AHCAL Saturation Study

CALICE week – Casablanca, Morocco 2010/09/22

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- **Study of single SiPM response function on AHCAL**
- **Compare FNAL & CERN calibration data**
- **Application of temperature correction**

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CALICE Calorimeter for ILC

Calibration chain: ADC to MIP

AHCAL signal chain:

Particle shower → MIPs → scintillator → photons (UV) → SiPM (non-linear) → photo-electrons → amplification → electronics

$$E_i[MIP] = \frac{A_i[ADC]}{C_i^{MIP}} \times f_{sat}(A_i[pix])$$

Calibration:

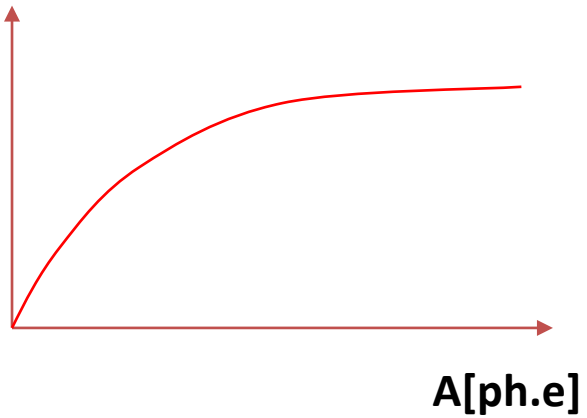
convert detector signal into number of MIPs deposited by particle traversing the tile & correct for non linear response of SiPM

$$f_{sat}(A_i[pix]) = f_{sat}\left(\frac{A_i[ADC]}{I_C} \times G_{pix}\right)$$

What do we need:

Lightyield in [pix/MIP]:

- **MIP amplitude** in ADC bins ... C_i^{MIP}
- **SiPM gain**: (CalibMode) ADC bins converts to pixel ... G_{pix}
- **Electronics Intercalibration**: between PM/CM mode ... I_C
- **SiPM response function:** corrects the non-linear response of the SiPM ... $f_{sat}(A_i[pix])$

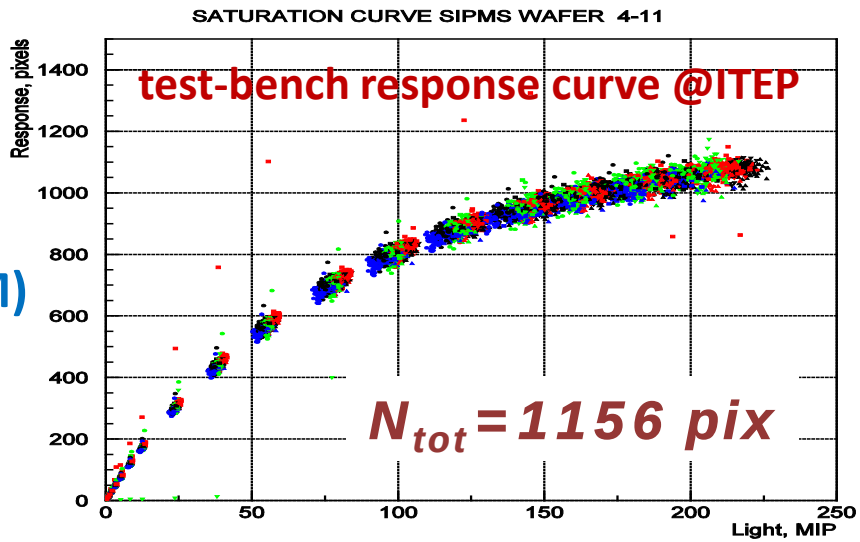


Saturation curves

- Saturation curves for single SiPM should be universal…

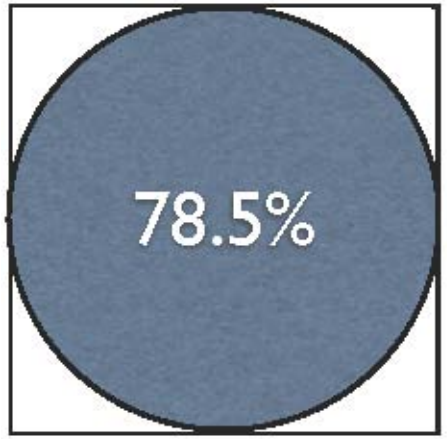
BUT:

- Disagreement between ITEP (bare SiPM) and in-situ (on-tile) measurement



$$A_{pix} = N_{tot}\left[1 - \exp\left(-A_{ph.e.}/N_{tot}\right)\right]$$

- Not all pixels illuminated by WLS light!
- Ratio of geometrical area it is expected that only 78.5 % of the SiPM area (square) is illuminated by the WLF fiber
- different number of dead pixels in each SiPM could change this number

