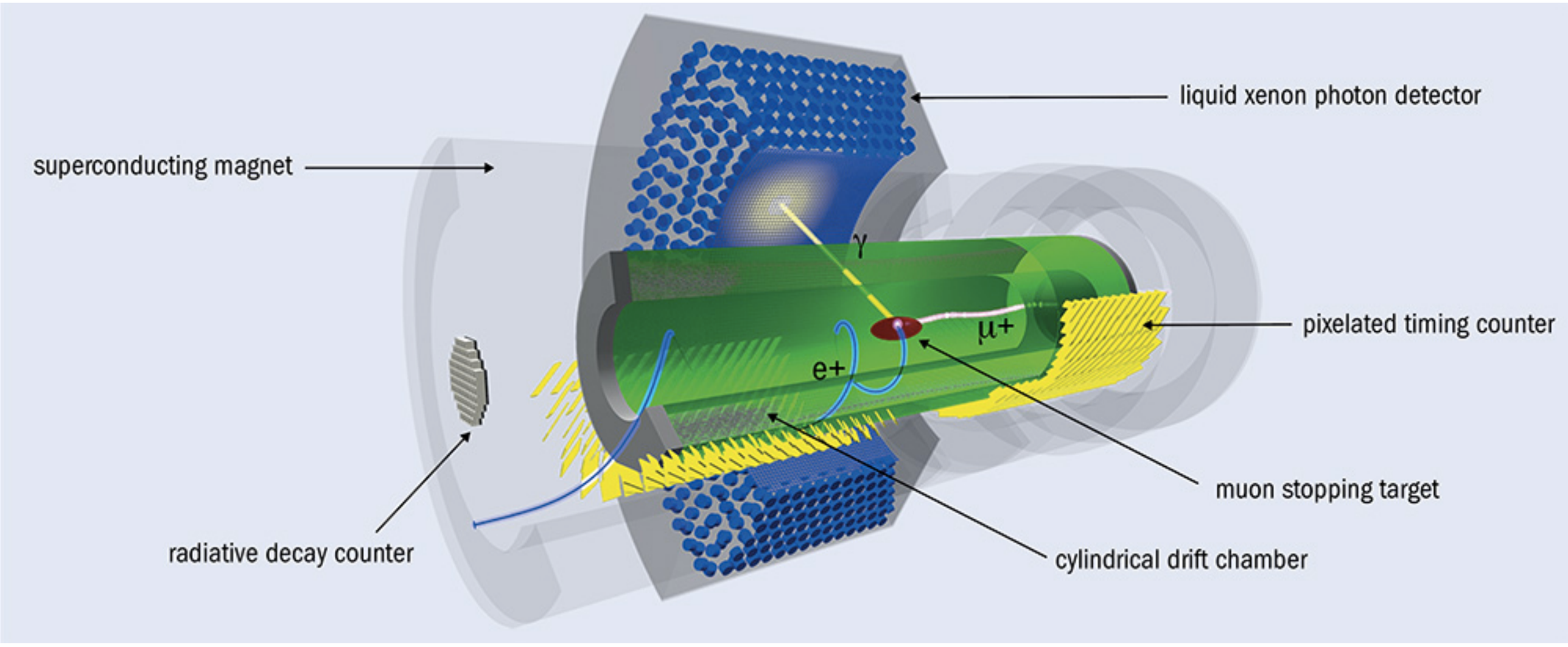

Searching for the X17 boson at MEG II

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