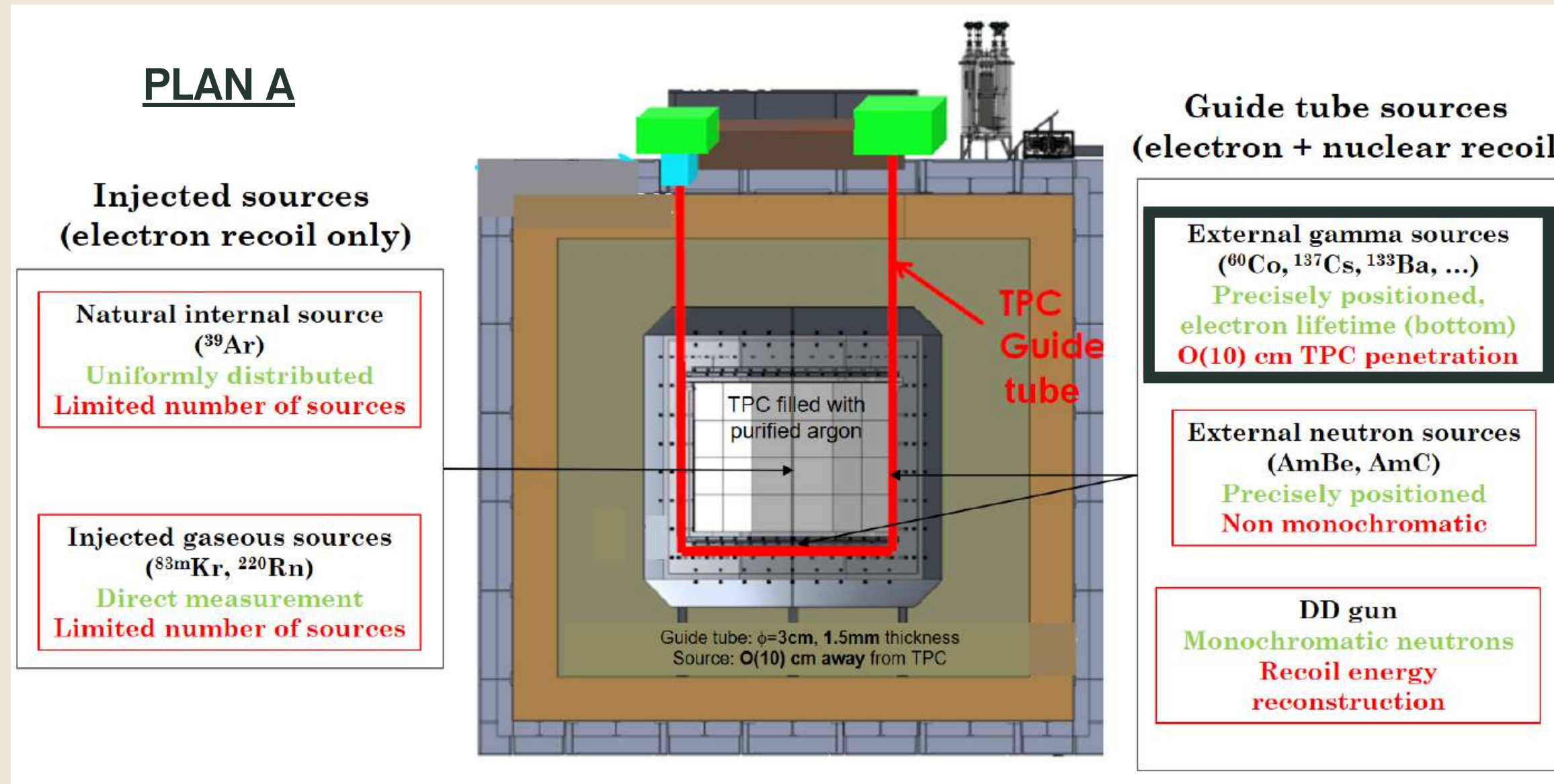


Théo Abounnasr--Martins, summer student

RAPPORT D'ACTIVITÉS 12/07/2021

GUIDE TUBE CALIBRATION DARKSIDE20K



Before calibrating the detector with sources in the guide tube, it is necessary to estimate the **background rate of events generated in the TPC by the tube material in itself**



FOCUS ON ELECTRONIC RECOIL

There are two kind of events :

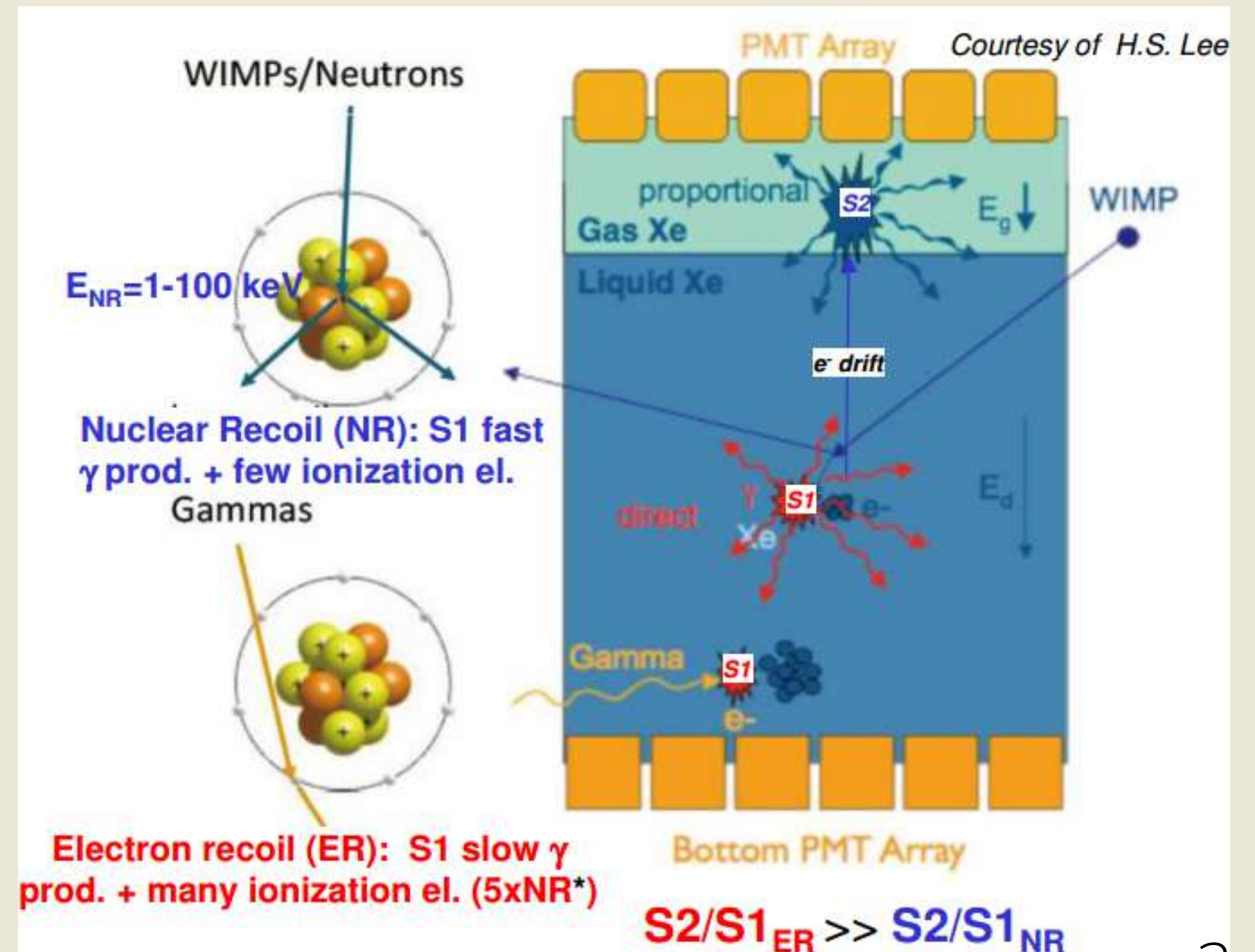
- Nuclear Recoil events

- Particle scatters on nucleus (if WIMP : through unknown process)
- Fast but small γ production, few e-
- nucleus-nucleus and WIMP/nucleus interactions *apriori* undistinguishable from
 - > Events discriminated with veto outside of TPC

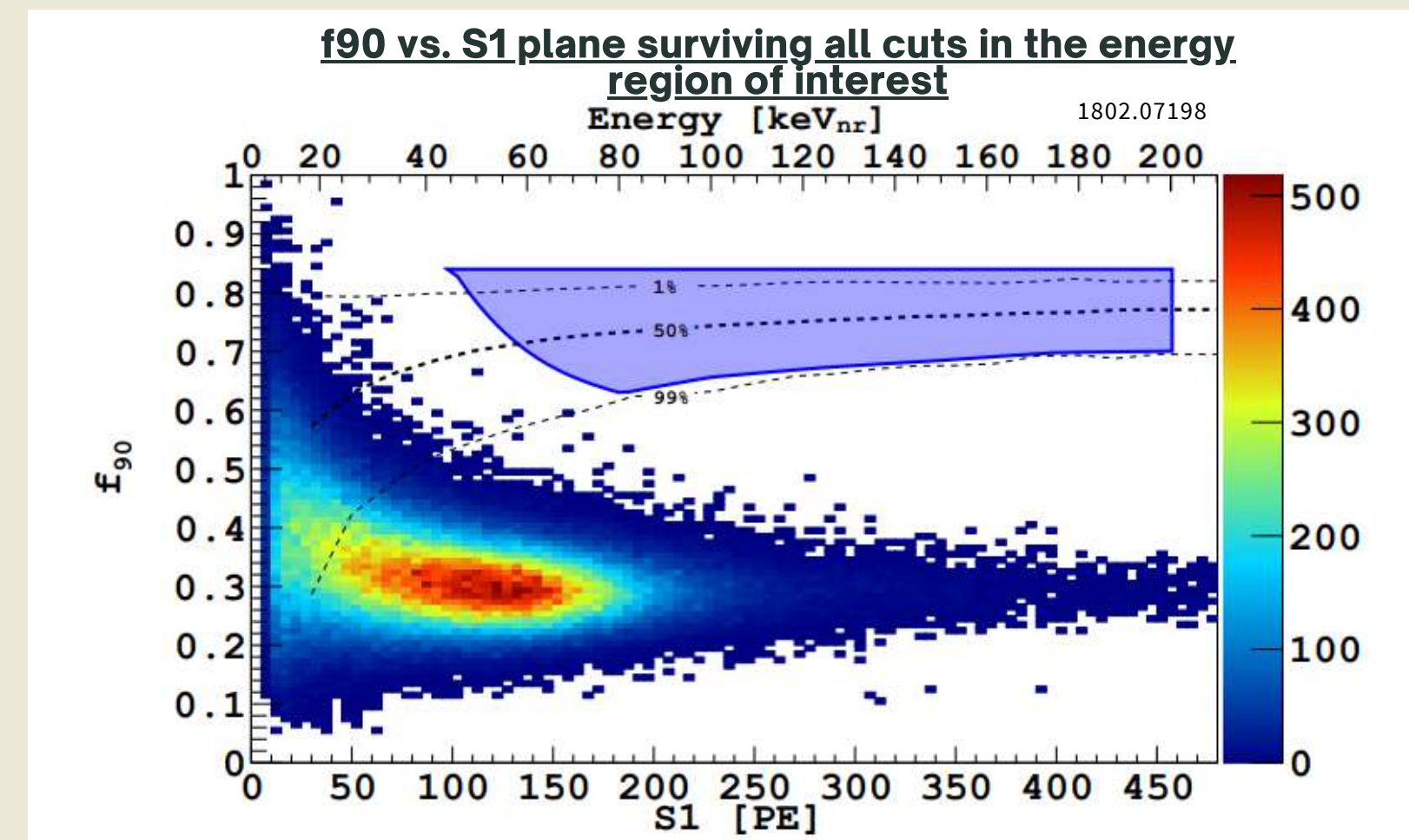
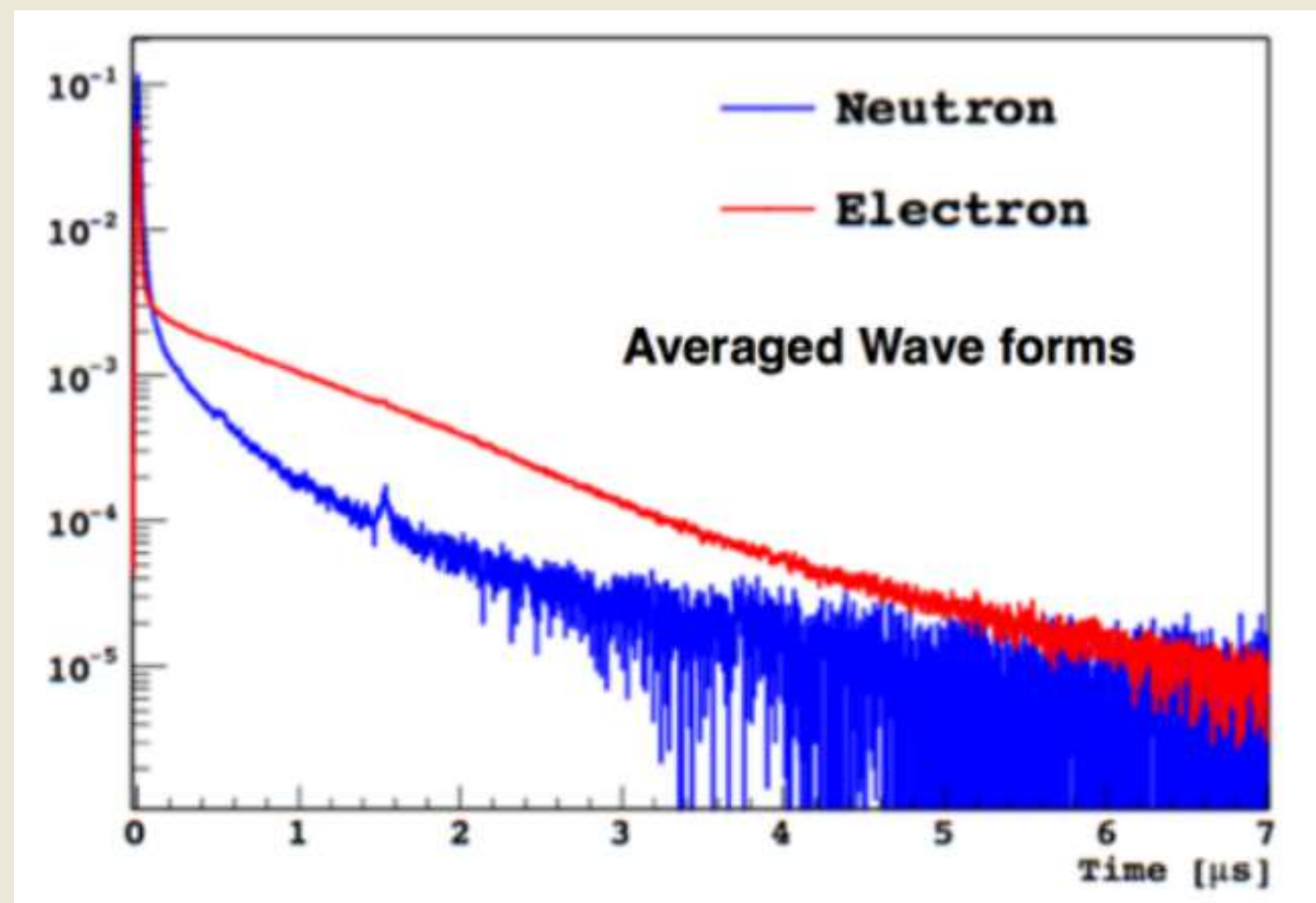
- **Electronic Recoil events**

