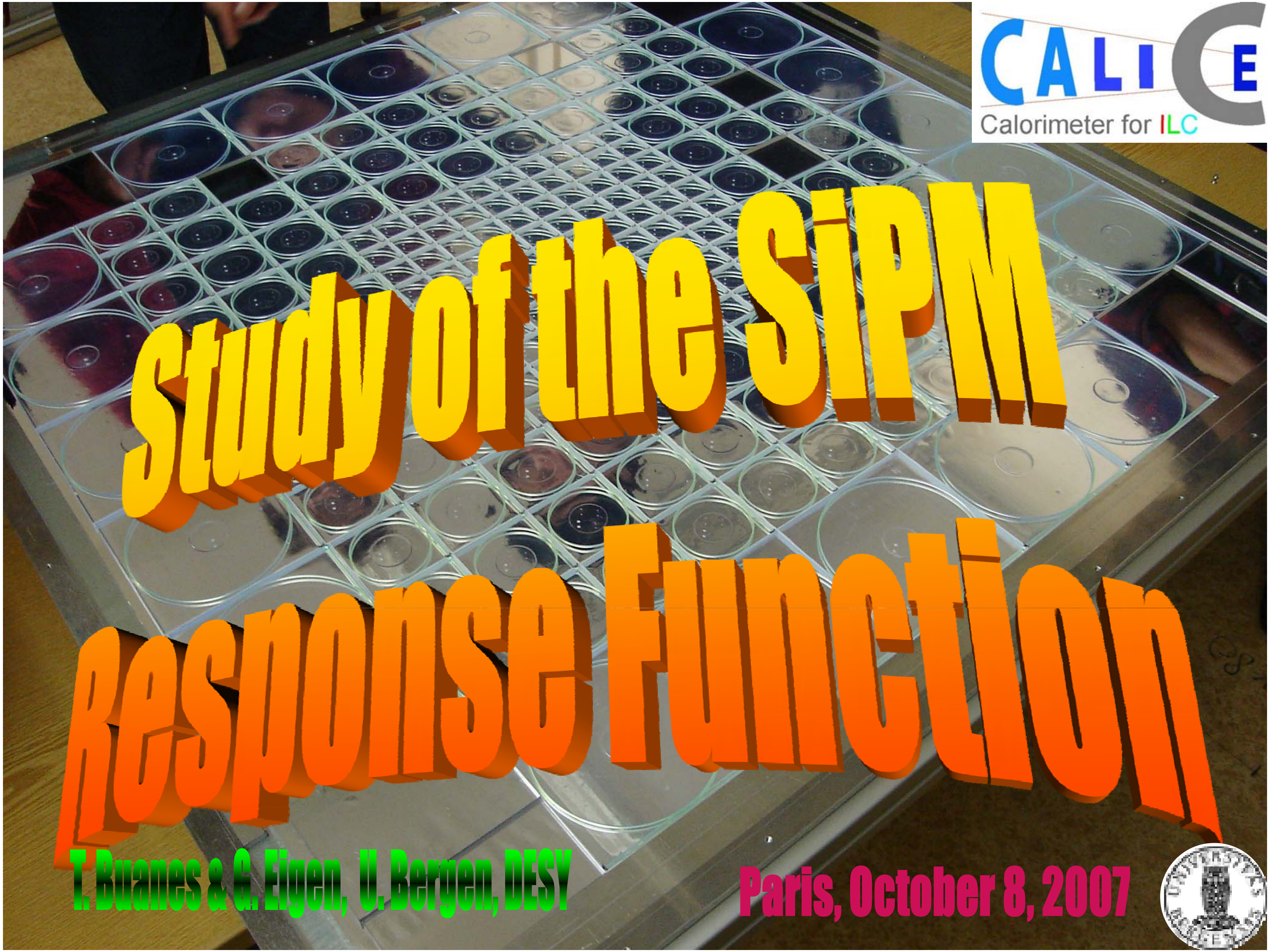

CALICE
Calorimeter for ILC

Study of the SiPM Response Function

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Paris, October 8, 2007

Introduction

- The SiPM response is non-linear and depends on operating voltage ($V-V_{bd}$) and temperature ➔ SiPMs need monitoring
- In the AHCAL physics prototype we use an LED-based monitoring system that can measure the full SiPM response function in each channel (one LED monitored by a PIN feeds 18 scintillator tiles)
- Since the present monitoring system is rather elaborate, one may ask if the system can be simplified in a full ILC calorimeter without sacrificing stable performance (<1%)?
- This requires a characterization of the SiPM response curves that can be determined with a few reference measurements
- During the 2006 testbeam program we took 4 runs recording the full SiPM response
- We are analyzing this data to extract essential characteristics of the SiPM response curves to address above question ➔ shape, saturation point,...

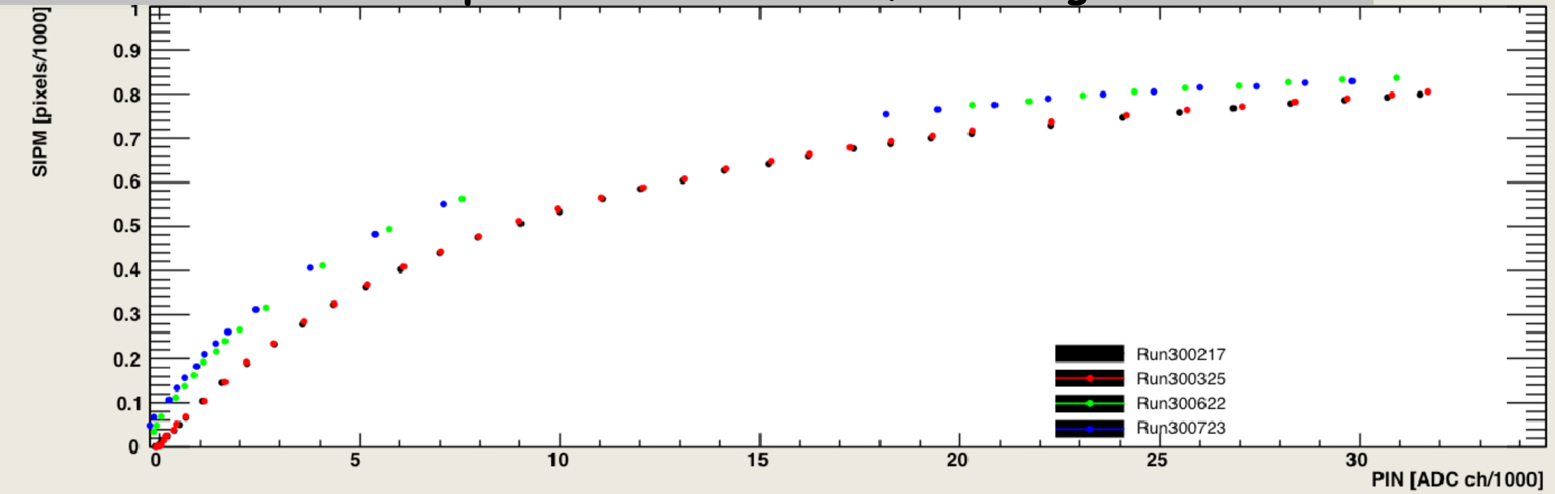
Analysis Procedure

- Use run type ahcPMVcalibScan and extract SiPM & PIN diode values from LCIO files (pedestal events are now included)
- Gain correction and intercalibration is taken into account here
- Pedestal subtraction is based on pedestal events from beam runs that weretaken shortly before or after Vcalib run
- We calculate average of SiPM & PIN for each Vcalib value & plot SiPM vs PIN correlation (➔ "uncorrected" SiPM response curve)
- Rescale PIN values to force initial slope to be one and start at a common origin (➔ "corrected" SiPM response curve)
- Small negative sipm/pin values occurring for low Vcalib values are set to (0,0) in fits to different models
- Compare 4 runs from August & October for all modules 3-15 (we have left out modules 1 &2)

