Study of Solid State Photon Detectors Read Out of Scintillator Tiles

A. Calcaterra, R. de Sangro, G. Finocchiaro, P. Patteri, M. Piccolo
INFN - Laboratori Nazionali di Frascati

E. Kuznetsova
Università di Roma "Sapienza"

Outline

- Scope of the Work
- Test Beam Set Up
- Calibrations
  - Calorimeter (# of MIPS in detector)
  - External Tracker (Resolution and Residuals)
  - Temperature Monitoring
  - PD Gain Measurement
- *Preliminary* Results on
  - Charge vs V_{bias}
  - Light Collection
    - Amplitude X,Y Scans
  - Efficiency Measurement
    - X,Y Radiographies
  - Cosmic Ray Test Stand Results
    - Timing Resolution
- Summary

Scope of Study

- Present LC hadron calorimeter prototype (CALICE) uses WLS fibers and MEPhI SiPM. Since its design and construction:
  - Newer solid state PD have been made available from several producers: Hamamatsu, SensL, IRST
  - New devices are more sensitive to blue light
    - avoid WLS fiber

➢ Test other possible combination of scintillator material, thickness, geometry with different kind of PD for calorimetry applications

➢ Study other SiPM/MPPC characteristics such as excellent time resolution and noise rate, important also for other kinds of applications, i.e. medical devices etc.

10 Configurations all 3x3 cm^2 Tiles

5 mm

- Ch.1 – BC400 5mm, Hamamatsu 400 pixel (50x50 μm^2)
- Ch.2 – BC400 5mm, Hamamatsu 1600 pixel (25x25 μm^2)
- Ch.3 – Vladimir (Russia) Scintillator 5mm, Hamamatsu 400 pixel

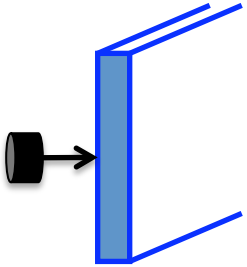
2 mm

- Ch.4 – EJ212(~BC400) 2mm, Hamamatsu 400 pixel
- Ch.5 – EJ212(~BC400) 2mm, Hamamatsu 1600 pixel
- Ch.6 – BC400 5mm, Ham 3x3mm^2 3600 pixel (50x50 μm^2)
- Ch.7 – CALICE Vladimir tile w/Kuraray Y11 1mm fiber, MEPhI/ Pulsar SiPM 1156 pixel (20x20 μm^2 – 1mm^2) *
- Ch.8 – BC400 5mm, IRST 625 pixels (40x40 μm^2)
- Ch.9 – BC400 5mm, SensL SPMScint1000X04, 1000 pixel
- Ch.10 – EJ212(~BC400) 2mm, SensL as above, 1000 pixel

(* Dr. V. Rusinov, ITEP Moscow)

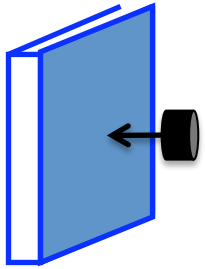
PD-Scintillator Coupling

- **Side Centre**
- Attached to the centre of one side of the tile using optical glue



Config 1 to 5

Config 6

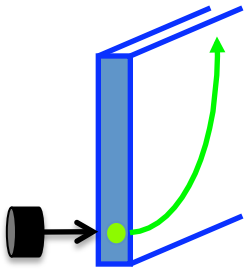


Face Centre

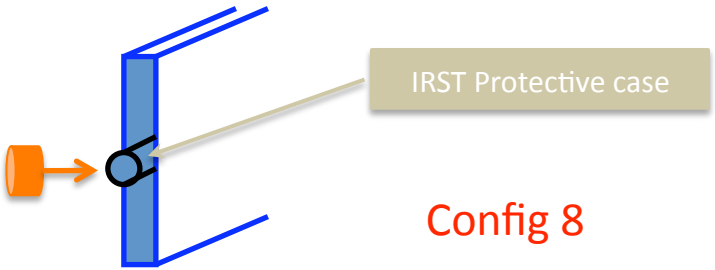
3x3 mm^2 Hamamatsu MPPC attached to the centre of the tile face with optical glue

CALICE

Green WLS fiber, 100 μm of air between the fiber and the SiPM



Config 7

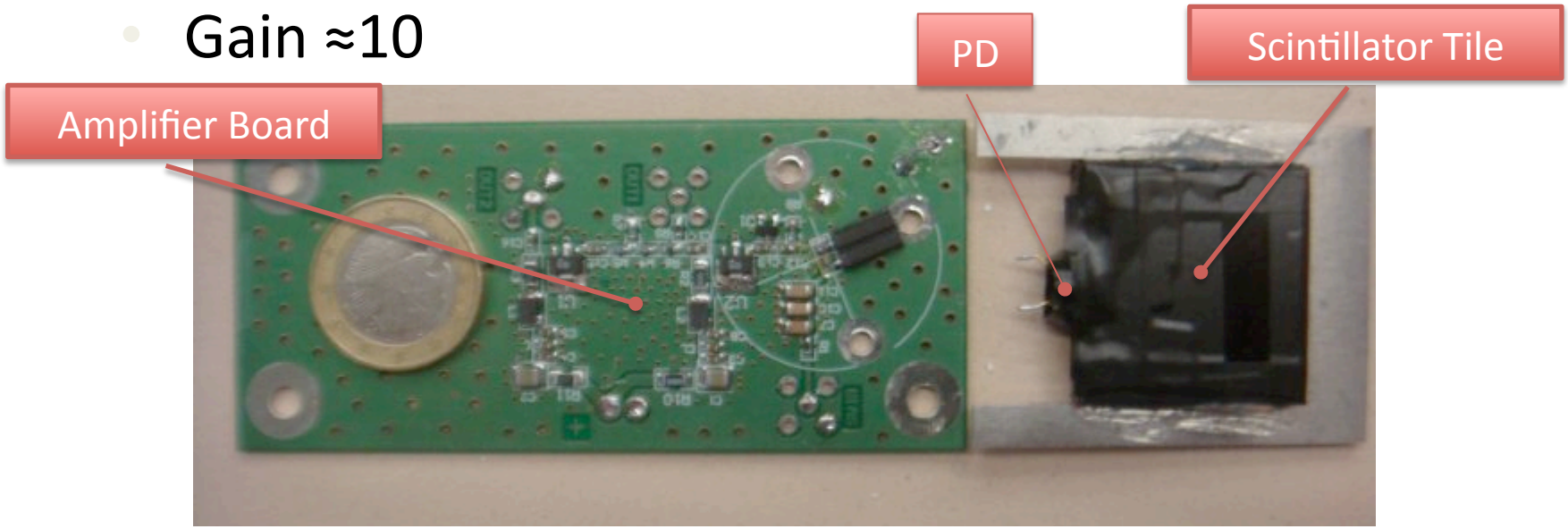


Config 8

"Standard" configuration but the IRST SiPM is fitted in a protective case with a transparent window glued to the tile (IRST SiPM does not have a protective coating on its face)

