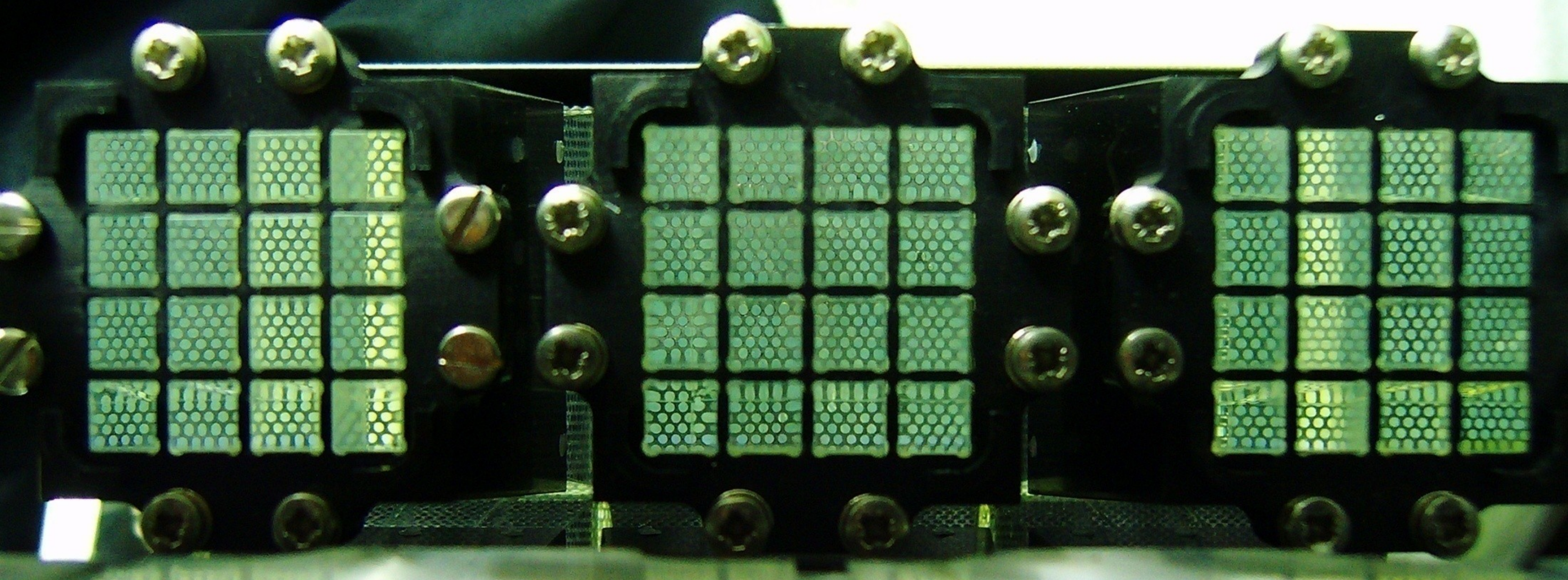
# A prototype of fine granularity lead-scintillating fiber calorimeter with imaging read-out



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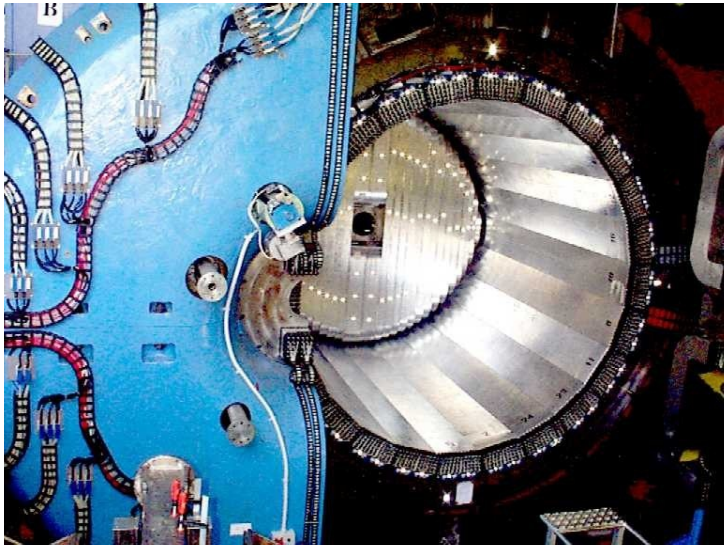
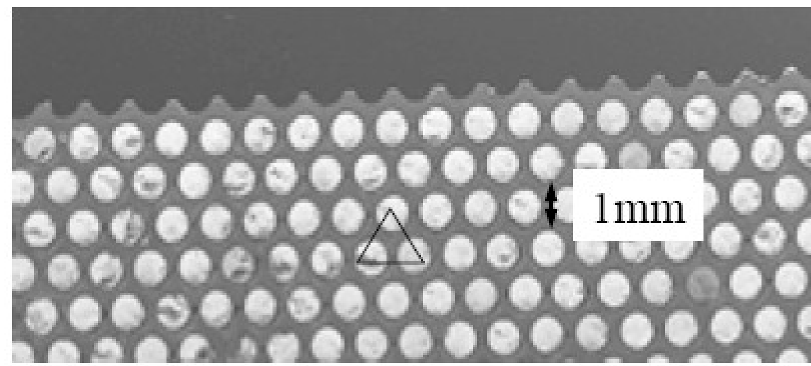
11° Topical Seminar On Innovative Particle and Radiation Detectors

1-4 October 2008, Siena Italy

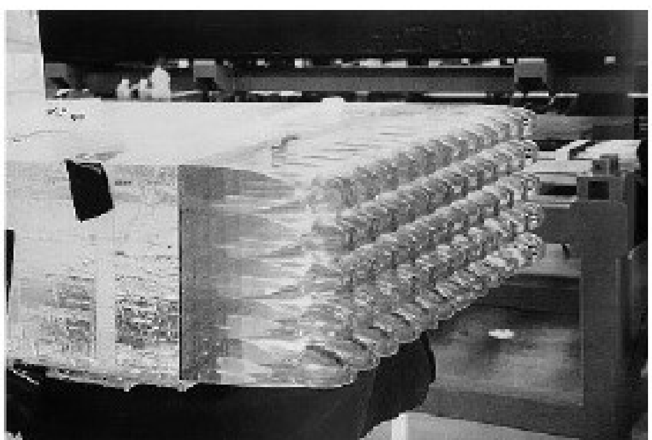
# The starting point: the KLOE Calorimeter



| | |
|---|---|
| Volume composition | Fib : Pb : glue = 48 : 42 : 10 |
| ⟨ Density ⟩ | $\rho \sim 5$ g cm$^{-3}$ |
| Rad. Length | $X^0 \sim 1.2$ cm |
| Light att. Length | $\lambda \sim 400$ cm |
| Sampling fraction | 12 % |




**Light readout in 4.4x4.4 cm$^2$ cells on both sides via light-guides + fine mesh PMs**



**Excellent performances :**

**$\sigma_E/E = 5.7\% / \sqrt{E(\text{GeV})}$**

**$\sigma_T = 54$ ps $/ \sqrt{E(\text{GeV})} \oplus 50$ ps**

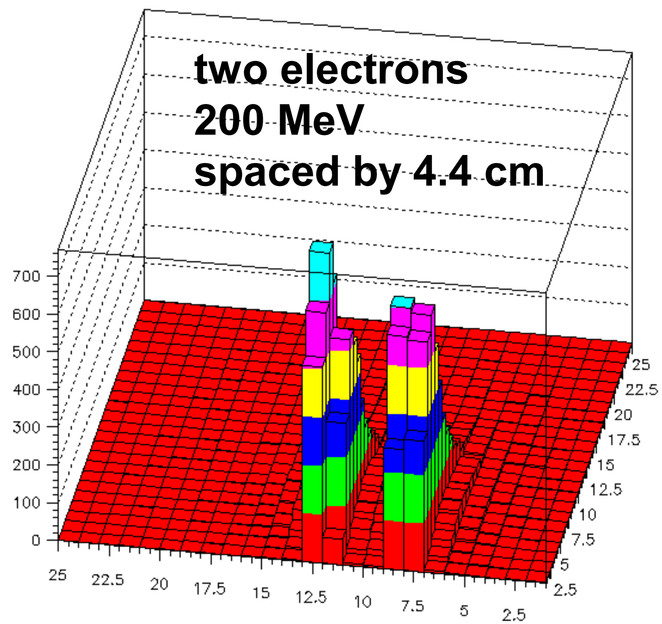
PID mostly from TOF

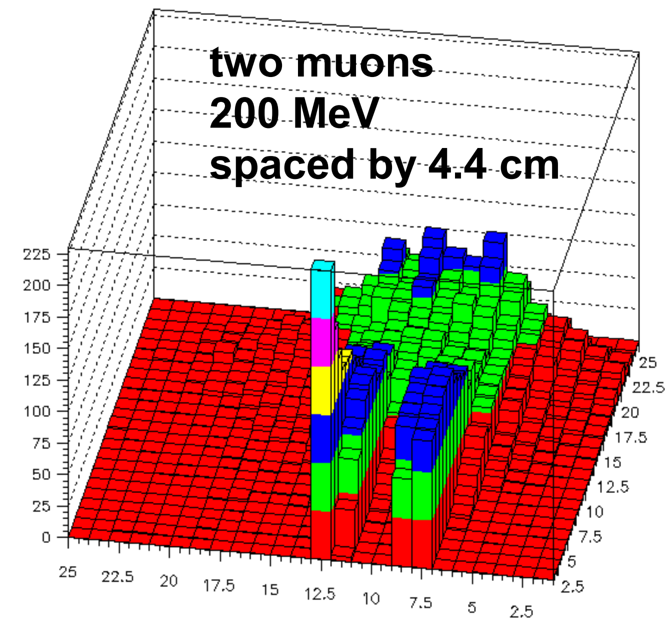
# Motivation

**Exploit the KLOE calorimeter homogeneity to build a dense imaging device.**
**Accurate cluster shape reconstruction would allow:**

- **efficient PID**
- **near energy depositions separation**
- **study details of the energy release process for different particles types and tune clustering algorithms accordingly.**

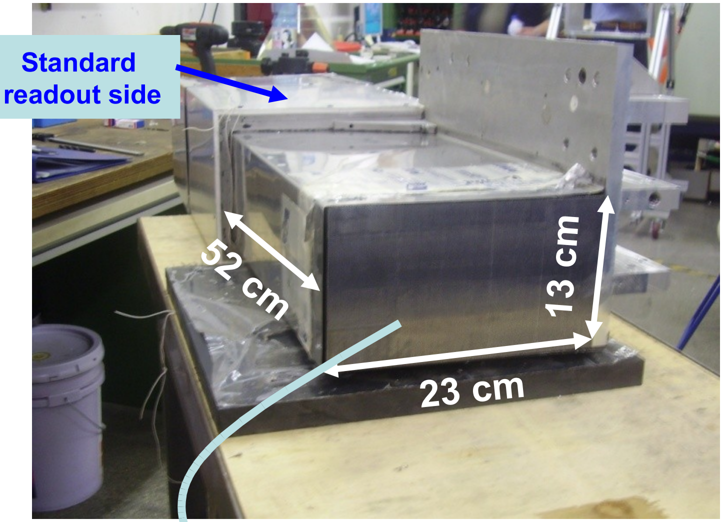
**Example from detailed FLUKA simulation:**

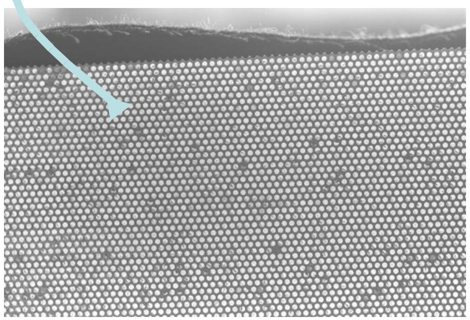



**Note: this idea has started in the KLOE-2 project, but its implementation into an upgrade of the KLOE calorimeter turned ou to be very difficult. Then it has to be considered an independent development.**

# The concept : thin light guides + multi-anode PMs



A KLOE calorimeter prototype was available

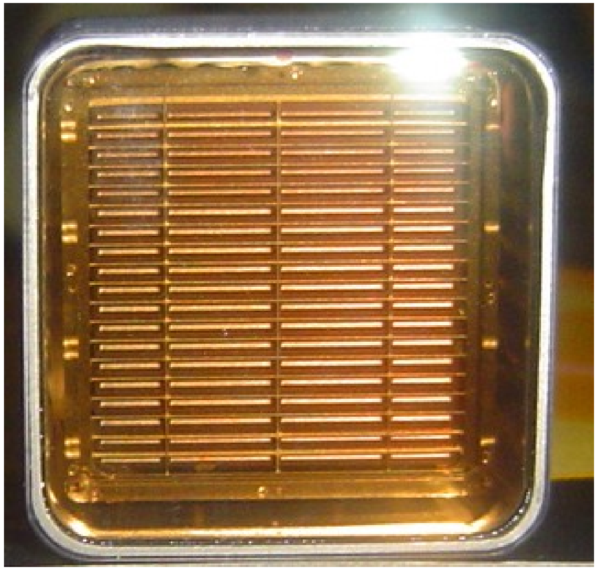
Standard light readout already present on one side: 15 cells 4.2 x 4.2 cm² over 5 planes, each instrumented with a standard 1" PM.

