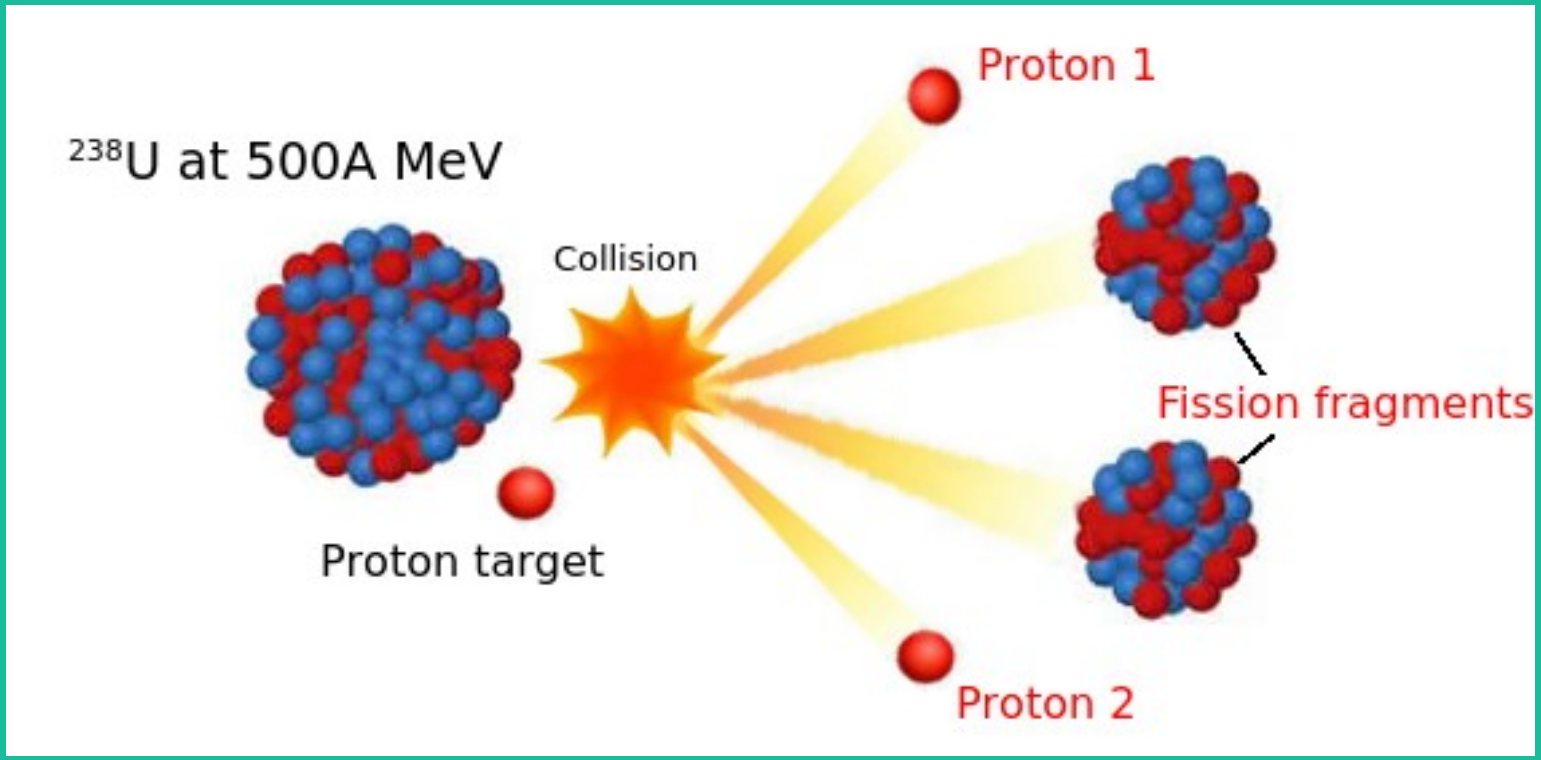


Simulation of (p,2p) reactions for fission studies: Reconstruction with ALPIDE detectors

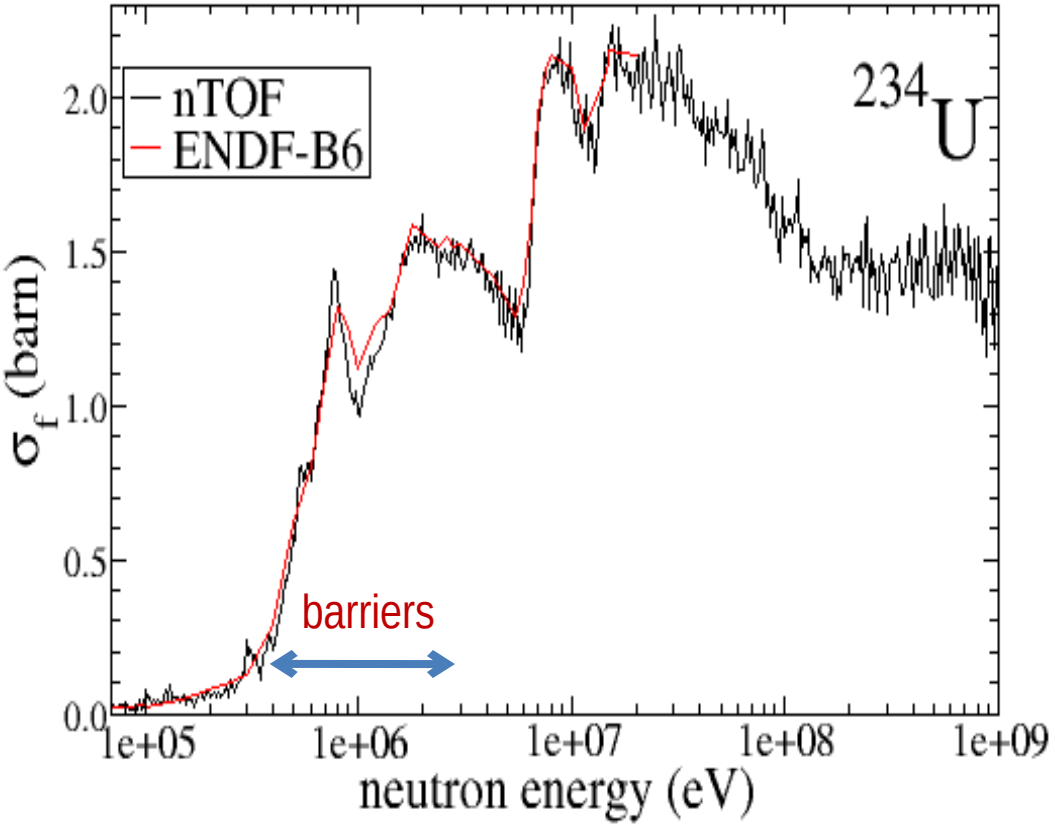
José Luis Rodríguez-Sánchez
University of Santiago de Compostela
3rd December 2020

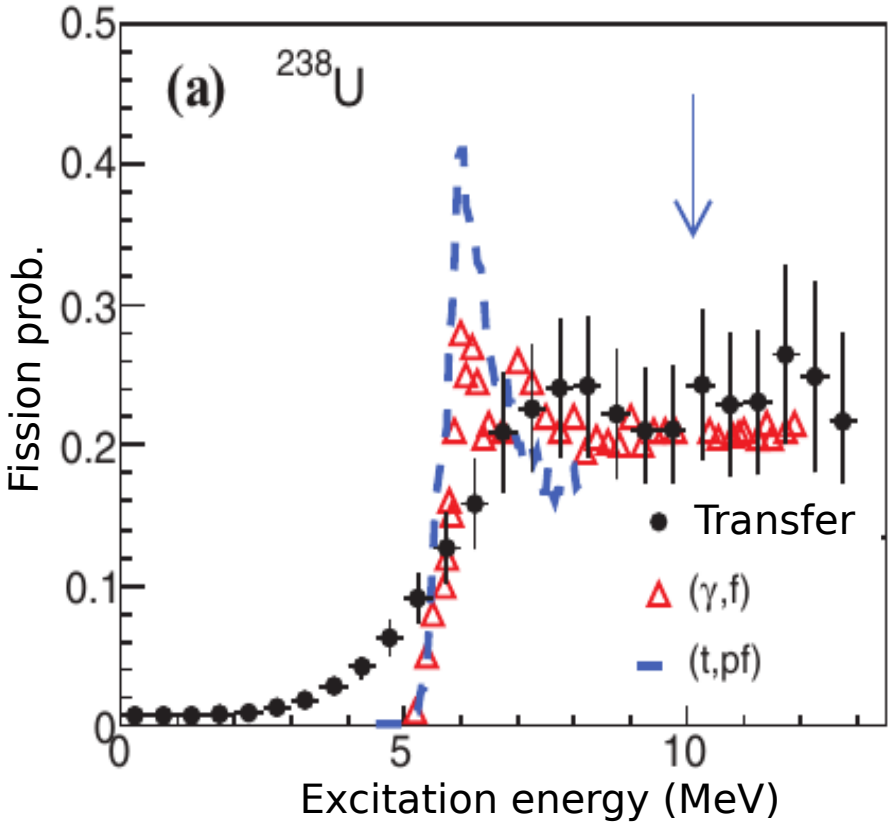
R3B IGFAE Instituto Galego de Física de Altas Enerxías USC Universidade de Santiago de Compostela XUNTA DE GALICIA

What could be investigated

Fission barriers

- Most of the measurements were performed in direct kinematics within neutron induced fission reactions or using transfer reactions
- Only experimental data for stable nuclei with resolutions from few keVs to 3 MeV



