Determination of the Non-Linearity Parameter of LAB Based Scintillators: Status Report

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DFG

JUNO

SFB 1258 | Neutrinos Dark Matter Messengers

Outline

- Introduction
- Experimental Setup
- Determination of the kB Parameter
- Latest Results
- Summary and Outlook

Liquid Scintillator Nonlinearity

- Scintillator response known to be a nonlinear function of the incident γ-energy

- Empirical formula for nonlinearity:

Birks‘ law: $\frac{dL}{dx} = S \frac{\frac{dE}{dx}}{1+kB\frac{dE}{dx}}$

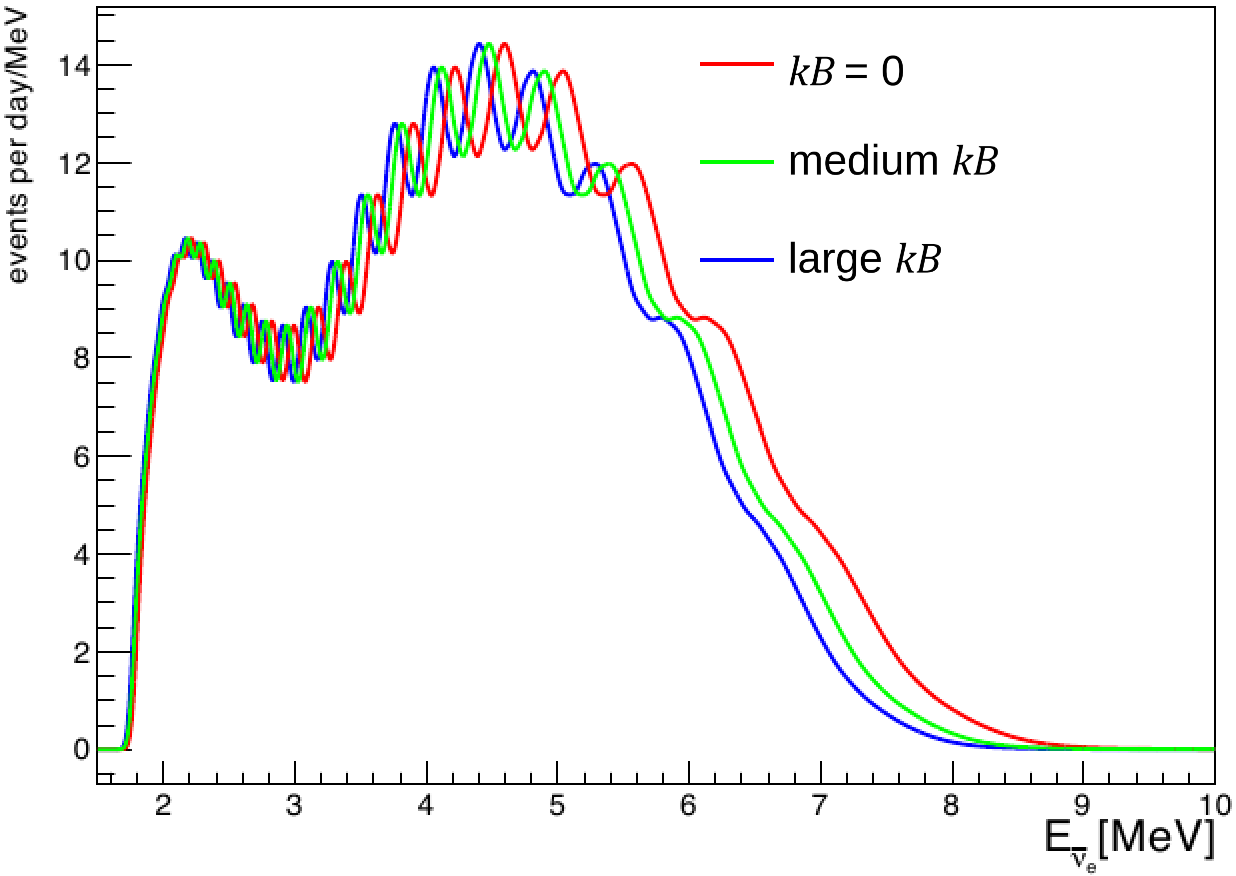
L: light yield

S: scintillation efficiency

$\frac{dE}{dx}$: energy loss per path length

kB: Birks‘ parameter

Effect of kB on JUNO Result Interpretation



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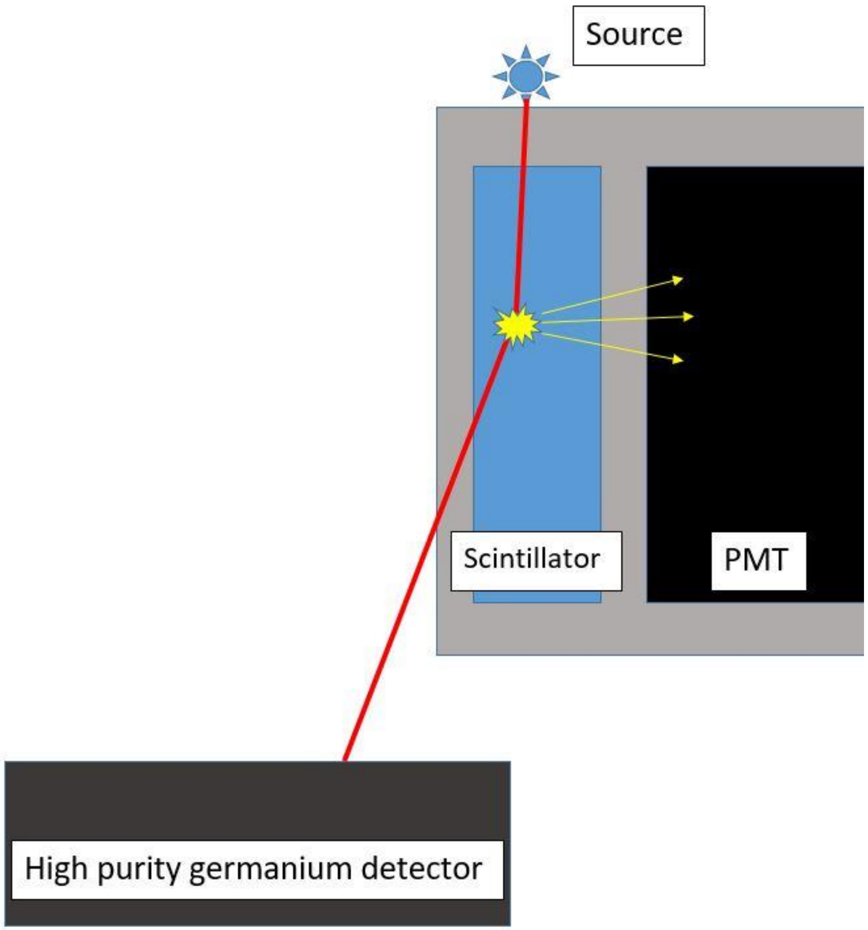
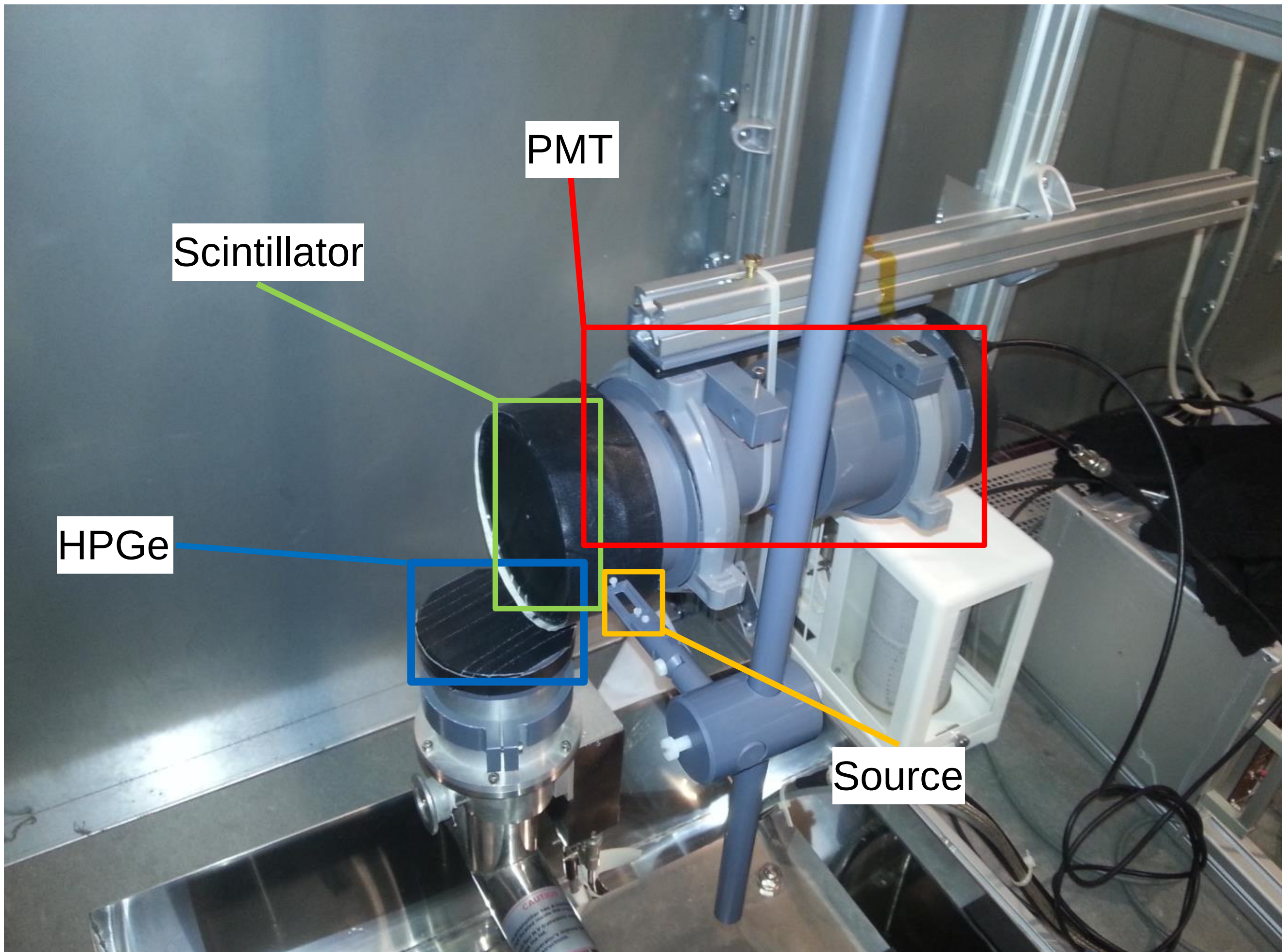
Experimental Setup

