Center for Frontiers in Nuclear Science

X17: Reports, Explanations, and Other Searches

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DARKLIGHT

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New In This Edition

- News from the g-2 world
- MEG II No (slightly)
- PADME Yes (slightly)
- Some more work on how to fit these in with the Standard Model

- *Note: I include arxiv links for convenience. Most of these are peer-reviewed and published, too.*

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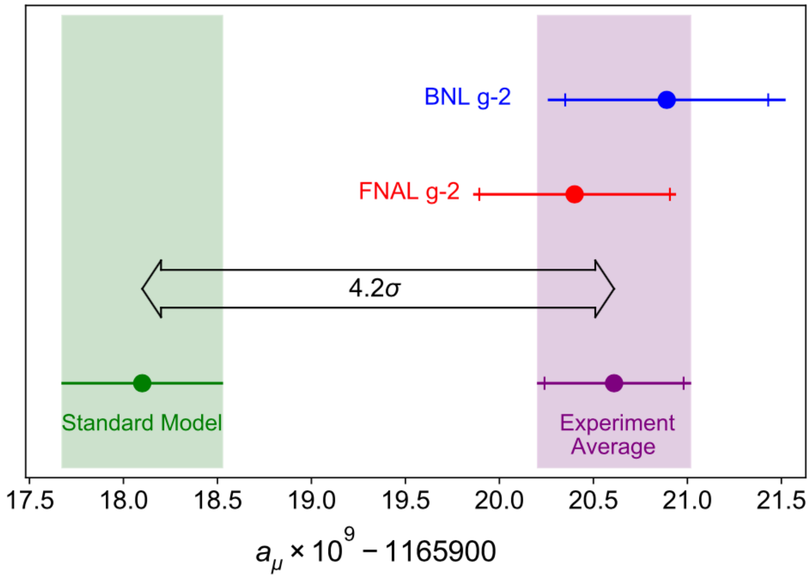
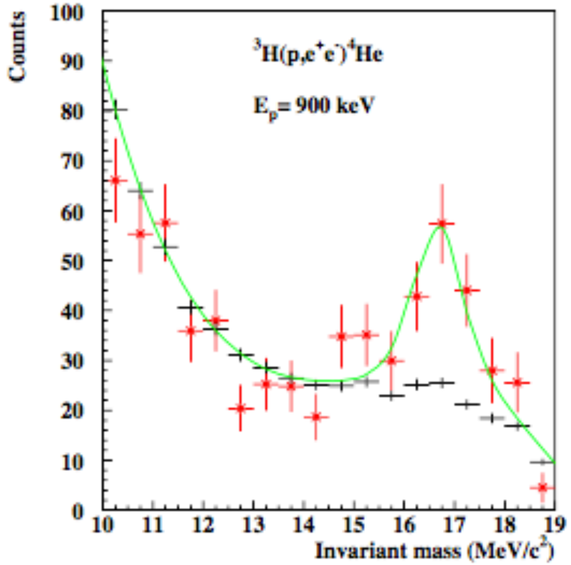
Various Anomalies

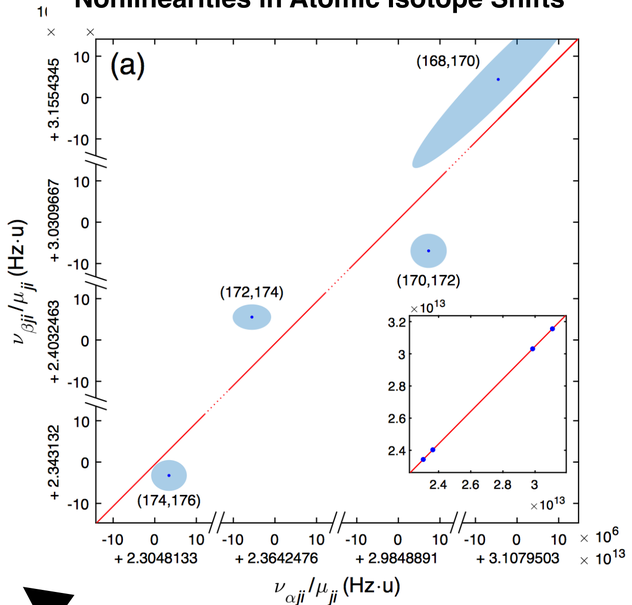
Muon g-2 Discrepancy



X17 in 4He and 8Be

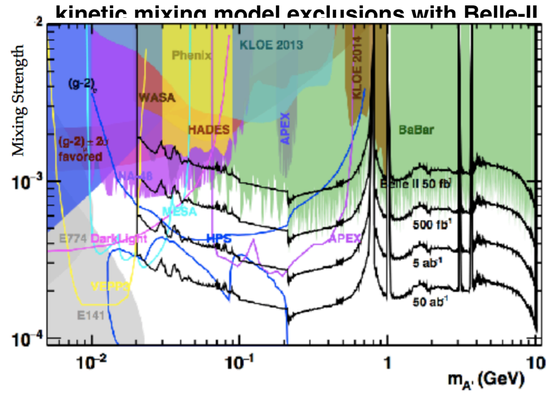


Nonlinearities in Atomic Isotope Shifts



Anomalies could be resolved with a new interaction that:

- Couples to the muon and electrons
- Couples to the nucleus
- ...and not trivially, or we would've seen it by now:



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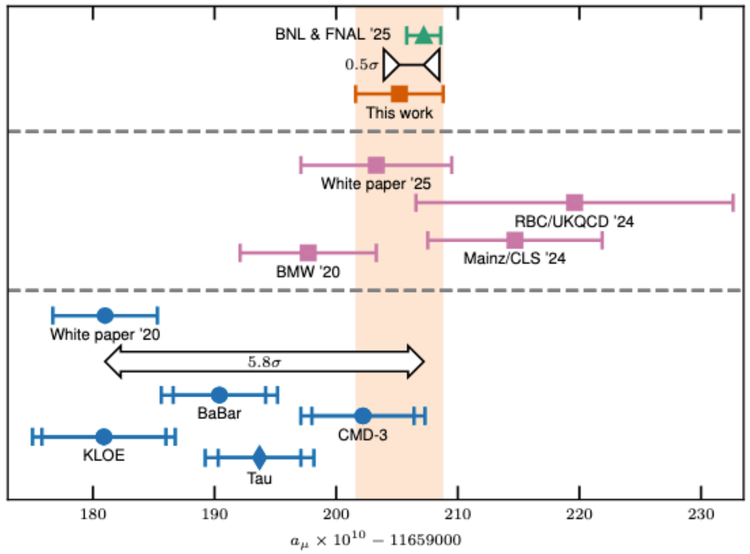
Various Anomalies

Muon g-2 Discrepancy



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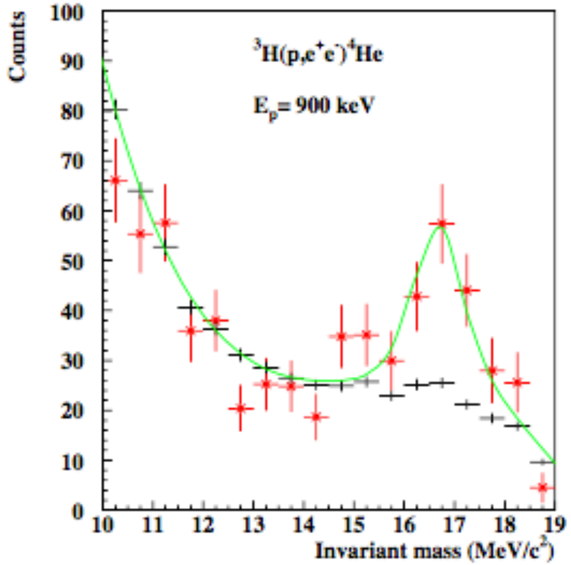

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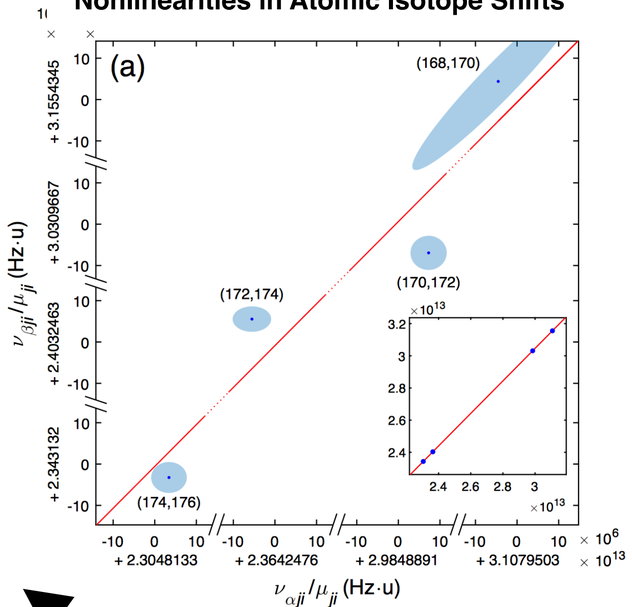

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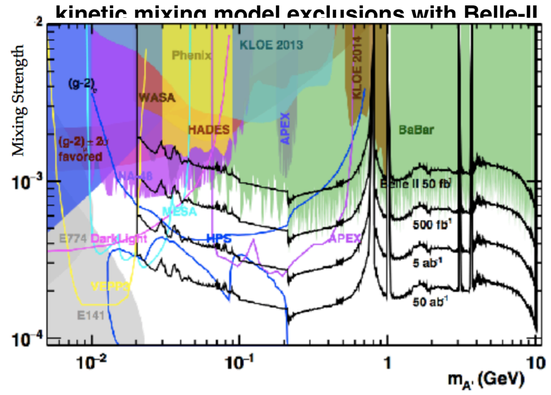

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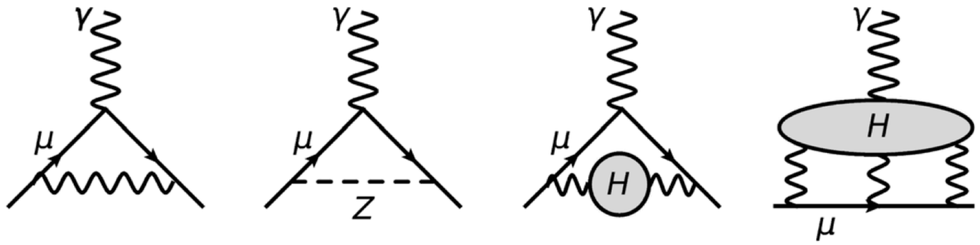
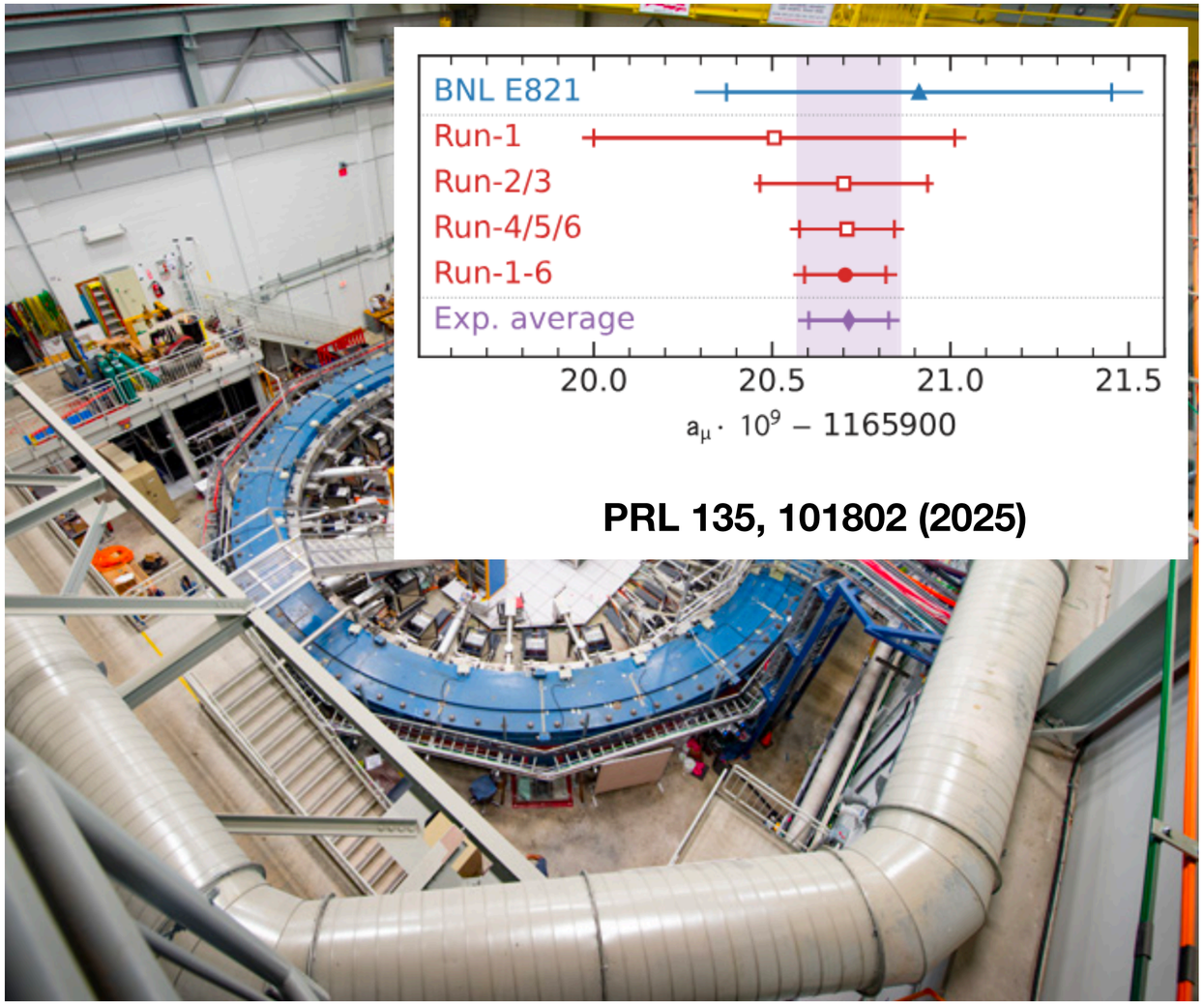
Fermilab g-2



- NLO effects in ***μμγ*** vertex yield 'anomalous' magnetic moment
- Measured anomalous moment is *anomalously* large.
- BSM physics would also appear here too (and generally have a larger effect than for electron)



PRL 135, 101802 (2025)

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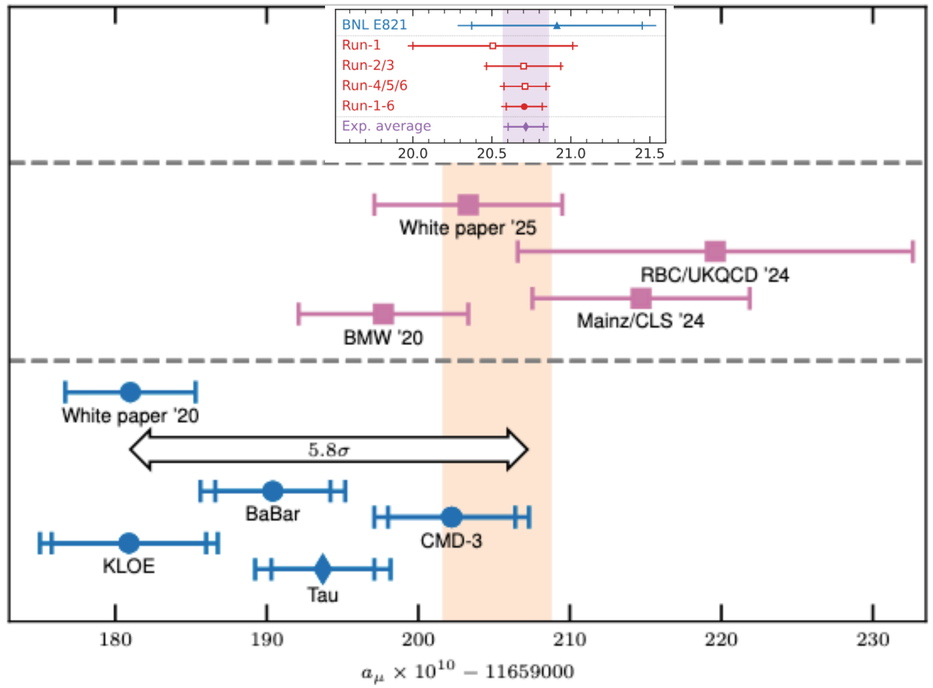
Combined Result

