Evidences of Čerenkov light from a TeO_2 crystal

Nicola Casali, Università degli studi dell'Aquila, INFN Laboratori Nazionali del Gran Sasso

F. Bellini, N. Casali, I. Dafinei, M. Marafini, S. Morganti, F. Orio, D. Pinci, M. Vignati, C. Voena

Why searching Čerenkov radiation in TeO_2 crystal?

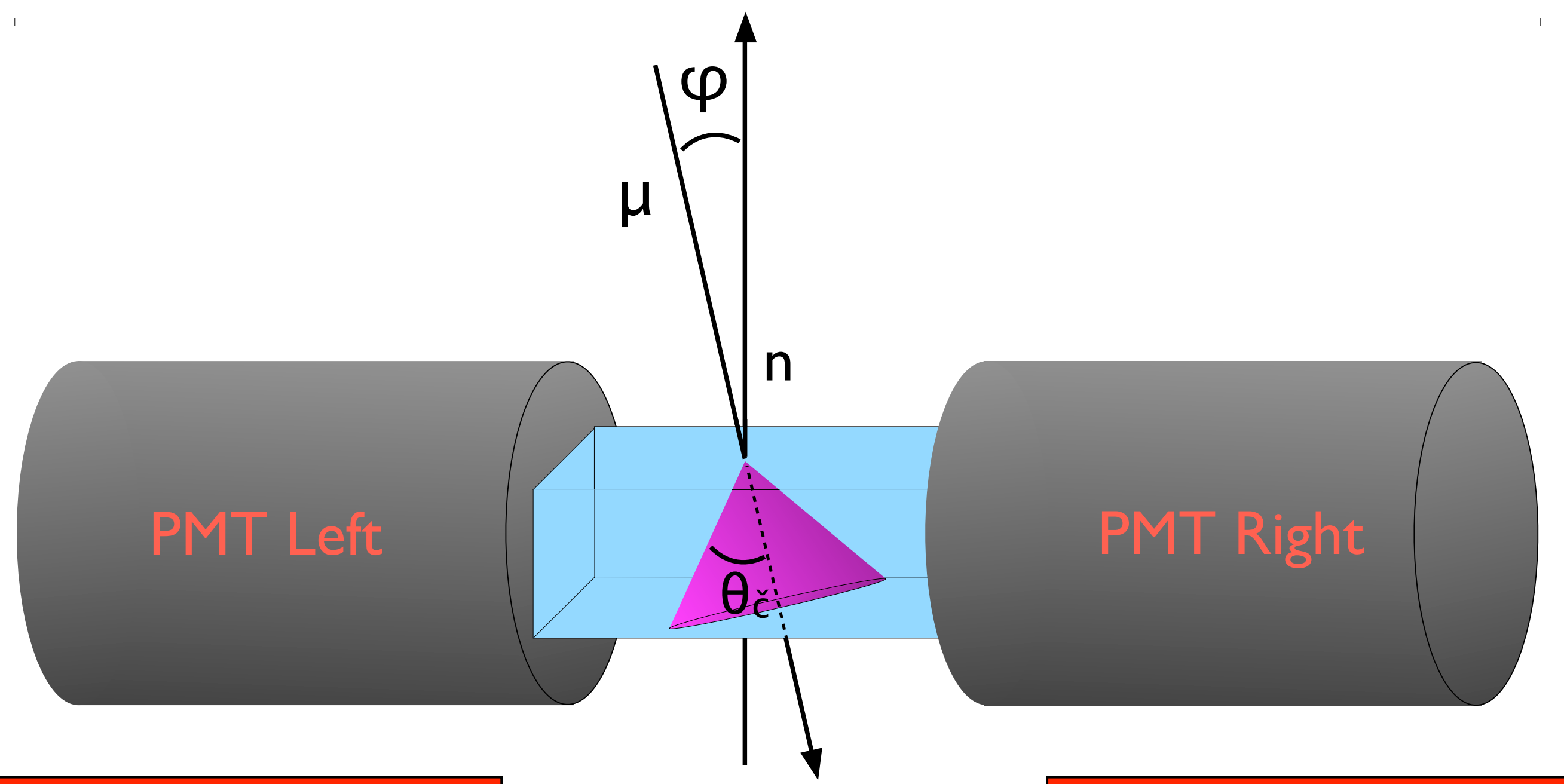
The TeO_2 crystals are currently used as bolometers in experiments searching for rare processes like double beta decay or Dark Matter interaction. The natural radioactivity represents for these experiments the main background source. The background component produced by α particles can be discriminated by the detection of Čerenkov light emitted at low energies (50 keV ÷ 400 MeV) only by electrons.

