X17 analysis status

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Intense Meeting

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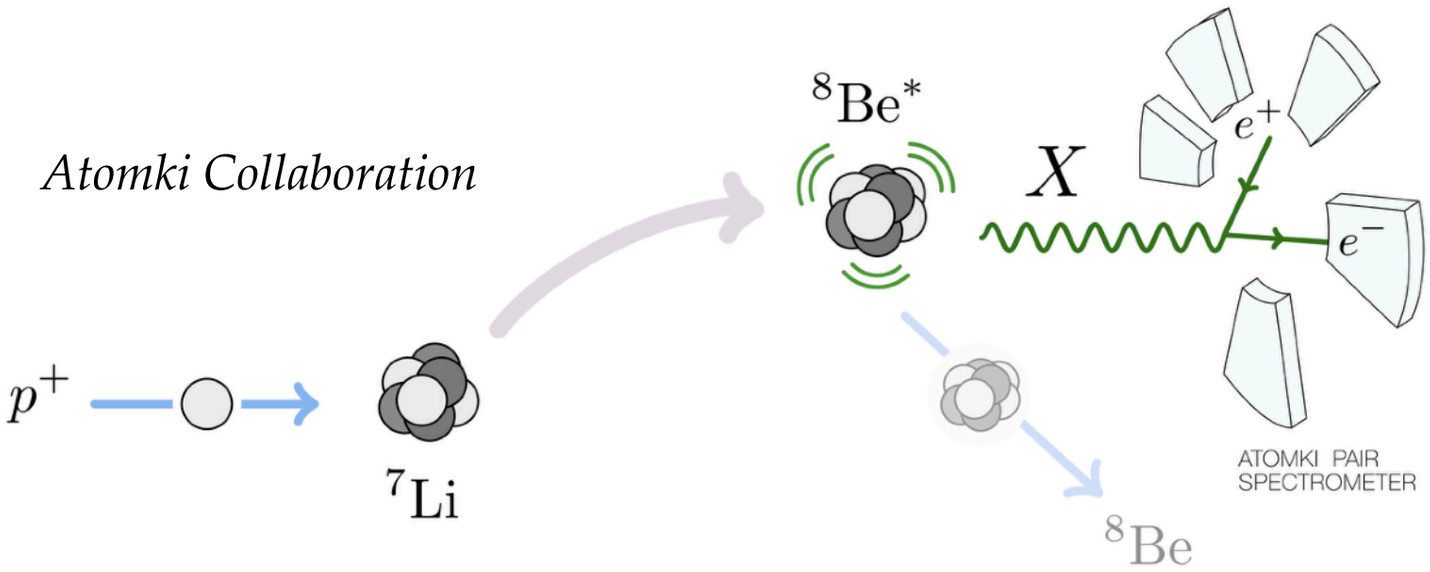
The Beryllium Anomaly

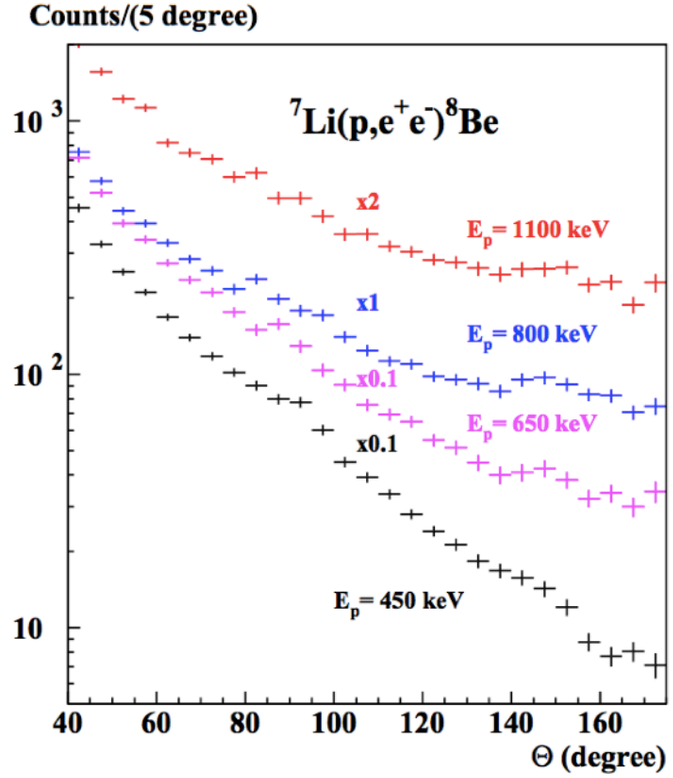
Atomki Collaboration

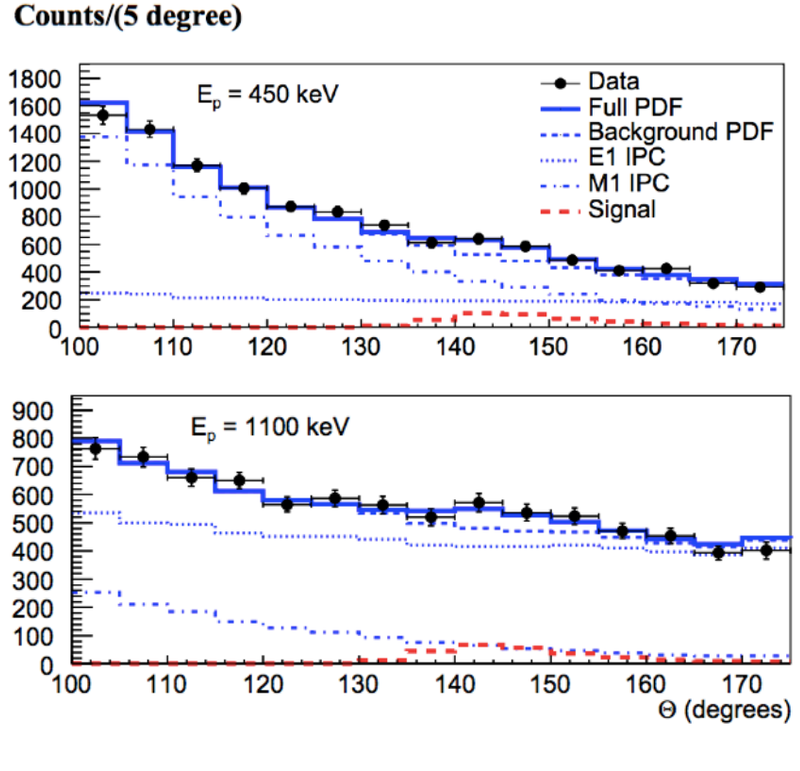


$^7\mathrm{Li}(p, e^+e^-)^8\mathrm{Be}$ studied at

$E_p = 450,\ 650,\ 800,\ 1100$ keV

→ e+/e- energy sum and angular correlation **Θ**





- Internal Pair Conversion (IPC) distribution shows excess at **Θ**~140° at several beam energies

→ decay of a light particle emitted during proton capture

→ best fit $m_X = 16.95\ \mathrm{MeV/c^2}$, $BR(X) = 6 \times 10^{-6}$

→ protophobic vector boson X17? mediator of a fifth force?

arXiv:2205.07744 | Phys. Rev. Lett. 116, 042501 | Phys. Rev. D 95, 035017

Status

- 2023 physics run **DONE**
- Reprocessing of all 2023 data **FINISHED**
- Definition of blinded signal region, sidebands and likelihood **DONE**
- Checks of data from AUX detectors (XEC, BGO, Brillance) **DONE**
- Sidebands checks **ONGOING: in this presentation**
- MC mass production **TO BE STARTED**
- Unblinding **TO BE DONE**

Outline

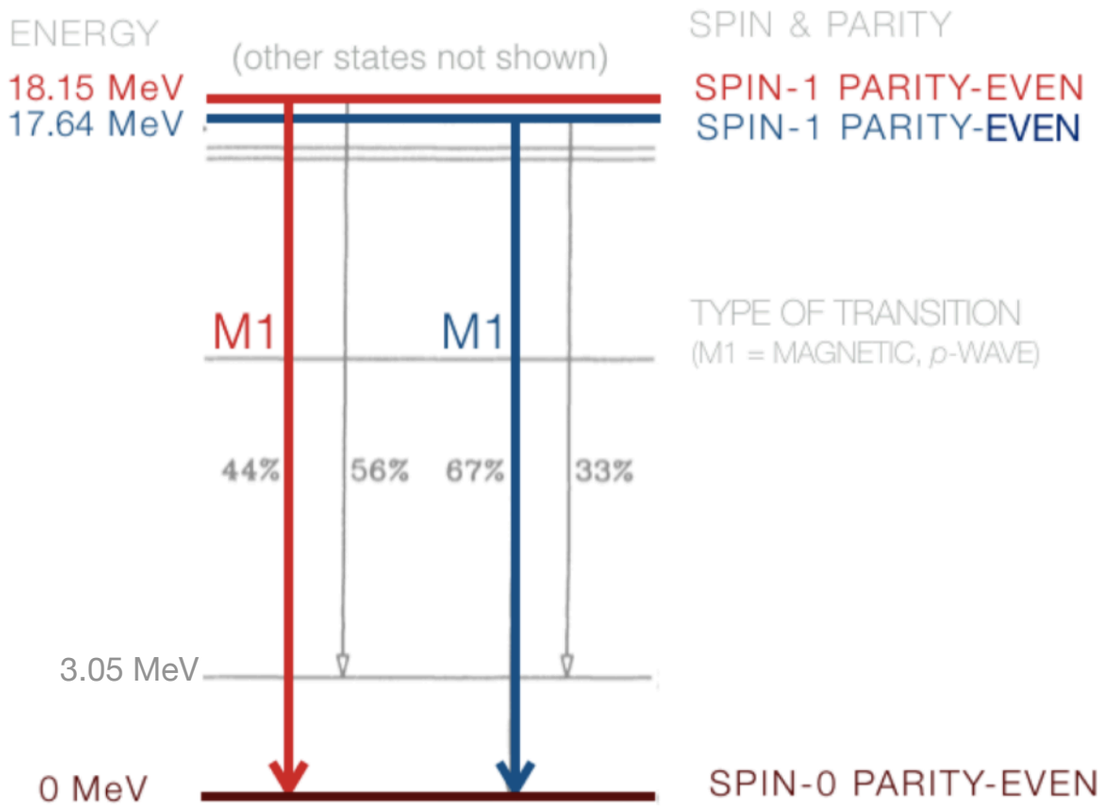
1) 2023 data are dominated by 17.6 MeV line. Evidence:

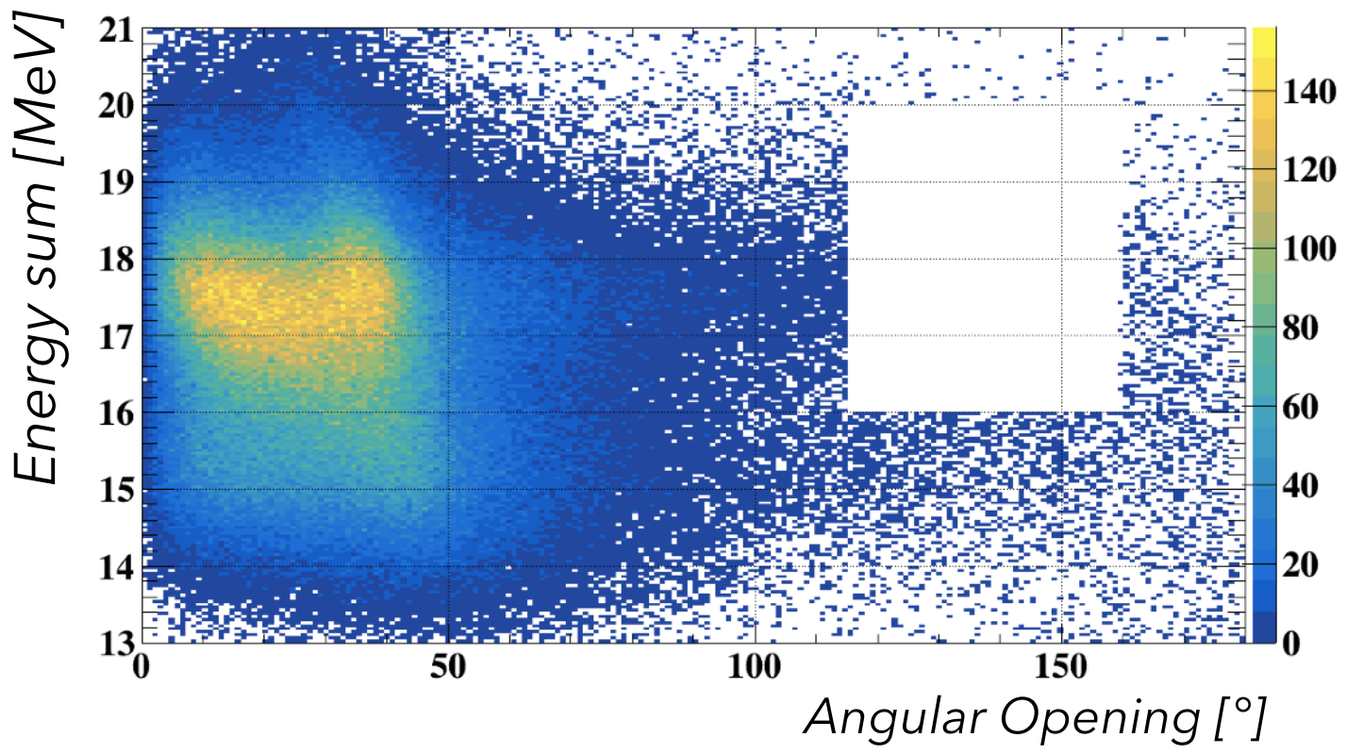
A) Target investigation
B) BGO analysis
C) Angular opening shape

2) Energy scale

3) Blinding and sidebands comparisons

4) Next steps



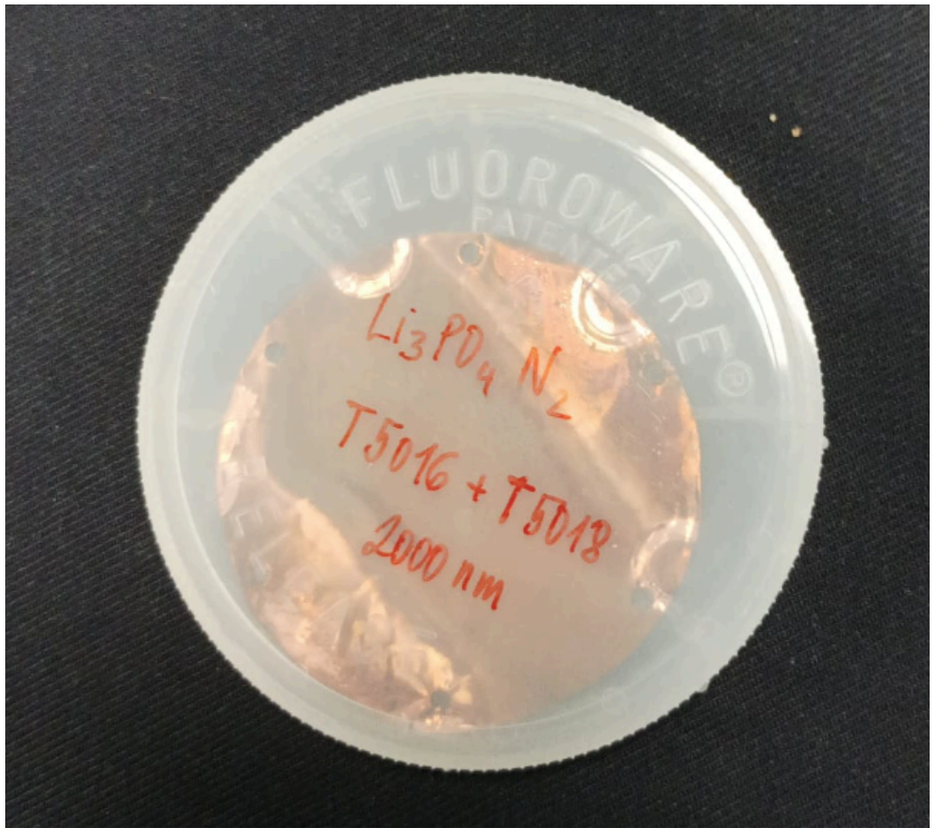


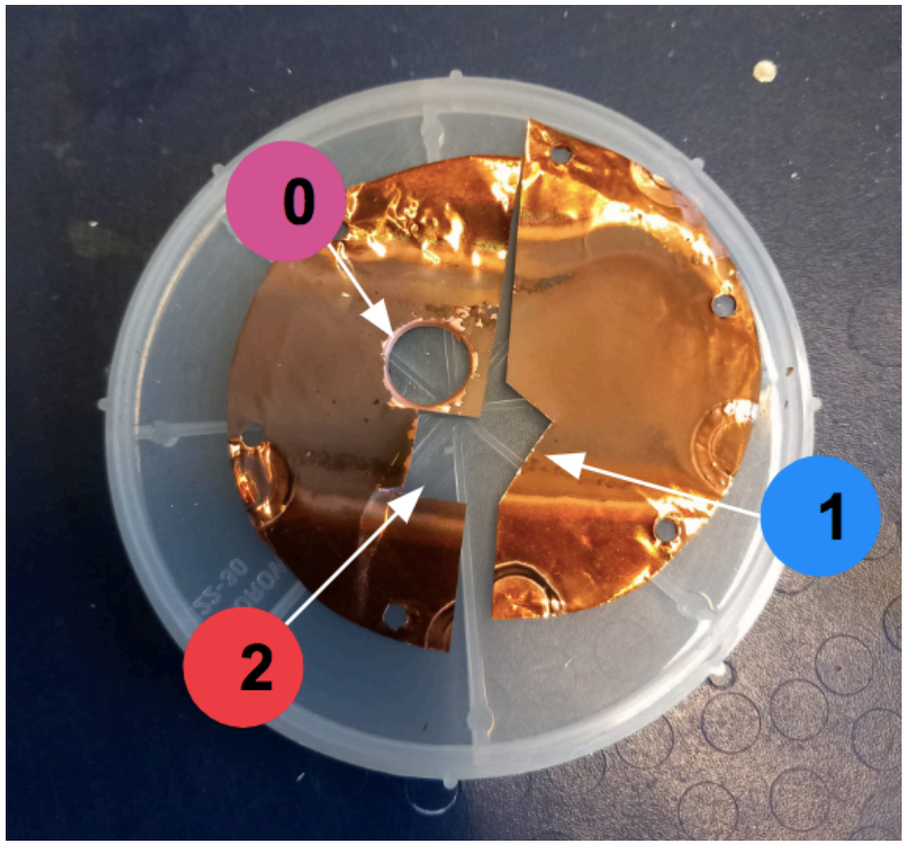
1) Data dominated by 17.6 MeV line

A) Target investigation

Target investigation by PSI group

- B. Lelotte & V. Siller at PSI investigated **one of the produced « 2um » LiPON targets**
- Not the 2023 physics run target but should be same quality and thickness

