MAPMT

hints and tips

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SST meeting. Liverpool 7-8 September

REQUIREMENTS LIST

GAIN : The intrinsic gain of the photo-detector must be much larger than the readout noise. The Gain must be at least 10^4.

Q.E. : Quantum Efficiency and Collection Efficiency must be as high as possible. Quantum efficiency is the single most important parameter of the signal detection in any application. 25% is the practical number based on conventional bi-alkali photo cathode.

Noise Factor : Noise Factor (*NF*) must be as close as possible to unity to clearly observe single photoelectron peaks, it must be smaller than 1.3.

Entrance Window: The photo-detector window must be transparent to the light from wavelength of 300 *nm up to 650 nm.*

Dark current : The intrinsic dark pulse rate should be much less (2 order of magnitude less) than the diffuse NSB noise rate.

Photo-cathode Uniformity : Pixel to pixel uniformity of photo-cathode and photoelectron collection efficiency must be reasonably good; fluctuation less than 10% is desirable (20% is still tolerable).

Anode Uniformity : Anode uniformity (i.e. Gain uniformity) on the other hand is less important, since the detector can count the number of photoelectrons, providing the single photoelectron level is calibrated pixel by pixel. Less than 20% non-uniformity is desirable.

Filling Factor : A filling factor (or sensor active area) approaching to 100% avoids using light guides.

Cross talk : Cross talk between pixels should be reasonably small. Less than 2% is desirable.

After pulses : After-pulses should not contribute to the signal level. Less than 1% is desirable.

Linearity : Linear response has to be in agreement with the experiment requirement.

Long Term Stability : Long-term stability for 10 or more years operation is required. Attempt to limiting, in case of PMTs, the anode current is mandatory to avoid ageing with consequent loss of detection performances.

DETECTORS

HAMAMATSU

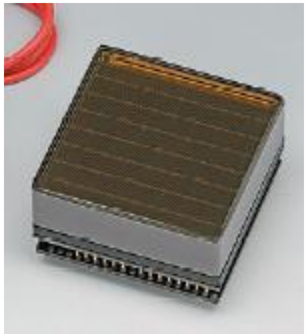
FEATURES

- 8 x 8 multianode
- Metal channel dynode
- High speed response
- Low cross-talk
- Low weight

25.7 mm x 2 5.7 mm x 27.1 mm

R7600-03-M64

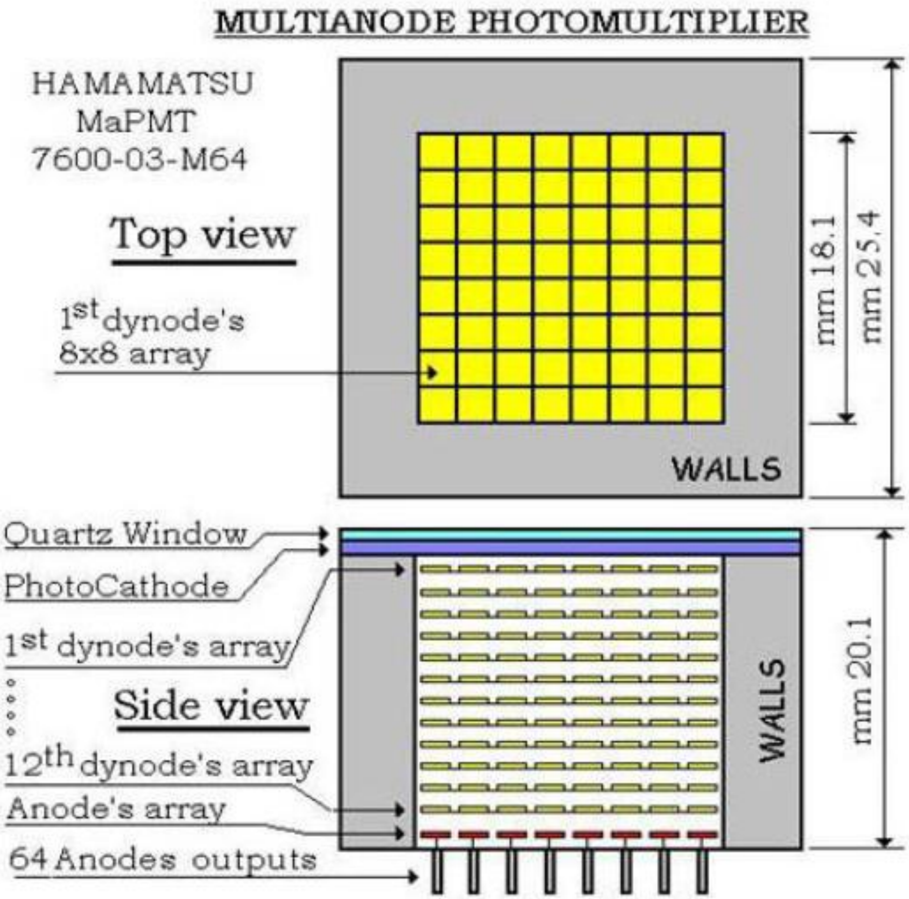
52 mm x 52 mm x 27.4 mm

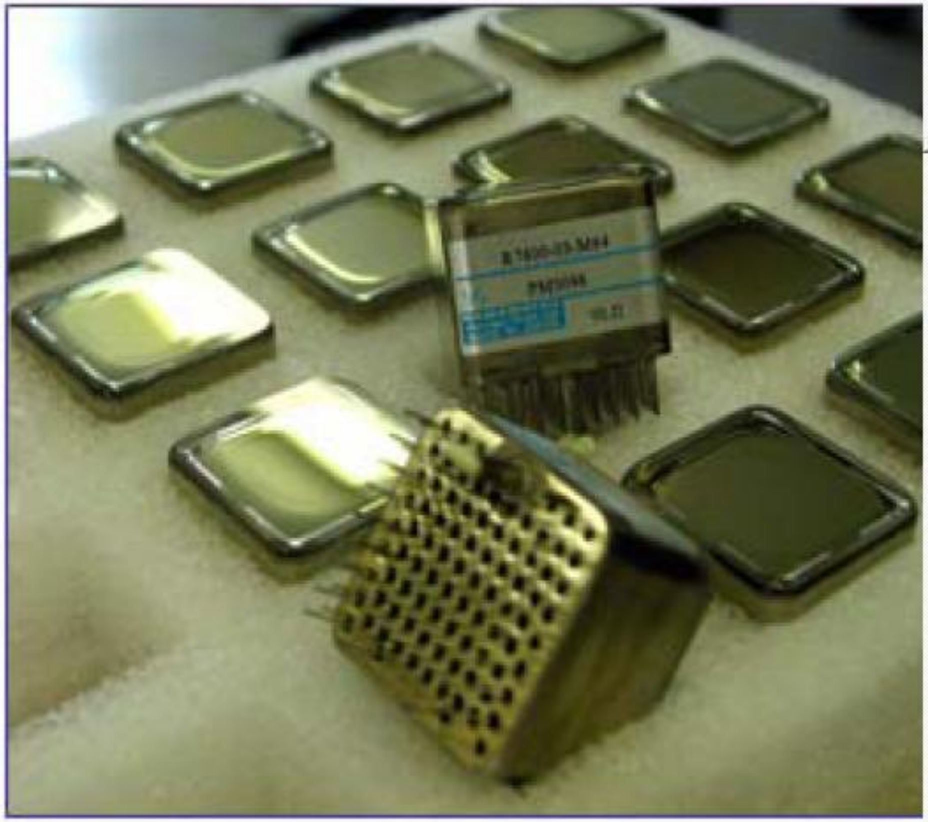


H8500 (12 Dy)
H10966 (8 Dy)

CHARACTERISTICS	*R7600-03-M64*	*H8500*
Spectral Response	300 to 650 nm	300 to 650 nm
Anode size	2 x 2 mm^2	5.8 x 5.8 mm^2
Effective area	18.1 x 18.1 mm^2 (~50%)	49 x 49 mm^2 (~90%)
Quantum efficiency (420 nm)	20%	24%
Gain at 800V	$3.0x10^5$	$3.0x10^5$
Anode Dark Current per channel	0.2 nA	0.6 nA
Time Response per channel	1.5 ns (Rise Time)	0.8 ns (Rise Time)
Cross-talk	2%	3%
Uniformity among all anodes	1:3	1:3