- Method used: coinicidence measurement
  - ➢PMT detects scintillation light
  - ➢HPGe detector measures remaining energy

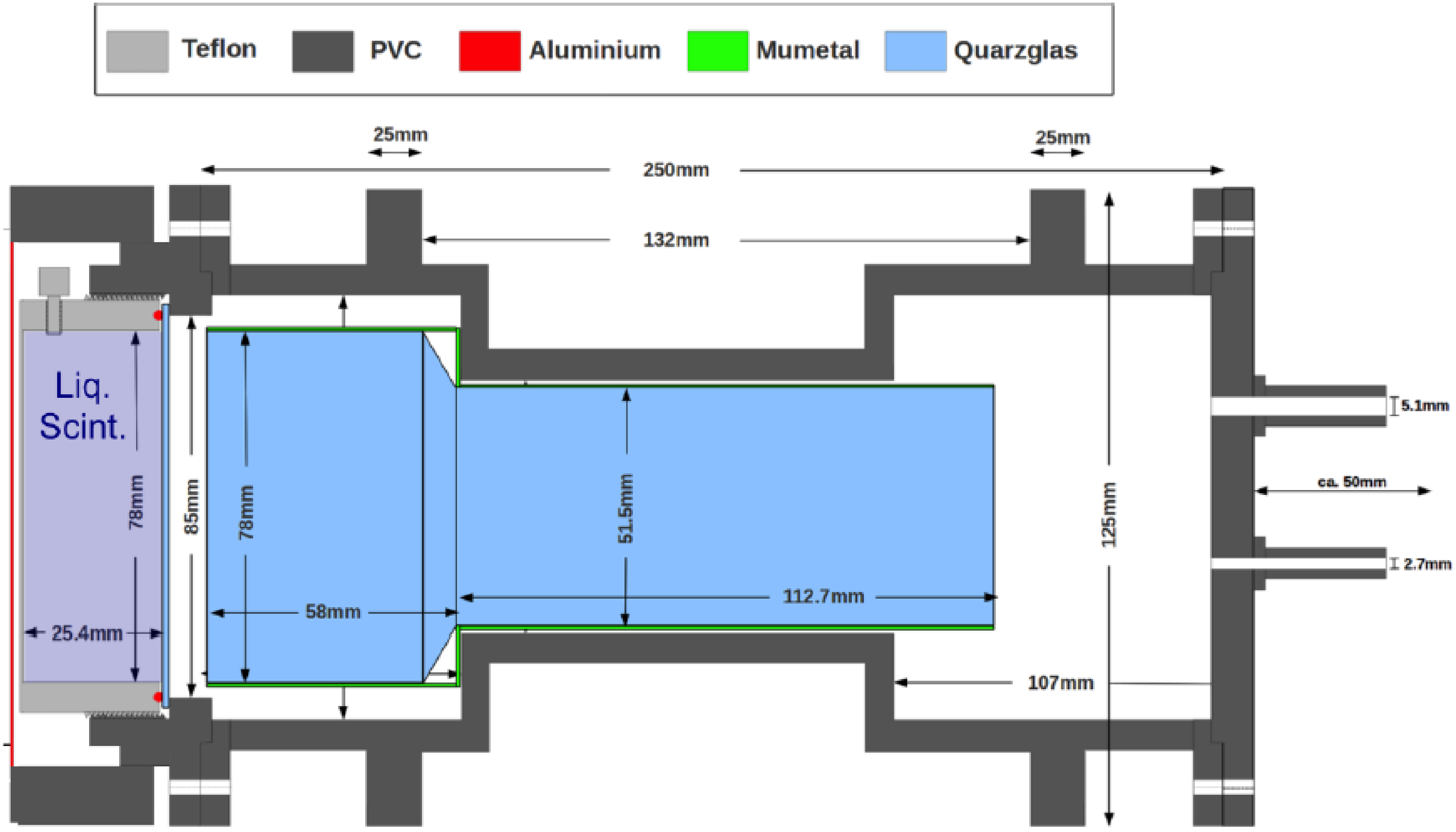
- γ-source: Cs-137 (peak at 662 keV)



