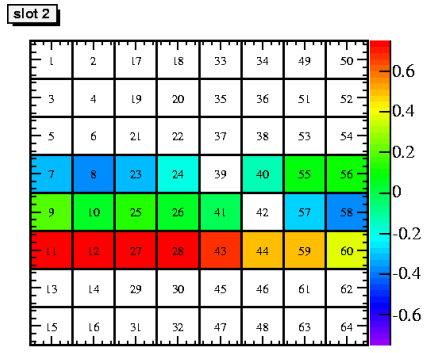


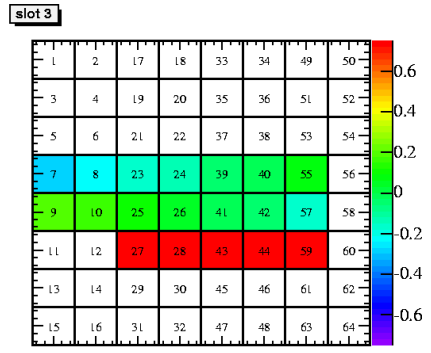
epsilons position 1

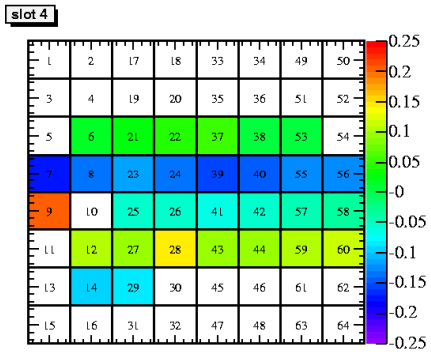
(peak 2: 0.4ns offset subtracted)

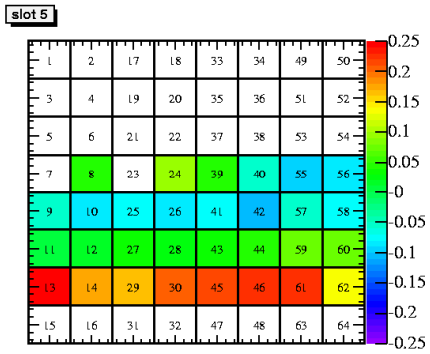


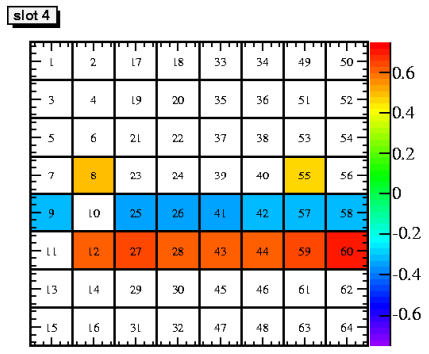


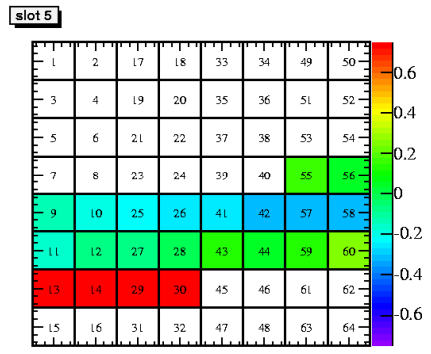


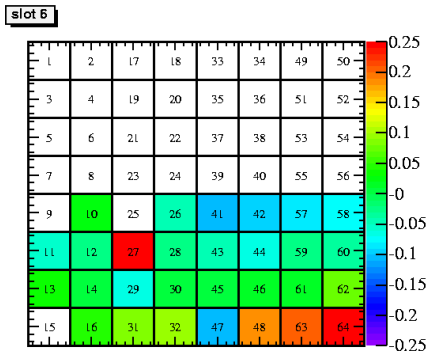






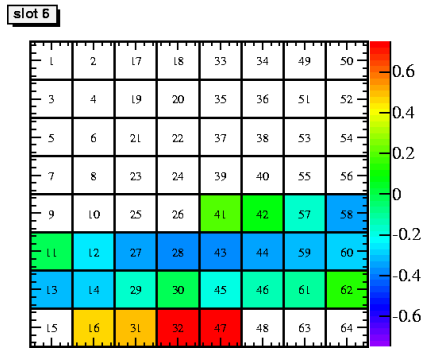






epsilons GEANT4 position 1

(peak 1: 0.2ns offset subtracted)



epsilons GEANT4 position 1

(peak 2: 0.4ns offset subtracted)

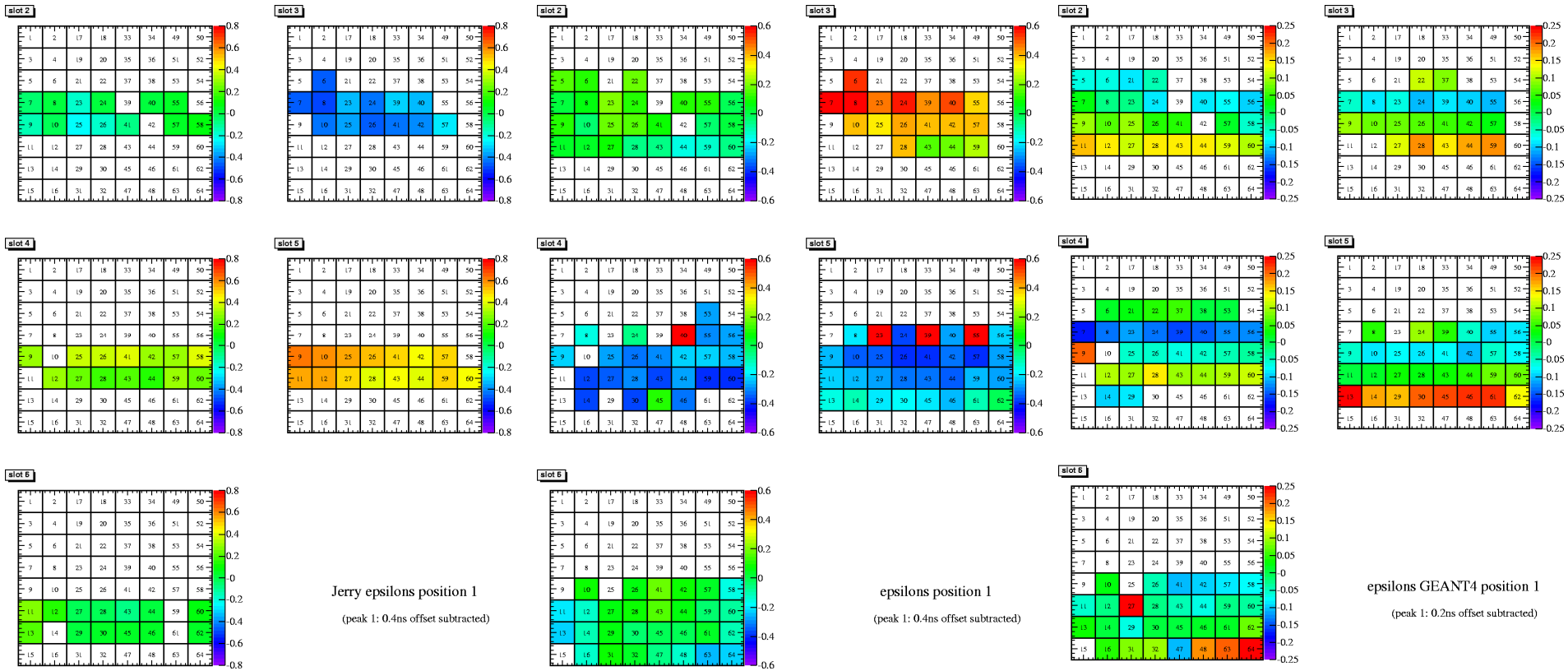
I found a bug in my own epsilons.