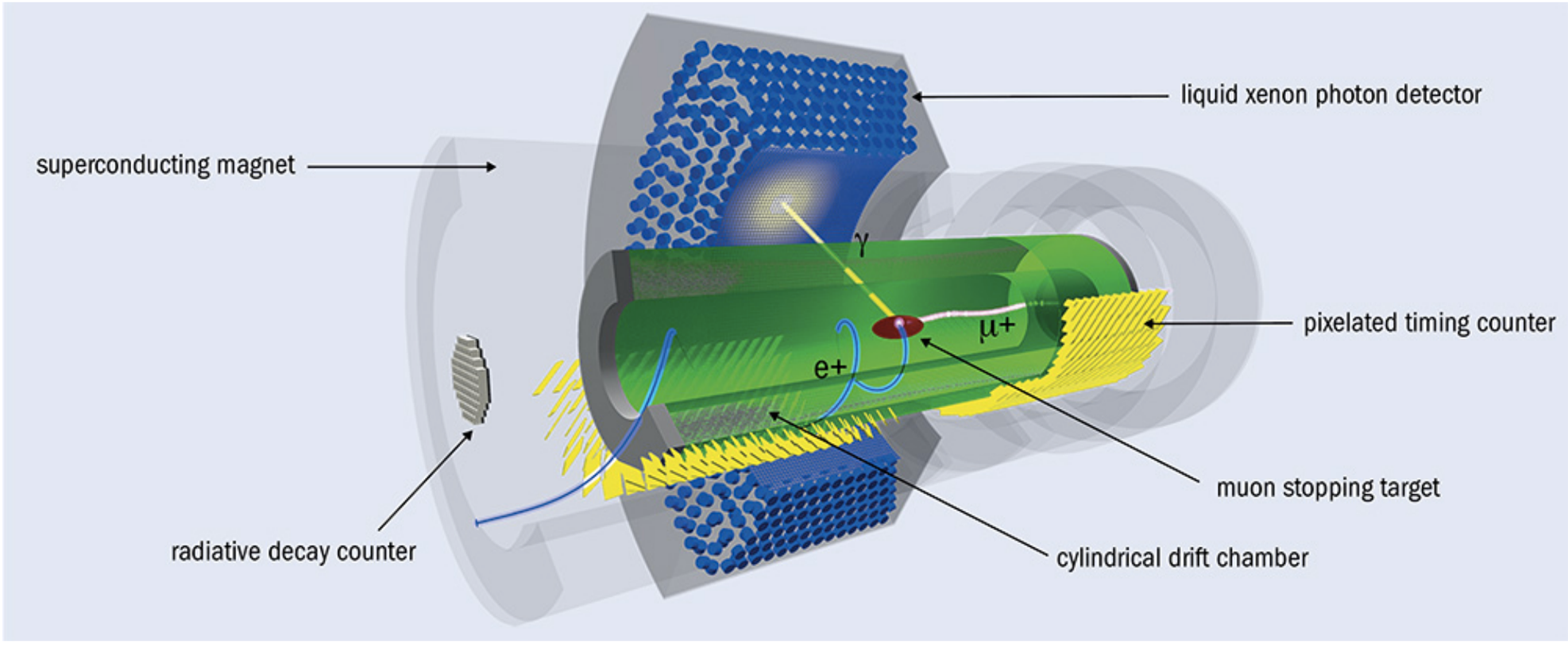
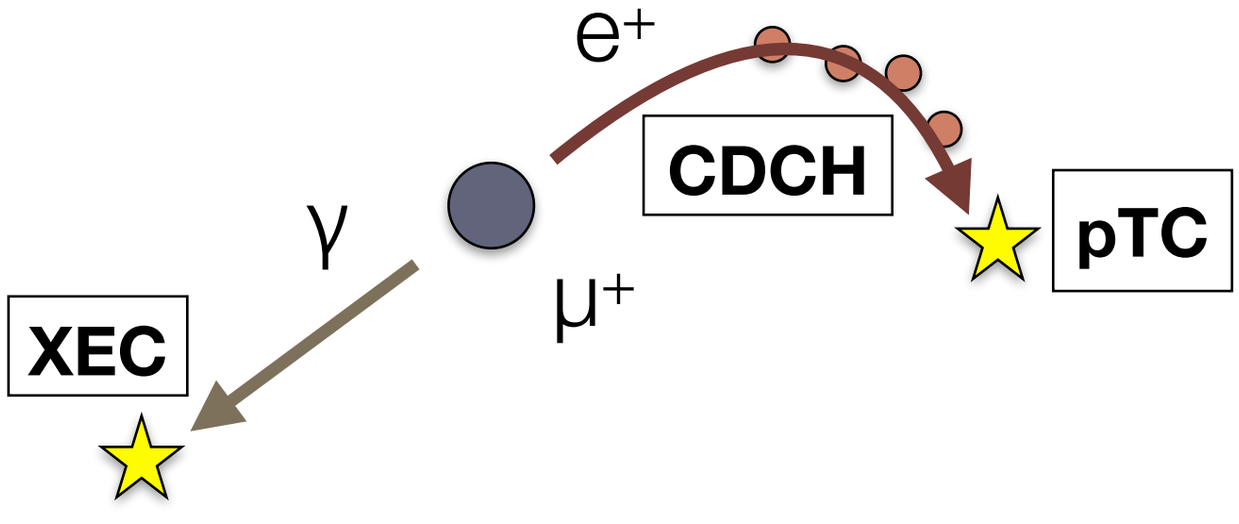
MEG II at the Paul Scherrer Institut (PSI)



