Measurement of the $^{235}U(n,f)$ cross section relative to n-p scattering up to 1 GeV

A. Manna for the n_TOF Collaboration

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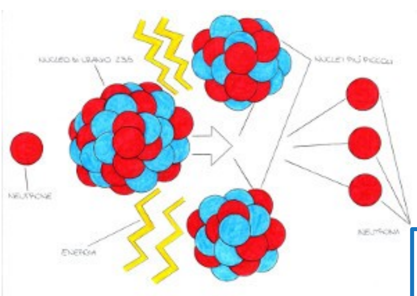
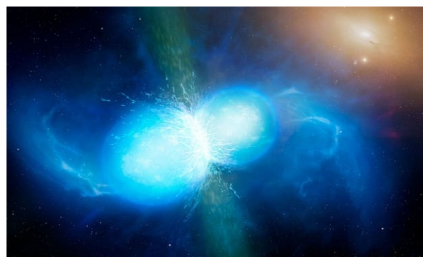
Motivations

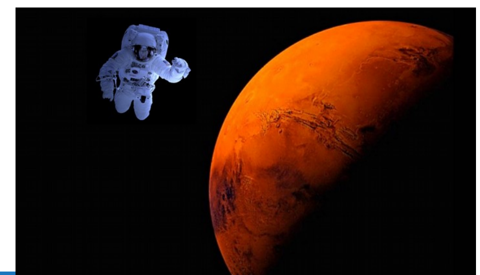
INDC International Nuclear Data Commitee

*"...Our analysis indicates that the new absolute measurements of the neutron induced fission cross section (e.g. **relative to n-p scattering**) on **Uranium**, Bismuth, Lead and Plutonium have the highest priority in establishing neutron induced fission reaction standard **above 200 MeV**..."*

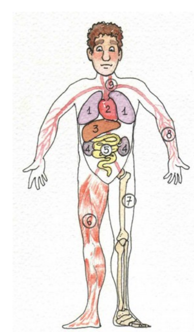
(INDC(NDS)-0681 Distr. ST/J/G/NM, IAEA 2015)

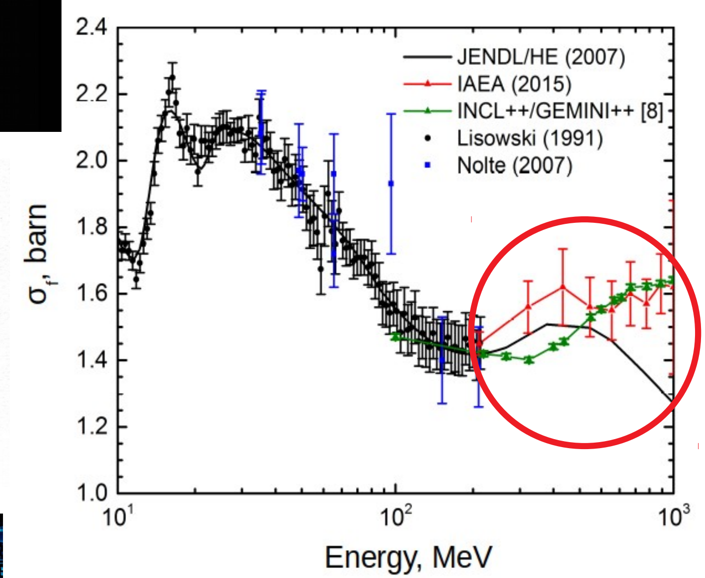


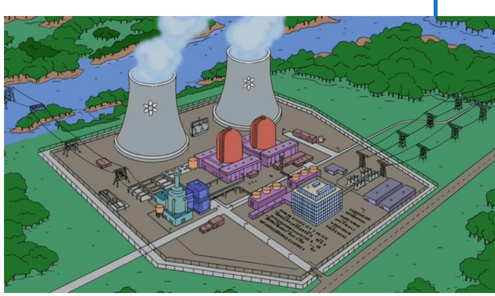


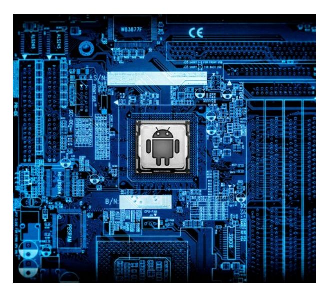


^{235}U(n,f) is one of the most significant cross-section standards at 0.025 eV and [0.15-200] MeV **BUT** there are **no experimental data above 200 MeV**



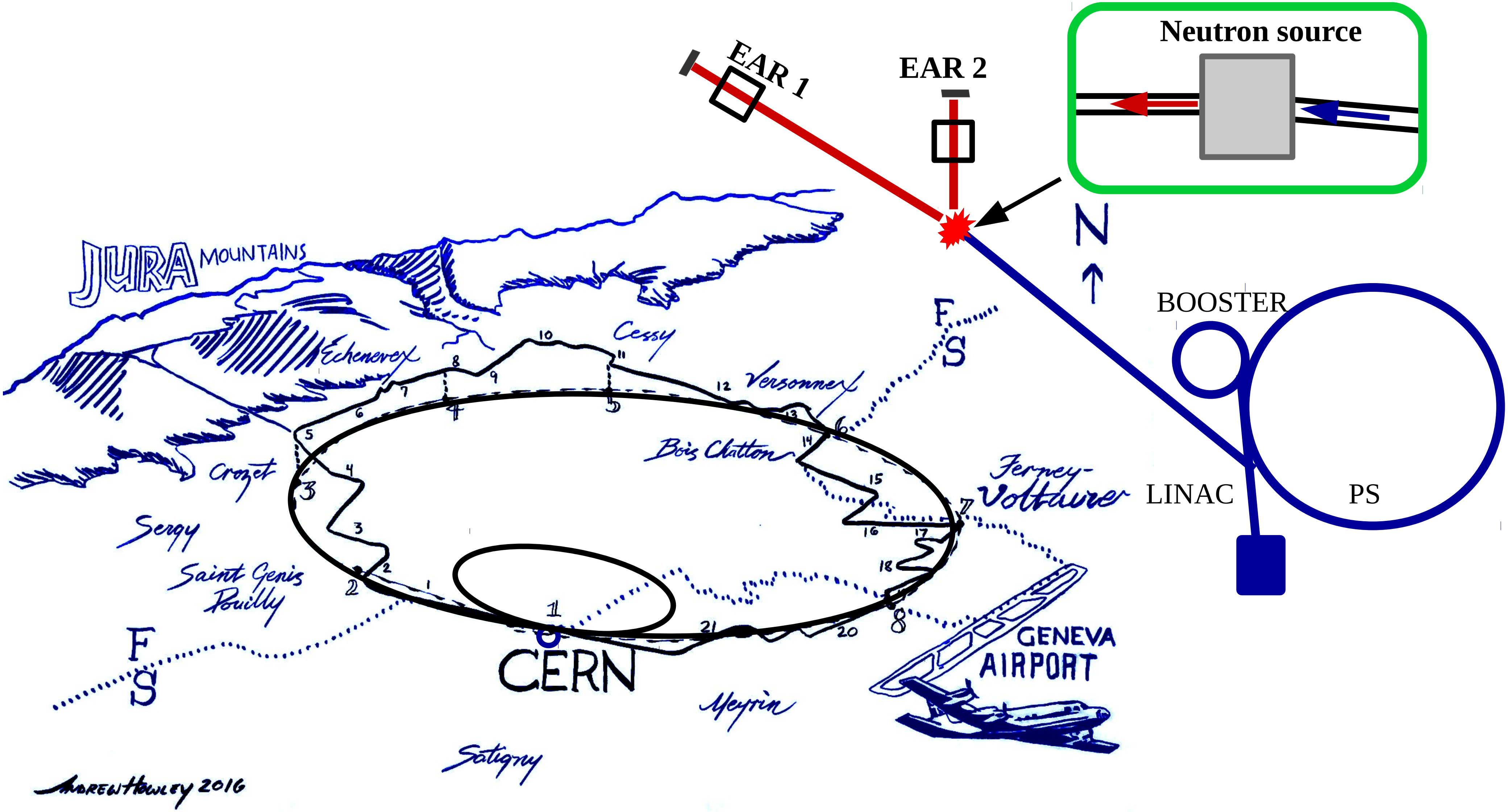






The n_TOF facility

neutron **T**ime **O**f **F**light



The n_TOF facility

neutron **T**ime **O**f **F**light

High energy resolution

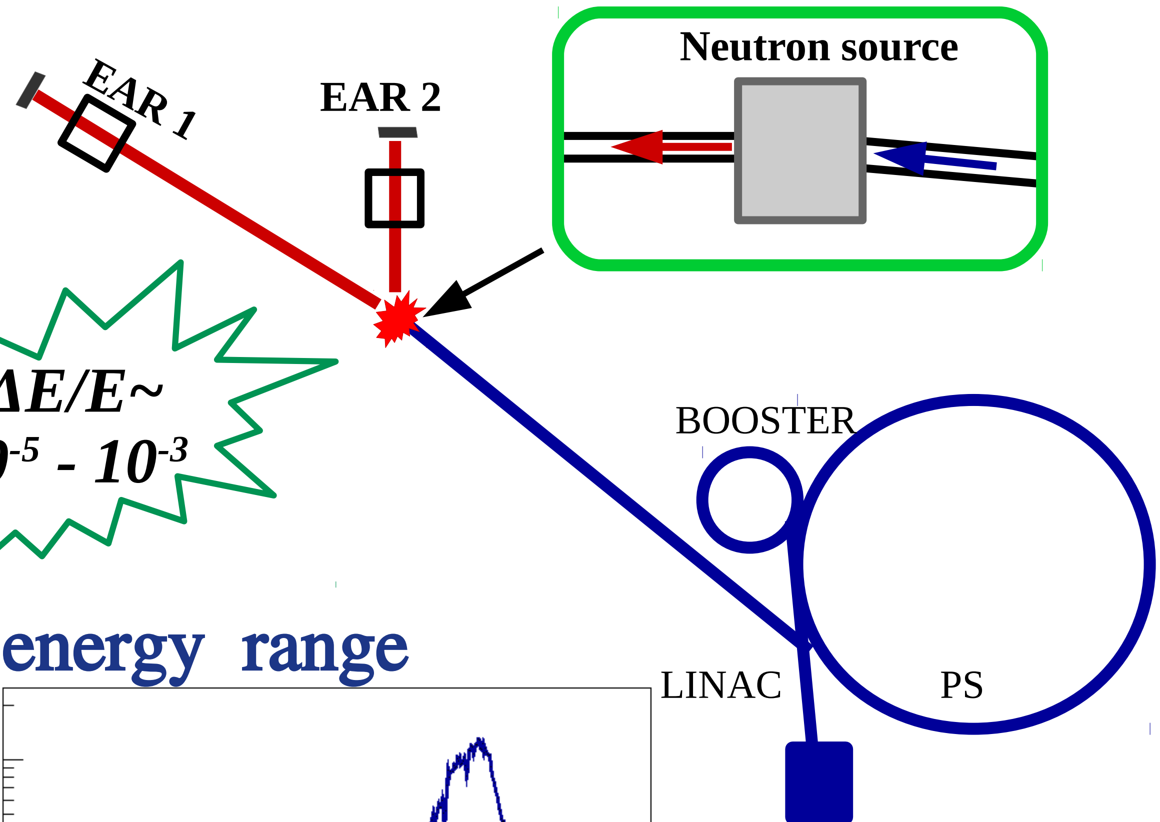
→ **Time of Flight (ToF) technique**

with a long flight path:

→ 185 m @ EAR 1

20 m @ EAR 2

$\Delta E/E \sim 10^{-5} - 10^{-3}$



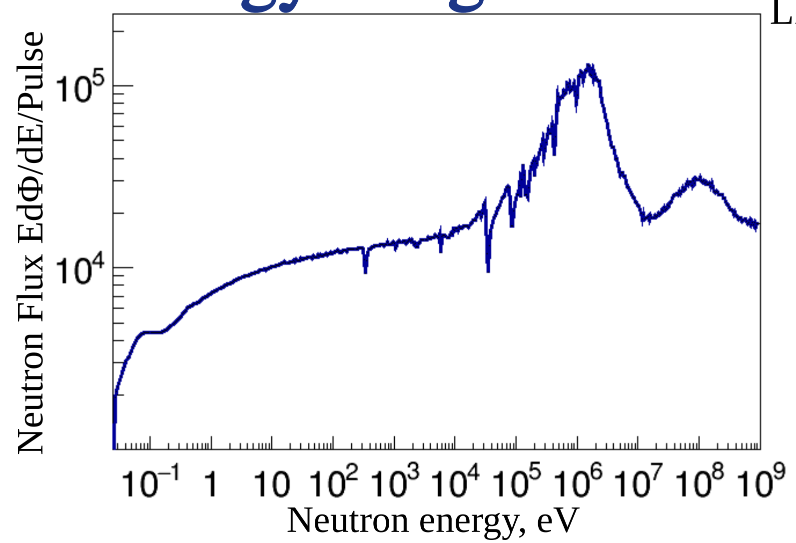
High neutron flux & wide energy range

→ **Spallation reaction**

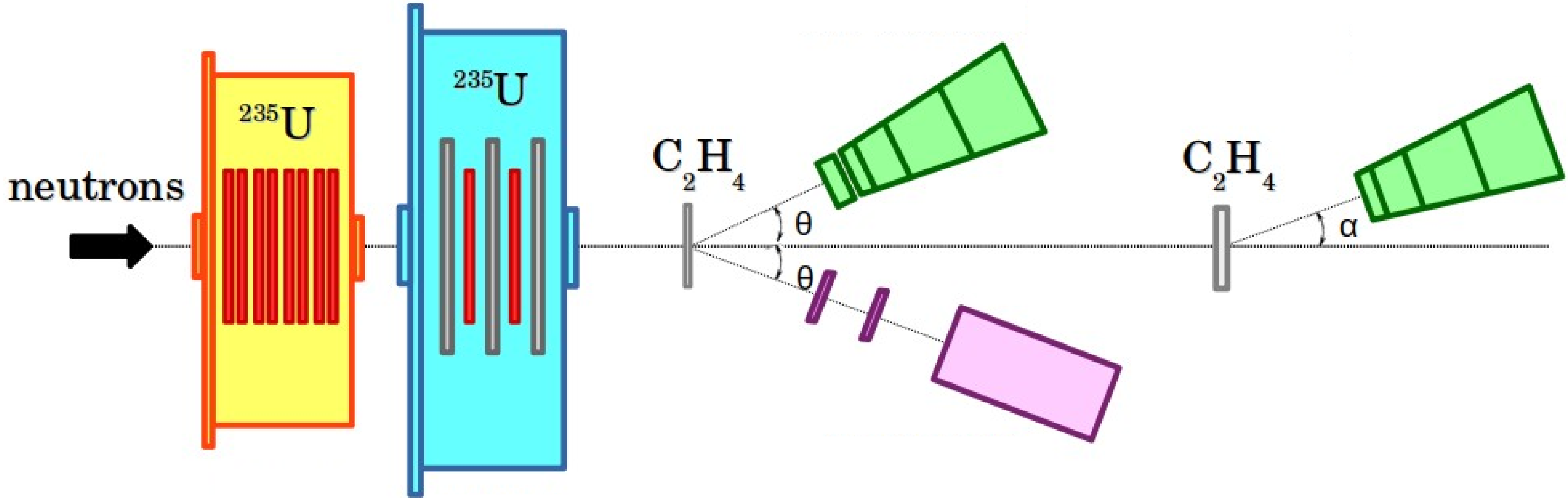
$7 \cdot 10^{12}$ protons,
20 GeV/c momentum