- New combined-combined result nails this down, fulfilling their promise of 0.5x error bars from Run-1
- Good agreement with previous measurements.
- Causing a mild schism in calculations:
  - Lattice can ~match it
  - Data-Driven (dispersive) less so
  - Both have big spreads



arxiv:2407.10913

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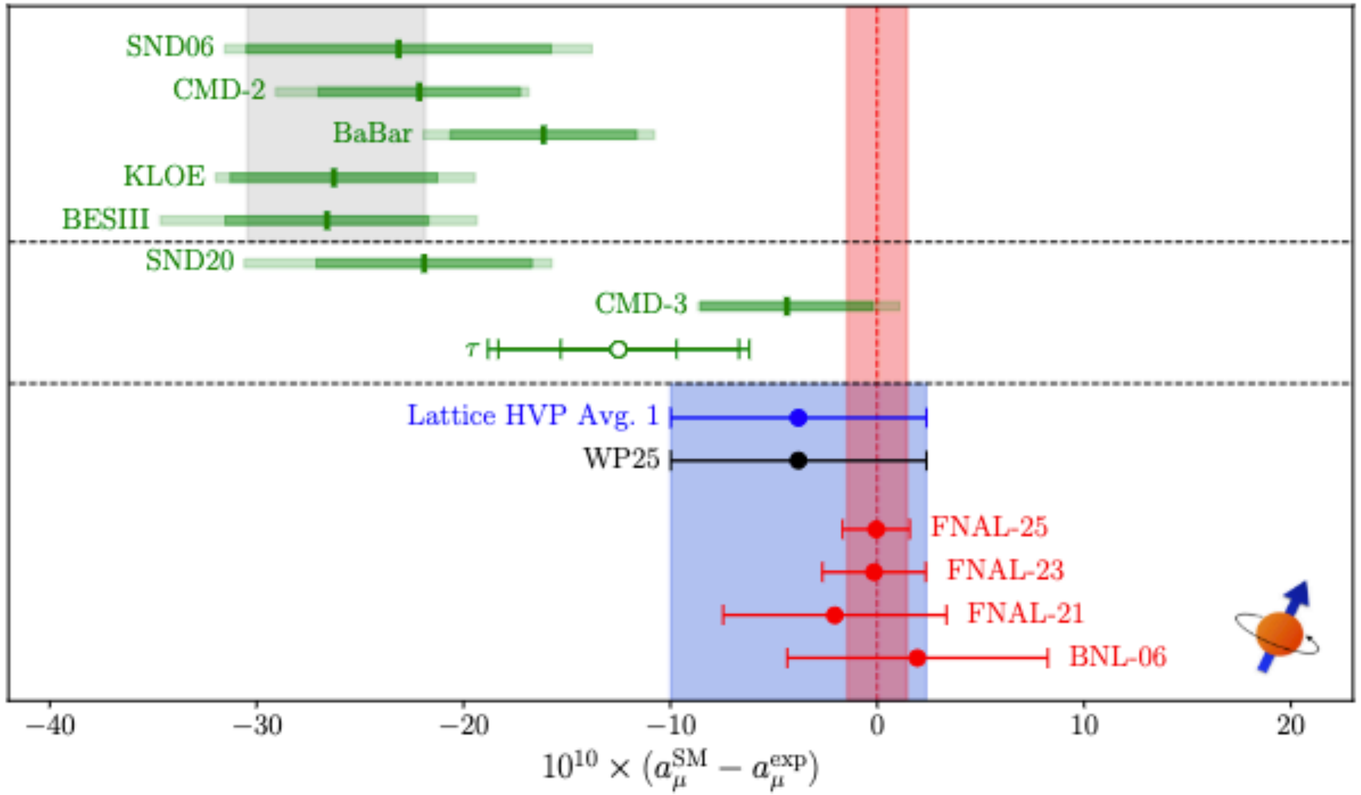
g-2 Progress

- Muon g-2 Theory Initiative published a white paper (arxiv:2505.21476) with a new *Lattice Consensus*.
  - And apparently they're meeting again this year.
- And J-PARC g-2 (E34) (300 MeV) is still planning to begin data taking in 2028, different systematics.
- No glaring need for the X17



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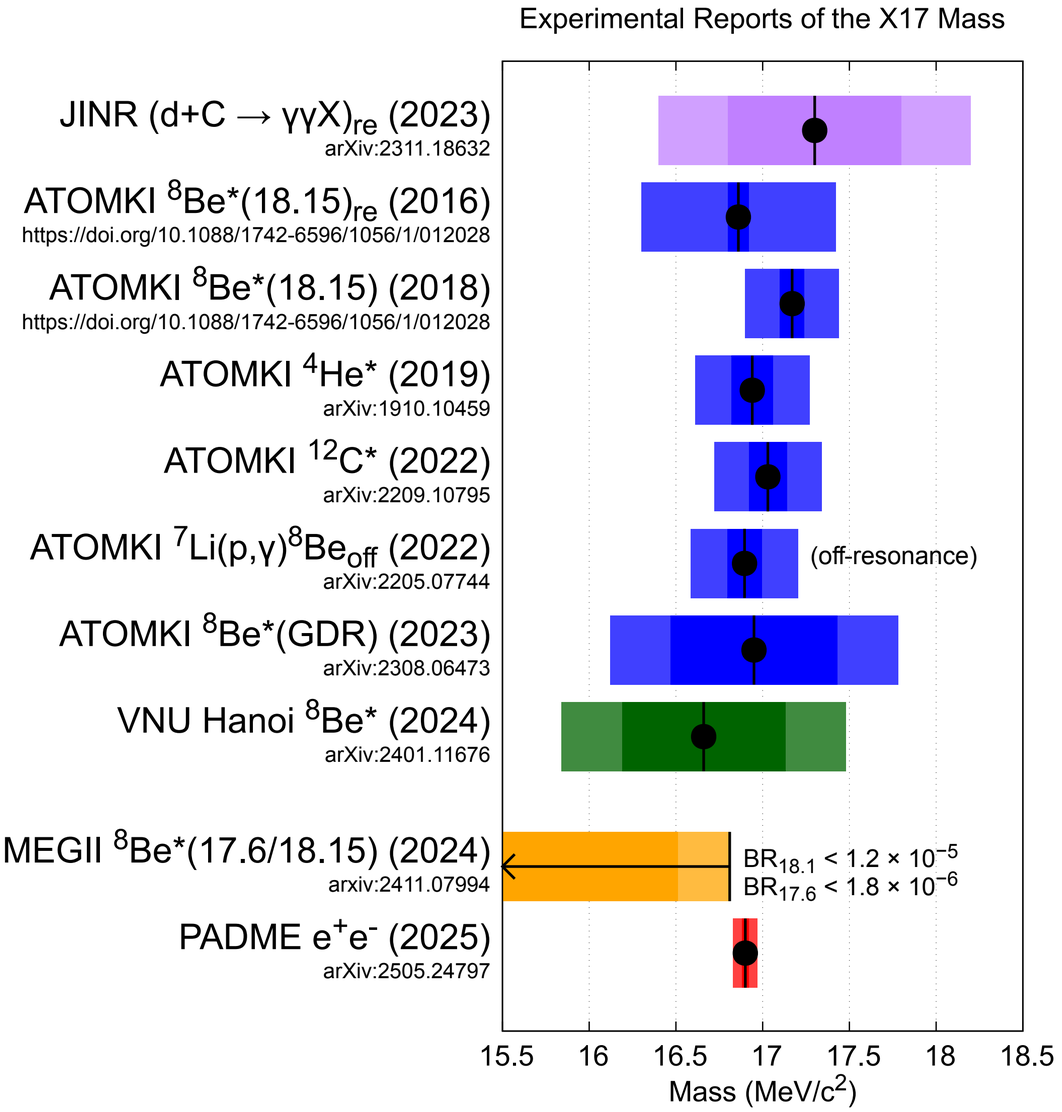
X17: Still Going

- ATOMKI: Keeps seeing it in various places
- MEGII: Disfavors it
- PADME: Teasingly possible!

***Not shown: Do these couplings agree?**



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X17

- ATOMKI group sees anomaly in ^{8}Be, ^{4}He, ^{12}C
- Persists in original 5-fold and new 6-fold geometry
  - most detector angles are the same, but the *resonance angle* moves with species
- *Very* incompatible with simple kinetic mixing model
  - would have been seen in pion decay etc.

X17 in 4He and 8Be

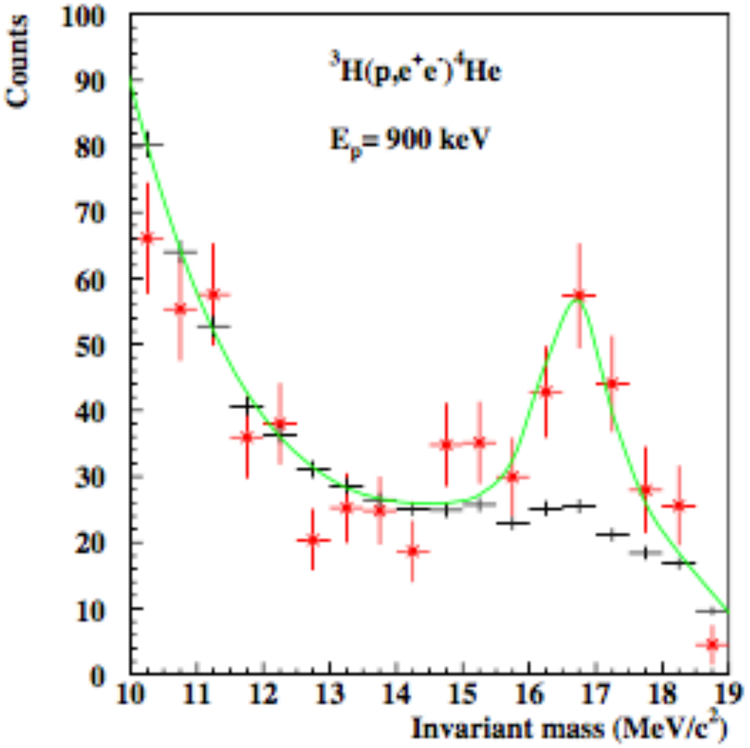

FIG. 3. *Invariant mass distribution derived for the 20.49 MeV transition in ^{4}He.*

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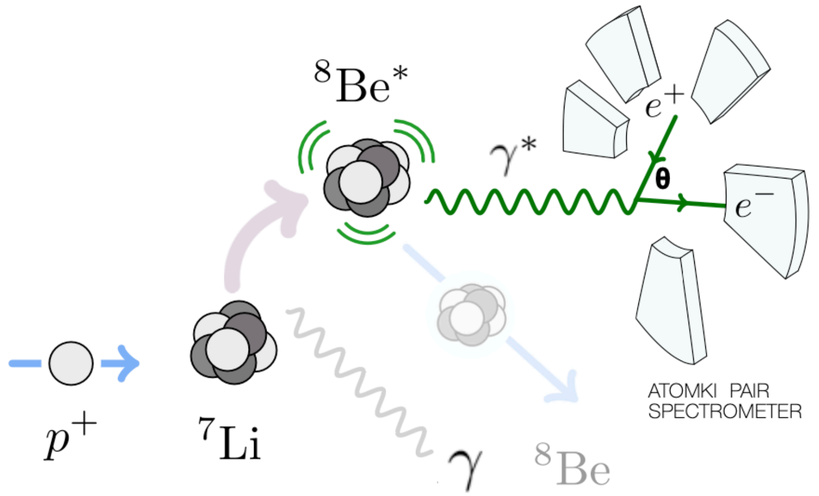
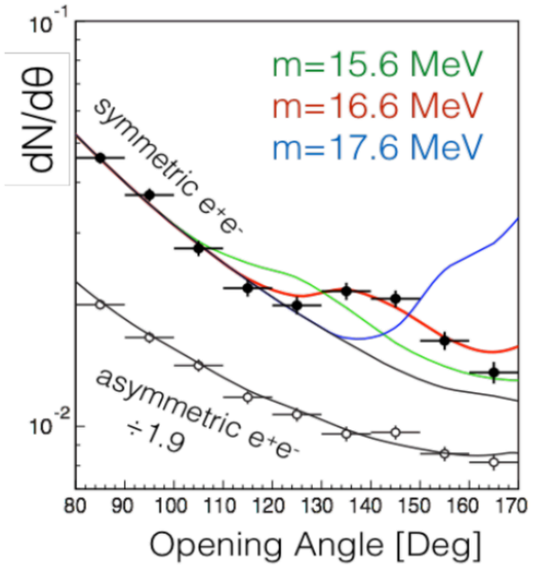
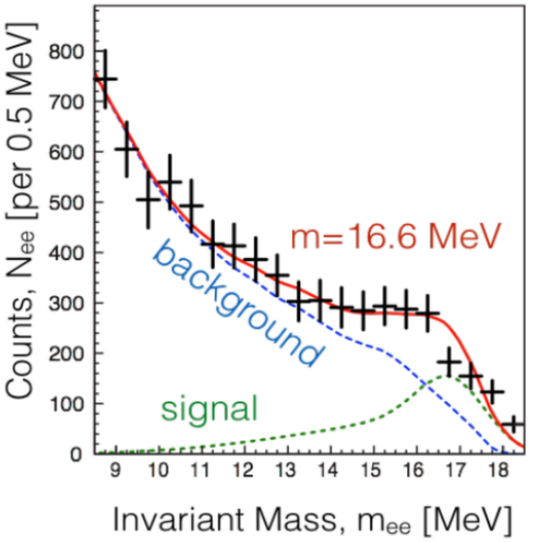
X17

- Very rarely, p+Li produces very excited ^{8}Be state
- Rarely, ^{8}Be will de-excite through photon/ internal pair creation (IPC)
- Detect e^+e^- pairs, construct spectra, verify against nuclear model
- ...and find an anomaly consistent with massive particle







arxiv:1707.09749

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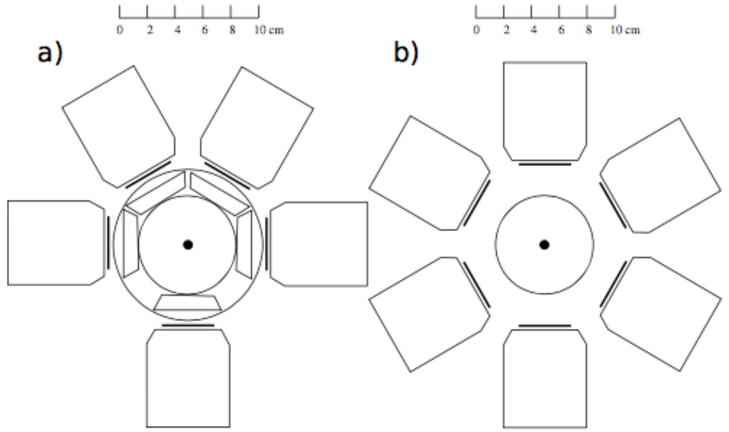
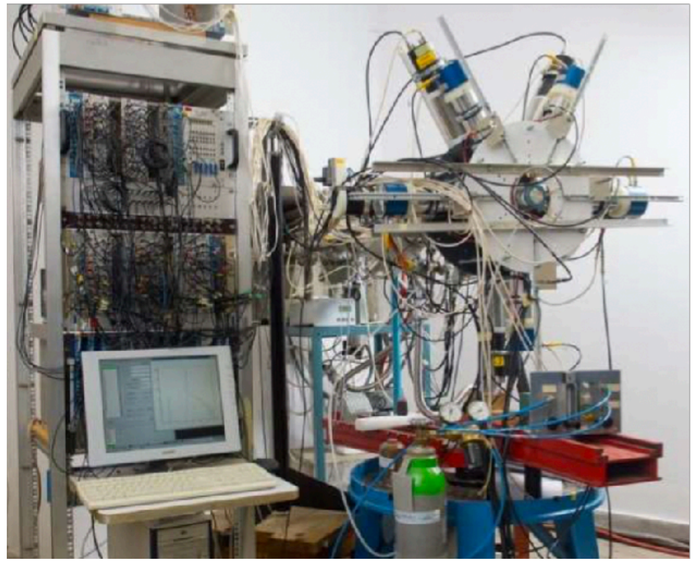
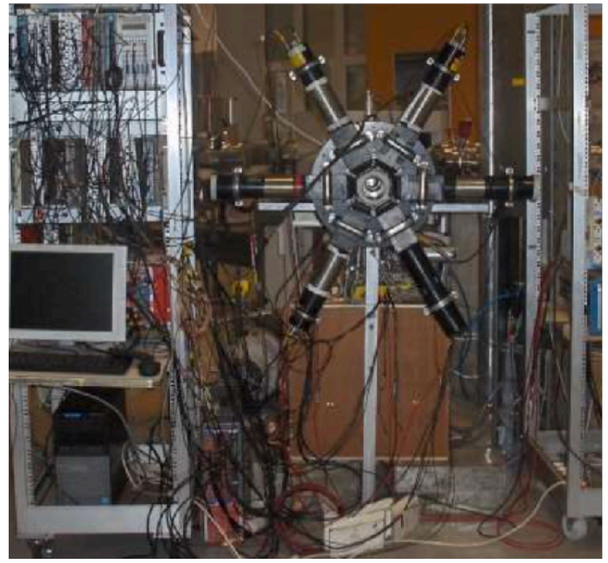
X17

- Seen in 5- and 6-fold detectors
- Seen in 3 different nuclei
- Could be nuclear effects, maybe intermediate state, interference, anomalous form factor... but no clear explanation yet.



