Muon induced neutron in lead measurement by fast neutron detector

in the context of Minidex

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Motivation

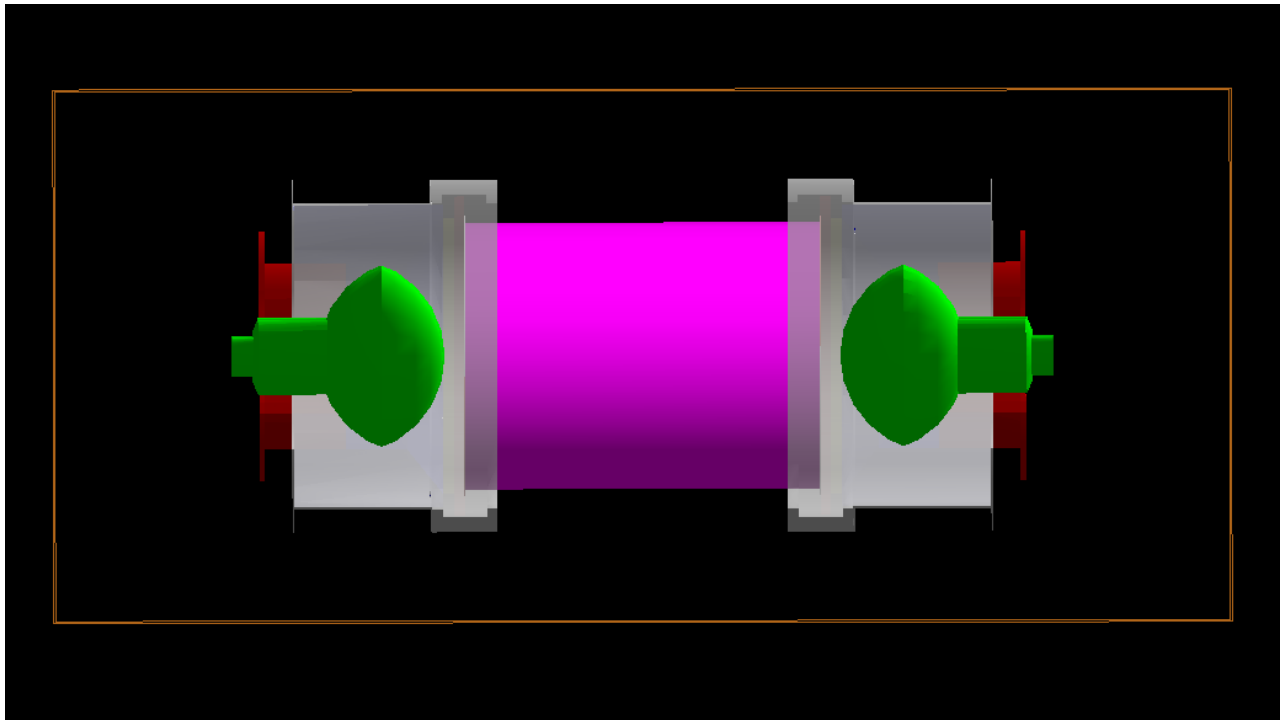
- Muon induced neutron in high-Z materials:
  background for dark matter or ($0\nu\beta\beta$) experiment.
- Lead shielding system:
  commonly used by underground experiments.
- Gd-doped liquid scintillator detector:
  measure the muon induced neutron in lead.
- Cross check with Minidex (see Raphael Kneiβl's talk).

Outline

1. Neutron detector introduction

2. Neutron detector along with Minidex
   - Neutron detector along with Minidex

Neutron detector introduction



- 28.27 liters liquid scintillater doping with 0.5% gadolinium
- Quartz glass container with size of $\Phi 30 \times 40$ cm
- Use pulse shape discrimination(PSD) and time coincidence to select neutron events from background.

Neutron detector γ/μ energy calibraion

available γ/μ energy calibration points

calibration source	^{60}Co	H(n,γ)D	^{228}Th	AmBe	muon minimum ionization peak
energy(MeV)	1.17/1.33/2.5	2.2	2.6	4.4	50.98

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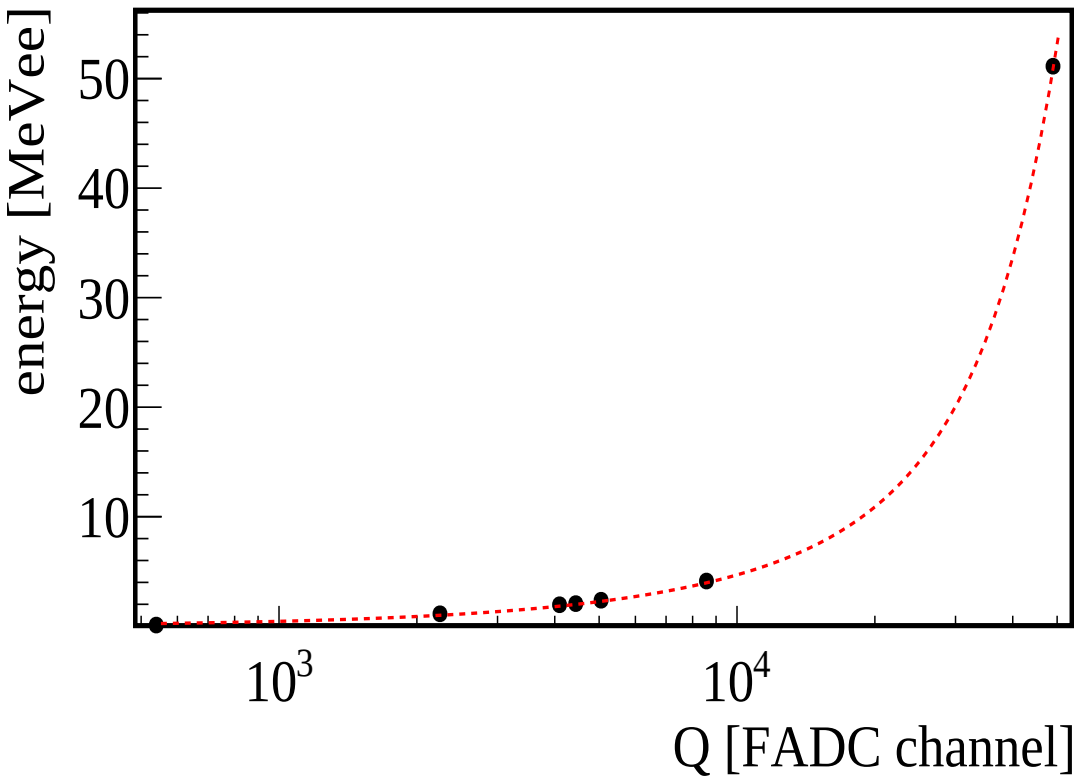
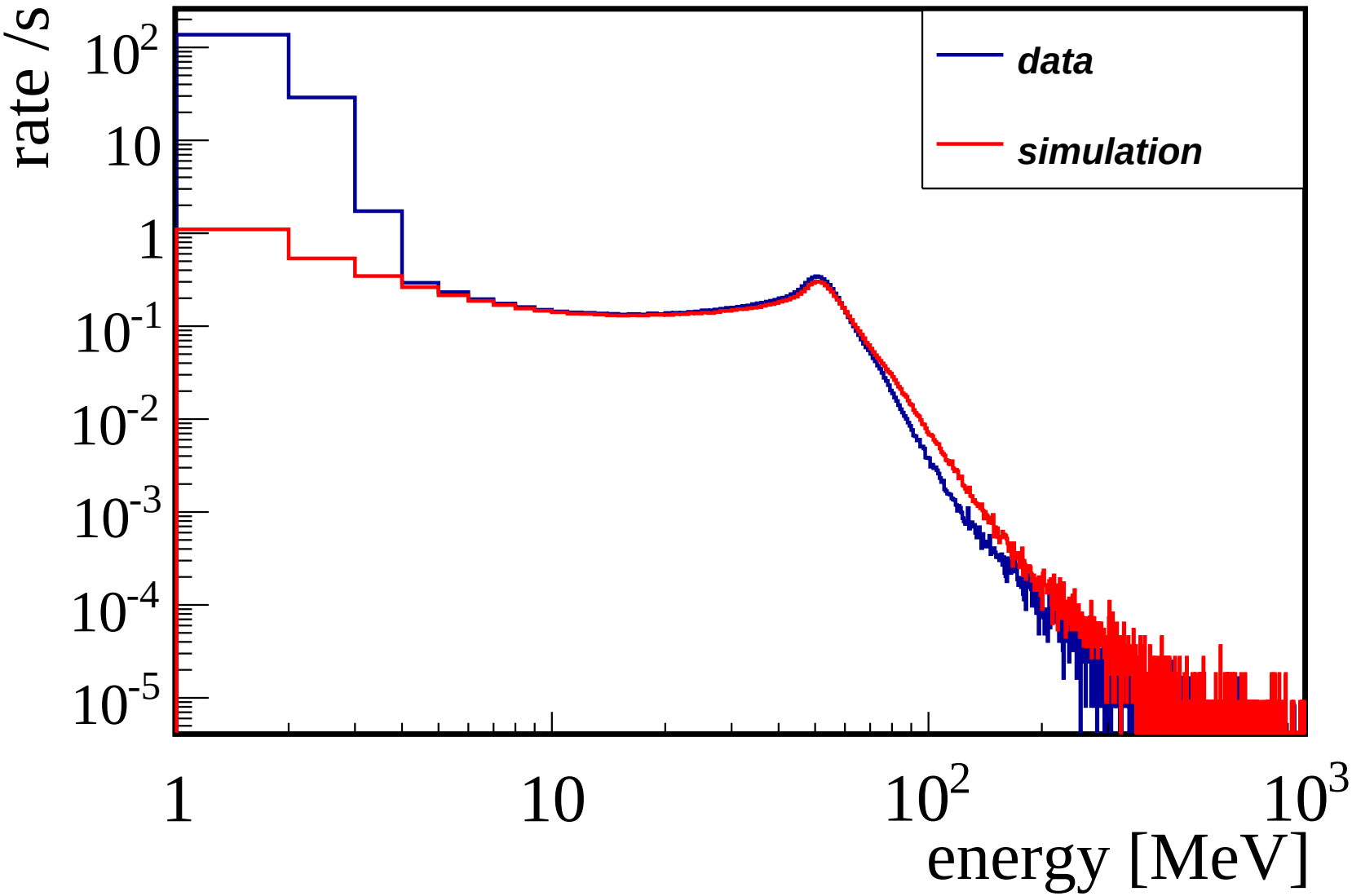


