The HPD DETECTOR

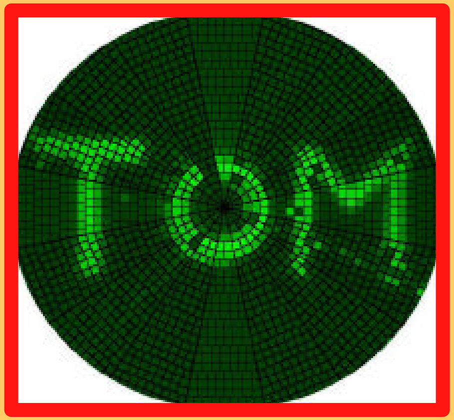
Michele Giunta

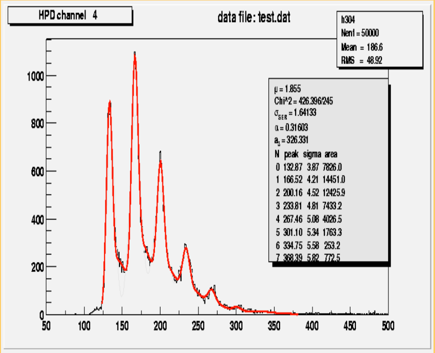
VLVnT Workshop

"Technical Aspects of a Very Large Volume Neutrino Telescope in the Mediterranean Sea"

In this presentation:

- The HPD working principles
- The HPD production
- CLUE Experiment
- The TOM Project
- The TOM HPDs
- LAB/Mountain HPD Measurements





HPD is for...

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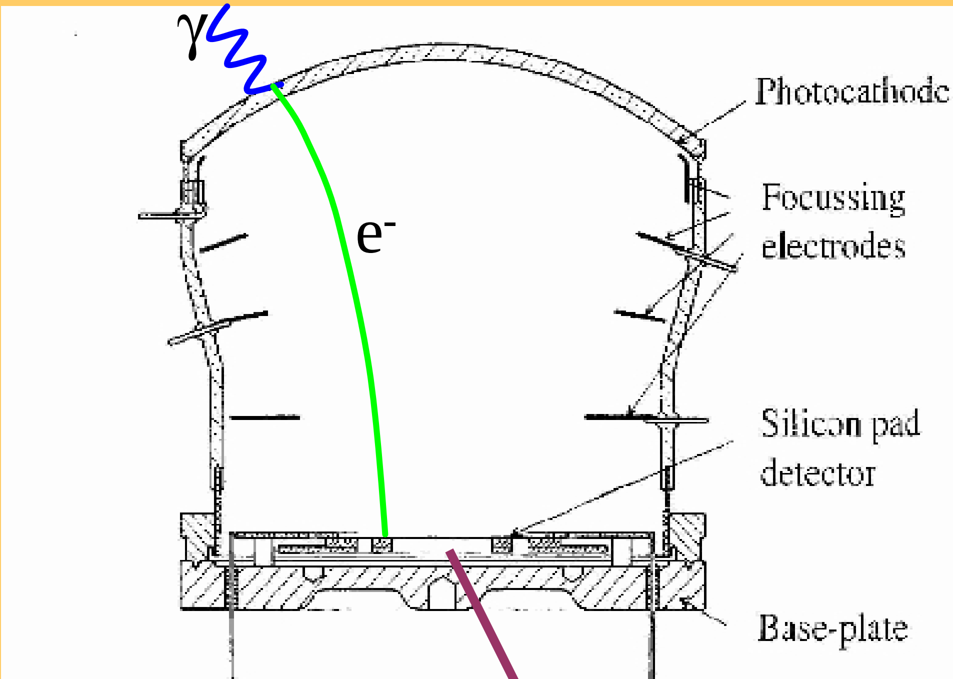
Hybrid
Photon
Diode/Detector

(also called Hybrid PMT)

H because it joints the
photoconversion principle of a PMT
with the
spatial resolution and the low fluctuations of a semiconductor
device

HPD Working Principles: vacuum tube



The HPD is a Hi-vacuum tube with a photocathodic layer on the entrance window and a silicon on the baseplate

↓

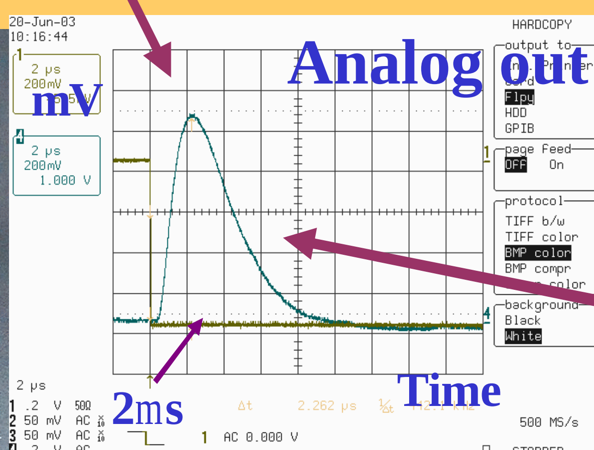
Photoelectrons are accelerated to the sensor by a 20/30 KV potential

↓

The E field shape provides the linear demagnification from the window to the silicon sensor

↓

Photoelectrons are absorbed in the silicon giving a signal, that is amplified & shaped.

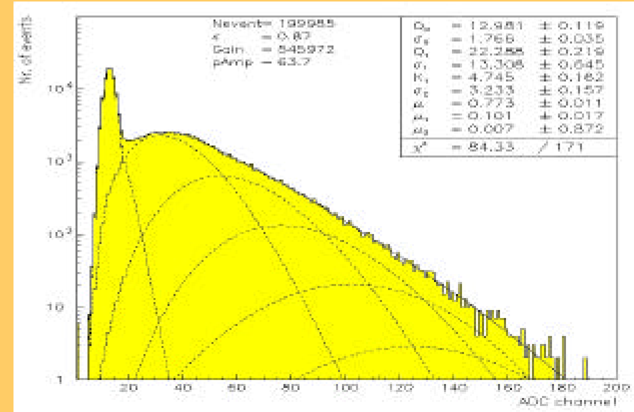


HPD Working Principles: G fluctuations

In a **PMT** there is electron multiplication (with fluctuations) by secondary emission at every dynode.

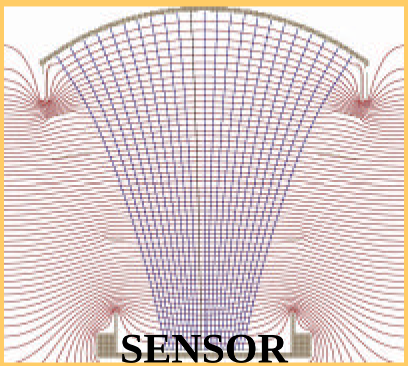
$$G_{PMT} \simeq 10^6$$

$$\left.\frac{\sigma_G}{G}\right|_{PMT} = \sqrt{\left(\frac{\sigma_1}{k_1}\right)^2 + \frac{1}{k_1}\left(\frac{\sigma_2}{k_2}\right)^2 + \frac{1}{k_1 k_2}\left(\frac{\sigma_3}{k_3}\right)^2 + \cdots} \simeq 0.4$$



In a **HPD** a phe gains a 20/30 KeV energy, which is relased in the silicon layer.
The signal is formed in a SINGLE STEP: gain fluctuations are much smaller.

The Pulse Height Spectrum has <u>**VERY SEPARATED PEAKS**</u>



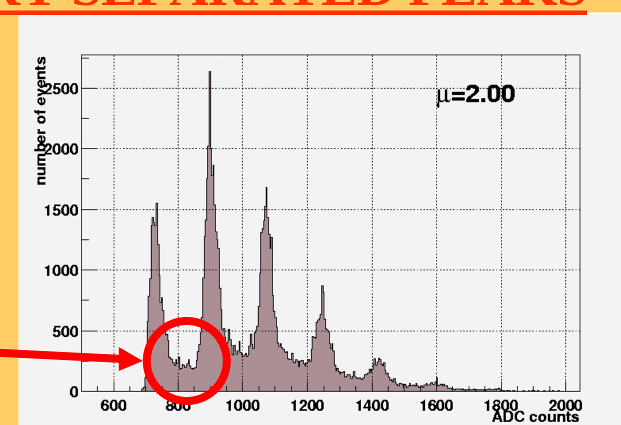
$$G_{HPD} = \frac{e\Delta V - K}{3.62eV} \simeq 5000\ (20\ KV)$$

$$\left.\frac{\sigma_{Si}}{G_{Si}}\right|_{HPD} = \sqrt{n \cdot F \cdot G_{Si}} \simeq 0.005$$

$$\frac{\sigma_{tot}}{G} = \frac{\sqrt{\sigma_{BS}^2 + \sigma_{Si}^2}}{G} \simeq 0.05$$

