# $^{14}N(p,\gamma)^{15}O$

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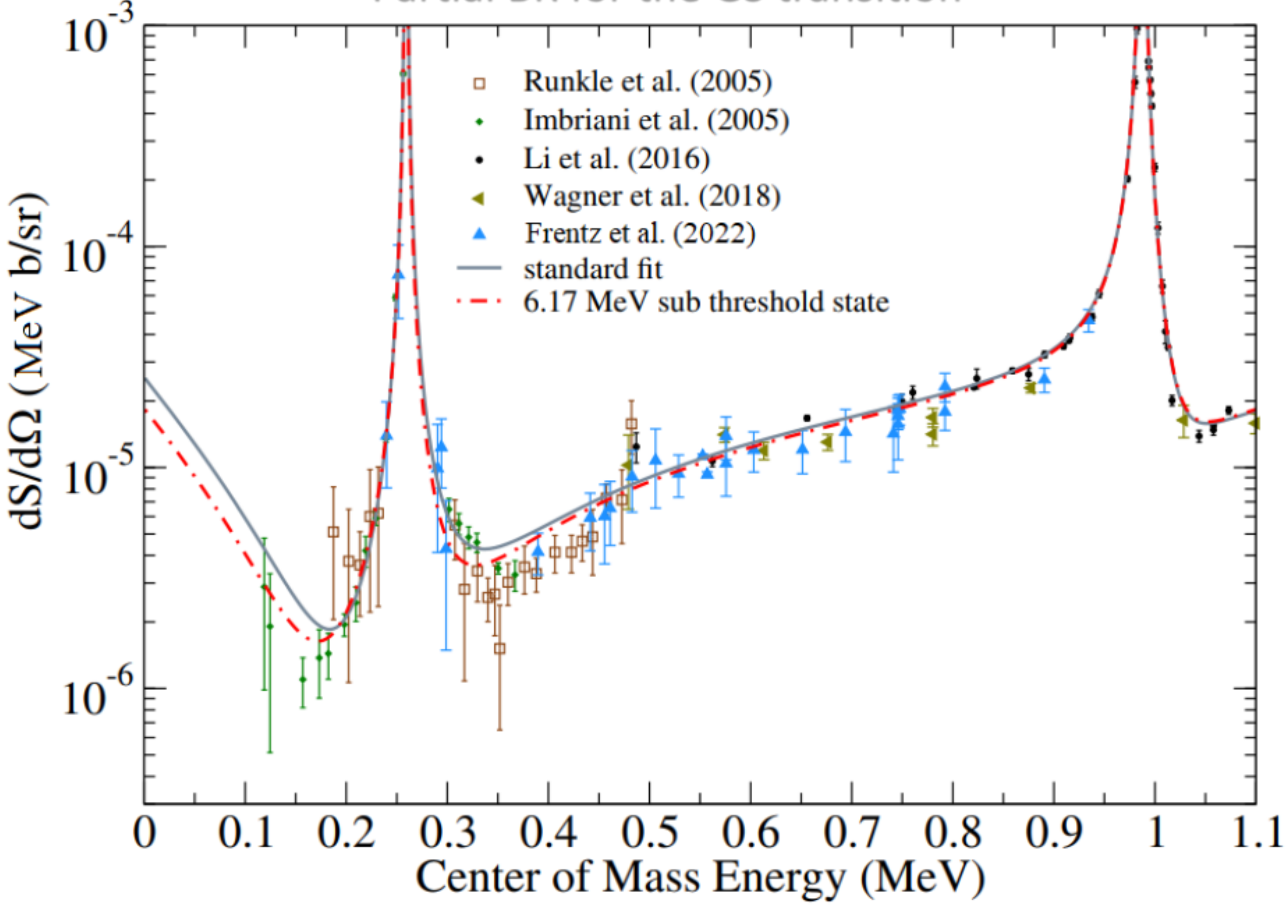
# Study of the $^{14}N(p, \gamma)^{15}O$ reaction

## State of art

Partial BR for the GS transition




*Significant discrepancy between experimental data and R-matrix fits around the resonance at $E_{cm}$ = 259 keV*

## Main goal

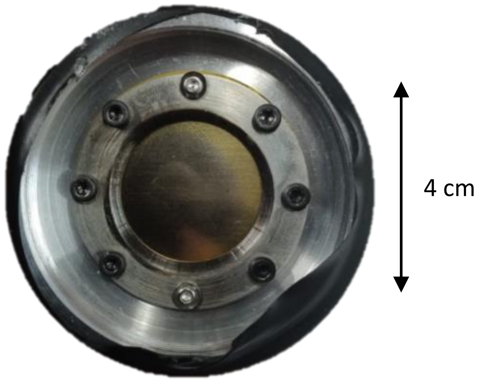
Determine the $^{14}N(p,g)^{15}O$ branching ratios in the 100 - 400 keV energy range.

# Study of the $^{14}N(p, \gamma)^{15}O$ reaction

## Solid Targets

TiN sputtered targets + Ti inter-layer + Ta backing produced @ LNL

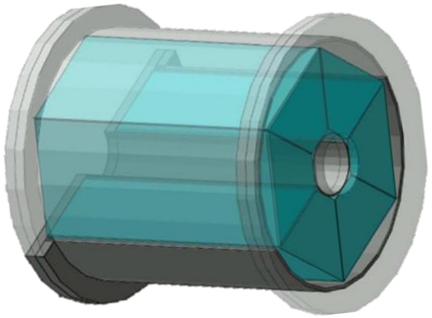
| Target | Nominal Thickness (nm) |
|---|---|
| Dep159_1 | 140 |
| Dep159_2 | 140 |
| Dep158_3 | 100 |
| Dep166_1 | 100 |
| Dep166_2 | 100 |
| Dep165_1 | 70 |
| Dep165_2 | 70 |
| Dep165_3 | 70 |

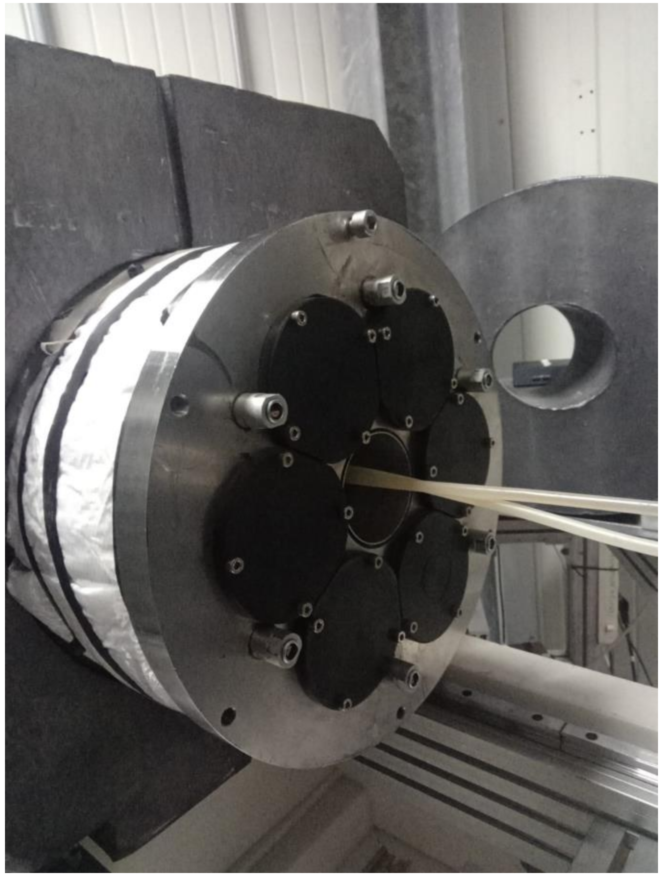



every day we performed a scan of the 278 keV resonance to monitor target stability

## Detectors

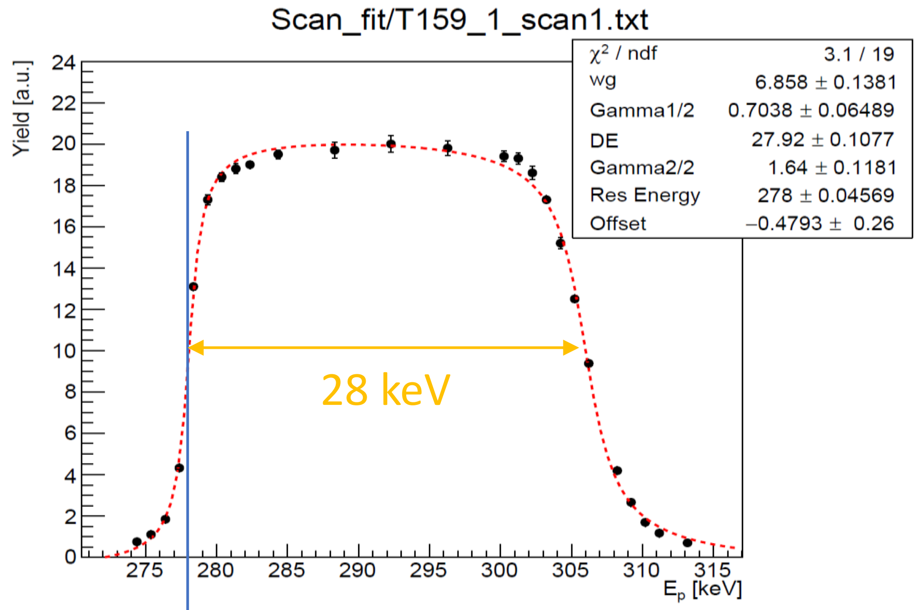
4π-BGO + lead shielding all around

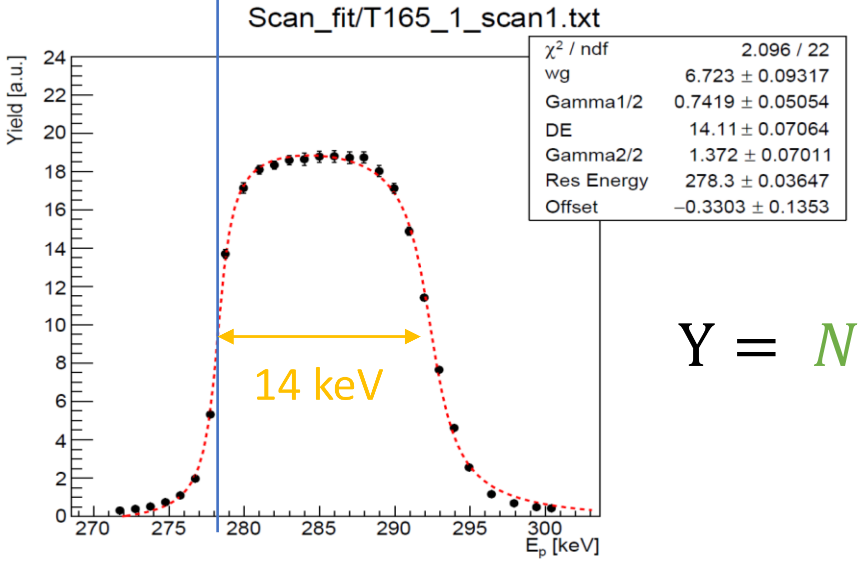




# Study of the $^{14}N(p,\gamma)^{15}O$ reaction

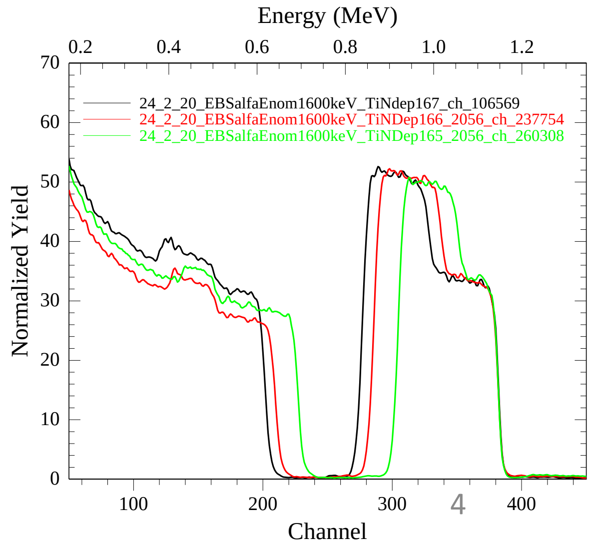
## Target scan analysis




| Target | Nominal Thickness (nm) | Nominal Thickness (keV) | Measured thickness from M. Campostrini (keV) | Measured thickness (keV) | Accumulated Charge (C) |
|---|---|---|---|---|---|
| Dep158_3 | 100 | 17 | 20,7 | 20,2 +- 0,2 | 245 |
| Dep159_1 | 140 | 24 | 27,7 | 27,9 +- 0,1 | 96 |
| Dep159_2 | 140 | 24 | 27,7 | 27,2 +- 0,1 | 62 |
| Dep165_1 | 70 | 12 | 14,4 | 14,11 +- 0,07 | 81 |
| Dep166_1 | 100 | 17 | 20,4 | 20,02 +- 0,09 | 193 |
| Dep166_2 | 100 | 17 | 20,4 | 20,03 +- 0,08 | 68 |
| Dep165_2 | 70 | 12 | tbd | 14,2 +- 0,07 | 126 |
| Dep165_3 | 70 | 12 | tbd | Analysis still ingoing | |

$$Y = N * \left[\tan^{-1}\frac{E-E_r}{\Gamma_1} - \tan^{-1}\frac{E-E_r-\Delta E}{\Gamma_2}\right] + h$$



