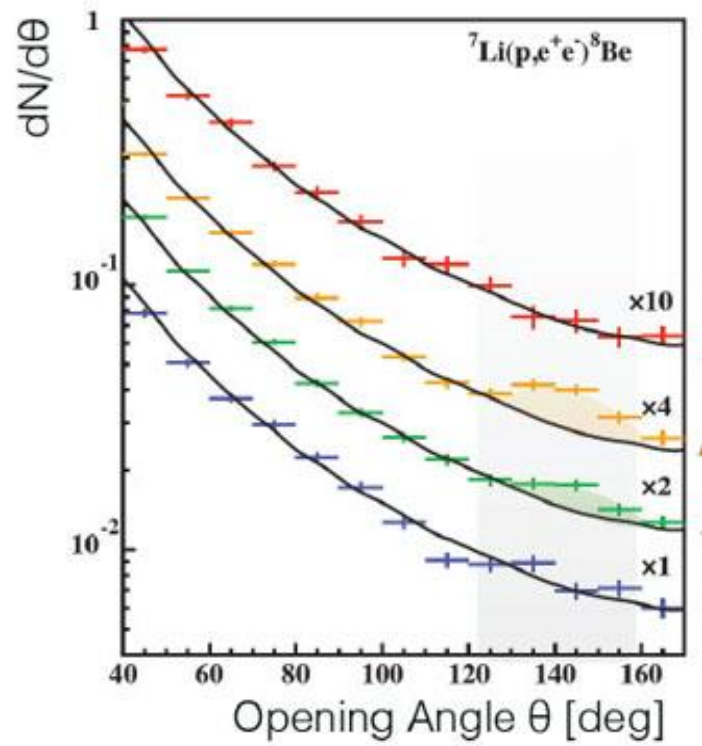
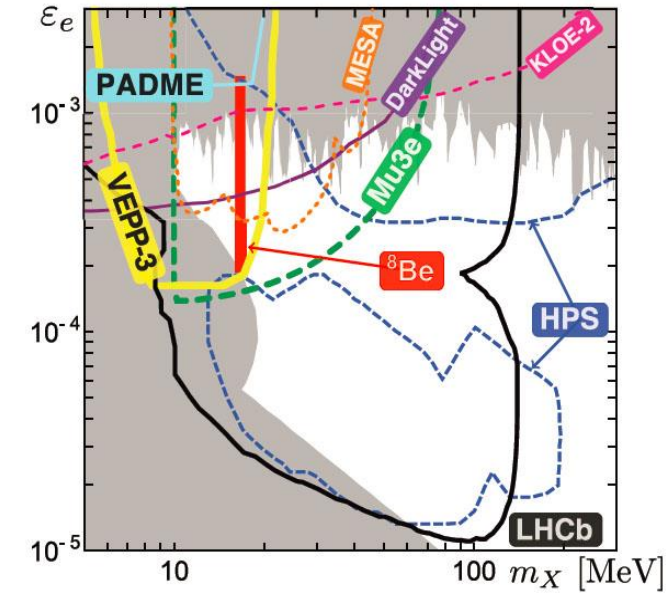
Search for New Physics in Beryllium

- ^{8}Be* as a Particle Physics Lab
- ^{8}Be* Decay via Internal Pair Creation
- The ATOMKI Anomaly
- Physics Interpretations
- The UdeM – CTU Prague project





A 6.8σ Evidence for a New 17 MeV Boson?

PRL 116, 042501 (2016) PHYSICAL REVIEW LETTERS week ending 29 JANUARY 2016

Observation of Anomalous Internal Pair Creation in ^{8}Be: A Possible Indication of a Light, Neutral Boson

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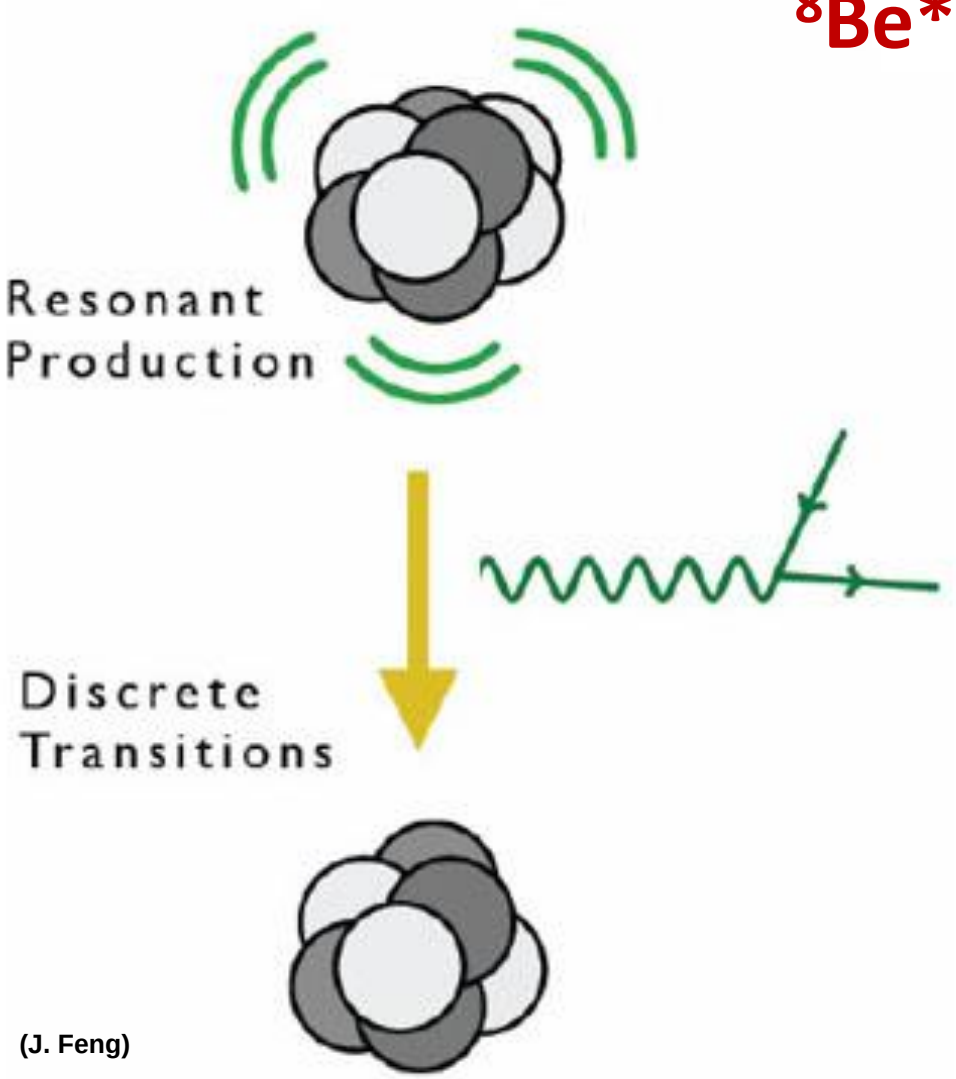
(Received 7 A

Electron-positron angular correlations were measured for the isovector magnetic dipole 17.6 MeV ($J^\pi = 1^+$, $T = 1$) state → ground state ($J^\pi = 0^+$, $T = 0$) and the isoscalar magnetic dipole 18.15 MeV ($J^\pi = 1^+$, $T = 0$) state → ground state transitions in ^{8}Be. Significant enhancement relative to the internal pair creation was observed at large angles in the angular correlation for the isoscalar transition with a confidence level of $> 5\sigma$. This observation could possibly be due to nuclear reaction interference effects or might indicate that, in an intermediate step, a neutral isoscalar particle with a mass of $16.70 \pm 0.35(\text{stat}) \pm 0.5(\text{syst})$ MeV/c^2 and $J^\pi = 1^+$ was created.

not have a nuclear physics related origin.

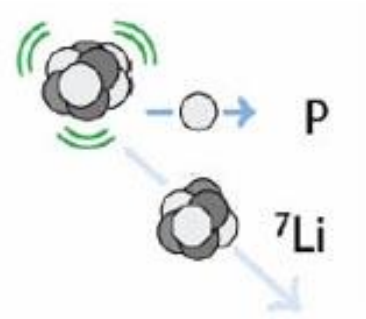
The deviation observed at the bombarding energy of $E_p = 1.10$ MeV and at $\Theta \approx 140°$ has a significance of 6.8 standard deviations, corresponding to a background fluctuation probability of 5.6×10^{-12}. On resonance, the $M1$ contribution should be even larger, so the background

^{8}Be* - A New Particle Physics Lab!