- γ scatters on electronic orbitals
- Many but slow γ production, many e-
- Distinguishable to an extent through Pulse Shape Discrimination (PSD) method

We will focus on the **electronic recoil events** generated in the TPC by radioactive elements of the type



PULSE SHAPE DISCRIMINATION (PSD)



→ PSD with error $\varepsilon=10^{-8}$

ER* BACKGROUND RATES



A

Estimate decay rates from
radioactive elements of the tube

B

Find the number of events in the
TPC volume through GEANT4DS
simulation of the tube for each
radioactive source

C

Apply various cuts to estimate
the number of remaining events
in a given fiducial volume



A - DECAY RATE

RADIOACTIVE COMPONENTS

Properties of radioactive elements in SSArDM (The Lund/LBNL Nuclear Data Search)

| Element | Halflife (years) | Activity (Bq/mg) | Proportion in SSArDM (ng/kg) | Contamination in SSArDM (mBq/kg) |
|-------------------|------------------|------------------|---------------------------------|-------------------------------------|
| ^{137}Cs | 30.18 | 3.20e+09 | 4.69e-10 | 1.50 |
| ^{40}K | 1.28e+09 | 2.59e+02 | 0.02 | 6.40 |
| ^{60}Co | 5.27 | 4.18e+10 | 3.11e-10 | 13.00 |
| ^{238}U | 4.47e+09 | 12.44 | 4.01 | 50.00 |
| ^{232}Th | 1.40e+10 | 4.06 | 4.92 | 20.00 |



A - DECAY RATE

DECAY PER YEAR ESTIMATION

$$\text{Rate} = \text{Activity} \times M(\text{tubes})$$

Number of decay / time

$(\text{Time} \times \text{Mass})^{-1}$

Mass

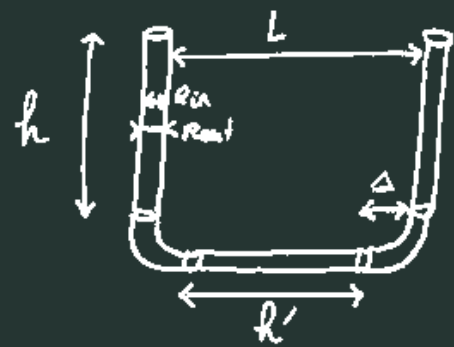
I

A - DECAY RATE

DECAY PER YEAR ESTIMATION

TUBE MASS

Masse tube



$$\begin{aligned} \rho_{ss} &\approx 8000 \text{ kg/m}^3 \text{ (20}^\circ\text{C)} \\ R_{in} &= 3,2 \text{ cm} = 3,2 \times 10^{-2} \text{ m} \\ R_{out} &= R_{in} + e, \quad e = 1,5 \text{ mm} \\ &= 3,35 \text{ cm} \\ h &= 3,5 \text{ m} \\ h' &\approx h \\ L &= 4,01 \text{ m} \\ \Delta &= \frac{L - h'}{2} \text{ ou } \Delta^* = \Delta + R_{out} \end{aligned}$$

• 1 tube de longueur h :

$$V_{\text{tube}} = \pi h (R_{out}^2 - R_{in}^2)$$

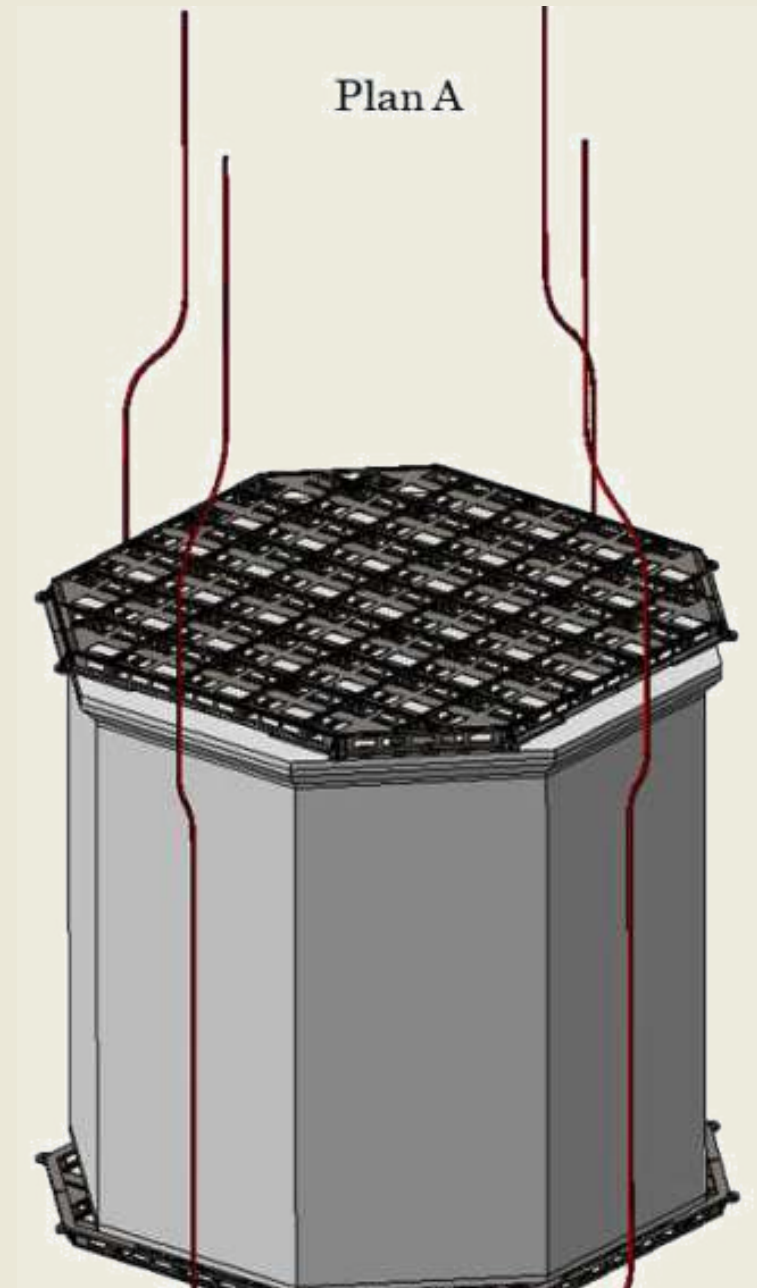
• 1 coude \equiv 1 demi-cercle de rayon Δ^* :

$$\frac{1}{4} \text{ de périmètre de longueur: } 2 \frac{\pi \Delta^*}{4} \Rightarrow V_{\text{coude}} = \frac{\pi \Delta^*}{2} \times \pi (R_{out}^2 - R_{in}^2)$$

$$\Rightarrow M_{tot} = (3V_{\text{tube}} + 2V_{\text{coude}}) \times \rho_{ss}$$

$$= \rho_{ss} \pi (R_{out}^2 - R_{in}^2) \left(h \left(3 - \frac{\pi}{2} \right) + \frac{\pi L}{2} \right)$$

AN : $M_{tot} \approx 28 \text{ kg}$



2 tubes en U

$$M(\text{tubes}) = 56 \text{ kg}$$



A - DECAY RATE

DECAY PER YEAR ESTIMATION

ACTIVITY

STAINLESS STEEL ACTIVITY

| Sample identifier | Radioactive contamination [mBq/kg] | | | | |
|-------------------|------------------------------------|------------------|------------------|-----------------|-------------------|
| | ²³² Th | ²³⁸ U | ⁶⁰ Co | ⁴⁰ K | ¹³⁷ Cs |
| SS | 10 | 10 | — | — | — |
| SS ArDM | 20 | 50 | 13 | 6.4 | 1.5 |

Example ¹³⁷Cs

$$\text{Activity} = 0.0015 \text{ Bq/kg}$$

$$\begin{aligned} \text{Rate} &= 0.0015 \text{ Bq/kg} \times 56 \text{ kg} = 0.084 \text{ decay/s} \\ &= 2.6 \times 10^6 \text{ decay/y} \end{aligned}$$



NUMBER OF SURVIVING EVENTS

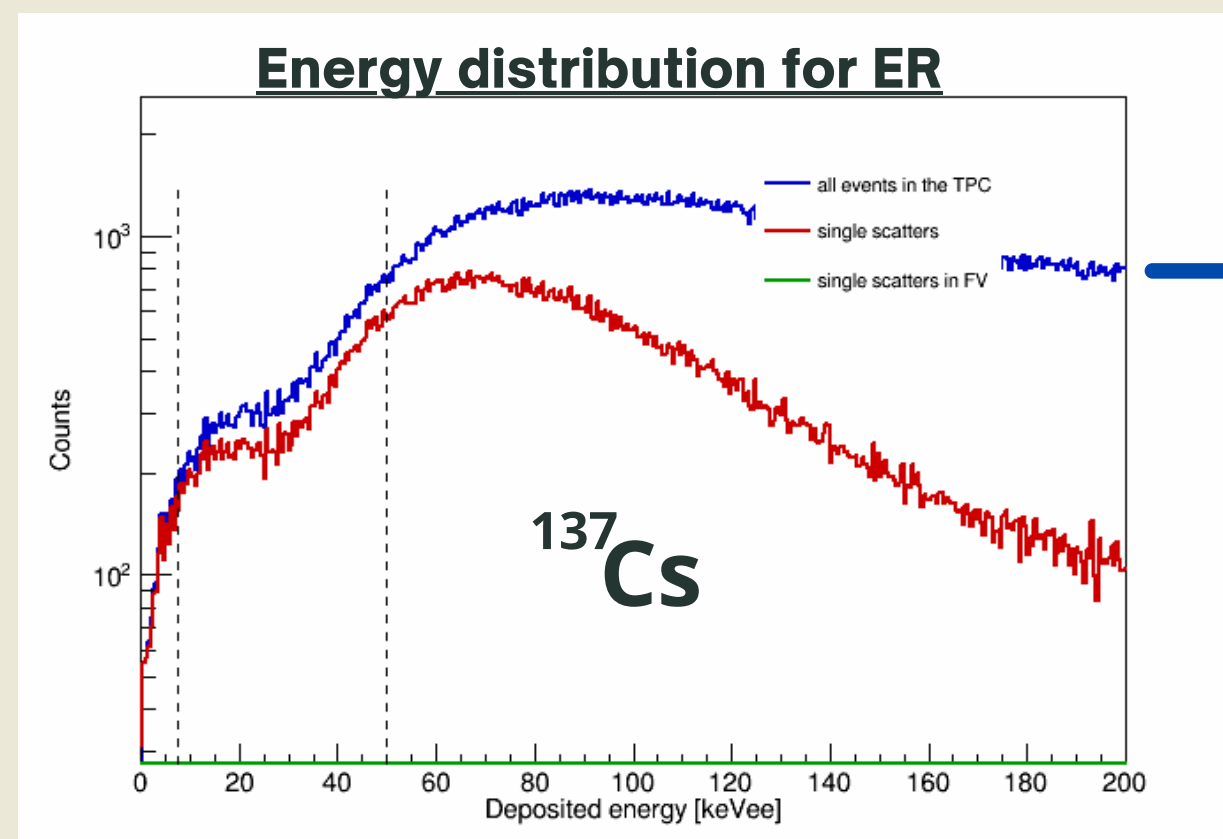
$$\text{Surviving Events Rate} = \frac{\text{Events in Volume}}{\text{Total of events simulated}} \times \text{Rate}$$

10^7 events simulated



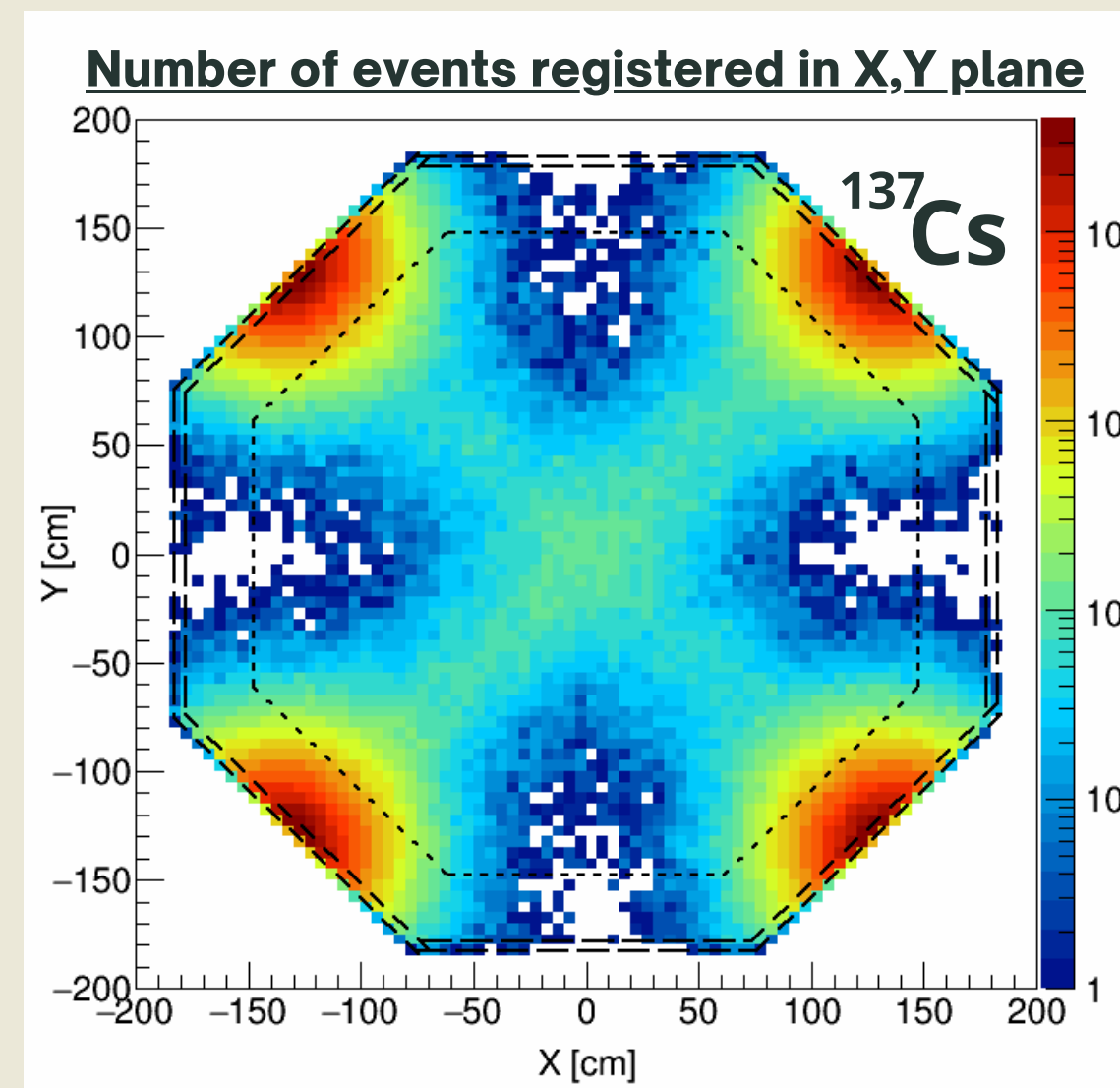
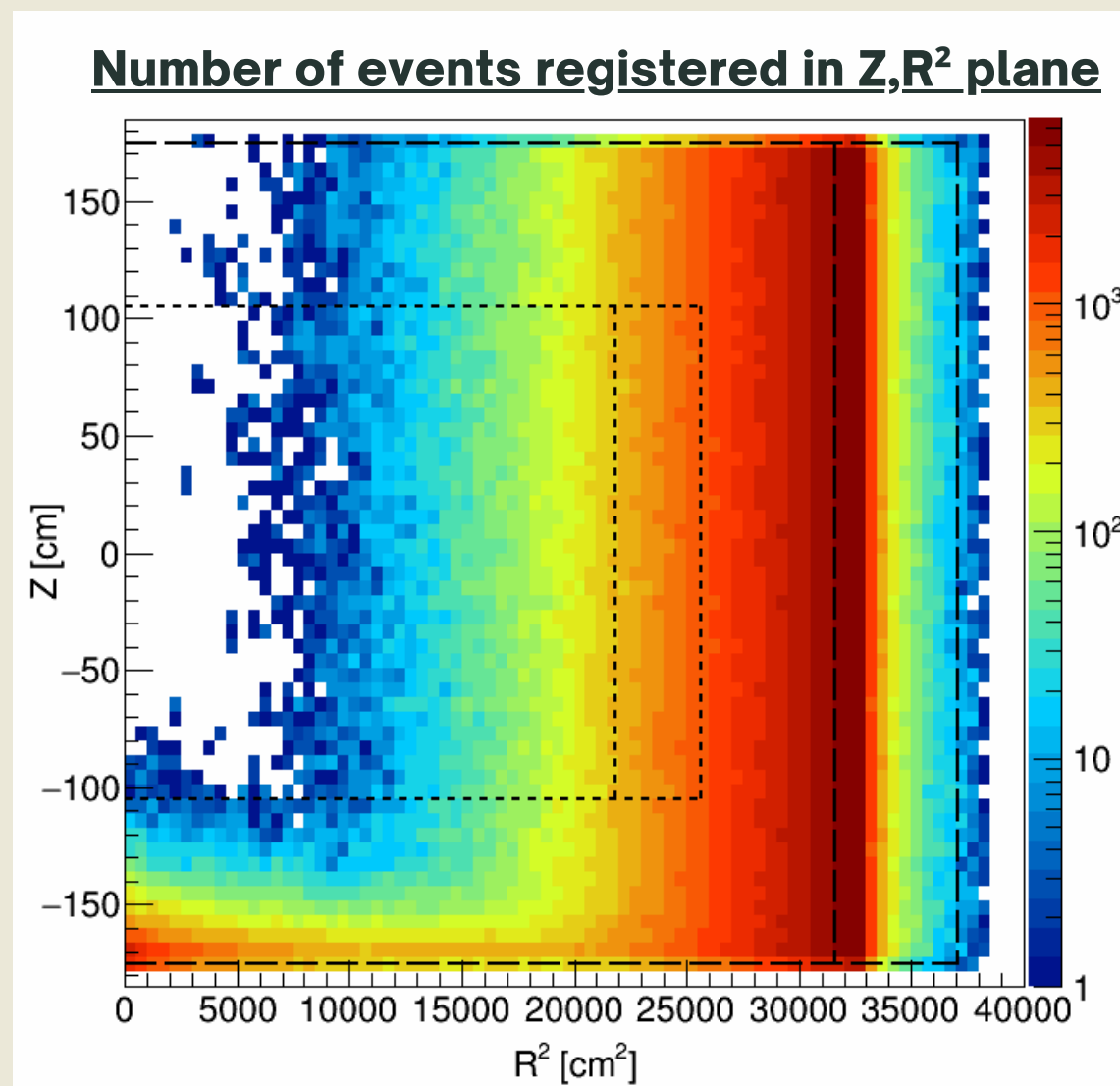
I

