Quasi-free reconstruction of (p,2p) induced fission on 238U : CALIFA + AMS

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R3B Collaboration Meeting. June 2022

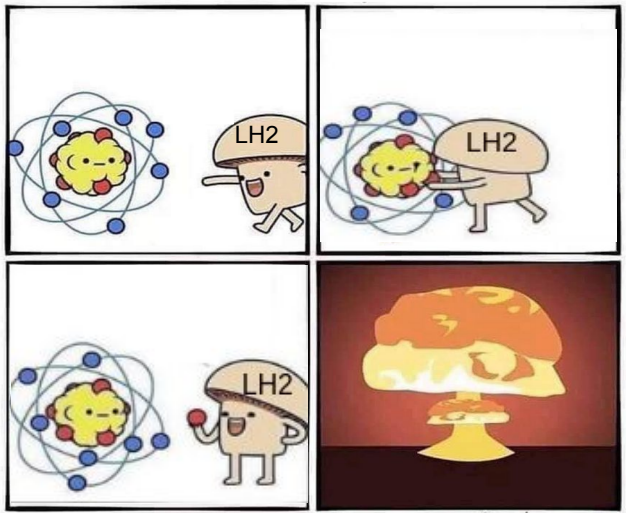
OUTLINE

1. **Introduction**
   - 1.1 Experimental motivation
   - 1.2 Set-up
2. **Analysis of the channel : (p,2p)**
   - 2.1 Event selection in Califa
   - 2.2 Califa correlations
3. **Analysis of the channel : (p,2p) + fission**
   - 3.1 Event selection in Califa
   - 3.2 Twim selection
   - 3.3 Fragment distributions
4. **Some Numbers**
5. **AMS**
6. **Conclusions and next steps**

- Excitation energy of the fissionning system has a huge impact on fission probabilities and observable yields (mass and charge).

- The knowledge of this excitation energy allows to have an insight into the dynamics of the process and into the nucleus structure (shell effects at low temperature)

s455 : Excitation energy reconstruction of fissioning systems through the (p,2p) reaction mechanism



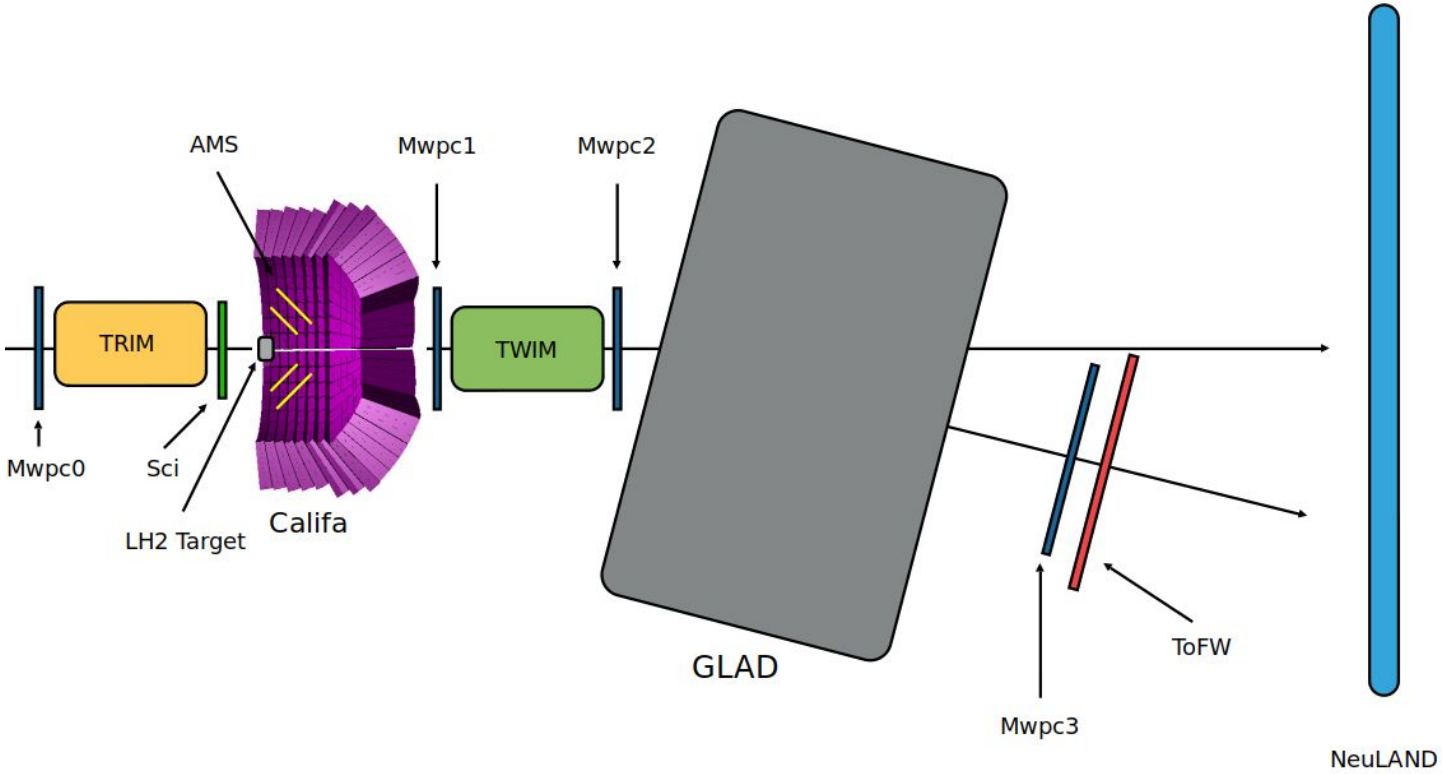
GOALS AND ANALYSIS

- This experiment was designed as a proof of concept for testing the possibility of having quasifree induced fissions.
- Reconstruction of low excitation energies will allow to characterise the fission mechanism (charge and mass distributions, fission yields) and the fission barrier.

Itinerary :

1. Study ^{238}U(p,2p)^{237}Pa (No fission, in green) channel.
2. Learn about the angular and energy correlations in Califa
3. Use this to isolate quasifree from all the knockout
4. Study the fragment charge distribution evolution by selecting these two processes in the ^{238}U(p,2p)^{237}Pa + Fission channel (in red)

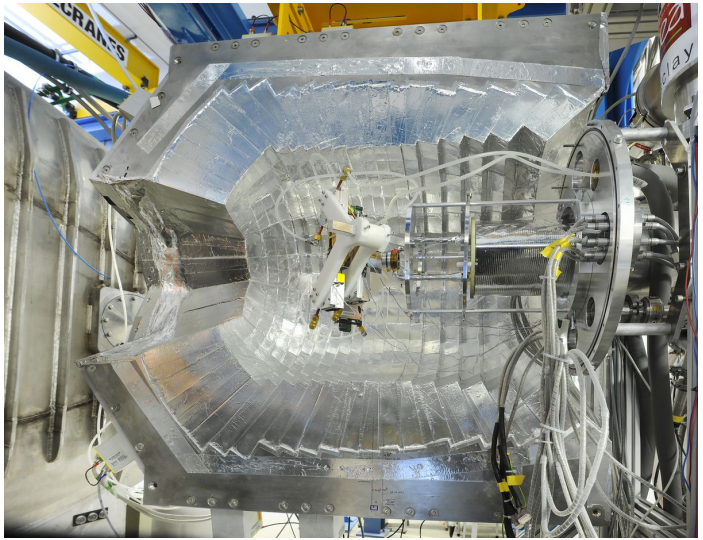
INTRODUCTION : s455 Set-Up



INTRODUCTION : s455 Set-Up

We select the main features of a (p,2p) in Califa .

