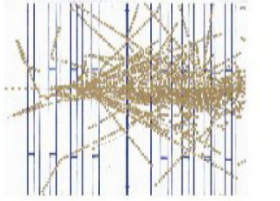

Effects of Temperature Dependence of the Signals from Lead Tungstate Crystals

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On behalf of the Dream Collaboration

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- **Texas Tech University**, Lubbock (TX), USA
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- **Università di Cagliari and INFN Cagliari**, Cagliari, Italy
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- **Università della Calabria and INFN Cosenza**, Cosenza, Italy
- **Università di Roma La Sapienza and INFN Roma**, Roma, Italy

Dual Readout Calorimetry

Performances of hadronic calorimeters is limited by:

- Different response to EM and non-EM shower components
- Fluctuations in EM fraction (f_{em}): large, non-poissonian
- hadron signal non-linearity, poor hadronic energy resolution , non gaussian response function.

A possible solution to overcome this limitation is to measure f_{em} event-by-event:

- Separation between scintillation and Cherenkov light (created only by EM component of the hadronic shower)
  - In different media (quartz and scintillating fibres)
  - Crystals

See R. Wigmans's talk: Tue, CT session

Outline

Capability of Scintillation/Cherenkov separation in crystals has been proved in 2006 and 2007 testbeams

Quantitative measurements on this separation are shown here

- Temperature dependency measurements is not a technique to analyze data "real life"
- It's a way to assess Cherenkov light production and evaluation

CONTENT:

- 2007 test beam
- Analysis & Results
  - Temperature measurements
  - ADC spectra studies
  - Time structure studies
- Conclusions

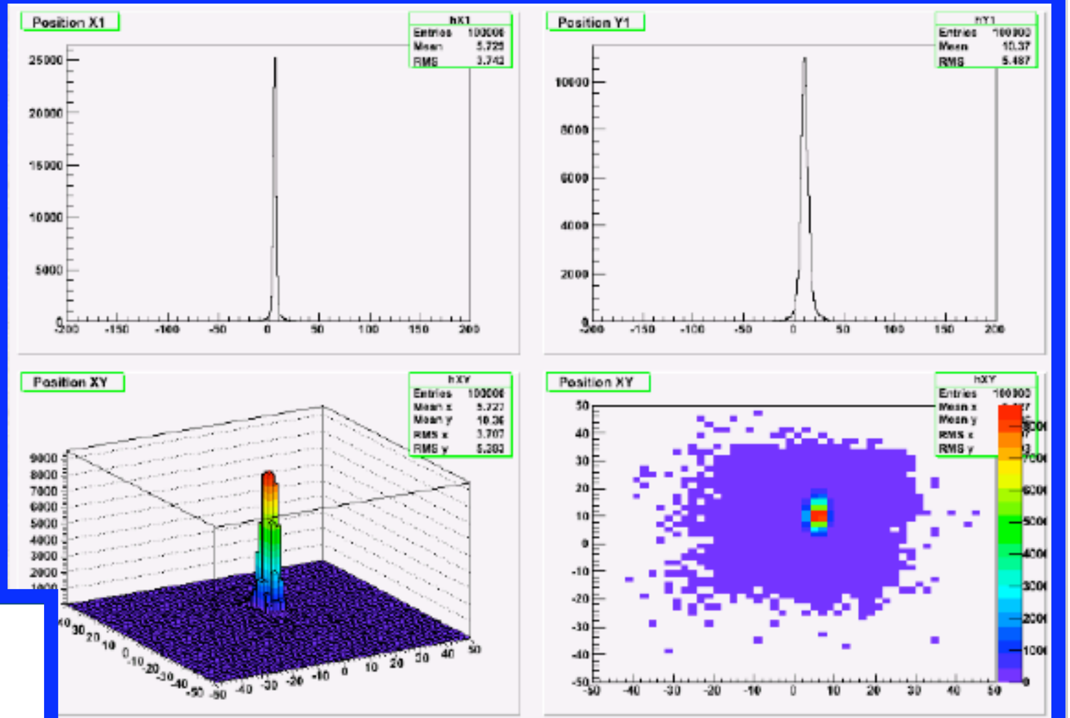
Test Beam 2007: Setup

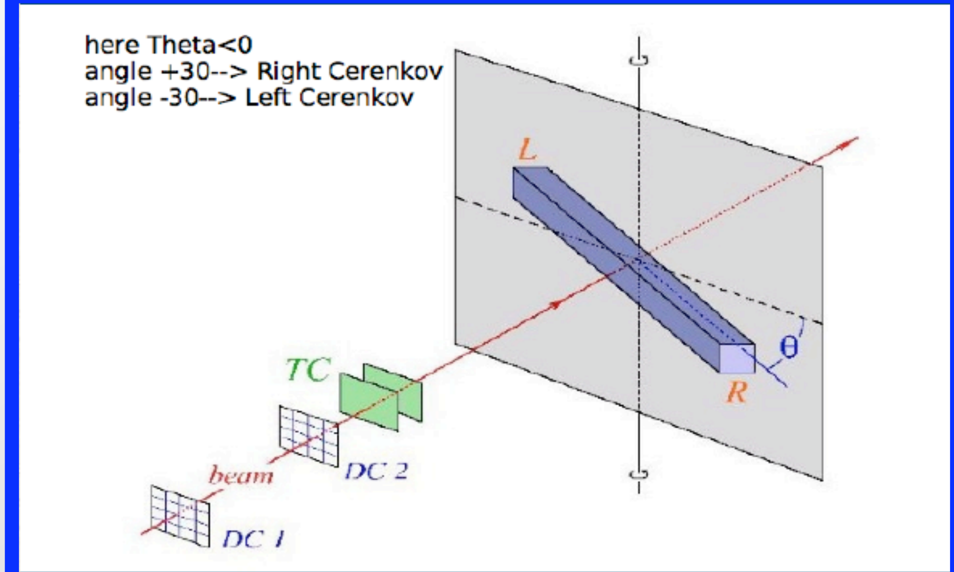
H4 beam Line SPS (CERN)

The Crystal response to different beams has been studied:

