Hadronic ϕ Intercalibration Status

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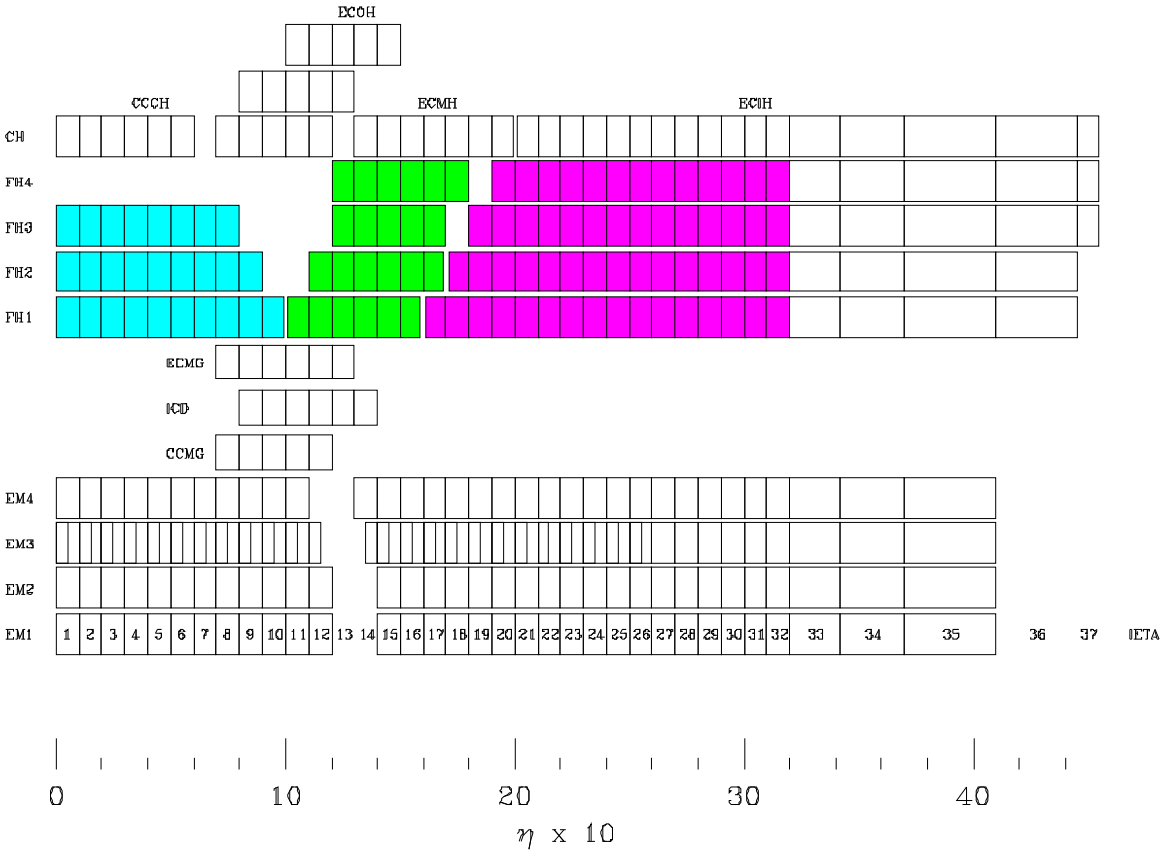
Motivation

- Equalising of the hadronic calorimeter response in ϕ has not been performed so far.
- Current physics analyses assume detector ϕ uniformity which actually does not hold as seen e.g. in EM calorimeter.
- There is an observed ϕ variation in JES.
- Once we calibrate the hadronic calorimeter we expect to obtain better resolution.
- ϕ intercalibration is the first step in the hadronic calorimeter calibration, the second being calibration of η-rings.
- Here we aim the Fine Hadronic part of the calorimeter.

The Idea and Data Used

- As in the case of the EM calibration we simply count events in each Precision Readout tower above some E_{T} threshold, here $9\,\mathrm{GeV}$.
- From the ϕ symmetry of the physics at the DØ (unpolarized beams) we can choose almost any quantity to equalise cells in ϕ at given η.
- We use special data collected during physics running starting March 12^{th} 2005.
- In short, the trigger requires L1 tower above $5\,\mathrm{GeV}$, $5\,\mathrm{GeV}$ at L2 in Fine Hadronic and L3 tower (matched to L2) above $7\,\mathrm{GeV}$ in FH.
- At the moment, we have 11M events, here looking at 6.5M from 51 runs ($>$ 11 stores).
- We build on the code on EM calibration by Matt Wetstein and J.S.

