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

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DPG-Frühjahrstagung
Dresden 2023

Supported by BMBF (05P21PKFN1)

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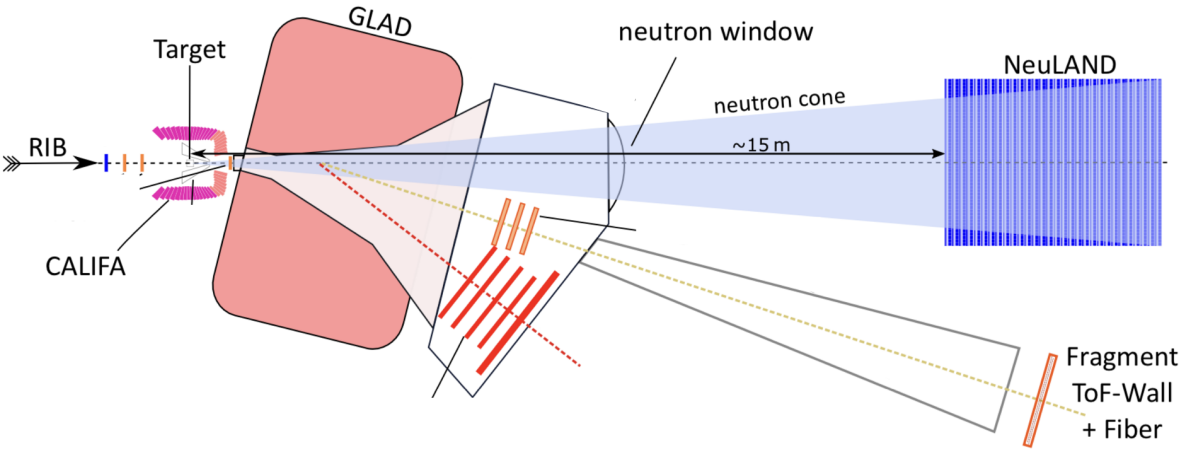
NeuLAND setup in R^3B

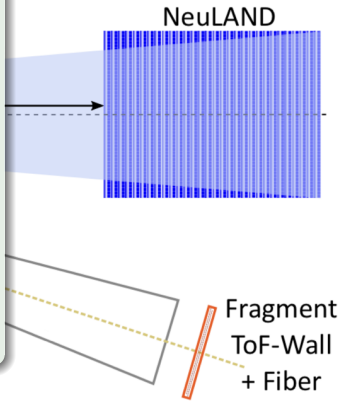


K. Boretzky *et al.*, Nucl. Instrum. Methods. Phys. Res. B **1014**, 165701 (2021)

NeuLAND setup in R^3B

Geometry:

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



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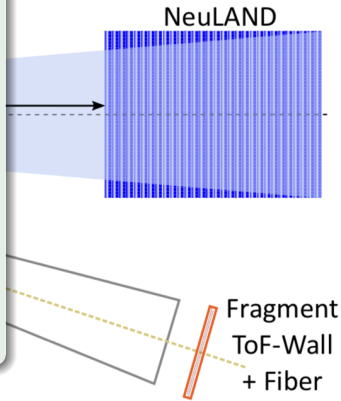
Measurement:

- neutron 4-momentum
- neutron multiplicity



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Why do we need a simulation?

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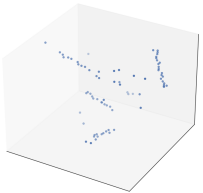
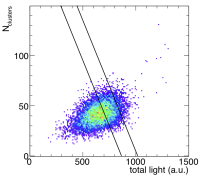
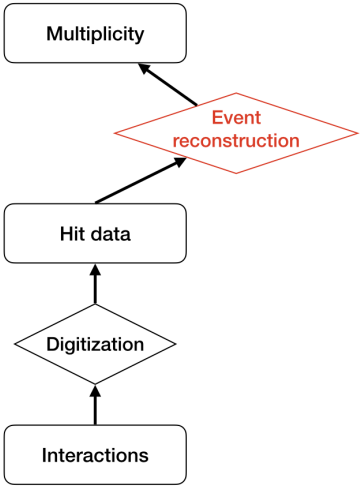