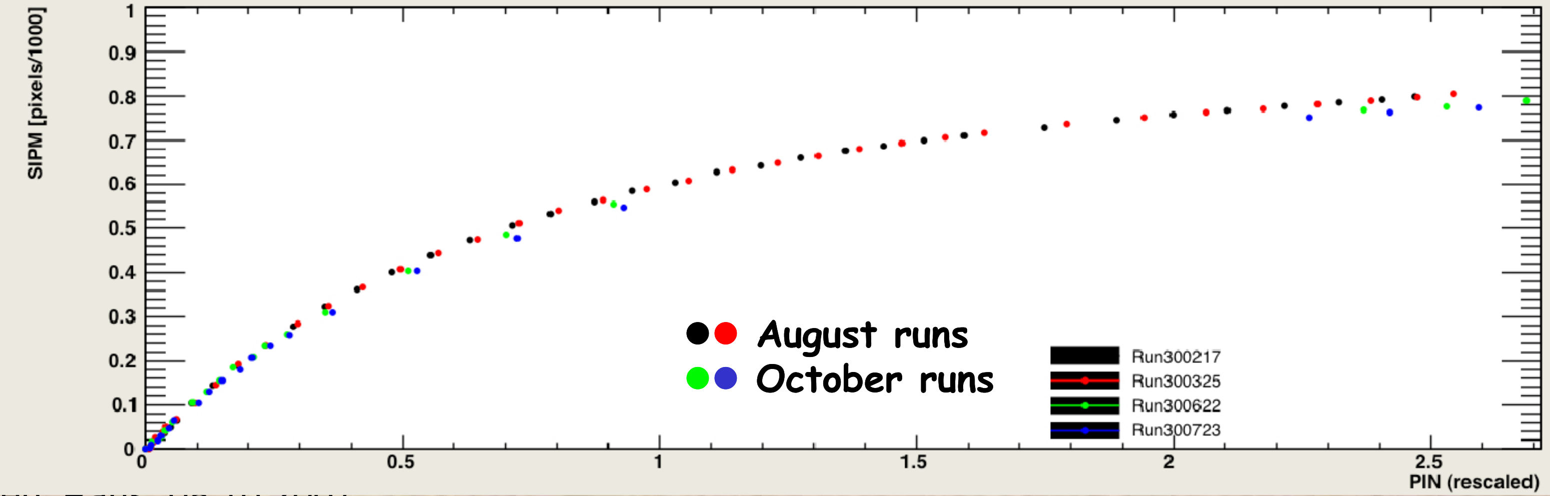
Saturation Curves for Module 13, 5-6

- Compare 4 runs from August & October

Saturation curve after pedestal subtraction, PIN & gain correction



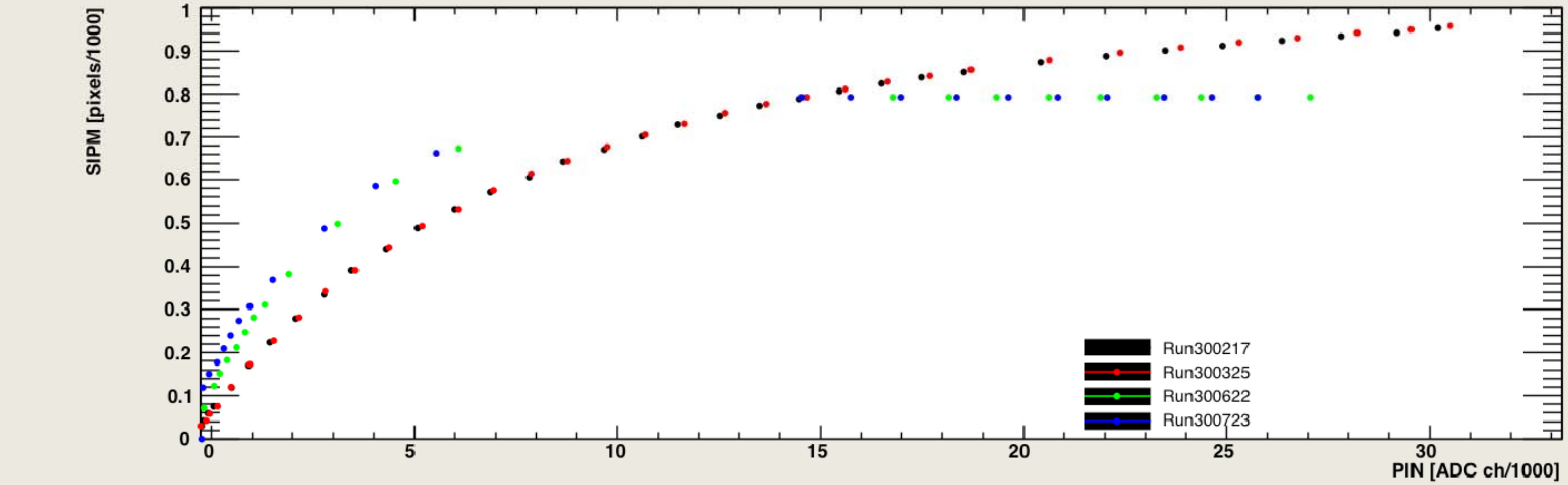
Saturation curve after adjustment to common origin with slope one



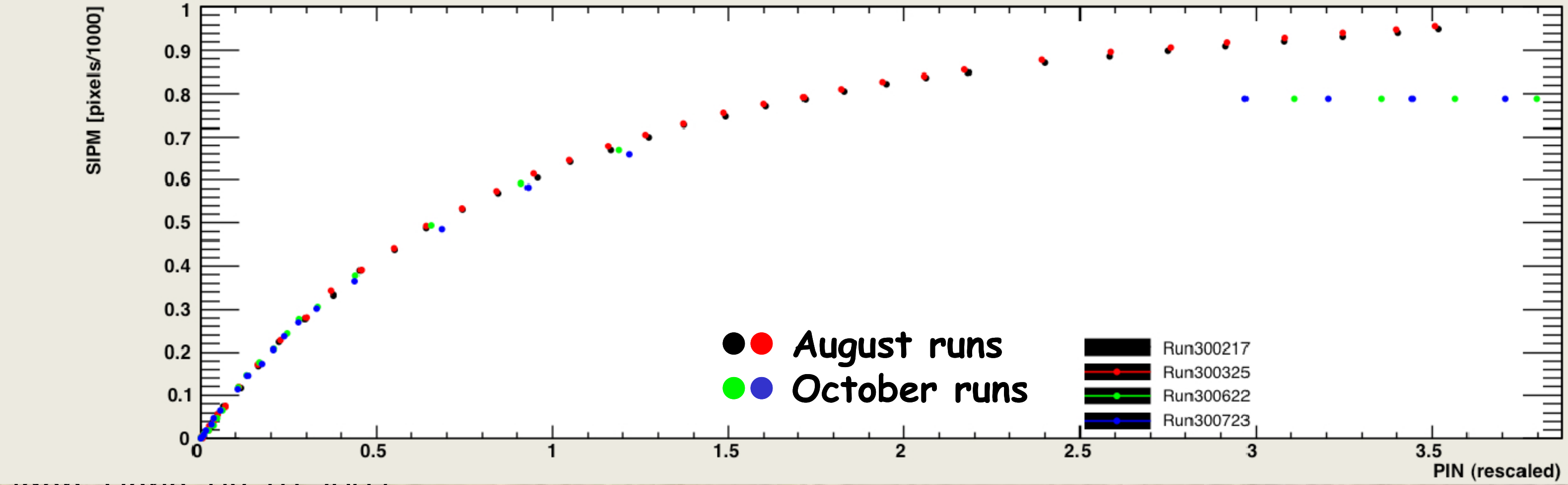
Saturation Curves for Module 5, 5-6

- Compare 4 runs from August & October

Saturation curve after pedestal subtraction, PIN & gain correction



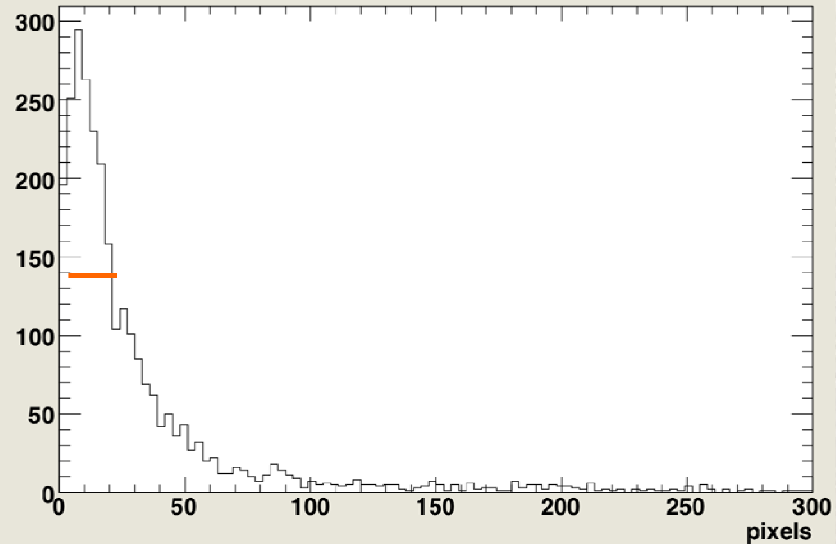
Saturation curve after adjustment to common origin with slope one



