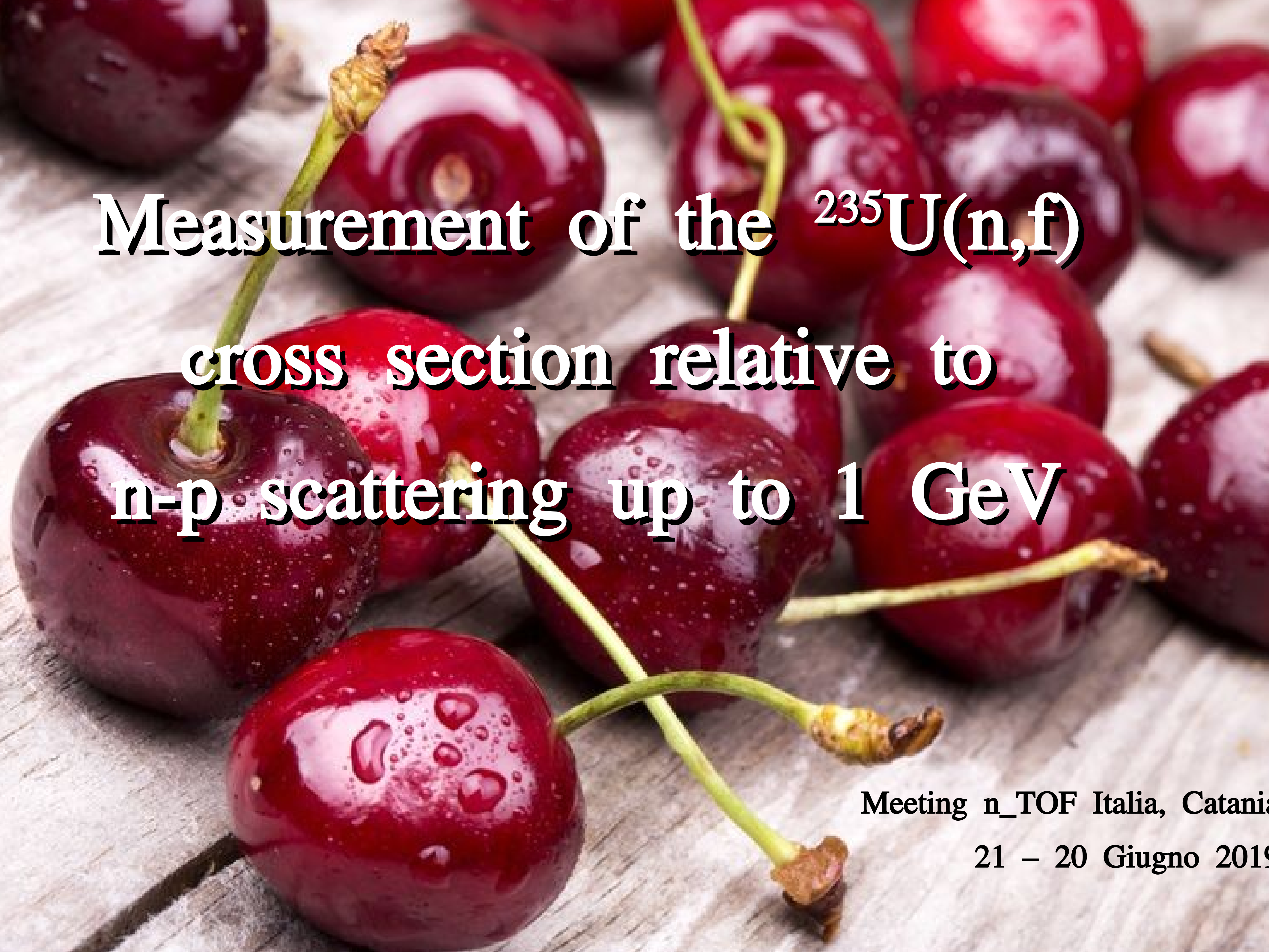


Measurement of the $^{235}U(n,f)$ cross section relative to n-p scattering up to 1 GeV

Meeting n_TOF Italia, Catania

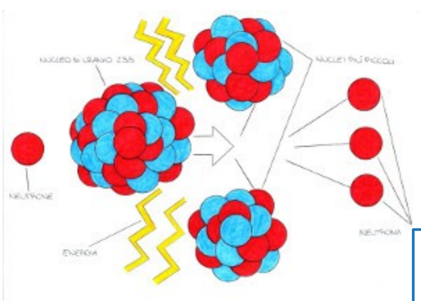
21 – 20 Giugno 2019

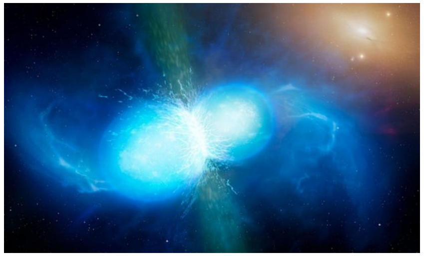
Motivations

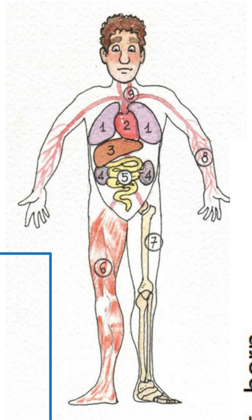
INDC International Nuclear Data Commitee

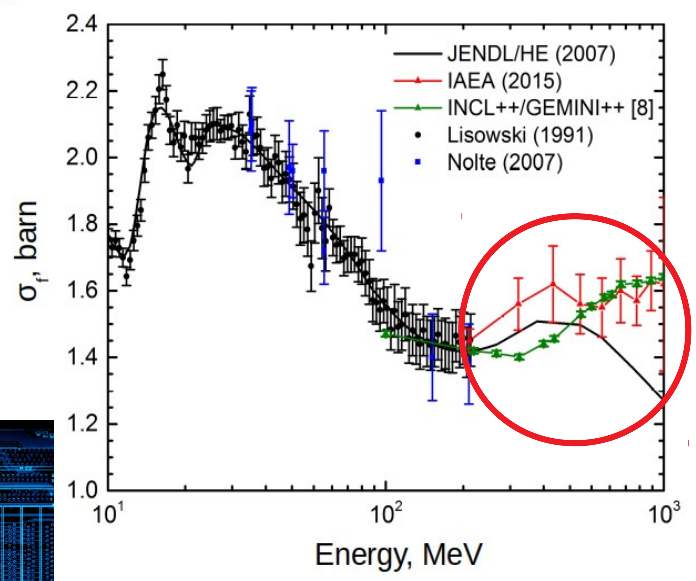
*“…Our analysis indicates that the new absolute measurements of the neutron induced fission cross section (e.g. **relative to n-p scattering**) on **Uranium**, Bismuth, Lead and Plutonium have the highest priority in establishing neutron induced fission reaction standard **above 200 MeV**…”*

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

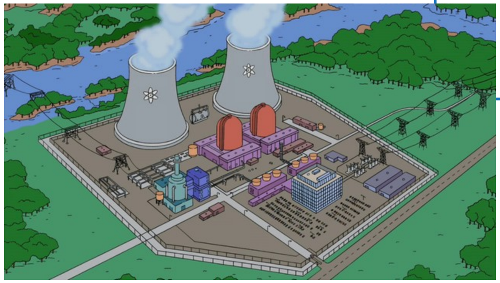


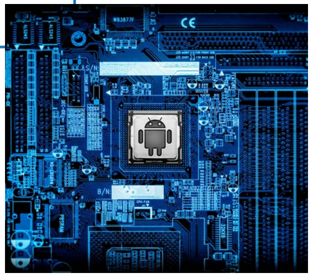




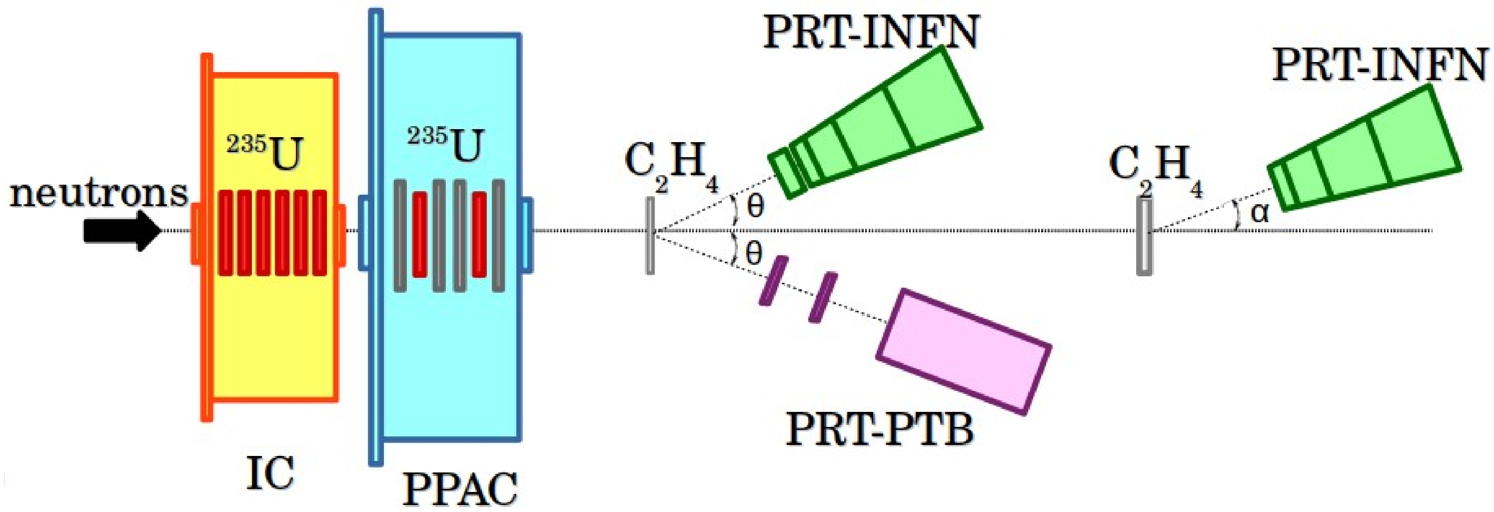


^{235}U(n,f) is one of the most significant cross-section standards at 0.025 eV and [0.15-200] MeV **BUT** there are **no experimental data above 200 MeV**, despite its importance