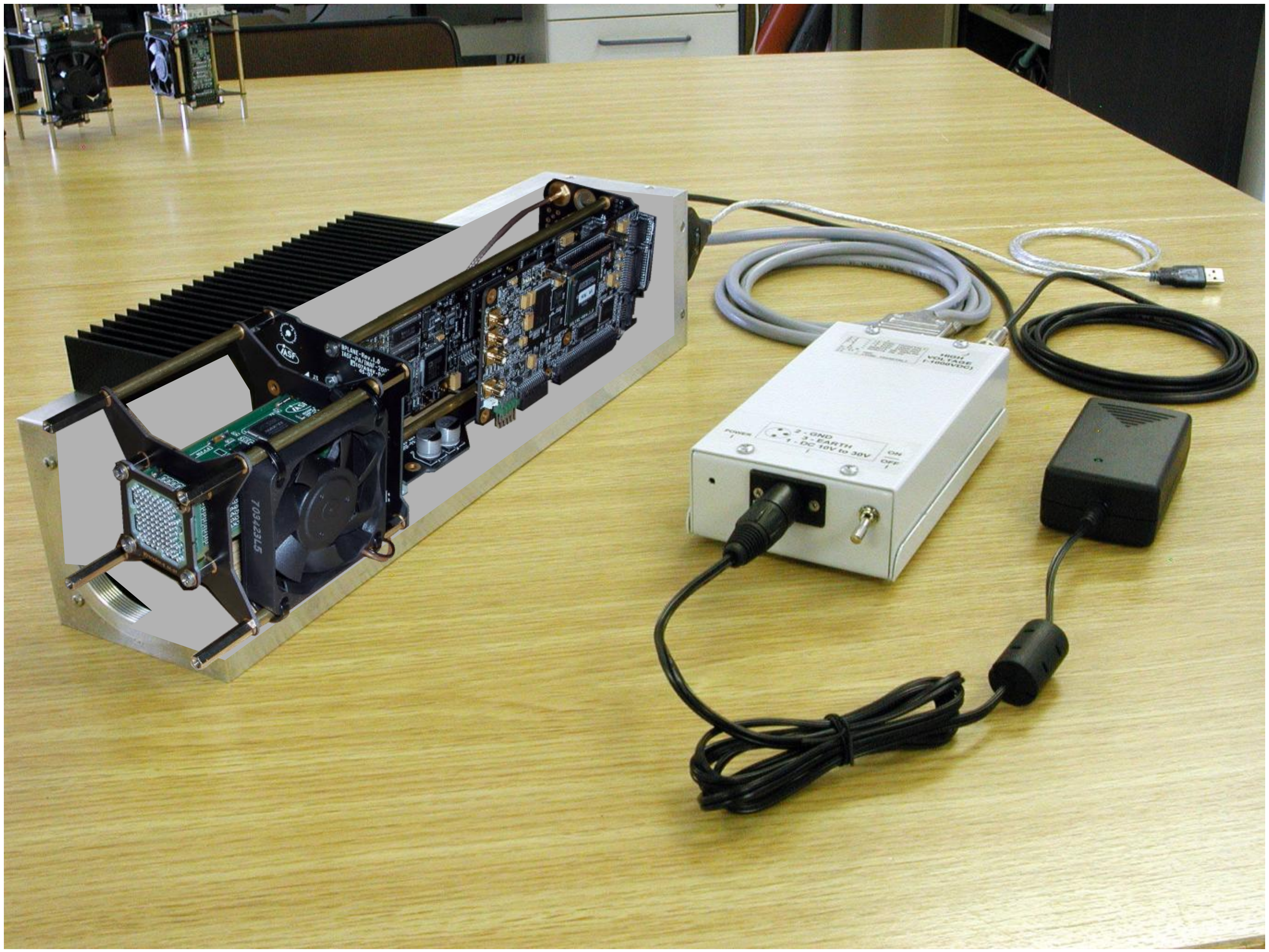
Hamamatsu: MAPMT R7600-03-M64



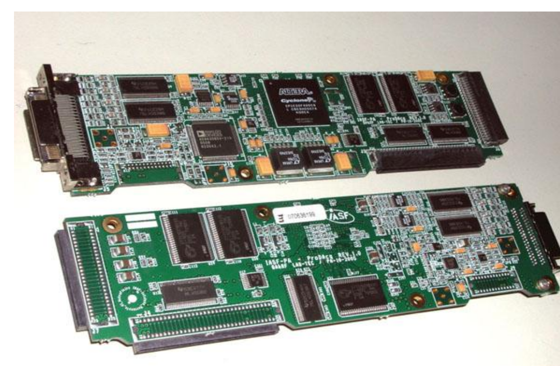


FRONT-END AND DAQ ELECTRONICS

64 Single Photon Counting channels in a compact instrument

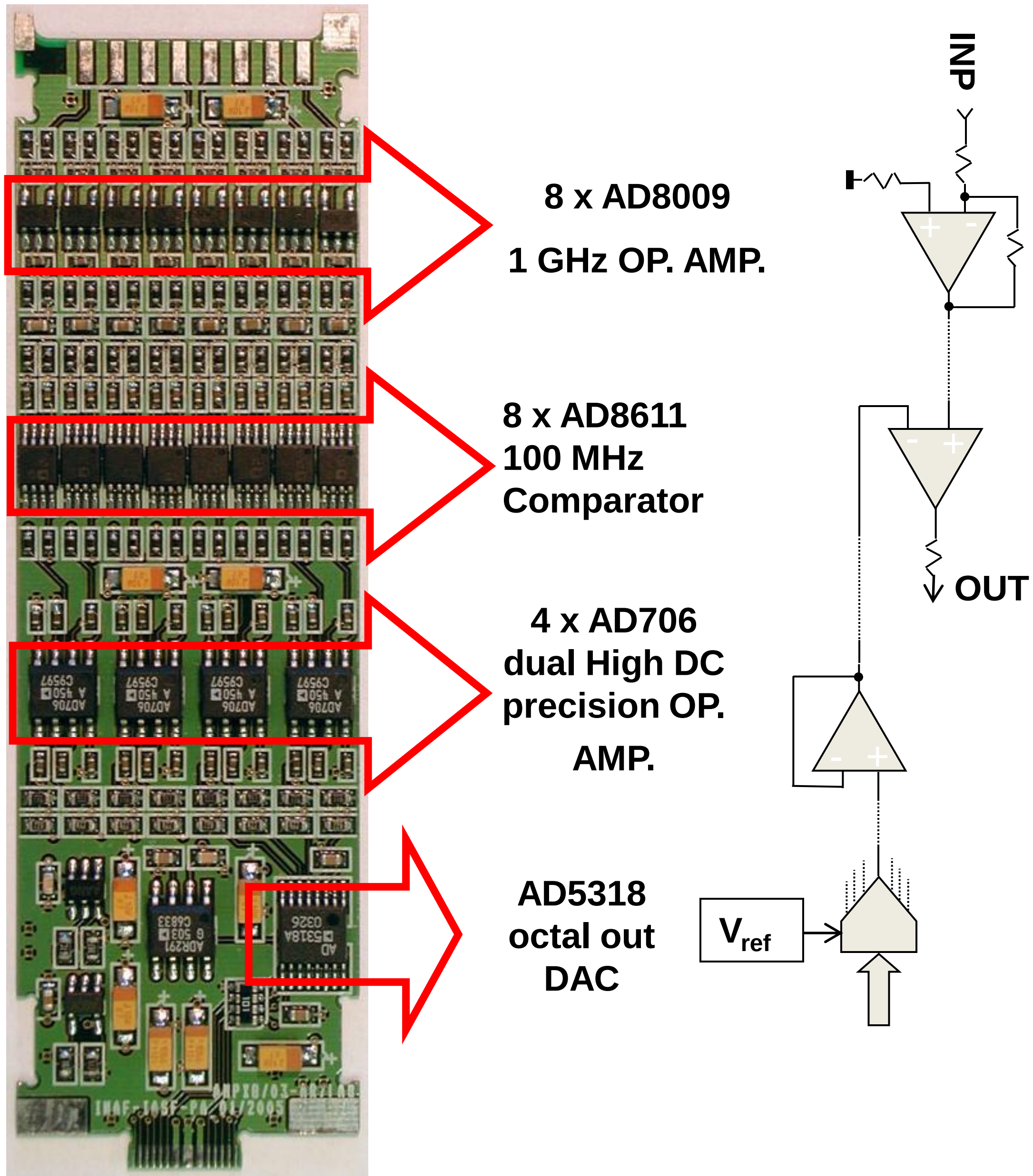


FRONT-END



DAQ

F/E electronics



Features:

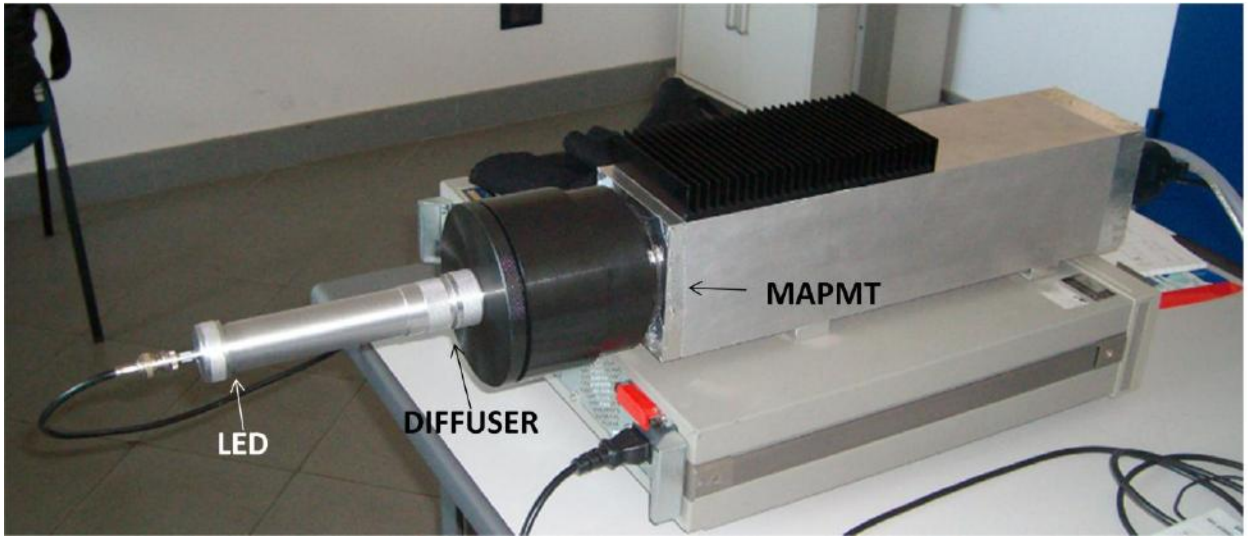
Single Photon Detection.
an amplifier and a discriminator for each channel (anode).

Programmable discriminator threshold.
A signal amplifier and a programmable threshold discriminator are provided for each of the 64 channels. Each discriminator threshold adjusted individually through DACs.

Low power active high voltage divider.
Two separate high voltage lines are provided to supply the PMT: one line supplies directly the last dynode and the other one supplies the other dynodes through a low power active divider.

Charge integration channel
A fast charge integrator, one for the last dynode of each PMT.

Digital reading temperature sensor.



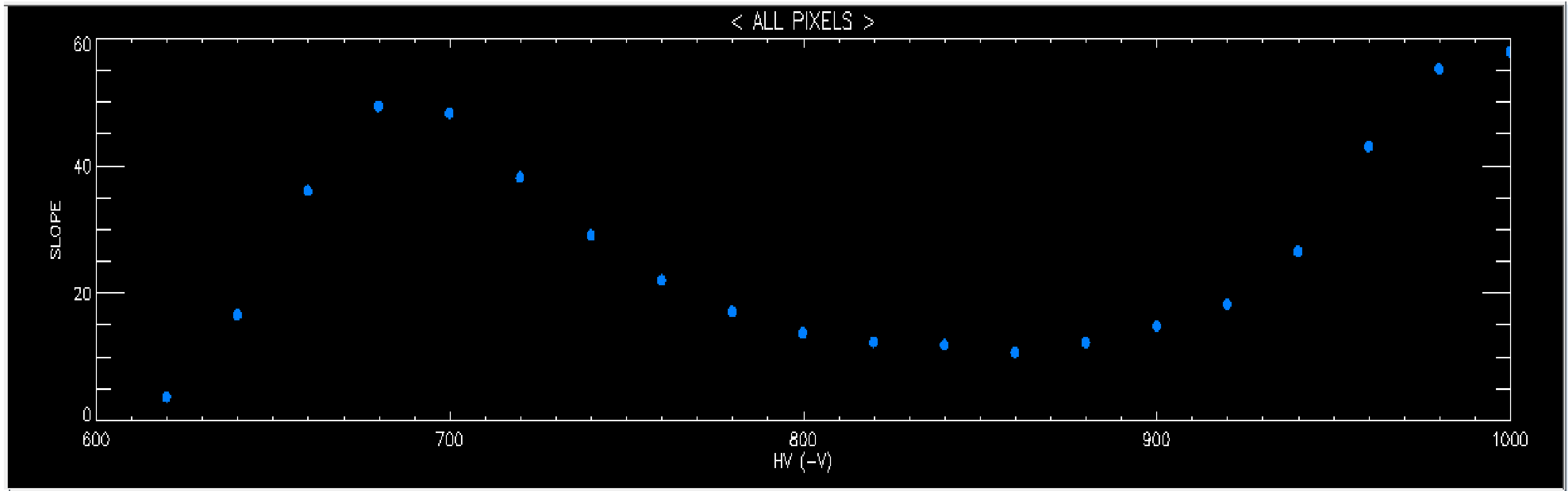
The unit used in the Lab. for the relative and absolute MAPMT calibration

From April 2009 this telescope operates continuously taking data to measure the UV diffuse BKG (Los Leones - AUGER).

