

supernemo



collaboration

# Study of radon background in SuperNEMO

2026/06/30 Collaboration meeting, Bratislava

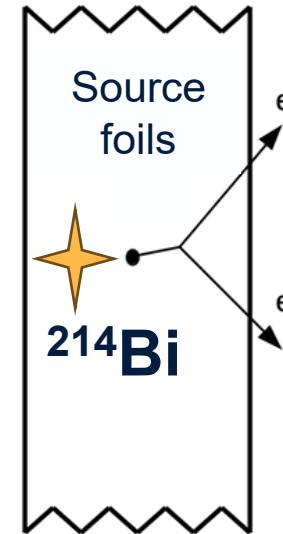
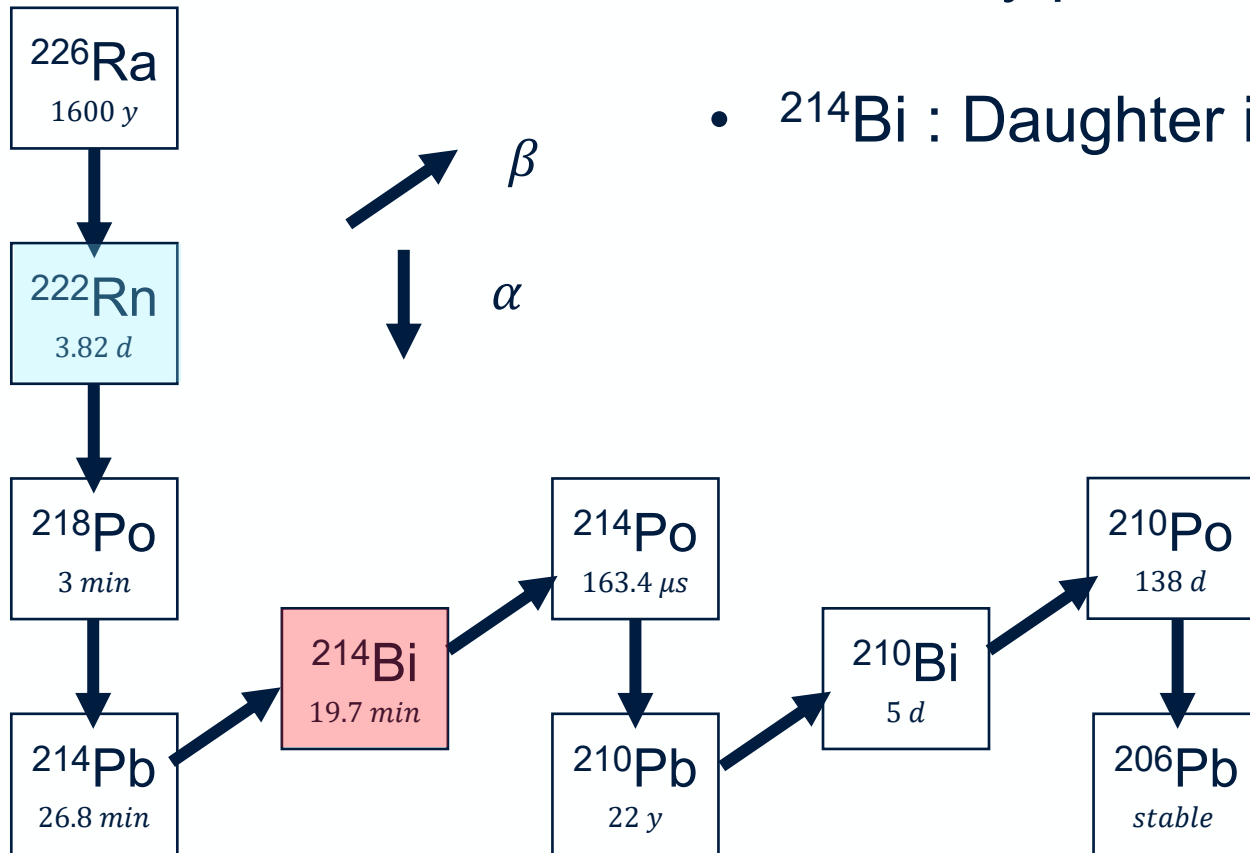
cnrs

Antoine Lahaie, LP2IB



# Radon as background : $\beta\beta 2\nu$ & $\beta\beta 0\nu$

- Naturally present in environment ( $^{238}\text{U}$  chain decay)
- $^{214}\text{Bi}$  : Daughter isotope of Rn  $\rightarrow Q_{\beta^-} = 3.269 \text{ MeV}$



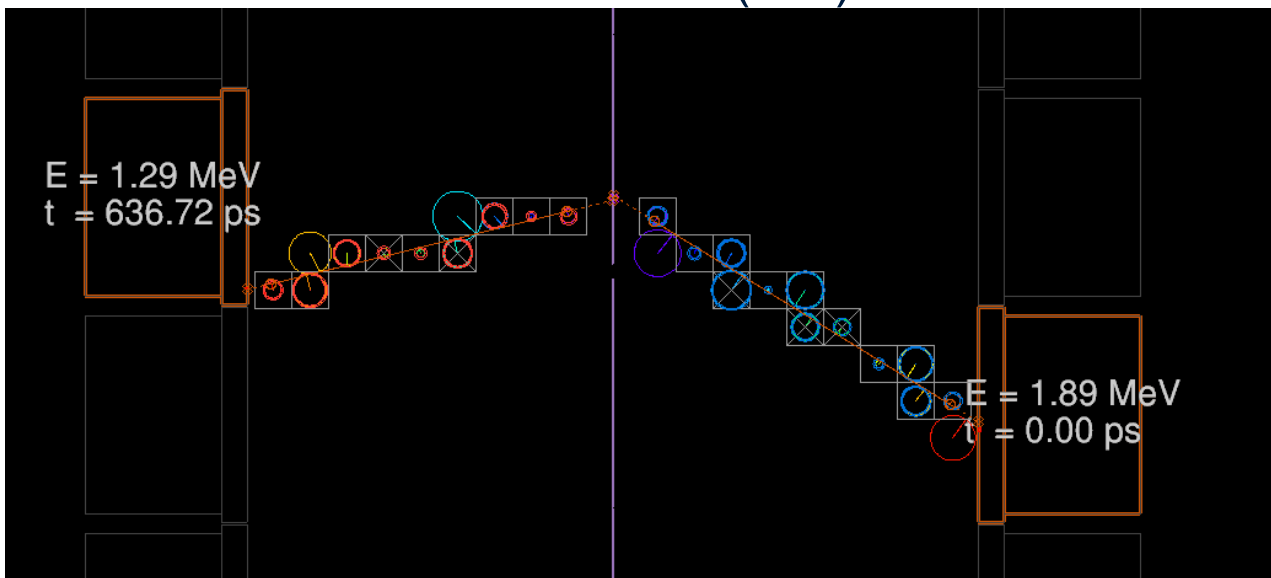
$\beta$  particle emitted from  $^{214}\text{Bi}$  in or on source foils can create 2 electrons and mimic  $\beta\beta 0\nu$  event

$\beta$  decay  
&  
Moller scattering

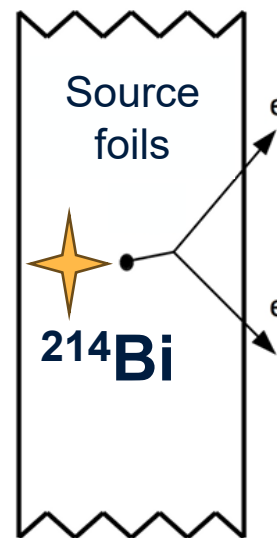
# Radon as background : $\beta\beta 2\nu$ & $\beta\beta 0\nu$

- Naturally present in environment ( $^{238}\text{U}$  chain decay)
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Top view of 2 electrons produced by  $^{214}\text{Bi}$  decay from source foil bulk (MC)



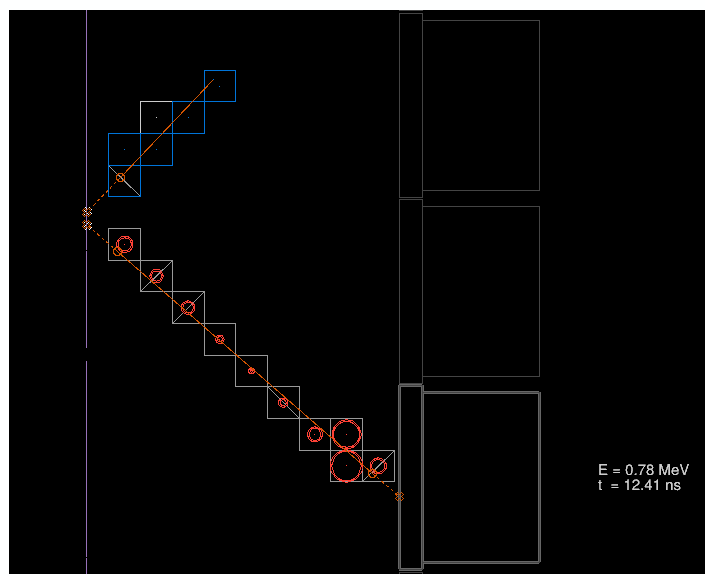
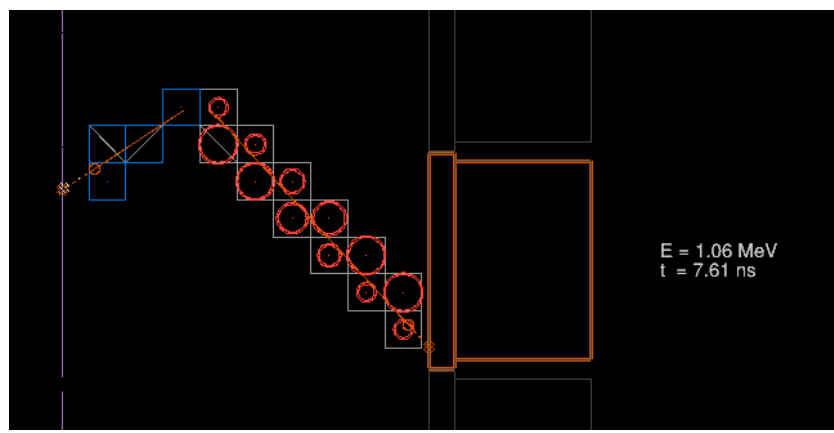
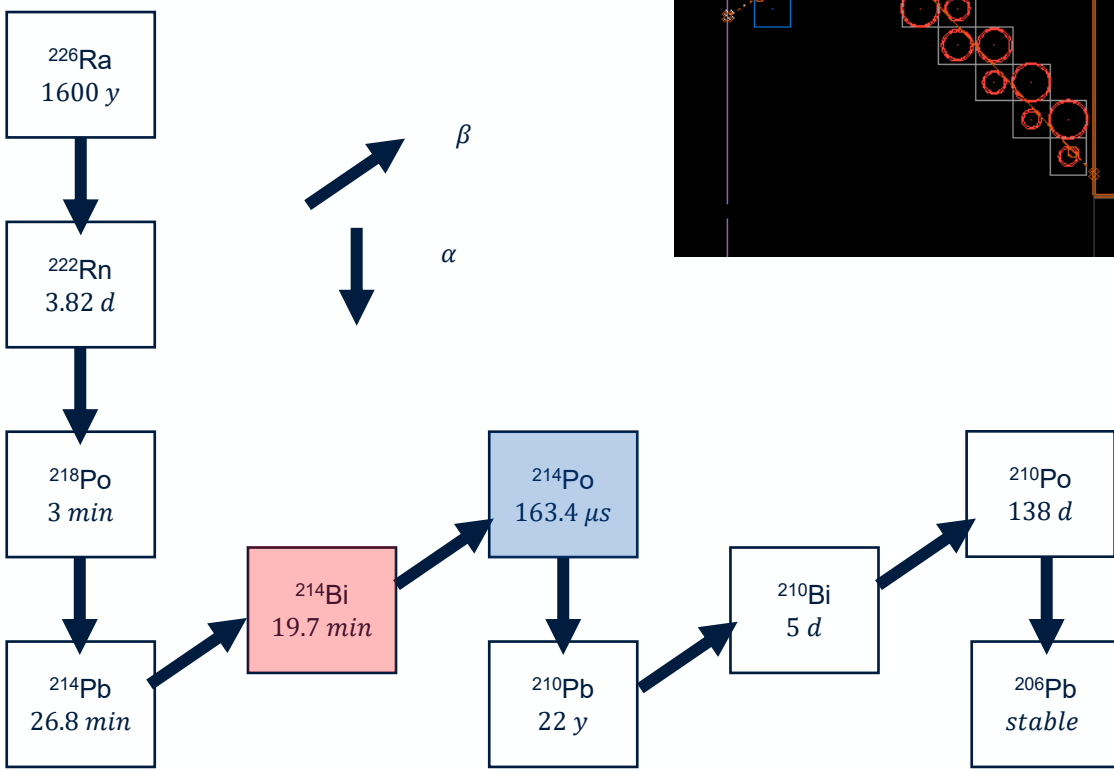
$$\sum_i E_i > 3 \text{ MeV}$$



$\beta$  particle emitted from  $^{214}\text{Bi}$  in or on source foils can create 2 electrons and mimic  $\beta\beta 0\nu$  event

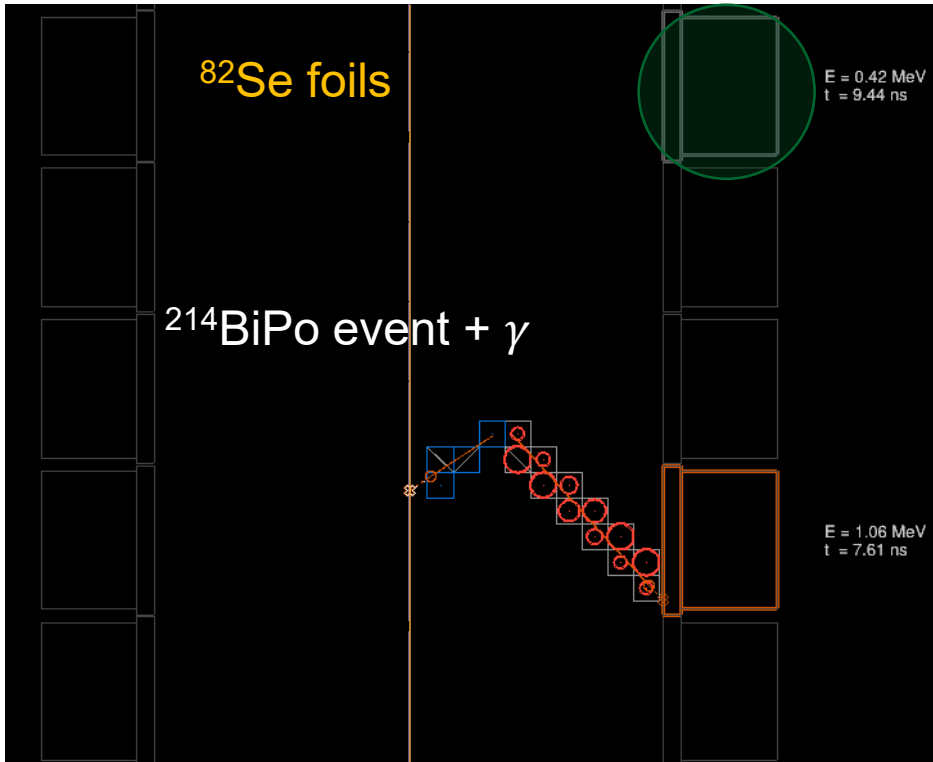
$\beta$  decay  
&  
Moller scattering

# BiPo selection



- Searching for **1 electron** and **1 delayed alpha** from source foils or Tracker