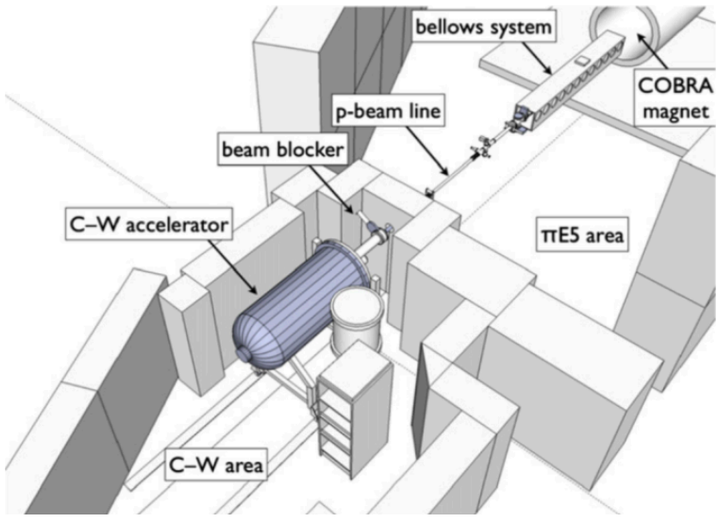


The MEG II Cockroft Walton accelerator

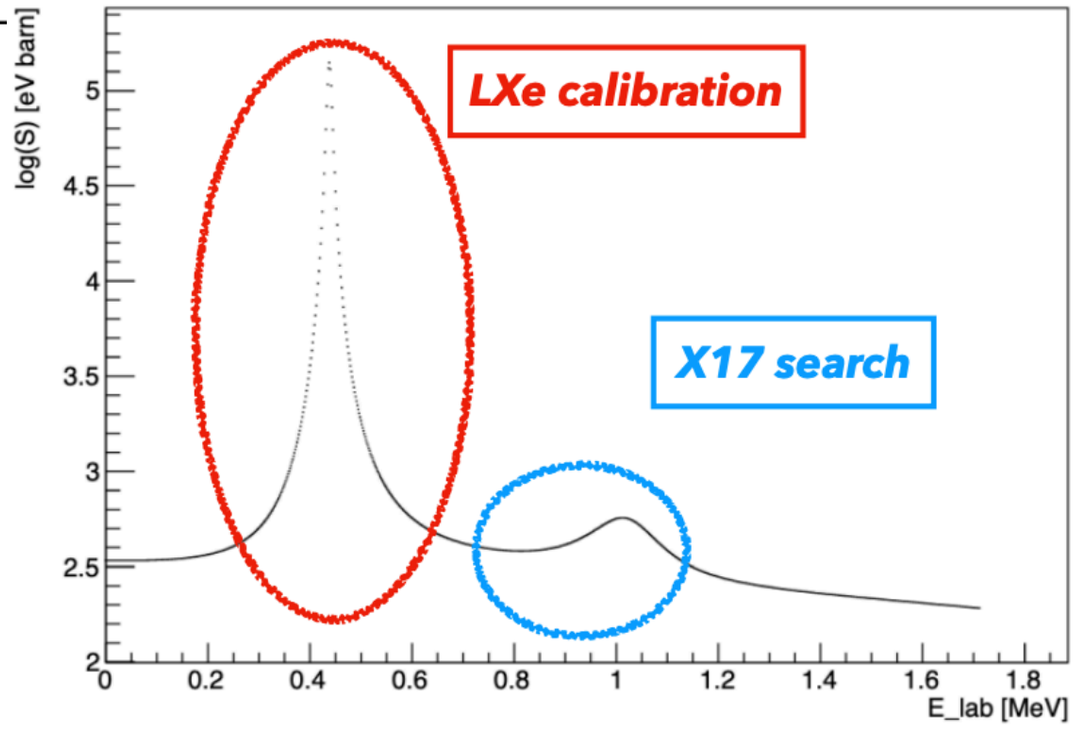
Proton beam properties	MEG C–W
Energy (keV)	300–1000
Energy spread (FWHM) (keV)	< 0.5
Angular divergence (FWHM) (mrad × mrad)	$< 3 \times 3$
Spot size at 3 meter (FWHM) (cm × cm)	$< 3 \times 3$
Energy setting reproducibility (%)	0.1
Energy stability (FWHM) (%)	0.1
Range of the average current (μA)	1–10
Current stability (%)	3
Current reproducibility (%)	10
Duty cycle (%)	100

upgraded to 1100 keV

upgraded to 100 uA

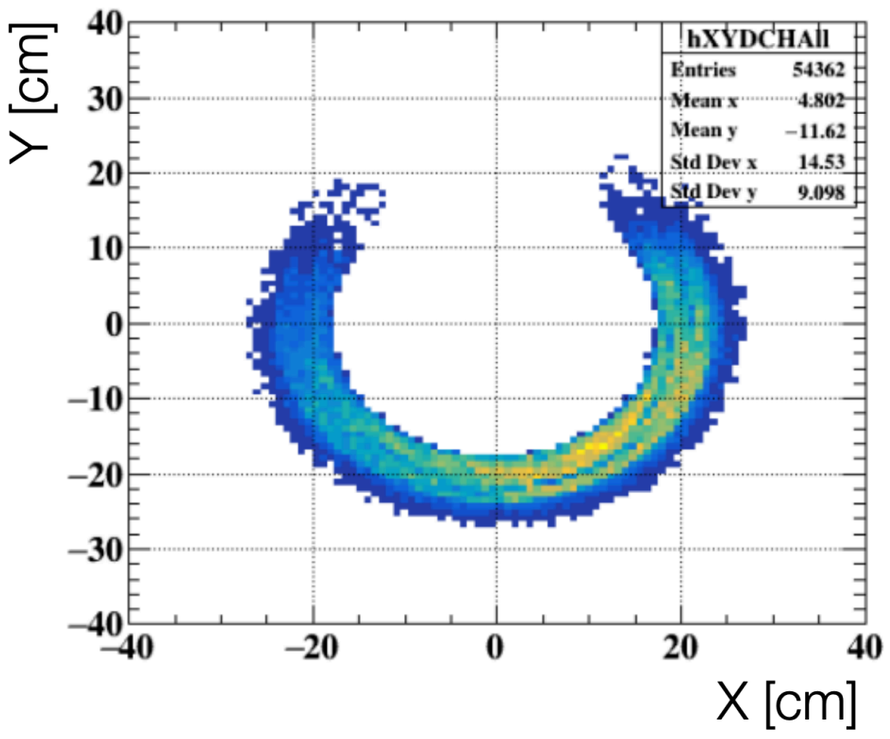


p+Li cross-section



Search strategy

- X17 produced in p + Li reactions at ~ 1 - 1.08 MeV
- X17 -> e^+e^- reconstructed in the MEG II magnetic spectrometer (Drift chamber + timing counters)
  - Excellent momentum resolution O(100 keV)
  - Excellent intrinsic angular resolution O(10 mrad)
- Challenges and limitations
  - partial angular acceptance
  - dedicated design of the target region (cooling, low material budget)