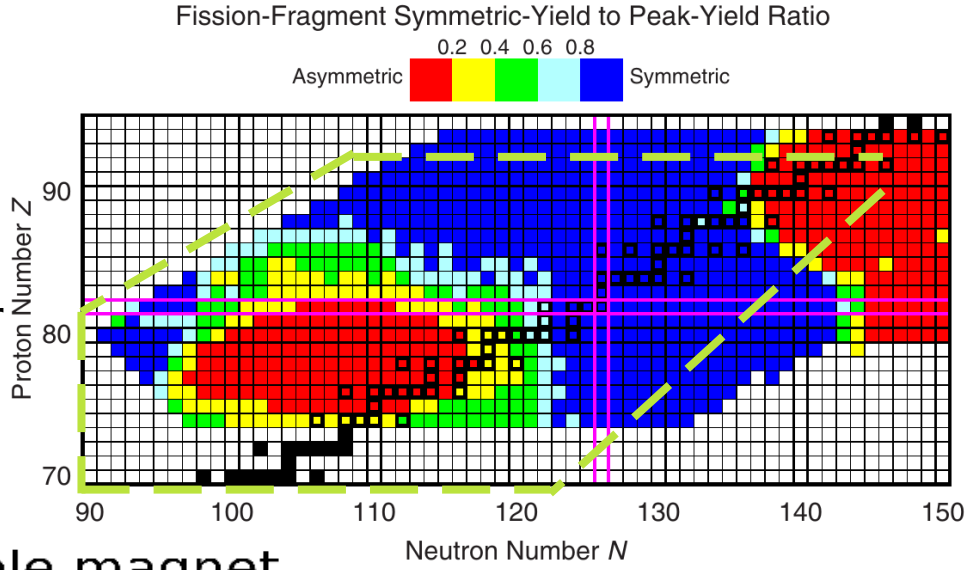


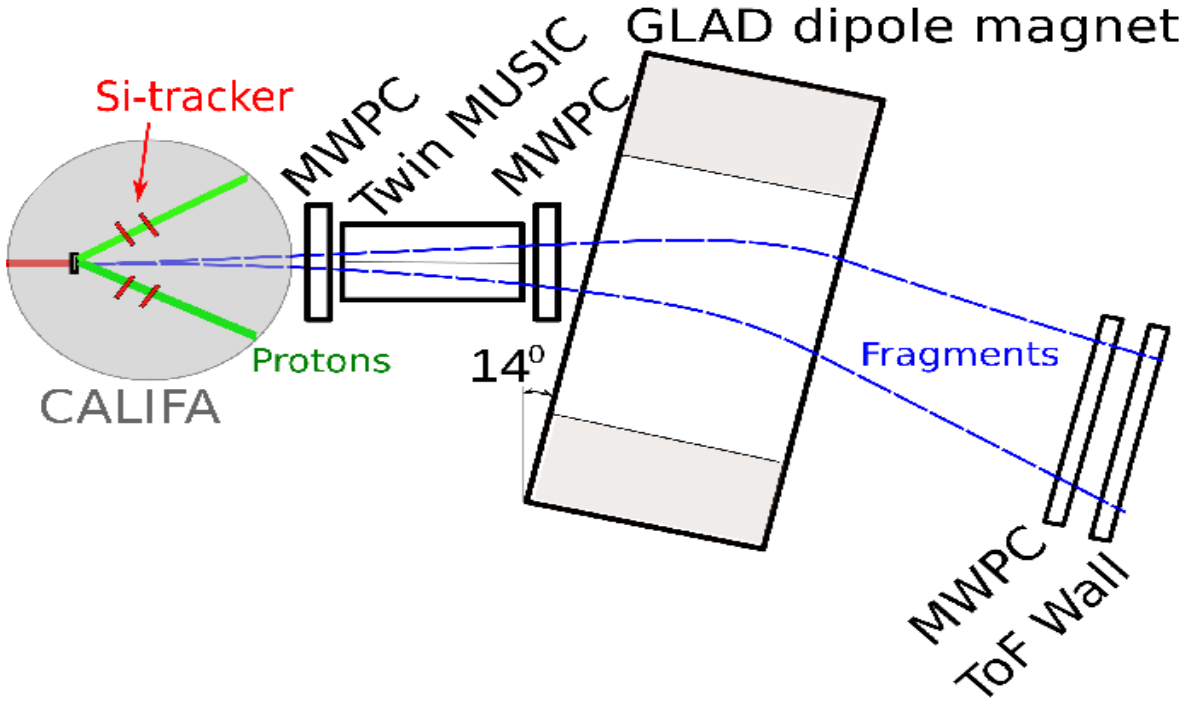
What could be investigated

Fission barriers with (p,2p) reactions

Inverse kinematics

- Exotic nuclei covering a large range on charge and neutron excess *(N/Z)*
- Excitation energy from CALIFA+Si-tracker
- Fission probabilities from SOFIA





What could be investigated

Fission barriers with (p,2p) reactions

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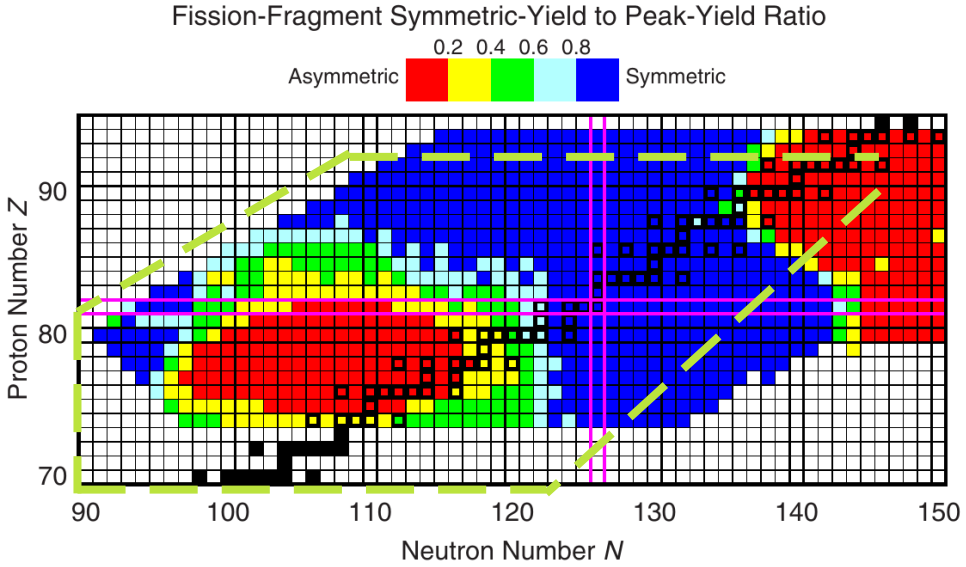


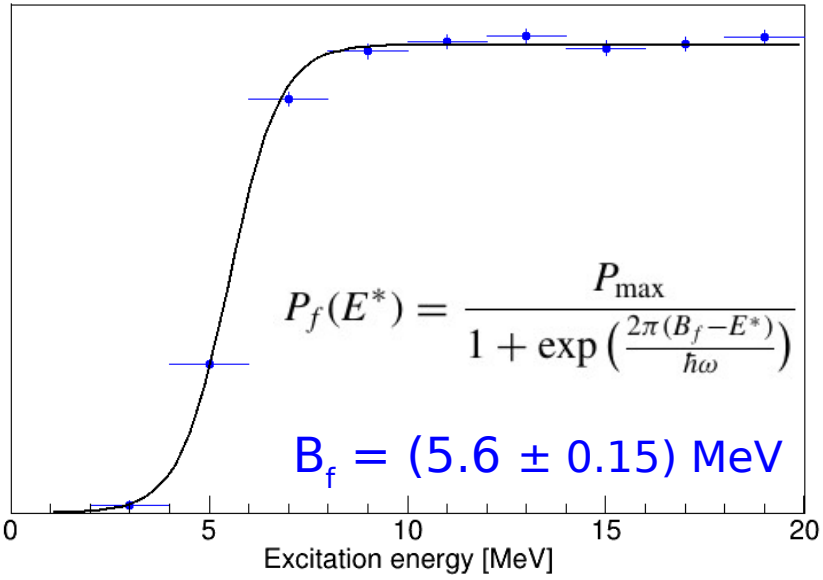
Observables

- Fission barriers for nuclei in the transitions from symmetric to asymmetric fission
- Measure fission barriers of neutron-rich nuclei

Important inputs for r-process calculations

Requirement:
Missing mass resolutions **of 1-2 MeV (FWHM)**

Measuring fission barriers with an uncertainty of **~ 150 keV**



What could be investigated

Fission yields

- Most of the measurements were performed in direct kinematics for stable nuclei
- Inverse kinematics allowed to measure this observable for exotic nuclei using coulex induced fission reactions (K.-H. Schmidt, J. Taïeb et al.)

Fission yields with (p,2p) reactions

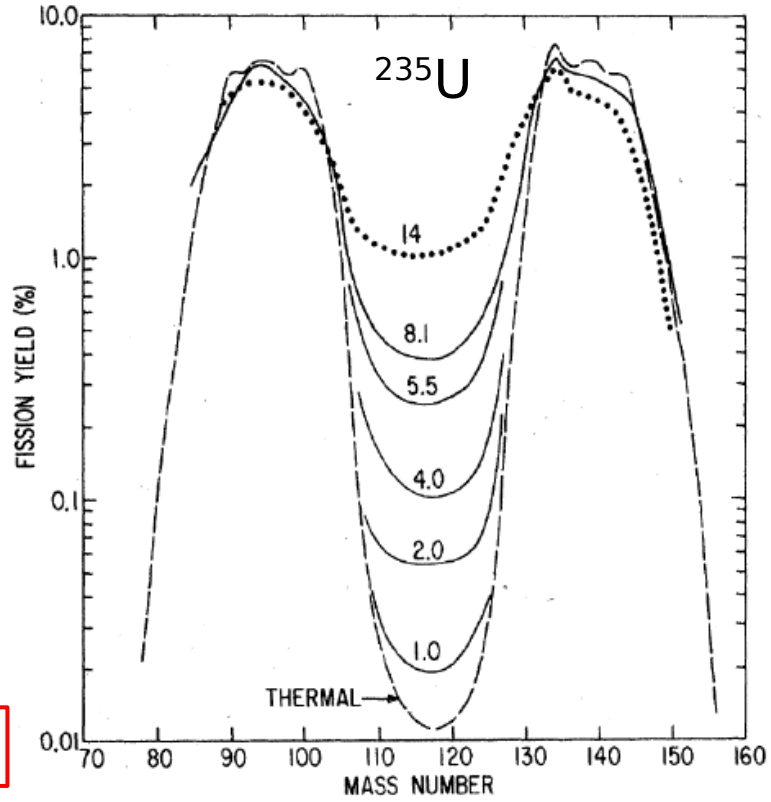
Evolutions with the excitation energy

- Excitation energy from CALIFA+Si-tracker
- Mass and charge distributions from SOFIA

