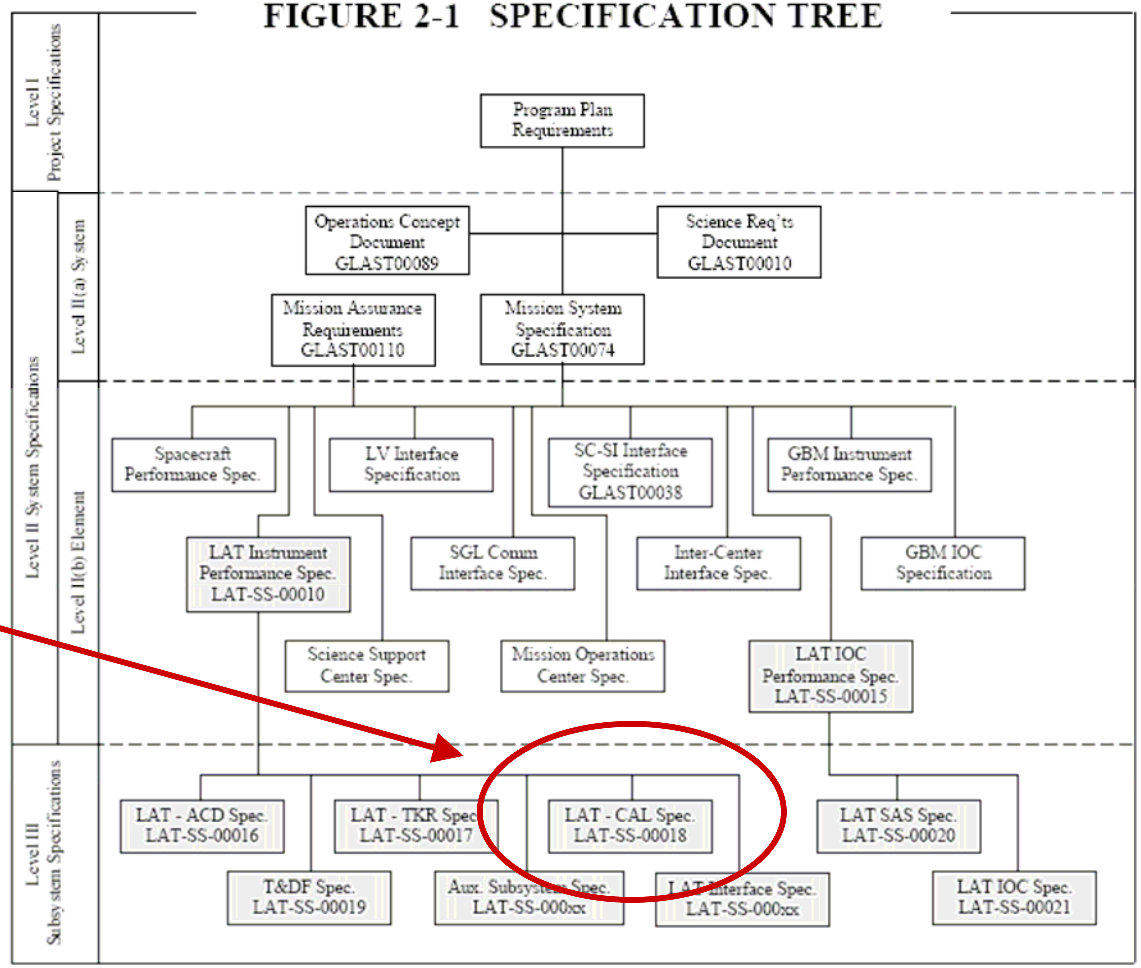
Testing some CAL specs

- Level 3 CAL requirement 5.5.5: <3 cm xyz position resolution per layer ("CAL MIP centroid")
- Level 3 CAL requirement 5.5.6: $<15^{o}\cos^{2}\theta$ for cosmic muons ("μ PSF")
- Want LAC settings to be at 1 or 2 MeV (zero suppression), without overly hot channels nor overly inefficient channels.
- Tools used: my usual TKR extrapolation to CAL, as well as CALMip.

GLAST LAT System Specification	Document # LAT-SS-00018-10	Date Effective 21 Nov. 2004
	Prepared by(s) W. Neil Johnson	Supersedes LAT-SS-00018-09
	Subsystem/Office Calorimeter Subsystem	
Document Title LAT CAL Subsystem Specification - Level III Specification		

FIGURE 2-1 SPECIFICATION TREE



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This talk

Table 6-1. Requirements Verification Matrix

Note: Verification methods are T = Test, A = Analysis, D = Demonstrate, I = Inspect

Req't #	Title	Summary	Verif. Method
5.2.1	Energy Range	20 MeV – 300 GeV	A
5.2.2	Single CsI Crystal Energy Measurement Range	5 MeV – 100 GeV	A
5.3.1	On-axis Energy Resolution – Low Energies	<50% (20 – 100 MeV) <10% (100 MeV – 10 GeV)	A
5.3.2	On-axis Energy Resolution – High Energies	<20% (10 – 300 GeV)	A
5.3.3	Off-axis Energy Resolution – High Energies	<6% (> 10 GeV)	A
5.3.4	Single Crystal Energy Resolution	< 2% for high energy carbon	T,A
5.4	On-Orbit Calibration	Relative: <3%; Absolute <10%	A
5.5.1	Depth	> 8.4 radiation lengths of CsI	I
5.5.2	Hodoscopic Layers	Hodoscopic design	I
5.5.3	Active Area	>1050 cm^2/module on axis	I
5.5.4	Passive Material	No more than 10% of total mass of CAL	I
5.5.5	Position Resolution	< 3 cm in all 3 dimensions/layer	T
5.5.6	Angular Resolution	$<15 \times \cos^2(\theta)$ degrees for cosmic muons	T
5.6	Command and Data Interface	LAT standard protocols	I
5.7	Measurement Dead Time	<100 μsec	T
5.8	Overload Recovery	<500 μsec	T
5.9	Low Energy Trigger Signal	CAL to provide low-energy trigger signal to the LAT trigger system	I
5.10	High Energy Trigger Signal	CAL to provide high-energy trigger signal to the LAT trigger system	I
5.11	Operating Modes	Continuous thru orbits	A
5.12	Calorimeter Mass	Not to exceed 1440 kg.	I
5.13	Calorimeter Power	Not to exceed 71 W).	T
5.14	Environmental	Must withstand environmental conditions in LAT Instrument Performance Spec.	T
5.15	Performance Life	Specified performance for a minimum of 5 years	A
5.16	Reliability	Reliability minimum of 96% in 5 years.	A

The Method

[Review my IA Workshop #4 presentation if you like (14 July 2005).]

