

Simulation framework for the digitization module of scintillators and its implementation in NeuLAND

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Institute for Nuclear Physics, University of Cologne

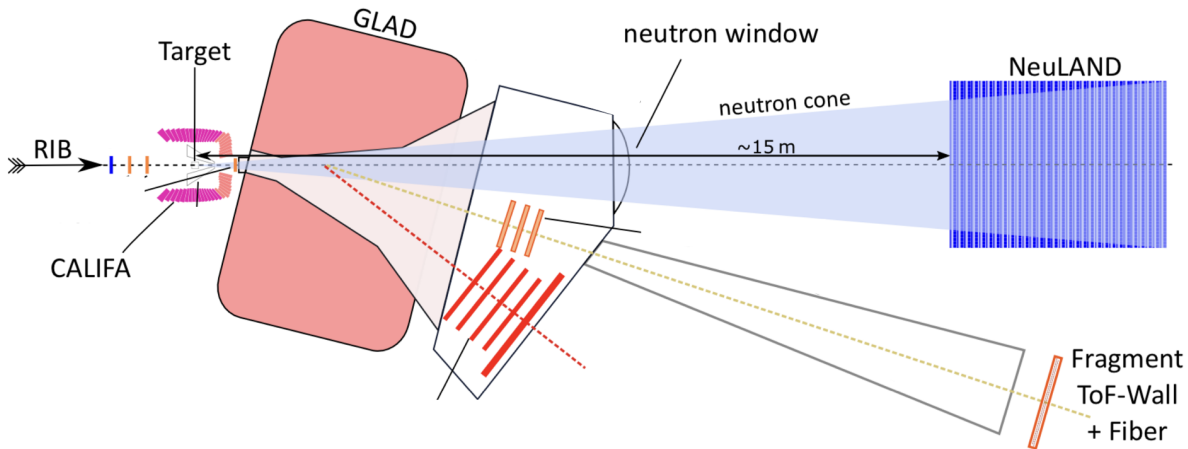
HK 25.2
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Dresden 2023

Supported by BMBF (05P21PKFN1)



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NeuLAND setup in R³B

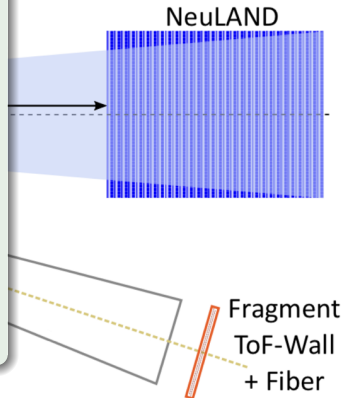


NeuLAND setup in R³B



Geometry:

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



NeuLAND setup in R³B

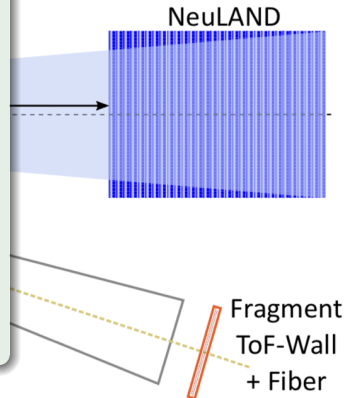


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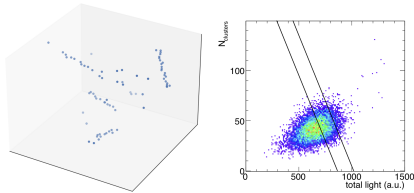
Measurement:

- neutron 4-momentum
- neutron multiplicity



Why do we need a simulation?