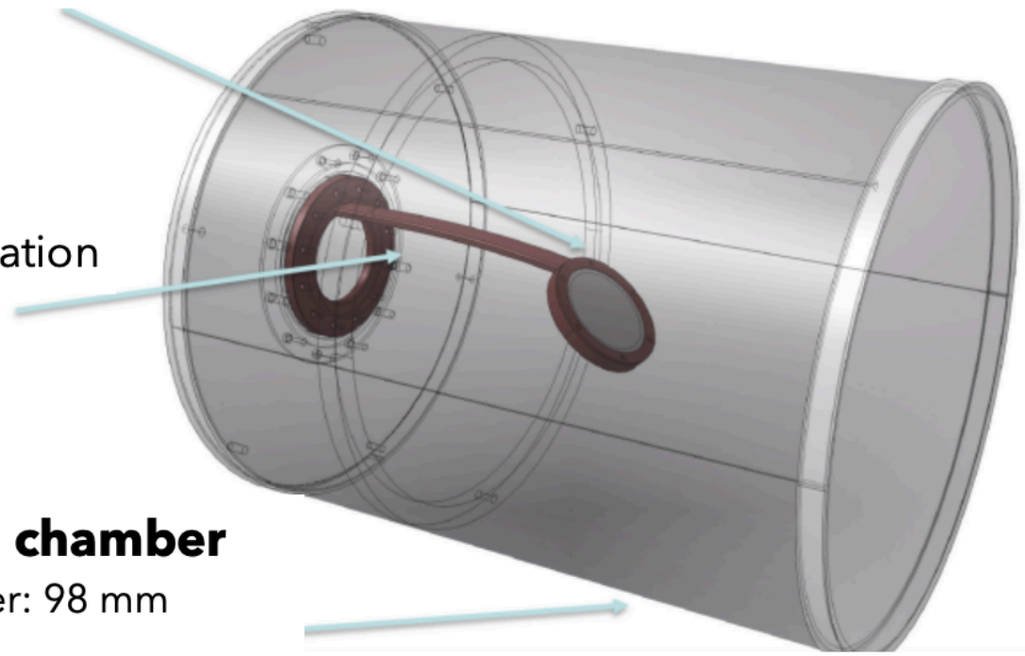
Target region

- 400 μm-thickness carbon fiber vacuum chamber to minimize multiple scattering
- 5 μm LiF on 10 μm copper (@ INFN Legnaro)
- 2 μm LiPON on 25 μm copper (@ PSI)

Li target
at COBRA center
45° slant angle

Mechanical and heat dissipation simulations carried out

Target arm
Cu for heat dissipation

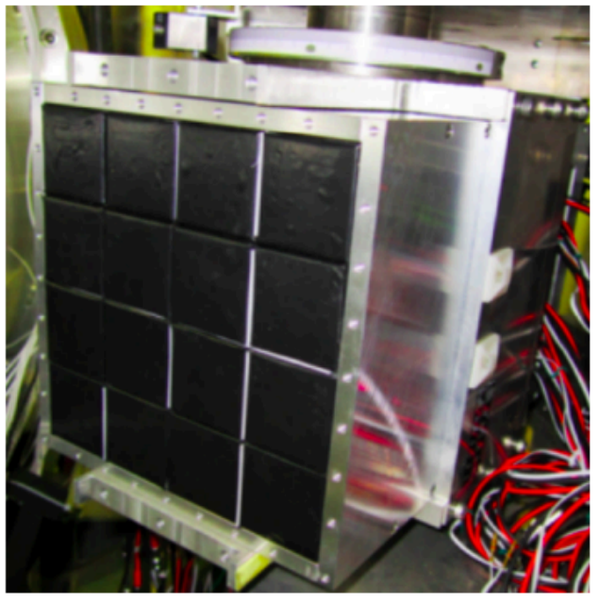


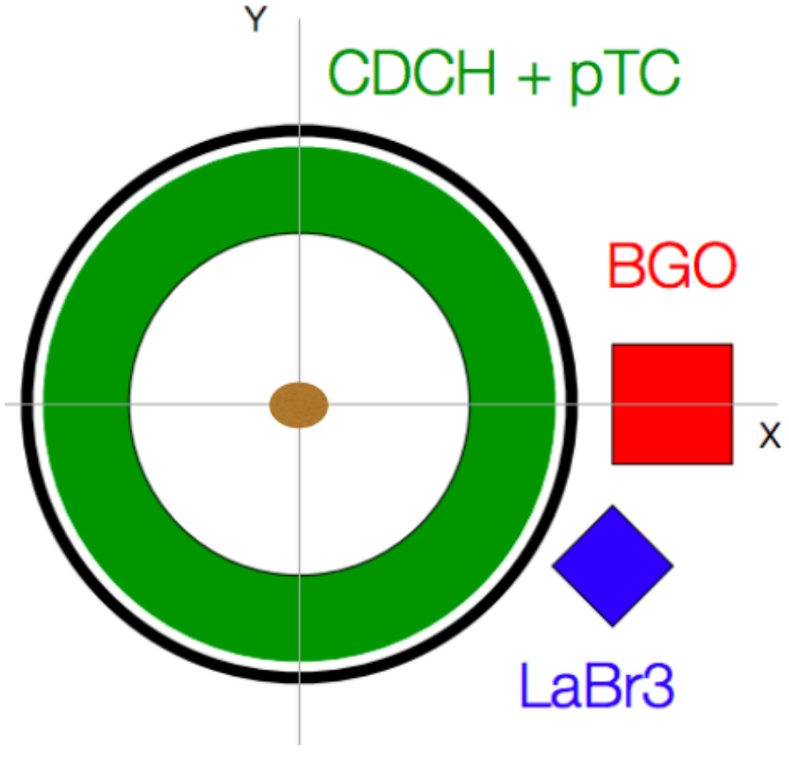
Carbon fiber vacuum chamber
Thickness: 400 μm, Diameter: 98 mm
Length: 226 mm

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

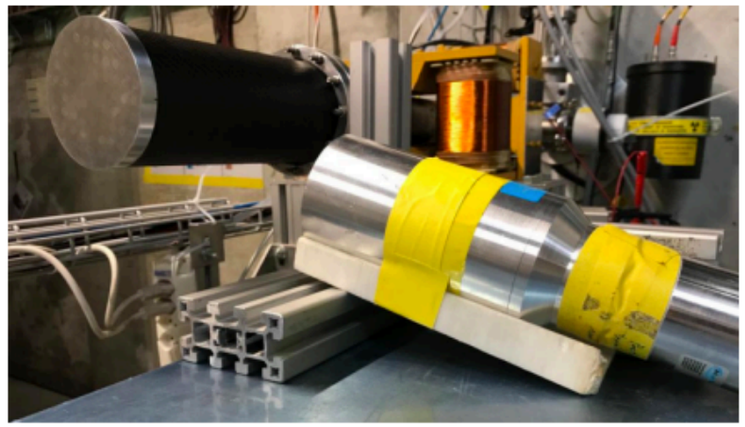
Ancillary gamma detectors

Bismuth Germanate (BGO) crystal matrix (4x4)





