Photo-Sensors for a Multi-PMT Optical Module in KM3NeT

- PMT tests
- improving collection efficiency (Winston cone)

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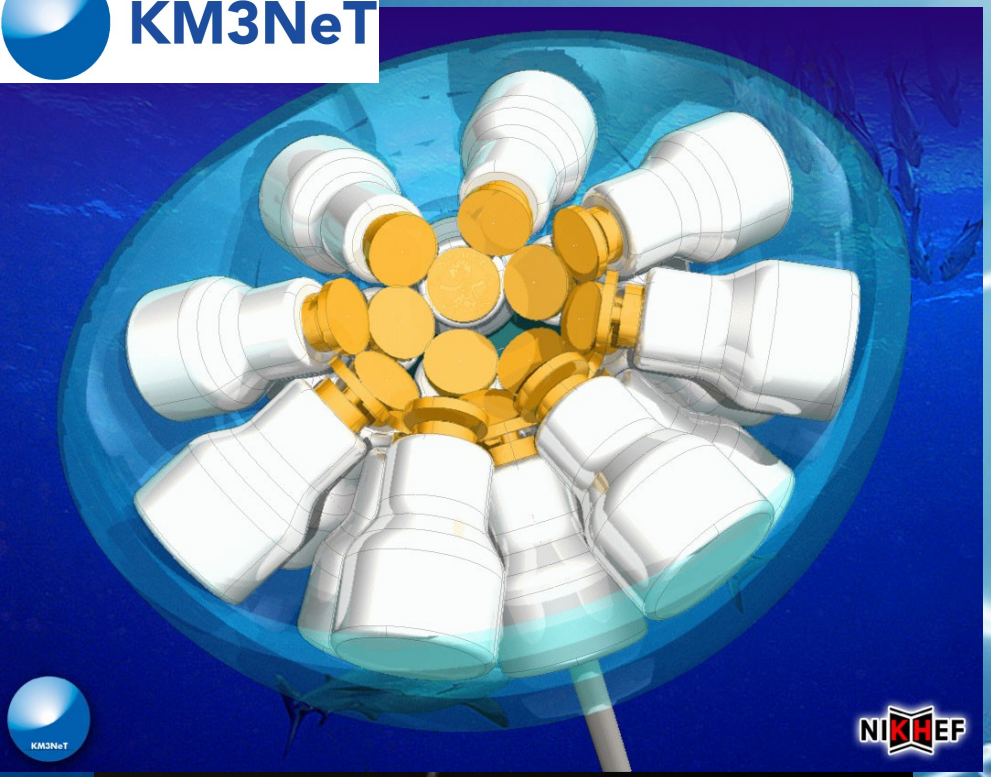
Motivation



Advantages of Multi-PMT:

- Homogeneous photon acceptance
- Reduced environmental background from local coincidences
- Better directional sensitivity
- Better two-photon separation
- Longer ph.cathode lifetime
- Higher reliability of the OM (due to independent PMT's)

3-inch Photomultiplier tubes

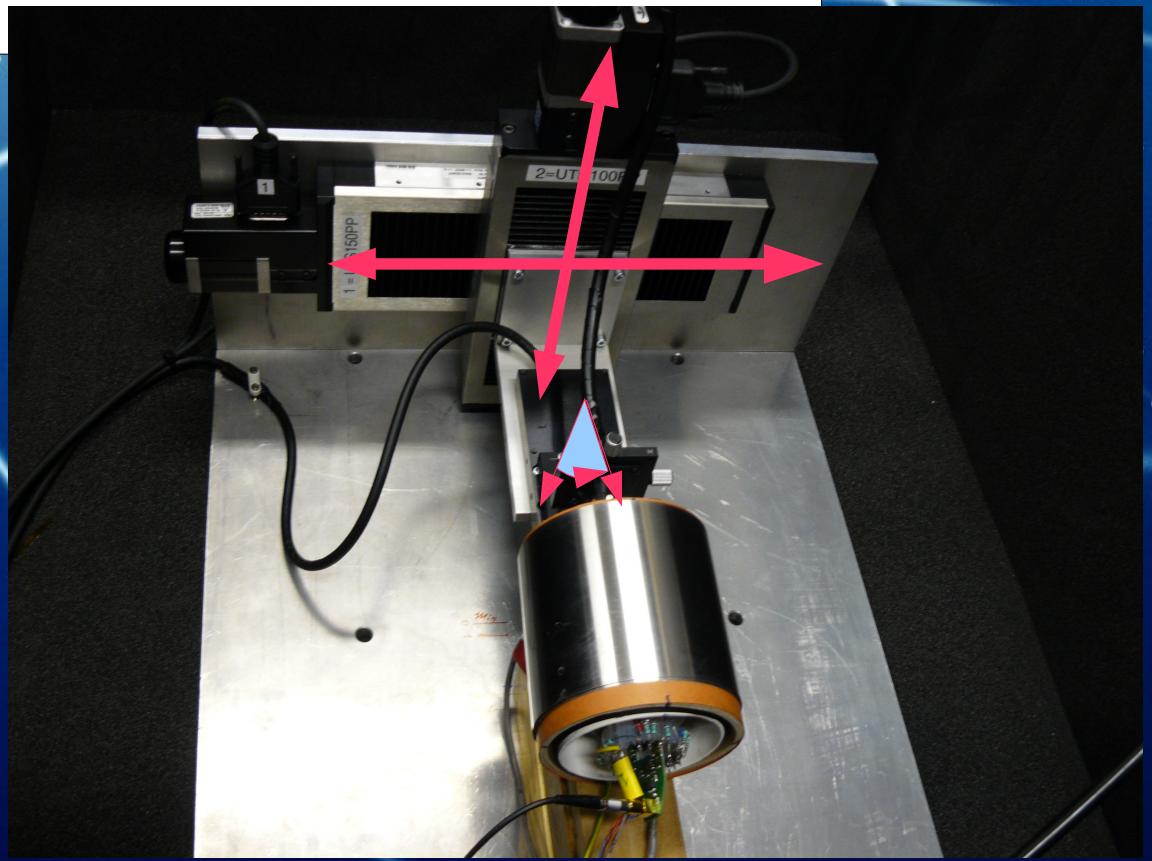
Optimum performance requires:

- high collection efficiency and low dark noise
- homogeneous photocathode response
- excellent coincidence properties

	Photonis XP53B20	ETL 9822B
Window material	lime glass	borosilicate
Photocathode	Bi-alcali	Bi-alcali
Spectral range [nm]	290-700	285-630
Multiplier structure	10 stage	10 stage
	Box & Linear	Linear