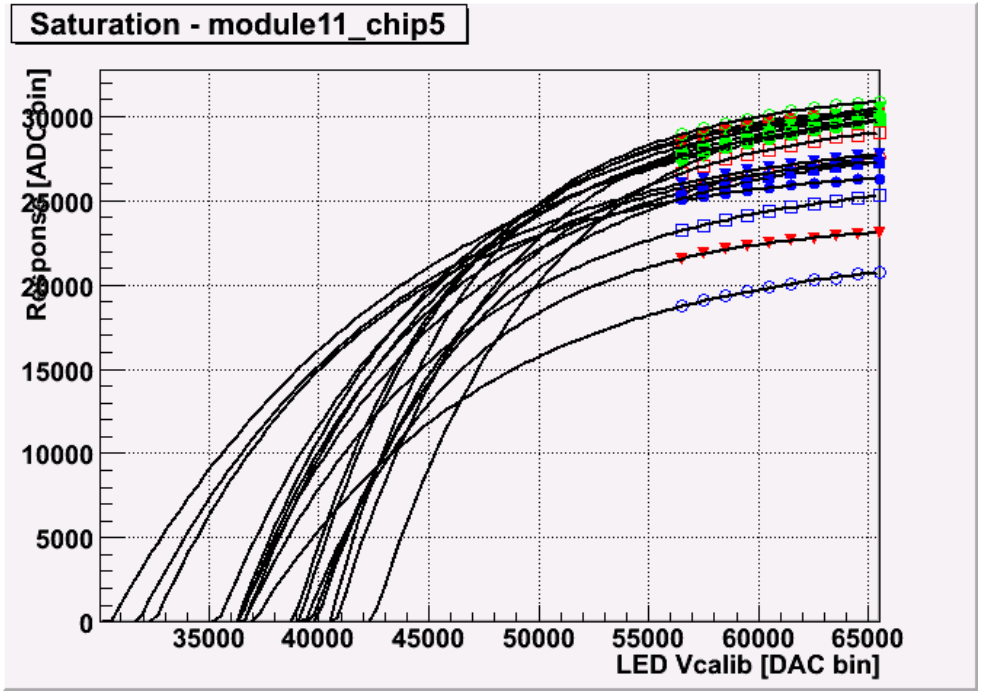


- Total number of pixels in a SiPM = 1156

Try to determine saturation factor for each channel separately

LED light intensity scan

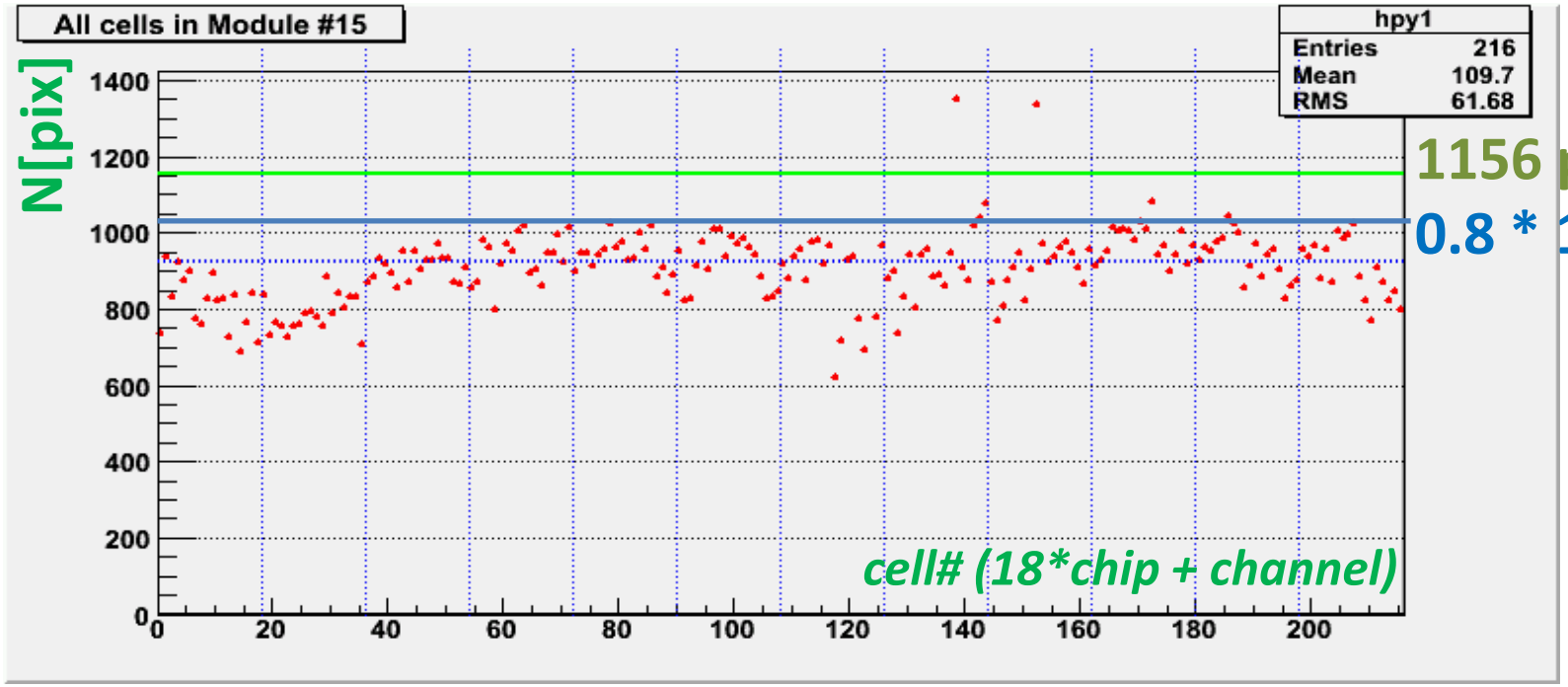
Example: 18 different channels



- **Runs:**
  - LED light intensity scan using physics mode of the ASIC chip
  - FNAL 2008 & 2009, CERN 2007 periods
- **Fitted 10 (or more) points**

- **Fit simple Exponential formula for saturation:**
- **$F(A_{ADC}) = N * [1- Exp(-(X+C)*B)]$ X … LED intensity**
- **Extract parameter N -> 'Saturation factor' (Slope = B * N, Shift = -C)**

Calibration in pixels



- Calibration of single cell formula: $N_{pix} = N_{ADC}(T_2) * I_C / G^0_{pix}(T_1)$
- $G_{pix} = G^0_{pix} + dG/dT * \Delta T, \quad \Delta T = (T_1 - T_2)$
- use G^0_{pix} , I_C , dG/dT from DB for individual channel
- T from 5 temperature sensors on each module (closest one chosen)