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

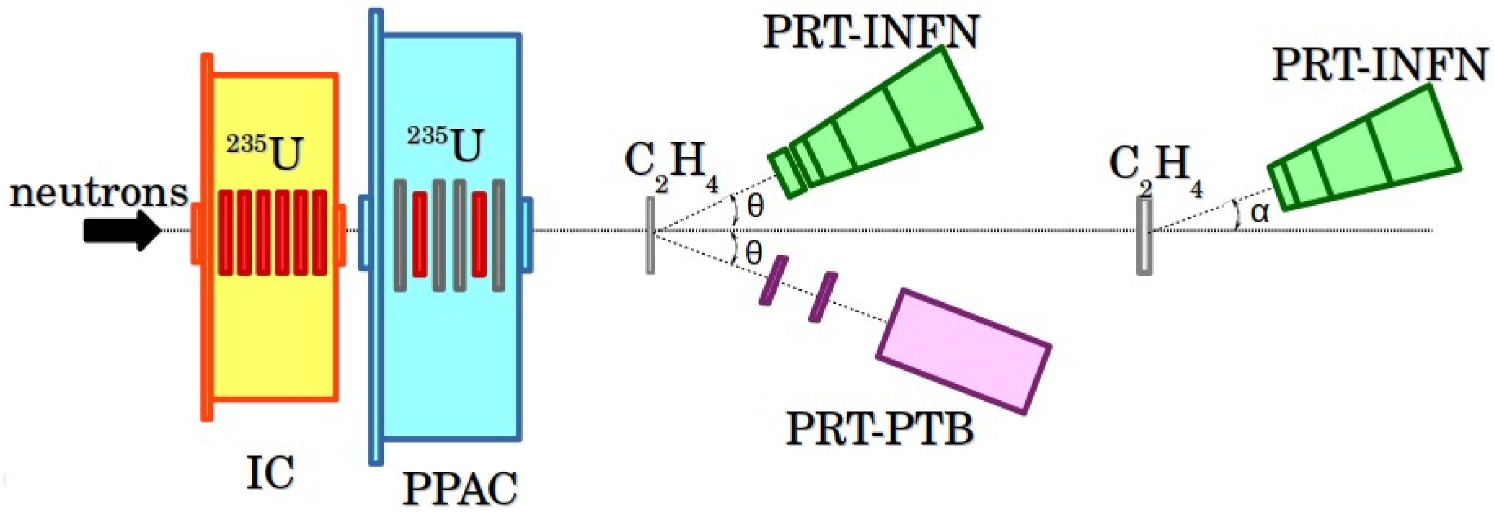
3 Proton Recoil Telescopes

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

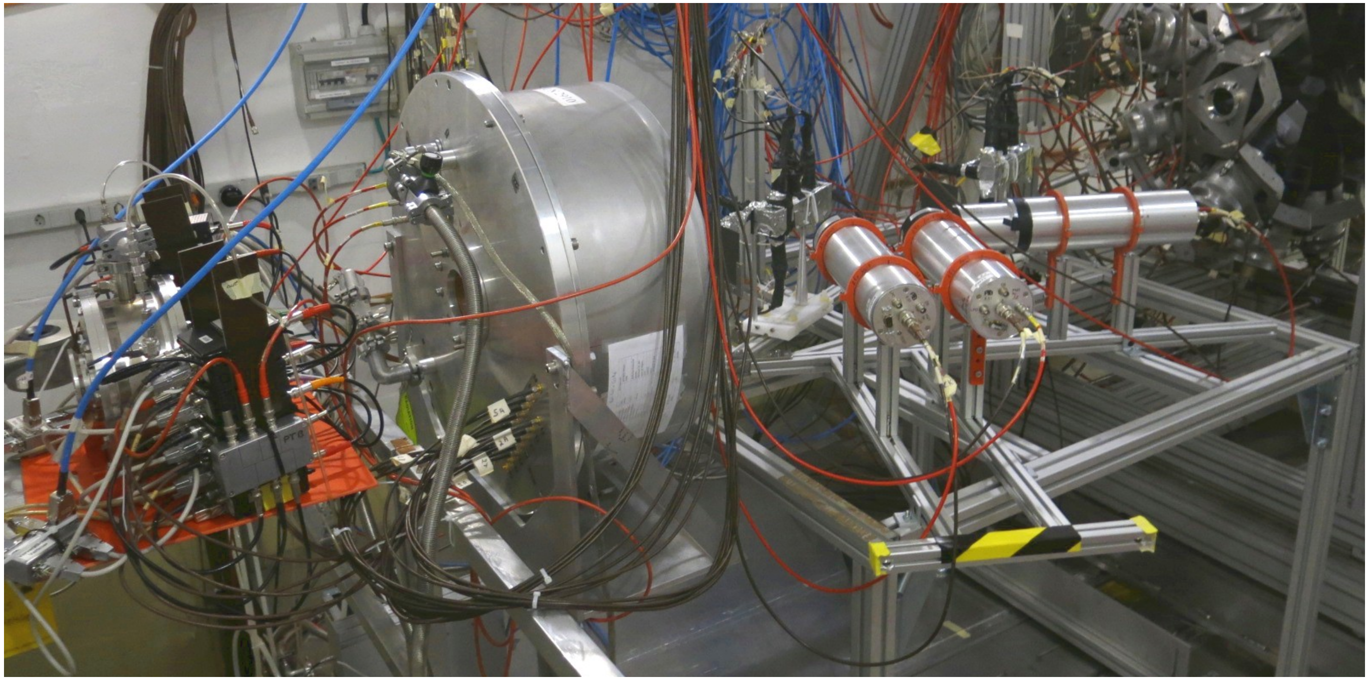
Experimental setup



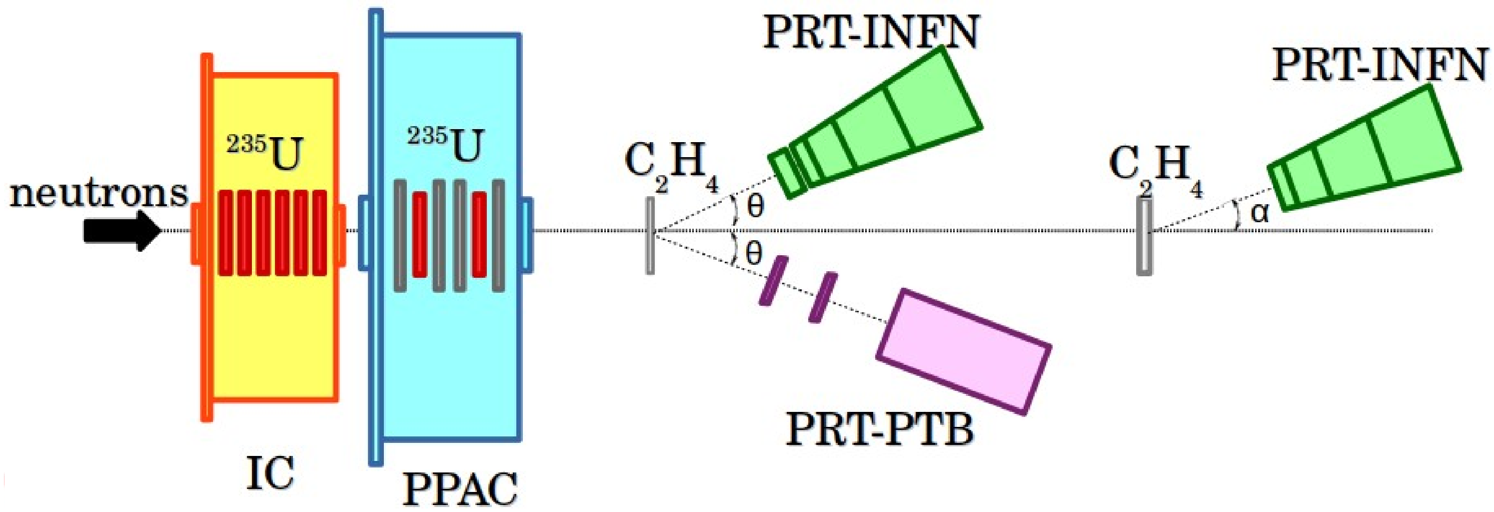
Measurement campaign

Sept 17th Oct 29th

Pot = 3.95 · 10^{18}



Experimental setup

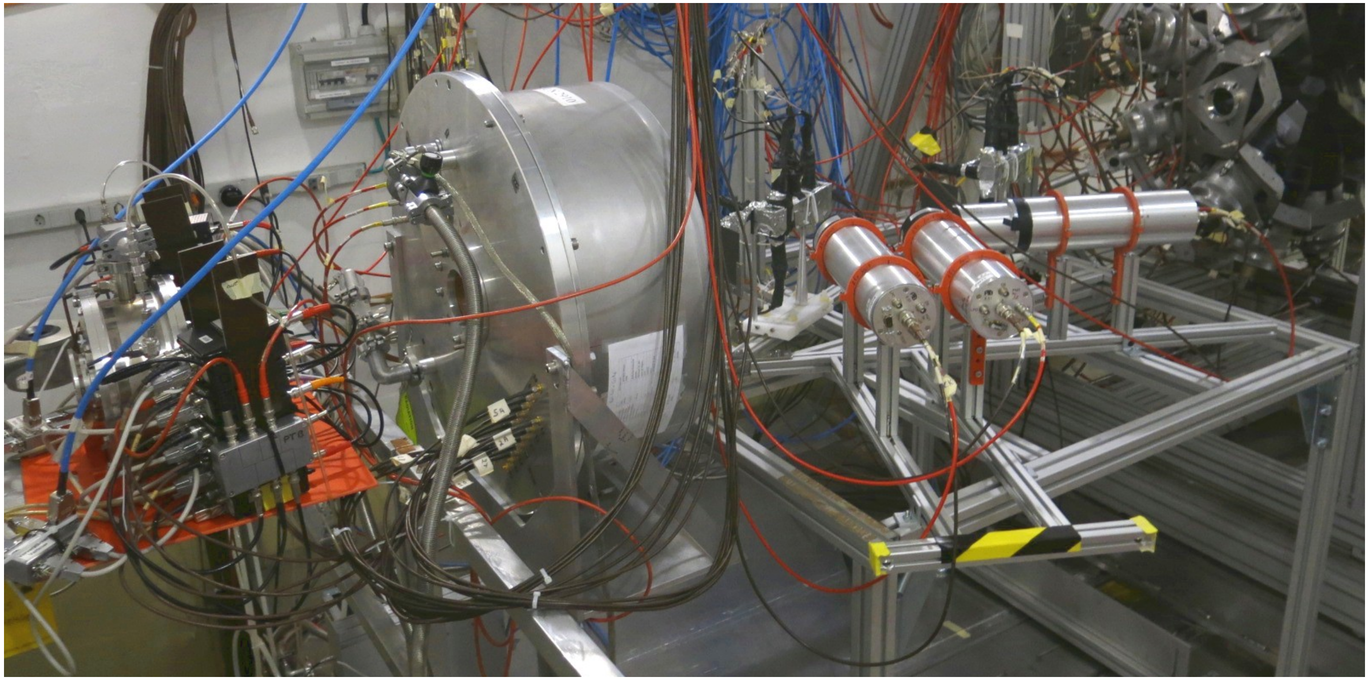


Measurement campaign
Sept 17th Oct 29th

↓

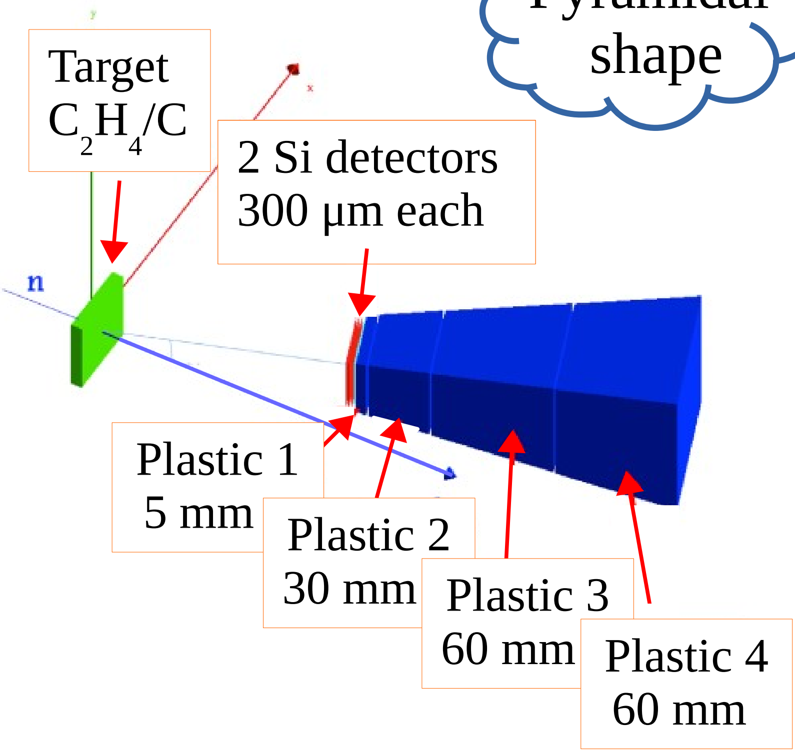
Pot = $3.95 \cdot 10^{18}$

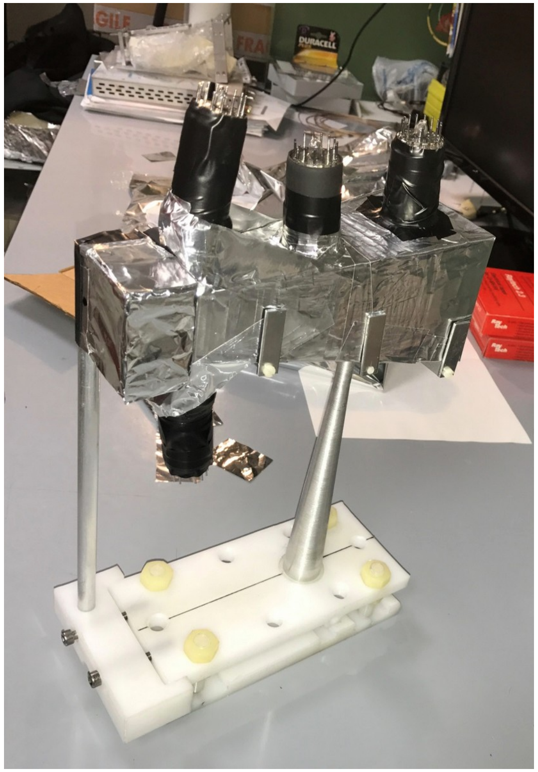
1. INFN – Telescopes
2. PPAC

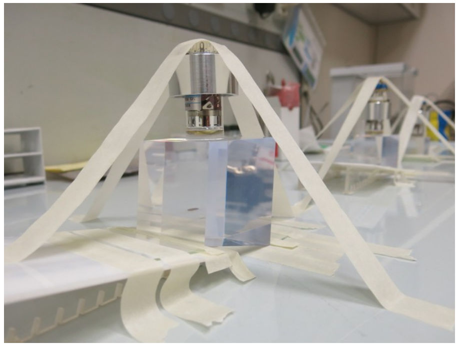


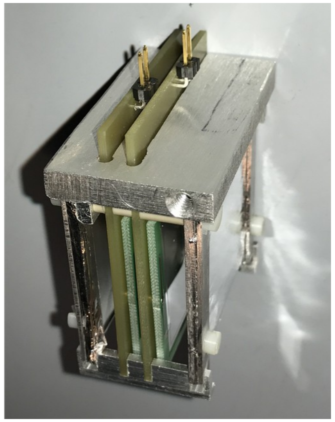
A Proton Recoil Telescope

Pyramidal shape

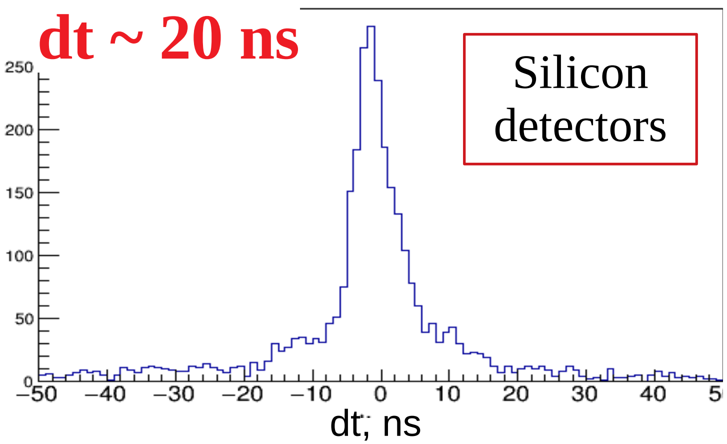


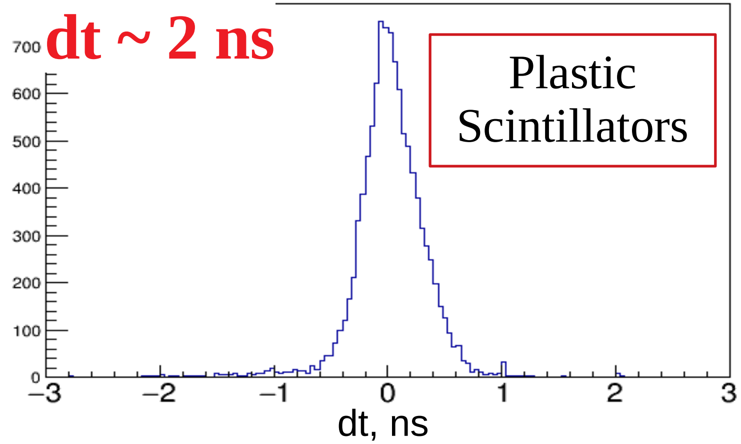




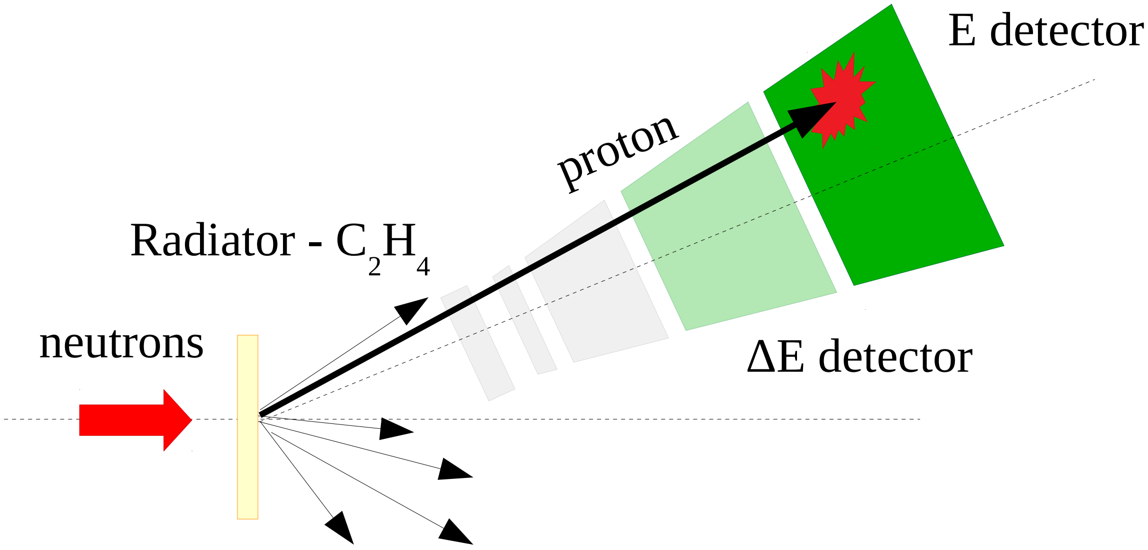


Timing properties:





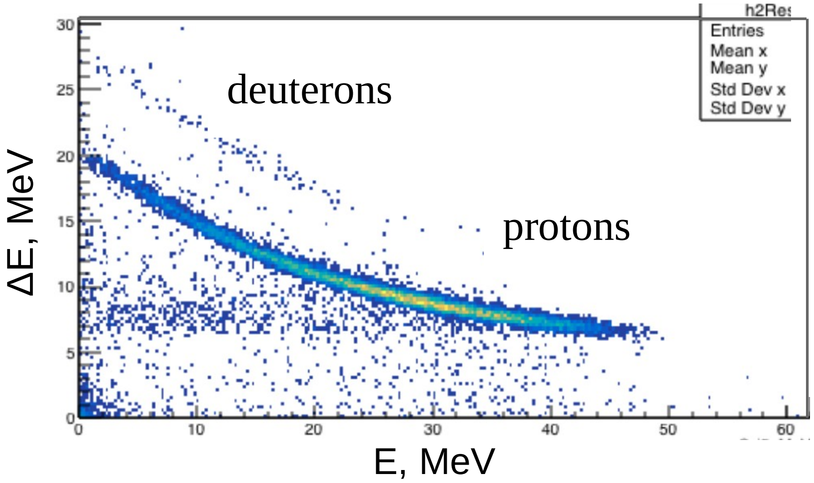
ΔE - E Matrix



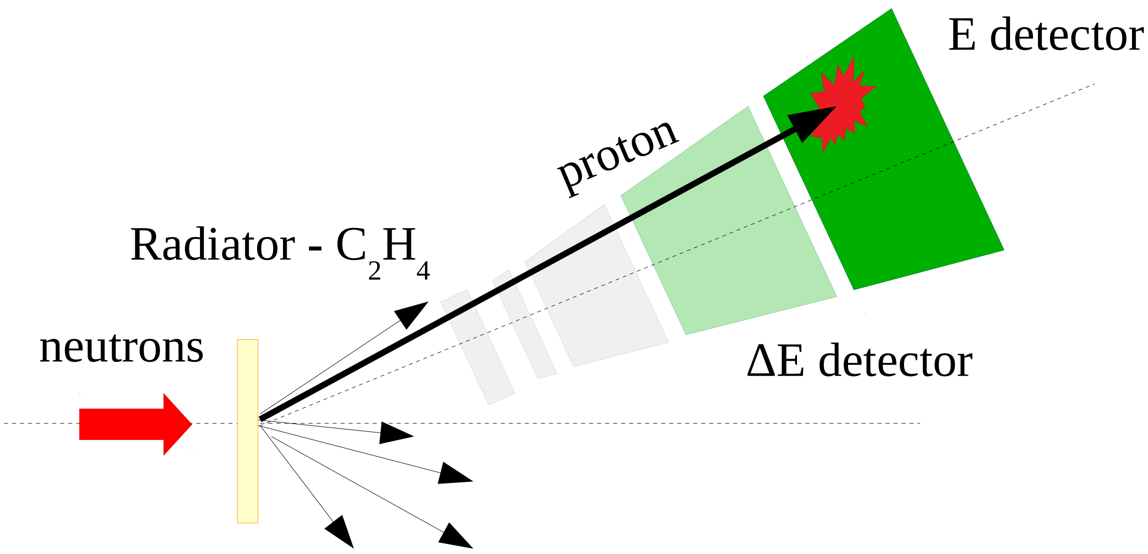
$$\boxed{\Delta E} \cdot \boxed{E} \propto k \cdot z^2 \cdot M$$

k: material absorption properties

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



Pulse Reconstruction



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

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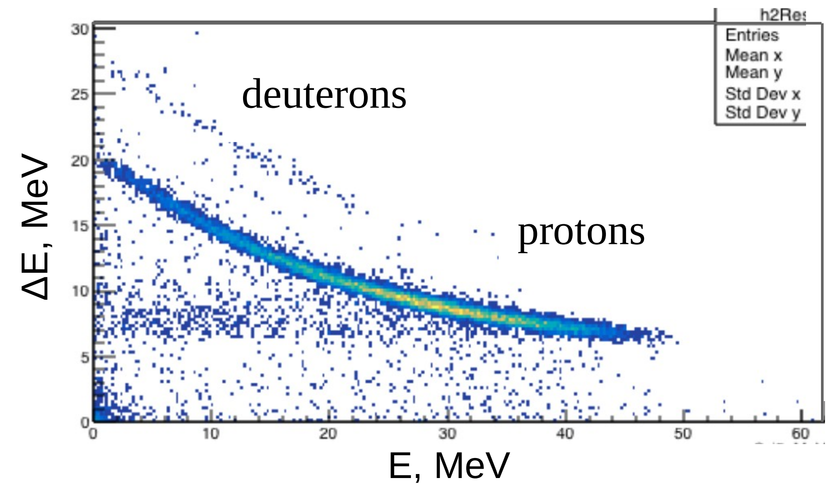
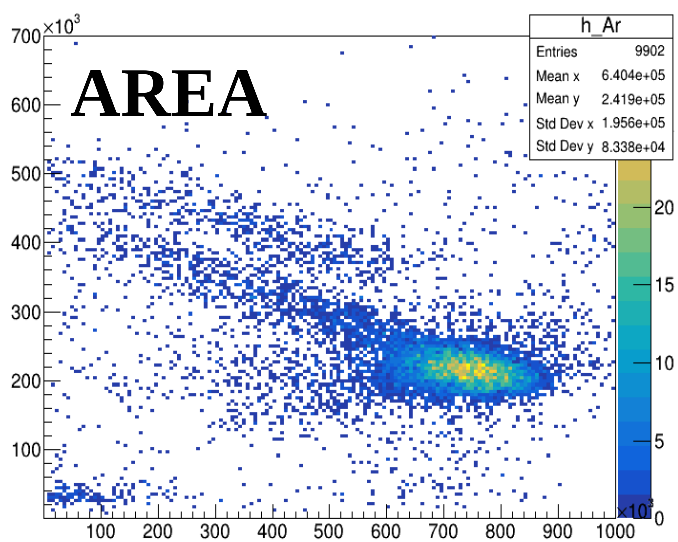
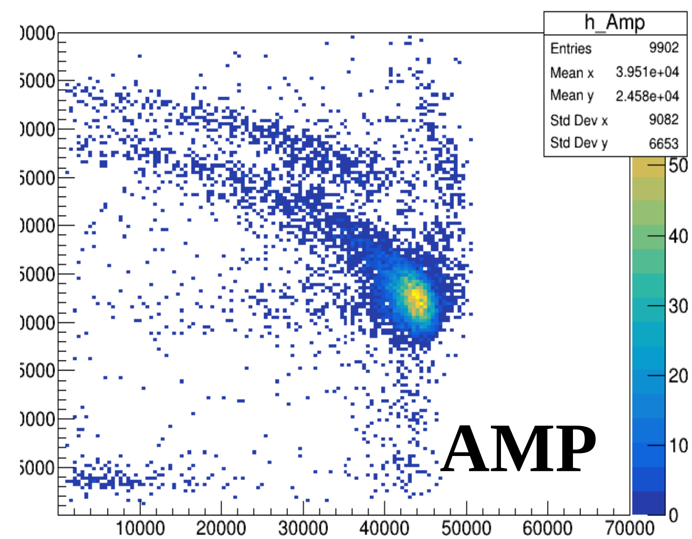


Deposited energy range in the Plastic Scintillators:

- 1st: 1-20 MeV
- 2nd: 1-50 MeV
- 3rd & 4th: 1-70 MeV





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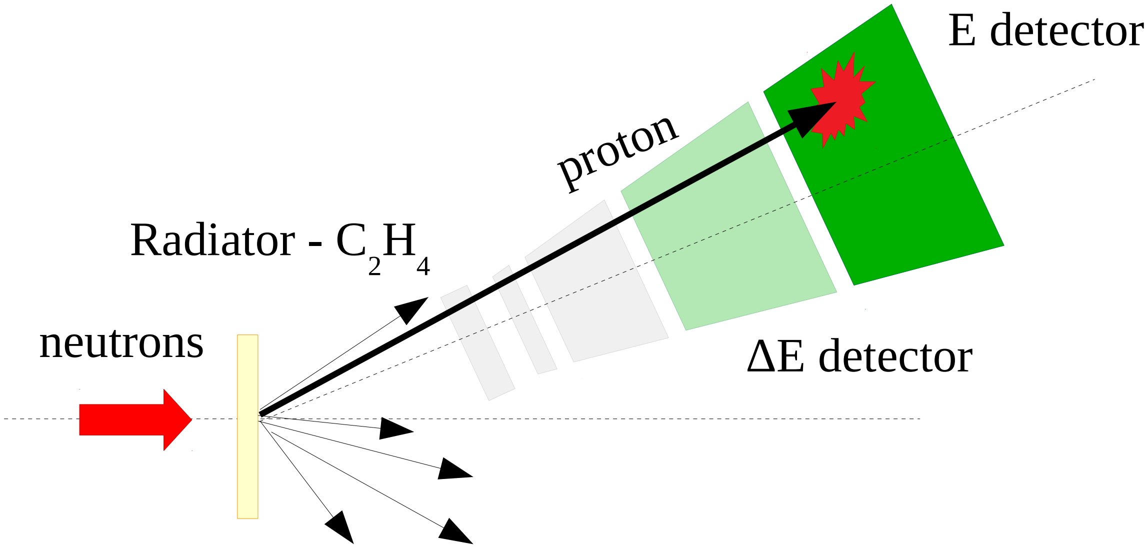

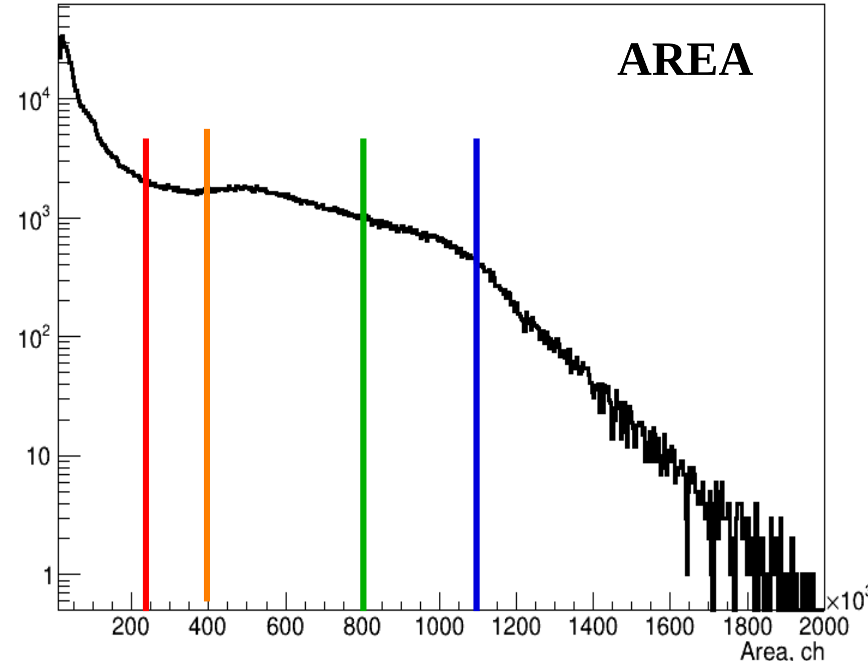

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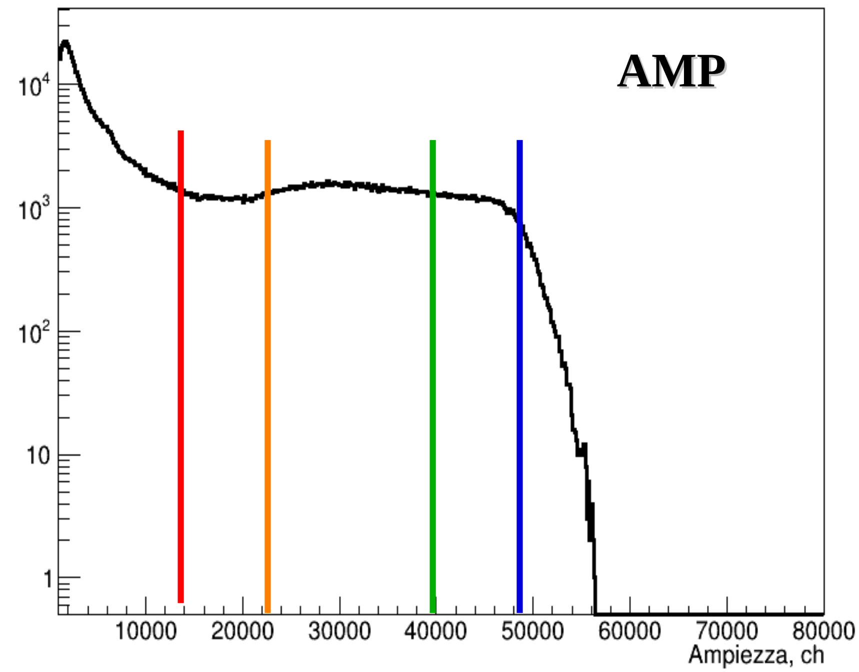


