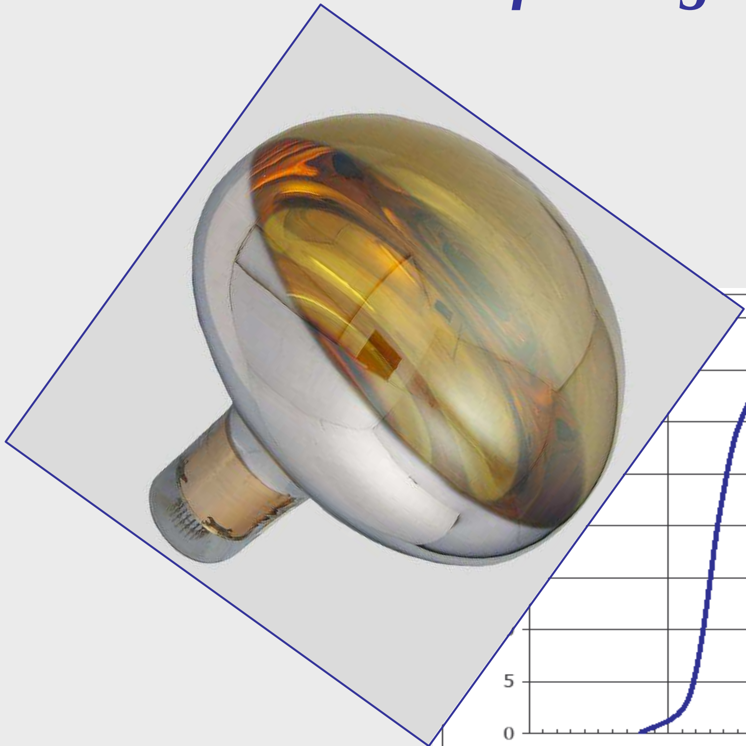
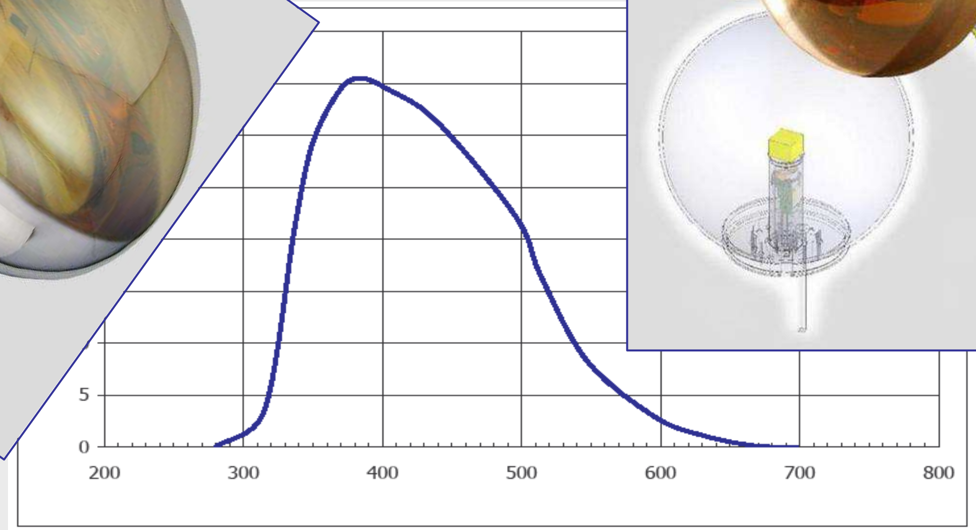
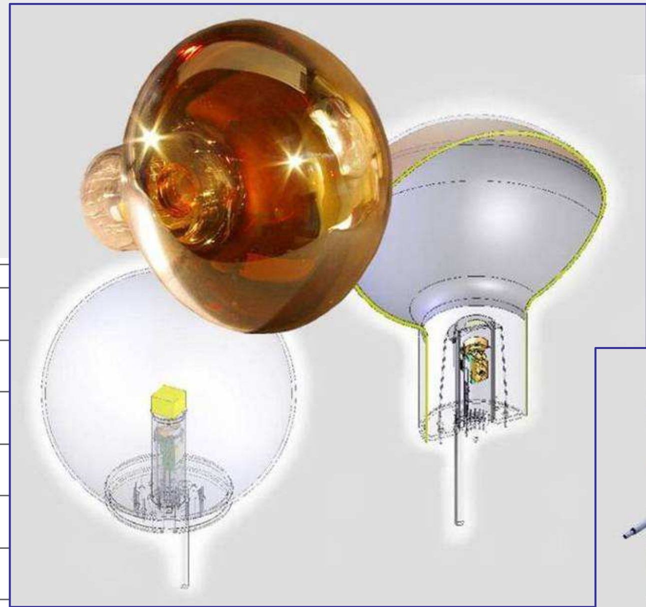
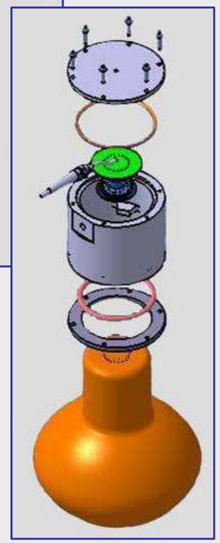
PHOTONIS

PHOTONIS tubes for large scale experiments









Bruno Combettes

NNN08
Paris Rive Gauche

PHOTONIS

Contents

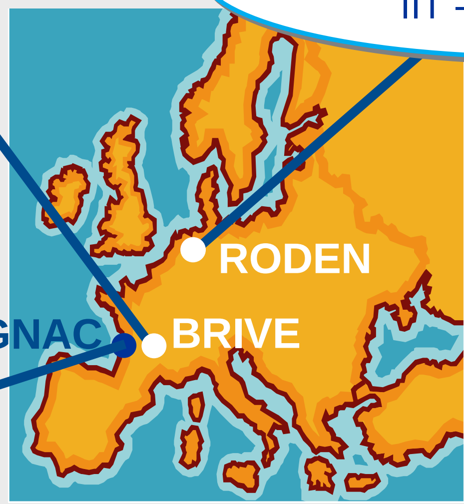
1. PHOTONIS Group and its production capability
2. Underground Neutrino Experiments
3. Underwater Neutrino Experiments
4. Reactor Neutrino Experiments
5. Atmospheric Cherenkov experiments
6. New perspectives