pure signal

with backscattering



HPD Working Principles: The Sensor

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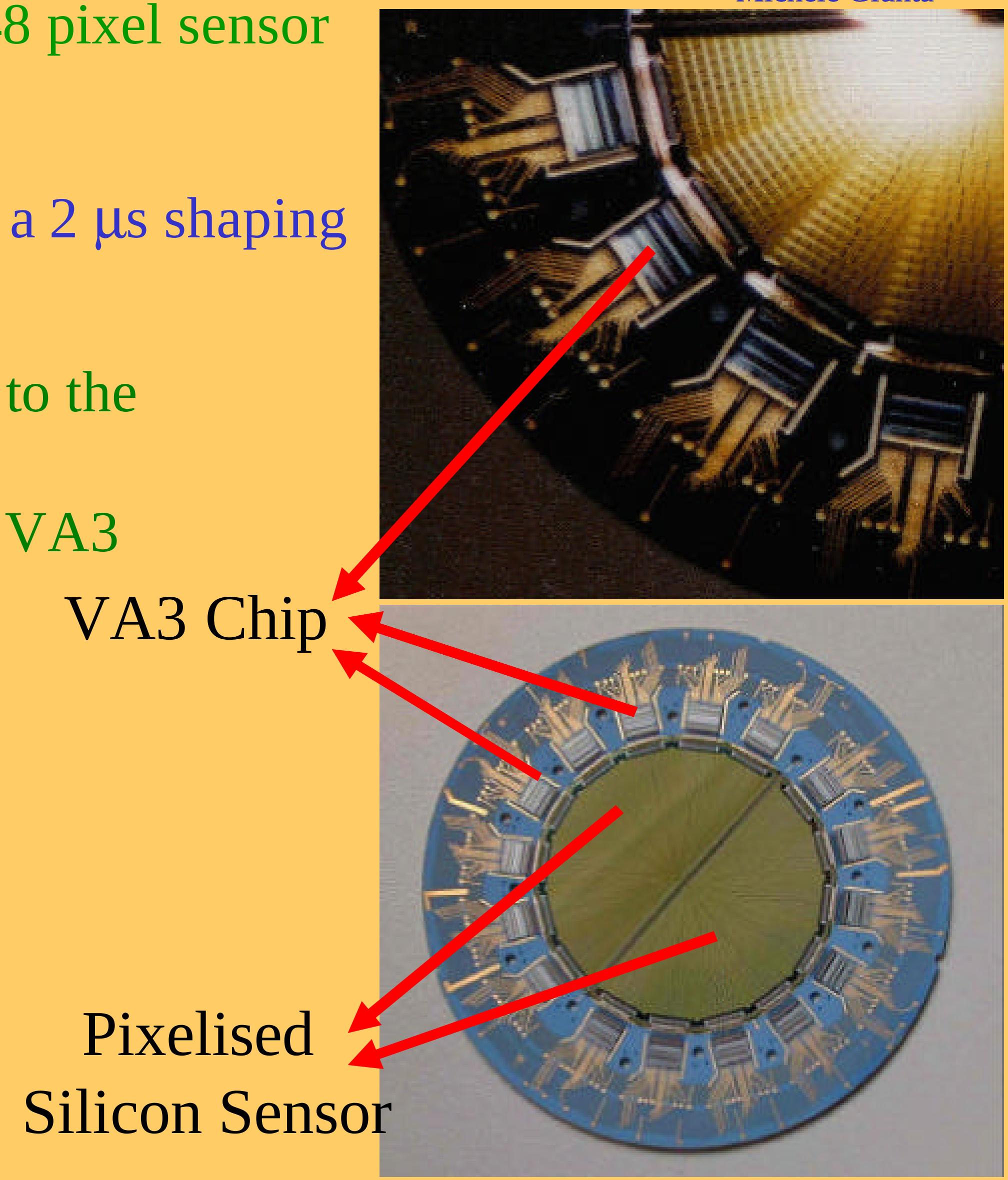
• INFN-Pisa/CERN HPDs use a 2048 pixel sensor with integrated readout electronics.

• The IDEAS Viking VA3 chip has a 2 μs shaping time and requires external Trigger.

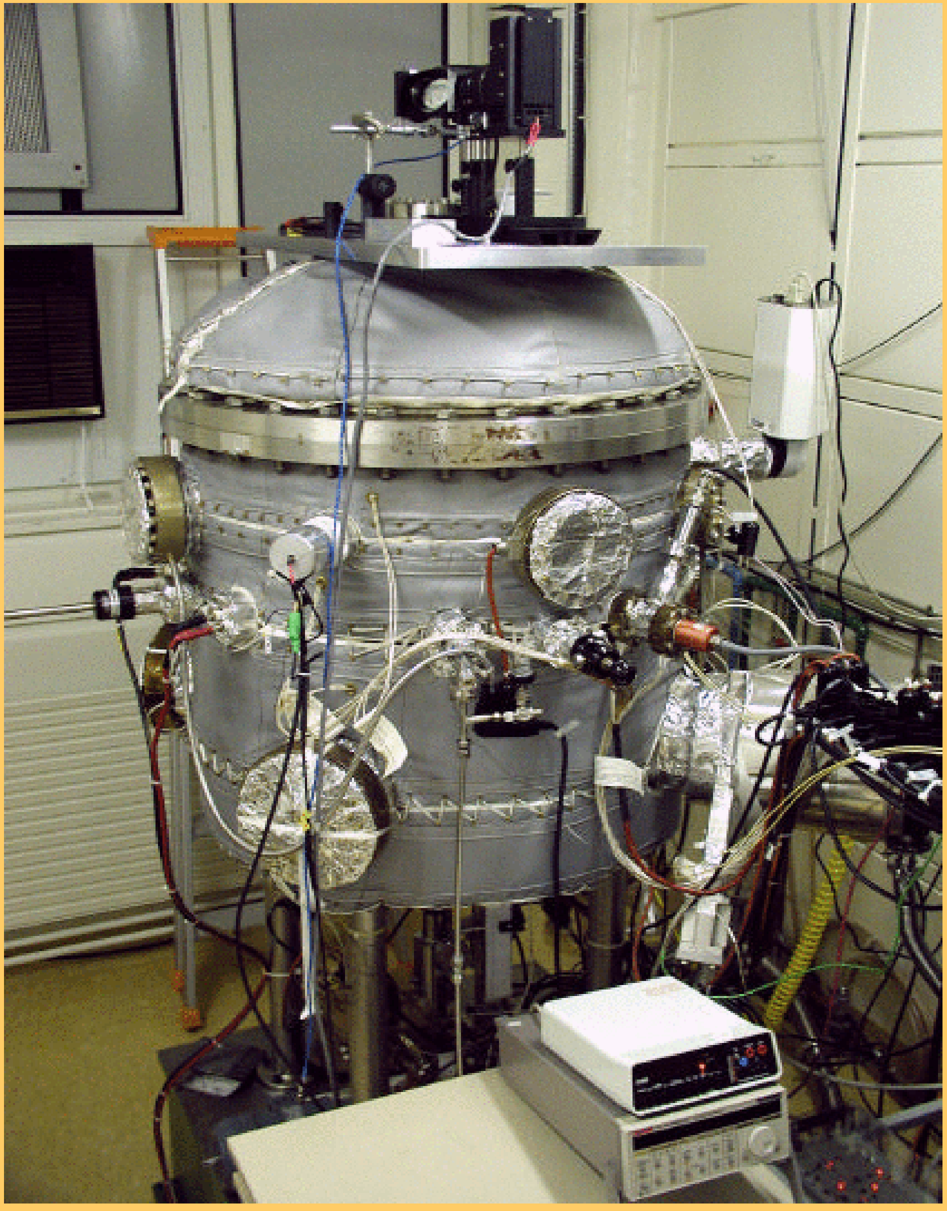
• 2.5 KHz serialised acquisition due to the ADC max. clock time;
5 KHz acquisition possible with the VA3

• A new chip (IDEAS VA-TA GP3) is autotriggering and ready to use. It has a fast-shaper (150 ns) for the trigger and a 3μs analog part shaping time.

• Sparse readout included.



HPD Production: Evaporator @CERN



- High vacuum in a large tank.
- Evaporation process provided by a moving carriage with heated source of photosensitive material.
- Baking is made at 300 °C.
- Evaporation process is online monitored with a light beam and a calibrated photodiode.
- The process is stopped when the photocurrent reaches the maximum value.
- The baseplate with the silicon sensor is sealed to the tube body by a cold indium press seal and kept apart during evaporation.

HPD Production: Photocathodes

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Visible photocathodes have been produced (**Bialkali**) and a **QE peak of 25%** can easily be reached.

