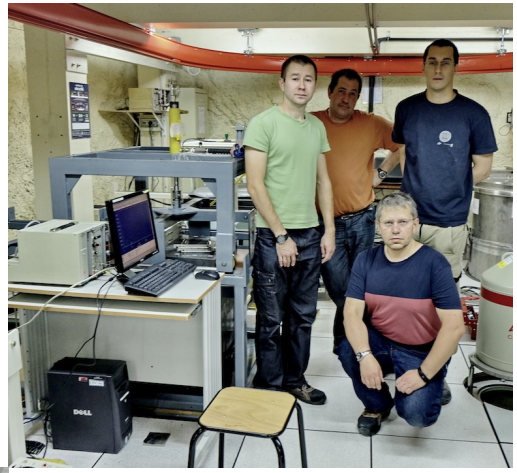
Geant4 model of HPGe detector Gentiane @LSM

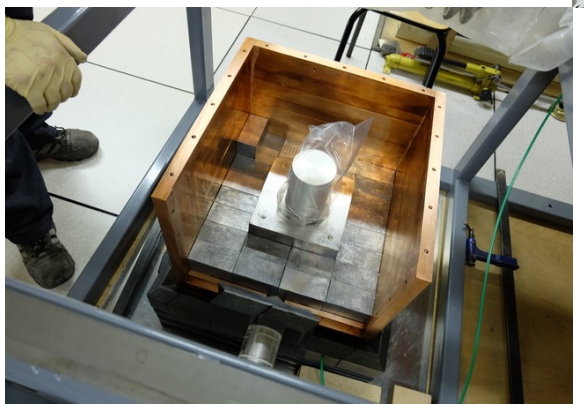
Maryvonne De Jésus

December 16th 2021

Gentiane detector @ LSM

(available for EDW–I since november 97)

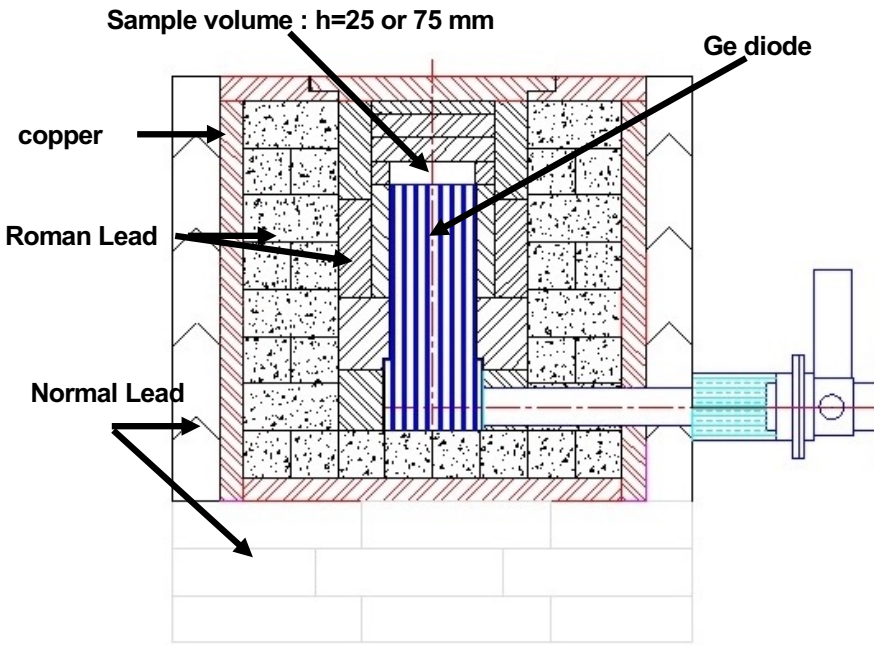




Moved to main room end october 2017

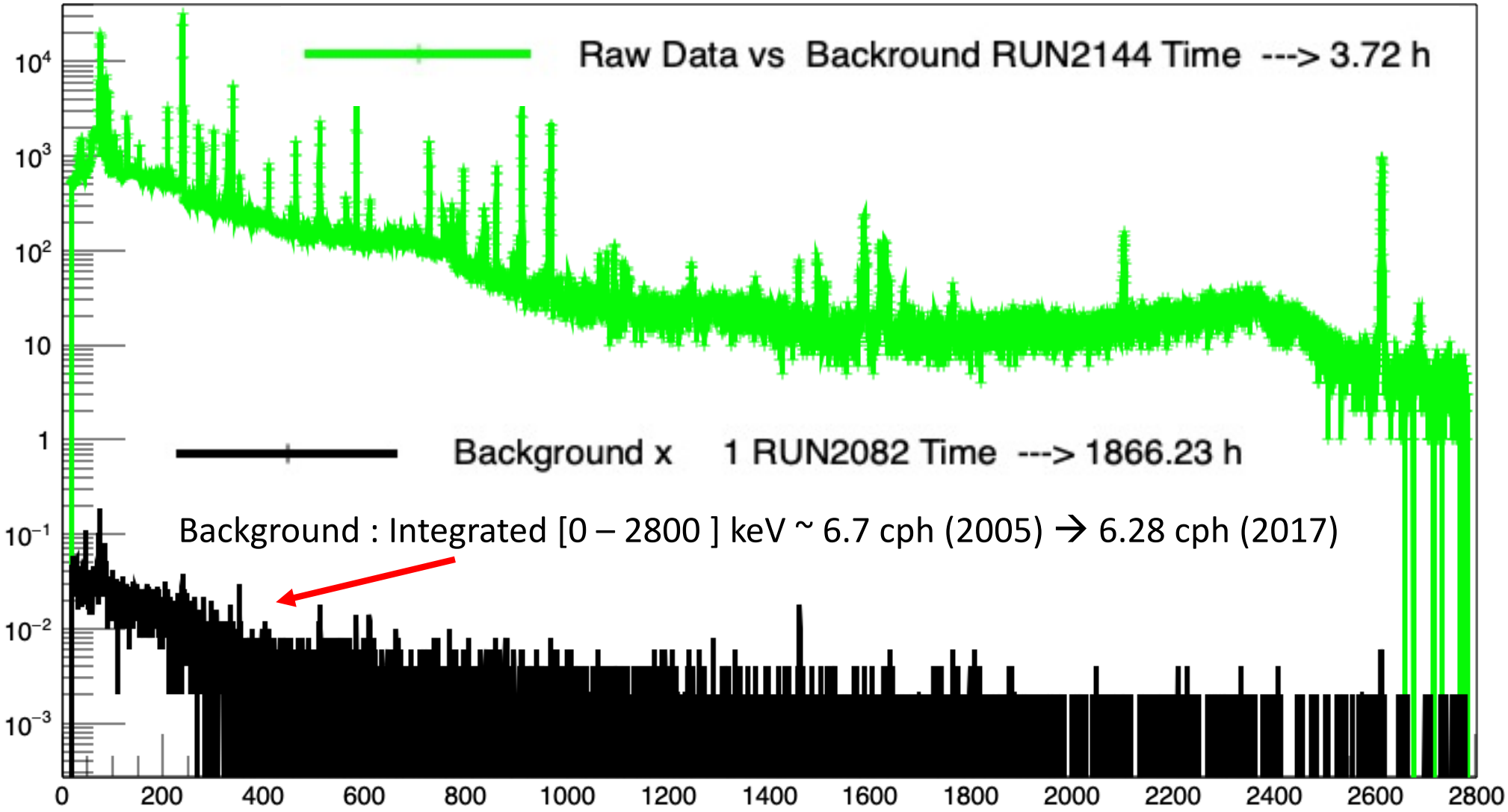
High Purity Ge diode of 210 cm^3 n-type :

- **Closed-ended coaxial, detector operated at 77 K**
- **Ultra-low-background cryostat, archeological lead shielding**
- **Nitrogen flux: 150cc/mn N2**



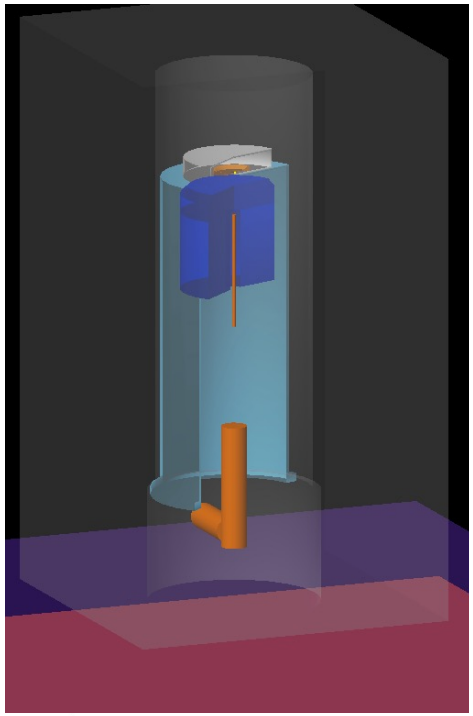
- **Sensitivities :**
  - **Background counting rate: < 6.7 counts/hour 0-3000 keV (~ 2005)**
  - **~ mBq/kg (0.1 – 0.2 ppb for U/ Th)**
  - **10 μBq / kg (tests of ^{60}Co in Cu)**
- **Two configurations h = 25 mm and h = 75 mm for sample volume**
- **On December 16th 2021: sample # 2207**