<u>50 GeV electrons</u>
100, 200, 300 GeV π^-,
50, 70 GeV π^+,
200 GeV μ^+

Beam profile as seen from beam chambers

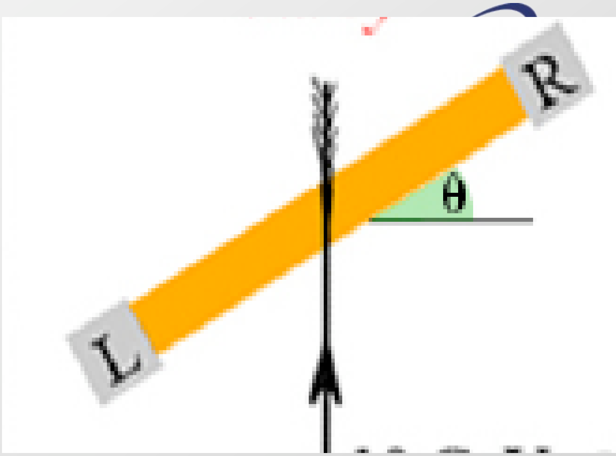




Single Crystal positioned on a rotating platform to perform angular scan

Temperature Control: thermoelectric system (Peltier effect)

Test Beam 2007: Setup



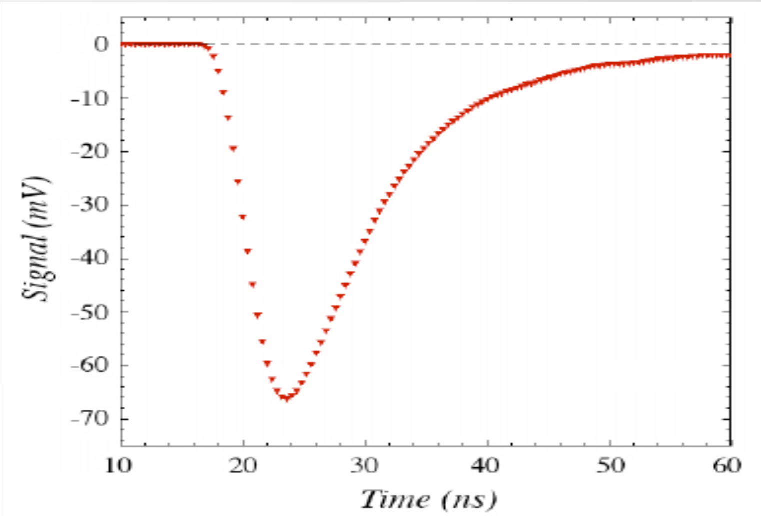
θ = angle between beam and crystal axes

Single crystal $PbWO_4$
18cm length,
cross section 2.2 X 2.2 cm^2

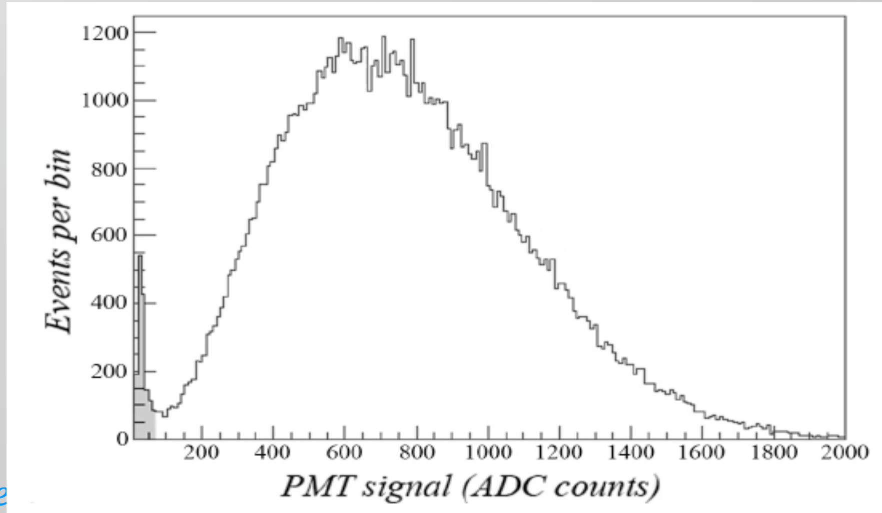
2,5 X_o

2 PM (Left & Right) both sides

Time structure : sampling oscilloscope (rate 2.5GHz)
time windows 112 ns



Charge : 12-bit ADC (100fC/count)

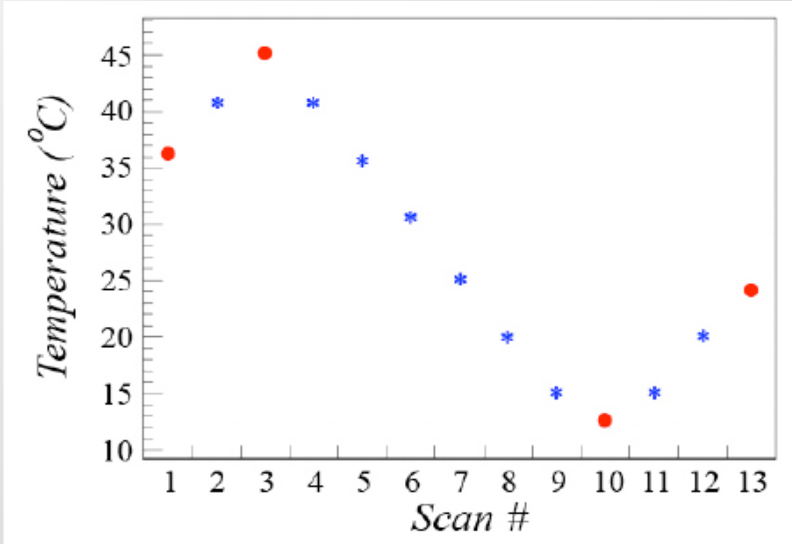


New te

Temperature Scans

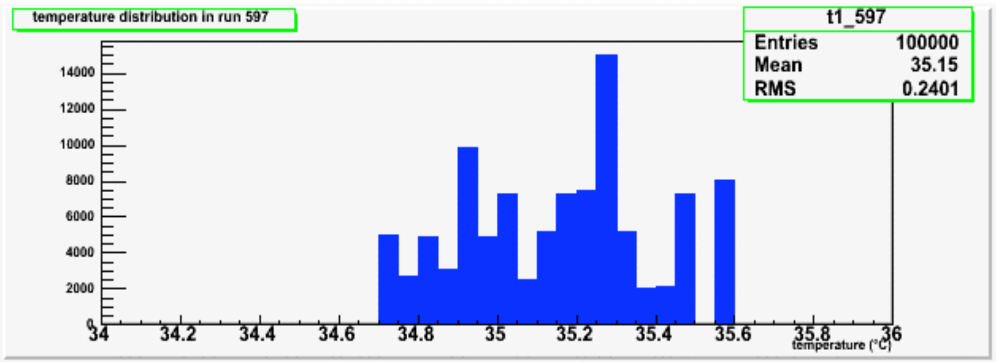
INFN Istituto Nazionale di Fisica Nucleare