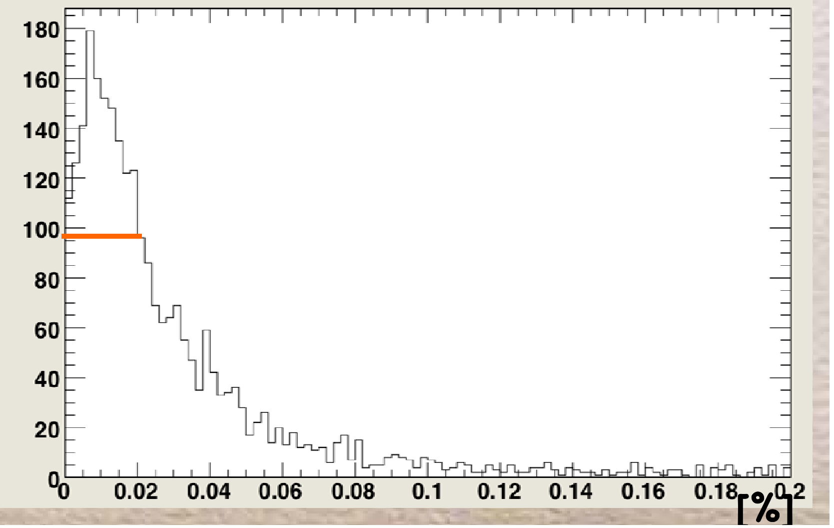
Spread of Endpoints in Different Runs

- Difference between maximum and minimum Δ value of SiPM response endpoint for the 4 runs
- Distribution peaks at ~10 pixels but has long high-side tail
  ➔ need to understand this
- FWHM ~ +13 -10 pixels
- Relative spread by normalizing Δ to average of 4 endpoint values
- Peaks is ~1%
- FWHM is ~1%, but distribution has very long tail on high side
- The long tails need to be understood and possibly reduced

Spread of endpoints from 4 runs

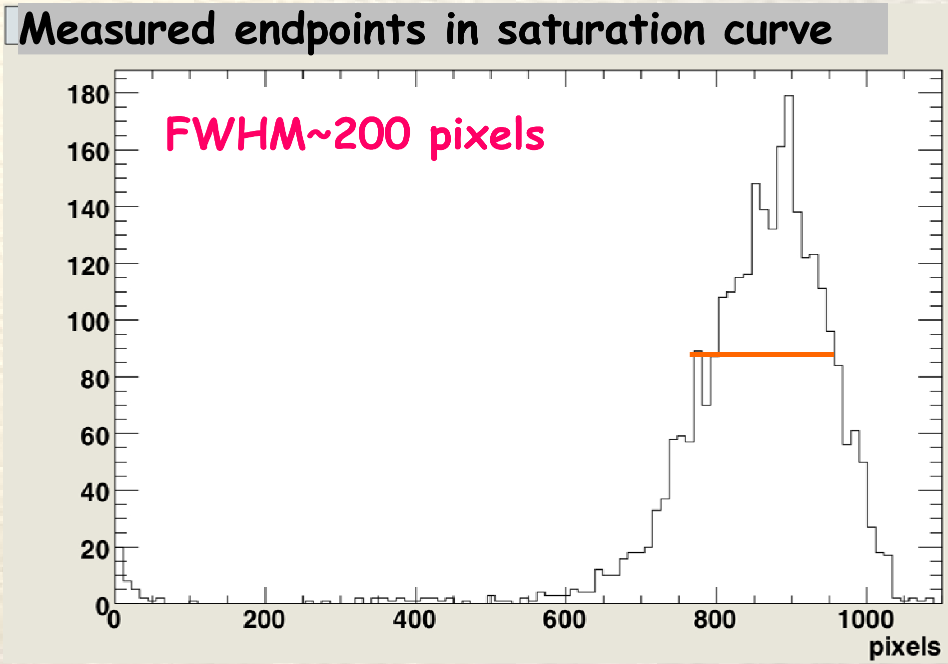


Relative spread of endpoints



Spread of SiPM Response Curve Endpoints

- This represents the variation in SiPM responses
- The distribution peaks near ~900 pixels & has a tail on low-side
- The FWHM is ~200 pixels ➔σ ~ 85 pixels
- The SiPMs have 1024 pixels



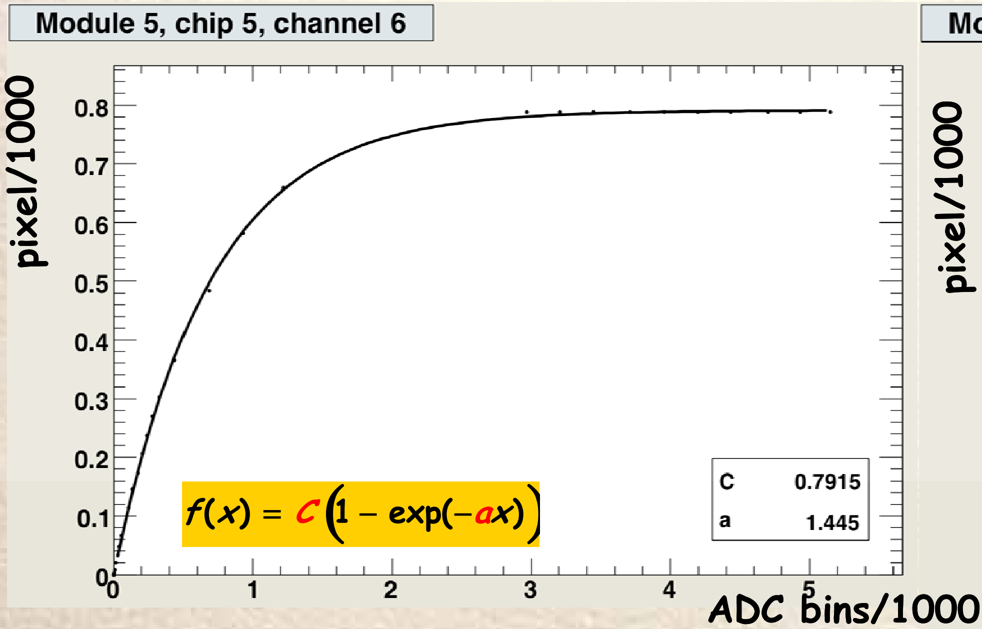
from run 300723

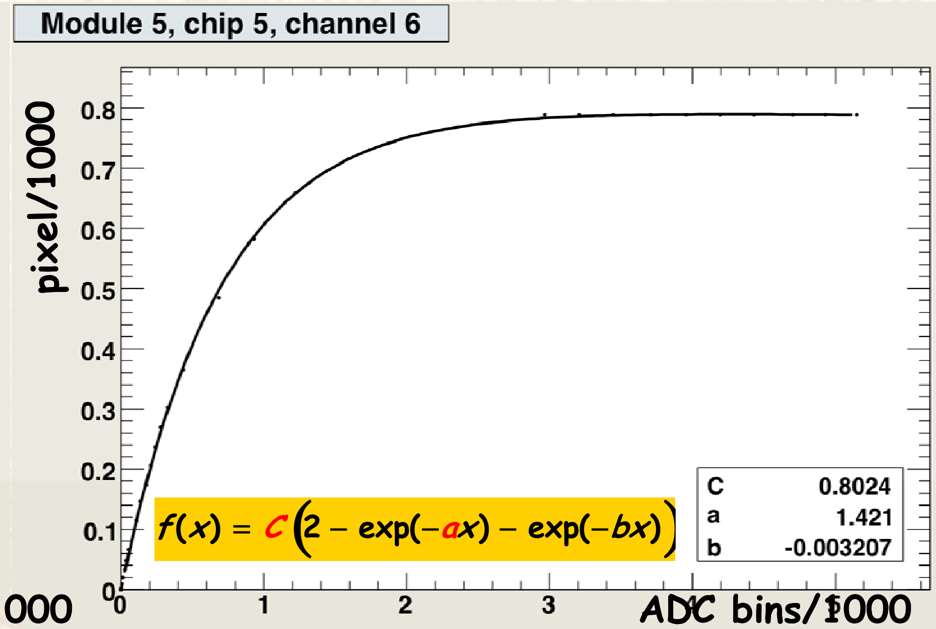
- We need to understand the ~100 pixel shift and the large spread (is pedestal subtraction too big?)
- Since the measured endpoint may not correspond to the true saturation value (non-zero slope at endpoint), we are exploring different fitting models

