Gigi Cosentino

Proton Recoil Telescope *ver. 2017*

The role of the ^{235}U(n,f) reaction

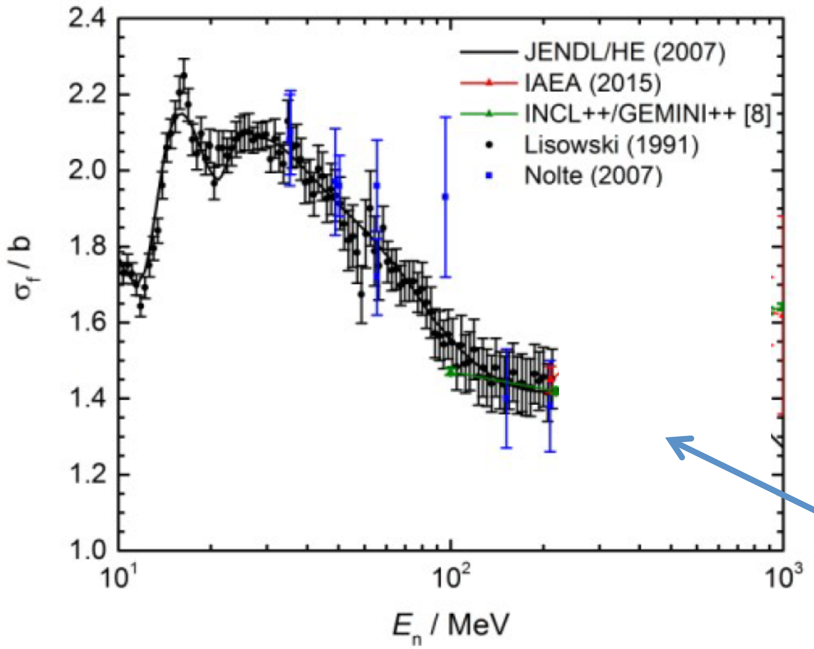
Neutron Cross Section Standards are essential for measurements and evaluations of other neutron cross sections

*The ^{235}**U(n,f)** cross section is one of the most important standard for neutron fluence measurements and for several applications, such as accelerator-driven nuclear systems, biological effectiveness of high-energy neutrons, etc..*

^{235}U(n,f) is a standard reaction at

- ***Thermal energy: 0.025 eV***
- ***Energy range: 0.15MeV ÷ 200MeV.***

Status of the $^{235}U(n,f)$ cross section



Two sets of experimental data in the range 20 MeV – 200 MeV

No experimental data above 200MeV. Only theoretical models

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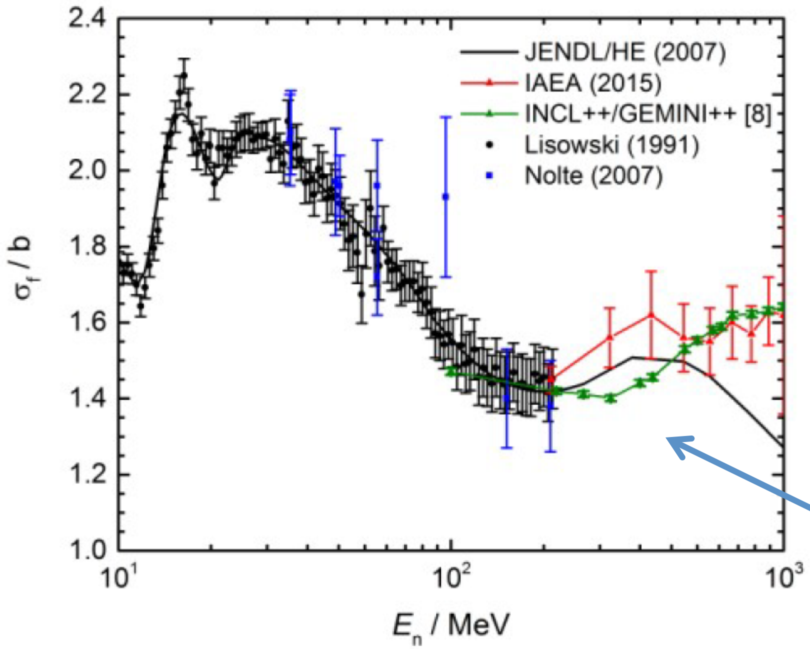

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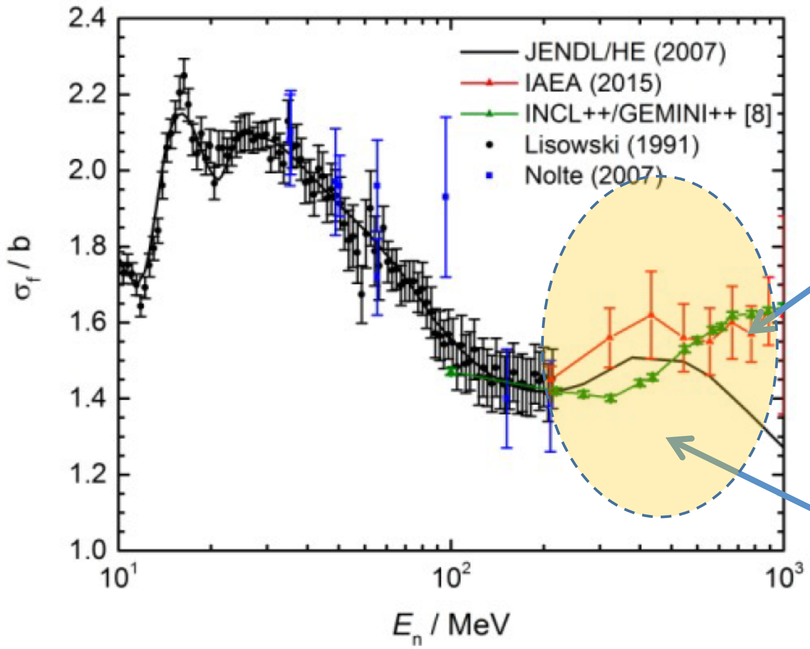

The theoretical cross section above 200MeV may be substantially different, depending on the model used for the calculations.

No experimental data above 200MeV. Only theoretical models

Two sets of experimental data in the range 20 MeV – 200 MeV

The International Atomic Energy Agency (IAEA) strongly requests new data for the $^{235}U(n,f)$ cross section up to 1GeV, in order to improve the uncertainty within 5%.

New measurements above 20 MeV are needed!

The Technique: Two measurements to be made simultaneously with a suitable neutrons beam.

- **^{235}U(n,f) reaction vs neutron energy**
- **H(n,n)H reaction vs neutron energy**

The experimental approach to measure the ^{235}U(n,f) cross section

The Technique: Two measurements at the same time with a neutron beam.

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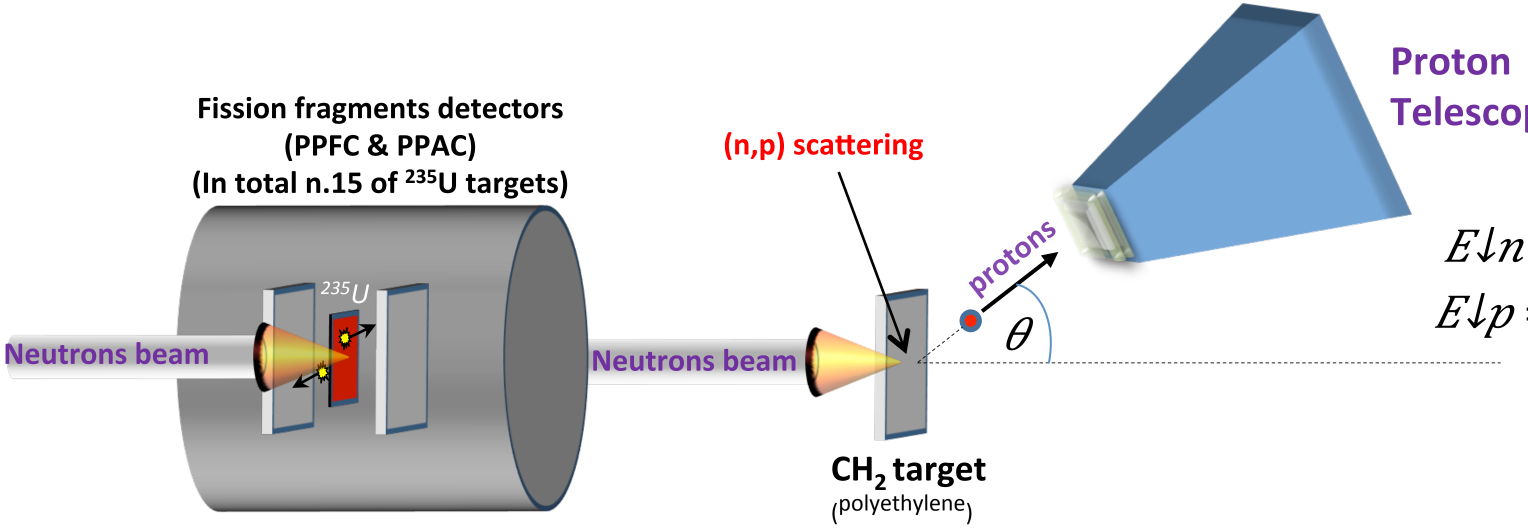

$E_n < 1\,\text{GeV}$

$E_p = E_n \cdot \cos^2\theta$

The experimental approach to measure the ^{235}U(n,f) cross section

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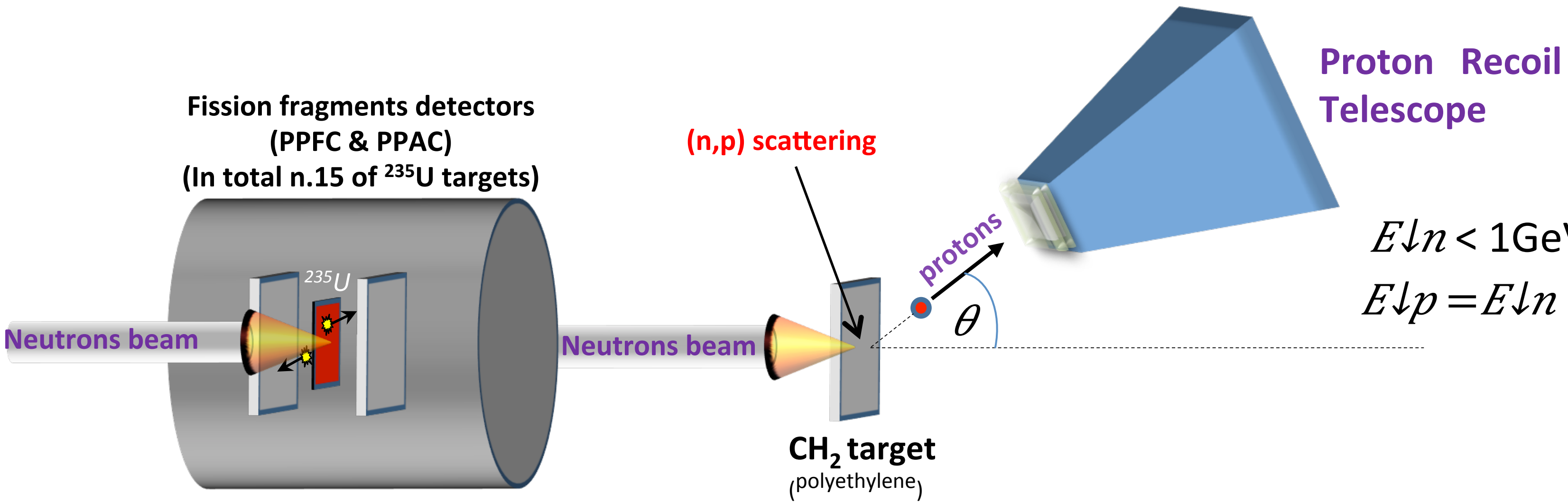

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- **The (n,p) scattering is used as a reference reaction for the ^{235}U(n,f) cross section**
- **The Proton Recoil Telescope (PRT) detects the recoil protons emitted by the target, to measure the neutron flux vs. neutron energy**

The experimental approach to measure the ^{235}U(n,f) cross section

The Technique: Two measurements at the same time with a neutron beam.

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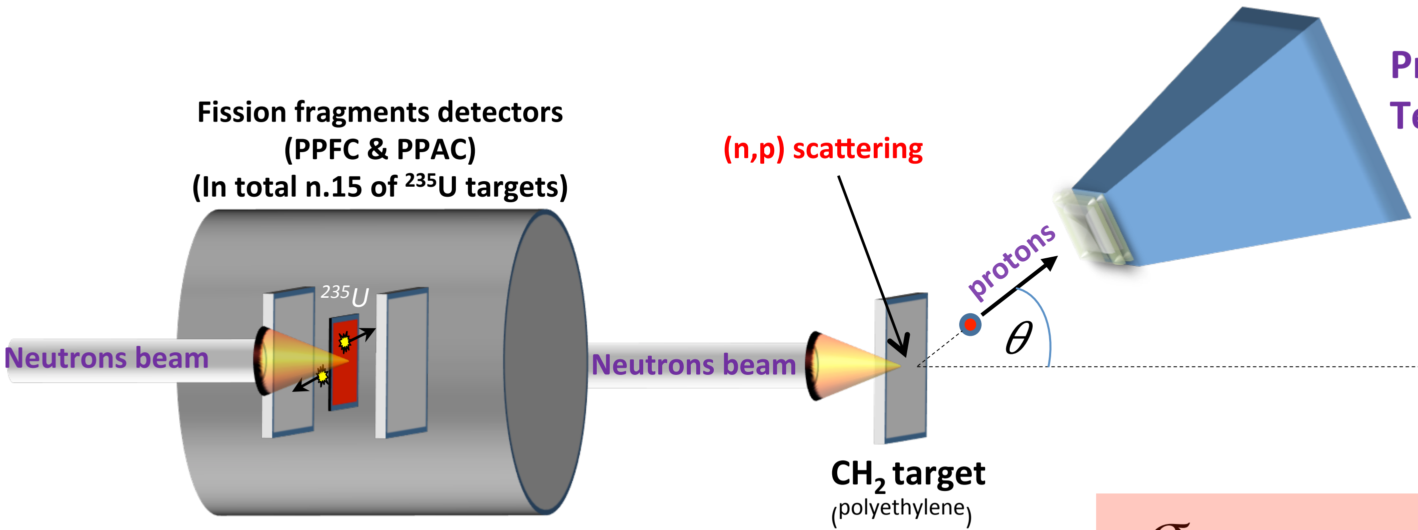

