Search of the 16.7 MeV X boson with the MEGII detector

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X boson working group
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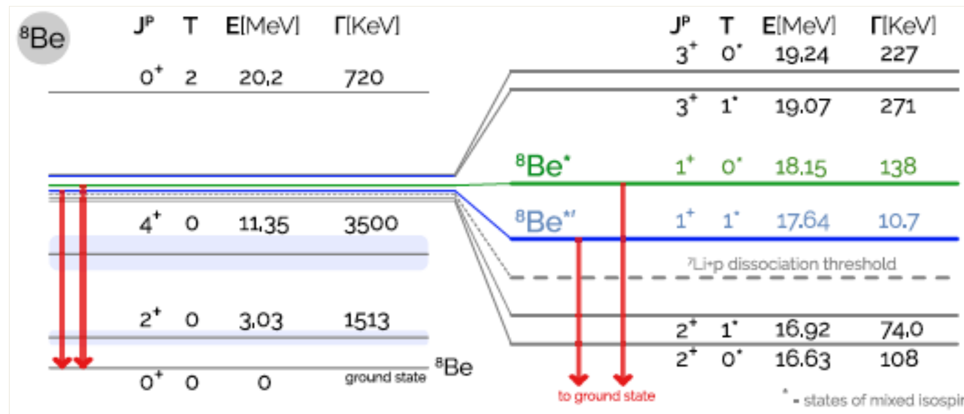
Tokyo Meeting 5-6 April 2018

Outline

- The Atomki anomalies in ^{8}Be transitions
- Possibile interpretations
- Future experiments
- The measurement at MEGII
  - experimental setup
  - expected rate
  - efficiency and resolutions from simulation (F. Renga@Sep2016 CM)
  - plans (to be completed by A. Papa in next presentation)

^{8}Be transitions

p->^{7}Li reactions to populate ^{8}Be excited states



Be* ,
E=18.15 MeV, Γ=138 KeV
J^P=1+, mostly isoscalar

Be*' ,
E=17.64 MeV, Γ=10.7 KeV
J^P=1+, mostly isovector

$$\mathrm{BR}(^8\mathrm{Be}^{*\prime} \to {}^8\mathrm{Be} + \gamma) \approx 1.4 \times 10^{-3},$$
$$\mathrm{BR}(^8\mathrm{Be}^{*} \to {}^8\mathrm{Be} + \gamma) \approx 1.4 \times 10^{-5}.$$

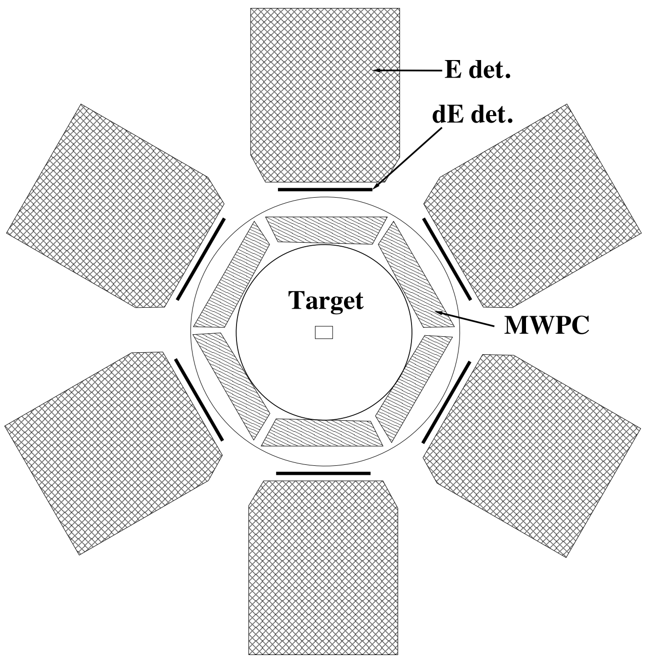
Decays:
- primarly to Li+p
- can decay radiatively
- can decay via Internal Pair Creation (IPC)

