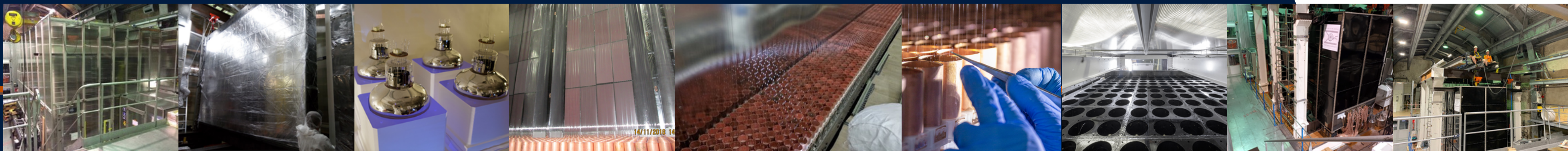


supernemo



Double beta analysis

Granjon Mathis



Data used

Data since April 2025 are divided in 5 phases:

General conditions:

Algo = Cimirman

309.5 days of data

Phase 0

HT + 7% tracker missing

37.9 days of data

Phase 1

LT + 7% tracker missing

25.6 days of data

Phase 2 + 3

LT + full tracker

90.8 days of data

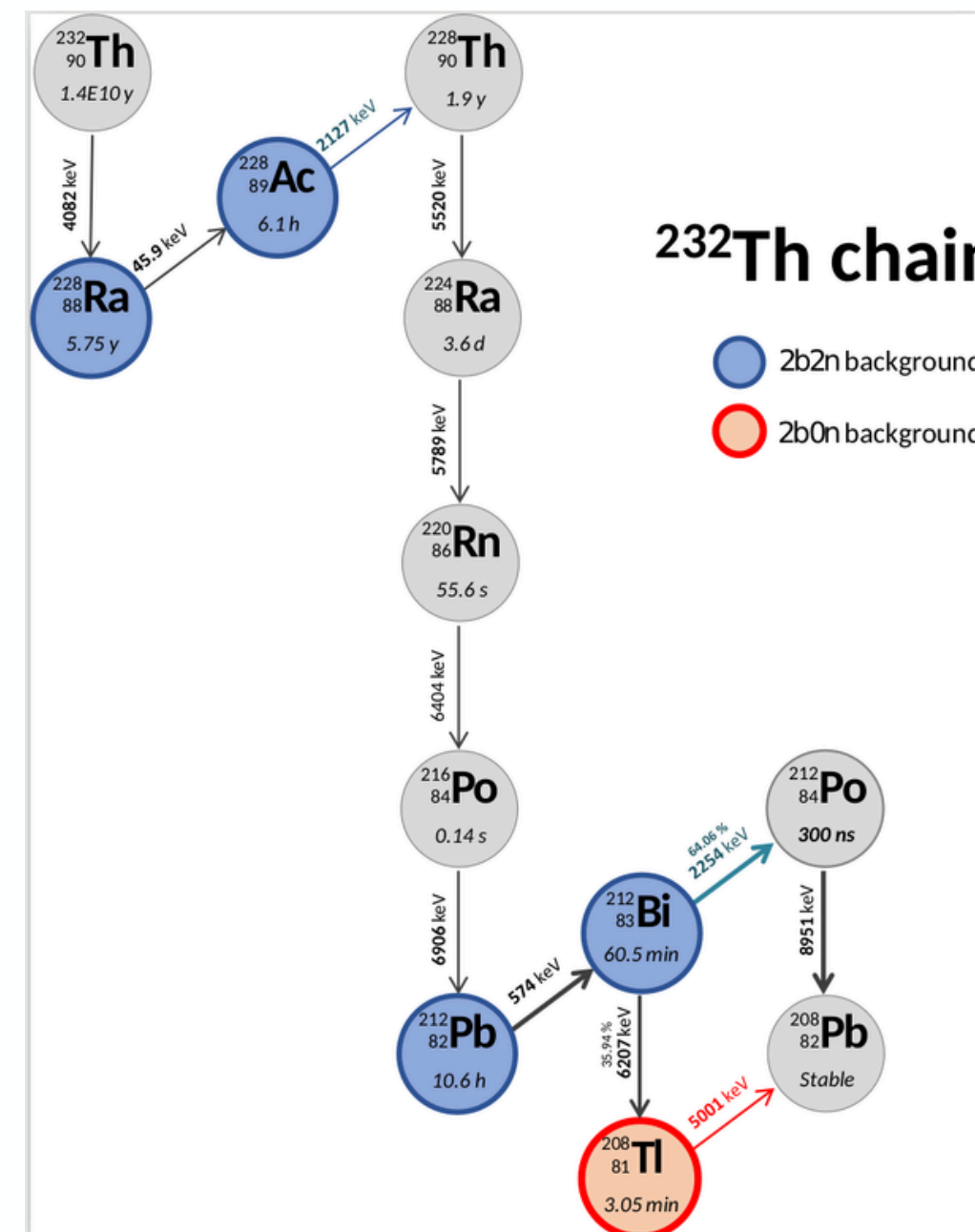
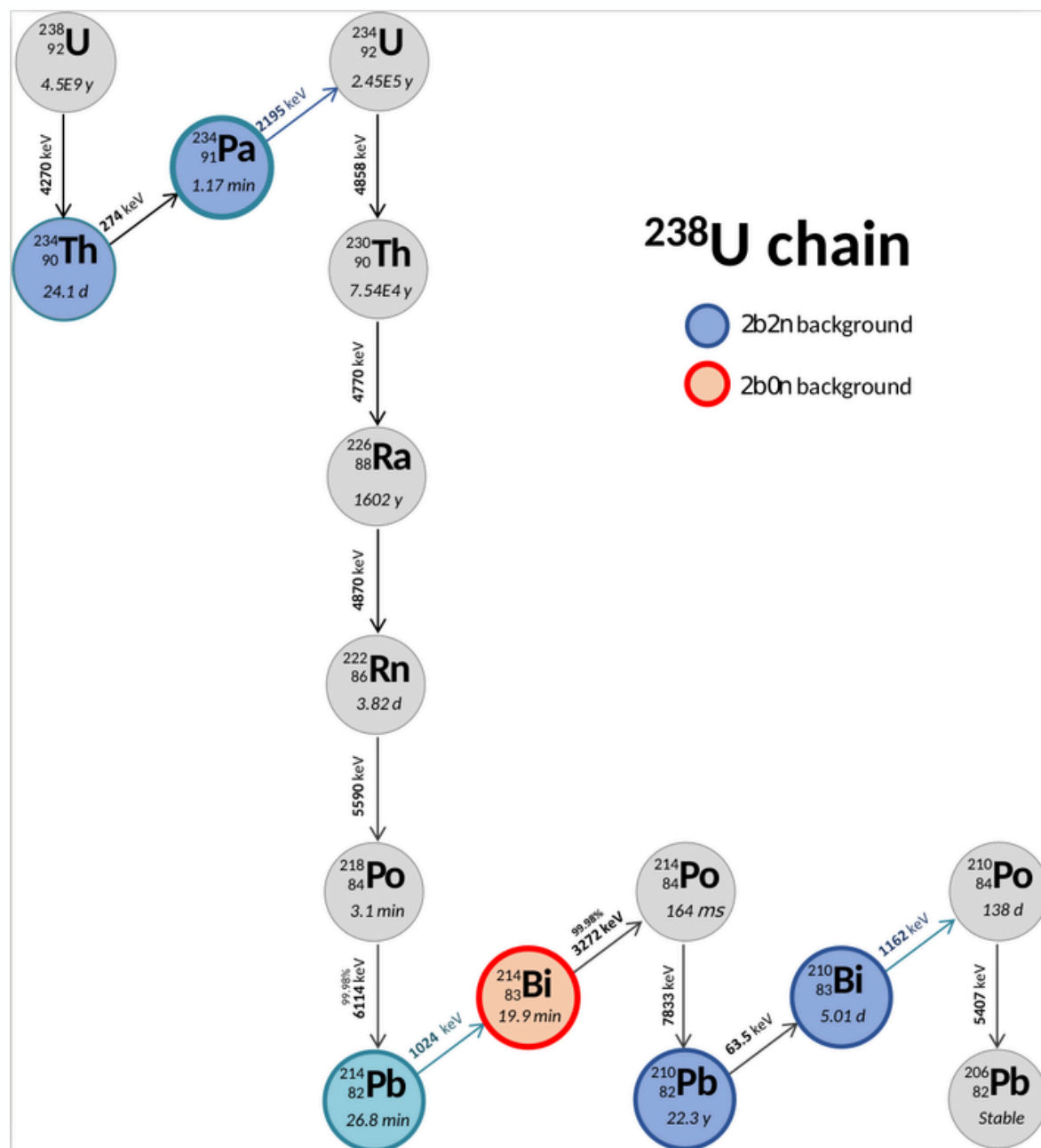
Phase 4

LT + full tracker + low radon

155.2 days of data

Simulations used

Internal backgrounds considered



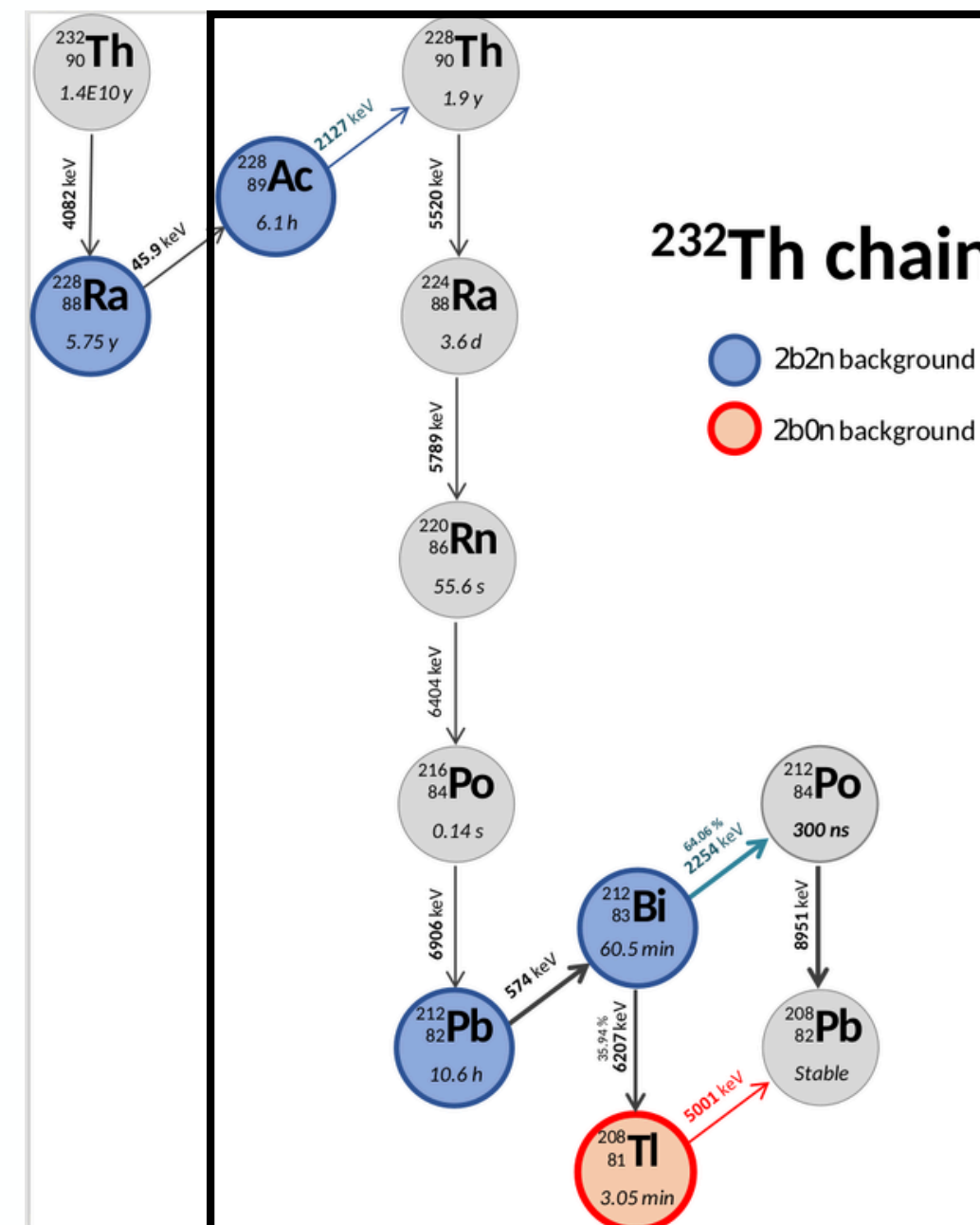
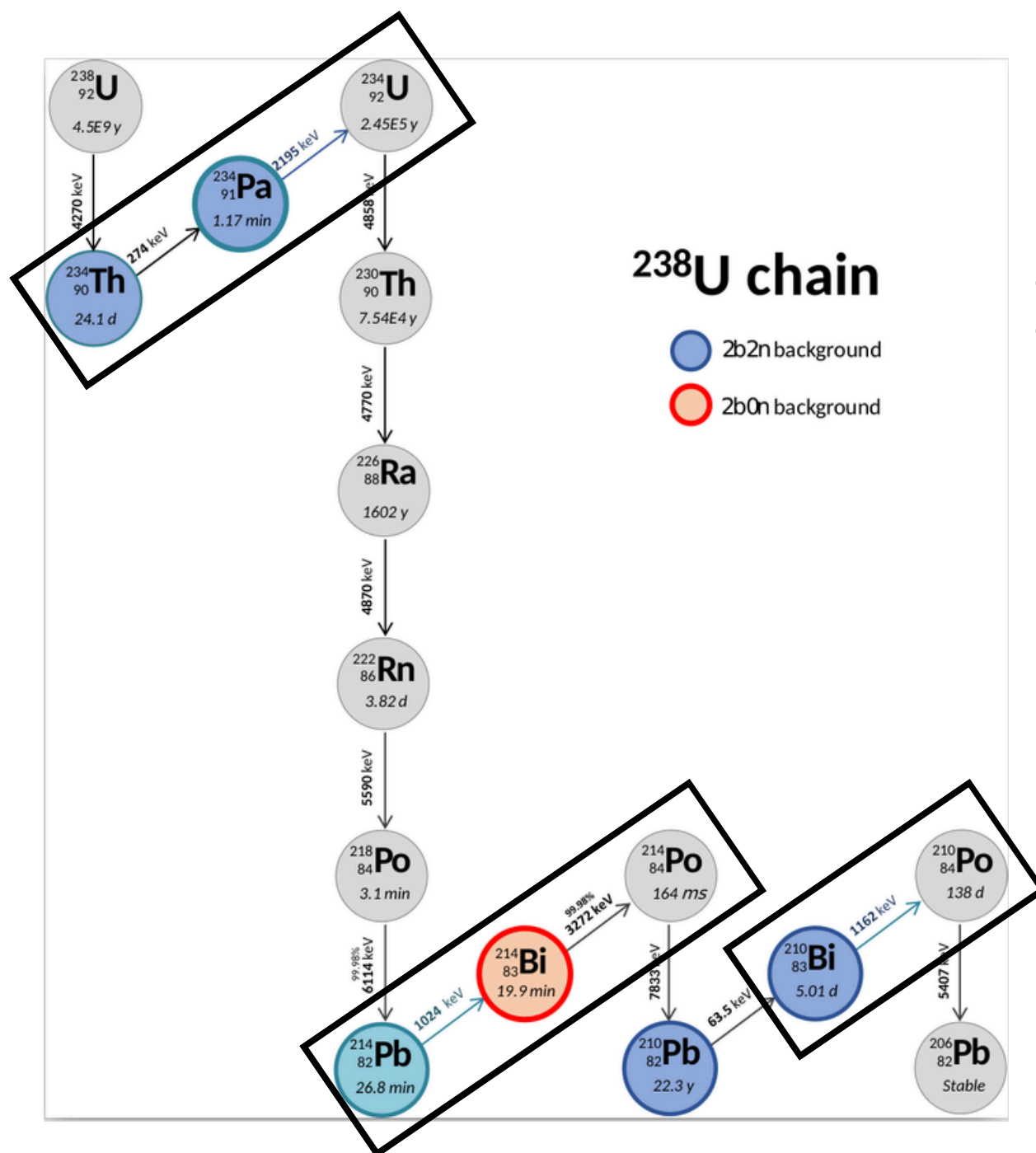
Simulations used

Internal backgrounds considered

= secular equilibrium

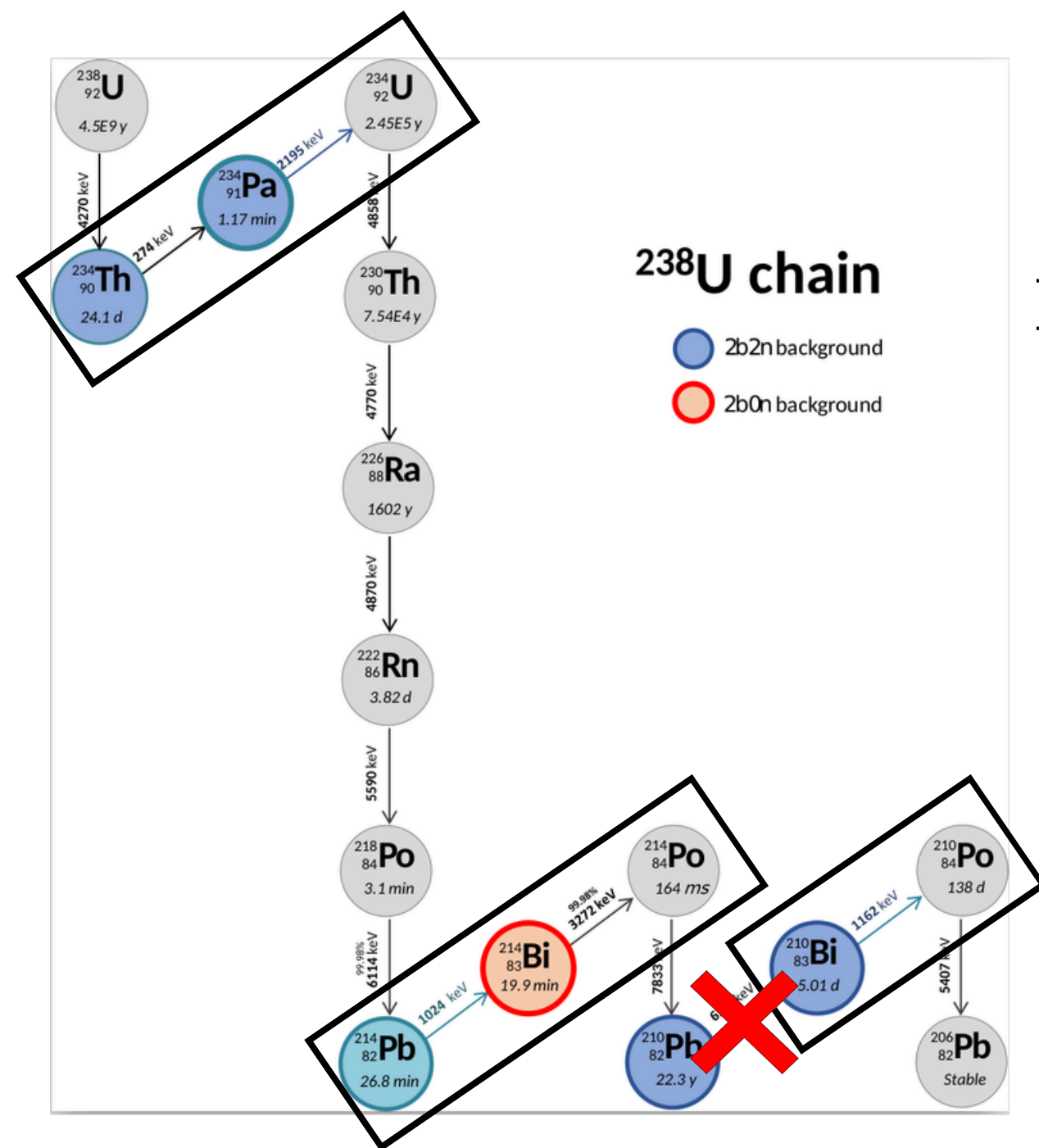
Means $A_{\text{first}} = A_{\text{second}}$