B - SIMULATION



150 224 LE events in TPC

ALL ER
at $\text{LE} \in [0, 200 \text{ keV}]$





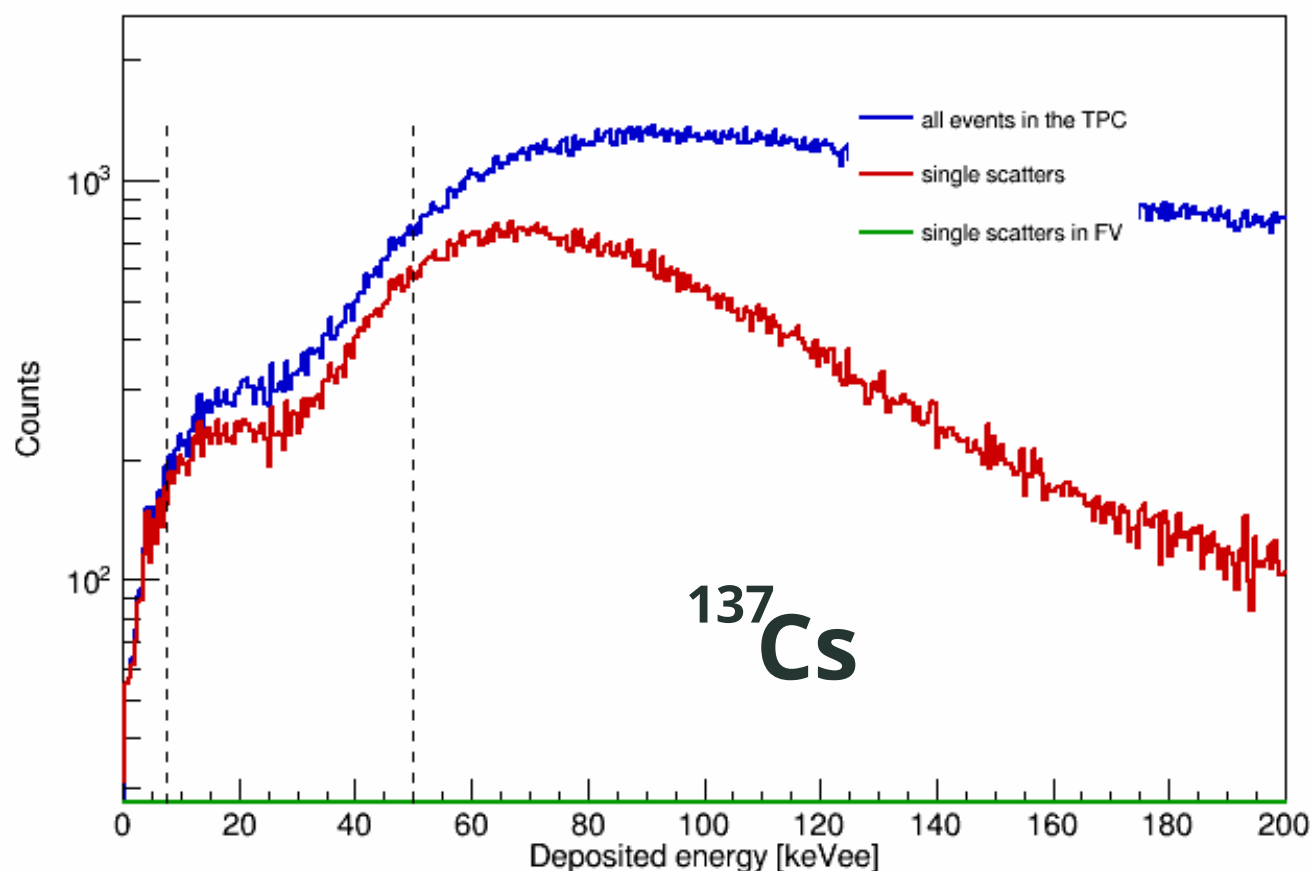
B - SIMULATION

Taking detector response into account

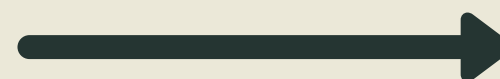
$$\text{Res}(E)=0.0023 + 0.334/\sqrt{E}$$