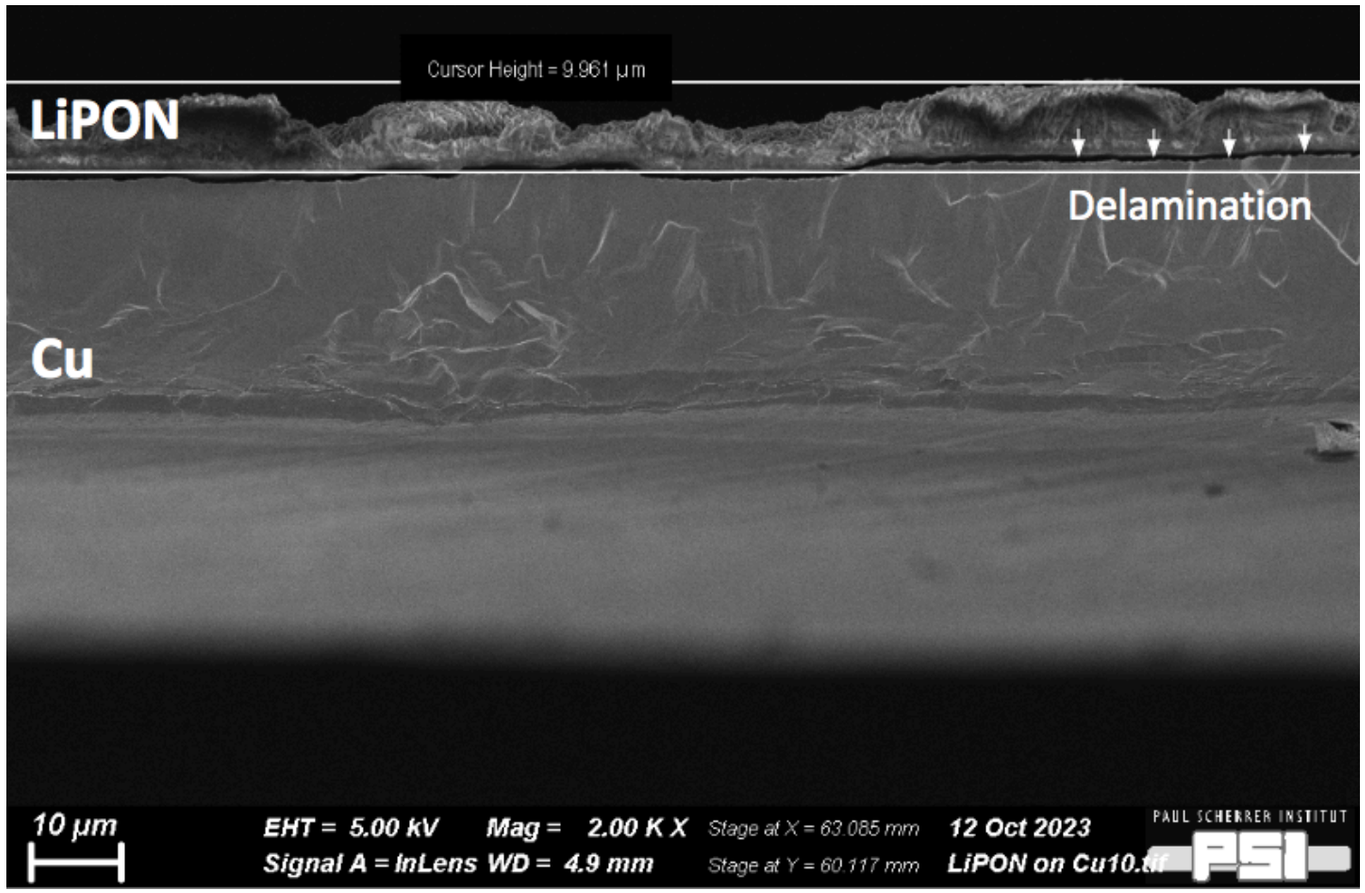


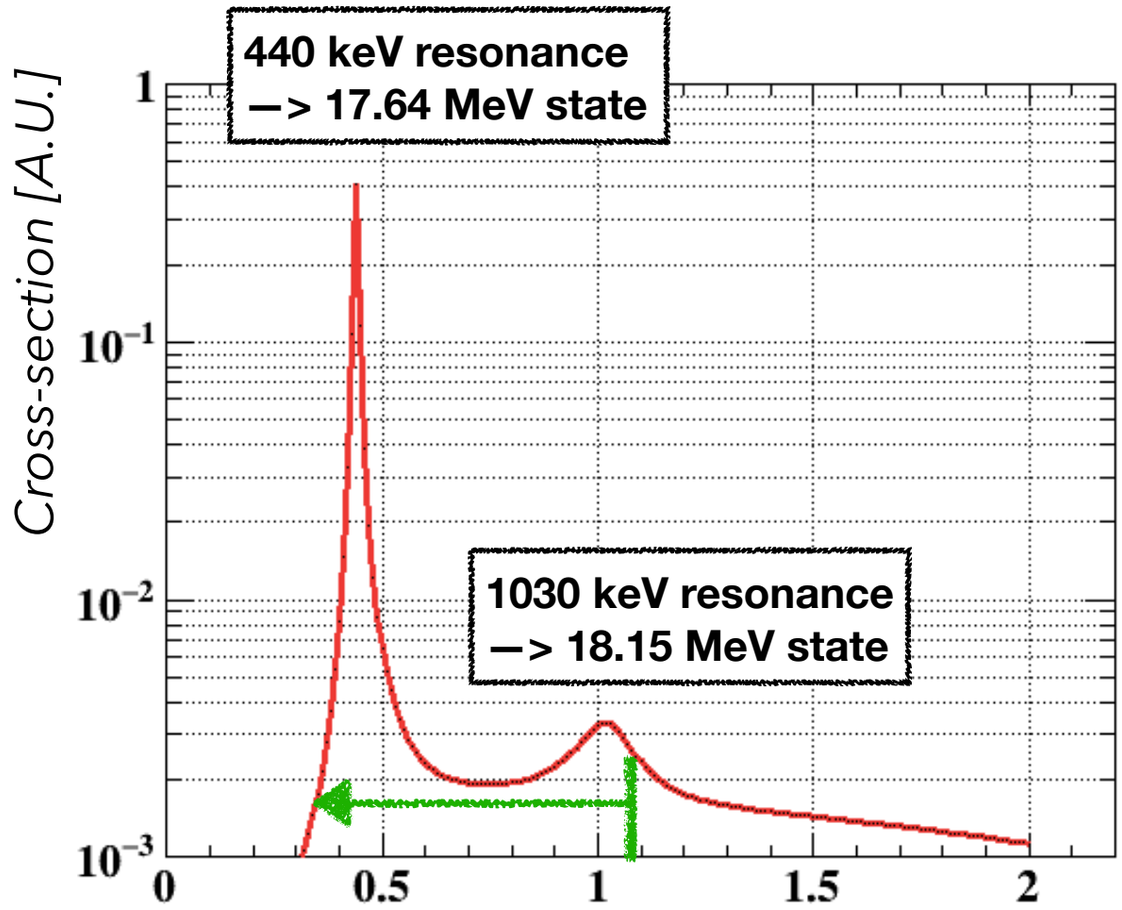


- Scanning Electron Microscopy (SEM)
- Energy-Dispersive Xray analysis (EDX)

0: Puncher (strong delamination)
1: Scissor
2: Scissor then milling

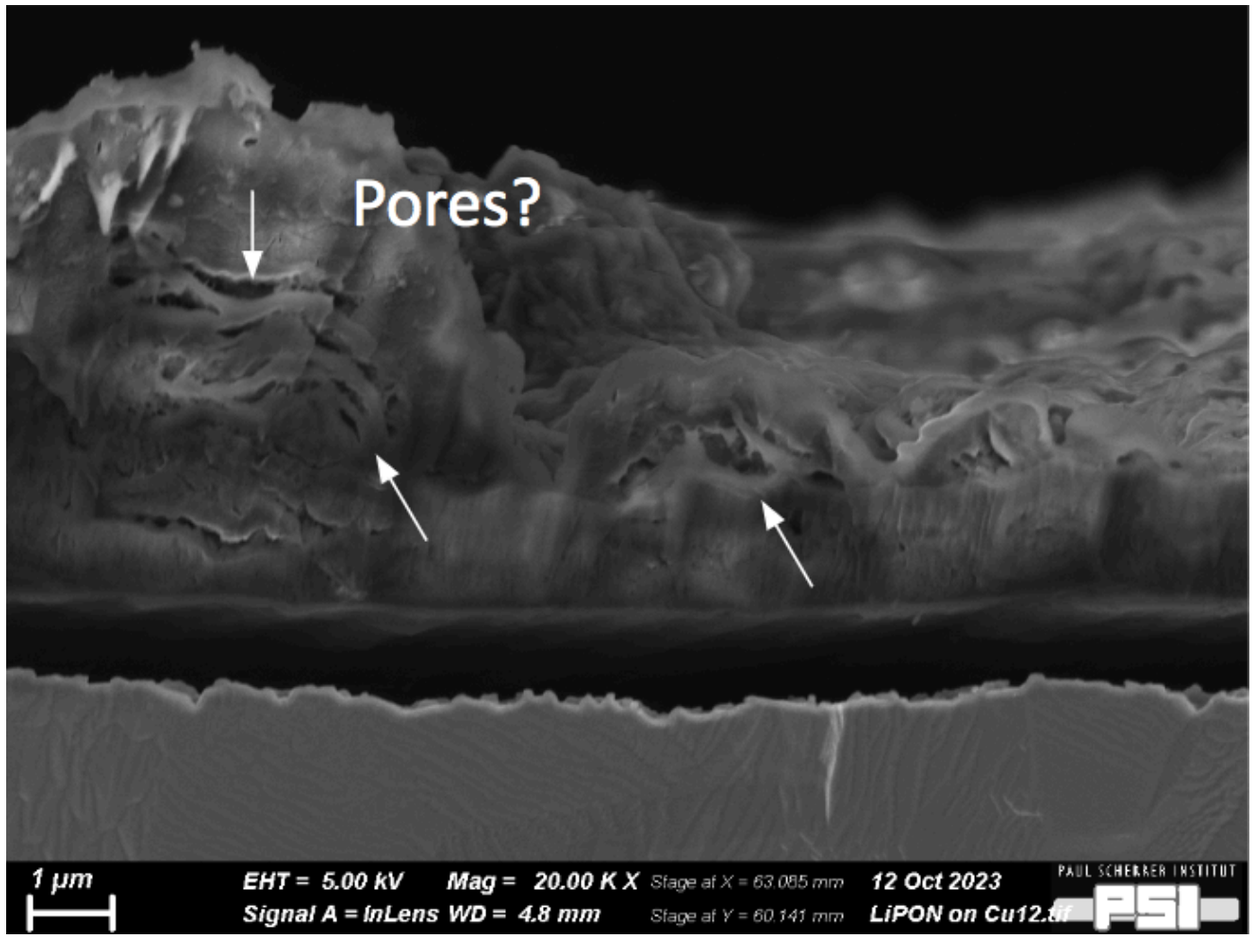
Target investigation by PSI group

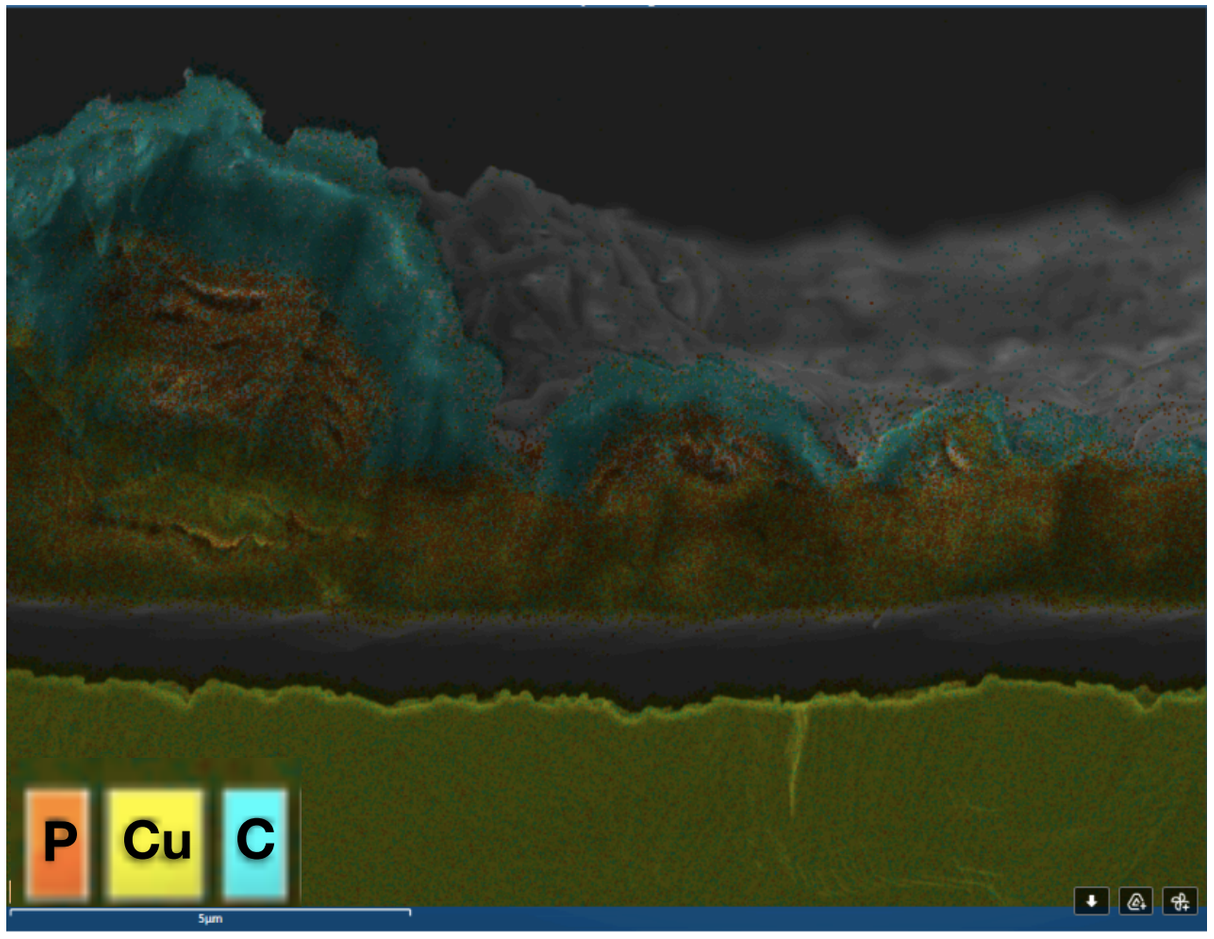




- Peak-to-peak **thickness = 10 microns**. **Instead of 2 microns** expected!
- Protons can lose enough energy to scan the (strong) 440 keV resonance

Target investigation by PSI group





- Non-uniform LiPON layer
- Porous structure

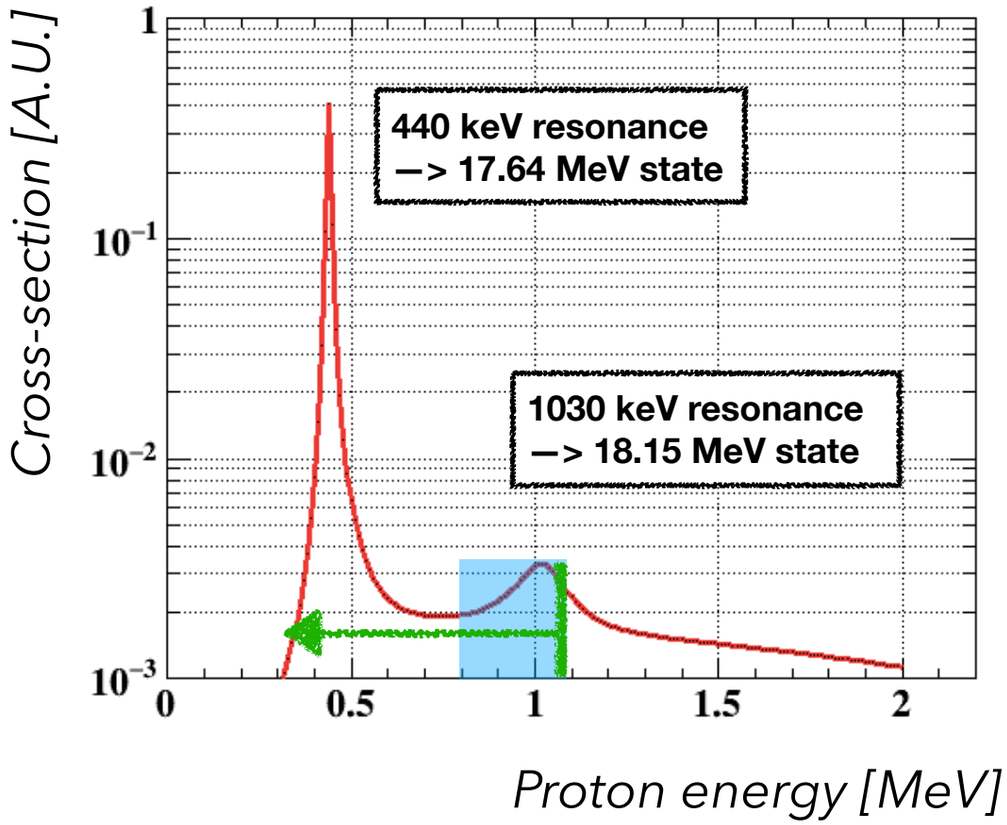
- Cu in LiPON
- $LiCO_3$ on the surface due to contact with air

→ **Poor quality** target. Hard to reproduce in MC.