$$\sim 3 \times 10^{-3}\mathrm{BR}(\gamma)$$

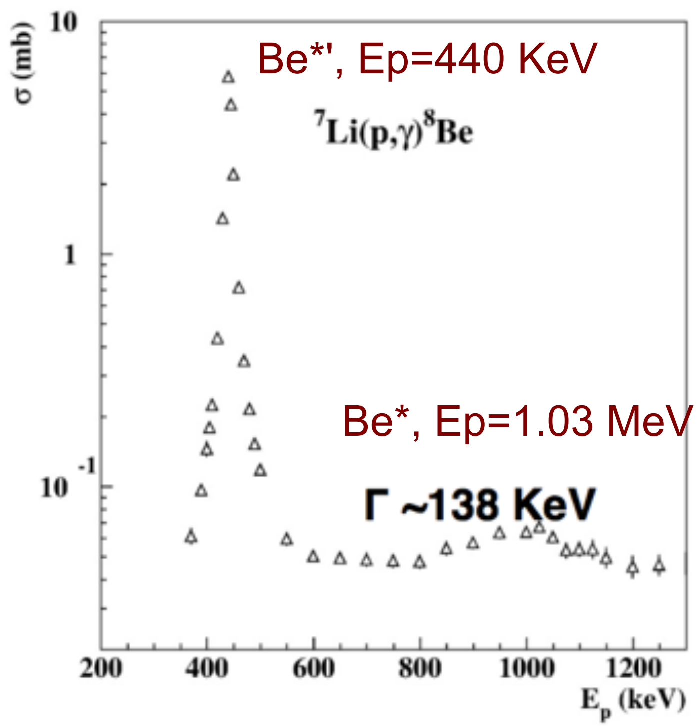
- investigating the possibility of decay to a new particle A'->e+e-

ATOMKI Be* anomaly (2016)

- ATOMKI lab, 5MV Van de Graaff accelerator
- Proton current = 1.0μA on 15μm/cm^2 thick LiF_2 target and 300μm/cm^2 LiO_2 target evaporated on 10 μm Al backings
- Vacuum chamber = 1mm carbon fiber tube



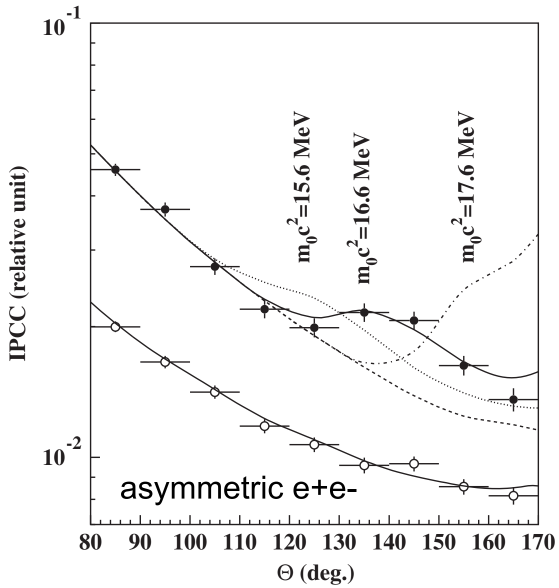
σ(θ)~7° FWHM
σ(e+e- mass) ~1.2 MeV

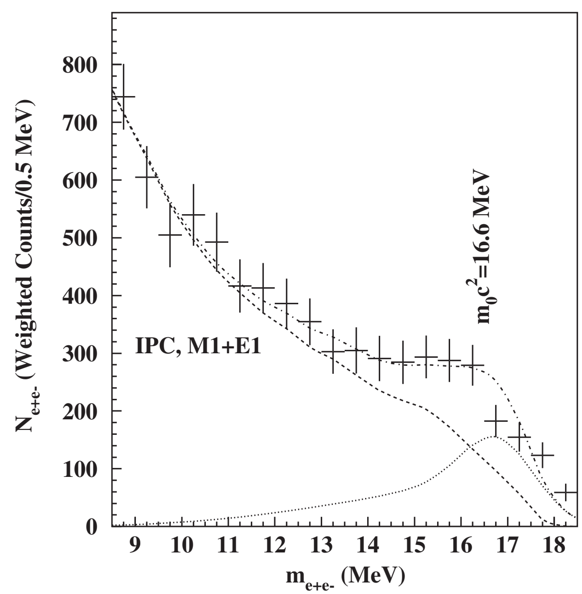


ATOMKI Be* anomaly (2016)