..... $\text{Res}(E)=0.009 + 0.485/\sqrt{E}$

Energy distribution for ER before resolution

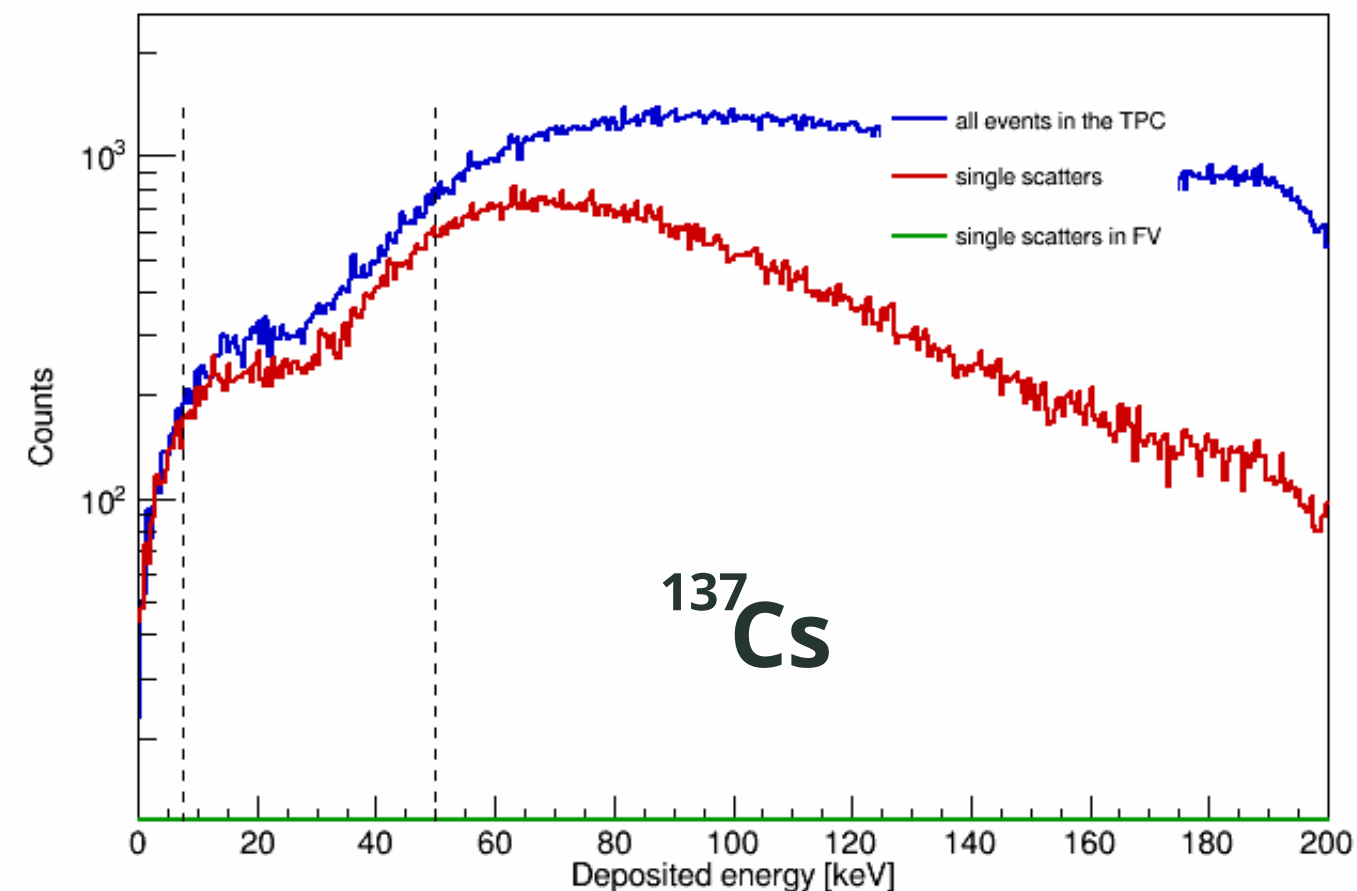


+28 LE events



+117 ROI events

Energy distribution for ER with resolution

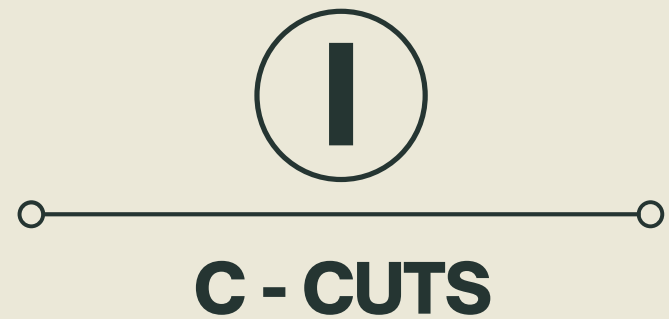


33234 ROI events in TPC

150 224 LE events in TPC

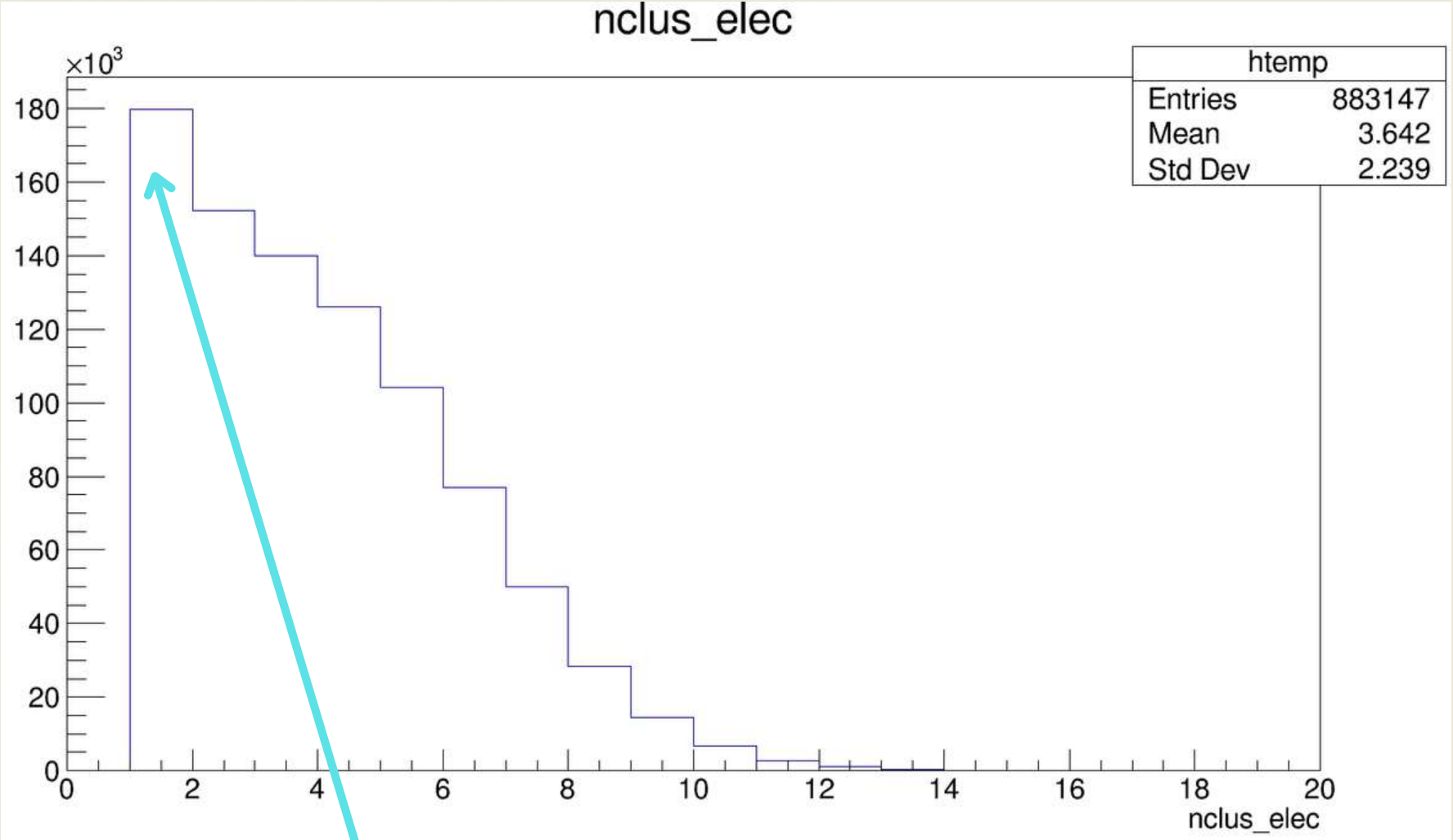
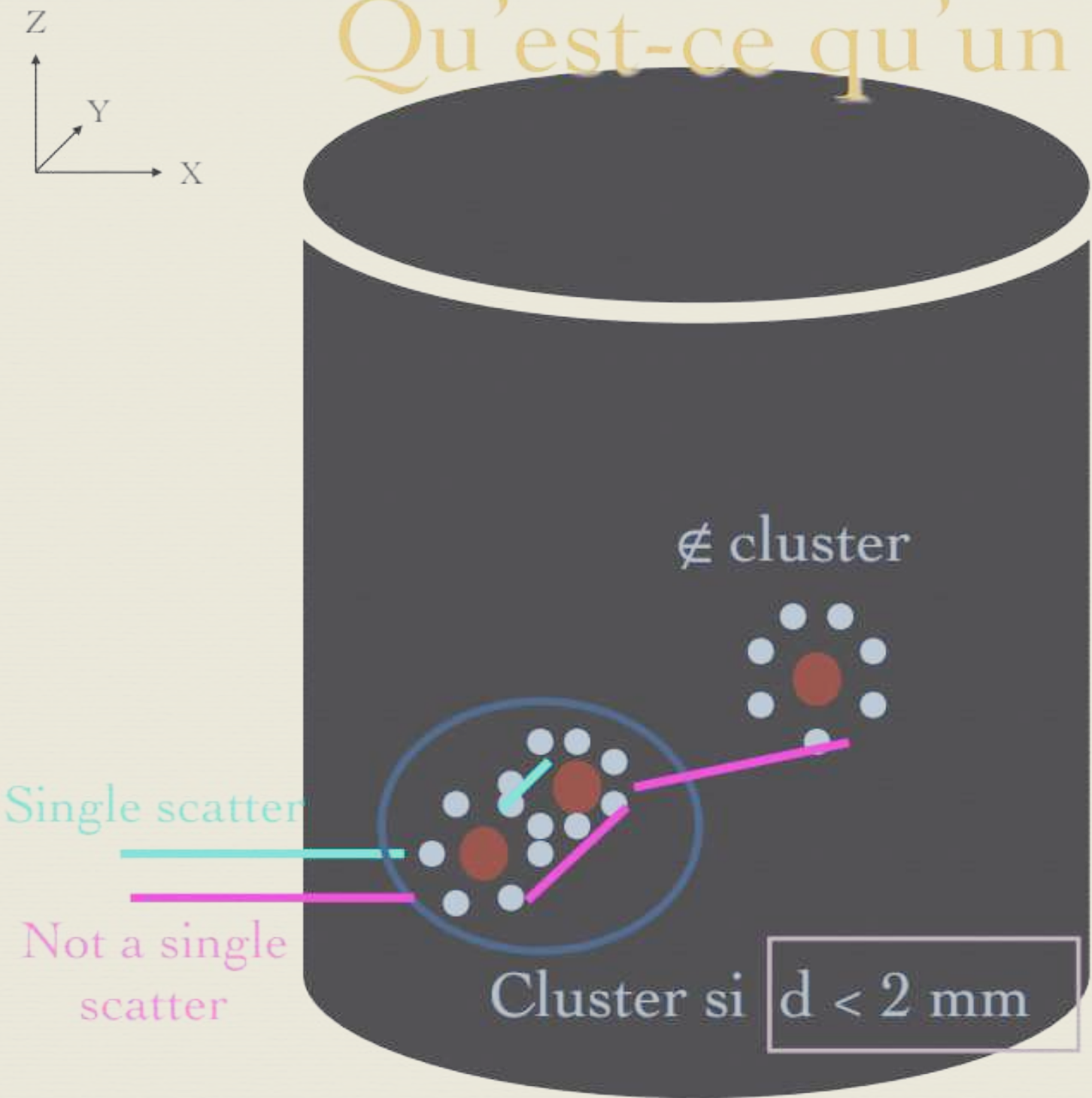
33347 ROI events in TPC

150 352 LE events in TPC



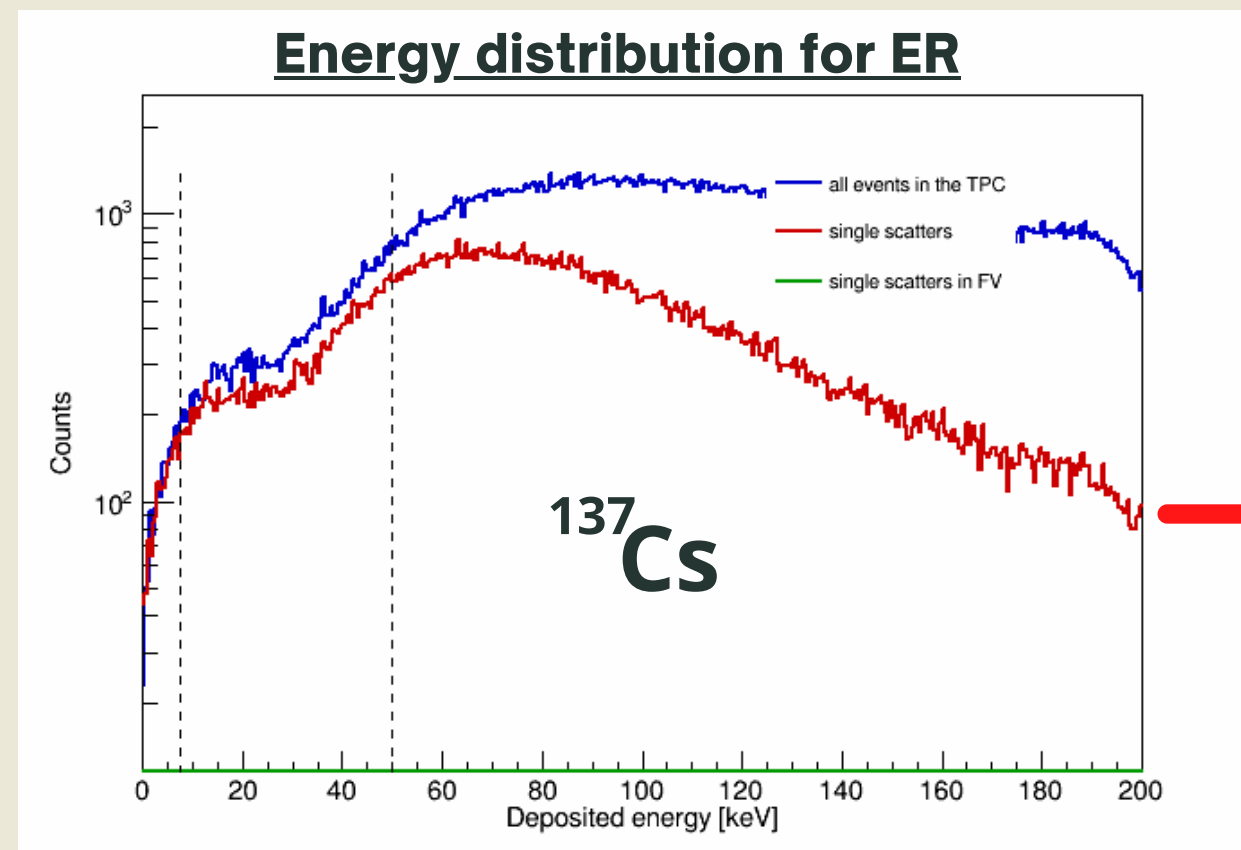
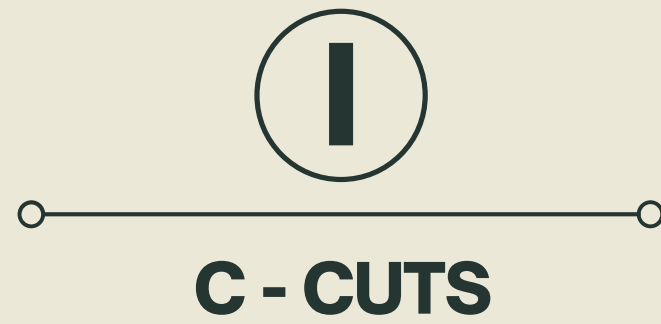
Exclude non-single scatter events

Qu'est-ce qu'un single scatter ?

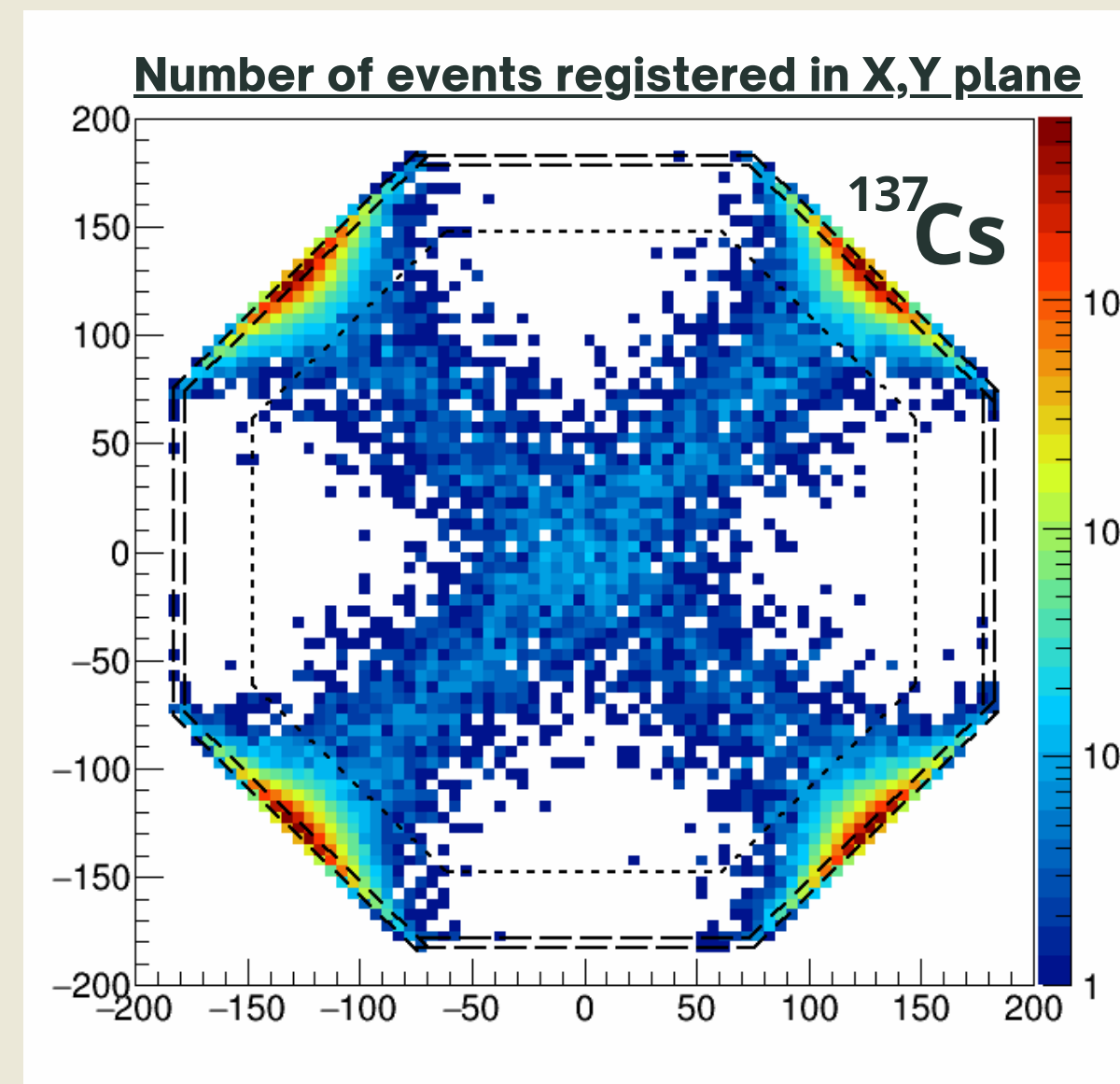
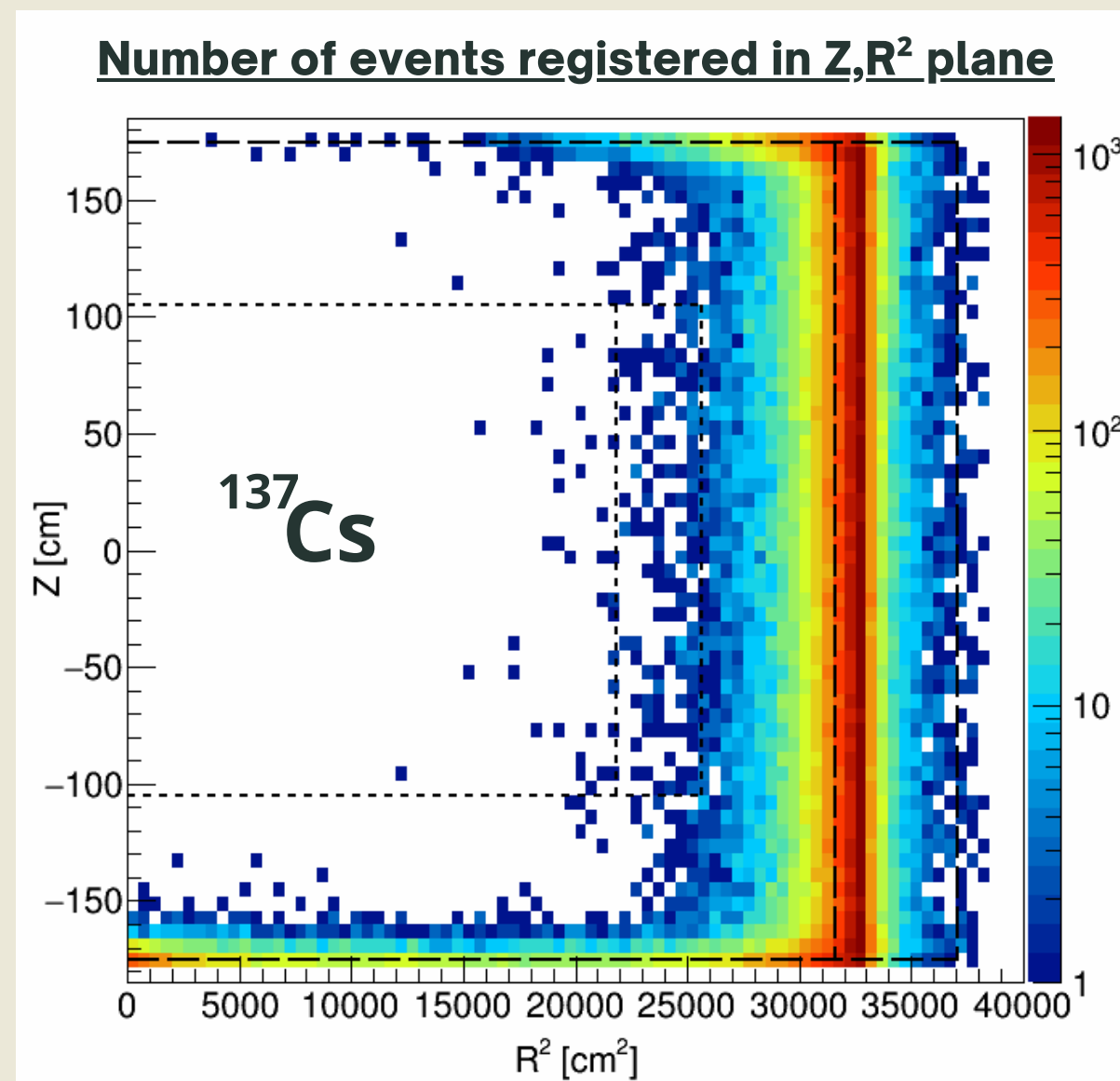