Goal of the measurement

Assessment and measurement of the Čerenkov component in the light output of a TeO_2 crystal at room temperature and disentanglement from a possible scintillation component:

Process	Emission	Rise Time	Decay Time	Spectrum	Polarization
Scintillation	isotropic	prompt	exponential $\tau > 10 \div 15$ ns	visible peak?	no
Čerenkov	$\cos\theta_C = (\beta n)^{-1}$	prompt	prompt	UV ~ $1/\lambda^2$	yes

Experimental setup



Photonis XP2970 PMT
fast ~ ns
UV sensitive > 200 nm

TeO_2: 2.5x2.5x5 cm^3
no wrapping

Photonis XP2970 PMT
fast ~ ns
UV sensitive > 200 nm

$\theta_{\check{C}} = 68^\circ$

The crystal light output can be divided in two components:

- A: independent from the angle between the muon and crystal → Scintillation or diffused Čerenkov light
- B: dependent from the angle between the muon and crystal → Mainly Čerenkov light

$$\bar{L}(\varphi) = \frac{\alpha}{\cos\varphi}(A_L + B_L(\varphi)) \qquad \frac{1}{cos\varphi} \text{ = path length}$$

$$\bar{R}(\varphi) = \frac{\beta}{\cos\varphi}(A_R + B_R(\varphi)) \qquad \alpha \text{ and } \beta \text{ = different PMT gains}$$

if the setup is symmetric

$$A_L = A_R = A \qquad B_L(\varphi) = B_R(-\varphi) = B(\varphi)$$

we can define the following variables

$$\bar{L}(0) = \alpha\,(A + B(0)) = \alpha k$$

$$\bar{R}(0) = \beta\,(A + B(0)) = \beta k$$

$$L(\varphi) = \frac{\bar{L}(\varphi)}{\bar{L}(0)} = \frac{1}{k\cos\varphi}(A + B(\varphi))$$

$$R(\varphi) = \frac{\bar{R}(\varphi)}{\bar{R}(0)} = \frac{1}{k\cos\varphi}(A + B(-\varphi)).$$

