X17 discovery potential from $\gamma D \rightarrow e^+e^-pn$ with neutron tagging

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1. What is X17?

The ATOMKI group found **anomalous signals** in the decays of excited ^{8}Be (bottom figure), ^{4}He, and ^{12}C nuclei with **statistical significances exceeding 6σ**. To account for these anomalies, they proposed the existence of **X17**, a light boson with a mass of 17.02(10) MeV. This conjecture has sparked a **global experimental effort** to replicate the anomaly.

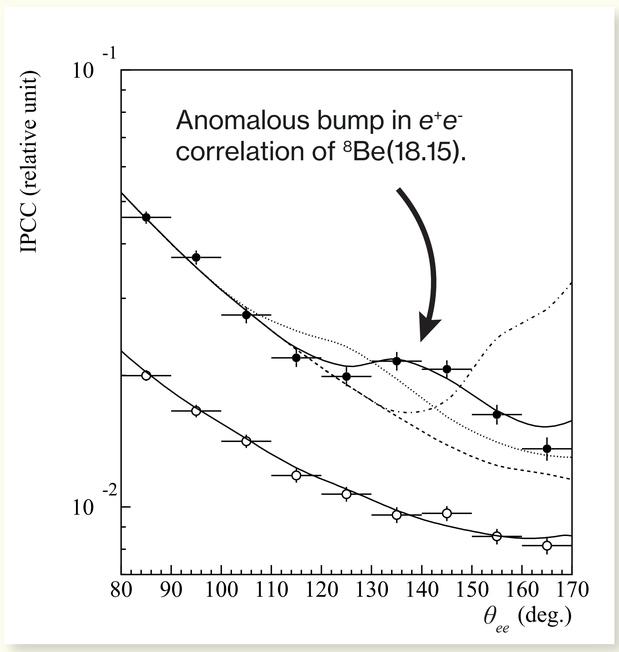
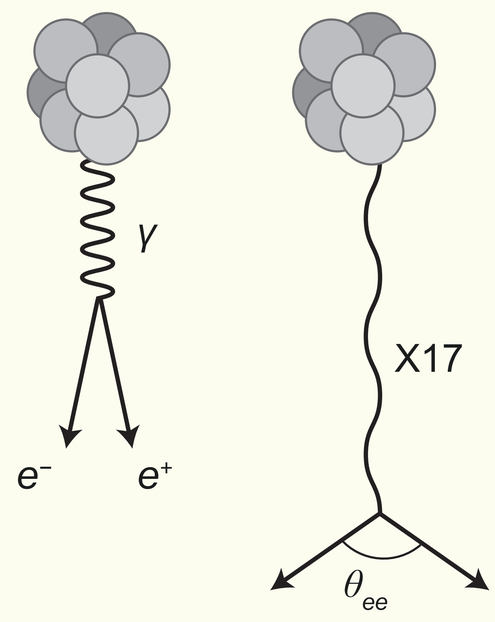


Image from Phys. Rev. Lett. 116, 042501 (2016)
Illustration adapted from Quanta Magazine

Internal pair creation and X17 emission in ^{8}Be(18.15)



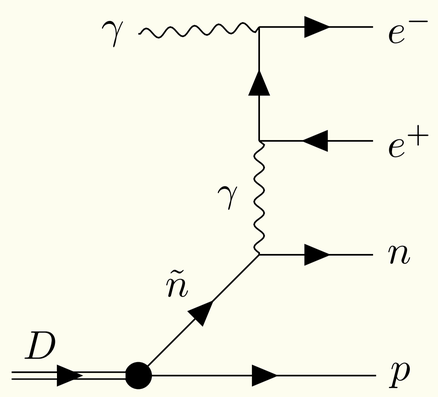
State	Scalar	Pseudoscalar	Vector	Axial vector
^{8}Be(18.15)		$\ell = 1$	$\ell = 1$	$\ell = 0, 2$
^{8}Be(17.64)		$\ell = 1$	$\ell = 1$	$\ell = 0, 2$
^{4}He(21.01)		$\ell = 0$		$\ell = 1$
^{4}He(20.21)	$\ell = 0$		$\ell = 1$	
^{12}C(17.23)	$\ell = 1$		$\ell = 0, 2$	$\ell = 1$