Vient de la résolution lors de la reconstruction en z

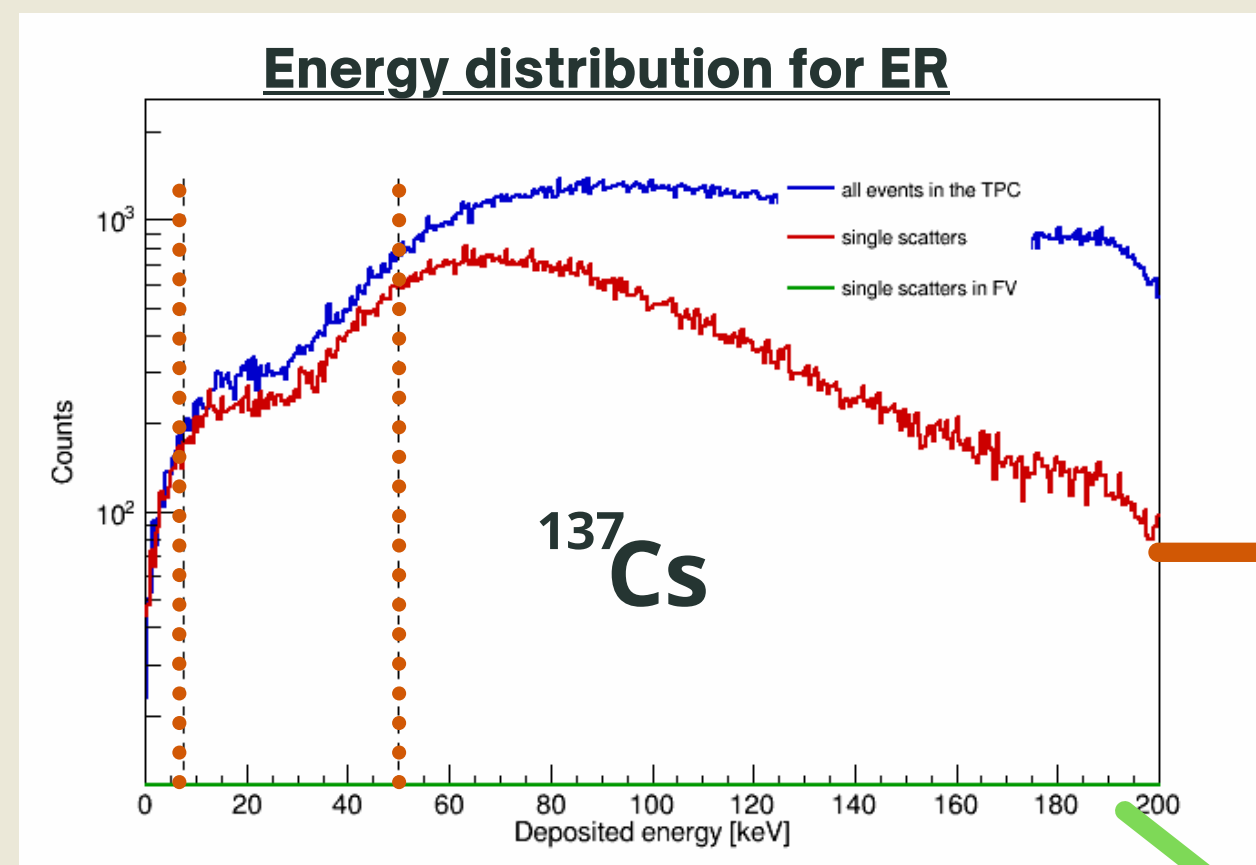
Single scatter



94702 LE SS in the TPC

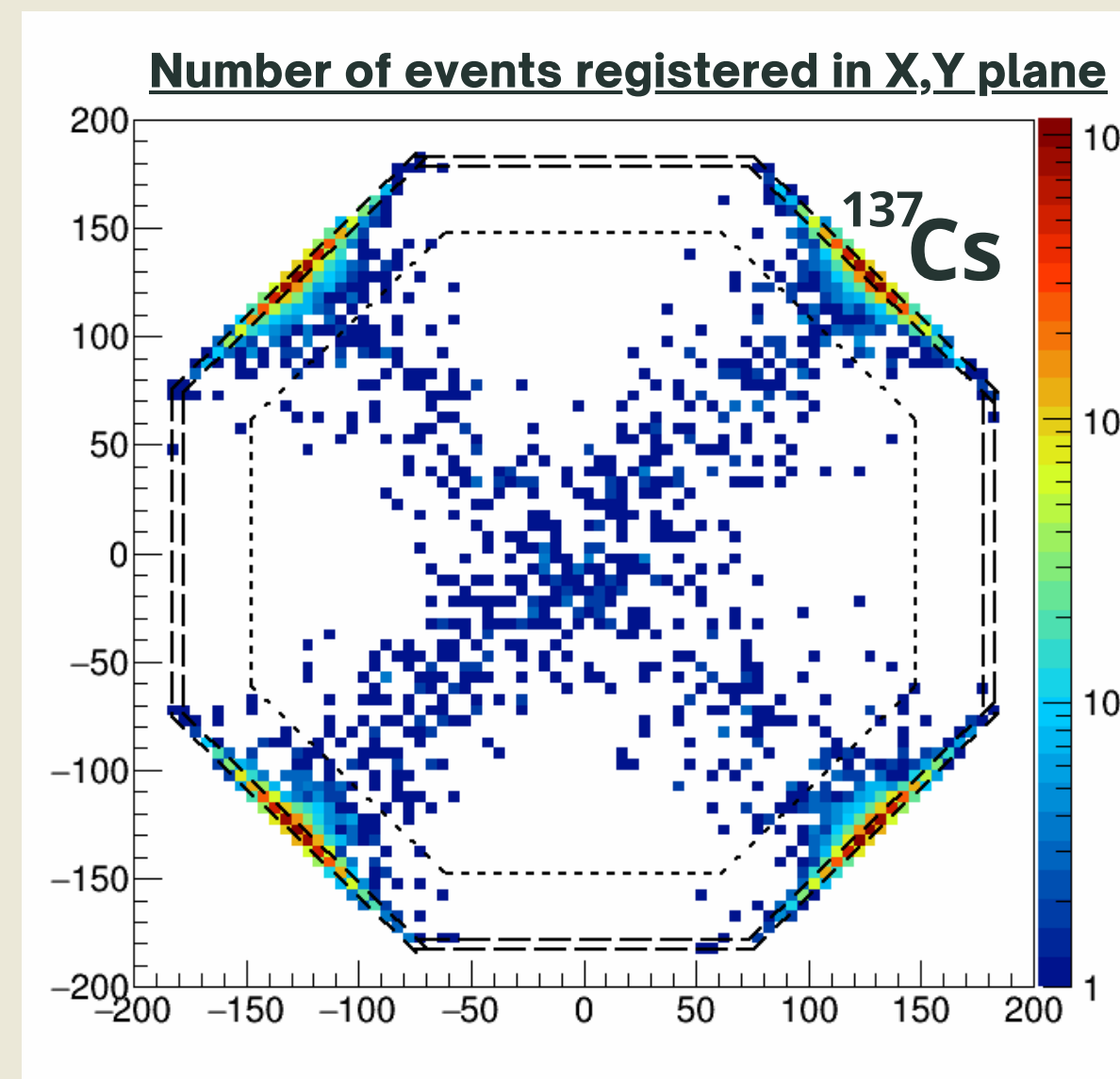
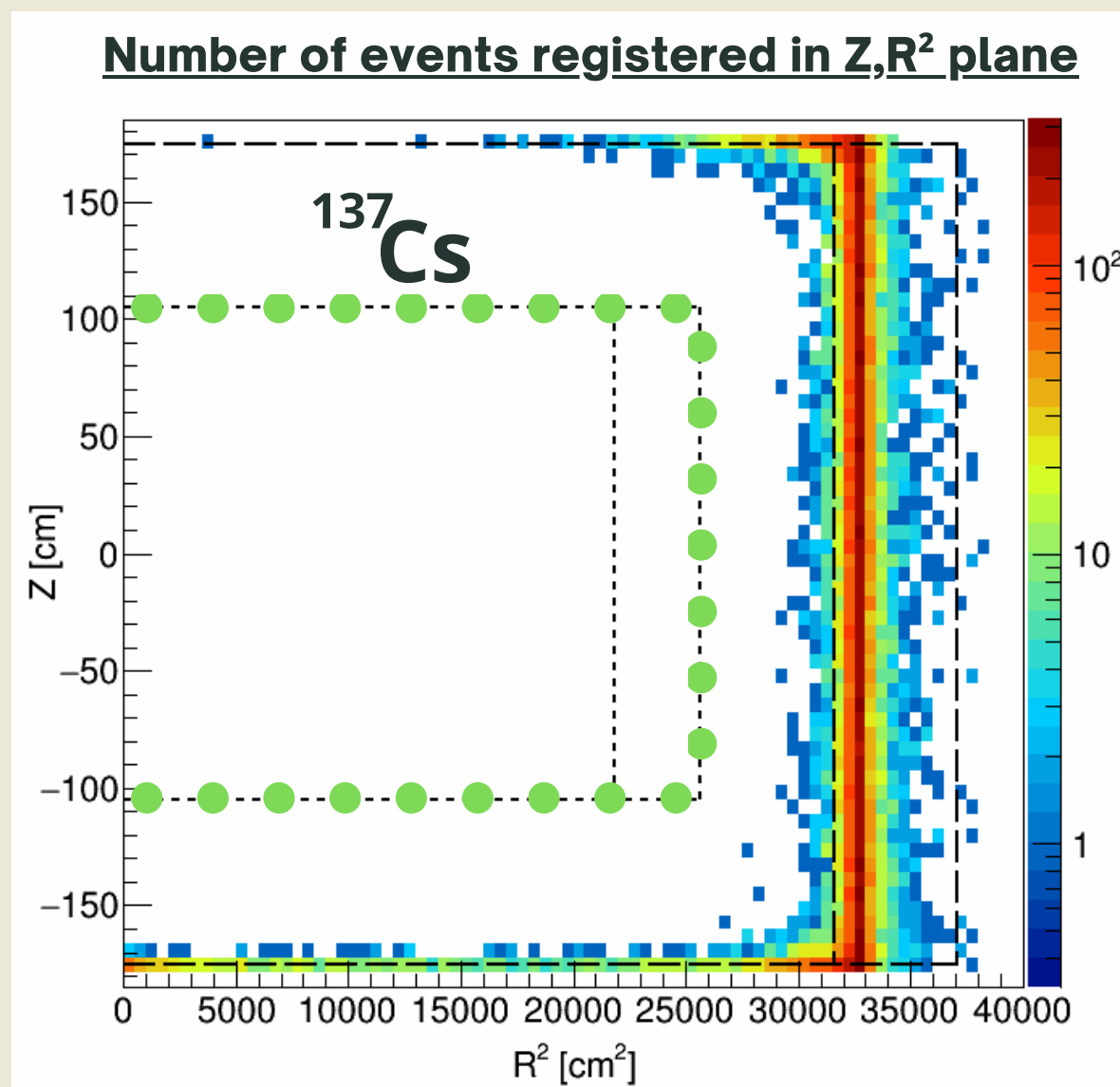


**ONLY SINGLE
SCATTERS (SS)
at LE \in [0,200 keV]**



**ONLY SINGLE
SCATTERS (SS)
IN ROI**

26478 SS at ROI



0 SS in FV (ROI)

**SINGLE SCATTERS
IN ROI
INSIDE FV**



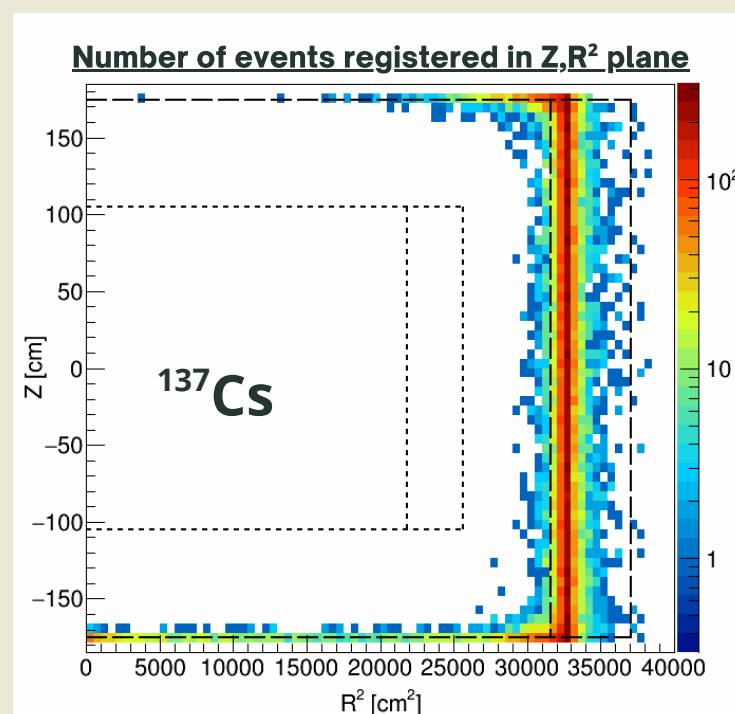
ER BACKGROUND RATES

DECAY PER YEAR ESTIMATION

ACTIVITY

STAINLESS STEEL ACTIVITY

| Sample identifier | Radioactive contamination [mBq/kg] | | | | |
|-------------------|------------------------------------|------------------|------------------|-----------------|-------------------|
| | ^{232}Th | ^{238}U | ^{60}Co | ^{40}K | ^{137}Cs |
| SS | 10 | 10 | — | — | — |
| SS ArDM | 20 | 50 | 13 | 6.4 | 1.5 |