Our project:

- Collect the light with segmented guides
- Detect the light with multianode PMs
  1 KLOE cell → 16 pixels

3 x 5 4.2x4.2 $cm^2$ cells → 240 small cells 1.05x1.05 $cm^2$

# The multi-anode PM



**Hamamatsu R8900-M16**

***Window material***: **Borosilicate glass**

***Arrangement and Type***: **4 x 4 grid**

***Number of channels:*** **16 (each 5.7x5.7mm$^2$)**

***Effective Window Area***: **23.5x23.5mm$^2$**

***Photocathode material***: **Bialkali**

***Spectral response range***: **300 to 650 nm**

**Compact design**

**Operation HV: 800-900 V**

**A signal with sum of all the 16 last dynodes is also provided**

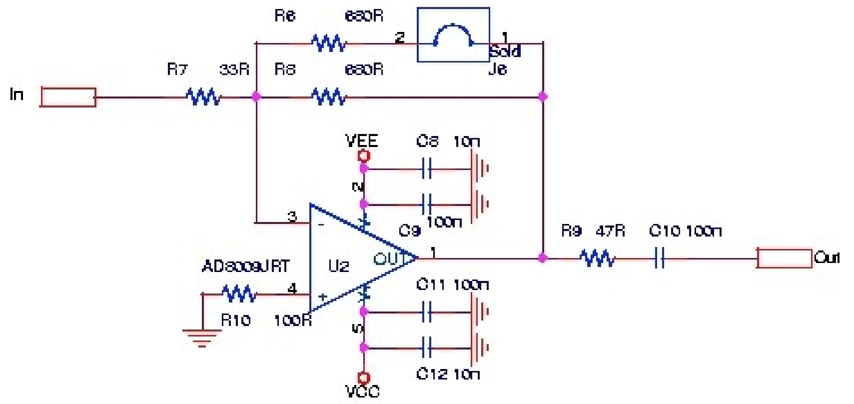
**Up to 30% gain variation between the 16 pixels**

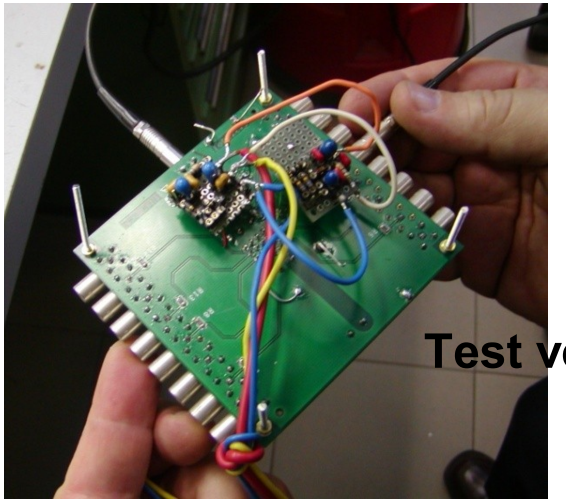
**We purchased 12 standard R8900 + 3 with higher quantum efficiency**

# Multi anode signal pre-amplification stage

**A dedicated 16+1 channel pre-amplification stage has been developed using simple inverting x10 amplifiers.**

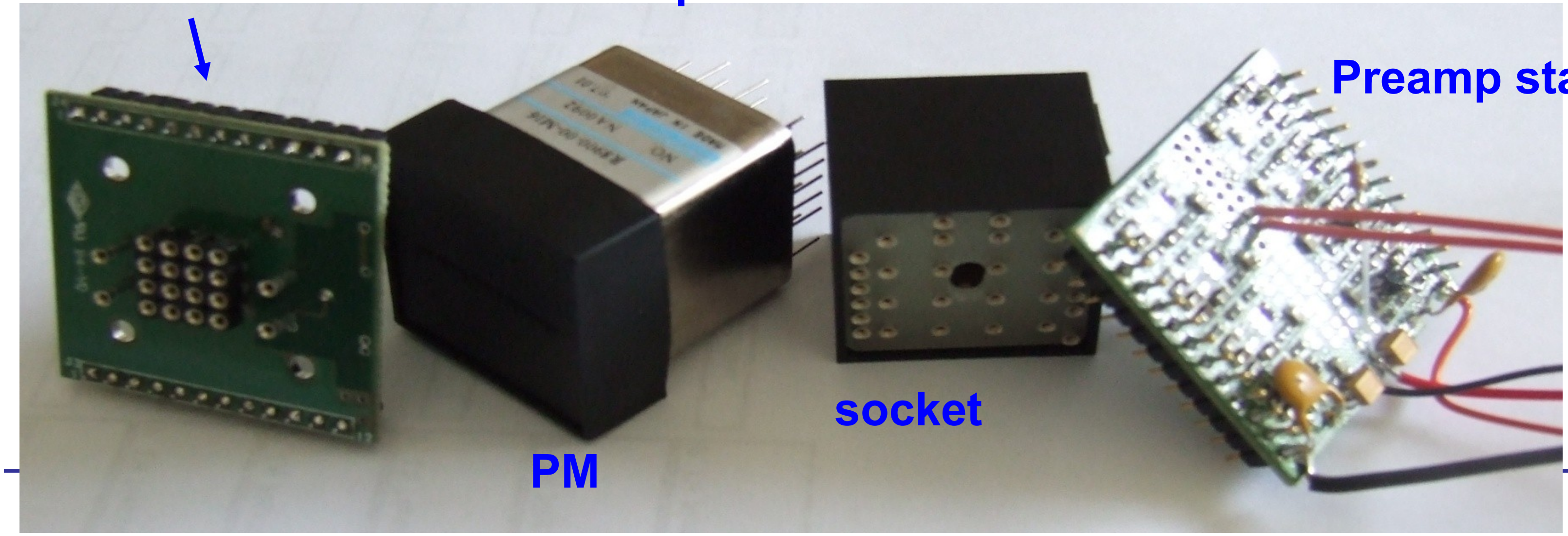
**Positive signals are needed to be able to use the KLOE electronic chain.**



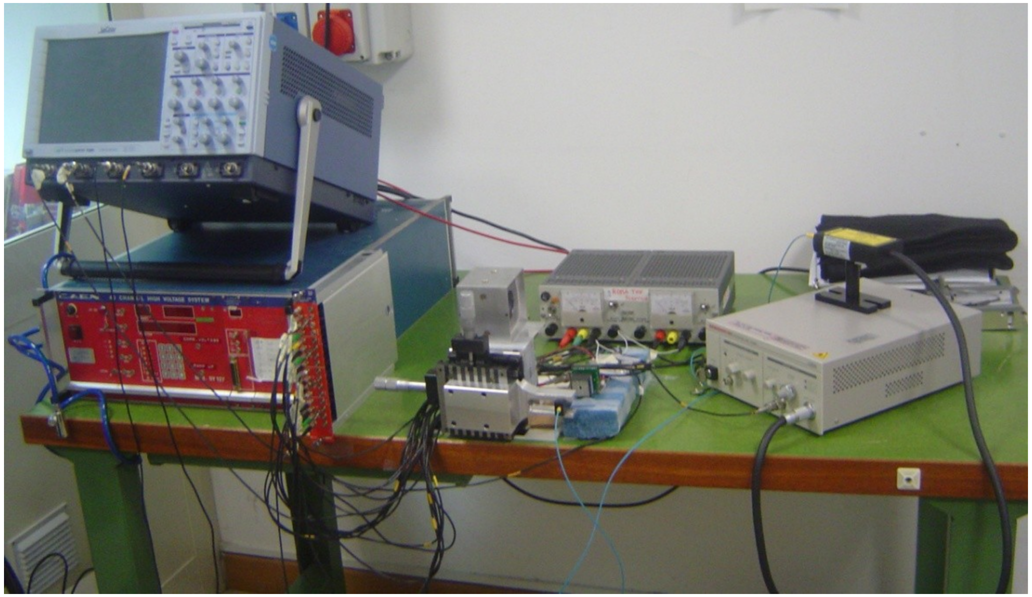



**Test version**

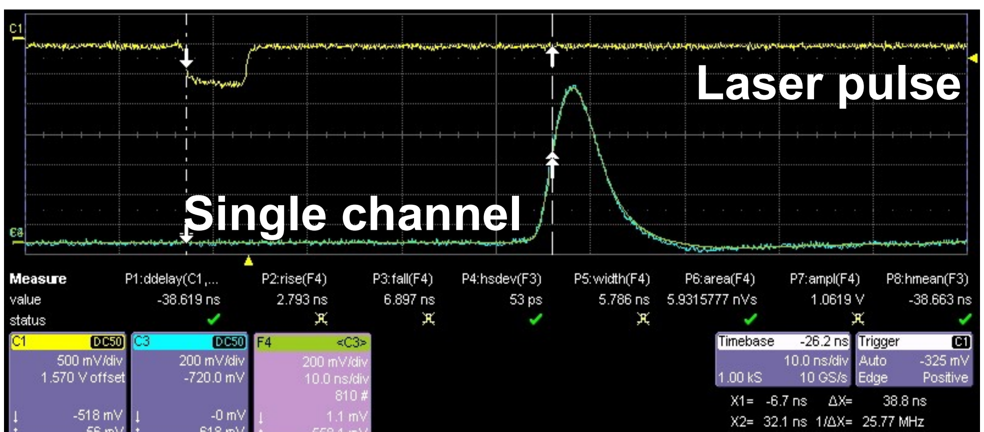
**16 ch HV distribution board also produced**



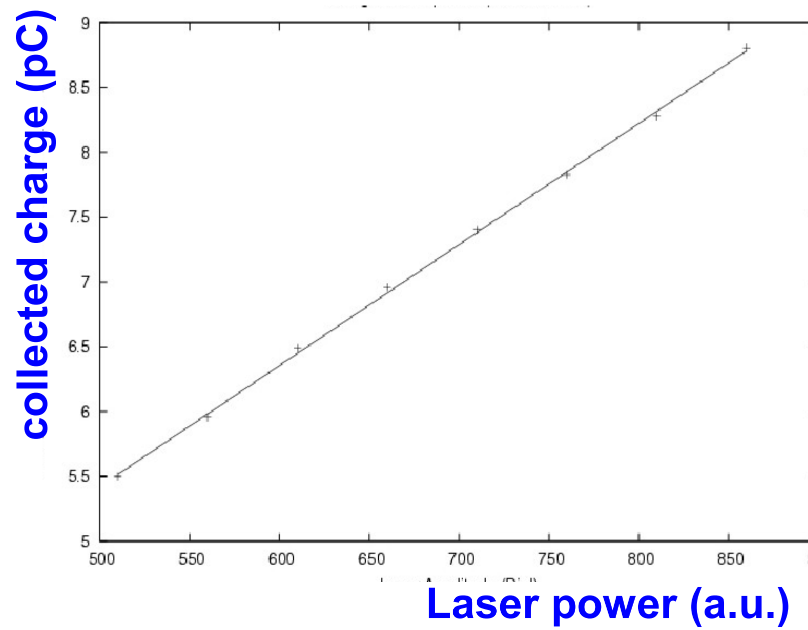
# Multi anode characterization



A ps laser pulse used to illuminate single pixels and study the multi-anode response.