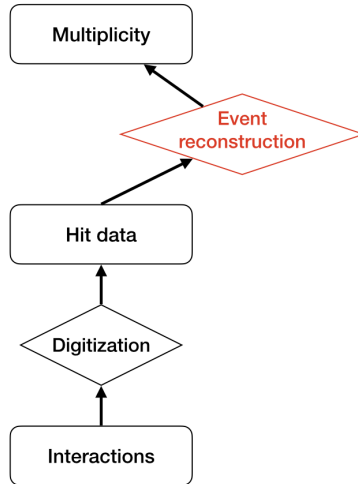
Method 1: Clustering¹



Method 2: Bayes WCP

$$P(H|\vec{\mathbf{E}}) = P(H) \frac{P(\vec{\mathbf{E}}|H)}{\sum_h P(\vec{\mathbf{E}}|H_h)P(H_h)}$$

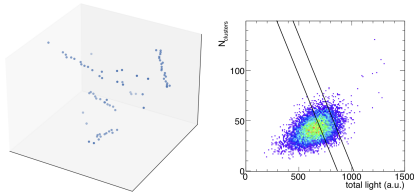
Method 3: Convolutional neural network



¹ Technical Report for the Design, Construction and Commissioning of NeuLAND 2011.

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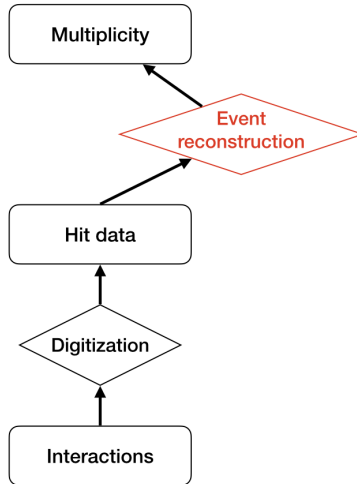


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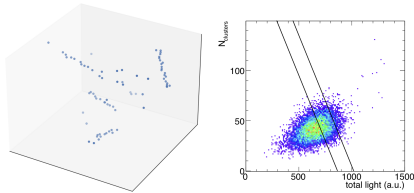
Validation?



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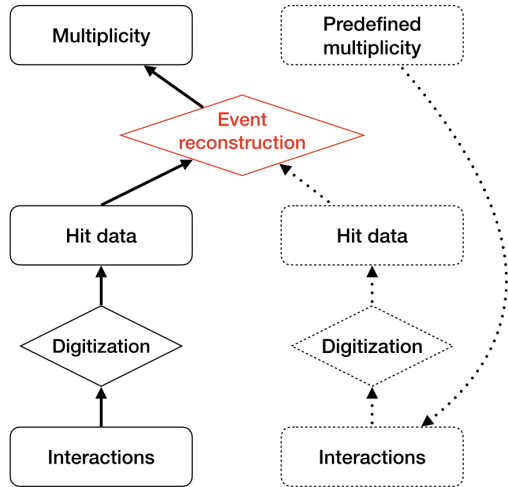
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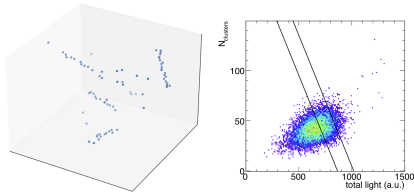
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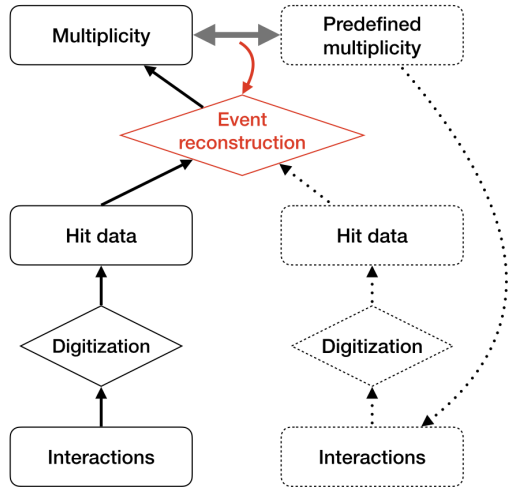
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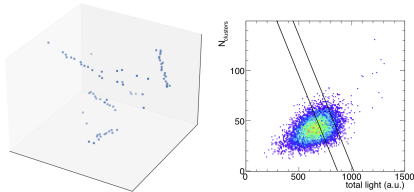
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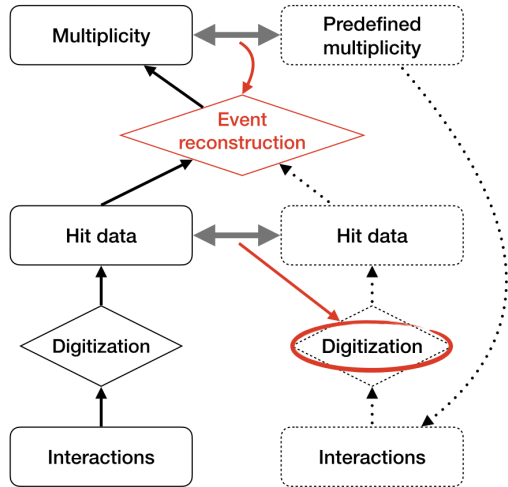


