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

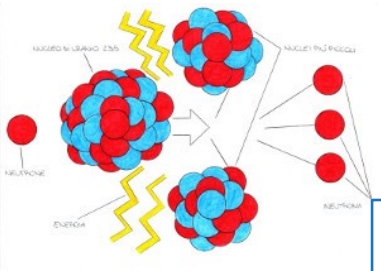
Meeting n_TOF Italia, Bologna

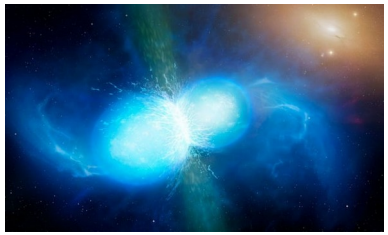
12 – 13 Novembre 2018

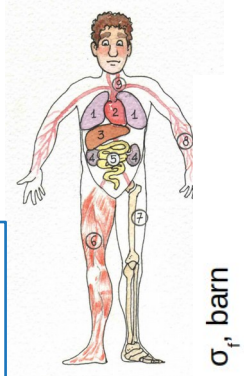
Motivations

INDC International Nuclear Data Commitee

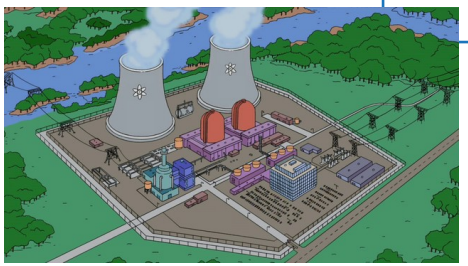
*"...Our analysis indicates that the <u>new absolute measurements of the neutron induced fission cross section</u> (e.g. **<u>relative</u>** **<u>to</u>** **<u>n-p</u>** **<u>scattering</u>**) on **<u>Uranium</u>**, Bismuth, Lead and Plutonium have the highest priority in establishing neutron induced fission reaction standard **<u>above 200 MeV</u>**..."* (INDC(NDS)-0681 Distr. ST/J/G/NM, IAEA 2015)

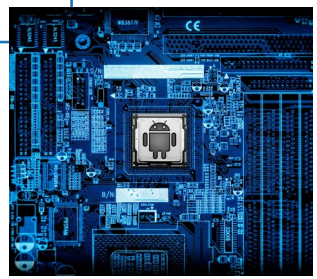


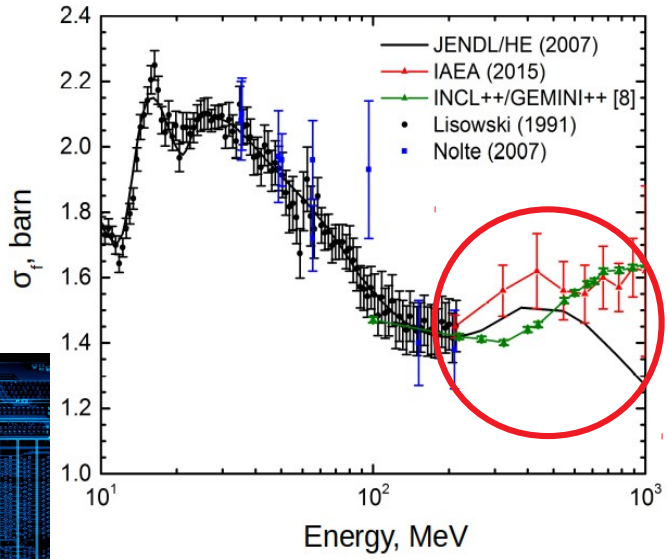




^{235}U(n,f) is one of the most significant cross-section standards at 0.025 eV and [0.15-200] MeV **<u>BUT</u>** there are **<u>no experimental data above 200 MeV</u>**, despite its importance



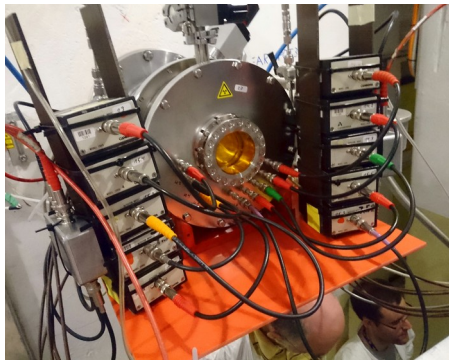




Experimental setup

^{235}U fission reaction

Fission fragment



Parallel Plate
Ionization Chamber
(**IC**)

→ Ambient gas pressure

Neutron energy:
(10-200) MeV

Parallel Plate
Avalanche Counter
(**PPAC**)

→ Low gas pressure
~ 4 mbar

Neutron energy:
(100-1000) MeV

Neutron flux

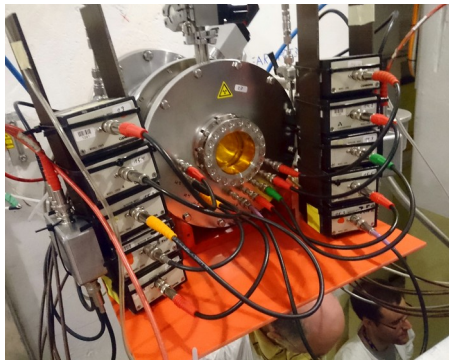
Elastic scattering

n + H → n + p

Experimental setup

^{235}U fission reaction

Fission fragment



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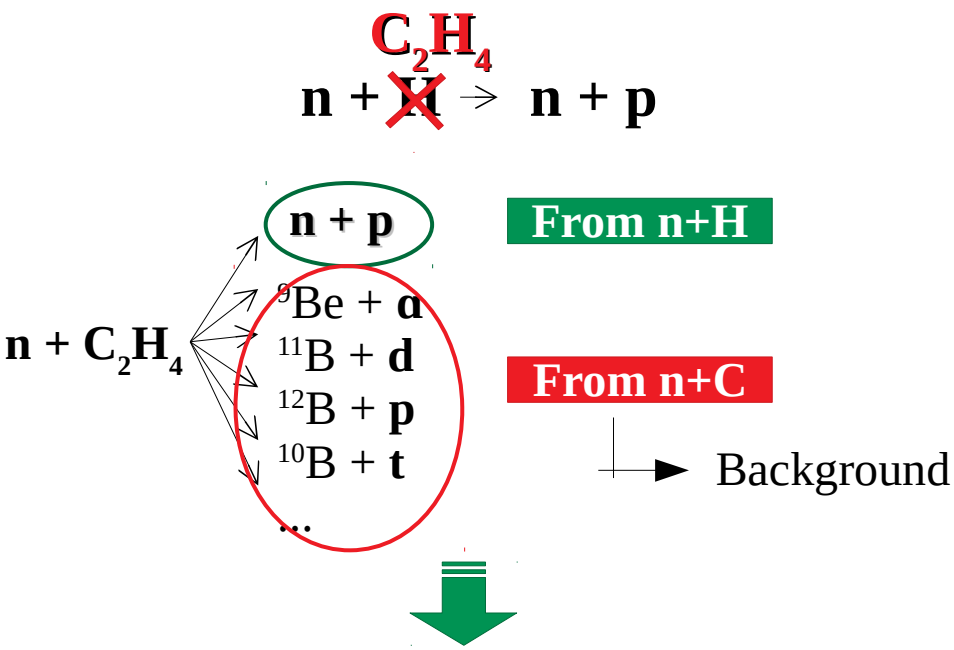


A **P**roton **R**ecoil **T**elescope

can discriminate the different emitted particles

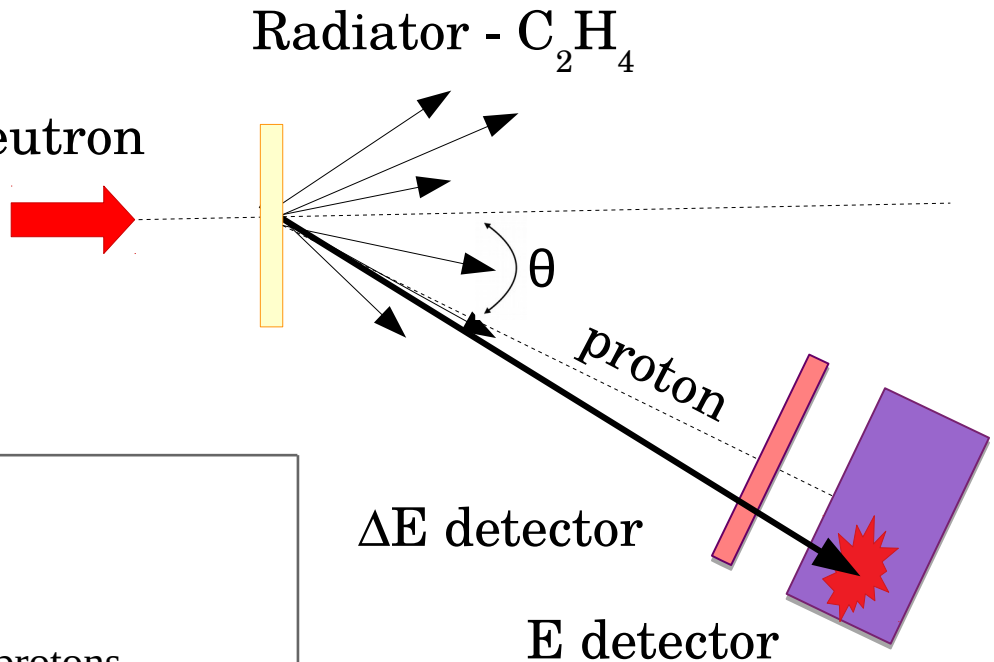
ΔE - E Matrix

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

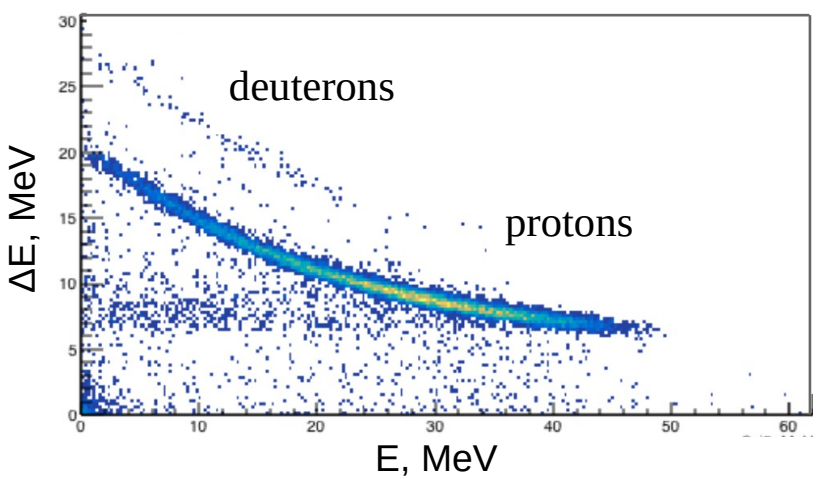
k: material absorption properties

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

Particles with different z and M produce **distinct hyperbolas** in ΔE – E plot



If the particle stops inside the telescope



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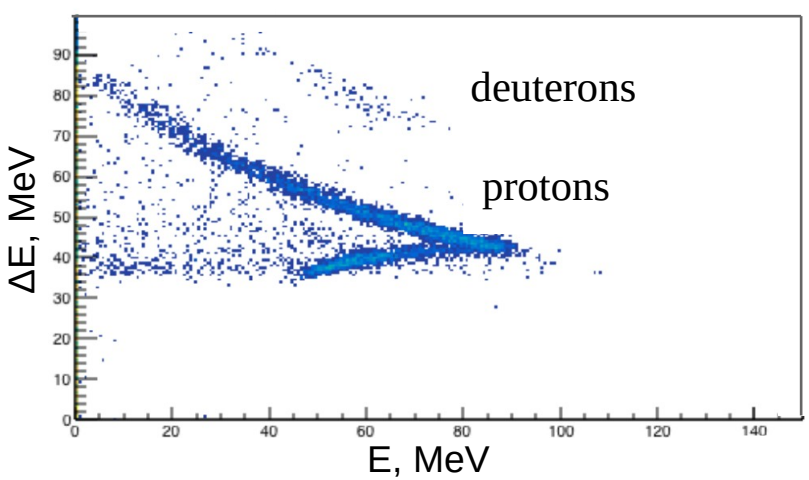
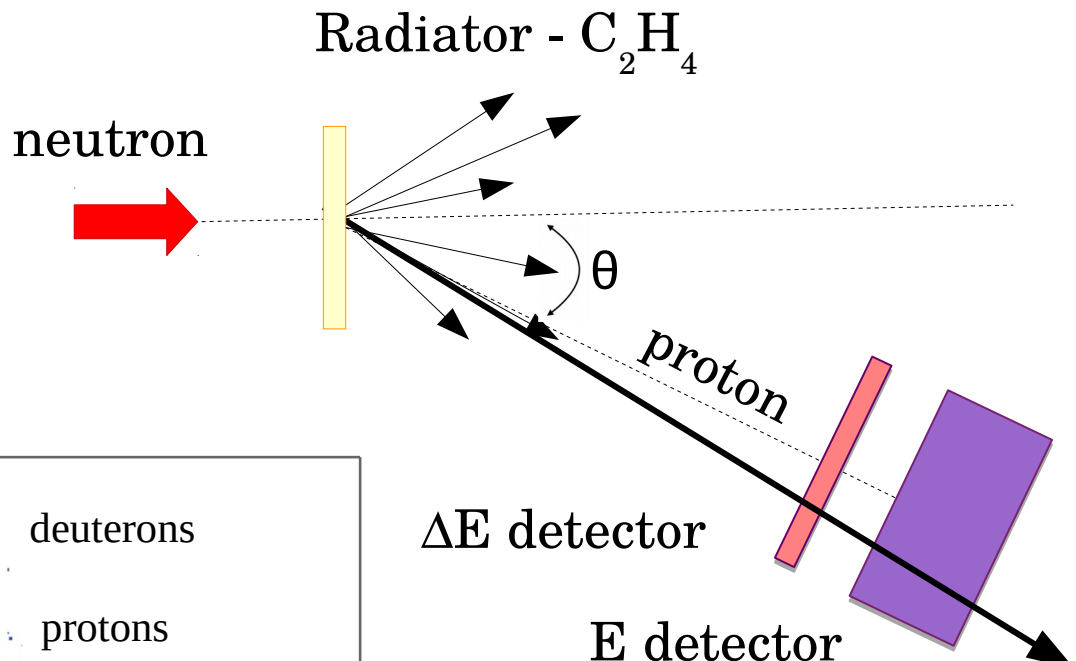
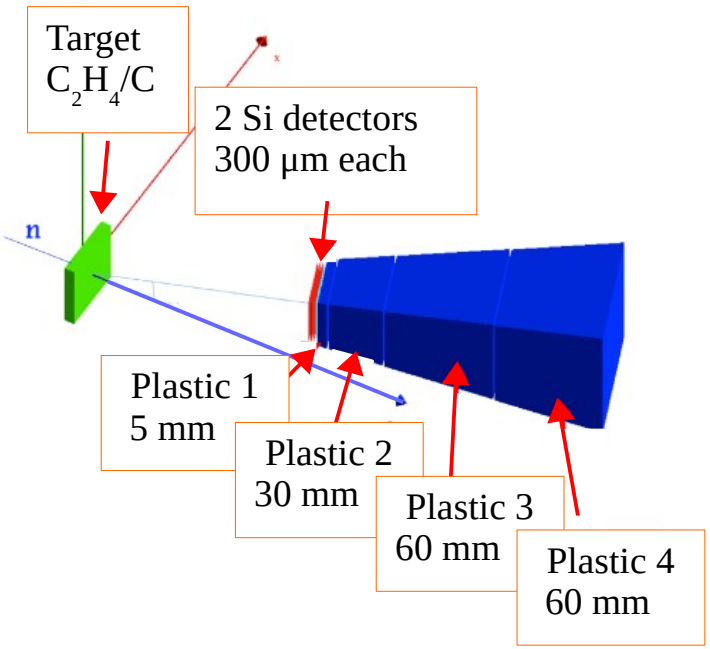
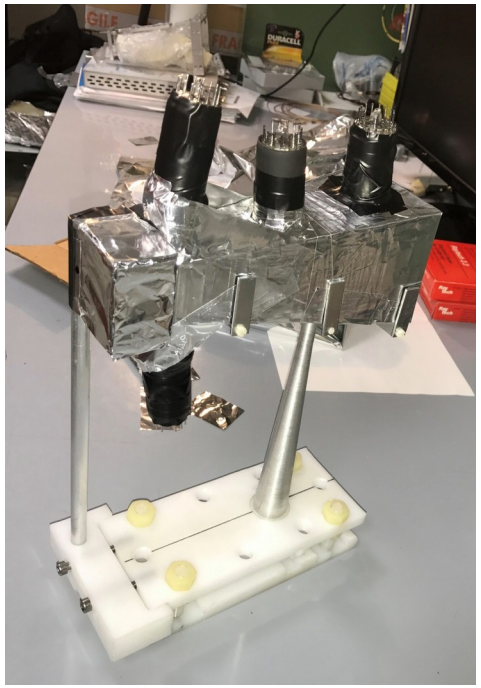
If the particle crosses the telescope