E_p (MeV)	B_x $\times 10^{-6}$	Mass (MeV/c^2)	Confidence
1.50	1.1(6)	16.81(15)	3σ
1.70	3.3(7)	16.93(8)	7σ
1.88	3.9(7)	17.13(10)	8σ
2.10	4.9(21)	17.06(10)	3σ
Averages	3.6(3)	17.03(11)	
Previous [14]	5.8	16.70(30)	
Previous [28]	5.1	16.94(12)	
Predicted [30]	3.0		





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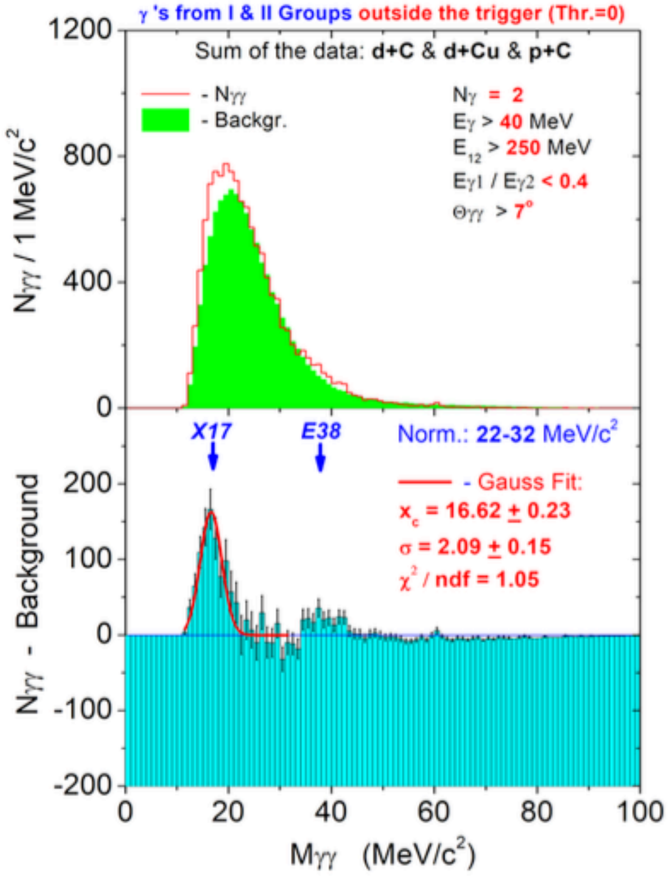
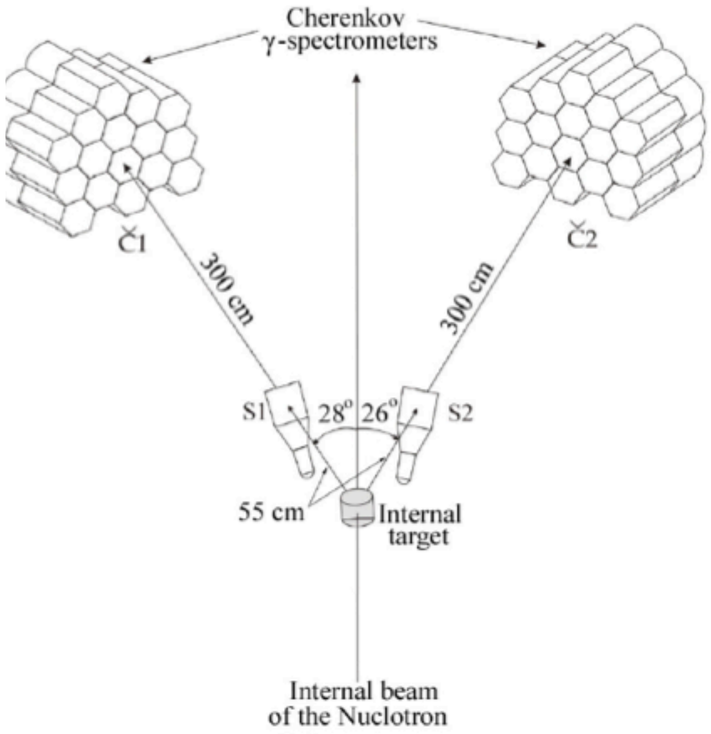
X17 at JINR

- *not* ATOMKI.
- re-analysis of data from Phys.Rev.C80:034001,2009
- p+C→γγ+X @ 5.5GeV/c (and d,p on C,Cu, 2.7-3.8 GeV/*c*/*n*)
- Designed for eta mesons spread across arms, but can look at γγ within a single arm.
- Combinatoric background from mixed events
- Signal shows up at low edge, but not 'last bin'.





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arxiv:2311.18632

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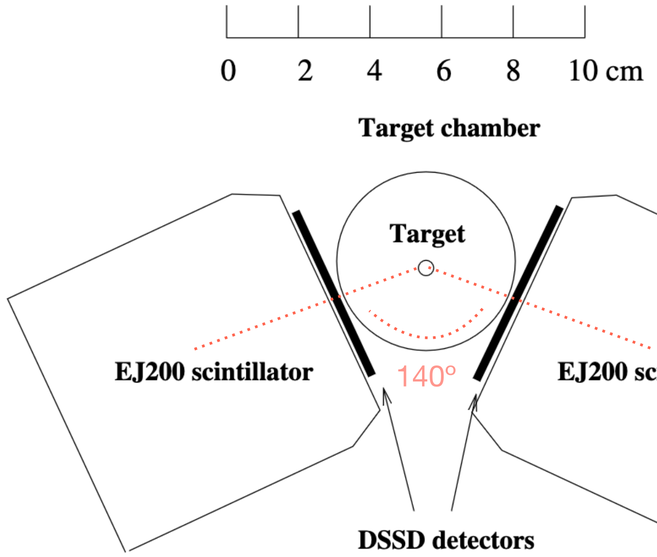
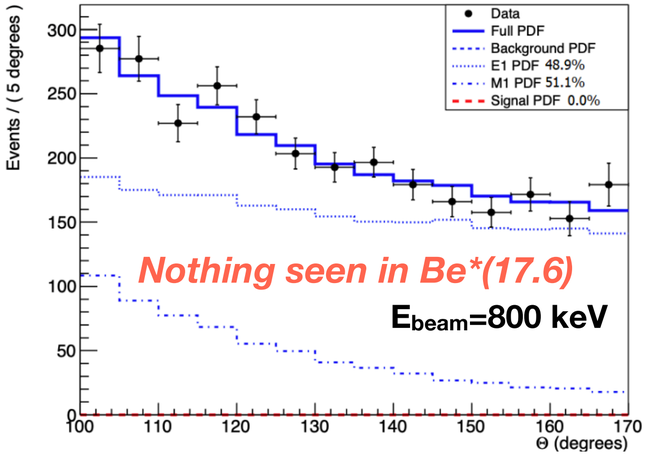
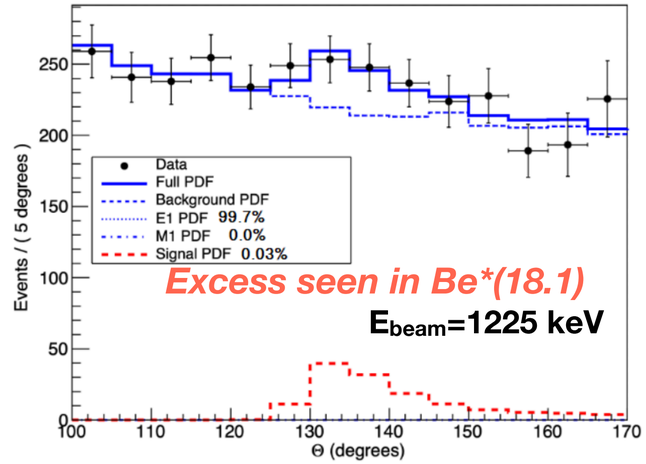
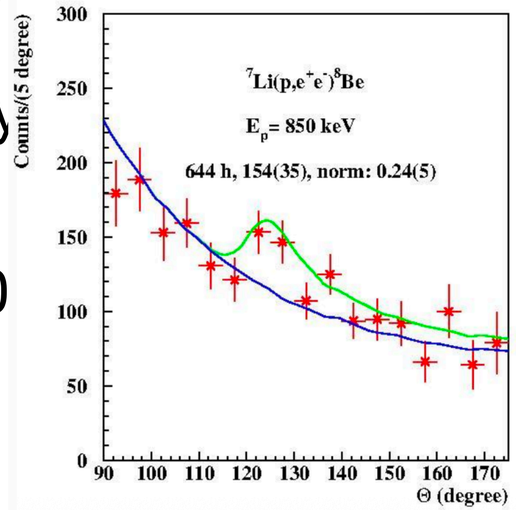
X17 in Hanoi

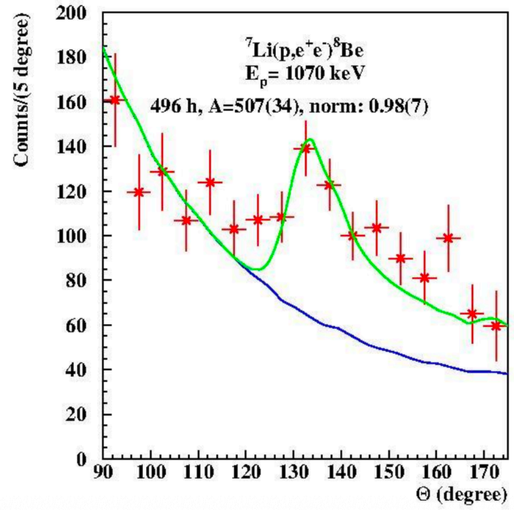
- *somewhat* ATOMKI.
- Repeats ^{7}Li(p,$e^{+}e^{-}$)^{8}Be
- Scintillator + double Si Strip detectors (DSSD)
- Many problems with the target (burned through)
- Follows ATOMKI analysis as far as they can
- Presented at ISMD 20 (and not since)











arxiv:2401.11676

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X17 Through Mundane SM?

- **NLO corrections and careful interference handling?** maybe, but explanation does not yet fit all observations (A. Aleksejevs et al.)(arxiv:2102.01127)
- **EFT framework?** requires unrealistic form factors for ^{8}Be (Zhang and Miller) (https://doi.org/10.1016/j.physletb.2017.08.013)
- **nuclear decay chain with $\gamma\gamma \rightarrow e^{+}e^{-}$?** can match rates and kinematics, but reaction 'not favoured in established nuclear models', and doesn't explain isospin structure (https://doi.org/10.1016/j.nuclphysa.2021.122143)
- ***Ab initio* calculations with No-Core Nuclear Shell Model?** good match to smooth backgrounds, cannot generate the resonant decayeasonable agreement with ^{7}Li(p,$e^{+}e^{-}$)^{8}Be resonance (Gysbers, Navratil et al.)(arxiv:2308.13751)
- **...Just more careful detector modeling?** (No one seems interested in doing the grunt work.) (Your name here) (arxiv:tbd)

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X17 Through Exotic SM?

- **tetraquark?** Can fit resonance, but predicts second resonance that should have been observed (Chen)(arxiv:2006.01018)
- **...QED meson?** (Wong)(arxiv:2001.04864v4)

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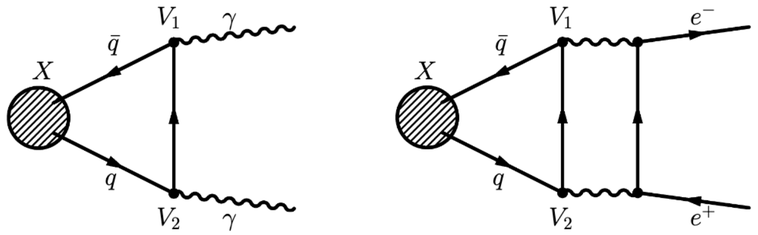
QED Mesons

- Bound by QED:
  - "Maybe there's a 1+1D stringy QED flux tube that can be formed"
  - QED binding > QCD binding
  - but BE still small
  - ~18 MeV isoscalar, ~36 MeV isovector
- Neat side effect: In principle, this can form BEC. Decay mode depends on object mass:
  - astro-light: emits e^+e^-
  - astro-medium: emits only γ
  - astro-heavy: entirely dark



(a) (b)

		I	S	$[I(J^\pi)]$	Experimental mass (MeV)	Semi-empirical mass formula (MeV)	Meson mass in massless quark limit (MeV)
QCD meson	π^0	1	0	$[1(0^-)]$	134.9768±0.0005	134.9‡	0
	η	0	0	$[0(0^-)]$	547.862±0.017	498.4±39.8	329.7±57.5
	η'	0	0	$[0(0^-)]$	957.78±0.06	948.2±99.6	723.4±126.3
QED meson	isoscalar	0	0	$[0(0^-)]$		17.9±1.5	11.2±1.3
	isovector	1	0	$[1(0^-)]$		36.4±3.8	33.6±3.8
Possible QED meson candidates	X17			(1^+)?	16.70±0.35±0.5†		
	X17			(0^-)?	16.84±0.16±0.20#		
	E38			?	37.38±0.71⊕		
	E38			?	40.89±0.91⊖		
	E38			?	39.71±0.71⊗		

arxiv:2001.04864v4

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X17 at Face Value

- EFT: X17-nucleon coupling depends on the J^P
- Angular momentum conservation in the different decays constrains the X17 J^P
- ATOMKI measurements mostly consistent with vector/axial vector
  - different BRs in two He modes

	scalar 0^+	pseudo-scalar 0^-	axial vector 1^+	vector 1^-
8Be(17.64) $1^+ \rightarrow 0^+$	✘	✔	✔	✔
8Be(18.15) $1^+ \rightarrow 0^+$	✘	✔	✔	✔
4He(20.21) $0^+ \rightarrow 0^+$	✔	✘	✘	✔
4He(21.01) $0^- \rightarrow 0^+$	✘	✔	✔	✘
12C $1^- \rightarrow 0^+$	✔	✘	✔	✔

based on table by Daniel Firak (SBU)

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With Careful SM Effects?