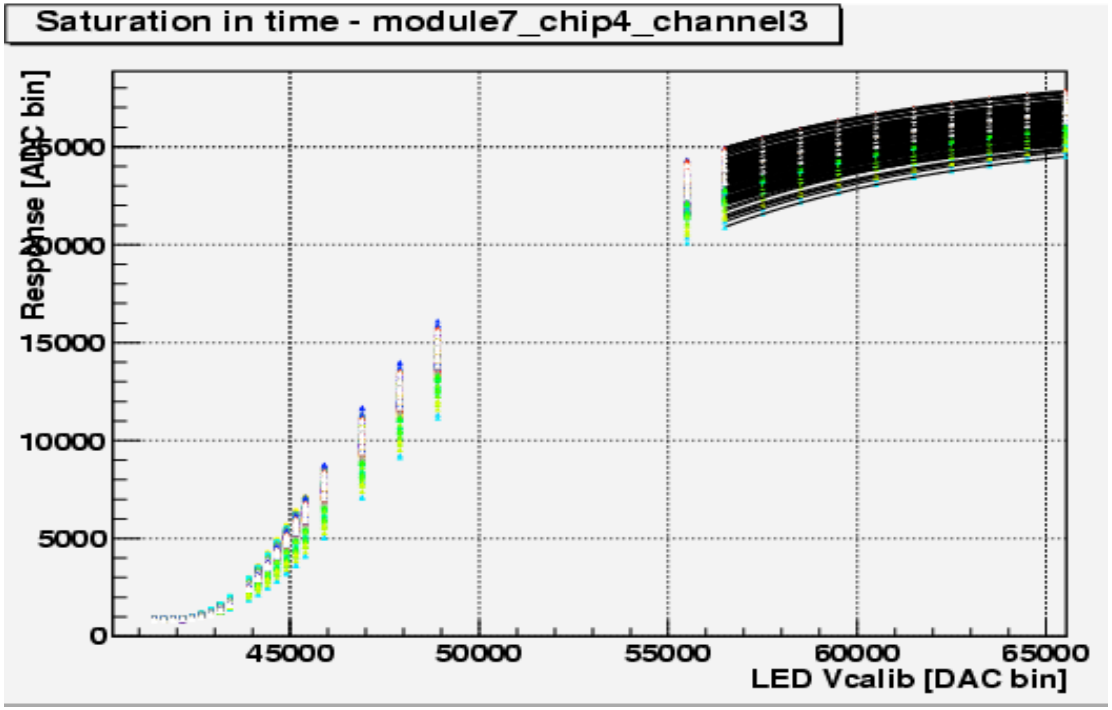
Procedure

- **Good events - curves:**
  - Tags: graph, fit function, Chi2(Ndf !=0) available
  - Calibration constants, slopes & temperatures exist in DB for ch.
  - No saturated curves: no ADC saturation + smooth increasing fce
  - Fit parameters lay in (wide) ranges: saturation, shift, slope, errors
  - At least one good fitted curve among run in the groups
- **using one intensity scan run only ~50% of curves fit**
- **extending the sample of curves studied to all available calibration runs (144/66 at FNAL/CERN) the number of converged fits increases to ~82-84% (of tot. 7608)**
- **for the other channels used default value 0.8**

Performance & Stability

Fits: one channel, all runs

N[ADC]

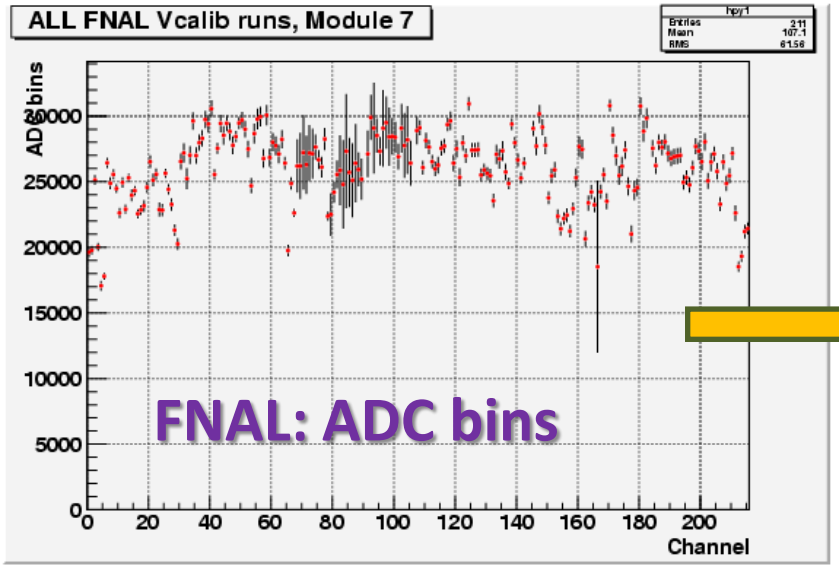


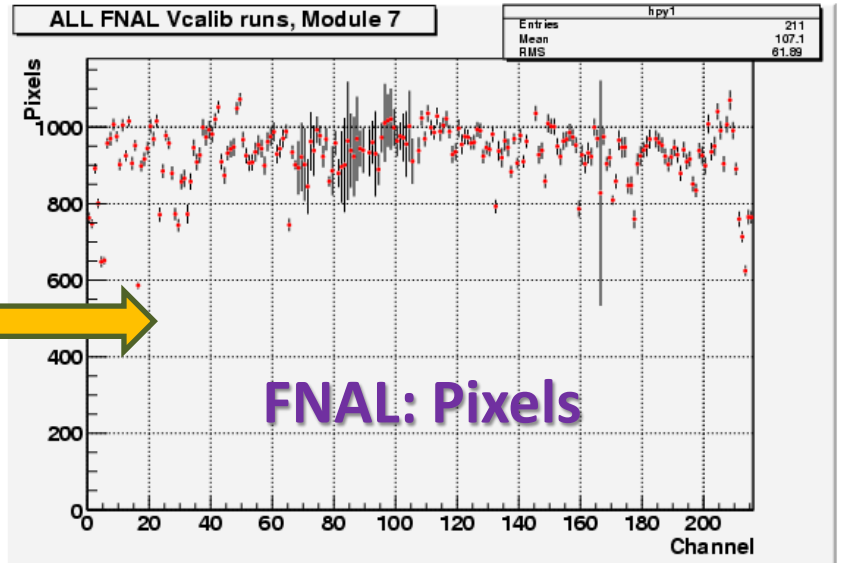
Example:
144 fits (FNAL)
for one channel

