Study of $^{234}U(n,f)$ fission fragment angular distribution at the CERN n_TOF facility

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IPN-Orsay (France)

(n_TOF Collaboration)

Motivation

The fission fragment angular distributions (FFAD) are needed to:

- Provide information about the nuclei state at the saddle point and the nuclear fission dynamics (Different transition states give different FFAD).

- Calculate the detection efficiency in order to improve the values of the cross section, in particular in the threshold regions.

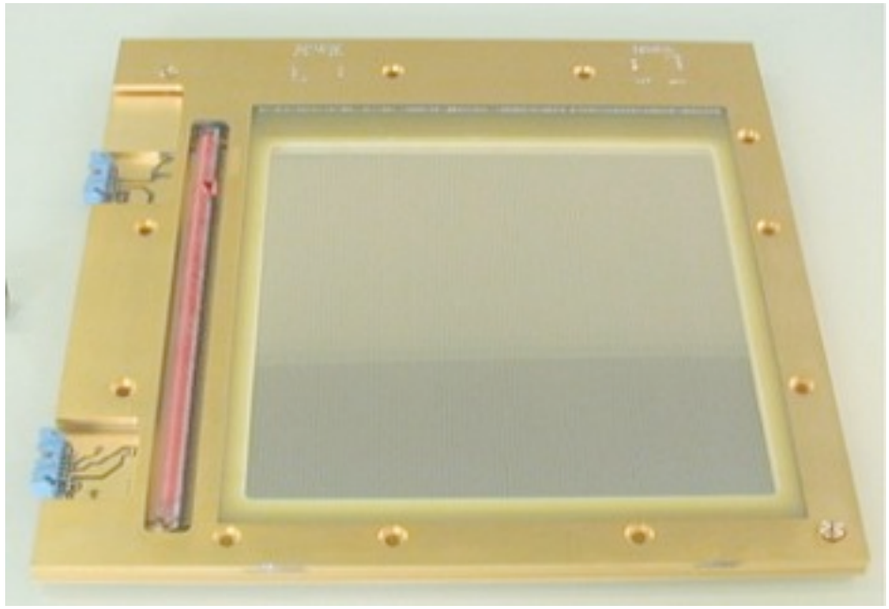
The ^{234}U(n,f) FFAD:

- Large anisotropy values at the fission threshold.

- There are no experimental data above 15 MeV.

- It will allow us to improve the cross section with increased statistics.

The IPN-Orsay PPACs

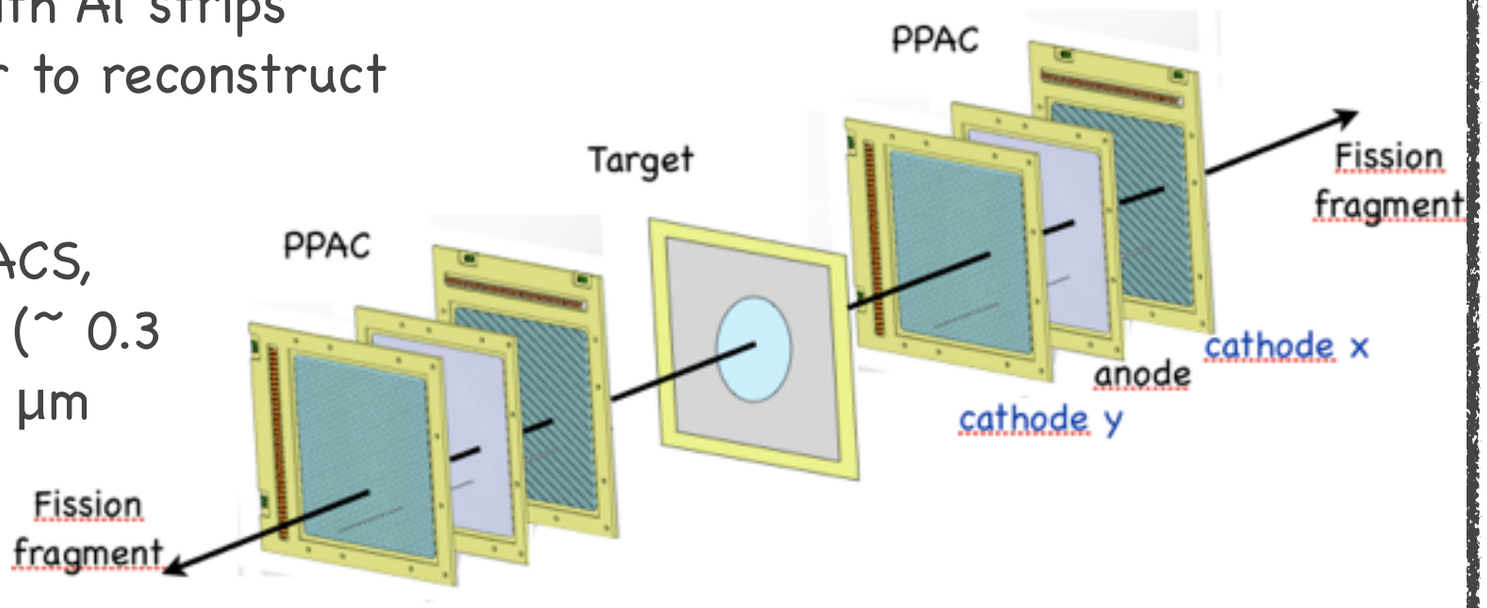


- The Parallel Plate Avalanche Counters (PPACs) are detectors filled with C_3F_8 at 4 mbar pressure.

- The central anode with a very fast signal response (time resolution 500 ps).

- The two segmented cathodes with Al strips connected to a delay line in order to reconstruct the position of the FF hit.

- The targets, flanked by two PPACS, consist in a thin radioactive layer (~ 0.3 mg/cm^2) deposited in an Al foil (2 μm and 0.7 μm).



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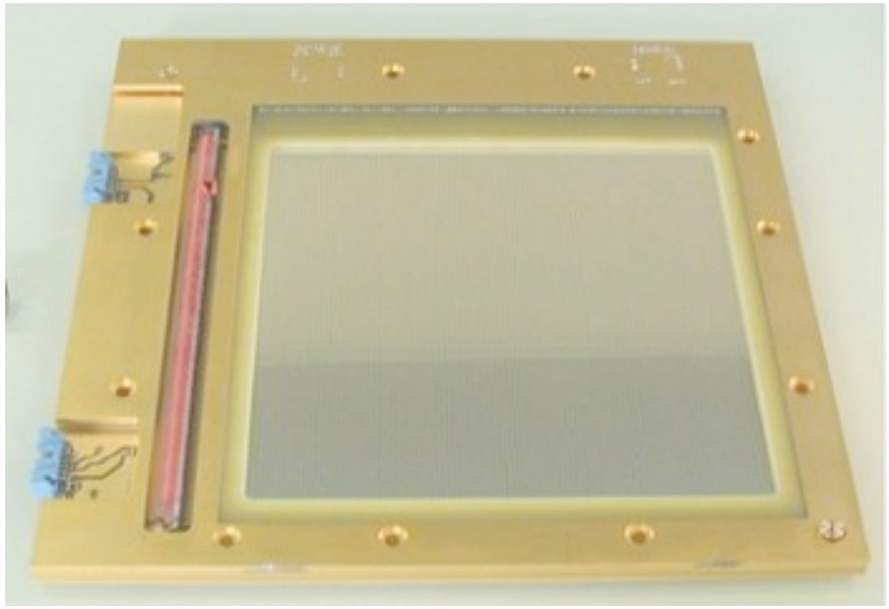

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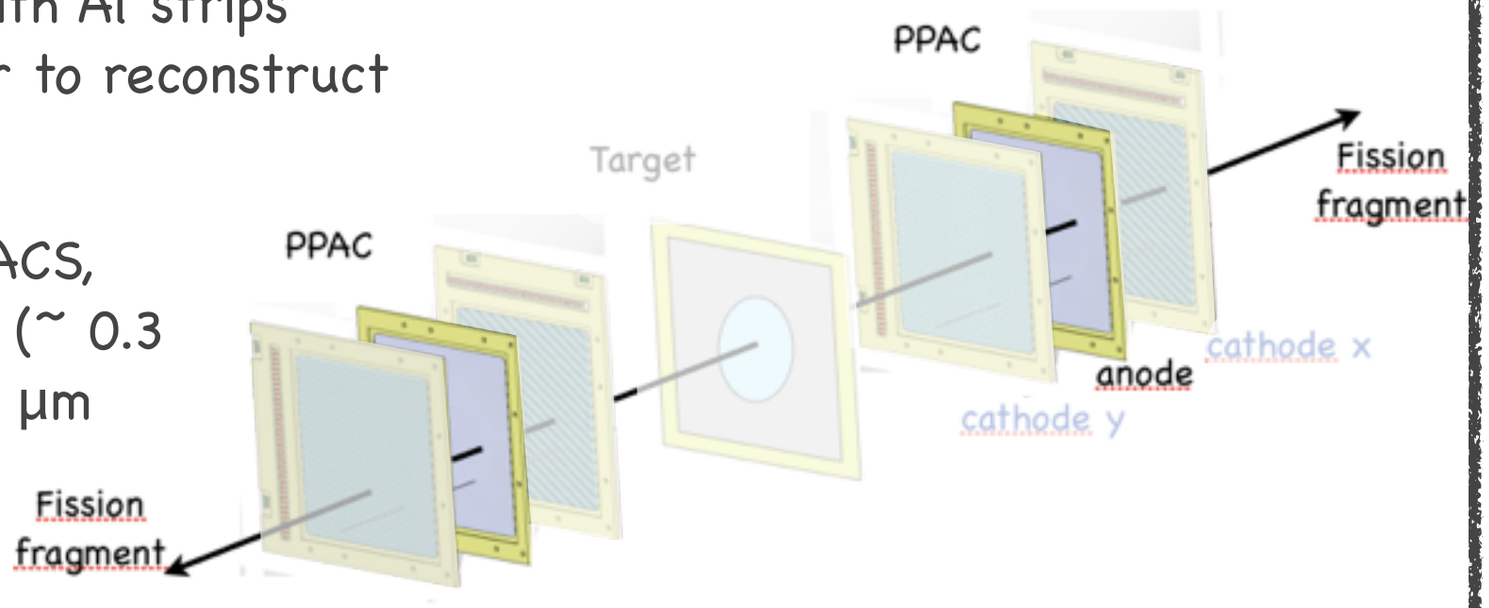

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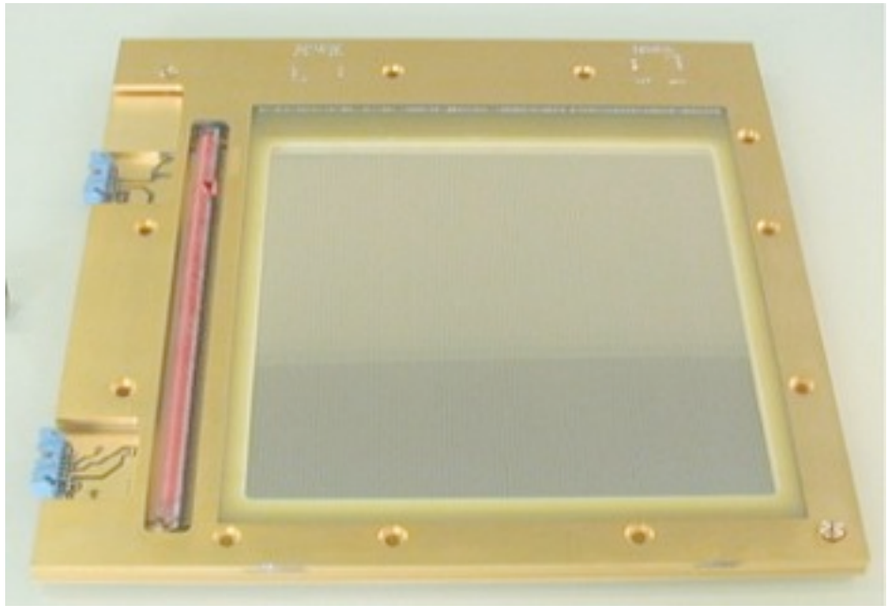

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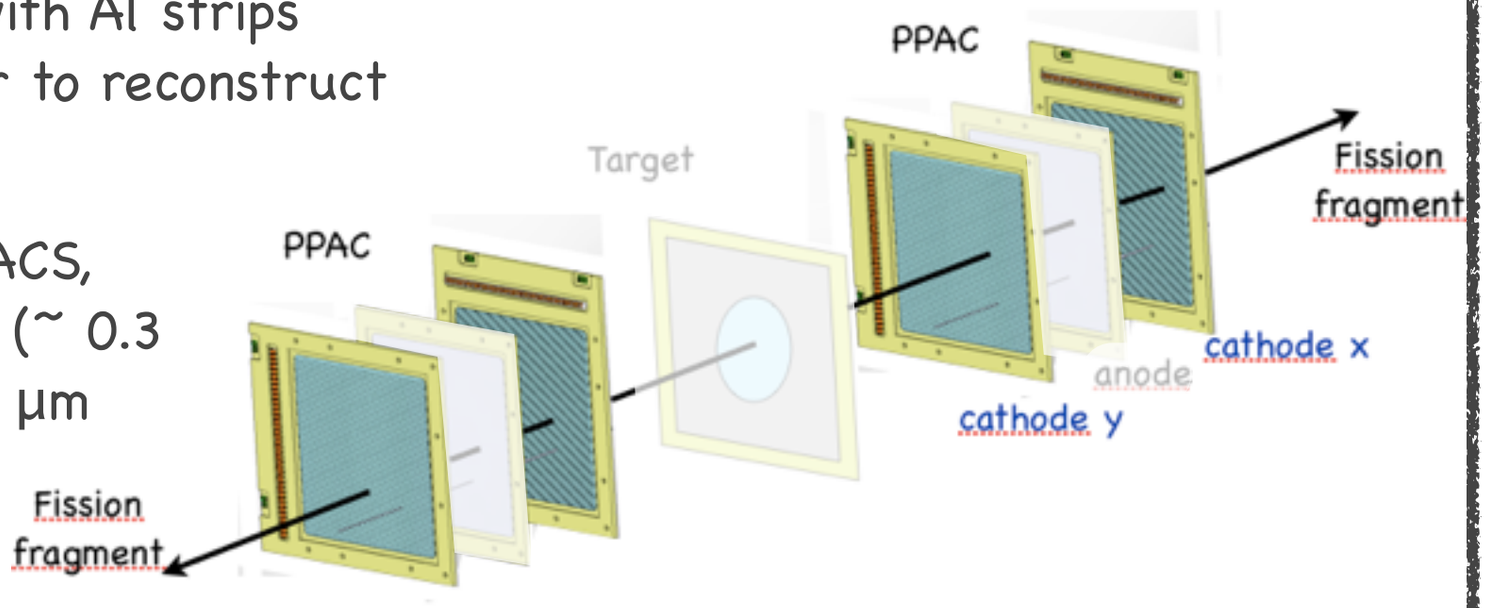

