Andrea Bersani

On behalf of the Genova NEMO-ANTARES group

Development of Direction Sensitive and Large Effective Area Photodetectors

VLVνT

NIKHEF, Amsterdam, October 5-8, 2003

Large Volume Neutrino Detectors

- For UHE neutrinos is necessary a large ($\sim 10^{12}$t or more) Cherenkov radiator because of small flux (pole ice or sea)
- Cost and feasibility $\rightarrow$ low density of active elements
- Radioactive and biological background $\rightarrow$ "local" and "far" coincidences necessary for noise rejection

- Is it possible to reduce the number of optical modules (OMs) without affecting efficiency?
- Is it possible to improve the efficiency in reconstruction of short tracks?

We believe both this tasks are possible.

Outline

- To achieve maximum information from each OM → many direction sensitive active elements

- Light collectors:
  - Light guides for arrays of PMTs
  - Directionality preserving collectors for multianodic photodetectors

- Hybrid photomultipliers
  - Silicon based
  - Gas based
  - Scintillator based

- Present and future

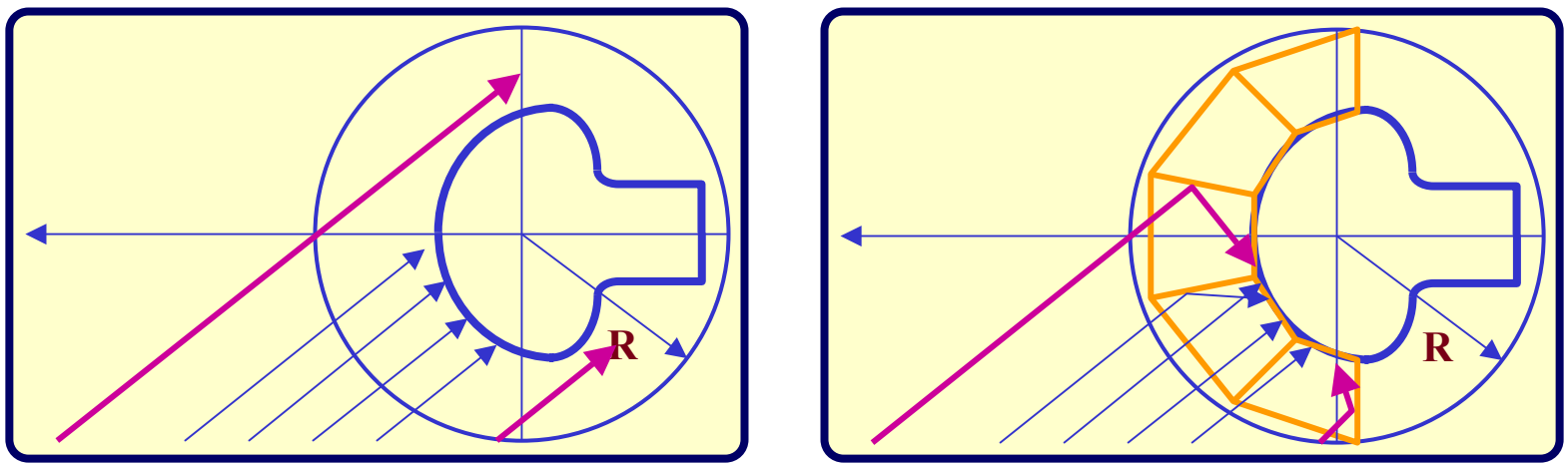
Sense of Sensitive Elements Multiplication

Direction sensitive and multianodic devices have 2 main features, one sure and one to be investigated:

- Multiple detection in a single OM
  - From an ANTARES cluster to a single OM?
  - In reconstruction: local coincidences instead of P.E. cut
  - Large sensitive area with small TTS
  - In case of light guides: a kind of redundancy
- Better sensitivity to the track position w.r.t. the OM
  - Reconstruction of short track?
  - Reconstruction of events on detector side?

