An overview of data calibration algorithms of NeuLAND in the R^3B setup

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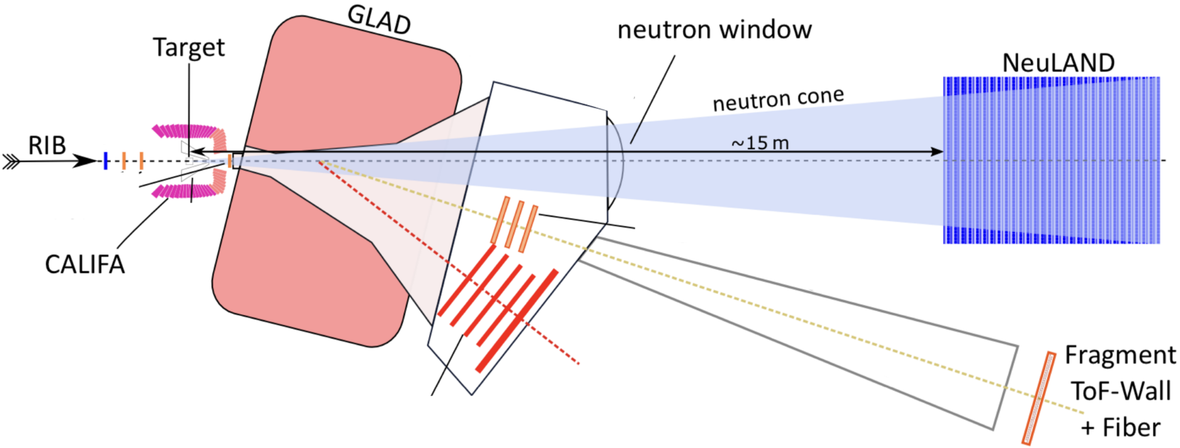
NeuLAND setup in R^3B[1]

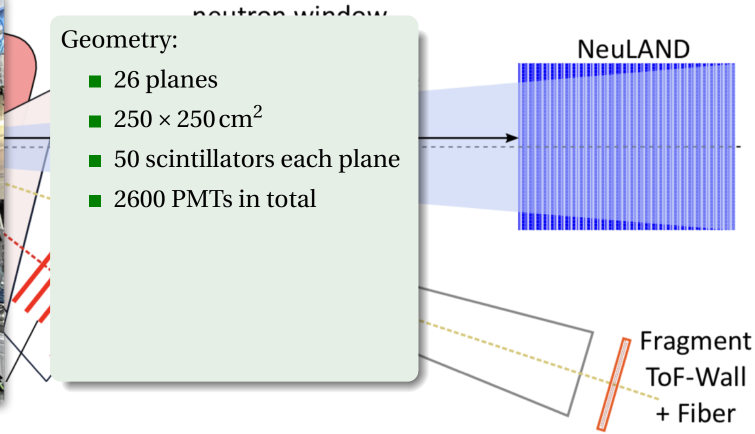


[1] K. Boretzky *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A **1014**, 165701 (2021).

NeuLAND setup in R3B[1]

Geometry:

- 26 planes
- $250 \times 250\,\mathrm{cm}^2$
- 50 scintillators each plane
- 2600 PMTs in total



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NeuLAND setup in R^3B[1]

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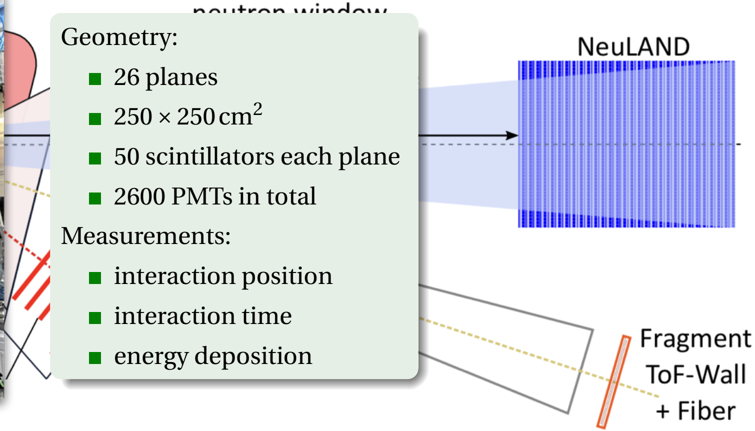
Measurements:

- interaction position
- interaction time
- energy deposition



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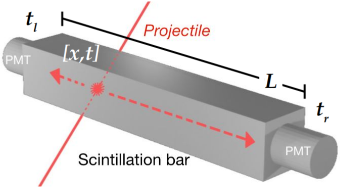
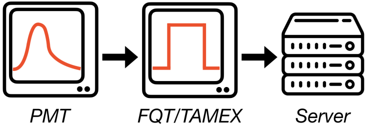
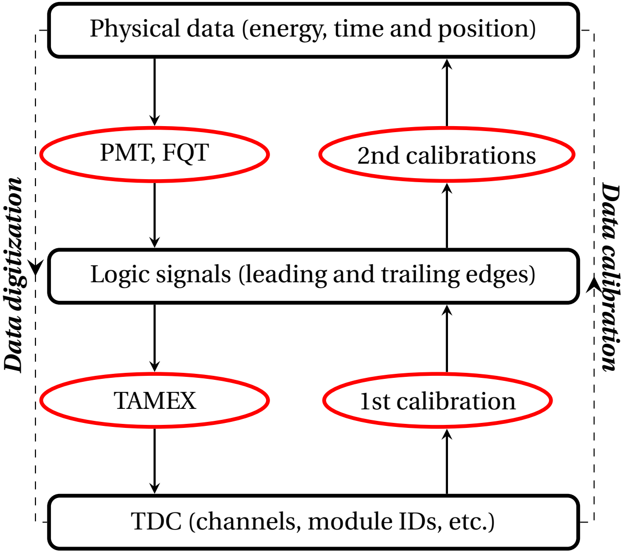
Processes of digitization

Physical interactions:

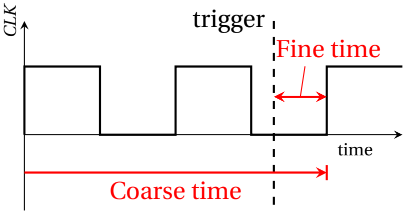


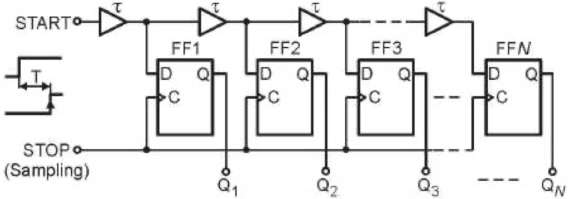
Digitization of PMT signals:





Time measurement with clocks:





Tapped Delay Line (TDL)[1]

Real time calculation:

$$T_{\text{real}} = T_{\text{coarse}} - T_{\text{fine}}$$

- T_{real}: Time value relative to START detector
- T_{coarse}: Clock cycles with a frequency of 200 MHz (period = 5 ns)
- T_{fine}: Fine channel numbers (TDL)

[1] J. Kalisz, Metrologia **41**, 17 (2003).

Time measurement and TDC calibration

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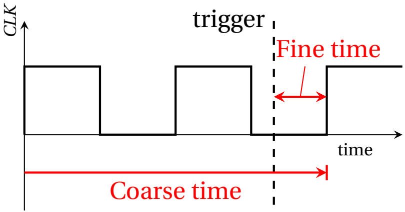

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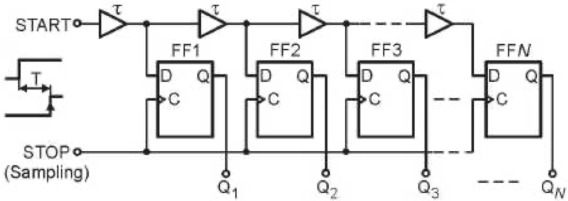

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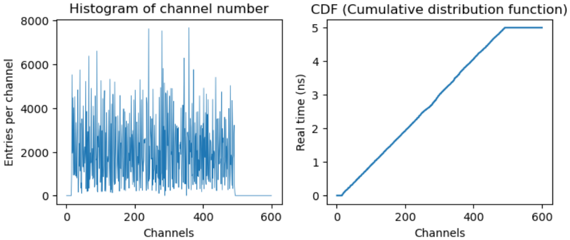

TDC Calibration (Time resolution ~ 10 ps)

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Position calibration from cosmic muons

Calibration relations

Interaction position:

$$x = \frac{C_e}{2}\left(t_r - t_l + t_{\text{offset}}\right) \tag{1}$$

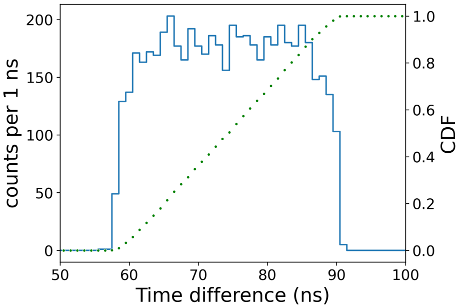
Interaction time:

$$t = \frac{t_r + t_l}{2} - \frac{L}{2 \cdot C_e} + t_{\text{sync}} \tag{2}$$

Position calibration steps

1. Collect time difference values of adjacent PMT signals from cosmic muons
2. Normalize the distribution and convert to the CDF for each bar
3. Linear fitting of the CDF within its quantiles of 0.05 to 0.95