< 2.3 events

Statistical margin

Exemple ^{137}Cs

$$\text{Activity} = 0.0015 \text{ Bq/kg}$$

$$\begin{aligned} \text{Rate} &= 0.0015 \text{ Bq/kg} \times 56 \text{ kg} = 0.084 \text{ decay/s} \\ &= 2.6 \times 10^6 \text{ decay/y} \end{aligned}$$

$$\begin{aligned} \text{Surviving Events Rate} &< \frac{2.3 \text{ events}}{10^7 \text{ events}} \times 2.6 \times 10^6 \text{ decay/y} \\ &= \\ &0.60 \text{ events/y} \end{aligned}$$

$$\text{PSD} : \times 10^{-8}$$



ER BACKGROUND RATES

Background event rates for 56kg of stainless steel, 1e7 events simulated

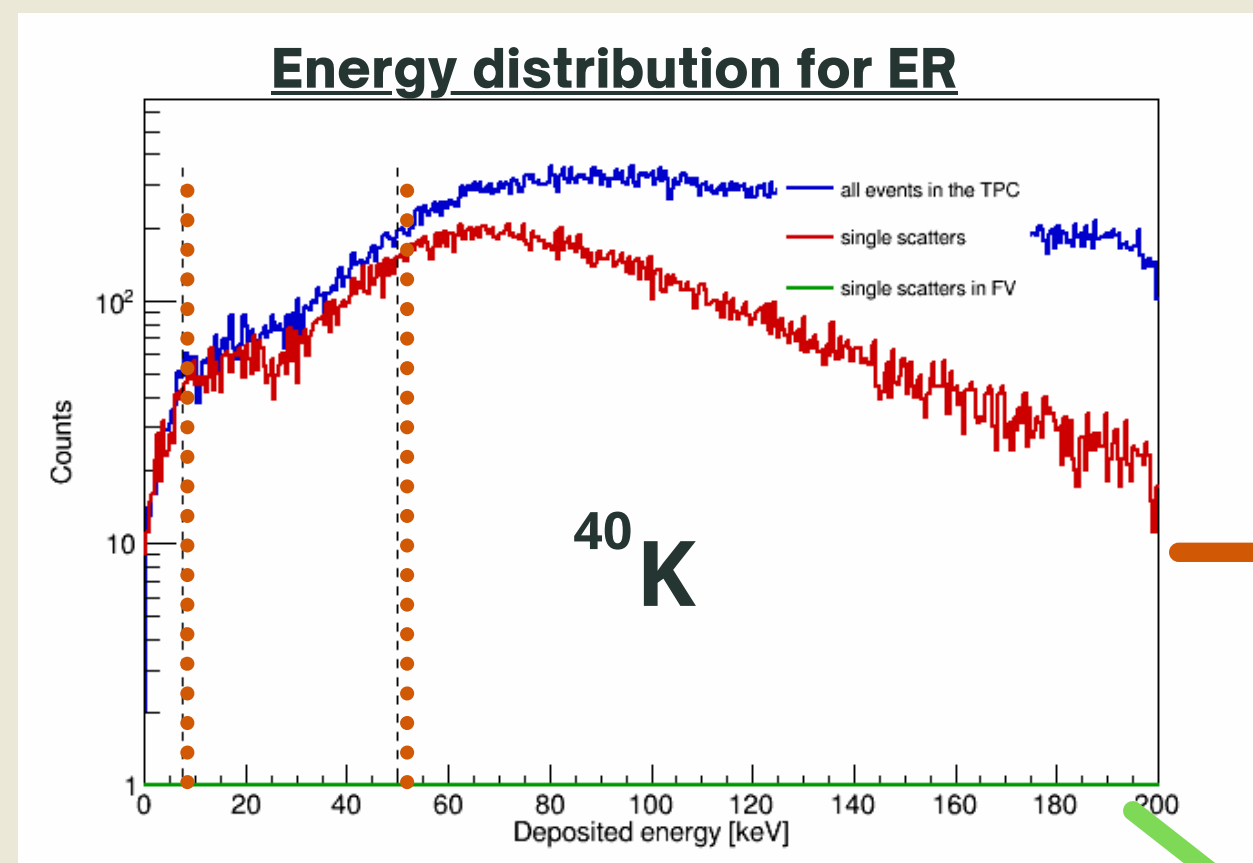
| Element | Contamination (mBq/kg) | Decay/s | decay/y | events sim FV | events/y | events/y PSD |
|-------------------|------------------------|---------|----------|---------------|----------|--------------|
| ^{137}Cs | 1.5 | 0.08 | 2.65e+06 | <2.30 | <0.60 | <0.00 |
| ^{40}K | 6.4 | 0.35 | 1.13e+07 | <2.30 | <2.59 | <0.00 |
| ^{60}Co | 13.0 | 0.72 | 2.30e+07 | <2.30 | <5.28 | <0.00 |
| ^{238}U | 50.0 | 2.80 | 8.83e+07 | <2.30 | <20.30 | <0.00 |
| ^{232}Th | 20.0 | 1.12 | 3.53e+07 | <2.30 | <8.12 | <0.00 |

| Predicted background rate [events/year] | | | | |
|---|------------------|------------------|-----------------|-------------------|
| ^{232}Th | ^{238}U | ^{60}Co | ^{40}K | ^{137}Cs |
| <1.6 | <2.4 | — | — | — |
| <4.4 | <12.2 | <1.1 | <0.5 | <0.1 |

A. Kish's results for 25 kg tube, and statistical margin of 1 (instead of 2.3)

BACKUP

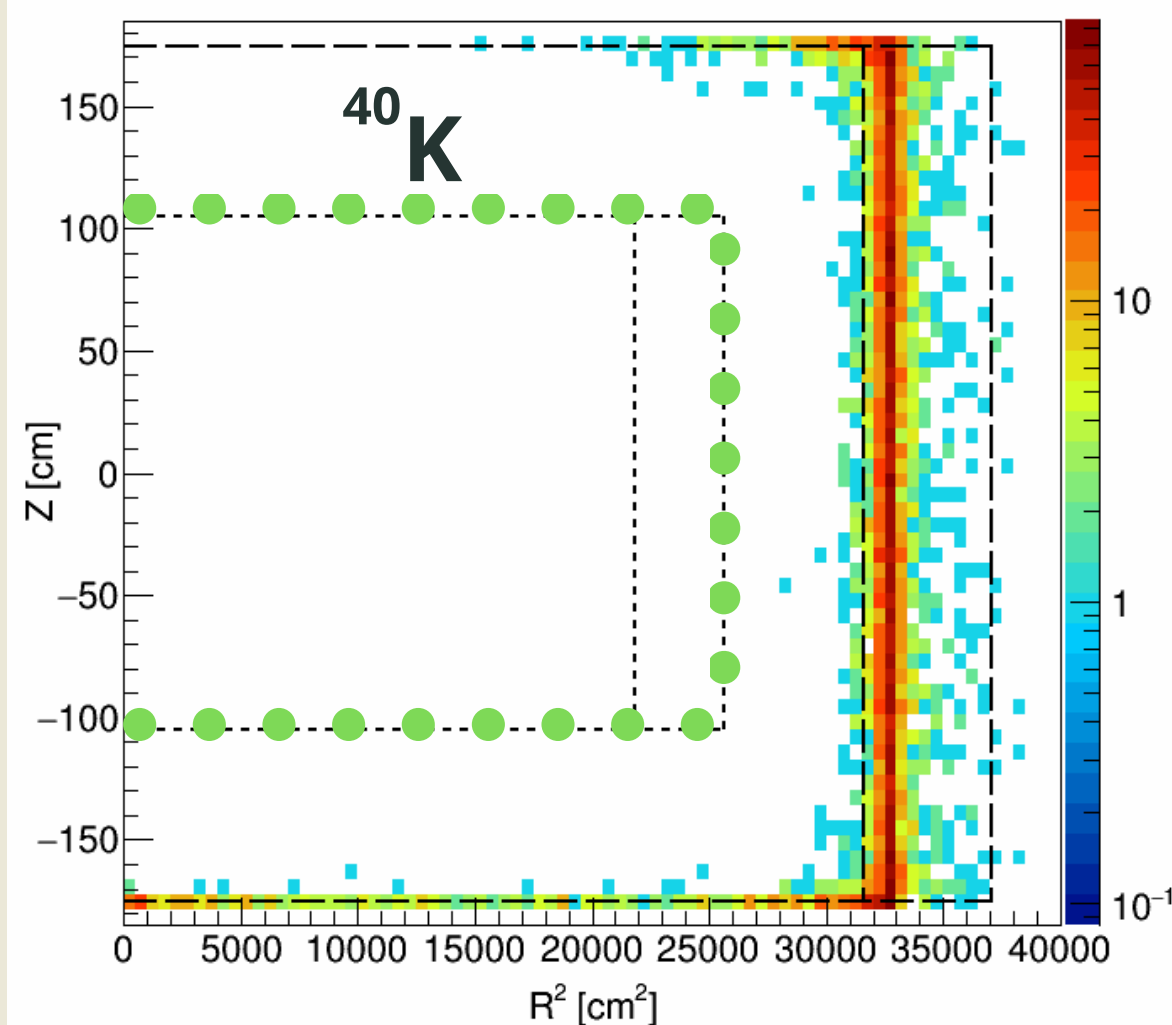




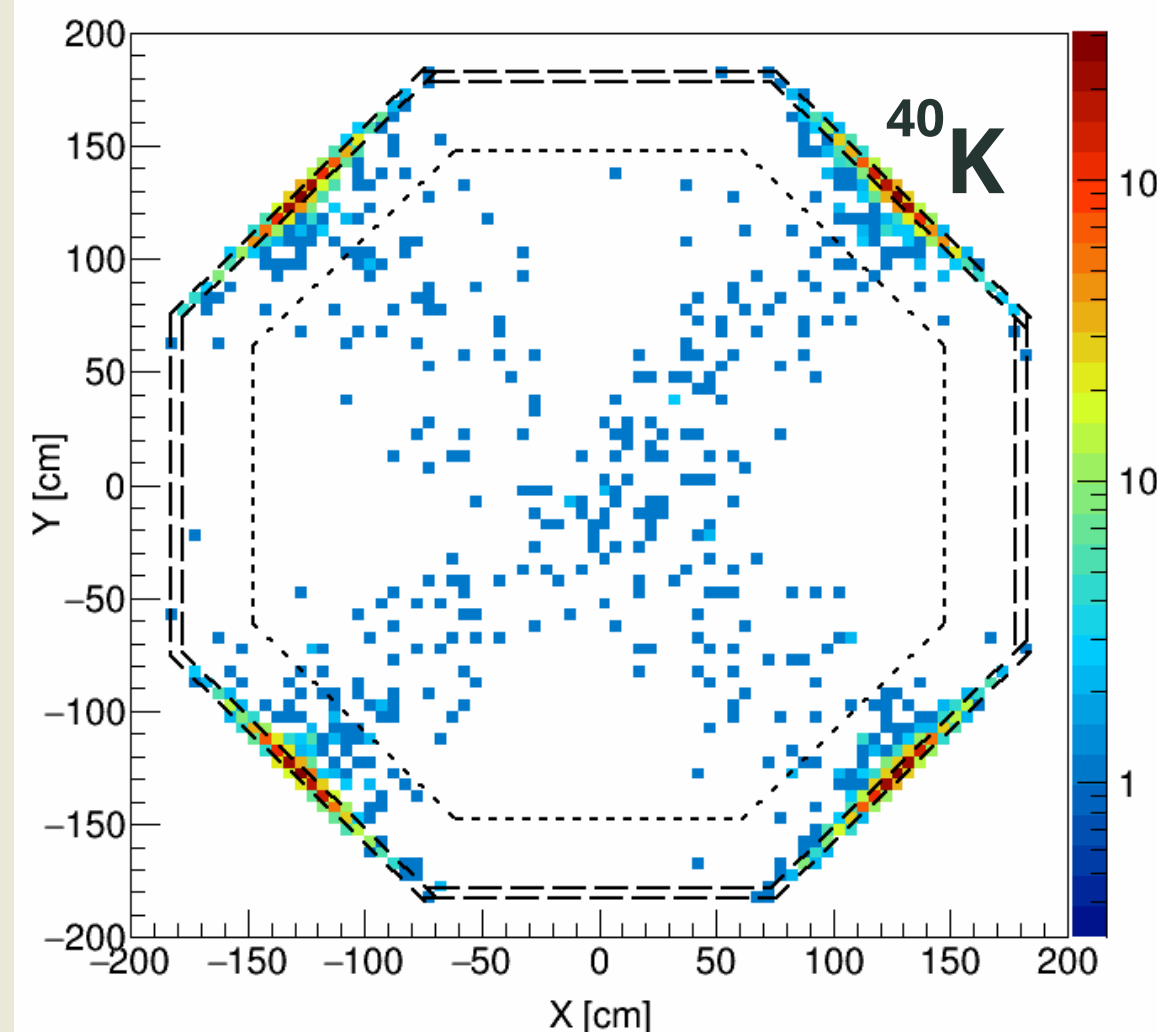
**ONLY SINGLE
SCATTERS (SS)
IN ROI**

6557 SS at ROI

Number of events registered in Z,R² plane

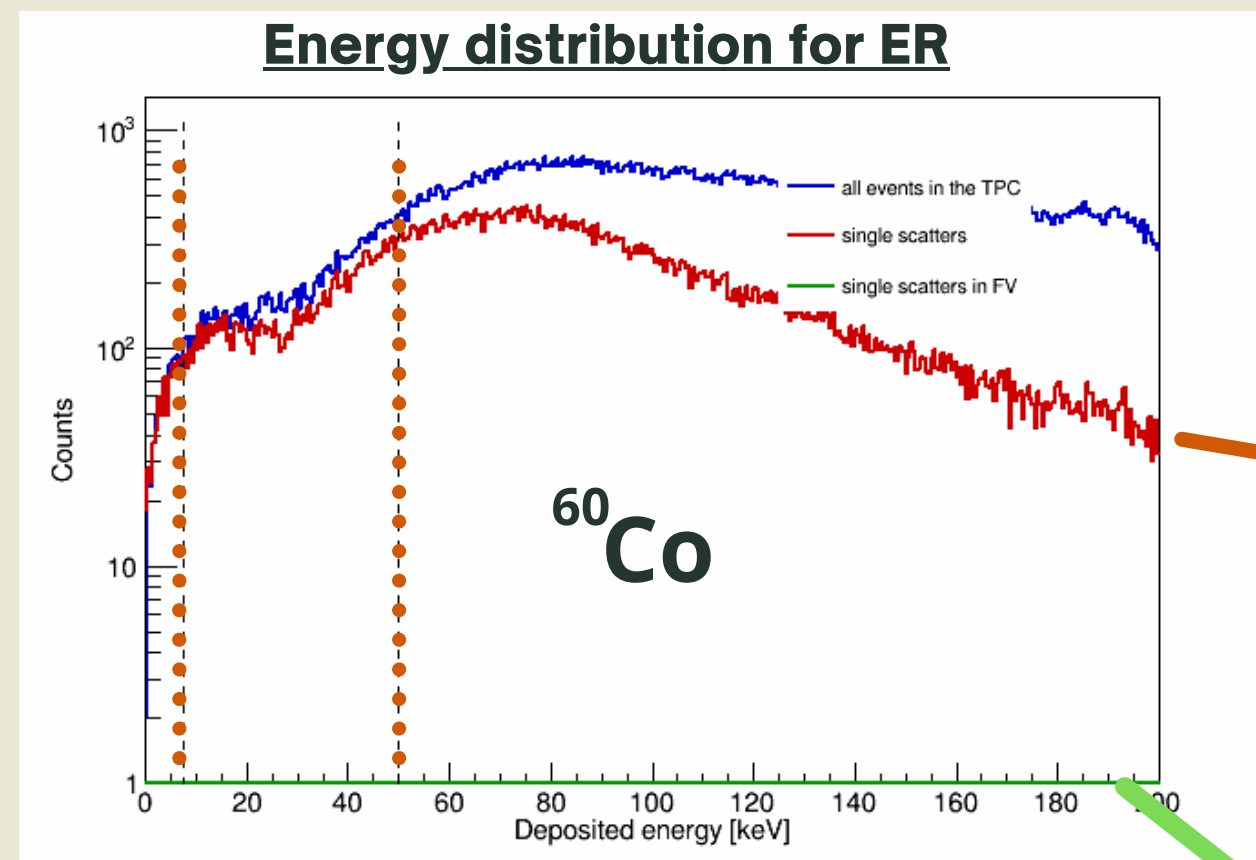
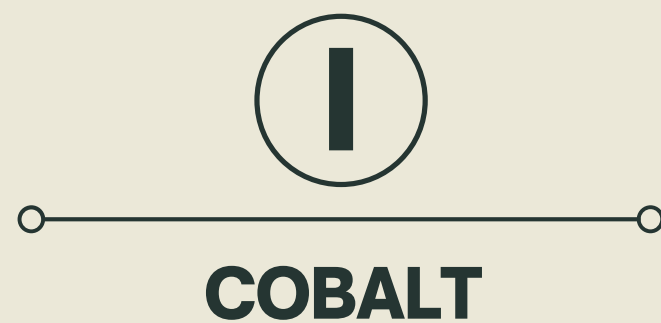