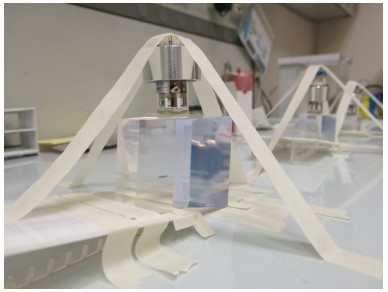
The INFN Proton Recoil Telescope

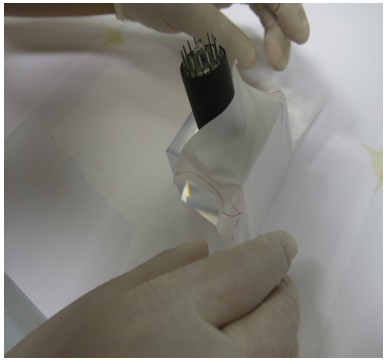


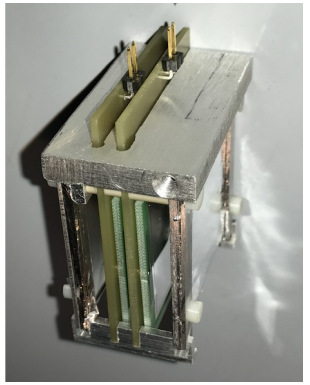


= 5 Telescopes

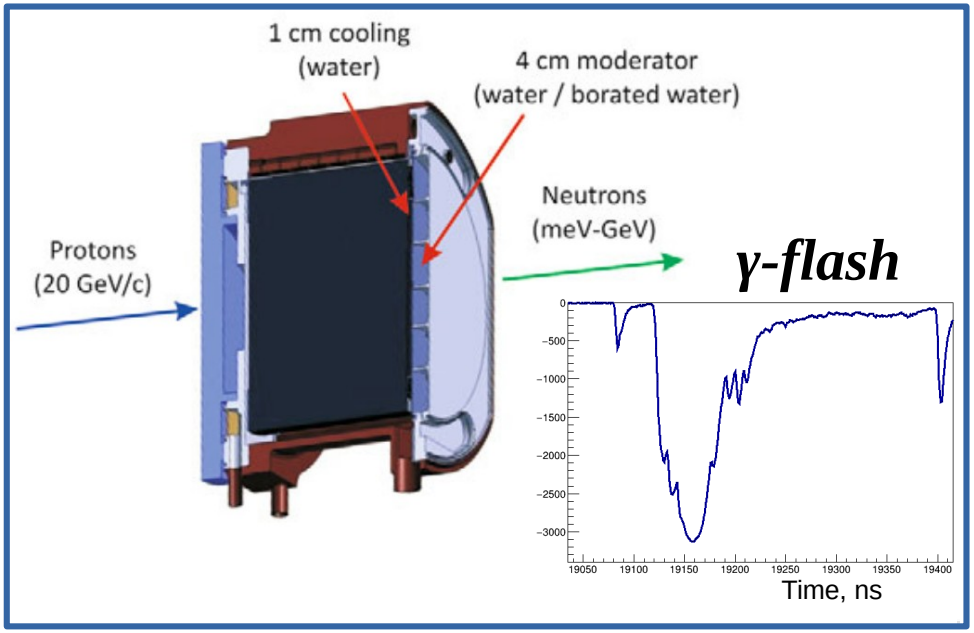
Coincidences		Neutron energy
1. 1st & 2nd Silicon	→	< 15 MeV
2. + 1st Plastic	→	15 – 35 MeV
3. + 2nd Plastic	→	35 – 70 MeV
4. + 3rd Plastic	→	70 – 130 MeV
5. + 4th Plastic	→	> 130 MeV

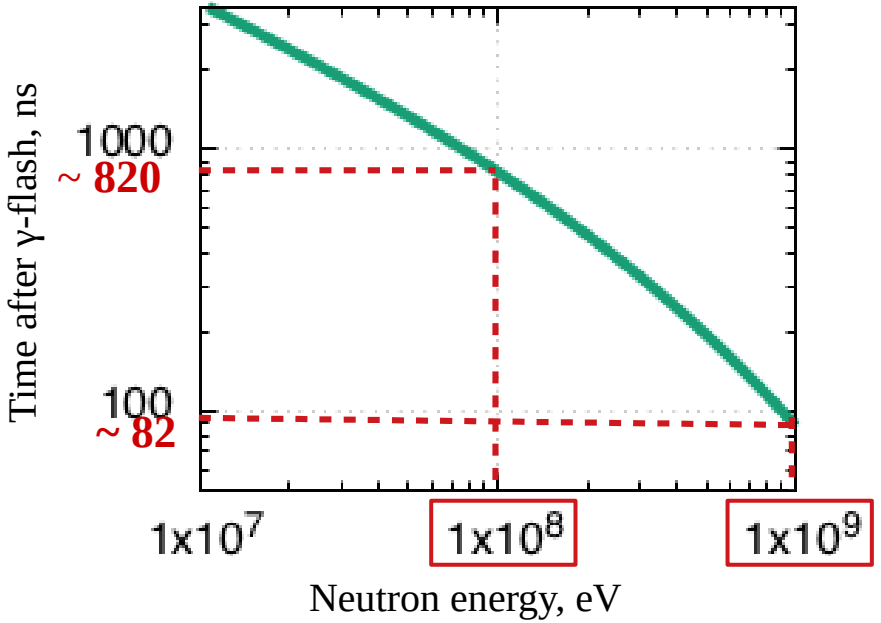






Results: PRT response to the γ-flash





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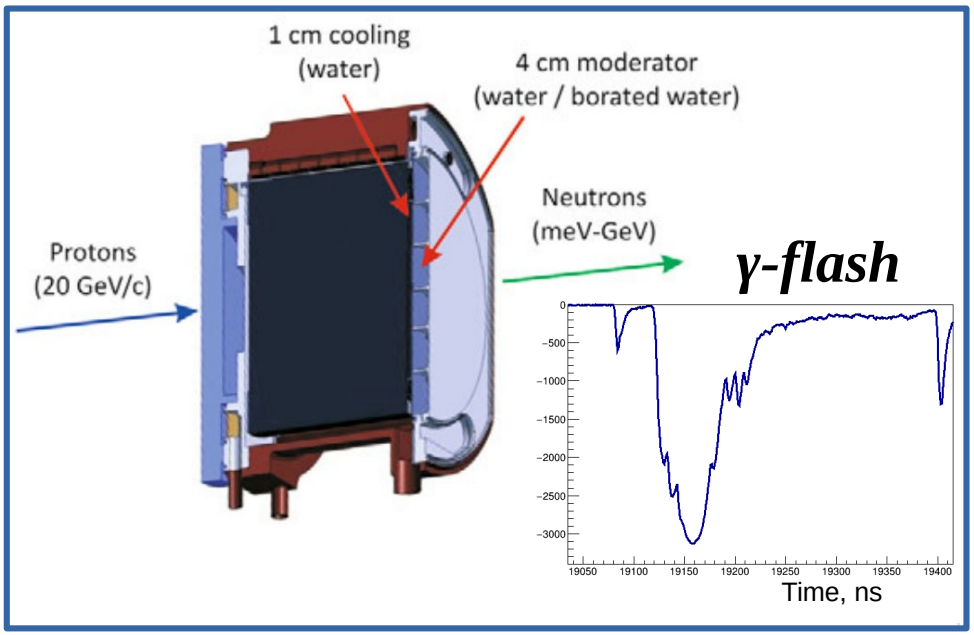
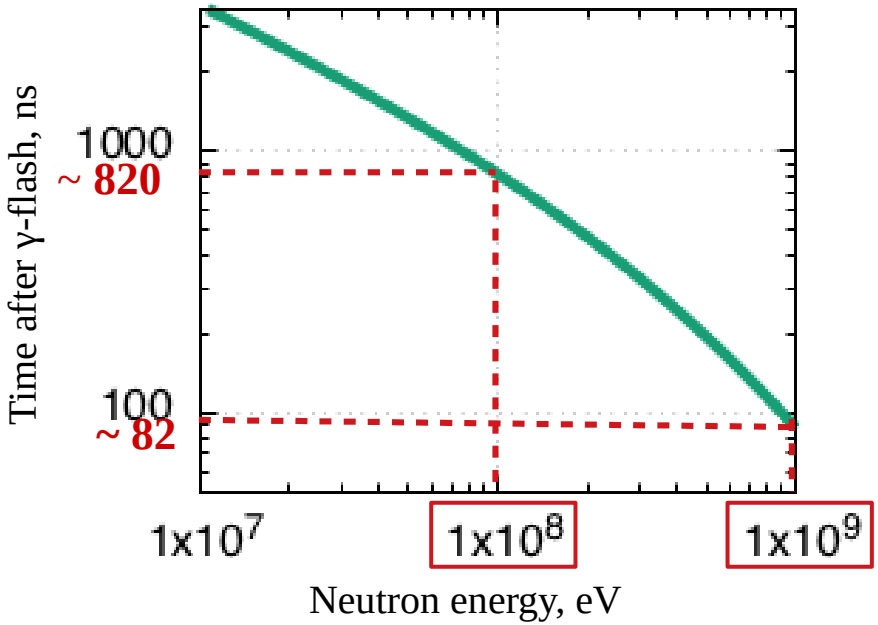
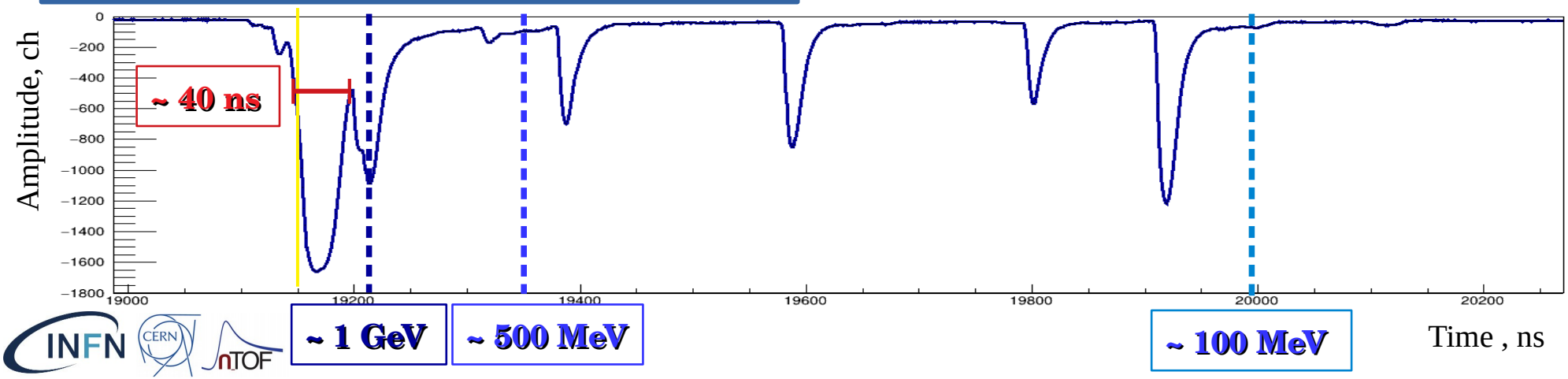




