SiPM arrays

DPG-Frühjahrstagung 2009

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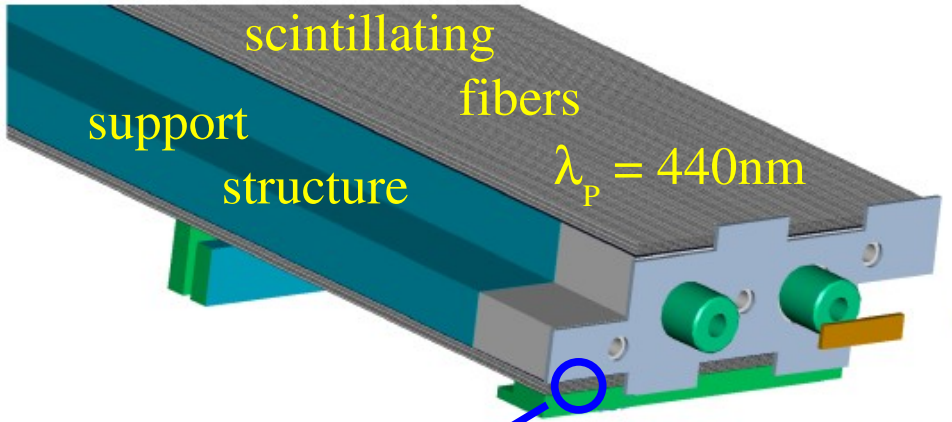
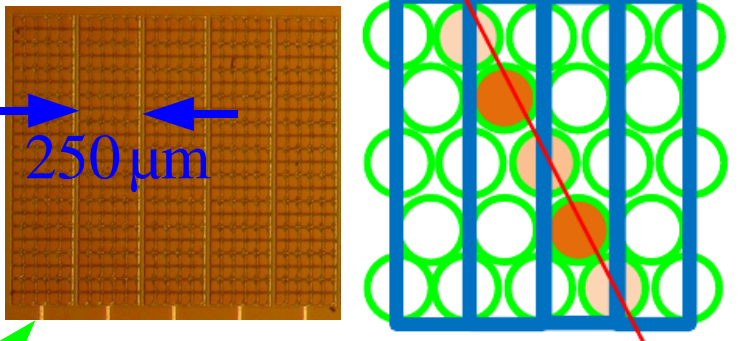
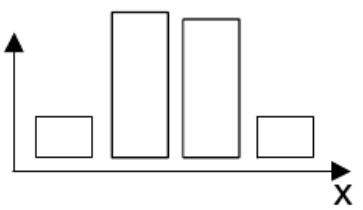
Tracker module

