

The X17 search with the MEGII apparatus at PSI

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INTENSE: Particle Physics Experiments at the Intensity Frontier

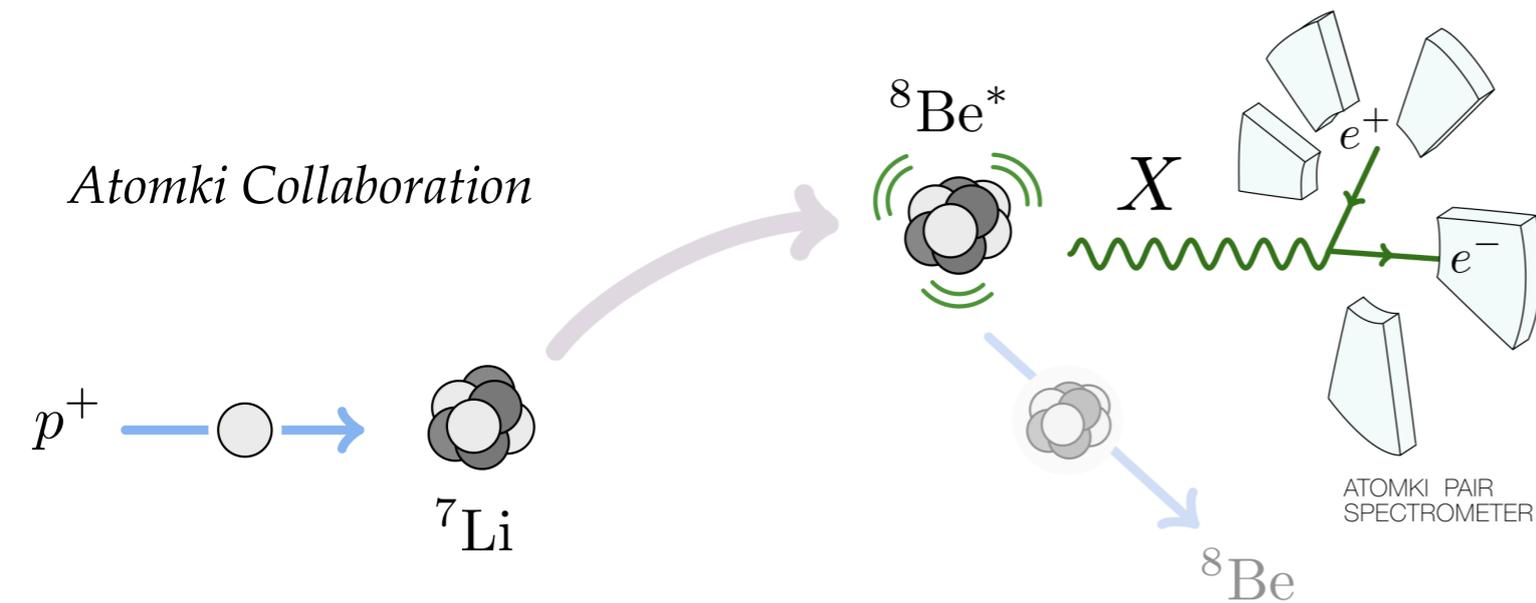


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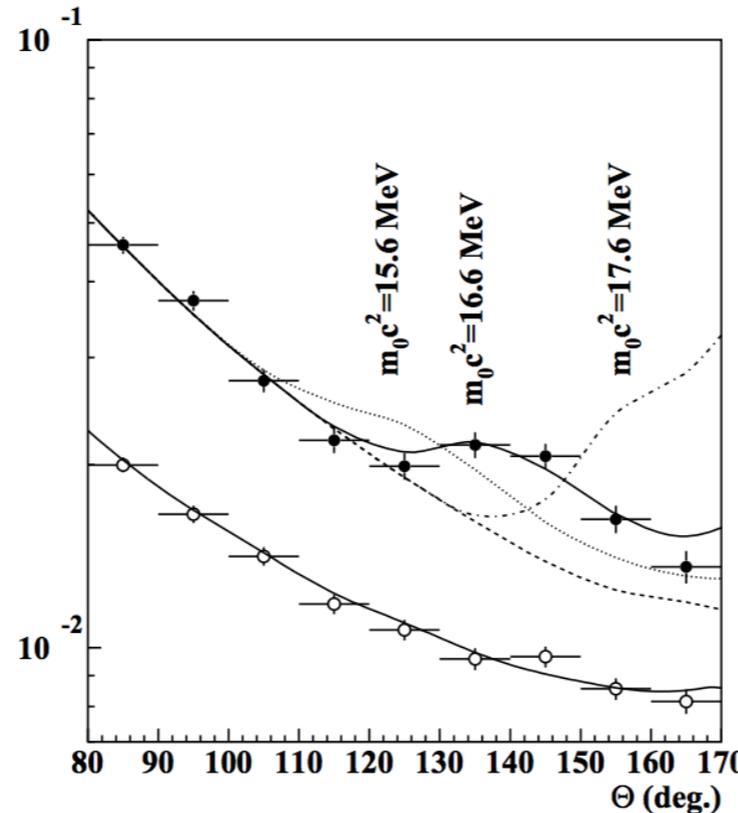
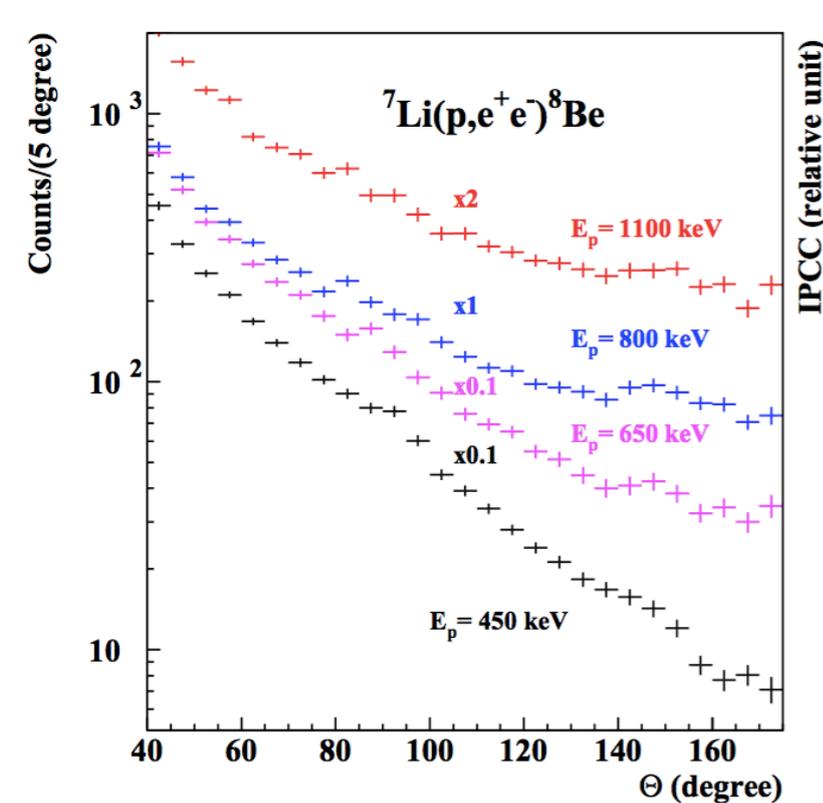
The Beryllium Anomaly

Atomki Collaboration



${}^7\text{Li}(p, e^+e^-){}^8\text{Be}$ studied at
 $E_p = 450, 650, 800, 1100$ keV

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



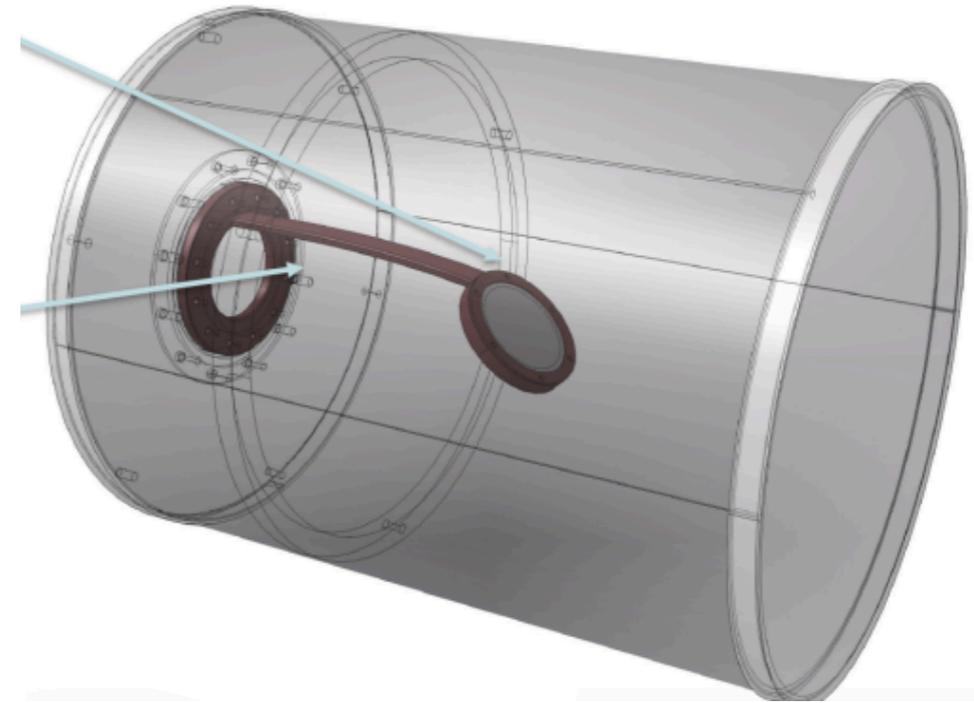
- Internal Pair Conversion (IPC) distribution shows excess at $\Theta \sim 140^\circ$ at several beam energies

→ decay of a light particle emitted during proton capture

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

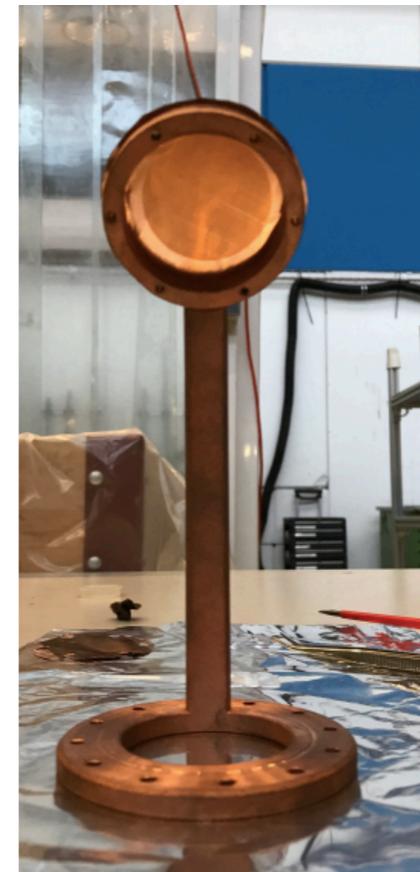
→ protophobic vector boson X17? mediator of a fifth force?