Method 2: Bayes WCP

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

Method 3: Convolutional neural network



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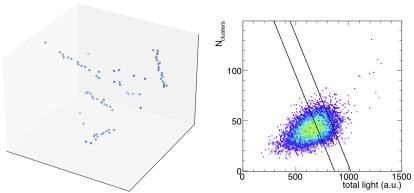

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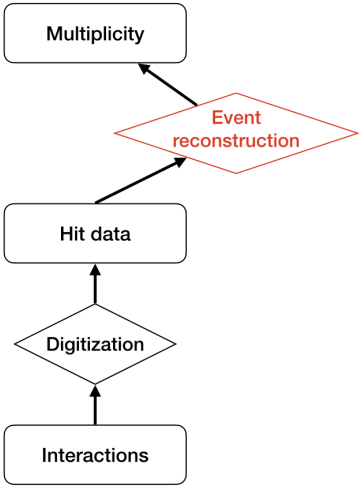

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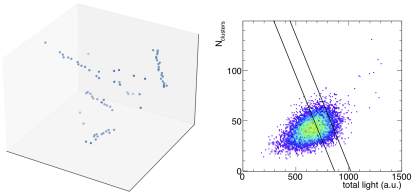

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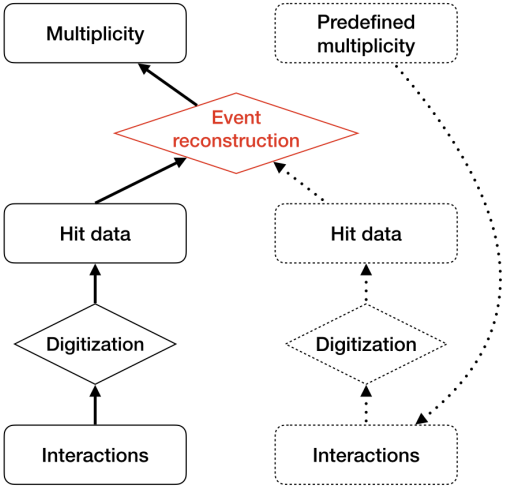

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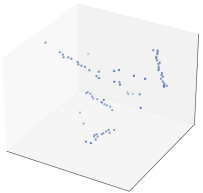

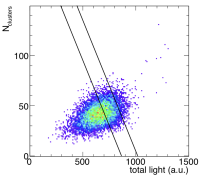

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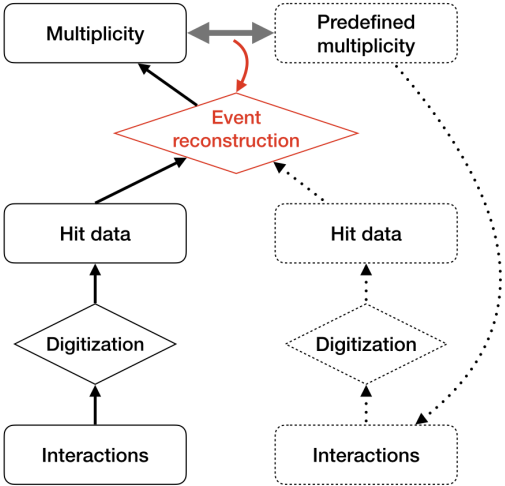

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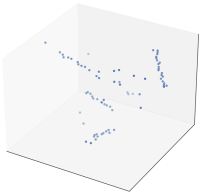

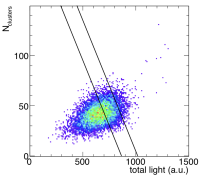

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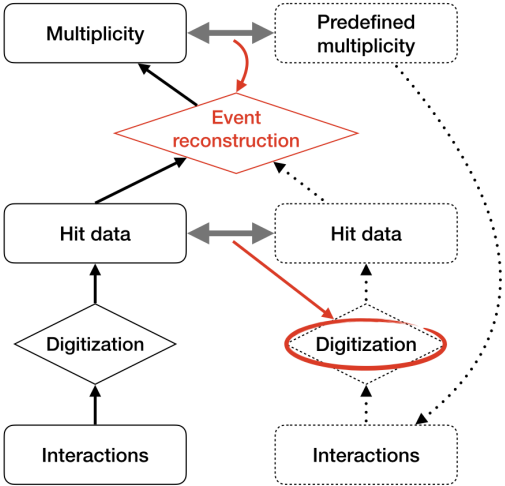