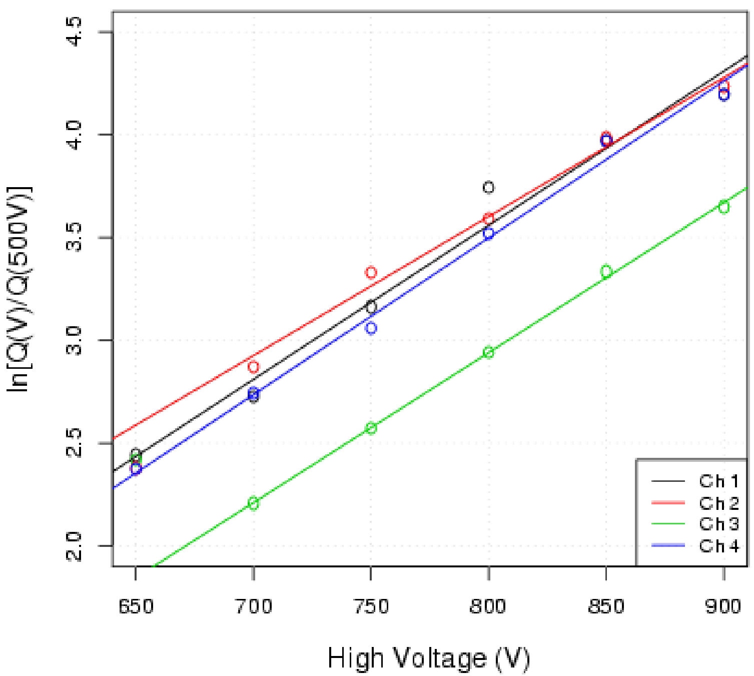

## Linearity

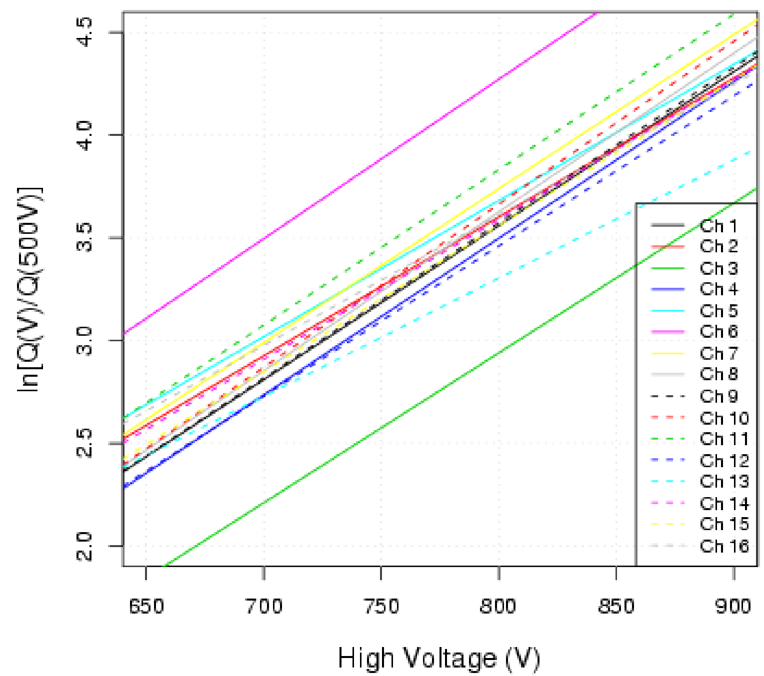


# Gain (non) uniformity

**For each channel the response has been measured relatively to the one @ 500 V**

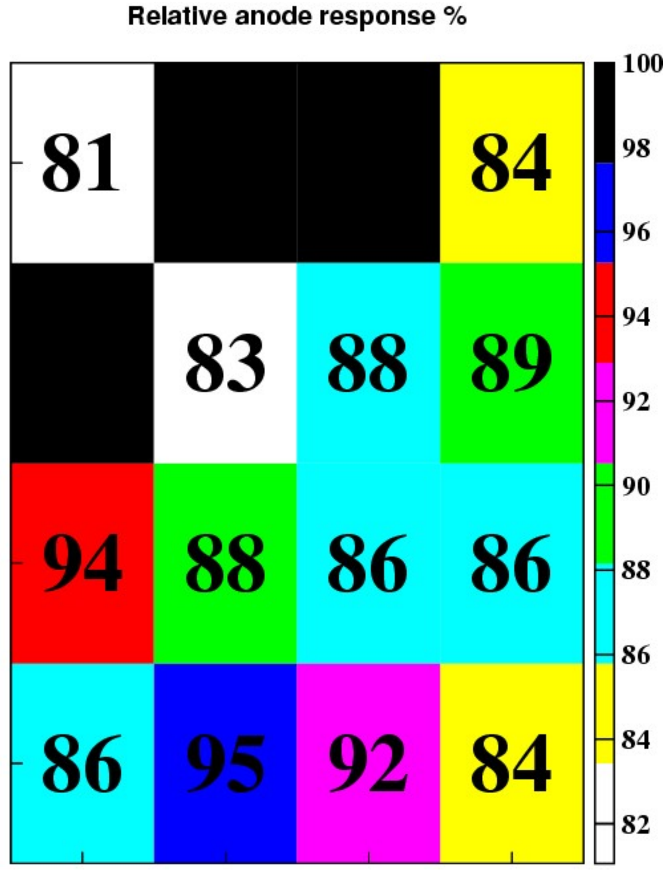
- **Slopes with HV are essentially the same**
- **Offset is quite different from channel to channel**

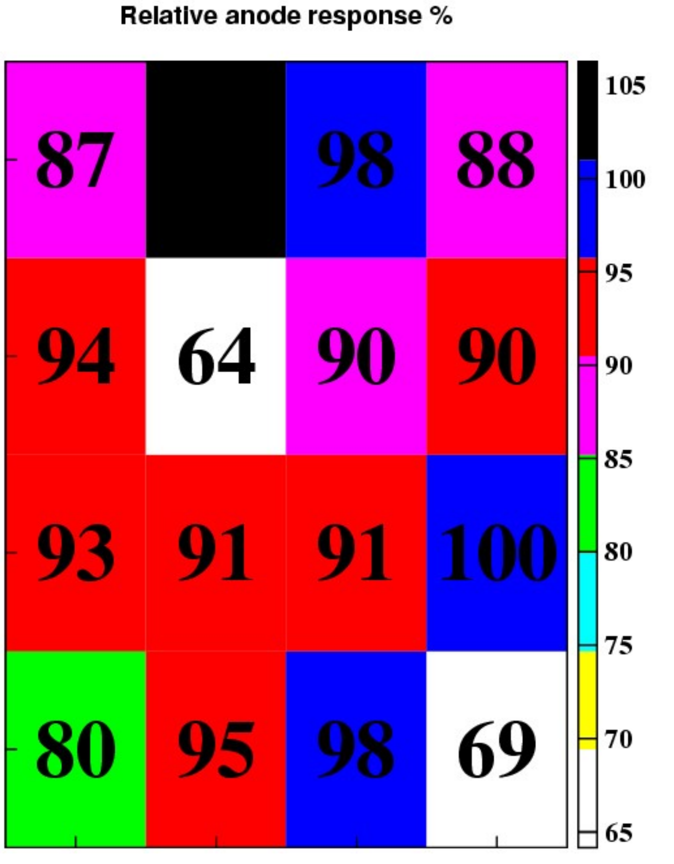


# Gain variation @ 800 V

**Two sample cases :**



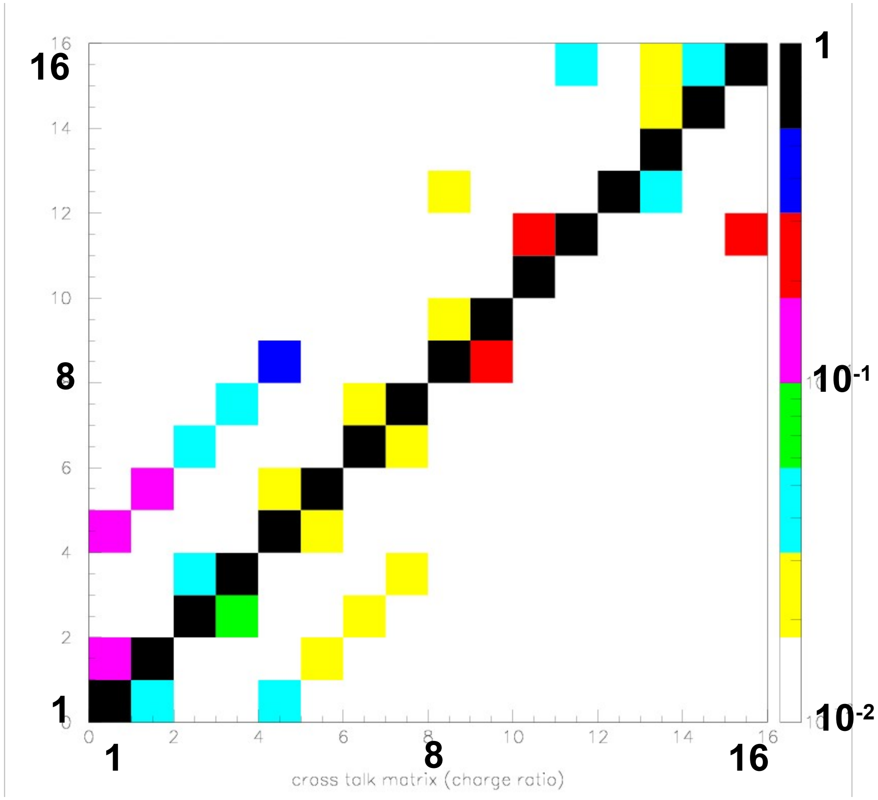




**Gain non-uniformity measured for all our multianodes.**
**Similar behaviour always found**

# Cross talk

**Laser pulse injected in individual pixels,**
**Charge response measured in all the others.**

**For each PM we obtain a 16x16 cross talk matrix:**




**Electronic cross talk between nearby channels can be as much as few %**

**Non adjacent channels have almost negligible cross talk**

# Light guides

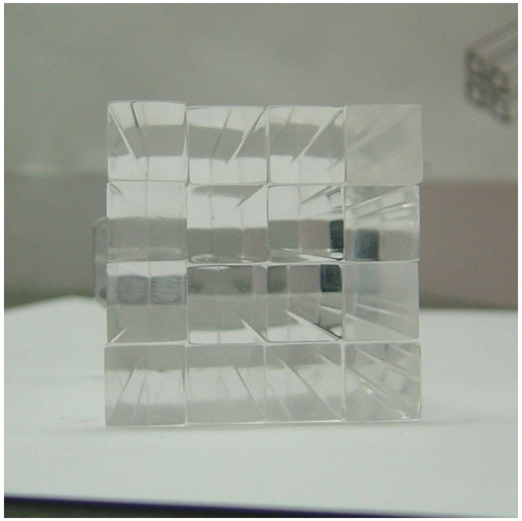
**Want to map 16 contiguous cells 1.05x1.05 $cm^2$**

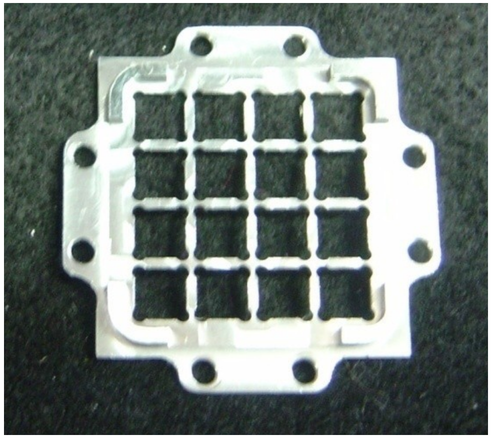
**into 16 cells 0.53x0.53 $cm^2$ each separated by a 0.11 cm dead zone** (multinode cell area is indeed 0.57x0.57 cm2).