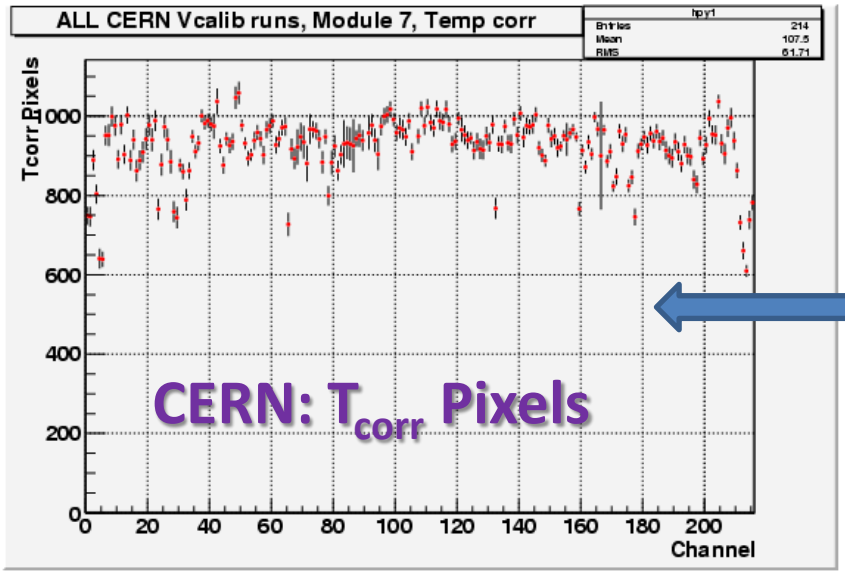
• for 'good' runs
similar behavior

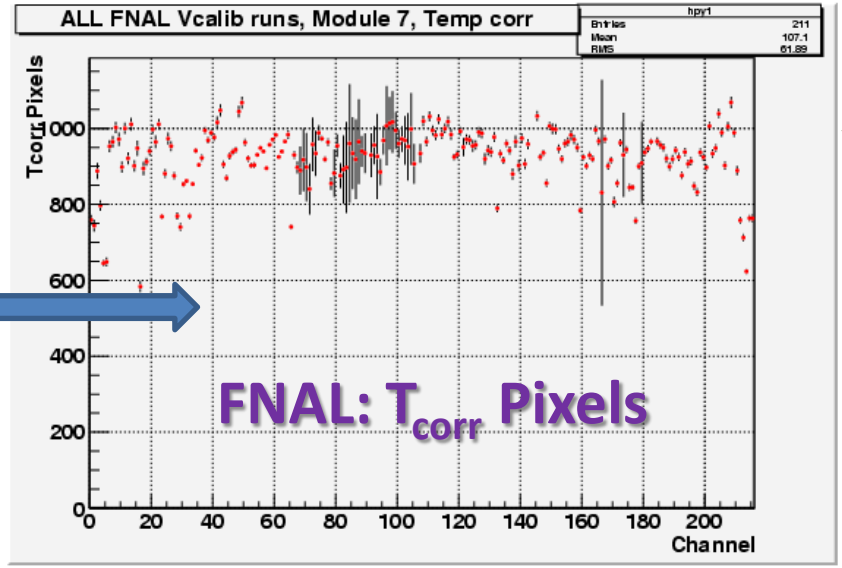
→ extract saturation factor N[ADC] for all channels
→ apply calibration to pixels & temperature corrections → N[pix]
→ consistent results for all runs? → averaged over all runs
→ unique curve for all channels?

Results I: ADCbins,Pixels,T_{corr}Pixels...