# Study of the $^{14}N(p, \gamma)^{15}O$ reaction

## Data taking

- First campaign (February 2024):
  - Targets: 158_3 (100nm), 159_1 (140nm) and 159_2 (140nm)
  - Energies measured: 400, 397, 368, 350, 324, 305, 270, 250, 200 keV
- Second campaign (April 2024):
  - Targets: 165_1 (70nm), 166_1 (100nm) and 166_2 (100nm)
  - Energies measured: 400, 385, 350, 337, 315, 276, 270, 260, 180 keV
- Third campaign (June 2024):
  - Targets: 165_2 (70nm) and 165_3 (70nm)
  - Energy measured: 150 keV

| $E_p$ [keV] | Target thickness @ 278 keV [keV] | Beam charge [C] |
|---|---|---|
| 400 | 14.11 | 17.3 |
| 400 | 27.08 | 21.6 |
| 397 | 20.25 | 20.2 |
| 385 | 14.06 | 23.3 |
| 368 | 27.60 | 13.2 |
| 368 | 20.25 | 17.2 |
| 350 | 13.96 | 20 |
| 350 | 27.60 | 6.3 |
| 337 | 13.96 | 17.7 |
| 324 | 20.03 | 23.4 |
| 315 | 13.74 | 18.5 |
| 305 | 19.83 | 17.6 |
| 276 | 19.64 | 22.1 |
| 270 | 27.00 | 31.4 |
| 260 | 19.73 | 43.0 |
| 251 | 19.77 | 35.8 |
| 230 | 19.52 | 64.0 |
| 200 | 27.22 | 108.1 |
| 200 | 19.37 | 38.2 |
| 180 | 19.22 | 161 |
| 150 | 14.16 | 237 |

## Total S-factor

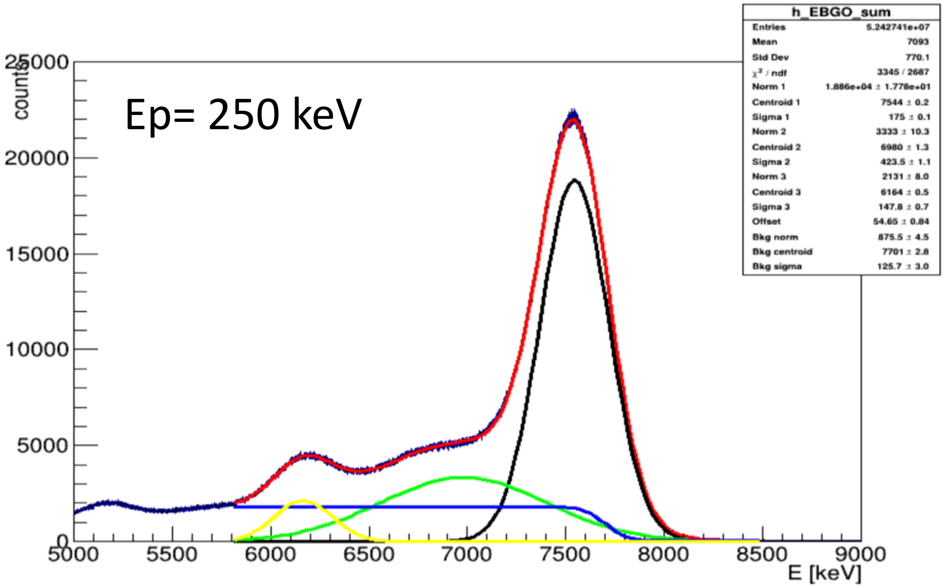
- Target profile included for each run
- Approx. efficiency (60%)
- Constant S-factor approximation (as a preliminary analysis )

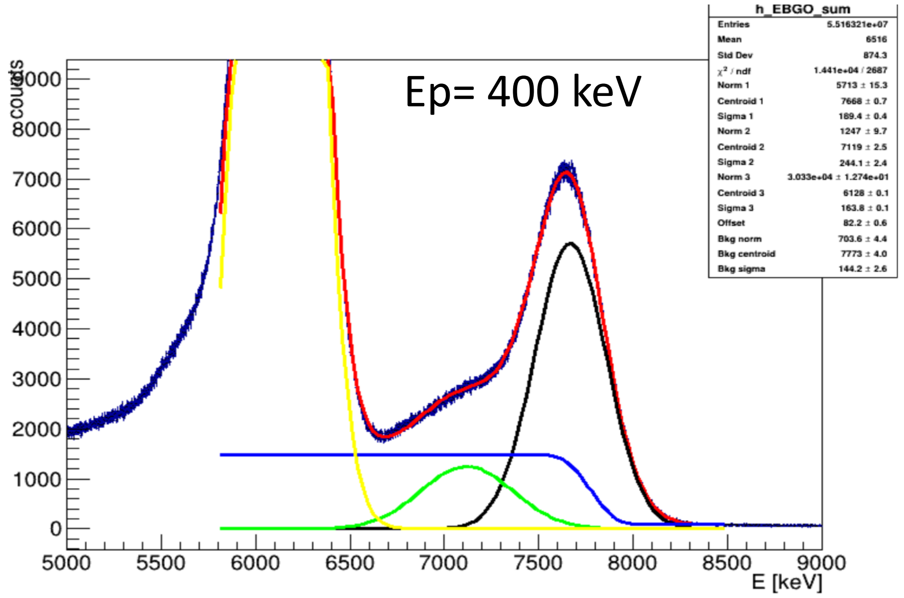
$$S = \frac{Yield(E_0)}{\int_{E_0-\Delta E}^{E_0} \frac{P(x)e^{-2\pi\eta}}{\epsilon_{eff}(E_0)E_{CM}}\, dE} \qquad x = \frac{\mathrm{dE}}{\epsilon(E_0)}$$

**Fit:**
**Sum-peak**
**First escape or first escape + 6791 keV**
**Fluorine or 6175 keV**
**Error function for continuum Compton**

Resonance populated at 340 keV

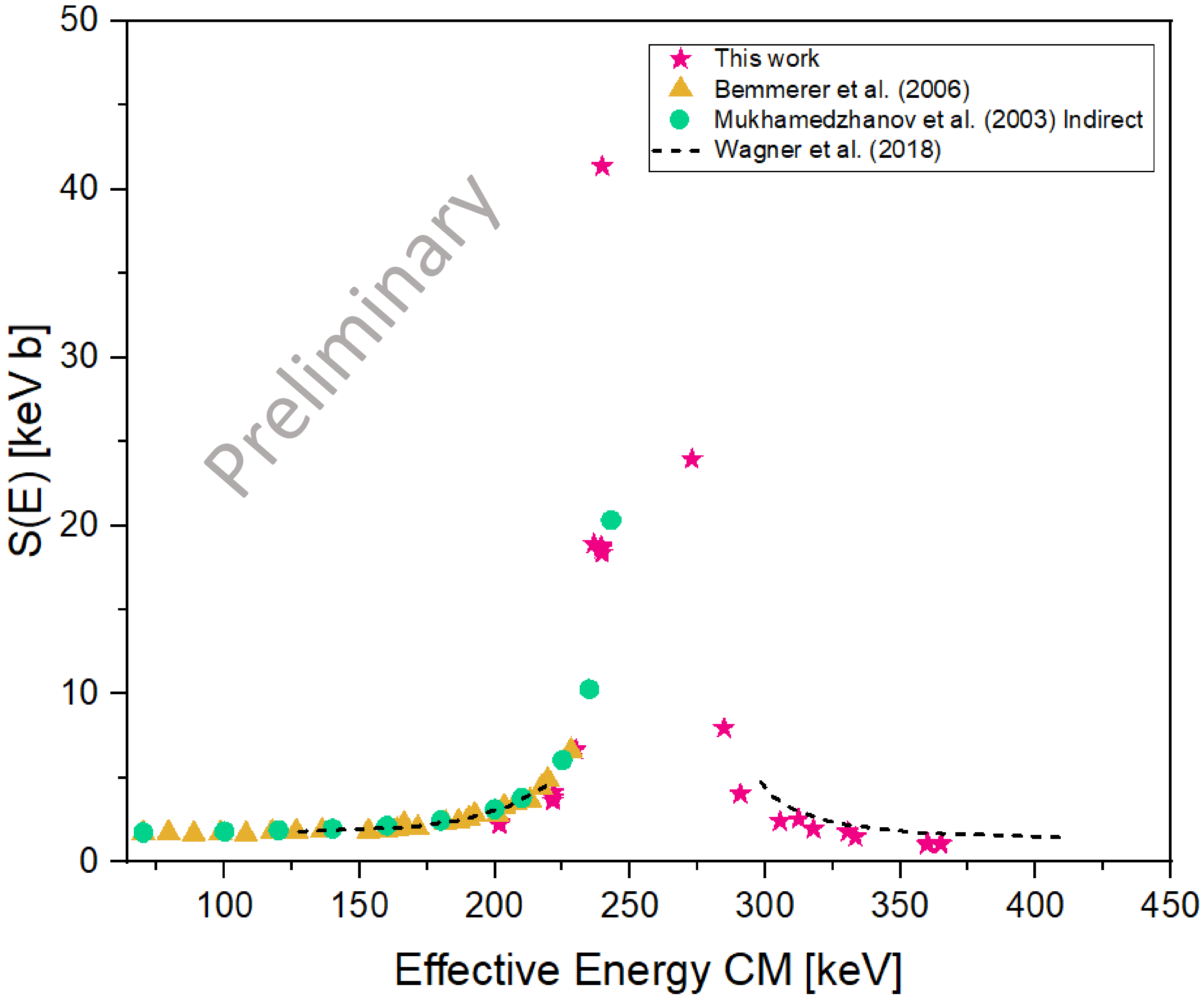
$^{19}F(p,\alpha)^{16}O$
$E_\gamma = 6128\ keV$



