

Application of Millepede algorithm to Time and Position Calibration of NeuLAND

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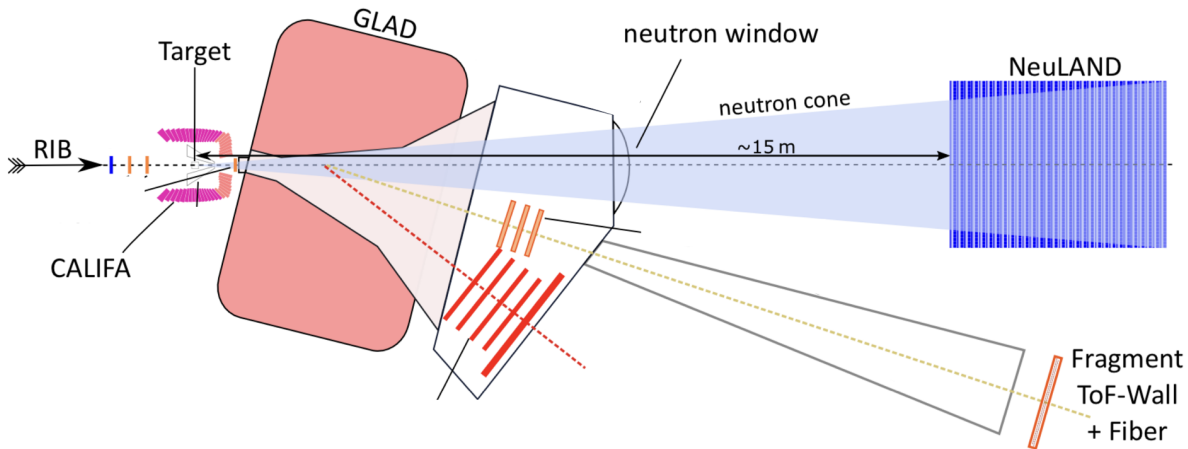
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NeuLAND setup in R^3B

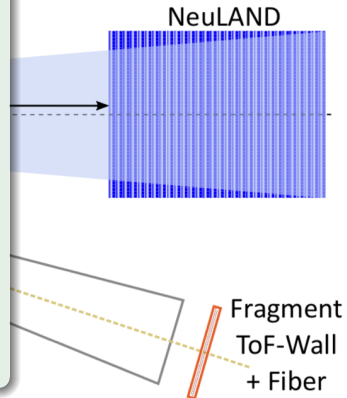


NeuLAND setup in R³B



Geometry:

- 26 planes
- $250 \times 250 \text{ cm}^2$
- 50 scintillators each plane
- 100 PMTs each plane



NeuLAND setup in R³B

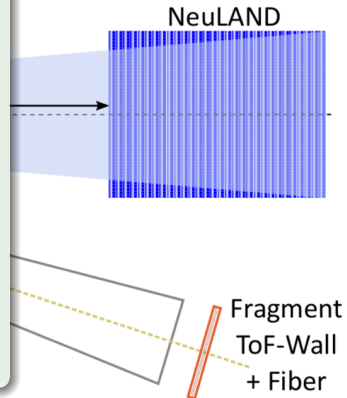


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Measurements:

- interaction position
- interaction time
- energy deposition



NeuLAND setup in R³B

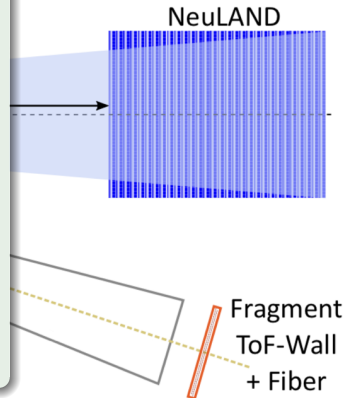


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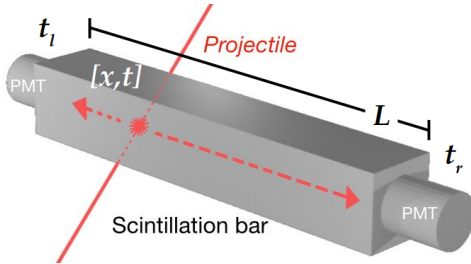
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Measurements:

- **interaction position**
- **interaction time**
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Position and time calibration



Symbols:

x : position of the interaction

t : time of the interaction

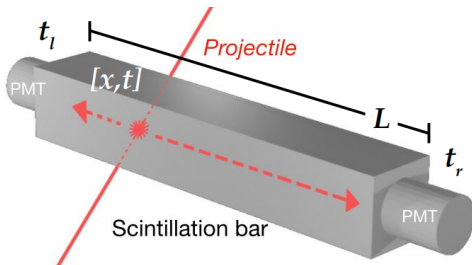
L : length of the scintillator

t_l : time of the left PMT signal

t_r : time of the right PMT signal

C_e : effective speed of light

Position and time calibration



Time relation:

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

Position relation:

$$x = \frac{C_e}{2} (t_r - t_l)$$

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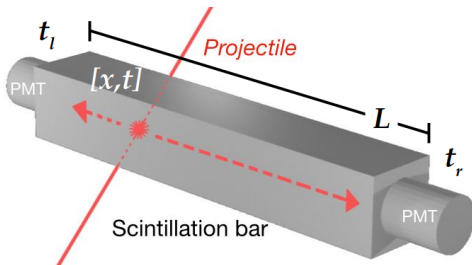
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Position and time calibration



Time relation:

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

Position relation:

$$x = \frac{C_e}{2} (t_r - t_l)$$

Additional calibration parameters:

- t_{sync} : time synchronization among scintillators

Symbols:

x : position of the interaction

t : time of the interaction

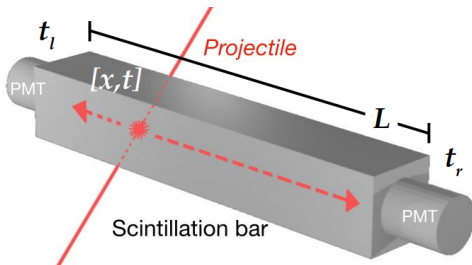
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Additional calibration parameters:

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

Symbols:

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t : time of the interaction

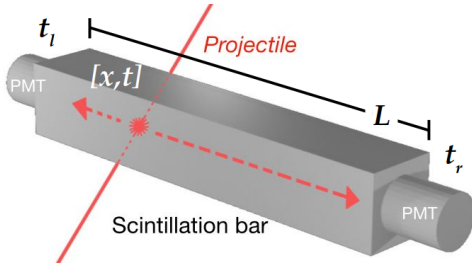
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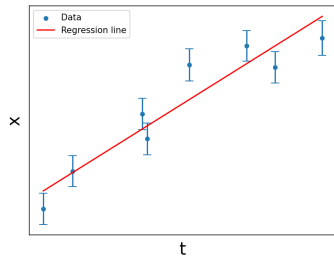
- t_{sync} : time synchronization among scintillators
- t_{offset} : time offset between adjacent PMTs

Total number of calibration parameters: **3900**

Calibration relation

$$x = C_1 \cdot t + C_2$$

Data fitting:



(t_1, x_1)

(t_2, x_2)

...

(t_i, x_i)

...

(t_n, x_n)

Minimize

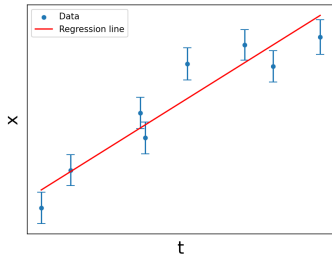
$$\text{residual} = \sum_i \frac{(x_i - x(t_i, C_1, C_2))}{2 * \sigma_i^2}$$

Calibration principle

Calibration relation

$$x = C_1 \cdot t + C_2$$

Data fitting:



$$(t_1, x_1)$$

$$(t_2, x_2)$$

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Minimize

$$\text{residual} = \sum_i \frac{(x_i - x(t_i, C_1, C_2))}{2 * \sigma_i^2}$$

Calibration with muon tracks

$$t = (t_r + t_l)/2 - L/(2 \cdot C_e) + t_{\text{sync}} \quad (1)$$

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

$$x_\mu = a_x^i \cdot z_\mu + b_x^i \quad (3)$$

$$y_\mu = a_y^i \cdot z_\mu + b_y^i \quad (4)$$

$$t_\mu = a_t^i \cdot z_\mu \quad (5)$$

Calibration parameters for the i th event:

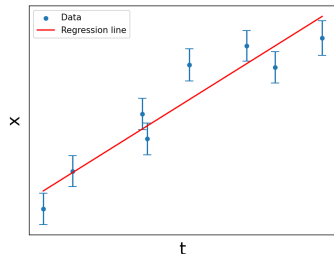
$$C_e, t_{\text{sync}}, t_{\text{offset}}, a_x^i, a_y^i, a_t^i, b_x^i, b_y^i$$

Calibration principle

Calibration relation

$$x = C_1 \cdot t + C_2$$

Data fitting:



$$(t_1, x_1)$$

$$(t_2, x_2)$$

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$$(t_i, x_i)$$

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Minimize

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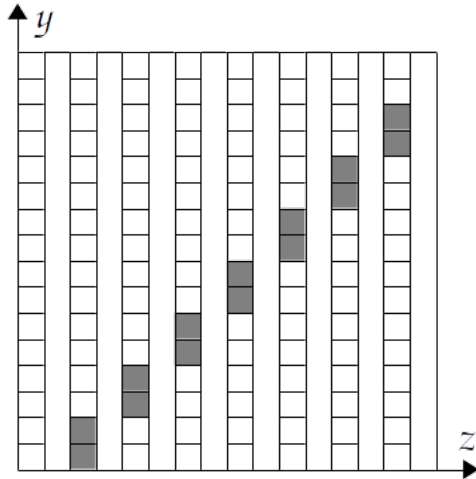
$$t_\mu = a_t^i \cdot z_\mu \quad (5)$$

