Neutrons in FOOT

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Department of Physics and Astronomy

Program

today

- Introduction (neutron detectors)
- **Neutrons** produced in the **target** (MC simulations)
- **Neutrons** produced in the **environment** (MC simulations)

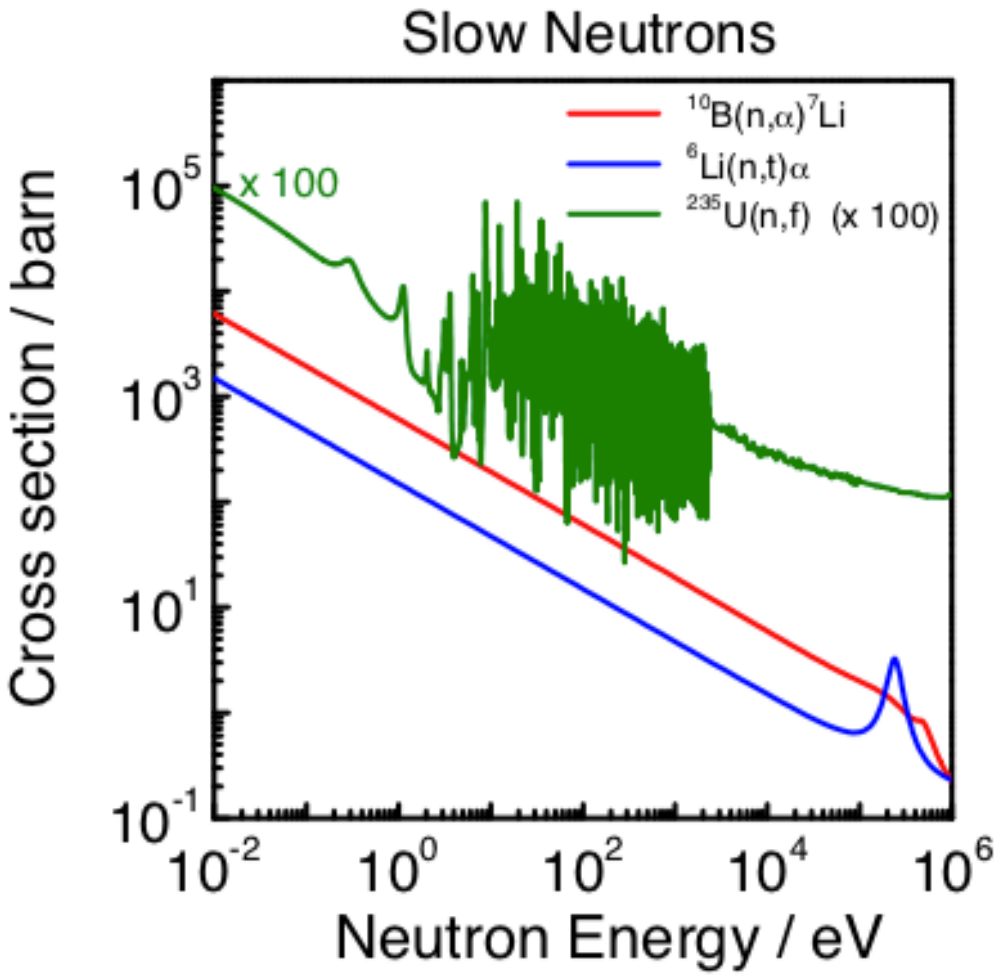
1) Detecting **neutrons** with the **existing setup** (efficiency?)

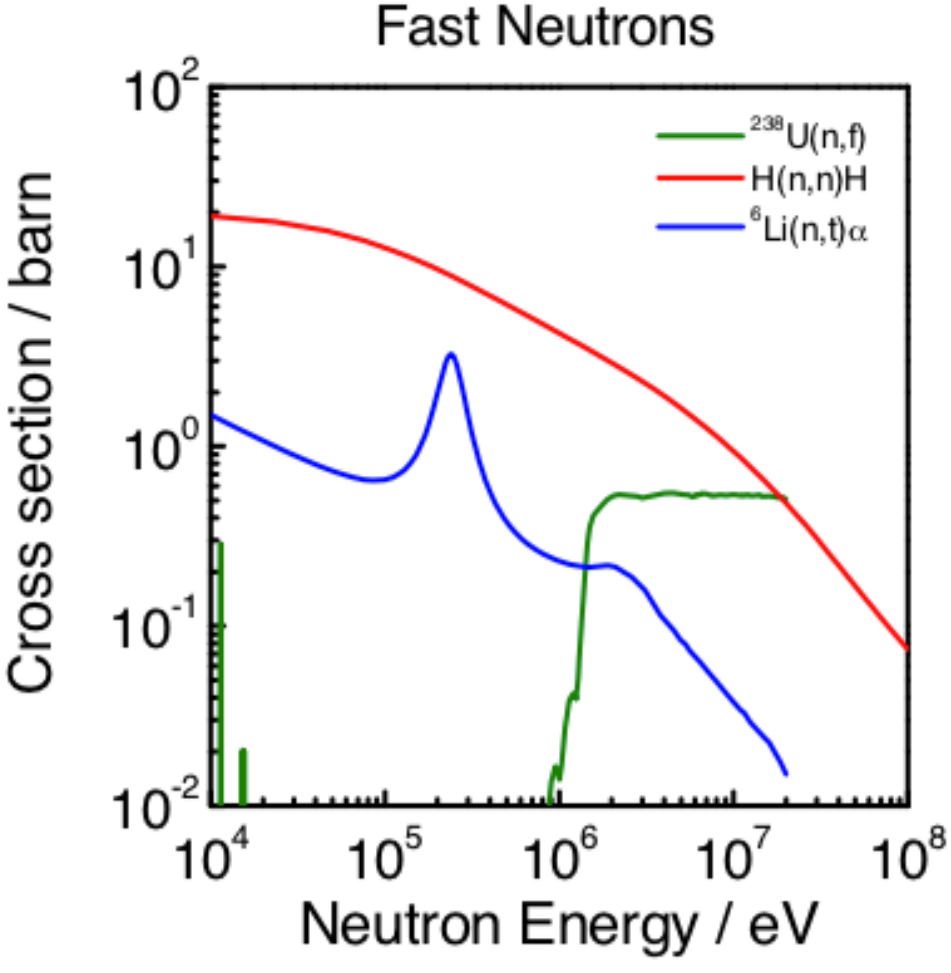
2) Detecting **neutrons** by adding a **new detector** (known efficiency)

Introduction

Neutrons detectors are based on the **conversion** of neutrons either to charged particles or γ rays (nuclear reactions, elastic and inelastic scattering).

Some **reference** reactions and their standard cross sections





Introduction

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Other reaction cross sections? If not well known,
the efficiency of the detector must be estimated
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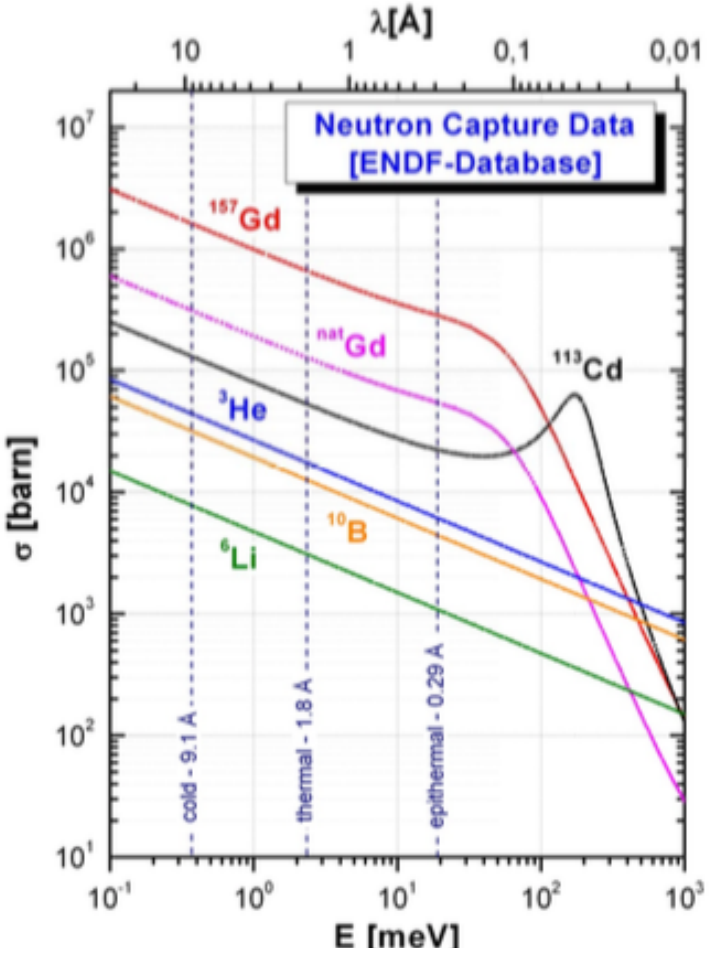


Detectors are commonly based on neutron cross section standards, i.e.: any detector + converter of Li, B, H, U.

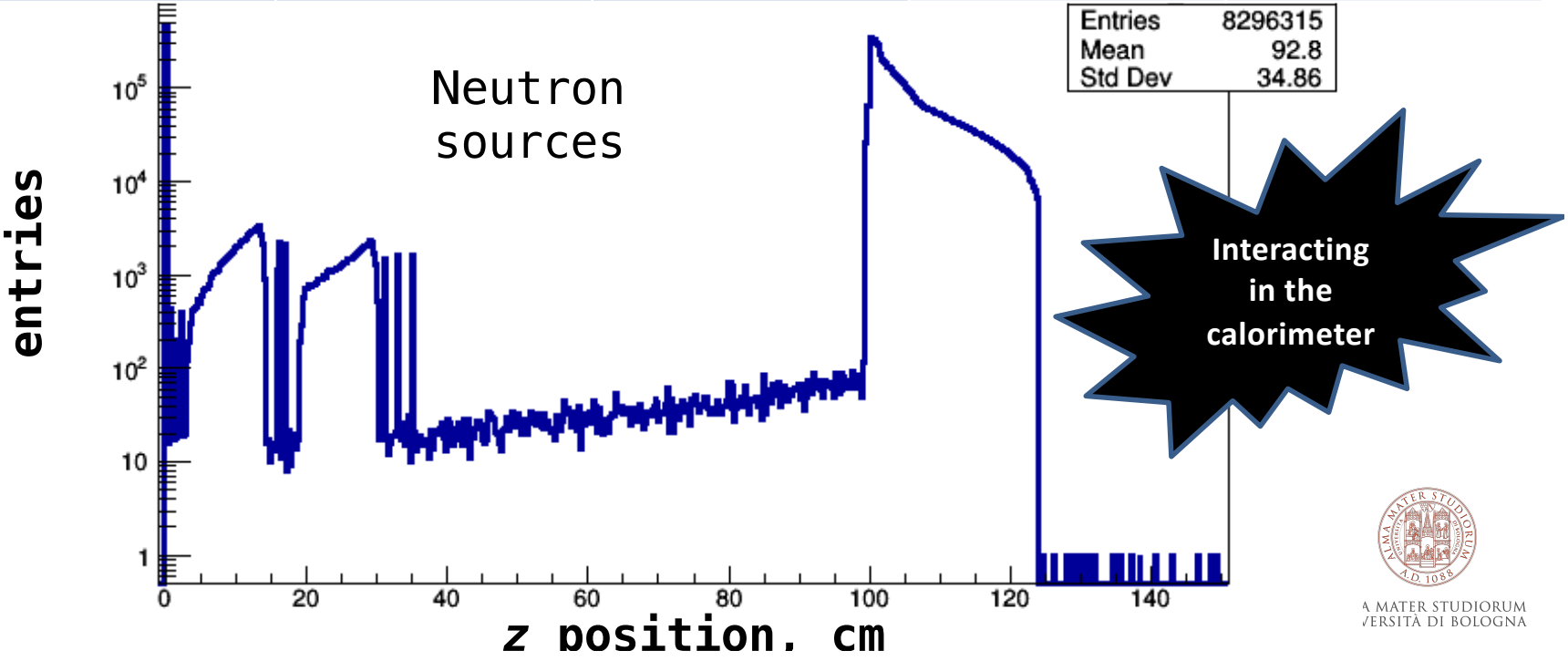
1. In combination with **time-of-flight technique** if we are interested in **neutron energy.**

2. In combination with a **moderator** to **enhance** the **detection efficiency**, information in energy less accurate or lost.