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

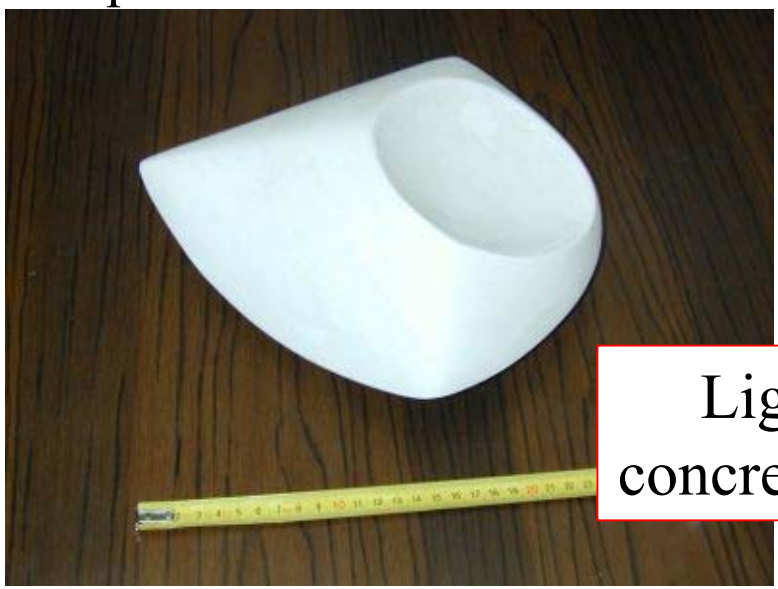


Light Guide

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

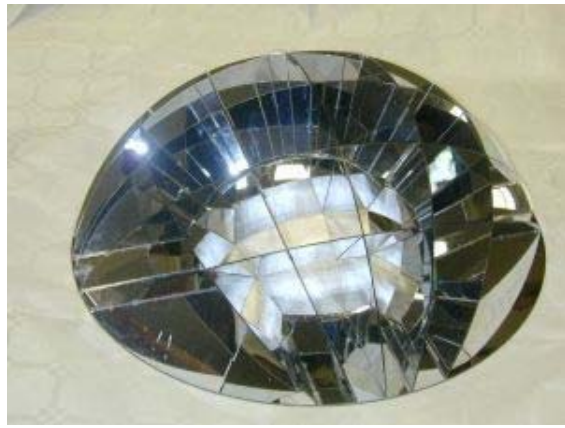


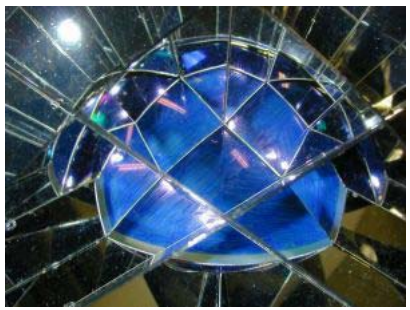
Light guide concrete prototype

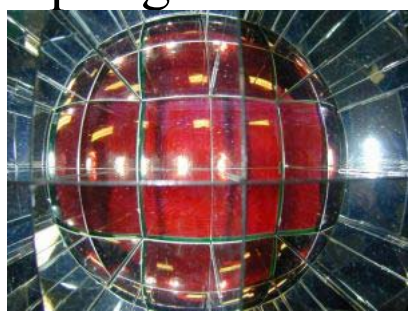
Light Collector

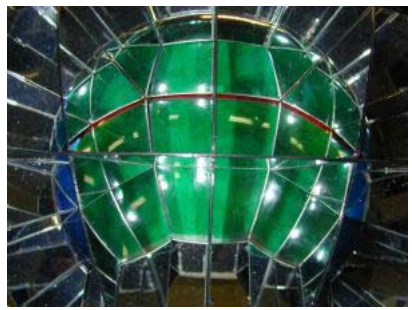
Light collector for multianodic PMT (or HPD)