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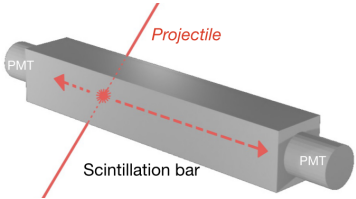
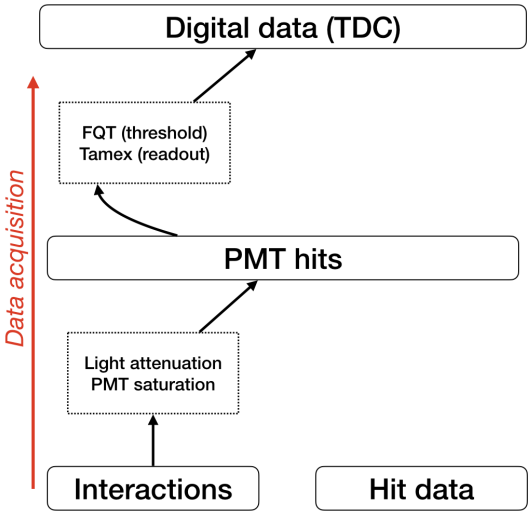
Digitization process

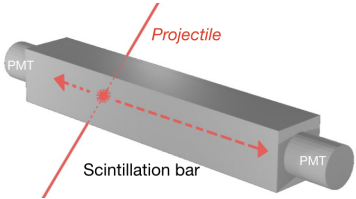


Interactions

Hit data

Digitization process





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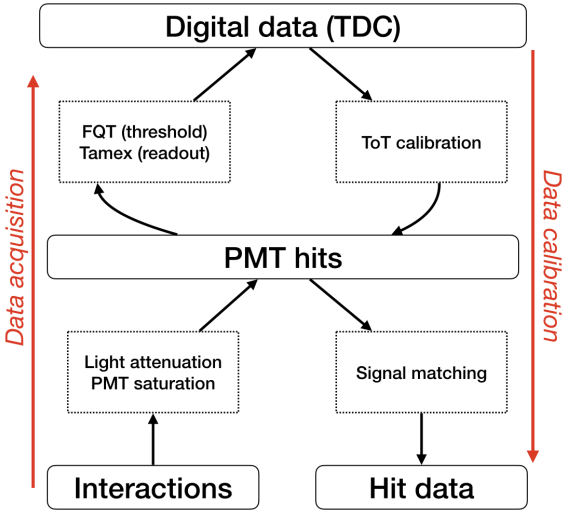

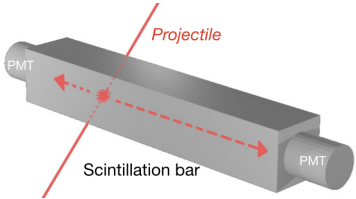

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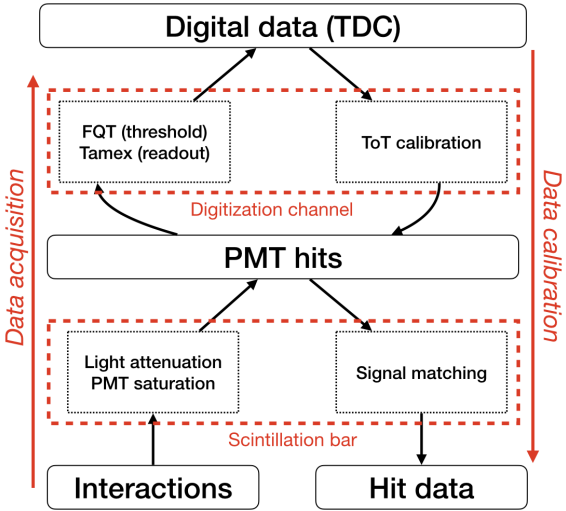