PHOTONIS

EUROPEAN SITES

PHOTONIS Netherlands BV
IIT - 159 persons

PHOTONIS France SAS
PMT–IIT– Special Products
600 persons



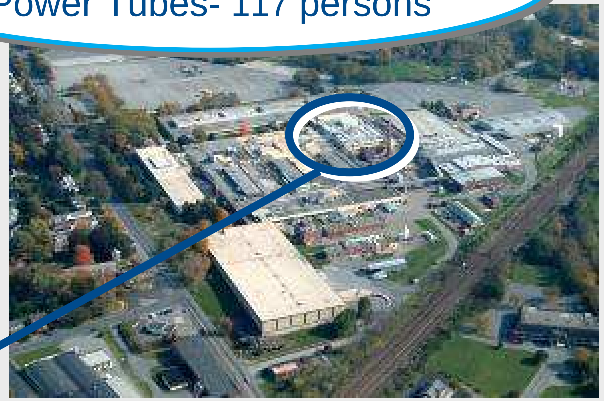
PHOTONIS Group Headquarters
10 persons

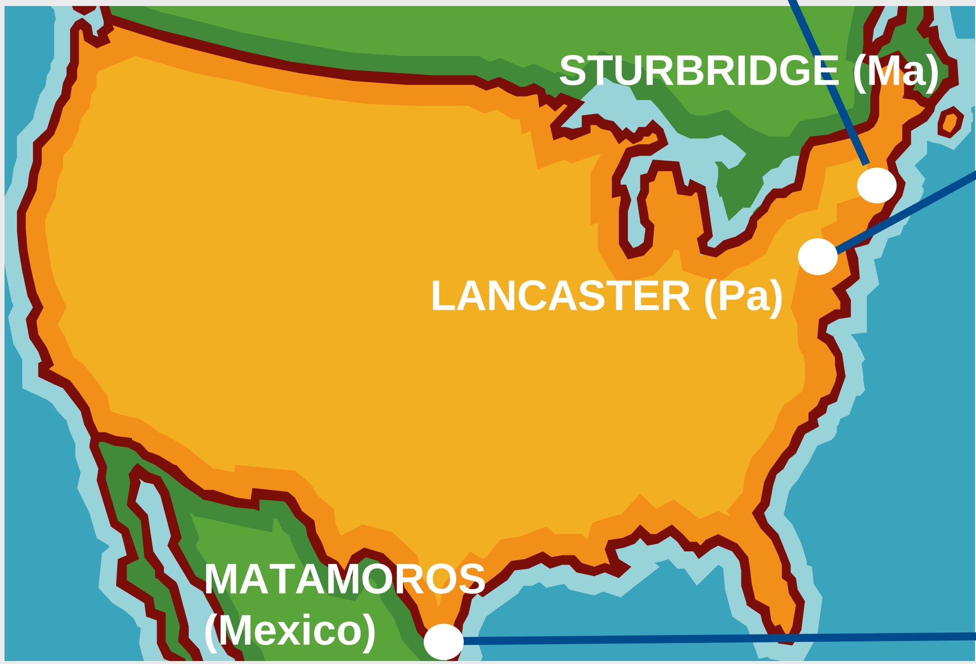
PHOTONIS

AMERICAN SITES

PHOTONIS USA, Inc.
Electro-Optic Products
50 persons

BURLE Industries, Inc
Power Tubes- 117 persons





PHOTONIS MEXICO,
S. de R.L. de C.V.
PMT - 157 persons

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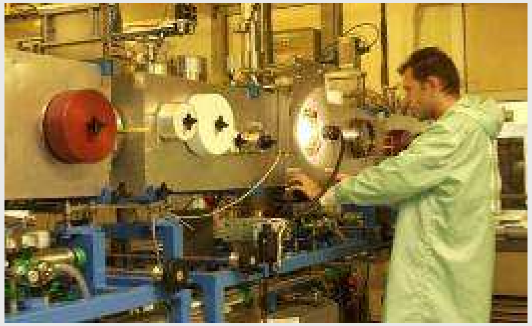
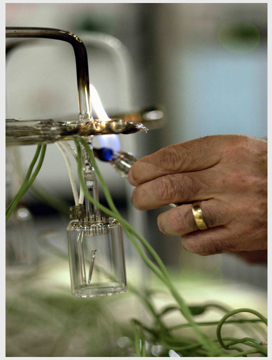
PRODUCTS



- **Photomultiplier Tubes:**
  - **Medical Imaging**
  - **Industrial Applications**
  - **Physics Research**
- **Image Intensifiers Tubes:**
  - **Night Vision (defence or surveillance)**
  - **Intensified Charge Coupled Devices**
  - **Scientific, Medical and Industrial Applications**
- **Industrial and Scientific Detectors:**
  - **Streak Tubes**
  - **Micro Channel Plates**
  - **Neutron and Gamma Detectors**
  - **Single Channel Electron Multipliers**
  - **Multichannel Photomultipliers**
  - **Ion Guides / Drift tubes**
- **Power Tubes**