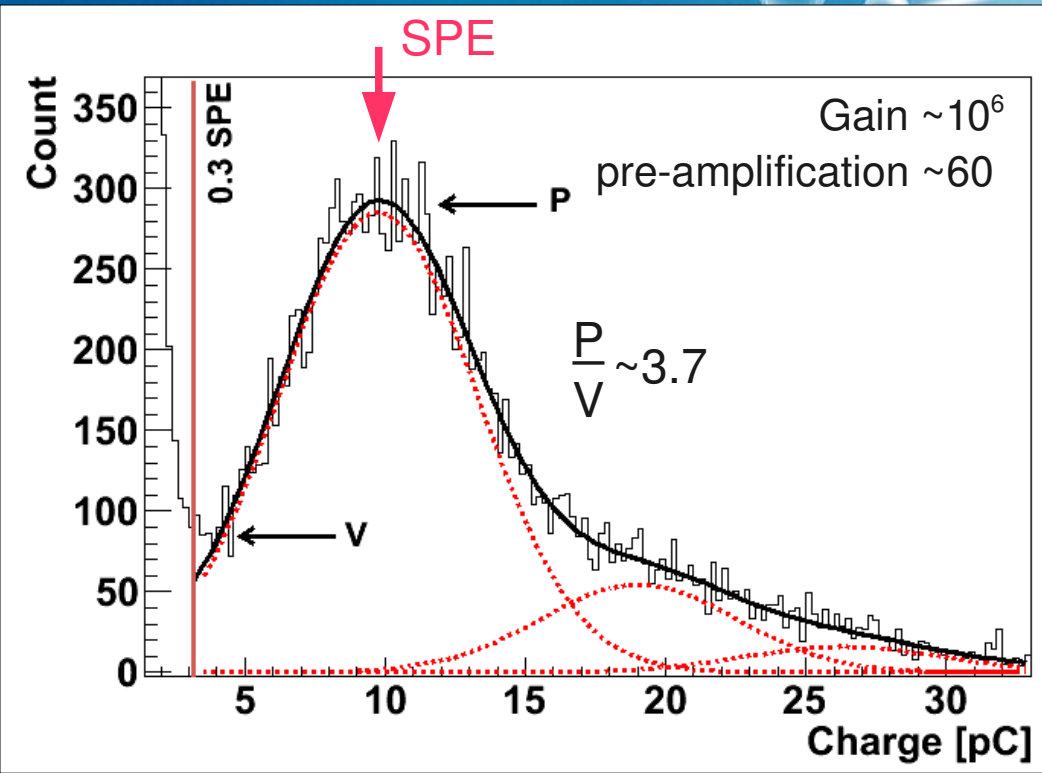
Test Bench

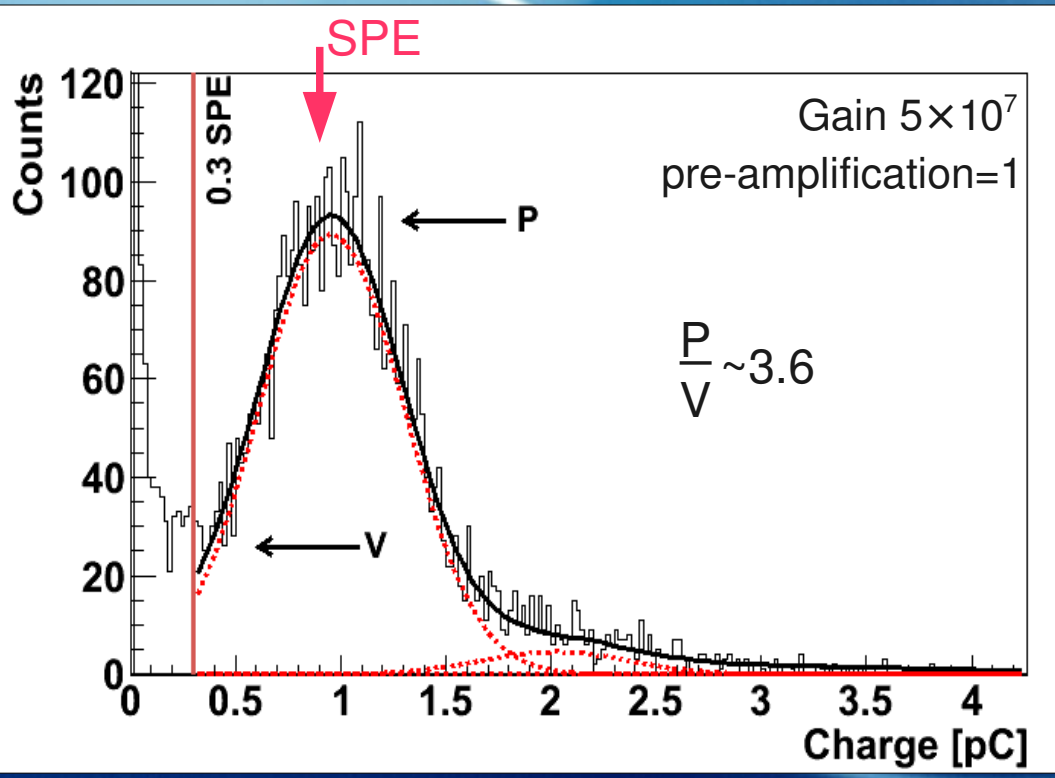
- light source: Laser (λ=405 nm), pulse jitter <70ps
- quartz light fiber inside the Dark Box
- spot size 1.4 mm (at PMT surface)
- signal shapes recorded by fast Sampling ADC
- 2D scanning system



