

# The X17 search in Italy

Carlo Gustavino  
INFN-Roma

## OUTLINE:

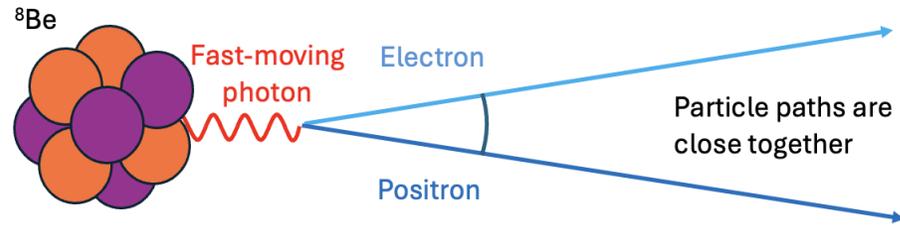
- The ATOMKI results
- Theoretical Framework
- The Aipac8Be experiment at LNL
- MEG-II experiment result
- PADME experiment results
- The  ${}^3\text{He}(n, X17){}^4\text{He}$  experiment at n\_TOF
- Conclusion



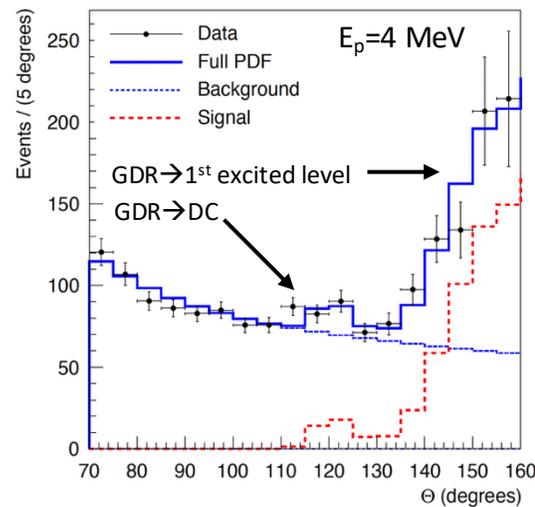
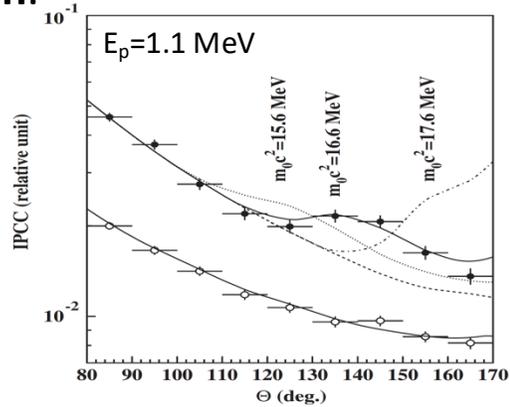
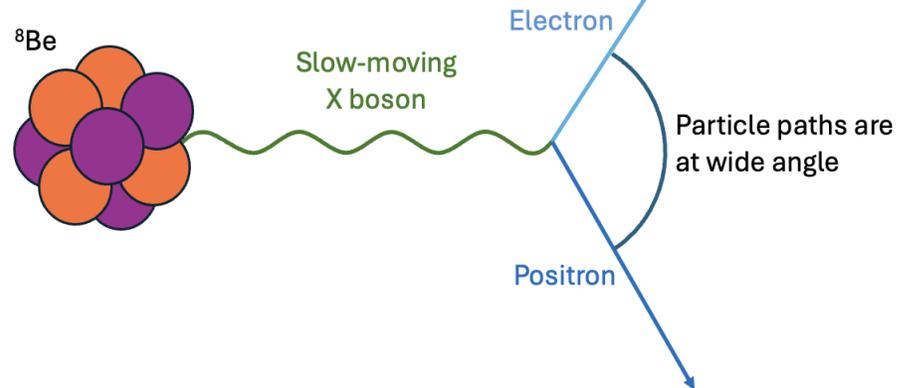
# The X17 anomaly

The ATOMKI group observed an excess of  $e^-e^+$  pairs emitted at large relative angle in the  ${}^3\text{H}(p,e^-e^+){}^4\text{He}$ ,  ${}^7\text{Li}(p,e^-e^+){}^8\text{Be}$ ,  ${}^{11}\text{B}(p,e^-e^+){}^{12}\text{C}$  nuclear reactions. This excess can be explained with the creation (and successive decay into  $e^-e^+$  pairs) of a new particle with mass  $\sim 17$  MeV, called **X17 boson**.

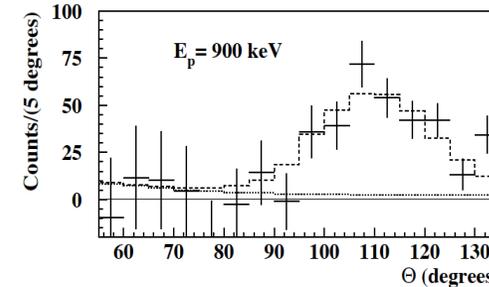
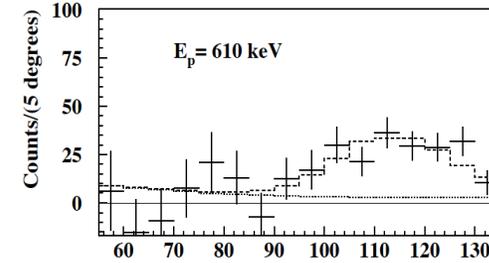
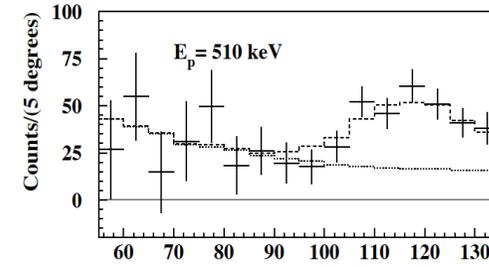
## Expected ${}^8\text{Be}$ Transition



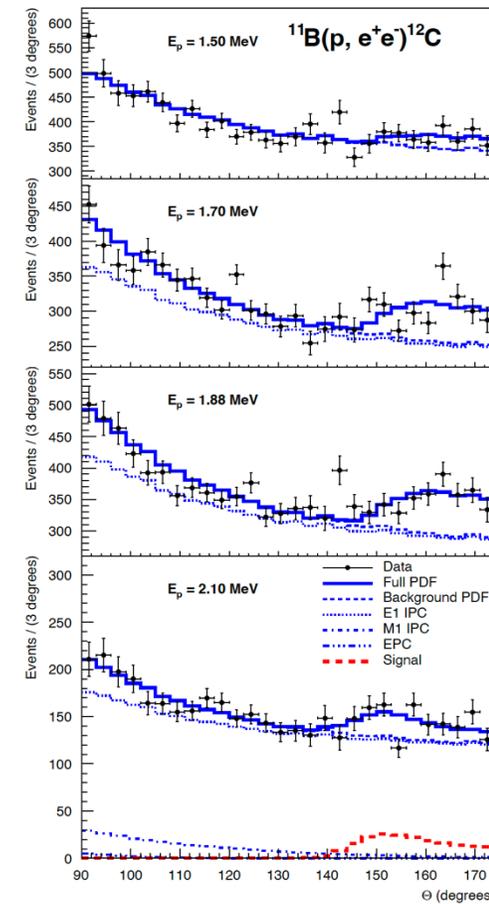
## Hypothetical



${}^7\text{Li}(p,e^-e^+){}^8\text{Be}$



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

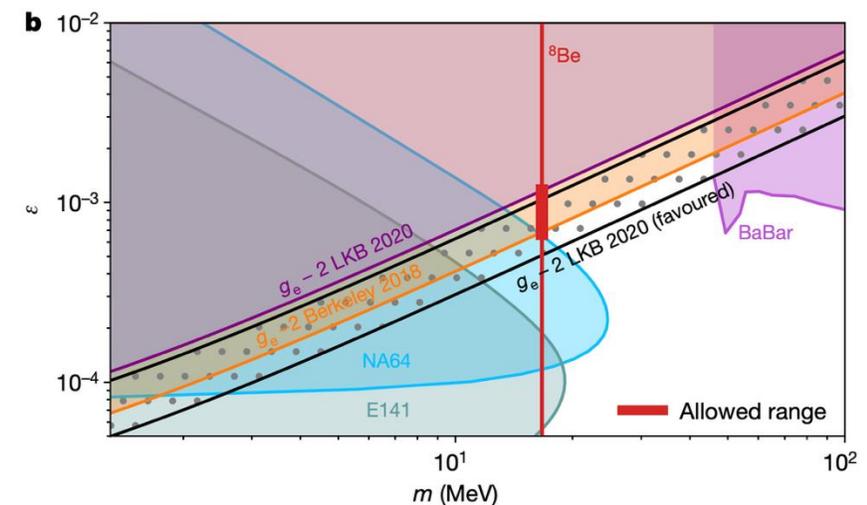
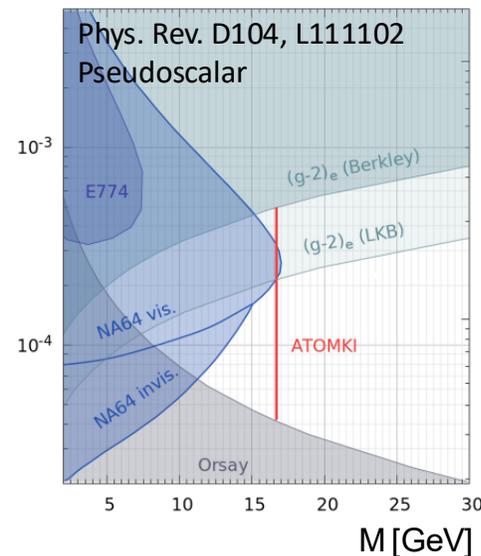
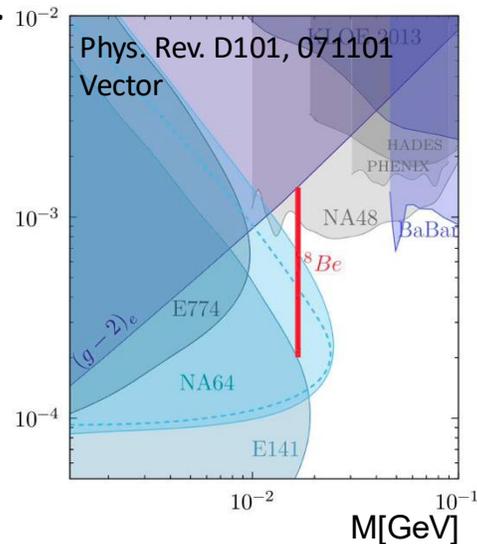


${}^{11}\text{B}(p,e^-e^+){}^{12}\text{C}$

# Theoretical Framework in a nutshell

- The first theoretical interpretation of the experimental results was performed by Feng et al (2016). They explained the anomaly with a **vector gauge boson X17**, which may mediate a **fifth fundamental force** with some coupling to Standard Model (SM) particles. From searches for  $\pi_0 \rightarrow Z' + \gamma$  by the NA48/2 experiment, Feng postulated that the X17 particle couples much more strongly to neutrons than to protons, **“protophobic force”**.
- This scenario could explain the long standing anomaly on the muon magnetic moment. Also the recent measurement of  $g_e - 2$  (Morel 2020), is compatible with the vector boson hypothesis.
- Ellwanger and Moretti (2016) suggested another interpretation of the experimental results in view of a light, pseudoscalar particle. They predicted about ten times smaller branching ratio in case of the 17.6 MeV transition compared to the 18.15 MeV one.
- Zhang and Miller (2017) investigated the nuclear transition form factor as a possible origin of the anomaly, but they concluded the hypothesis unrealistic for the  $^8\text{Be}$  nucleus.
- Delle Rose (2019) showed that the anomaly can be described with a very light  $Z_0$  bosonic state, with significant axial couplings.