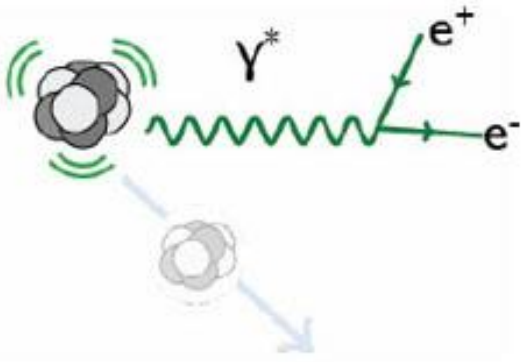
- ^{8}Be* composed of 4 neutrons and 4 protons
- Resonant production via $p + {}^{7}Li \rightarrow {}^{8}Be^{*}$
- Large production rate → high statistics
- Excited states decay to ground state with large transition energies (~ 20 MeV)

^{8}Be* - Decay



- Hadronic:
  Br(^{8}Be* → p +^{7}Li) ~ 100%

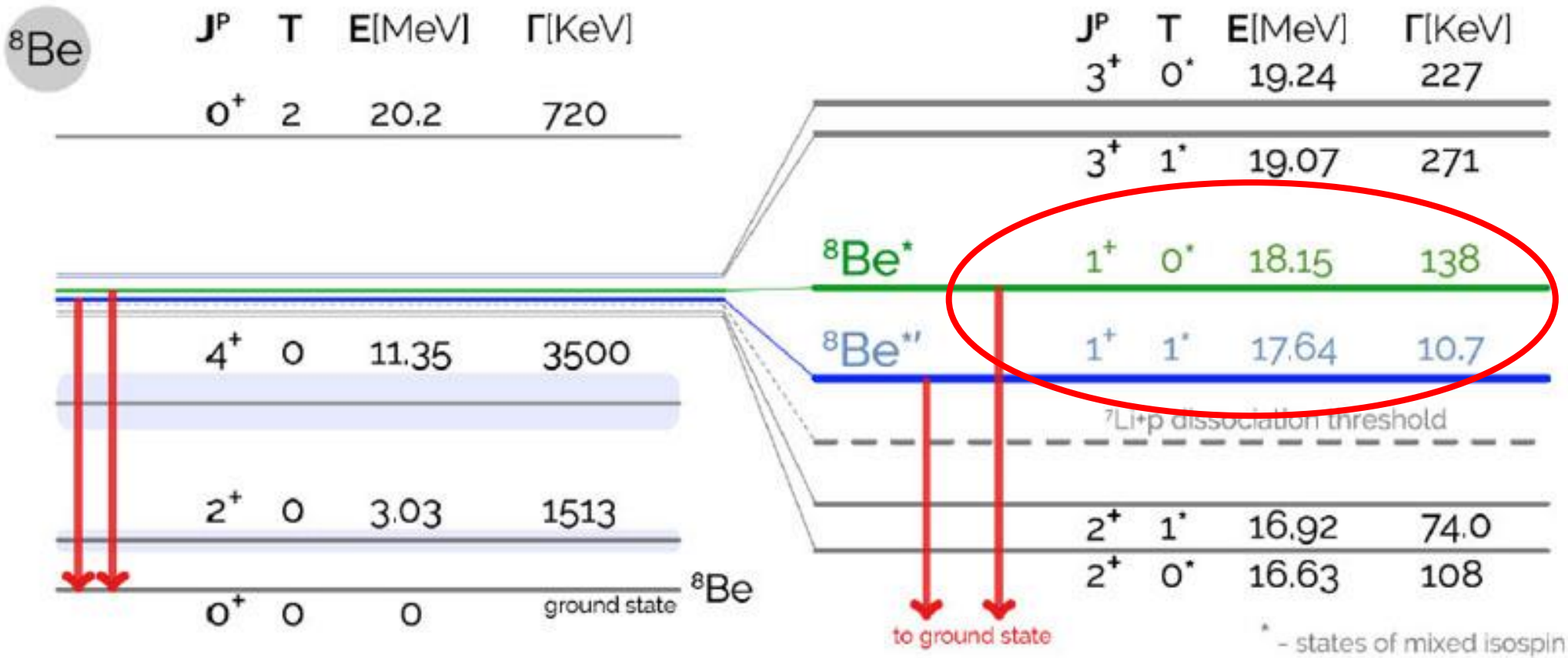
- Electromagnetic:
  Br(^{8}Be* → γ + ^{8}Be) ~ 1.5 x 10^{-5}



- Internal Pair Creation:
  Br(^{8}Be* → e^+e^- + ^{8}Be) ~ 5.5 x 10^{-8}

(J. Feng)

^{8}Be* - Decay Scheme

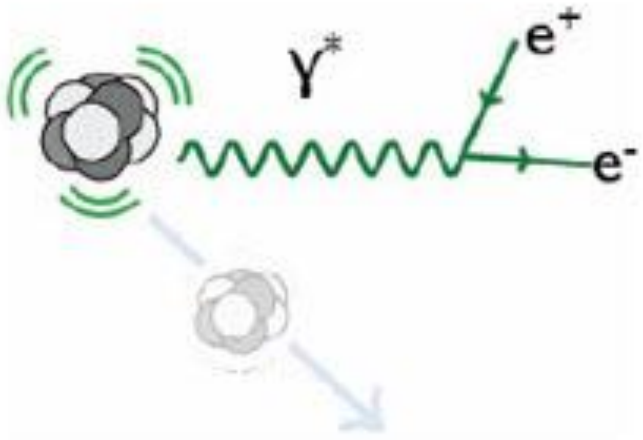


States of interest!

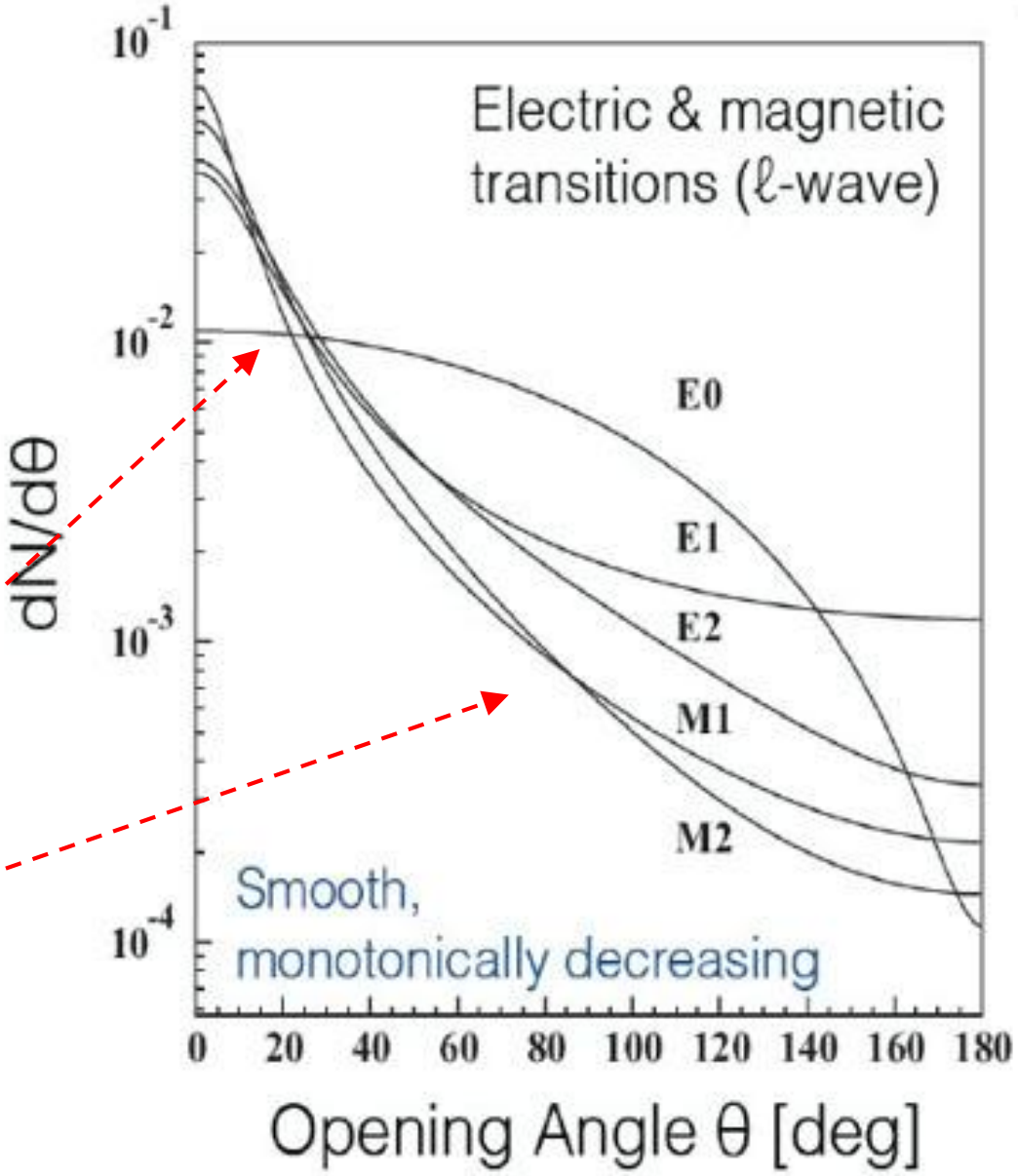
1609.07411; based on Tilley et al. (2004); National Nuclear Data Center, http://www.nndc.bnl.gov/nudat2/

(J. Feng)

$^{8}Be^{*}$ - Decay and Internal Pair Creation (IPC)

