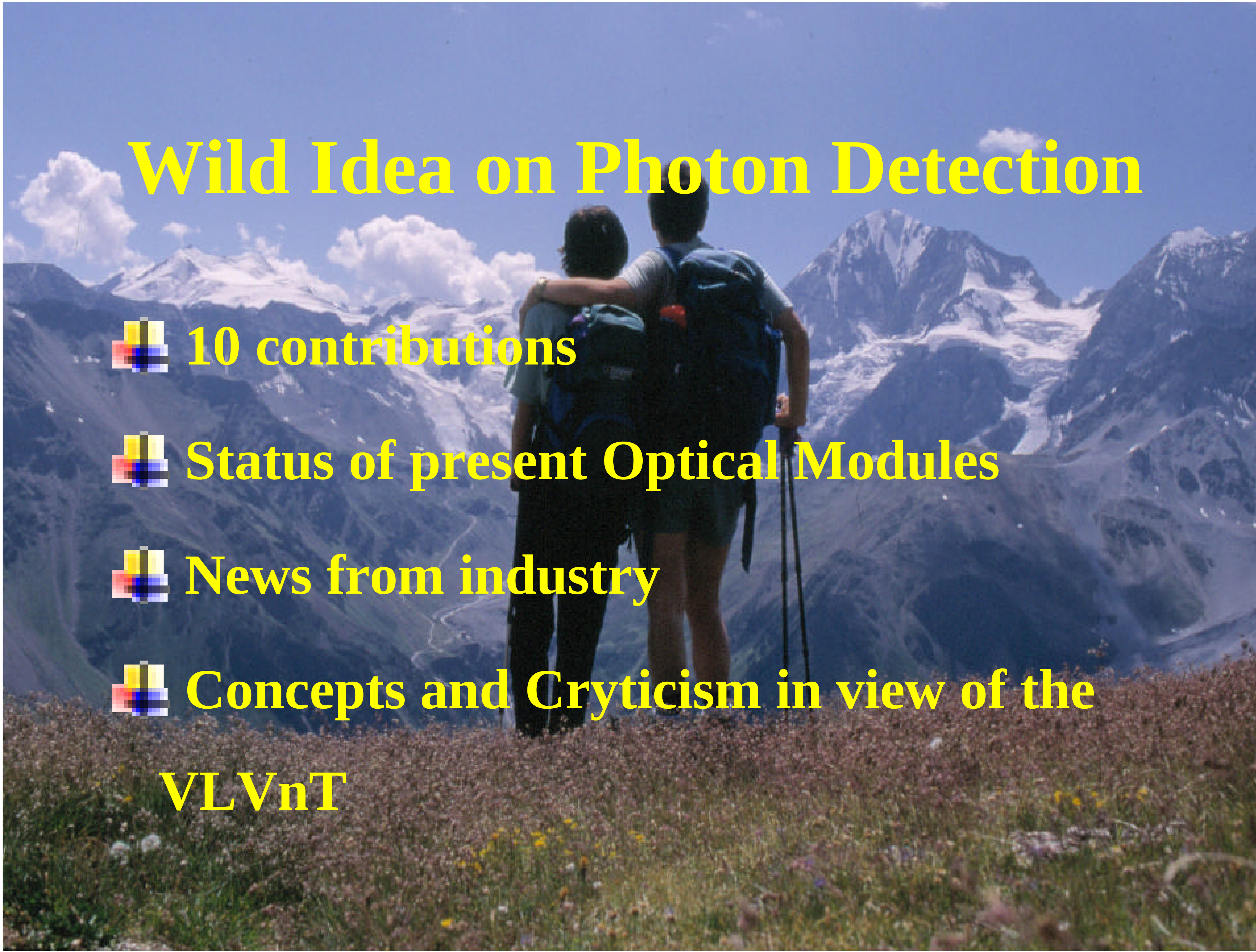

Wild Idea on Photon Detection
10 contributions
Status of present Optical Modules
News from industry
Concepts and Cryticism in view of the VLVnT

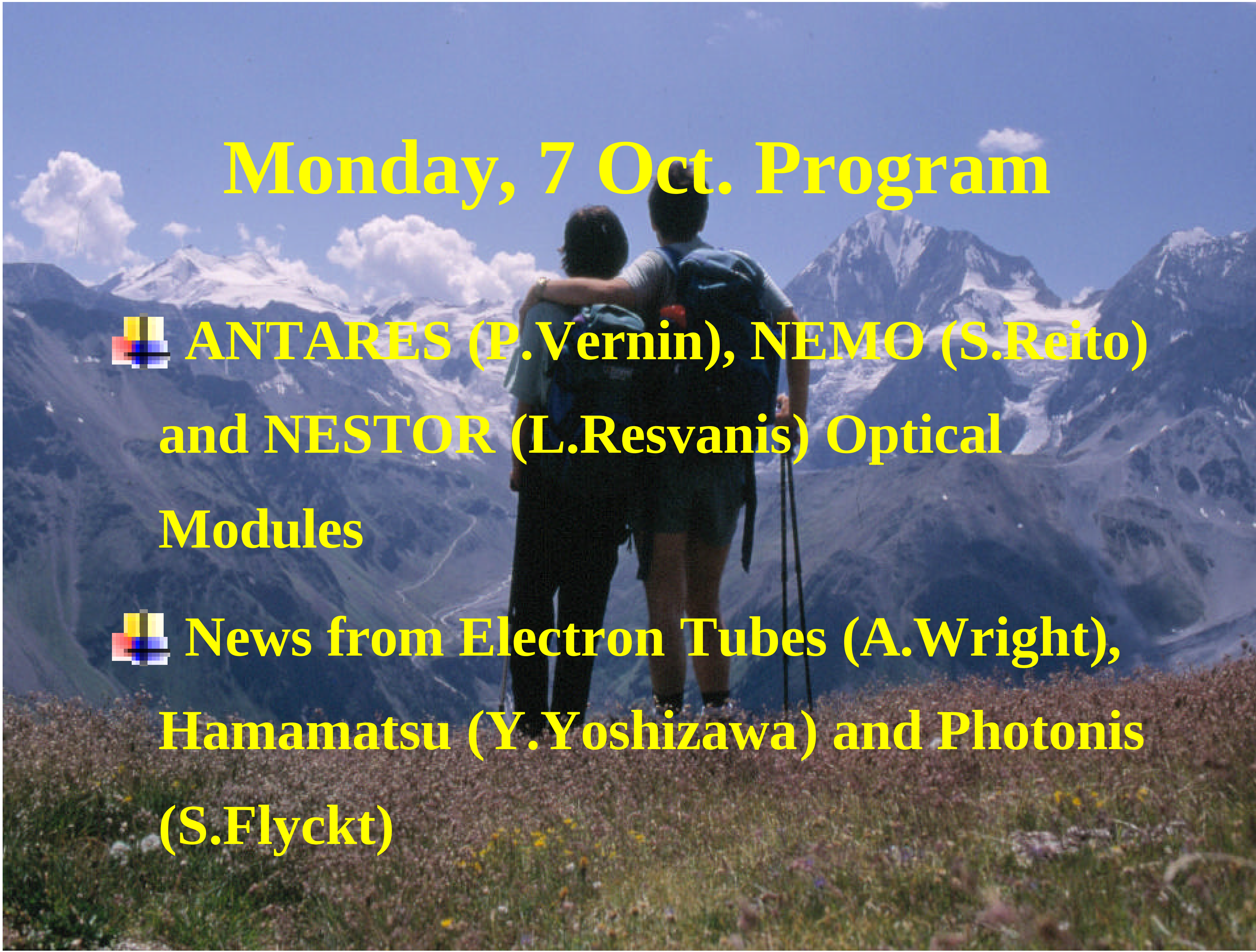
Conditions:

- 3000 m under water at least
- ^{40}K background of single photons at 300Hz/cm^2
- Some bioluminescent background
- Signal depends on energy and distance
  - Low energy muon : R~50m photon flux = 0.02/cm^2
  - High energy muon : R~50m photon flux = 0.2/cm^2
  - Hadronic shower: R~50m photon flux = 1.0/cm^2
  - Electron shower E=1TeV close by flux > 100/cm^2
  - Electron shower E=1PeV close by flux > 10^5/cm^2

Requirements:

- Large area
- High quantum efficiency
- Good single photon resolution
- High dynamic range
- 4π solid angle

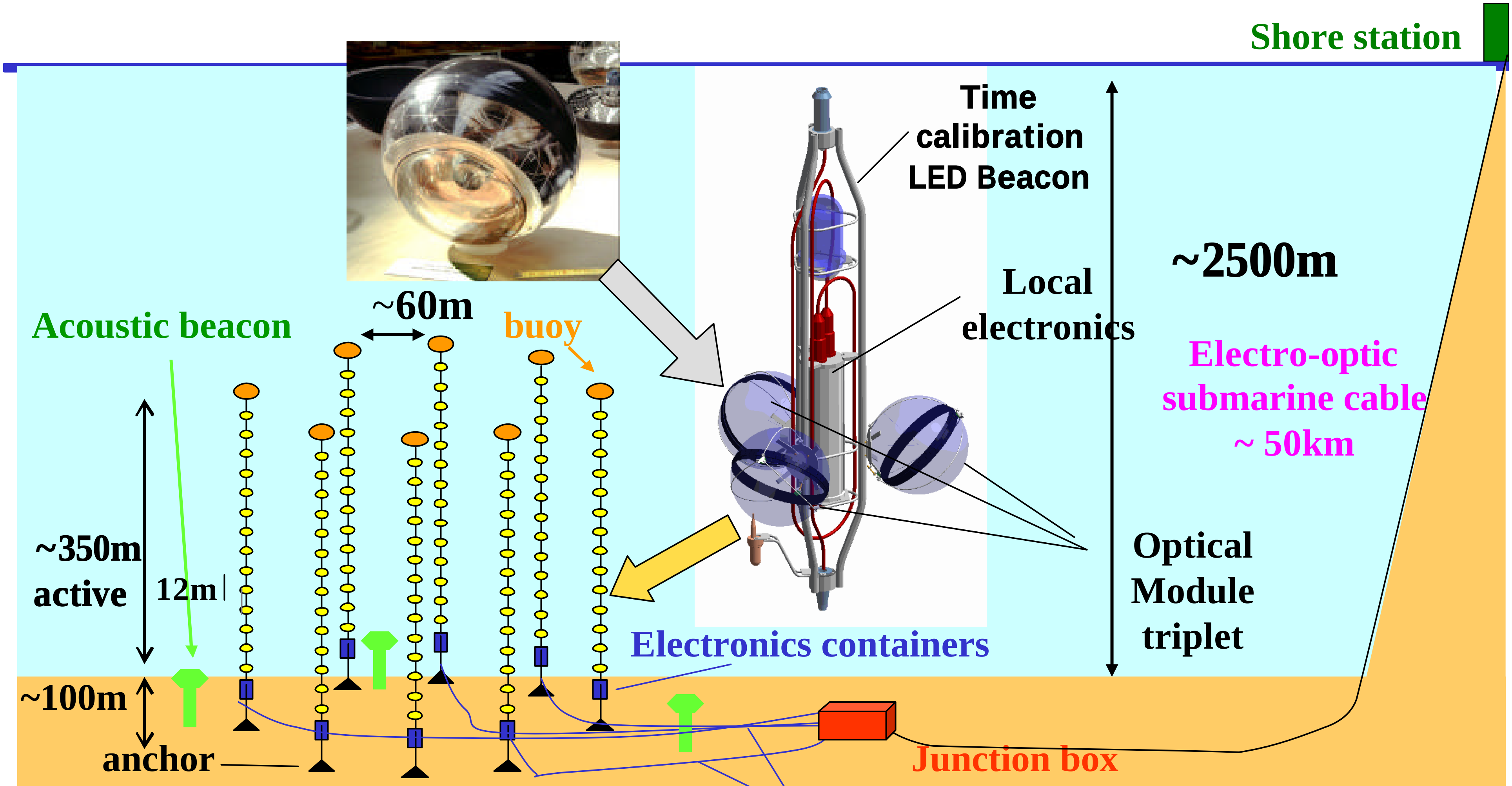
Has to fit in a transparent pressure vessel



