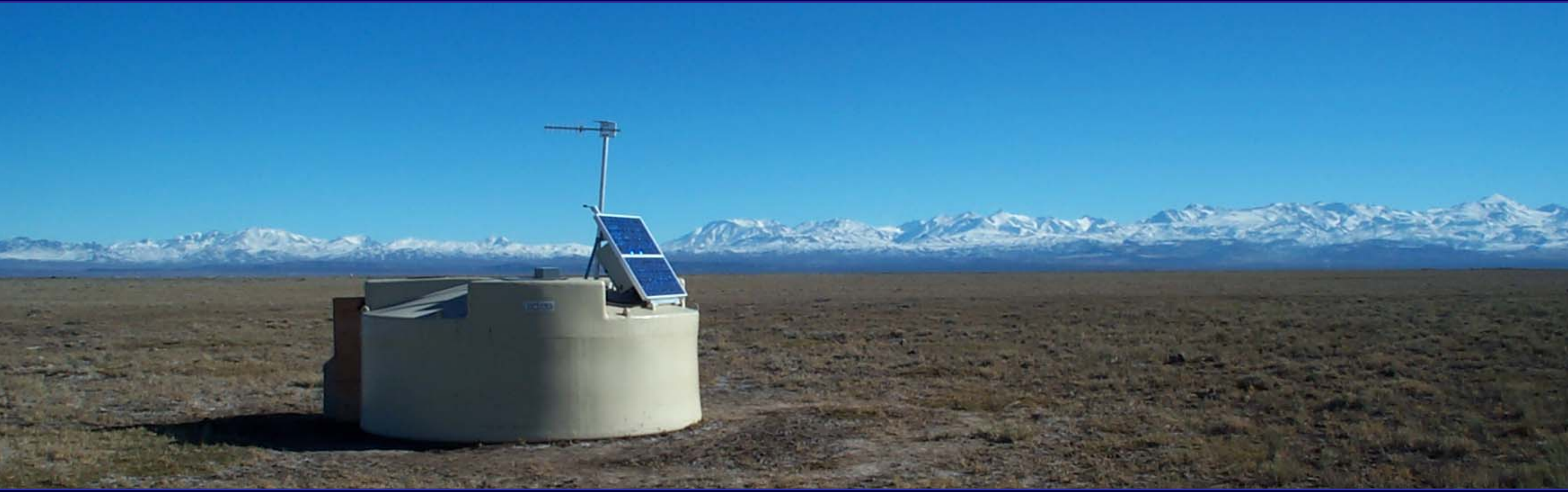
Large Photodetector Developments in Europe

Joël Pouthas IPN Orsay France

Photodetectors - Requirements

UHCR (Ultra High energy cosmic ray)



Pierre Auger Observatory (Argentina)

Very high dynamic range

Low after pulse rate

Photodetectors - Requirements

Deep underwater neutrino telescopes

[Dumand (Hawaï)]

Baikal Lake (Russia)

ANTARES (France)

NESTOR (Greece)

NEMO (Italy)

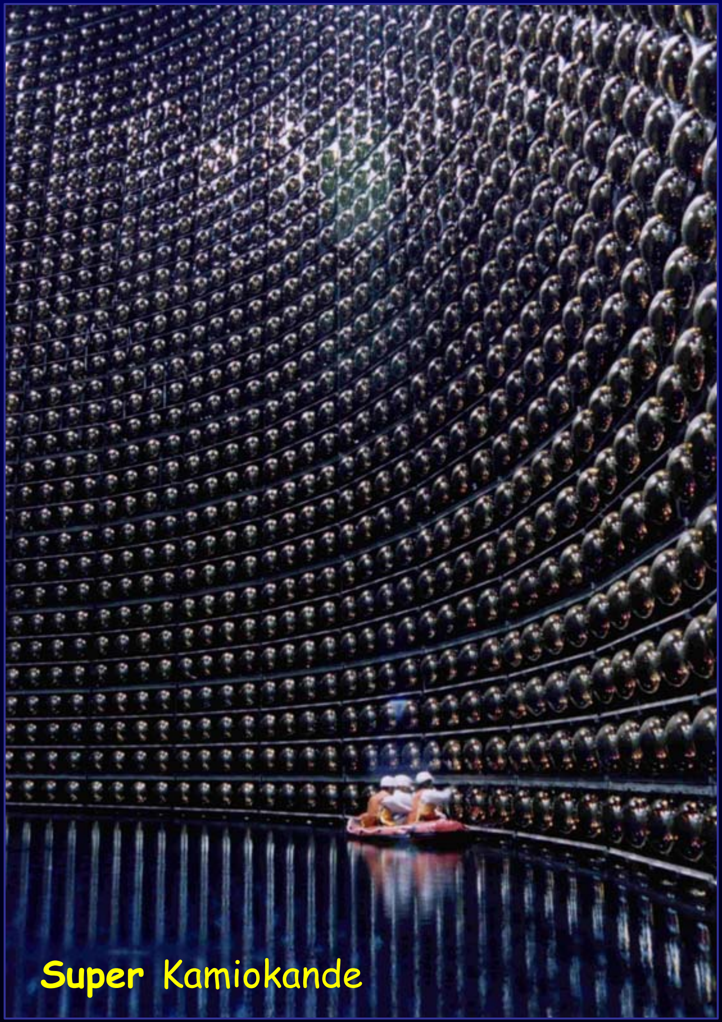
AMANDA / Ice Cube (South Pole)

Large area
with maximum efficiency

Good SER
(Single electron response)
in charge and time

Photodetectors - Requirements

Nucleon decay and neutrino detectors



KamiokaNDE

Super KamiokaNDE

KamLAND

(Japon)

SNO (Canada)

MiniBooNE (USA)

Borexino (Italie)