- Anomaly in the angular correlation of e+e- for the *Be IPC distribution

Phys.Lett.116 042501 (2016)





m_X=16.70±0.35±0.5 MeV
significance=6.8σ

$$\frac{BR(^8Be^* \rightarrow X\,^8Be)}{BR(^8Be^* \rightarrow \gamma\,^8Be)} = 5.8\cdot 10^{-6}$$

- Sanity checks:
  - excess disappears out of resonance energy
  - excess present only for symmetric e+e- pairs
  - excess more pronounced for energy around resonance peak
  - cannot be explained by nuclear effects (jphysletb.2017.08.2013)

ATOMKI Be* anomaly interpretation

PRL 117, 071803 (2016) PHYSICAL REVIEW LETTERS 12 AUGUST 2016

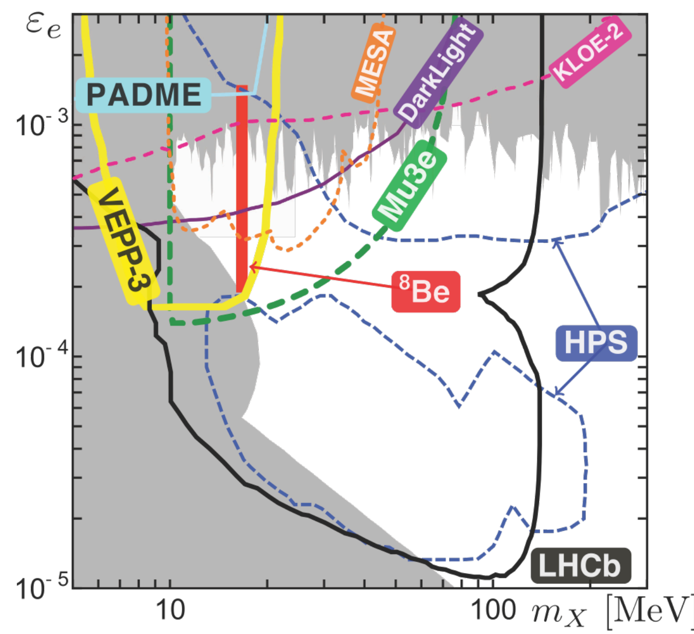
Protophobic Fifth-Force Interpretation of the Observed Anomaly in ^{8}Be Nuclear Transitions

Jonathan L. Feng,[1] Bartosz Fornal,[1] Iftah Galon,[1] Susan Gardner,[1,2] Jordan Smolinsky,[1] Tim M. P. Tait,[1] and Philip Tanedo[1]

- "Classic" U(1) dark photon cannot explain Be* anomaly due to Na48/2 bound on $\pi^0 \to X\gamma$

- NA48/2 results does not exclude a general vector boson interpretation of the ^{8}Be anomaly
  => protophobic fifth-force

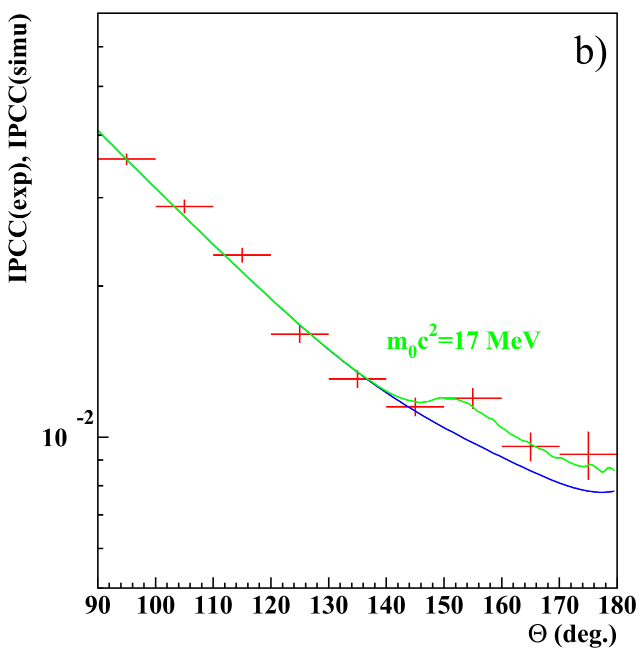
- $1.3\times10^{-5} < |\varepsilon| <\sim 2\times10^{-4}$