- ....
- ....



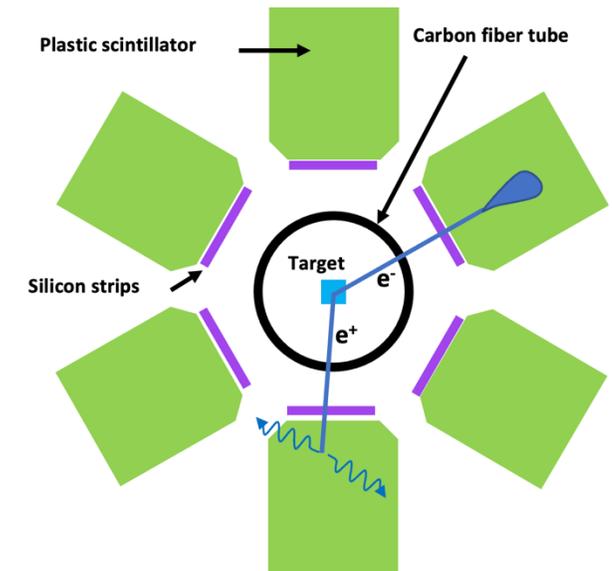
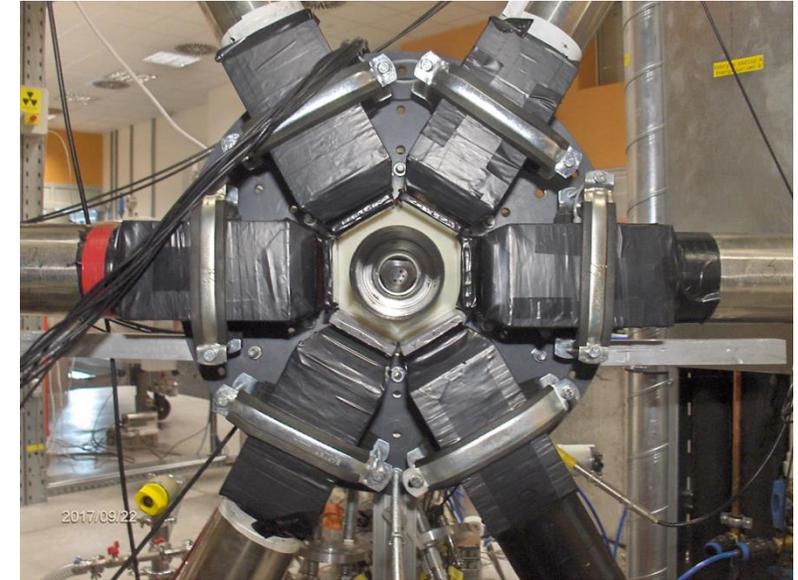
# The ATOMKI setup

Let consider the setup used for the  ${}^3\text{H}(p, e^+e^-){}^4\text{He}$  experiment.  
(similar setup were used in the other ATOMKI experiments)

- Proton beam with  $E_p < 1$  MeV (to prevent neutron production)
- ${}^3\text{H}$  thin target deposited on a thin Titanium backing
- Thin (1 mm thick) carbon fiber tube
- To limit multiple scattering of ejectiles.
- 6 double-sided silicon strip detector 3 mm wide strips, 0.5 mm thick
- Measurement of the particle impact point, to deduce the aperture angle
- 6 massive plastic scintillator  $82 \times 86 \times 80$  mm<sup>3</sup>
- Measure of kinetic energy of ejectiles

**Well suited for electron and positron detection. However:**

- Detector acceptance only around  $90^\circ$  with respect to the beam axis
- No tracking.
- No charge and particle identification.

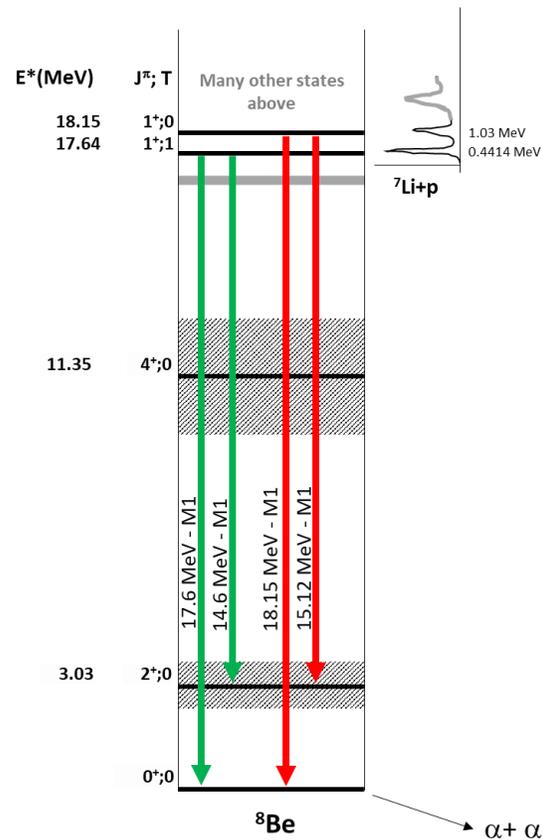
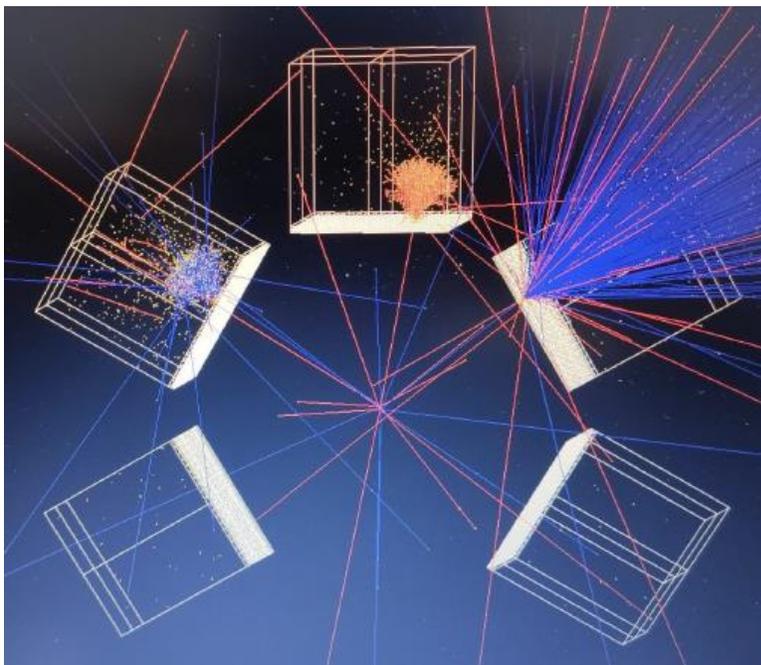
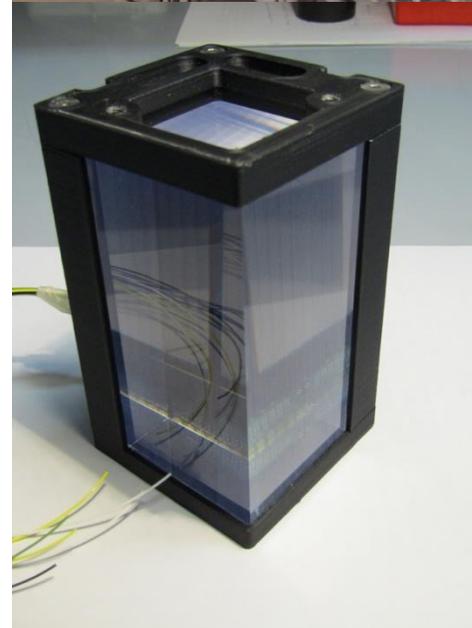
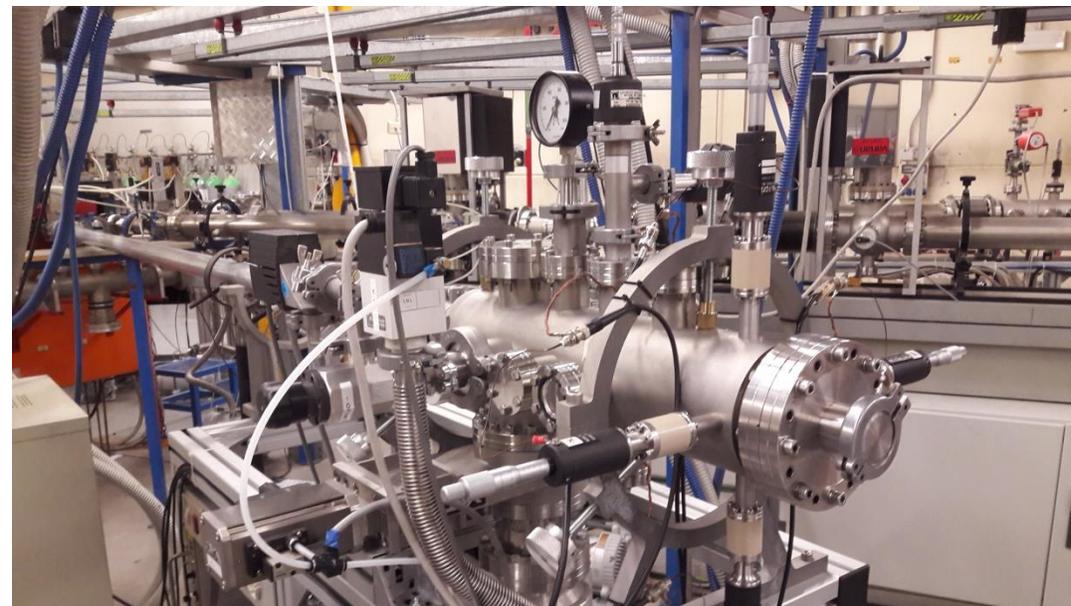


# The Aipac8Be apparatus at LNL

Setup quite similar to the ATOMKI one.

-The impact point of particles is provided by scintillator sticks placed in front of massive cubic scintillators.