1) 2023 data taking:
conditions, trigger and reconstruction



2) Gamma analysis

3) MC vs Data comparison



2023 data taking conditions

- 2 μm LiPON^(*) on 25 μm copper substrate (by PSI)
- 400 μm -thickness carbon fiber vacuum chamber to minimize multiple scattering
- Target-supporting and heat-dissipating copper structure attached to CW nose

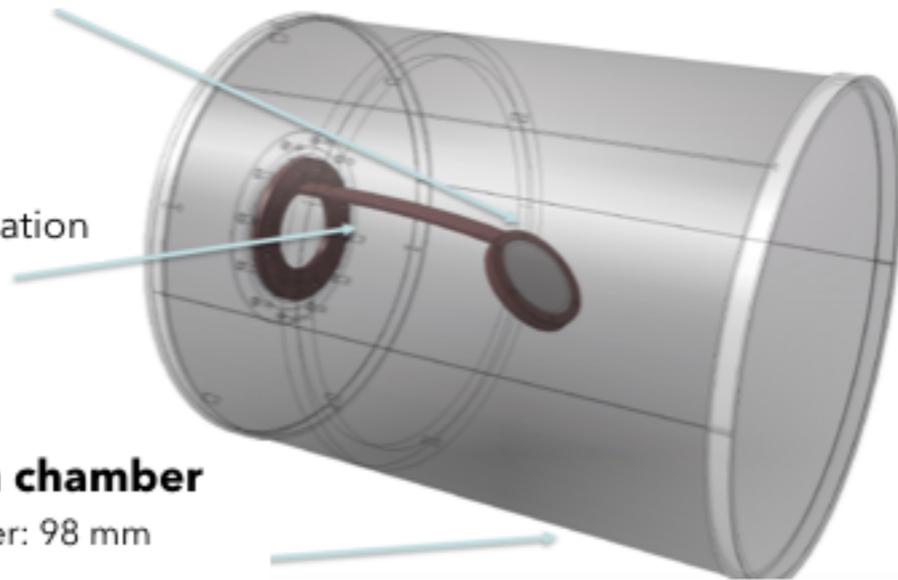
(*) Lithium phosphorus oxynitride ($\text{Li}_{3-x}\text{PO}_{4-y}\text{N}_{x+y}$)

Li target

at COBRA center
45° slant angle

Target arm

Cu for heat dissipation

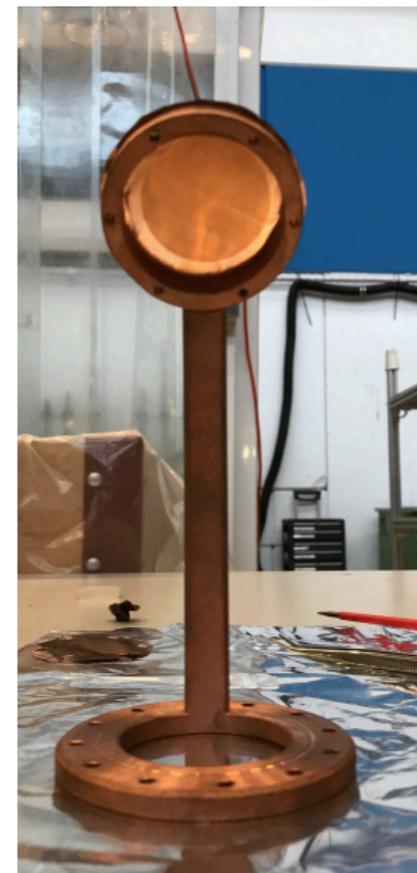


Carbon fiber vacuum chamber

Thickness: 400 μm , Diameter: 98 mm
Length: 226 mm

Ring thickness

OLD
11 mm



NEW
2 mm



- Copper ring for heat dissipation

→ main EPC source

→ thickness and EPC reduced by a factor 5

→ stability of gamma rate showed good heat dissipation capabilities of thinner ring at high proton currents

- CW energy **1080 keV**

→ CW stable

- CW current **10 μ A**

→ gamma rate stable,
no degradation of the target

- Cobra field **0.15B scaling**

→ samples taken at 0.16B and 0.17B:
no evidence of improvement

- Trigger **CDCH 18&18 >60mV, TC \geq 1**

→ samples taken at lower and higher multip.:
no evidence of improvement

Trigger rate estimate based on MC and 2023 gamma rate (at $I_{cw} = 6\mu A$)

Thin ring
(2.1 mm)

- EPC18+15 + Compton:

60 kHz \rightarrow **23 Hz** in trigger

0.039% induce trigger

- IPC18+15:

60 kHz \rightarrow 190 IPC generated \rightarrow **12 Hz** trigger

BR 3.2e-3

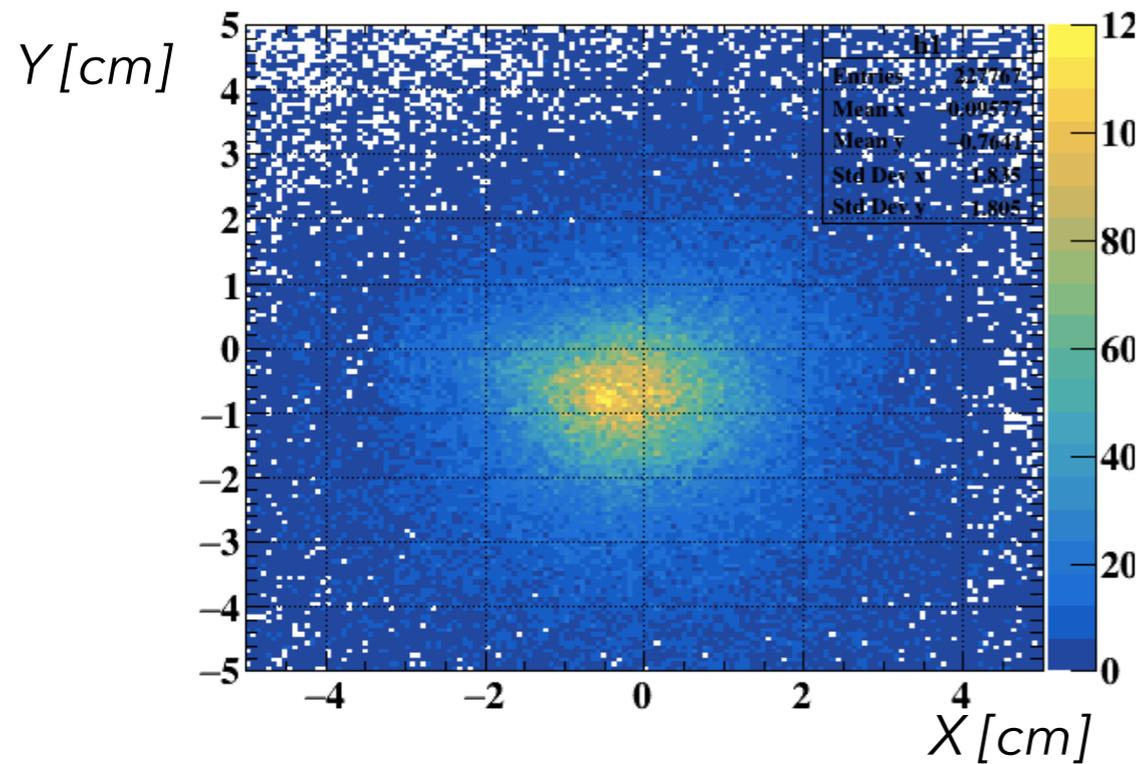
6.5% induce trigger

MC \rightarrow total rate \sim **35 Hz**

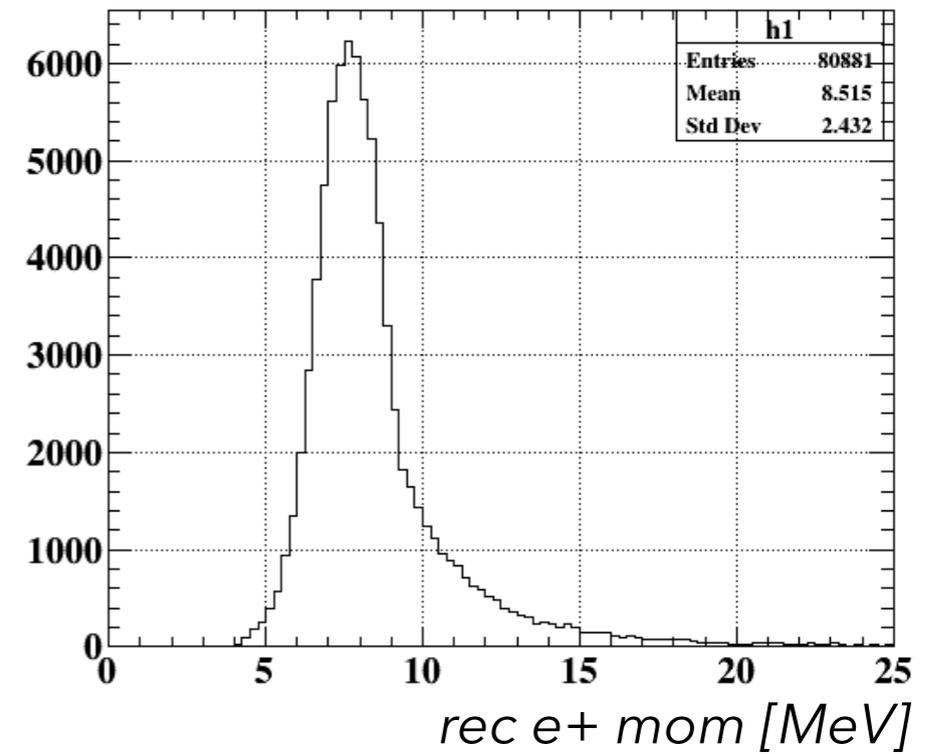
to compare with

Data \rightarrow \sim **30 Hz**

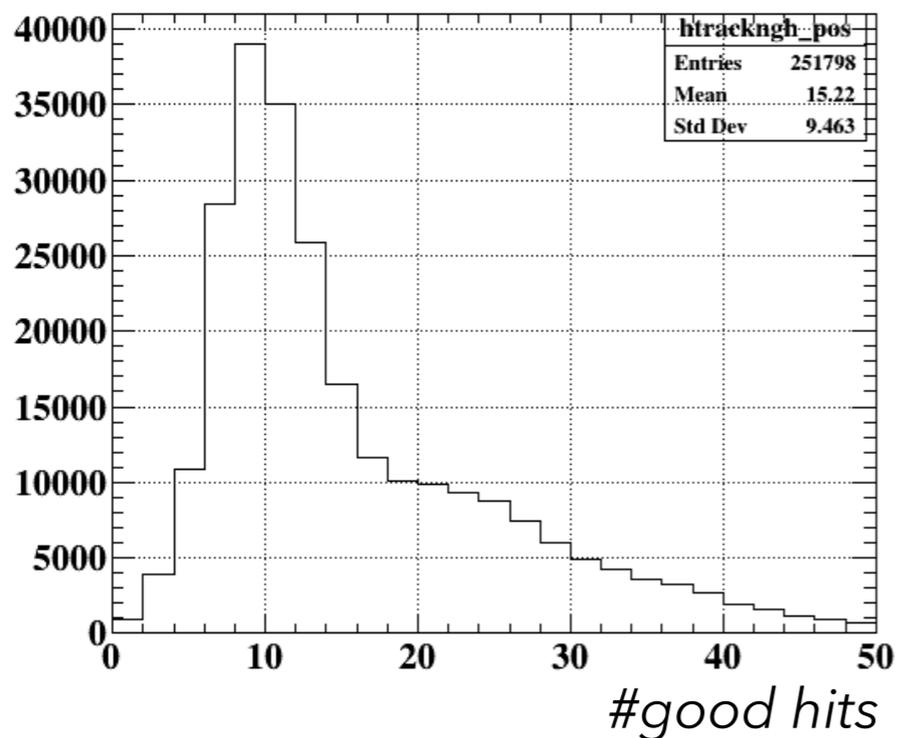
Vertex position on target



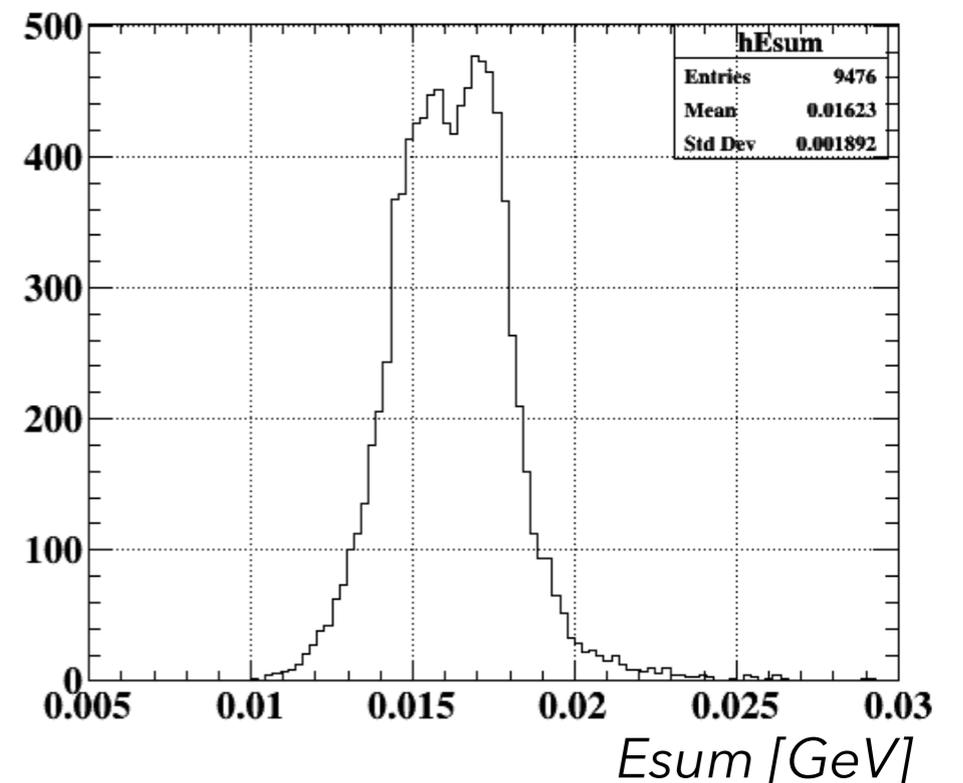
Reconstructed positron momentum on target



Number of good hits / track



Energy sum spectrum ($E_{e^+} + E_{e^-}$)

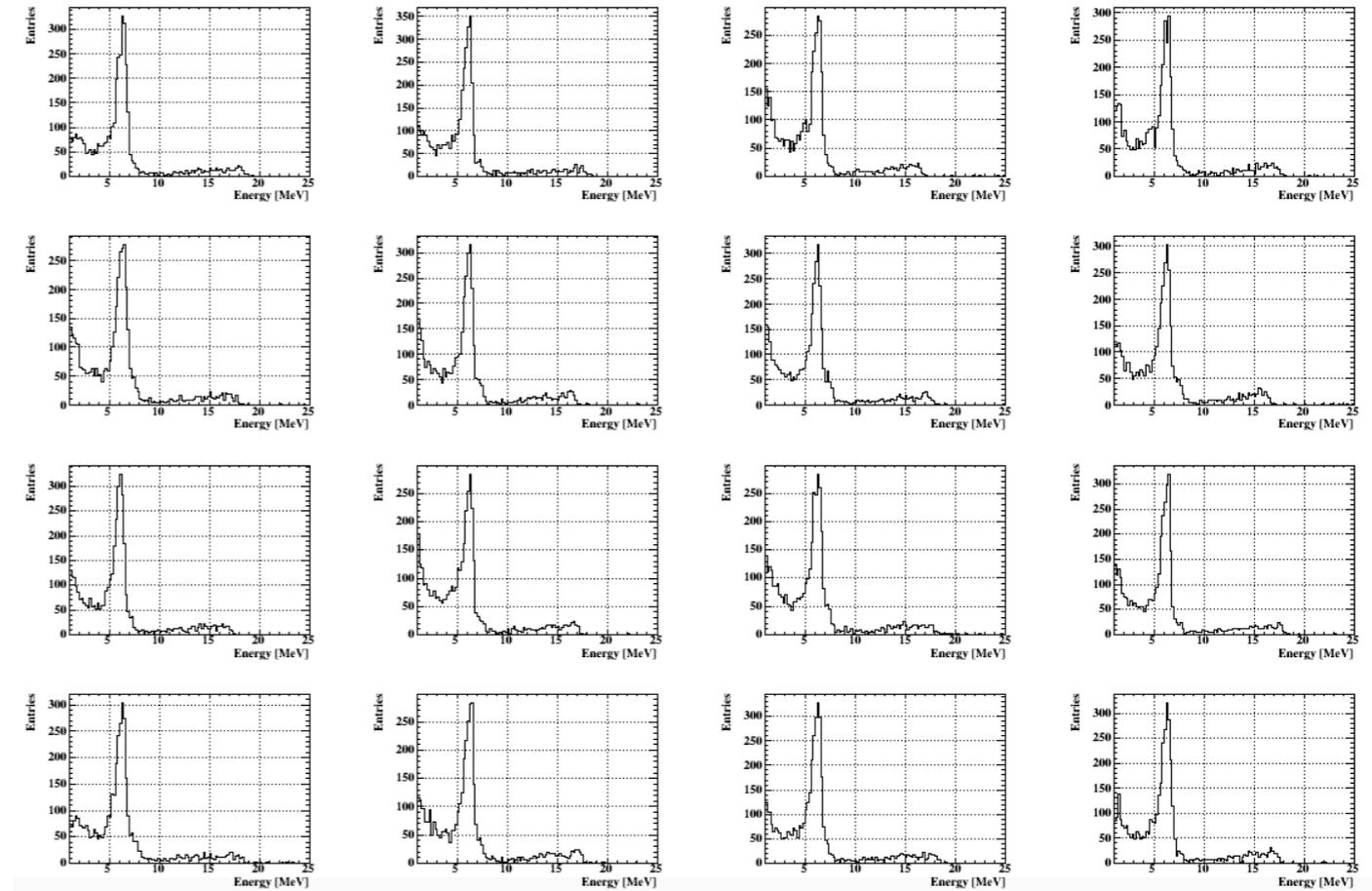
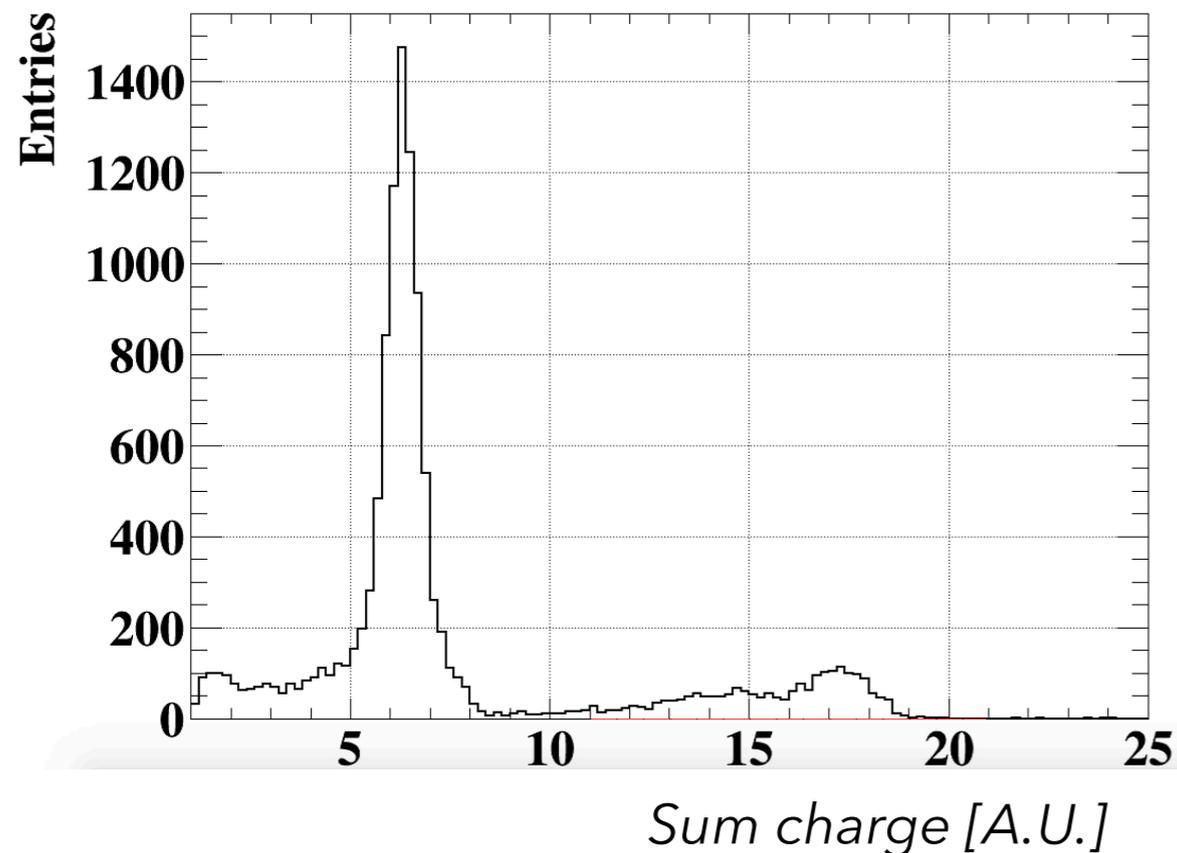