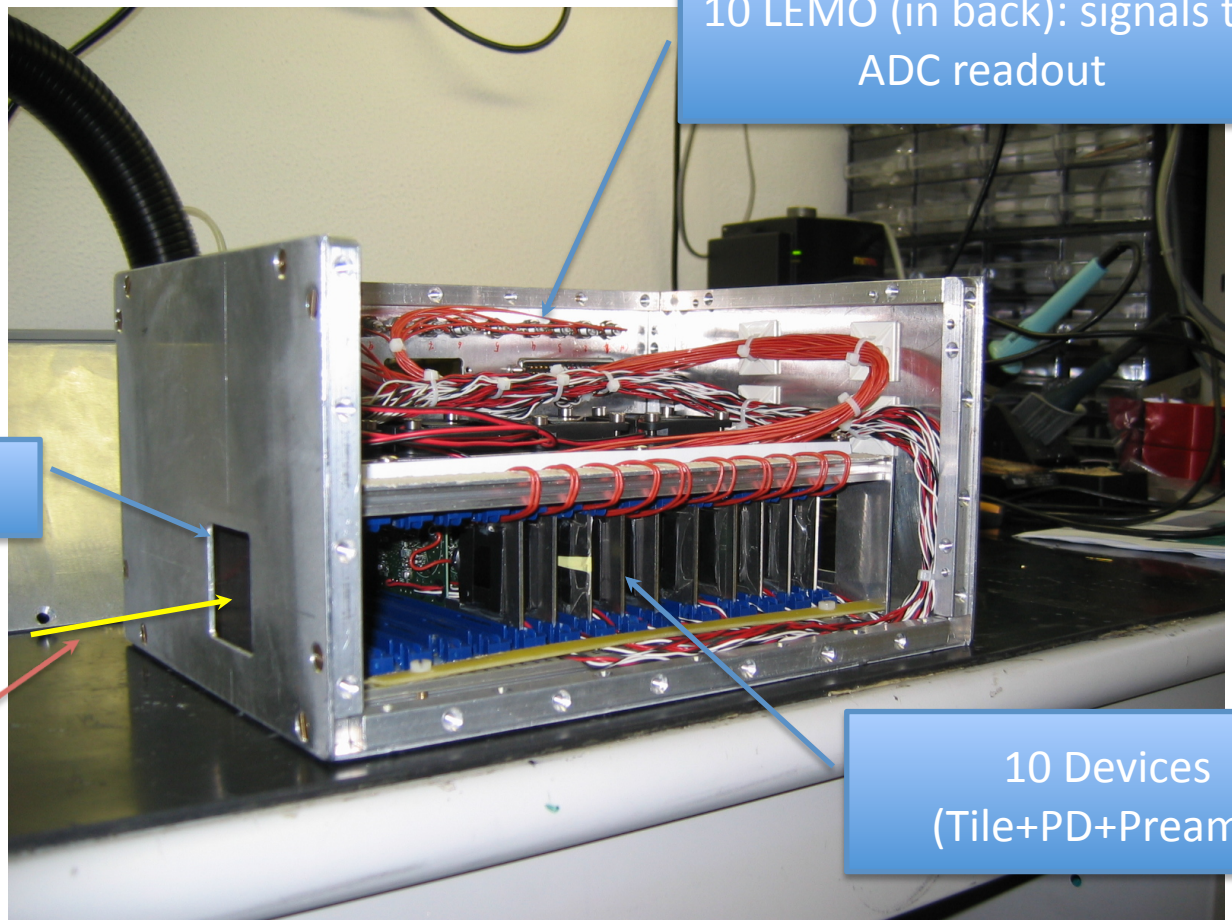
Preamp-Tile Assembly

- INFN-Pisa design based on the GALI-5 chip
- Gain ≈10

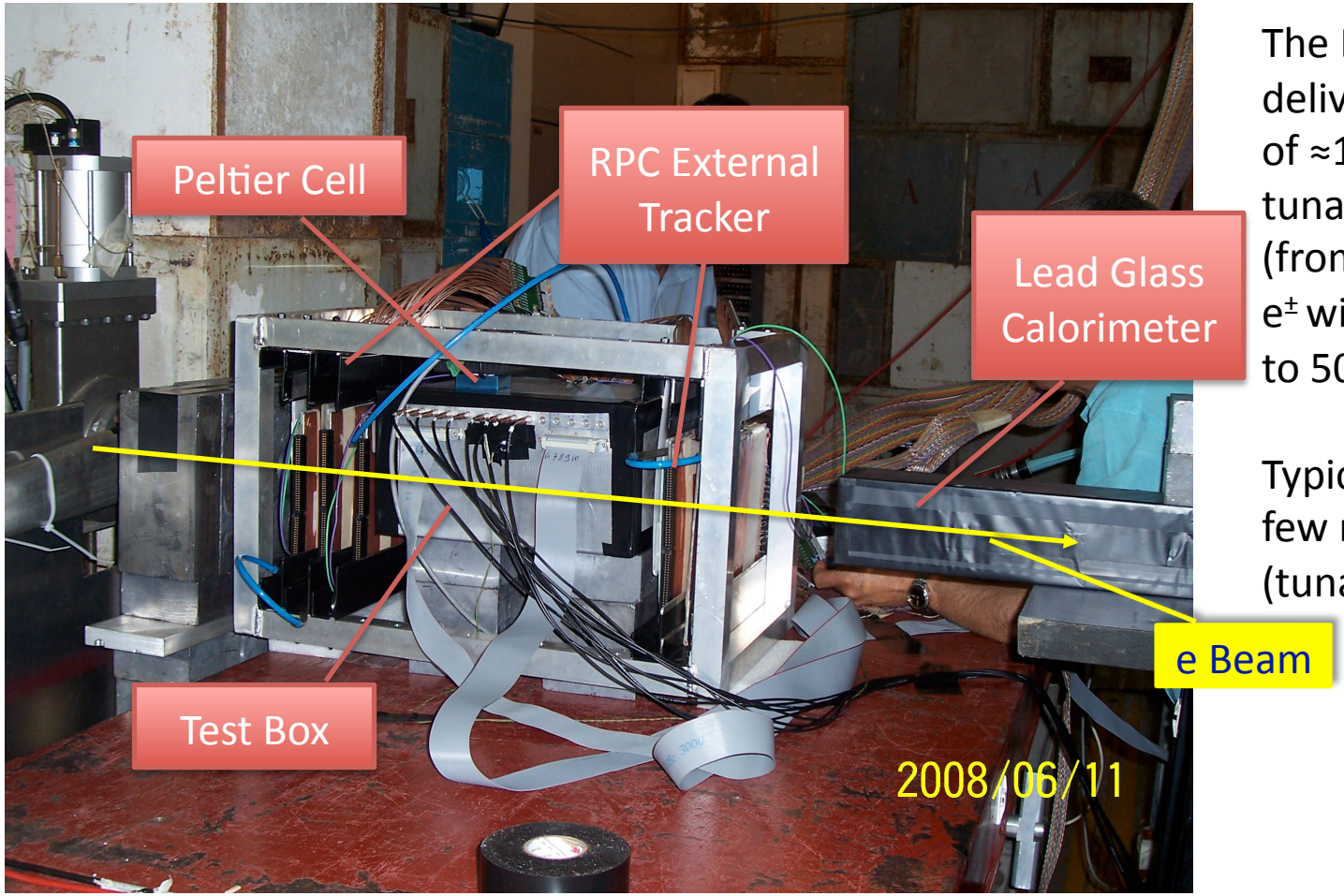


- A custom NIM module distributes (via a flat cable) both V_{bias} to the PM and the low voltage supply (8V) to the preamp

10-Channel Test Box



BTF Set Up

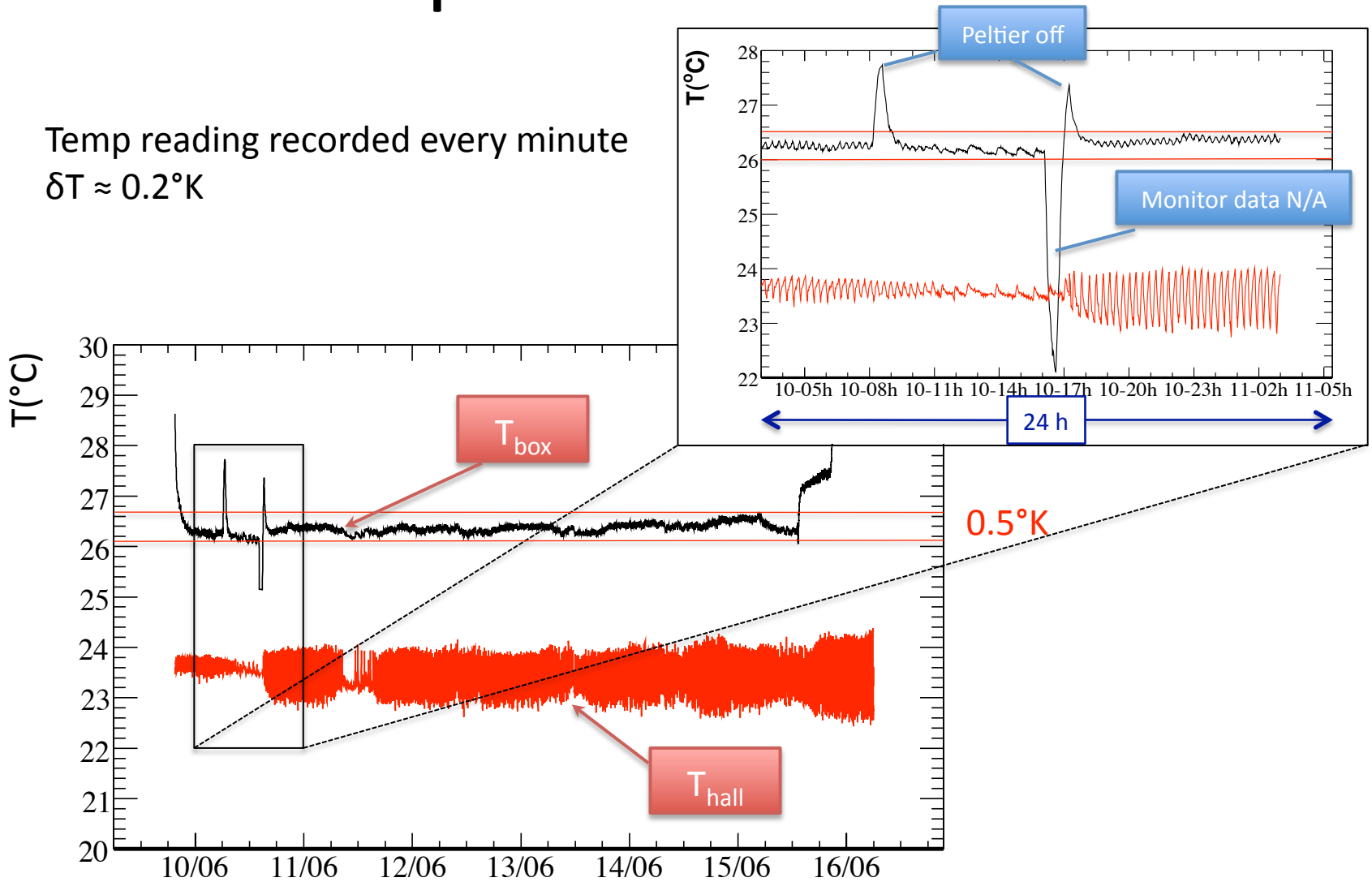


The BTF can deliver up to 50Hz of ≈1ns pulses of a tunable number (from 1 to 10^4) of $e^{\pm}$ with energy up to 500 MeV

Typical beam size few mm^2 (tunable)

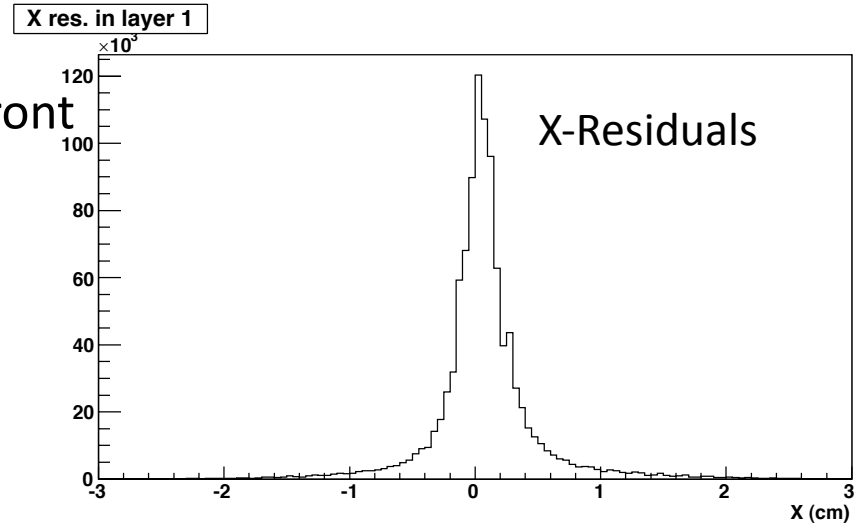
Temperature Monitor

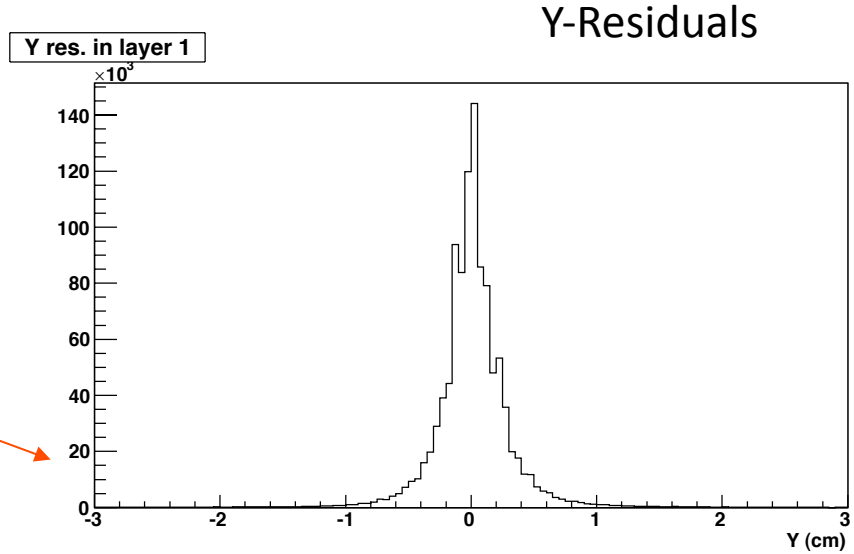
Temp reading recorded every minute
δT ≈ 0.2°K

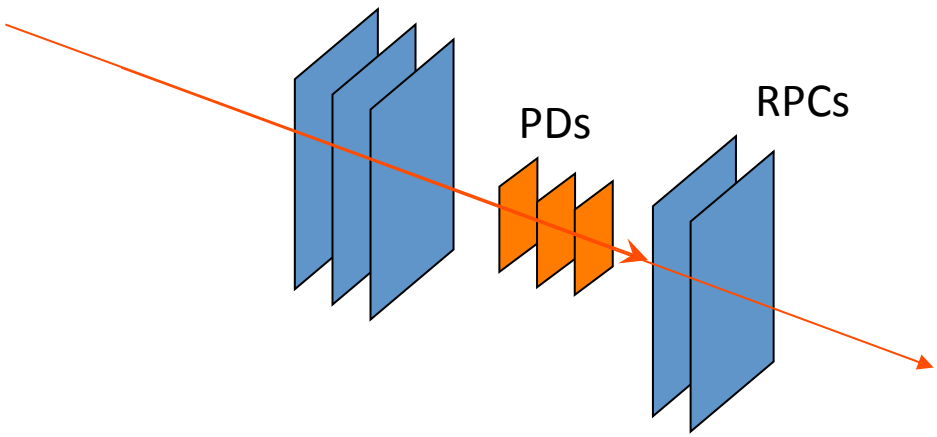


External Tracker

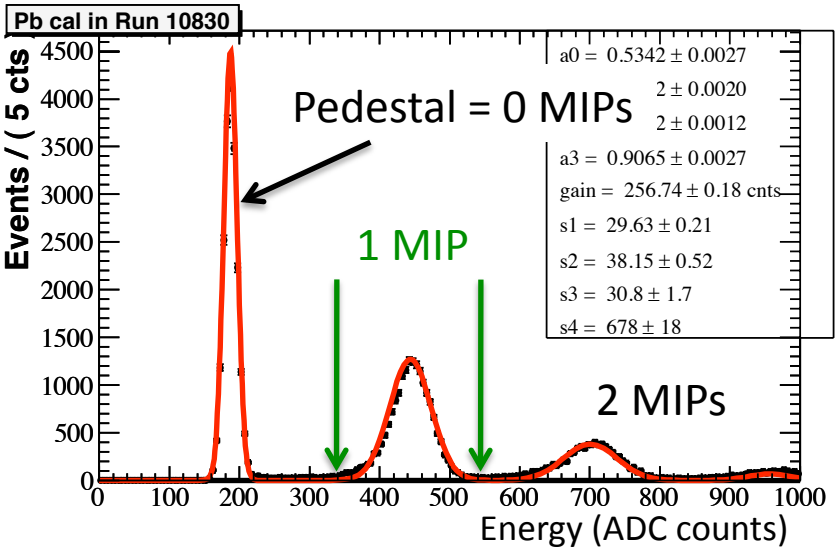
- 5 layers of 50x50 cm^2 glass RPC: 3 in front and 2 in the back of the test box
-
- Digital read out of 8 mm wide strips in both X-Y projections (≈ 25x25 cm^2)
-
- Point resolution ≈ 2.3mm

