Experimenting on a new method of NeuLAND position calibration and the fine tuning with Millepede algorithm

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R3B Collaboration Meeting
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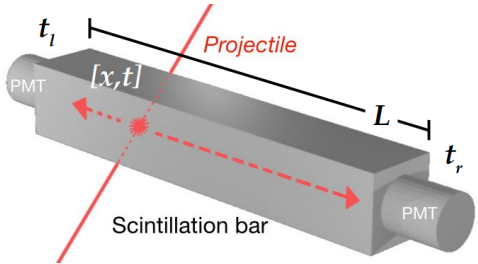
Time and Positional calibration parameters



Time relation:

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

Position relation:

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

Symbols:

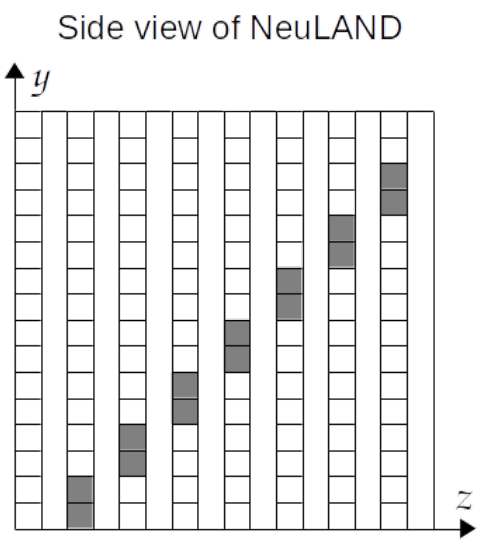
- x : position of the interaction
- t : time of the interaction
- L : length of the scintillator
- t_l : time of the left PMT signal
- t_r : time of the right PMT signal
- C_e : effective speed of light

Additional calibration parameters:

- t_{sync} : time synchronization among scintillators
- t_{offset} : time offset between adjacent PMTs

Total number of calibration parameters:
3900

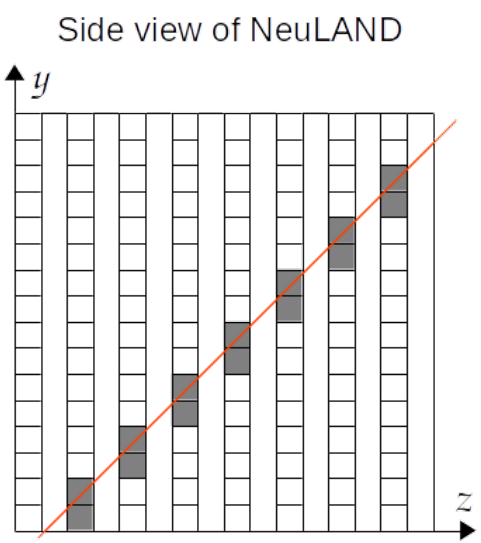
Current calibration method



Procedures

1. Obtain the positions of bars with signals

Current calibration method



Procedures

1. Obtain the positions of bars with signals
2. Reconstruct the muon track from the bar positions

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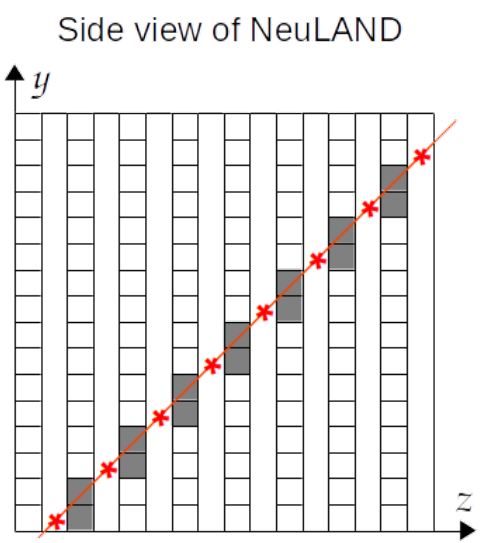

Procedures

1. Obtain the positions of bars with signals
2. Reconstruct the muon track from the bar positions
3. Calculate the positions of the interaction points of the muon

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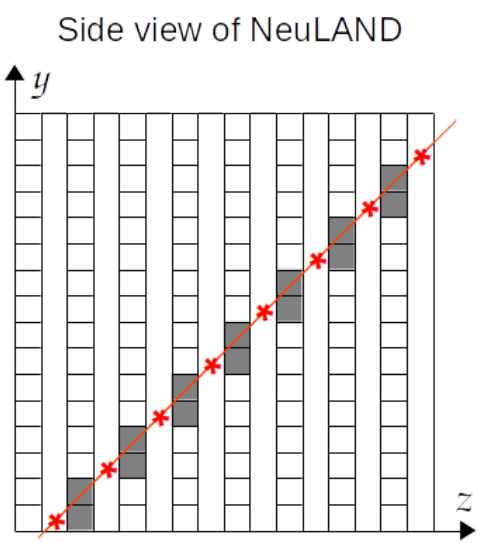