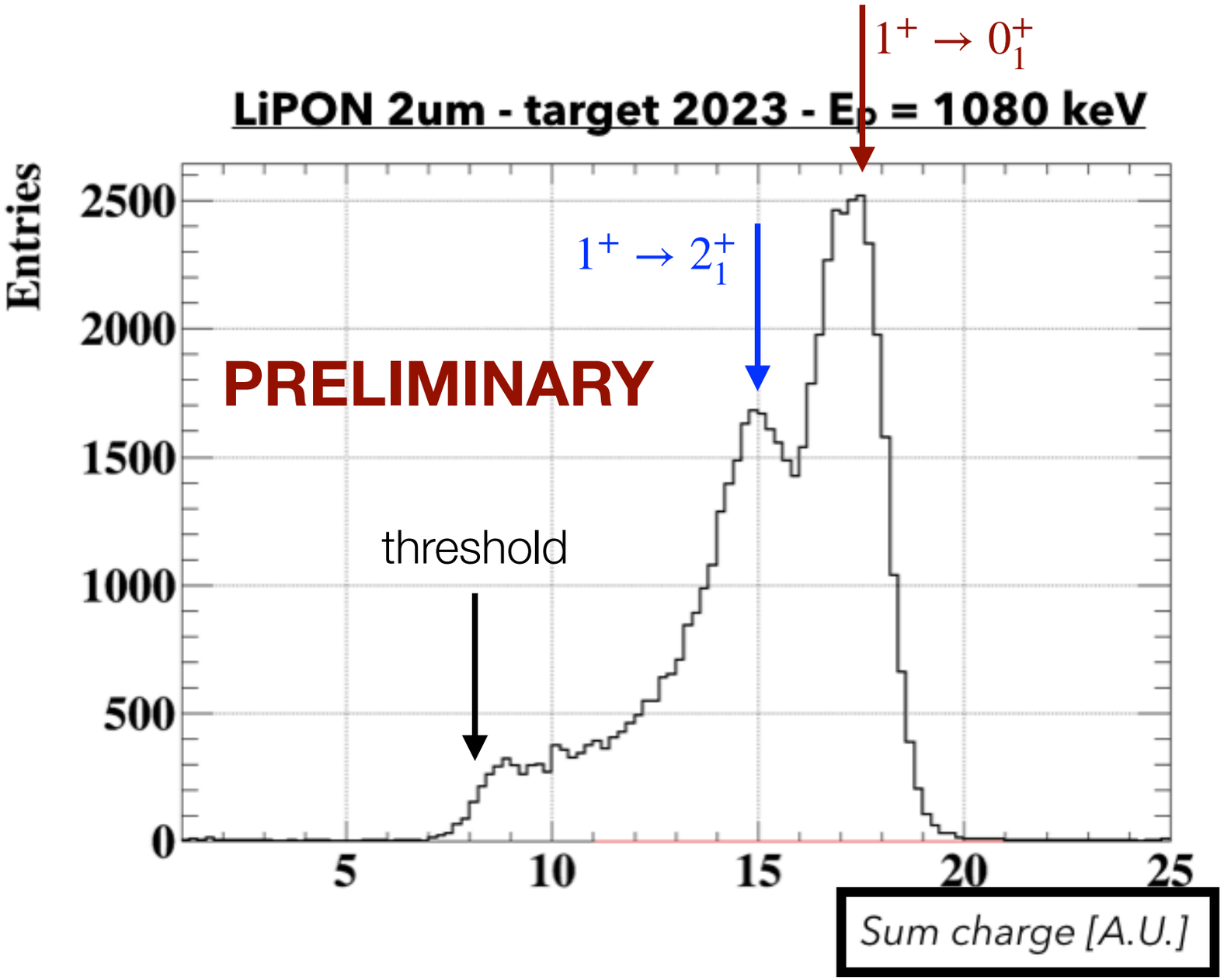
Lanthanum Bromide (LaBr3) crystal



—> background studies
—> target stability monitor
—> normalization

- Plans to use the LXe calorimeter for a more precise and larger acceptance measurement of the photon spectrum

Measured gamma ray spectrum



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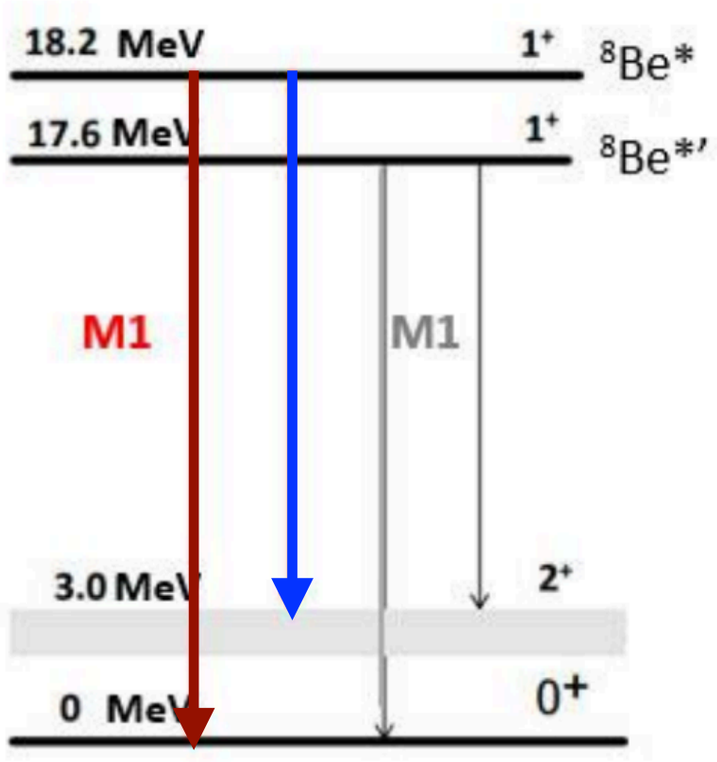