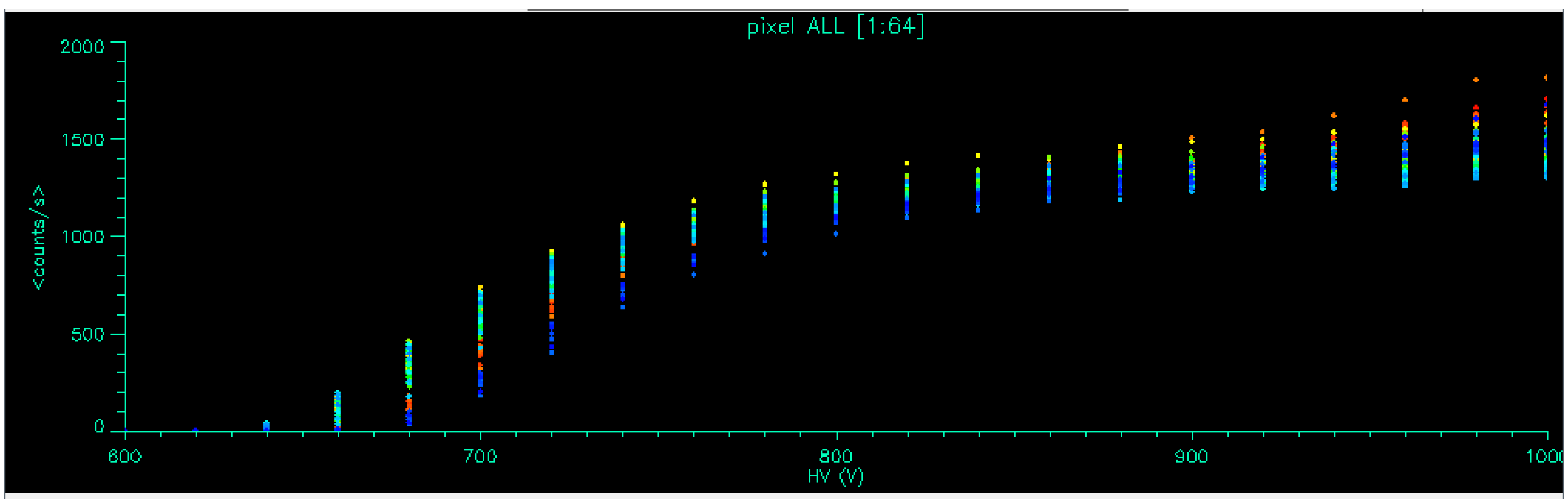
MEASUREMENTS

- Optimum Working Point determination (HV & Threshold)
- Dark current
- SER (Single electron response)
- Anode Uniformity
- After Pulses
- Cross-Talk
- Angular response
- Absolute calibration → Detection eff. (λ)

Optimum Working Point determination

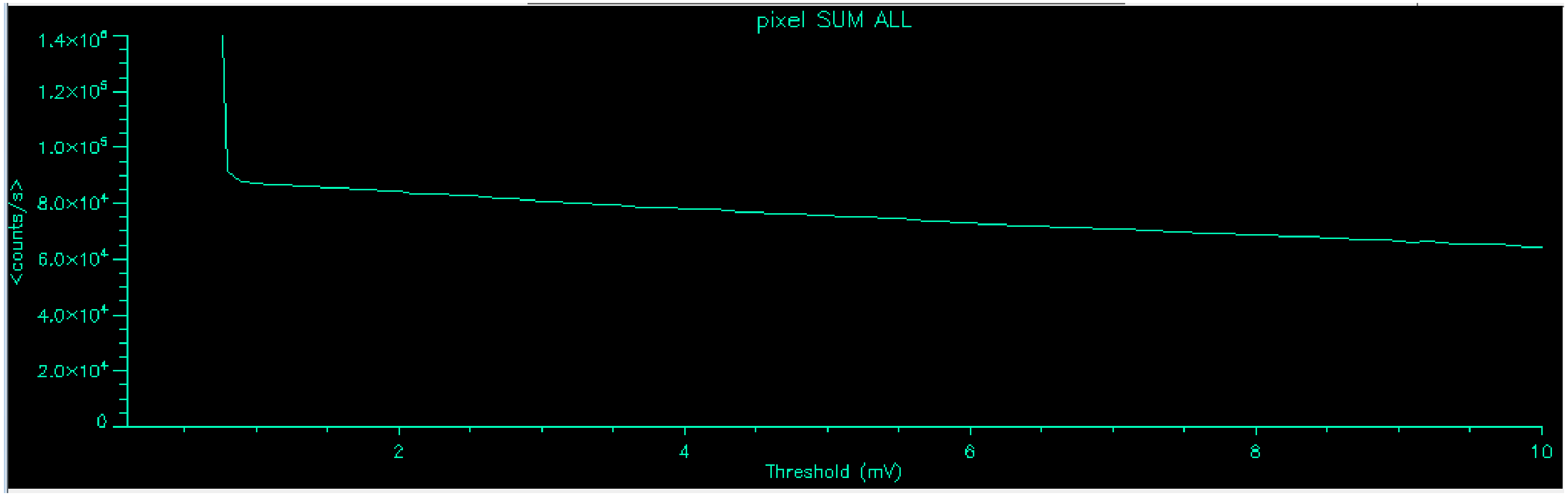


HV PLATEAU

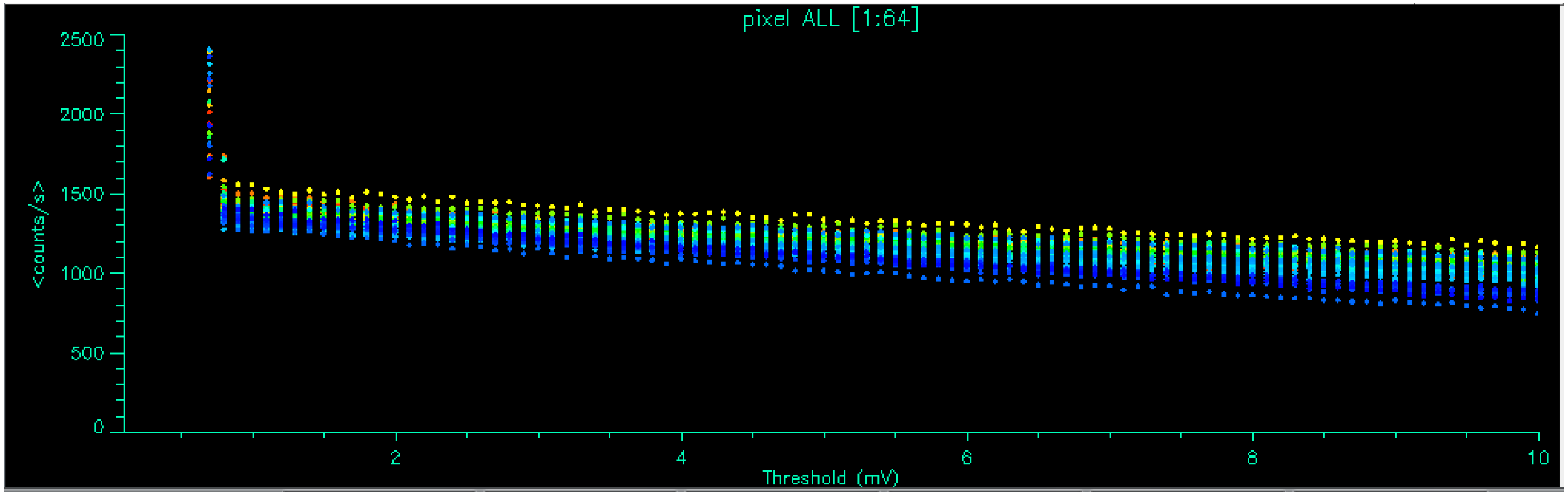


The plateau has been obtained varying the voltage supply from -600 V to -1000 V and setting the threshold at 2 mV.

Optimum Working Point determination

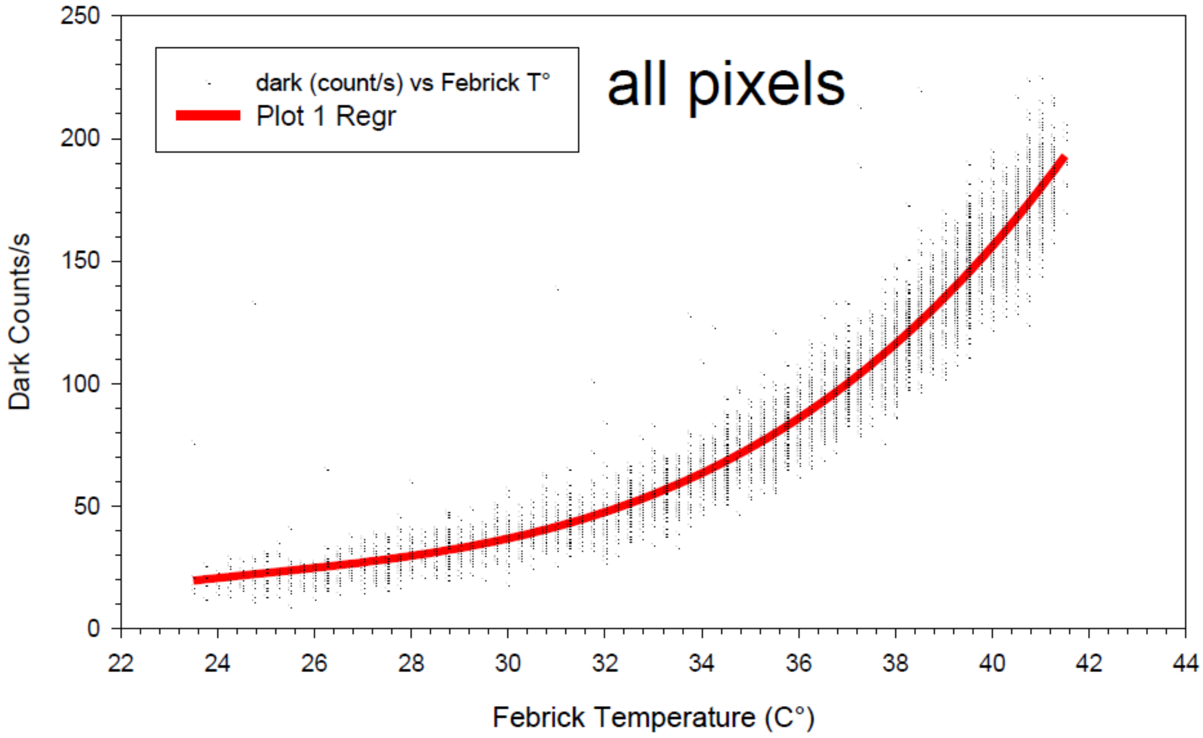


Threshold PLATEAU



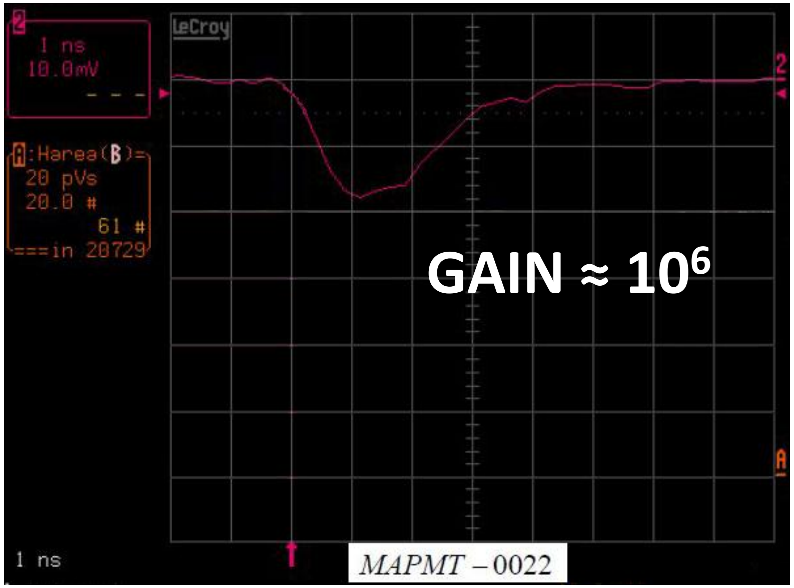
The plateau has been obtained varying the threshold from .1 mV to 10mV and setting the HV to -840 V.