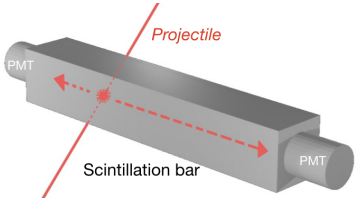

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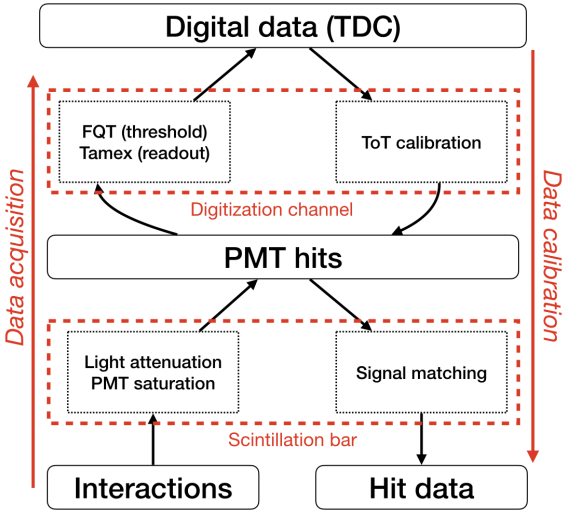
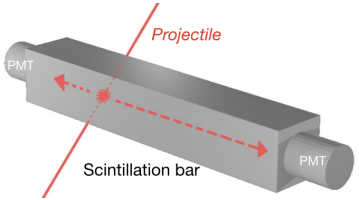
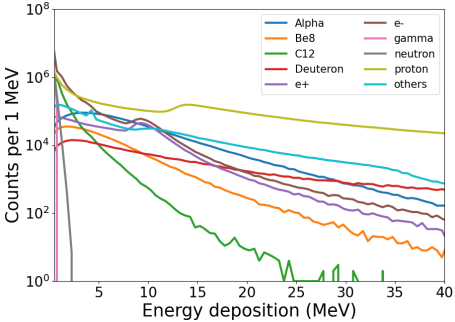
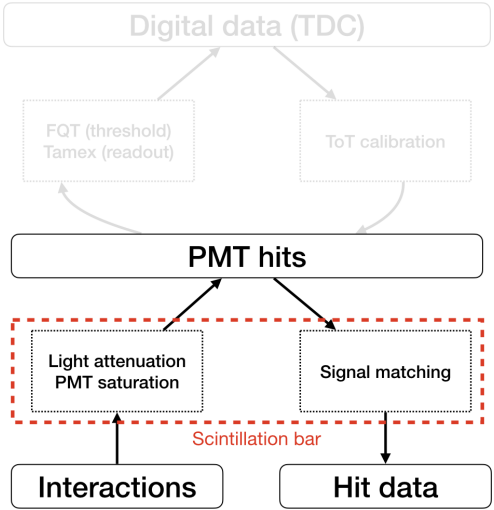




Energy depositions of different particles ($E_n = 600$ MeV)



Simulation of scintillation bar



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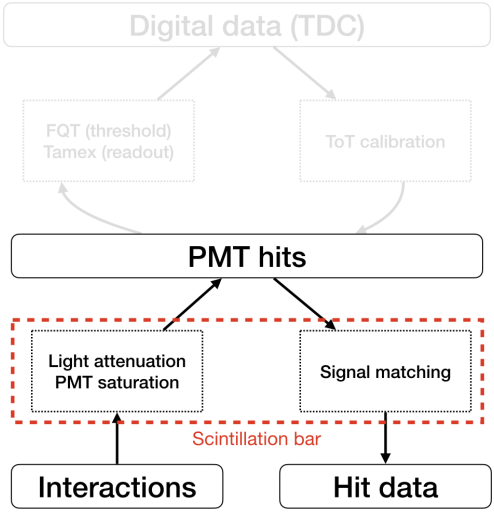
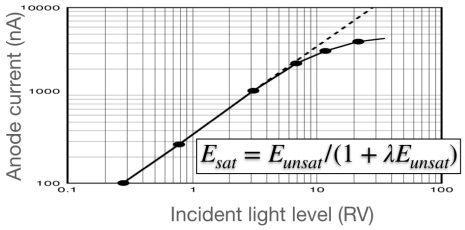


PMT saturation[1]