MC simulations – neutrons from target & environment

$^{16}O+C_2H_4$ @200MeV/u (V15) statistics: 2.9E6 fragmentations

	Neutrons (10^6) Produced	Neutrons (10^6) interacting Magnets	Neutrons (10^6) towards Calorimeter	Neutrons (10^6) interacting Calorimeter	Neutrons (10^6) arriving to the world
target	7.4	3.2	1.4	0.9 (~60%)	3.1 (=2.6+0.5)
magnets	17.1			0.15	31.8
Cal.	28.8			7.1	



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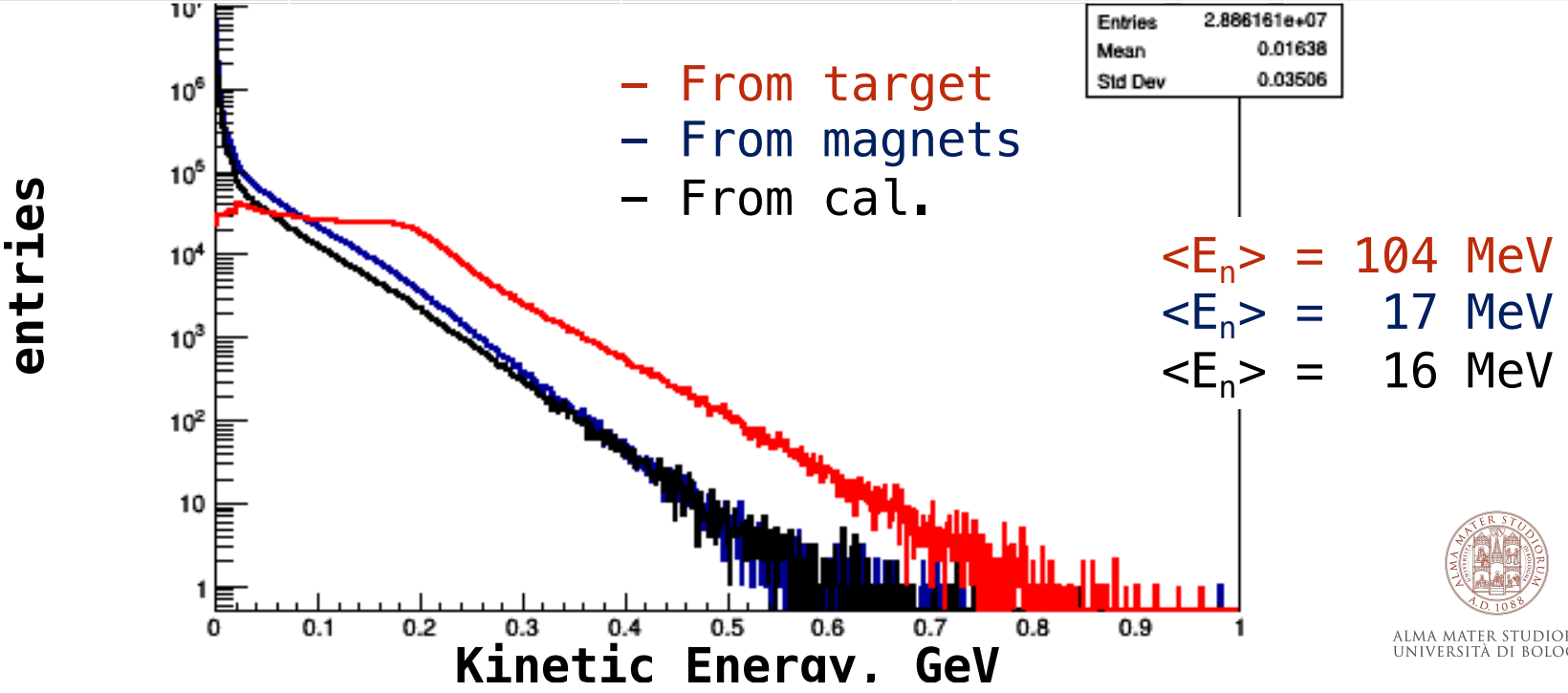

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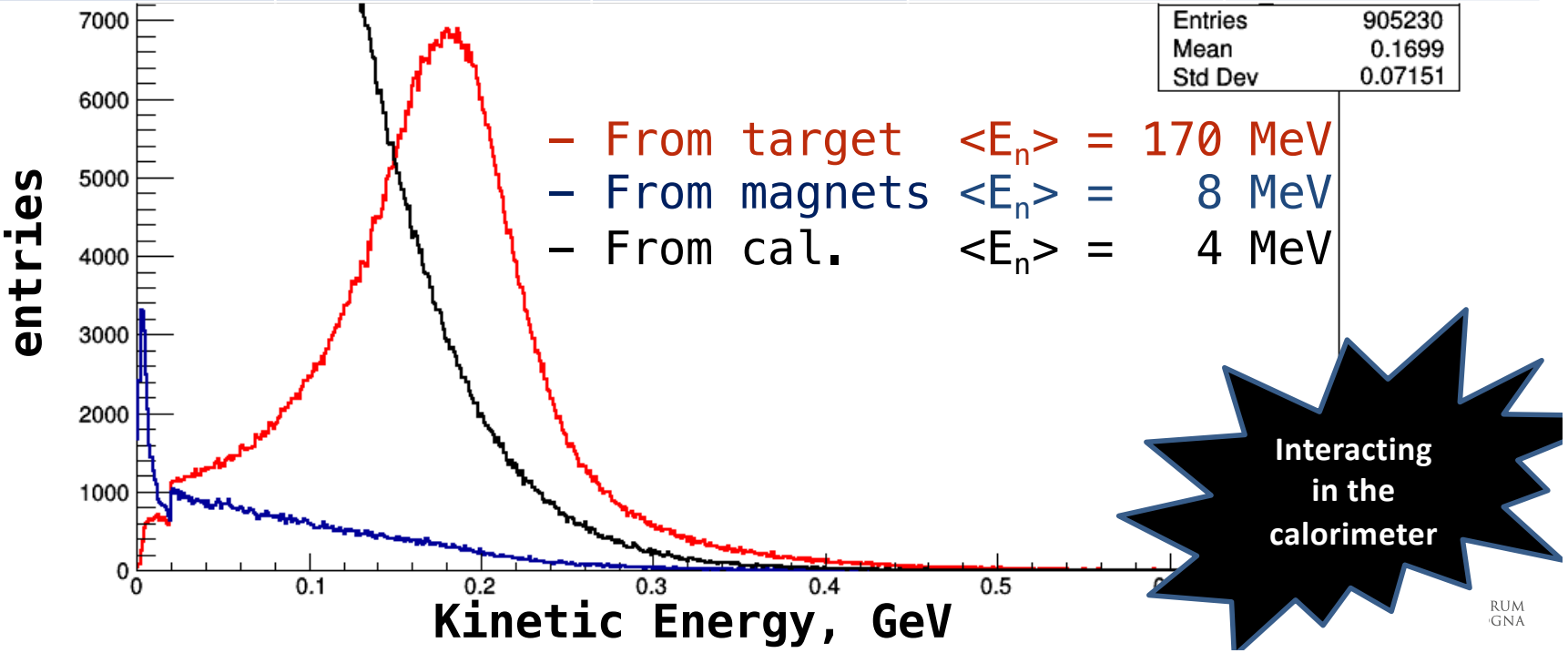

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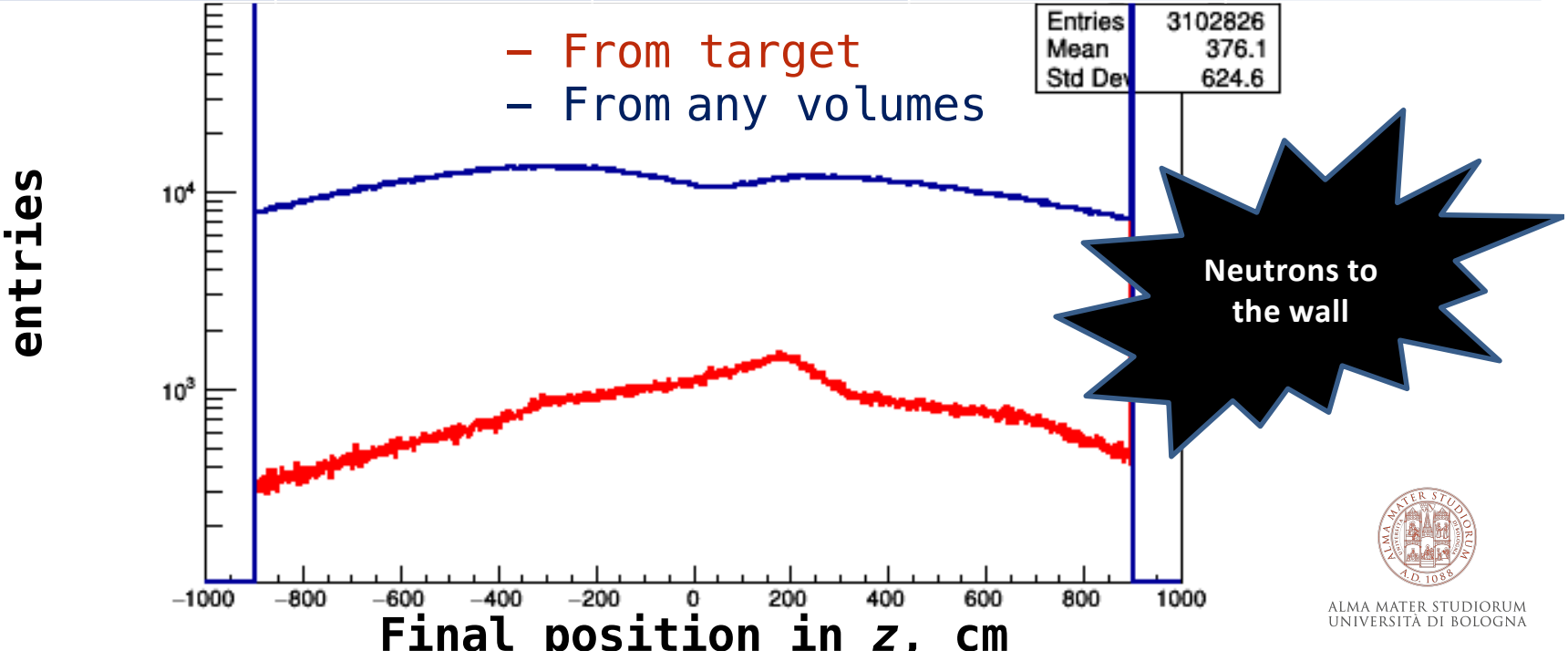

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MC simulations – neutrons from target & environment

Some comments:

- **Large production** of **neutrons** outside the C_2H_4 target.
  - → **Avoid** moderation (detectors sensitive to thermal) neutrons.
  - → Only **high-energy neutrons** originating from target have experimental **signature higher than background** .