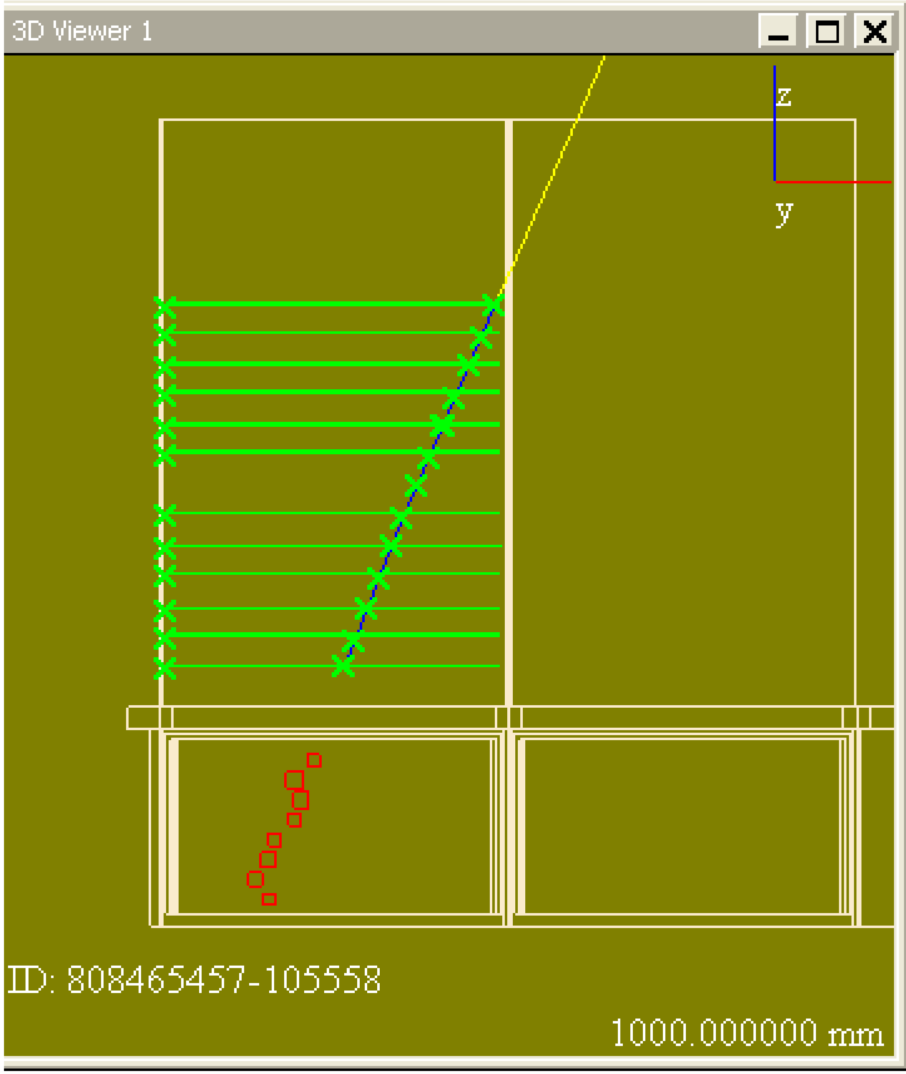
- Extrapolate TKR track to CAL, predict which crystals get hit. Look at energy deposits, positions.

- Use Tkr1EndPos, Dir. Stay a few cm away from crystal ends.

- Require:
TkrNumTracks == 1
Tkr1KalThetaMs < 0.03
Tkr1NumHits > 15

<2 MeV in adjacent crystals
Extrapolation of track must traverse top & bottom of crystal.

- Energy corrected for cosθ.



The data sample

Red: six B30 runs (135005404 to 14)

Blue: ~22 (twenty-two) B2 runs (135005345 to 89), re-processed with the “muon track” hypothesis

Yellow: 4M Surface Muons (v5r0703p5)

CAL level 3 req’t 5.5.5: <3cm xyz position resolution per layer

5.5.5 Position Resolution

[Derived from LAT SS-00010 5.2.2, 5.2.12]

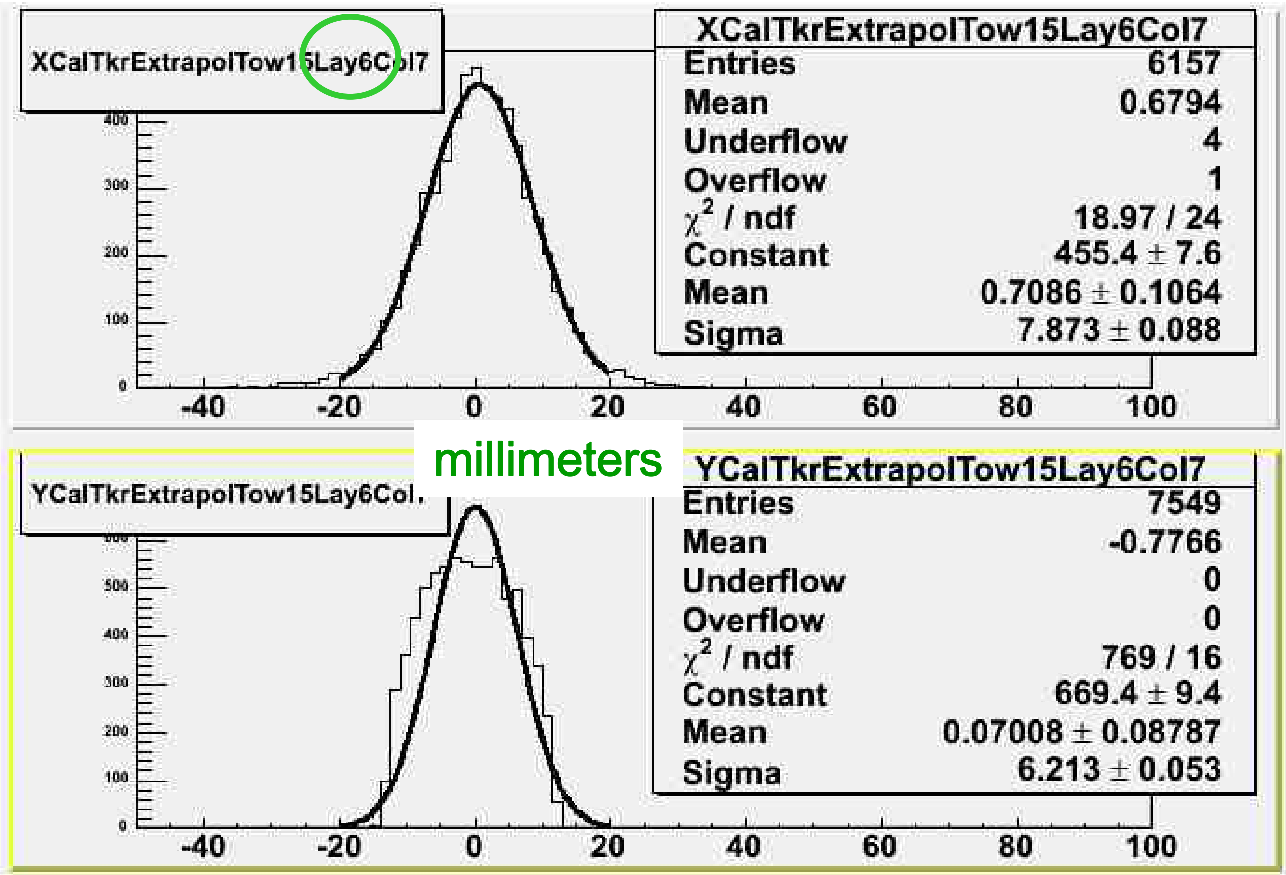
Each layer of the calorimeter shall position the centroid of a Minimum Ionizing charged particle energy deposition to less than 3.0 cm (1σ) in all three dimensions for particle incident angles of less than 45 degrees off axis.

This is an *even* layer…

…so the x-direction is the *longitudinal* meas’t (light ratio from the two crystal ends)…