# Study of the $^{14}N(p, \gamma)^{15}O$ reaction

## Total S-factor



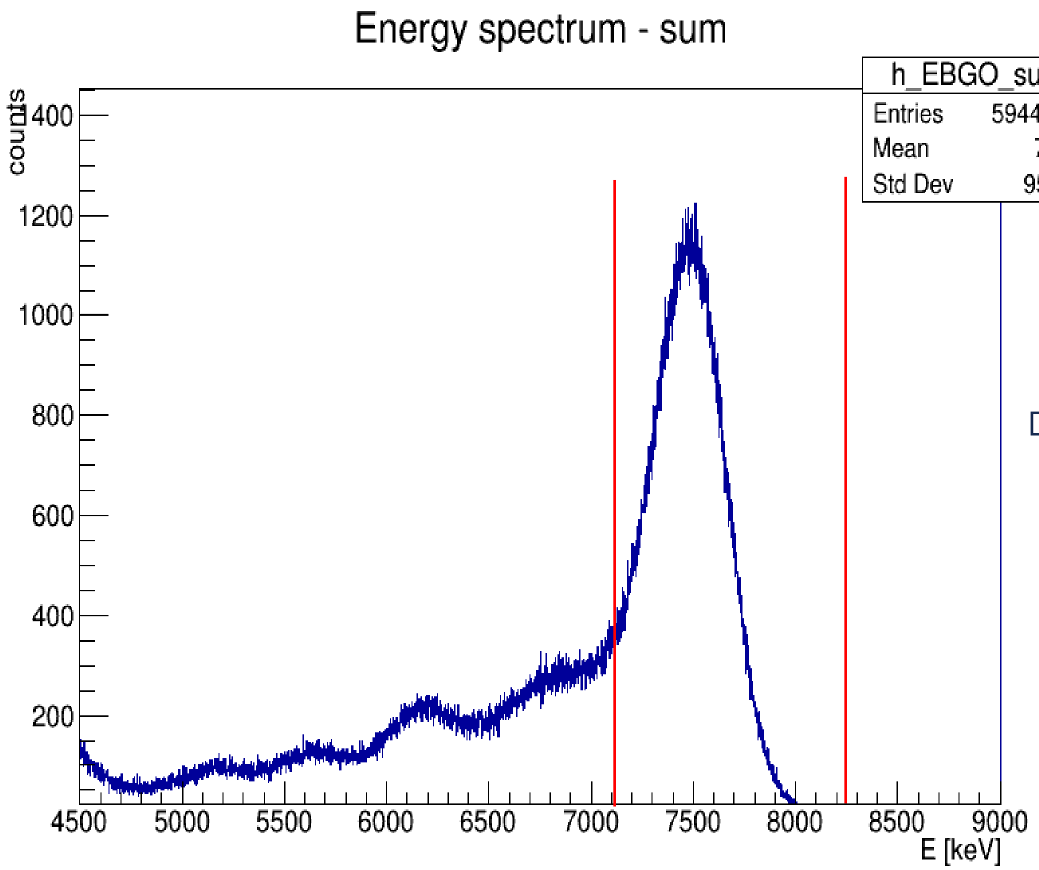

Some corrections still needed:

- the S-factor is not constant within the target
- Experimental efficiency to be checked

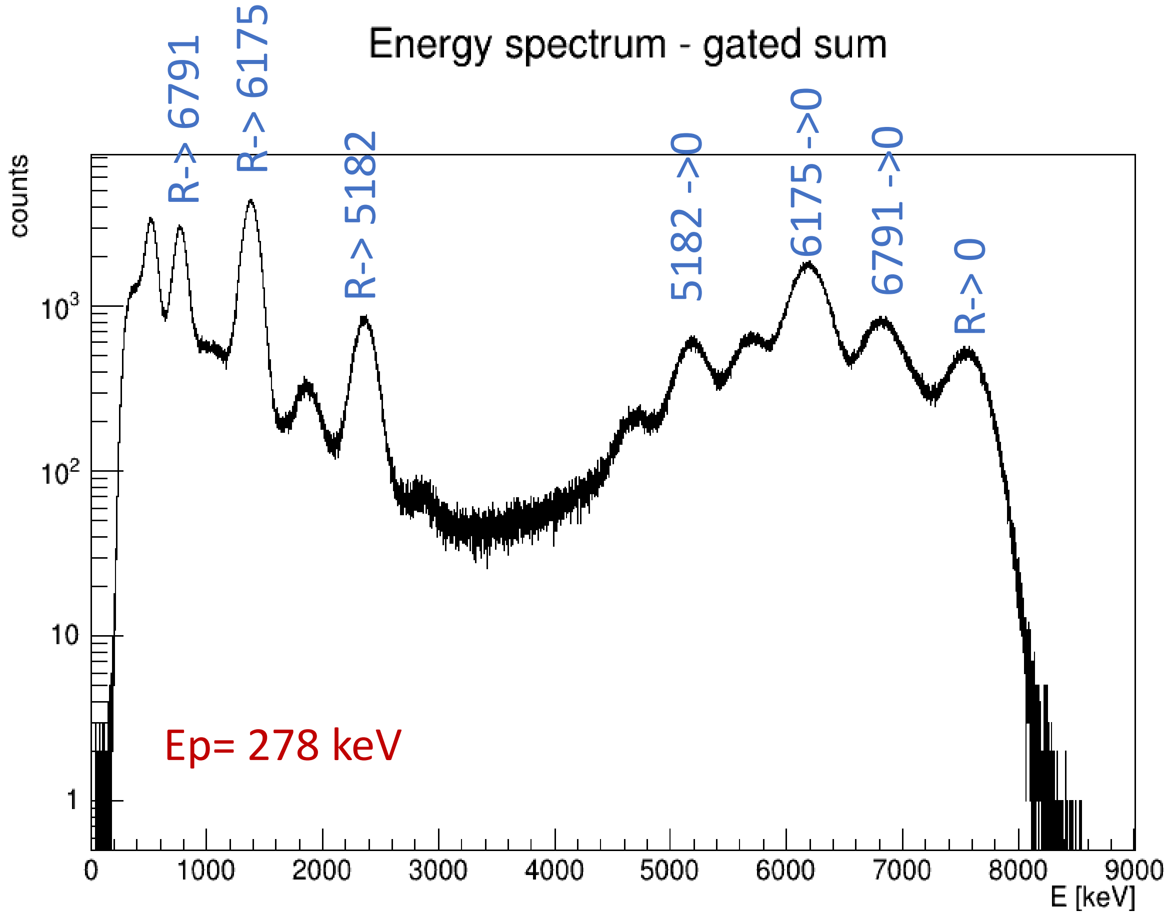
# Study of the $^{14}N(p, \gamma)^{15}O$ reaction

**Branching ratio**

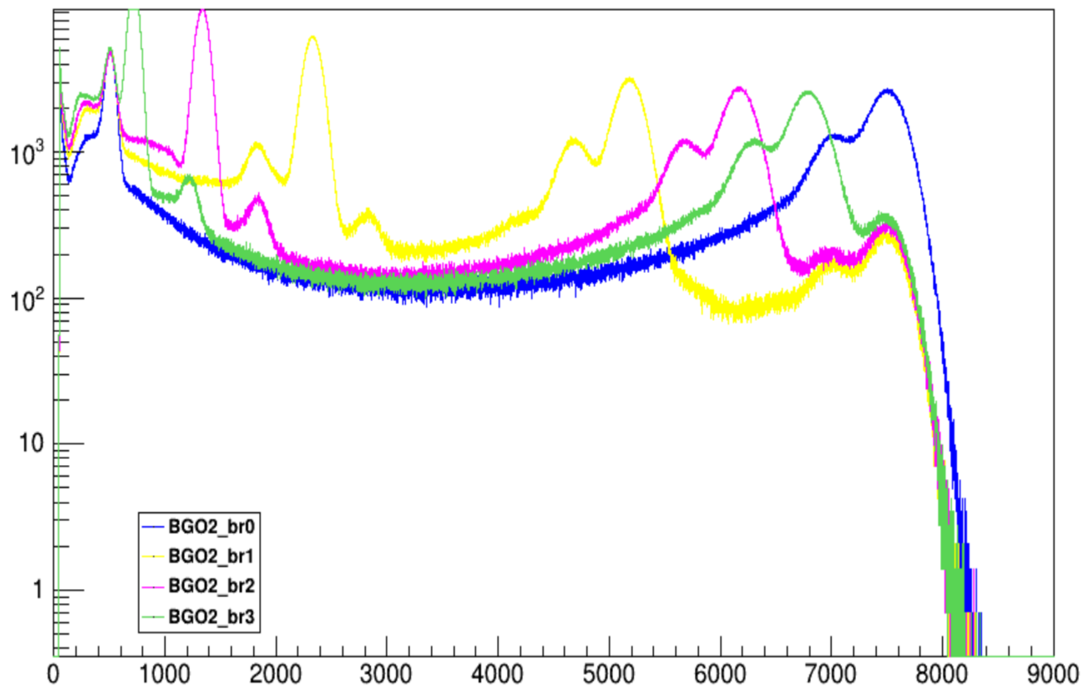
Gated spectrum: Energy distribution of events that contribute to the sum peak