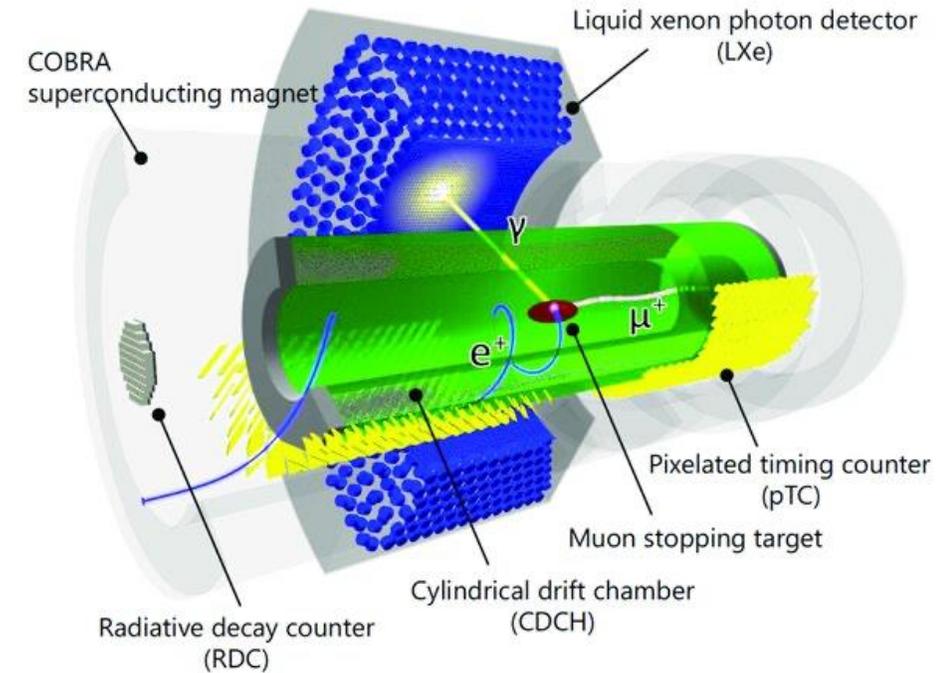
- Operation in vacuum → No need of a carbon fibre tube
- Beam line: AN2000 at LNL :  $E_p = 0.2 - 2$  MeV,  $I \sim 1$  uA
- Still no result on the  ${}^7\text{Li}(p,e^-e^+){}^8\text{Be}$  reaction.



# The ${}^7\text{Li}(p, e^+e^-){}^8\text{Be}$ experiment with the MEG-II apparatus

- Protons from a Cockcroft-Walton accelerator ( $E_p \leq 1.1$  MeV)
- Magnetic field to measure particle momenta
- Cylindrical drift chamber
- LXe detector
- 400  $\mu\text{m}$ -thickness carbon fibre vacuum chamber to minimize multiple scattering
- 5  $\mu\text{m}$  LiF target on 10  $\mu\text{m}$  copper (produced @ INFN-LNL)
- >2  $\mu\text{m}$  LiPON target on 25  $\mu\text{m}$  copper (produced @ PSI)
- 4 weeks of DAQ in February 2023
- 300k reconstructed  $e^+e^-$  pairs

- > 2  $\mu\text{m}$  LiPON on 25  $\mu\text{m}$  copper (@ PSI)

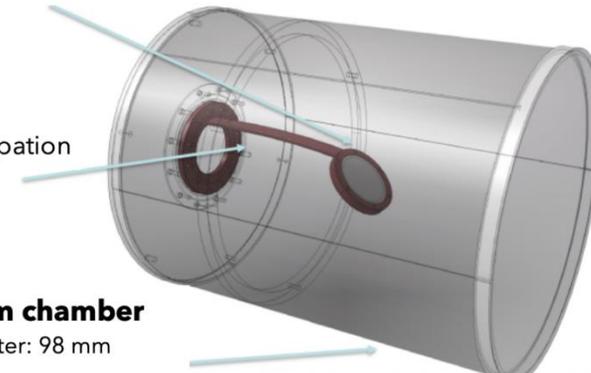


## Li target

at COBRA center  
45° slant angle

## Target arm

Cu for heat dissipation



## Carbon fiber vacuum chamber

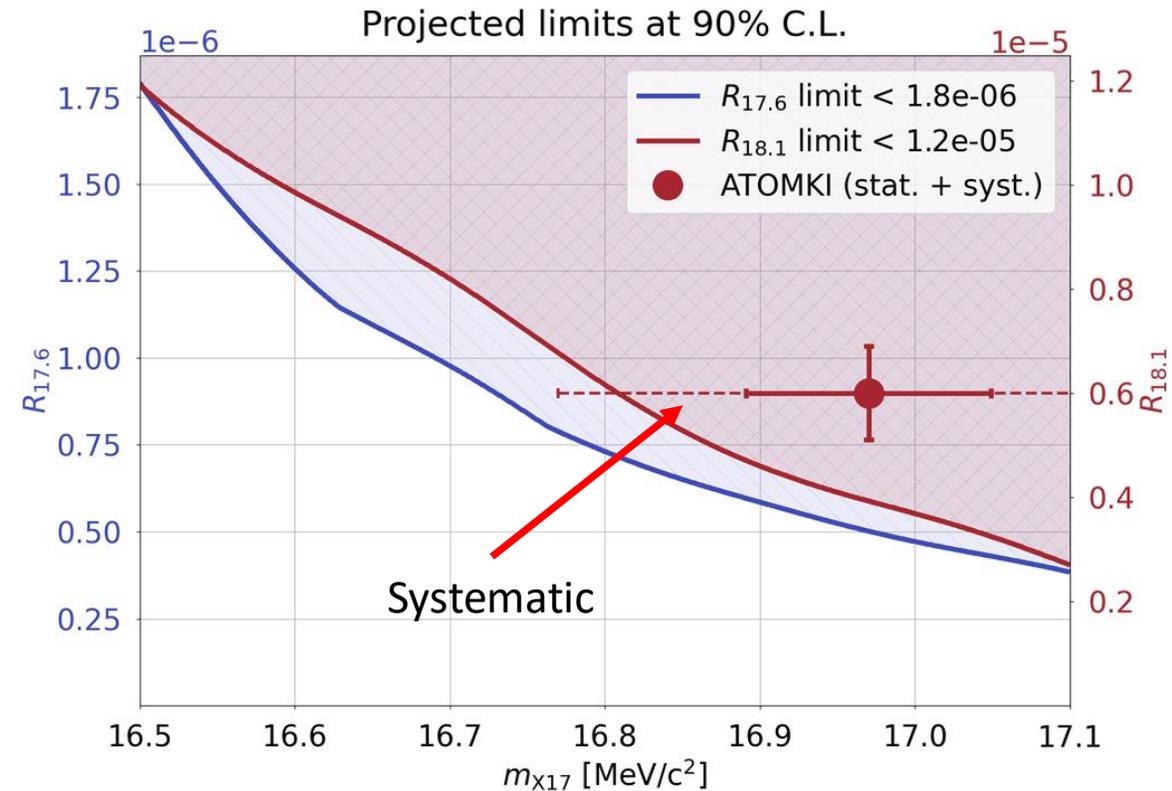
Thickness: 400  $\mu\text{m}$ , Diameter: 98 mm  
Length: 226 mm

# The ${}^7\text{Li}(p, e^+e^-){}^8\text{Be}$ experiment with the MEG-II apparatus

$$R_{\chi_{17}/\gamma, 18.1} < 1.2 \times 10^{-5}$$

$$R_{\chi_{17}/\gamma, 17.6} < 1.8 \times 10^{-6}$$

“The hypothesis  $m_{\chi_{17.6}} = 16.97 \pm 0.22$  MeV/,  $R_{18.1} = 6 \pm 1 \pm 10^{-6}$  and  $R_{17.6} = 0$  was tested and a 6.2%  $p$ -value ( $1.5\sigma$ ) was obtained.”

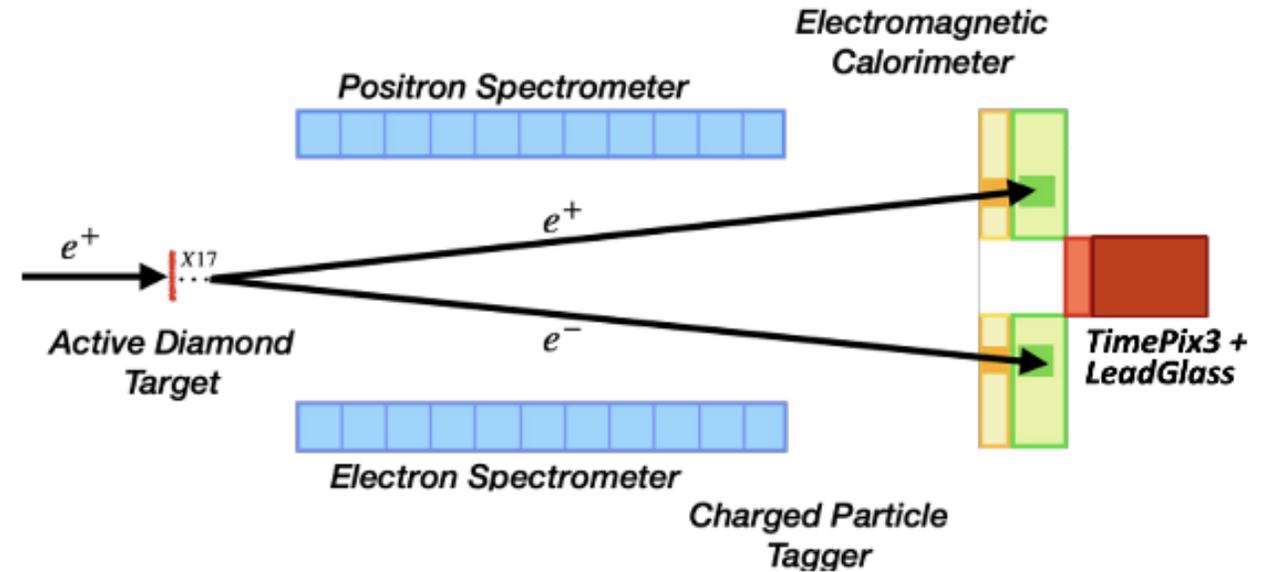


EPJ. C (2025) 85:763

<https://doi.org/10.1140/epjc/s10052-025-14345-0>

# Search for the X17 at PADME in LNF

- Active target**, polycrystalline diamond
- **Ecal**: > 600 21x21x230 mm<sup>3</sup> BGO crystals
- Newly built **hodoscope** in front of Ecal for e/ $\gamma$  discrimination
- **Timepix** Silicon-based detector for beam spot
- **Lead-glass** beam catcher

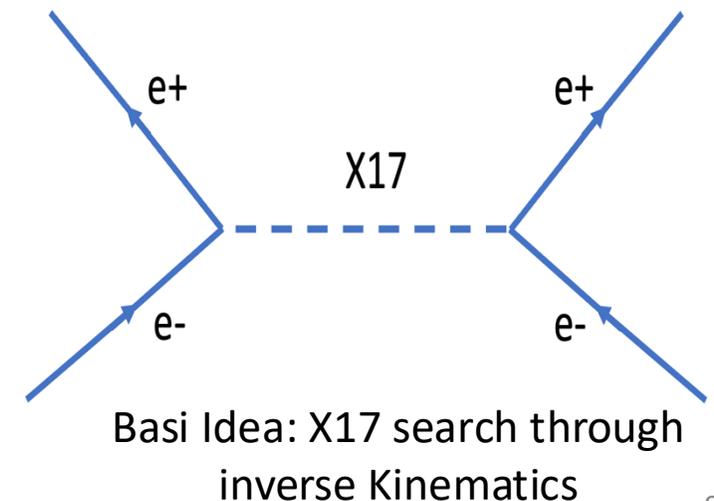


**PADME** (**P**ositron **A**nnihilation into **D**ark **M**atter **E**xperiment) is devoted to the Dark Photon search.

Regarding the X17, a diamond target is used and positron beam with energy around 250 MeV.