Parameterize SiPM Response Functions

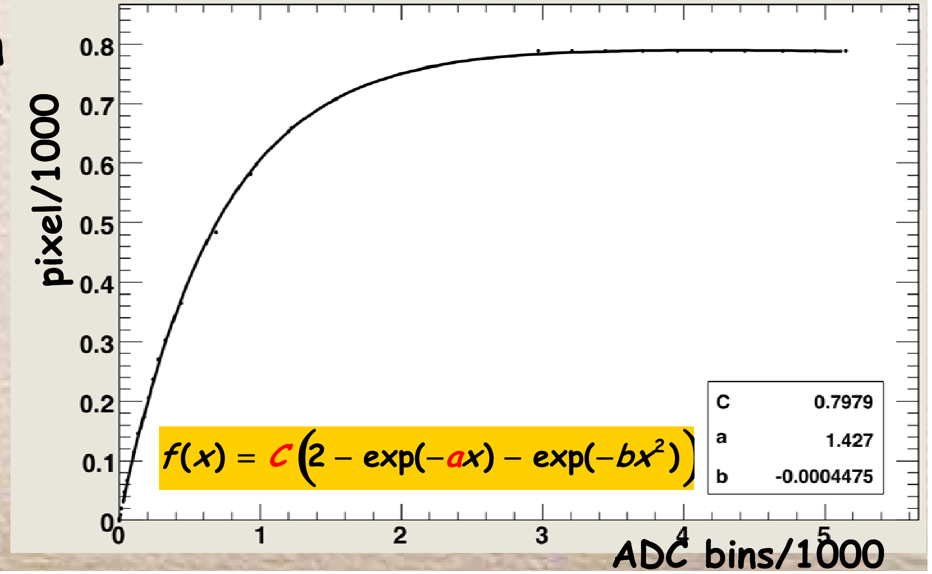
- The idea is to fit SiPM response to a function and extract the saturation value from the fit
- We have started with 3 model distributions
  - 1. $f(x) = C\left(1 - \exp(-ax)\right)$ ➔ zero slope at endpoint
  - 2. $f(x) = C\left(2 - \exp(-ax) - \exp(-bx)\right)$
  - 3. $f(x) = C\left(2 - \exp(-ax) - \exp(-bx^2)\right)$
- In first model C yields saturation value if slope is ~ zero at EP, otherwise saturation is underestimated
- To extract saturation value for latter two models is complicated as it varies between C and 2C depending on slope (not corrected)
- We are further looking into more refined functions

Fit Saturation Curves of Module 5,5-6

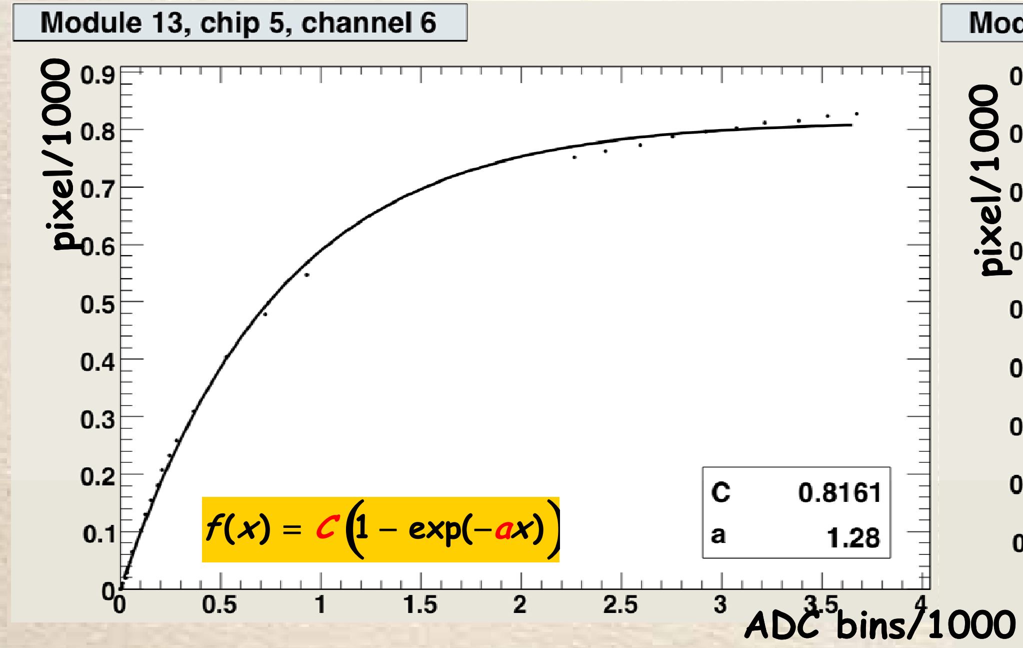


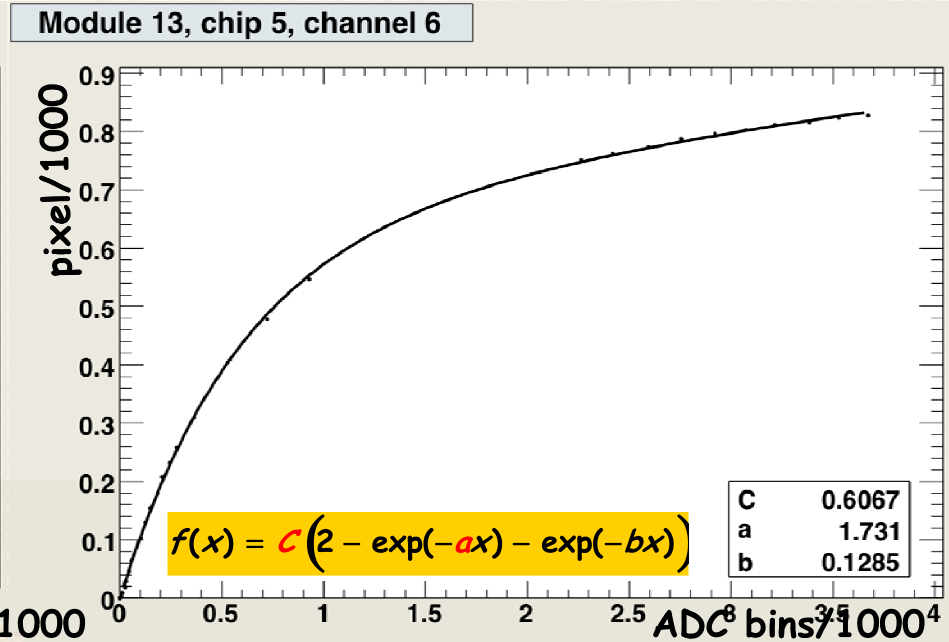


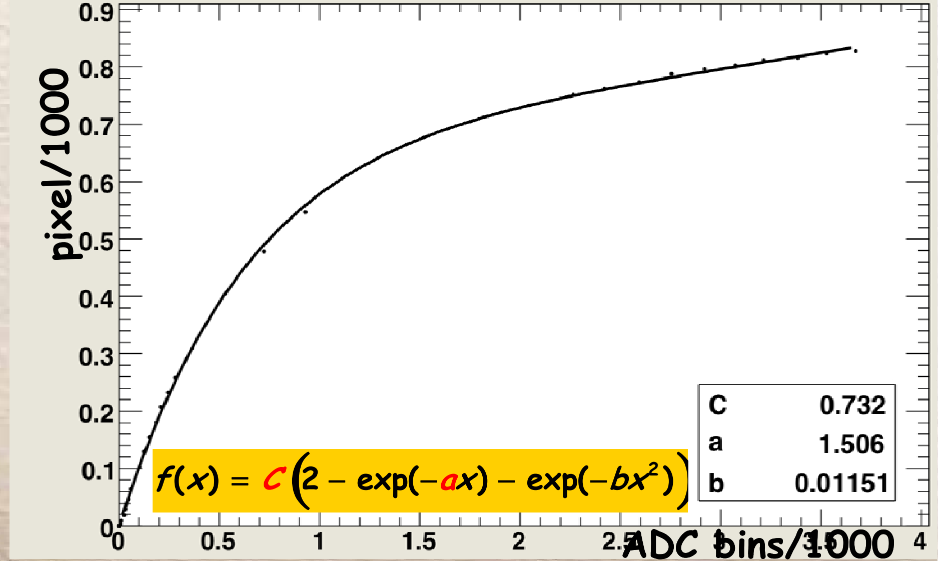
- High data points lie in saturation
- Single exponential provides a good fit
- Fits with 2 exponentials or exponential plus gaussian do not yield an improvement (values for C and a are similar in all 3 fits)