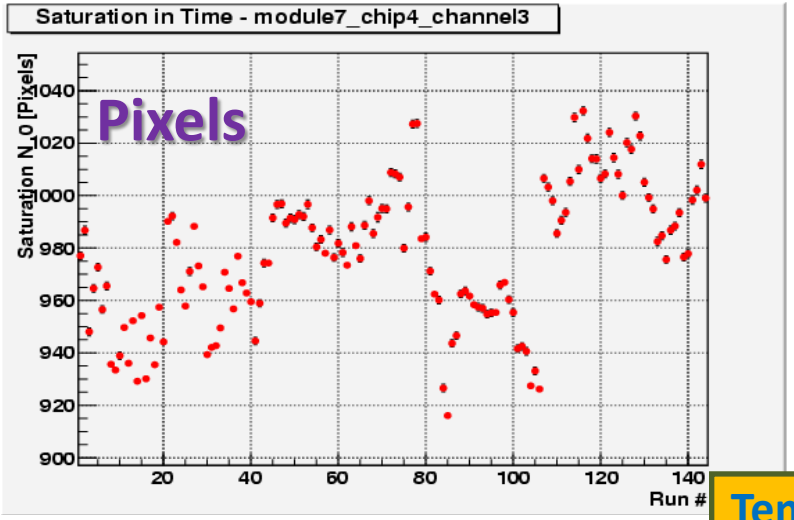


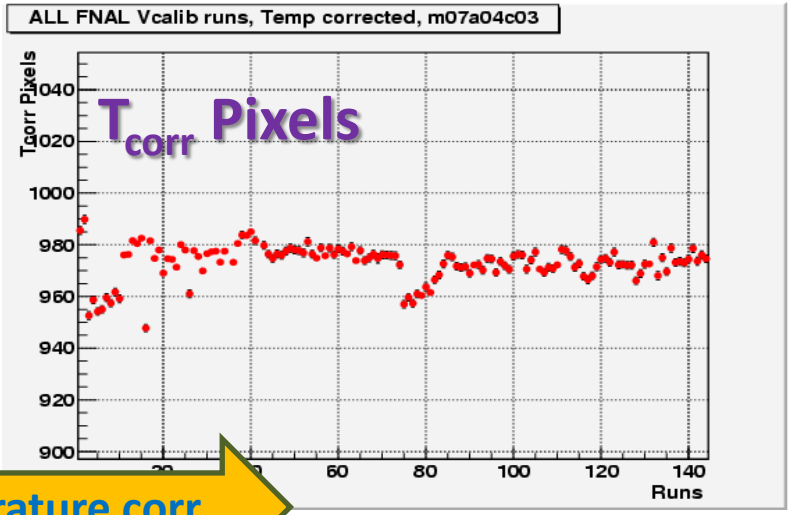




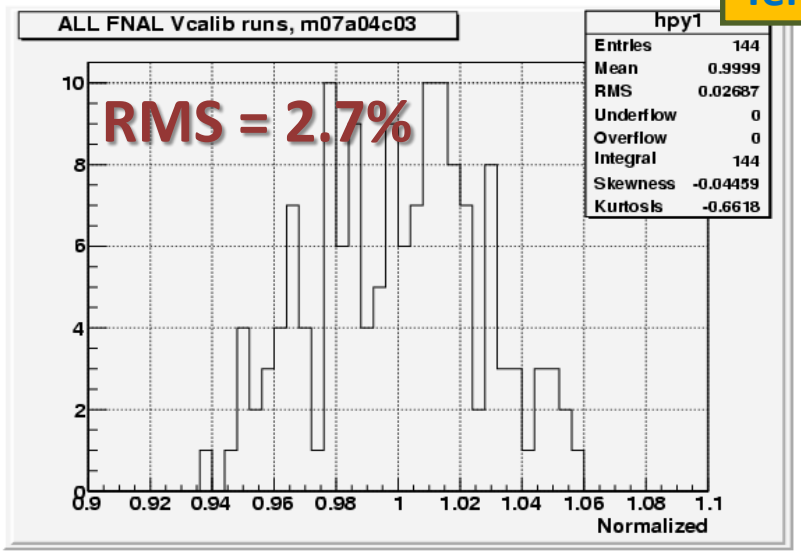
*X-axis: cell# (18*chip + channel)*

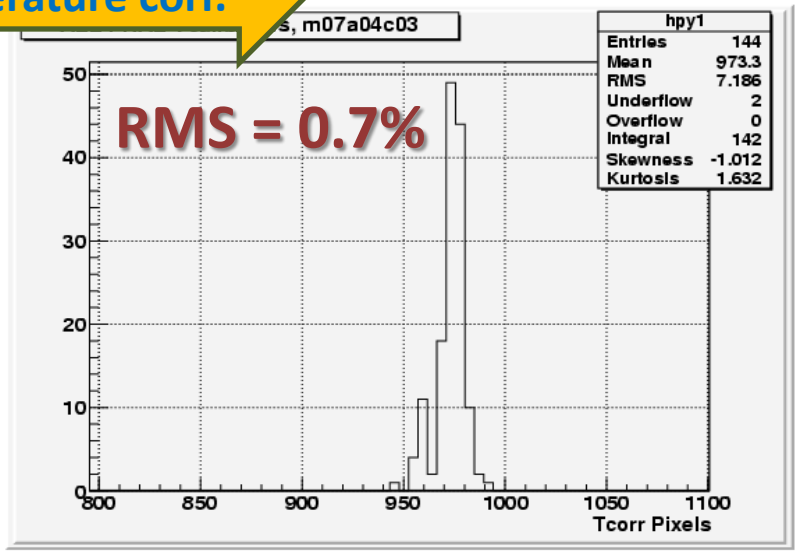
Results II: Temperature correction





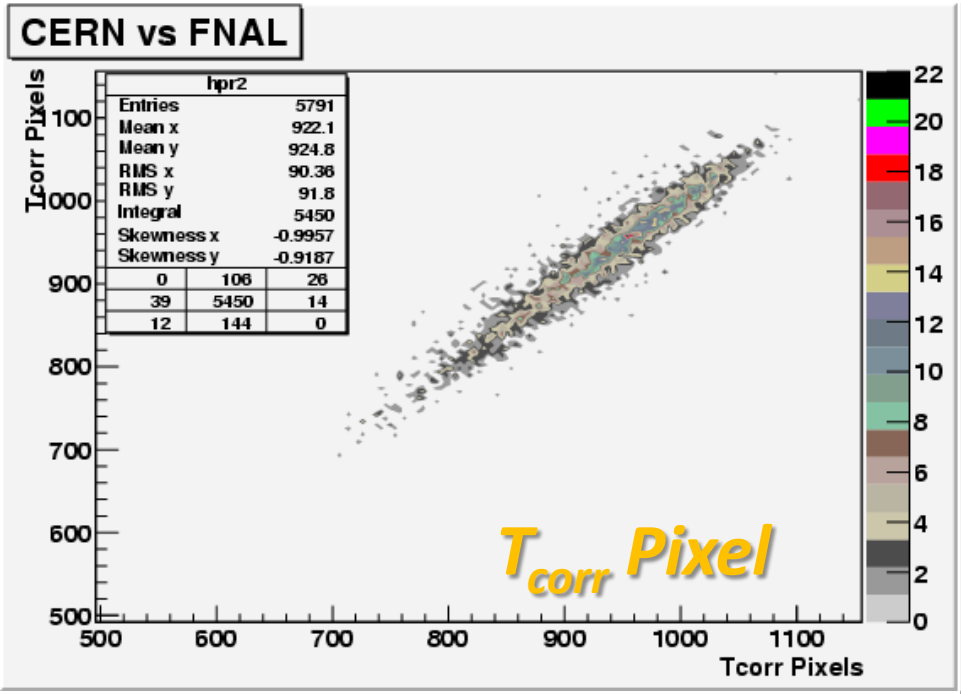
Temperature corr.