→ We must compute only 4 internal activities



Simulations used

Internal backgrounds considered

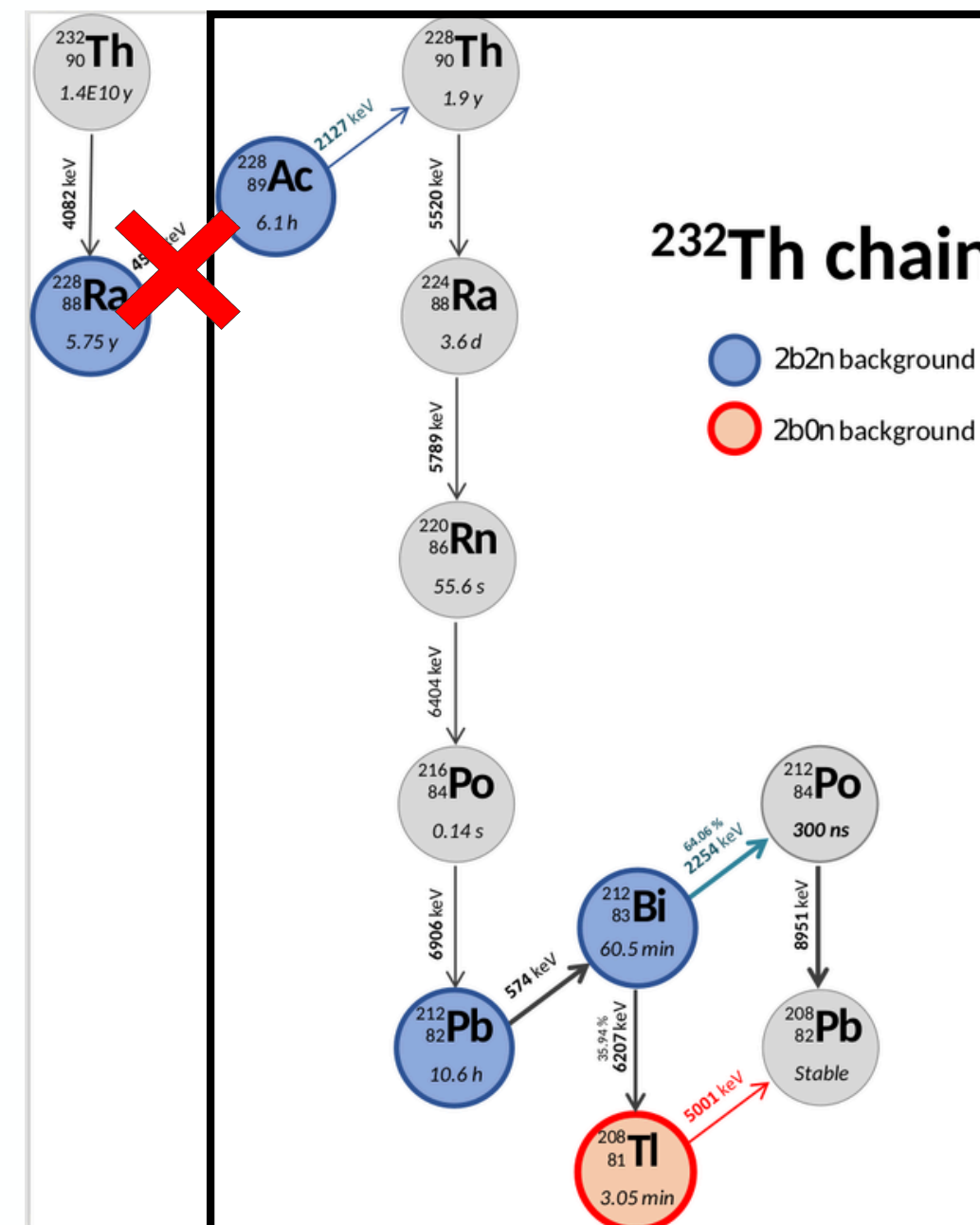


= secular equilibrium

Means $A_{\text{first}} = A_{\text{second}}$

→ We must compute only 4 internal activities

Some electron are suppressed by the **energy threshold**



Simulations used

Generation
foil bulk
Wire and foil surface
PMT glass
Neutrons (Sam Pratt work)

$^{234}\text{Pa} = 17 \text{ mBq/kg}$ [NEMO-3]

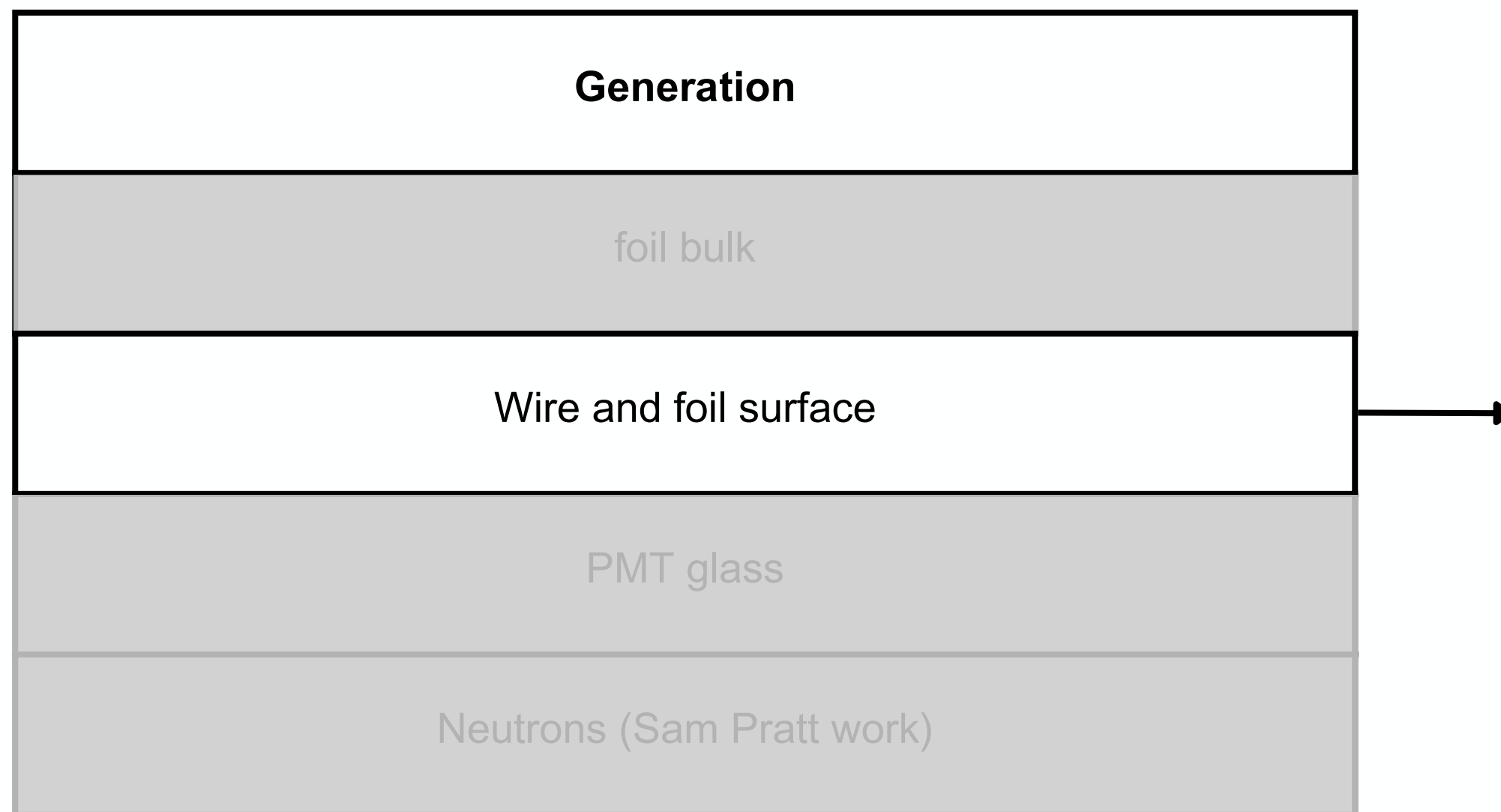
$^{40}\text{K} = 58 \text{ mBq/kg}$ [NEMO-3]

$^{208}\text{Tl} = 54 \text{ }\mu\text{Bq/kg}$ [BiPo weighted average]

^{214}Bi foil = 290 $\mu\text{Bq/kg}$ [BiPo upper limit]

^{210}Bi foil = ?? not measured

Simulations used

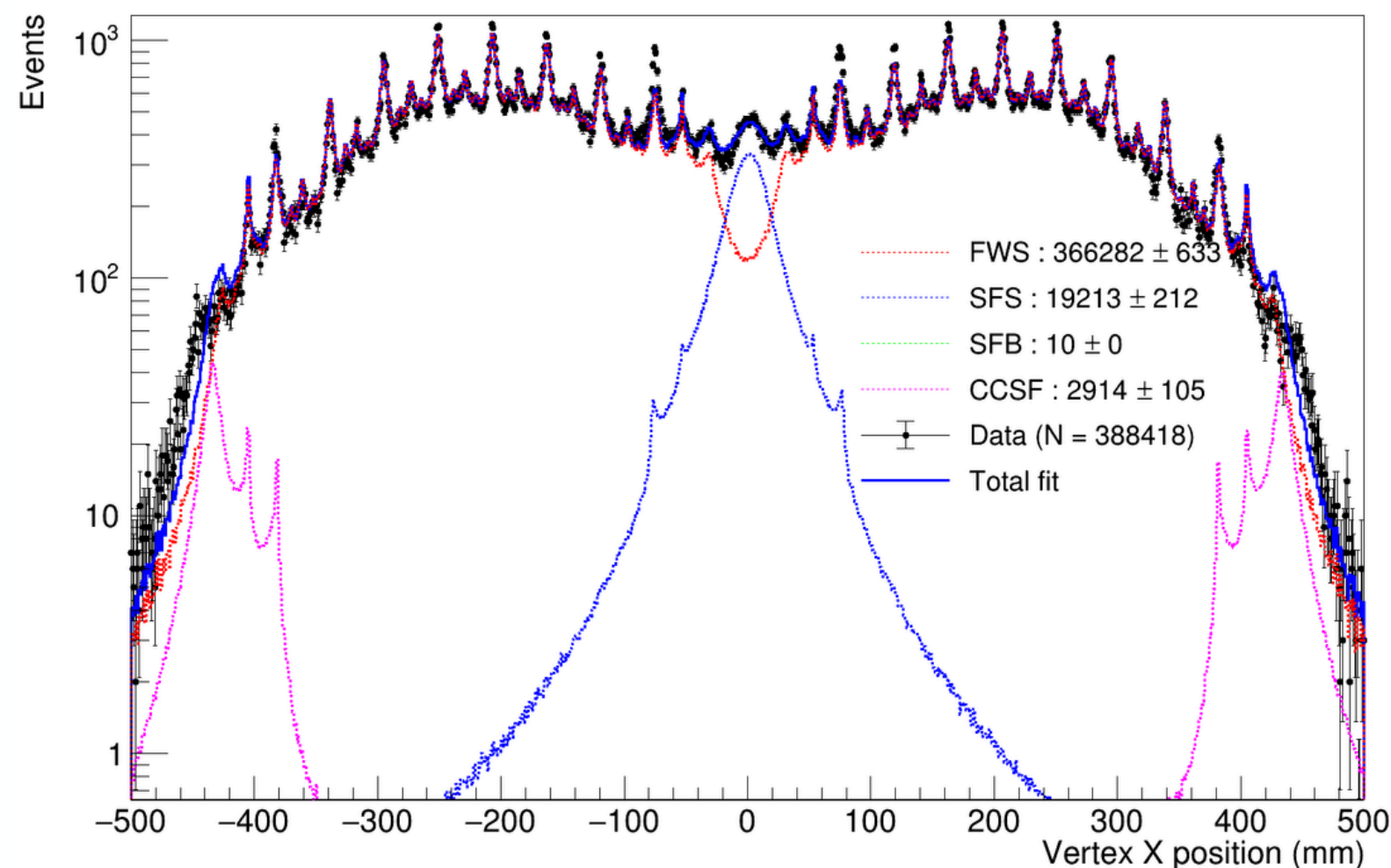


Only Radon 222 taken into account

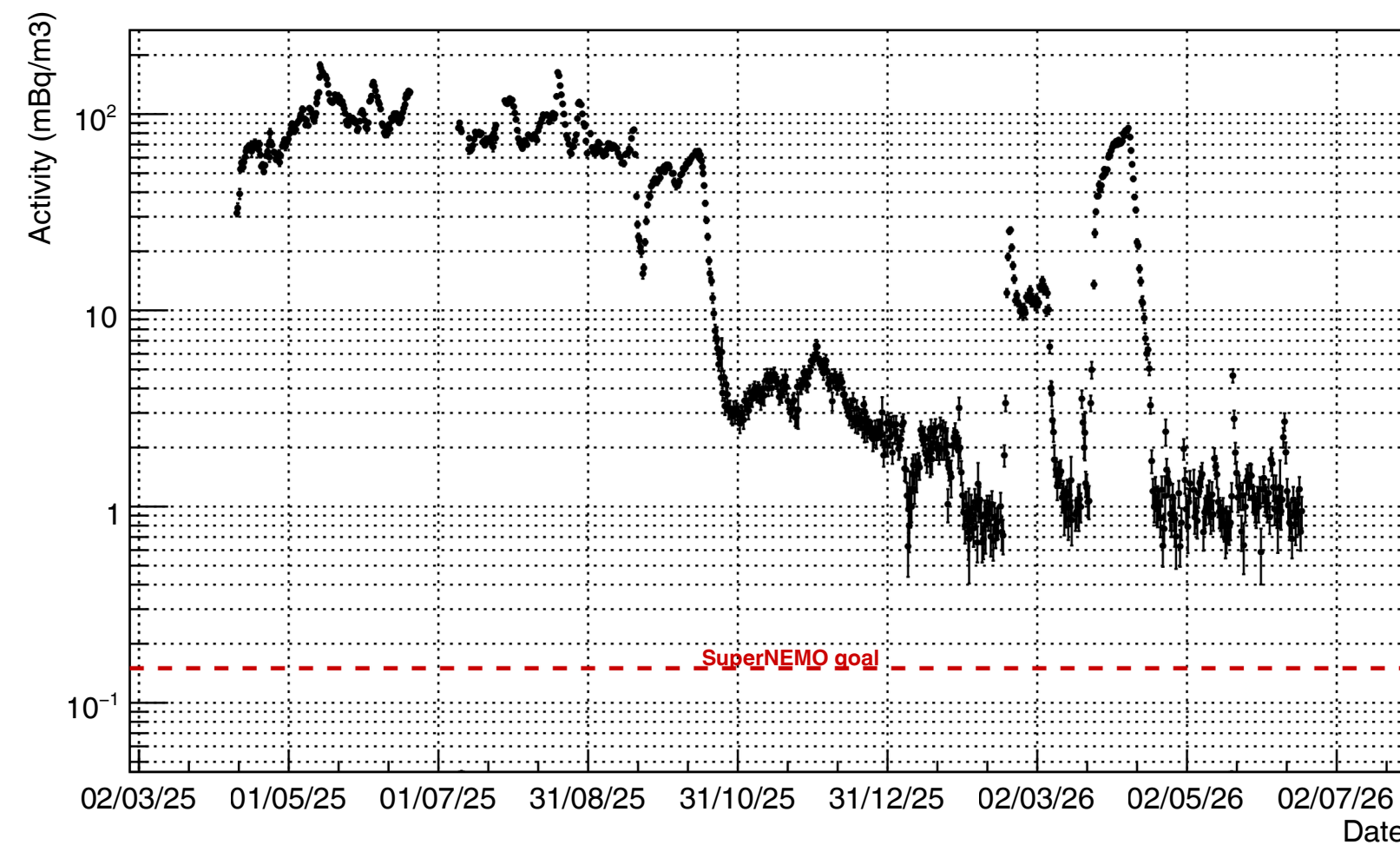
Phase 0	Phase 1
88 mBq/m ³	101 mBq/m ³
Phase 2 + 3	Phase 4
76.3 mBq/m ³ + 65.7 mBq/m ³	9.7 mBq/m ³

Simulations used

External backgrounds considered



Radon 222

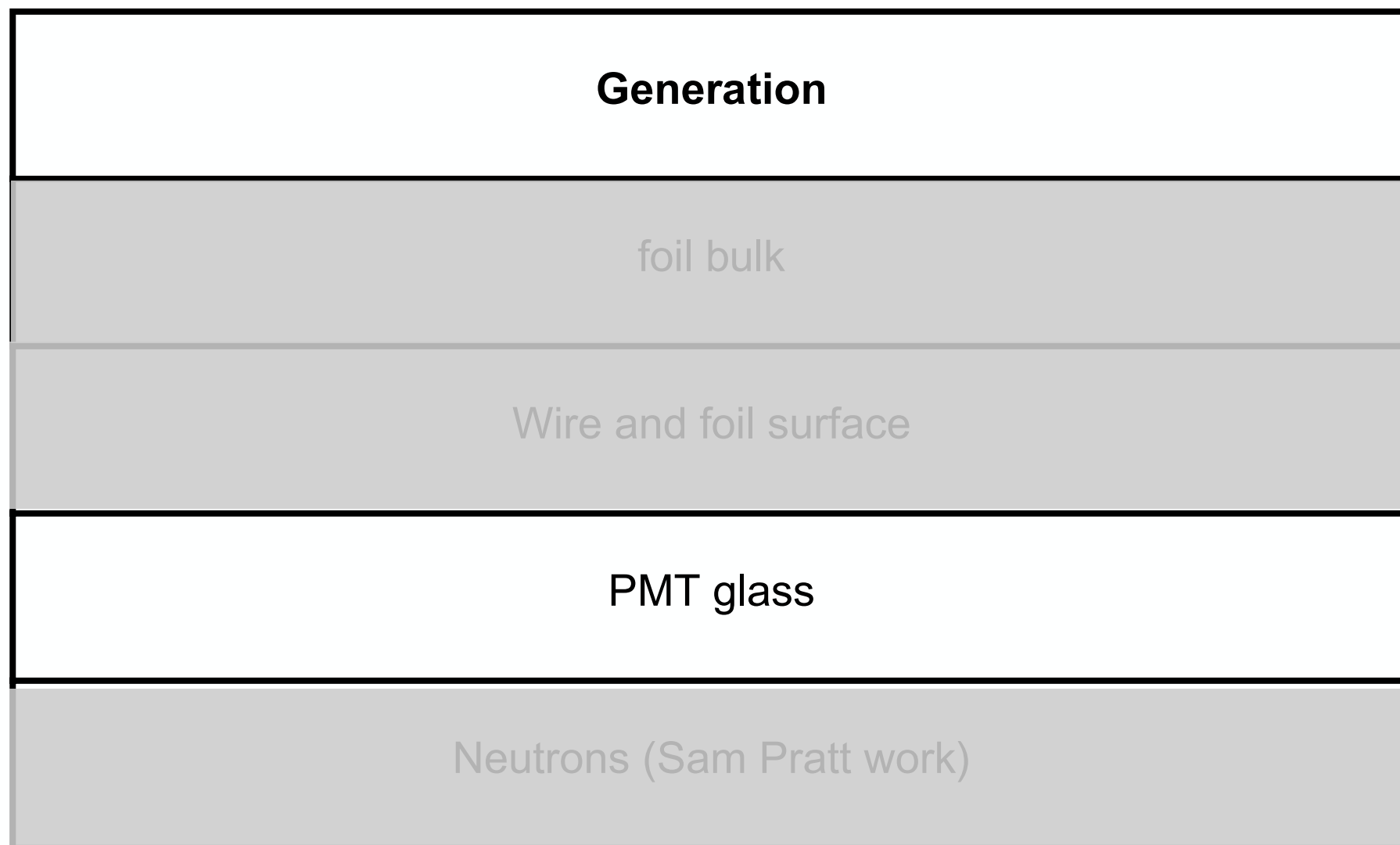


foil surface activity $\simeq 5 \%$

tracker activity $\simeq 95 \%$

Plot and measurement from Antoine Lahaie

Simulations used



3 activity simulated in PMT glass 8"

$$A(^{214}\text{Bi}) = 141 \text{ Bq} \quad A(^{208}\text{Tl}) = 40 \text{ Bq} \quad A(^{40}\text{K}) = 417 \text{ Bq}$$

