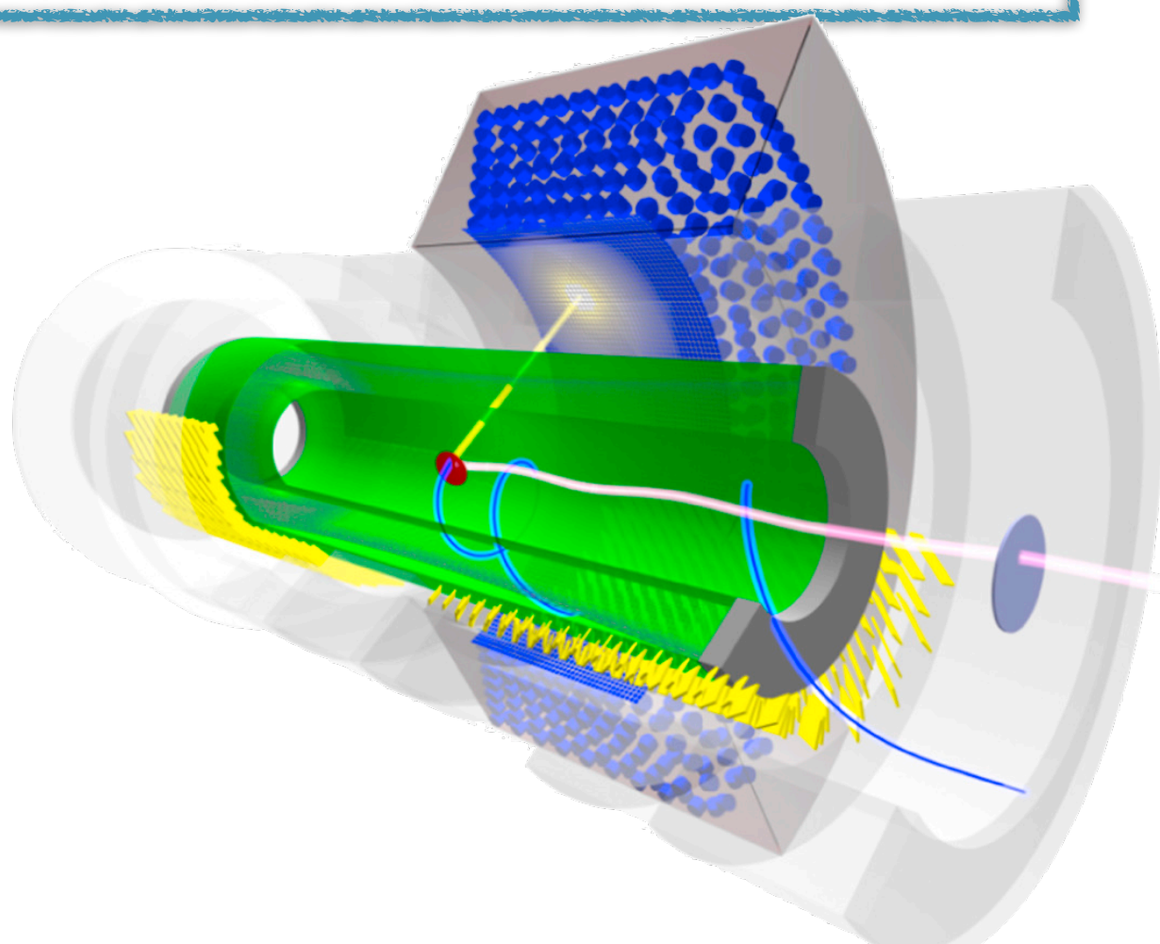
H2020 MSCA ITN
G.A. 858199

Search for the X17 particle with the MEG-II apparatus

Hicham Benmansour, INFN Pisa
on behalf of the MEG-II collaboration

ICHEP XLI, Bologna, July 7th 2022



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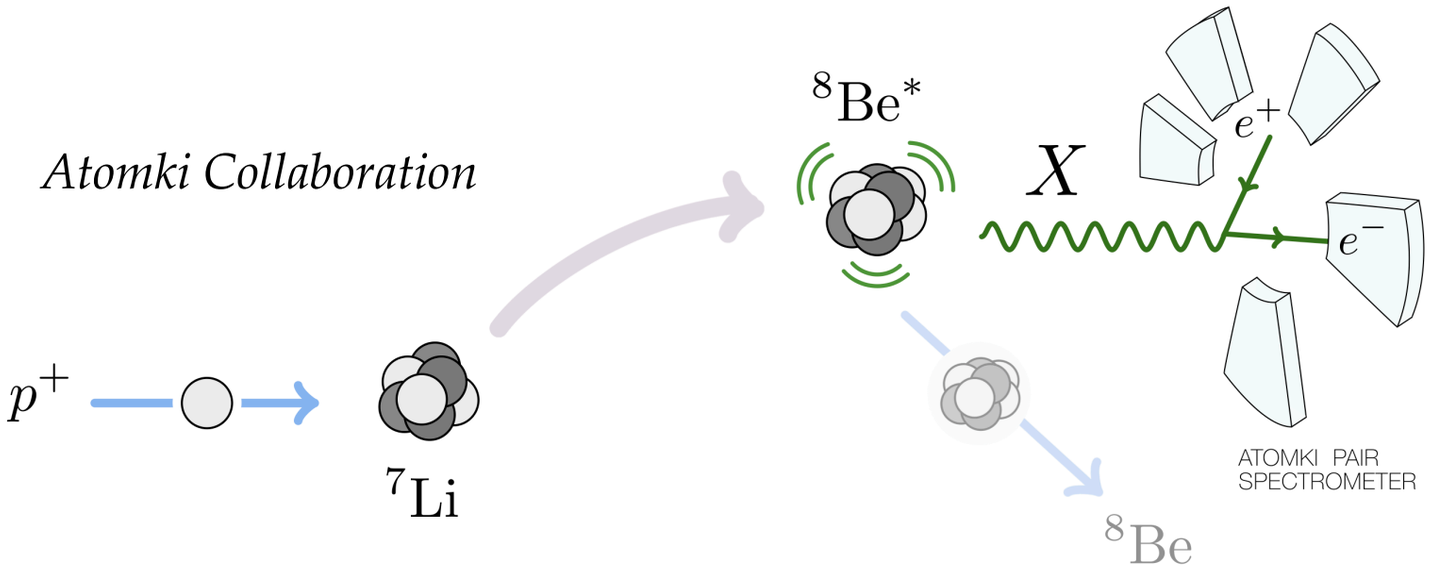
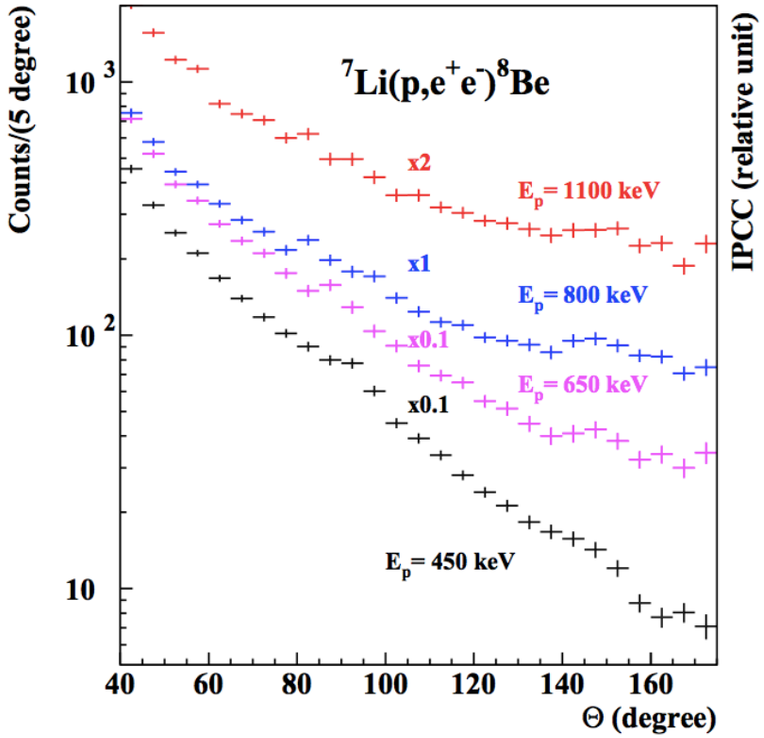
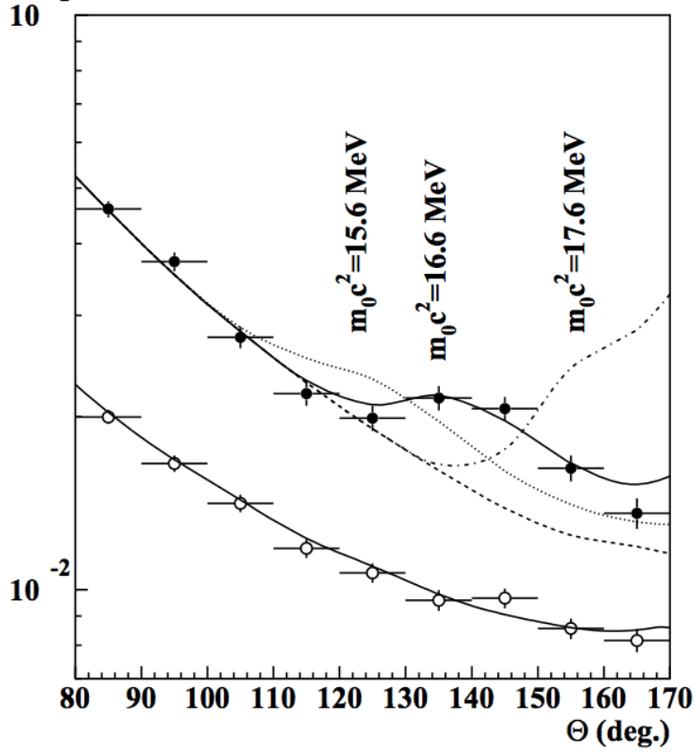
The Beryllium Anomaly

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?