Fine Hadronic Layer Map



- In CC basically only 3 FH layers, in ECs mostly 4.
- L1 trigger information is available up to $i\eta$ of 32.
- Technically, we have to properly deal with missing layers.

Data Quality

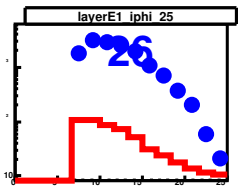
- Data quality issue is important to separate bad detector part issues from those which can be calibrated.
- Calibration constants for bad towers/cells are set to 1.
- For fixed η we look for deviations from the ϕ-average in layer energies and fractions distributions.
- For more details and lists of towers/cells see Krisztián's talk on our data quality at CALOP meeting, April 21st 2005.
- We still keep finding more problems e.g. bad high energy noisy cells (η, ϕ, layer): (-4, 5, 2), (-5, 50, 1).

Observed Problems Categories

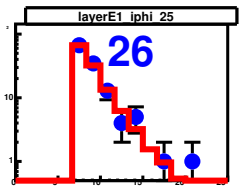
- Dead L1 towers (2×2 neighbouring PR towers in $\eta \times \phi$).
- Dead and low occupancy PR towers.
- Dead cells, low occupancy cells.
- High energy noisy cells.
- Low energy noisy cells.
- `dq_calo` (online calorimeter data quality monitoring system) does not report any of these problems...
- We a few see L3/offline discrepancies (e.g. $i\phi$ 31, 32 in CC)
- High energy noisy cells can trigger the PR tower, content of other layers being unphysical (low energies) so they may look like low energy noisy...

Bad Data Quality Examples I

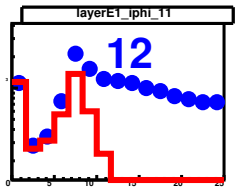
- Energy distributions (logscale on y axis, $E \in \langle 0., 25. \rangle$).
- ϕ-averaged reference, actual $i\phi$.
- High energy noisy cells:



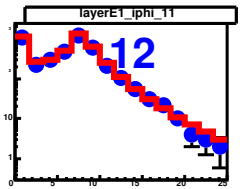
$i\eta = -10$



$i\eta = 10$



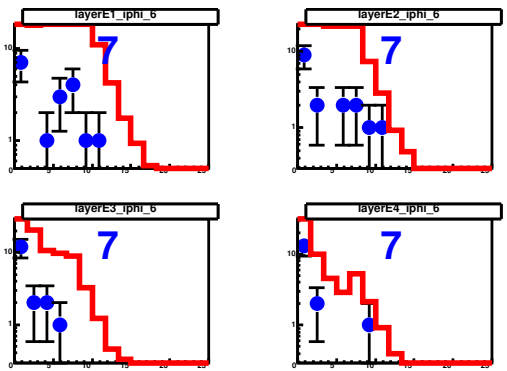
$i\eta = -2$



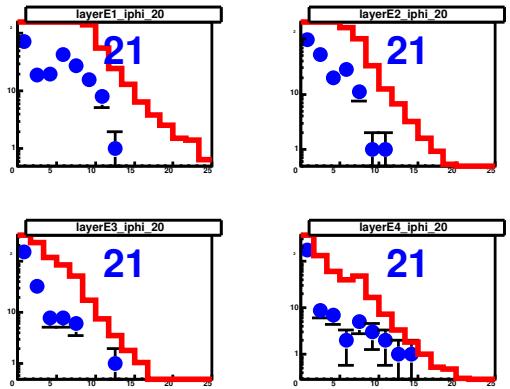
$i\eta = 2$

- Low occupancy towers:

$i\eta$ 26, $i\phi$ 7, FH 1-4



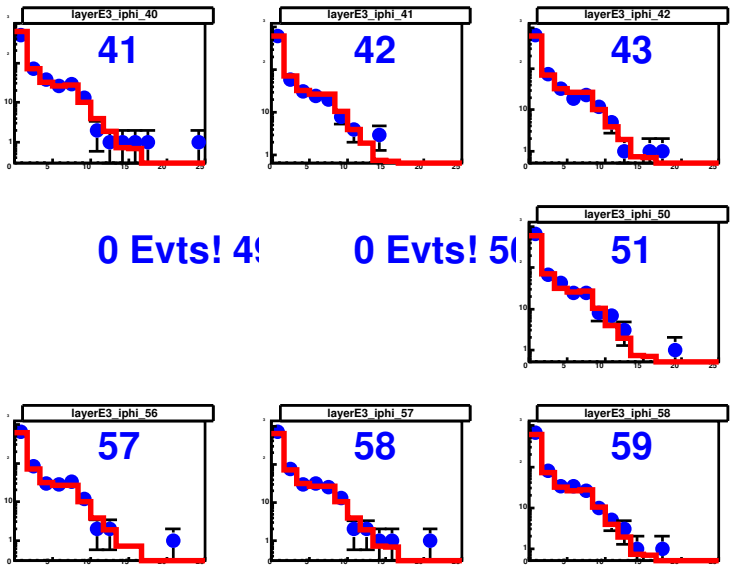
$i\eta$ 16, $i\phi$ 21, FH 1-4



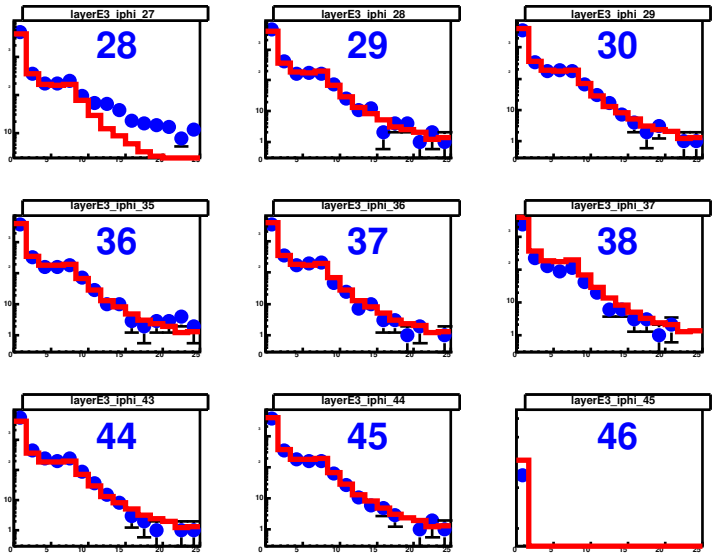
Bad Data Quality Examples II

- L1 dead tower and dead cell:

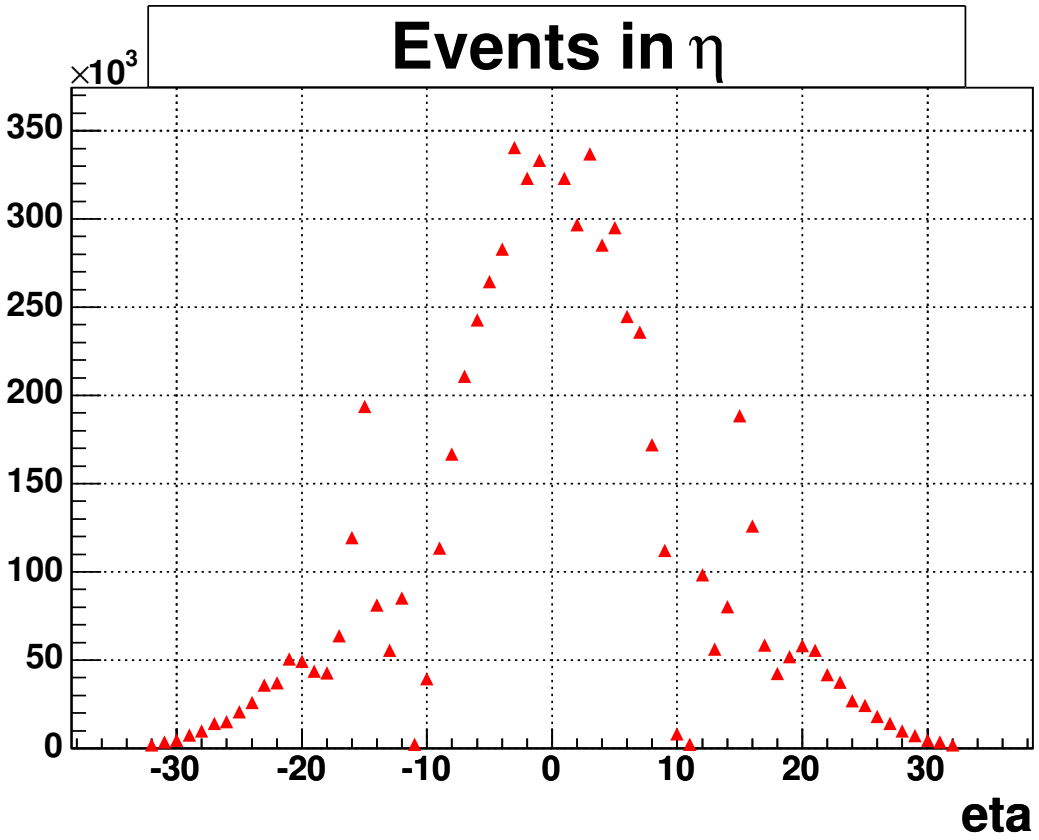
$i\eta = -20$, layer 3



$i\eta = 1$, layer 3



Number of events



- Number of single PR towers above $7\,\mathrm{GeV}$ in our data sample as a function of η (summed over $i\phi$).
- ECs and ICD suffer from low statistics but we already have more data.

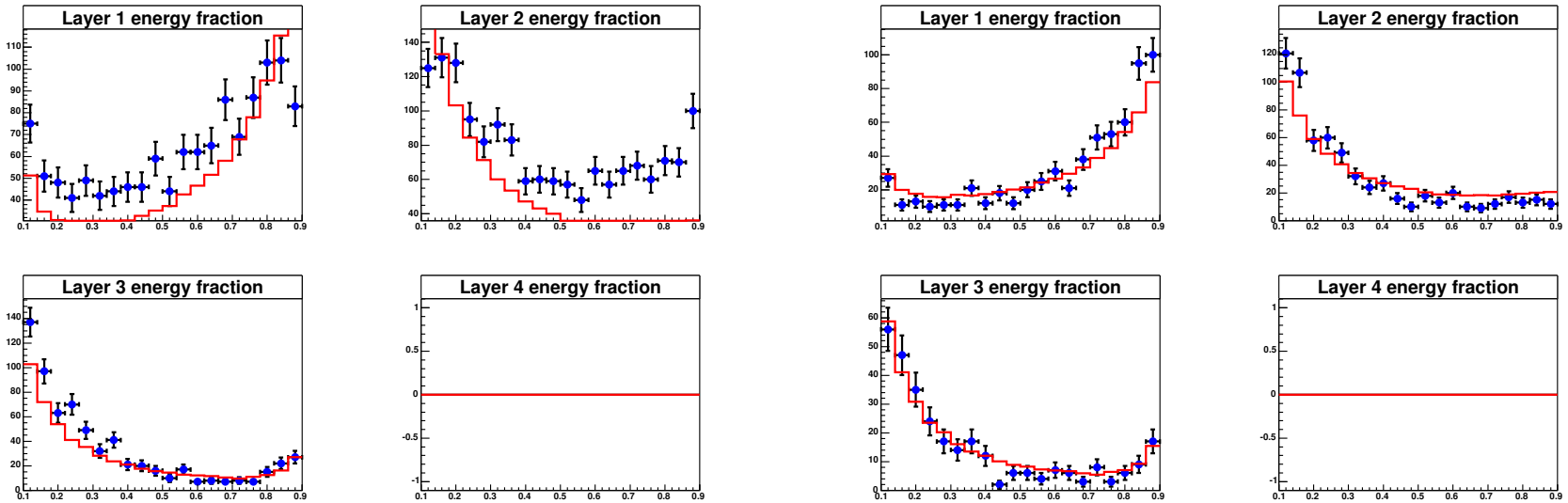
The Method

- We choose the E_{T} cut of $9\,\mathrm{GeV}$ which gives lowest tower calibration constant error.
- The cut value is enough above the trigger cut of $7\,\mathrm{GeV}$, yet providing us with sufficient amount of data.
- Our cut selection thus balances resulting statistics and trigger bias at low energies.
- Tower constants are derived by varying the cut so that each tower at given η reports the ϕ-averaged number of events above its individual threshold (sometimes the tolerance must be lowered from exact to difference of 1 or 2).
- The ratio of cut values (at given ϕ and starting one) gives us the calibration constant.
- Layer constants calibrate cells inside the tower.