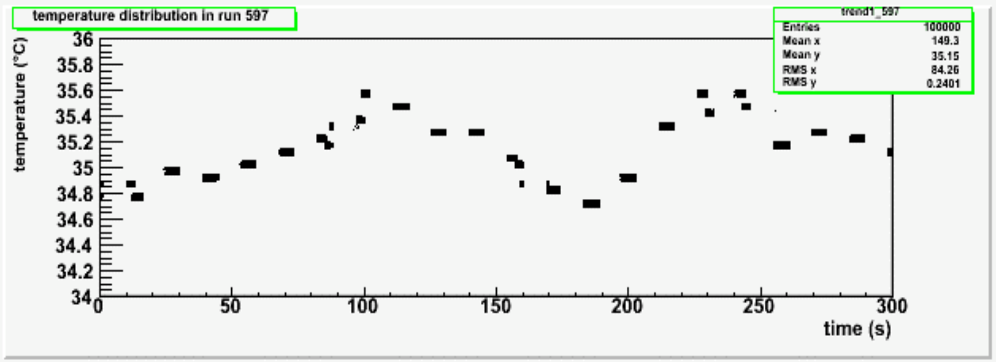
- ✓ 13 angular scans performed at different temperatures
- ✓ At each temperature an angular scan is performed
  - ✓ 4 complete scans from -60° to 60°, step of 5°
  - ✓ 9 quick scans (θ = 0°, ±25°, ± 30°)
- ✓ At each angle collection of:
  - ✓ 100 000 events
  - ✓ 10 000 randomly triggered events for pedestal subtraction
  - ✓ 1 temperature reading per event



- *Temperature controlled measurements with crystal 2*
  Angular scans at different temperatures. Logbook pages 42
  NB. No information from downstream beam chamber fo
  - Runs 597 - 625, $T = 35°C$, $\theta = -60°$ to $+60°$
  - Runs 627 - 635, $T = 40°C$, $\theta = -35°$ to $+35°$
  - Runs 636 - 663, $T = 43°C$, $\theta = -60°$ to $+60°$
  - Runs 664 - 671, $T = 40°C$, $\theta = -35°$ to $+35°$
  - Runs 672 - 679, $T = 35°C$, $\theta = -35°$ to $+35°$
  - Runs 682 - 688, $T = 30°C$, $\theta = -35°$ to $+35°$
  - Runs 692 - 698, $T = 25°C$, $\theta = -35°$ to $+35°$
  - Runs 699 - 705, $T = 20°C$, $\theta = -35°$ to $+35°$
  - Runs 706 - 712, $T = 15°C$, $\theta = -35°$ to $+35°$
  - Runs 713 - 743, $T = 12°C$, $\theta = -60°$ to $+60°$
  - Runs 744 - 752, $T = 15°C$, $\theta = -35°$ to $+35°$
  - Runs 753 - 759, $T = 20°C$, $\theta = -35°$ to $+35°$
  - Runs 760 - 790, $T = 25°C$, $\theta = -60°$ to $+60°$

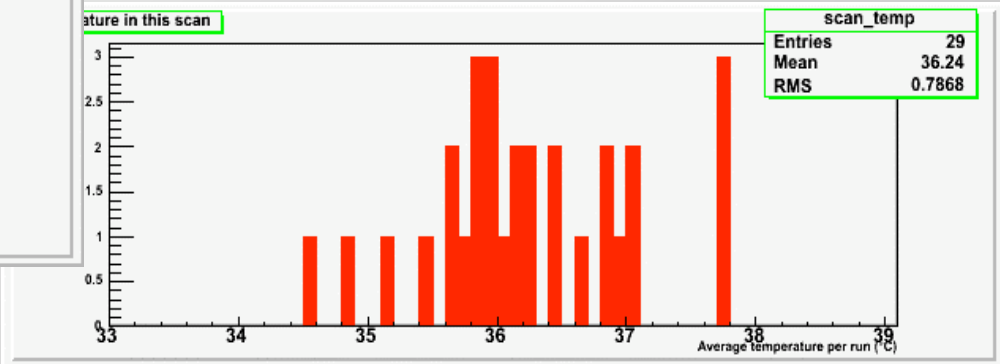
Temperature stability checks

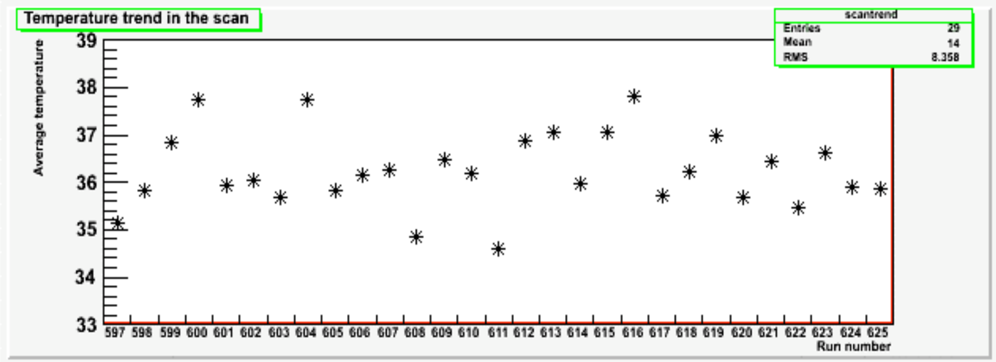




Check temperature stability within a run

- semi-dispersion ± 0.5 °C
- no visible trend
- using average temperature for the run