Recent work has focused on understanding the nuclear couplings in greater detail:

- Particularly wanted: Carbon nuclear matrix element.
- **Multipole expansions?** Fits the older measurements, but hard to accommodate ^{12}C into the rest of the couplings. Strongly prefer Axial-Vector (Barducci and Tony) (arxiv:2212.06453)
- ***Ab initio* calculations with No-Core Nuclear Shell Model?** put in the X17 and it matches quite nicely in $^{7}Li(p,\gamma)^{8}Be^{*}$ decay. (Gysbers, Navratil et al.)(arxiv:2308.13751)
  - Working on ^{12}C, but many more resonances to consider
- ***Ab initio* chEFT calculations of Internal Pair Creation?** matches with 4He channel, predicts small effects in $^{2}H(p,e^{+}e^{-})^{3}He$ and $^{2}H(p,e^{+}e^{-})^{3}H$ (Viviani et al.)(arxiv:2104.07808)
  - working on testing X17 coupling properties

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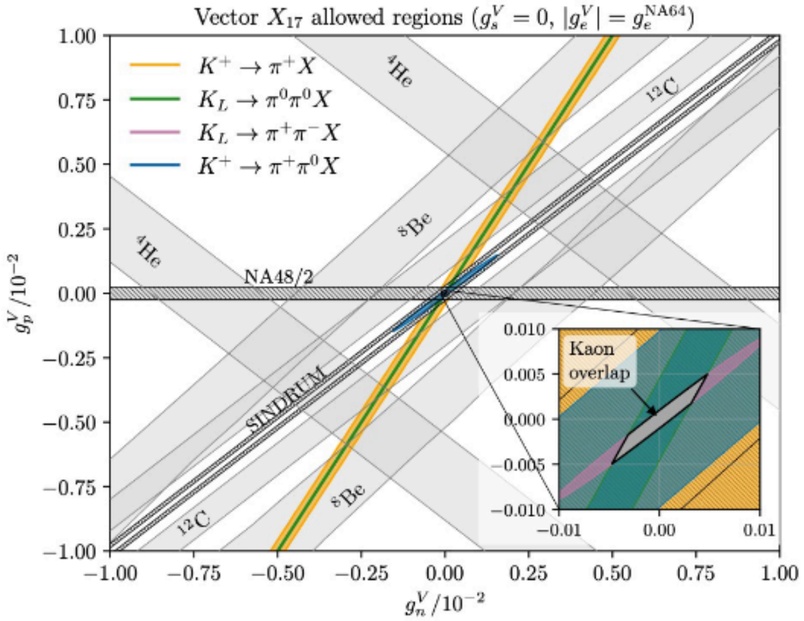
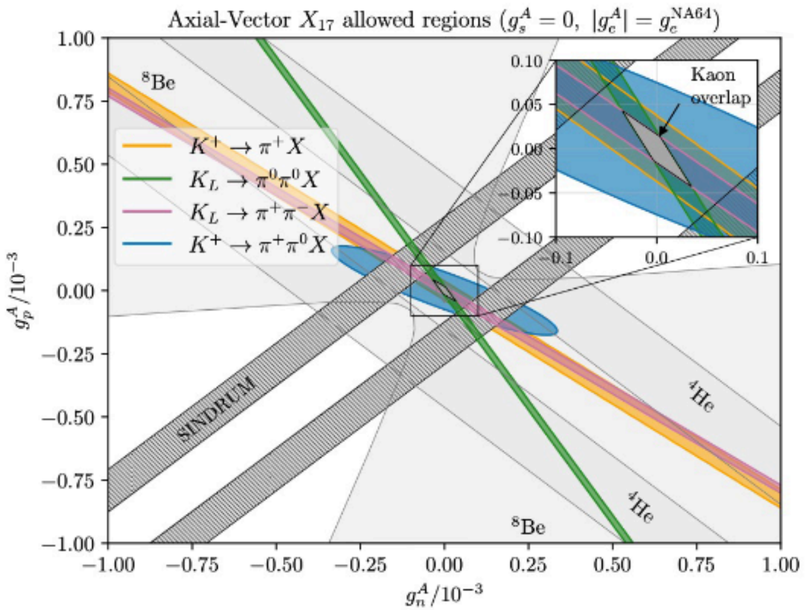
X17 Vector vs Axial Vector vector

- $K_L \rightarrow \pi^0\pi^0(X \rightarrow e^+e^-)$ (KTeV)
- $K^+ \rightarrow \pi + \gamma(X \rightarrow e^+e^-)$ (NA48/2)
- $K_L \rightarrow \pi^+\pi^-(X \rightarrow e^+e^-)$ (NA48/2)
- $K^+ \rightarrow \pi + XX$ (NA62)
- $e^+e^- \rightarrow e^+e^-(X \rightarrow e^+e^-)$ (KLOE)
- $\pi + \rightarrow e\nu_e$ $(X \rightarrow e^+e^-)$ (SINDRUM)
- Structure:
  - We set the electron coupling as big as NA64 lower bound allows.
  - Pairs of bands because there is a sign choice for $g_e{}^V$
- Still room to agree with electron g-2
- But can't resolve the ^{12}C tension easily. Unknown matrix element can only move it by factor of few. (not in range on Axial)





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ECT* X17-2026 Conference overview
adapted from: arXiv:2602.19479

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Frascati Punchline

- Any coupling produces "Tension at best".
- More exotic choices (Spin-2, parity violation)
- ...so these results still don't fit together

Perhaps we need to refine the analysis including the direct proton capture!

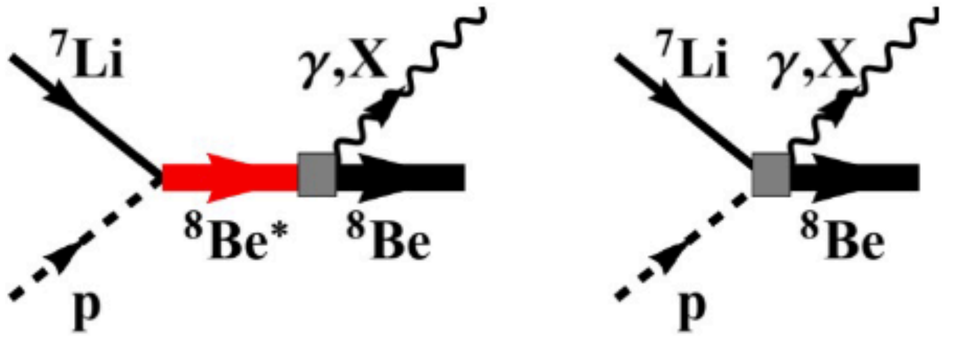

Figure from Zhang and Miller, PLB 773 (2017) 159-165

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A Survey of Searches

- Resonance in Nuclear Decays:
  - COPE (ATOMKI) - **built! sees it again.** ✅
  - MEGII - **Published 2023 8Be run** ❌
  - Montreal/Project X17 - 8Be this year, blinded
  - *et al*.
- General-Purpose Accelerator:
  - Belle II - stats available. analyzing
  - FASER - closes from below, maybe upgrade in 2029
  - LHCb - stats in 2026 or so, no recent news
- Dark-Photon Specific:
  - NA64 - **Published 2022 data** ❌
  - PADME - **Published 2022 run** ✅
  - PRad - Installing now
  - *et al*.

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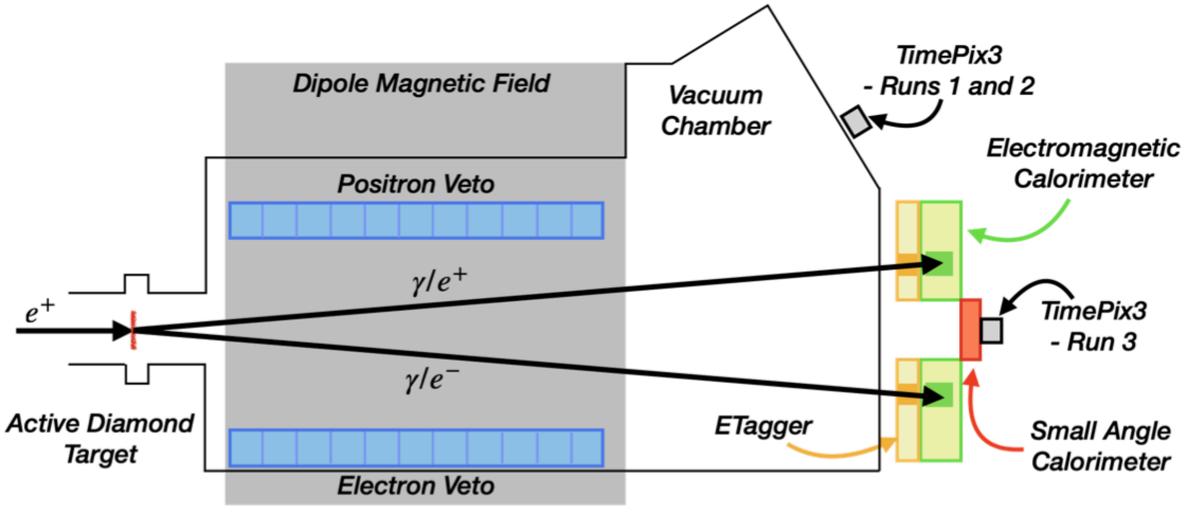
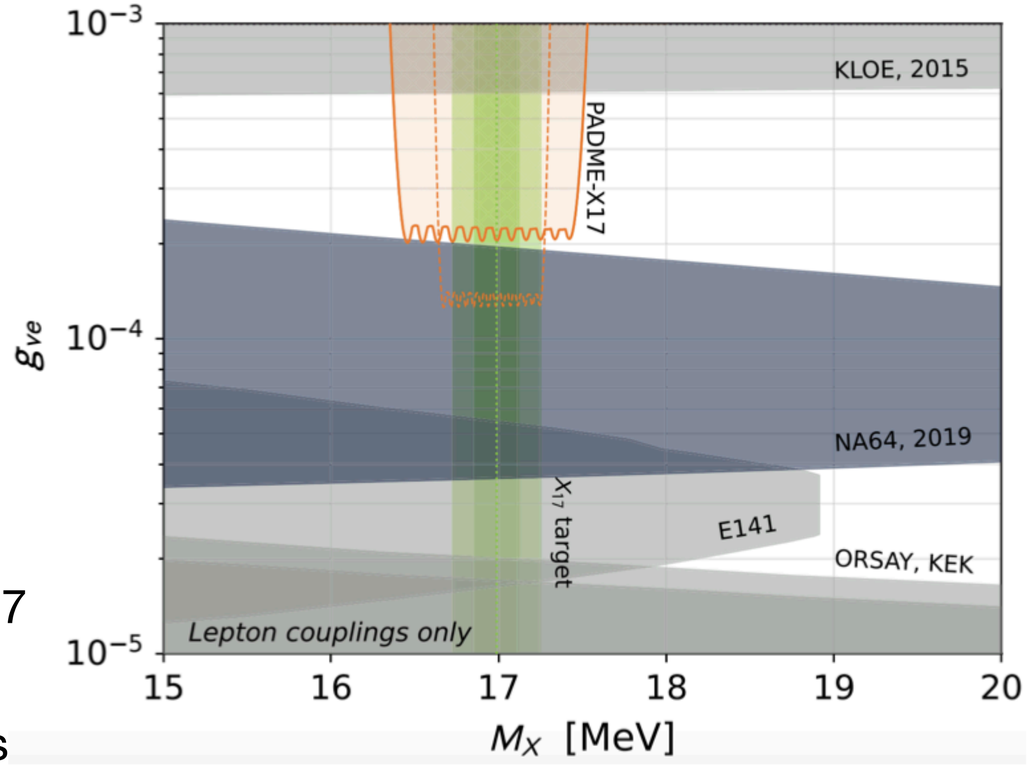
PADME





- Built at DAFNE for $e^+e^- \rightarrow \gamma A'$. Run-3 modified for $e^+e^- \rightarrow X17 \rightarrow e^+e^-$ production. Took data in 2022:
- 47 E_{beam} steps [16.35 MeV - 17.5 MeV] 10^{10} PoT each, covers X17 mass and coupling range
- Look for excess of two-cluster events per PoT (counting, not shape) (X17 coupling predicts ~1% excess)
  - back-to-back in CM frame
  - main analysis did not distinguish γ/e : If they see it, γ/e can tell Vector vs Pseudo-Scalar

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arxiv:2505.24797
WPCF 2023 presentation

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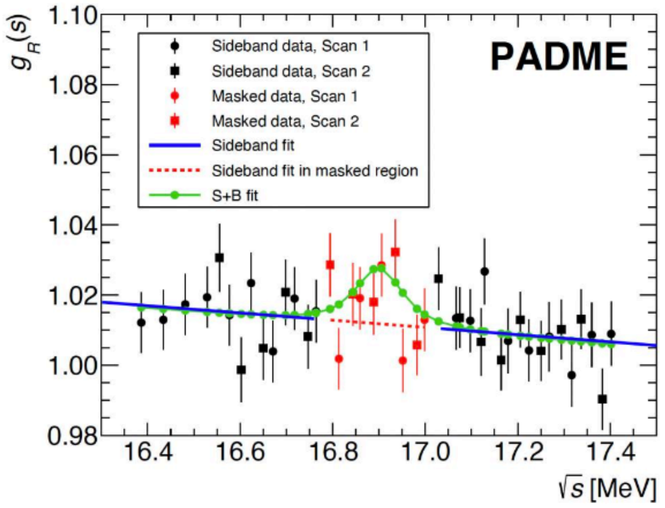
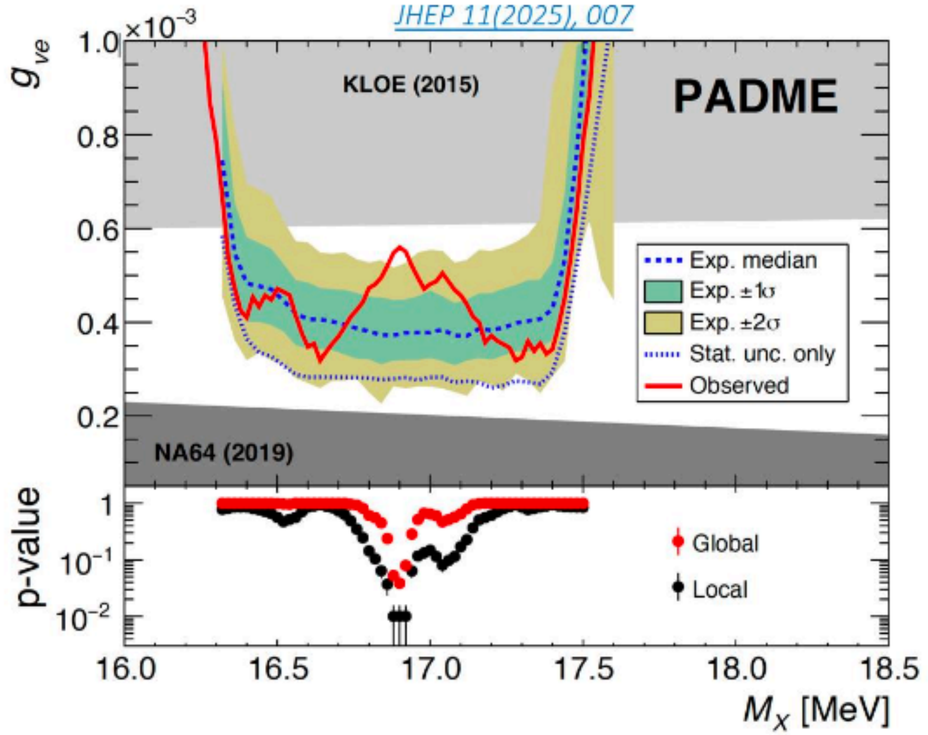
PADME

Blinding: (tested on MC)

- Automate scan over all E_{beam} find interval that minimizes χ^2 of a linear fit of g(√s) sideband regions
- Check that pulls are gaussian and have no √s dependence
- If fit is within 2σ of expected shape, open the box:
- (lots of post-unblinding checks)



JHEP 11(2025), 007



- M_X = 16.90(2) MeV, $g_{ve} < 5.6 \times 10^{-4}$ has ~1.7σ excess, including look-elsewhere
- e^- orbital motion in target smears the mass resolution! They model this, but to finish reaching NA64, they need more data

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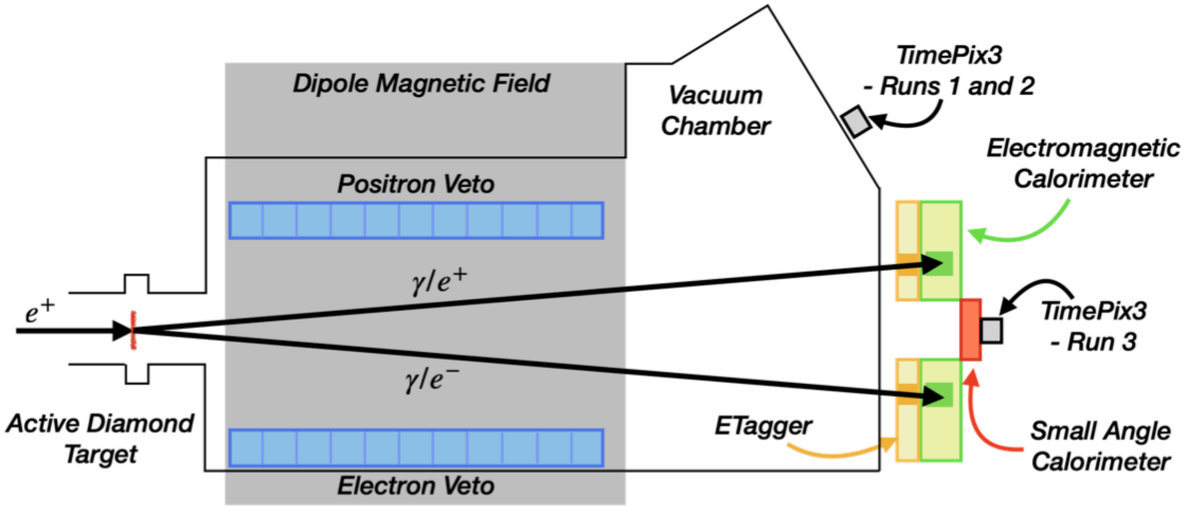
PADME 2025+



- Target moved downstream: increased acceptance
- PadMMe and TMM (uMegas) improve Etagging and beam monitor
- Run IV is on tape: 36 energy steps, 2x beam intensity, 2x detector acceptance ==> 4x data per point.
- future: maybe different target (Li/Be? W?) to reduce electron motion