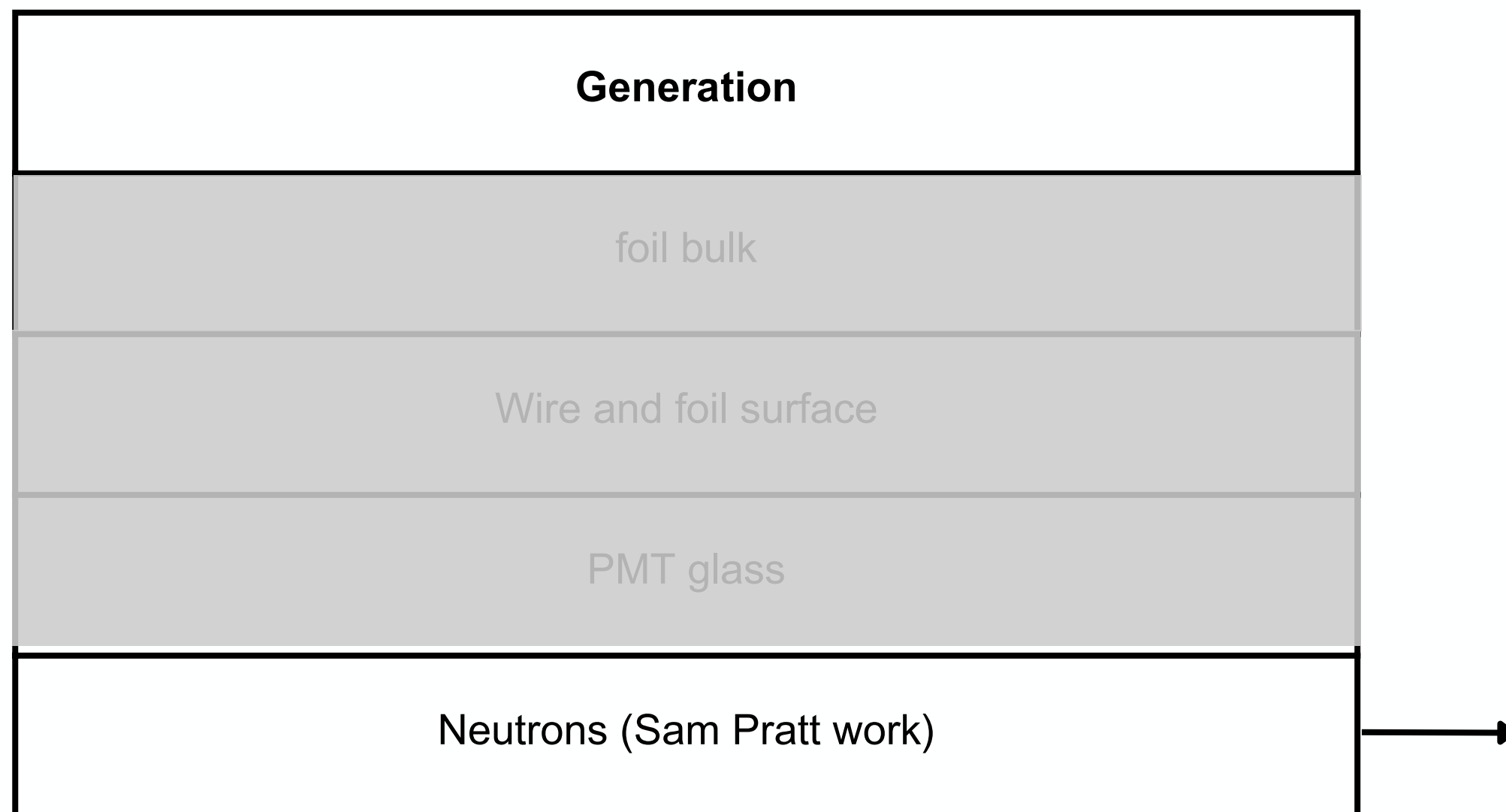
3 activity simulated in PMT glass 5"

3 simulation generator = g_veto, x_wall, MW

$$A(^{214}\text{Bi}) = 56 \text{ Bq} \quad A(^{208}\text{Tl}) = 3.15 \text{ Bq} \quad A(^{40}\text{K}) = 123 \text{ Bq}$$

Measured by BiPo docDB #4263

Simulations used



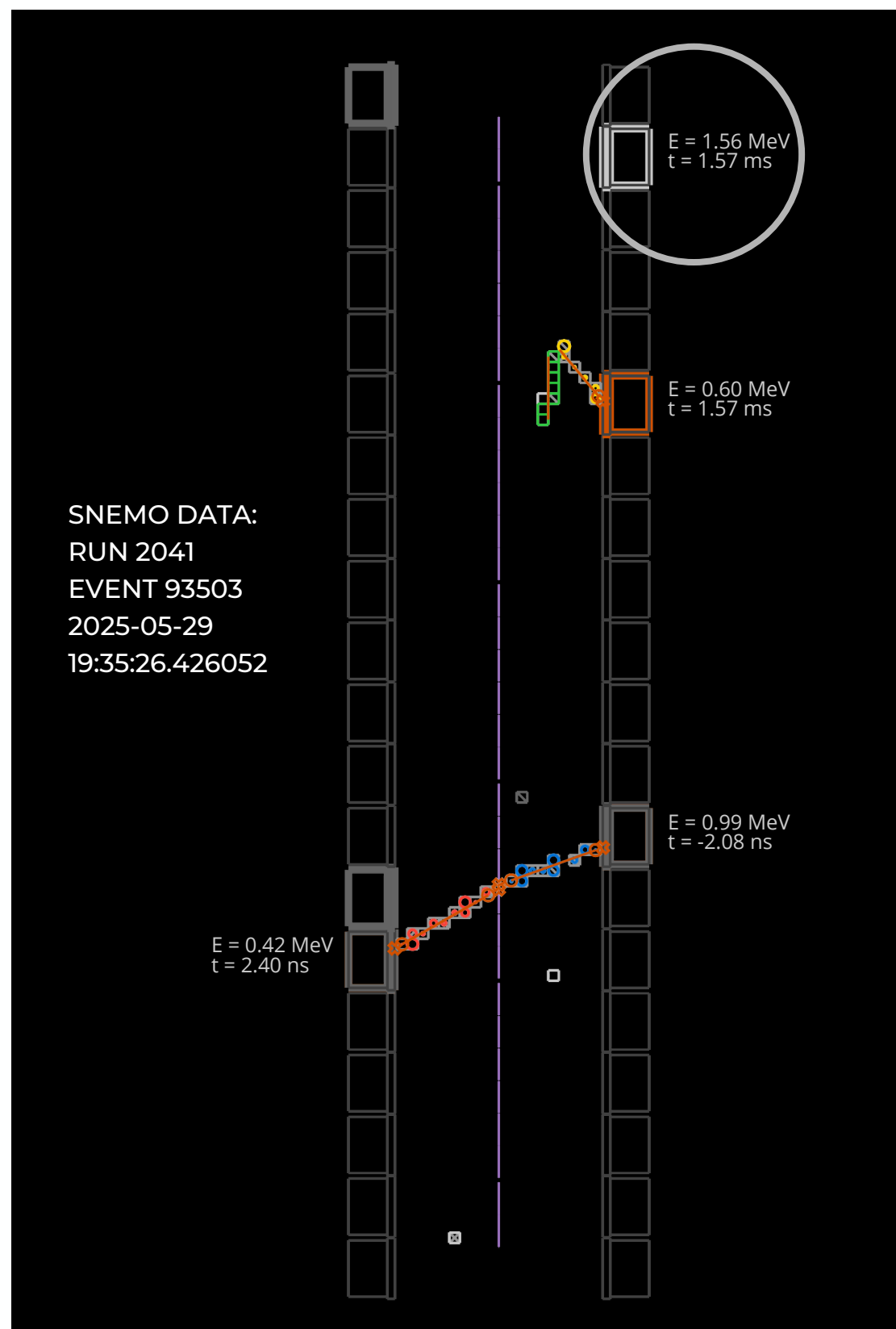
Flux, scaling factors, simulation results
has been done by Sam Pratt
→ included = fast + thermal neutrons
isotopes: Cu64 Cu66 deuteron Fe55 Fe57

Simulations used

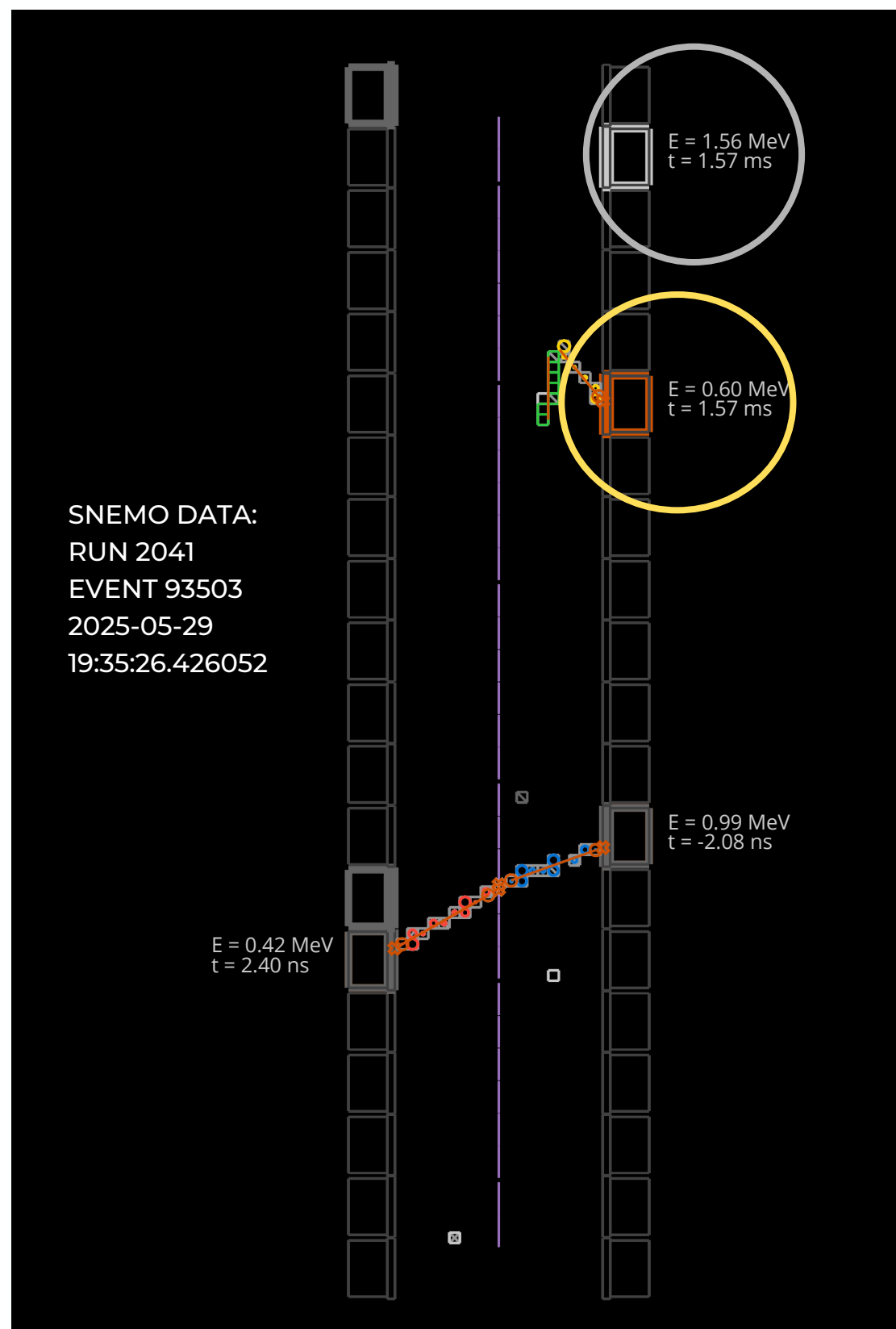
Generation
foil bulk
Wire and foil surface
PMT glass
Neutrons (Sam Pratt work)