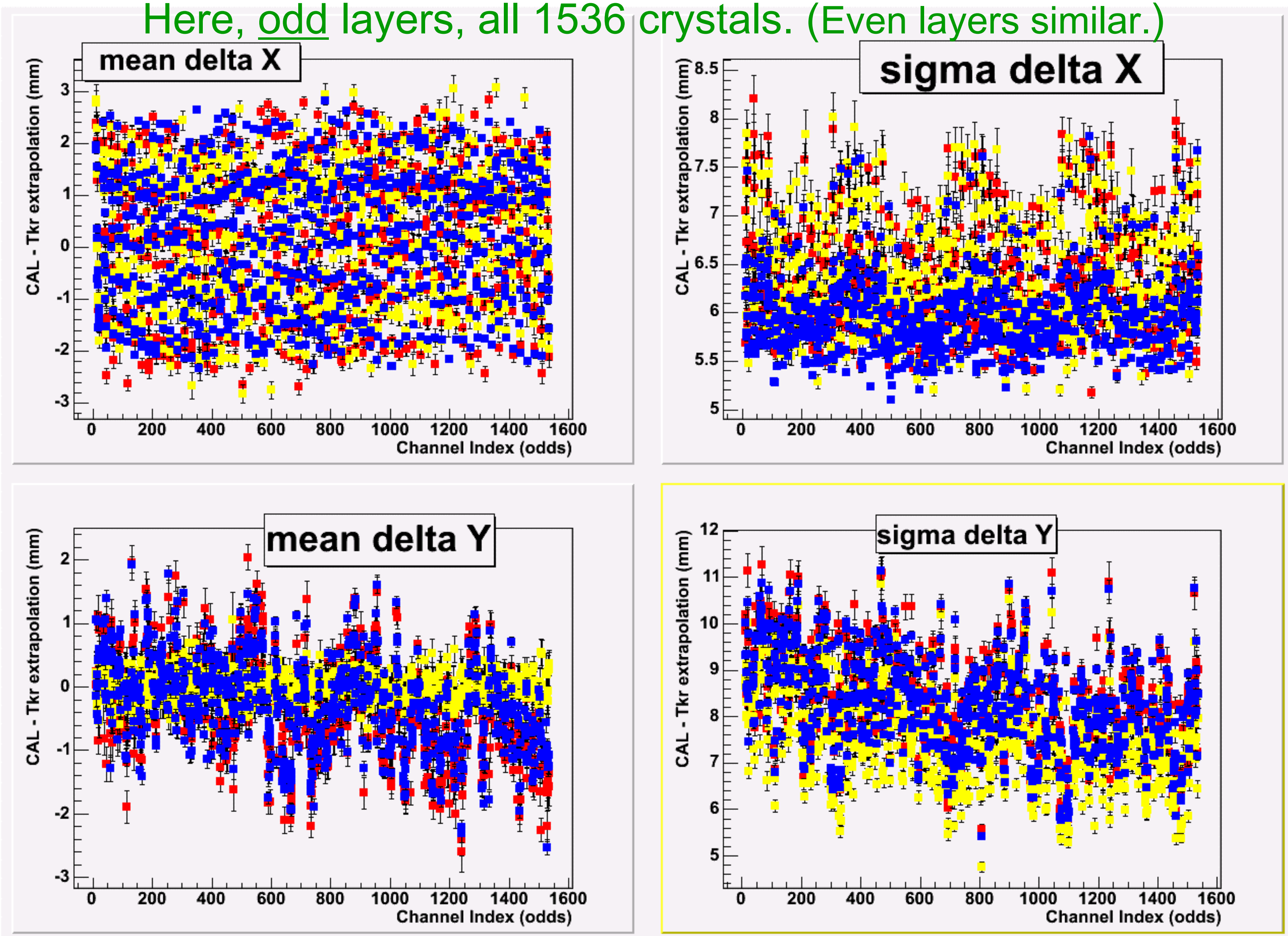
…whereas the y-direction is just the *transverse* crystal profile.

Z-direction like y.

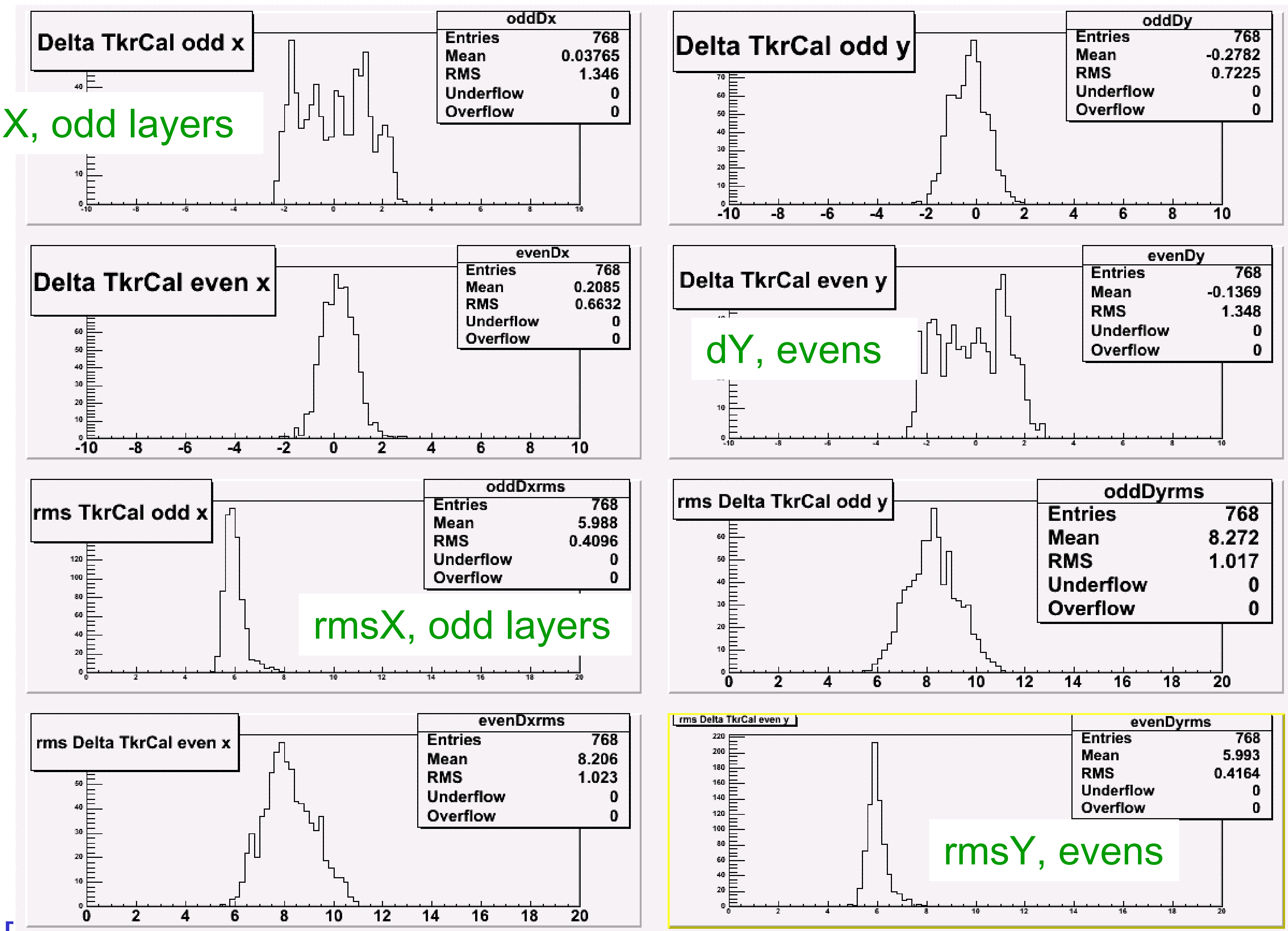


CAL position vs extrapolated TKR position

Here, odd layers, all 1536 crystals. (Even layers similar.)



All rms's << 30 mm: req't met



CAL level 3 req't 5.5.6: <15°cos²θ for cosmic muons

5.5.6 Angular Resolution

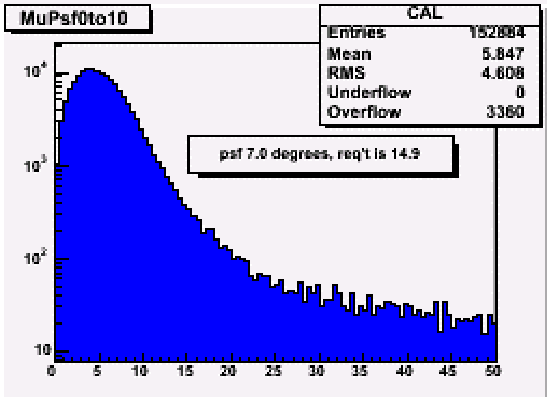
[Derived from LAT SS-00010 5.2.2, 5.2.12]

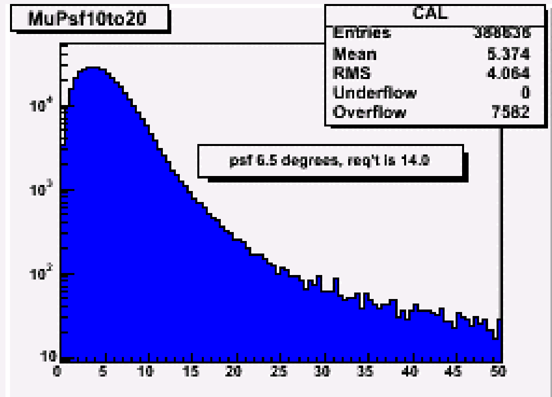
The single particle angular resolution at 68% containment for the calorimeter shall be better than $15 \times \cos^2(\theta)$ degrees for cosmic muons traversing all eight layers. (θ is the off-axis angle.)

