Search for the X17 particle with the MEG-II apparatus

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

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The Beryllium Anomaly

Atomki Collaboration

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

- 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?

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Phys. Rev. Lett. 116, 042501  
Phys. Rev. D 95, 035017

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ICHEP XLI, Bologna  
The X17 search with MEG-II  
H. Benmansour
• Excess in IPC background at 115° angular opening: $>6\sigma$
• Possible explanation: a 16.84 MeV neutral boson (X17?)
• Other indirect searches (NA64, NA48/2): no evidence for X17 but strong constraints

Can the measurement be performed with an independent setup, the MEG-II apparatus?
• 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: \( \mu \rightarrow e\gamma \)
- 1 order of magnitude sensitivity improvement wrt MEG: \( BR(\mu \rightarrow e\gamma) \rightarrow 6 \times 10^{-14} \)

See Renga's talk at ICHEP tomorrow

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

Proton beam direction for X17 search

Muons beam direction for MEG-II search

35 ps resolution

Single volume He:iC4H10
- 9 concentric layers of 192 drift cells each
The Cockcroft-Walton accelerator

- **LXe calibration**
  - MEG-II Cockcroft-Walton accelerator: used for calibration of LXe calorimeter
  - Proton beam impinging on Li target (440 keV resonance): 17.6 MeV $\gamma$ line

- **X17 search**
  Max proton current and energy: 100 $\mu$A and 1.1 MeV
  $\rightarrow$ ideal for X17 search (1 MeV resonance and 18.15 MeV $\gamma$ line)

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**LXe calibration**

**X17 search**

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**p+Li cross-section**
• 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

**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

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

- for X17: energies $\sim 6$ times lower $\rightarrow$ 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 $\rightarrow$ beam spot centered and covering the Li area
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

Data - LaBr3 Spectrum

LiPON target

No normalization

Beam OFF
Beam ON (low thresh)
Beam ON (high thresh)

Clear Li region
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)

  → define optimal experimental setup and final TDAQ configuration

• Objectives:
  → 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
$BR(X) = 6 \times 10^{-6} \rightarrow 1 \text{ X17 every } 1.7 \times 10^5 \text{ Li-}\gamma$

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

- Assuming IPC as main background
  
  $5\sigma \sim O(500 \text{ X17})$

- 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

- Mean: 0.01098
- Std: 0.00453

Data (including IPC and EPC)

- Mean: 0.01100
- Std: 0.00569

Single particle momentum
Pair event display from LiPON data

**Event A**

<table>
<thead>
<tr>
<th>Y [cm]</th>
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<td>-30</td>
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**Event B**

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<th>Y [cm]</th>
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LiPON, 1050 keV, 2 uA, 2022-02-18

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**Event A**

- e- hit
- e+ hit
- target

**Event B**

- e- hit
- e+ hit
- target

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Conclusion and outlook

- Anomalous excess observed in the angular correlation of $^7\text{Li}(p, e^+e^-)^8\text{Be}$ 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
• 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