UV Solar Blind photocathodes have been produced (**Rb_2Te**, Rubidium Telluride) with ITO conductive layer. **QE peak of 15%** can be reached with a **quartz** window. Spectral response is from 190 nm (15%) to 300 nm (1%).

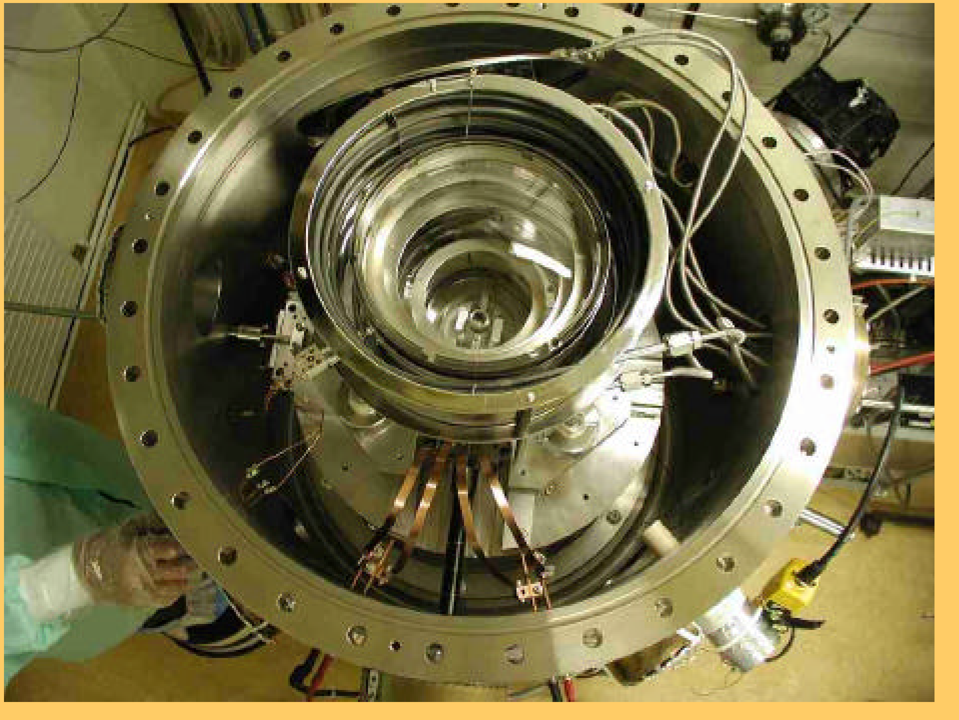
Ageing of these QE had been proved to be good over 2 years.
Up to now, ther's no data for longer periods.

HPD Production: the CERN facility

The evaporation setup has been extended by INFN Pisa workshop for 10” HPD production.
This is the new parts installation @CERN

The 10” heater is mounted

Top view of the 10” HPD



HPD Production: Quartz

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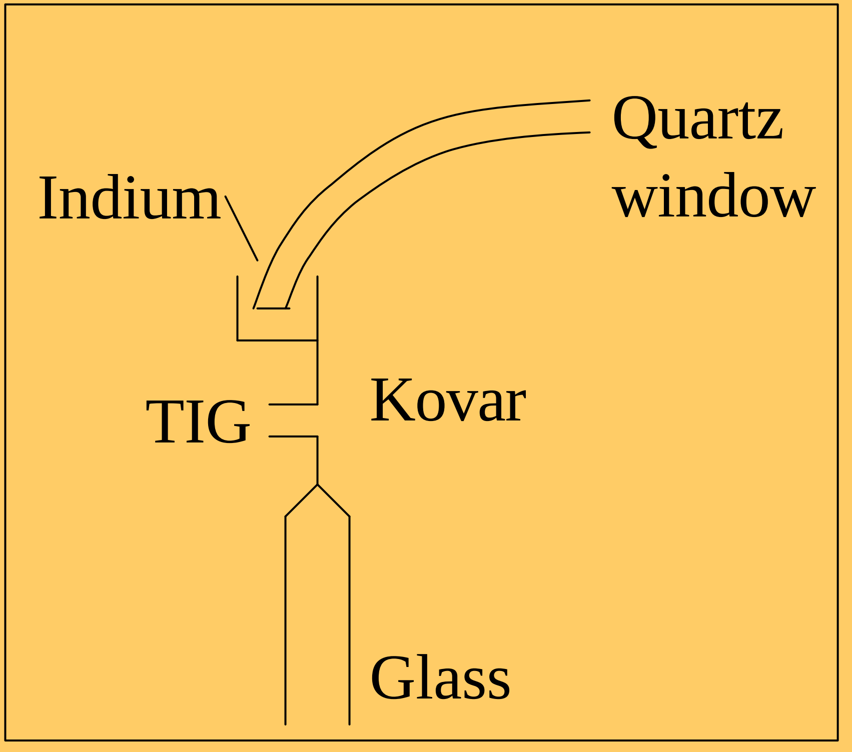
Sealing a quartz (UV transparent) window to glass or Kovar flange is a problem (over 10” dimensions):

$$\left.\begin{array}{l}\Lambda_{quartz} = 0.54 \\ \Lambda_{kovar} = 4.0 \div 5.0 \\ \Lambda_{pyrex} = 5.7\end{array}\right\} \times 10^{-6}\,{}^{o}C^{-1}$$

→ Cracks during baking

Solution proposed: will be checked during 2003 →



CLUE (Cherenkov Light Ultraviolet Experiment)

INFN PISA
ISTITUTO NAZIONALE DI FISICA NUCLEARE

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- Site: La Palma (Canarian Islands), 2200 m a.s.l.

- 9 mirrors F1 1.8 m diameter, 45 m spaced.

- Experiment sensible to UV light: detects the Cherenkov photons produced by the charged components of VHE showers in the lower part of atmosphere, near the observation level.

    - Advantage: no NSB.
    - Disadvantage: not many photons.

- On focal planes there are MWPC chambers with TMAE as photoconverter gas and with quartz window.

The TOM Project

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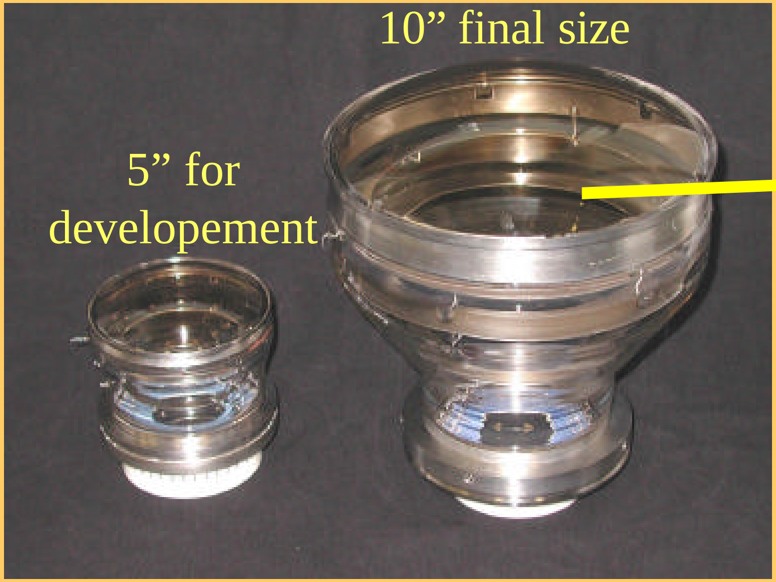
Tom Ypsilantis (1928-2000)

• The TOM Project was born in 2001 to develop HPDs for CLUE requirements.

• The CLUE Collaboration proved to get **20 times more light** with Rb_2Te PCs detectors than with MWPC. This is due to spectral response and atmosphere transparency.



