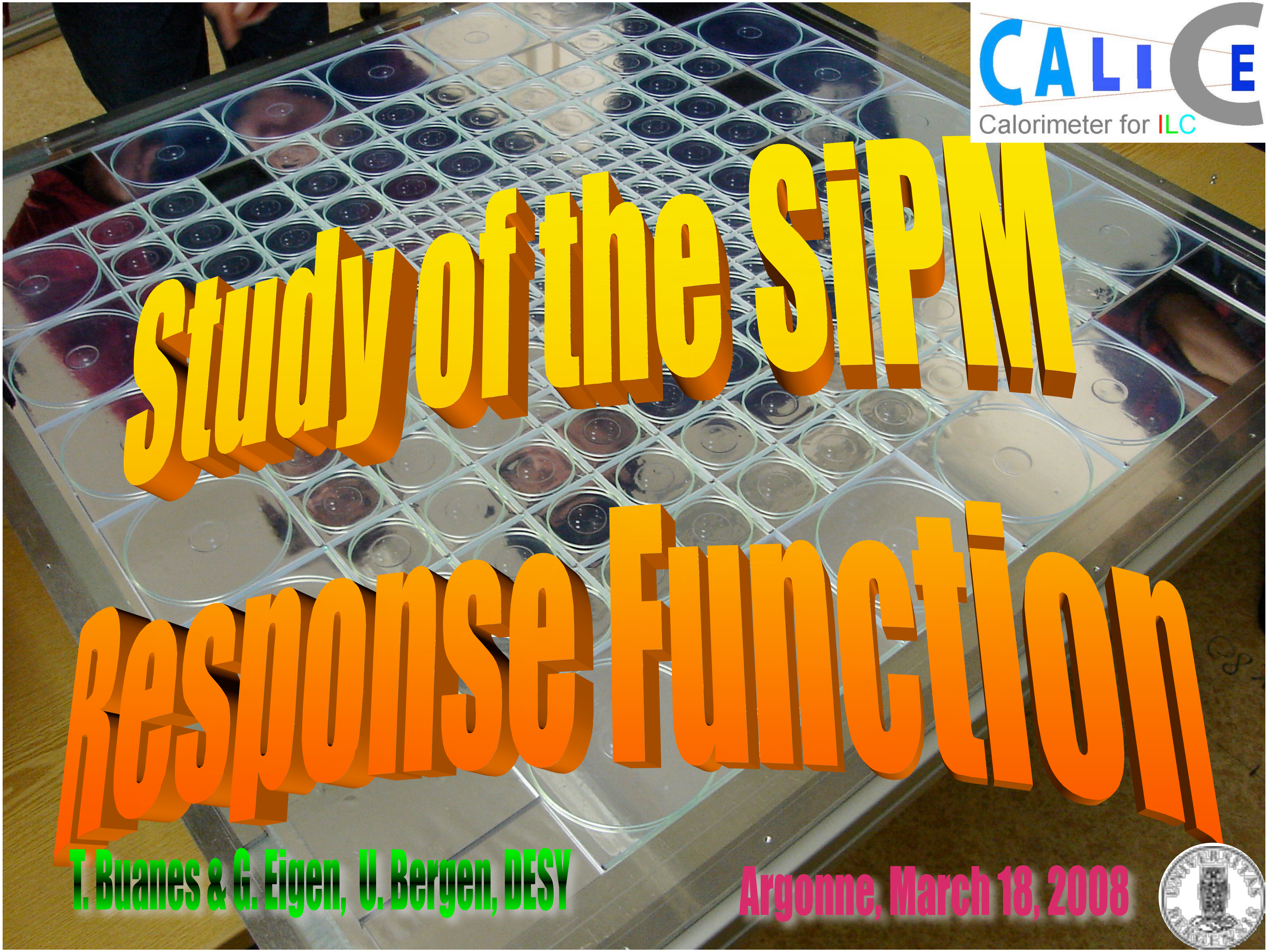

CALICE
Calorimeter for ILC

Study of the SiPM Response Function

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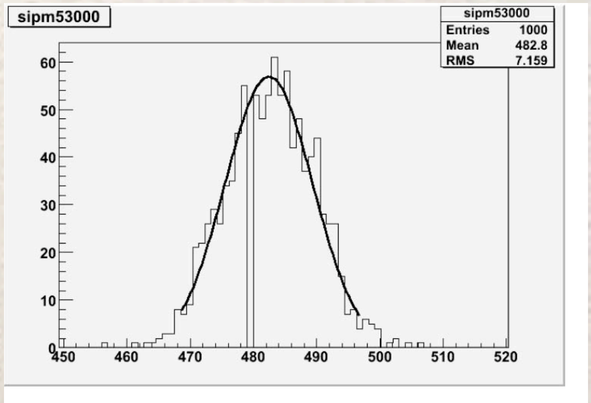
Argonne, March 18, 2008

Introduction

- Monitoring the stability of SiPMs is an important task
- We have built an elaborate LED/PIN based monitoring system that measures the SiPM gain, monitors the SiPM response for a fixed light intensity and is capable to record the full SiPM response function
- If we manage to parameterize the SiPM response by an analytic function, we may achieve the same precision with a simplified monitoring scheme
- Presently, we have focused our studies on runs in October 2006 to determine the shape and the saturation point of individual SiPMs

Analysis Procedure

- Extract SiPM & PIN diode values from LCIO files
- Perform pedestal subtraction using beam events taken shortly before or after VCalib run
- Apply gain corrections and use intercalibration constants
- Perform Gaussian fit for each Vcalib to SiPM & PIN response
  ➔ determine mean and error on the mean
- Plot PIN response vs SiPM response
- Rescale PIN values to force the initial slope to be one and to start at a common origin