More on the Method

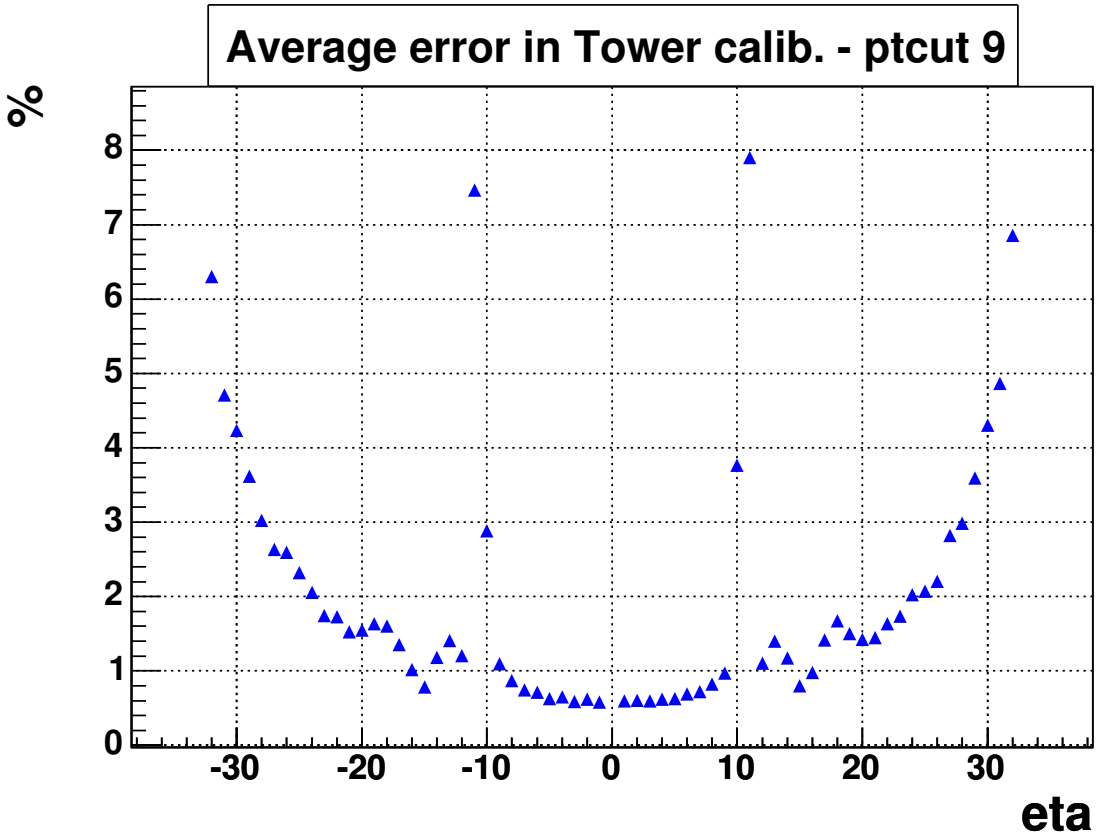
- We look at energy fraction distributions in each ϕ, compare to the average, compute individual layer χ^2_i's and minimise $\chi^2_{\text{all}} \equiv \sum_i \chi^2_i$ using `Minuit`.
- We fix the first layer constant to 1 (we are constrained by the tower constant) and vary up to 3 layer constants.
- In each minimisation step we recompute the tower energy $E' = E_0 + c_1 E_1 + c_2 E_2 + c_3 E_3$ as well as layer energy fractions $f_i \equiv c_i E_i / E'$, fill new histograms and search for best solution in terms of (c_1, c_2, c_3).
- Then we iterate this procedure, i.e. find a relative tower constant w.r.t. previous iteration using current tower and layer constants, fit χ^2_{all} etc., until stability is reached.