Observables

- Mass and charge distributions for different excitation energies (E^*), in particular for **low excitations energies** between **0** & **5 MeV**

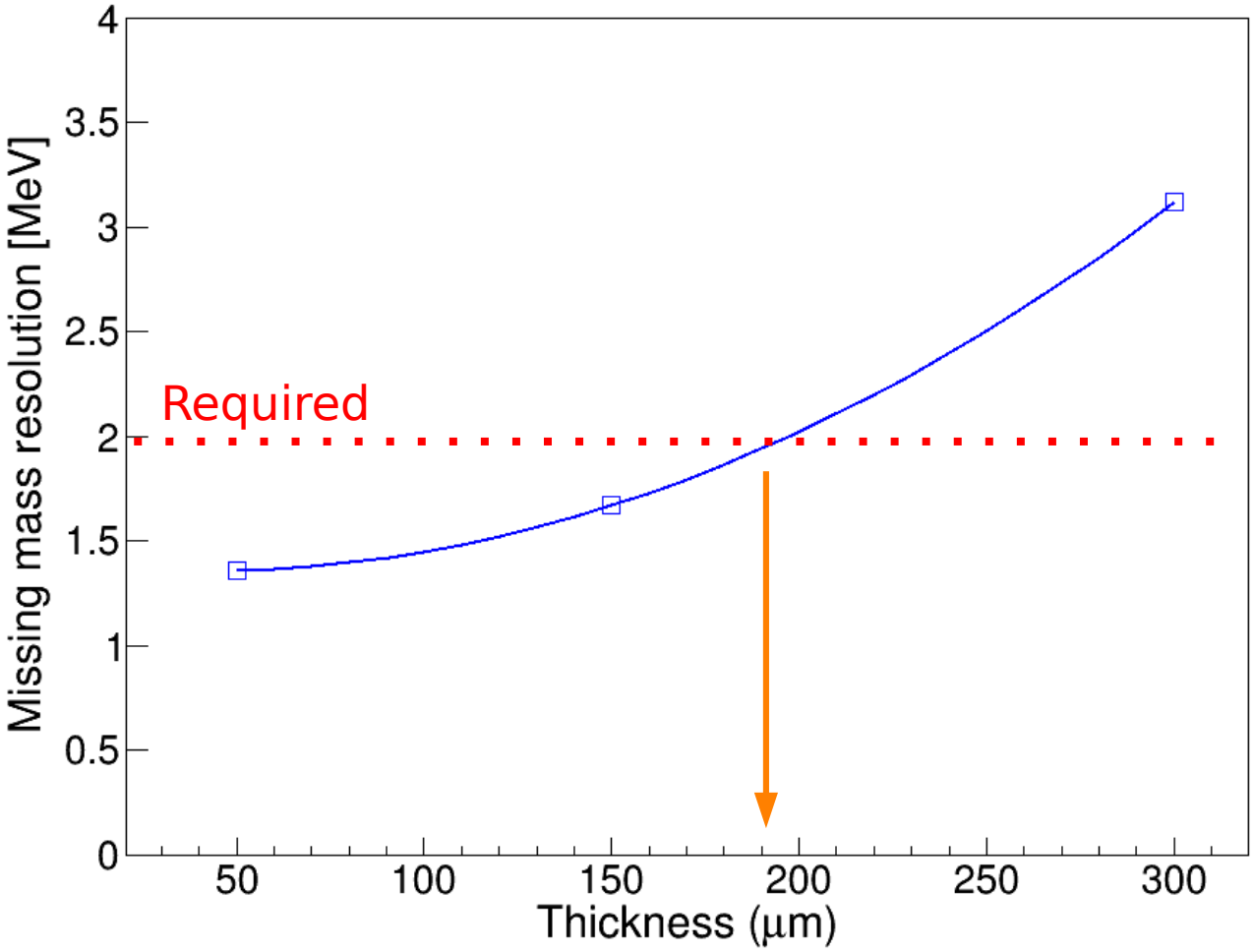
Also an important input for r-process calculations



Requirement: Missing mass resolutions **of 1-2 MeV (FWHM)**

Requirements

Missing mass resolution

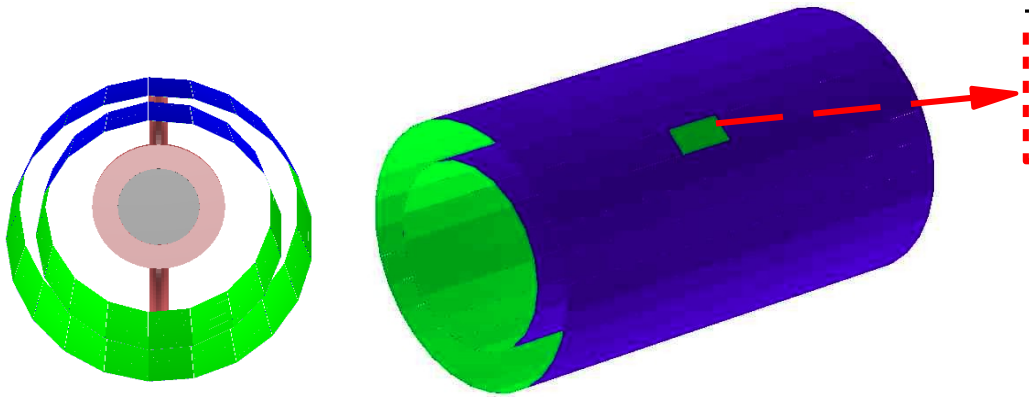


We will need thin Si-detectors to get resolutions better than 2 MeV

This could be reached using ALPIDE detectors (50 µm thickness)

Simulations within ALPIDE sensors

Two barrels of pixel sensors



Parameter	IB
Sensor thickness (μm)	50
Spatial resolution (μm)	5
Dimensions (mm^2)	15 × 30
Power density ($mW\ cm^{-2}$)	300
Time resolution (μs)	30
Detection efficiency (%)	99
Fake hit rate[a]	10^{-5}
TID radiation hardness[b] (krad)	2700
NIEL radiation hardness[b]	1.7×10^{13}

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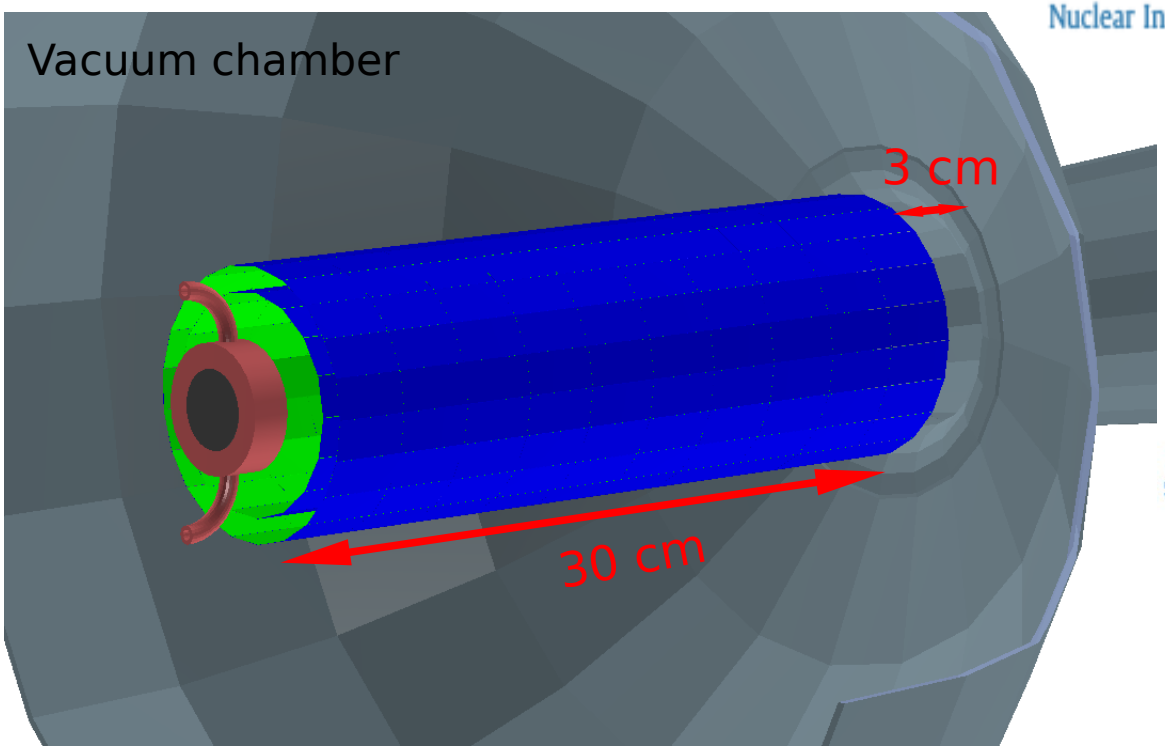
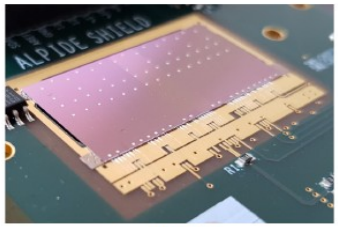
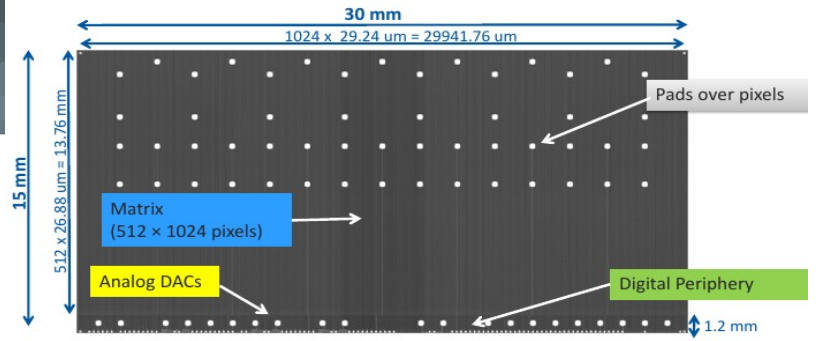
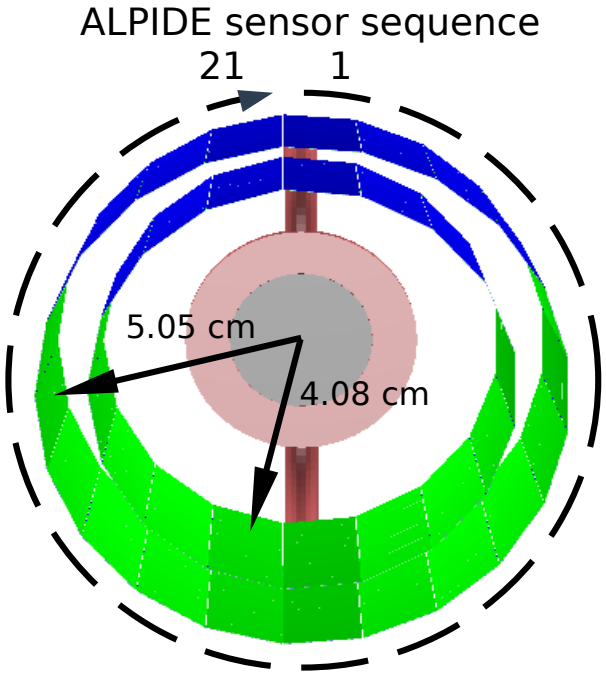