Data taking campaigns

- Data taking performed during the winter shutdown of the PSI proton accelerator complex
  - no conflict with the MEG II experimental program
- 12 days of engineering run in 2022:
  - test of LiF and LiPON target from 1 to 10 μA
  - background studies
  - trigger and DAQ development

Trigger configuration

- The trigger exploits hit multiplicity in drift chamber (CDCH) and timing counter

- Lesson learned from 2022 run:

  - converting gammas from 6 MeV Fluorine line overcrowd the trigger when the LiF target is used **—> only good for calibration of ancillary detectors, LiPON has to be used for X17 search**

  - cannot exploit zero-suppression techniques to increase the DAQ speed (tracking efficiency strongly deteriorated)

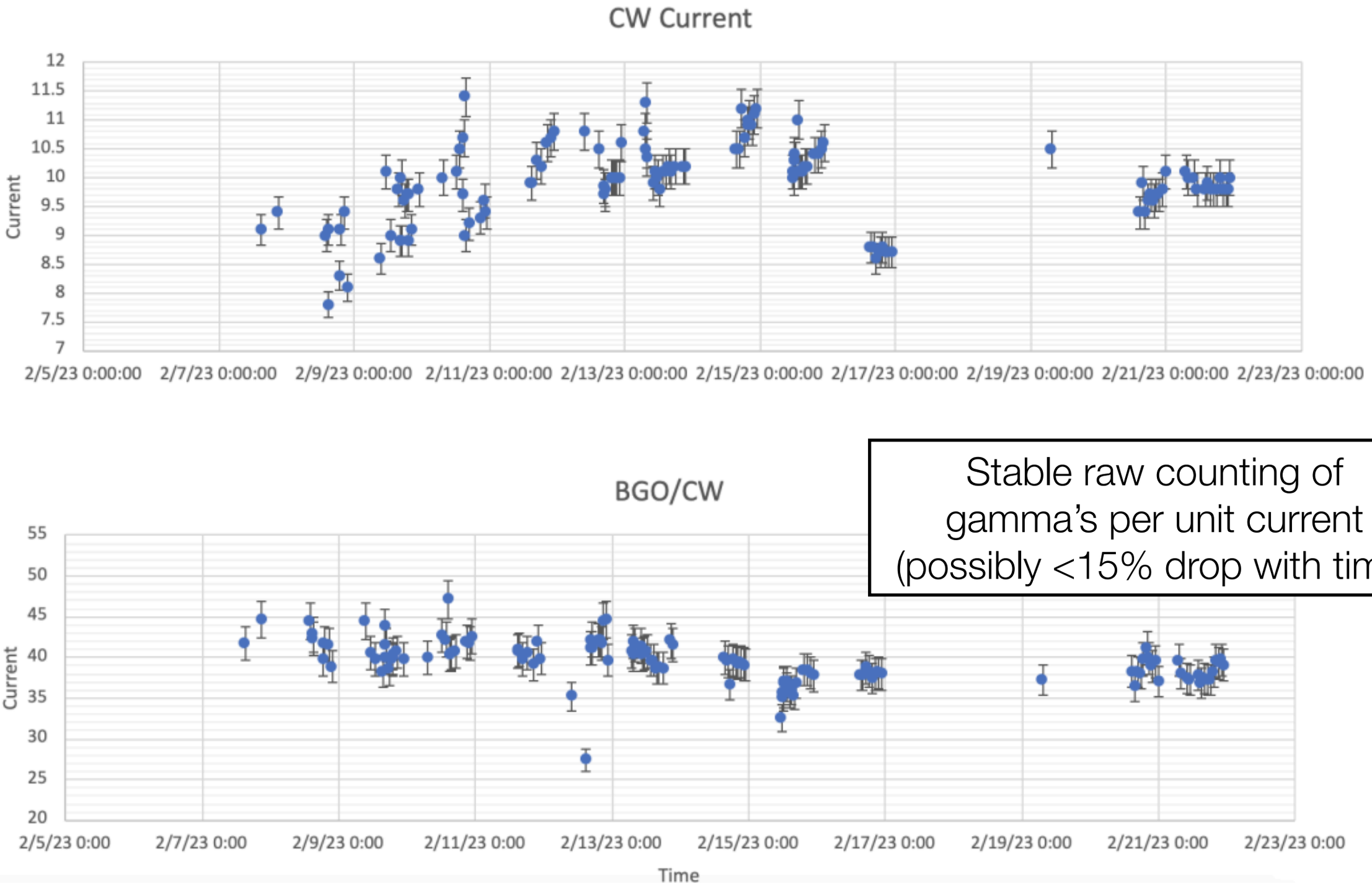
  - CDCH multiplicity condition (18 hits on each detector end) strongly suppresses the trigger contamination from external photon conversion (EPC) and Compton

Data taking campaigns

- Data taking performed during the winter shutdown of the PSI proton accelerator complex
  - no conflict with the MEG II experimental program
- 12 days of engineering run in 2022:
  - test of LiF and LiPON target from 1 to 10 μA
  - background studies
  - trigger and DAQ development
- **25 days of run in 2023 with LiPON target**
  - 10 μA
  - 50-100 Hz DAQ rate