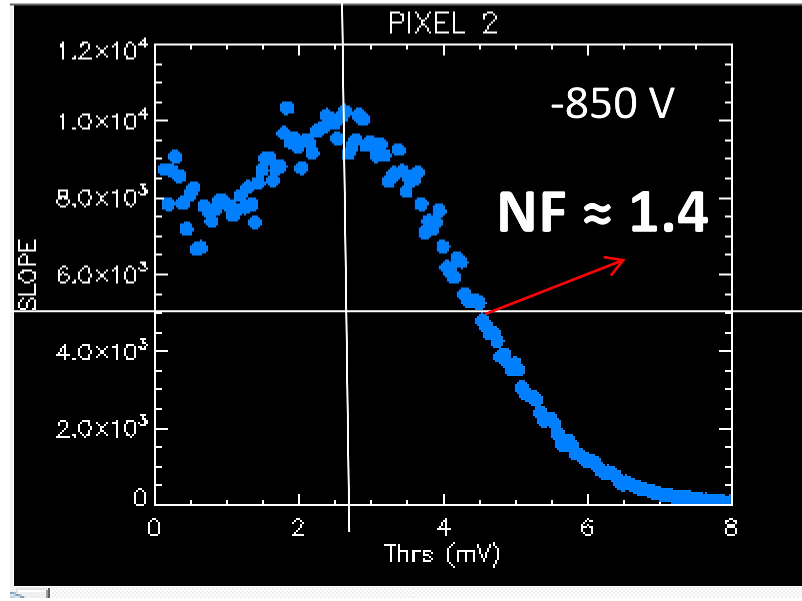
Dark Counts

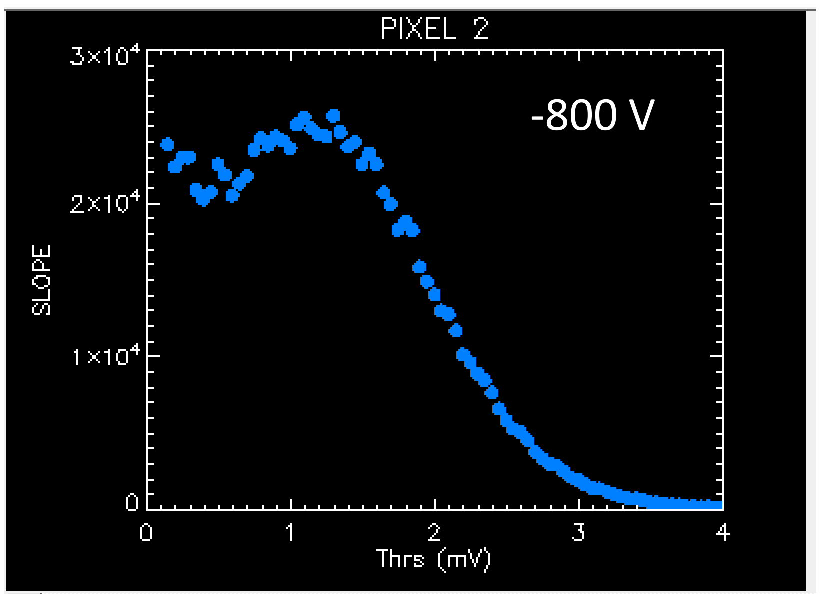


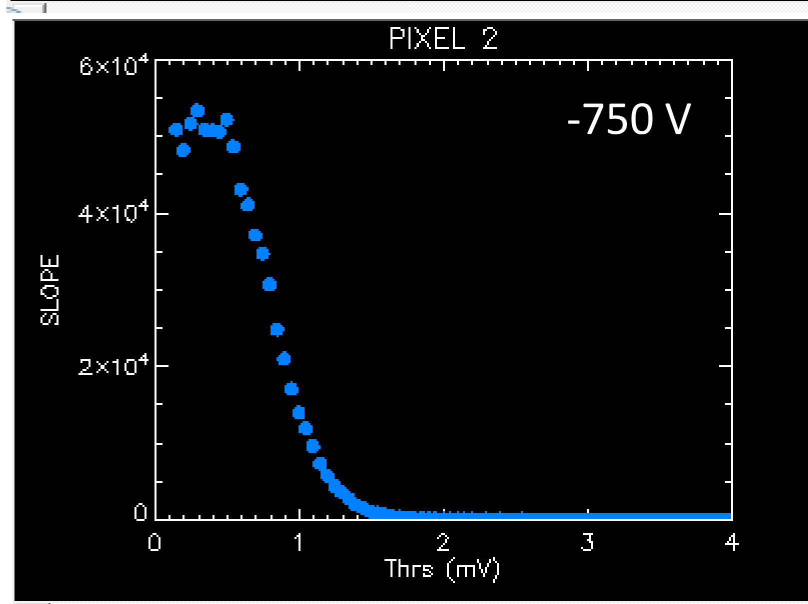
Very low dark counts rate.
@ 23° → 0.3 counts/s
@ 42° → 3 counts/s

Single Electron Response



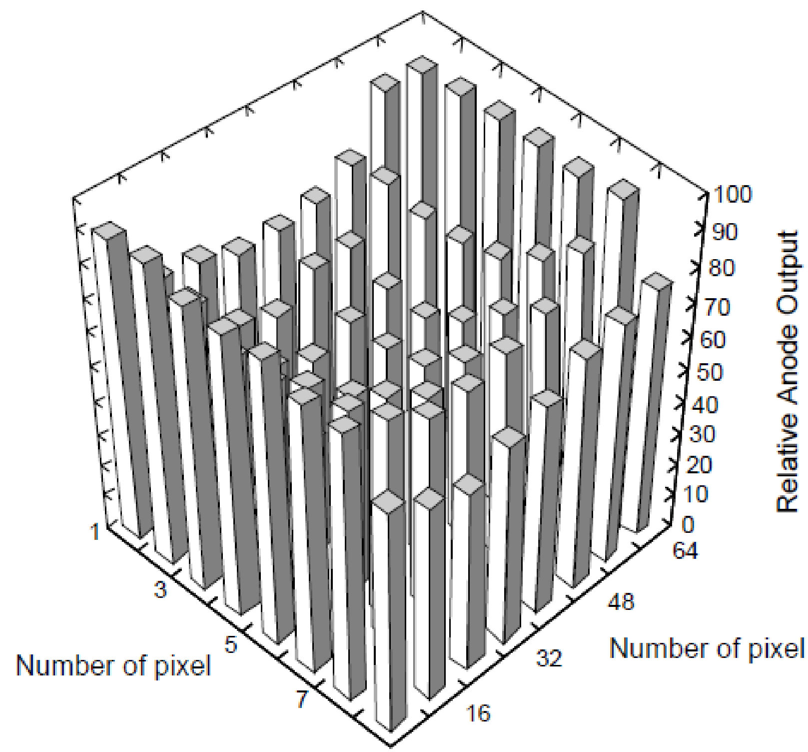




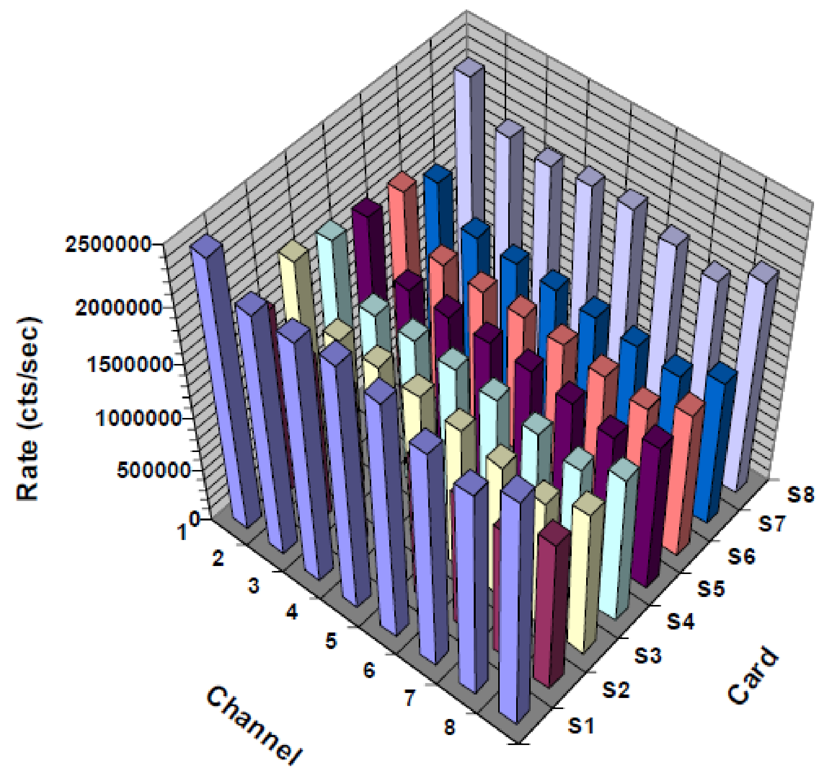


ANODE UNIFORMITY

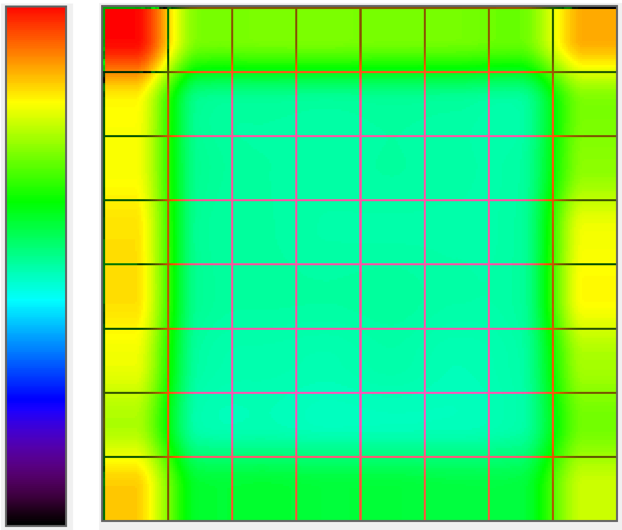
Figure 5: Typical Anode Uniformity (by Hamamatsu)



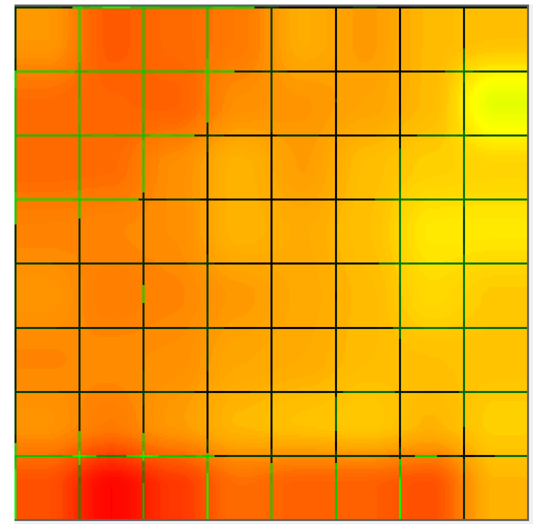
Relative pixels gain measured in Lab.