ATOMKI 2017 measurements

- New Tandetron accelerator, improved detector
  - MWPC replaced by double strip silicon detectors
  - new electronic

- Study Be*' resonance (Ep=441keV)
  - decay to XBe kinematically suppressed with respect that of Be* due its low energy



- Repeat measurement at Be* resonance->same result

m_X=17.0±0.2 MeV

$$\frac{BR({}^8Be^{*\prime} \to X\,{}^8Be)}{BR({}^8Be^{*\prime} \to \gamma\,{}^8Be)} = 4.0 \cdot 10^{-6}$$

epjconf 142, 01019 (2017)

(Some) Future experiments

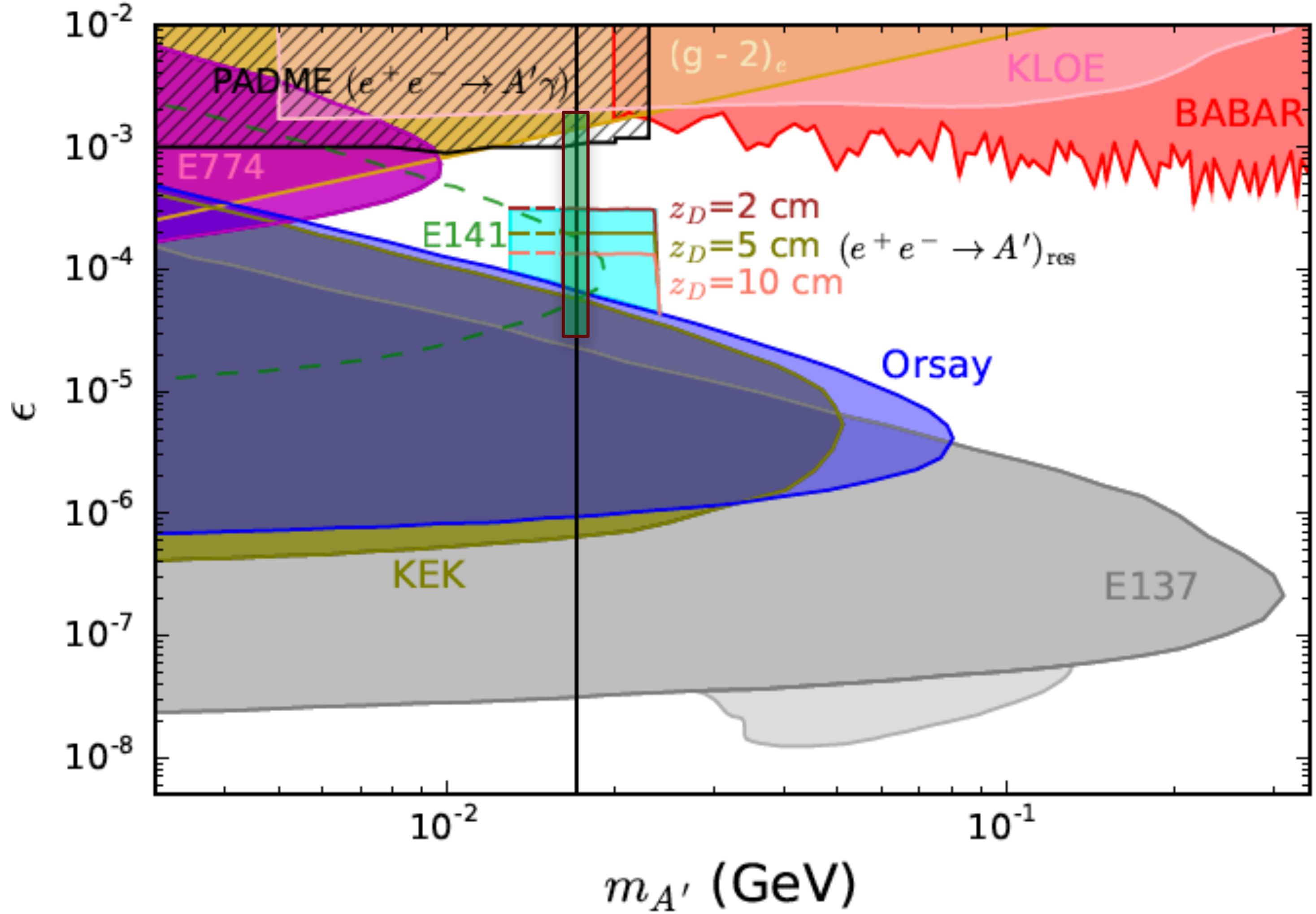
- Future ATOMKI plans: $0^- \rightarrow 0^+$ 21.01 MeV transitions in ^{4}He