~70M events collected

Beam and target stability

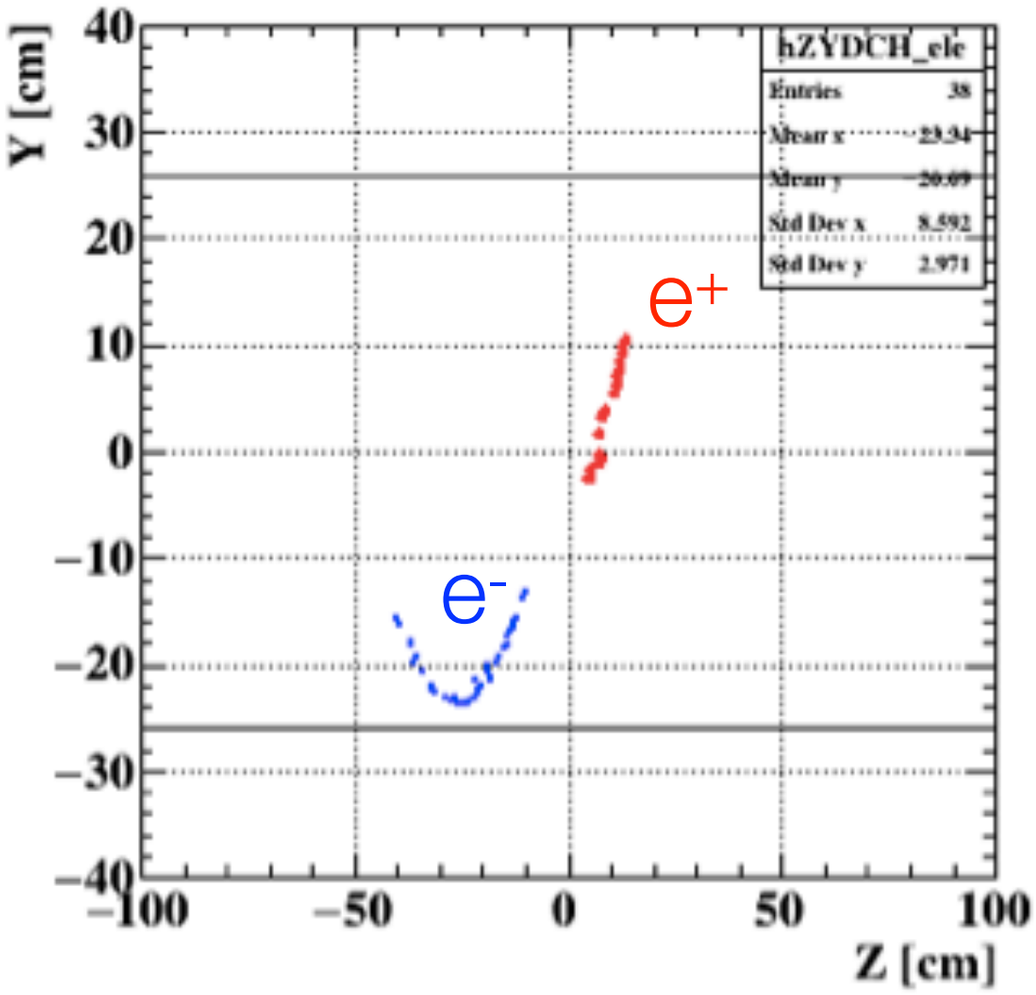


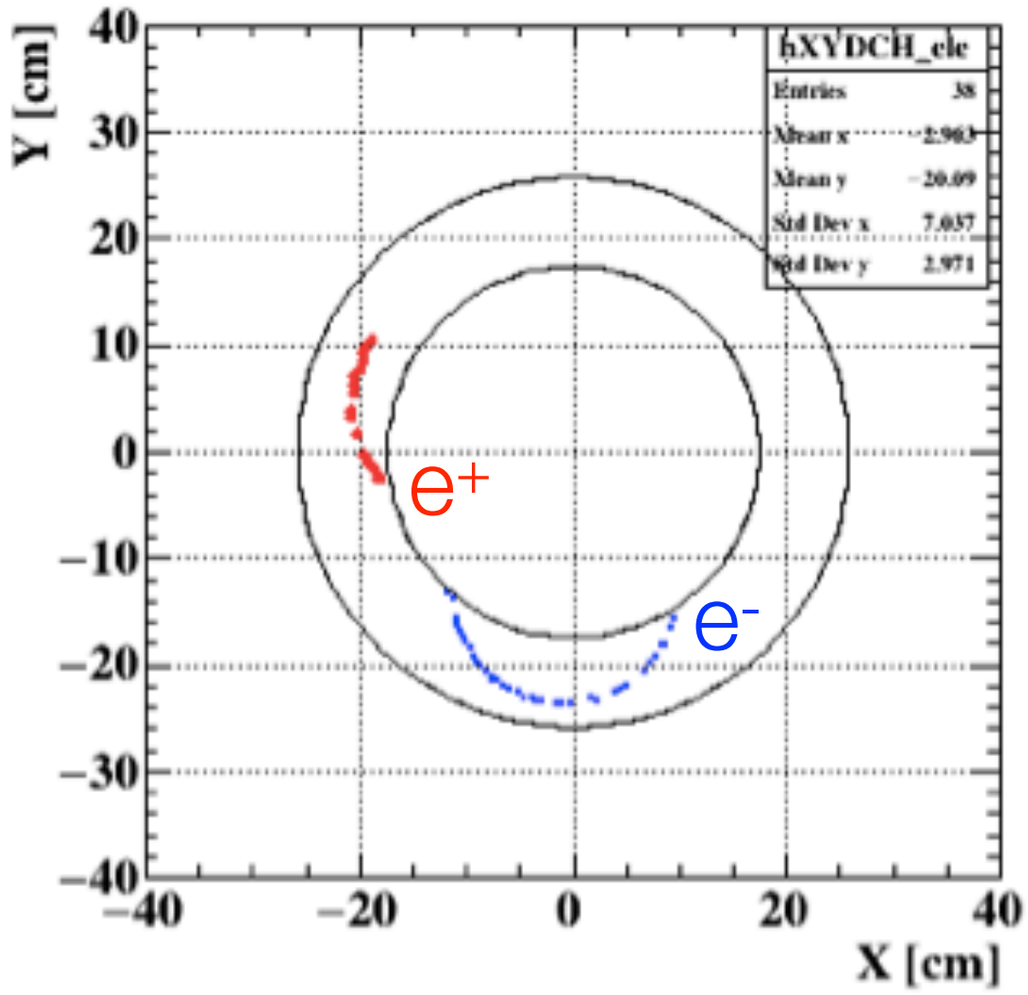
Stable raw counting of gamma's per unit current (possibly <15% drop with time)