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$E_p = E_n \cdot \cos^2\theta$

$$\frac{\sigma_{^{235}\mathrm{U(n,f)}}}{(\mathrm{d}\sigma_{\mathrm{np}}/\mathrm{d}\Omega)} = \frac{n_{\mathrm{H}}\varepsilon_{\mathrm{p}}\Omega_{\mathrm{geo}}N_{\mathrm{FF}}}{n_{\mathrm{U}}\varepsilon_{\mathrm{FF}}N_{\mathrm{p}}}$$

N: detected events
n: sample areal density
Ω: PRT solid angle
ε: efficiency
σ: cross section

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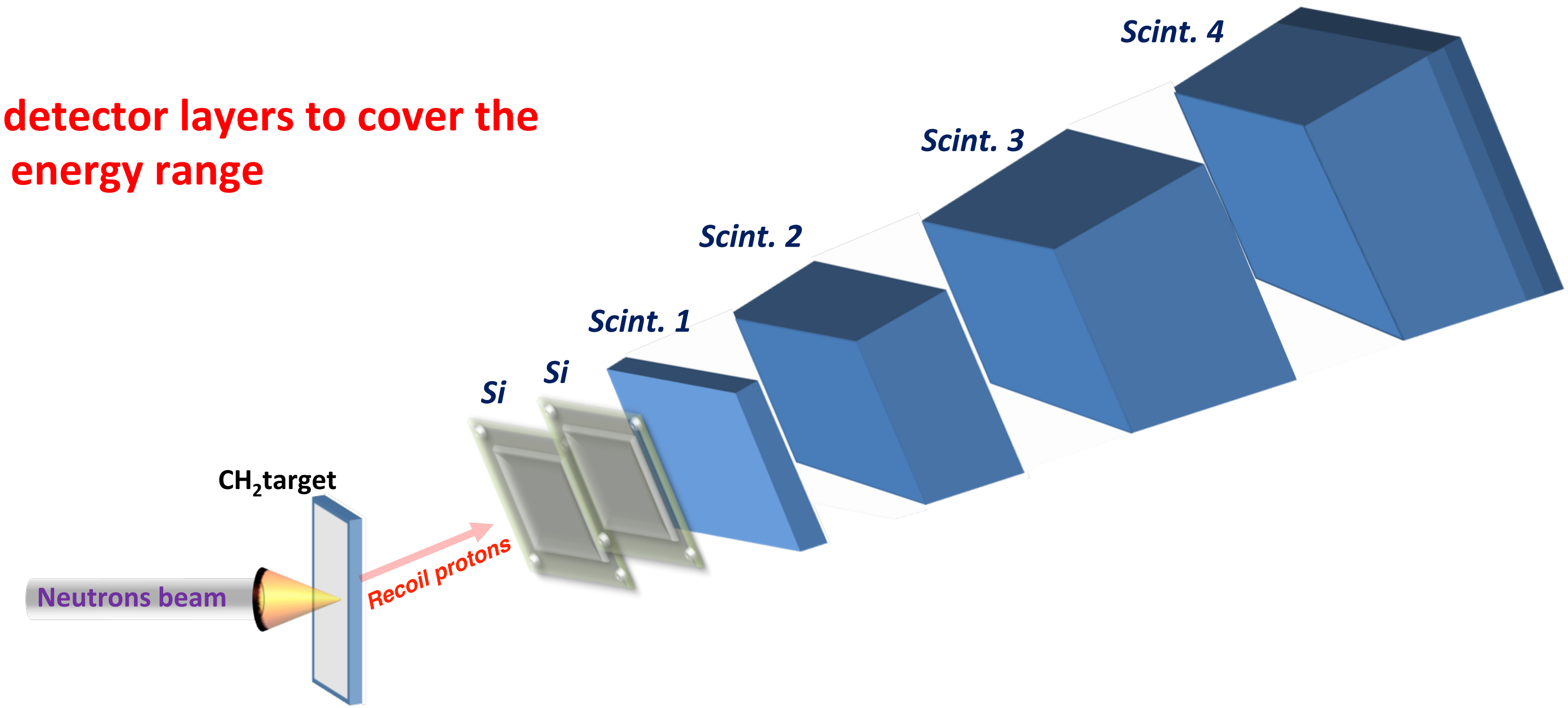
The multilayer Proton Recoil Telescope

Six detector layers to cover the full energy range



- **2 Silicon detectors 300 um thick**
- **4 plastic scintillators BC408 (τ = 2.1 ns) 0.5cm, 3cm, 6cm, 6cm**
- **Fast PMT (Hamamatsu R1924A)**
- **CH_2 target (*polyethylene*): 2mm – 10mm**

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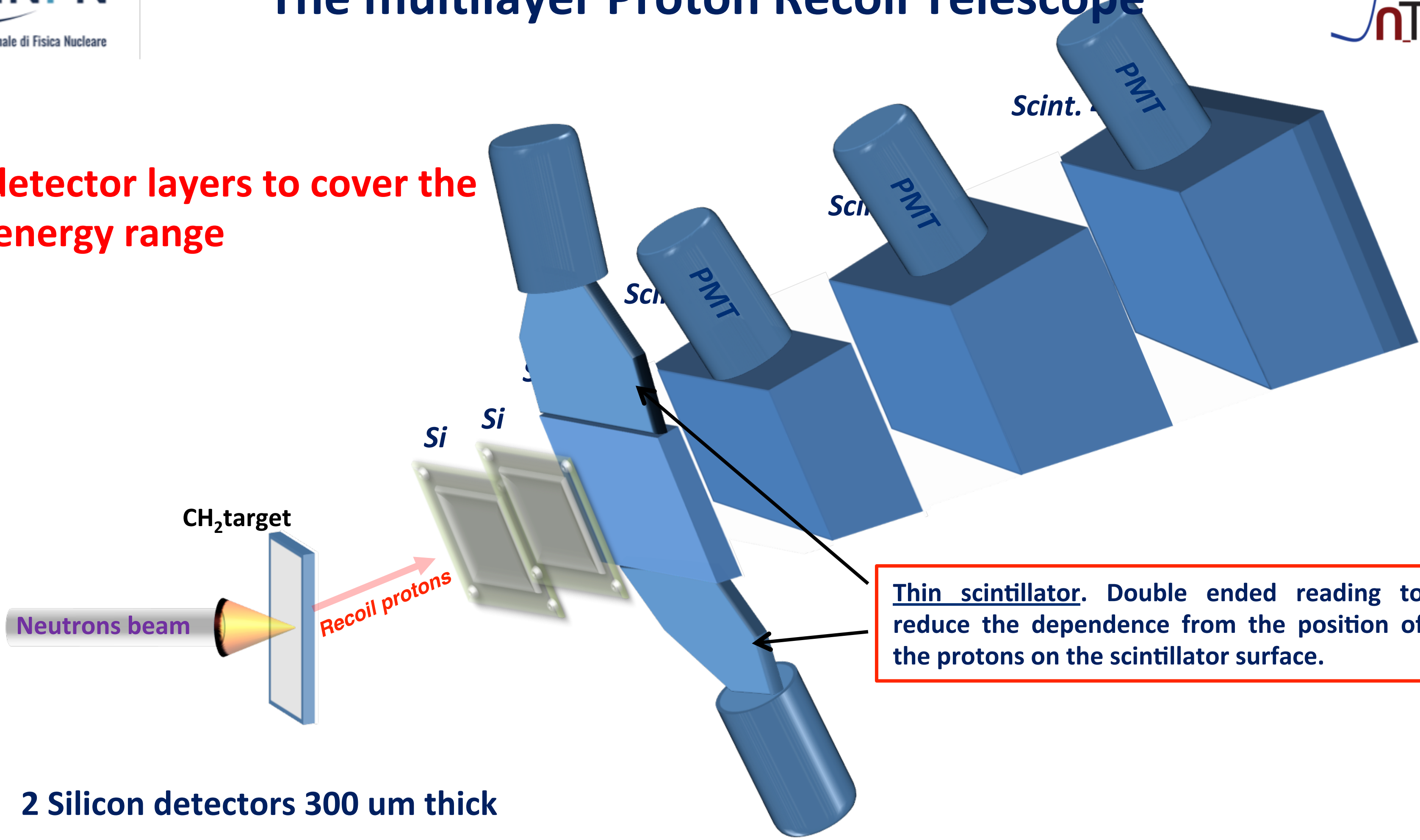

Thin scintillator. Double ended reading to reduce the dependence from the position of the protons on the scintillator surface.

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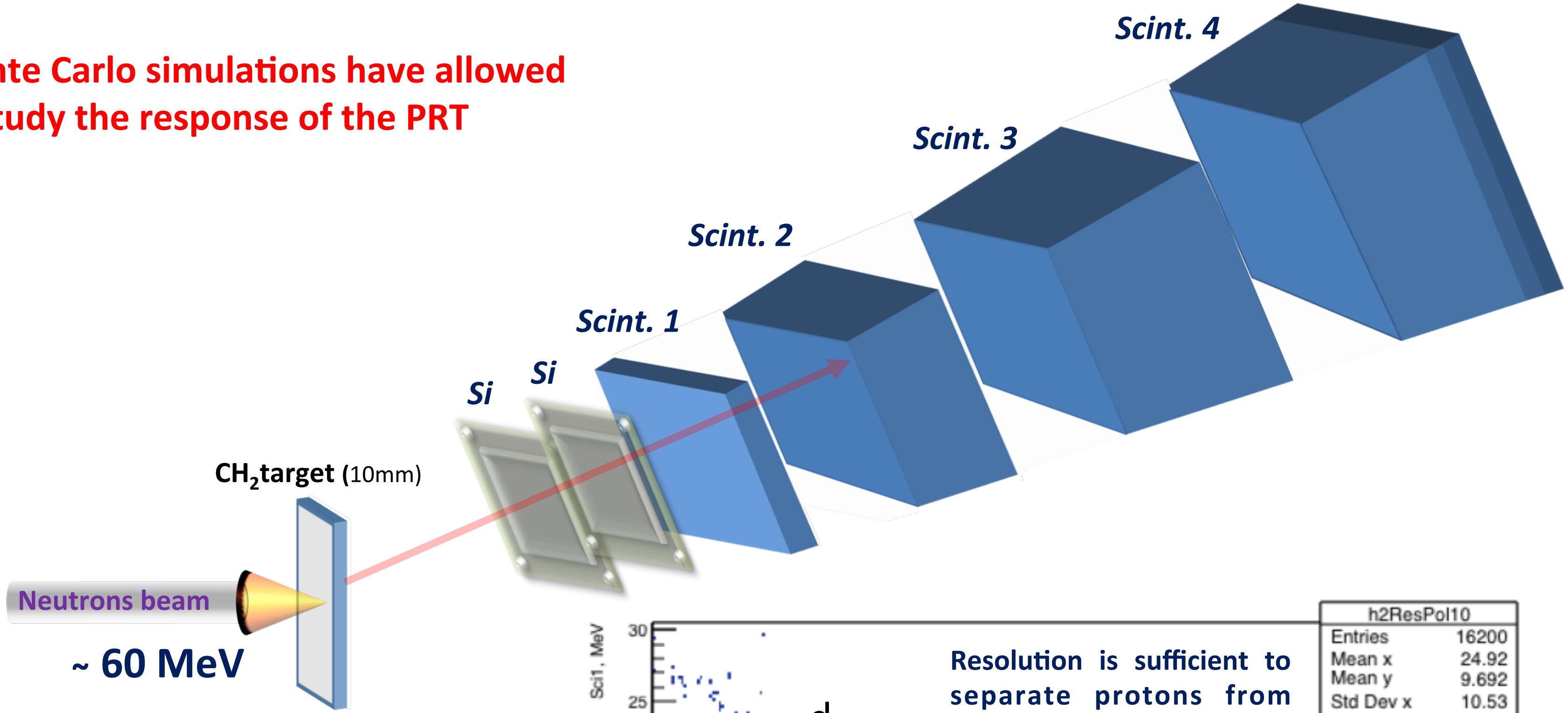
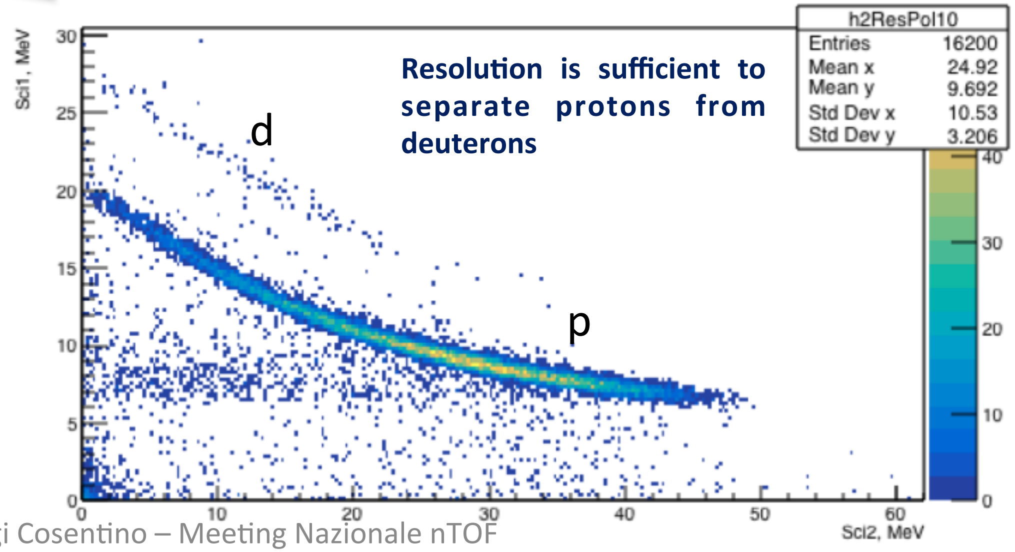
Monte Carlo simulations