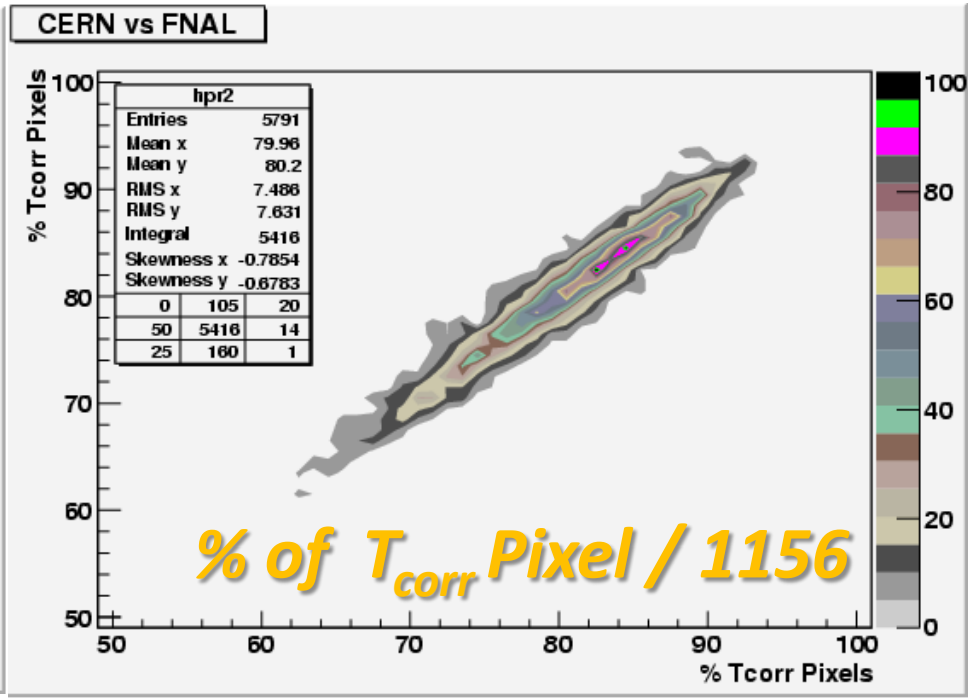




- **Temperature correction is working well**

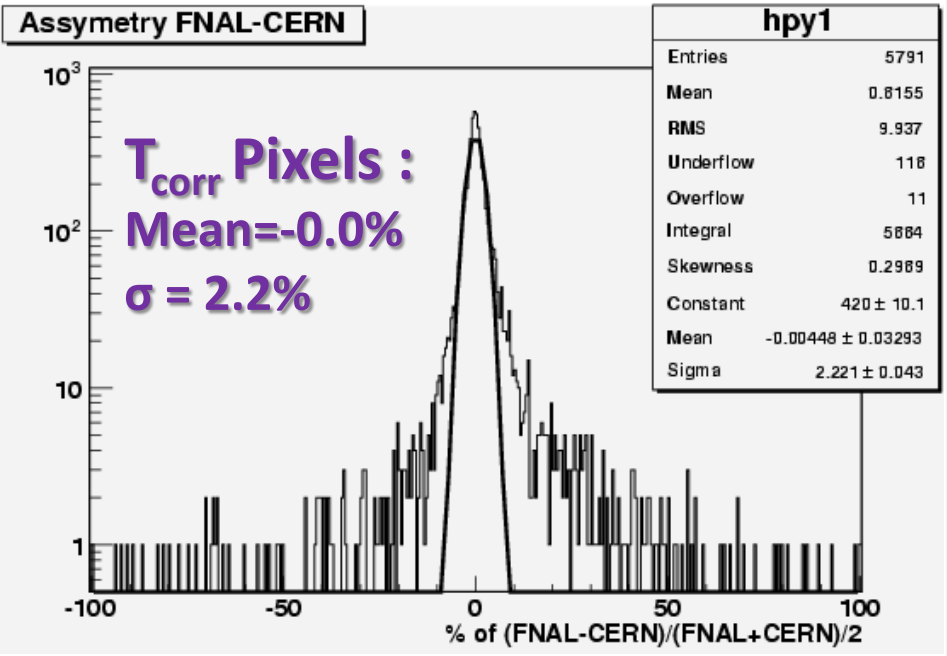
Comparison: FNAL versus CERN

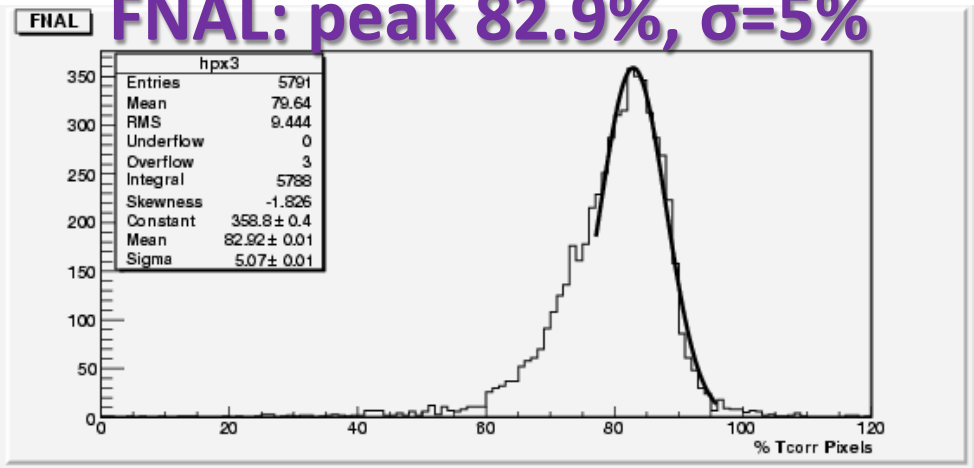


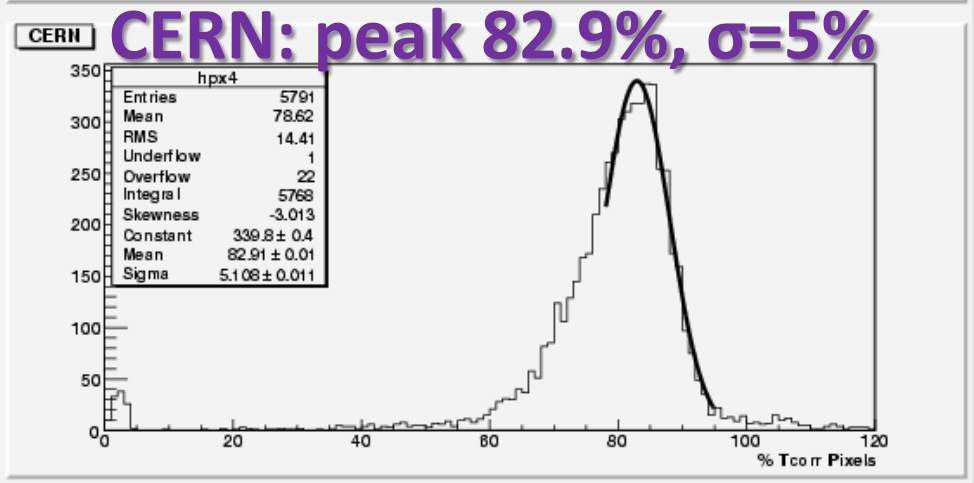


- Good correlation between saturation point extracted from CERN and FNAL data
- Both data sets shows average effective number of pixels at a level of 80% of phys. number (w/ RMS ~ 7%)