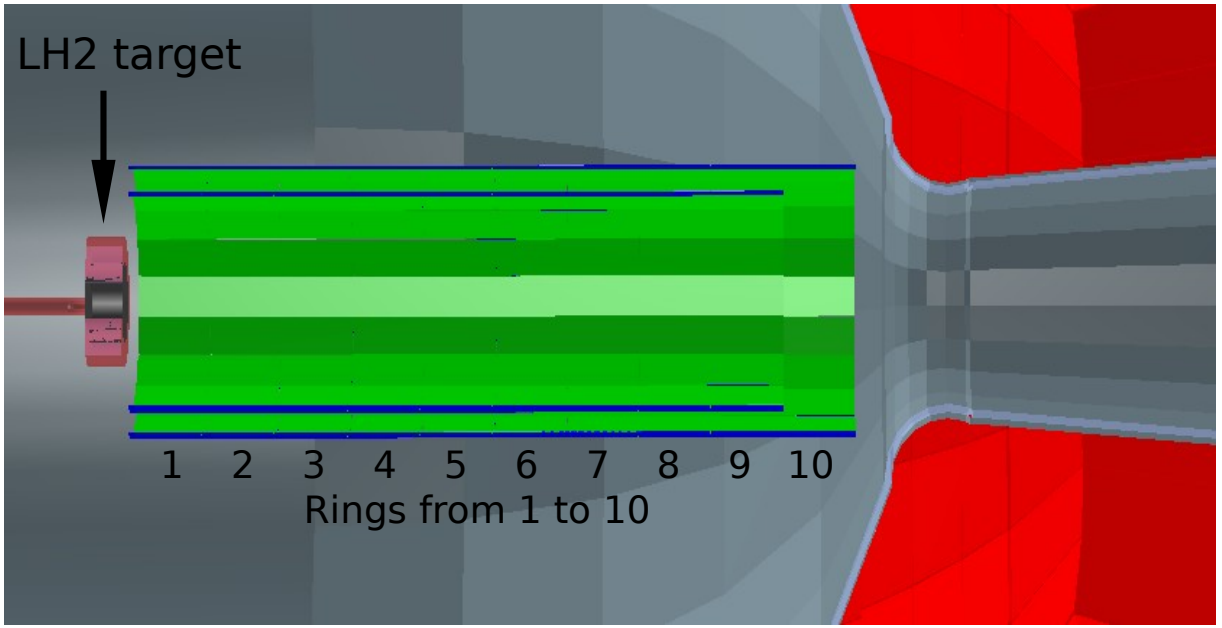




Simulations within ALPIDE sensors

Two barrels of pixel sensors

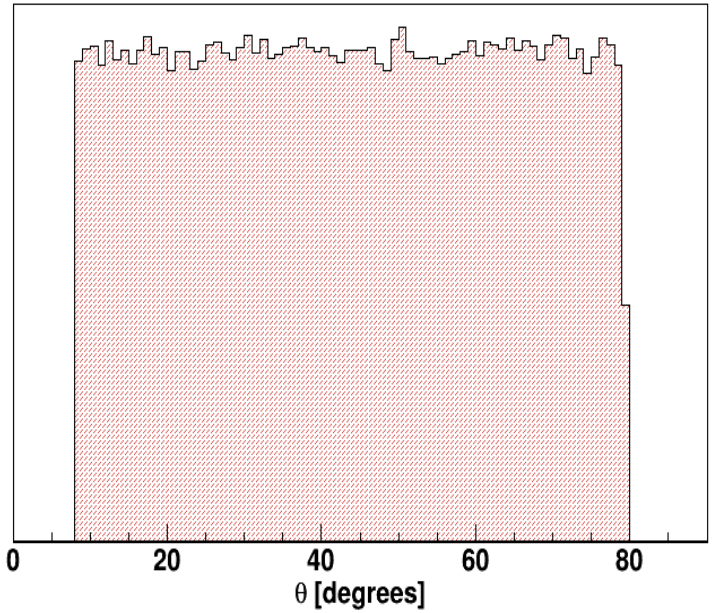


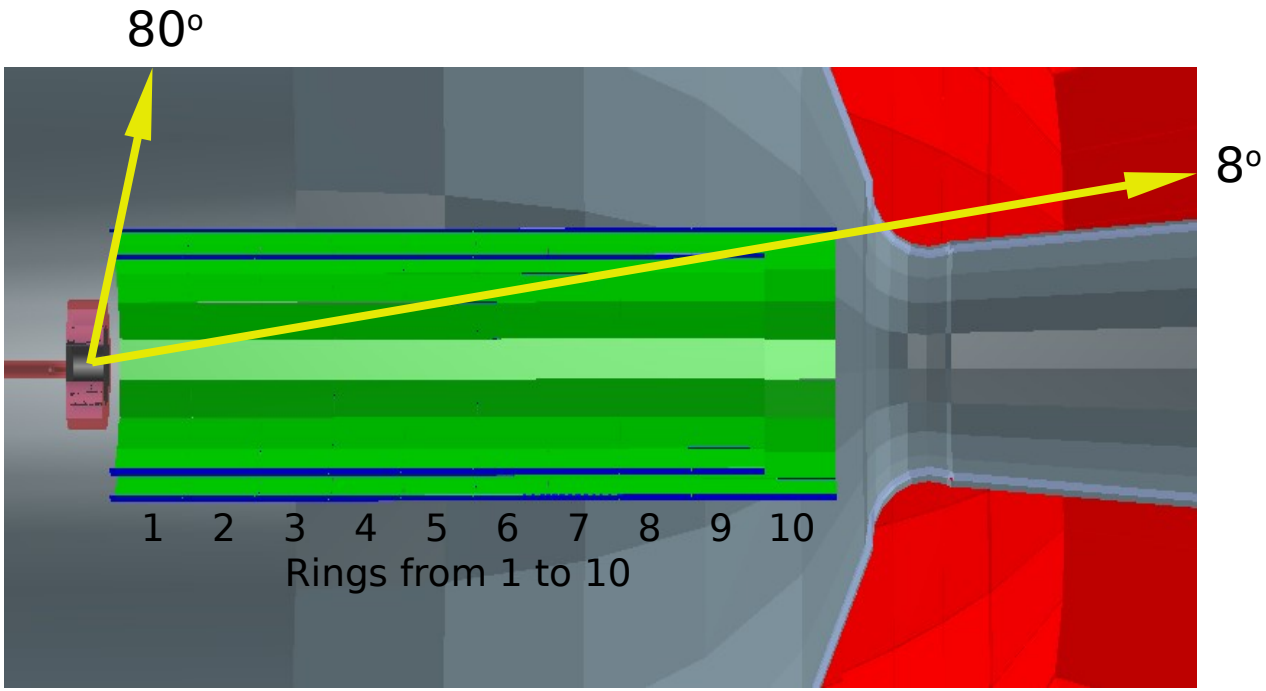


Barrel	Radius (cm)	ALPIDE sensors per ring	Distance between sensors (μm)	Number of rings
Inner	4.08	17	2	9
Outer	5.05	21	2	10