## BiPo event



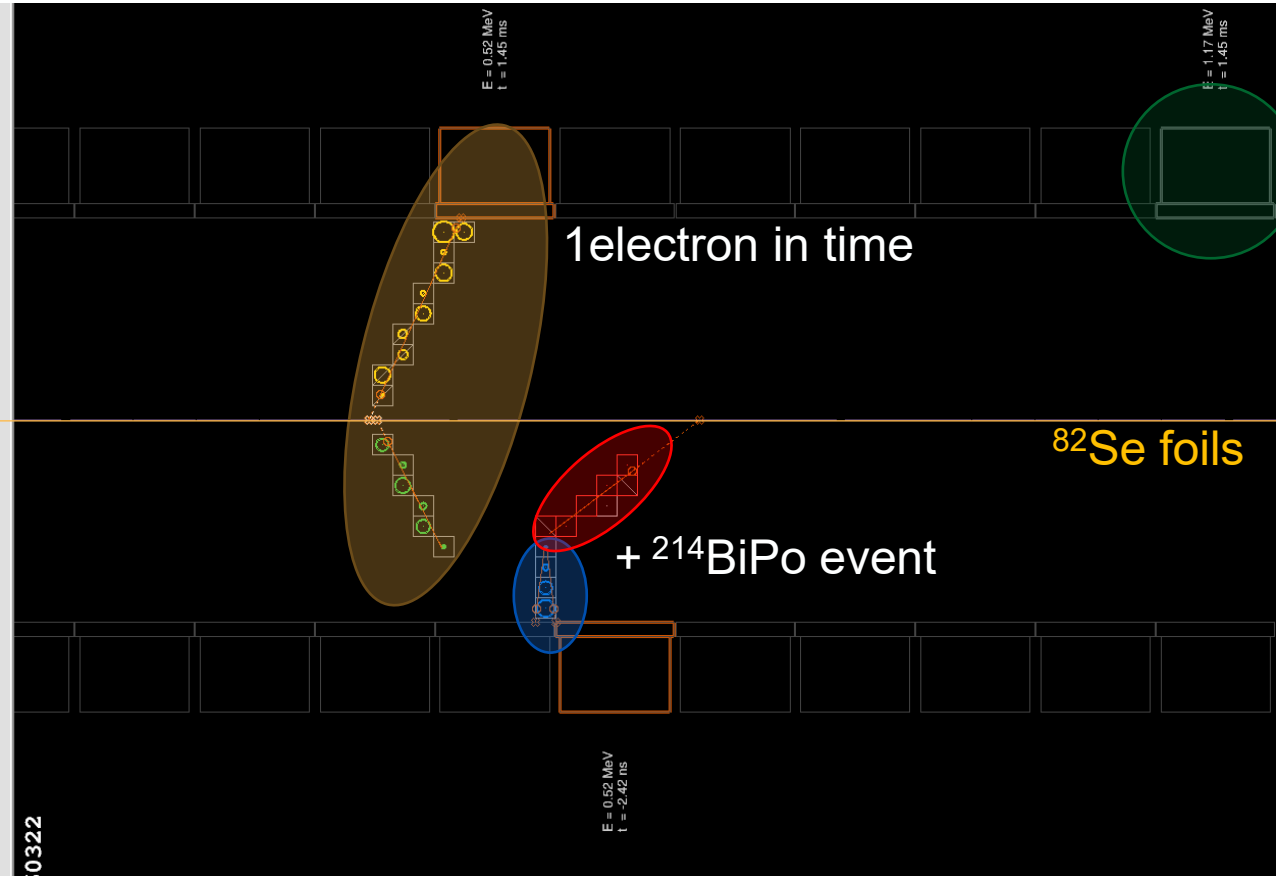
Top view

## TrackFIT

- 1  $e^-$  in the tracker
- 1 short track (alpha)
- 1 gamma in time with  $e^-$

# BiPo selection

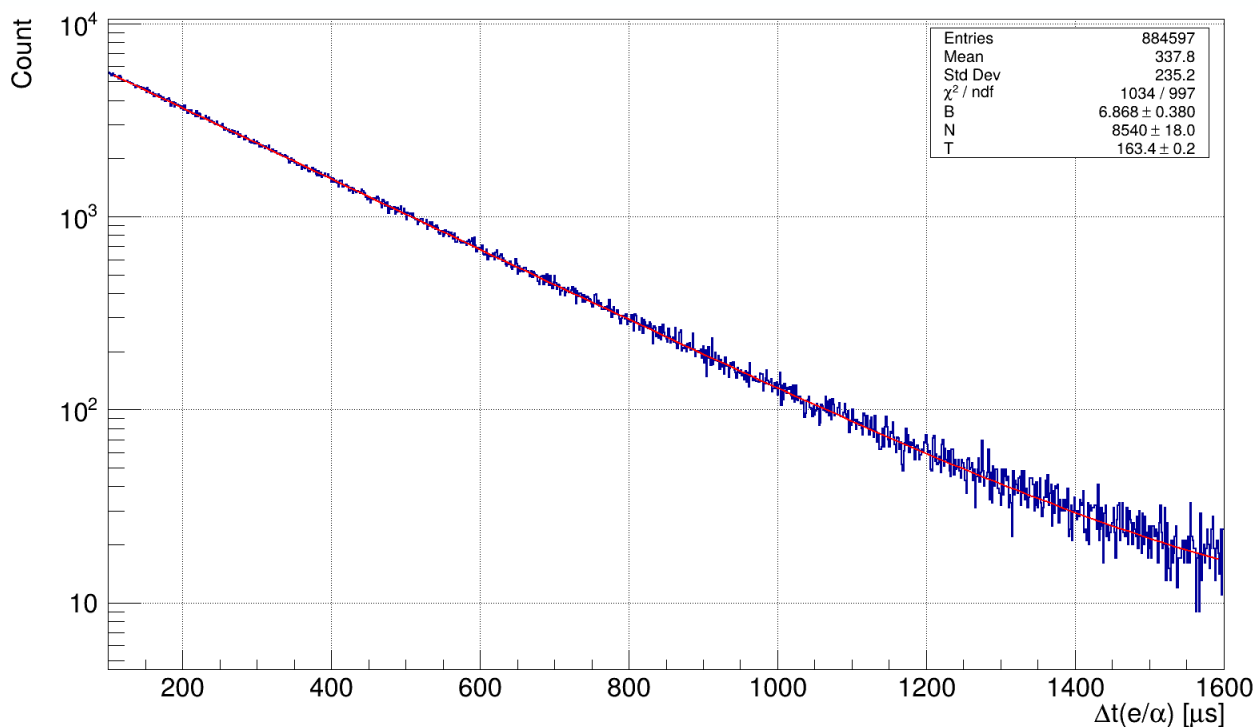
## BiPo event + random particles



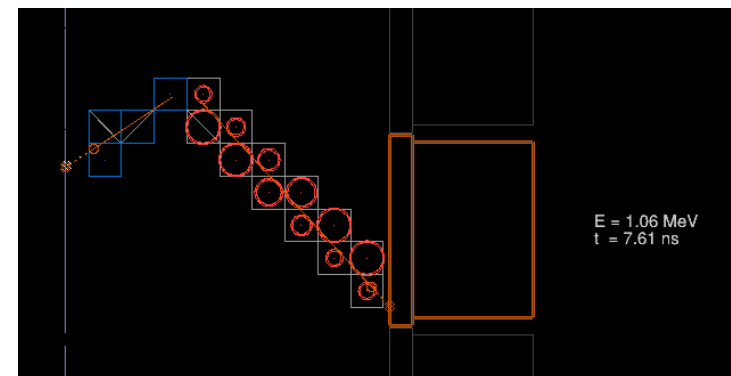
- 1  $e^-$  crossing the source foils
- 1  $e^-$  in the tracker
- 1 short track (alpha)
- 1 gamma

# $\Delta t_{e/\alpha}$ time delay between $e^-$ & $\alpha$

Time delay between  $e^-$  from  $^{214}\text{Bi}$  &  $\alpha$  from  $^{214}\text{Po}$



Plot with  $E = aQ$  calibration for more stat



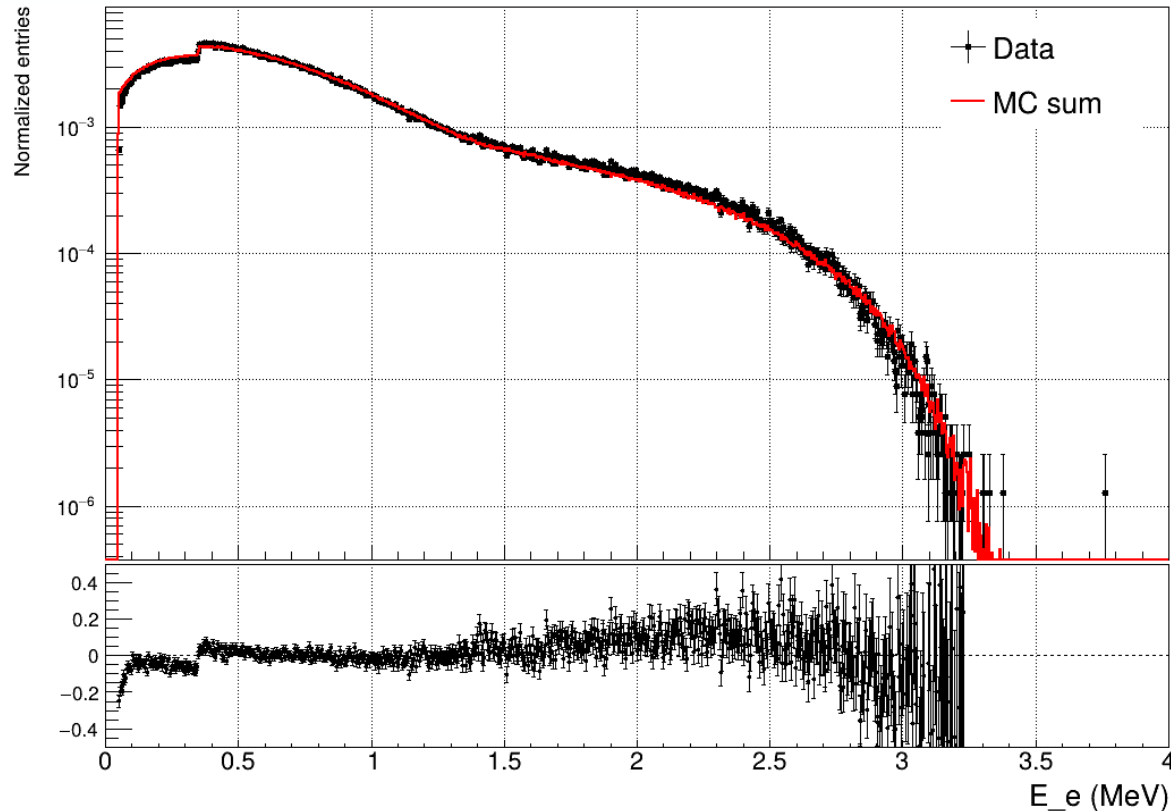
- Half life of  $^{214}\text{Po}$ :  **$163.4 \pm 0.2 \mu\text{s}$**   
fully consistent ( $163.4 \mu\text{s}$  expected [2])  
→ Get more and more clean value !
- Recommended  $^{214}\text{Po}$  half-life value (NUDAT)  
change during my phd to this value 😊

→ Good channel analysis to measure radon activity

[2] E N Alexeev et al 2020 J. Phys.: Conf. Ser. 1690 012029

# Electron energy spectra from $^{214}\text{Bi}$

## $^{214}\text{Bi}$ electron energy spectra

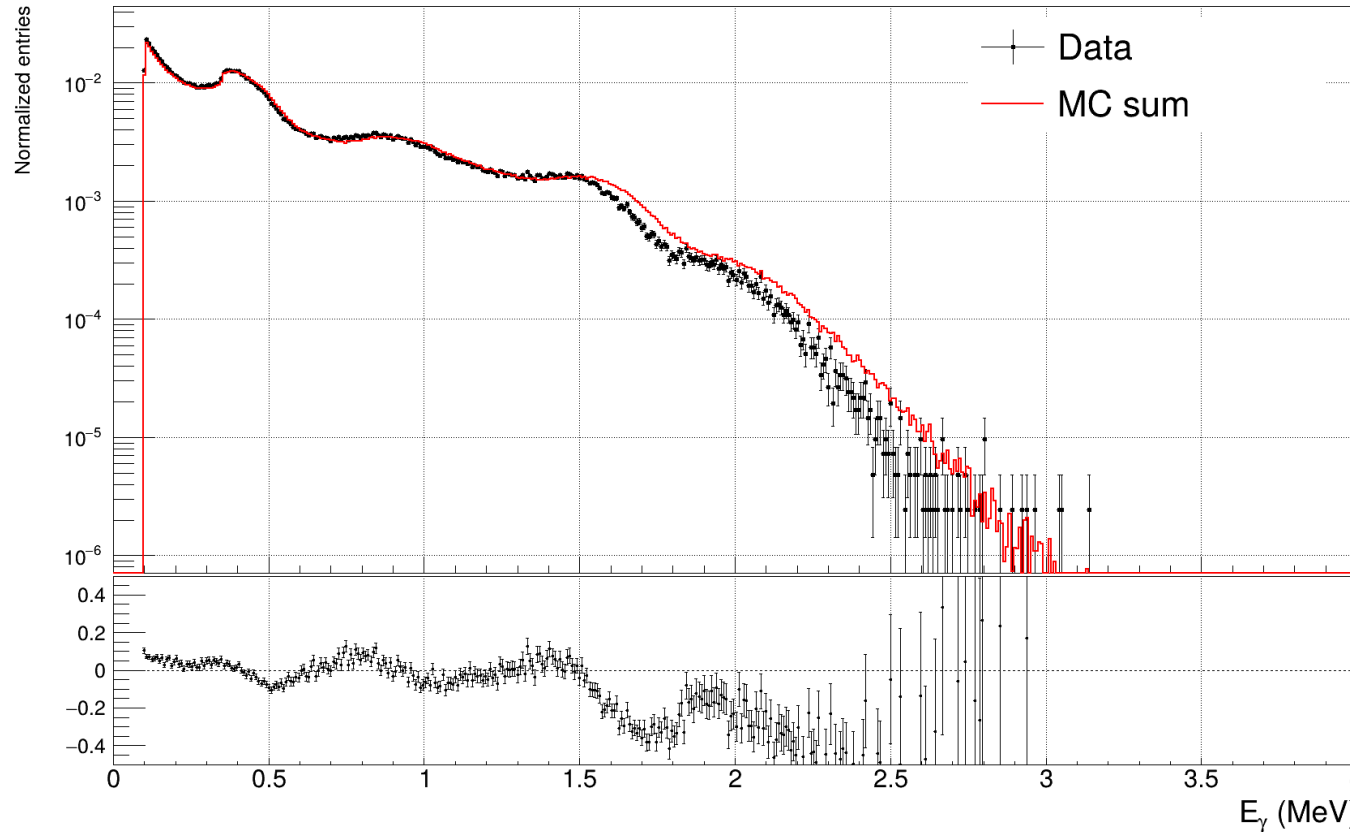


359.8 days

- MC : Field Wire Surfaces (FWS) only

- Energy calibration (only weekly  $^{207}\text{Bi}$  data) :  $E = aQ + b$  from Mathis, great work !
- Good agreement between data & MC but not perfect from 1.5 MeV