Gentiane detector @ LSM : Background level

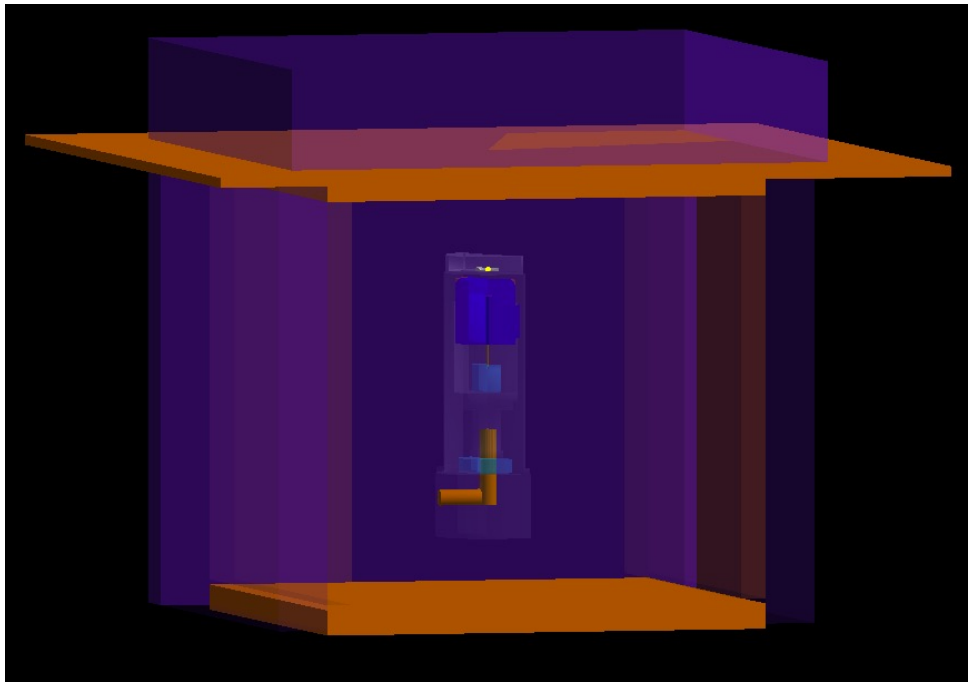


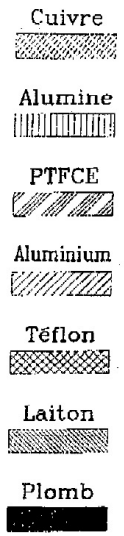
Implementation of Gentiane geometry in Geant4

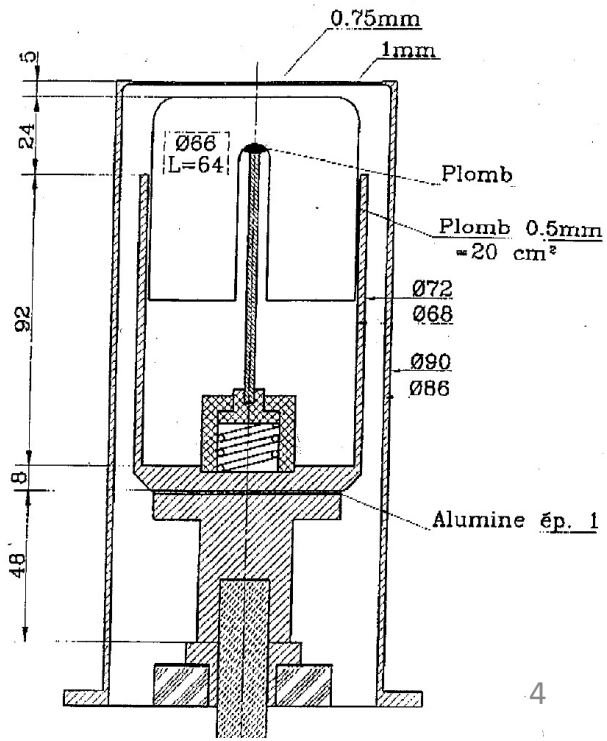
```
physicsList->AddPhysicsList("radioactive_decay");

export G4DATA=/Applications/Geant4/share/Geant4-10.4.2/data
export G4RADIOACTIVEDATA=$G4DATA/RadioactiveDecay5.2
export G4LEVELGAMMADATA=$G4DATA/PhotonEvaporation5.2
export G4NEUTRONHPDATA=$G4DATA/G4NDL4.5
export G4LEDATA=$G4DATA/G4EMLOW7.3
export G4REALSURFACEDATA=$G4DATA/RealSurface2.1.1
export G4ABLADATA=$G4DATA/G4ABLA3.1
export G4LENDDATA=$G4DATA/LEND_GND1.3_ENDF.BVII.1/
```



A **time window (t_τ = 4 μs)** is applied to decide whether adjacent detections need to be combined. Detection entries falling within the same t_τ window will be added.
No time pile-up window has been set.





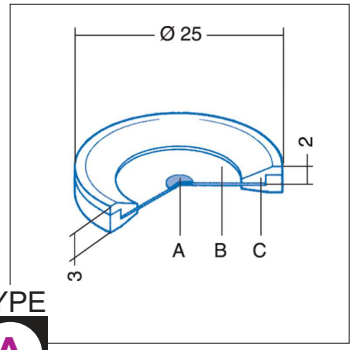


Run2116: Eu152 Calibration H25

Radionucléide et période	Référence	Flux γ dans 4 π sr s^{-1} /raie d'émission (min et max)	Activité kBq (*)	µCi	Conditionnement Diamètre mm	Type	Incertitude de mesure à k=2 %
^{152}Eu	EU152EGMA10	5,2 à 1,1 x 10^3	4	1,1 x 10^{-1}	25	A	2 à 6

Légende : *(1) Campagne de production 2 fois/ans : mars et septembre de chaque année. (*) Tolérance de fabrication ±30%*

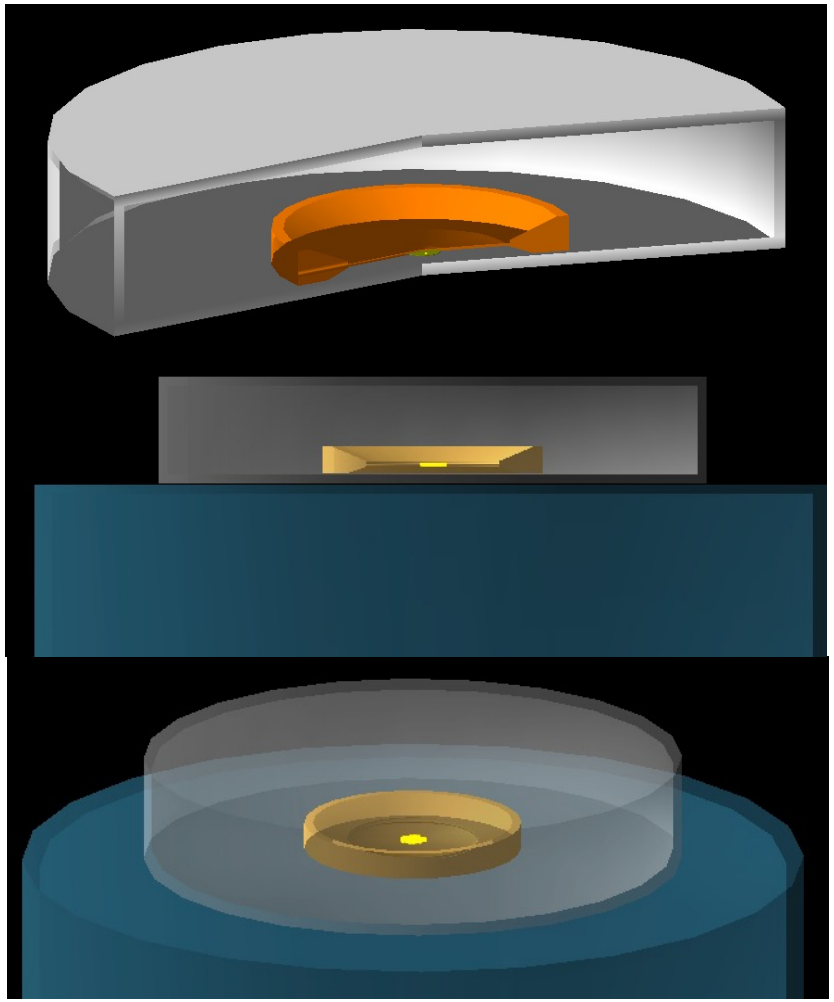
Toutes les activités sont mesurée en flux théorique.