Simulations within ALPIDE sensors

Two barrels of pixel sensors

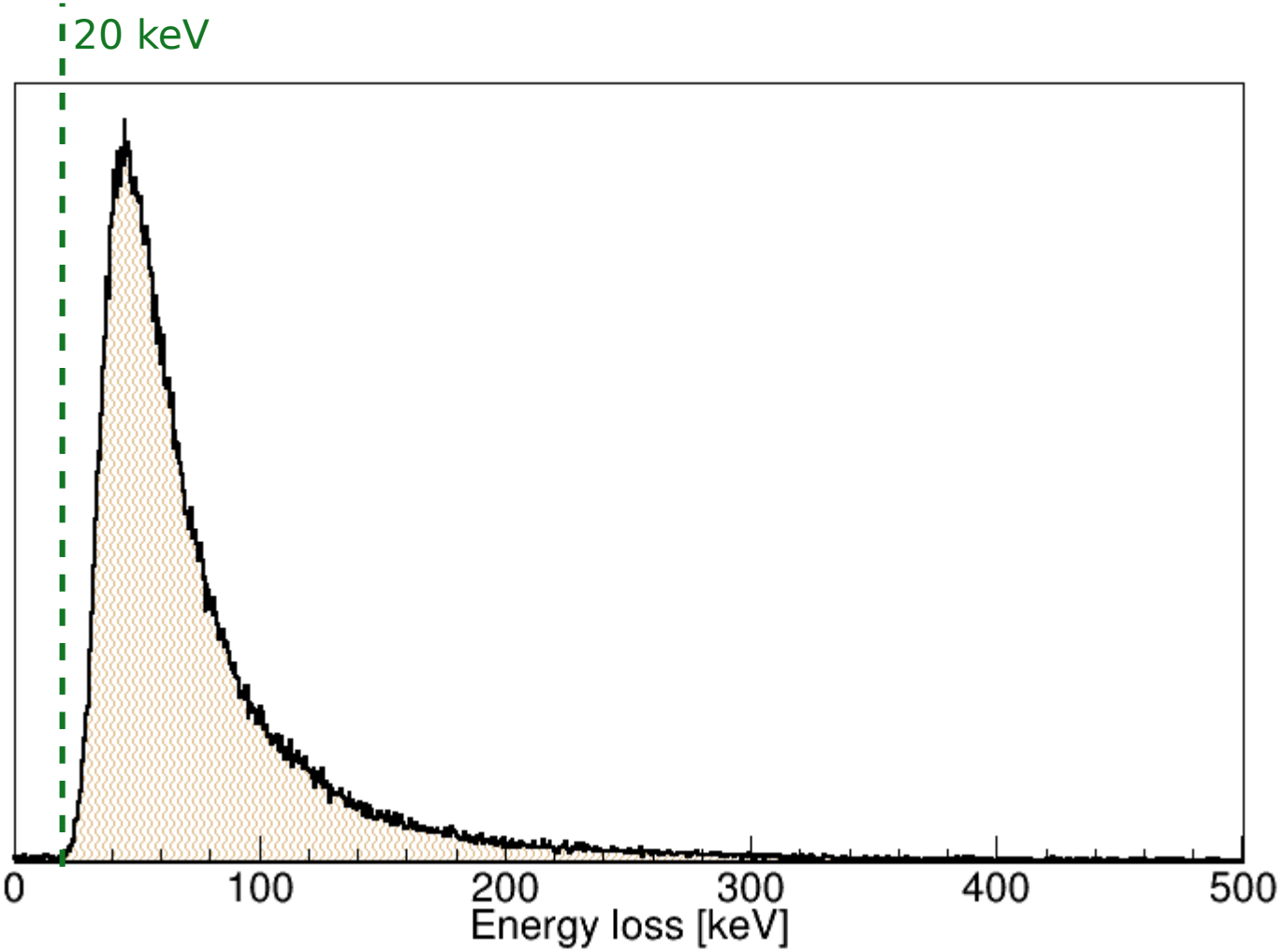




Barrel	Radius (cm)	ALPIDE sensors per ring	Distance between sensors (μm)	Number of rings	Θ range in degrees
Inner	4.08	17	2	9	8 - 80
Outer	5.05	21	2	10	8 - 80

Simulations within ALPIDE sensors

Energy loss range for protons

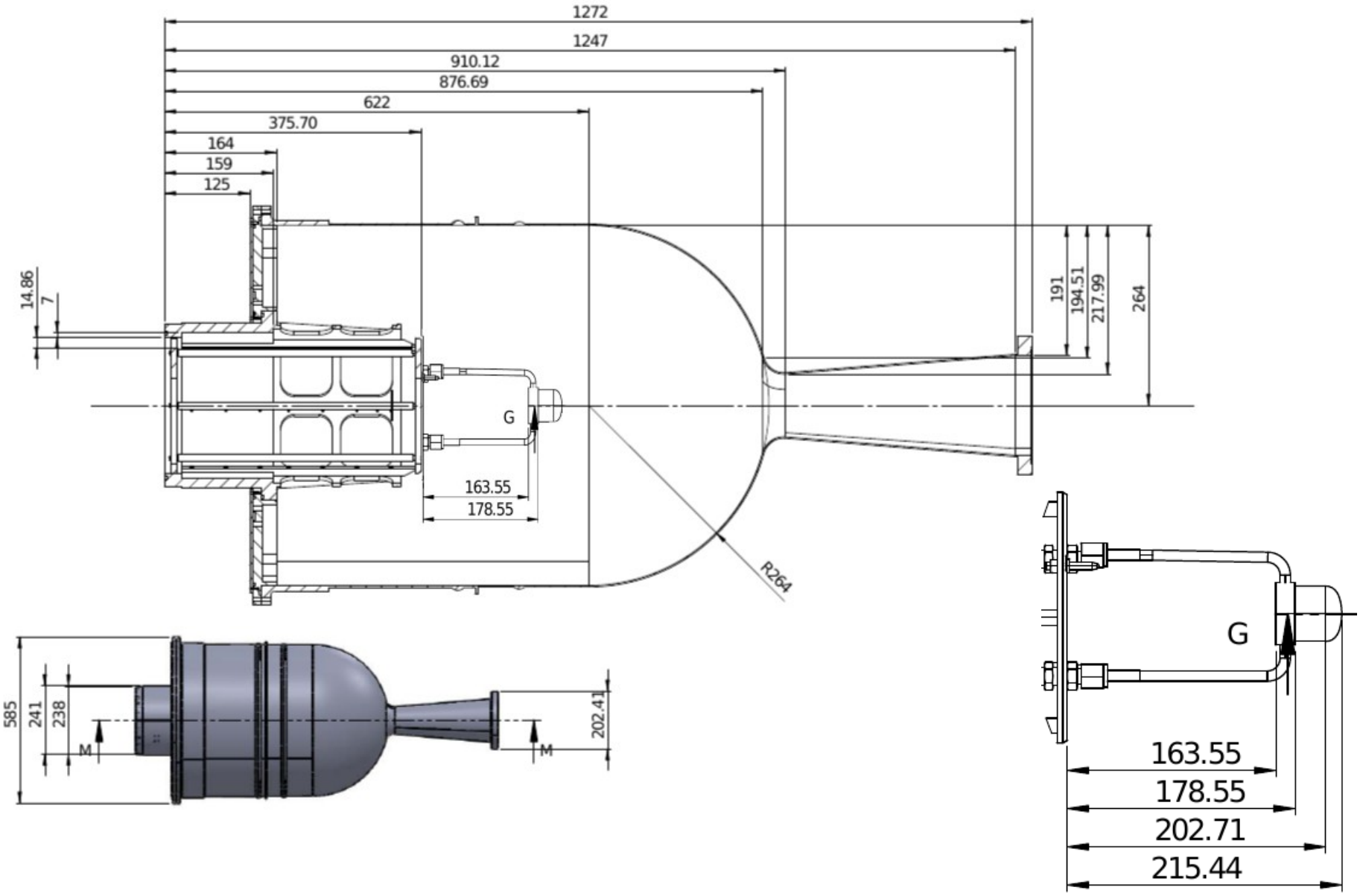


- We will need at least a threshold of (20±2) keV

- ALPIDE sensors allow to set up the thresholds with resolutions of a few electron volts