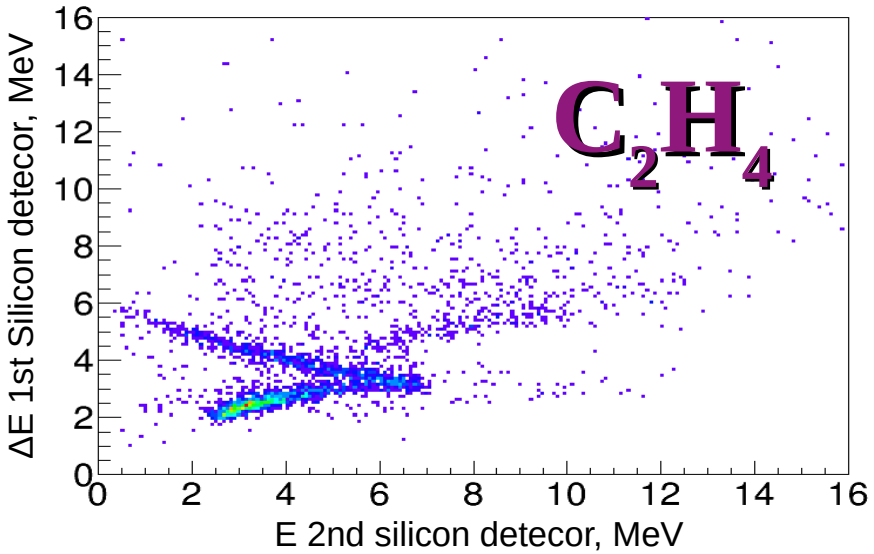


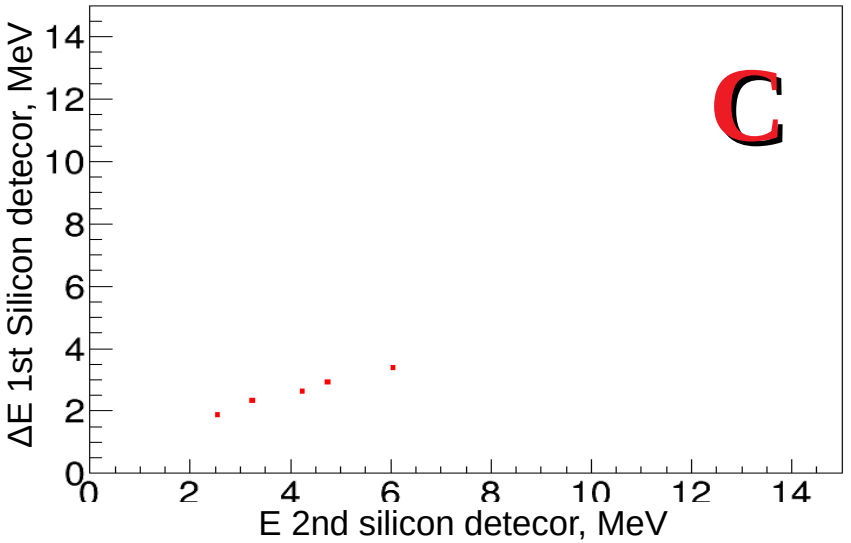
Results: ΔE - E Matrix

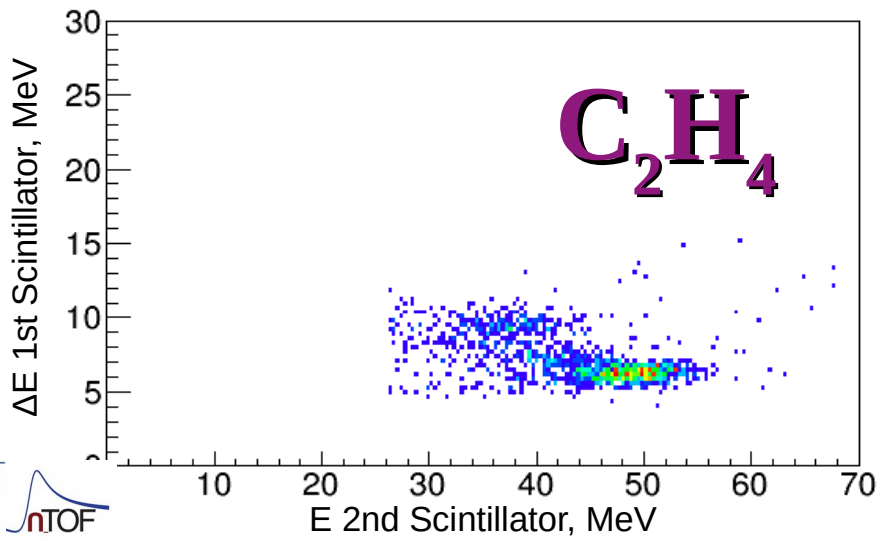
15 MeV

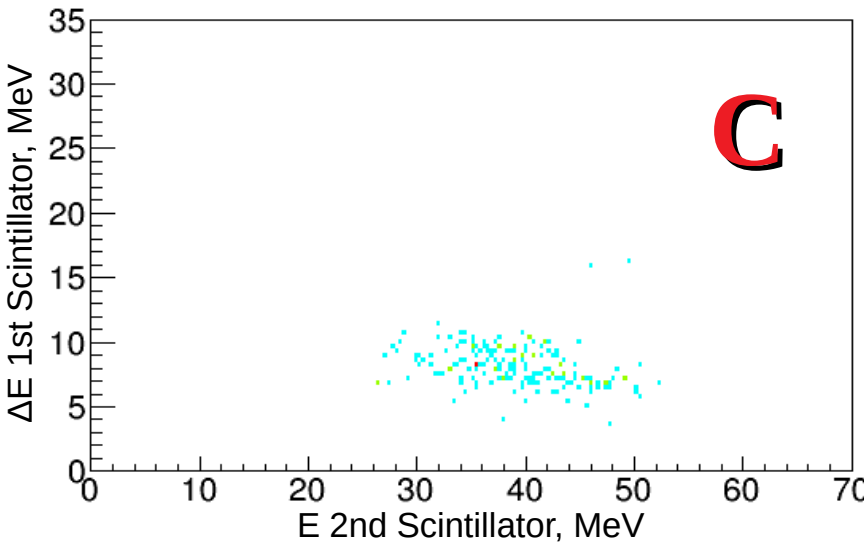
Neutron energy

70 MeV

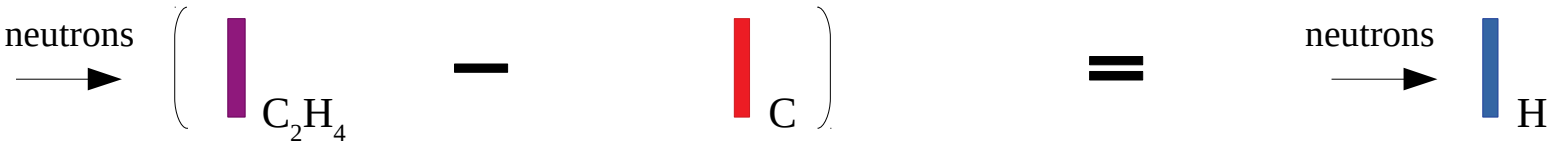




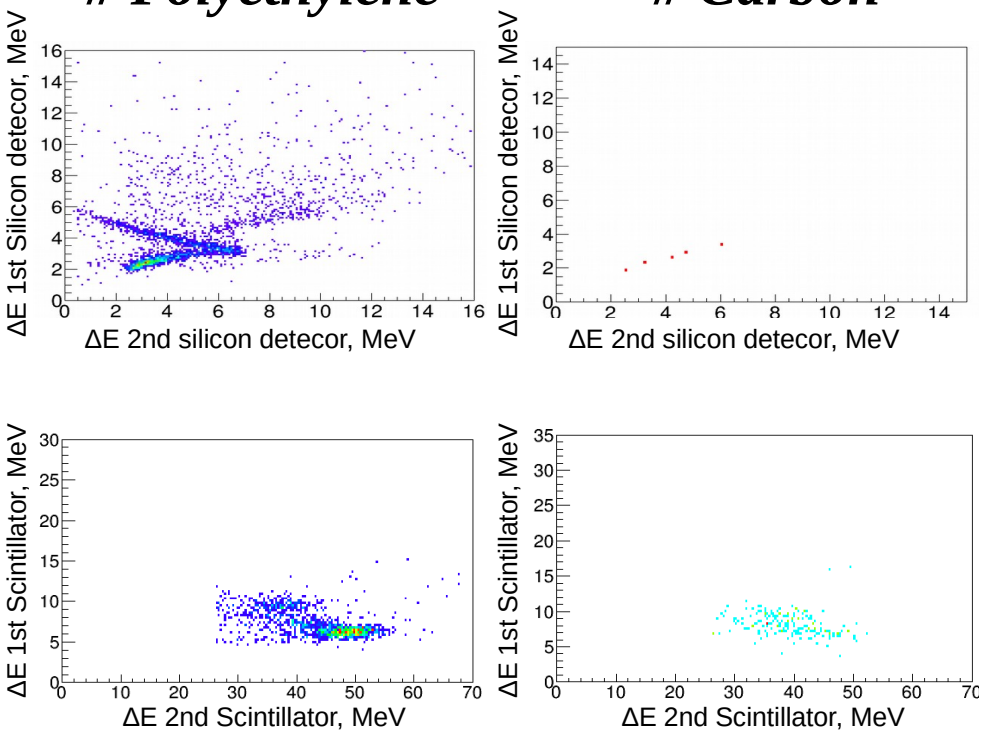


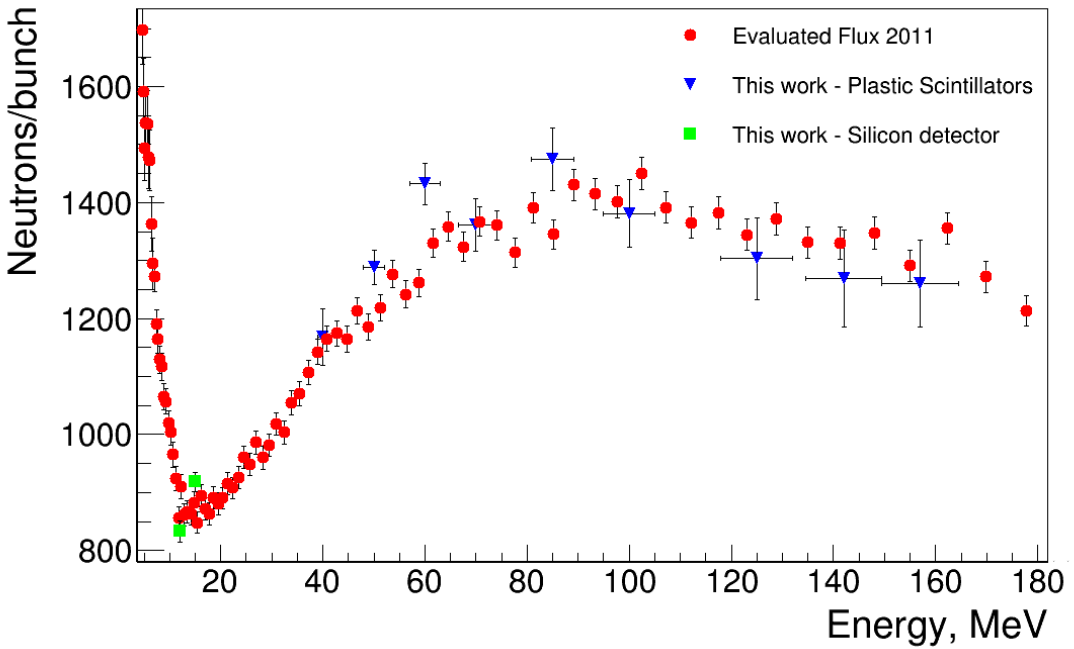


Results: Neutron Flux

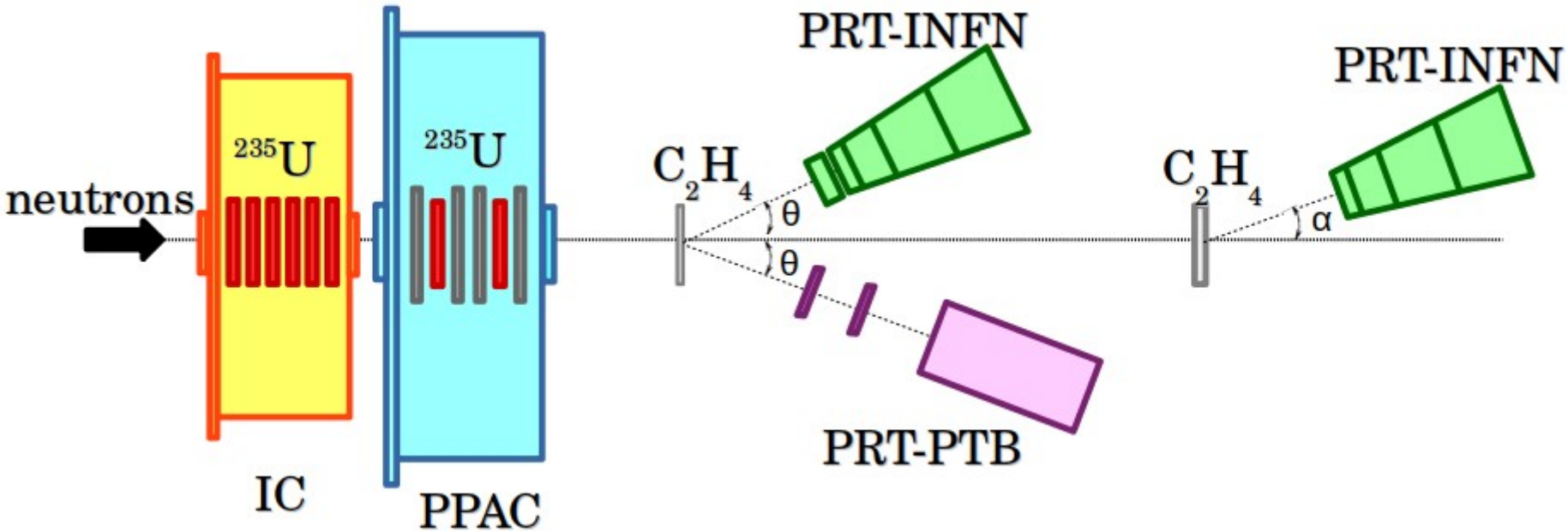


 # Polyethylene - # Carbon = Extracted neutron flux

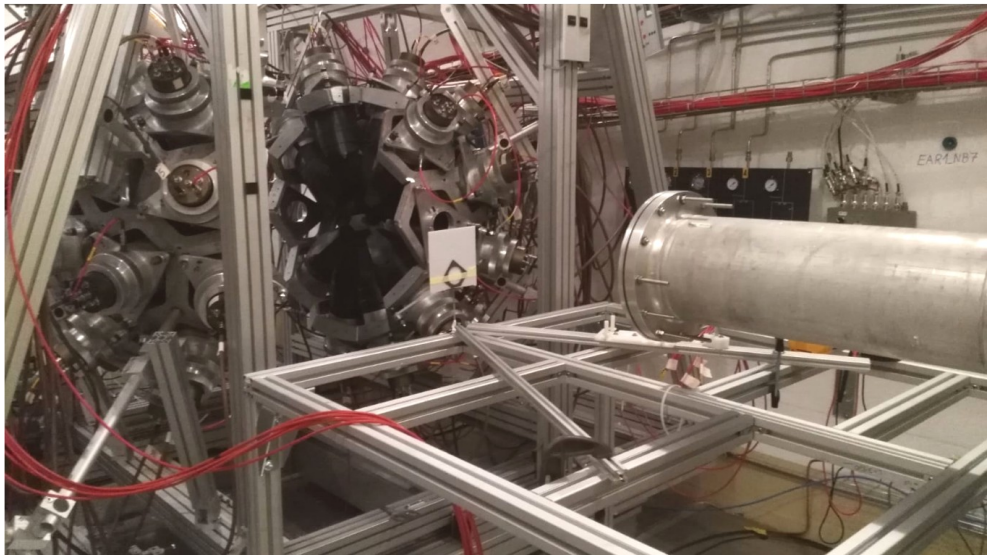


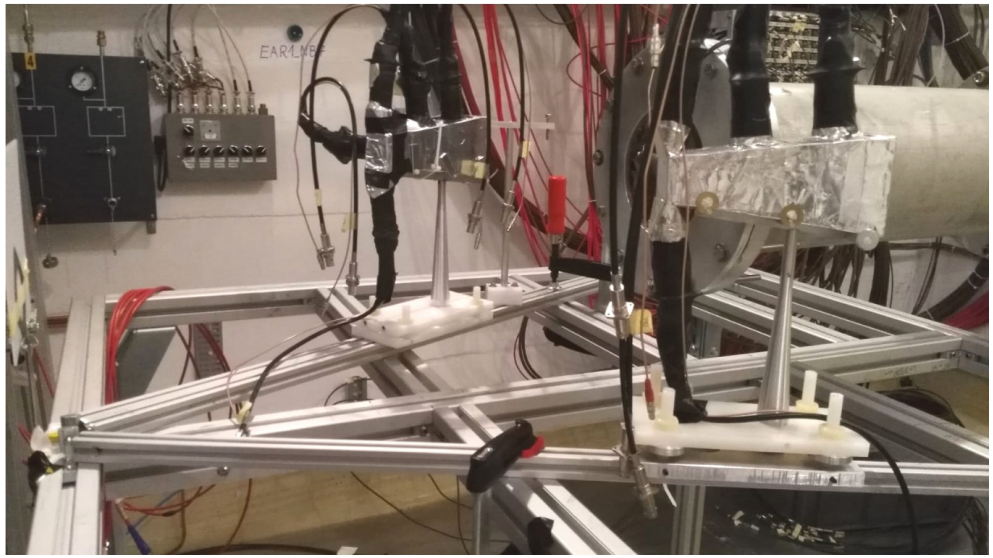


Results: final experimental setup



PRT: further tests





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Sci 1-A	750	790
Sci 1-B	745	820
Sci 2	640	640
Sci 3	650	650
Sci 4	680	660

G	New (V)	Old (V)
Sci 1-A	640	670
Sci 1-B	630	700
Sci 2	580	580
Sci 3	585	585
Sci 4	610	595

O	New (V)	Old (V)
Sci 1-A	810	840
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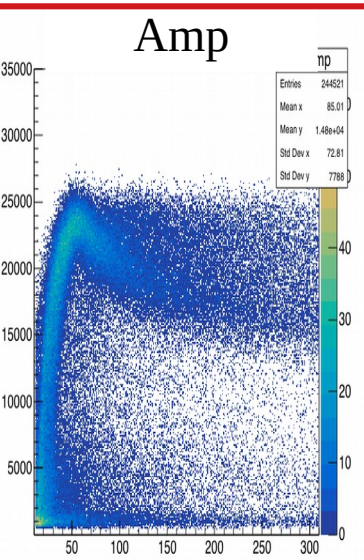

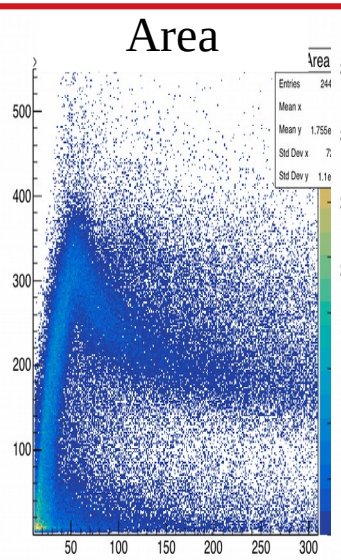

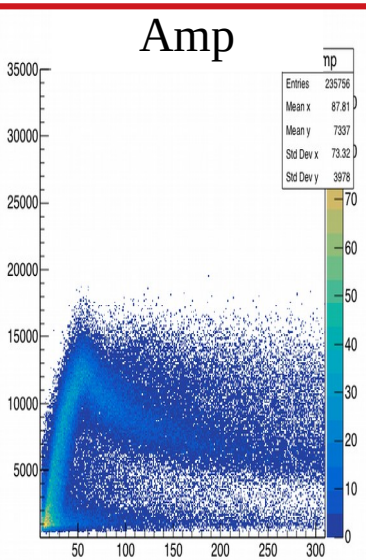

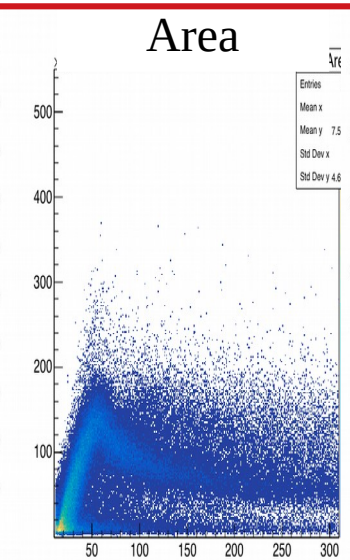

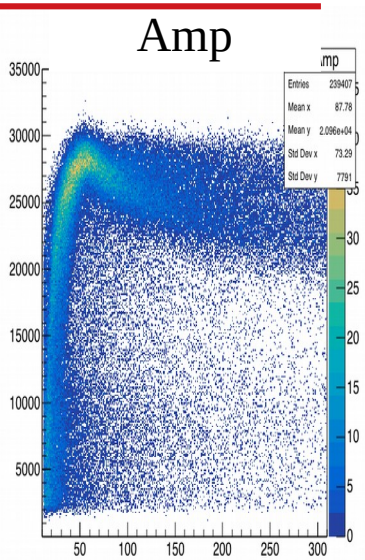

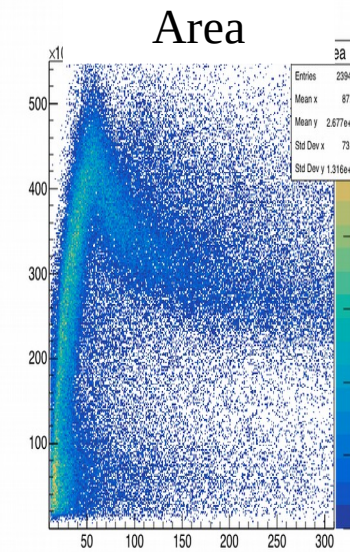

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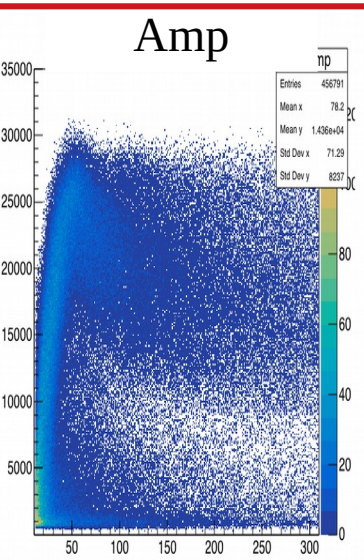

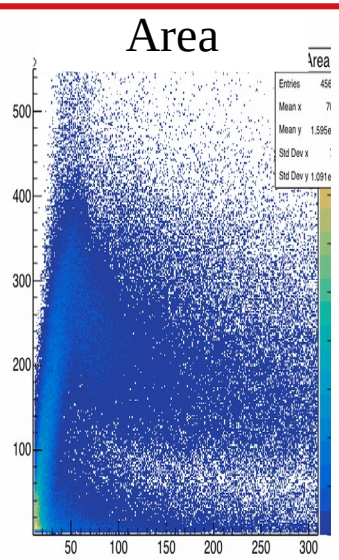

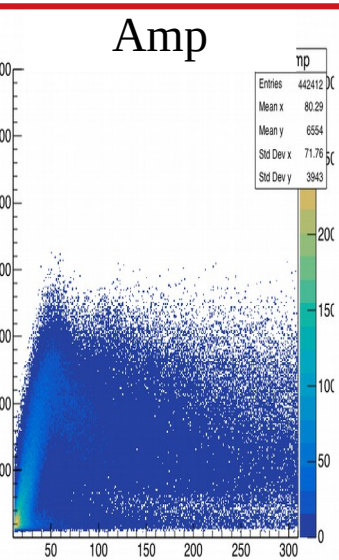

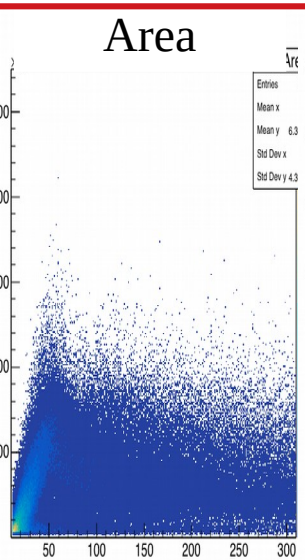

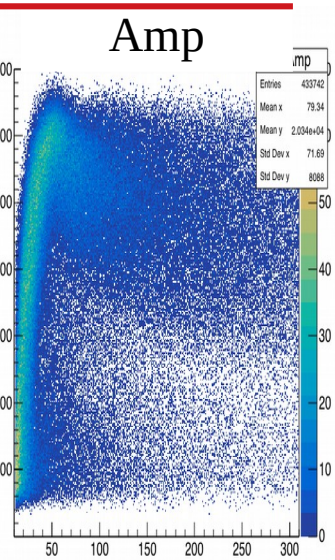

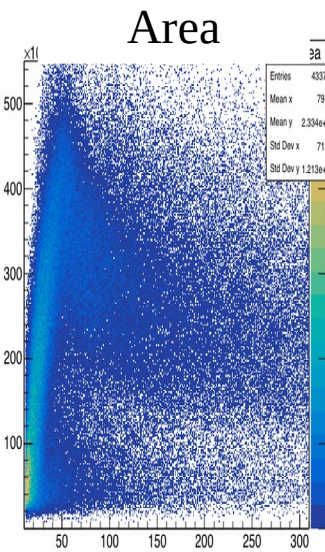

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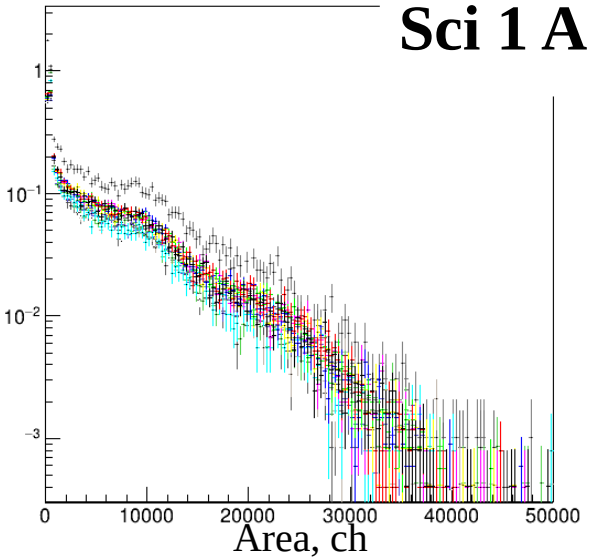
PRT: test with gamma source