## $^{214}\text{Bi}$ gamma energy spectra

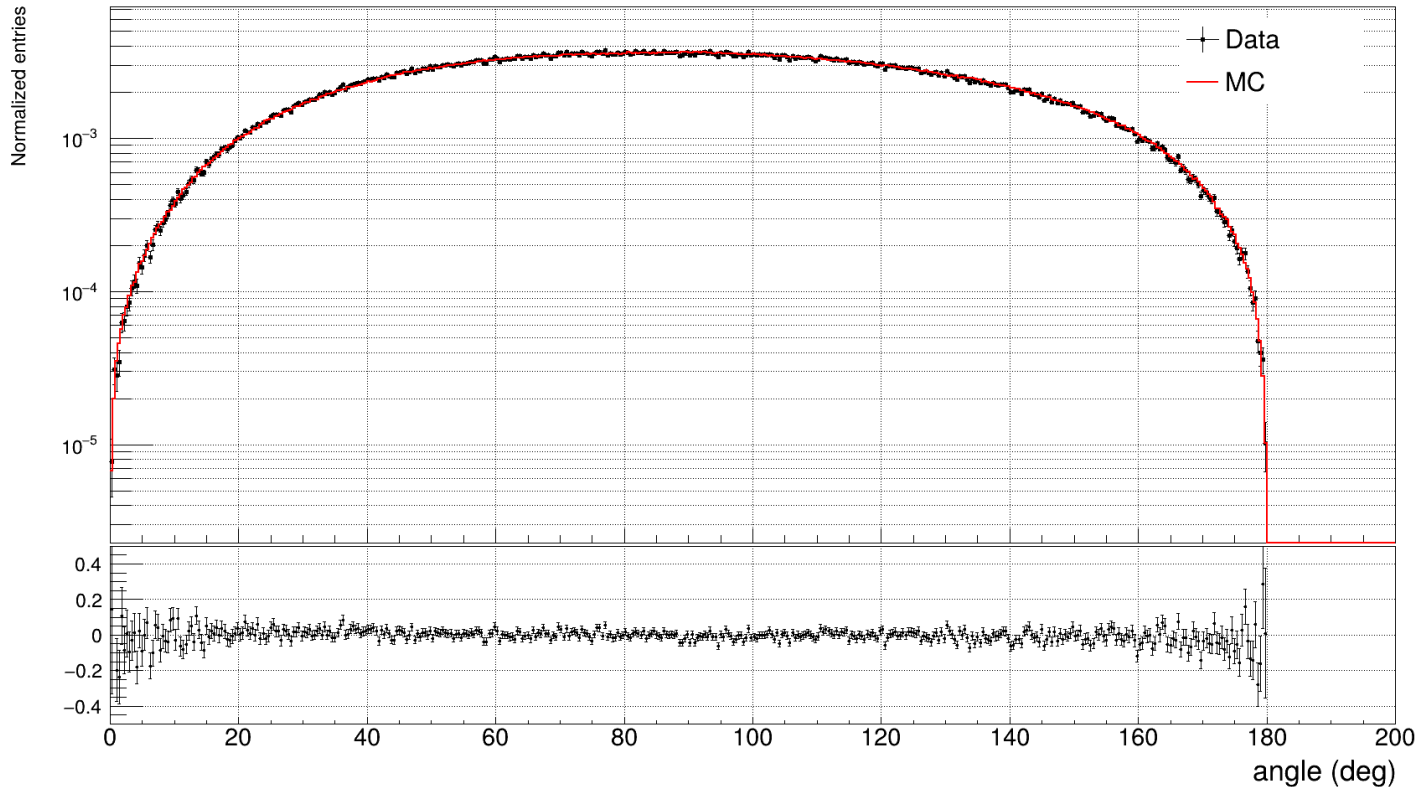


359.8 days

- Energy calibration (only weekly  $^{207}\text{Bi}$  data) :  $E = aQ+b$  from Mathis, great work !
- $E > 1\text{MeV} \rightarrow$  Bad agreement between data & MC  $\rightarrow$  electron calibration used !

# 3D angle between $e^-/\alpha$ from BiPo events

## 3D angle between $e^-/\alpha$ (BiPo)

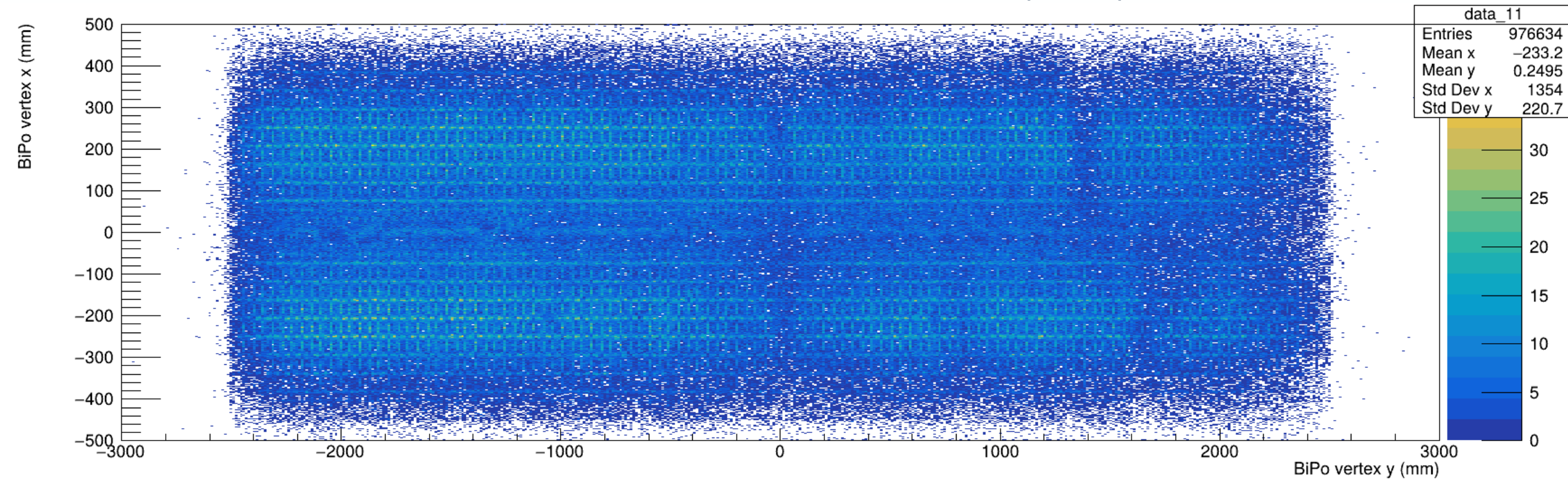


359.8 days

- Excellent agreement between data & MC

# BiPo vertex distribution in SuperNEMO

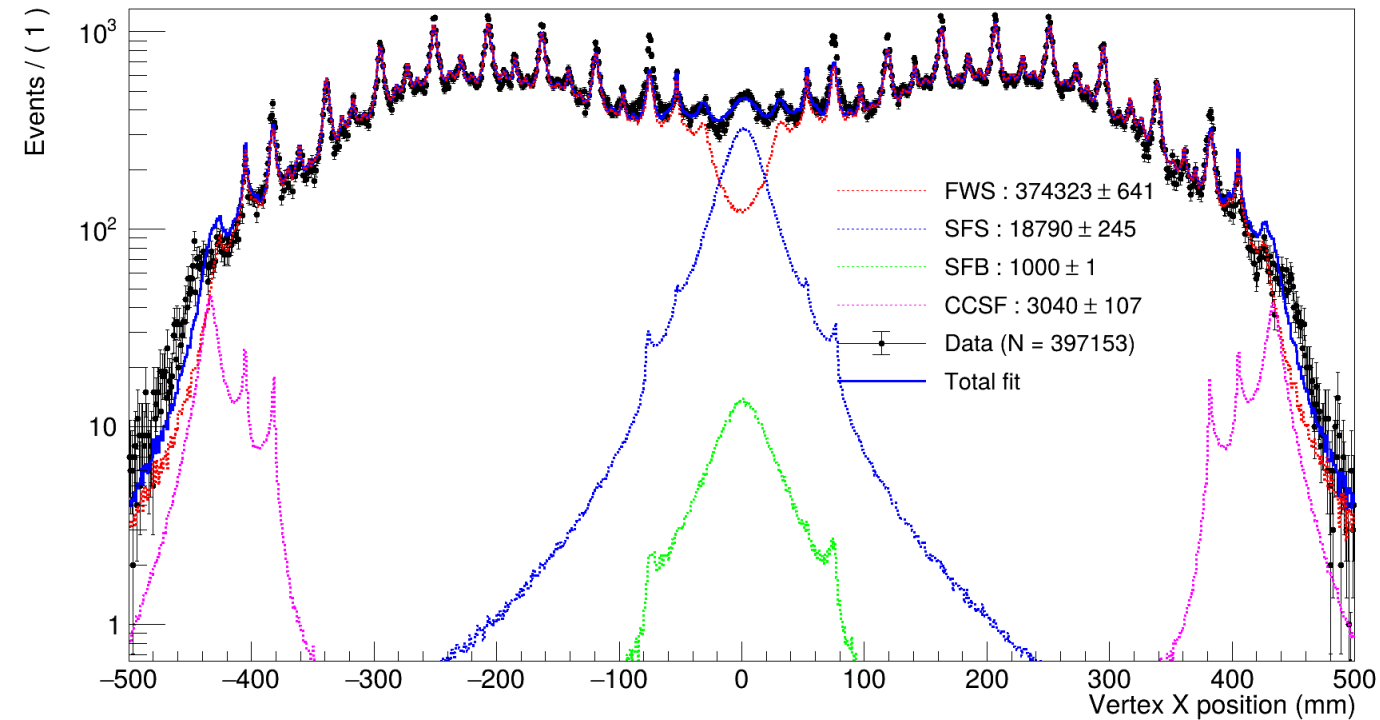
Top View of BiPo vertex (Data)



**Small left-right asymmetric distribution**  
probably due to asymmetric helium flushing inside the tracker

# BiPo vertex contribution

## BiPo vertex projection on X axis – Comparisons with different vertex simulations

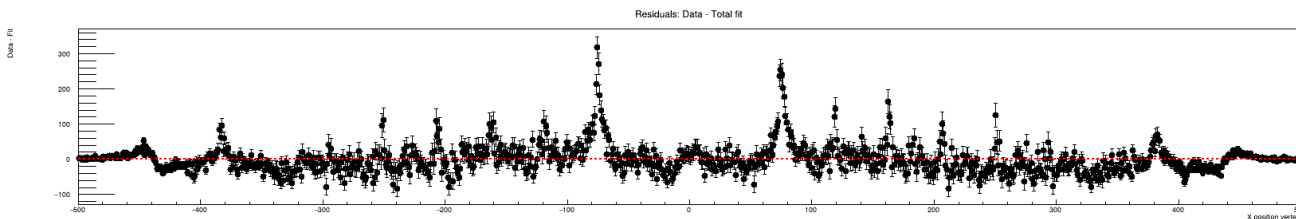


Simulations:

- Field Wire Surface: FWS
- Source Foil Surface <sup>82</sup>Se : SFS
- Source Foil Bulk <sup>82</sup>Se : SFB
- OMs surfaces : CCSF