energy calibration function:

$$y = ax^3 + bx^2 + cx + d$$

Neutron detector background spectrum



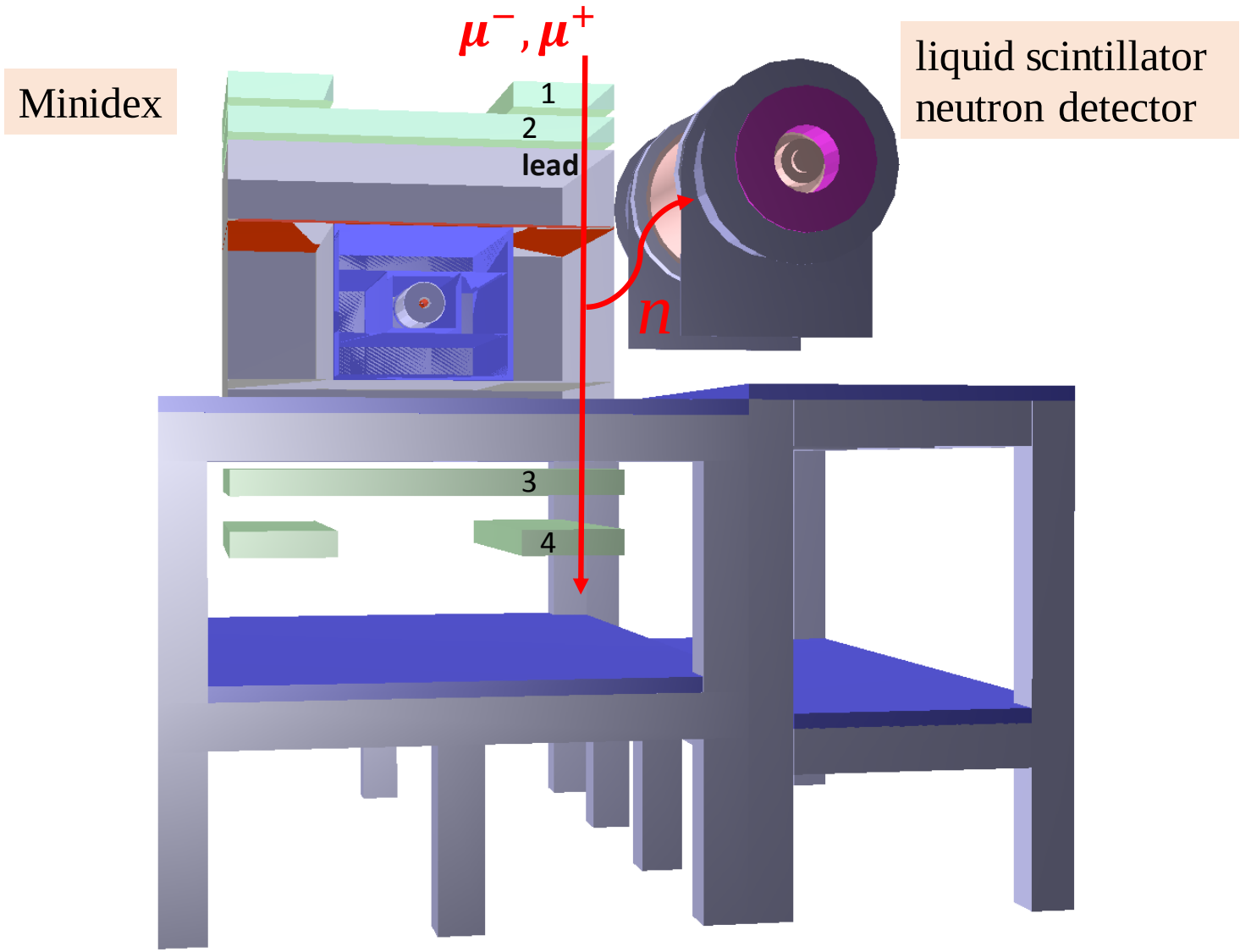
Outline

1 Neutron detector introduction

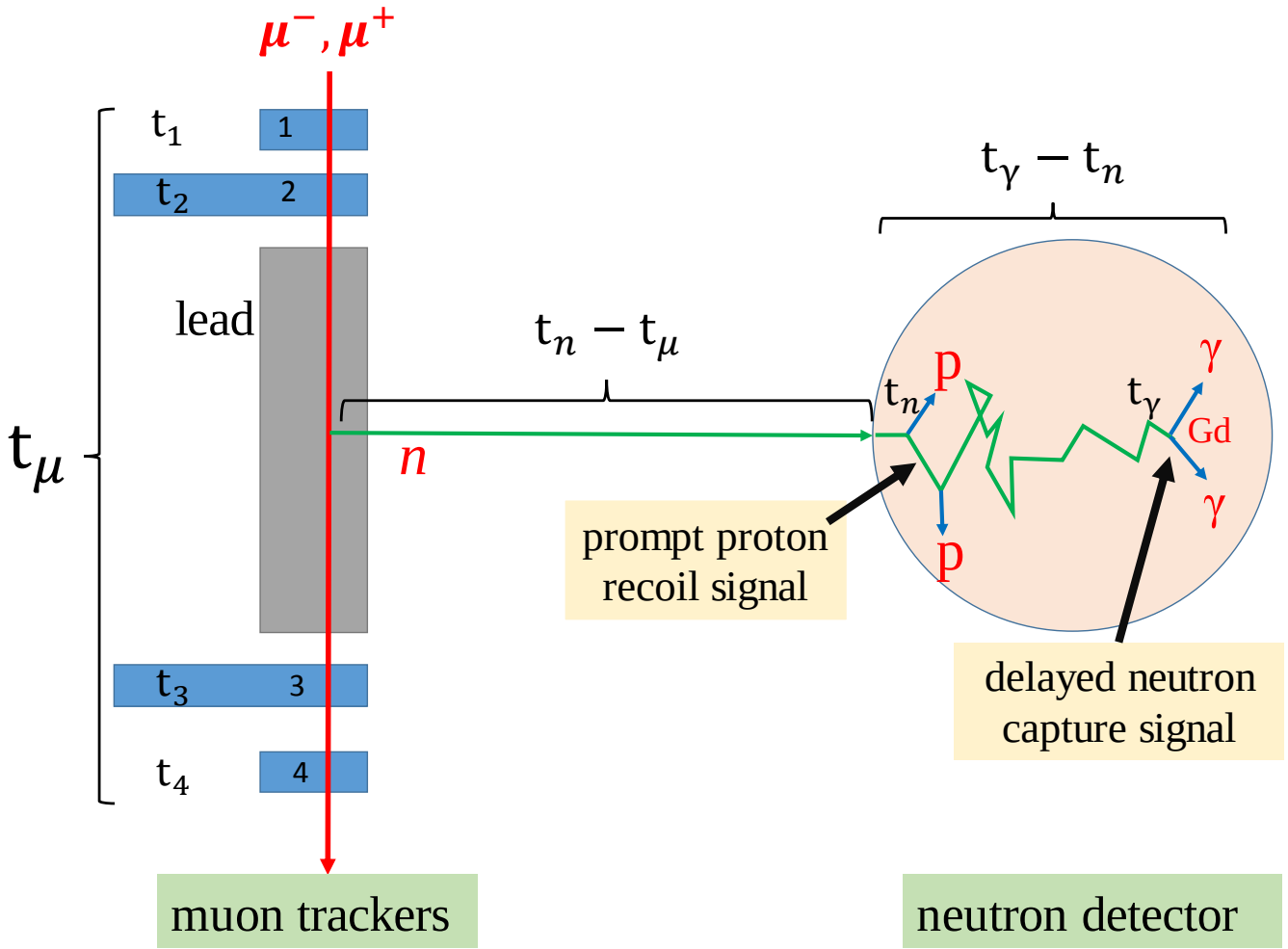
2 Neutron detector along with Minidex
- Neutron detector along with Minidex

Neutron detector along with Minidex in Tübingen

I. Abt et al., Astropart. Phys. 90, 1 (2017)



Selection process for muon induced neutron in lead



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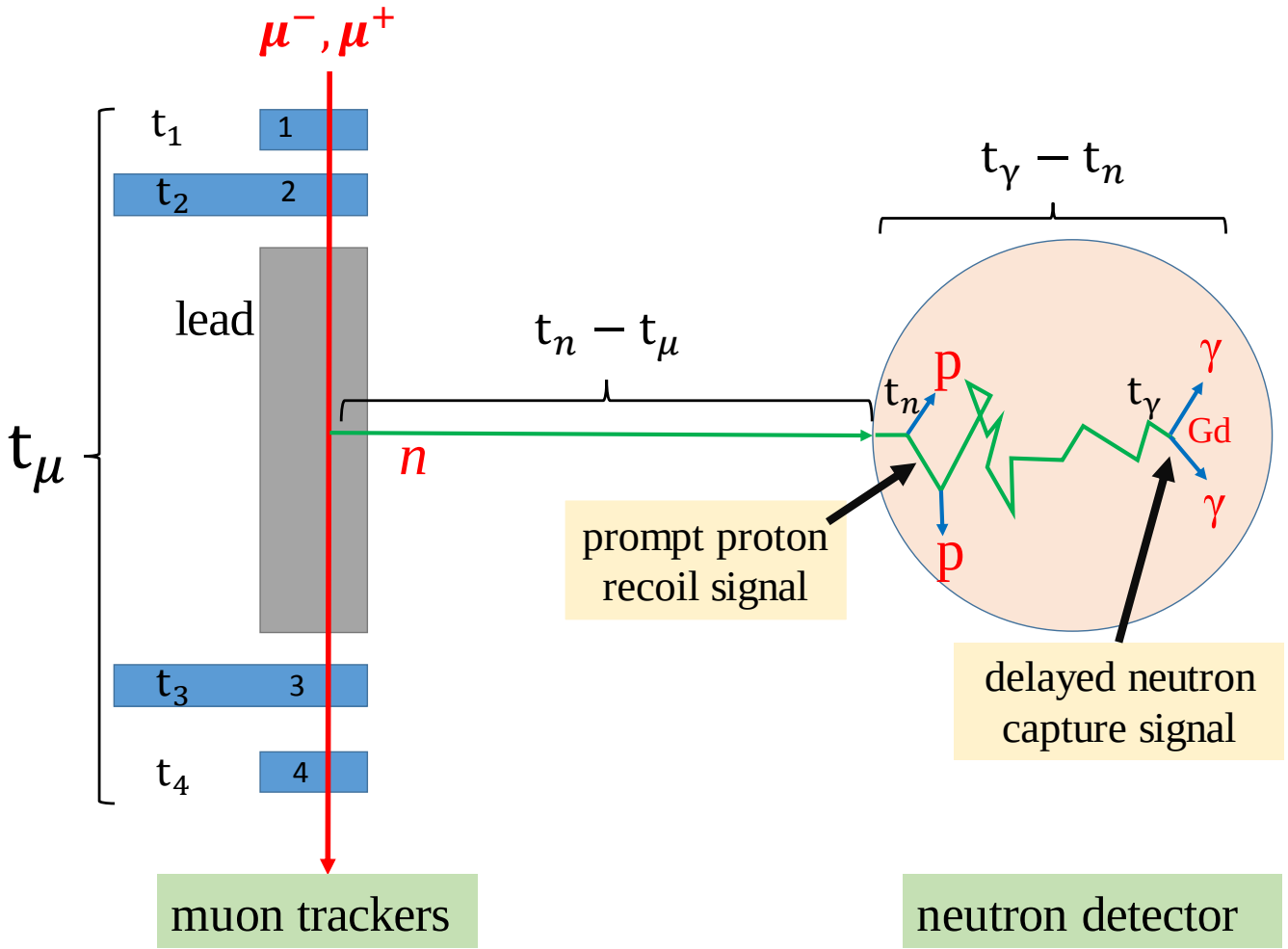