Numerical Integration

Fit with different shapes

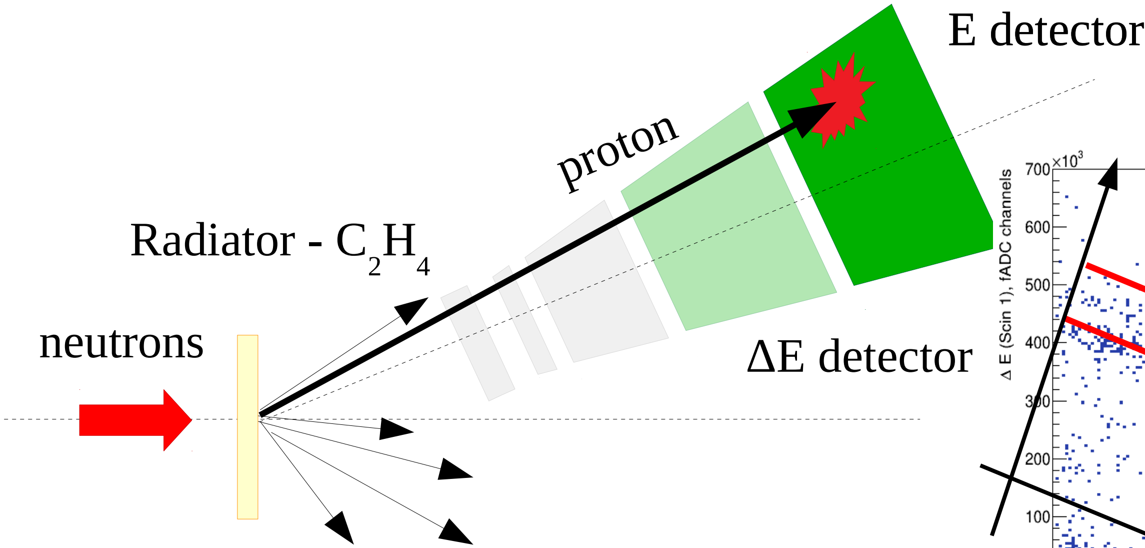
“Bigger” Signal

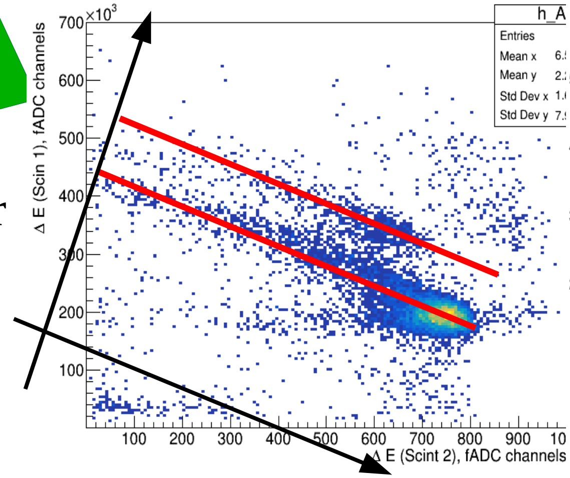
“Medium” Signal

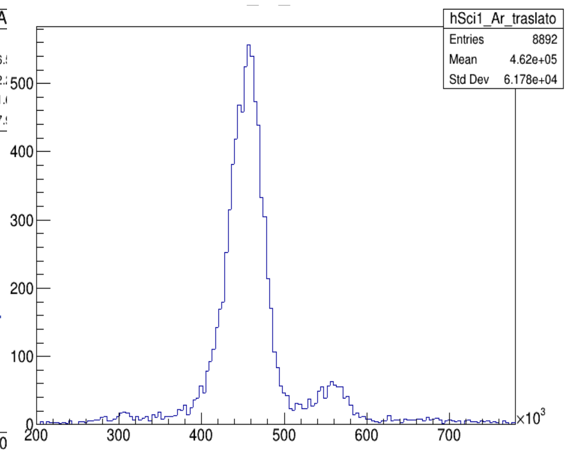
“Small” Signal

“Big” Signal

Pulse Reconstruction







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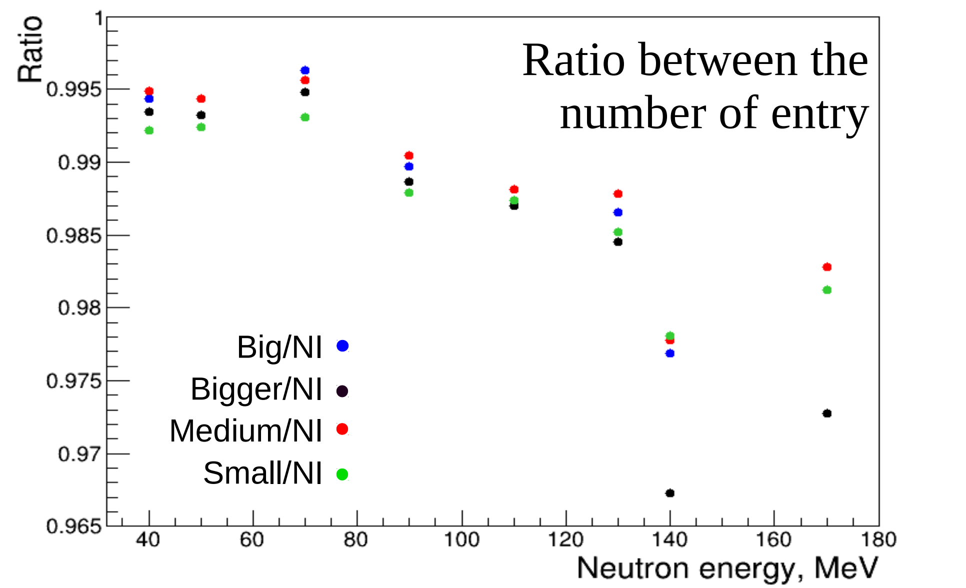
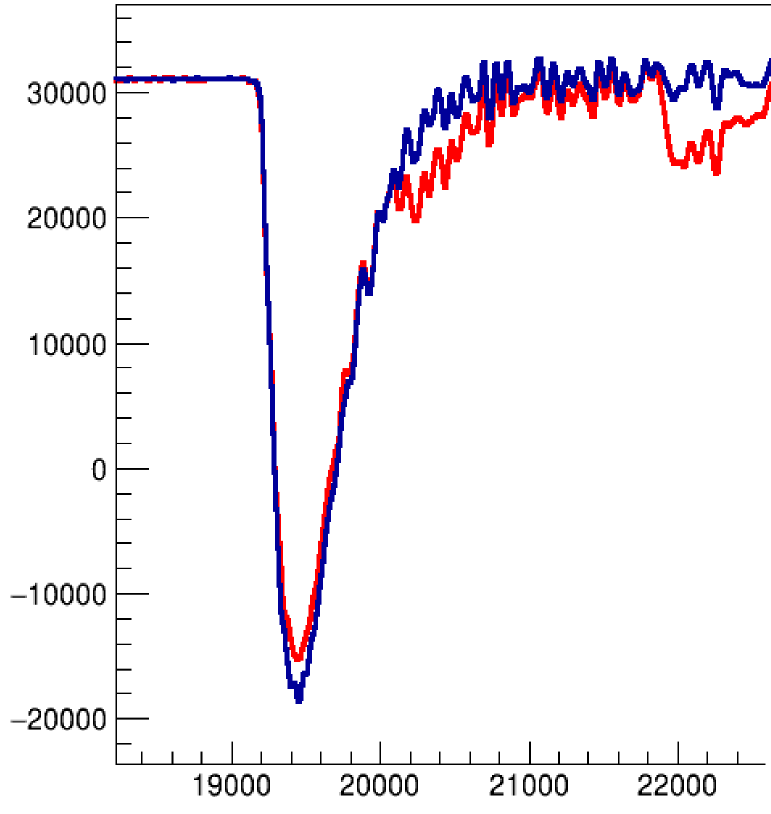
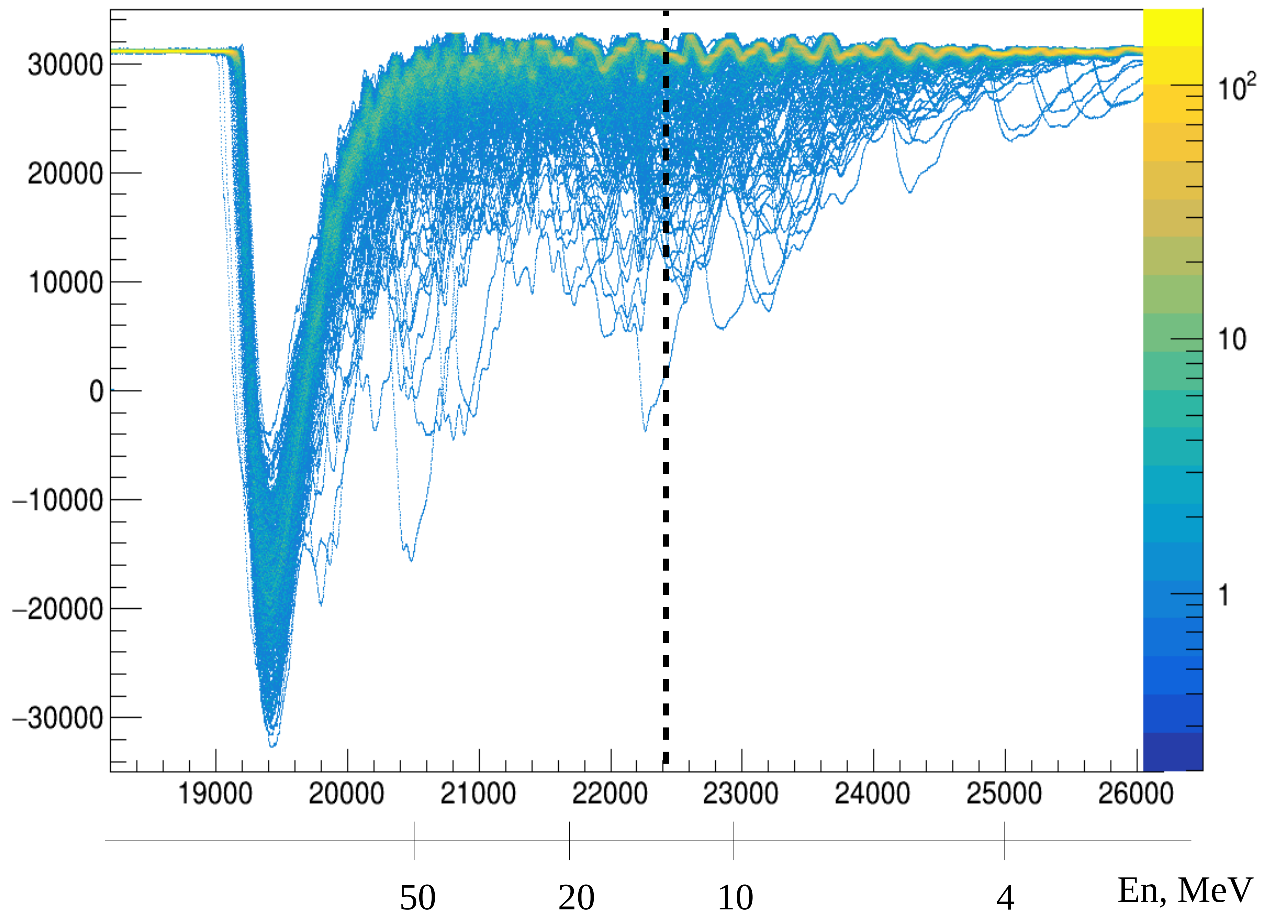