PHOTONIS

MARKETS

RADIATION & PHOTON DETECTION

HEALTHCARE
Nuclear Medicine

INDUSTRIAL
Instrumentation
Nuclear Power

SCIENCE & RESEARCH
Physics, Space…

HOMELAND SECURITY
Detect hazardous substances

DEFENSE
Night Vision

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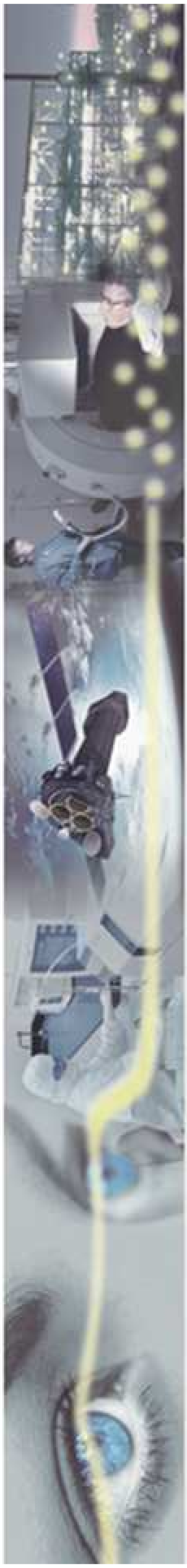
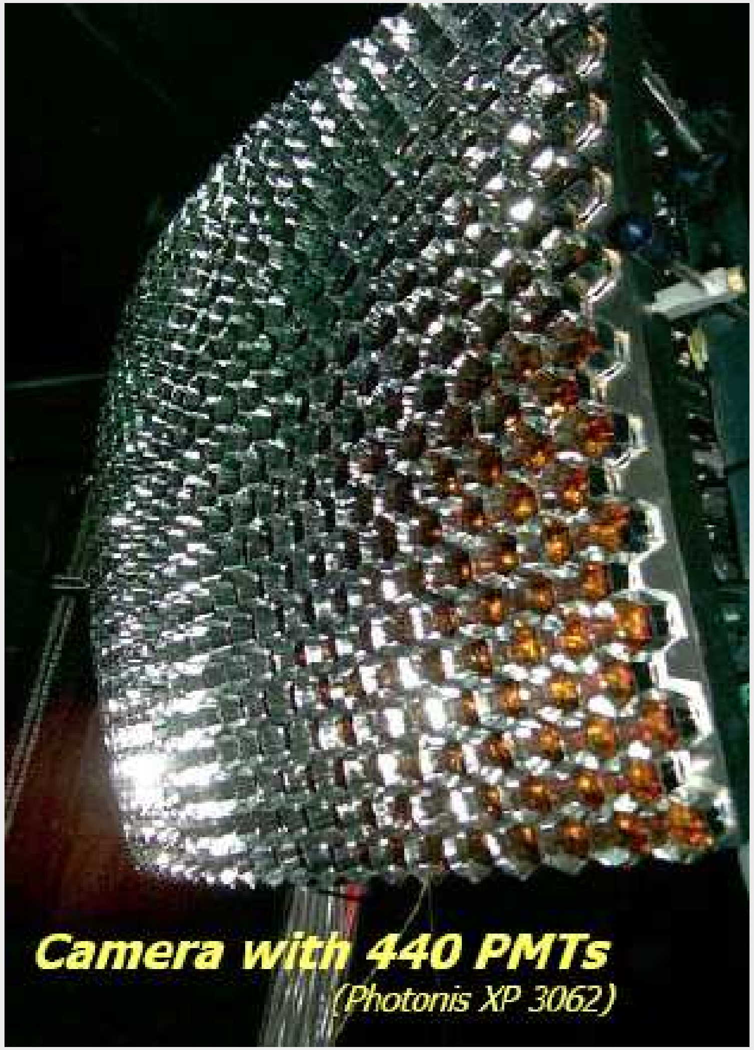
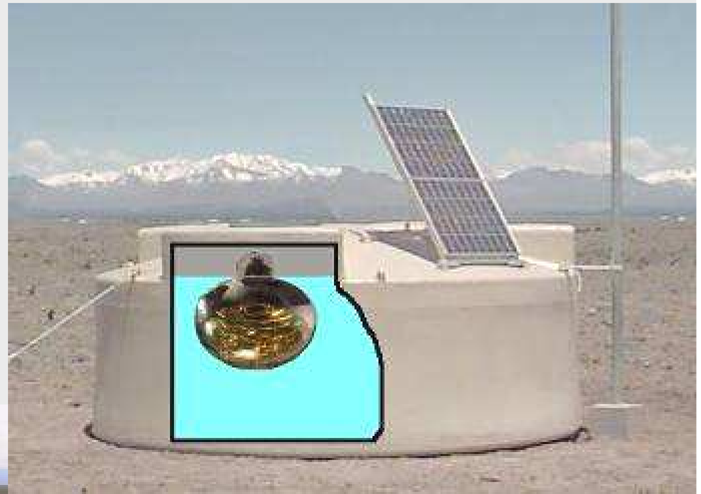




AUGER in Argentina

(9“ PMT *XP1805)*



VERITAS XP2970 (UV sensitive)

HESS in Namibia

(*XP2960)*

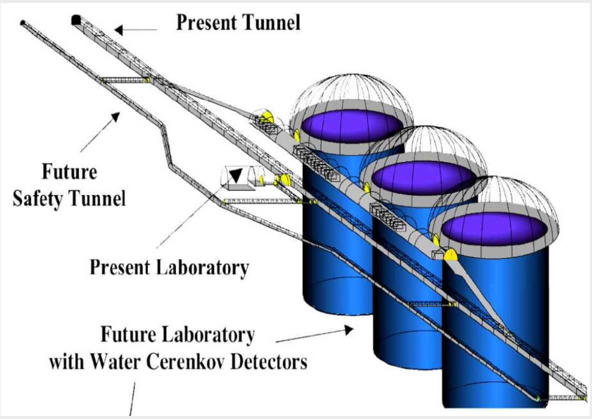
HESS COSMIC-RAY TELESCOPE

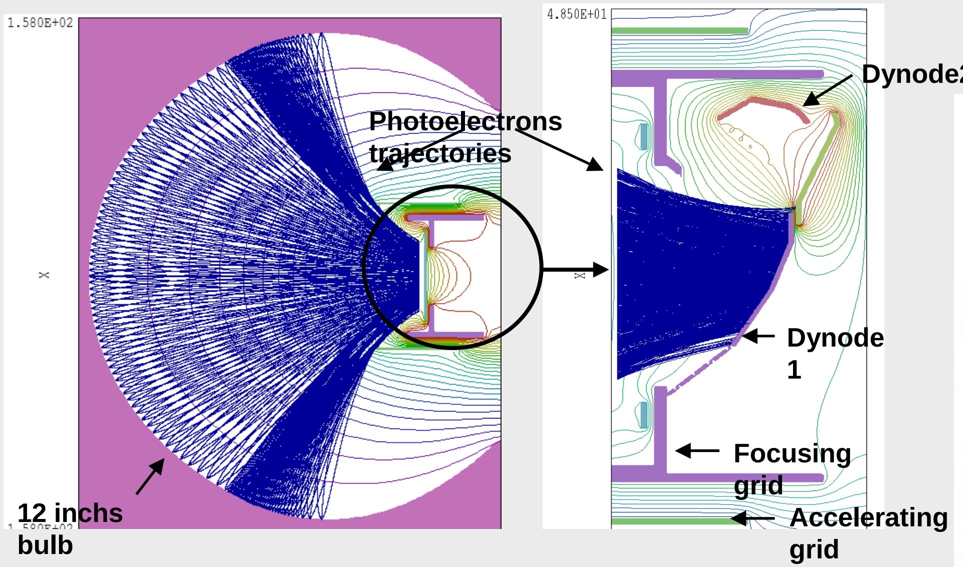
PHOTONIS

1. PHOTONIS Group and its production capability
2. Underground Neutrino Experiments

   MEMPHYS, DUSEL, hyper K…
3. Underwater Neutrino Experiments
4. Reactor Neutrino Experiments
5. Atmospheric Cherenkov experiments
6. New perspectives

Since water tanks are used for Cherenkov light detection, the goal is to design 12 inches tube (XP1812) to be suited for high pressure experiments.
Therefore a new bulb has been designed in collaboration with IPNO in the PMm² programm. Will withstand 10 bars (90m water height).
New optic design will also improve detection efficiency.