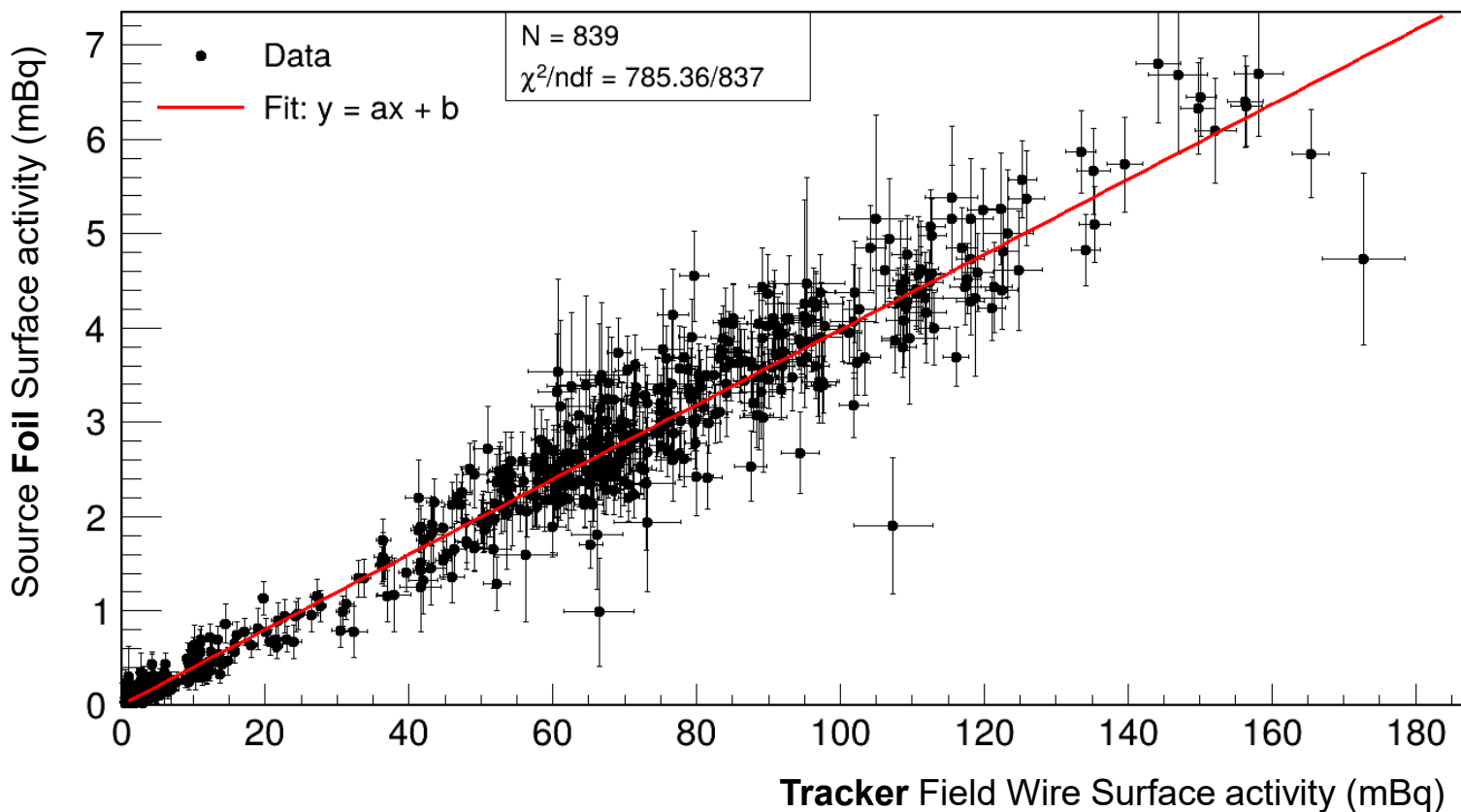
→ Few events from source foils surfaces  
(in dashed blue)

$$R = \frac{N_{SFS}}{N_{tot}} = 4.73 \pm 0.06\%$$



# BiPo vertex contribution

## Radon activity dependency as function of Vertex



Linear relation between Rn activity from **field wires** and **source foils surfaces**

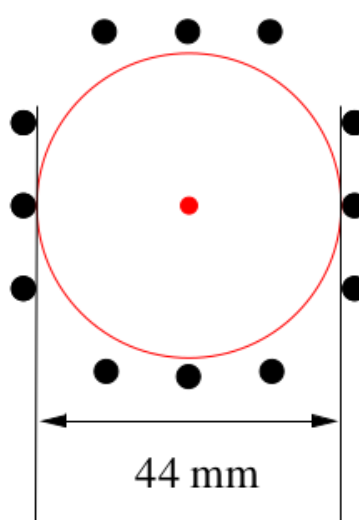
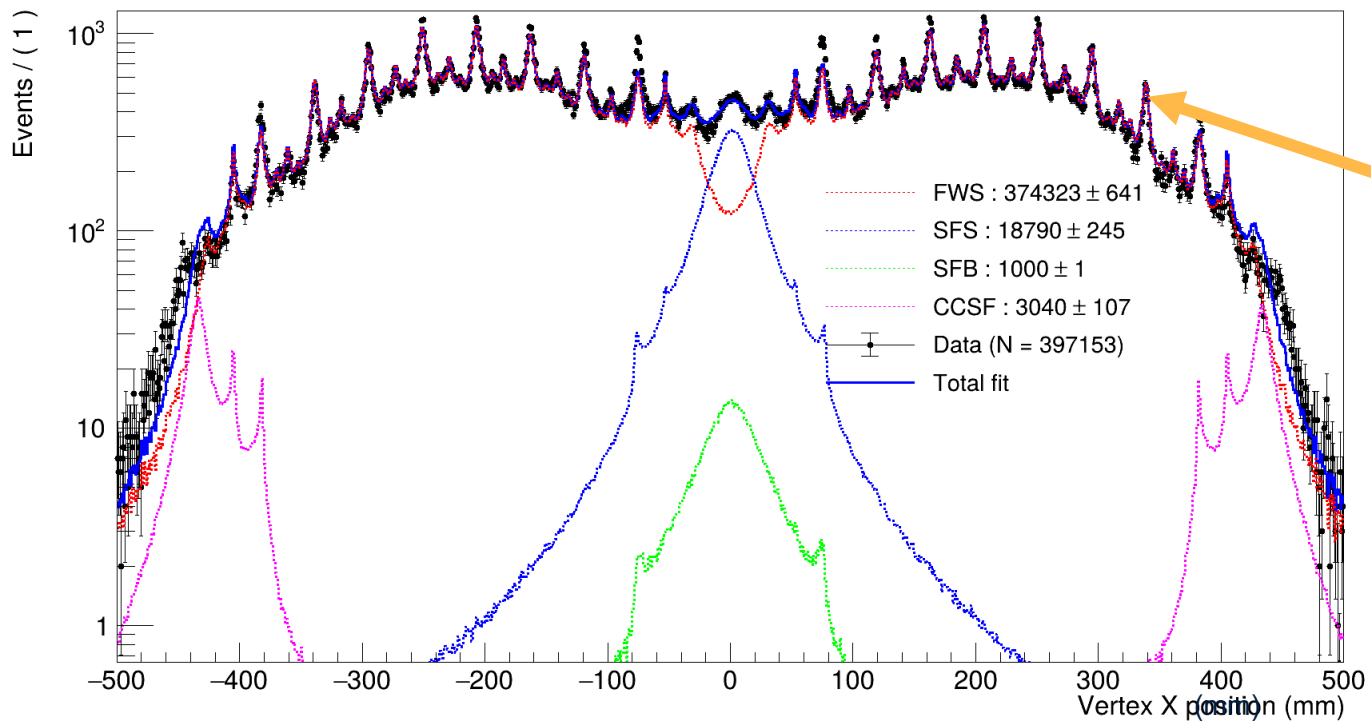
$$b = 8.4 \pm 2.6 \mu\text{Bq}$$