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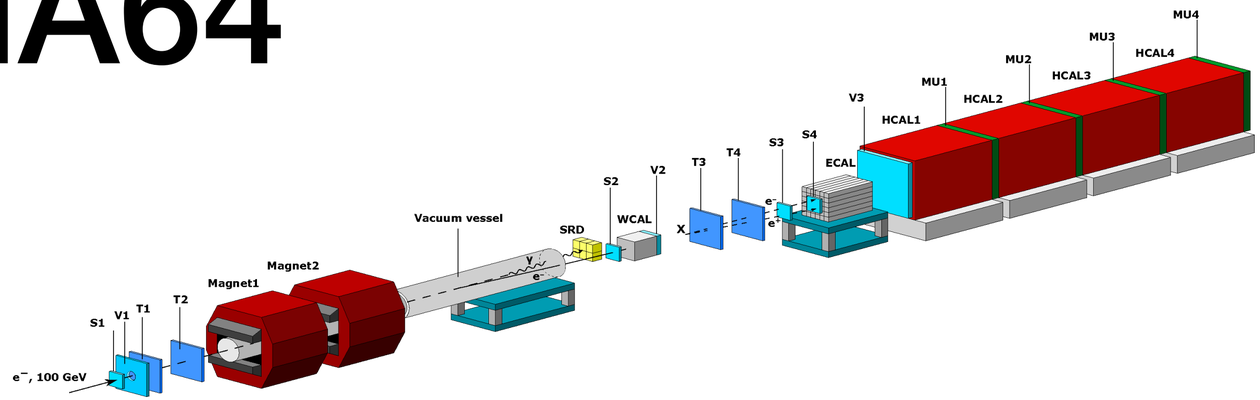
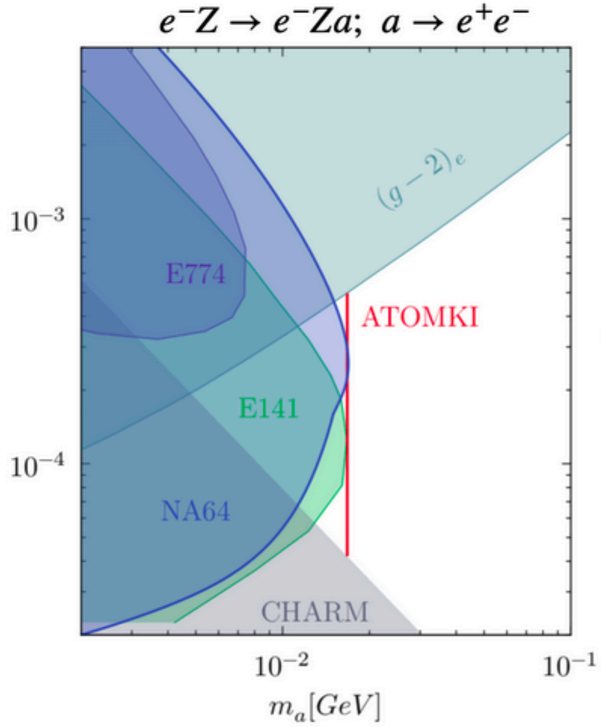
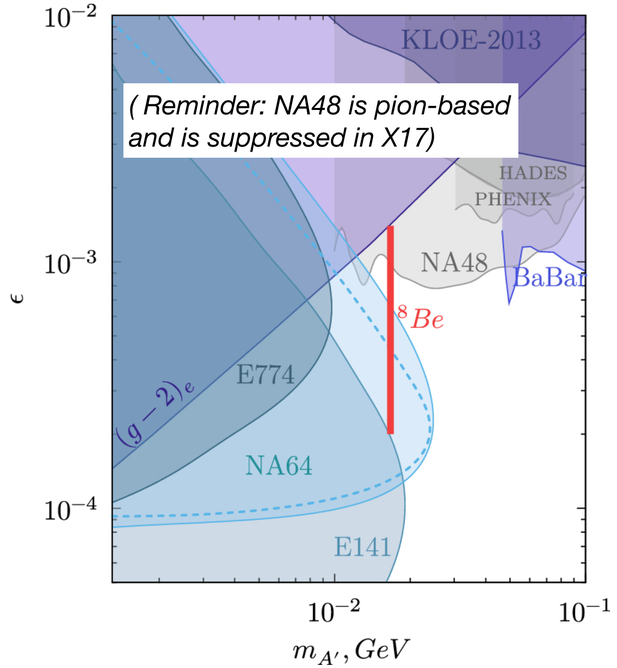
NA64

- e and mu fixed target experiment (SPS)
- 2020 combined analysis covers much of original ^{8}Be
- With the new setup, projected reach $\varepsilon \approx 1.4 \times 10^{-4}$ in ~2 mo
- Z+a pseudoscalar search (2025) with visible final states does not reach
- Other analysis ongoing (2026) may reach.





arxiv:2505.14291



PhysRevD.101.071101

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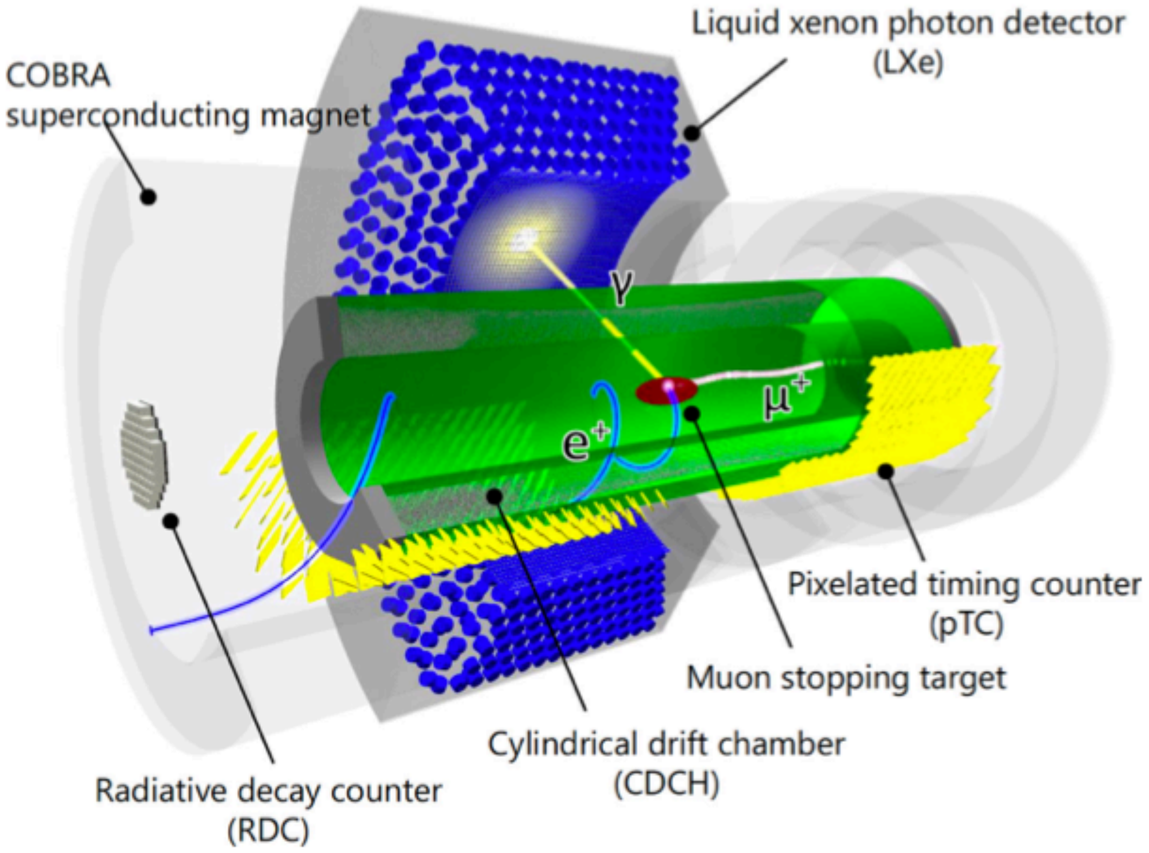
MEGII



- Built at PSI for $\mu^+ \rightarrow e^+ \gamma$ BR. Adapted to run $^7Li(p,e^+e^-)^8Be$. Physics run in 2023.
- Li target already present. Proton beam at E_{beam}=1.08MeV produces both 17.6 and 18.15 excitation.
- 75 M triggered events, ~300k e+e- pairs
- Look for excess of ~symmetric pairs with large opening angle
  - Resolution: 90keV momentum, ~5.5°

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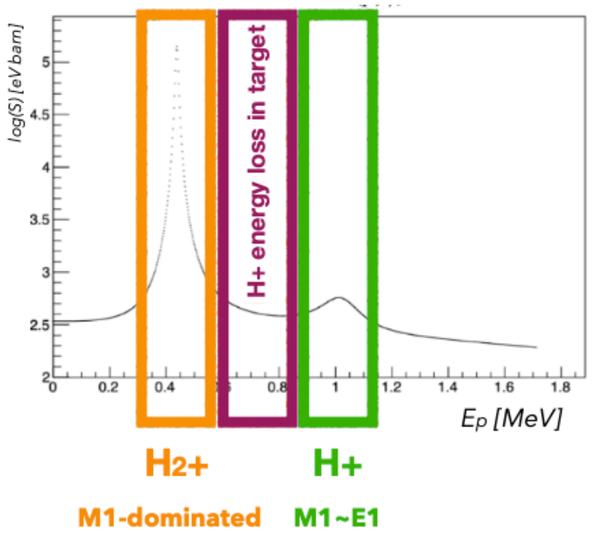
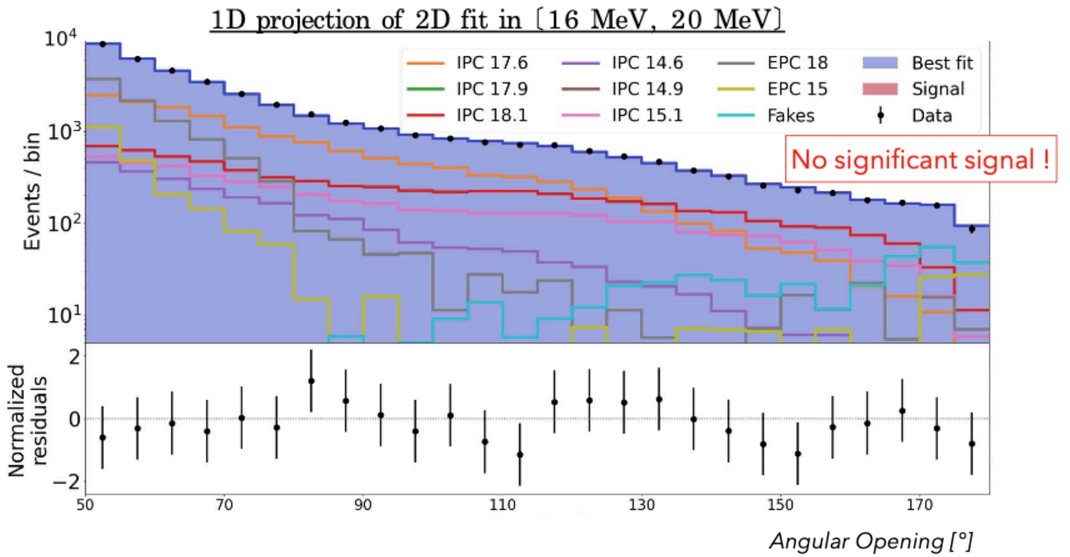
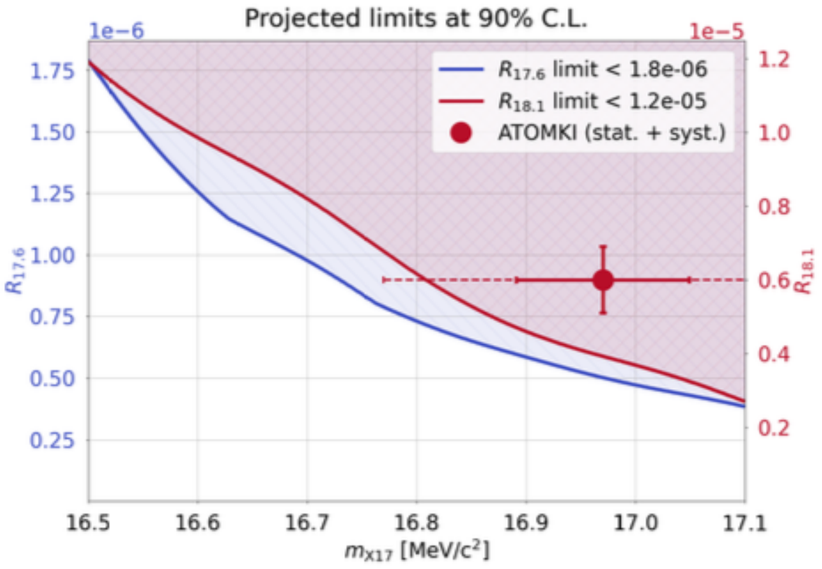
MEGII

- Limited by beam contamination and energy loss in target:
  - look at IPC angular slope to distinguish resonances





- Blind the signal region 16-20MeV, 115-160° opening angle
- Use sidebands to build templates for signal region (combination of IPC, EPC, fake coincidence, + signal)
- ~10 events compared to O(100) expected from ATOMKI coupling: Excluded at ~2σ



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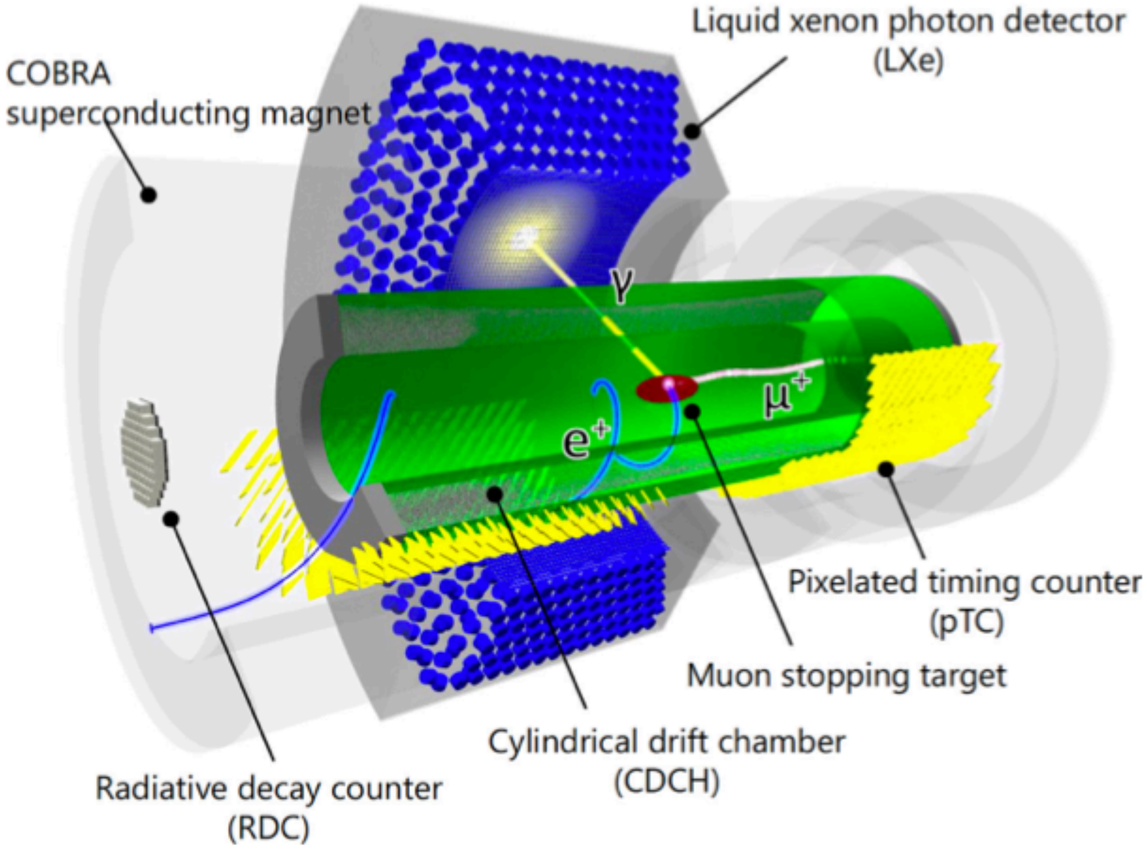
MEGII 2025+

"In preparation" as of March 2026

- Improved accelerator configuration
- Pure H+ beam
- Thinner LiPON target (less energy loss)
- Lighter target support to reduce EPC