Parameter fitting:



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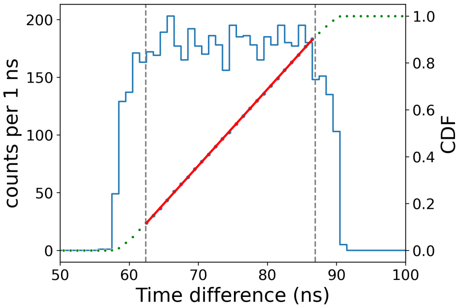


Fitting function:

$$y = a \cdot x + 0.5 - a \cdot b$$

Calculation of parameters:

$$C_e = 2 \cdot a \cdot \text{bar length}$$

$$t_{\mathrm{offset}} = b$$

Current energy calibration method (WIP)

Energy calibration relations

PMT signal amplitude:

$$I_{\mathrm{PMT}} = E_{\mathrm{dep}} \cdot \exp(-\alpha \cdot l) \quad (1)$$

Applying PMT saturation effect:

$$I_{\mathrm{sat}} = I_{\mathrm{PMT}} \big/ (1 + \lambda \cdot I_{\mathrm{PMT}}) \quad (2)$$

Logic signal width:

$$W = \mathcal{G} \cdot I_{\mathrm{sat}} + W_0 \quad (3)$$

Assumptions

- PMT saturation factor is proportional to the gain factor:

$$\lambda = 0.00175 \times \mathcal{G}$$

- Cosmic muon's stopping power is $1.73\,\mathrm{MeV\,cm^{-1}}$
- Adjacent PMTs have the same gain factor

Calculation of parameters:

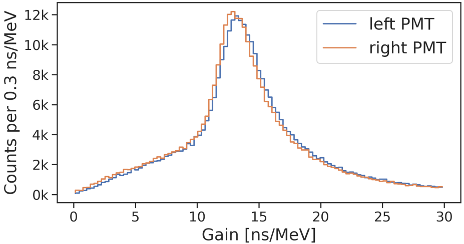
- Signal width baseline W_0 is determined by the minimum cut on signal widths (i.e. trailing time – leading time).
- Calculation of attenuation factor:

$$\alpha = \ln\big((W_r - W_0)/(W_l - W_0)\big)\big/(2 \cdot x)$$

- Calculation of gain factor:

$$\mathcal{G} = \frac{W - W_0}{I_{\mathrm{PMT}}\,(1 - 0.00175(W - W_0))}$$

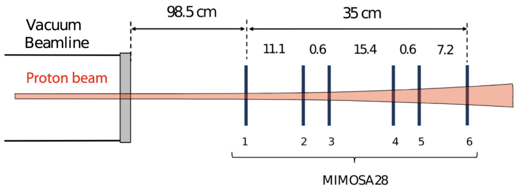
PMT gains from all events:



Parameter fine tuning with Millepede-II

Characteristics

- Simultaneous fitting of all parameters
- Separation to global and local parameters
- Computation complexity independent of local parameter size
- **No particle track reconstruction**
- Calibration relation **must be linear**



Alignment of silicon pixel detectors[1]

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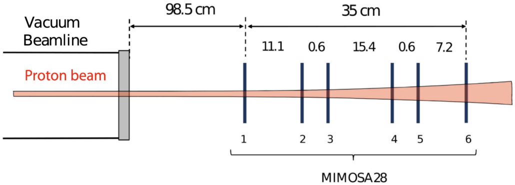
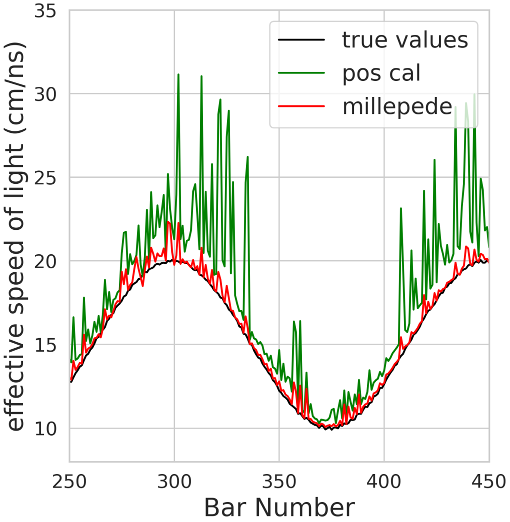


Alignment of silicon pixel detectors[1]

Verification through simulation:



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Summary and outlook

Summary

- Principle of digitization processes
- Calibration with TDC for time values
- Calibration with time values for physical values
- Fine tuning with the Millepede-II algorithm

Outlook

- Improve energy calibration
- Apply Millepede-II algorithm on energy-related parameters
- Verify energy parameters via simulation