Other new features :

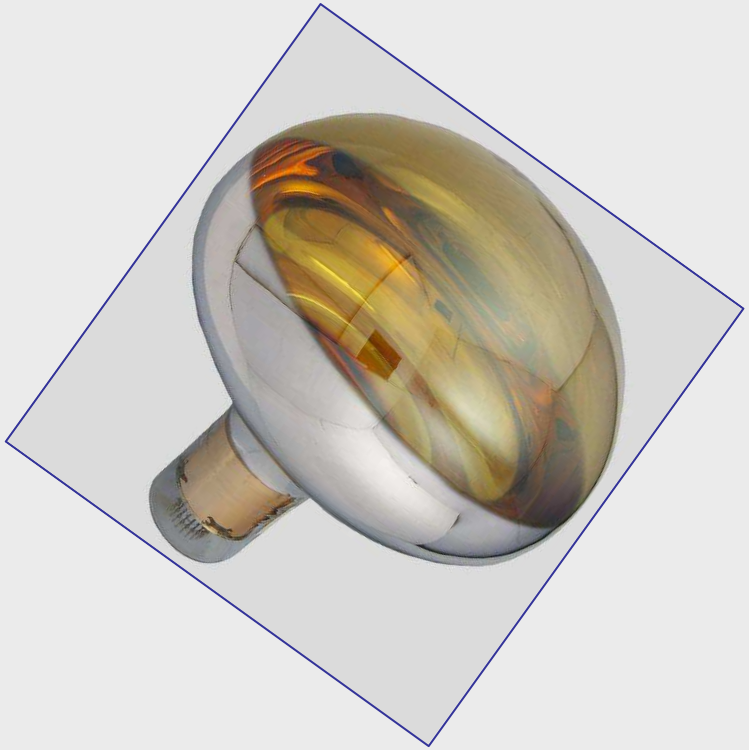
✓Higher Quantum Efficiency

✓Higher Collection Efficiency

✓Low After Pulses Rate

✓High Peak to Valley Ratio

✓Water-proof base available



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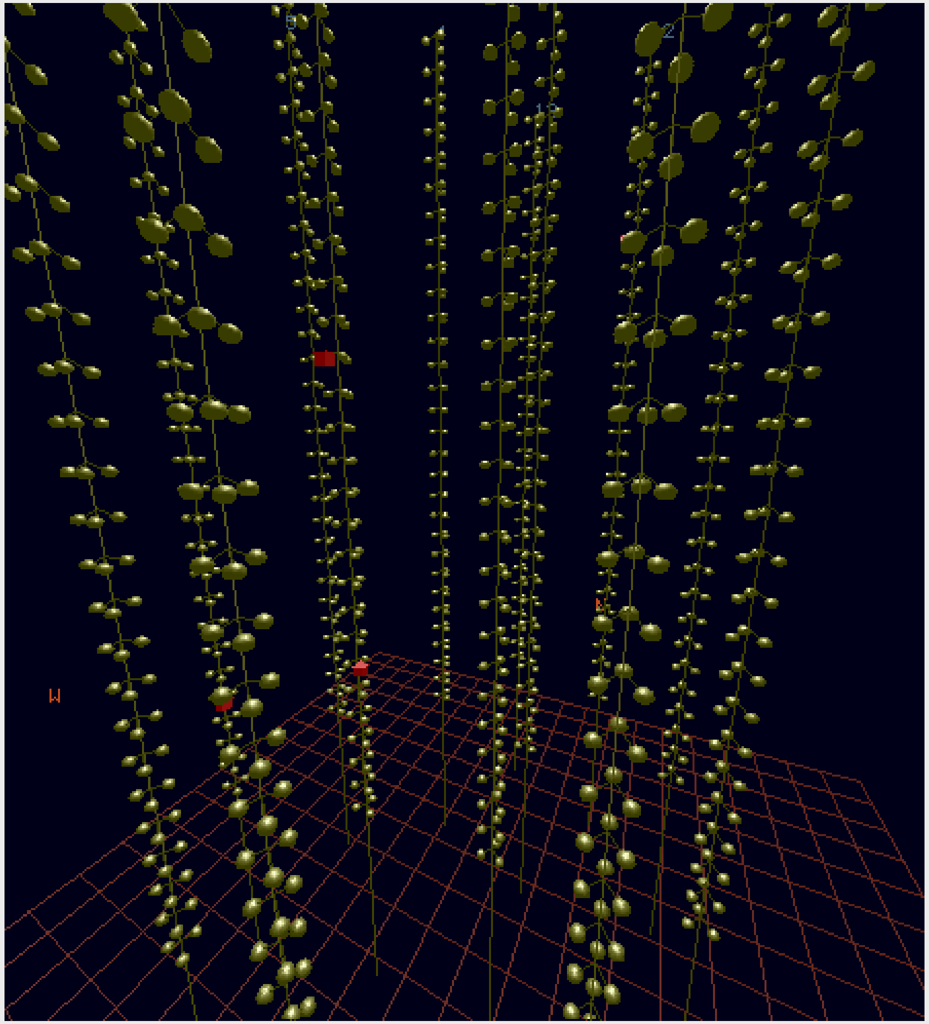
2. *Underground Neutrino Experiments*
3. *Underwater Neutrino Experiments*

   Km3, Baïkal
4. *Reactor Neutrino Experiments*
5. *Atmospheric Cherenkov experiments*
6. *New perspectives*

The goal is to design 10 or 12 inches tube to be suited for underwater muon tracking.

- ✓High QE
- ✓Large photocathode areas
- ✓Wide angular coverage
- ✓Good single photon resolution



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QE vs DQE : a key difference

It is not only important to convert photons into electrons : QE
but also not to lose them before multiplication effect : Collection Efficiency