Typical charge spectra

Photonis XP53B20	ETL 9822B

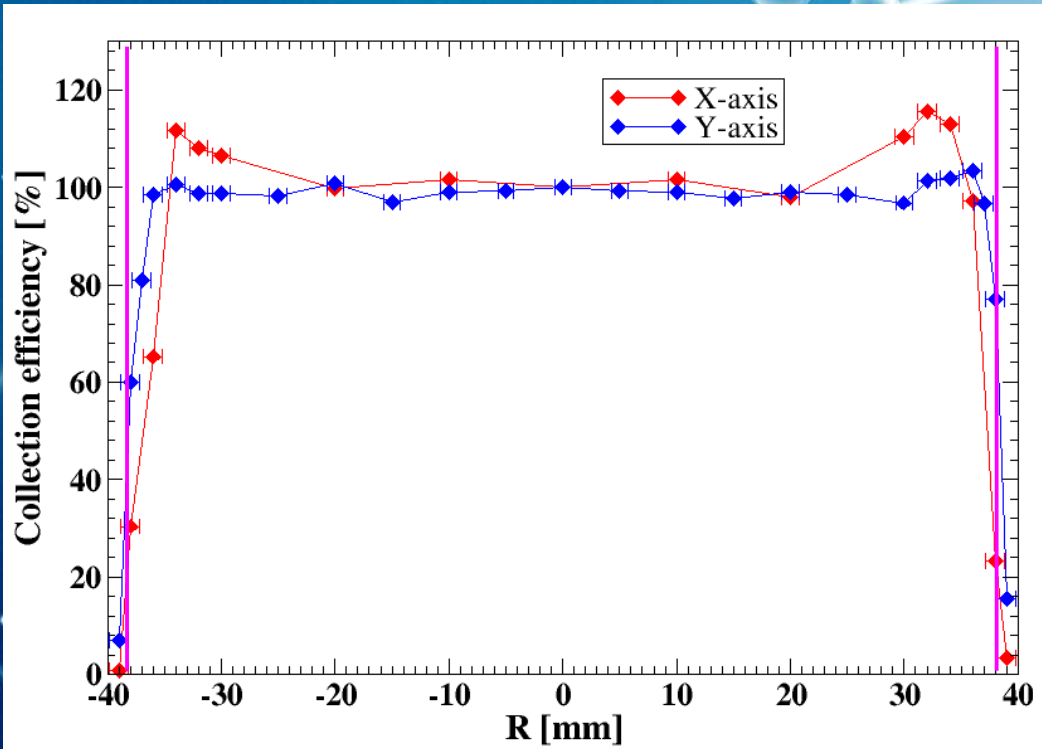


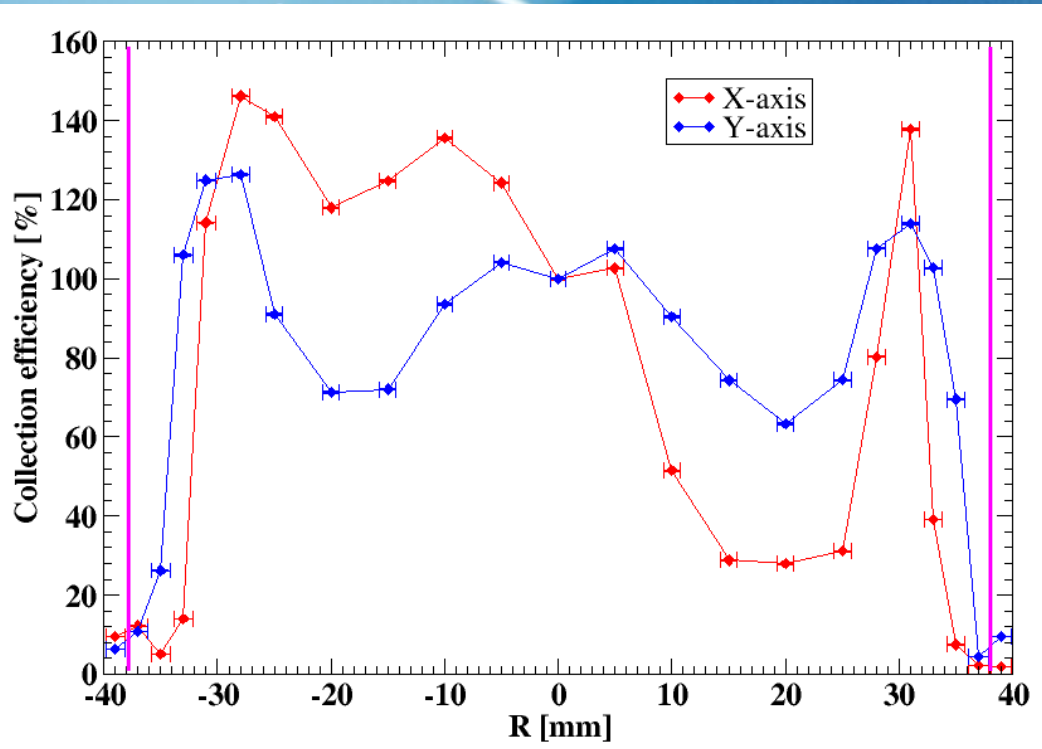


Photocathode homogeneity

Photonis XP53B20

ETL 9822B

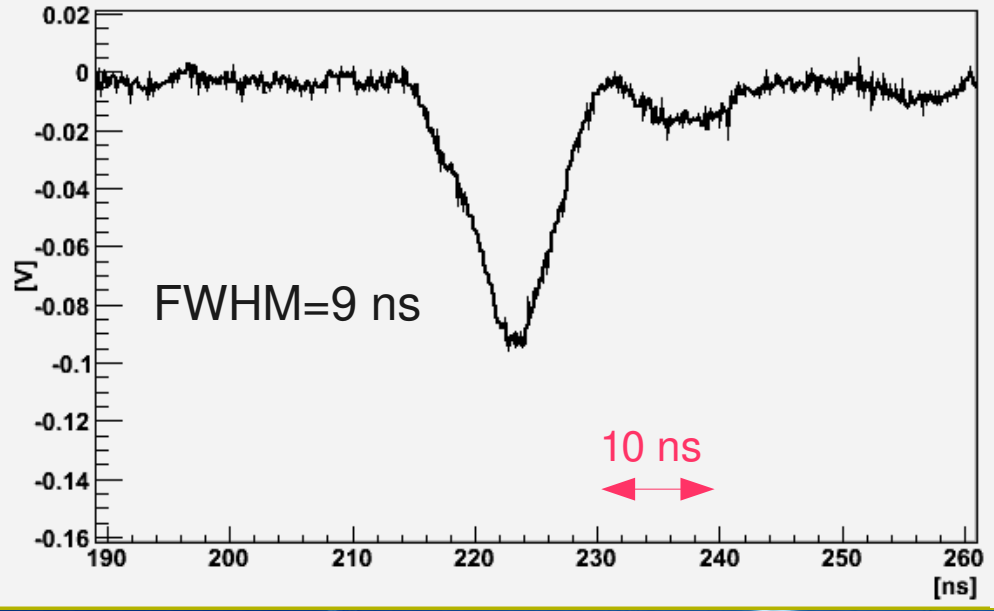




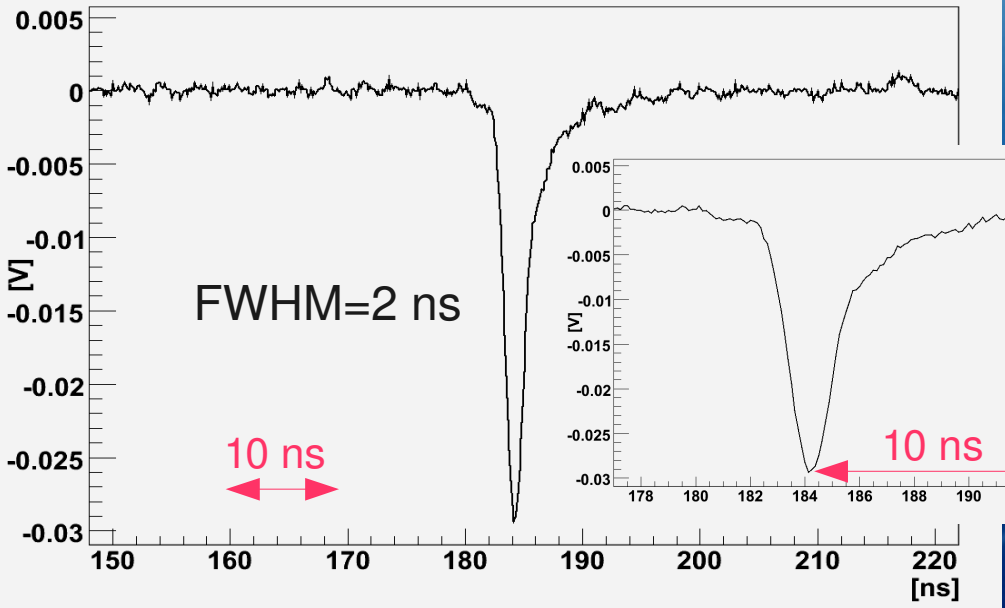
Further improvement needed

Timing characteristics

Photonis XP53B20



ETL 9822B



Time stamp: leading edge, trigger 3×noise level

Time resolution (centre) fixed position:

FWHM=5.4(0.05) ns	FWHM=1.28(0.01) ns
σ=2.30(0.02)ns	σ=0.54(0.01) ns

Transit-time spread over photocathode (worst-case value) weighted with collection efficiency:

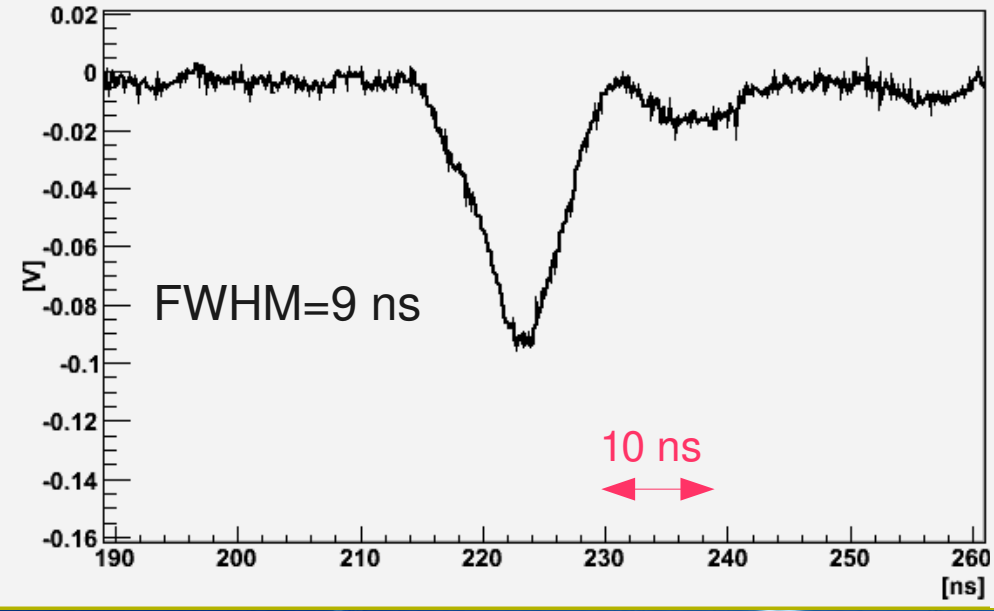
TTS = 0.4 ns	TTS=0.7 ns

Dark count rate:

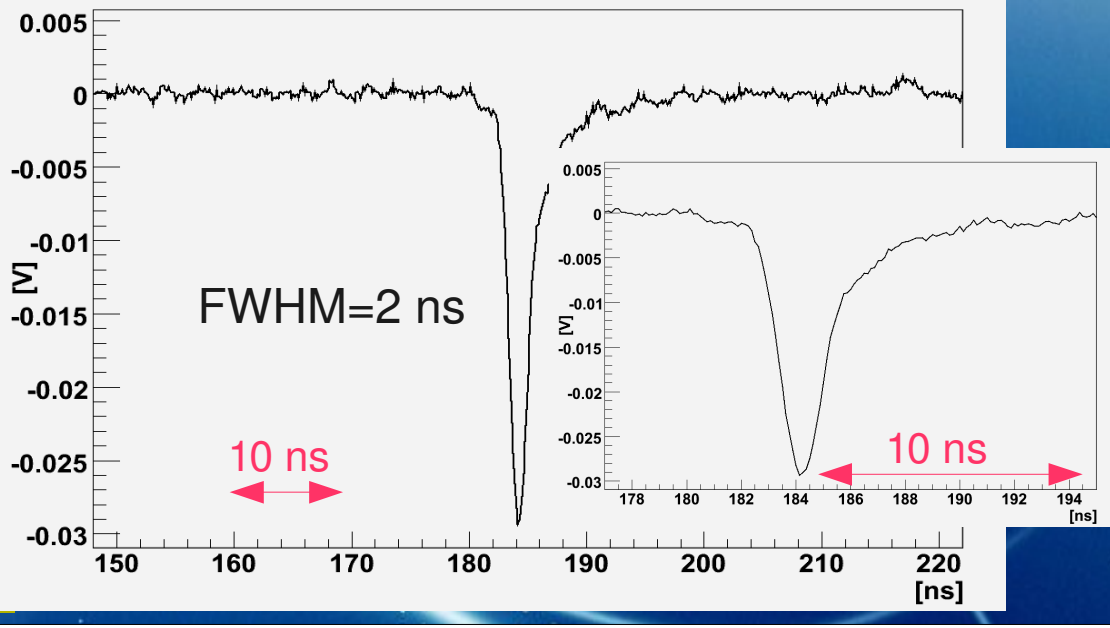
R=5-15 kHz	R=2 kHz

Timing characteristics

Photonis XP53B20



ETL 9822B



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Improving collection efficiency

Photonis XP53B20
~ 4.5 mm at the circumference available for the entrance of light from the side

This surface can be exploited for light collection

a glass or perspex (PMMA) ring may be employed to guide the light to the photocathode

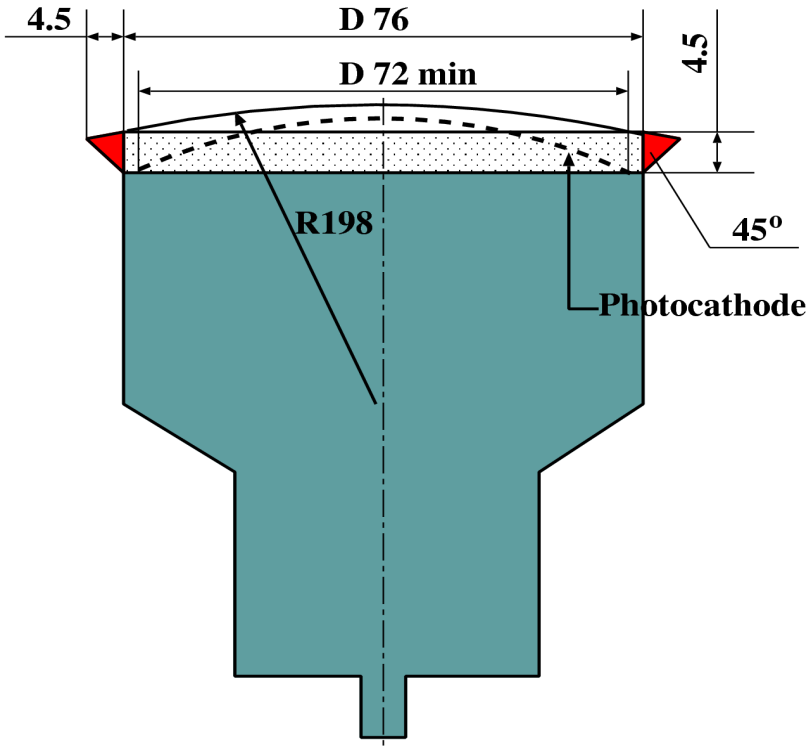
Idea and Realisation

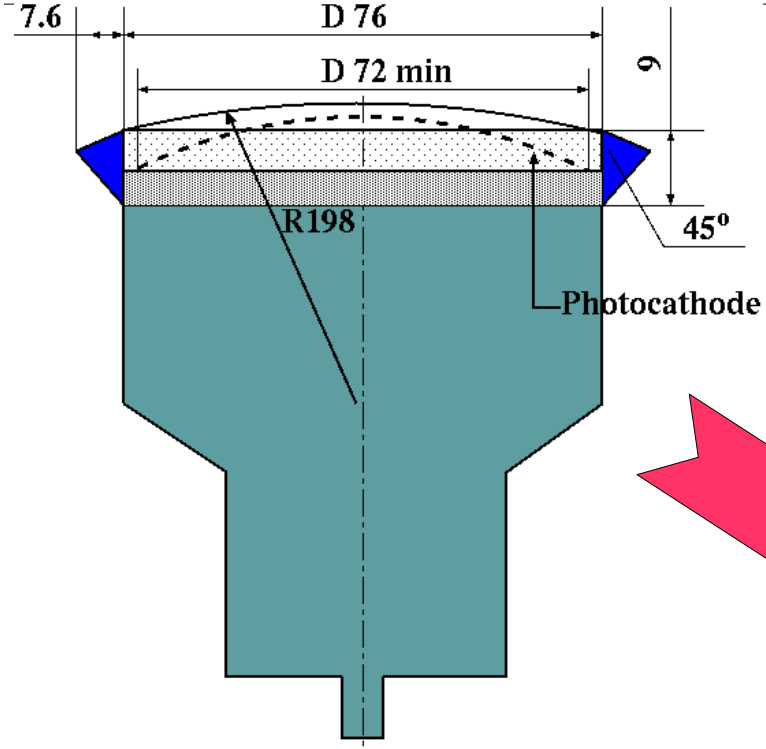
Prototypes manufactured at KVI:

Rings: **4.5 mm** and **9 mm** thick rings

Material: polished PMMA reflecting light from the side onto the photocathode

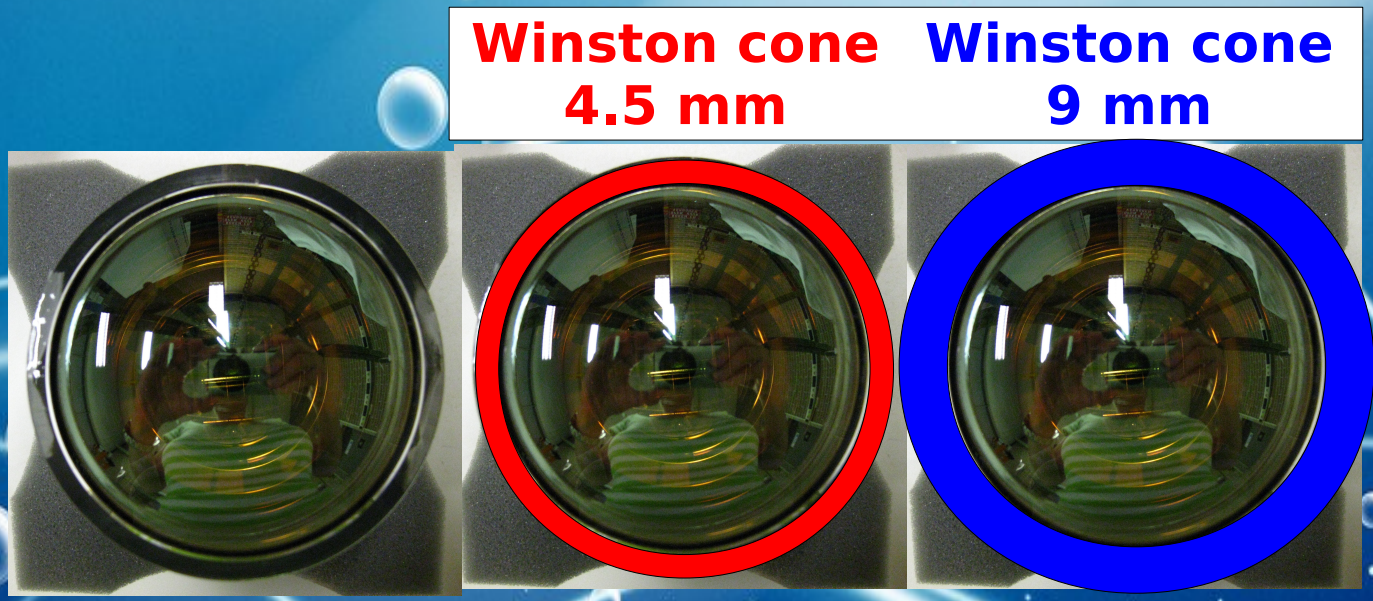
Reflection surface: 45° tilted surface, improved by silver evaporation





