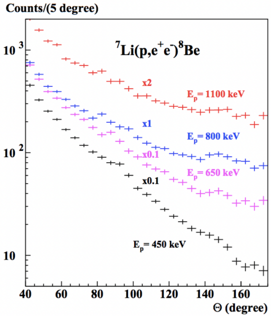
Measurement of the X17 anomaly with the MEG II detector

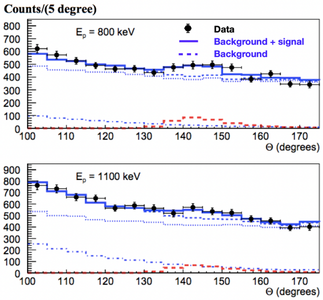
Giovanni Dal Maso for the MEG II collaboration

Joint Annual Meeting of SPS APS, Universität Basel

X17 anomaly at ATOMKI

Beryllium anomaly

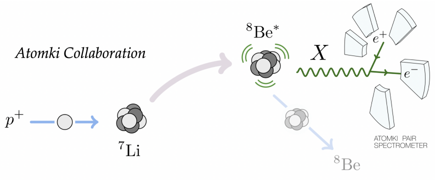




arXiv:2205.07744

Phys. Rev. Lett. 116, 042501

Phys. Rev. D 95, 035017



In 2016 the ATOMKI collaboration claims the existence of an anomaly in the $^7\mathrm{Li}(\mathrm{p}, \mathrm{e}^+\mathrm{e}^-)^8\mathrm{Be}$ reaction: an excess of event is found in the internal pair conversion (IPC) angular distribution later confirmed for a number of proton energies (E_p = 450 keV, 650 keV, 800 keV, 1100 keV) and in $^3\mathrm{H}(\mathrm{p}, \mathrm{e}^+\mathrm{e}^-)^4\mathrm{He}$.

Excess was attributed to a light boson:

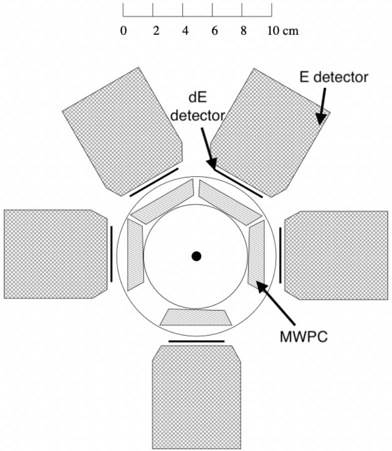
- $m_X = 16.95\,\mathrm{MeV}/c^2$
- $\mathrm{BR}(X/\gamma) = 6 \times 10^{-6}$

Experimental set-up

The detector used at ATOMKI in 2015 was composed of 5 telescopes arranged to obtain a uniform response in IPC angular aperture. Each telescope was structured as follows:

- MWPC: multi wire proportional chamber for angle measurement.
- dE detector: thin plastic scintillator
- E detector: bulky plastic scintillator

Scintillators were coupled to PMTs.



arXiv:1504.00489

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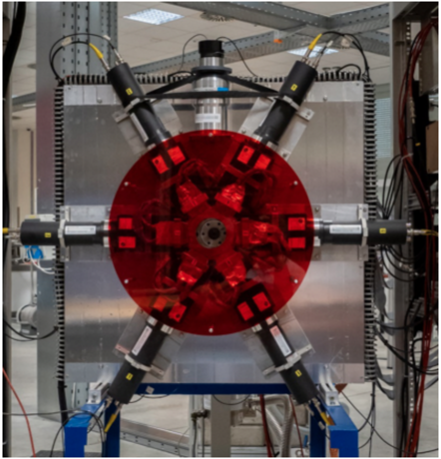
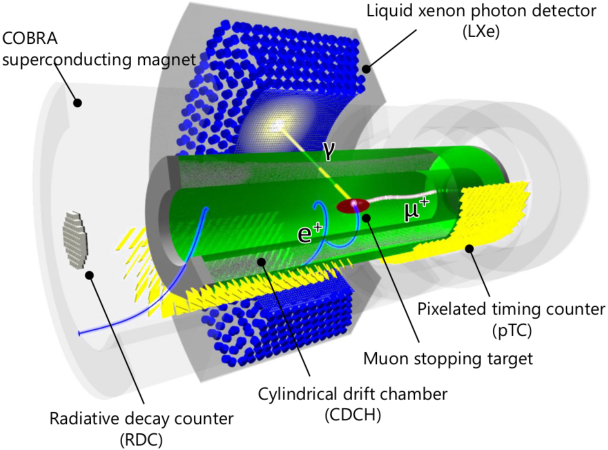
The set-up has been upgraded to increase acceptance using 6 uniformly spaced telescopes.