Fit Saturation Curves of Module 13,5-6

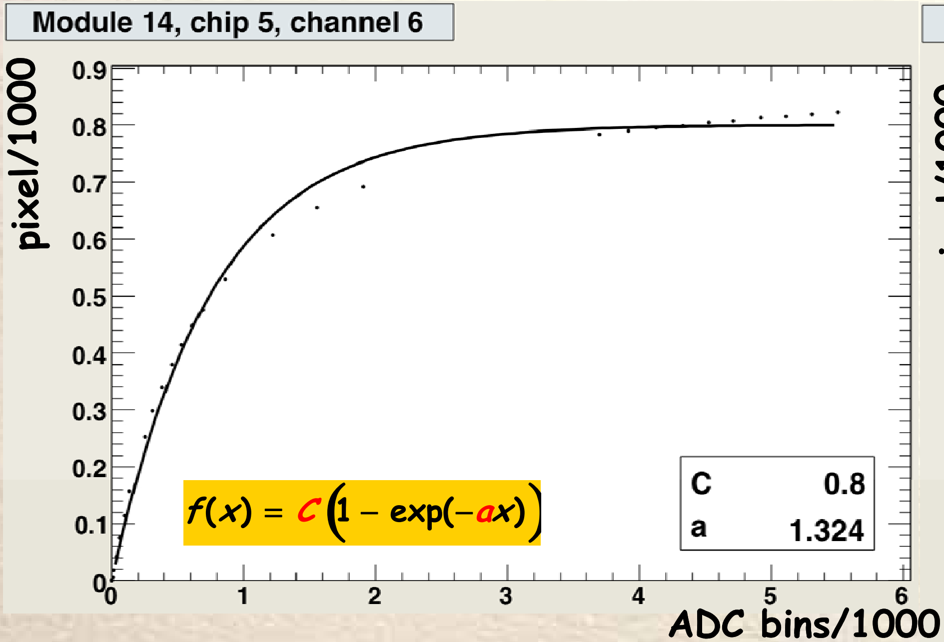


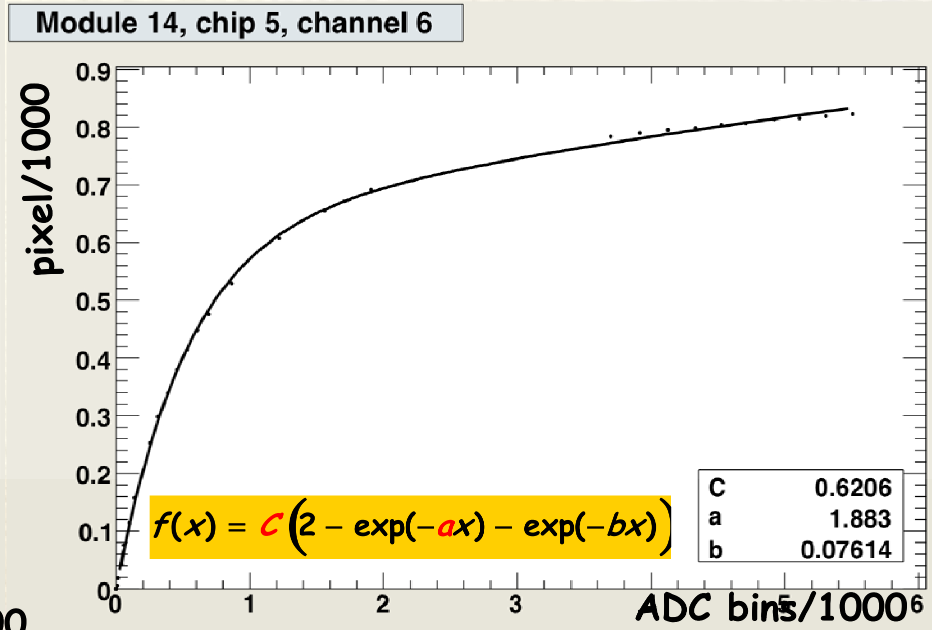




- High data points are not in saturation, observe nonzero slope
  ↳ single exponential does not give good fit
- Fits with 2 exponentials or exponential plus gaussian do better

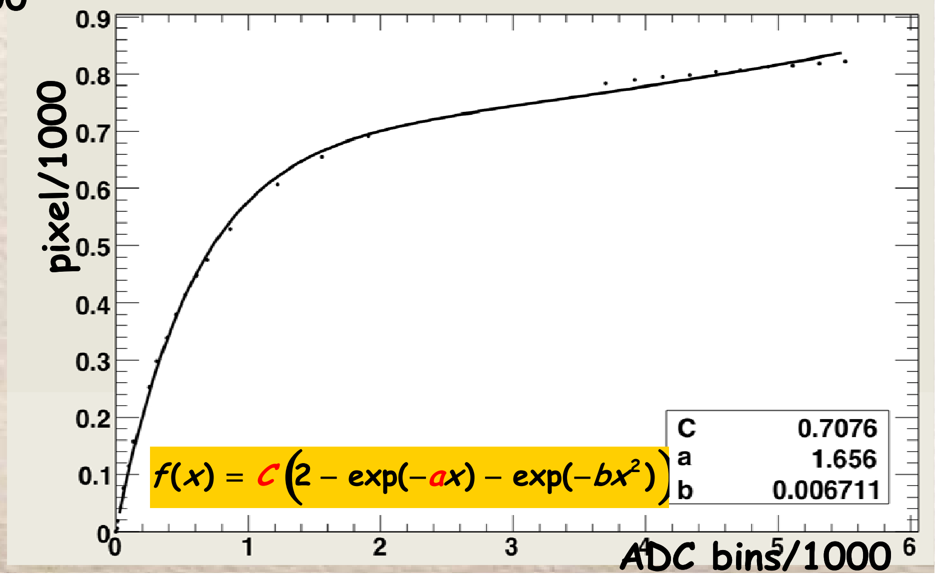
Fit Saturation Curves of Module 14,5-6





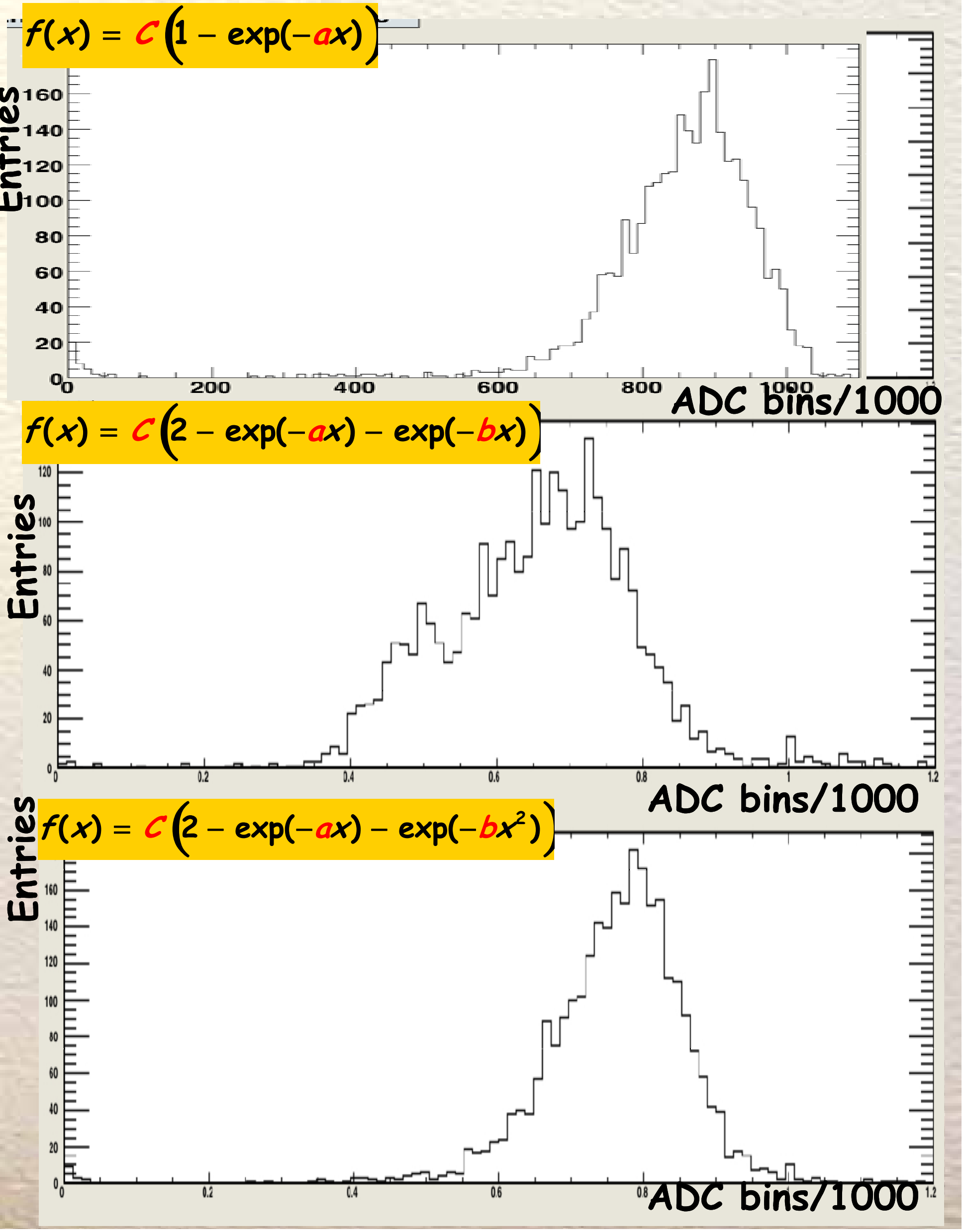
- Here the 2-exponential or exponential plus gaussian fit do not provide a good description