- $\Delta t_{\mu\mu}$: time difference between each two muon trackers

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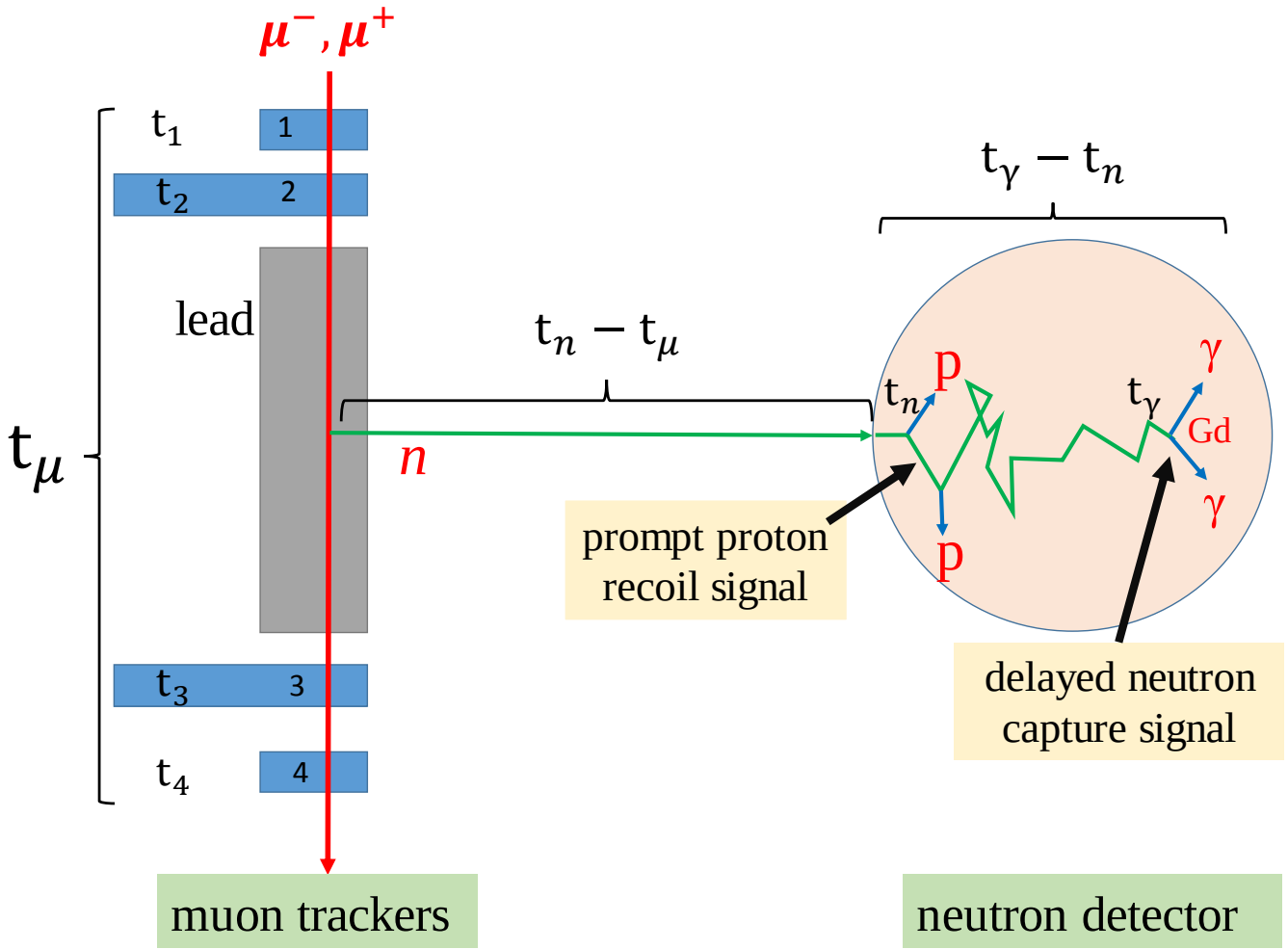

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- $\Delta t_{n\mu}$: time difference between prompt signal and muon trigger

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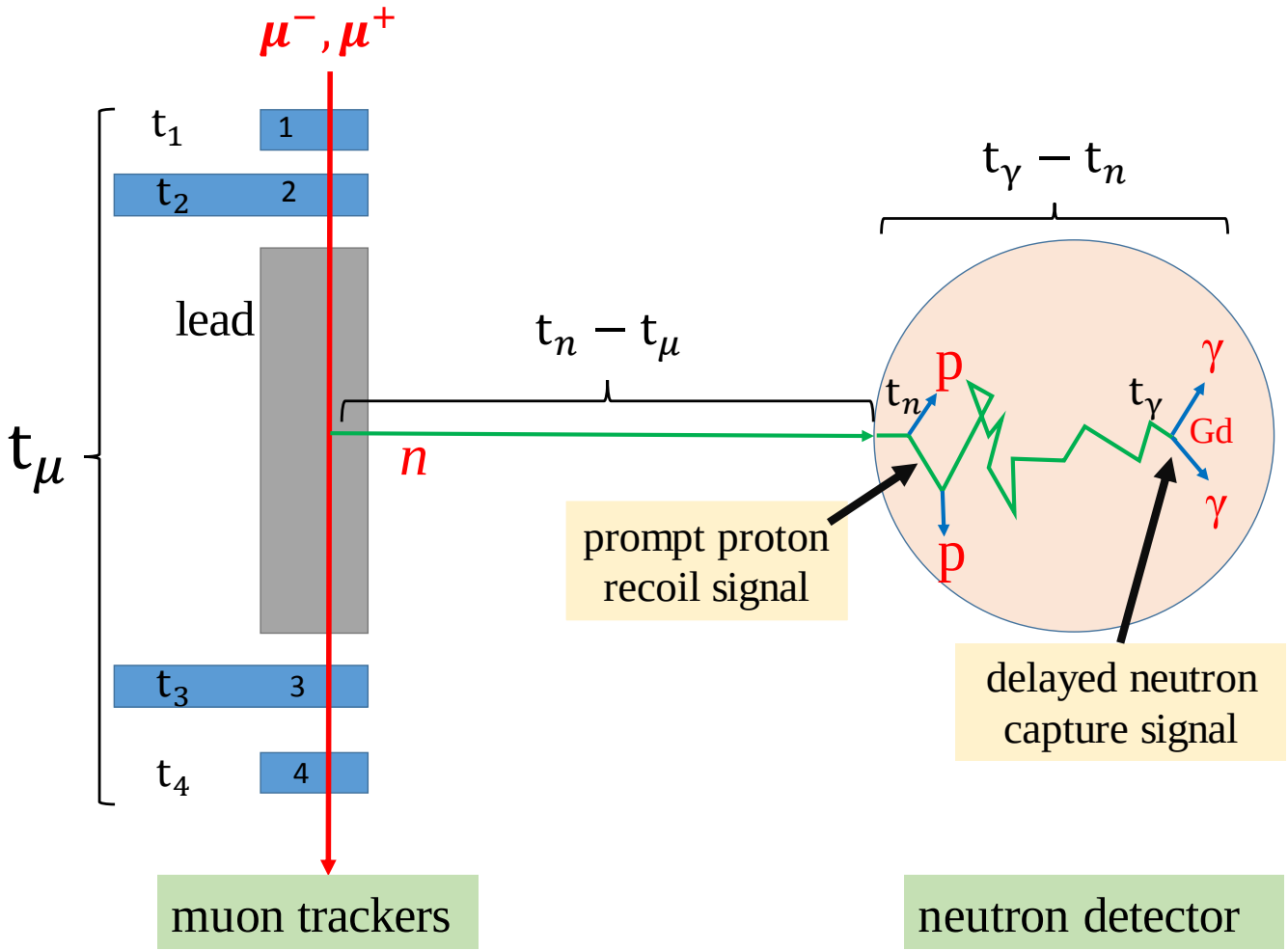
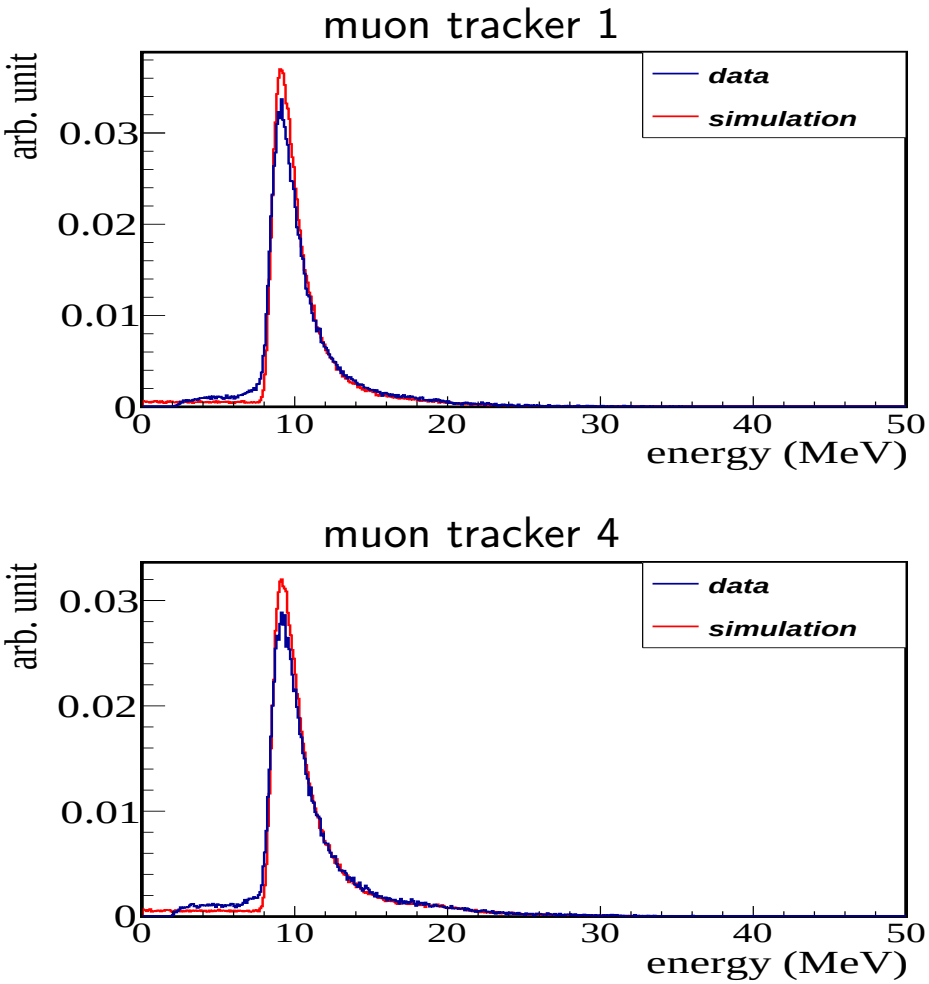