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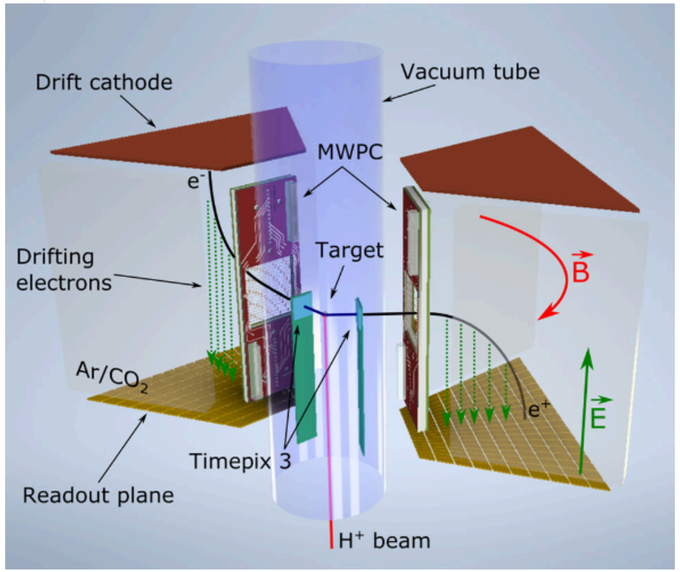
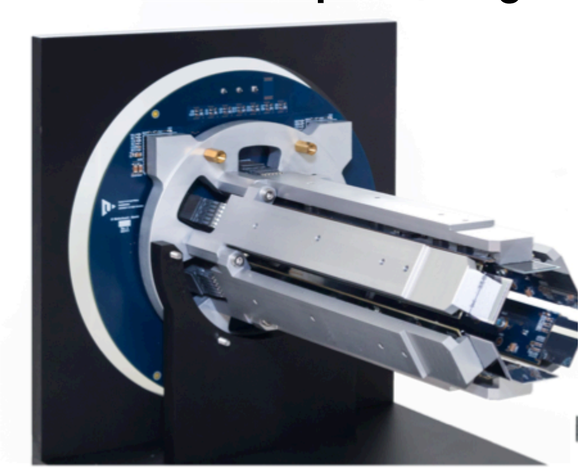
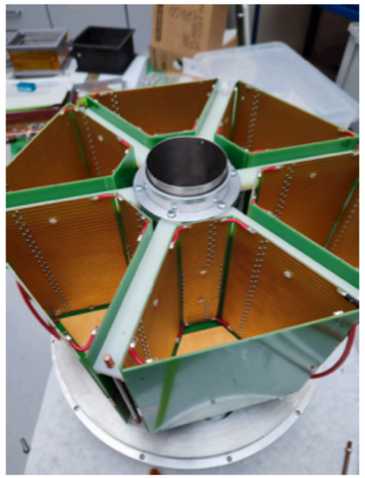
COPE*

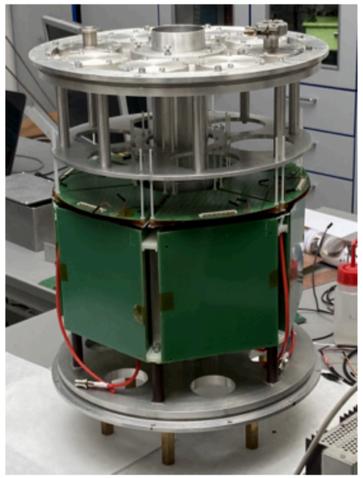


200um Timepix3 hexagon

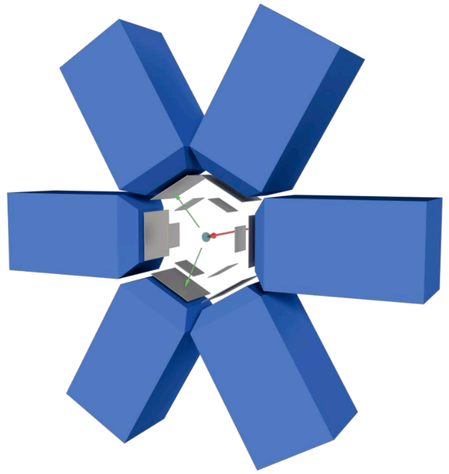


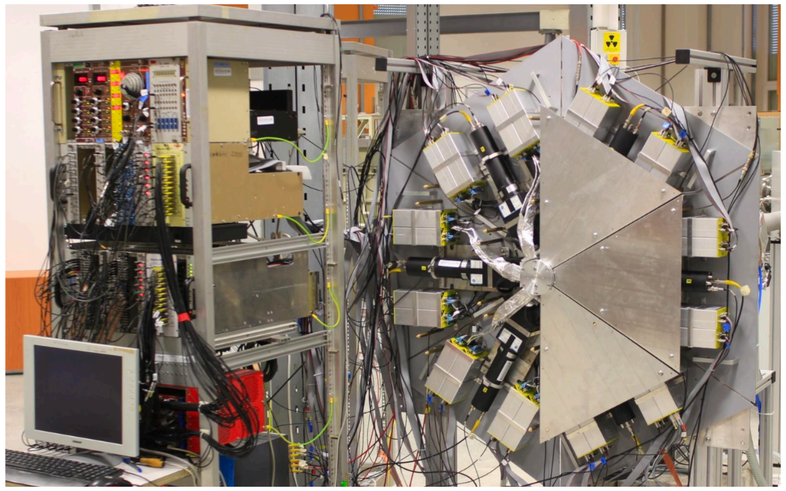
TPC units assembled - but no readout yet





- COmpact Positron Electron spectrometer @ CTU Prague
- Proton beam on 7Li to produce 8Be and 4He
- Thinned Timepix3 ASICs in vacuum, MWPC+TPC in toroidal field
- And then in 2026 they built this: (?)





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ECT* X172026 update

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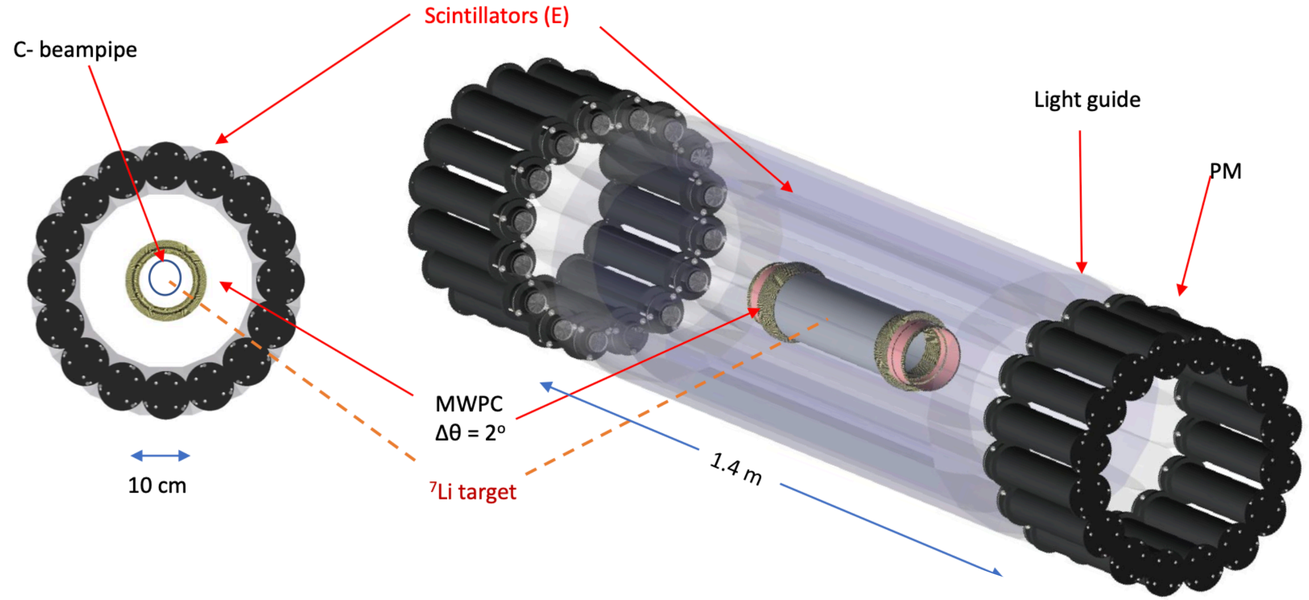
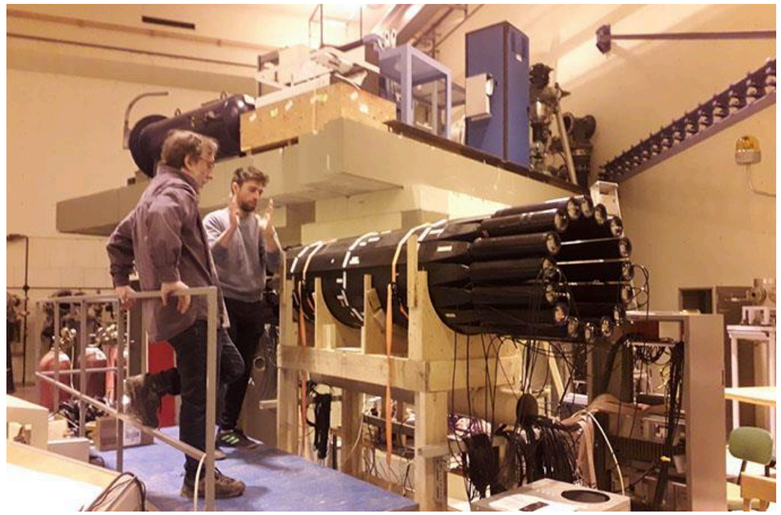
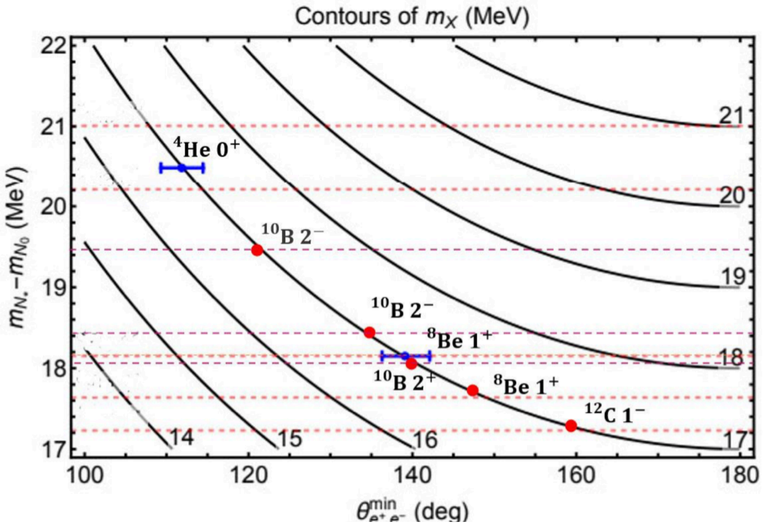
Montreal/Project X17







- High-acceptance, high resolution (~2º) verification of ATOMKI using DAPHNE parts, MWPCs, Scints
- Commissioning. Planning to take ^{8}Be data 06/2026
- Future prospects for ^{10}B, ^{12}C, ^{4}He, ... GDR also accessible

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(ECT2026 presentation)

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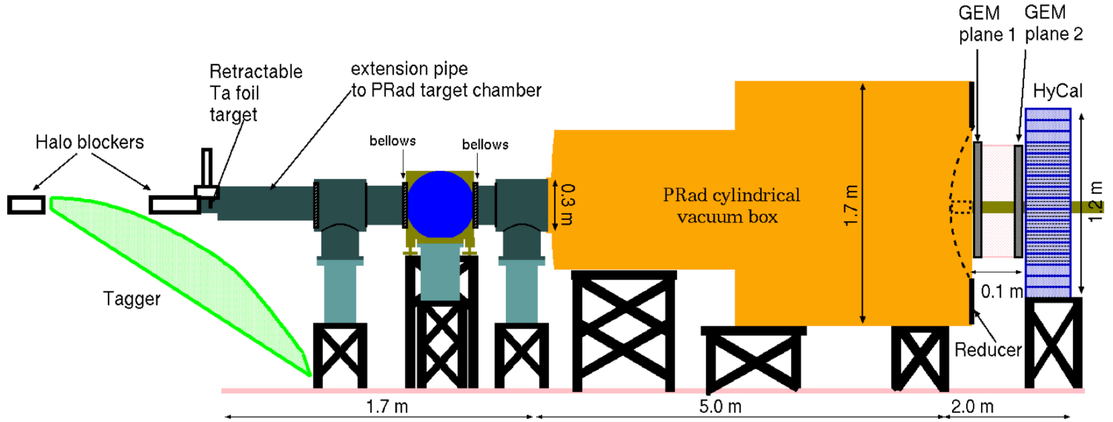
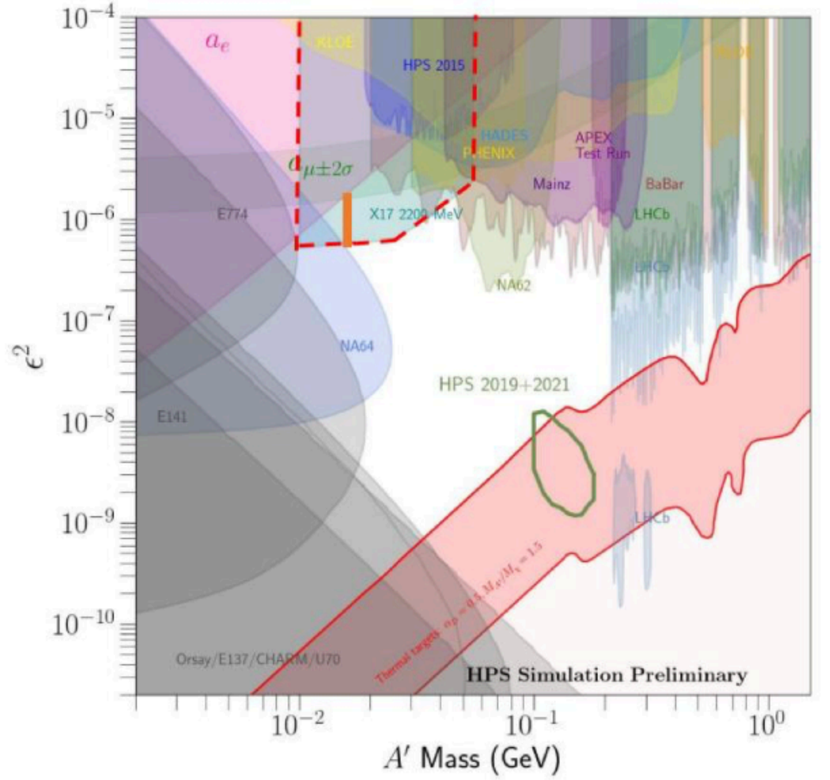
PRad



- Detect full e-e-e+ in fixed target e- (JLab)
- Add γ-tagger, 1um Ta targets, GEM tracker planes
- Projection of ~~2.3σ~~ 5.1σ coverage (red)
- Approved for **60** days, PAC50 (2022)
- Installation ongoing.
- Expecting to run in July 2026