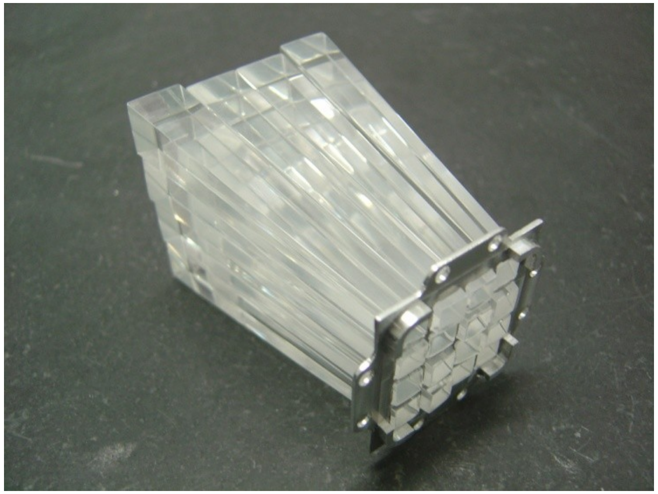
**UV transparent plexiglass BC800 has been used**, to fully match the R8900 spectral response

**Not trivial mechanics:**

- all surfaces at different angles
- guides are 6 cm long and touch each other only on the calorimeter surface.
- a small aluminum grid keeps the 16 guides in place at the PM side





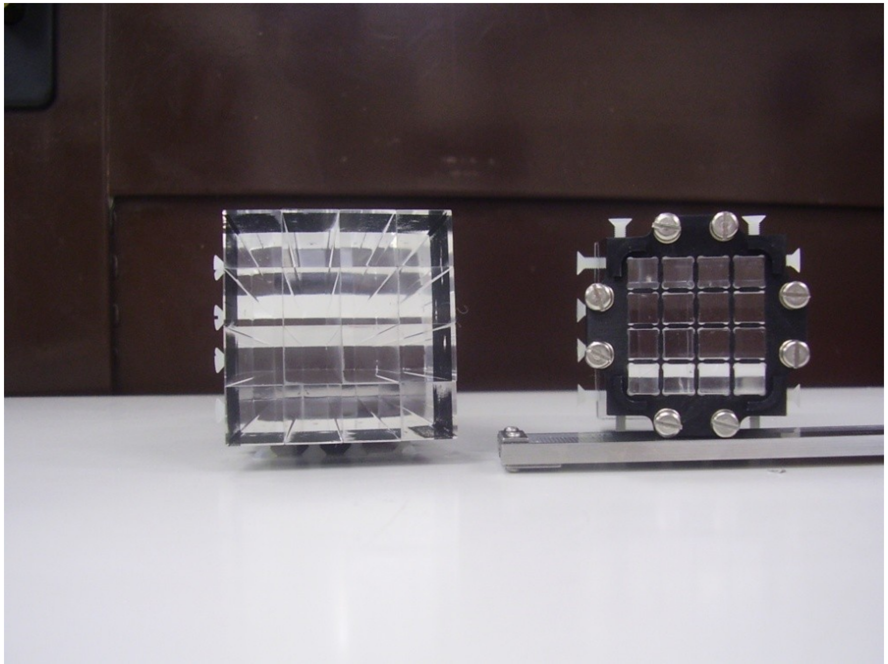


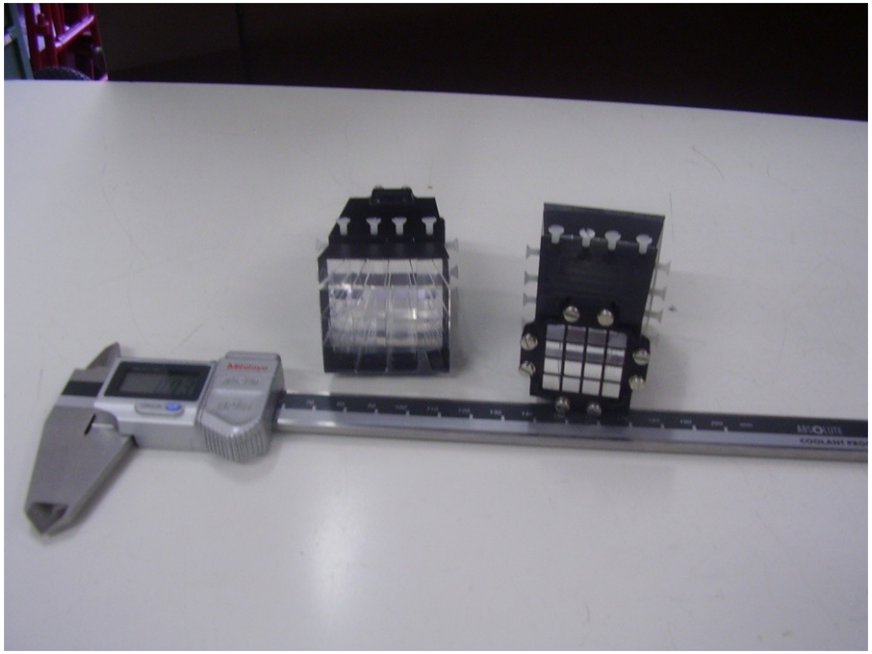
# Light guides: final product

**No black painting or envelopes on individual guides.**

**Air/plexiglass surface considered the best compromise.**

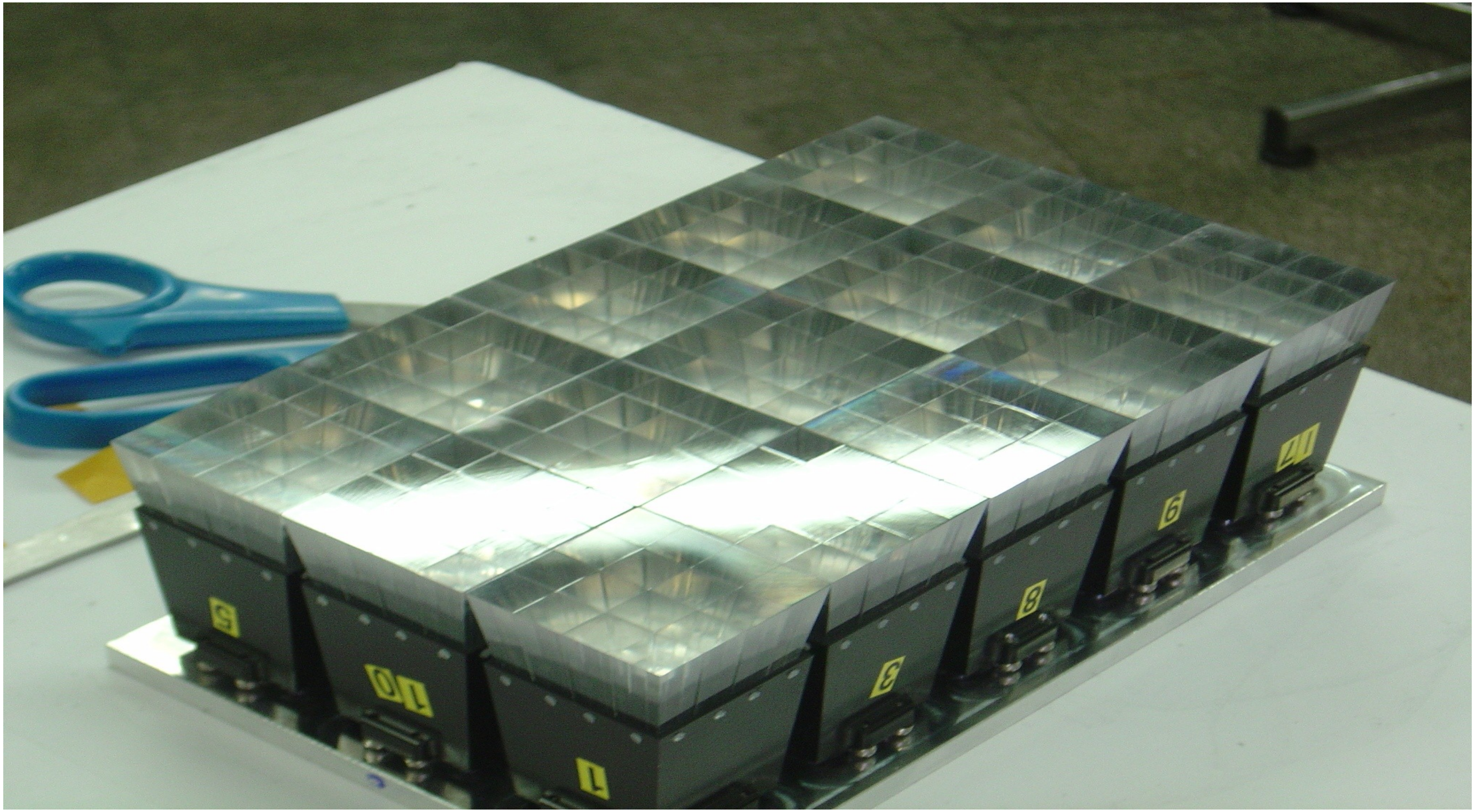
**Optical cross talk will have to be checked out.**