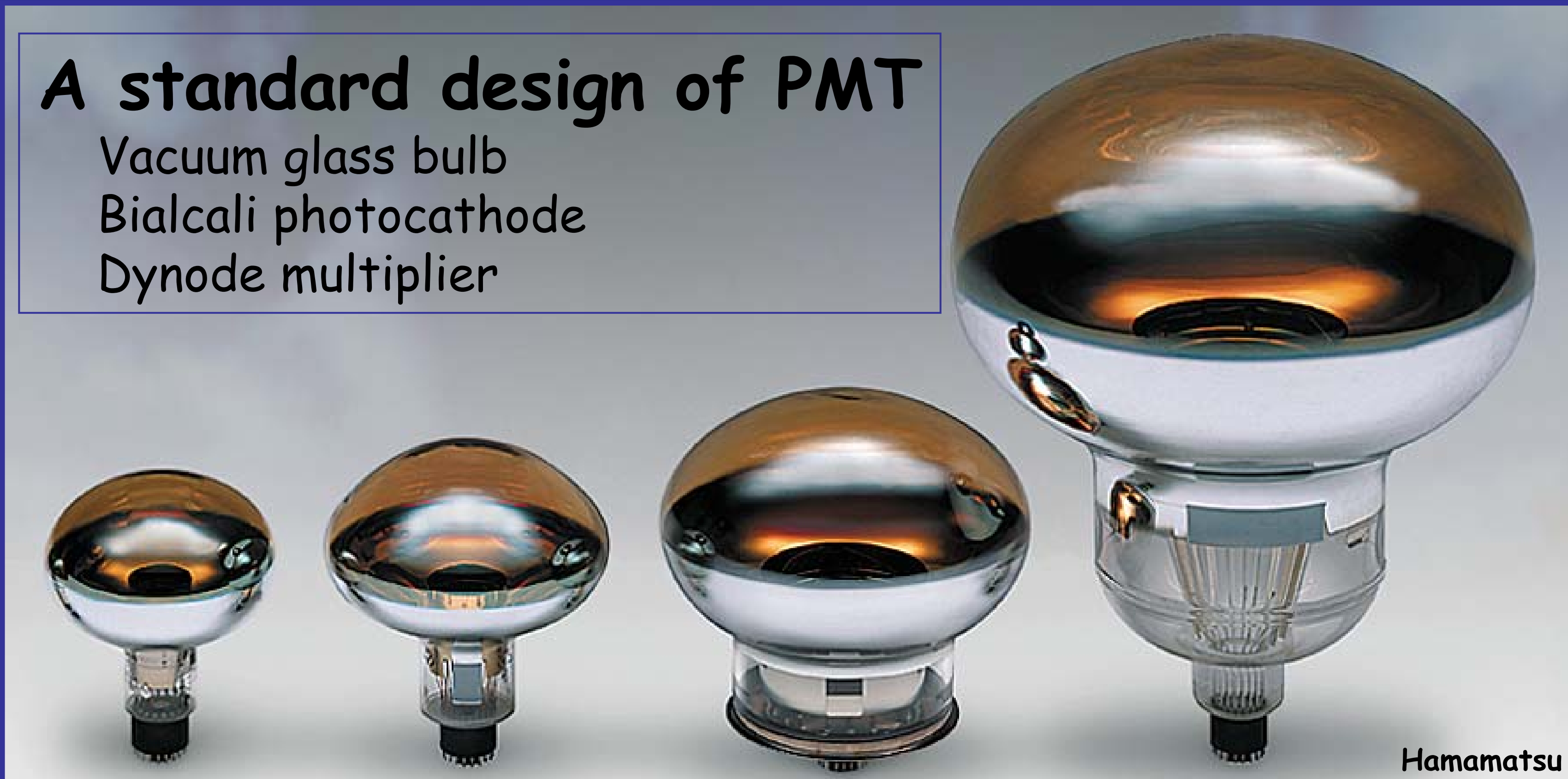
Large area
with maximum efficiency

Good SER
(Single electron response)
in charge and time

Low noise

First remark

Nearly all the present experiments make use of :



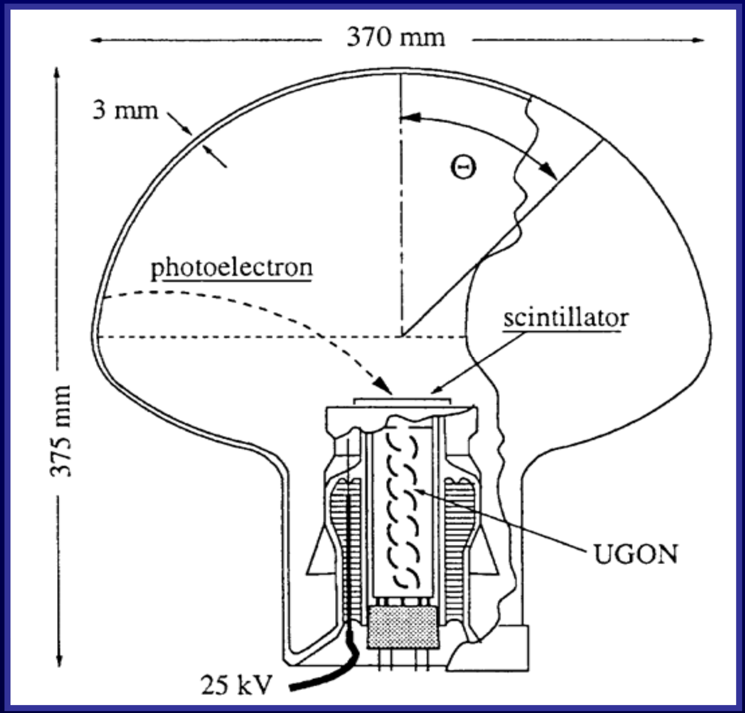
… with an interesting exception …

Baikal neutrino experiment

First developments (1983)

Philips XP 2600
Dumand project & Baikal

Baikal neutrino experiment



Quasar 370

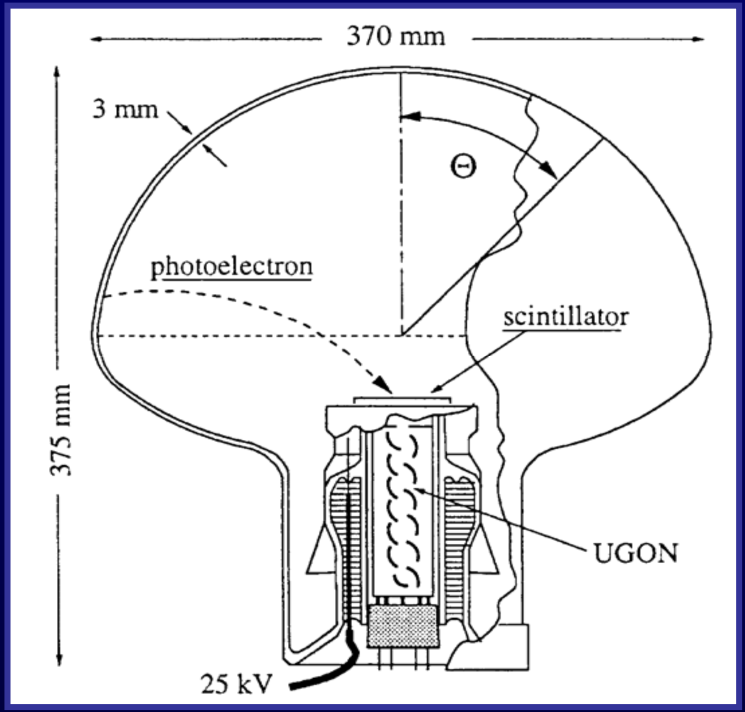
First developments (1983)

Philips XP 2600
Dumand project & Baikal

Then in Russia

Baikal experiment
Quasar 300 ; Quasar 350
Quasar 370

Baikal neutrino experiment



Quasar 370

Glass bulb
Photocathode (SbKCs)

Acceleration PE (25 kV)
Scintillator (YSO)

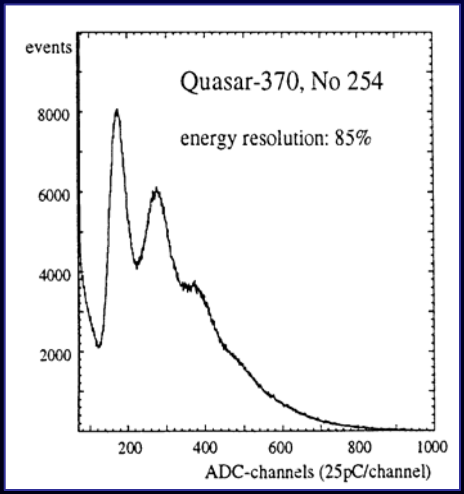
Conventional PMT (UGON)

Characteristics

Large area

Good SER (Gain 1st stage : 25)

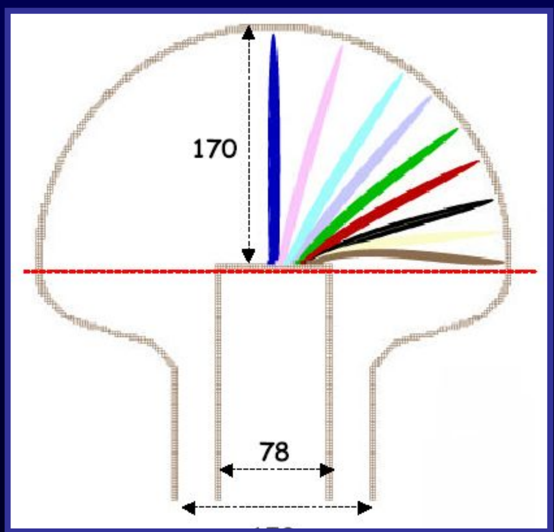
Good TTS : 2.5 ns (FWHM)