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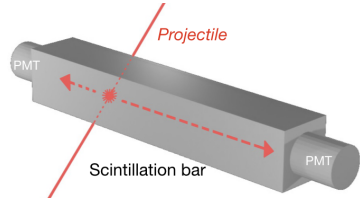
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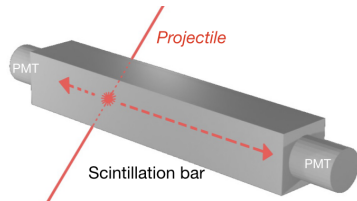
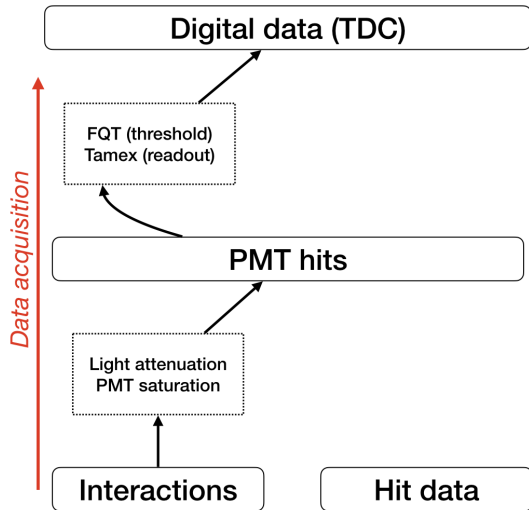
Digitization process



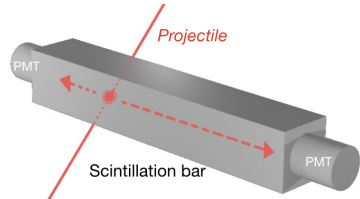
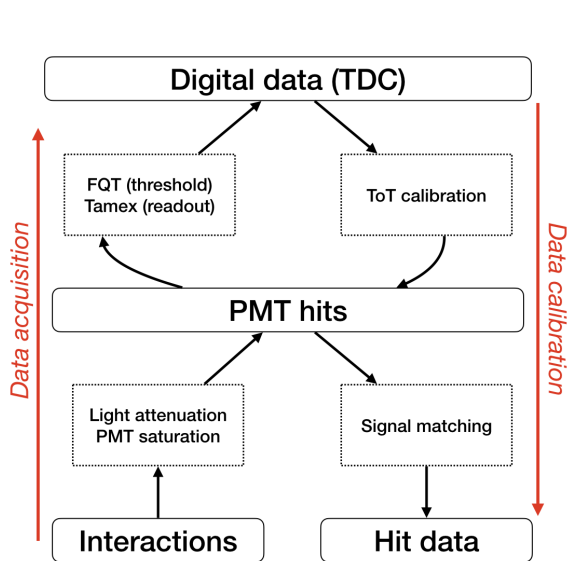
Interactions