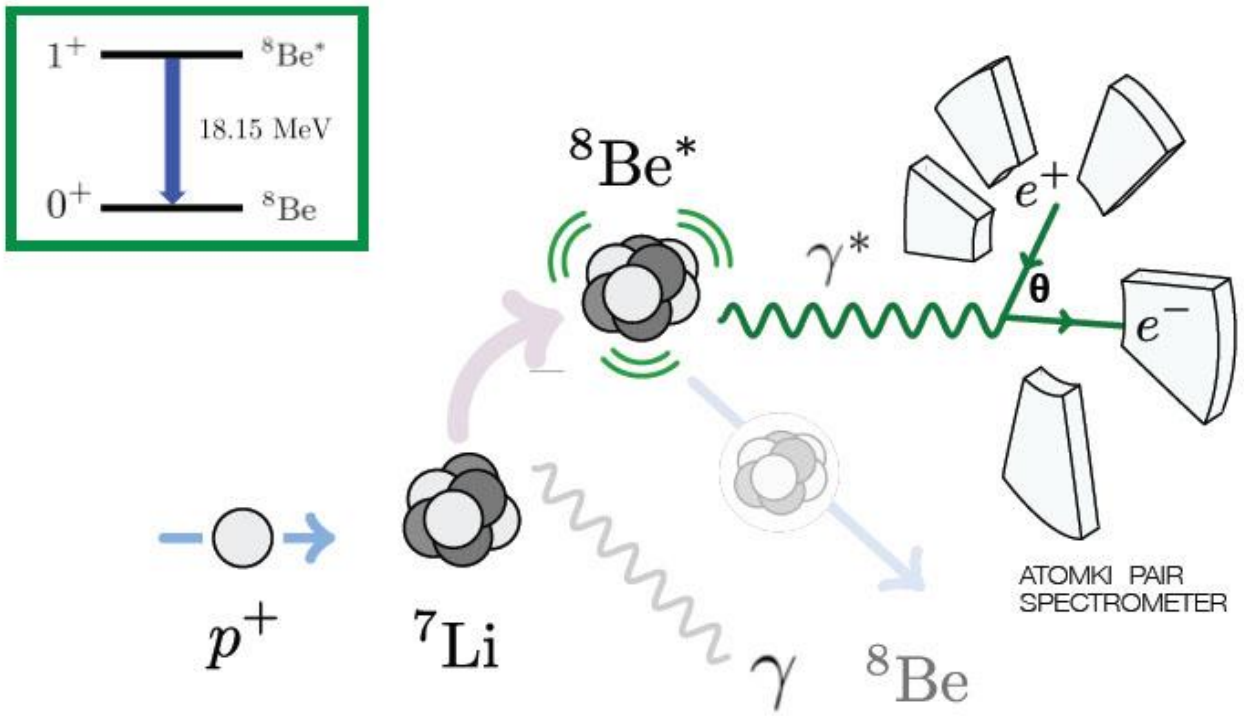


- Branching ratio: B ($^{8}Be \rightarrow e^{+}e^{-}$) ≈ 5.5 x 10^{-8}
- dN/dθ peaked at small opening angles
- dN/dθ decreases steadily with increasing θ



Gulyas et al.; http://arxiv.org/abs/1504.00489v1

The ATOMKI ^{8}Be - Experiment



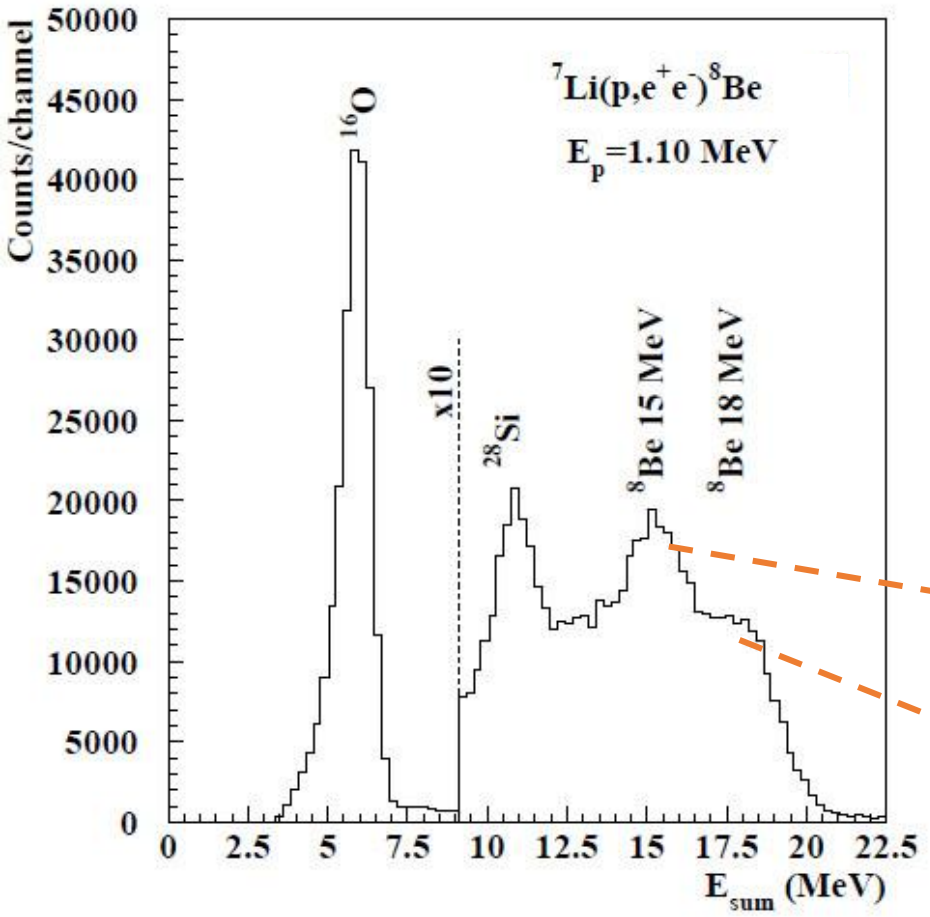
(J. Feng)

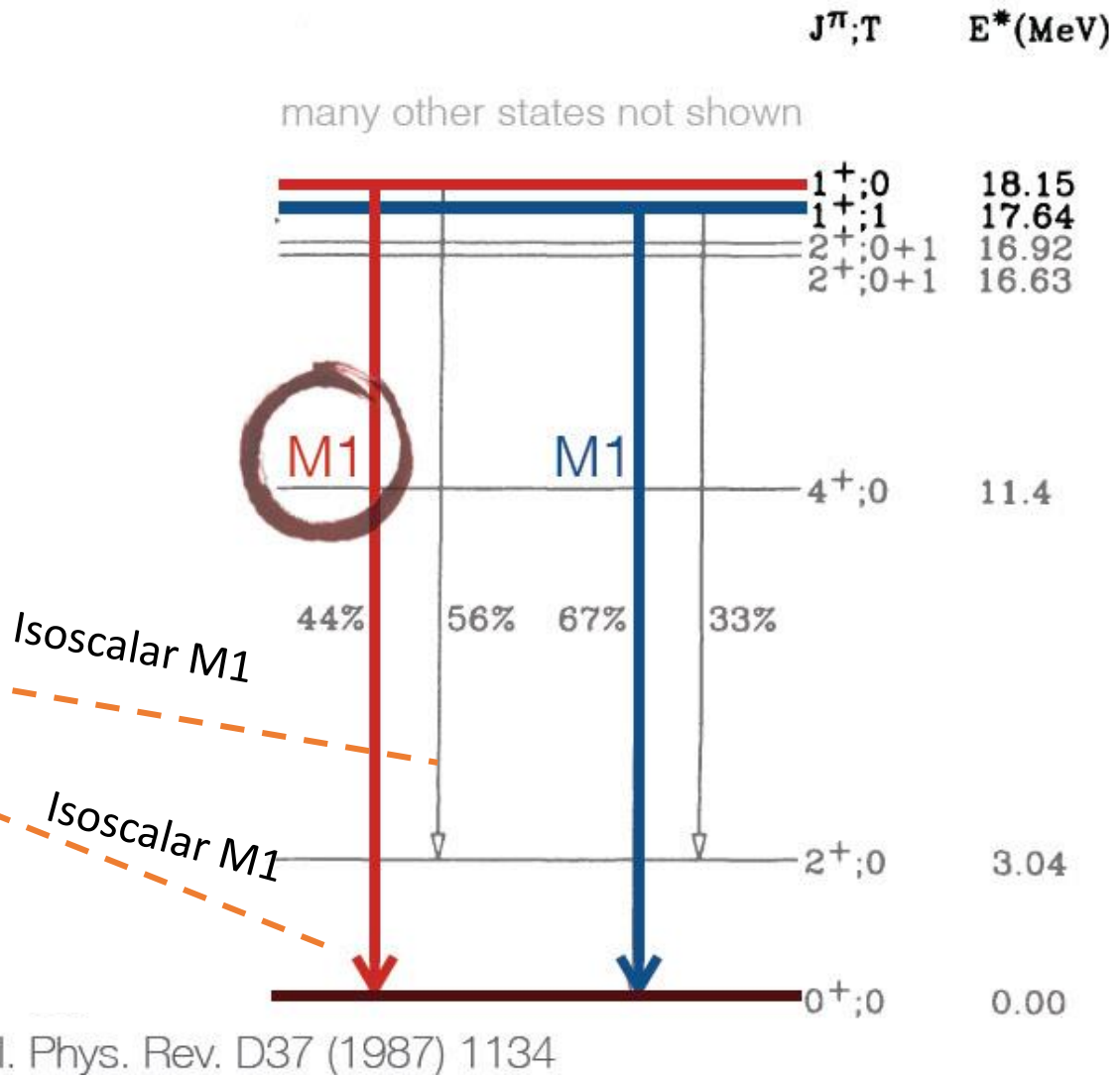
- Excited states of ^{8}Be produced through p +^{7}Li - reaction with high statistics
- Beam energy around 1 MeV adjusted to select various resonances
- Beam current ≈ 1μ A; ΔE ≈ 10 keV
- Measure angular distribution of e^+e^- pairs

Perfect environment to search for new MeV-scale physics!