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









Hybrid PMTs

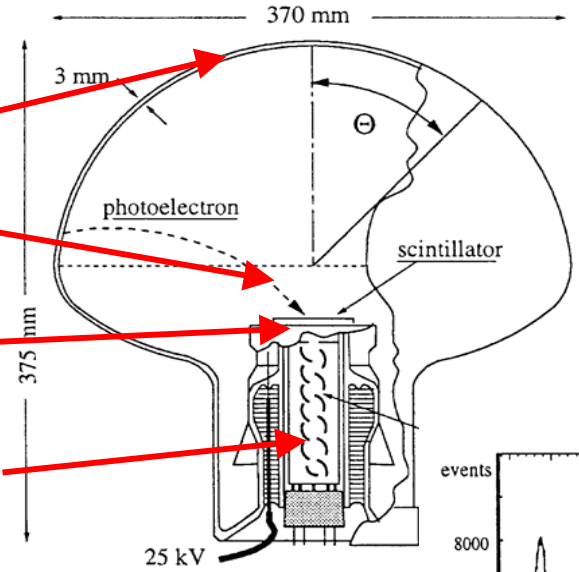
The second way: hybrid multianodic photomultipliers

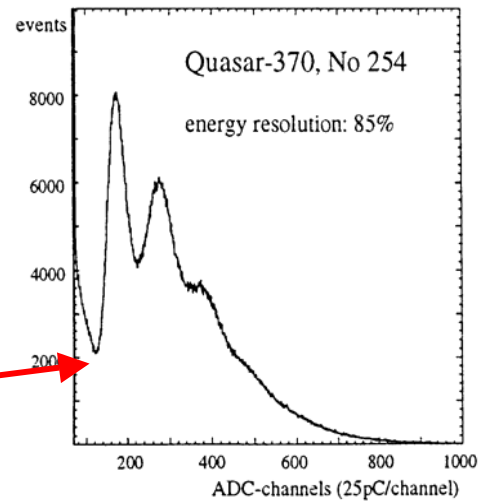
- As large as possible sensitive area → 13” or more
- As small as possible transit time spread → Improved Quasar370 design
- As much as possible information → Sensitive area segmentation
- As simple as possible design → Ok, this is not so obvious…

(What We Know About) Quasar370

Quasar370 was developed for Lake Bajkal Experiment

- Large sensitive area (14.5”dia.)
- HV to accelerate photoelectrons
- A second scintillator to reconvert primary photoelectrons into photons
- A commercial, small-diameter PMT for final reading





- It needs HV (20 to 30 KV) inside the OM
- TTS can be strongly reduced
- It has an astonishing resolution