Curious: Jerry's epsilons are shifted to positive values for slot 5, negative for slot 3.
Note: after the meeting established that Jerry used GEANT $TOP_{expected}$(vari λ) for his epsilons while I use GEANT $kBar_{expected}$(vari λ) and assume <λ>=410nm to determine $TOP_{expected}$ Jerry's epsilons will definitely be less wavelength dependent.

That's opposite from what I find. I don't understand the difference in the method but I indeed flipped the sign.
Note: I need to repeat this analysis using the expected TOP from vari λ; Ivan will produce new TOP values.

When using the correct (flipped) sign the corrected time peaks are centered to within 20ps for most channels.

Therefore, I flipped the sign in my analysis code and promptly improved my thetaC(TOP) resolution very significantly.



Test the influence of the epsilons on the deltaT resolution per slot.

Comparing new eps, Jerry's old eps, and no eps.
(Note that fits are not great. Only peak 1 fits shown.)

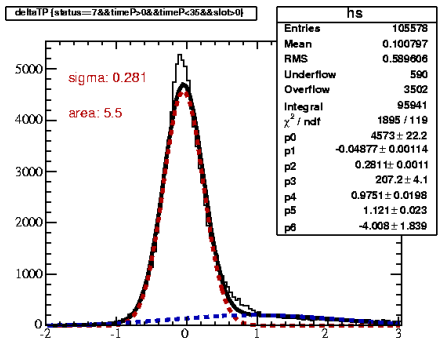
Naively I expect the resolution to improve as the eps corrects for
the performance limitation of the TDC calibration.

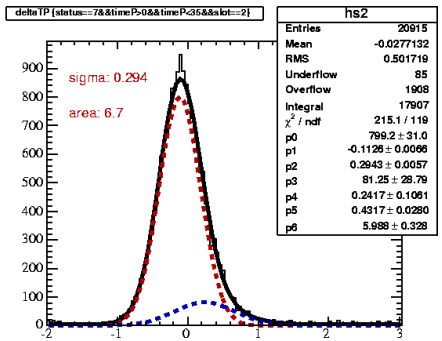
That appears to be mostly true but little effect of epsilons in some slots
and slot 5, peak 1 gets a little worse. Not sure why.

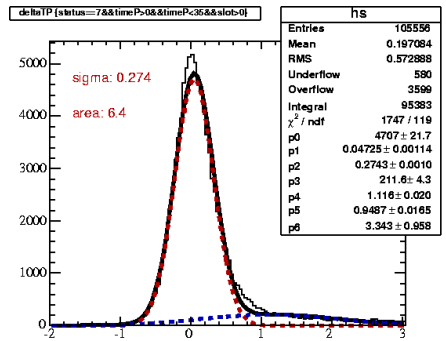
As usual, things don't seem to be that simple…

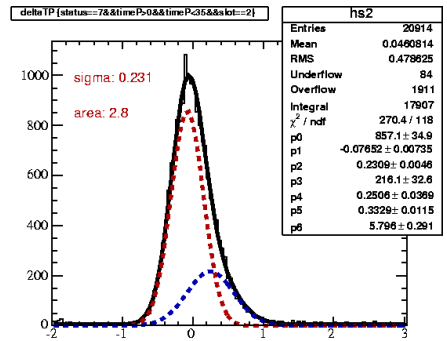
	peak1			peak2		
sigma (ps)	latest	Jerry	no	latest	Jerry	no
slot 2	231	294	231	955	1105	786
slot 3	297	365	289	702	800	872
slot 4	221	254	235	465	492	365
slot 5	244	221	210	756	949	788
slot 6	213	268	255	1052	1108	314
all slots	**274**	**281**	**469**	**664**	**743**	**824**

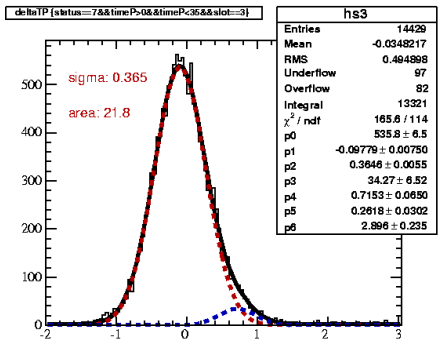
Comparison of deltaT for peak 1 with old epsilons and new epsilons.