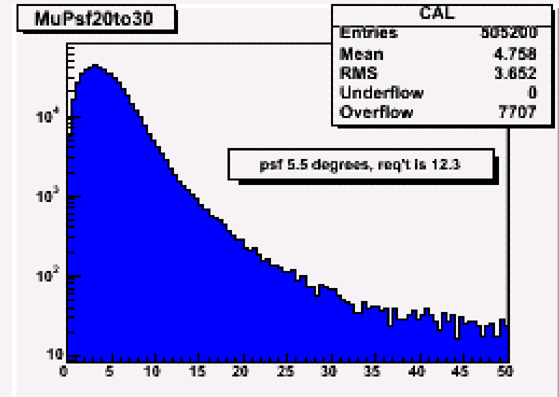
- Use *all* B2 "muon TKR hypothesis" MeritTuple files (runs 135005345 to 89)
- TCut OneTrack = "TkrNumTracks==1 && CalMipNum==1"
- TCut AteLayers = "CalELayer0>8 && …&& CalELayer7>8 "
- Let cosξ = -CalDir•VtxDir (angle between CALMIP and TKR tracks)

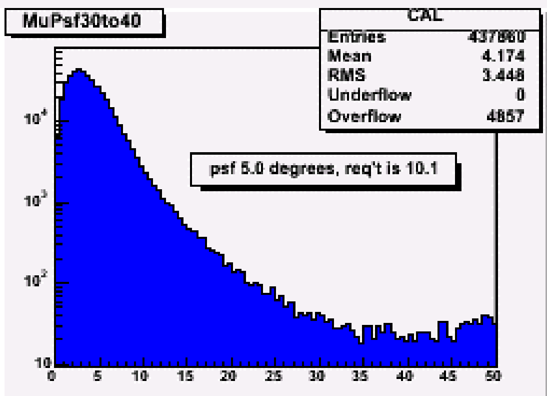
  (using Montpellier MIP finder.)
- Make 9 bins of 10 degrees each, histogram ξ, find 68% point.

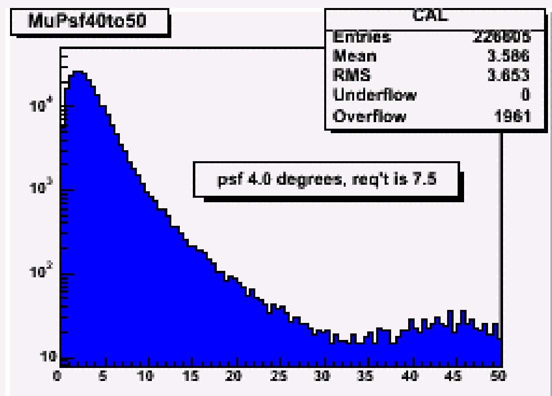
Nine 10º zenith angle intervals

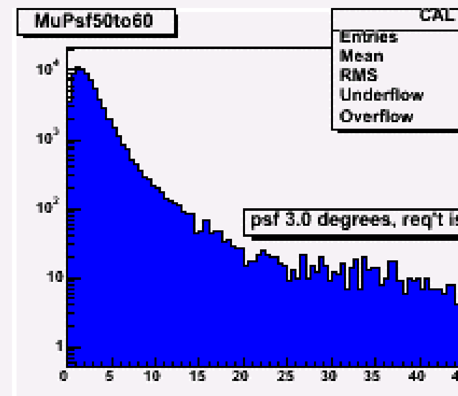


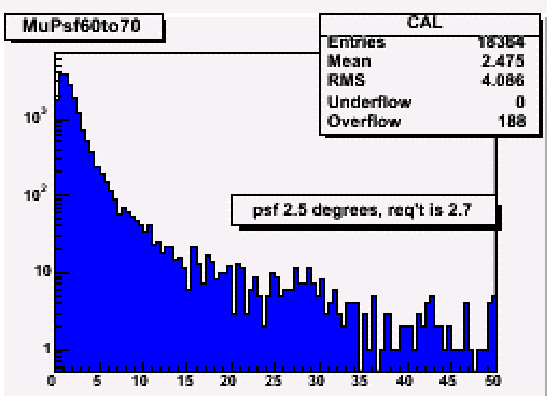


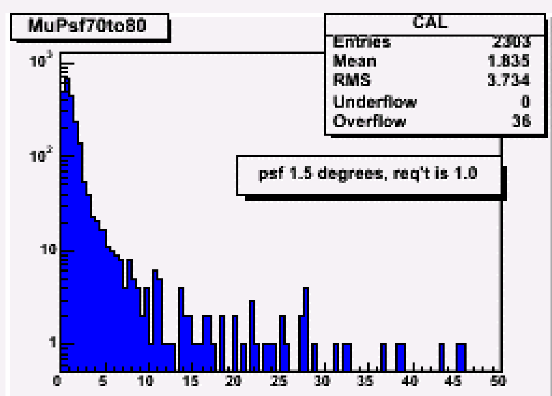












Psf	req
7.0	15
6.5	14
5.5	12
5.0	10
4.0	8
3.0	5
2.5	2.7
1.5	1.0

req't met:

Gets marginal beyond 70 degrees off axis.

Reminder: req't 5.3.4 satisfied at GSI

- Level 3 CAL requirement 5.3.4: <2% single crystal $\delta E/E$ for carbon
- Look at figures 5 and 14 from *Response of the GLAST LAT calorimeter to relativistic heavy ions* B. Lott[a], F. Piron[b], B. Blank[a], G. Bogaert[c], J. Bregeon[a], G. Canchel[a], A. Chekhtman[d], P. d'Avezac[c], D. Dumora[a], J. Giovinazzo[a], J.E. Grove[d], M. Hellström[e], A. Jacholkowska[b], W.N. Johnson[d], E. Nuss[b], Th. Reposeur[a], D.A. Smith[a], K. Sümmerer[e] and for the GLAST collaboration, Nucl. Instr. Meth. A, accepted 17 December 2005, available online

For Si, Z=14, and
12 MeV x 14^2 = 2352,
where 12 is what we get
for muons (Z=1).

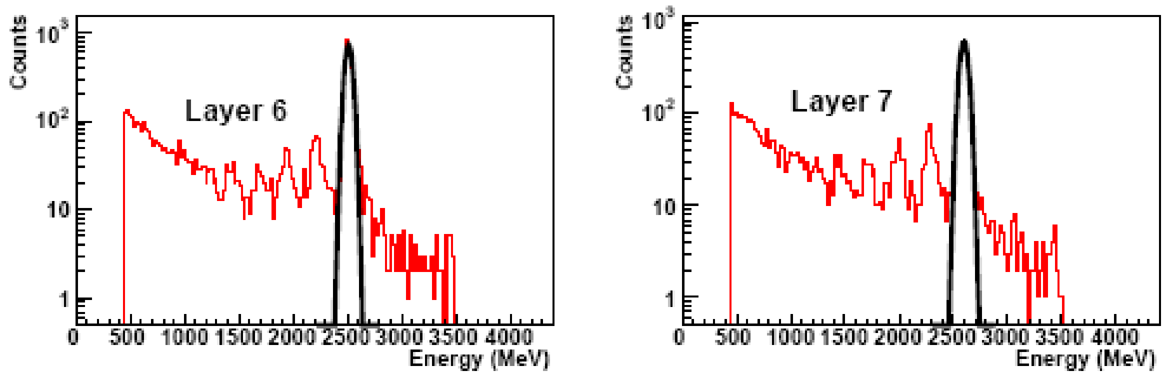


Fig. 5. Deposited-energy distributions measured in the eight EM layers for 1.7 GeV/nucleon Si ions. The black curves correspond to the gaussian fits of the ionization peaks. The secondary peaks at lower energy correspond to charge-changing events in which the primary ions lost 1, 2, 3, ..., protons.

5.3.4 Single Crystal Energy Resolution

[Derived from LAT SS-00010 5.2.2]

The energy resolution (1σ) shall be less than 2% for high energy (100 to 1000 MeV/nucleon) Carbon ions of normal incidence at a central point in the crystal with beam spot size less than 3 mm diameter.

[COMMENT: This resolution shall be tested in accelerator beams on a limited number of CDEs, which shall be read out with flight or flight-like electronics. The remaining crystals shall be qualified by similarity to the test crystals.]

- Here: For minical, 23 MeV (~1.3%) for carbon (A = 12).
- From NIM: for EM with flight-like electronics, add 6 MeV in quadrature. Still get ~1.3%.
- Following plots confirm that after integration, the crystals are still quite uniform for muons ($\delta E/E$ ~ 7% for Z=1).