Gamma analysis

LiF target and intercalibration

- BGO PMT HVs optimized to minimize offline intercalibration
- intercalibration based on F line

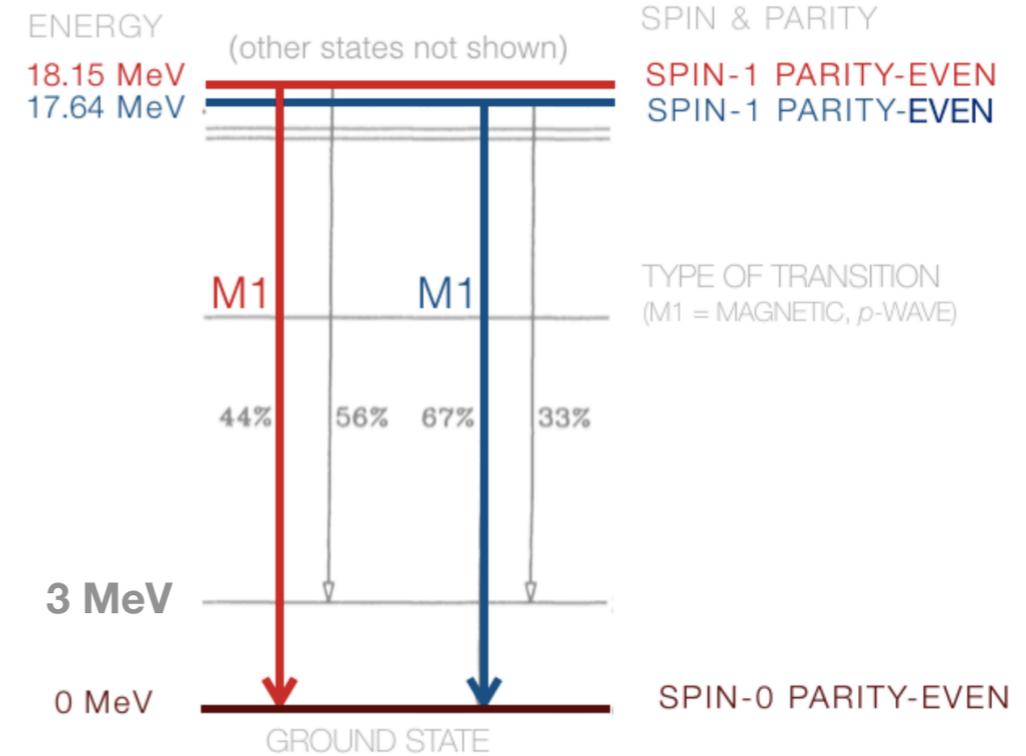
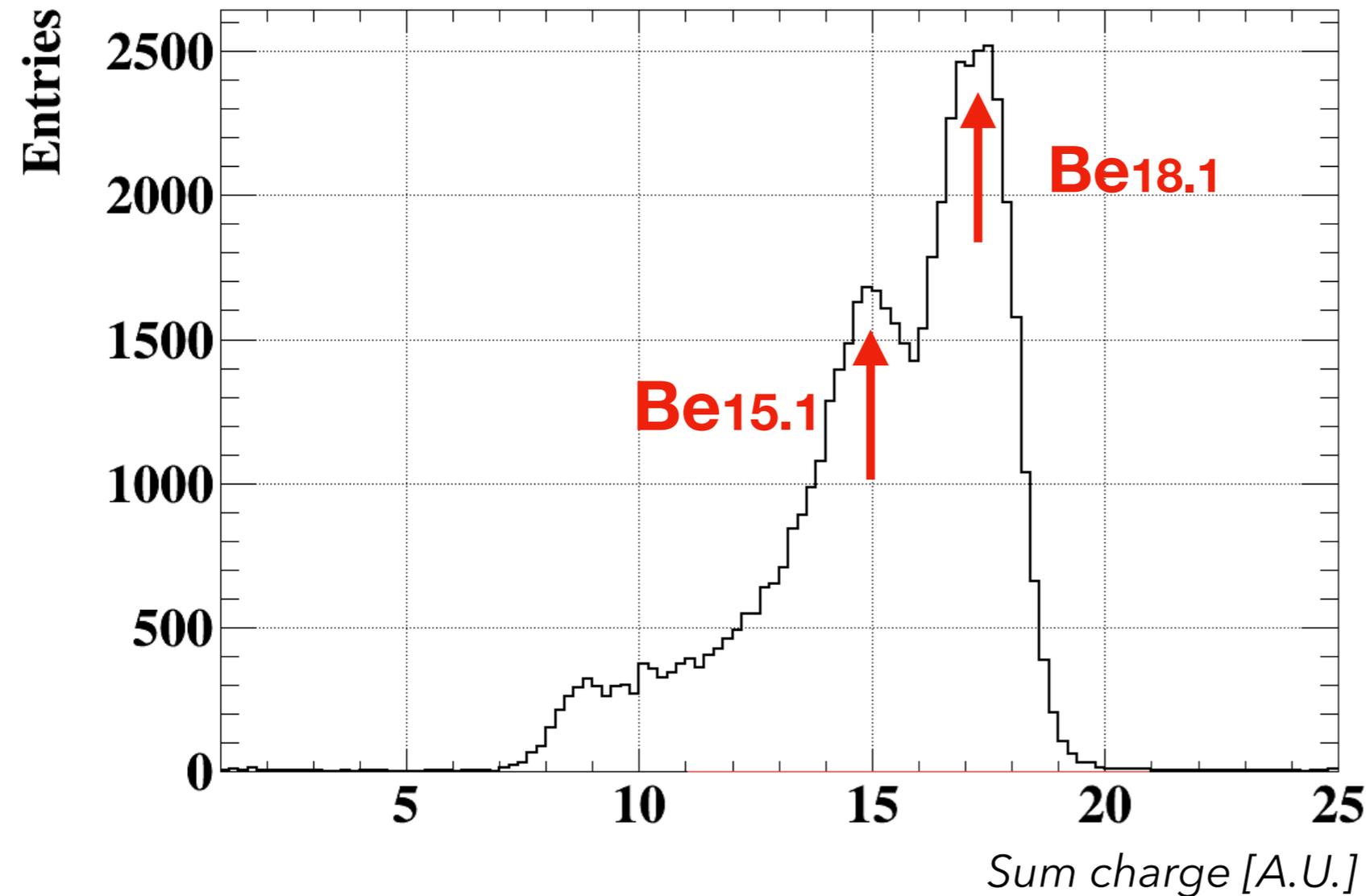
LiF 5um - target 2022 - $E_p = 500$ keV



→ **F, Be14.6 and Be17.6** clearly visible

- intercalibration based on F line only
- to be optimized based on **Be17.6** line
- trigger threshold at ~ 8 MeV

LiPON 2um - target 2023 - $E_p = 1080$ keV



BGO rate 6 μ A \sim 300 Hz
Be₁₅₊₁₈ rate \sim 60kHz

2022

 $I_{cw} = 2\mu A$ - 130 Hz in BGO

PRESCALING 2

→ **12 Hz** of Be-lines in 4 central crystals of BGO

2023

 $I_{cw} = 6\mu A$ - 300 Hz in BGO

x 5.5 (wrt 2022)

→ **65 Hz** of Be-lines in 4 central crystals of BGO

 $I_{cw} = 9\mu A$ - 380 Hz in BGO

x 7 (wrt 2022)