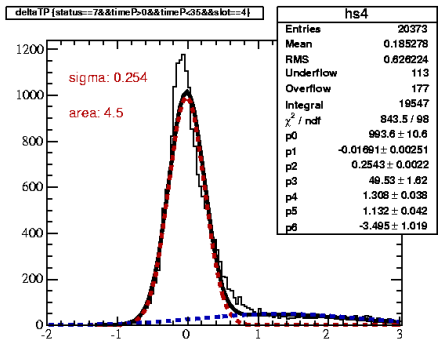


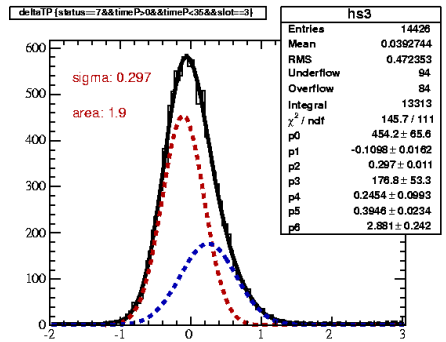


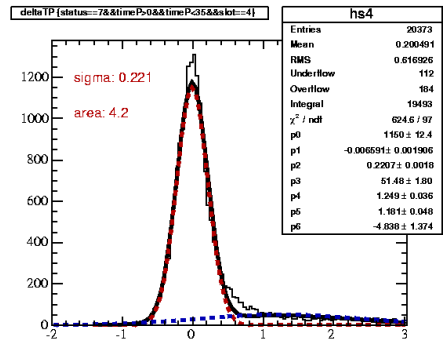


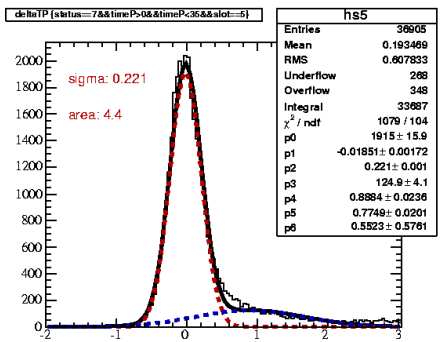


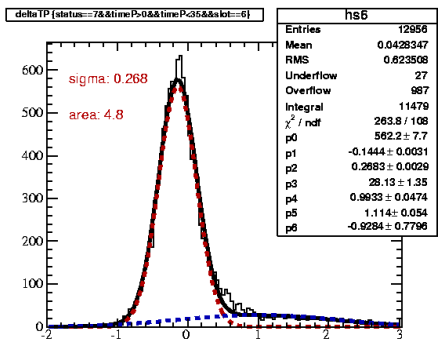




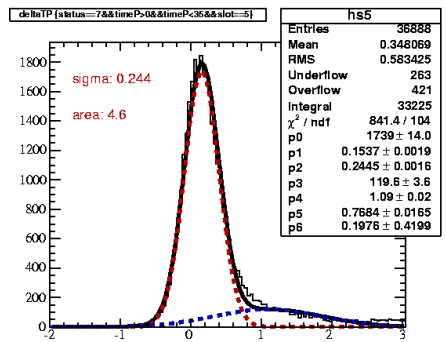


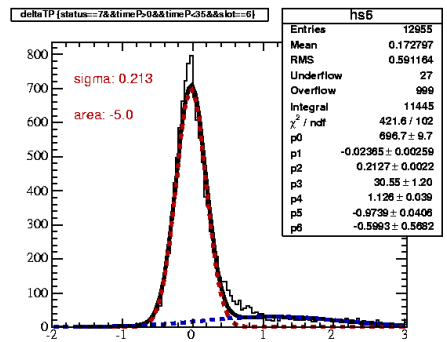






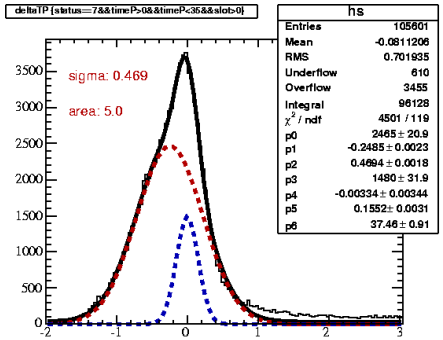
run 12b old epsilons, first peak

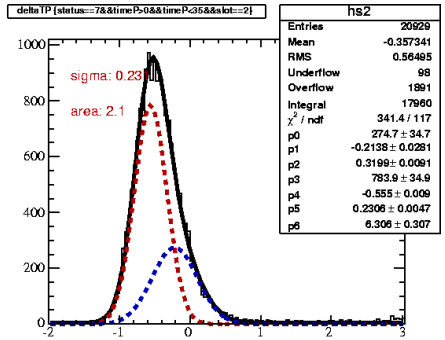


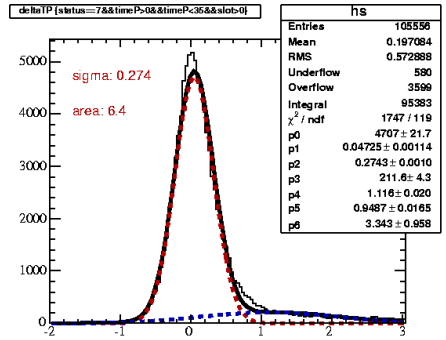


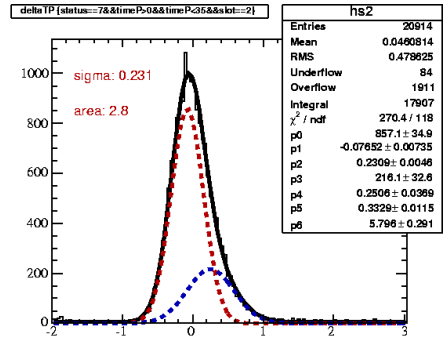
run 12b latest epsilons, first peak

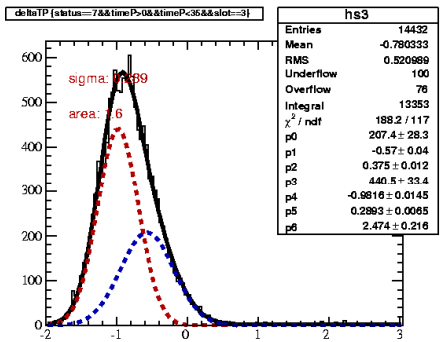
Comparison of deltaT for peak 1 with no epsilons and new epsilons.