E_{beam} = 2.2 GeV; I_{beam} = 50 nA; 40 PAC days



ECT* X17 2026

arxiv.:2301.08768

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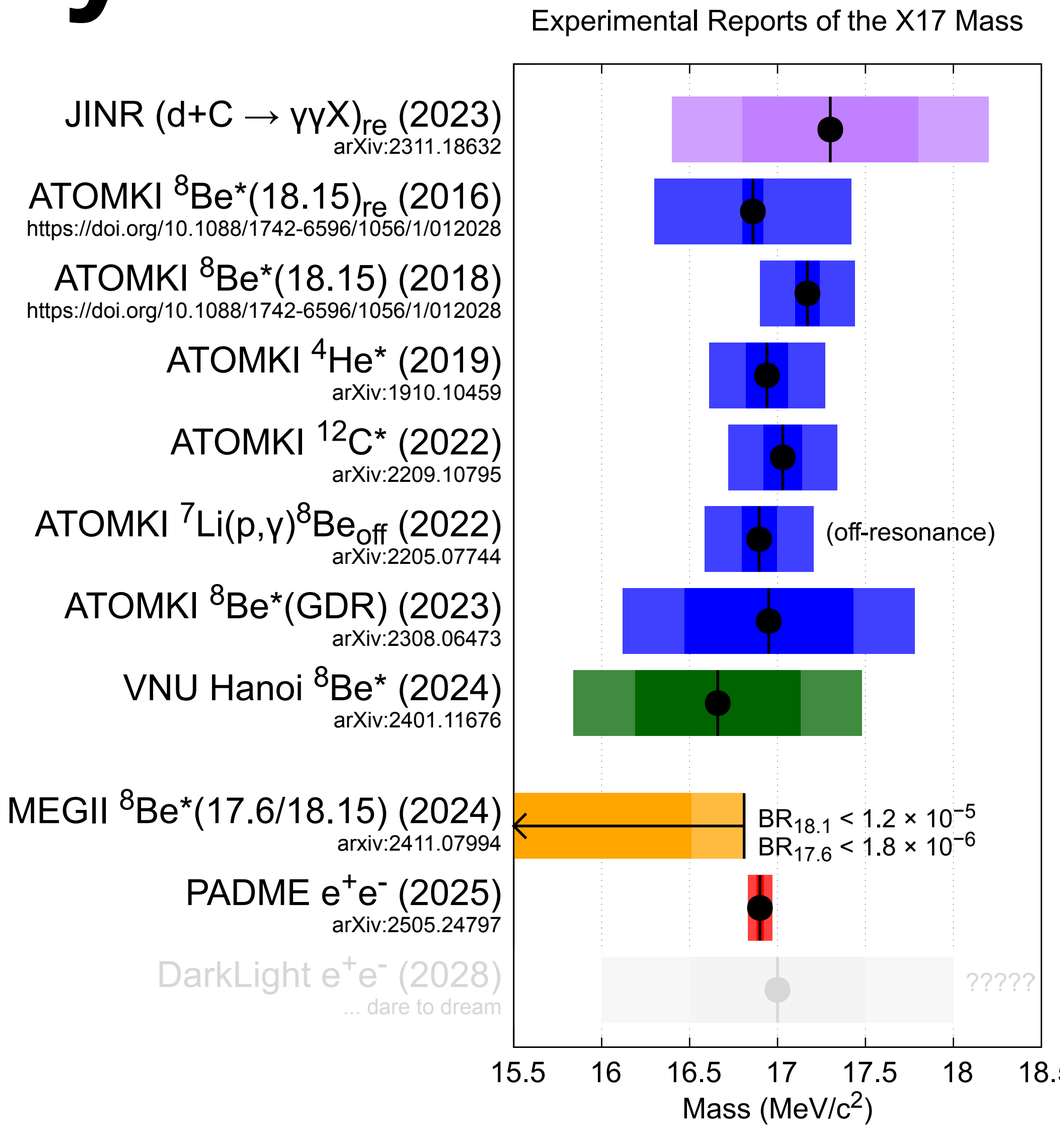
Summary

- Anomalies persist, and PADME is a first real resonant production hint
- Nuclear X17 signals continue to appear, not all from ATOMKI group
  - And mild tension from MEGII.
- Lots of theories, still no SM explanation!
- 2023: "*This [area] is exciting and timely. The measurement/search is needed, and it will receive significant attention if completed before their competitors.*"



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Community Report: https://doi.org/10.1140/epjc/s10052-023-11271-x

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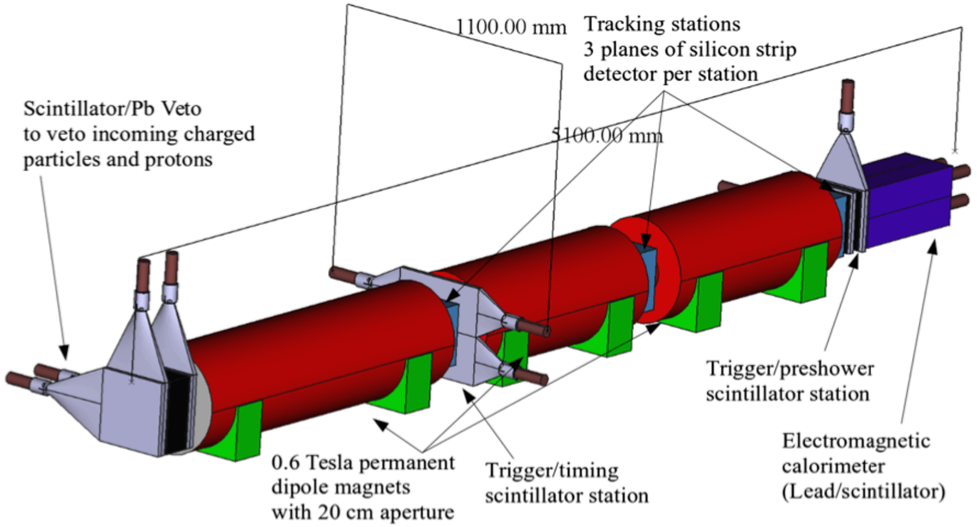
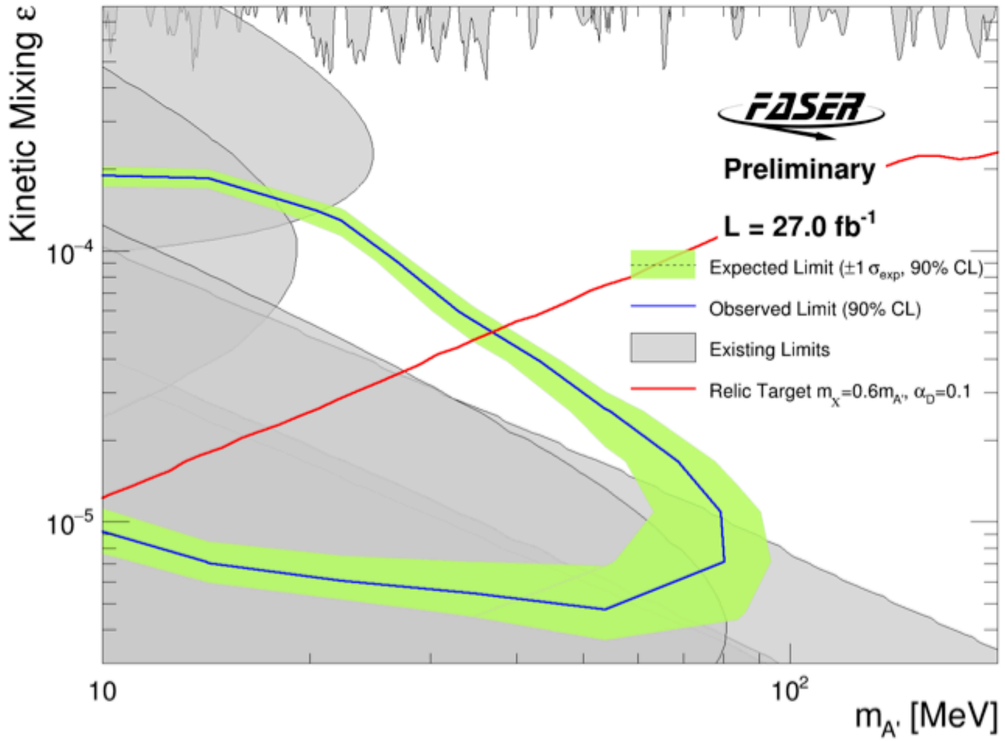
FASER





- ForwArd Search ExpeRiment, 480m downstream of ATLAS at LHC
- ECAL + Tracking stations with long dipole magnets
- Look for boosted A' decay to e^+e^- inside FASER volume.
- Beats NA64 only from below
- Prelim 27fb^{-1} from 2022 run closes/double-covers low-coupling

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arXiv:2305.08665

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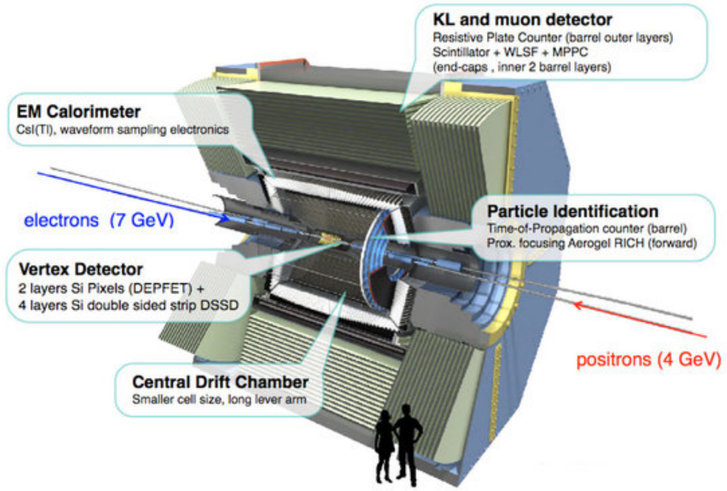
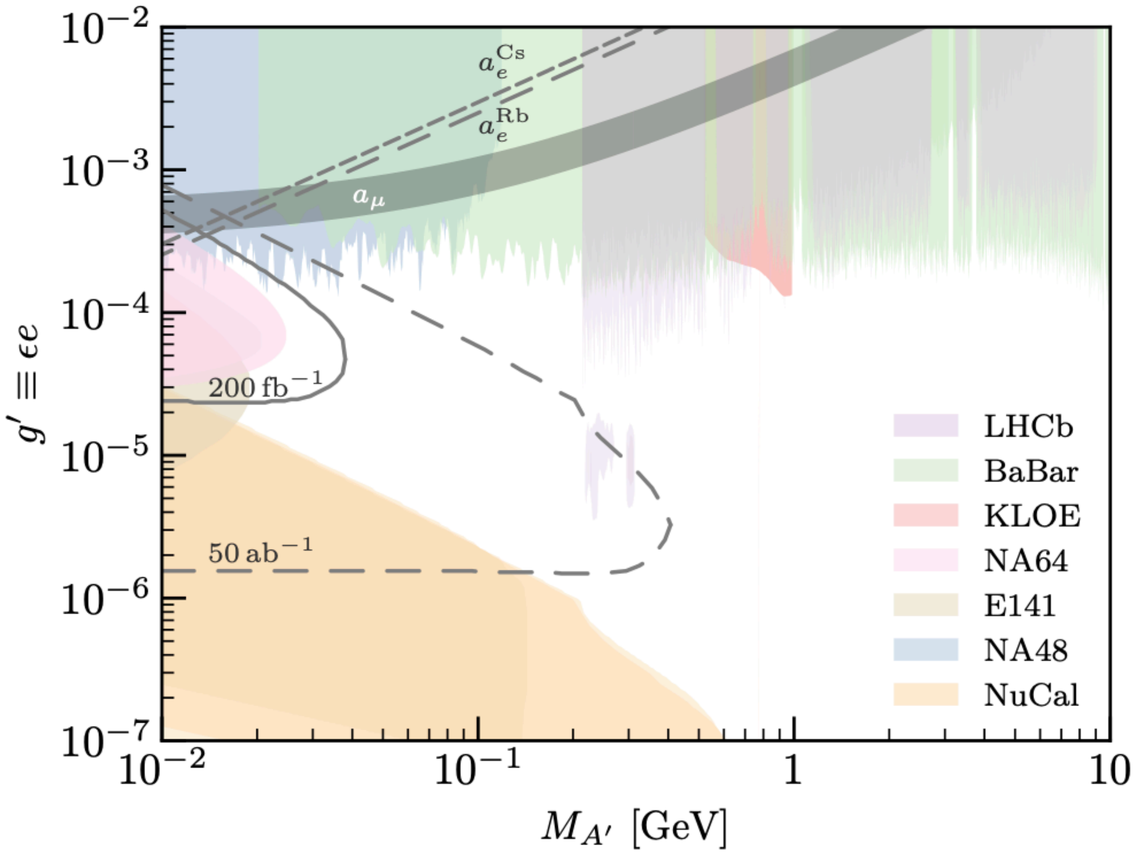
Belle-II





- Direct measurements don't reach down far enough even with full dataset. arxiv.:2012.04190
- X17-specific search (right) uses displaced vertices in J/Ψ decay
- ~200fb^{-1} collected as of 2023, 50ab^{-1}, expected by ~2025
- Analysis underway. **Claim that existing stats enough to exhaust protophobic X17 region** ($2\epsilon_u + \epsilon_d < 0.1\epsilon_u$).

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arxiv.:2203.03280

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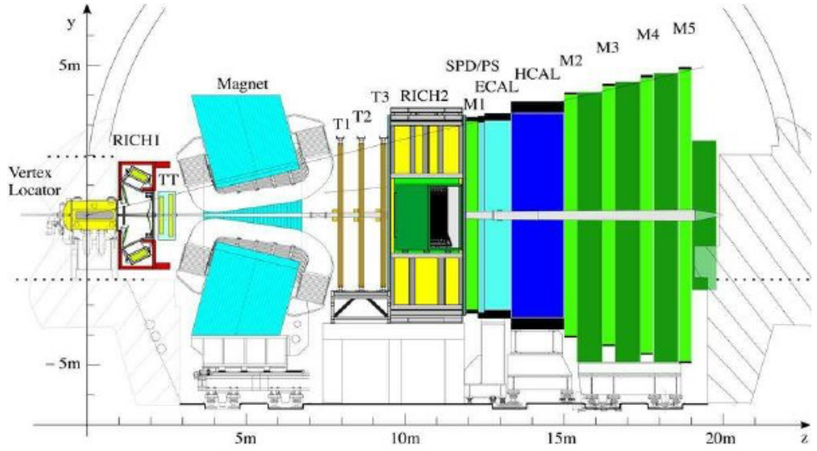
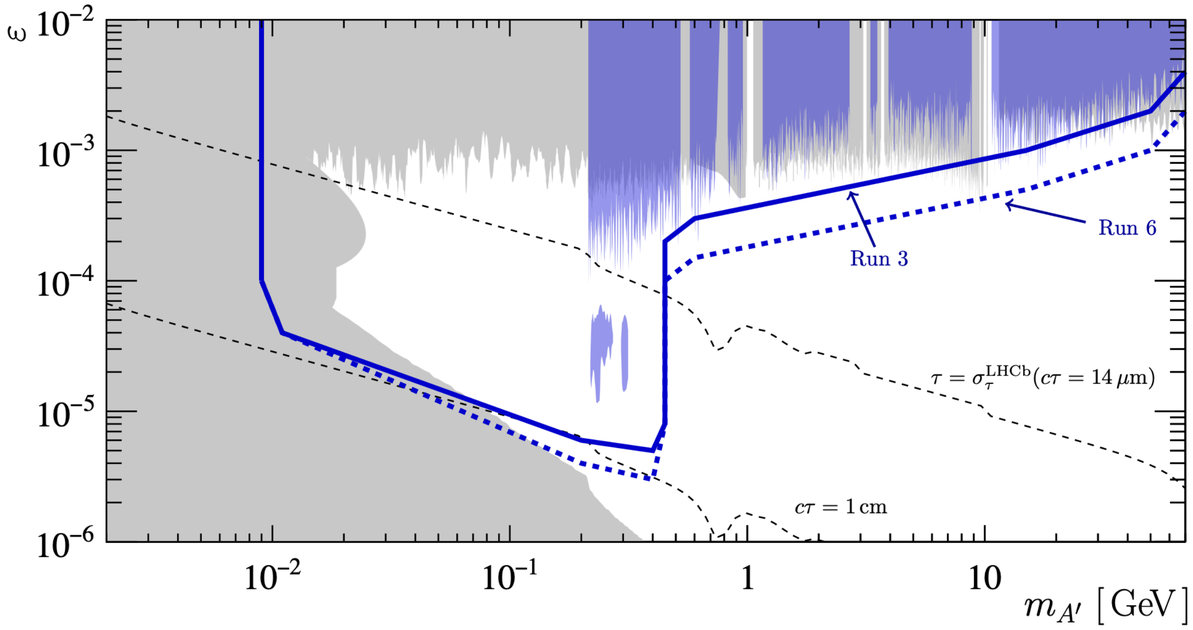
LHCb



- Upgrade for current run allows softer final states to be recorded
- 'recent advances' in trigger enable e+e- final states
- Can exhaust parameter space even with protophobic with sufficient data, (solid blue line, 2022-2026)
- No news yet (about dark matter) in 2024...



arXiv:2203.07048

(P. Ilten paper (arXiv:1801.04847) allows to recast simple dark photon measurements in more complex models)