2. X17 at electron accelerators

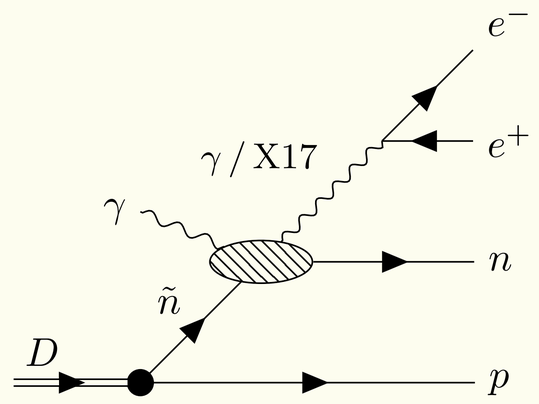
- Ongoing experiments focus on nuclear decays.
- X17 must take part in other processes.
- In $\gamma n \rightarrow e^+e^-n$ the **X17 signal** would be **clearly visible over the QED background**.
- Direct search in this way would provide a **timely** and **independent confirmation of X17's existence**.
- **MAGIX experiment at MESA is ideal** for such a search.
  - Low energy yet high-intensity beam (E_γ = 105 MeV)
  - High-resolution spectrometers (δm_{ee} = 0.1 MeV)

3. Neutron tagging

- **Neutron target** is **not available** in the lab.
- $\gamma D \rightarrow e^+e^-pn$ with **neutron tagging** instead.
- **Bound neutron** is **quasi free, proton** a **spectator**.
- Scattering events primarily on quasi-free neutron.



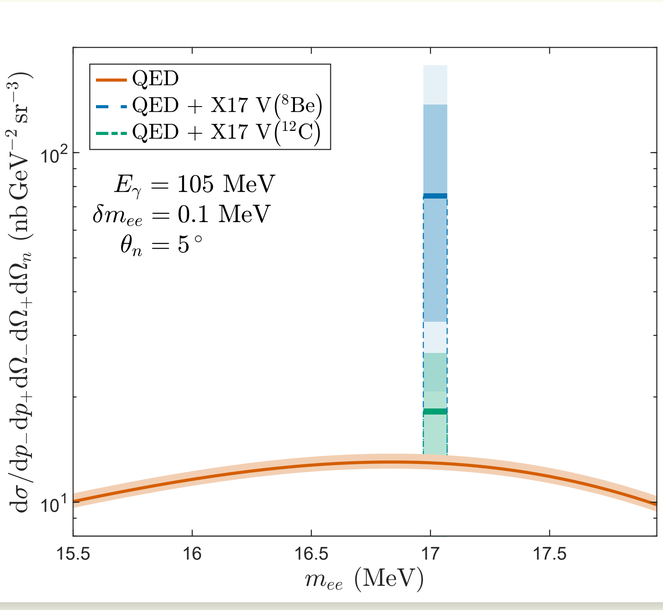
The Bethe-Heitler process. Here, X17 is off resonance, so its contribution is negligible.



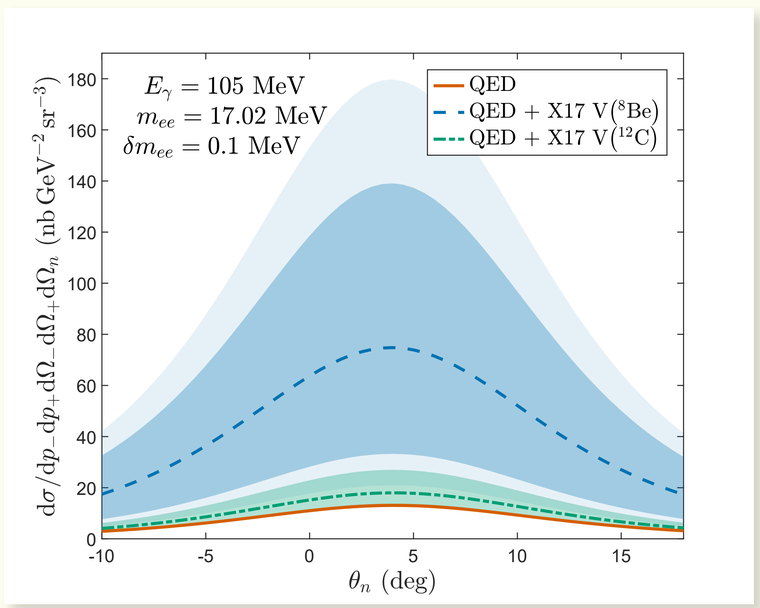
The Compton (Born, π^0 t-channel exchange, and electric and magnetic nucleon polarizability) and X17 production processes.