→ **82 Hz** of Be-lines in 4 central crystals of BGO

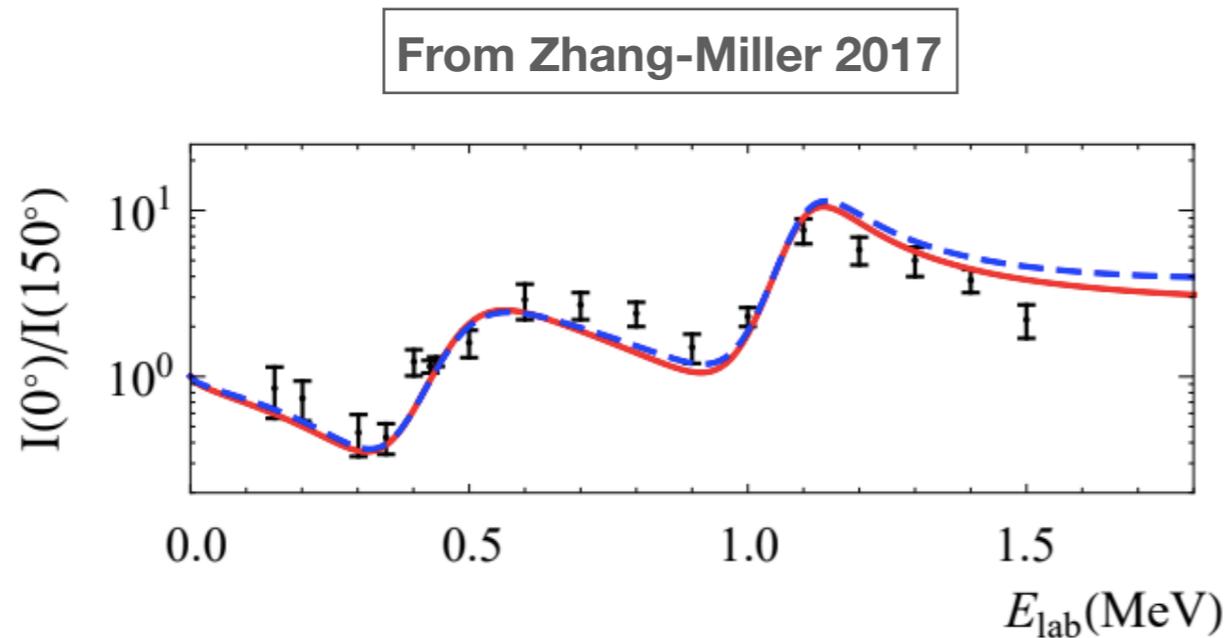
accounting for livetime drop at 9uA

x 12 more pairs/s on disk (wrt 2022)

(x 10 was expected)

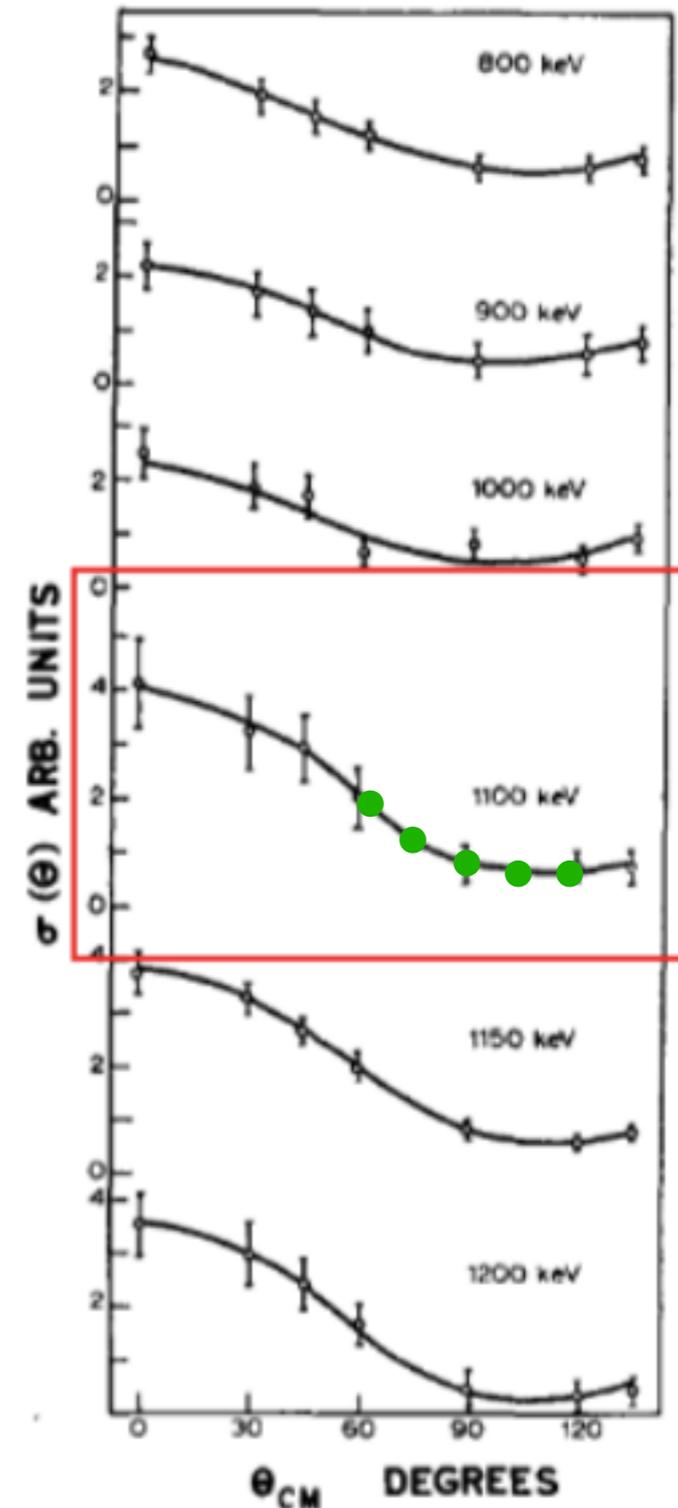
Gamma from p+Li known to be anisotropic

forward / backward

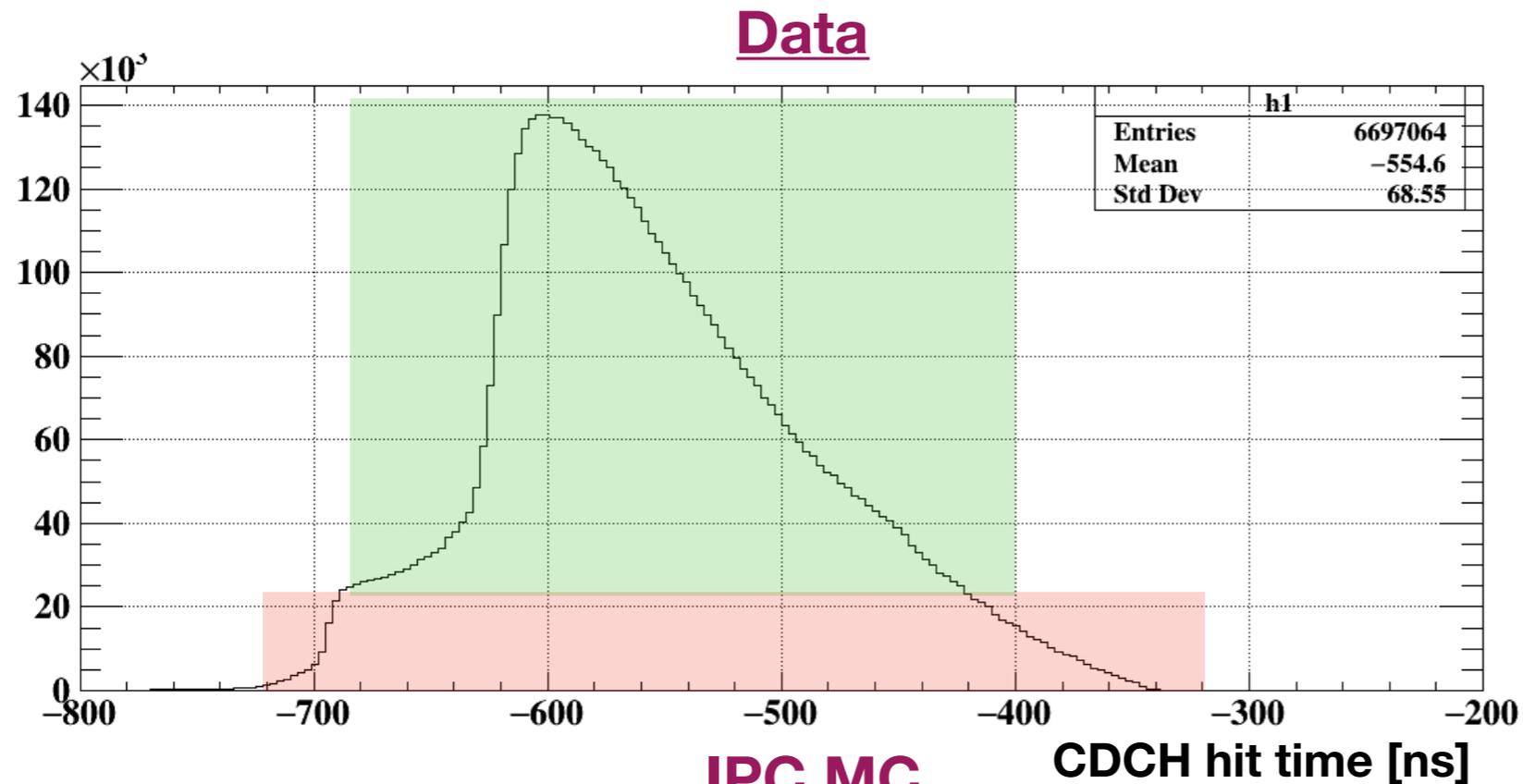


- As a check, anisotropy of gamma rate was measured by moving the BGO at
→ **5 positrons along z at $\phi=0^\circ$:**
(-35 cm, -18 cm, 0 cm, 18 cm, 35 cm)
→ **3 positions along ϕ at $z = 0$ cm**
(-25°, 0°, 25°)
- Brilliance detector kept at fixed position and used as reference for normalization