TOM Project: Insulating the Envelope

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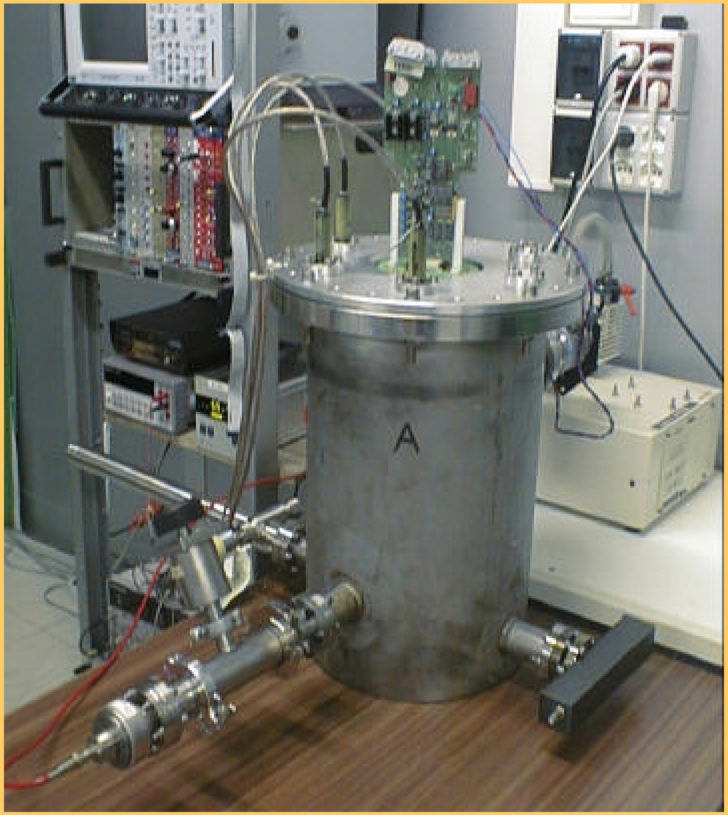
Operating @ 20-30 KV in normal condition requires HV insulation.
We used a <u>SYLGARD</u> coating.



The first time we tested the HPD we used vacuum as electric insulator.

1)

2)

3)

4)

TOM Project: Test Setup

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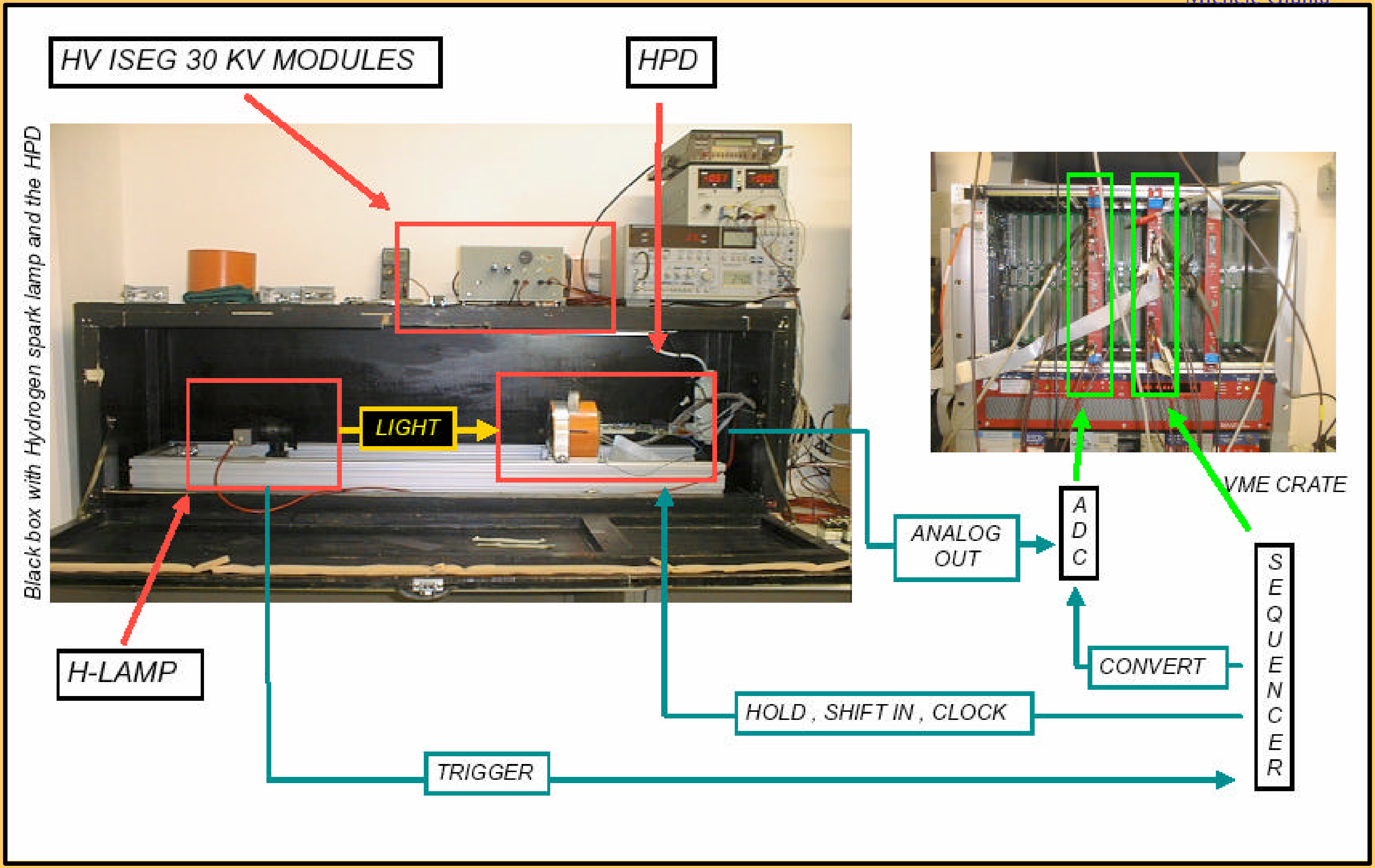

The 5”,10” (and 20”) HPDs

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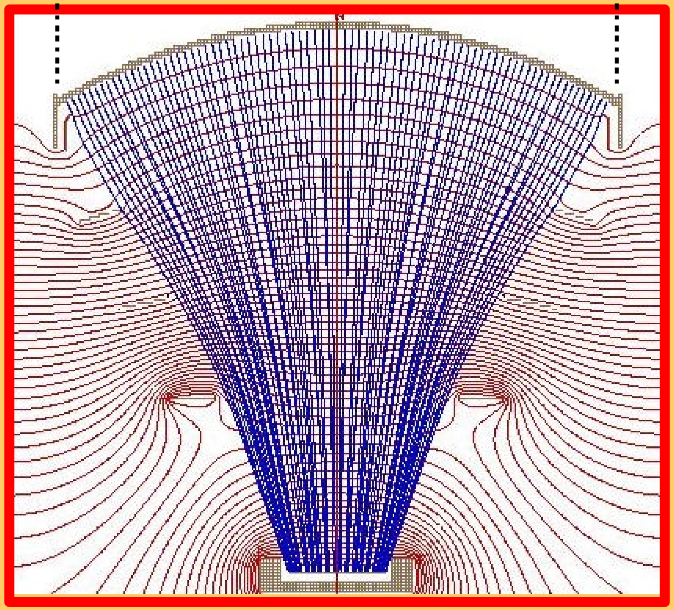
Currently the TOM HPDs are:

5” Bialkali &
5” Rb_2Te
borosilicate

10” Bialkali
borosilicate window

20” (!) only simulated
in the e optics



HPD: Imaging Linearity

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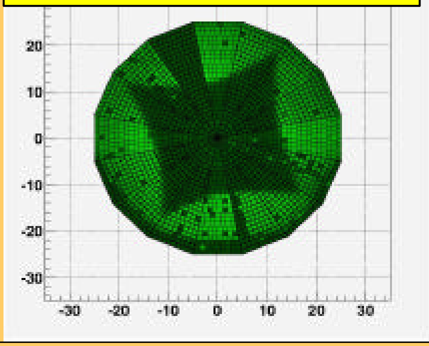
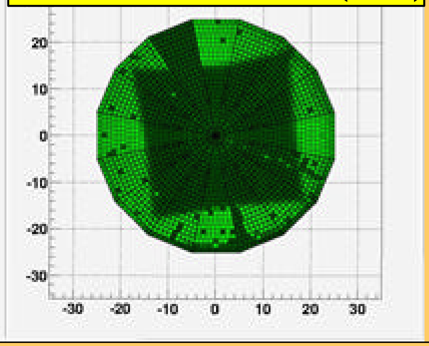
The **demagnification** is the ratio between the $(x,y)_{PC}$ and the $(x,y)_{SENSOR}$ coordinates (z is the simmetry axis).

HV: 20/18.8 /14 /3 (-KV)



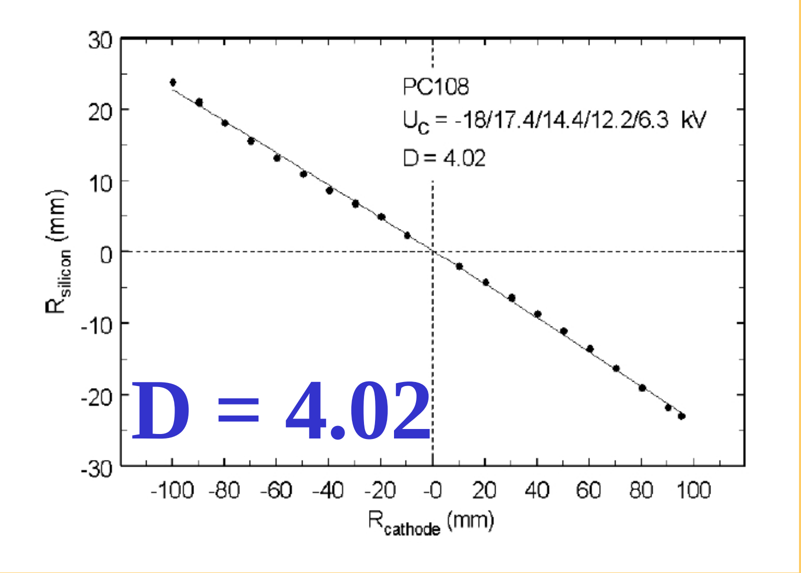
HV: 20/17.4 /7.5 /3 (-KV)



Here is shown the image of the same square mask on PC for different HV combinations on electrodes.