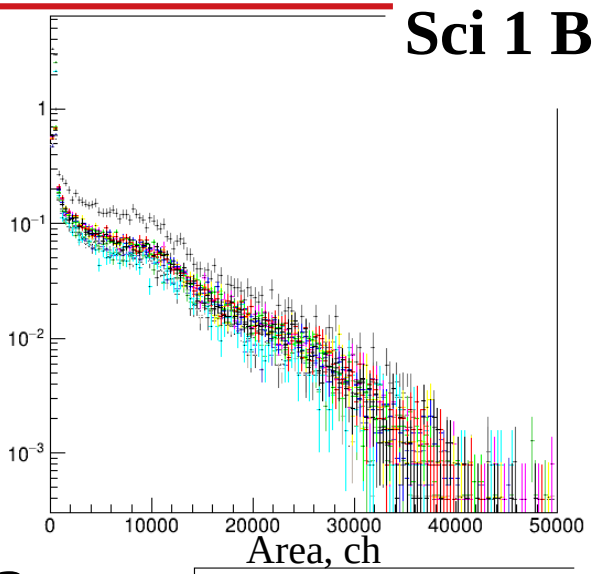
^{88}Y

High voltage: 640 V
630 V
590 V
605 V
630 V

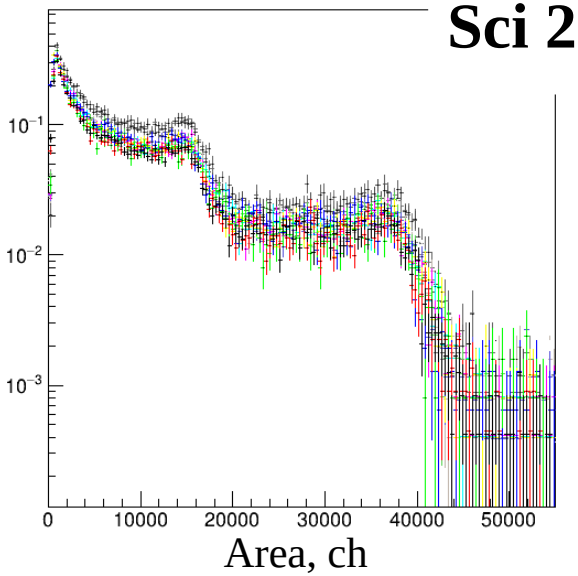
Sci 1 A



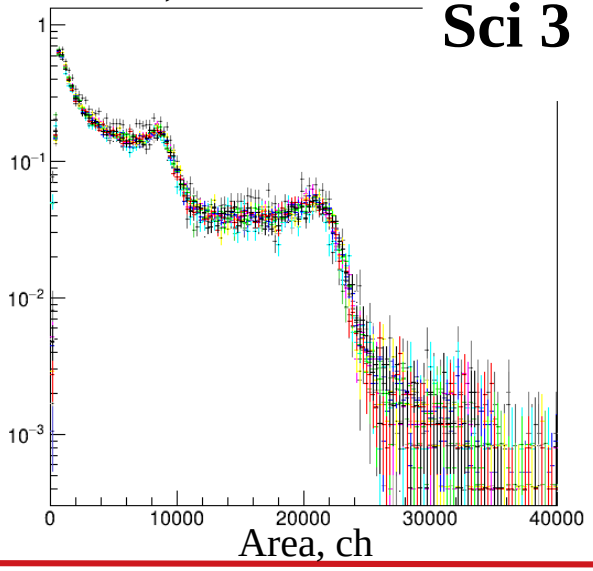
Sci 1 B



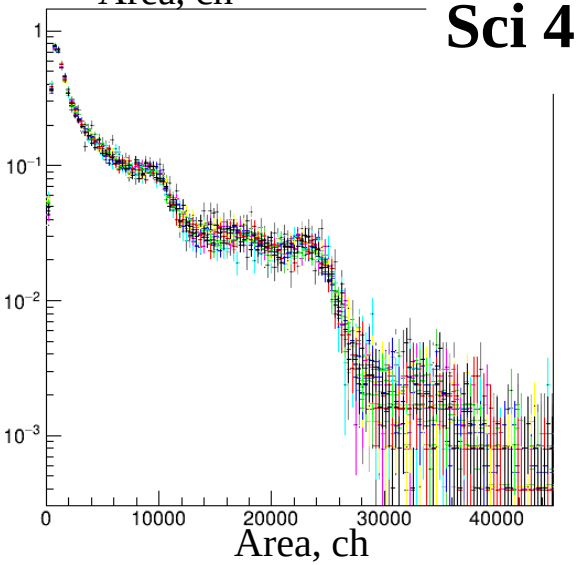
Sci 2



Sci 3



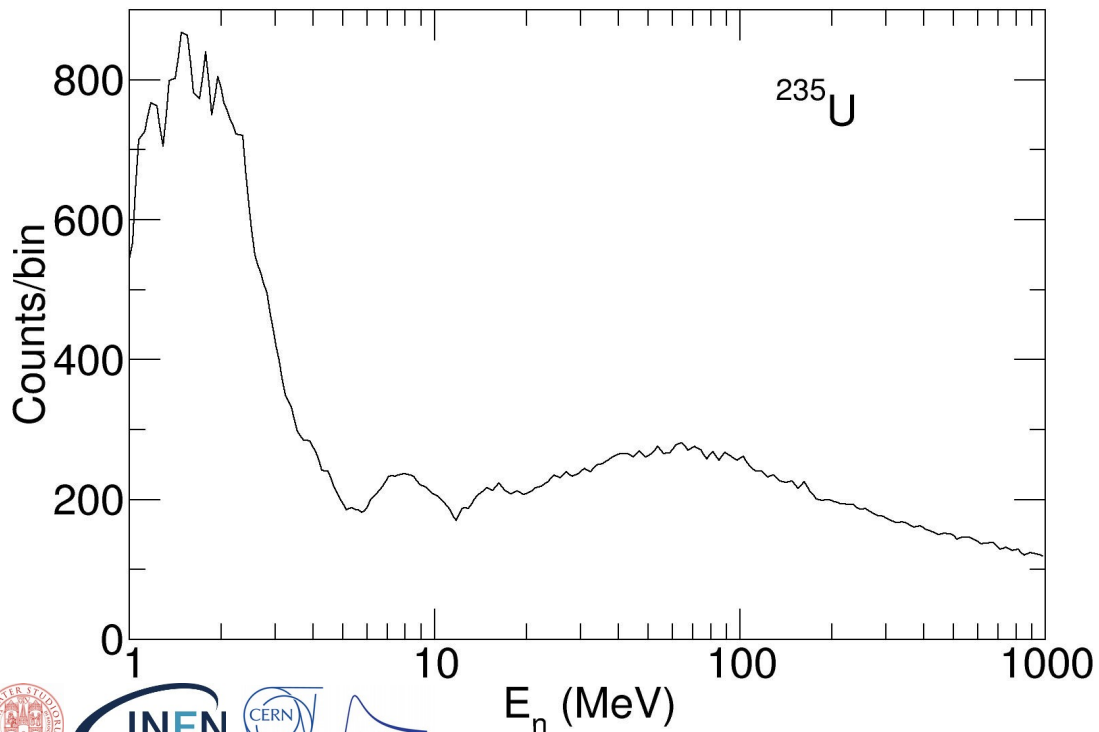
Sci 4

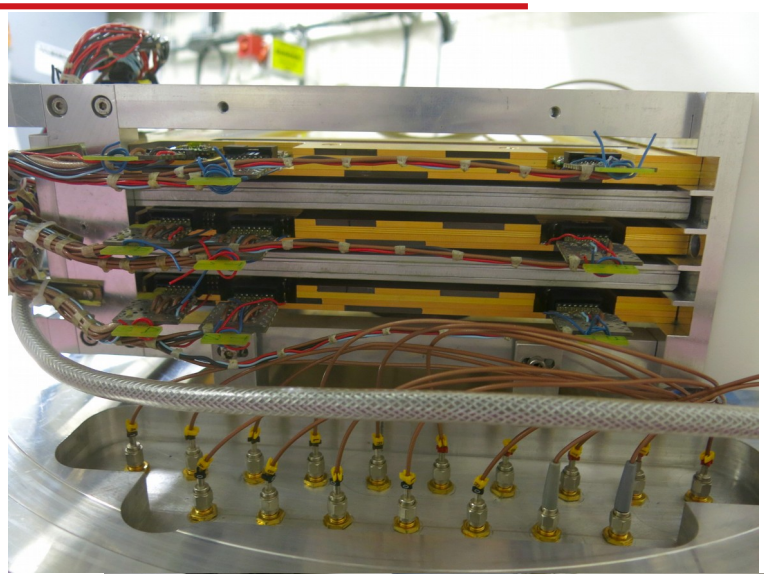


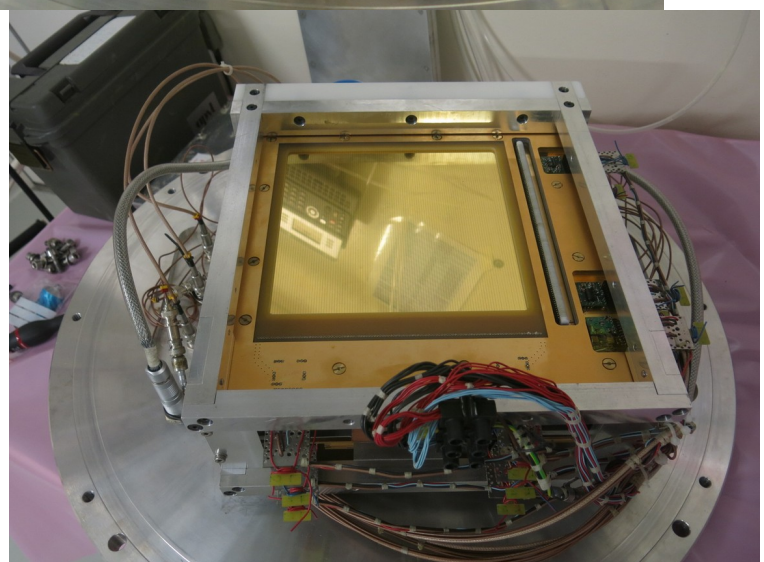
PPAC

2 targets of 15 mg of ^{235}**U**,
total activity **27.3 kBq per target**, divided in:

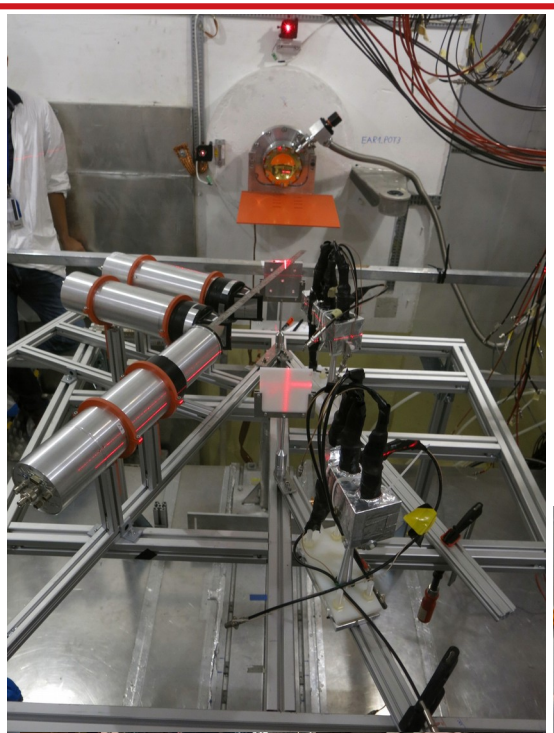
- 1.2 kBq of ^{235}U
- 26 kBq of ^{234}U
- 0.1 kBq of ^{236}U