A. J. Krasznahorkay et al.; *Phys. Rev. Lett.* **116** no. 4, (2016) 042501, arXiv:1504.01527 [nucl-ex].

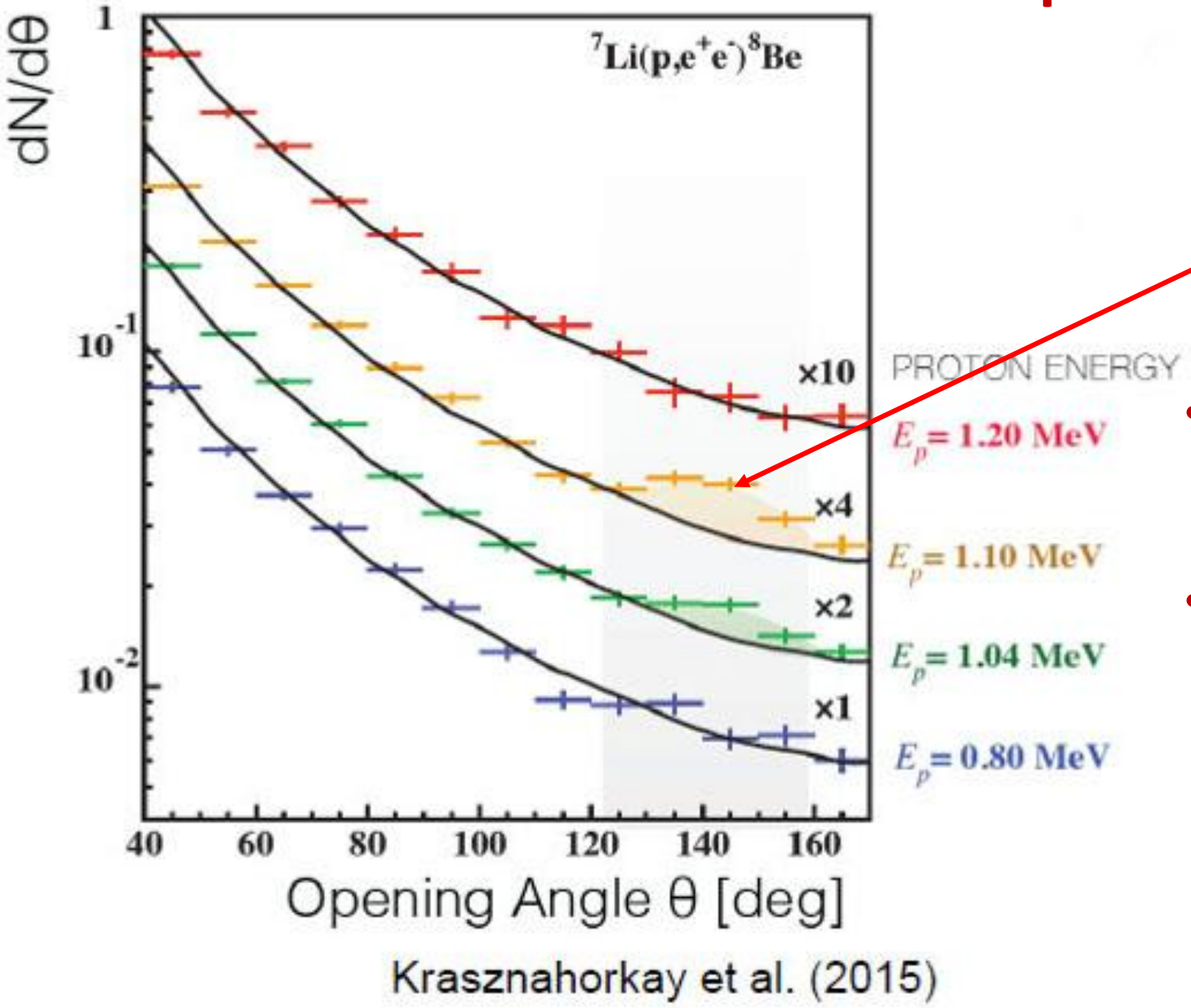
The ATOMKI ^{8}Be - Experiment





A. J. Krasznahorkay et al.; *Phys. Rev. Lett.* **116** no. 4, (2016) 042501, arXiv:1504.01527 [nucl-ex].

The ATOMKI ^{8}Be - Experiment

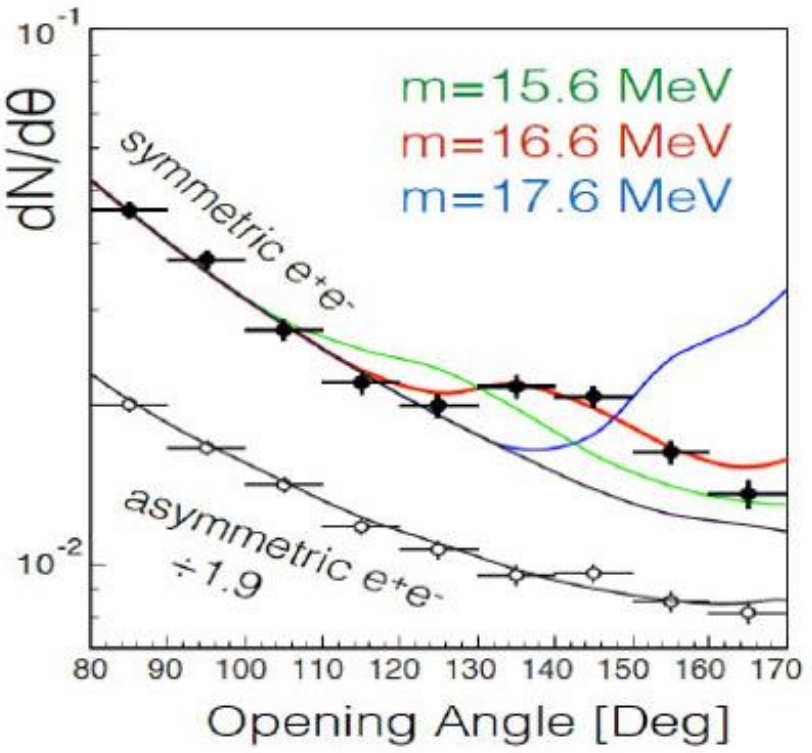


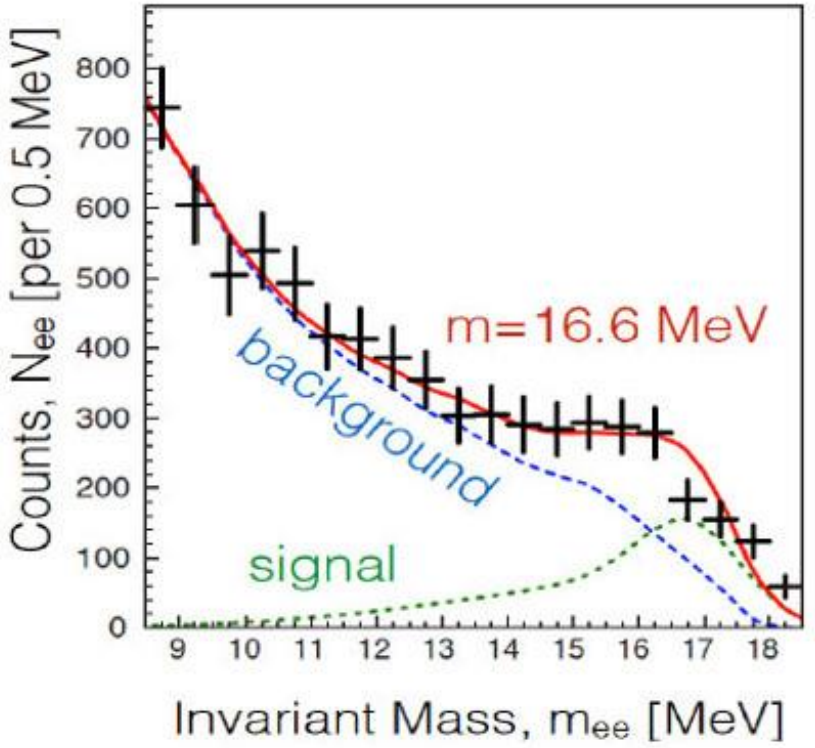
The Anomaly!