Monday, 7 Oct. Program

- ANTARES (P.Vernin), NEMO (S.Reito) and NESTOR (L.Resvanis) Optical Modules
- News from Electron Tubes (A.Wright), Hamamatsu (Y.Yoshizawa) and Photonis (S.Flyckt)

The 0.1 km^2 Detector



12 lines + 1 instrumented line

Optical modules – PMT's Specs

To summarise:

- Sensitive area ≅ **500 mm²**
- (quantum ⊕ collection) efficiencies > **16 %**
- Amplification **2. 10^8** for HV < **2500 V**

At working point (≡ amplification = 5. 10^7)

- Transit time spread < **3.6 ns** (FWHM)
- Dark count (@ 0.3 spe) < **10 kHz**
- Peak/valley > **2**
- Shape of signal t_r < **5 ns** t_w < **12 ns** and t_f < **15 ns**
- Pre, late and after pulses < **1 %, 2%, 10 %**

Pre: in the window [-100, -10] ns before the true pulse

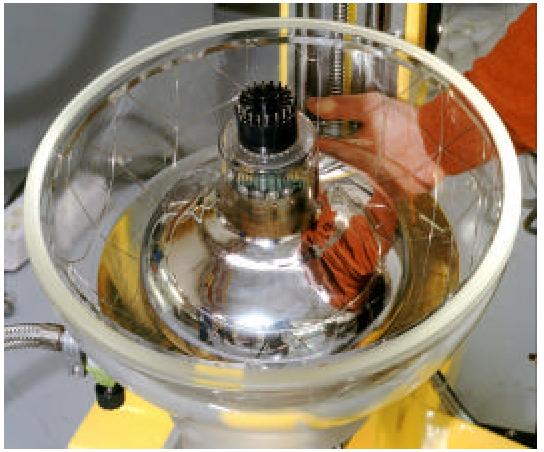
Late: in the window 10, 100] ns after

After: in the window [.1, 16] ms after

Optical module - Assembly (2)

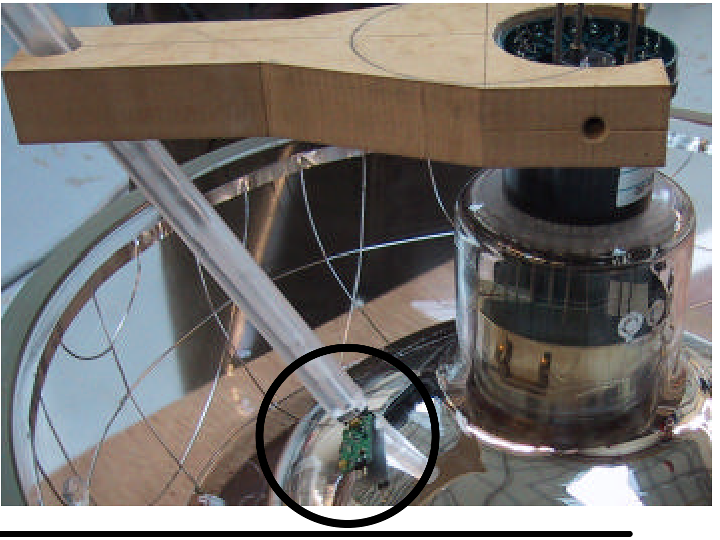
The PMT is going down

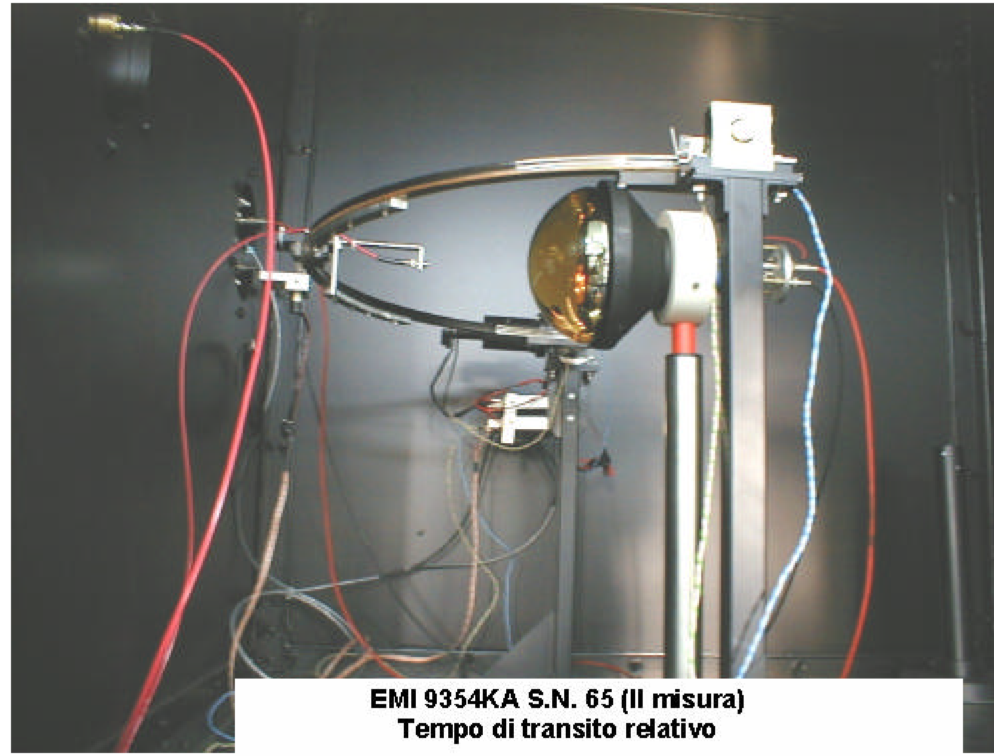
24 h later…

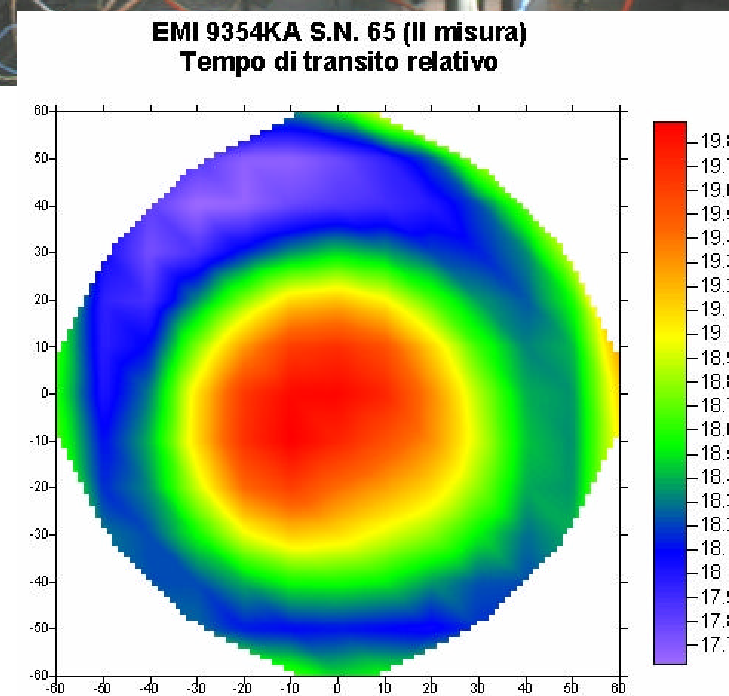


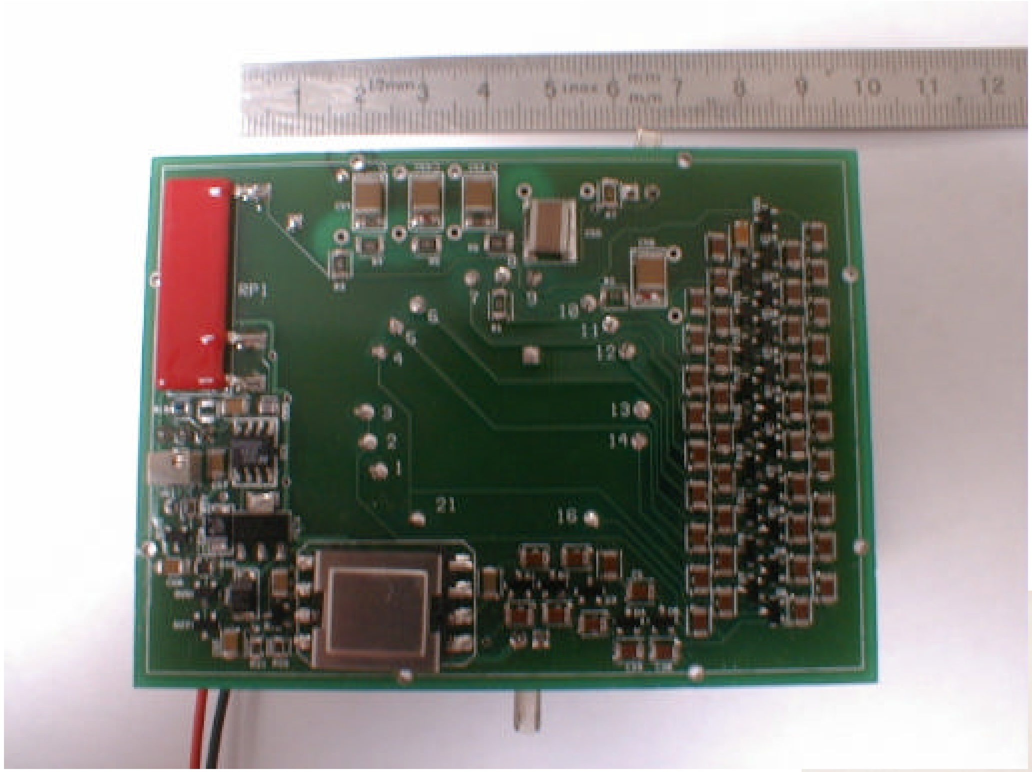
The last step for this hemisphere:

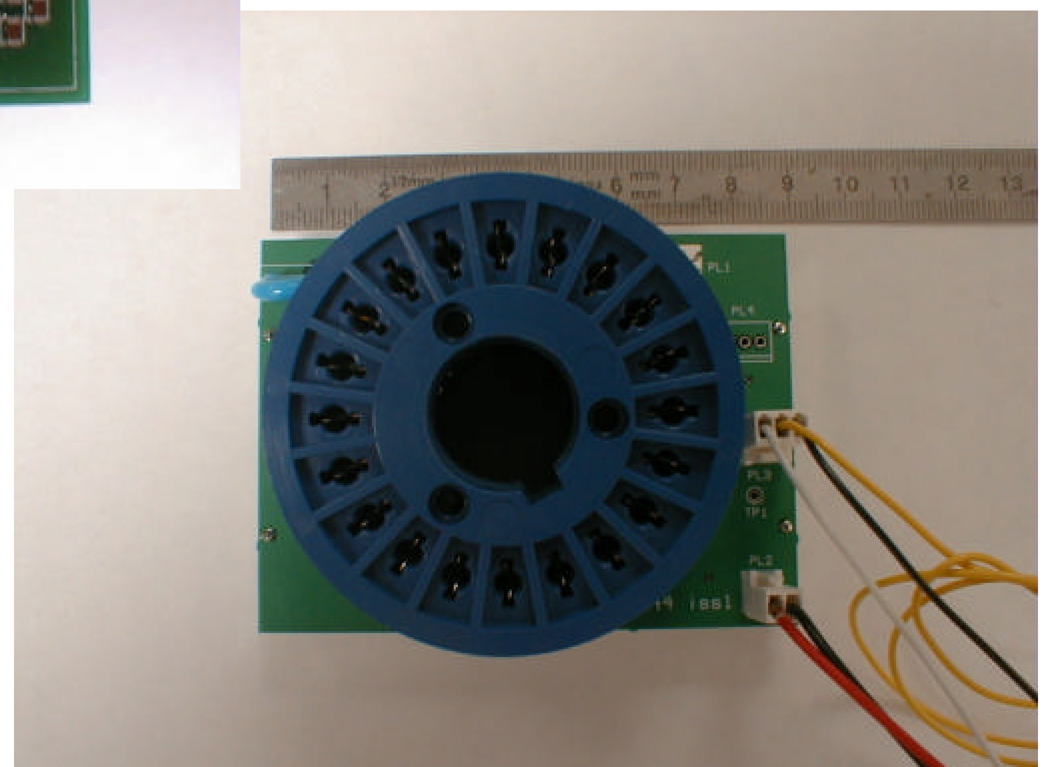
the gluing of
the LED and
pulser circuit

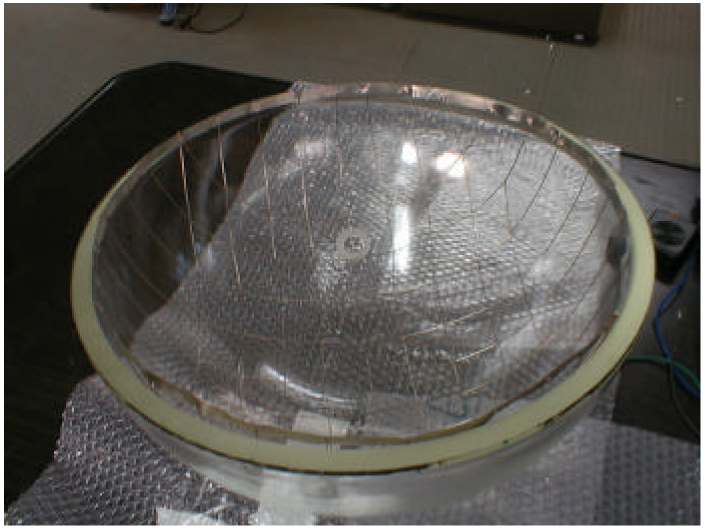





EMI 9354KA S.N. 65 (II misura)
Tempo di transito relativo
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60
19.8
19.7
19.6
19.5
19.4
19.3
19.2
19.1
19
18.9
18.8
18.7
18.6
18.5
18.4
18.3
18.2
18.1
18
17.9
17.8
17.7