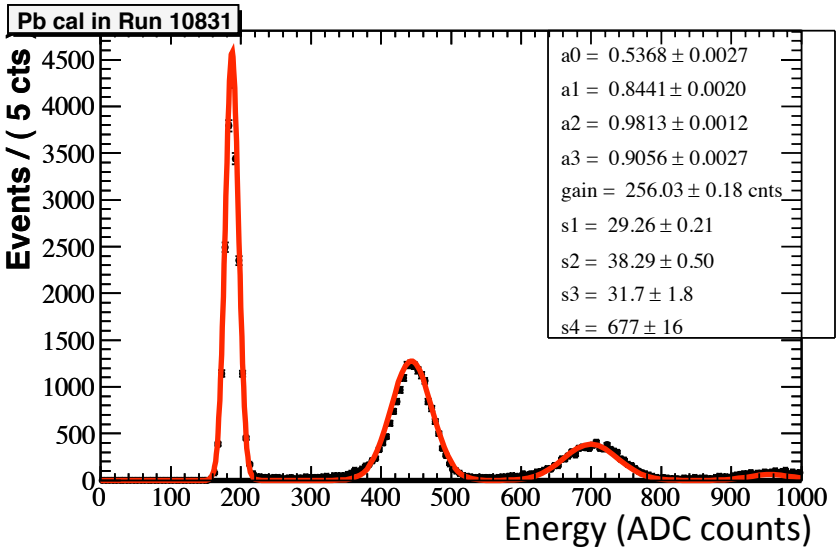


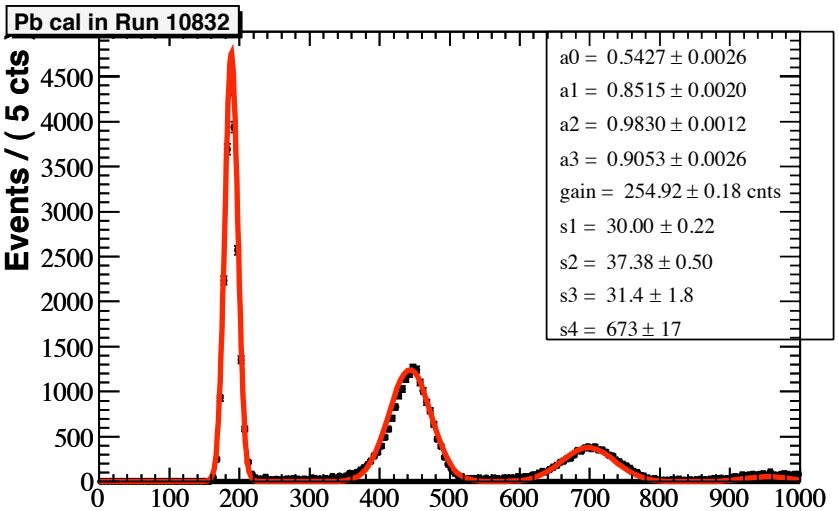


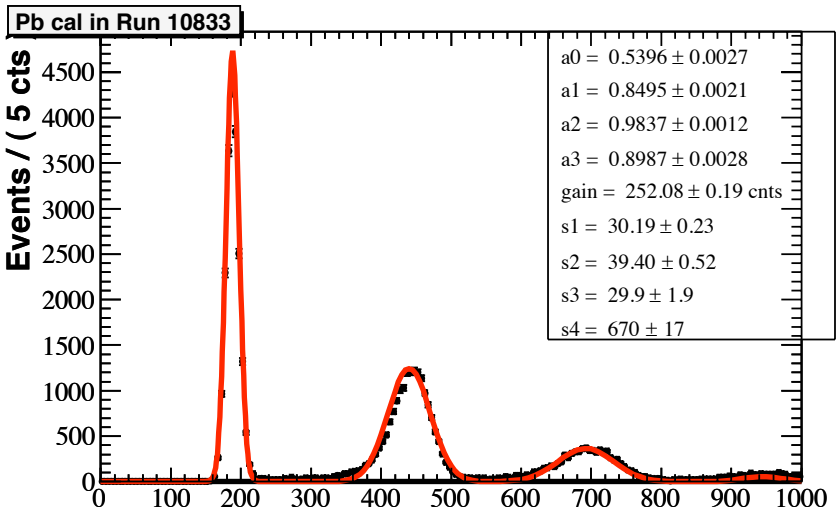


Calorimeter Selection of # MIPs

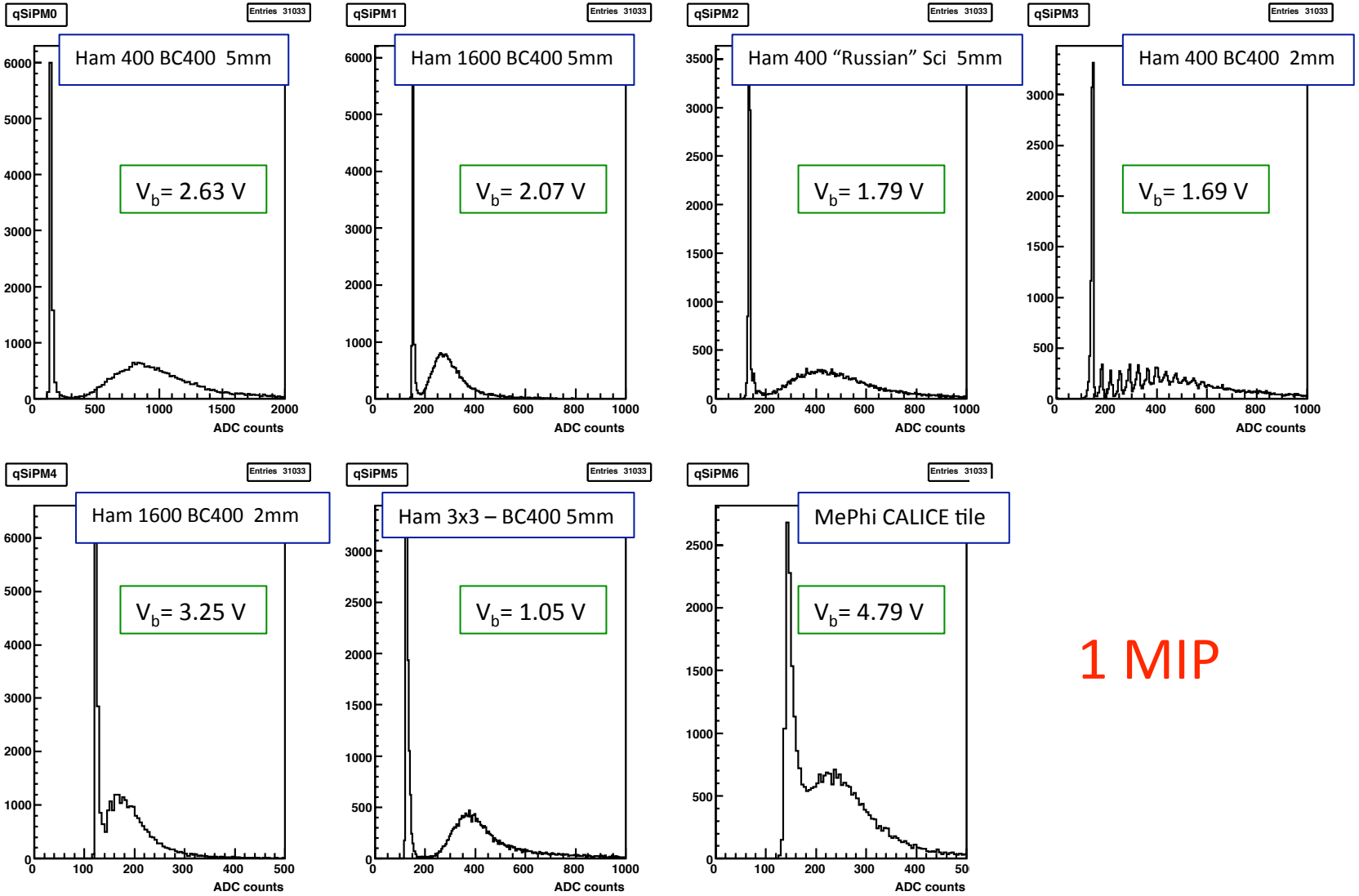






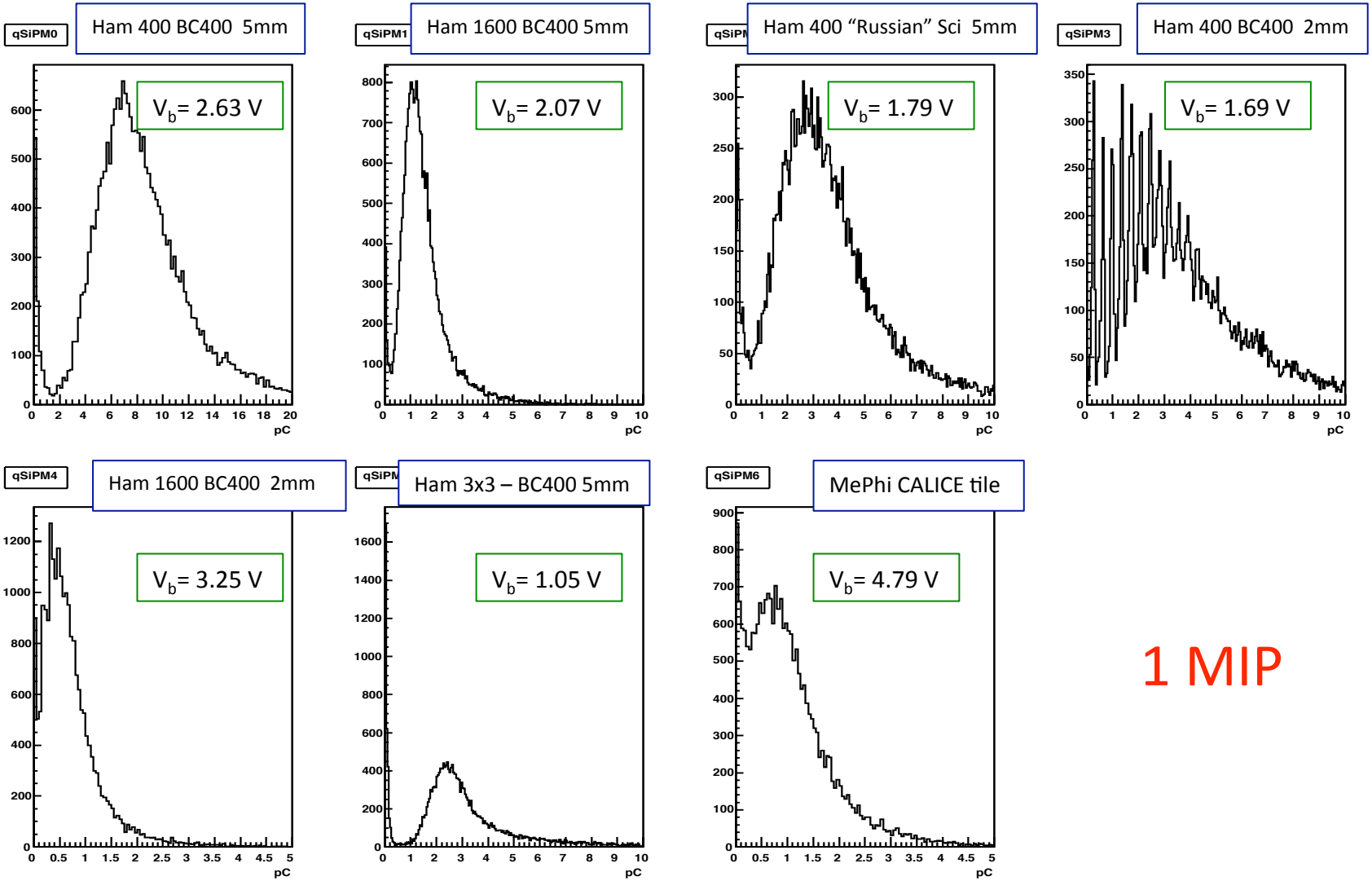


PD Response: ADC counts



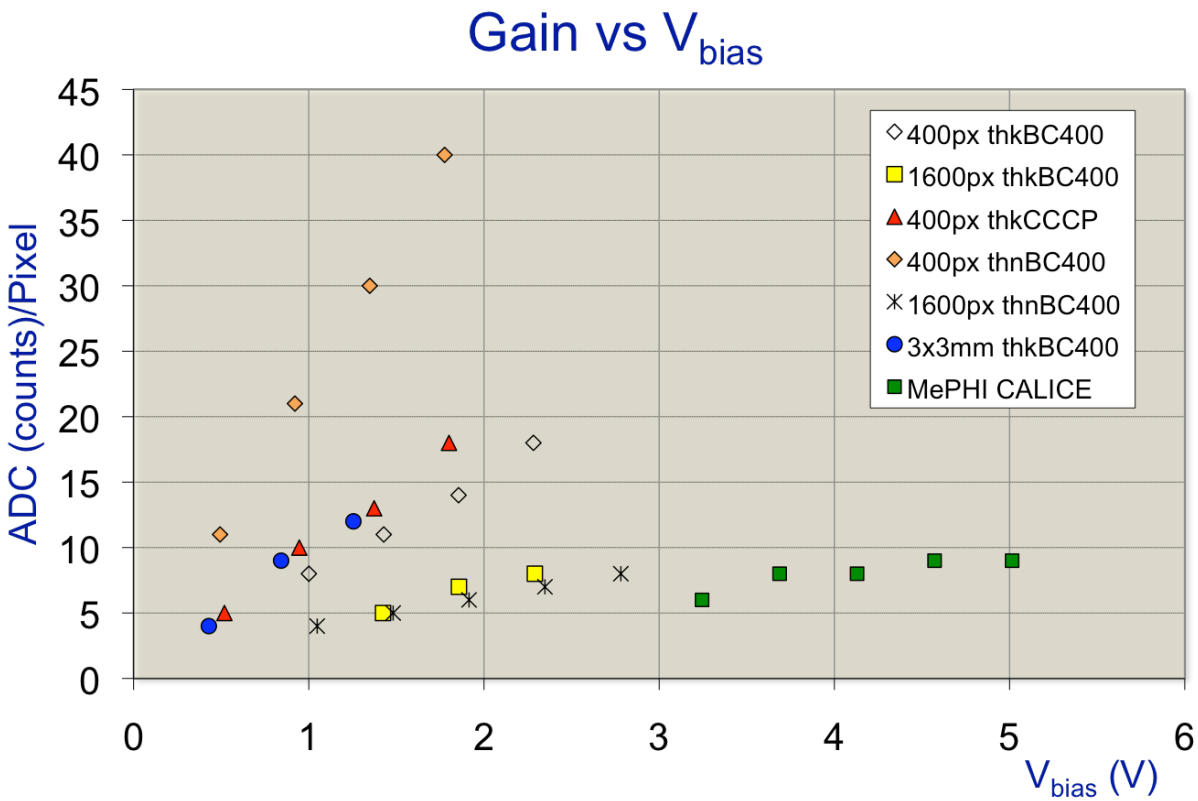
1 MIP