47 different energy points collected data collected for  $16.35 < M_{X_{17}} [\text{MeV}] < 17.5 \text{ MeV}$

Analysis to see the X17 excess over the Bhabha scattering background, at  $E_{\text{cm}} = M_{X_{17}}$



Basi Idea: X17 search through inverse Kinematics

# Search for the X17 at PADME in LNF

**data set contains 3 subset**

- **On resonance points (263-299) MeV**
- **Below resonance points (205-211) MeV**
- **Over resonance, energy 402 MeV**

**1 over resonance energy point**

**Used to calibrate POT absolute measurement**

**On resonance points, mass range 16.4-17.5 MeV**

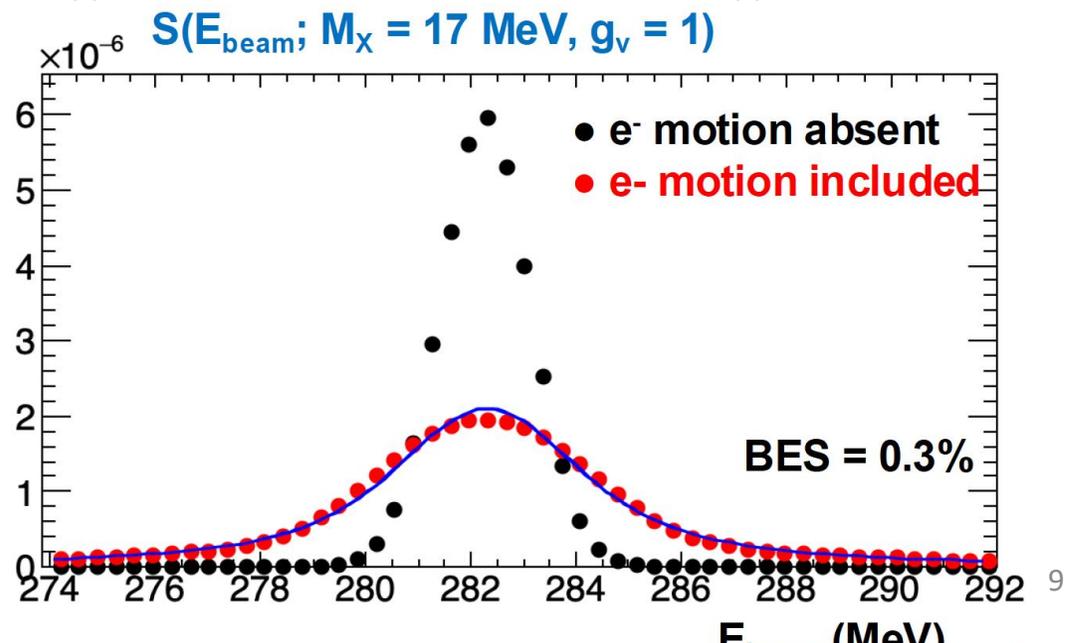
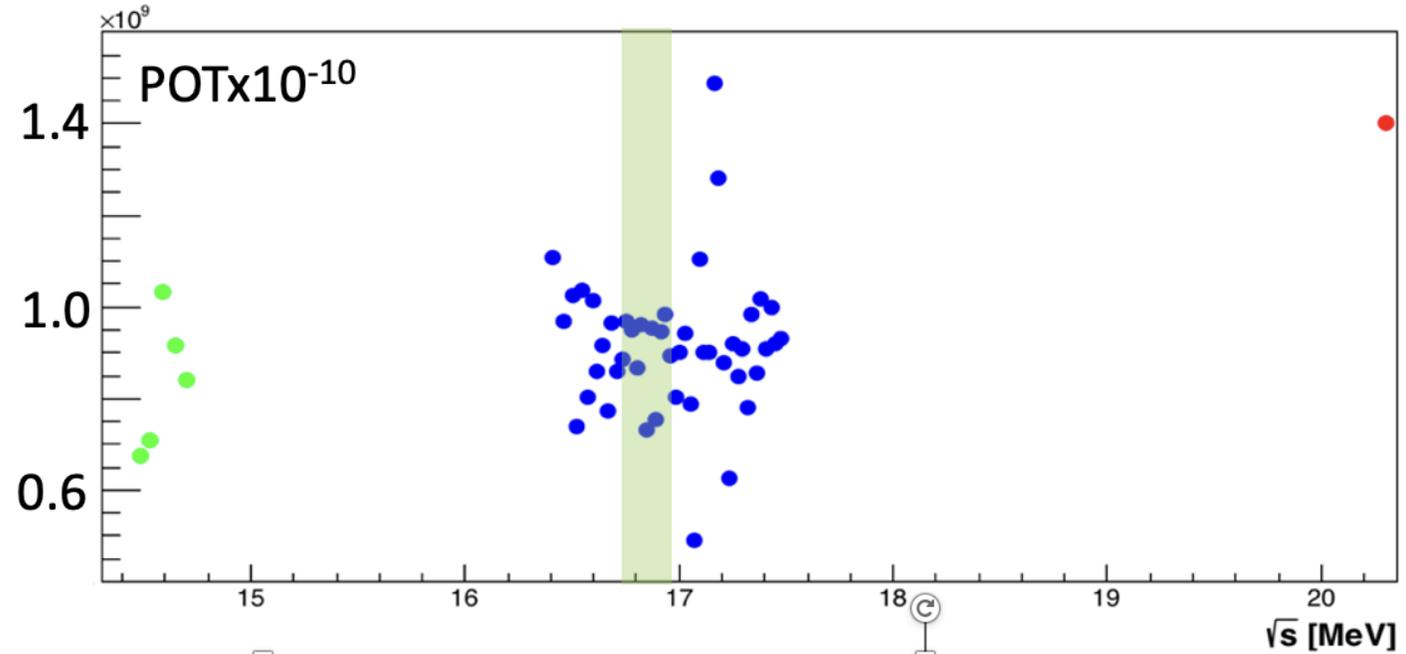
**Beam energy steps  $\sim 0.75$  eV**

**Energy spread 20 keV in mas**

**Below resonance points**

**Beam energy steps  $\sim 1.5$  MeV**

**Used to cross-check the flux scale**



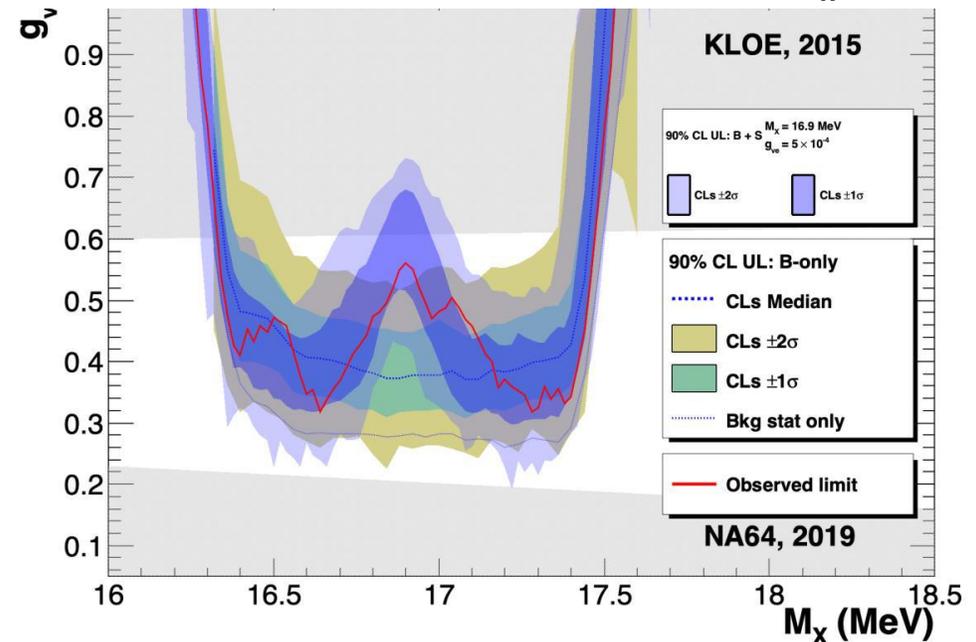
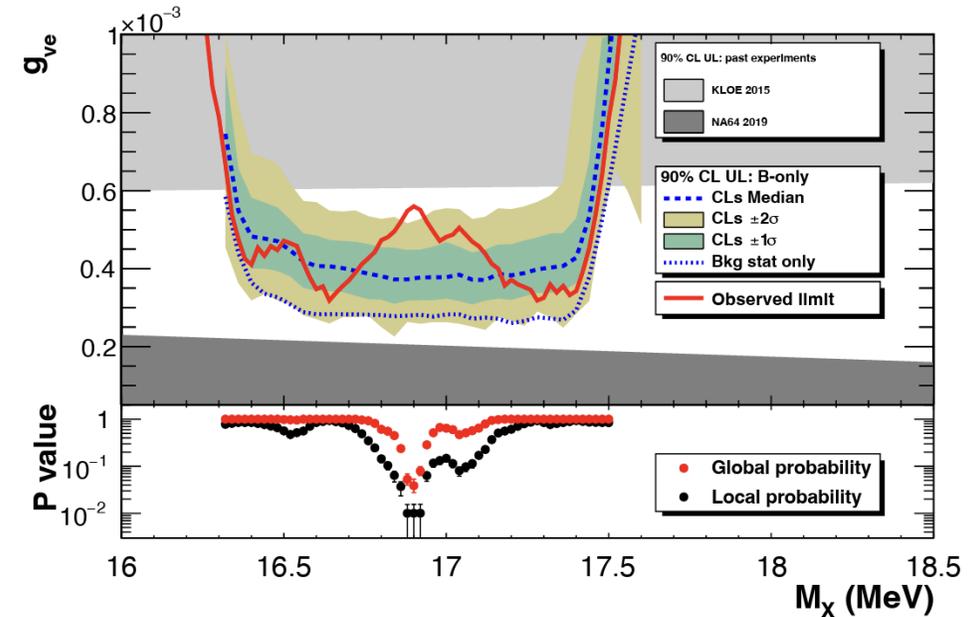
# Search for the X17 at PADME in LNF

No indications of X17 well beyond two-sigma-equivalent global p-values

An excess has been observed, with global p-value equivalent to  $1.77(15) \sigma$ .

New data to be acquired to better clarify:

- New detector for Run IV
- New micromegas-based tracker to separately measure the absolute cross sections of  $ee/\gamma\gamma$  thus allowing a combined analysis

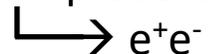




# What about X17 quantic numbers?

ATOMKI measurements indicate the existence of a particle with a mass of  $\sim 17$  MeV. However, the properties of X17 ( $J^\pi$ , coupling with ordinary matter,..) are unknown, because of the limited experimental information.