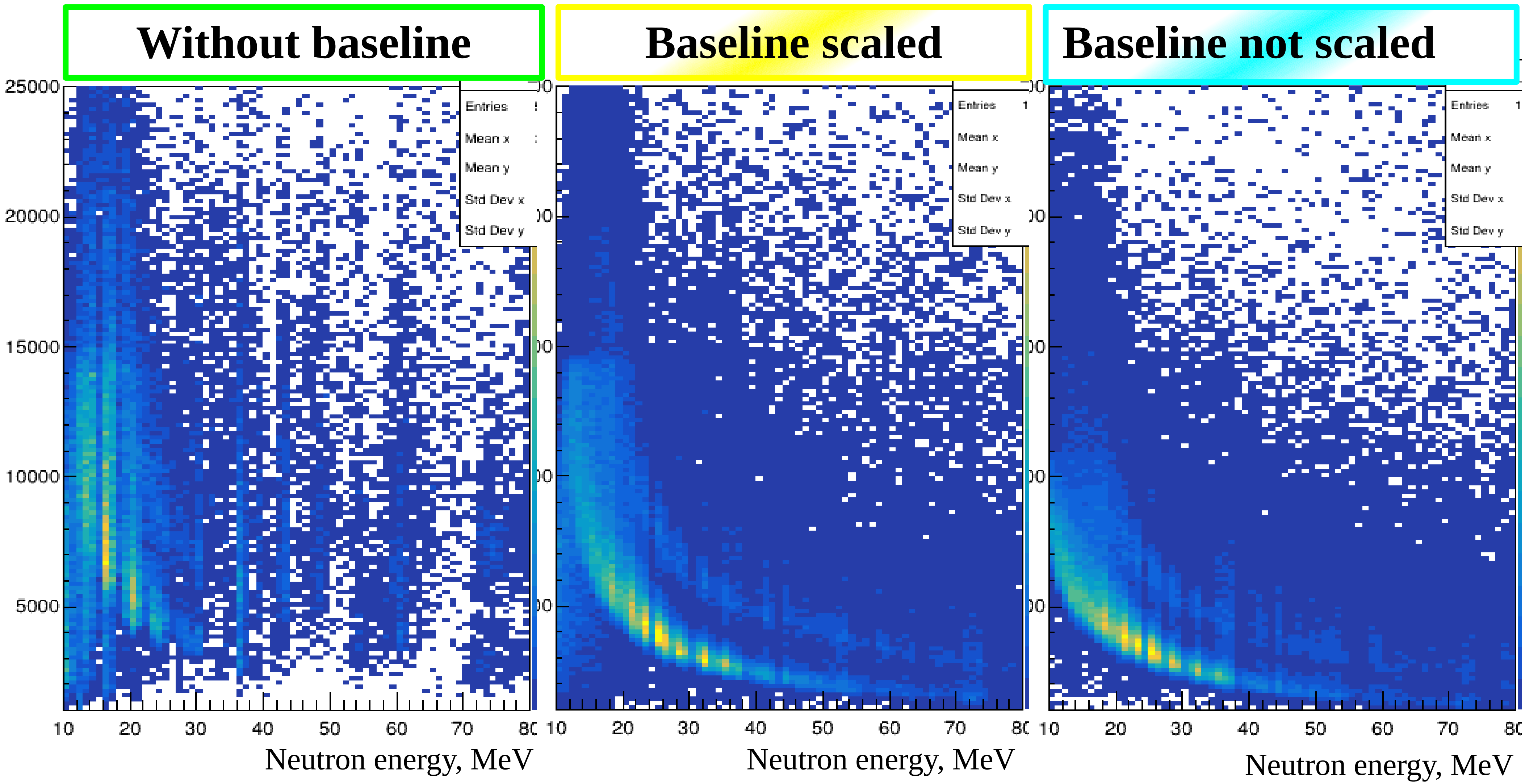
Silicon Detectors - baseline



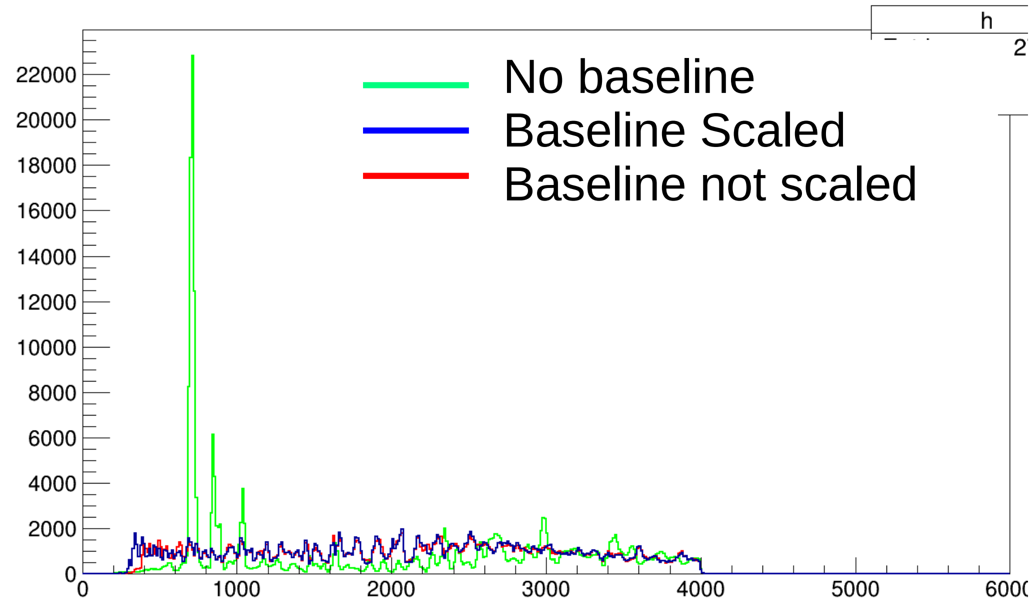
- Baseline scaled
- Baseline not scaled

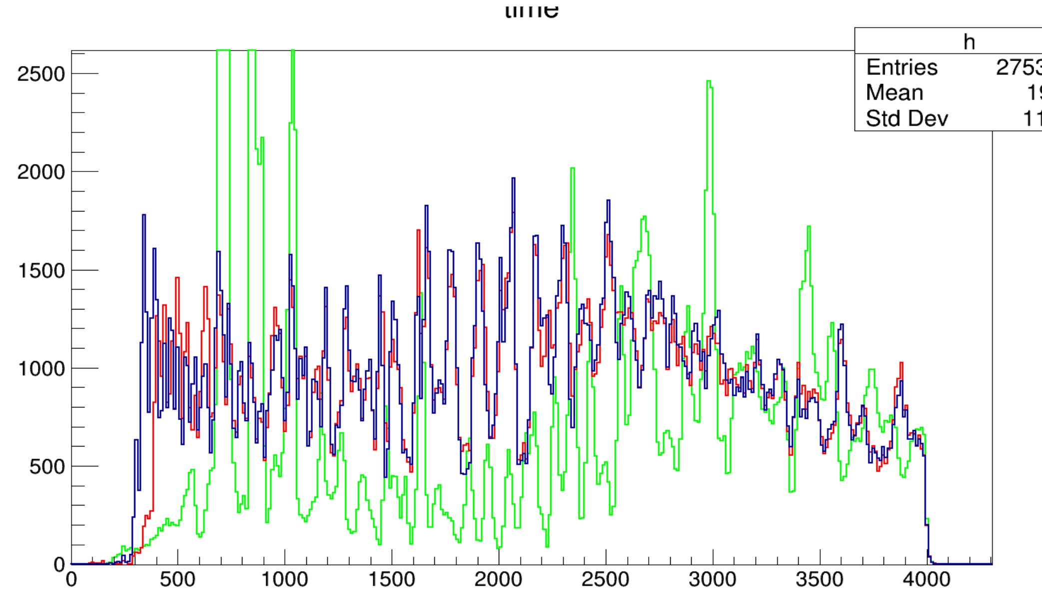


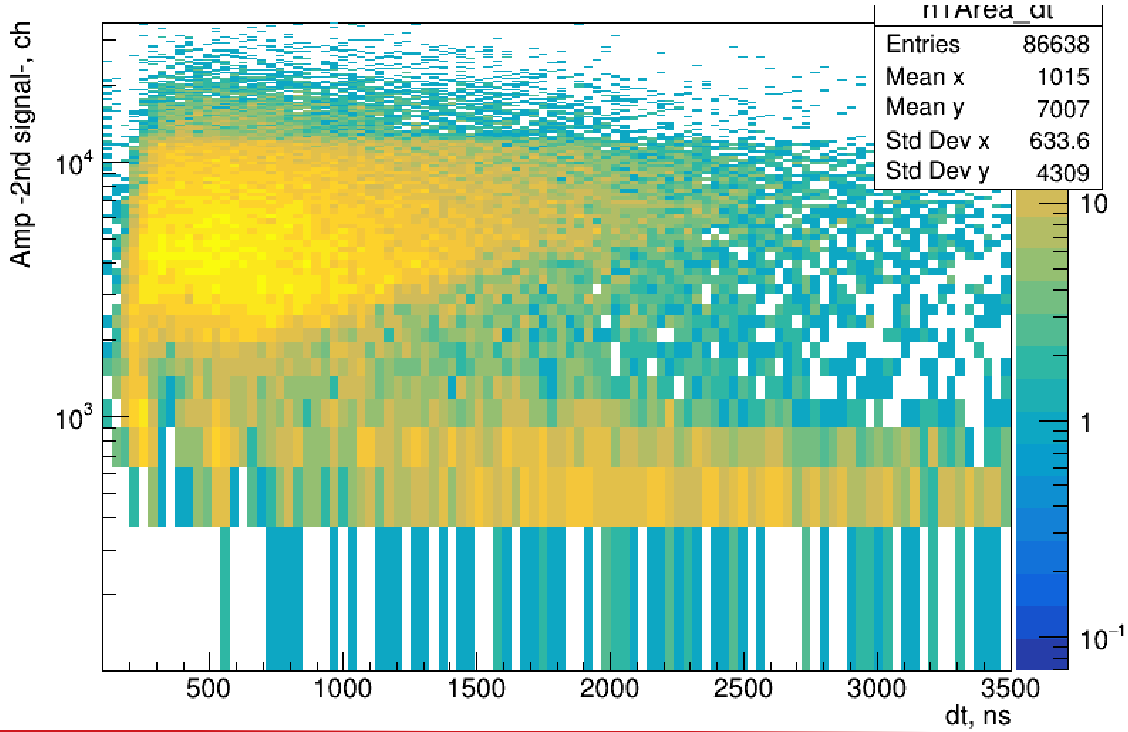
Amplitude vs Neutron energy



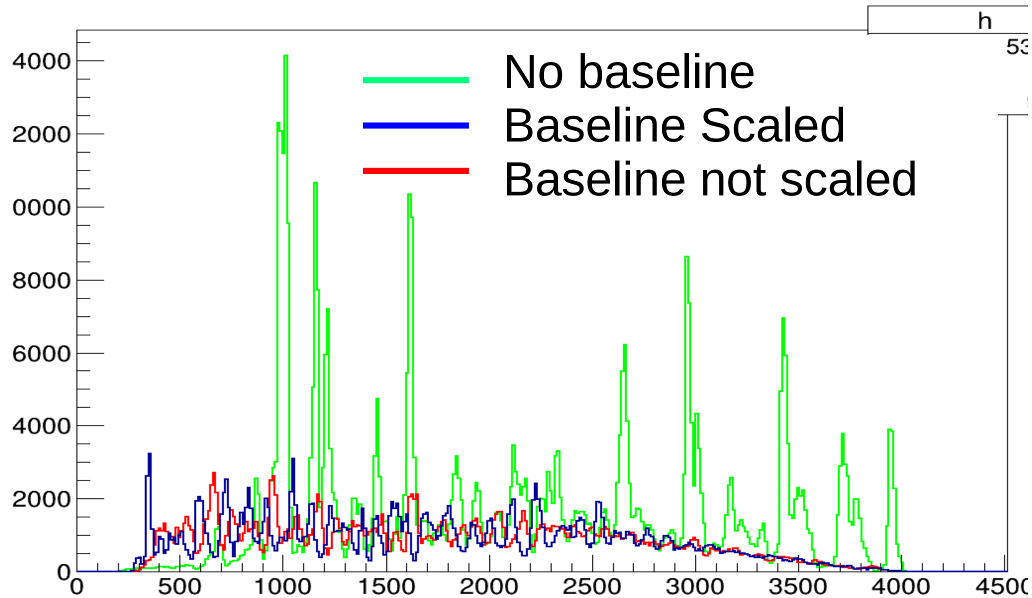
1st Silicon Detector - TOF

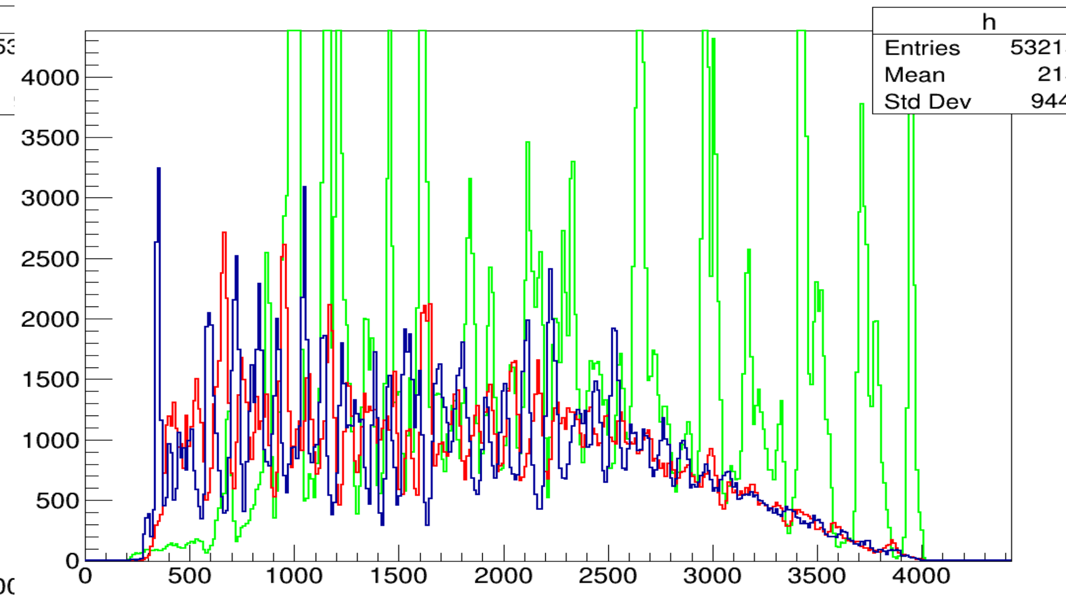


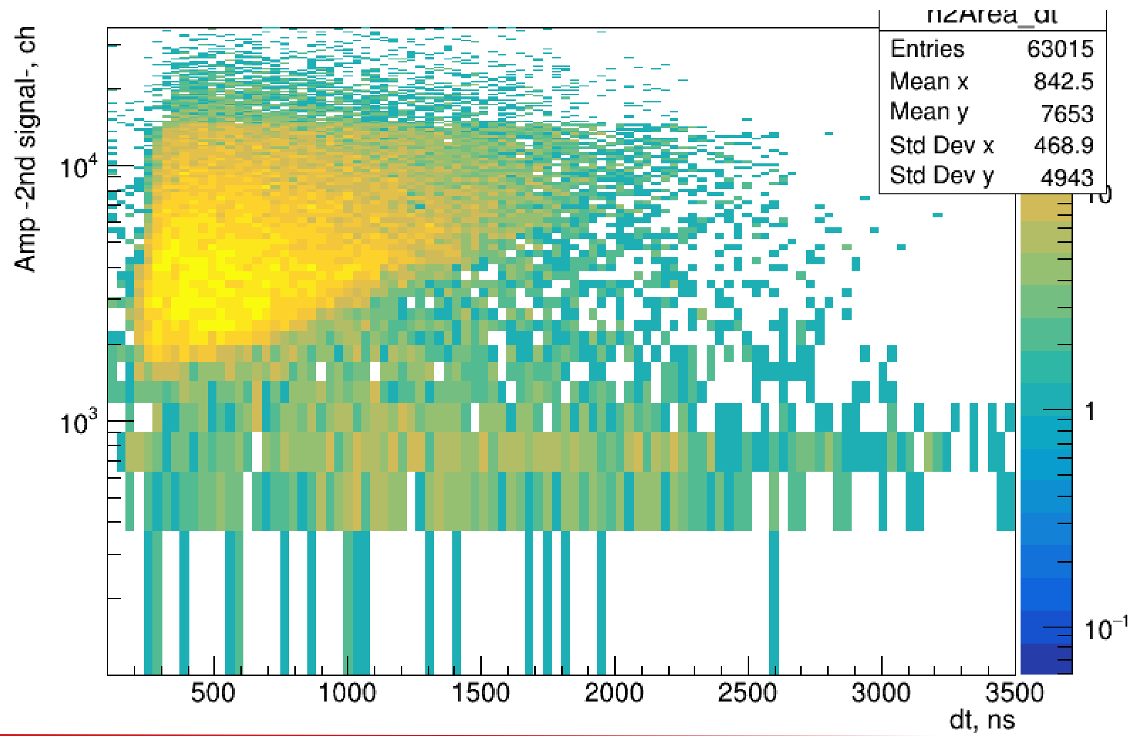




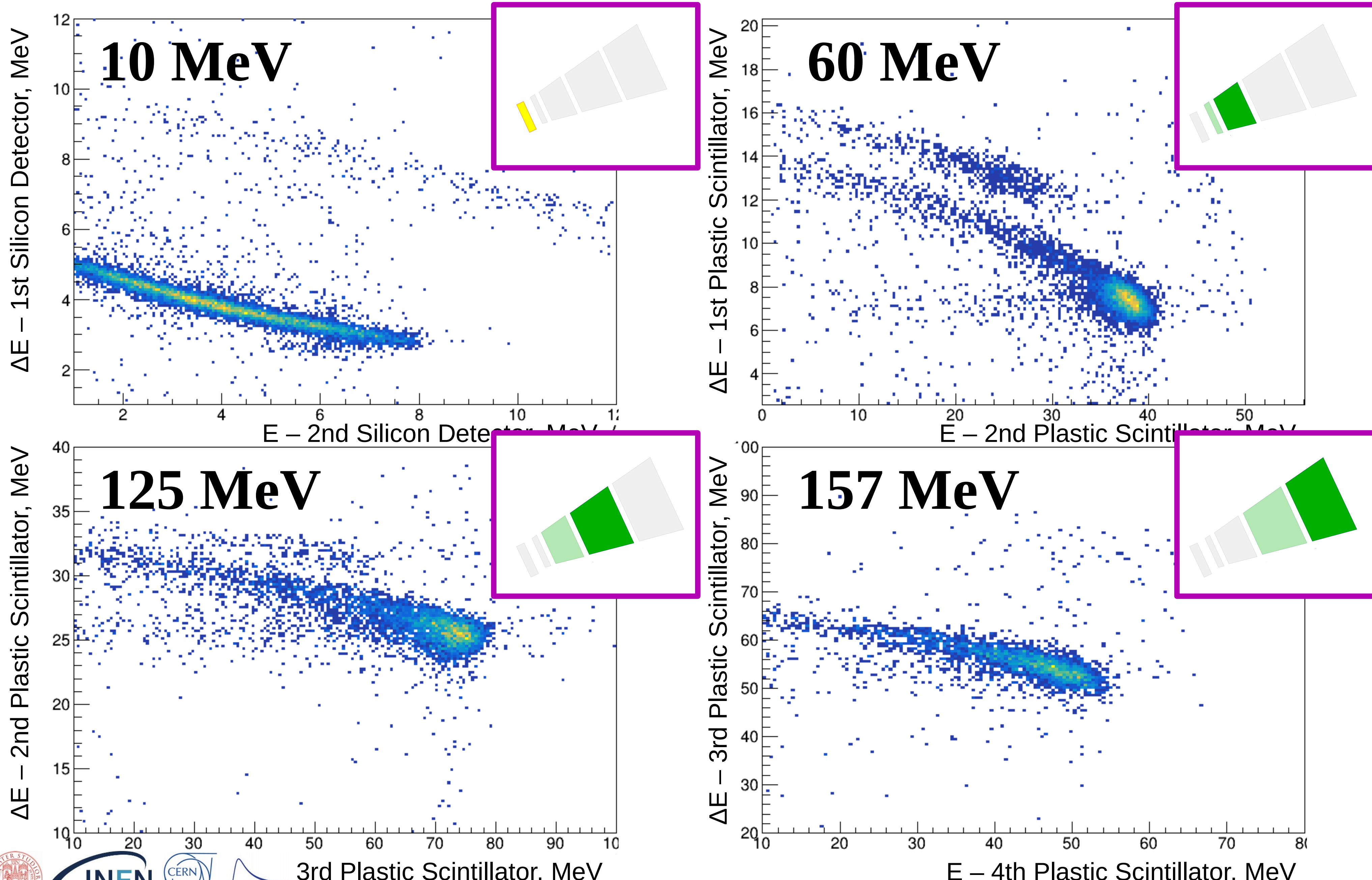
2nd Silicon Detector - TOF





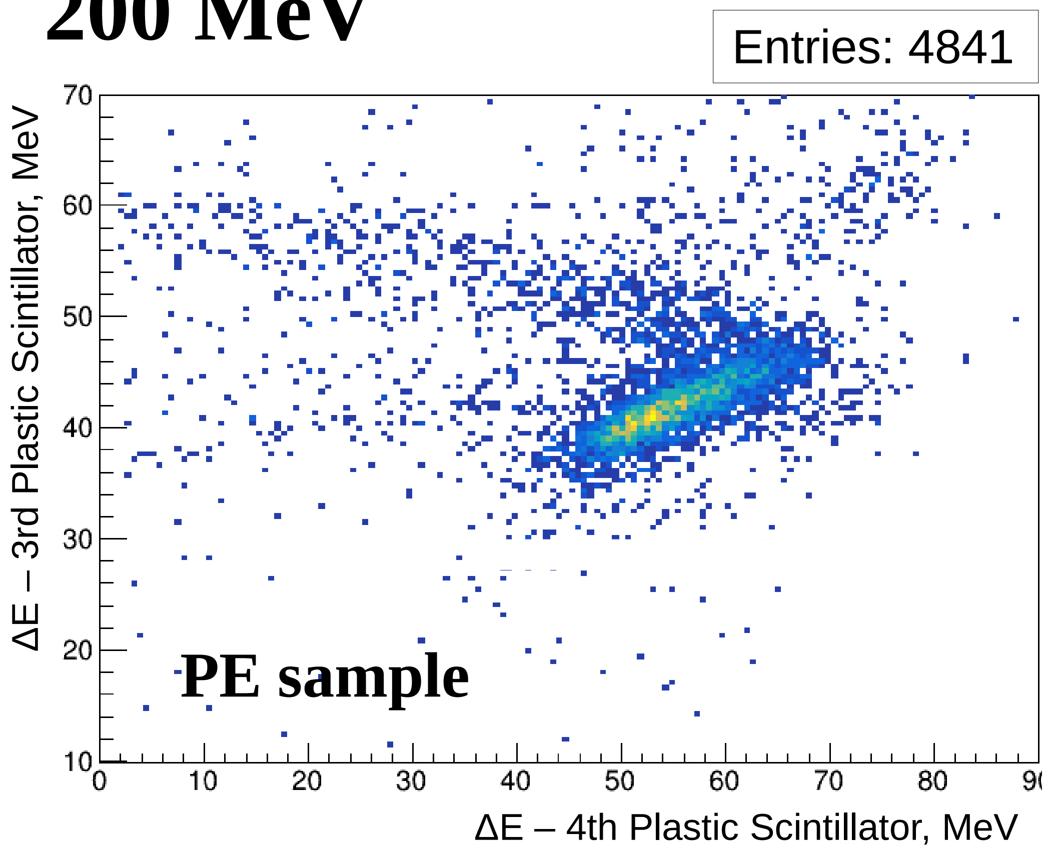


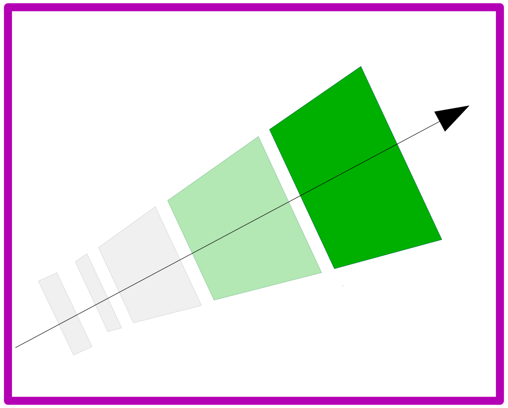
ΔE - E Matrix

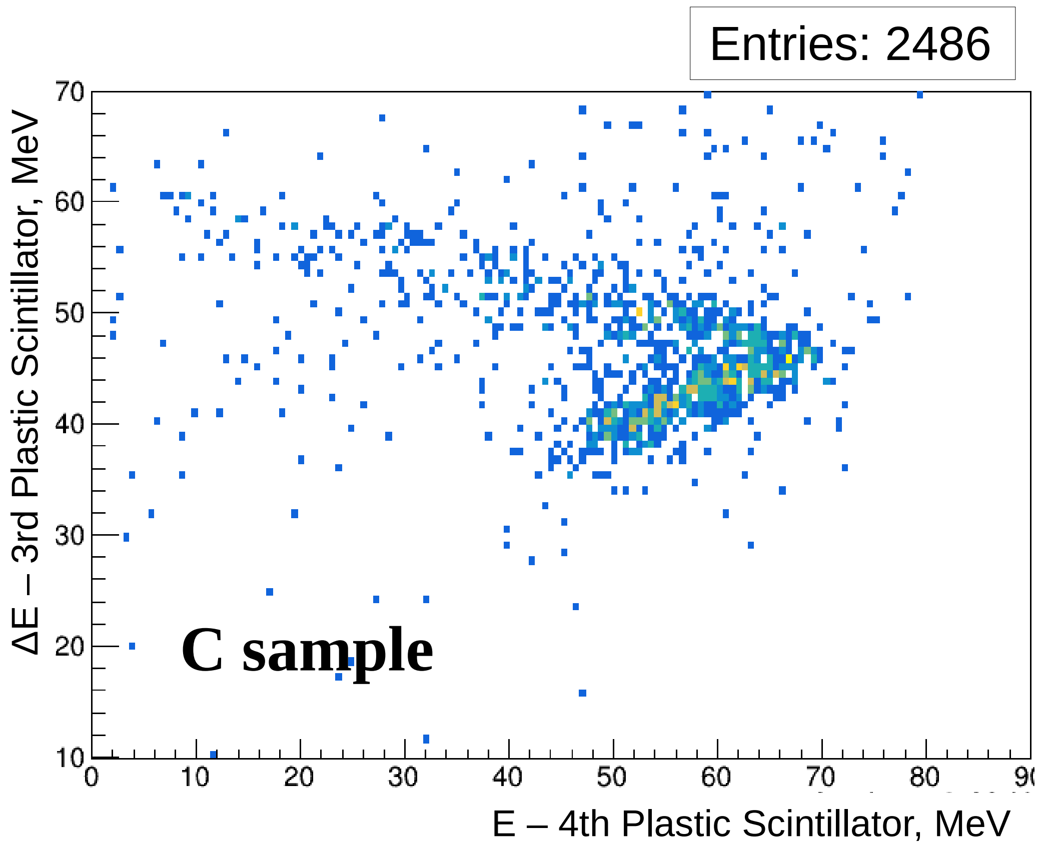

10 MeV
ΔE – 1st Silicon Detector, MeV
E – 2nd Silicon Detector, MeV
60 MeV
ΔE – 1st Plastic Scintillator, MeV
E – 2nd Plastic Scintillator, MeV
125 MeV
ΔE – 2nd Plastic Scintillator, MeV
3rd Plastic Scintillator, MeV
157 MeV
ΔE – 3rd Plastic Scintillator, MeV
E – 4th Plastic Scintillator, MeV