  - higher energy for X boson and smaller e+e- angle at maximum
  - less background
  - study gamma-gamma decay to test the 0^- hypothesys for the X boson

- Padme arXiv:1802.04756

  - positron on fixed target (LNF Frascati)
  - main goal: invisible dark photon decays A'->$\chi\chi$
  - start data taking : May 2018
  - running in thick target mode (tungsten) and lower beam energy:
    => production from e+- annihilation @^{8}Be anomaly

Padme sensitivity



Searching the X boson with MEGII

- Possibility to check the ^{8}Be anomaly with MEGII

- Protons from CW
  - need thinner target
  - need to push energy up to the maximum ~1MeV

- CYLDCH to detect e+e- tracks
  - need lower B field (factor ~0.17)
  - need development of dedicated tracking

- Preliminary results from simulations presented by Francesco @Sep 2016 collaboration meetings

- 5kE from INFN for target R&D and construction already available

X boson kinematics & expected rate

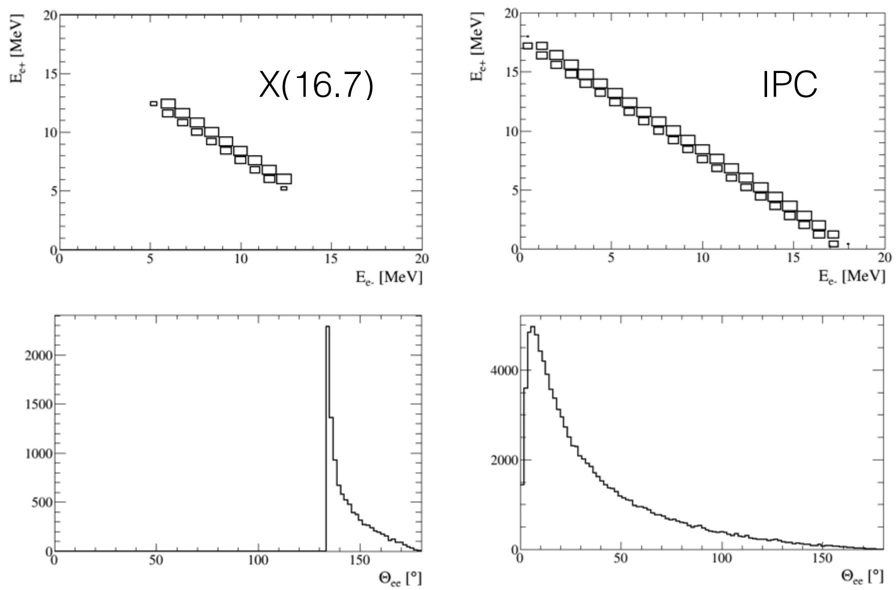
- Expected rate:
  - assuming proton current of 100μA,$Li_2B_4O_7$ target, 1MeV protons
  => R_γ=32.5kHz (Rate of resonant photon events)

Assuming Atomki observed value $\frac{BR(^8Be^* \to X\,^8Be)}{BR(^8Be^* \to \gamma\,^8Be)} = 5.8 \cdot 10^{-6}$

$\boxed{\text{700~signal events/hour}}$

- The range of 1.1MeV protons is 15μm. With a 10μm target thickness, 98% of the above total production rate would be reached with residual kinetic energy of protons~500keV
  => proton dump? target heating?