FNAL-CERN Asymmetry







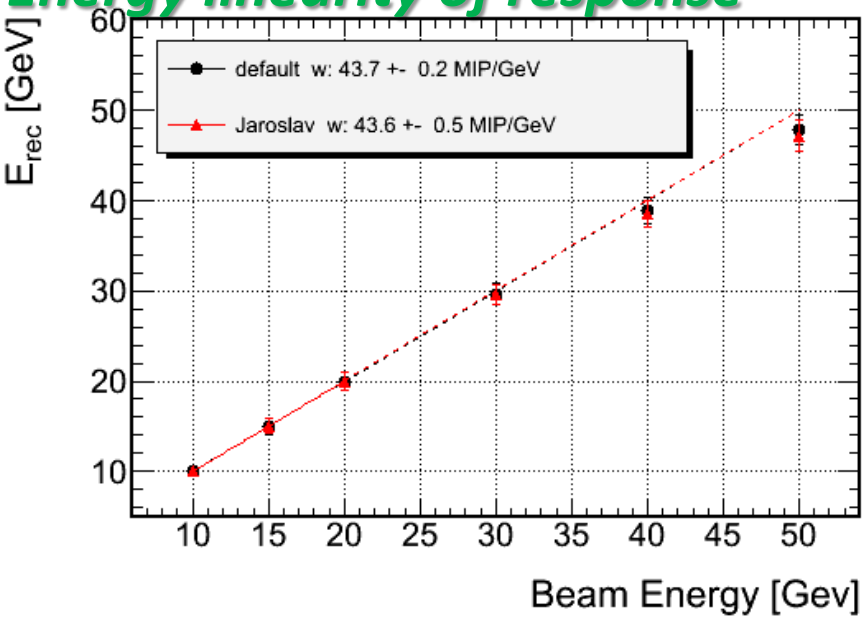
~10% outside 3σ-range

- **Temperature correction cancels the difference in mean.**
- **The signal does not degrade (small error of T correction factor)**
- **But long tails with wrong fit either at CERN or FNAL or both.**

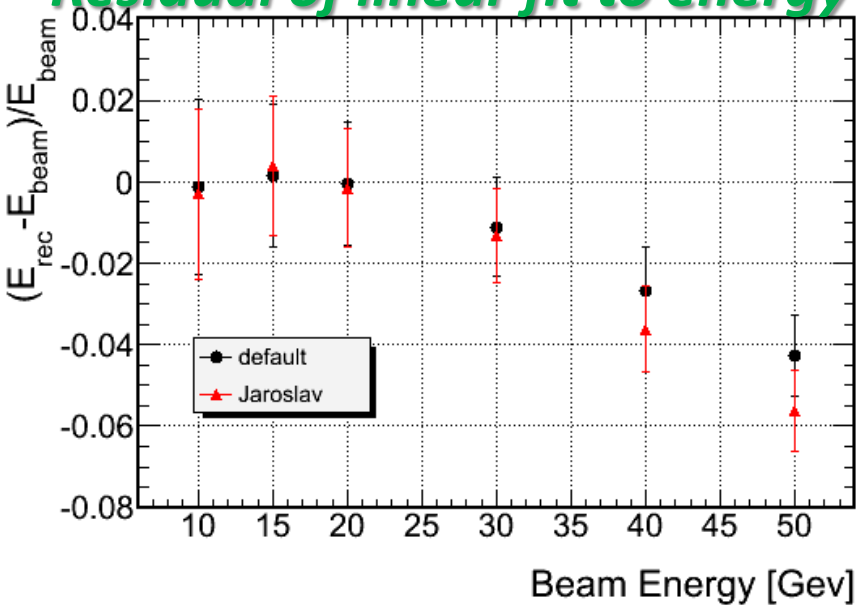
Effect of channel-by-channel corrections on EM analysis