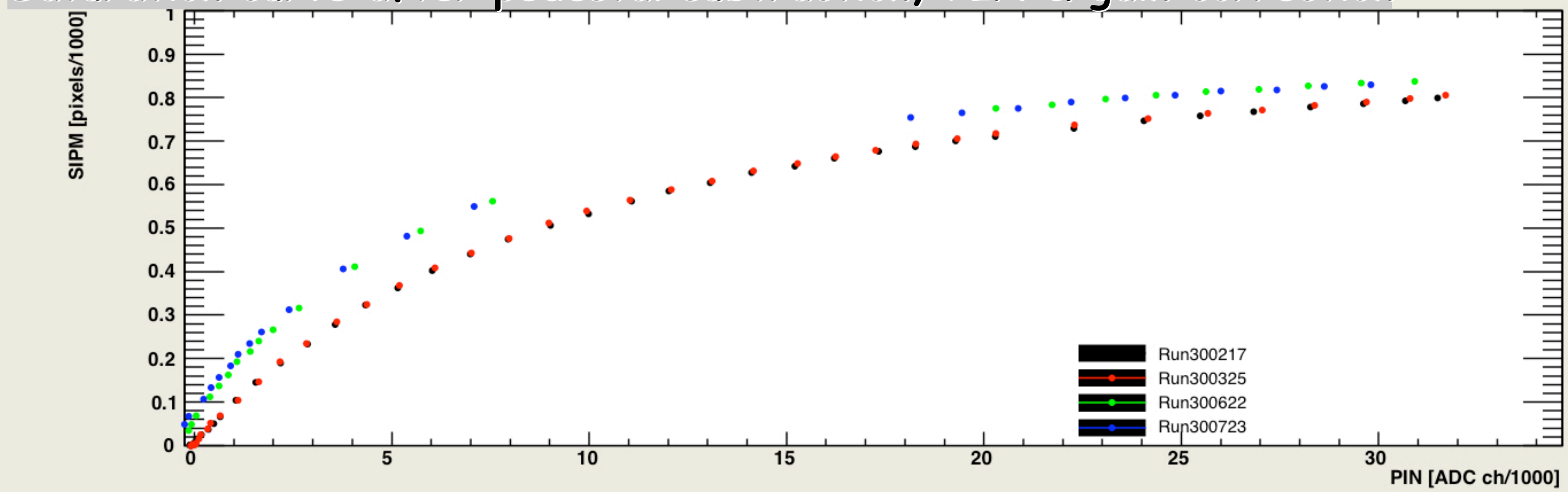


- Focus on October for all modules 3-15, though August runs have been studied as well

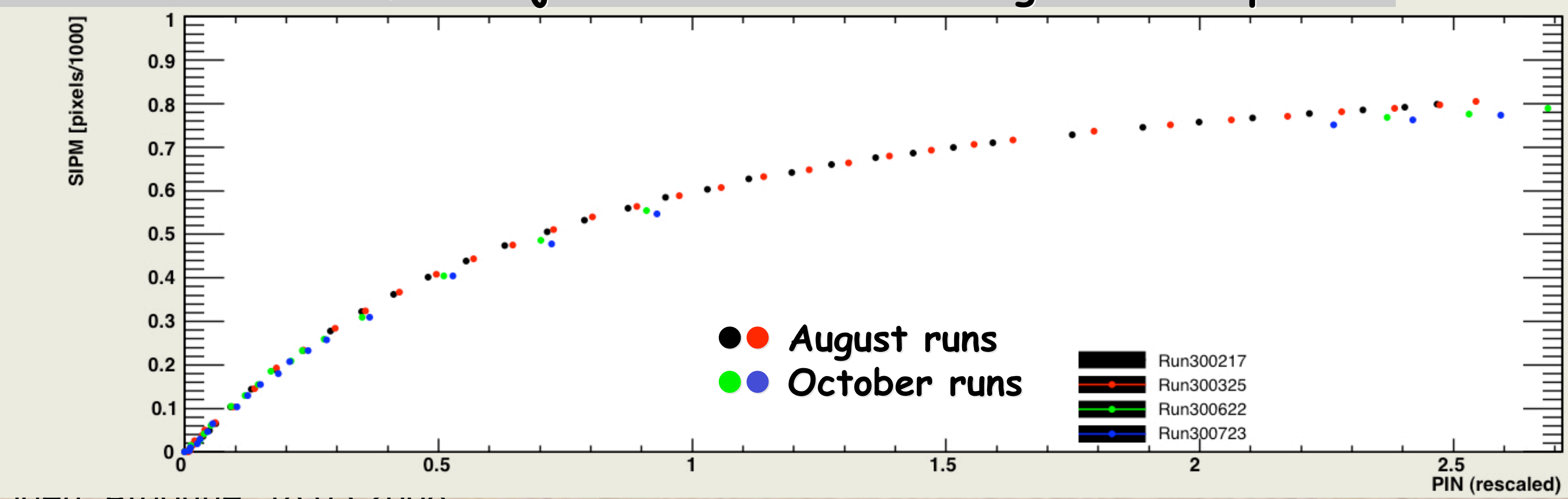
Saturation Curves for Module 13, 5-6

- Compare 4 runs from August & October

Saturation curve after pedestal subtraction, PIN & gain correction



Saturation curve after adjustment to common origin with slope one



Parameterize SiPM Response Functions

- The SiPM response curves all have similar shapes
- We need to find an analytical function with sufficient flexibility to fit all SiPM response curves
- We have focused on the function

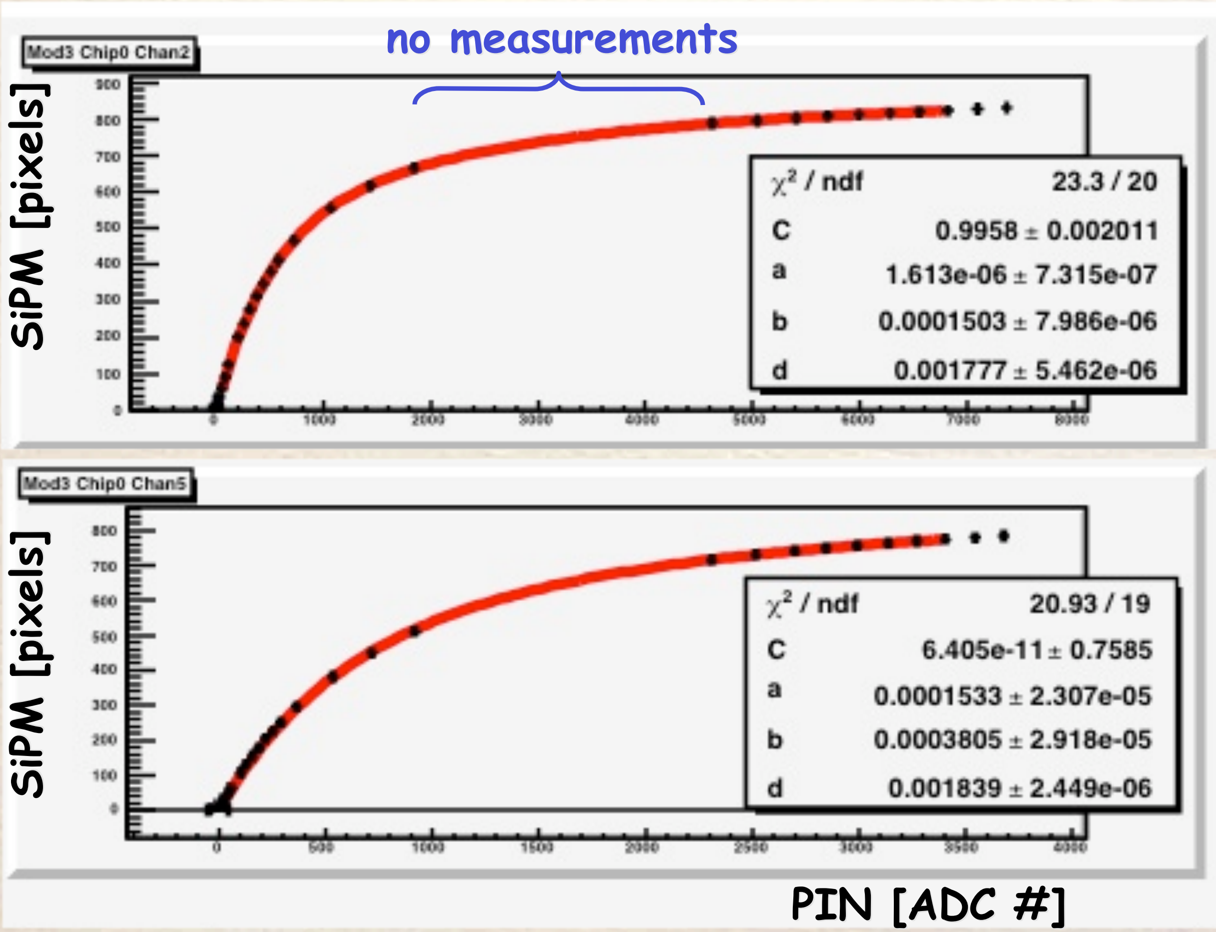
$$f(x) = \frac{(C-1)^2}{a-(b+d)(C-1)} \frac{Exp[-b*x] + Exp[-d*x]}{C - Exp[a*x]} - 2\underbrace{\frac{(C-1)}{a-(b+d)(C-1)}}_{\text{saturation}}$$