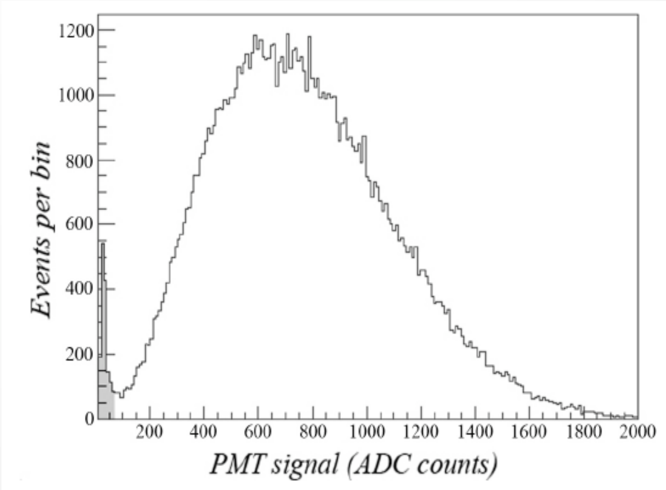




Check temperature stability within an angular scan performed at the same nominal temperature

- Semi-dispersion ± 1.5 °C
- No visible trend

ADC Analysis

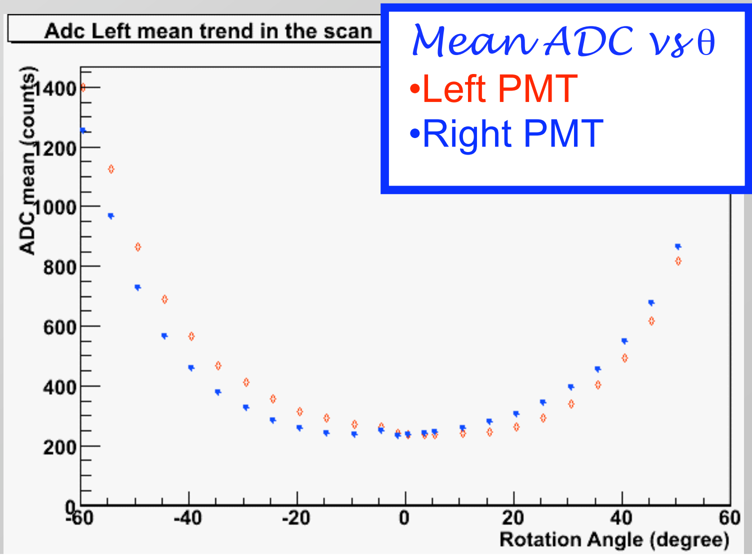


- ADC charge distribution shows
  - the pedestal
  - the electromagnetic shower distribution
  - a MIP peak
- Pedestal subtraction done using the mean value from pedestal events

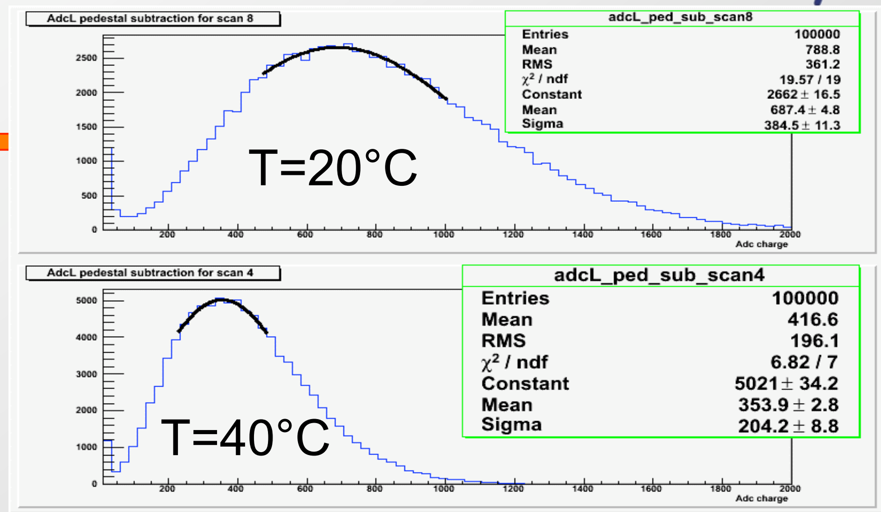
$$\frac{\text{Integral MIP peak}}{\text{Total Integral}} \approx 1\%$$

Systematics in ADC signal :

- Beam content (MIP contamination)
- Beam position (cut on position chamber)
- ADC signal parameterization
  - Peak/mean ratio shows about 5% variation
- Studies on presence of long tails
  - Less than 5‰ of events