ΔE - E Matrix

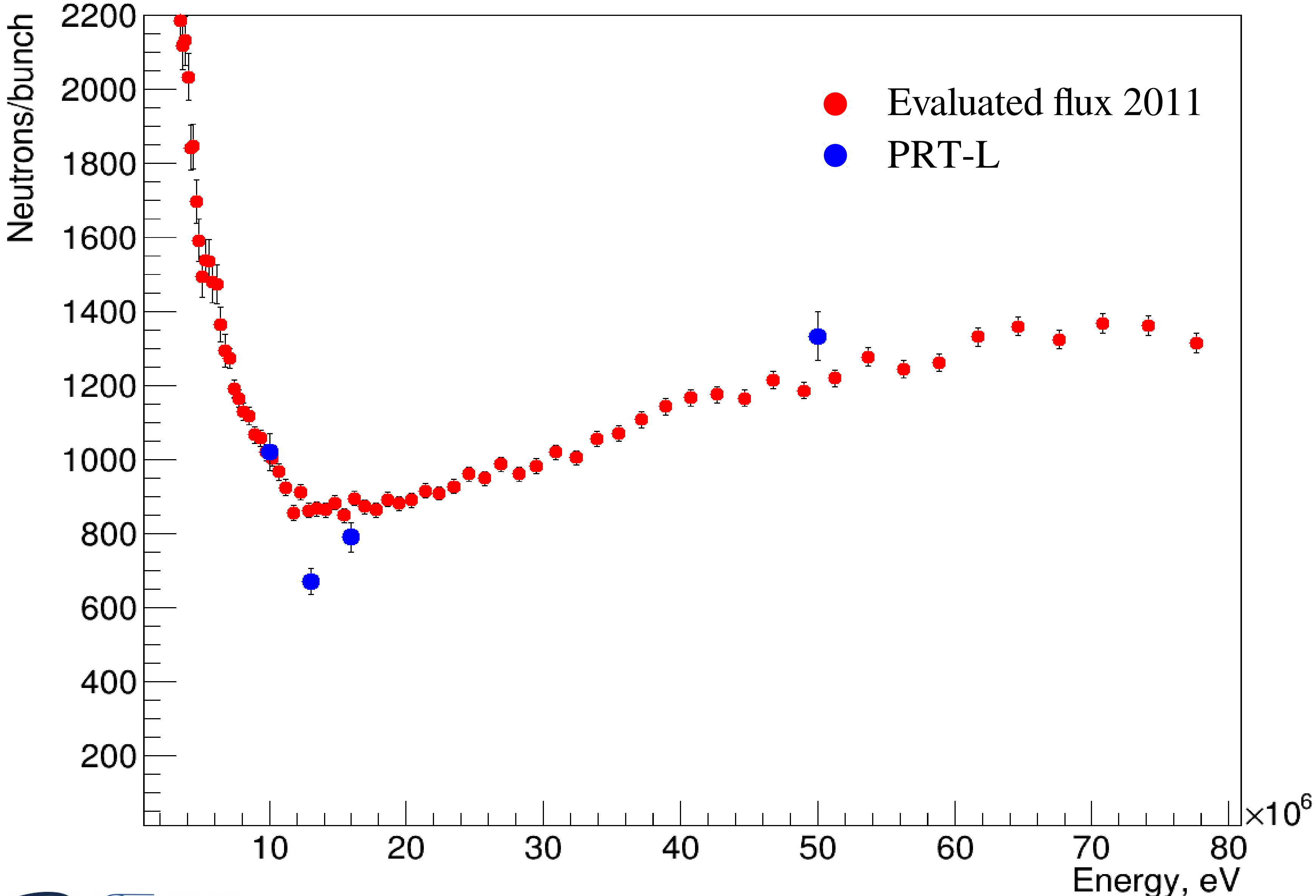
200 MeV



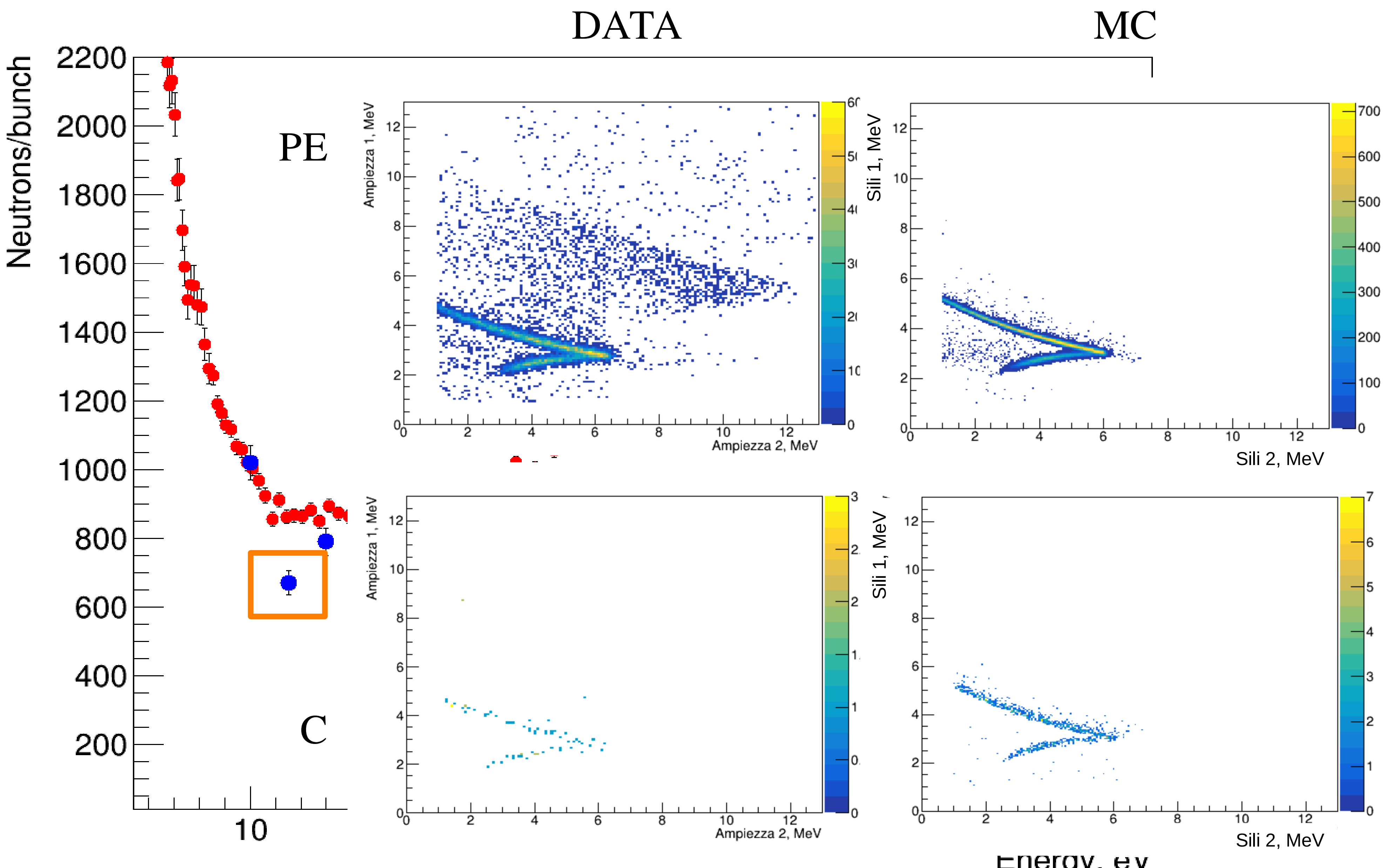




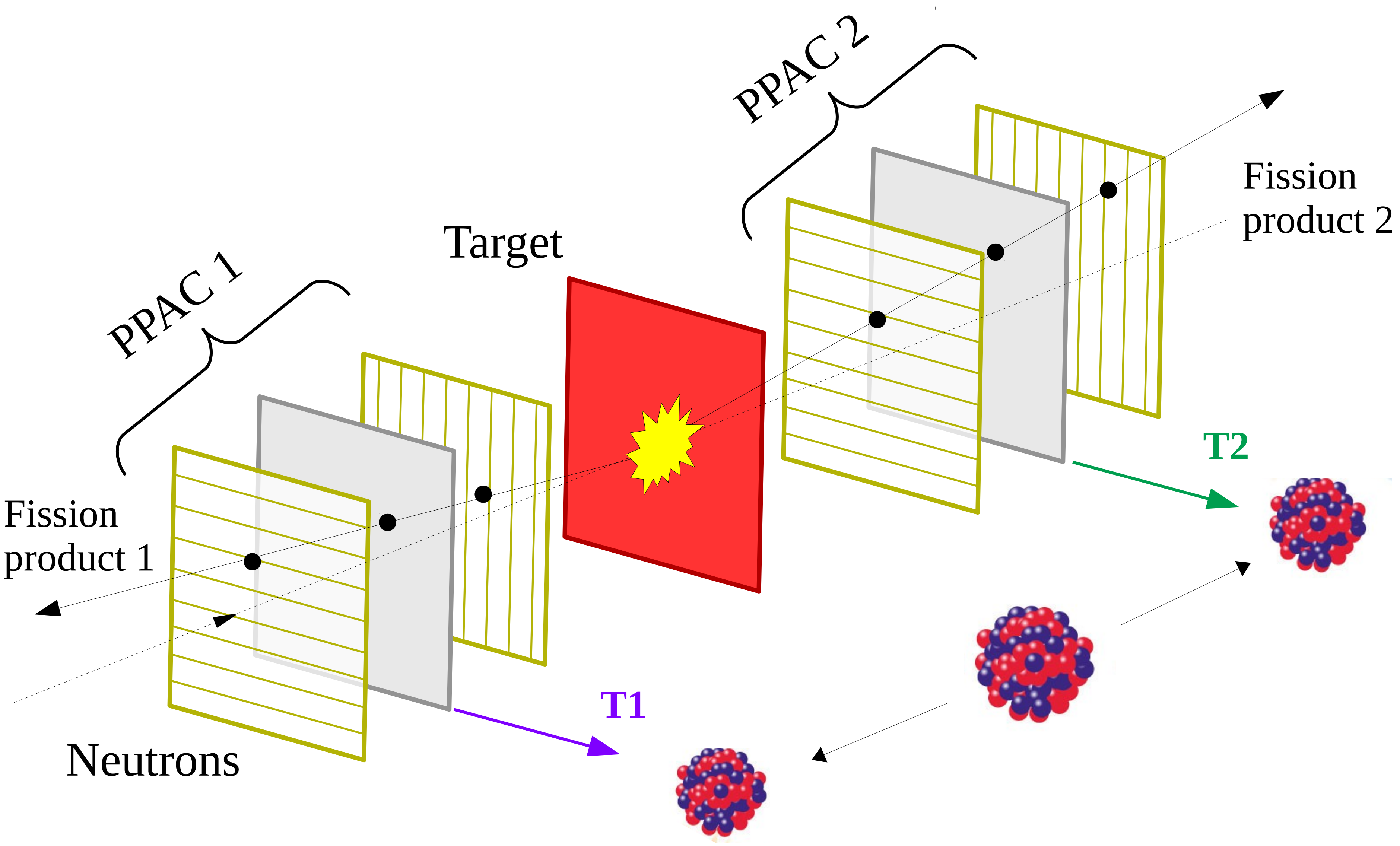
Neutron Flux



Neutron Flux

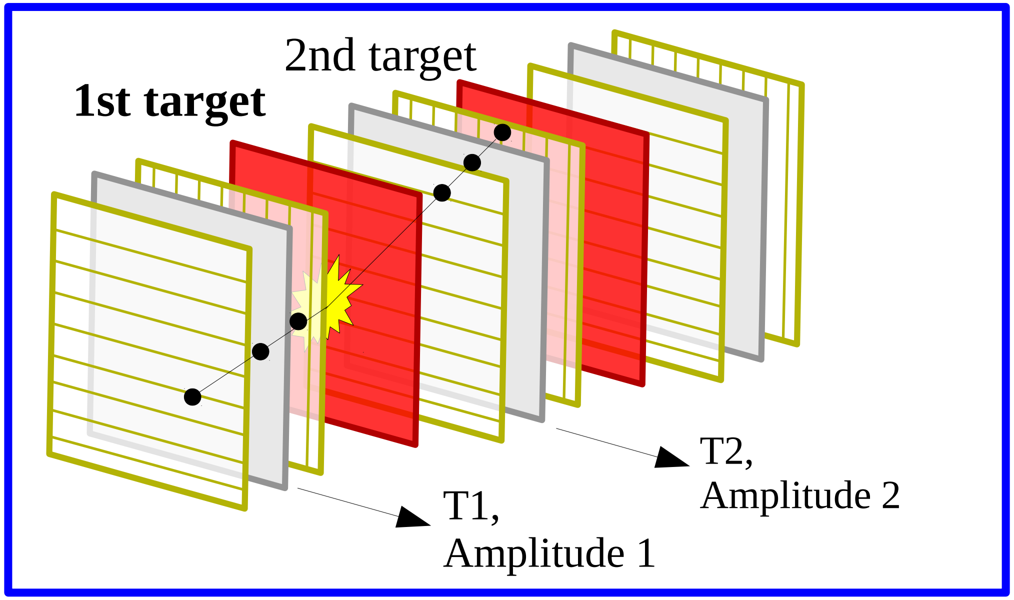


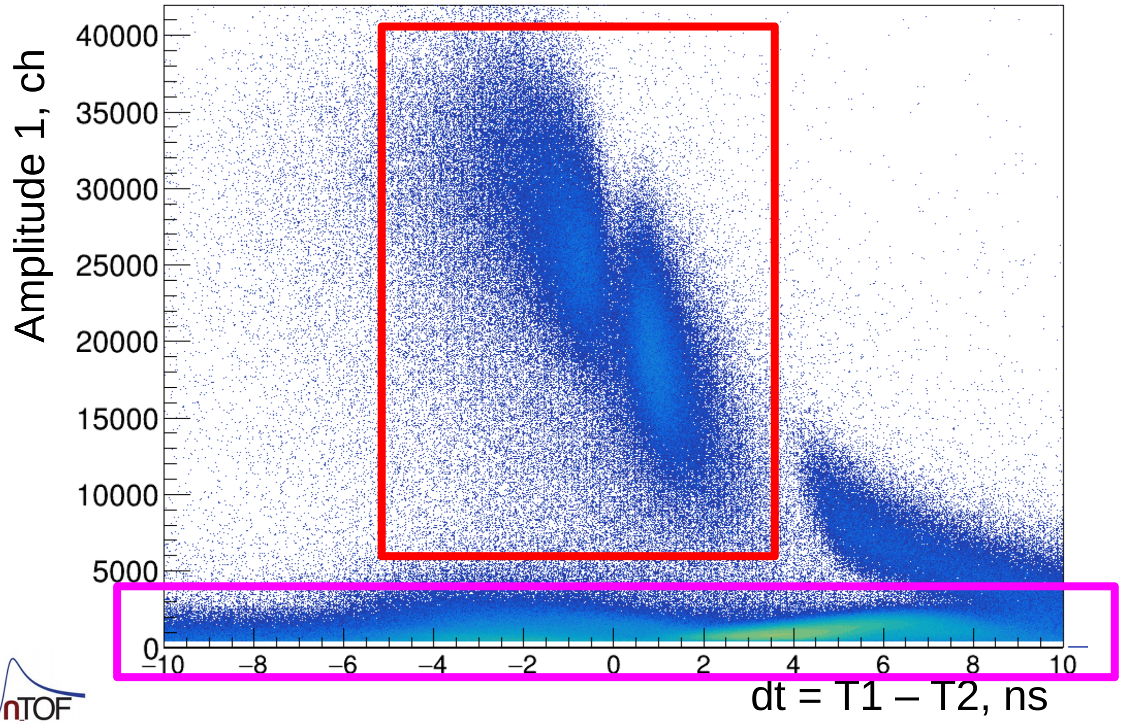
PPACs



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

Coincidences between fragments

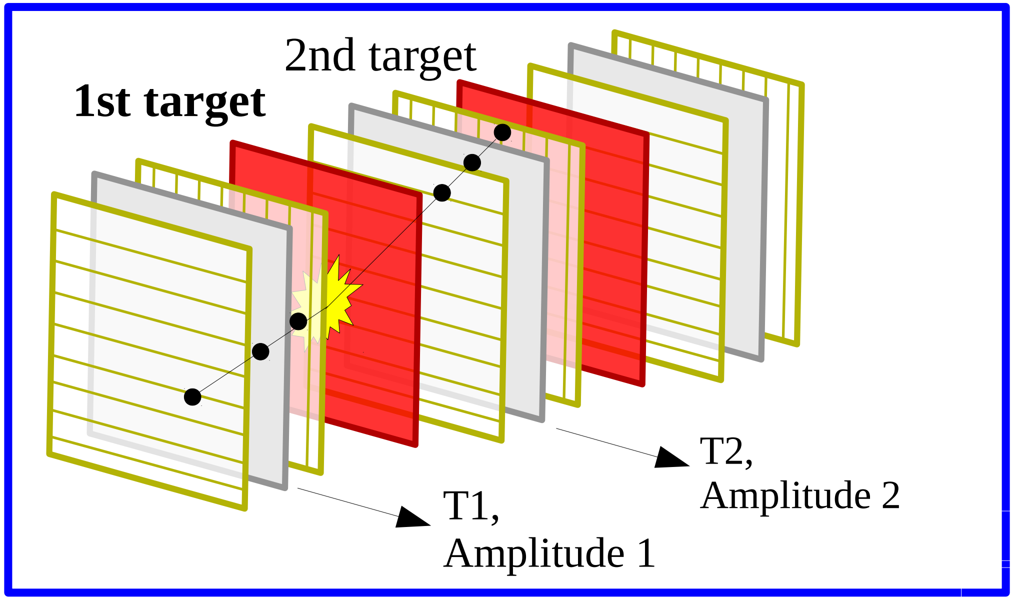




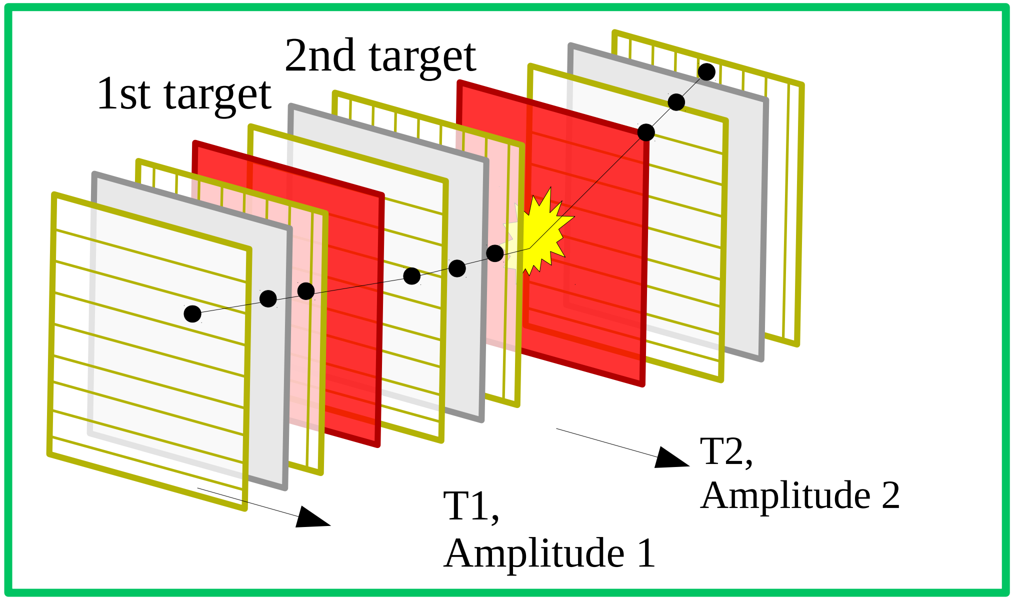
FF from 1st ^{235}U

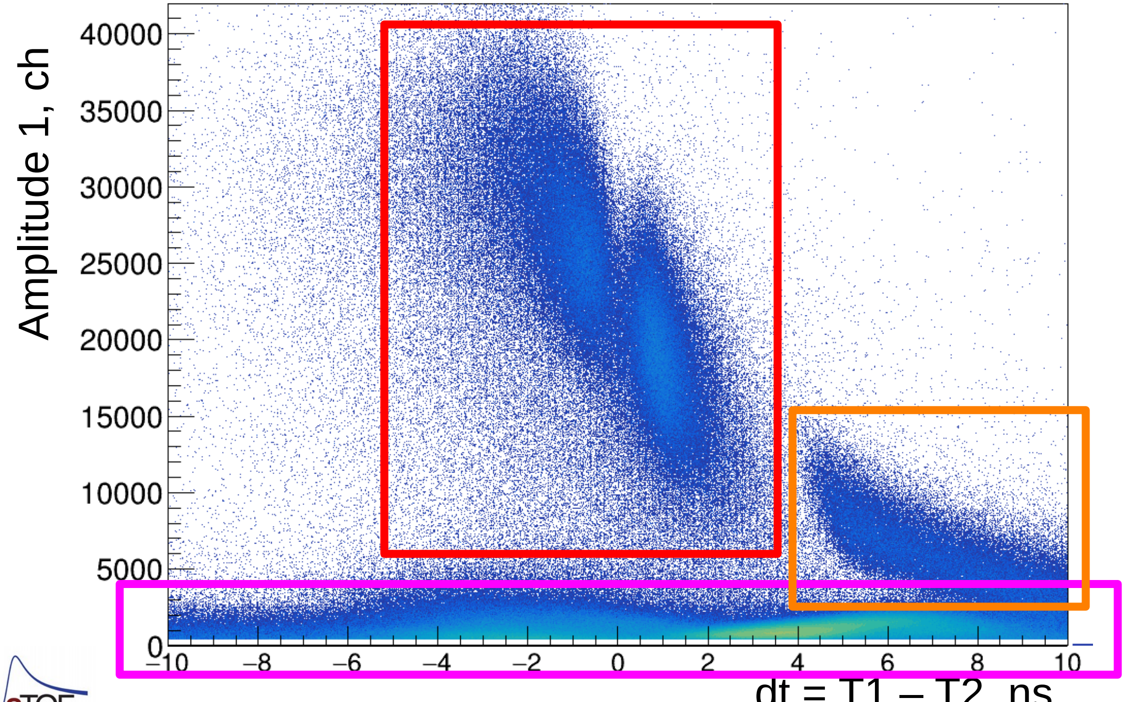
α from 2nd ^{235}U

Coincidences between fragments



+



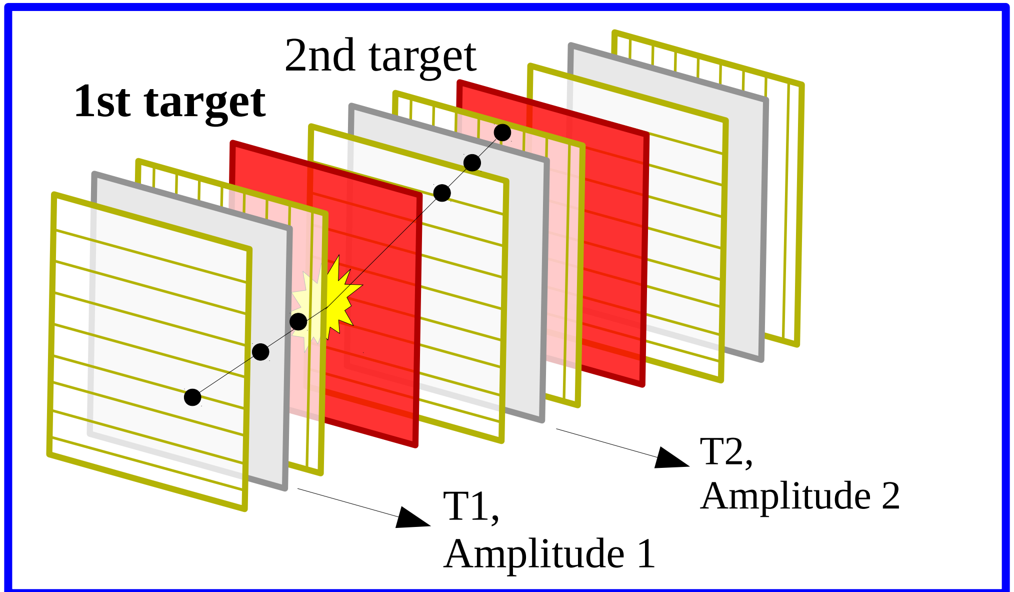


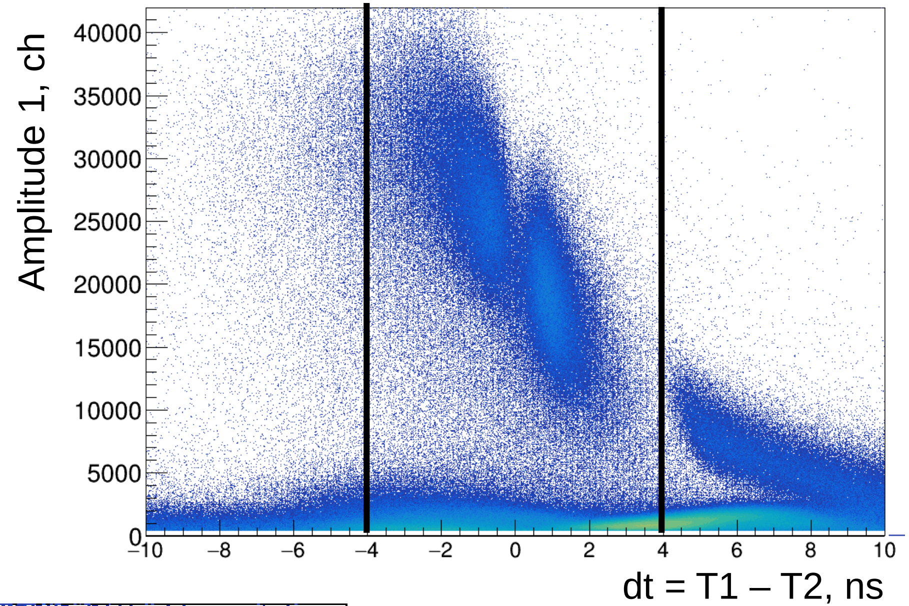
FF from 2nd ^{235}U

FF from 1st ^{235}U

α from 2nd ^{235}U

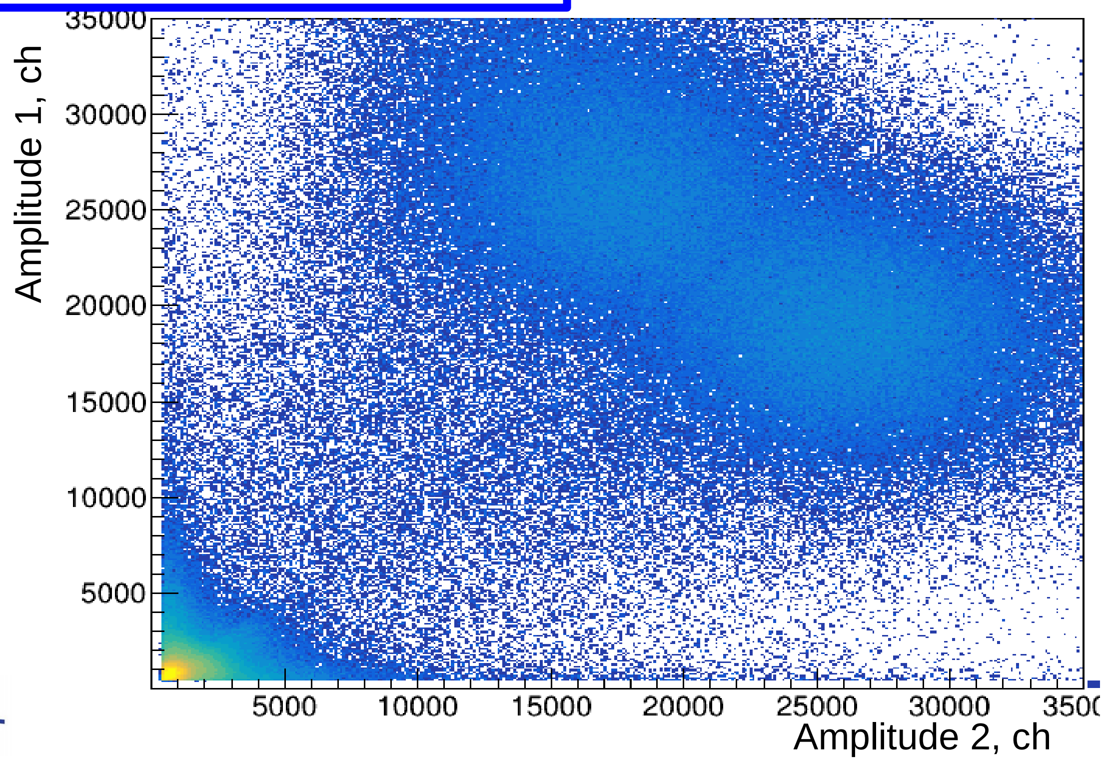
Coincidences between fragments



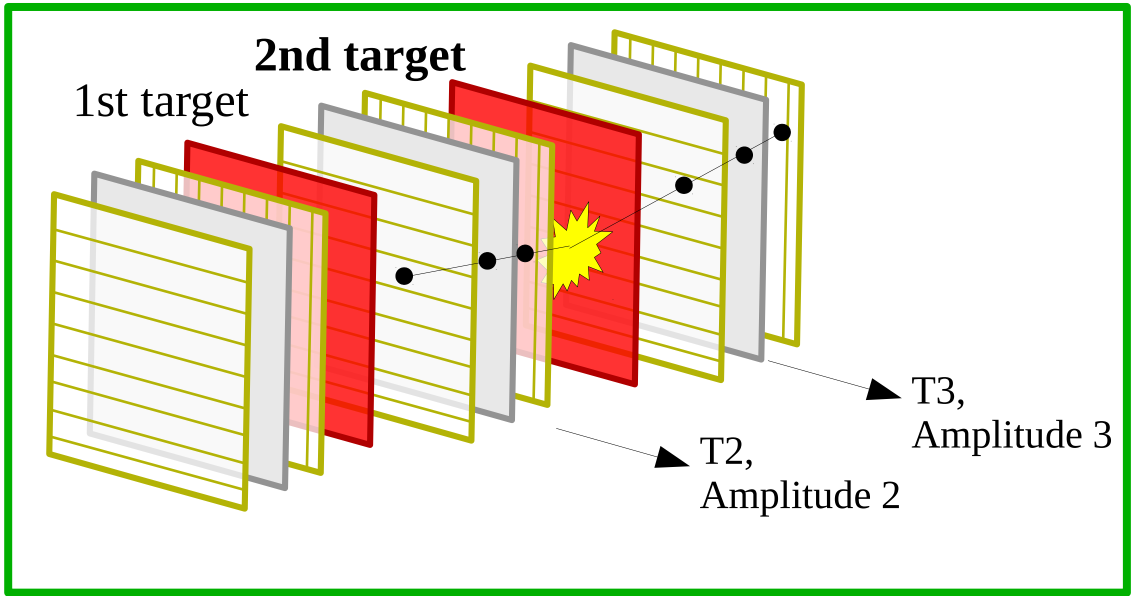


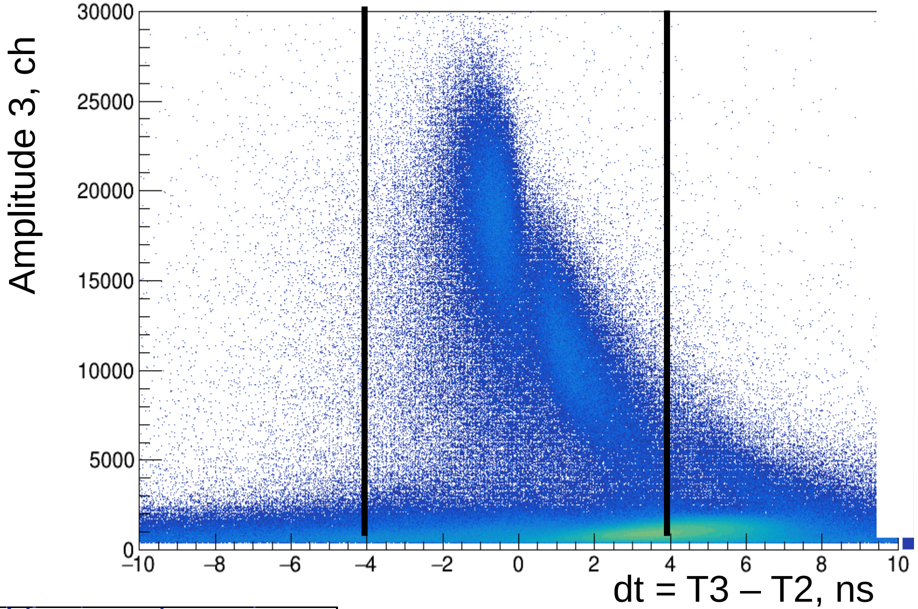
FF from 1st ^{235}U

FF from 2nd ^{235}U