RP1

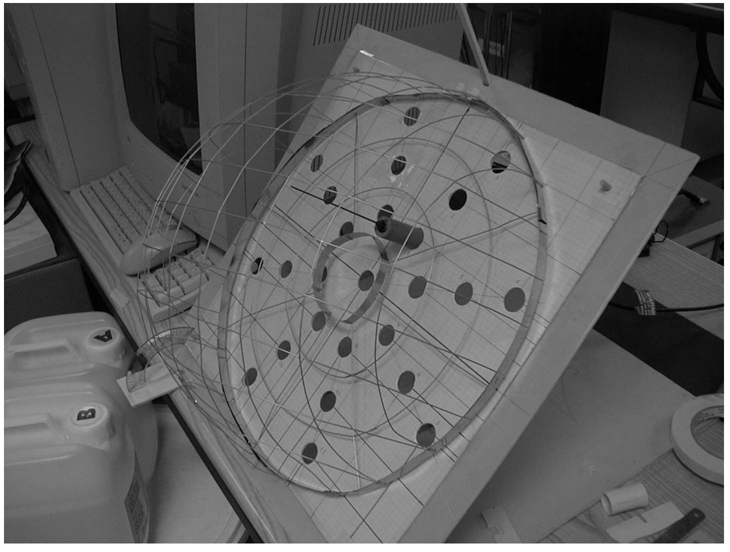

PL1
PL4
PL3
TP1
PL2

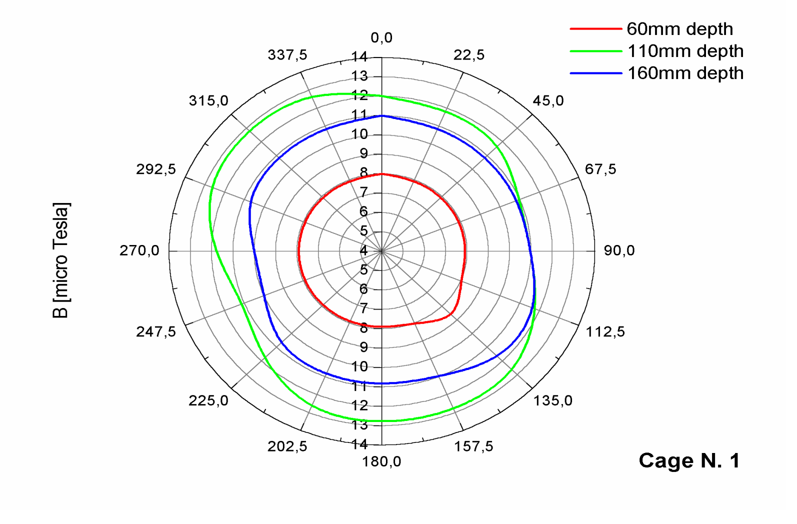


Mu-metal wire 1 mm

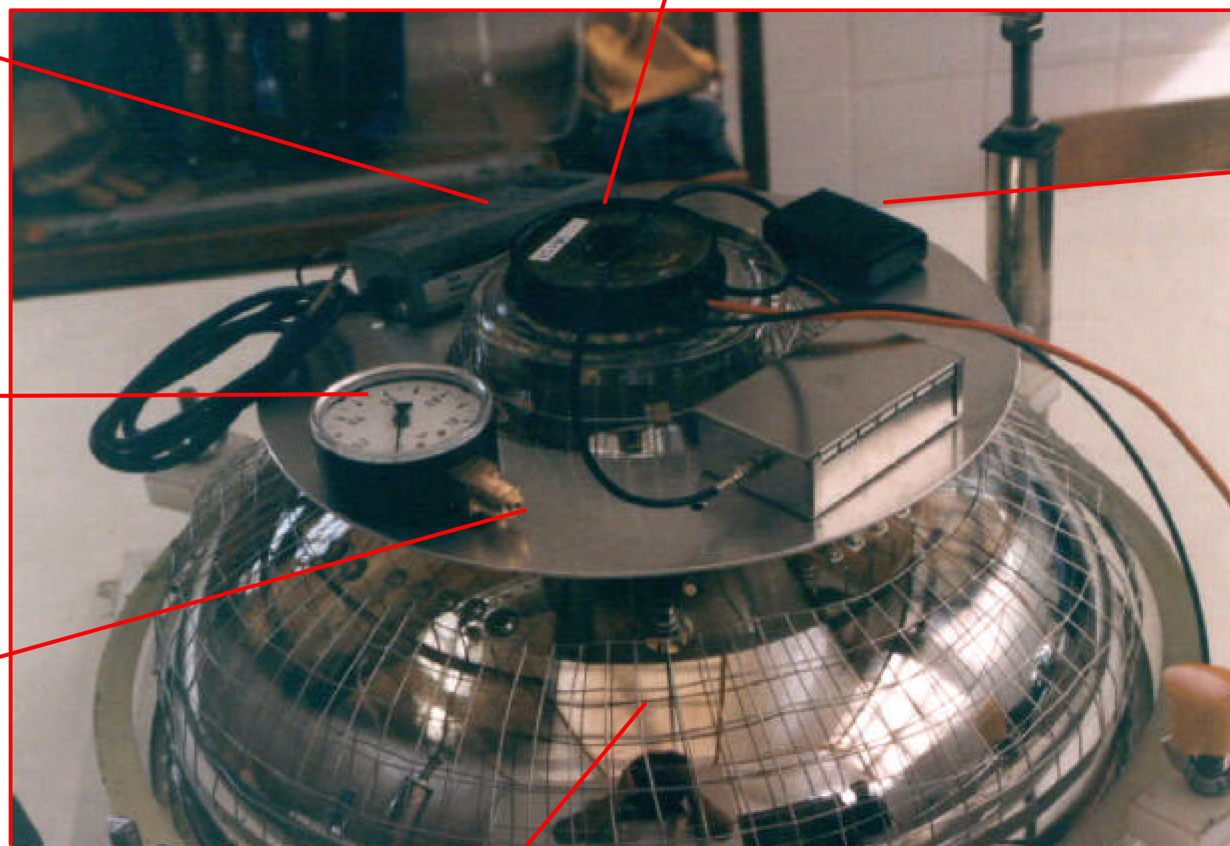
Strip 11x0.25 thk

Total shadow 3-4 %



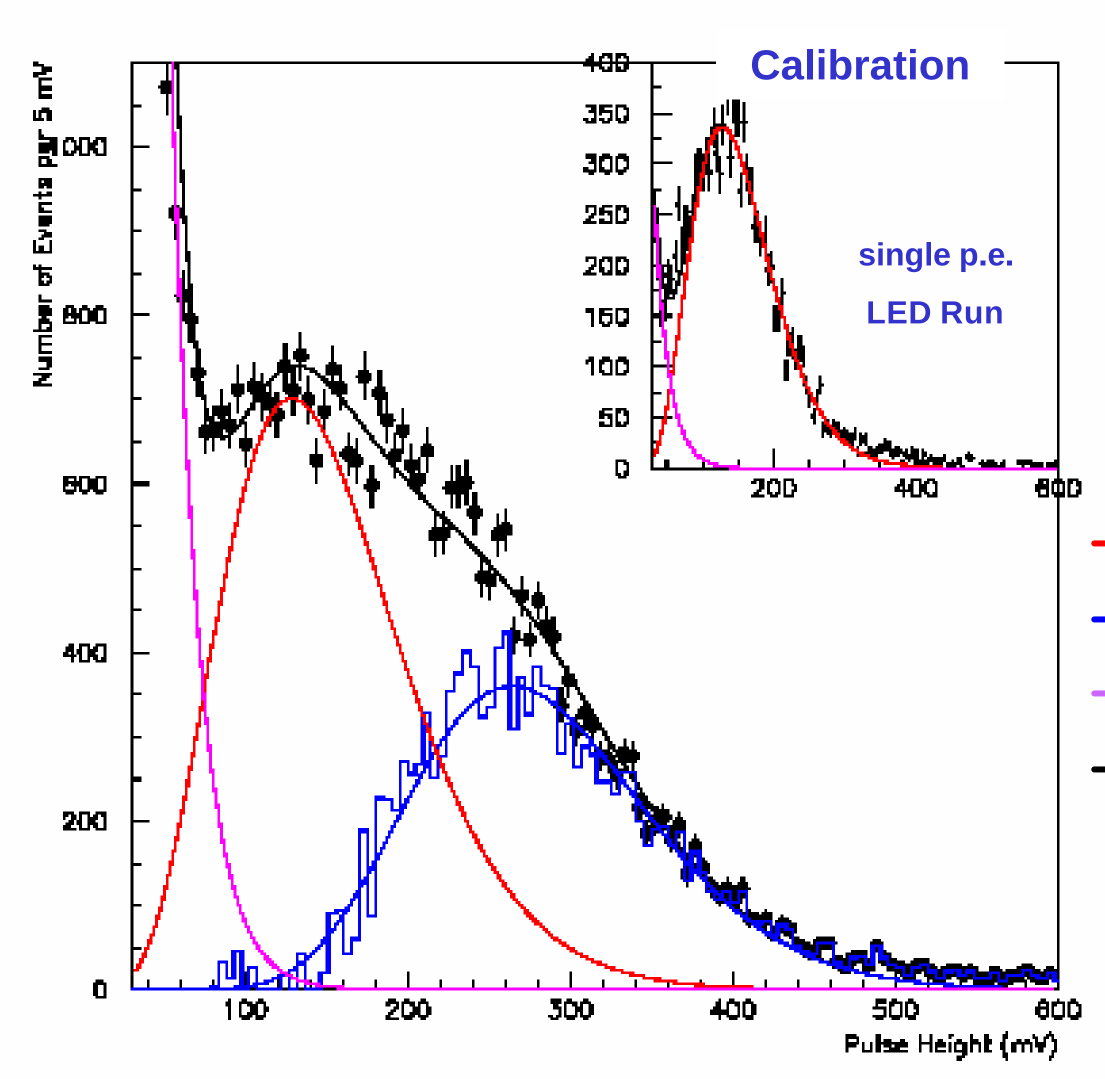


The NESTOR Optical Module



Data from a depth of 4000 m

PMT Pulse Height Distribution



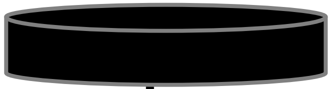
single p.e. pulse height distribution

two p.e.s pulse height distribution

dark current pulse height distribution

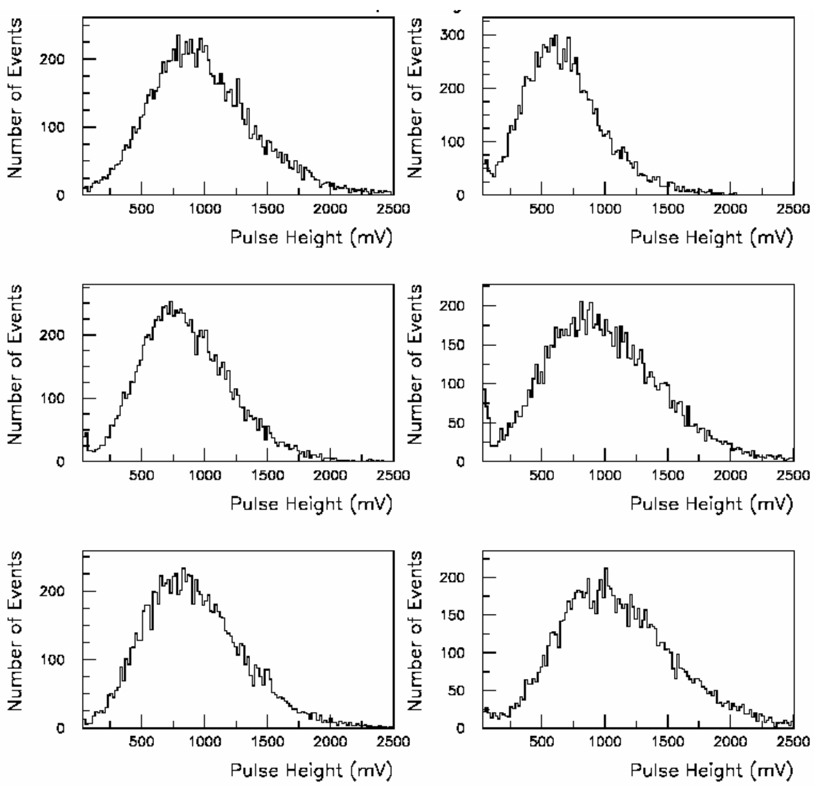
sum of the above

Data from a depth of 4000 m
Calibration Run

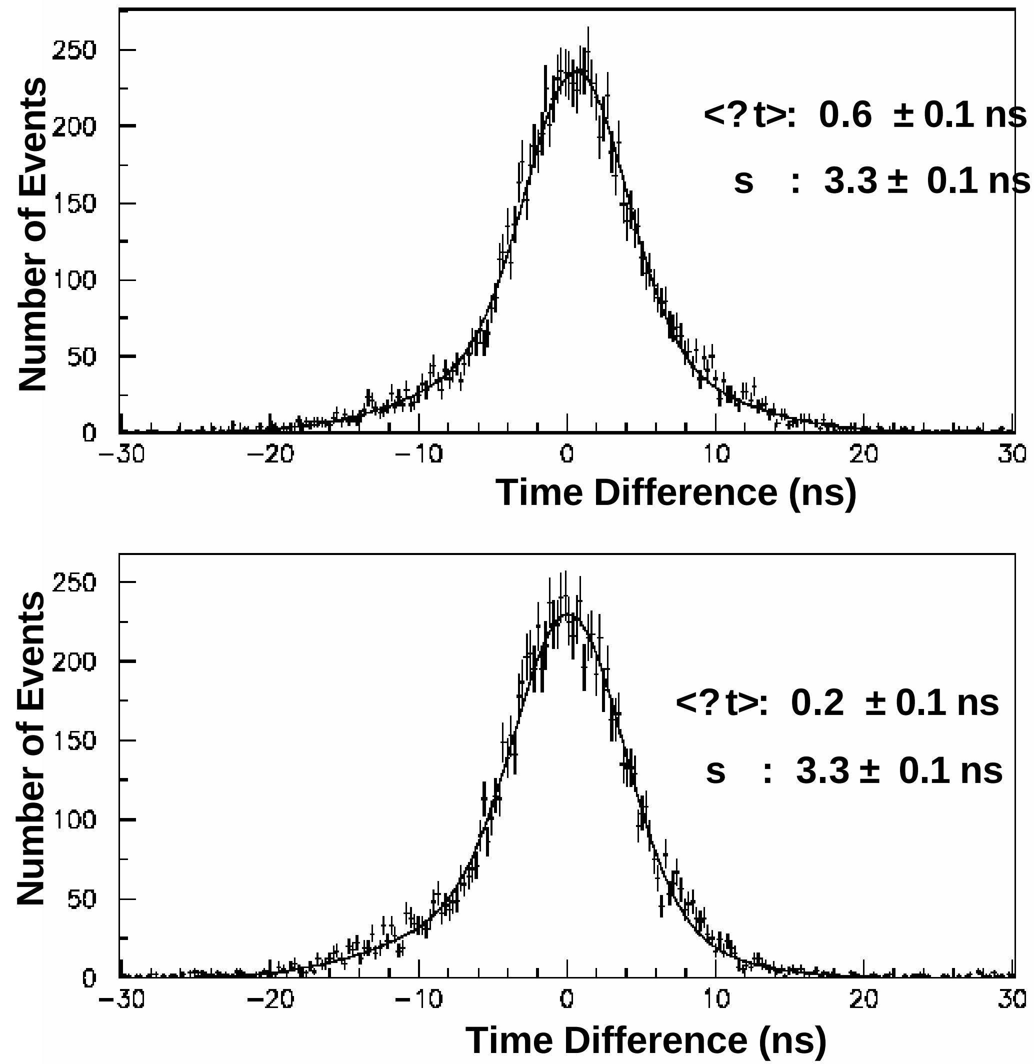


Calibration Data Analysis