Number of events registered in X,Y plane



0 SS in FV (ROI)

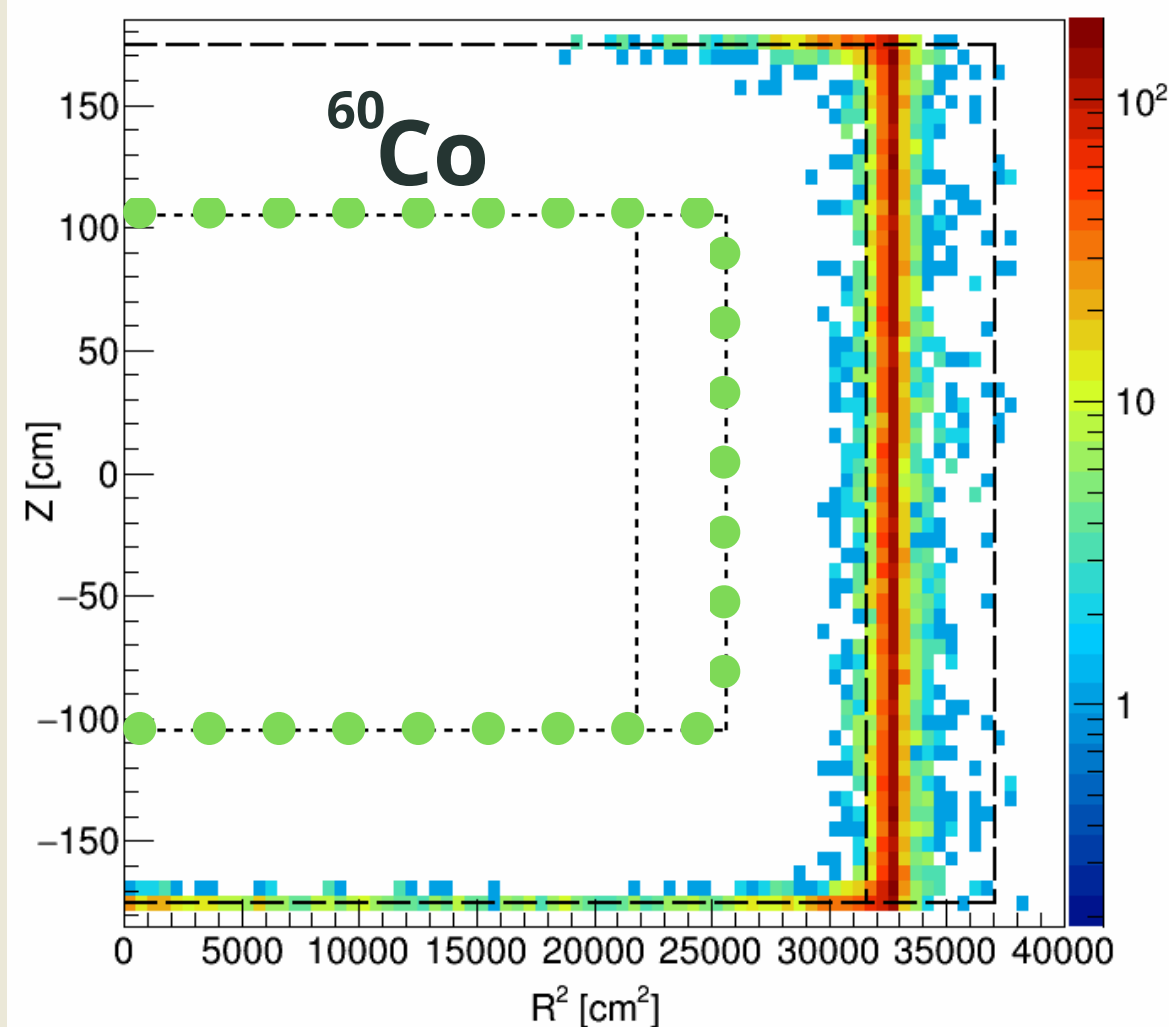
**SINGLE SCATTERS
IN ROI
INSIDE FV**



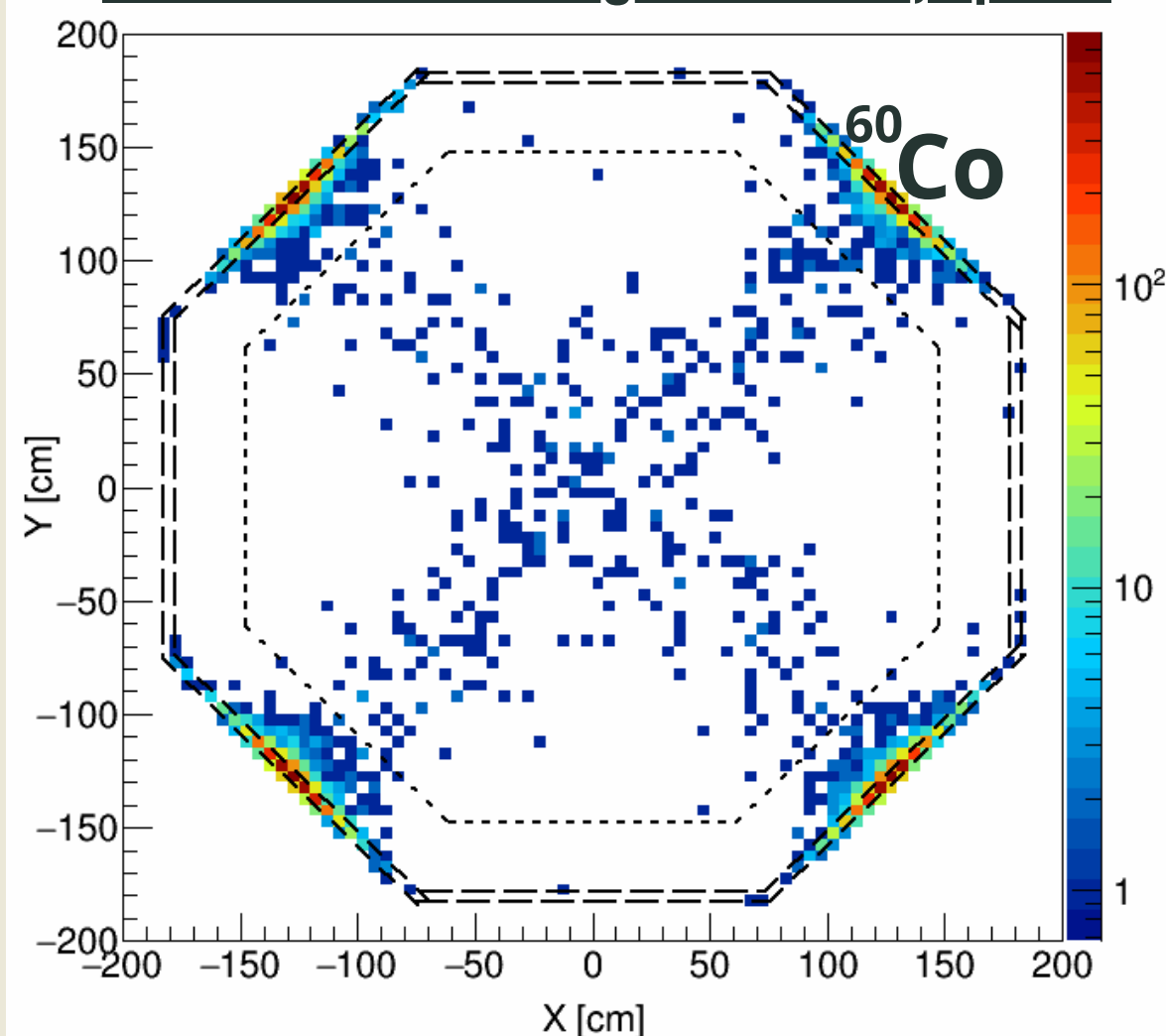
**ONLY SINGLE
SCATTERS (SS)
IN ROI**

68564 SS at ROI

Number of events registered in Z,R² plane

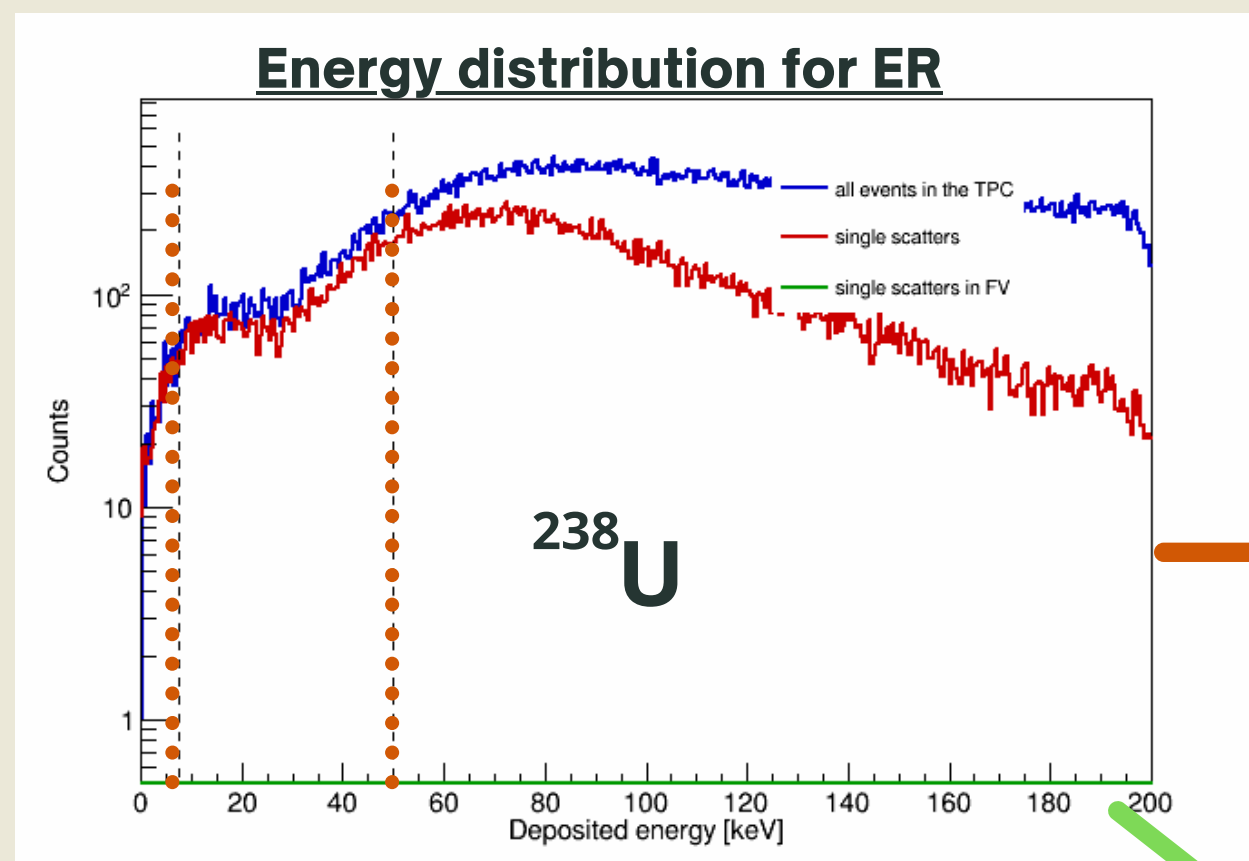


Number of events registered in X,Y plane



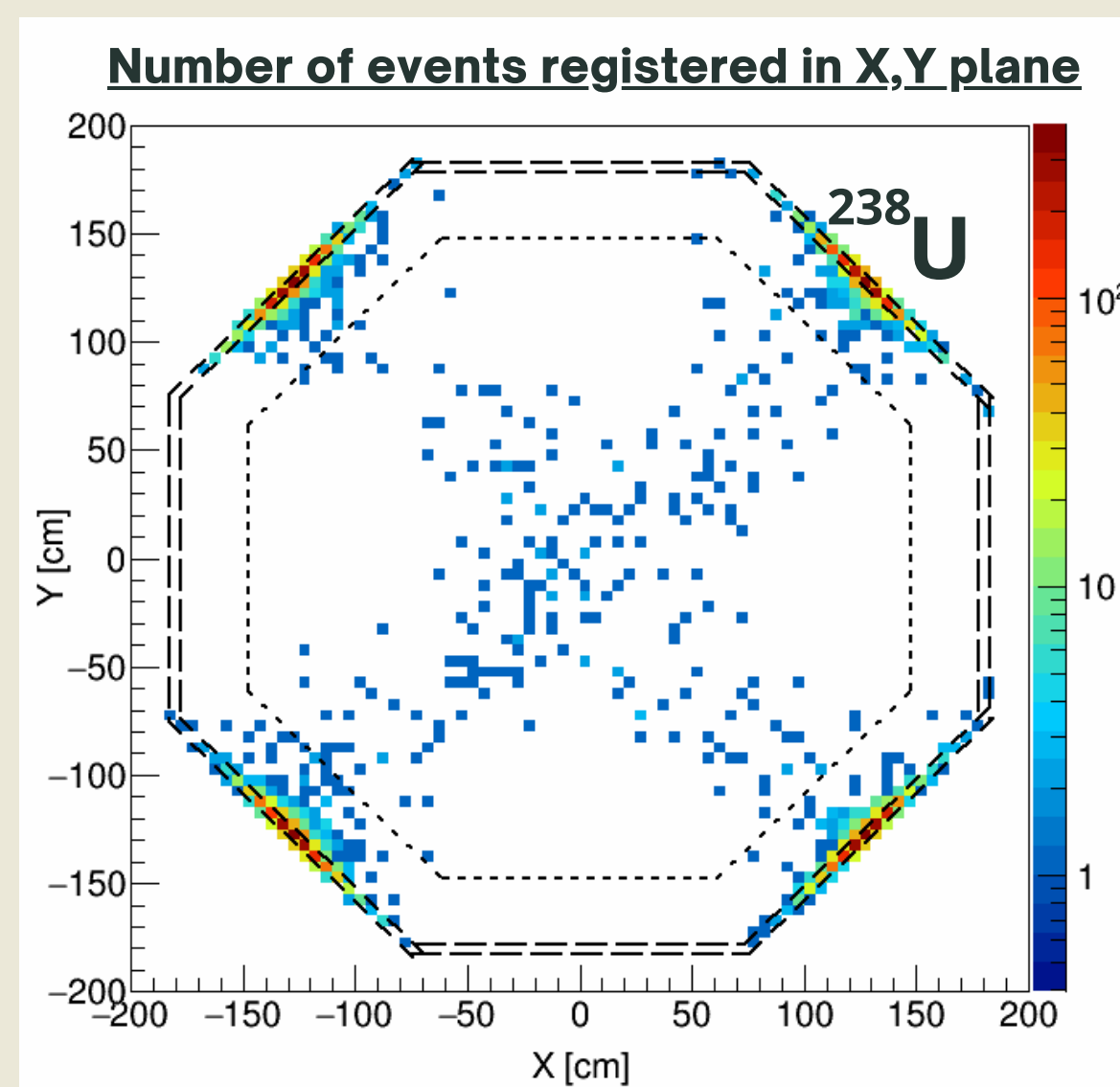