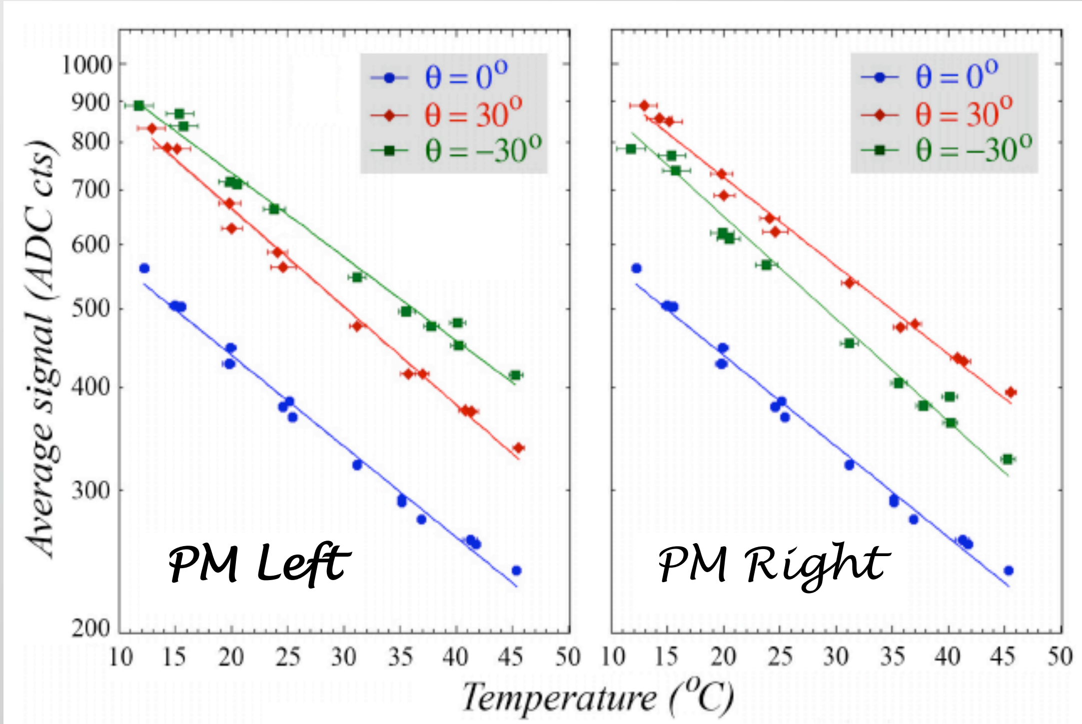


Light yield vs T



- Downstream PMT: Cherenkov signal is temperature independent; smaller effect in the LY decrease
- Upstream PMT: <u>only scintillation</u>: greater effect of the decrease in the LY
- θ=0: smaller fraction of Cherenkov signal, reduction of decrease effect in LY less visible

Angle θ	Slope PMT L (% / °C)	Slope PMT R (% / °C)
$-30°$	2.61 ± 0.02	2.99 ± 0.02
$0°$	2.81 ± 0.02	2.80 ± 0.02
$30°$	2.95 ± 0.02	2.66 ± 0.02



Light yield vs T

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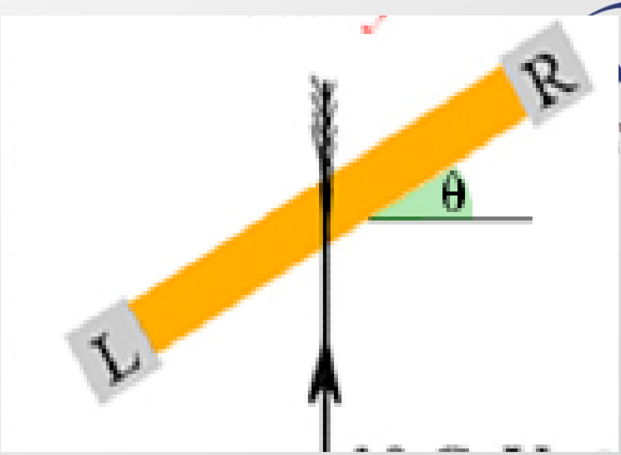

θ =+30: R-PMT is downstream
θ =-30: L-PMT is downstream

Angle θ	Slope PMT L (%/°C)	Slope PMT R (%/°C)
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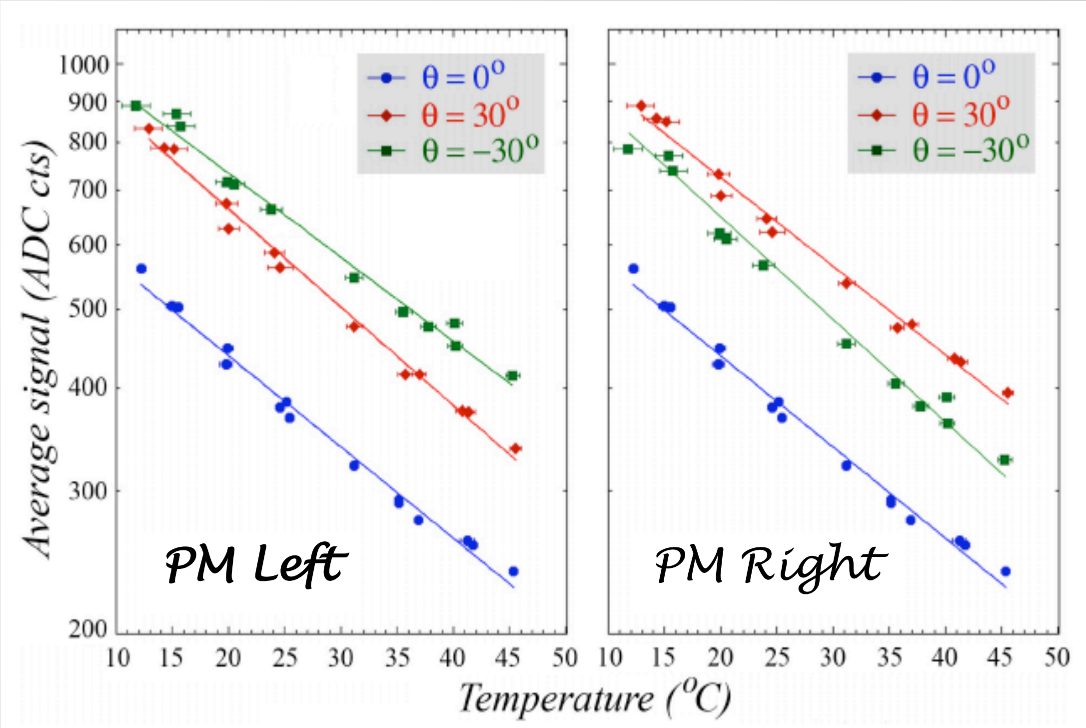
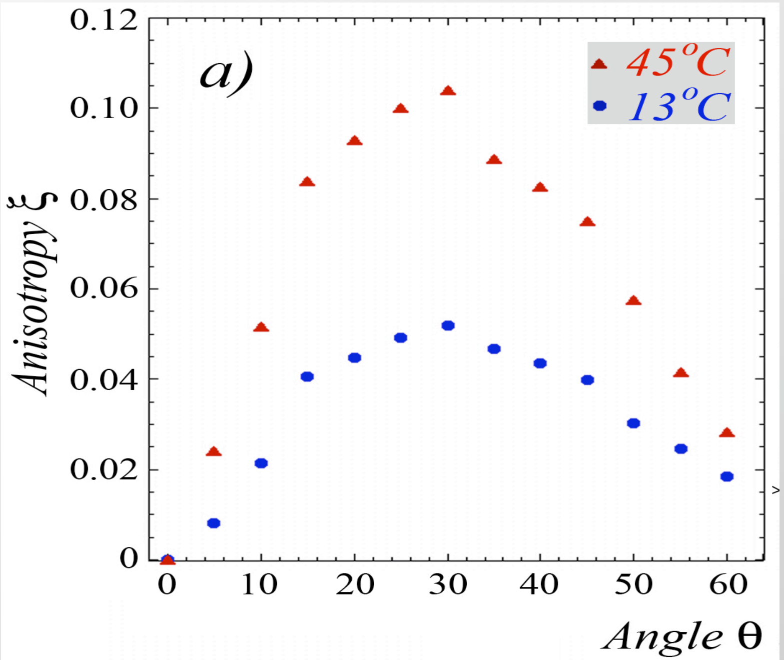
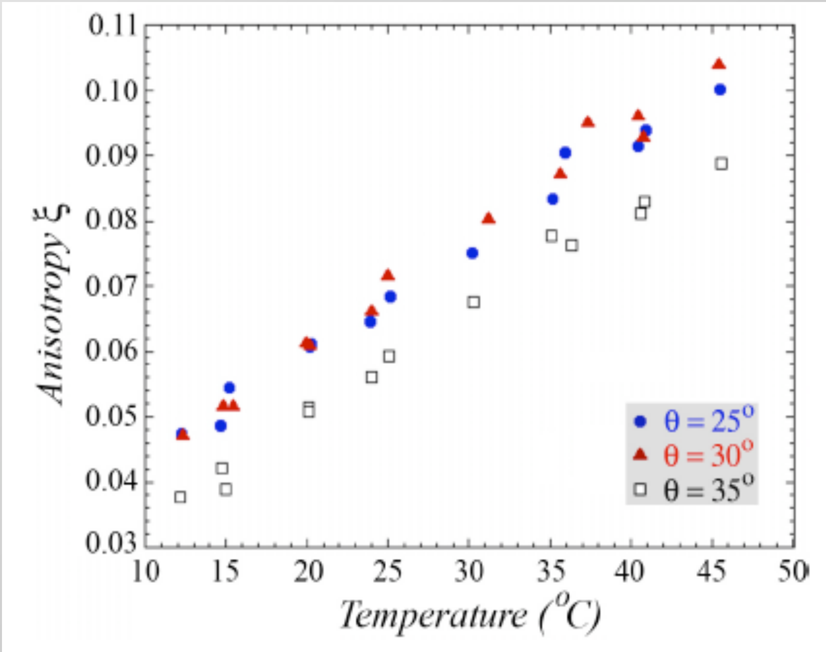