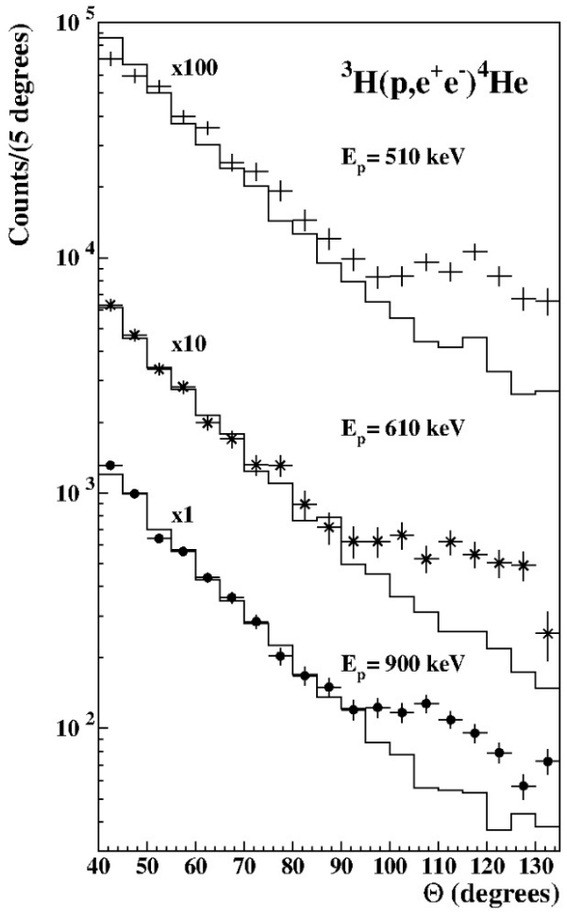
arXiv:2205.07744 Phys. Rev. Lett. 116, 042501 Phys. Rev. D 95, 035017

Standard physics or new boson?

Phys. Rev. C 104, 044003

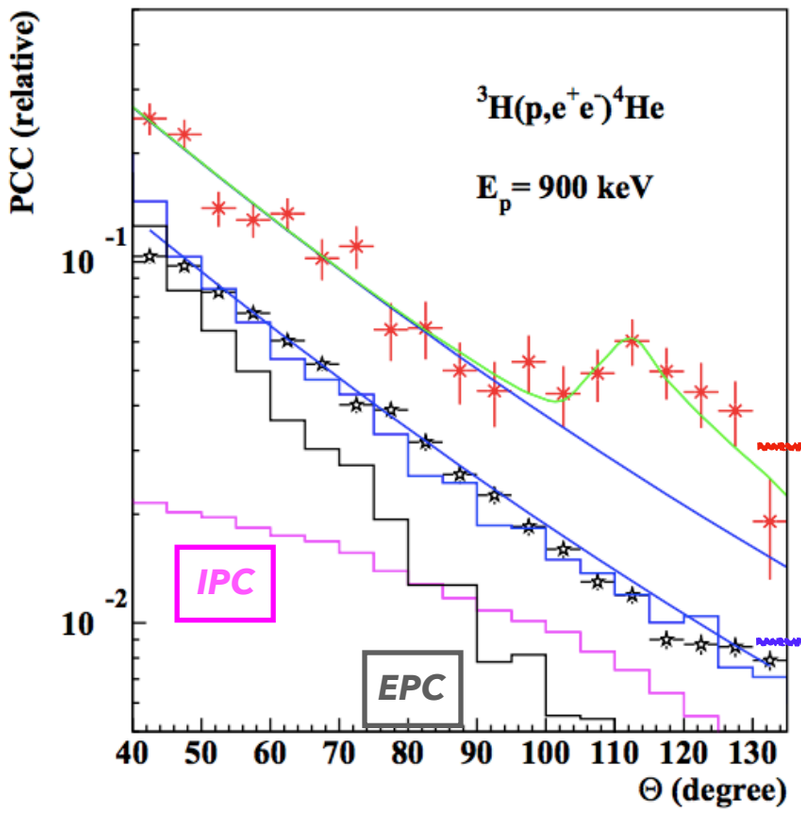
arXiv:1910.10459

Signal region



Study repeated with Tritium target

$$^3\mathrm{H}(p, e^+e^-)^4\mathrm{He}$$



Esum = **E**e+ + **E**e-

IPC = Internal Pair Conversion –> direct e+/e- pair creation

EPC = External Pair Conversion –> γ-conversion outside N

Esum signal region

Esum background region

- Excess in IPC background at 115° angular opening: >6σ
- Possible explanation: a 16.84 MeV neutral boson (X17?)
- Other indirect searches (NA64, NA48/2): no evidence for X17 but strong constraints

Phys. Rev. D, 101:071101 Phys. Lett. B 746, 178

- Can the measurement be performed with an independent setup, the MEG-II apparatus?

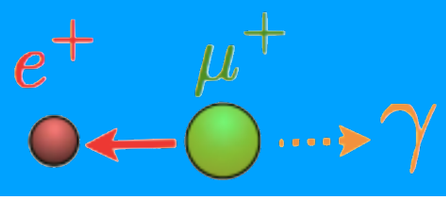
MEG-II objectives

- Hint for the production of a neutral, 17 MeV boson, potential mediator of a fifth force: X17

- Need for experimental confirmation: MEG-II has all elements to carry out the measurement
  - → Reproduction of excess?
  - → Better invariant mass resolution
  - → Production in full solid angle

- First « X17 » data was taken by MEG-II

The MEG-II experiment



- MEG-II experiment searches for charged lepton flavour violating decay: $\mu \longrightarrow e\gamma$

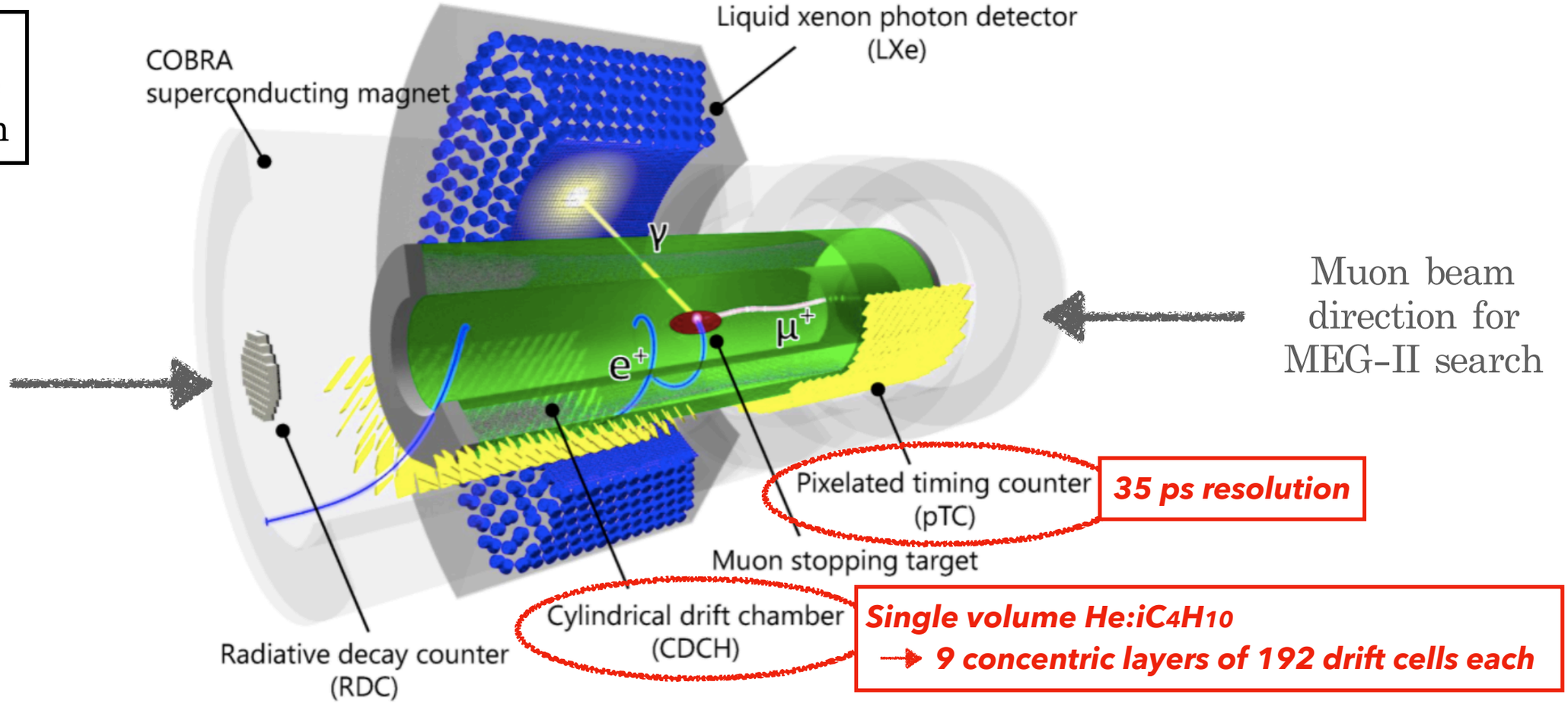
Eur. Phys. J. C, 76(8):434

- 1 order of magnitude sensitivity improvement wrt MEG: $BR(\mu \longrightarrow e\gamma) \rightarrow 6 \times 10^{-14}$