+

1.3 ton Pb Target



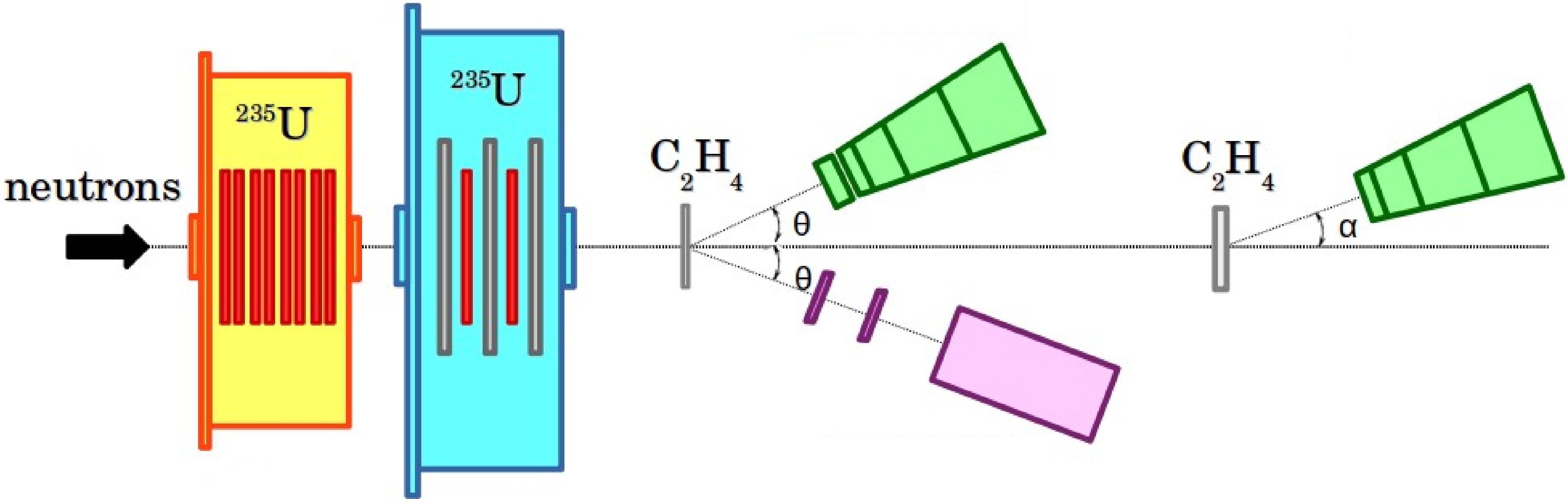
Experimental setup



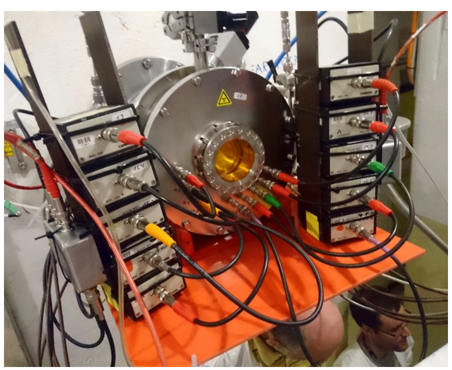
^{235}U fission reaction

Neutron flux

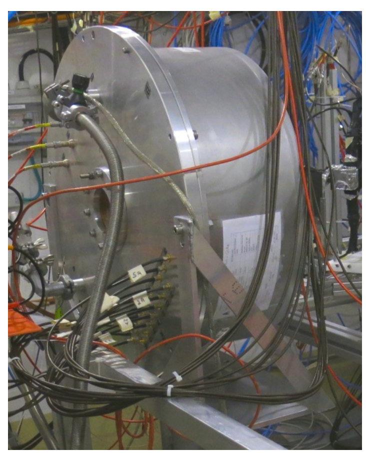
Experimental setup



^{235}U fission reaction



Parallel Plate Fission Chamber (**PPFC**)



Parallel Plate Avalanche Counter (**PPAC**)

Neutron flux

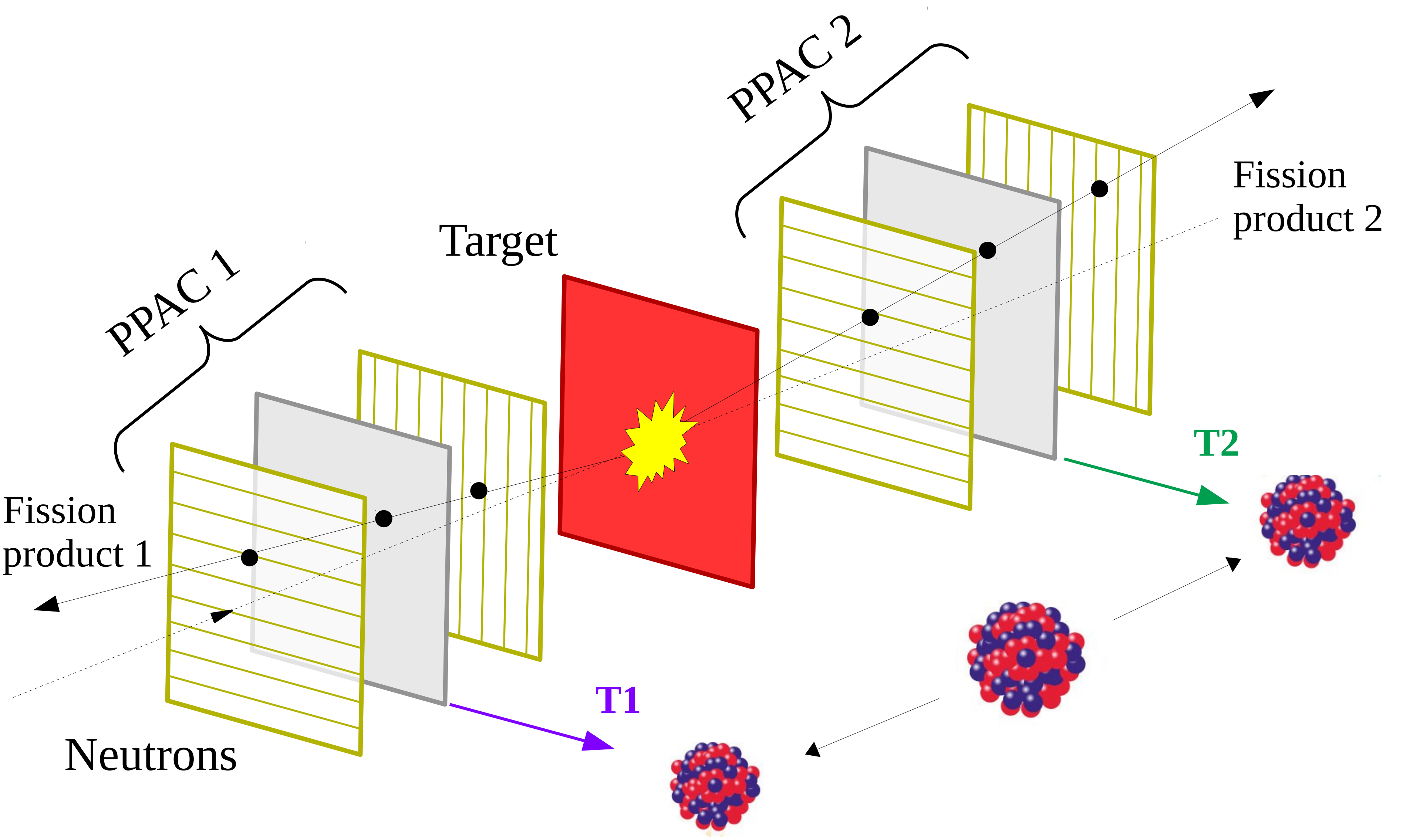
C_2H_4

n + ~~H~~ → n + p

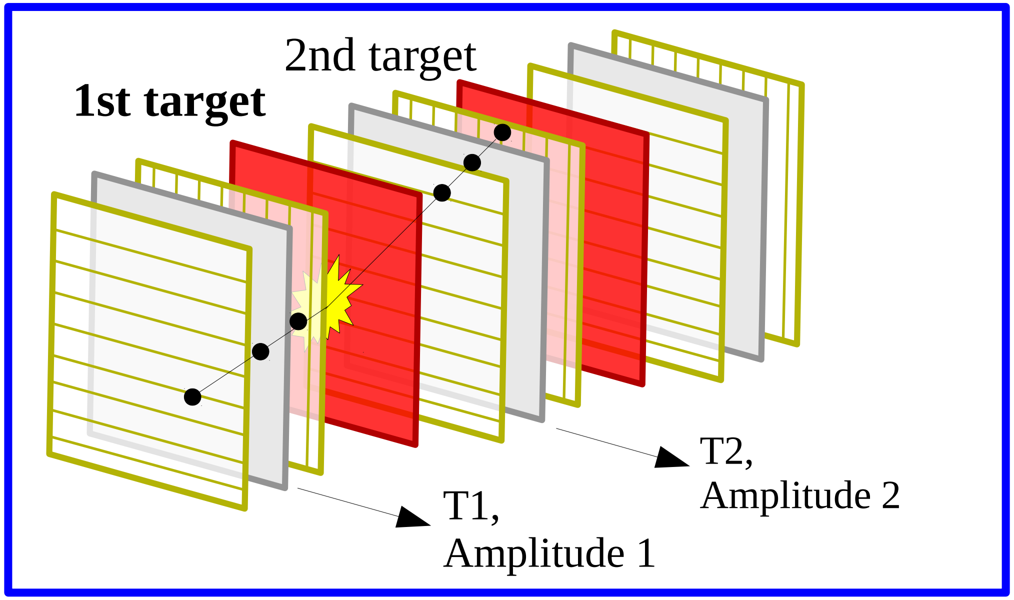
n + C_2H_4 →
- **n + p** — From n+H
- ^{9}Be + **α**
- ^{11}B + **d**
- ^{12}B + **p**
- ^{10}B + **t**
- ...