global rescaling factor X single cell saturation

Energy linearity of response



Residual of linear fit to energy

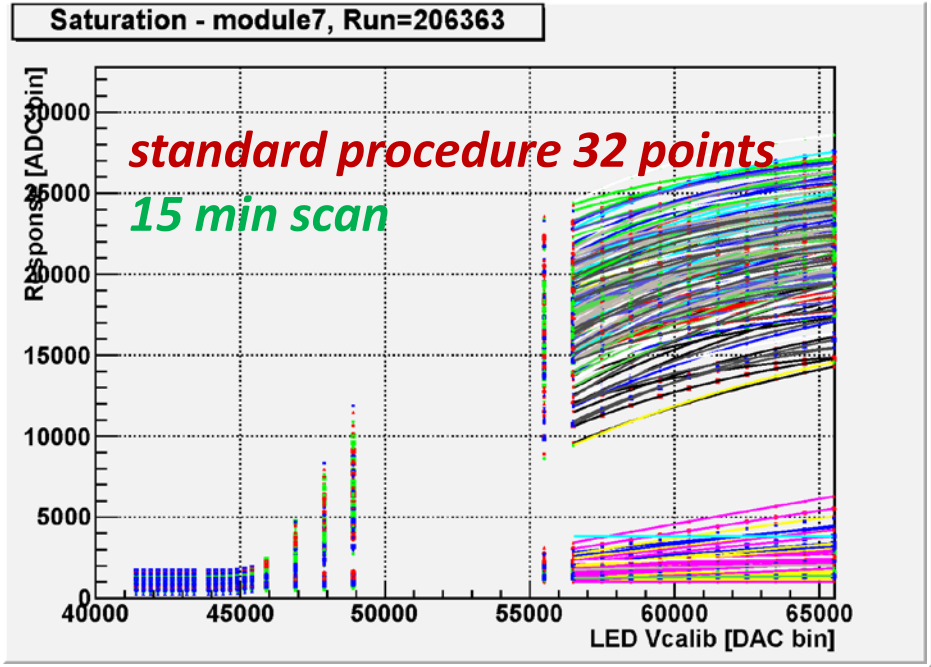


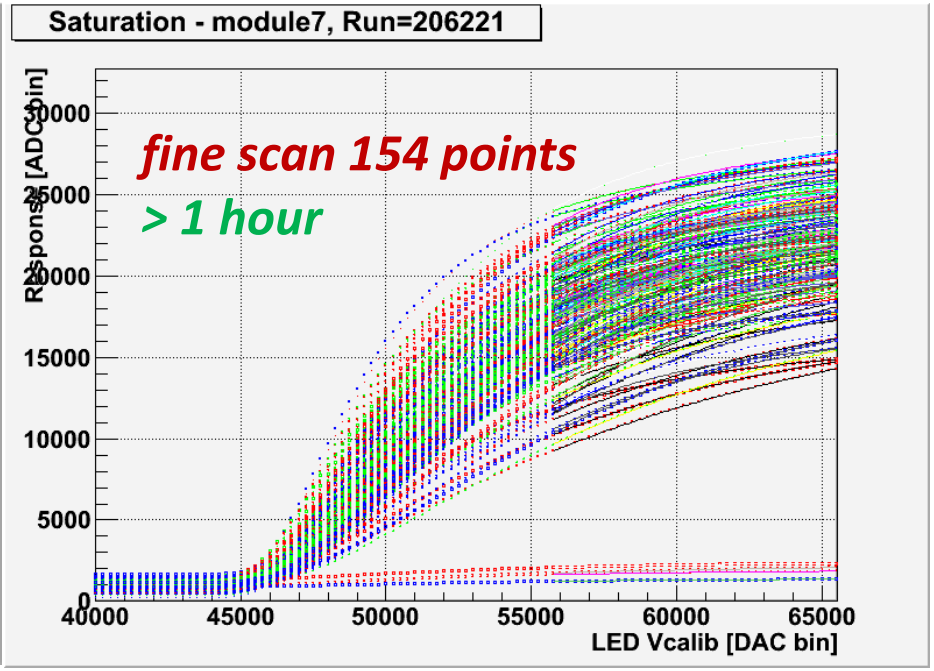
- single-cell calibration does not improve the linearity w.r.t. a common rescaling factor

→ simplifies calibration chain of high-multi channel calor.

ToDo & Improvement

- The measurement of the saturation curves is being done with re-commission AHCAL for W-option 2010 tests at CERN
- Much more data points are taken for curves to cover all ranges (154 steps @ > 1h data taking → not possible during beam data)





Conclusion

- Analysis gives results for single SiPM saturation curves over all available calibration runs from TB at CERN & FNAL 2007-09
- Performance is improved with averaging of the results over all runs from both periods up to 6360 (84%) ch. after sel. criteria
- The calibration and temperature correction seem to work very well and improve the results
- Both data sets FNAL & CERN give consistent results: ~83% of pixels illuminated by WLS fiber light
- Still remaining outliers channels which are not or can not be fitted properly