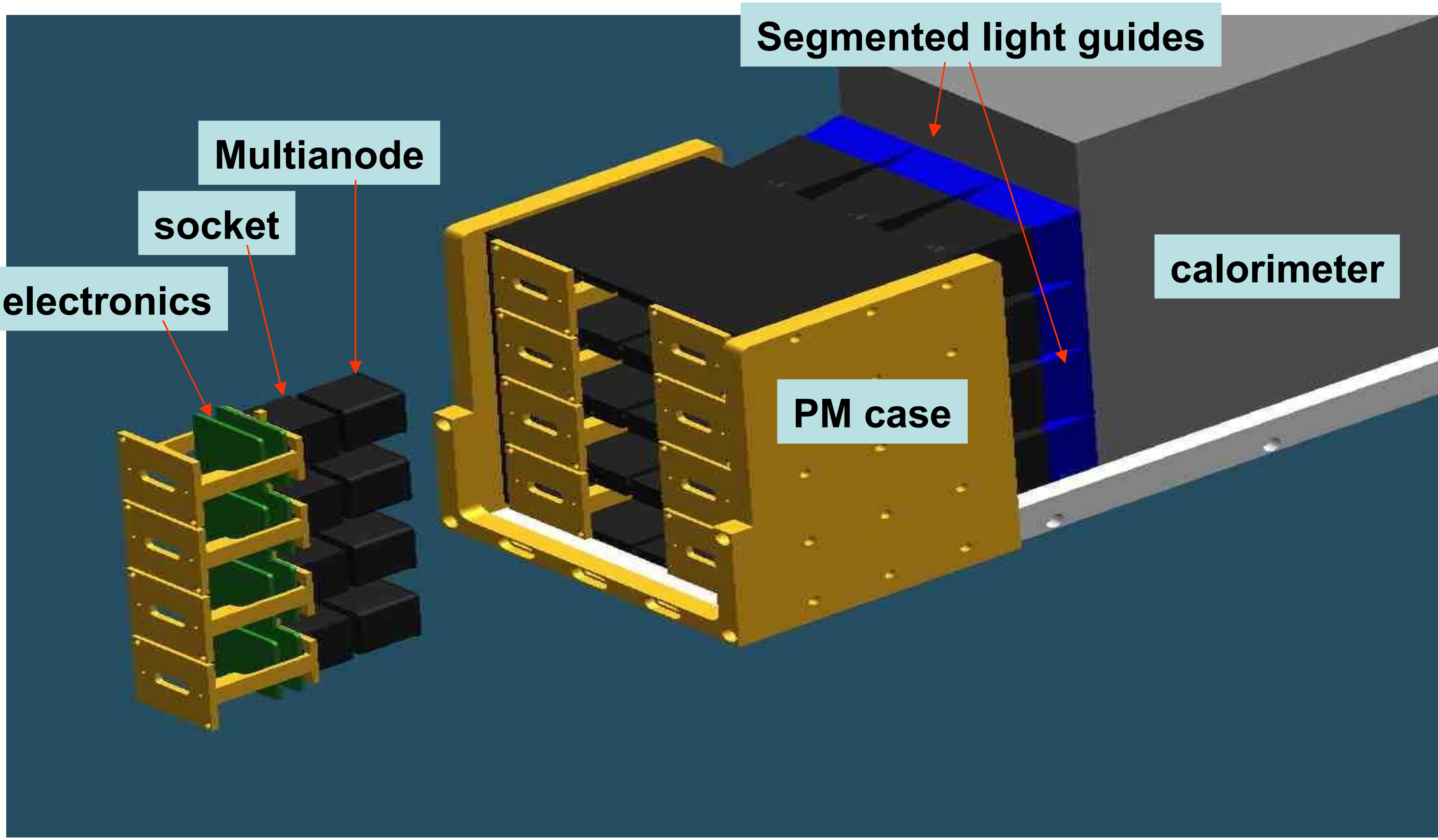


## Final assembly in a 3 x 5 matrix

## Ready to be glued on the calorimeter surface

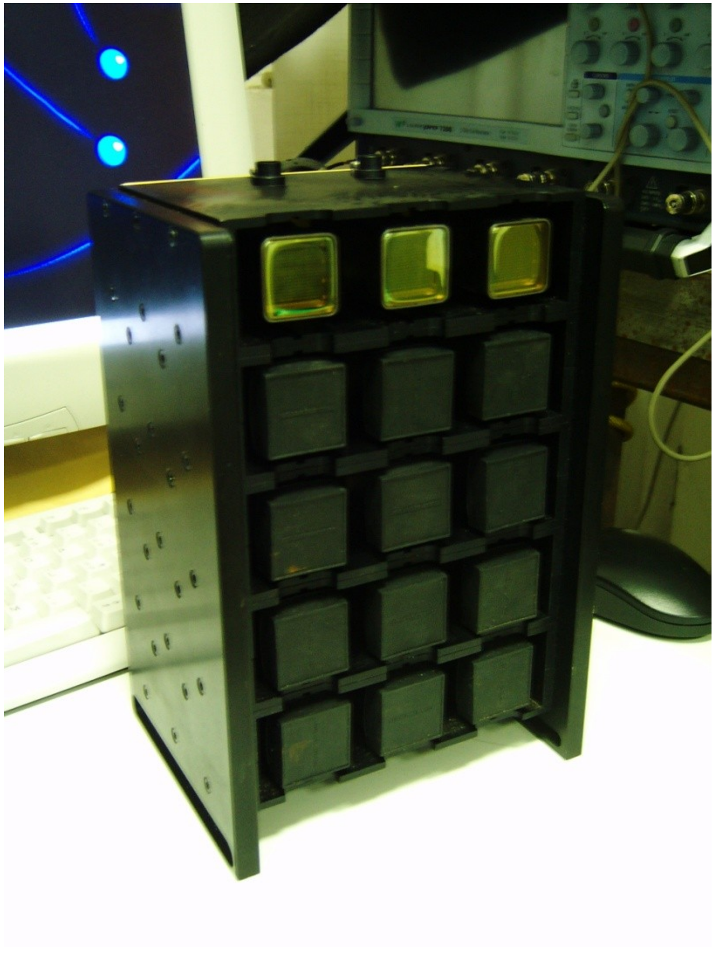


# Full mechanical design

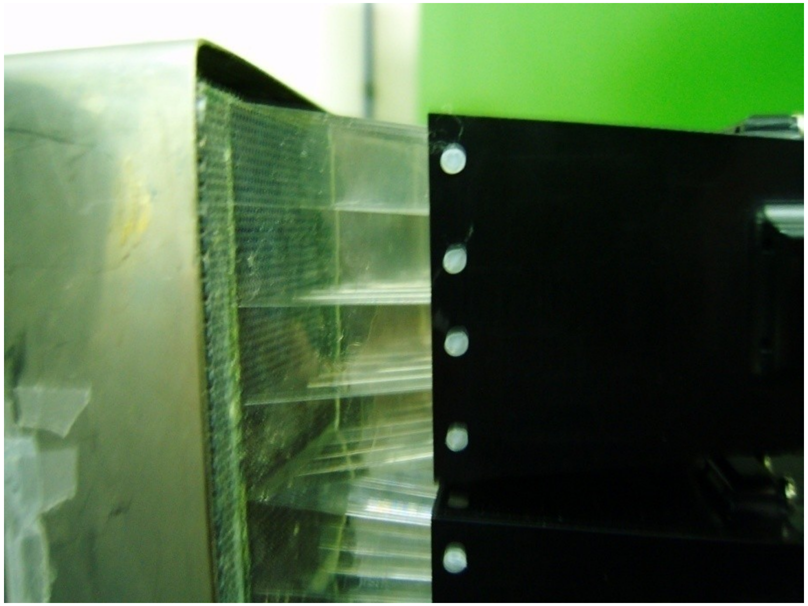


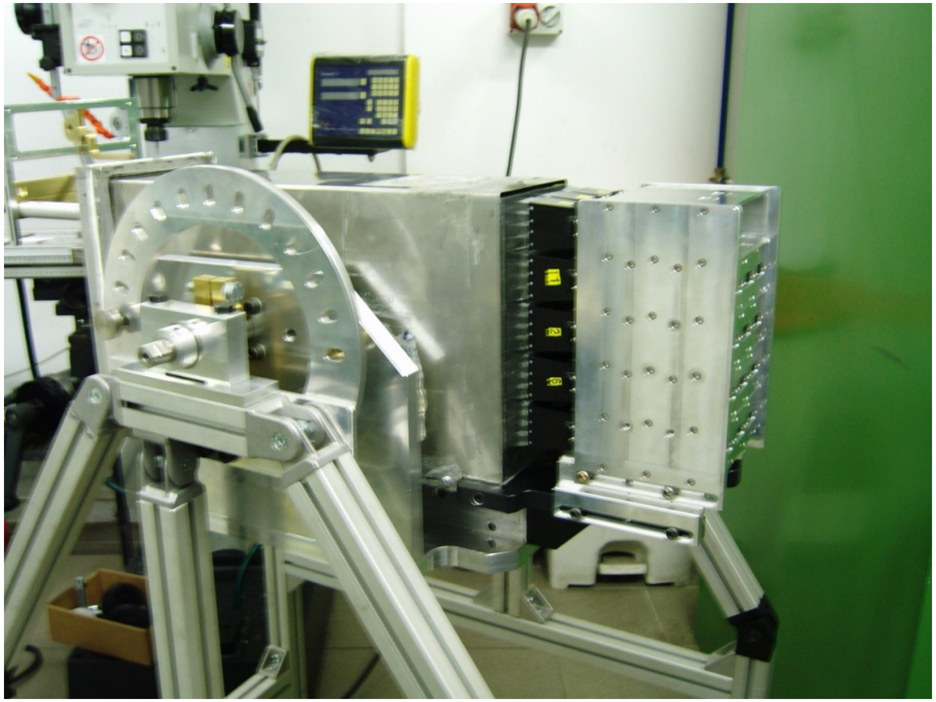
# PM case holds also HV distribution and preamp board

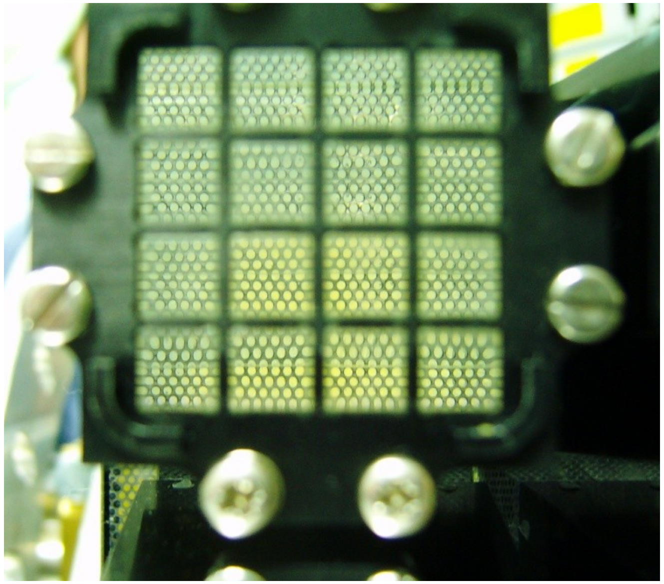
## The full case is light tight



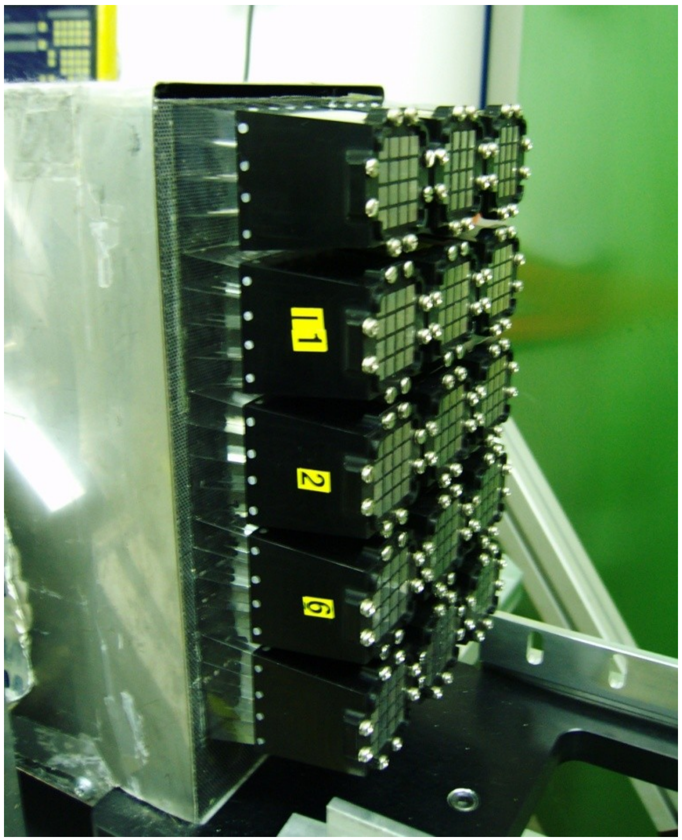
## Prototype mounted on a support that allows $180^0$ rotation

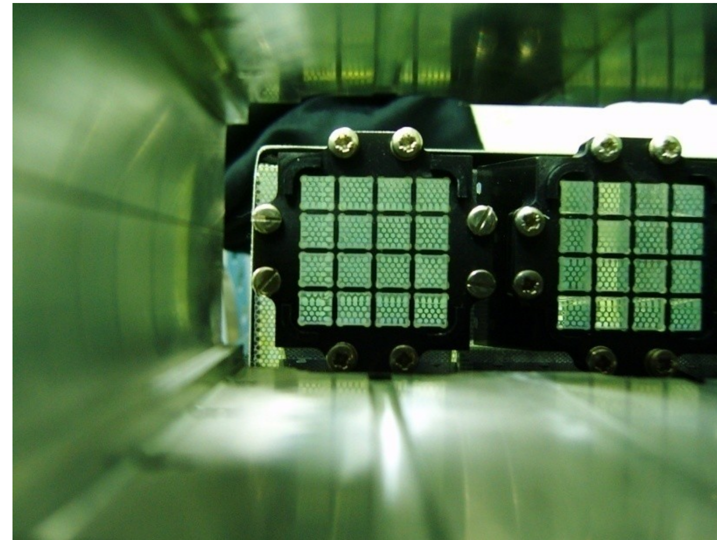






# Finally the optical contact !



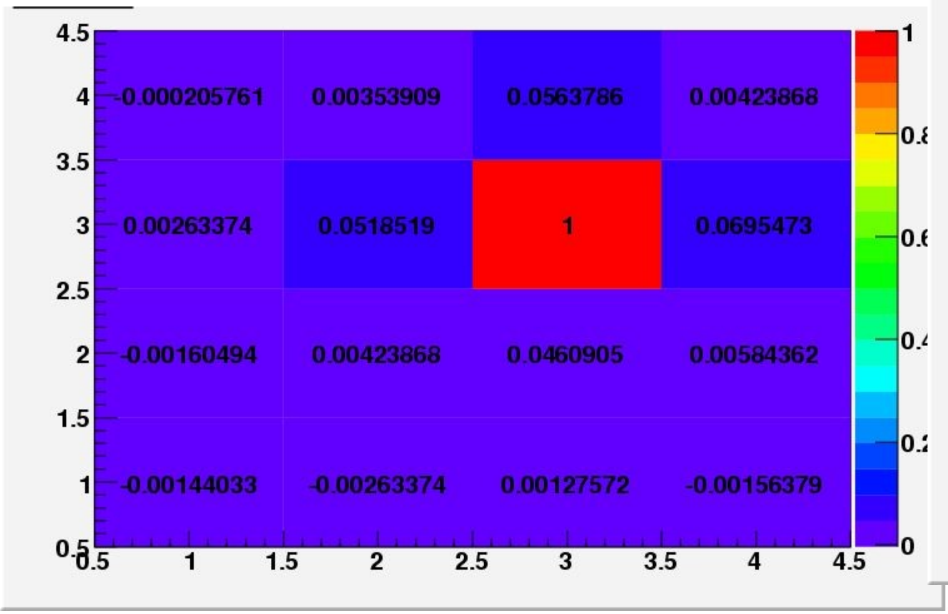


# Cross talk : electronic vs optical

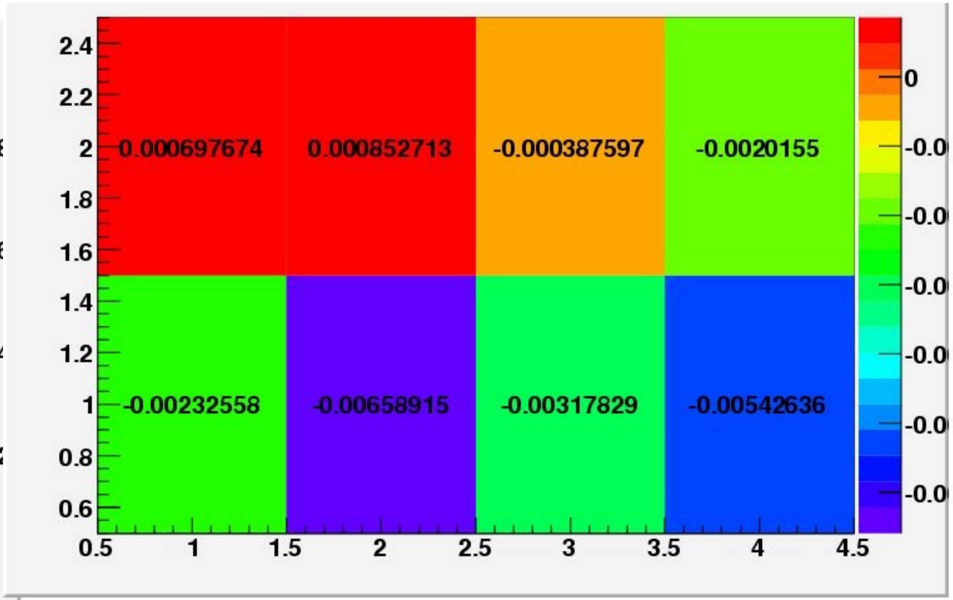
**We dismantled the opposite side light readout system (later on we reinstalled it).**