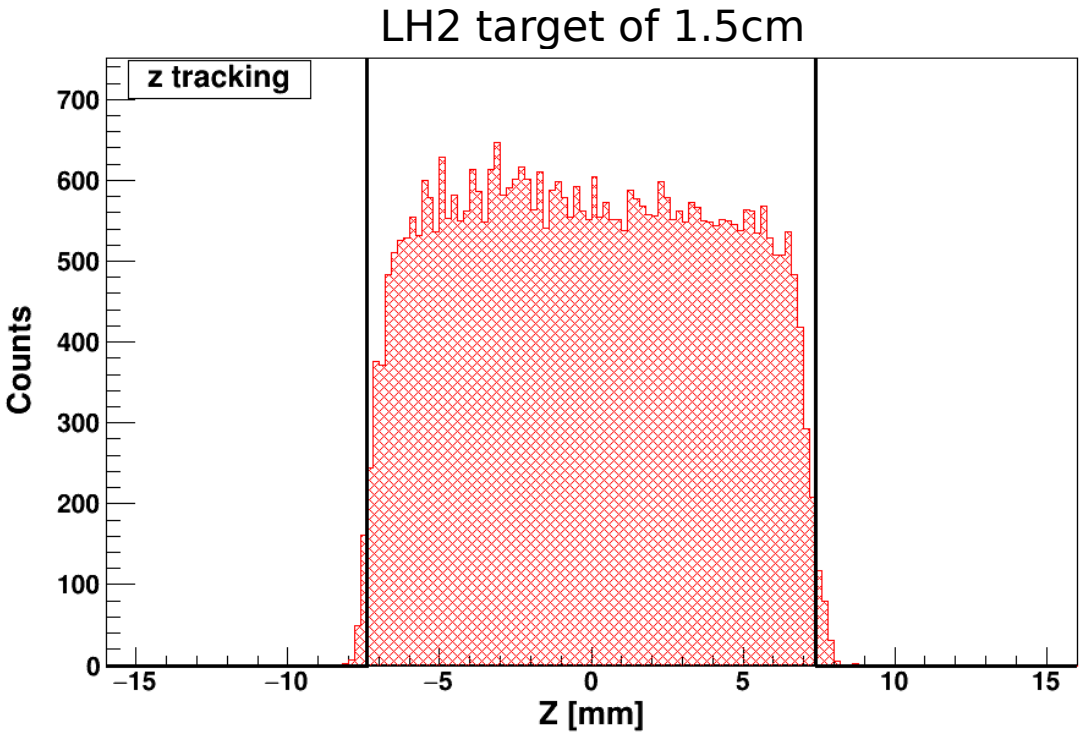
LH2 target and vacuum chamber

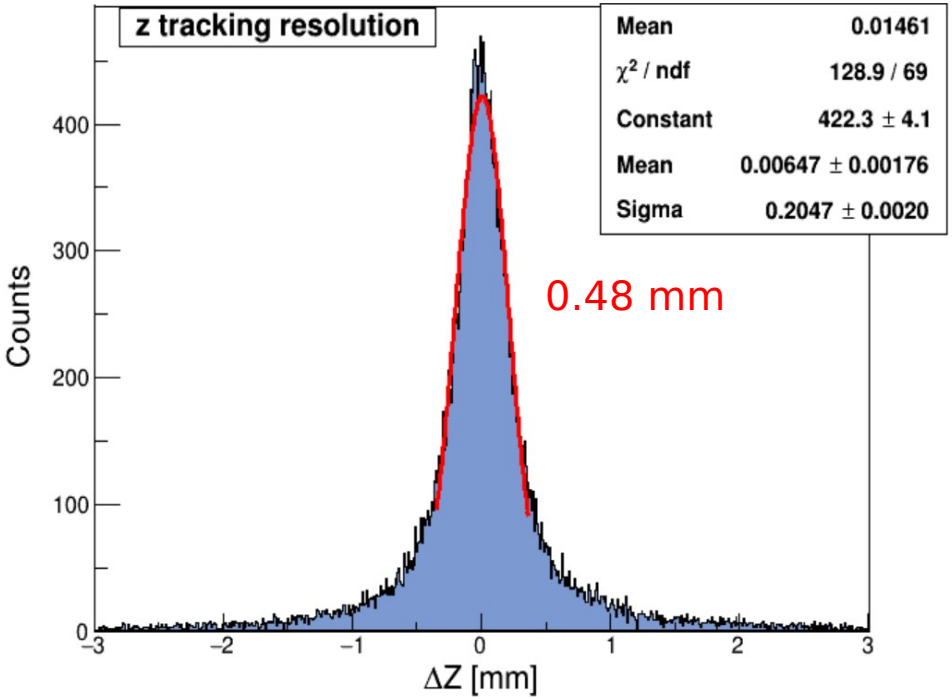
Geometry from technical drawings *(E. Casarejos, A. Corsi et al.)*

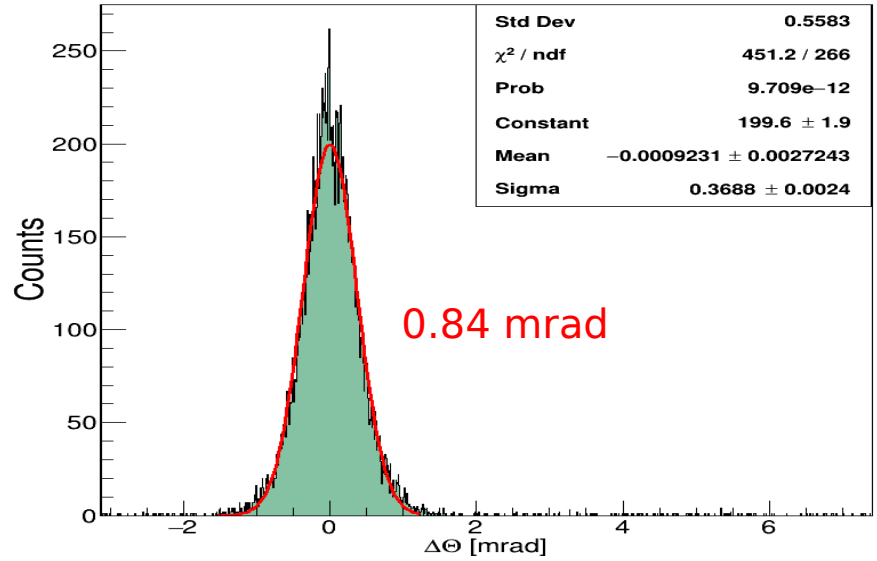


ALPIDE barrel: Tracking resolution

Vertex reconstruction



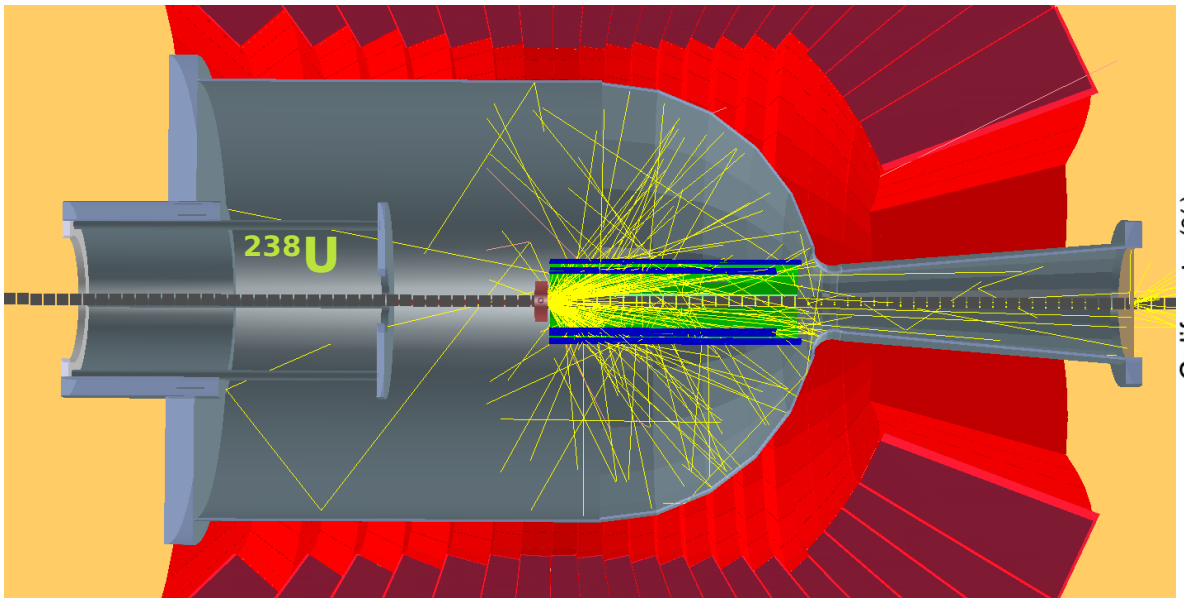


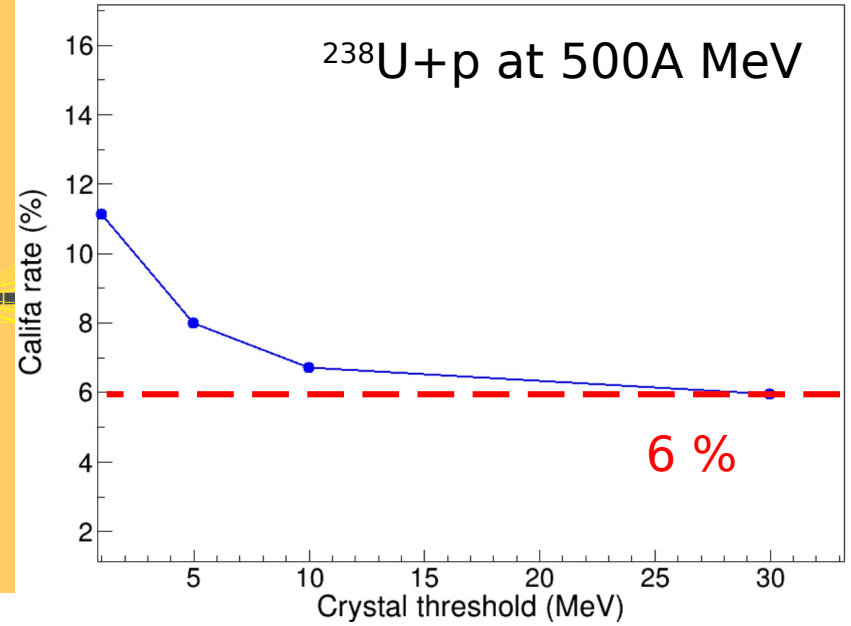


- Vertex resolution better than 0.5 mm (FWHM)
- Angular resolutions better than 1 mrad (FWHM)

Configuration for (p,2p) fission studies

CALIFA + ALPIDE barrels





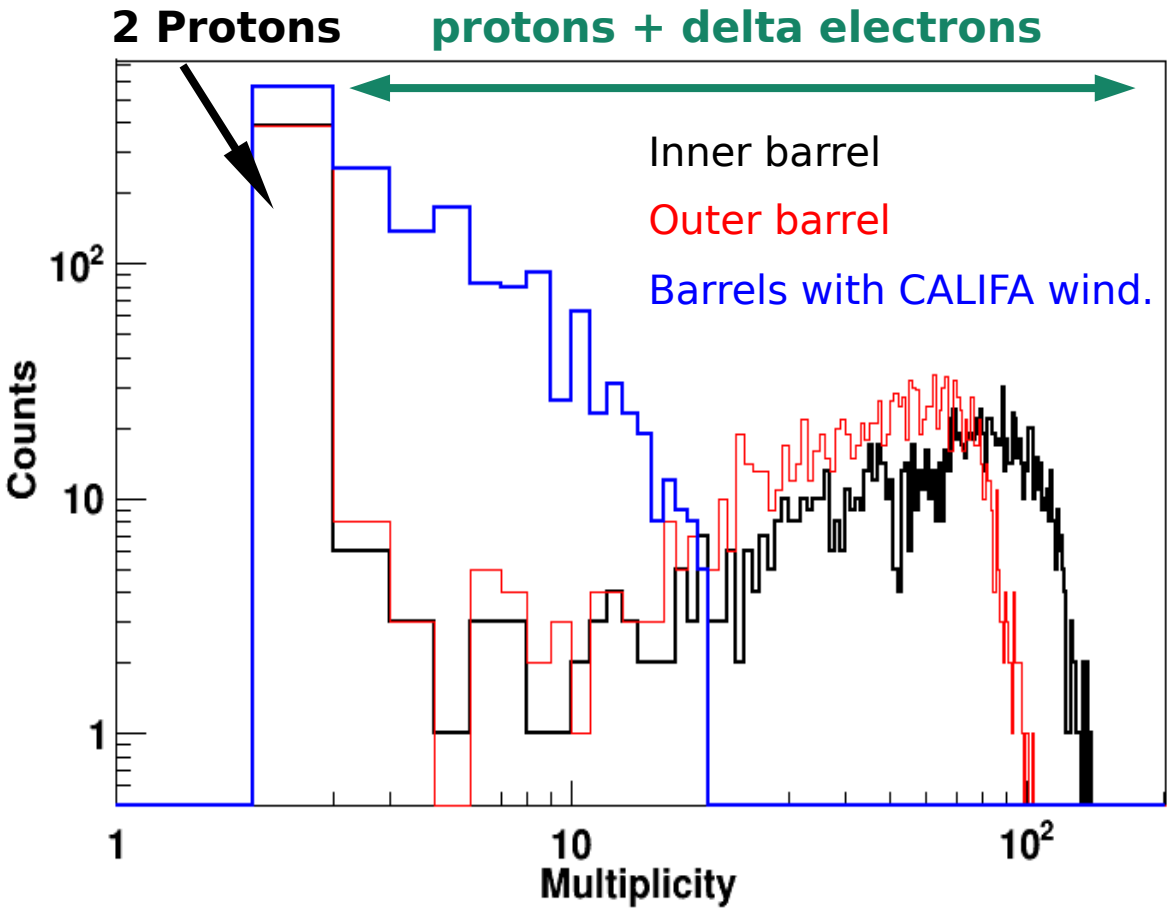
- **Califa rates** around 6 % of the total number of projectiles