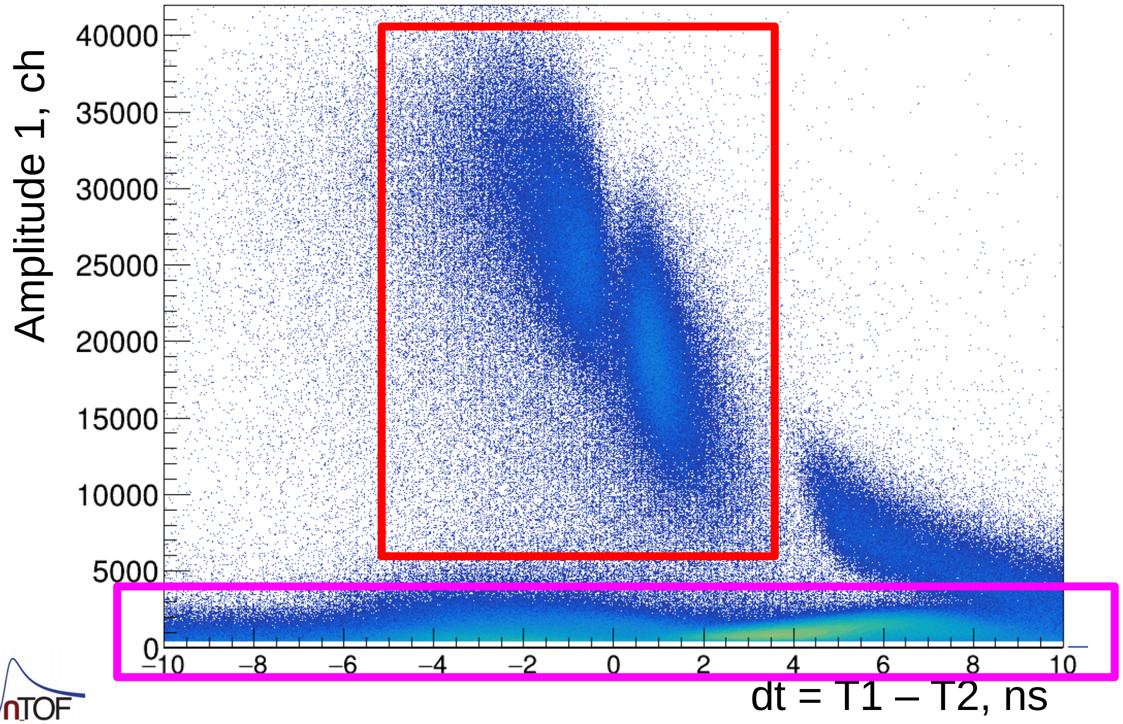
From n+C → Background

PPACs


PPAC 1
PPAC 2
Target
Fission product 2
Fission product 1
T2
T1
Neutrons

Coincidences between fragments

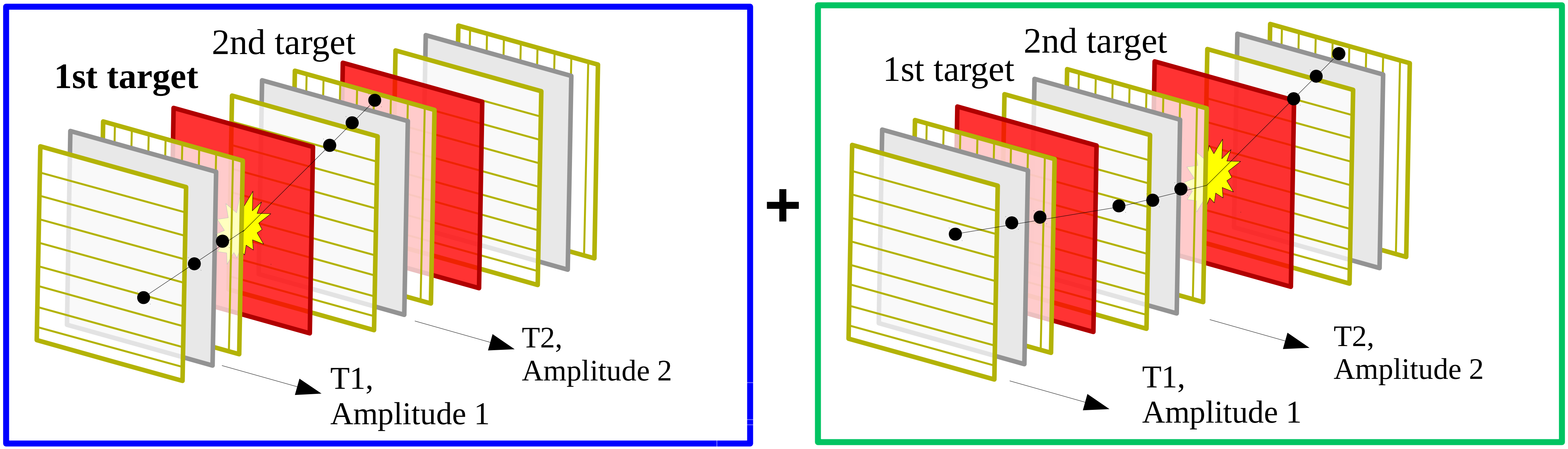


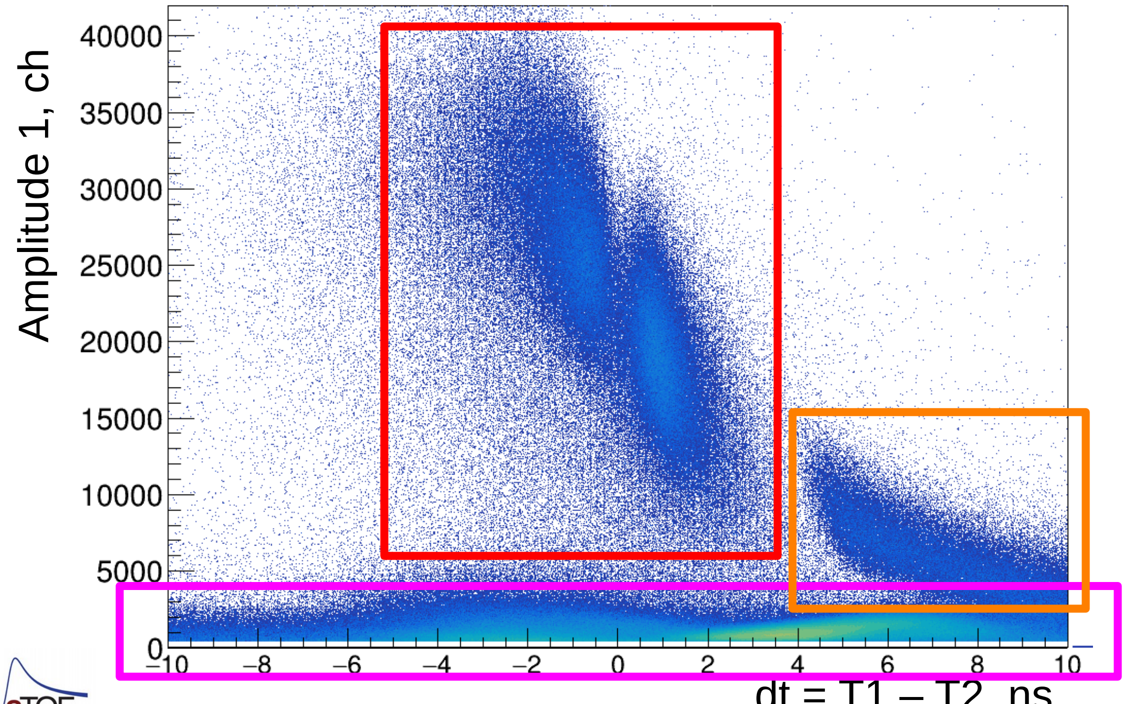


FF from 1st ^{235}U

α from 2nd ^{235}U

Coincidences between fragments



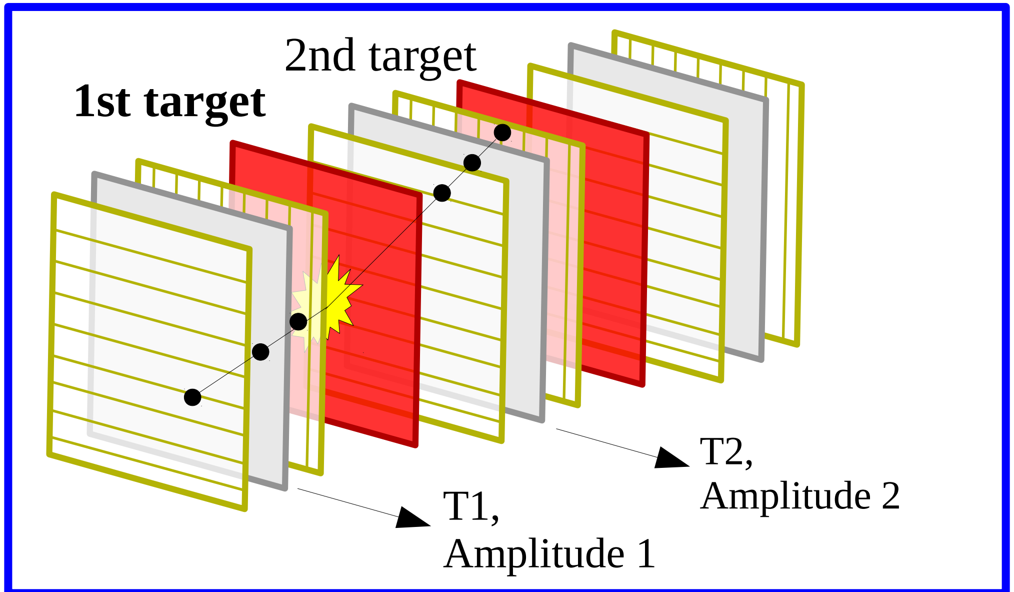


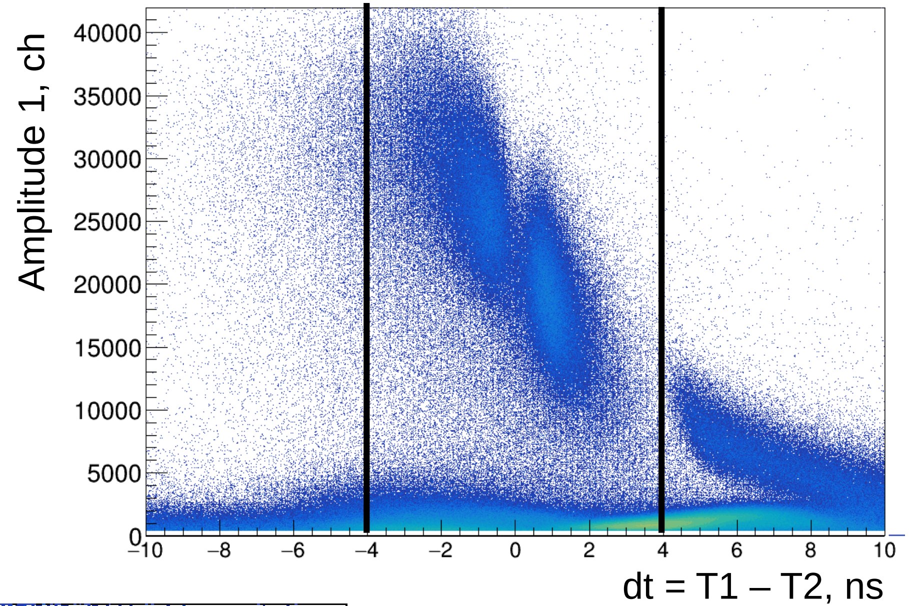
FF from 2nd ^{235}U

FF from 1st ^{235}U

α from 2nd ^{235}U

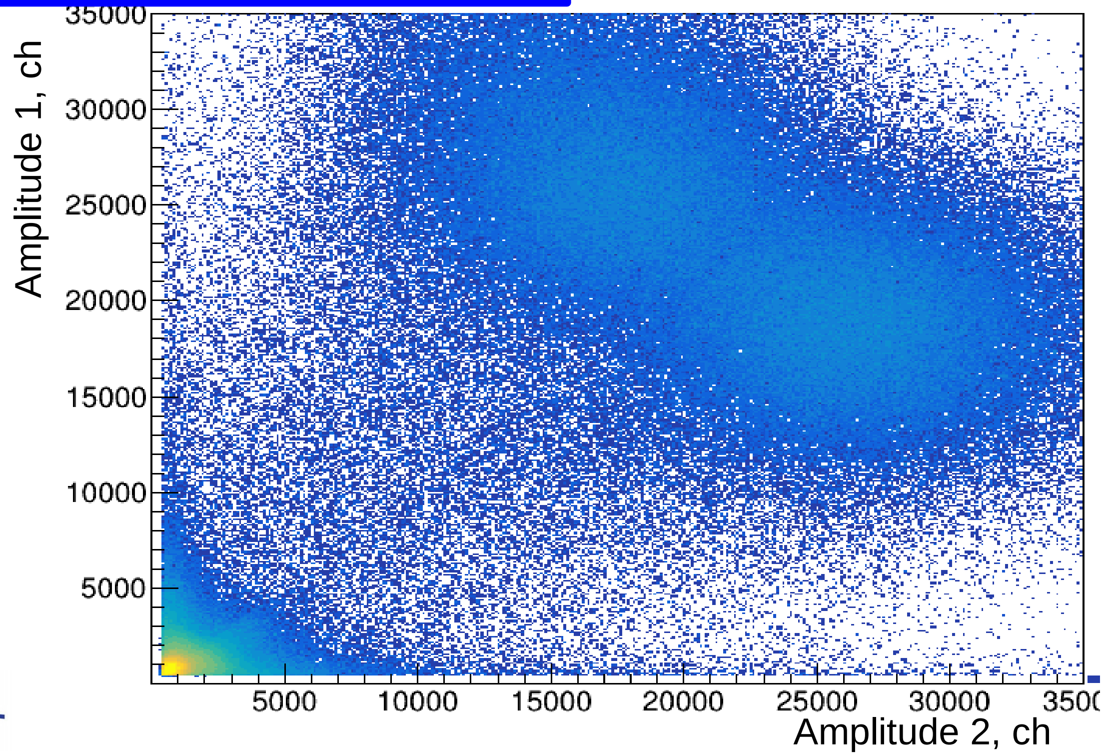
Coincidences between fragments





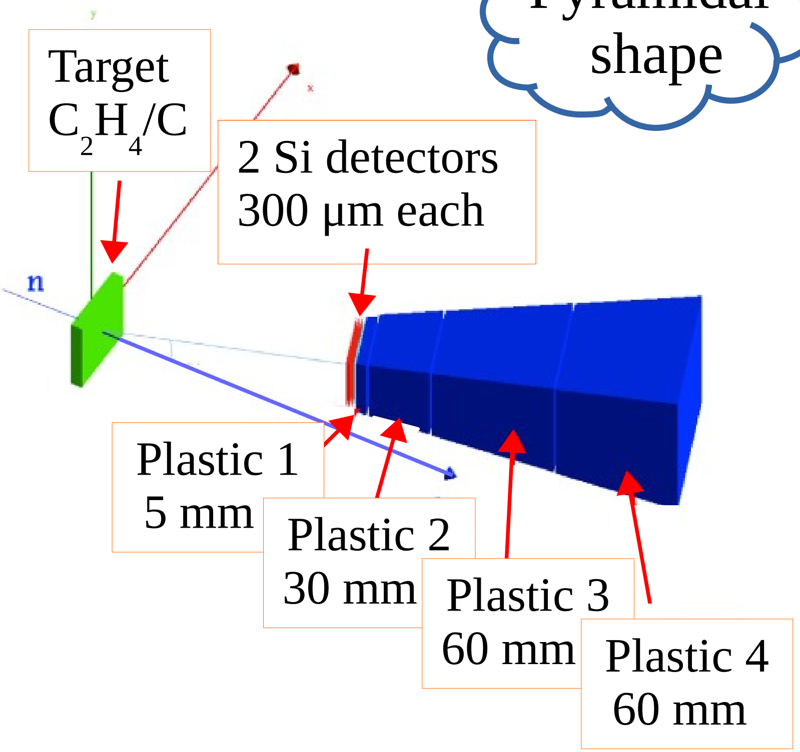
FF from 1st ^{235}U

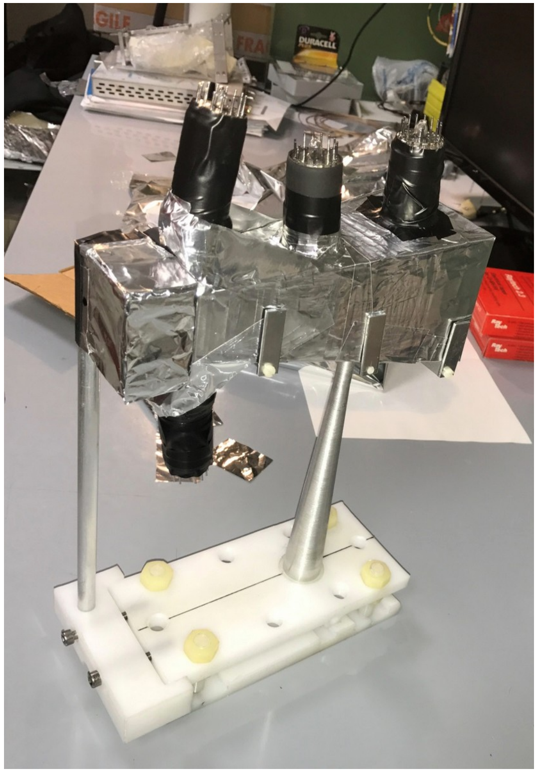
FF from 2nd ^{235}U

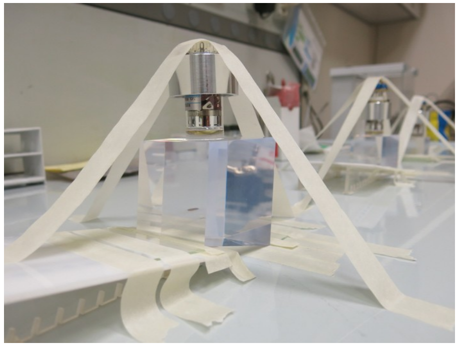


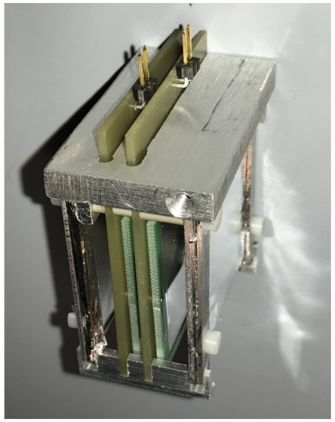
A Proton Recoil Telescope

Pyramidal shape

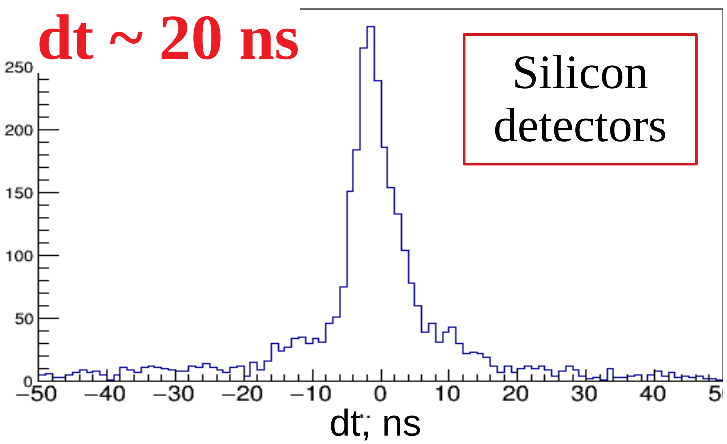


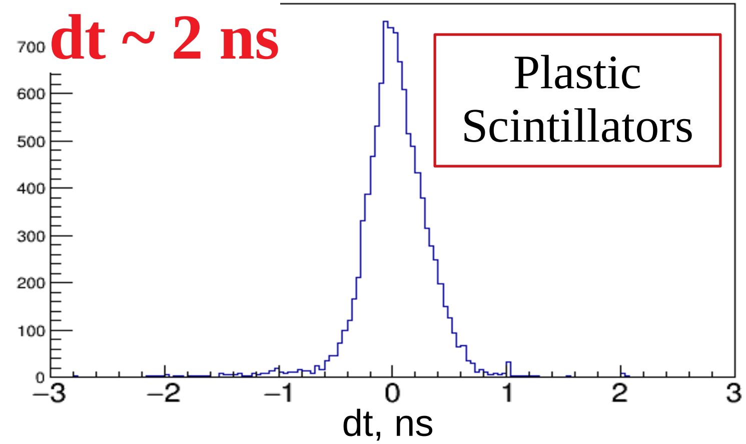




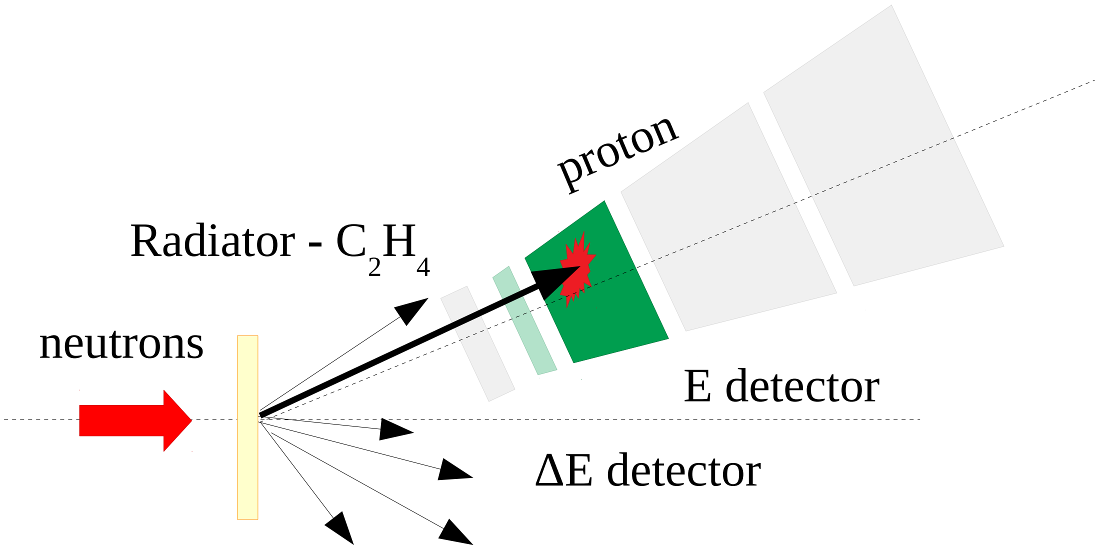


Timing properties:





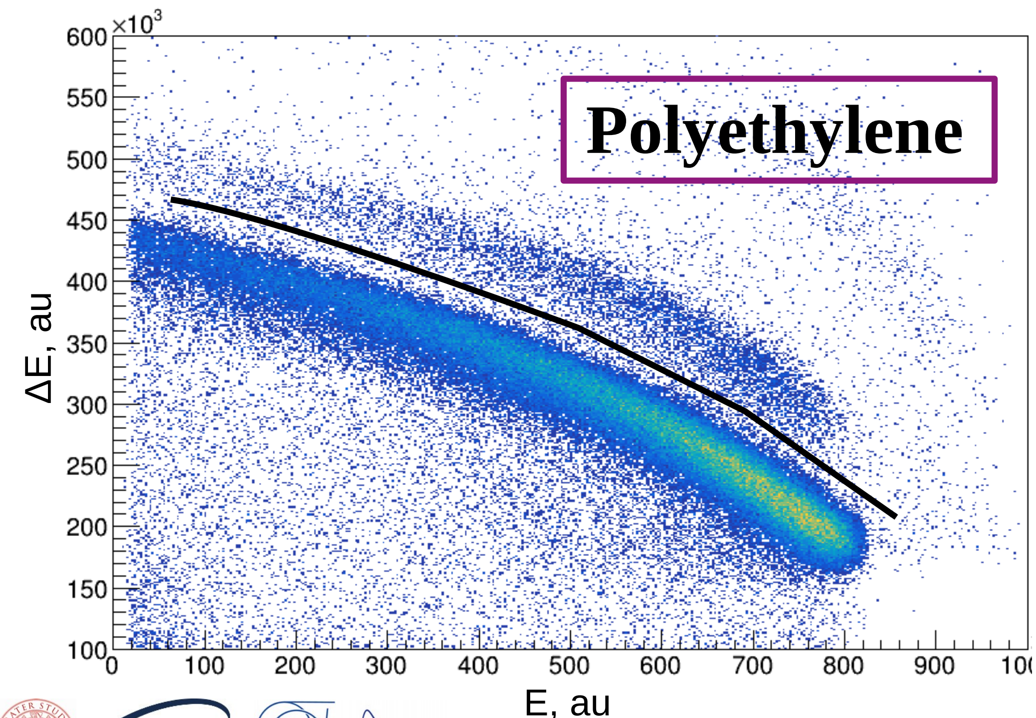
ΔE - E Matrix

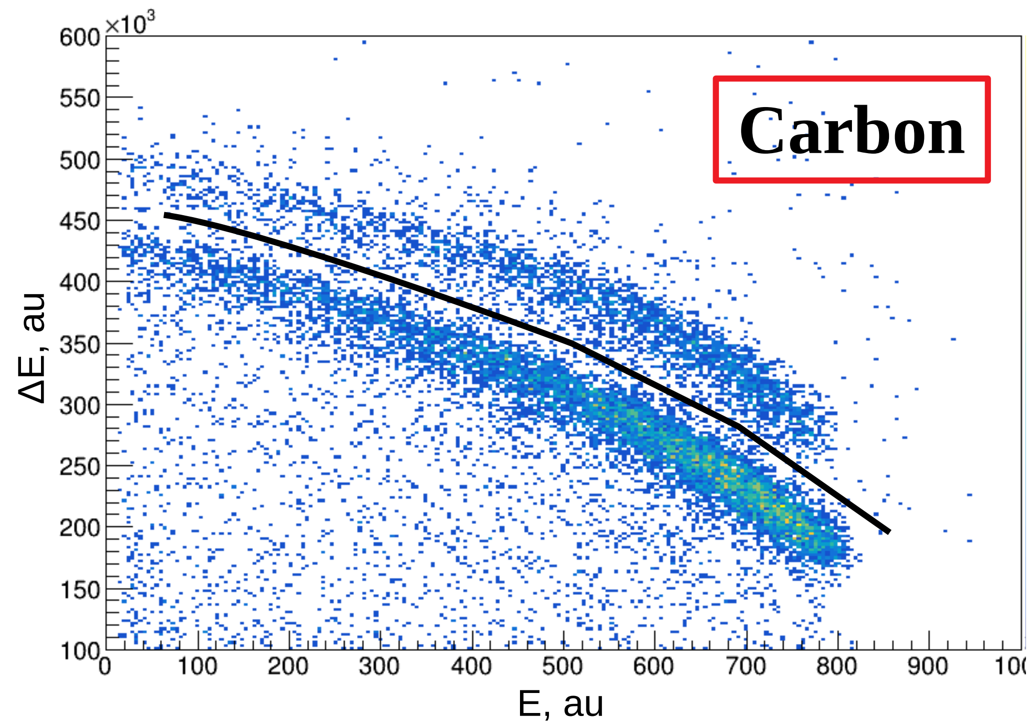


$$\Delta E \cdot E \propto k \cdot z^2 \cdot M$$

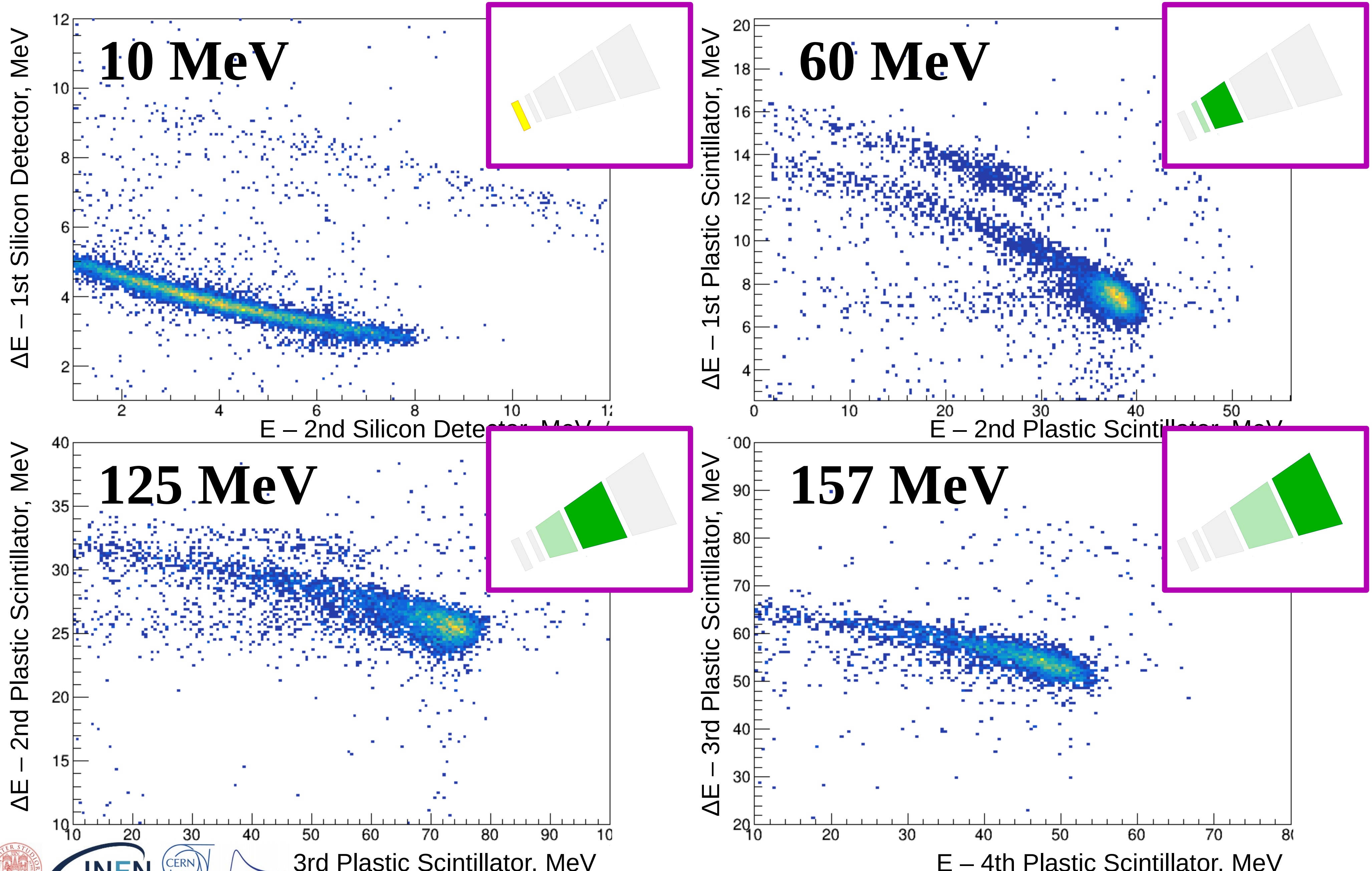
k: material absorption properties

M, *E*, *z*: interacting particle properties



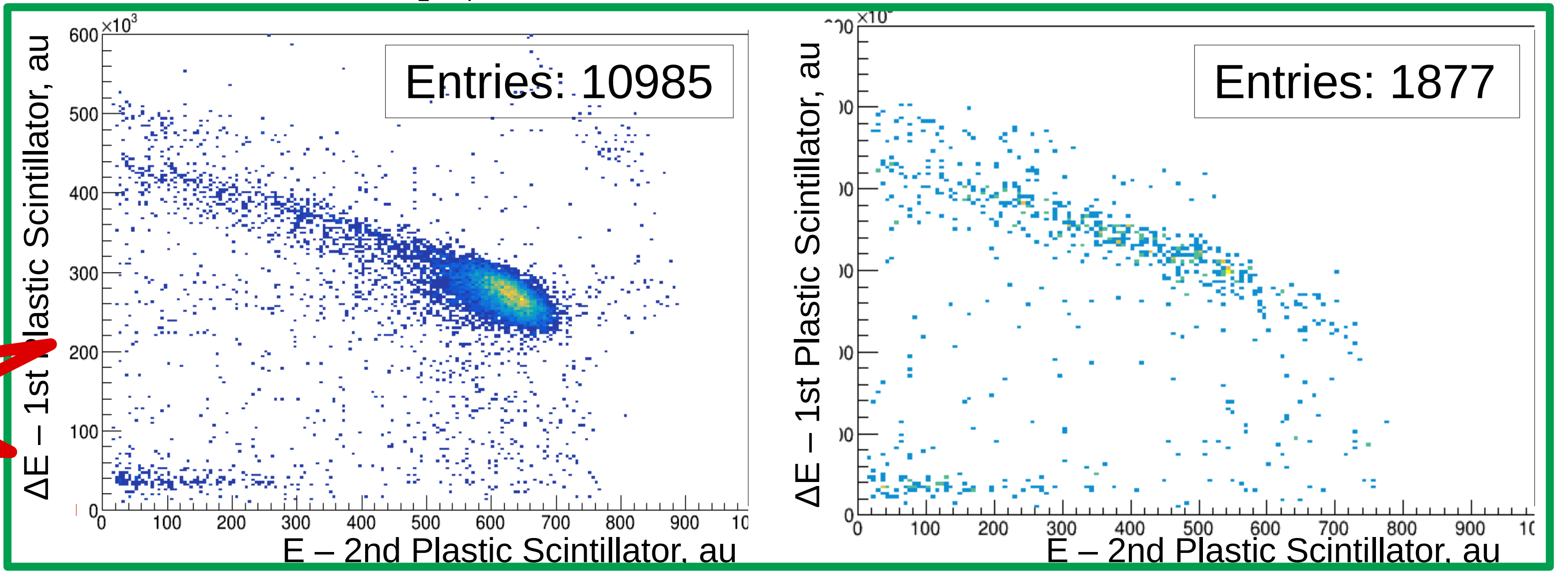


ΔE - E Matrix


10 MeV
ΔE – 1st Silicon Detector, MeV
E – 2nd Silicon Detector, MeV
60 MeV
ΔE – 1st Plastic Scintillator, MeV
E – 2nd Plastic Scintillator, MeV
125 MeV
ΔE – 2nd Plastic Scintillator, MeV
3rd Plastic Scintillator, MeV
157 MeV
ΔE – 3rd Plastic Scintillator, MeV
E – 4th Plastic Scintillator, MeV