4. X17 signal would be visible over QED background

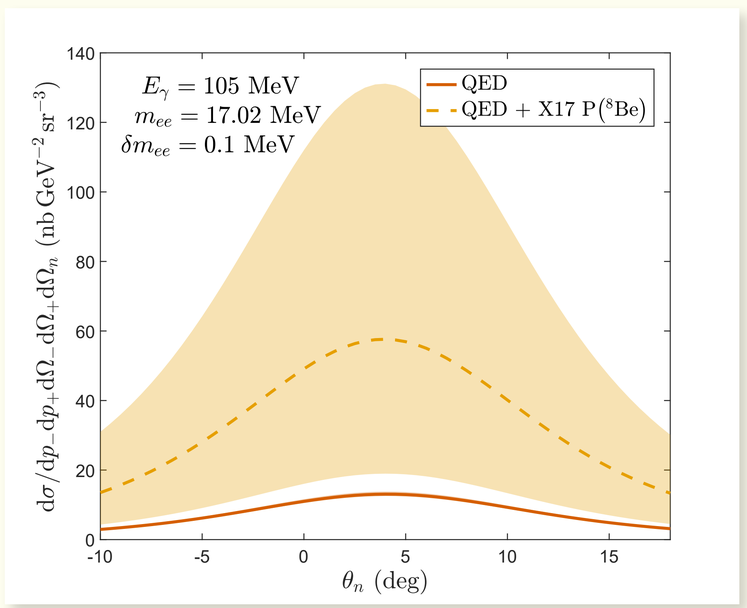
X17 signal would appear as a **sharp spike** in a **single bin**.

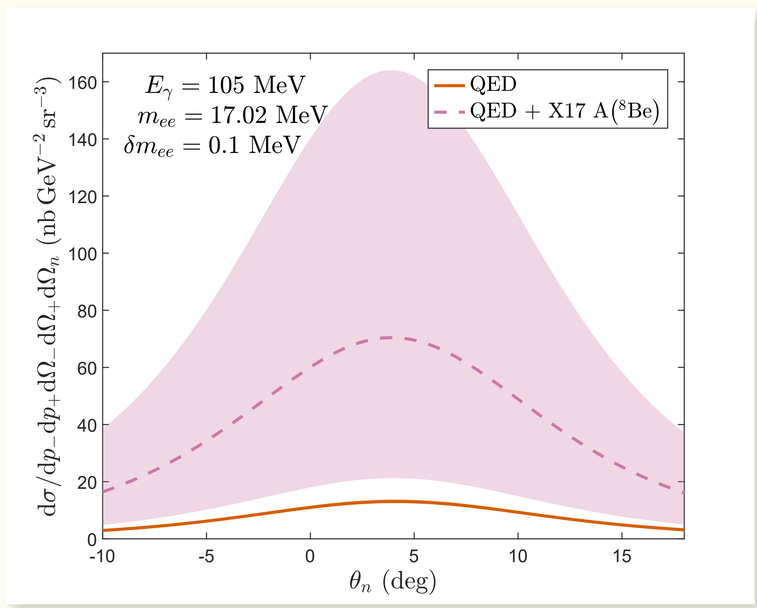


- Consider models for a pseudoscalar (P), vector (V) and axial-vector (A) X17.
- Use beryllium and carbon measurements to constrain X17 coupling to nucleons.
- **X17 signal** (dashed) is **visible over the QED background**.
- Slight tension between couplings derived from beryllium and carbon nuclear decays highlights need for independent verification.



Dark and light bands indicate a 2σ and 3σ variation in the couplings. Uncertainties in the QED background come from nucleon polarizabilities.





Light bands indicate a 1σ variation in the couplings.