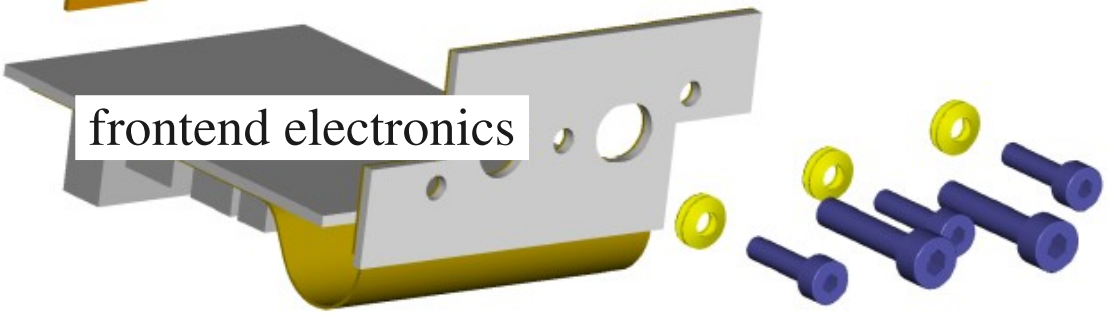


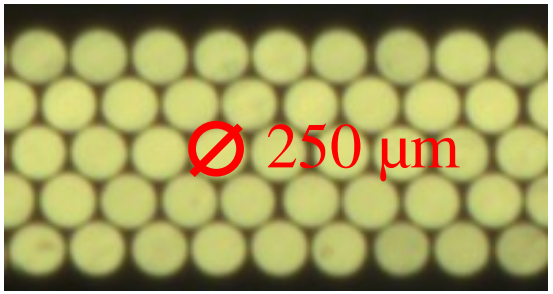




~20 photons/MIP

SiPM arrays

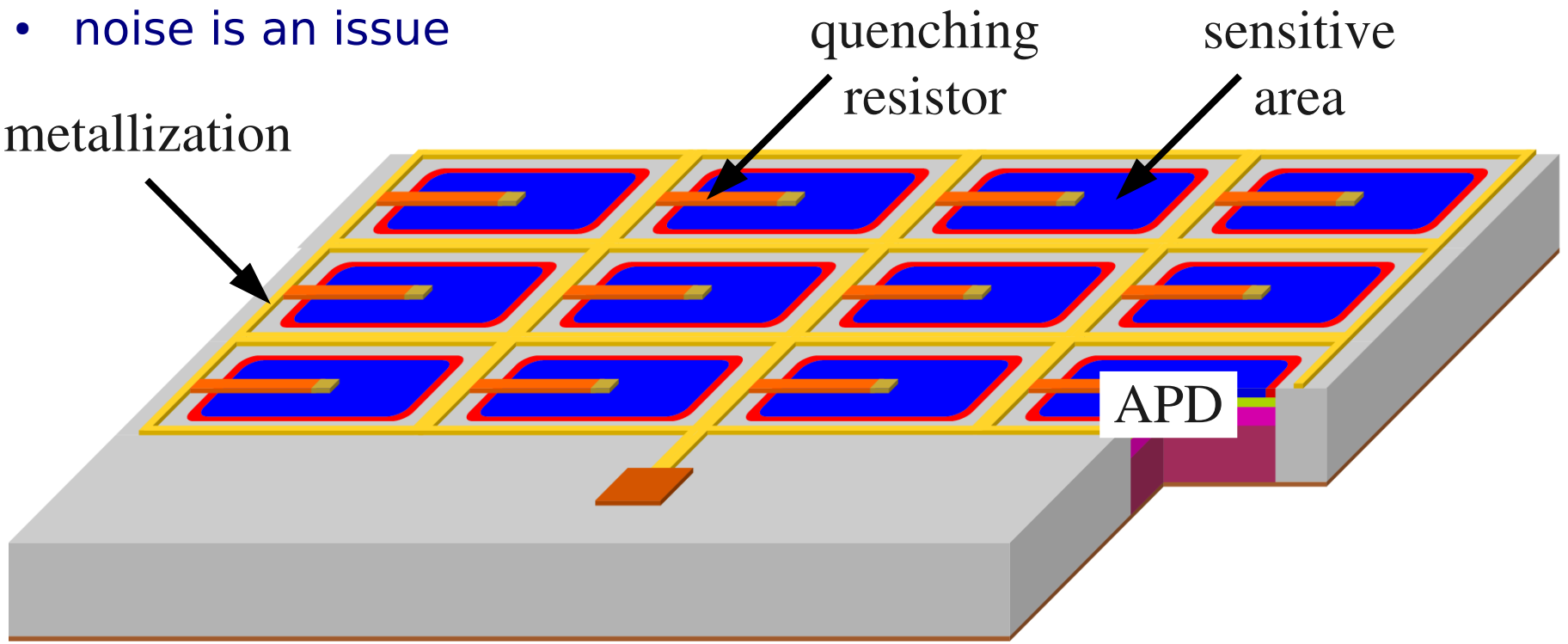




Silicon photomultipliers

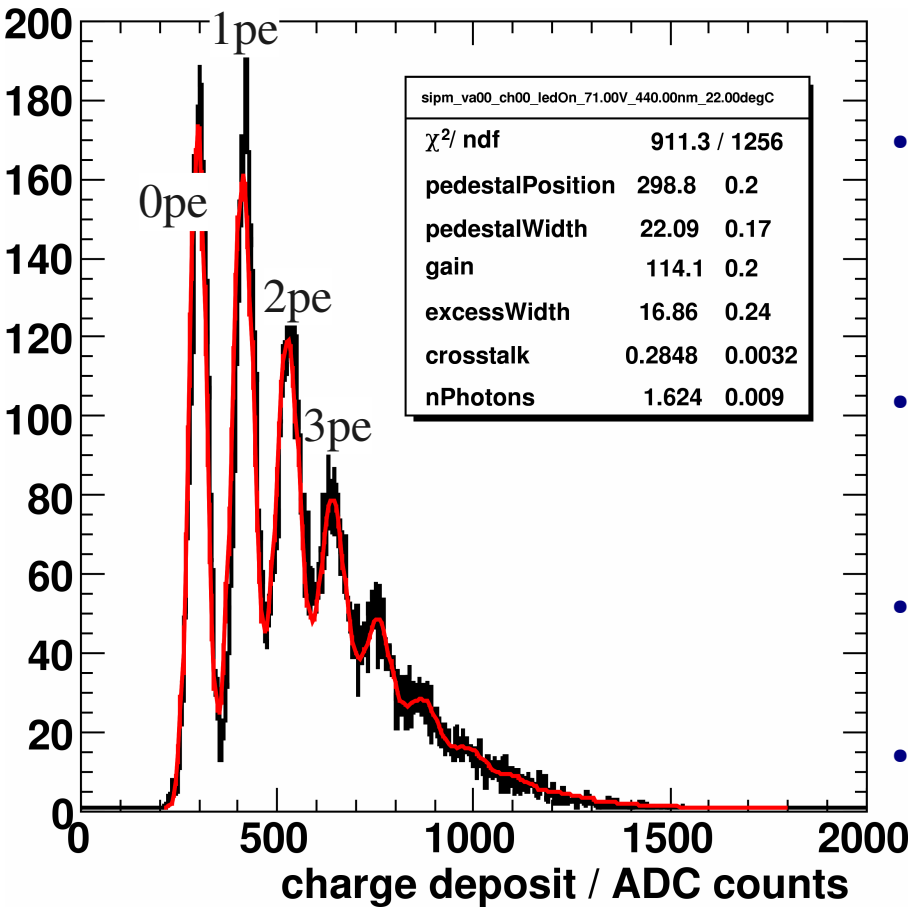
G-mode APD, MPPC

- avalanche photo diodes (APD) operated in Geiger-mode
- internal Gain ~10^6, compact, insensitive to magnetic fields, low bias voltage
- noise is an issue



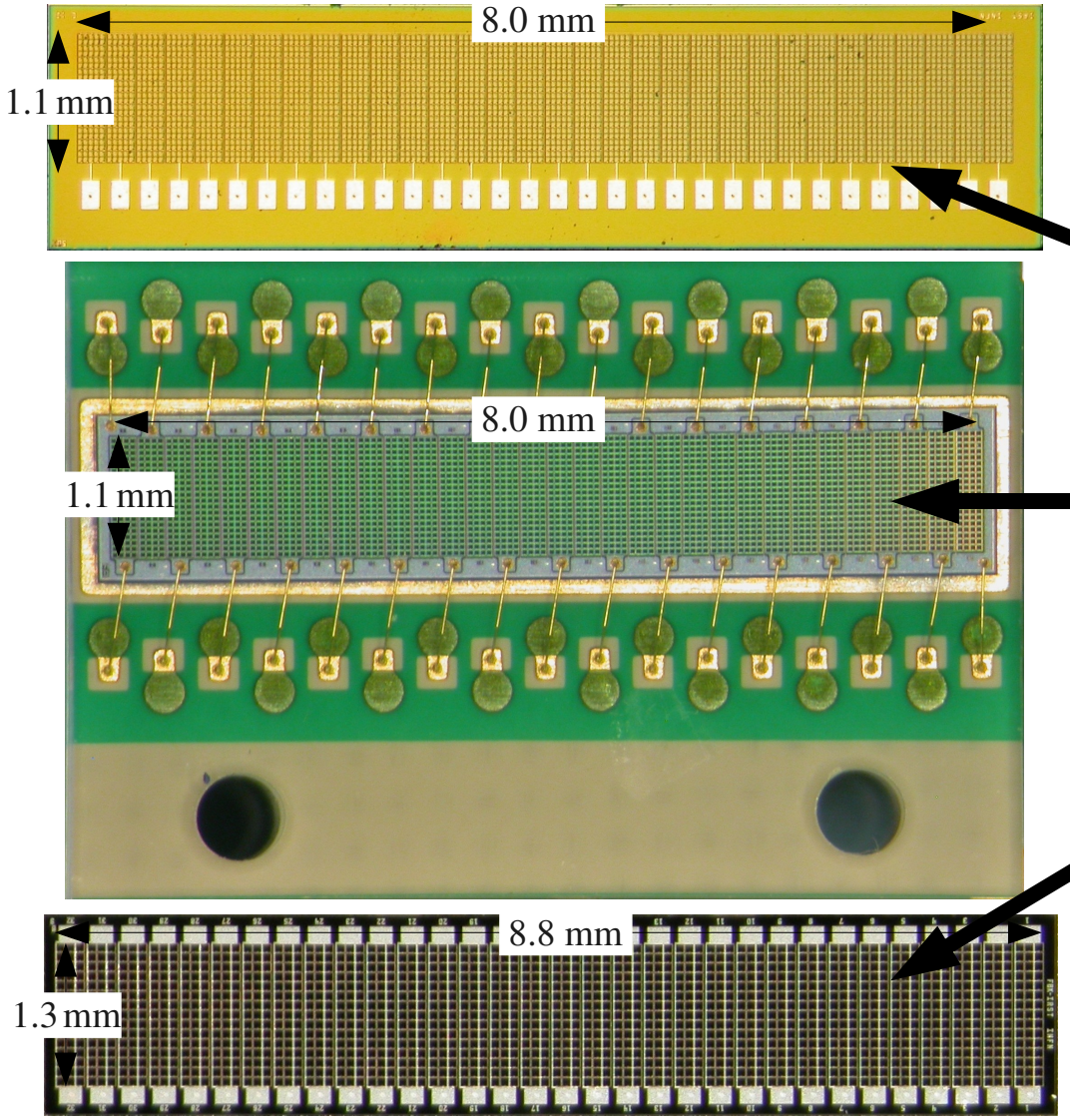
Silicon photomultipliers

autocalibration, photon detection efficiency



- photons hitting the surface lead to pixel breakdowns
- charge deposit is propotional to the number of pixels fired and thus to the number of photons (at low intensities)
- limited number of pixels lead to saturation effects at high intensities
- response modified by pixel crosstalk, excess noise, ...
- photon detection efficiency
  = fill factor
  x quantum efficiency
  x avalanche breakdown probability