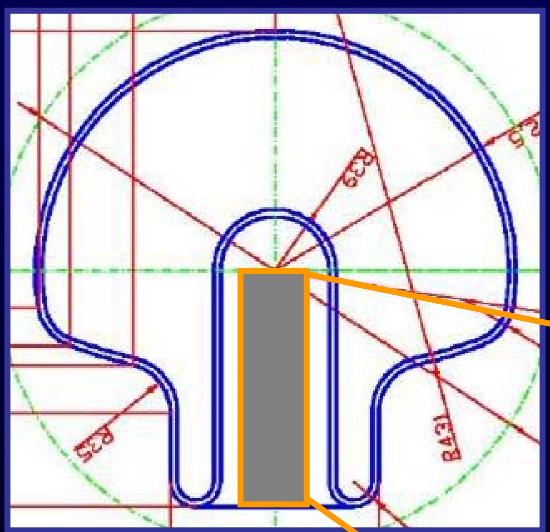


Hybrid Photomultiplier (HPMT)

Baikal NT 200 — Completed 1998 — 192 HPMT installed.
R&D on scintillators : ScBO-Ce ; YAP ; LSO

Very Large Volume Neutrino Telescope in the Mediterranean Sea
VLVνT Workshop — Oct. 2003
A. Bersani on behalf NEMO-ANTARES Group





4 PMTs

Bulb shape and focalisation (Simulations)

Other Ideas (for localization)

VLVνT Workshop (2003)

Other Ideas (for localization)

A. Bersani on behalf NEMO-ANTARES Group

Replace a PMT

by several
small PMTs

VLVvT Workshop (2003)

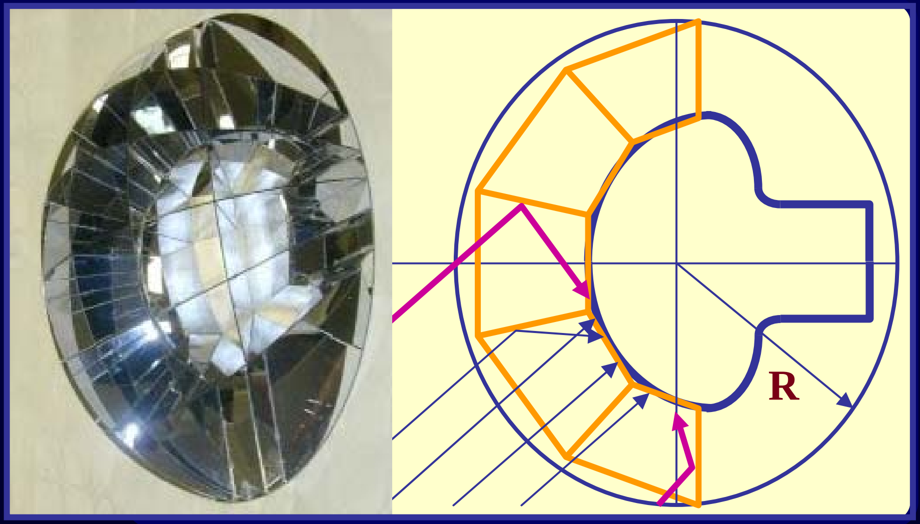
Other Ideas (for localization)

A. Bersani on behalf NEMO-ANTARES Group

Replace a PMT

by several
small PMTs

Introduce an optical system
(an array of Winston's cones)



Light collection efficiency ?

Second remark

All ideas on

photodetection designs are certainly interesting

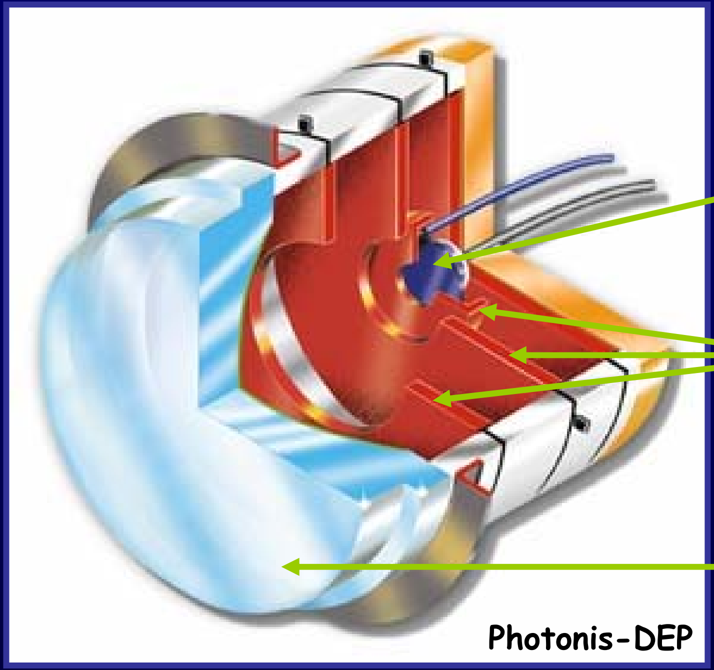
But…

…if a mass production is foreseen

Constraints from industry

must be considered from the begining

Hybrid Photon Detector (HPD)



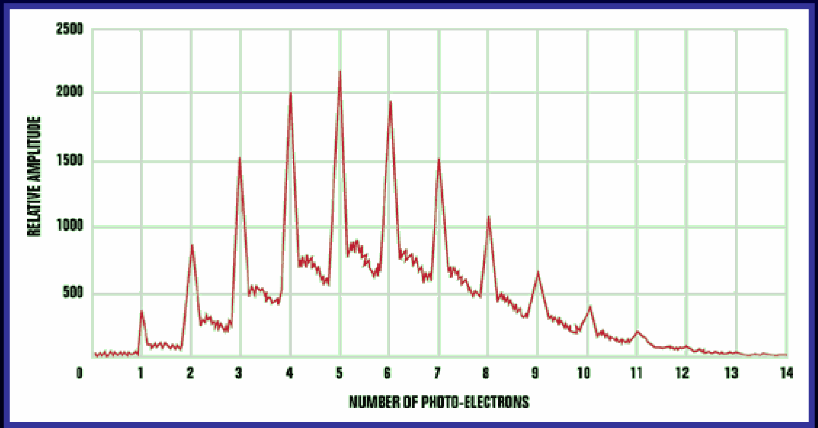
Silicon PIN diode
(2 mm diameter)

Focussing electrodes
(Total HV : - 15 kV)

Phocathode (18 mm usefull)

Excellent photon resolution
(Very good SER)

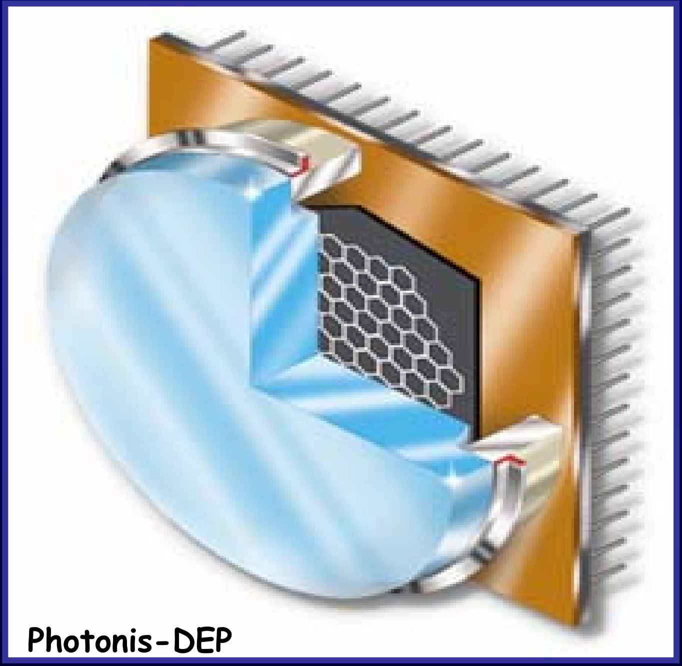
Low gain : 3500 @ 15 kV
(needs low noise electronics)