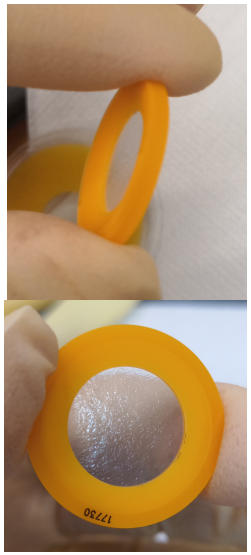


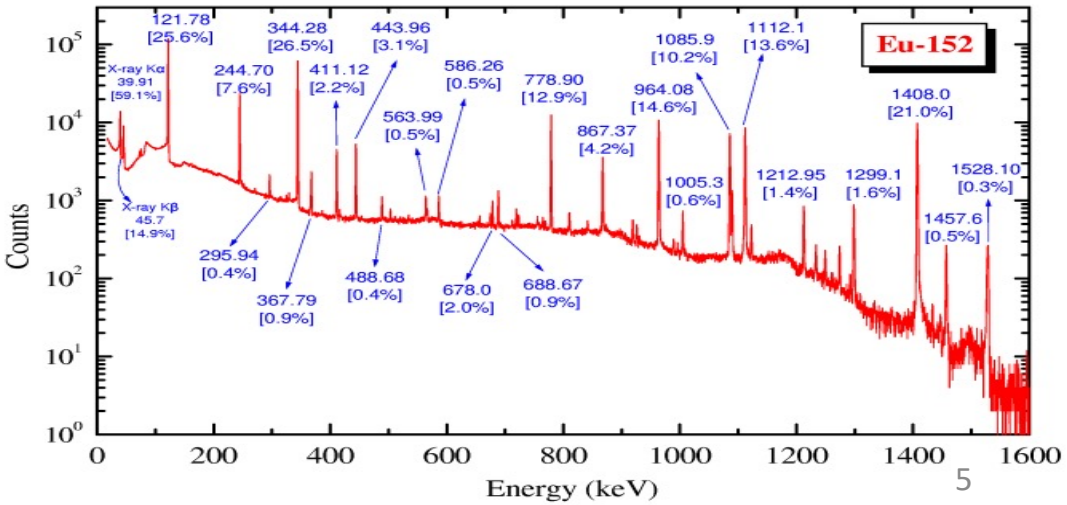
Couleur non contractuelle

TYPE

***A** : surface active diamètre 3 mm*
***B** : diamètre 15 mm*
***C** : anneau plastique épaisseur 3 mm*







Run2116 Eu152 Calibration

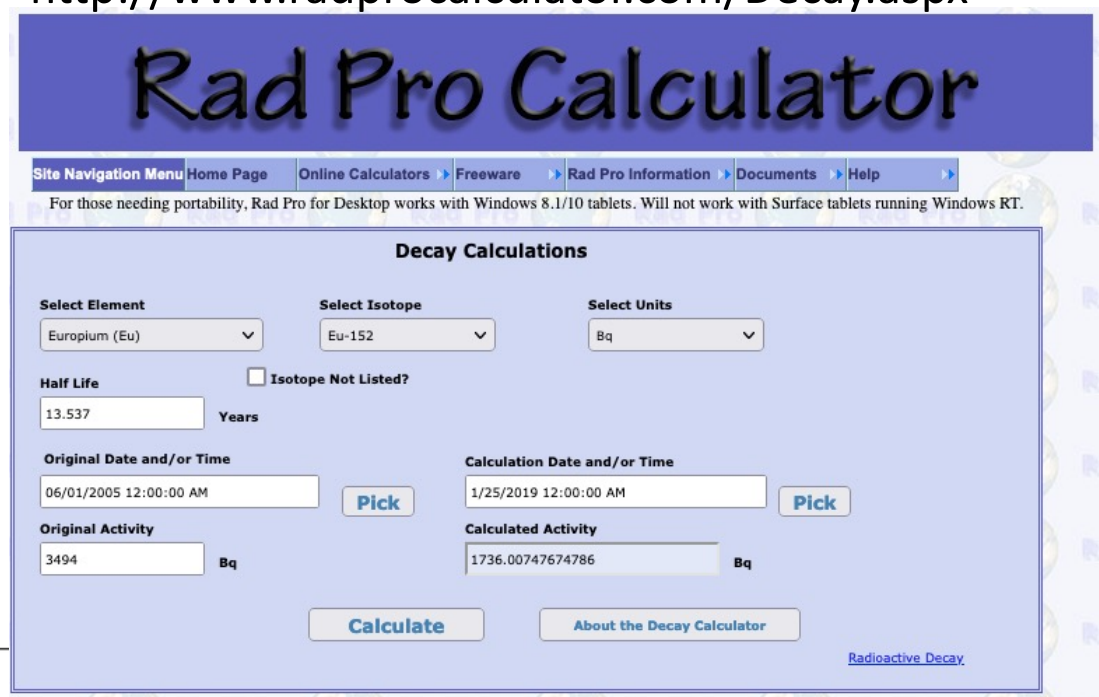
Maximum Likelihood Method used to fit 152Eu data with Geant4

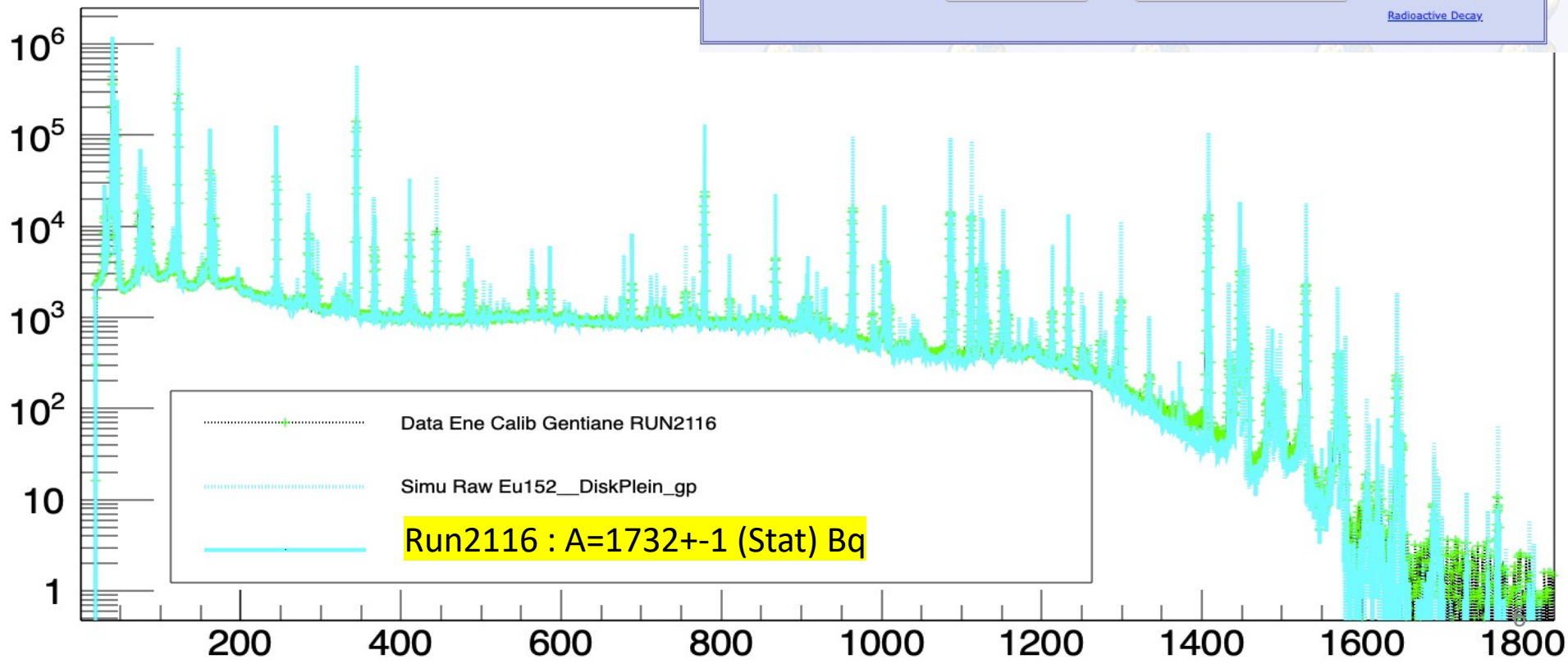
Fine tuning of the details of the geometry by minimizing the chi2 of the fit !!!