Hit data

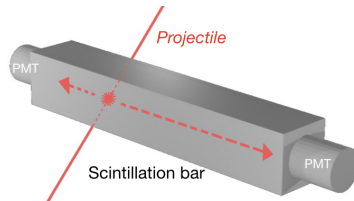
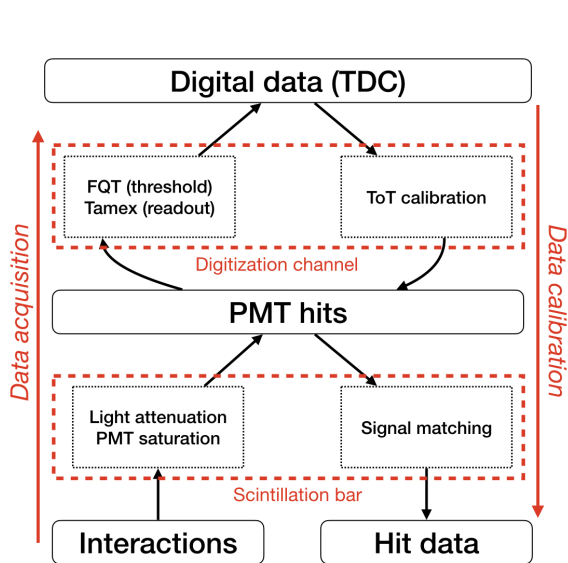
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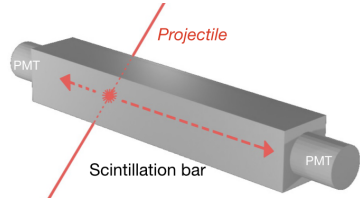
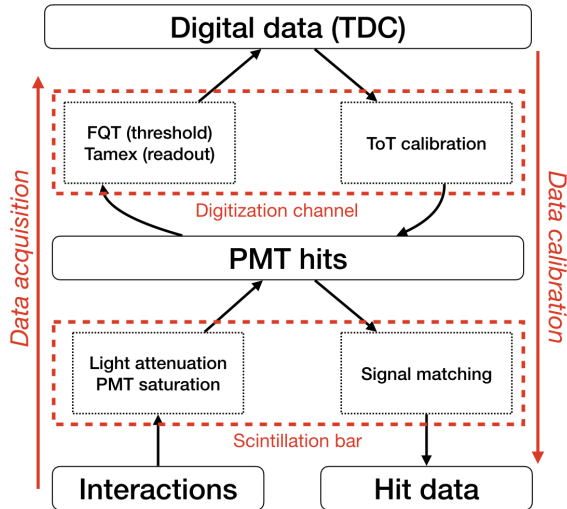
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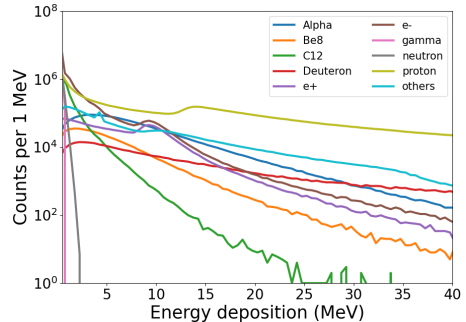
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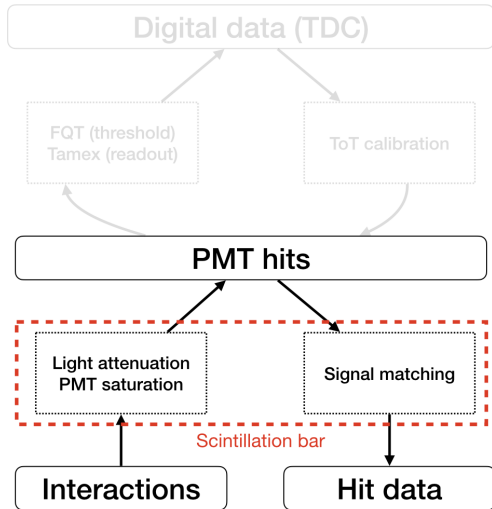
Digitization process