where C, a, b & d are free parameters determined from the fit

- For C=0 get a 2 exponential fit, for C=1 Fermi function like
- We have also tried a function without the Exp[-d*x] term, but here the χ^2 becomes too large for most fits ➔ we need a term for low intensity and one for high intensity (used Mathematica to try out various functions)

Fitted SiPM Response Functions

- Two examples of fits for October runs

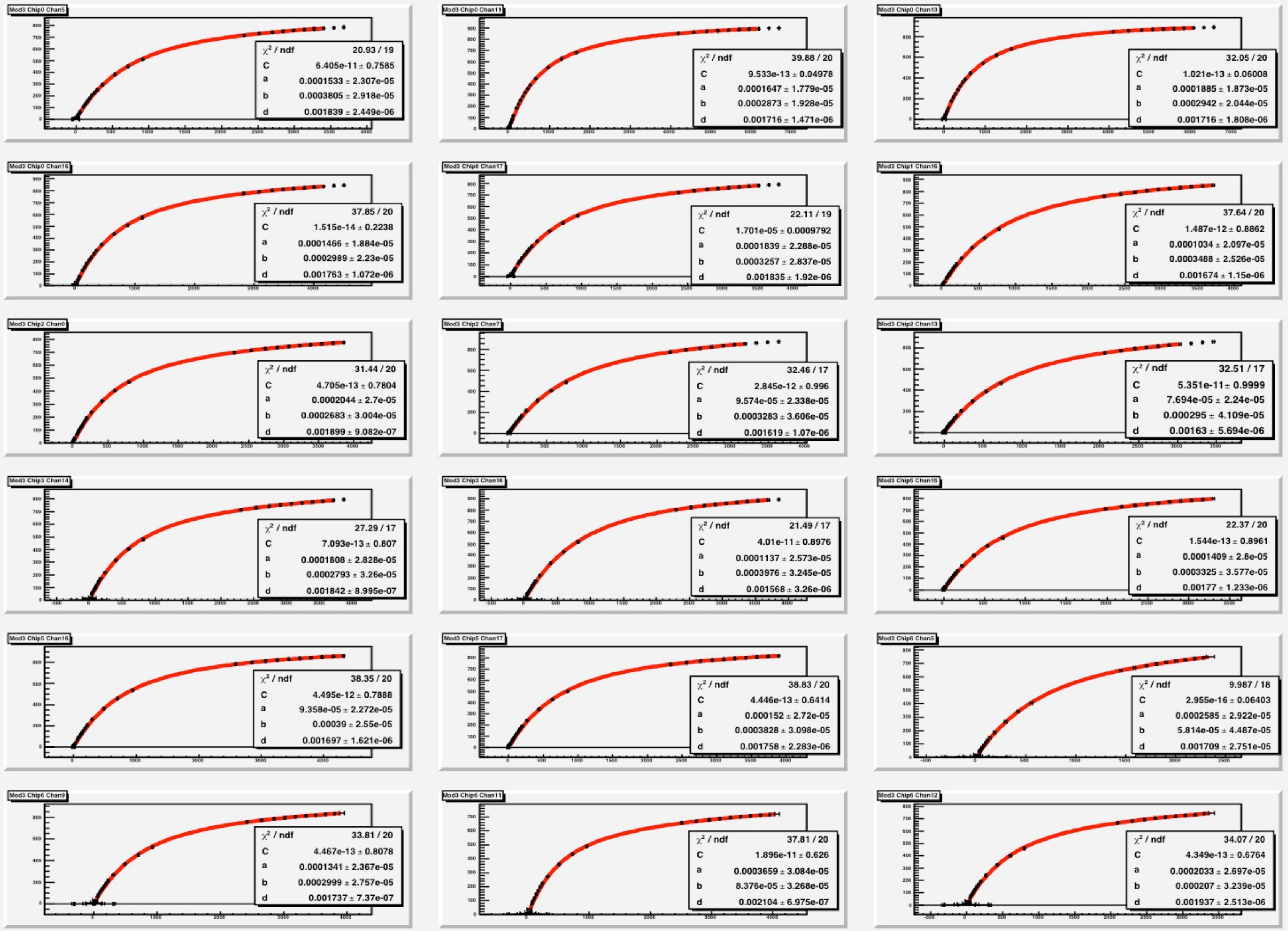


C close to 1

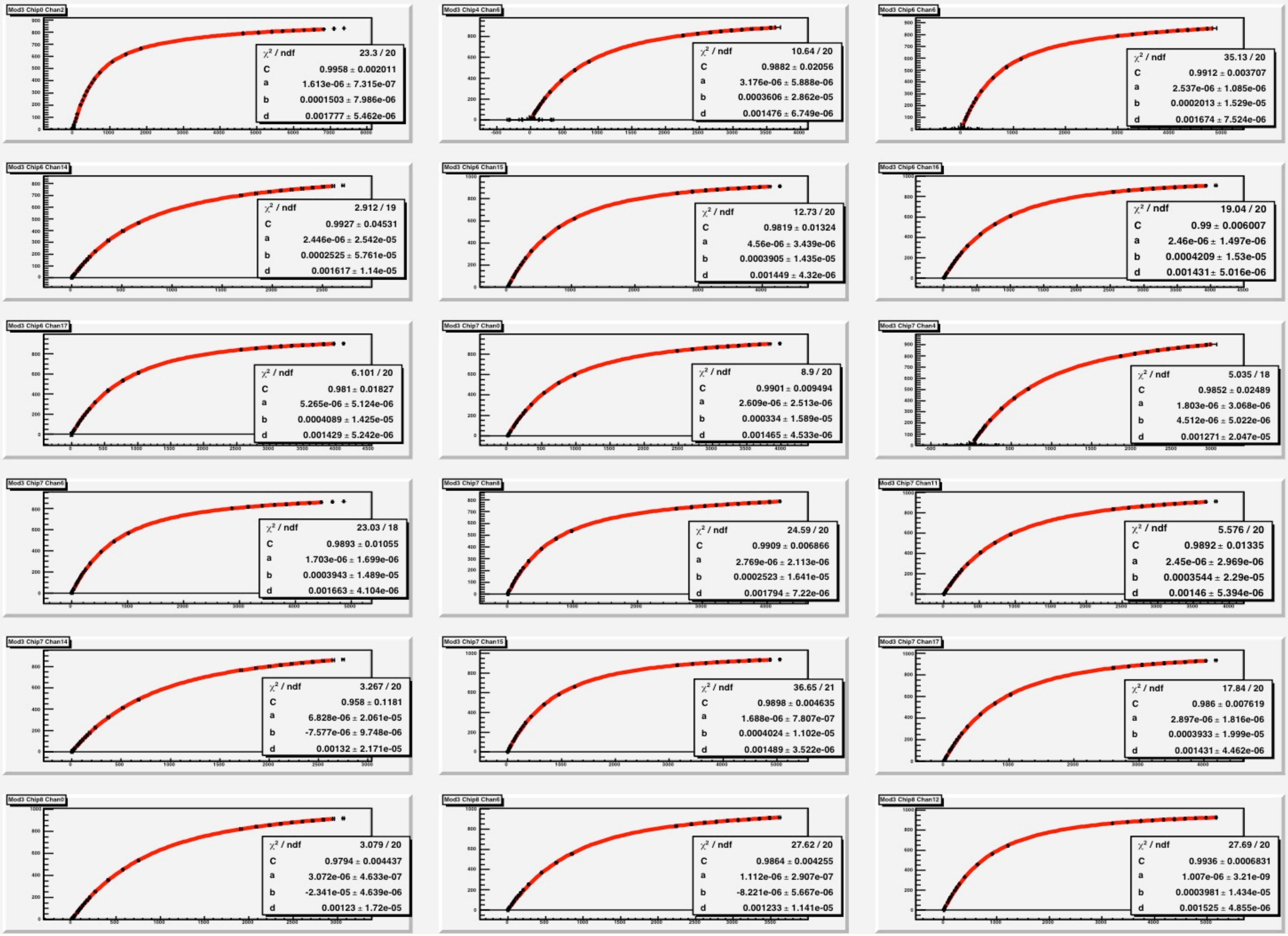
C close to 0