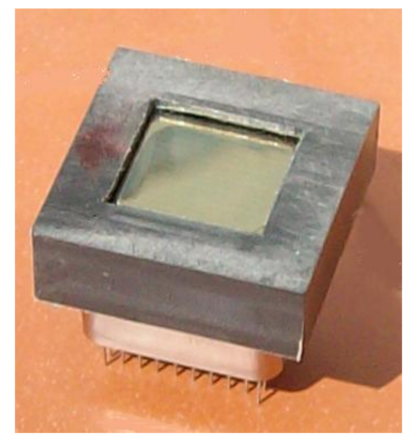


ANODE UNIFORMITY

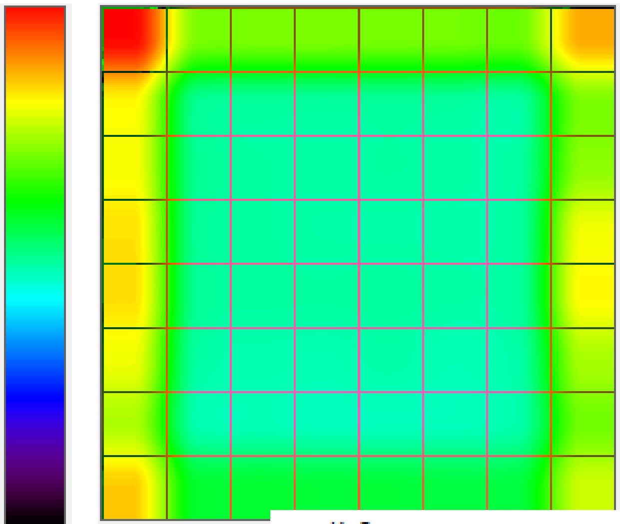


corrected

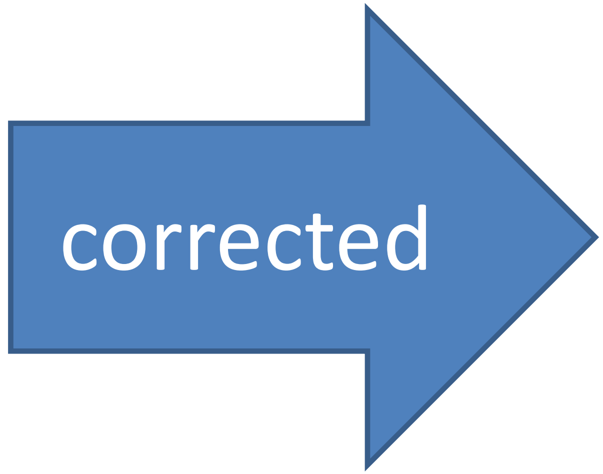


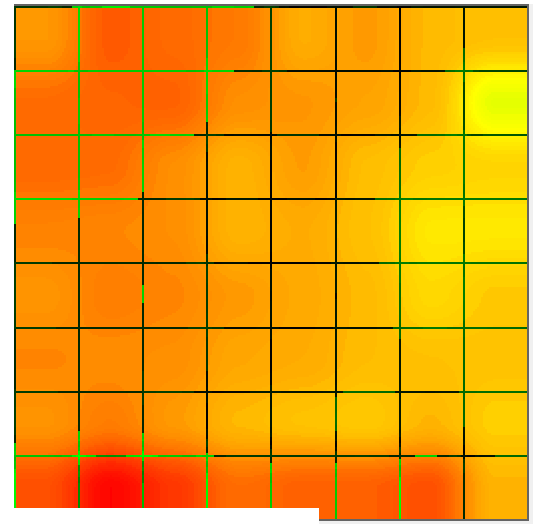


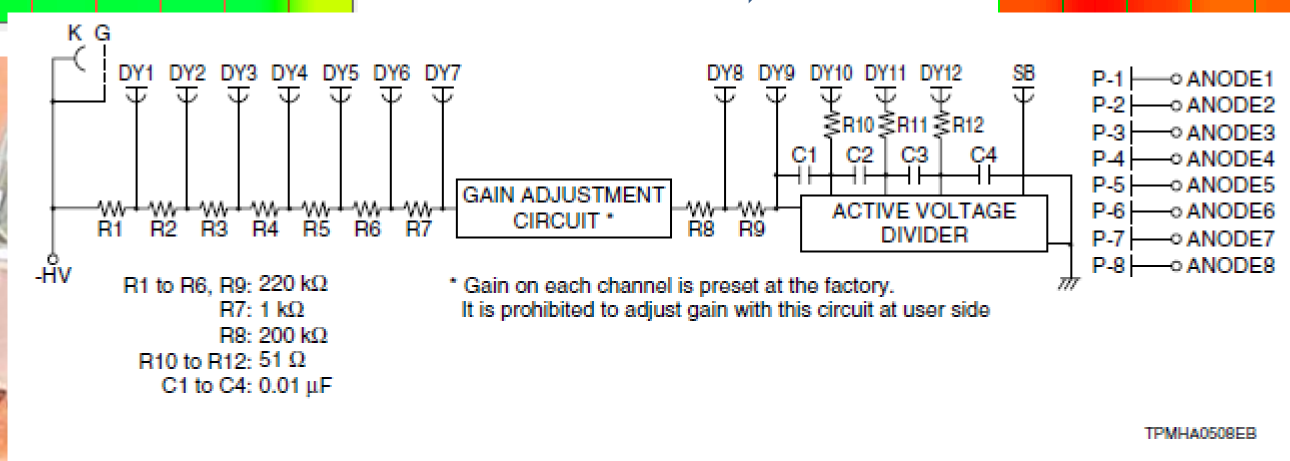
ANODE UNIFORMITY

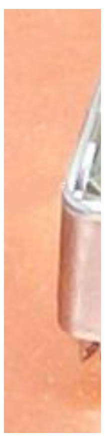


corrected

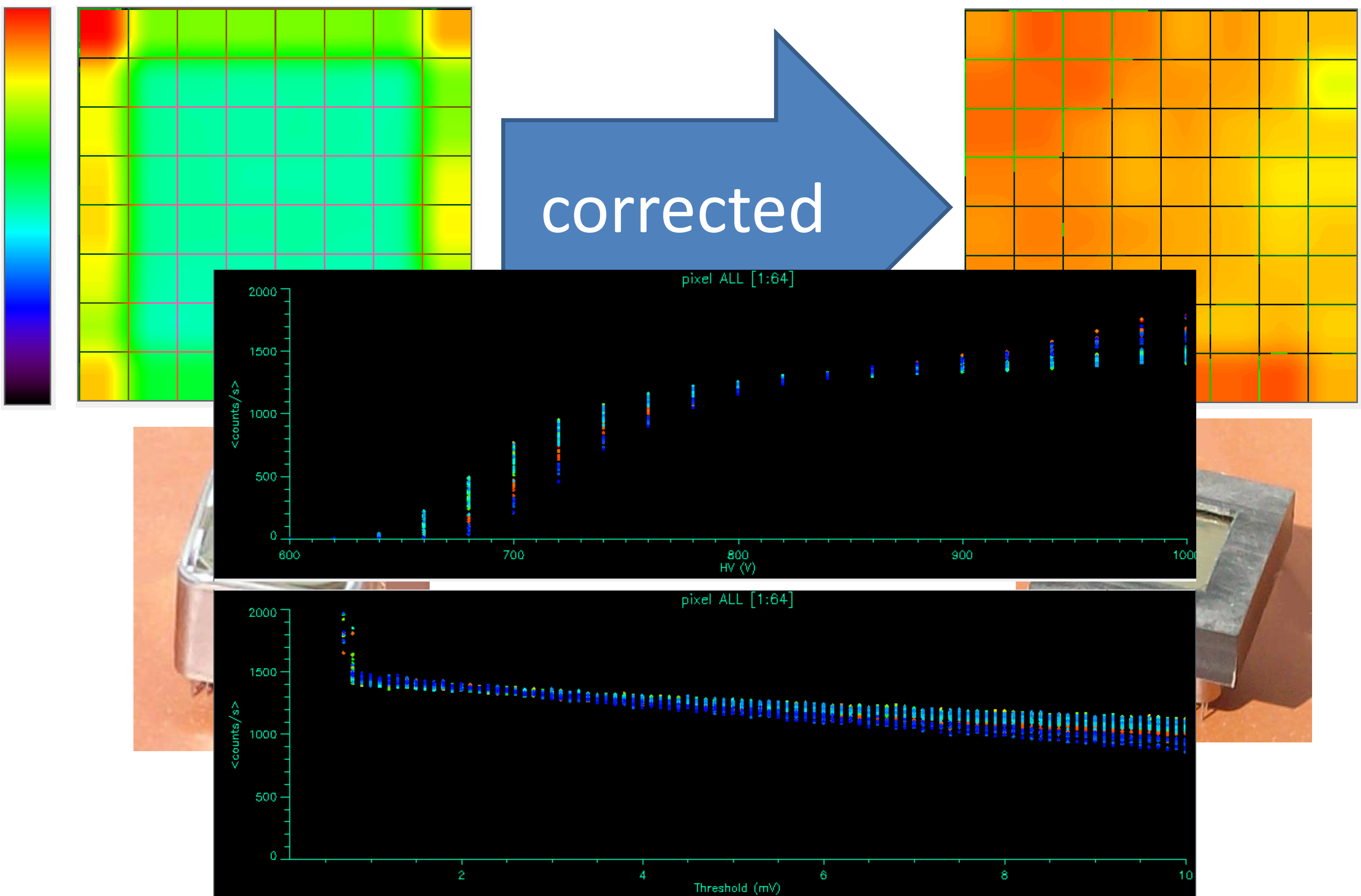




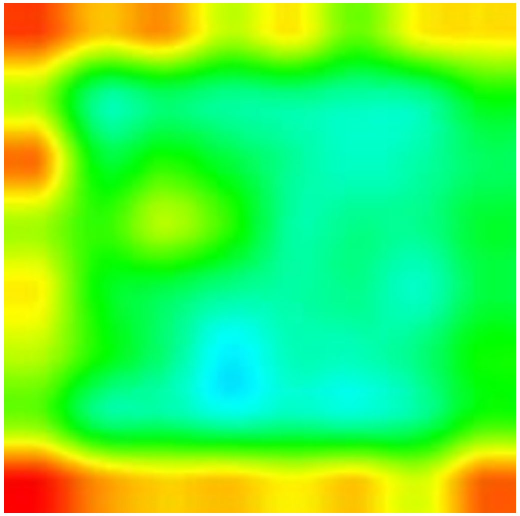


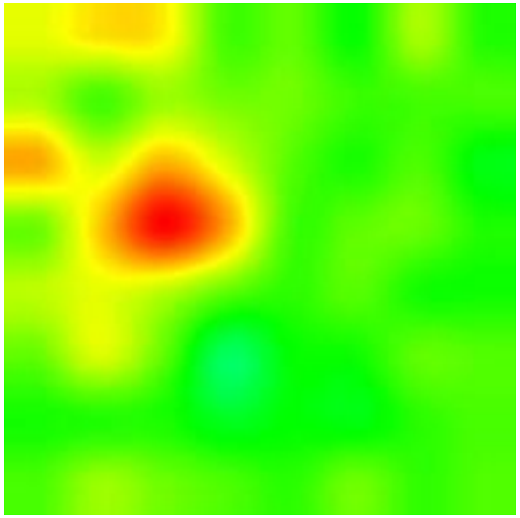


ANODE UNIFORMITY



ANODE UNIFORMITY

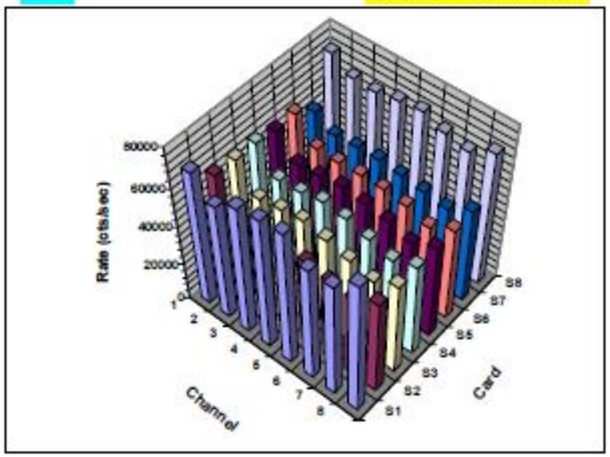




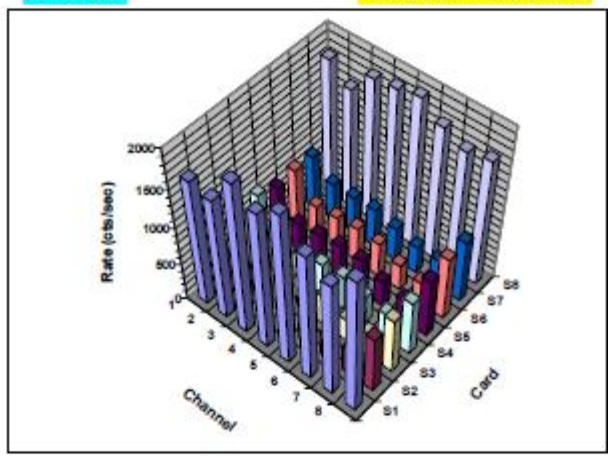
Looking to three faint stars in the FOV of the telescope

AFTER PULSES

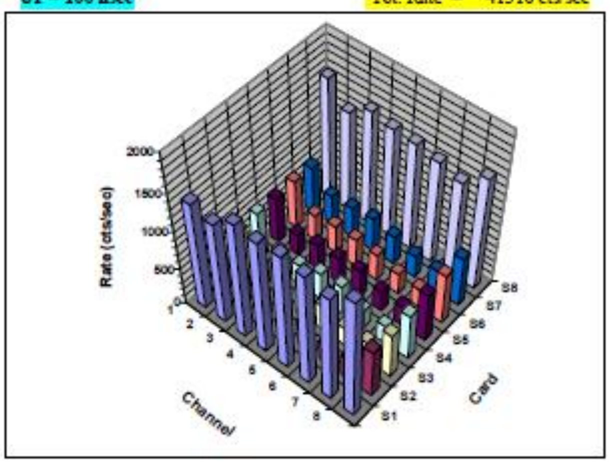
δT = 0 Tot. Rate = 3355108 cts/sec



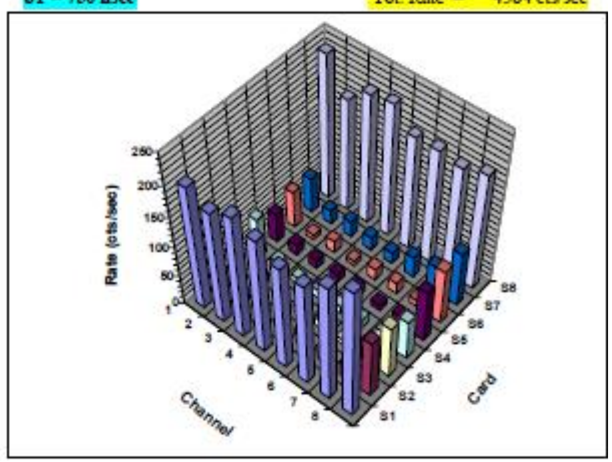