Energy depositions of different particles ($E_n = 600$ MeV)

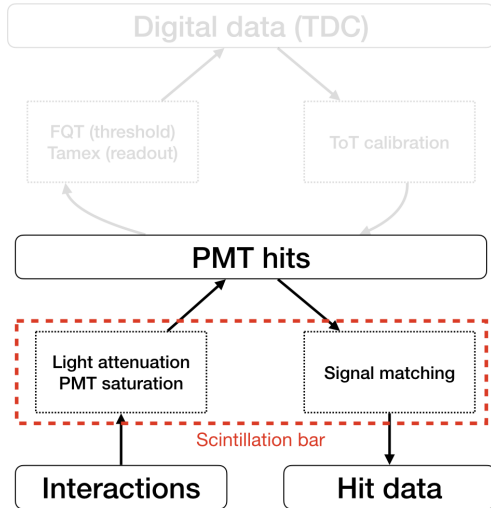


Simulation of scintillation bar

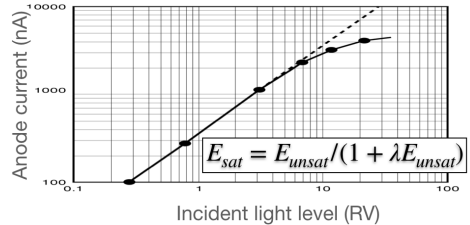


¹ Photomultiplier tubes: basics and applications, 3a, Hamamatsu (Nov. 2007), p. 197

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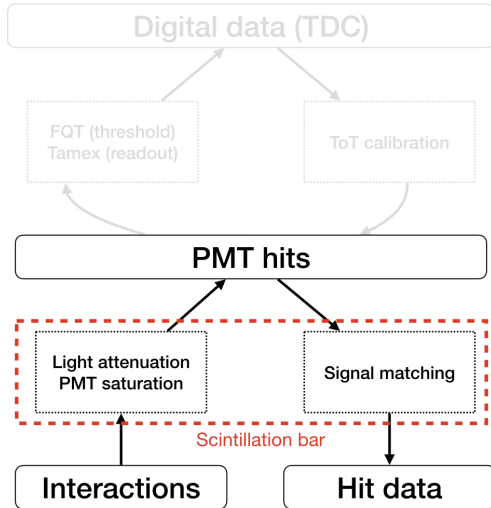


PMT saturation¹

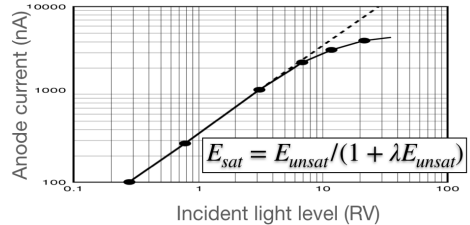


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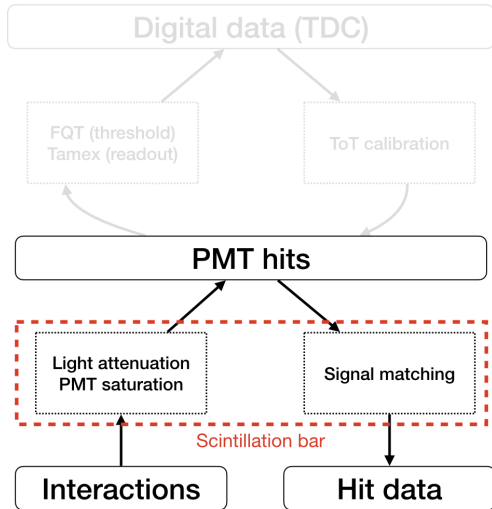
Light attenuation

