(Un)expected Frontiers of Fundamental Physics

¿X17?

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TU Vienna

based on arxiv.org/abs/2003.05722

String group meeting TU Vienna
09.11.2020

Outline

- Expected and unexpected frontiers
- X17 anomaly: Observation and interpretation
- Idea: Hard $\gamma + \gamma$ process
- Conclusion

- Expected and unexpected frontiers

From a phenomenological perspective …

Lagrangian

- Expected and unexpected frontiers

unknown sector

$$S = \int_{-T}^{T} dt \int_{-L}^{L} d^3x \left\{ \left[(\partial_\mu \phi)(\partial^\mu \phi) - m^2 \phi^2 \right] + \phi \cdot g \cdot \psi \quad + \left[(\partial_\mu \psi)(\partial^\mu \psi) - M^2 \psi^2 \right] \right\}$$

$$+ \int_{Bound,L,T} (\phi \partial^\mu \phi)$$

known sector

For large M:
"high energy frontier"

"high energy frontier"

Search strategy

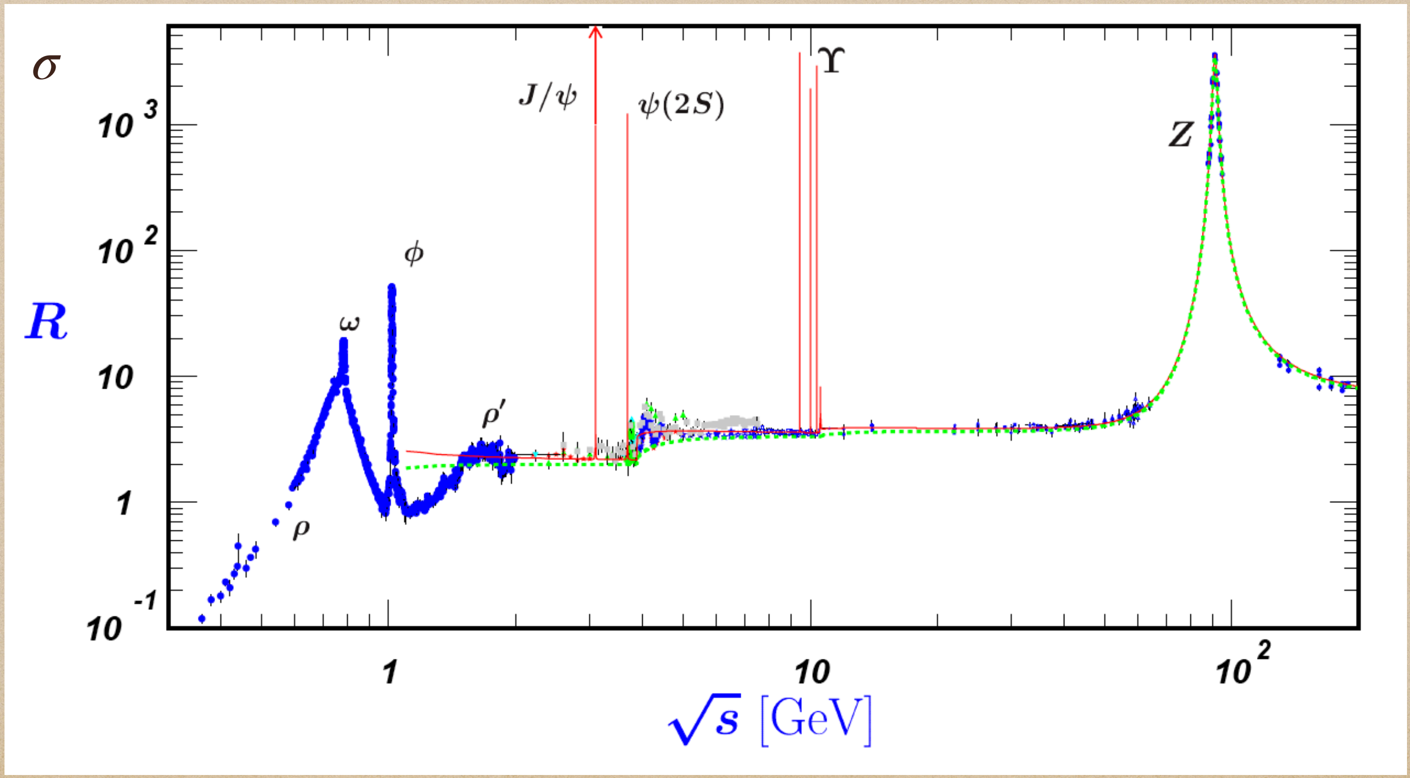
$$\frac{1}{\Delta x} \sim E \geq M$$

Increase energy find new things

Long lasting sucess story

“high energy frontier”

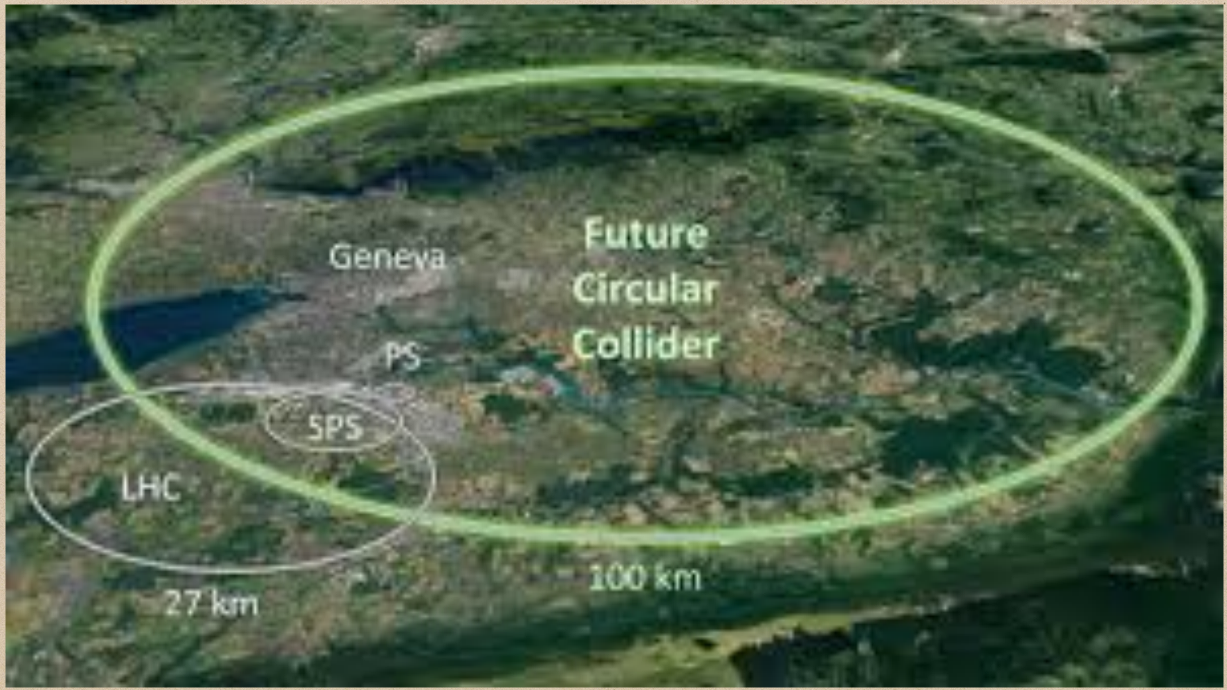
Long lasting sucess story



…

“high energy frontier”

Future:



… ?