- Need modified function



Fit Results for C

- Distributions of measured endpoints and endpoints from fit model 1 (one exponential) are similar
- Measured distributions seems to be shifted up by order 10 pixels wrt C from fit
- C distributions for fit models 2&3 are hard to interpret, ➔need to muliply C by factor ( ) at $x=x_{max}$
- We need to explore and understand large spread
- In model 3 distribution seems better behaved ➔ refine fit function



Conclusion and Outlook

- The procedure of adjusting SiPM response functions to common origin with slope one after individual gain correction looks promising (➔procedure needs fine-tuning)
- Measured endpoint distribution and fit result from 1-exponential show reasonable agreement for saturation, though measured endpoints are shifted up by ~12 pixels wrt fitted endpoint
- Peaks of distributions are ~100 pixels lower than #SiPM pixels, and spread (FWHM ~ 100 pixels) is rather large ➔ needs further exploration
- We need to understand non-vanishing slopes at endpoint, improve fit model to deal with different shapes near endpoint, and determine the χ^2 to evaluate the fit quality
- We will look at saturation curves in 2007 runs (increase statistics)
- We will try to extract parameters from one run, apply them to to data of another run and see if we can reproduce the shape

Acknowledgments

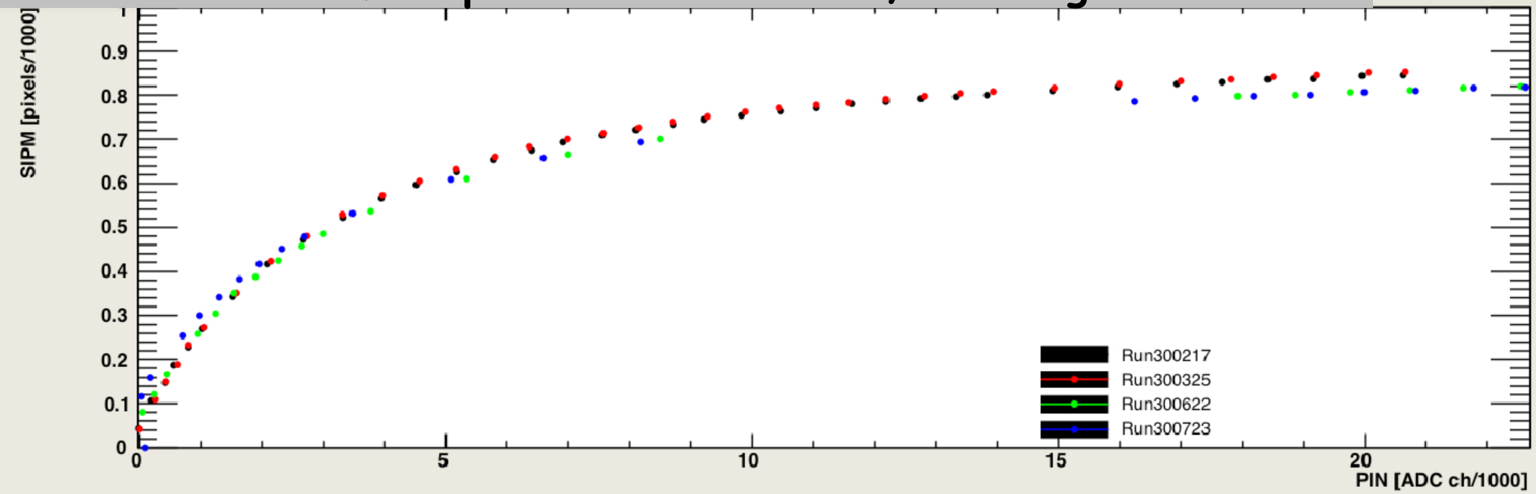
- This work was conducted in collaboration with the DESY AHCAL group, in particular we would like to thank S. Schaetzel for his help in setting us up to performing these studies

Backup Slides

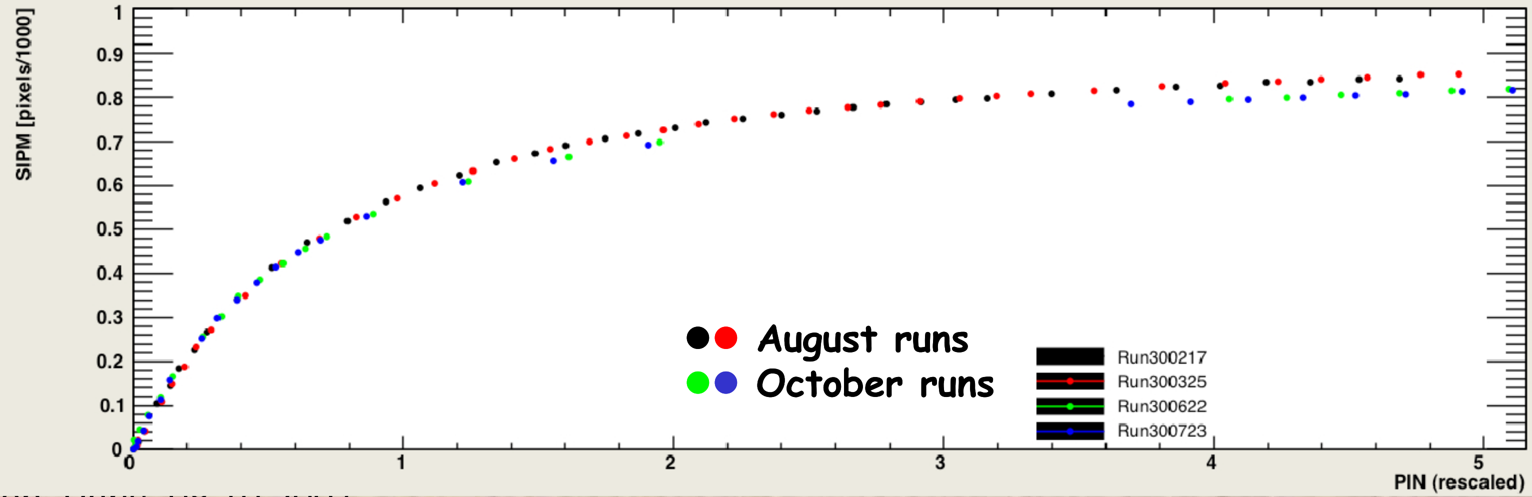
Saturation Curves for Module 14, 5-6

- Compare 4 runs from August & October

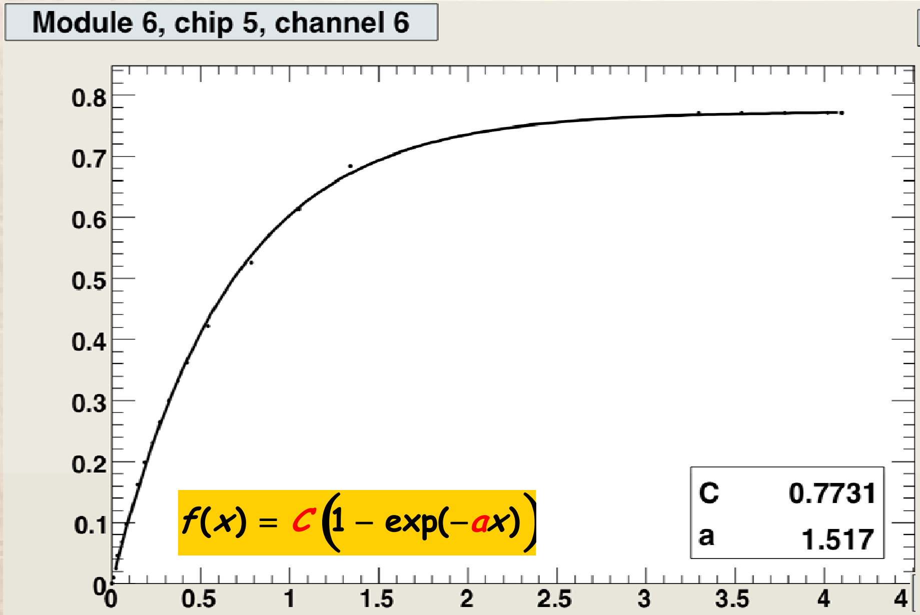
Saturation curve after pedestal subtraction, PIN & gain correction