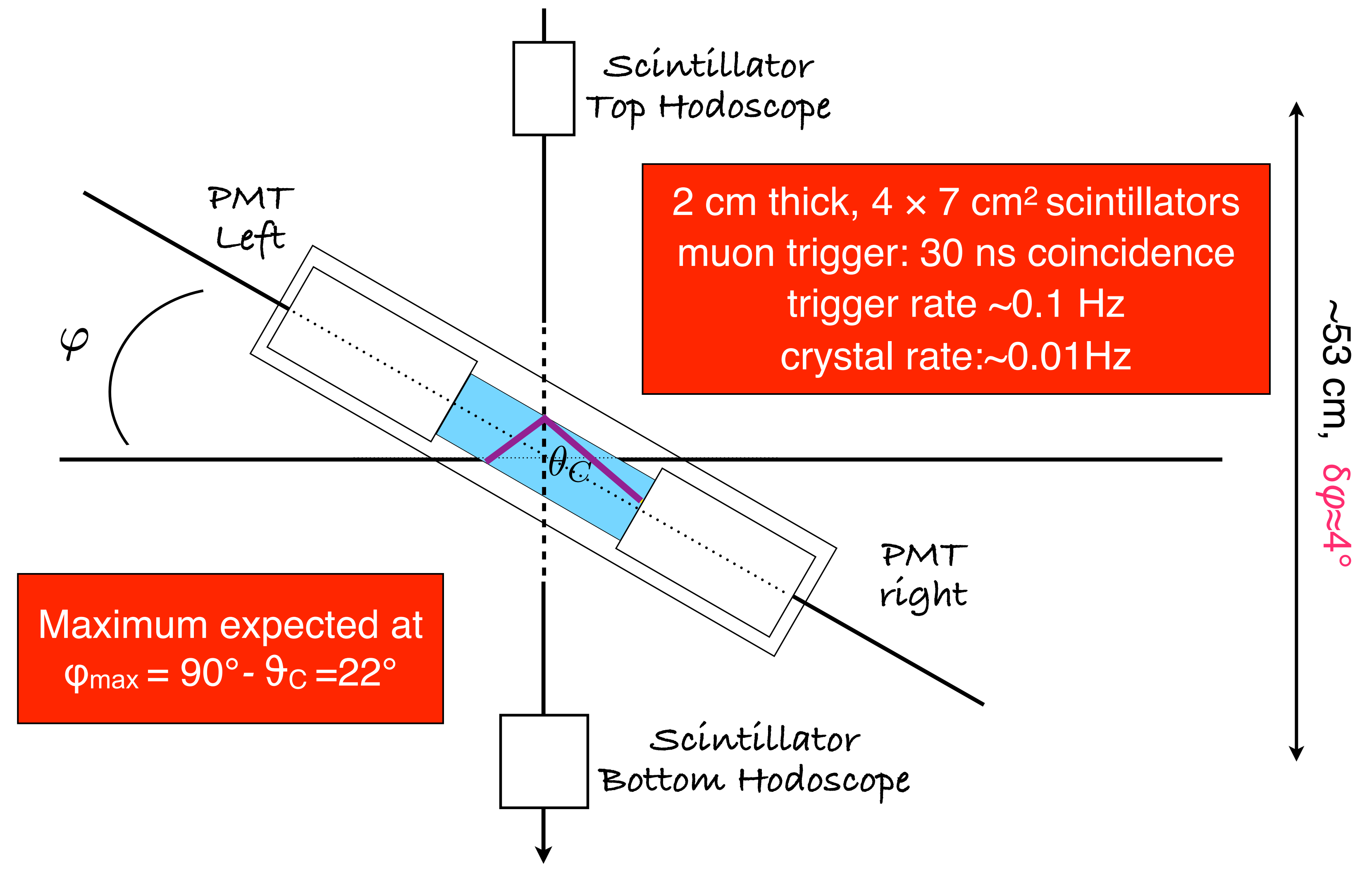
$$L(\varphi) = R(-\varphi)$$

Conclusions

- TeO_2 crystal emits light when crossed by a fast charged particle
- The signal is very fast: rise and decay time of the order of few ns
- There is a clear angular dependence compatible with Čerenkov emission
- There is a flat component: most likely Čerenkov light diffused by crystal lateral faces
- The directional component is 60% of collected light

Acknowledgements: This work was made in the frame of LUCIFER experiment funded by the European Research Council under the European Unions Seventh Framework Program (FP7/2007-2013) / ERC grant agreement n. 247115