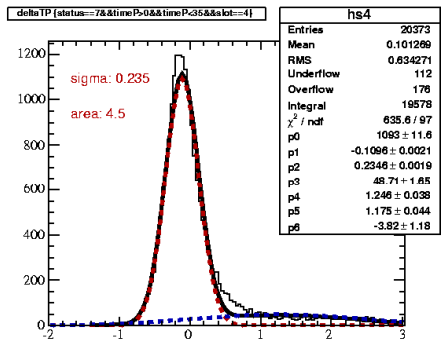


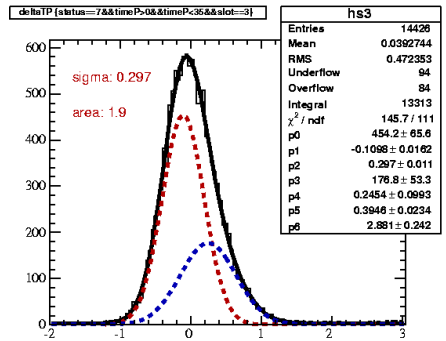


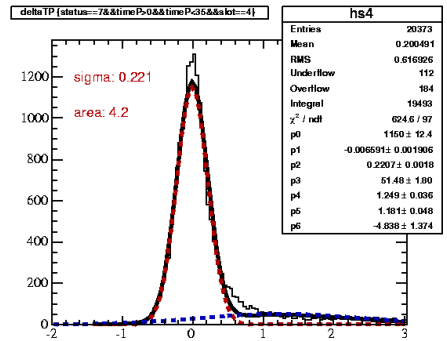


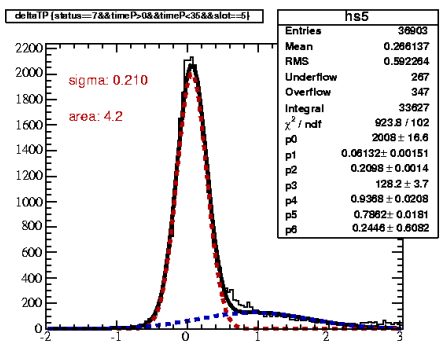


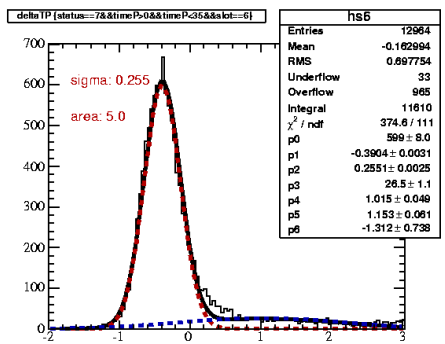




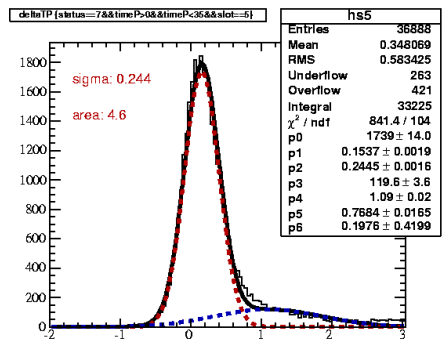


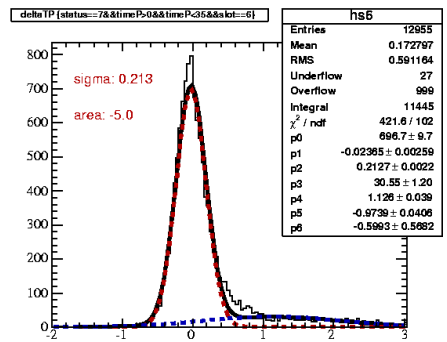






run 12b no epsilons, first peak



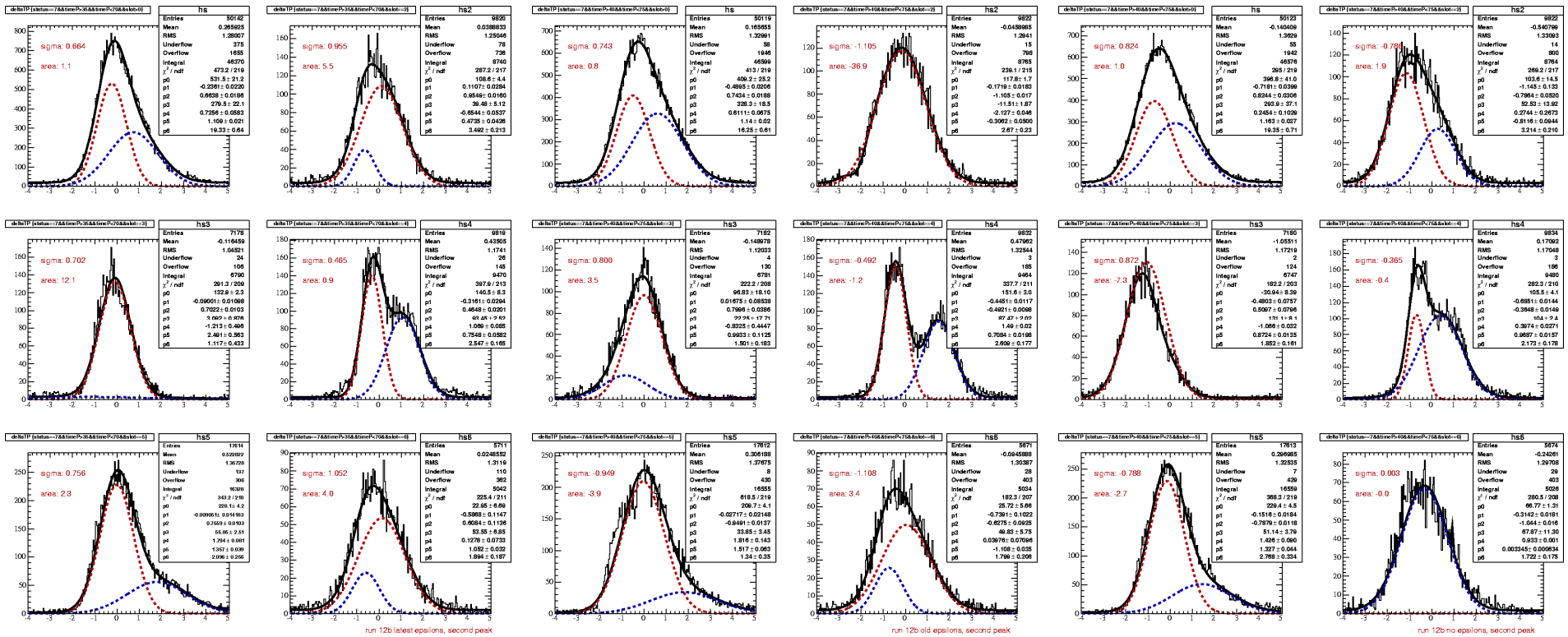


run 12b latest epsilons, first peak

Comparison of deltaT for peak 2 with old, no, and new epsilons.