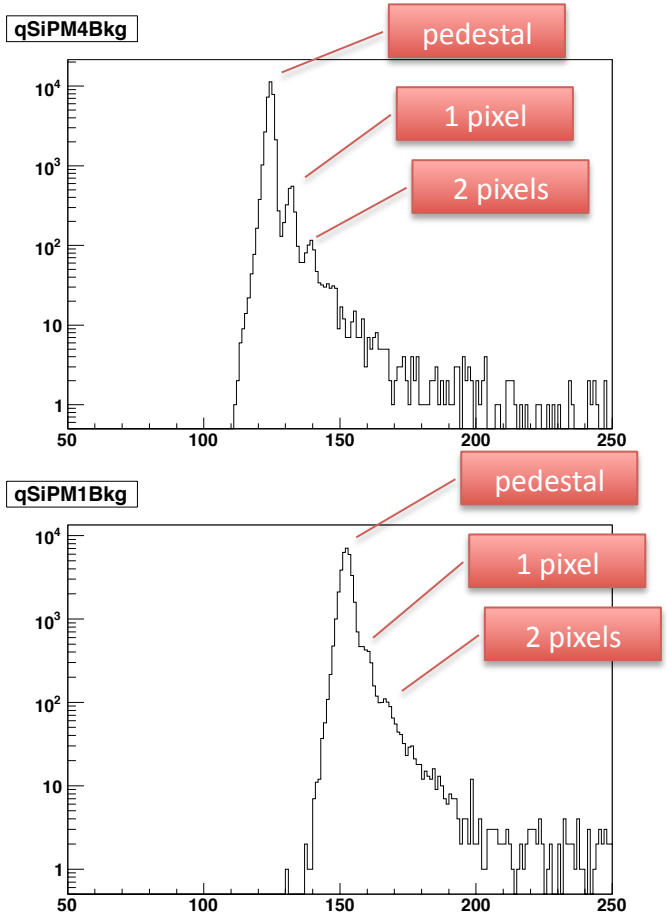
PD Response: Charge (pC)



1 MIP

PD Response: Gain vs Bias

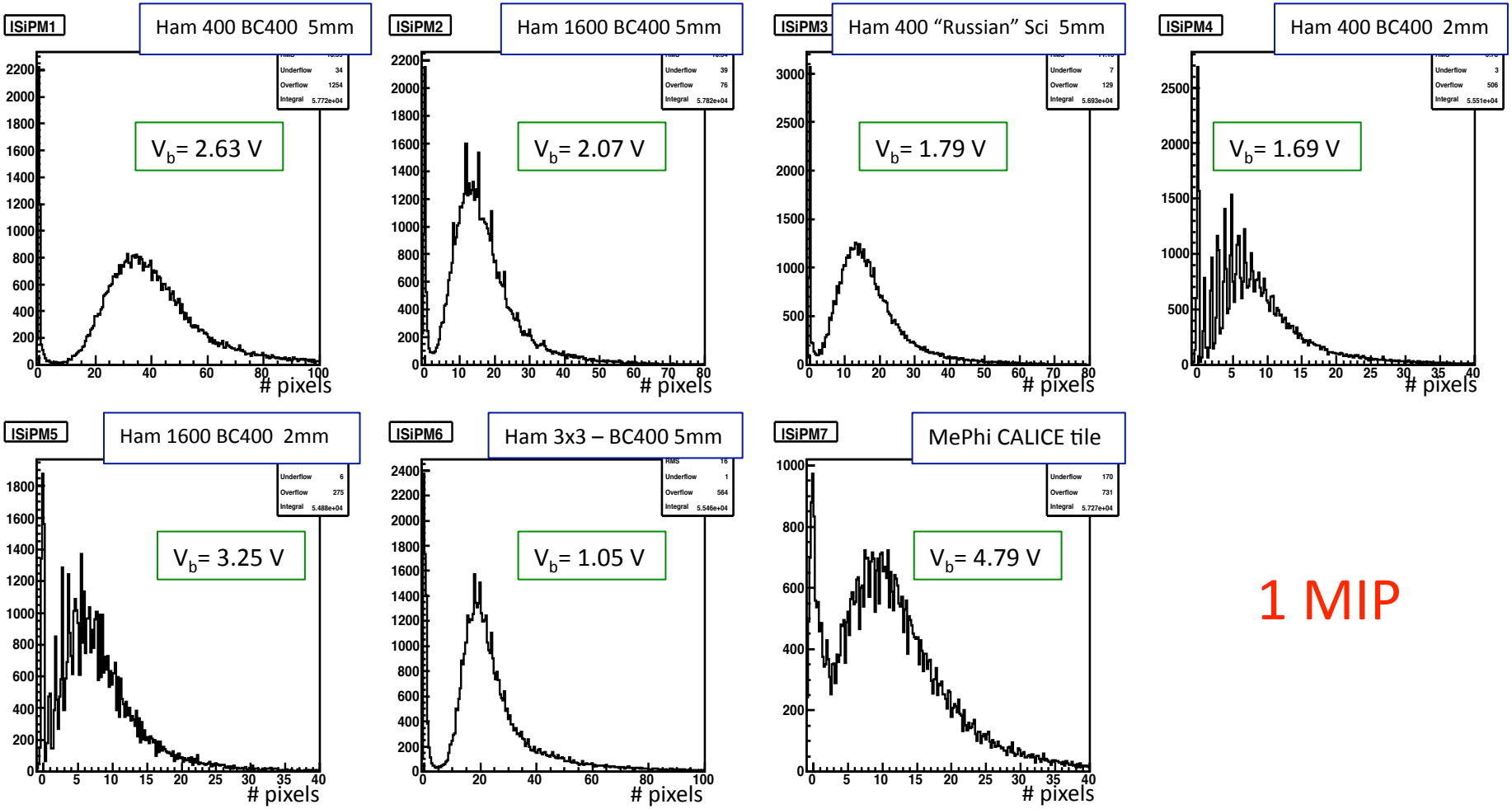




0 MIPs

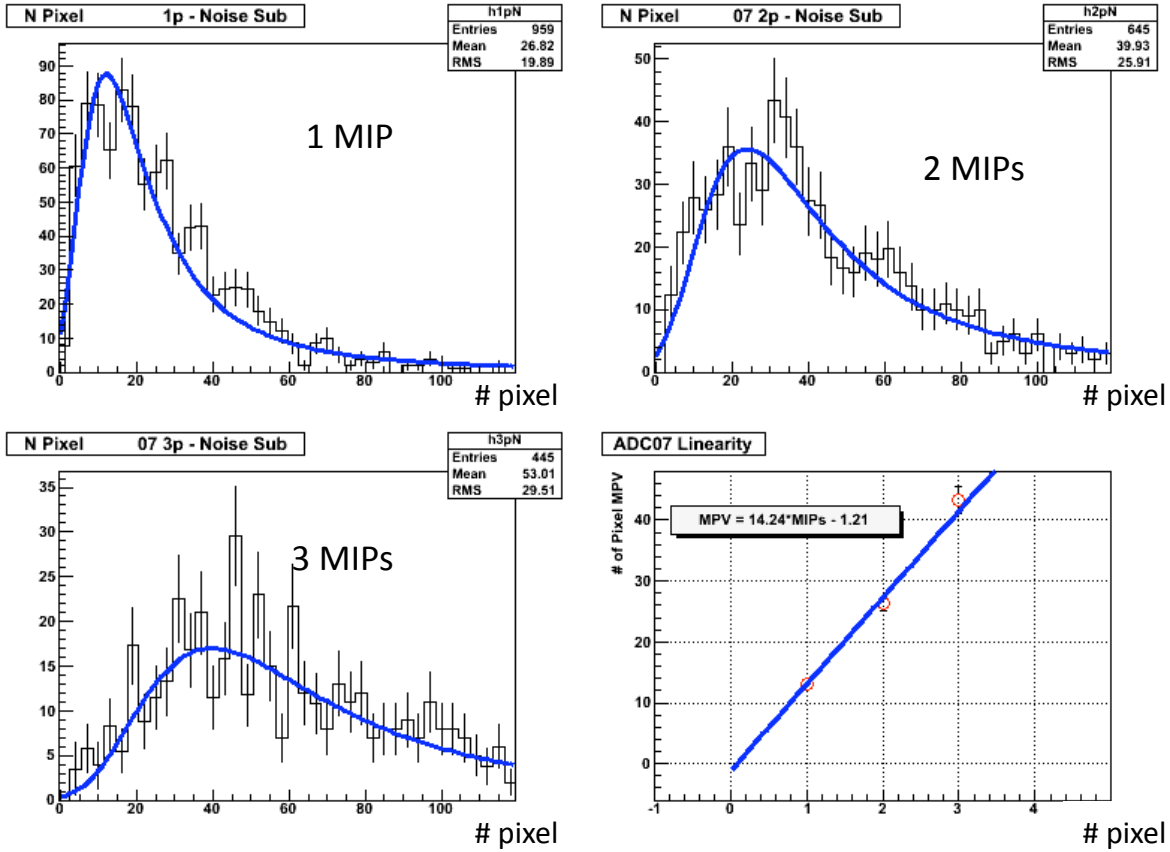
- Measure gain vs V, extrapolate to 0 pixels to get V_{break}
- Subtract from V to obtain $V_{bias}=V-V_{break}$
- Plot G vs Vbias
- All PD show good linearity