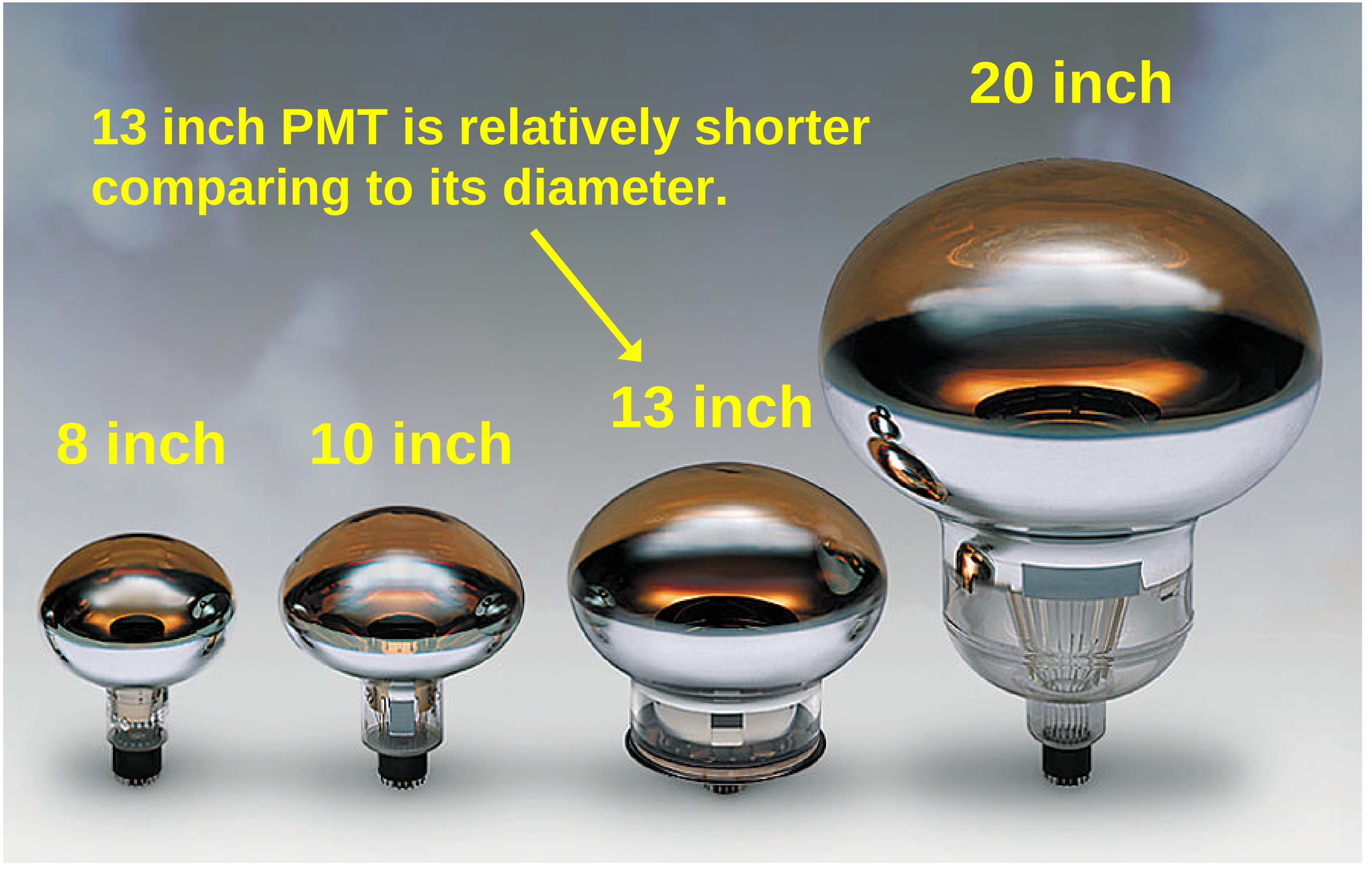
Calibration Database
Quality Histograms



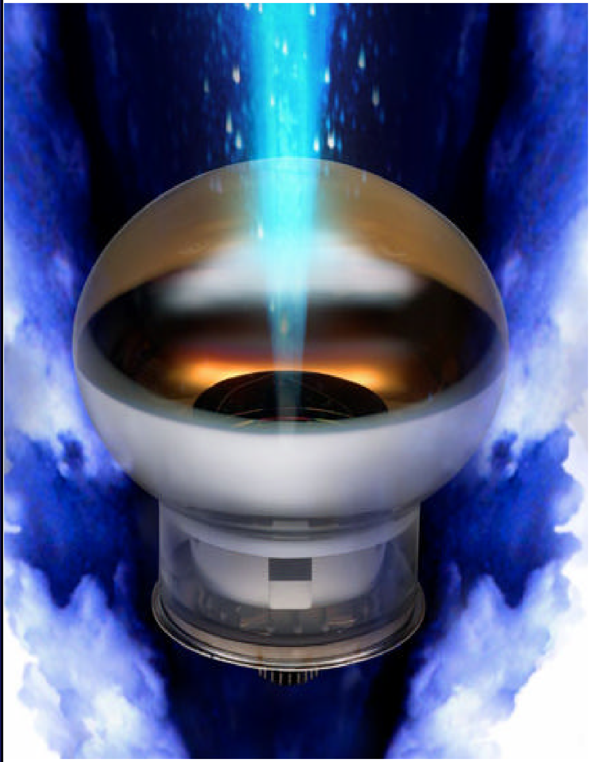
a



Large Format PMT Lineup



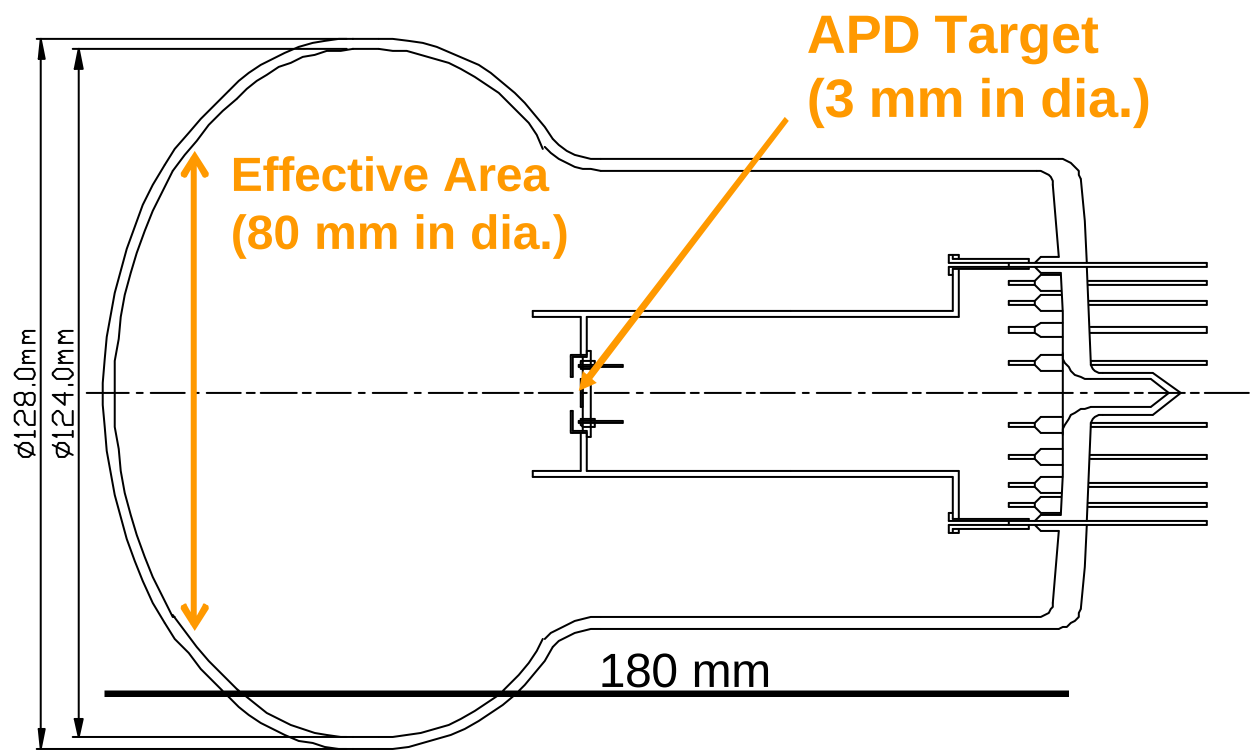
General Specification of R8055



Window	:	**Borosilicate**
Photocathode	:	**Bialkali**
Tube Diameter	:	13 inch (332 mm)
Tube Length	:	332 mm
Dynode Type	:	Box and Line / **10-stage**
Nominal Gain	:	**1E+07 at 1500V**
TTS (FWHM)	:	**2.8 ns typ.**
Rise Time	:	6.0 ns typ.
P/V ratio	:	**2.7 typ.**
Dark Counts	:	10 KHz typ.

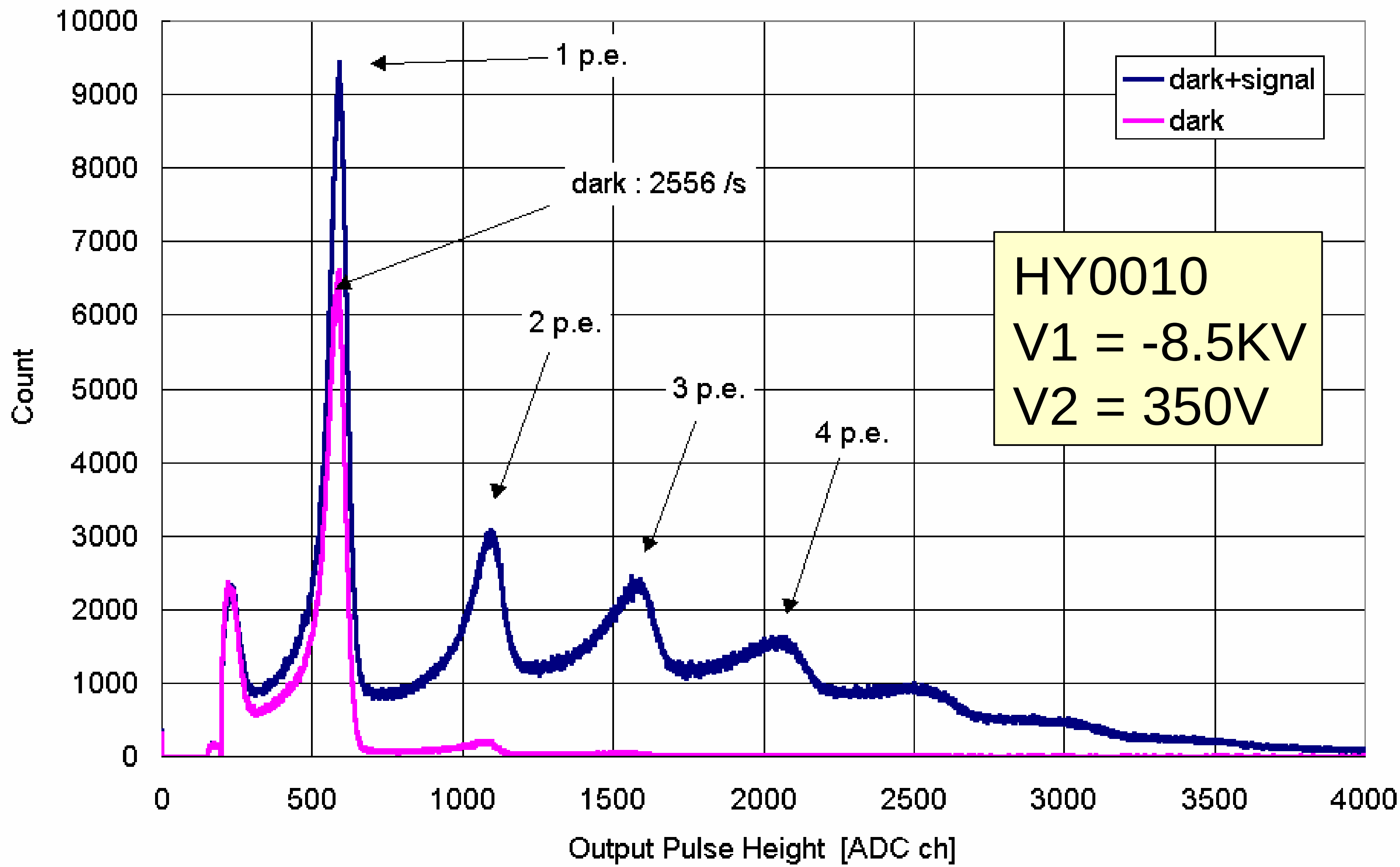
Sketch of 5 inch HPD

This 5 inch HPD was made as feasibility study.
Glass bulb of 5 inch hemispherical PMT was used.