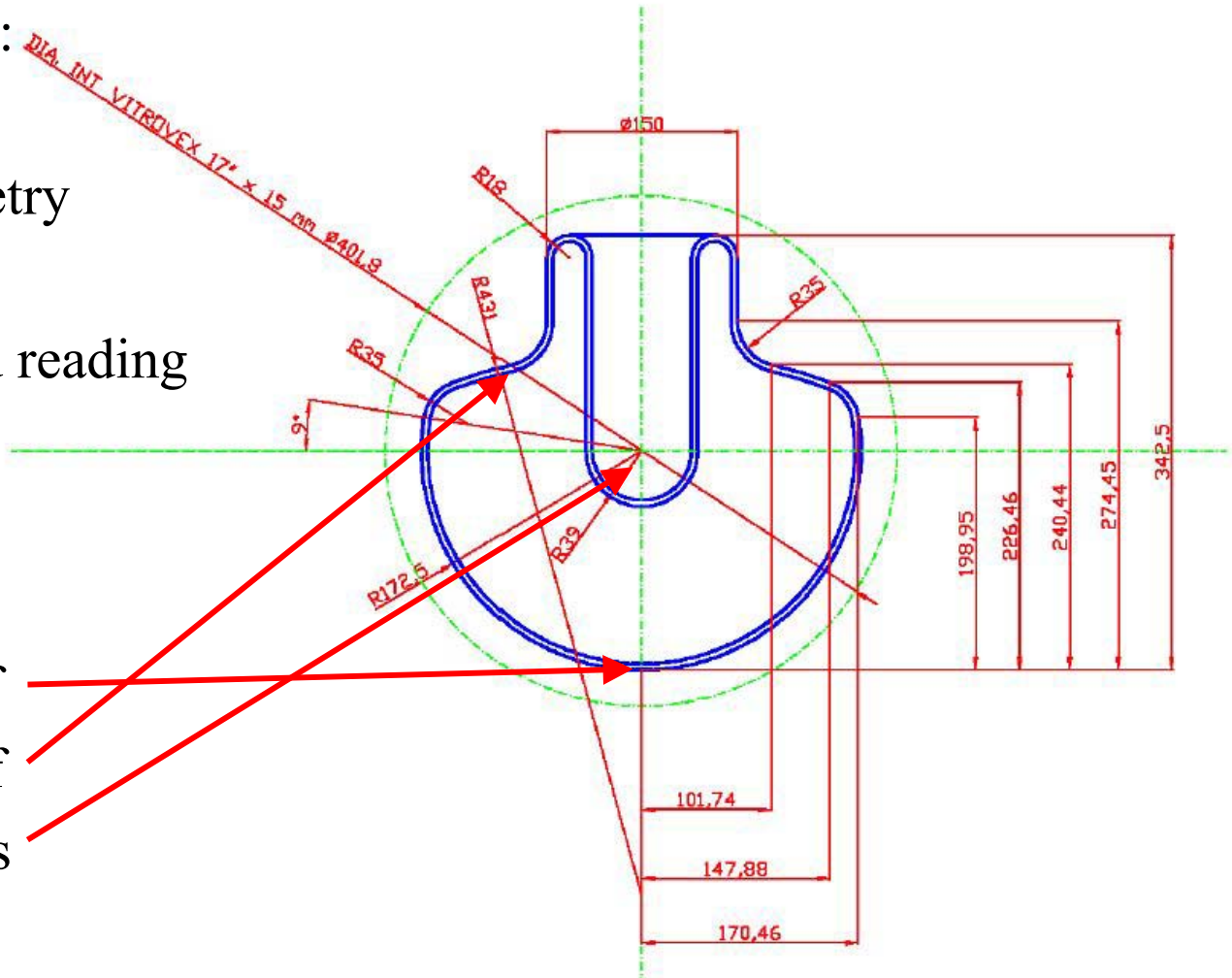
Features for a Hybrid PMT

Take a Quasar370 and:

- Simplify the geometry
- Optimize TTS
- Create a segmented reading

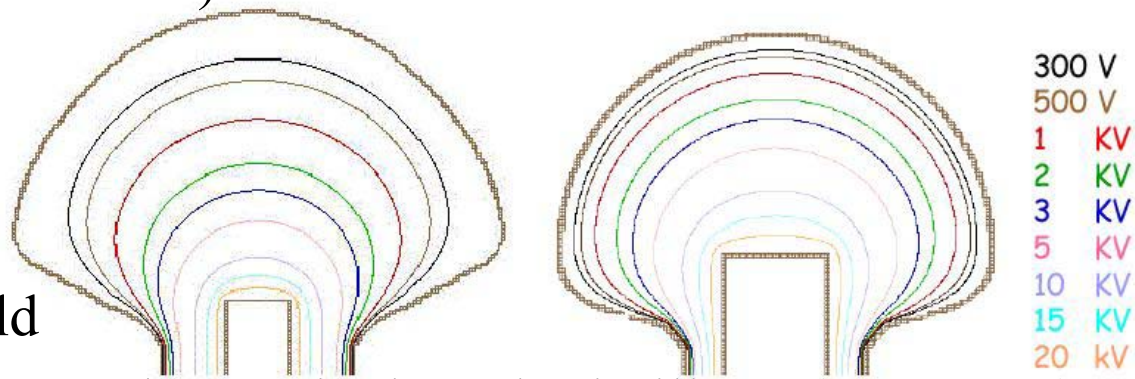
You get:

- Spherical front half
- Improved back half
- Place for 4 1”PMTs

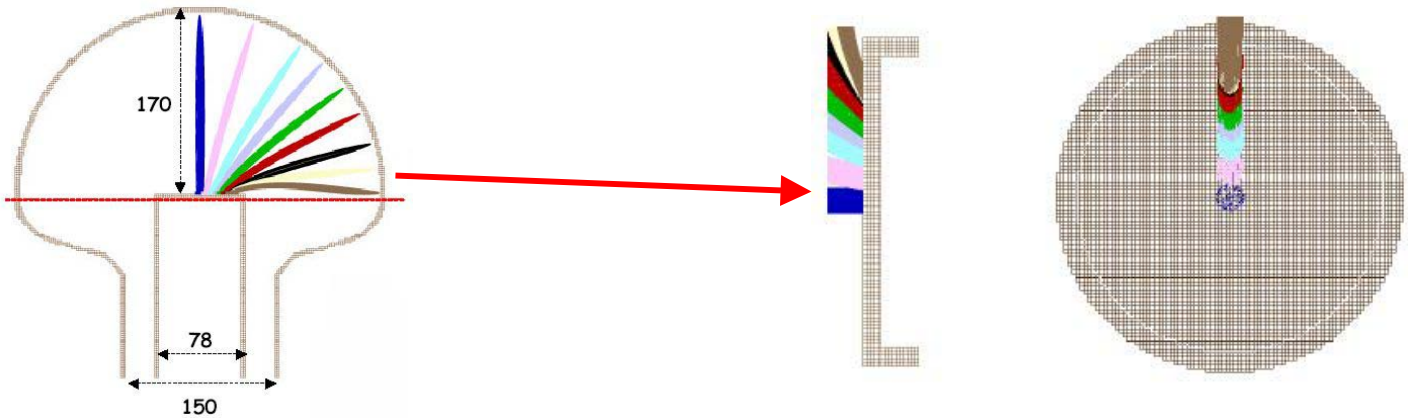


Improved Geometry Effects

The new design guarantees (at 25KV):



- More uniform electric field
- 1to1 correspondence between photocathode and scintillator (5mm spot)



- Extremely uniform transit time (0.9ns FWHM, 6ns average)

Hybrid Solutions: Silicon Detectors

Also a silicon diode array can be used to see photoelectrons (in fact a sort of HPD, see Joram's work at CERN)

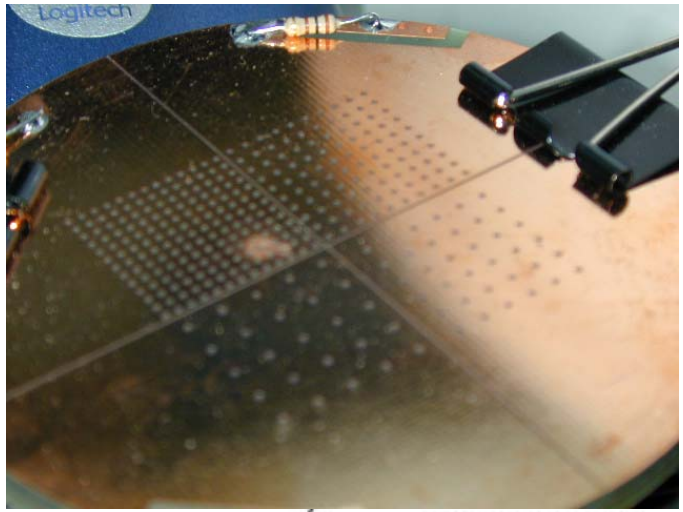
- Extremely efficient
- Highly sectorized
- Easy to operate
- Easy to be integrated in a HPMT