δT = 10 nsec Tot. Rate = 51648 cts/sec



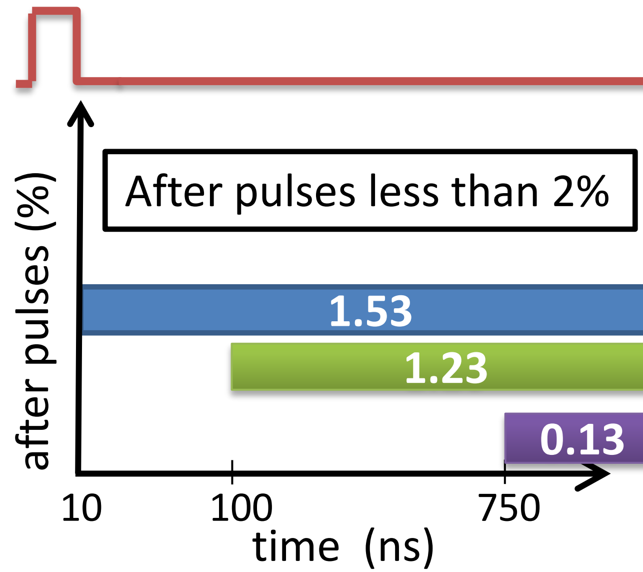
δT = 100 nsec Tot. Rate = 41316 cts/sec



δT = 750 nsec Tot. Rate = 4584 cts/sec



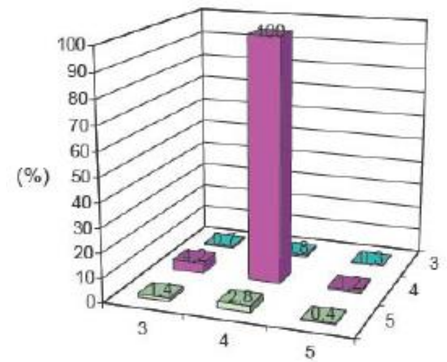
Light pulse on

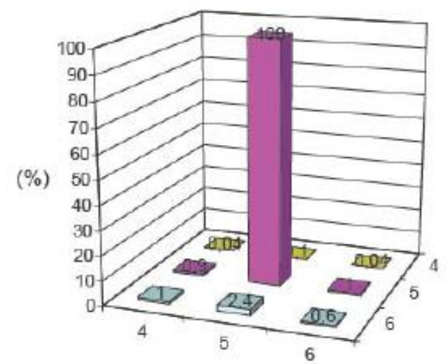


≈ 10^{-5} pe/10 ns/ pixel

CROSS -TALK

Anodes selected for Cross-Talk measurements





CROSS-TALK (all pixels) less than 2%

Angular Response

Preliminary results on the angular dependence of MAPMT response

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Dipartimento di Astronomia e Scienza dello Spazio, Università di Firenze, Firenze (Italy)
INFN Sezione di Firenze, Firenze (Italy)

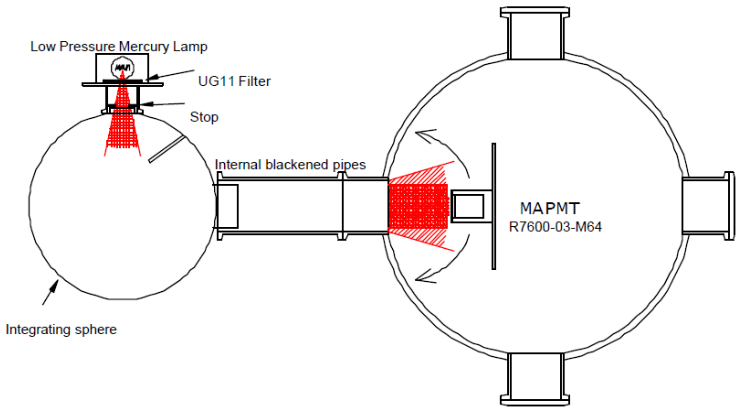


Figure 2. Sketch of the experimental setup for the preliminary tests on MAPMT.