- Need different functional forms to describe low & high intensity
- Most response curves are only at~85% of saturation

Fits of SiPM Response Functions with C≈0



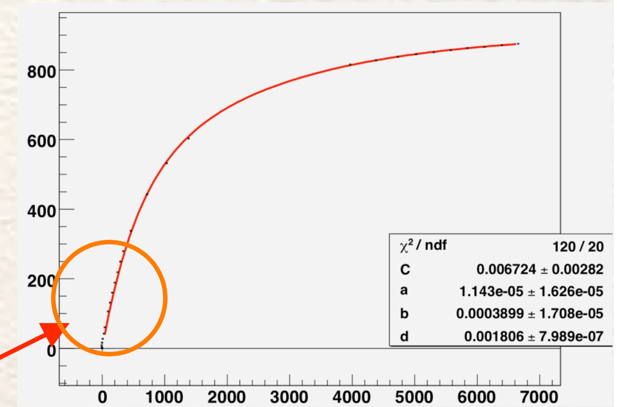
Fits of SiPM Response Functions with C≈1

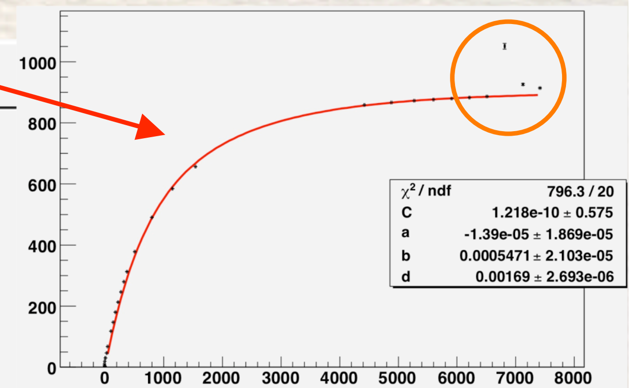


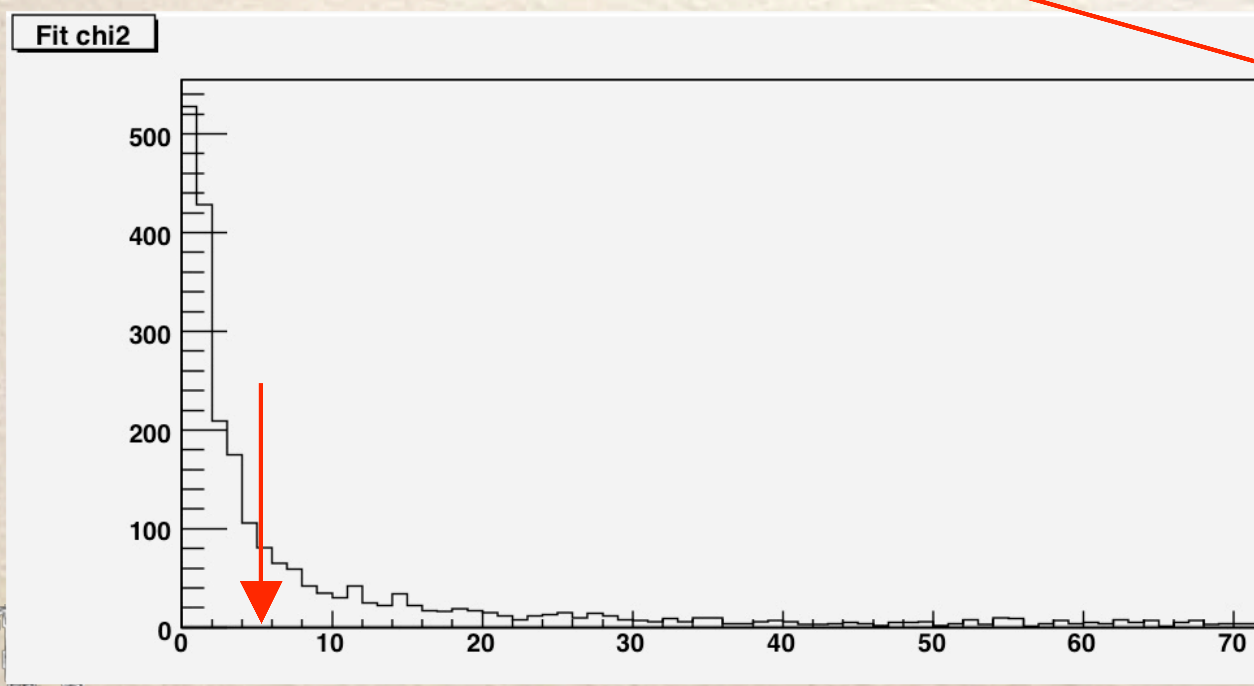
G

χ^2/dof of Fits

- About~52% of the fits have χ^2/dof< 5
- About ~16% of the fits have χ^2/dof> 100
- Fits with χ^2/dof >5 result from 3 classes
  - Dead channels (~3%)
  - Data points look fine but cannot be fit
  - A few data points are off