χ^2 Fitting Procedure Performance



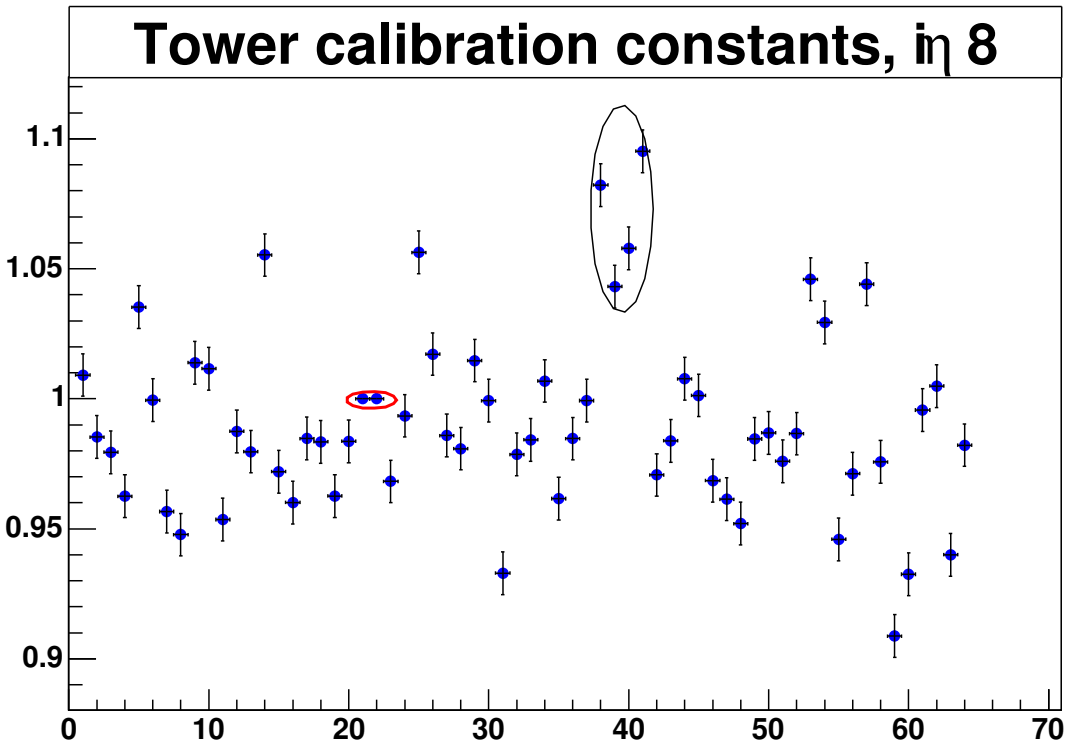
- Illustration of the reference and calibrated layers fraction distributions at different stages of the Minuit minimization.
- $i\eta = -2$, $i\phi = 64$, total 10 `Minuit` steps (first and last shown).
- Energy fraction distributions are completely different compared to EM.

Tower Constant Error



- The error of the tower constant as a function of η (6.5M events)
- We can easily calibrate CC below 1%, but have to wait for more data to move to higher $i\eta$'s.
- Dedicated trigger would be needed for highest η's.

Typical Tower Calibration Constants ($i\eta = 8$)

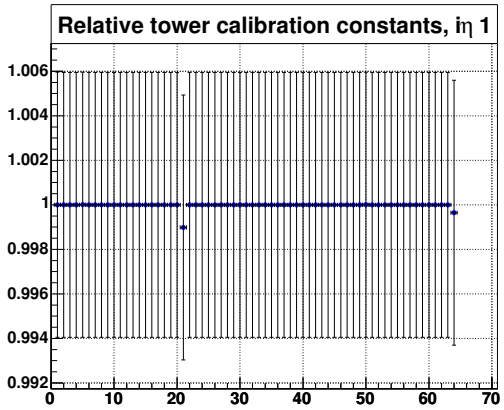


- Clearly visible problems, like dead L1 tower (constants fixed to 1).
- A whole module of lower response $i\phi$ 38, 39, 40, 41 in CC, needs to be boosted up, effect stronger at module edge.
- Same symptoms as famous Module 17 in EM (seen in more η's), but we don't know the problem origin yet.