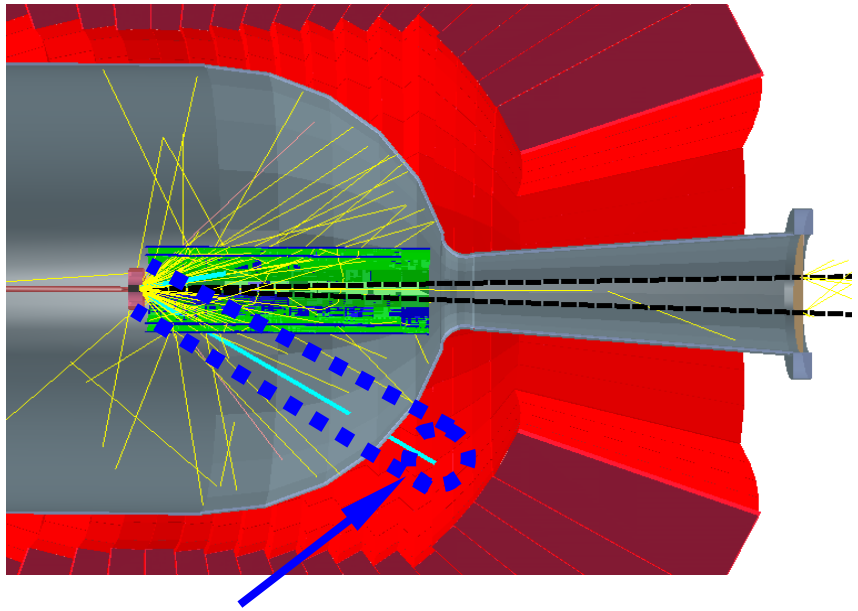
- **High rates** in the Si-tracker due to delta electrons, from simulations **80 %** of the total projectiles will induce at least one signal in the detectors

- **CALIFA trigger** can be used to reduce the rates for DAQ

Configuration for (p,2p) fission studies

Particle multiplicities in the ALPIDE barrels for (p,2p) induced fission





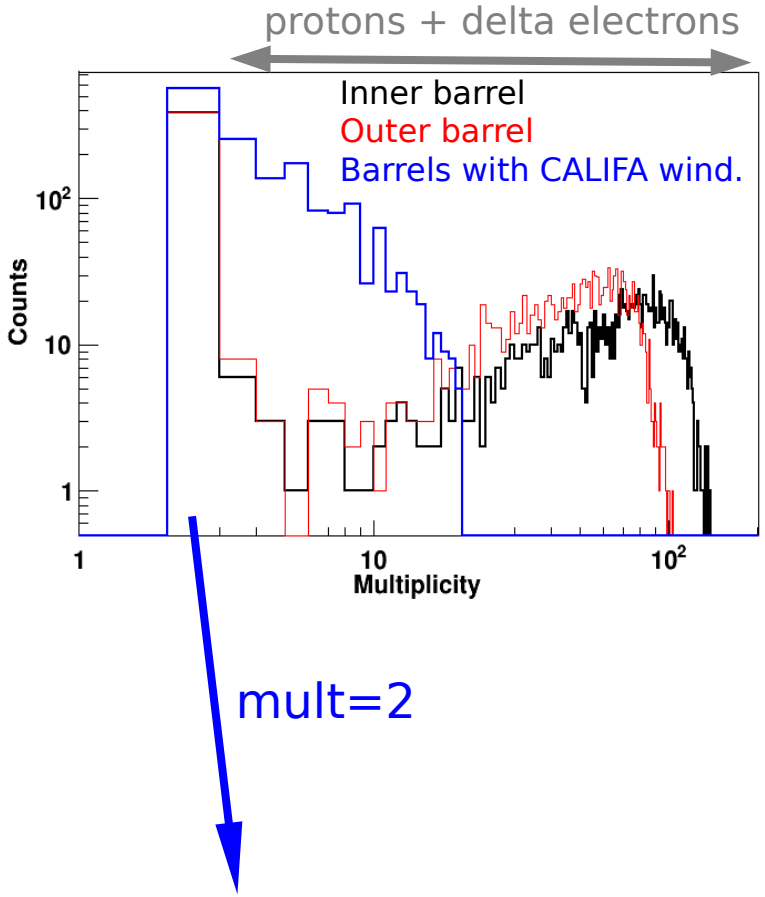
CALIFA selection in theta and Phi (±4º) to constrain the angular range for barrels

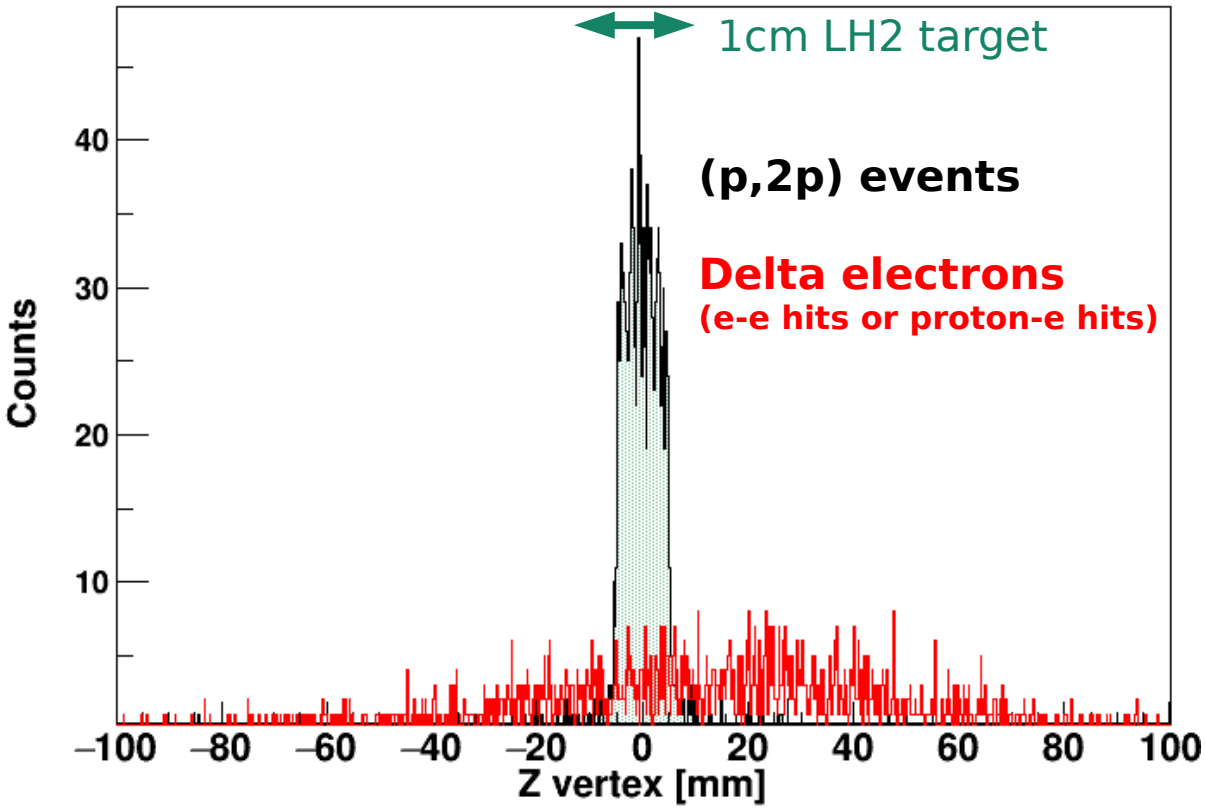
- CALIFA angles reduce the particle multiplicities in the barrels a factor of 10

- Around **37%** of pure (p,2p) events in both barrels (mult=2), without delta electrons inside the angular CALIFA windows

Configuration for (p,2p) fission studies

Vertex reconstruction to select the rest of (p,2p) events





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Configuration for (p,2p) fission studies