Monte Carlo simulations have allowed to study the response of the PRT





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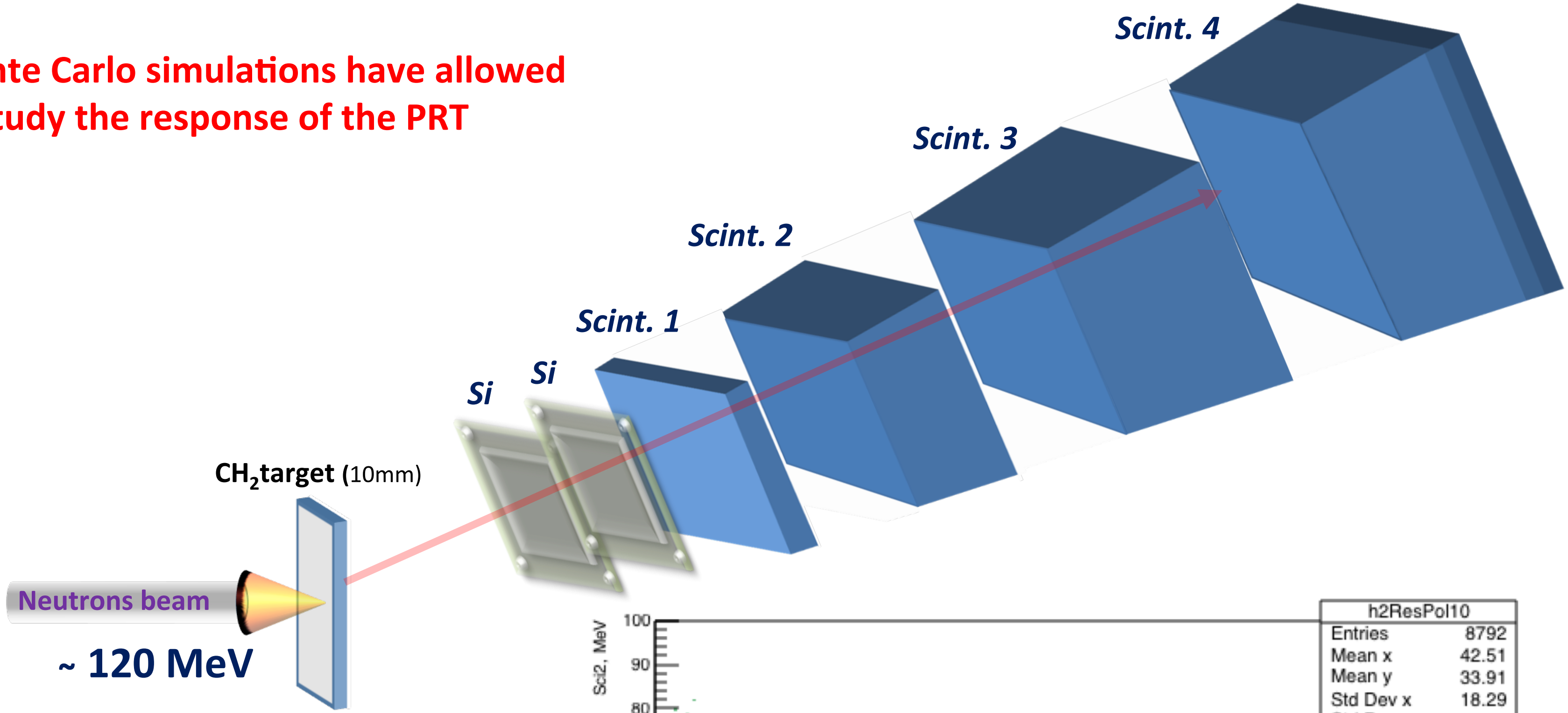

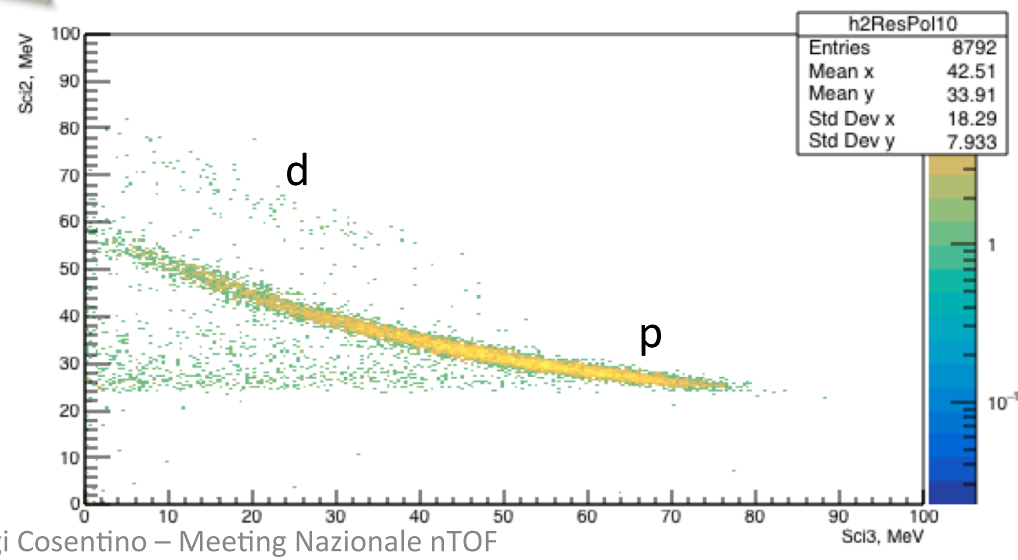

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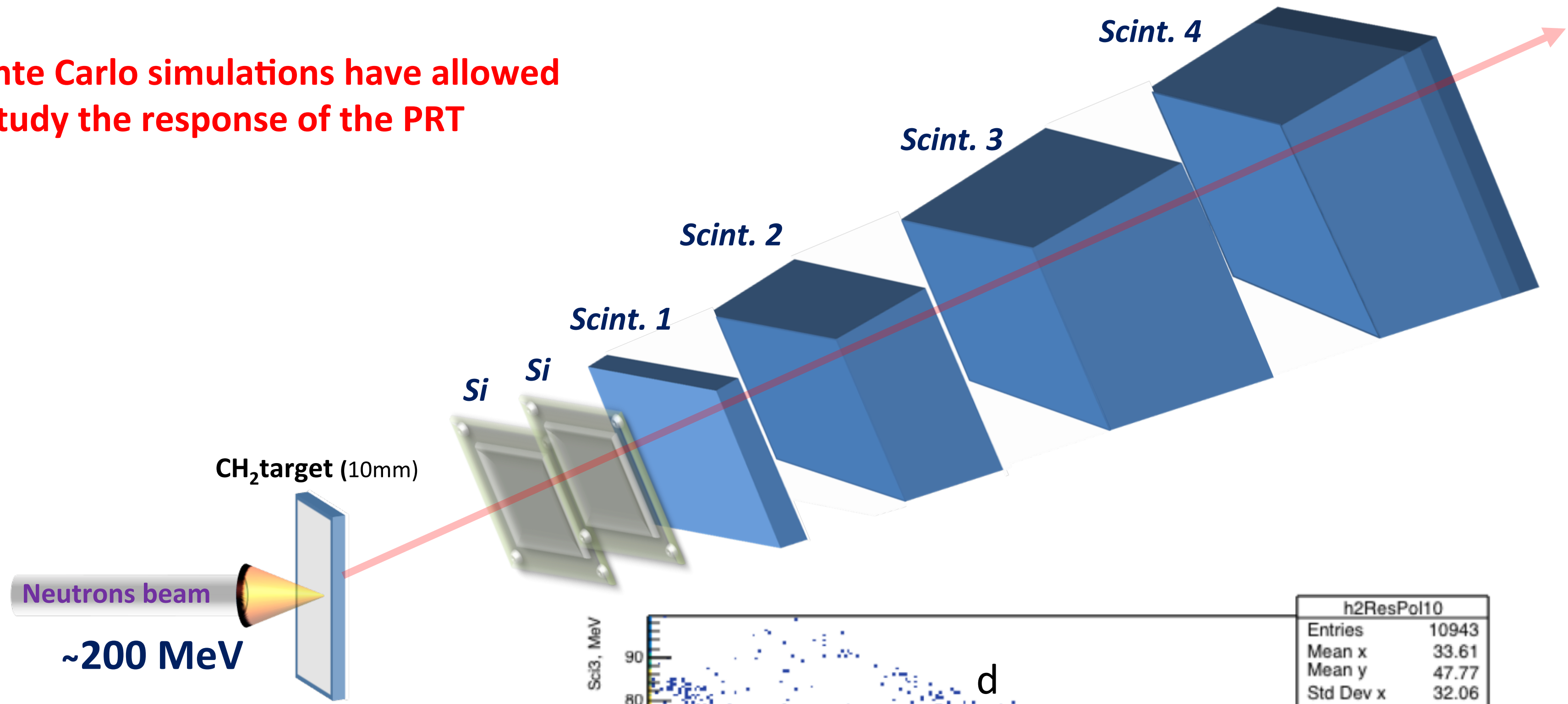
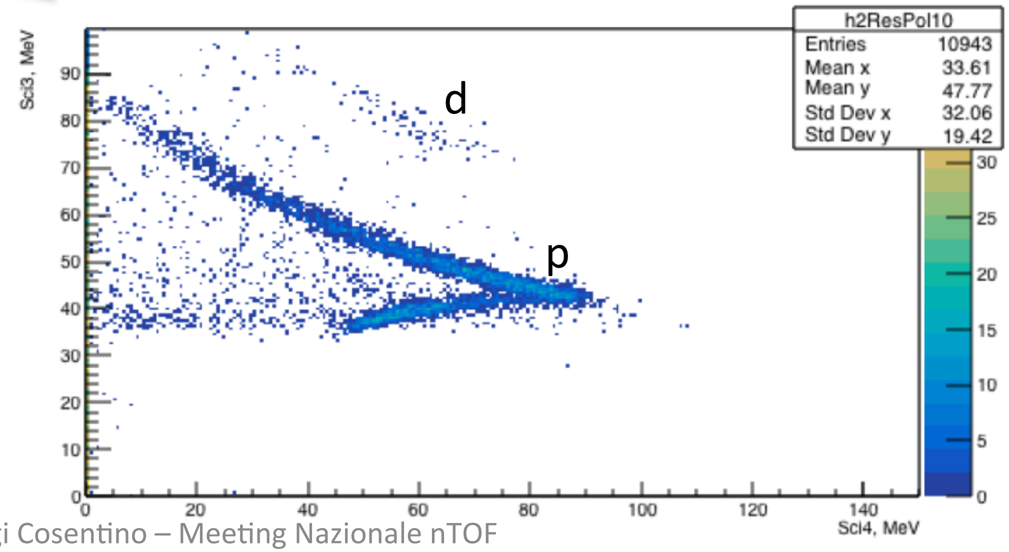
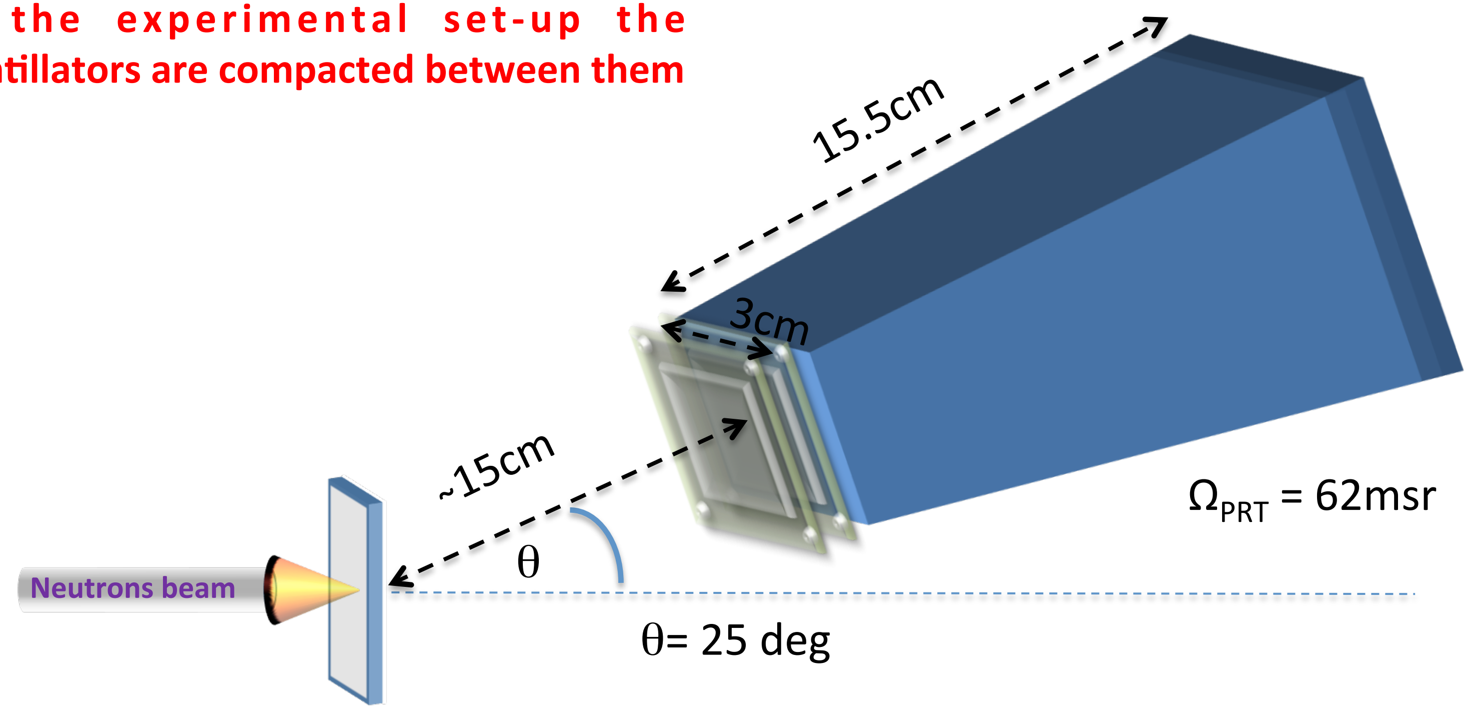