- $\Delta t_{\mu\mu}$: time difference between each two muon trackers
- $\Delta t_{n\mu}$: time difference between prompt signal and muon trigger
- $\Delta t_{\gamma n}$ time difference between prompt and delayed signal

Spectra and $\Delta t_{\mu\mu}$ of muon trackers



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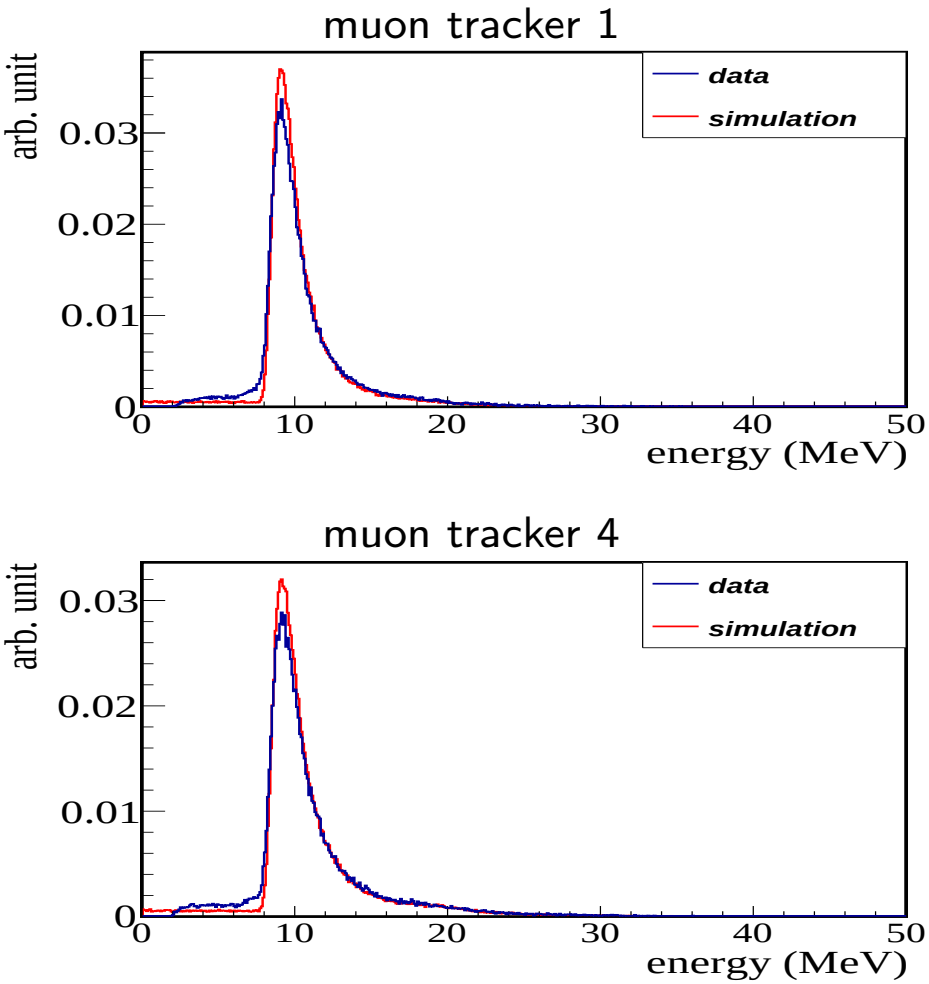
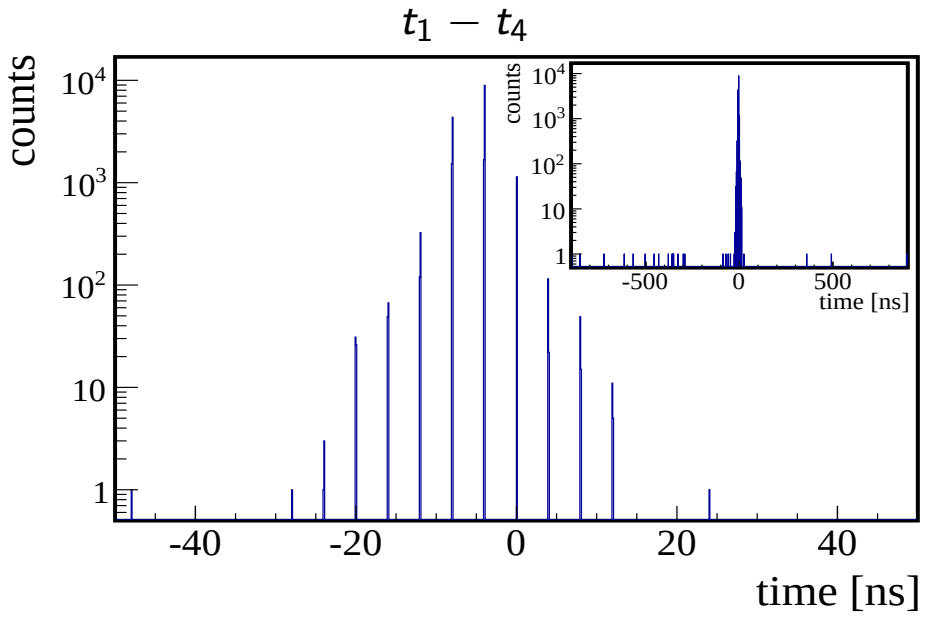
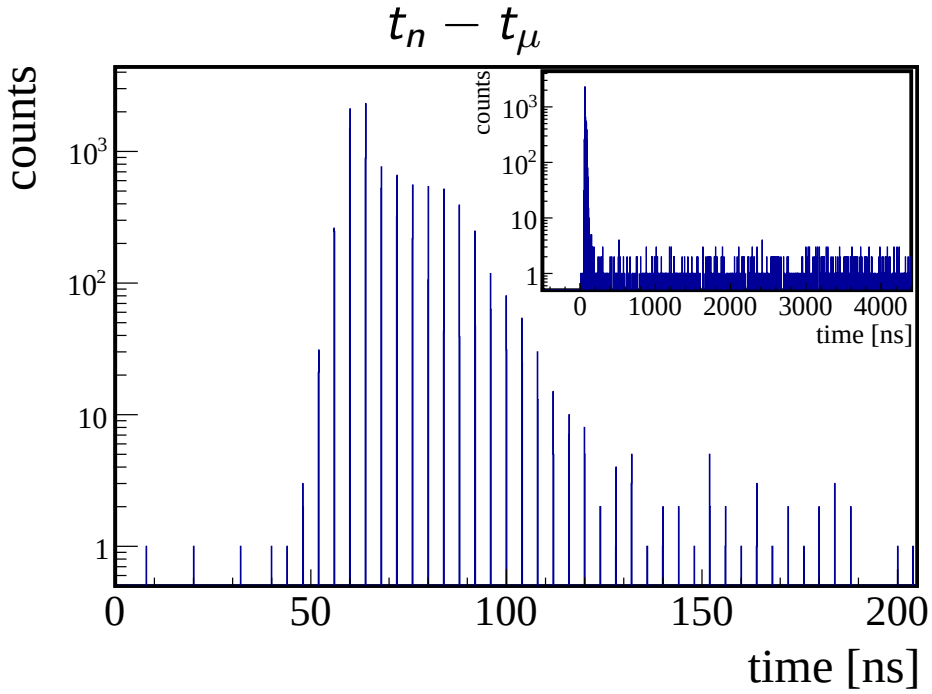




Require

- energy deposition $>$ 6 MeV for each muon tracker
- $\|\Delta t_{\mu\mu}\| < 30ns$