Then a fine reconstruction is done by using AMS nice granularity -> High precision at reconstructing angles



Picture from Gabi Otto

Some Califanitions (califa slang)

1. Nf & Ns : Fast and slow components . Useful for PID
2. Cluster (or addback) : group of several crystals around a high energy hit (for gammas or protons)
3. Iphos : Forward part of Califa (big crystals). Barrel : rear part
4. Calorimetric energy : energy sum for all crystals in a given event
5. Punch through : particle that cannot be stopped in the crystals and therefore loses only a fraction of its energy (i.e protons)

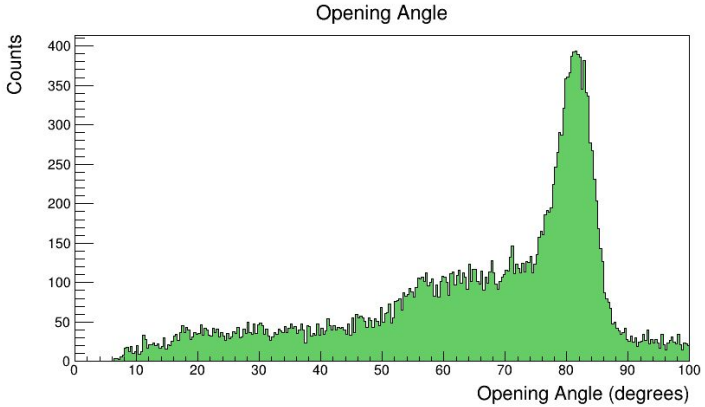
ANALYSIS OF THE CHANNEL: (p,2p)

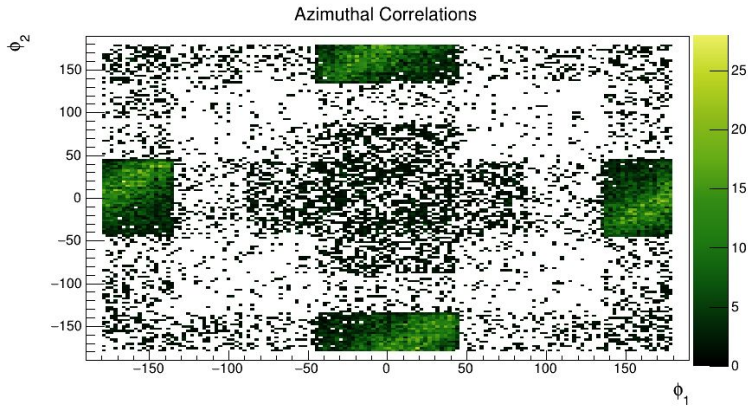
First we take a look to the $^{238}U(p,2p)^{237}Pa$ channel :

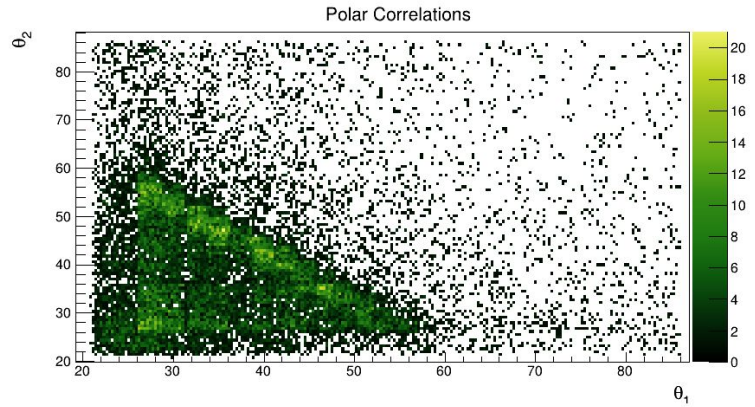
1. TPat 3 (or 9) : START && CALIFA AND && AMS(BUSY_AMS))
2. Calorimetric sum must be under 600 MeV (560 MeV @ target position)
3. Two high energy clusters in Califa

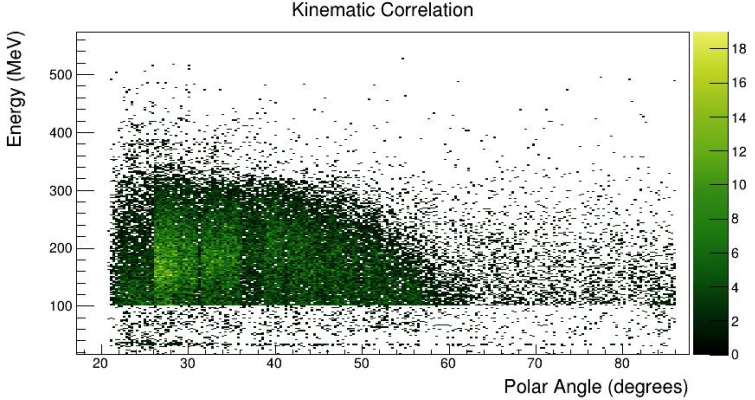
NO more conditions

ANALYSIS OF THE CHANNEL: (p,2p)

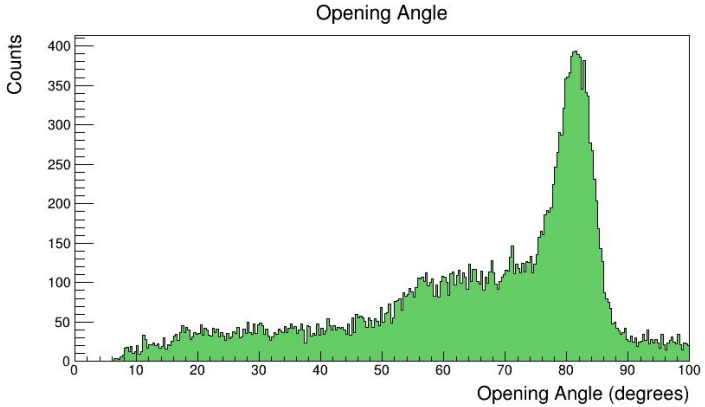


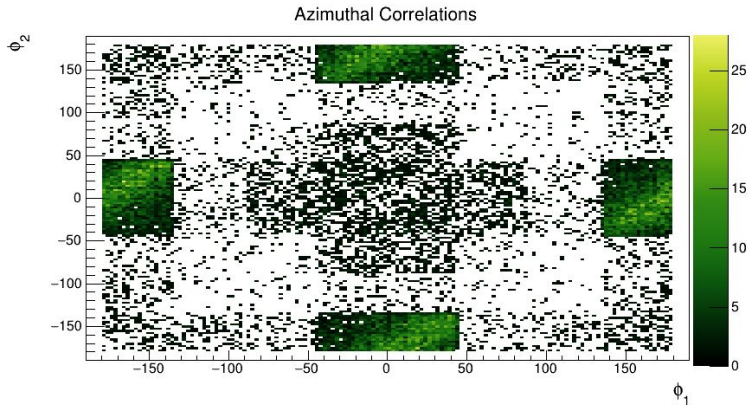


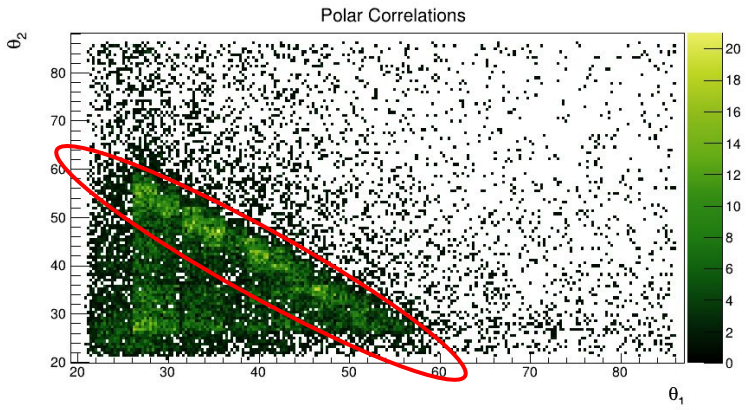


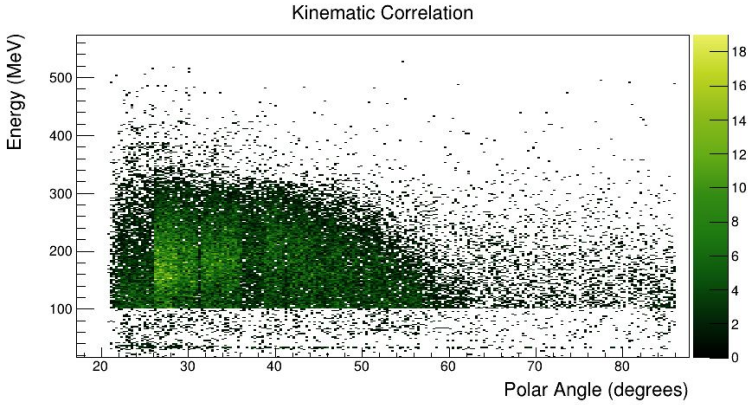


ANALYSIS OF THE CHANNEL: (p,2p)