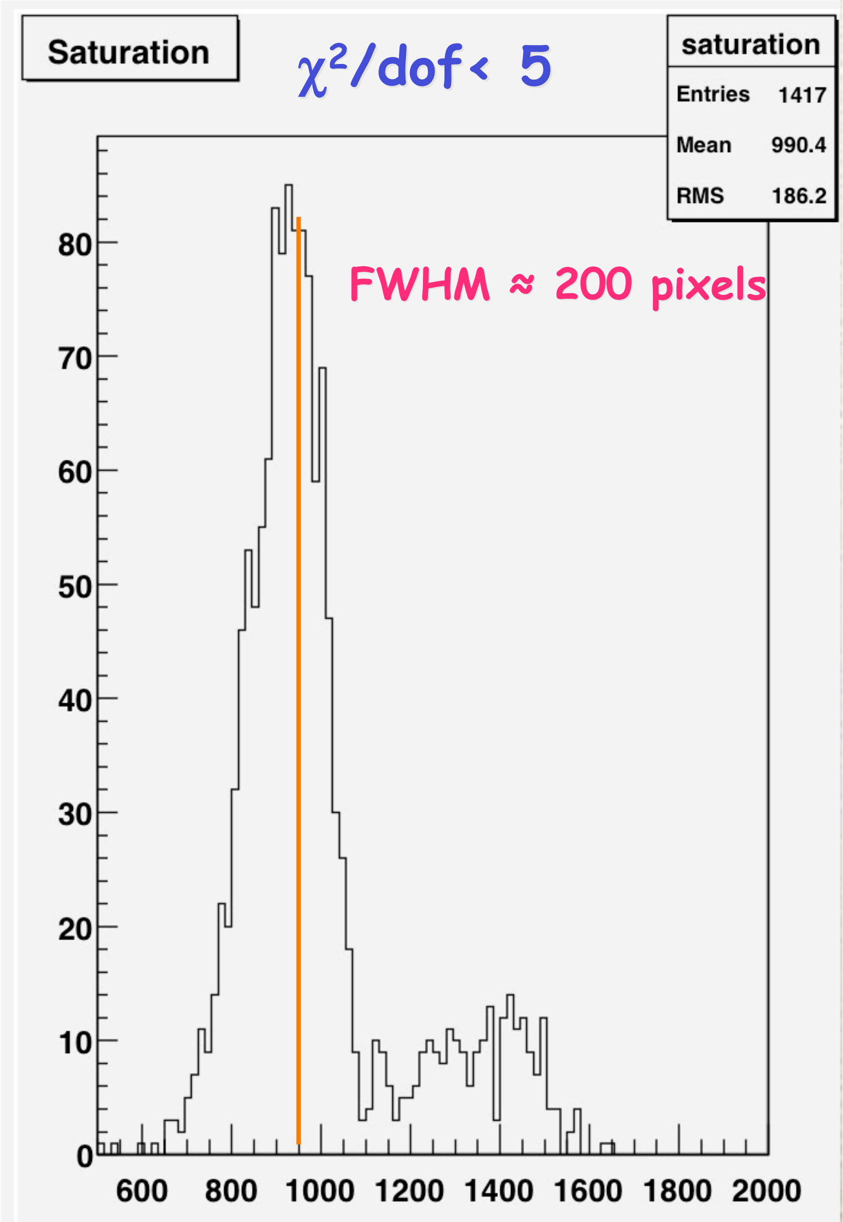






Results on Saturation

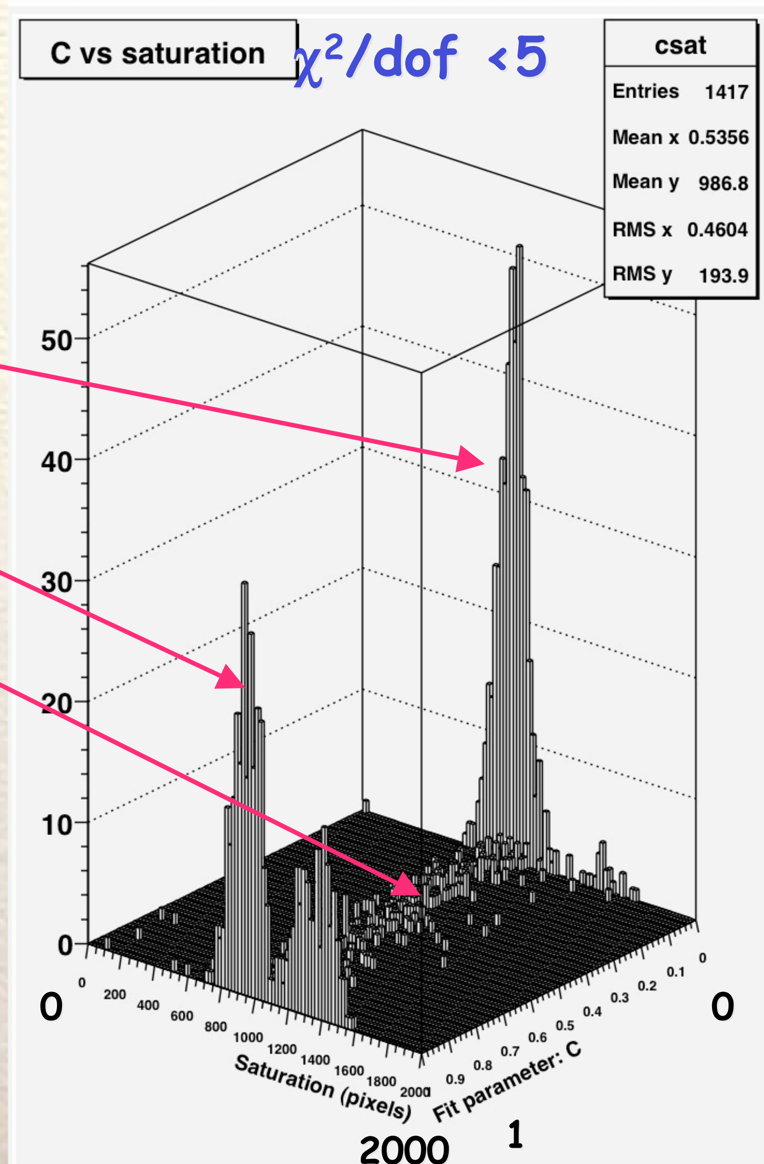
- Distribution peaks around 930 pixels
- Width is FWHM≈ 200 pixels
- Note that the highest measured point often is 85-90% of saturation value
- Below 1100 pixels distribution is slightly asymmetric towards small values
- About 15% of the fits yield a saturation > 1100 pixels ➔ need to explore reason