$$Y_{PMT} = Y_{edep} \exp(-\alpha \cdot L)$$

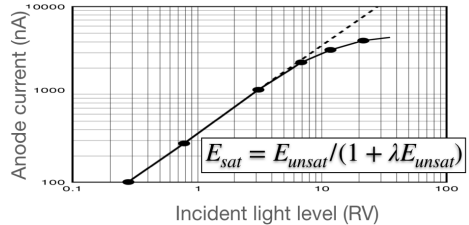
α : Attenuation factor

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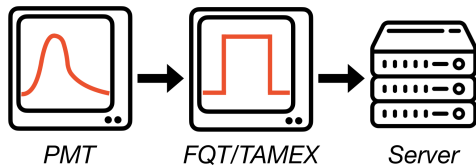
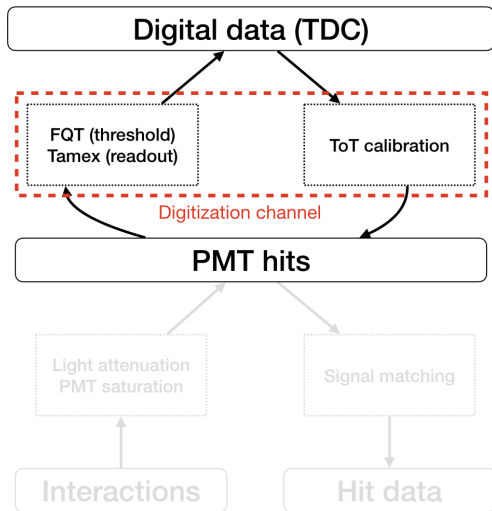
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PMT signal matching

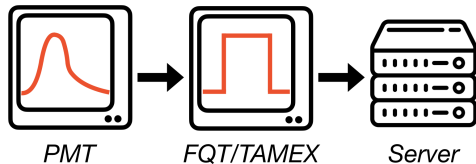
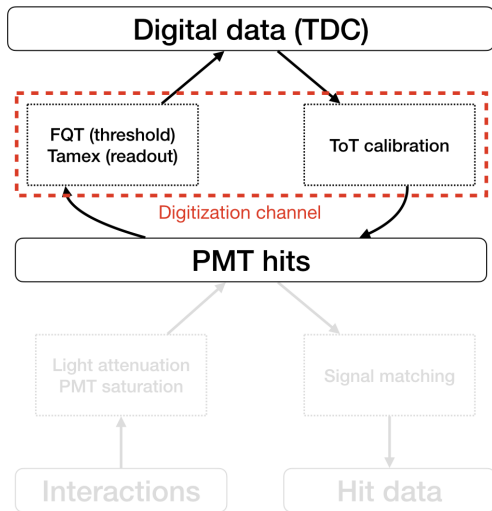
$$\min \Delta = \begin{cases} |E_1/E_2 \cdot e^{\alpha c(t_1 - t_2)} - 1|, & t_1 > t_2 \\ |E_2/E_1 \cdot e^{\alpha c(t_2 - t_1)} - 1|, & t_2 > t_1 \end{cases}$$

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Simulation of digitization channel



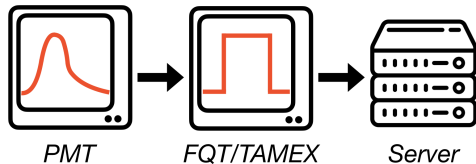
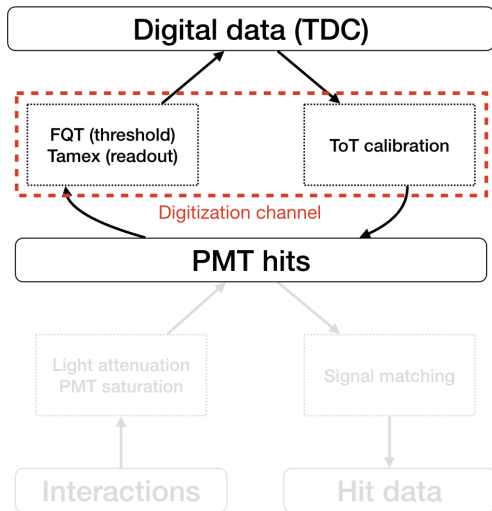
Simulation of digitization channel