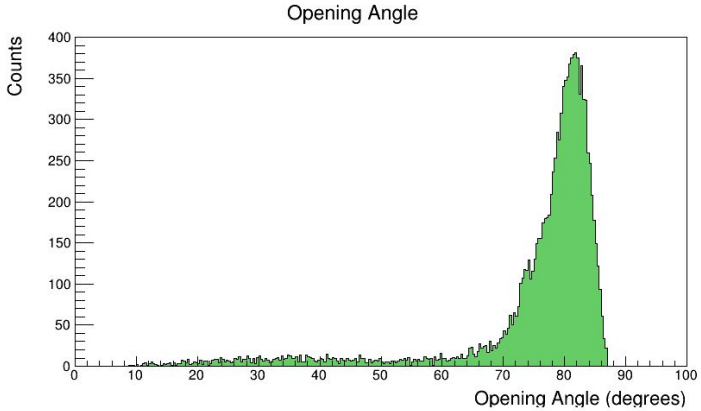


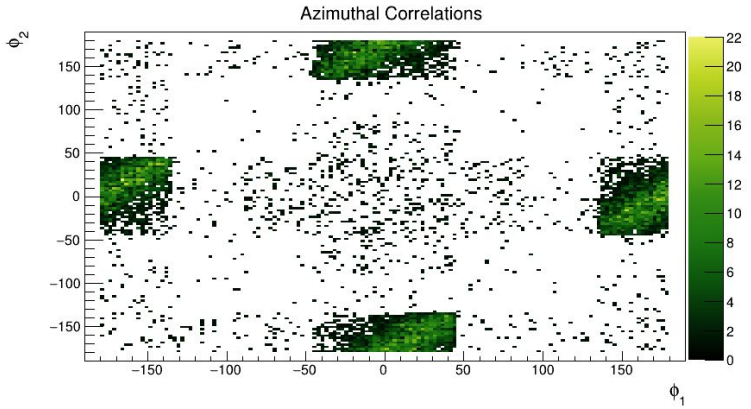


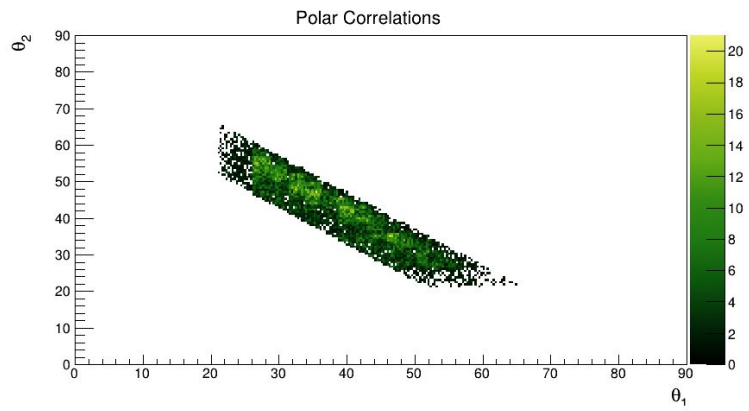


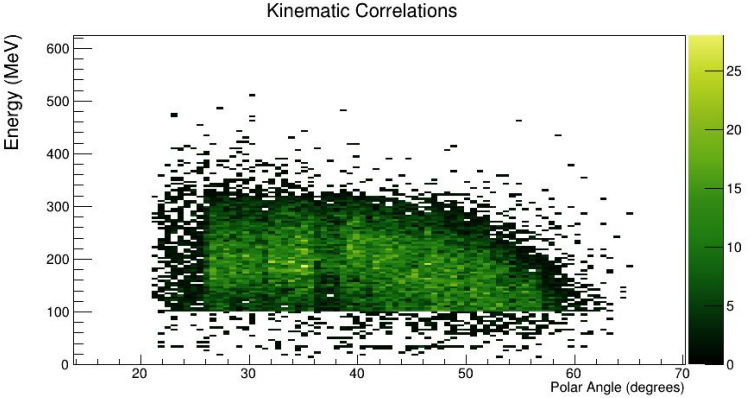


ANALYSIS OF THE CHANNEL: (p,2p)

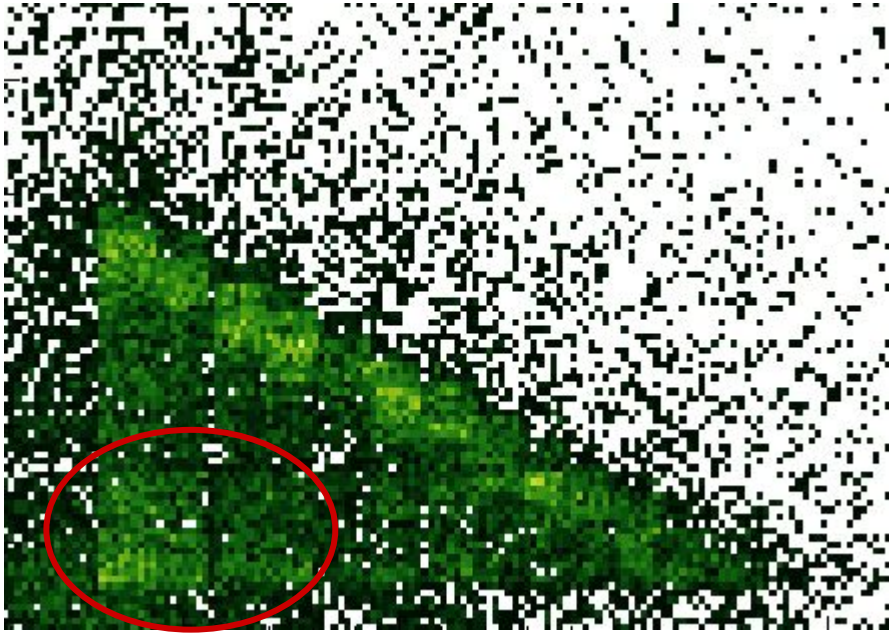




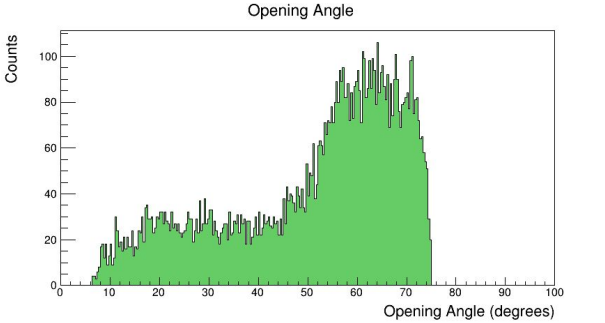


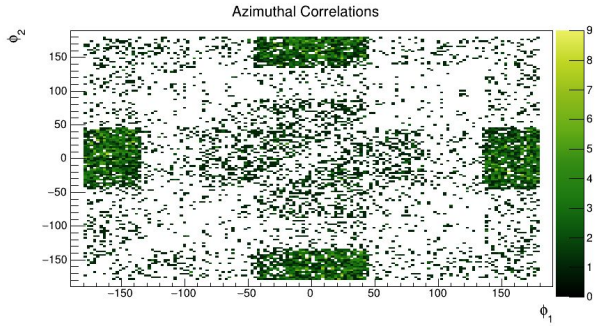


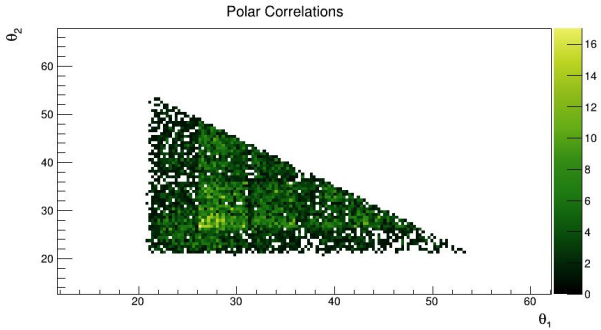
And what about the events at low polar angles?