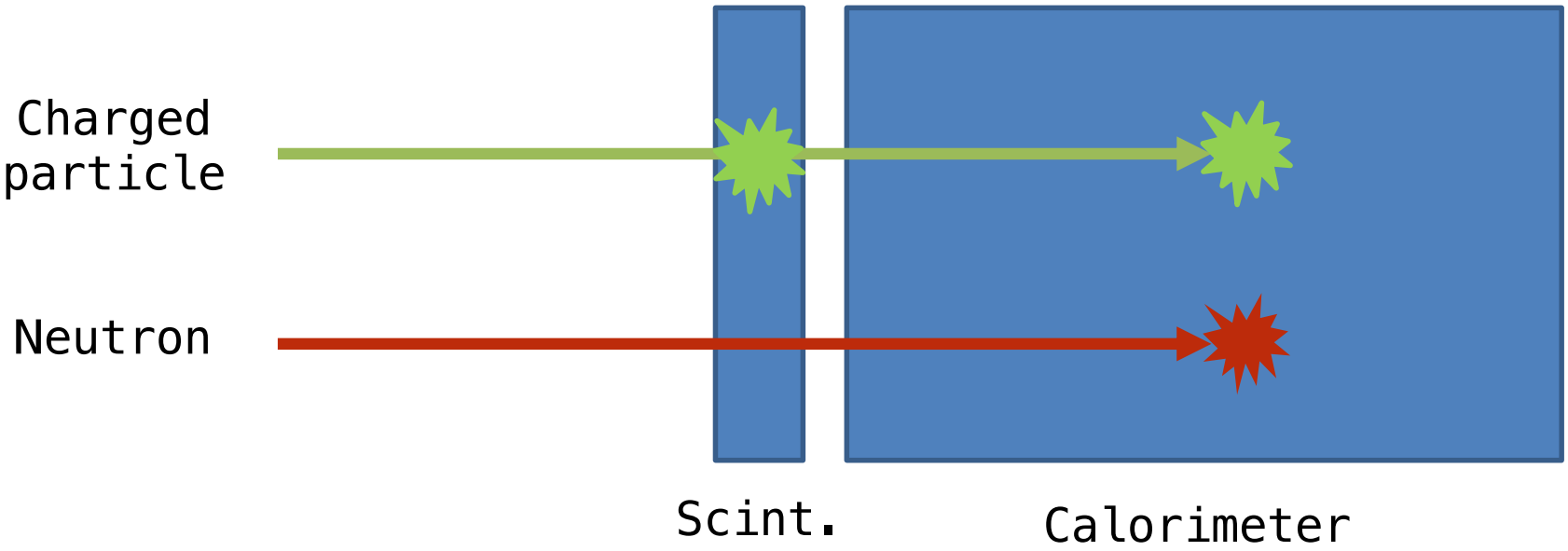
- **Neutrons from** the **target** interacting in the calorimenter are a **factor 6 > neutrons from** the **magnets.**

- **Neutrons from the calorimenter** are not an issue if they **can be tagged.**

- **Background** (neutrons from other sources than the target) can be **reduced** based on the time of flight (**TOF**).

Detecting neutrons with existing setup

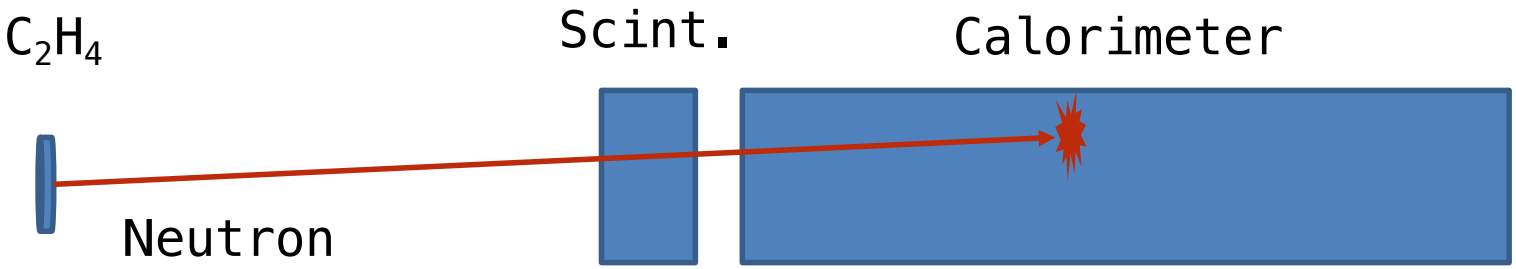
Basic idea: **anticoincidence scintillator – calorimenter**



Average number of particles produced per fragmentation: 9
Granularity of scintillator and calorimenter high enough?

Detecting neutrons with existing setup

Only events from the target



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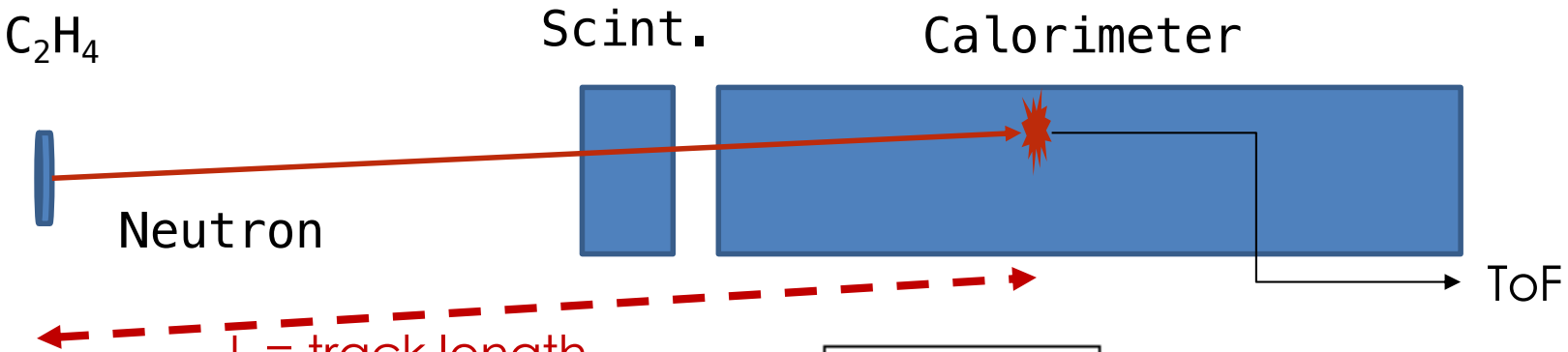
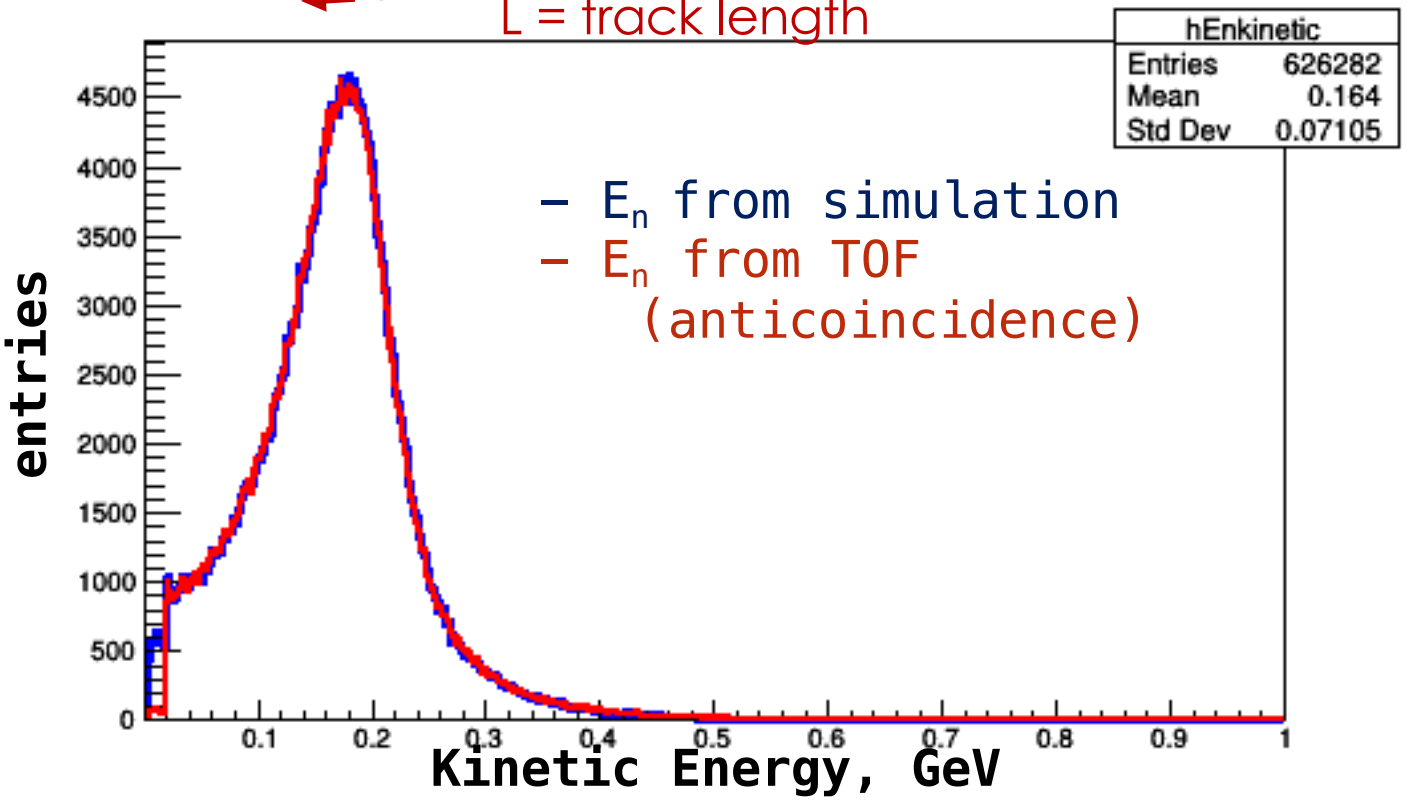