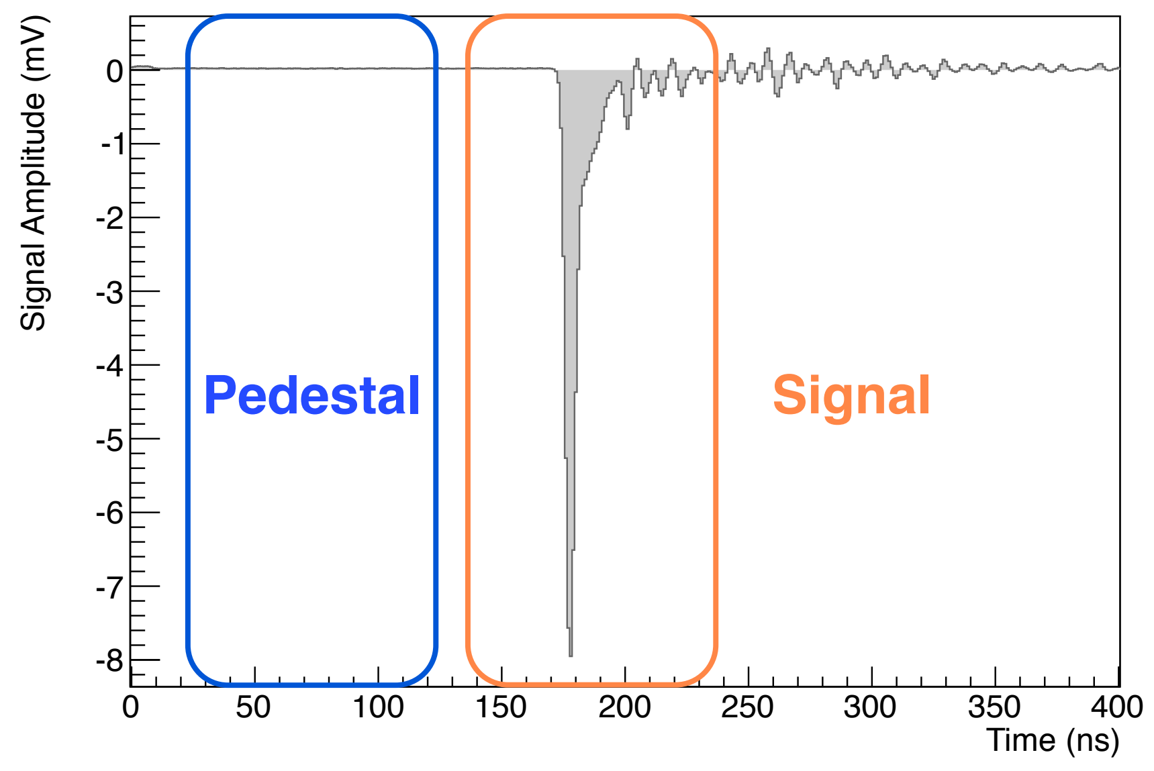
Muon trigger and signal read out



2 cm thick, 4 × 7 cm^2 scintillators
muon trigger: 30 ns coincidence
trigger rate ~0.1 Hz
crystal rate:~0.01Hz

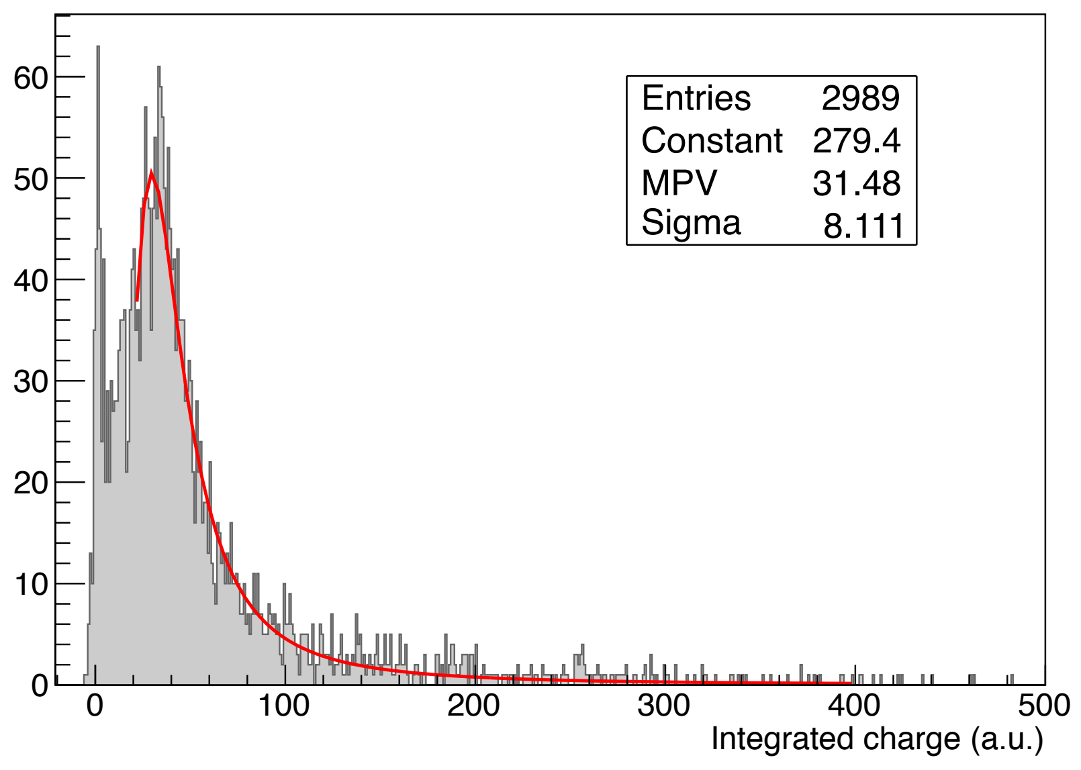
Maximum expected at
$\varphi_{max} = 90° - \vartheta_C = 22°$