- Expected and unexpected frontiers

unknown sector

$$S = \int_{-T}^{T} dt \int_{-L}^{L} d^3x \left\{ \left[(\partial_\mu \phi)(\partial^\mu \phi) - m^2 \phi^2 \right] \; + \phi \cdot g \cdot \psi \quad + \left[(\partial_\mu \psi)(\partial^\mu \psi) - M^2 \psi^2 \right] \right\}$$

$$+ \int_{Bound,L,T} (\phi \partial^\mu \phi)$$

known sector

For small M:

"small coupling frontier"

“small coupling frontier”

Search strategies

- High precision
- Large statistics
- Resonant effects
- Accumalative effects
- Low background (null experiments)
- …

“small coupling frontier”

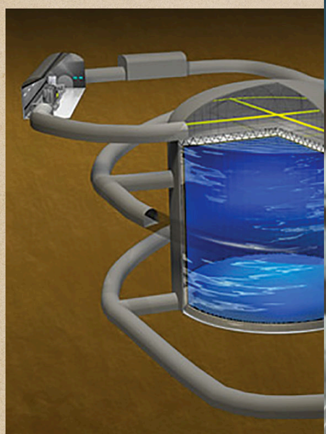
Prominent success

Neutrino oscillation

Graviational wave detection

“small coupling frontier”

Future



Neutrinos, graviational waves, dark matter,
multi-messanger

- Expected and unexpected frontiers

$$S = \int_{-T}^{T} dt \int_{-L}^{L} d^3x \left\{ \left[(\partial_\mu \phi)(\partial^\mu \phi) - m^2 \phi^2 \right] \qquad + \int_{Bound,L,T} (\phi \partial^\mu \phi) \right.$$

known sector

“Boundary frontier”

“Boundary frontier”

Strategy:

Use dualities like AdS/CFT to study
“theories in complicated regime (stongly coupled)
in terms of
other theories in simple limit (weakly coupled)

“Boundary frontier”

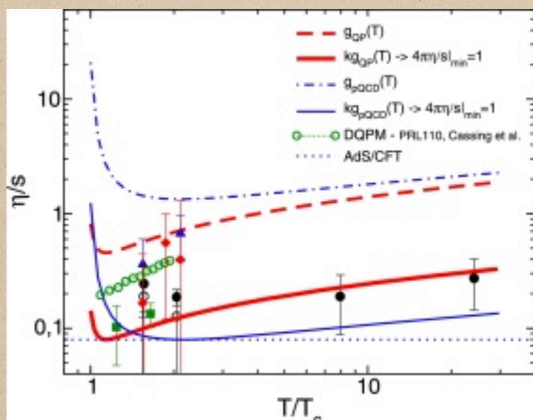
success:

The Large N limit of superconformal field theories and supergravity #1

Juan Martin Maldacena (Harvard U.) (Nov 28, 1997)

Published in: *Int.J.Theor.Phys.* 38 (1999) 1113-1133, *Adv.Theor.Math.Phys.* 2 (1998) 231-252 •
e-Print: hep-th/9711200 [hep-th]

pdf   DOI   cite   16,079 citations



AdS/QCD

AdS/CMT

Information theory

- Expected and unexpected frontiers

$$S = \int_{-T}^{T} dt \int_{-L}^{L} d^3x \left\{ \left[(\partial_\mu \phi)(\partial^\mu \phi) - m^2\phi^2 \right] \quad + surprise \right.$$

known sector

"unexptected Experimental evidence frontier"

“unexptected Experimental evidence frontier”

Strategy:

Be sceptical, but open for surprises

Sherlock Holmes

“How often have I said to you that when you have eliminated the impossible, whatever remains, however improbable, must be the truth?”

“unexptected Experimental evidence frontier”

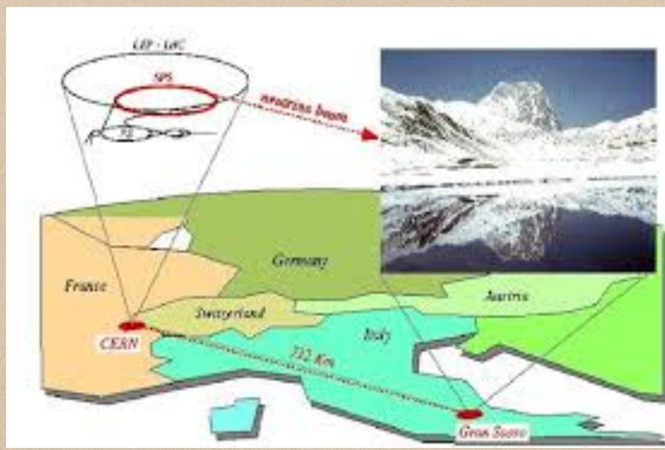
Prominent success

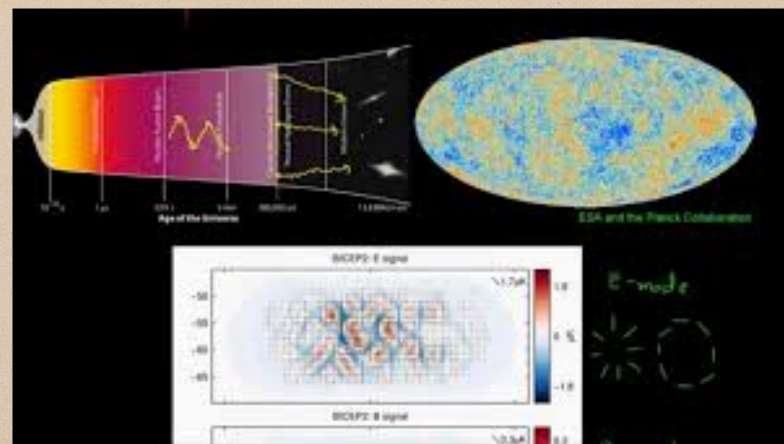
Röntgen: röntgen

Penzias, Wilson: CMB

“unexptected Experimental evidence frontier”

Prominent failure





Opera:
Superluminal neutrinos = loose cable

Bicep2: gravitational waves = dust

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- X17 anomaly: Observation and interpretation:
- Idea: Hard $\gamma + \gamma$ process
- Conclusion

- X17 anomaly: Observation and interpretation:

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

A.J. Krasznahorkay,* M. Csatlós, L. Csige, Z. Gácsi, J. Gulyás, M. Hunyadi,
I. Kuti, B.M. Nyakó, L. Stuhl, J. Timár, T.G. Tornyi, and Zs. Vajta
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CERN, Geneva, Switzerland and
Institute for Nuclear Research, Hungarian Academy of Sciences (MTA Atomki), P.O. Box 51, H-4001 Debrecen, Hungary

ex] 7 Apr 2015

Electron-positron angular correlations were measured for the *isovector magnetic dipole* 17.6 MeV state ($J^\pi = 1^+$, $T = 1$) $\rightarrow$ ground state ($J^\pi = 0^+$, $T = 0$) and the *isoscalar magnetic dipole* 18.15 MeV ($J^\pi = 1^+$, $T = 0$) state $\rightarrow$ ground state transitions in ^{8}Be. Significant deviation from 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 might indicate that, in an intermediate step, a neutral isoscalar particle with a mass of 16.70±0.35 (stat)±0.5 (sys) MeV/c^2 and $J^\pi = 1^+$ was created.