Correlation between Saturation & C

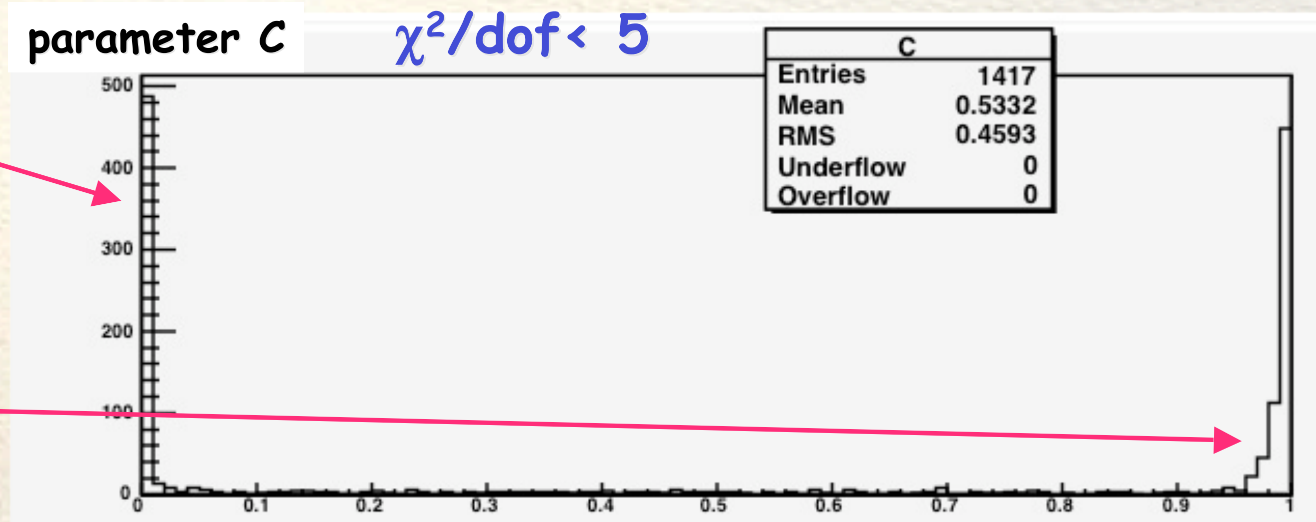
- Fits basically fall into 4 categories
  - dead channels (cut out)
  - C near zero
    ➔ 2 Exponential fit
  - C near one
    ➔ Fermi function fit
  - C values between

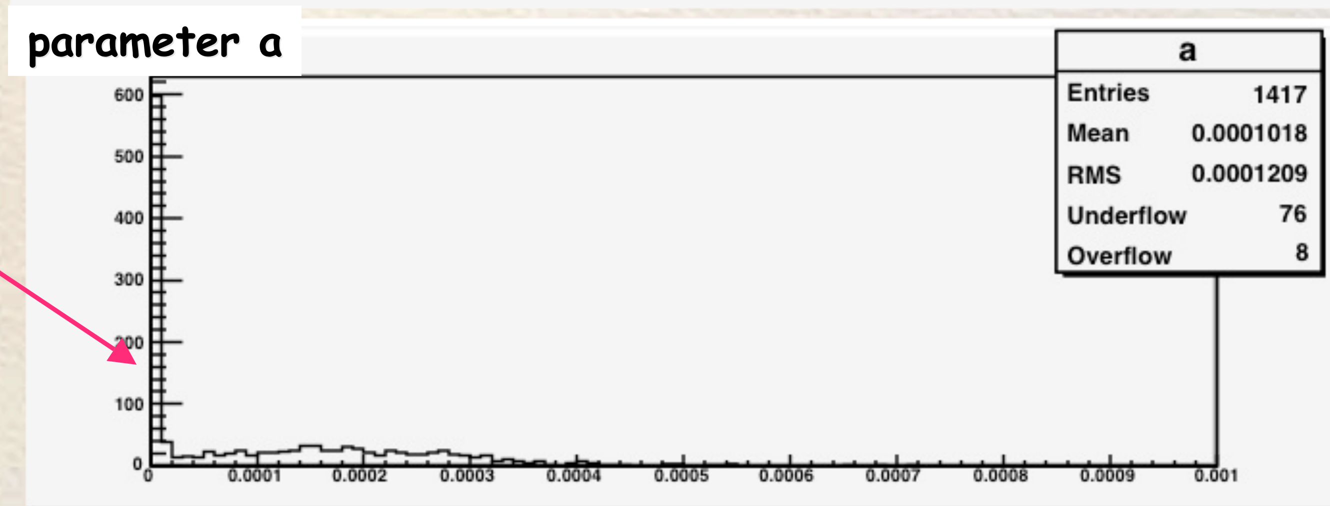
- High saturation values of > 1100 pixels basically come from fits with C~1



Fit Results for parameters C & a

- ~35% of the fits yield C≈0
- ~50% of the fits pile up near C=1
- For 42% of the fits the parameter a is very small