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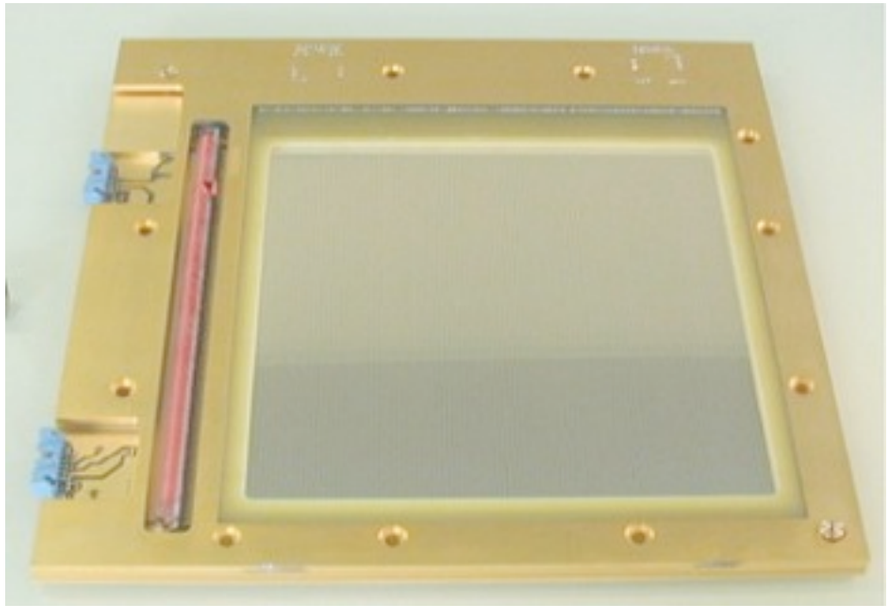

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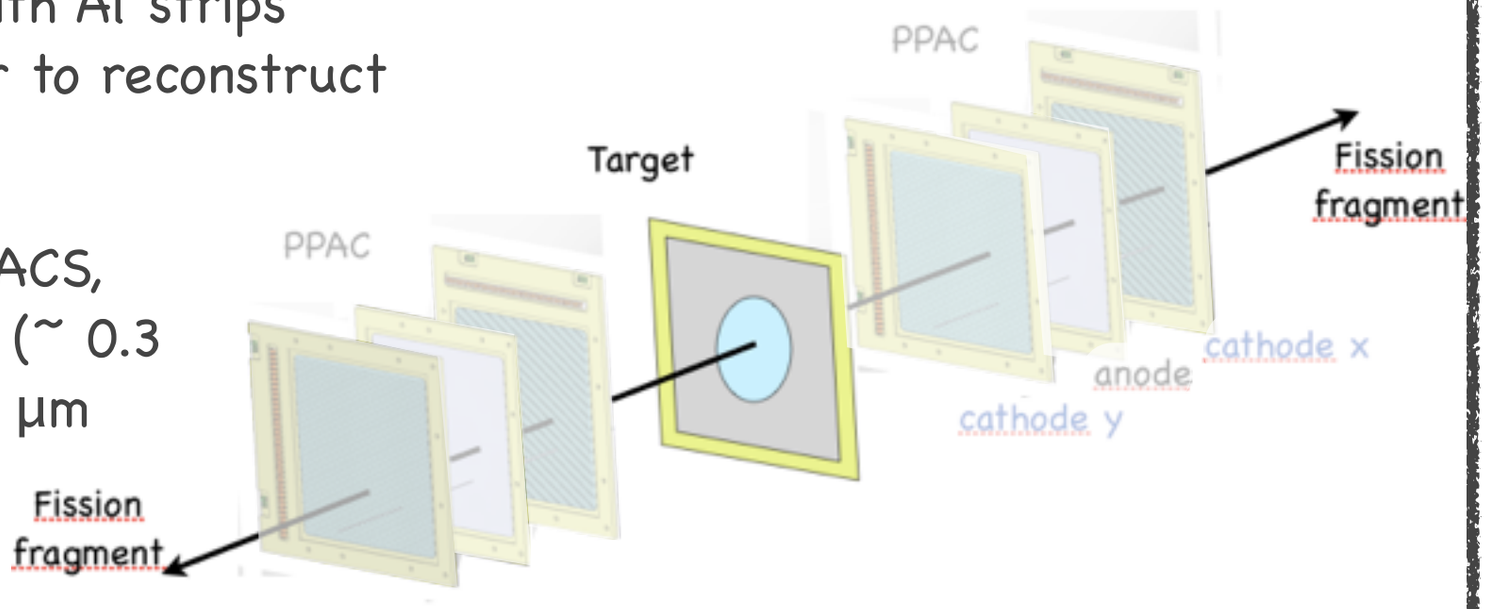
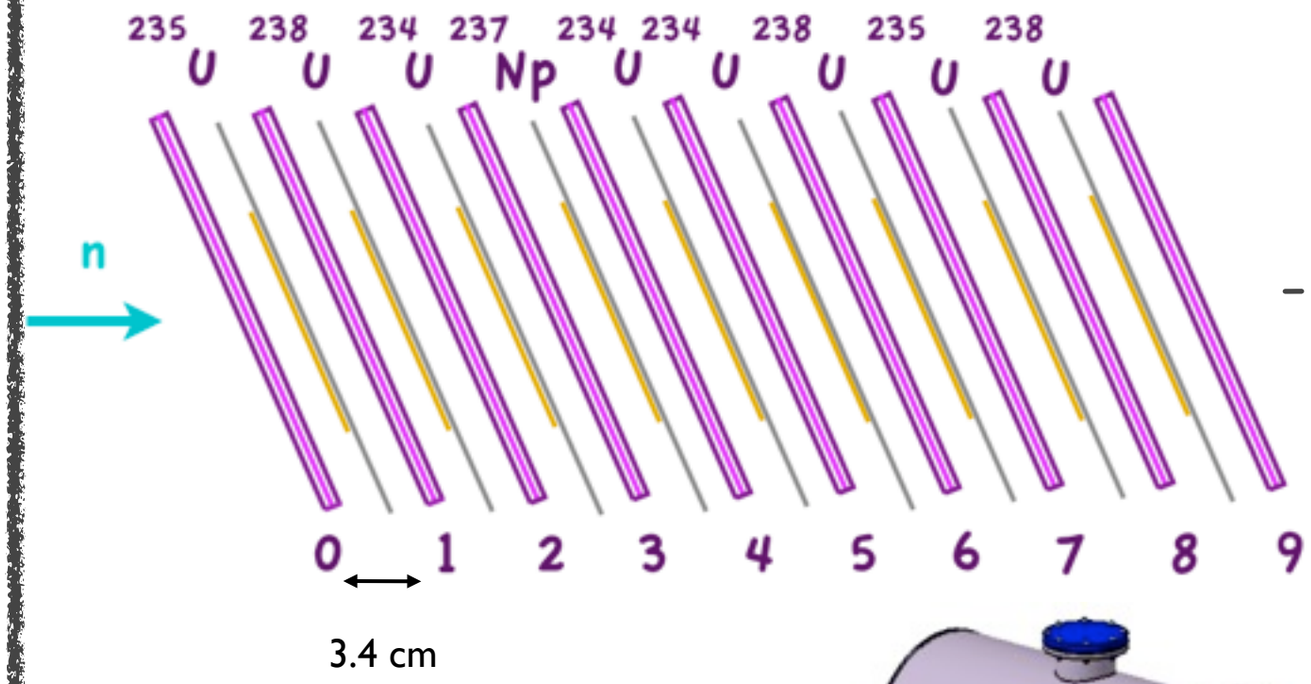


2012 setup

Distribution of targets and detectors:



Detectors (10) & targets (9)

^{238}U and ^{235}U used as references.

- 2 targets of ^{235}U (14 mg)
- 3 targets of ^{234}U (13.1, 13.4 and 13.6 mg)
- 3 targets of ^{238}U (11.5 and 15 mg)
- 1 target of ^{237}Np (15 mg)

- Preliminary results of one ^{234}U target analysis are presented.

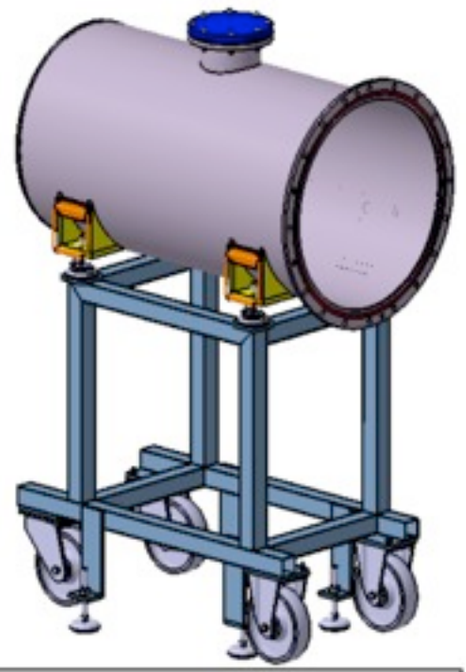


Figure 1 : stainless steel cylinder

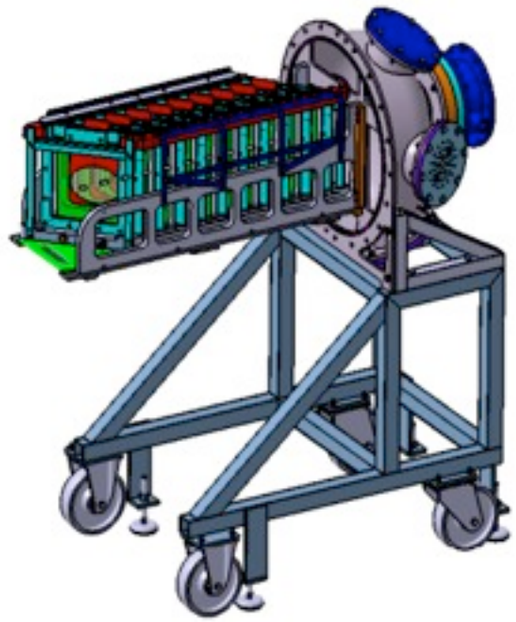


Figure 2: aluminum bottom + detectors and targets

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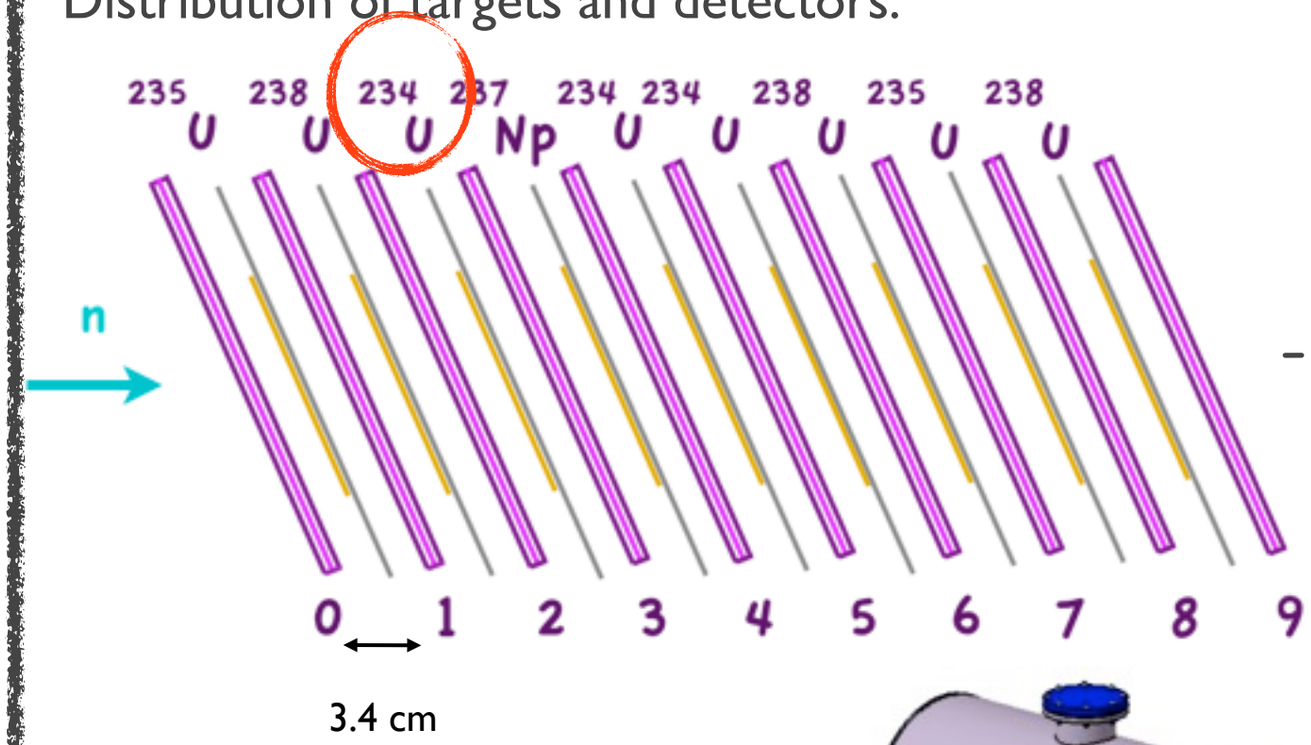