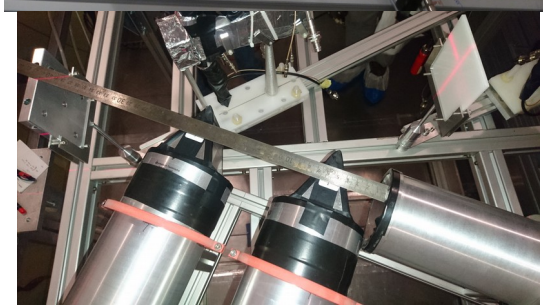


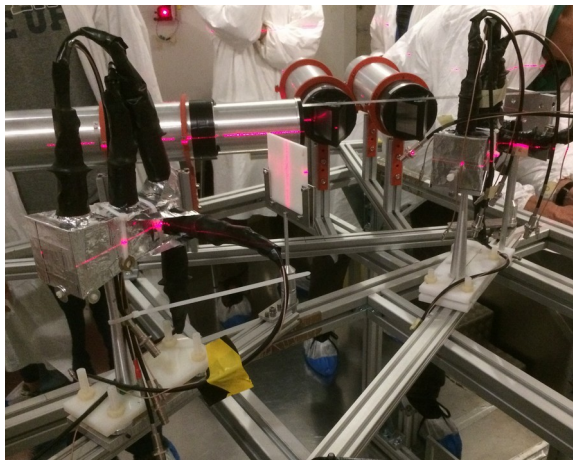


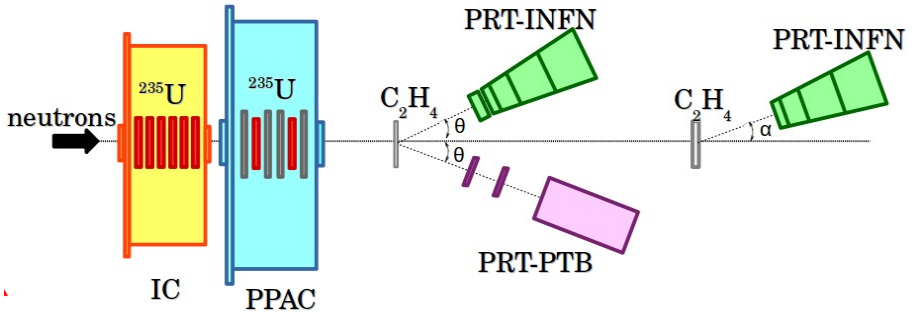


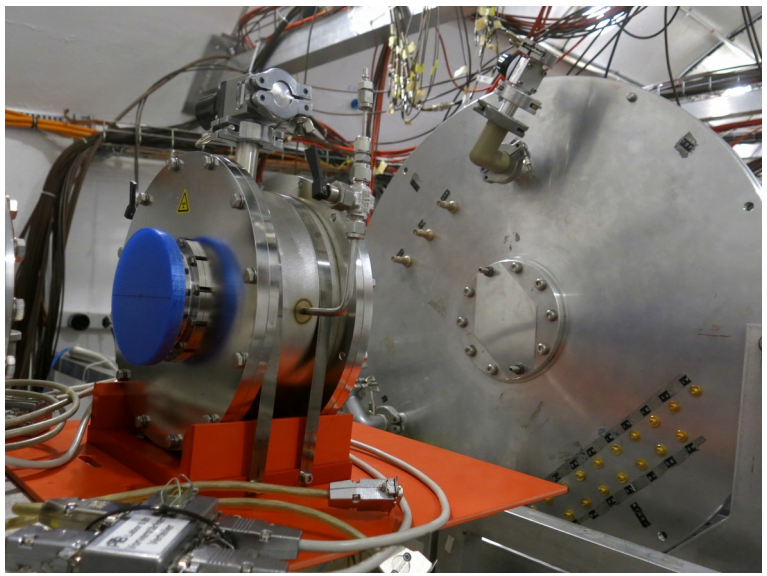
Mounting @ n_TOF

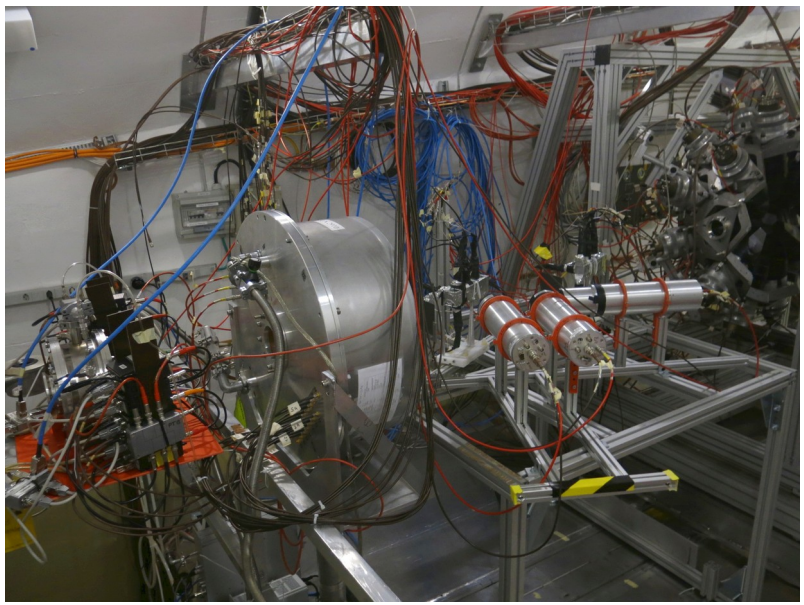




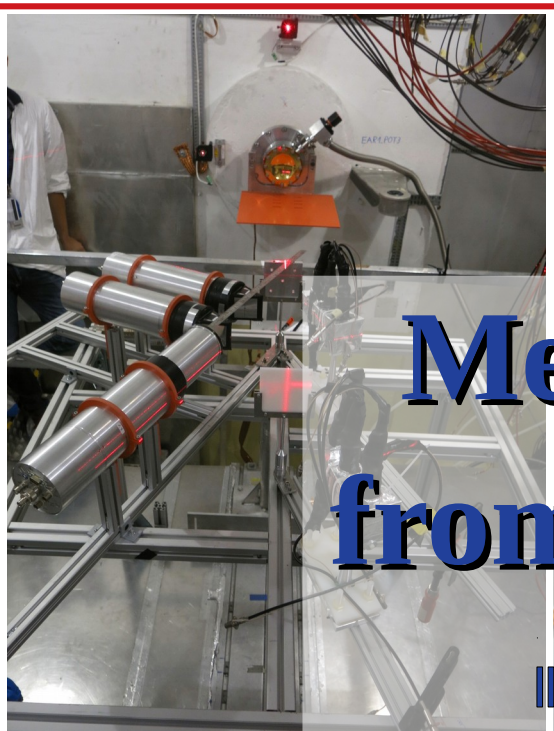


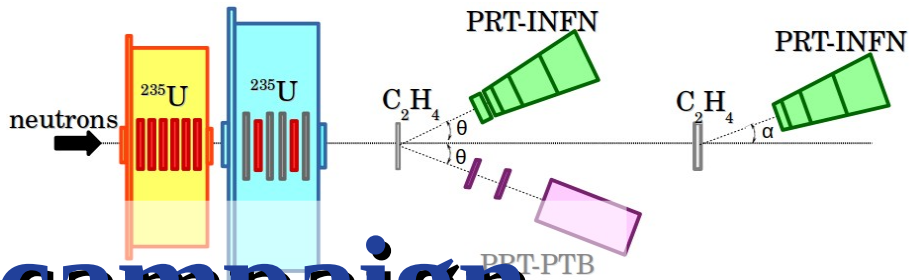






Mounting @ n_TOF

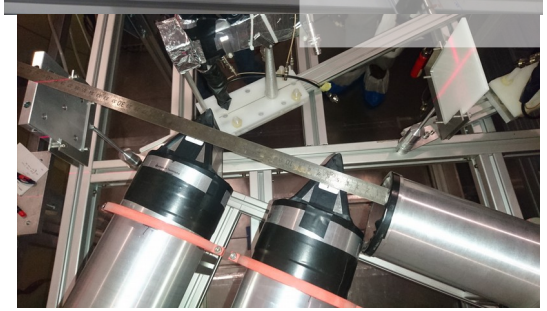




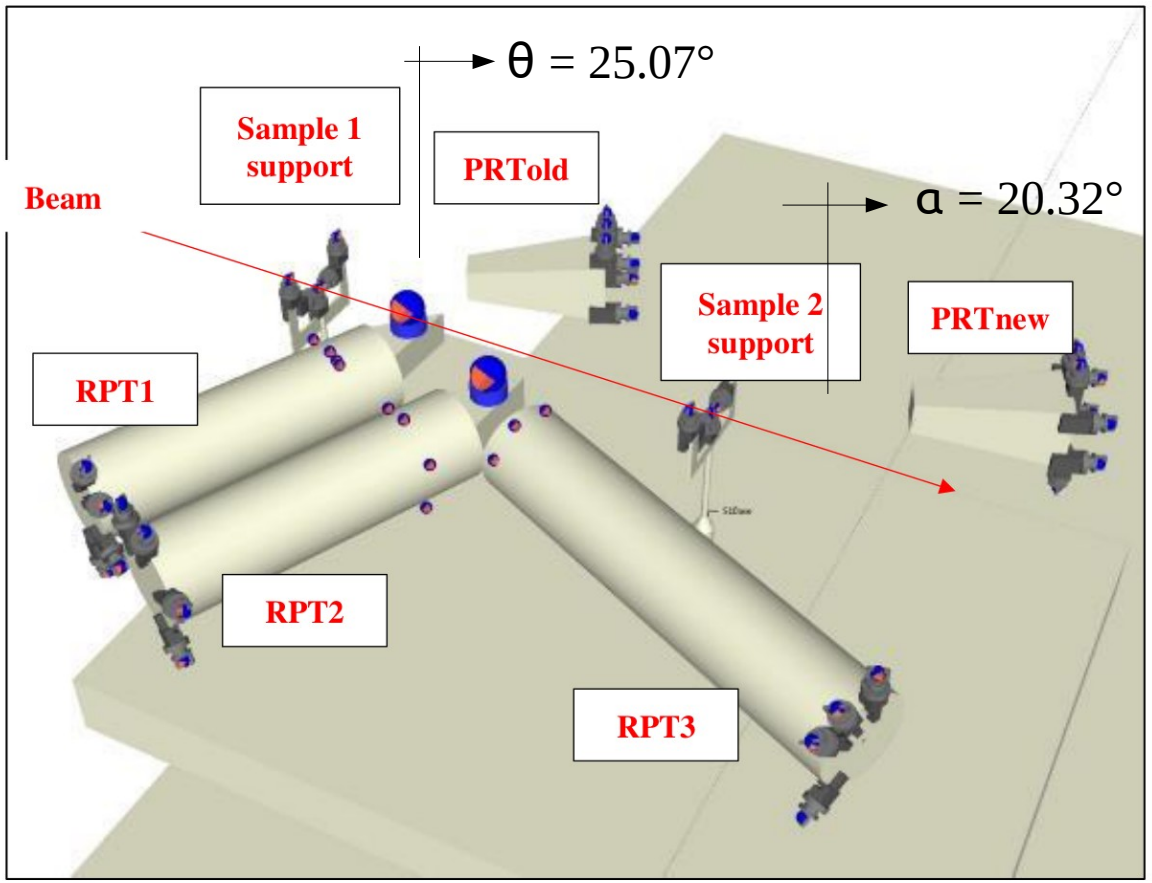
Measurement campaign

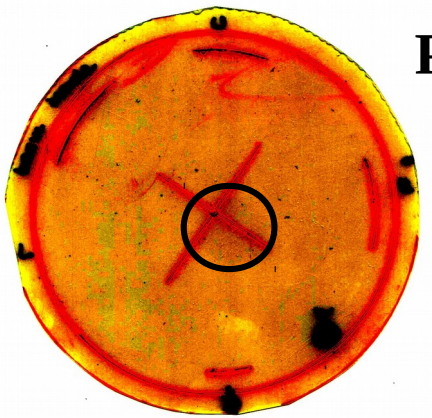
from Sept 17th to Oct 29th

➡ 4 extra days



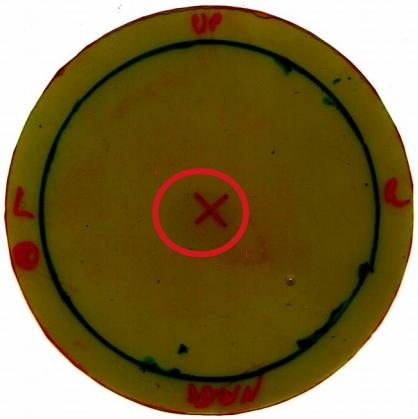
Alignment

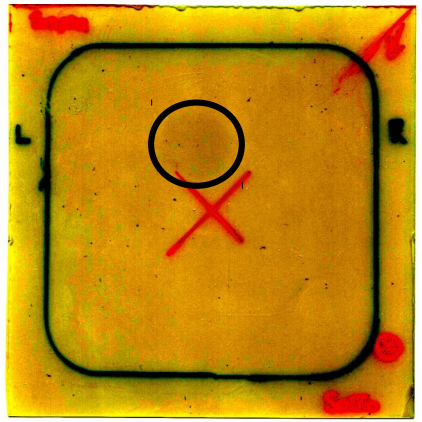




PPAC

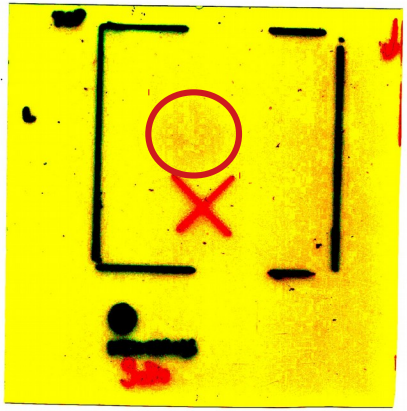
PPIC



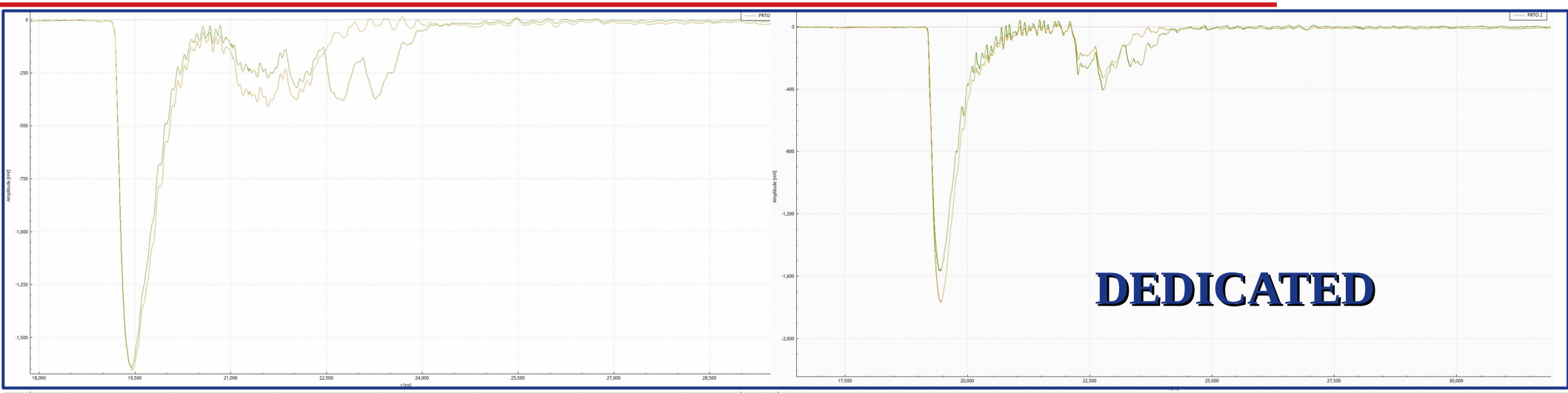


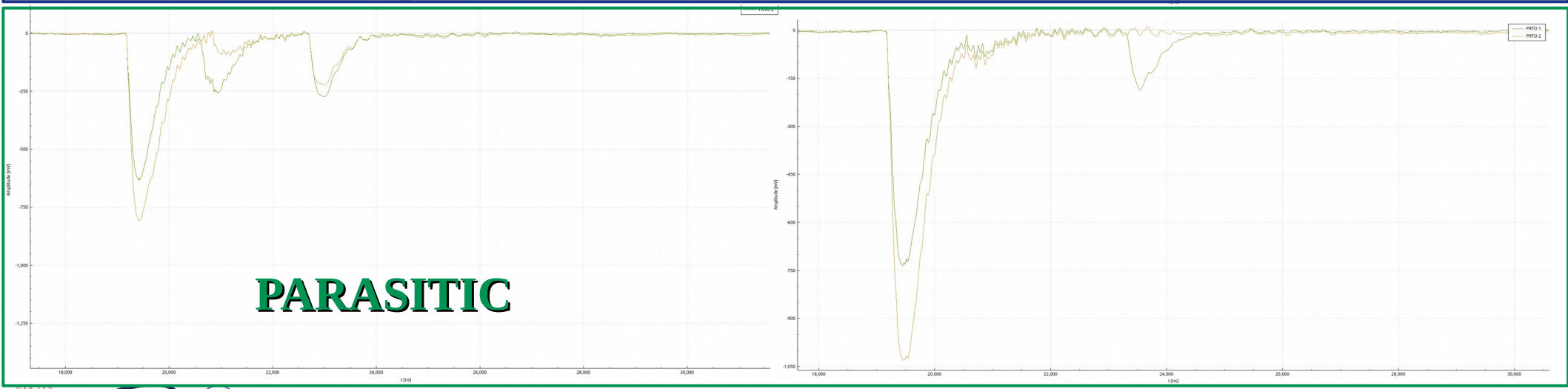
1st Target

2nd Target



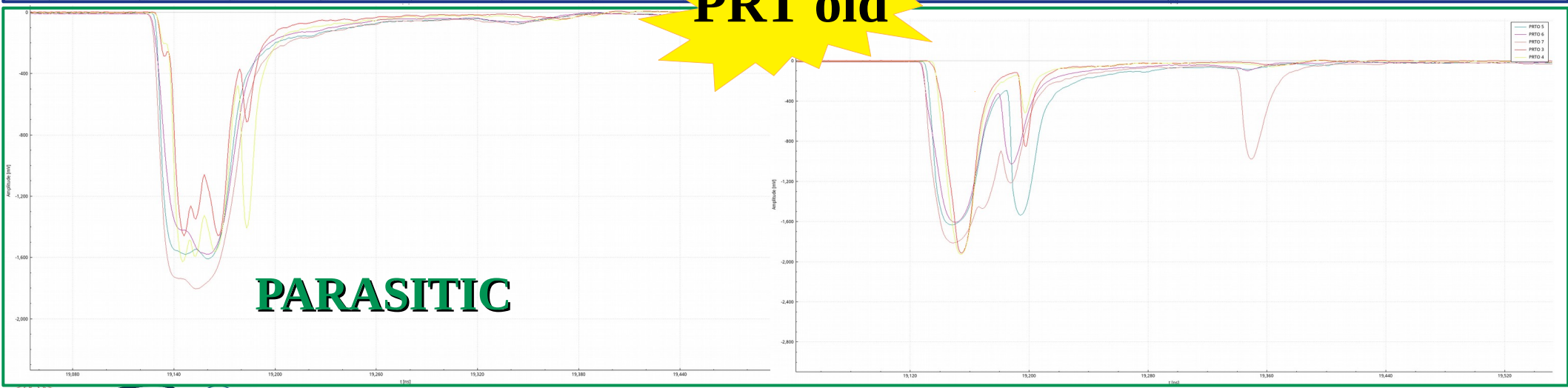
EventDisplay: Silicon detector



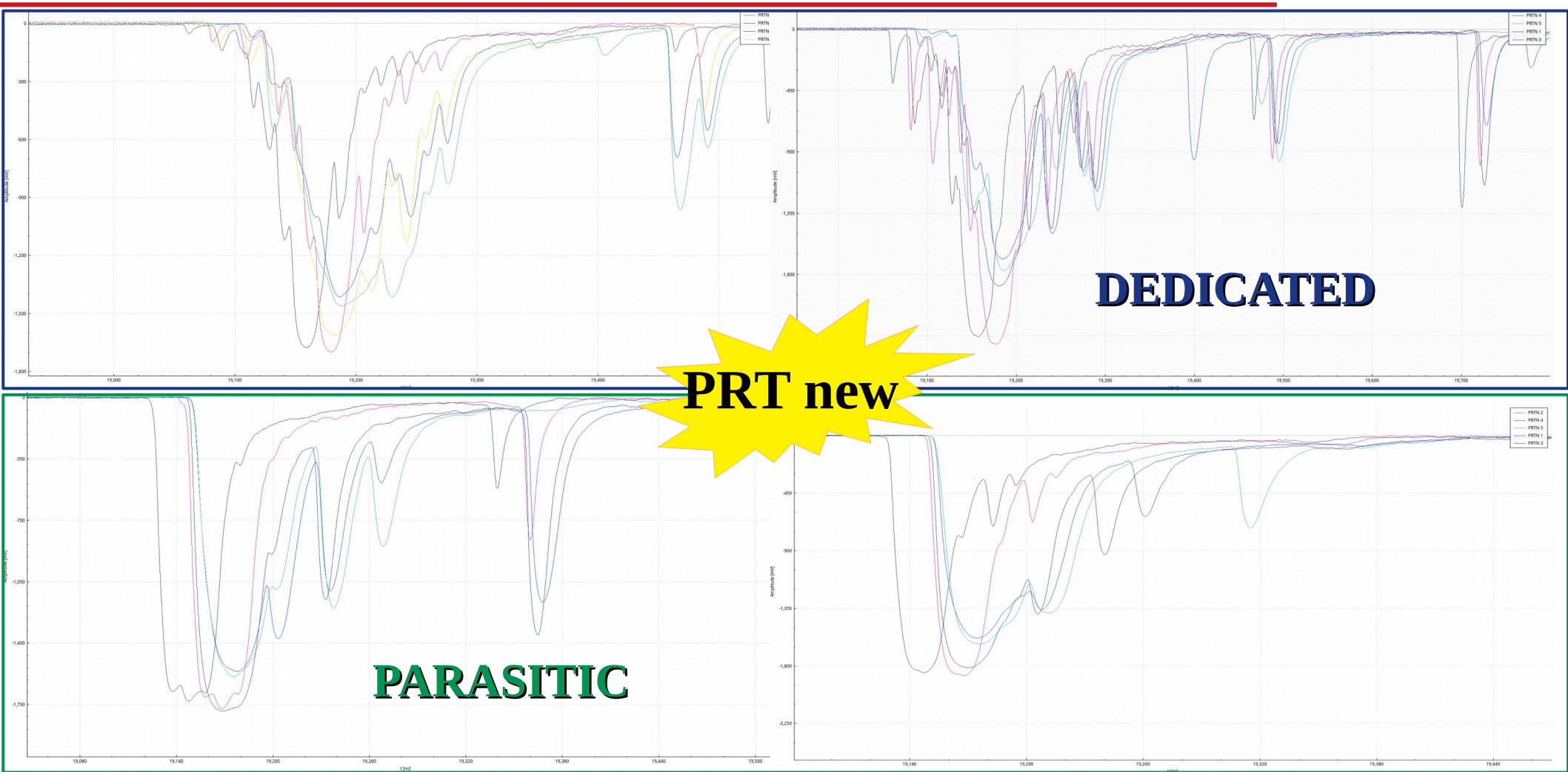