PD Response: # of Pixel



1 MIP

PD Response vs # of MIPs



Ham MPPC 1600 pixels

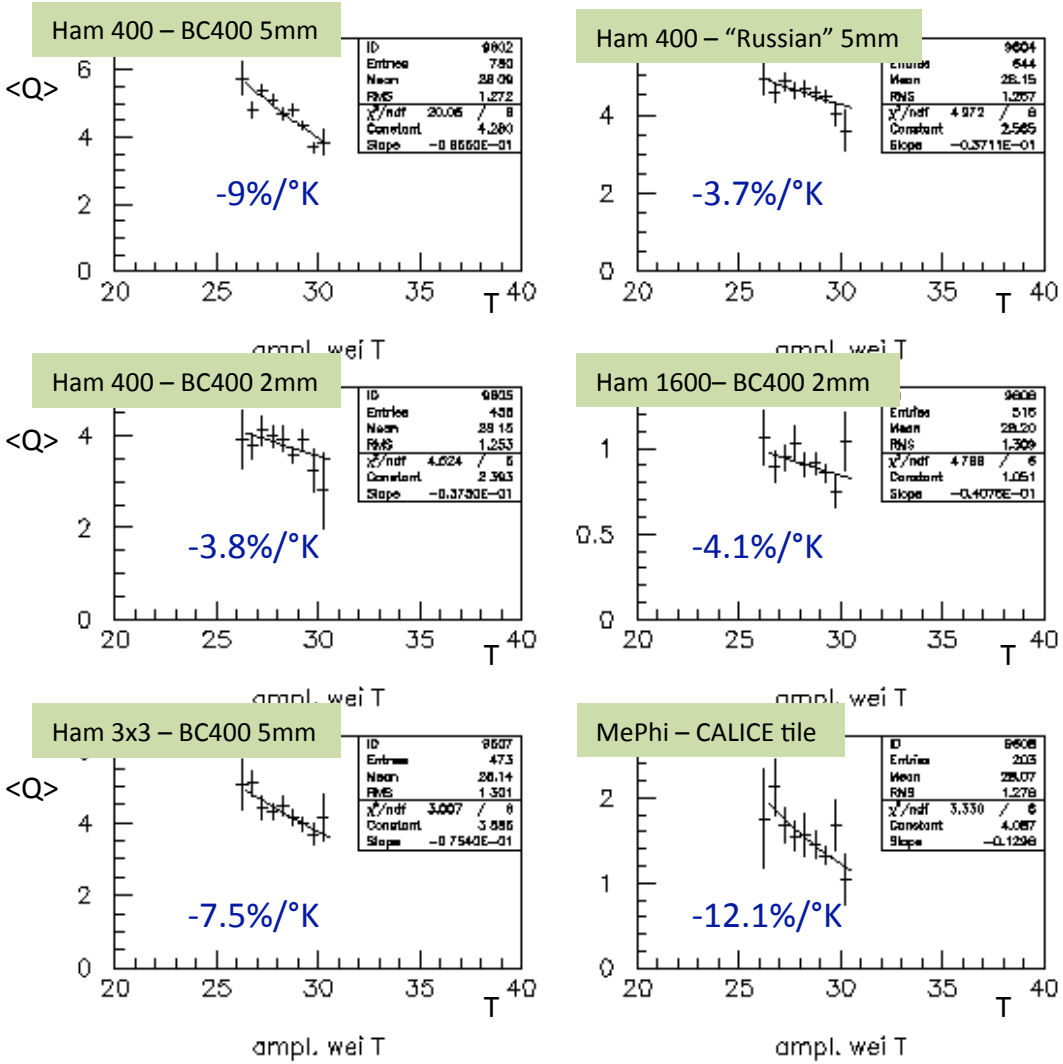
Charge collected as a function of the number of MIPs impinging on the scintillator tile

NOTE:
This data is from an older test beam

The BTF allows to have many more MIPS/event

Can measure dynamic range of the various configurations

PD Response: CR Data

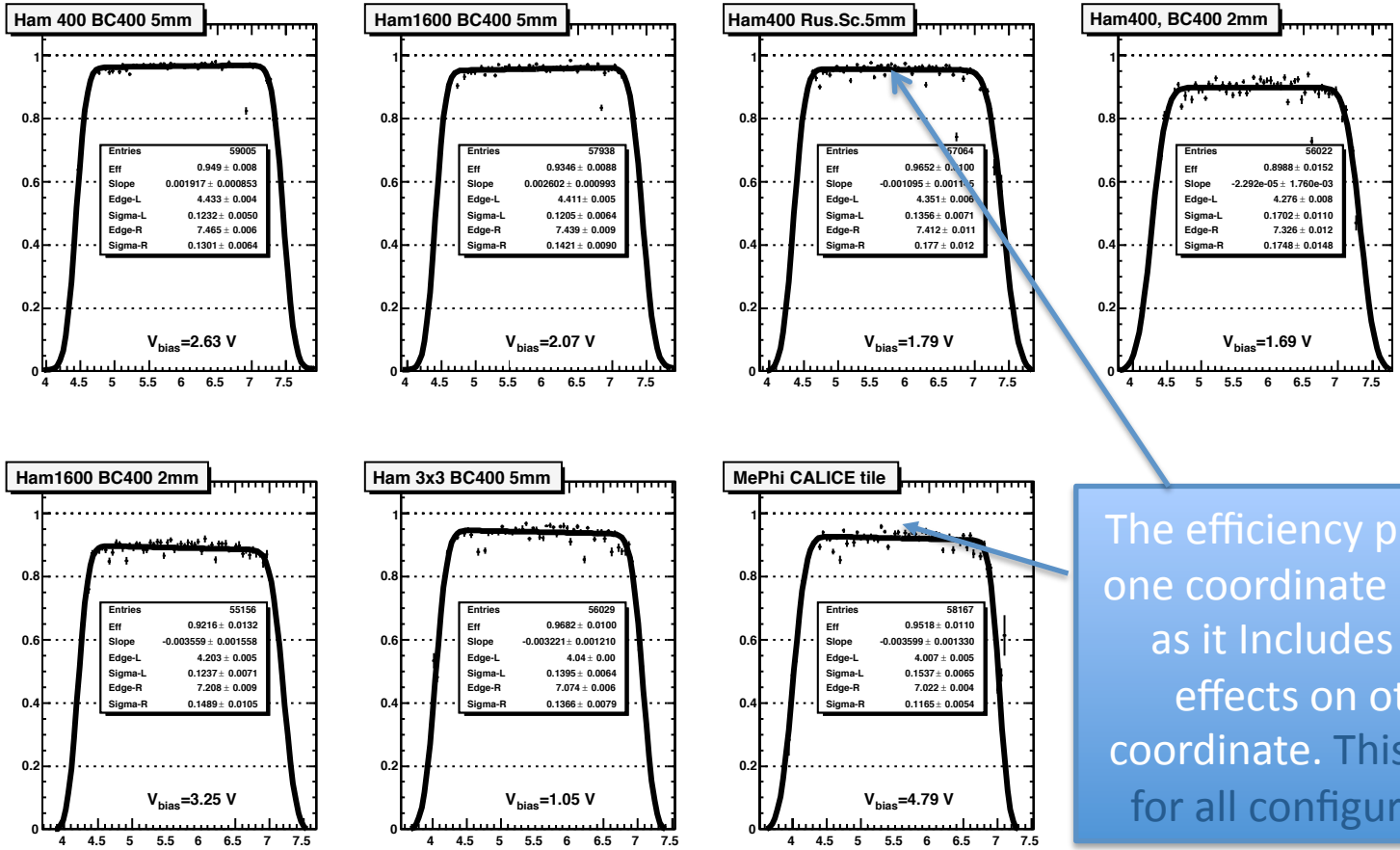


Temperature Dependence

Variation with T of the average collected charge per MIP (CR data) for different PMs

Efficiency Tile Profile X

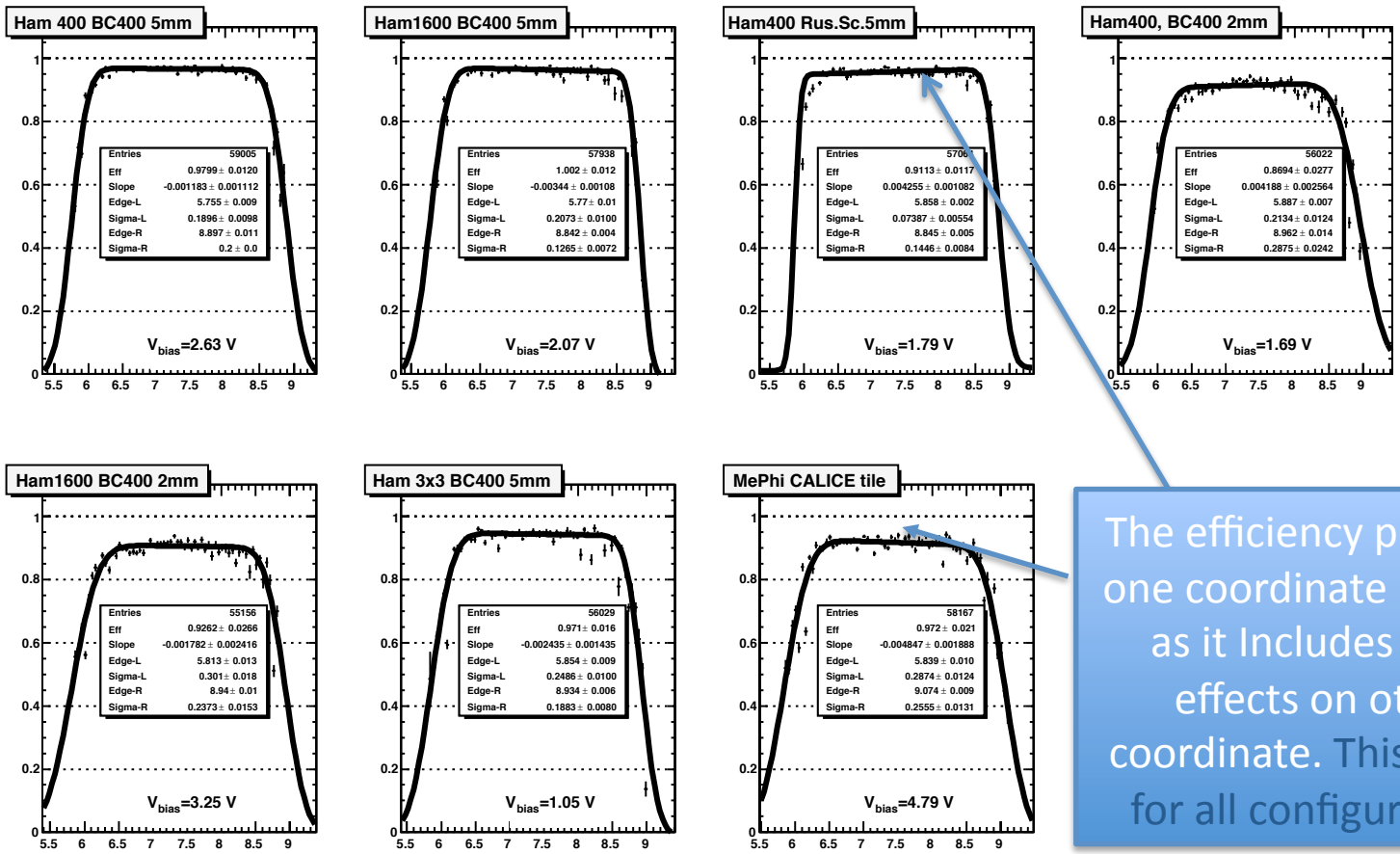
Cut at 2 pixels



The efficiency profile in one coordinate is lower as it Includes edge effects on other coordinate. This is true for all configurations