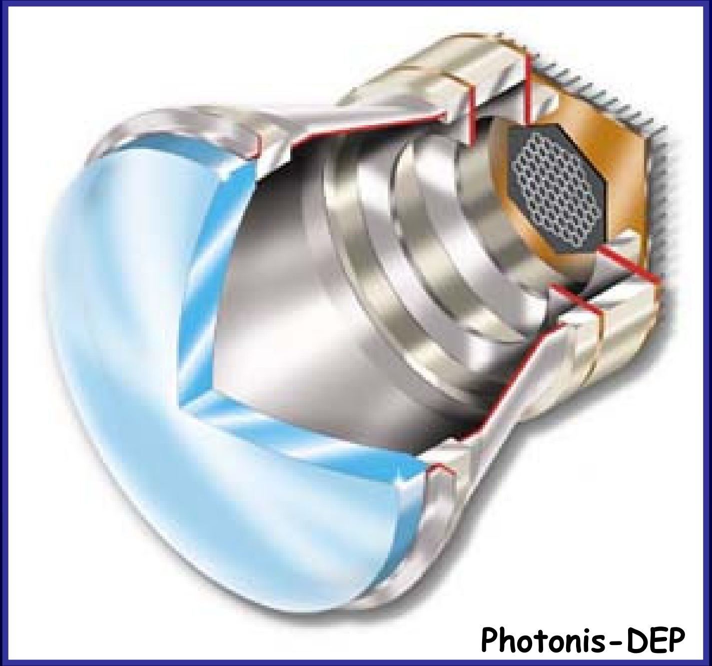


Hybrid Photon Detector (HPD)

Localization (Multi-pixel)

Proximity focussed	Electrostatically focussed





CMS @ CERN

HCAL (Hadronic calorimeter)
(19 or 75 pixels)
(4T field)

72 mm diameter

RICH
LHCB @ CERN

HPD for the LHCB RICH

G. Aglieri Rivella on behalf RICH LHCB Collaboration
IEEE 2004 NS, Roma

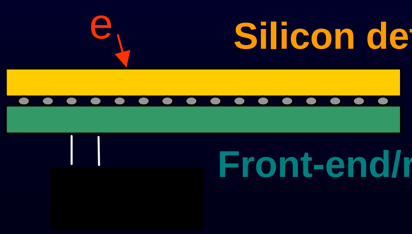
Vacuum tube

Quartz window
S20 photocathode
Cross-focusing electron optics

Hybrid pixel detector (16x16 mm^2)

32×32 pixel silicon detector
fully encapsulated in the vacuum tube

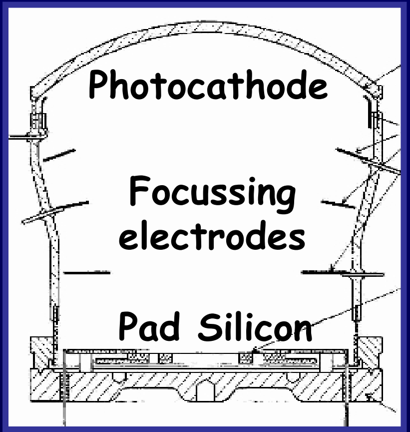
Analog and digital chain readout on chip



CMOS readout chip
bump-bonded onto the silicon detector

HPD Team @ CERN

HA. Braem, E. Chesi, C. Joram, J.Séguinot, P. Weilhammer
(T. Ypsilantis)
Started in 1997

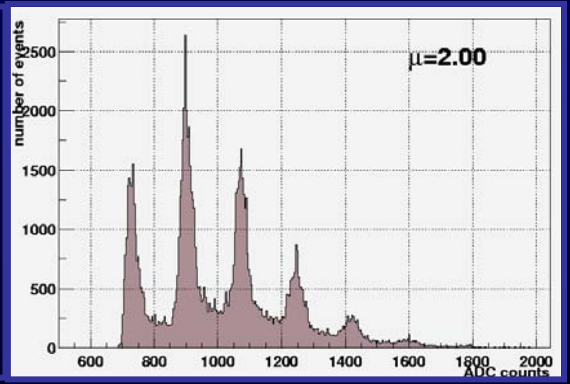


HPD 5-inch (Design for LHCb Rich)

Photocath. : Bialcali or Rb_2Te
HV : - 20 kV
PIN : 2048 pixels of 1x1 mm^2

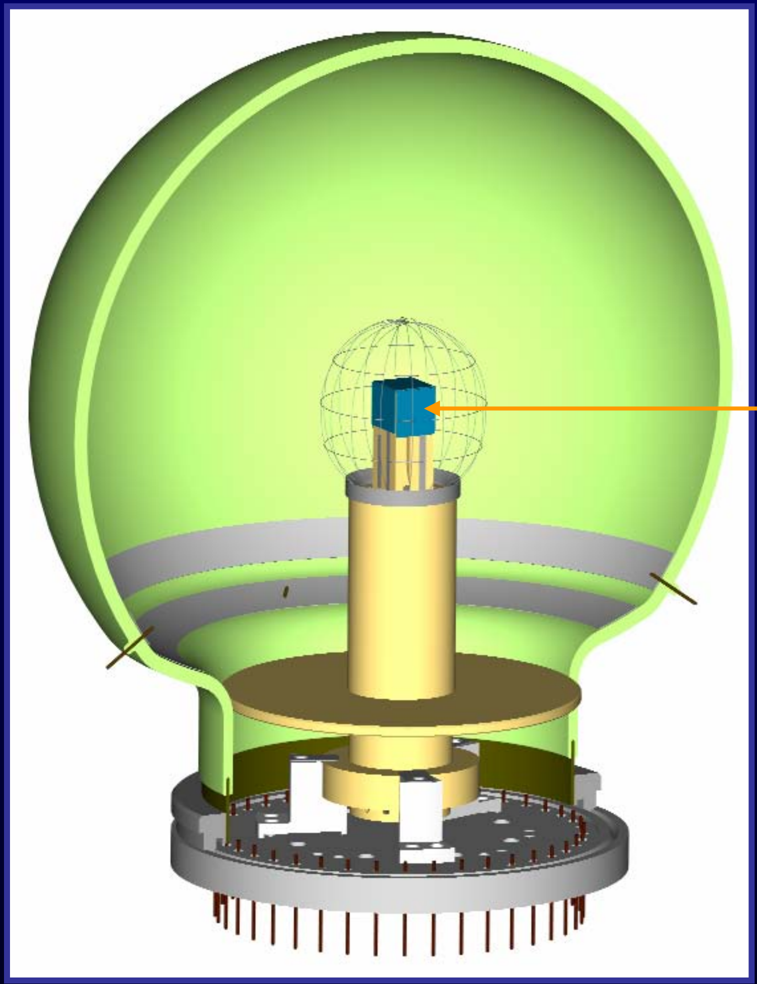
Electronics

Slow ASIC
VA chip, 2 μs
Encapsulated
in the vacuum



HPD 10-inch (TOM HPD)
Design for the CLUE Telescope (La Palma)