EventDisplay: γ-flash Plastic Scintillators

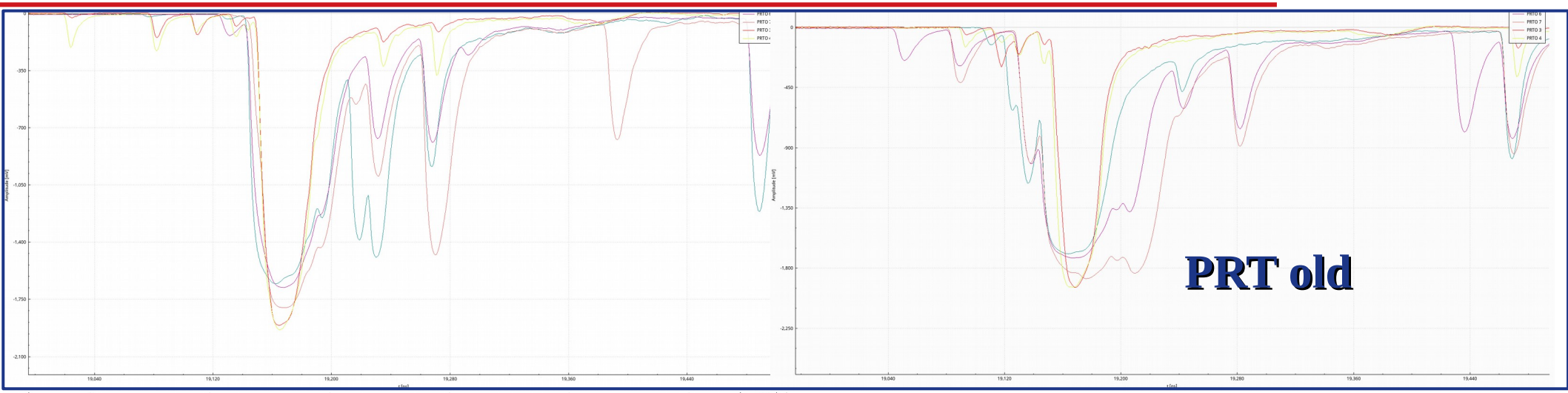
PRT old

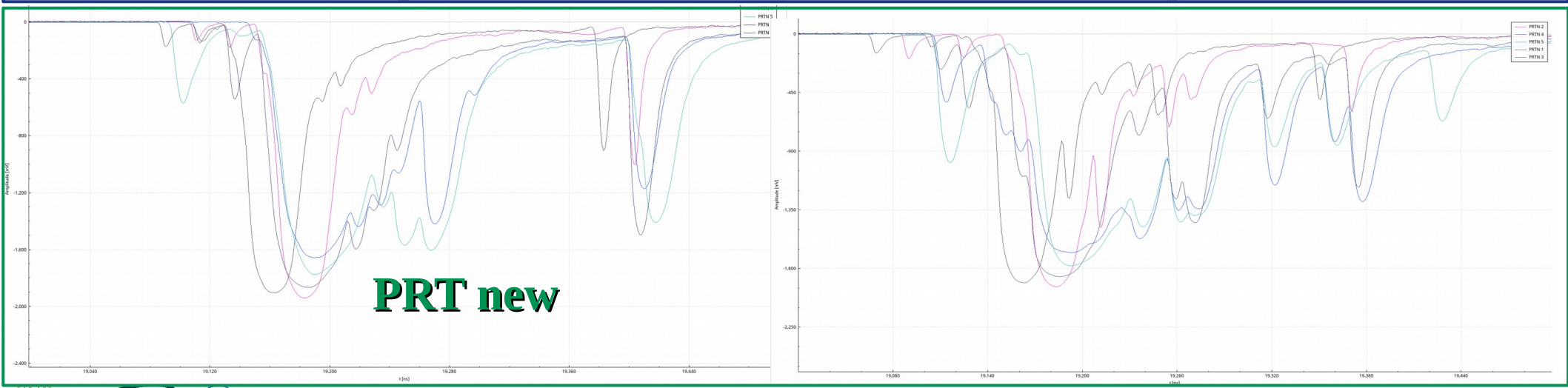


EventDisplay: γ-flash Plastic Scintillators



EventDisplay: RF test





Statistics

17 → 21 ⇄ Monting experimental setup / Alignment

From 21/09

^{235}U	$3.95 \cdot 10^{18}$

PPAC

PPIC

From 25/09

Old (V)	New (V)
PMT 1A	730	690
PMT 1B	710	680
PMT 2	640	640
PMT 3	650	650
PMT 4	660	680

PRT old

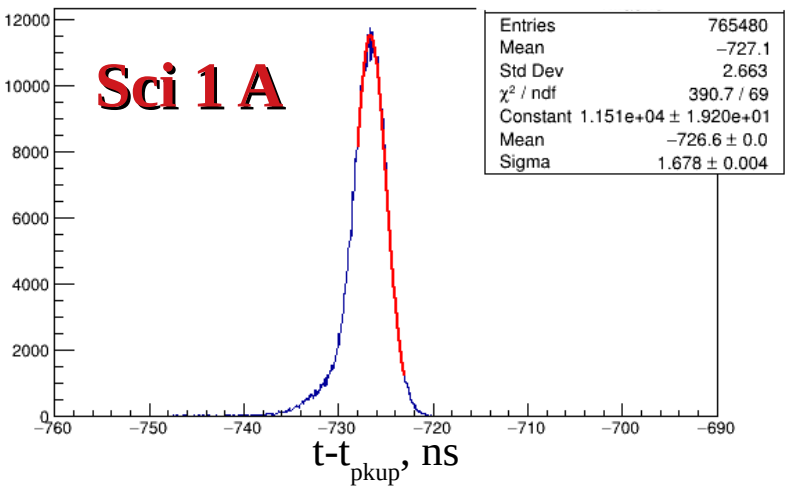
PE 1 mm	$7.08 \cdot 10^{17}$		
C 0.5 mm	$3.27 \cdot 10^{17}$		
PE 2 mm	$1,11 \cdot 10^{17}$		
C 1 mm	$3,88 \cdot 10^{17}$		
PE 5 mm	$7.44 \cdot 10^{17}$		
C 2.5 mm	$3.14 \cdot 10^{17}$		
Empty	$1.11 \cdot 10^{17}$	+	$1.46 \cdot 10^{16}$

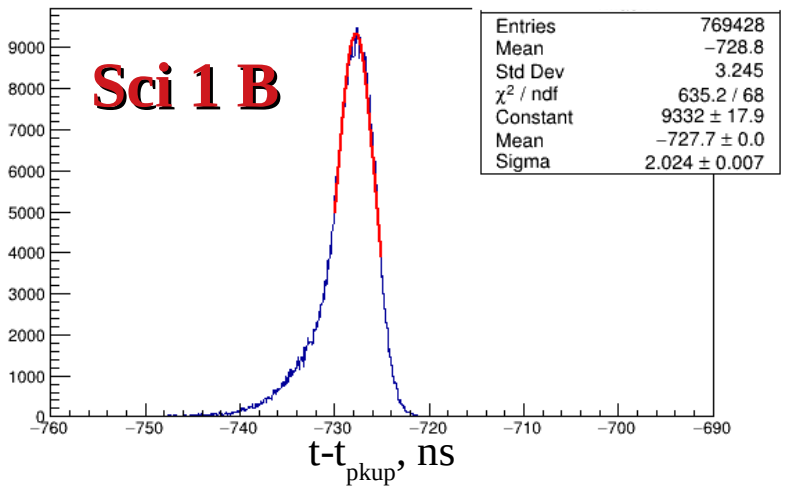
PRT new

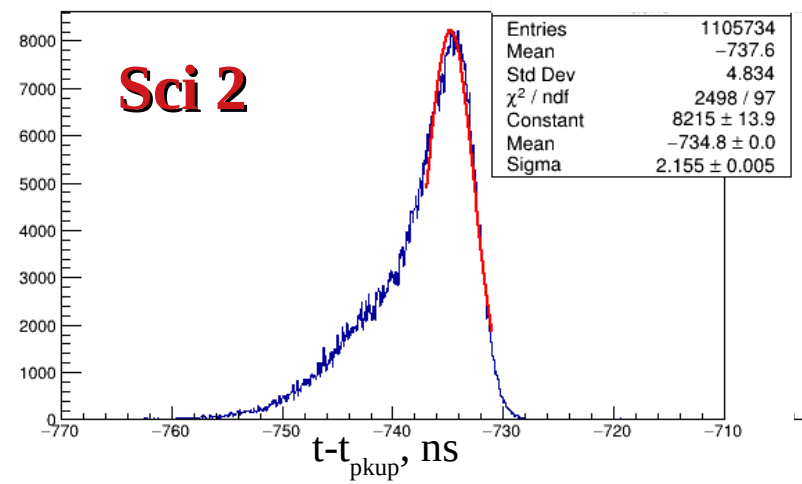
PE 5 mm	$2.06 \cdot 10^{18}$		
C 2.5 mm	$1.55 \cdot 10^{18}$		
Empty	$1.11 \cdot 10^{17}$	+	$1.12 \cdot 10^{17}$