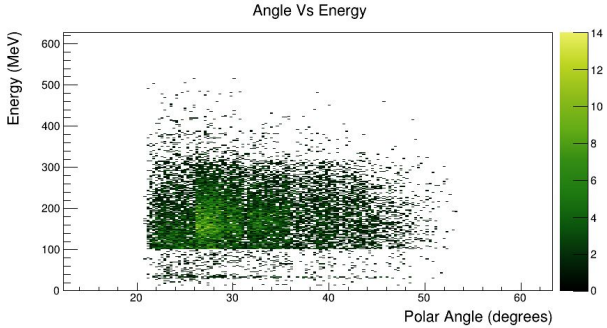


And what about the events at low polar angles? with a cut on this events we get this :





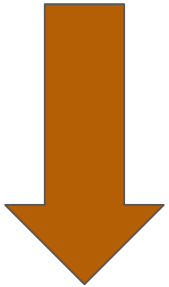




Guess : They are protons (Nf vs Ns and Twim) :
Non quasifree knockouts. Let's wait a little bit….

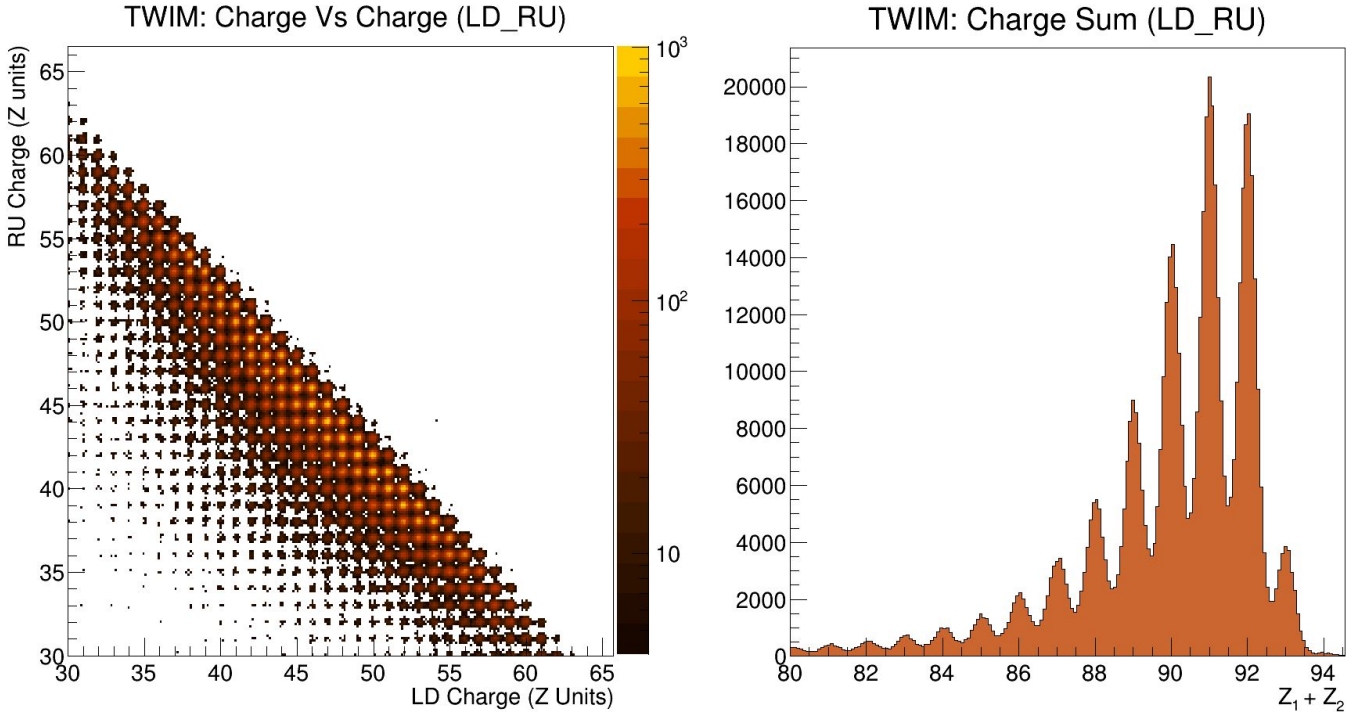
ANALYSIS OF THE CHANNEL: (p,2p) + Fission

PLAN : Study proton correlations and fragment distributions for pure quasifree and non quasifree knockout



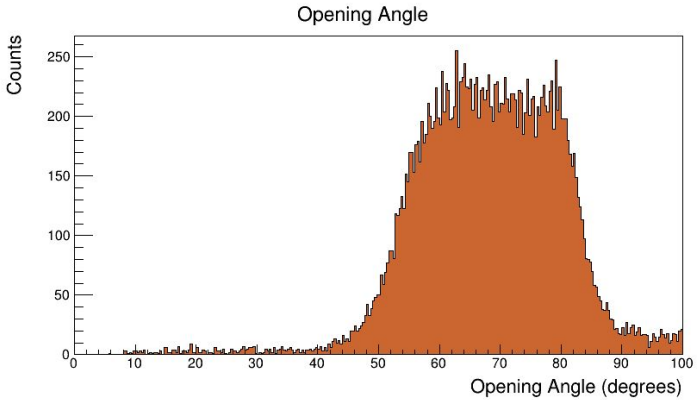
No restrictive cuts for the (p,2p) + Fission (Z1 + Z2 = 91)

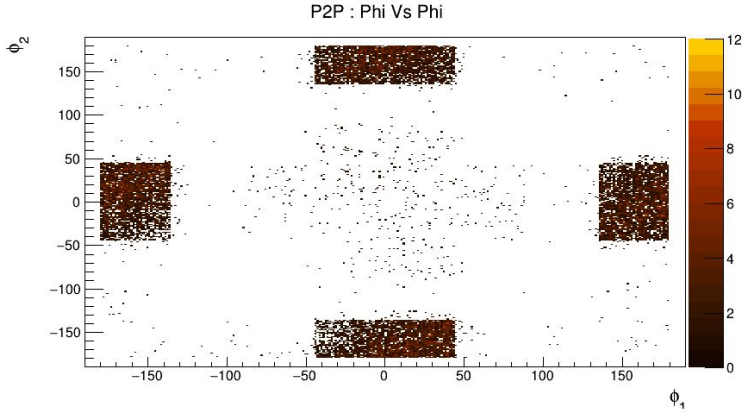
ANALYSIS OF THE CHANNEL: (p,2p) + Fission. TWIM Selection

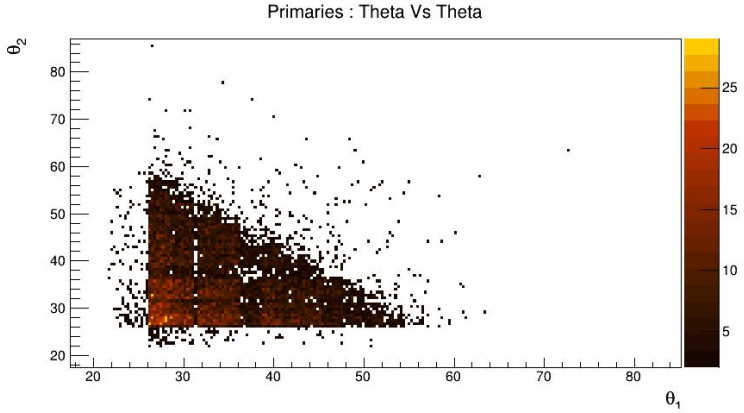


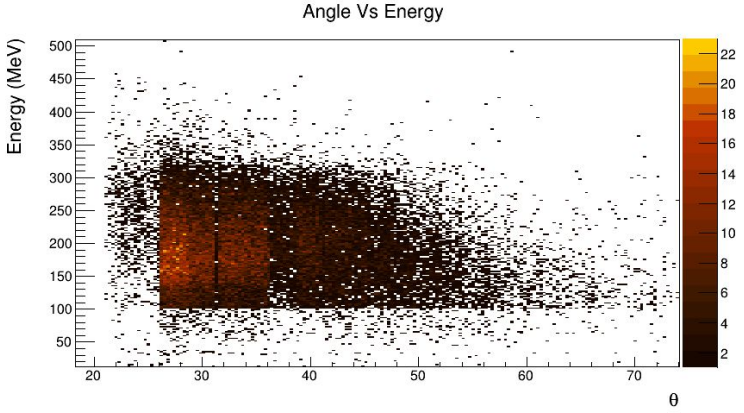
Wonderful calibration for the TWIM courtesy of Antía Graña