- Need to evaluate the background rate



Preliminary simulations

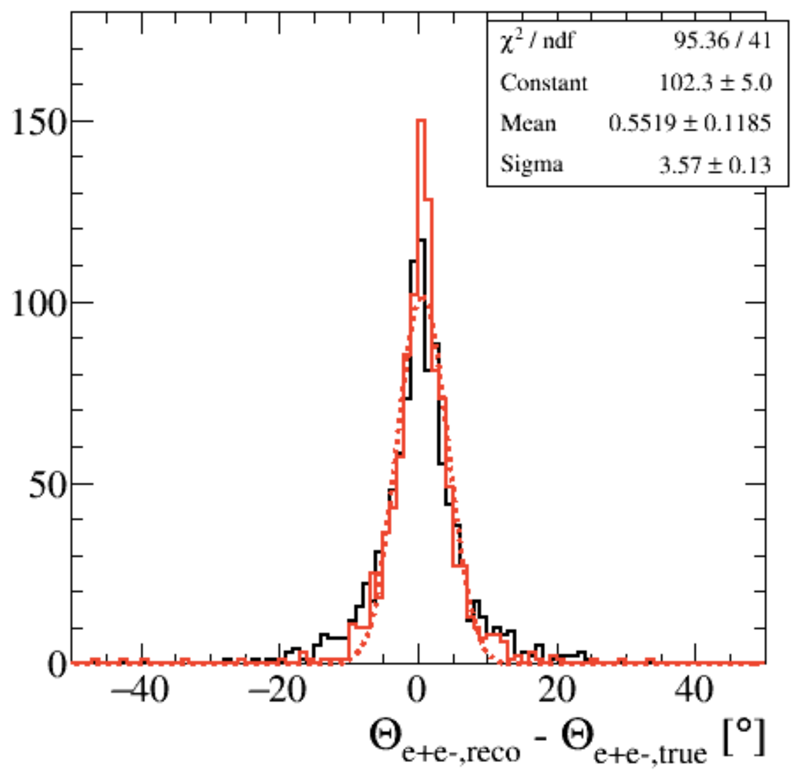
- Already presented by Francesco

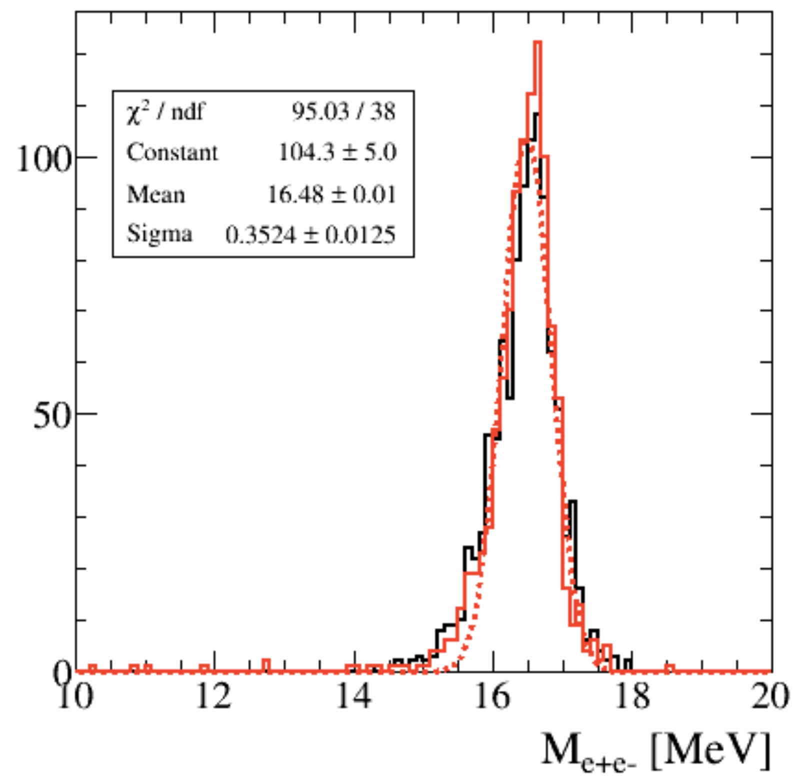
- Simulation setup:
  - 0.8mm fiber carbon beam pipe with 0.1mm Be window in the bulk of the CYLDCH acceptance
  - 10μm $Li_2B_4O_7$ +10μm Al or 5μm pure Lithium
  - Reduced COBRA and BTF fields by a factor 9.6/55 MeV~0.174 to match the e+e- spectrum
  - Isotropic decays of X at fixed depth in the target+IPC background