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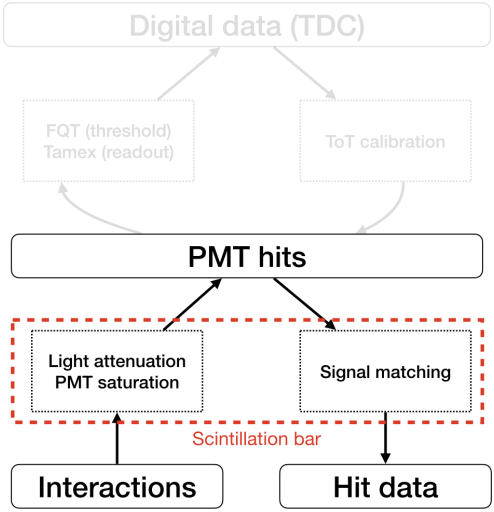

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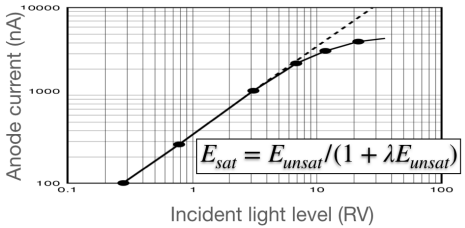

Light attenuation

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

α: Attenuation factor

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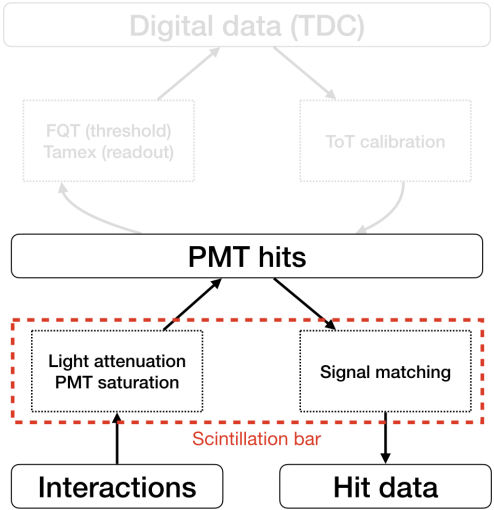

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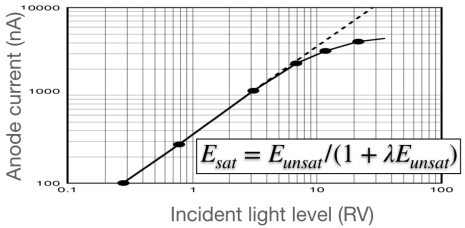

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PMT signal matching

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

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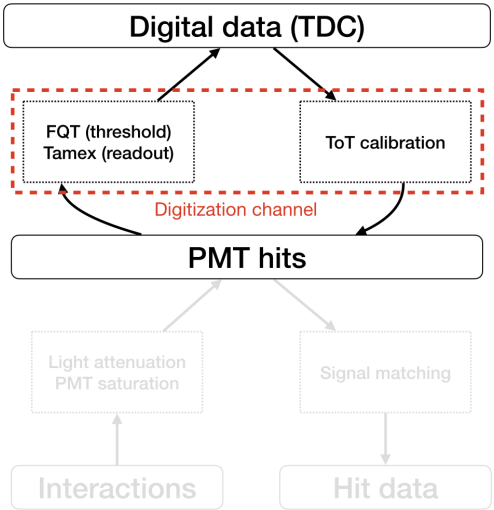

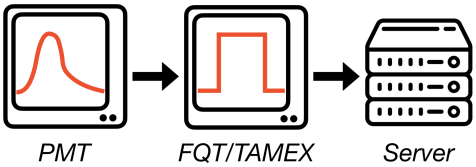

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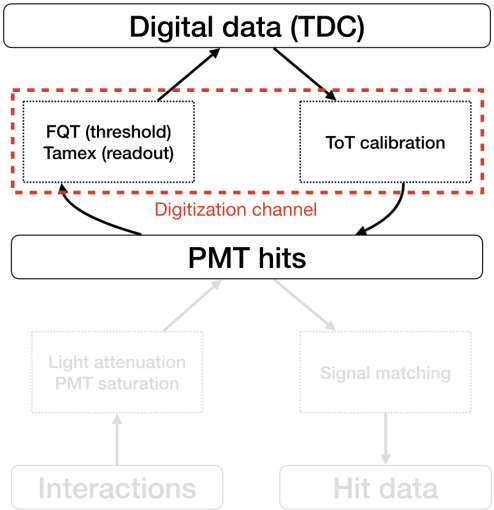