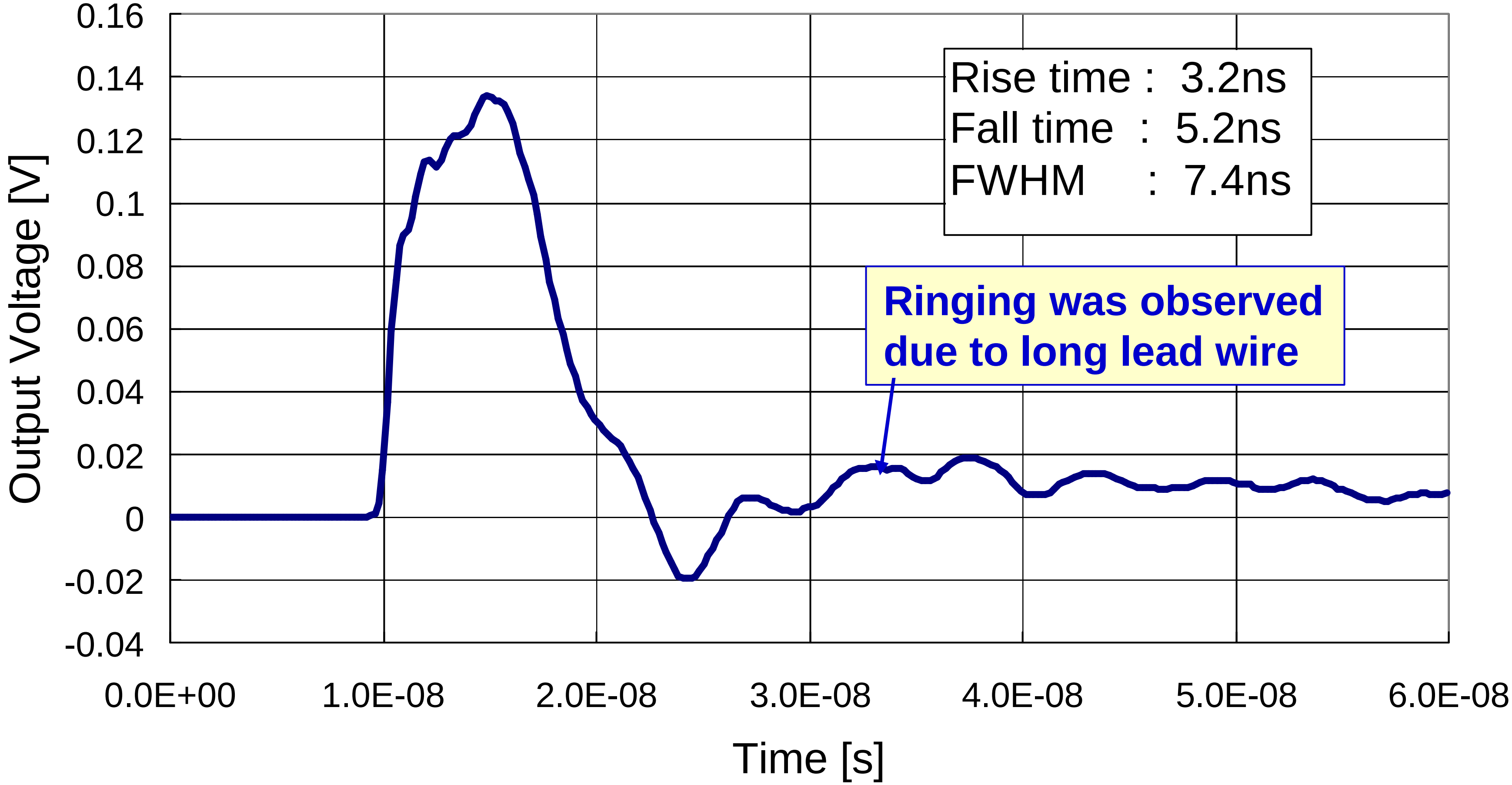
HPD : Hybrid Photo Detector

PHD with Multi photoelectrons



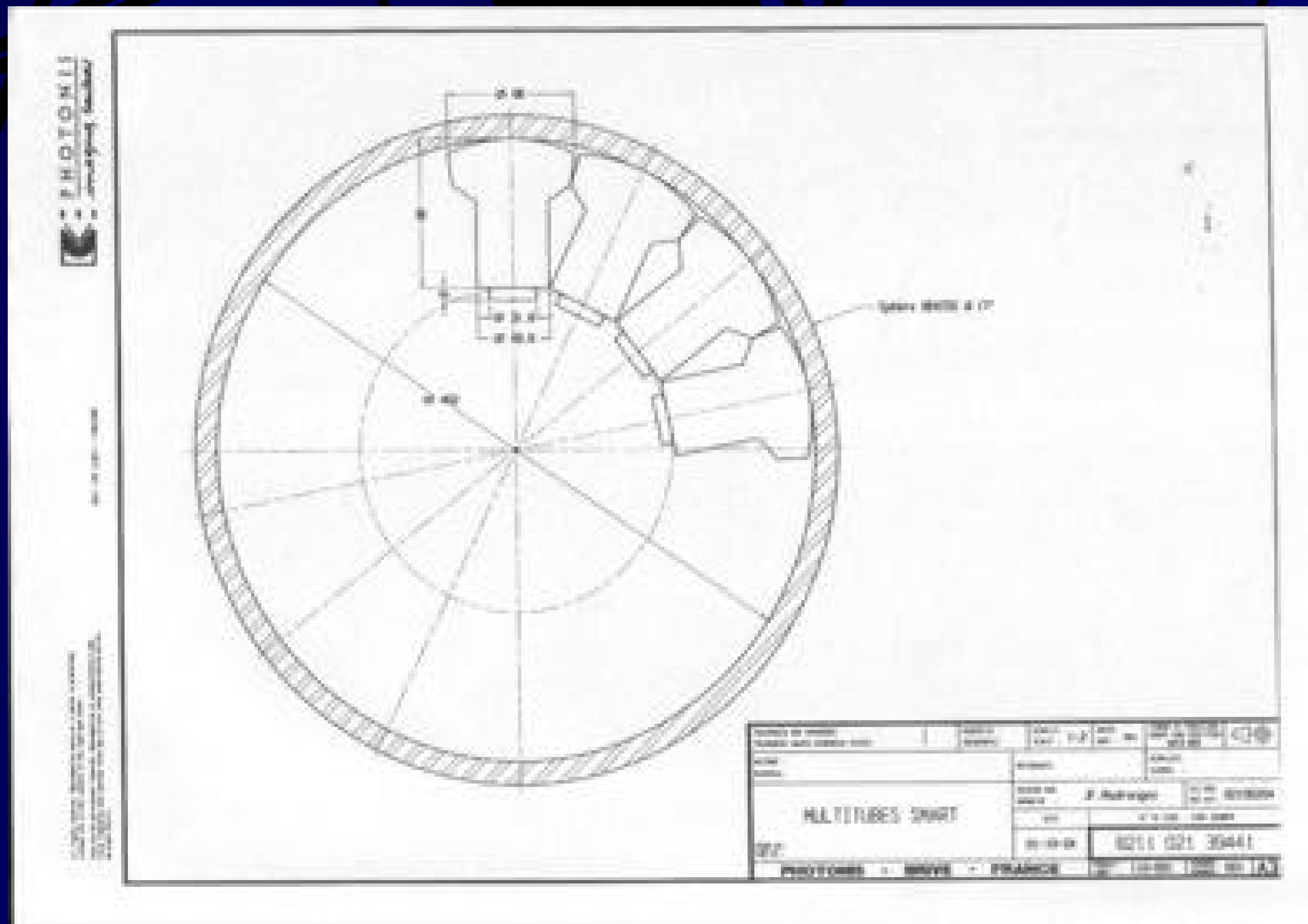
Output Waveform : HY0005 (8kV, 153V)

<Bombardment Gain : 900, Avalanche Gain : 30>



(TO-8 type HPD : Rise time = 1.2 ns, Fall time = 13 ns)

Multiple PMTs/OM

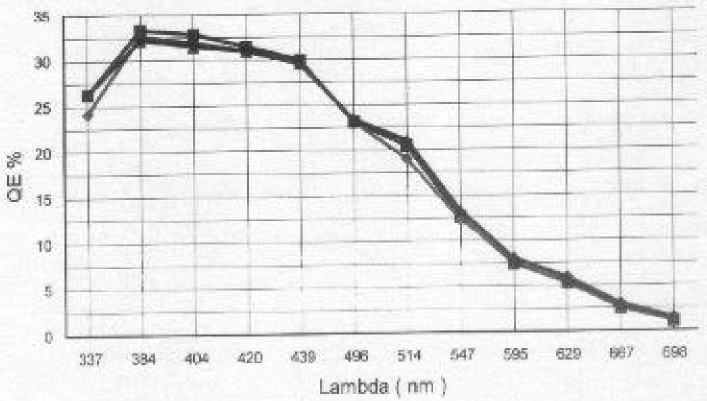


High QE

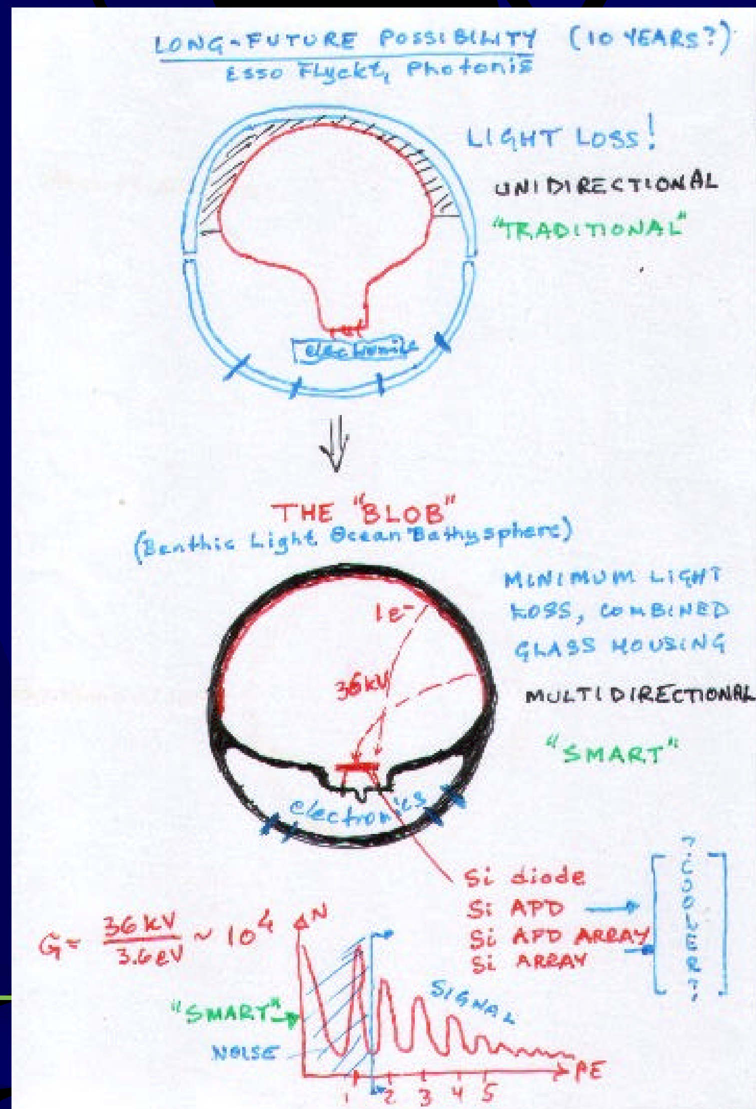
lambda en nm	QE n° 93599	n° 93600	n°93601
337	26	24	26
384	33	33	32
404	33	32	31
420	31	31	31
439	30	30	30
496	23	23	23
514	20	19	21
547	13	12	13
595	7	8	8
629	5	6	6
667	3	3	3
698	1	1	1
blanc	164	165	165
bleu	13.4	13.6	13.1