$\Delta t_{n\mu}$ and $\Delta t_{\gamma n}$ distribution



Require

$40ns < \Delta t_{n\mu} < 200ns$

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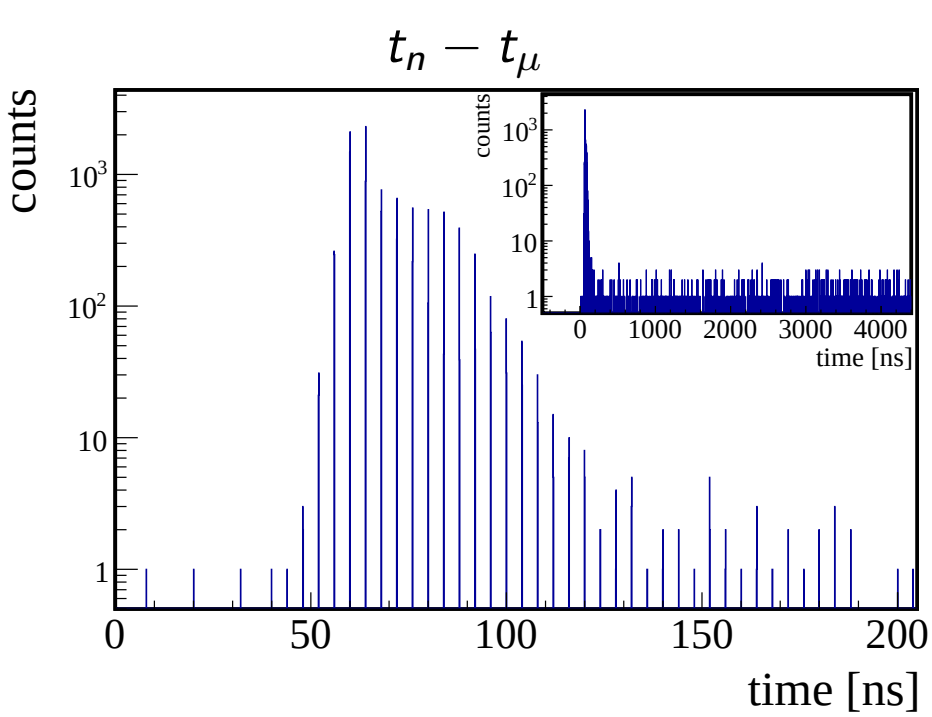
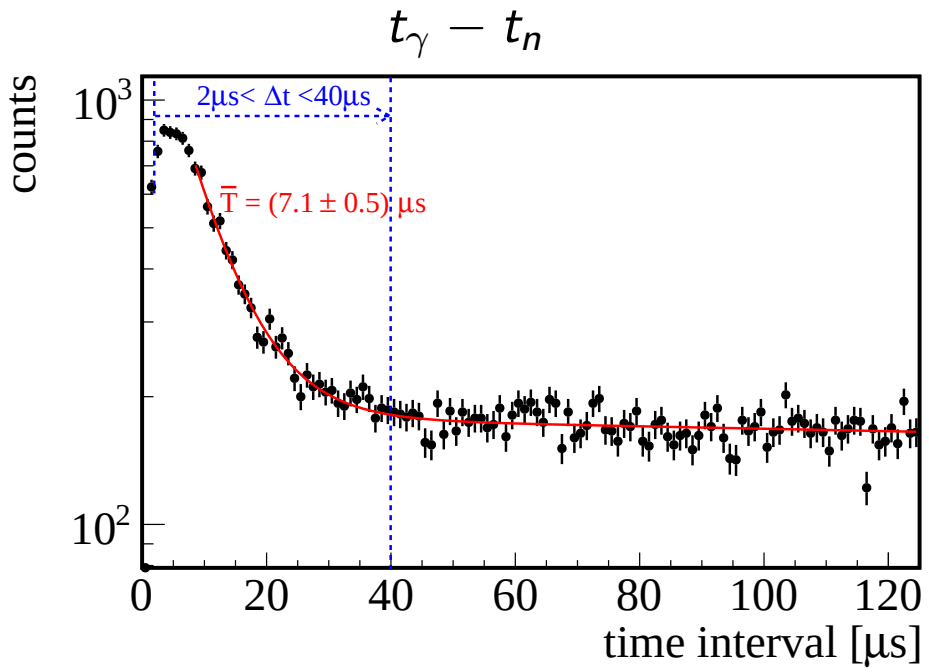