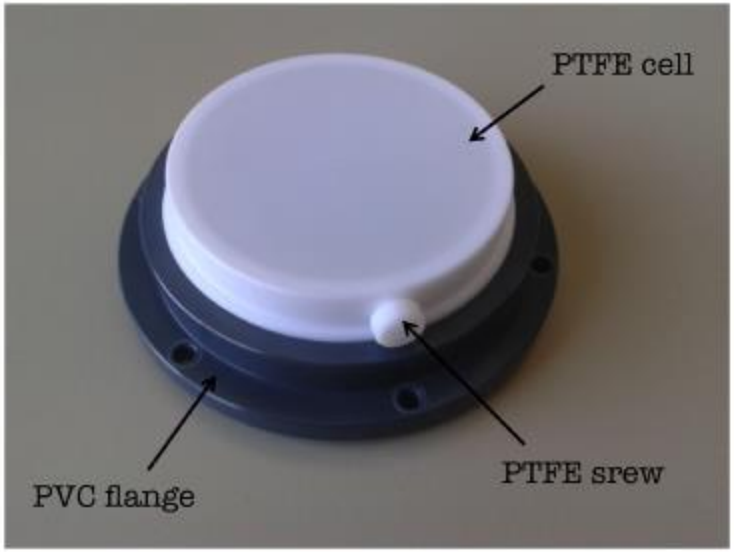
Experimental Setup

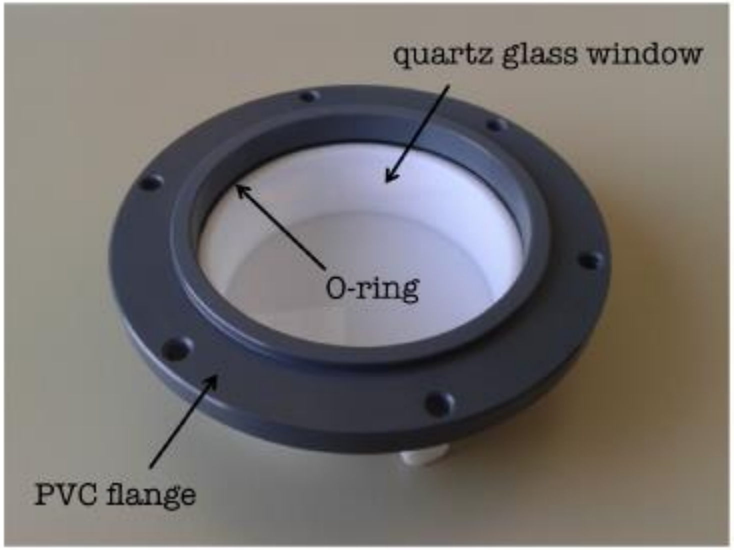


Scintillation Light Detector



Scintillator Container





Determination of the Light Yield

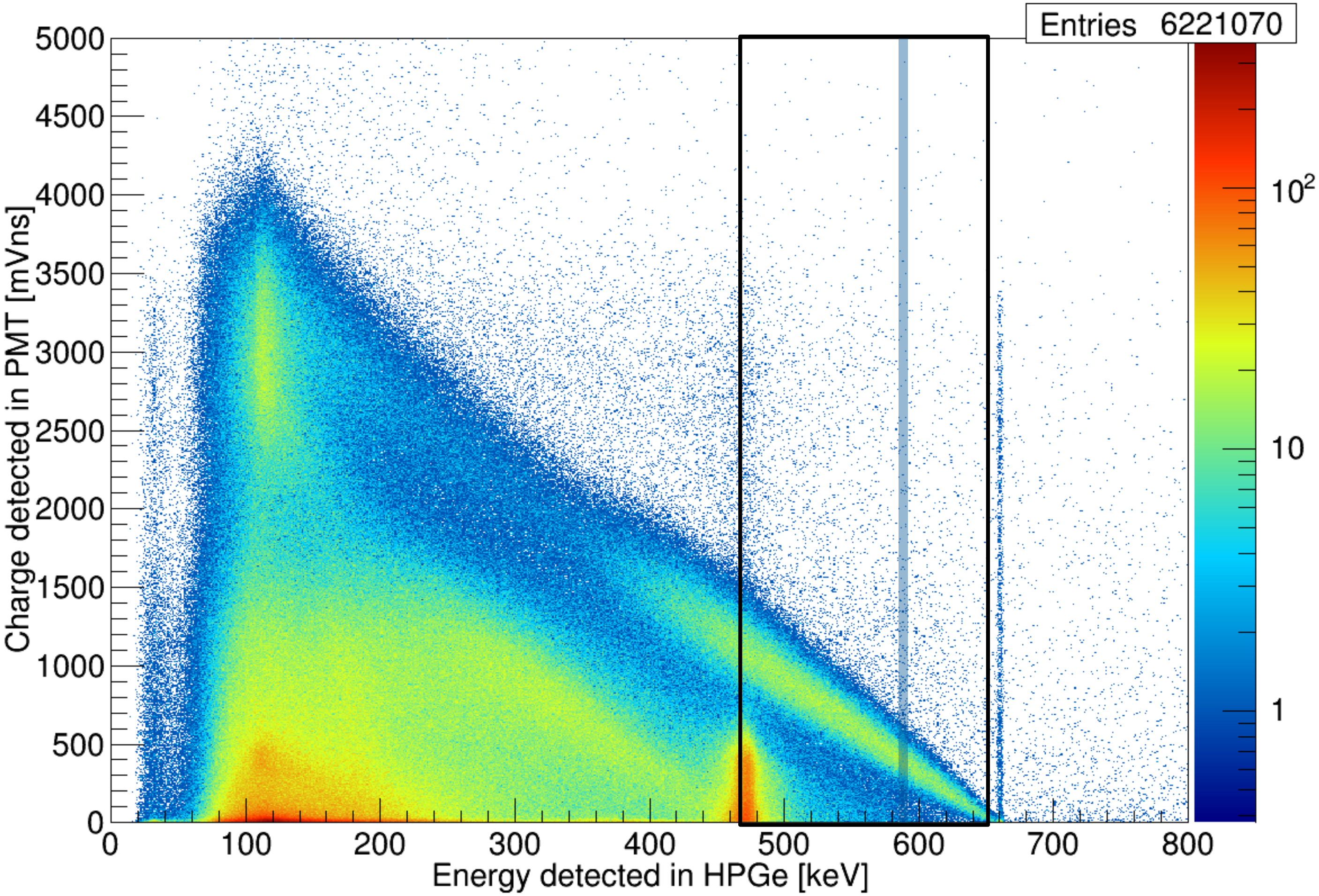
- Birks' law: $\frac{dL}{dx} = S \frac{\frac{dE}{dx}}{1+kB\frac{dE}{dx}}$

- Relative light yield: $\frac{Charge\ of\ PMT}{Energy\ deposited\ in\ scintillator}$

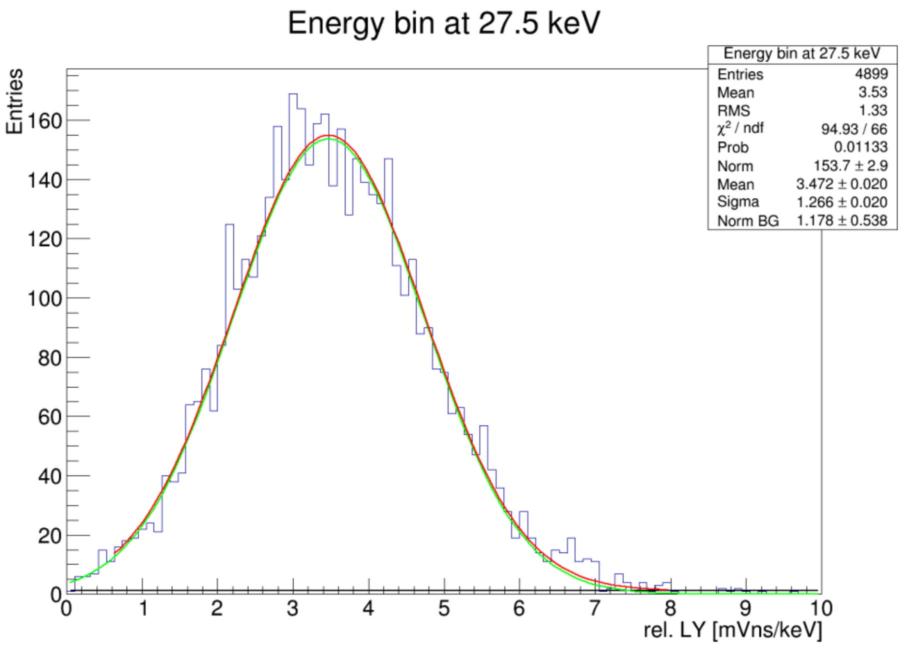
- Birks' parameter kB derived from light yield as a function of energy

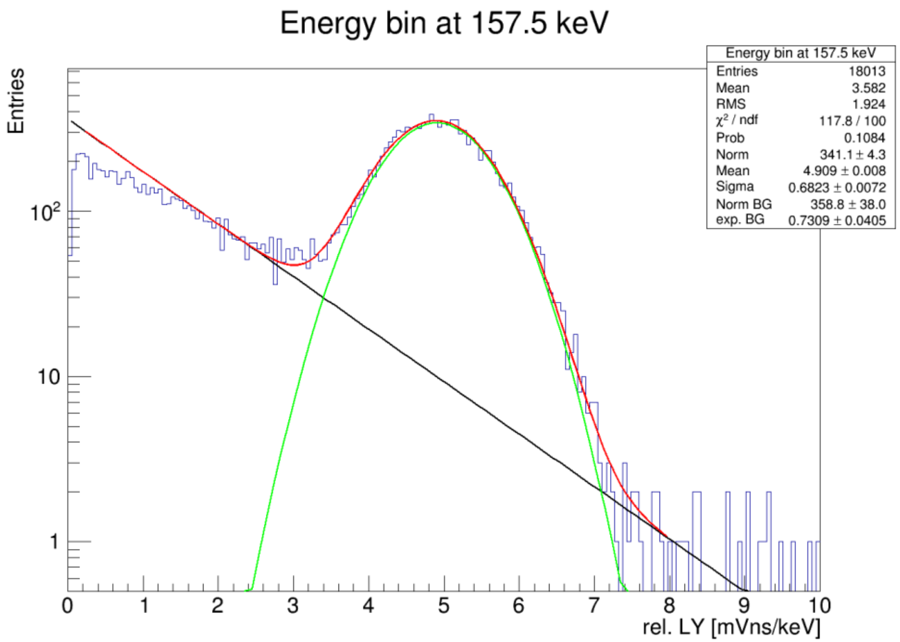
→ Sliding window over energy detected in HPGe