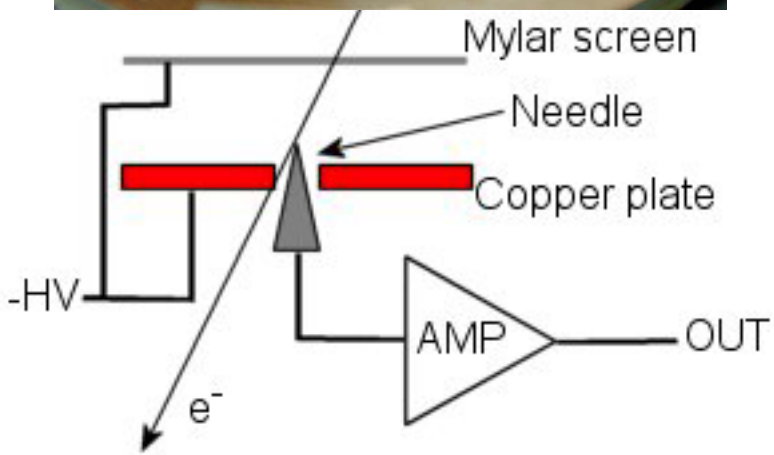
More in Michele Giunta's talk.

Hybrid Solutions: Leak Microstructures (i)

Photoelectrons can be detected by a proportional chamber

- Copper plate at -1500V
- Aluminized Mylar screen at –1500V (distance 1mm)
- Needles at 0V (step 1mm)
- Isobuthane (C_4H_{10}) gas
- Fast amplifier





In collaboration with Mariano Lombardi (INFN – LNL, Padova)

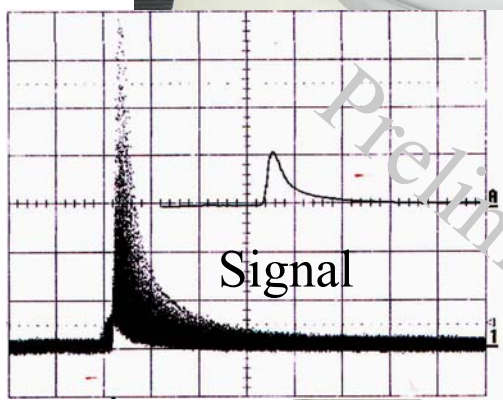
Hybrid Solutions: Leak Microstructures (ii)

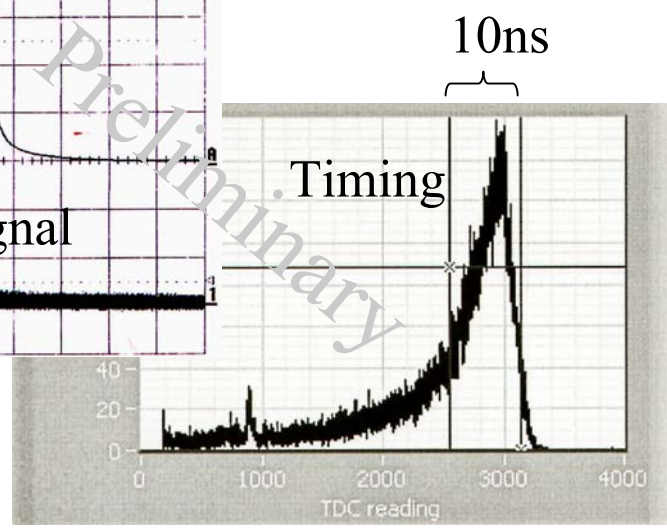
Many advantages

- Extremely cheap
- Extremely resistant
- Easy to operate
- The same signal of a PMT

Some troubles

- TTS is not optimized (10ns FWHM, to be optimized to less than 4ns)
- Integration in a HPMT is challenging