Q.E.on 3 XP5382 3" tube

Soda lime window thickness = 3mm



The BLOB



LONG-FUTURE POSSIBILITY (10 YEARS?)
Esso Flyckt, Photonis
LIGHT LOSS!
UNIDIRECTIONAL
"TRADITIONAL"
electronics
THE "BLOB"
(Benthic Light Ocean Bathysphere)
MINIMUM LIGHT LOSS, COMBINED GLASS HOUSING
MULTIDIRECTIONAL
"SMART"
1e-
36kV
electronics
Si diode
Si APD
Si APD ARRAY
Si ARRAY
COOLER?
G = 36kV / 3.6eV ~ 10^4
N
SIGNAL
"SMART"
NOISE
PE
1 2 3 4 5

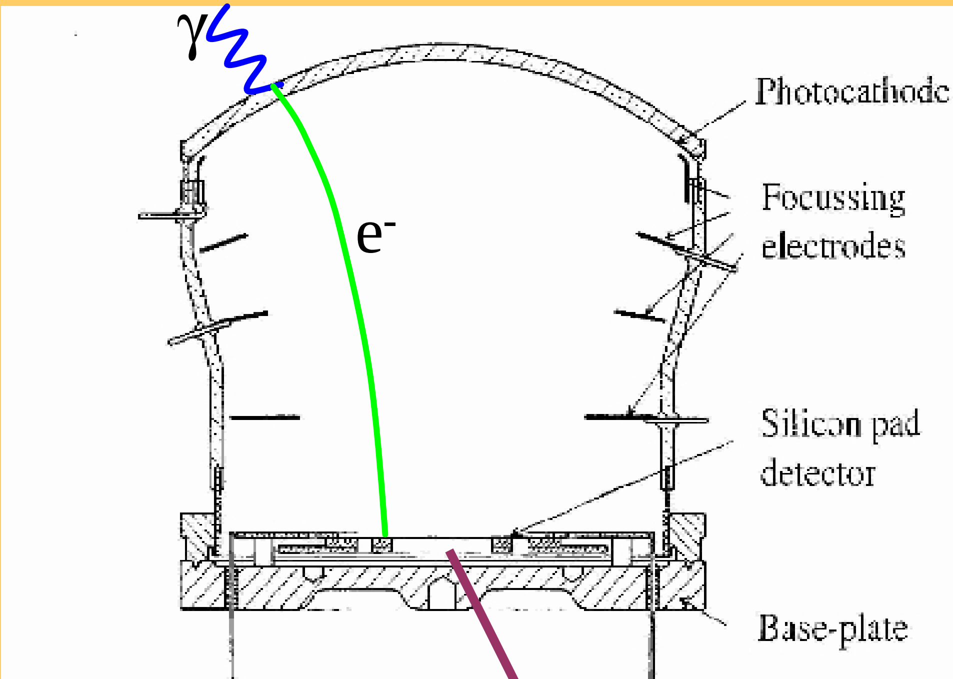
Status „smart“ PMTs

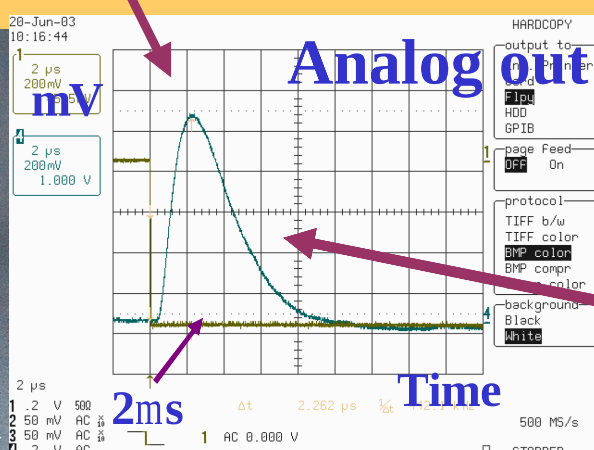
- Philips made ~ 30; invested 1 M$!
- 200 Quasars in Lake Baikal!!!
- No ongoing production

Tuesday, 8 Oct. Program

- M.Giunta (INFN-PI), A.Bersani (INFN-Ge), G.Anton (U.Erlangen), P.Kooijman (NIKHEF)

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.

The 5”,10” (and 20”) HPDs

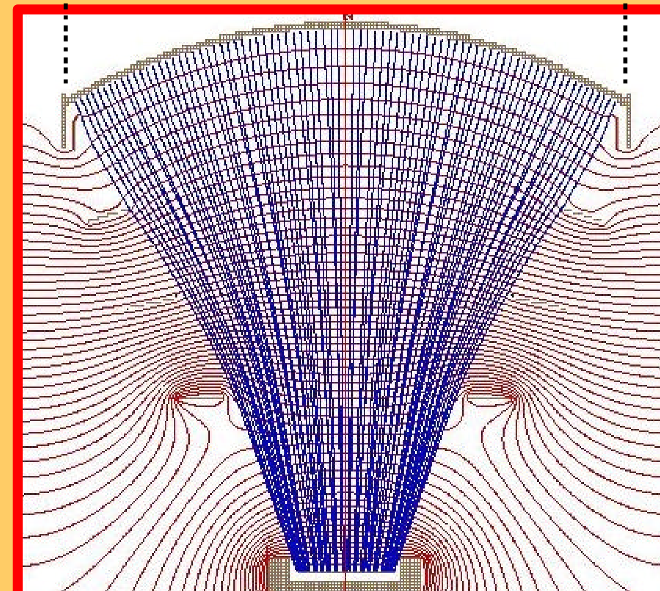
INFN PISA
ISTITUTO NAZIONALE DI FISICA NUCLEARE
Michele Giunta

Currently the TOM HPDs are:

5” Bialkali & 5” Rb_2Te borosilicate

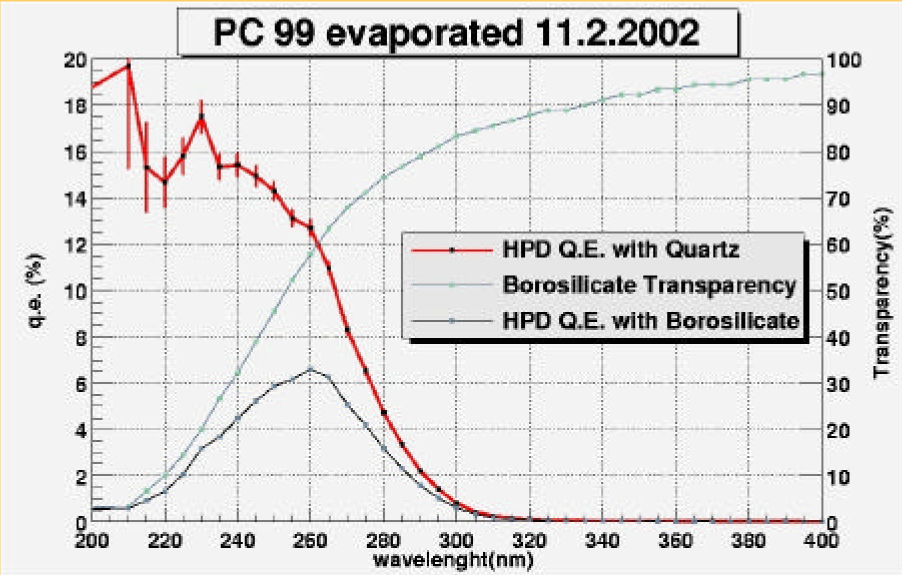
10” Bialkali borosilicate window

20” (!) only simulated in the e optics



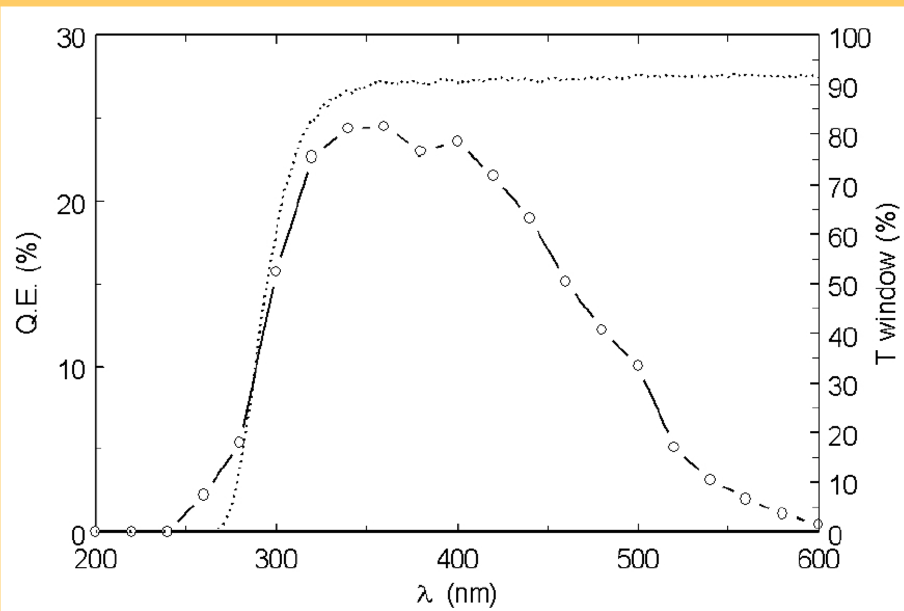
HPD: Quantum Efficiency

Michele Giunta



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.

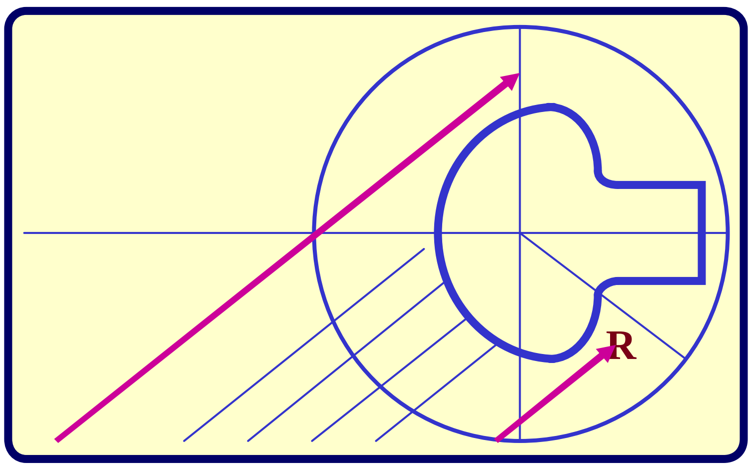


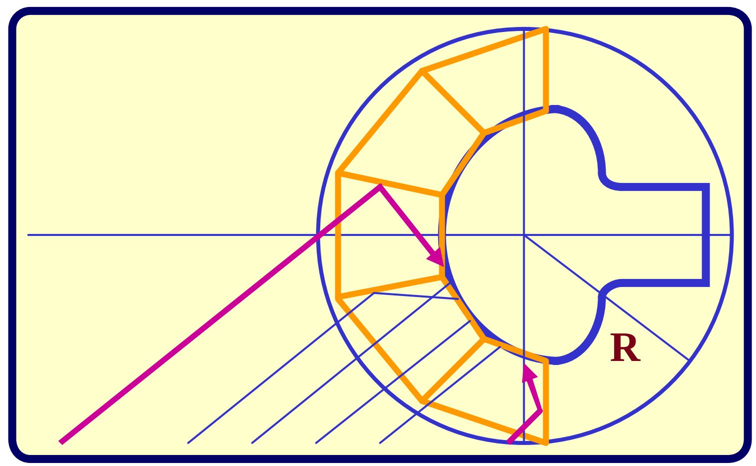
Visible Bialkali 10” Q.E

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

Direction Sensitive Light Collection

- A PMT cannot determine incoming photons direction
- This can be achieved with a proper light collection system
- This can be used with a multianodic PMT or with an array of PMTs