From Schlueter 1964



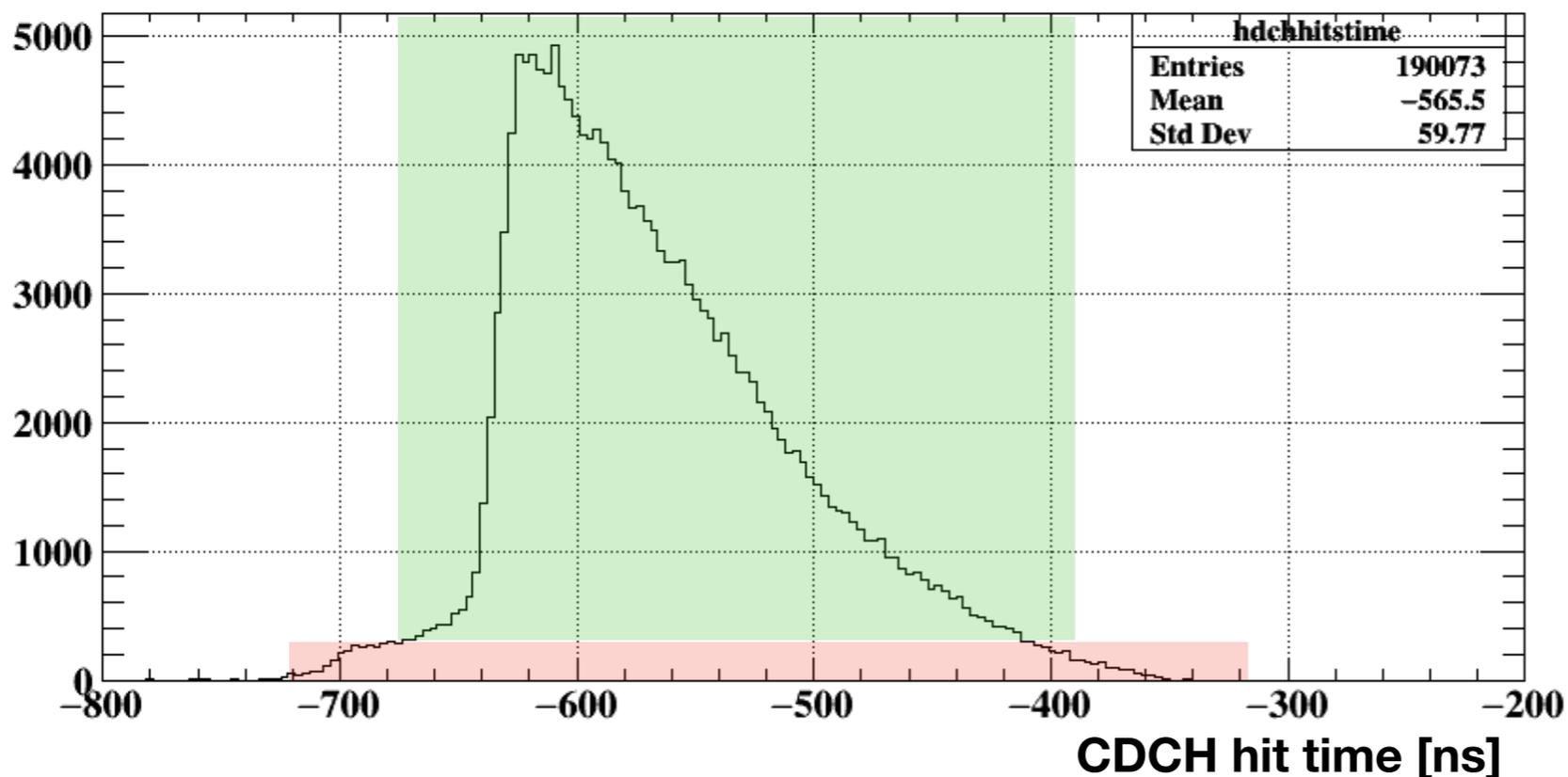
MC vs data 2023



→ **40 hits/event in pedestal**

→ **90 hits/event in signal**

(consistent with 130 hits in total)



→ **10 hits/event in pedestal**

→ **65 hits/event in signal**

(consistent with 70 hits in total)

Data

40 hits/event in **pedestal**

90 hits/event in **signal**

MC

10 hits/event in **pedestal**

65 hits/event in **signal**

- **data have 30 more noise hits per event**

→ MC noise will be generated in a way to reproduce the noise from data

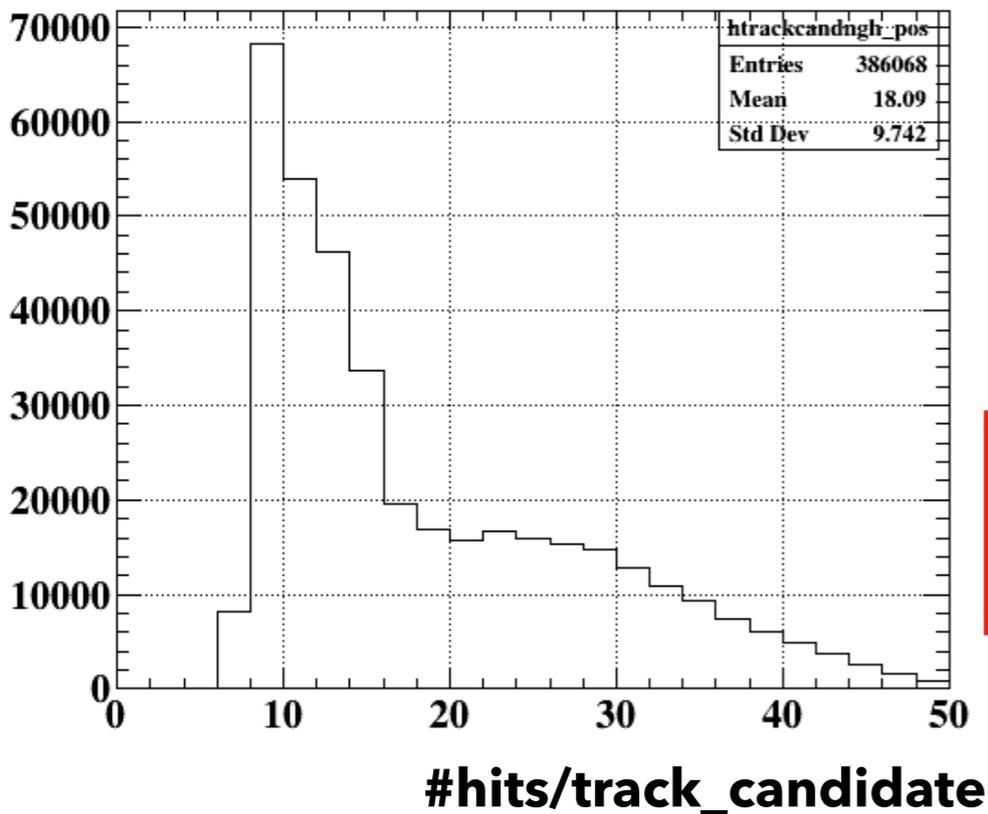
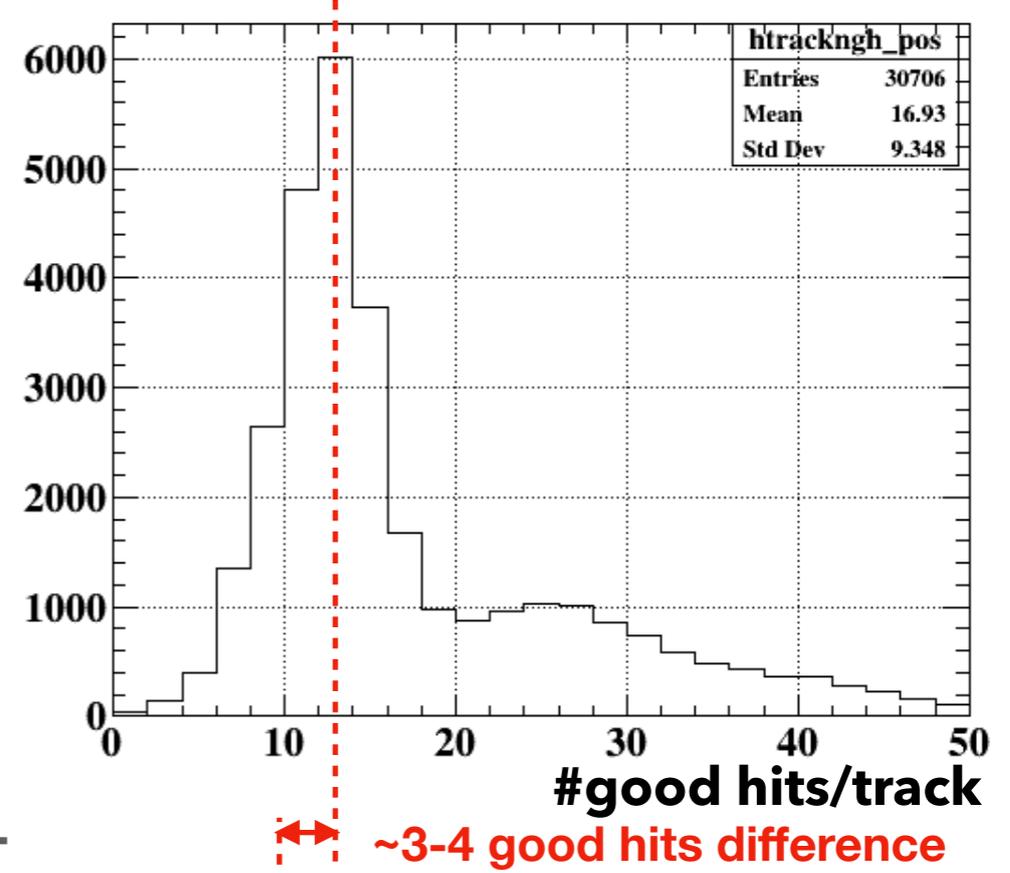
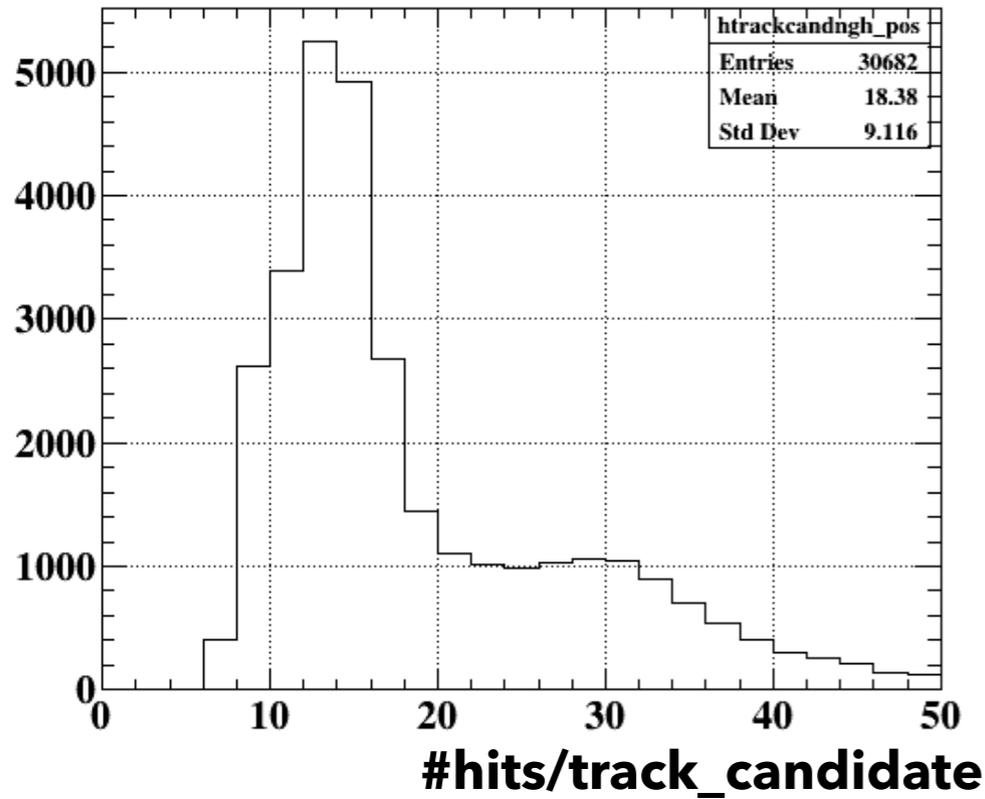
→ identify potential additional noisy channels in data