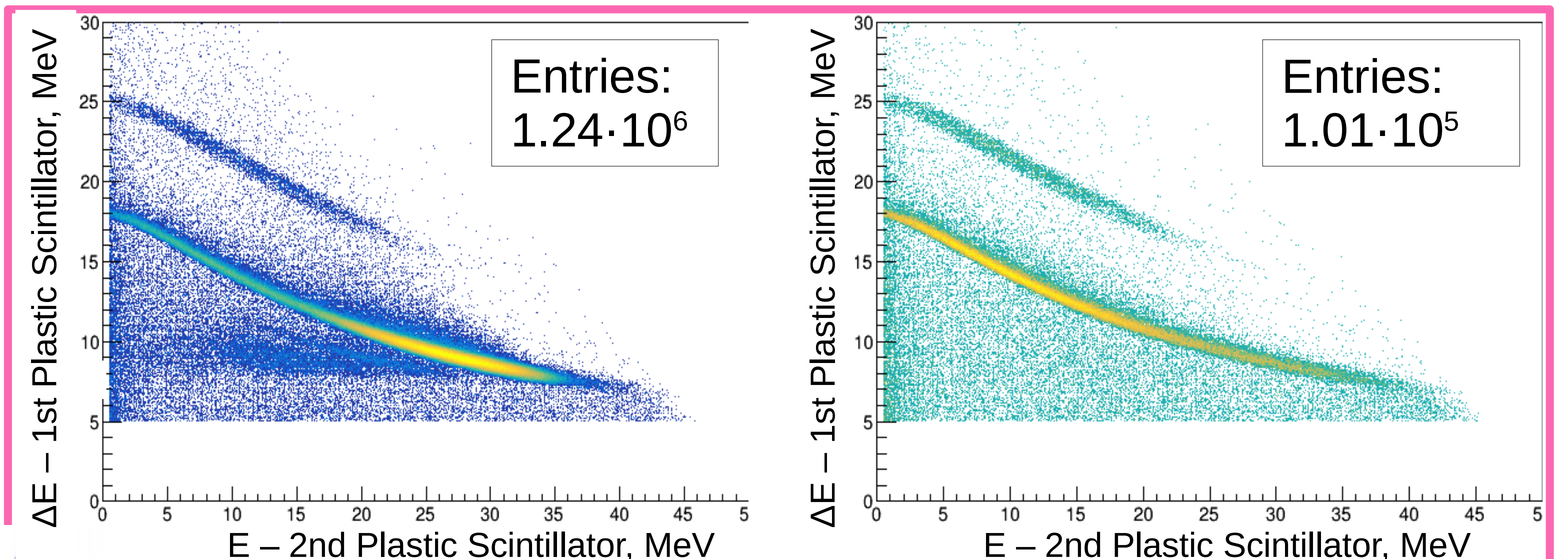
Extraction of the neutron flux

DATA



MC Simulation

#n = $5.12 \cdot 10^{10}$

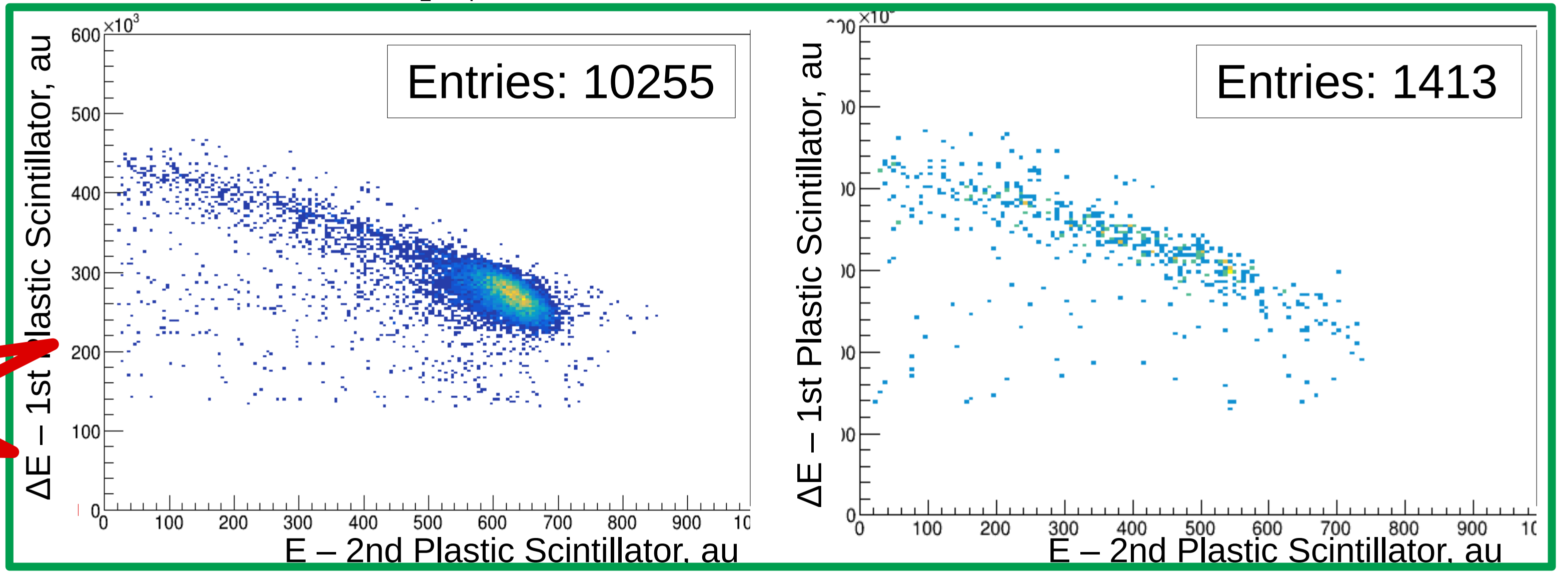


Extraction of the neutron flux

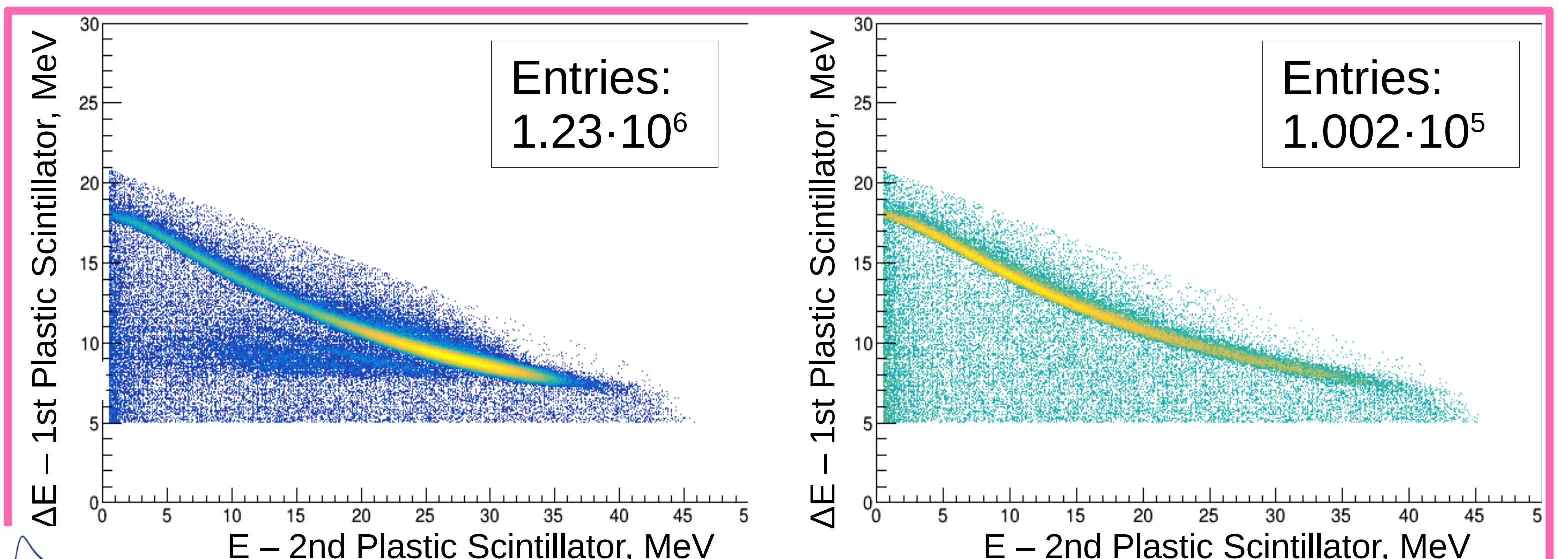
neutrons → (C_2H_4 − C) = neutrons → H

DATA

50 MeV

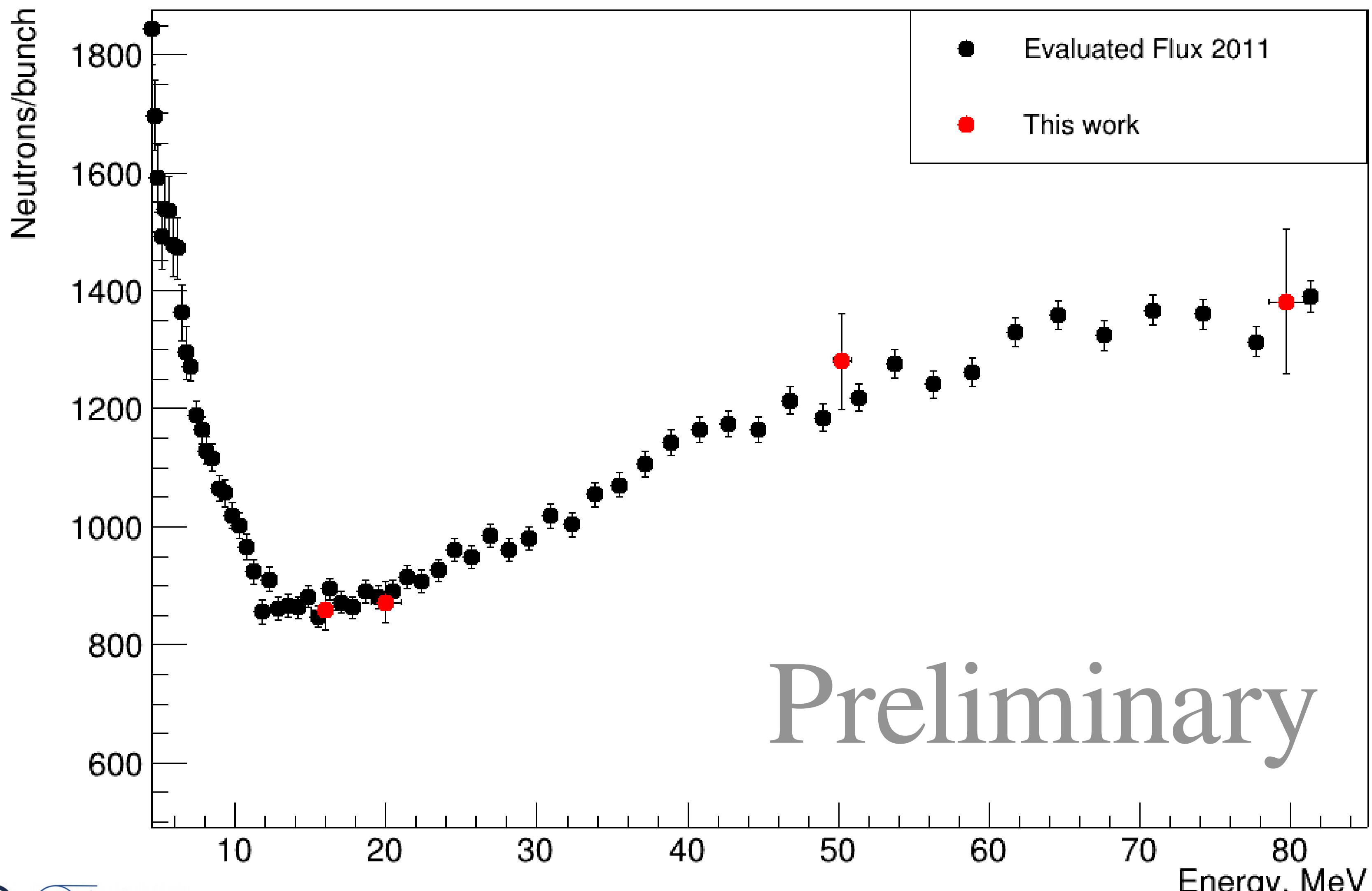


MC
Simulation
$\#n = 5.12 \cdot 10^{10}$

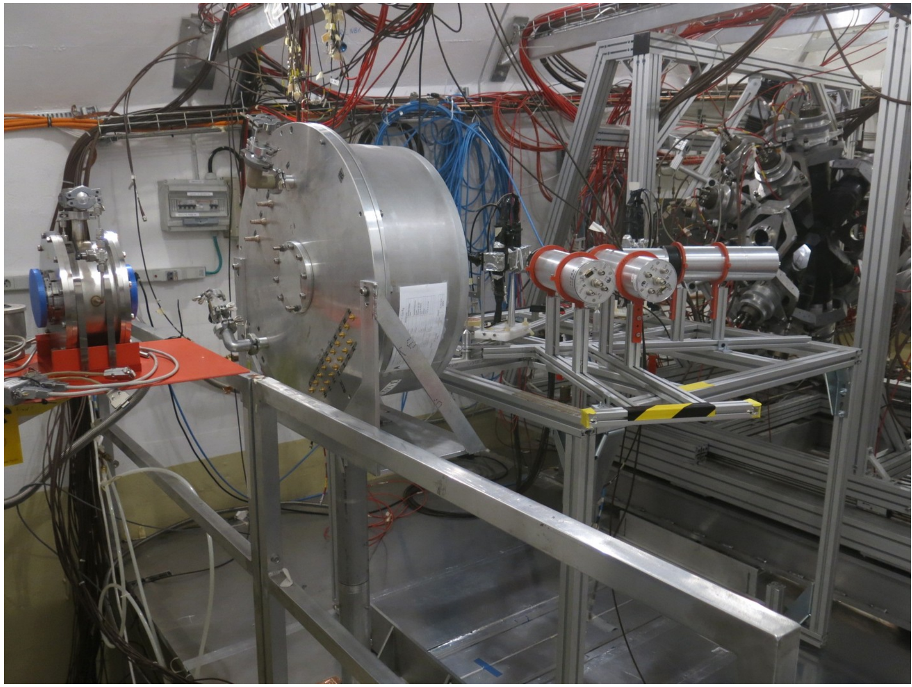


Extraction of the neutron flux

$$\left(\text{neutrons} \rightarrow \ \big|_{C_2H_4} \ - \ \big|_{C} \right) = \text{neutrons} \rightarrow \ \big|_{H}$$