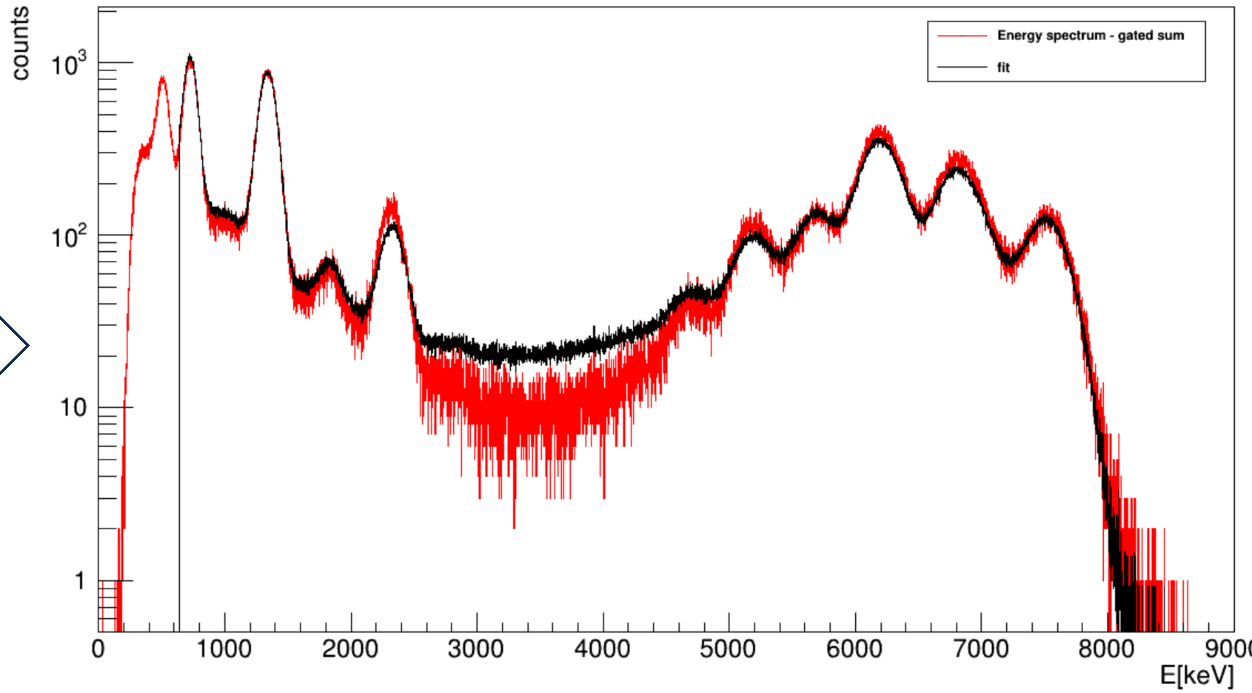

Gated spectrum



## Test on resonance branching ratios




Fit

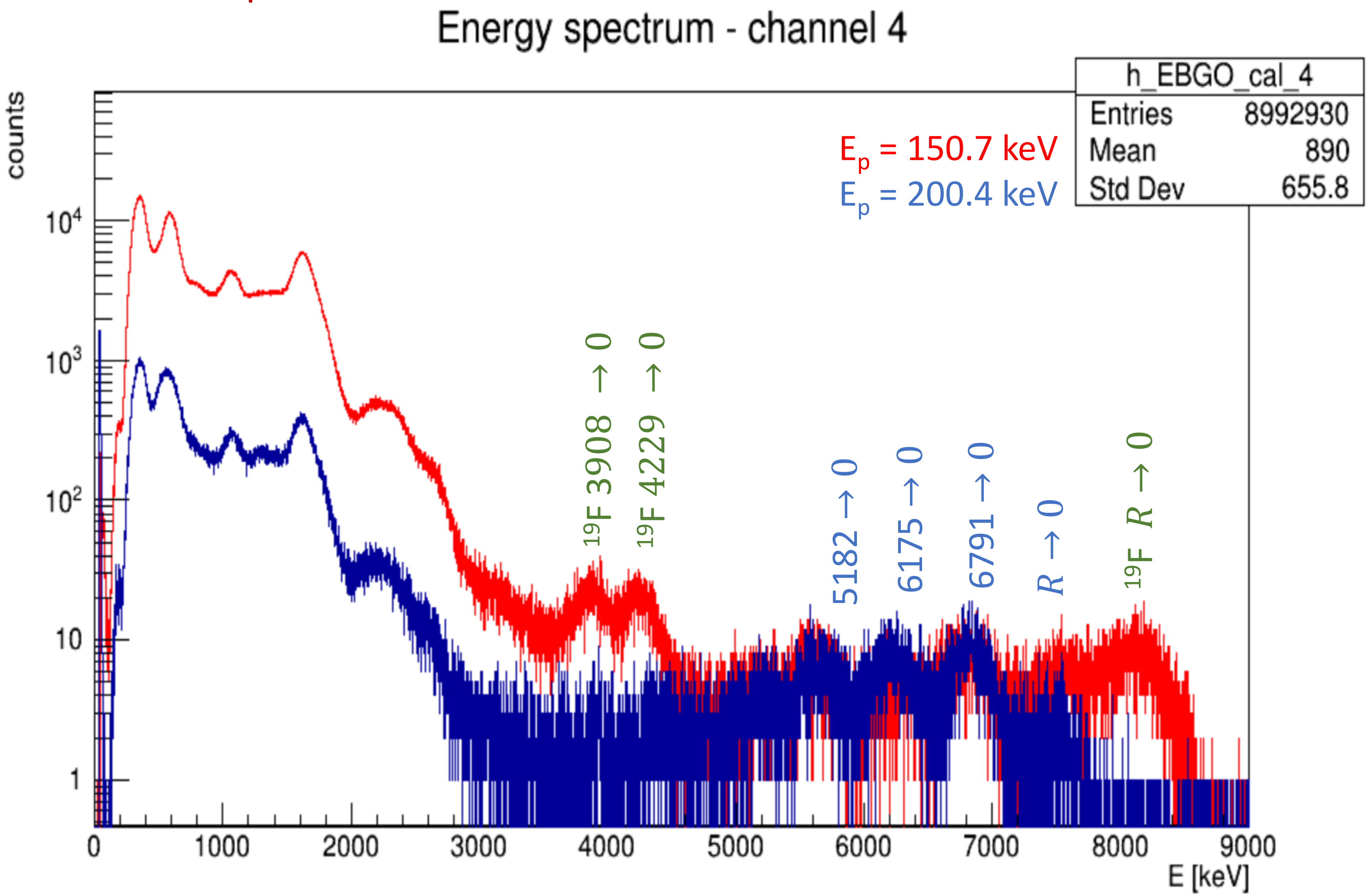



- Done with a very preliminary MC geometry (see Matteo presentation)
- Summing effect should be checked

| | Fit on resonance | *A. Formicola et al. PLB (2004)* |
|---|---|---|
| R->0 | 10,2 * | 1,67 +- 0,10 |
| R->5182 | 10,8 | 16,6 +- 0,2 |
| R->6175 | 60,0 | 58,4 +- 0,3 |
| R-> 6791 | 18,8 | 23,3 +- 0,3 |