- **data have 20/30 more signal hits per event**

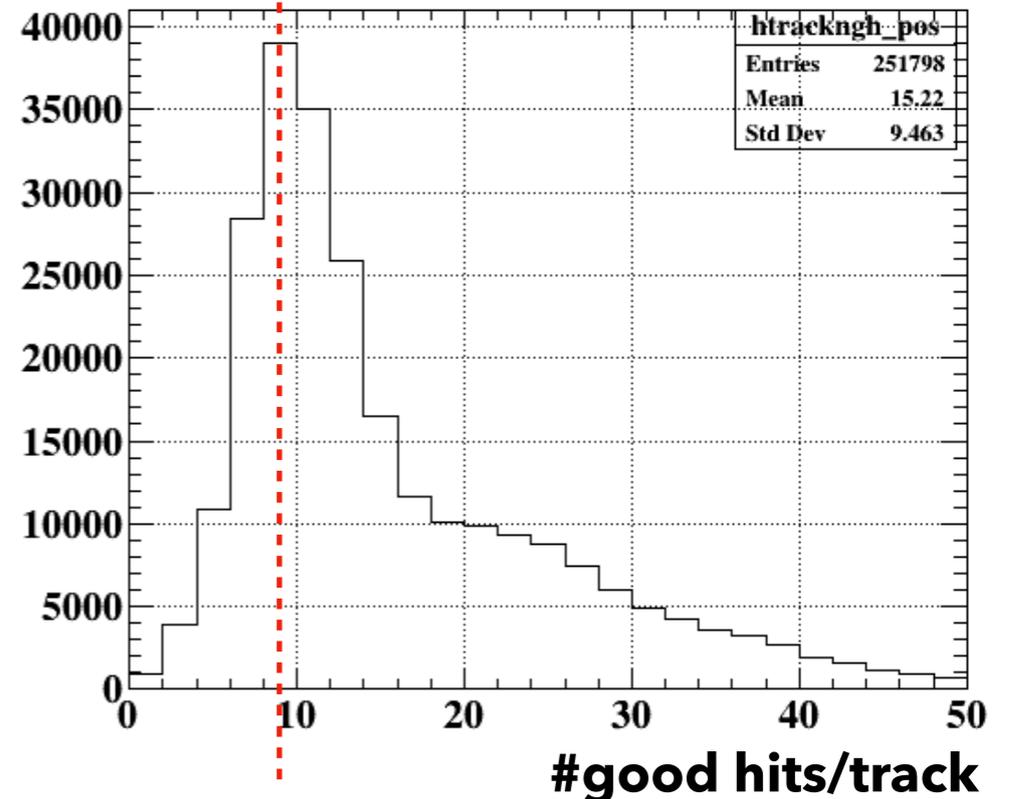
→ beam related background:

X-ray? (test with copper only as target)

secondary particles?



#good hits selection adapted for MC and data



Trigger 18&18 (60mV) and 6 uA (Icw)

15 MeV

- EPC15 + Compton:

30 kHz \rightarrow 10 Hz in trigger \rightarrow **4.4e-2** pairs/s

0.034% induce trigger

0.44% pair reco

- IPC15:

30 kHz \rightarrow 96 IPC generated \rightarrow 6.0 Hz trigger \rightarrow **7.4e-2** pairs/s

BR 3.2e-3

6.2% induce trigger

1.2% pair reco

18 MeV

- EPC18 + Compton:

30 kHz \rightarrow 13 Hz in trigger \rightarrow **7.2e-2** pairs/s

0.045% induce trigger

0.55% pair reco

- IPC18:

30 kHz \rightarrow 96 IPC generated \rightarrow 6.7 Hz trigger \rightarrow **9.3e-2** pairs/s

BR 3.2e-3

7.0% induce trigger

1.4% pair reco

in 34' from MC:

- $IPC/EPC = 60/40$
- #EPC₁₈₊₁₅ = **240**
- #IPC₁₈₊₁₅ = **340**
- **#EPC+IPC = 580**

in 34' of data:

- **#EPC+IPC = 307**

\rightarrow ~factor 2 discrepancy

\rightarrow part of it due to lower quality of tracks in data

Region:

- $z^+ \times z^- < 0$

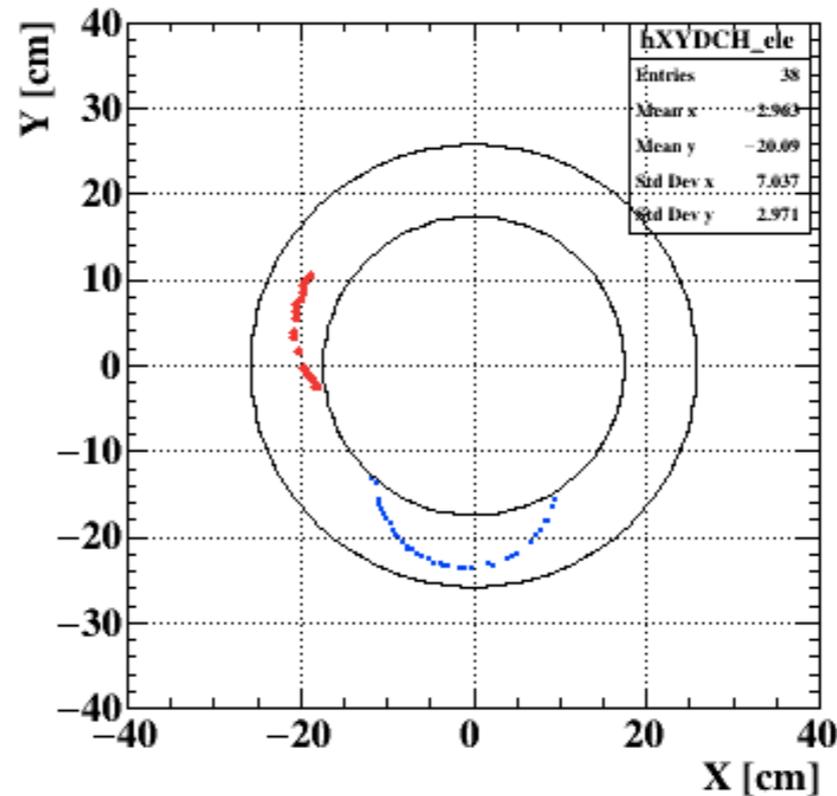
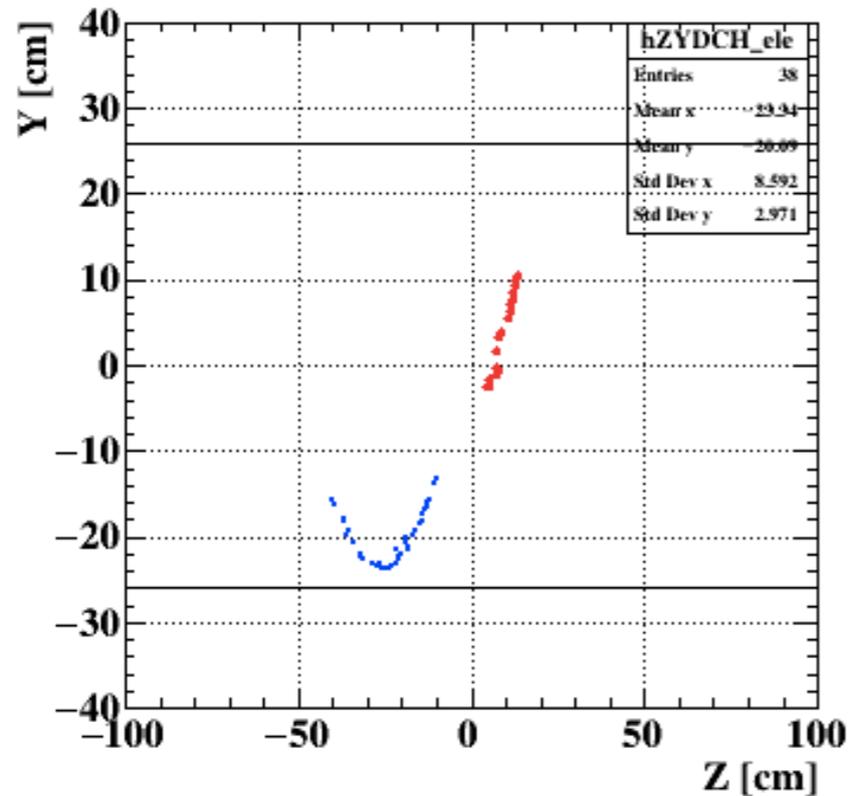
For data:

- scan of parameters to tune X17 CDCH WF analysis
- fine tuning (+/- 1 ns) for SPX and CYLDCH signal timing needs to be implemented for best reconstruction: will be done based on DOCA residuals

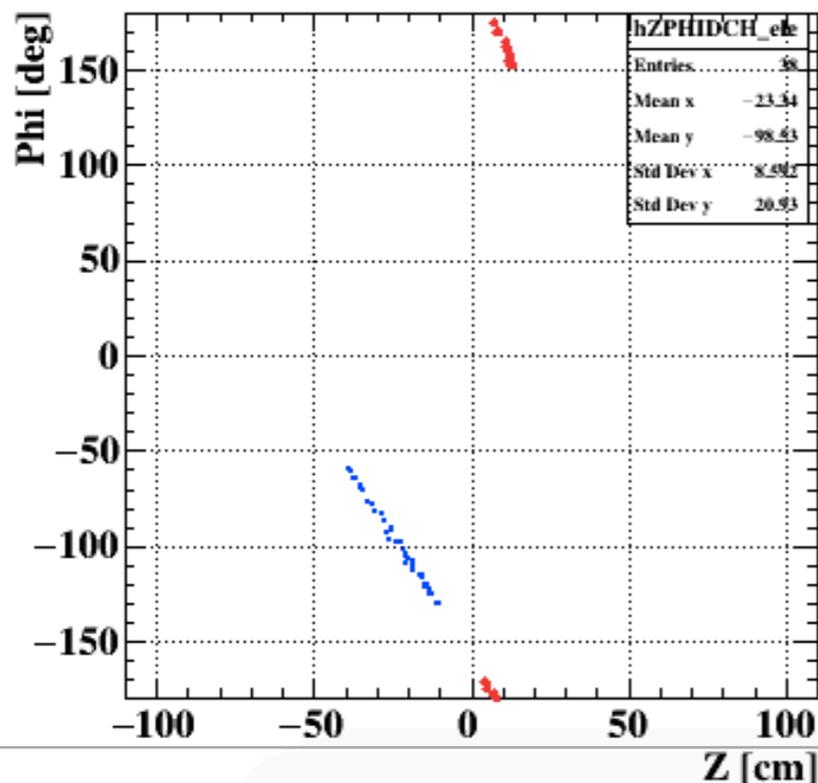
For MC:

- artificial degradation of track quality to match data quality:
explain pair count discrepancy?
- MC will be updated in order to match data better (gain, noise):
explain worse data quality?