**We injected the ligh pulse on individual fibers on this now free calo side and study the response of the pixels on the other side:**

**Single multi anode cross talk confirms what previously observed: few % on nearby channels.**




**The response of the two nearest row of the adjacent PM show really Negligible optical cross talk !!!**



# Readout and Data acquisition

**It is fully made with KLOE electronics:**

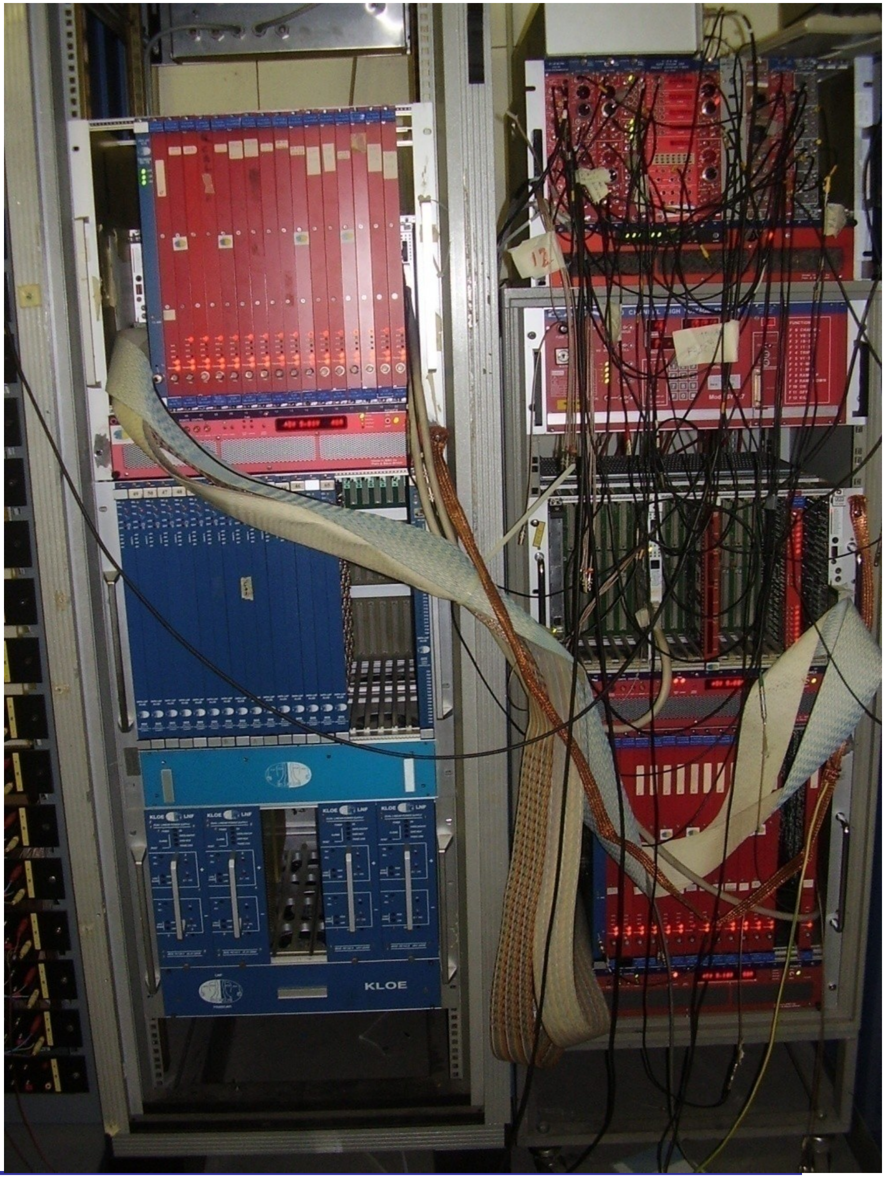
- **signals are first splitted, discriminated and summed (SDS boards)**

- **KLOE ADCs and TDCs are then used to digitize them**

- **DAQ goes via asyncronous readout Using 2 custom buses and a chain of ROCKs (read out controller for KLOE)**

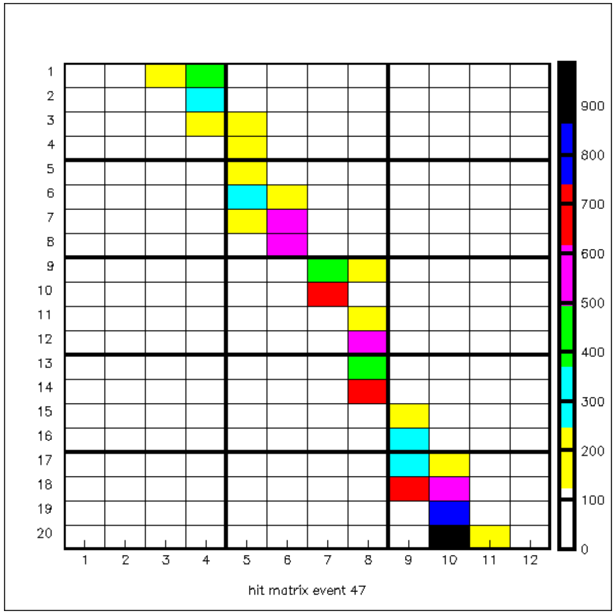
- **online CPU is the only new element: a Motorola MVME6100**

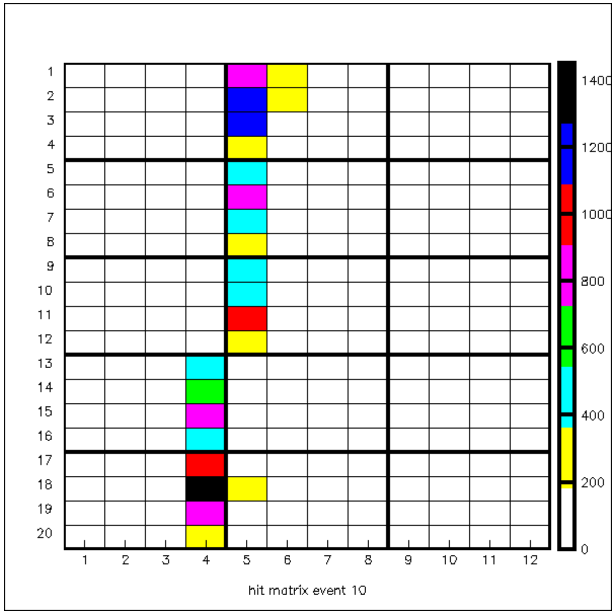
- **Trigger exploits the signal sums provided By SDS, but it is simply done by NIM**

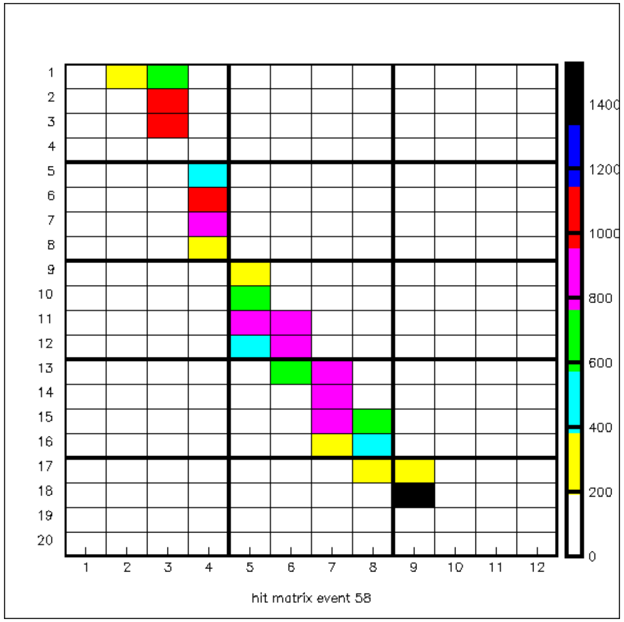


# First cosmic rays !

## Calorimeter in auto-trigger on the coincidence of first and last plane of m-anodes:



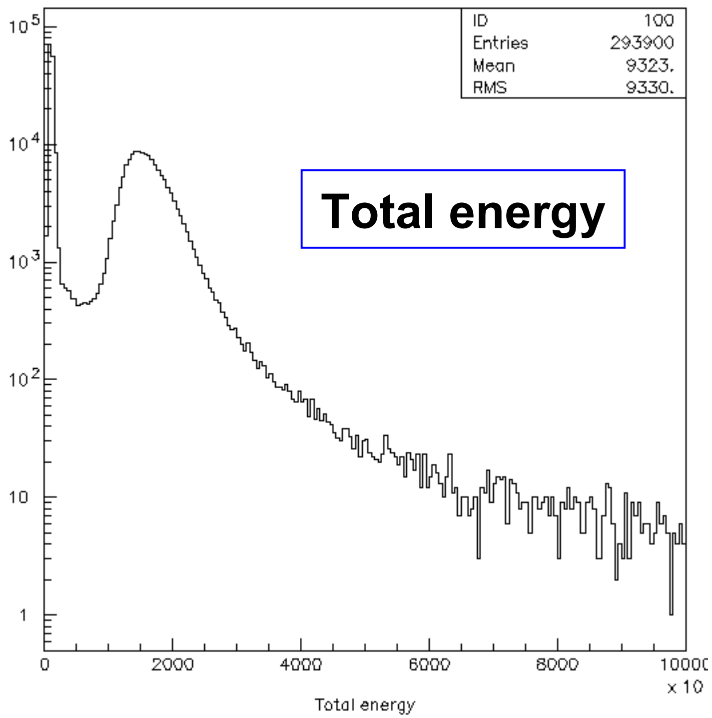



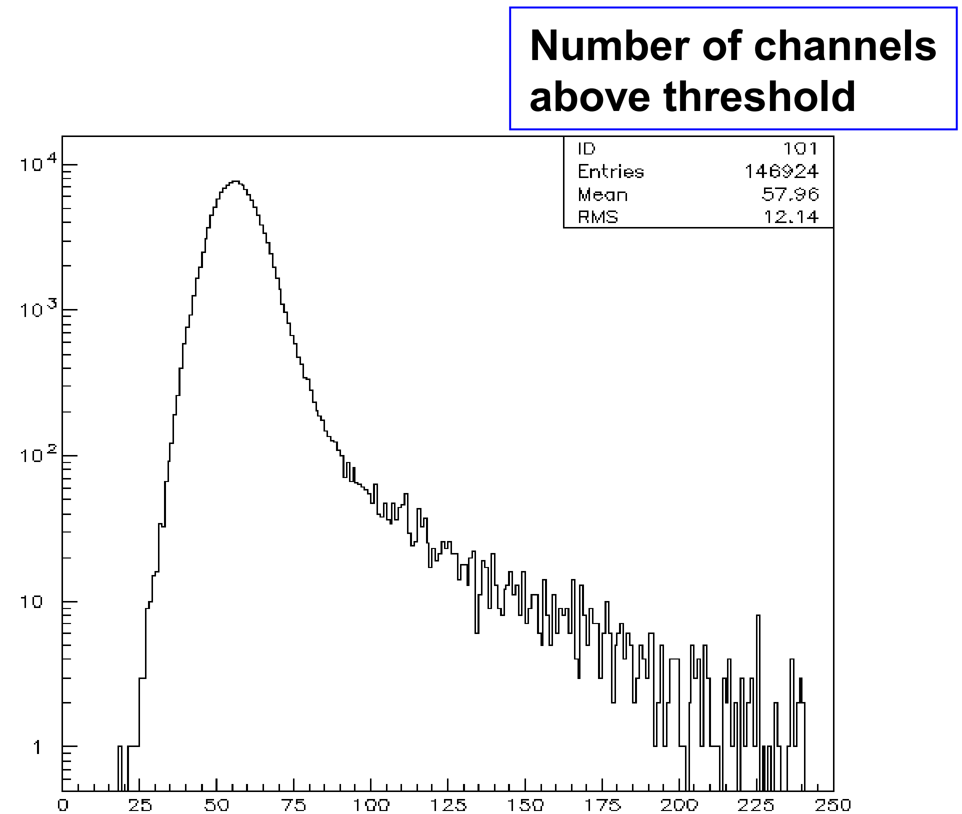

**Simple event display shows the imaging power of the detector**

**Interesting topology can be searched for (muon range, muon decay, protons…)**

# Looking for MIPs …

**Total energy has nice Landau shape as also the number of channels…**
**Pixel counting at this level is a good energy esimate !**