See Renga's talk at ICHEP tomorrow

Eur. Phys. J. C 78, 380

MEG-II results from an intense upgrade program



- The new MEG-II highly performing spectrometer can be used for X17-boson search:

→ X17-dedicated target in place of the muon target
→ MEG-II CW accelerator as proton beam
→ adjusted magnetic field
→ gamma auxiliary detectors
→ optimized TDAQ

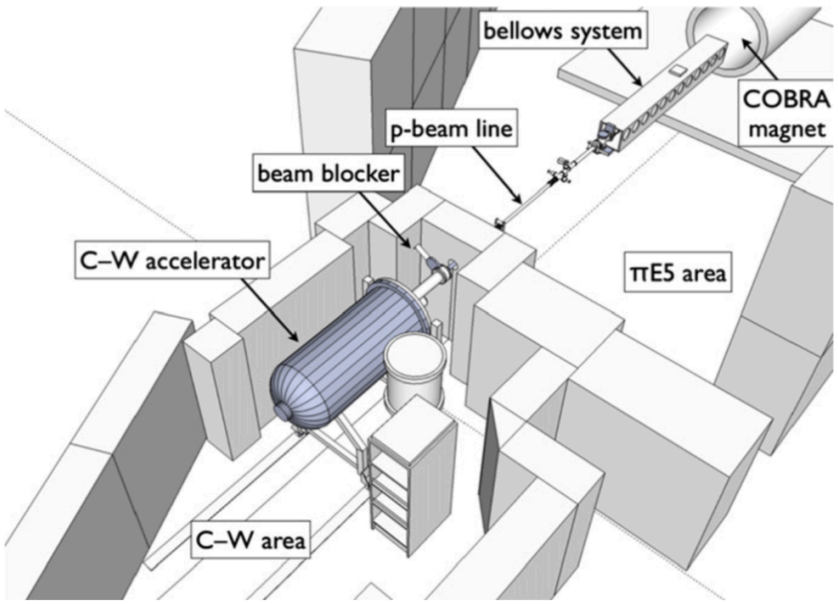
The Cockcroft-Walton accelerator

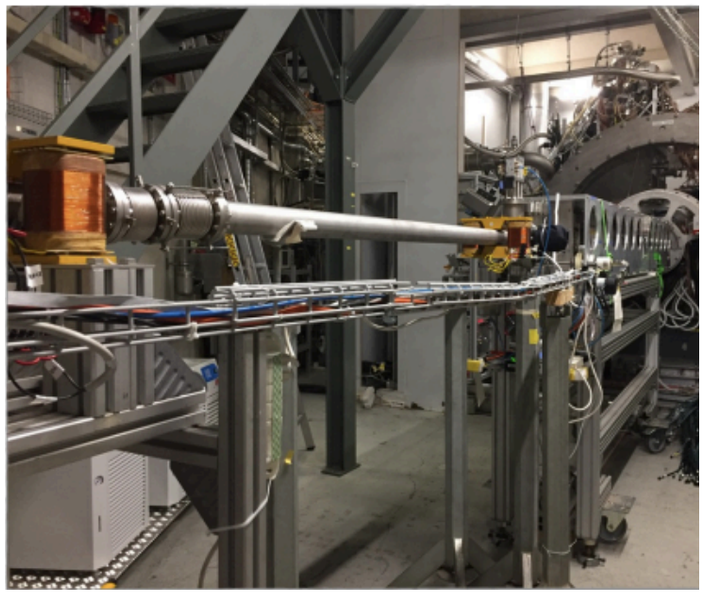
- <u>LXe calibration</u>
  - MEG-II Cockcroft-Walton accelerator: used for calibration of LXe calorimeter
  - Proton beam impinging on Li target (440 keV resonance): 17.6 MeV γ line

- <u>X17 search</u>

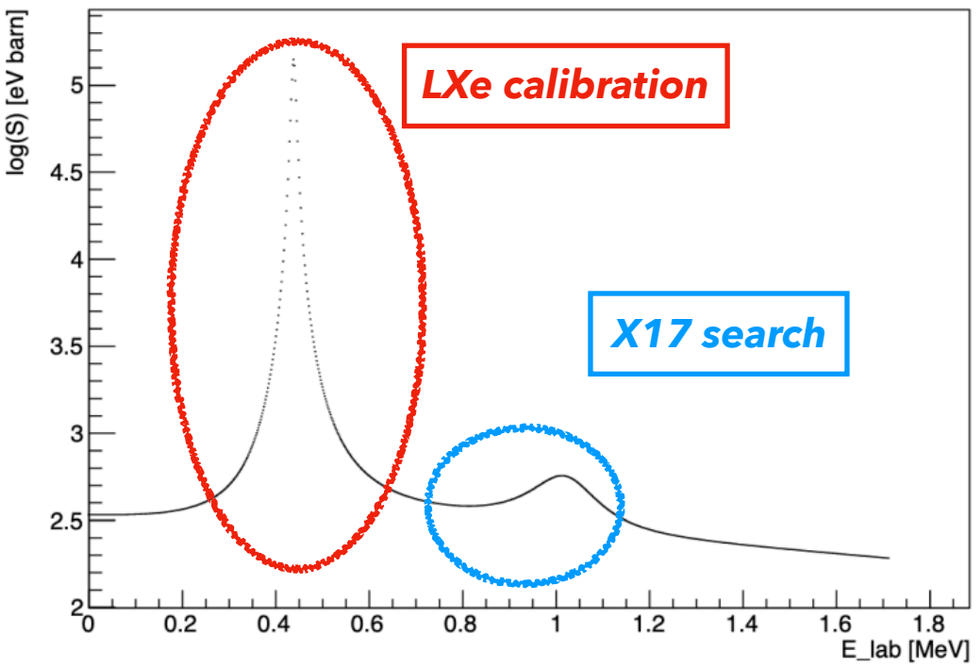
  Max proton current and energy: 100 μA and 1.1 MeV

  → ideal for X17 search (1 MeV resonance and 18.15 MeV γ line)





p+Li cross-section



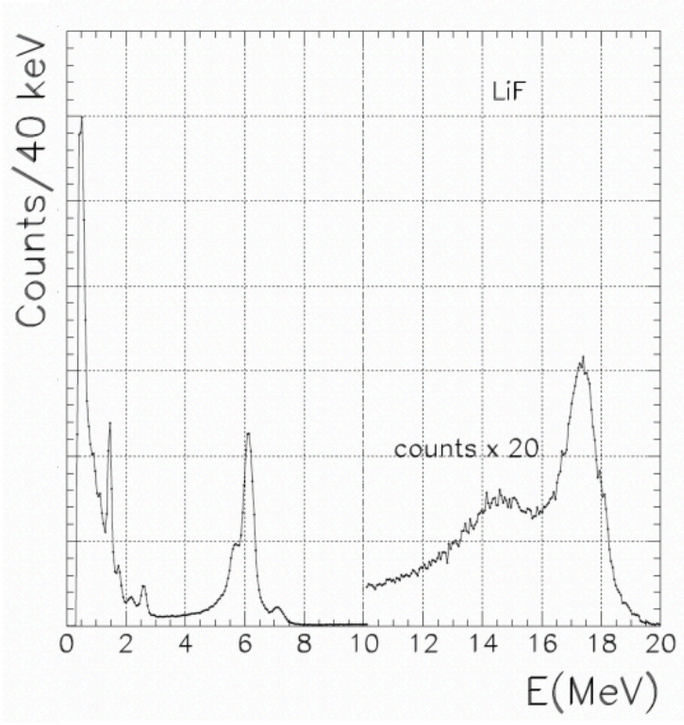
The new target region

- 400 μm-thickness carbon fiber vacuum chamber to minimize multiple scattering

- 5 μm LiF on 10 μm copper substrate (by INFN Legnaro)
- 2 μm LiPON (*) on 25 μm copper substrate (by PSI)