Simulation steps

- 1 Apply threshold
- 2 Perform pileup of PMT signals (addition)
- 3 PMT signals \Rightarrow FQT signals
- 4 Perform pileup of FQT signals (merge)
- 5 Energy and time value smearing

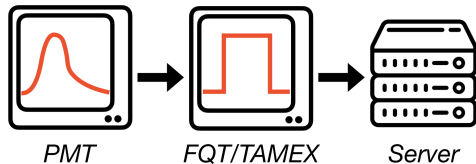
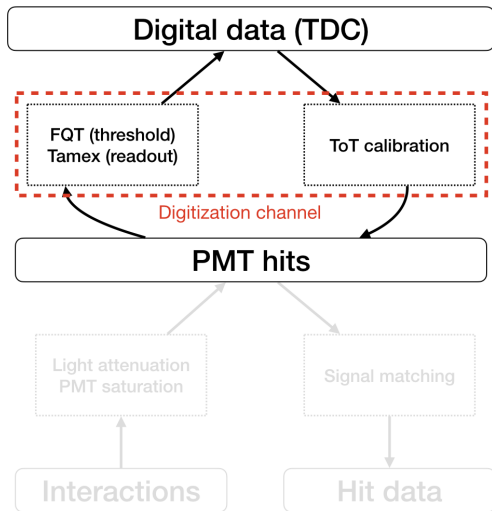
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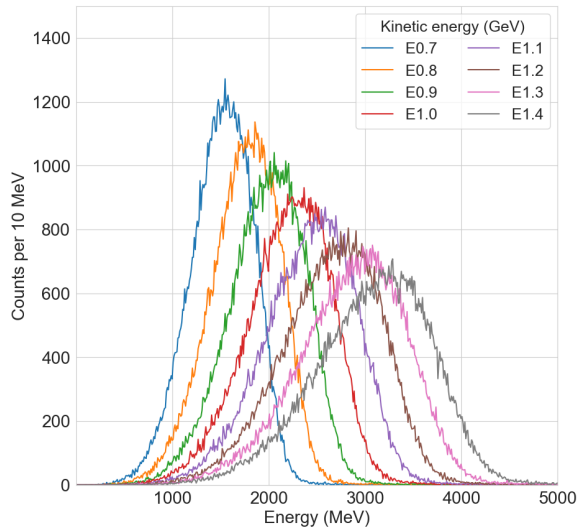


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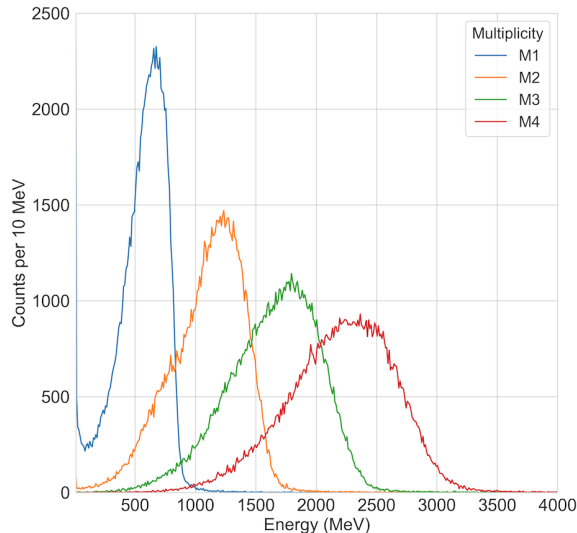
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Total energy deposition