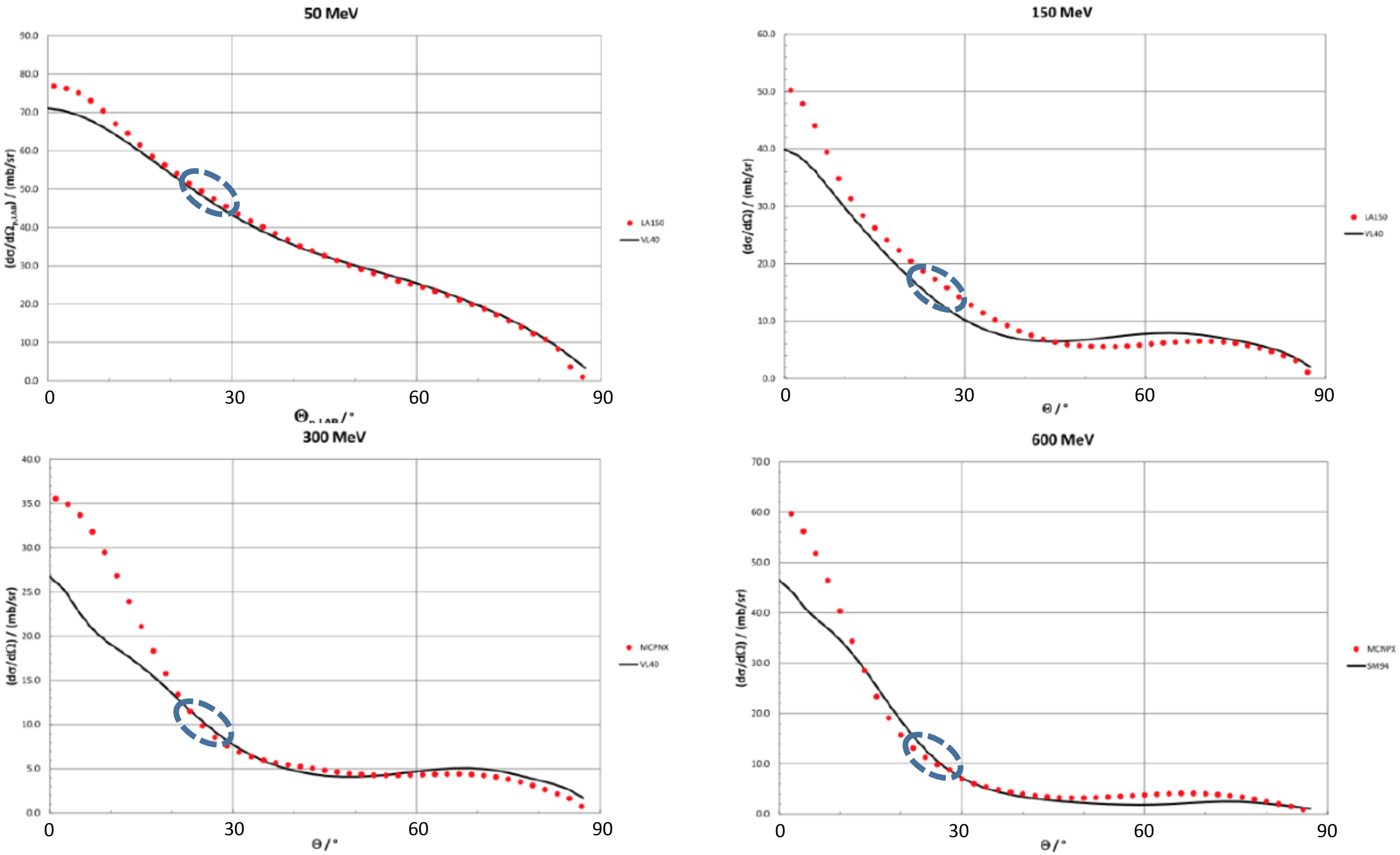
How to place the PRT

In the experimental set-up the scintillators are compacted between them



The aim is to reach a statistical uncertainty around 2% within neutron energy regions of 5% relative width.

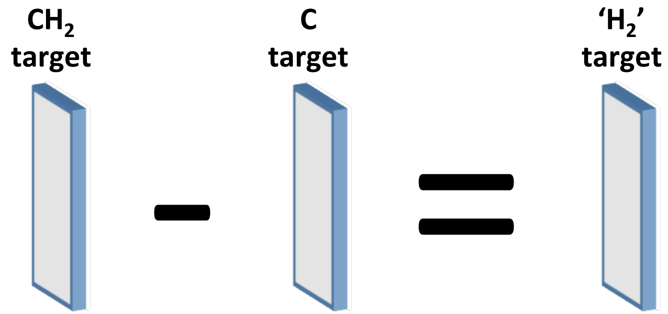
(n,p) cross section vs. angle of recoil protons

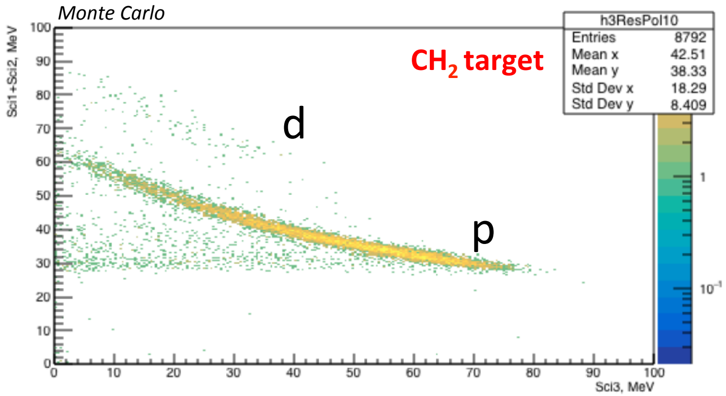


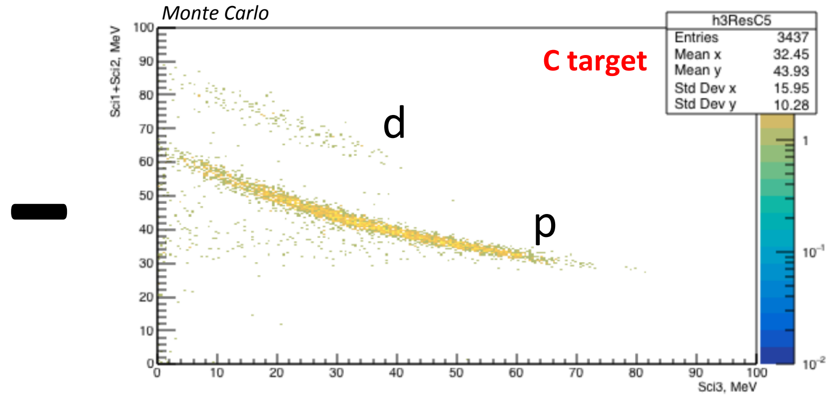
20 – 30 deg

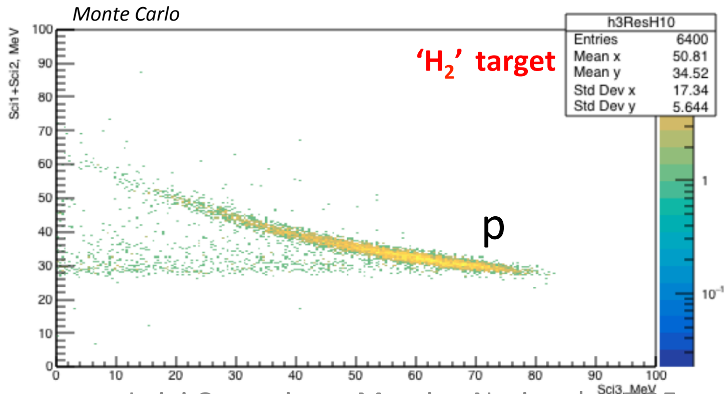
Select only the events due to hydrogen atoms in the CH_2 target

Measurements with graphite targets to subtract the contribution of the Carbon in the CH_2 (polyethylene) target

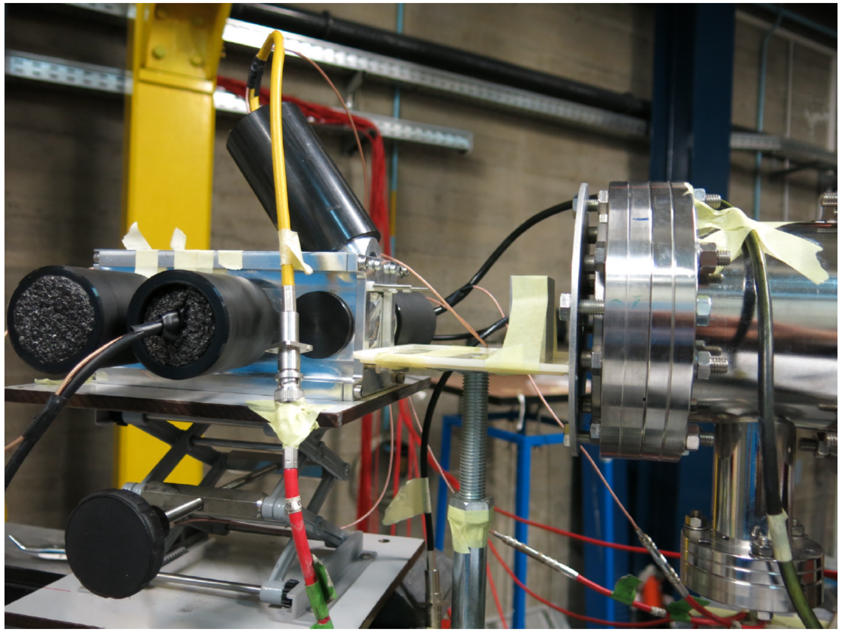


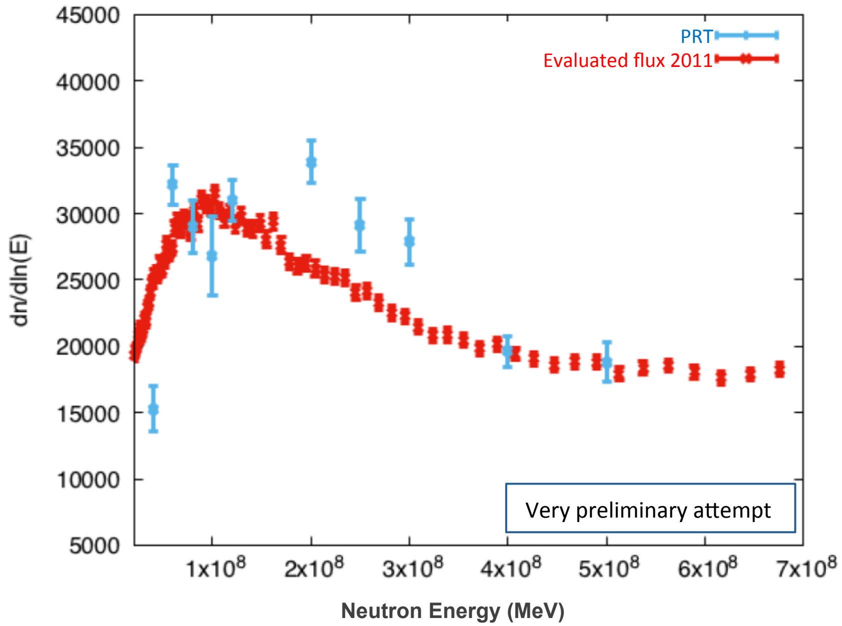






Neutron Flux in EAR1.
A first attempt of reconstruction with the first PRT prototype (2016)





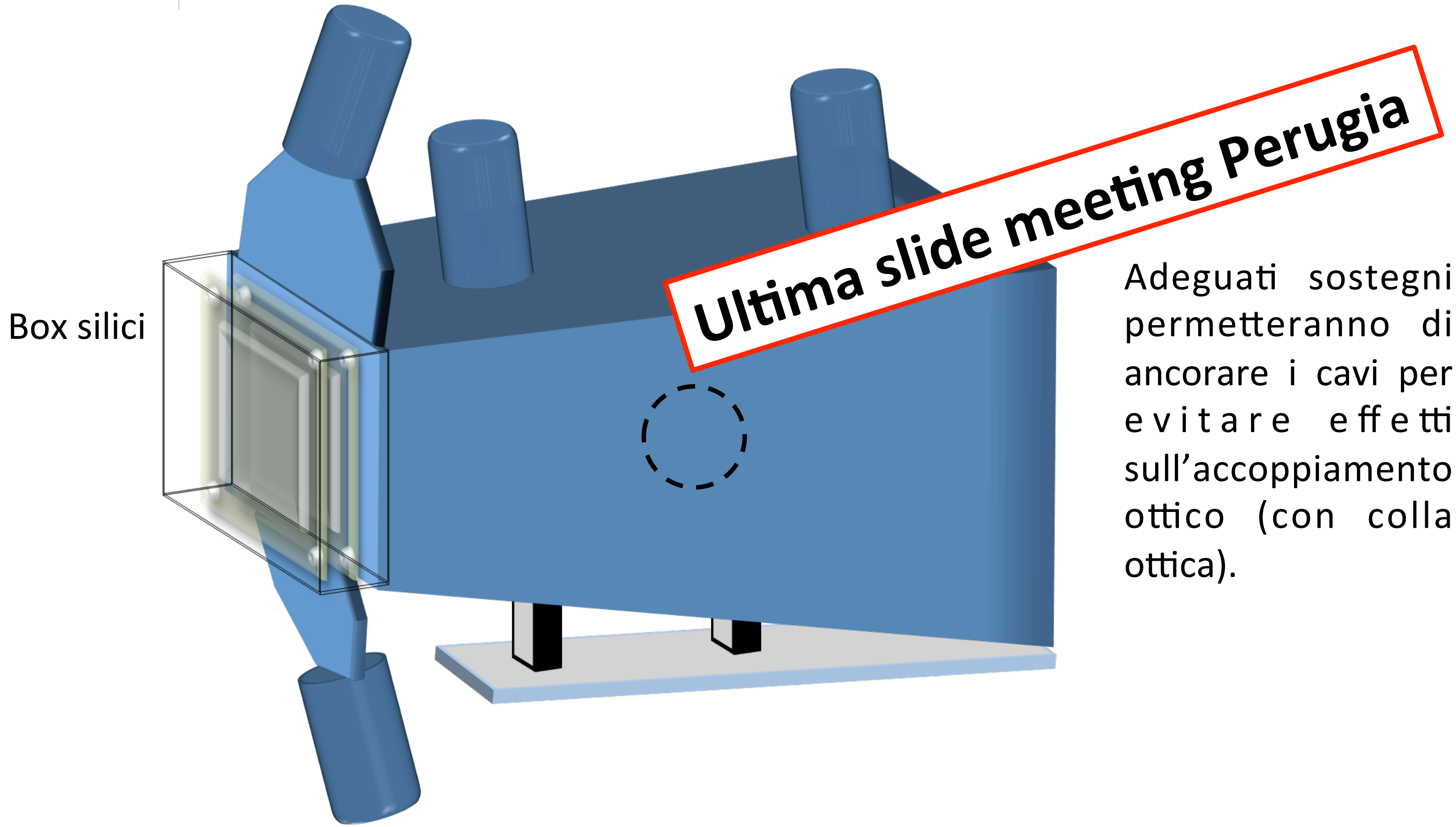
Alignment of the PRT to the neutron beam was not perfect

The amount of material in the PRT mechanics must be reduced, in order to cut down the background events

$$\varphi_n = C / n\Omega\varepsilon\sigma$$

C: counts
n: sample areal density
Ω: solid angle
ε: efficiency
σ: (n,p) cross section

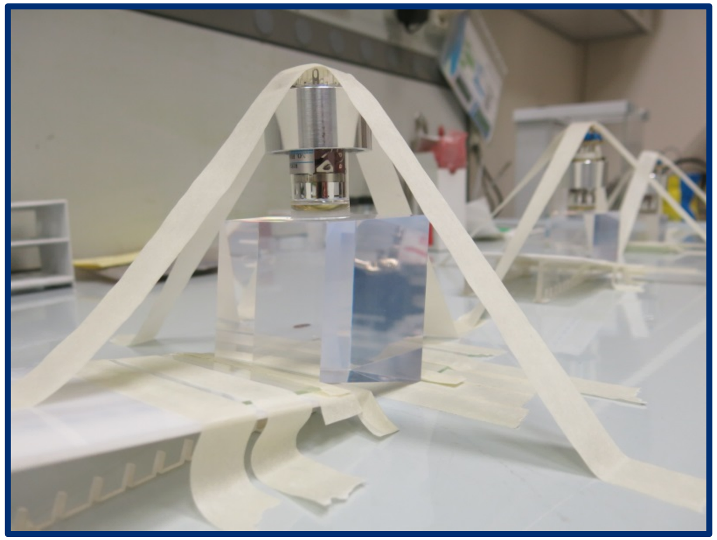
Configurazione proposta per il 2017



Adeguati sostegni permetteranno di ancorare i cavi per evitare effetti sull'accoppiamento ottico (con colla ottica).