Procedures

1. Obtain the positions of bars with signals
2. Reconstruct the muon track from the bar positions
3. Calculate the positions of the interaction points of the muon
4. Calculate the calibration parameters via data fitting

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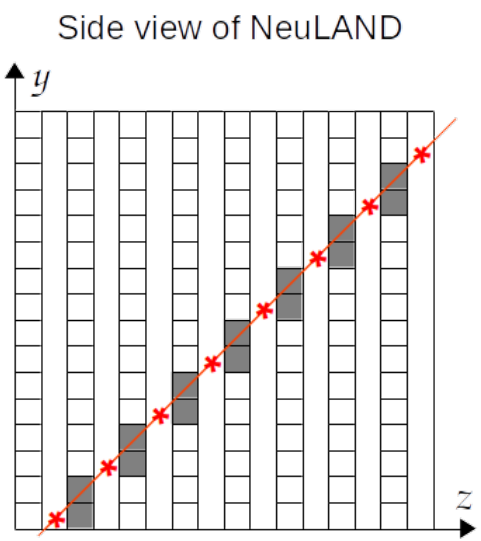

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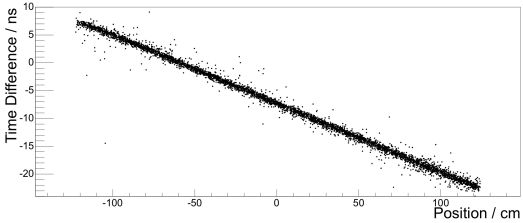
Data fitting in the position calibration:



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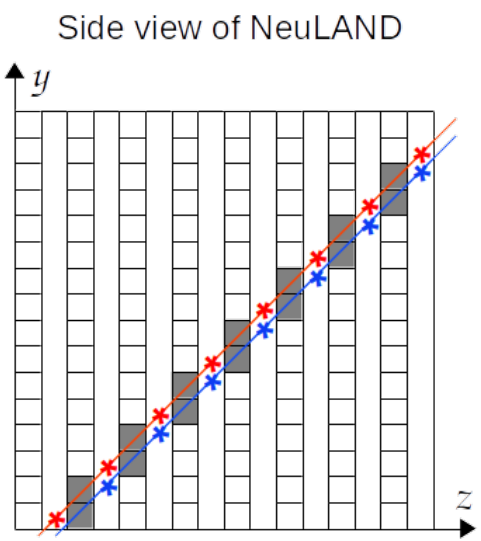

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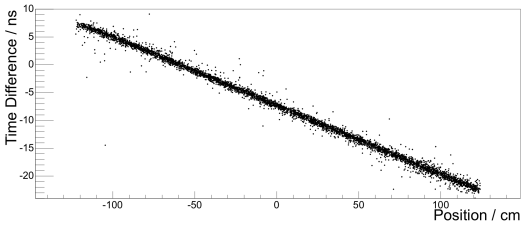

Simultaneous fitting using Millepede algorithm

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Calibration with muon tracks:

$$\text{pos} = C_e \cdot (t_r - t_l + t_{\text{offset}})/2 \quad (1)$$

$$t = (t_r + t_l)/2 - L/(2 \cdot C_e) + t_{\text{sync}} \quad (2)$$

$$\vec{x}_\mu = \vec{a}^{\,i} \cdot z_\mu + \vec{b}^{\,i} \quad (3)$$

where $\vec{a} = (a_x, a_y, a_t)$, $\vec{b} = (b_x, b_y, b_t)$

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Horizontal bars:

$$b_x^i - g_{ct}^i/2 + g_c^i \cdot \Delta t^i/2 + a_x^i z_\mu = 0$$

Vertical bars:

$$b_y^i - g_{ct}^i/2 + g_c^i \cdot \Delta t^i/2 + a_y^i \cdot z_\mu = 0$$

Time sync:

$$b_t^i + g_s^i + L/(2 \cdot g_c^i) - t_{\text{sum}}/2 + a_t^i z_\mu = 0$$

with $g_c^i = C_e$, $g_c^i = C_e \cdot t_{\text{offset}}$ and $g_s^i = t_{\text{sync}}$

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Millepede input:

(1) $\partial f/\partial q_j$: 1st order derivative of local parameters

(2) $\partial f/\partial p_l$: 1st order derivative of global parameters

(3) z : "measurements" (**constant values**)

σ : measurement errors

Simultaneous fitting using Millepede algorithm

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Solutions to the rank deficit error

- Reduce global or local parameters
- Applying additional constraints

Introducing local constraints:

Horizontal bars : $b_y^i - Y_{bar}^i + a_y^i \cdot z_\mu = 0$

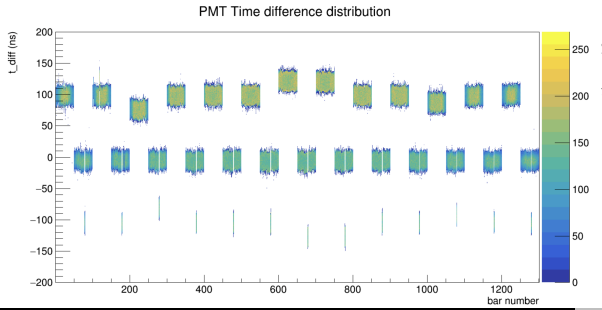
Vertical bars : $b_x^i - X_{bar}^i + a_x^i \cdot z_\mu = 0$

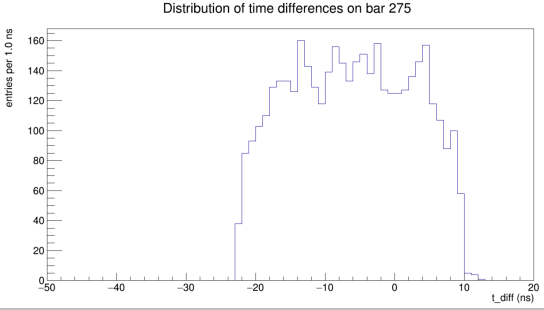
Predetermination on position parameters

Purposes of predetermination

- Use good initial values from a crude calibration method to reduce the rejected entries ($< 33.3\%$)
- Select one bar from the plane when muon crosses multiple bars of the same plane
- Remove outliners caused by the background γ rays

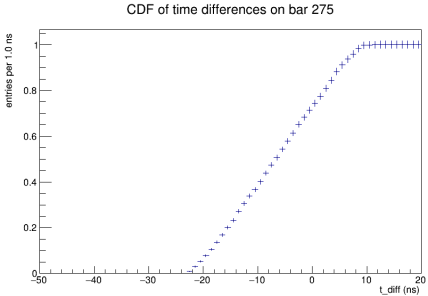
Step 1: Collect time differences of adjacent PMT signals





Predetermination on position parameters

Step 2: Normalize the distribution and convert to CDF for each bar



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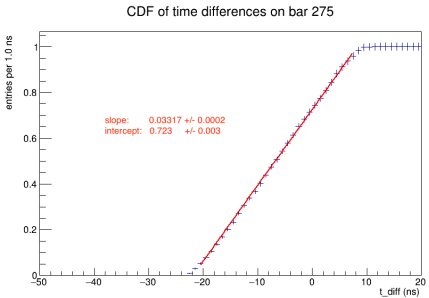

Step 3: Linear fitting from 0.05 to 0.95

Calculation of parameters:

$$C_e = 2 \cdot \text{BarLenght} \cdot \text{slope}$$

$$t_{\text{offset}} = (0.5 - \text{intercept})/\text{slope}$$

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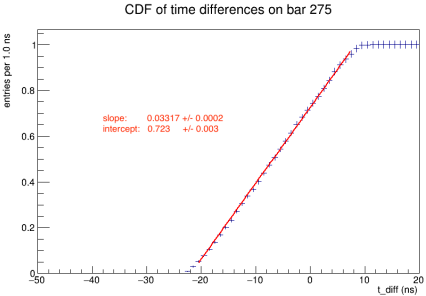

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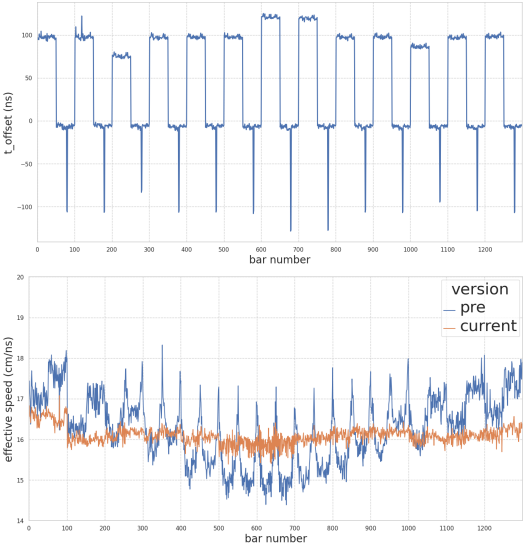
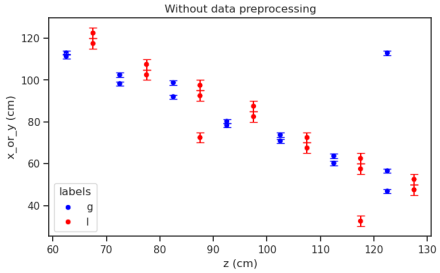
Evaluation results:



Fine tuning with Millepede algorithm

Data preprocessing

1. Scale the time/position values ($\times 10^{-1}$)
2. Select bars with only one signal per event
3. Remove isolated bars of each plane
4. Average bar positions for local constraints
5. Linear fit with $z - x$ and $z - y$ functions on bar positions
6. Choose the bar closest to the linear function for each plane
7. Remove the bar with a large residual



Comparison of time offset parameters

Comparison of effective speed parameters