Simulation produced by Xalbat Aguerre

Double beta selection



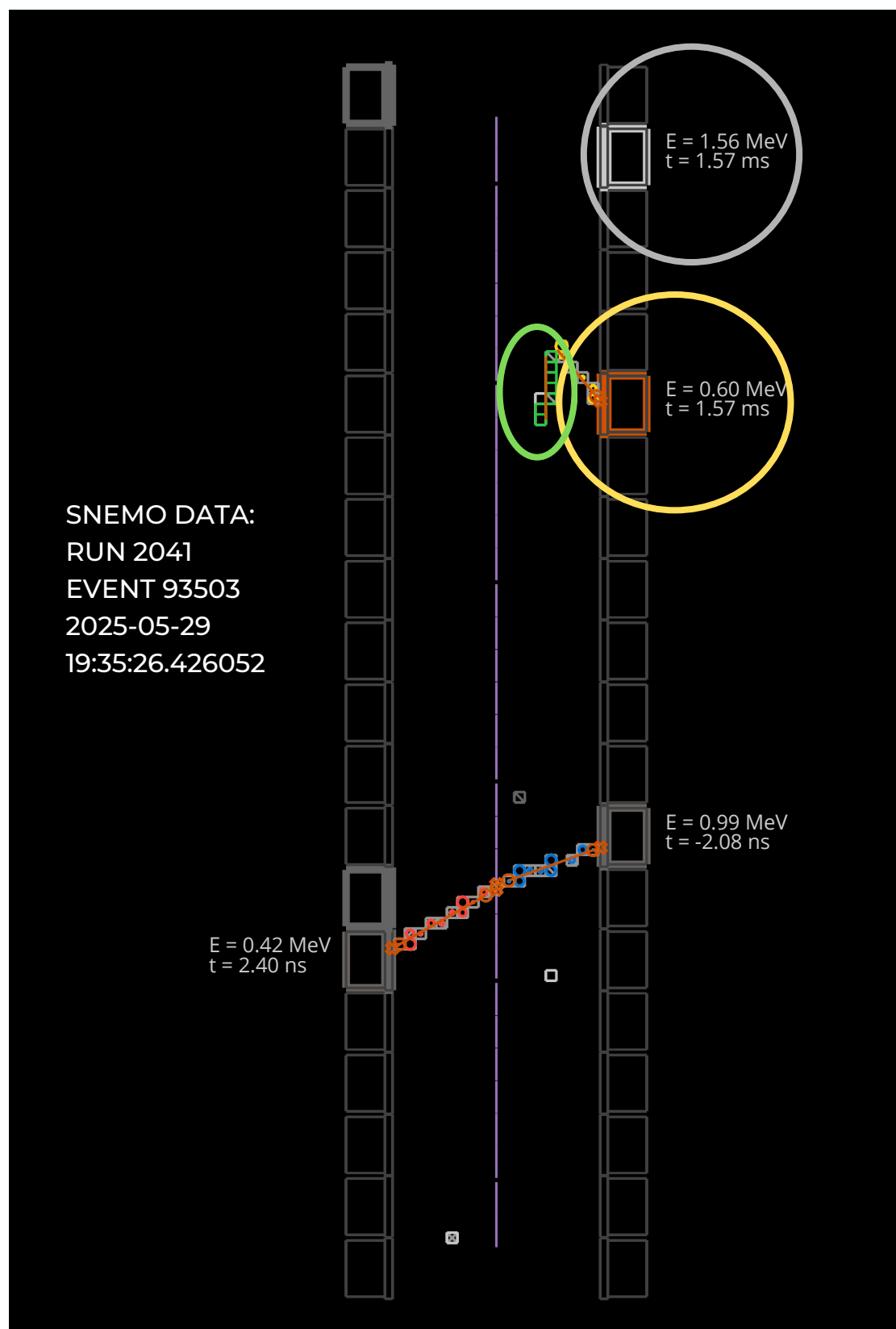
Double beta selection



γ

calo e^-

Double beta selection

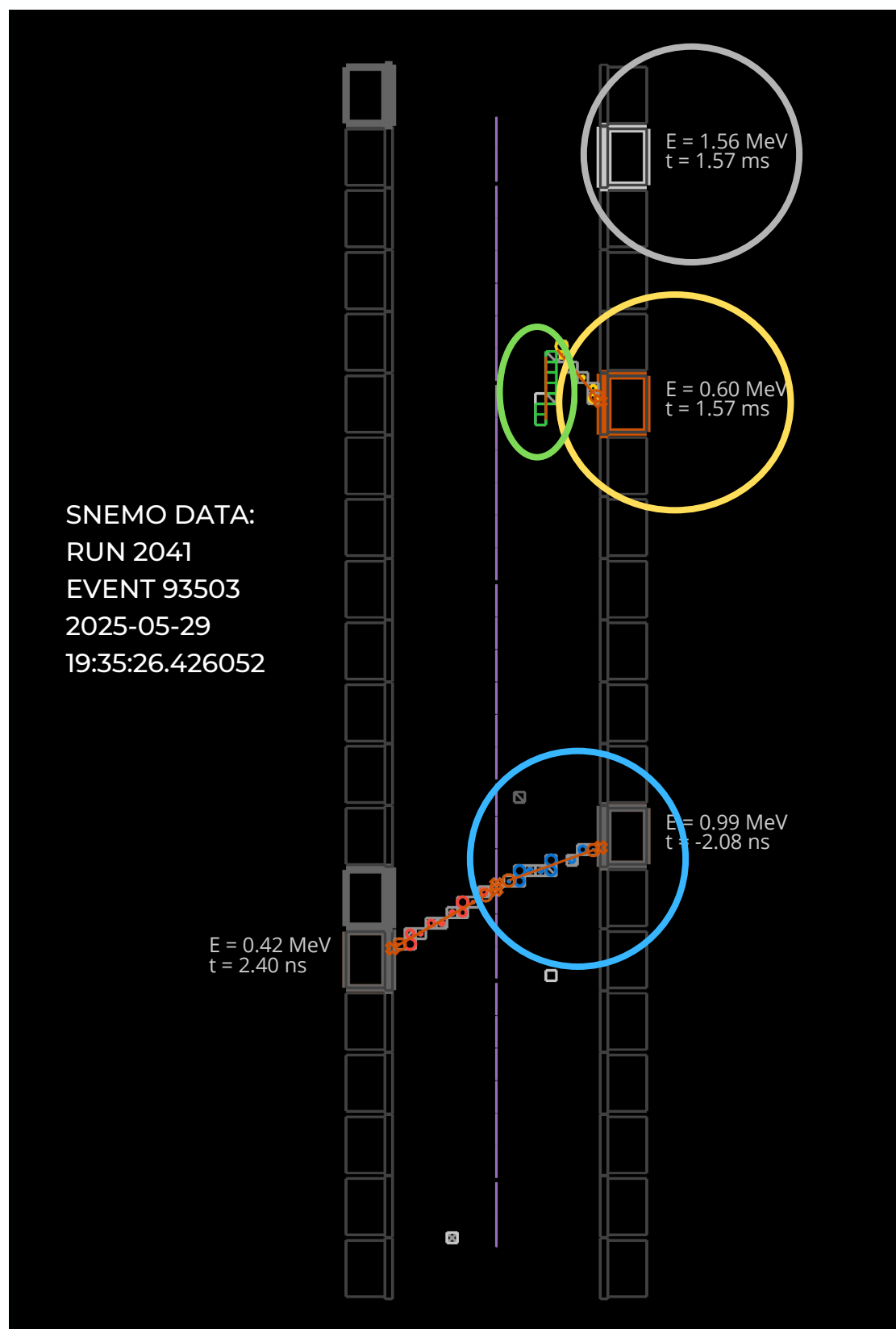


γ

calo e^-

α

Double beta selection



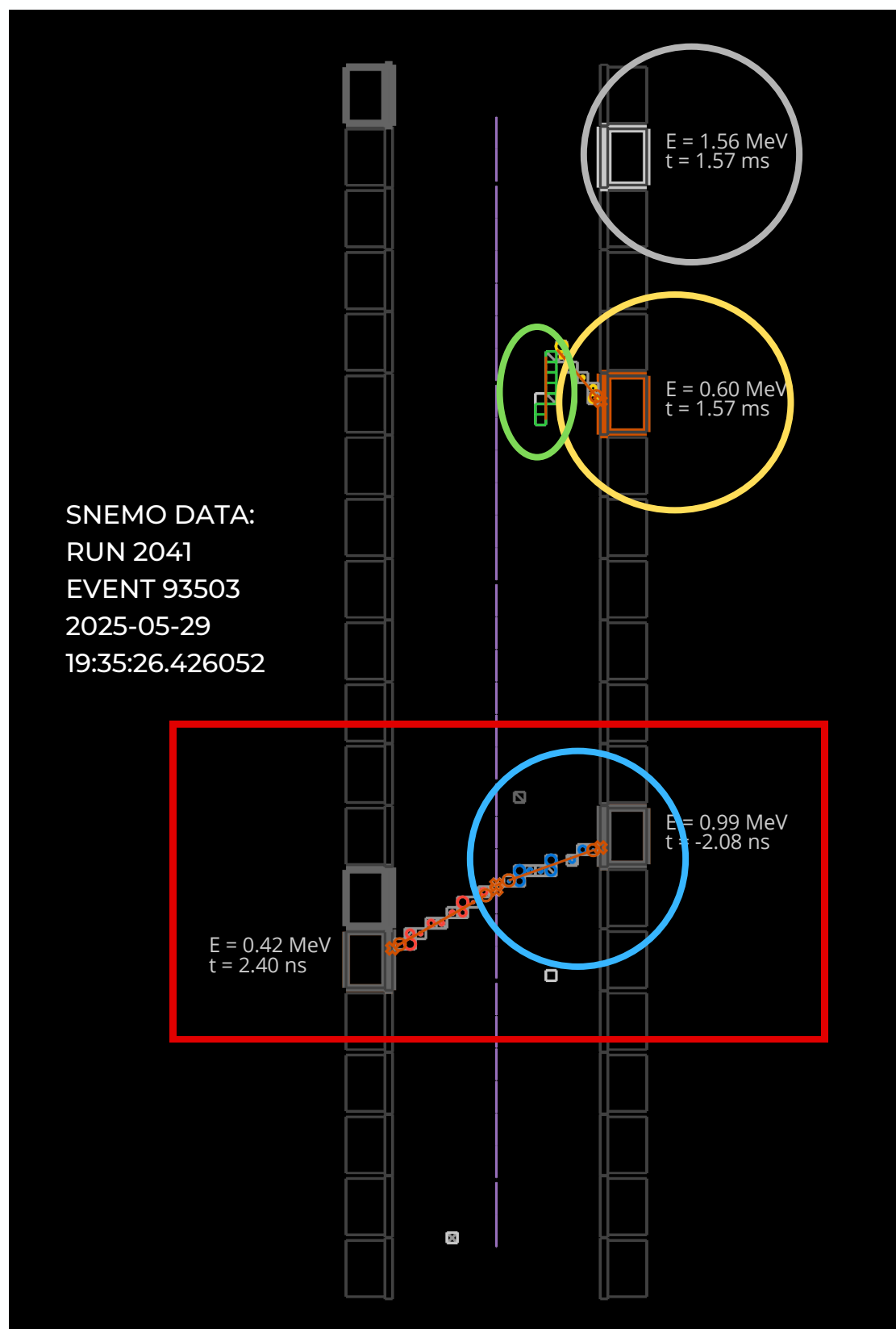
γ

calo e^-

α

golden e^-

Double beta selection



γ

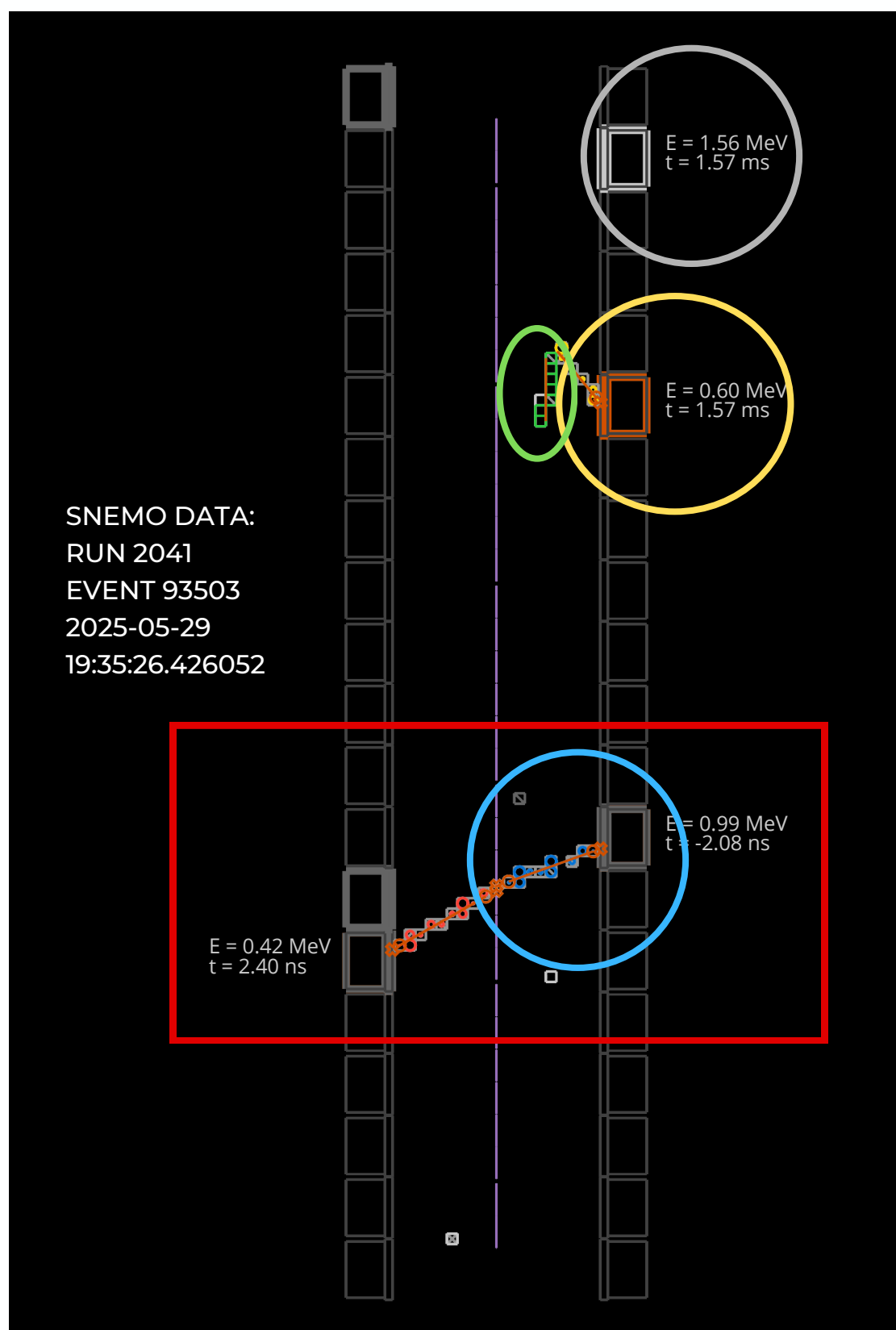
calo e^-

α

golden e^-

$\beta\beta$

Double beta selection



γ

calo e^-

α

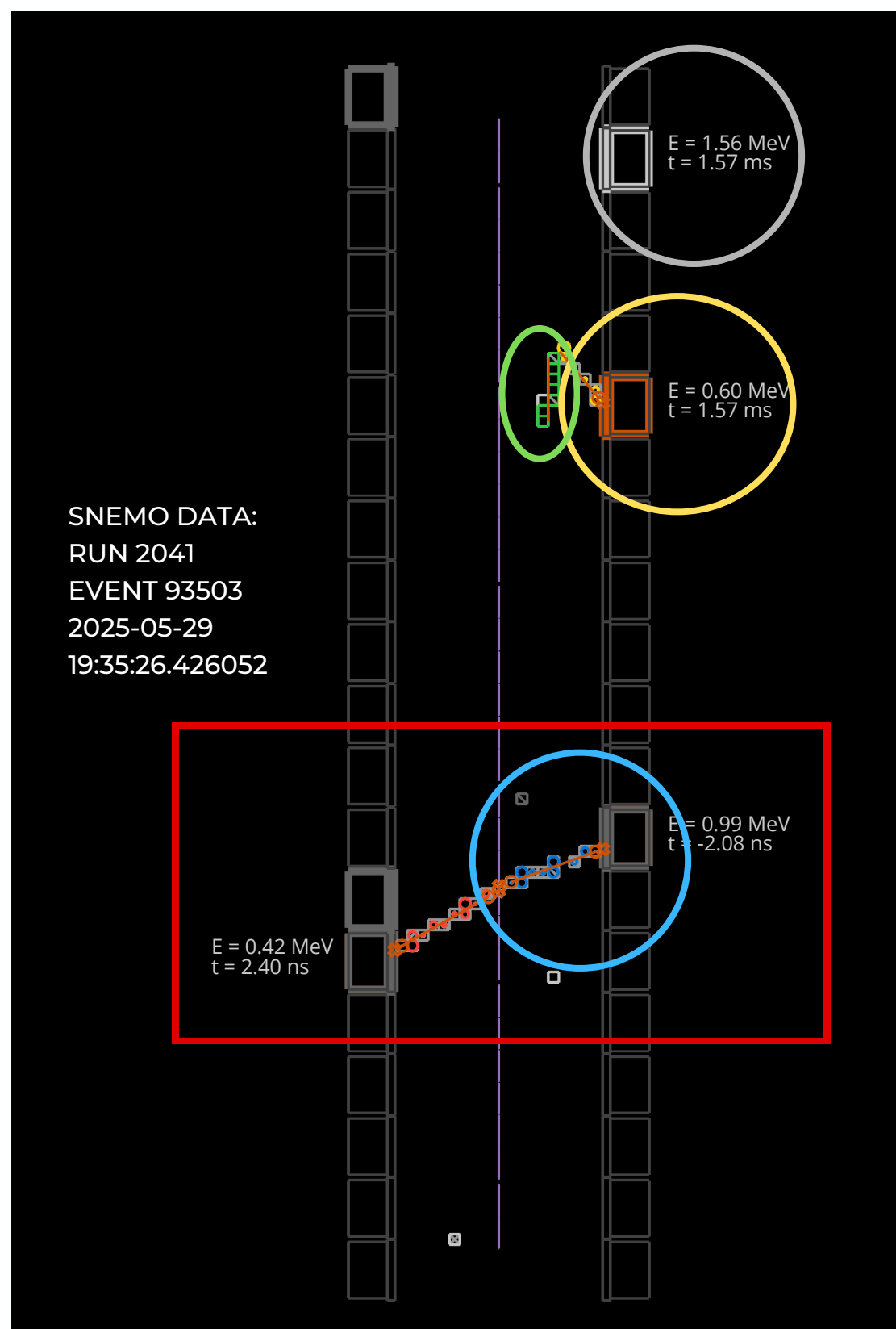


If $e^- < \text{energy threshold} \rightarrow \alpha$

golden e^-

$\beta\beta$

Double beta selection



γ
 α
 e^-
 e^-
 $\beta\beta$

Condition of selection:

At least 2 golden e^-

Choose 2 time closest golden e^-

$$\Delta TOF < 1.5 \text{ ns}$$

$$\sqrt{\Delta y^2 + \Delta z^2} < 100$$

$$t_{\beta\beta} - t_{e^-} > 25 \text{ ns}$$

$$t_{\beta\beta} - t_{\gamma} > 50 \text{ ns}$$

$$\Delta t_{\alpha-\beta\beta} > 10 \mu\text{s} \text{ and } \Delta r_{\beta\beta-\alpha} > 200 \text{ mm}$$

No kink for each electrons

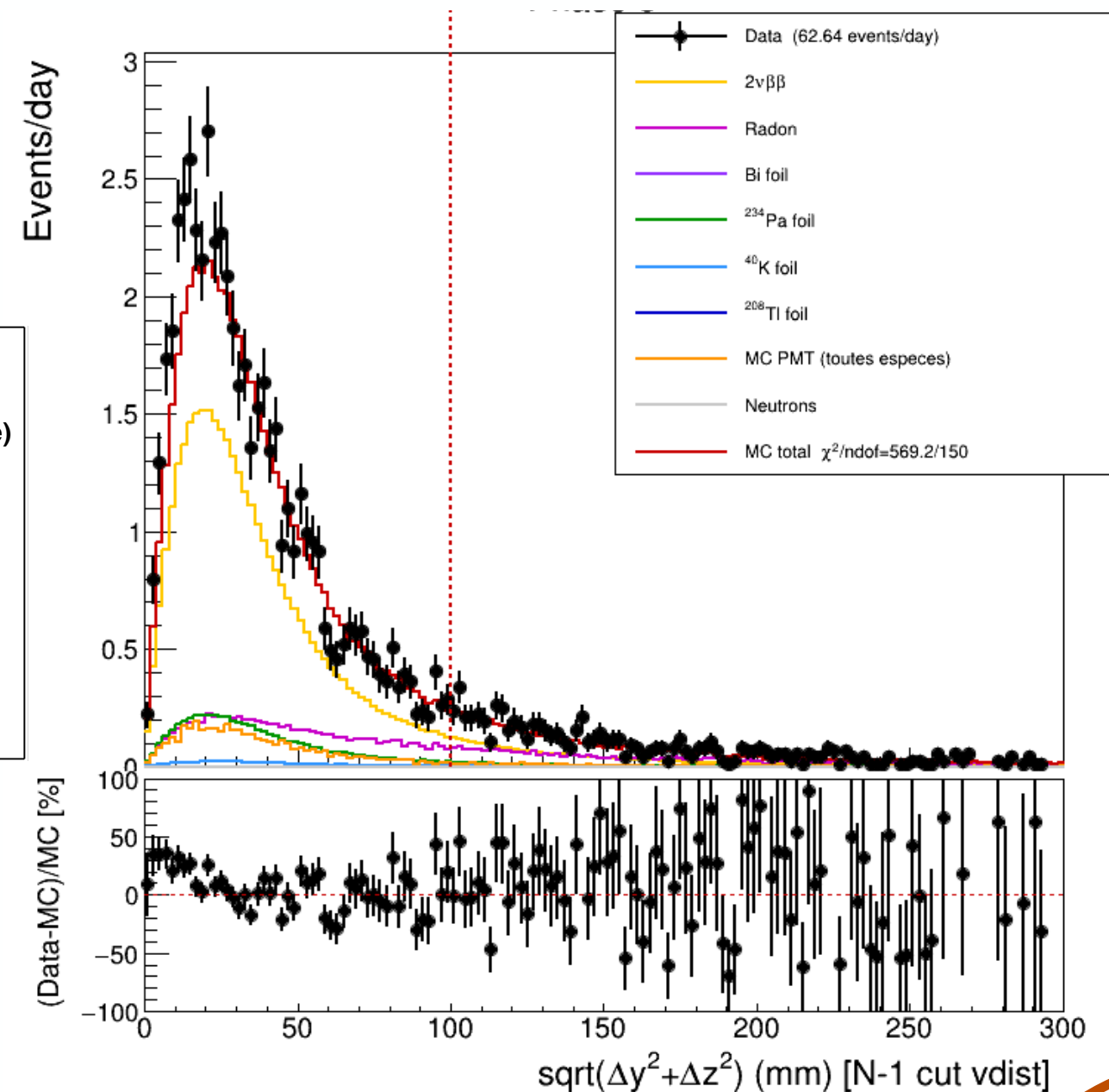
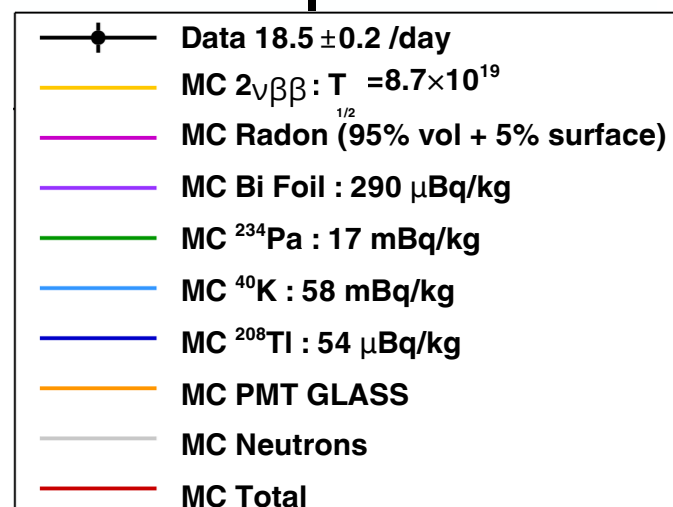
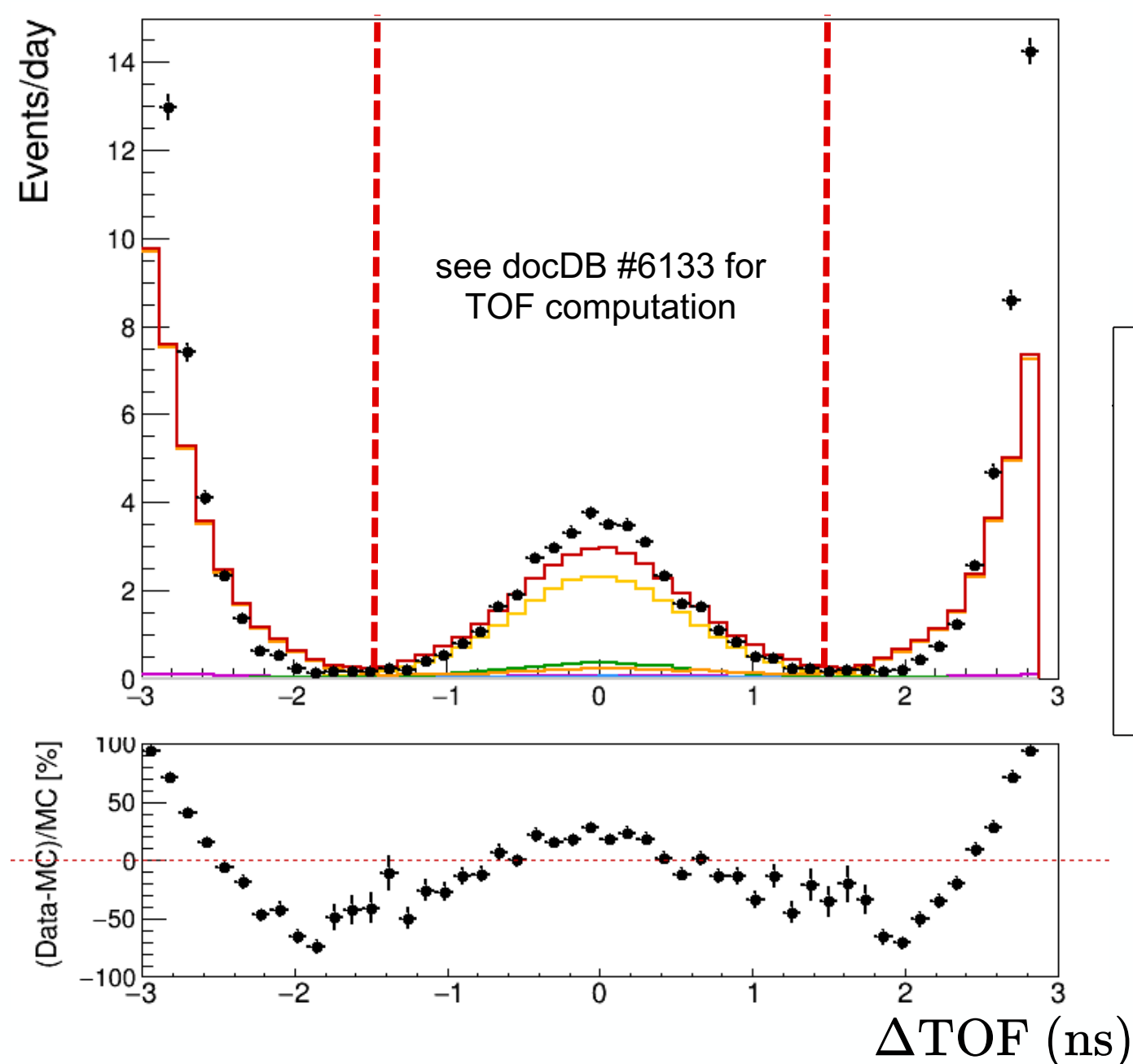
No $\beta\beta$ in hot spots