Anisotropy

$$\xi(\theta) = \left| \frac{R_\theta - R_{-\theta} - L_\theta + L_{-\theta}}{R_\theta + R_{-\theta} + L_\theta + L_{-\theta}} \right|$$

- *Left and right PMT equalized at θ=0*
- *Non-zero anisotropy is due to non-isotropic component in the ADC signal: Cherenkov*
    - *Maximum anisotropy at Cherenkov angle*
    - *Anisotropy increases with the Cherenkov fraction (higher temperature)*

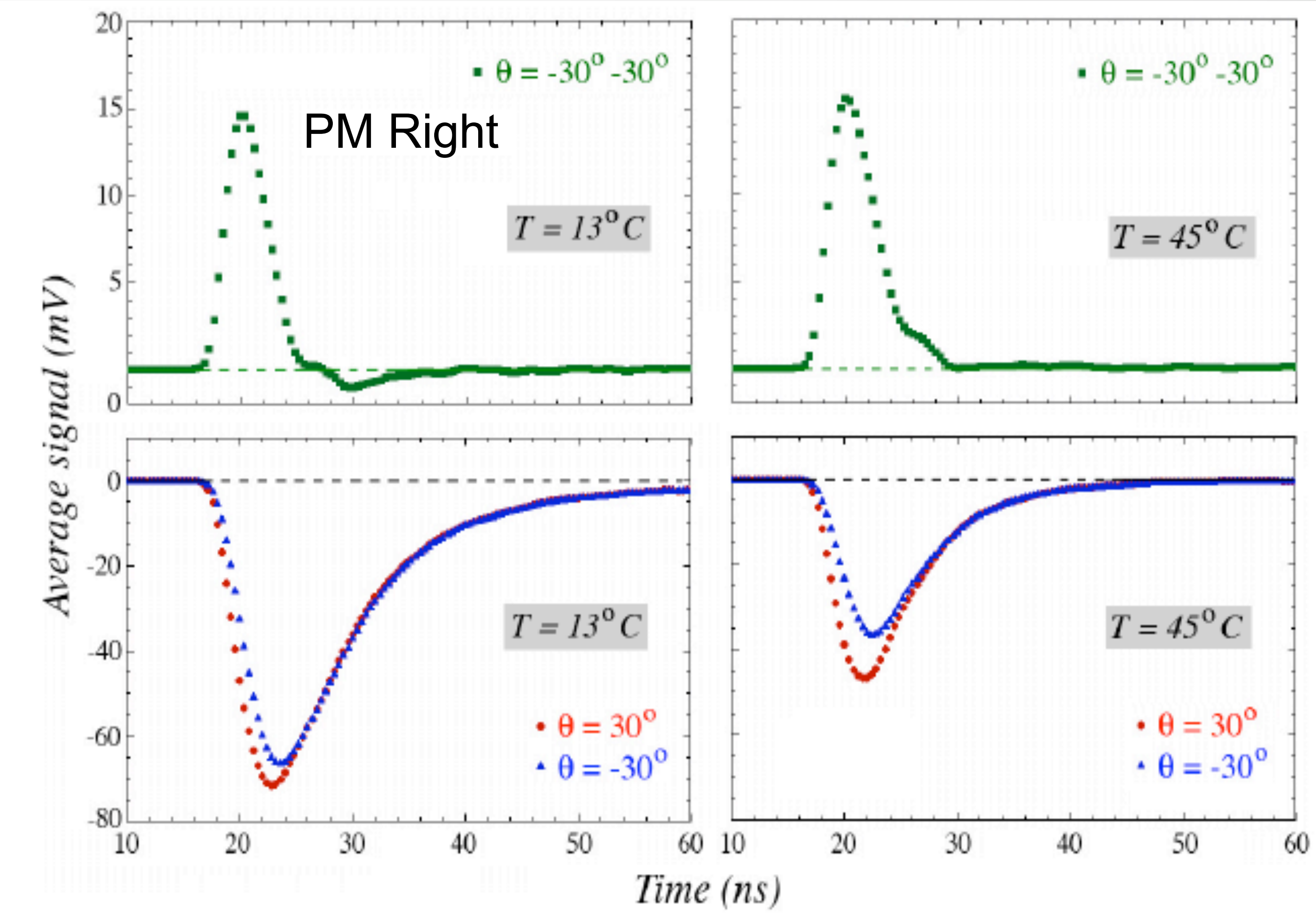




Time Structure Analysis

Leading edge: dominated by prompt Cherenkov

Trailing edge: scintillation



θ(30)-θ(-30)