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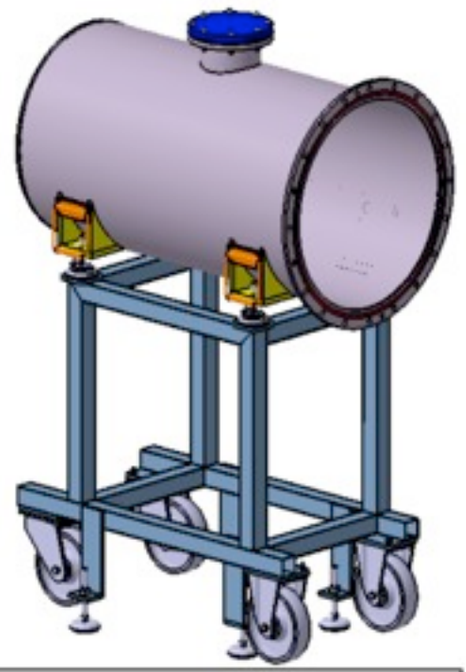

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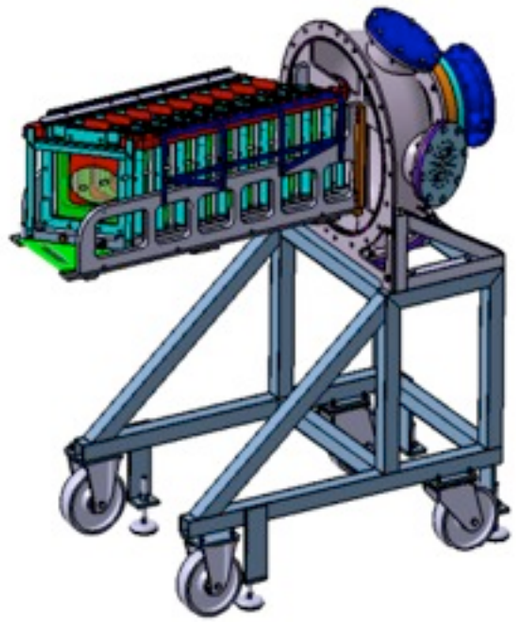
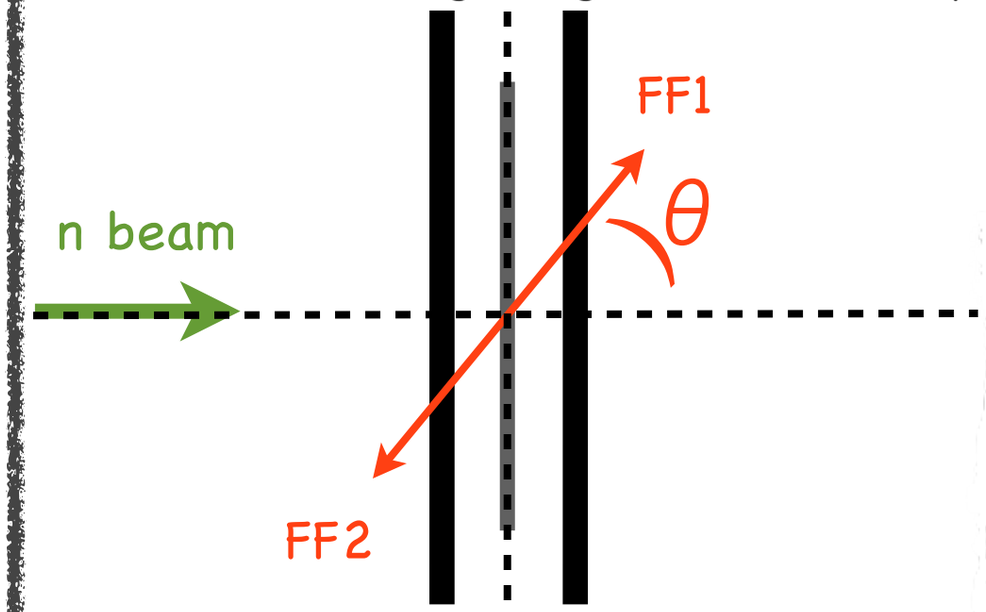


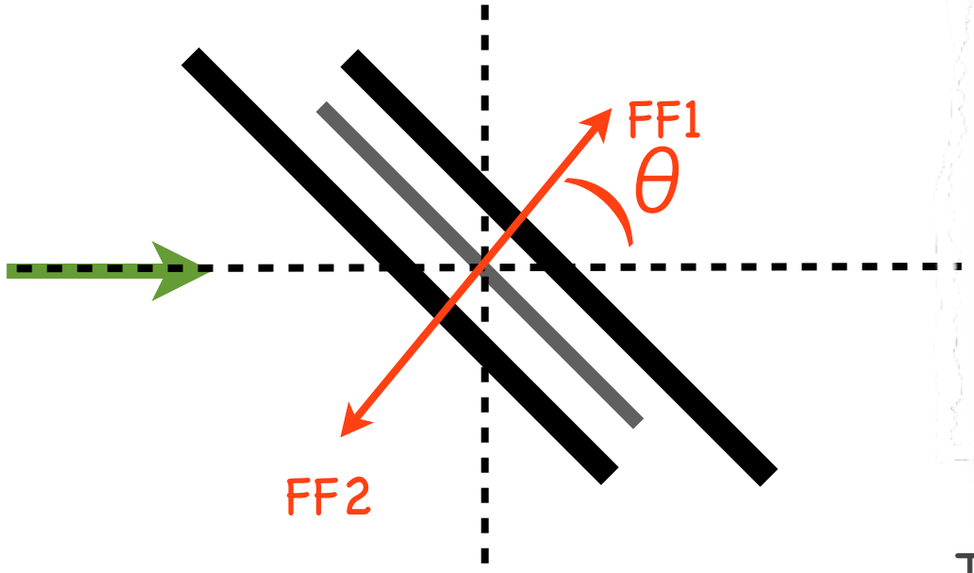
Figure 2: aluminum bottom + detectors and targets

Angular range covered

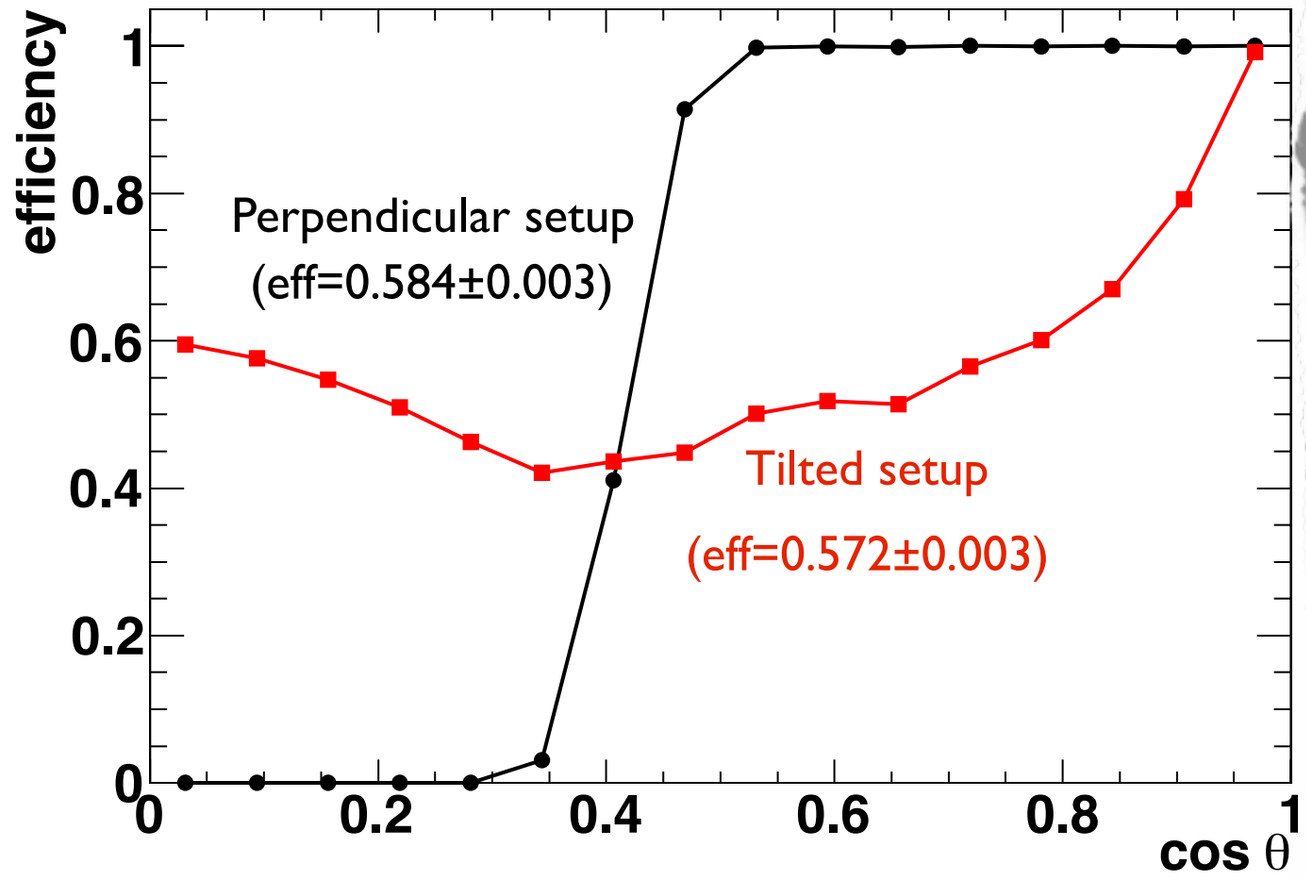
PPACs and targets geometrical disposition with respect to the incident neutron beam:



Perpendicular (*Phase I, 2002-2003*)
angular range: θ =(0°, 63°)



Tilted 45° *(Phase II, 2010-2012)*
angular range: θ = (0°, 90°)



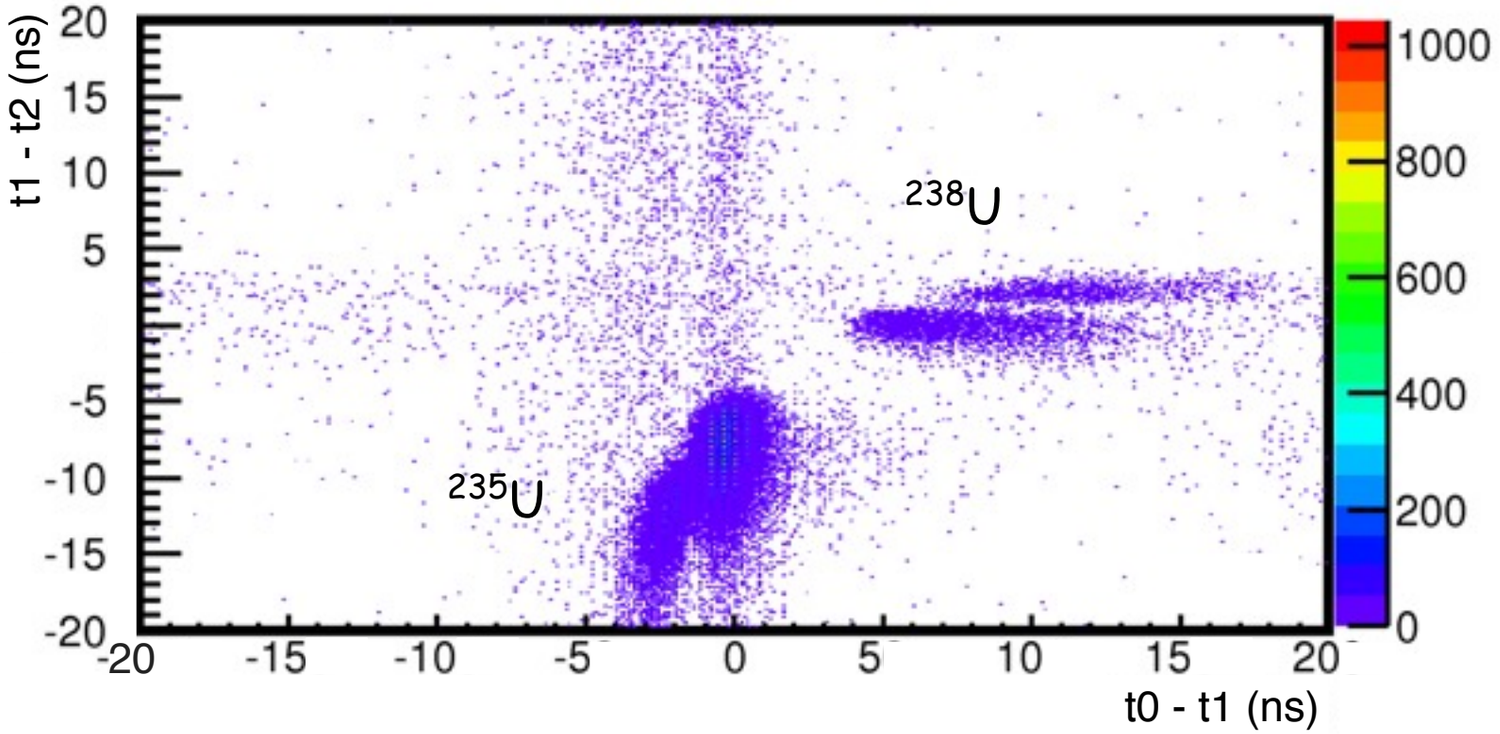
D. Tarrío et al. submitted to NIM.

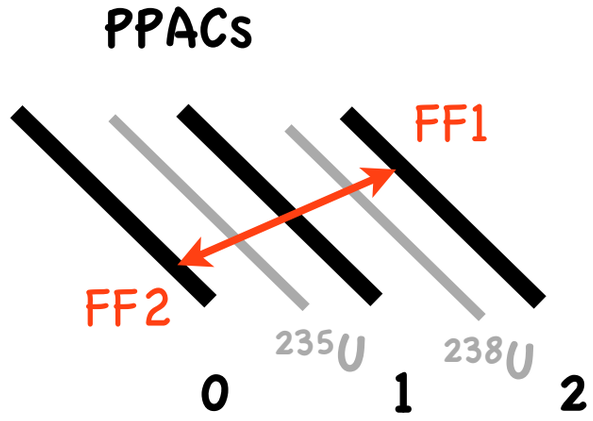
The overall detection efficiency for both positions is almost the same.