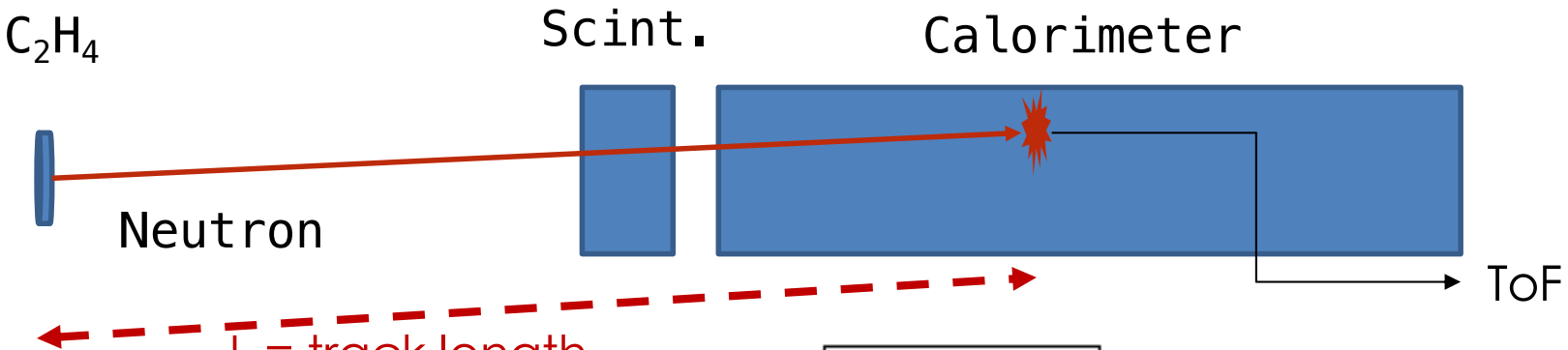
$$\gamma = \frac{1}{\sqrt{1-\beta^2}} = \frac{c\mathrm{ToF}}{\sqrt{c^2\mathrm{ToF}^2 - L^2}}$$

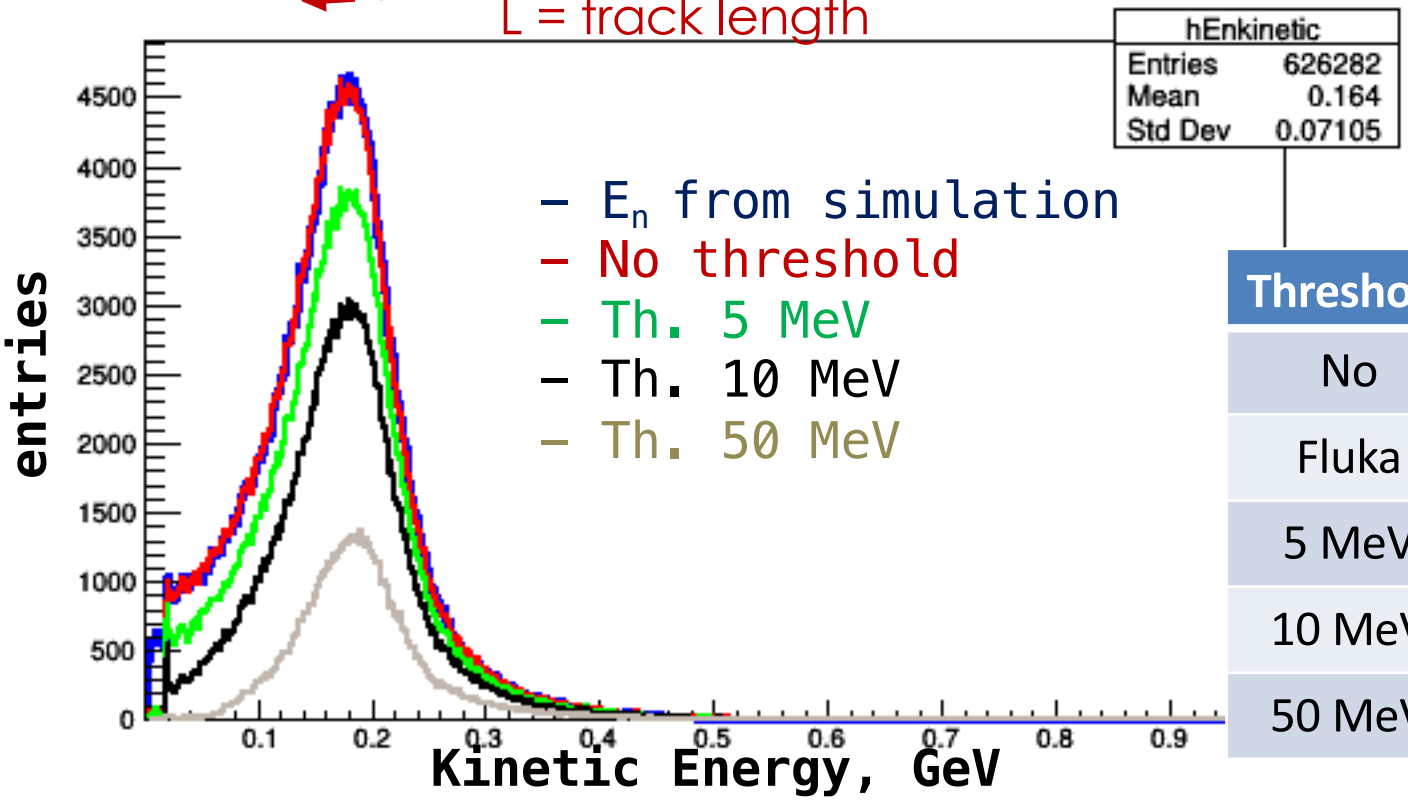
$$E_n = mc^2(\gamma - 1)$$

E_n	TOF
10 MeV	25 ns
20 MeV	18 ns
200 MeV	6.5 ns
500 MeV	4.8 ns

Detecting neutrons with existing setup EFFICIENCY

Only events from the target

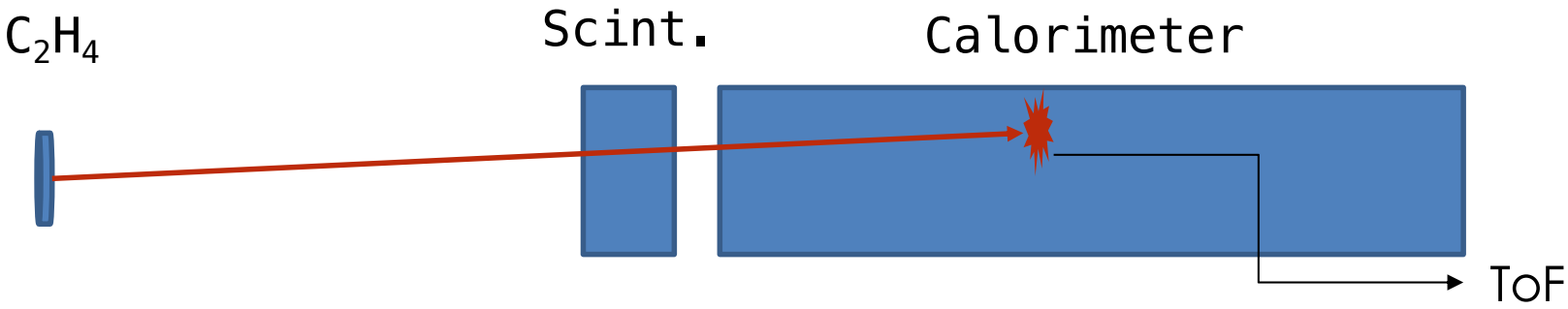


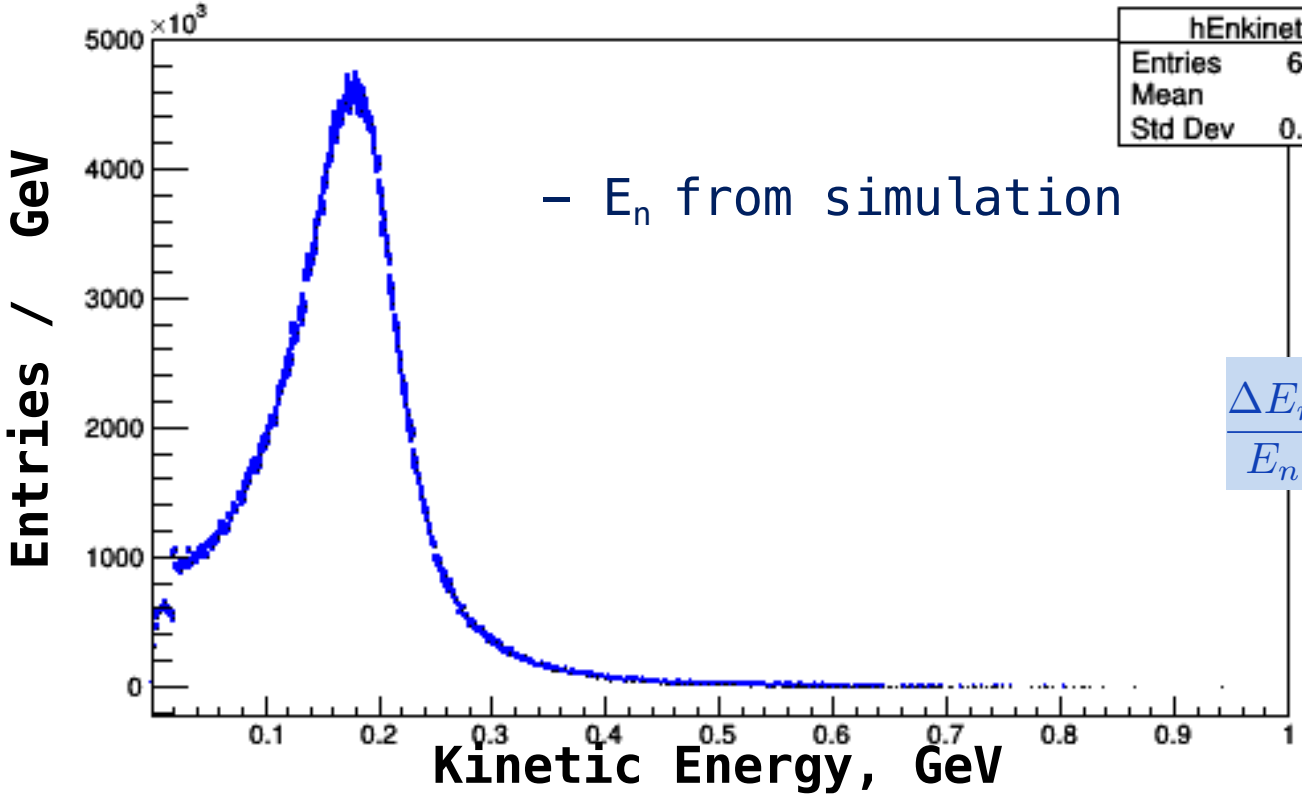


Threshold	Efficiency	
No	100%	**64%**
Fluka	70%	**41%**
5 MeV	65%	**36%**
10 MeV	42%	**27%**
50 MeV	16%	**10%**