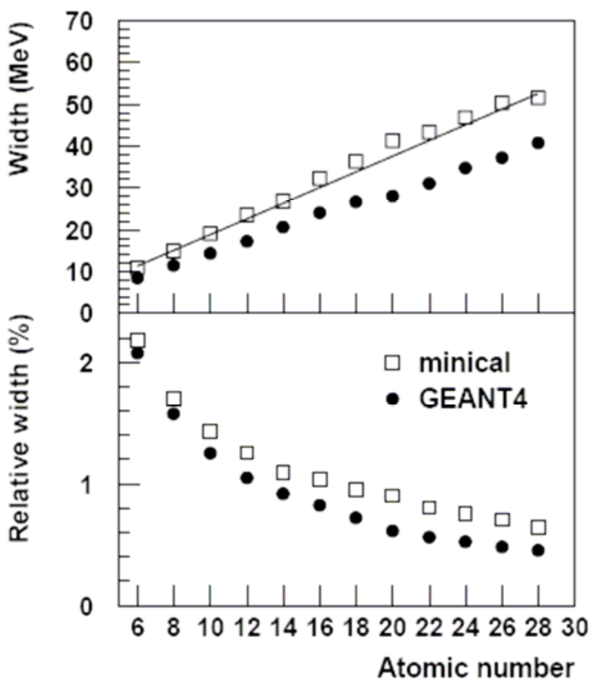


Fig. 14. Top: Widths of the measured (open squares) and calculated (solid dots) deposited-energy distributions plotted as a function of the ion atomic number. Bottom: same as top for the relative widths.

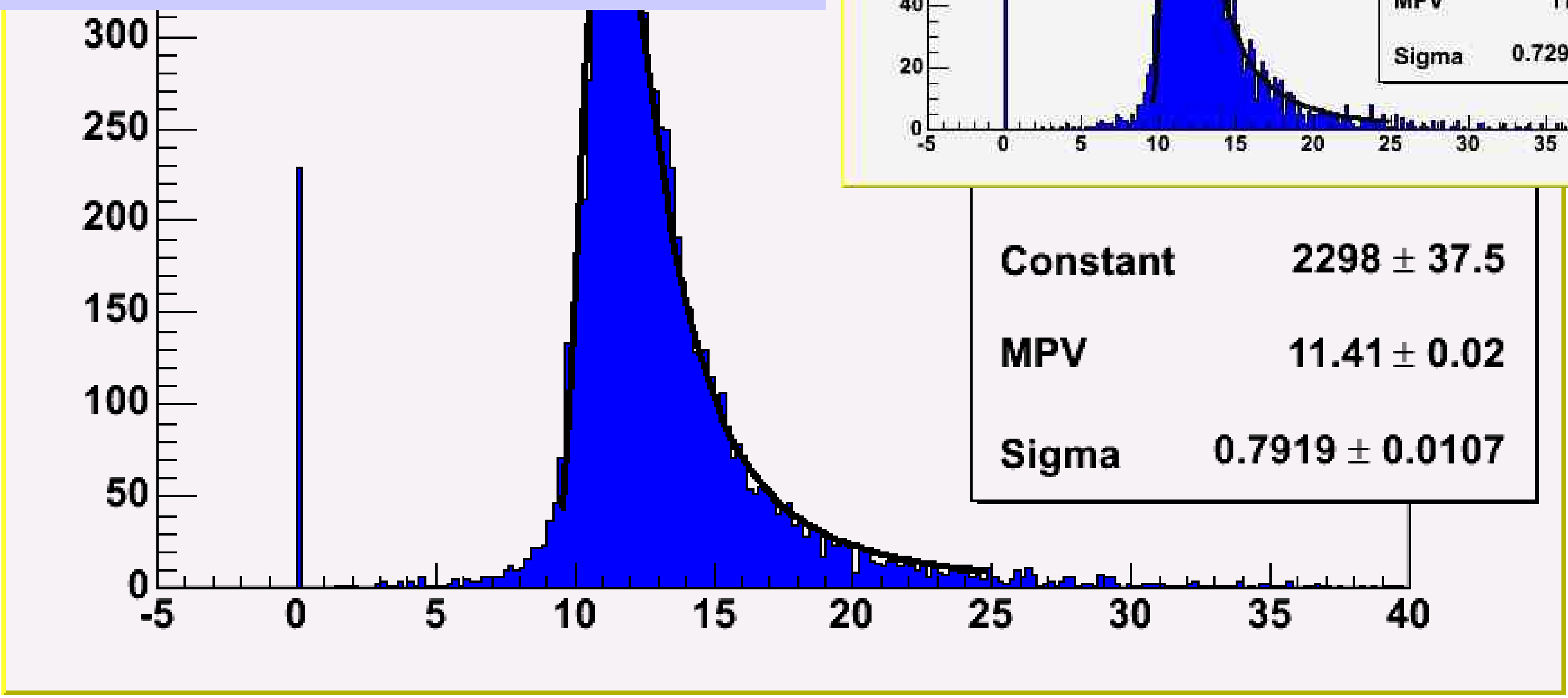
A typical crystal: tower 9 Layer 7 Column 5

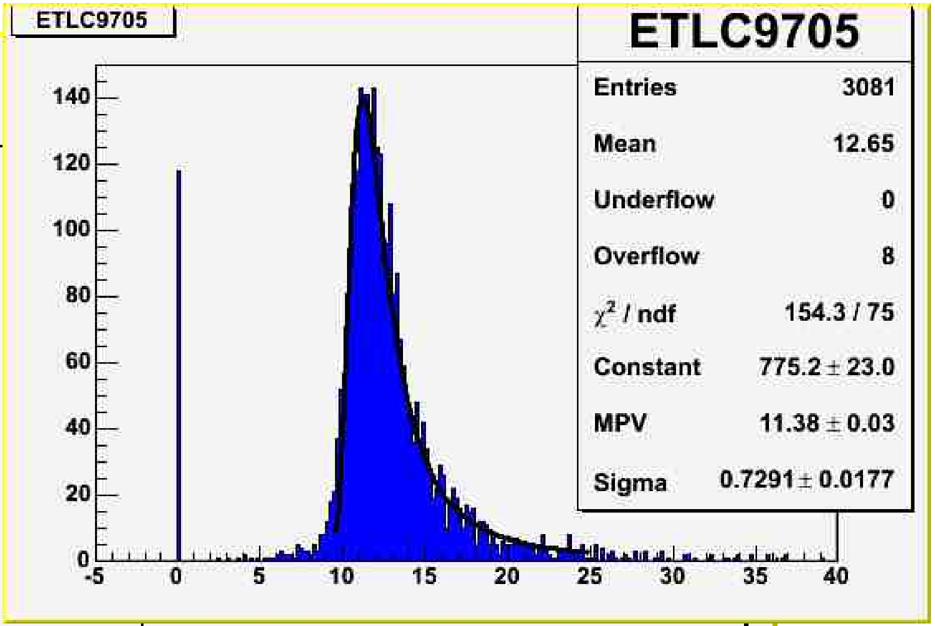
Red: six B30 runs (135005404 to 14)

Blue: eight B2 runs (135005345 to 59)