Time and space correlation

$$\Delta TOF < 1.5 \text{ ns}$$

2 β channel

$$\sqrt{\Delta y^2 + \Delta z^2} < 100$$



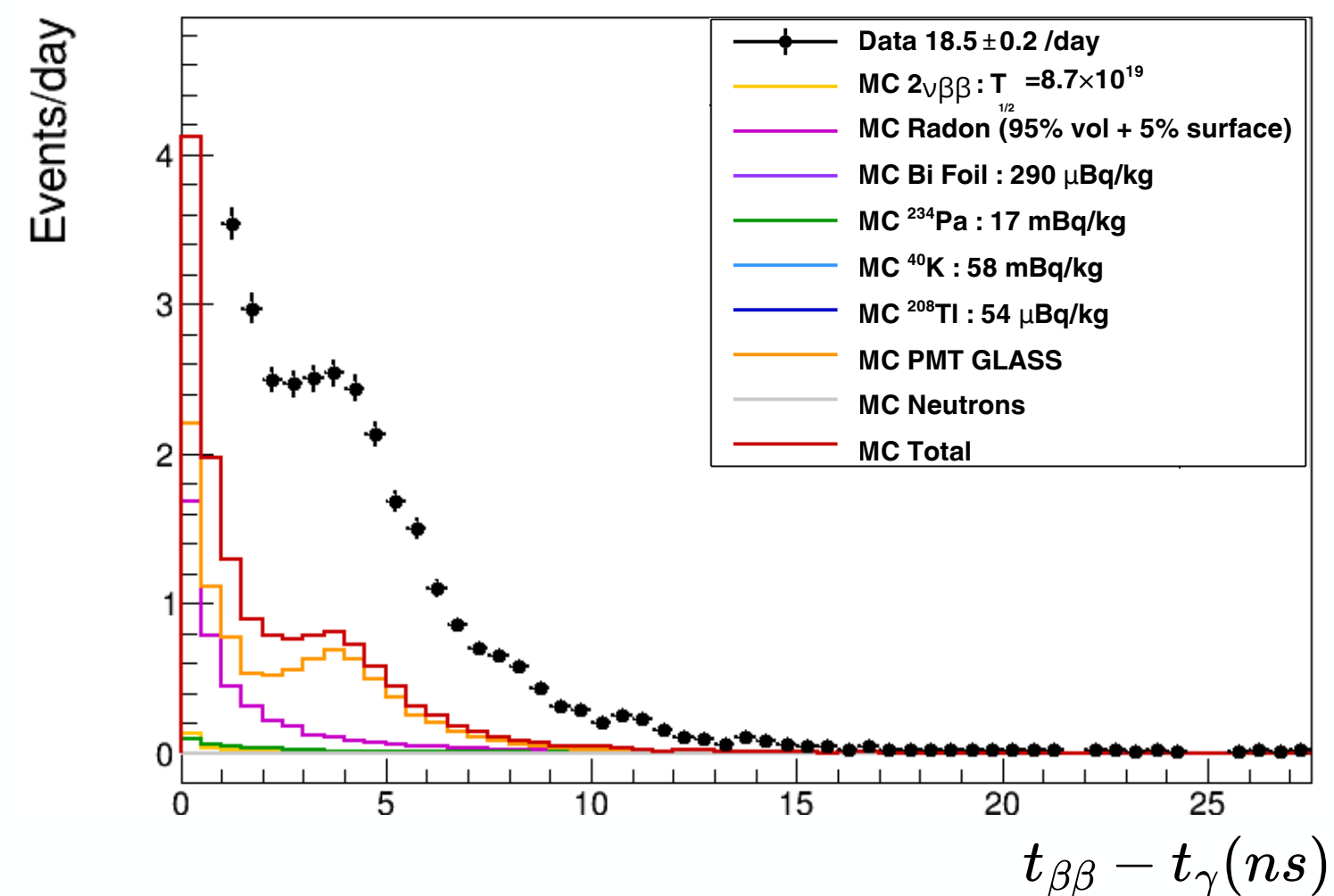
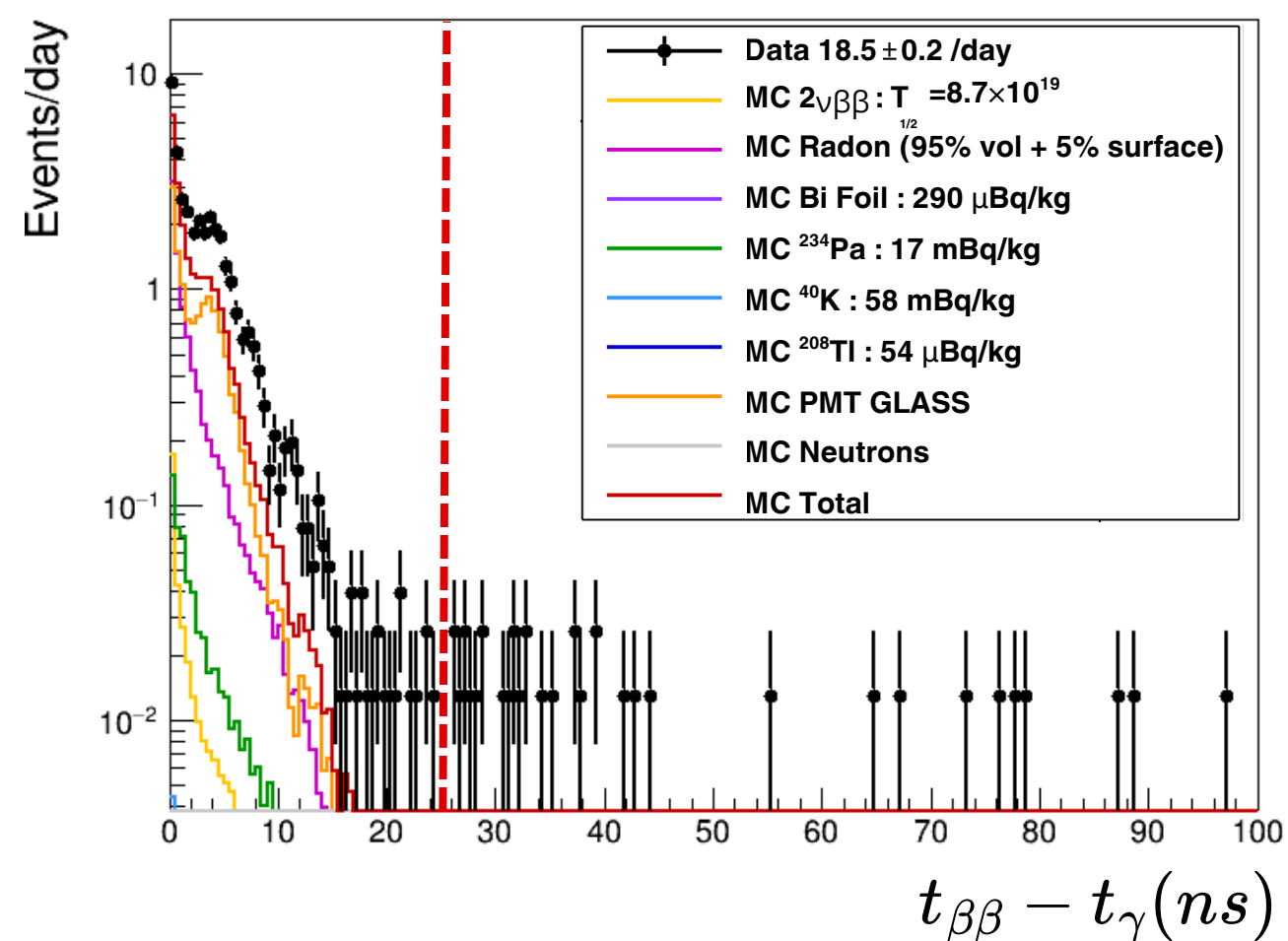
Possible improvement \rightarrow compute S/B to find the optimal cut

Electron and gamma cut

$2\beta 1\gamma$ channel

$$t_{\beta\beta} - t_{\gamma} > 25 \text{ ns}$$

ZOOM

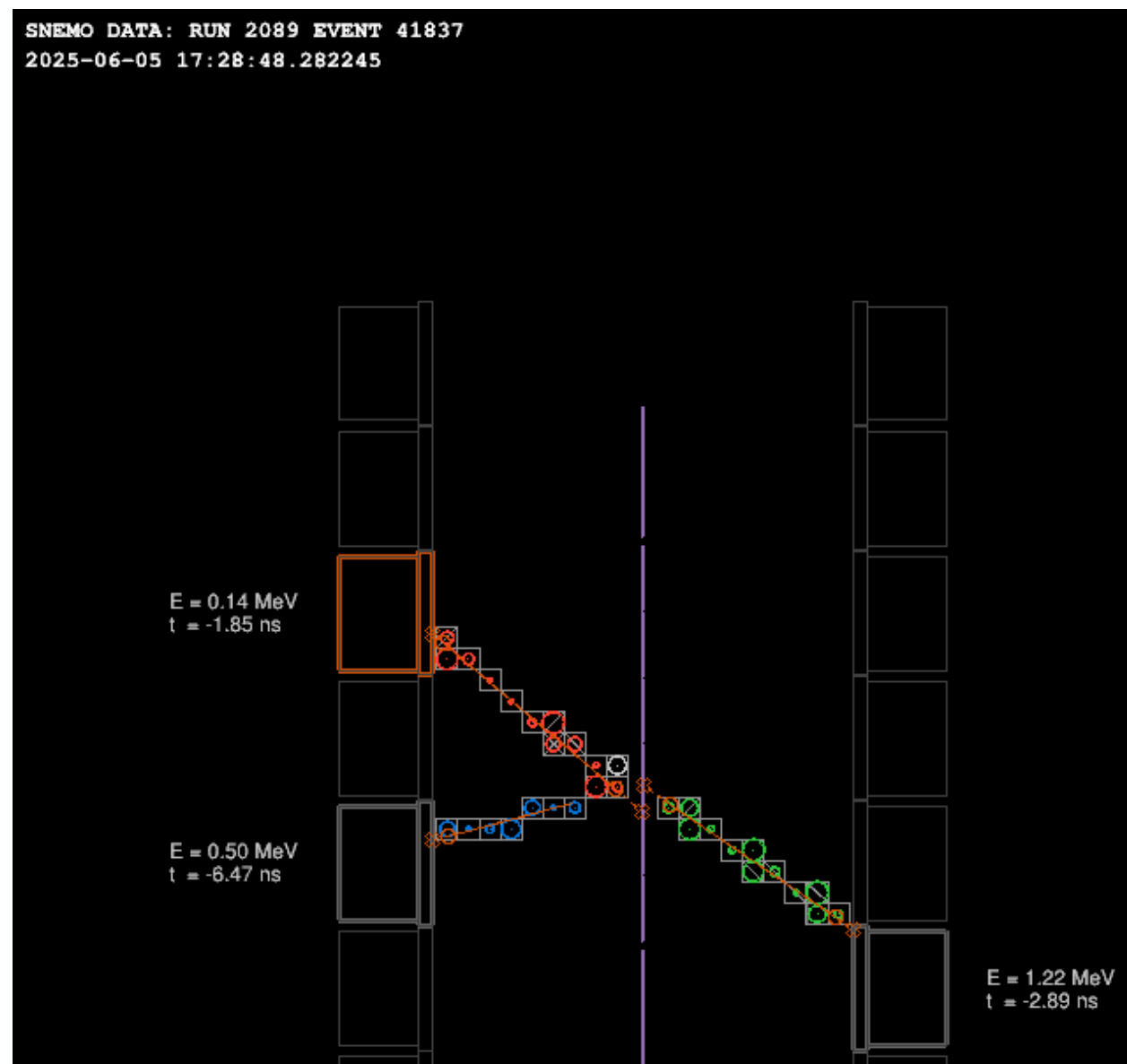


- Somme gamma isotops missing?
- More gammas in data?
- Needs some investigation

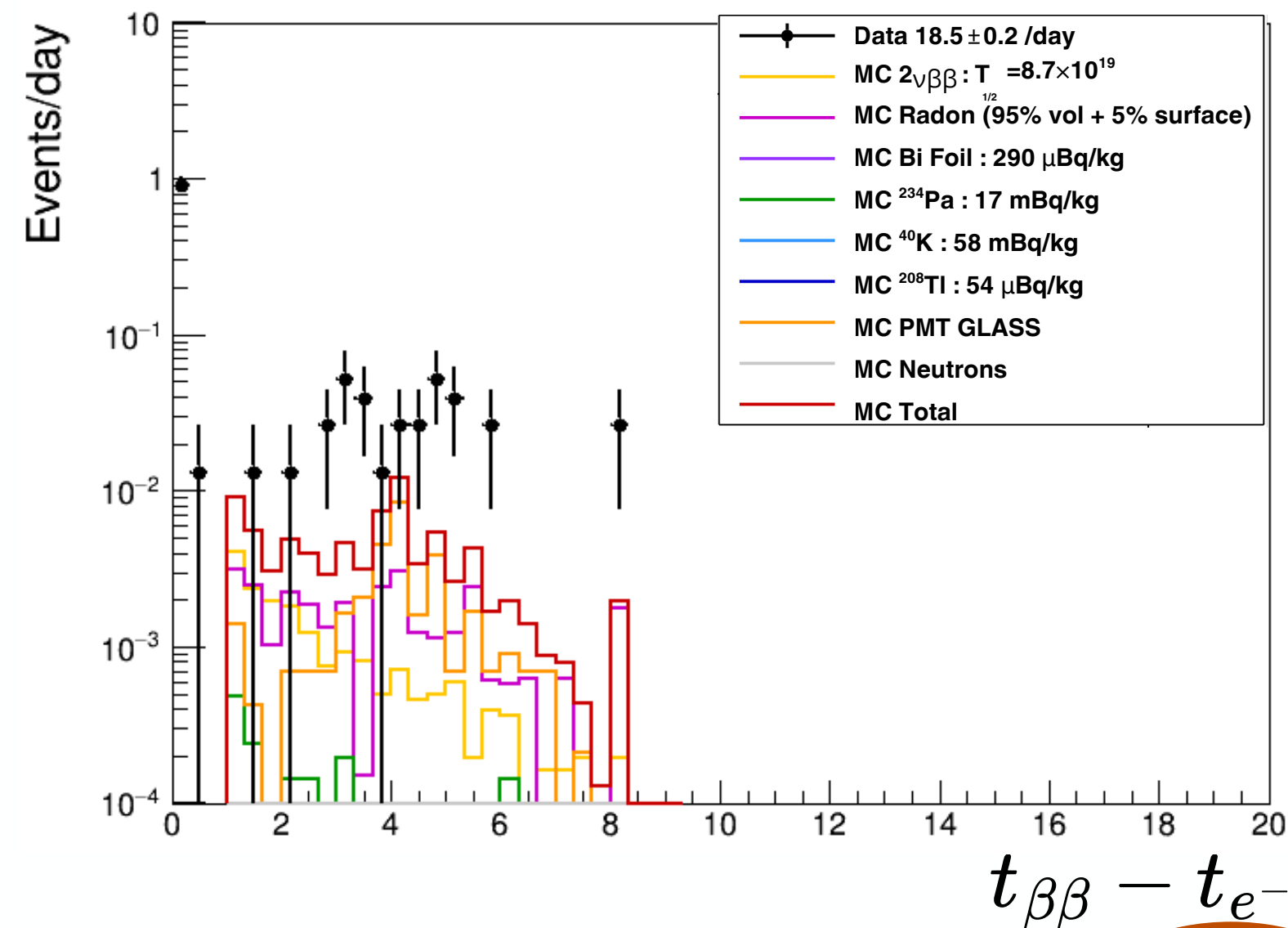
Electron and gamma cut

3β channel

$$t_{\beta\beta} - t_{e^-} > 25 \text{ ns}$$



We could keep energy sum of three electrons but S/B is quite low

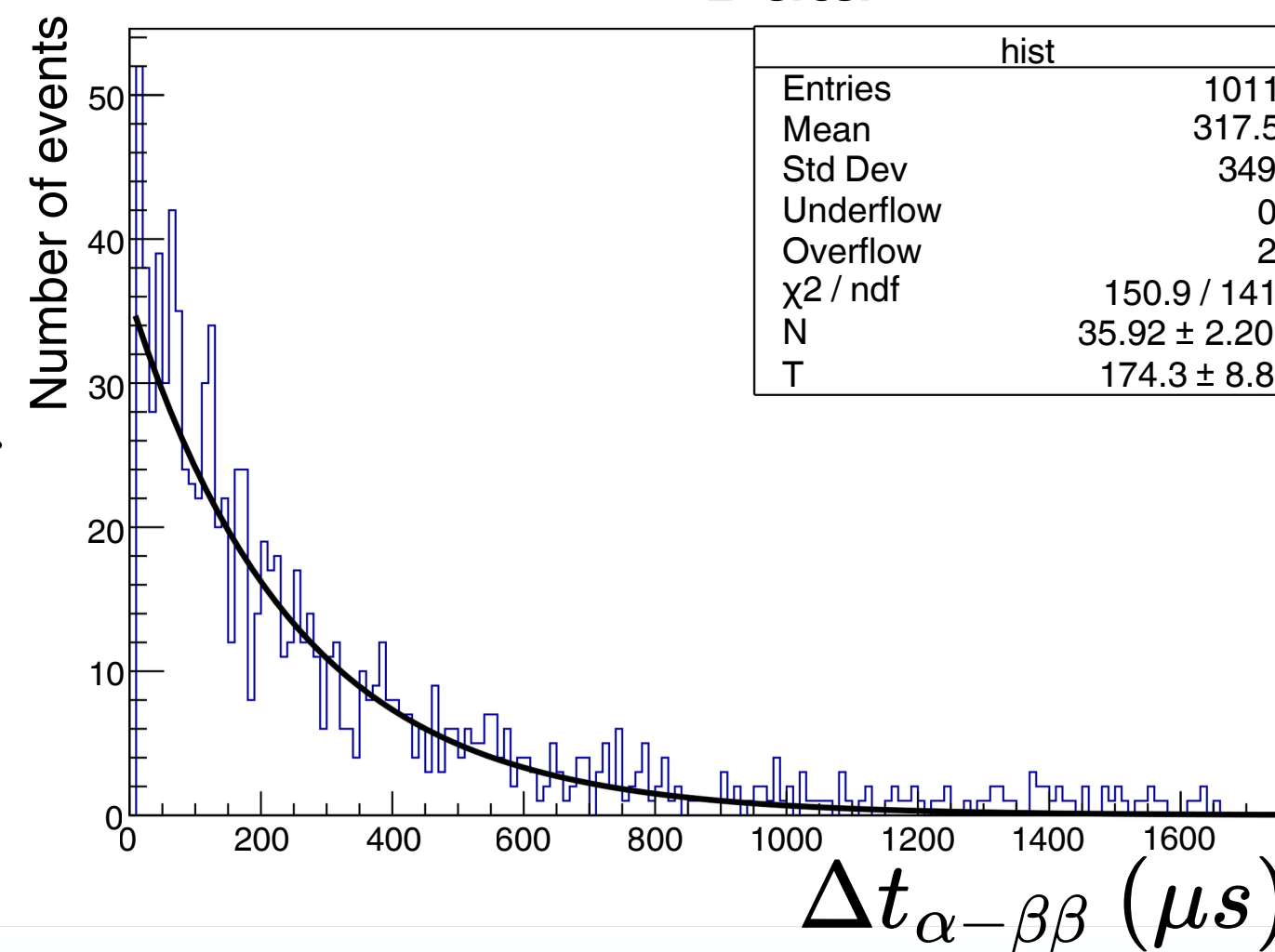
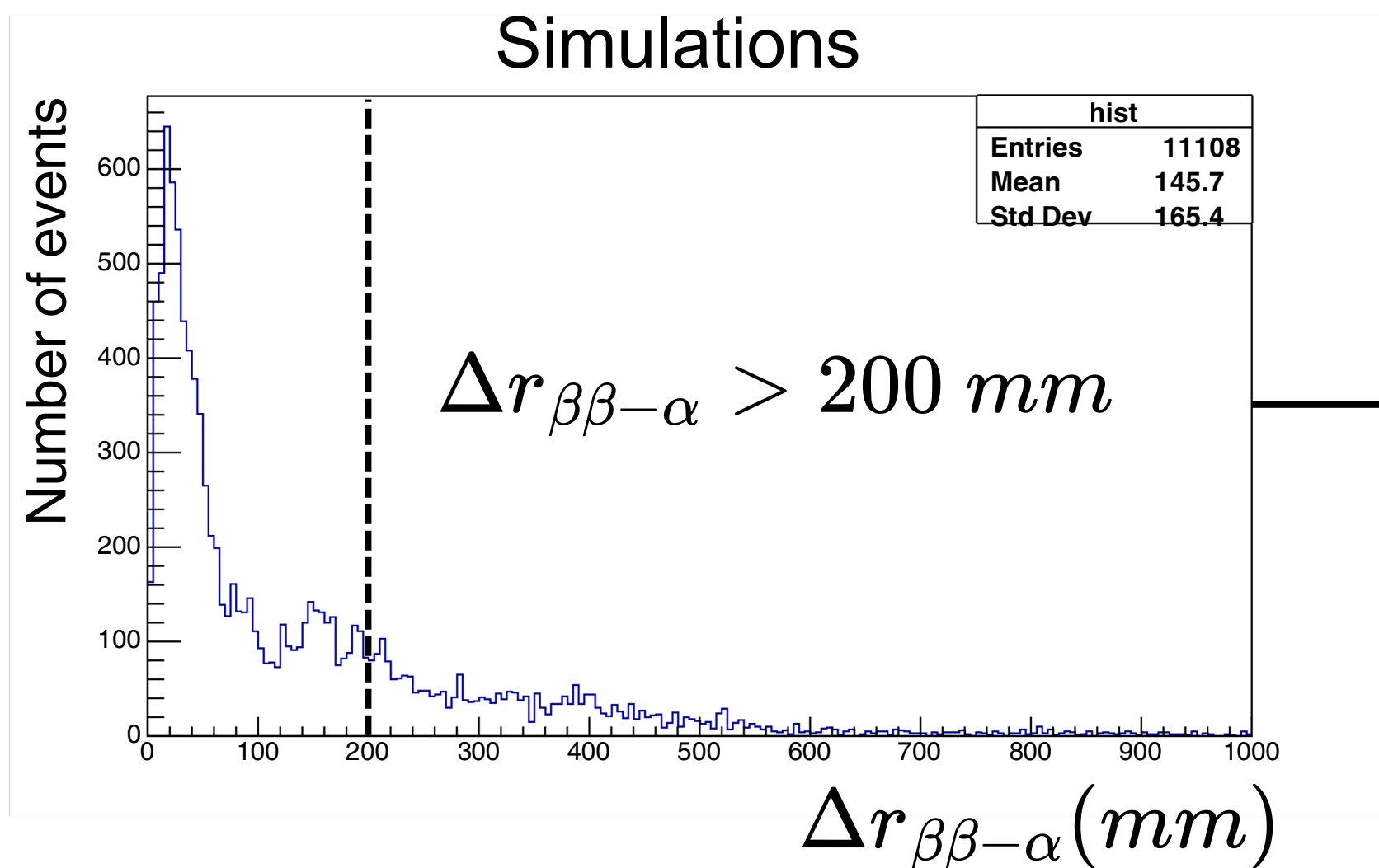