We don't seem to be able to do a great job in slot 4.

latest Jerry none



Okay, now use my new epsilons and run the TOP analysis.

Ran Jerry's code with some modifications:

- removed charge-sharing treatment
- removed time-walk correction to prototype

Don't see much effect from charge-sharing treatment.

Time-walk correction seems to deteriorate the TOP thetaC resolution slightly although it appears to improve resolution for some pads. More work needed to understand this.

Jerry's analysis code position 1

with time walk correction, no charge-sharing treatment

	peak 1	peak 2	
2	11.9	6.3	
3	17.8	4.7	
4	10.7	3.4/4.3	peak 2 is a double-peak
5	10	6.5	
6	12.2	4.9	
all	**14.4**	**7.7**	

no time walk correction, no charge-sharing treatment

	peak 1	peak 2	
2	11.5	6	
3	15.2	4.7	
4	9.1	3.4/4.3	peak 2 is a double-peak
5	9.3	6.5	
6	10.4	5.1	
all	**12.9**	**7.4**	

no time walk correction, with charge-sharing treatment

	peak 1	peak 2	
2	12.2	6	
3	15.6	4.8	
4	9.4	3.4/4.3	peak 2 is a double-peak
5	9.6	5.9	
6	12.0/9.4	5	peak 1 fit is unstable
all	**11.2**	**7.2**	

Status of my thetaC (TOP) analysis with latest epsilons and bug fix in usage of my epsilons:

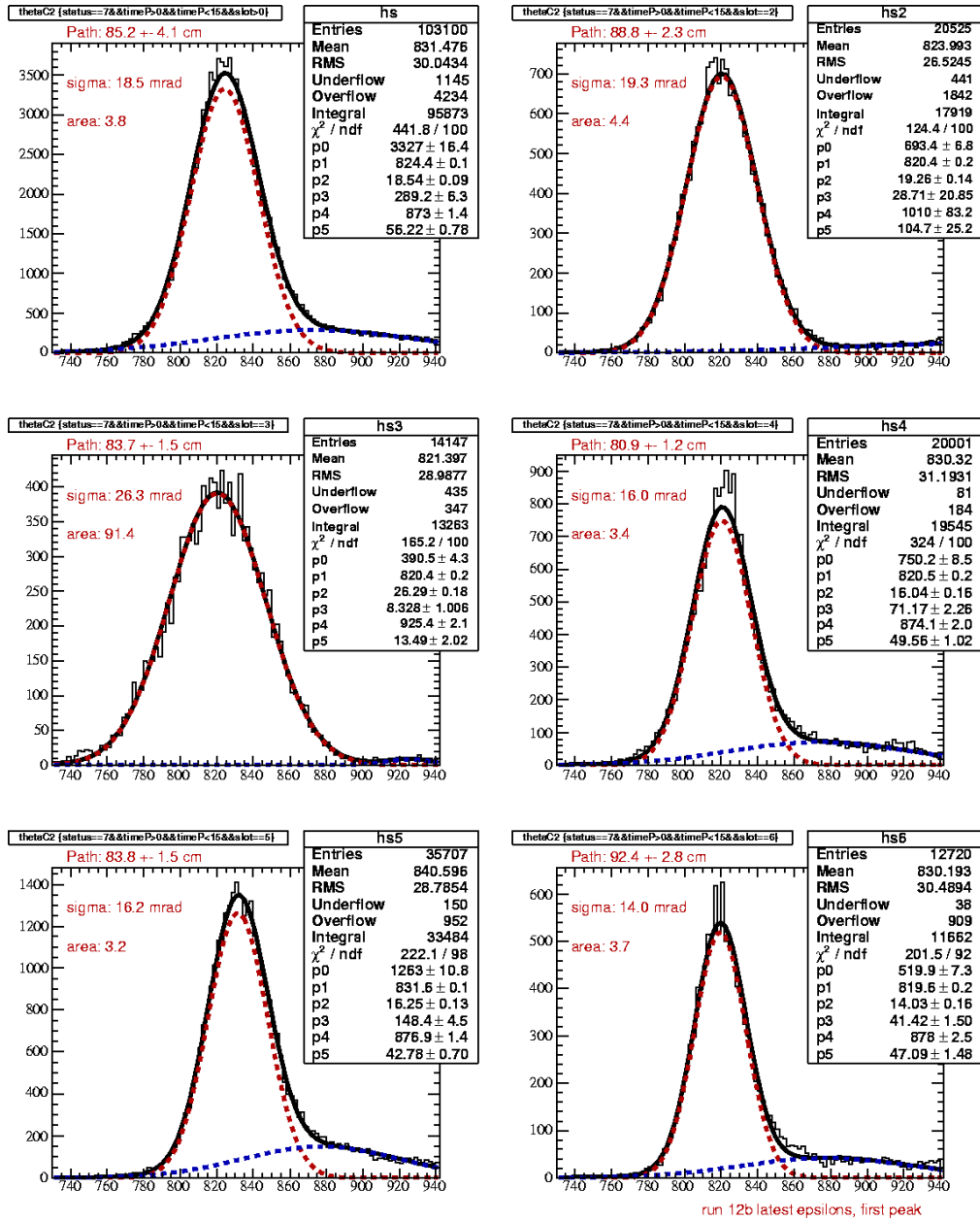
current analysis features

- my new epsilons, determined for each run
- no cut on start counter ADCs
- no correction for start counter time walk
- no charge sharing or cross-talk treatment
- thetaC from fit to thetaC vs. n_group based on Melles Griot
- no correction with or to pixel thetaC so far
- double-Gaussian fit to thetaC from TOP for each peak/slot