HPD Team @ CERN



"Artistic view" of
the half-scale prototype

C2GT Project (in the Golf of Taranto)

Detection in a sphere of 432 mm

Photodetector 380 mm

5 Silicon sensors (12 x 13.2 mm^2)
in a grounded field cage

PIN

Signal at 20 kV: $5 \cdot 10^3$ e, G = 1

C_d = 35 pF/cm^2 , ENF ~ 1

APD

2-3 $\cdot 10^5$ e, G ~ 50

C_d = 300 - 1500 pF/cm^2, ENF = 2 - 5

Third remark

With silicon devices

and particularly with PIN diodes

the signal is very weak

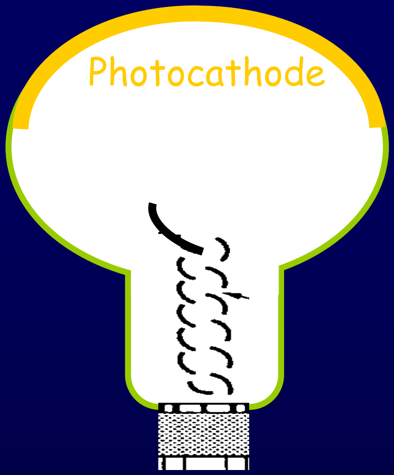
And ...

Electronics

must be considered from the begining

Summary

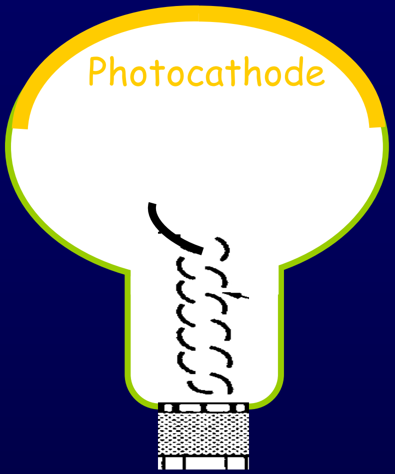
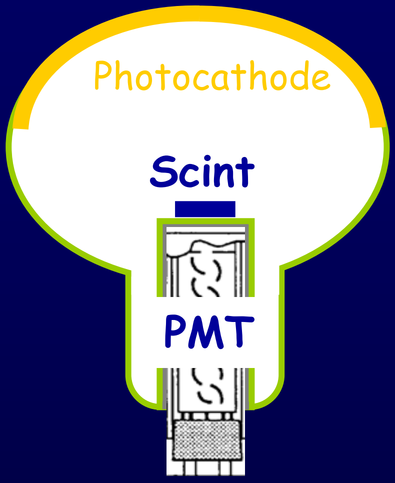
PMT



Medium
SER and TTS
(depend of size)

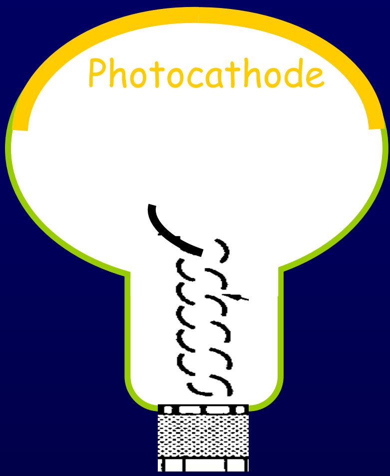
HV
2 or 3 kV

Summary

PMT	HPMT
	
Medium SER and TTS (depend of size)	Good SER and TTS (depend of scint)
HV 2 or 3 kV	HV 20 to 30 kV

Summary

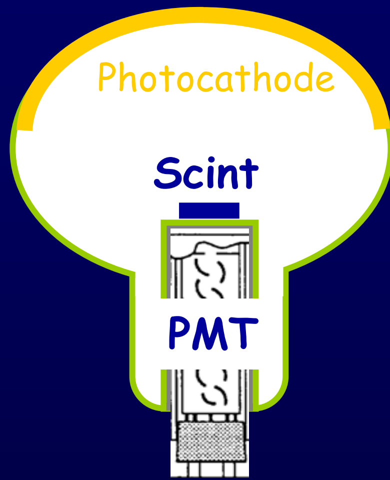
PMT



Medium
SER and TTS
(depend of size)

HV
2 or 3 kV

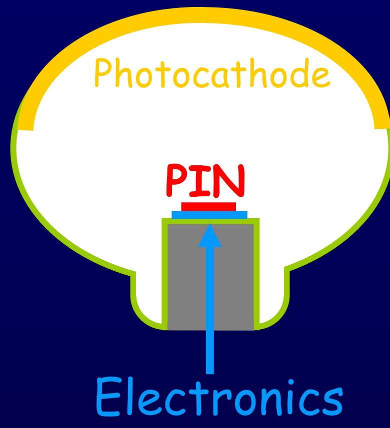
HPMT



Good
SER and TTS
(depend of scint)

HV
20 to 30 kV

HPD



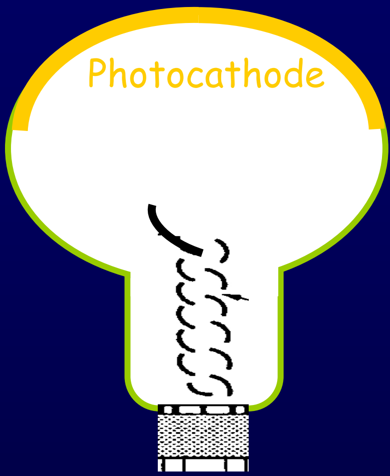
Very good
SER

TTS ?
(depend of FEE)

HV (negative)
15 to 30 kV

Summary

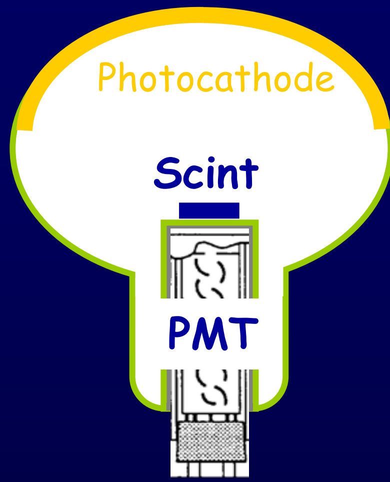
PMT



Medium
SER and TTS
(depend of size)

HV
2 or 3 kV

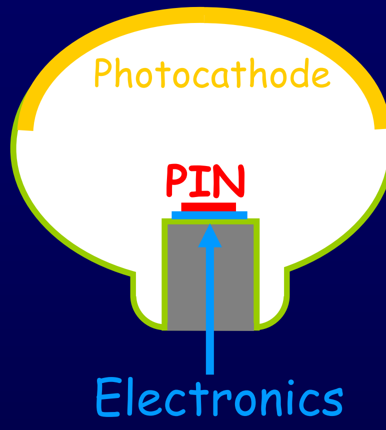
HPMT



Good
SER and TTS
(depend of scint)

HV
20 to 30 kV

HPD

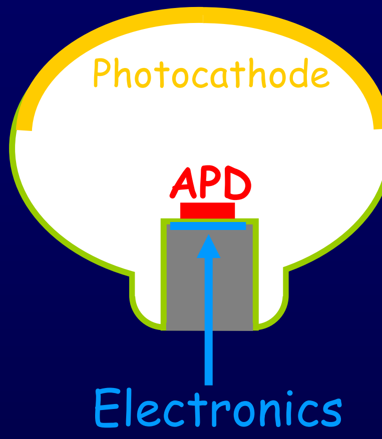


Very good
SER

TTS ?
(depend of FEE)

HV (negative)
15 to 30 kV

HAPD



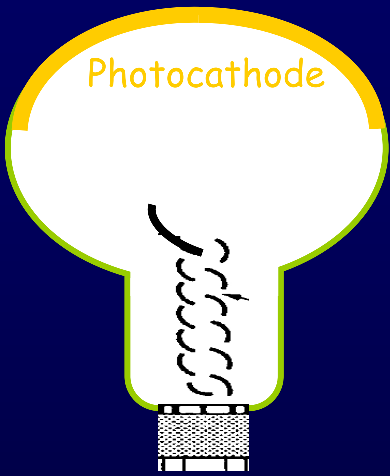
Expected ?