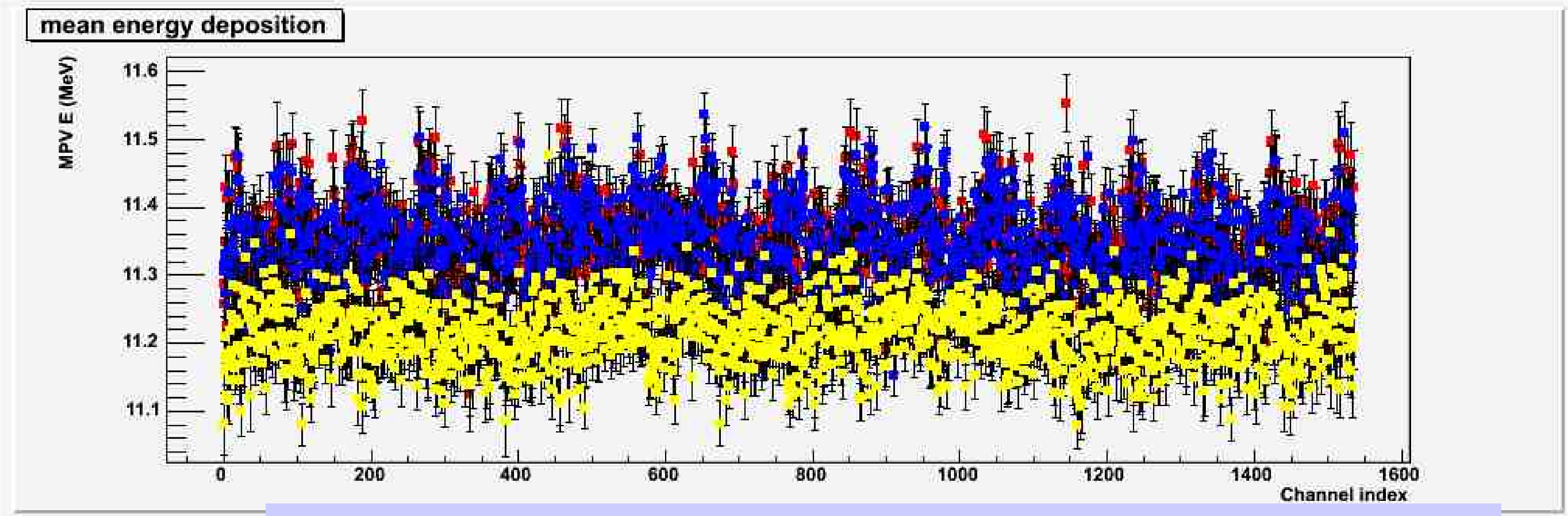
Dave check 2% in the spike

Yellow: 4M Surface Muons (v5r0703p5)

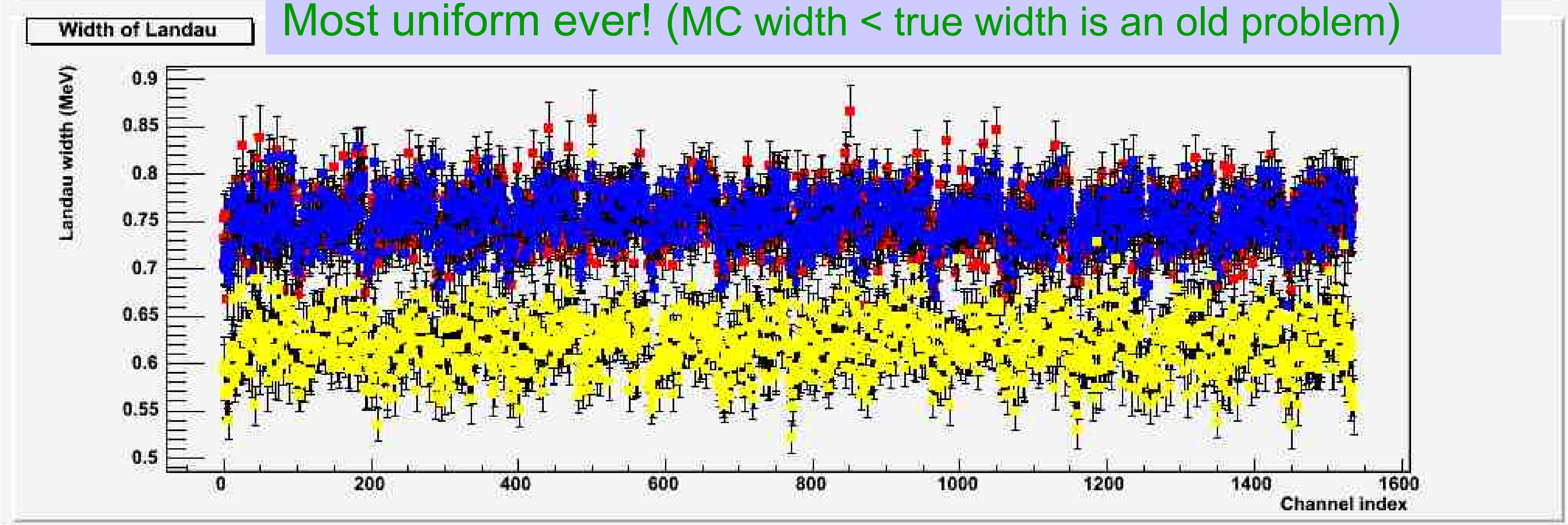




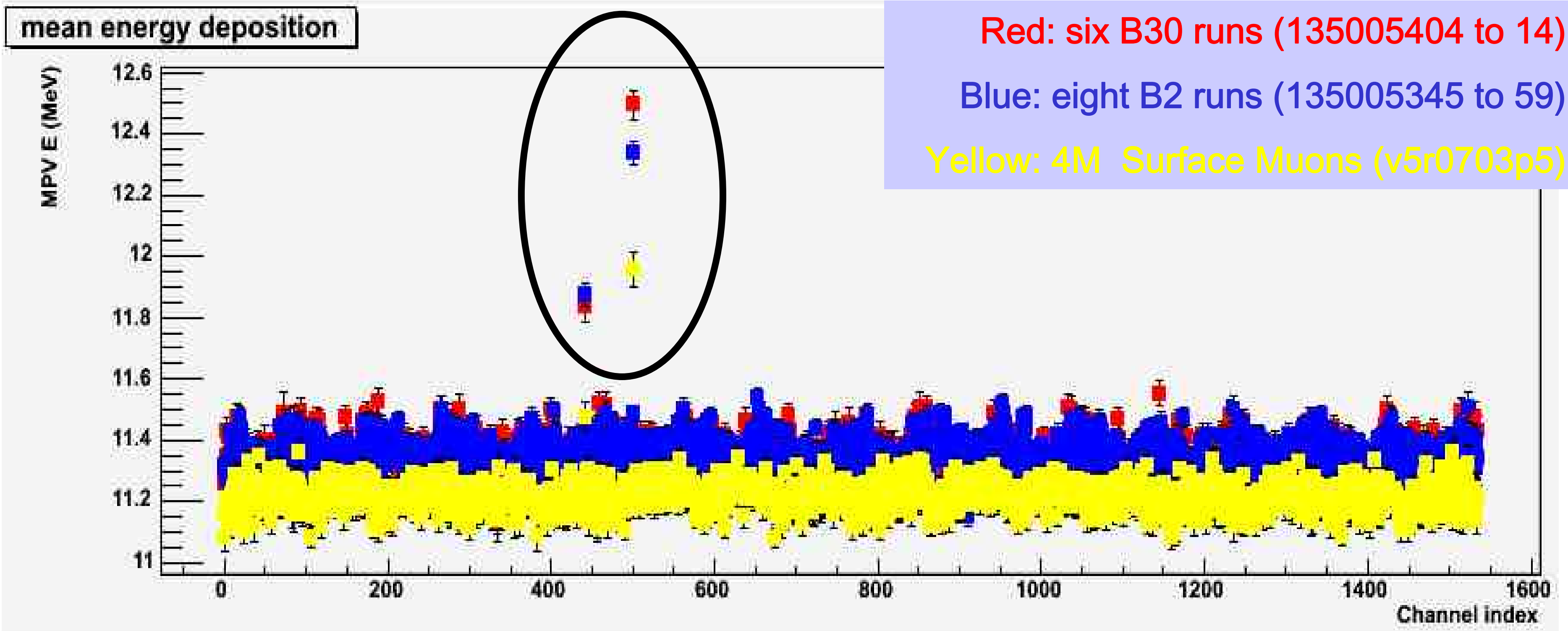
Energy deposit vs crystal index



Most uniform ever! (MC width < true width is an old problem)



Un-zoom y-axis of energy deposit vs crystal



2 of the 3 channels with LAC DAC = 127.