PACS numbers: 23.20.Ra, 23.20.En, 14.70.Pw

New evidence supporting the existence of the hypothetic X17 particle

A.J. Krasznahorkay,* M. Csatlós, L. Csige, J. Gulyás, M. Koszta, B. Szihalmi, and J. Timár
Institute of Nuclear Research (Atomki), P.O. Box 51, H-4001 Debrecen, Hungary

D.S. Firak, Á. Nagy, and N.J. Sas
University of Debrecen, 4010 Debrecen, PO Box 105, Hungary

A. Krasznahorkay
CERN, Geneva, Switzerland and
Institute of Nuclear Research, (Atomki), P.O. Box 51, H-4001 Debrecen, Hungary

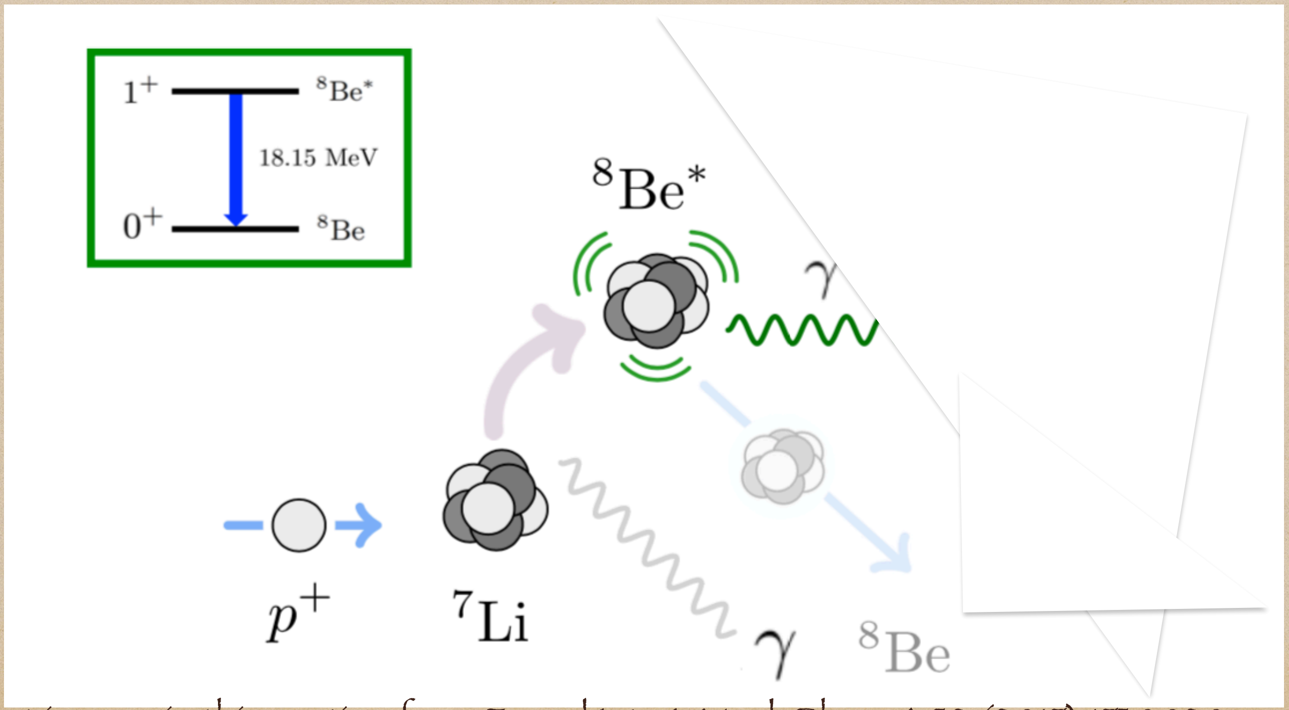
23 Oct 2019

We observed electron-positron pairs from the electro-magnetically forbidden M0 transition depopulating the 21.01 MeV 0^- state in ^{4}He. A peak was observed in their e^+e^- angular correlations at 115° with 7.2σ significance, and could be described by assuming the creation and subsequent decay of a light particle with mass of $m_X c^2$=16.84±0.16($stat$) ± 0.20($syst$) MeV and Γ_X= 3.9 × 10^{-5} eV. According to the mass, it is likely the same X17 particle, which we recently suggested [Phys. Rev. Lett. 116, 052501 (2016)] for describing the anomaly observed in ^{8}Be.

PACS numbers: 23.20.Ra, 23.20.En, 14.70.Pw

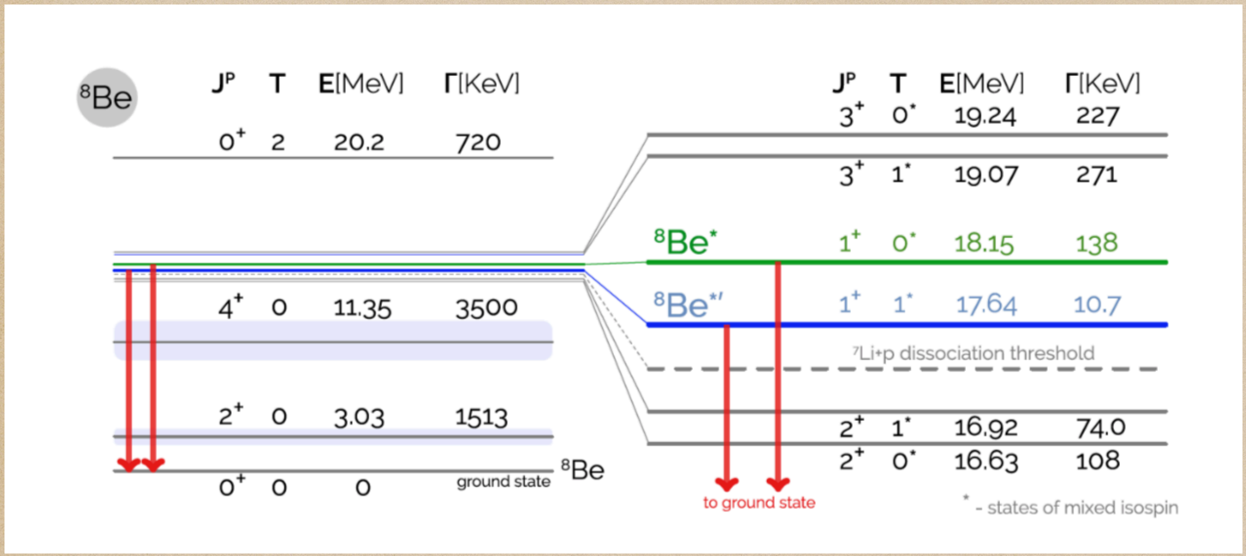
- X17 anomaly: Observation and interpretation:

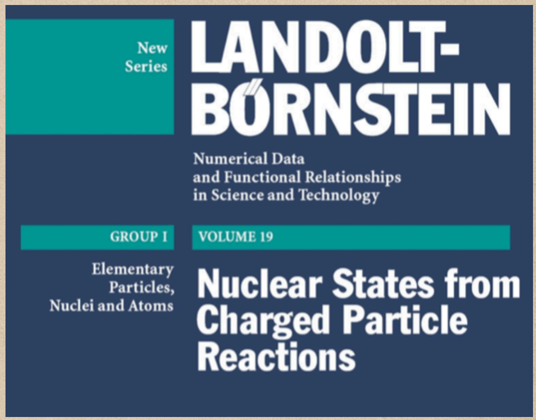
Collide $p + {}^7Li$, some processes go through excited ${}^8Be^*$



Most images in this section from Fornal Int. J. Mod. Phys. A 32 (2017) 1730020

- X17 anomaly: Observation and interpretation:



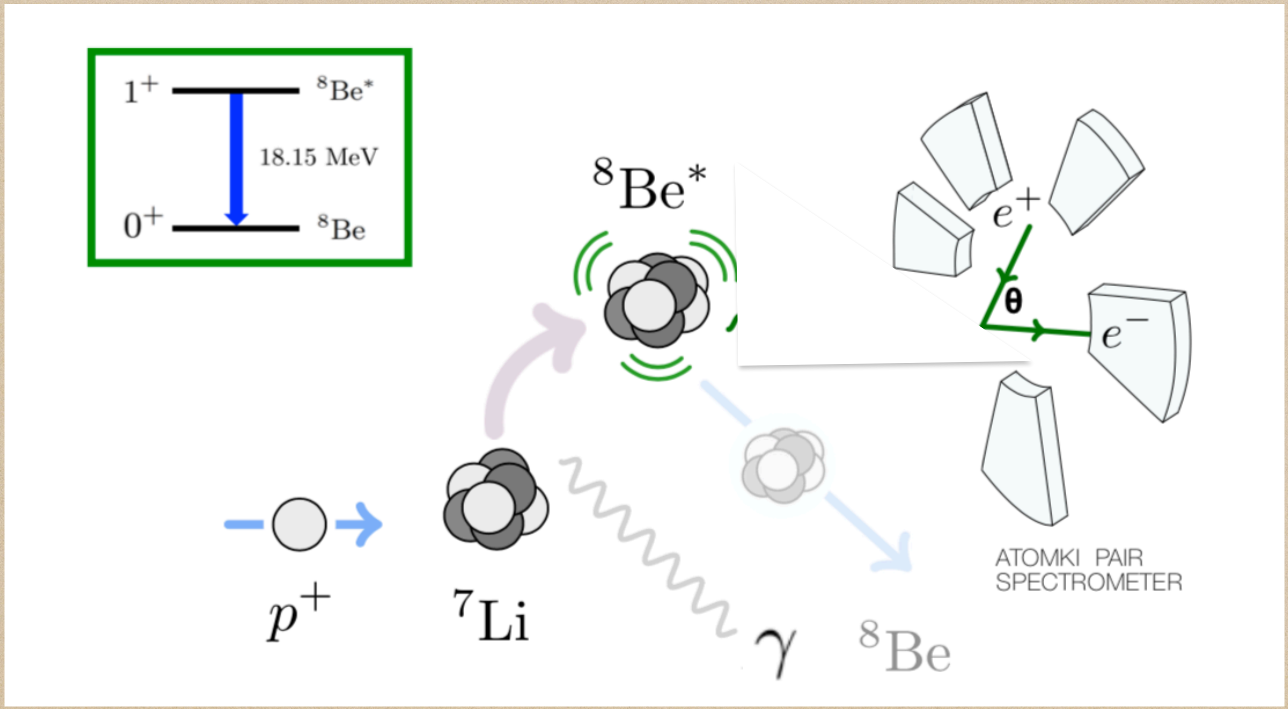


on 2741 pages

EM transition from nuclear spectroscpoy tables

- X17 anomaly: Observation and interpretation:

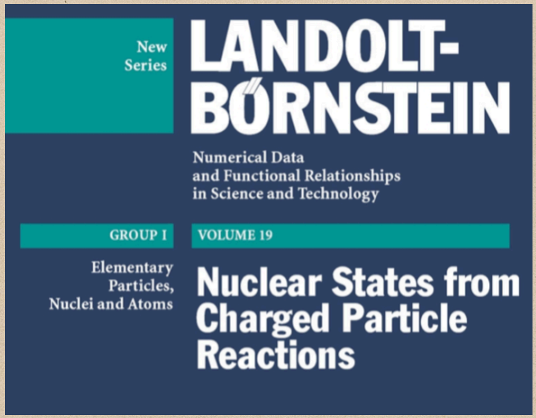
$$^{8}Be^{*} \to {}^{8}Be$$



Measured coincident charged lepton pairs

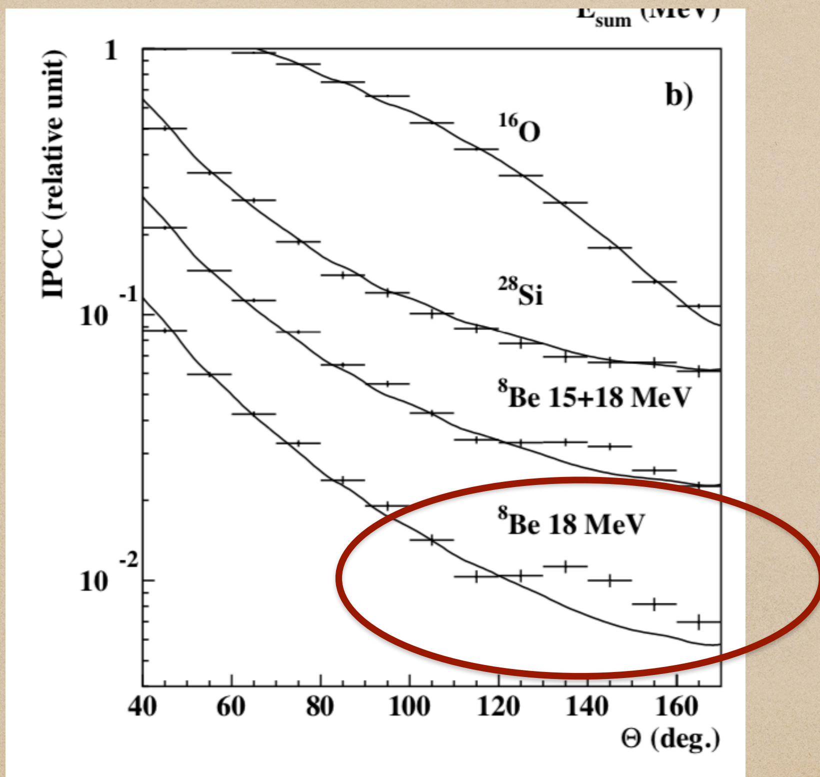
- X17 anomaly: Observation and interpretation:

all as planned: "2741 + 1 pages"



+*surprise*!