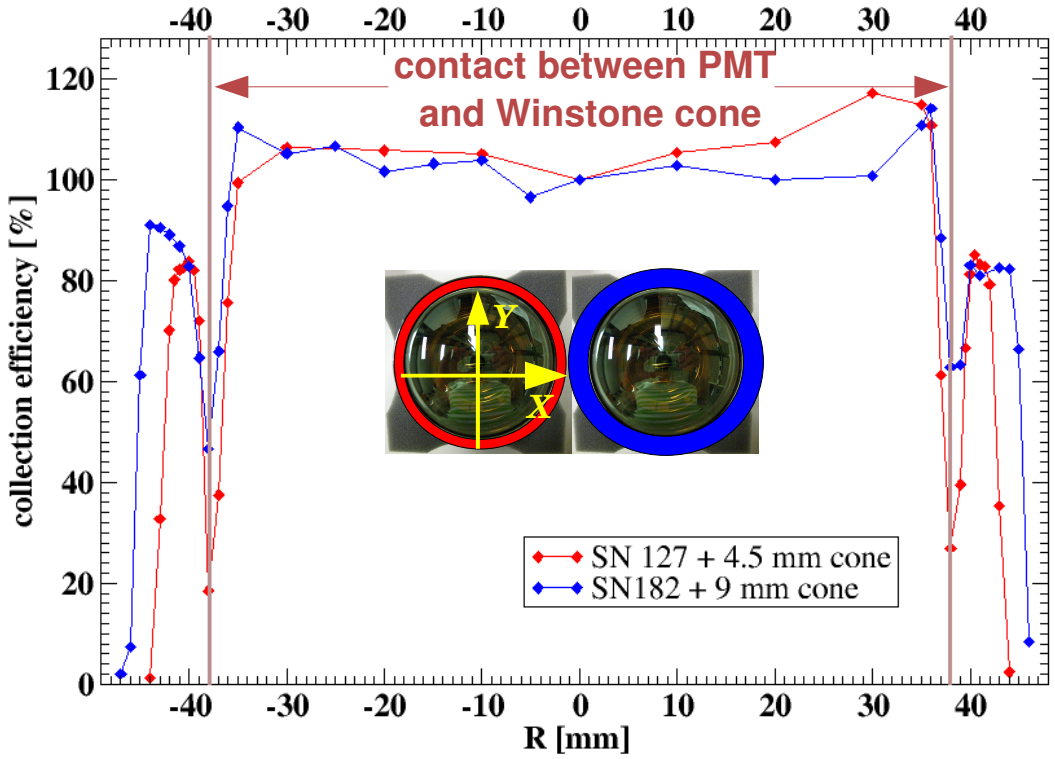
PMT with a Winston cone attached to the circumference of the entrance window

Idea and Realisation

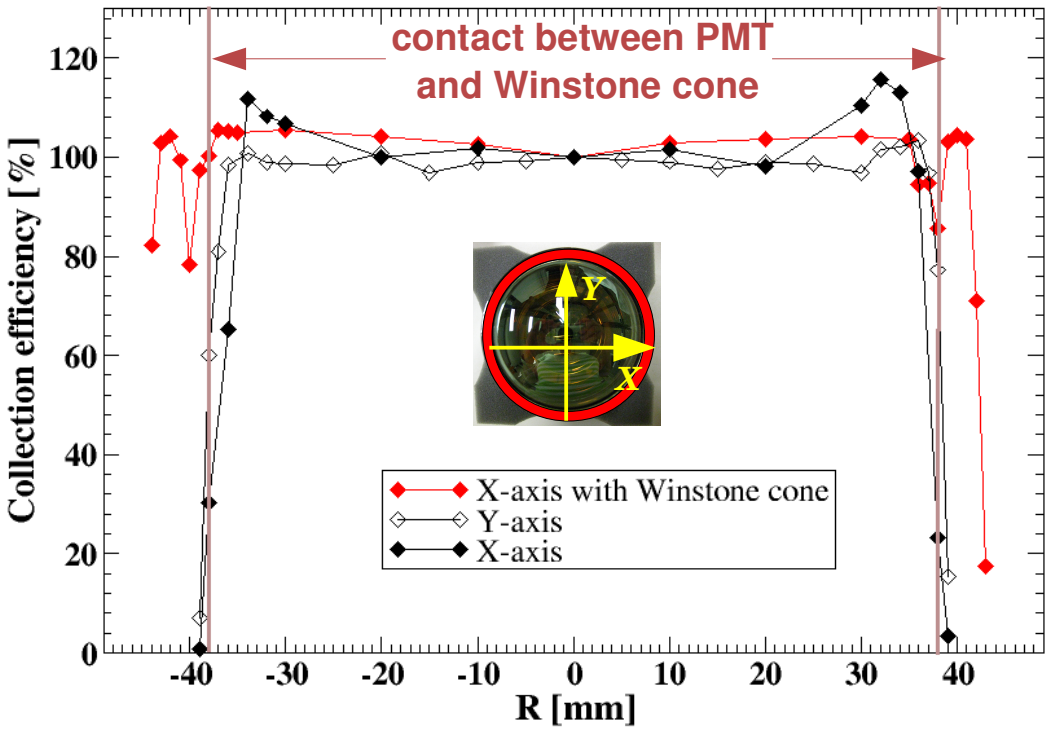


Collection efficiency

Laser λ=405 nm



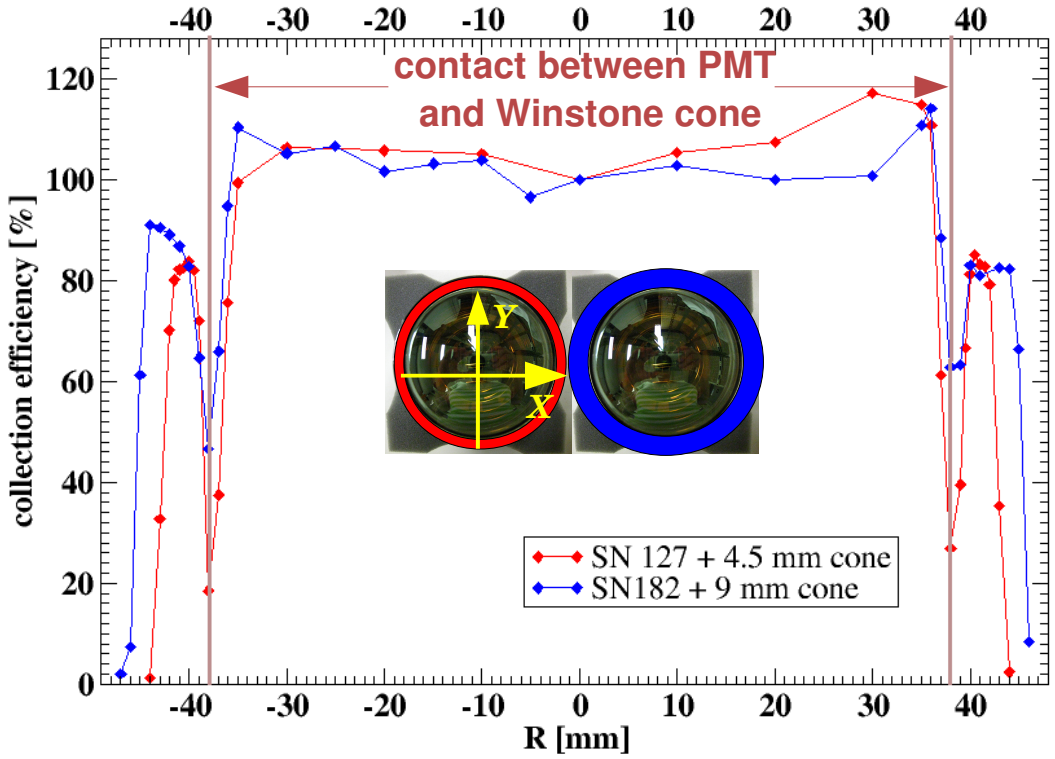
Sheffield pulser
LED λ=472 nm



- **perspex** materials have maximum transmission 92% of quartz
- **at 400 nm** the transmission can drop dramatically, e.g. for Perspex VA Clear004 to about **60%**
- **glass needs to be used**