Preliminary results

Coincidence detection of the FF

Coincidence events between three consecutive PPACs:





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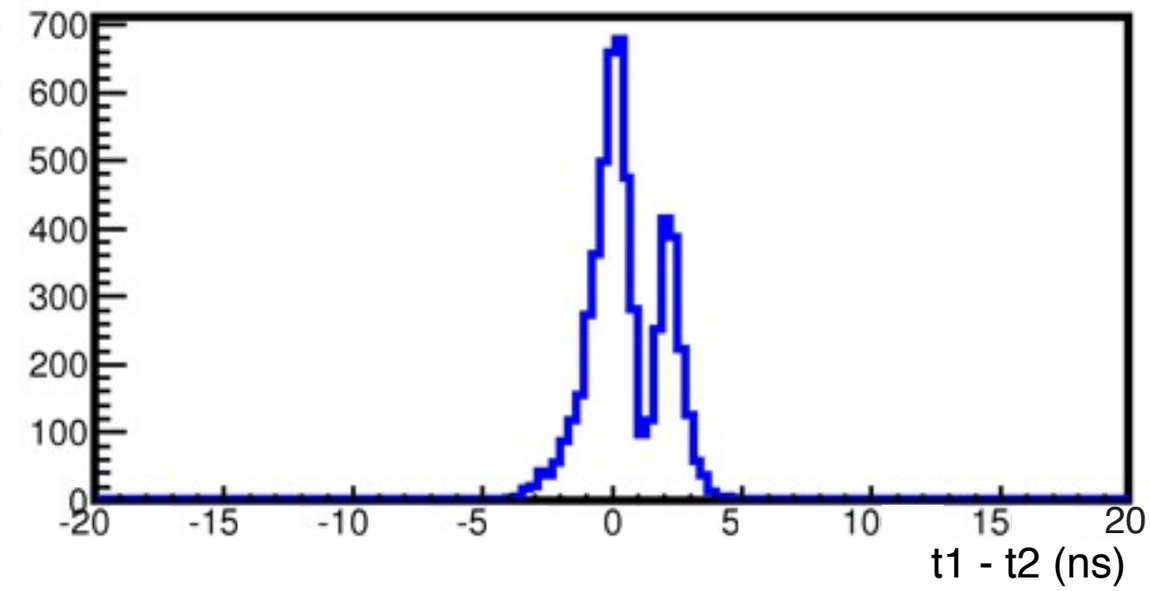

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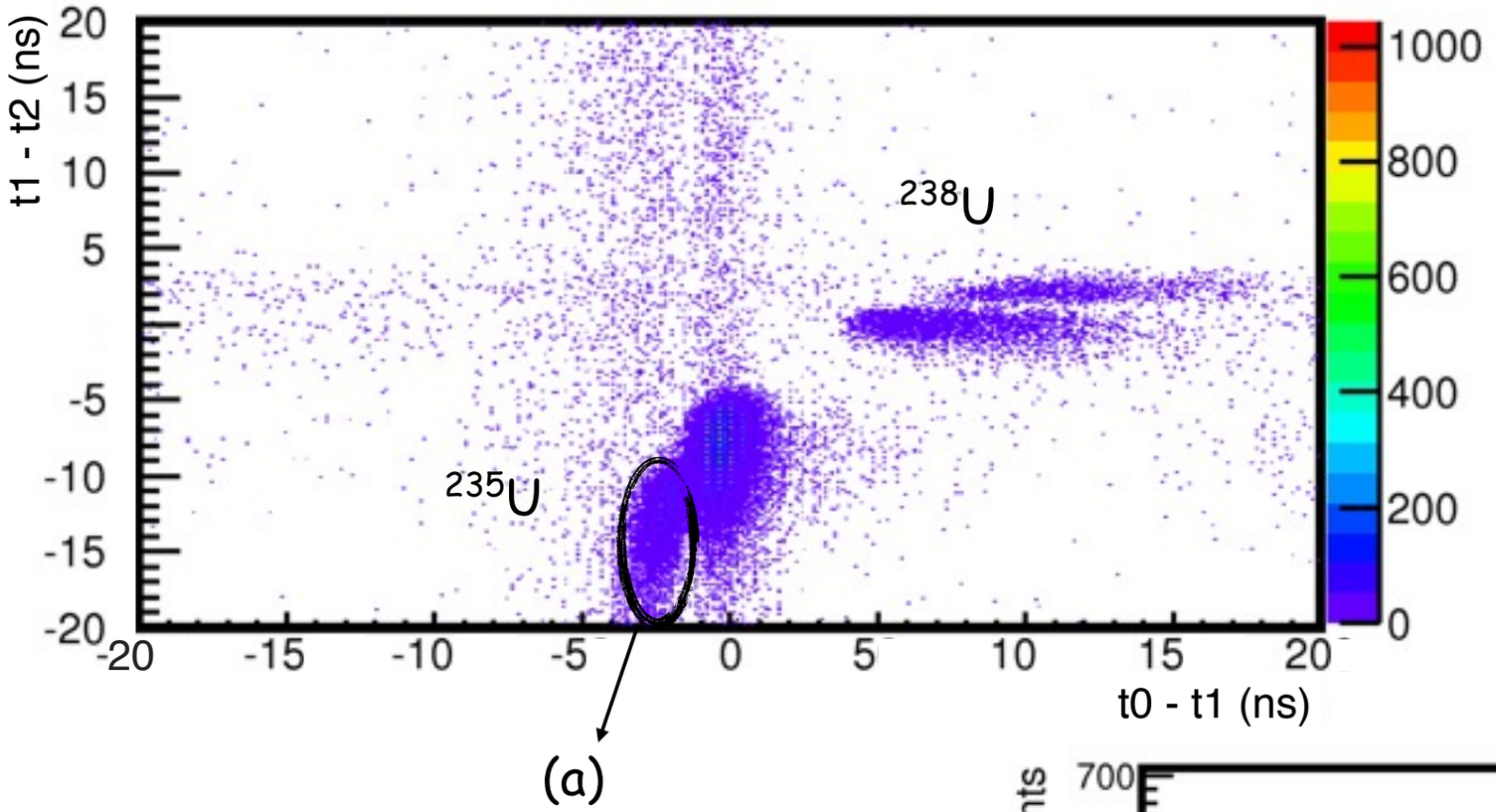

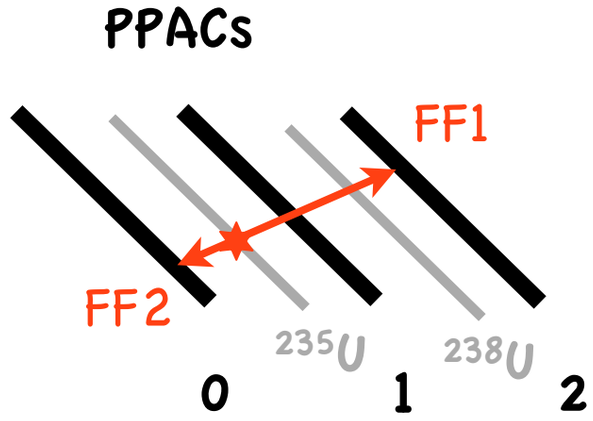

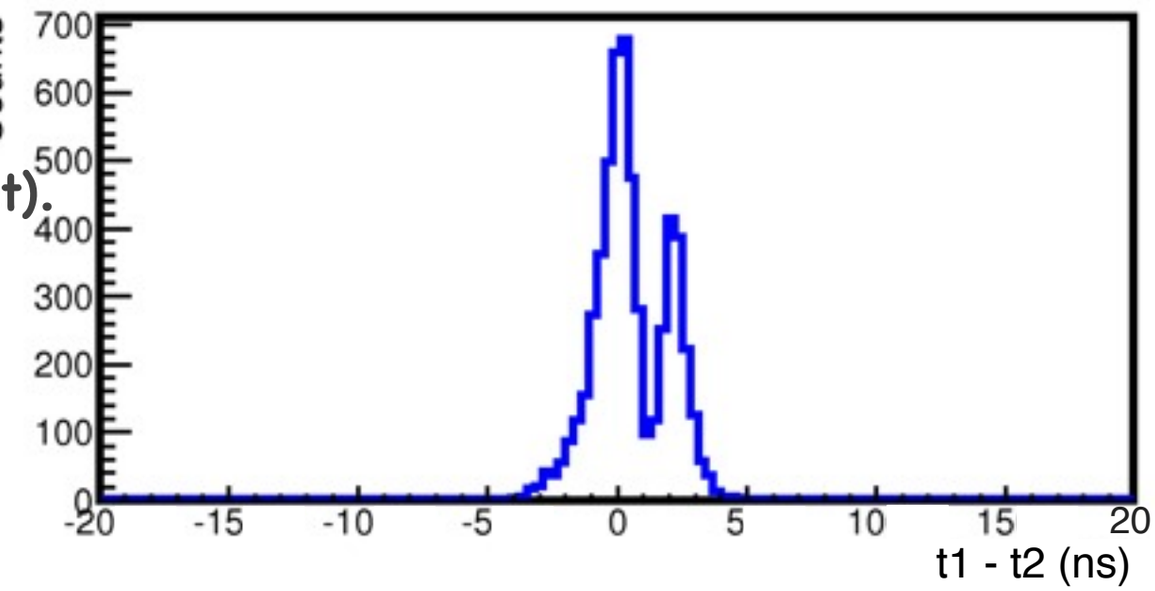

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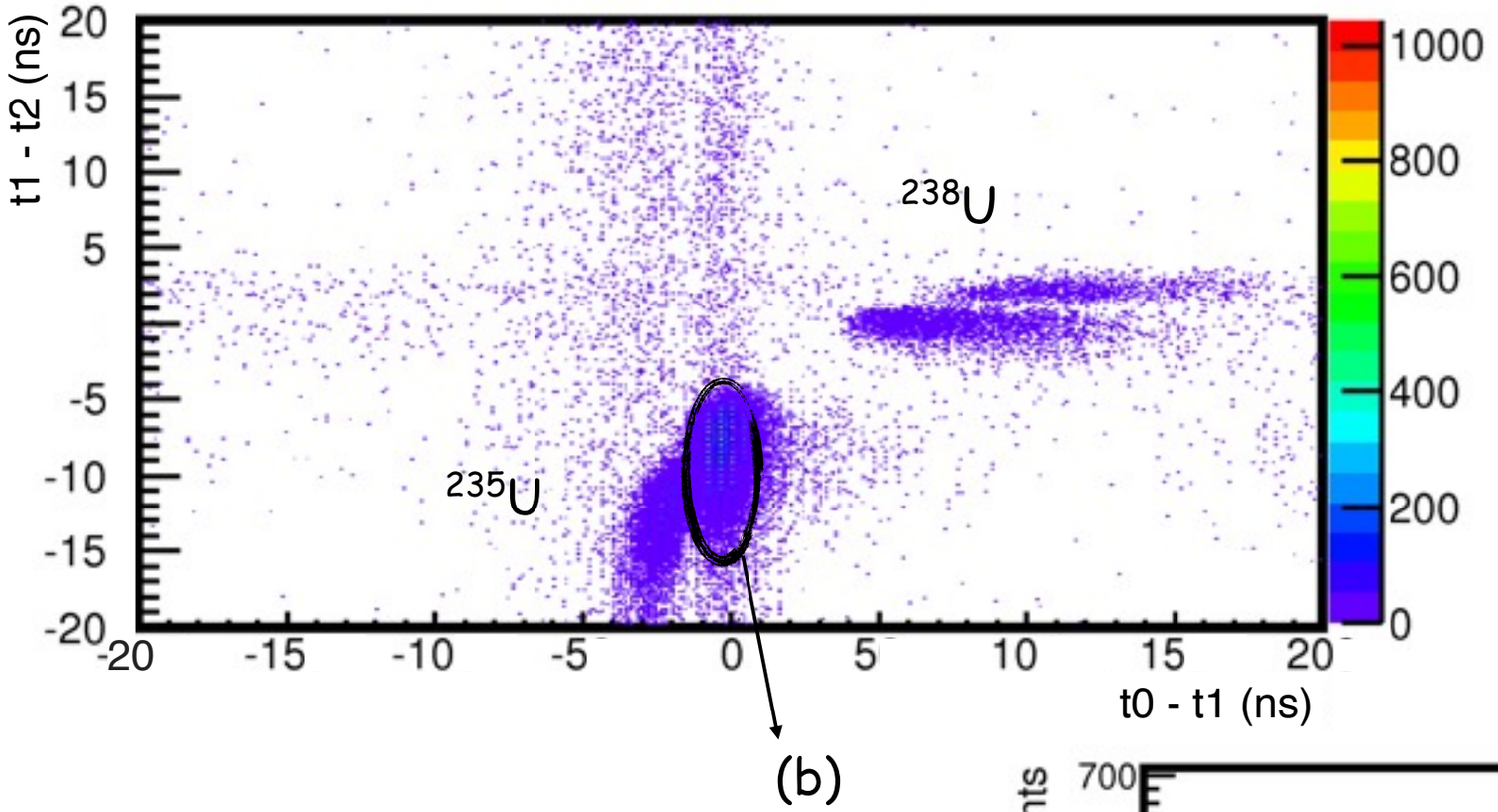