- X17 anomaly: Observation and interpretation:



unexpected bump at large e^+, e^- relative angles

homogenous background

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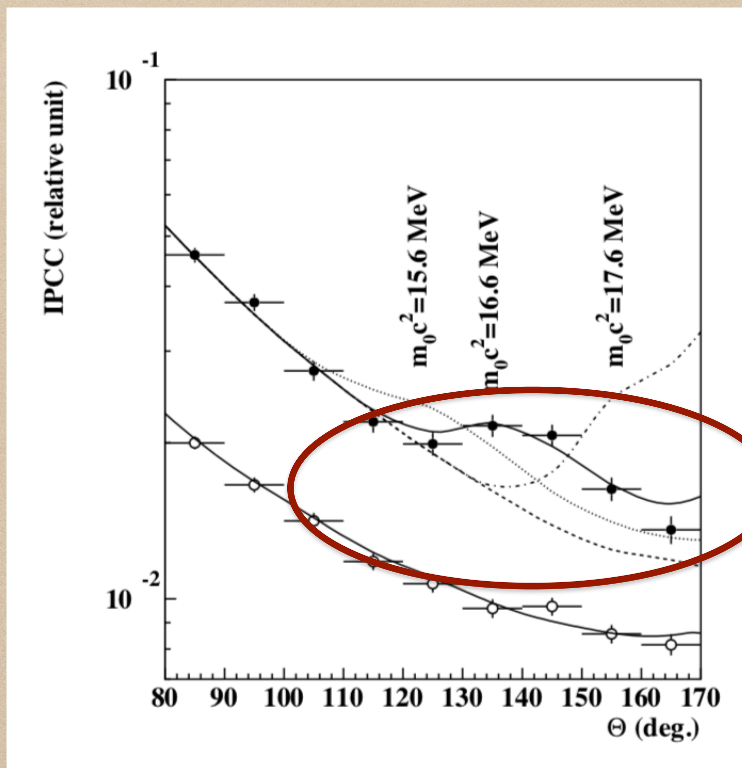
- X17 anomaly: Observation and interpretation:



Interpretation in terms of
massive intermediate state … fits

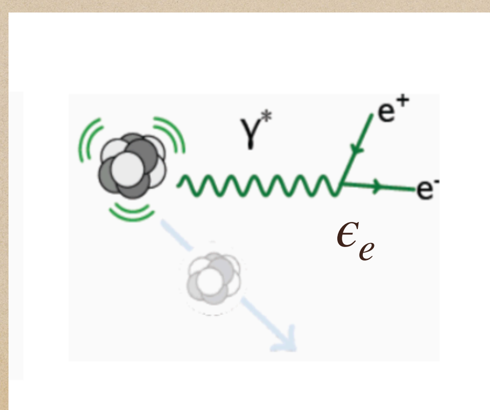
$$M_X \sim 17MeV$$

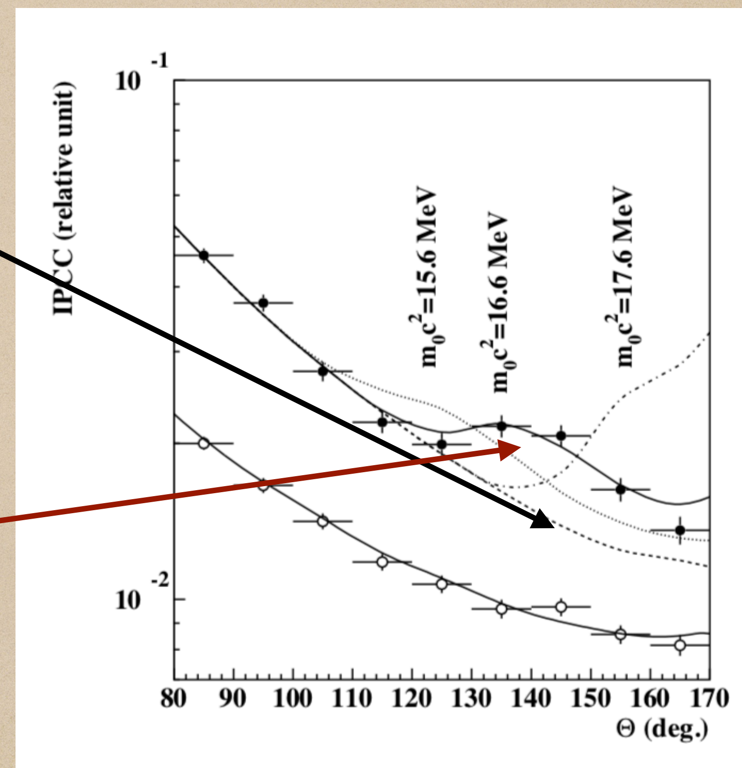
- X17 anomaly: Observation and interpretation:

SM background:

- Internal pair creation
- External pair creation
- Multiple lepton scattering
- Nuclear interference
- …

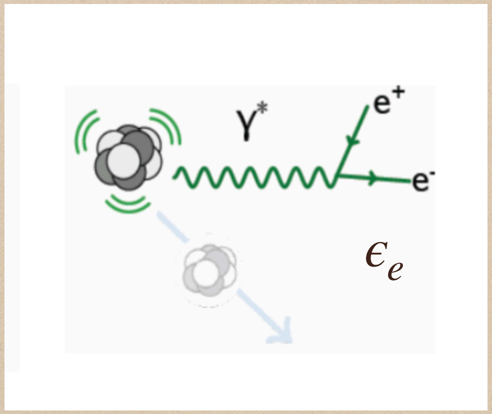
BSM:





- X17 anomaly: Observation and interpretation:

BSM:



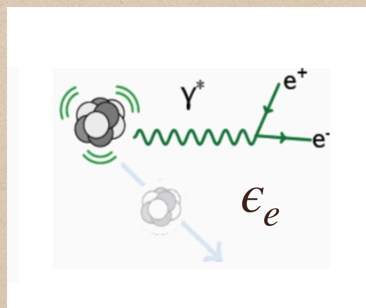
Type: "weak coupling frontier"