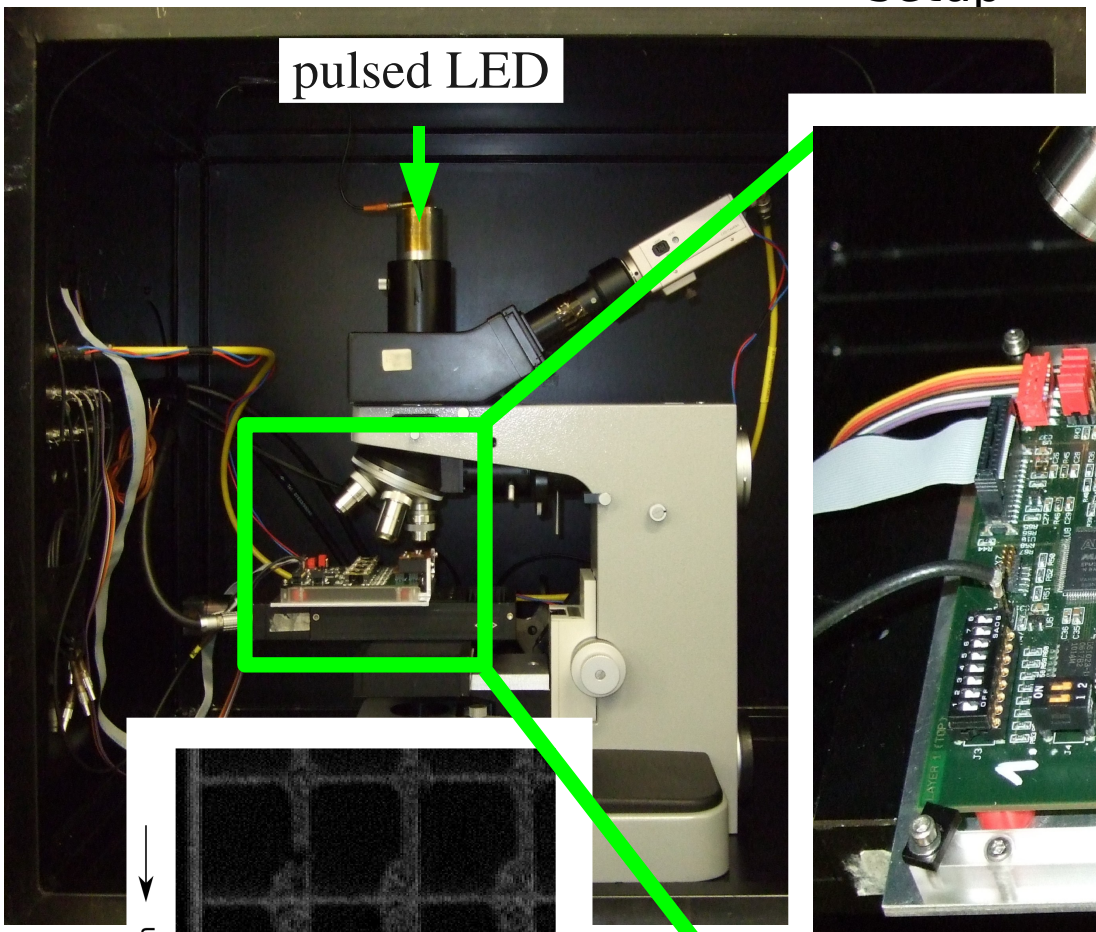
32 channel SiPM array models

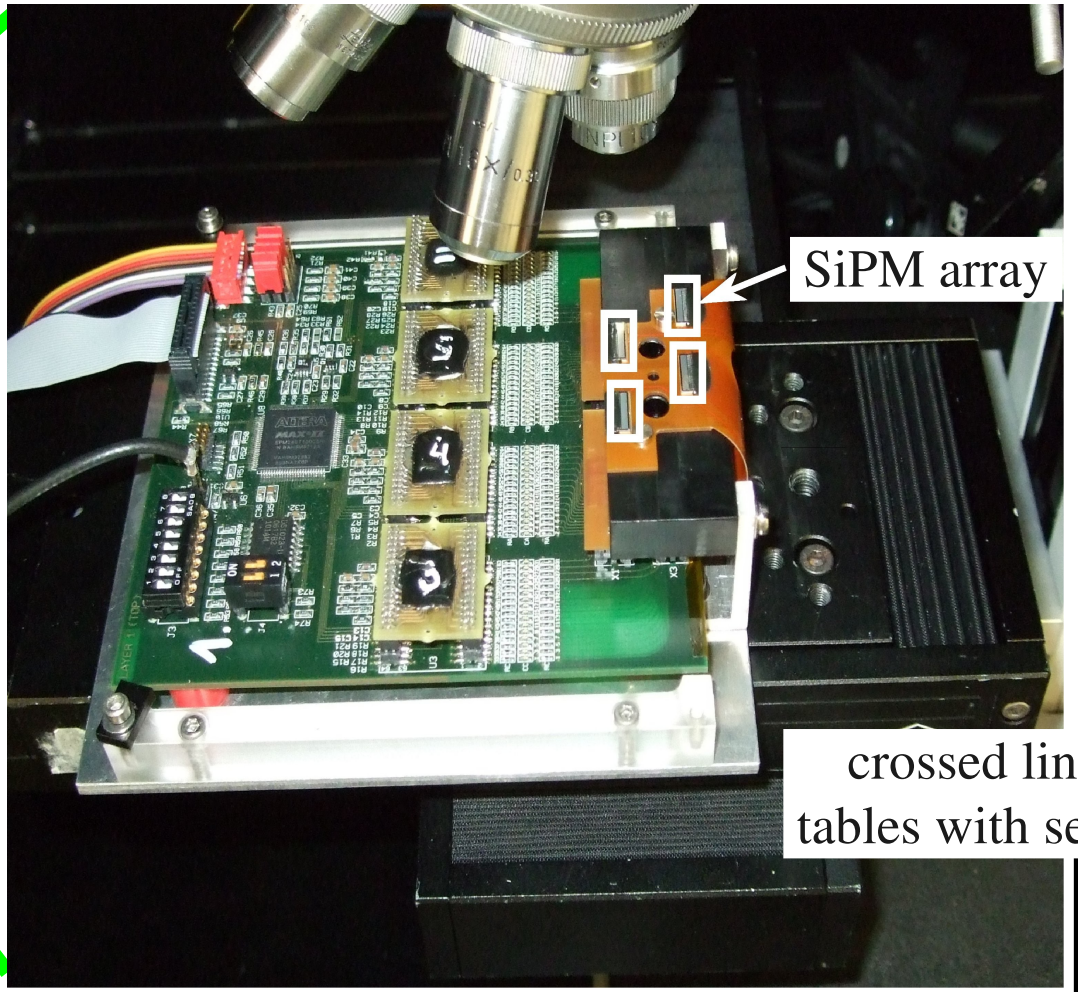


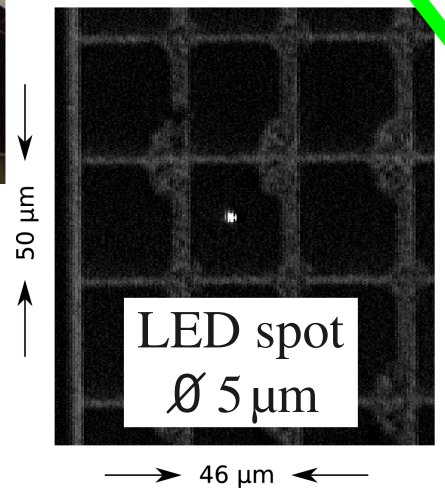
- FBK-irst 2007
  - 5x22 pixels, 46x50 µm²
  - 250 µm pitch
  - red-green sensitive
- Hamamatsu MPPC 5883
  - 4x20 pixels, 55x58 µm²
  - 250 µm pitch
  - blue sensitive
  - bonded, epoxy layer
- FBK-irst 2008
  - 3x15 pixels, 85x85 µm²
  - 275 µm pitch
  - red-green sensitive