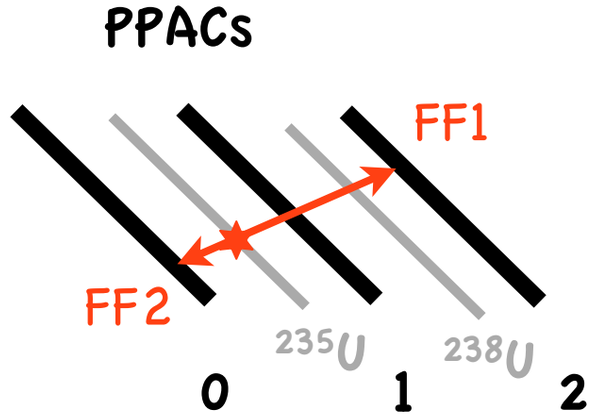

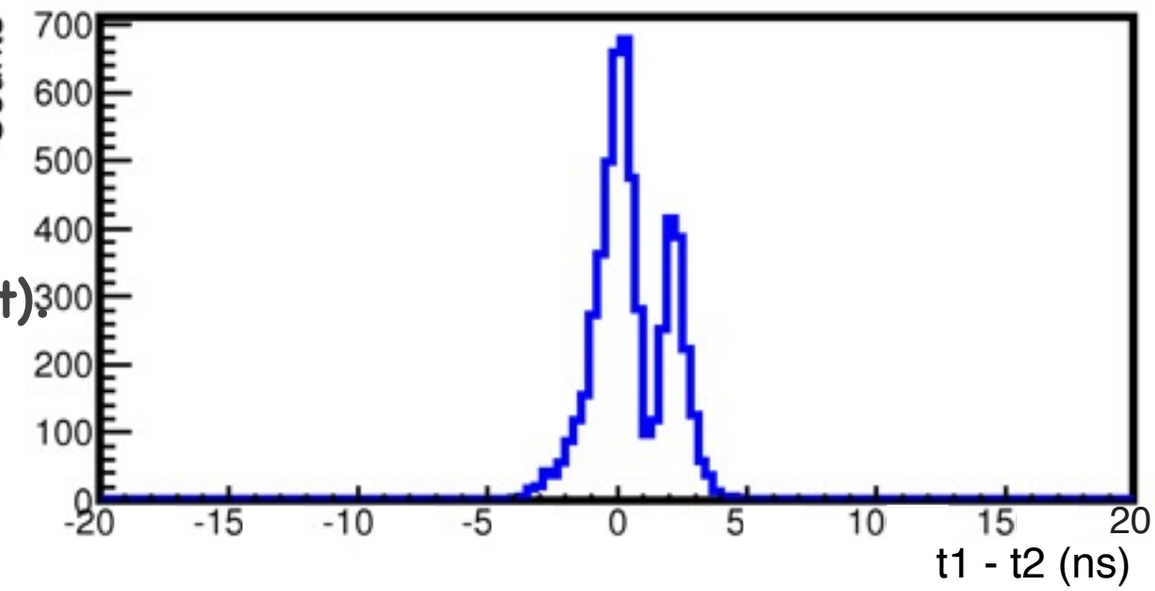

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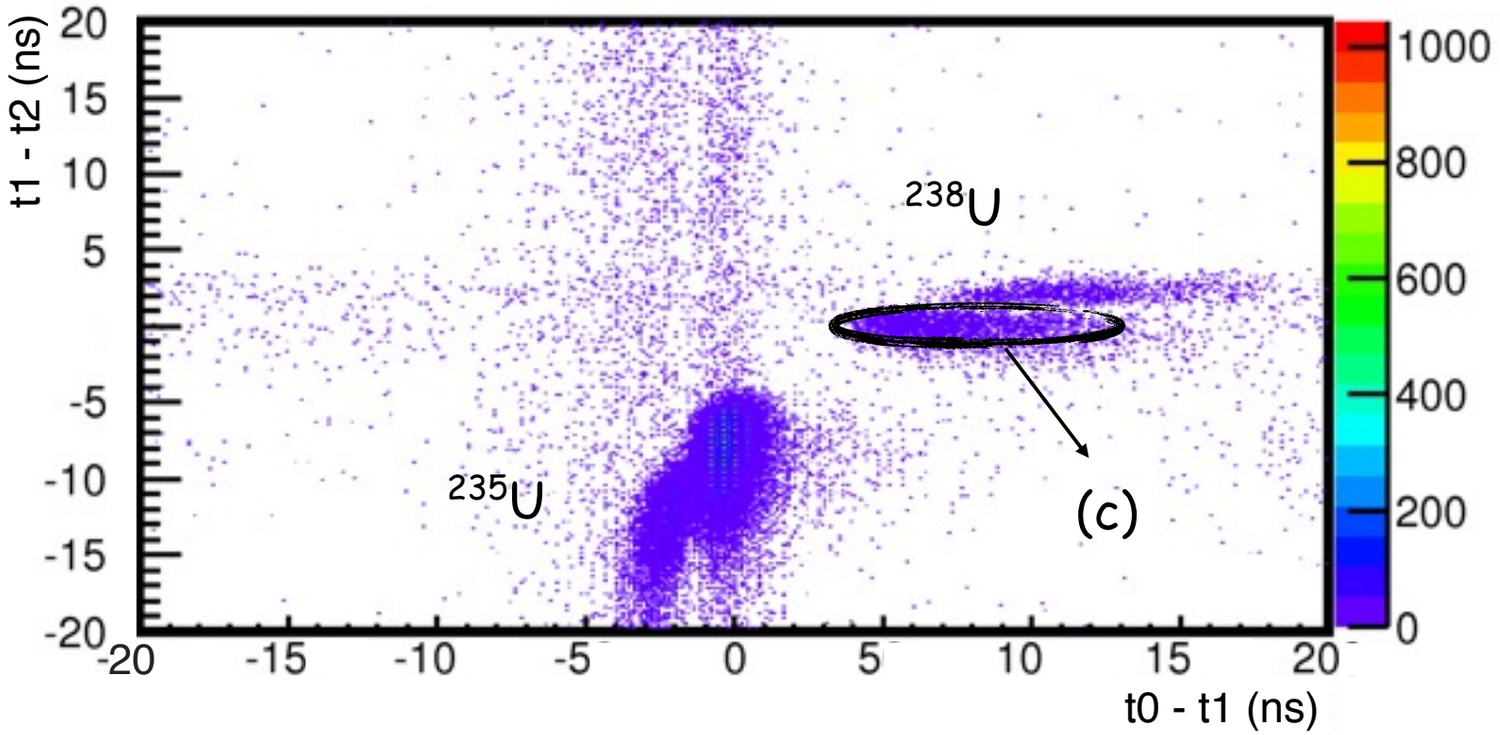

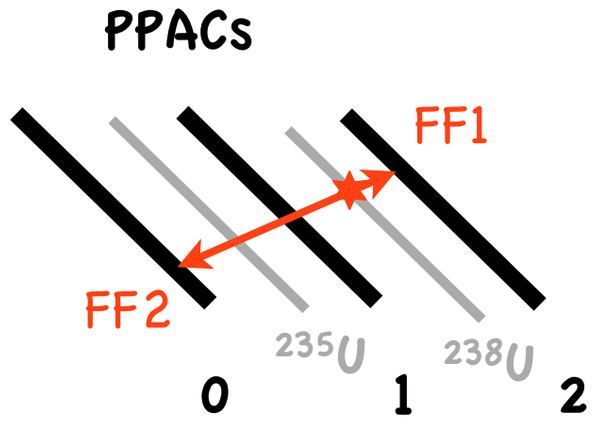

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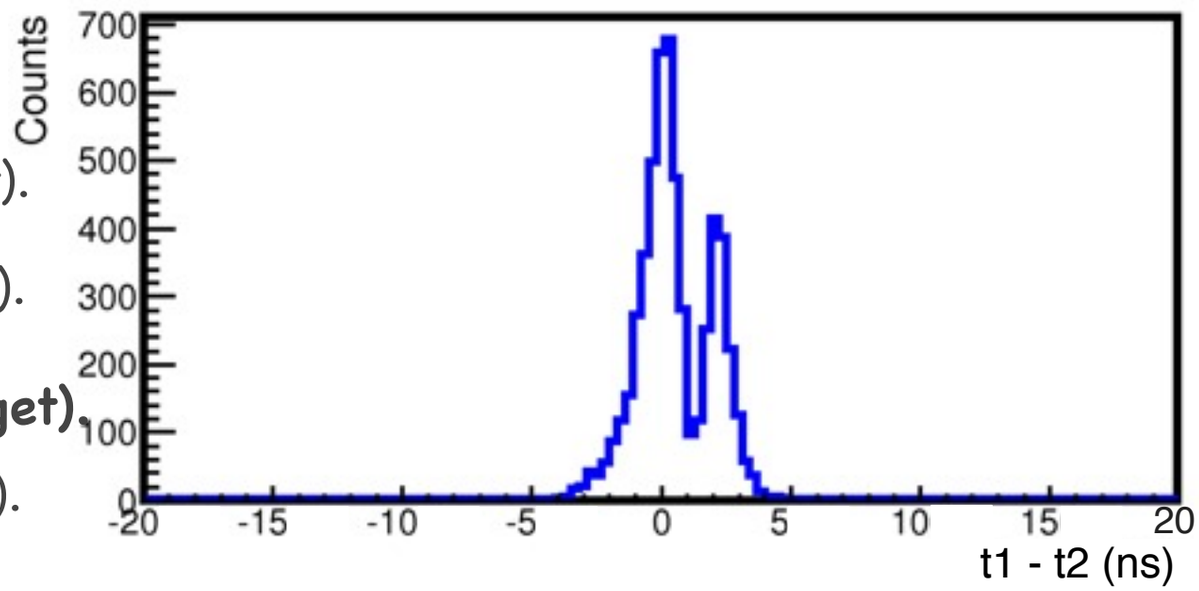

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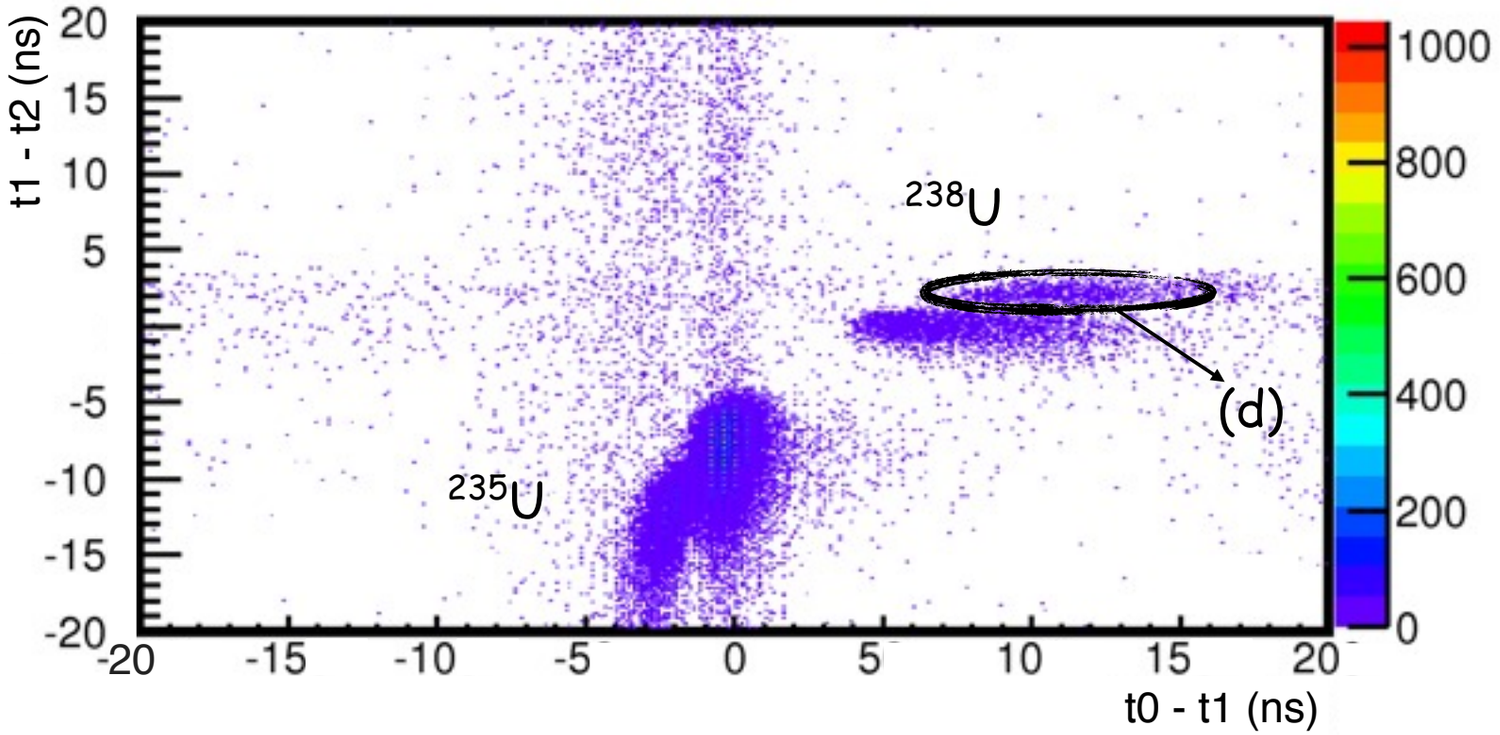