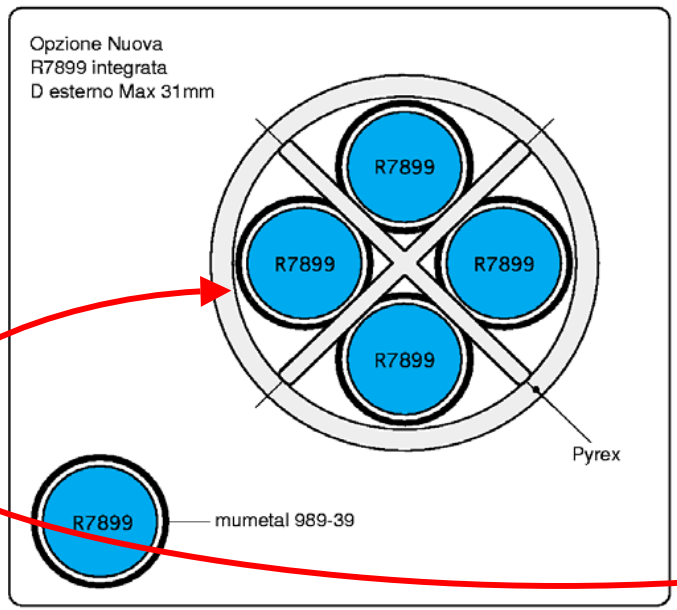




Hybrid Solutions: Double Photocathode

Born as “direct improvement” of Quasar370

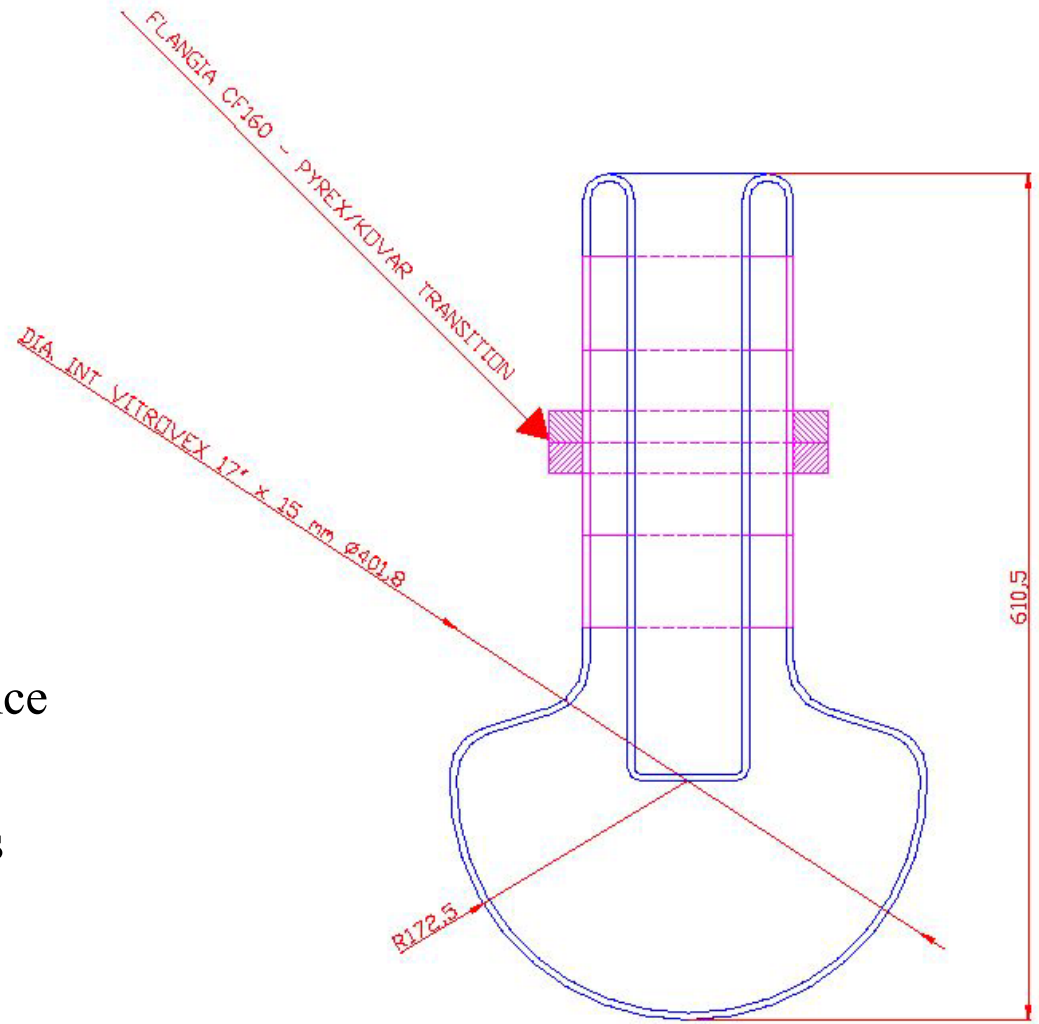
- YAP inorganic scintillator layer
- 4 Hamamatsu R7899 1” PMTs
- 12/24V to 20/30KV converter