* Very preliminary, to be checked

**Analysis @ $E_p$ = 150 keV**




$^{18}O(p,g)^{19}F$

In the target or build-up

# Study of the $^{14}N(p, \gamma)^{15}O$ reaction

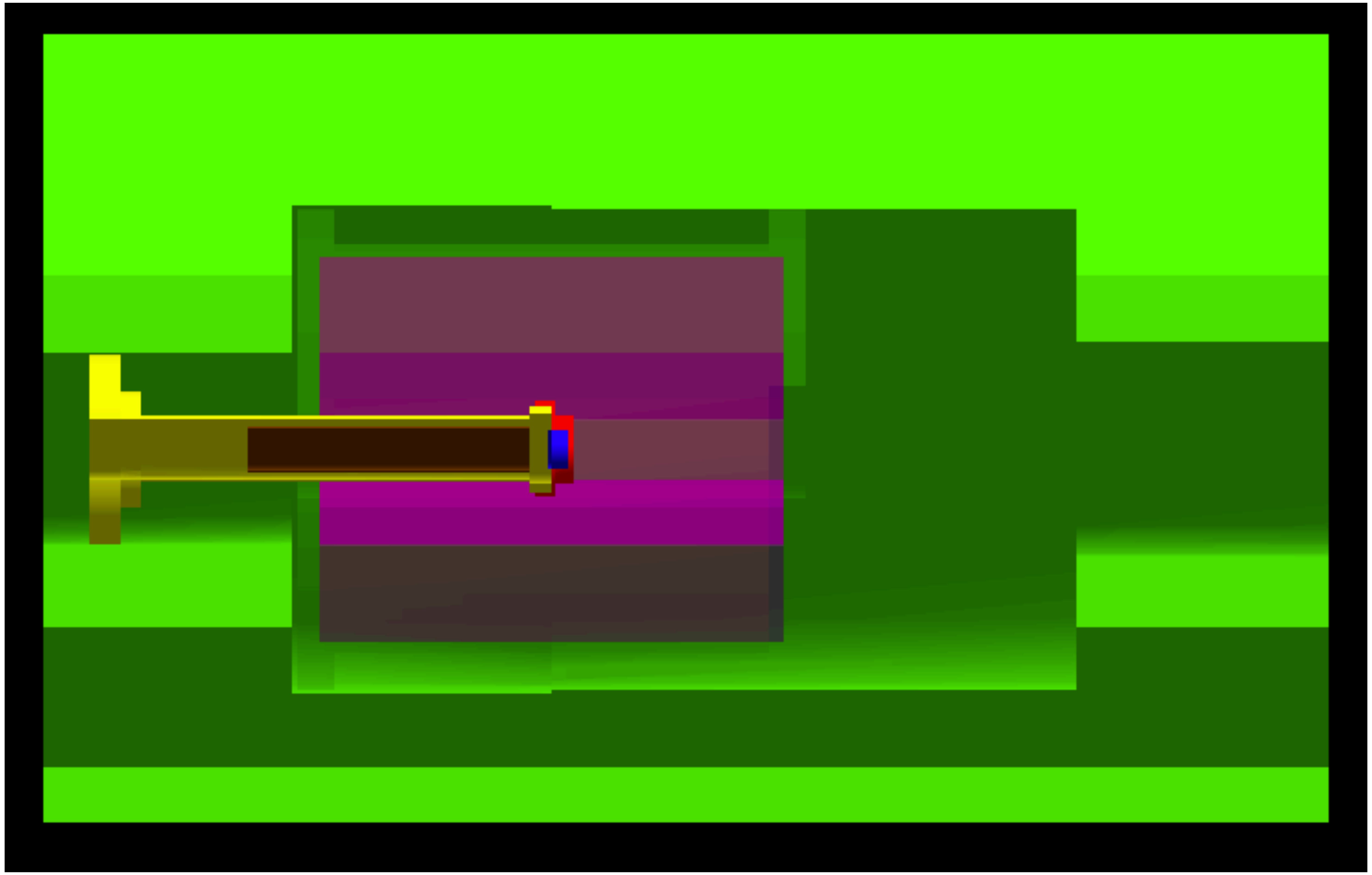
## Summary

Energies to be measured: 140, 110 keV

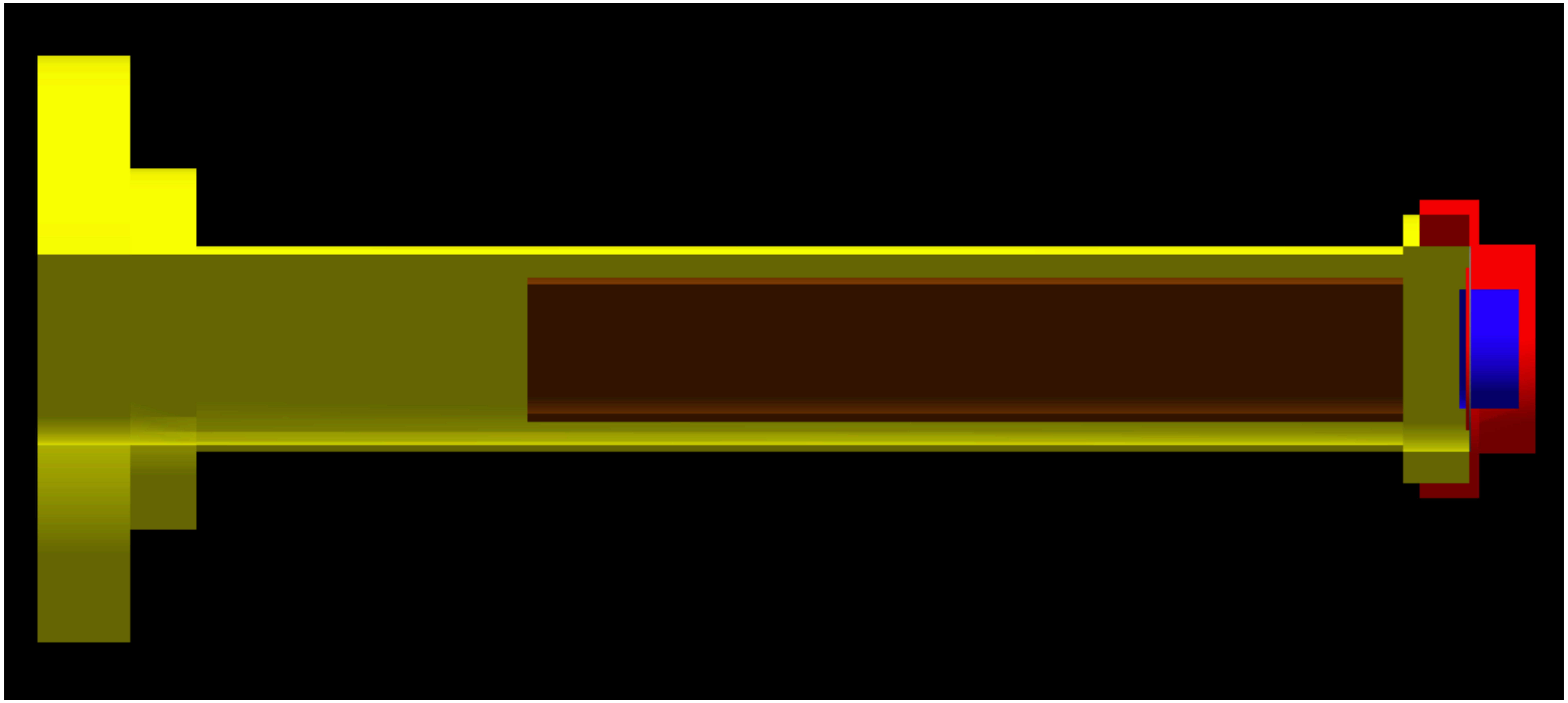
**Next steps with data analysis:**

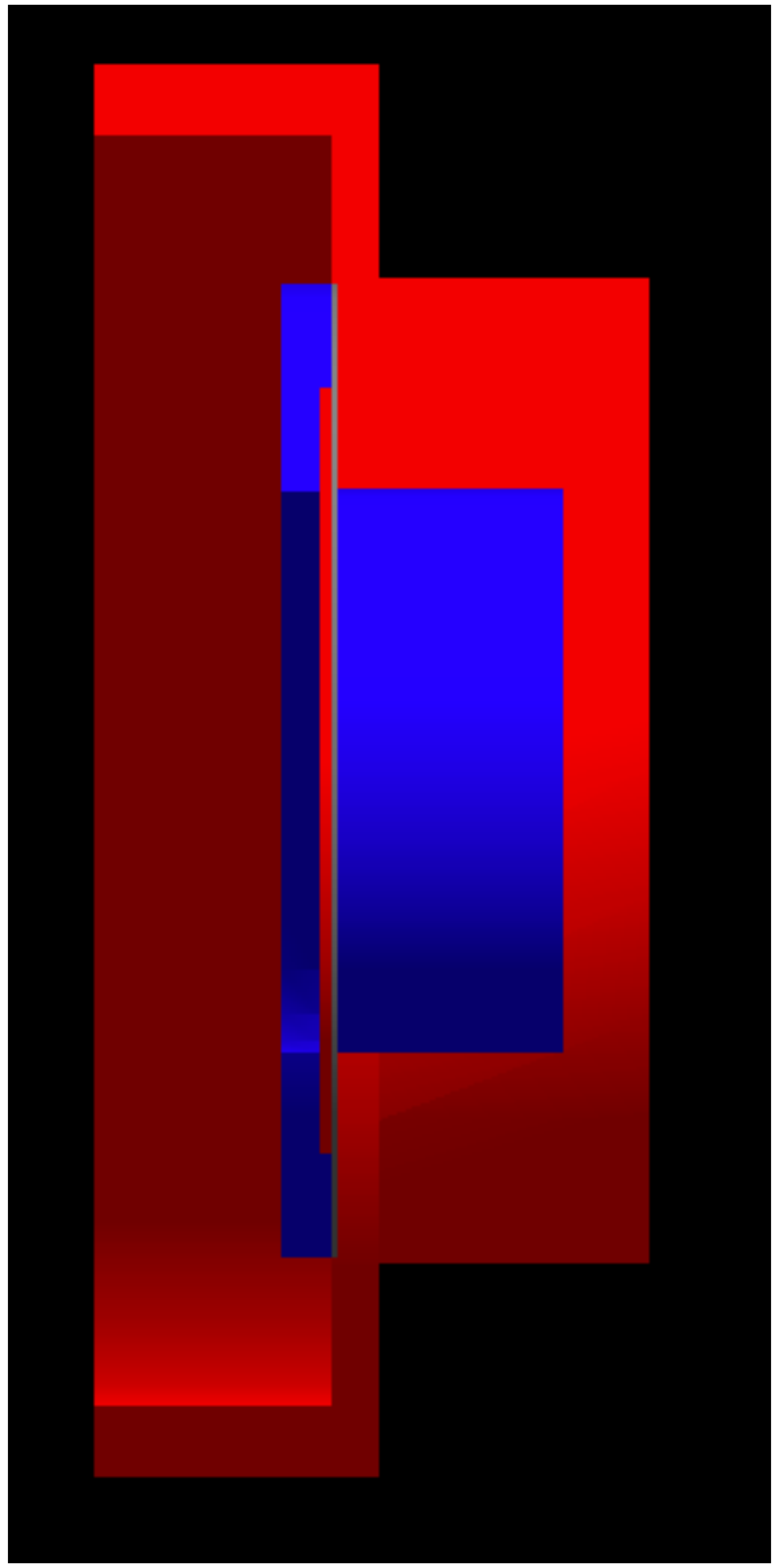
- Fine tune simulations
- Refine total S-factor calculation
- Run fits on gated spectra to evaluate branching's at all energies