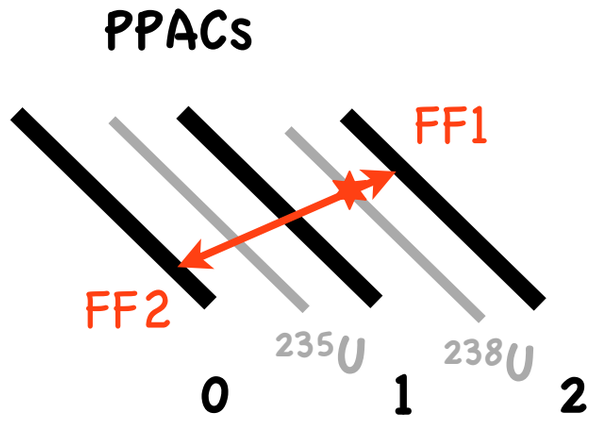

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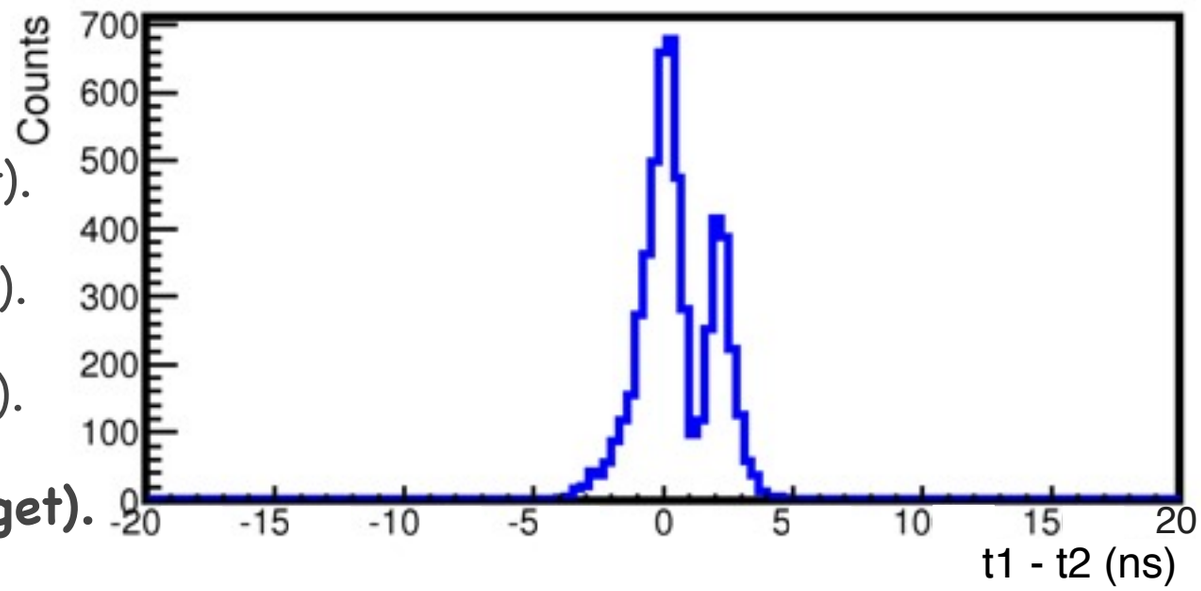


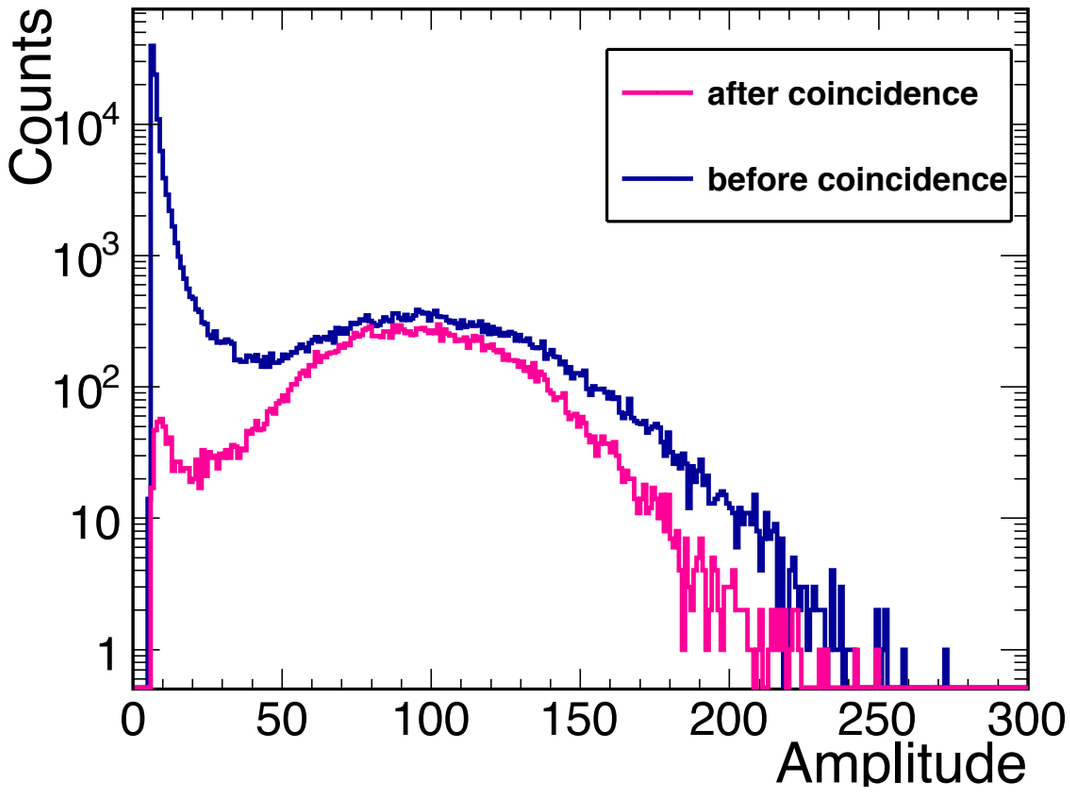
Preliminary results

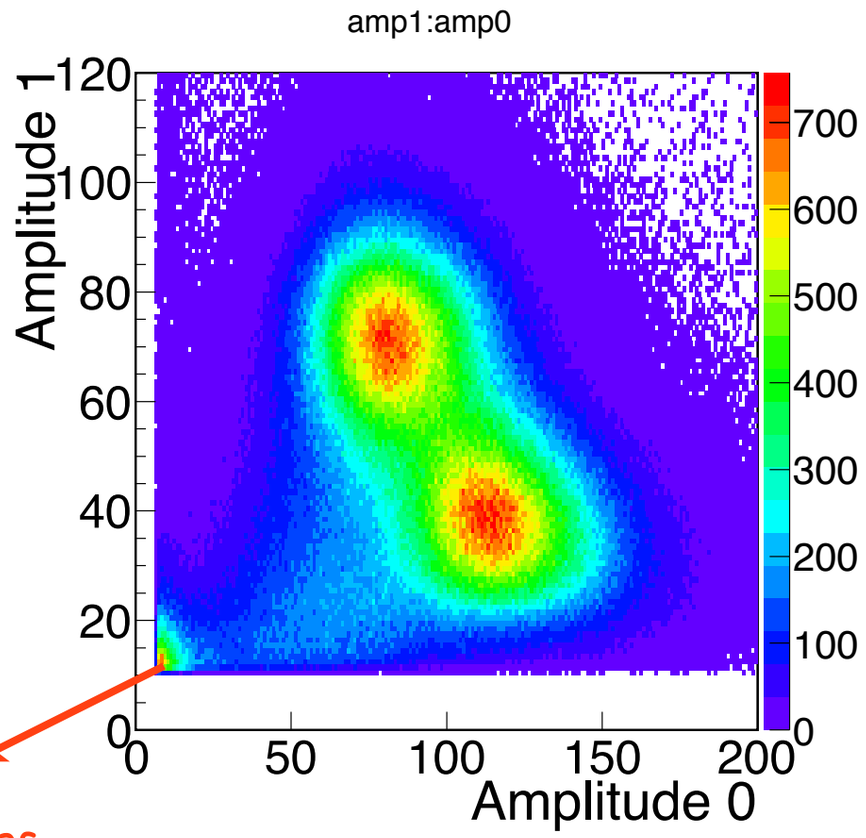
Coincidence detection of the FF

- The PPAC detectors are almost insensitive to gamma rays.

- Detection in coincidence of both fission fragments in two consecutive PPACs.

- The coincidence method allow us to **discriminate** the alpha activity and spallation reactions products.





Random coincidences

Preliminary results

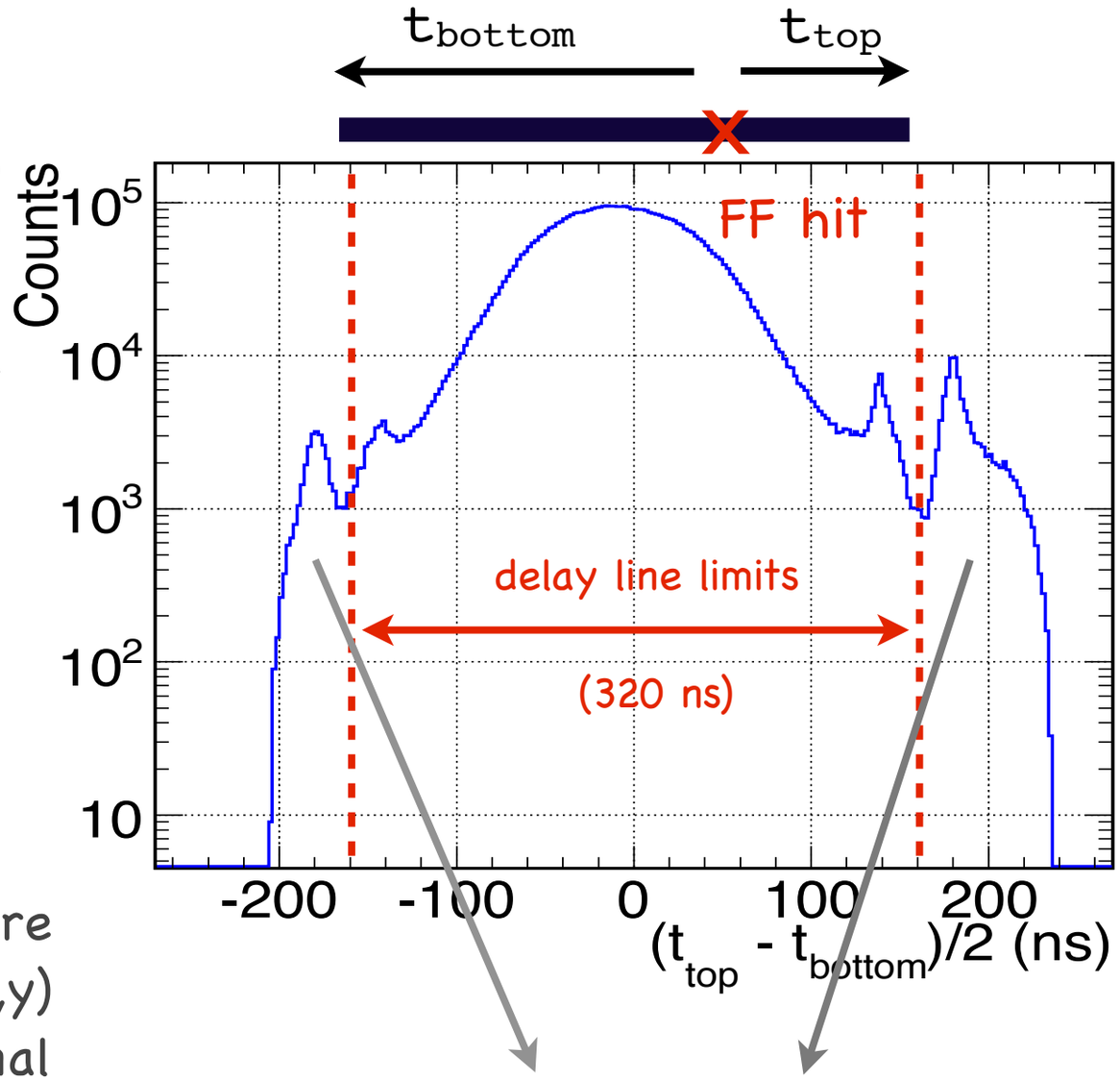
Reconstruction of the FF trajectory

- The Al strips of the cathodes are connected to a delay line, where the signals are propagated, with two preamplifiers at both ends.

- The total delay line length in units of time is 320 ns.

- The FF hit position is obtained from the time difference between the signals reaching both delay line ends.

- The strips in both cathodes are oriented in perpendicular directions (x,y) in order to provide two dimensional information of the position.



Reflections at the connections

Preliminary results

Angular distribution

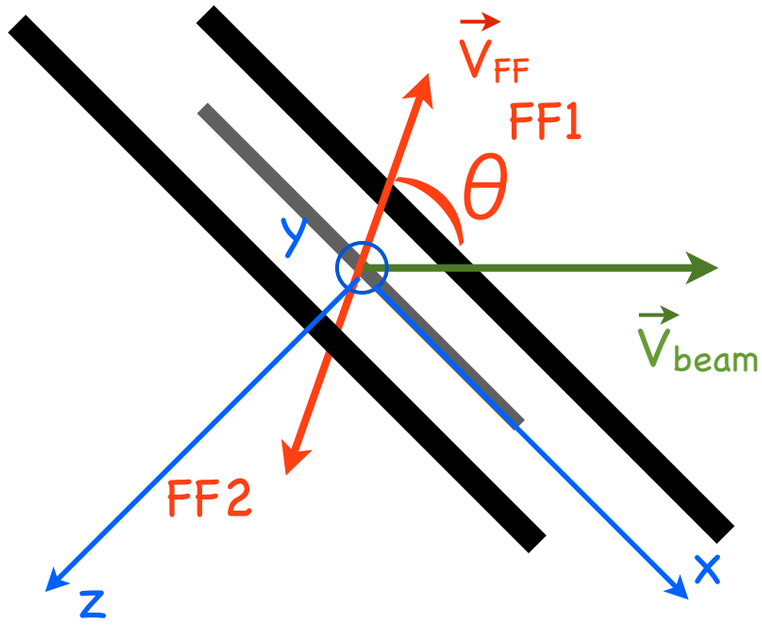
- The knowledge of the FF position in the PPACs (P_0 and P_1) allow us to obtain the emission angle (θ) by reconstructing the FF trajectory.