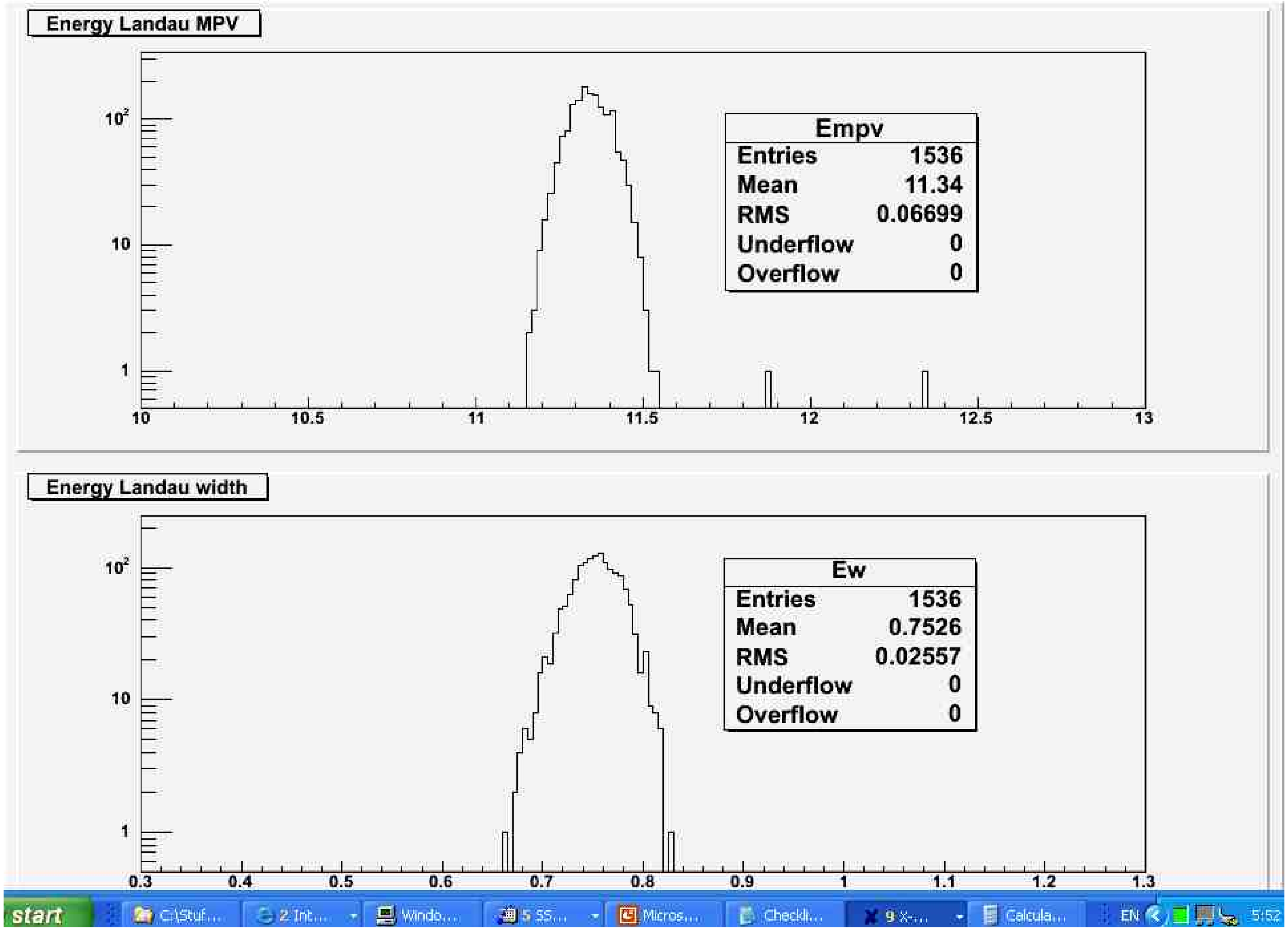
Note that simulation (nearly) reproduces the effect.

11.2 MeV by design and in MC, but 11.3 MeV in data, both B2 and B30.

(B30 used for calibration.)

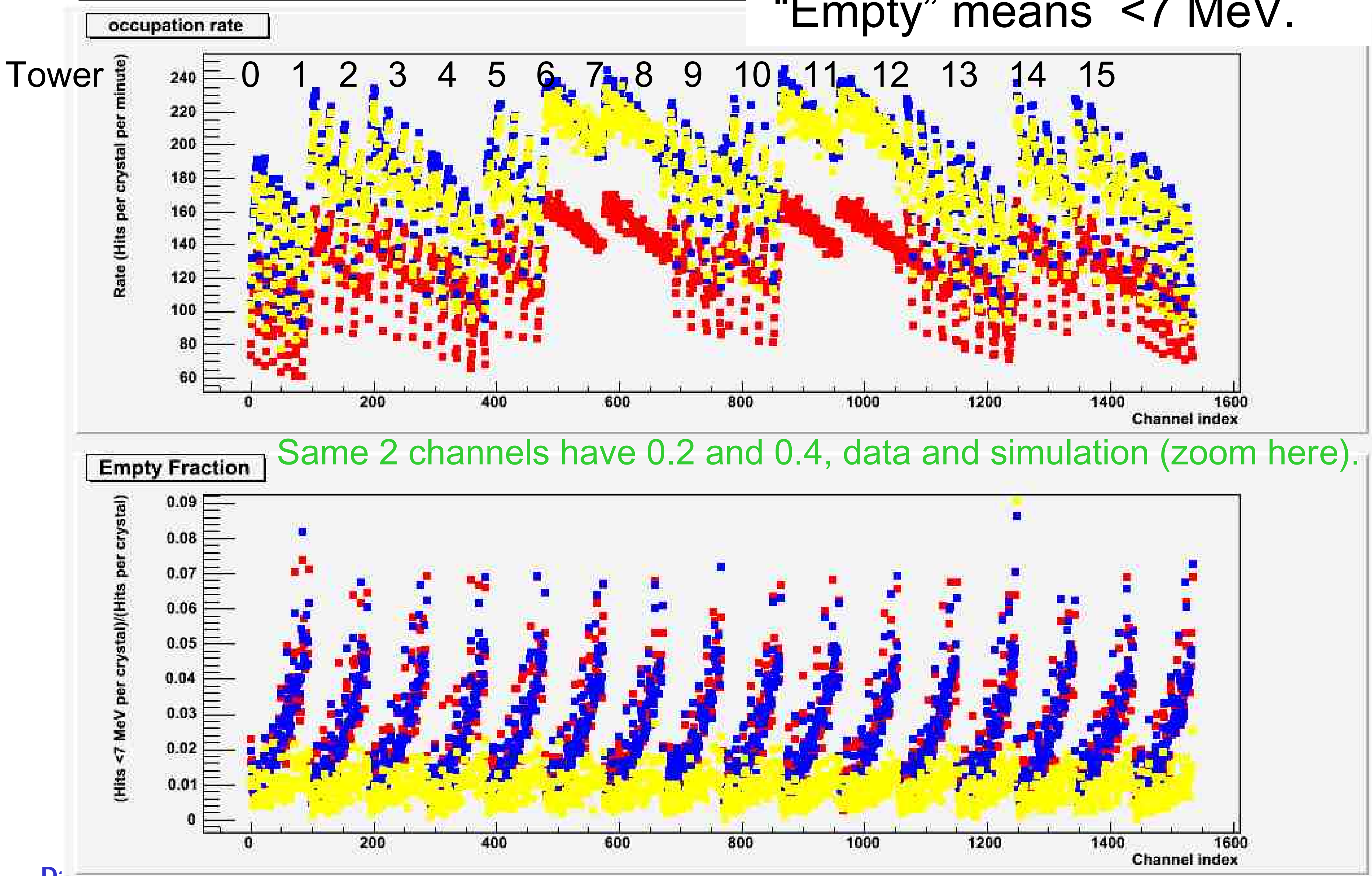
Energy deposit histograms

Here, B2. B30 looks same, MC looks real similar.