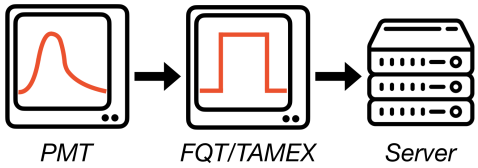

Simulation steps

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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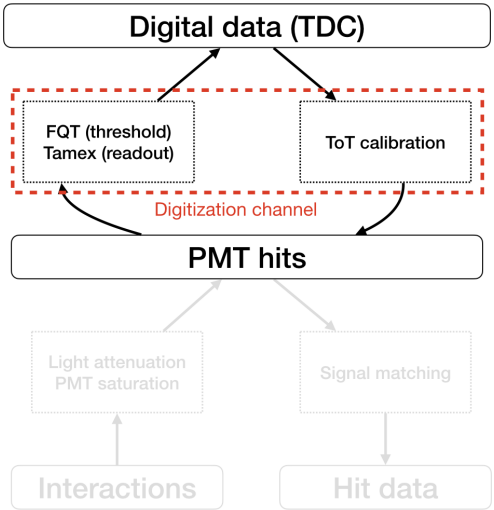

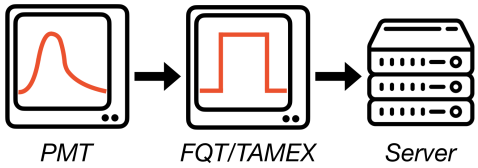

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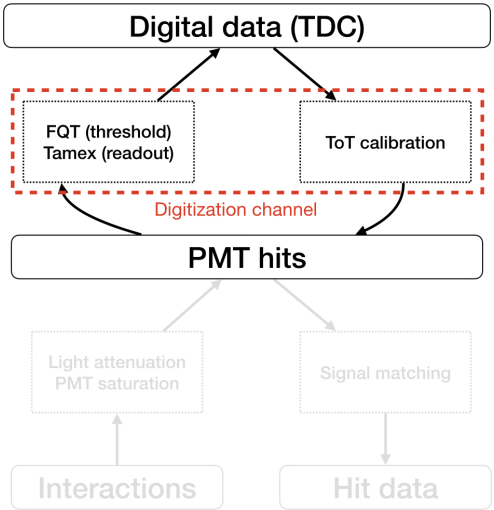

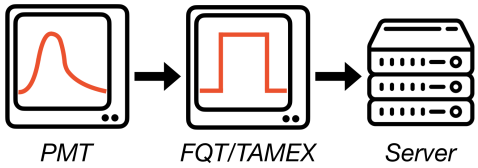

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Total energy deposition

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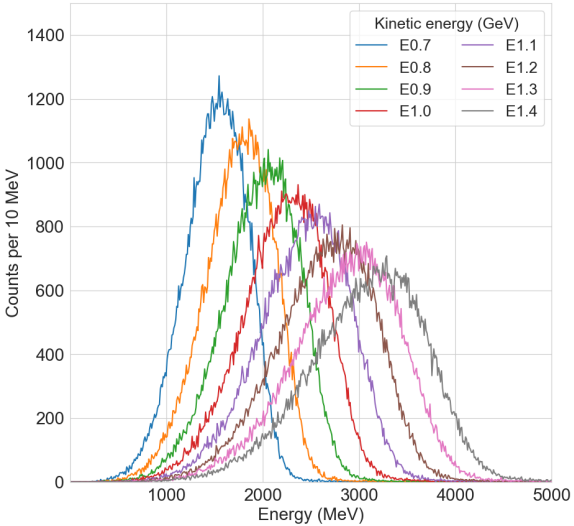
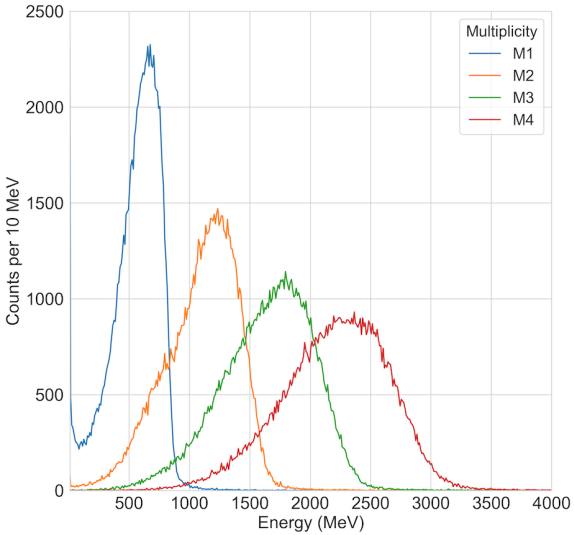
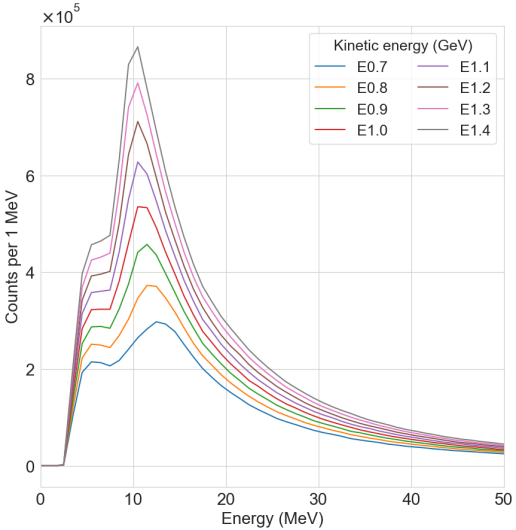