Fill factor

setup

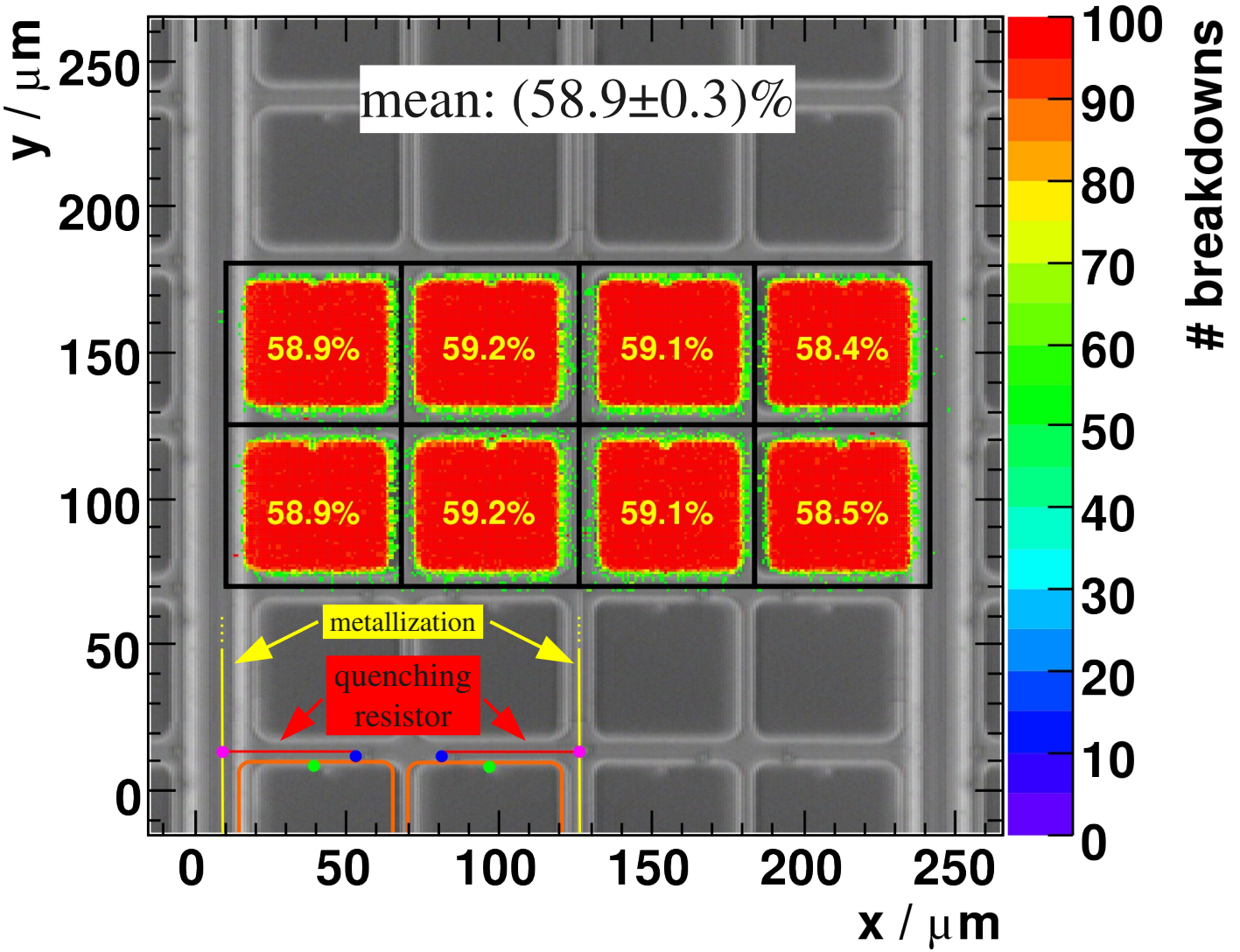






Fill factor

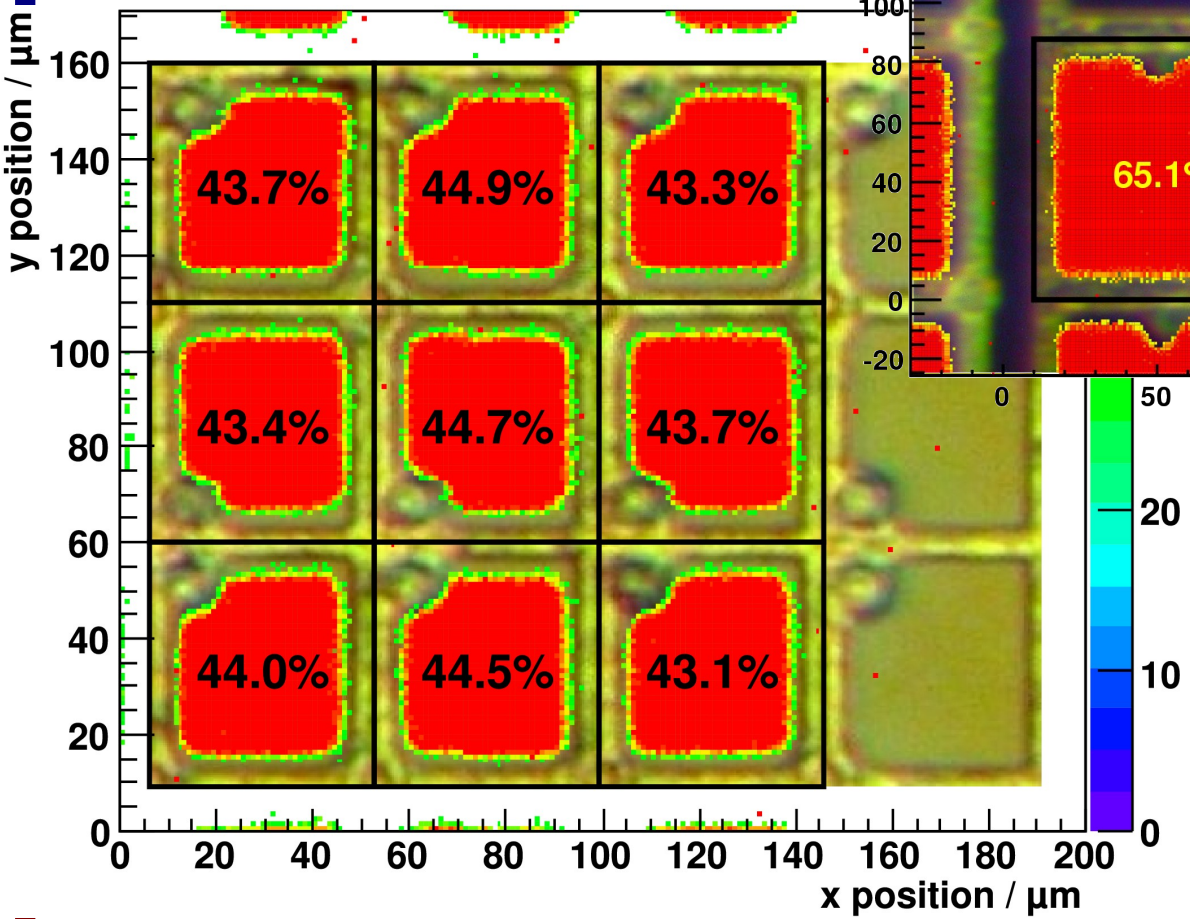
Hamamatsu MPPC 5883

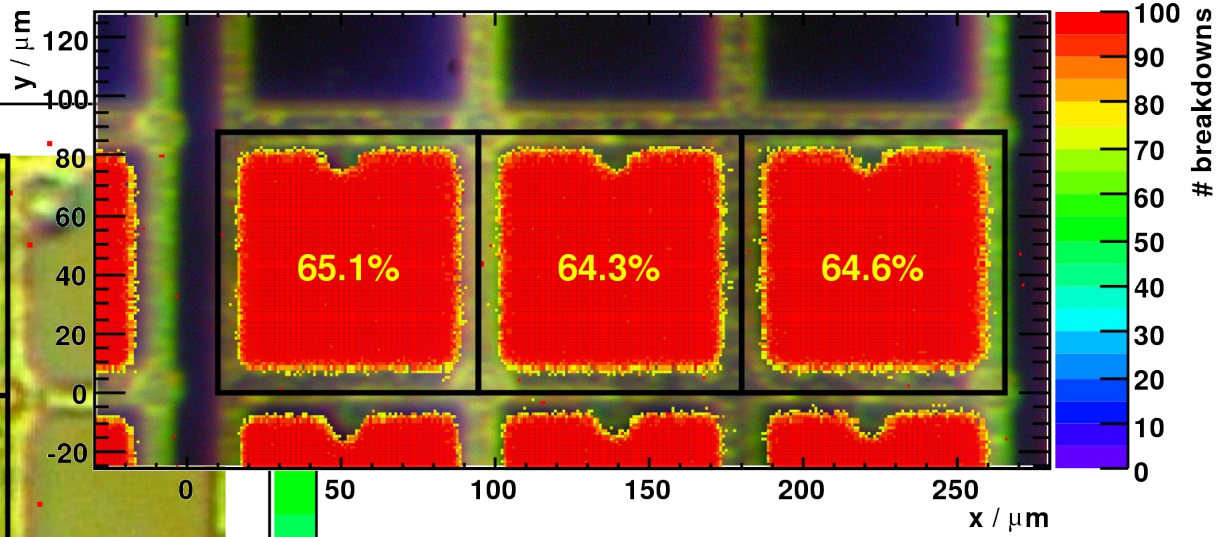


Fill factor

FBK-irst

FBK-irst 2007
(43.9±0.6)%

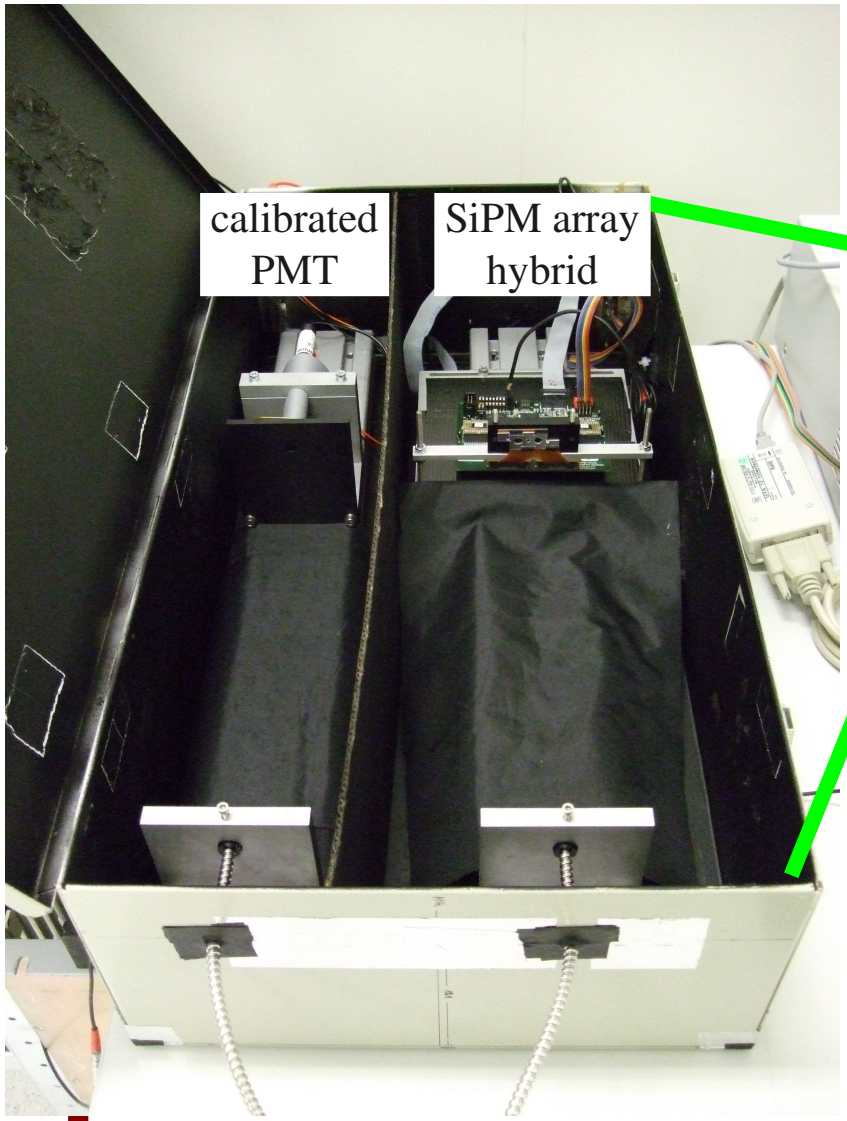


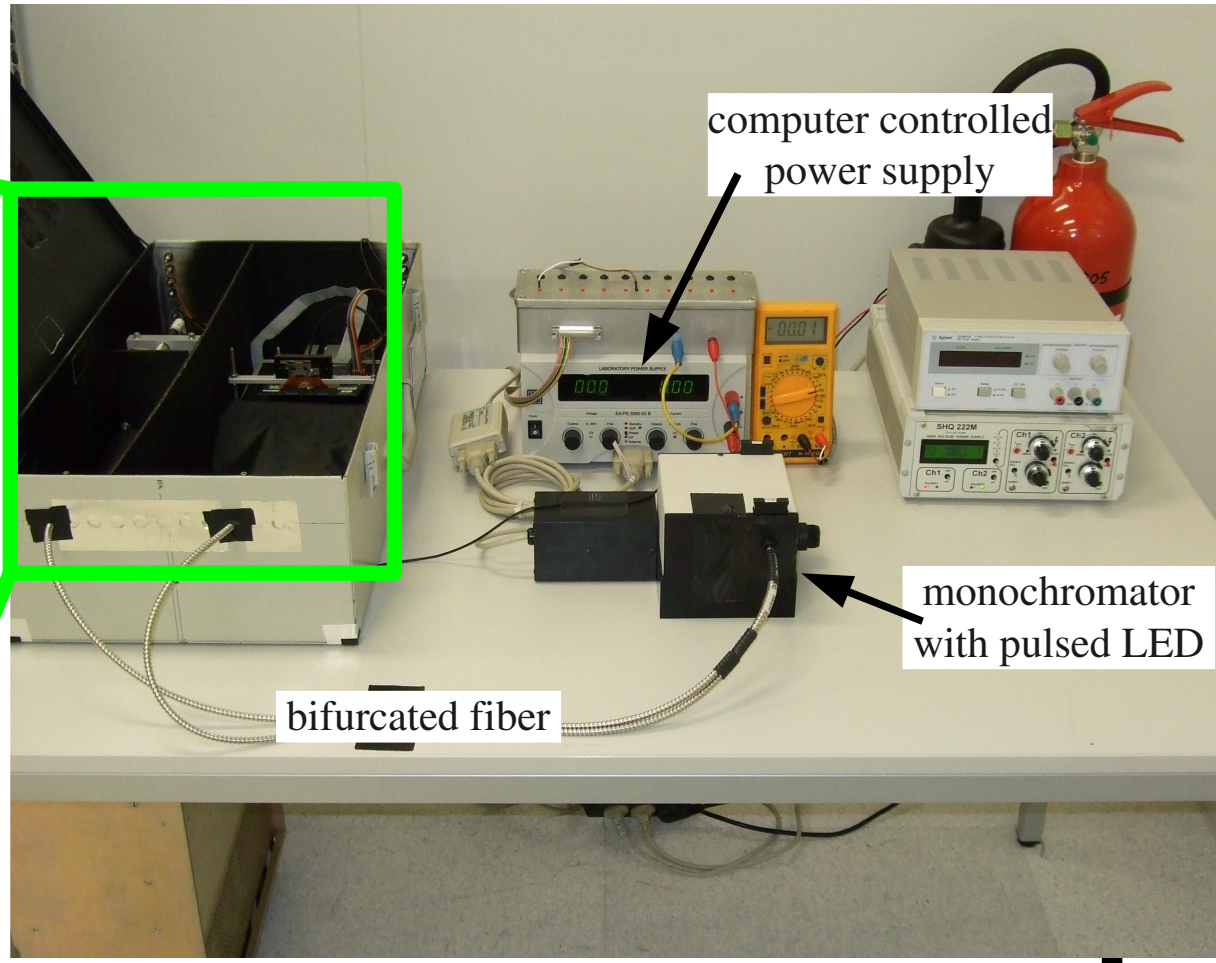


FKB-irst 2008
(64.6±0.4)%

Photon detection efficiency

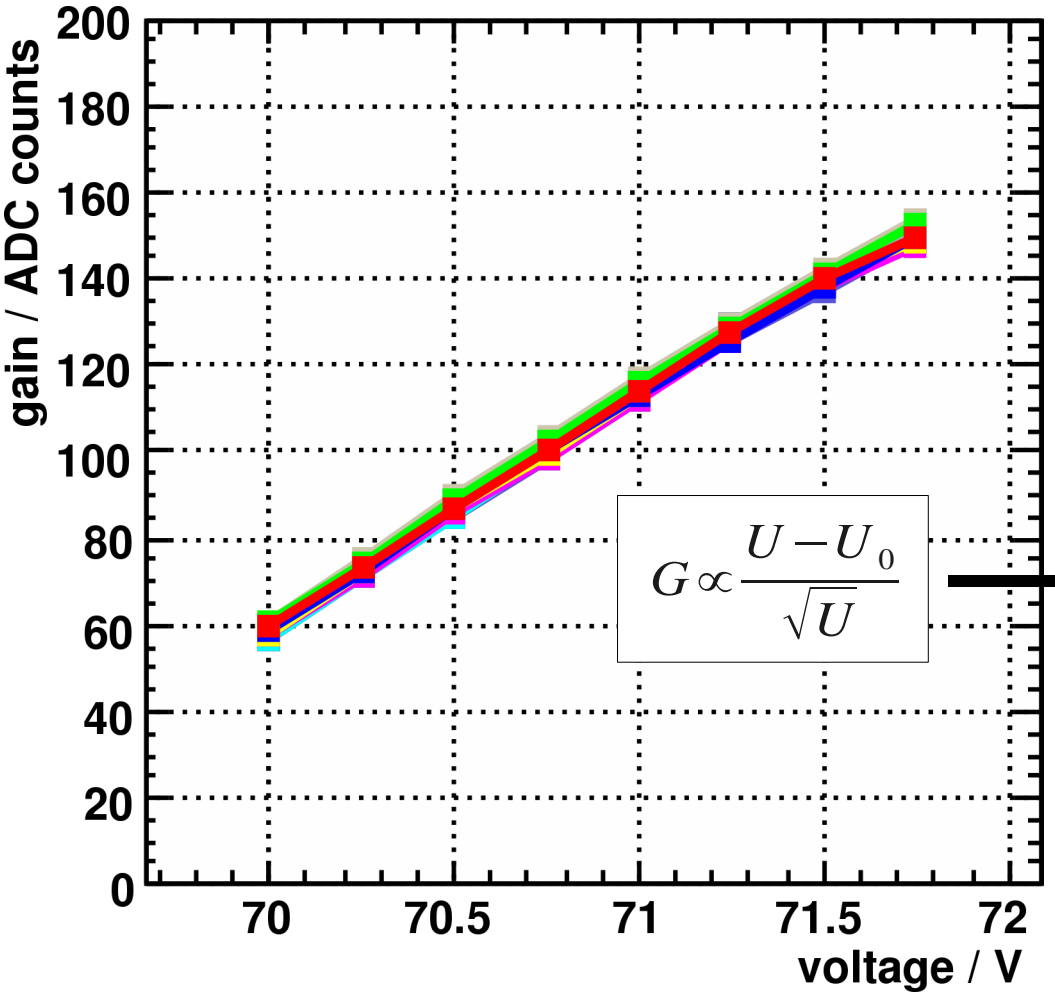