When the demagnification value does not depend on the position, it's linear (ideal case).

LINEARITY: here is plotted, for the Bialkali 10" HPD, the $R_{silicon}$ vs $R_{cathode}$ function.
An excellent linearity is reached.



HPD: PSF

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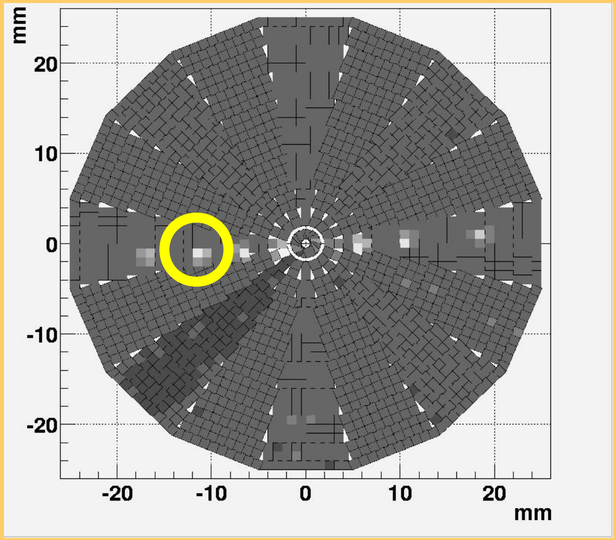
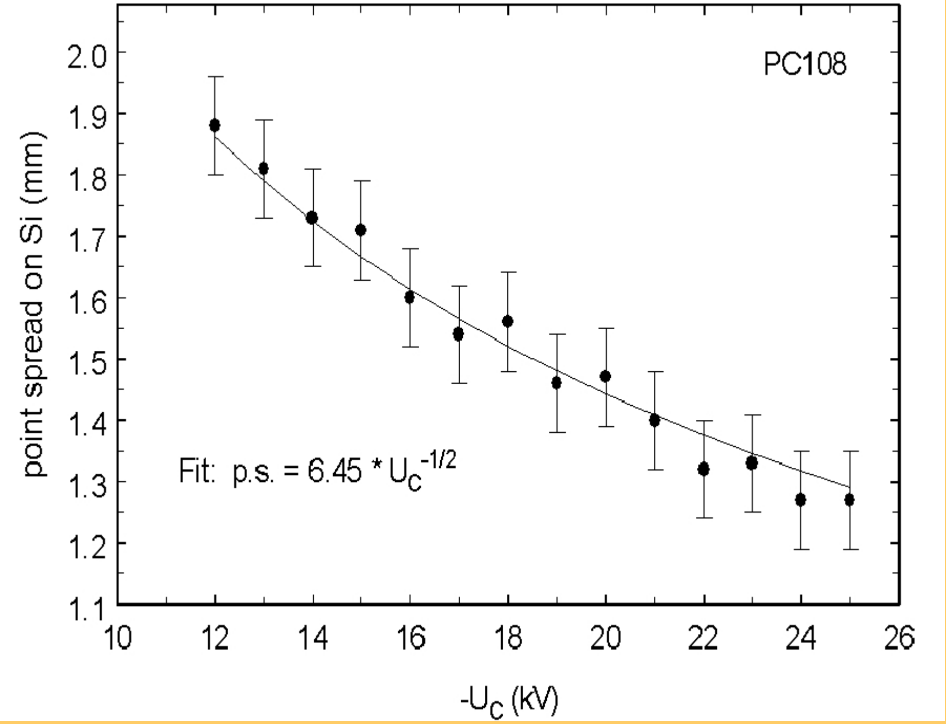
The **Point Spread Function** (PSF) is the electron distribution on the sensor when a point-like light source is used.



The PSF SDEV is plotted as a function of the Voltage applied to 10" HPD.



A $\frac{1}{\sqrt{\Delta V}}$ dependance is expected and observed.

S_{PSF} = 1.3 mm (10" 20KV)

S_{PSF} = 0.3 mm (5" 20KV)

HPD: Pulse Height Spectrum Analysis

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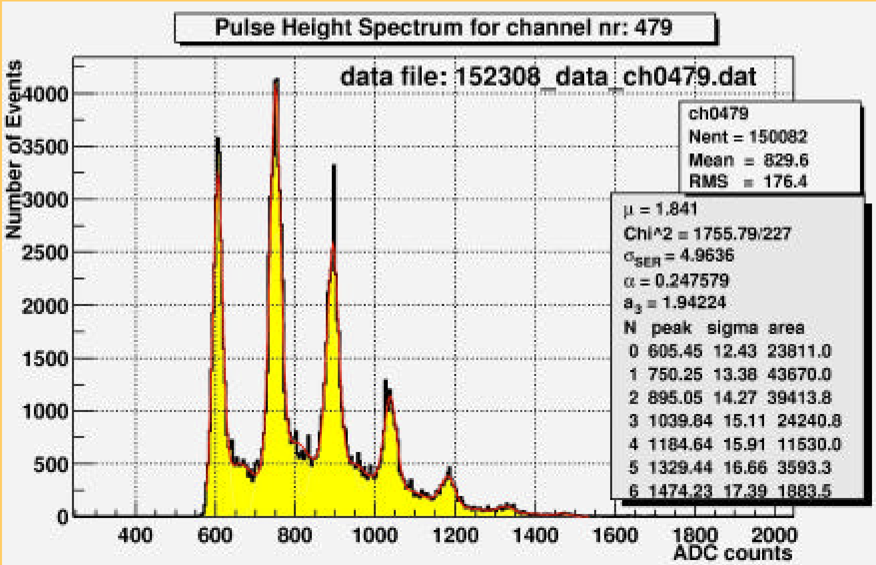

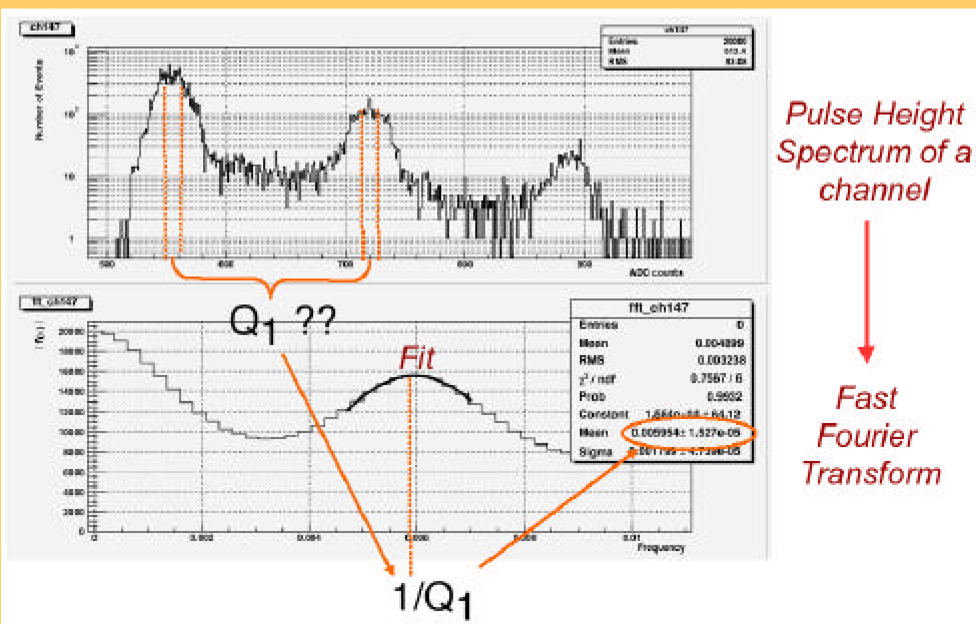

The channel calibration is the measure of the gain value (Q_1). It's the distance between two adiacent peaks.

The Q_1 value can be extracted from the spectrum fit...

… or, more fastly and precisely, from the FFT spectrum.