Alpha cut

$2\beta 1\alpha$ channel

$$\Delta t_{\alpha-\beta\beta} > 10 \mu s \text{ and } \Delta r_{\beta\beta-\alpha} > 200 \text{ mm}$$

Data

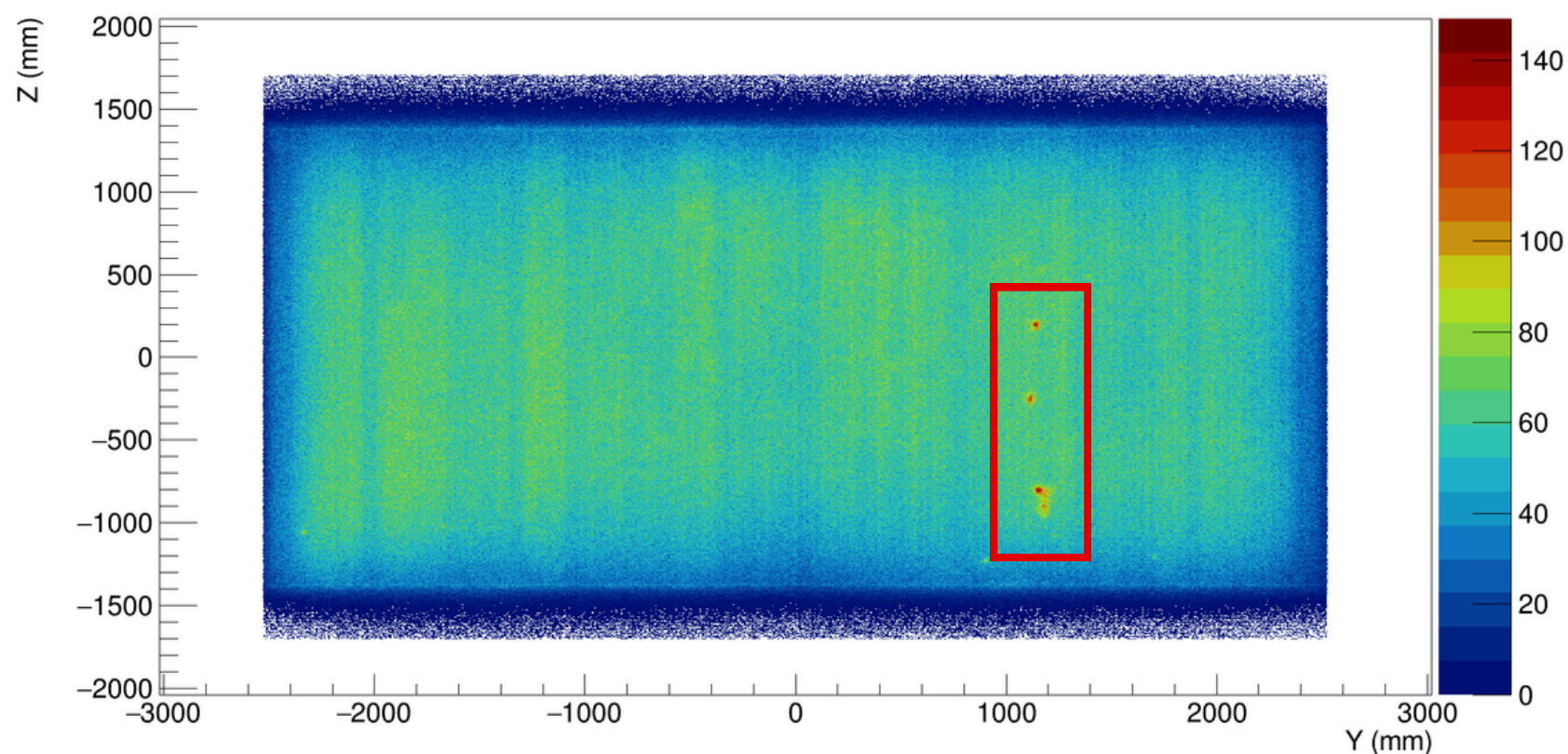


$T_{1/2} = 174.3 \pm 8.8 \mu s$ in agreement with theoretical value $163.4 \mu s$

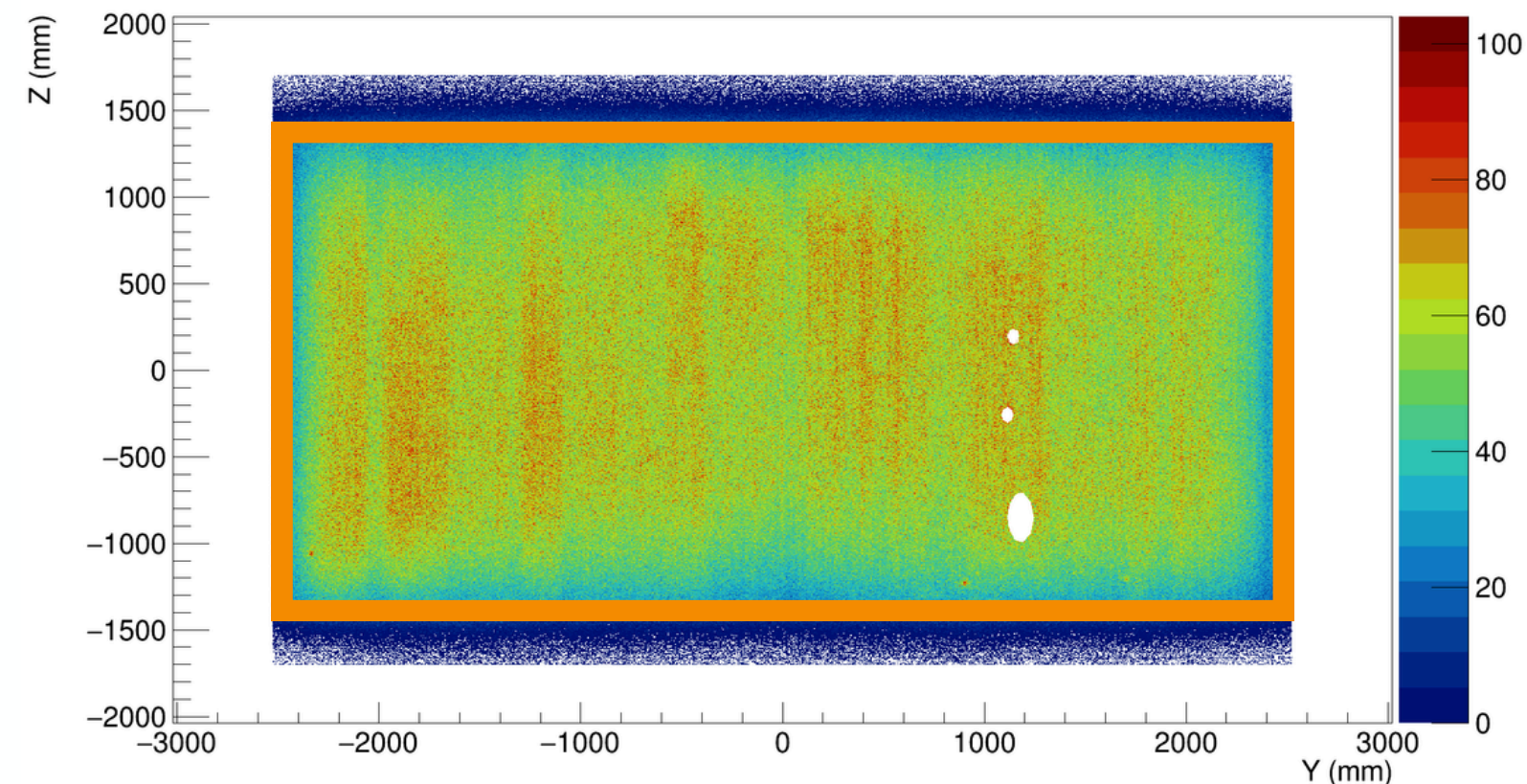
Hot spot cut

1 electron selection

Before hot spots removed



After hot spots removed



$$\left(\frac{y - 1180}{60}\right)^2 + \left(\frac{z + 850}{140}\right)^2 \leq 1 \vee \left(\frac{y - 1144}{25}\right)^2 + \left(\frac{z - 196}{40}\right)^2 \leq 1 \vee \left(\frac{y - 1114}{25}\right)^2 + \left(\frac{z + 257}{40}\right)^2 \leq 1 \vee |y| > 2360 \vee |z| > 1340.$$

Ellipse spot removing

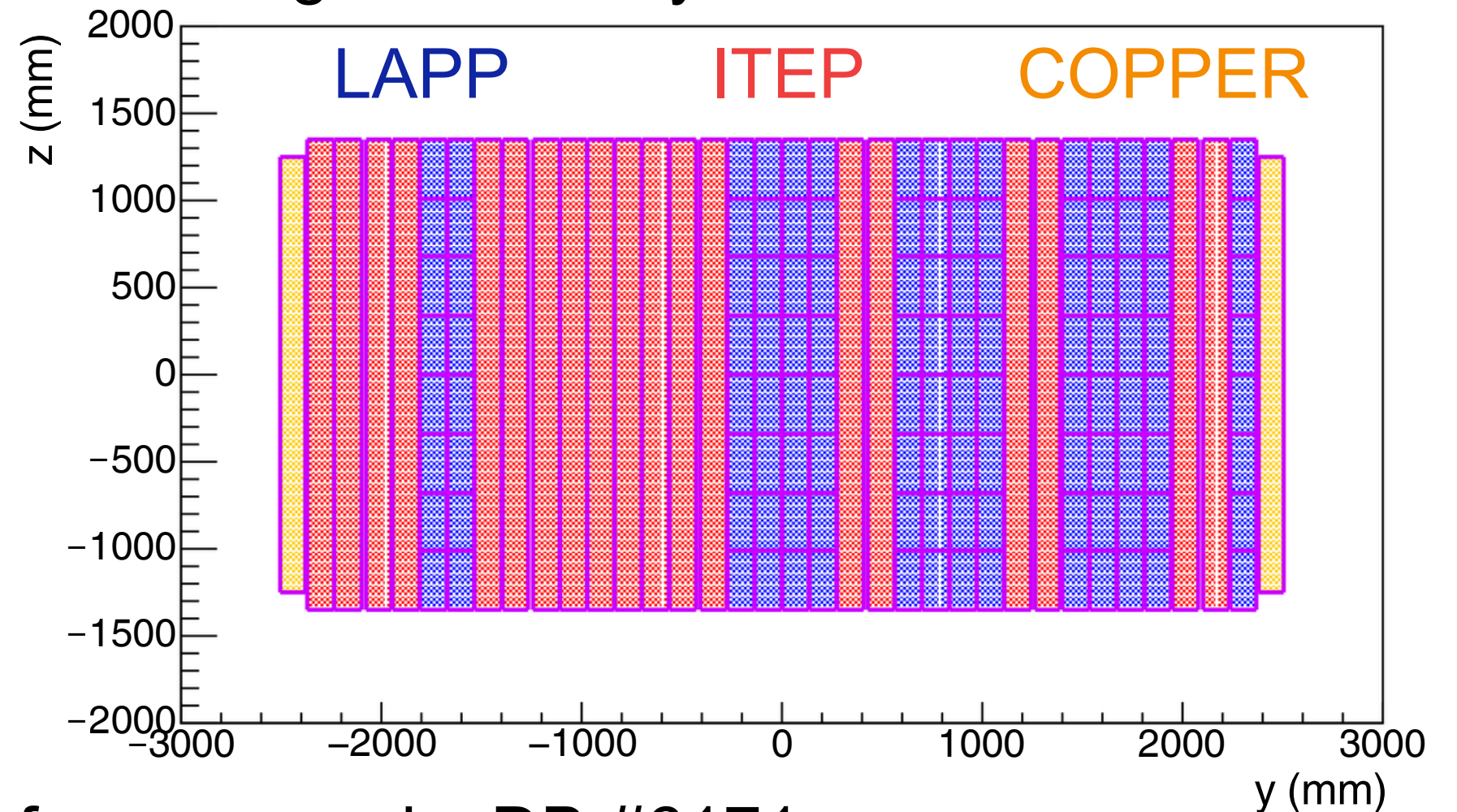
Mylar events rejection

LAPP foils cut

Because of MC problems (see Antoine's talk) → bulk itep foils has problems

We choose only **lapp foil** with geometrical y cut:

$$\begin{aligned}
 y_{\text{mid}} \in & [-1807.0, -1537.5] \text{ mm} \\
 \cup & [-271.5, 271.5] \text{ mm} \\
 \cup & [564.5, 1108.0] \text{ mm} \\
 \cup & [1400.5, 1941.5] \text{ mm} \\
 \cup & [2239.0, 2368.0] \text{ mm}
 \end{aligned}$$

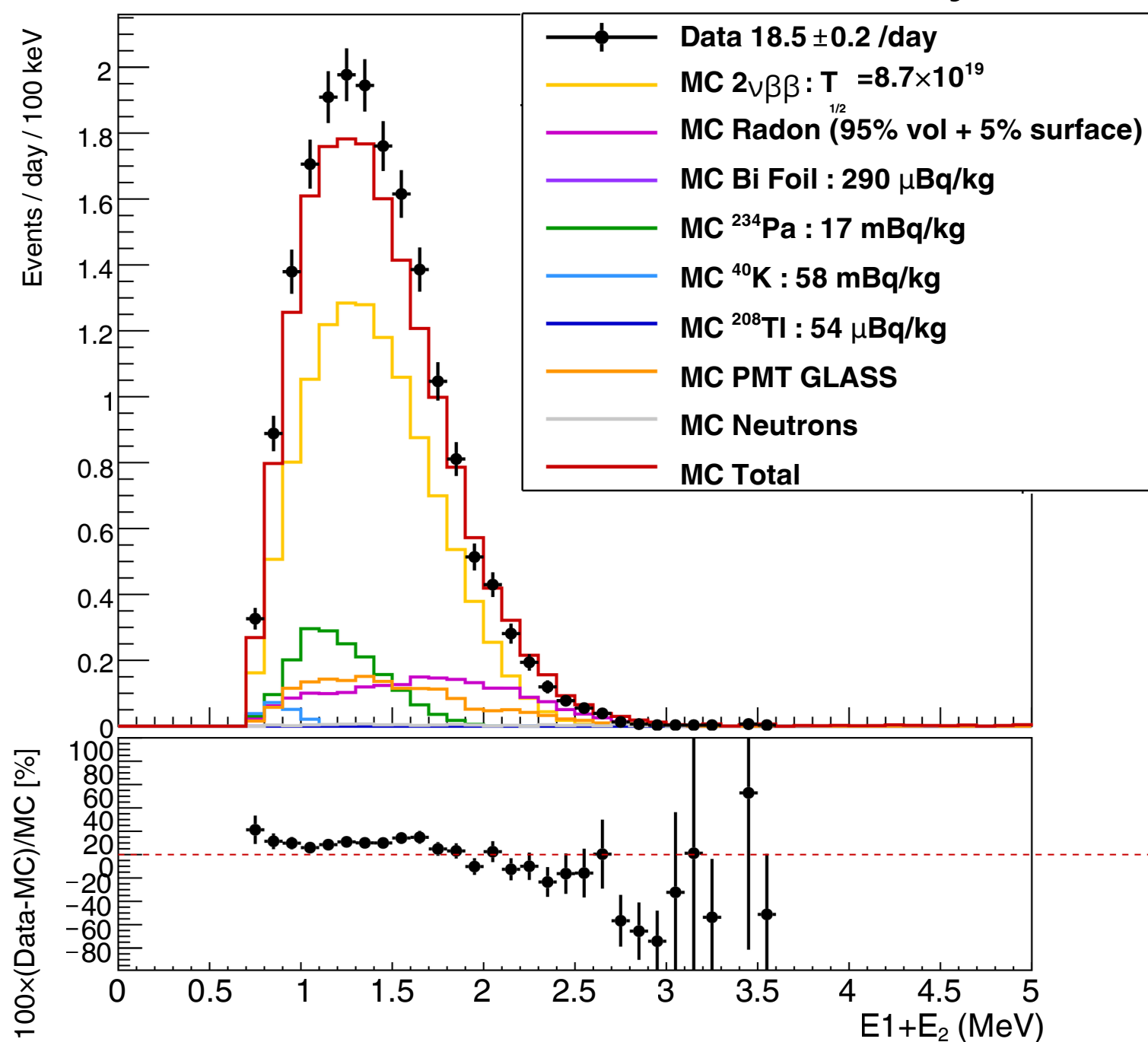


+ same criterias on OMs as before → see docDB #6171

+ cut on electron energy > 350 keV → avoid low energy spectra

Double beta energy spectra

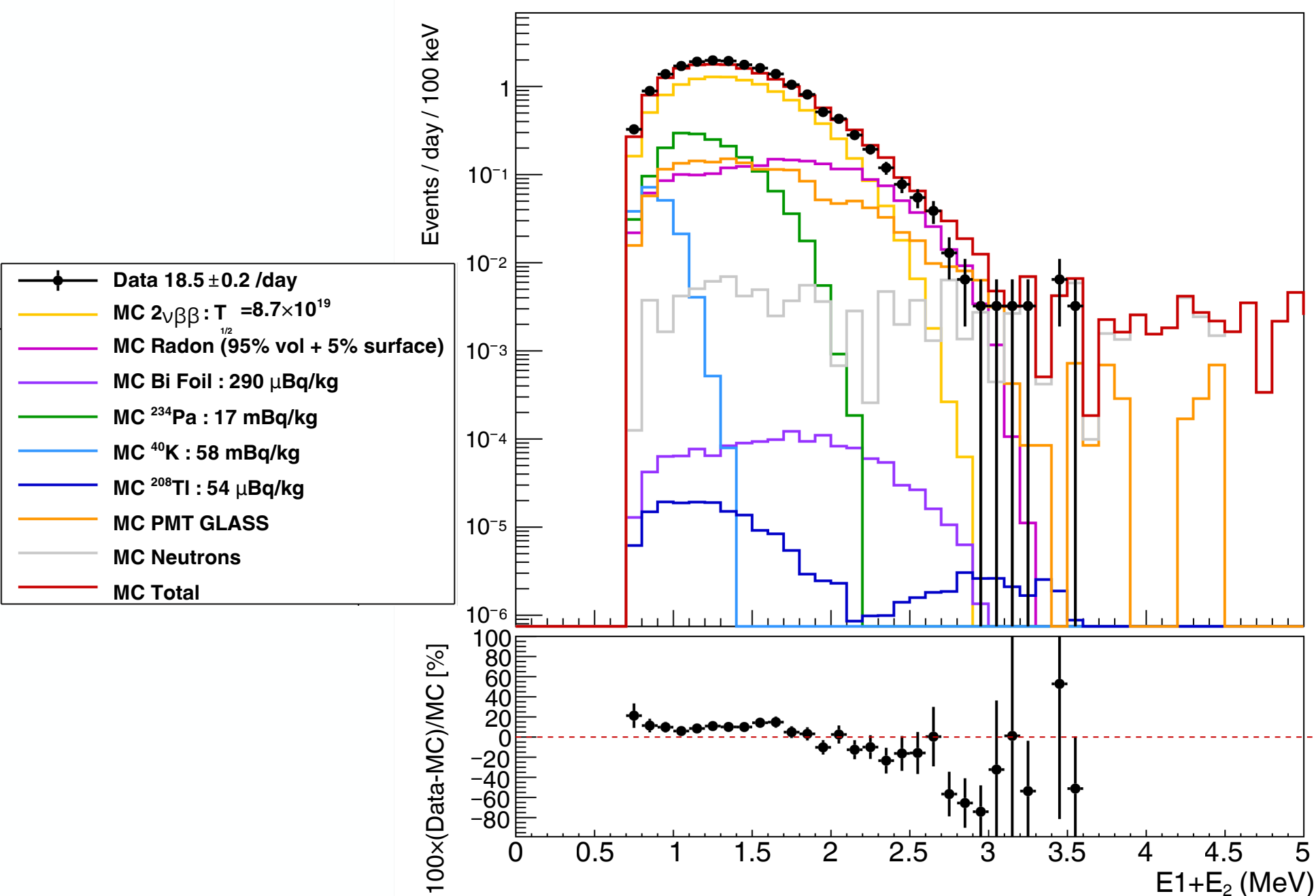
betabeta energy spectra for Phases
0+1+2+3+4 - LAPP foils only