Neutron kinetic energy = 1 GeV



Energy deposition of hits

Neutron multiplicity = 4



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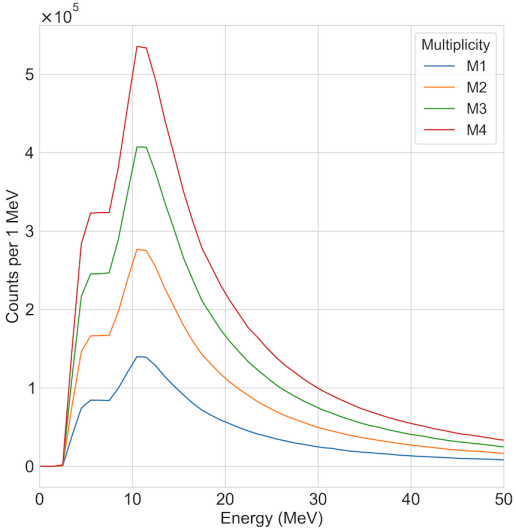
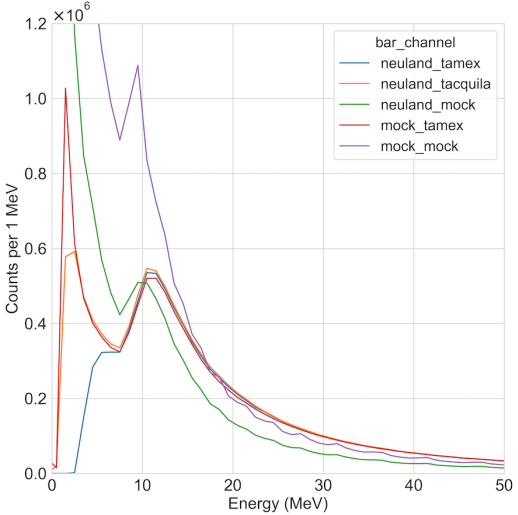


Comparisons to Tacquila and mockup

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



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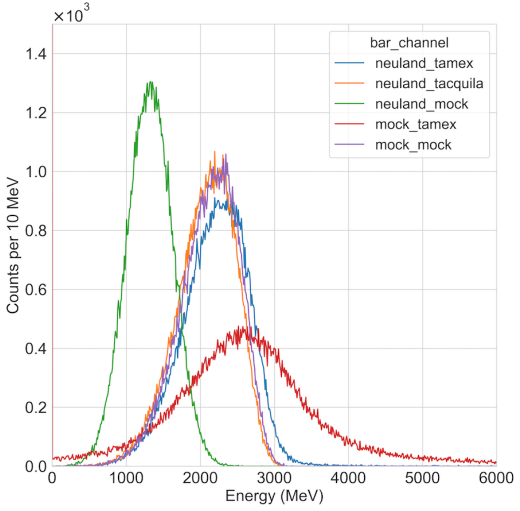

Summary and outlook

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