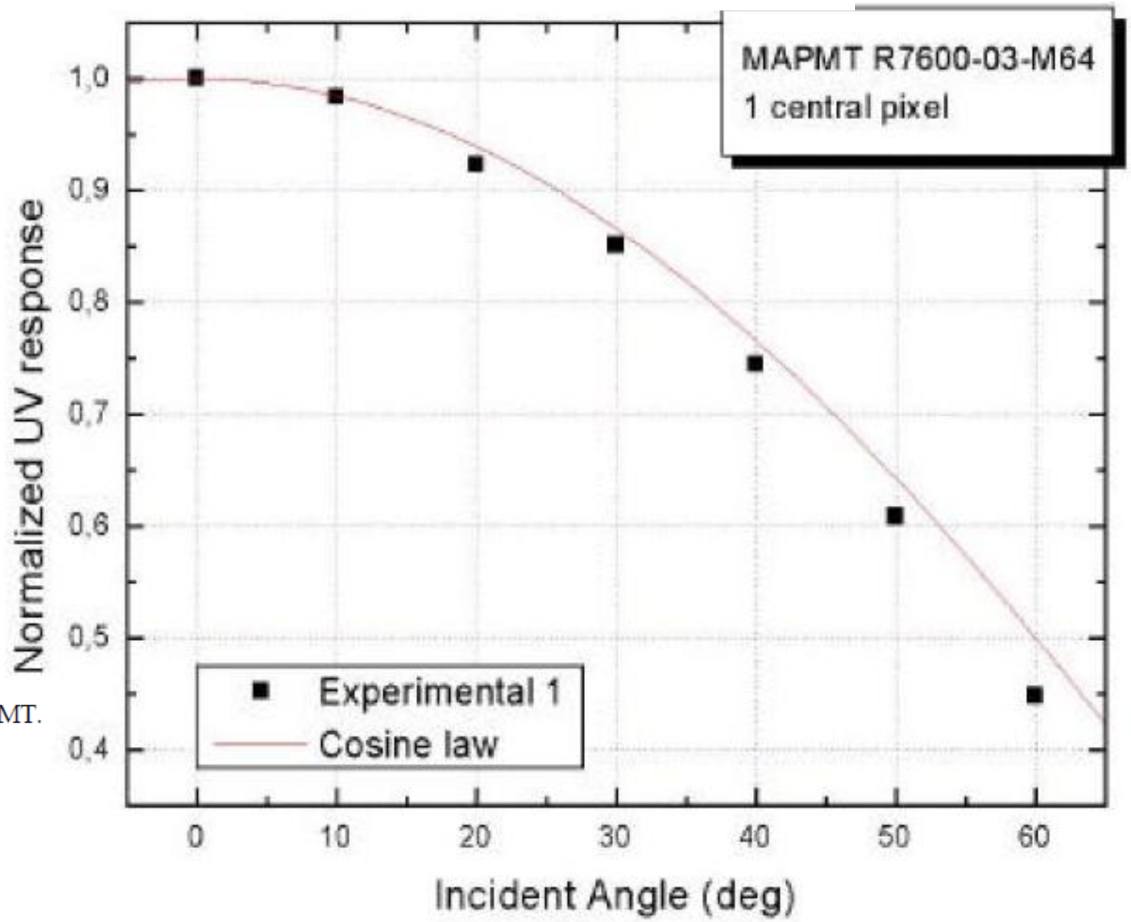
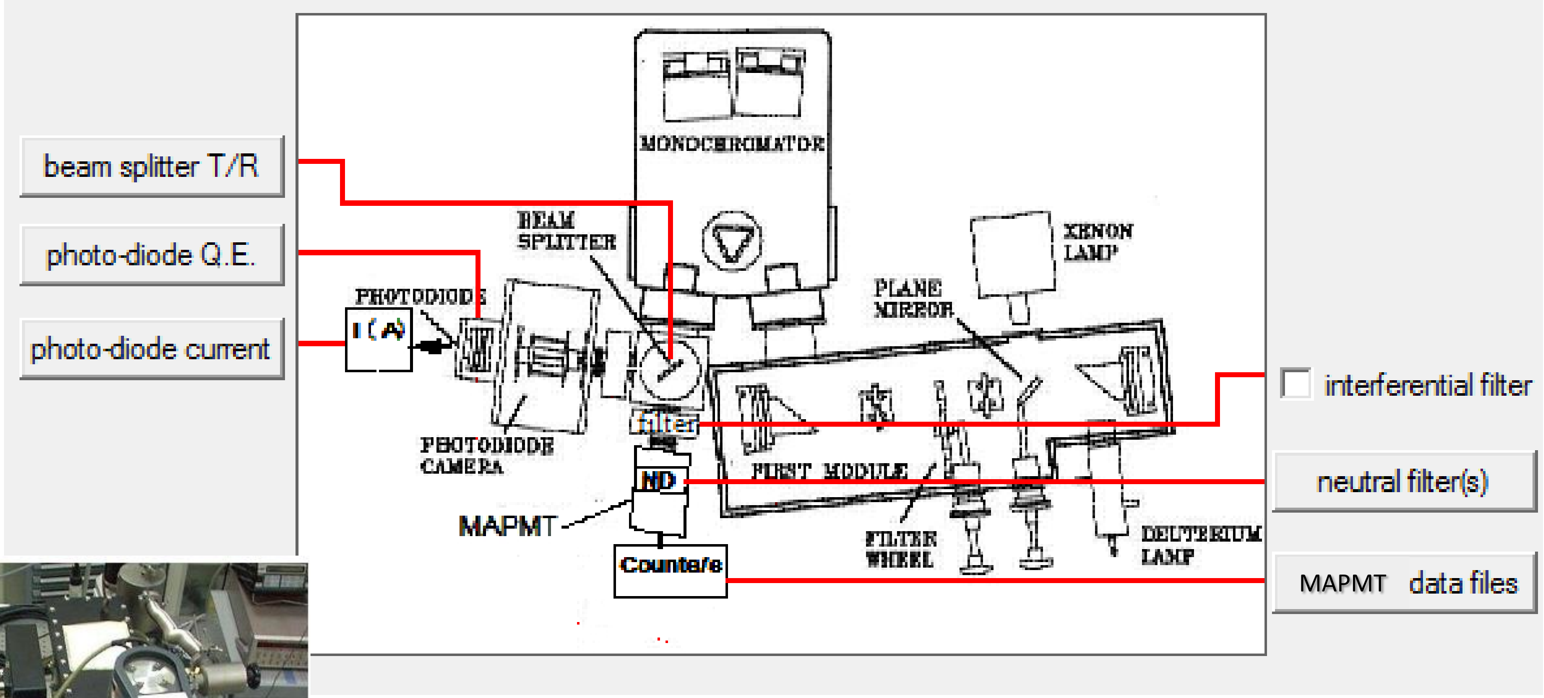
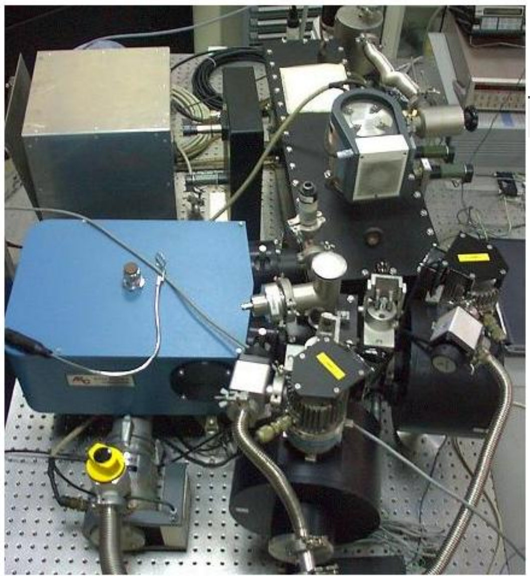


Figure 6. Angular dependence of the UV response for the central pixel (P28).

ABSOLUTE CALIBRATION

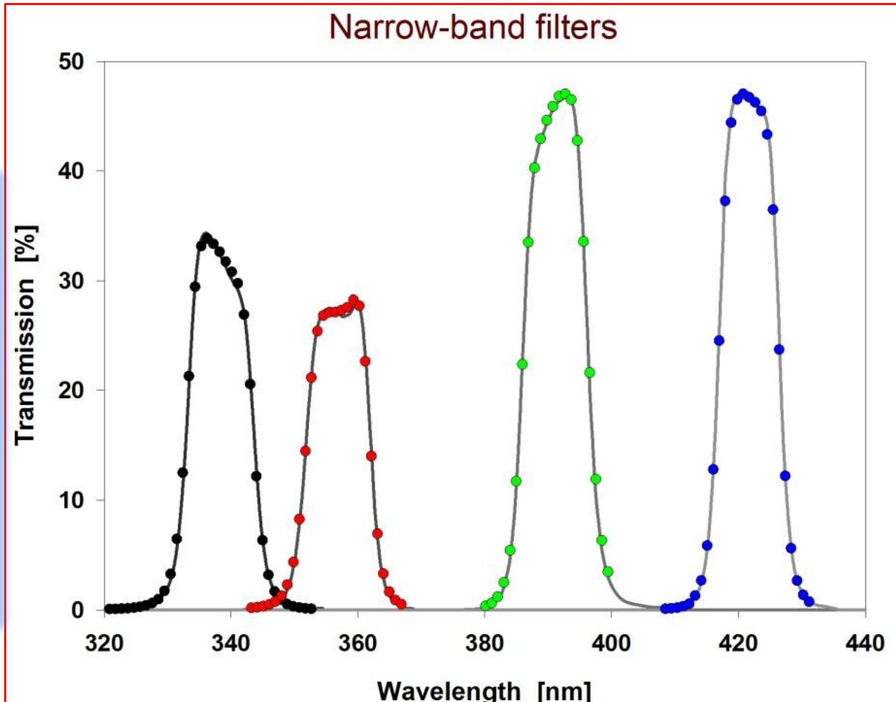
The MAPMT calibration at different wavelengths has been performed in the Catania Astrophysical Observatory Lab. for detectors (OACT /INAF).

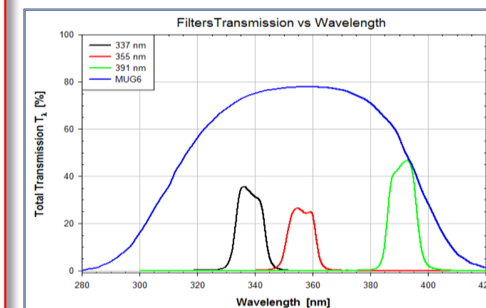




The instrumental apparatus for QE measurements in the 125 - 1100 nm

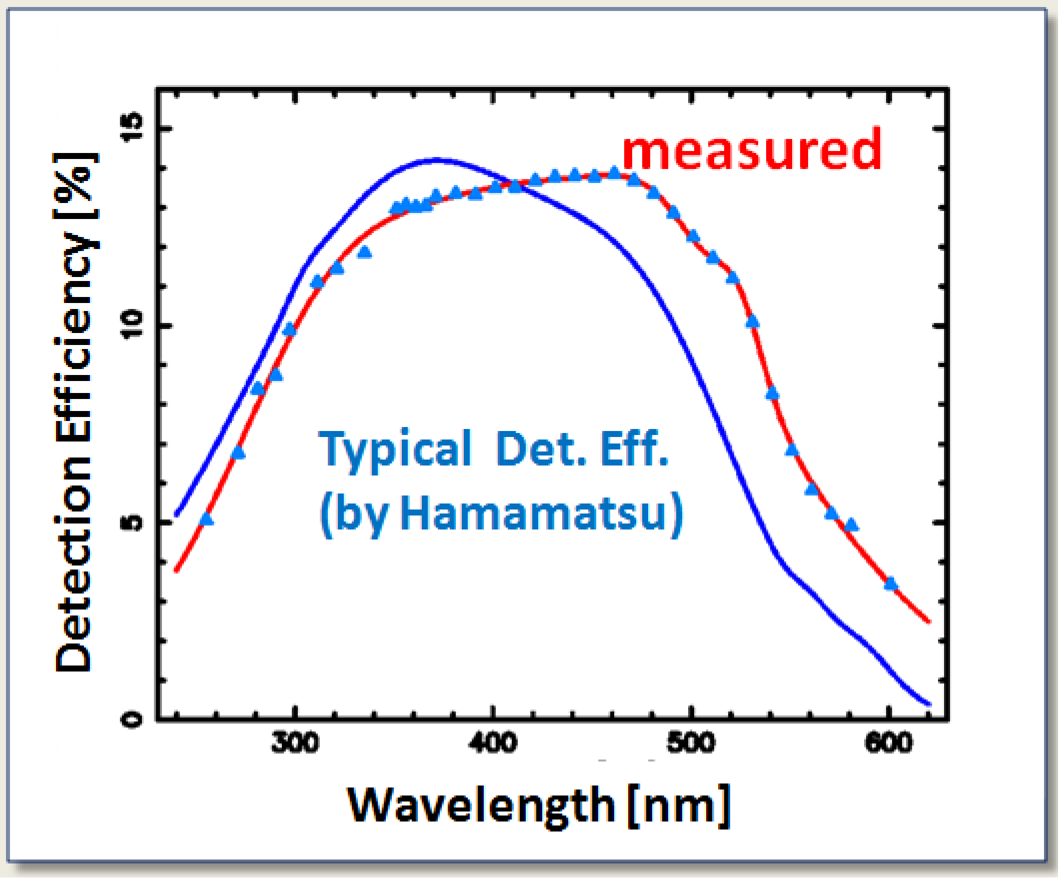
ABSOLUTE CALIBRATION





The illumination wavelength (from monochromator) is verified by comparing, for narrow band filters, the measured transmission data with the spectralphotometric curve (continuous line) provided by manufacturer (Andover)