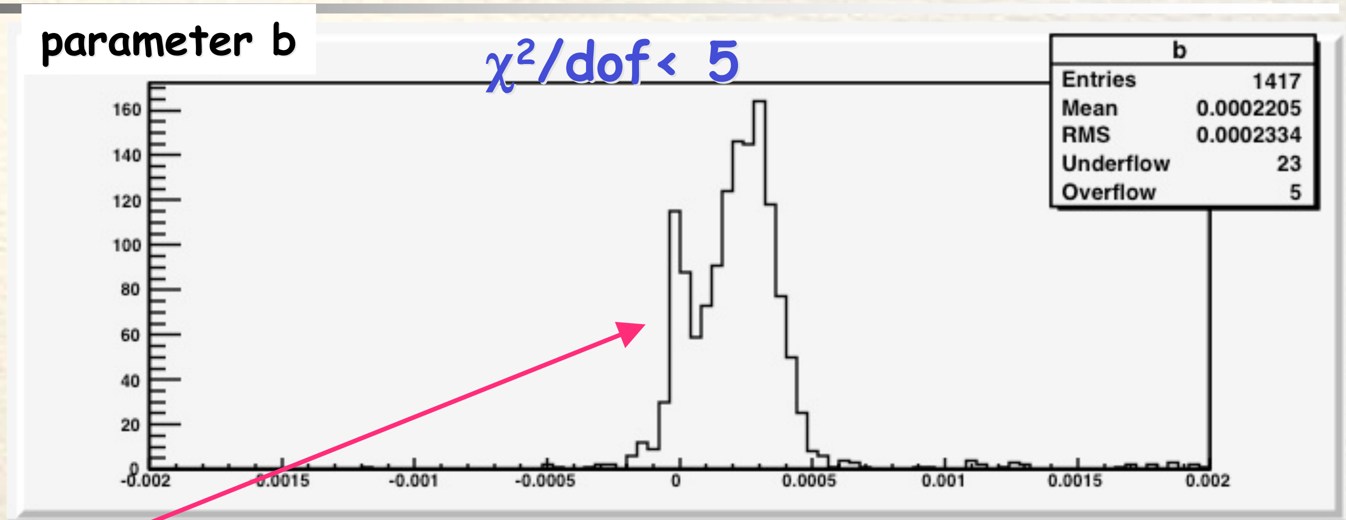


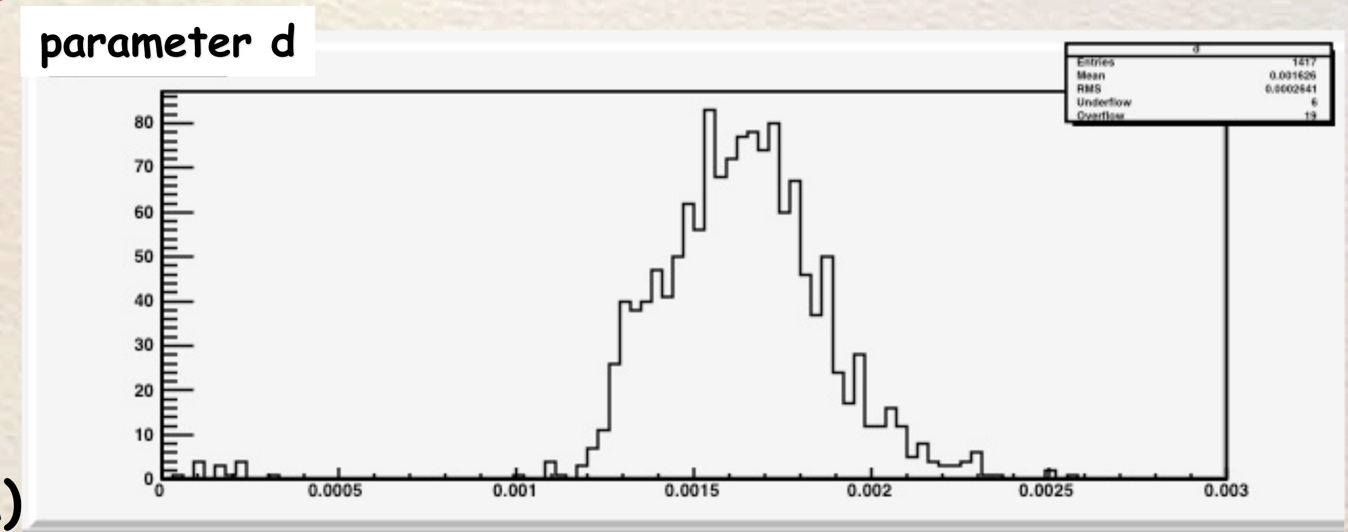
Fit Results for Parameters b & d

- Distribution for parameter d is rather narrow
  ➔ for most fits 0 < b< 0.0005 with peak at ~0.0003

- 15% of fits are in spike near 0

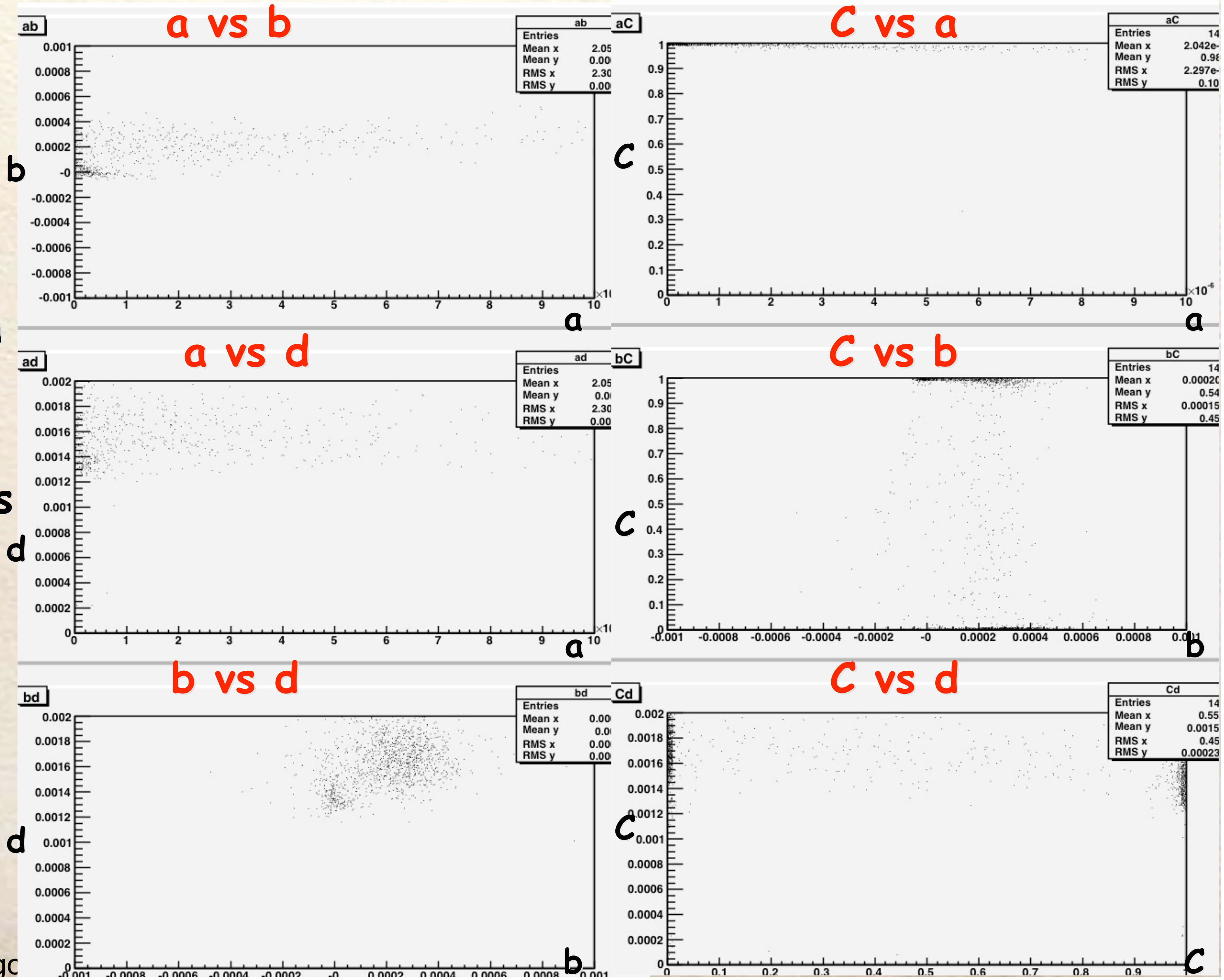
- Distribution for parameter d is less narrow
  ➔ peak is at ~0.0017
  ➔ width (FWHM) is ~0.0005