Collection efficiency

Laser λ=405 nm



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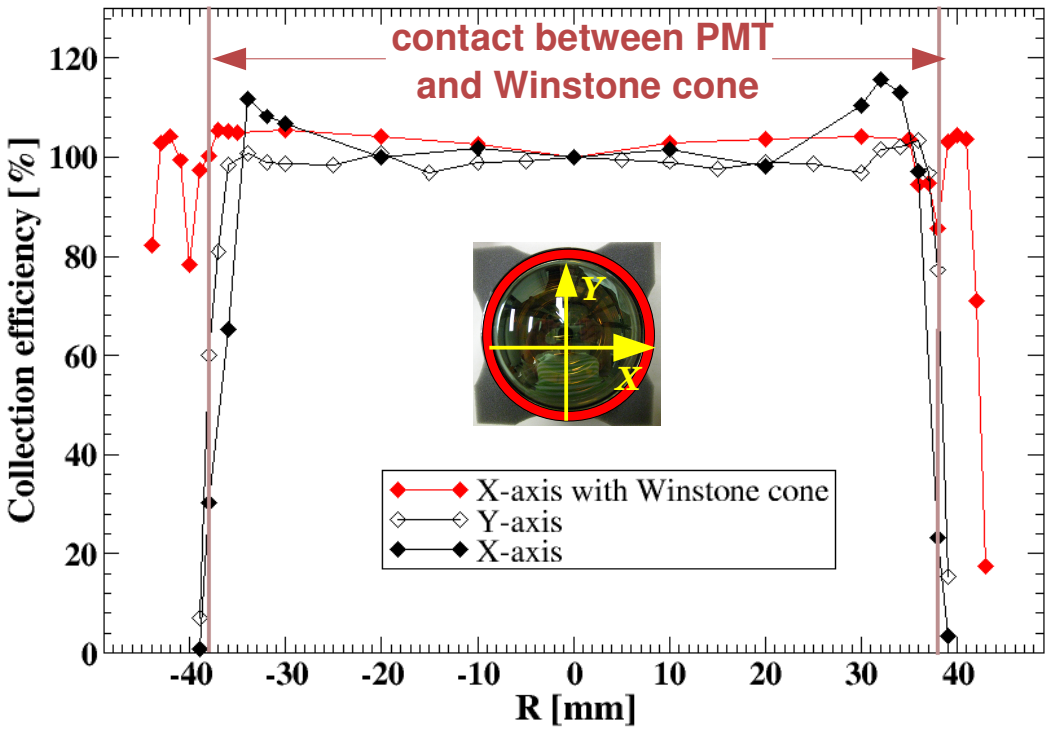


- collection efficiency from the area outside the photocathode is very high (about **80-100%** of the value in the centre)
- Application of such a cone increases the sensitive photocathode radius:

4.5 mm cone from **36±1.6** mm to **41.5±1.6** mm (**by 33%**)

9 mm cone from **36±1.6** mm to **44±1.8** mm (**by 50%**)

Conclusions

- **ETL 9822B** has **good timing characteristics** and **low dark count rate**
- might be an alternative for use in Multi-PMT OM if
  - **-> Multiplier structure redesigned**
  - **-> Photocathode homogeneity improved**

Winston cone in Multi-PMT OM

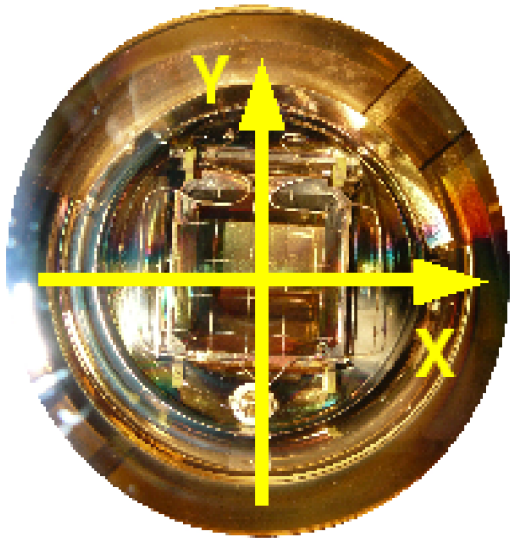
- **Charge and time spectra** measured with light shining on the cone are **the same** as when shining on the entrance window of the PMT
- collection efficiency from the area outside the photocathode is high **80-100%** of the value in the centre
- Application of such a cone increases the sensitive photocathode radius:
  - **4.5 mm cone** from **36±1.6** mm to **41.5±1.6** mm (**by 33%**)
  - **9 mm cone** from **36±1.6** mm to **44±1.8** mm (**by 50%**)
- Glass needs to be used
- For production: the entrance window and the ring could be manufactured as one homogeneous unit

KM3NeT

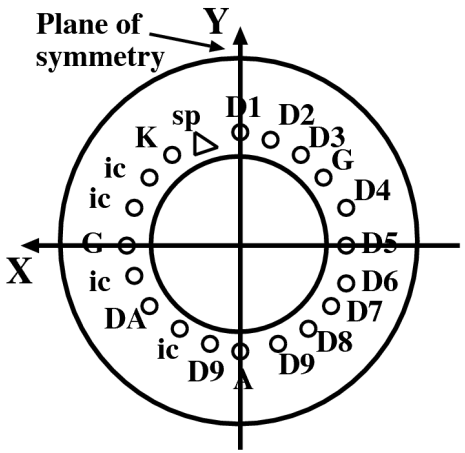
Backup slides

Coordinate system

Photonis XP53B20

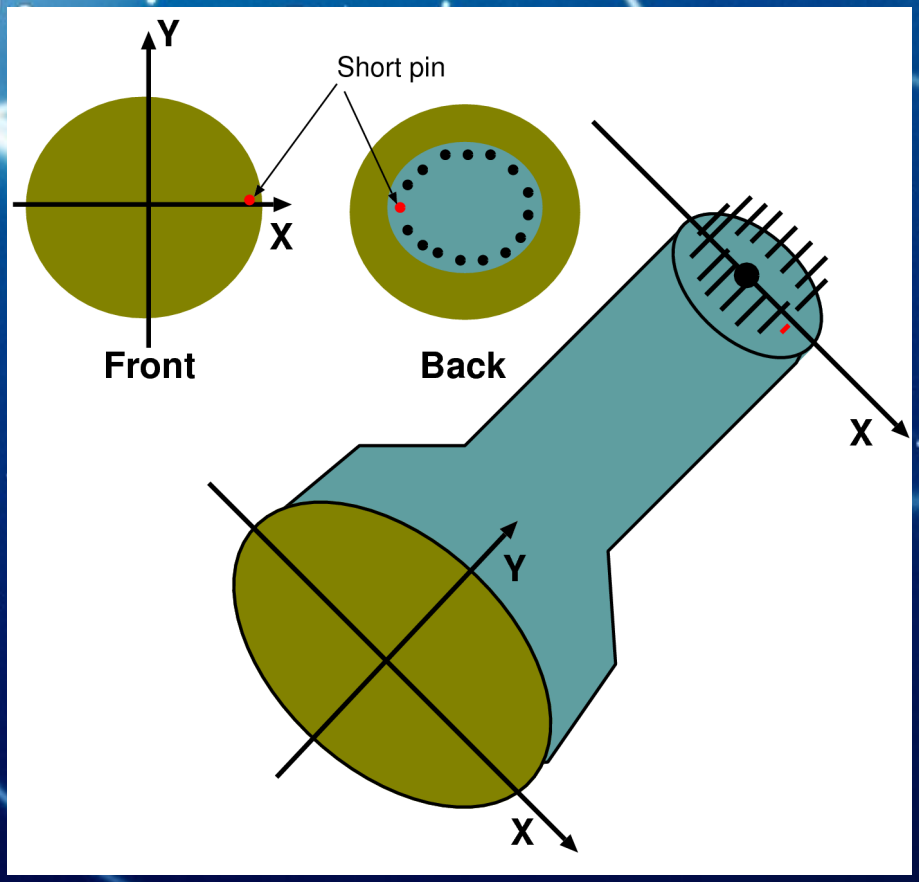


PMT Front



PMT Back

ETL 9822B



Idea and Realisation

Winston cone

Definition:

A nonimaging light-collection device with a parabolic shape and a reflective inner surface.
A Winston cone concentrates the light passing through a relatively large entrance aperture through a smaller exit aperture.
Winston cones are often used to concentrate light from a large area onto a smaller photodetector or photomultiplier.