Neutron multiplicity = 4

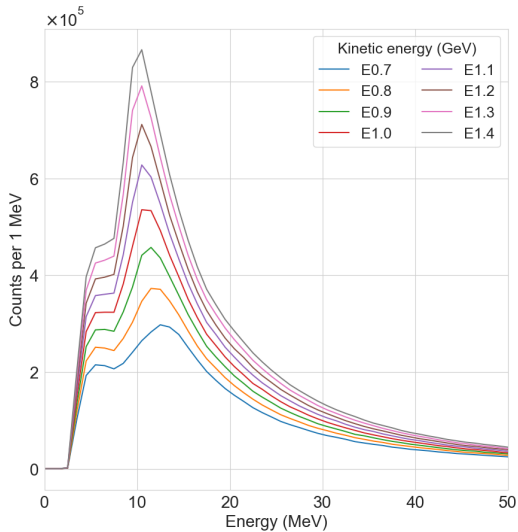


Neutron kinetic energy = 1 GeV

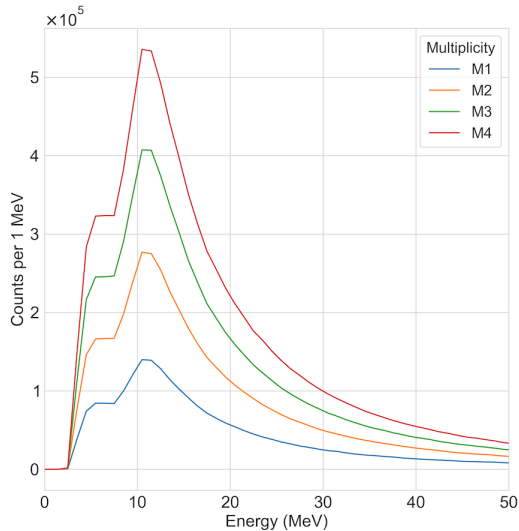


Energy deposition of hits

Neutron multiplicity = 4

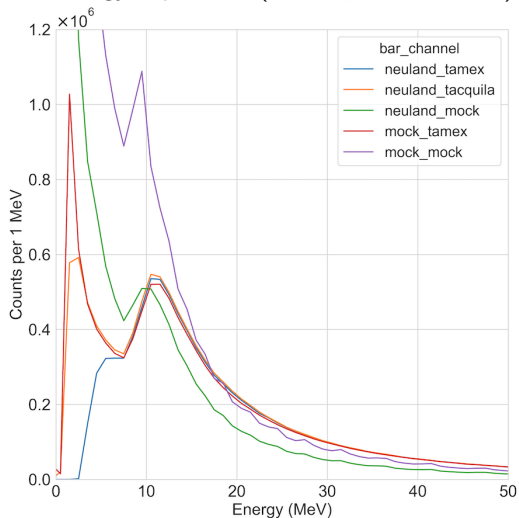


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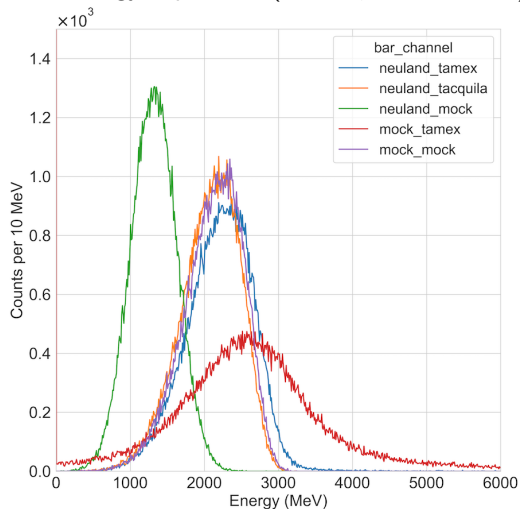


Comparisons to Tacquila and mockup

Hit energy deposition ($M = 4, KE = 1 \text{ GeV}$)



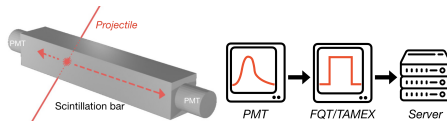
Total energy deposition ($M = 4, KE = 1 \text{ GeV}$)



Summary and outlook

In this talk

- simulation on scintillation bars and digitization channels
- multi-hit capability
- distribution on total energy deposition and hit energies
- better performance on low energy filtering



What to do next

- integration time window on Tamex
- comparison to real calibrated data
- applications on other detectors