- Target-supporting and heat-dissipating copper structure attached to CW nose

Mechanical and heat dissipation simulations carried out

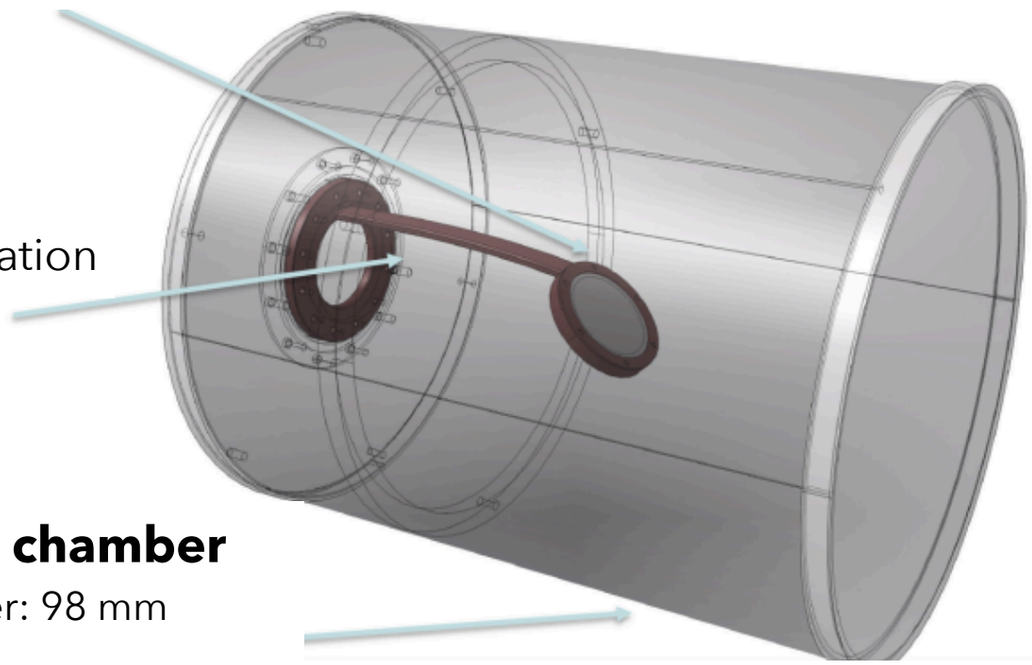


Li target

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

(*) Lithium phosphorus oxynitride ($Li_{3-X}PO_{4-Y}N_{X+Y}$)

Reduced magnetic field and beam tuning

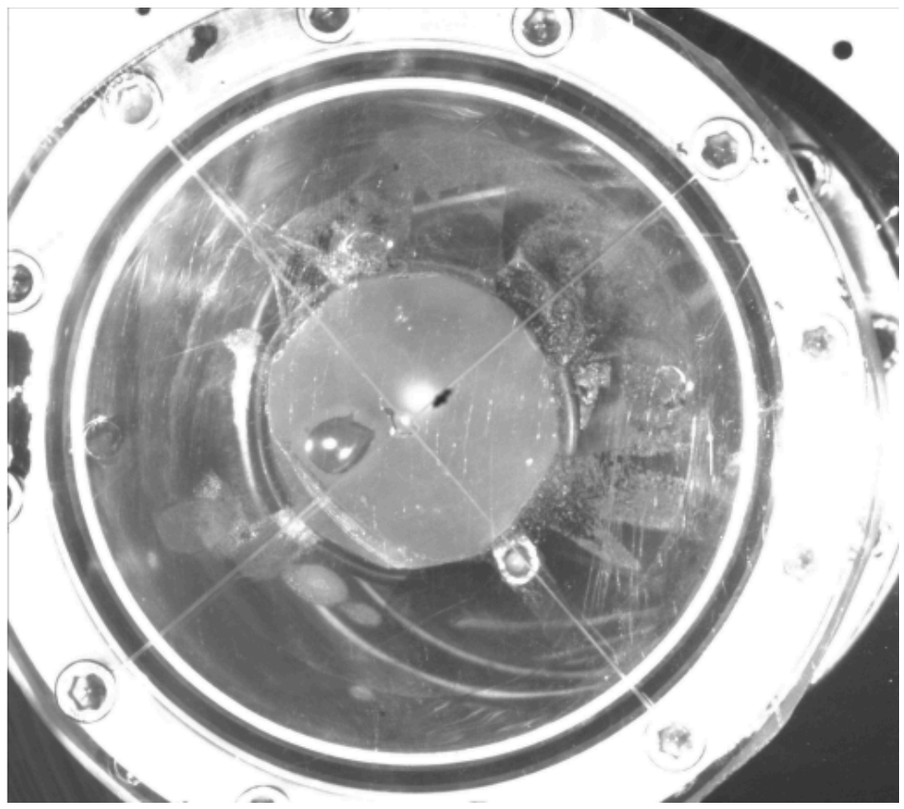
- $\mu \longrightarrow e\gamma$ search relies on 52.8 MeV positron search with default magnetic field (1.27T at COBRA center)

- for X17: energies ~6 times lower → scaling of the field by a factor 0.15

- CW tuned using a quartz target: proton-induced fluorescence in the quartz, visible emission

- Tuning made varying 3 dipolar fields along the beamline to center the beam
  → beam spot centered and covering the Li area

megCam - COBRA OFF



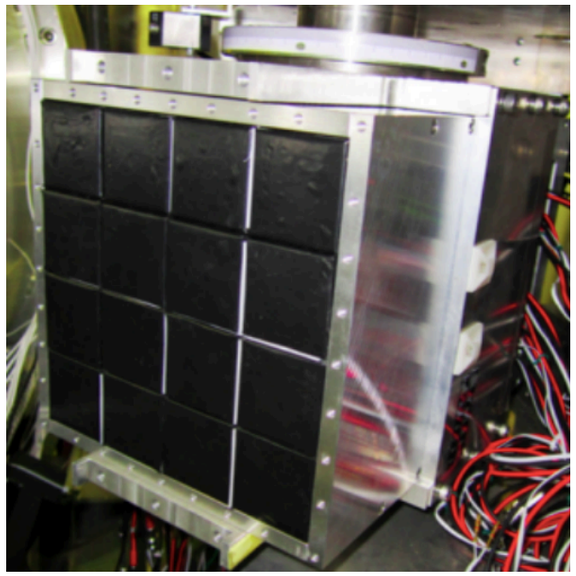
CCD camera - COBRA ON

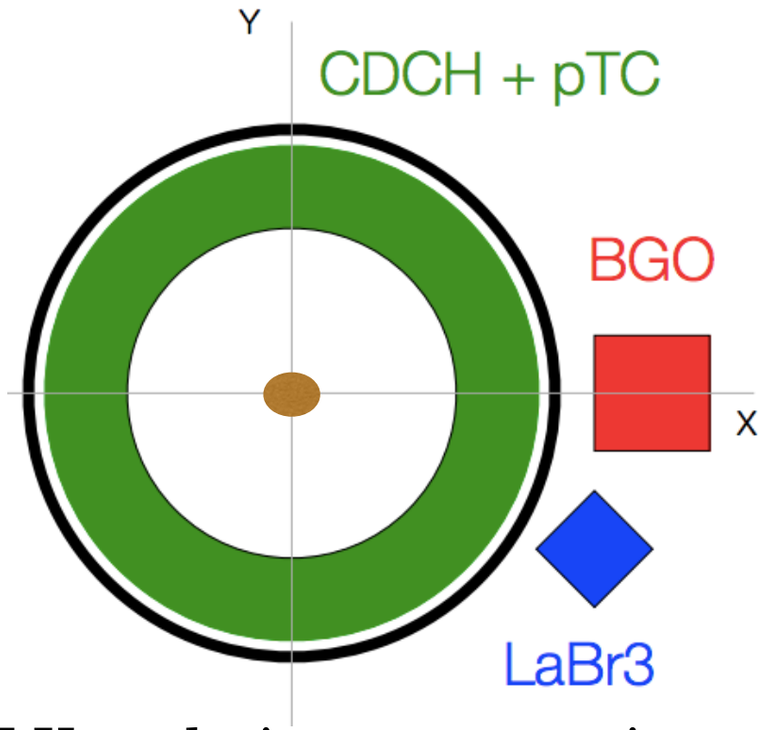
Gamma detectors

- Two gamma detectors

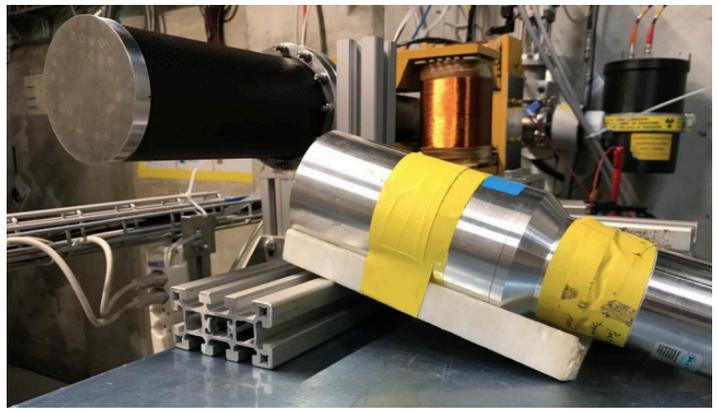
→ Understanding of background → Stability monitoring → Signal normalisation