# Monte Carlo geometry update



# Monte Carlo geometry update

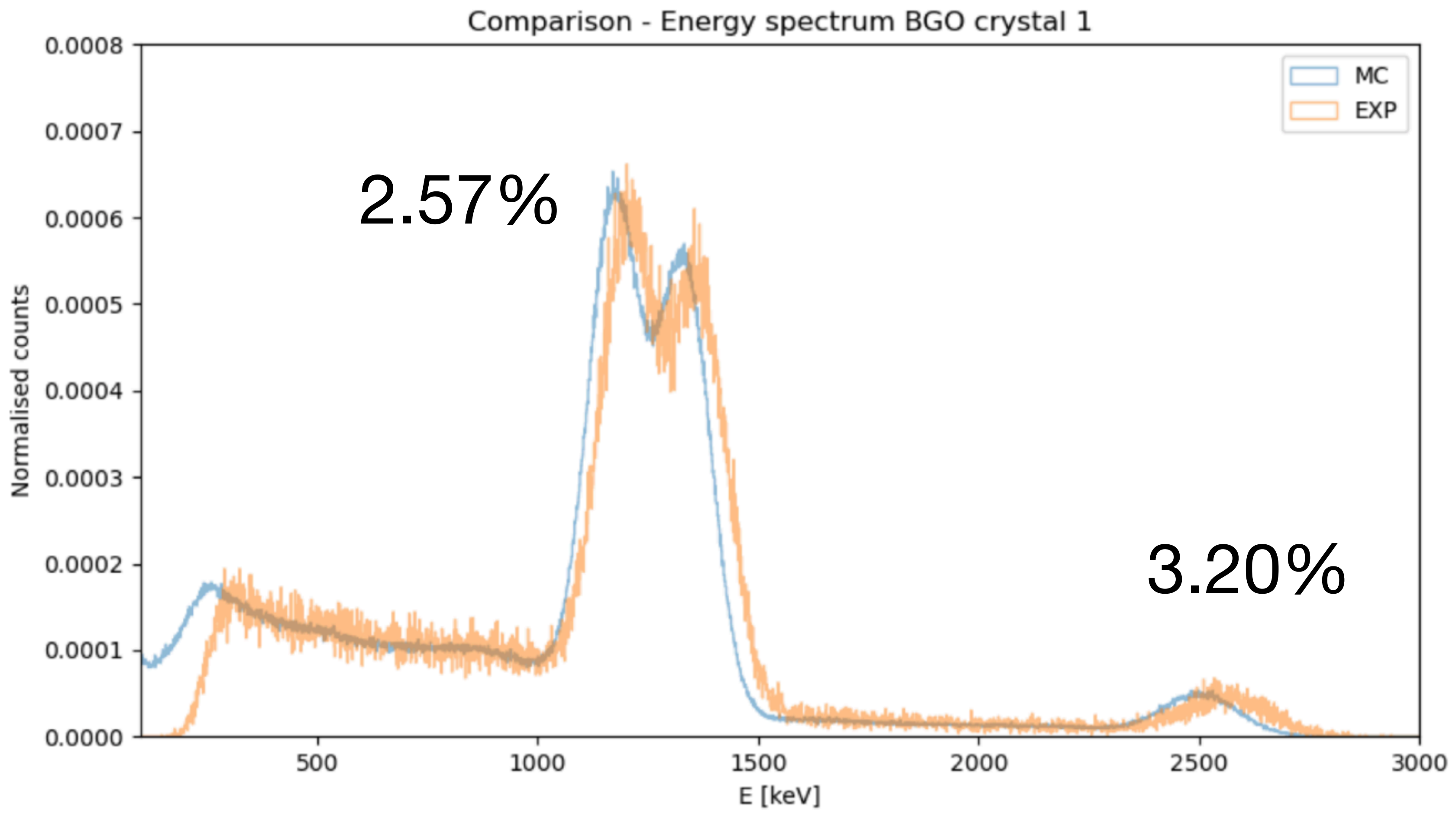


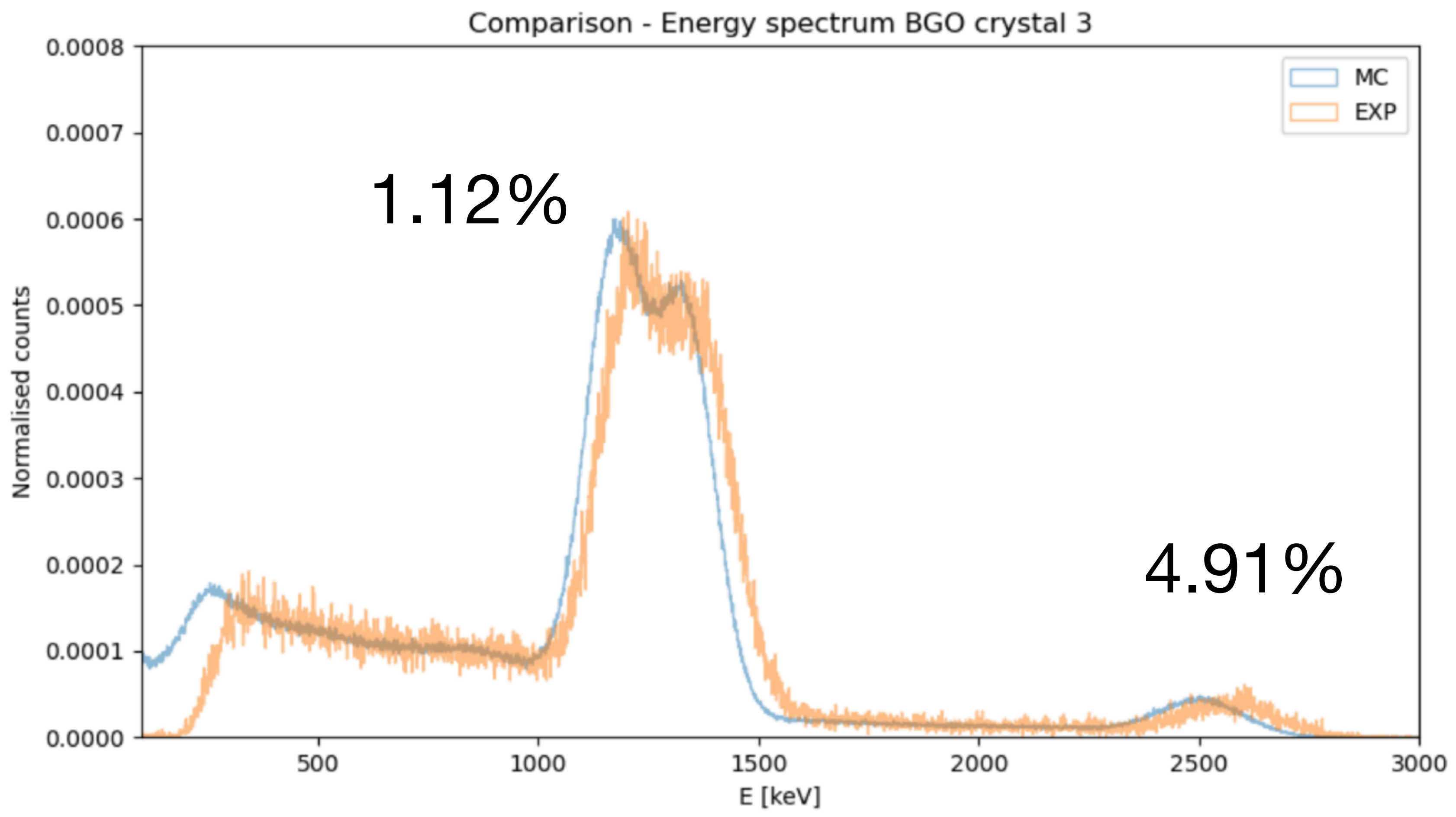


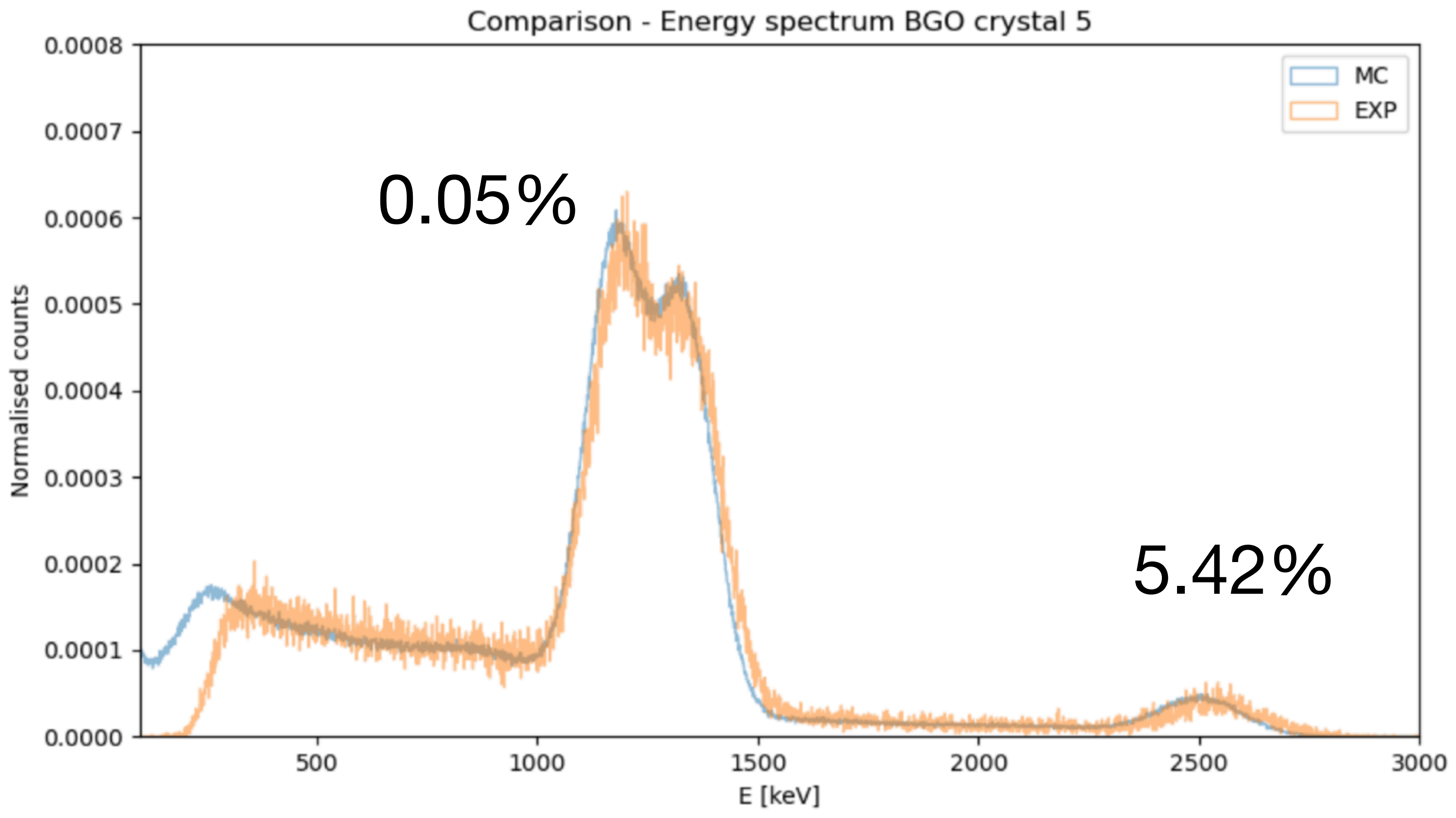
# Spectra - $^{60}$Co

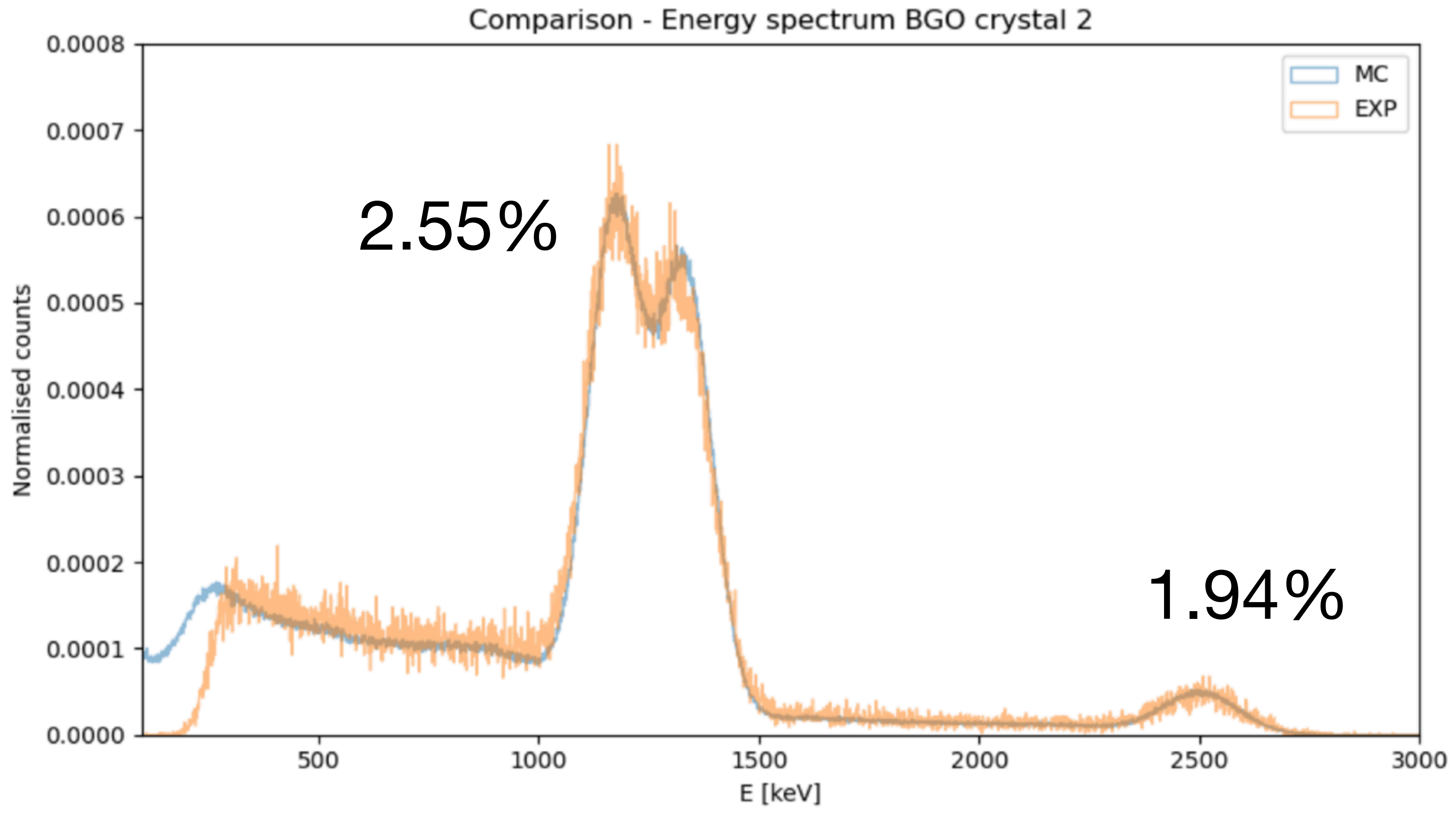
$$\frac{Area_{EXP} - Area_{MC}}{Area_{EXP}}$$

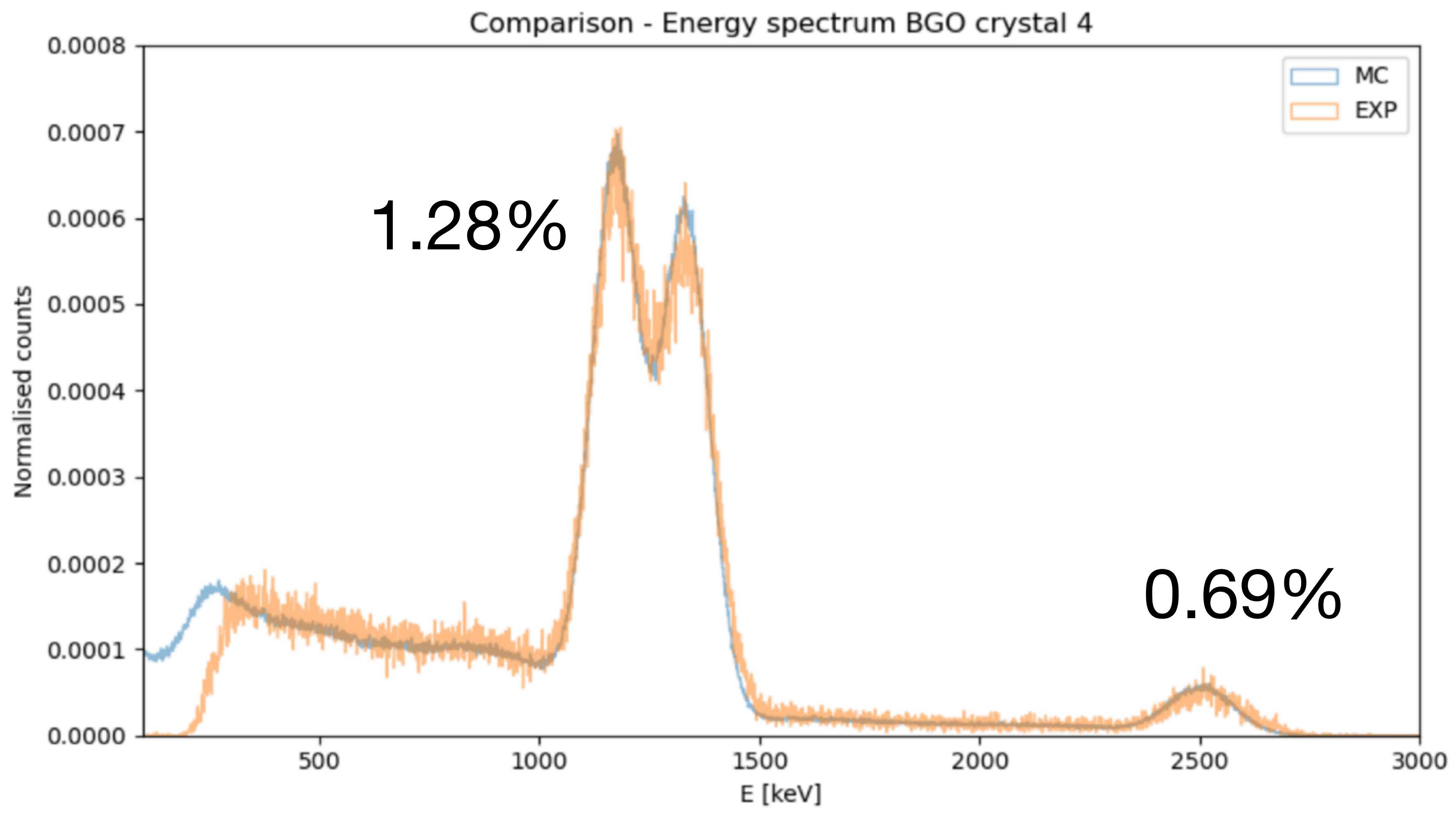
Spectrum integral in [850,1750] keV and [2300,2700] keV