- Excess around θ = 140° passing through 18 MeV ^{8}Be*resonance
- Probability for backg. fluctuation: 5.6×10^{-12} (6.8σ)

A. J. Krasznahorkay et al.; *Phys. Rev. Lett.* **116** no. 4, (2016) 042501

The ATOMKI ^{8}Be - Experiment



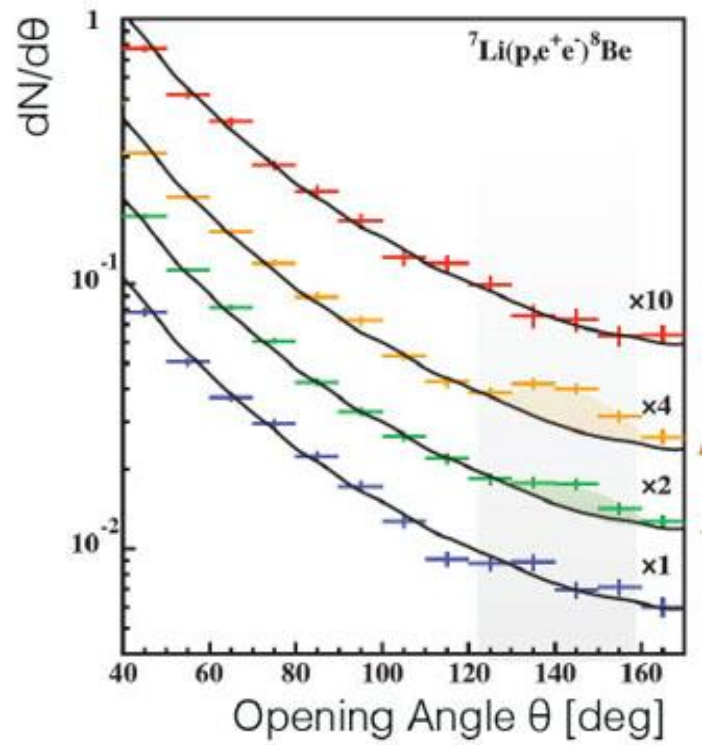


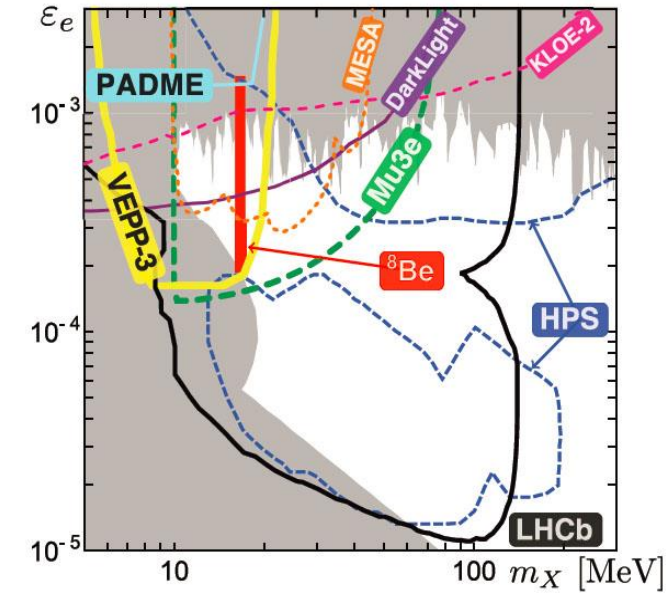
Krasznahorkay et al. (2015)

Opening angle and invariant mass consistent with decay of new particle!

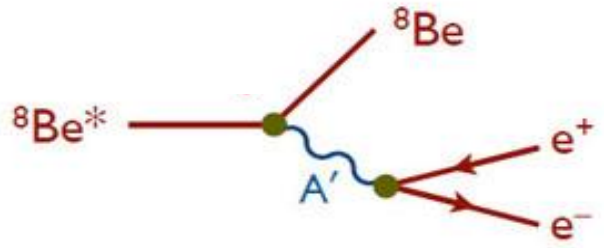
M_X = 16.7 ± 0.35 (stat) ± 0.5 (sys) MeV χ^2/dof = 1.07

Possible Physics Interpretations?

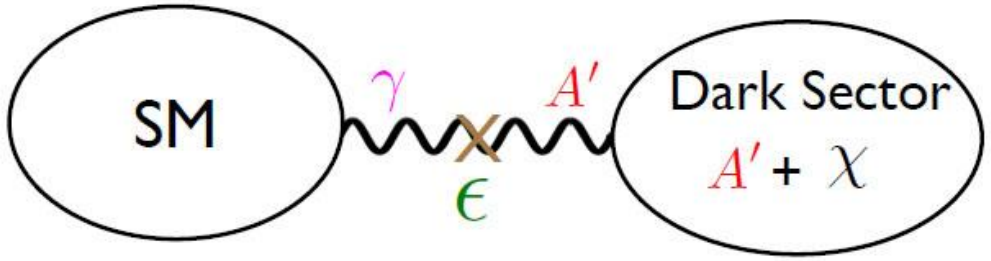




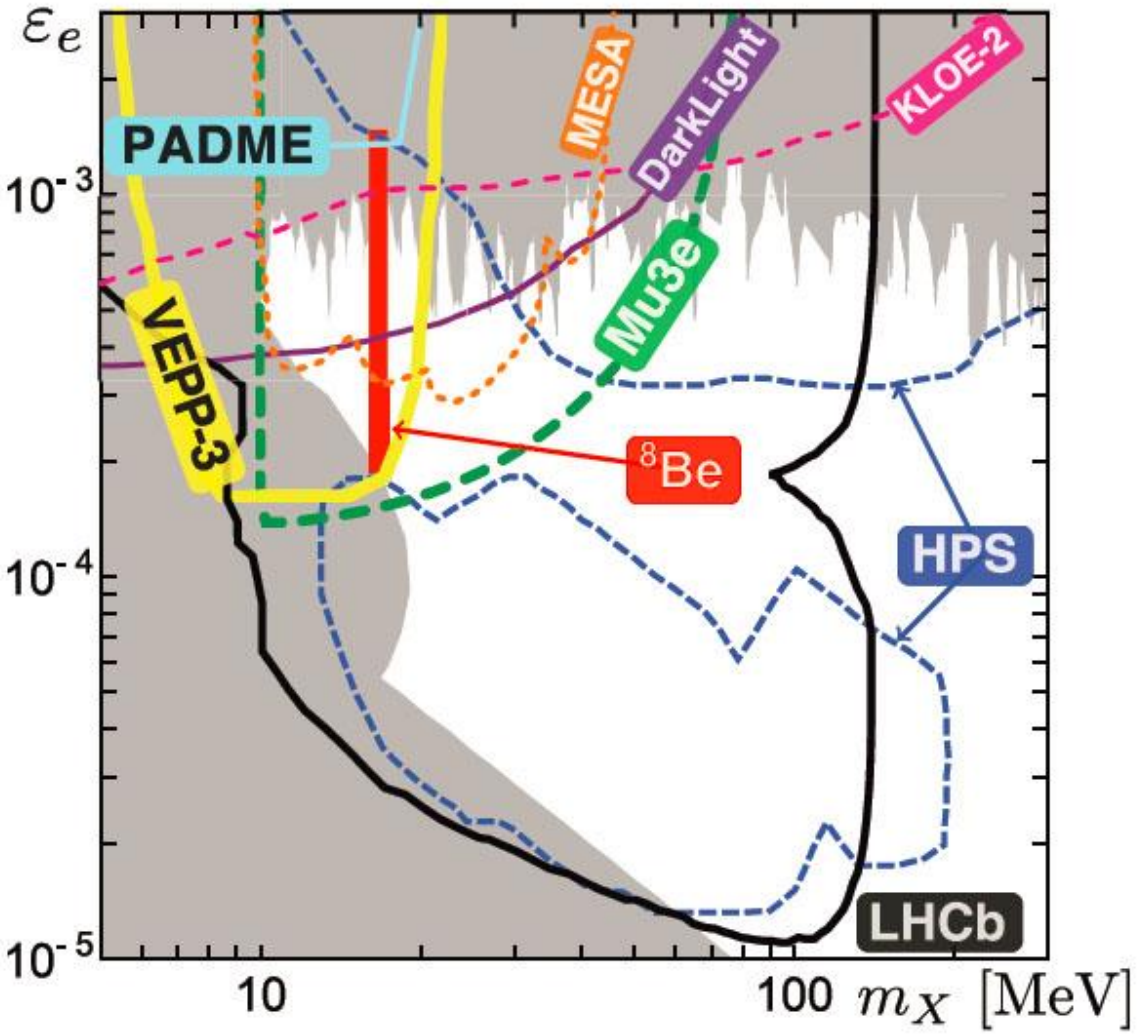
Maybe a Dark Photon *A'* ?