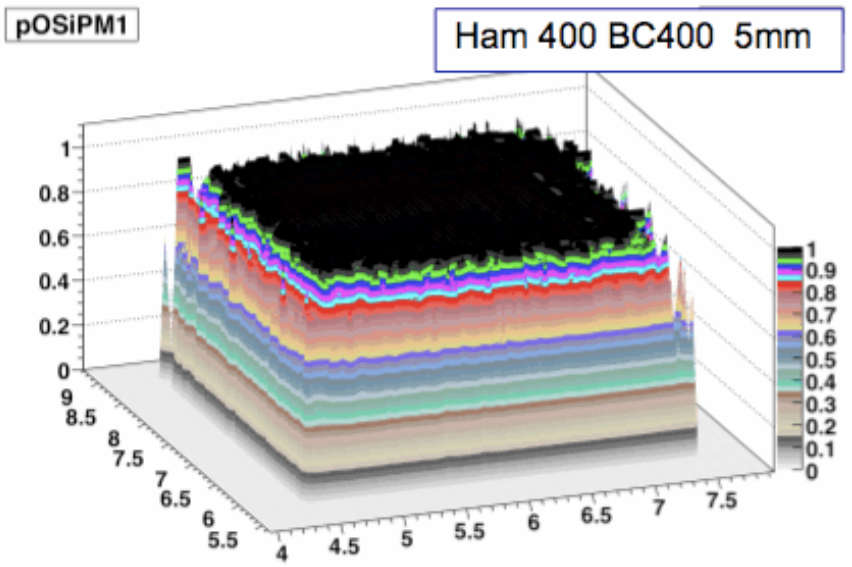
Efficiency Tile Profile Y

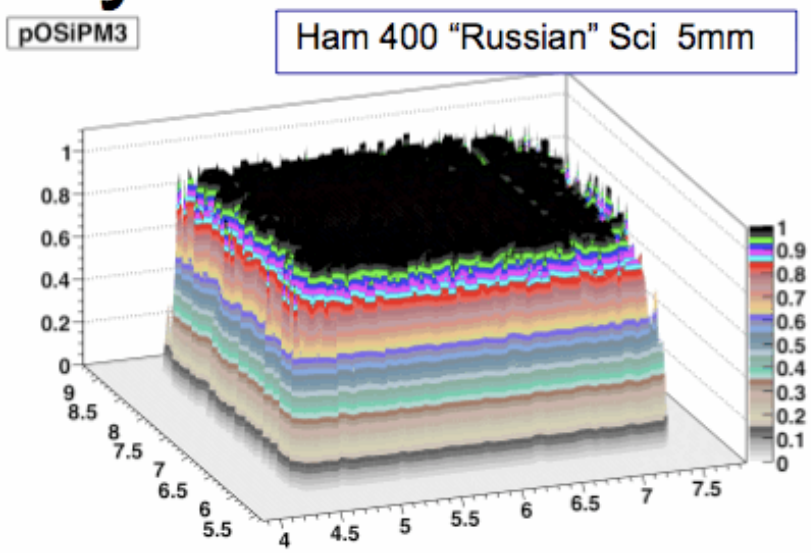
Cut at 2 pixels

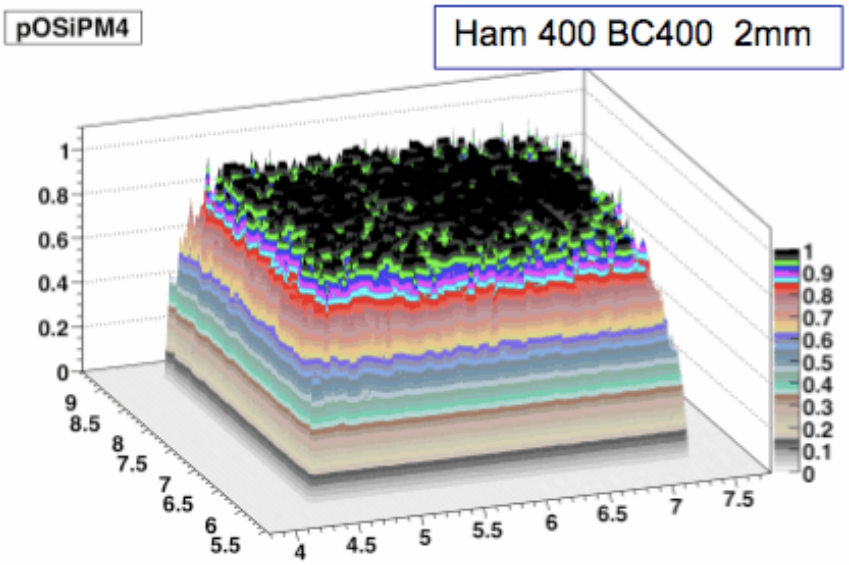


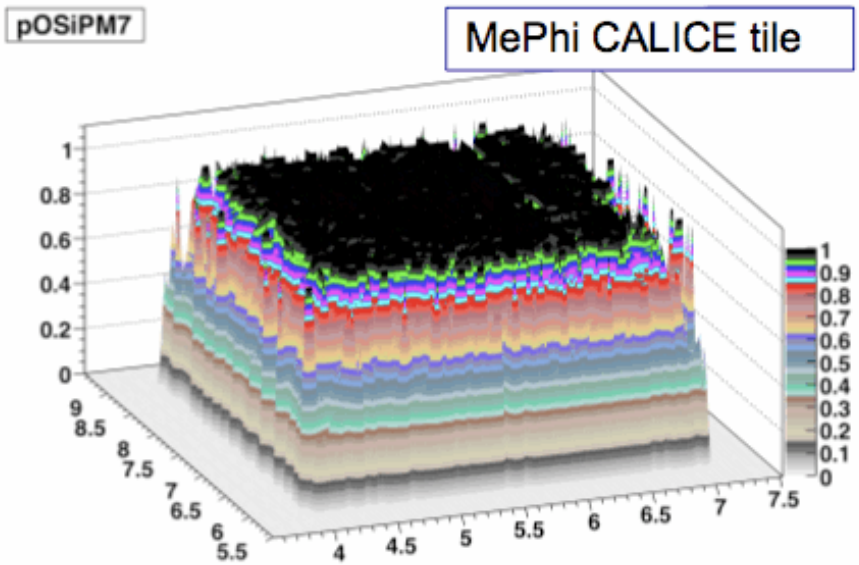
The efficiency profile in one coordinate is lower as it Includes edge effects on other coordinate. This is true for all configurations