➔ Small contribution from internal contaminations

Work in progress with  $(e, n\gamma)_{\text{int}}$  analysis

# BiPo vertex contribution

BiPo vertex projection on X axis – Comparisons with different vertex simulations

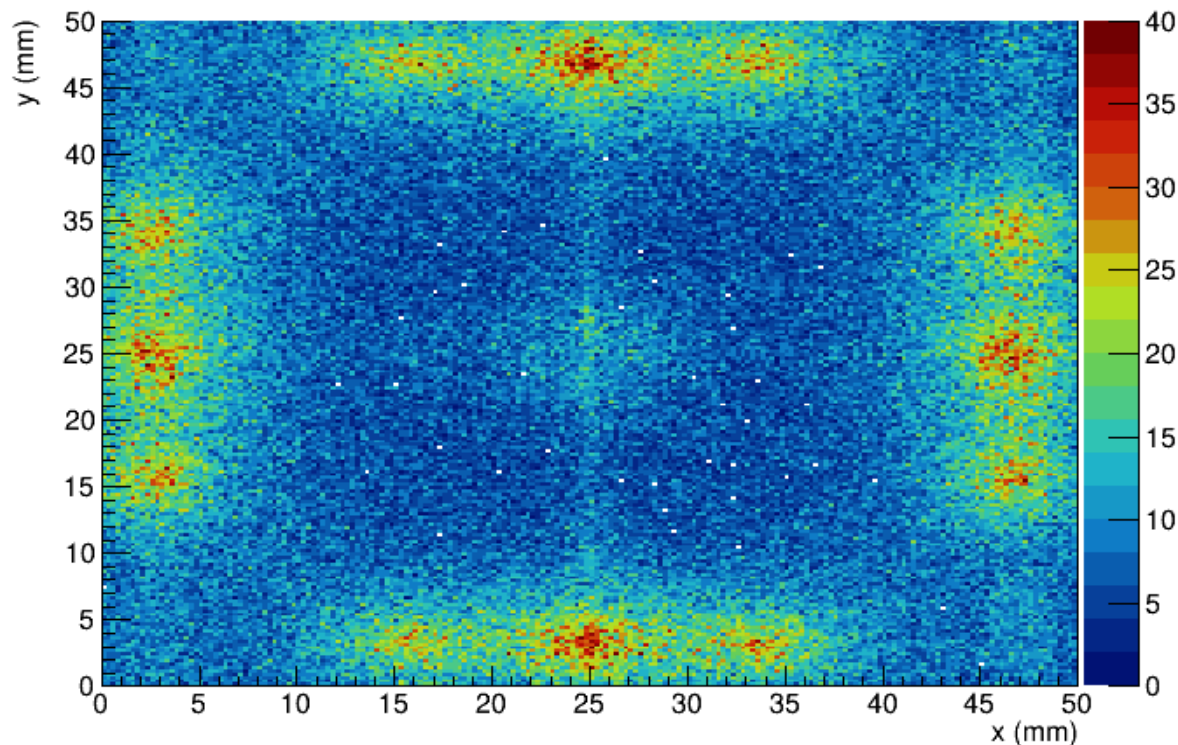


Geiger cell geometry

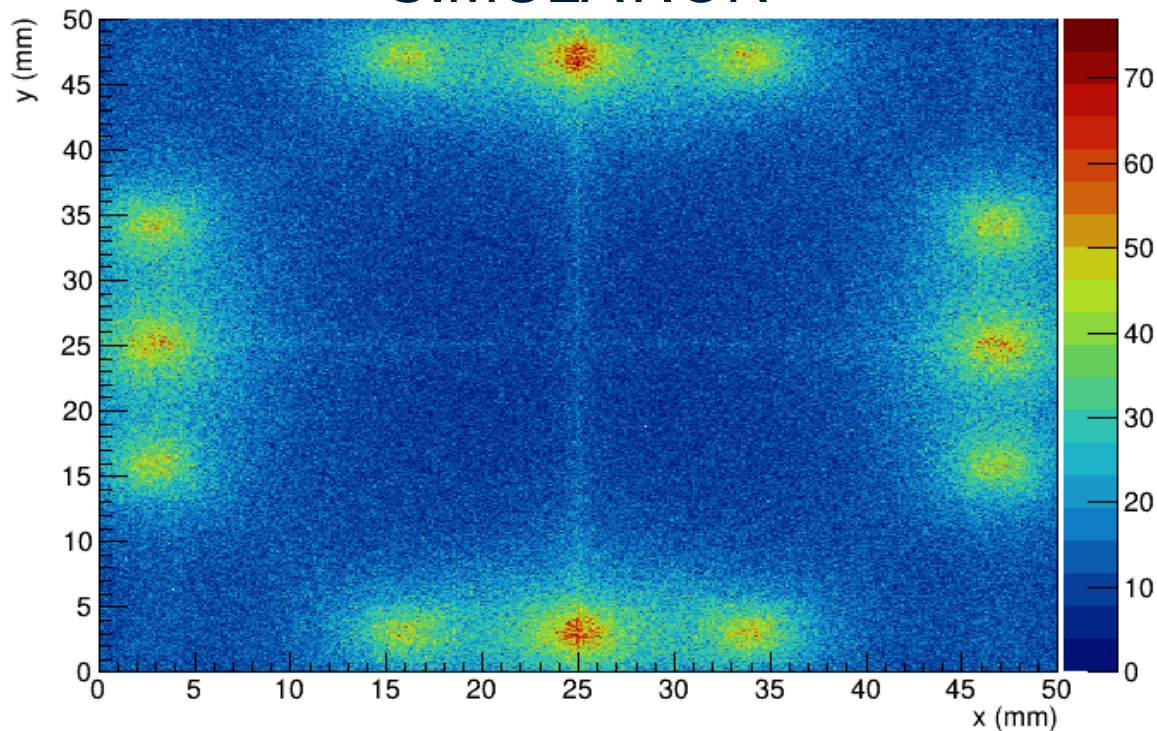
# BiPo vertex: Geiger cell

All BiPo vertex in the tracker merged in on cell geometry

DATA



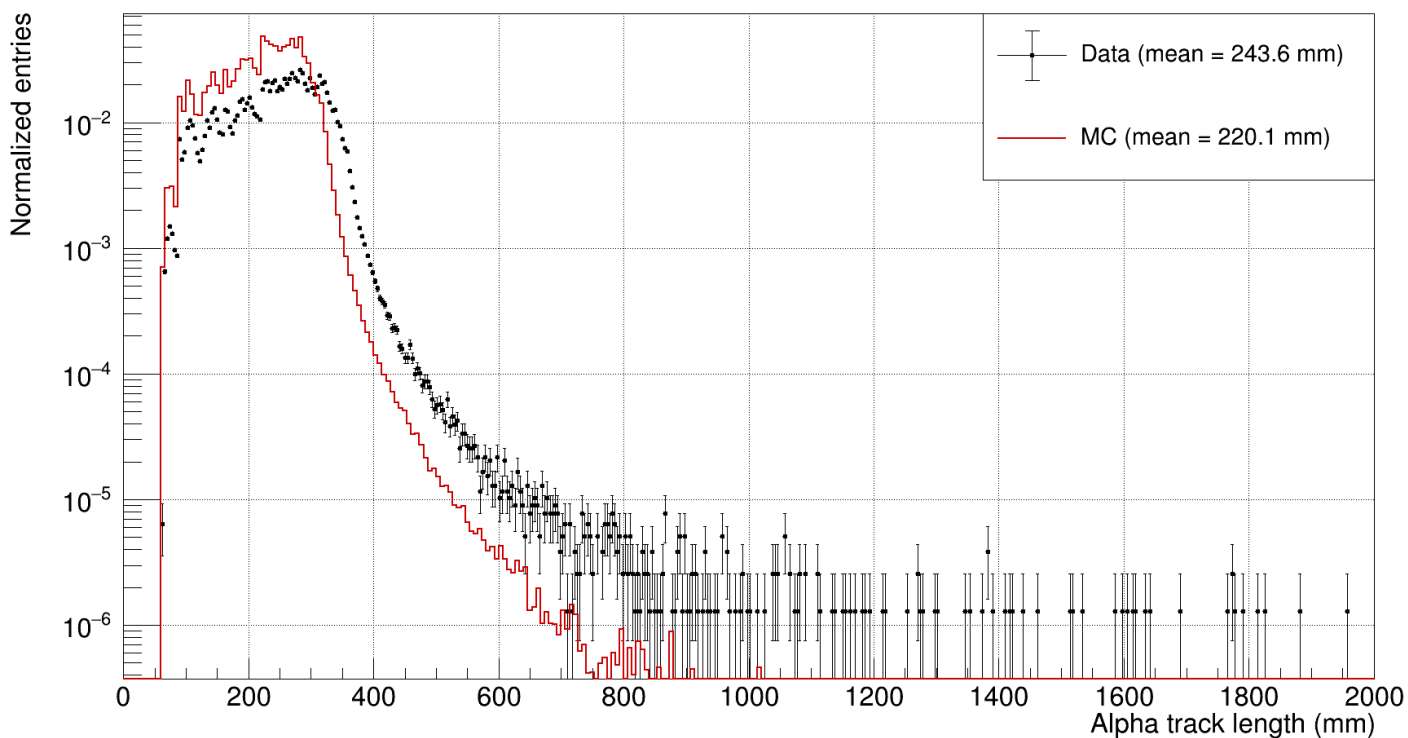
SIMULATION



Proof that BiPo come from field wires surfaces

# Alpha track length in 3D (x,y,z)

alpha track length distribution



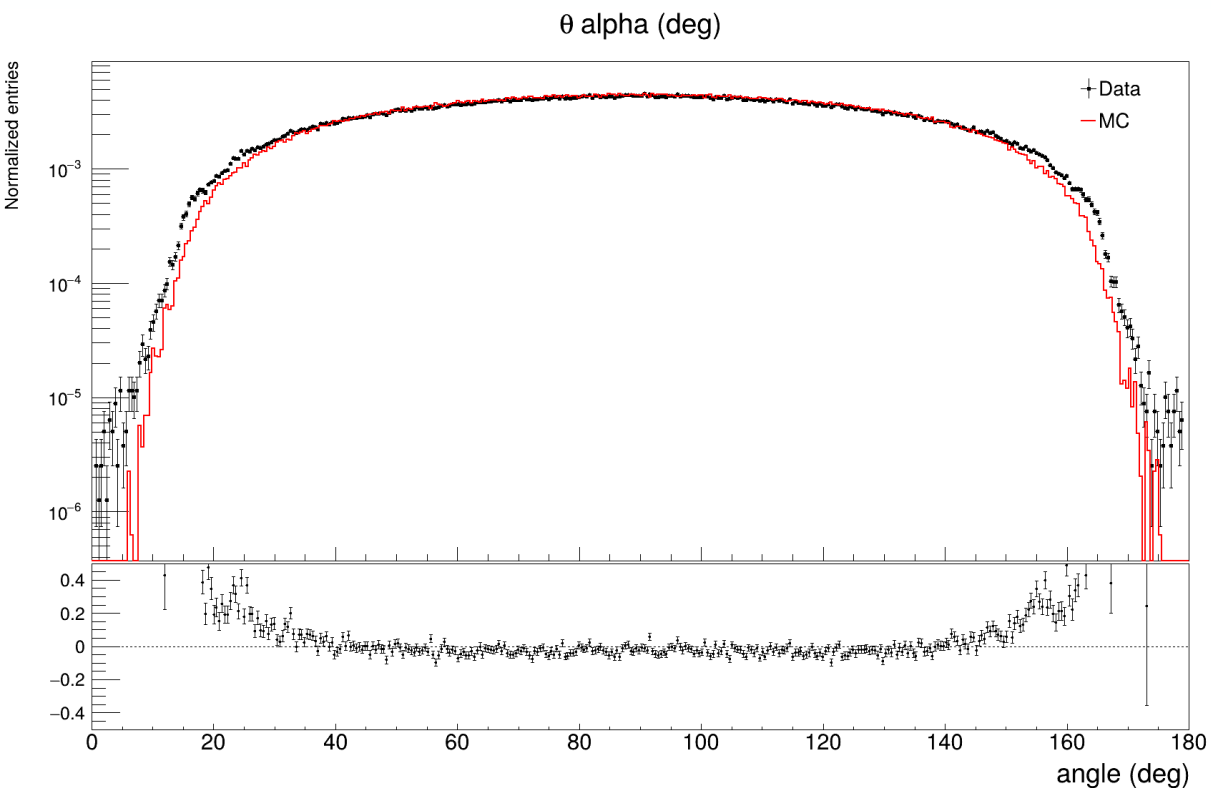
Discrepancy between data & MC

Maximum alpha cell number  $\leq 11$

	Mean alpha track length
Data	$243.6 \pm 73,8$
MC	$220.1 \pm 63,1$

$$\Delta_{3D} = 23.5 \text{ mm}$$

# Alpha track length investigation : z out of the tracker

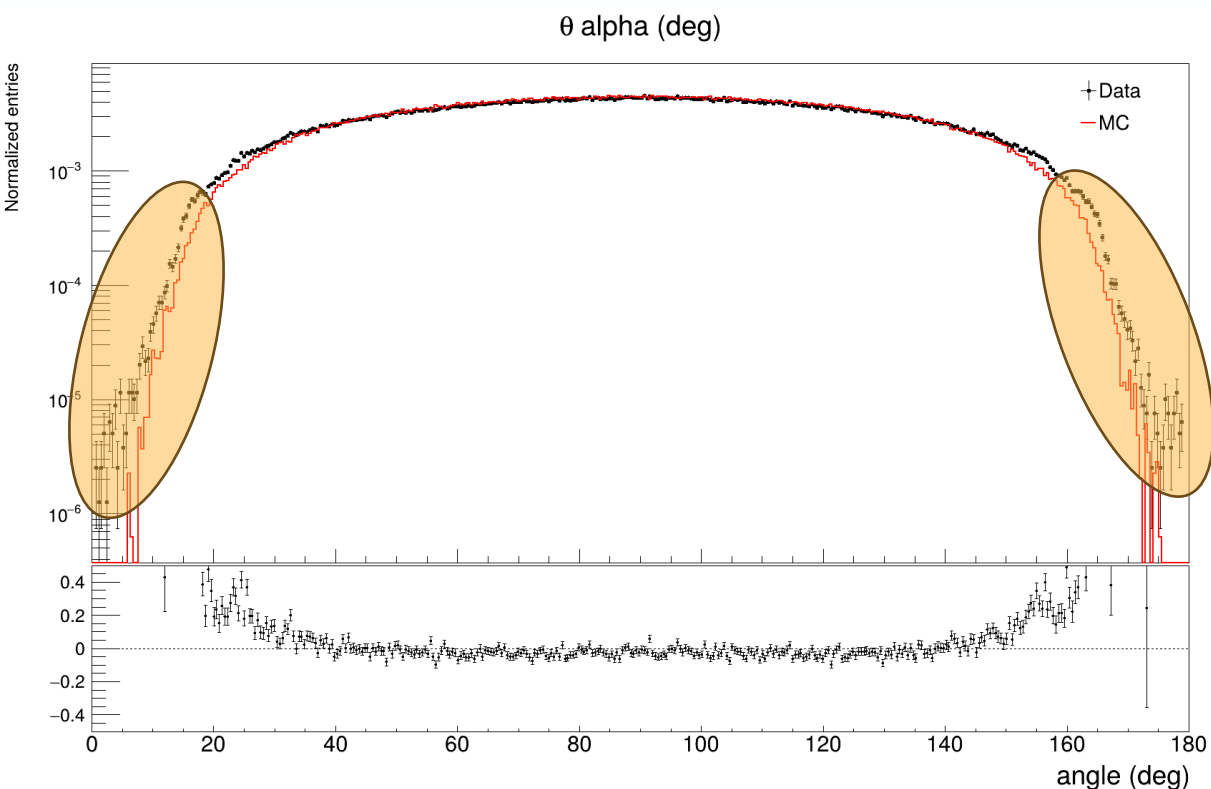


$\theta_\alpha$  : angle from z axis

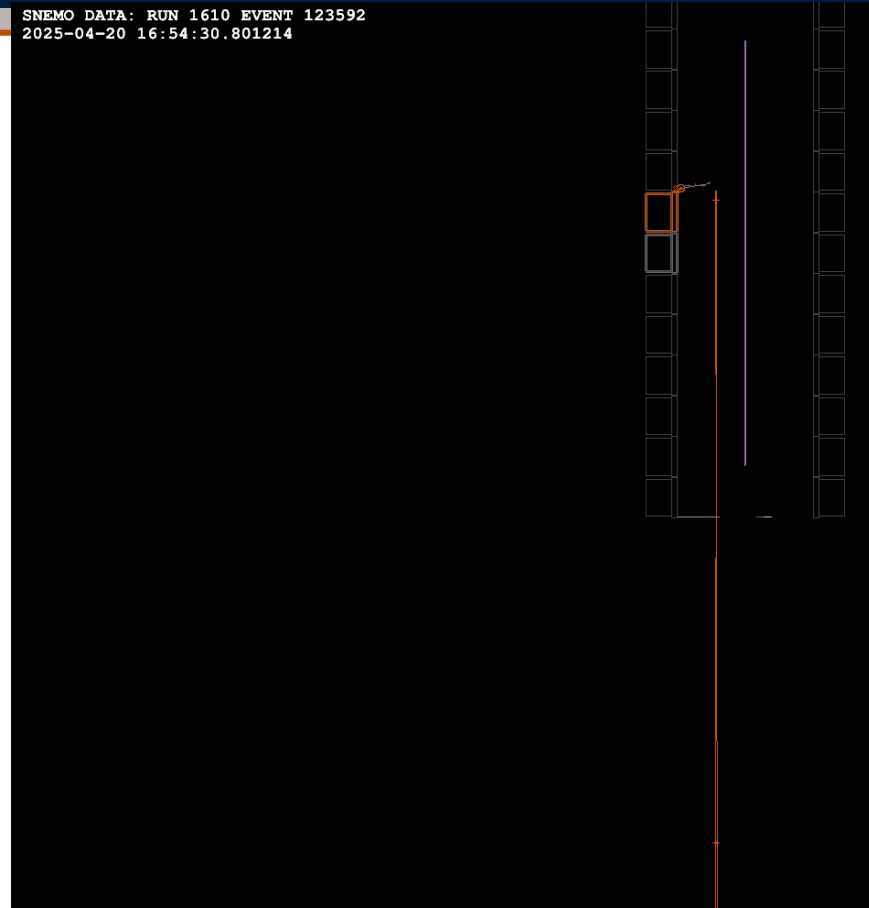
$90^\circ \rightarrow$  normal to z axis

$0^\circ$  &  $180^\circ \rightarrow$  straight down/up

# Alpha track length investigation : z out of the tracker



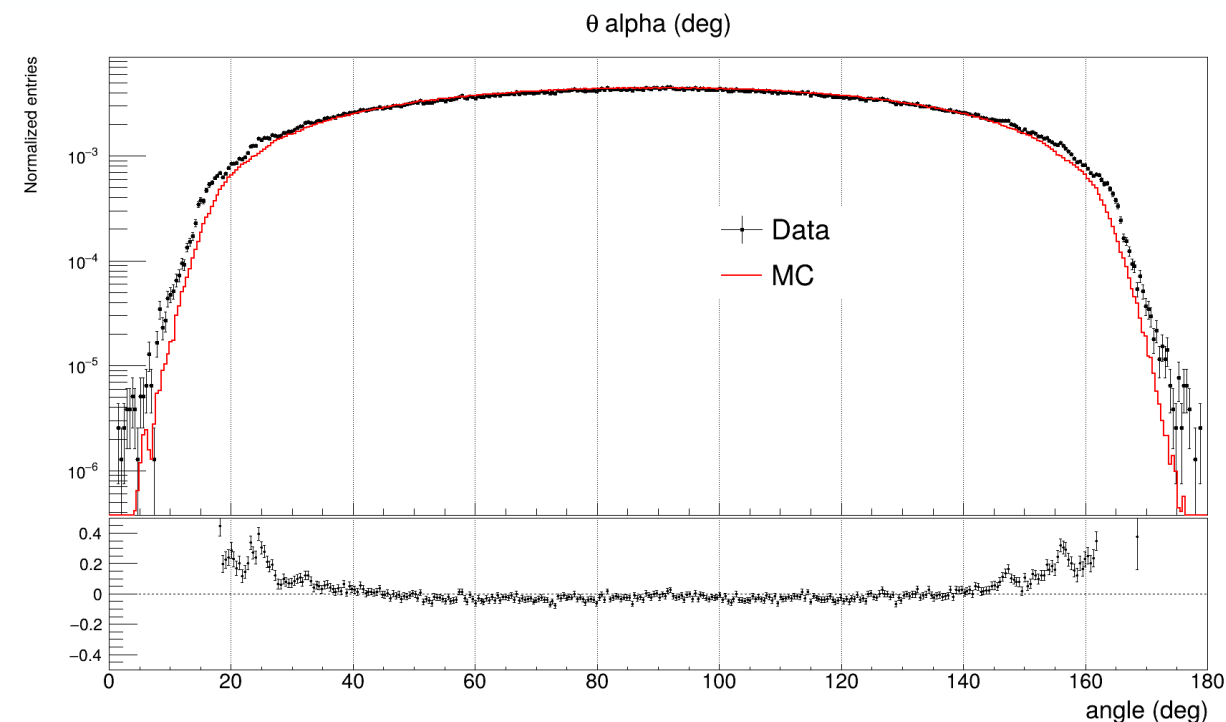
SNEMO DATA: RUN 1610 EVENT 123592  
2025-04-20 16:54:30.801214



We can have alpha cell out of the tracker...

➔ Let's remove these events !