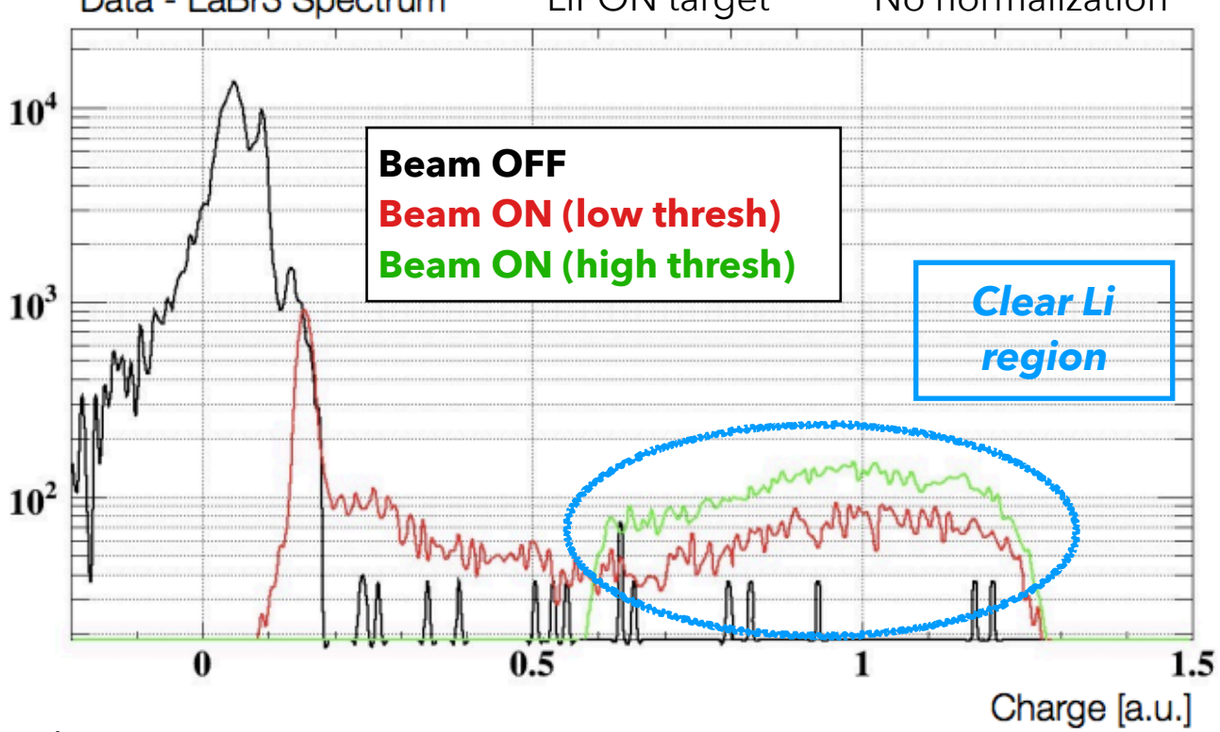
Bismuth Germanate (BGO) crystal matrix (4x4)





Lanthanum Bromide (LaBr3) crystal





- LXe calorimeter on maintenance during run

First data taking

- With all elements mentioned above, first X17 data taking period last February

- X17 runs from February 10th to February 22nd: sample of 90 M events
  → 10-17: LiF target (55 M) → 17-22: LiPON target (35 M)

- Objectives:
  - → define optimal experimental setup and final TDAQ configuration
  - → have a complete understanding of the backgrounds
  - → develop reconstruction algorithm
  - → estimate sensitivity

- Different TDAQ configurations have been studied and data in different conditions were taken

→ CDCH multiplicity requirement + 1 pTC hit extensively used

→ CW current ranging from 1 to 5 μA (up to 10 μA for short periods)

- Online data suppression: factor 5 data taking speed increase

→ >100 Hz event rate recording

Sensitivity estimate

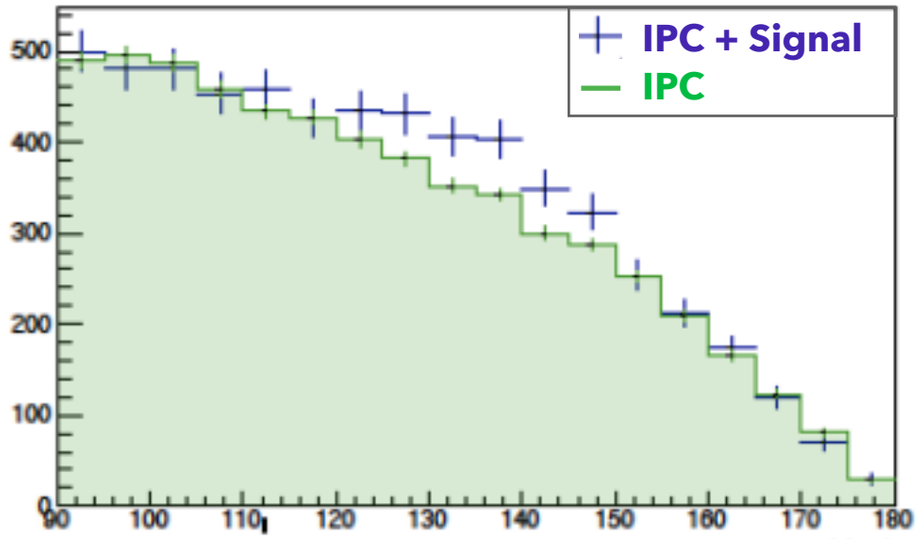
$BR(X) = 6 \times 10^{-6}$ → 1 X17 every 1.7×10^5 Li-γ

$BR(\mathrm{IPC}) = 3 \times 10^{-3}$

- Assuming IPC as main background

$5\sigma \sim \mathrm{O}(500\ \mathrm{X17})$

Monte-Carlo simulation



- Significance in already taken data is being evaluated
  → depending on that, potential new data taking

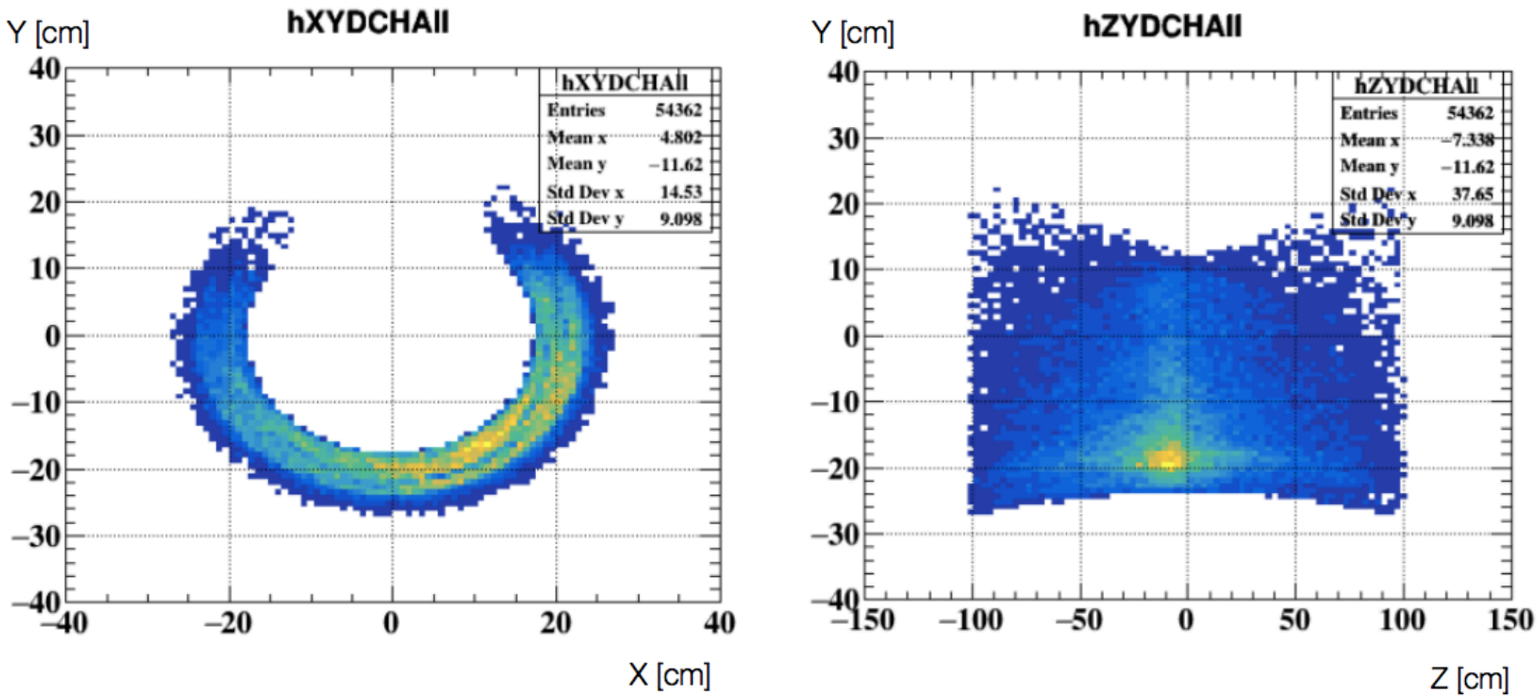
- Additional EPC Background and Pair Reconstruction:
  → determining factors for precise sensitivity estimate

- Work ongoing:
  - → solid angle acceptance
  - → trigger acceptance
  - → pair reconstruction efficiency
  - → CW current
  - → online data suppression