Analog signals acquired by CAEN V1731 8-bit 1 Vpp, 1 GS/s sampling rate, BW = 250MHz; sensitivity ~ 4 mV, rise time = 2.2/(2πBW) = 1.4 ns



Average waveform for 1000 muons

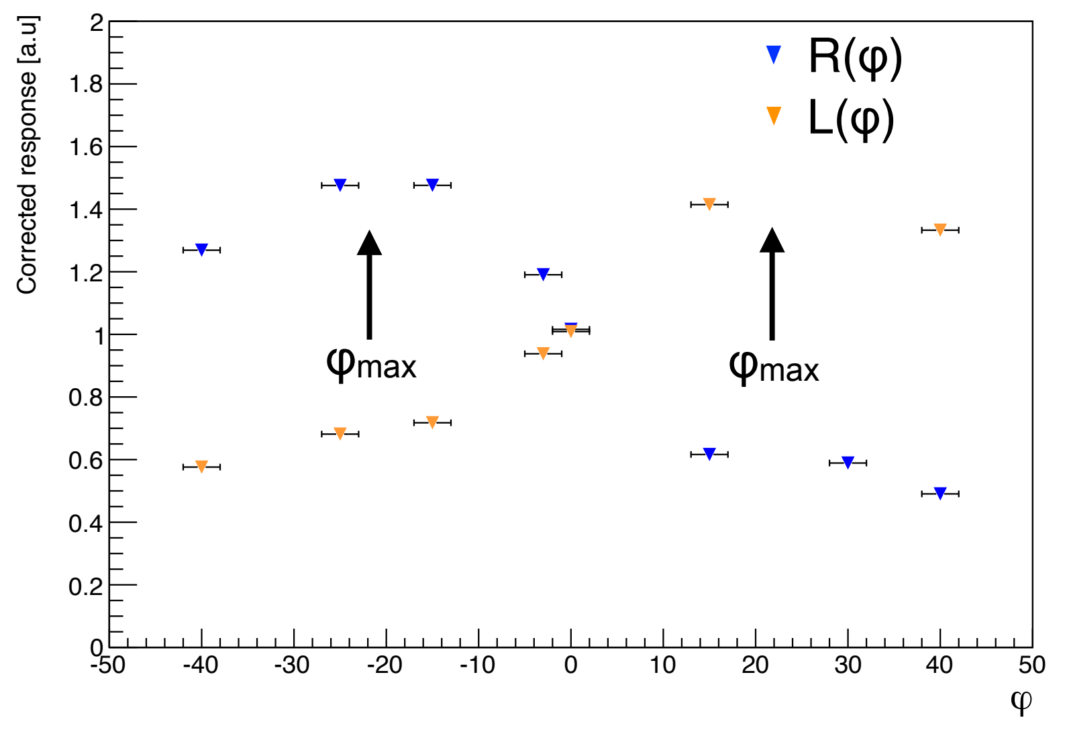
- Fast signal: rise and decay time of the order of few ns