Efficiency


pOSiPM1
Ham 400 BC400 5mm

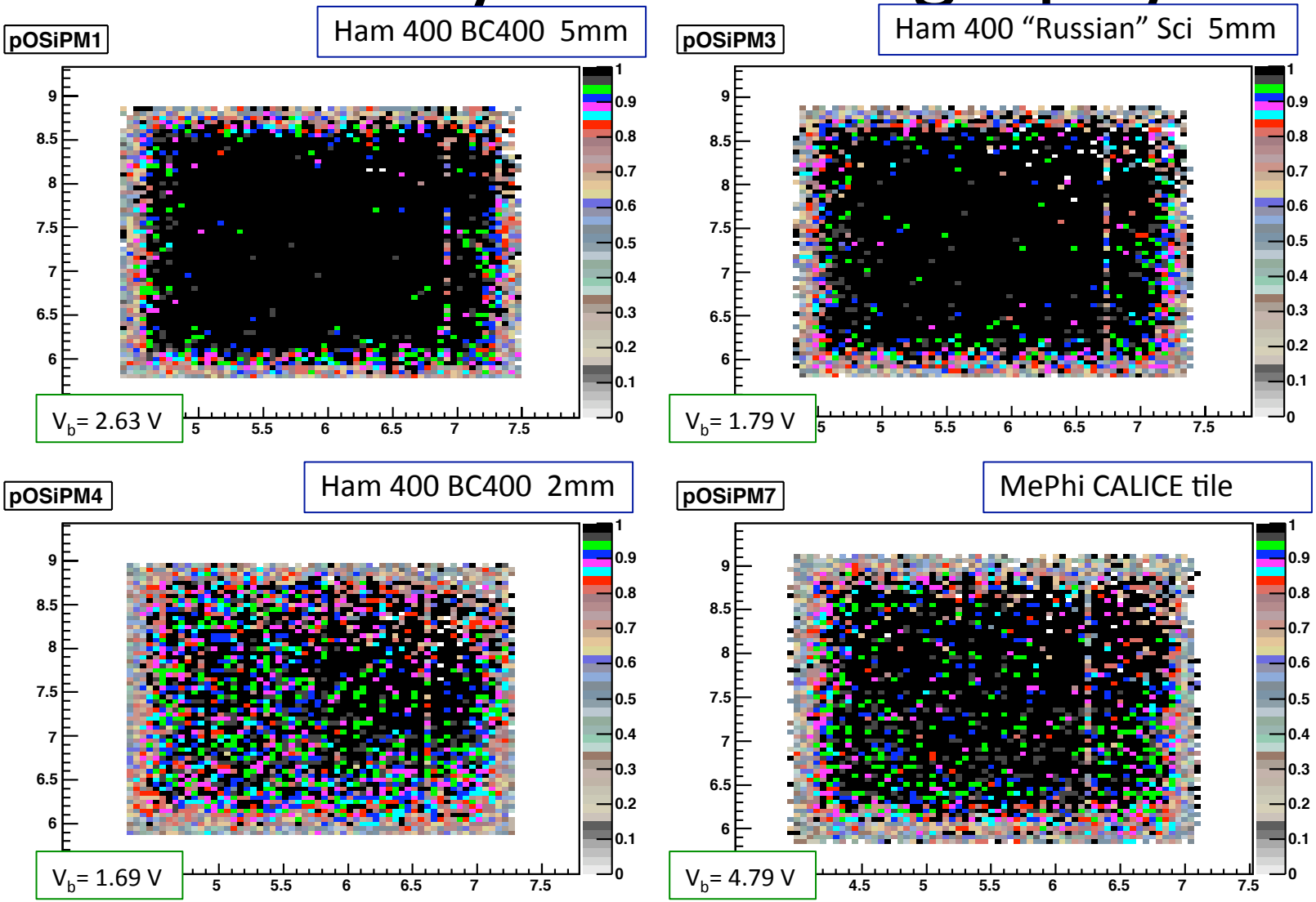

pOSiPM3
Ham 400 "Russian" Sci 5mm


pOSiPM4
Ham 400 BC400 2mm


pOSiPM7
MePhi CALICE tile

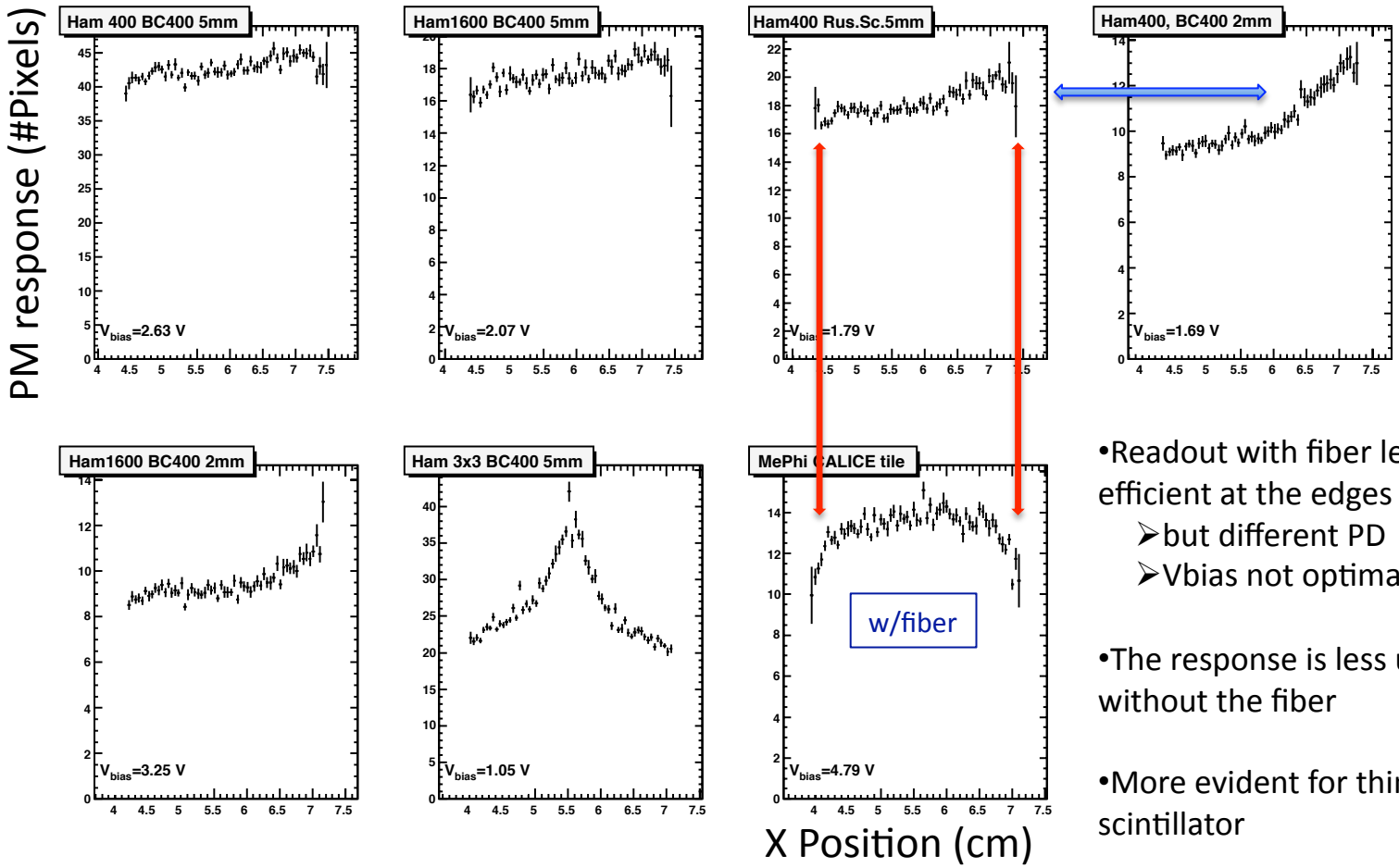
Cut at 2 pixels

Efficiency: X-Y Radiography



PD Response to 1 MIP - X

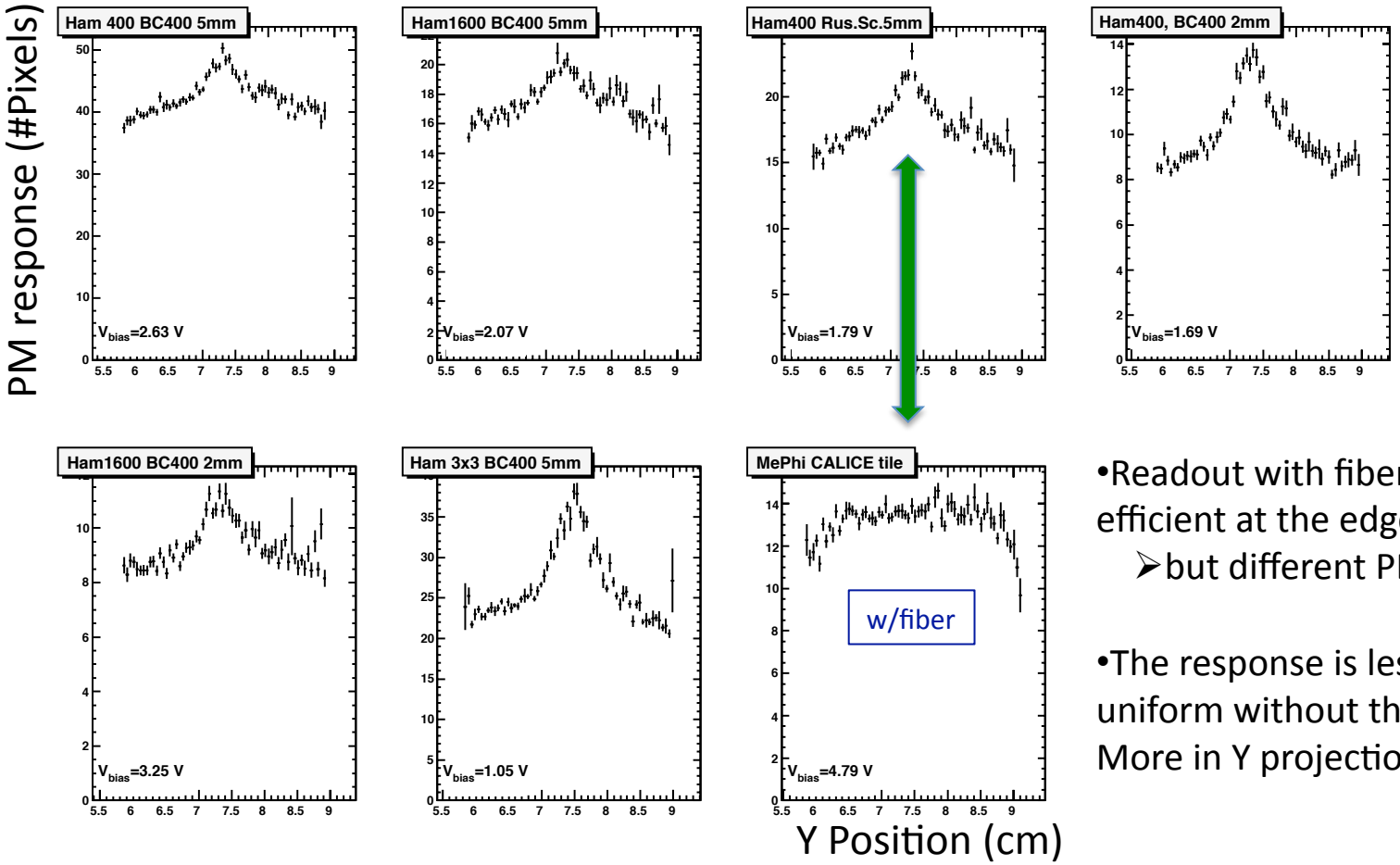
Cut at 2 pixels



- Readout with fiber less efficient at the edges
  - ➢ but different PD
  - ➢ Vbias not optimal?
- The response is less uniform without the fiber
- More evident for thinner scintillator

PD Response to 1 MIP - Y

Cut at 2 pixels

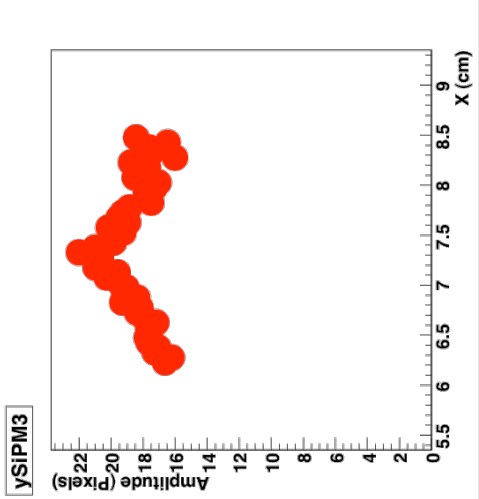


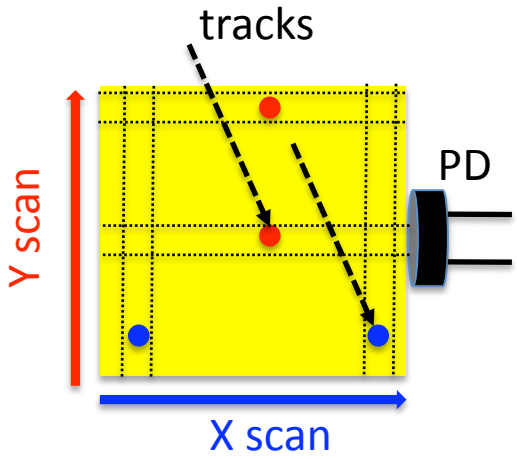
- Readout with fiber less efficient at the edges
  - ➢ but different PD

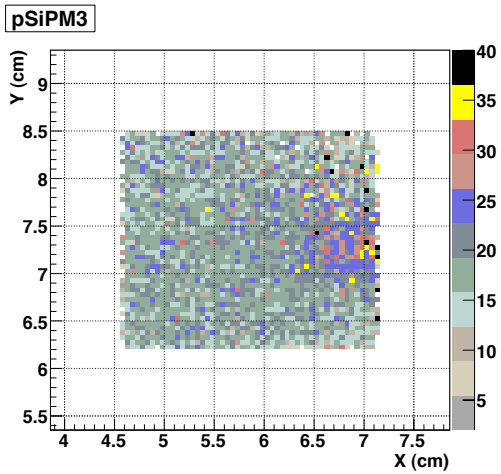
- The response is less uniform without the fiber. More in Y projection