ANALYSIS OF THE CHANNEL: (p,2p) + Fission









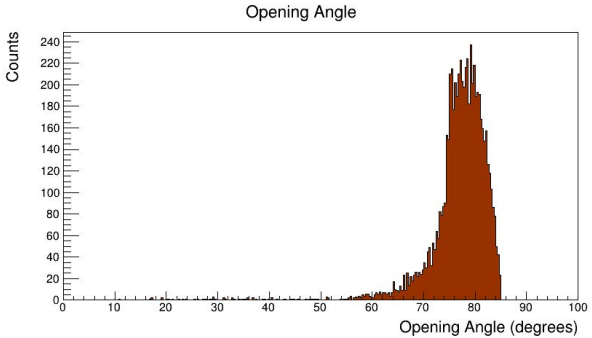
ANALYSIS OF THE CHANNEL: (p,2p) + Fission

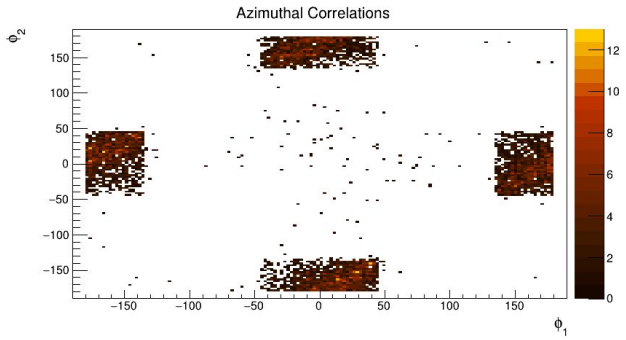
1. This shows that almost all undergoing fissions after a knockout are non quasifree ones.
2. On the same way, the (p,2p) no fission plot shows that a non fissioning channel with knockout will be almost always a quasifree…

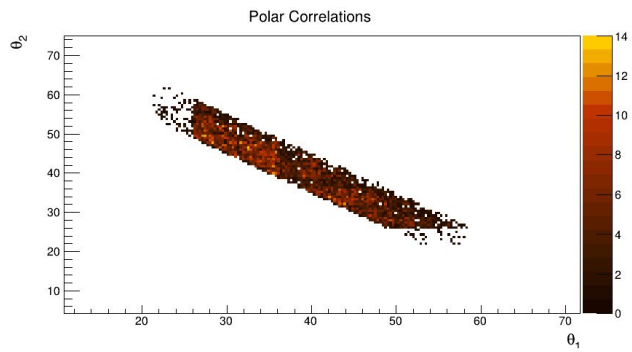
Let’s make some cuts…

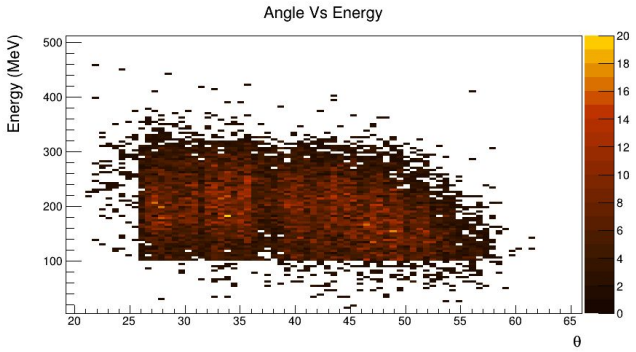
ANALYSIS OF THE CHANNEL: (p,2p) + Fission. Sensitivity to the excitation energy of the nucleus

Quasifree cut :









ANALYSIS OF THE CHANNEL: (p,2p) + Fission. Sensitivity to the excitation energy of the nucleus

Now take a look to the fragment distribution on the TWIM :

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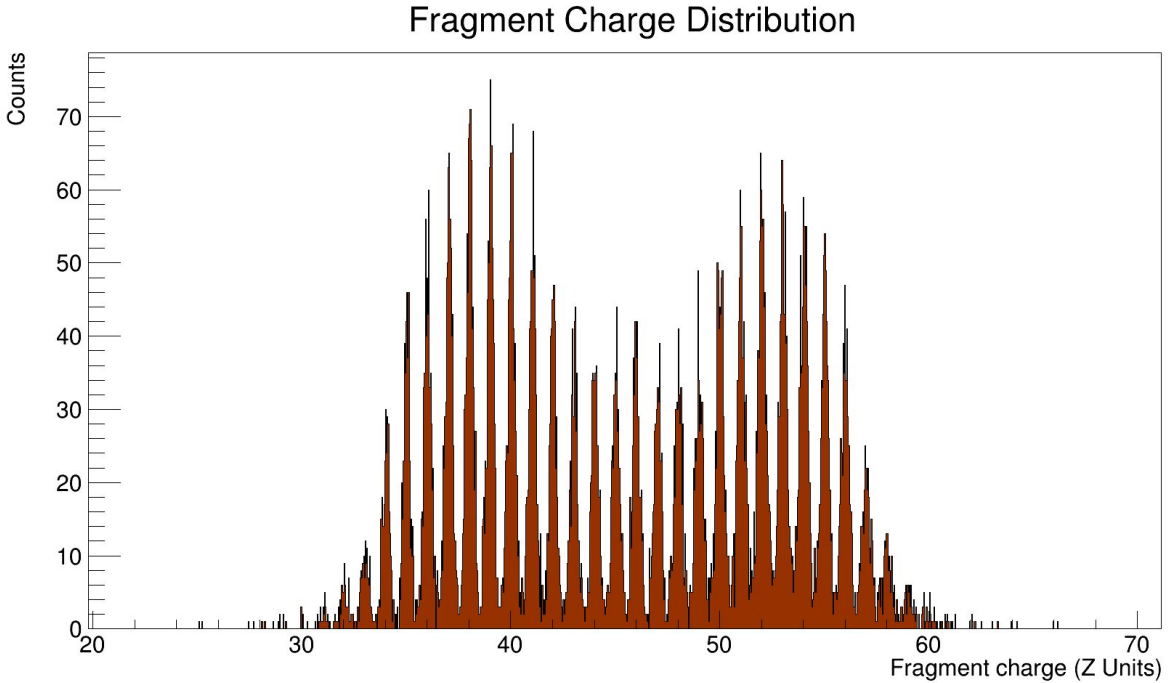

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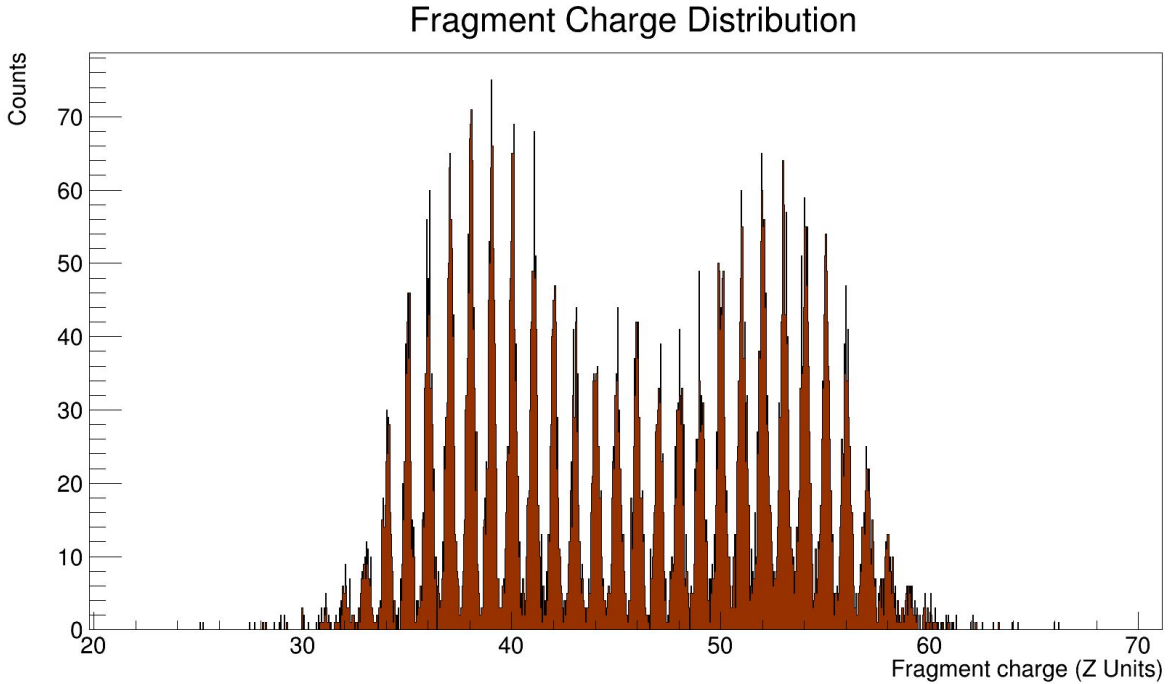

Fission coming from low energy excitation : First evidence of quasifree induced fission!!!