Target investigation by Roma3 group

- Group in Roma Tre University investigated an equivalent « 2 um » target with Secondary Ion Mass Spectrometry (SIMS)
- They conclude:
  - → Average thickness between 5 um and 7 um
  - → Large roughness
  - → Non-uniformity

- With such thickness, **17.6 MeV photons can be produced**



In these conditions,
18.15 MeV line represents:

10% of total production

1) Data dominated by 17.6 MeV line

B) BGO analysis

BGO analysis

- Due to non-uniformity of LiPON layer, relative position of beamspot on target can have large impact. May23 XEC data had target rotated towards XEC.
  → Not representative of CDCH data config.

- Let's have a look at **BGO data** instead. All runs at 500 keV and 1080 keV acquired back-to-back were analyzed:

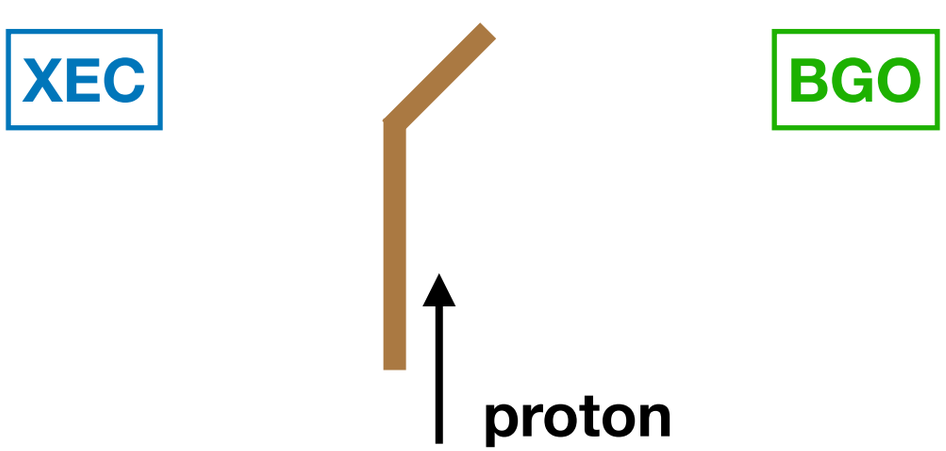
1) Fit of **500 keV data with (G15+G17.6)**.
2) **Mean** and **width of 17.6 MeV** line is **fixed**.

Widths of 17.6 and 18.1 MeV line are considered equal.

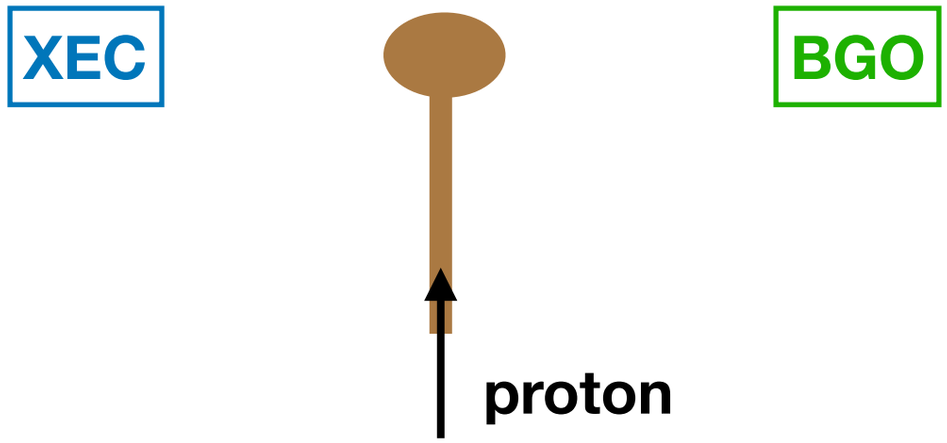
3) Fit of **500 keV** and **1080 keV** data with **(G15+G17.6+G18.1)**

Two configuration for these datasets

Rotated (towards BGO)

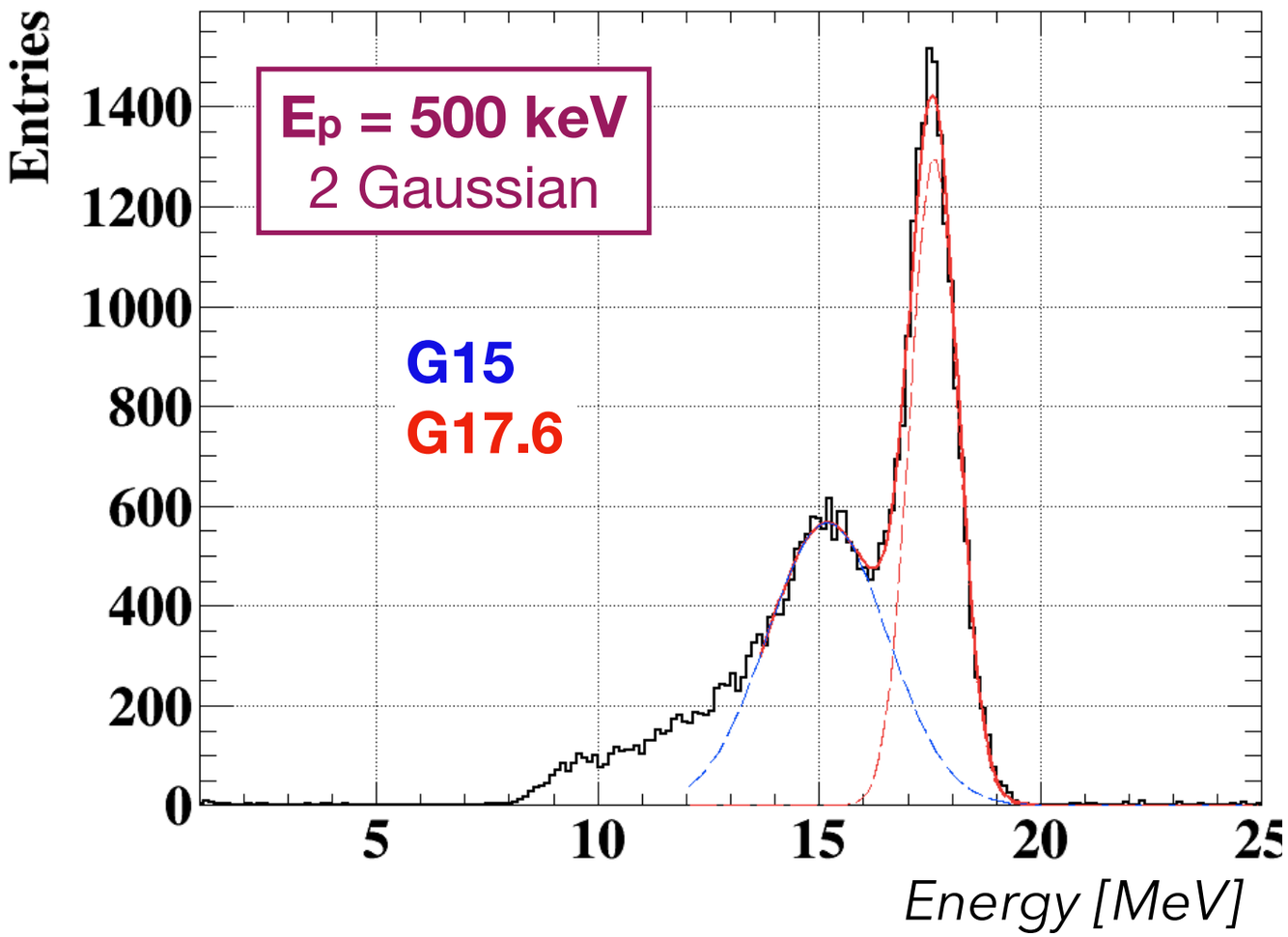


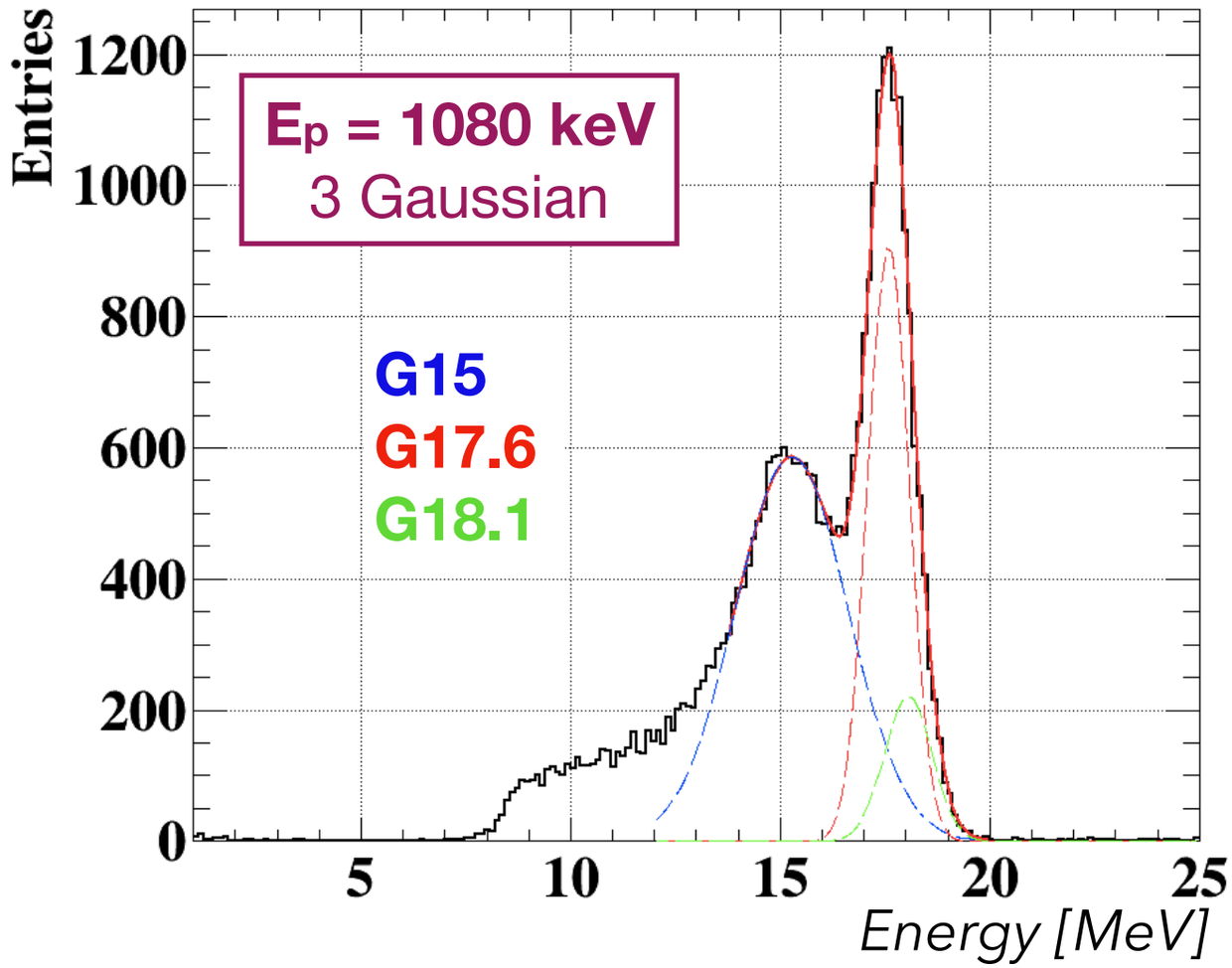
Not rotated (same as physics run)



BGO analysis

Example





Position and **width of 17.6 MeV** line **fixed from 500 keV data**

Fraction of 18.1 MeV line then estimated

Target investigation by Rome3 group

All sets back-to-back were analyzed. Unfortunately, only one set in physics configuration.