Gain uniformity over the 2048 pad has been found to be 10%

HPD: Gain Linearity

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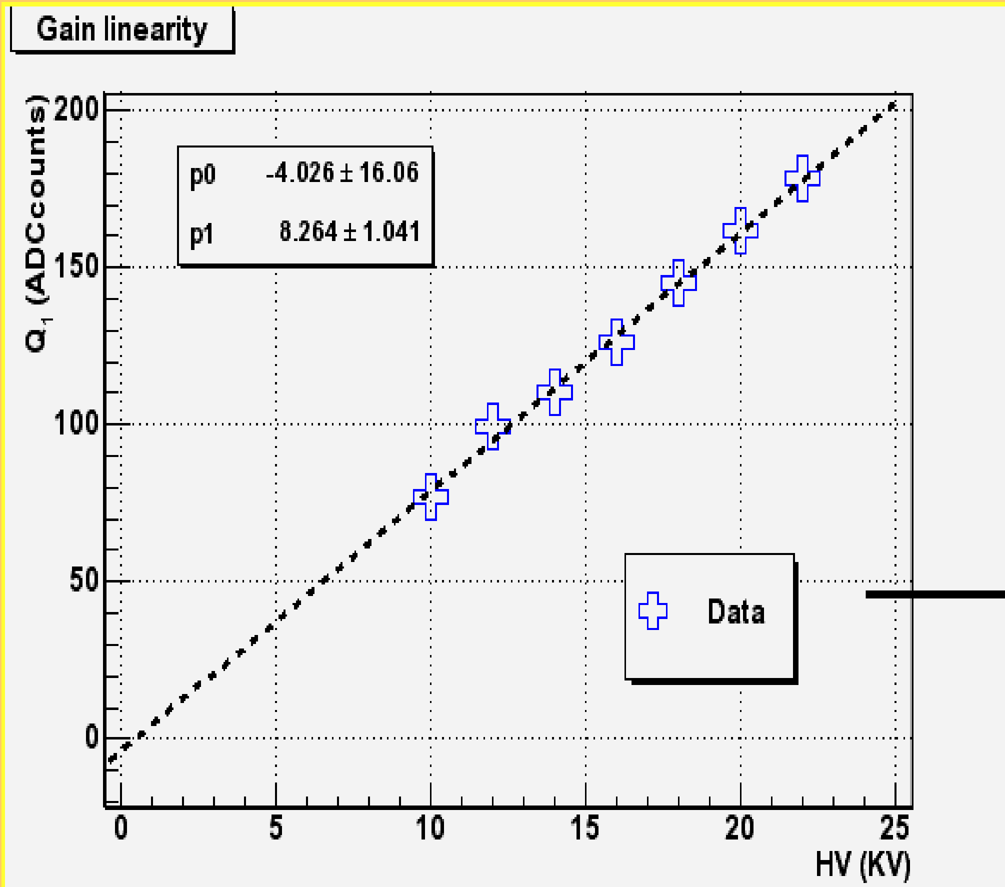
Gain, as expected, was found to be a linear function of the applied voltage.



- This is a clear evidence of the single-step multiplication process.
- This allows a very easy absolute calibration.

$$G_{HPD} = \frac{e\Delta V - K}{3.62eV} \simeq 5000 \; (20\;KV)$$

$$Y[ADC] = p_1\, KV + p_0$$

1) 1 ADC count = 33.43 electrons

2) 20 KV: 5525-134=5391 e^-

3) K = 134 e^- = 480 eV

HPD: Quantum Efficiency

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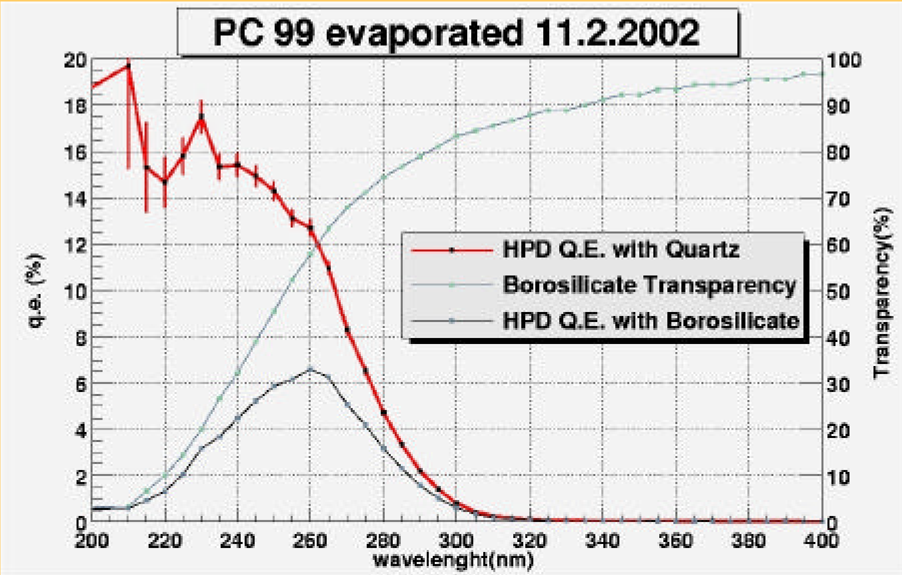
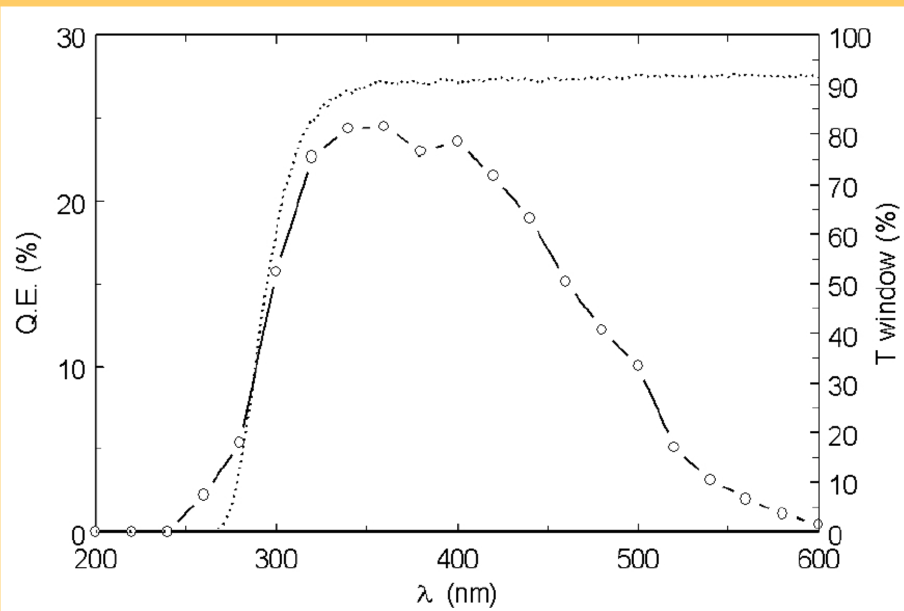


UV Rb_2Te 5” Q.E

The low value measured is due to the borosilicate cut. The red line is the expected value if the HPD had a quartz window.



Visible Bialkali 10” Q.E

Measured spectral response in the visible band. A 24% peak is reached.