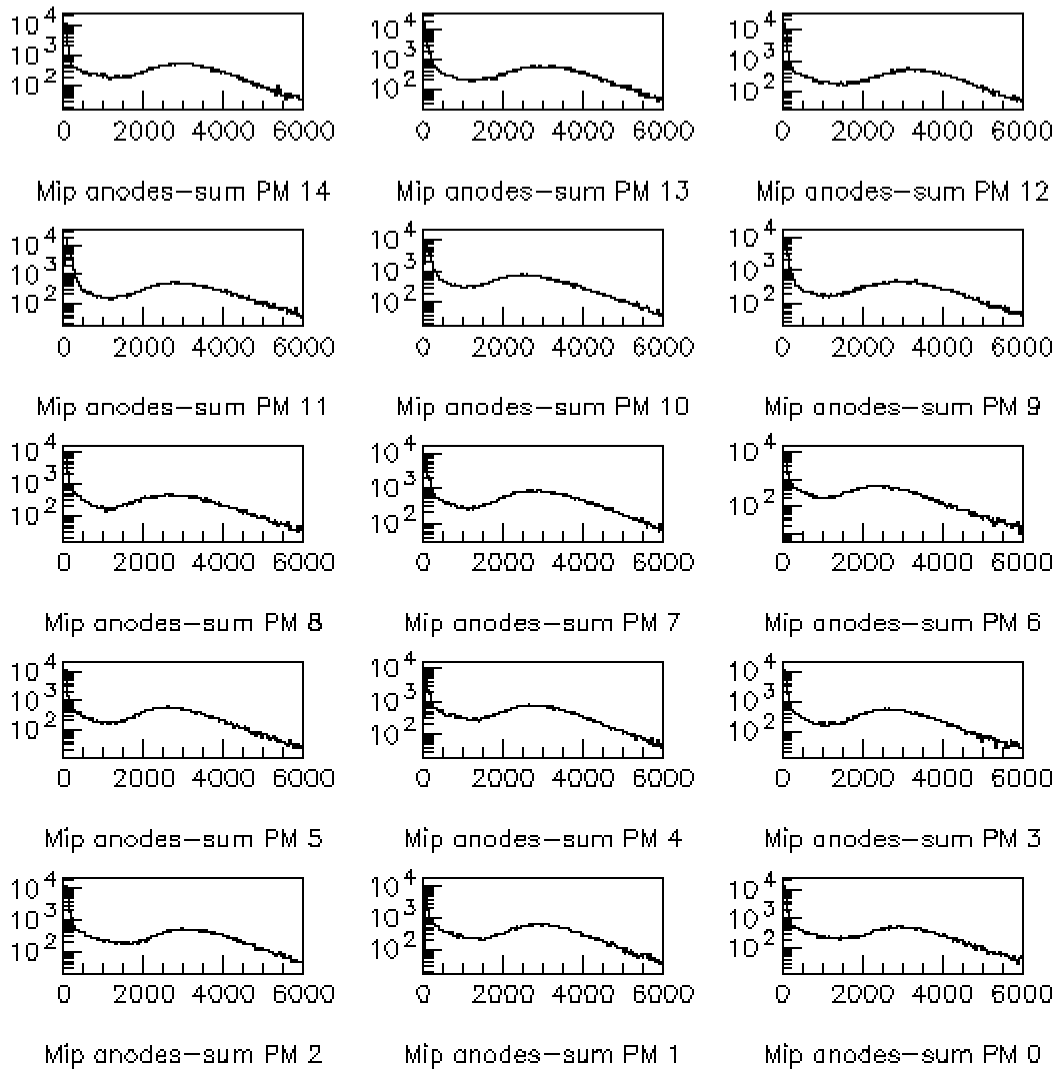


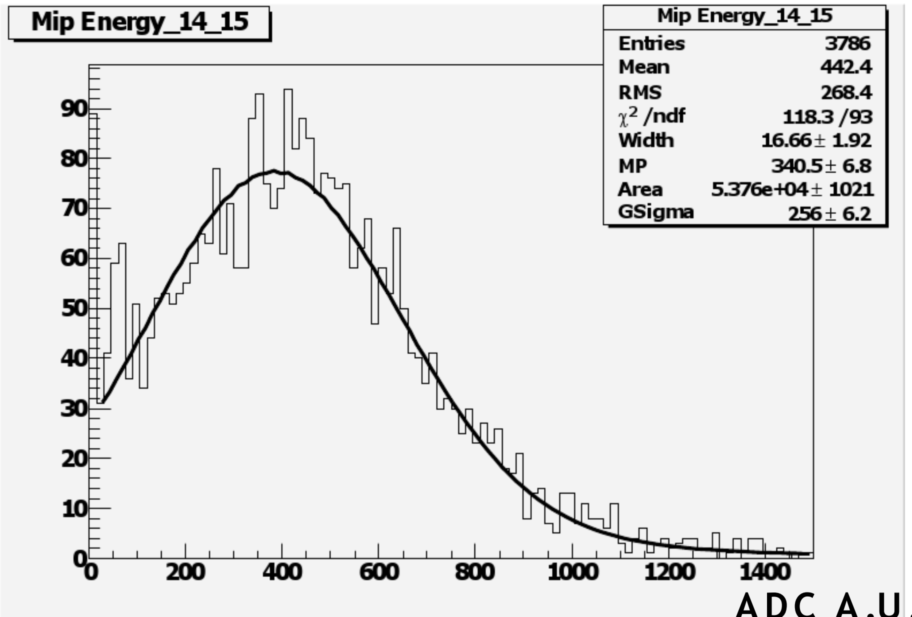
# Equalization :

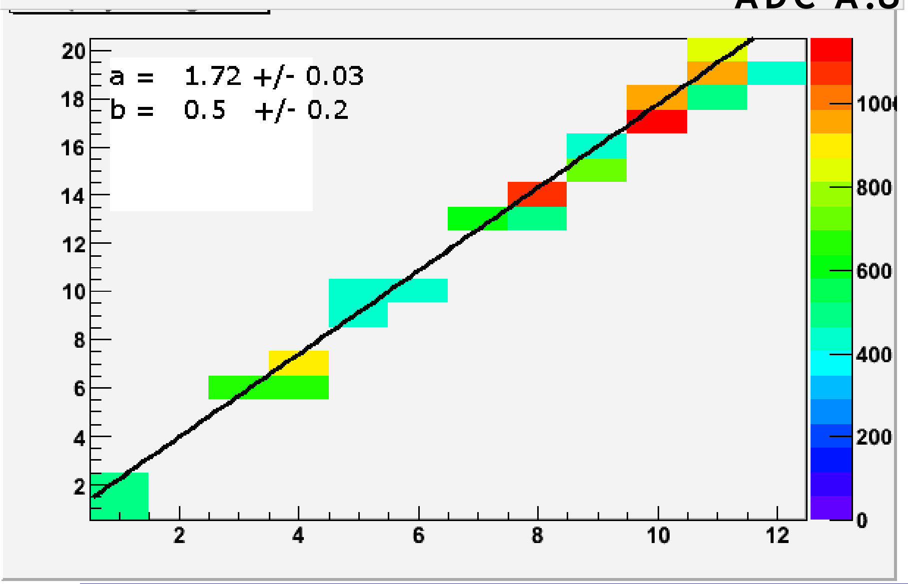
**Due to gain non-uniformity HV can be used only to equalize the full multianode response.**