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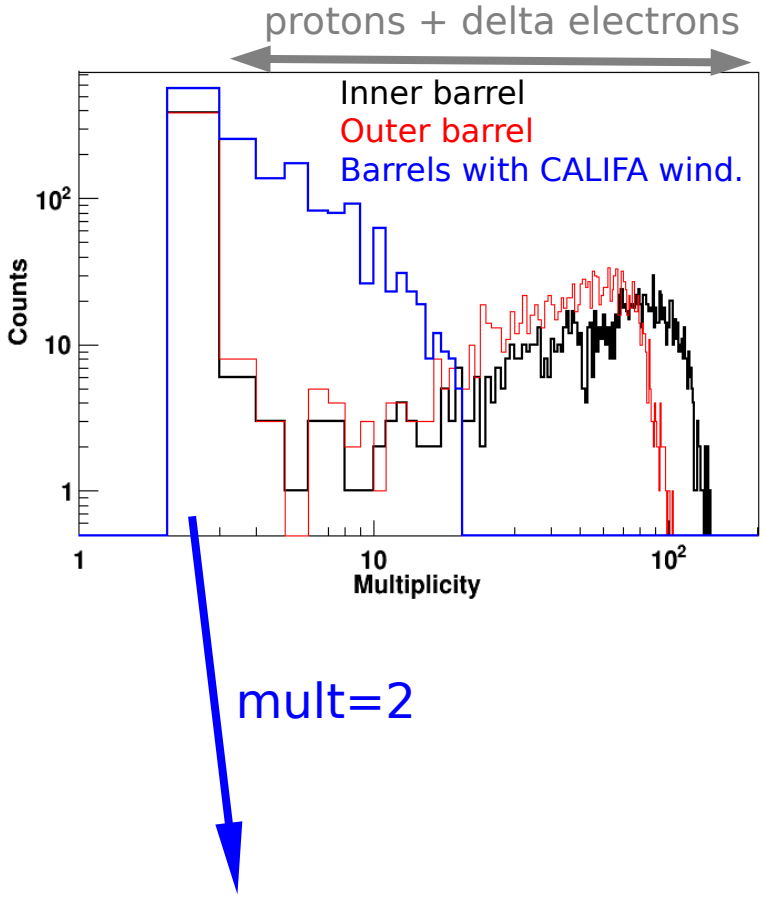
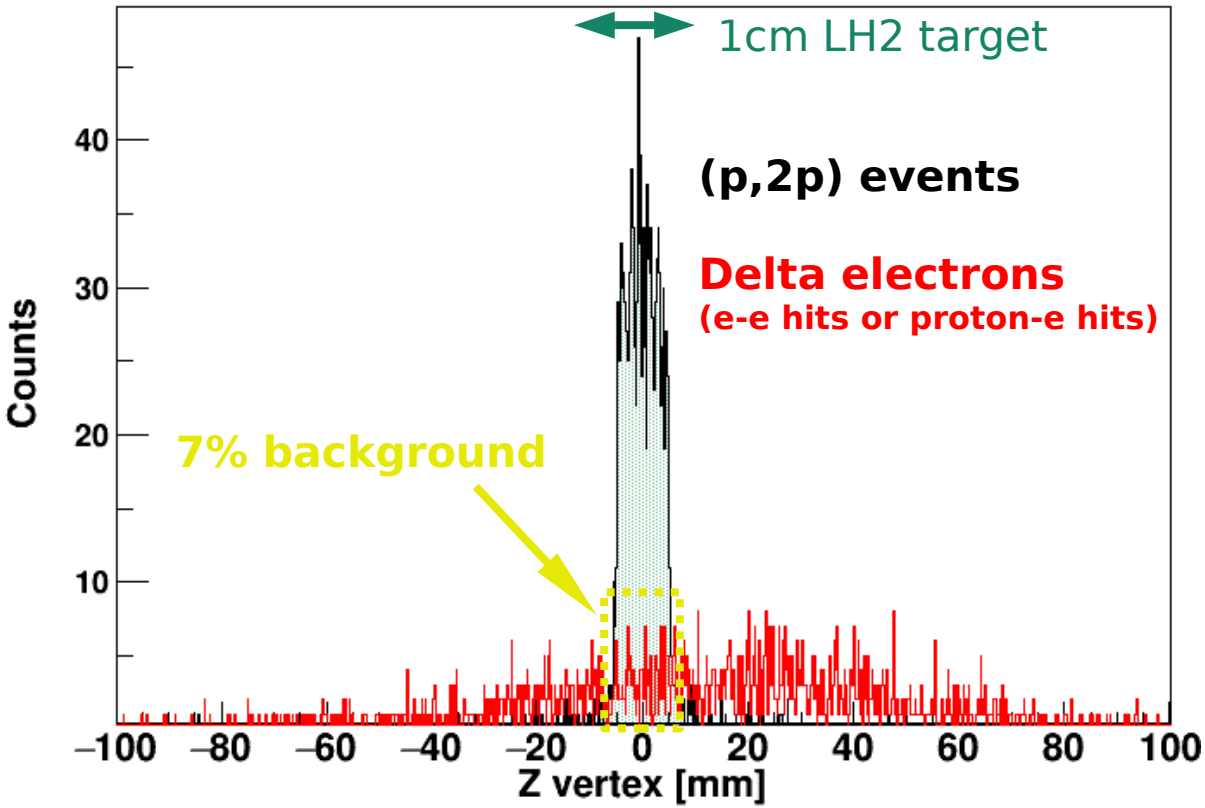




- Around **37%** of pure (p,2p) events in both barrels (mult=2)

- Around **56%** of (p,2p) events can be recovered from vertex reconstruction

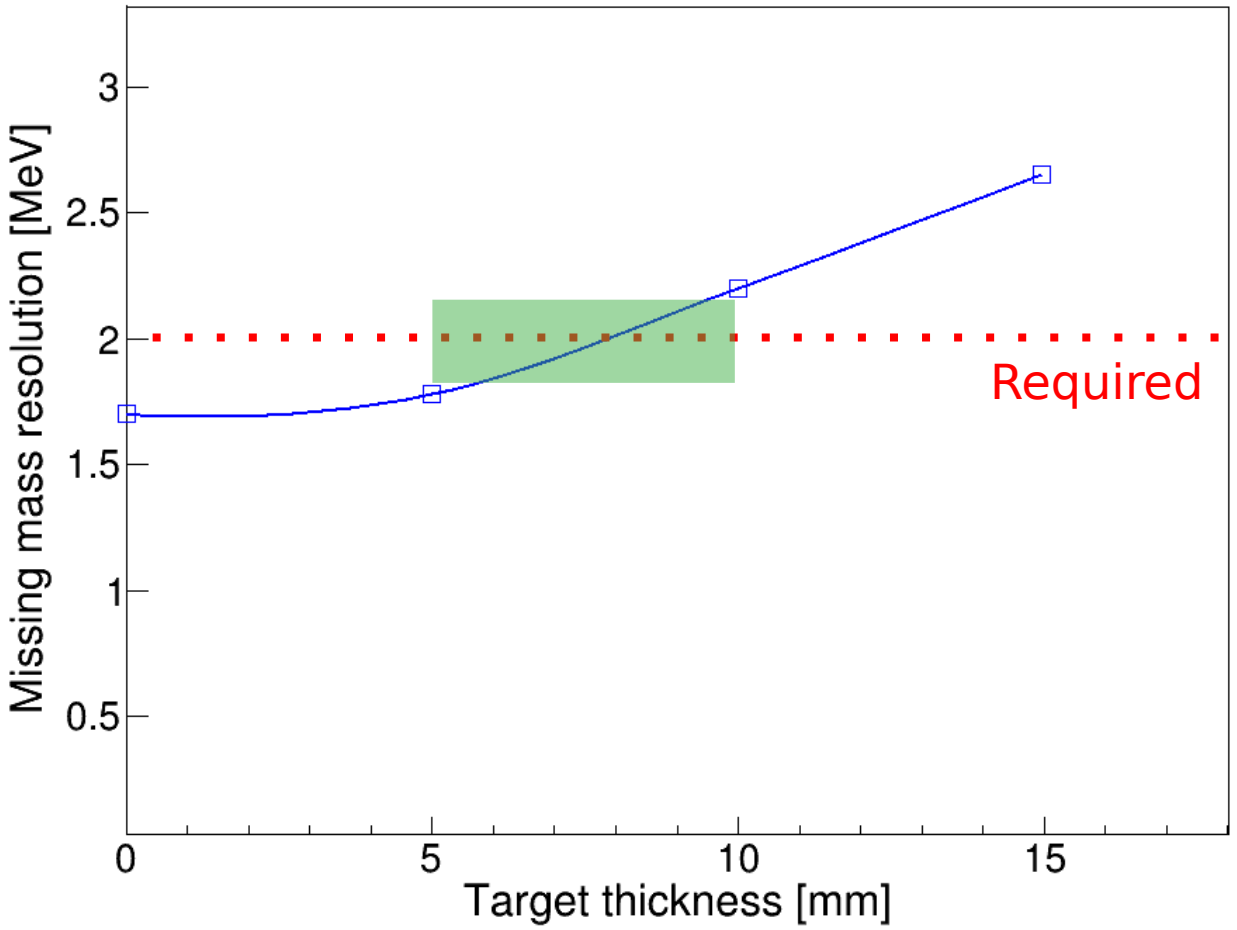
- In total, we recover 37+56 = **93 % of (p,2p) events**

Missing mass resolution

Contributions

- ALPIDE tracking resolution of 5 μm (FWHM)
- CALIFA energy resolutions of around 1 % (FWHM)

	Resolution in MeV (FWHM)
Si thickness + 5 μm spatial res.	1.45
Si detectors + CALIFA (1%)	1.7



Summary

(p,2p) induced fission reactions could be used to measure fission barriers and fission yields of heavy exotic nuclei between Hg (Z=80) and U (Z=92)

The measurement of fission barriers and fission yields to provide inputs for r-process calculations needs missing mass resolutions of 1-2 MeV (FWHM), in particular, for obtaining the excitation energy dependece at very low energies (< 5 MeV)

ALPIDE sensors

- Energy loss range between **20 and 500 keV**
- Vertex reconstruction with a resolution of **0.5 mm (FWHM)**
- Angular resolution better than **1 mrad (FWHM)**

CALIFA angles and the vertex reconstruction allow to distinguish delta electrons from protons, recovering the 93% of the total (p,2p) events

Missing mass spectra could be obtained with a resolution of **2 MeV (FWHM)** for LH2 target with a thinkness between 5 and 10 mm

Thank you for your attention!