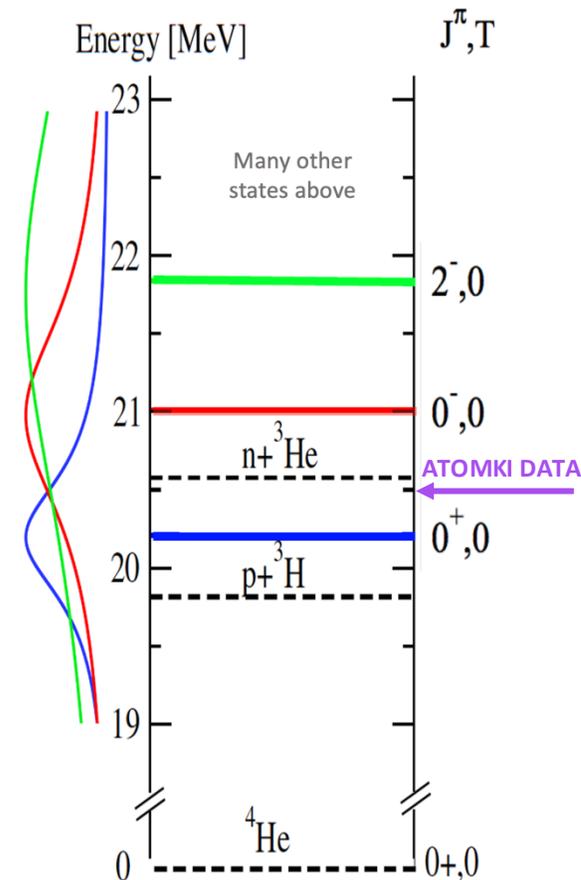
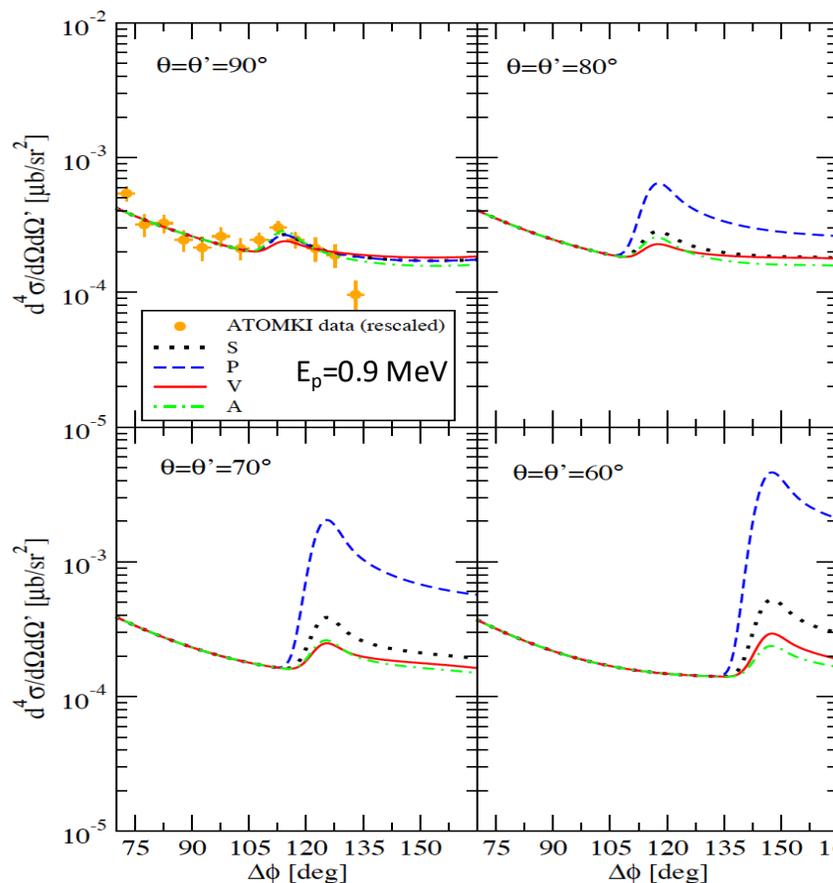
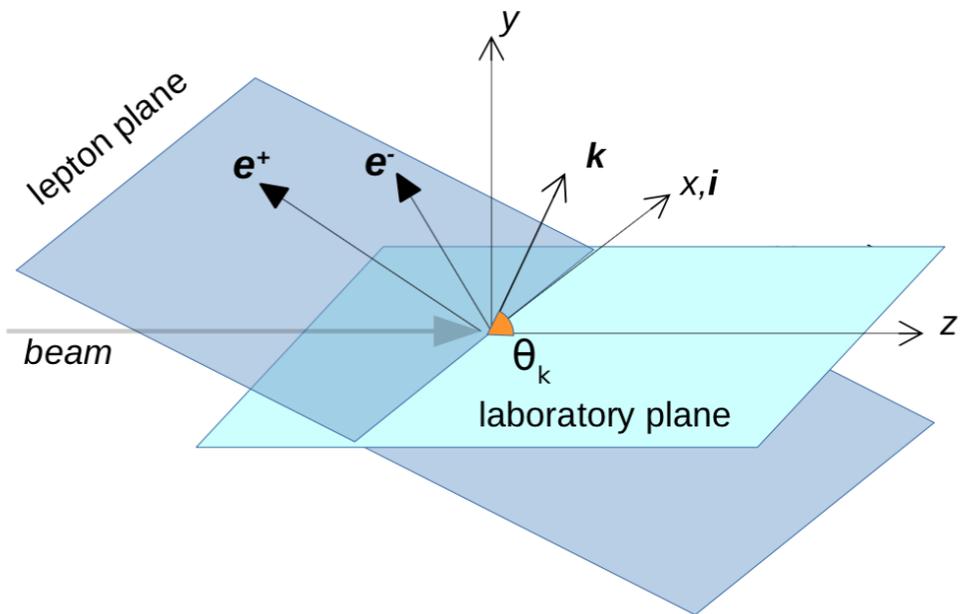
Concerning the  ${}^4\text{He}^* \rightarrow {}^4\text{He} + \text{X17}$  process:



The angular distribution of  $e^+e^-$  pairs from the X17 decay strongly depends on its  $J^\pi$

e.g. if it is a Scalar/Pseudoscalar/Vector/Axial Boson

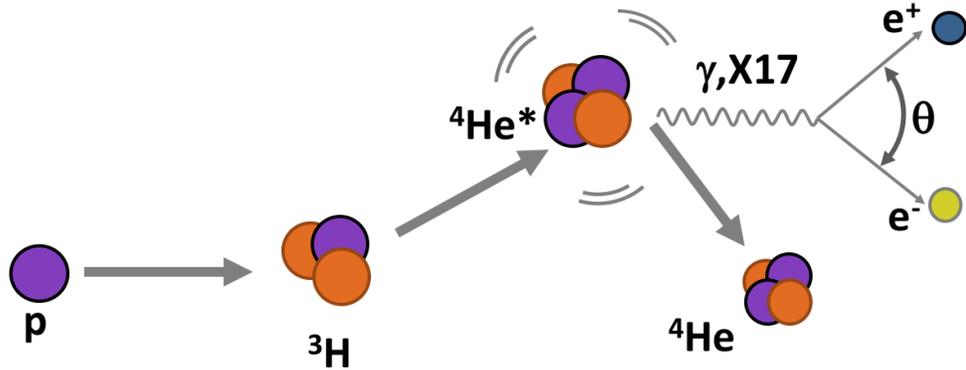
$\rightarrow$  Large acceptance detector needed



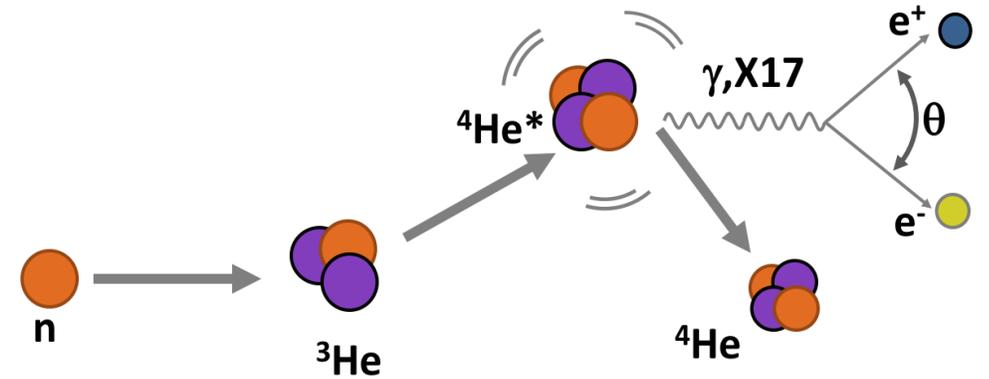
M. Viviani et al.: PRC 105, 014001 (2022)

# X17 @ n\_TOF

Basic idea: study of excited  ${}^4\text{He}$   
exploiting both the conjugated reactions:



ATOMKI REACTION



n\_TOF REACTION

## Physics:

- Probing X17 existence
- X17 Mass, quantic numbers,
- Data Vs Theoretical nuclear physics

# Search for the X17 at n\_TOF

## Neutron beam:

Pulsed neutron beam with a wide energy range  $10^{-2} < E < 10^8$

The Energy of the interacting neutron is derived with the Time-of-flight technique.

## Detector:

-4 large  $\mu$ Rwells with a large (3 cm) ionization gap,  $380 \times 460 \times 30 \text{ mm}^3$  active volume

→ 3D tracking

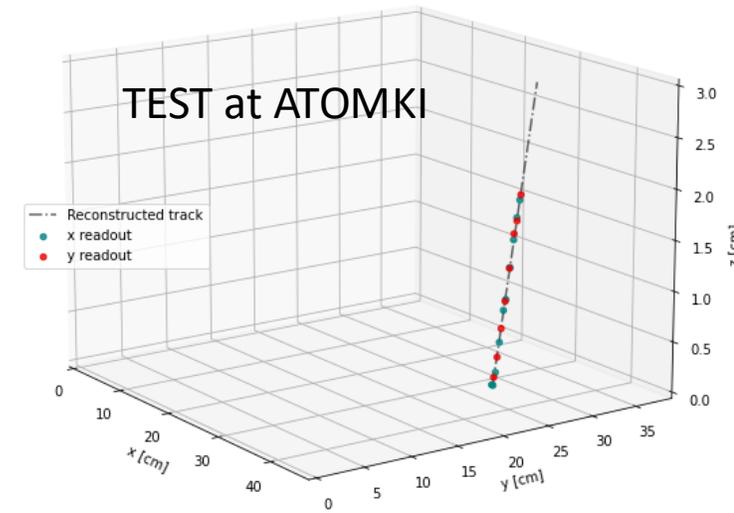
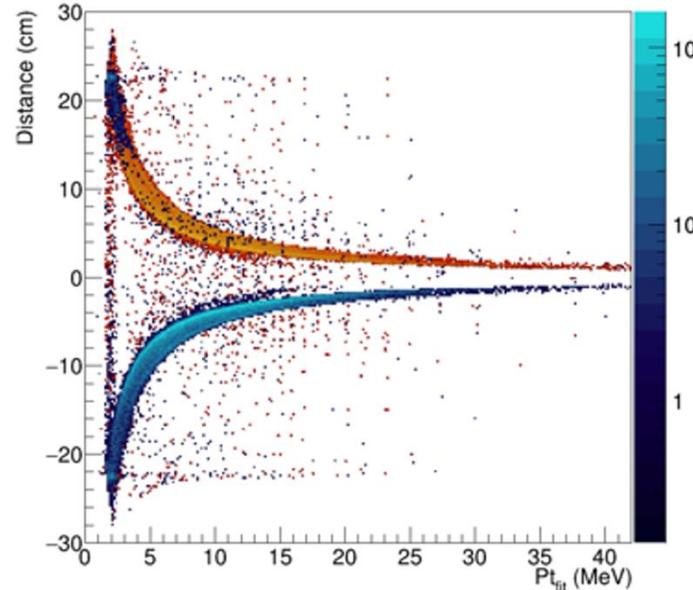
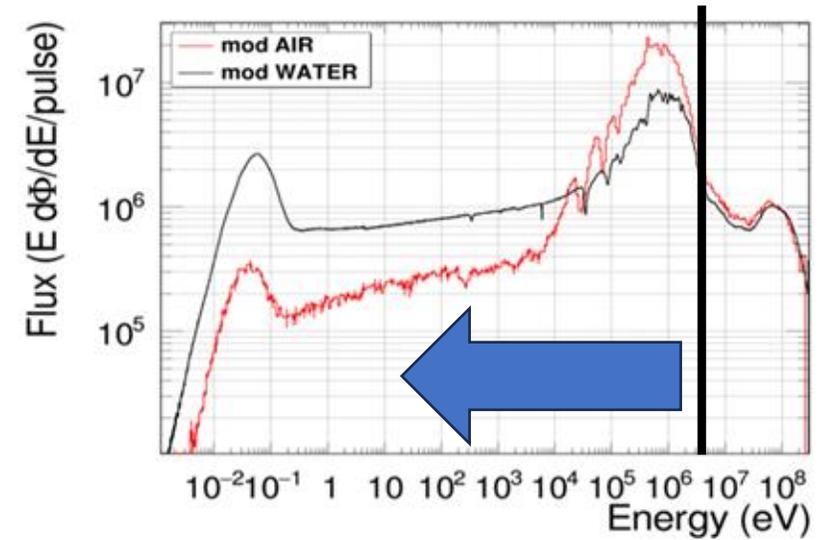
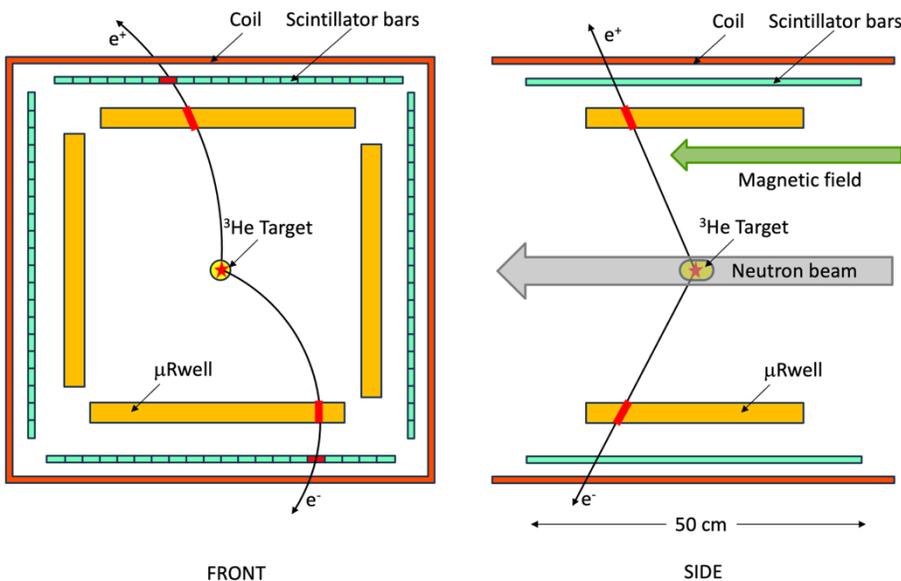
-4 planes  $50 \times 50 \text{ cm}^2$ , each one composed by 20 scintillator bars  $3 \times 25 \times 500 \text{ mm}^3$  →