Detecting neutrons with existing setup ΔE/E

Only events from the target





– E_n from simulation

$$\gamma = \frac{1}{\sqrt{1-\beta^2}} = \frac{c\mathrm{ToF}}{\sqrt{c^2\mathrm{ToF}^2 - L^2}}$$

$$E_n = mc^2(\gamma - 1)$$

$$\frac{\Delta E_n}{E_n} = (\gamma+1)\gamma\sqrt{\left(\frac{\Delta t}{t}\right)^2 + \left(\frac{\Delta L}{L}\right)^2}$$

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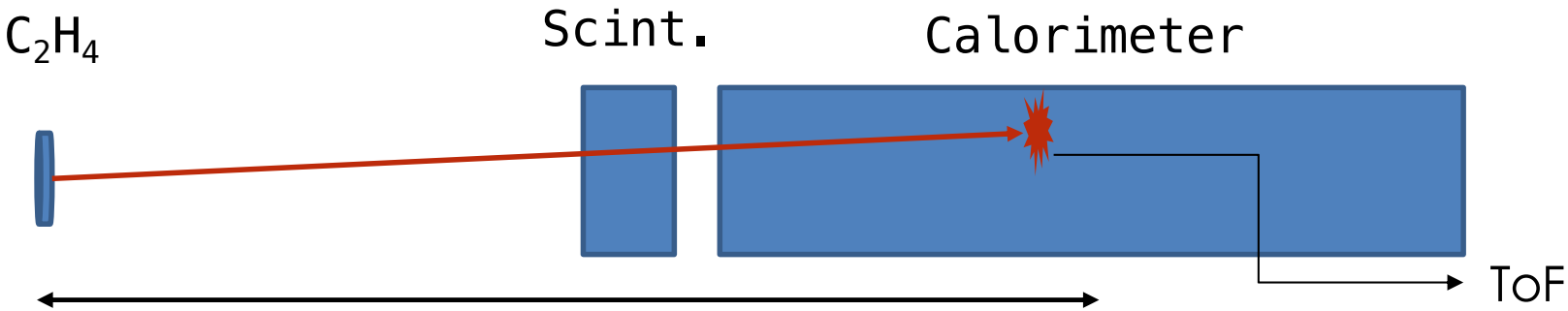
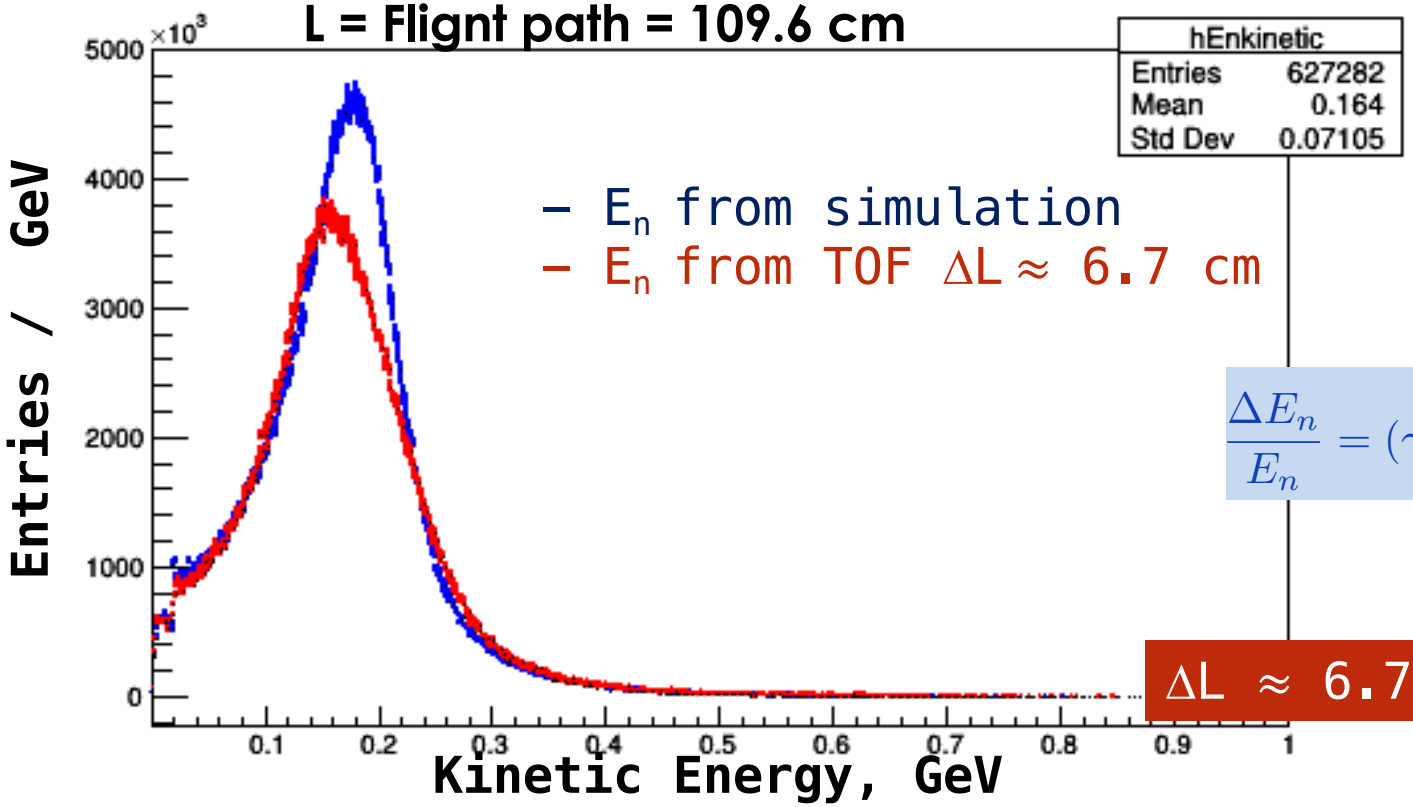
Detecting neutrons with existing setup ΔE/E

Only events from the target



L = Flignt path = 109.6 cm



- E_n from simulation
- E_n from TOF $\Delta L \approx 6.7$ cm

$$\gamma = \frac{1}{\sqrt{1-\beta^2}} = \frac{c\mathrm{ToF}}{\sqrt{c^2\mathrm{ToF}^2 - L^2}}$$

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Detecting neutrons with existing setup ΔE/E

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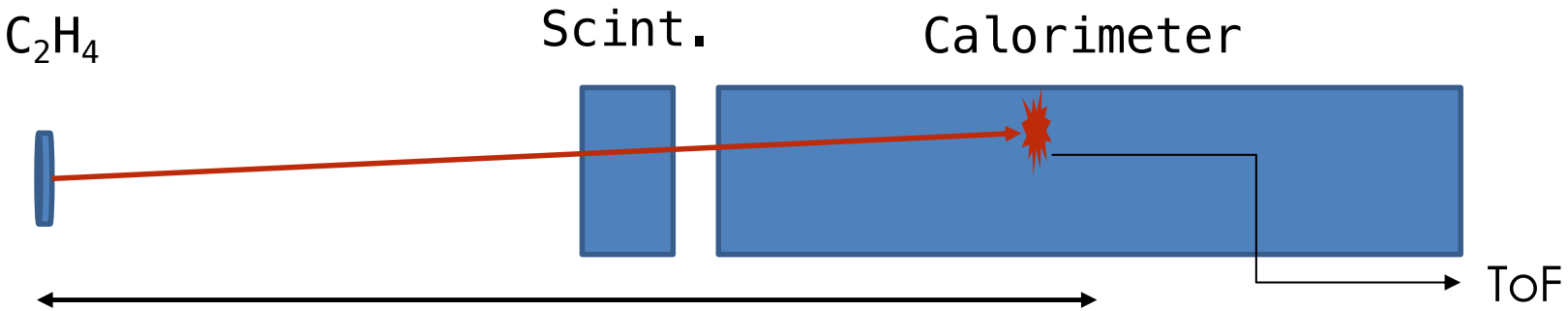

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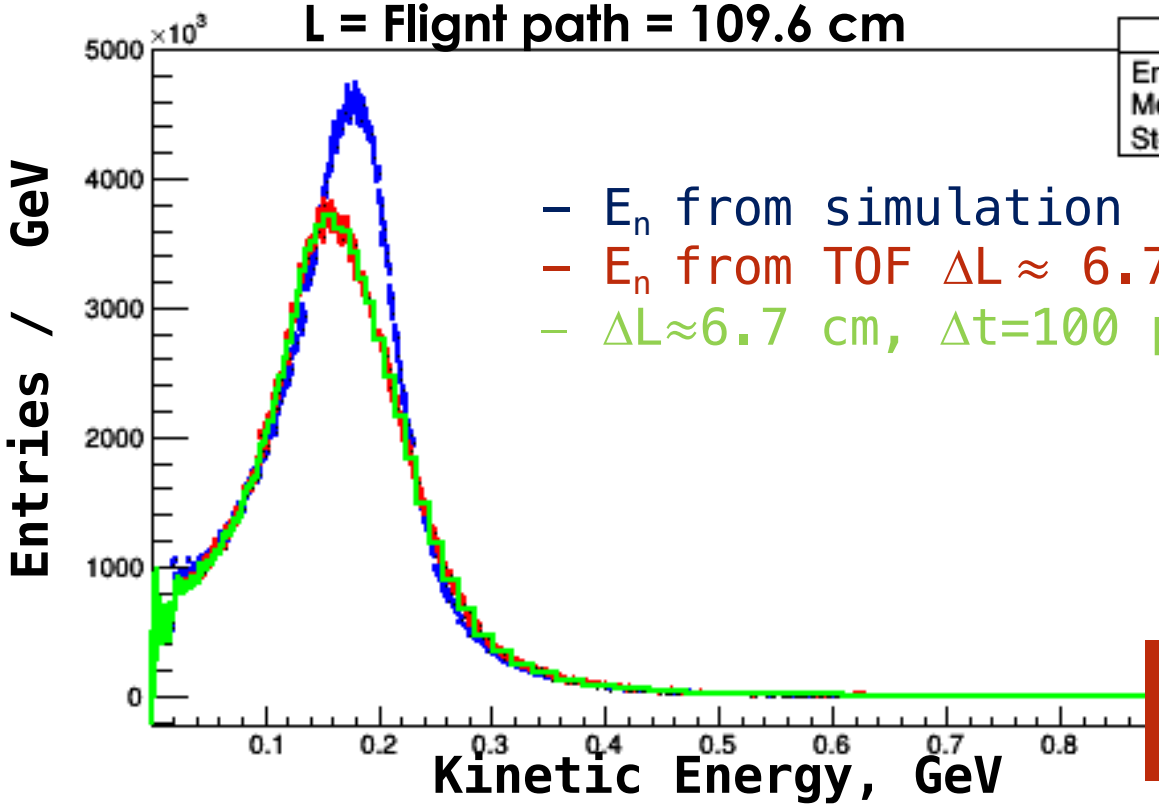