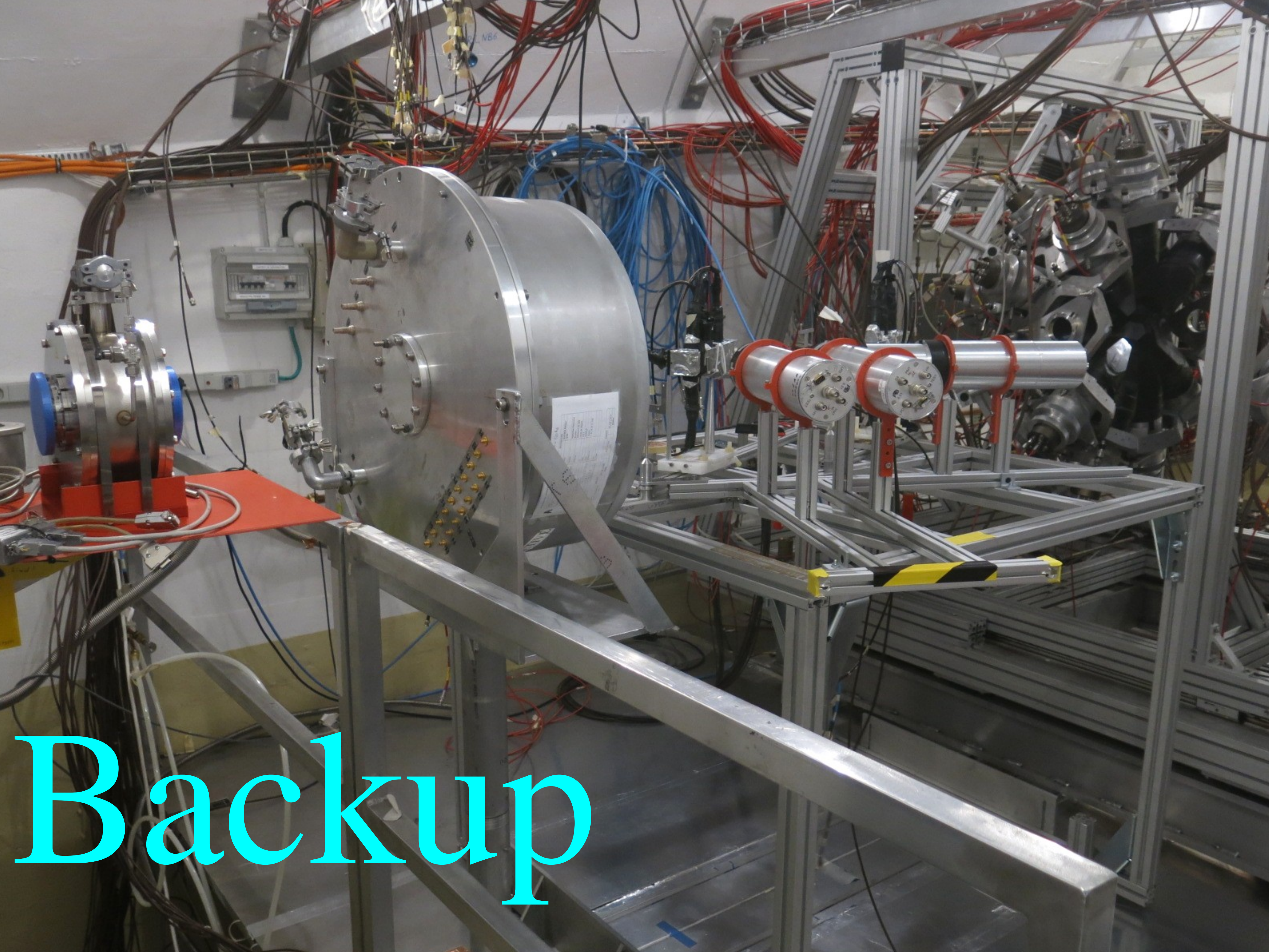
Conclusions



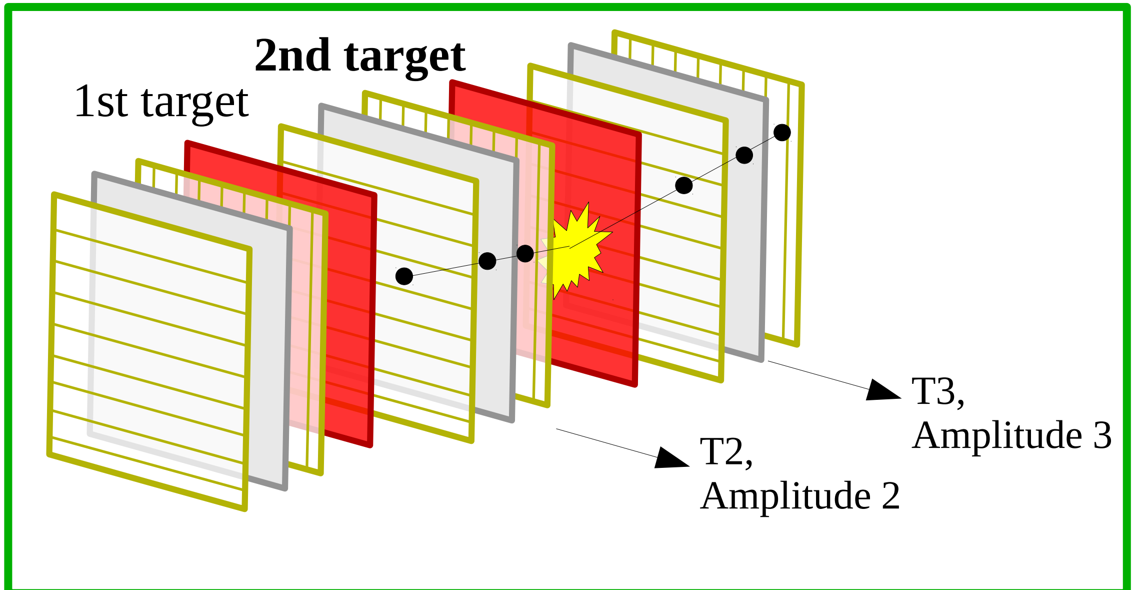
- Demanding measurement:
  - experimental setup → Neutron Flux
  - beam time
- Large effort for the MC simulation
  - ➡ evaluate the efficency

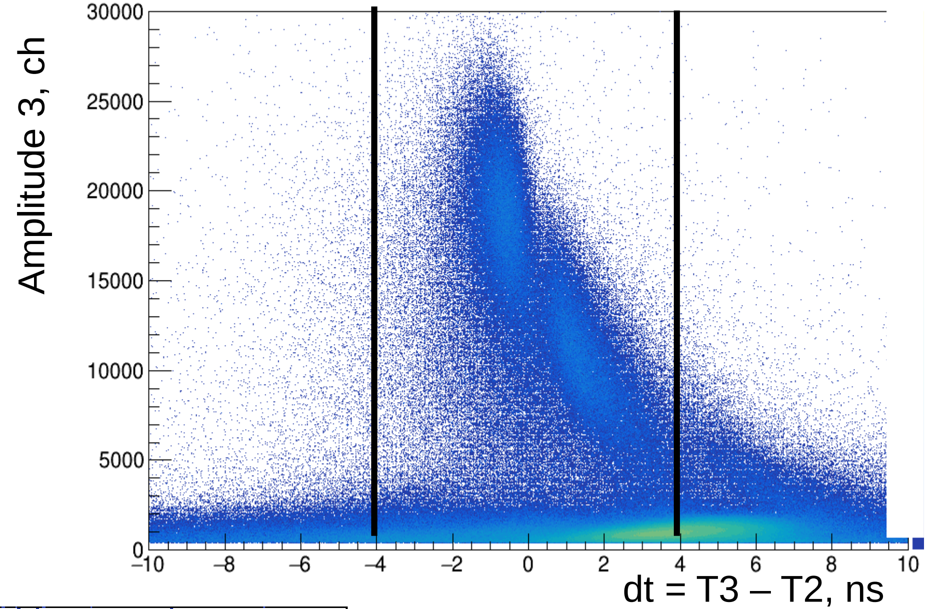
NEXT STEPS:

- Extract the n_TOF flux up to 1 GeV with the Proton Recoil Telescopes
- Count the fission fragments → $^{235}U(n,f)$ from 10 MeV to 1 GeV
- Evaluation of systematic uncertainties