setup

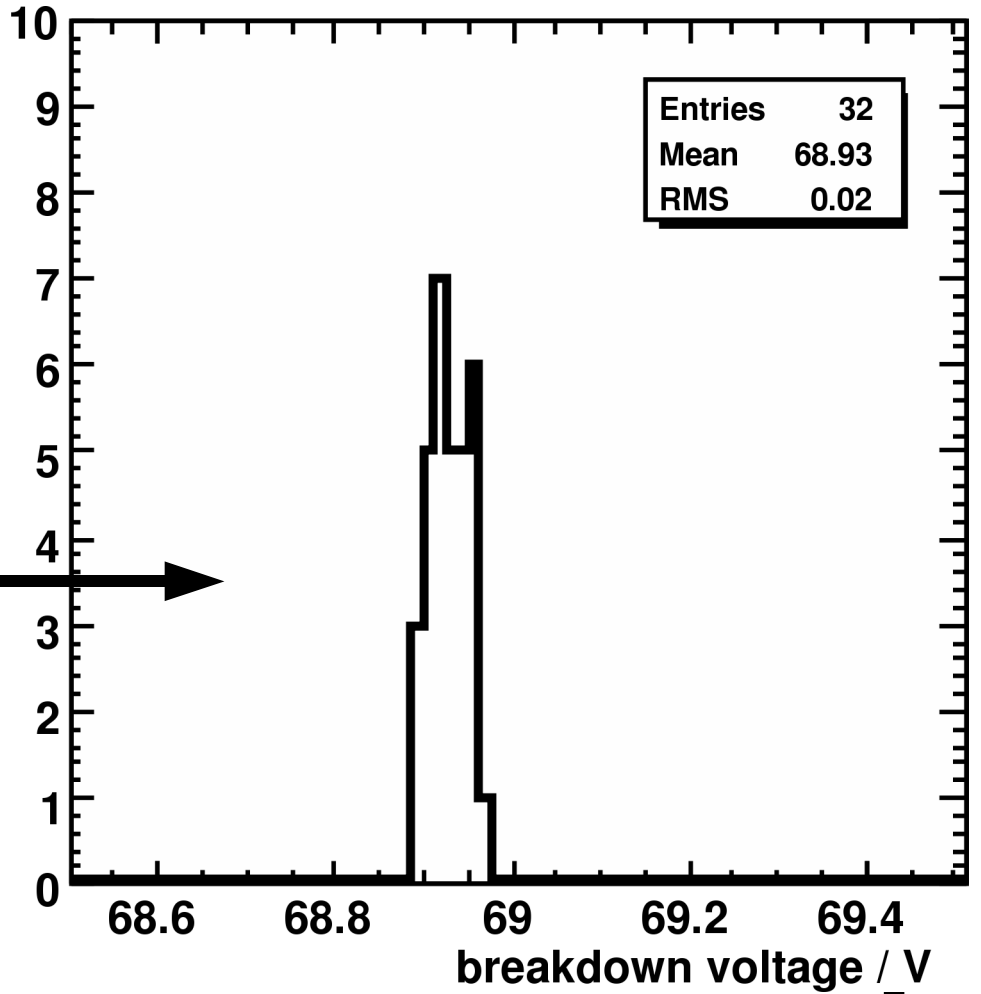




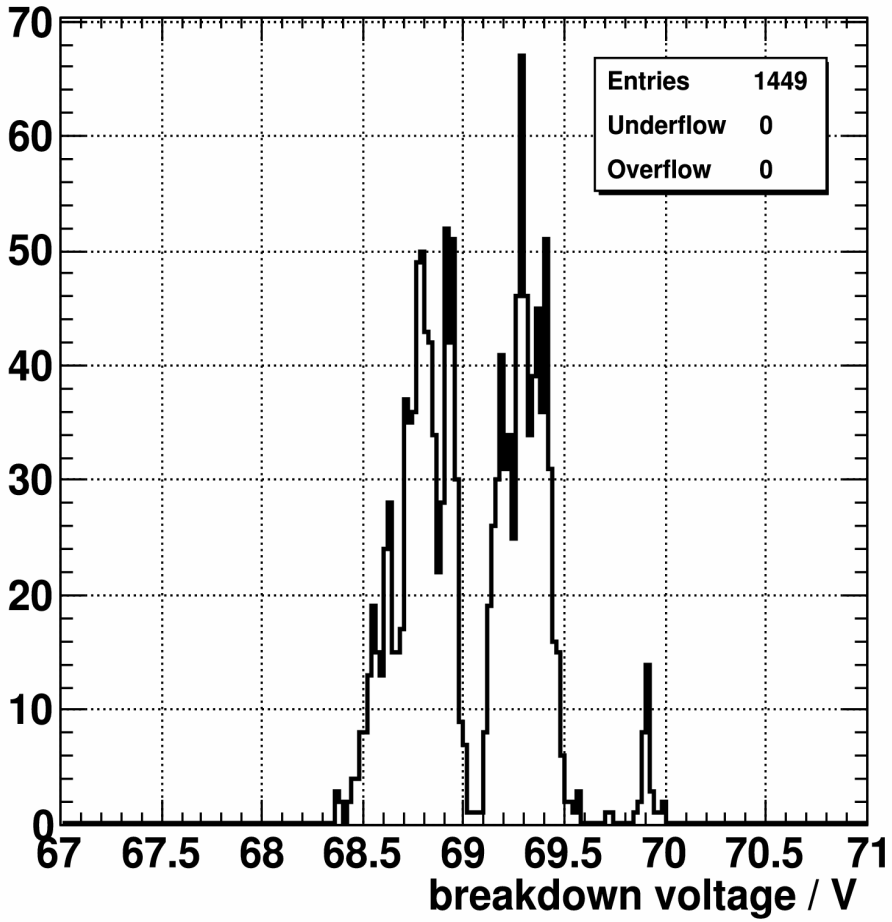
Breakdown voltage

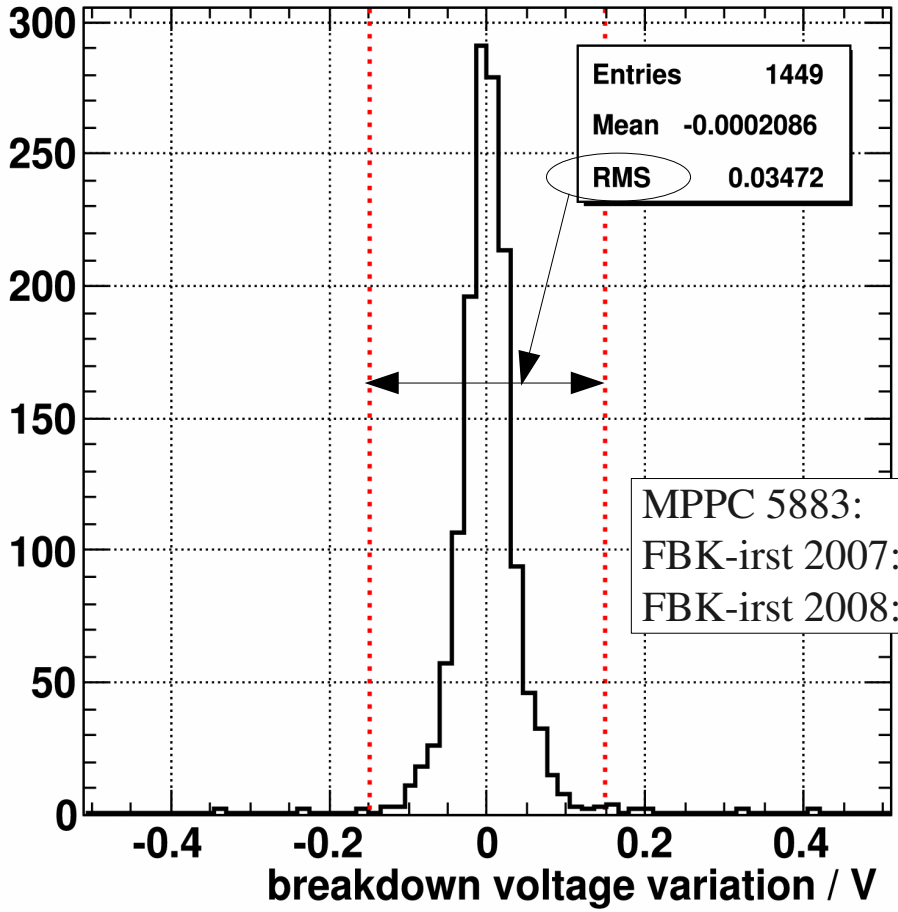
Hamamatsu MPPC 5883



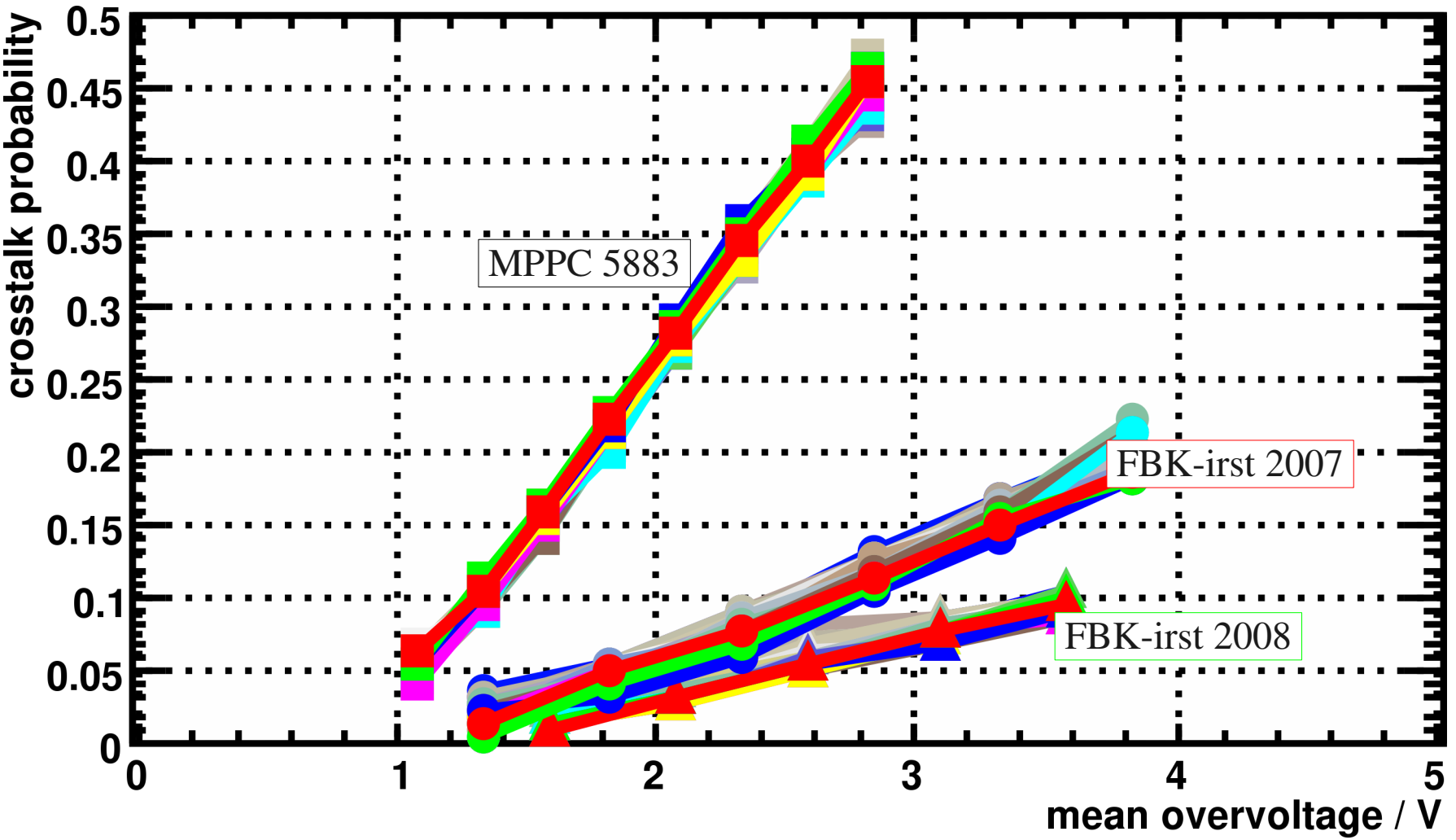


Breakdown voltages



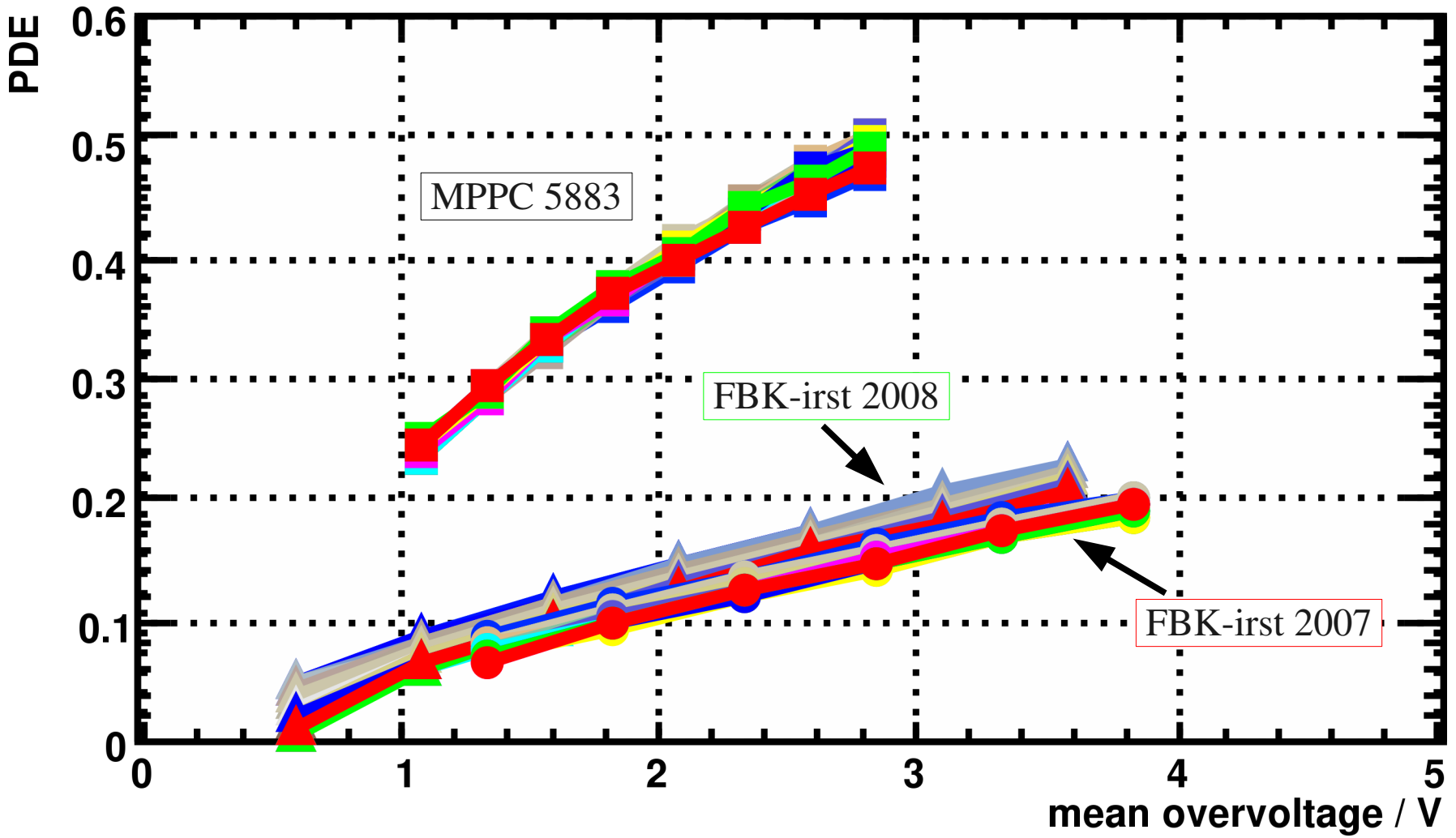


Pixel crosstalk



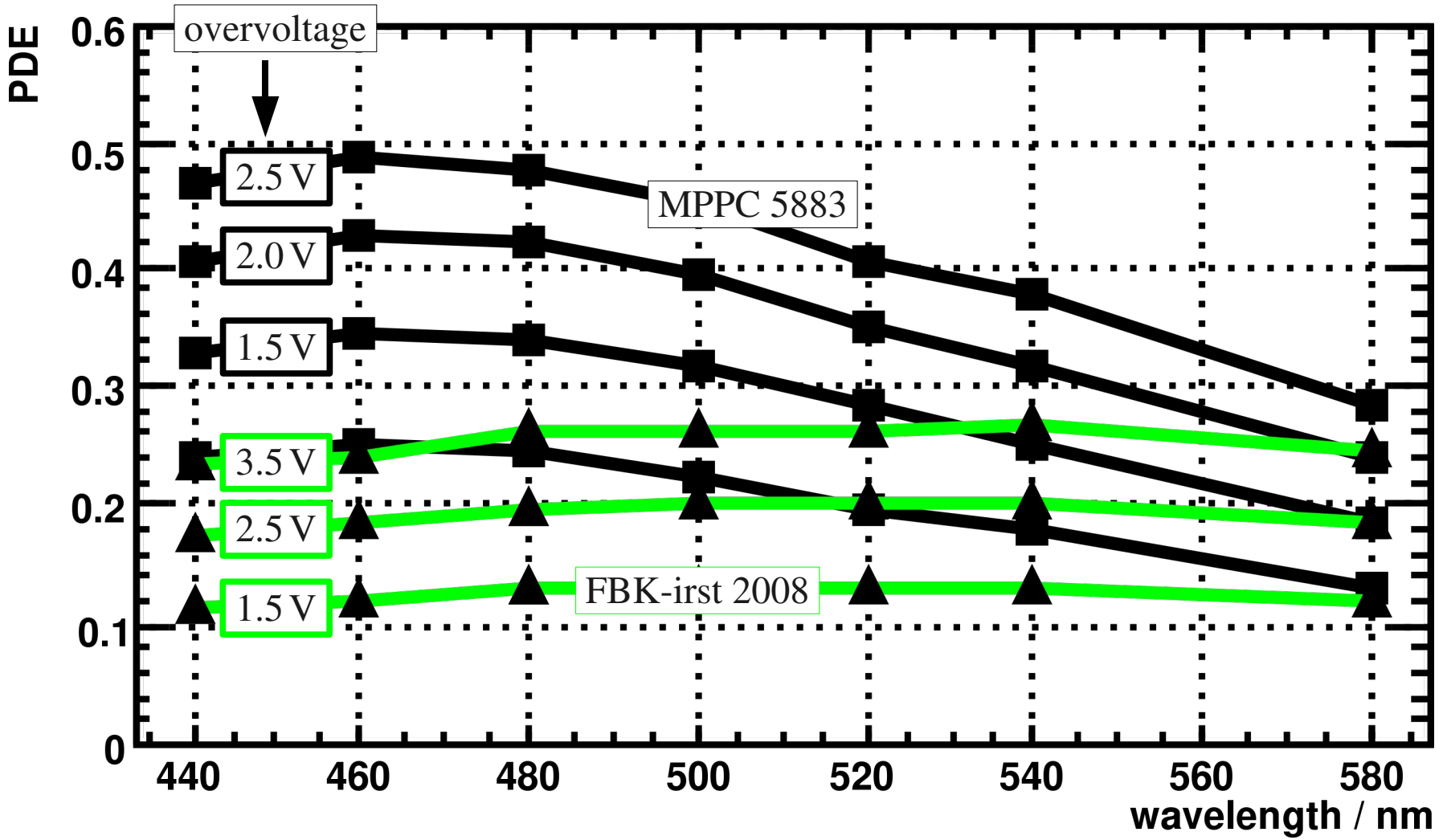
Photon detection efficiency

@ 440nm



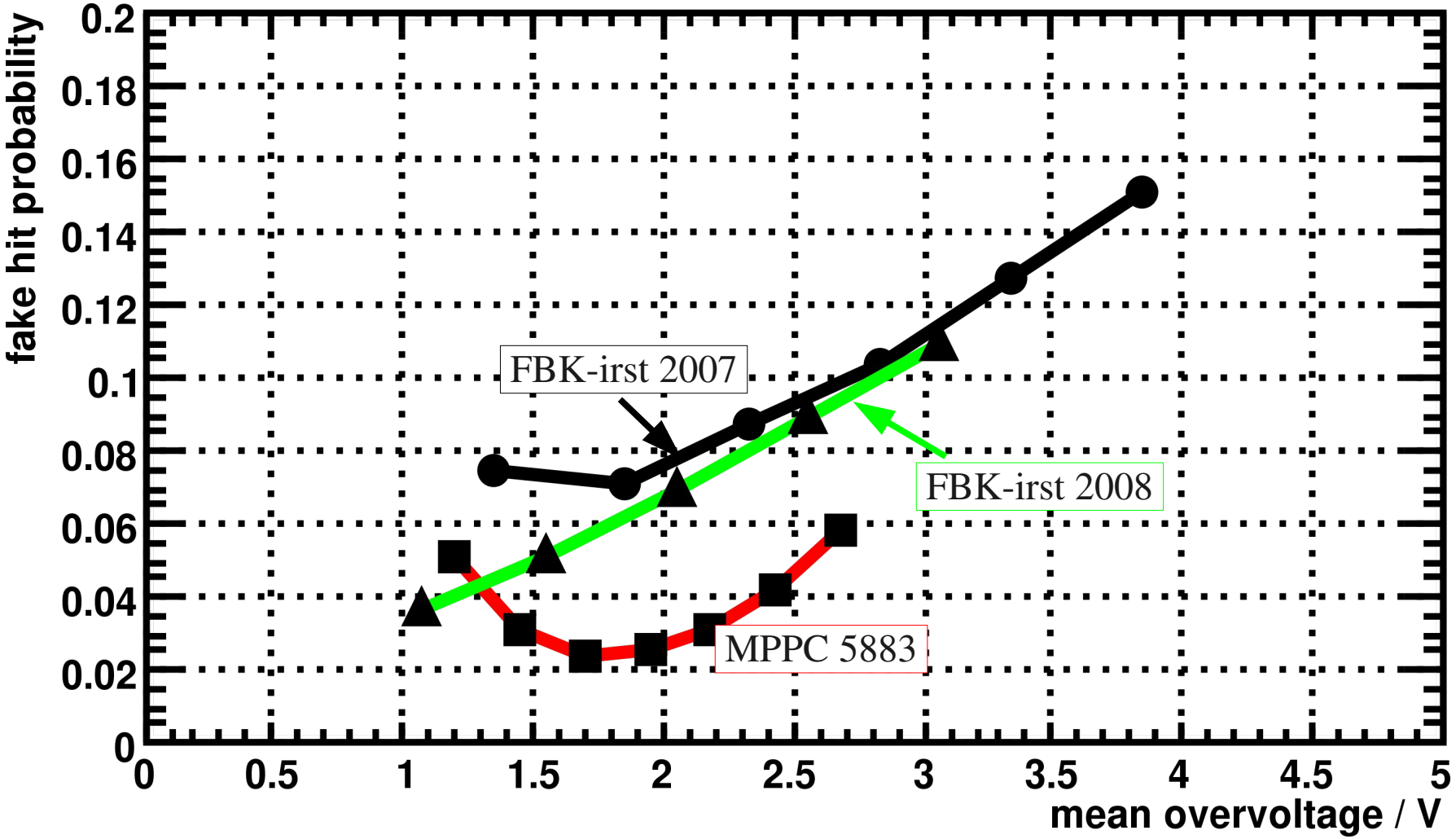