Charge distribution for a PMT

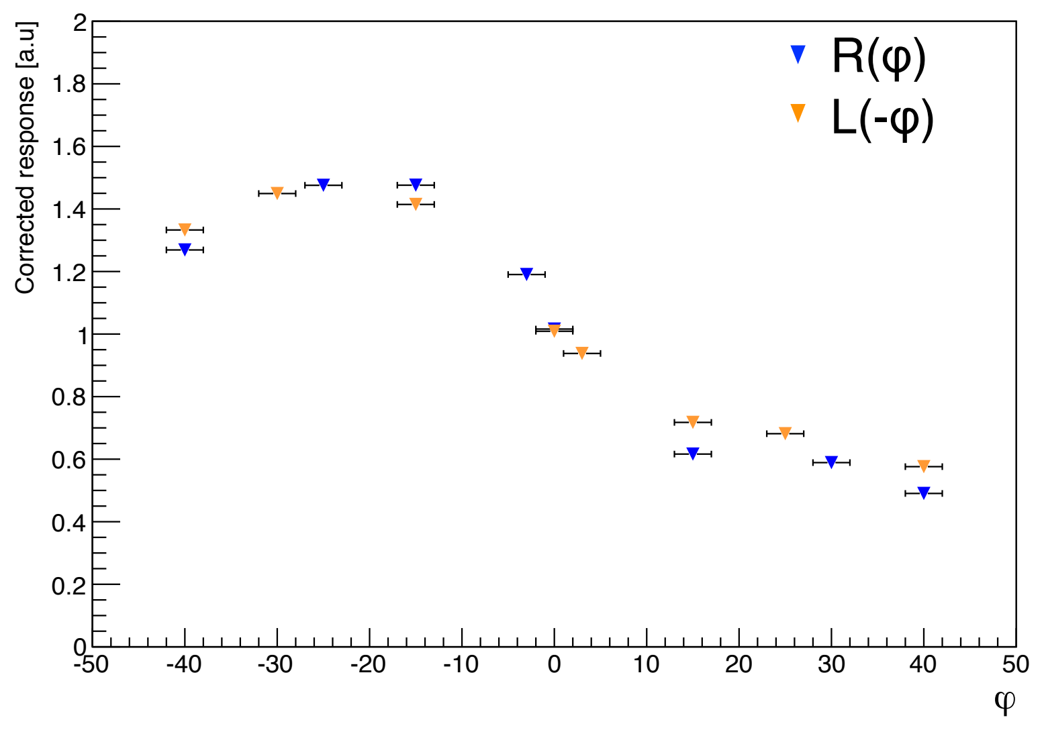
- For each angle the signal is fitted with a Landau distribution