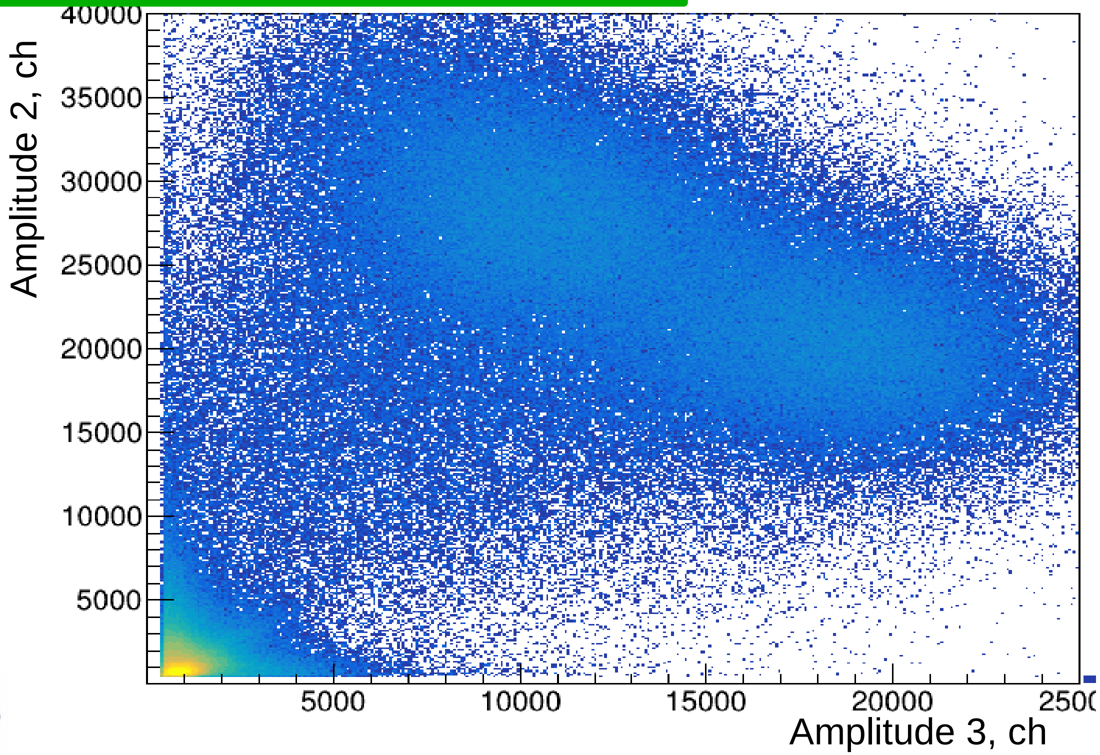
Coincidences between fragments





FF from 1st ^{235}U

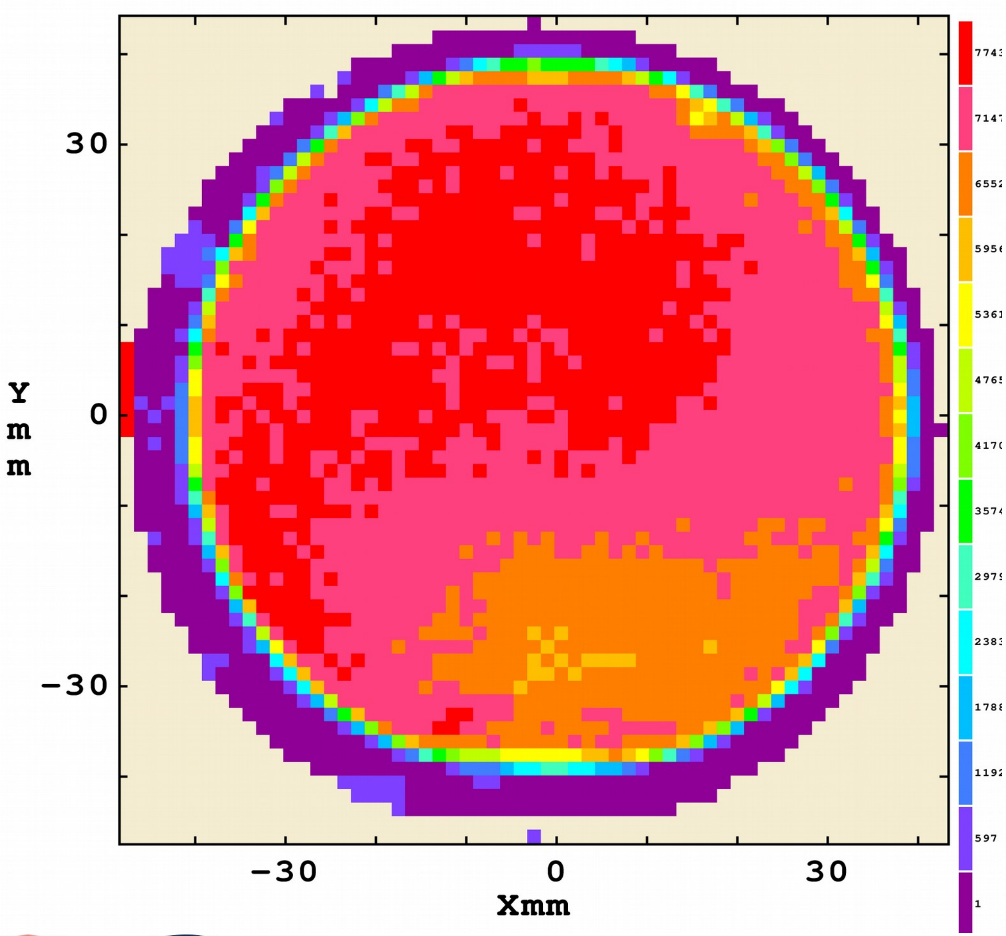
FF from 2nd ^{235}U



^{235}U - 2nd target

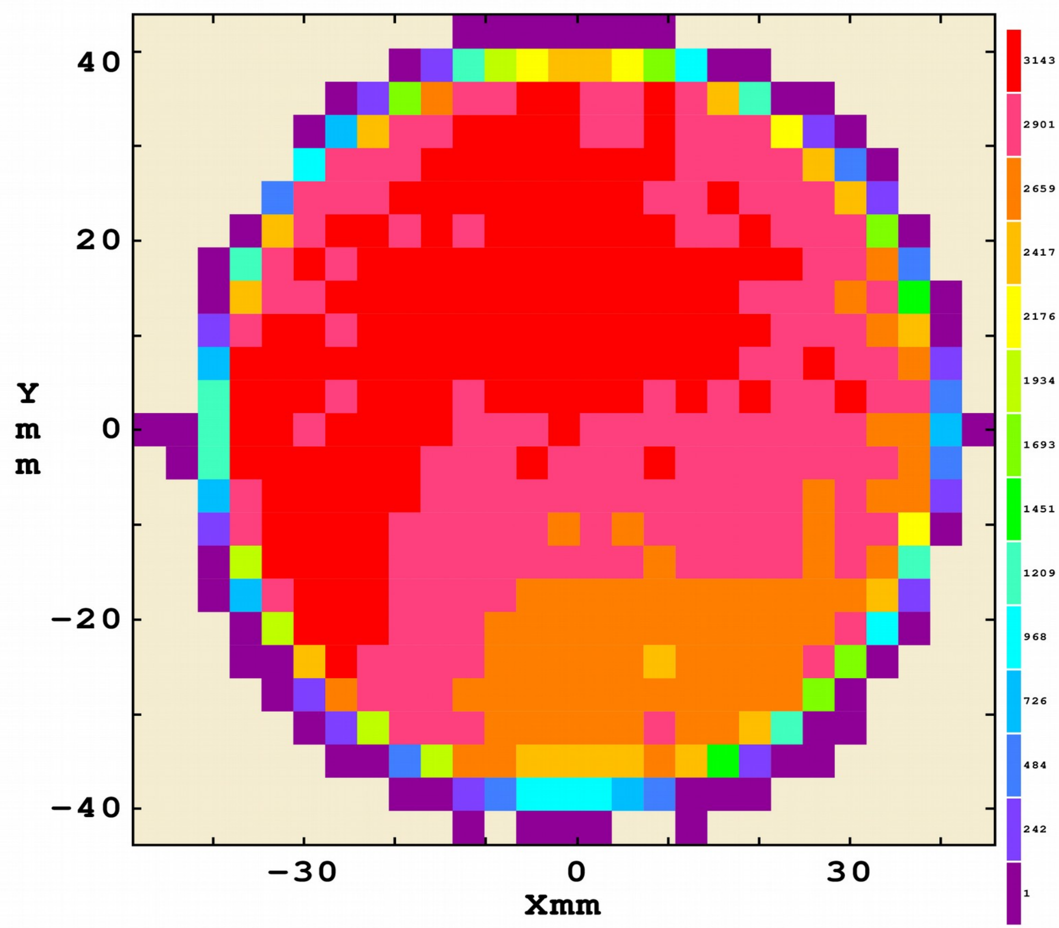
Coulomb scattering

Proton beam
Spatial Resolution = 1.5 mm



α activity → ^{234}U

^{234}U/^{235}U = 0.007472
Spatial Resolution = 3.5 mm

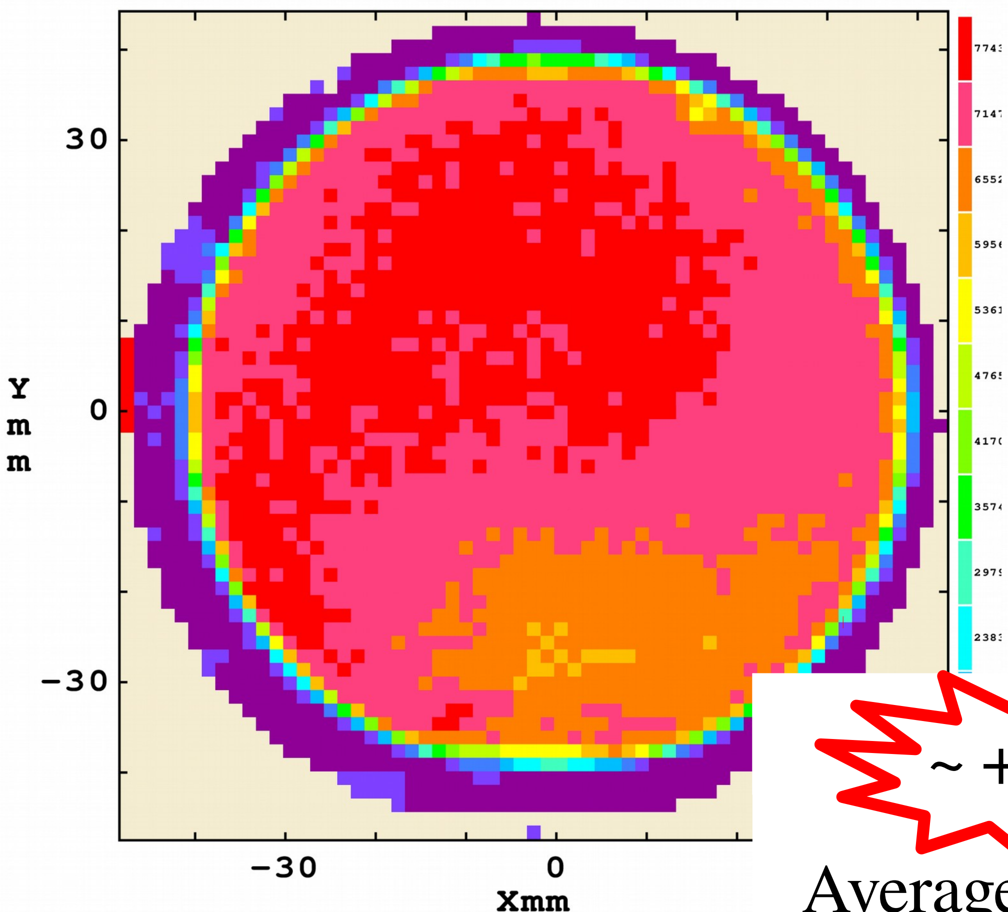


INFN CERN nTOF

^{235}U - 2nd target

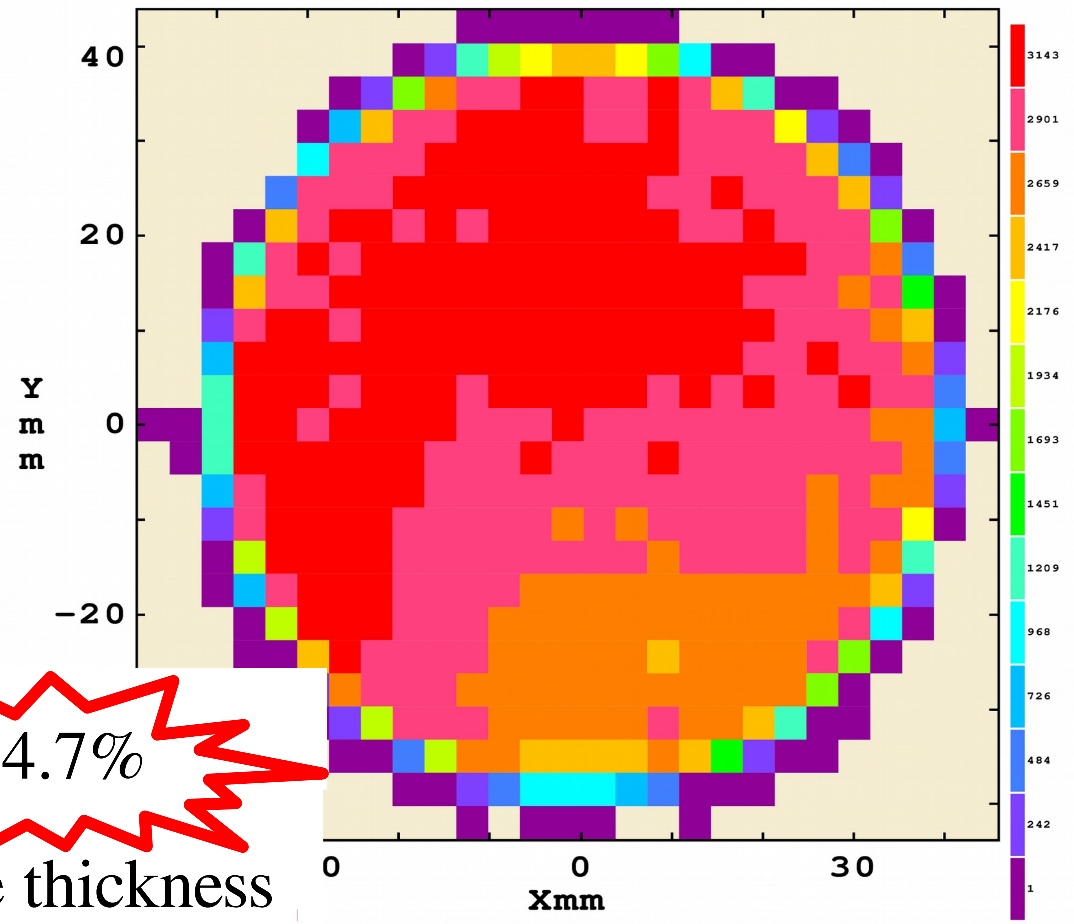
Coulomb scattering

Proton beam
Spatial Resolution = 1.5 mm



α activity → ^{234}U

$^{234}U/^{235}U = 0.007472$
Spatial Resolution = 3.5 mm

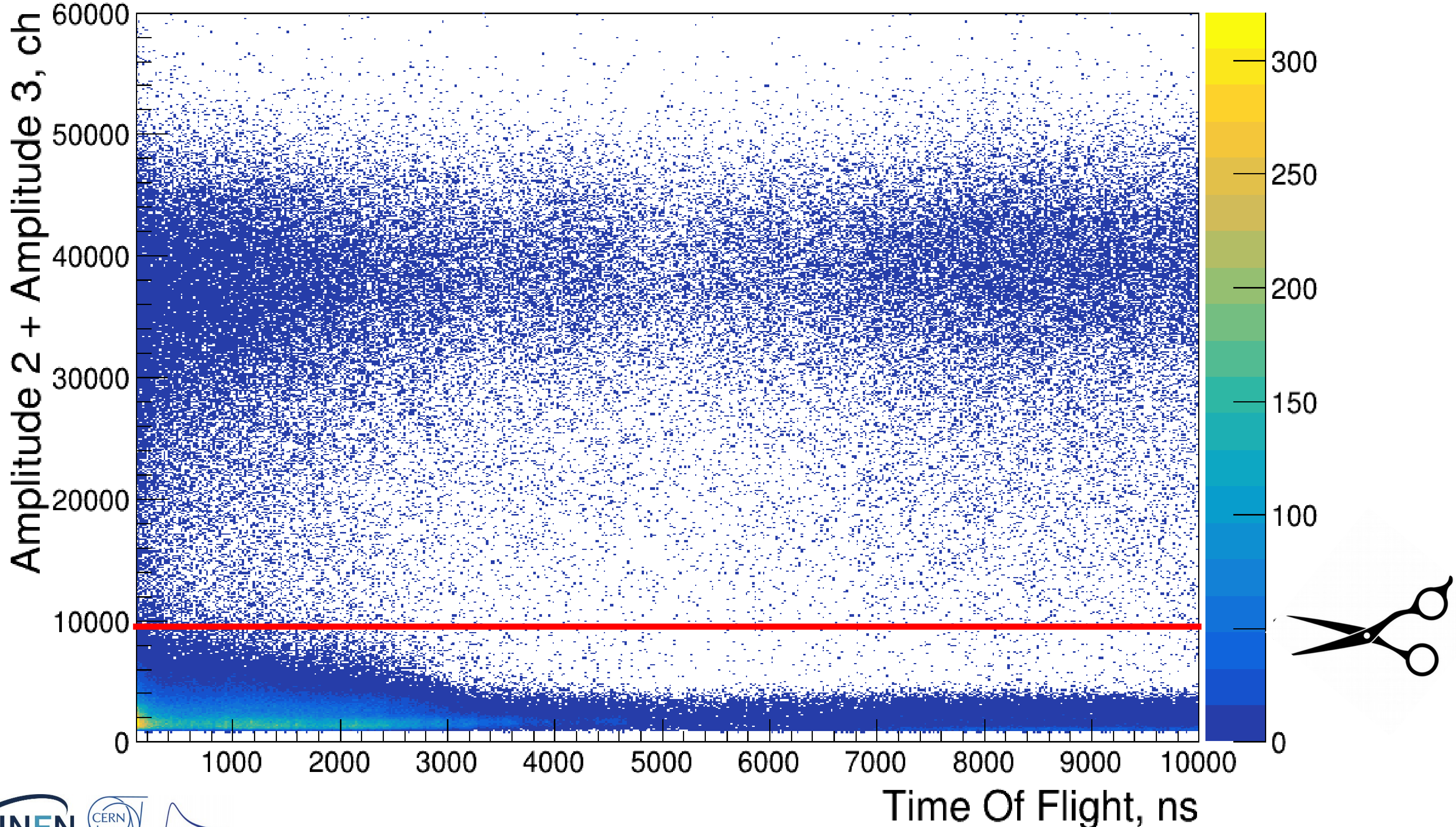


~ +4.7%

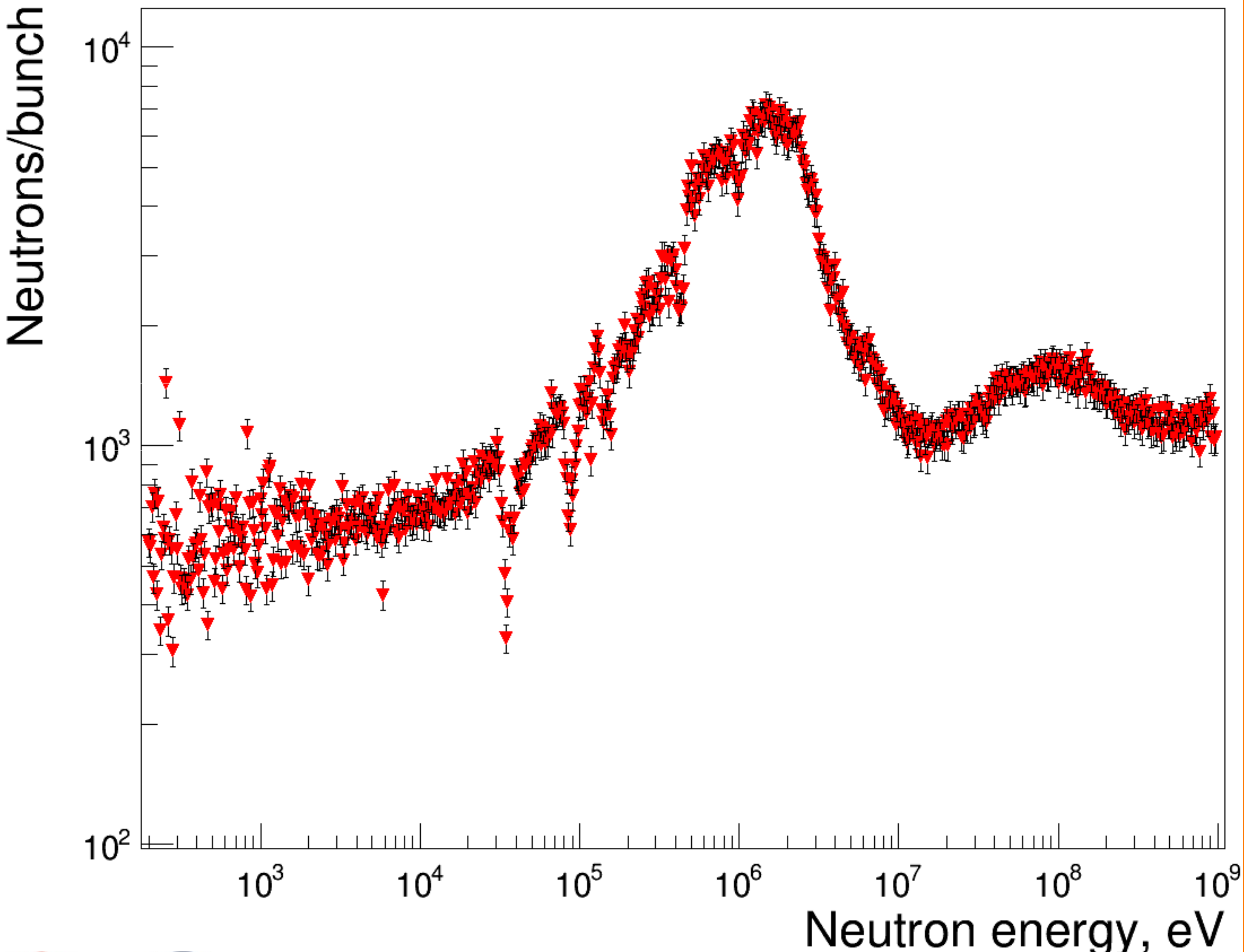
Average thickness
14.0 mg/50 cm^2

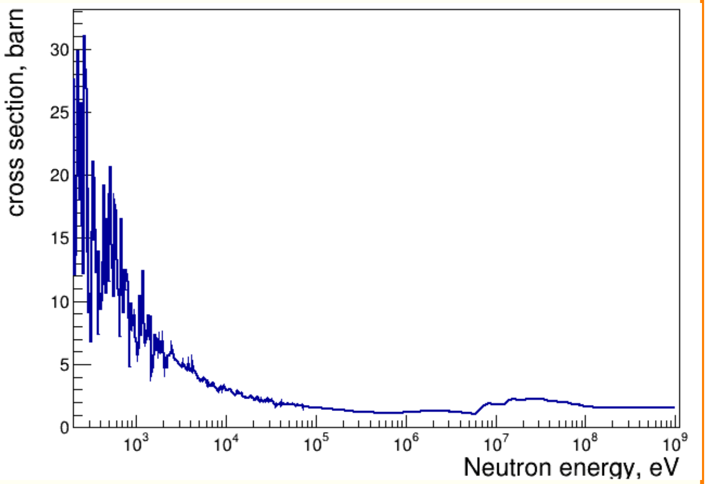
Amplitude Cut

- 2nd target of ^{235}U
- $| dt | = | t_2 - t_3 | < 4$



Flux with PPAC