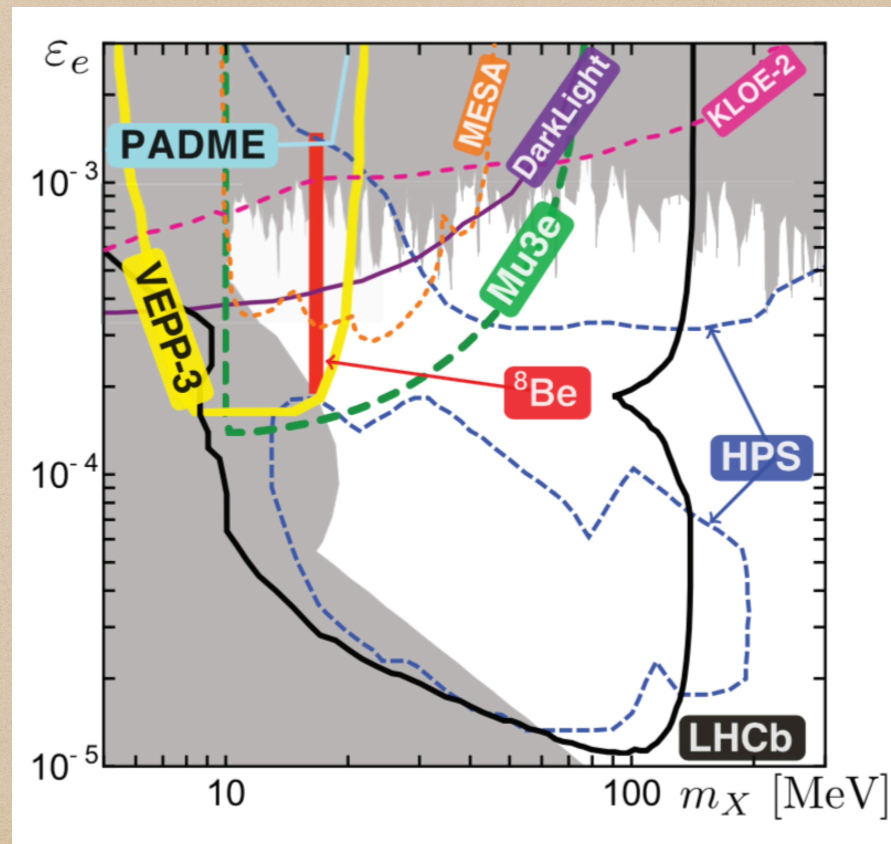
$$L \sim L_{SM} \;\; +\epsilon_e \bar{\psi}\psi\gamma^\mu A^*_\mu - \frac{1}{4\pi}(F^*)^2 + M_X^2 (A^*)^2$$

numerous models …

- X17 anomaly: Observation and interpretation:

BSM:





Most important paramters:

ϵ_e and M_X

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- Idea: Hard $\gamma + \gamma$ process
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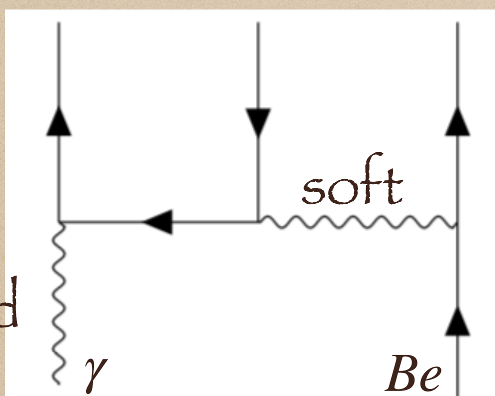
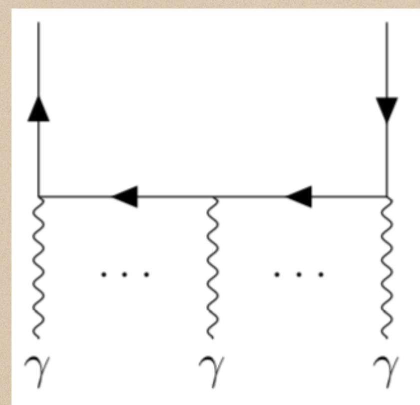
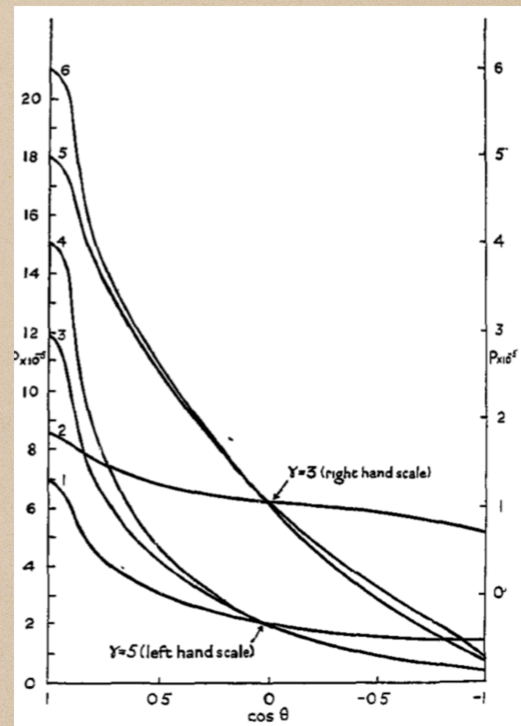
- Idea: Hard $\gamma + \gamma$ process

Usual background consider at least one soft γ
from electric/magnetic background field