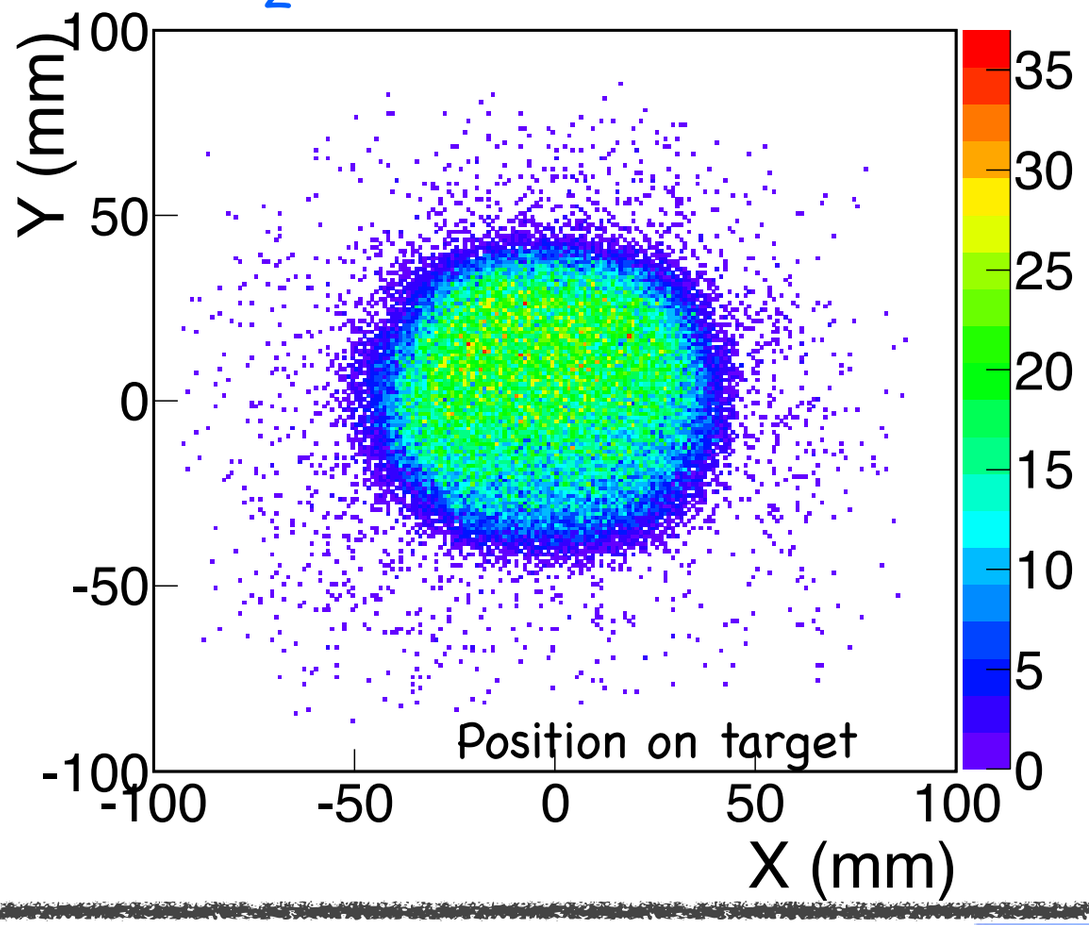
$$\vec{V}_{FF} = (x_0 - x_1, y_0 - y_1, z_0 - z_1)$$

$$\vec{V}_{beam} = (1,0,-1)$$

- The cosθ is calculated as the scalar product of both vectors:

$$\cos\theta = \frac{\vec{V}_{FF} \cdot \vec{V}_{beam}}{\left|\vec{V}_{FF}\right| \cdot \left|\vec{V}_{beam}\right|}$$



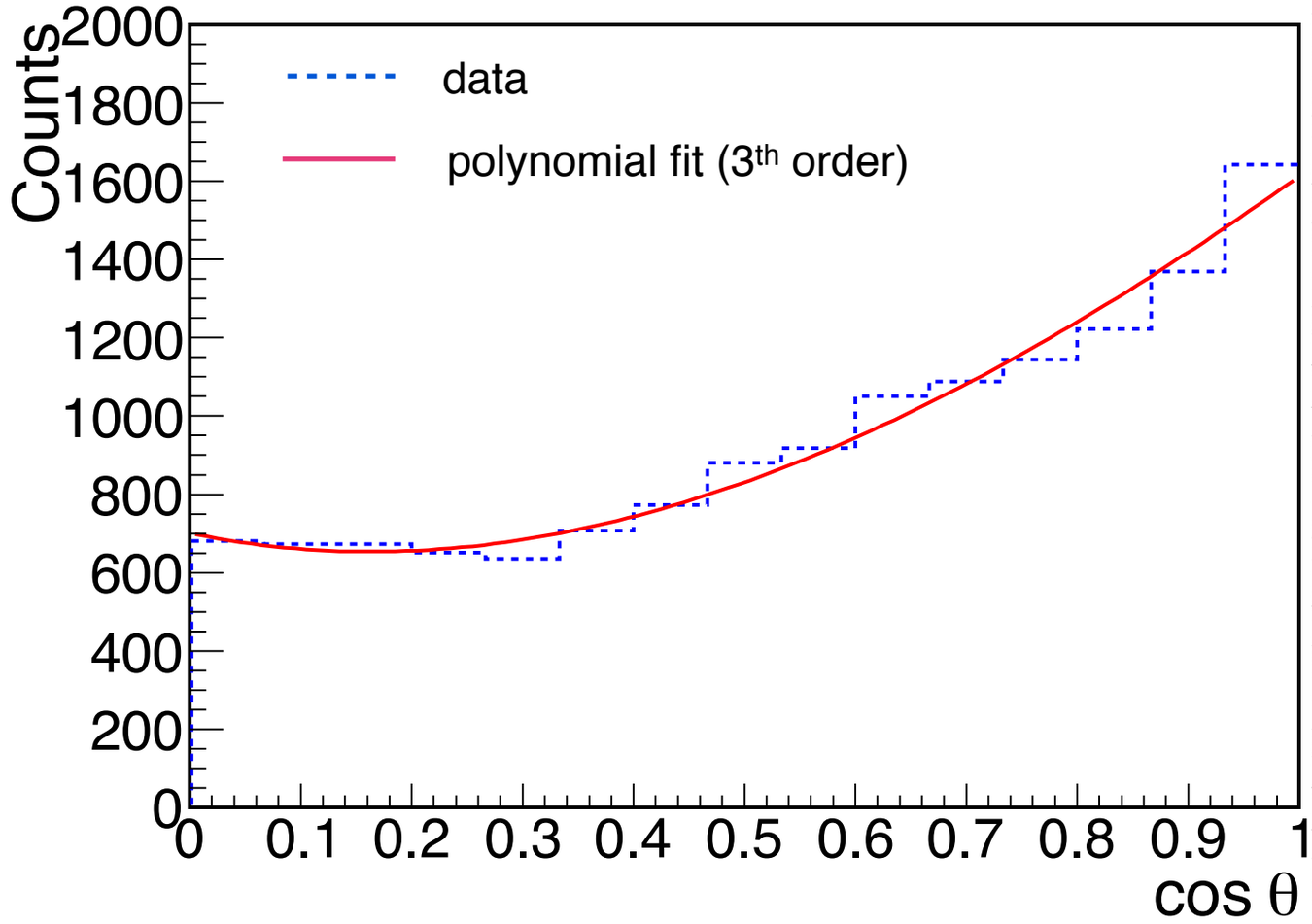


Preliminary results

Angular distribution

- Because the ^{234}U(n,f) FFAD is isotropic at low neutron energies (below 1keV), we used it to characterize the detection efficiency of the tilted setup.

- This efficiency factor is used to correct the angular distributions in the full energy range.



Angular distribution

Preliminary results

- Preliminary results of one of the three ^{234}U targets.

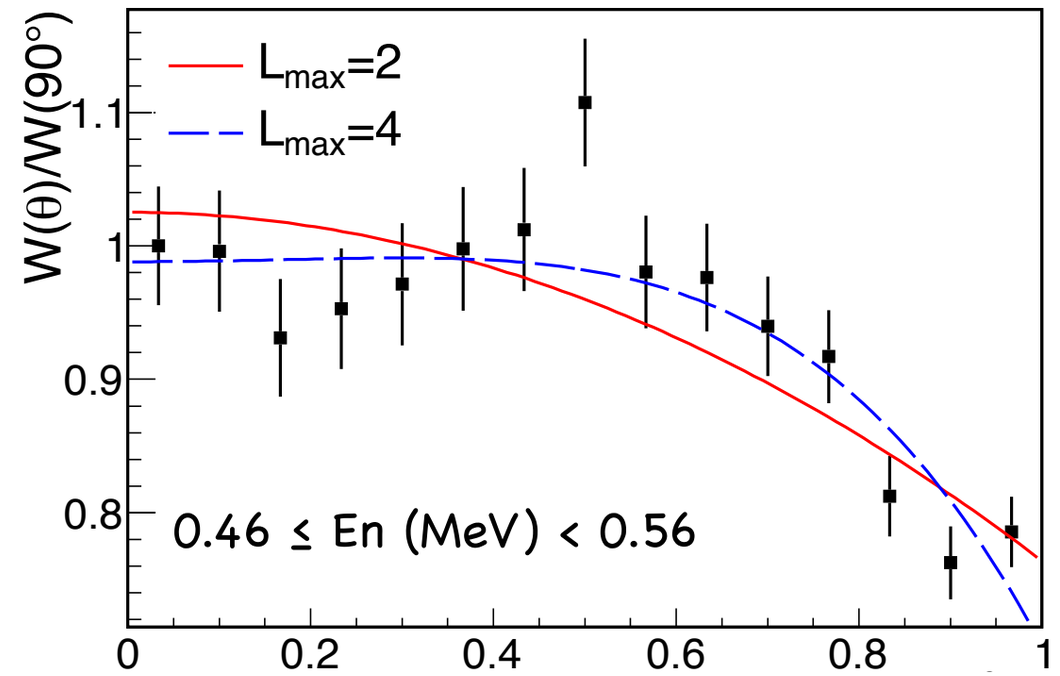
- The cosine distributions have been parametrized by a sum of Legendre polynomials.

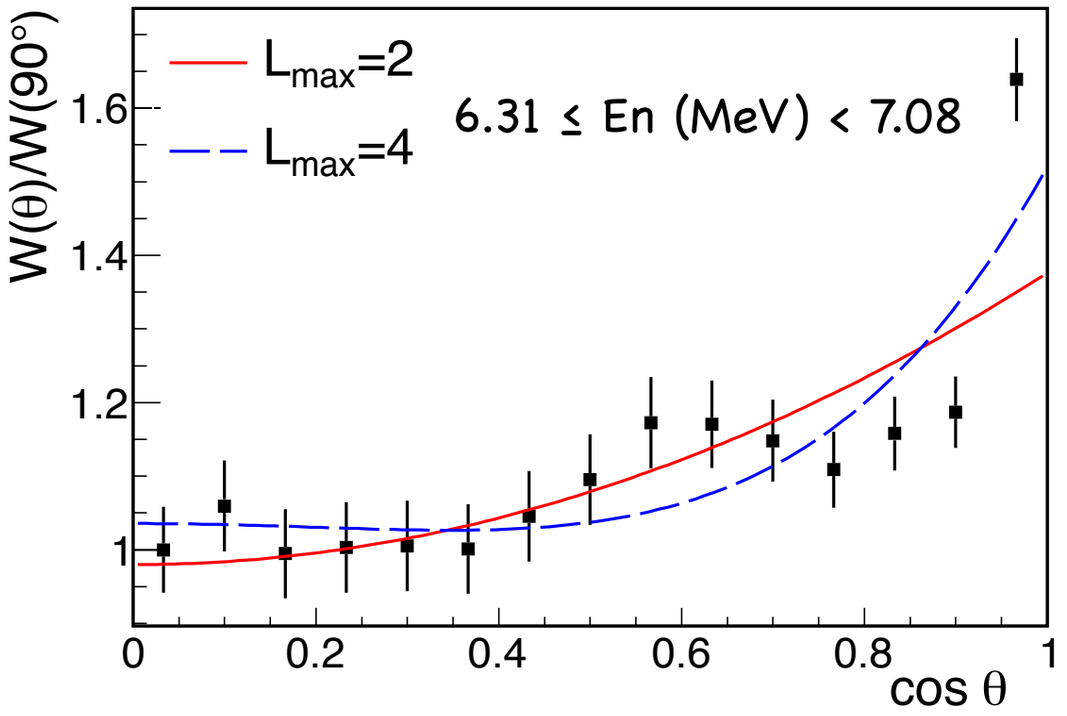
- Only even terms in $\cos\theta$ are considered.

$$W(\theta) = A_0\left[1 + \sum_{L=2}^{L_{max}} A_L P_L(\cos\theta)\right]$$

- Fits up to the 2nd and 4th order polynomials have been performed to calculate the coefficients (A_L).

- The best fit has been chosen in each energy range depending on the value of chi-square.



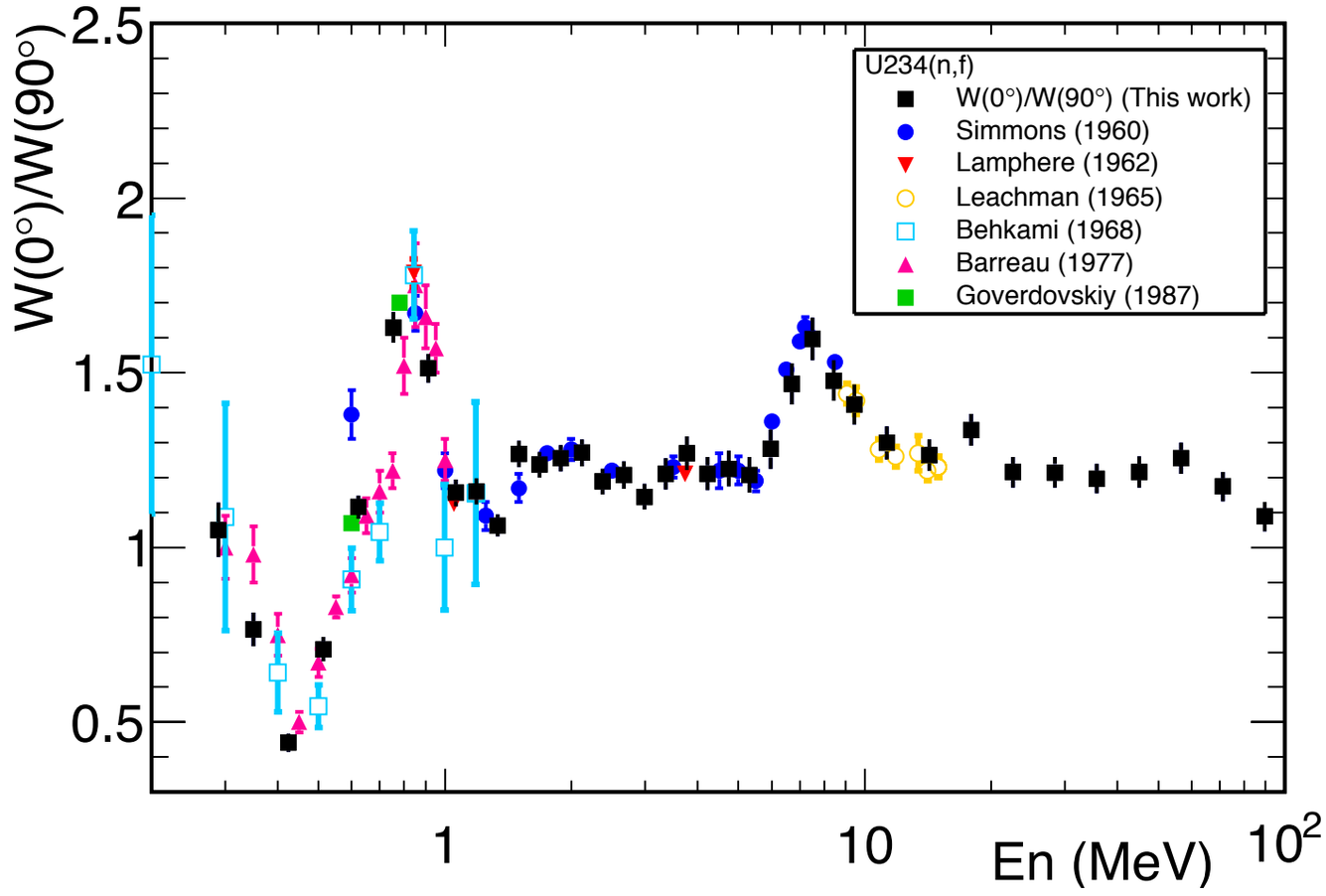


Anisotropy parameter

Preliminary results

- The anisotropy parameter is used to study the behaviour of the angular distribution with the energy.

