Large Photodetector Developments in Europe

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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:

A standard design of PMT:
Vacuum glass bulb
Bialcali photocathode
Dynode multiplier

... with an interesting exception ...
Baikal neutrino experiment

First developments (1983)

Philips XP 2600
Dumand project & Baikal
Baikal neutrino experiment

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
VLVvT Workshop
Oct. 2003
A. Bersani on behalf NEMO-ANTARES Group

Bulb shape and focalisation (Simulations)
Other Ideas (for localization)
Other Ideas (for localization)

A. Bersani on behalf NEMO-ANTARES Group

Replace a PMT

by several small PMTs
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 beginning
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

Photonis-DEP

Joël Pouthas  IPN Orsay
**HPD for the LHCB RICH**

**Vacuum tube**
- Quartz window
- S20 photocathode
- Cross-focusing electron optics

**Hybrid pixel detector (16x16 mm²)**
- 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

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Joël Pouthas  IPN Orsay

G. Aglieri Rivella on behalf RICH LHCB Collaboration
IEEE 2004 NS, Roma
HPD Team @ CERN

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

HPD 5-inch (Design for LHCb Rich)
Photocath.: Bialcali or Rb₂Te
HV: - 20 kV
PIN: 2048 pixels of 1x1 mm²

Electronics
Slow ASIC
VA chip, 2 µs
Encapsulated in the vacuum

HPD 10-inch (TOM HPD)
Design for the CLUE Telescope (La Palma)
C2GT Project (in the Golf of Taranto)

Detection in a sphere of 432 mm
Photodetector 380 mm

5 Silicon sensors (12 x 13.2 mm²)
in a grounded field cage

PIN
Signal at 20 kV: 5·10³ e, G = 1
C_d = 35 pF/cm², ENF ~ 1

APD
2-3 ·10⁵ e, G ~ 50
C_d = 300 - 1500 pF/cm², 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 beginning
Summary

PMT

Photocathode

Medium
SER and TTS (depend of size)

HV
2 or 3 kV
Summary

**PMT**

- Photocathode
- Medium SER and TTS (depend of size)
- HV 2 or 3 kV

**HPMT**

- Photocathode
- Scint
- Good SER and TTS (depend of scint)
- HV 20 to 30 kV
**Summary**

- **PMT**
  - Photocathode
  - Medium SER and TTS (depend of size)
  - HV 2 or 3 kV

- **HPMT**
  - Photocathode
  - Good SER and TTS (depend of scint)
  - HV 20 to 30 kV

- **HPD**
  - Photocathode
  - Very good SER
  - TTS ? (depend of FEE)
  - HV (negative) 15 to 30 kV

**Electronics**
Summary

**PMT**
- Photocathode
- Medium SER and TTS (depend of size)
- HV 2 or 3 kV

**HPMT**
- Photocathode
- Good SER and TTS (depend of scint)
- HV 20 to 30 kV

**HPD**
- Photocathode
- PIN
- Very good SER
- TTS ? (depend of FEE)
- HV (negative) 15 to 30 kV

**HAPD**
- Photocathode
- APD
- Expected ?
- Very good SER and TTS (depend of FEE)
- HV (negative) 10 kV or more ?
Large photodetectors in Europe

PMT
- Photocathode

HPMT
- Photocathode
  - Scint
  - PMT

HPD
- Photocathode
  - PIN
  - R&D HPD CERN
  - R&D PHOTONIS DEP

HAPD
- Photocathode
  - APD

Companies
- ETL
- PHOTONIS +
- Labs (Characterization)

Quasar (Russia)
- R&D VLVvT
- R&D PHOTONIS (+ IPNO)

R&D PHOTONIS

Discussions
- More?
Concluding remarks

Most of the photodetectors follow 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

**Main features:**

- Close collaboration with industry
- Quartz window with thin S20 pK
- Cross-focussing optics (tetrode structure):
  - De-magnification by ~5
  - Active diameter 75mm
- \( \Rightarrow 484 \) tubes for overall RICH system
- 20 kV operating voltage (~5000 e\(^-\) [eq. Si])
- 32\(\times\)32 pixel sensor array (500\(\mu\)m\(\times\)500\(\mu\)m each)
- Encapsulated binary electronics readout chip

http://www.cern.ch/~gys/LHCb/PixelHPDs.htm
HPD flow chart: HPD tube part (DEP)

1. Tube body assembly
2. Photo-cathode deposition and vacuum sealing
3. Vacuum bake-out @ 300°C
4. Anode testing
5. QE measurement and anode testing
6. HPD cabling and potting
7. Anode incoming inspection and testing
8. Final HPD testing
Completed HPD tube
Quelques résultats

SER et Temps

XP 1806, 8 pouces, type ANTARES

Température

« Bursts »
Quelques résultats

Post impulsions
(Mesures à l’oscilloscope numérique)
XP 1806, 8 pouces, type ANTARES