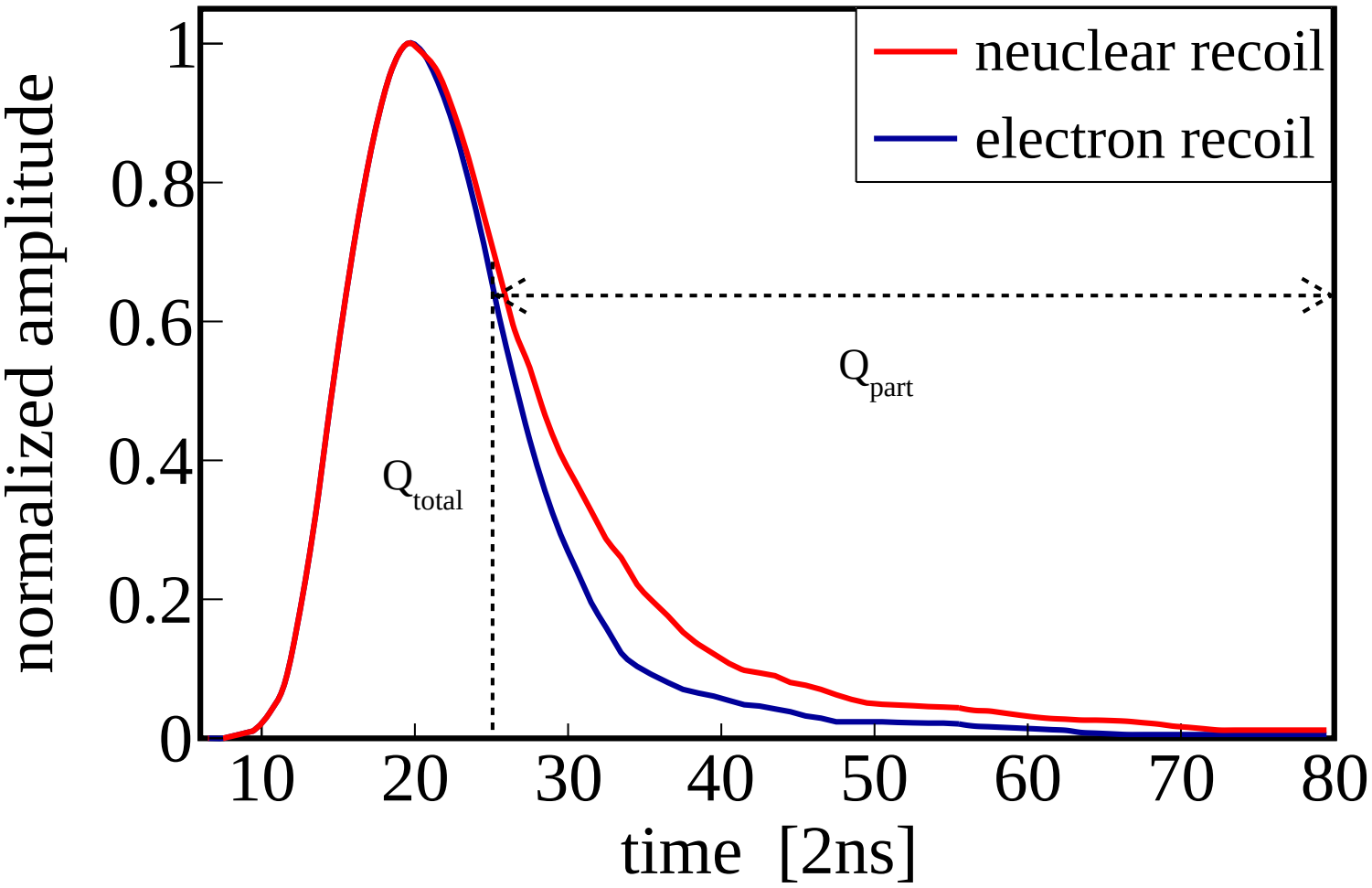
Require

$40ns < \Delta t_{n\mu} < 200ns$

Require

$2\mu s < \Delta t_{\gamma n} < 40\mu s$,
$0.5MeV < E_\gamma < 9MeV$

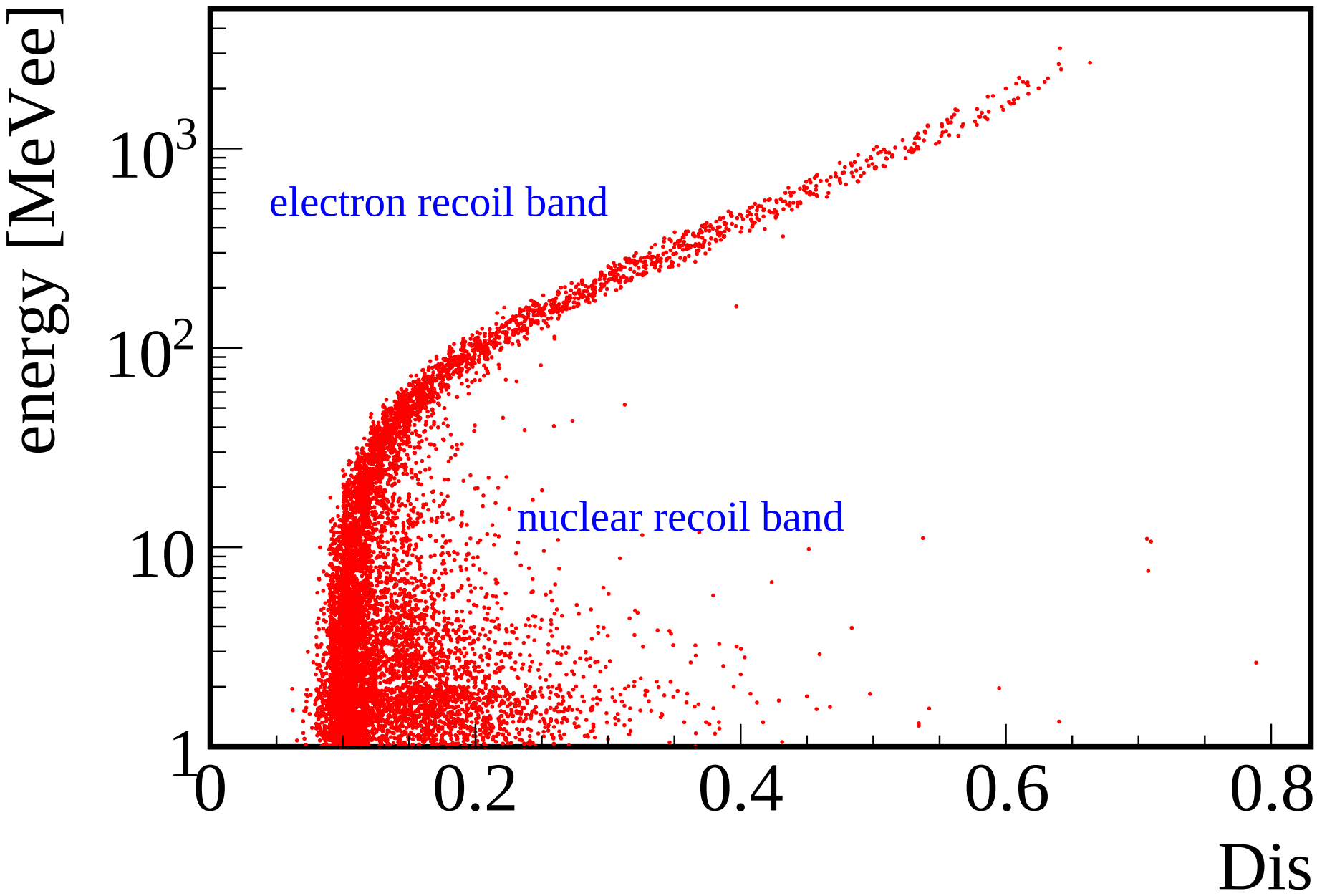
Pulse shape discrimination



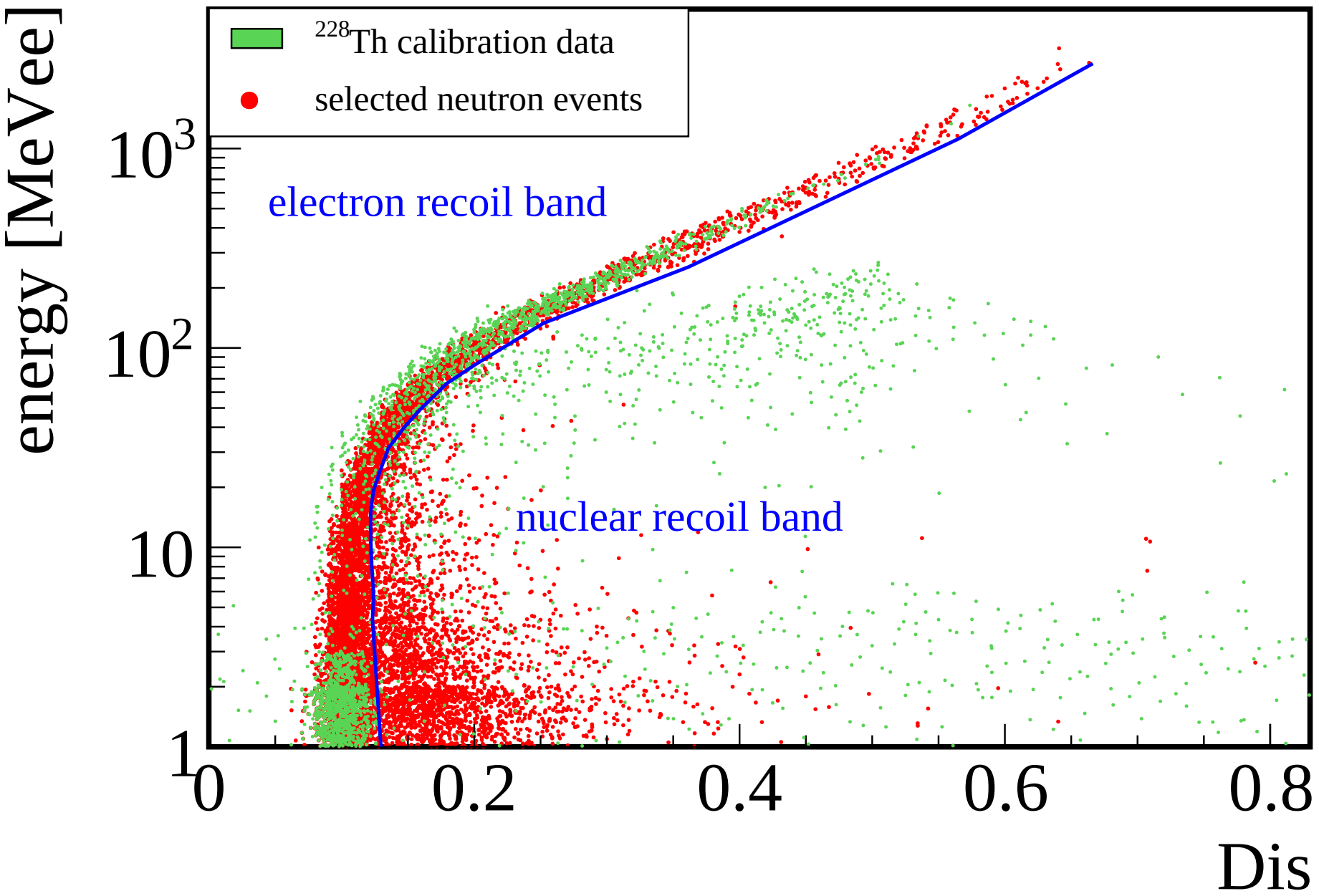
Define

$Dis = Q_{part}/Q_{total}$

Selected neutron events after $\Delta t_{\mu\mu}$, $\Delta t_{n\mu}$, $\Delta t_{\gamma n}$ cut



Selected neutron events compare to ^{228}Th data



Preliminary results

selection process	selected number
muon trigger events	$(7.301 \pm 0.003) \times 10^6$
events detected by neutron detector following the muon trigger events 0.5 MeVee threshold	$(4.283 \pm 0.007) \times 10^5$
captured events $0.5MeV < E_{delayed\gamma} < 9MeV$ $2\mu s < \Delta t < 40\mu s$	$(1.78 \pm 0.01) \times 10^4$
accidental events	$(4.89 \pm 0.54) \times 10^3$
selected muon induced neutron events	$(1.29 \pm 0.06) \times 10^4$
lively time	151.6 days

Summary and outlook

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- A Gd-doped liquid scintillator detector was put along with the Minidex.
- Around 5 months data had been taken from Jan. to July 2016.
- The events of muon induced neutron in lead have been selected.

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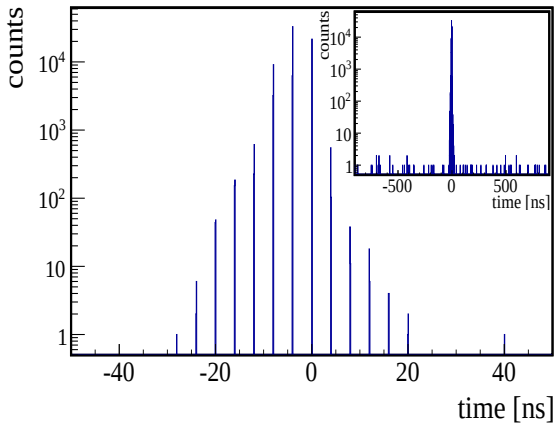
Outlook

- Simulate the efficiencies.
- Reconstruct the energy spectrum of muon induced neutron in lead.