Photon detection efficiency

spectral response



Fake hit probability

@ 0.5 photoelectron cut



Summary

- three SiPM array models have been testet

	number of pixels	pixel size µm²	breakdown Voltage	PDE @ 440nm	crosstalk probability	fake hit probability
FKB-irst 2007	5x22	45x50	30 V	20%	20%	15%
FBK-irst 2008	3x15	85x85	35 V	25%	10%	10%
MPPC 5883	4x20	55x58	70 V	40%	30%	5%

- all models are homogeneous over 32 channels
- the Hamamatsu MPPC 5883 device is better for a high resolution scintillating fiber tracker, due to less noise and higher PDE

Fit method for LED spectra

V. Balagura et. al., NIM A 564 (2006)

- measured LED spectra R(x) are a convolution of B(x) and L(x)

$$R(x)=\int_{\mathbb{R}} dy\, B(y)\cdot L(x-y)$$

- convolution theorem $\tilde{R}(k)=\tilde{B}(k)\cdot\tilde{L}(k)$
- gaussian pedestal B(x)
- poissionian based signal function L(x)

$$\tilde{L}(k)=\exp(-\mu)\sum_0^\infty \frac{\mu^n}{n!}\tilde{P}(k)^n=\exp(\mu(\tilde{P}(k)-1))$$

- charge deposit P(x) including crosstalk

$$\tilde{P}(k)=\frac{\tilde{Q}(k)+\epsilon\,\tilde{Q}(k)^2+\epsilon^2\tilde{Q}(k)^3+\ldots}{1+\epsilon+\epsilon^2+\ldots}=\tilde{Q}(k)\frac{1-\epsilon}{1-\epsilon\cdot\tilde{Q}(k)}$$

- gaussian singel pixel response Q(x)