- L'oscuramento sarà ulteriormente garantito da un telo nero.
- Assemblare i silici un una box elettricamente schermata (alluminio e mylar alluminizzato nelle finestre).
- Il preamplificatore 'Bassini' garantisce una risposta in tempo adeguata, meno di 2usec dal g-flash.
- Calibrazione preliminare ai LNS (se possibile..)?

Assemblaggio PRT_2017



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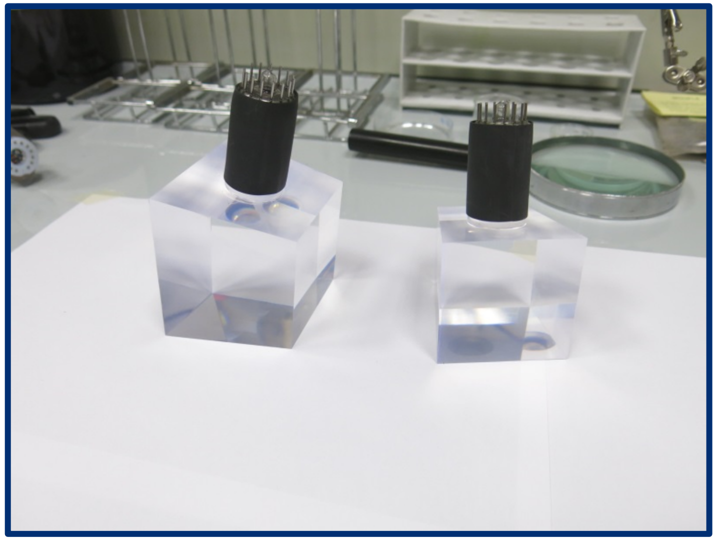

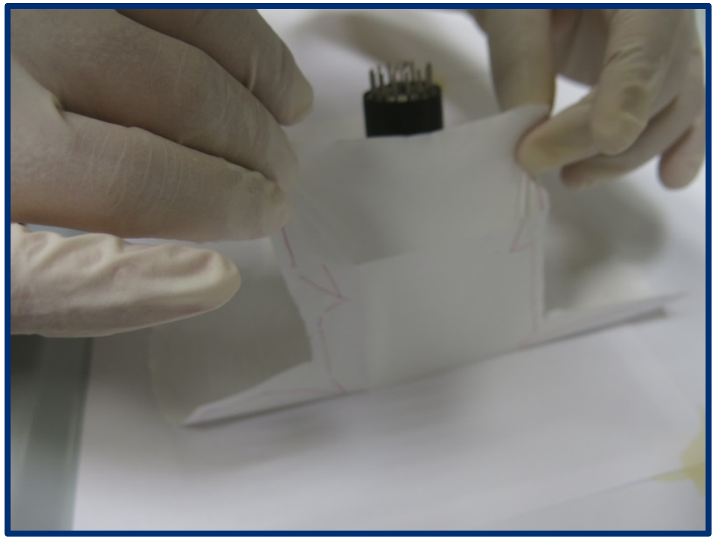

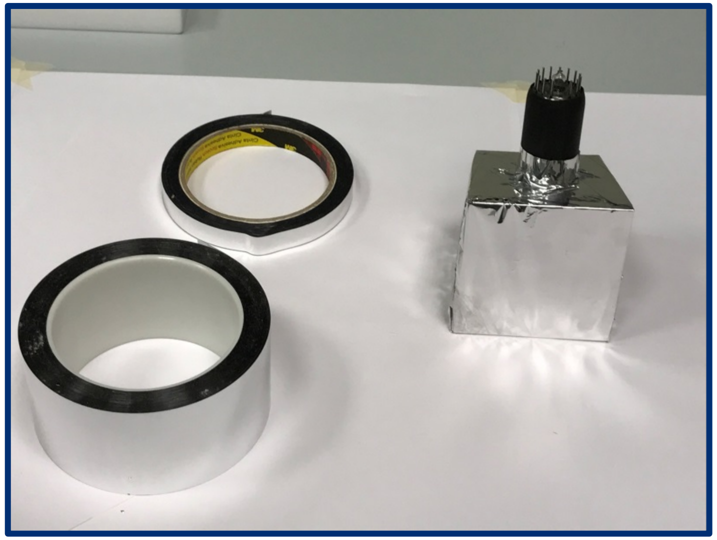

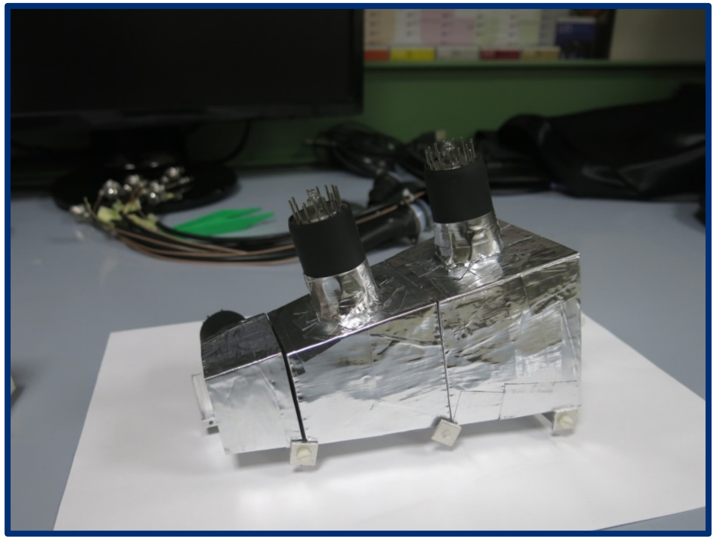

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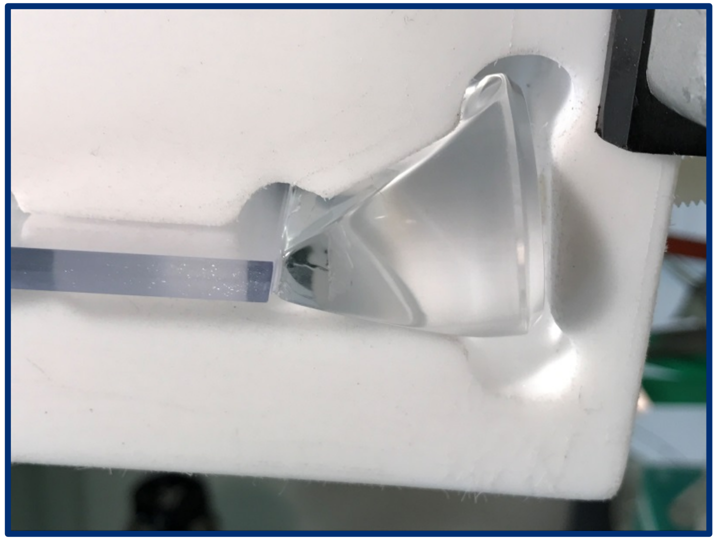
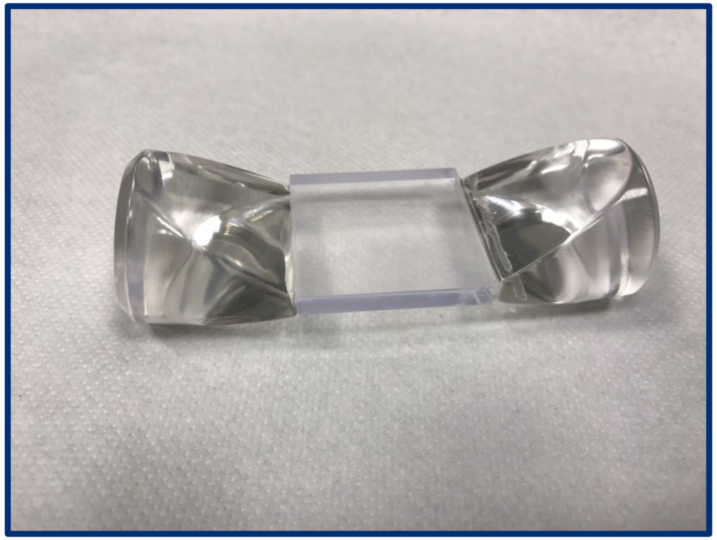
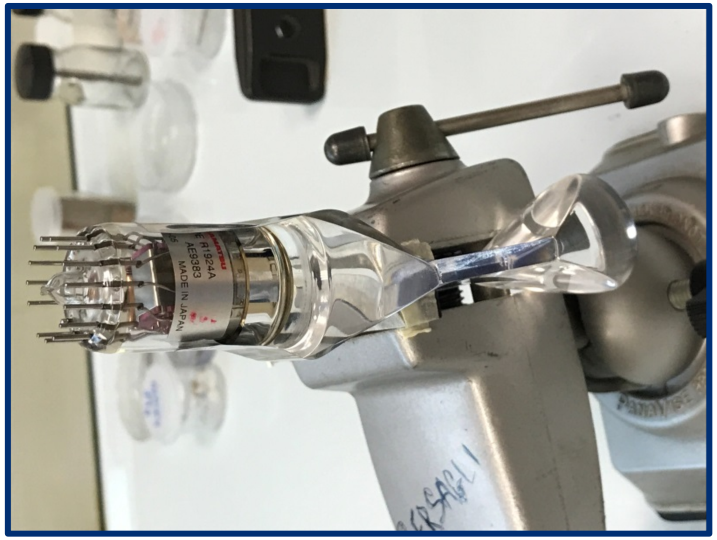


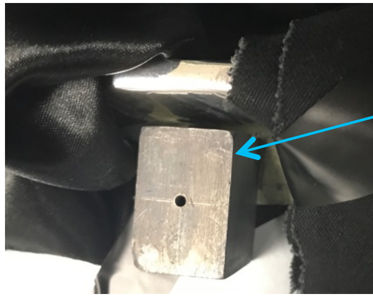




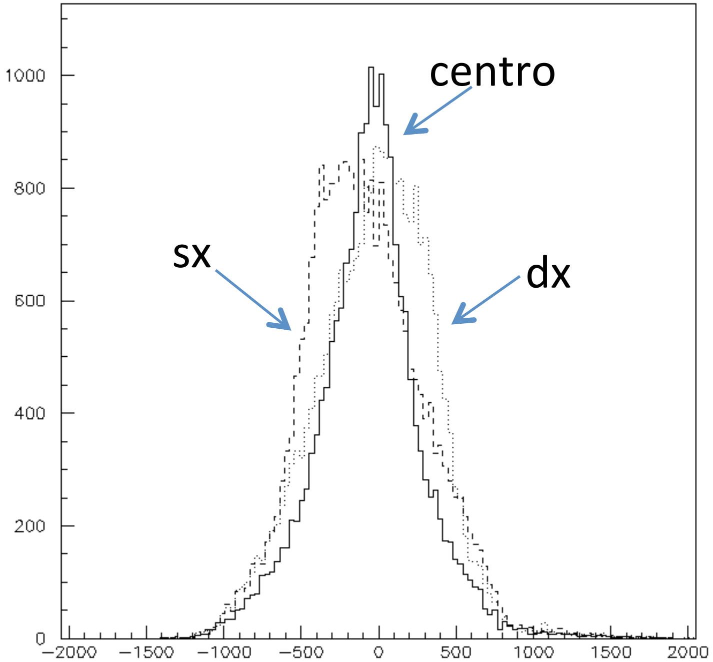
Assemblaggio PRT_2017

Test su banco per valutare la dipendenza dalla posizione con lo scintillatore sottile

Sorgente collimata di ^{137}Cs

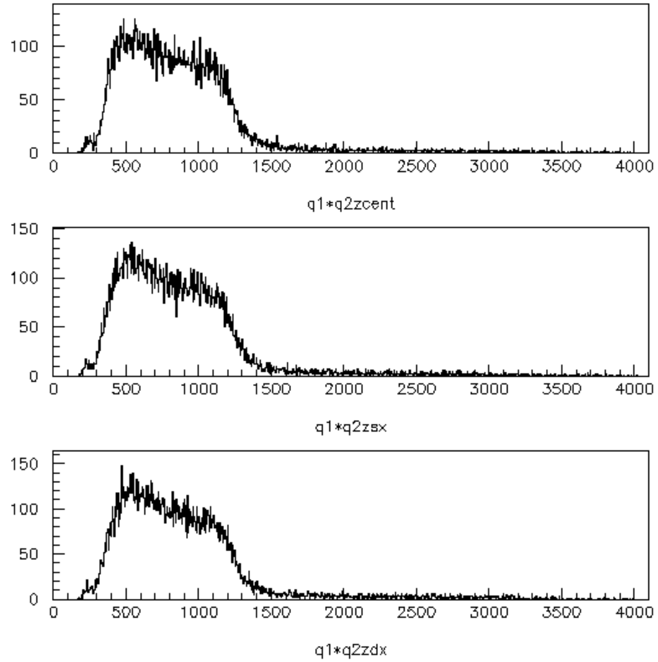


Collimatore piombo
(Φ=1mm)



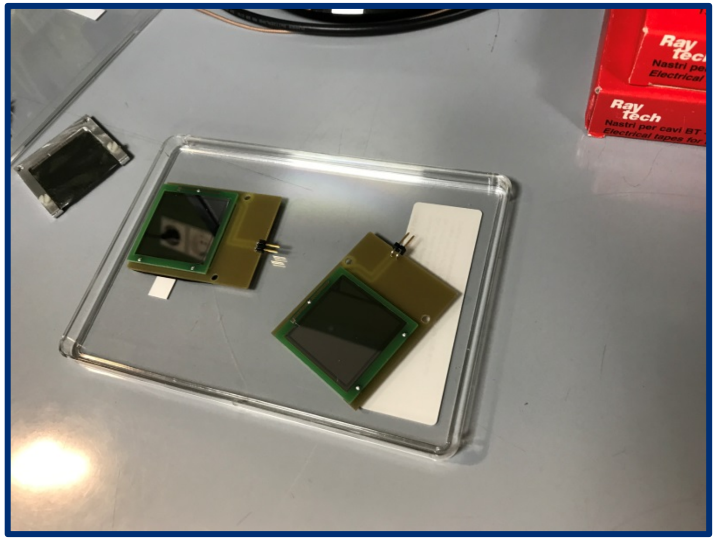
Differenza segnali PMT normalizzata alla radice del prodotto (i.e. energia rilasciata), per le 3 posizioni.