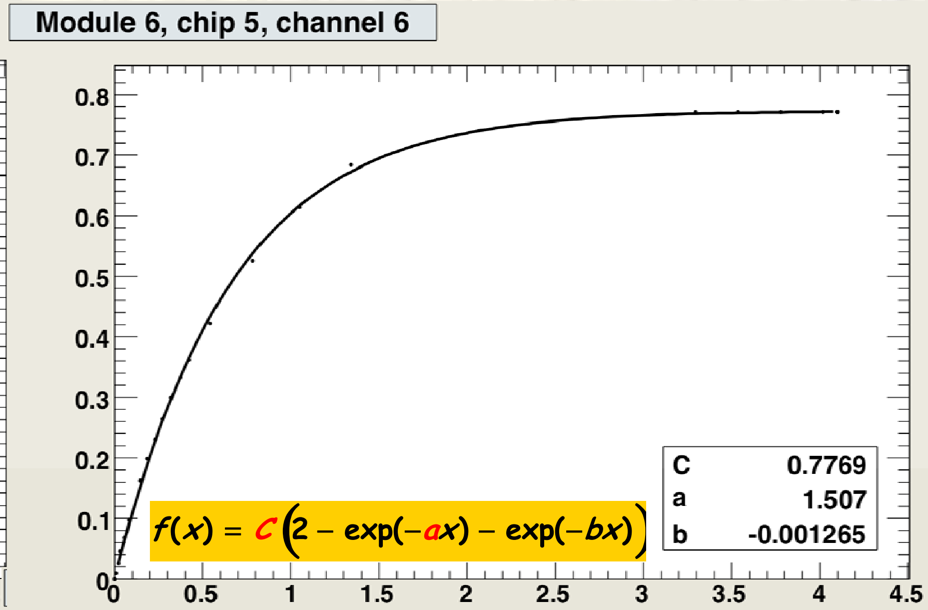


Saturation curve after adjustment to common origin with slope one

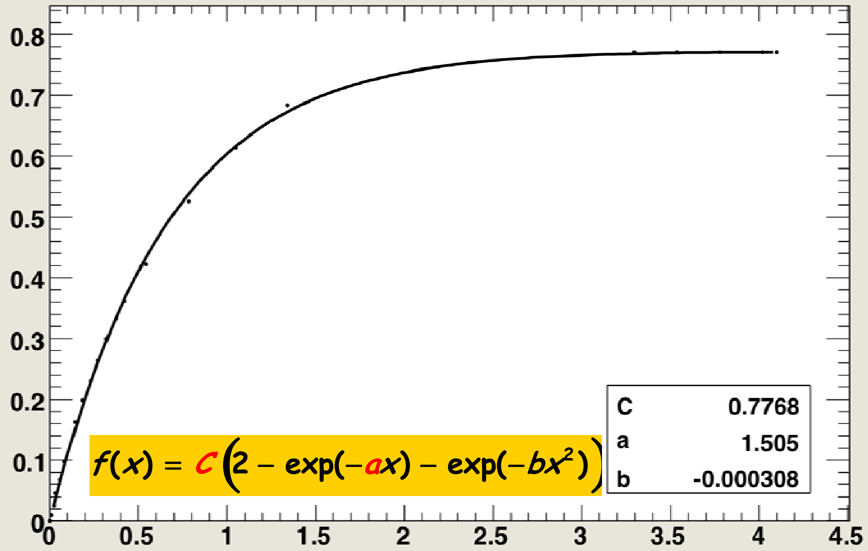


Saturation Curves for Module 6,5-6

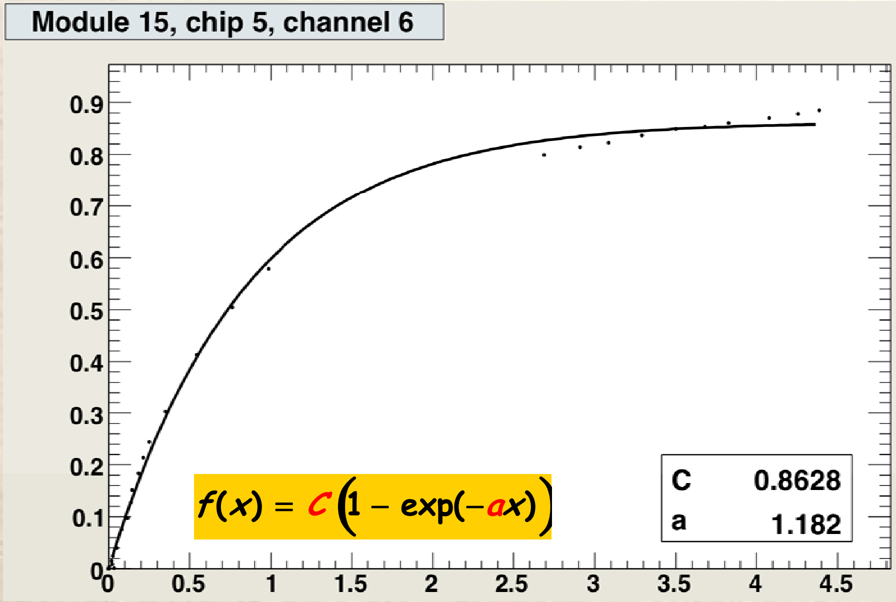


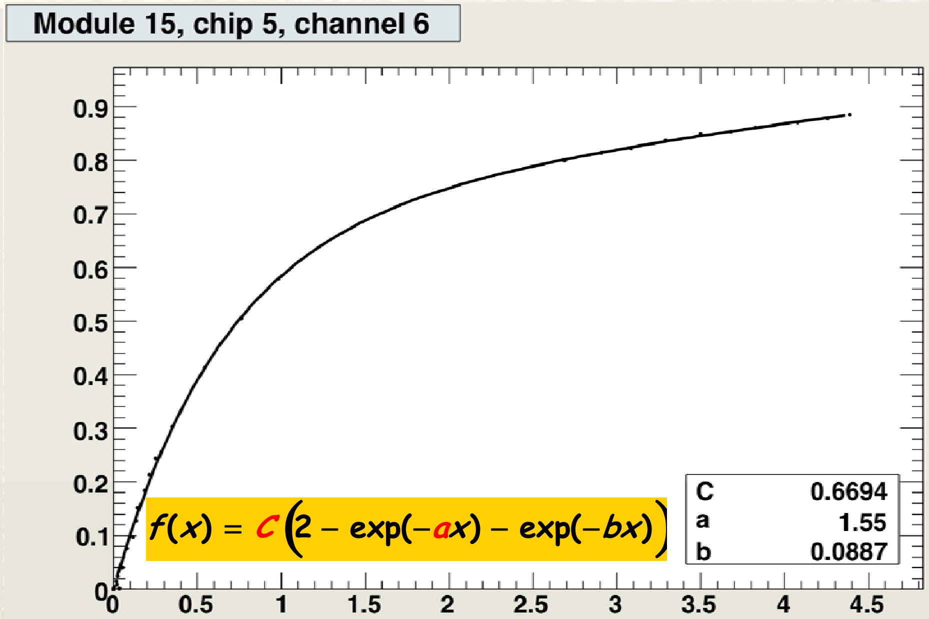


- High data points lie in saturation
- Single exponential provides a good fit
- Fits with 2 exponential do not yield an improvement (values for C and a are similiar in all 3 fits)