HPD Measurements: La Palma Setup

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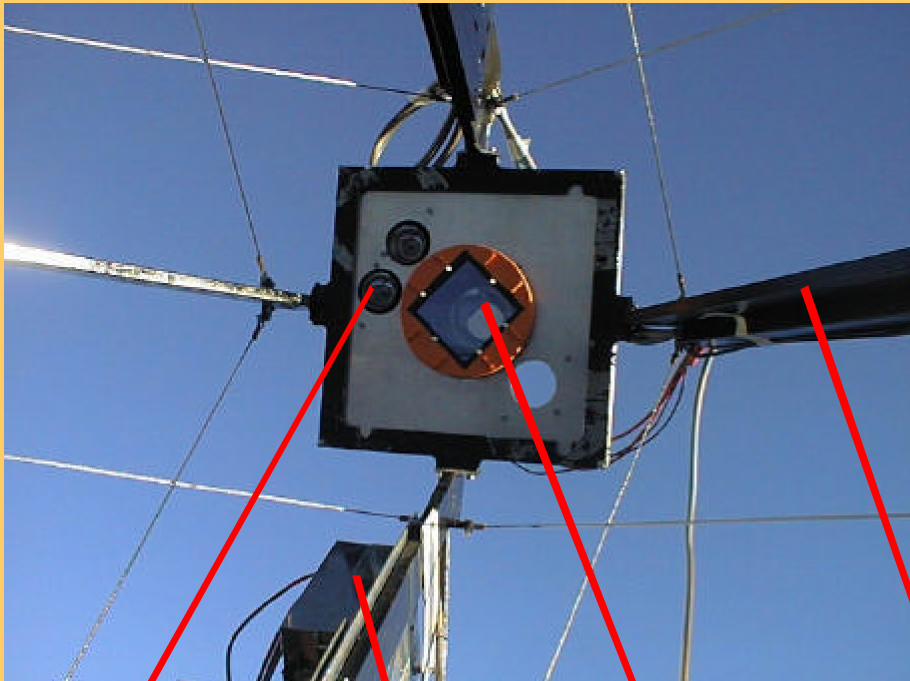
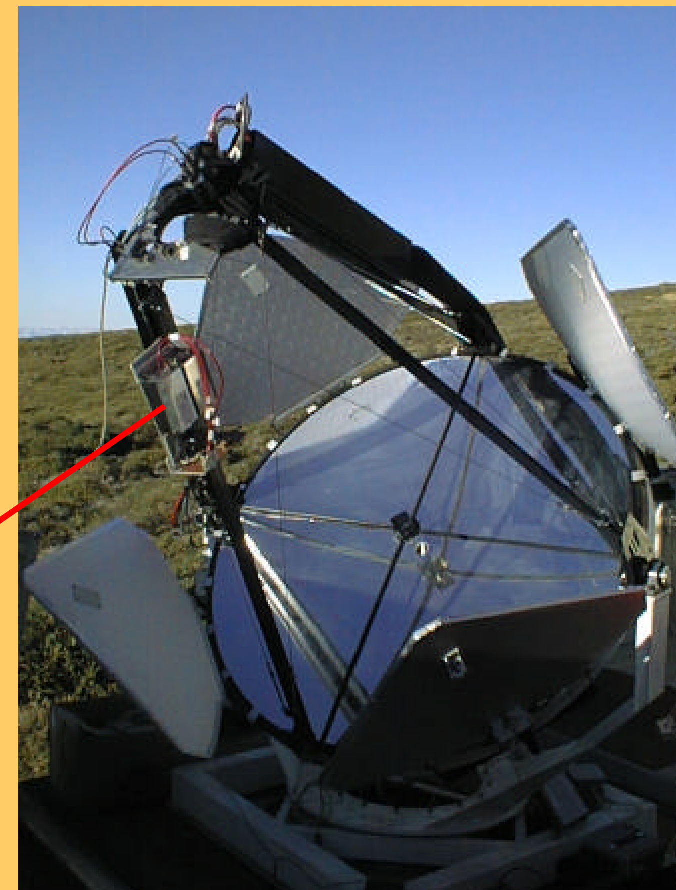
In September 2003 we went to the CLUE site for the first HPD test on the mirror (NSB measure).





Camera support

HPD

Rb_2Te PMTs

HV modules

HPD Measurements: NSB

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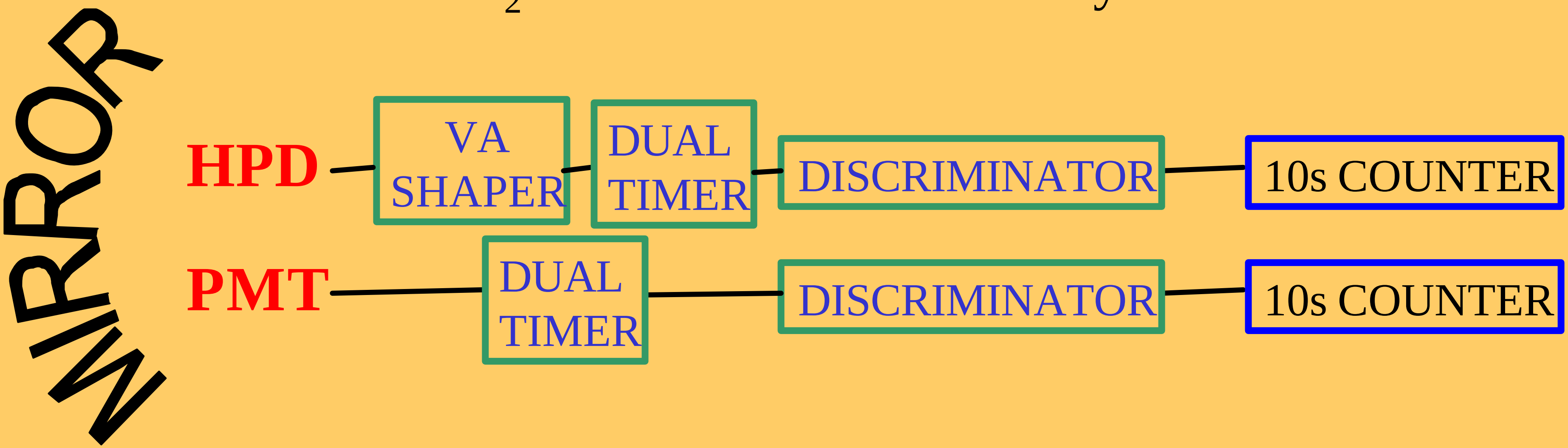
The Rb_2Te 5” HPD was mounted on a CLUE mirror focal plane at La Palma, 2200 m a.s.l.

<u>One pixel</u> (#570) <u>was</u> chosen and <u>used</u> in analogic mode <u>as a PMT</u>.

A Rb_2Te PMT was mounted very close to the HPD



We wanted to:

1) Measure the NSB rate with and without an interferometric filter (300 nm cut).

2) Show the HPD spectrum quality with respect to the PMT one.

HPD Measures: NSB data

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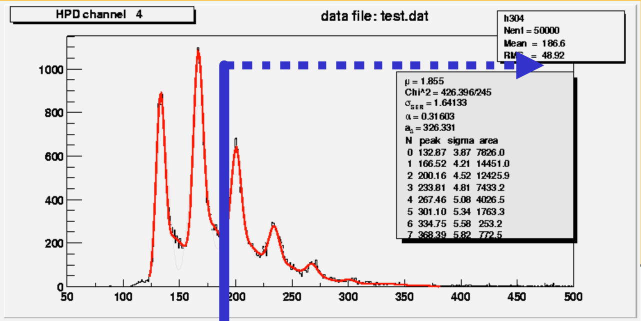
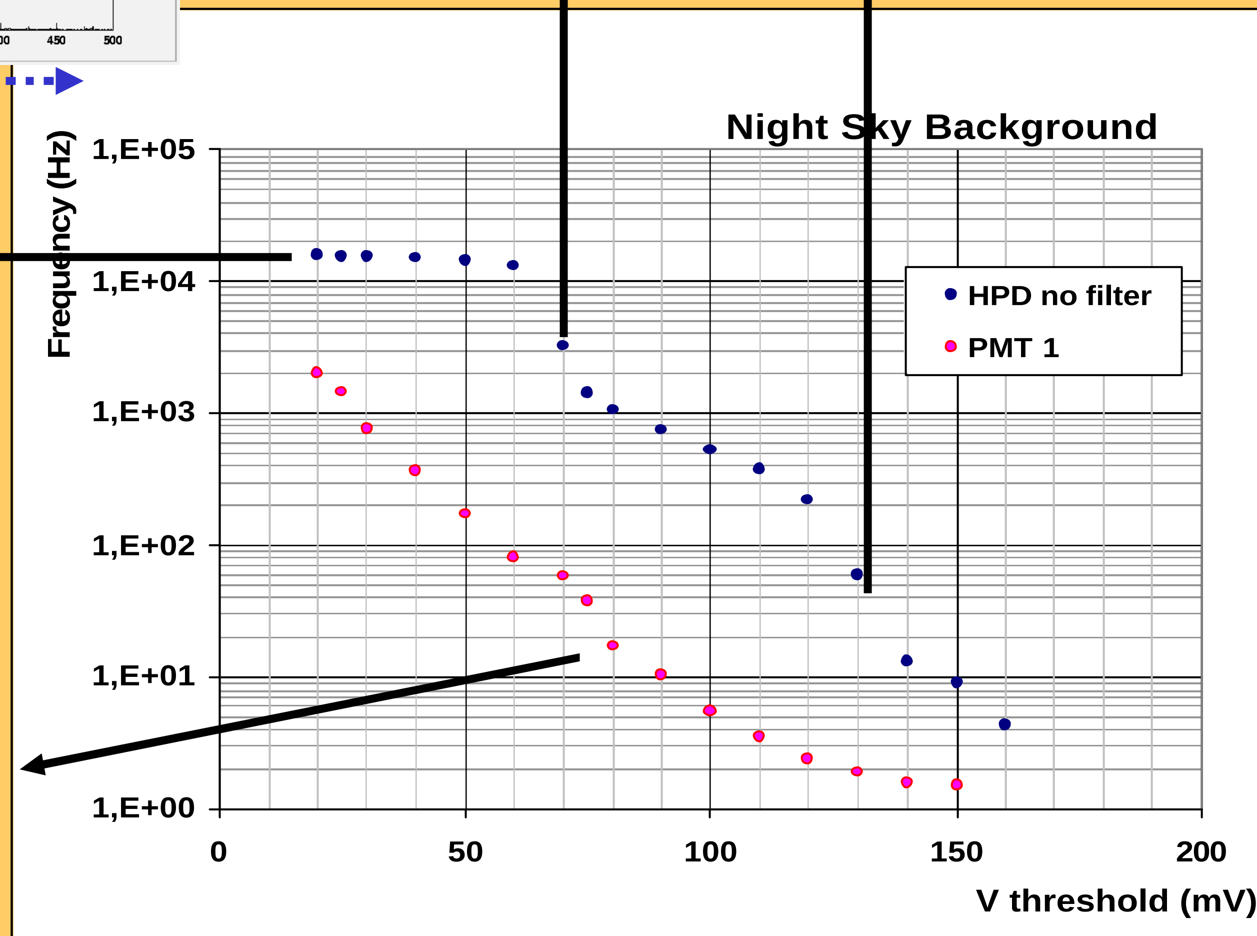