A (CERCA) = 1736 +- (35 to 105) Bq

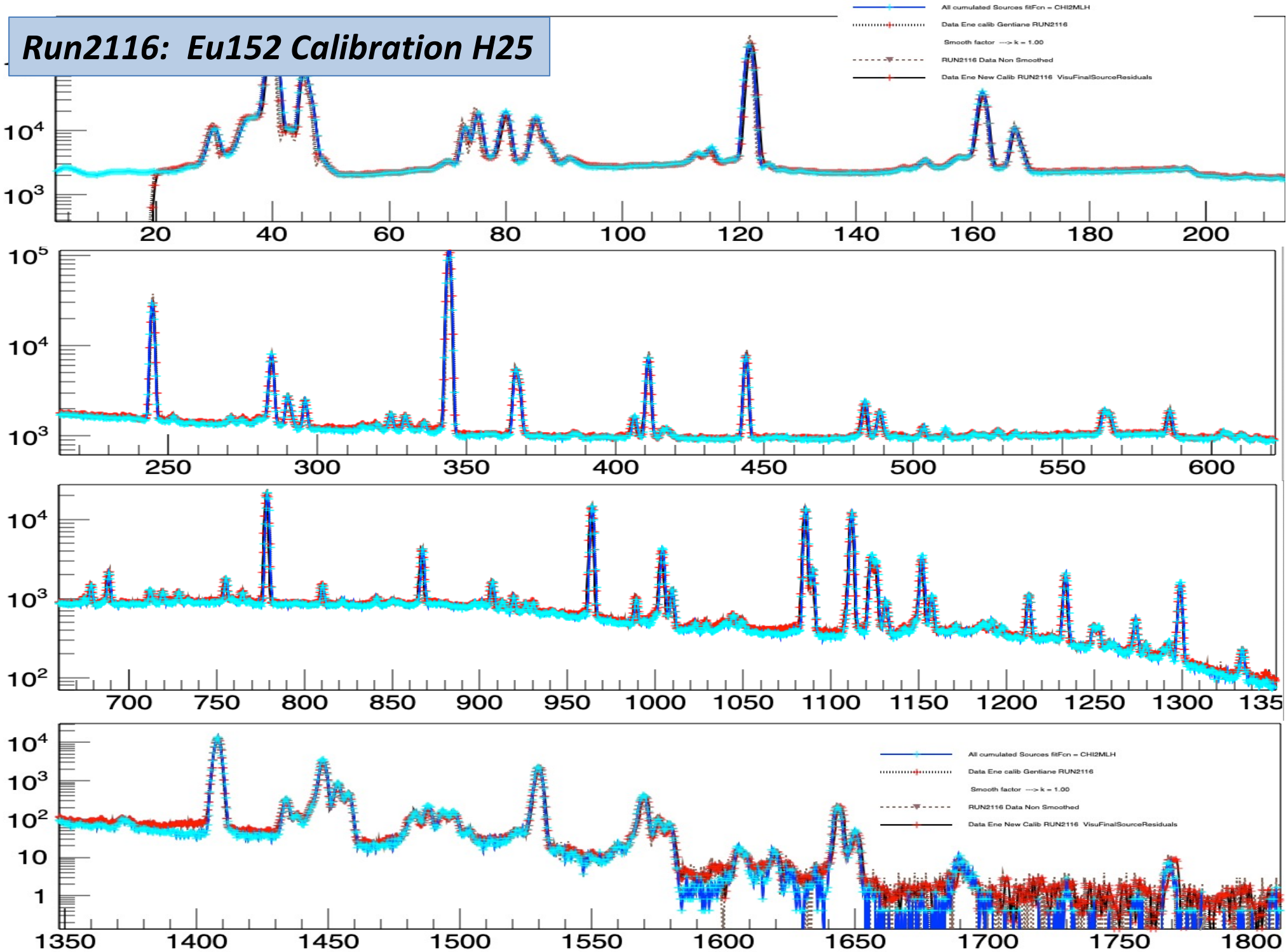
A(G4) = 1732+-1 Stat +- 10% Syst Bq

http://www.radprocalculator.com/Decay.aspx





Run2116: Eu152 Calibration H25

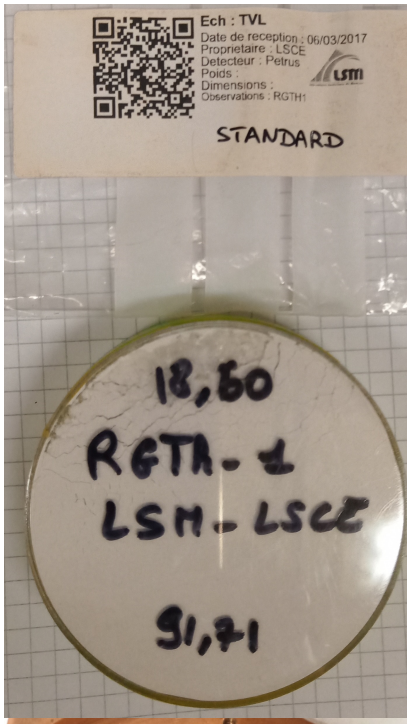


RUN2144: IAEA Standards : RgTh-1 H25

(Thanks to Irene Lefevre for lending different standards)

IAEA-RG-Th1		IAEA-RG-U1	
Radionuclide	Activity (Bq kg^{-1})	Radionuclide	Activity (Bq kg^{-1})
^{232}Th	3250	^{232}Th	< 4
^{235}U	3.6	^{235}U	238
^{238}U	78	^{238}U	4940
^{40}K	6.3	^{40}K	< 0.68

Table 3: IAEA-RG-Th1 (thorium ore) and IAEA-RG-U1 (uranium ore) certified values of activities.
https://core.ac.uk/download/pdf/54029967.pdf



Mass of the sample (91.71 – 18.60)
M_{RgTh-1}= = 73.11 g

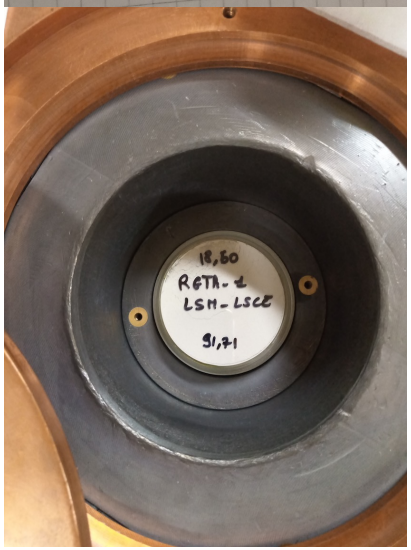
IAEA/RGTh-1

CERTIFICATE OF ANALYSIS

COMPONENT	CONCENTRATION*	CONFIDENCE INTERVAL**
Thorium	800 µg/g	± 16 µg/g
Uranium	6.3 µg/g	± 0.4 µg/g
Potassium	0.02%	± 0.01%

*Expressed on dry weight basis (constant weight at 130°C)
**At a significance level of 0.05

https://inis.iaea.org/collection/NCLCollectionStore/_Public/18/088/18088420.pdf?r=1