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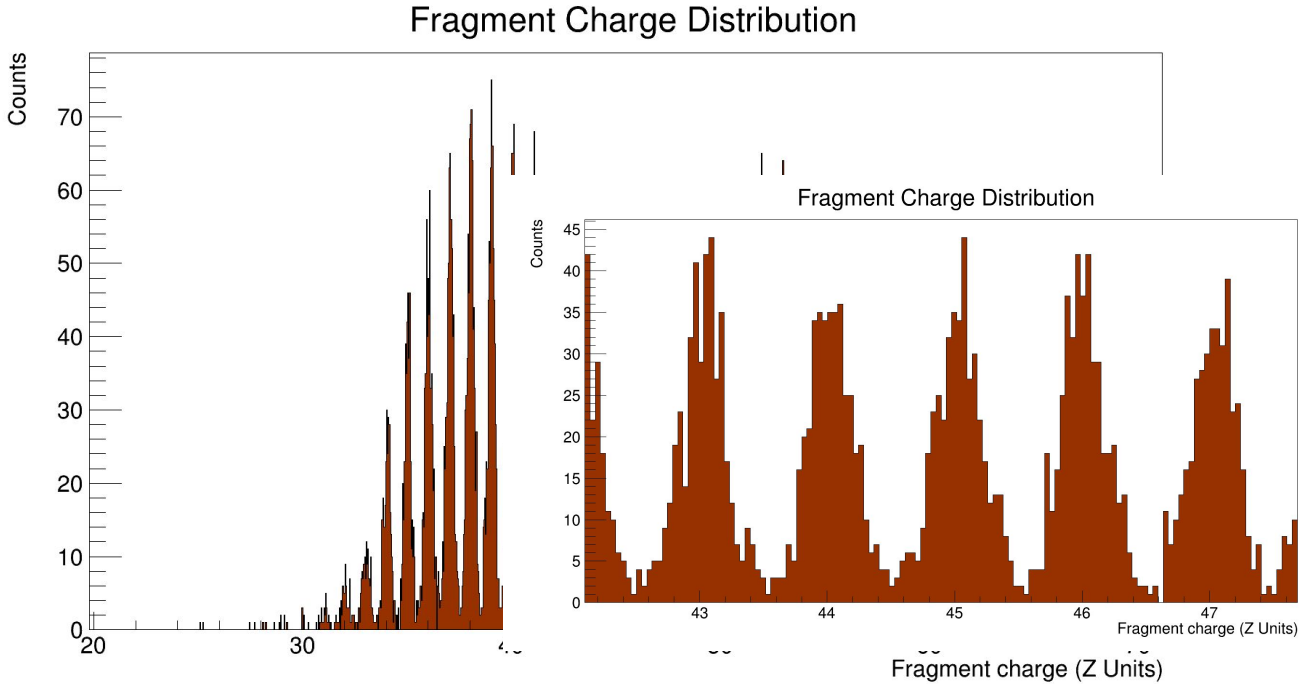


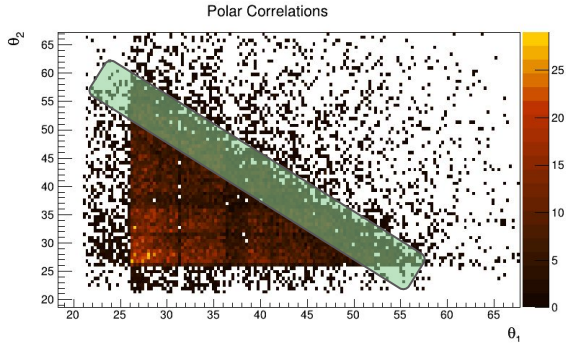
Fission coming from low energy excitation : First evidence of quasifree induced fission!!!

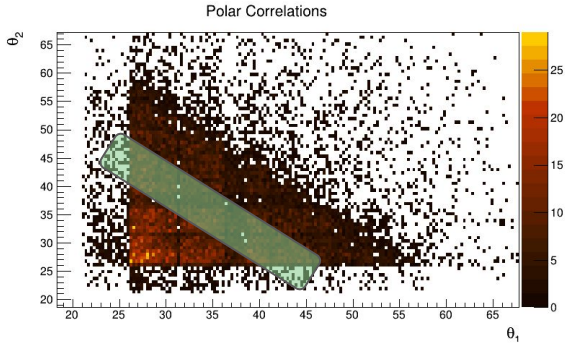
ANALYSIS OF THE CHANNEL: (p,2p) + Fission. Sensitivity to the excitation energy of the nucleus

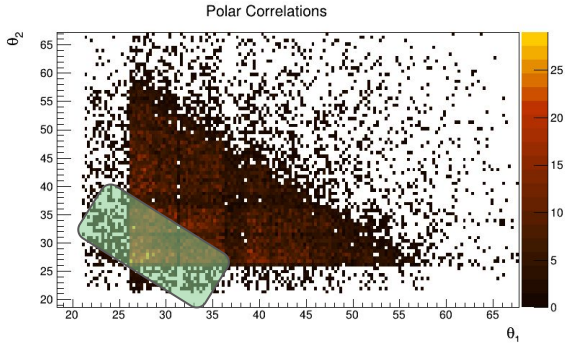
Let’s move the cut…

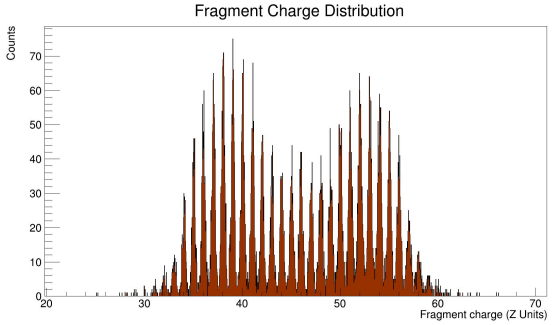
Fission coming from low energy excitation : First evidence of quasifree induced fission!!!