$$A = \frac{W(0^\circ)}{W(90^\circ)} = \frac{1 + A_2 + A_4}{1 - \frac{1}{2}A_2 + \frac{3}{8}A_4}$$



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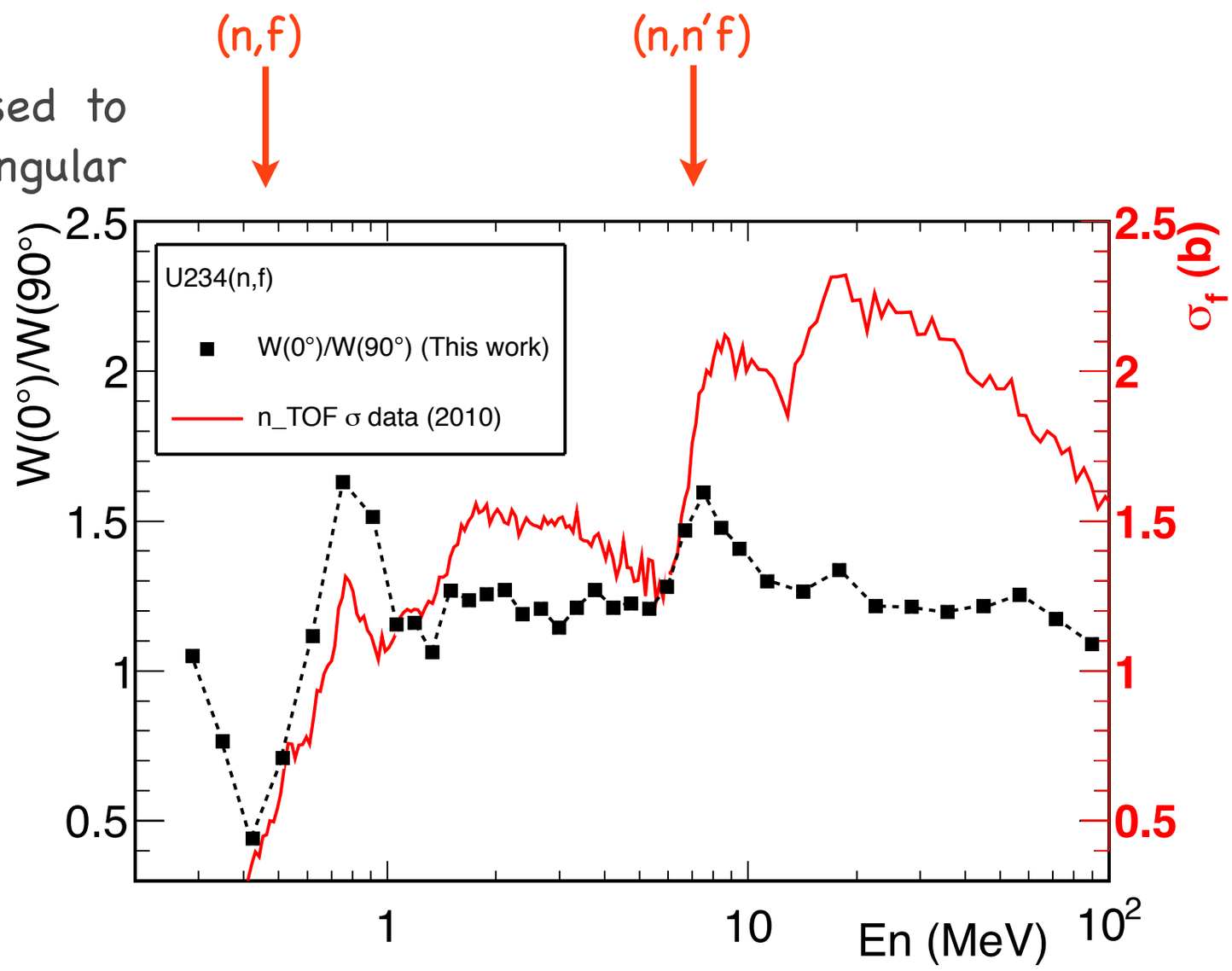
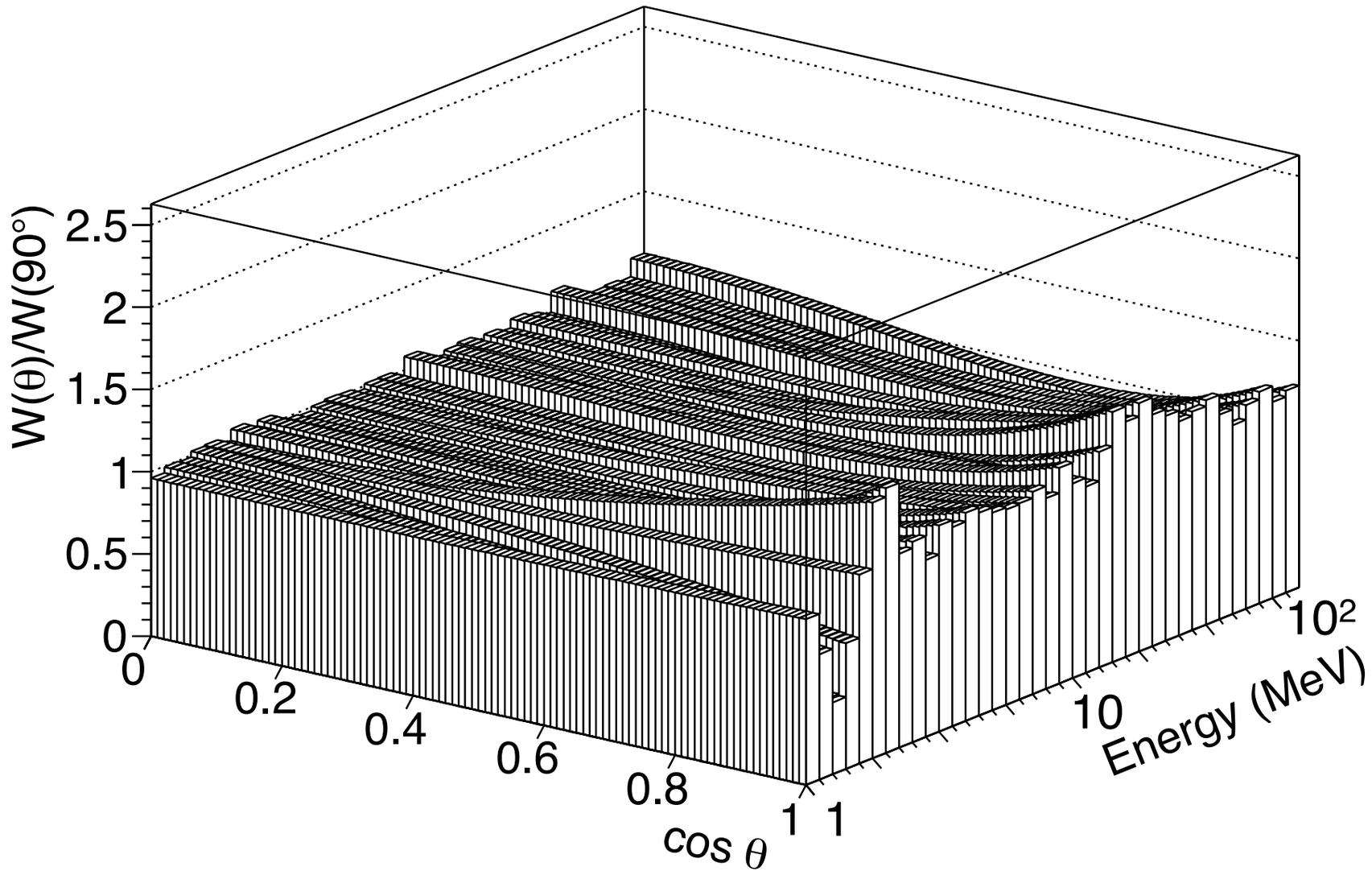


Preliminary results

Anisotropy parameter

- A value of the anisotropy parameter equal to one does not imply an isotropic distribution, but one different to one corresponds to an anisotropic distribution.



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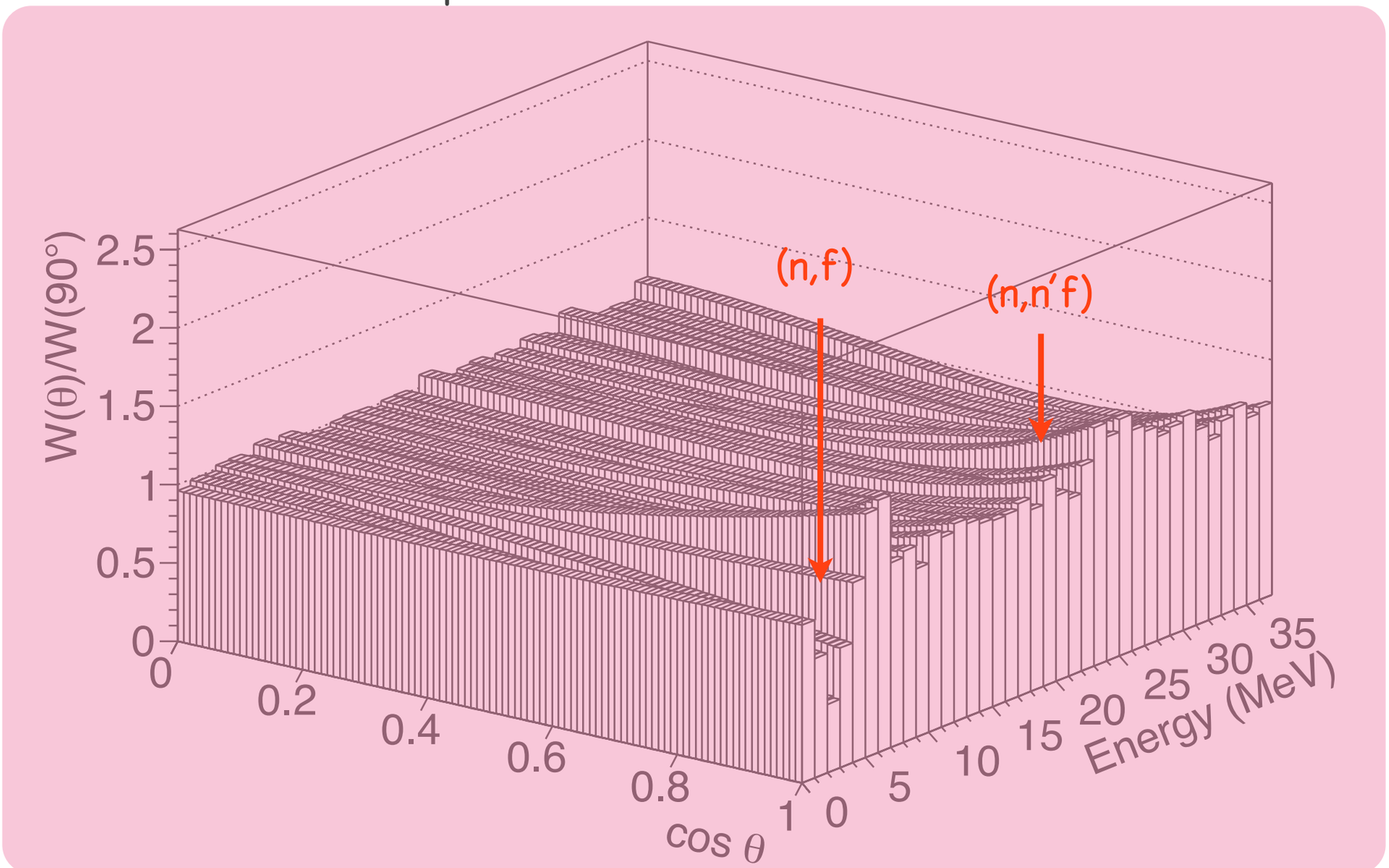

Status and outlook

Conclusions:

- The method has been proved with ^{232}Th [1] and now with ^{234}U.

- The analysis here shown includes only one target of ^{234}U.
  The preliminary result is in good agreement with previous results up to 20 MeV.

- We are confident to provide FFAD reliable data up to 100 MeV.

Outlook:

- To perform the analysis of the three ^{234}U targets in order to increase the statistics and also to analize the rest of the targets (^{235}U and ^{238}U).

- To obtain a more precise value of the cross section and the resonance analysis of the ^{234}U(n,f).

- Test the recent method [2].

- Planned measurements with ^{231}Pa. Experiment possible date will depend on target manufacture by CACAO-Orsay (probably 2015).

[1] D. Tarrío's Thesis.

[2] L.S. Leong's Thesis.