Idea and Realisation

the Sheffield pulser uses a InGaN blue LED
HLMP-CB15 with mean wavelength 472 nm +-35 nm.

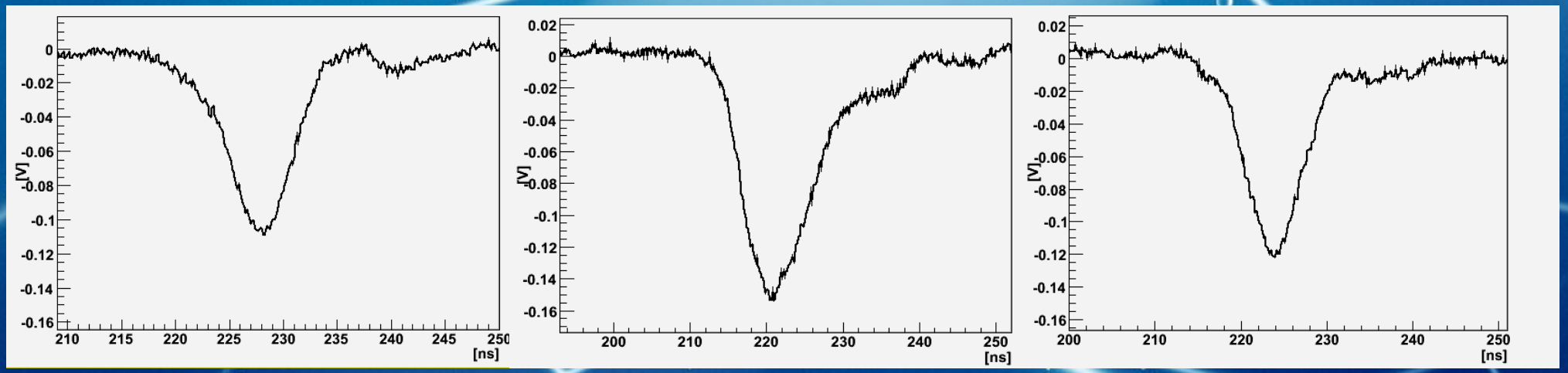
At this wavelength the "clear" type Perspex materials have maximum transmission which is 92% of quartz.
Still only 92% !!!
At 400 nm the transmission can drop dramatically, e.g. for Perspex VA Clear004 to about 60%.

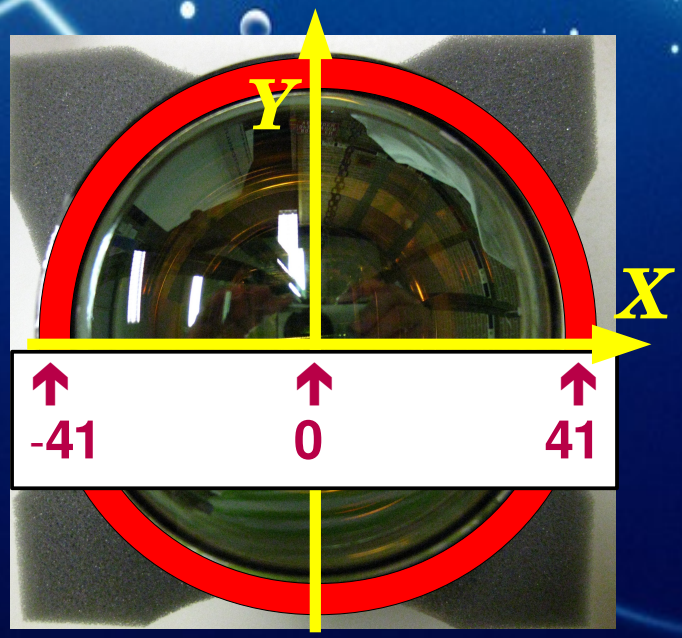
So it is necessary to know the type of perspex used.
It is also obvious that glass needs to be used.
In any case, the wavelength dependence explains the drop in transmission.

Results

Signal shapes

Radius: -41 mm **0 mm** **41 mm**





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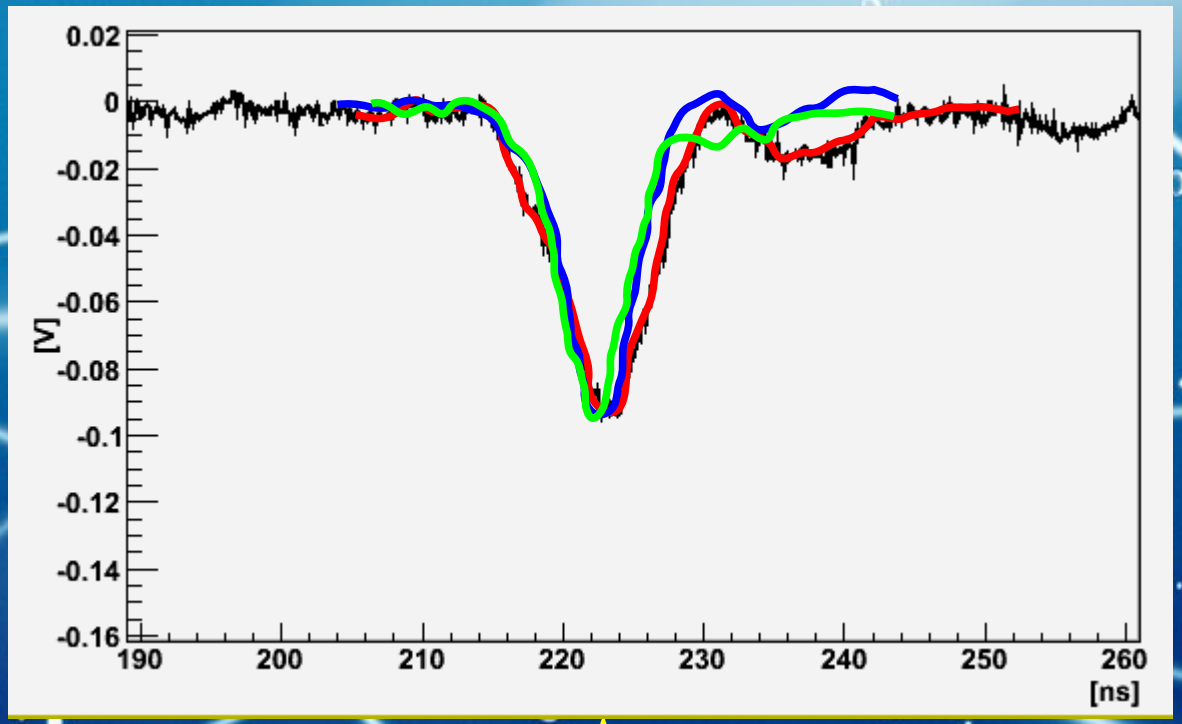
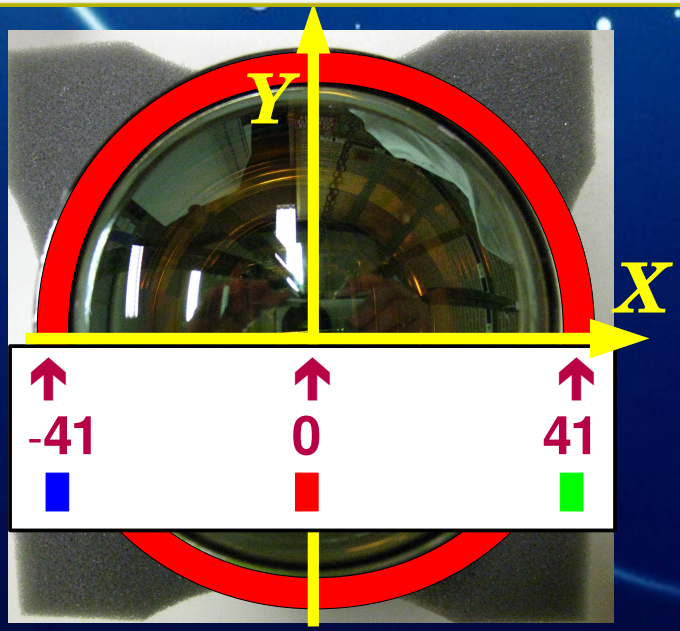
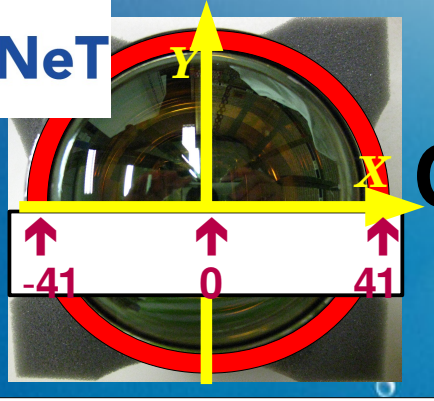