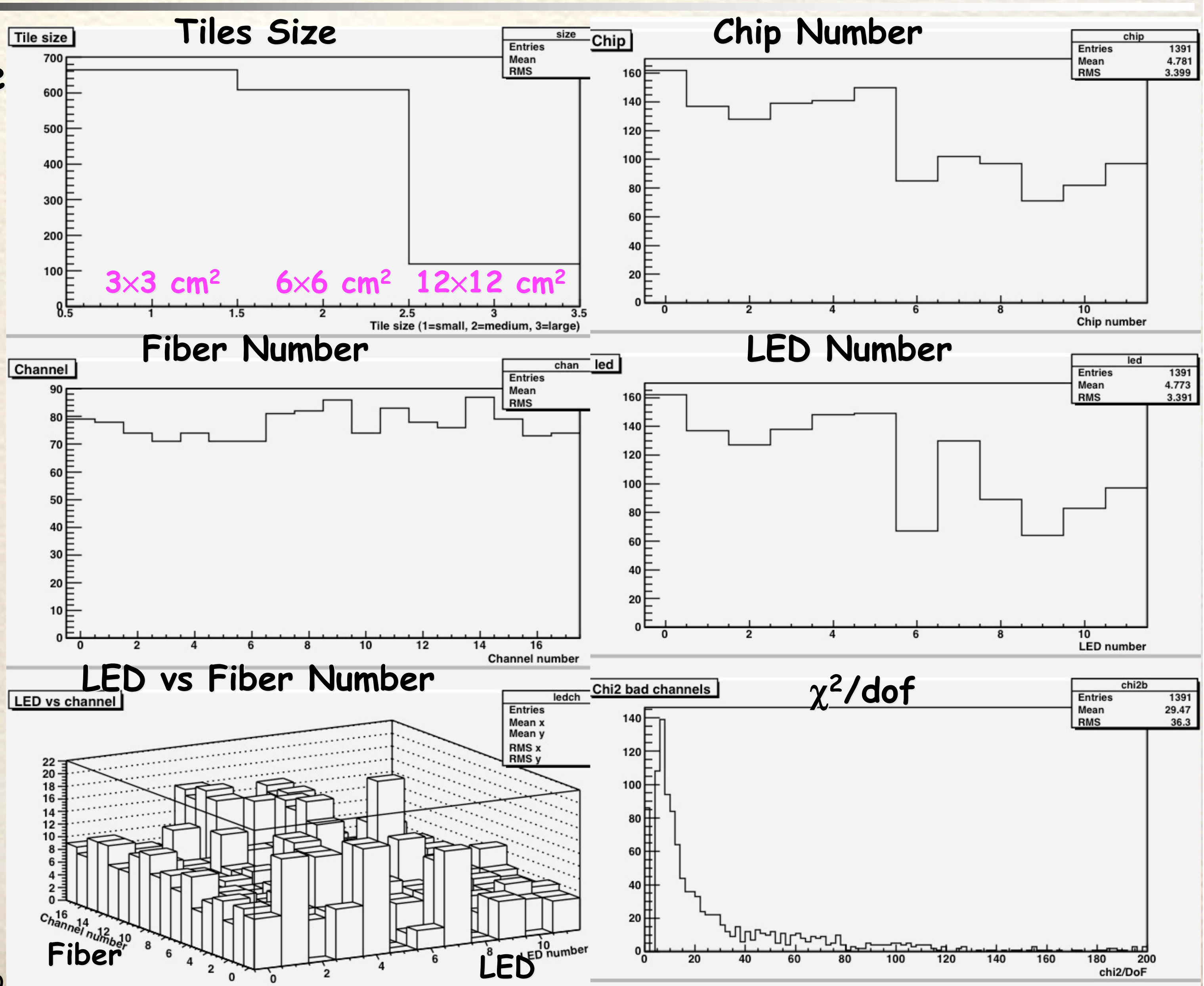
Correlations between Fit Parameters

- See no obvious correlation between fit parameters



First Look at Bad Fits

- Bad fits are independent of tile size
- 60% of bad fits come from LEDs 0-5
- Fibers 7-9 11, 14-15 yield more bad fits than other fibers



Conclusion and Outlook

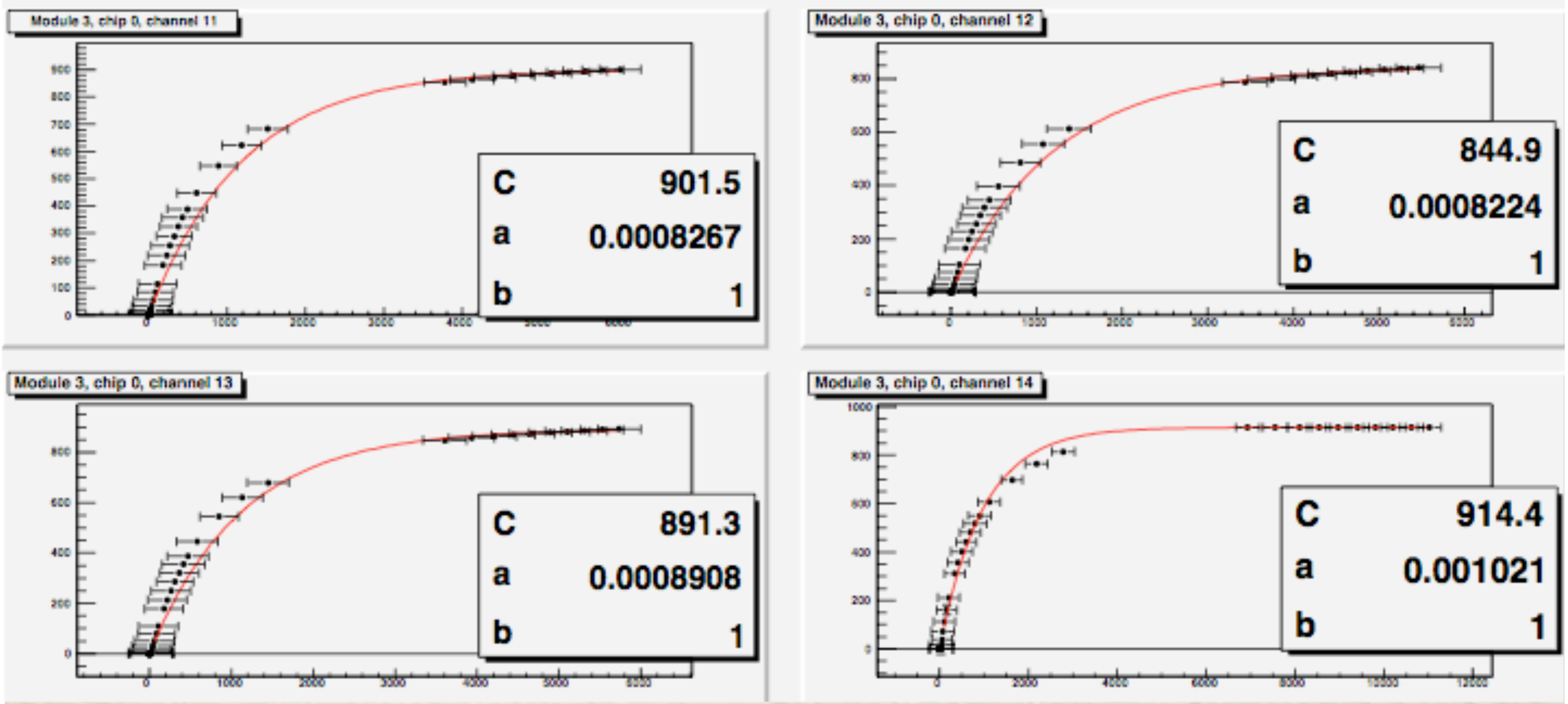
- We have found a 4-parameter fit function that describes the SiPM response rather well ➔ ~60% good fits (when we exclude bad channels)
  - Saturation value is around 930 pixels
  - Distribution has FWHM of ~200 pixels
- We need to understand the results of the fit parameters, spike around zero in parameter b
- We need to investigate the bad fits and try to recover them
- We need to investigate fits with high saturation values ➔ understand the origin of the problem and fix it
- We plan to correlate our saturation values with measurements at ITEP
- We will look at the 2007 test beam data and perform fits of all SiPMs (7608 channels)

Acknowledgments: This work was conducted in collaboration with the DESY AHCAL group

Backup Slides

Fits of SiPM Response Functions

- The SiPM response curves are consistent with $f(x) = C\left(1 - \exp(-ax)\right)$



Fits of SiPM Response Functions

- Fit for August runs