Fraction of 18.1 MeV line	LiPON #1 Rotated trgt BGO (z,phi) = (0,0°) 28 Feb	LiPON #1 Rotated trgt BGO (z,phi) = (0,-25°) 1st Mar	LiPON #1 Rotated trgt BGO (z,phi) = (0,+25°) 1st Mar	LiPON #1 Rotated trgt BGO (z,phi) = (0,0°) 1st Mar	LiPON #1 Non-rotated trgt BGO (z,phi) = (0,0) 28 Feb
Ep = 1080 keV	16 (+/– 2) %	3 (+/– 1) %	<1 %	5 (+/– 1) %	7 (+/– 1) %

Target was rotated. Not representative of physics run. To estimate precision of method

Physics run configuration

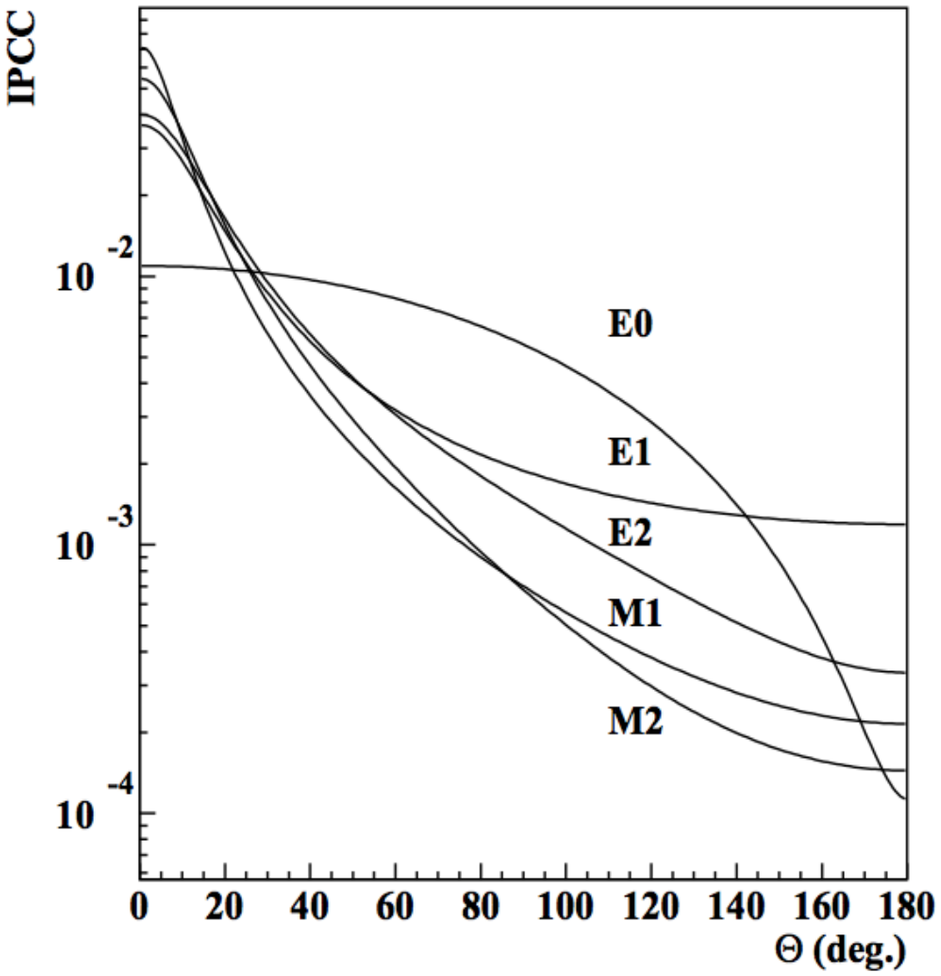
- From these numbers, fraction of 18.1 MeV line in physics data close to **10%**
- Consistent with target analysis

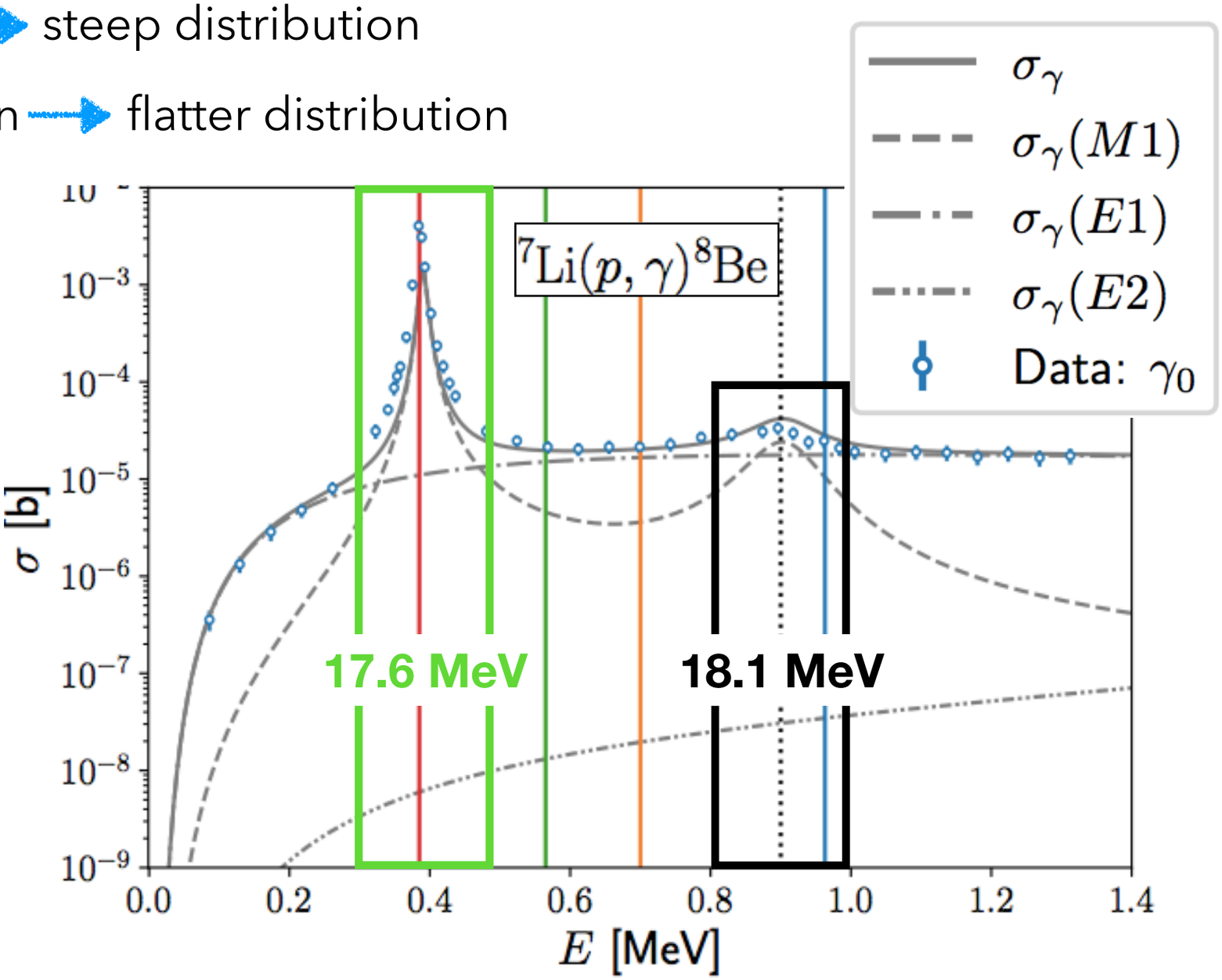
1) Data dominated by 17.6 MeV line

C) Angular opening shape

Angular opening shape

- IPC angular opening distribution is very dependent on the multipolarity of the transition
- M1 from resonant production → steep distribution
- E1 from non-resonant production → flatter distribution