Preliminary Coincidence Spectrum

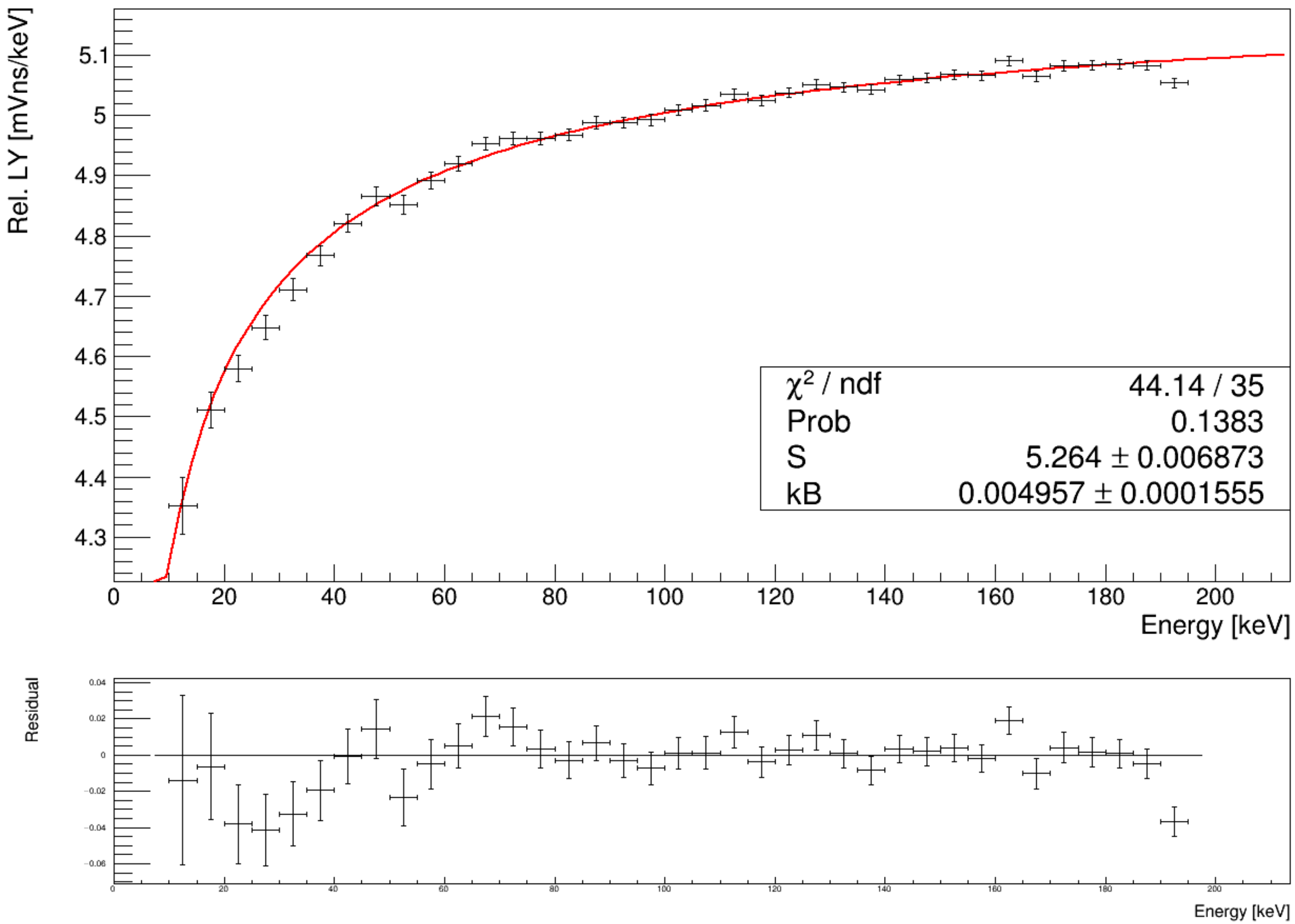


Determine Light Yield for Energy Intervals





Birks‘ Parameter Determination



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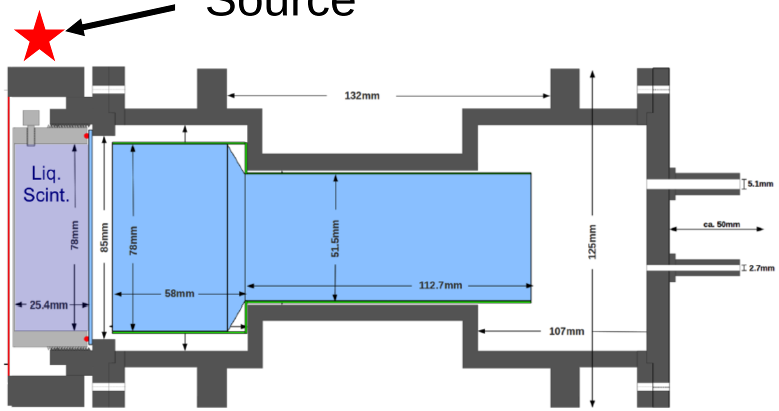
Source Position Depenedence of the Light Yield

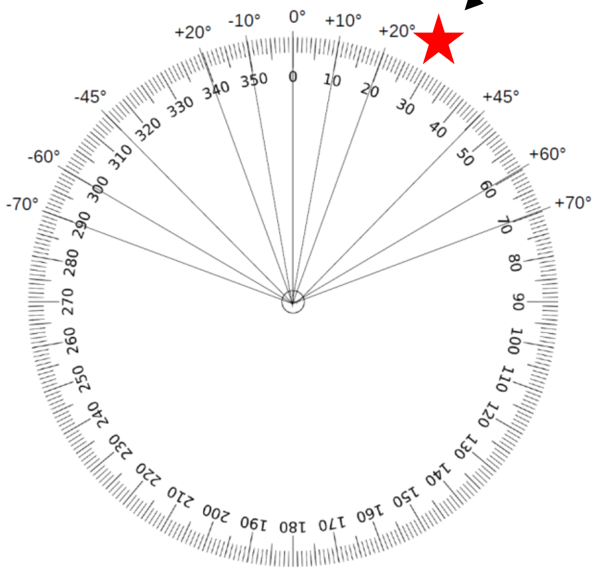
Source



Germanium detector

Side view

Source



Front view

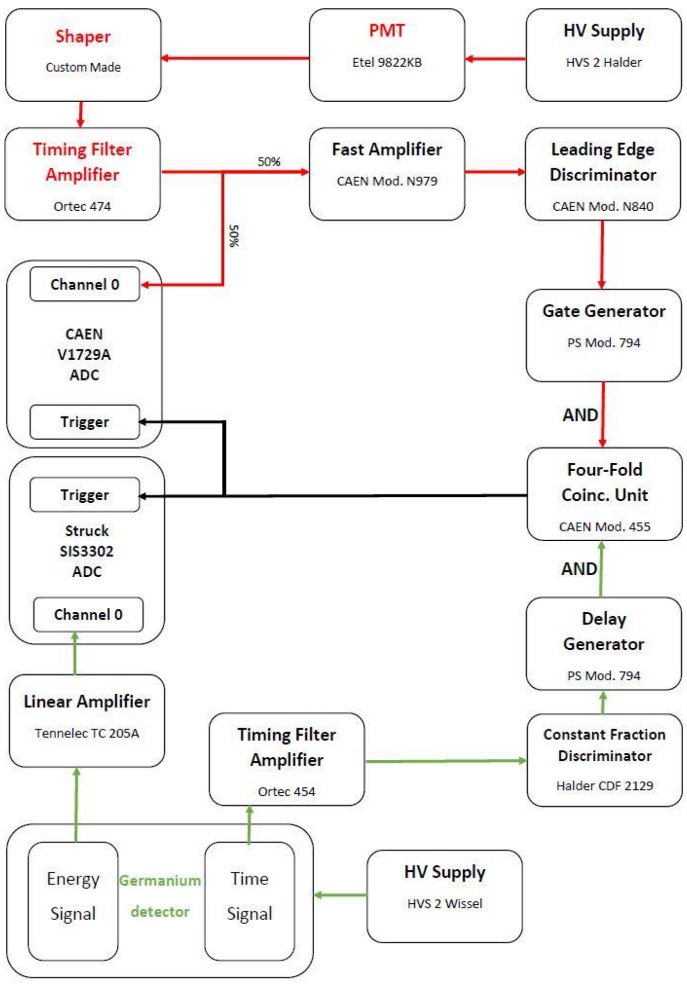
Results inconclusive!