slot	path	sigma	mean
0	85.2	18.5	824
0	231.2	9.7	824.7
0	376.8	8.6	825.7
2	88.8	19.3	820.4
2	241.1	8.3	821
2	393.4	6.5	821.3
3	83.7	26.3	820.4
3	227.4	10	821
3	371	6.1	813.5
4	80.9	16	820.5
4	219.8	8.2	822.9
4	358.8	6.9	823.8
5	83.8	16.2	831.6
5	227.5	9.4	831.3
5	371	8.3	833.9
6	92.4	14	819.6
6	250.8	7.6	820.3
6	409.3	6.4	820.7

peak 1

peak 1

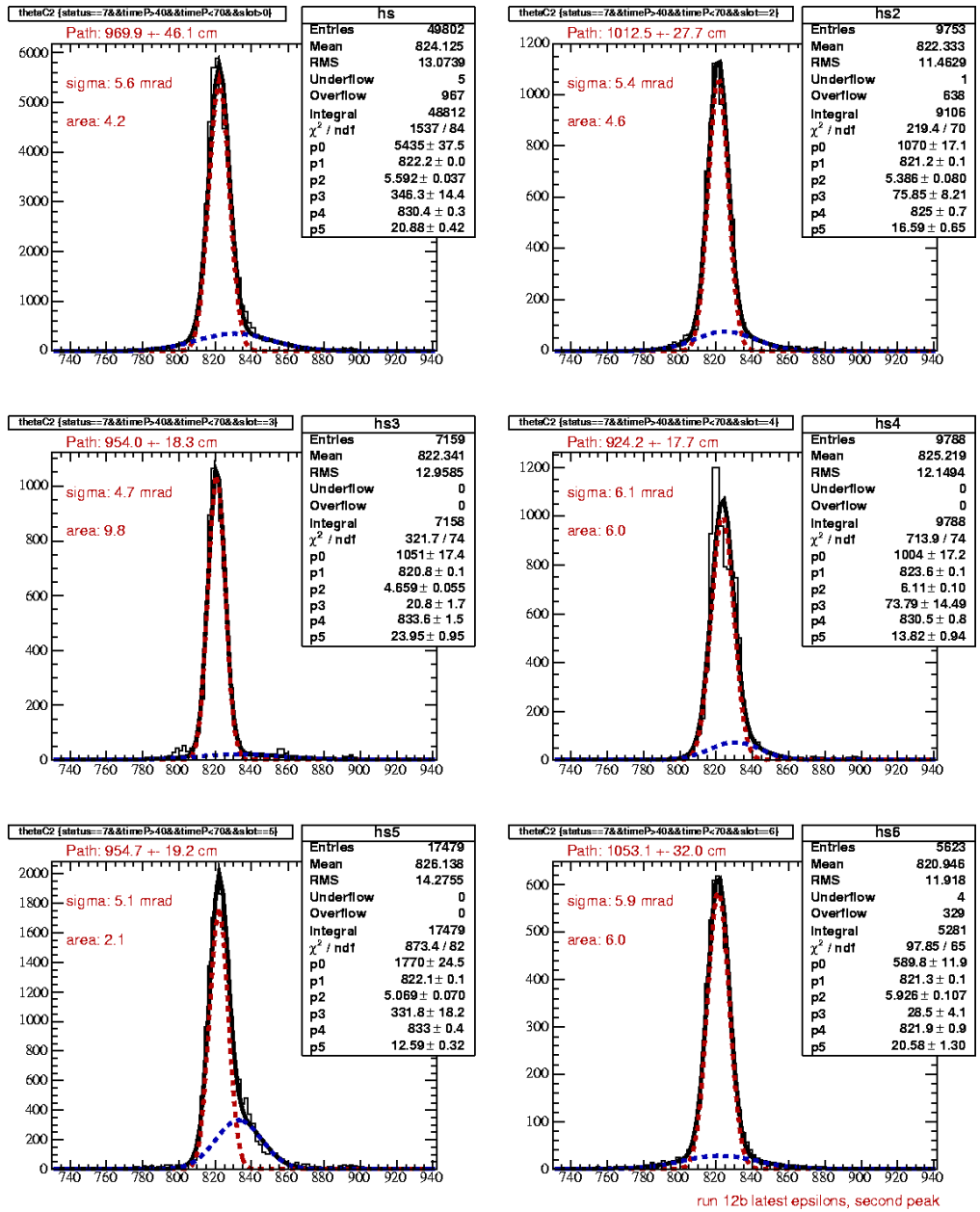


Status of my thetaC (TOP) analysis with latest epsilons and bug fix in usage of my epsilons:

slot	path	sigma	mean
0	678.1	6.9	824.3
0	823.3	6	822.8
0	969.9	5.6	822.2
2	707.3	5.8	821.3
2	829	5.6	821.3
2	1012.5	5.4	821.2
3	666.6	4.8	820.9
3	810.1	4.6	820.9
3	954	4.7	820.8
4	645.5	2.6	818.6
4	784.1	6.3	824.6
4	924.2	6.1	823.6
5	667.2	6.9	828.6
5	810.7	6.1	824.5
5	954.7	5.4	822.1
6	736	5.5	820.9
6	894.3	6.2	821.5
6	1053.1	5.9	821.3