- E_n from simulation
- E_n from TOF $\Delta L \approx 6.7$ cm
- $\Delta L \approx 6.7$ cm, $\Delta t = 100$ ps

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$\Delta L \approx 6.7$ cm
$\Delta t = 100$ ps

Detecting neutrons with existing setup ΔE/E

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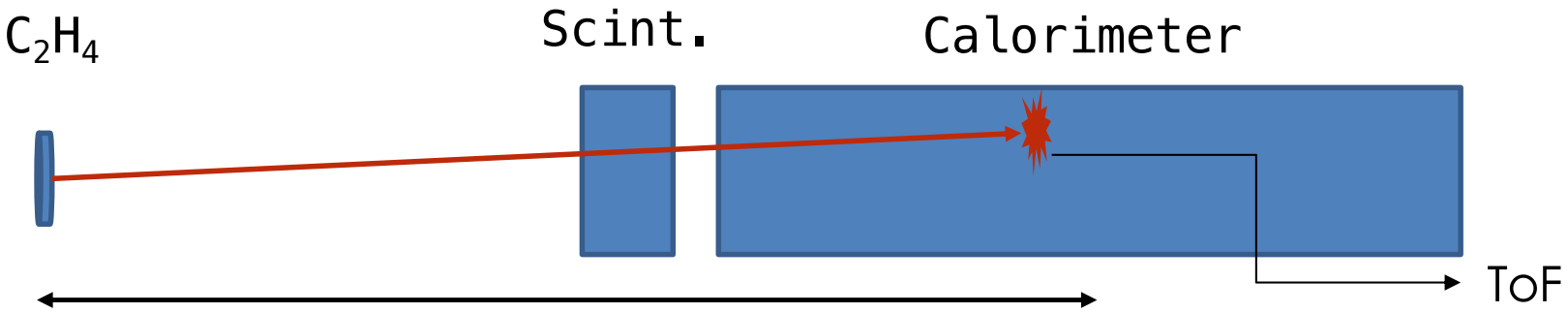

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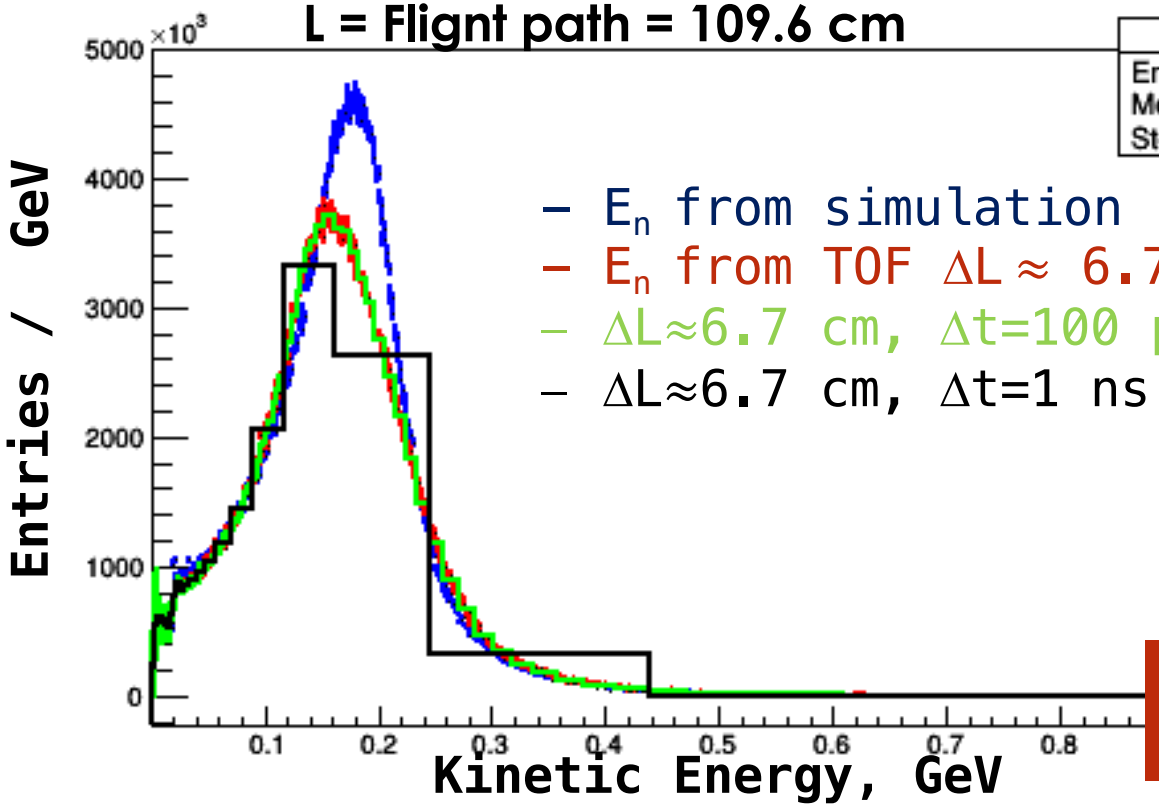

- E_n from simulation
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- $\Delta L \approx 6.7$ cm, $\Delta t = 100$ ps
- $\Delta L \approx 6.7$ cm, $\Delta t = 1$ ns

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$\Delta L \approx 6.7$ cm
$\Delta t = 1$ ns

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Detecting neutrons with existing setup ΔE/E

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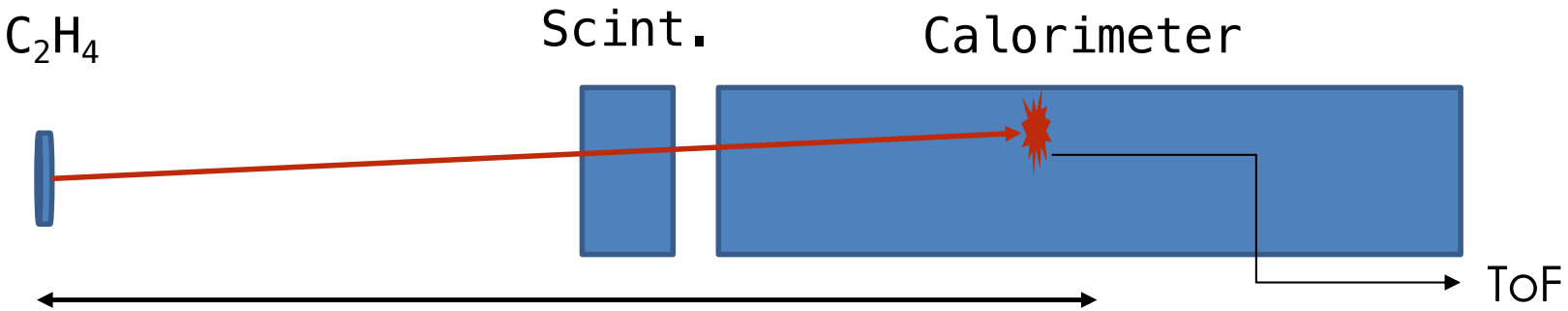

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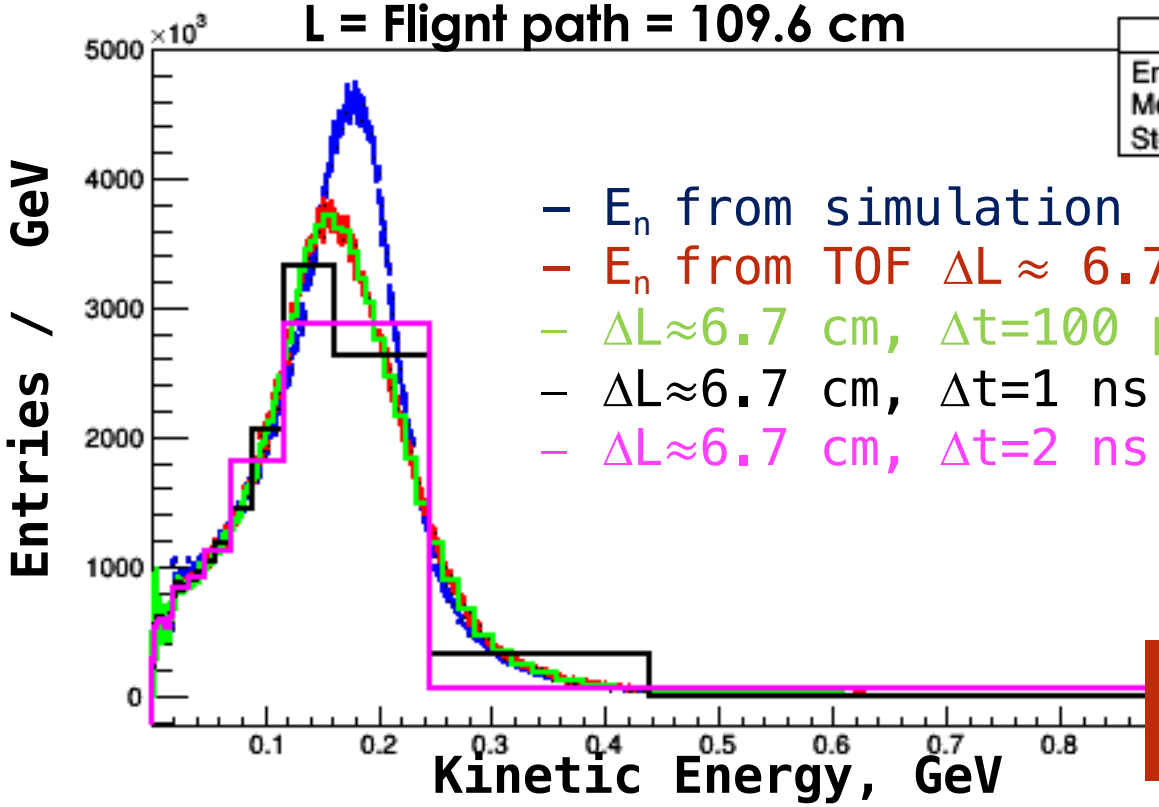

- E_n from simulation
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- $\Delta L \approx 6.7$ cm, $\Delta t = 100$ ps
- $\Delta L \approx 6.7$ cm, $\Delta t = 1$ ns
- $\Delta L \approx 6.7$ cm, $\Delta t = 2$ ns

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$\Delta L \approx 6.7$ cm
$\Delta t = 2$ ns