- Interaction with ord. matter mediated by "dark force" *A'*
- Gauge boson *A'* mixes kinetically with γ and $\varepsilon \sim 10^{-3}$
- *A'* couples to SM – particles with prop. to ε and SM charges
- Region of special interest $m_{A'} \sim$ 1 – 100 MeV and $\varepsilon \sim 10^{-3}$ → $(g\text{-}2)_\mu$ anomaly
- Light vector mediator decays to low mass WIMPs



Comparison with Other Experiments



The ^{8}Be anomaly can be explained by a "protophobic" vector gauge boson with:

$$\varepsilon_u \approx \pm 3.7 \times 10^{-3}$$

$$\varepsilon_d \approx \mp 7.4 \times 10^{-3}$$

$$2 \times 10^{-4} \leq |\varepsilon_e| \leq 10^{-3}$$

$$\sqrt{\varepsilon_e \varepsilon_\nu} \leq 7 \times 10^{-5}$$

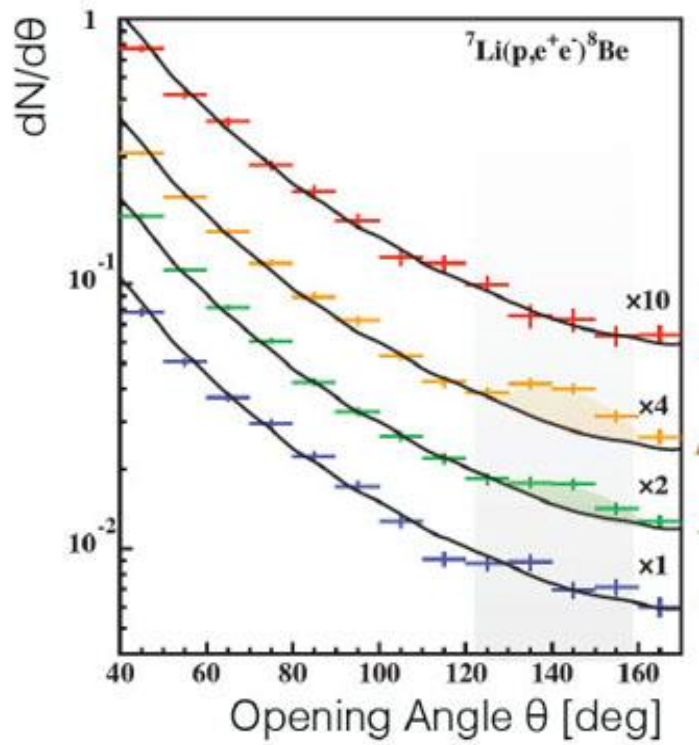
J. L. Feng, *Phys. Rev.* **D95** no. 3, (2017) 035017, arXiv:1608.03591 [hep-ph].

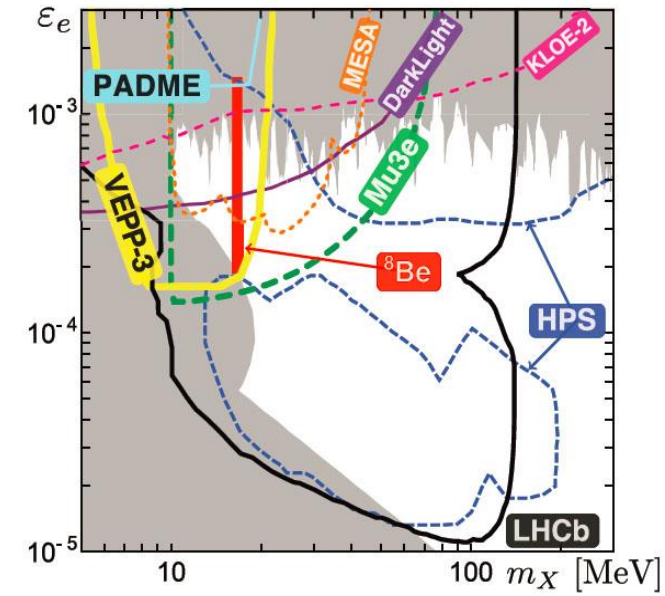
Checking the ^{8}Be Anomaly

U. Montreal - CTU Prague

Aim of Project:

- Confirm/refute ATOMKI result
- Needs rapid follow – up
- Use existing equipment (low cost)
- Improve angular & energy resolution ?
- Extend to other excited states (16.6/16.9 MeV)
- Extend to other nuclei: ^{10}B, ^{10}Be… ?

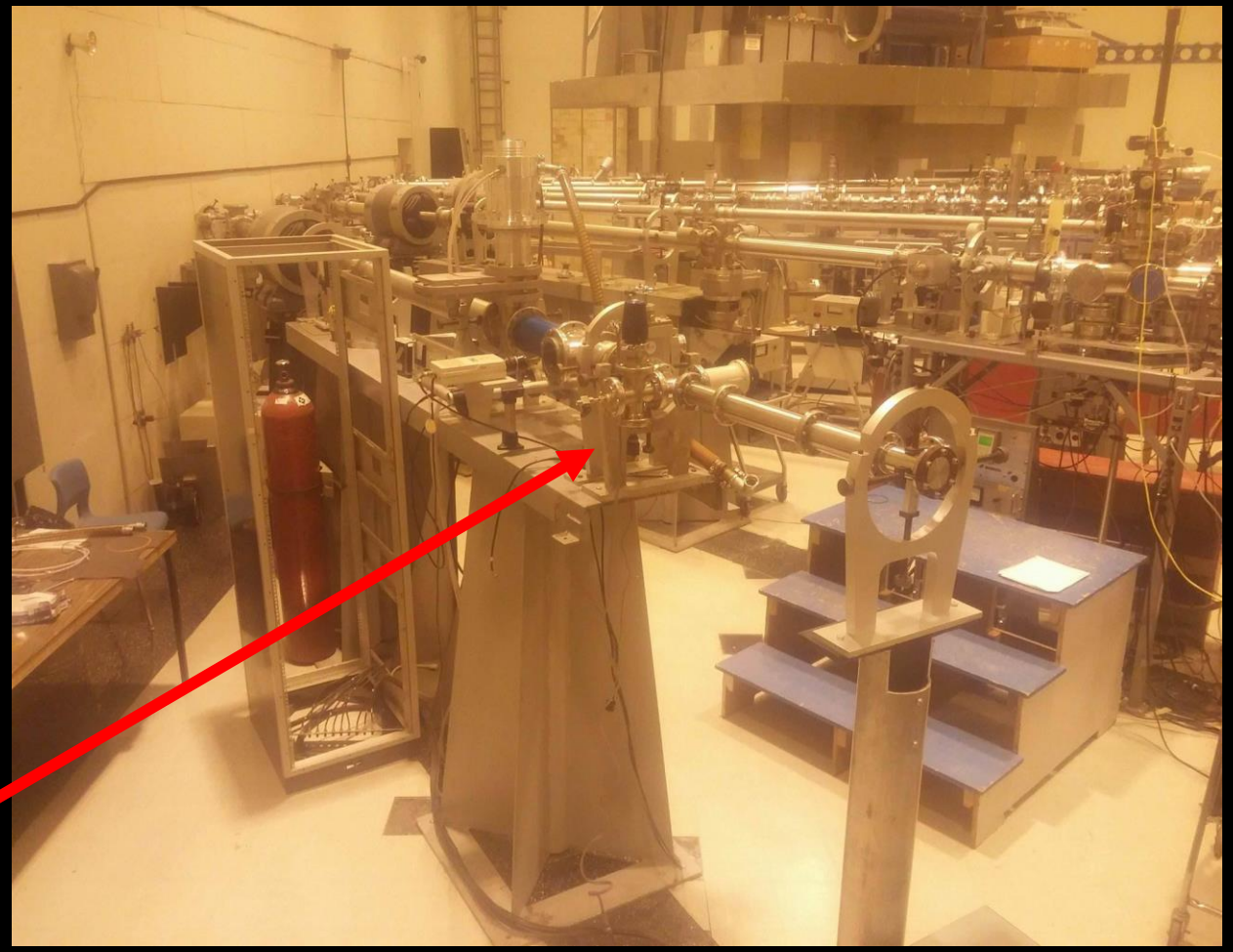




Checking the ^{8}Be Anomaly

(UdeM/CTU-Prague)

Montréal UdeM
6 MeV Tandem
Van de
Graaff Facility



E - resolution ok for
$E_p > 1$ MeV

Dedicated Beam Line
for ^{8}Be – project ready

Prague CTU
1 MeV Van de
Graaff Facility

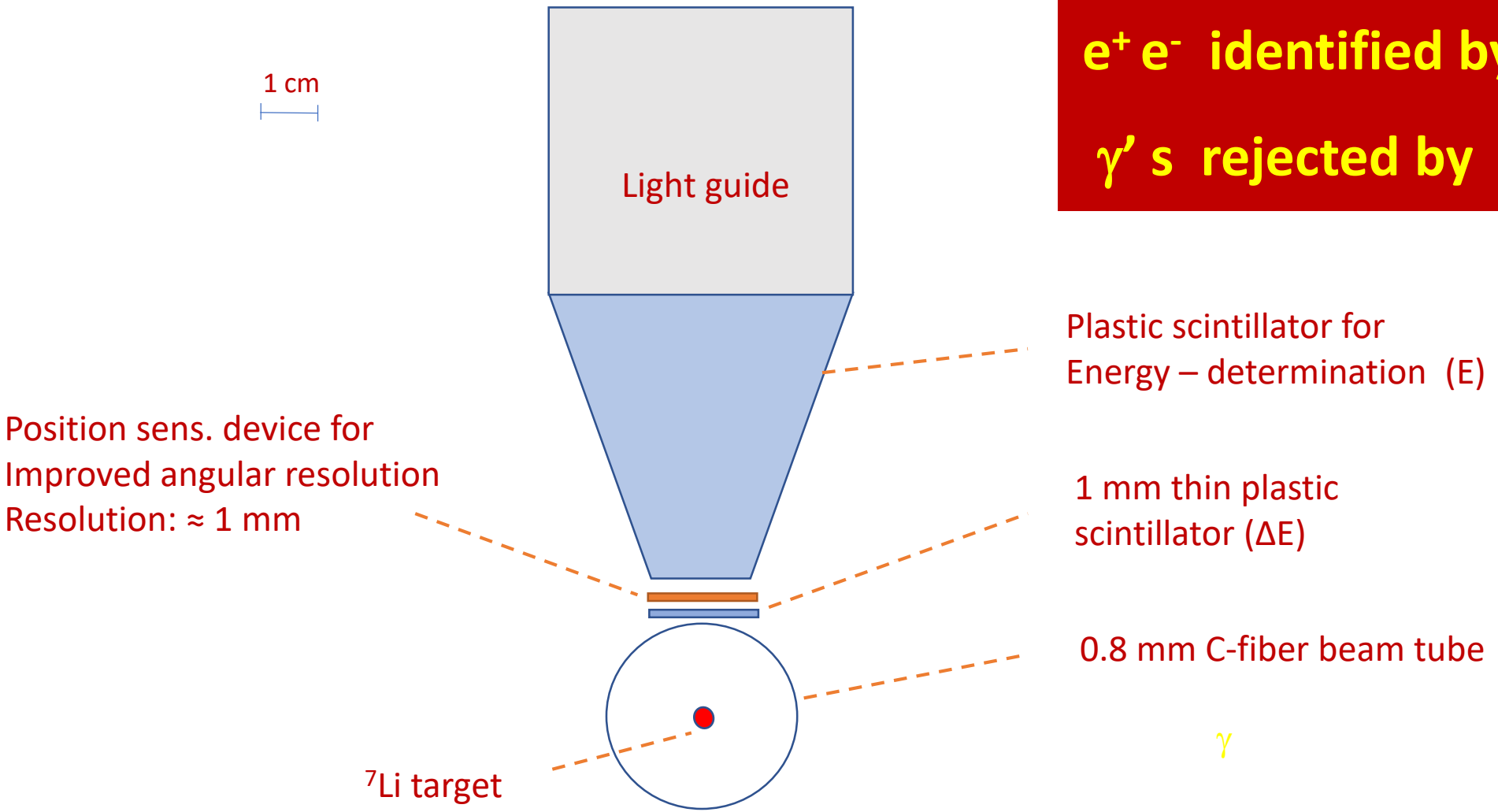
Interesting for lower
proton energies :
$0.4 < E_p < 1$ MeV