peak 2

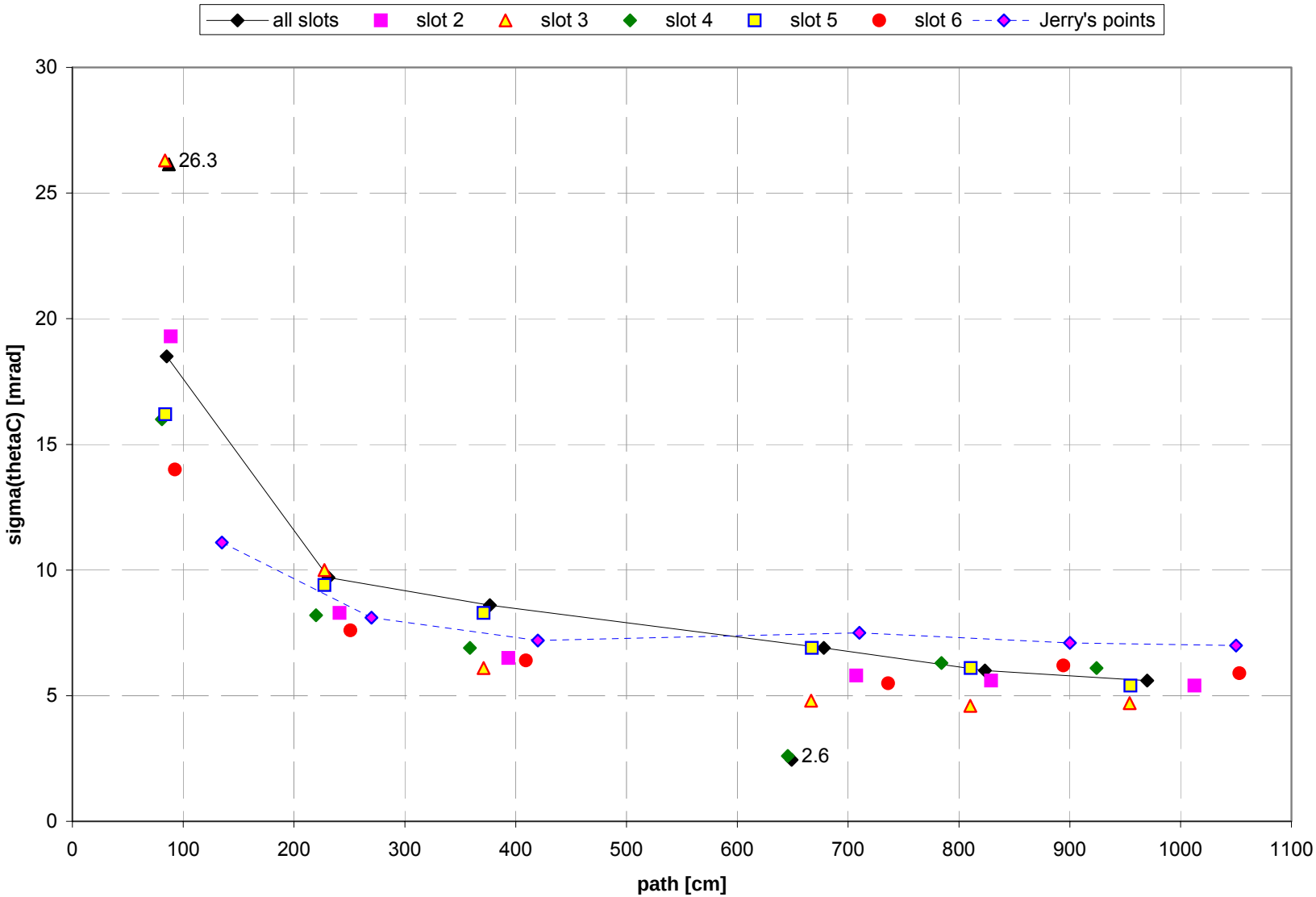
peak 2



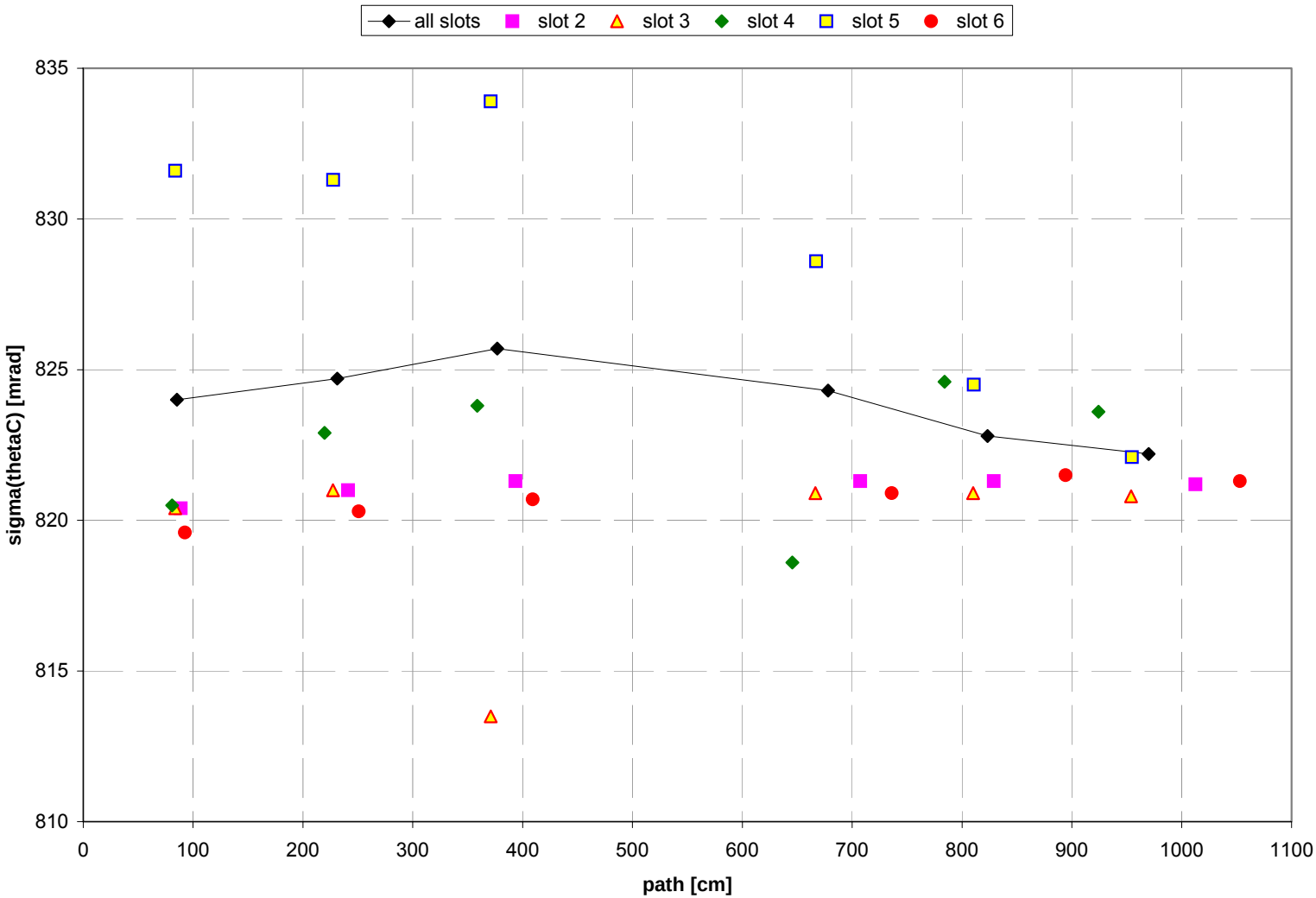
run 12b latest epsilons, second peak

Comparison of my latest thetaC(TOP) resolution to Jerry's values from last week

- my resolution has improved at long paths, is now consistent with Jose's 5-6mrad
  (keep in mind that Jerry's per-slot resolution is also at the 5mrad level)
- at short paths my resolution is still much worse than Jerry's – more work needed