Detecting neutrons with existing setup

ΔE/E

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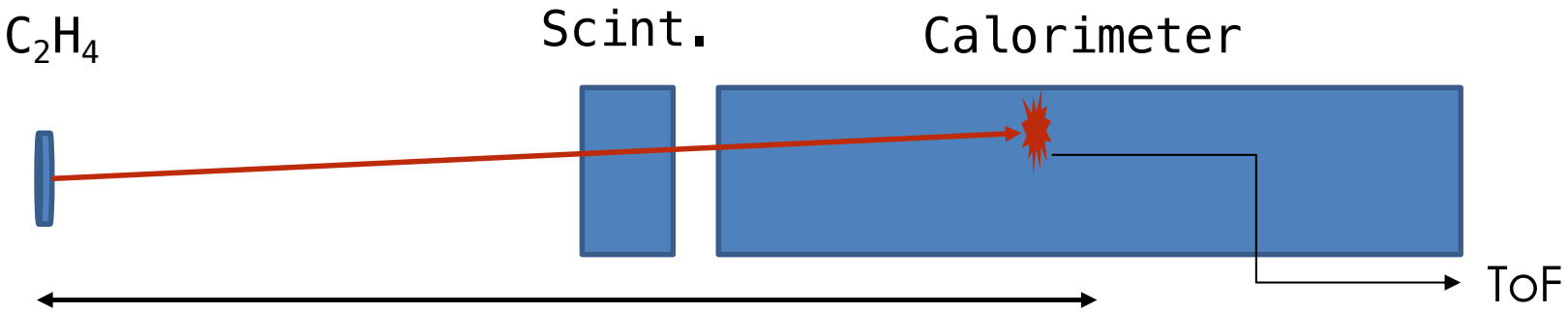

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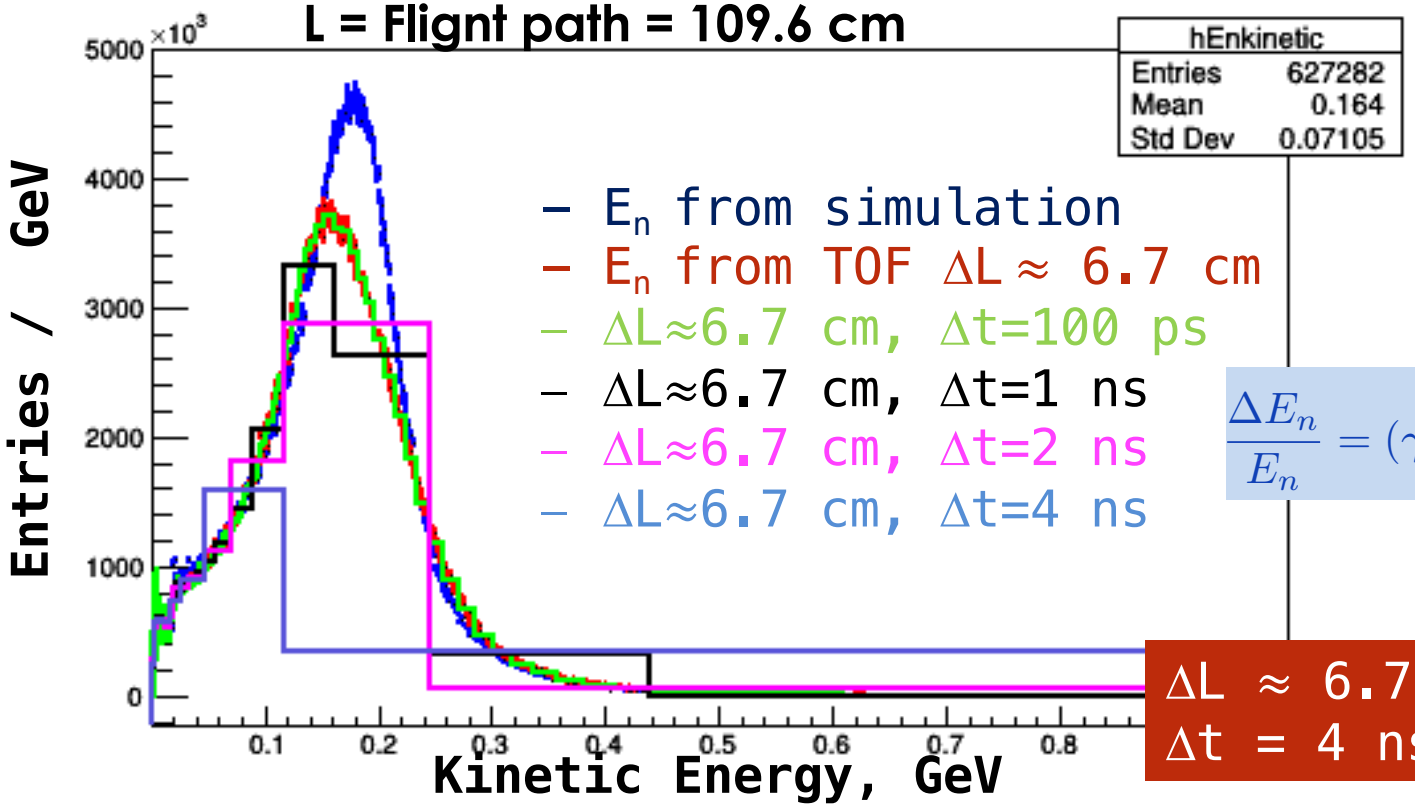

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ΔL ≈ 6.7 cm
Δt = 4 ns

Conclusions

- We have studied the possibility of using the **present setup** to have some information about **neutrons**.
- Due to the large production of neutrons in the FOOT setup, neutron detectors based on their moderation are not suited.
- It seems feasible for **high-energy neutrons only**, by **using the (traker +) scintillator and the calorimenter**, provided that the **calorimenter time resolution** is better than **1 ns**.
- Typical efficiency of the current setup ~ 30%.
- **Concern 1**: the efficiency is derived from a simulation.
- **Concern 2**: the impact of **γ rays** is **not considered** in the study.

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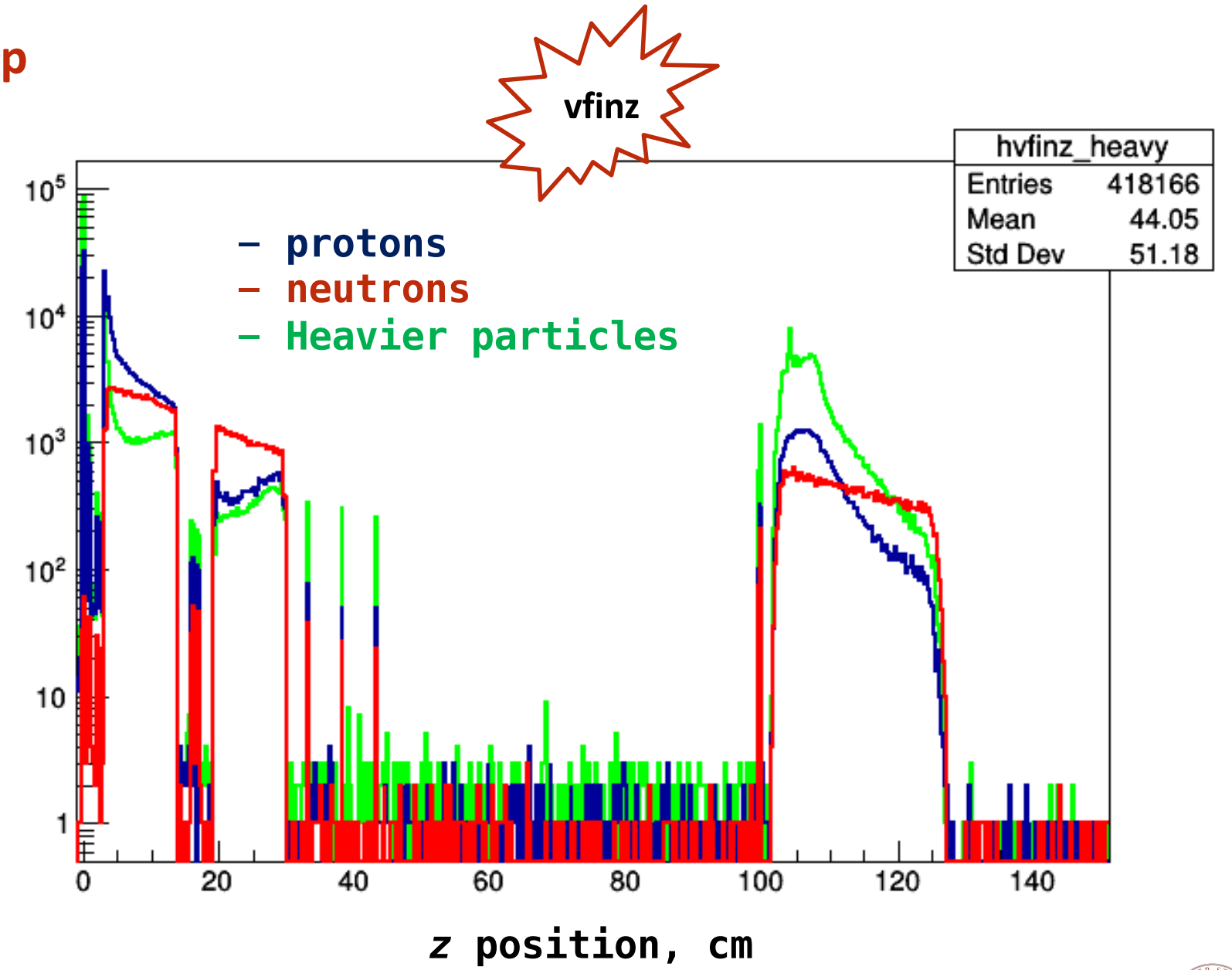
vfinz
hvfinz_heavy
Entries 418166
Mean 44.05
Std Dev 51.18
– protons
– neutrons
– Heavier particles
10^5
10^4
10^3
10^2
10
1
0
20
40
60
80
100
120
140
z position, cm