$$DQE \equiv \frac{(\#PE\_captured\_by\_1st\_Dynode)}{(\#Insident\_Photons)}$$

$$= QE \cdot CE$$

Detection QE

New improvements on QE and CE have been made to increase DQE

Some key technical parameters to increase photocathode QE

1. Surface structure and cleanliness :
Impact on photocathode growth & diffusion of impurities

2. Photocathode interface :
Optical coupling with entrance window : internal reflection

3. Photocathode material :
Purity of basic materials (dispensers) - Composition

4. Photocathode growth :
Growth defects – Uniformity – Band bending

5. Photocathode thickness :
Compromise absorption of photons – recombination of electrons

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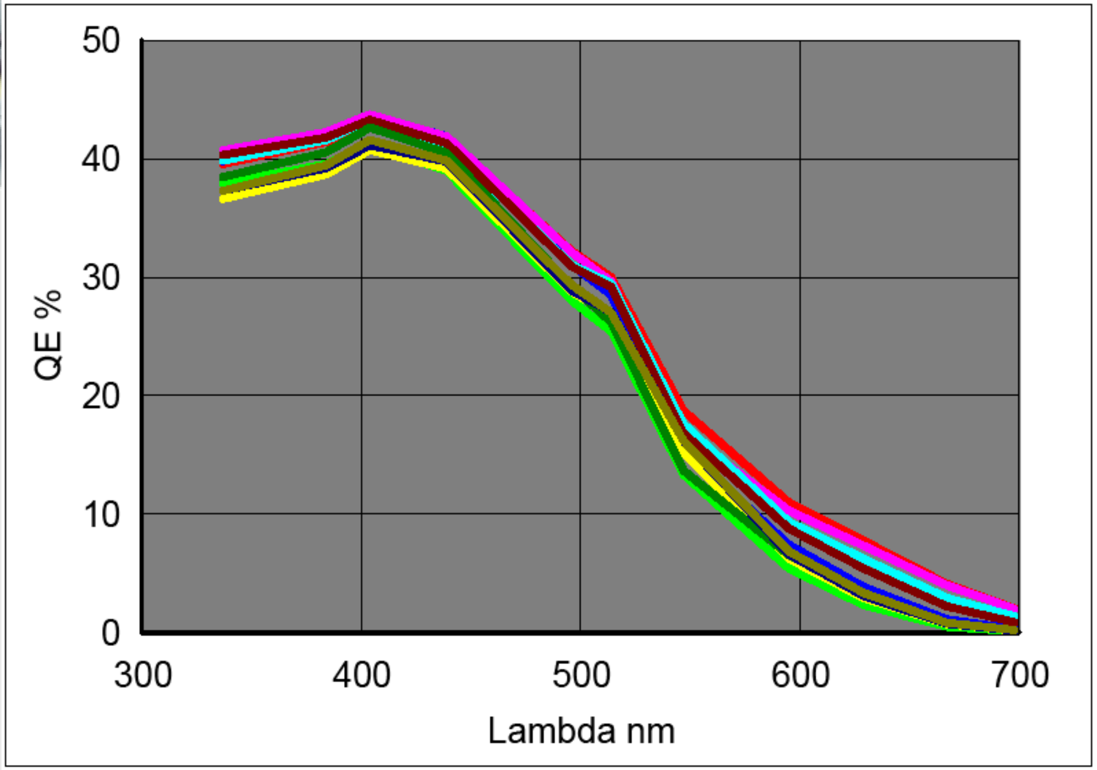
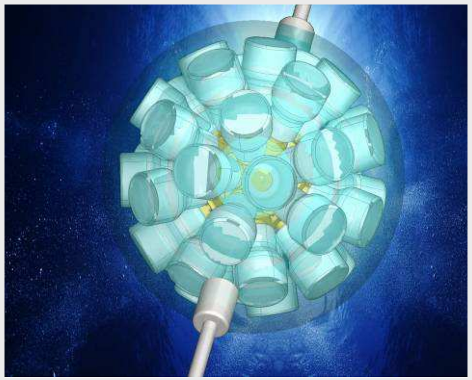
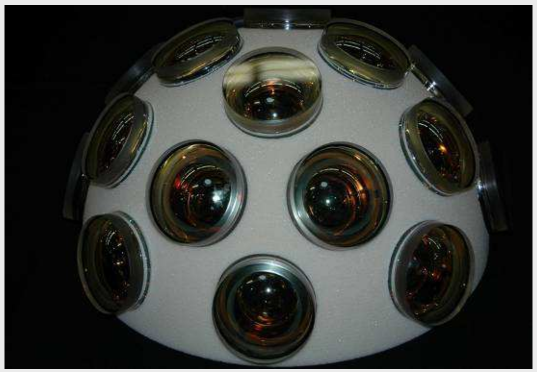
New bialkali photocathodes

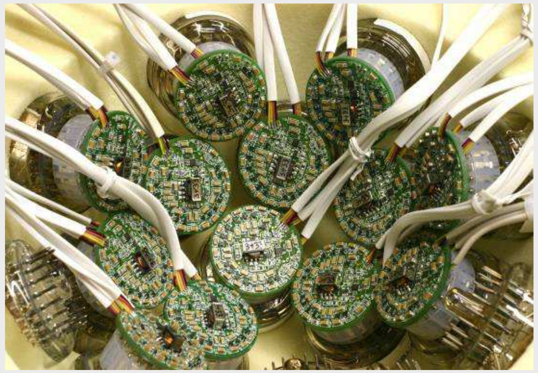


3'' tubes XP5302

Super² bialkali process
(400 nm 40 – 50%)







multi PMTs in one glass sphere

Ref. ICRC0489, P. Kooijman

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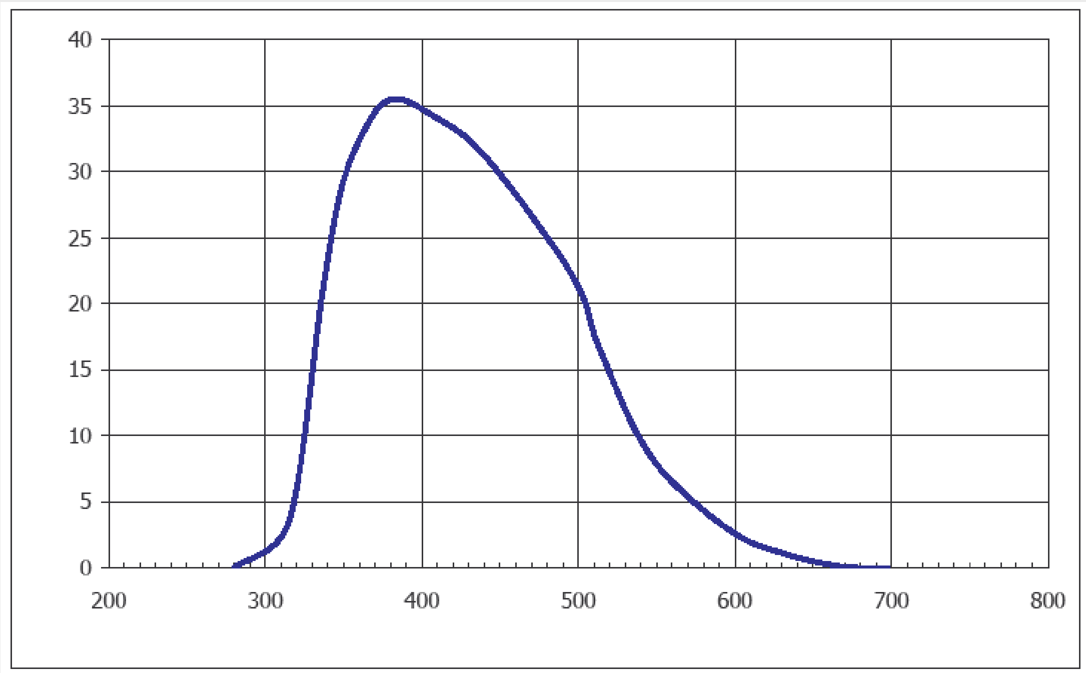
8'' XP1886 new process bialkali super²



SN 1161
QE 36% at peak

Drawbacks in high QE

- Drawbacks of increasing QE

1. Noise : increases with QE

    (not linear function, depending on improvement process)

    Resulting S/N ratio should be higher. This is the case with PHOTONIS new process for super3 PC. Leads to much higher S/N ratio.

2. AP : increases also with QE

    Which level of AP physicists can tolerate?