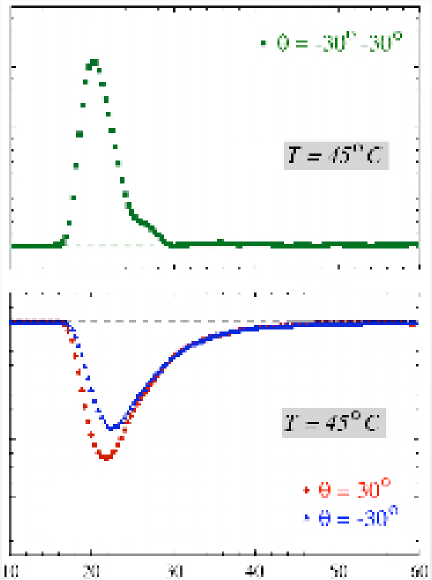
ONLY Cherenkov

Right PMT

θ = 30: C + S

θ = -30: S

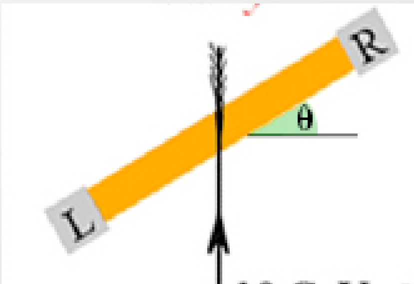
Cherenkov fraction vs Angle



Cherenkov fraction :

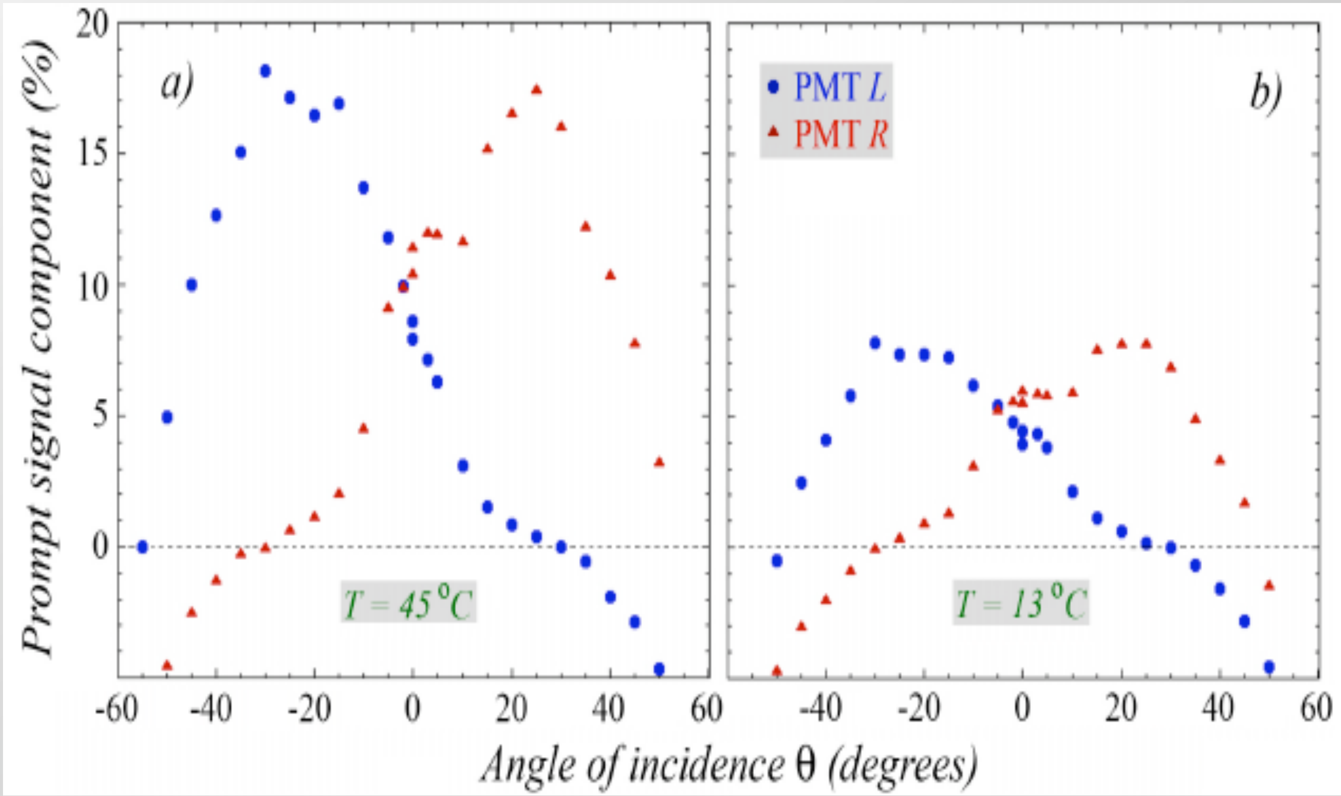
integral of difference between θ = 30° and θ = -30° signals, normalized wrt total signal integral ("anti-Cherenkov" angle)