Very good
SER and TTS
(depend of FEE)

HV (negative)
10 kV or more ?

Large photodetectors in Europe

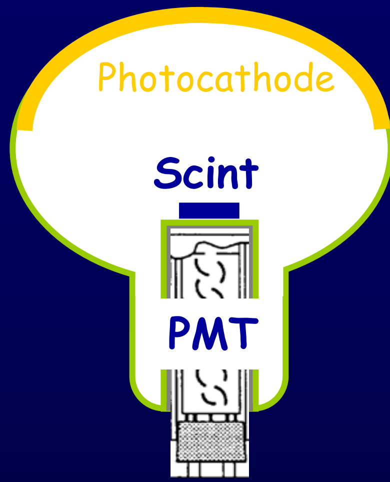
PMT



Companies

ETL
PHOTONIS
+
Labs
(Characterization)

HPMT

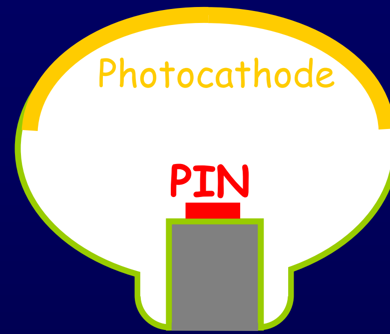


Quasar (Russia)

R&D VLVvT

R&D PHOTONIS
(+ IPNO)

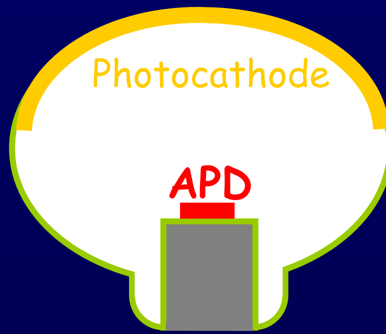
HPD



R&D
HPD CERN

R&D
PHOTONIS
DEP

HAPD



Discussions

More ?

Concluding remarks

Most of the photodetectors follows
a standard design

Some R&D are (or will be) performed on
HPD (Hybrid Photon Detector)

The design (particularly HPD) must include
Micro-electronics (Asic)

Collaboration with industry is mandatory
Mass production and cost are key parameters

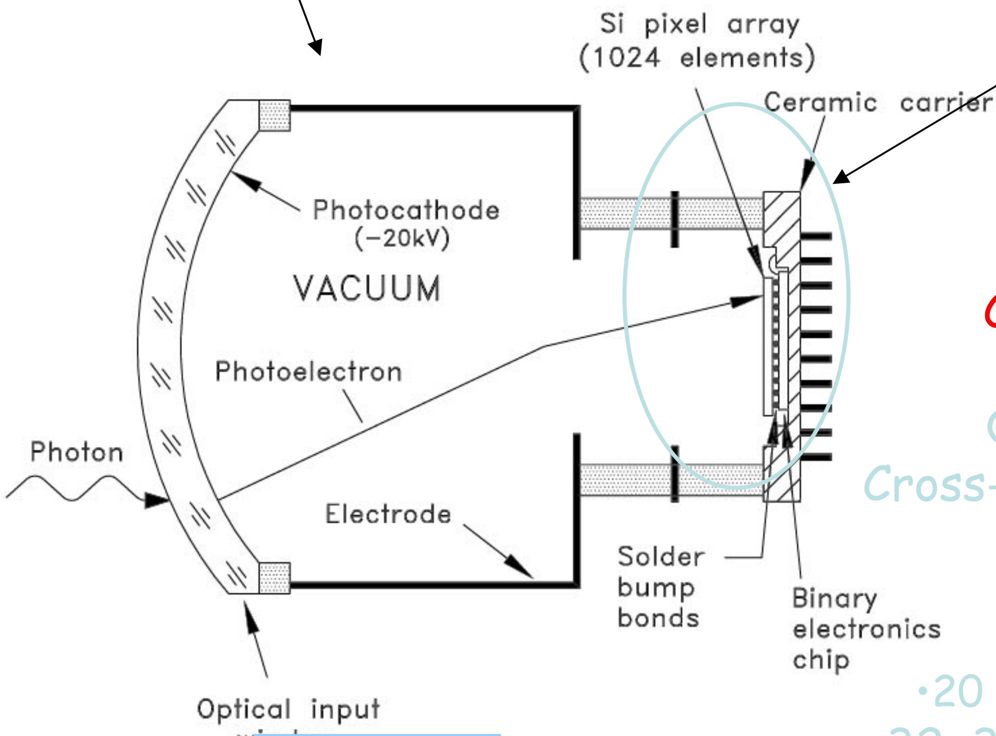
The best is generally not the cheapest … But …

Do we really need the best ?

Pixel-HPD description

Vacuum photon detector

Anode



Schematic view

http://www.cern.ch/~gys/LHCb/PixelHPDs.htm

Main features:

Close collaboration with industry

Quartz window with thin S20 pK

Cross-focussing optics (tetrode structure):