hard







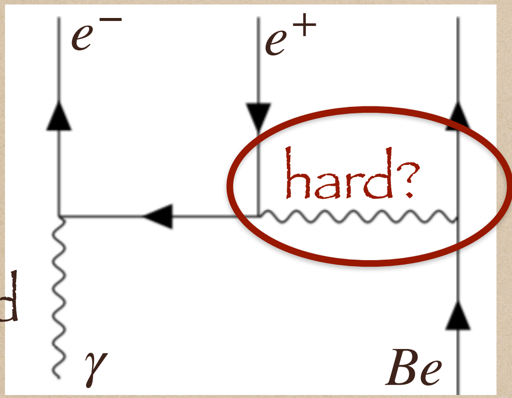
Bethe-Heitler process

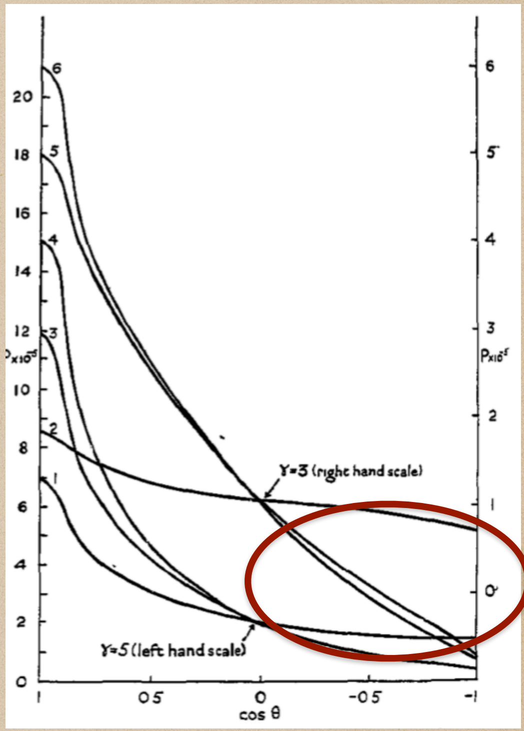
internal pair creation

- Idea: Hard $\gamma + \gamma$ process

With two hard γs the large angle distribution should change

hard

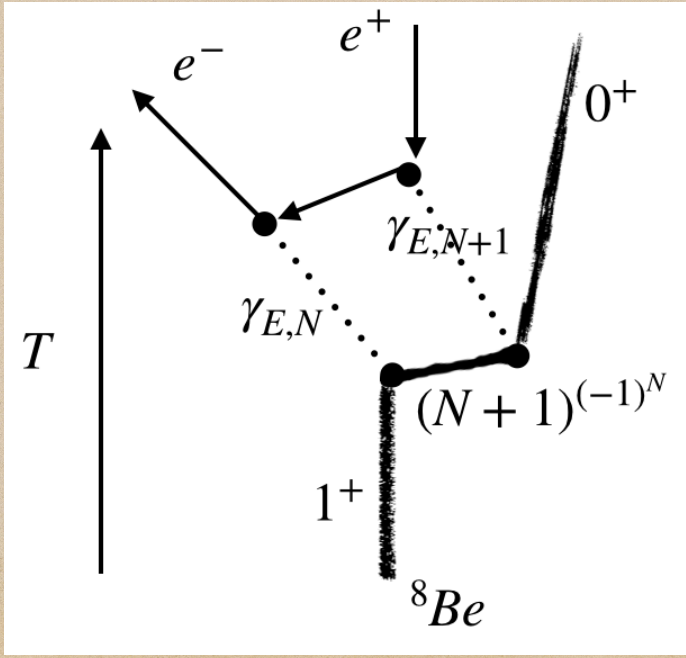




Where could the 2nd hard γ come from?

- Idea: Hard $\gamma + \gamma$ process

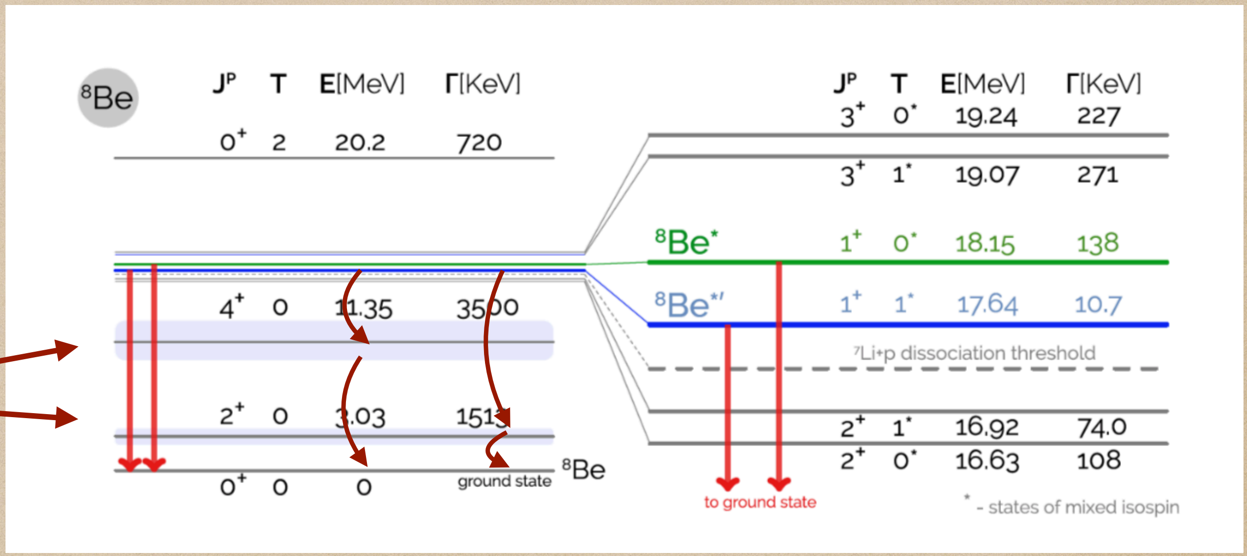
Where could the 2nd hard γ come from? $\Rightarrow$ Intermediate state



Two hard γ
one intermediate state

- Idea: Hard $\gamma + \gamma$ process

Where could the 2nd hard γ come from? $\Rightarrow$ Intermediate state



Two candidates

4^+ @ 11.35 MeV

&

2^+ @ 3.03 MeV

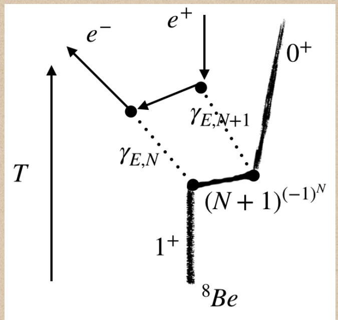
- Idea: Hard $\gamma + \gamma$ process

Conditions

1. Broad intermediate state
2. Angular orientation of multiple moments
3. Conservation con energy/momentum
4. Realistic emission and conversion rate

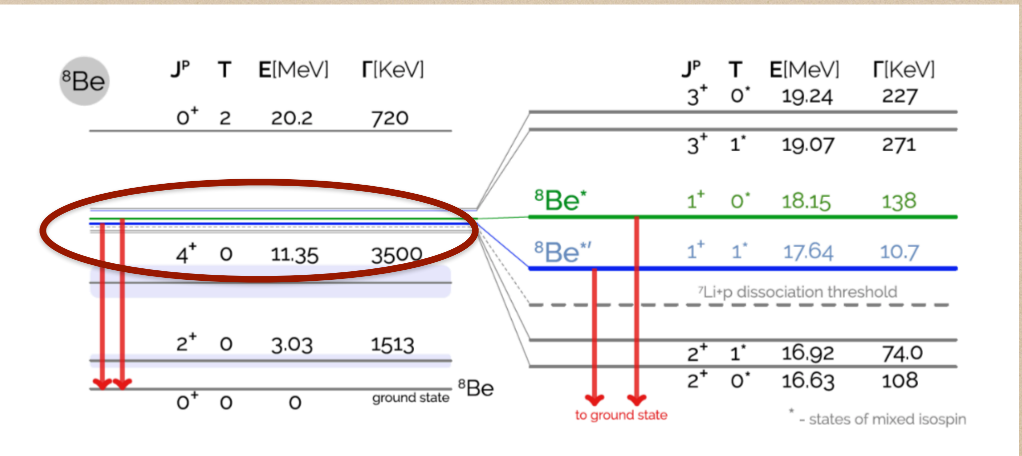
- Idea: Hard $\gamma + \gamma$ process

1. Broad intermediate state



area covered by first γ

$$A \approx \pi t^2 \approx \frac{\pi}{\Gamma^2}$$



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- Idea: Hard $\gamma + \gamma$ process