- Reconstruction:
  - Ideal hit reconstruction (+120μm Gaussian smearing)+ideal pattern recognition and kalman filter
  - No material implemented in Kalman
  - Separation of vertices<6cm
  - Vertex constraint applied to e+e- pair

Preliminary simulation results

- Overall ~10% efficiency (efficiency+reconstruction),





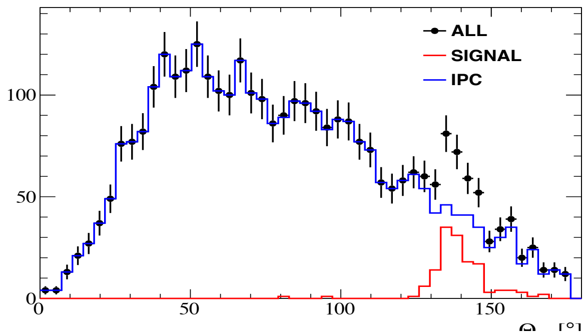
No Vtx Constraint (4.6°, 440 keV)

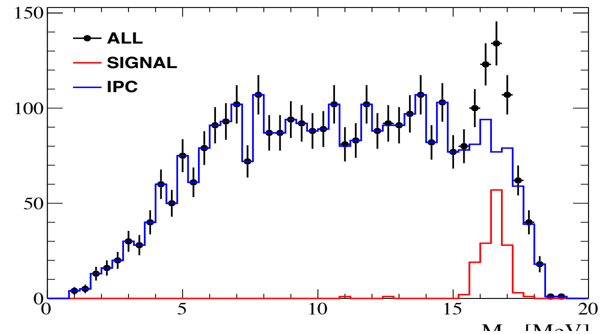
Vtx Constraint (3.6°, 350 keV)

Preliminary simulation results

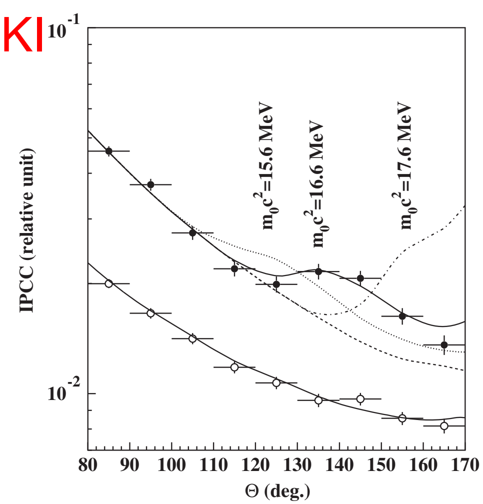
~ 140 X(16.7) events, ~ 3100 IPC

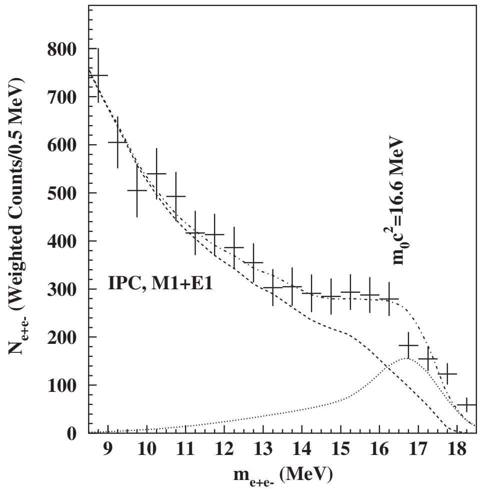
MEG





ATOMKI





Comments and to do

- MEGII has the possibility to confirm (or not) the ATOMKI *Be and Be*' anomalies with similar angular resolution but improved invariant mass distribution