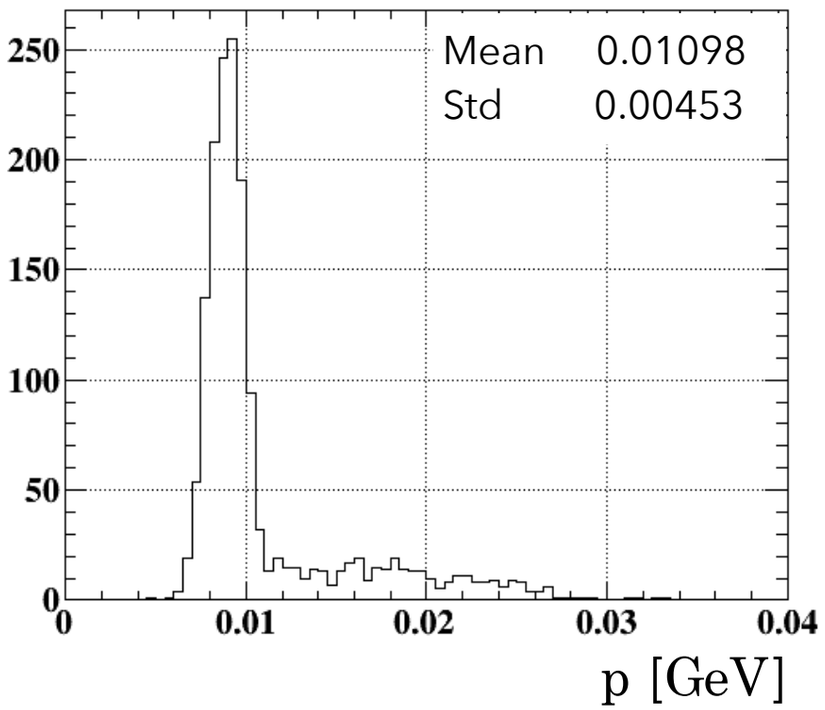
A first look at the data sample

- A first analysis was carried out

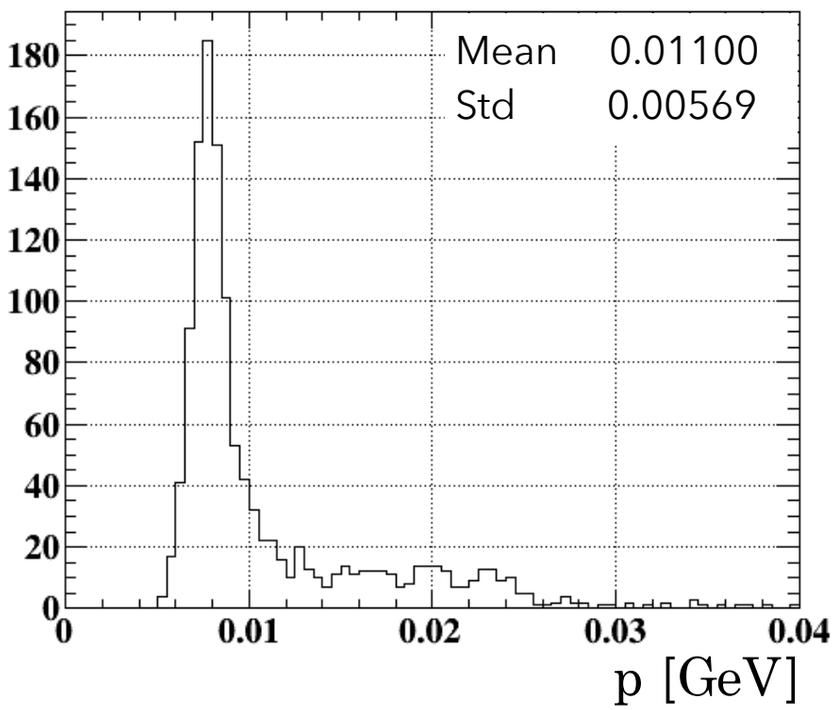
Hits distribution in the drift chamber



Monte-Carlo IPC



Data (including IPC and EPC)