# Alpha track length investigation : z out of the tracker



$\theta_\alpha$  : angle from z axis

$90^\circ \rightarrow$  normal to z axis

$0^\circ$  &  $180 \rightarrow$  straight down/up

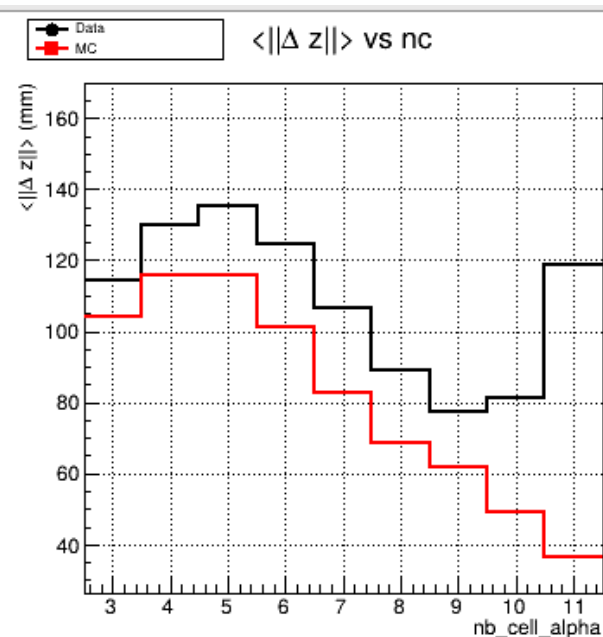
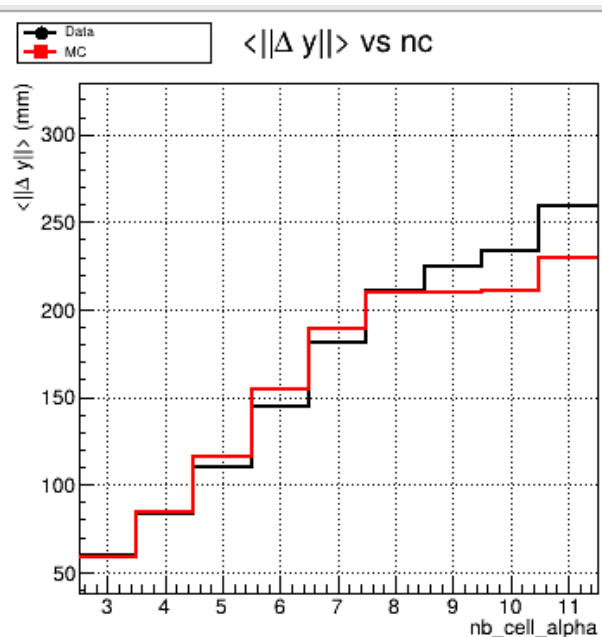
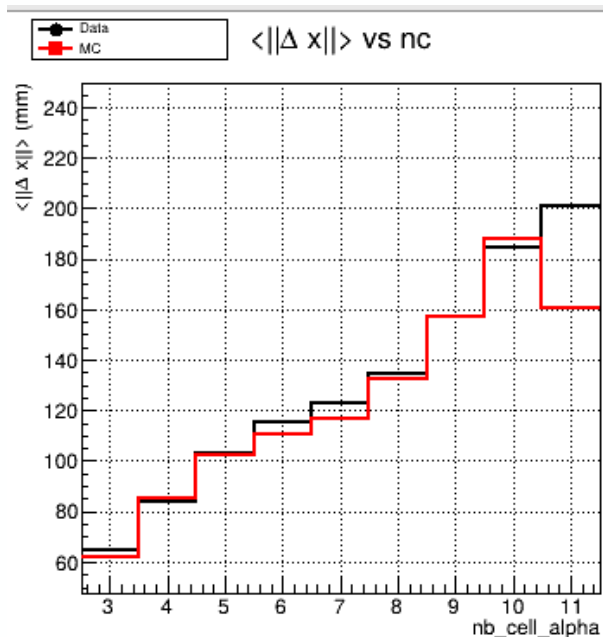
Better ! But don't explain alpha track length behavior...

Z reconstruction effect ?

Other angle distribution are fine..

# Alpha track length investigation : bad z reconstruction

nc = number of cell (alpha)

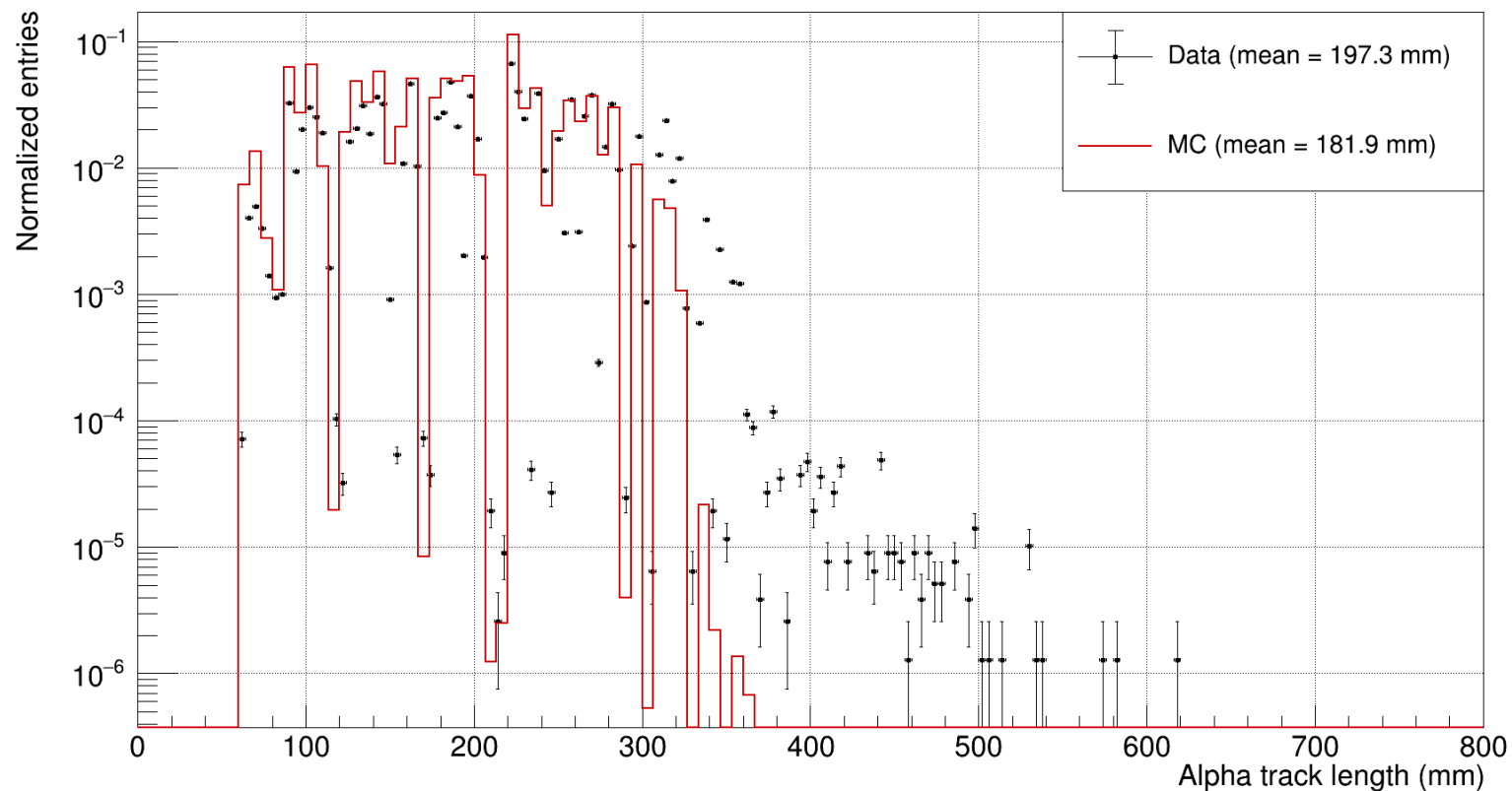


	$ \Delta x $	$ \Delta y $	$ \Delta z $
Mean diff (mm)	5.9	5.1	26.8
Mean diff (%)	4.4 %	2.0 %	48.6 %

- Good agreement between  $\Delta x$  &  $\Delta y$
- Systematic effect on  $\Delta z$  → Need Sam's z calibration

# 2D alpha track length (x, y)

alpha track length distribution (x, y)



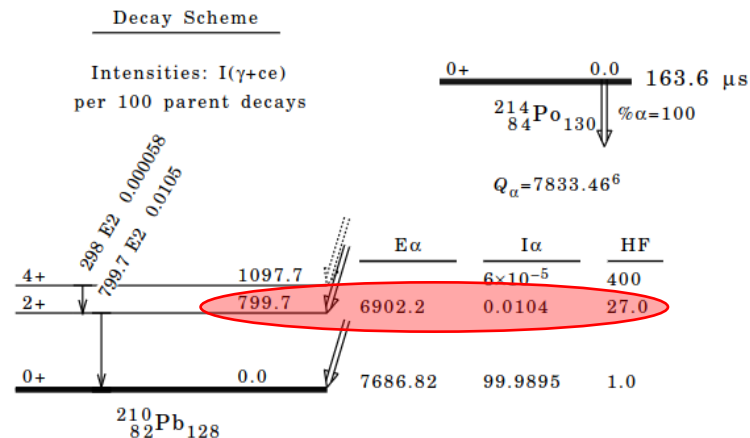
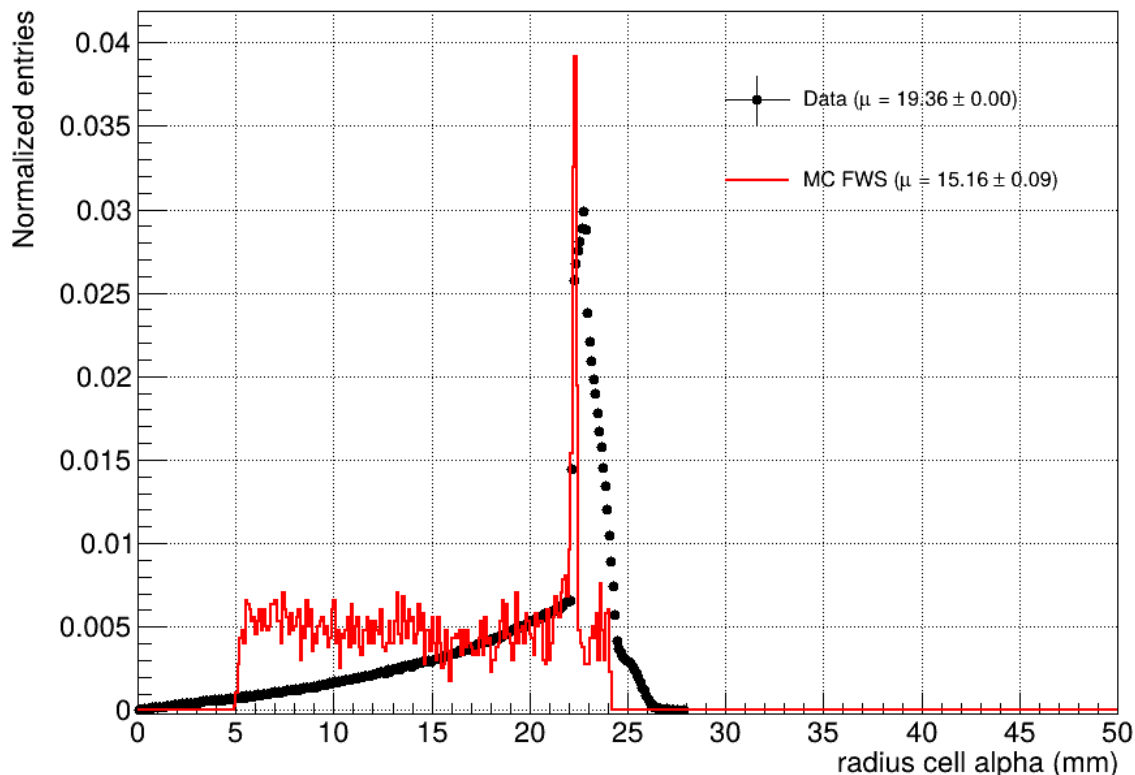
- Better agreement between  $\Delta x$  &  $\Delta y$
- Systematic effect on  $\Delta z$   
 ➔ Need Sam's z calibration
- Still an effect not reproduced in MC

$$\Delta_{3D} = 23.5 \text{ mm}$$

$$\Delta_{2D} = 15.4 \text{ mm}$$

# Reconstruction effect ?

Alpha cell radius distribution



	data	MC
Cell alpha with radius (%)	31%	0.01 %

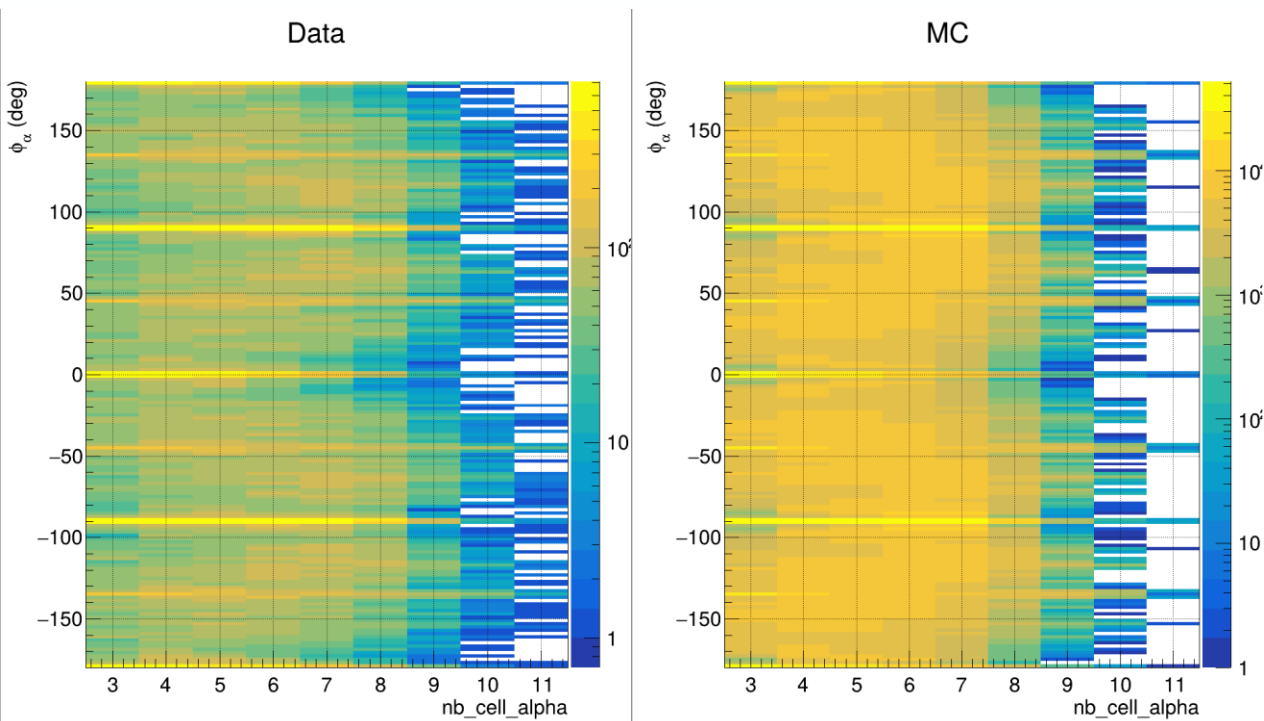
More alpha cell with radius in data than MC !

TrackFIT : alpha cell radius as free parameter for the fit, no informations available on PTD, TCD, etc ?

Does it affect alpha reconstruction ?