Calibration parameters for the i th event:

$$C_e, t_{\text{sync}}, t_{\text{offset}}, a_x^i, a_y^i, a_t^i, b_x^i, b_y^i$$

With 10'000 events, the total number of
calibration parameters: **53'900!**

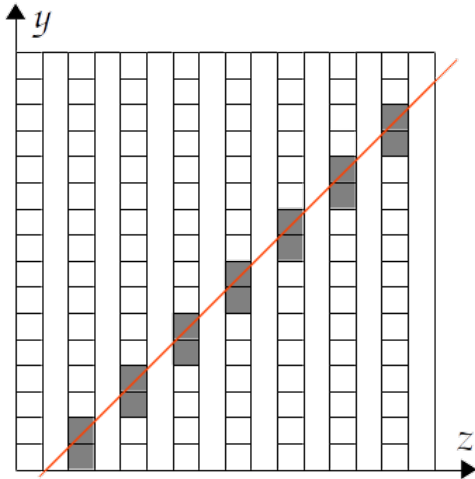
Side view of NeuLAND



Procedures

- 1 Obtain the positions of bars with signals

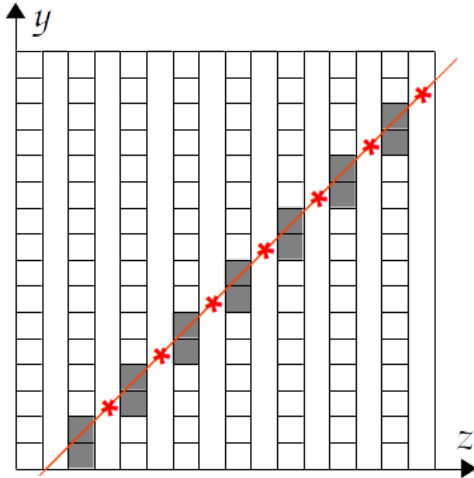
Side view of NeuLAND



Procedures

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

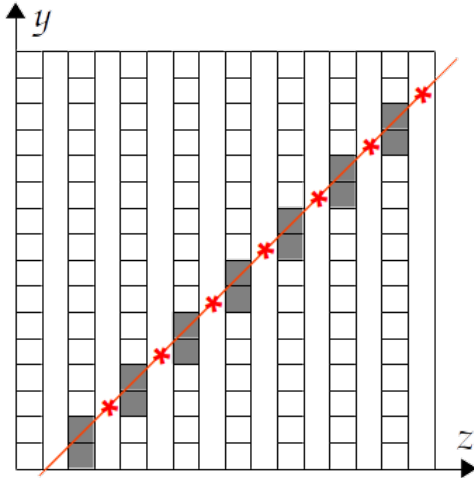
Side view of NeuLAND



Procedures

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

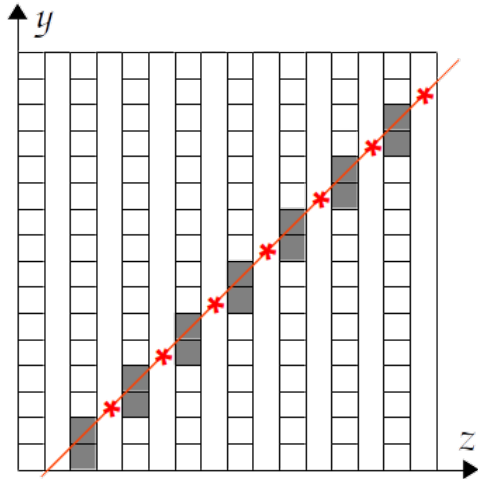
Side view of NeuLAND



Procedures

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- 2 Reconstruct the muon track from the bar positions
- 3 Calculate positions of interaction point of the muon
- 4 Obtain calibration parameters via data fitting

Side view of NeuLAND



Procedures

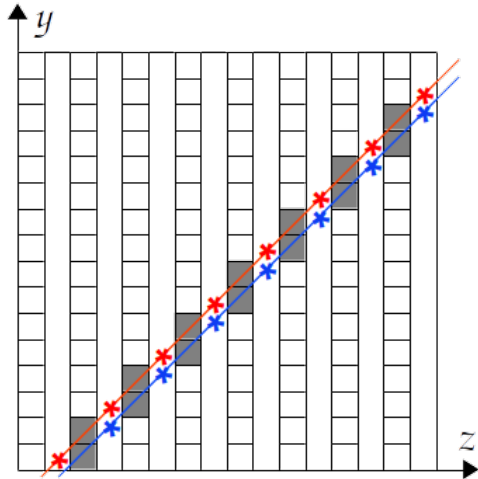
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Data fitting on positions:

Golden ratio

(Original size: 32.361 × 200 bp)

Side view of NeuLAND



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Data fitting on positions:

Golden ratio

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Simultaneous fitting of global and local parameters

Comparisons on PMT time offsets

Comparisons on effective speed of light

Comparisons on time synchronization

Summary and outlook