3. Stringent specs could lead to low yield and then higher cost.

4. Aging?

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4. *Reactor Neutrino Experiments*

   Daya Bay, RENO…
5. *Atmospheric Cherenkov experiments*
6. *New perspectives*

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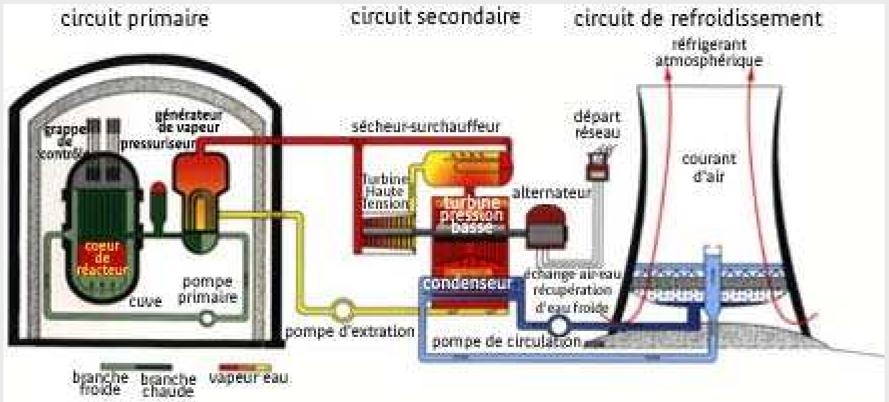
Proton decay experiments $\sin^2 2\theta_{13}$

Tube : 8'' or 10''

- ✓ *low radioactivity levels (ie glass and piece parts)*
- ✓ *water and oil proofness*
- ✓ *pressure withstandth (water pool)*



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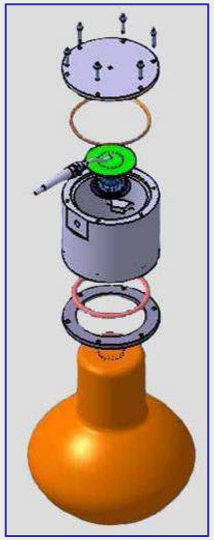
8'' tube and water/oil proof base



XP18060/P1

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Various glasses used by PHOTONIS

Glass Sample	^{40}K	^{137}Cs	^{238}U	^{226}Ra	^{228}Ra	^{228}Th
Quartz	44 ± 1	<0,015	2,3 ± 0,8	2,61 ± 0,04	2,1 ± 0,06	2,56 ± 0,05
ZNK7	14,7 ± 0,7	<0,03	4,8 ± 1,6	8,6 ± 0,1	7 ± 0,2	6,4 ± 0,1
8245 glass Schott	26	<0,02	9	12,6	2,3	2,6
D47.2	9,7	<0,008	0,9	0,84	0,45	0,51
D53X (mesure 1)	1,7 ± 0,1	<6	<0,12	1,59 ± 0,03	0,15 ± 0,02	0,1 ± 0,01
D53X (mesure 2)	3,9	<0,015	<0,33	3,6	0,22	0,04

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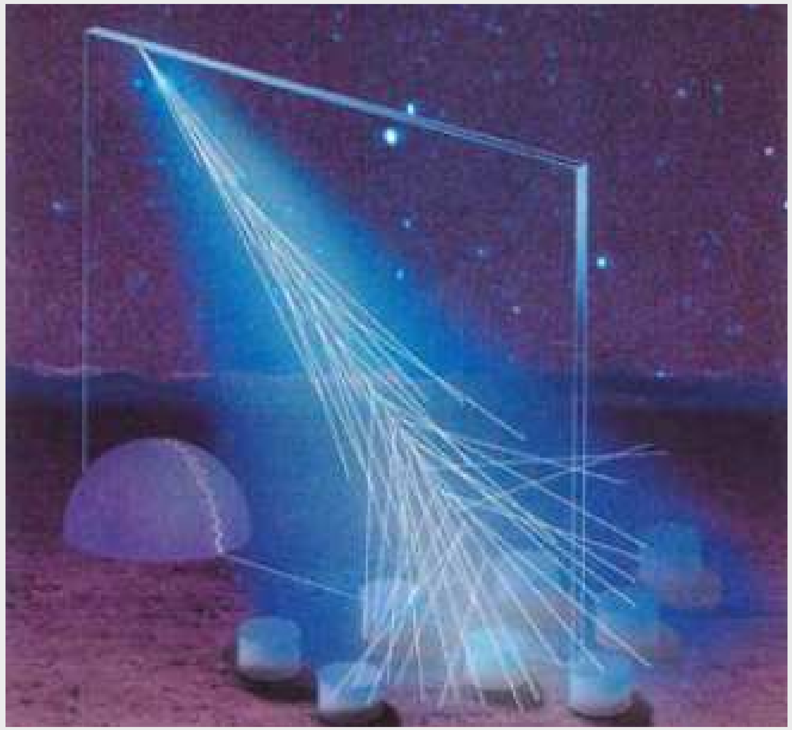
5. *Atmospheric Cherenkov experiments*
   AUGER, HESS, CTA…
6. *New perspectives*

Atmospheric Cherenkov detection

Tube : small (1’’) or large (9’’)

- ✓*Very low after pulses*
- ✓*High Collection Efficiency*



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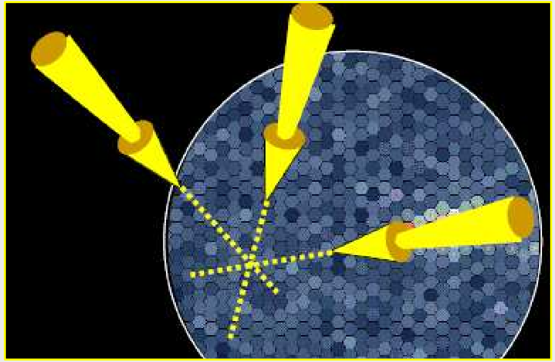
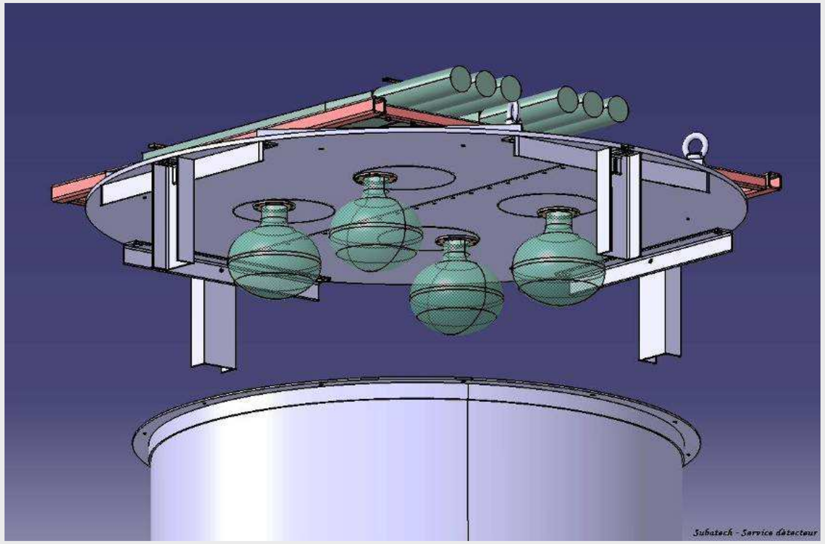
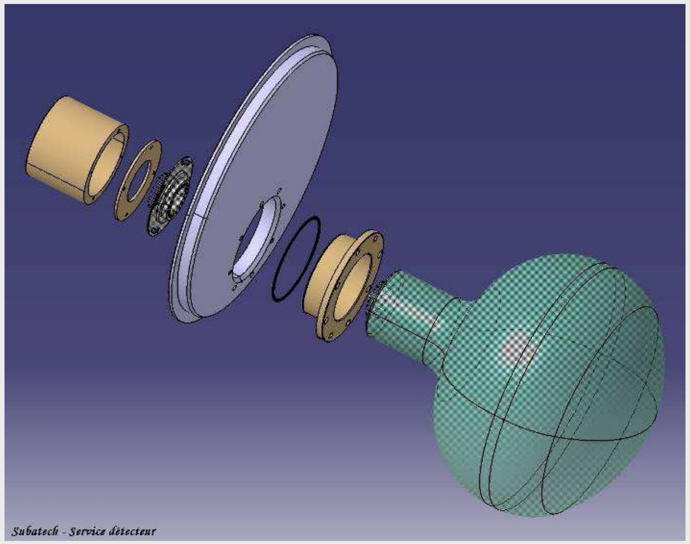