# Reconstruction effect ? Alpha angle preference in MC

$\Phi_{alpha}$  vs number of alpha cell

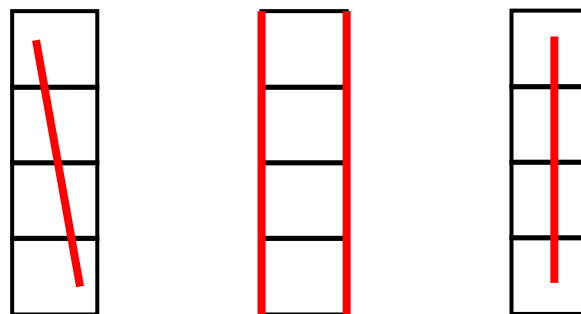


$\phi_\alpha \in [-180, 180]$  deg

- $\phi_\alpha \simeq 0^\circ \rightarrow$  alpha in + x
- $\phi_\alpha \simeq \pm 90^\circ \rightarrow$  Horizontal (+y & -y)
- $\phi_\alpha \simeq \pm 180^\circ \rightarrow$  alpha in - x
- $|\phi_\alpha| < 90^\circ \rightarrow$  alpha in + x
- $|\phi_\alpha| > 90^\circ \rightarrow$  alpha in - x

MC looks uniform along  $\phi_{alpha}$

Data with preferred  $\phi_{alpha}$

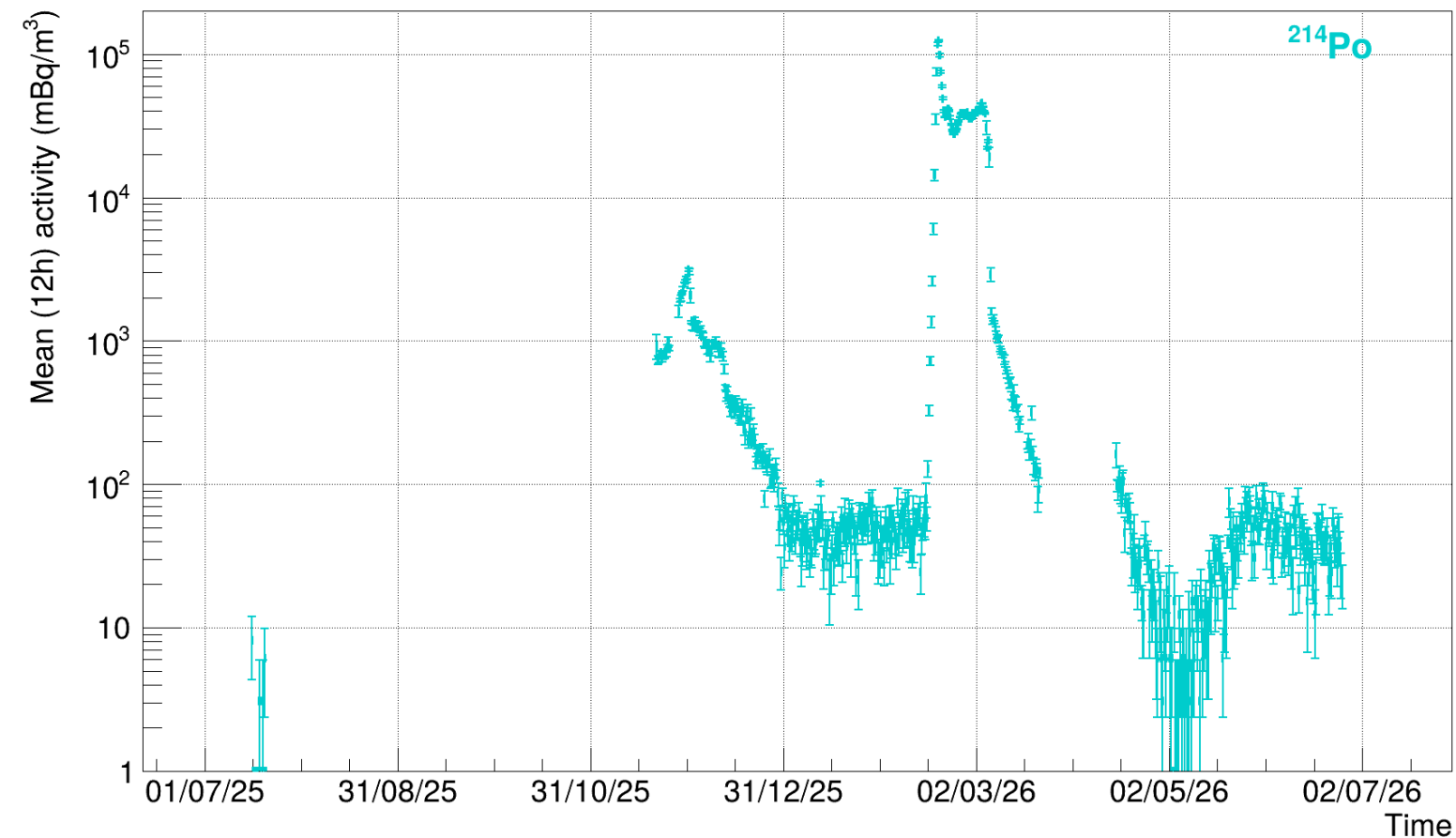


Where discrepancy is coming from ?

Let's discuss after if you have idea, plots idea 😊

# Anti Radon Factory (ARF)

Activity of Po-214 and Po-218

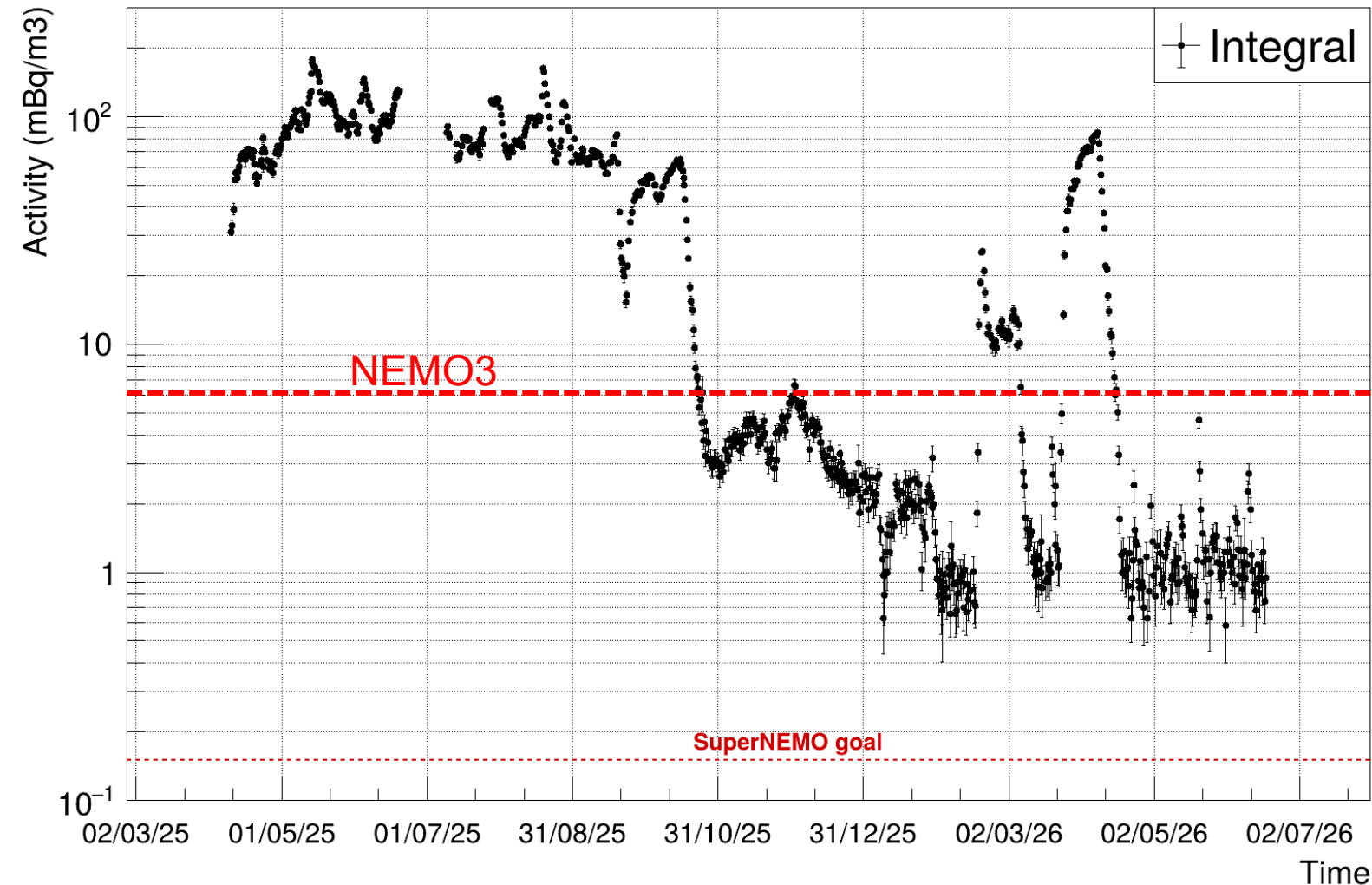


Long story of the Anti Radon  
Factory

➔ Still not stabilized...

Physical parameter on radon  
trapping from Charcoal done.

# Radon activity inside the tracker



Best radon level at 0.6 mBq/m<sup>3</sup>  
(with high He flux)

10 x better than NEMO3 !

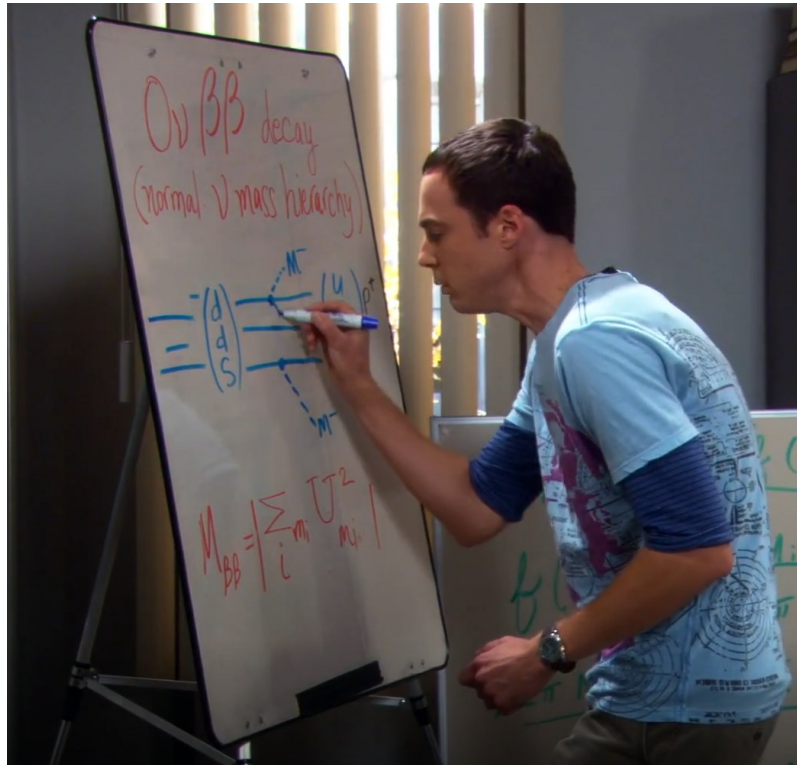
42.61 days below 1 mBq/m<sup>3</sup>

“Low” background since  
2026/04/18 :  $\sim 1 \text{ mBq} \cdot \text{m}^{-3}$

- Robust BiPo analysis, need to improve simulation/data understanding for  $\alpha$  track length
- Best radon activity :  $0.6 \text{ mBq. m}^{-3}$  → 10 times better than NEMO3!
- Some low background data acquisition periods (45.1 days below  $1 \text{ mBq/m}^3$ )
- For similar He flushing, anti Radon radon facility improved the Rn background by a factor  $\sim 24$
- Strong effect on the z reconstruction on alpha track length
- Still an effect on alpha track length (2D) : Reconstruction effect (cell radius) ? He gas mix ?
- BiPo vertex location is under study, almost done → study the remaining radiological contaminations of the source foils with  $(e, 2\gamma)_{\text{int}}$  analysis in progress (see my  $^{214}\text{Bi}$  talk)

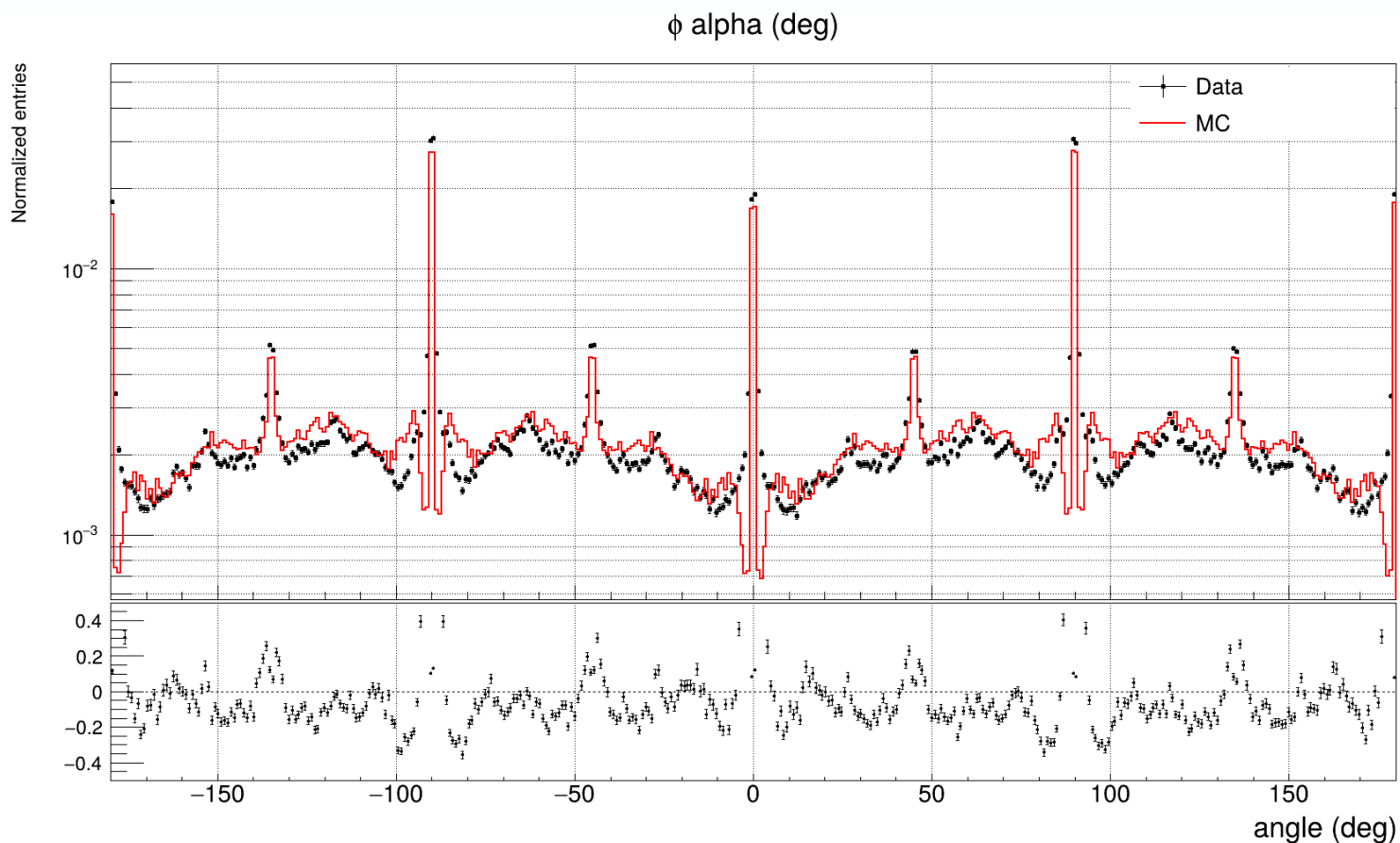
# Thank you !