Event reconstruction

- MEG II software has been revised to reconstruct e^+e^- pairs

DATA 2023





Future prospects

- Short run with LXe calorimeter, for a better determination of the gamma spectrum over a larger angular acceptance

- Work ongoing to complete the analysis of the 2023 data within this year:
  - main challenge: data-driven evaluation of acceptance and resolutions

- Possible additional data taking in the next years, during the winter shutdowns

Conclusions

- MEG II can search for the X17 in $^{7}Li(p,e^{+}e^{-})^{8}Be$

- After a test run in 2022, a successful 25-day run was performed in February 2023:

  - Stable gamma production and efficient trigger and DAQ configuration

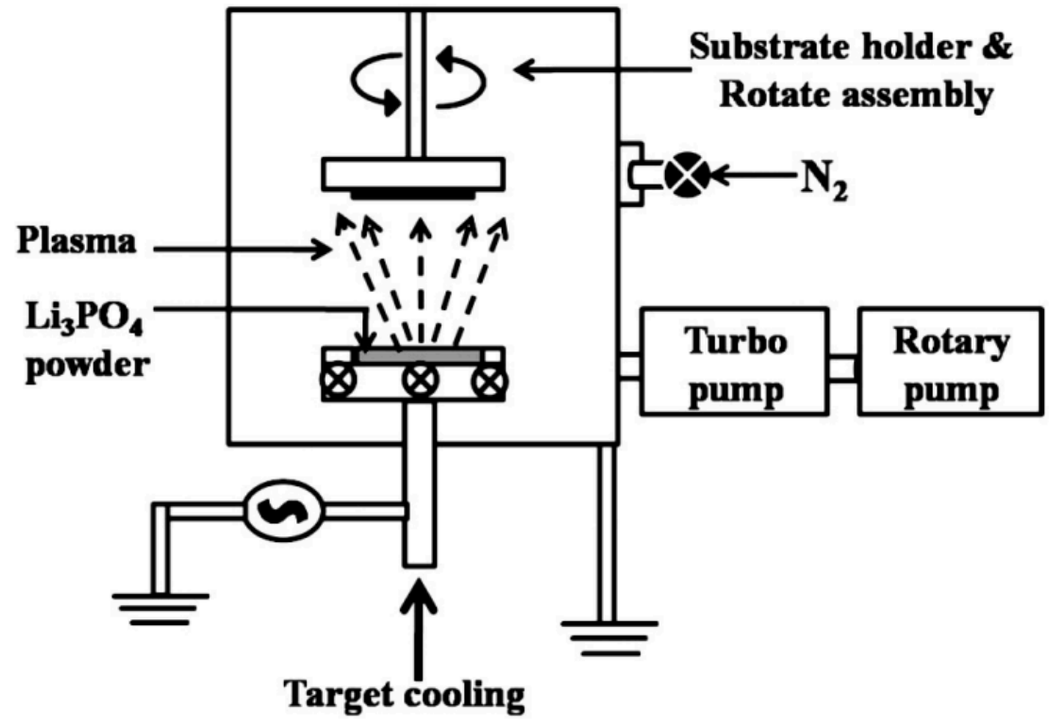
  - Intensive activity on $e^{+}e^{-}$ reconstruction

  - Possibility of an accurate measurement of the gamma spectrum from an upcoming run with LXe calorimeter

Backup

Li targets

- Li is highly reactive and flammable: targets are usually Li-compounds
  - **LiF**, Li2B4O7, Li2O, SiO2, Li3PO4, Li4SiO4, **LiPON**
- The high conductivity and stability of solid solutions of Li_3PO_4 and Li_4SiO_4 in ambient air has been the starting point of a large number of activities of the development of thin-film batteries
- The difficulty to deposit lithium orthosilicate has been overcome by sputtering trilithium phosphate in a nitrogen atmosphere and in this way incorporating nitrogen as further anion (lithium phosphorus oxynitride 'Lipon') for improving the ionic conductivity and thermal stability
  - $Li_{3-X}PO_{4-Y}N_{X+Y}$
  - Typical Temperature during target preparation ~300 deg



Sample[a]	Composition	(O+N)/P	Correction[b] (%)
0° Normal	$Li_{3.7}PO_{3.3}N_{0.7}$	4.0	+9
180° Shadowed	$Li_{2.1}PO_{3.0}N_{0.4}$	3.4	+5
90° Grazing 1	$Li_{2.8}PO_{2.9}N_{0.7}$	3.6	+23
90° Grazing 2	$Li_{2.9}PO_{2.9}N_{0.6}$	3.5	+17