1st phe position

2nd phe position

NSB total signal rate: 15 KHz without filter



The PMT behaviour shows no steps: no separated peaks

HPD Measures: The filter

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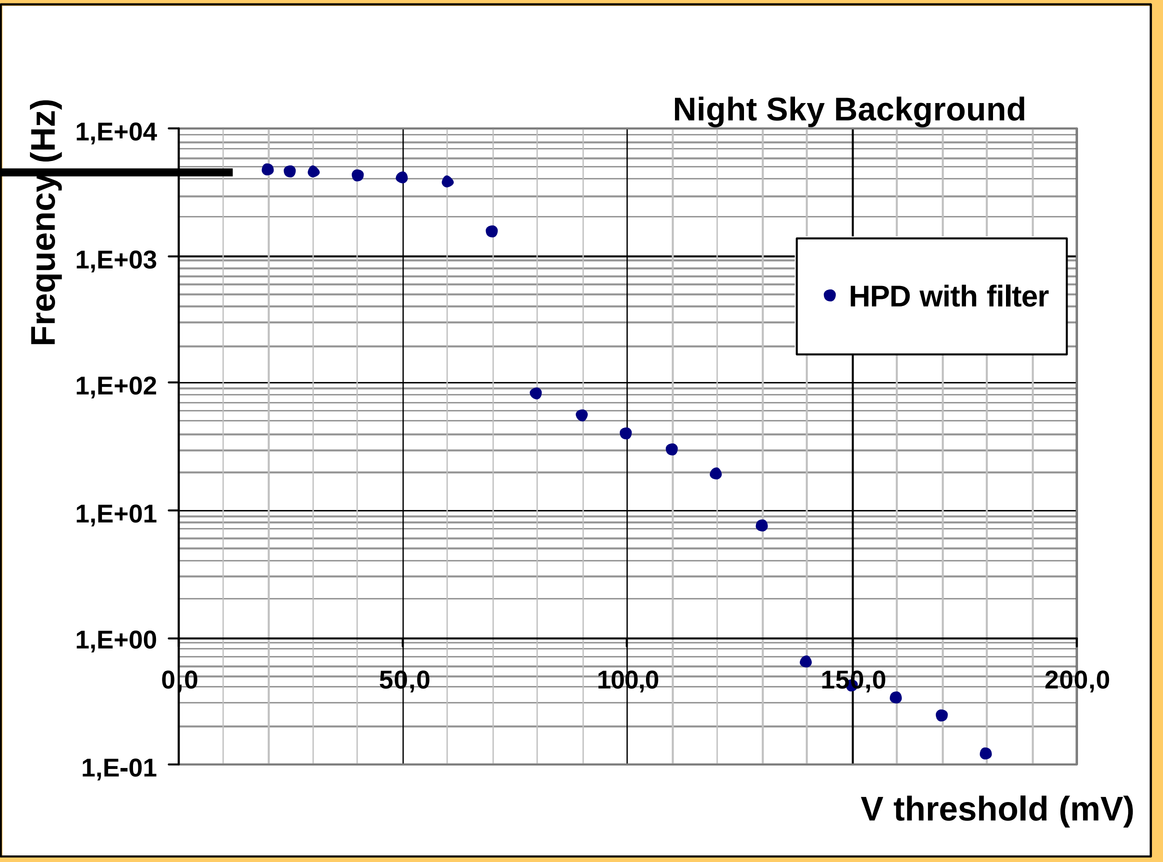
NSB total signal rate: 4 KHz **with** filter



Using the interferometric filter (cut at 300 nm) the rate goes from 15 to 4 KHz.

11 KHz counts are due to light with $l > 300nm$

Note that our QE for these frequencies was $< 1\%$!!

HPD Schedule

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- 5” solar blind Rb_2Te Photocathode (QE 15%) DONE
- 10” tube with Bialkali Photocathode (QE 25%) DONE
- NSB measurement @ La Palma with HPD in the mirror focal plane DONE
- 10” tube with QUARTZ window and Rb_2Te with very special technology to seal quartz window to glass body, developed together with PHOTEK and SVT 2003
- 10” tube with autotriggering electronics (VA-TA). Ready for CLUE. 2004

HPD Sunset View

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THE END

HPD Measures: NSB 2

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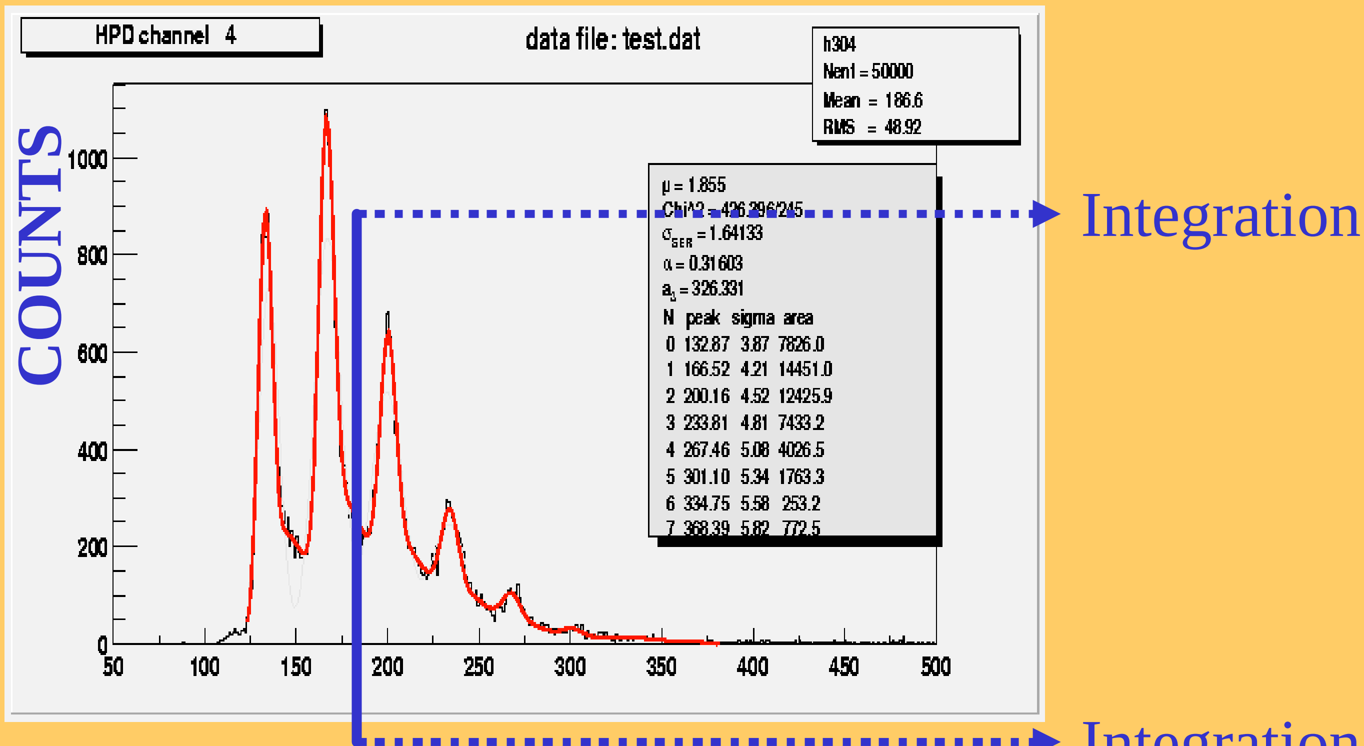
Setting a threshold for the integration is choosing the integration starting point.



We expected to see a stair-shaped, decreasing data plot

HPD Application to ANTARES

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