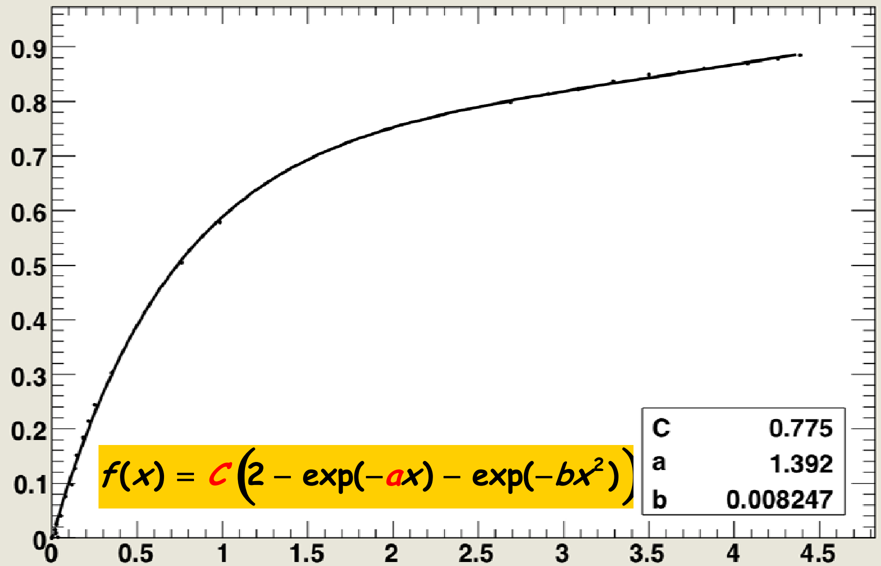
Saturation Curves for Module 15, 5-6





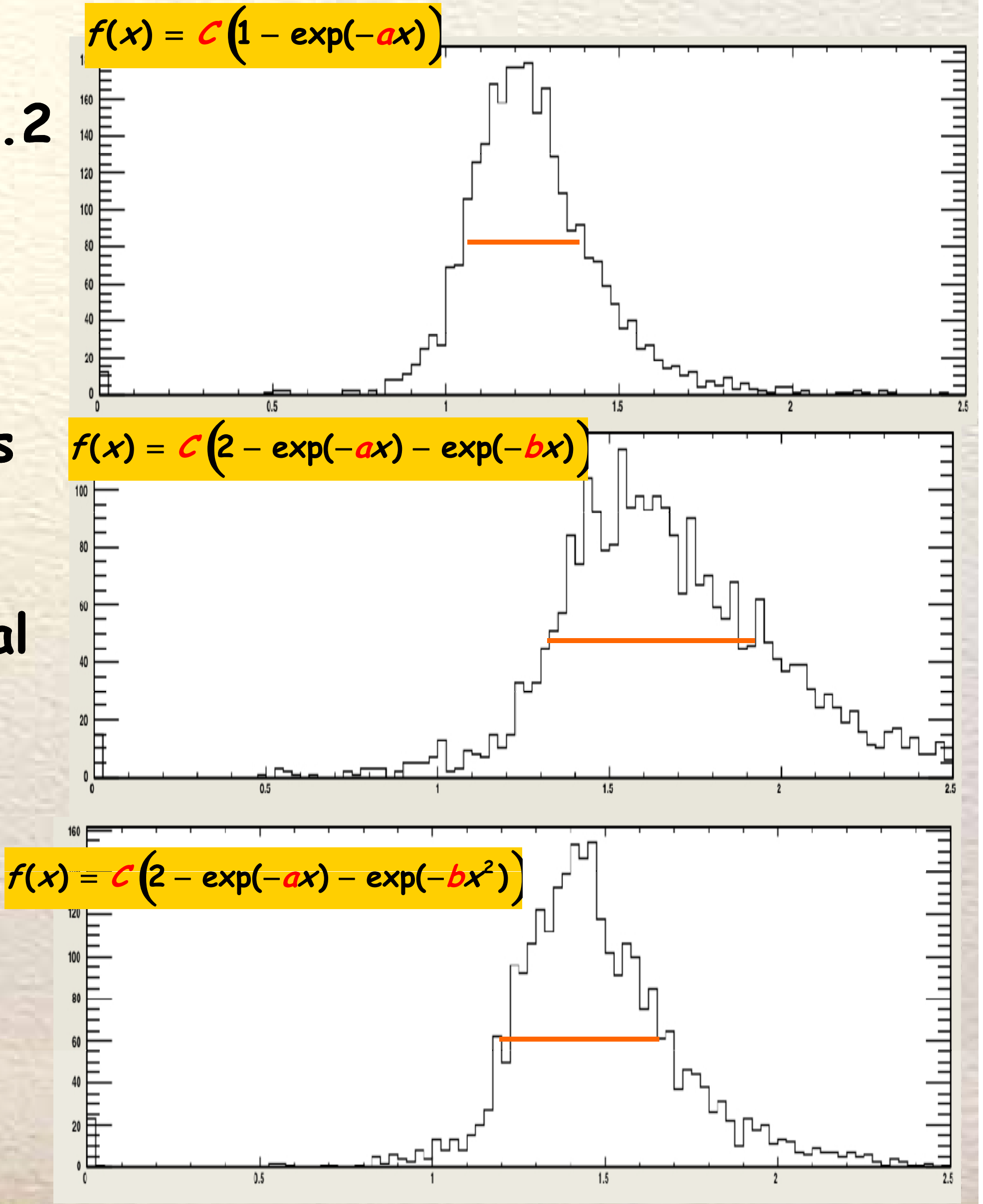
- High data points are not in saturation, observe nonzero slope
  ↳ single exponential does not give good fit

- Fits with 2 exponential do better

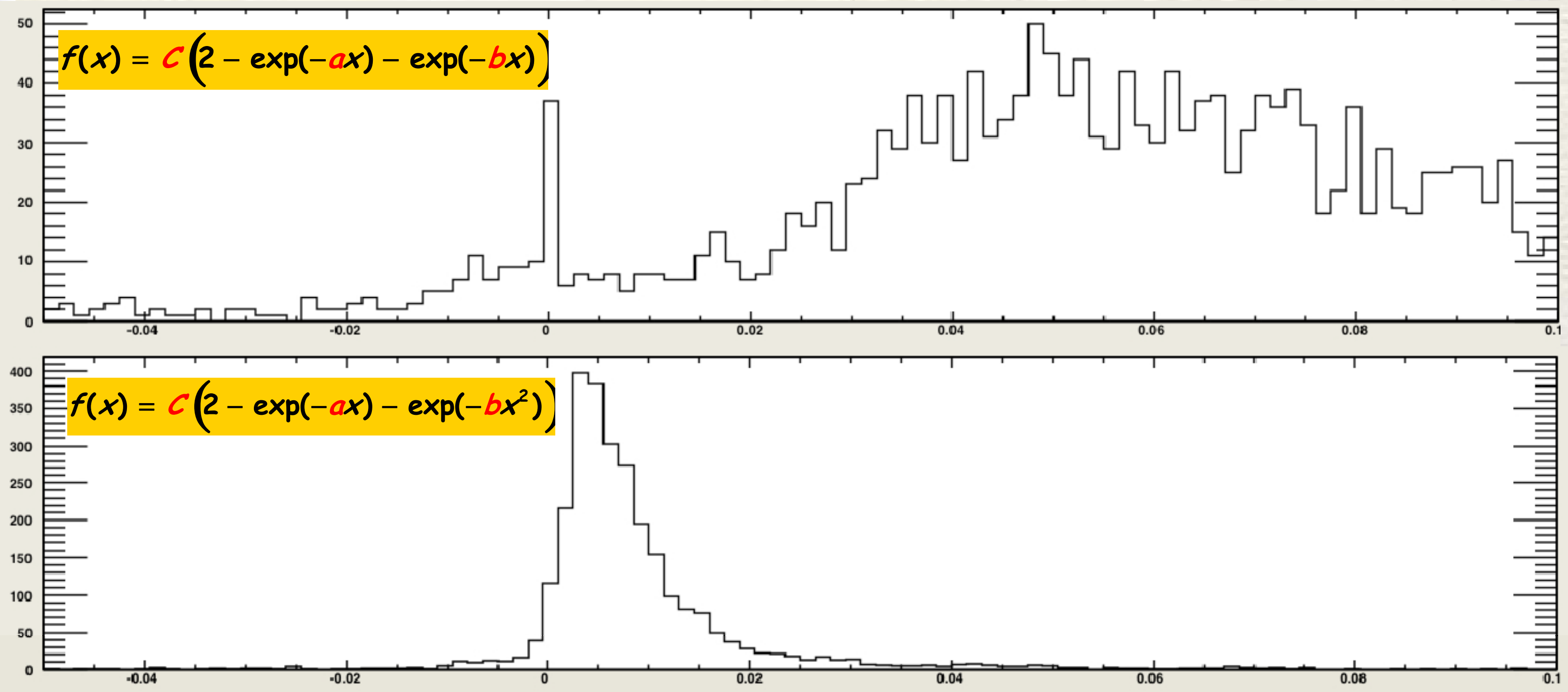


Results for a

- In the distribution of the exponential fit, a peaks at~1.2 and FWHM is ~0.4
- For distribution of the 2-exponential fit, a peak is shifted to ~1.6 and FWHM is ~0.6
- For distribution of exponential plus gaussian fit, a peaks at ~1.4 and FWHM is ~0.45
- We need to look at correlations among the parameters



Fit Results for b



- **In 2 exponential model b values near zero indicate good description by one-exponential model (see spike at zero), most probable value is ~0.05**
- **In exponential plus gaussian model peak is ~0.01, distribution is narrow with FWHM at ~0.01**