ABSOLUTE CALIBRATION



MAPMT detection efficiency, QE(λ) x Collect. Eff. x Trigg. Eff., is obtained by comparison with a NIST calibrated photodiode.
The estimated absolute calibration accuracy is about 10 %

CONSIDERATION

$$NSB_{pe} \approx 5.5\ 10^{-2} pe \cdot \frac{A_{mirror}}{10\,m^2} \cdot \left(\frac{\theta_{pixel}}{0.1°}\right)^2 \cdot \frac{\Delta t}{10\,ns} \cdot \frac{\varepsilon_{tot.}}{0.1}$$ **(No Moon)**

Supposing : A_{mirror}=10 m^2 , θ_{pixel} = .2°, $\varepsilon_{tot.}$ = .2, Δt= 1 s

Pixel NSB rate ≈ 44 MHz

Assuming a Gain of 10^6 and 64 pixels

$\langle i_{MAPMT} \rangle = 1.6\ 10^{-19} * 10^6 * 64 * 44\ 10^6 = 450\ 10^{-6} = 450\ \mu A$

MAXIMUM RATINGS (Absolute Maximum Values)

Parameter	Value	Unit
Supply Voltage (Between Anode to Cathode)	-1100	V
Average Anode Output Current in Total	100	µA

A factor 4.5 larger than the absolute maximum values.
GAIN or pixel size or Mirror size have to be reduced.

CONCLUSIONS

Good Features from measurements:

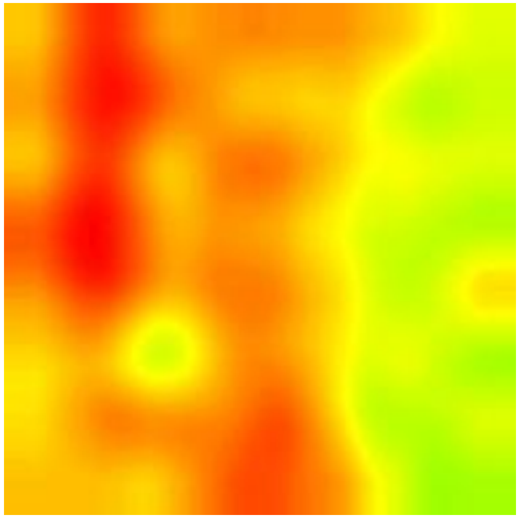
- High Gain
- Good pe Response
- Very low rate of after pulses and cross-talk
- Dark Count Rates almost negligible
- Easy relative and absolute calibration

Not So Good Features :

- Pixel Non-Uniformity 1:2 – 1:3 requires gain adjustment circuit
- Gains reduced to ~1E5 for NSB Rates,
  Spoils Resolution of Single pe response
- Quantum Efficiency ~20%, super-ultra bialkali photocathode

The tools developed in our Institute, could be used, with little modification, for the characterization of some H8500-H10966 units.

Very GOOD Imaging Capability



TRANSIT OF MUPHRID AND ARCTURUS

H10966

64 ch, 8x8 pixels, each 6 mm x 6 mm, 89% fill factor

sBa photocathode

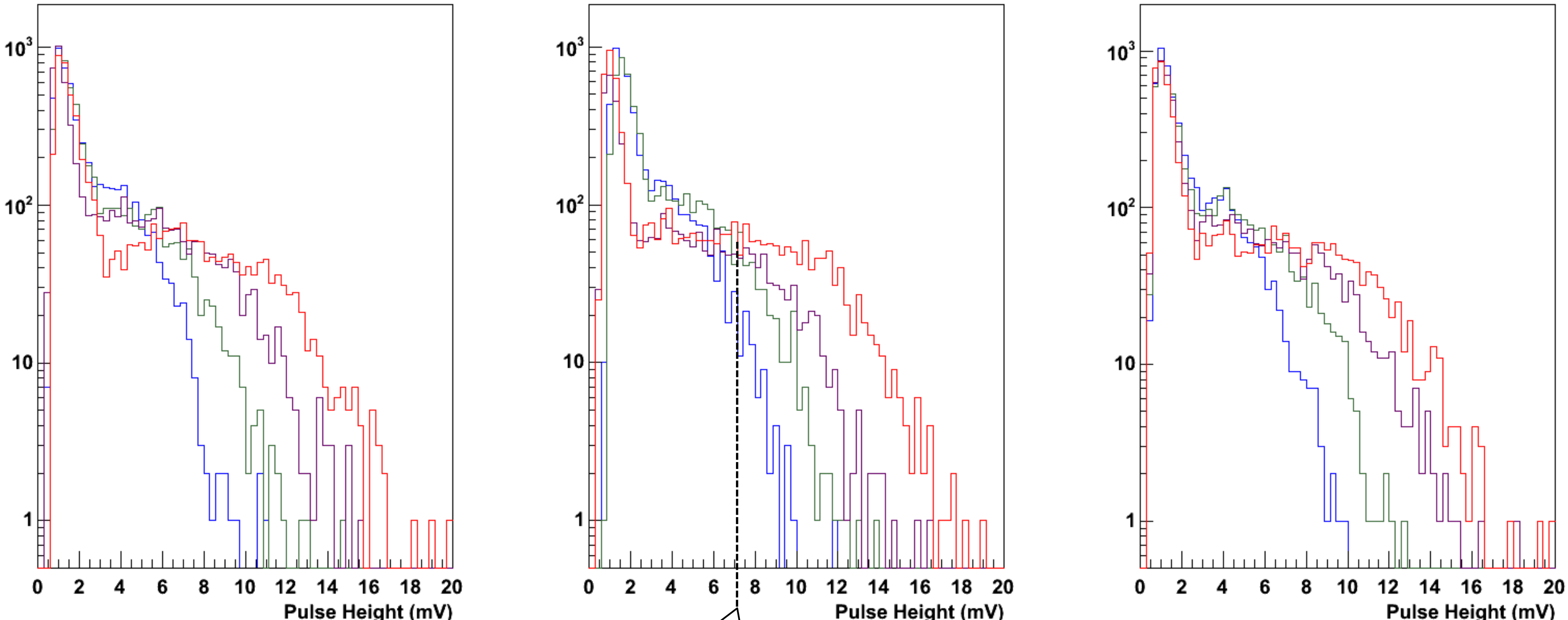
8 dynodes, G=1 – 3.3 x 10^5

PRELIMINARY

900 V 1000 V

950 V 1050 V

SPE 3 different channels



Sunni Homeschandra, Jim Hinton, Richard White

SPE resolvable on some channels at nominal voltage

1 pe is (very approximately) 7 mV at 1000 V

H10966

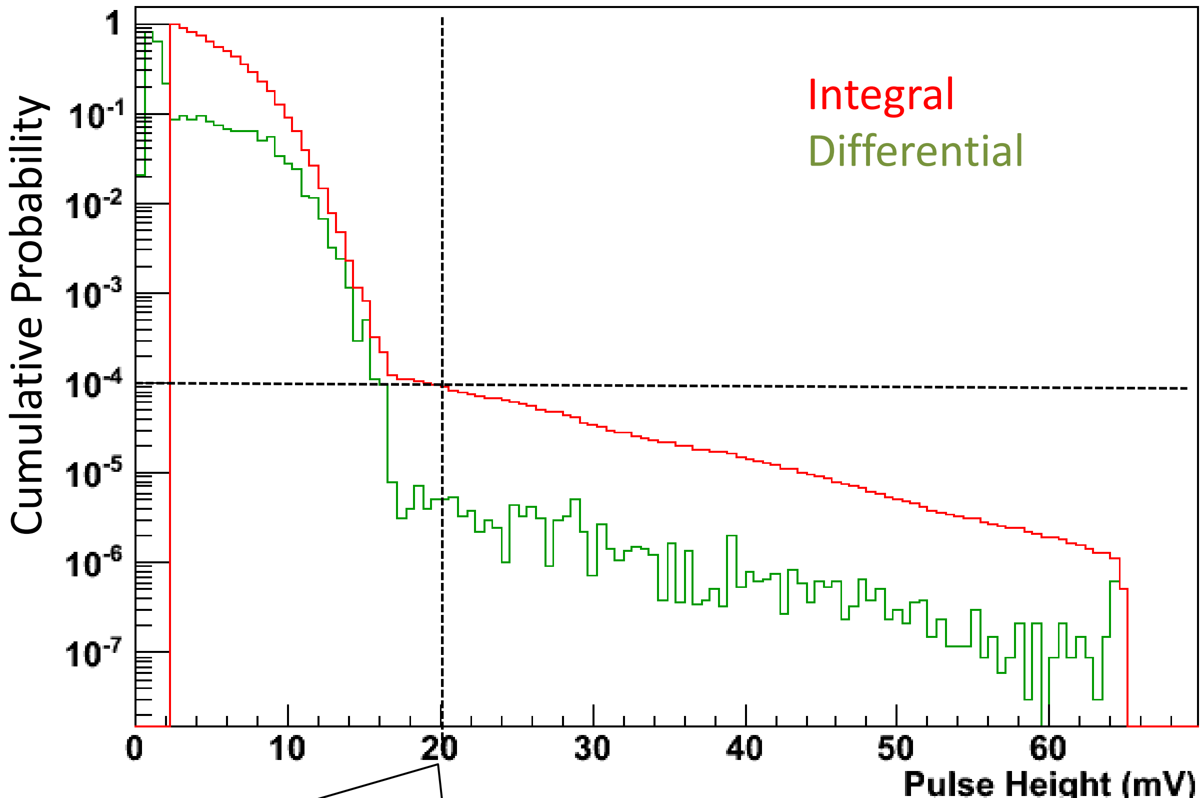
64 ch, 8x8 pixels, each 6 mm x 6 mm, 89% fill factor

sBa photocathode

8 dynodes, G=1 – 3.3 x 10^5

PRELIMINARY

Relative rate of pulses as a function of peak height for 1 ch at 1000 V



After pulse rate matches the goal spec. MPI Munich are looking for with 2” PMT (better than 10^{-4} at > 4 pe)

Sunni Homeschandra, Jim Hinton, Richard White