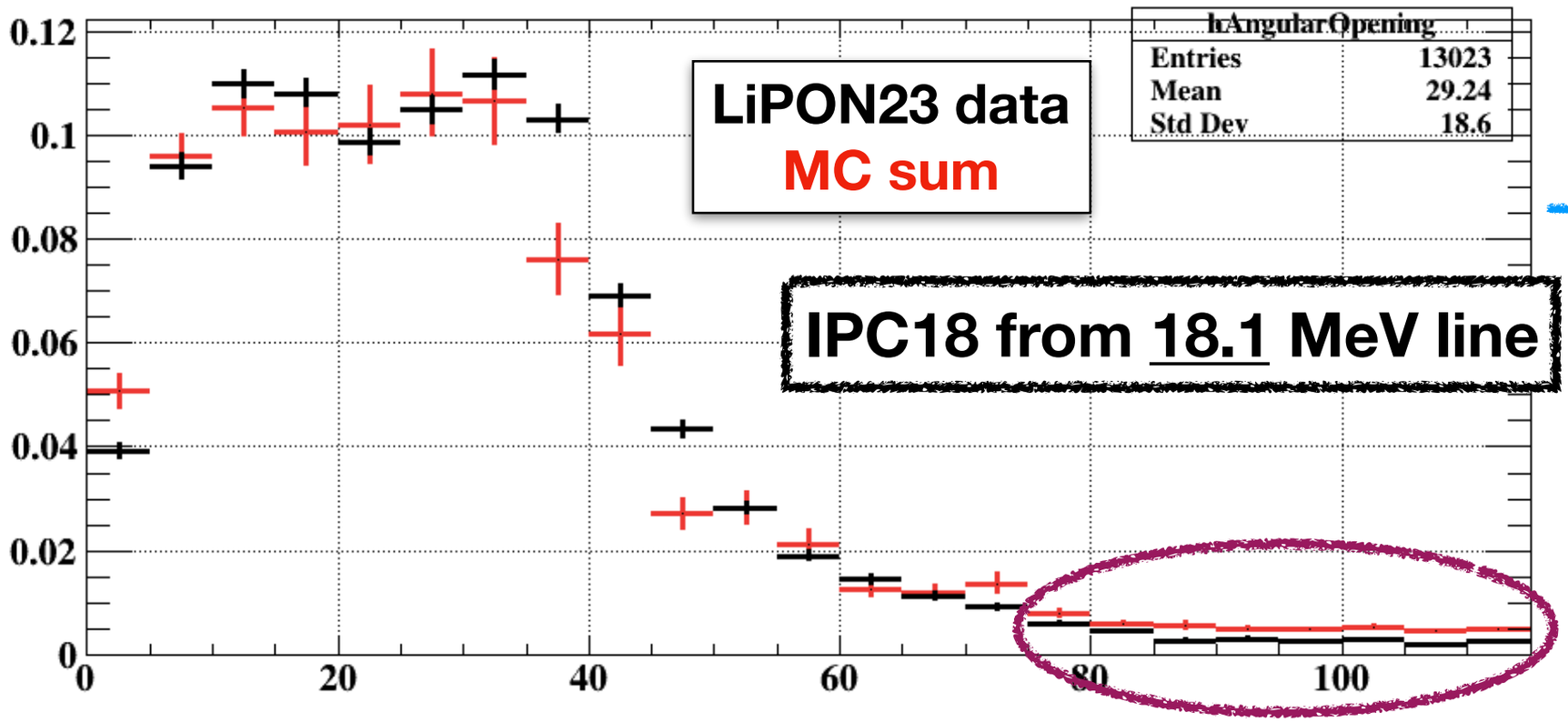




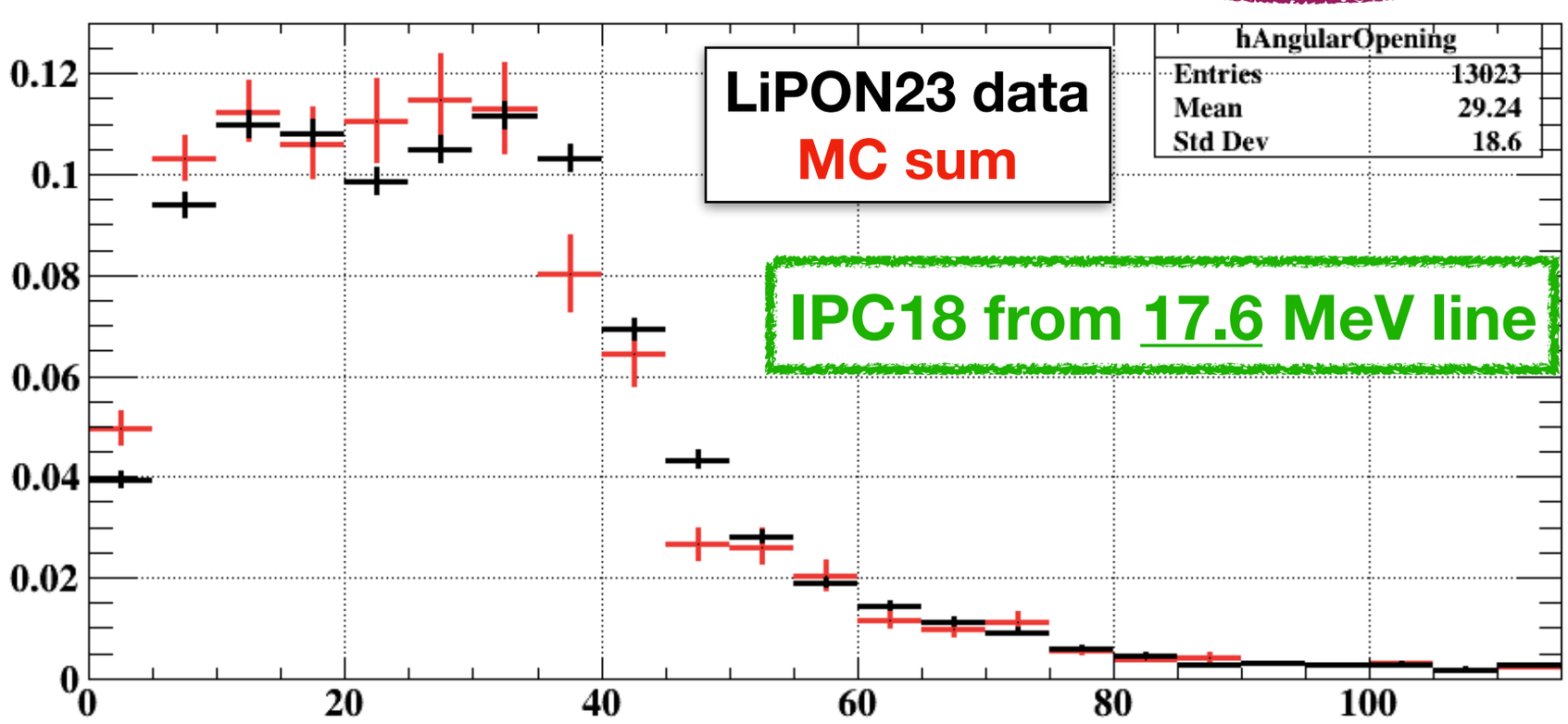
- **17.6 MeV** line is dominated by M1
- **18.1 MeV** line have similar amounts of E1/M1