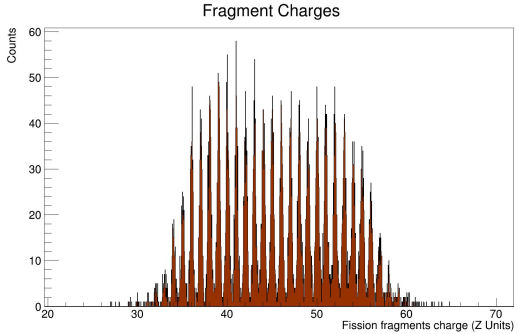
ANALYSIS OF THE CHANNEL: (p,2p) + Fission. Sensitivity to the excitation energy of the nucleus

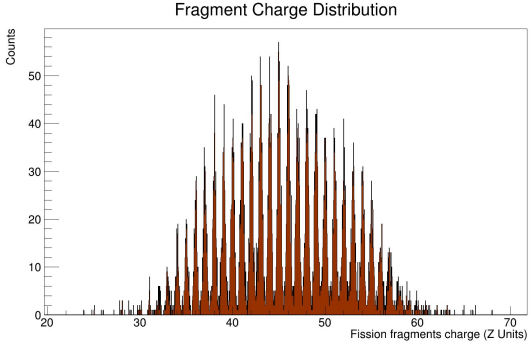












As we move into the non quasifree region the distribution becomes more symmetric :
Higher Excitation energies

CROSS SECTIONS ESTIMATIONS

	Cross Section (mb)
$^{238}U(p,2p)^{237}Pa$	115 ± 20 *
$^{238}U(p,2p)^{237}Pa$ Quasifree	40 ± 7
$^{238}U(p,2p)^{237}Pa$ AND Fission	106 ± 18 *
$^{238}U(p,2p)^{237}Pa$ AND Fission AND QF	24 ± 4

* = not corrected by califa efficiency for knockout, but for quasifree efficiency from simulations

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PRELIMINARY ESTIMATION

* = not corrected by califa efficiency for knockout, but for quasifree efficiency from simulations

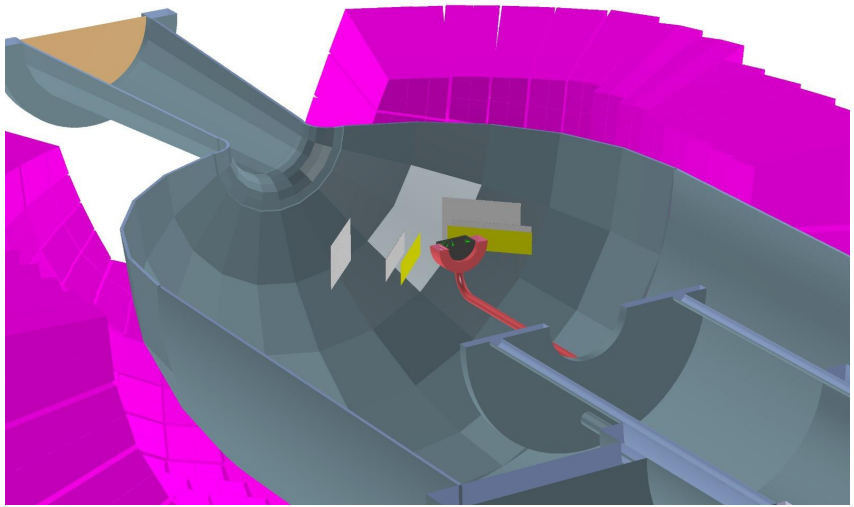
AMS ANALYSIS

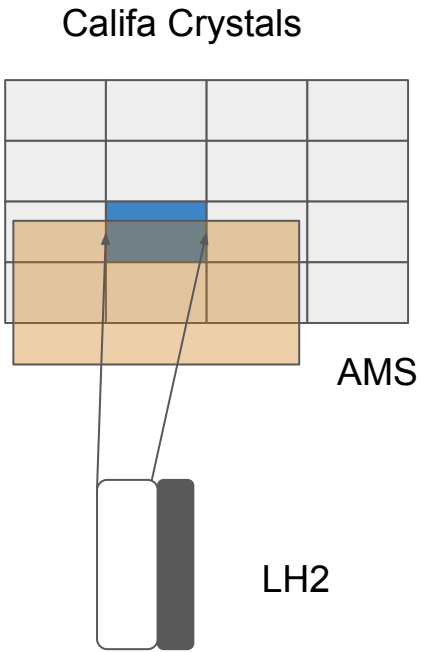
1. After a good identification in Califa, we started to look at AMS -> Critical for excitation energy reconstruction
2. We knew from simulations that delta electrons would be a problem , so a couple of gold layers were put in front of the inner detectors
3. Still some more deltas than expected….
4. But conditions on califa high energy hits for crystals behind AMS helped! -> ongoing analysis an procedures!

IDEA:

1. Select events with high energy deposition in crystals behind rear planes of AMS
2. Perform all combinations for K and S strips

AMS ANALYSIS





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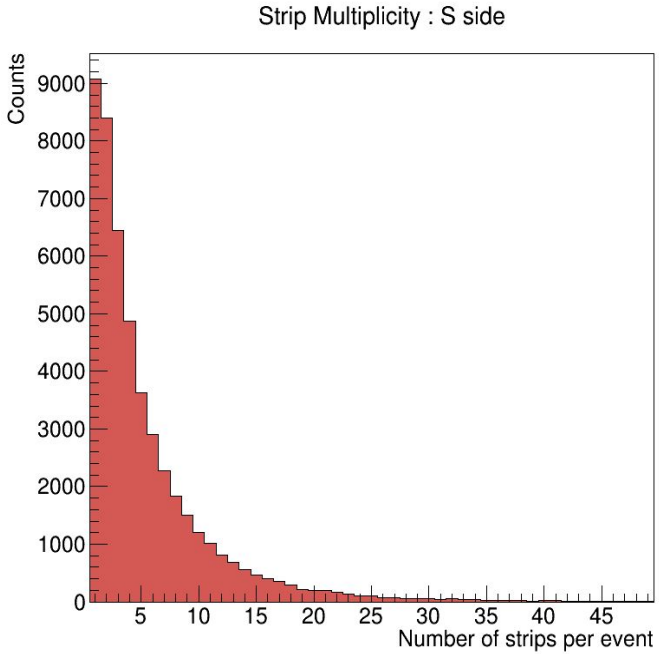