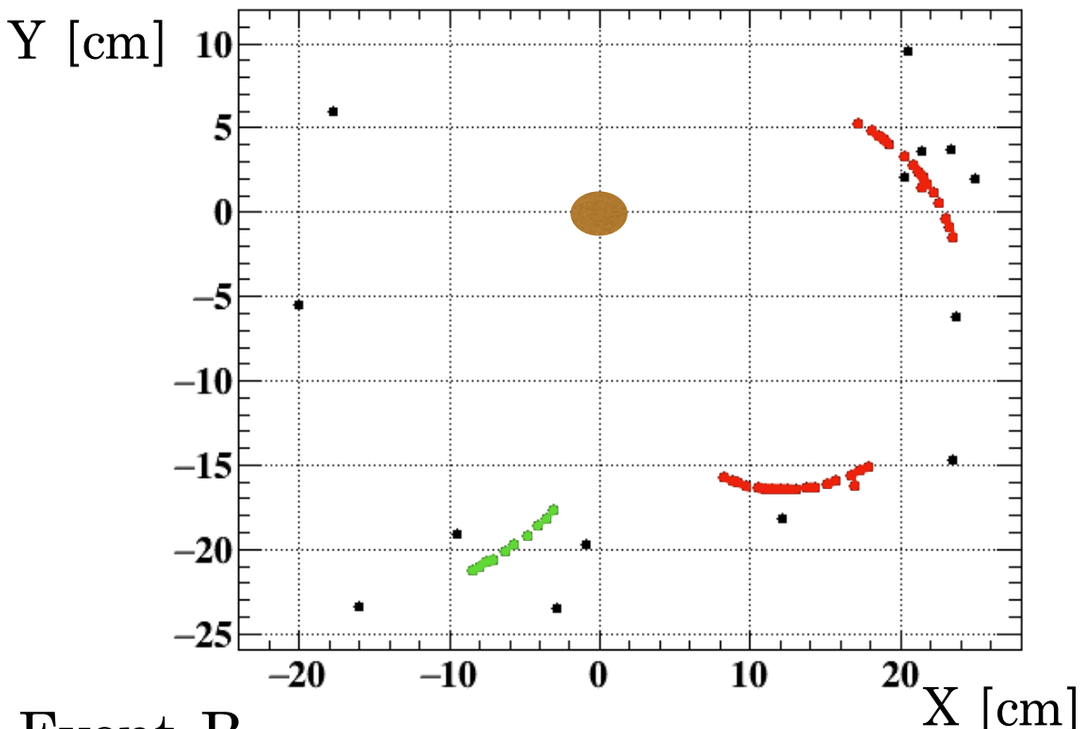


Single particle momentum

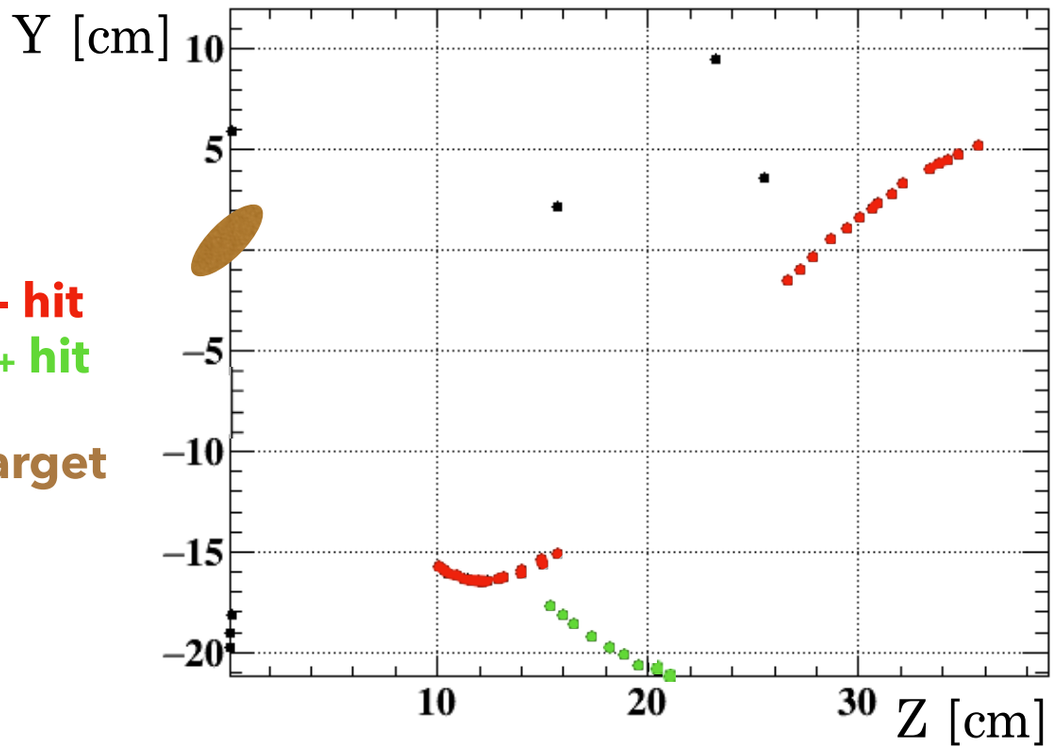
Pair event display from LiPON data

- Event A

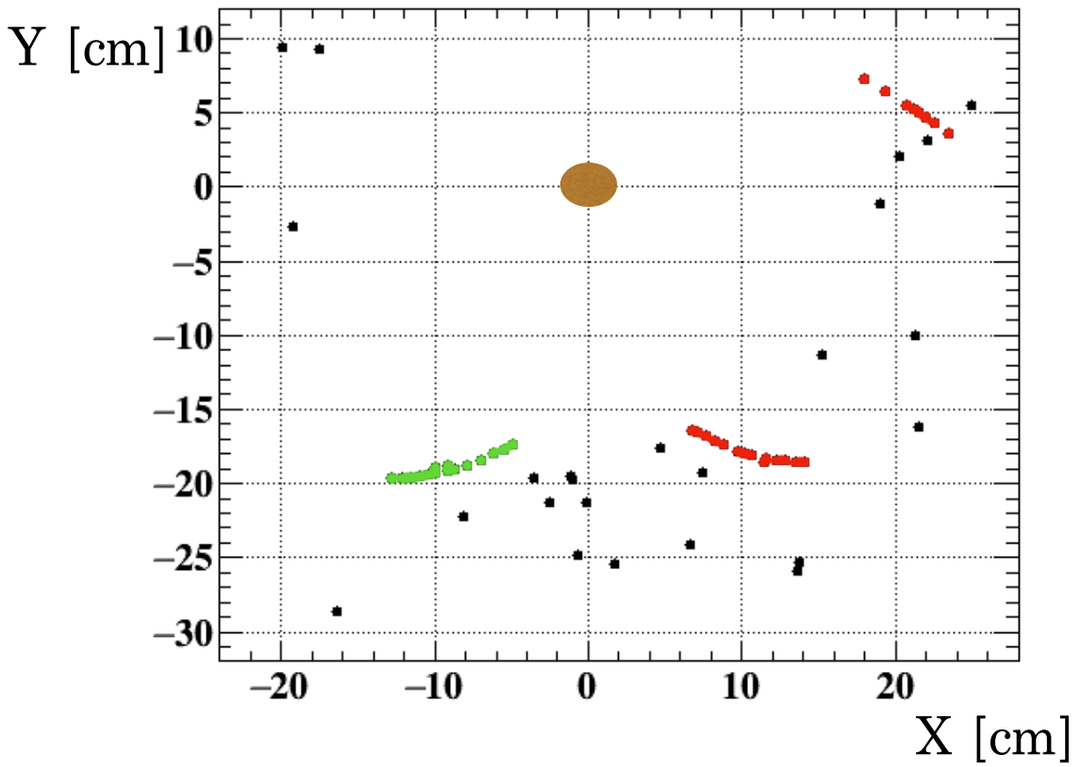
LiPON, 1050 keV, 2 uA, 2022-02-18

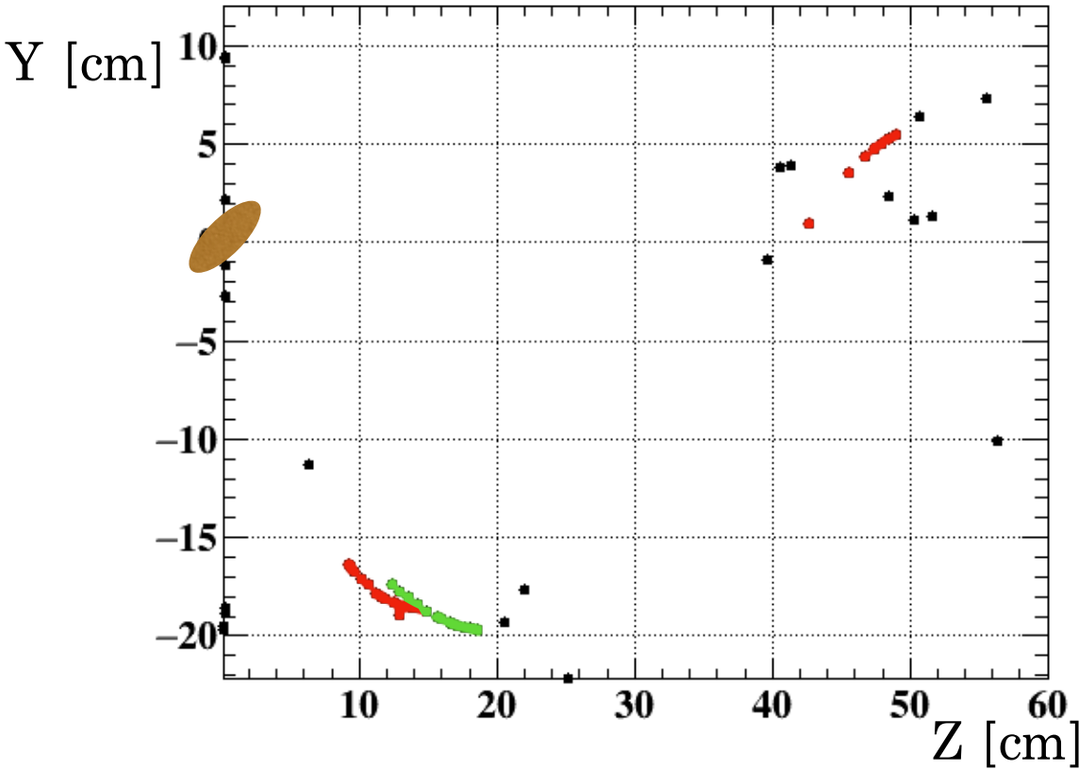


e- hit
e+ hit
target



- Event B





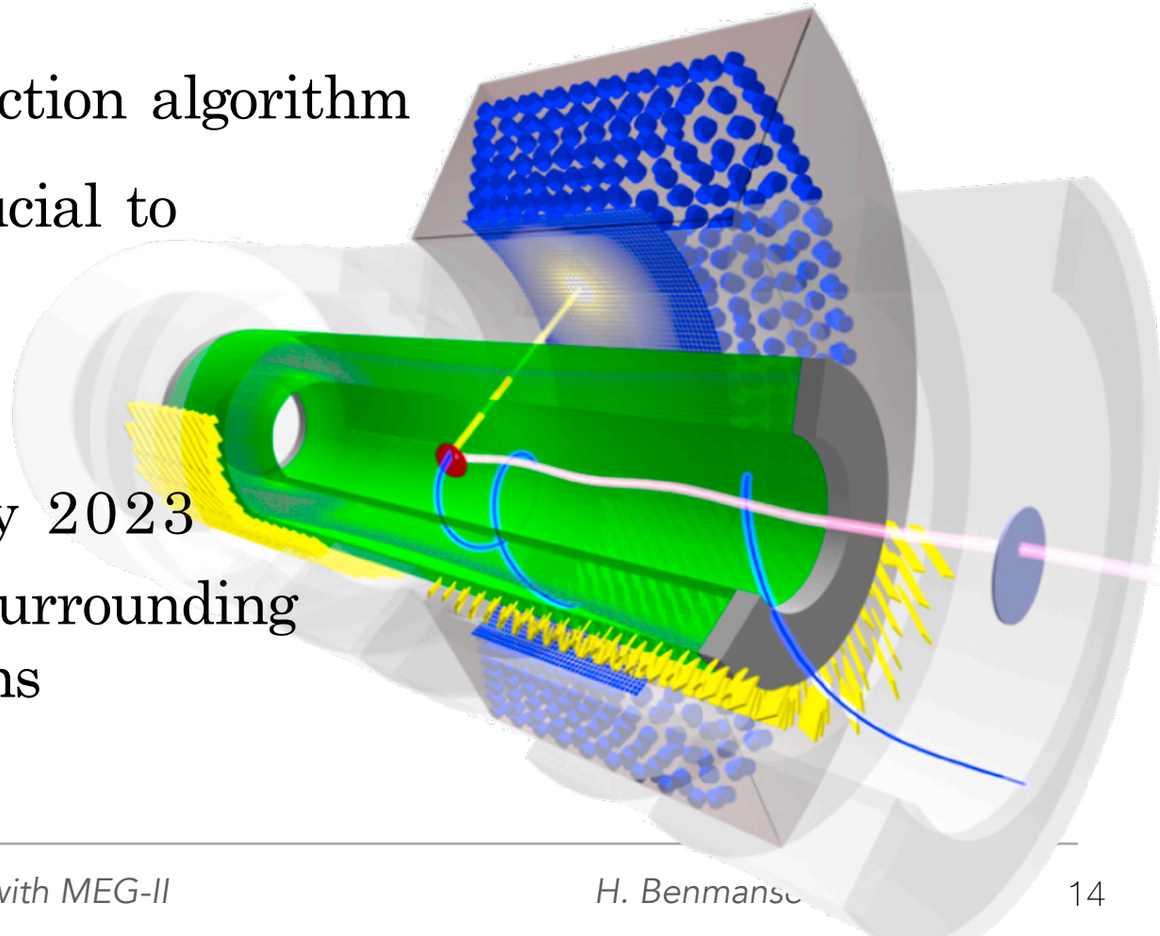
Conclusion and outlook

- Anomalous excess observed in the angular correlation of $^7\mathrm{Li}(p, e^+e^-)^8\mathrm{Be}$ by the Atomki collaboration
  - → Potential new boson X17

- The MEG-II collaboration has designed, tested and built all the elements to perform the X17 search in different conditions with respect to Atomki
  - → Better understanding of the X17 anomaly

- Data are currently under analysis
  - → Need for a performant pair reconstruction algorithm
  - → EPC and reconstruction efficiency crucial to determine significance

- If needed, additional data can be taken early 2023
  - → Potential optimization of target and surrounding region, trigger and DAQ configurations



Thank you for your attention!