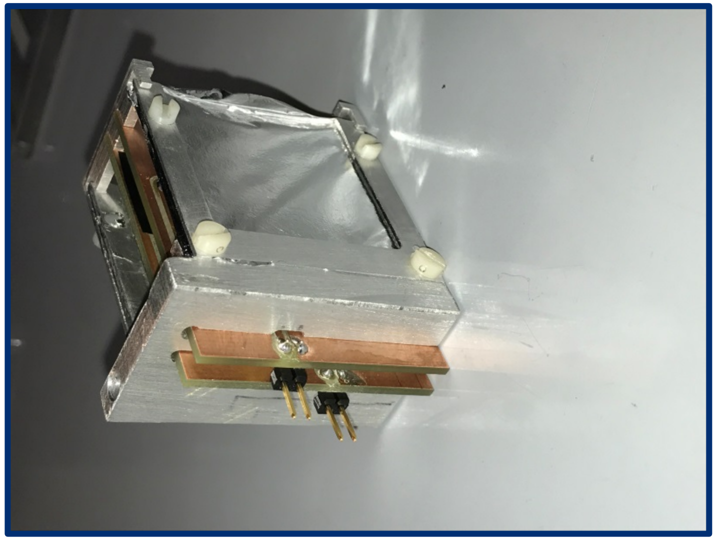
3 posizioni con step da 1cm

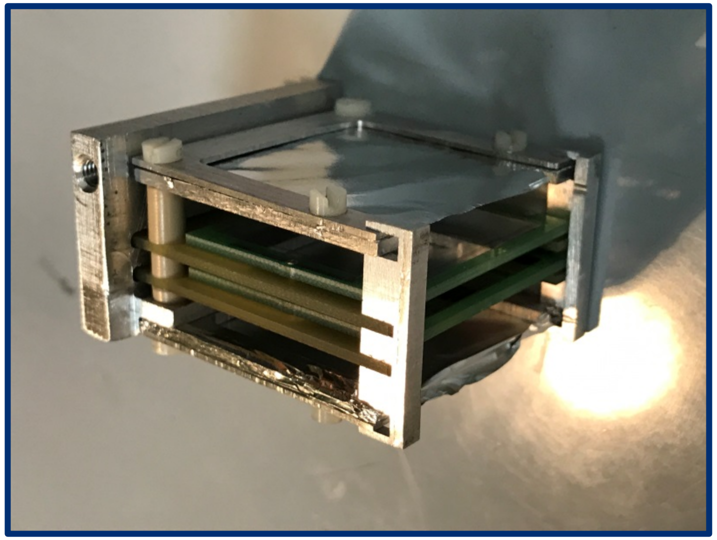


Spettri radice del prodotto per le 3 posizioni. Nel plot grande gli stessi sovrapposti.

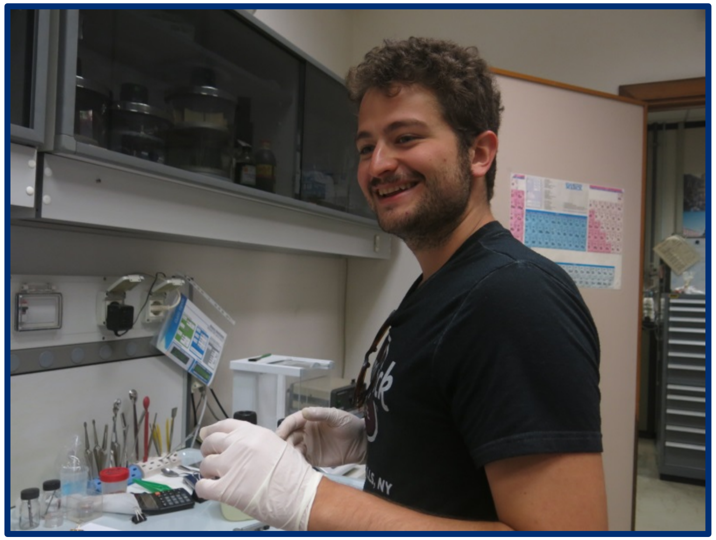
Assemblaggio PRT_2017

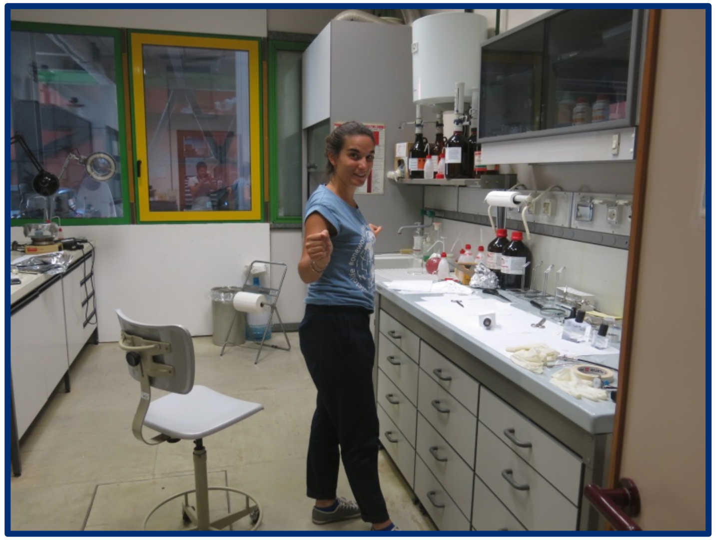






Assemblaggio PRT_2017
Il dream team ai LNS





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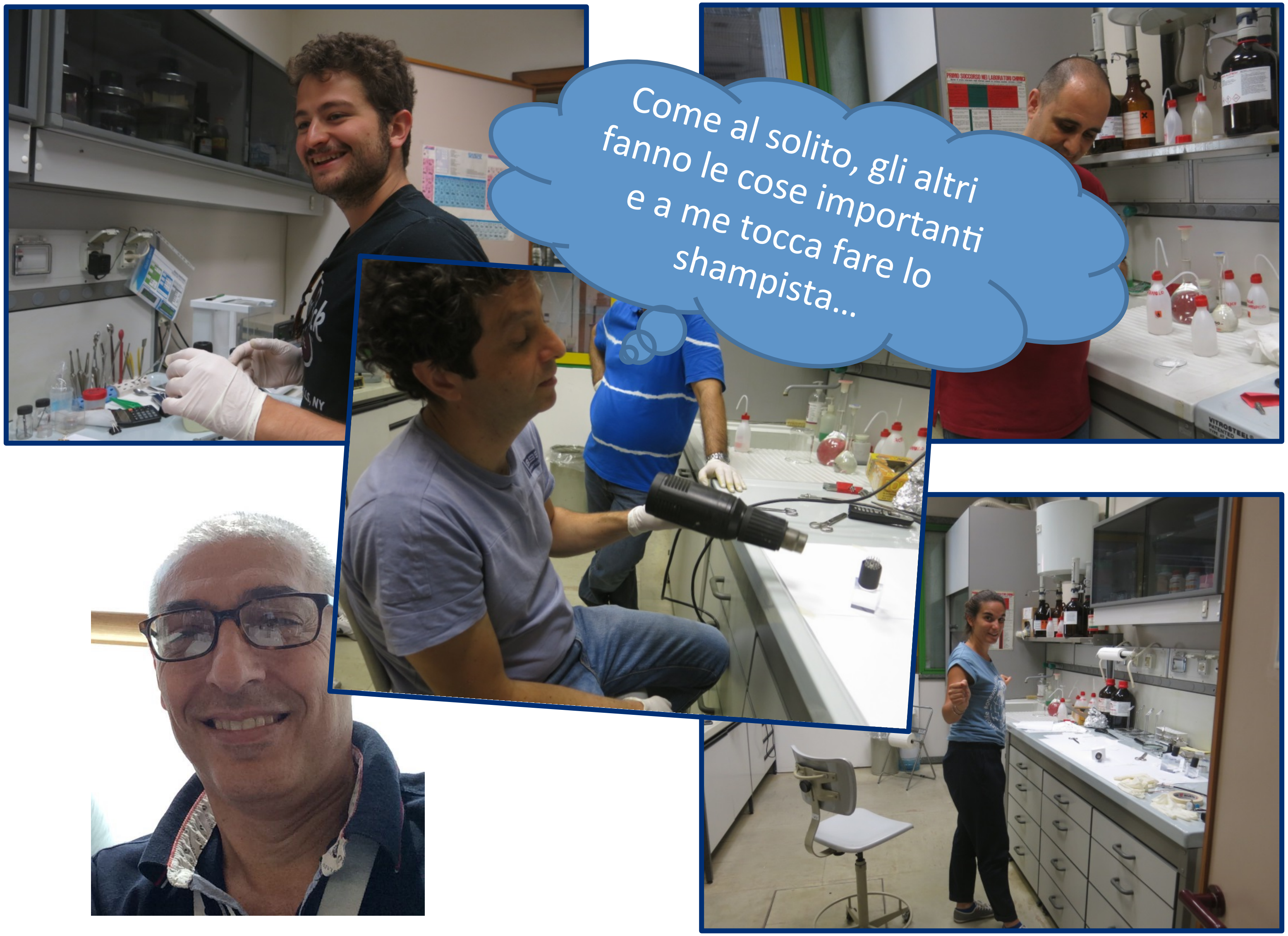
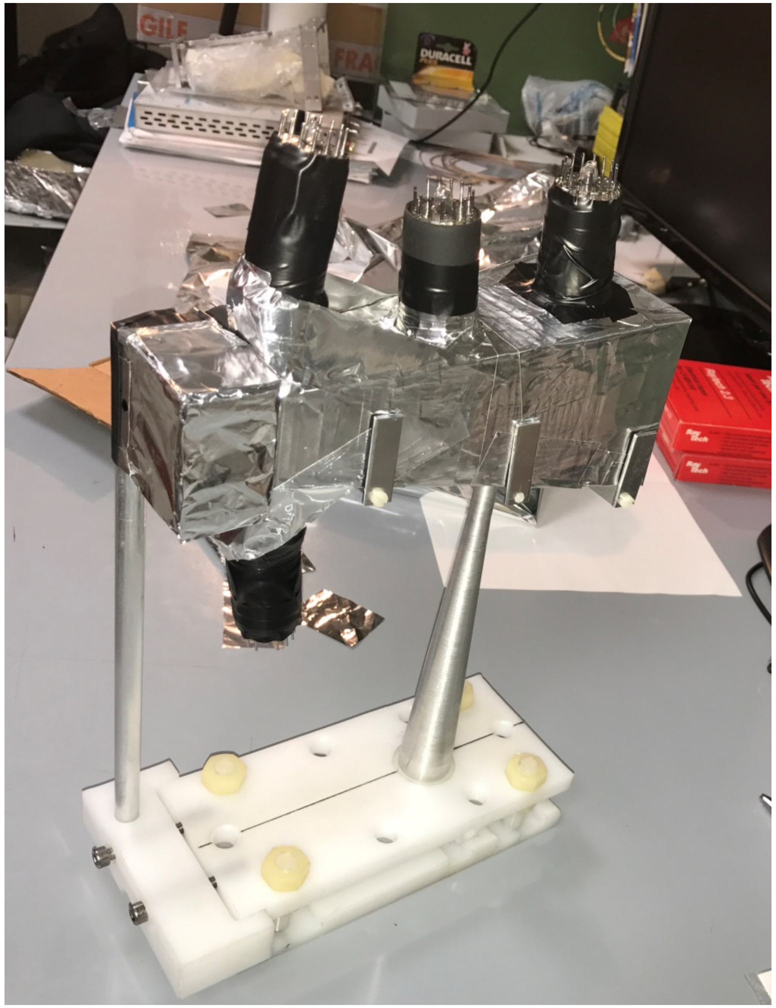
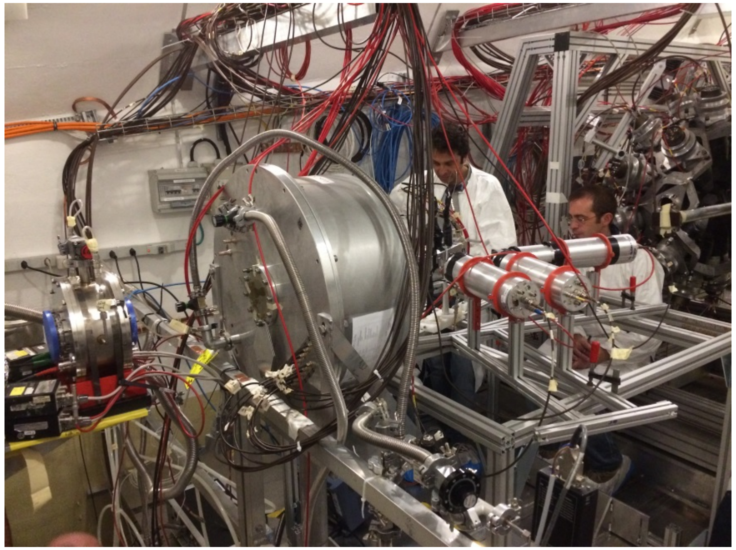