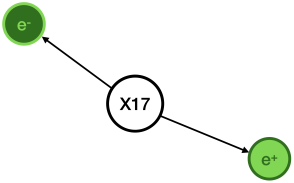
MEG II experiment

MEG II

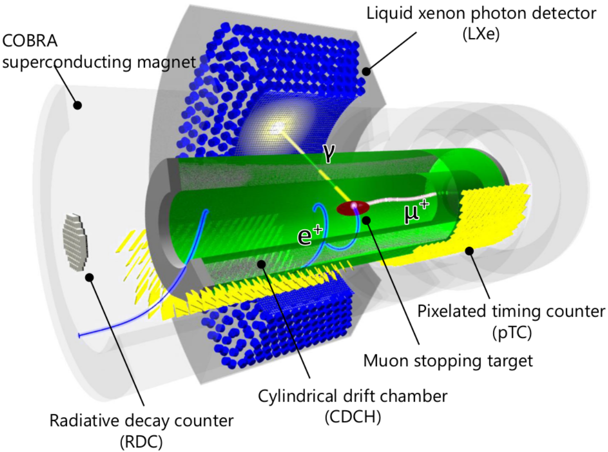
The goal of the MEG II experiment is to measure the decay $\mu^+ \to e^+ \gamma$. The current upper limit on this process - most stringent upper limit on any particle decay - was set by the MEG collaboration at PSI to $BR(\mu^+ \to e^+ \gamma) < 4.2 \times 10^{-13}$ (90 % CL). The upgrade aims at reaching a sensitivity of 6×10^{-14} (90 % CL).



MEG II detector: what do we need?



- We need to measure the angular aperture of the pair
- We need to measure the rest mass of the pair
- We need to measure timing



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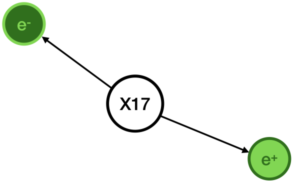

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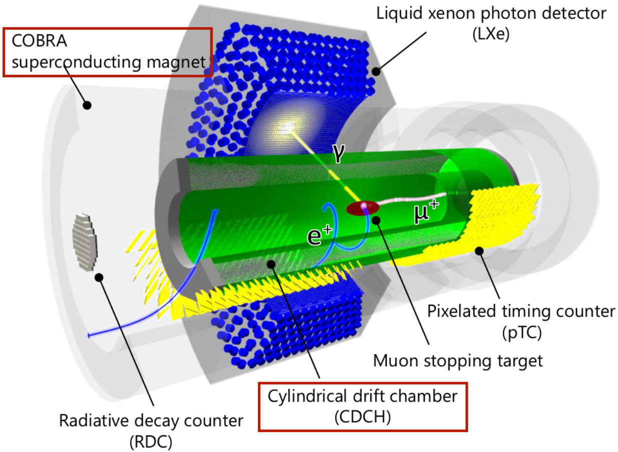

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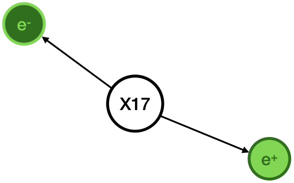

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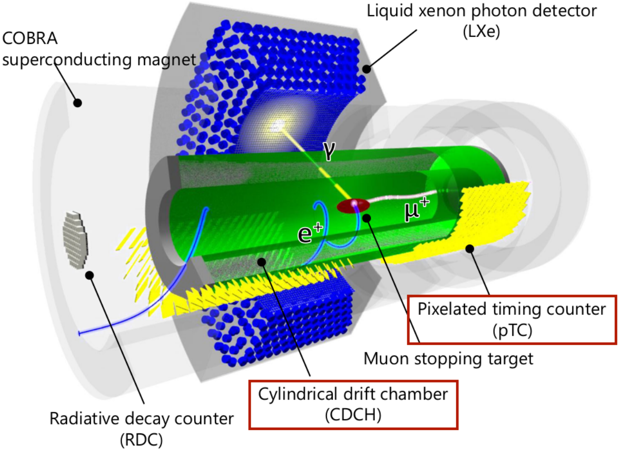
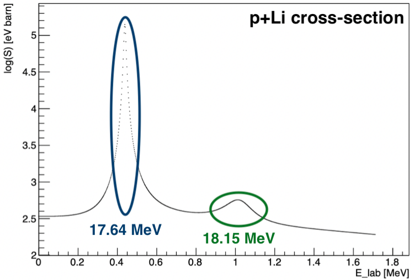
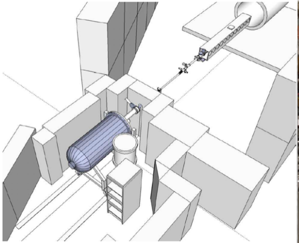