Evaluated for the two PMT separately



θ =+30: R-PMT downstream

θ = -30: L-PMT downstream



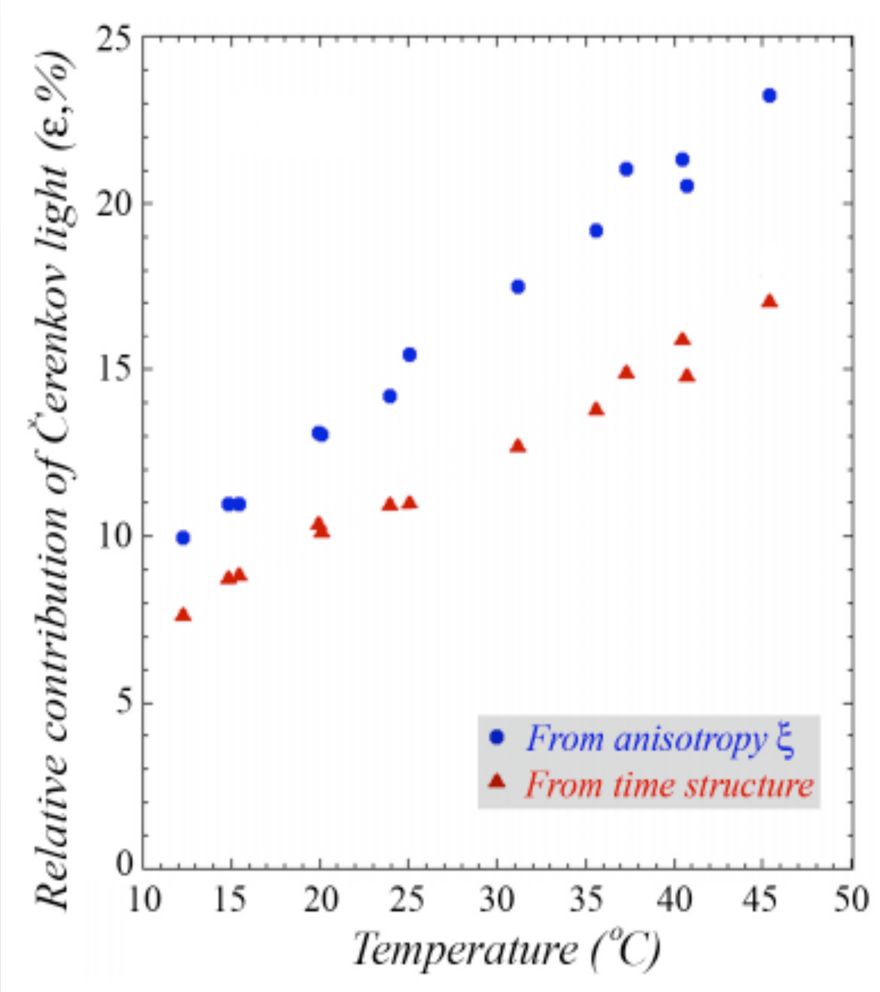
Cherenkov fraction vs Temperature

Studying temperature dependence of Cherenkov fraction

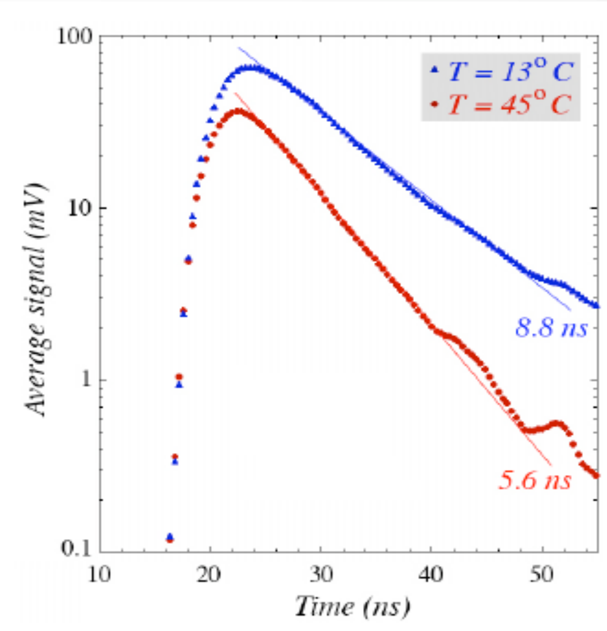
- Considering the two PMT separately
- Evaluating Cherenkov fraction at Cherenkov angle

Contribution of Cherenkov light increases about a factor 2

- Evaluated for ADC signal using anisotropy
- Evaluated for Time structure as described before
- Good agreement between the two methods

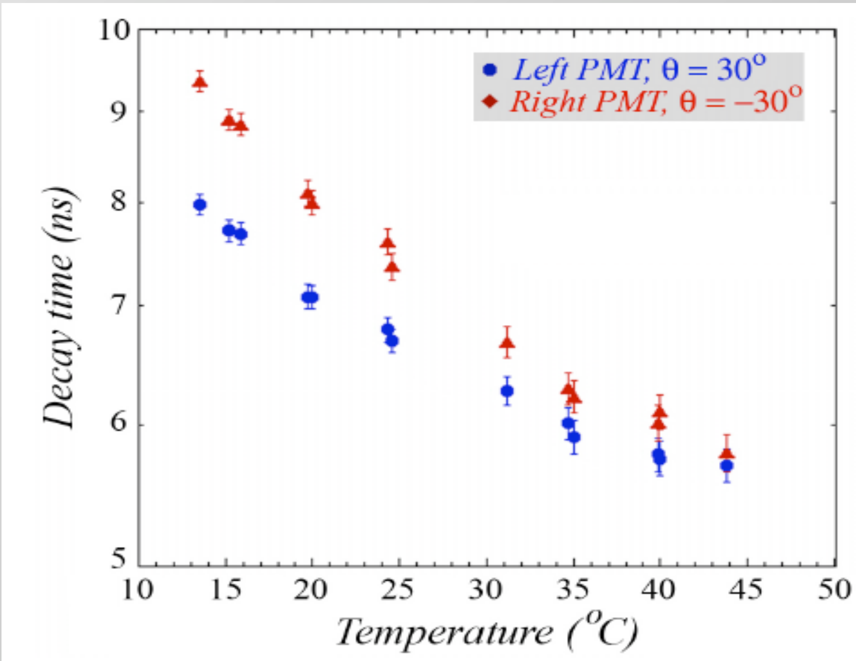


Scintillation decay time



- Trailing edge is dominated by scintillation component
- Fitting the trailing edge with an exponential function
  - Fit in the region between the peak and $(1/e^2)\cdot$ peak

- Trailing edge steeper at higher temperature
- Decay time of scintillation light in $PbWO_4$ decreases by 30-40% over the T range 13 -> 45°C



Conclusions

- Measuring EM fraction on the event by event basis allows for improving the hadronic calorimeter resolution
- Separation of Scintillation and Cherenkov light is a way to achieve it
- Quantitative measurements of the Cherenkov fraction can be obtained
  - Using Cherenkov light directionality vs Scintillation isotropy
  - Using temperature dependence of the Scintillation light

Publication

Effects of the Temperature Dependence of the Signals from lead Tungstate Crystals

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