Results



Response corrected for the muon path length and PMT gain equalize

The angle dependence is clearly visible and similar on the two sides

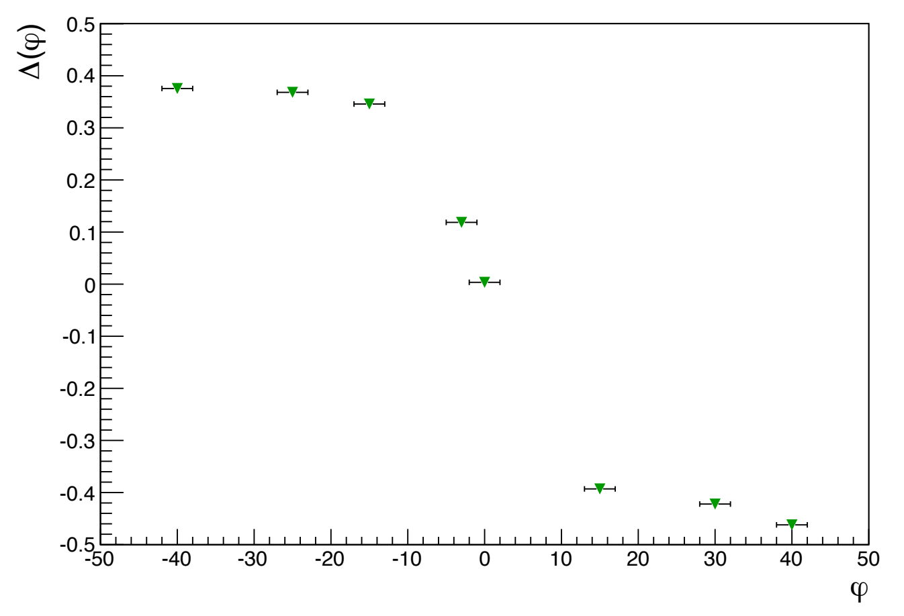


The symmetry of the setup is well verified

Flat component ~ 0.6
Directional component ~ 1.5

Charge asymmetry

$$\Delta(\varphi) = \frac{R(\varphi) - L(\varphi)}{R(\varphi) + L(\varphi)} = \frac{B(\varphi) - B(-\varphi)}{2A + B(\varphi) + B(-\varphi)}$$



Assuming B(22˚) = B_{MAX} and B(-22˚) = 0, Δ = 0.4 e B_{MAX} = 1.5 A.

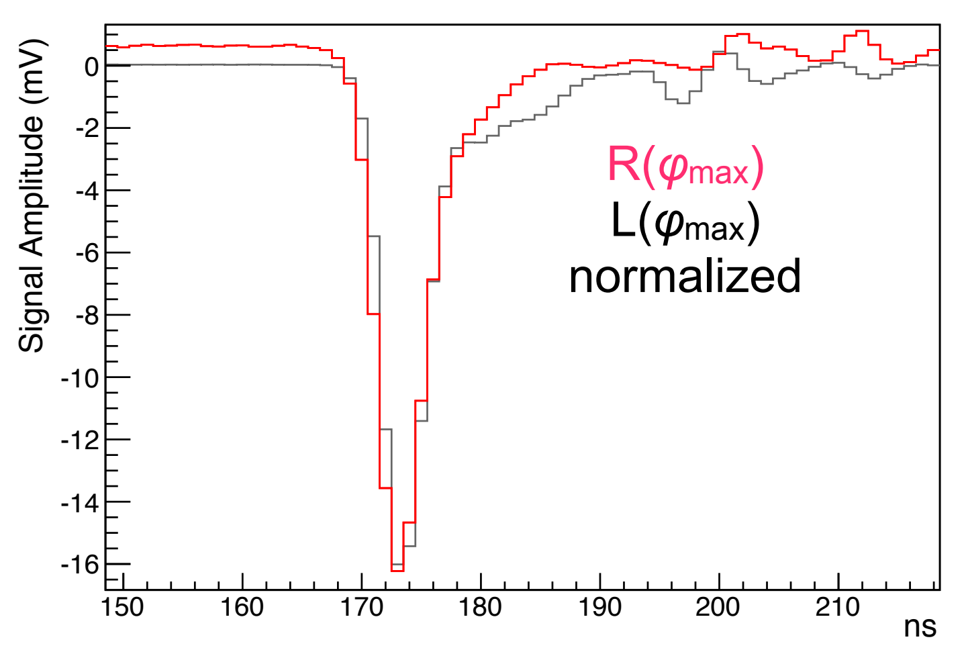
If the flat component is due to the scintillation alone, Čerenkov would be ~ 60 % of collected light.

Flat component

@ φ = 22˚

$R(\varphi_{max})$: mainly Čerenkov

$L(\varphi_{max})$ = flat component



Typical waveforms of Čerenkov and "flat component", evidence of similar time behavior (rise and decay).