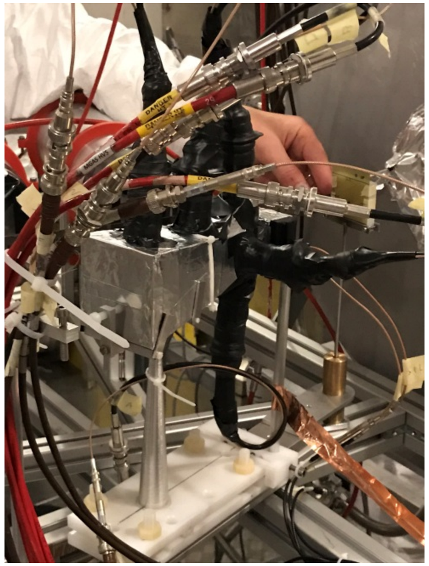
Pronto per il CERN (sett. 2017)

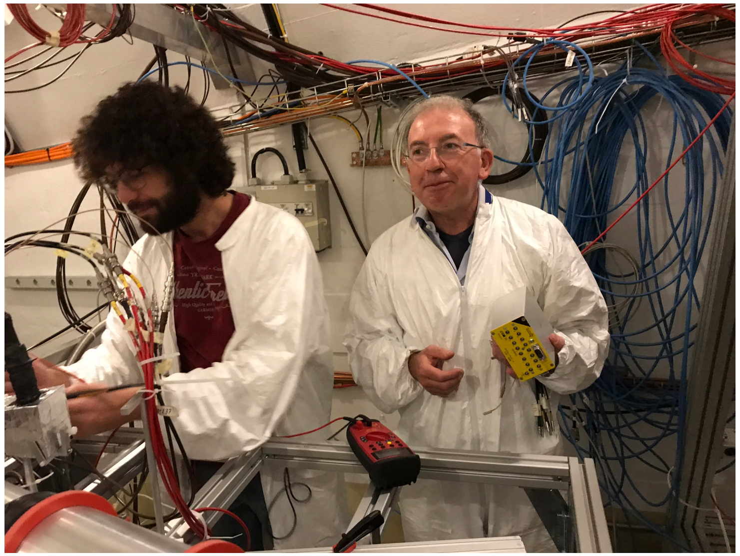


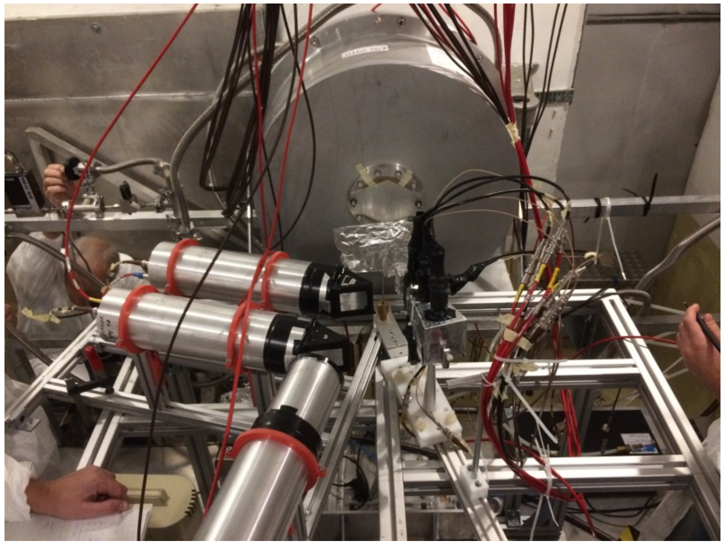
Pronto per rivelare protoni di rinculo, coprendo un range di energia (dei neutroni) da qualche MeV a 1 GeV

Installazione e avvio test (ott. 2017)



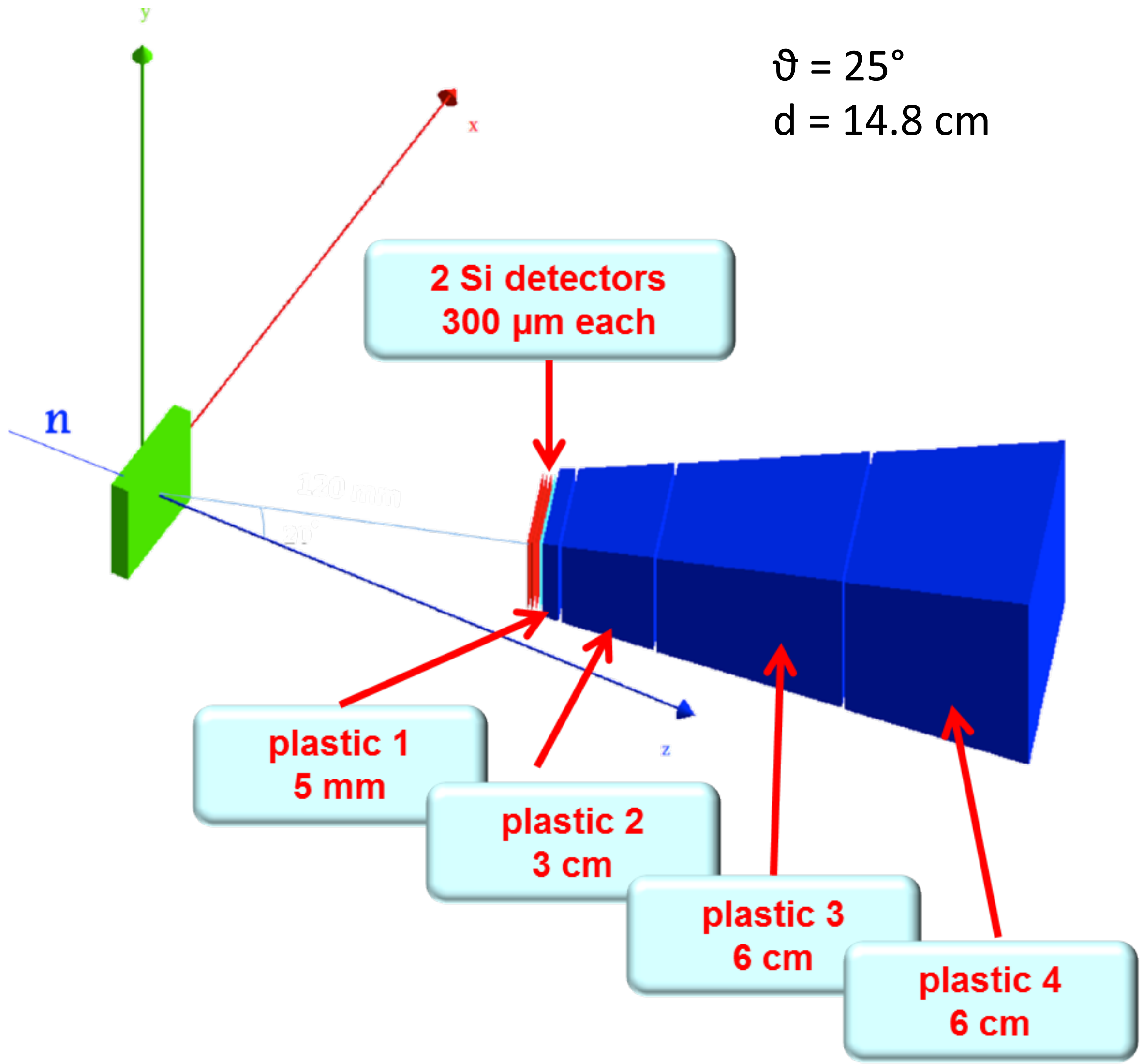




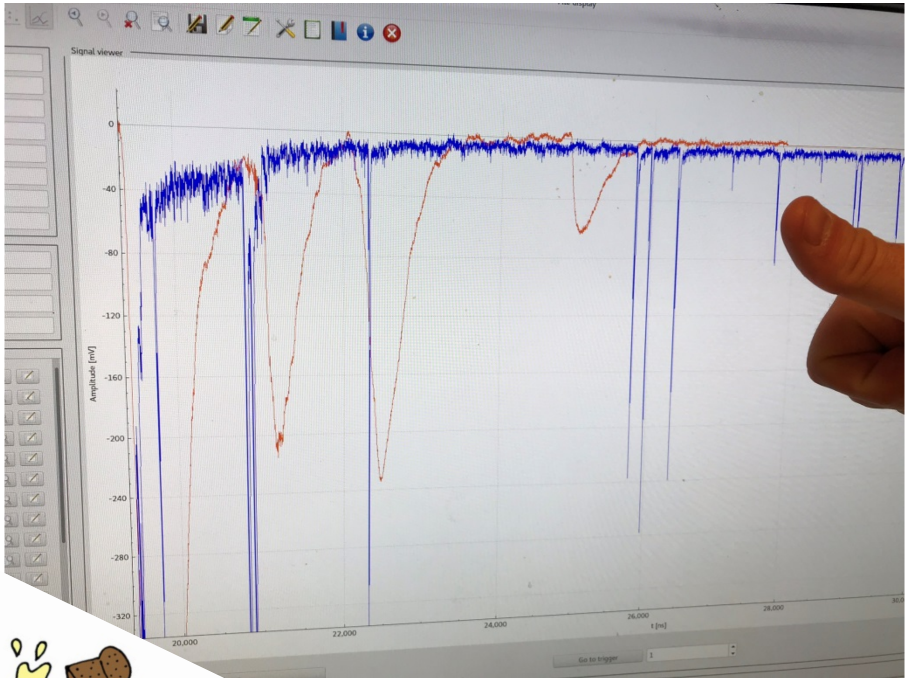


Installazione e avvio test (ott. 2017)