→ 17.6 MeV IPC is steeper

Angular opening shape



→ overestimate at large angles with 18.1 MeV IPC

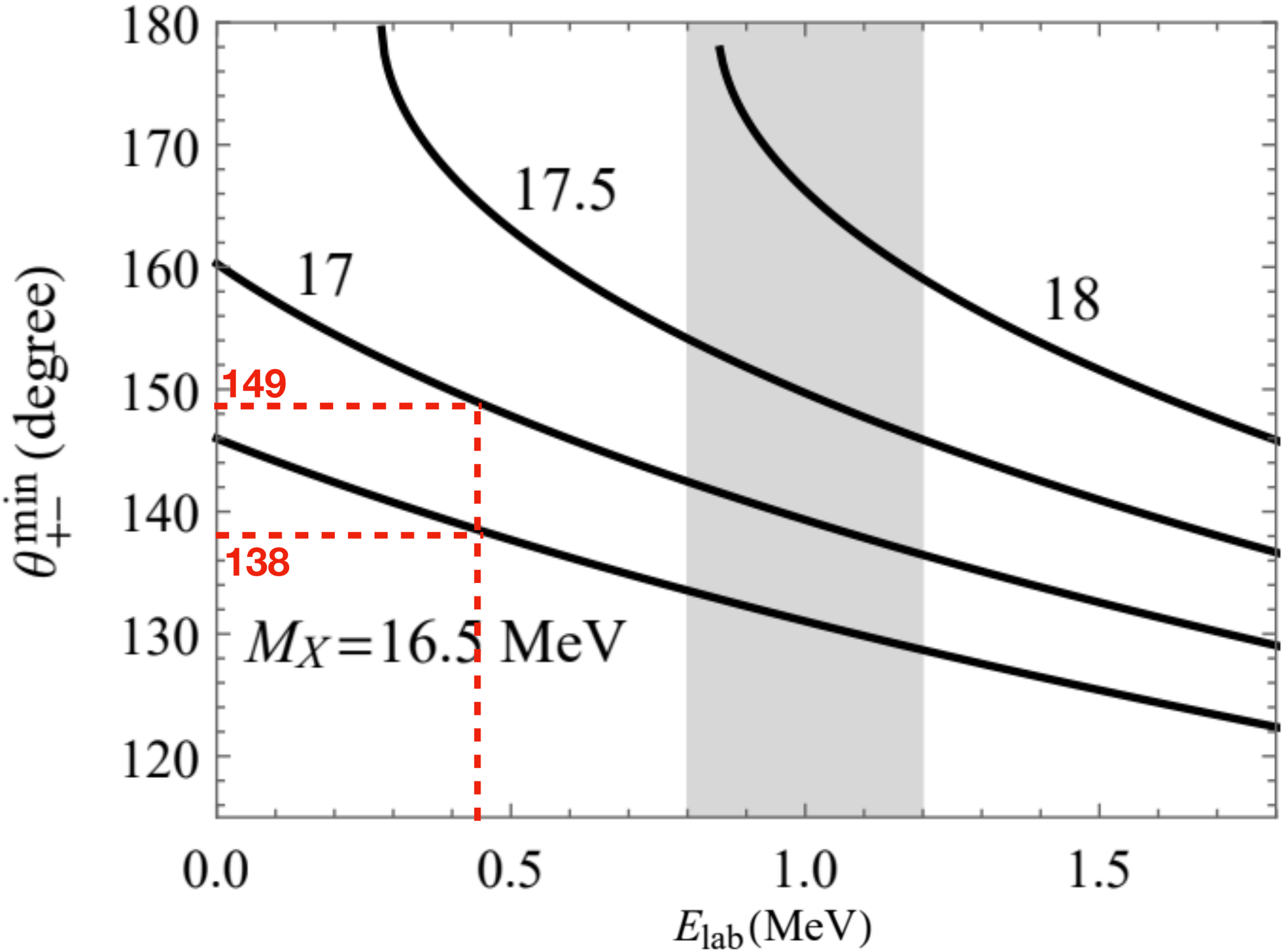


→ steeper IPC at 17.6 MeV allows to fit simultaneously small and large angles

→ points towards domination of 17.6 MeV line in data

→ consistent with target and BGO analysis

X17 from 17.6 MeV line



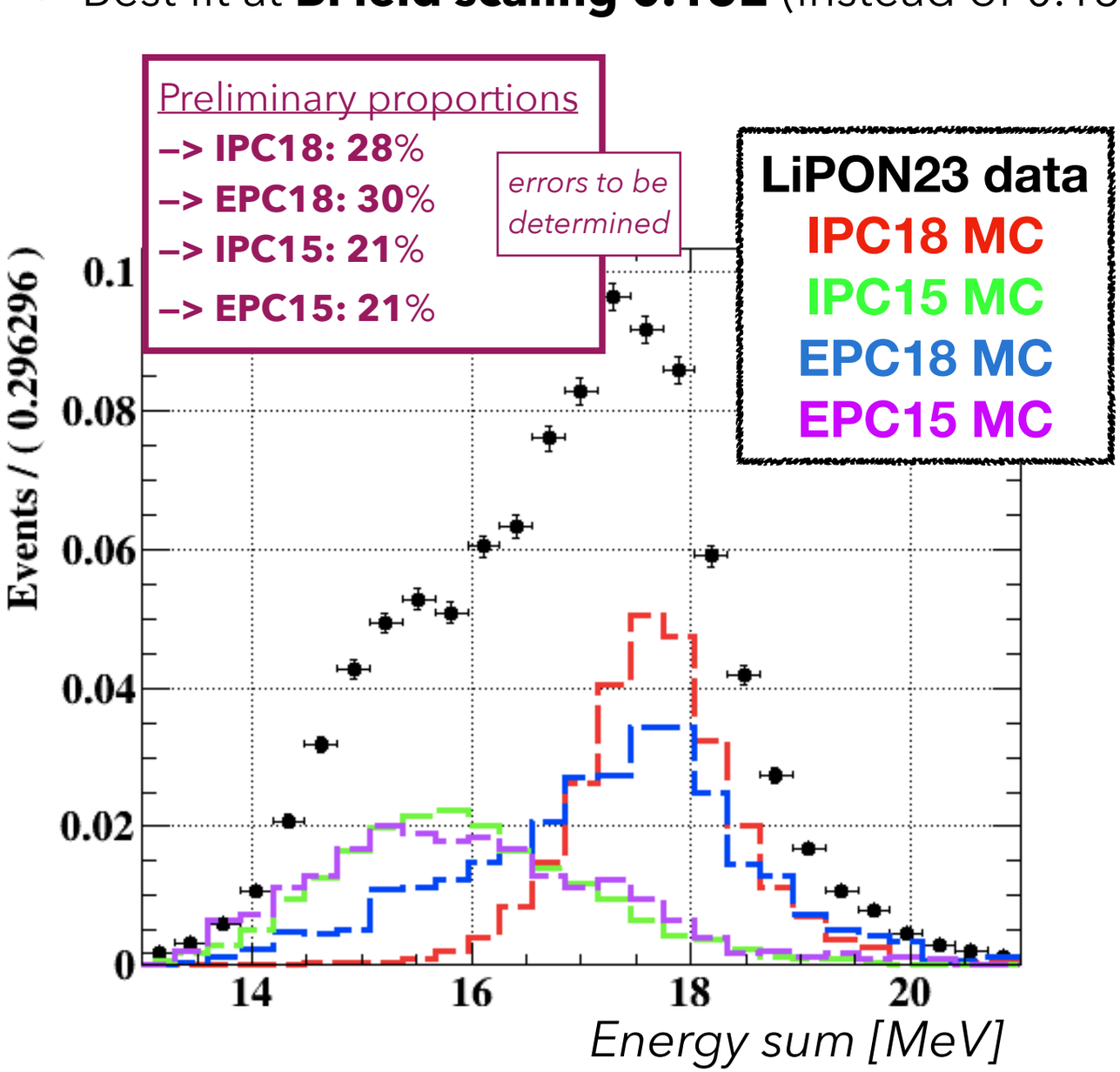
Zhang-Miller 2021

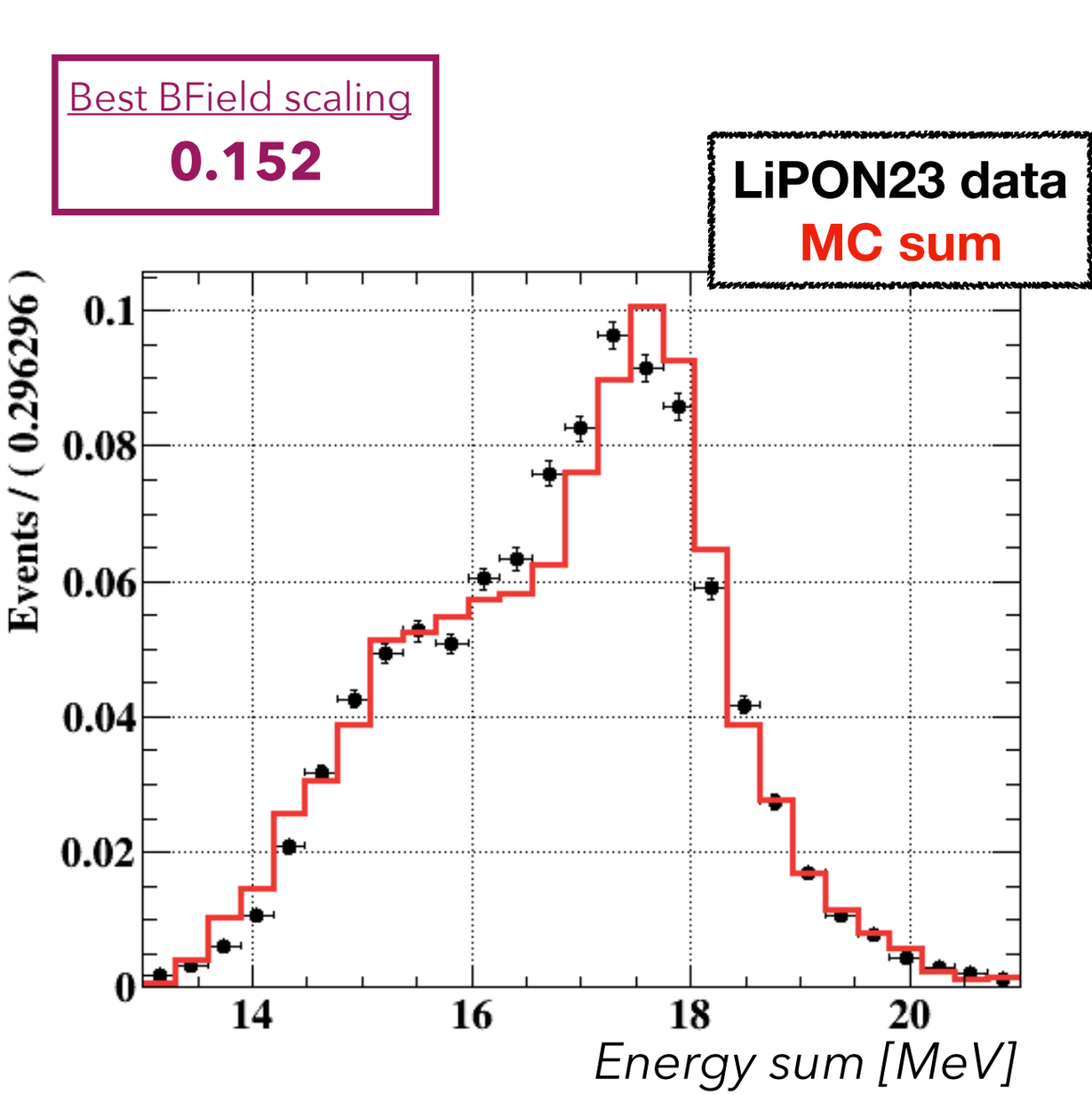
→ **X17 production from 17.6 MeV** line is at larger angular openings but still **within signal region**

2) Energy scale

Energy scale

- **Combined fit** of **Esum** and **Angular Opening** using pure 17.6 MeV MC and 5% of LiPON23 data
- Effect of neglecting 18.1 MeV line: 0.3% uncertainty on scale
- 4 fit parameters: relative proportions of 4 backgrounds
- Scan of BField scaling parameter
- Best fit at **BField scaling 0.152** (instead of 0.150): 1% effect





3) Blinding and sidebands

Blinding

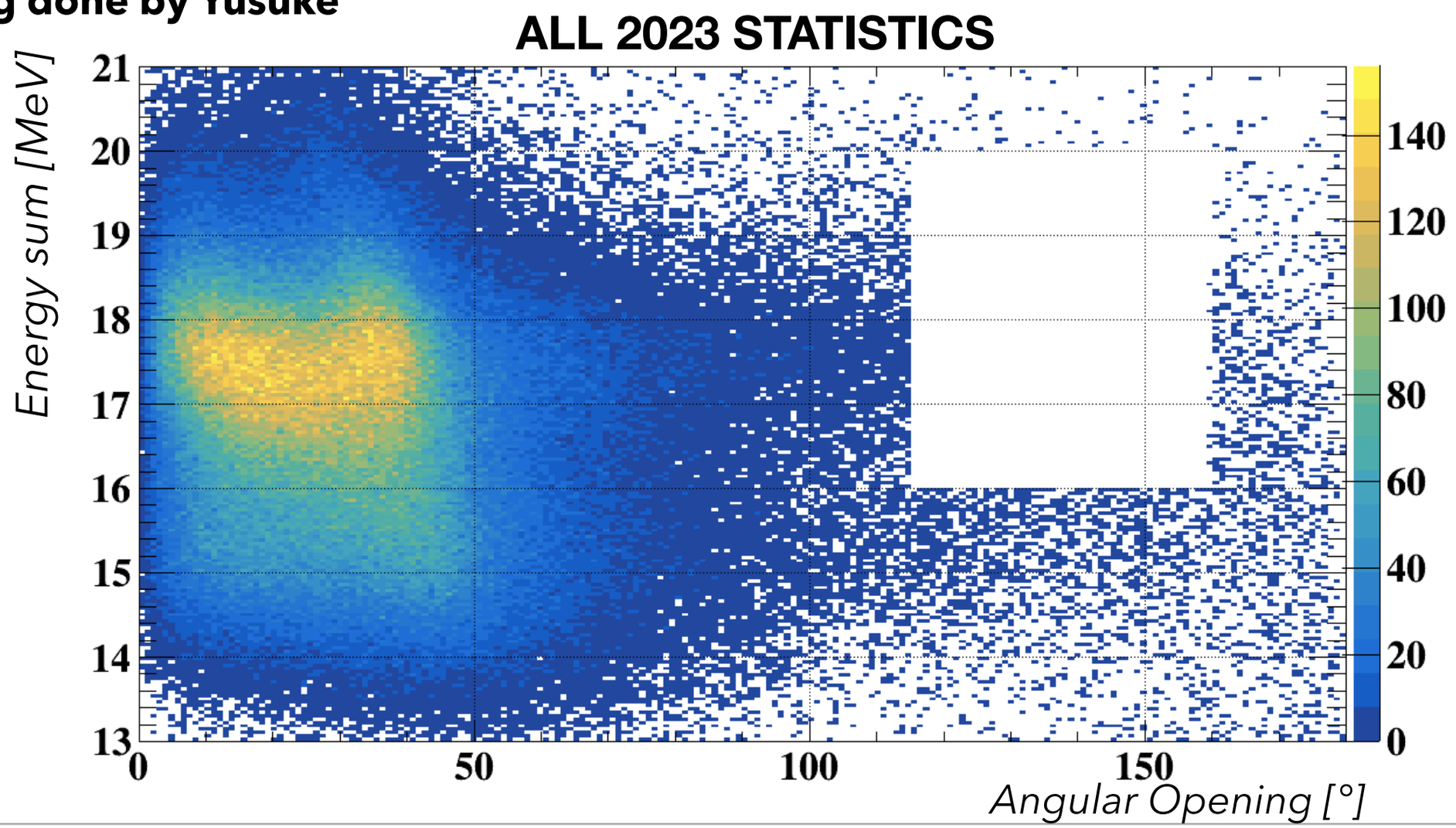
- With energy scale fixed, blinding of entire 2023 dataset can be done

- **Blinding macro** was pushed. It:
  - → Opens rec positrons and rec electrons file
  - → Selects single tracks which pass **quality conditions**
  - → Selects pairs which pass **pair quality conditions**
  - → **Separates pairs in two files**: a **sideband file** and a **signal file** (not accessible for now)