Latest Developments

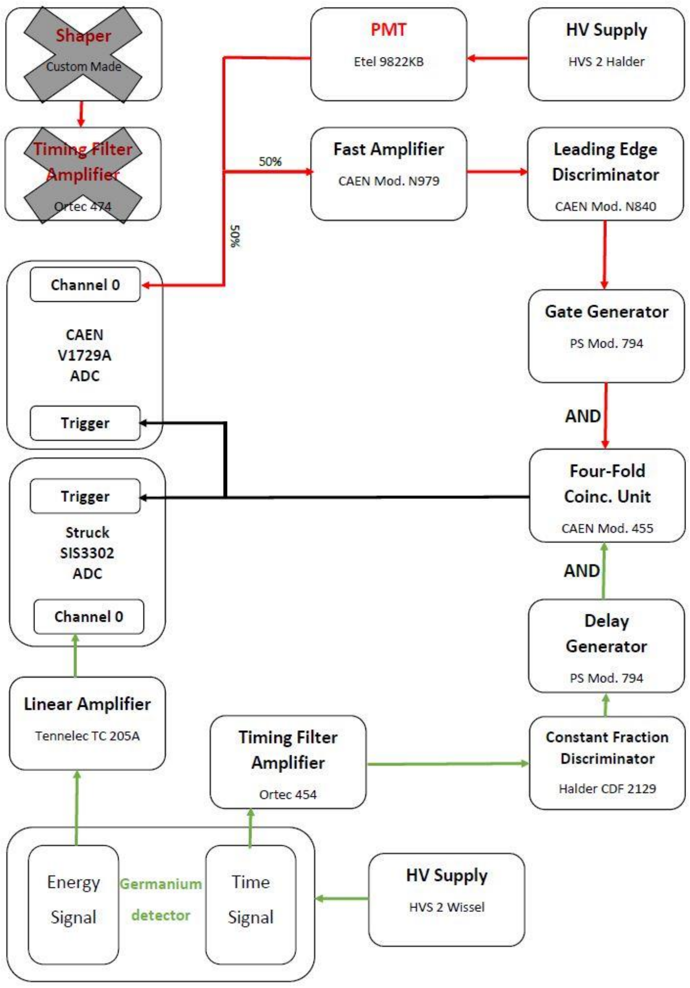
- Fresh scintillator
- PMT broke
- Realization of superfluity of multiple parts of setup with new scintillator → new electronic setup

New Electronics Setup

Old



New



Latest Developments

- Fresh scintillator
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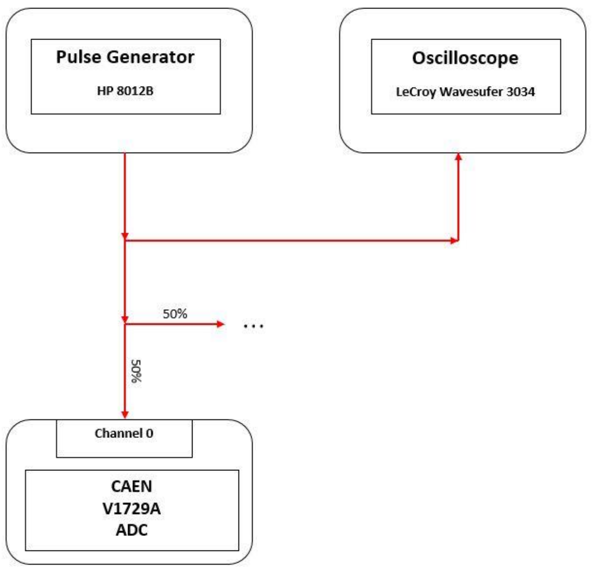
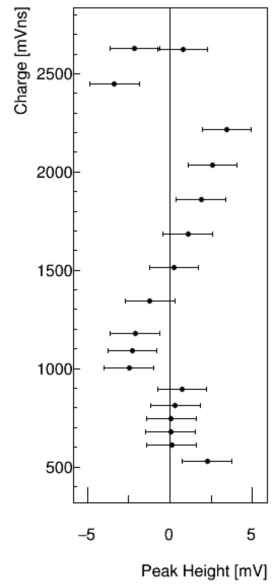
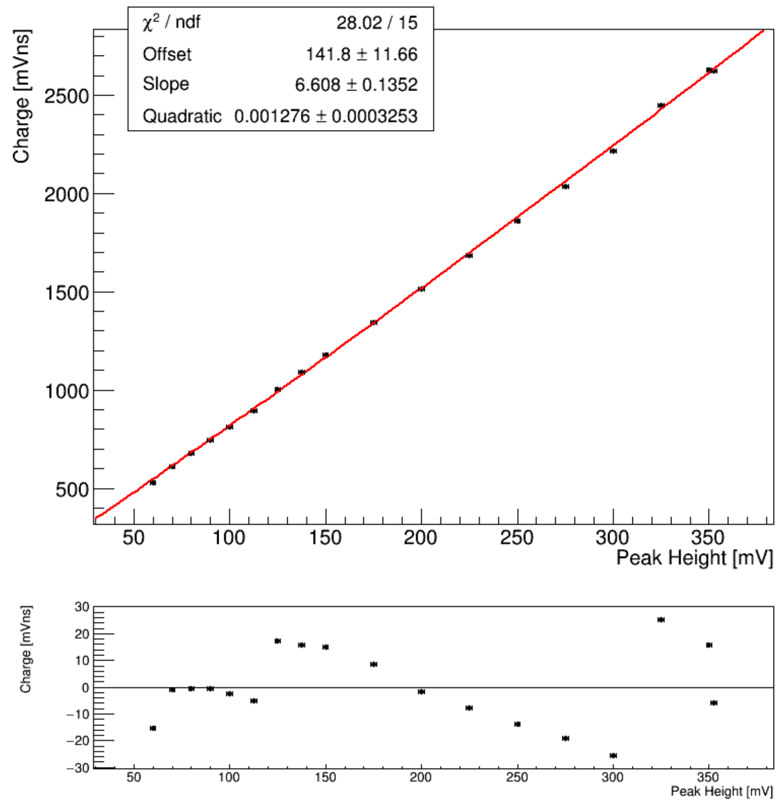
- Realization of superfluity of multiple parts of setup with new scintillator → new electronic setup
- Inspection of all electronic components
- Determination of FADC linearity

Determination of FADC Linearity

Setup







Latest Developments

- Fresh scintillator
- PMT broke
- Realization of superfluity of multiple parts of setup with new scintillator → new electronic setup
- Inspection of all electronic components
- Determination of FADC linearity

- Next steps:
  - Determination of PMT linearity
  - New scintillator non-linearity measurements

Summary and Outlook

- Knowledge of kB important for correct neutrino mass hierarchy interpretation
- Coincidence experiment has been set up
- Proof of principle achieved

- Understand detector behavior
- Precise measurement of the Birks‘ parameter kB of the JUNO scintillator

Thank you for your attention!

- Use Berger-Seltzer formula to determine $\frac{dE}{dx}$

$$\left.\frac{dE}{dx}\right]_{T<T_{cut}} = 2\pi r_e^2 mc^2 n_{el} \frac{1}{\beta^2} \left[\ln \frac{2(\gamma+1)}{(I/mc^2)^2} + F^{\pm}(\tau, \tau_{up}) - \delta \right]$$