**We used the summ of all pixels in same PM, and fixed it around 3000 counts.**

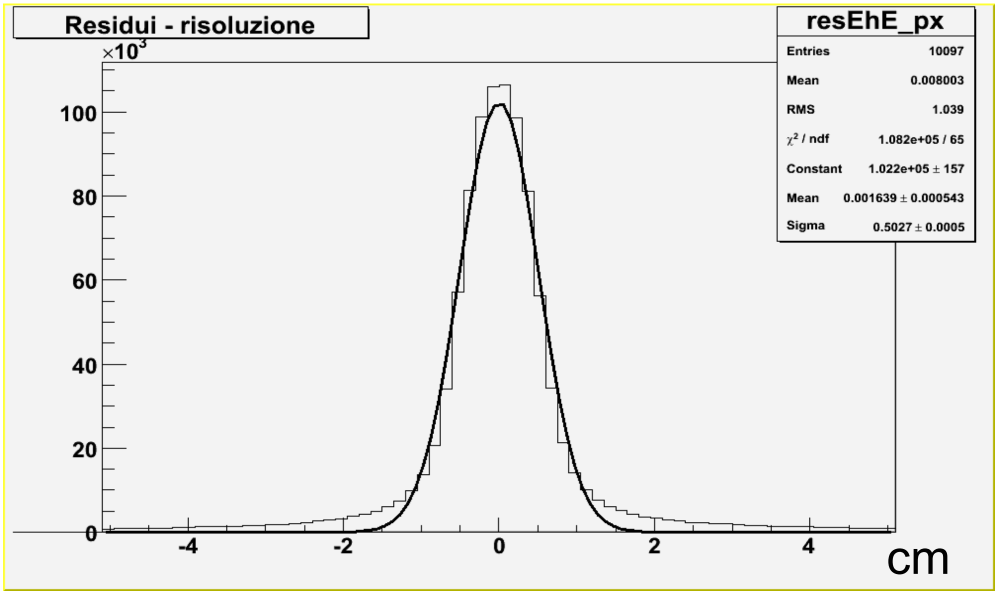


# Fitted track and residual distribution

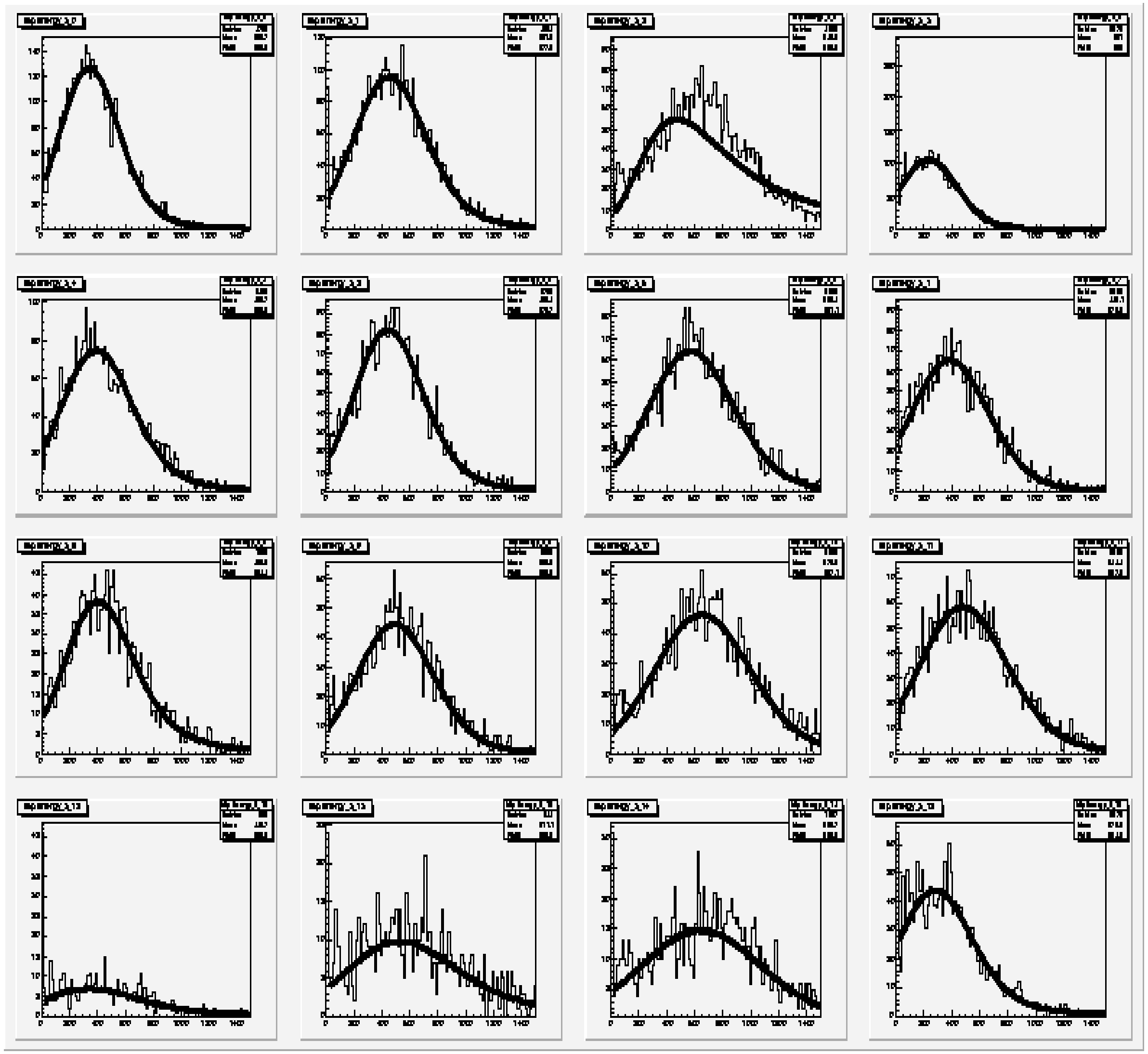



The MIP energy distribution is clearly visible also on single anode



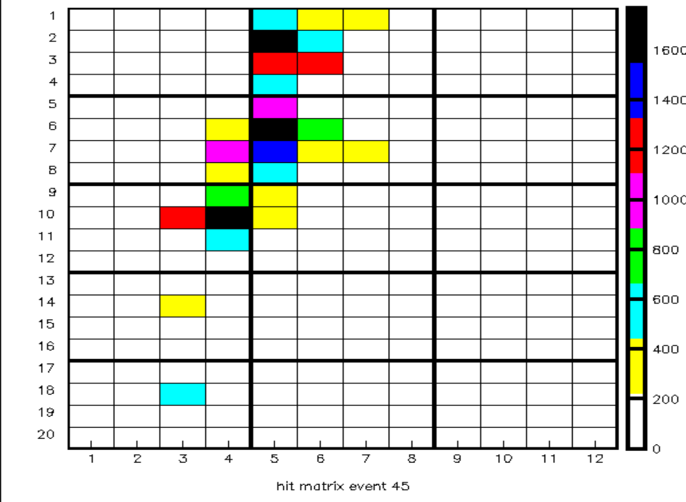
# MIP energy deposition in 1 Ma PMT

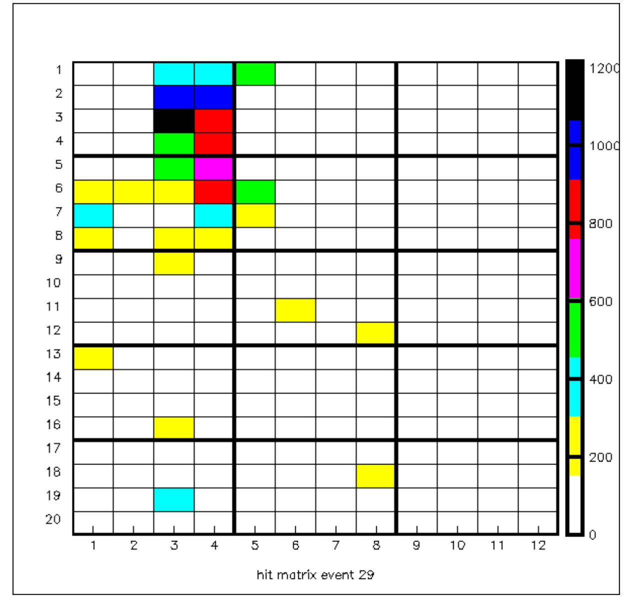


Mip energy deposition on a single anode of the Ma PMT

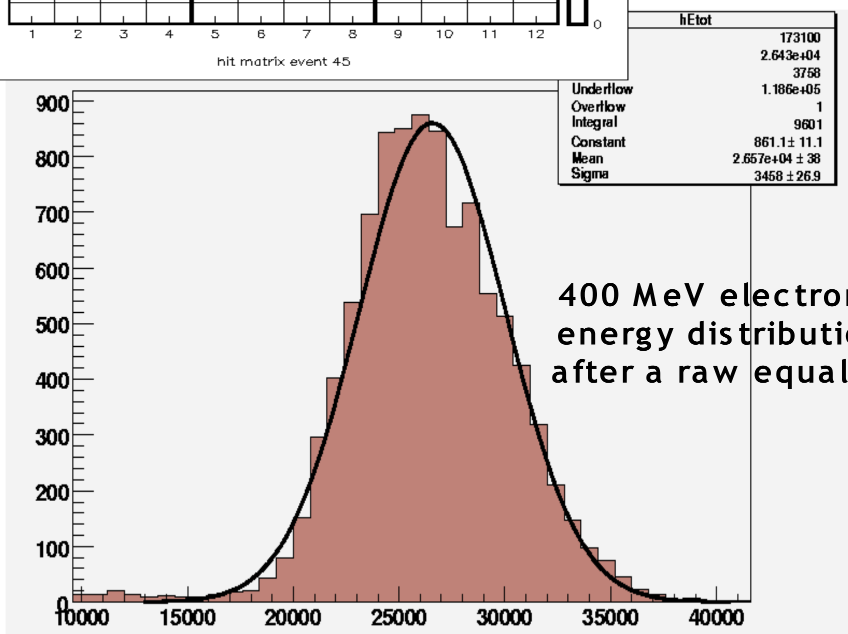
# A couple of displays from BTF

400 MeV electron in the calorimeter



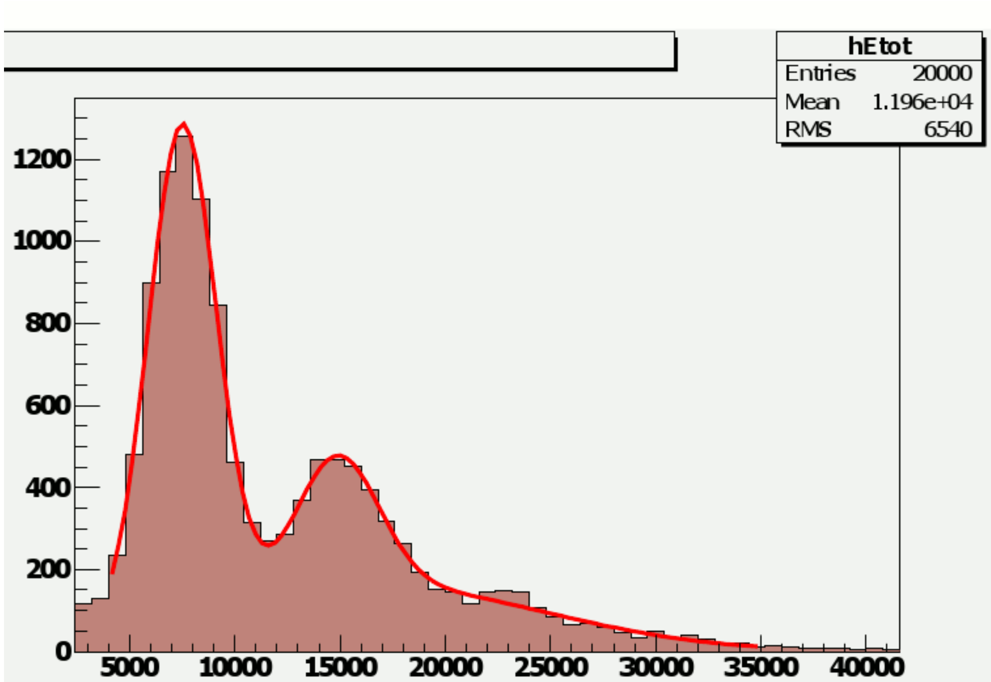

100 MeV electron in the calorimeter



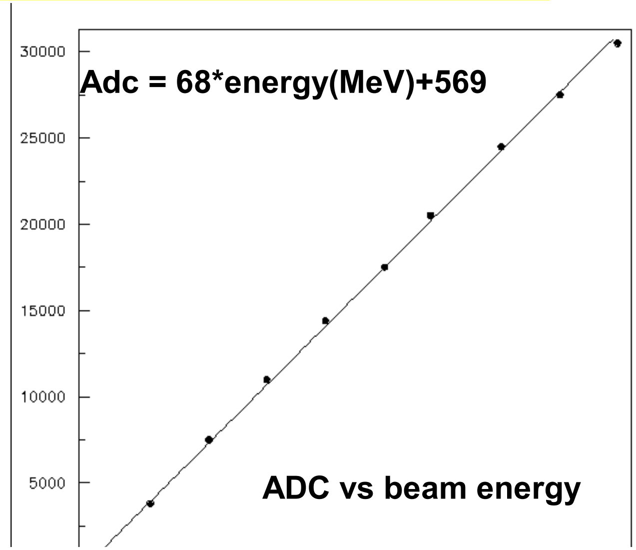

400 MeV electron energy distribution after a raw equalization.

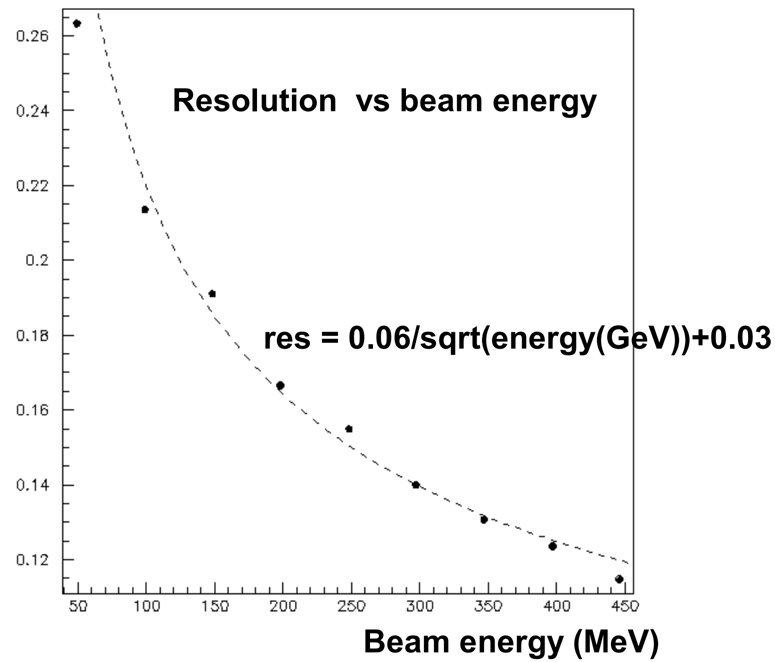
ADC A.U.

# Electron energy reconstruction and resolution




Single and double 100 MeV electron impinging the calorimeter



# Conclusions

A fine granularity calorimeter prototype has been realized using a KLOE calorimeter piece with segmented light guides and Hamamatsu multianode PMs.

The response of individual channels has been studied with a laser pulse and the cross talk measured. Optical cross talk is negligible.

A full system is now operating. Many cosmics rays have been acquired and are being analyzed.

A test beam with electron at BTF is now over and data are being analysed