Prototype Realization (i)

We are constructing a prototype

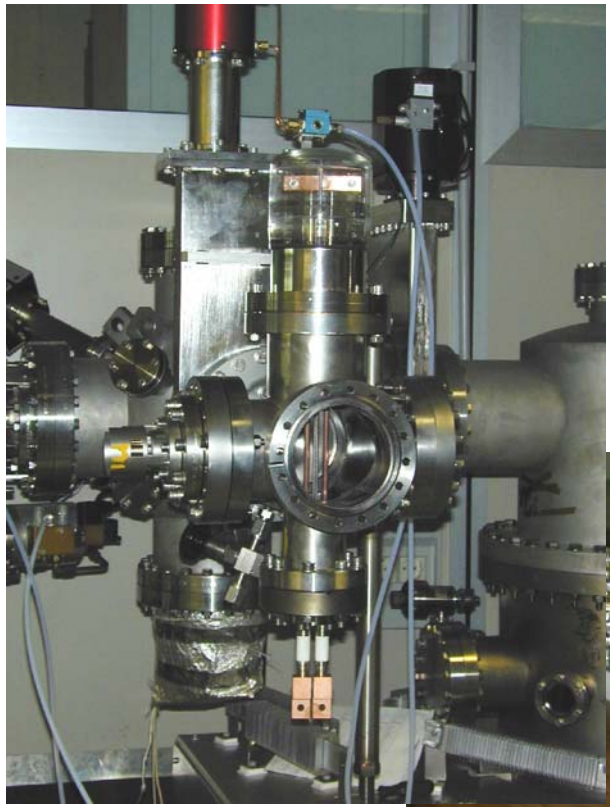
- Two flanged parts for several depositions (if the first goes bad)
- Ready for high vacuum
  - Tested for mechanical resistance
  - Annealing system ready
  - Ready for evaporation sources installation



Prototype Realization (ii)

Definition of evaporation procedure in a small glass dome

- Chromium (electrical support) evaporation → done
- Bialkali evaporation → ready for first try before the end of October



Where We Are, Where We Go

	Hybrid	Light Collector	Light Guide
Now	System ready	Prototype ready	Model ready
~1 month	First photocathode evaporation	four 3” PMTs integration	Prototype realization
~6 months	Prototype realization	HPD integration (?)	Integration in OM & characterization
~1 year	Comparison and result publication		

Concluding Remarks

- We are developing a direction sensitive large area light detection system to be integrated in an optical module following two main ways:
- Light collection systems for multianodic devices or arrays of PMTs
- Hybrid multianodic PMT based on Quasar370
- This systems are compatible with standard readout electronic
- This systems can give advantages in detection and reconstruction
  - More hits with less OMs
  - Direction info for short tracks
- Complete working prototypes should be ready before ~ summer 2004