Backup

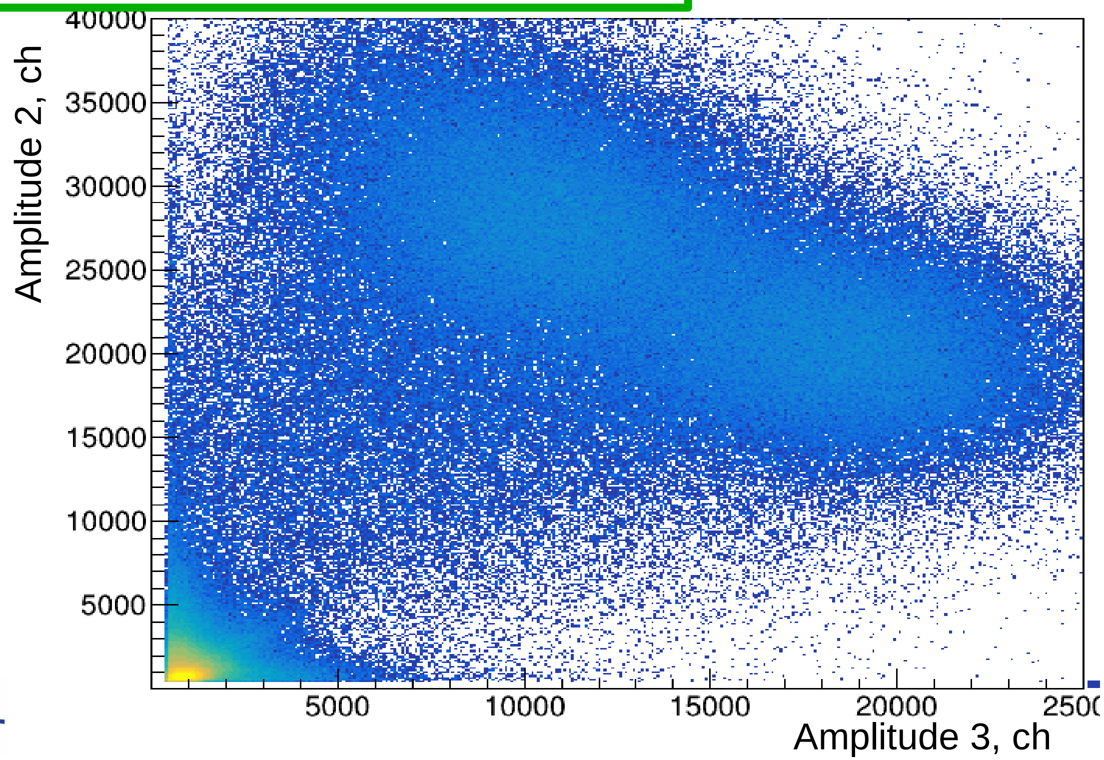
Coincidences between fragments



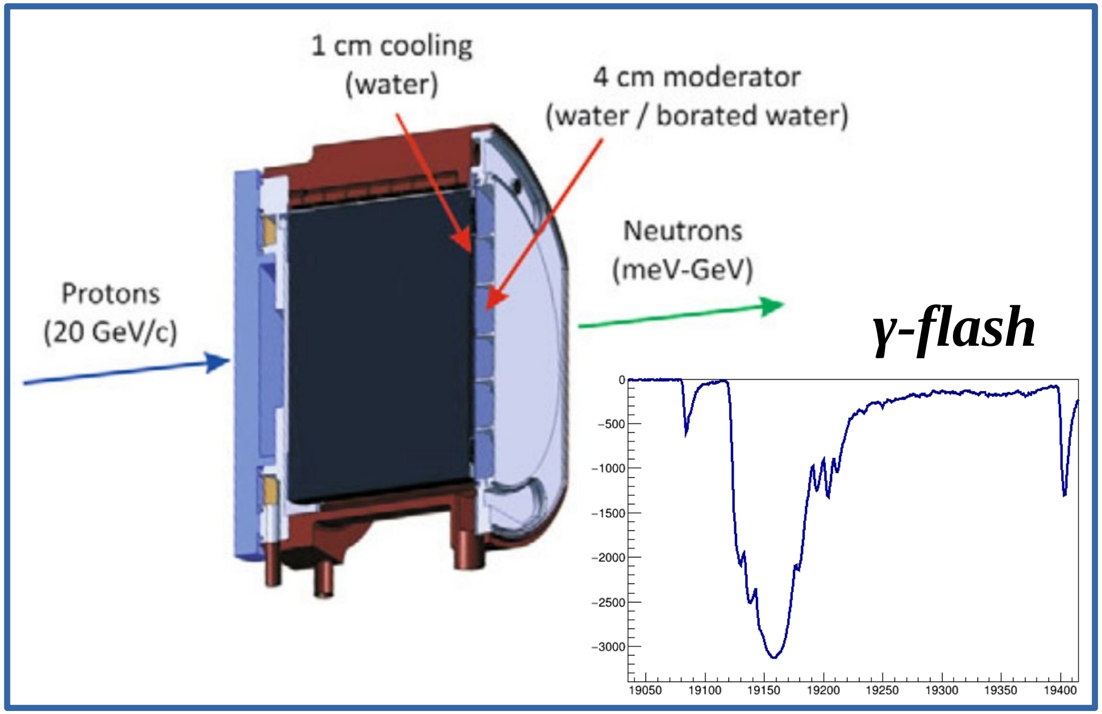


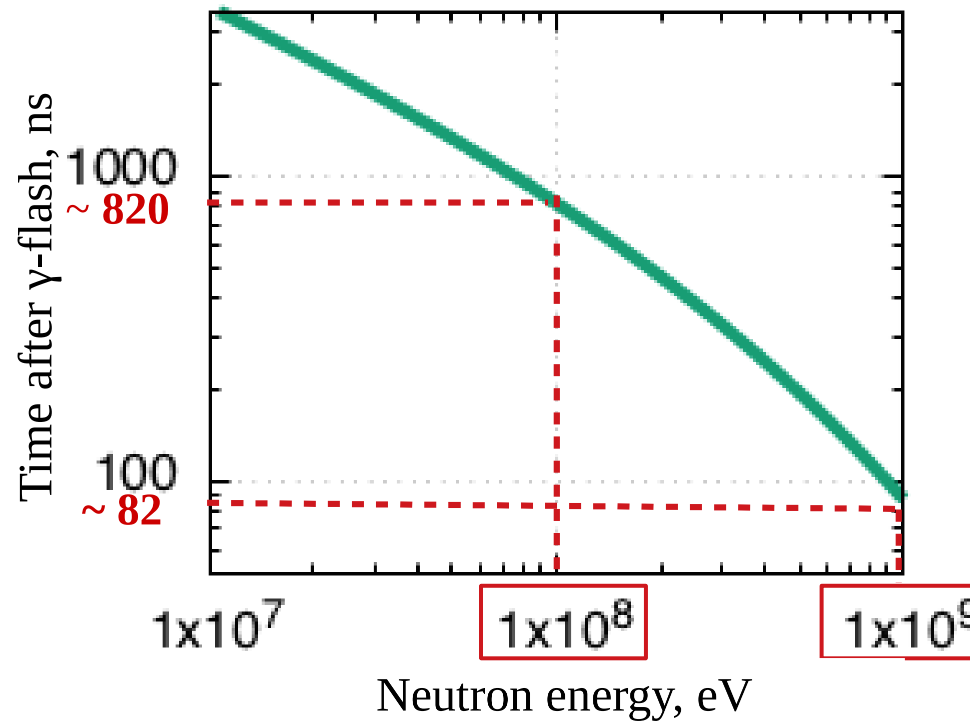
FF from 1st ^{235}U

FF from 2nd ^{235}U

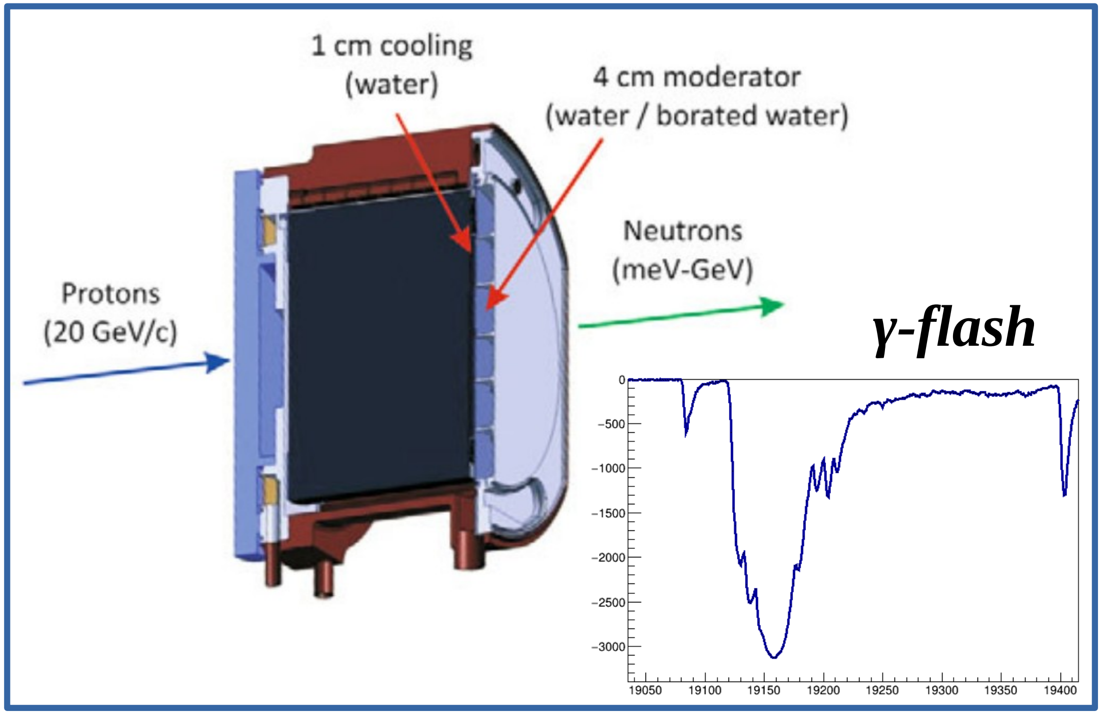


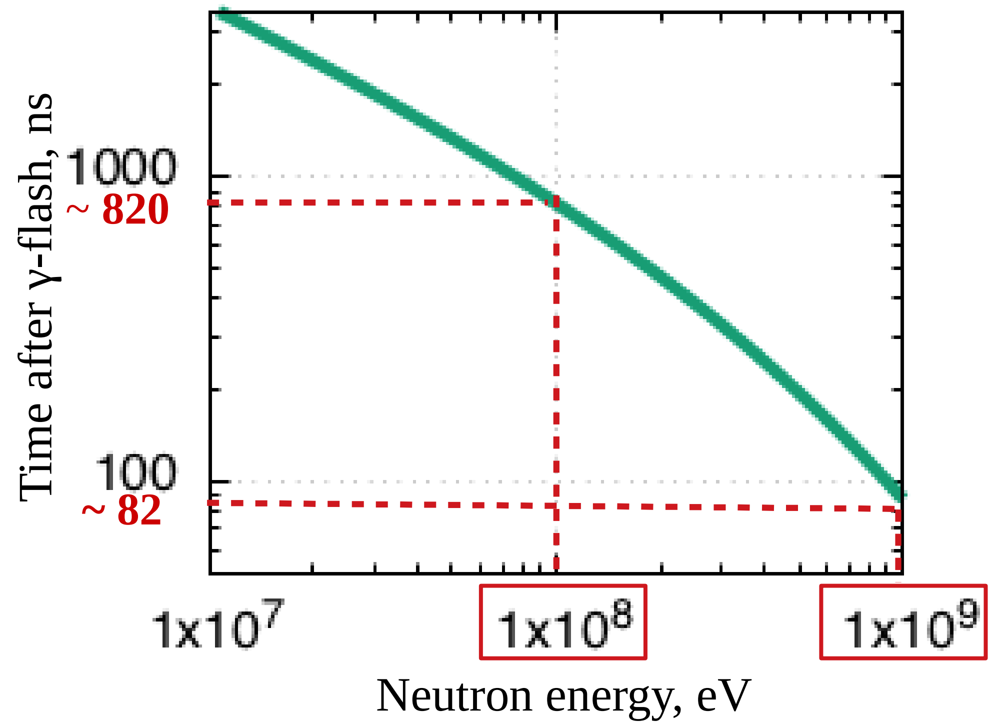
PRT - Response to the γ-flash

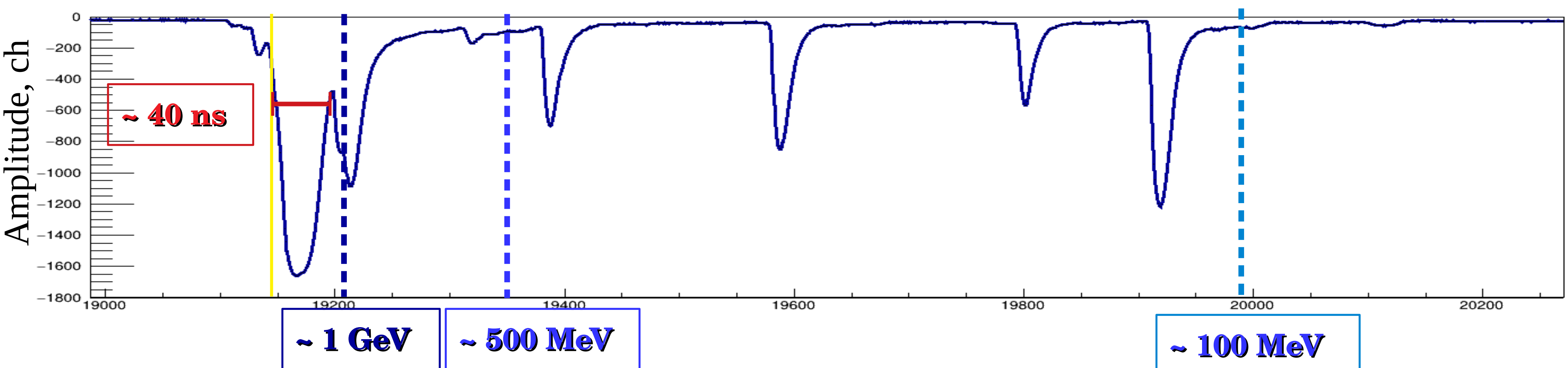




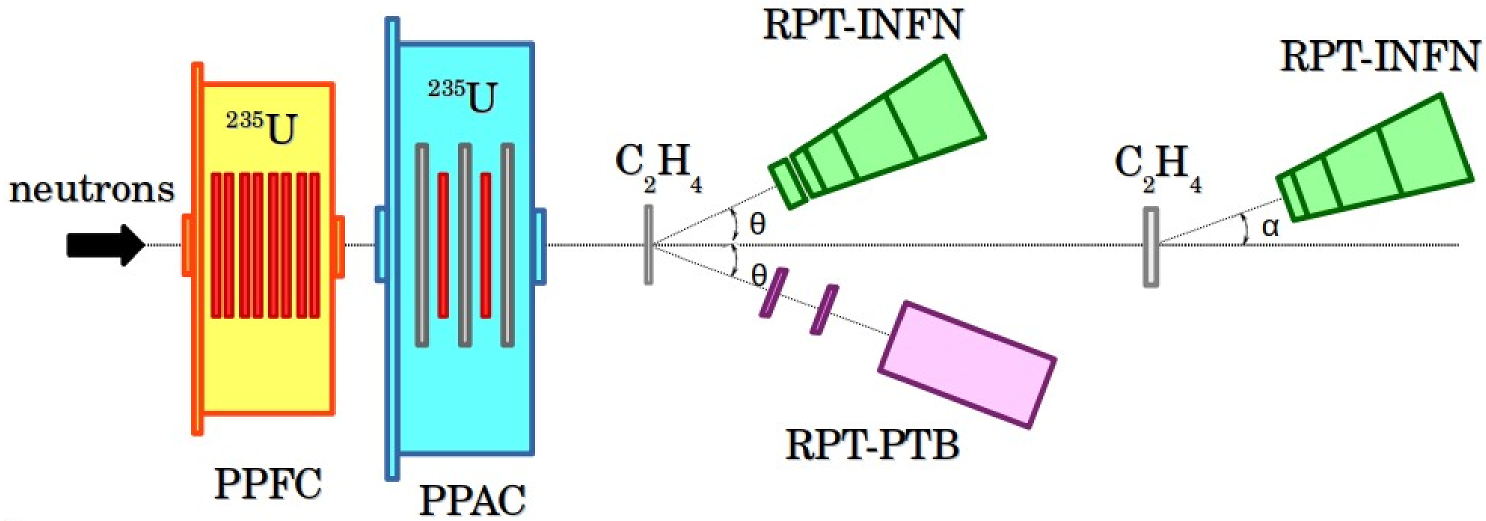
PRT - Response to the γ-flash







Experimental setup



^{235}U fission reaction

Fission fragment

IC

4 double sided U (99.93% ^{235}U) = 32,660 mg

PPAC

2 samples U (92.7% ^{235}U) = 28 mg