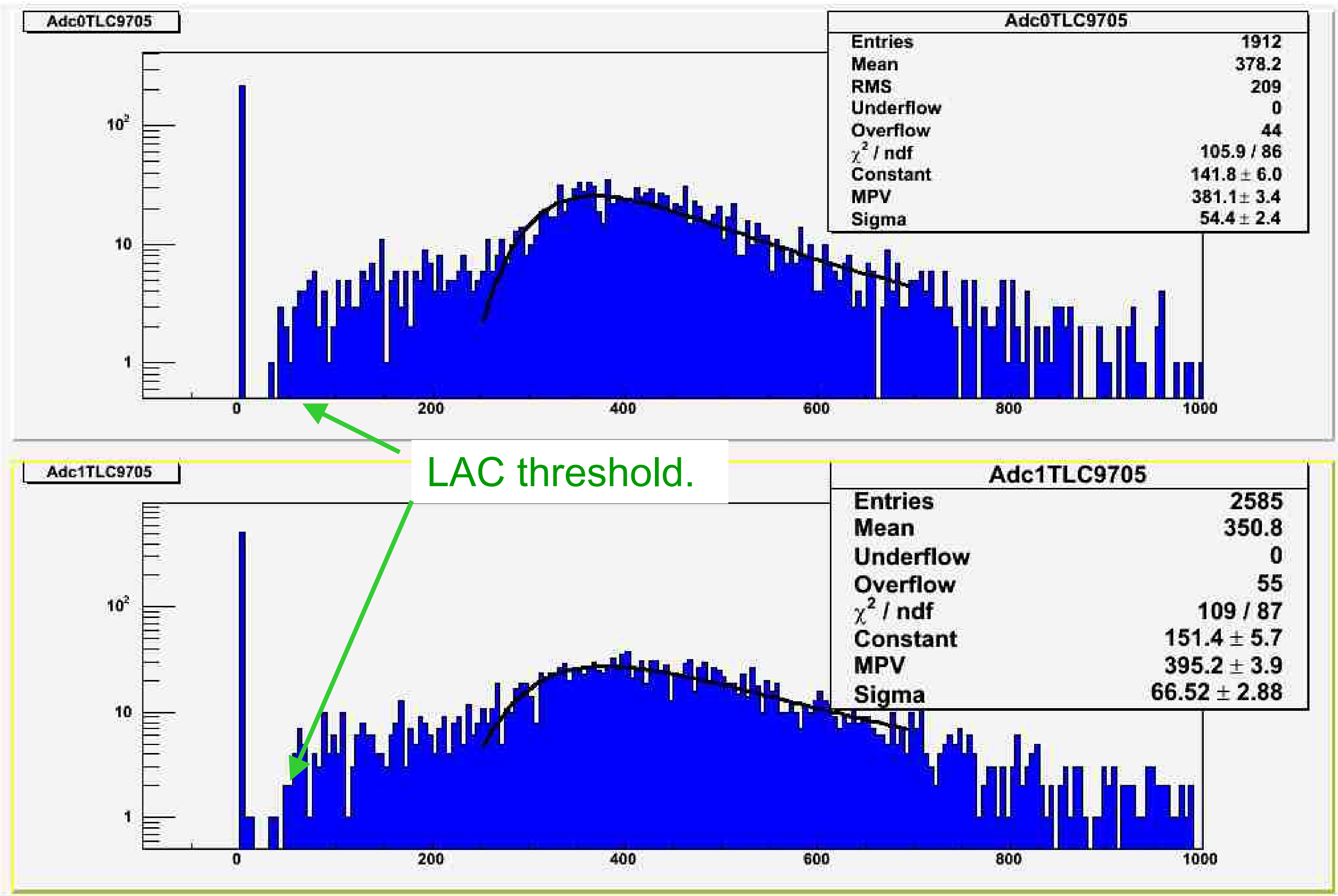
Fraction of events where expected energy deposit is absent, per crystal.

"Empty" means <7 MeV.



Same 2 channels have 0.2 and 0.4, data and simulation (zoom here).

Single diode pedestal-subtracted ADC counts



CalTuple is A.O.K.

Preceding plot took a while to make: the CalTuple

a) dropped empty events, fouling up the correspondence between

Merit<->SVAC<->CalTuple

b) Had different root structure from other tuples, and different versions between MC and real data.

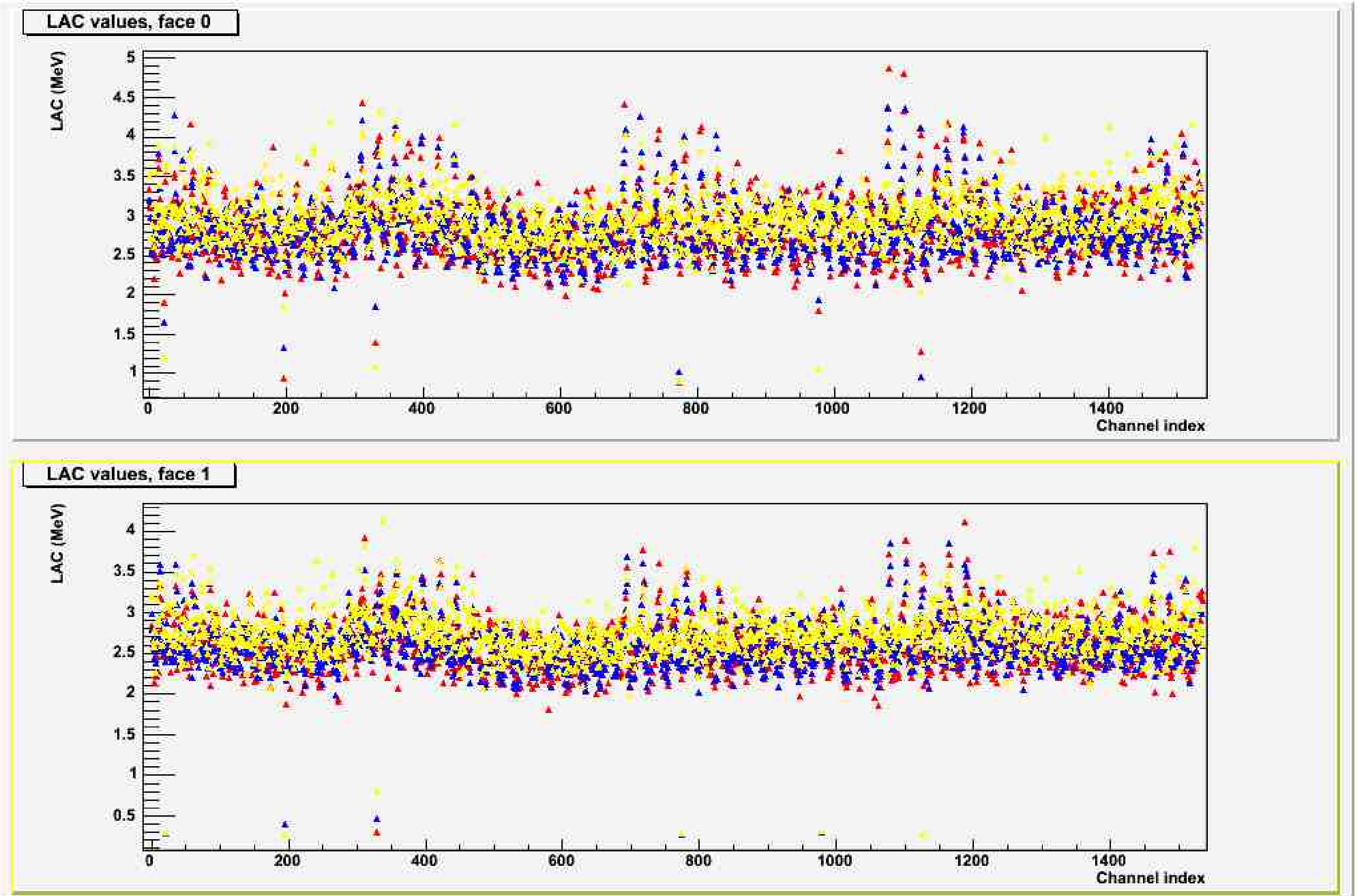
Thanks to Zach and Anders and Heather it is now “A #1”.

To express LAC in MeV: Landau fit gives MPV in ADC counts, then say

$$LAC\_MeV = 11.2 * LAC\_adc/MPV$$

Observed LAC thresholds for all channels

- Find the LAC turn on, in ADC counts, crystal-by-crystal.
- Tuning in progress -- presently what I find is (maybe) 2x too high.



IA, CERN testbeams and DC2

- In IA we've looked at mostly muons, at the micro micro level
- Beginning Wednesday, we hope to look at gammas at the macro macro level (*like, the Universe, man!*)
- How to transition? Real gamma rays coming this summer… here I attempt to look at some of the simulated test beam gammas but frankly, I don't know how to get there from here. Anybody want to give me a hand?

Conclusions

- < 30 cm MIP centroid requirement 5.5.5 is satisfied.
- $<15^{o}\cos^{2}\theta$ PSF for μ's requirement 5.5.6 is satisfied.
- LAC settings (zero suppression) are 1 or 2 MeV. A few warm and cool channels that are being taken care of.