Checking the ^{8}Be Anomaly

(UdeM/CTU-Prague)

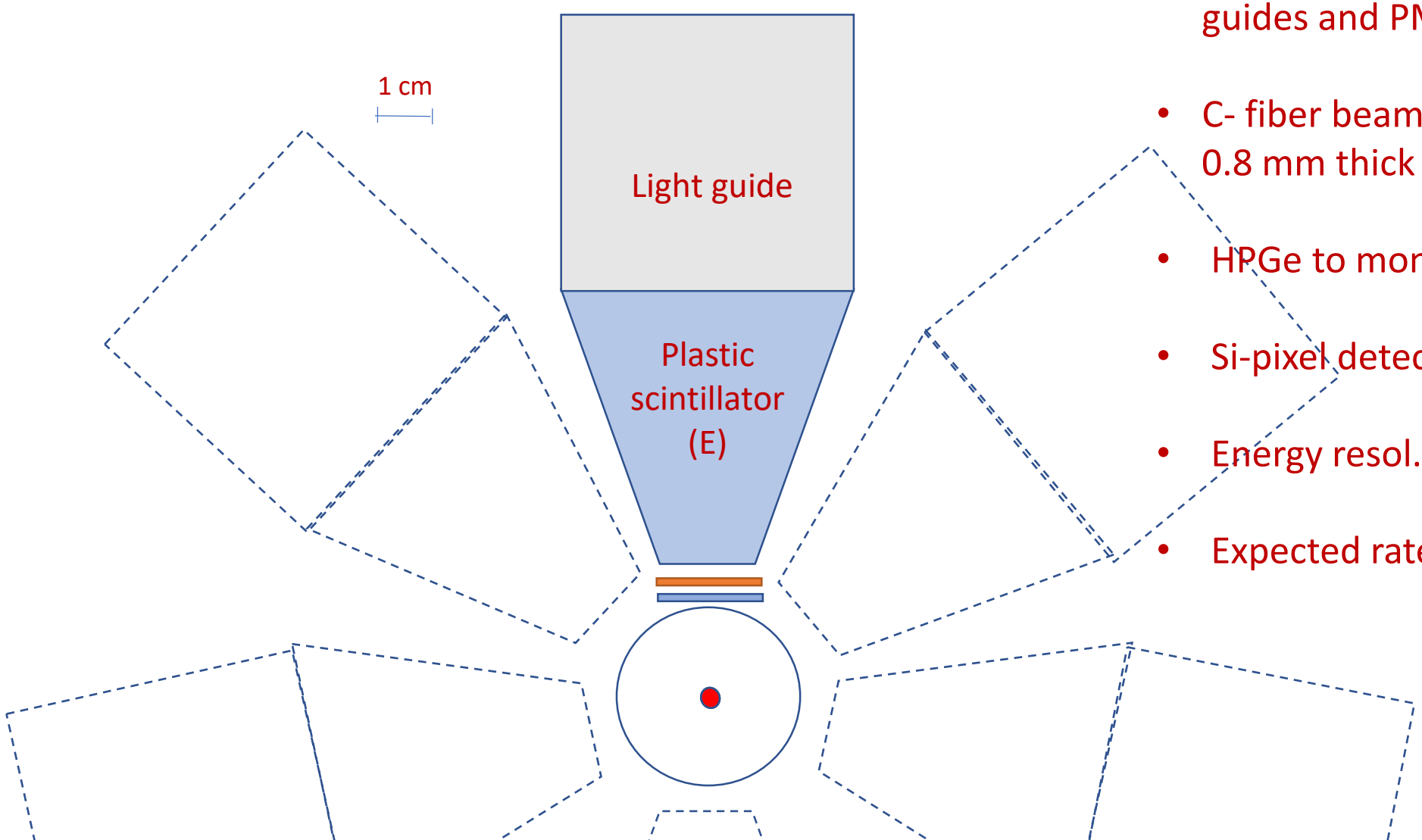
$e^+ e^-$ identified by $E \wedge \Delta E$

γ' s rejected by $E \wedge \overline{\Delta E}$



Checking the ^{8}Be Anomaly

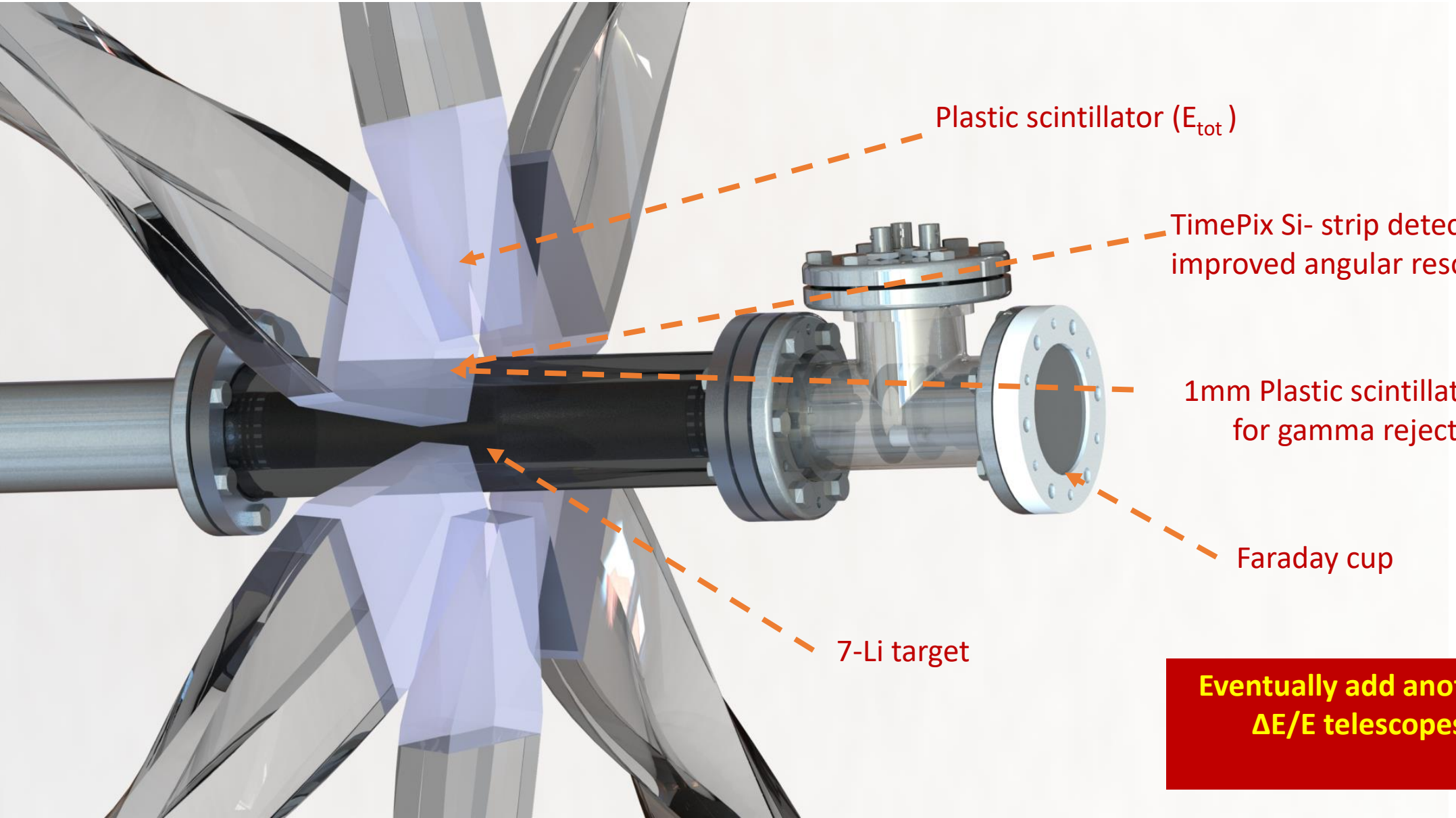
(UdeM/CTU-Prague)