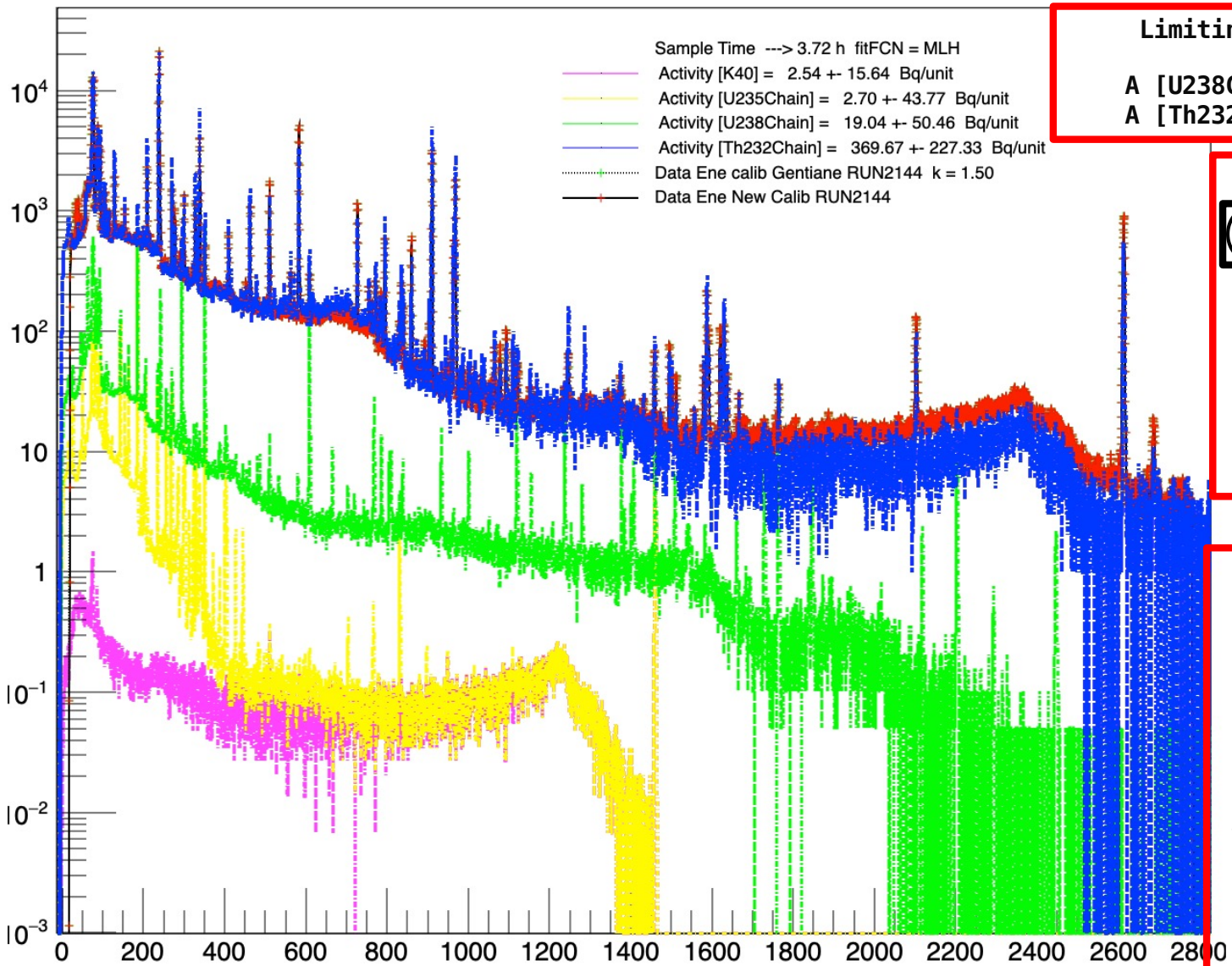


Equivalent Activities for
RgTh-1 TVL

$A(^{232}Th)$ = 237.6 +- 4.8 Bq
$A(^{238}U)$ = 5.70 +- 0.11 Bq
$A(^{40}K)$ = 0.46 +- 0.01 Bq
$A(^{235}U)$ = 0.26 +- 0.01 Bq

RUN2144: IAEA Standards : RgTh-1 H25

First attemp : try a fit with full chains and K40



K40 and U235 contributions negligible

Limiting to ^{238}U and ^{232}Th fulls chains

A [U238Chain] = 21.35 +– 0.35 Bq
A [Th232Chain] = 369.67 +– 0.02 Bq

Conclusions :

- **→ Chains are not in equilibrium ?**
- **→ Geant4 is not able to simulate accuratly a full chain ?**

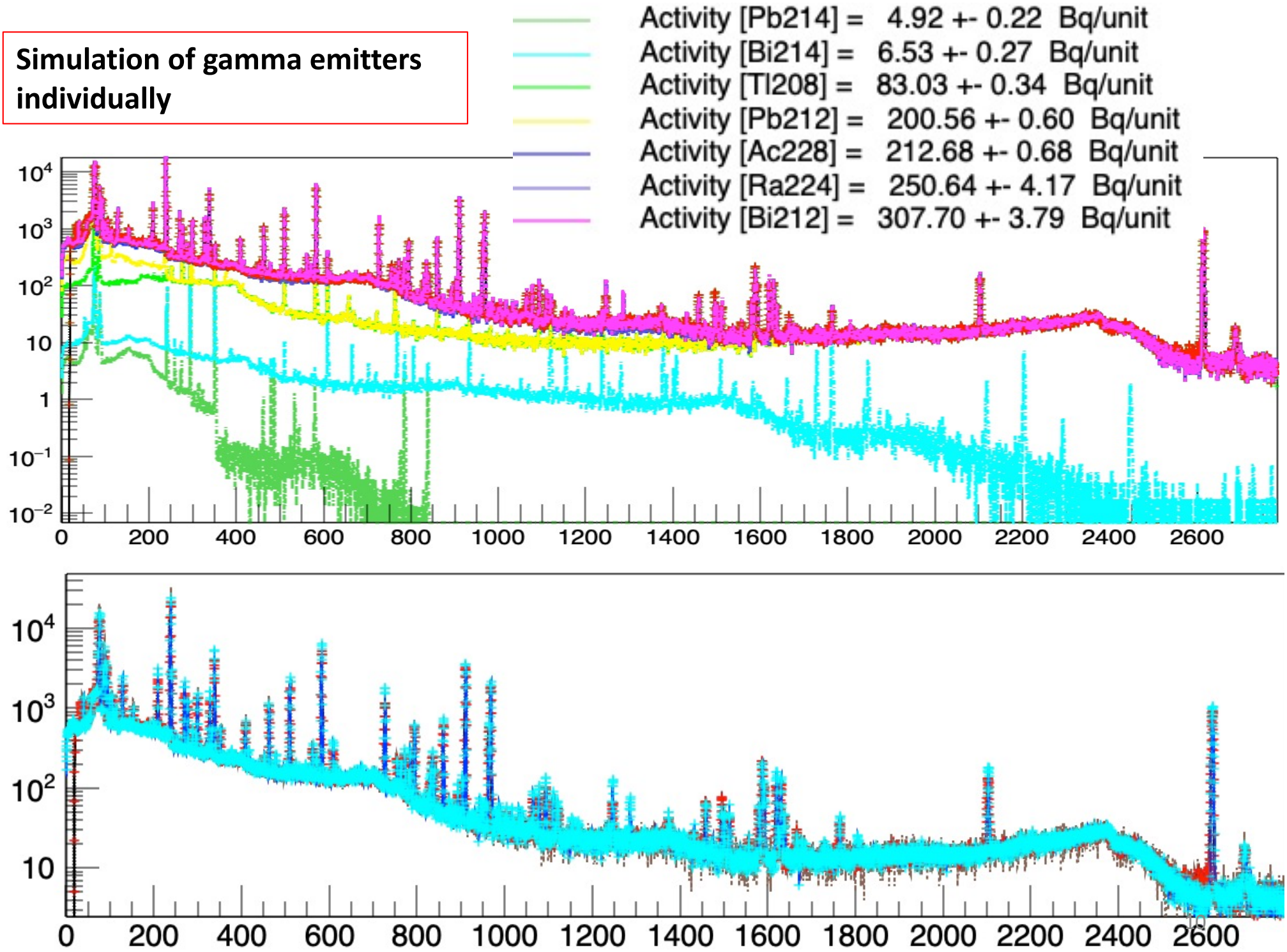
Simulate gamma emitters individually

OR

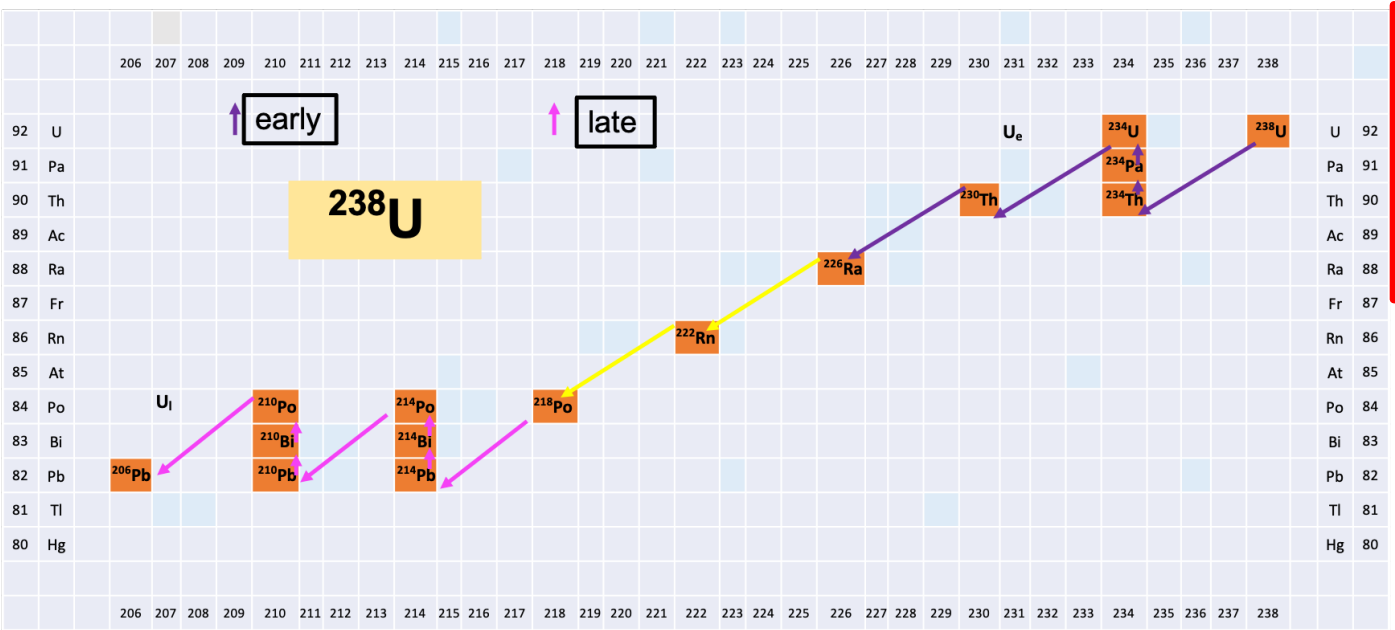
Split chains and simulate as out of equilibrium, early and late parts separatly