Trigger and neutron energy with TOF technique

-Coil 60 cm long and with a square section  $60 \times 60 \text{ cm}^2$  ( $B = 500 \text{ Gauss}$ ) → charge and momentum reconstruction of ejectiles

## Target:

$^3\text{He}$  target (358 bar,  $10 \text{ cm}^3$ ) in a quasi-cylindrical cell of  $10 \text{ cm}^3$  Inside a capsule of Aluminium alloy+Carbon fibre.



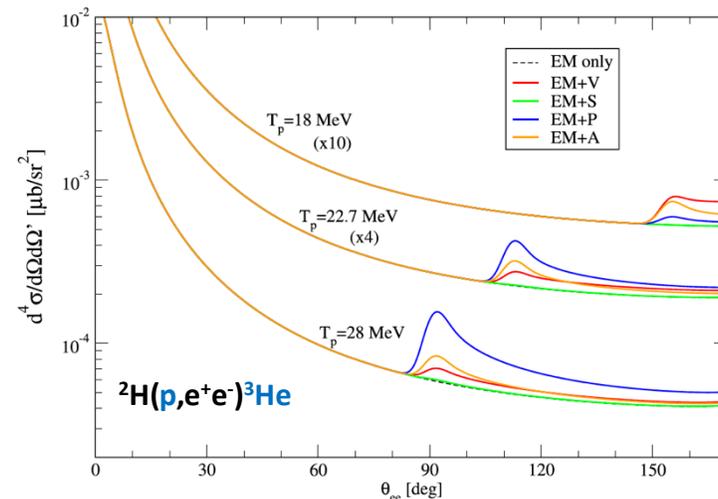
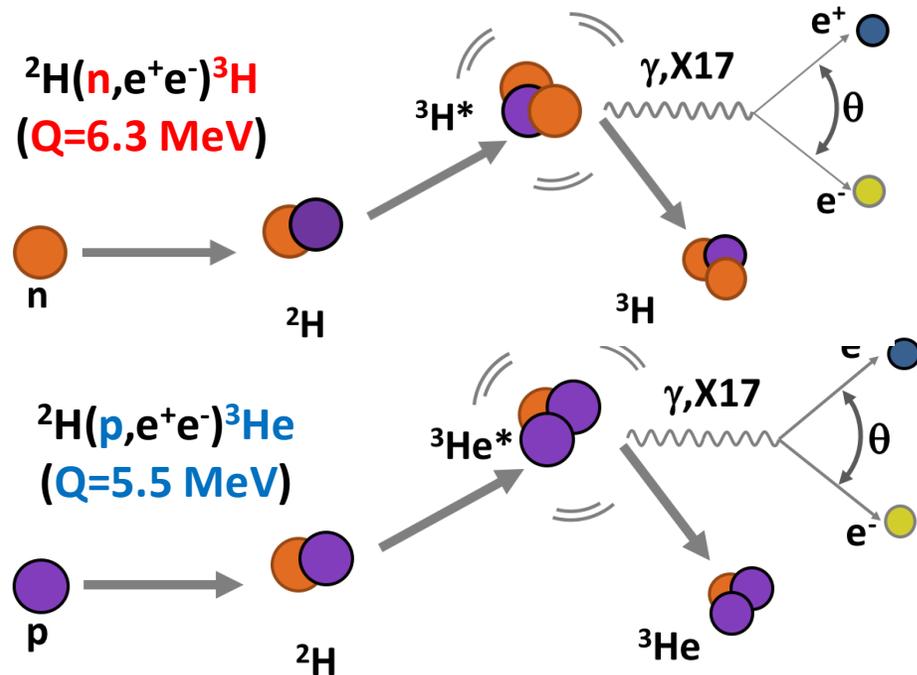
# Search for the X17 at n\_TOF

The n\_TOF detector can be also used for the study of many processes exploiting its large acceptance, its capability to reconstruct the kinematics and charge of ejectiles and the low sensitivity to photons and neutrons

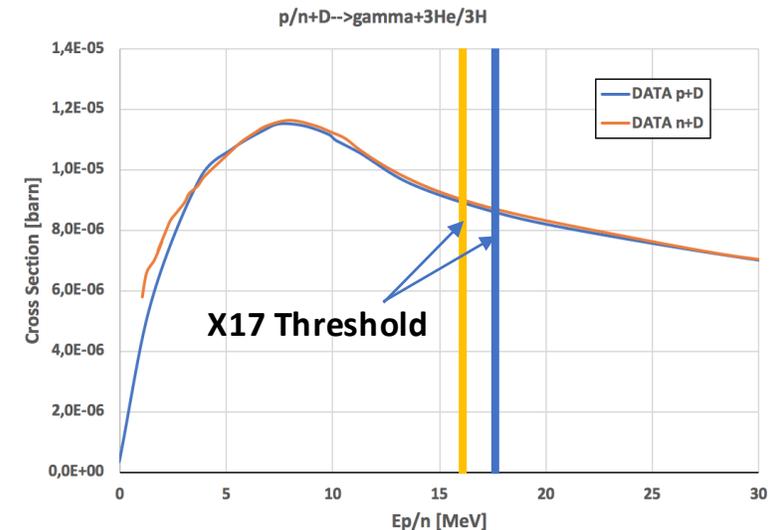
## Examples:

Renewed study of the  ${}^7\text{Li}(p,e-e){}^8\text{Be}$ ,  ${}^{11}\text{B}(p,e-e){}^{12}\text{C}$  reactions  $\rightarrow$  X17 search.

- Study of the  ${}^3\text{He}(n,e-e){}^4\text{He}$   ${}^3\text{H}(p,e-e){}^4\text{He}$  reactions, in a wide energy and angular range  $\rightarrow$  probing X17 quantum numbers. See *M. Viviani et al.: PRC 105, 014001 (2022)*.
- Study of the  ${}^2\text{H}(p,e-e){}^3\text{He}$  and  ${}^2\text{H}(n,e-e){}^3\text{H}$  “specular” reactions  $\rightarrow$  probing the protophobic coupling of X17. See *M. Viviani et al.: PRC 111, 034002 (2025)*.



*Viviani et al.: PRC 111, 034002 (2025)*



# Conclusion

Stay tuned! Many groups and theoreticians are working in Italy on X17. In particular PADME is planning a new run, with high statistics and an improved detector. n\_TOF perform a 2 months data taking this year, before the long shutdown.

Two workshop will be held very soon in Italy:

“X17 What if?”

March 19–20, 2026 Laboratori Nazionali di Frascati, INFN (Italy)

<https://agenda.infn.it/event/49565/>

→mainly focused on the new data taking at LNF.

“The X17 particle: status and new ideas”

March 23 to March 27, 2026, at ECT\* in Trento (Italy).

<https://www.ectstar.eu/workshops/the-x17-particle-status-and-new-ideas/>

→mainly focused on theoretical aspects of X17

**SPARES**

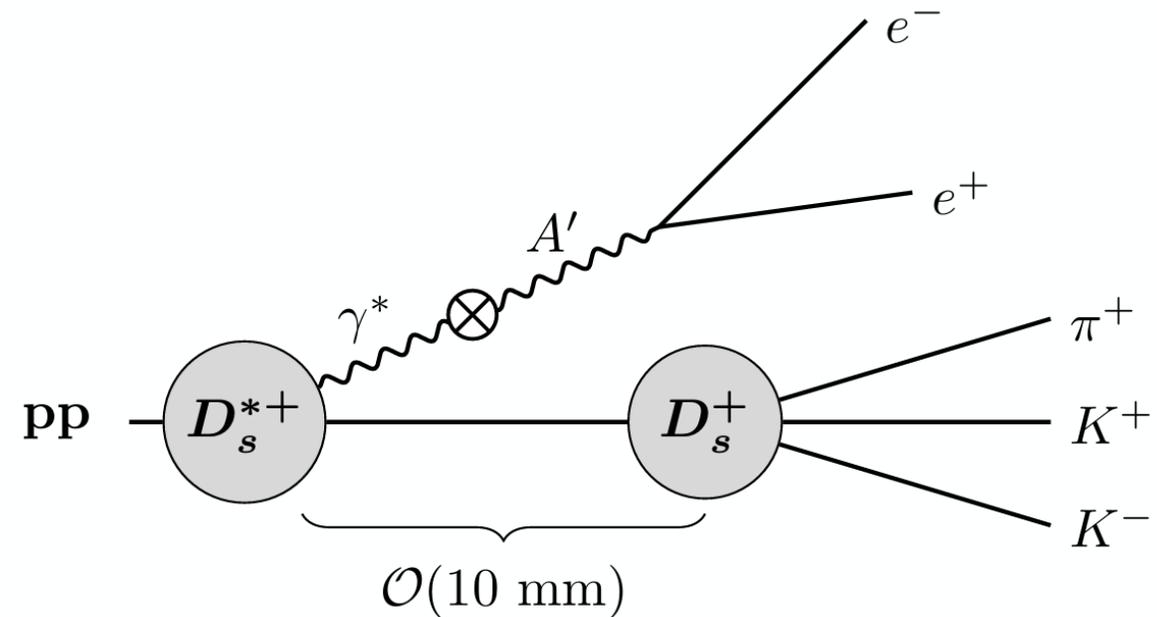
# Search for a $X \rightarrow e^+e^-$ resonance in radiative charmed meson decays at LHCb