29mm XP2960

Very low afterpulses due to new process (<0.1%)
Fast (1.8ns rise time)
High P/V
Gain stability in time

Mass production, cost reduction policy
Good yield (HESS knowhow)





Atmospheric Muons Detection
(Cherenkov light in water)

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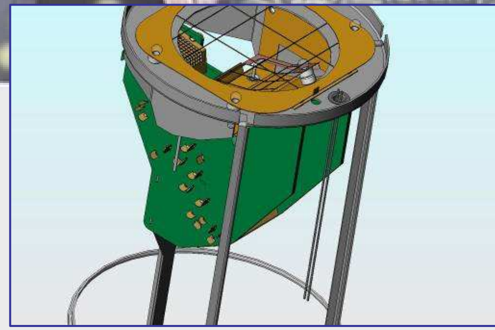
Foil vs focused



Multiplier with dynode	foil	linear focused
Collection uniformity	+++	+
Pk – D1 isochronism	+++	+
After pulses	<1%	<5%
P/V	--	+++
	aver. 1.4 max. at 1.8	typ. 3 (spec min. at 2)

- Improvement work : mix both concepts

  D1 foil and rest is standard dynodes : XP1805

- Improvement work on collection

Good to improve QE, do not forget to look at CE

Two types of hemispherical tubes available at PHOTONIS:

– **9'' tube** equiped with a first ''foil'' 1st dynode
(XP1805 AUGER tube).
– **5'', 8'', 10'' and 12''** equiped with a linear focused dynode

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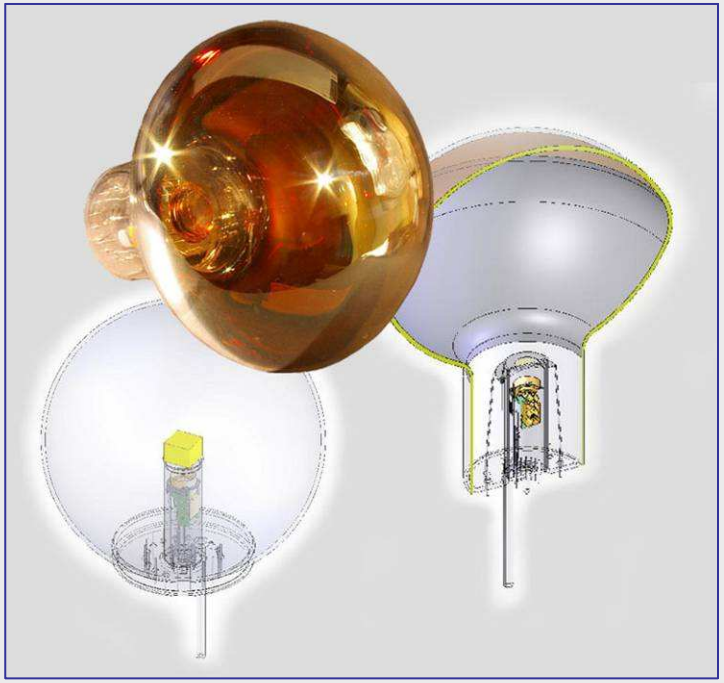
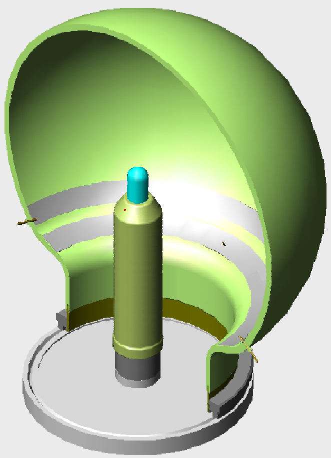
PHOTONIS

PHOTONIS designs a large spherical hybrid photodetector with a central anode and a scintillating crystal as a first amplification step : XHPD
This development performed together with teams at CERN and CNRS-CPPM is a modern extension of the Dumand Smart PMT principle.



Xtal-HPD tube has excellent time and very good single electron resolutions

- ✓ no prepulses
- ✓ low level of afterpulses (~0)
- ✓ ~100% effective collection effiency
- ✓ 1 ns TTS (FWHM)
- ✓ very good SER (competitive to HPD)
- ✓ immunity to terrestrial magnetic field
- ✓ >2π sensitivity