Neutron flux

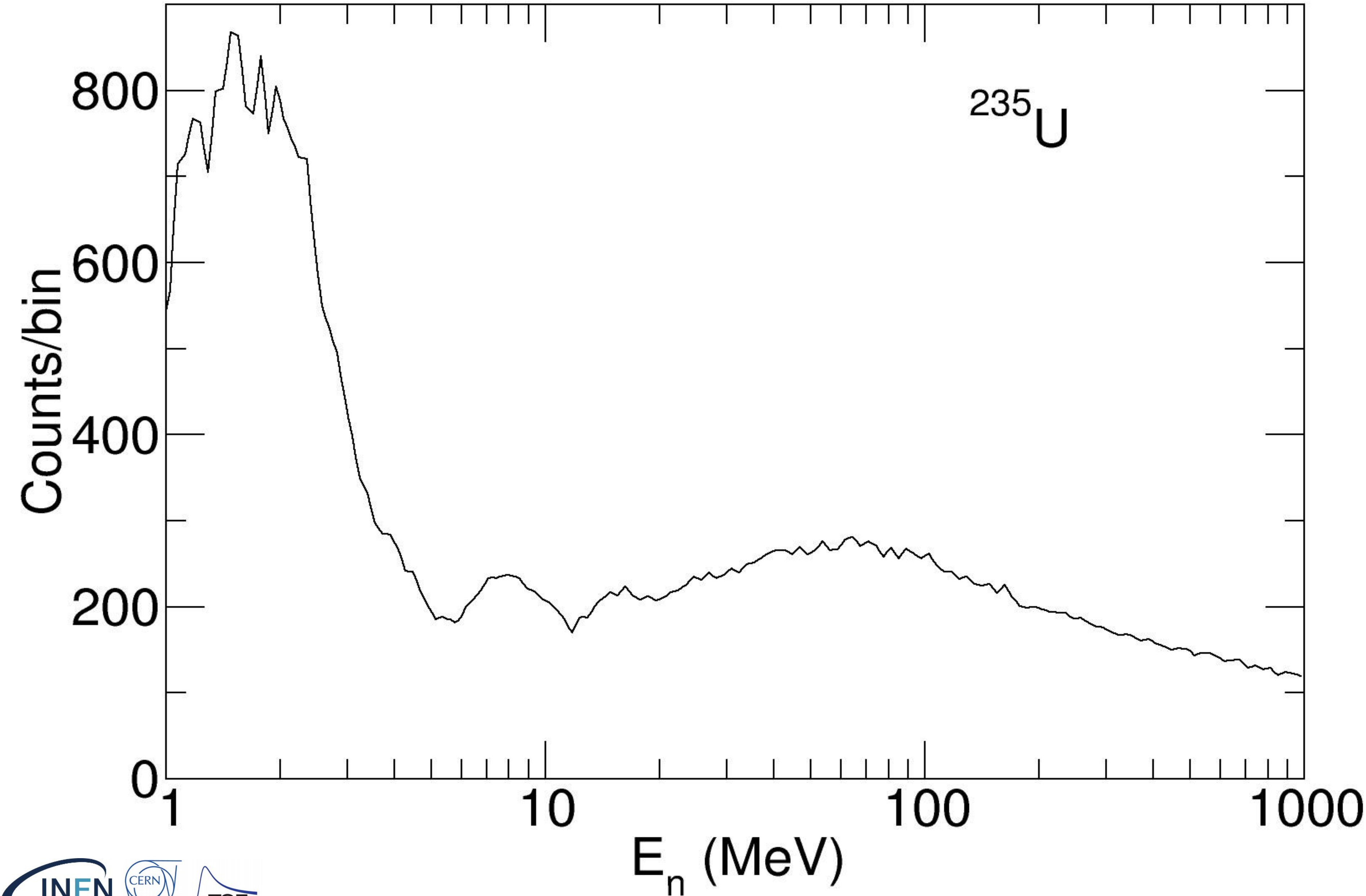
Elastic scattering

3 Proton Recoil Telescopes

located out of the neutron beam

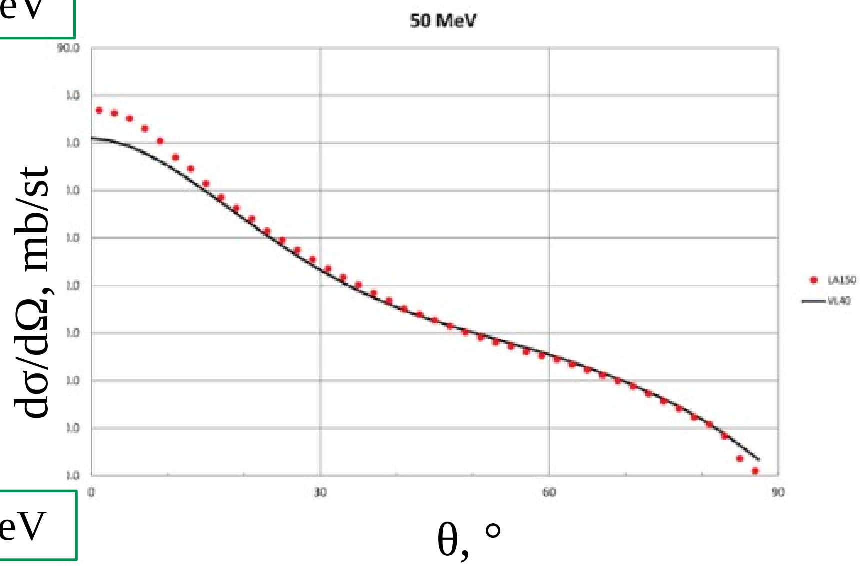
- 2 @ 25° pointing at a Polyethylene: 1/2/5 mm thick
- 1 @ 20° pointing a Polyethylene: 5 mm thick

$^{235}U(n,f)$ counts

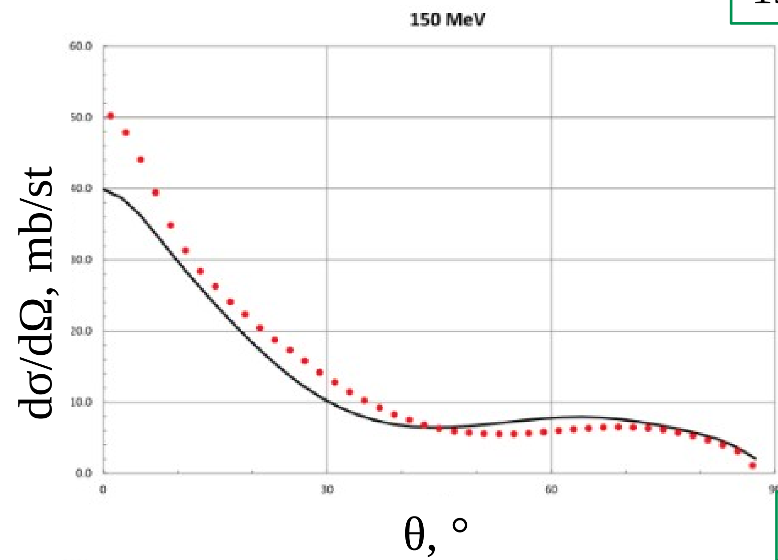


n-p scattering cross section

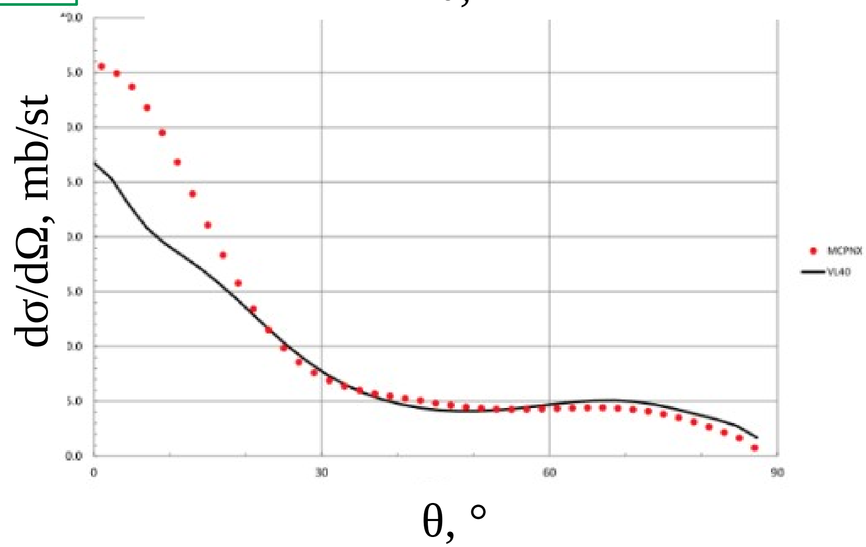
50 MeV



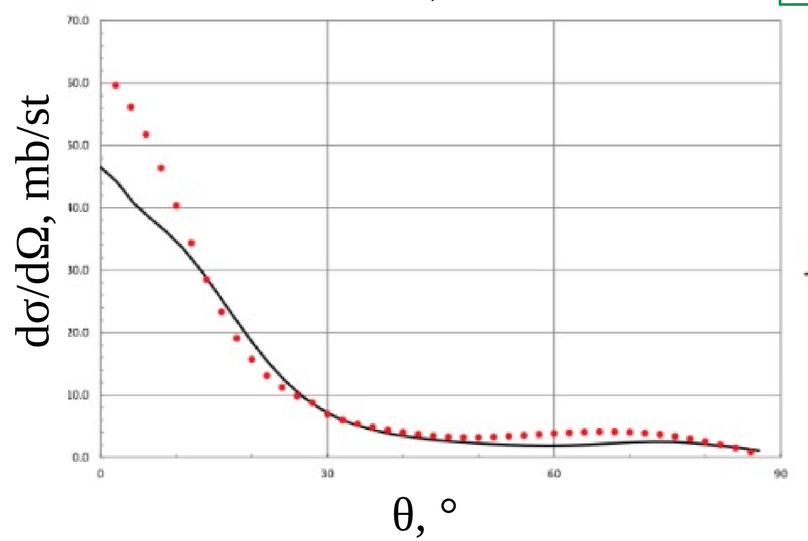
150 MeV



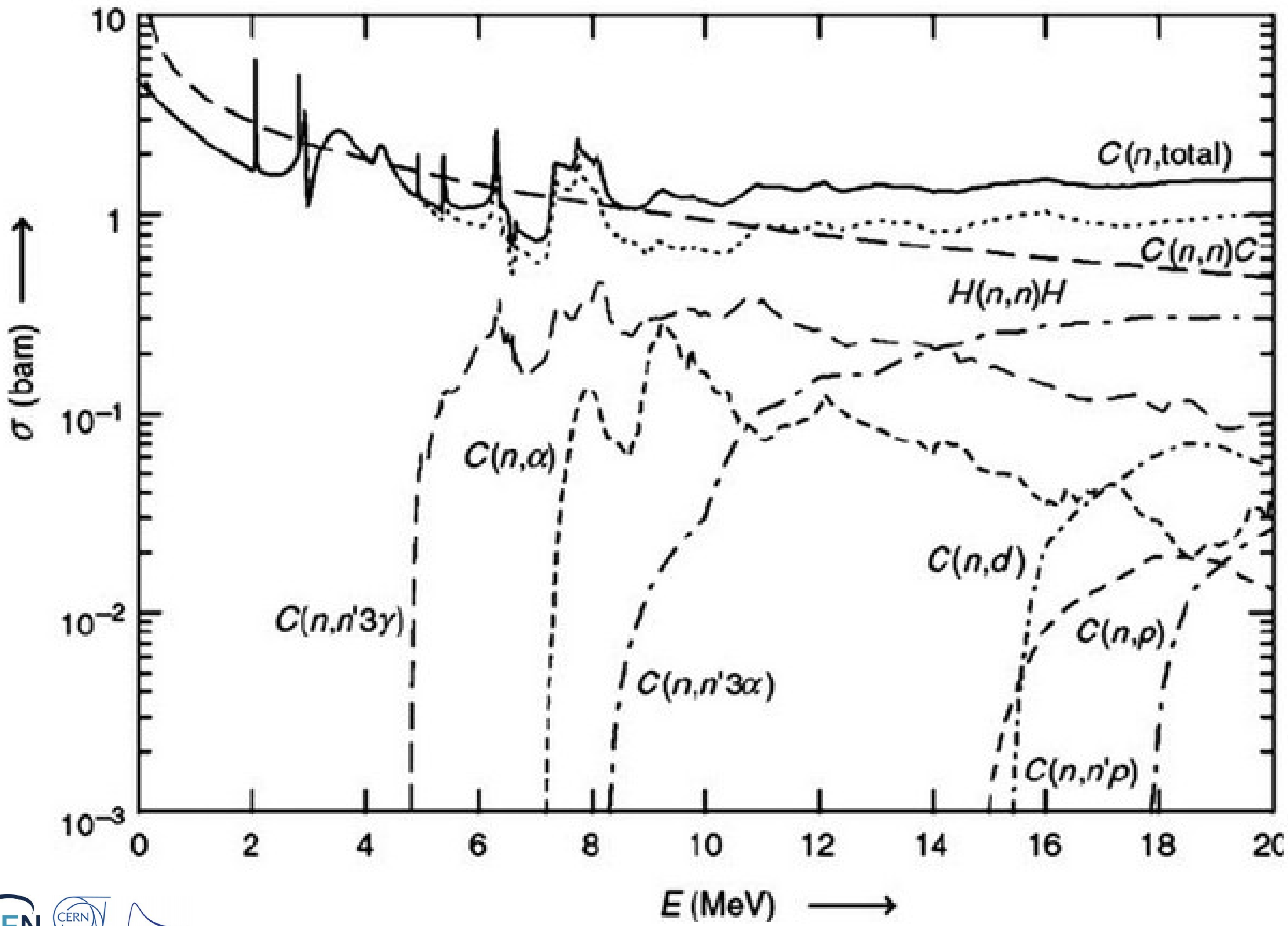
300 MeV



600 MeV



n-C scattering cross section



n-p scattering cross section