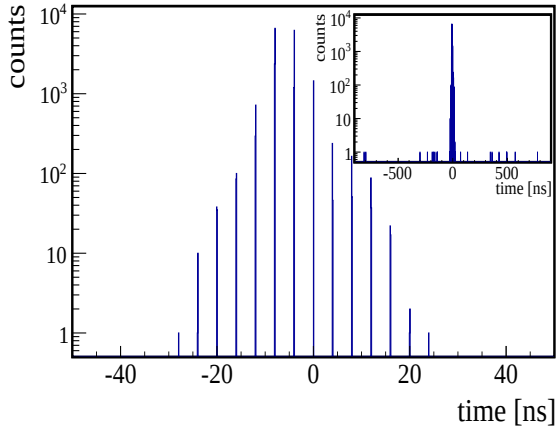
Backup

$\Delta t_{\mu\mu}$: time difference between each two muon trackers

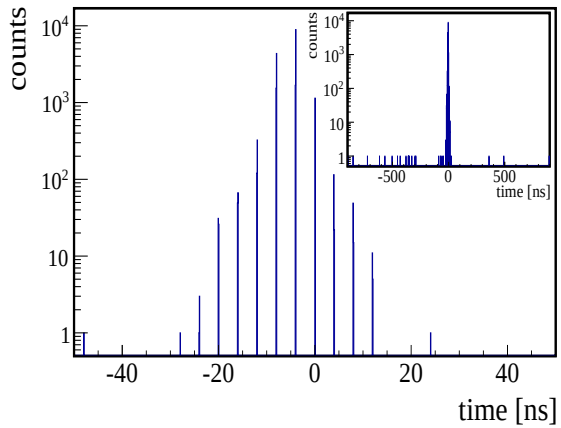
$t_1 - t_2$



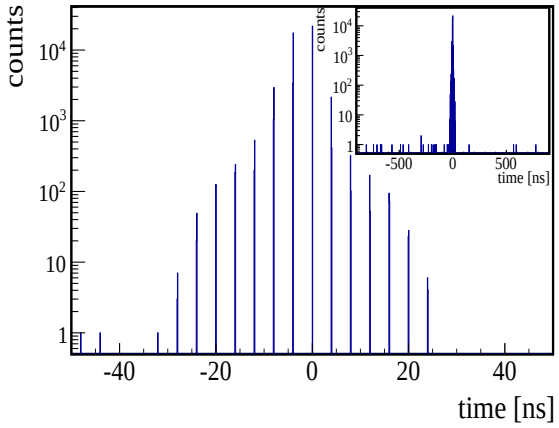
$t_1 - t_3$



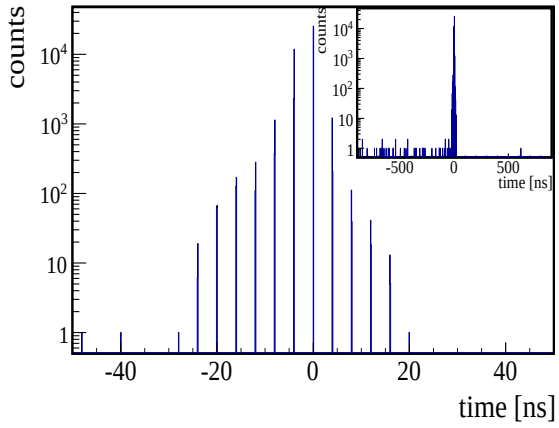
$t_1 - t_4$



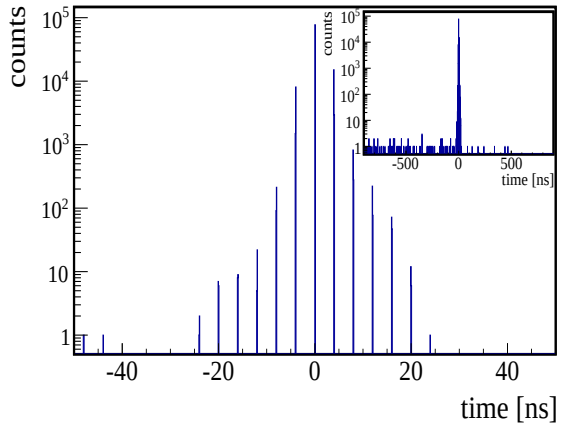
$t_2 - t_3$



$t_2 - t_4$



$t_3 - t_4$



$\|t_1 - t_2\| < 30ns$
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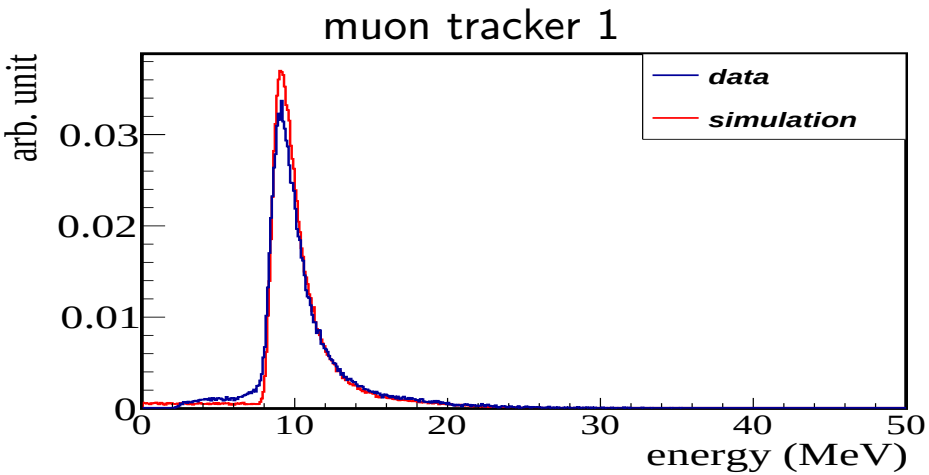
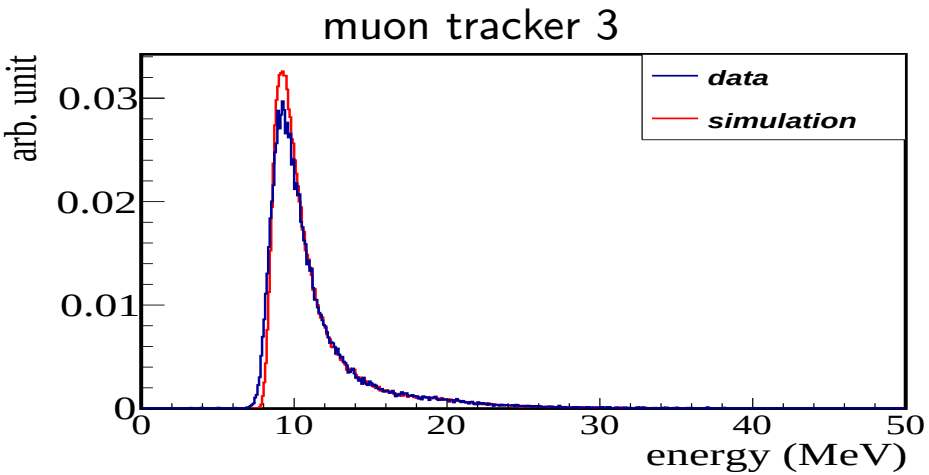
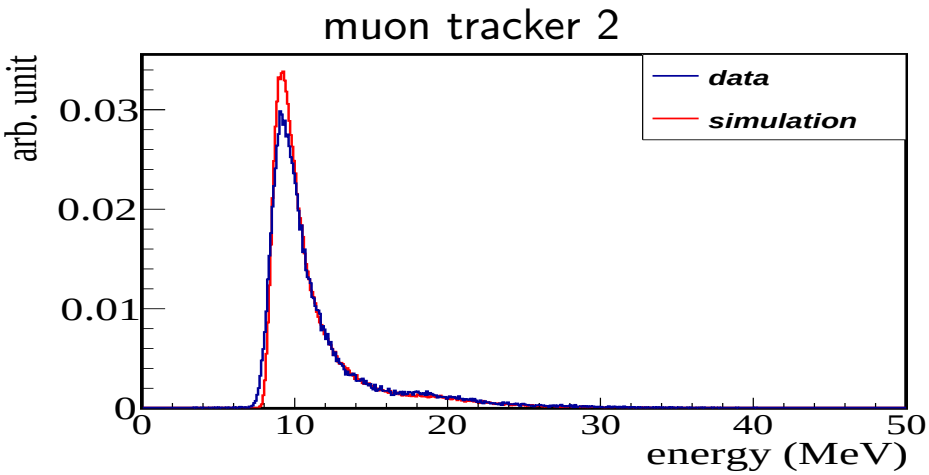
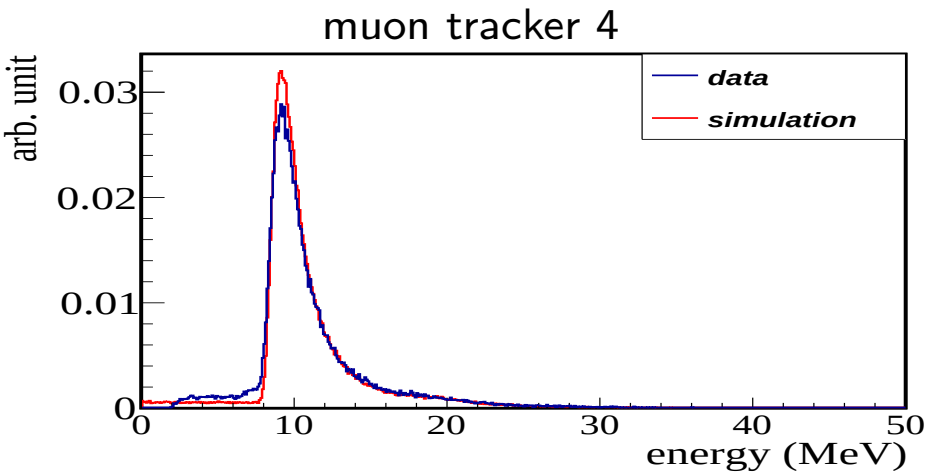
Spectra of muon trackers with muon trigger condition









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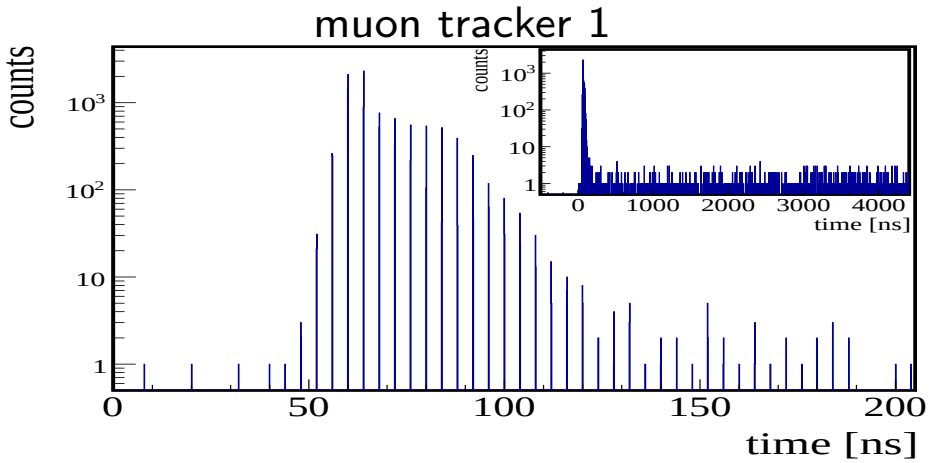
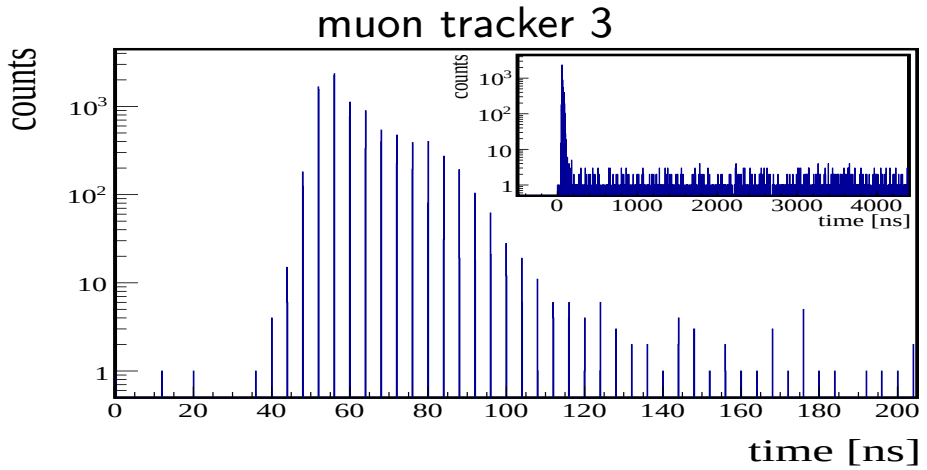
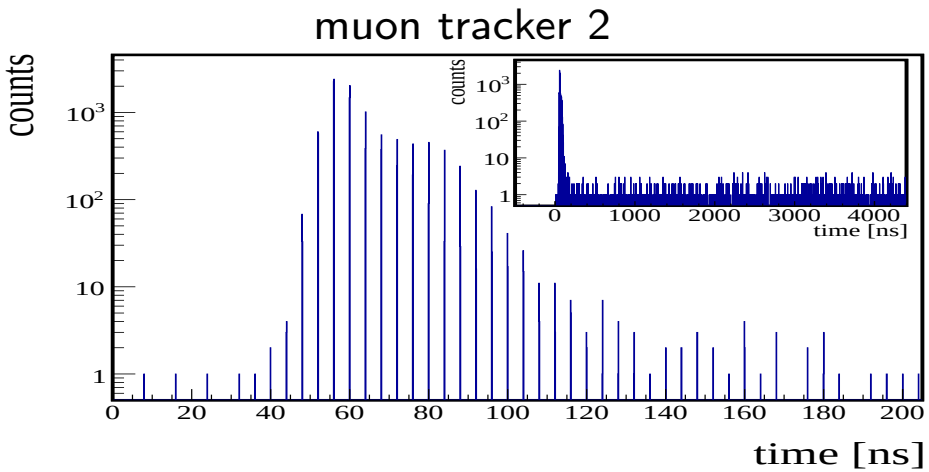
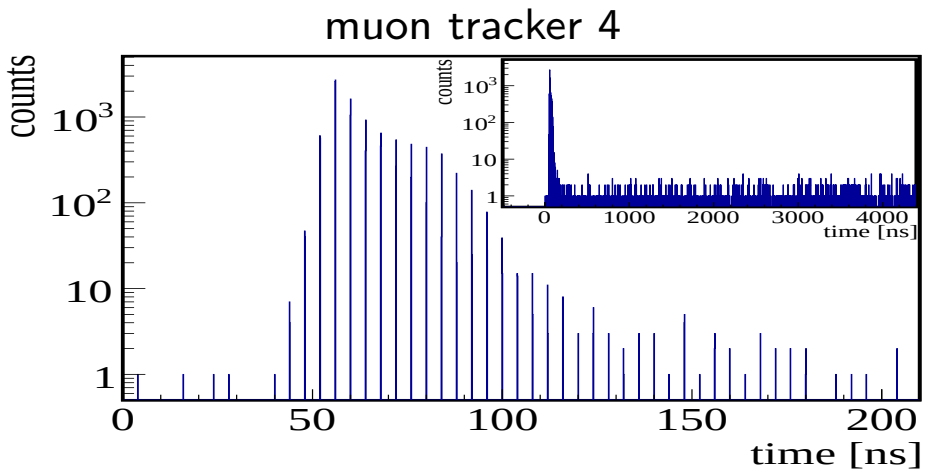
$\Delta t_{n\mu}$ distribution