- One calibration per week $E=aQ+b$
- **DATA** > **MC** for E in $[0,2]$ MeV
- **DATA** < **MC** for E in $[2.5,3.5]$ MeV

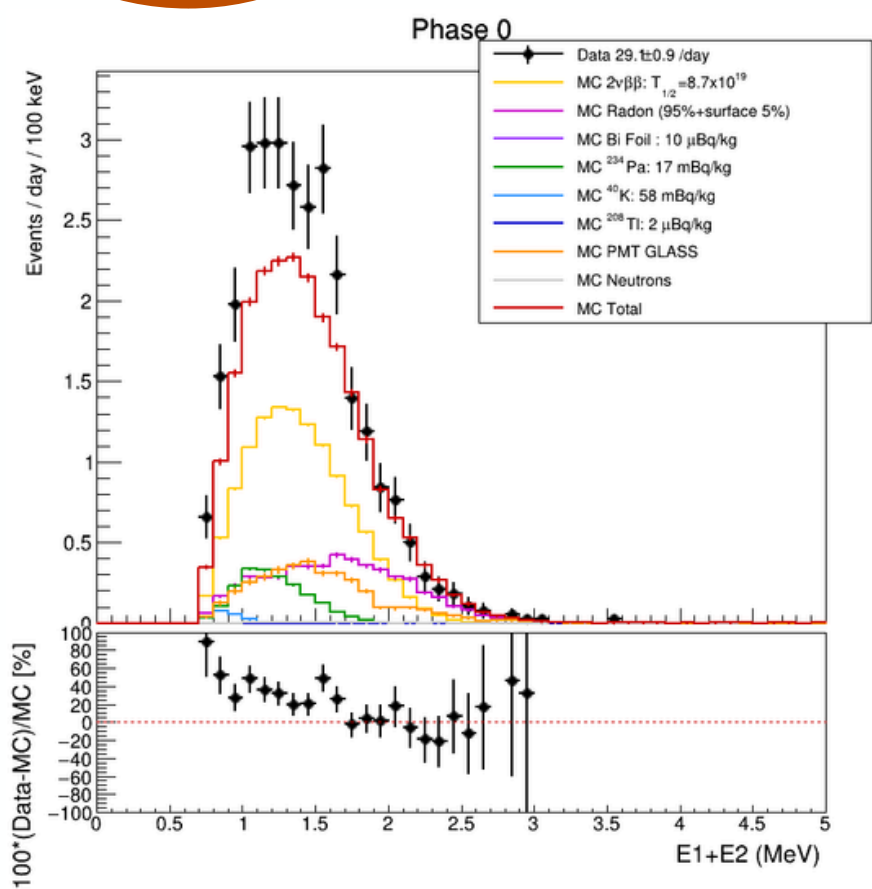
Double beta energy spectra

betabeta energy spectra for Phases
0+1+2+3+4 - LAPP foils only



- One calibration per week $E=aQ+b$
- **DATA** > **MC** for E in $[0,2]$ MeV
- **DATA** < **MC** for E in $[2.5,3.5]$ MeV
- **PMT** events are going to ~ 4.5 MeV!
- Lack of statistics for ^{208}Tl in PMT glass high energy

Double beta energy spectra per phase

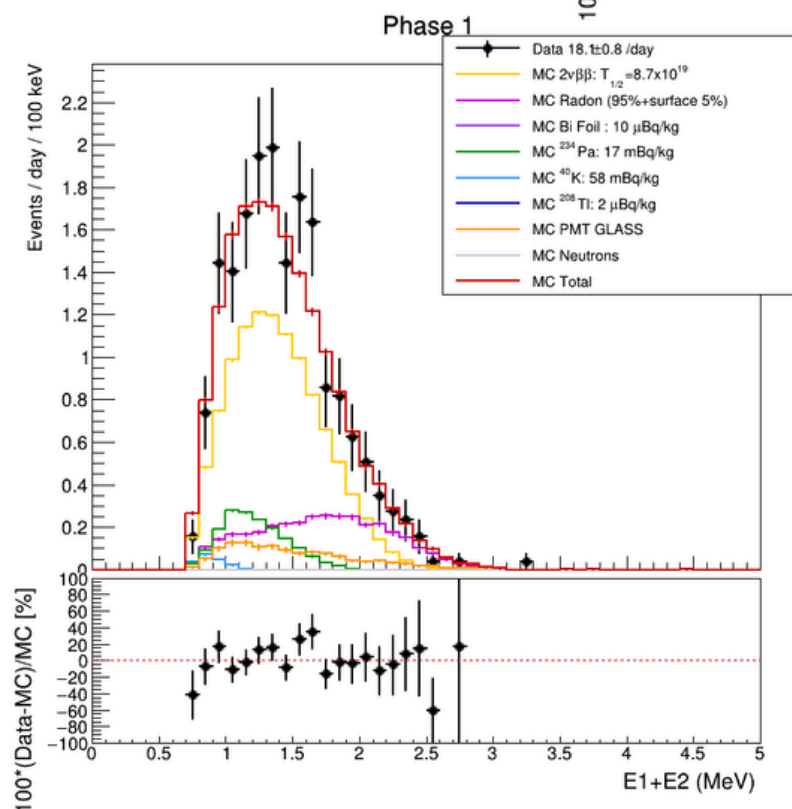


S/B = 2.19

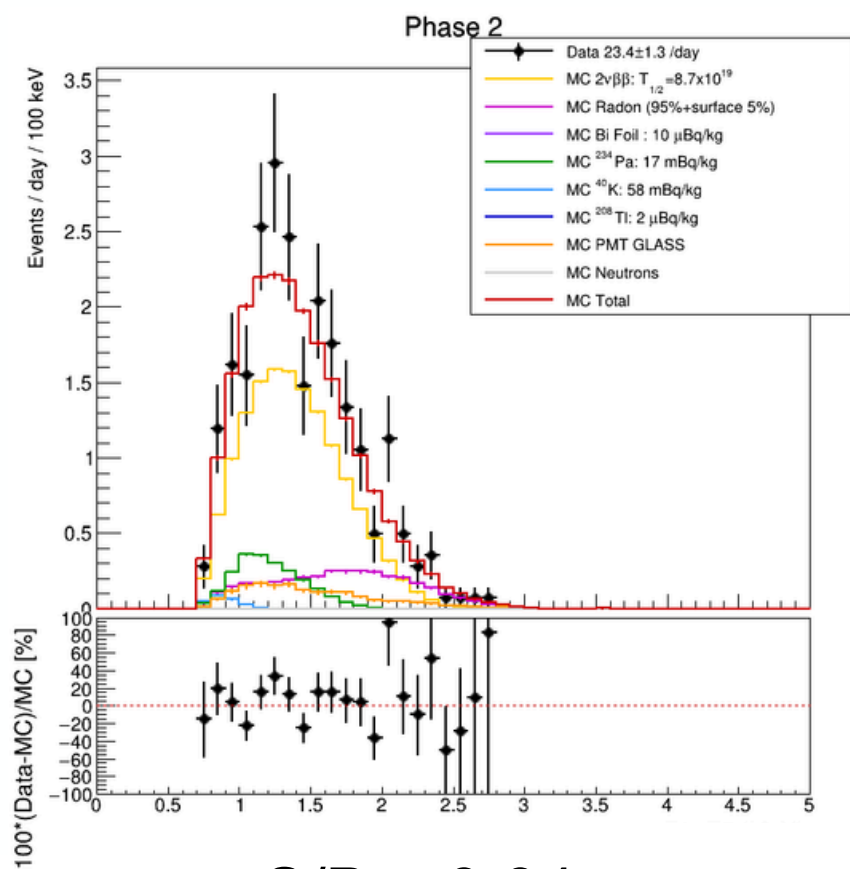
low S/B because of HT

$$\frac{S}{B} = \frac{2\nu\beta\beta}{\text{all}_{\text{simu}}}$$

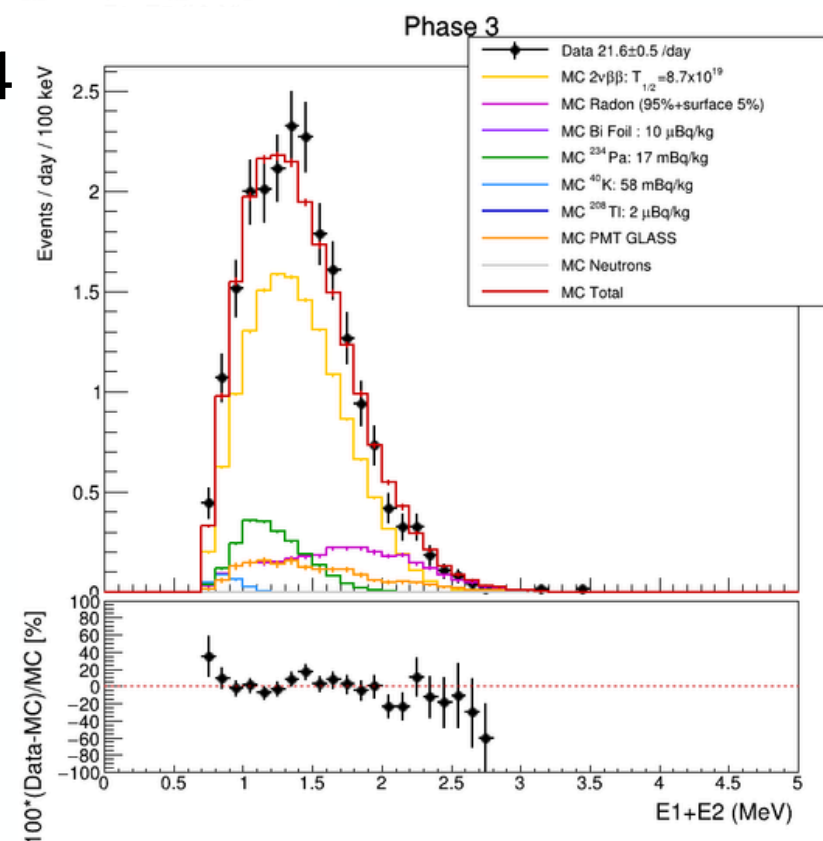
S/B = 3.30



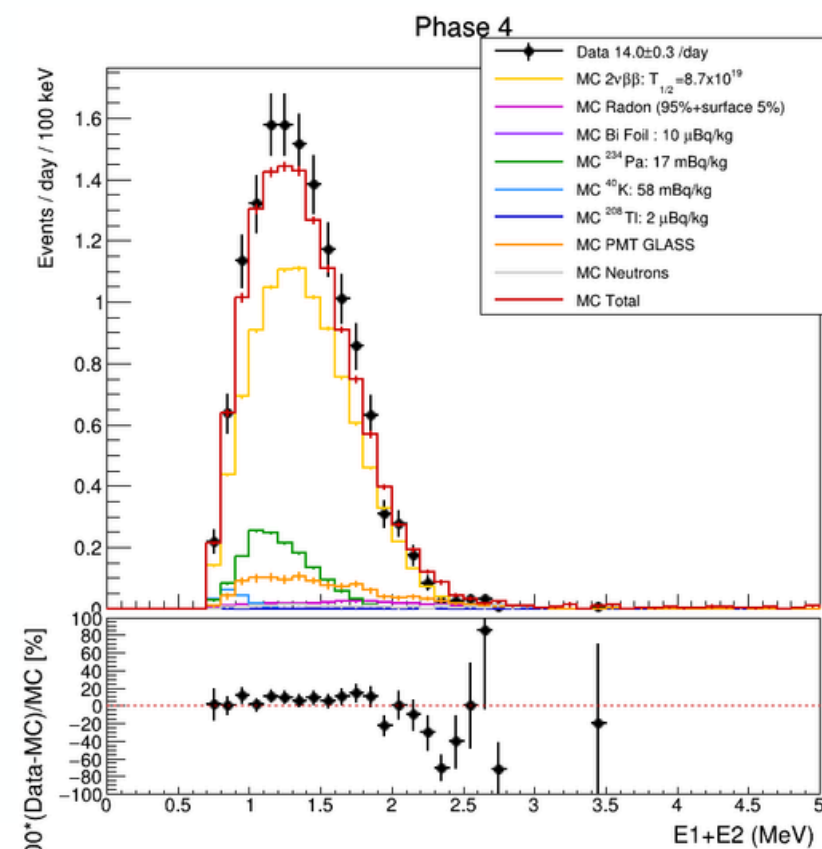
S/B = 3.84



S/B = 4.12



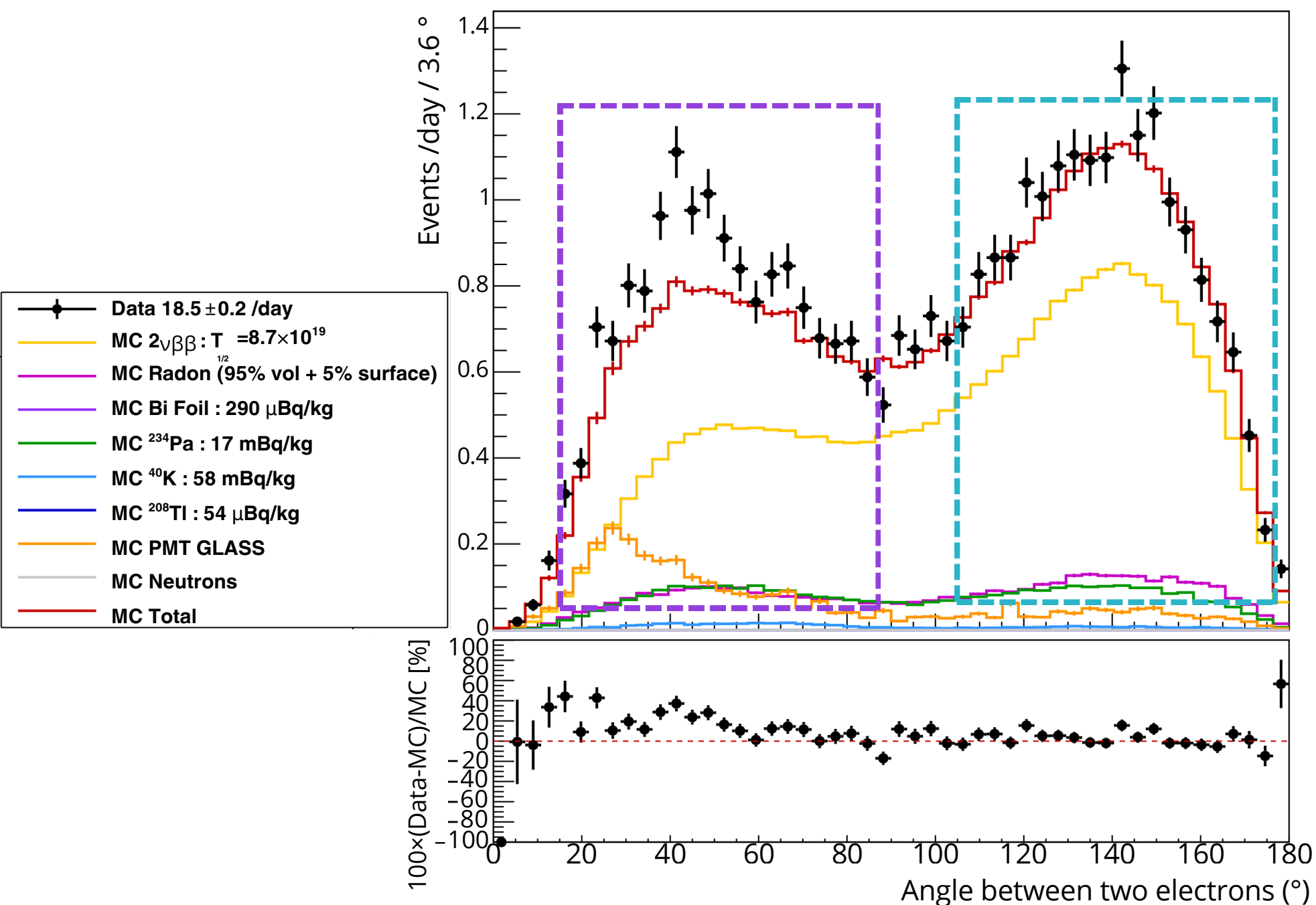
high S/B because of low Radon



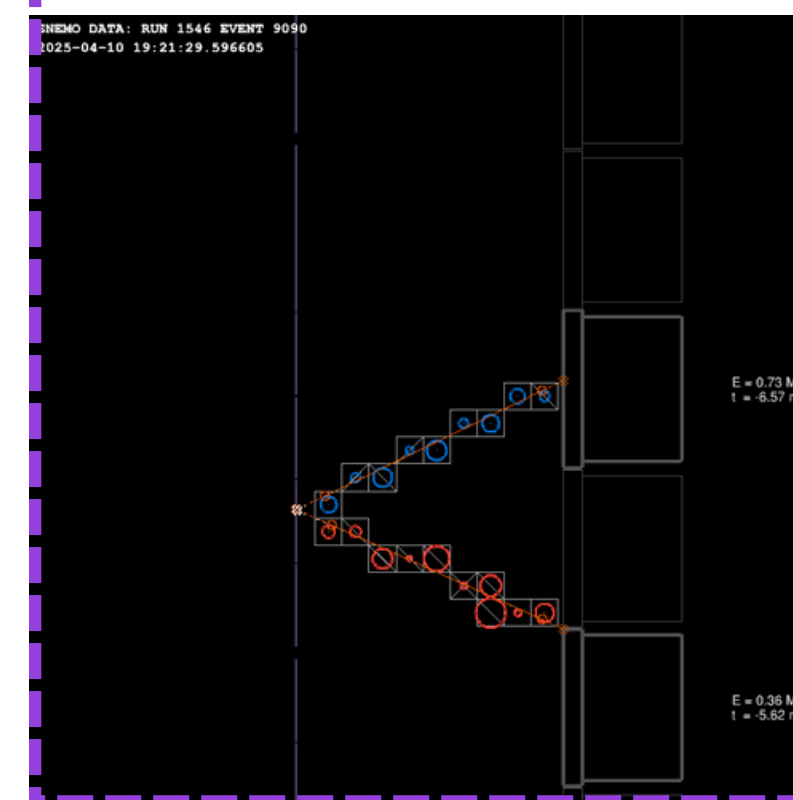
S/B = 5.61

Double beta angular spectra

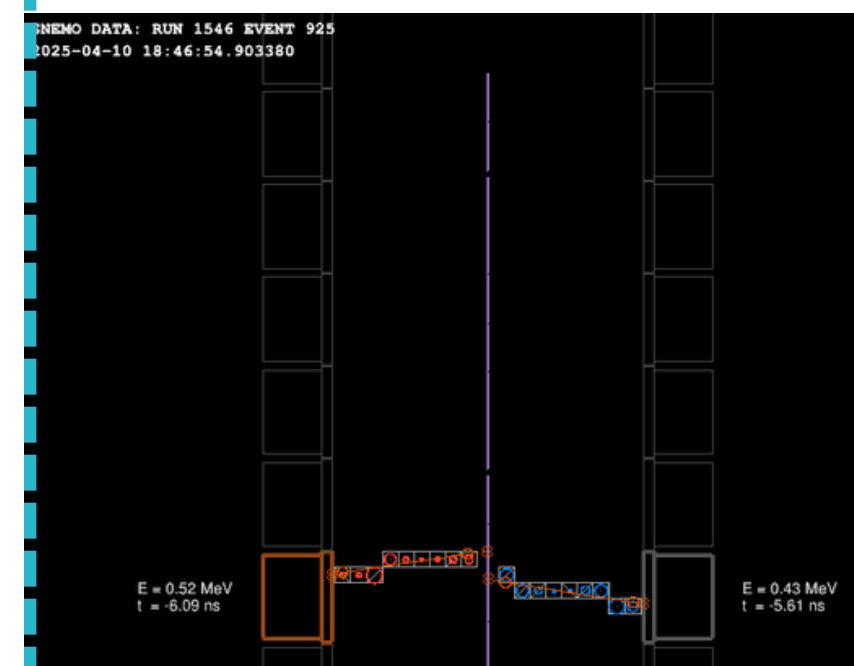
betabeta angular spectra for Phases
0+1+2+3+4 - LAPP foils only