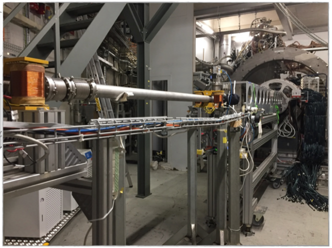
Proton beam

We already have a dedicated proton beamline in our experimental area for LXe calibrations: a 1.1 MeV Cockroft-Walton used to excite the 440 keV resonance of $^{7}\mathrm{Li}$ and produce a 17.64 MeV γ line.

→ **We can perform the measurements during HIPA (main accelerator) shut-downs**.





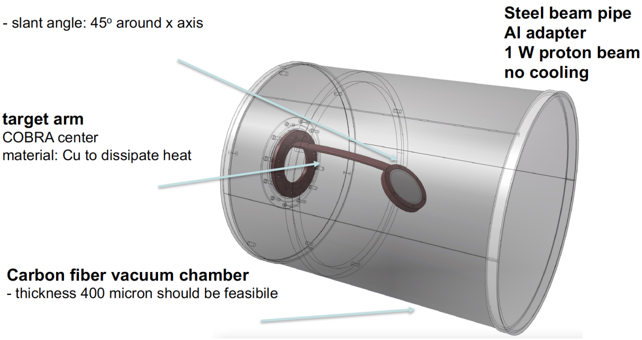


The anomaly can be produced in the full energy range between the two resonances.

Lithium target for X17 mesurement

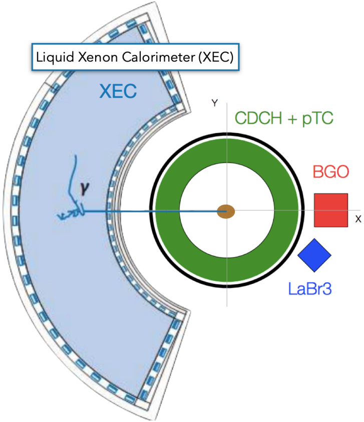
The target and its chamber are new:

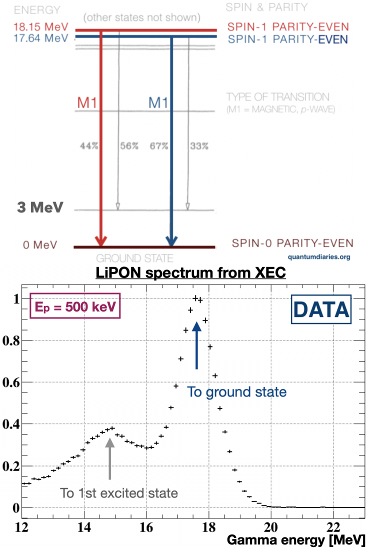
- We have tested two possible target arrangements:
  - $2\ \mu m$ LiPON deposited on $25\ \mu m$ copper substrate (by PSI) → physics run
  - $5\ \mu m$ LiF deposited on $10\ \mu m$ copper substrate (by INFN Legnaro) → gamma detectors calibration
- The copper arm is used for both hold the target in position and to dissipate to the CW beamline the heat deposited by the proton beam.
- The whole target structure is enclosed in a $400\ \mu m$-thick carbon fiber chamber to allow for vacuum and minimize multiple scattering.



Auxiliary detectors

- LXe calorimeter for background measurements
- auxiliary gamma detectors for online monitoring (BGO and LaBr crystals)

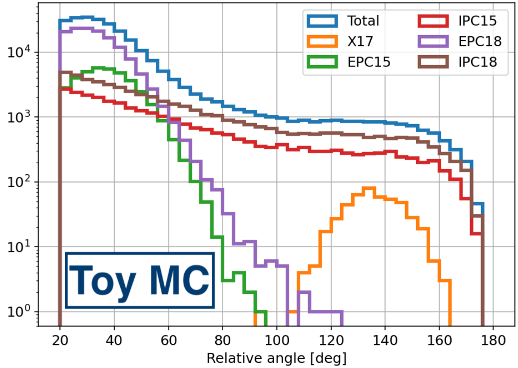


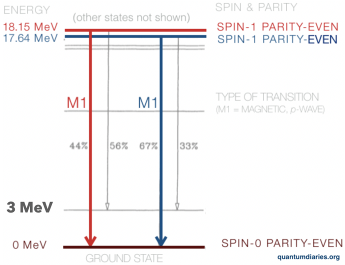


Backgrounds

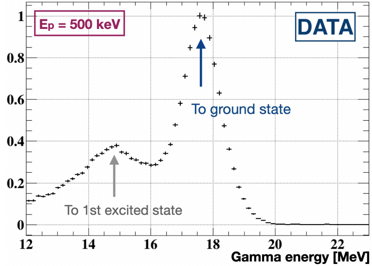
For each gamma line we have two contributions to background:

- internal pair conversion (dominant in signal region)
- external pair conversion





LiPON spectrum from XEC



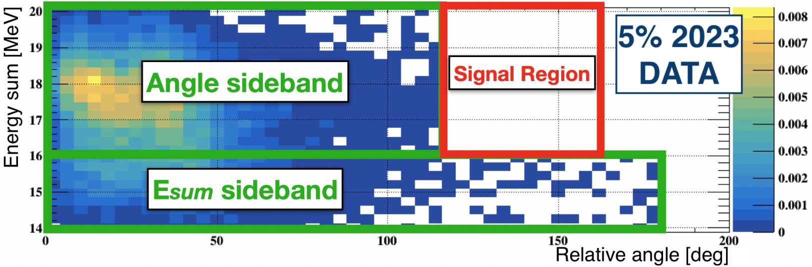
Data taking

We carried out two data taking campaigns:

- test-run 2022: different trigger settings tested, LiPON chosen as measurement target, heat dissipation tested at high current (up to $10\,\mu A$)
- physics run 2023: 4 weeks at $E_p = 1080\,\text{keV}$:
  - 75×10^6 events
  - 300×10^3 reconstructed pairs

We decided to use a blinding box for the signal region and two sidebands for background studies:

- sideband in energy sum: $E_{sum} < 16\,\text{MeV}$
- sideband in relative angle: $\theta_{e^+e^-} < 115°$, $16\,\text{MeV} < E_{sum} < 20\,\text{MeV}$
- blinding box: $115° < \theta_{e^+e^-} < 160°$, $16\,\text{MeV} < E_{sum} < 20\,\text{MeV}$



Data analysis

The analysis will be a full Feldman-Cousins construction to set CL on the X17 branching ratio and mass using E_{sum} and $\theta_{e^+e^-}$ as our variables. The binned likelihood is:

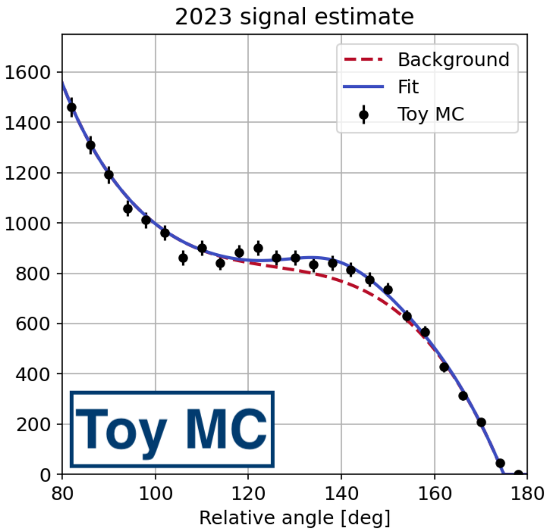
$$\mathcal{L} = \mathcal{L}(\mathbf{x}|\hat{\mathcal{N}}_S, \hat{\mathcal{N}}_{EPC15}, \hat{\mathcal{N}}_{IPC15}, \hat{\mathcal{N}}_{EPC18}, \hat{\mathcal{N}}_{IPC18})$$

$$\mathcal{L} = \frac{\hat{\mathcal{N}}^{\mathcal{N}} e^{-\hat{\mathcal{N}}}}{\mathcal{N}!} \prod_{i=1}^{m} \Big(\sum_{j=0}^{4} \frac{\hat{\mathcal{N}}_j}{\hat{\mathcal{N}}} pdf_j(x_i) \Big)^{N_i}$$

Based on ATOMKI results:

- BR(X17) = $6 \cdot 10^{-6}$ $\rightarrow$ 1 X17 every $1.67 \cdot 10^5$ every Li(p, γ)B reaction
- BR(IPC) = $3 \cdot 10^{-3}$

From 2023 dataset → O(400 X17)



Status

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- 2022 engineering run and 2023 physics run DONE
- Pair reconstruction and track selection DONE
- 2023 data reprocessing ONGOING
- Sidebands check ONGOING
- Mass MC production TO BE STARTED
- Unblinding TO BE DONE

Thank you for your attention!