- E & ΔE plastic scintillators w. light guides and PM's …at hand (12x)
- C- fiber beam tubes (x2) 0.8 mm thick …ready
- HPGe to monitor luminosity
- Si-pixel detector for tracking
- Energy resol. : ≈ 300 keV @ 18MeV
- Expected rate: ≈1kHz/6 det. (1μA)

Checking the ^{8}Be Anomaly

(UdeM/CTU)

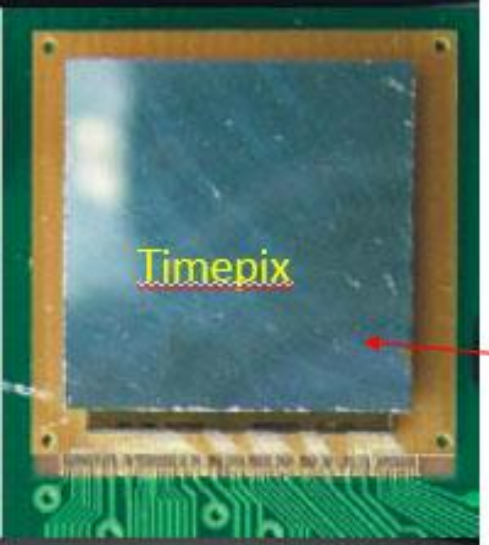


Eventually add another 6 ΔE/E telescopes?

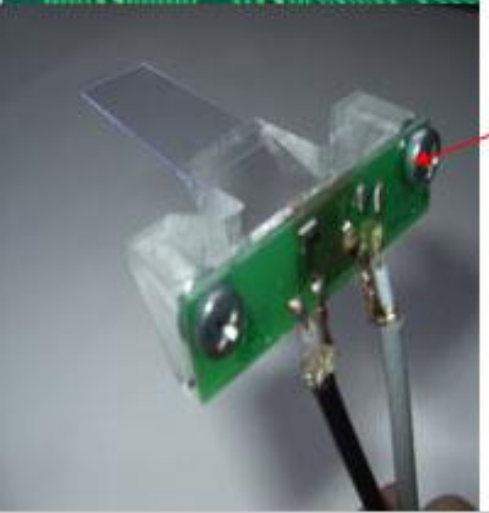
Testing the Telescopes

(CTU-Prague)

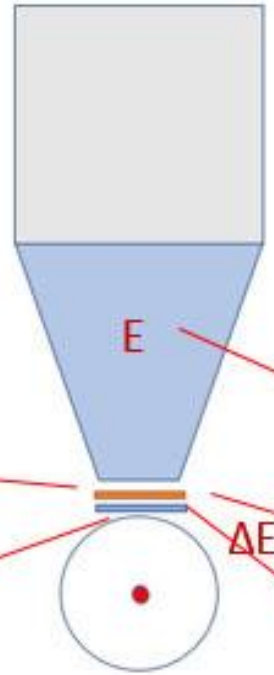
Electron hits
in coincidence
with E ∧ ΔE

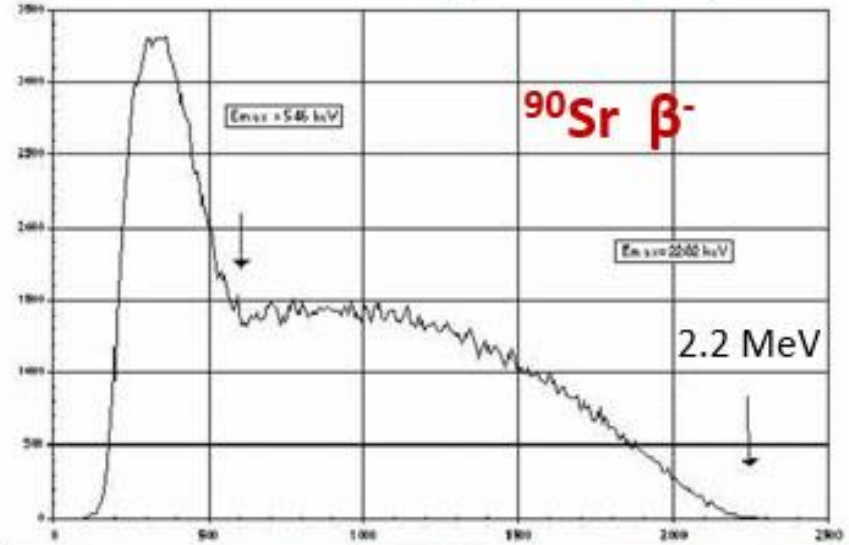


Si pixel detector
1.4 x 1.4 cm
pixel: 50 x 50 um



ΔE - counter
plastic scint.
1 mm
APD readout

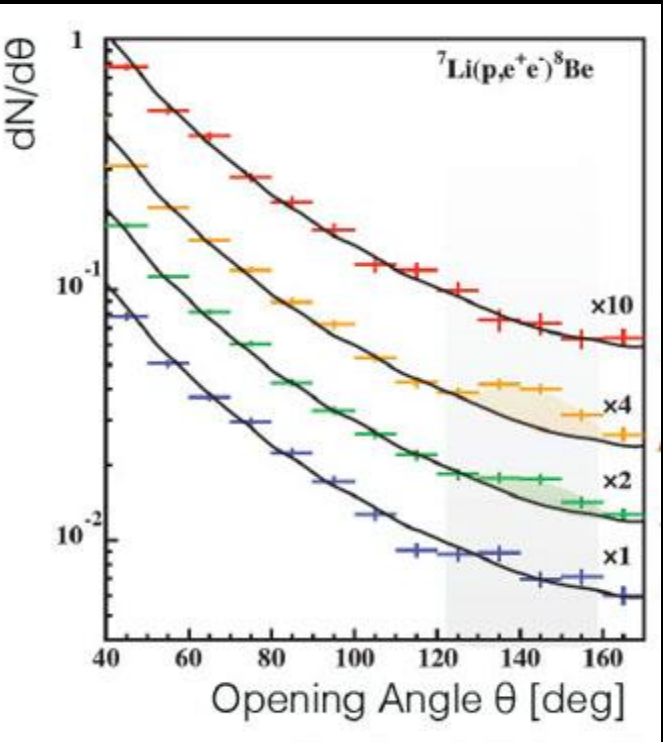


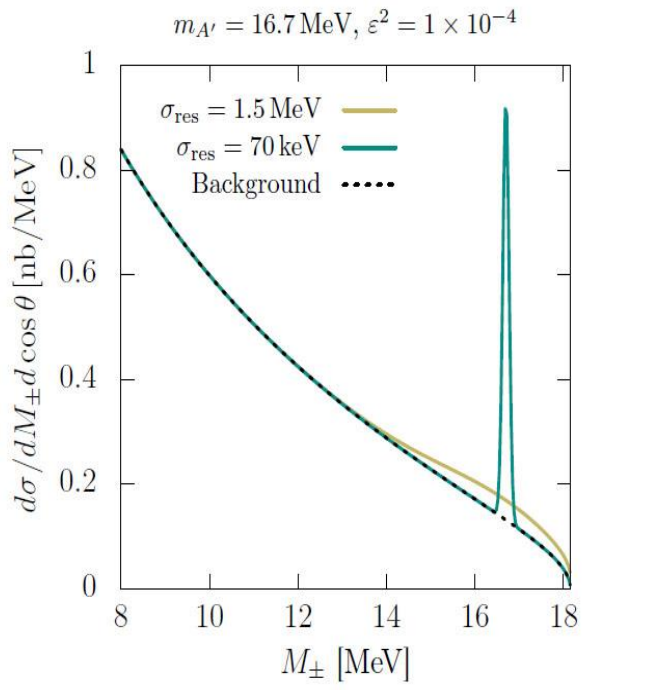


Triple x coïncidence E ∧ ΔE ∧SiPix

Conclusions

- Intriguing results by Atomki collaboration in Be*
- Evidence for a light new 17 MeV proto-phobic boson?
- UdeM – CTU Prague experiment for rapid verification
- Extend to other states & nuclei: ^{10}Be(17.8), ^{10}B(17.8), ^{10}B(19.3)… ?
- Later improved search wit HPGe detectors ? (res. 70 keV)
- Nucl. transition experiments can compete with upcoming collider & fixed target searches (SHiP, SeaQuest, LHCb, Mu3R)





^{8}Be - Anomaly - Bibliography

Experiment:

A. J. Krasznahorkay et al. *Phys. Rev. Lett.* **116** no. 4, (2016) 042501, arXiv:1504.01527 [nucl-ex].

J. Gulyas et al.; http://arxiv.org/abs/1504.00489v1

Theory:

J. L. Feng et al., *Phys. Rev. Lett.* **117** no. 7, (2016) 071803, arXiv:1604.07411 [hep-ph].

J. L. Feng et al., *Phys. Rev.* **D95** no. 3, (2017) 035017, arXiv:1608.03591 [hep-ph].

J. Kozacuk; arxiv: 1708.06349 [hep-ph].