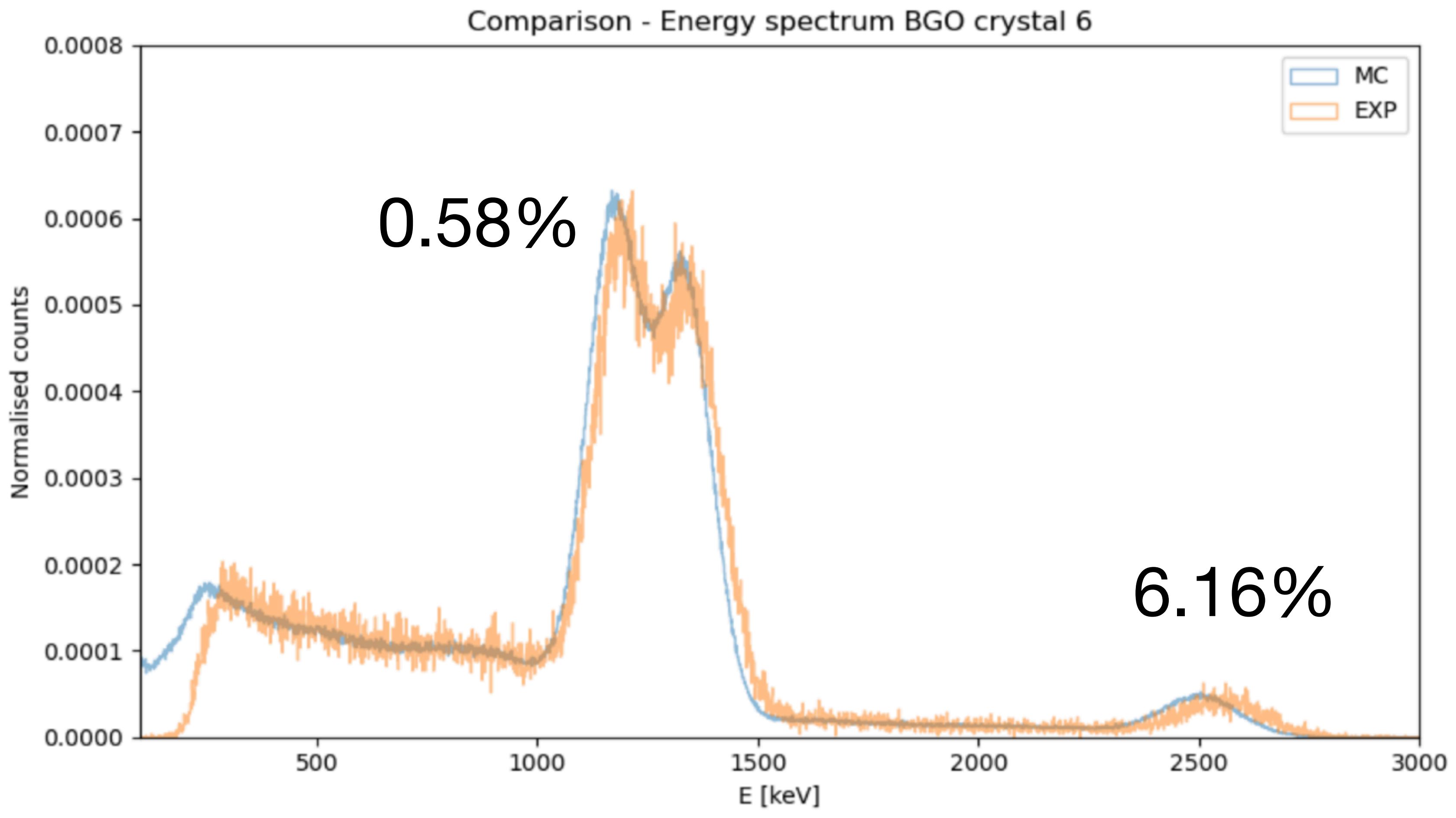


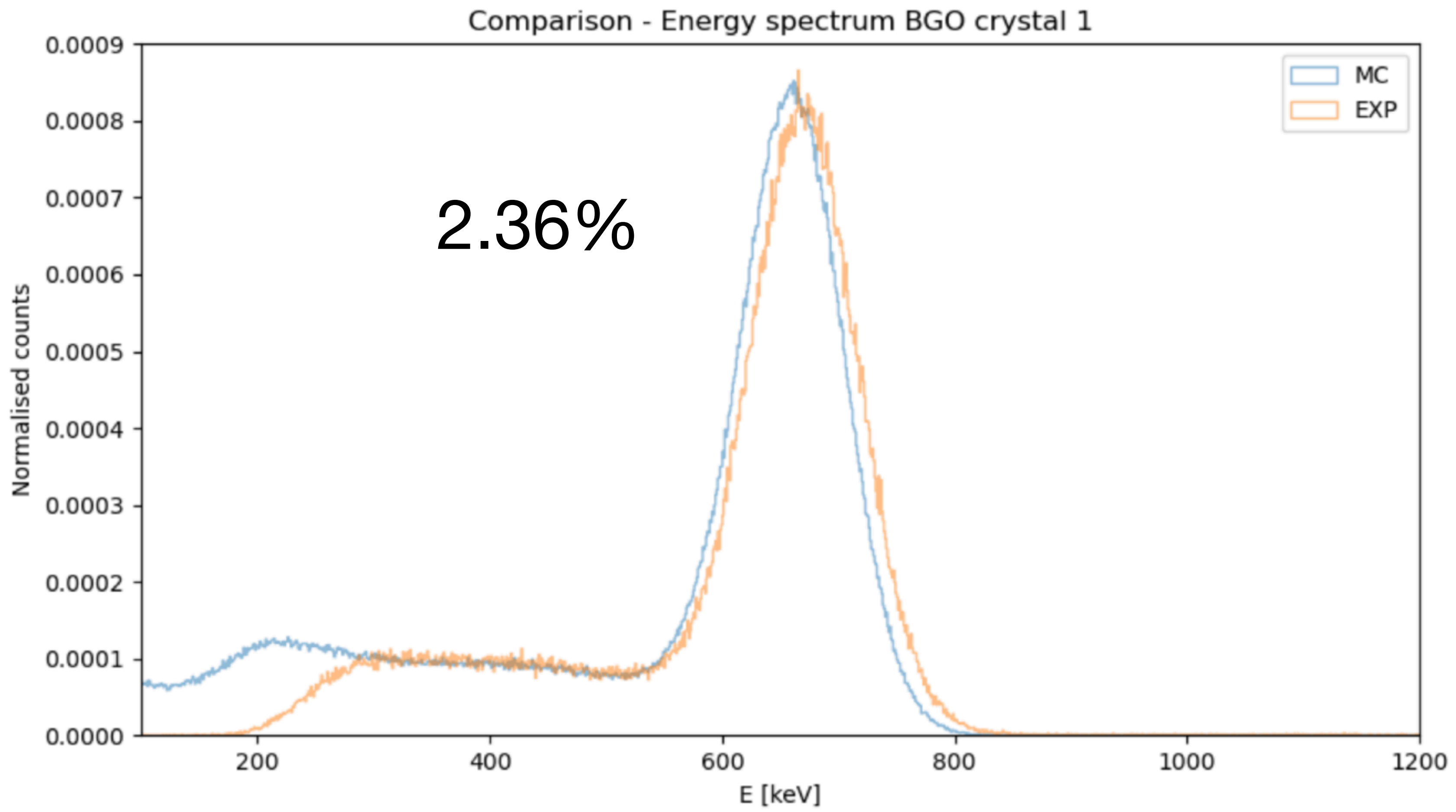



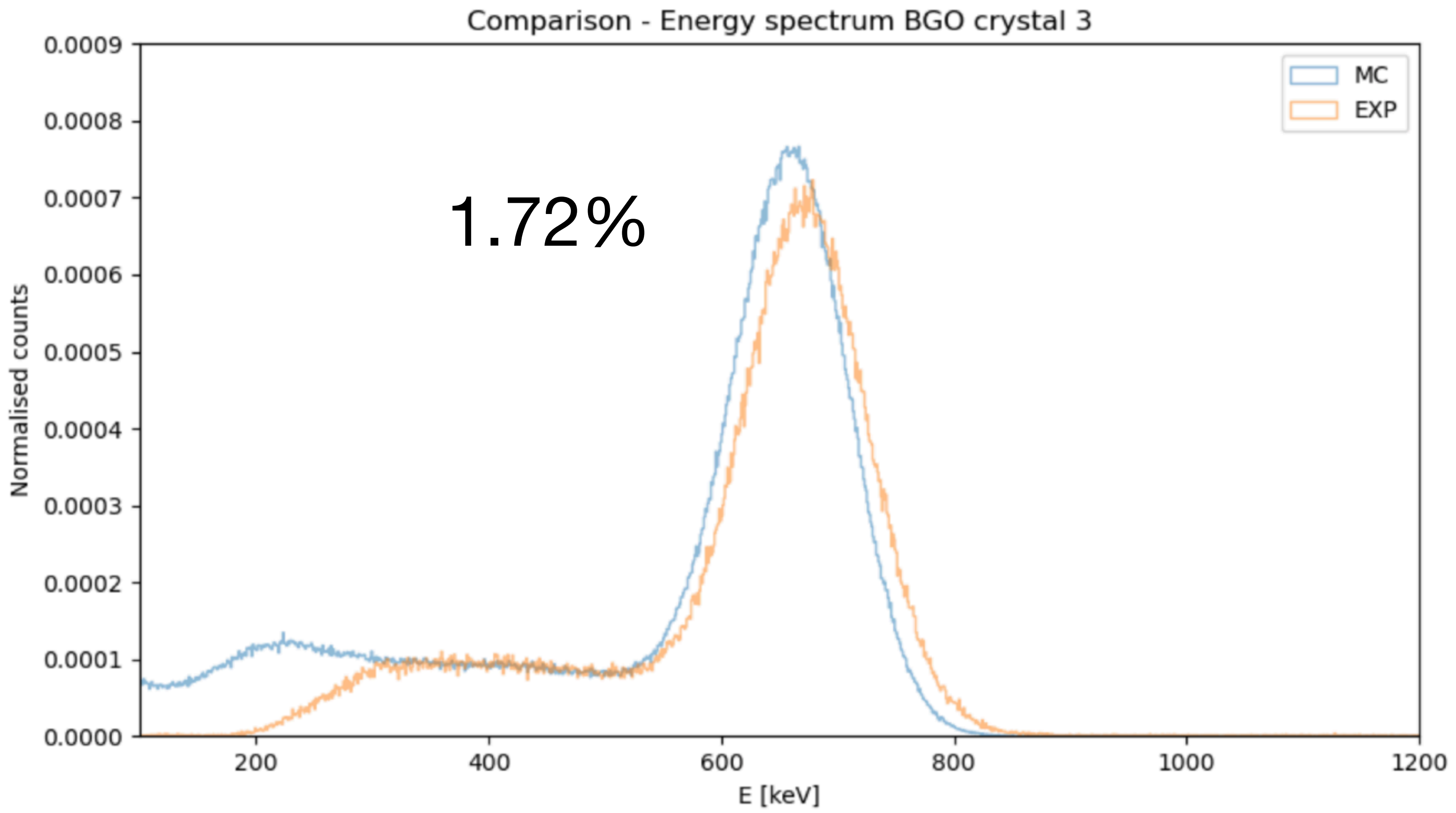



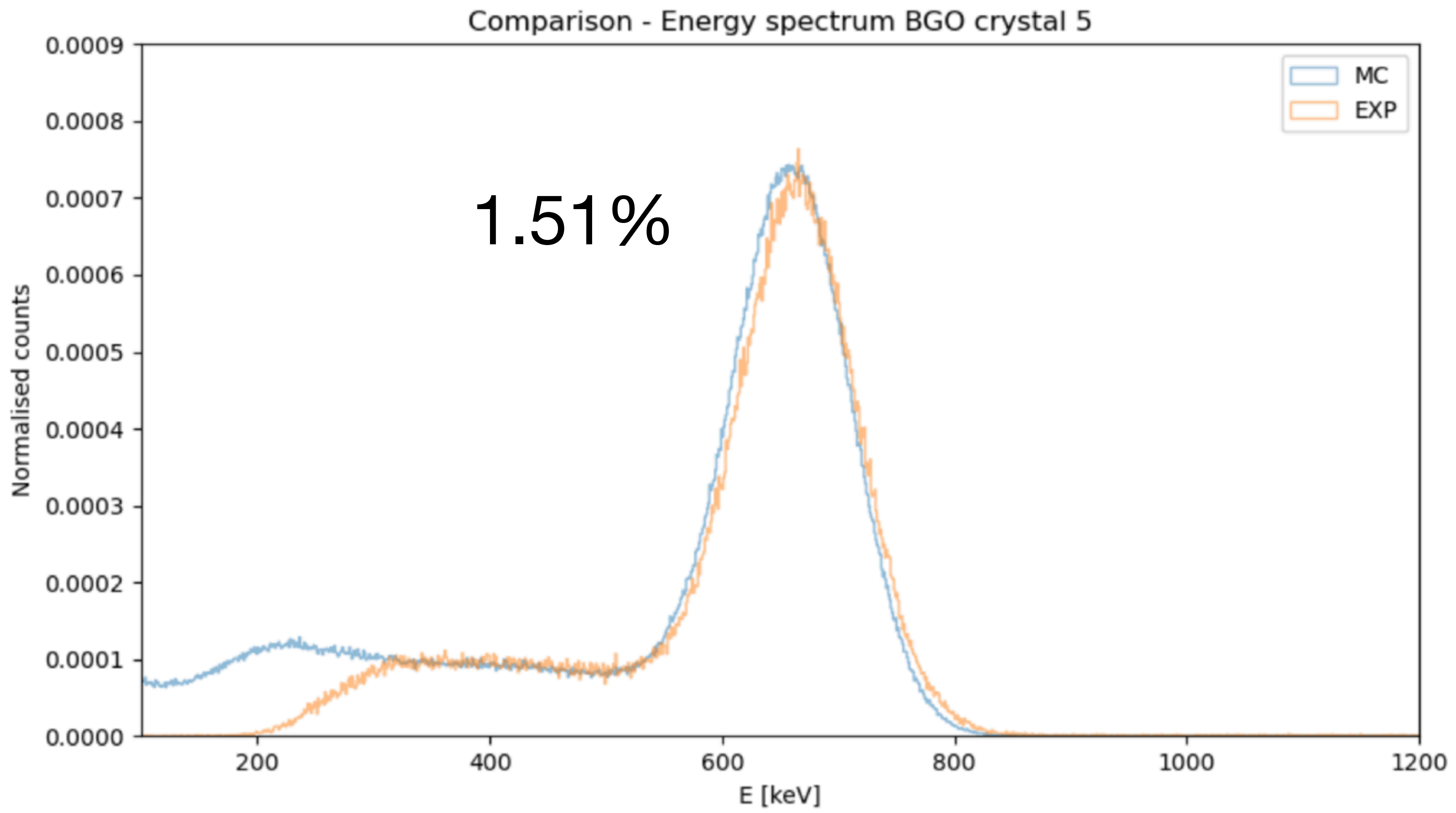
# Spectra - $^{137}Cs$

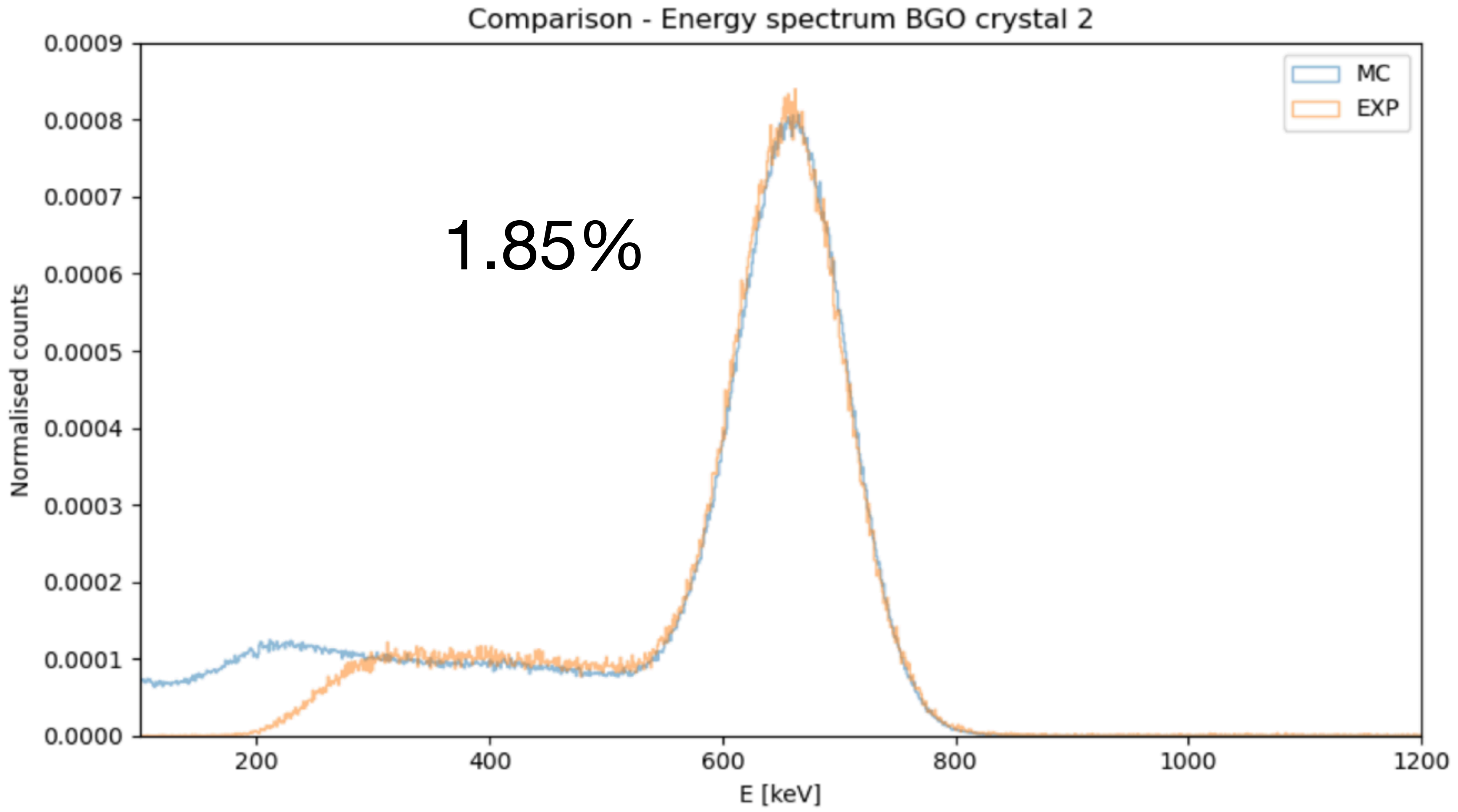
$$\frac{Area_{EXP} - Area_{MC}}{Area_{EXP}}$$