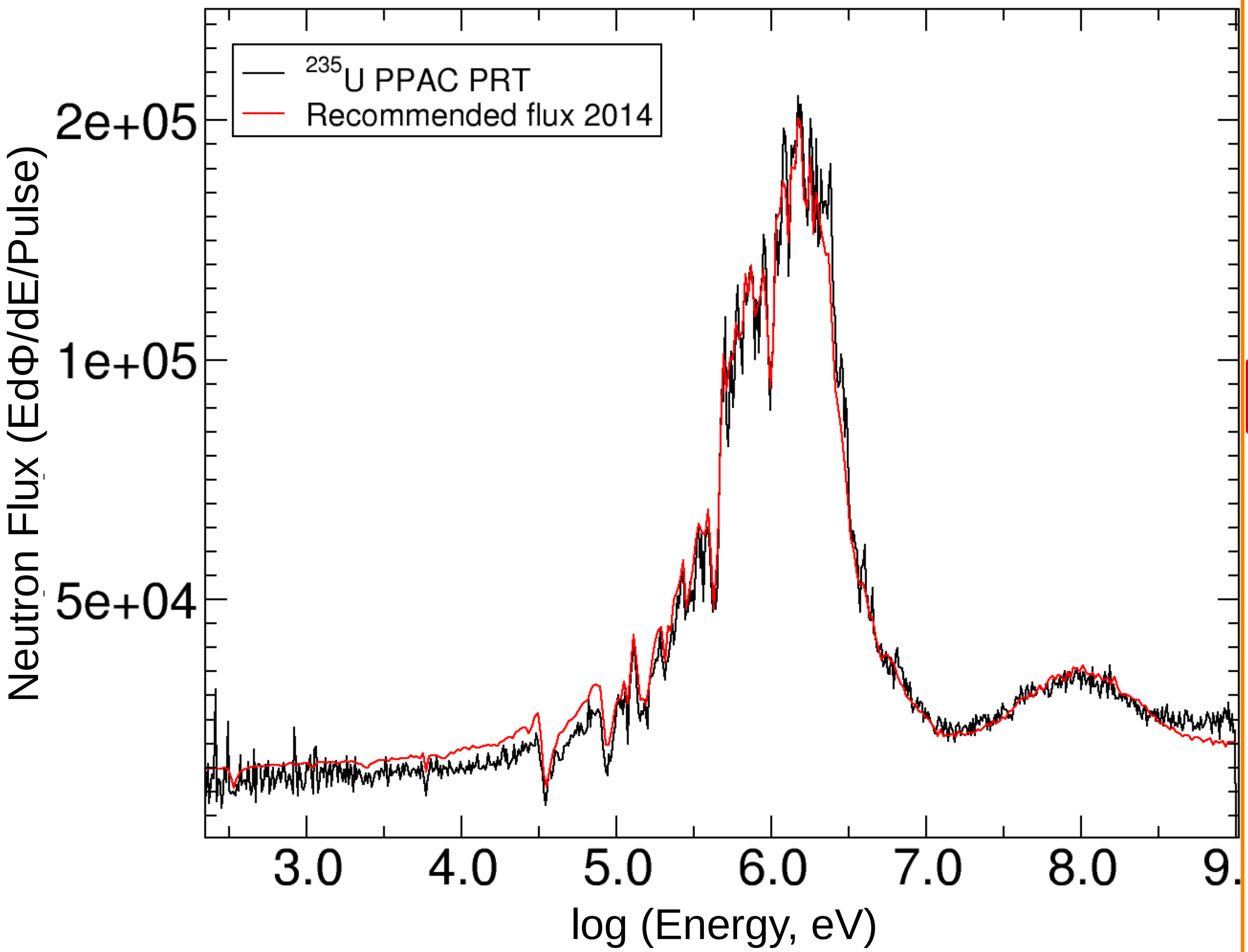


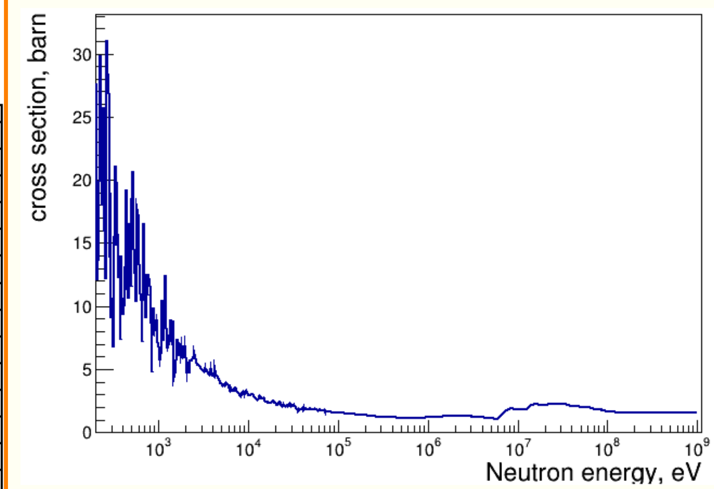
^{235}U:
- th-10 MeV ENDF/B-VIII
- (10 – 200) MeV IAEA
- >200 MeV costant

^{238}U: (6.283%)
- th-200 MeV IAEA
- >200 Mev costant

^{234}U + ^{236}U: (0.7472% + 0.2696%)
- th-30 MeV ENDF/B-VIII
- >30 MeV interpolation with ^{235}U and ^{238}U

Flux with PPAC





^{235}U:

th-10 MeV ENDF/B-VIII
(10 – 200) MeV IAEA
>200 MeV costant

^{238}U: (6.283%)

th-200 MeV IAEA
>200 Mev costant

^{234}U + ^{236}U: (0.7472% + 0.2696%)

th-30 MeV ENDF/B-VIII
>30 MeV interpolation with ^{235}U and ^{238}U

Conclusions

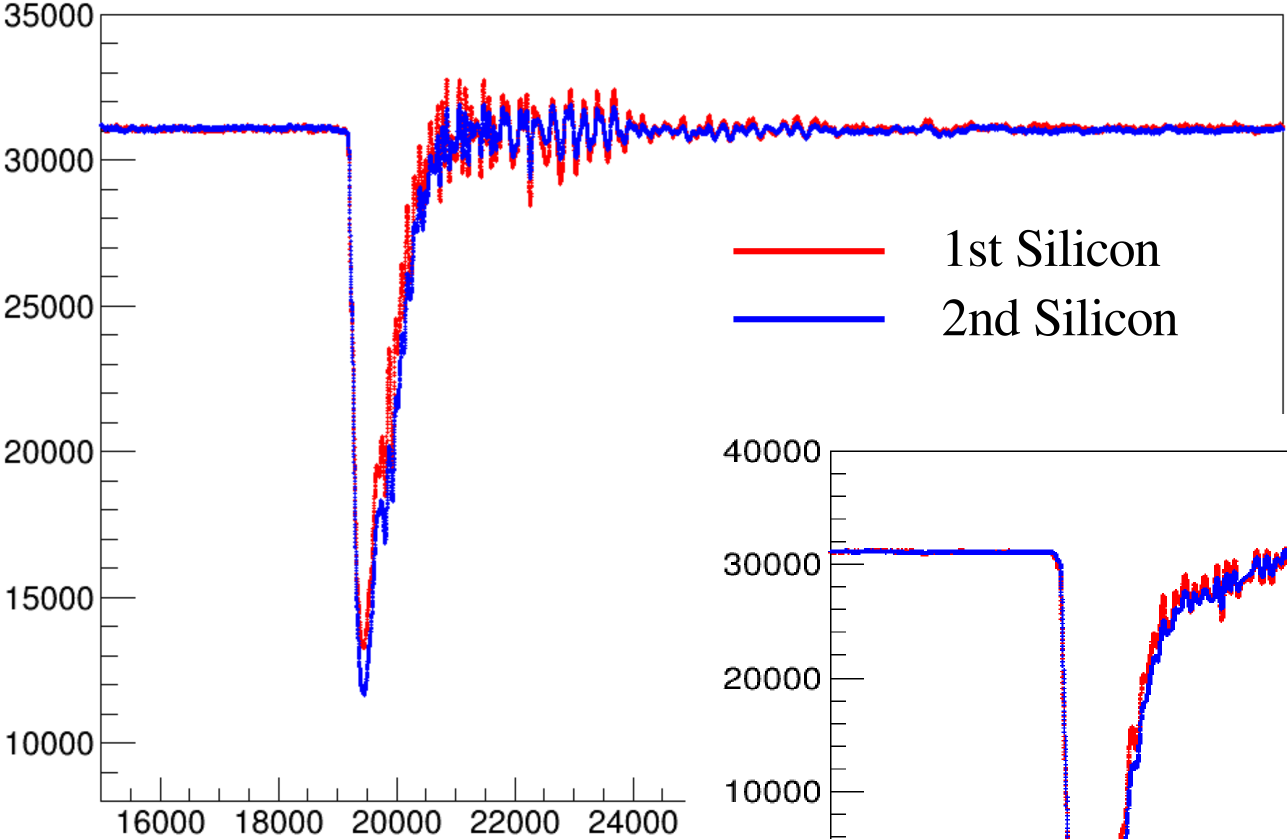
- Large effort for the MC simulation → ε

NEXT STEPS:

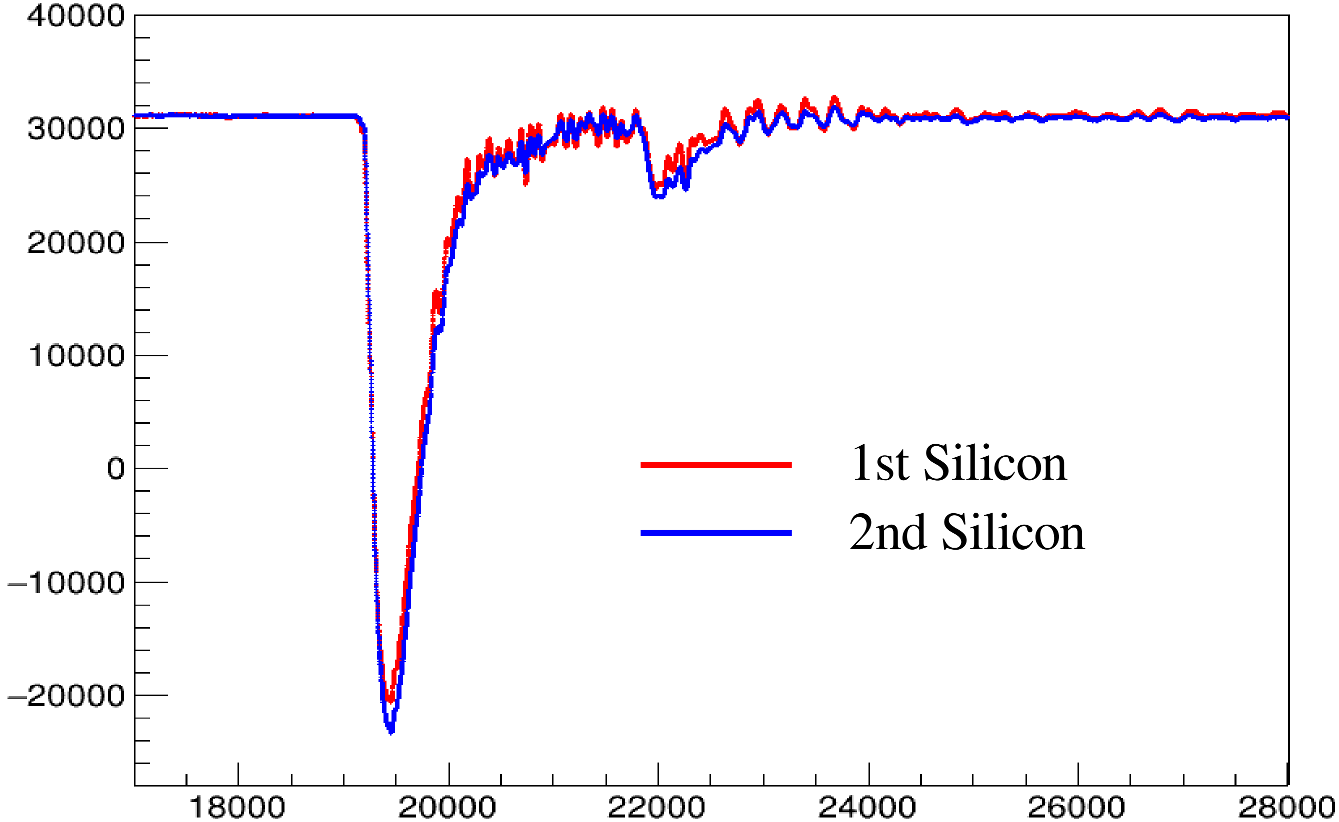
- Extract the n_TOF flux up to 1 GeV with the Proton Recoil Telescopes
- Count the fission fragments → $^{235}U(n,f)$ from 10 MeV to 1 GeV
- Evaluation of systematic uncertainties ➡ Comparison with PTB