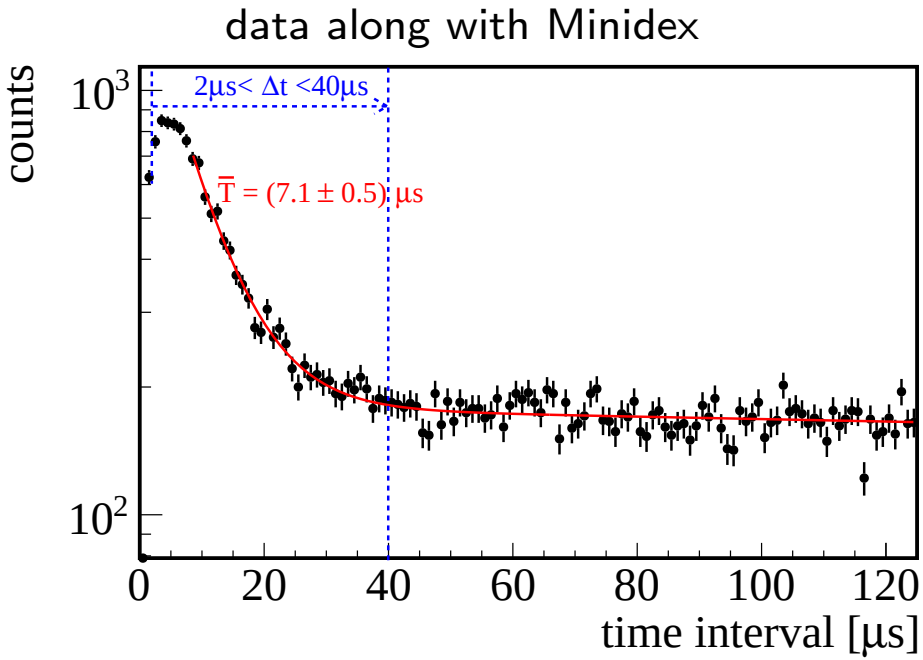


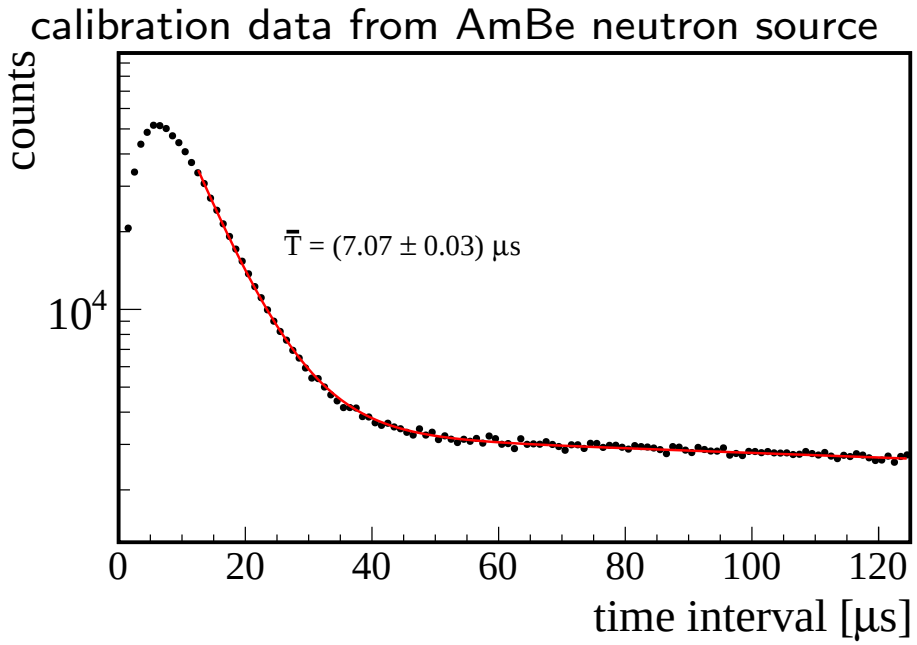


Require

$40ns < (t_n - t_{muon}) < 200ns$

$\Delta t_{\gamma n}$: time difference between prompt and delayed signal





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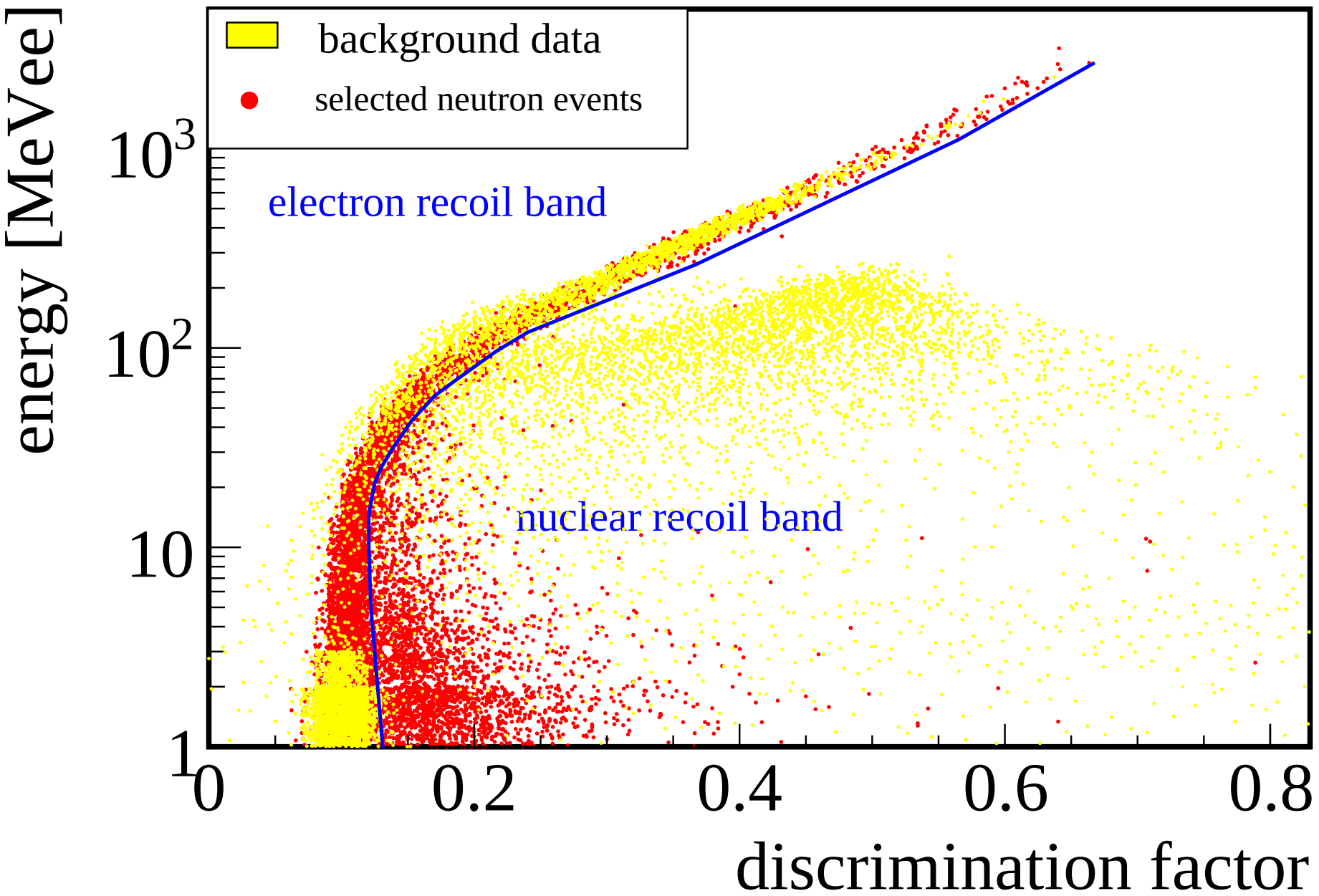
Selected neutron events compare to background