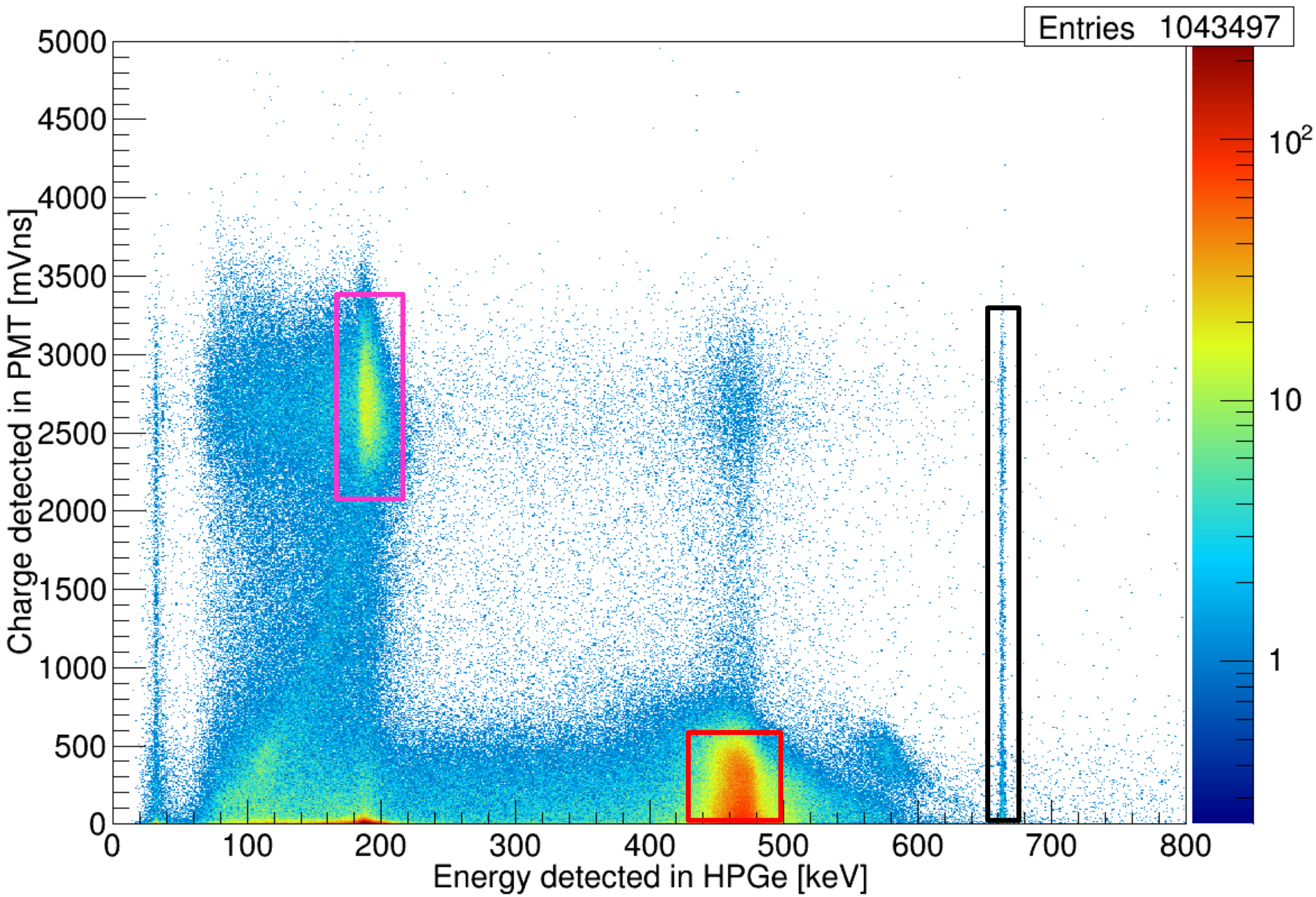
r_e	classical electron radius: $e^2/(4\pi\epsilon_0 mc^2)$
mc^2	mass energy of the electron
n_{el}	electron density in the material
I	mean excitation energy in the material
γ	E/mc^2
β^2	$1-(1/\gamma^2)$
τ	$\gamma - 1$
T_{cut}	minimum energy cut for δ -ray production
τ_c	T_{cut}/mc^2
τ_{max}	maximum energy transfer: τ for e^+, $\tau/2$ for e^-
τ_{up}	$\min(\tau_c, \tau_{max})$
δ	density effect function.

Experimental specifications

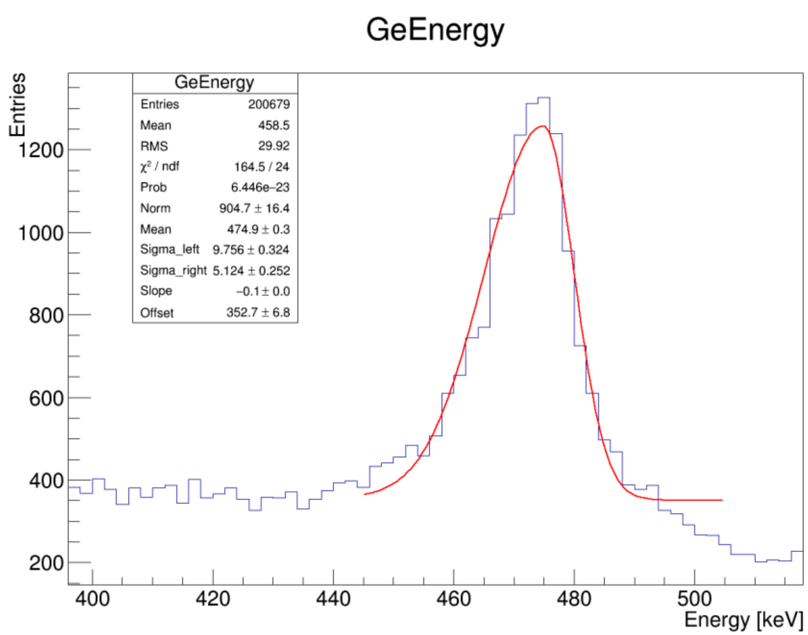
- PMT pulse recording
  - ETEL 9822KB
  - ADC: CAEN V1729A
  - 4 Channel
  - 2 GS/s
  - 14 bit (effective 13 bit)
  - Less than 2 % gain variations
  - Energy resolution @ 477.4 keV: ~ 8 %

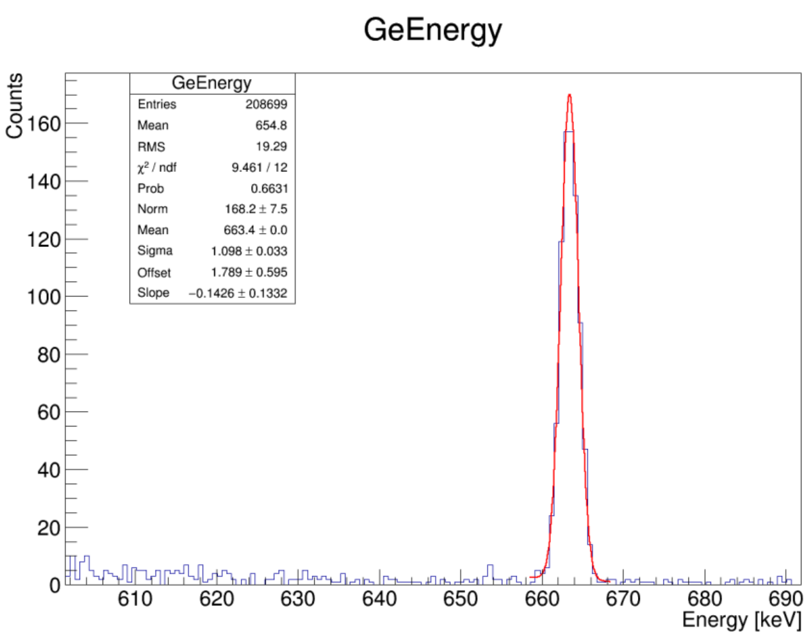
- HPGe pulse recording
  - EGPP 2000
  - ADC: SIS3302 by Struck
  - 8 Channel
  - 100 MS/s
  - 16 bit (effective 13 bit)
  - Less than 0.4 % gain variations
  - Energy resolution @ 662 keV: ~ 0.5 %