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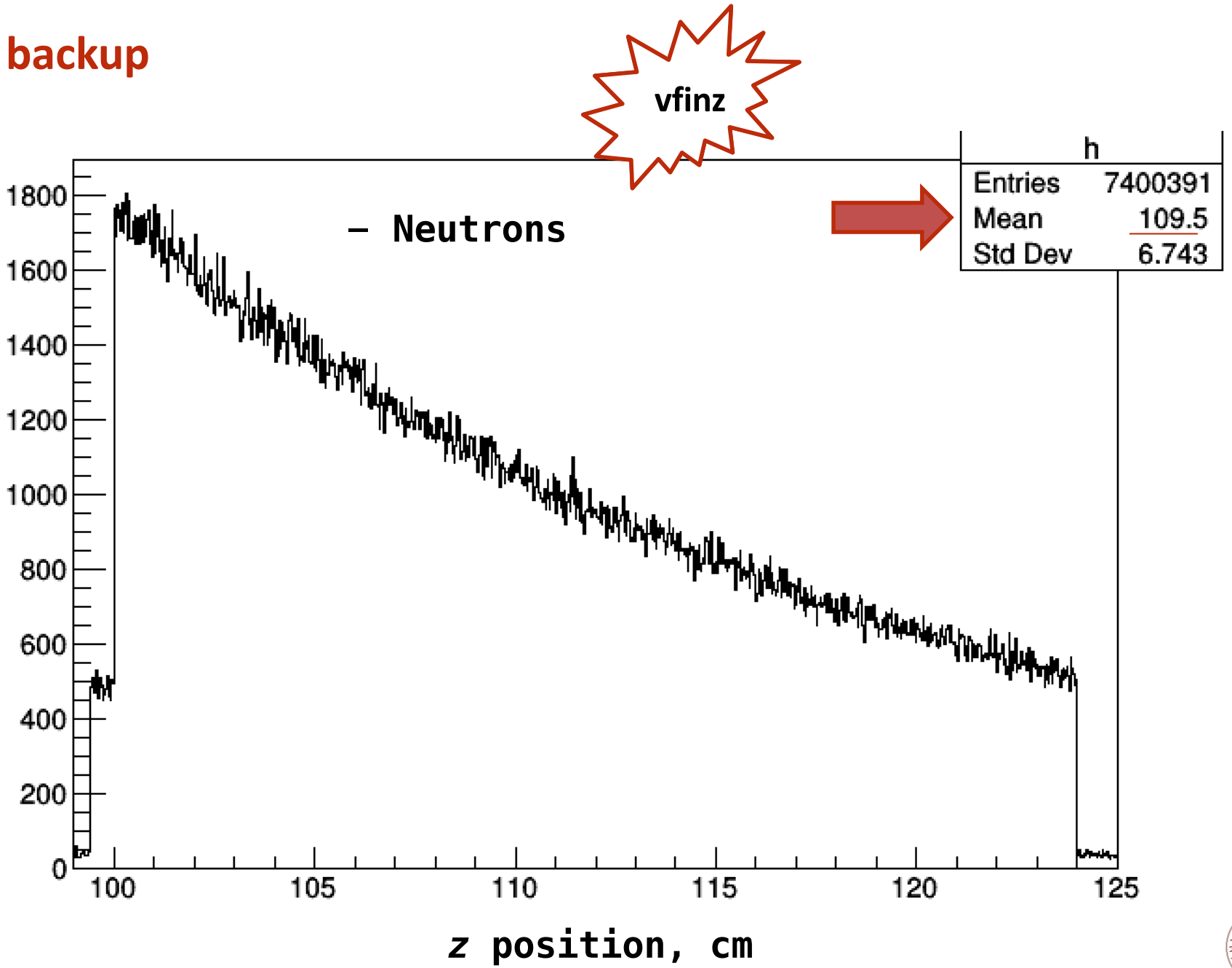
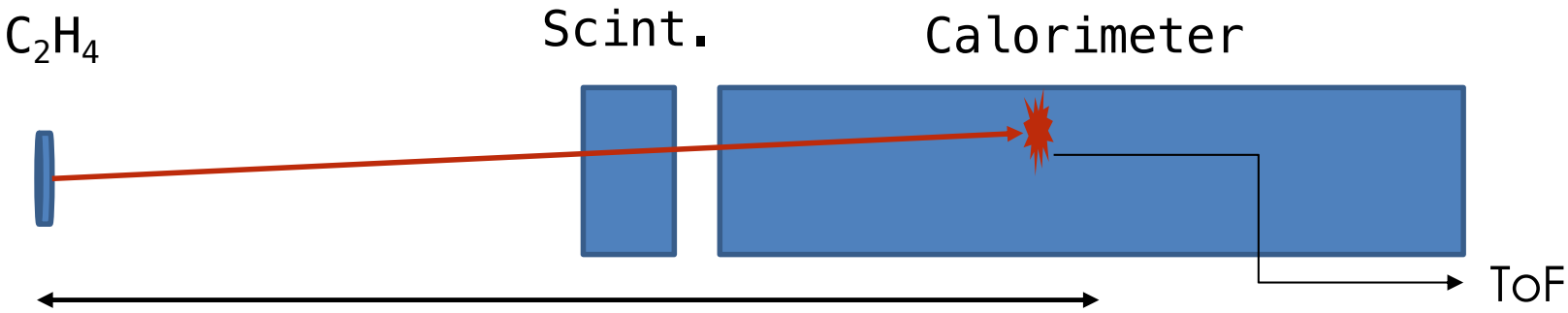


Detecting neutrons with existing setup

Only events from the target



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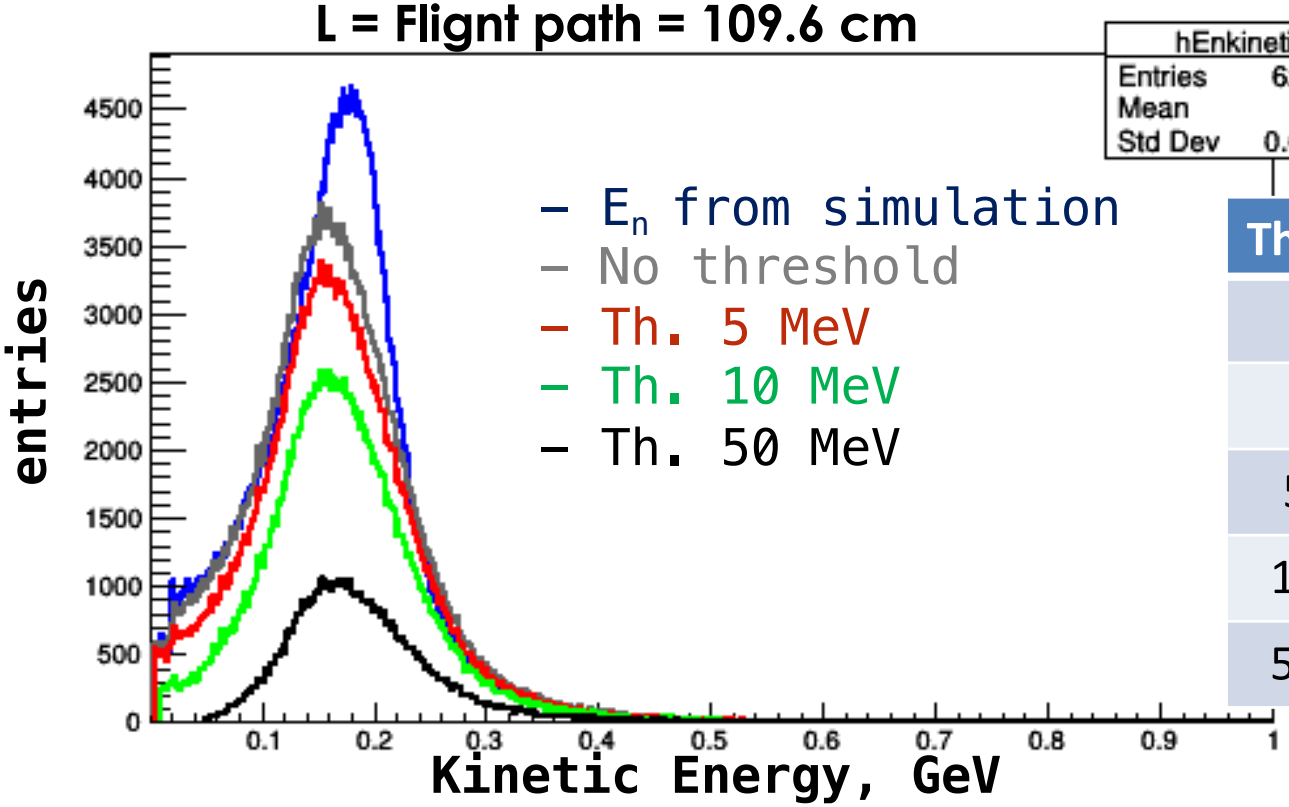

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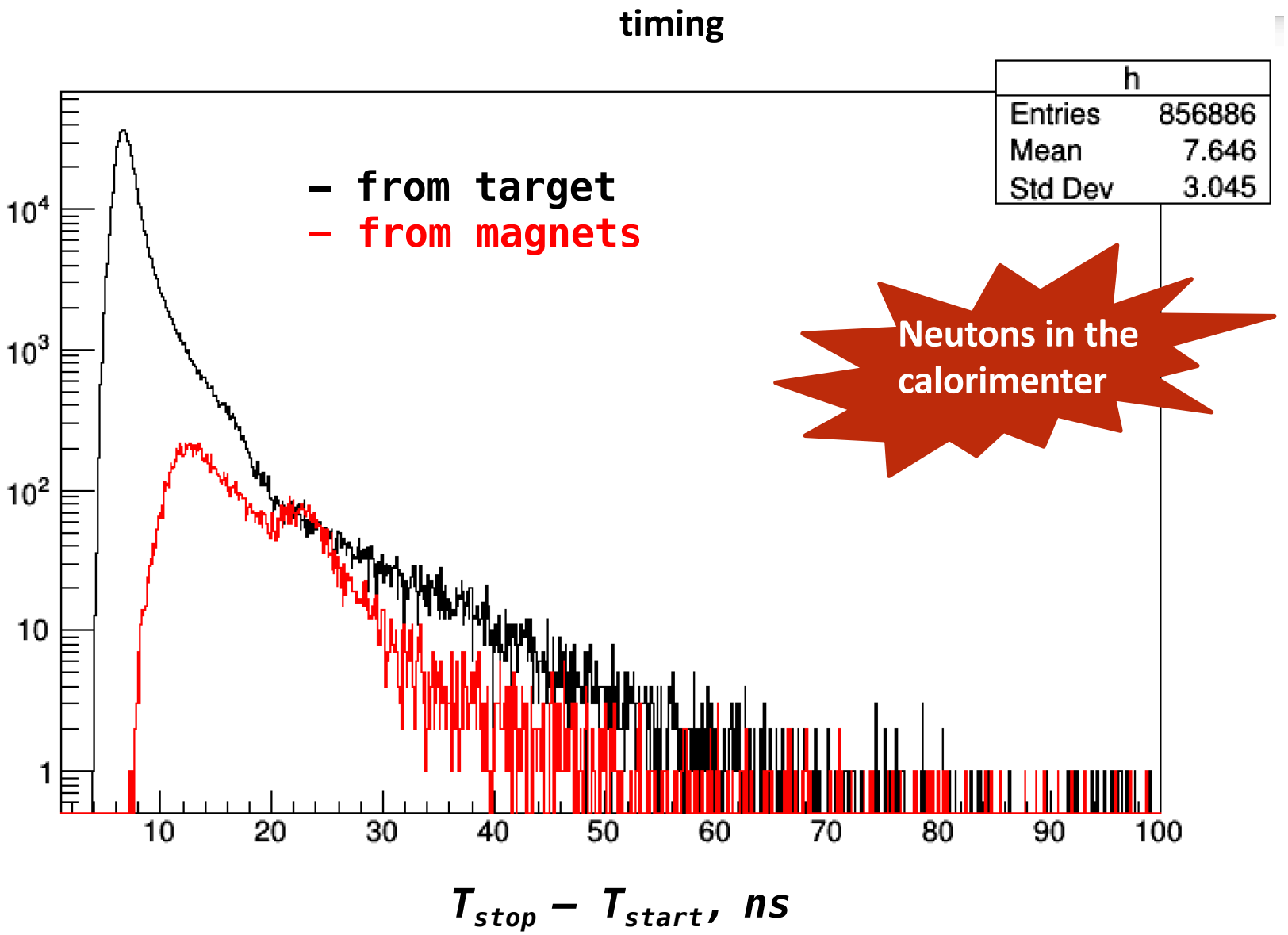
timing
h
Entries 856886
Mean 7.646
Std Dev 3.045
– from target
– from magnets
Neutons in the calorimenter
10^4
10^3
10^2
10
1
10 20 30 40 50 60 70 80 90 100
$T_{stop} - T_{start}$, ns

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