*Errors are statistical errors

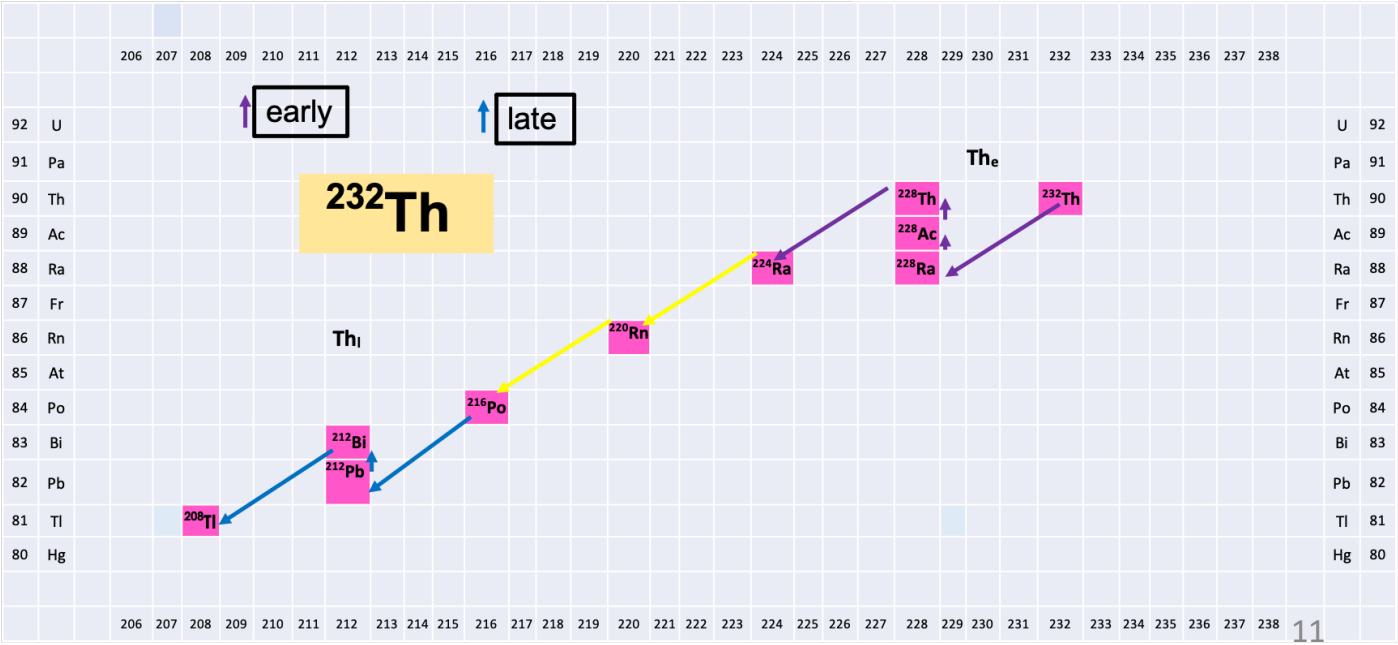
Simulation of gamma emitters individually

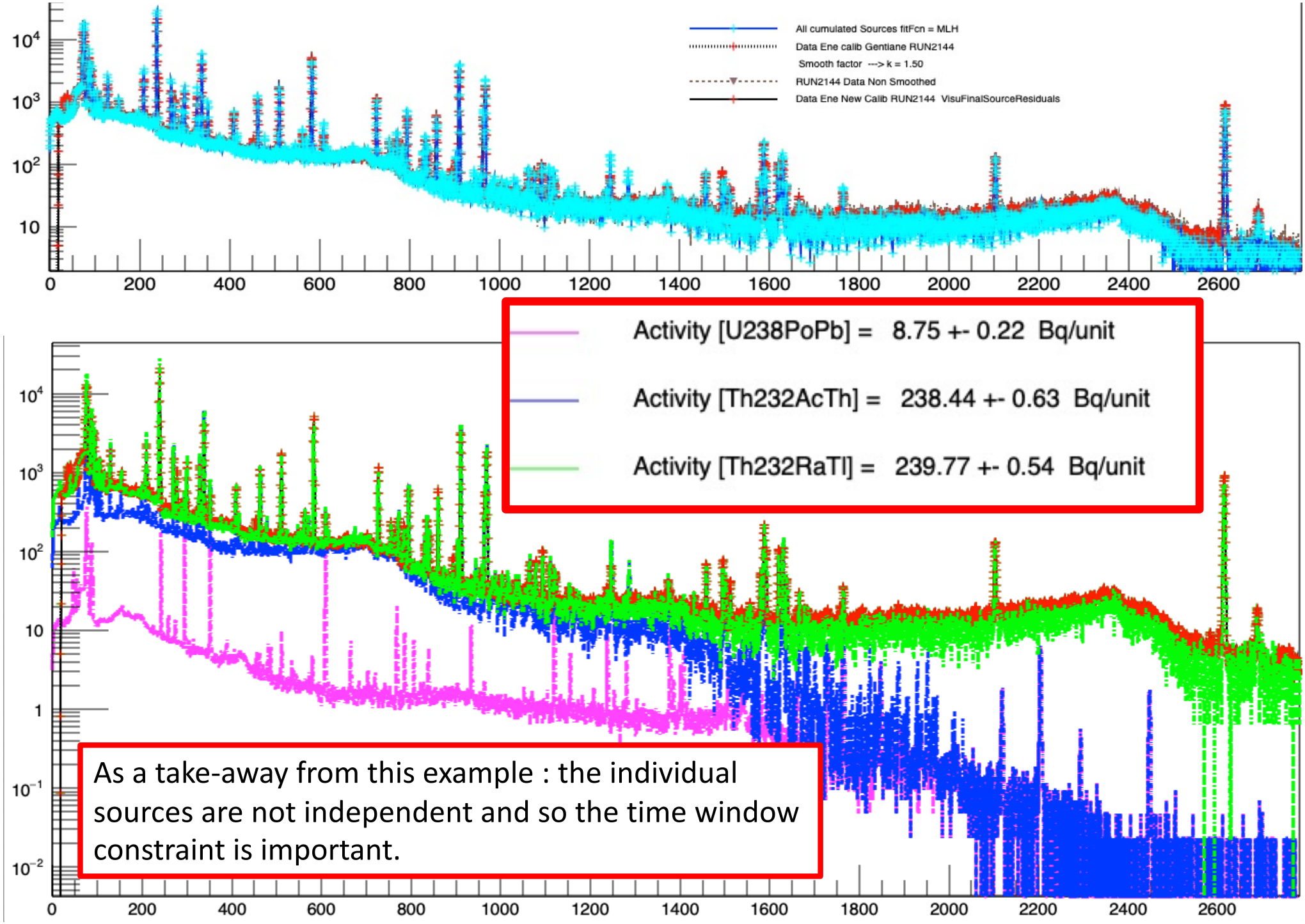


RUN2144: IAEA Standards : RgTh-1 H25



Split chains and simulate as out of equilibrium, early and late parts separatly

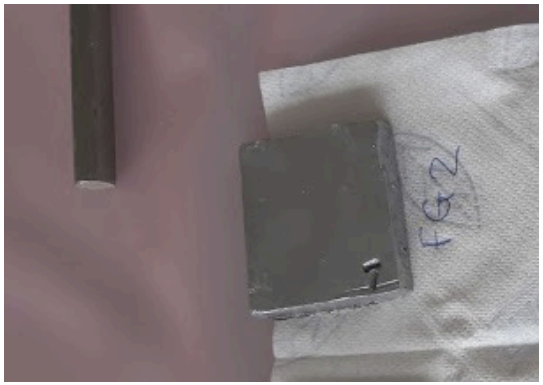




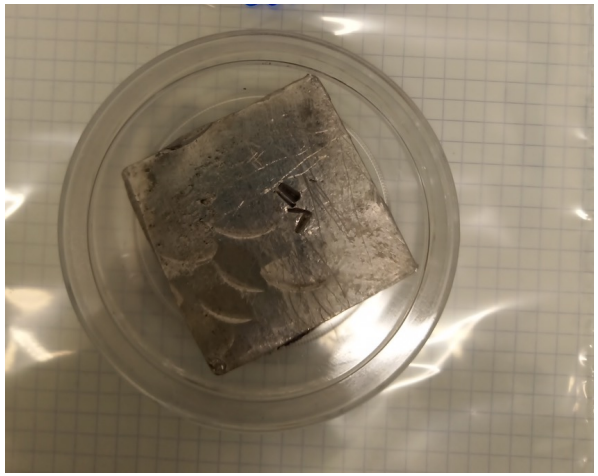
As a take-away from this example : the individual sources are not independent and so the time window constraint is important.