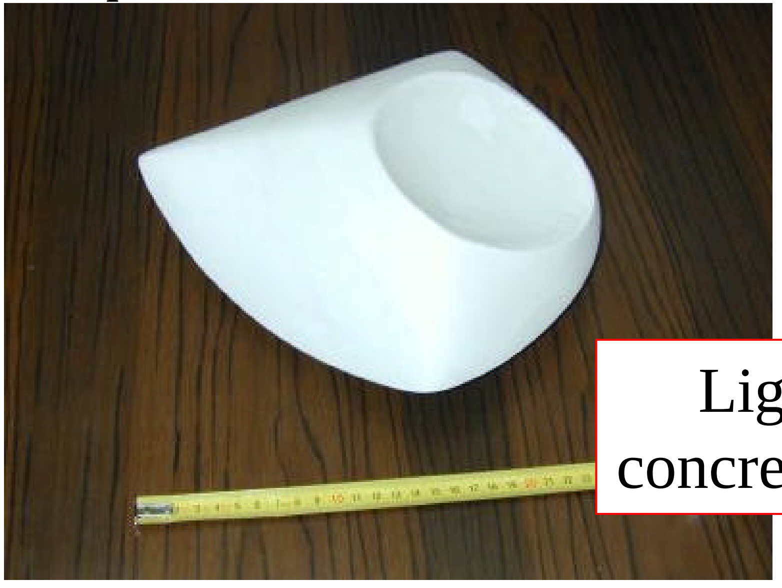


Light Guide

Light guide for a system of four 5”PMTs

- Simple structure
- Plexiglas light guides
- High reflectivity coating
- Good directionality and 10” effective equivalent area

PMT cluster

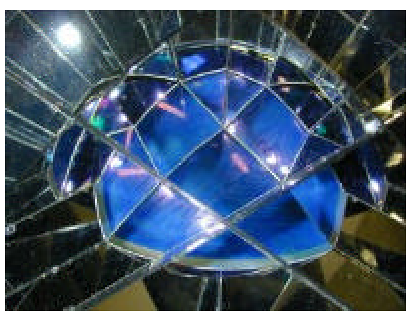


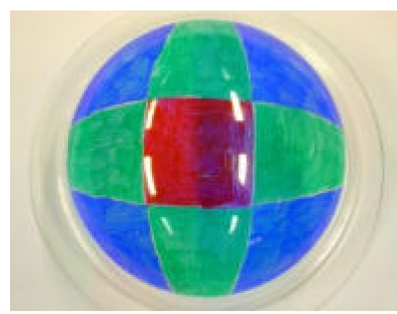
Light guide concrete prototype

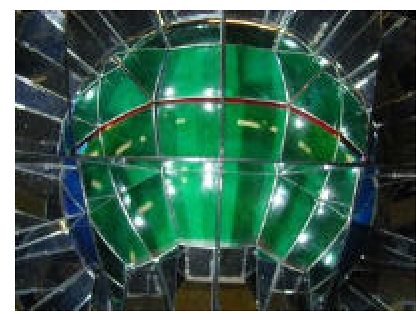
Light Collector

Light collector for multianodic PMT (or HPD)

- Simple and cheap material (aluminised PETG)
- Preserves directionality
- Slightly improves light collection efficiency
- Allow very good optical coupling with BS

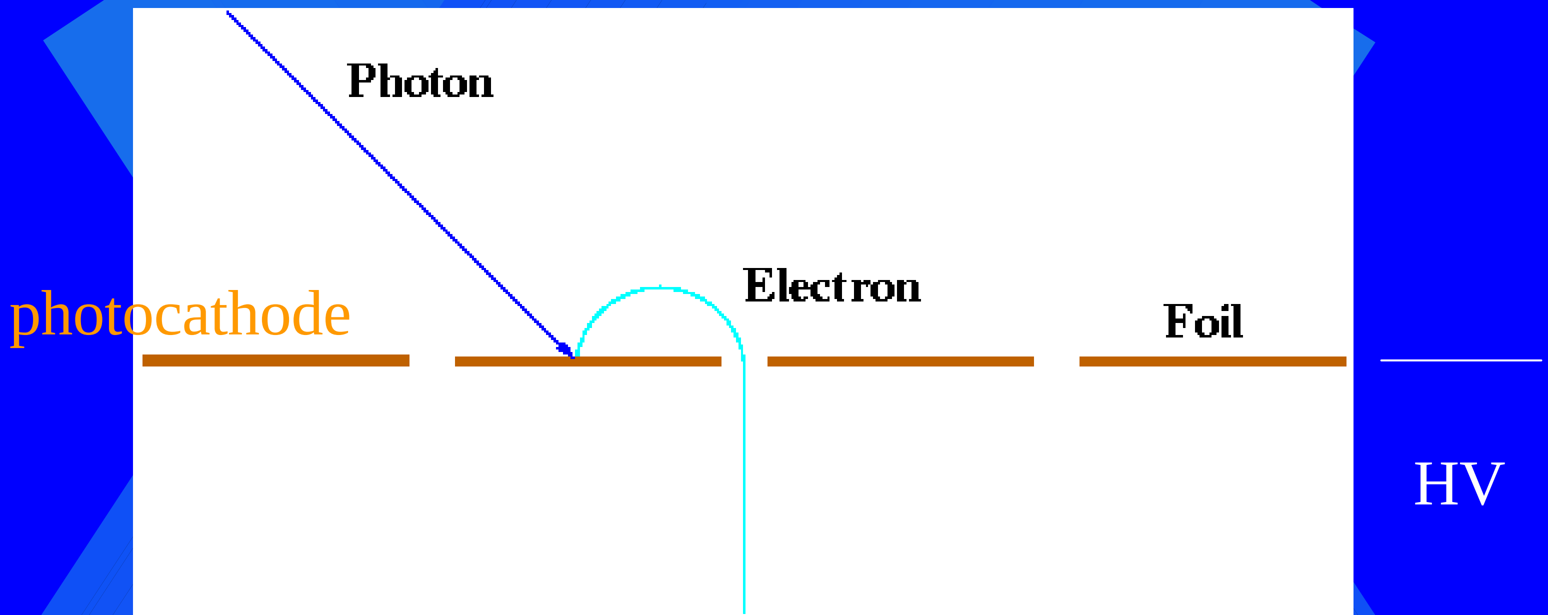






Use a “GEM” foil but not in gas??

Only use the foil to focus produced pe’s



APD or multiplication dynodes

Reflective cathode and HPD type device combined

Hard to make in a sphere shape, but maybe foil is not necessary. Could be more solid.

Even wilder….

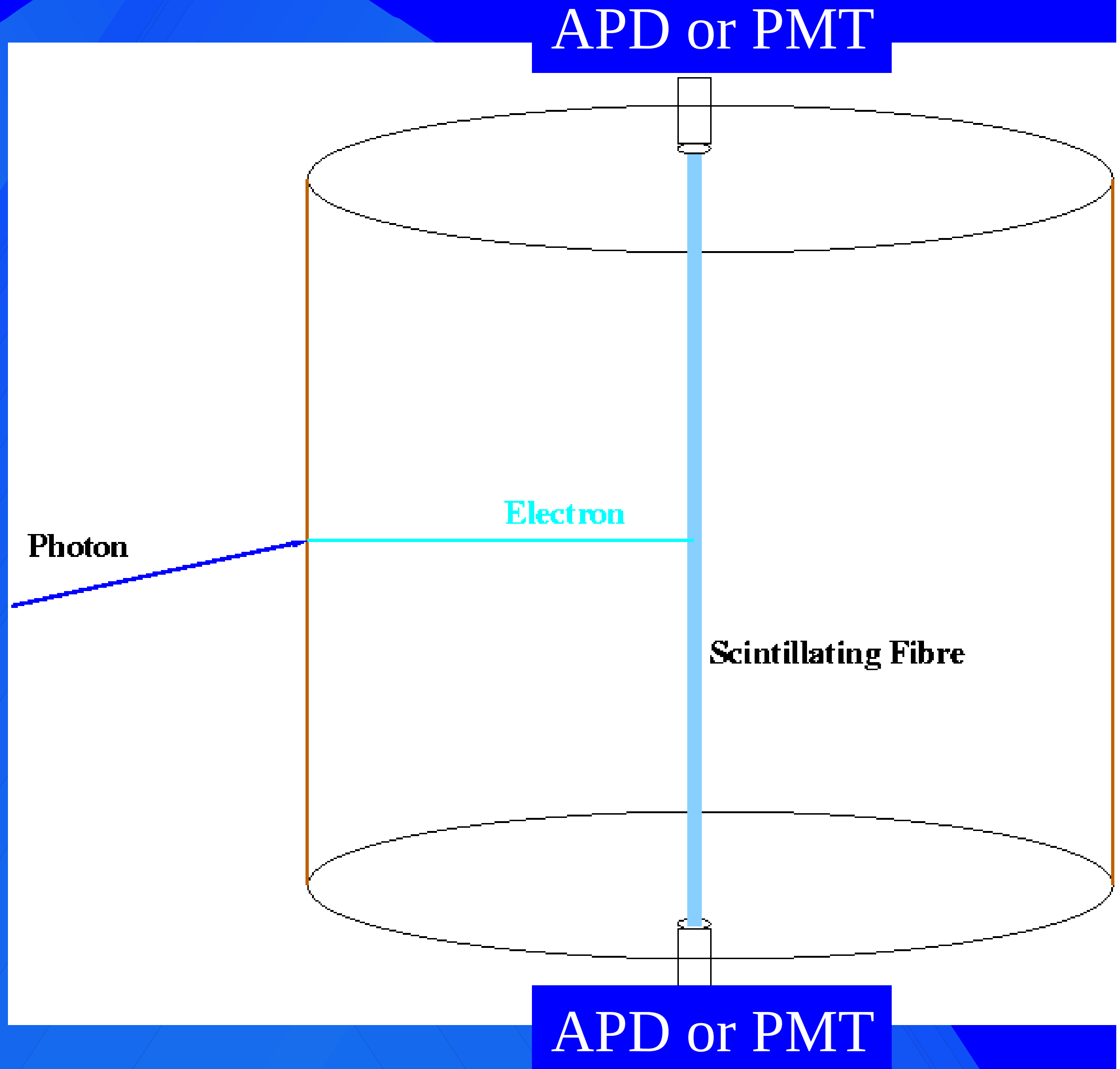
A la BAIKAL PMT

Could be made quite long

Double readout gives good timing

Obviously 30 kV is not easy.

Fairly simple device




Summary
New products or ideas from industries
New concepts (directionality, high collecting light efficiency)
but…

Conclusive Remarks

- **Detector design specifications and simulations are required to REALLY prove the effectiveness of the proposed improvements (Energy range, Shape, …)**

- **A photodetector development program should be included in the financial request to EU**