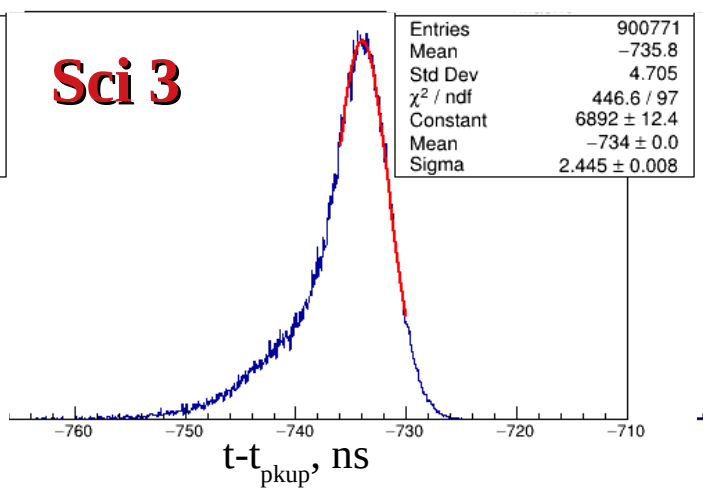
T start: t_0 - t_{pkup}

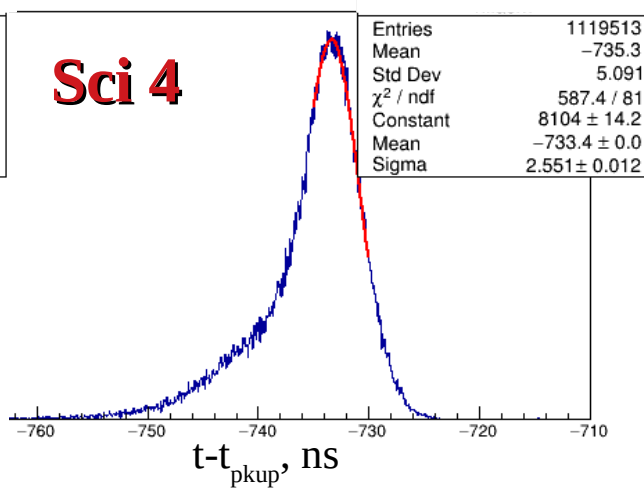
PRTO







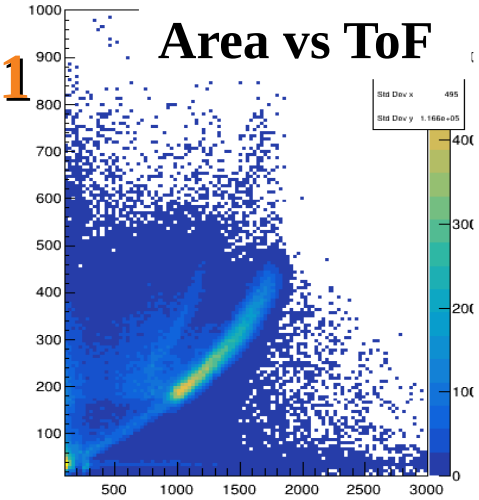


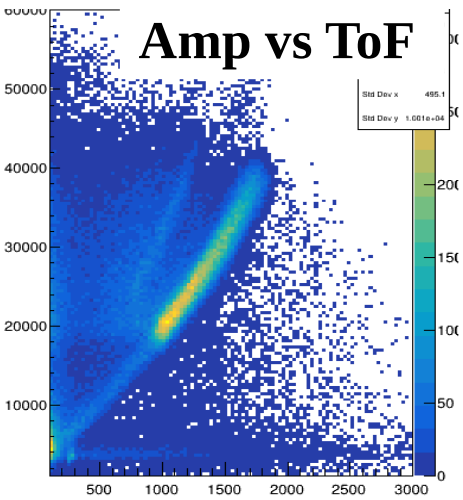


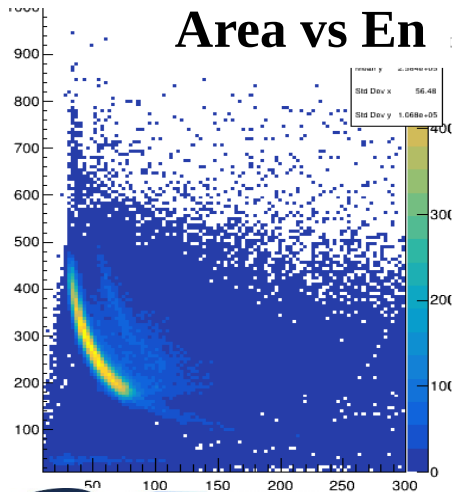
Coincidences 1st + 2nd

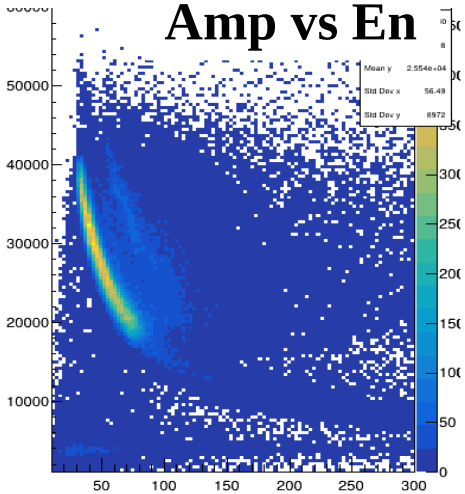
PRTO

Sci 1

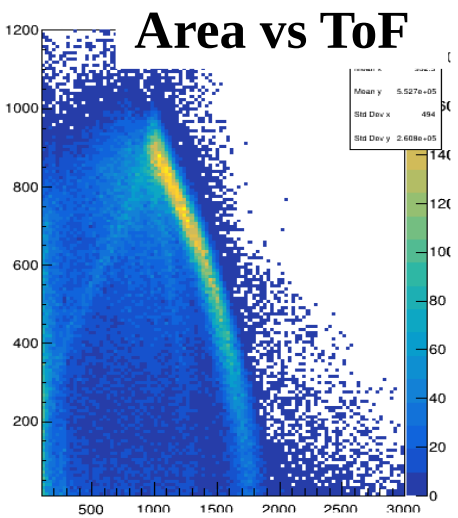


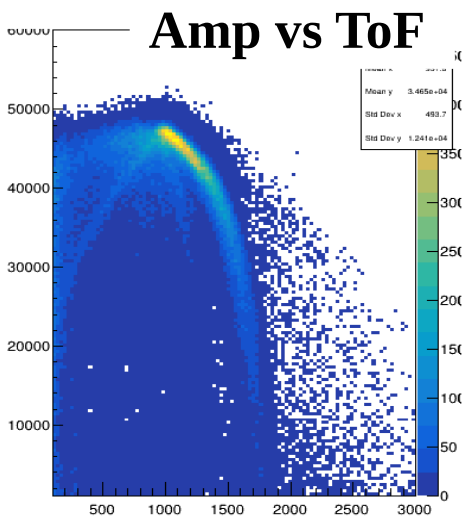


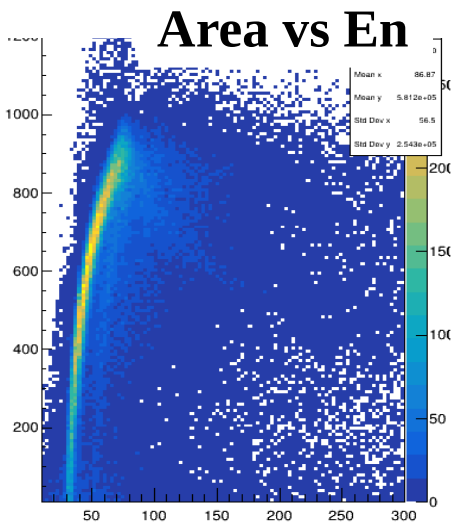


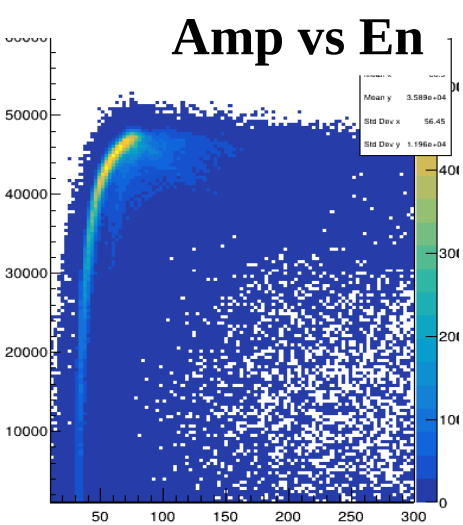


Sci 2







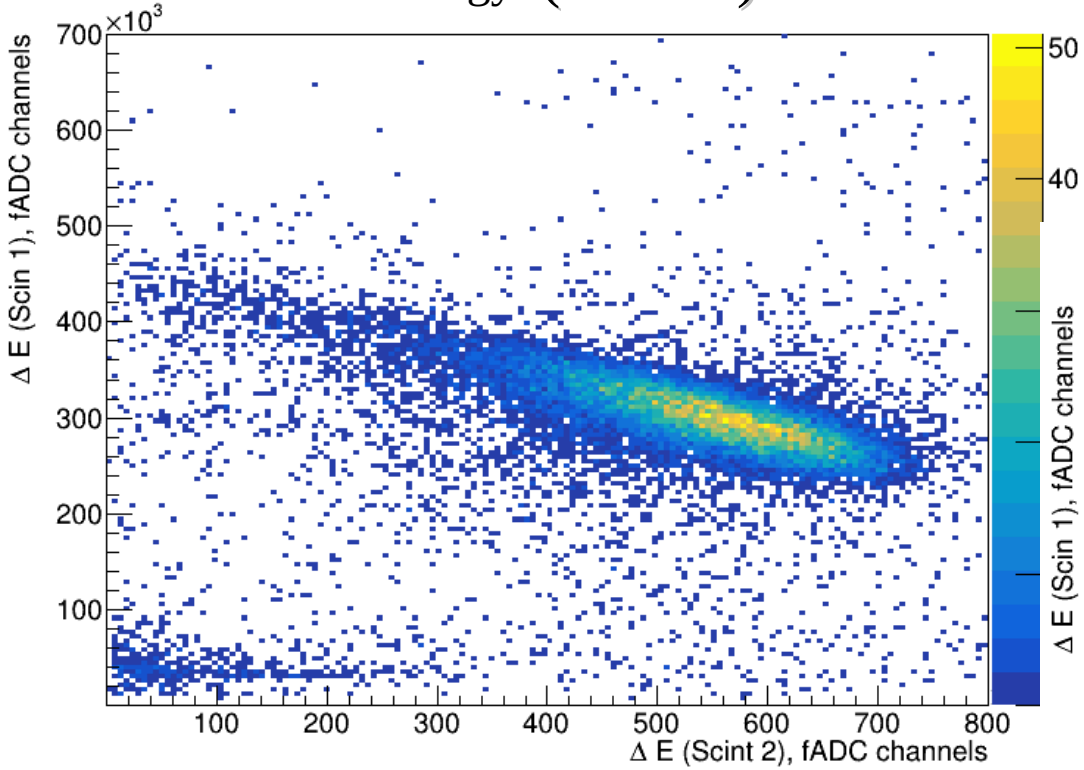


INFN CERN nTOF

ΔE - E Matrix

PRTO

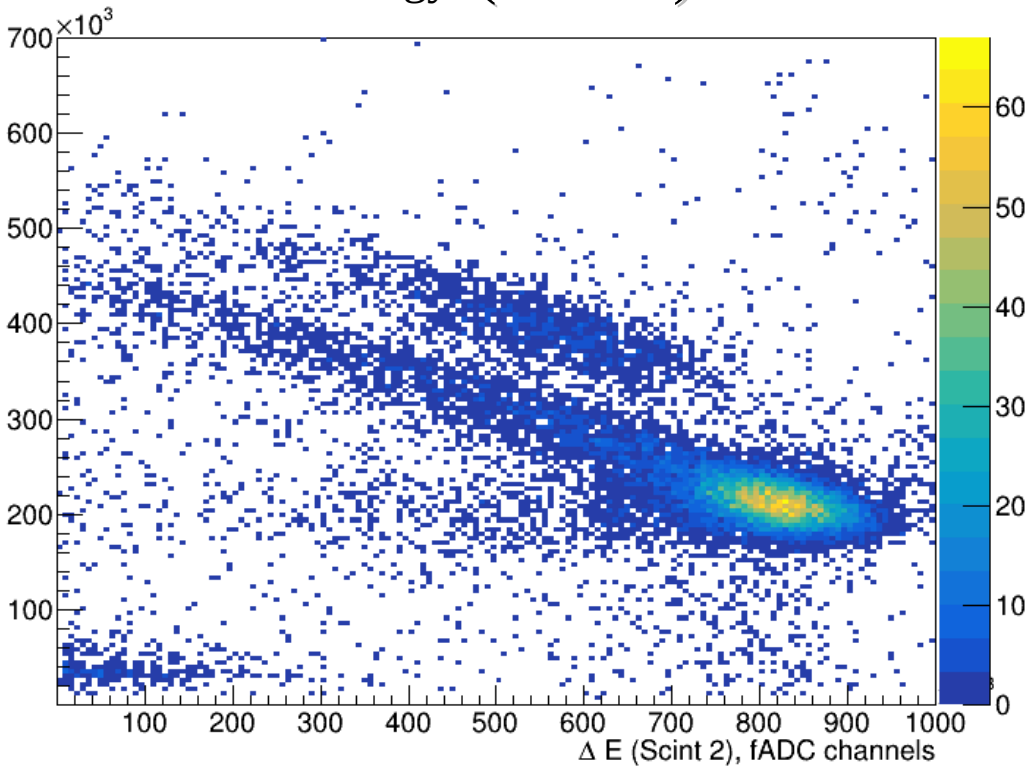
Neutron energy: (40 – 50) MeV



Polyethylene 2 mm

Coinc 1st-2nd Plastic

Neutron energy: (60 – 70) MeV

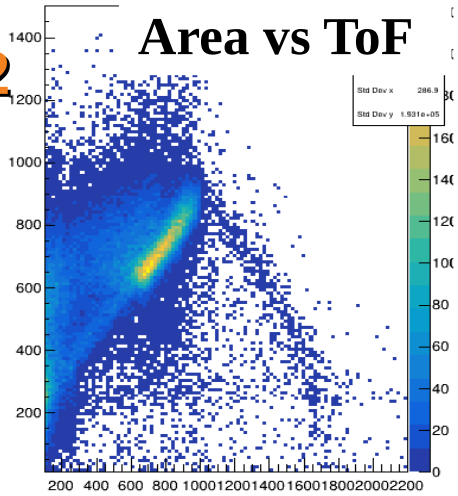


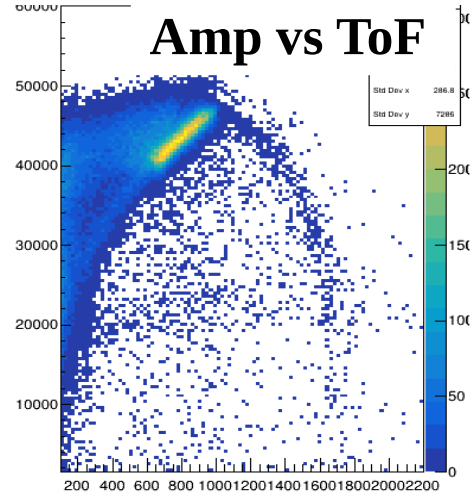
INFN CERN nTOF

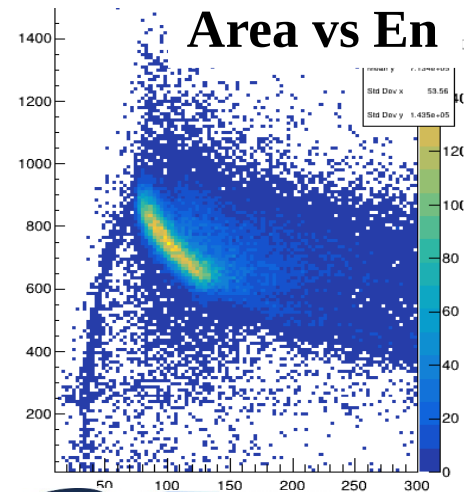
Coincidences 1st + 2nd + 3rd

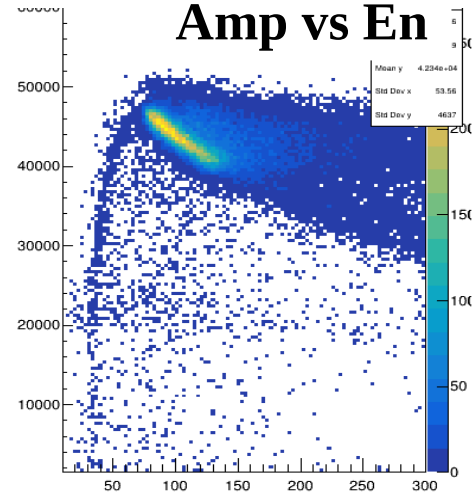
PRTO

Sci 2

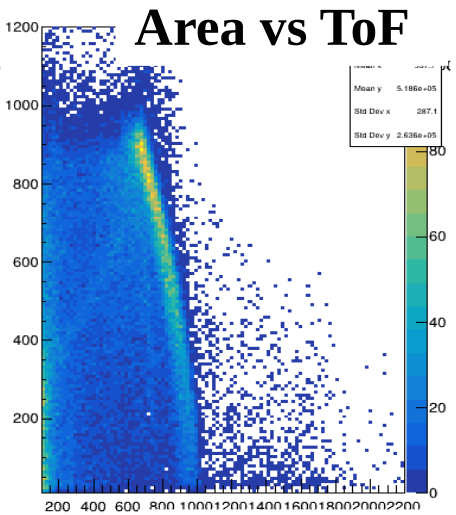


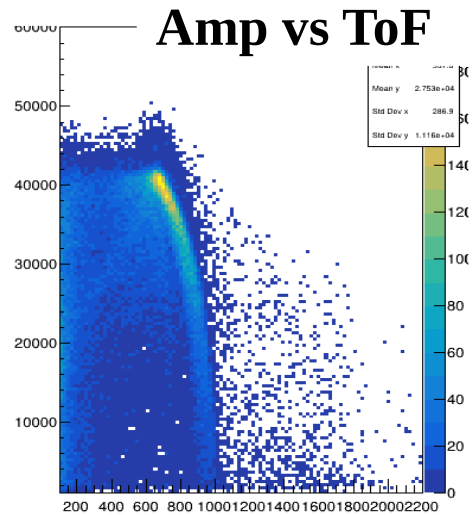


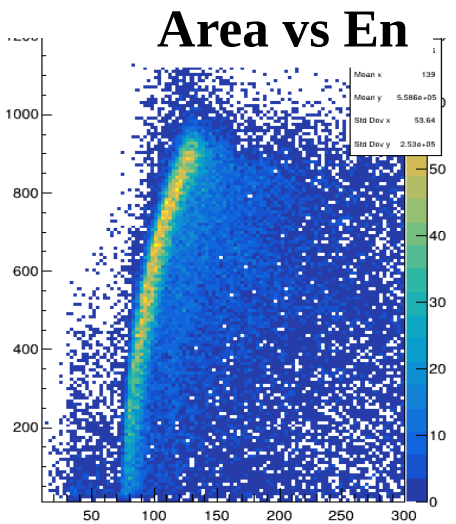


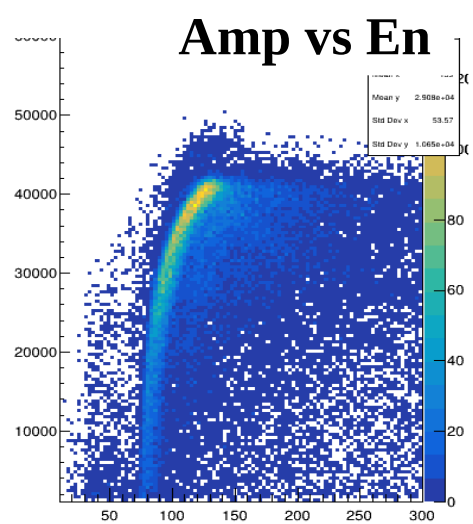


Sci 3





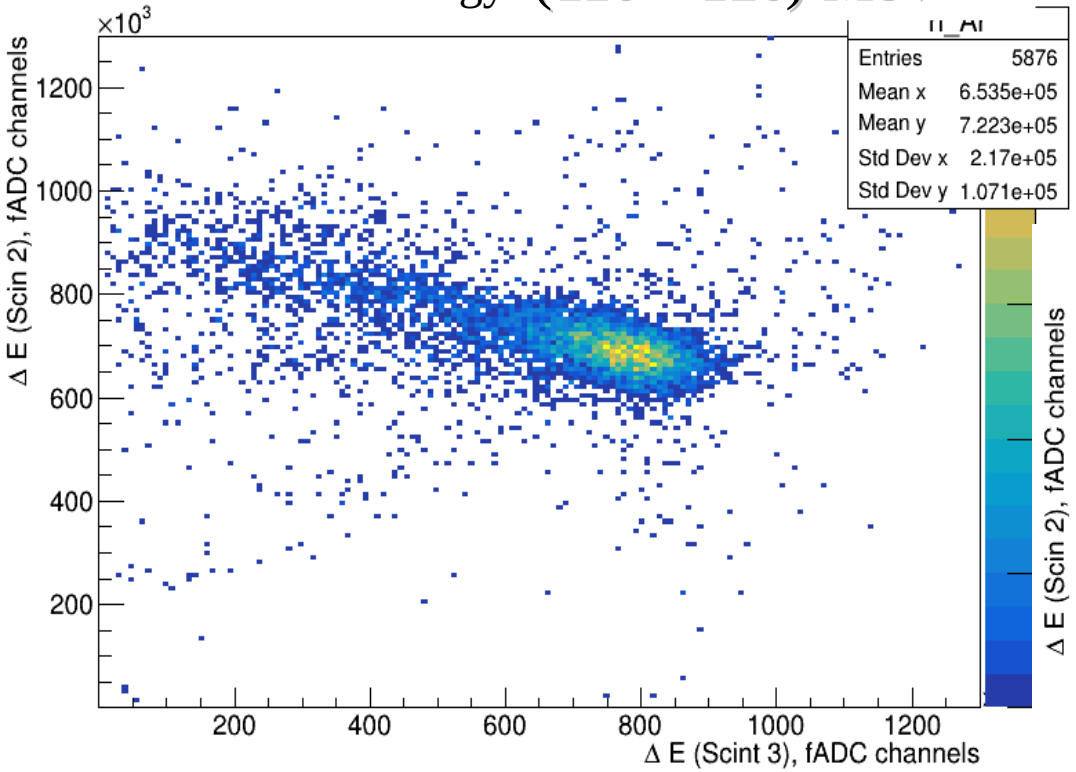




ΔE - E Matrix

PRTO

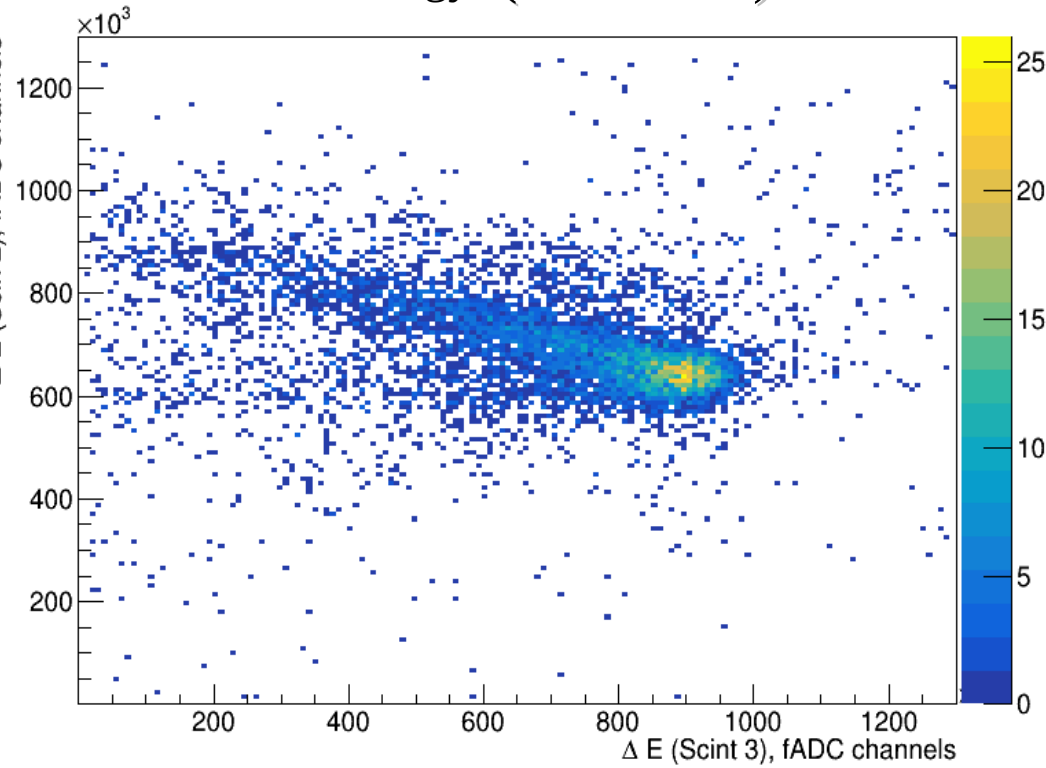
Neutron energy: (110 – 120) MeV



Polyethylene 2 mm