2. Angular orientation of radiation due to multiple moments

$$\frac{dP_{l0}}{d\theta} \sim \sin(\theta)\,|a_{l0}|^2\,|\vec{X}_{l0}(\theta)|^2,$$

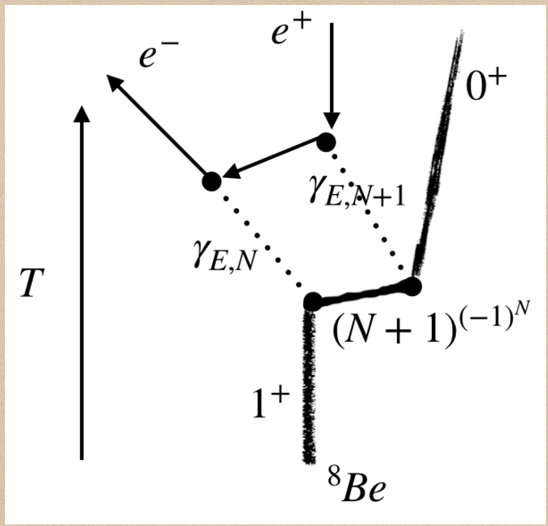
$$\theta_{rel} \pm \delta\theta_{rel} = \begin{array}{ll} (144 \pm 14)^o & \text{for} \quad N = 3 \\ (152 \pm 11)^o & \text{for} \quad N = 4 \end{array}$$

- Idea: Hard $\gamma + \gamma$ process

3. Conservation con energy/momentum

For small asymmetries and large nuclear mass

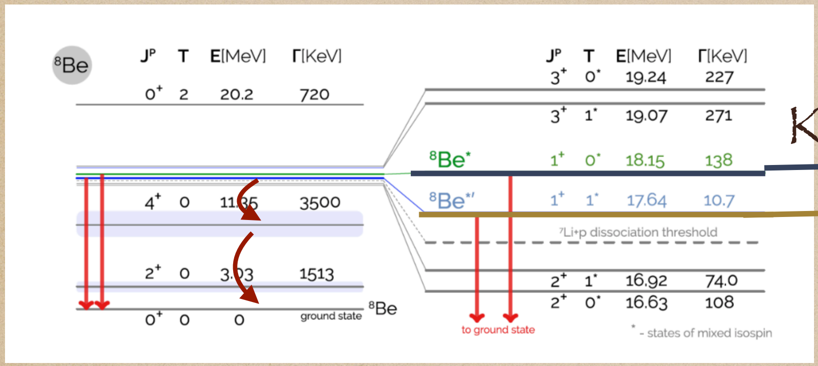
$$p_i^2 \gg (p_i - p_j)|^2_{i \neq j} \gg m^2,$$



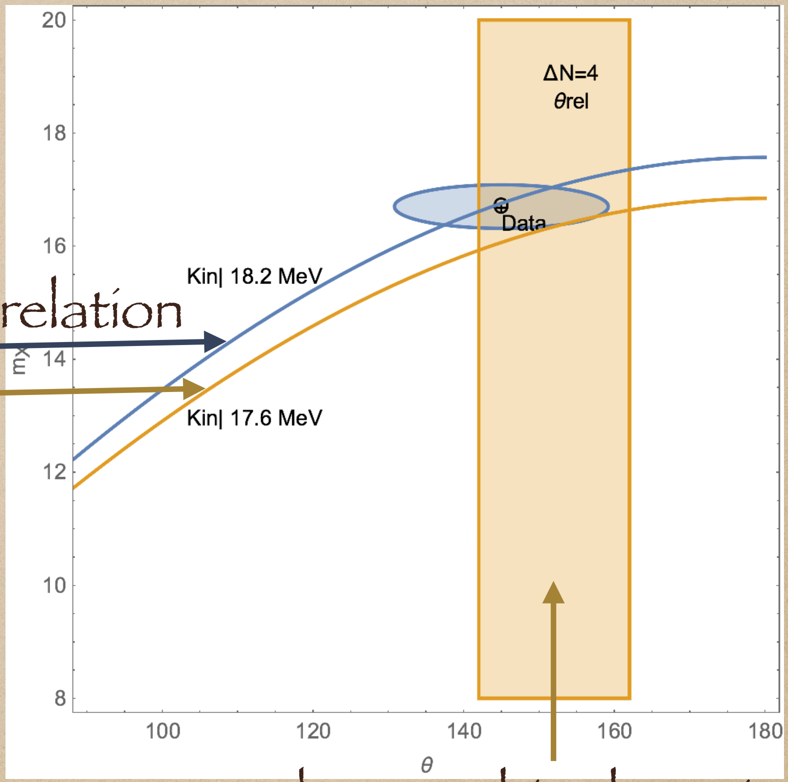
$$m_X^2 = (q_1 + q_3)^2 = 4(\Delta M_{12})(E_{13} - \Delta M_{12})\sin^2\left(\frac{\theta}{2}\right),$$

- Idea: Hard $\gamma + \gamma$ process

Results for 1-3



Kinematic relation

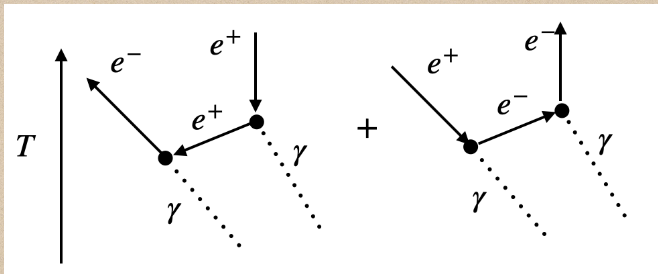


Too good to be true!

Jackson multipole region

- Idea: Hard $\gamma + \gamma$ process

4. conversion probability = spoiler alert



$$\sigma \approx 4\pi \frac{\alpha_0^2}{E_{CM}^2} .$$

Compare cross section to impact area estimated before:

$$p_{\gamma+\gamma\to e^+ + e^-} \approx \frac{\sigma}{A} \approx 4 \frac{\alpha_0^2 \Gamma^2}{E_{CM}^2} \approx 10^{-5}$$

- Idea: Hard $\gamma + \gamma$ process

4. conversion probability = spoiler alert

$$p_{\gamma+\gamma\to e^{+}+e^{-}} \approx \frac{\sigma}{A} \approx 4\frac{\alpha_0^2\Gamma^2}{E_{CM}^2} \approx 10^{-5}$$

Expect huge $\gamma + \gamma$ background, and strongly suppressed rate

- Idea: Hard $\gamma + \gamma$ process

Summary:

	Supporting	To be seen	Not supporting
Broadness of intermediate state			
Angular spectrum			
Kinematics			
Isospin			
Emission probability			
Conversion probability			
Complementary experimental evidence			

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"… eliminated the impossible,
whatever remains, however improbable, must be the truth?"

Simple hard $\gamma + \gamma$ process from intermediate nuclear state
seems to add to the list of excluded ("impossible")
explanations of the X17 puzzle

Question still open…

Thanks!