Tracks not propagated to target



● e+ hit
● e- hit



- positron was propagated to target but electron was not: e- POCA z = 3cm
- some tracks propagate to z close to target but not to target: angular dependence?
- if better understood: improvement of pair reconstruction efficiency

- **2023 XBoson run** has been ongoing for **4 weeks in February** in stable conditions
- **trigger rate consistent** in data and MC
- gamma analysis ongoing for **normalization** and **asymmetry study**
- **factor 2 discrepancy in #pairs estimate** between **data and MC**:
→ noise hits, propagation and quality of tracks under investigation

Backup

Track propagation to z axis POCA

- instead of requesting propagation to target, we can request propagation to the closest point (POCA) to the z axis (~beam axis) → called propagation ToVertex
- the POCA can be anywhere along z, so it doesn't allow to distinguish positrons and electrons

%X = %triggered events with 1+ X-track

Trigger 1 SPX hit 18&18 DCH hits	%track candidate	%ToVertex	%ToVertex ngh quality cut	%ToVertex ngh quality cut POCA z < 10cm	%pairs Ze+ X Ze- < 0
MC IPC18	93 %	90 %	73 %	60 %	1.4 %
MC EPC18	91 %	89 %	69 %	58 %	0.6 %
DATA2023*	88 %	84 %	75 %	50 %	0.6 %

*** 60:40 IPC:EPC expected mix**

→ track to vertex ~consistent in data and MC

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* 60:40 IPC:EPC expected mix



track to vertex ~consistent in data and MC



clear drop from MC when requesting POCA to have: **-10cm < z < 10cm**



part of drop due to lower quality tracks in MC

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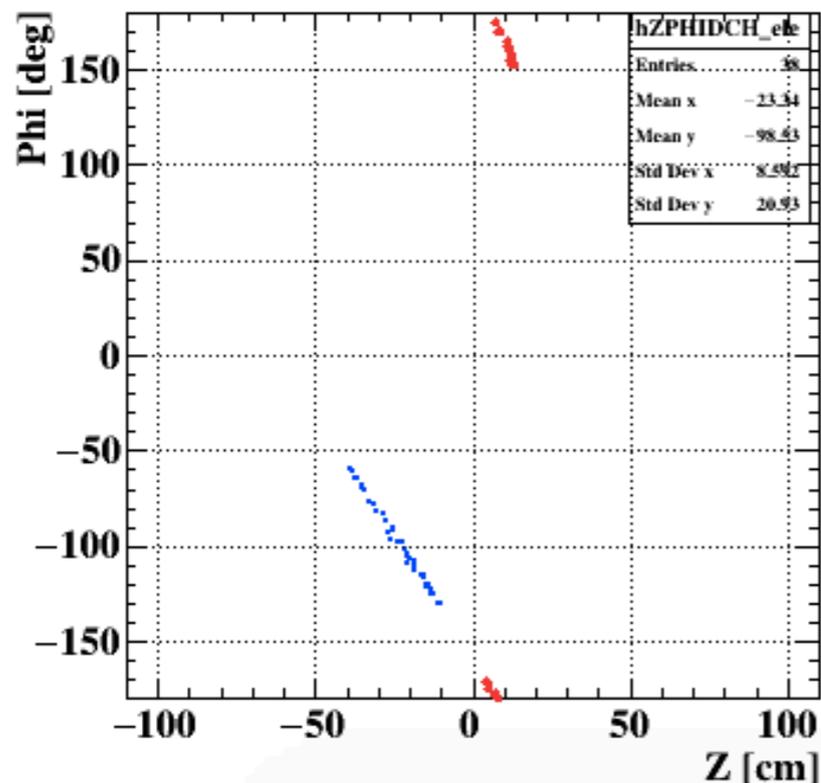
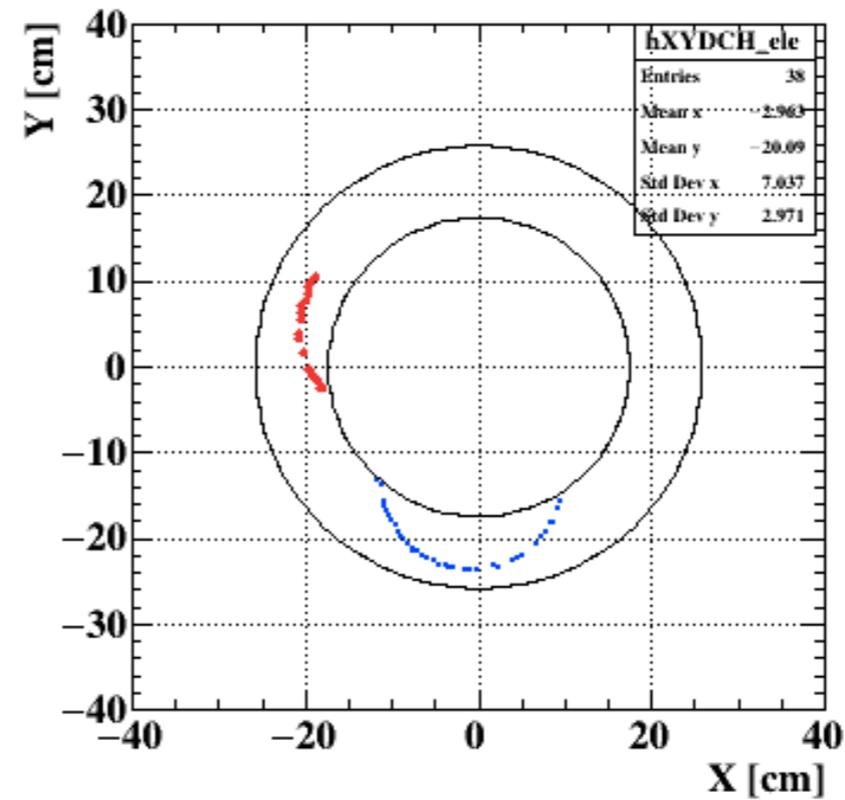
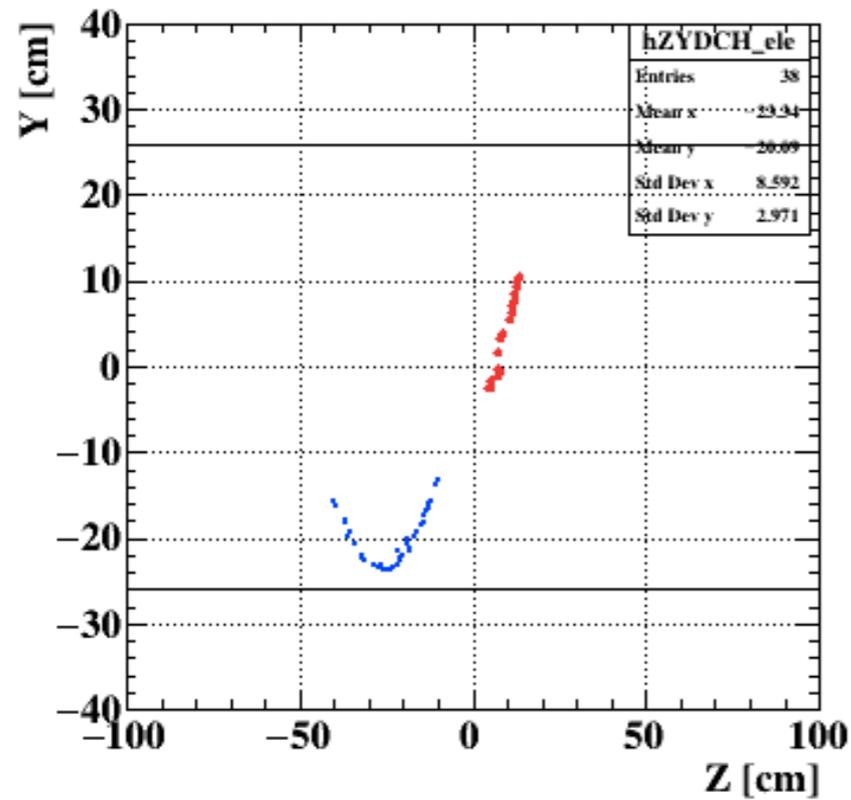
- track to vertex ~consistent in data and MC
- clear drop from MC when requesting POCA to have: **-10cm < z < 10cm**
- part of drop due to lower quality tracks in MC
- issue with material in target region? removed from reco but no strong effect

Track candidate and tracks

<u>Trigger</u> 1 SPX hit 18&18 DCH hits	#events triggered	#events with 1+track candidate	%events with 1+track candidate	#events with 1+track ToTarget	%events with 1+track ToTarget
MC IPC18	13894	12 906	93 %	9 530 (6267+5578-2315)	69 %
MC EPC18	306	279	91 %	155 (88+76-9)	51 %
DATA2023	50 748	46 057	91 %	22 179 (7697+17753-3271)	44 %

- ➡ track candidates number consistent in data and MC
- ➡ clear drop from MC when requesting propagation to target

Tracks not propagated to target



- e+ hit
- e- hit