Coinc 2nd-3rd plastic

Neutron energy: (130 – 150) MeV

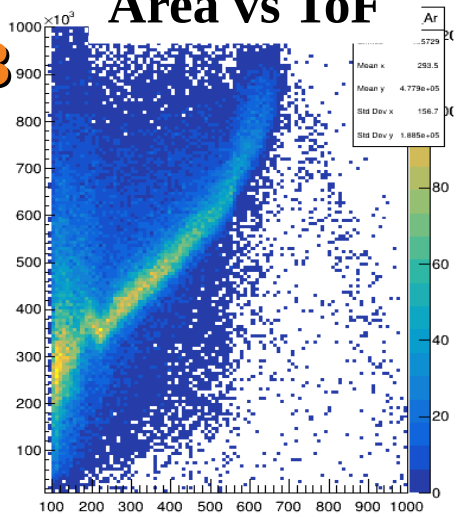


Coincidences 1st + 2nd + 3rd + 4th

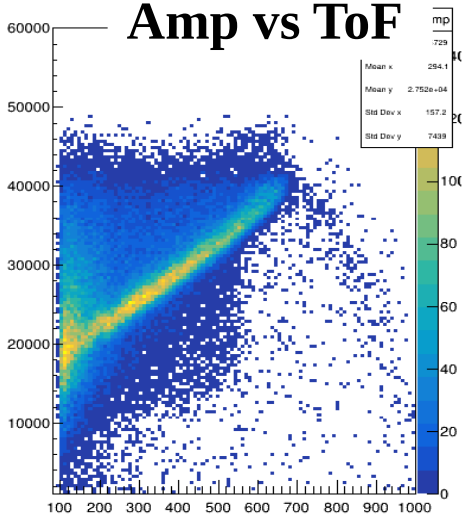
PRTO

Sci 3

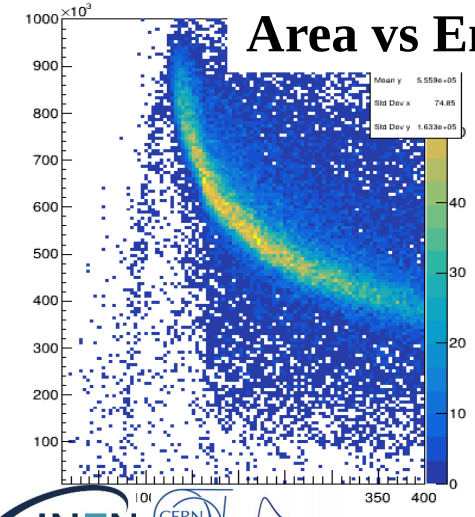
Area vs ToF



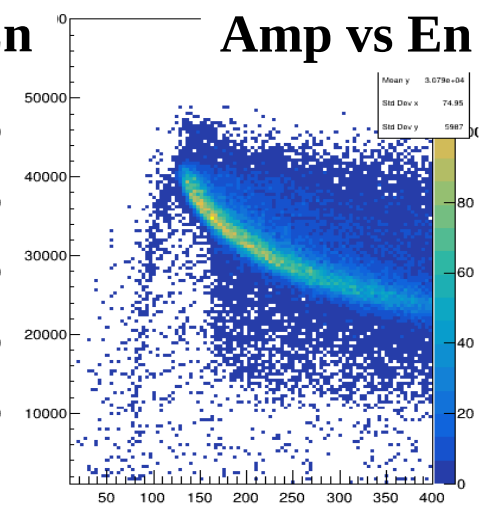
Amp vs ToF



Area vs En

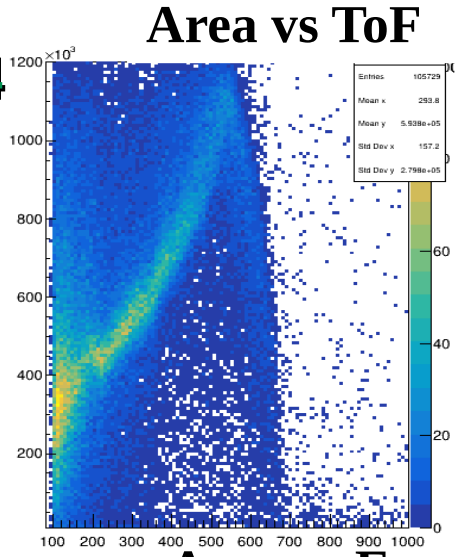


Amp vs En

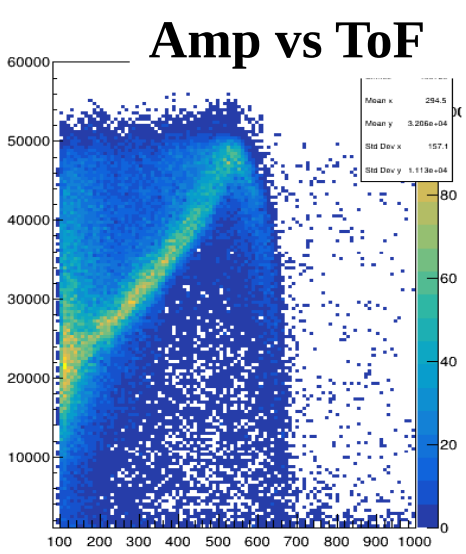


Sci 4

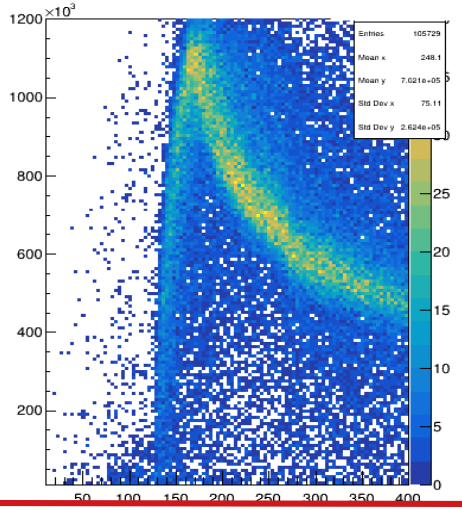
Area vs ToF



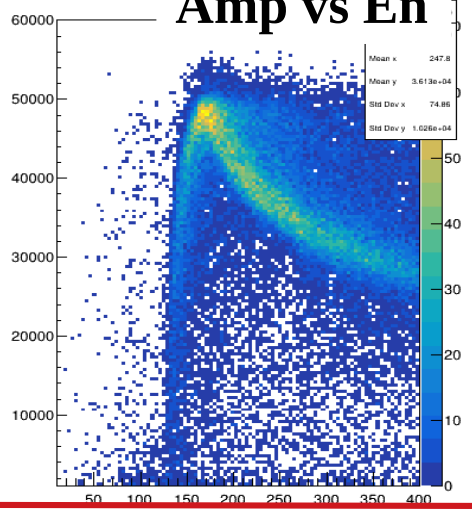
Amp vs ToF



Area vs En



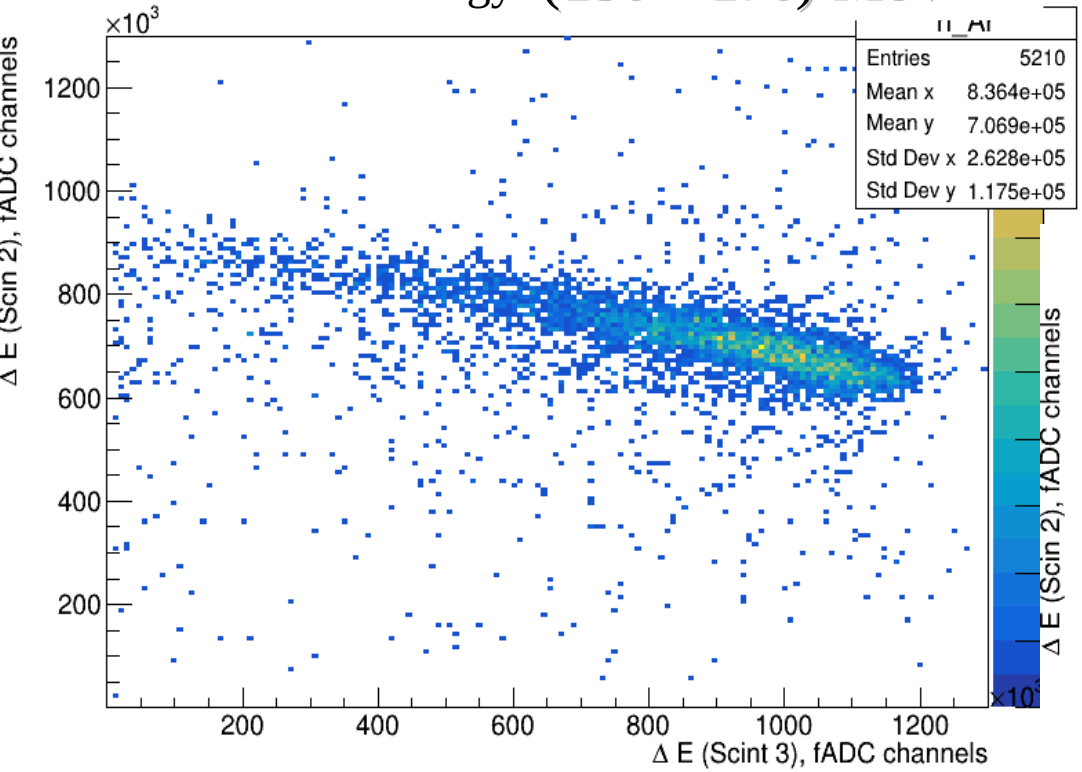
Amp vs En



ΔE - E Matrix

PRTO

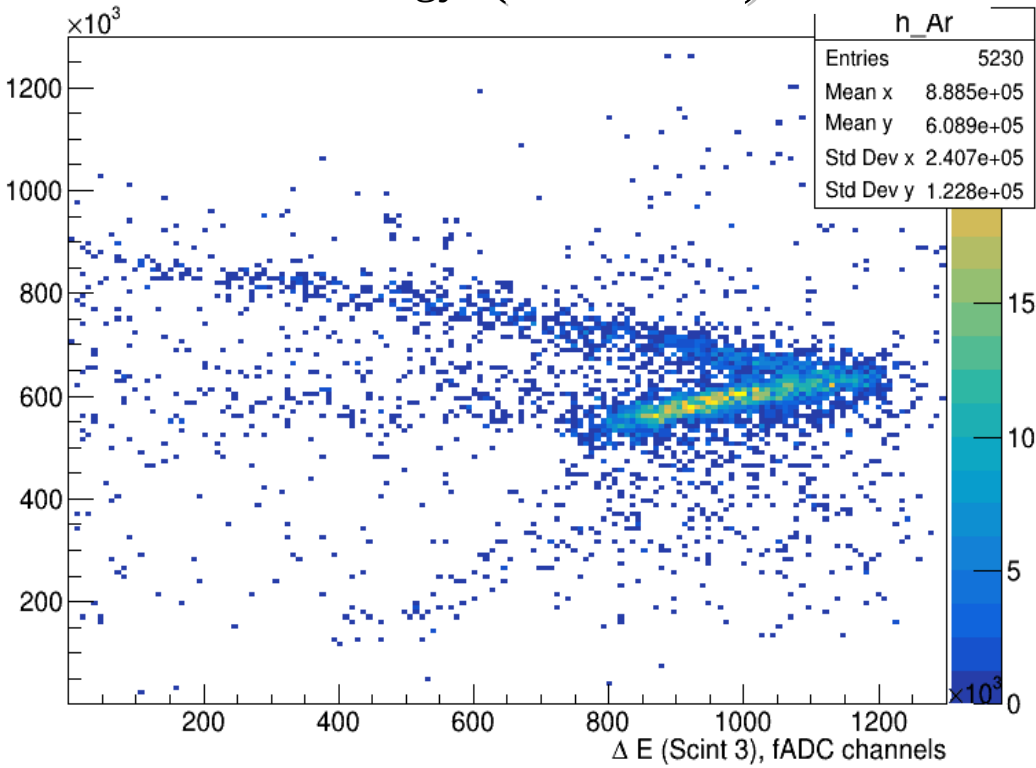
Neutron energy: (150 – 170) MeV



Polyethylene 2 mm

Coinc 3rd-4th plastic

Neutron energy: (180 – 200) MeV



Conclusions

The measurement campaign ended last week

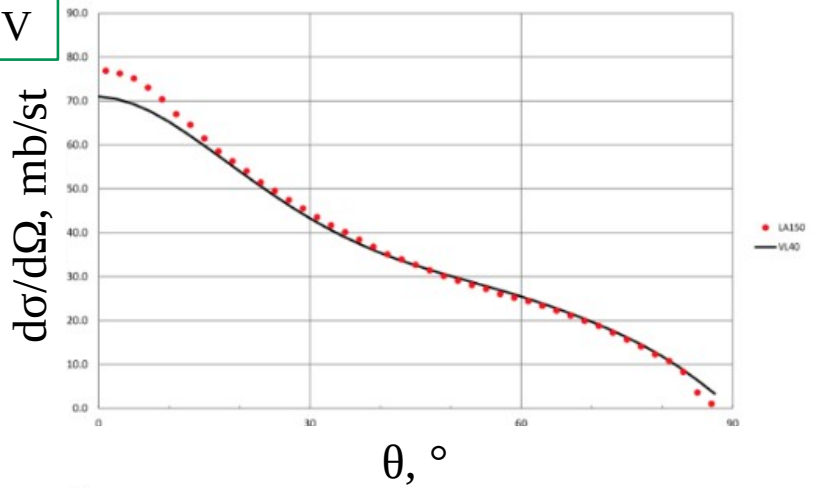
→ *First results indicate VERY NICE DATA from PRT detector!!*

Analysis ongoing

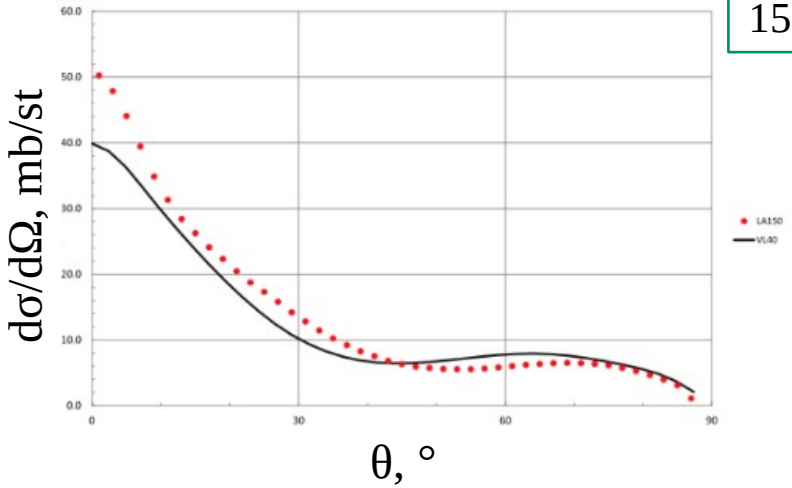
Calibration with protons at the PIF facility @ PSI

n-p scattering cross section

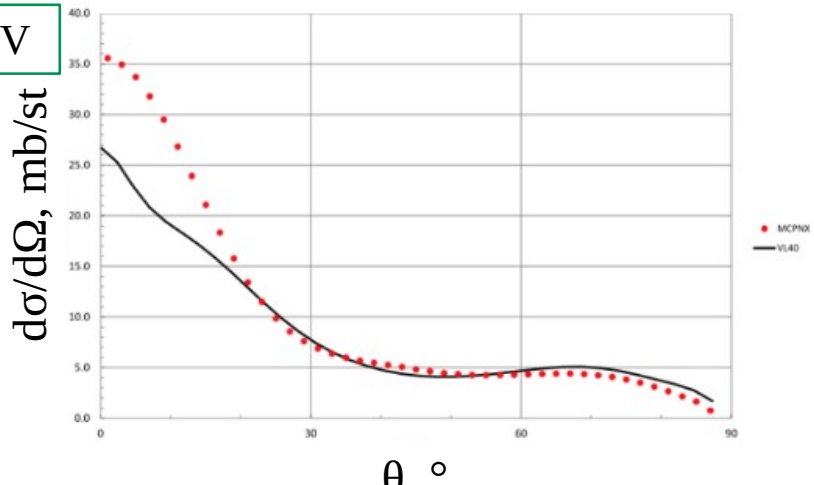
50 MeV



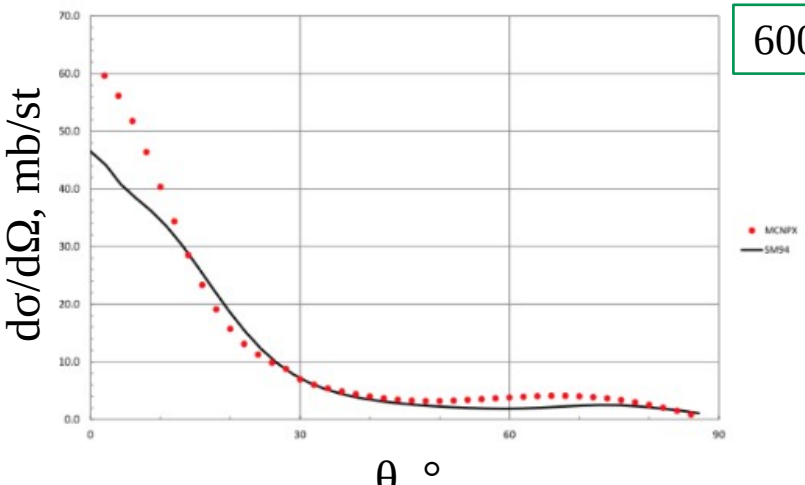
150 MeV



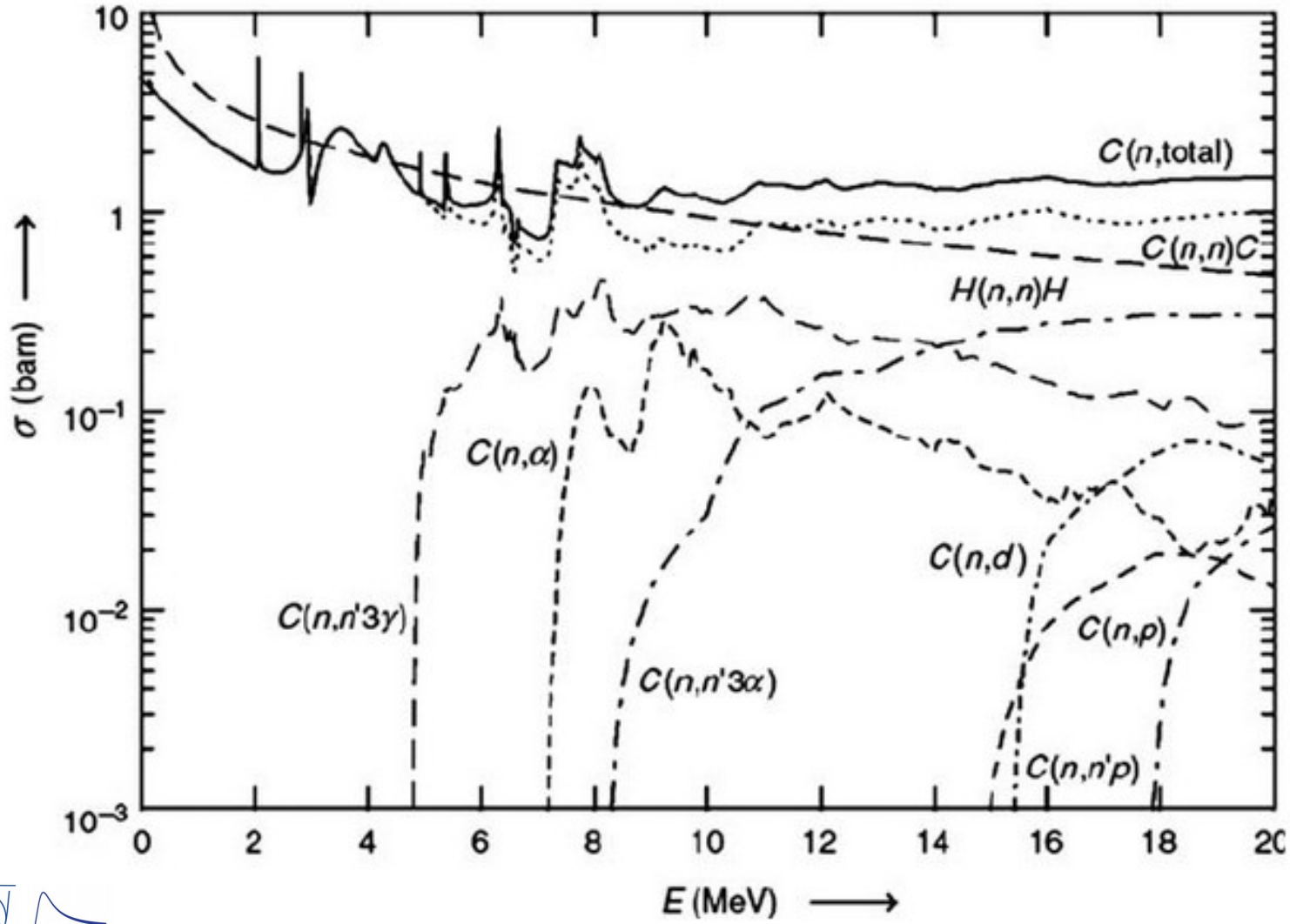
300 MeV



600 MeV



n-p scattering cross section



n-p scattering cross section