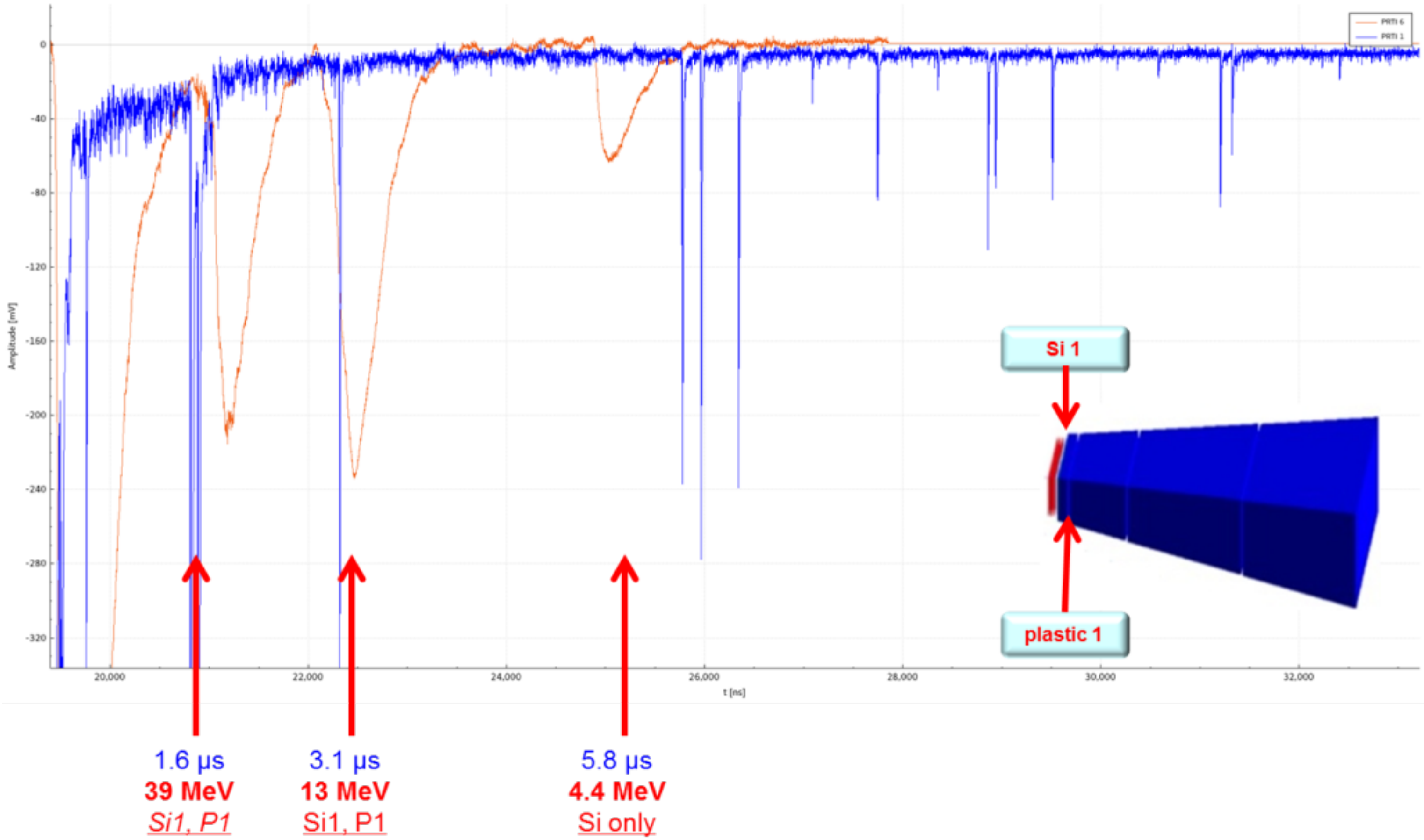
$\vartheta = 25°$
d = 14.8 cm



I primi segnali



INFN Proton Recoil Telescope



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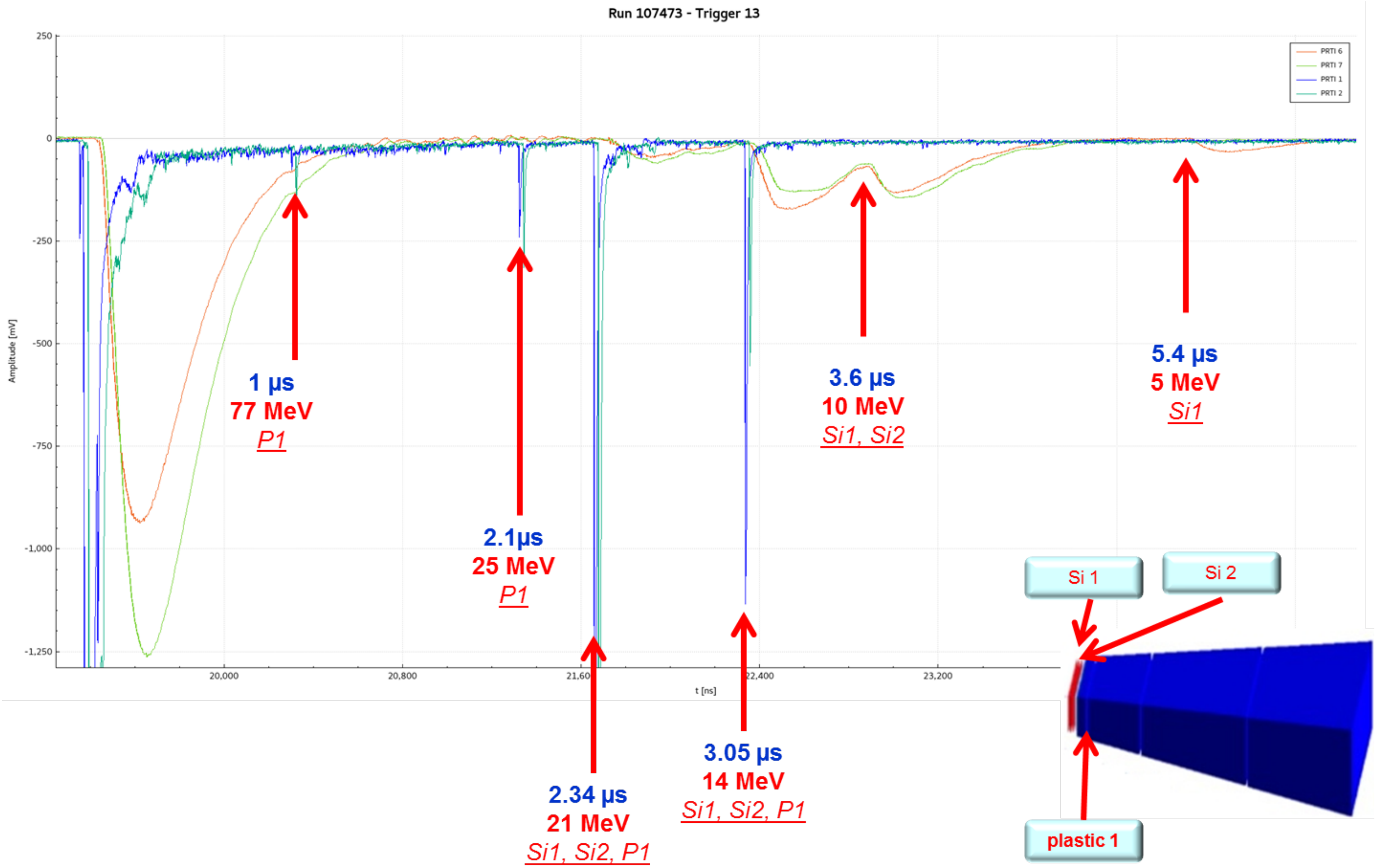

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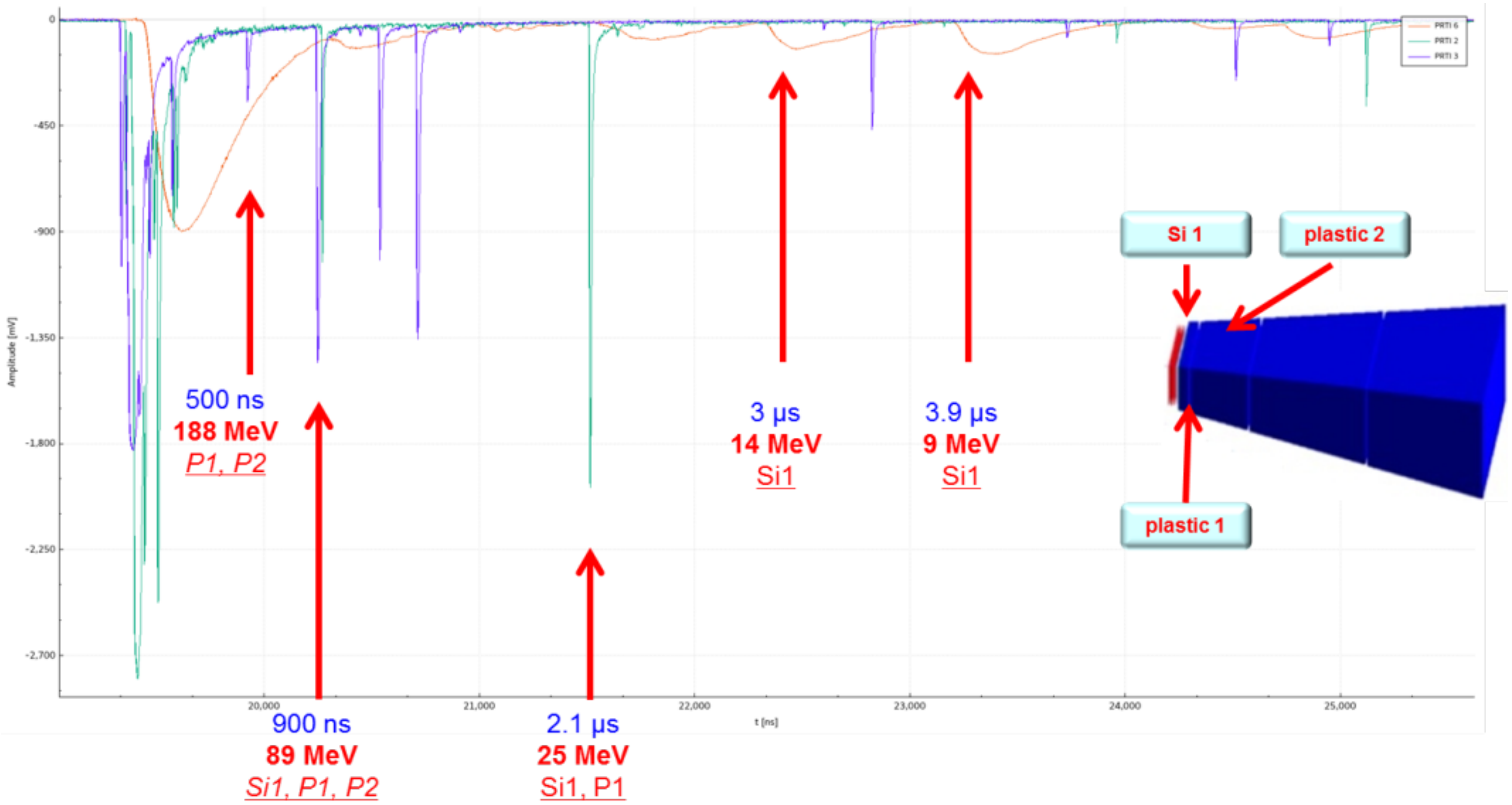

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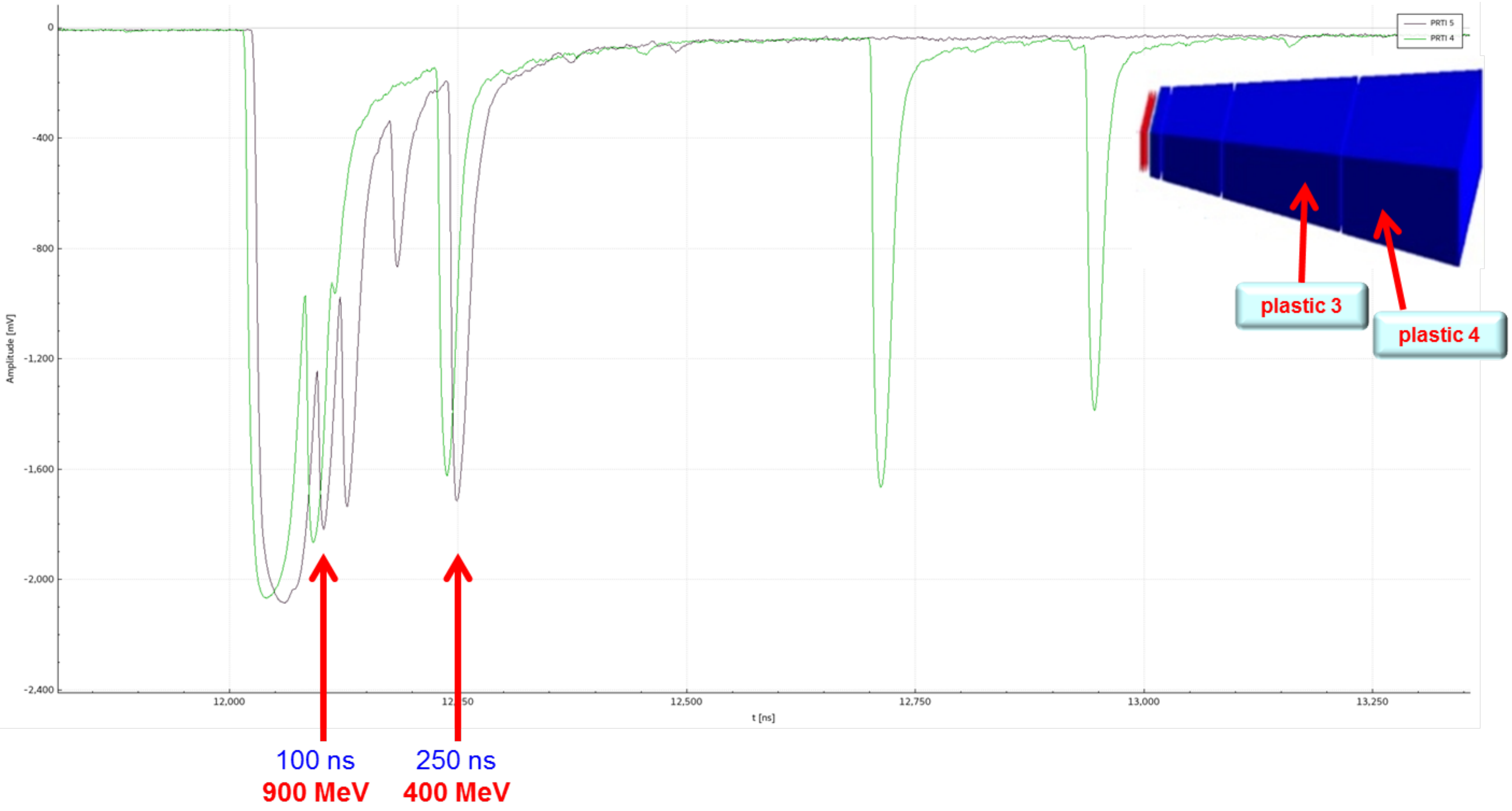
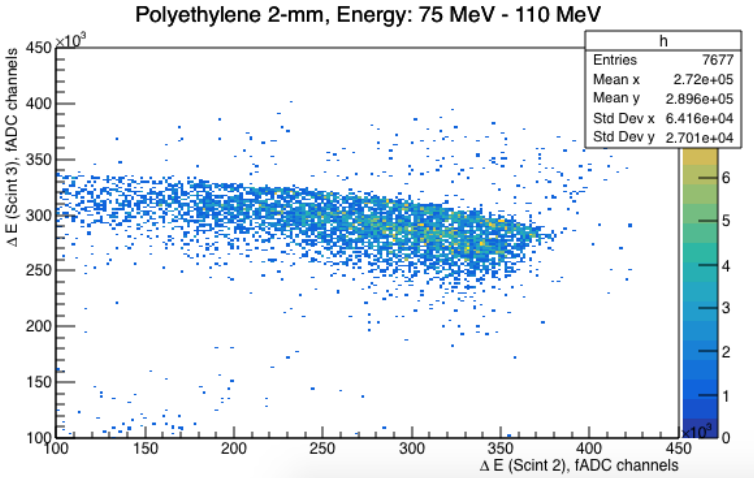
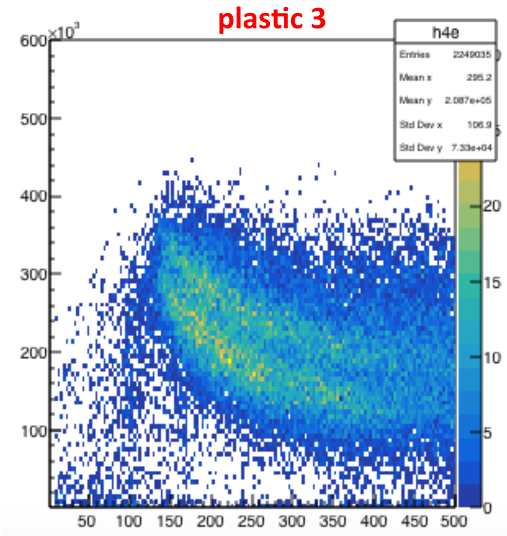
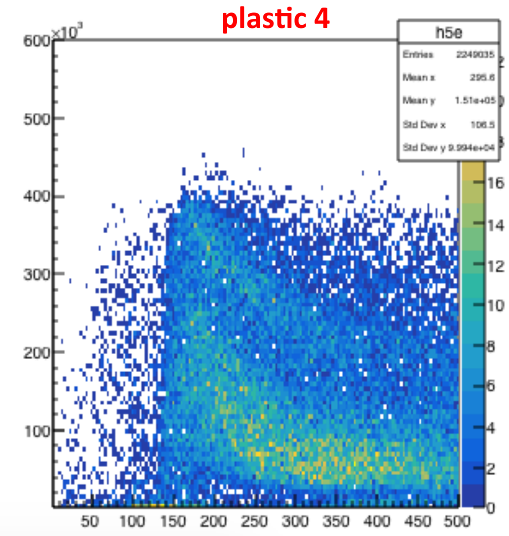


Very preliminary data







- **Il PRT pare abbia funzionato molto bene, riuscendo a rivelare segnali in un ampio range di energia dei neutroni, i.e da qualche MeV sino a circa 1GeV**
- **Gli scintillatori sembrano soffrire di una certa non linearità, dovuta a quenching degli scintillatori o ad abbassamento del guadagno nei PMT**
- **Attendiamo l'analisi dei dati acquisiti per stabilirne prestazioni, limiti e possibili margini di miglioramento**