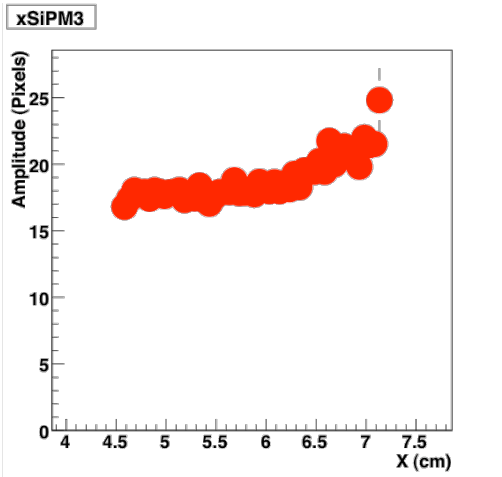
PD Response to 1 MIP – Side Centre

Cut at 2 pixels





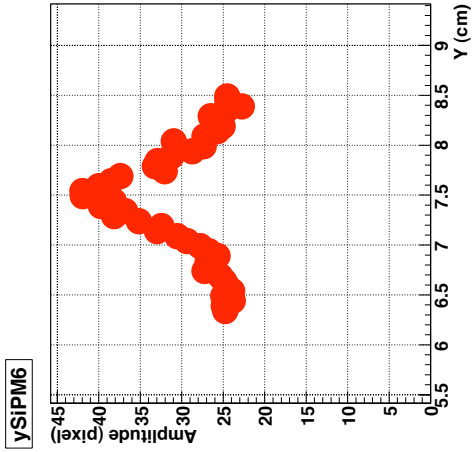


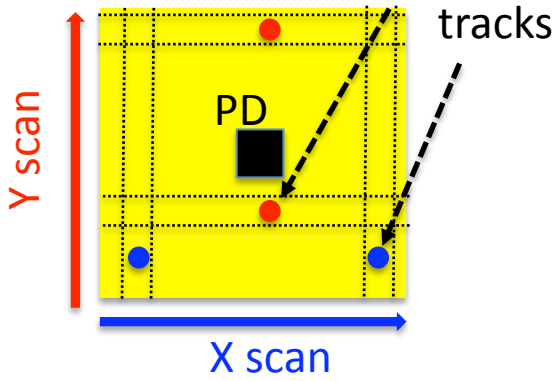


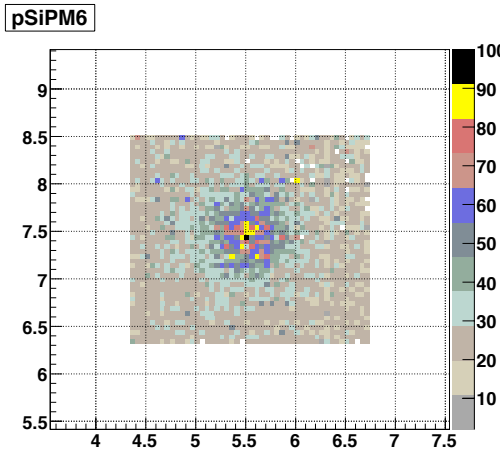
Tile edges excluded

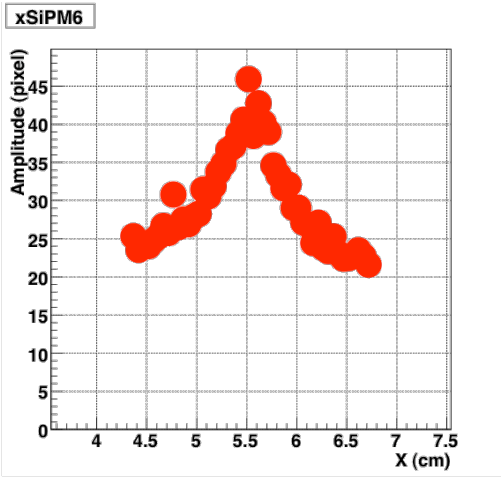
PD Response to 1 MIP – Face Centre

Cut at 2 pixels





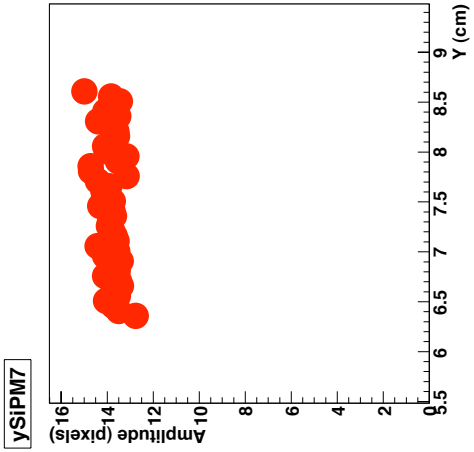


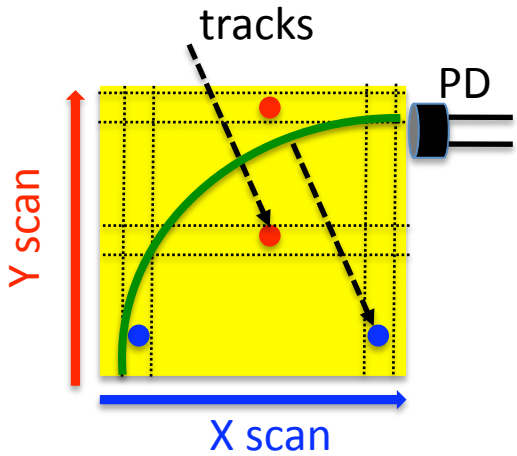


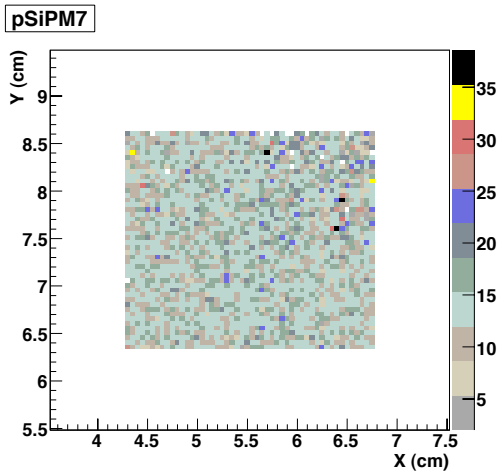
Tile edges excluded

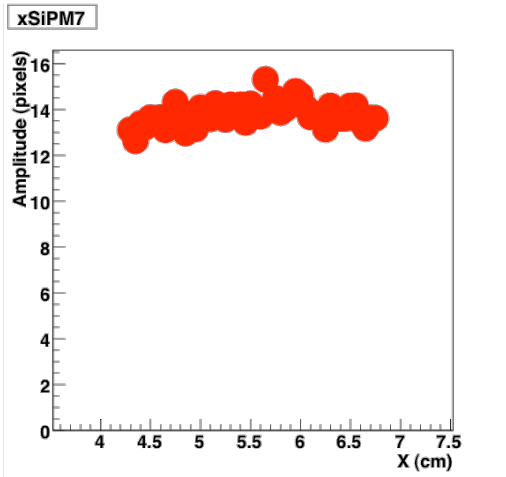
PD Response to 1 MIP – CALICE

Cut at 2 pixels



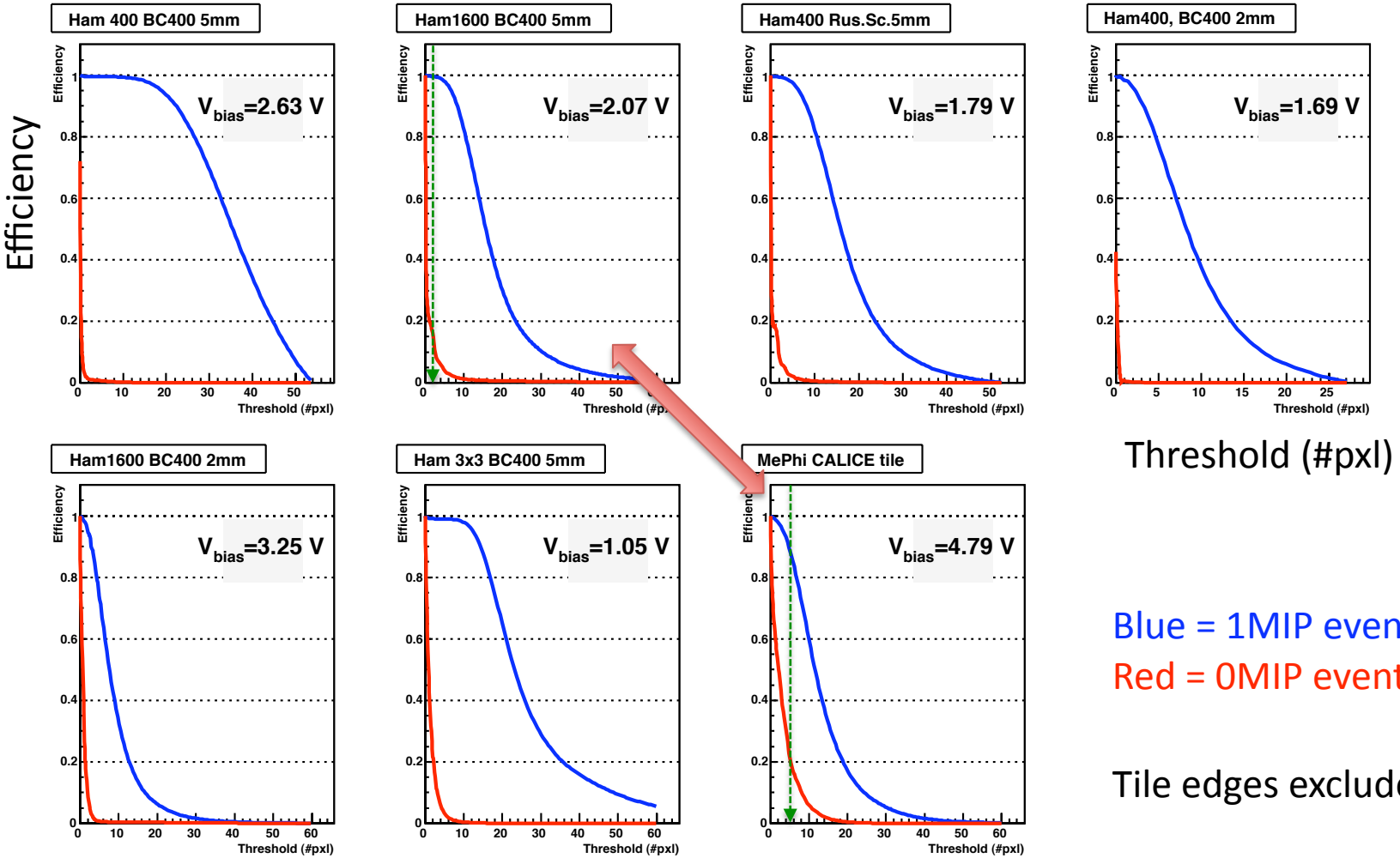






Tile edges excluded

Efficiency vs Threshold – 1 MIP



Threshold (#pxl)

Blue = 1MIP events

Red = 0MIP events

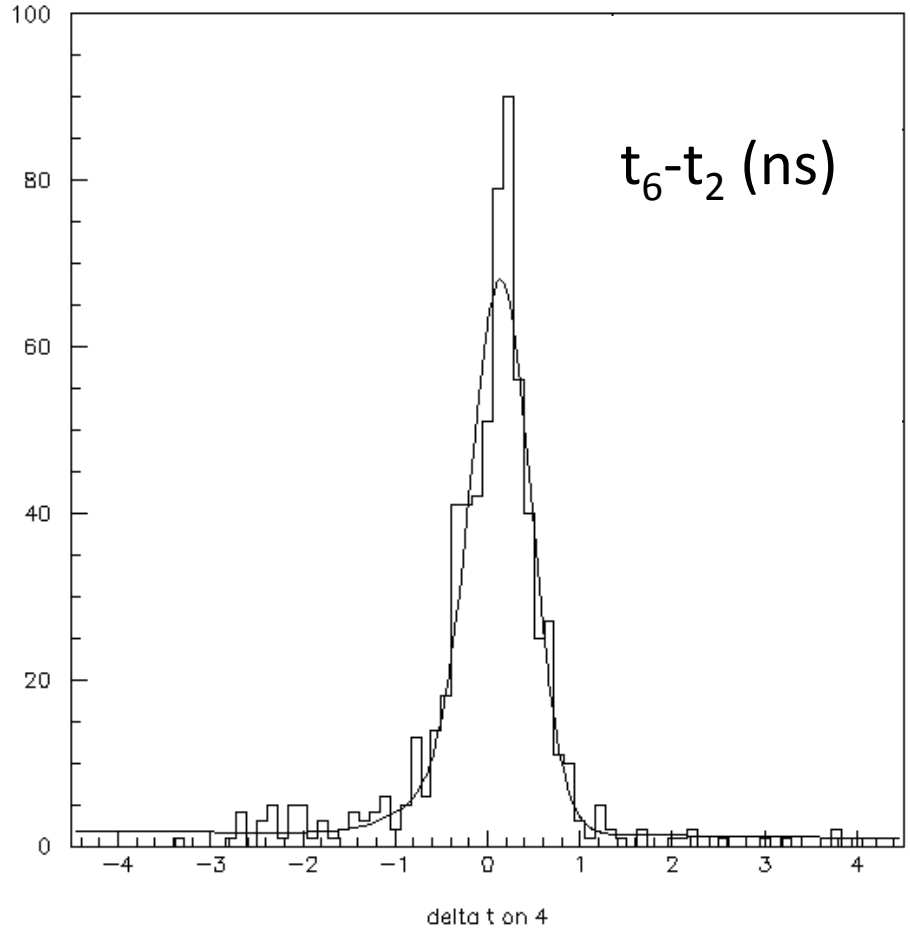
Tile edges excluded

Cosmic Ray Data

Time Measurement

- Preliminary measurement of the timing performances of the tile-SiPM device

- $\sigma \leq \approx 300$ ps without any corrections



Coming Soon

- Systematic comparison of different configurations
  - Different Silicon Photomultipliers
  - Different Tile Thickness/Material
  - Fiber vs No-Fiber
  - Measure Response vs # on MIPS (Dynamic Range)
- More results on timing performances

Summary and Outlook

- We have set up a test stand for systematic studies of solid state photon detectors applications to HEP
- We have shown preliminary results from a test beam comparing different tile/PD configurations
- We have a program to continue and improve these measurements with more statistics