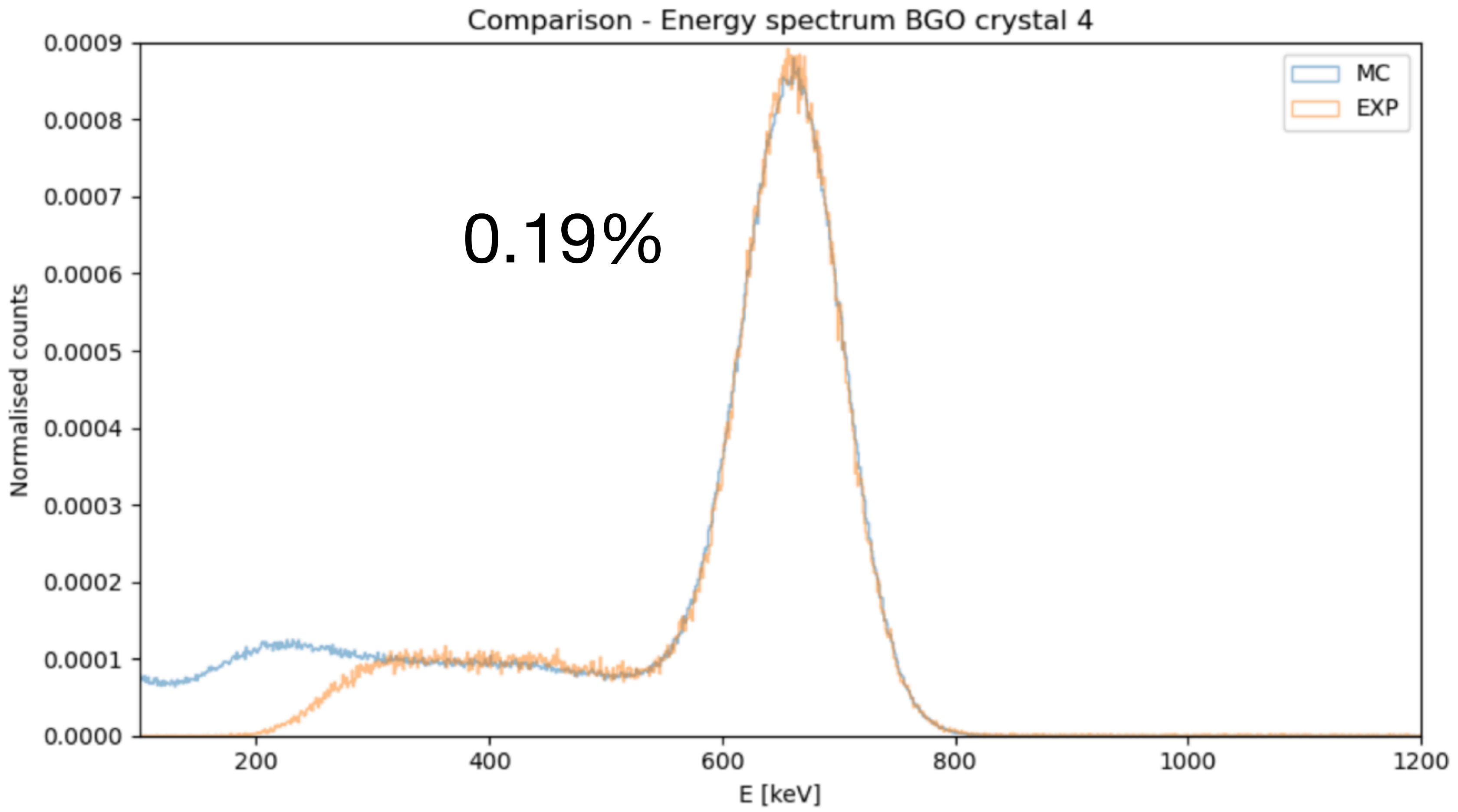
Spectrum integral in [460,860] keV

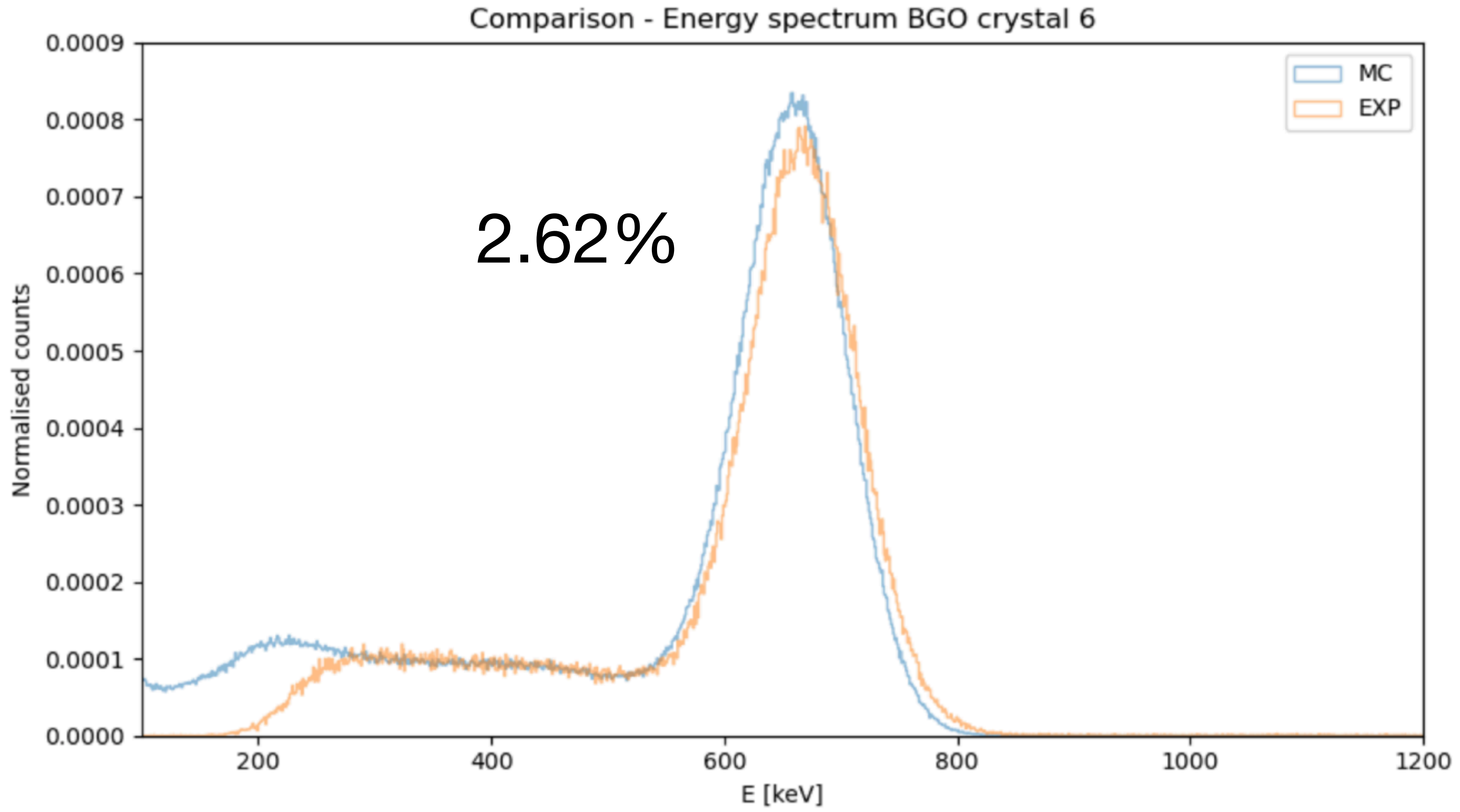


# What's next?

- Re-calibrate experimental energy spectra
- Calculate peak efficiency
- Simulate $^{14}N(p,\gamma)^{15}O$ resonance @ 278 keV