Same side events

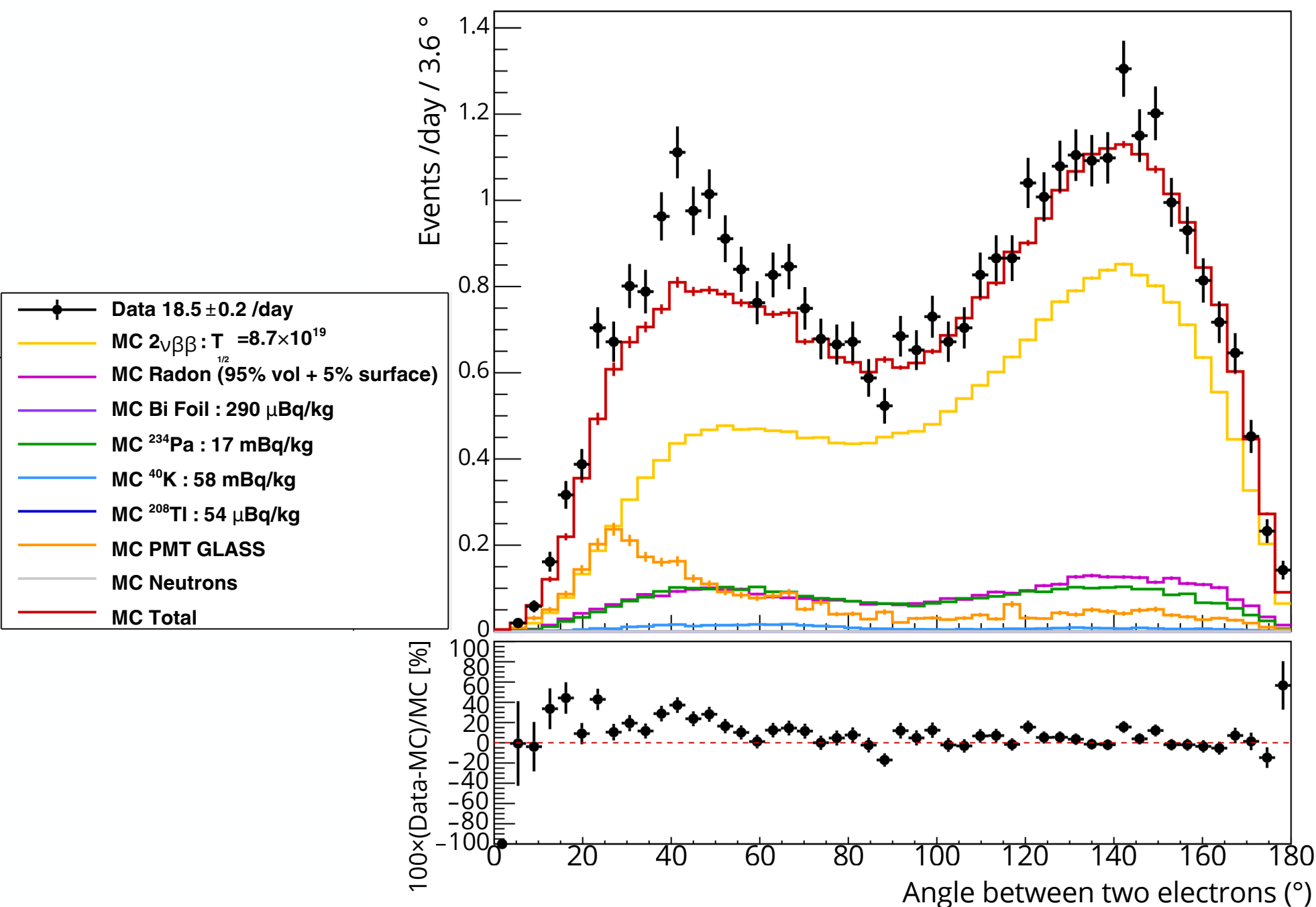


Opposite side events

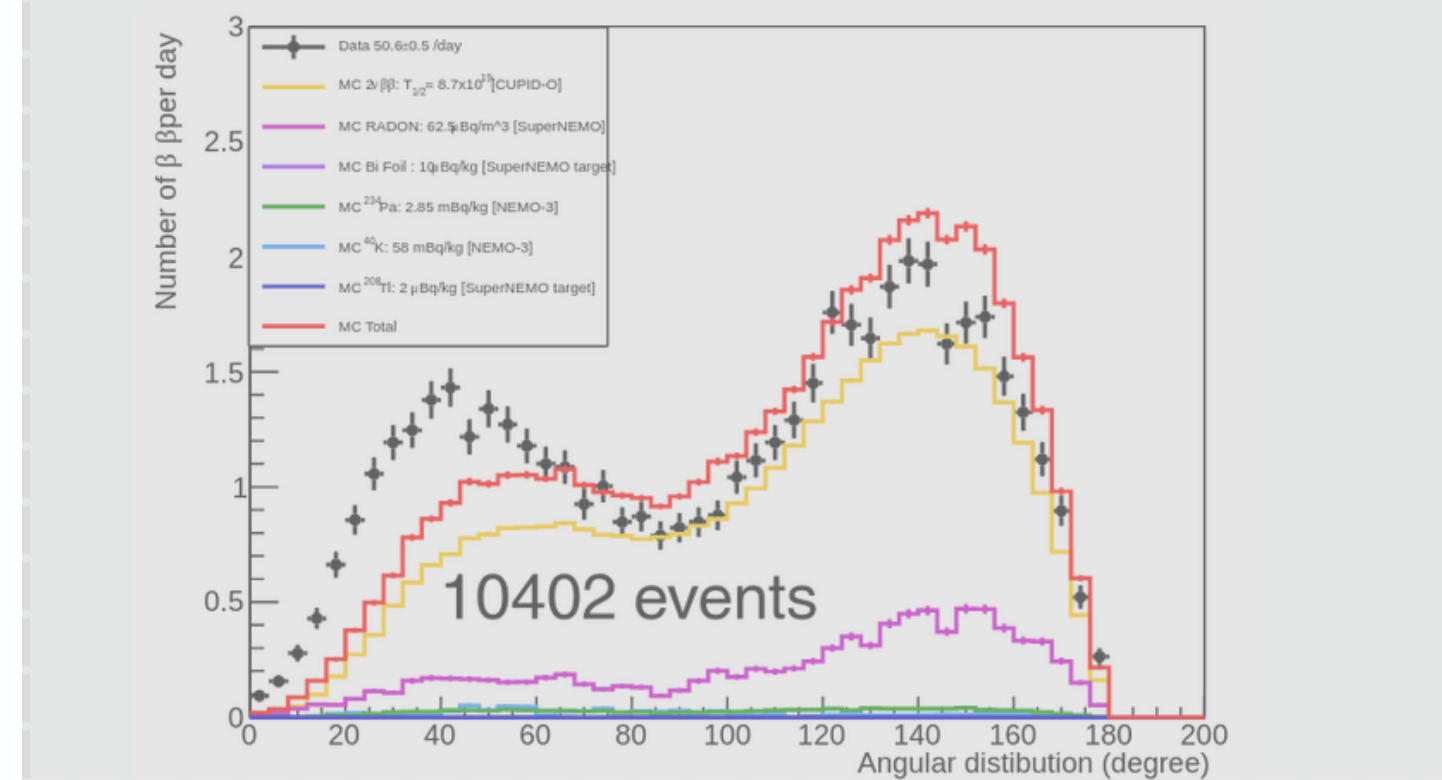


Double beta angular spectra

betabeta angular spectra for Phases
0+1+2+3+4 - LAPP foils only



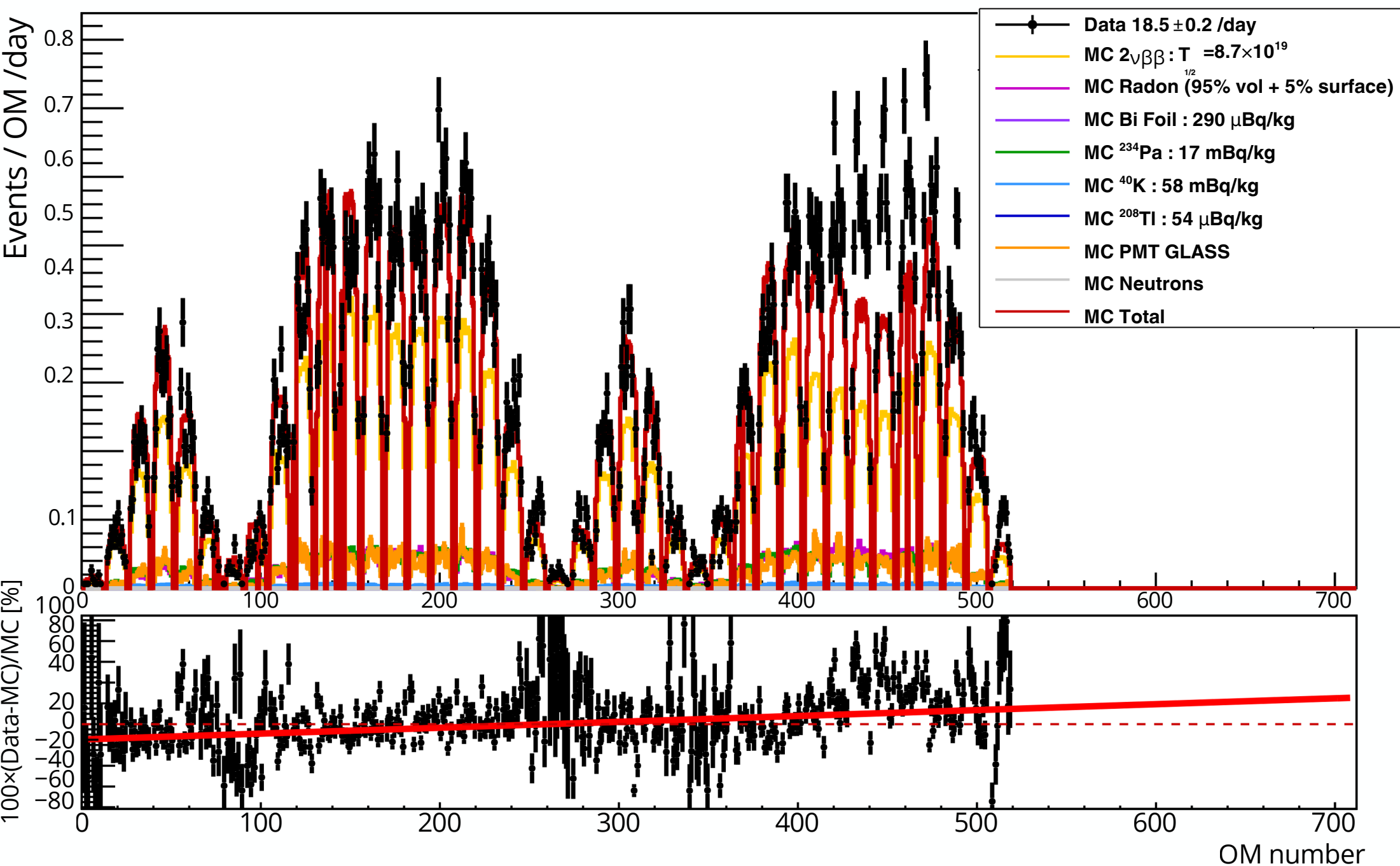
Reminder of angular spectra in Frimley



- One calibration per week $E=aQ+b$
- Good angular agreement
- **DATA** > **MC** for low angle \rightarrow missing ?
- Small discrepancy can be due to foil geometry

Double beta OM number spectra

betabeta angular spectra for Phases
0+1+2+3+4 - LAPP foils only



- Huge discrepancy of OM rate due to bad foils geometry cut?
 - Some OMs count more than others
- noisy PMT during periods should be removed?
- Small increase as a function of OM number?

Conclusion

- First double beta decay spectra including PMTs glass simulation
- Still small MC/data discrepancies on energy spectra
- MC/data small discrepancies observed in low angular distributions

Next steps:

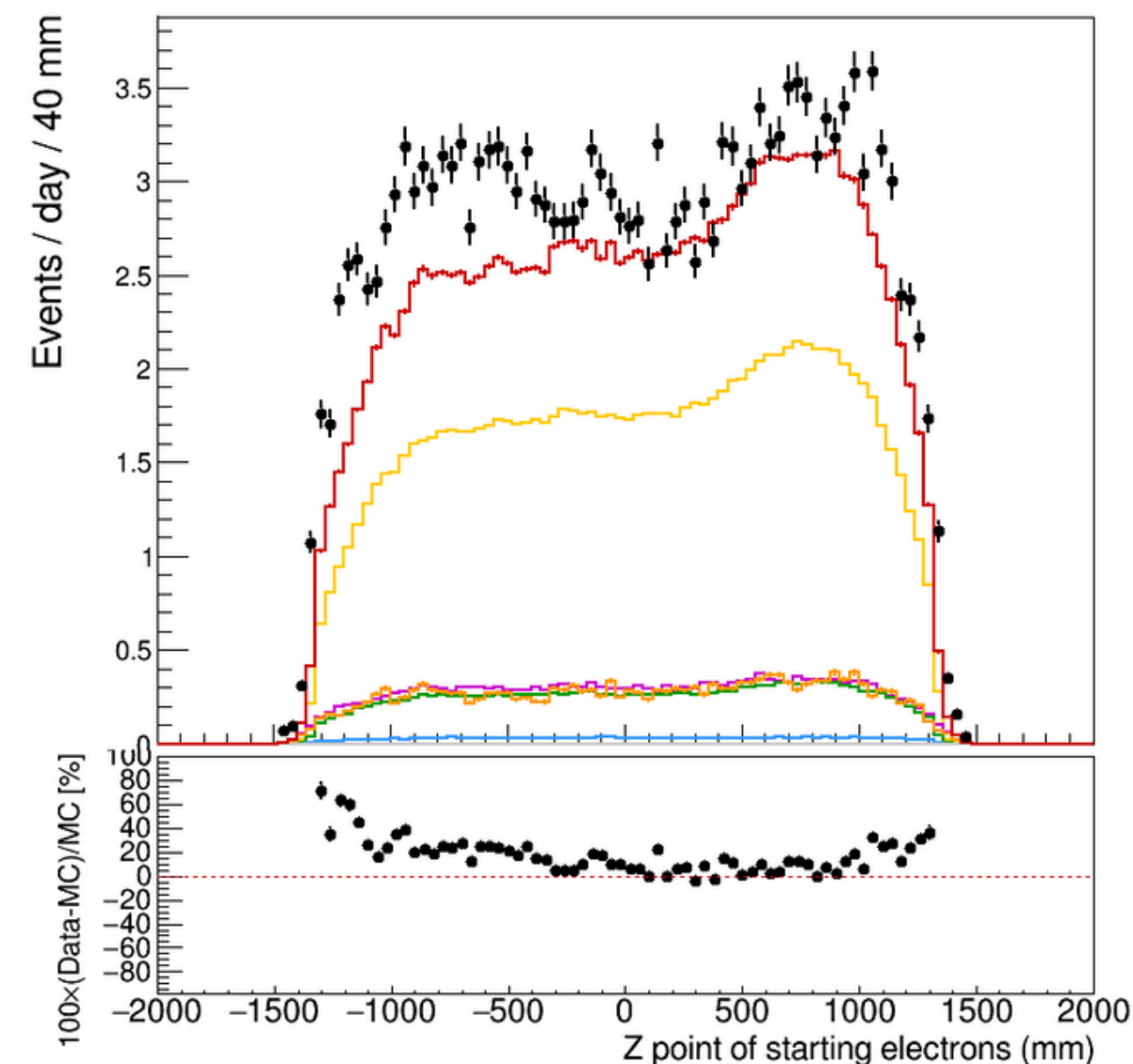
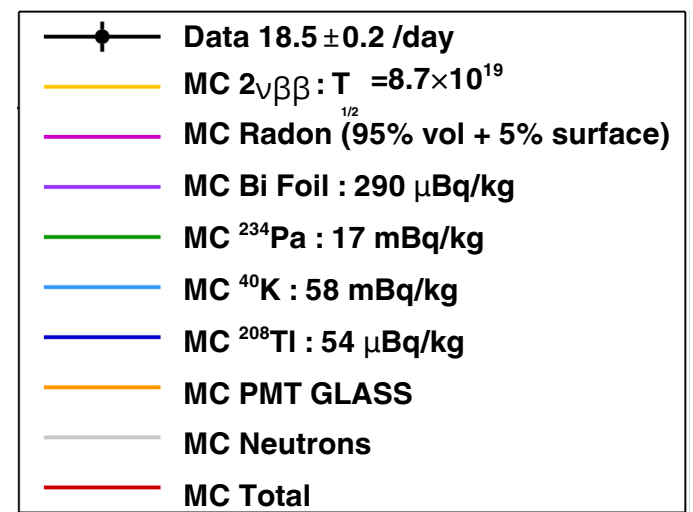
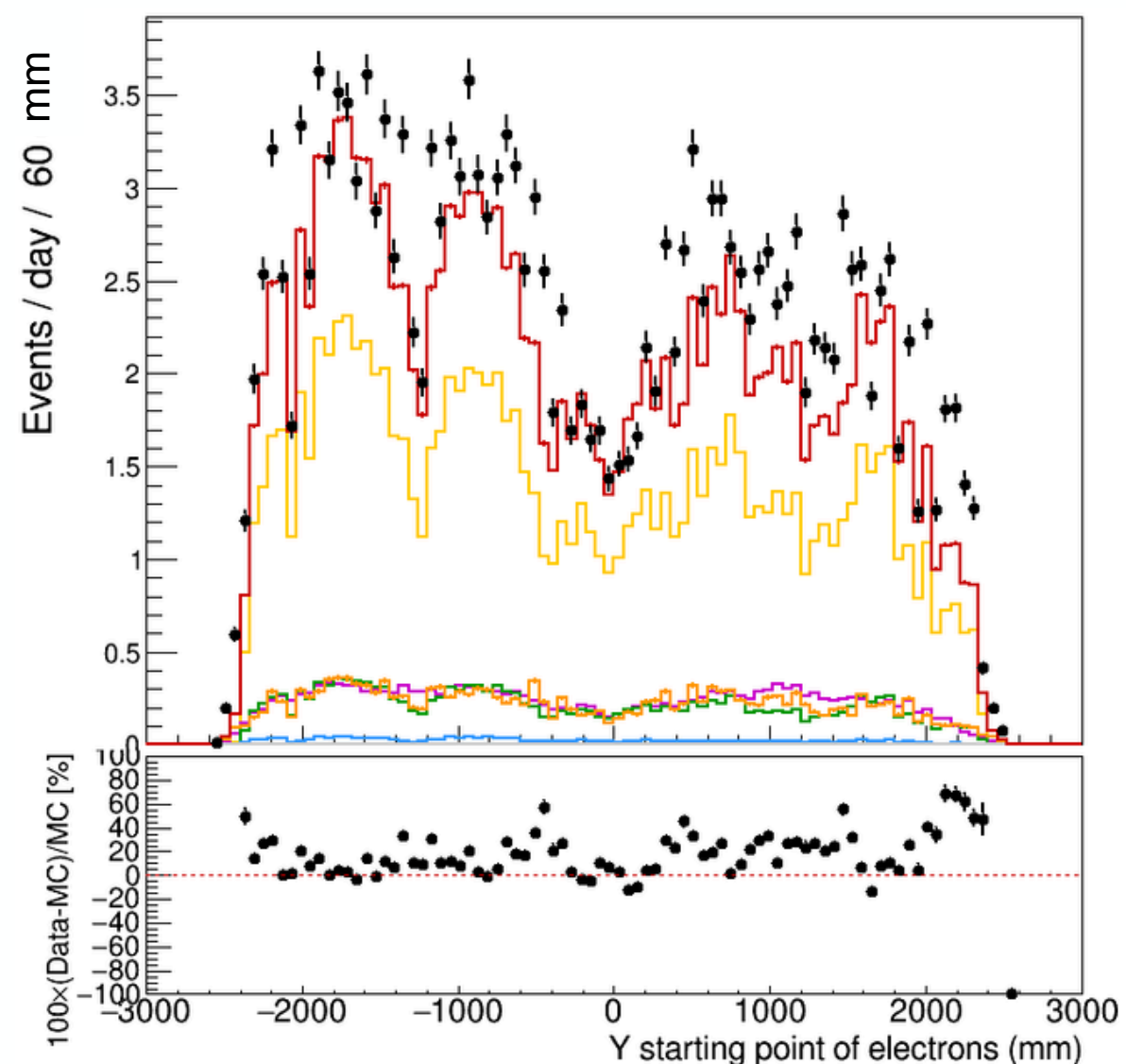
- Use new MC production with correct bulk for ITEP foils
- Use new reconstruction pipeline (simRC) including ON/OFF calibration
- Use curved Se foil measured by Antoine (waiting for official production)

Backup

Double beta OM number spectra

betabeta y vertices spectra for Phases 0+1+2+3+4 - LAPP foils only

betabeta z vertices spectra for Phases 0+1+2+3+4 - LAPP foils only



- Z discrepancy due to old reconstruction formulae
- Y discrepancy due to LAPP selection?

Total list of simulated isotopes

Try to fit Activity of ^{214}Bi and ^{208}Tl