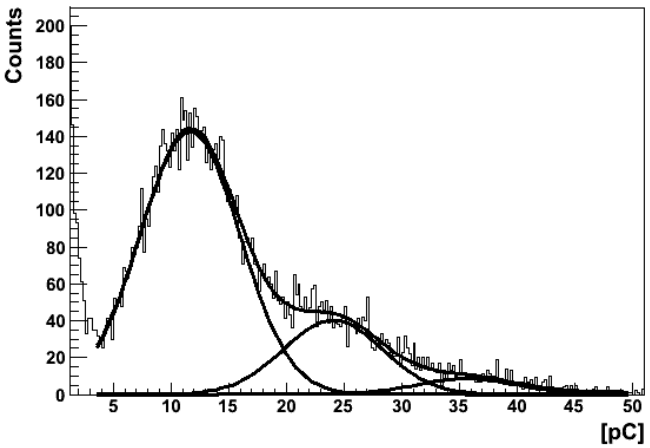


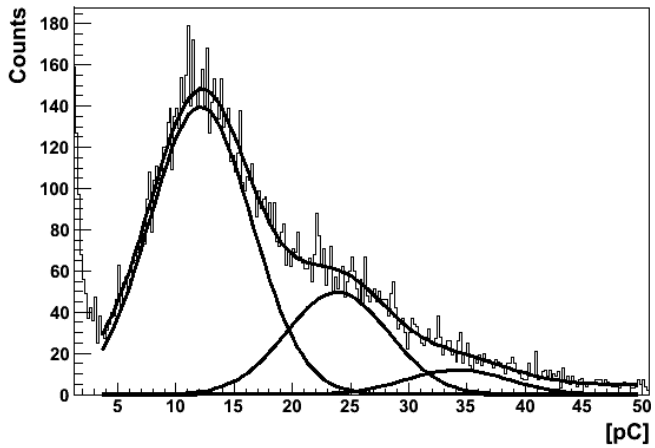


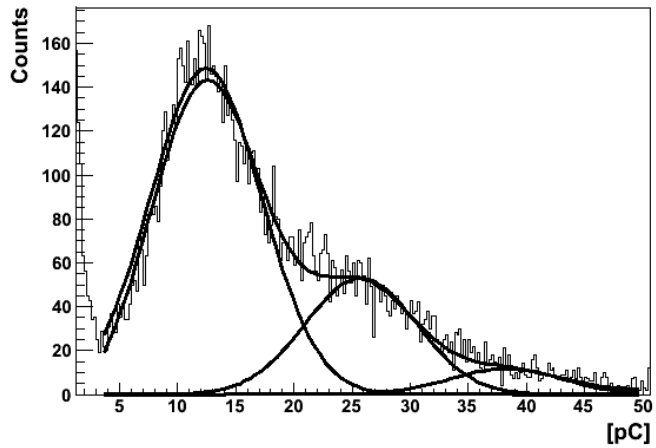
Charge distribution

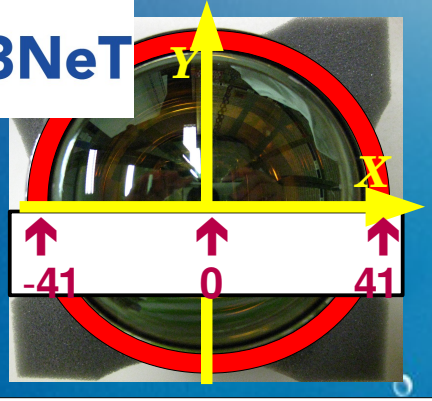
Radius: -41 mm	0 mm	41 mm
Gain: 1.18×10^6	1.22×10^6	1.25×10^6
-3 %		+2 %

Gain variation over the photocathode itself up to 5%









Time distribution

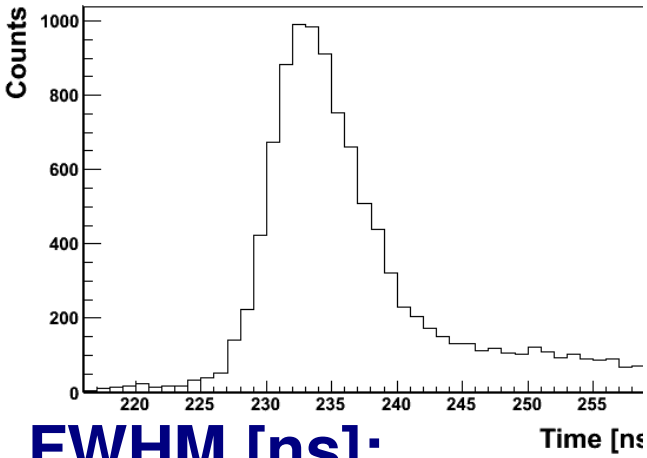
Radius: -41 mm | **0 mm** | **41 mm**

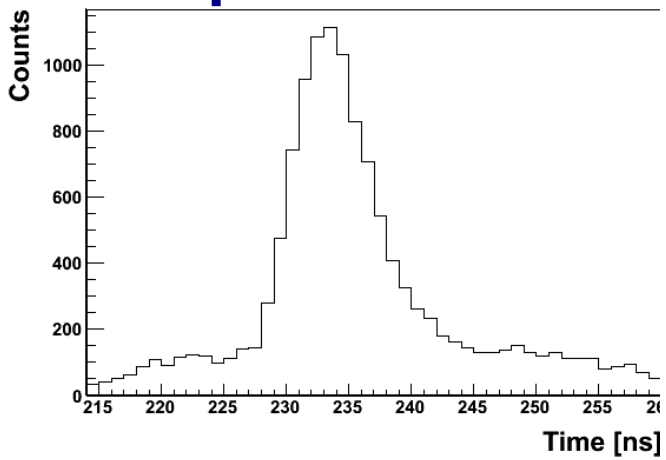
Time after trigger [ns]:

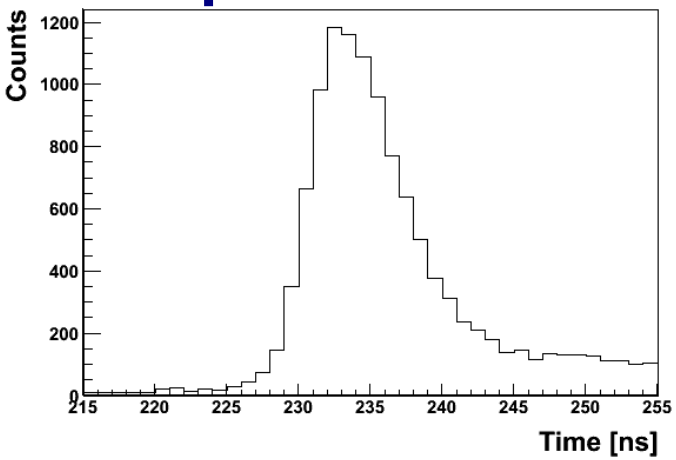
234.0±0.1 | 233.7±0.1 | 234.1±0.1

0.13 % | | 0.17 %

variation over the photocathode itself up to 0.6%







FWHM [ns]:

7.5±0.1 | 6.9±0.1 | 6.8±0.1

9% | | 1.5%

FWHM variation over the photocathode itself up to 17%