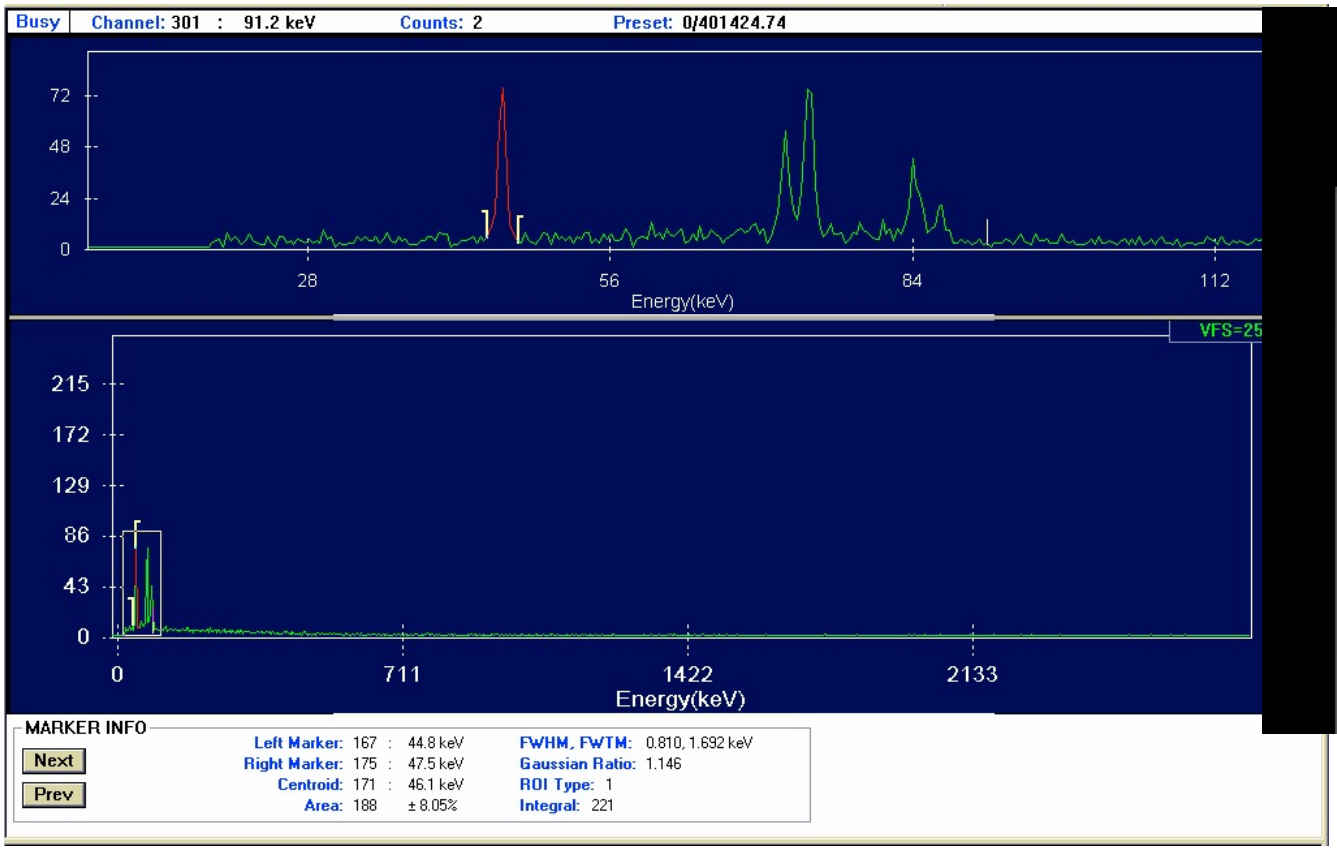
*Errors are statistical errors

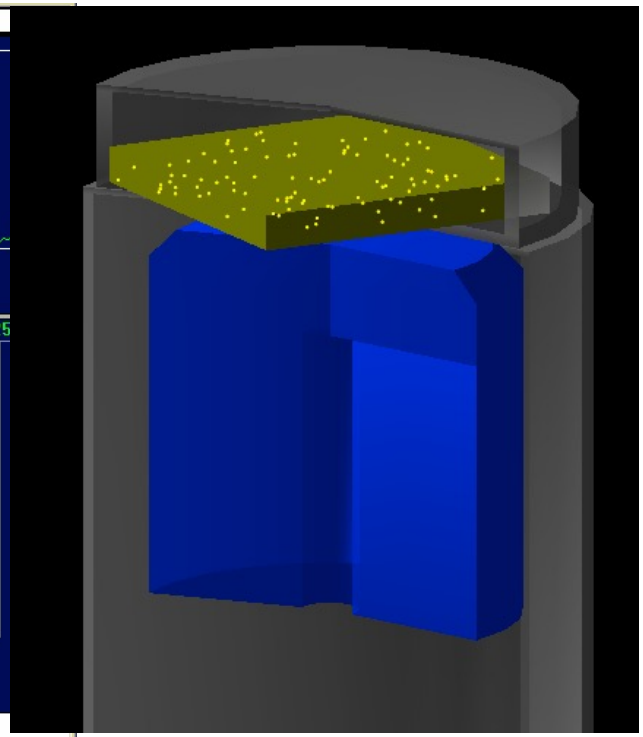
RUN2203: PbLSCE FG2



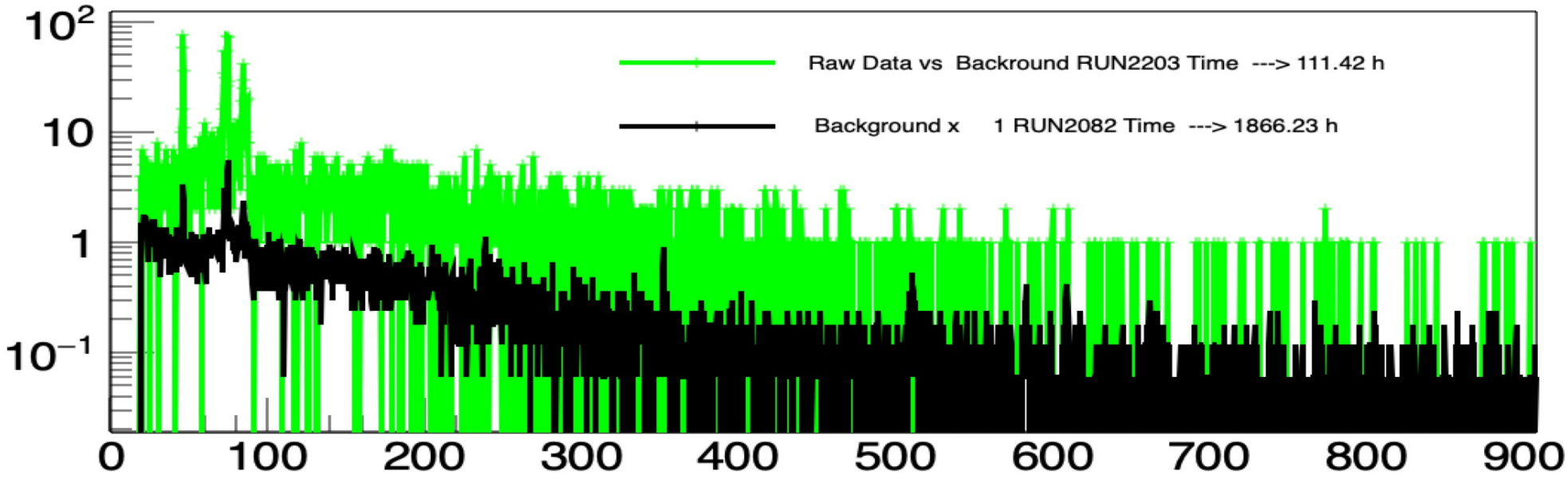
Mass=213.87 g
L= 55.2 mm
L= 55.0 mm
H= 6.2 mm