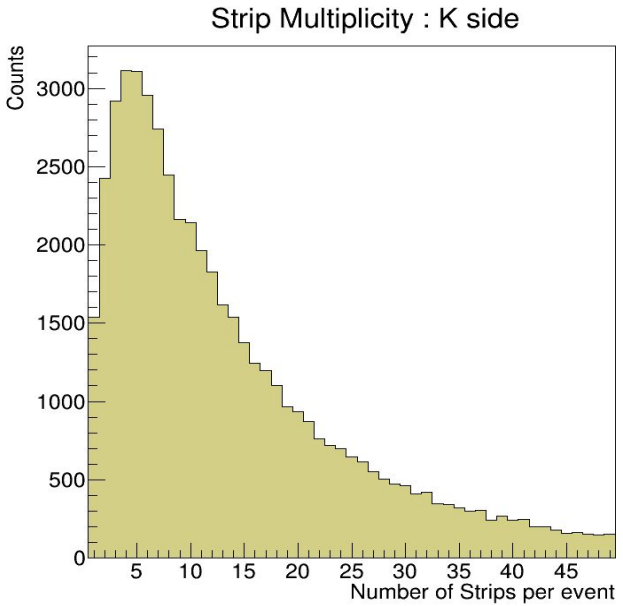

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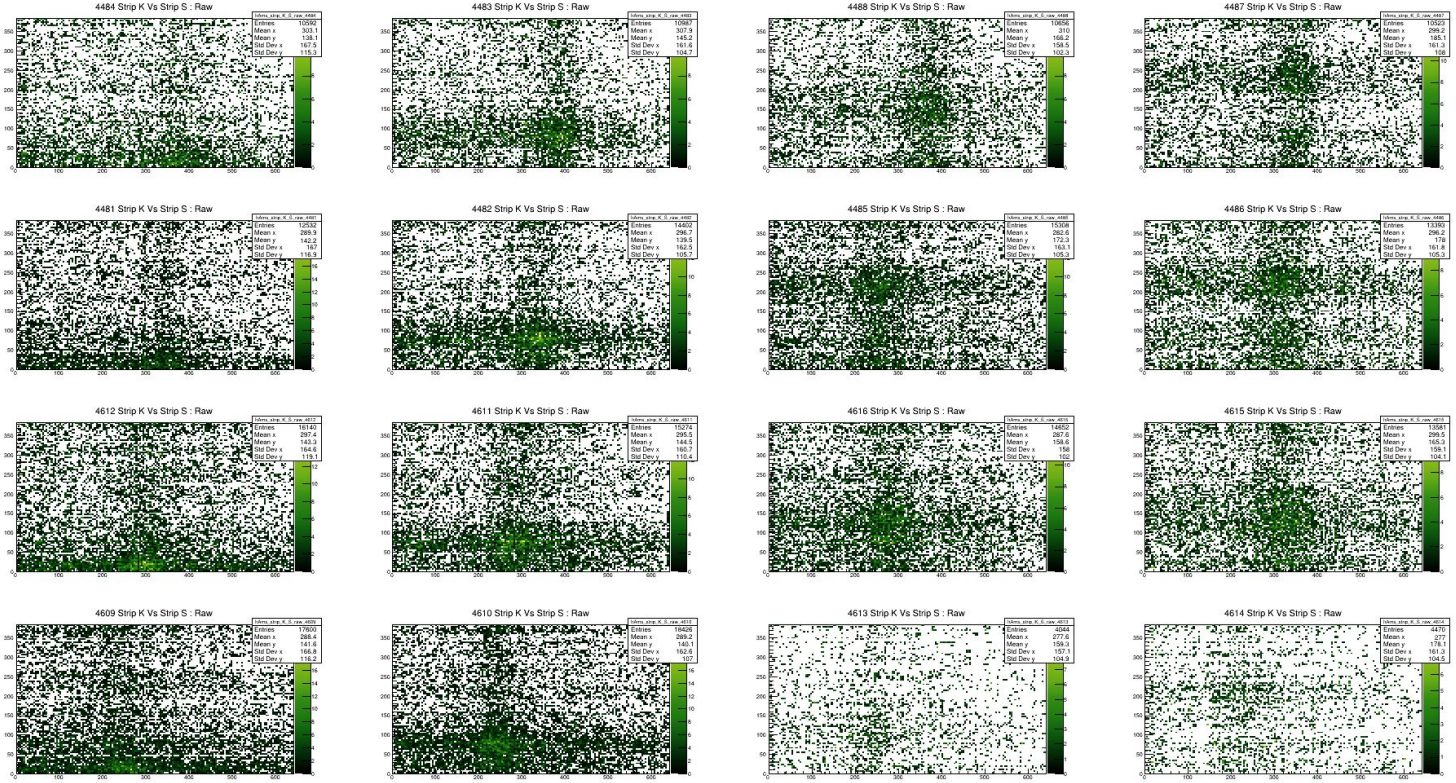

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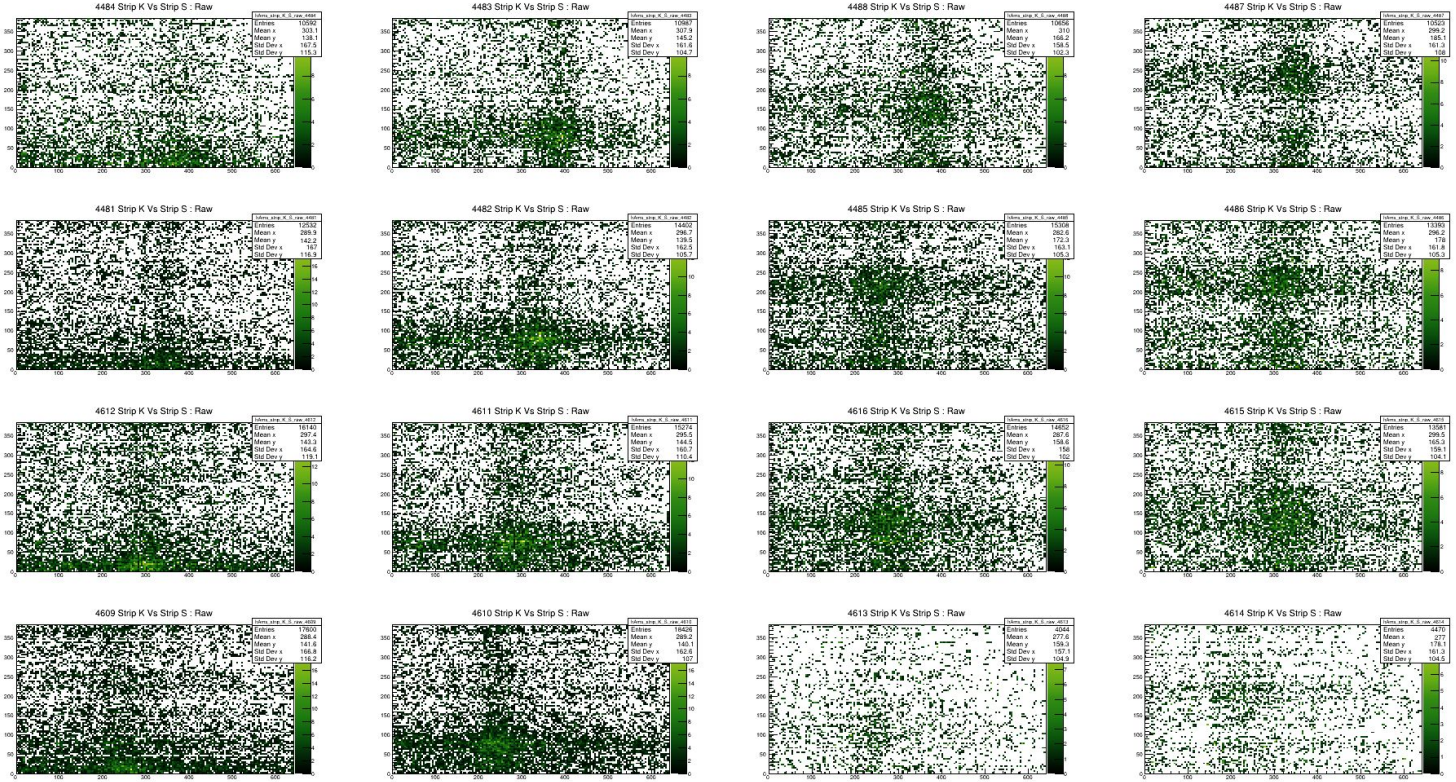


Still non trivial problem….

CONCLUSIONS

1 . Succesful results for quasifree induced fission reactions. Really nice evolution of the fission fragments according to selections in Califa.

2. Califa (p,2p) selection works well, and allows to charactherise the main correlations for this type of reactions.

3. Preliminary cross sections are in good agreement with predicted values.

4. Proof of concept for future (p,2p) fission experiments at GSI-FAIR with neutron rich heavy nuclei around N = 152 to constrain :

- Fission barrier heights
- Fission yields

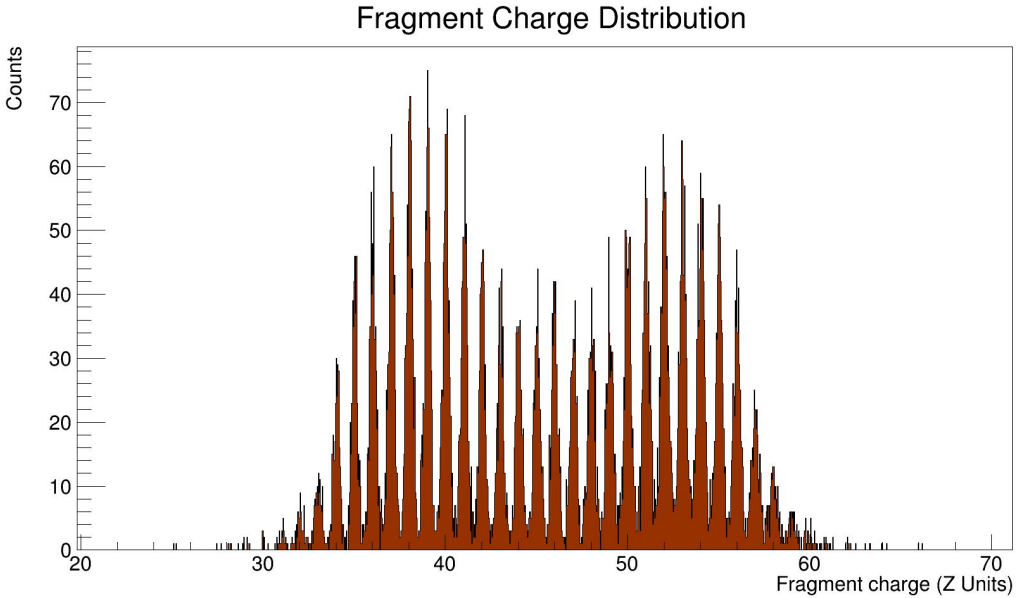
NEXT STEPS

1 . AMS Reconstruction

2. Punch-through in CALIFA

3. Improve quasifree and knockout selection criteria

THANKS FOR YOUR TIME!



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