I'm going back to write my  
thesis now



# PTD extraction module

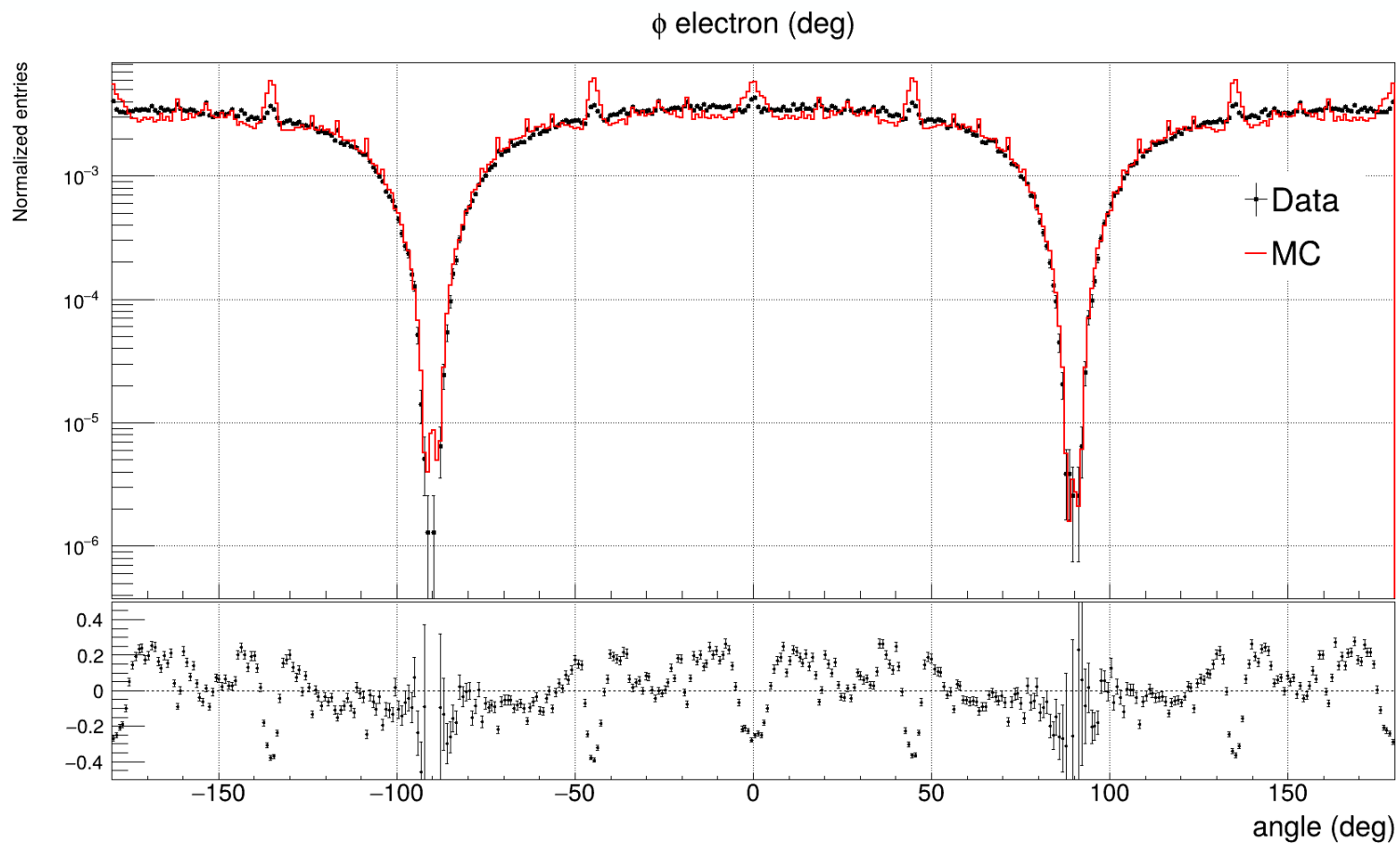
- Falaise Skeleton module → Reading PTD information from TrackFit
- 3 types of particles saved :
  1. **Gammas** (OMs hit without tracks) → Few ambiguities to corrects
  2. **Electrons**
    - i. Electron on one side of the tracker
    - ii. Electron crossing the source foil (needed for  $\beta^-$  background studies)
  3. **Undefined particle ("UND")** : → Few ambiguities to corrects
    - Short reconstructed track without associated OMs



$$\phi_\alpha \in [-180, 180] \text{ deg}$$

- $\phi_\alpha \simeq 0^\circ \rightarrow$  alpha in + x
- $\phi_\alpha \simeq \pm 90^\circ \rightarrow$  Horizontal (+y & -y)
- $\phi_\alpha \simeq \pm 180^\circ \rightarrow$  alpha in - x
- $|\phi_\alpha| < 90^\circ \rightarrow$  alpha in + x
- $|\phi_\alpha| > 90^\circ \rightarrow$  alpha in - x

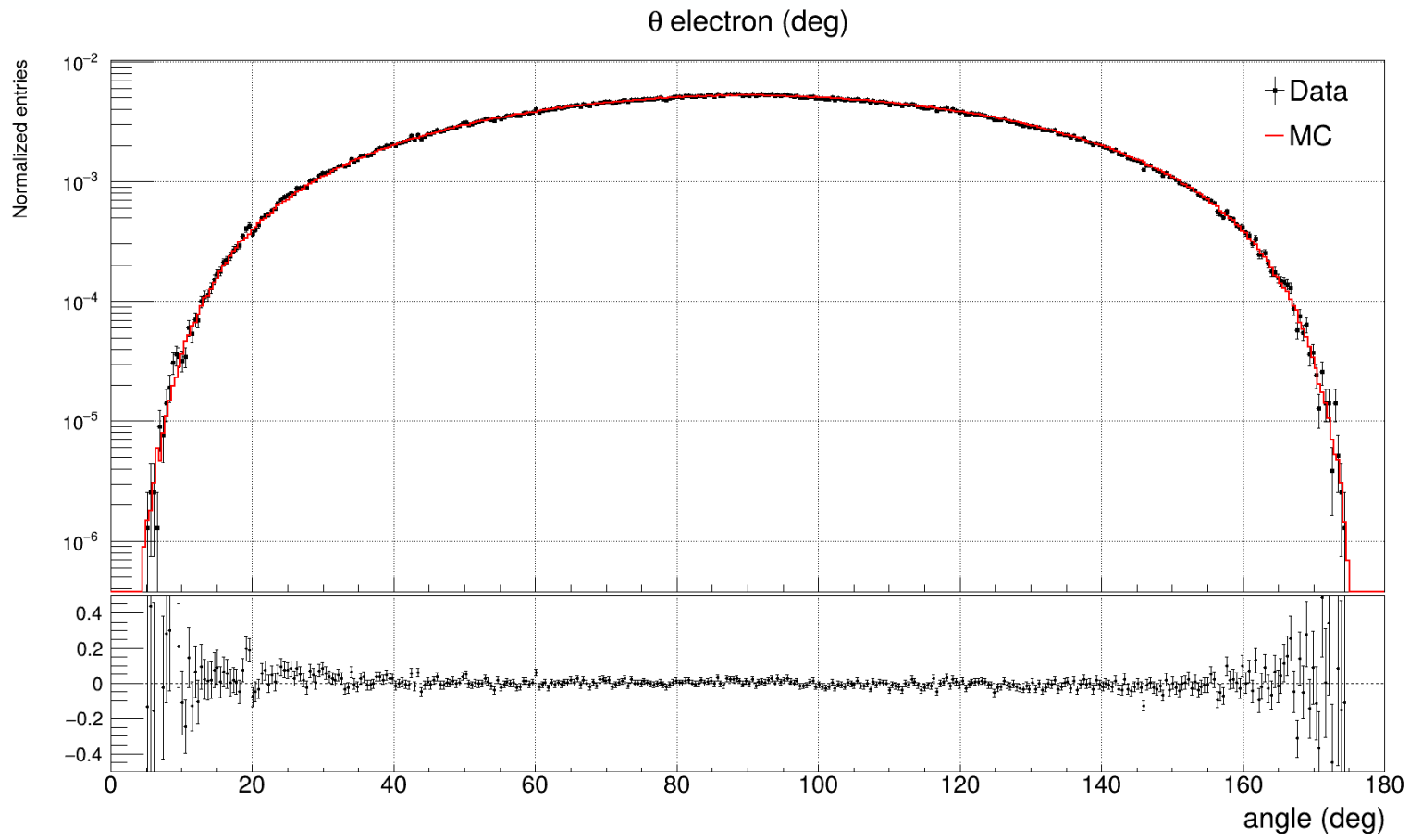
# Phi electron



$$\phi_\alpha \in [-180, 180] \text{ deg}$$

- $\phi_\alpha \simeq 0^\circ \rightarrow$  alpha in + x
- $\phi_\alpha \simeq \pm 90^\circ \rightarrow$  Horizontal (+y & -y)
- $\phi_\alpha \simeq \pm 180^\circ \rightarrow$  alpha in - x
- $|\phi_\alpha| < 90^\circ \rightarrow$  alpha in + x
- $|\phi_\alpha| > 90^\circ \rightarrow$  alpha in - x

# Theta electron



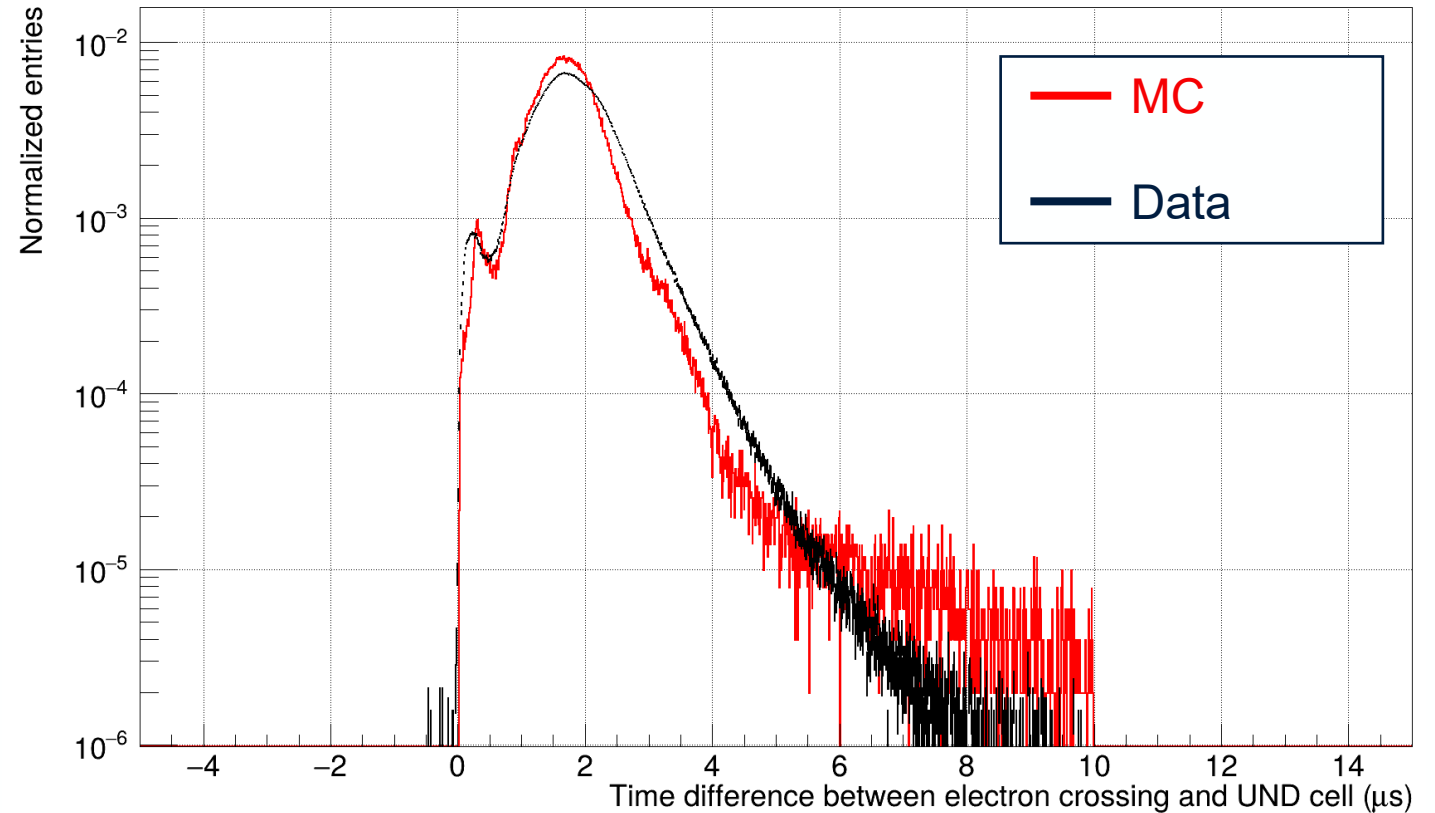
# Electron crossing source foil at low $\Delta t$

$\Delta t_{UND/e^-}$  cut

Mean time difference with  
OM of UND cells merged  
with electron

Cut applied :

$$-0.5 \mu s \leq \Delta t_{UND/e^-} \leq 10 \mu s$$



# Electron crossing source foil: vertex

## $\Delta r_{e^-/UND}$ cut

Vertex distance measured in the plane of the source foils

Selection Cut applied :

$$\Delta r_{e^-/UND} \leq 200 \text{ mm}$$