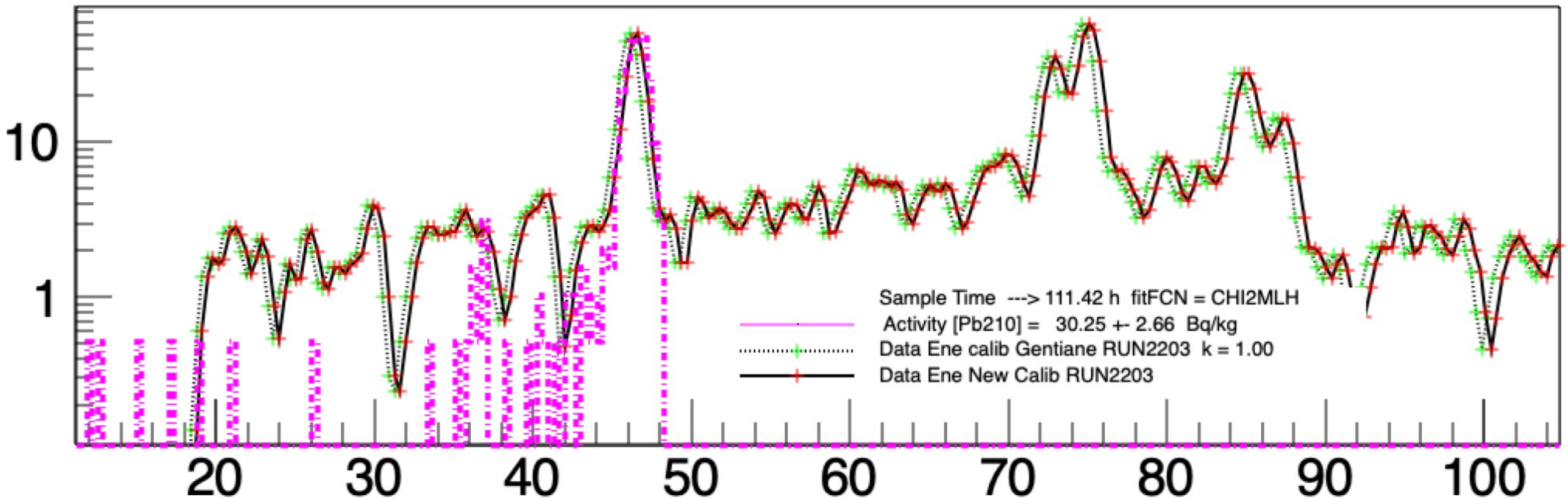




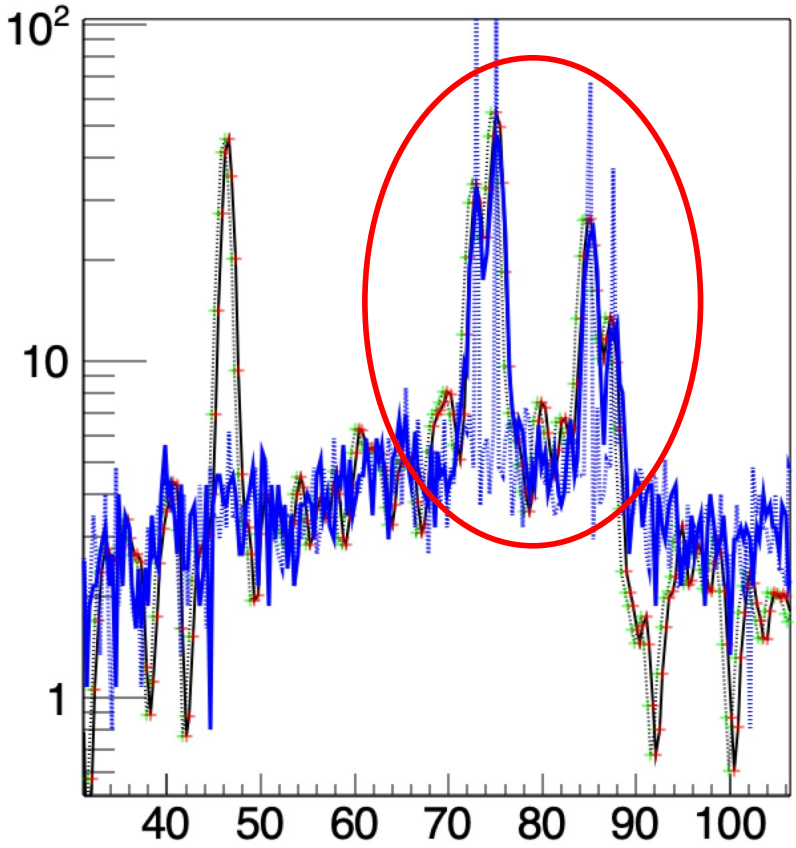


RUN2203: PbLSCE FG2

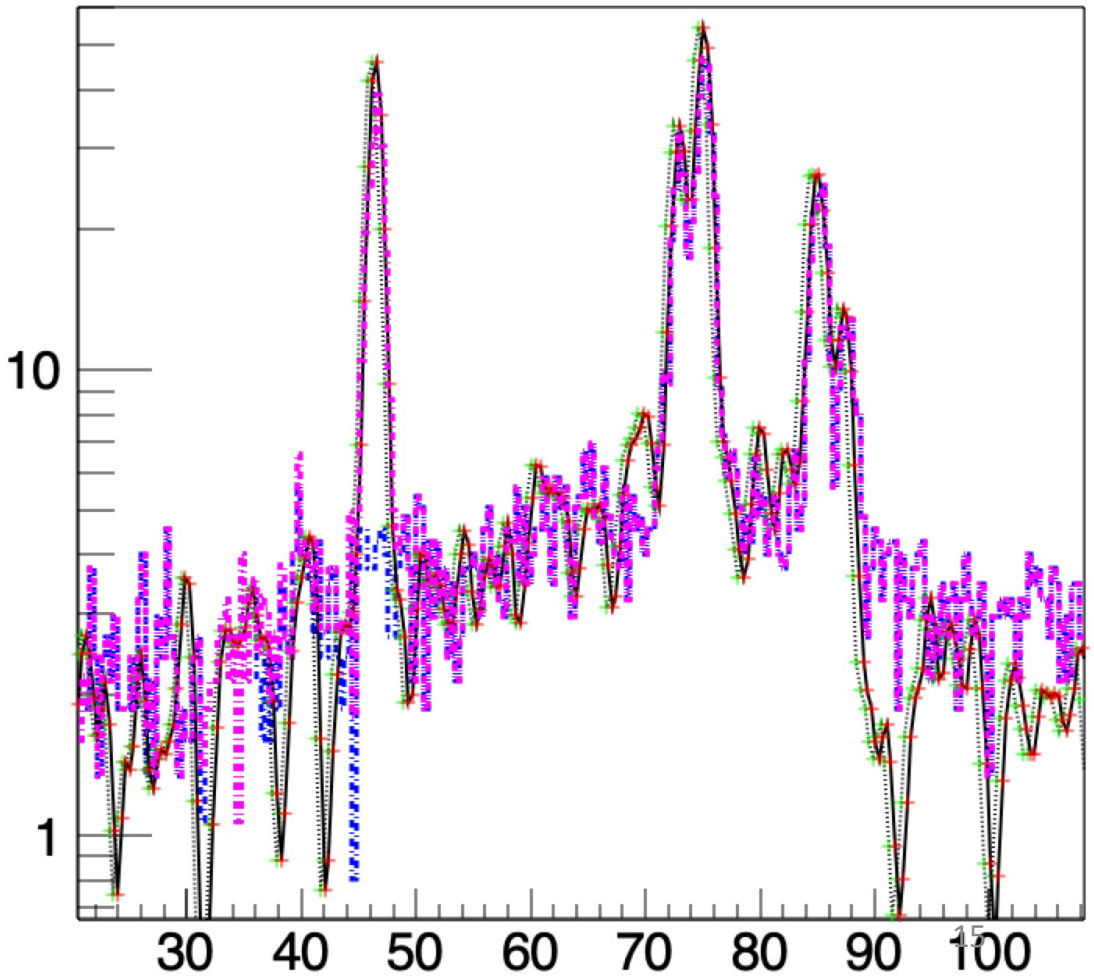




RUN2203: PbLSCE FG2



Use K40 to simulate high energy background inducing Pb X-rays, but the fitted activity for K40 has no physical meanning



Activity [Pb210] = 19.22 +- 2.43 Bq/kg

Data Ene calib Gentiane RUN2203 k = 1.20

Data Ene New Calib RUN2203

*Errors are statistical errors

Short Conclusion :

- Geant4 RadioactiveDecay physics list combined with maximum likelihood method analysis reliable to simulate common radioactive isotopes within materials.

- Geant4 application can well reproduce the typical spectral features such as the escape and summation peaks, and the Compton and back-scattering continua and edges.

Thank You