- The topic is present of great theoretical and experimental interest

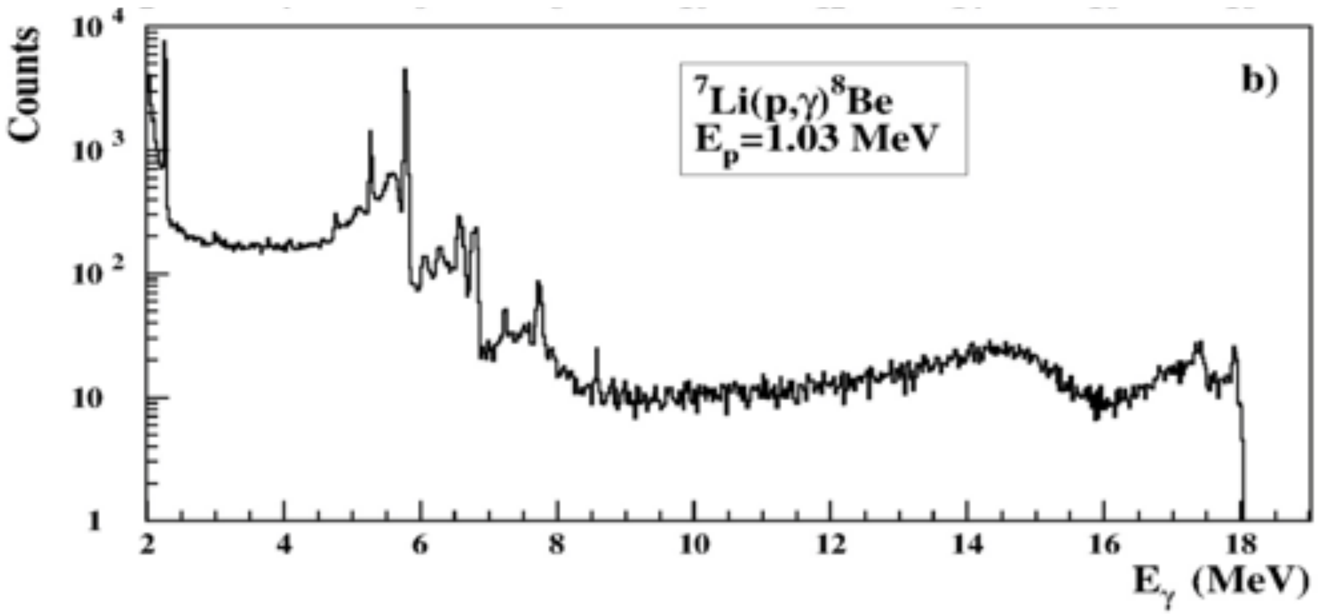
- On the CW side it is necessary: see Angela's talk
  - check the operability of the CW at the required energy
  - optimize the target design and address the technical challenges (thermoresistivity, low material budget)

- On the reconstruction e+e- side:
  - Background estimate
  - A dedicated track finder for negative tracks and special patterns has to be developed
  - Re-do simulations in realistic conditions (target)
  - Optimize magnetic field taking into account the possible need to have TC hits

- Sensitivity studies could be summarized in a paper to advertize the possibility that MEGII can perform this measurement

SPARE

Photon spectrum



Rate

$$\sigma_\gamma = \sigma_\gamma^0 \frac{\Gamma_{\rm res}^2/4}{(K-K_0)^2 + \Gamma_{\rm res}^2/4}$$

$$R_\gamma = \sigma_\gamma^0 \cdot \frac{I_p}{e} \cdot n_b \cdot \frac{\Gamma_{\rm res}}{2} \cdot \frac{1}{k} \left[\mathrm{atan} \frac{2K_0}{\Gamma_{\rm res}} + \mathrm{atan} \frac{2(K_i - K_0)}{\Gamma_{\rm res}} \right]$$

Simulation results

	Pure Lithium	Lithium Tetraborate
Angle Resolution	3.6°	3.8°
Mass Resolution	350 keV	400 keV
Efficiency	10%	11%

	Carbon Fiber + Be	Carbon Fiber
Angle Resolution	3.6°	6.0°
Mass Resolution	350 keV	490 keV
Efficiency	10%	9%