The resolution is slots is better than the combined resolution due to
remaining shifts in the mean value per slot – some of that expected due to wavelength effects

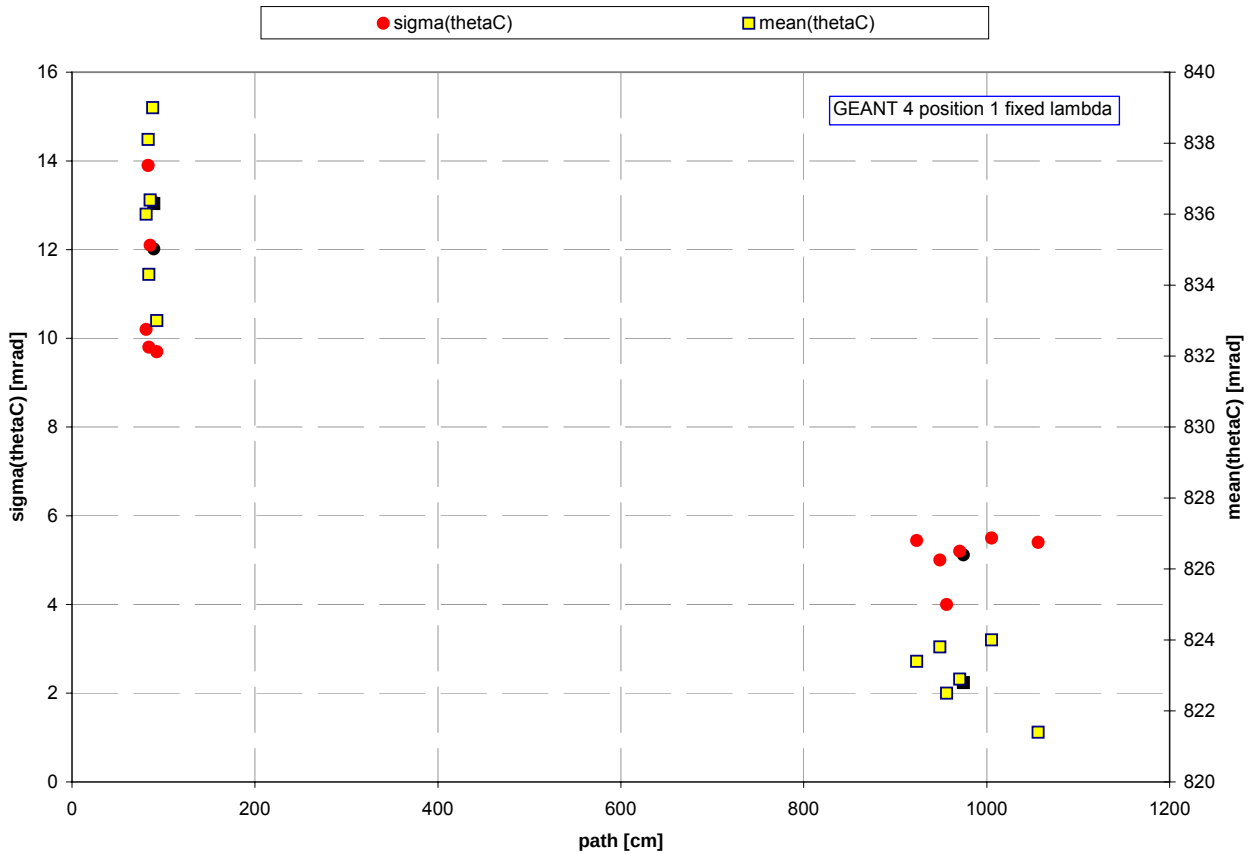


G4 simulation shows that we expect the peak 1 peak to be at larger mean thetaC (shorter wavelength) than the peak 2 (more UV photons have been lost)

G4 also predicts the best thetaC(TOP) resolution in Burle PMTs due to the better time resolution.

GEANT4 fixed wavelength			
	path	**sigma**	**mean**
all	**85.5**	**12.1**	**836.4**
2	88.3	13.1	839
3	83.4	13.9	838.1
4	81.1	10.2	836
5	84	9.8	834.3
6	92.7	9.7	833

all	**970.6**	**5.2**	**822.9**
2	1005.3	5.5	824
3	948.9	5	823.8
4	923.4	5.44	823.4
5	956	4	822.5
6	1056.2	5.4	821.4



A couple of open questions:

- why is the pixel thetaC resolution larger than the 8-9mrad we expect? Even in MC we don't see 8-9mrad. Does that mean that we have a problem with kBar/thetaC assignments?
- how do we correct the chromatic dispersion? Can we implement Blair's factorization idea?
- how should we treat charge sharing and crosstalk?
- what do the "epsilons" correct? Are epsilons just a way to correct for limitations of the TDC calibration or do we absorb some of the wavelength dependence in a probably model-dependent way? Try Jerry's TOP approach instead of my current kBar approach to determining the epsilons.
- why is the occupancy in slot 5 so high in data?
- what causes the events with zero hits in the prototype?
- what is a reasonable unbiased cut on the time for the pixel thetaC analysis (and TOP thetaC analysis)?
- why don't we see the mean thetaC(pixel) drop with path length? MC predicts ~15mrad shift.
- how much does the start counter rolling average correction help? Why don't I see improvement in slot plots?
- can we compare path overlaps from different beam positions? Or is the fact that the overlapping parts correspond to different slots too much of a bias?
- can we check with MC what influence a rotation of the end block has?
- what is the ultimate deliverable (for the conference)? thetaC from TOP? a pixel-corrected thetaC from TOP?
- how can I run multiple MC jobs in batch (random seed, merge ROOT files)?
- do the veto paddles help?
- can we make good use of SLAC TDCs?
- can we make good use of the pre-November runs with larger beam spots? Need calibration if we want to analyze the data.