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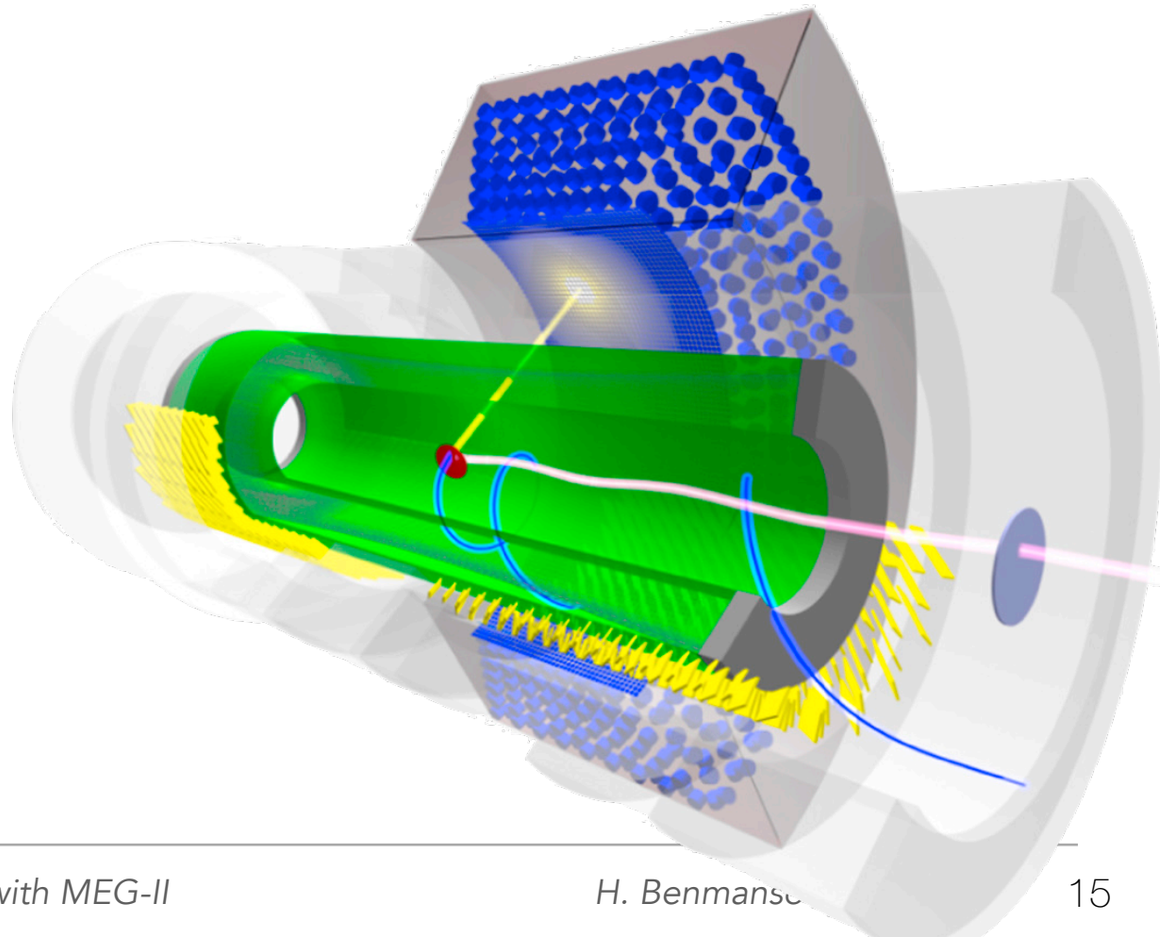
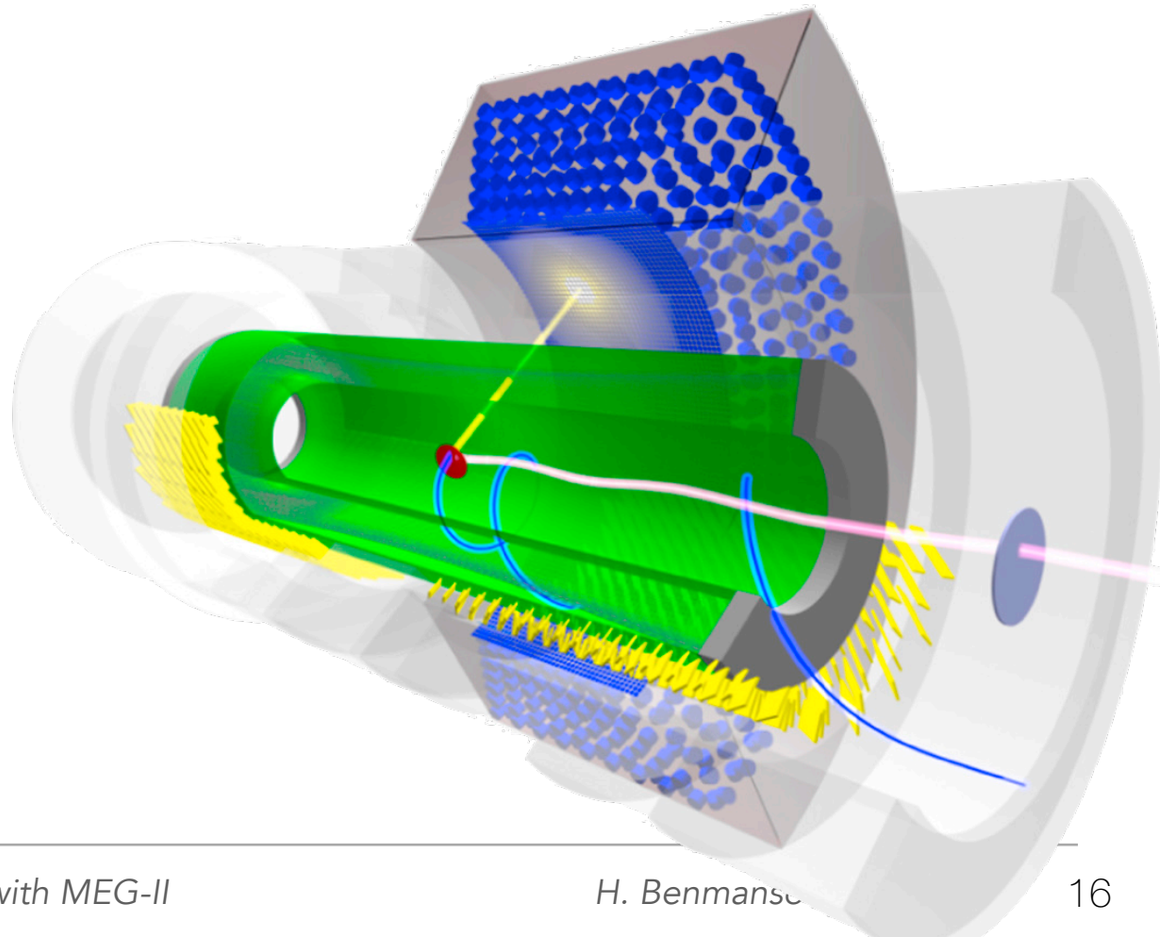


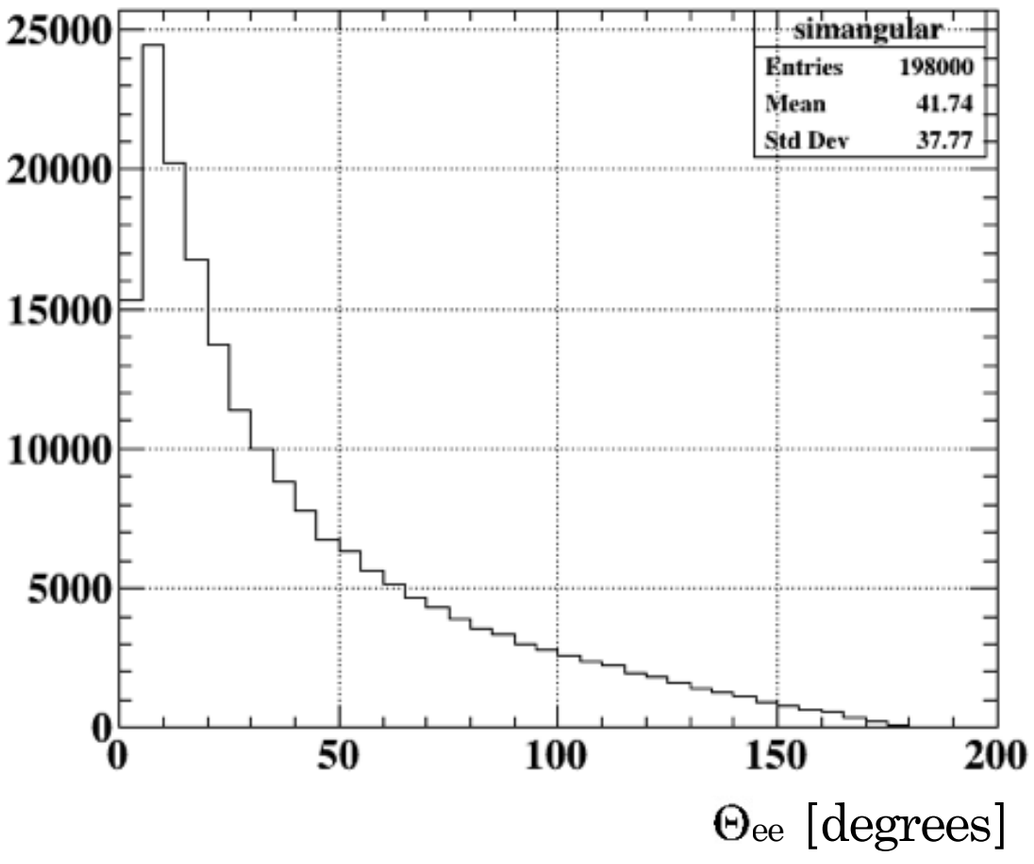
Backup slides



Development of pair reconstruction algorithm

- In MEG-II, track finding is optimized for positrons
- Current effort to identify both e+ and e-
- Very first algorithm is already running based on MEG II track finding: X17-dedicated track finder is under development

Simulated IPC angular correlation
(Zhang-Miller model)



Reconstructed IPC angular correlation