•De-magnification by ~5

•Active diameter 75mm

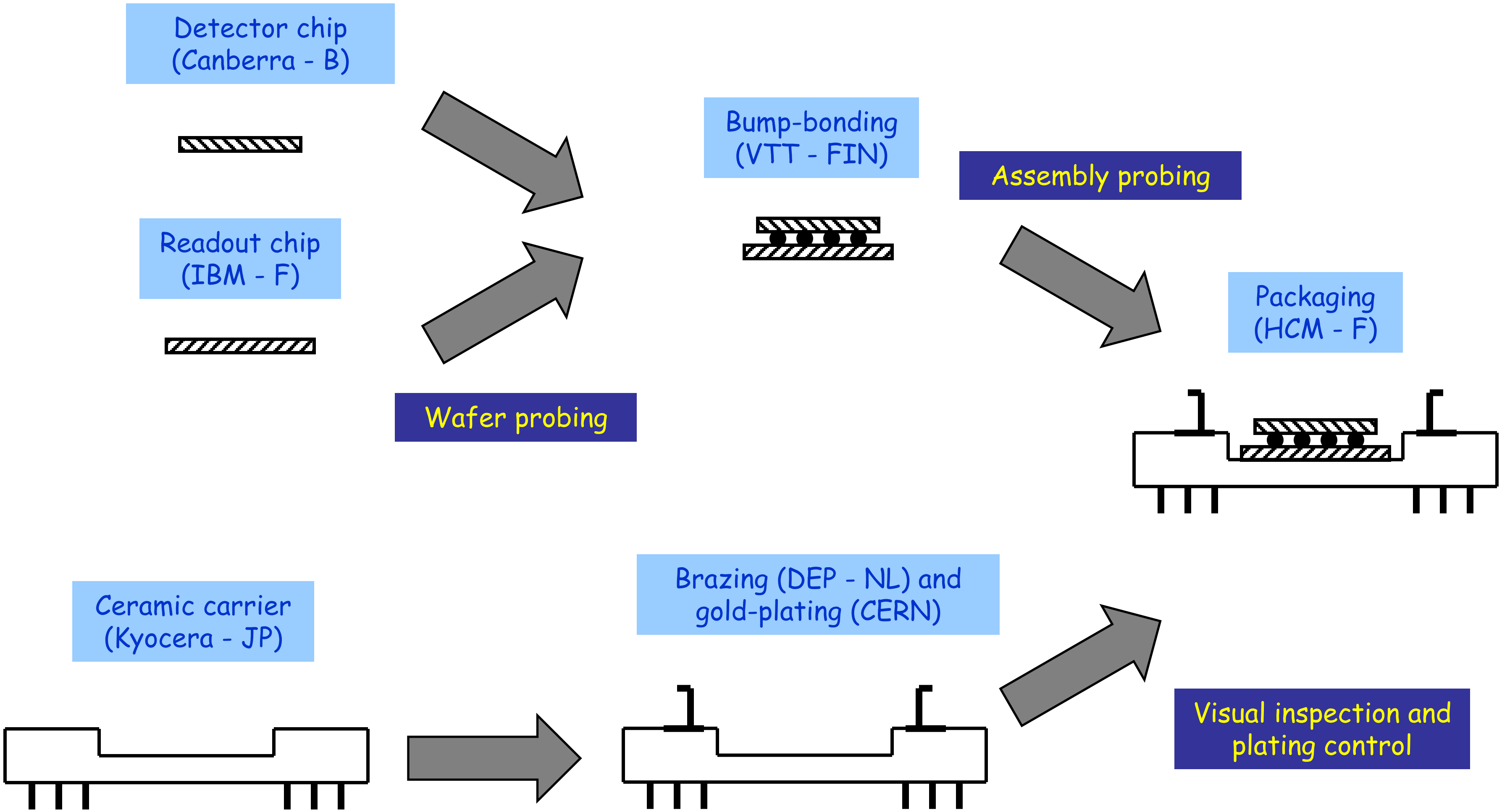
⇒ 484 tubes for overall RICH system

•20 kV operating voltage (~5000 e^- [eq. Si])

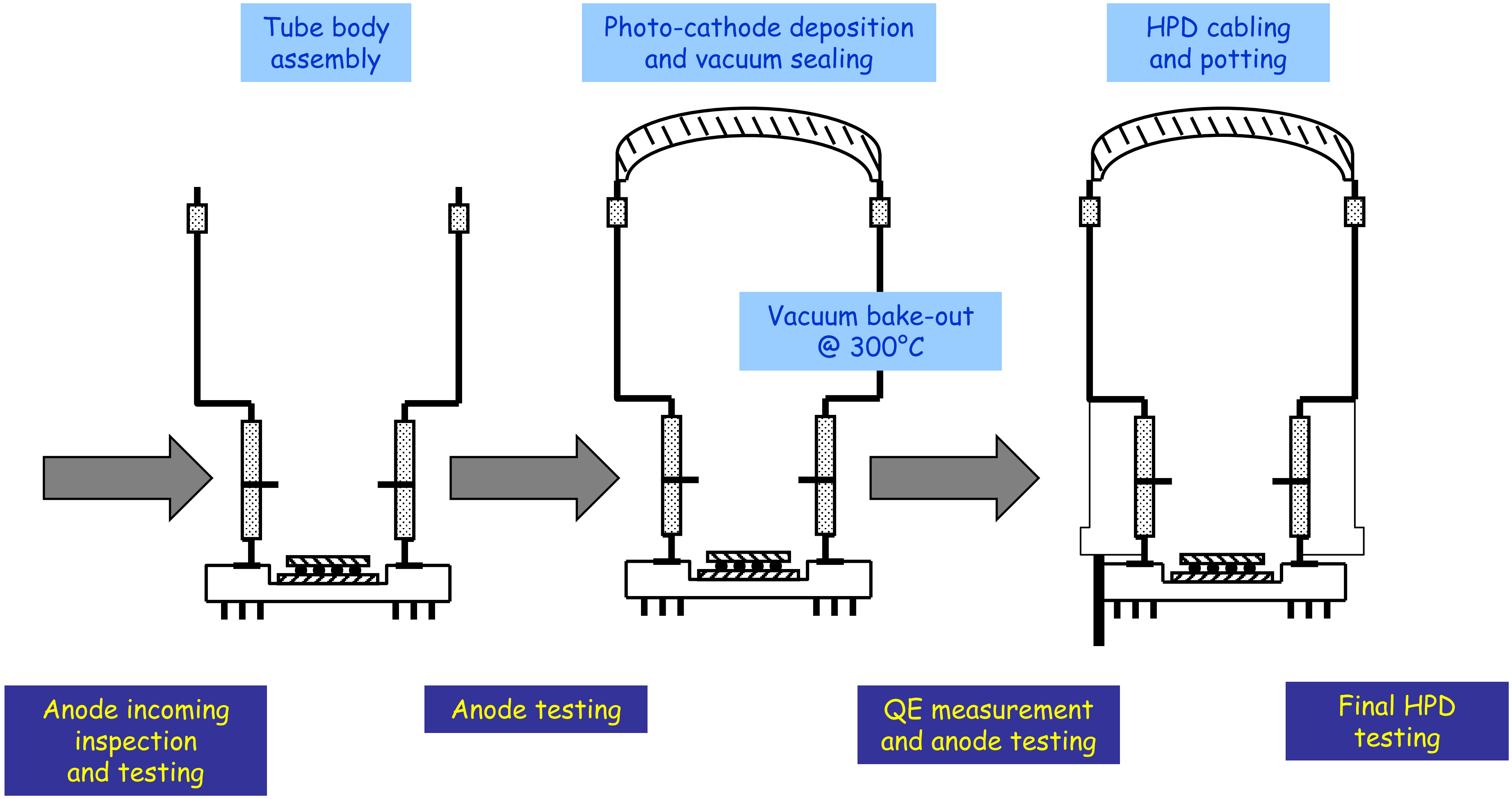
32×32 pixel sensor array (500μm×500μm each)

Encapsulated binary electronics readout chip

HPD flow chart: anode part

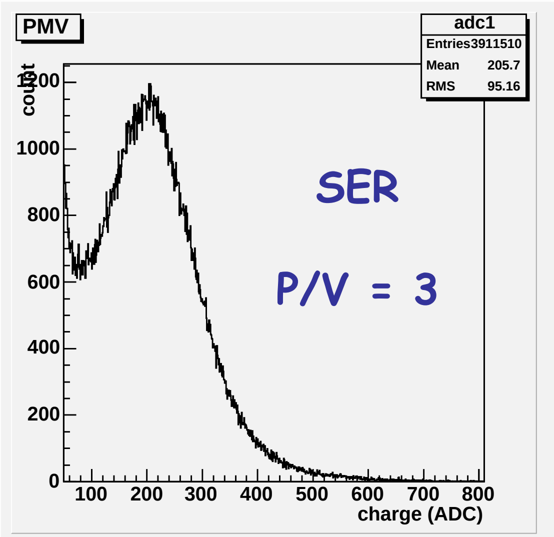


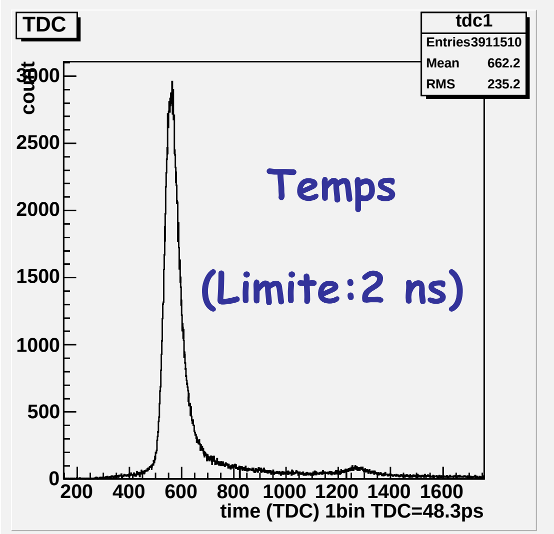
HPD flow chart: HPD tube part (DEP)