Preliminary Coincidence Spectrum

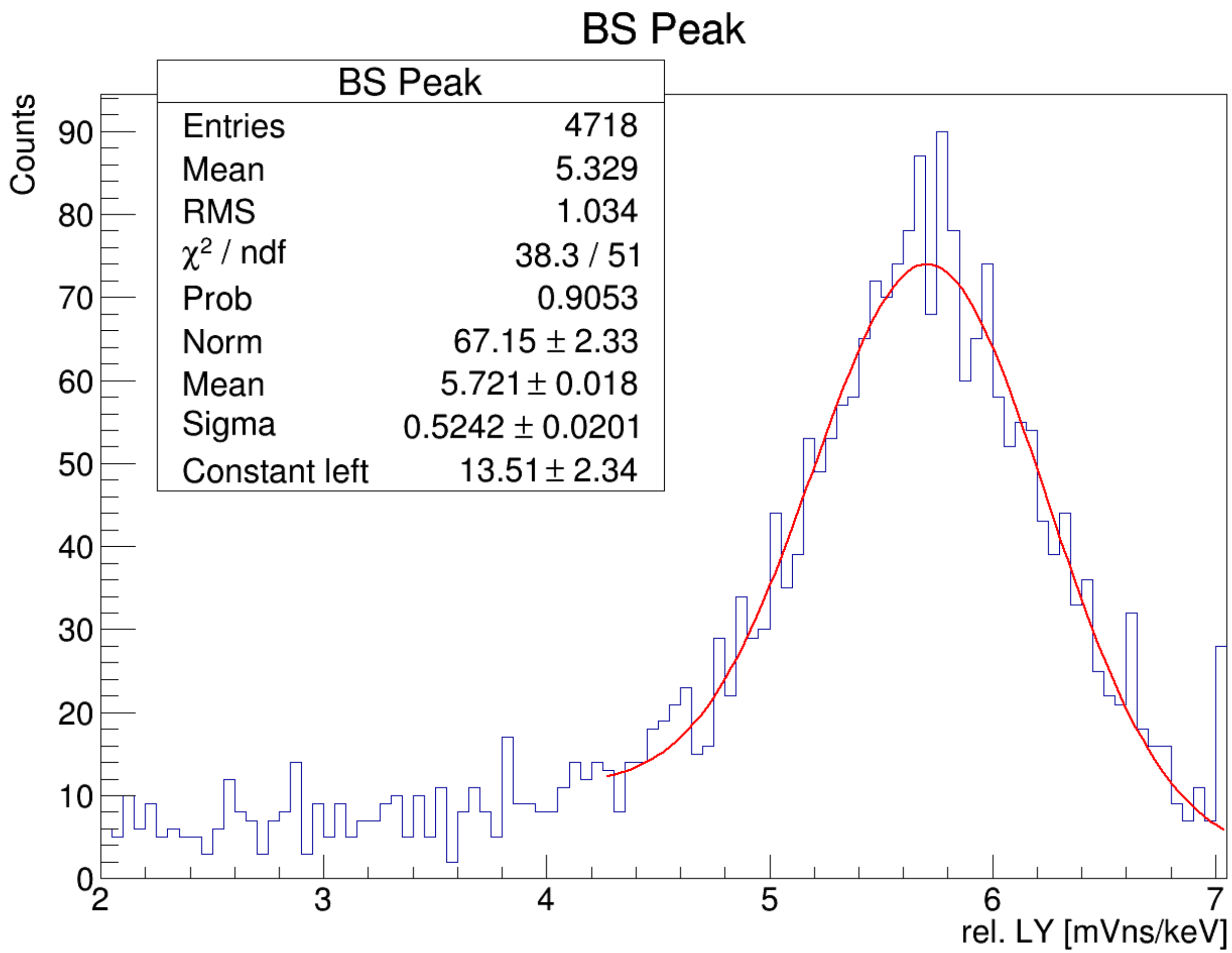


Germanium Detector Gain Stability Determination

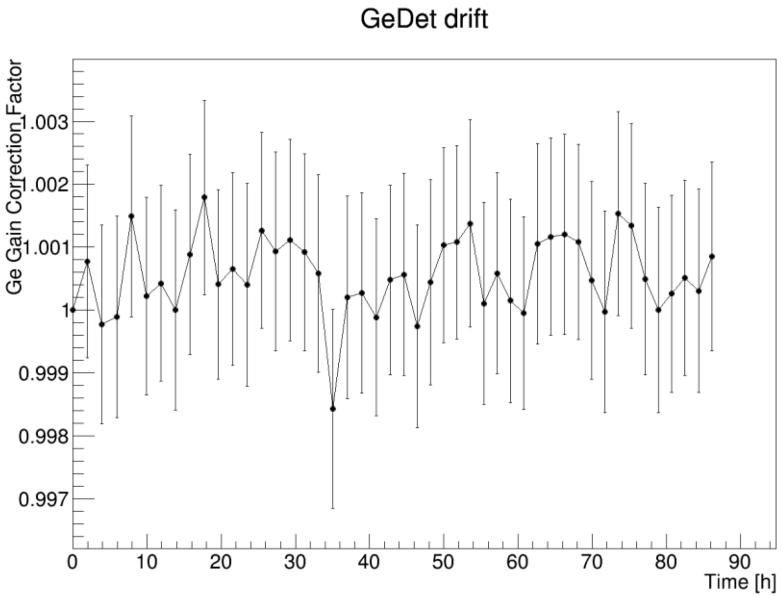


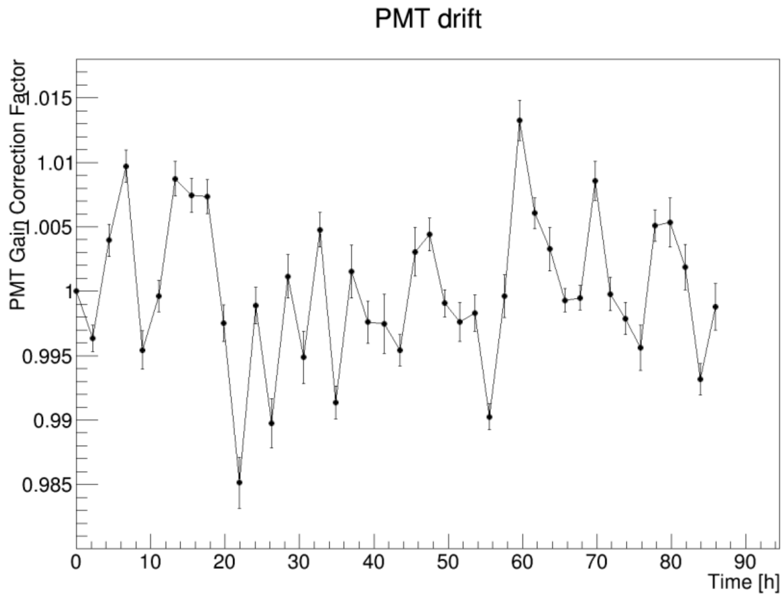


Scintillation Light Detector Gain Stability Determination

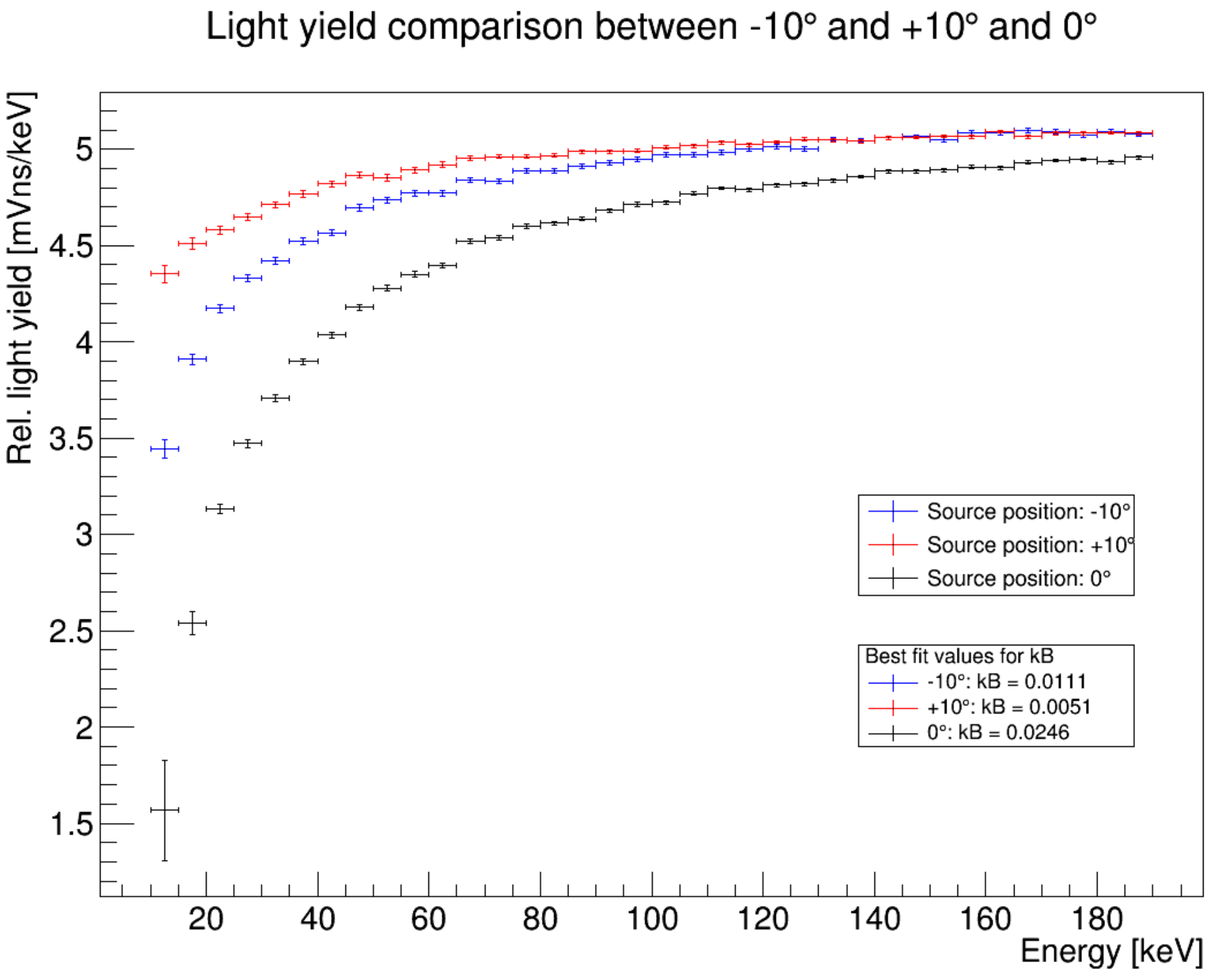