BACKUP

Silicon Detectors - Baseline

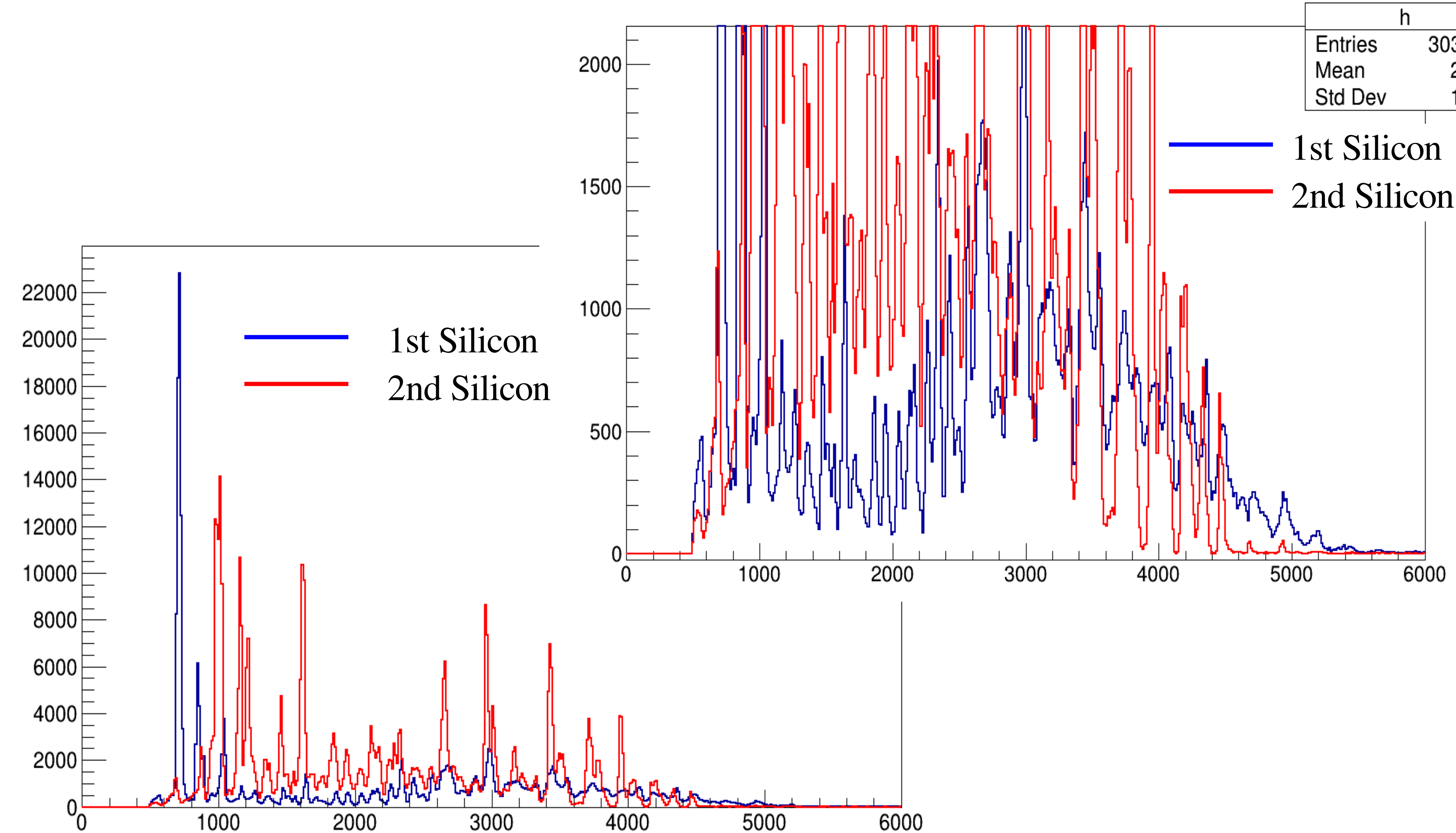


No sample

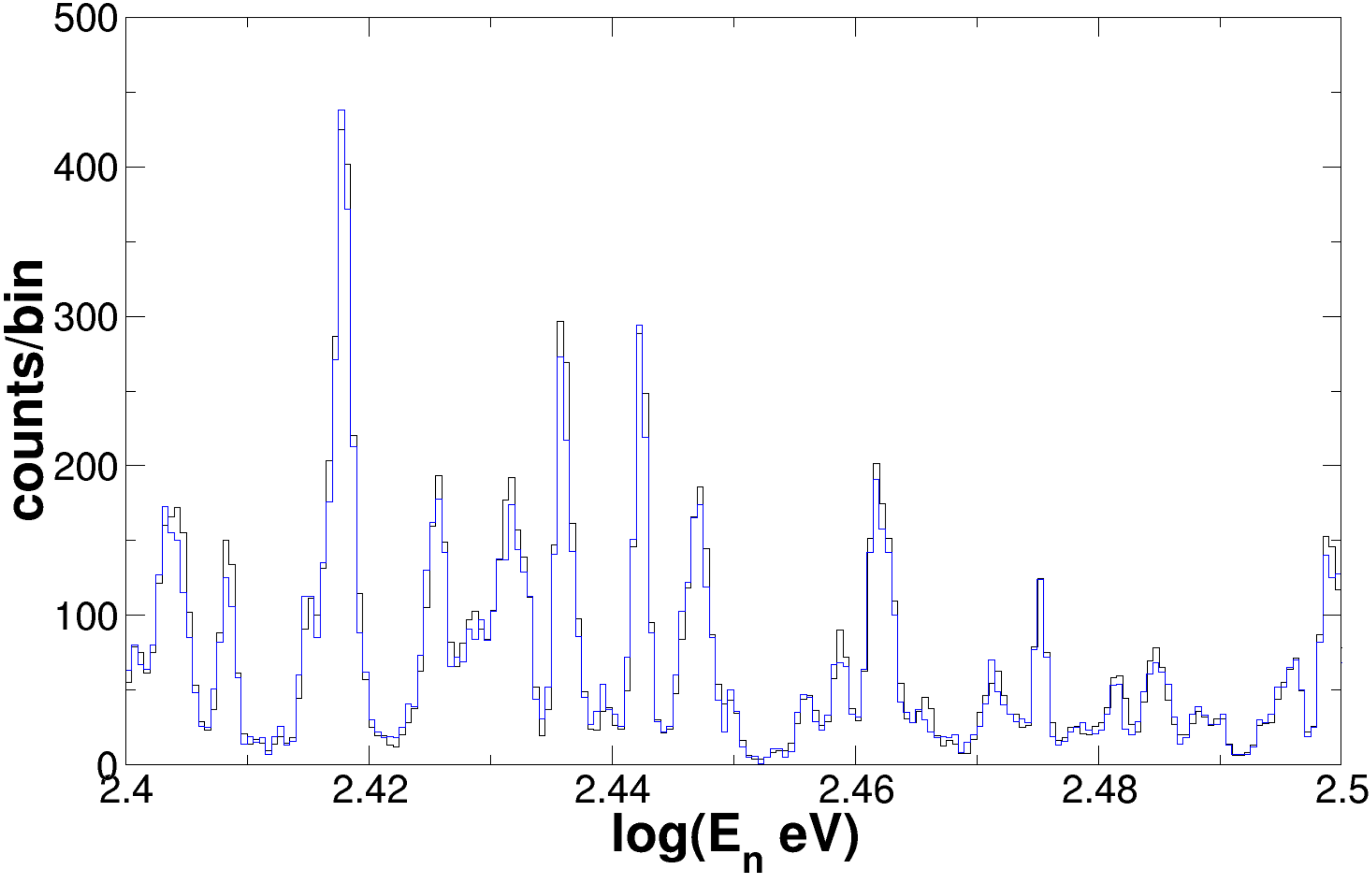


Poli 2 mm

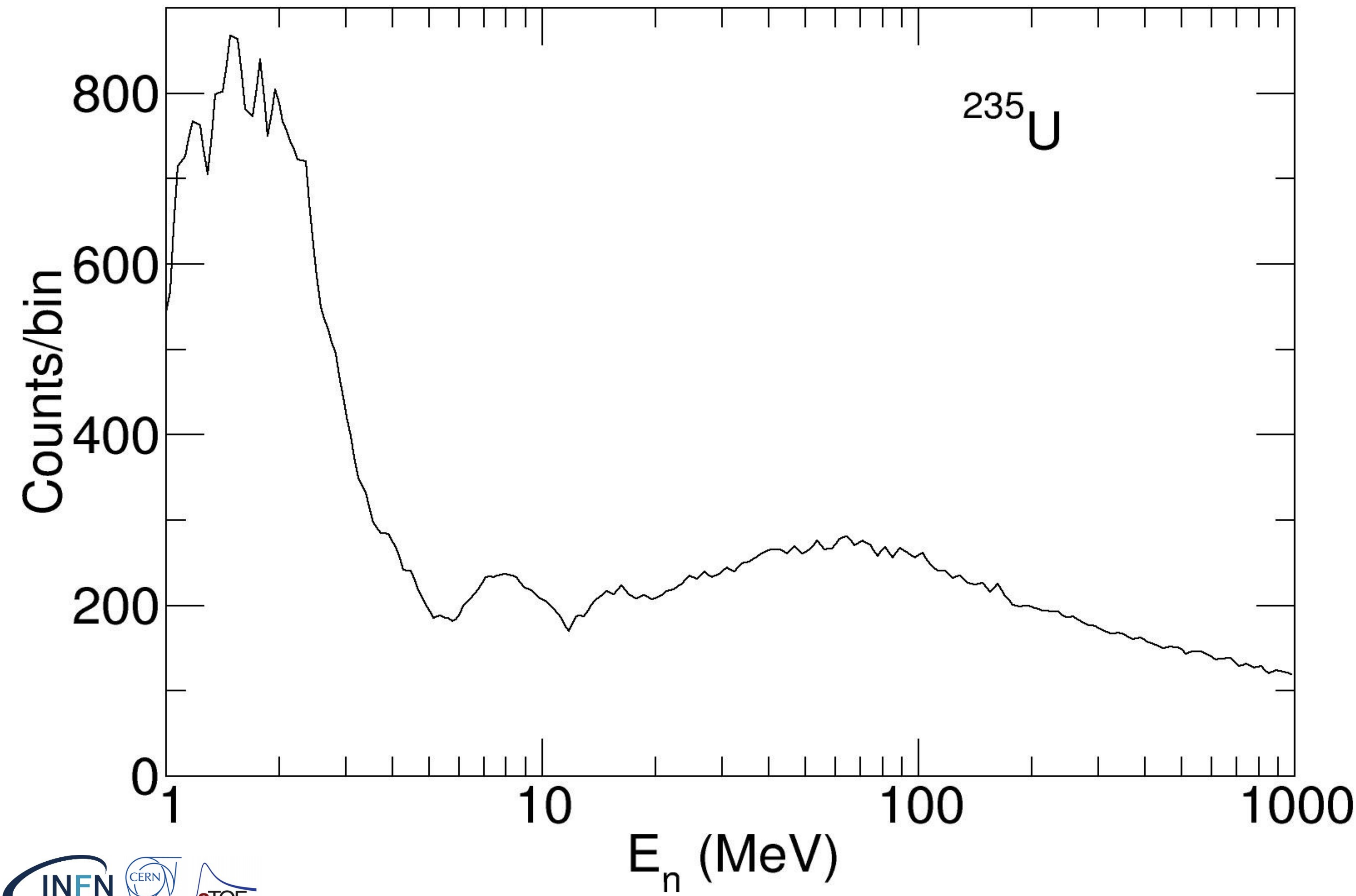
Silicon Detectors - Baseline



Resonances of ^{235}U

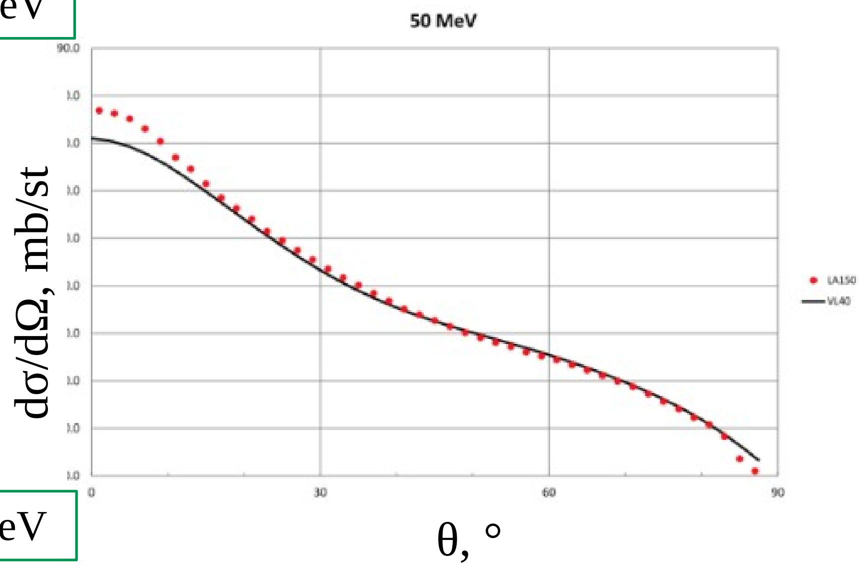


$^{235}U(n,f)$ counts

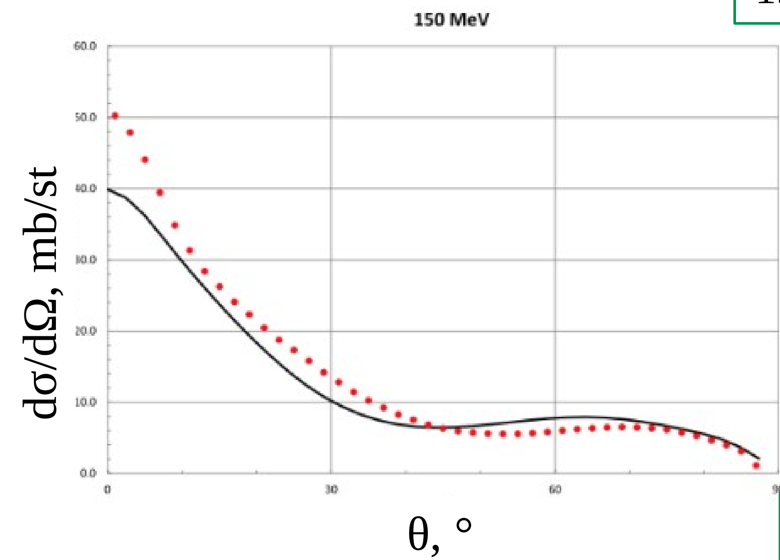


n-p scattering cross section

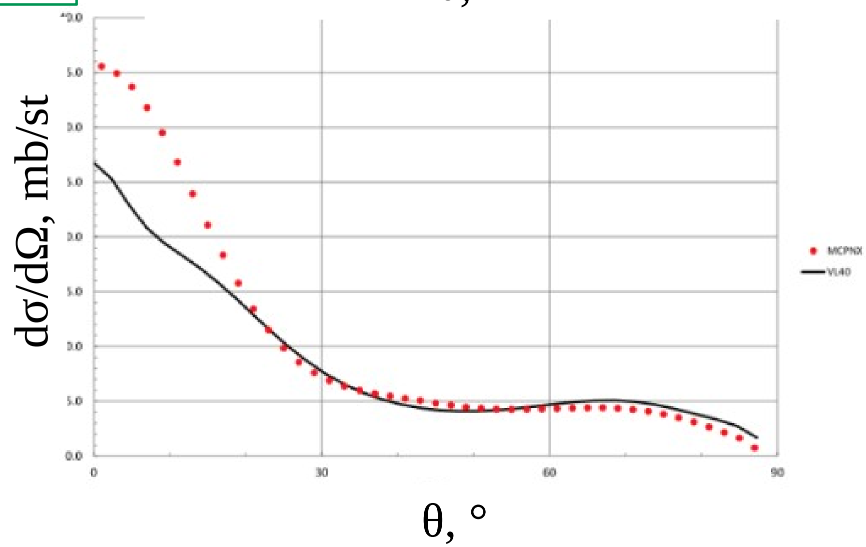
50 MeV



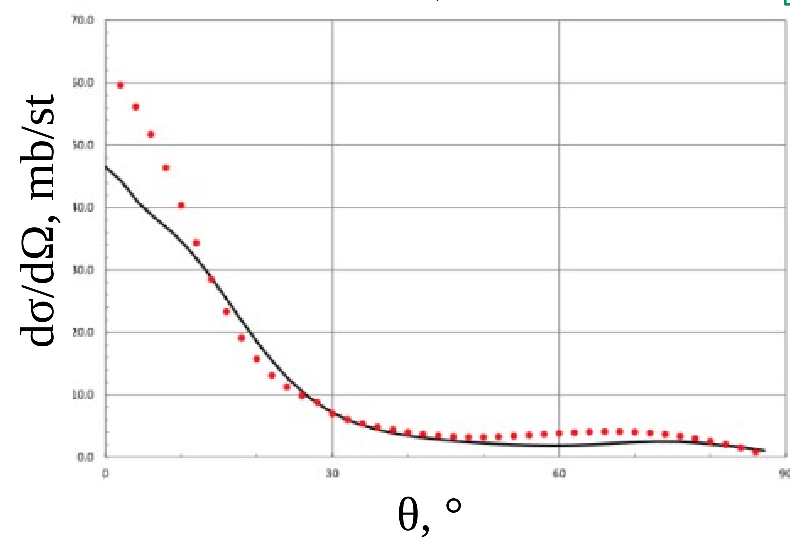
150 MeV



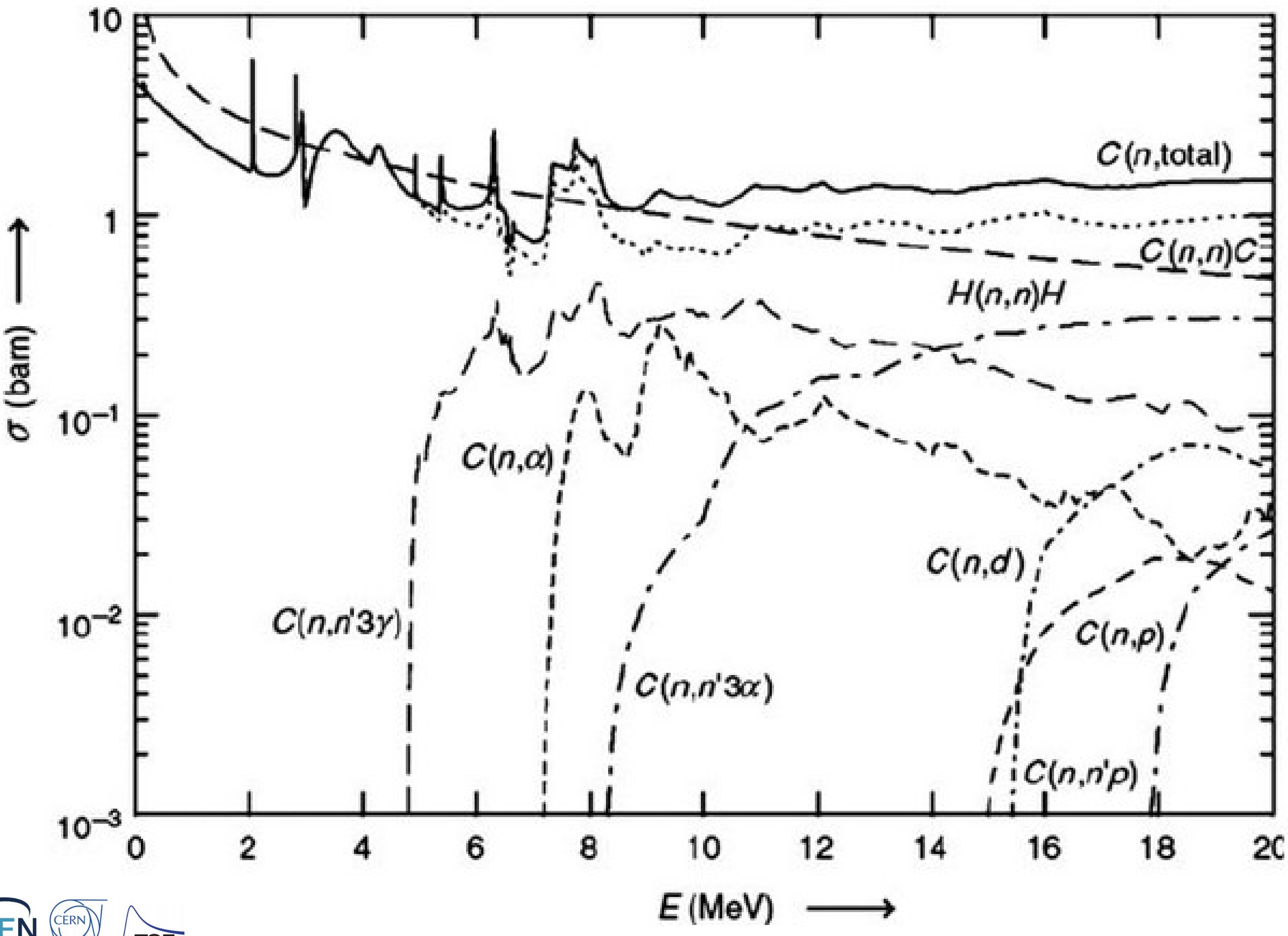
300 MeV



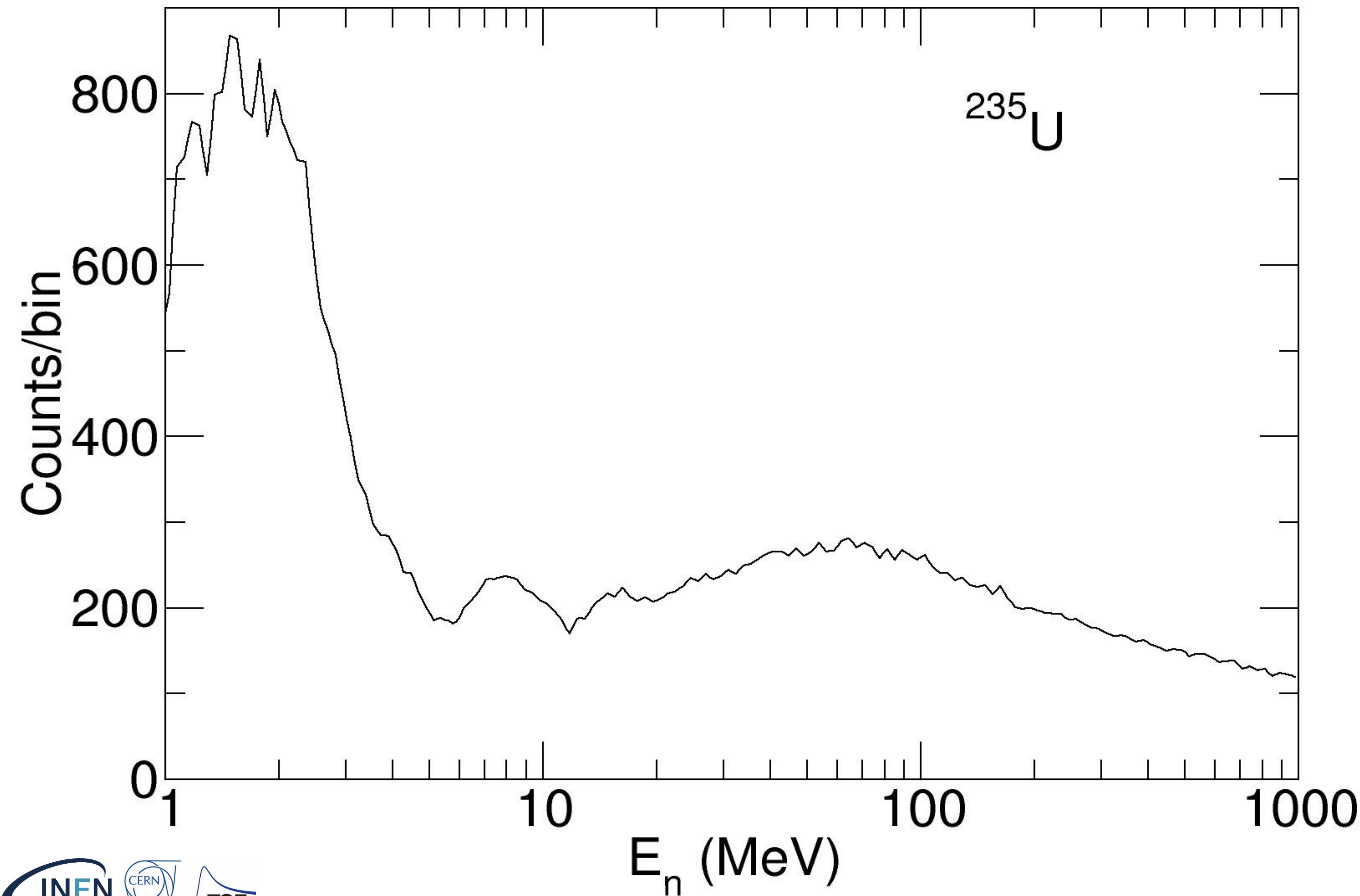
600 MeV



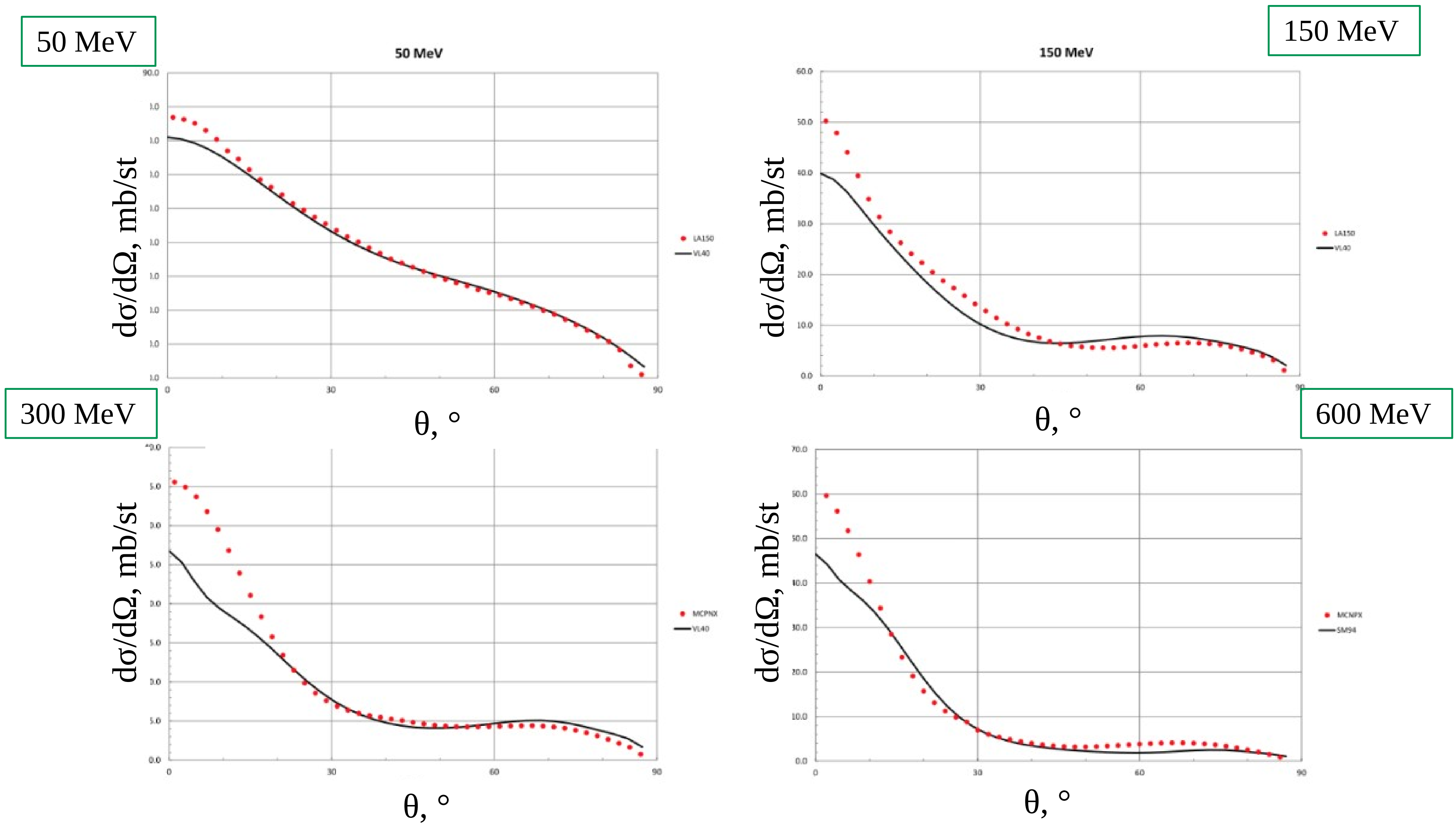
n-C scattering cross section



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



n-p scattering cross section



n-C scattering cross section