Christian JORAM et al, CERN

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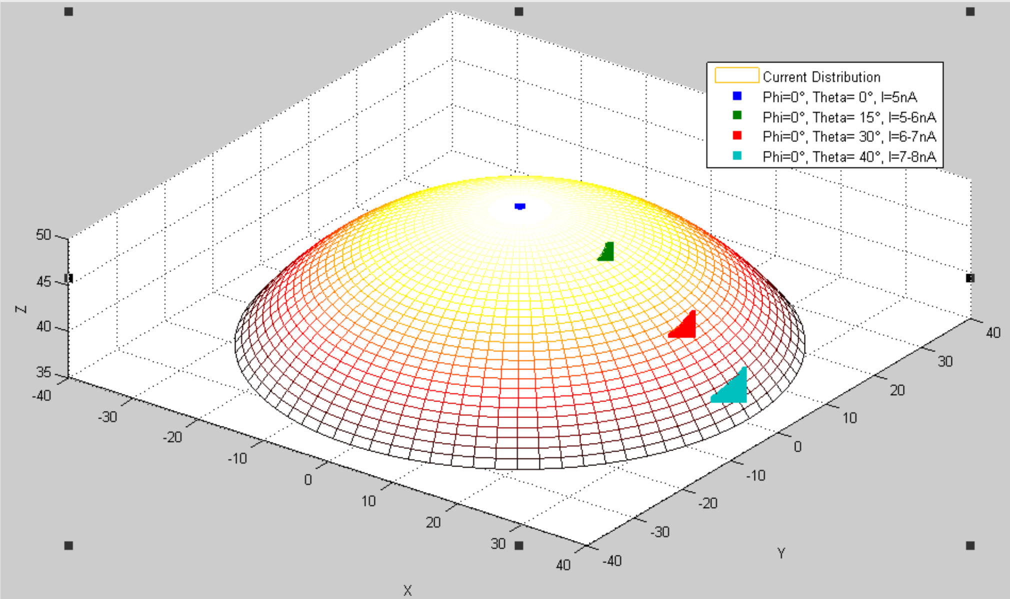
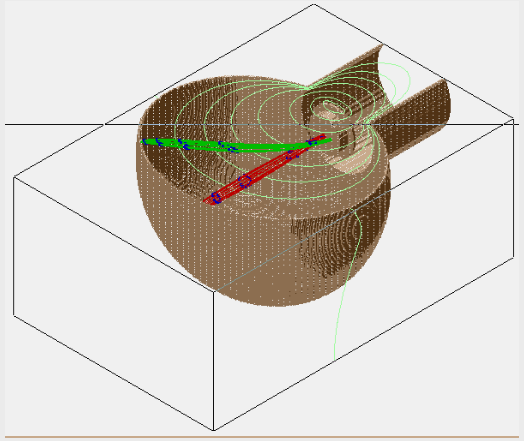
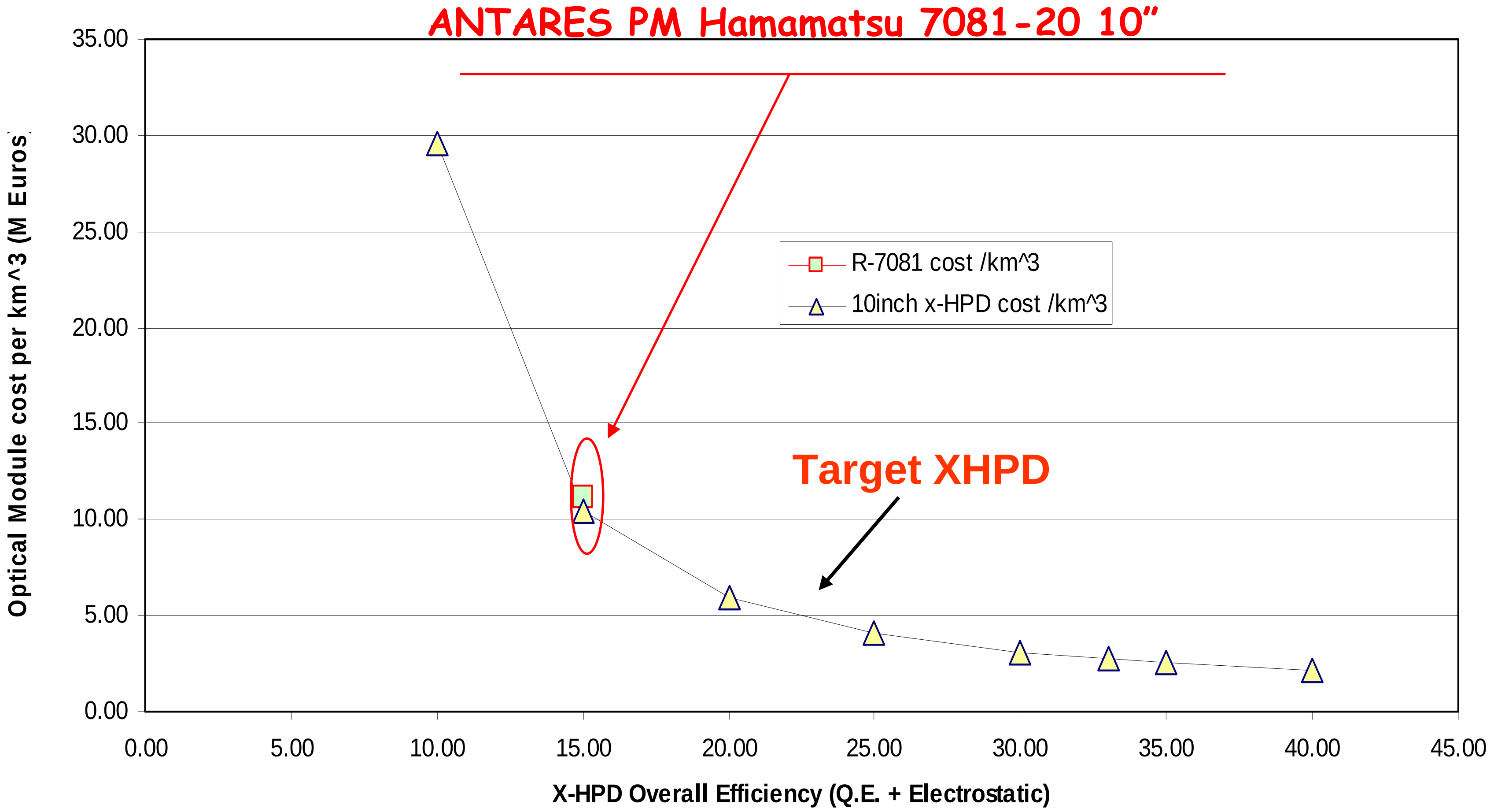




3-D (Simion-8 ®) electrostatic simulation and Photocathode mapping (polar angle 'double cathode' enhancements seen)

Greg Hallewell et al, CPPM Marseille

Comparison of X-HPD Optical Module Cost (inc. sphere, mechanics, electronics) per km^3
vs X-HPD overall efficiency
(assumed 22cm photocathode +/-120 deg polar angle: costed at 150% * 10" Hamamatsu R7081-20)



PHOTONIS

- Photonis have identified the envelope and pc.deposition technique as critical to cost
- **First prototype (above): all glass envelope**
  & fully internal bialkali photocathode deposition
- CPPM to measure of TT, sTT, HT behaviour, I-integrated photocurrent, multi-g res…

Mid 2008: Fabrication & test of prototype 8” tubes with metal anode (we are here)

End 2008: Fabrication & test of 8” HPD tubes with crystal anodes in different configurations

End 2009: Fabrication and test of prototype 15” X-HPD with best crystal anode

IPN Orsay

XHPD perf/cost

. X-HPD Performances are superior to traditional PMTs on major critical points.

. Manufacturing costs are higher (crystal, extra outer PMT)

. Manufacturing X-HPD is difficult : lower yield

Even if global cost is higher, the ratio Performance/Cost remains by far in favor of X-HPD

PHOTONIS

Thank you for your attention

Bruno COMBETTES

Photonis Group product management

b.combettes@photonis.com