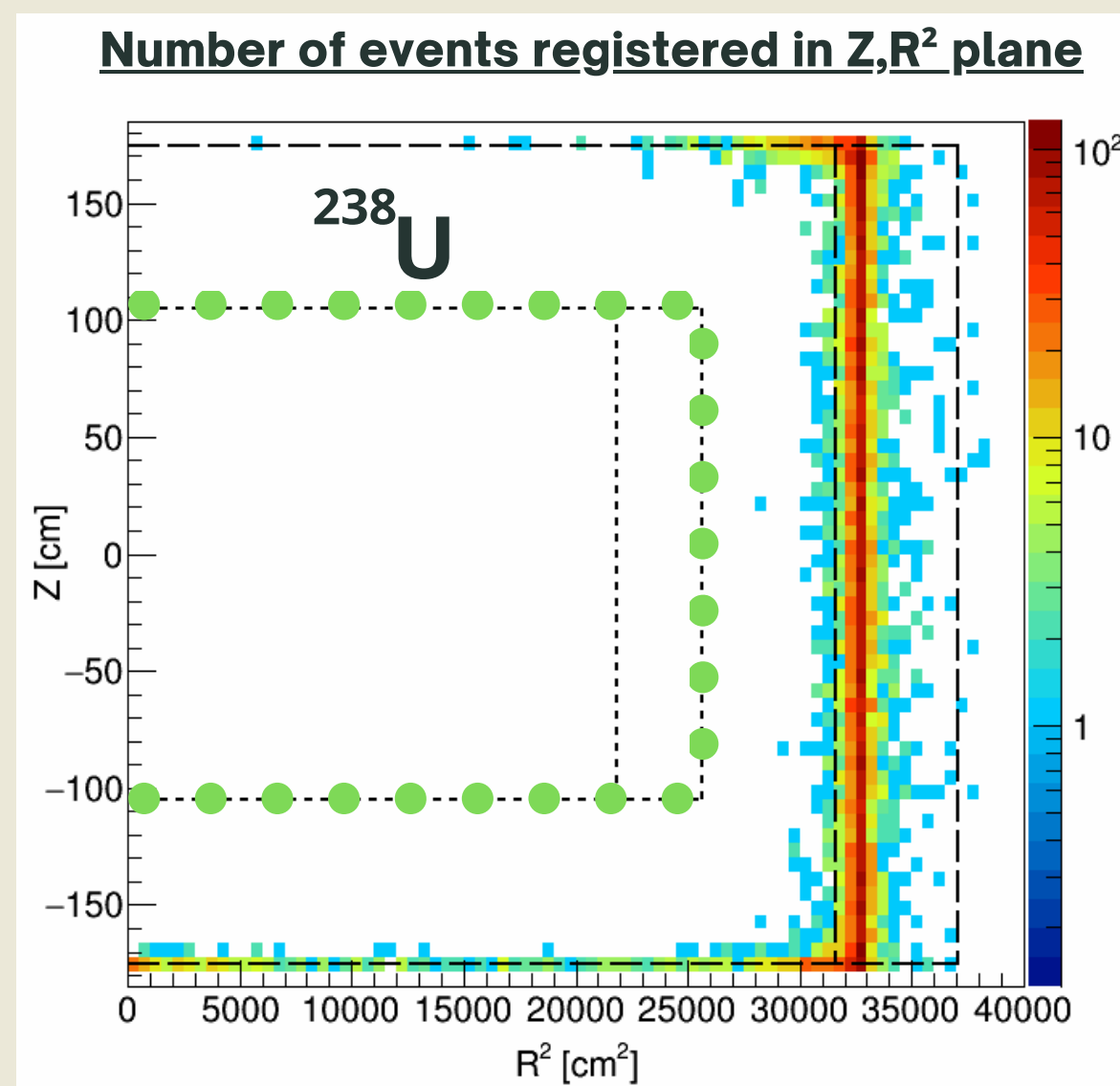
0 SS in FV (ROI)

**SINGLE SCATTERS
IN ROI
INSIDE FV**



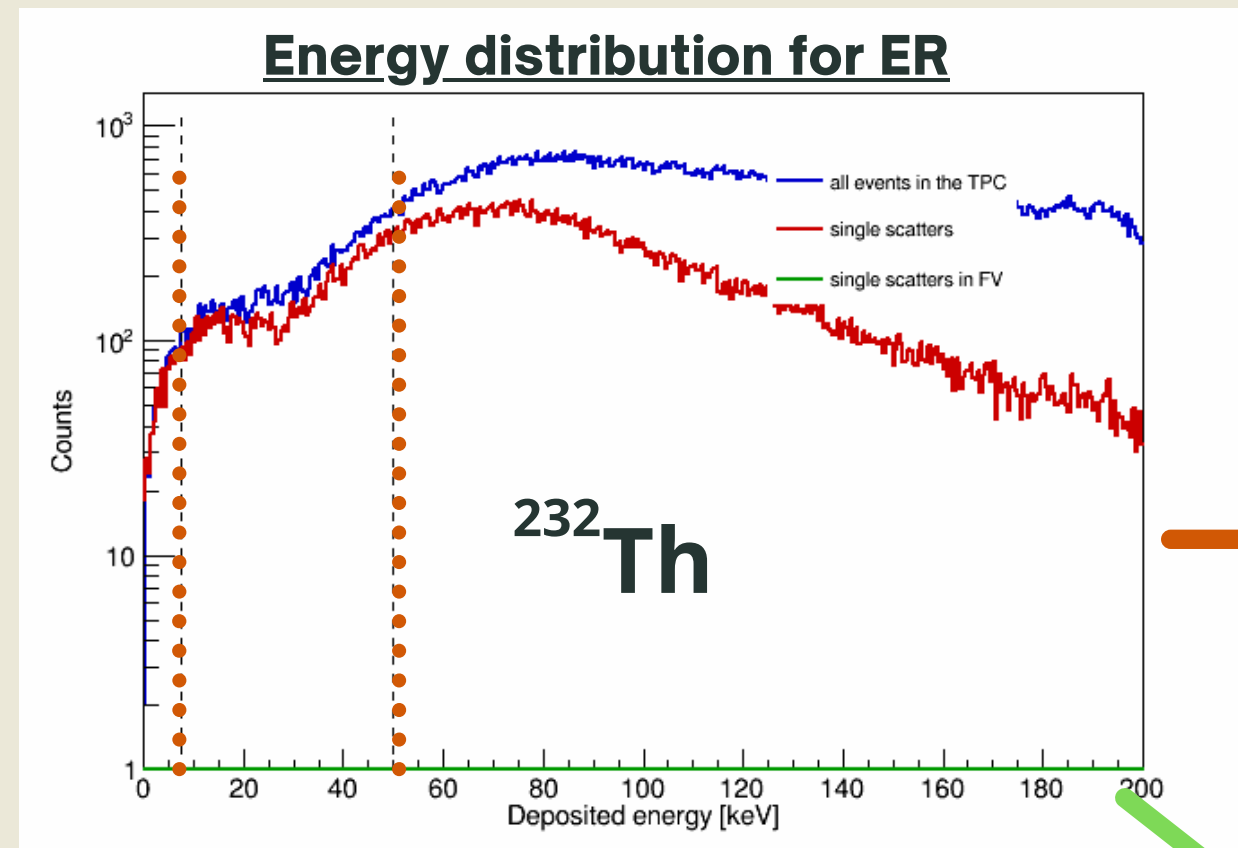
**ONLY SINGLE
SCATTERS (SS)
IN ROI**

8046 SS at ROI



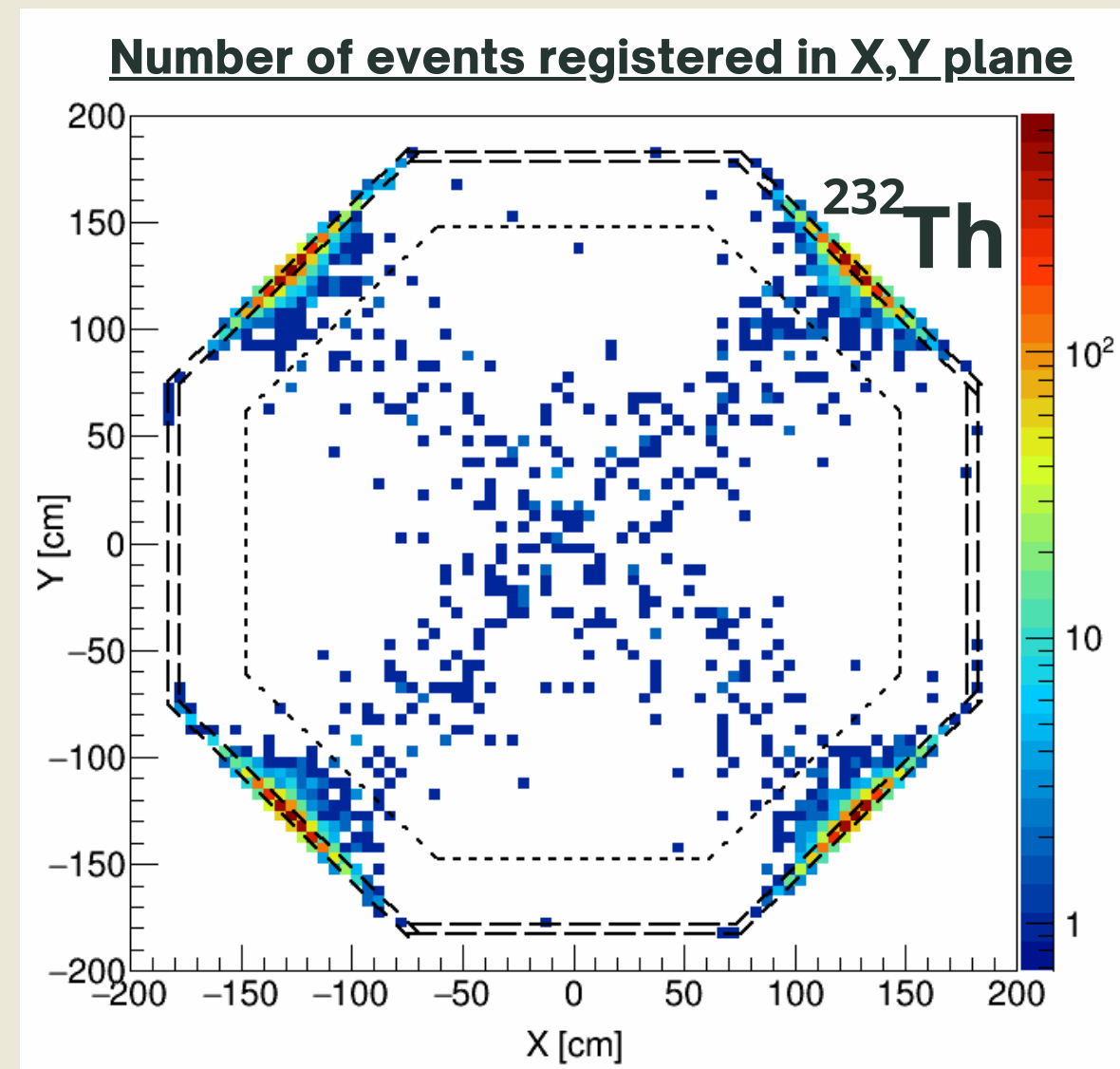
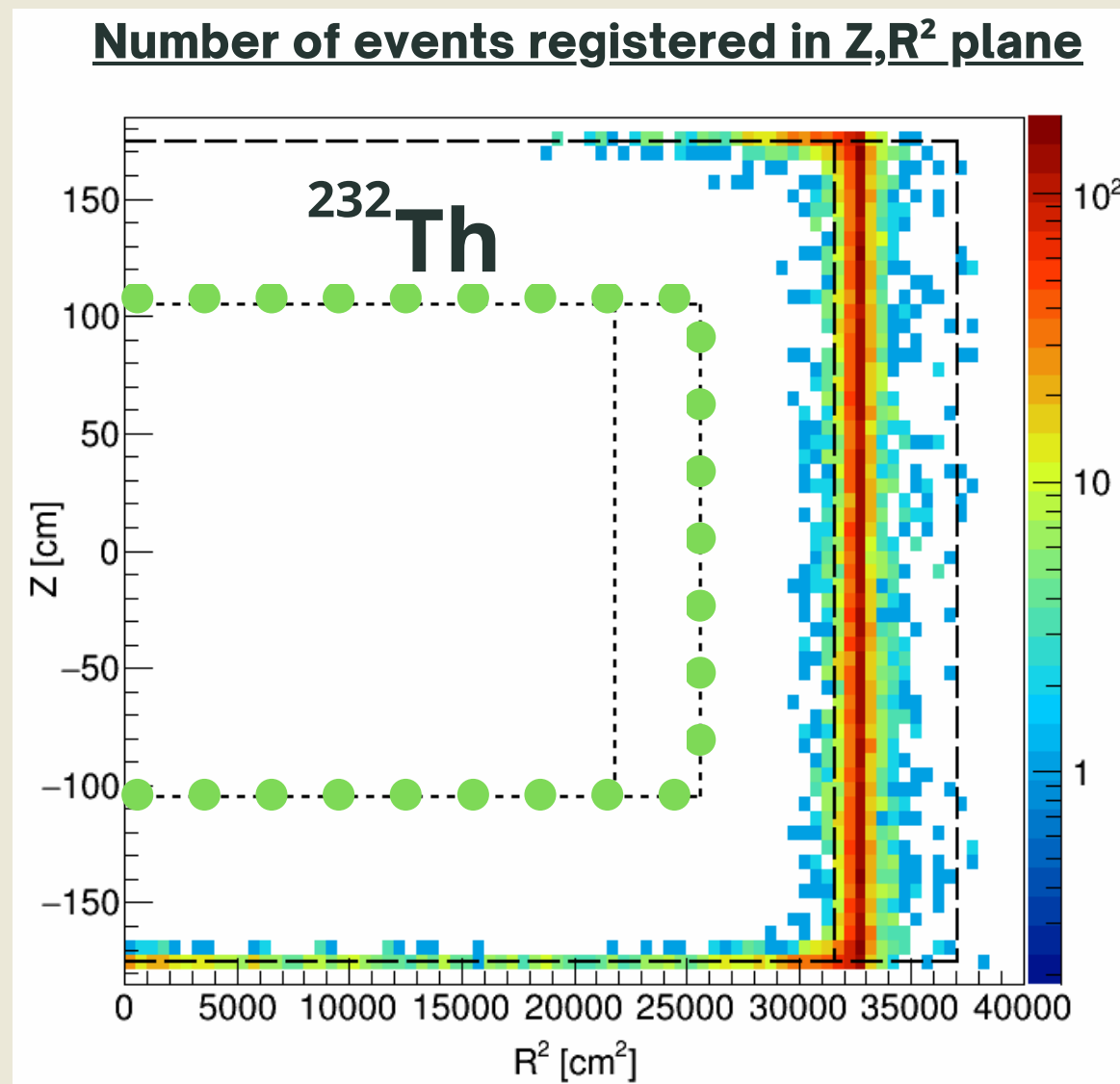
0 SS in FV (ROI)

**SINGLE SCATTERS
IN ROI
INSIDE FV**



**ONLY SINGLE
SCATTERS (SS)
IN ROI**

13833 SS at ROI



0 SS in FV (ROI)

**SINGLE SCATTERS
IN ROI
INSIDE FV**