Carlos Cocha, Martino Borsato  
on behalf of the LHCb Collaboration

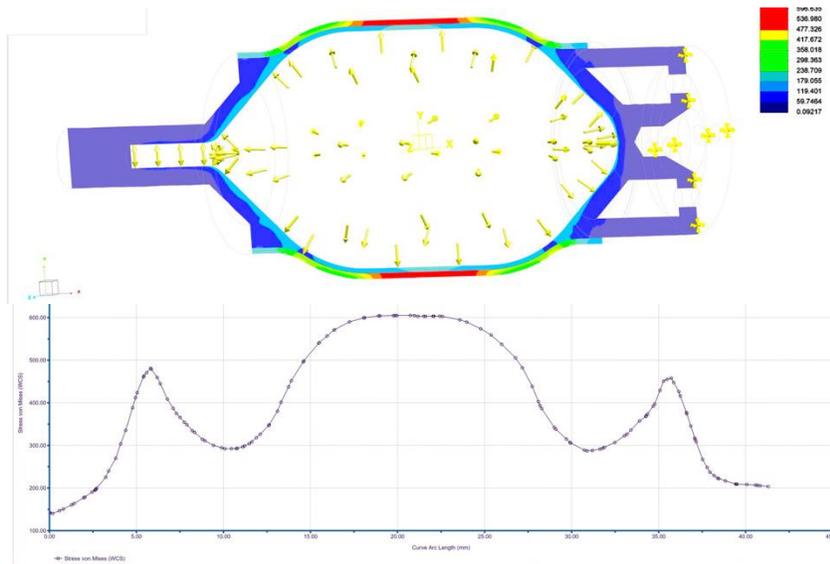
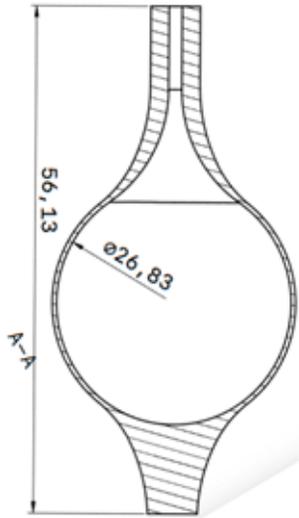
LHCC 164 Week  
November 17, 2025

- ▶ Search for a peak in  $m_{e^+e^-}$  spectrum
- ▶ Promising channel:  $D_s^{*+} \rightarrow D_s^+ \gamma^*$
- ▶ Very soft electrons:  $\gamma^* \rightarrow e^+e^-$
- ▶ Production rate at LHCb:  $\mathcal{O}(\text{kHz})$



# The Target

- $^3\text{He}$  target (358 bar,  $10\text{ cm}^3$ ) in a quasi-cylindrical cell of  $10\text{ cm}^3$  Inside a capsule of 0.3 mm SCALMALLOY 0.3 mm thick reinforced with 1 mm of carbon fibre, to limit Multiple Scattering and beam induced background.
- SCALMALLOY capsule realized with a 3D printer, to ensure a tight container
- Carbon fibre coat to increase the resistance to pressure.
- **First capsules (0.5 mm of SCALMALLOY and 1 mm of carbon fibre) filled with  $^4\text{He}$  at 200 bar successfully tested at CERN. No pressure decrease after >3 months of monitoring**
- R&D still in progress, to further optimize Pressure Vs thickness of capsule.



Images by P. Mastinu and E. Musacchio-Gonzales

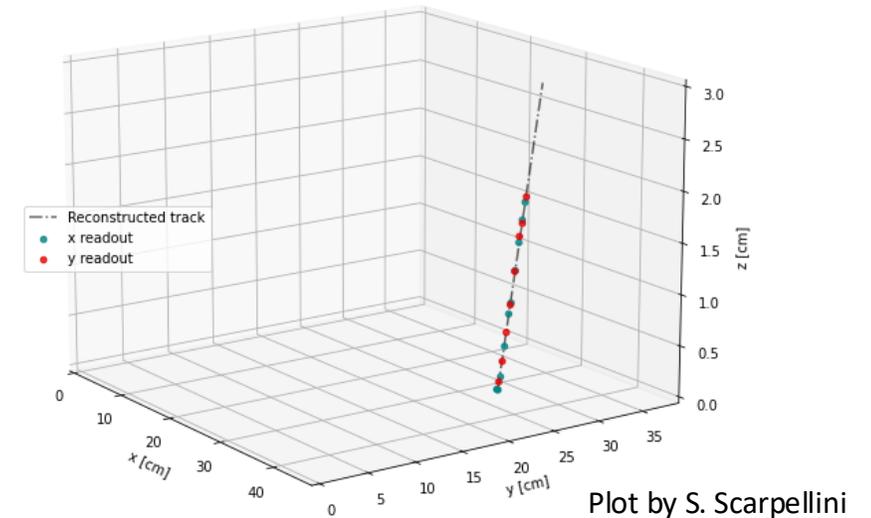
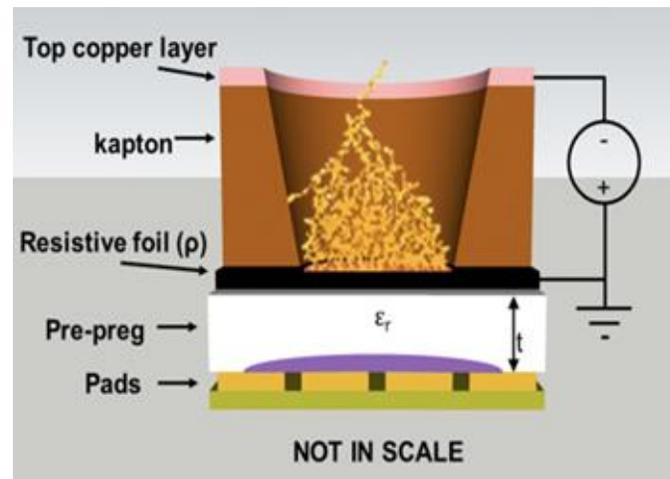
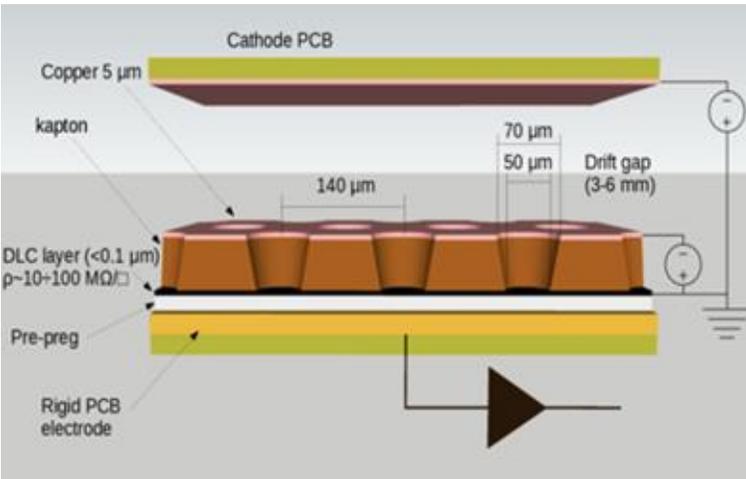
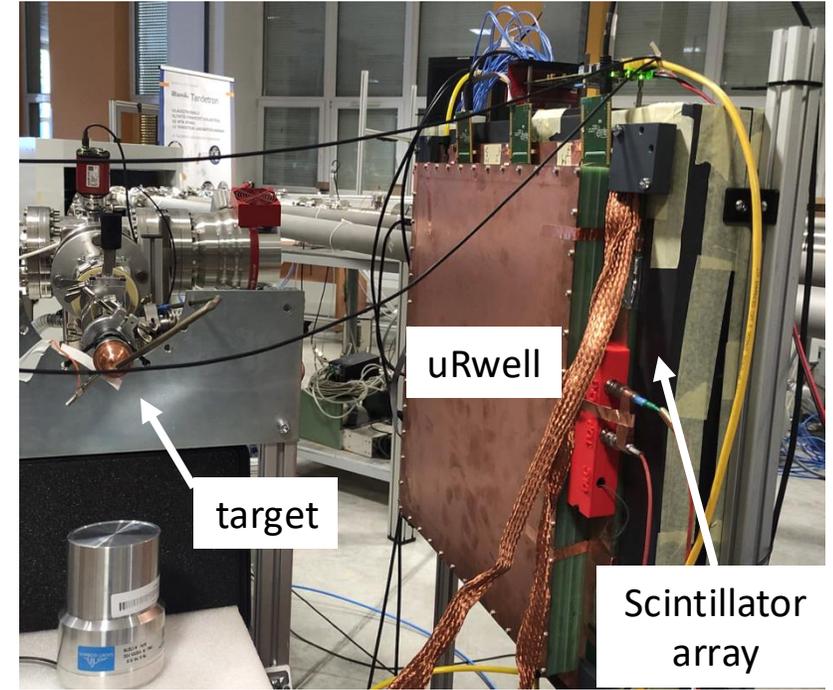
# The $\mu$ Rwells

-The  $\mu$ Rwells are MPGD like GEM and  $\mu$ Megas.

Our  $\mu$ Rwells are equipped with X and Y readout strips, with a pitch of 1.7 and 0.7 mm, respectively.

-The 3D reconstruction of the tracks is obtained by operating the chambers in TPC mode (gas gap is 30 mm)