Completed HPD tube

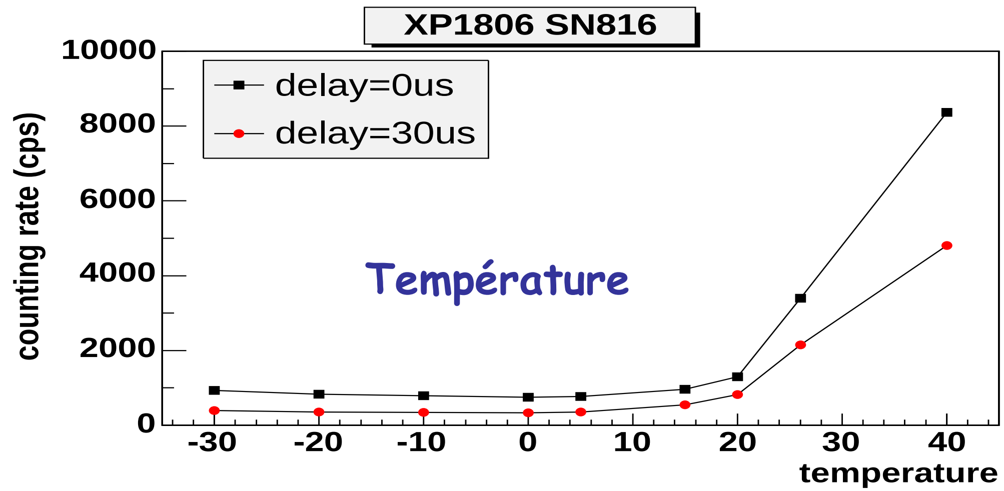
Quelques résultats

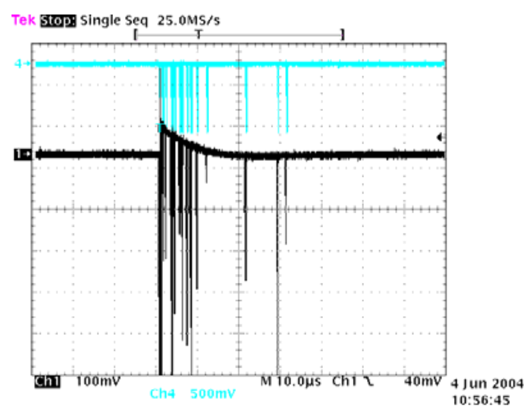




SER et Temps

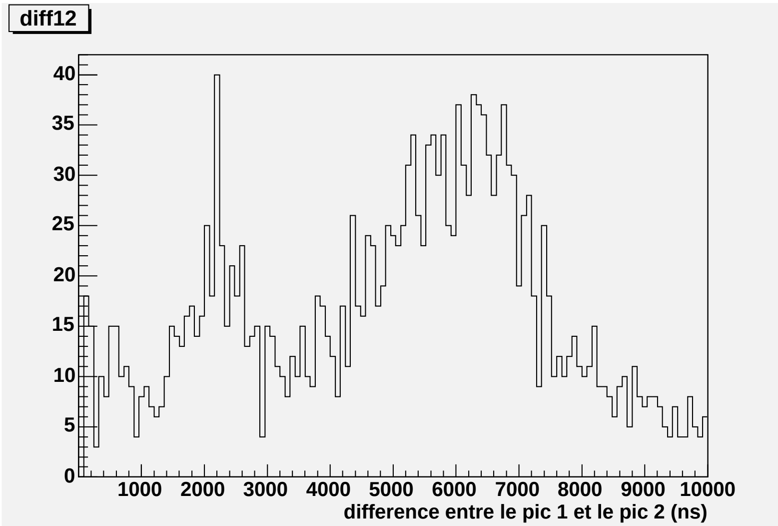
XP 1806, 8 pouces, type ANTARES



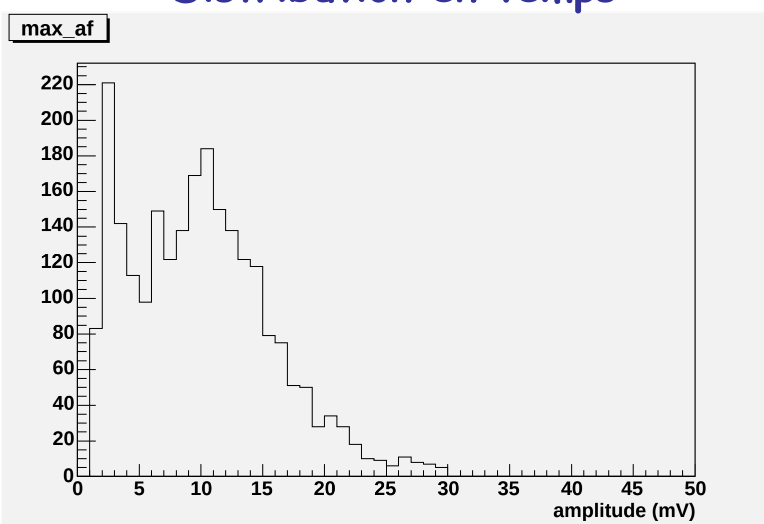


« Bursts »

Quelques résultats



Distribution en temps

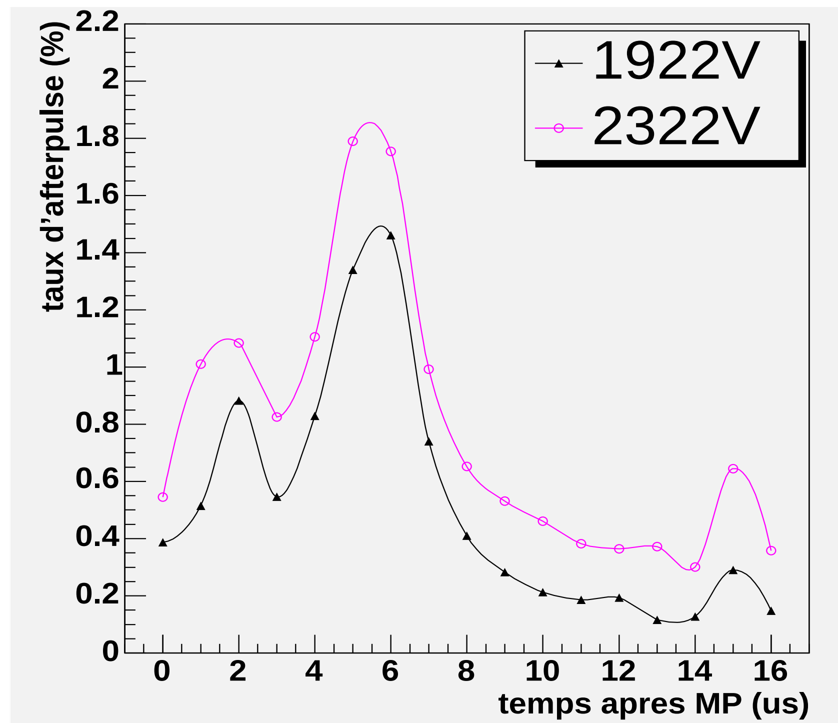


Distribution en amplitude

Post impulsions

(Mesures à l'oscilloscope numérique)

XP 1806, 8 pouces, type ANTARES



Taux de comptage différentiel