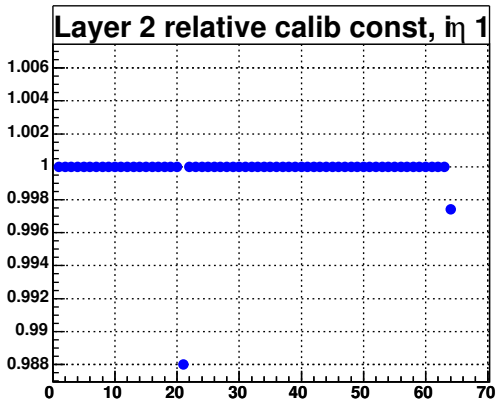
Calibration Constants after 7 iterations, $i\eta = 1$

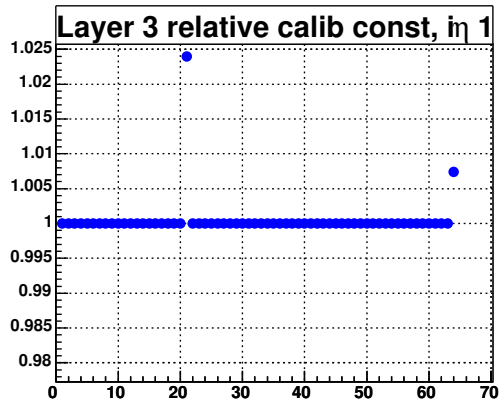
Relative (w.r.t. previous iteration) and final calibration constants.

Relative Tower Constants

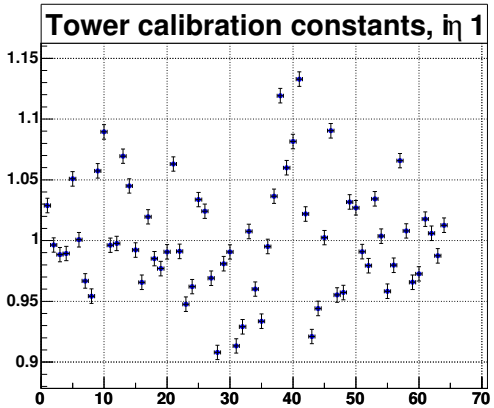


Relative Layer Constants

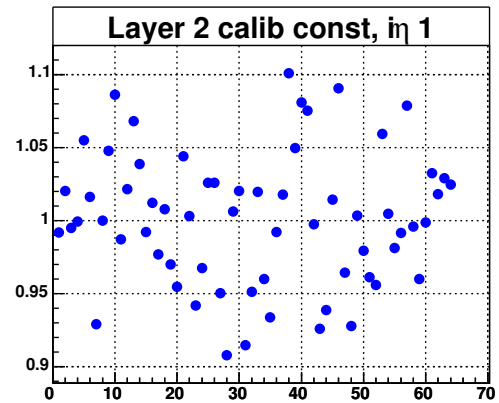


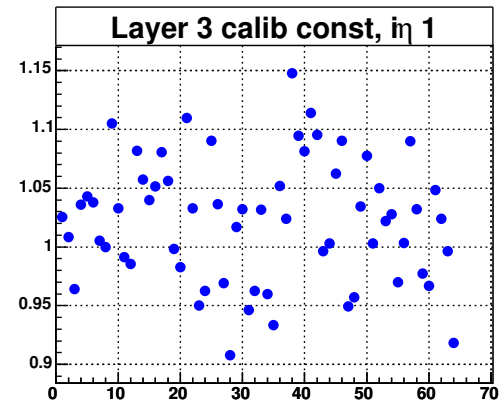


Relative Tower Constants



Resulting Layer Constants





Summary

- Preliminary results show the calibration is need!
- We can already calibrate CC to an approximate 1% precision.
- In CC also layer calibration is possible, prospect to higher η's optimistic with more data.
- We also identify many interesting calorimeter data quality problems.

Plans

- Finalise data quality and killing bad cells/towers in the calibration code.
- Now working on toy MC ensemble testing to estimate the error of layer constants.
- Further tune layer calibration (binning, fit range...)
- References:
  - DØ thesis by Qiang Zhu
  - Matt Wetstein's dØnote (in preparation), also talk at ADM, January 14^{th} 2005
  - Calorimeter Calibration meeting, March 16^{th} 2005
  - Krisztián's talk at CALOP meeting April 21^{st} 2005 (data quality)