Signal Region

- **16 MeV < E*sum* < 20 MeV**
- **115° < Angle < 160°**

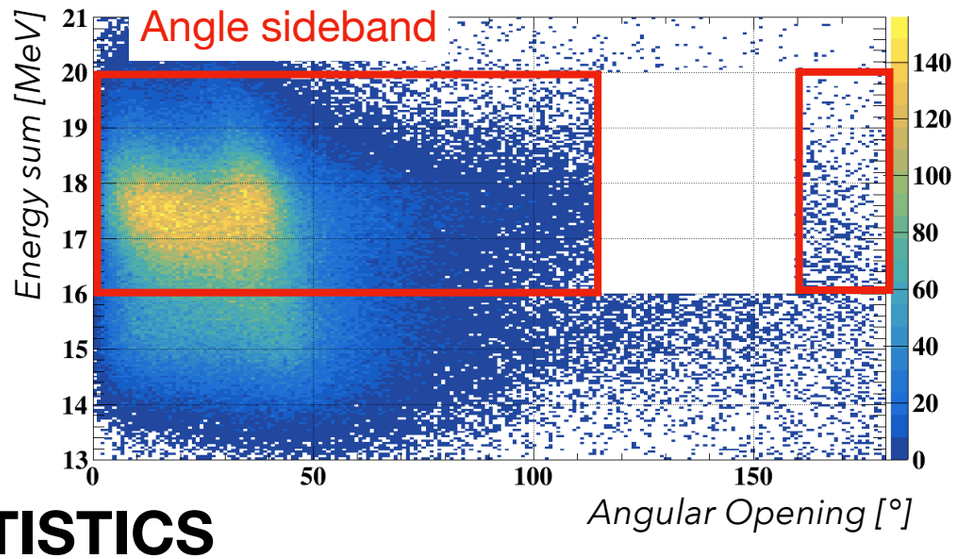
- **Blinding done by Yusuke**



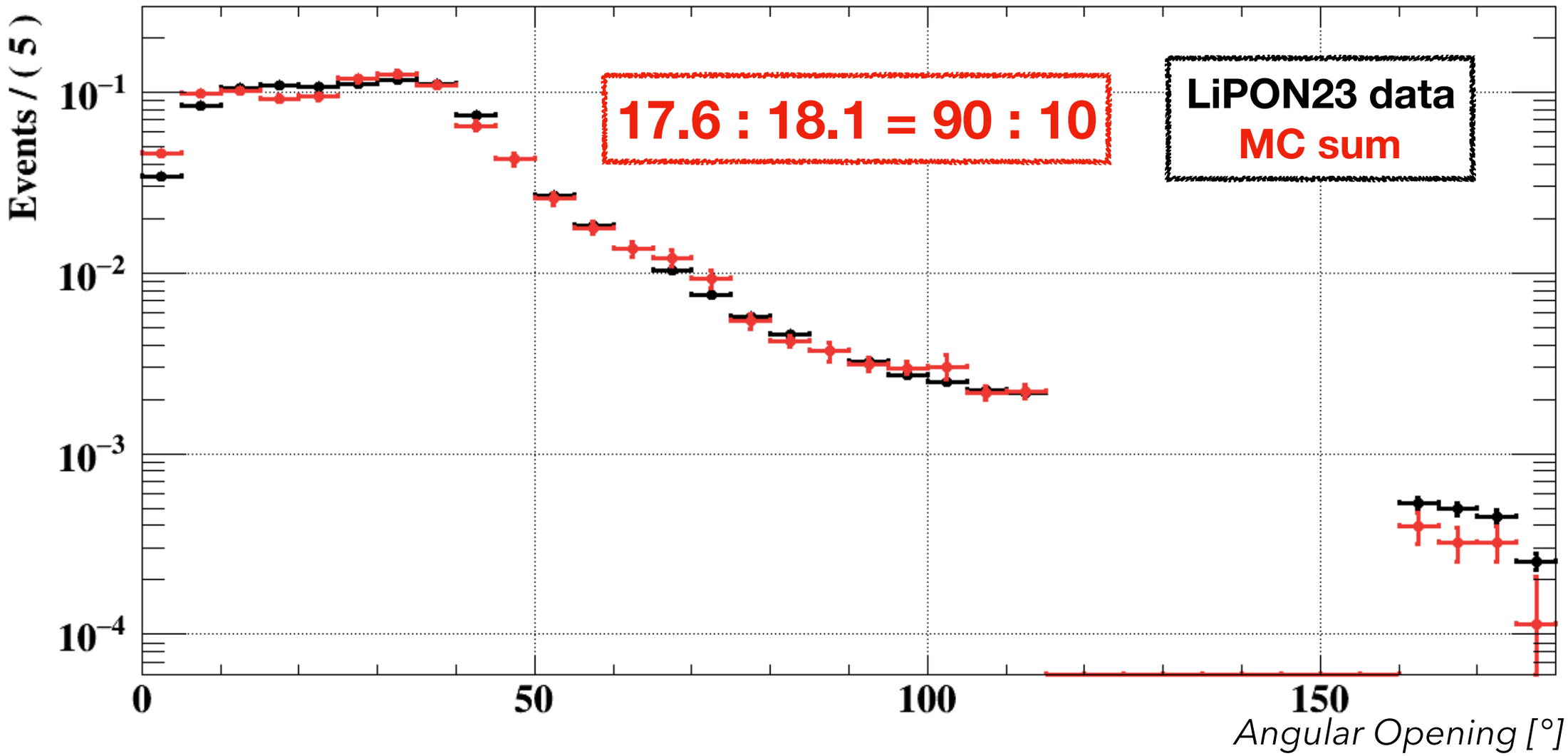
Angle sideband

- Using proportions from previous fit, **comparison MC/data in Angle sideband**
- **Good agreement up to signal region**
- Some **discrepancy at large angles**

→ Next: replace rough estimate of **17.6 : 18.1** proportions by exact mixing from MC

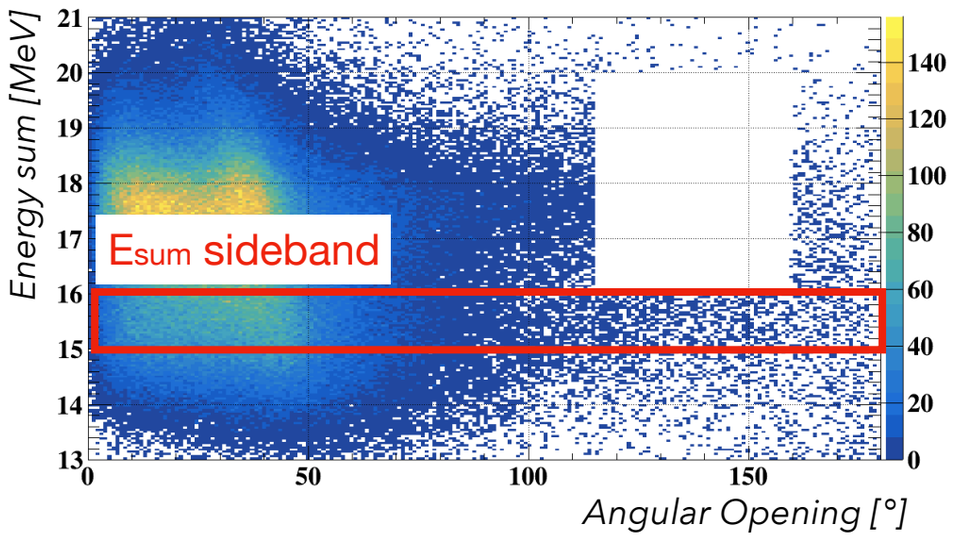


ALL 2023 STATISTICS



Esum sideband

- **Good agreement up to 120°**
- Again: **systematic underestimate at large angles**
- Looked into pairs at large angles:
  → not characteristic of fakes
- Next: replace rough estimate of **17.6 : 18.1** proportions by exact mixing from MC
- More E1 multipole required



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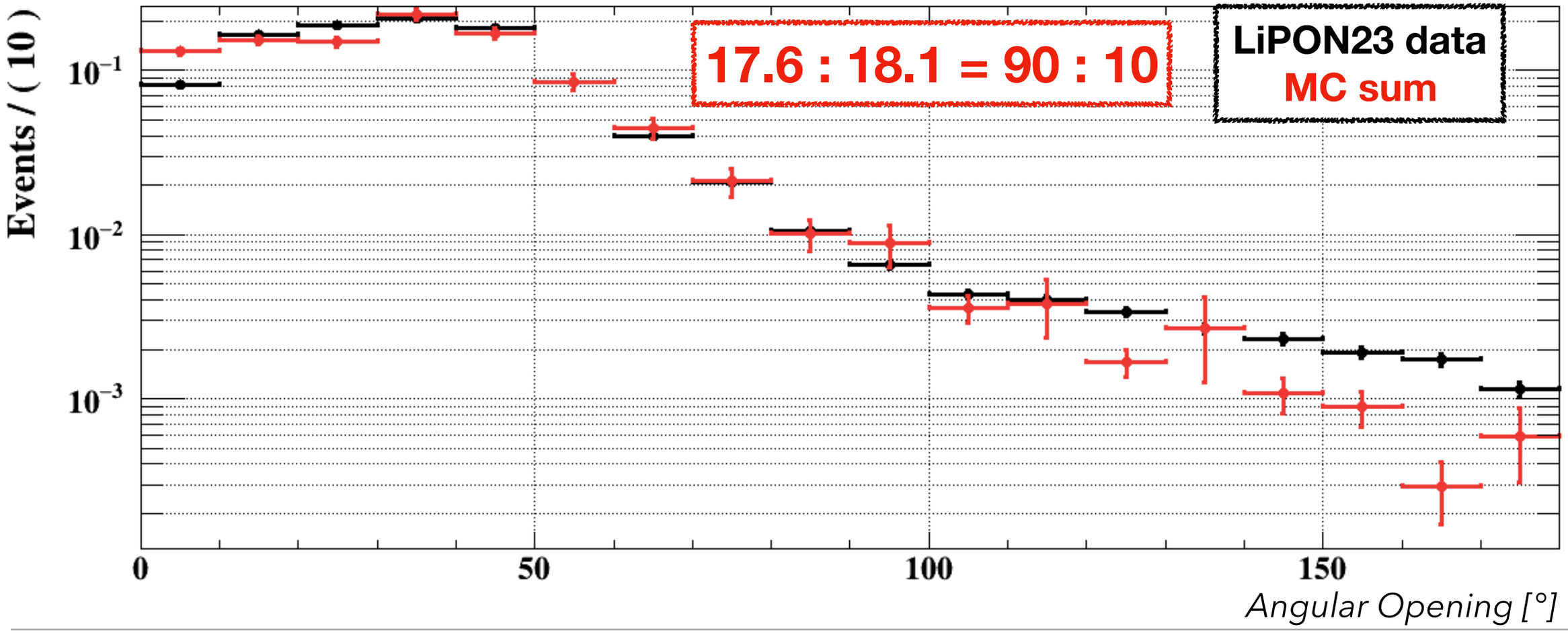


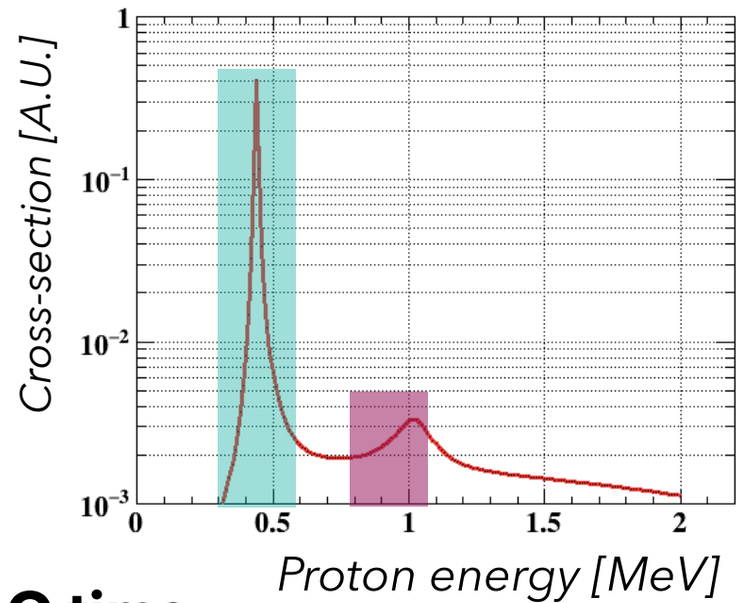
4) Next steps

Next steps

- 2023 data will be used for **X17 search in 440 keV resonance**

- When full understanding of sidebands and likelihood analysis ready:
  → Unblinding

update in December



What about **X17 search in 1030 keV resonance**?

- **Cross-section is lower** so same significance will require **more DAQ time**
- PSI group can produce **thin good-quality targets** (**500 nm available next week** - may be thicker up to 2um)
  B. Lelotte & V. Siller
- **Discussion with companies to make target up to 4um**

Ep	LiPON thickness	CW current (uA)	DAQ time for 3σ
1080 keV	4 um	20	40 days

- December: **some tests with XEC, BGO and spectrometer** with such **thin target** to understand if we can get a good DAQ rate

if good rates ↙

DAQ period with CDCH and TC in January/February @1030 keV

O(5/6 weeks)

↘ if not good rates or if target unavailable

DAQ period with CDCH and TC in January/February @440 keV

O(3 weeks) to improve significance

Conclusion

- All evidence point towards a **domination of the 17.6 MeV** production
- **X17 search** is still **doable and meaningful**
- Energy scale was fixed and background proportions were estimated
- **Blinding** of all 2023 statistics was **done**
- **Good agreement data/MC** of both **Angle and E_{sum} sidebands**
- **Behaviour at large angles** remains to be understood before unblinding
- 2024 DAQ period is foreseen

Backup