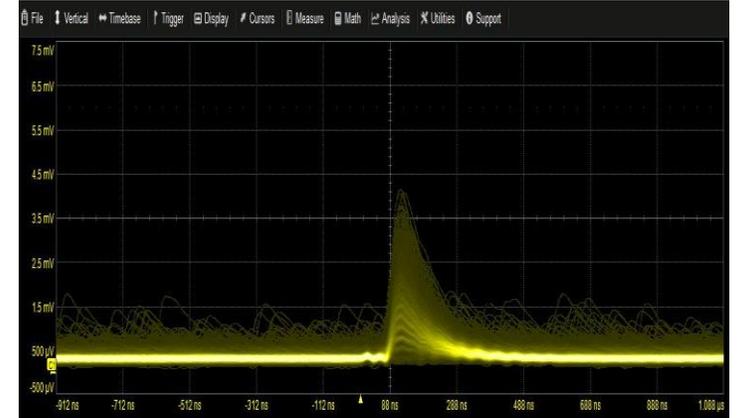
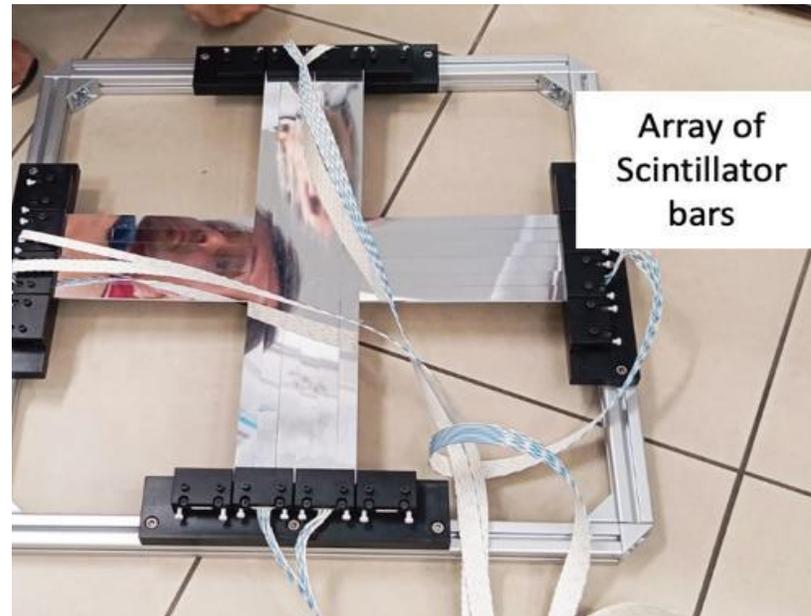
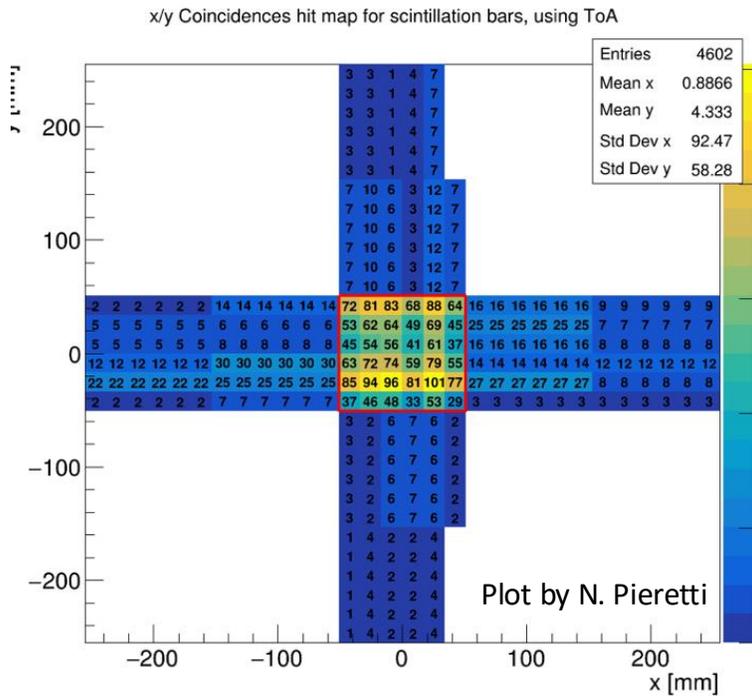
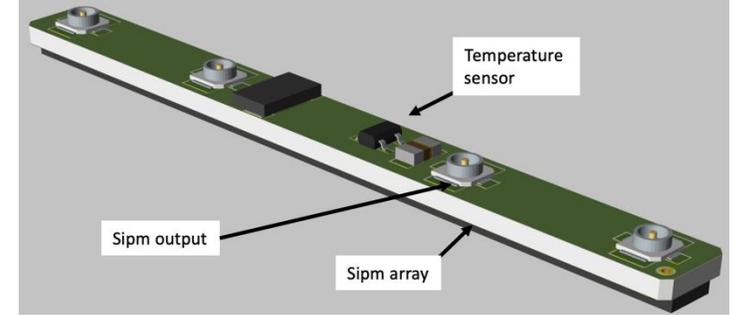
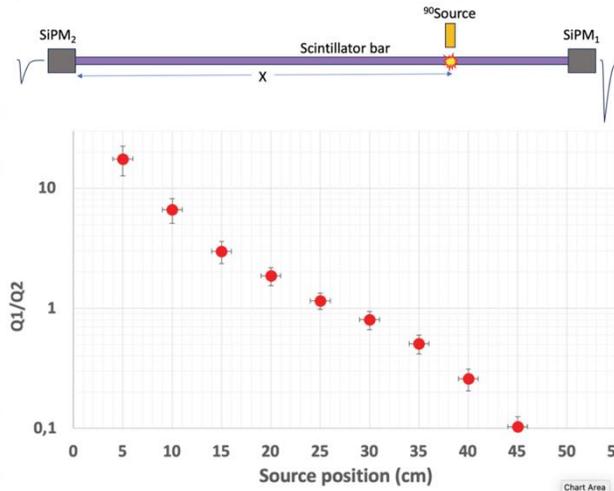
Tested at n\_TOF and ATOMKI neutron and proton beams, by using a demonstrator composed by a single  $\mu$ Rwell backed with a set of scintillator bars.



# The scintillator system

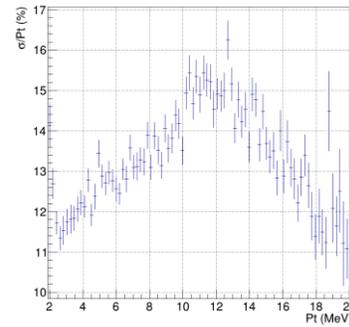
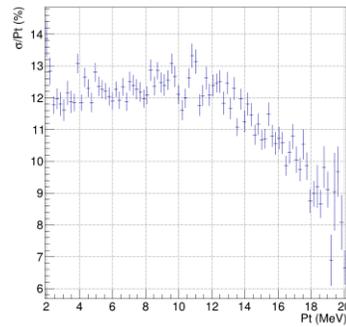
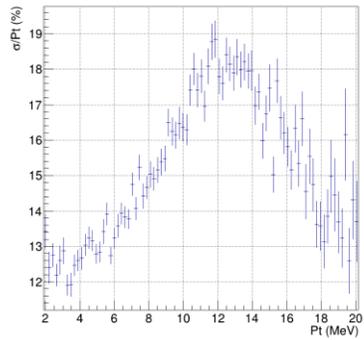
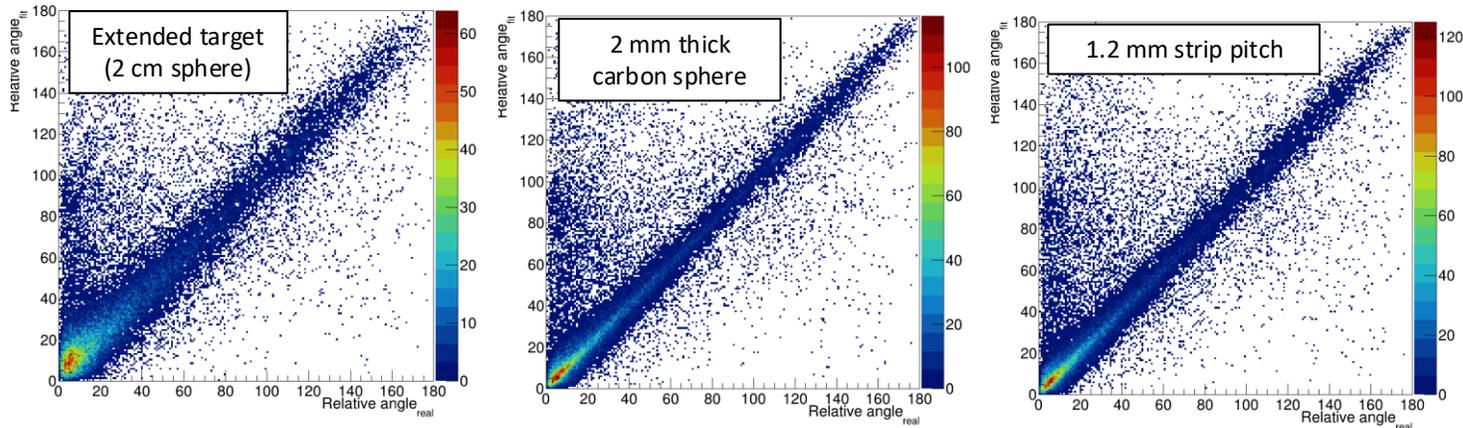
- Commercial scintillator bars by SCIONIX, 50x2.5x0.3 cm<sup>3</sup>
- readout performed with array of SiPM by Hamamatsu.

Tested at n\_TOF and ATOMKI neutron and proton beams.

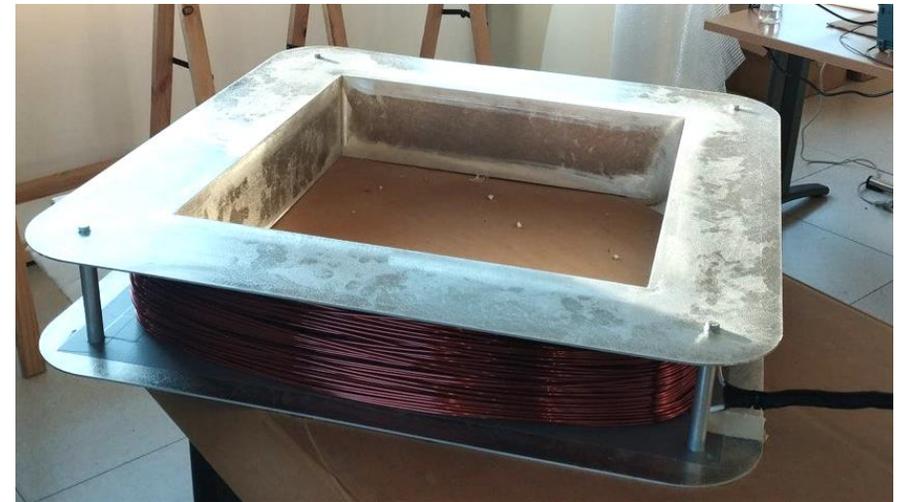
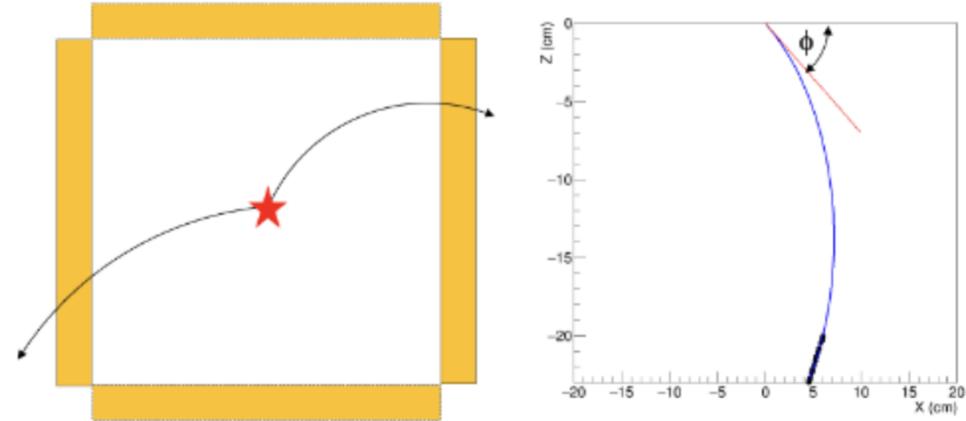


# The magnet

The magnet demonstrator has been realised and characterised. Tests at n\_TOF with the neutron beam and at LNL with the proton one in 2025). Simulations provide an overall momentum reconstruction of ejectiles at the 20% Level.



Plots by R. Mucciola



15x60x60 cm<sup>3</sup> magnet demonstrator

# The n\_TOF X17 detector demonstrator

Tests of Demonstrator (1/4 of the final detector):  
Neutron beam of N\_TOF at CERN (October 2023)  
Proton beam of ATOMKI, Debrecen (May 2024)