Detector Gain Correction



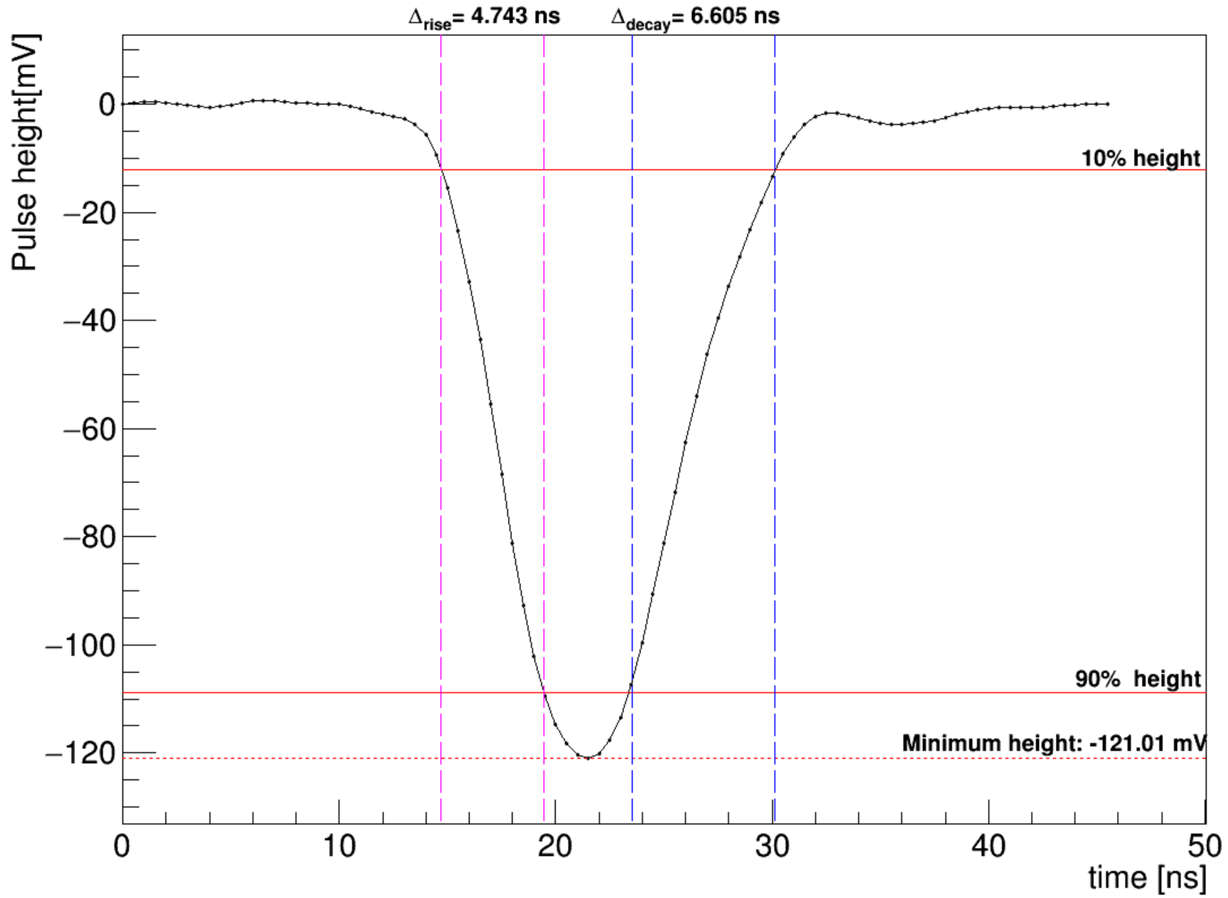


Light Yield Comparison for Different Source Positions

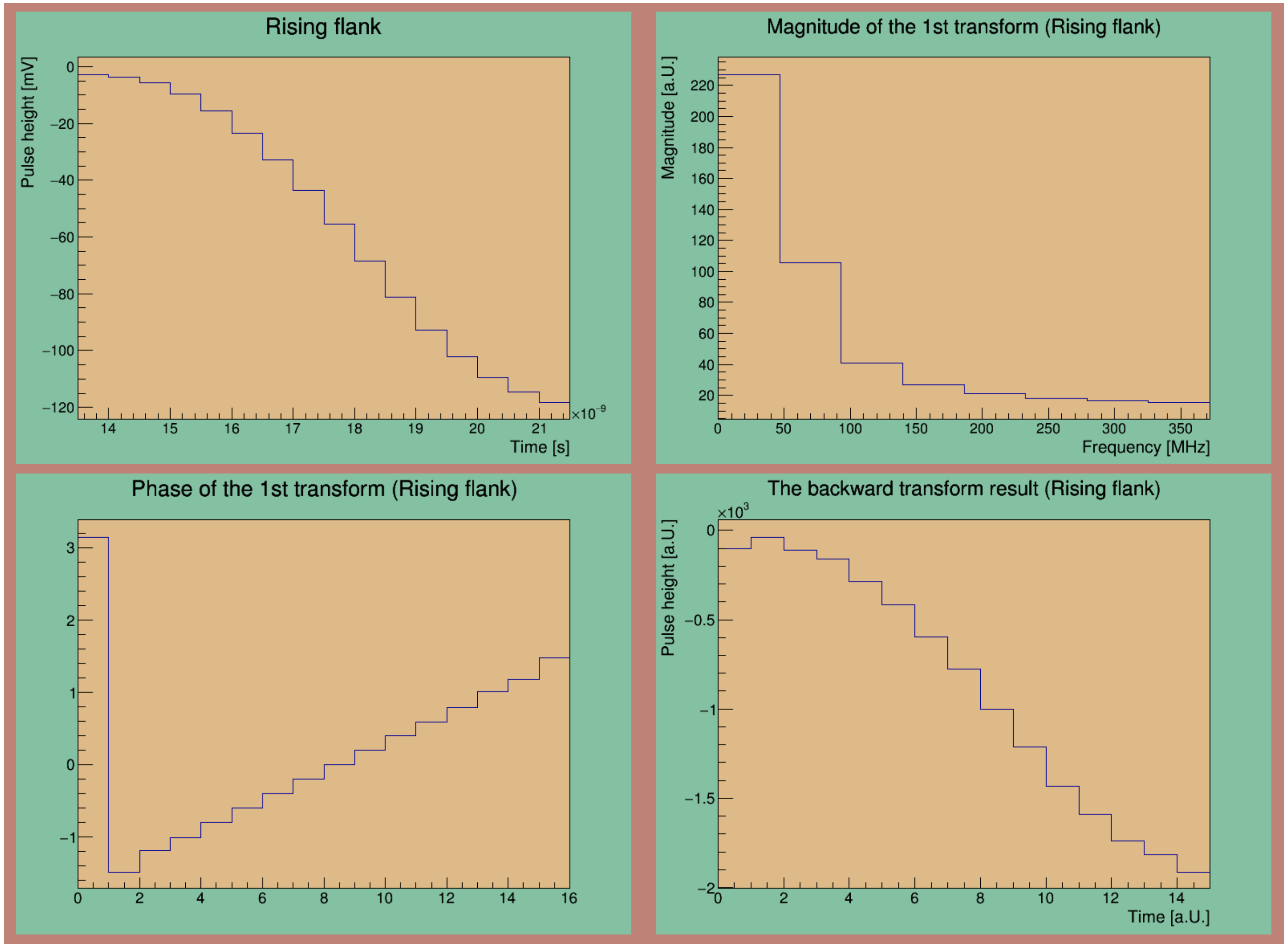


→ completely differently shaped light yield curves for similar source positions

Pulsegenerator Average Waveform



FFT Rising Flank



FFT Decaying Flank