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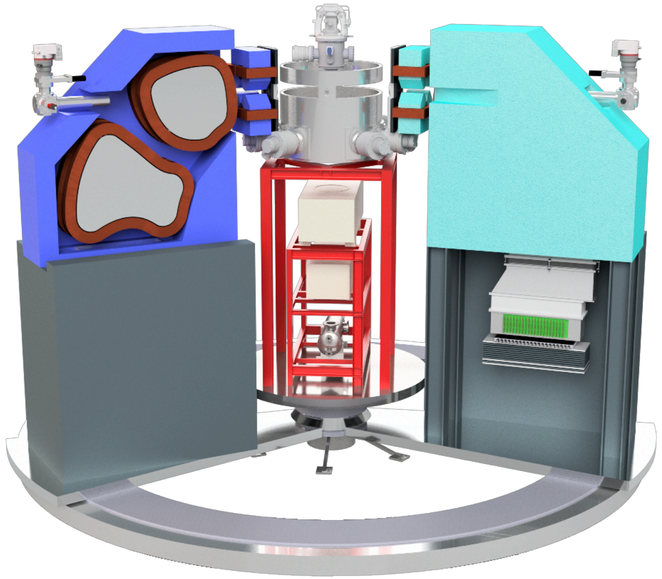
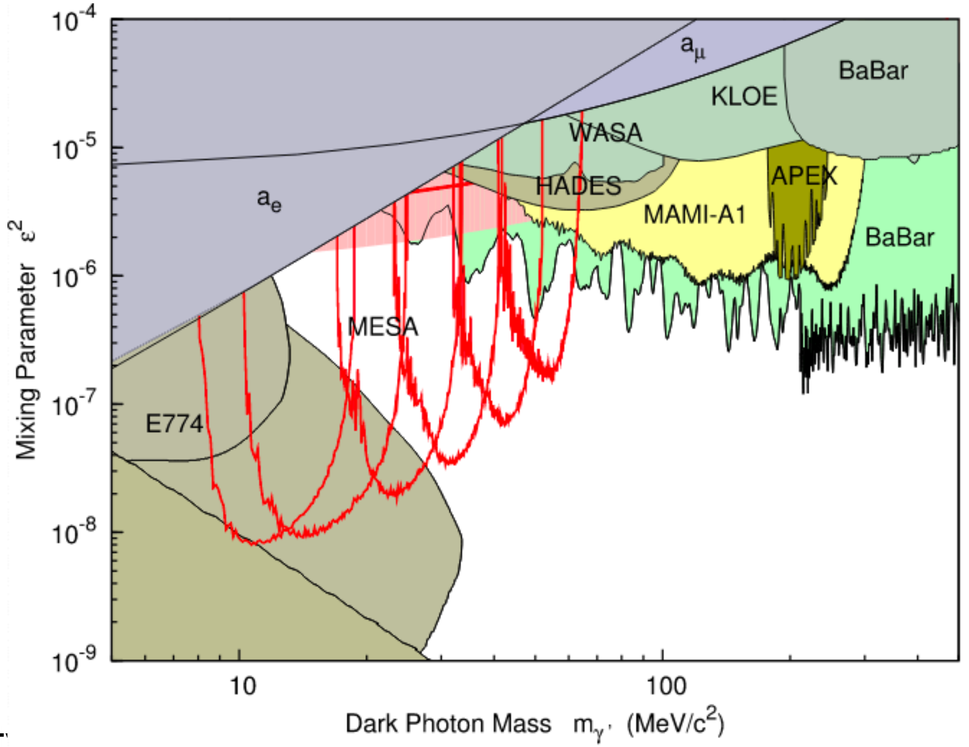
MAGIX





- Twin spectrometer, gas target @ MESA, 0.1MeV resolution
- Projects to reach X17 anomaly region w/ ~6mo at design luminosit,
- Direct e-X and also γD → e+e-pn bump-hunt
- MESA still under construction
- MAGIX start-up "shortly after" beam available

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arxiv:2307.02181 arxiv:2402.01027

https://magix.uni-mainz.de/physics.php

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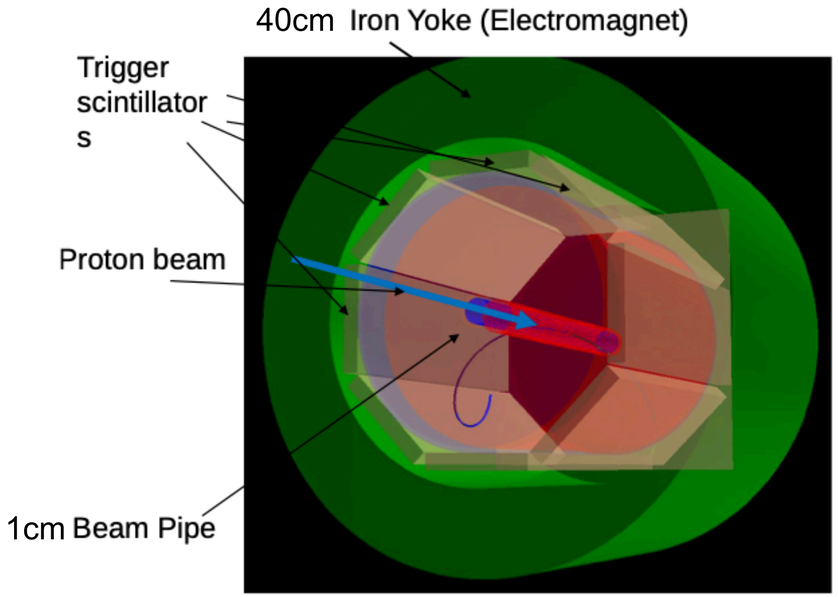
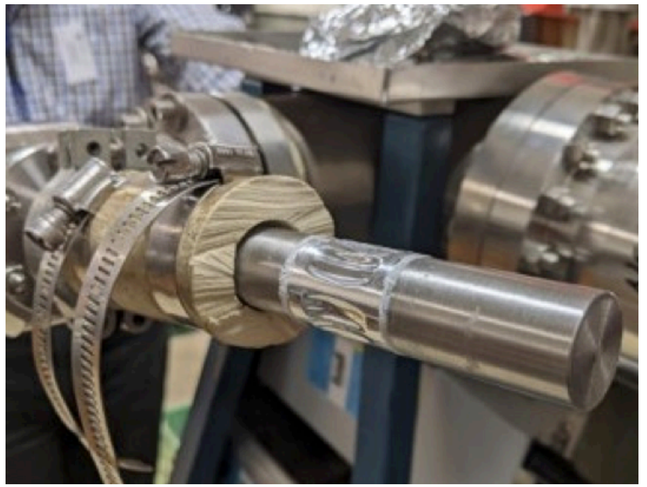
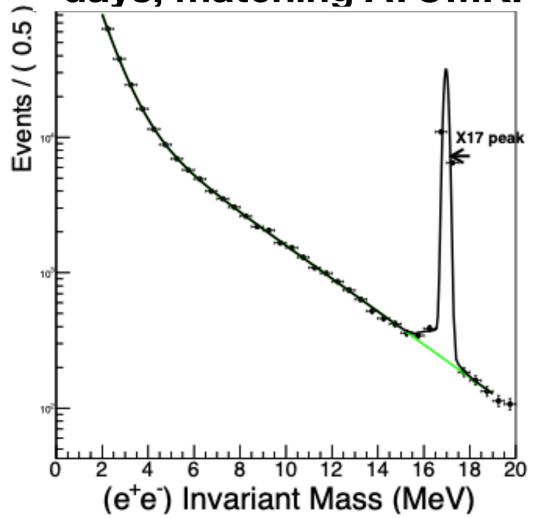
Melbourne TPC



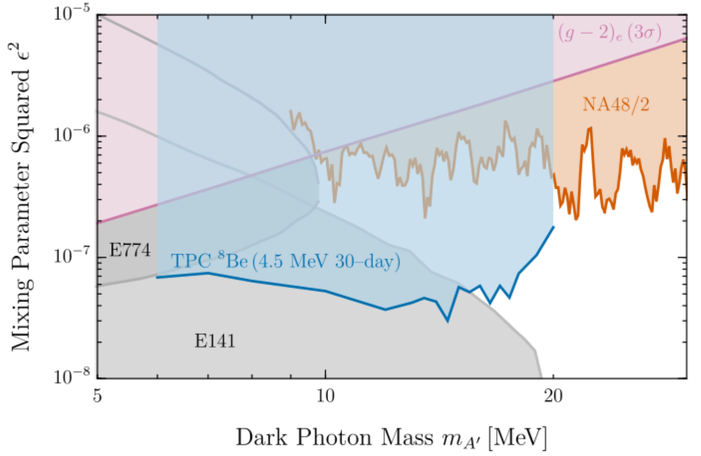
Prototype Chamber



Simulated Yield with 30 days, matching ATOMKI



- Purpose-built TPC for e+e- tracking, scintillating outer radius for trigger
- proton beam + target in vacuum, 50um mylar-window beampipe
- 8Be states off Li target, many other targets envisioned.
- Simulated including multiple scattering --> σ_M~100keV
- Proposed, some prototypes. No timeline yet.



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August presentation **arxiv:2302.13281**

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In the Backup

- Isotope shifts: New results don't need new physics, but are not sensitive enough to exclude X17.
- Additional analysis of ATOMKI results increases tension
- Belle reports data on tape
- COPE* making a lot of progress
- PADME releases more details of off-resonance analysis
- PRad schedule more concrete

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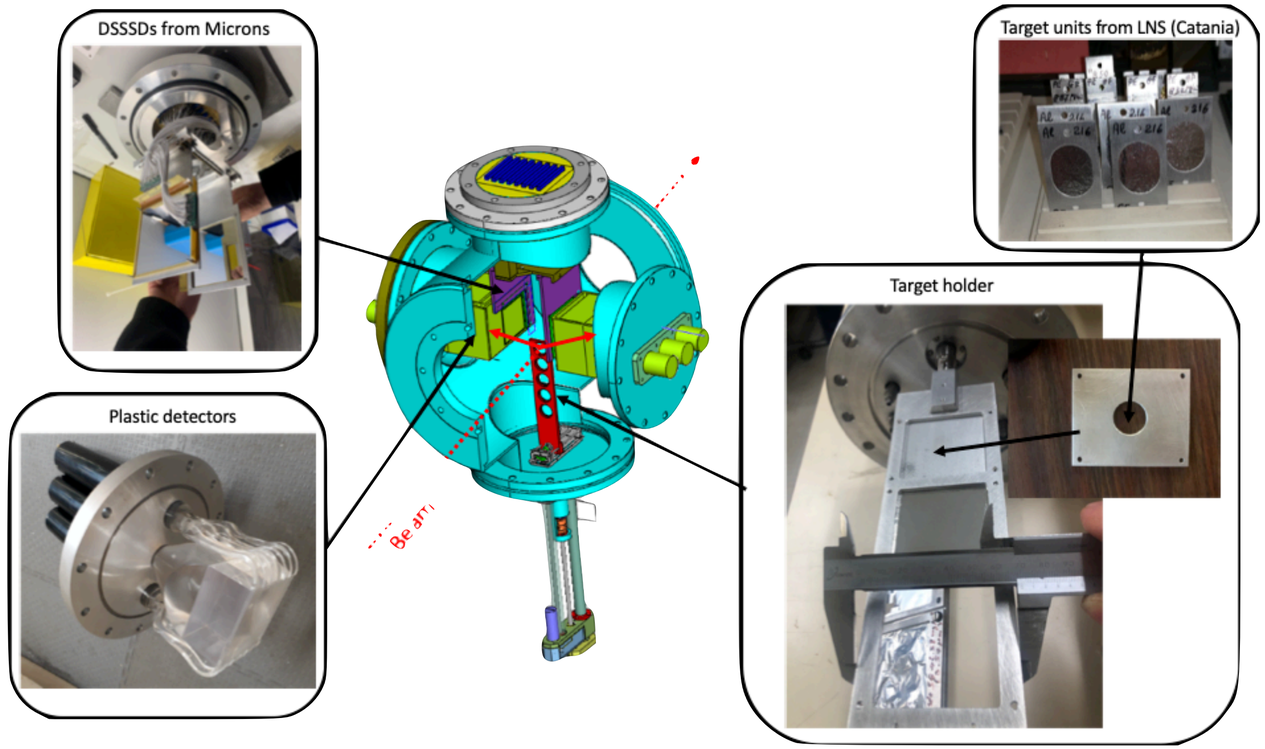
New JEDI

- LiF target on C backing to study $^{8}Be^{*}$
- Double-sided Si Strip Detectors: energy loss and angles for e+e-
- Plastic Scintillator: energy and veto of external events.
- Geometry chosen to focus on X17-like events



- Commissioning in 2020 at Rež tandetron, 470 and 1070keV proton beam.
- Multiple targets to disentangle fluorine contributions to signal
- Proposing MeV-scale program at SPIRAL2 (France)

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EPJ Web of Conferences 275, 01012 (Feb, 2023)

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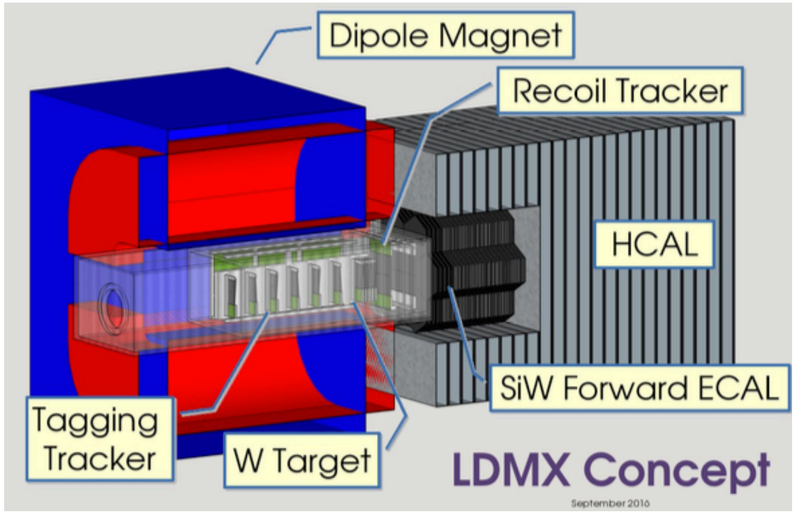
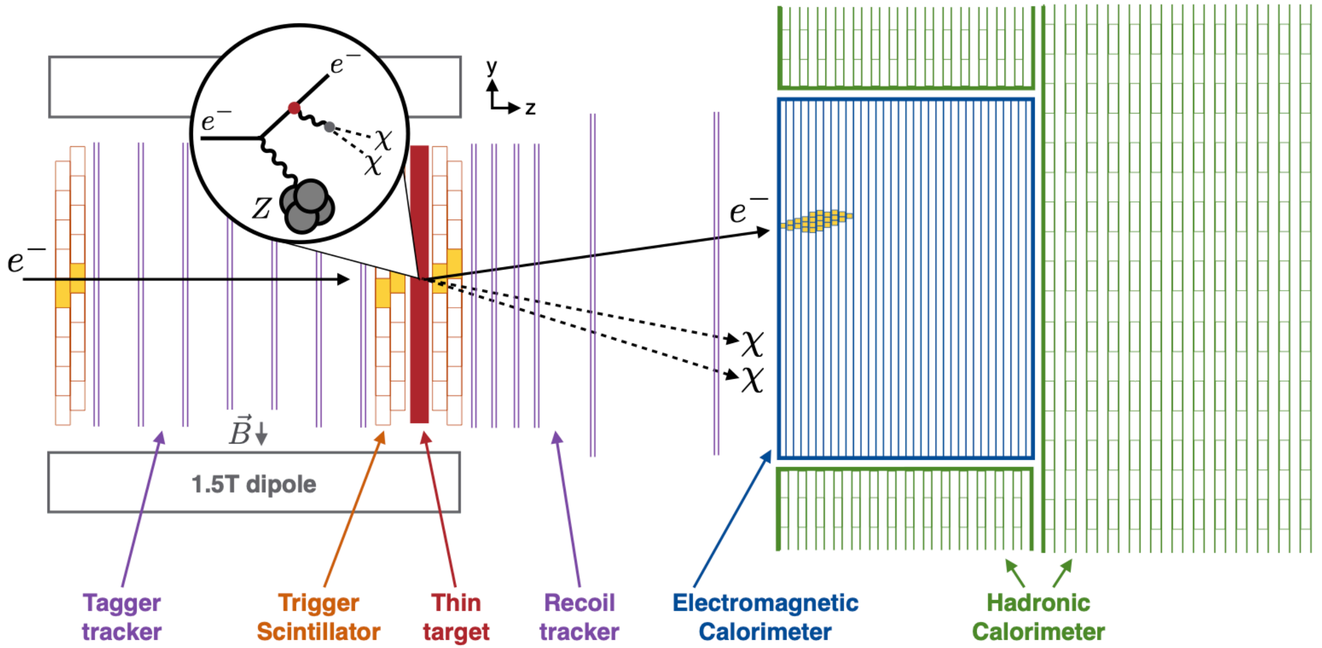
LDMX





- LCLS-II (SLAC) produces low-current, parasitic multi-GeV e^- beam
- Reconstruct e^- and recoil nucleus to detect invisible final states

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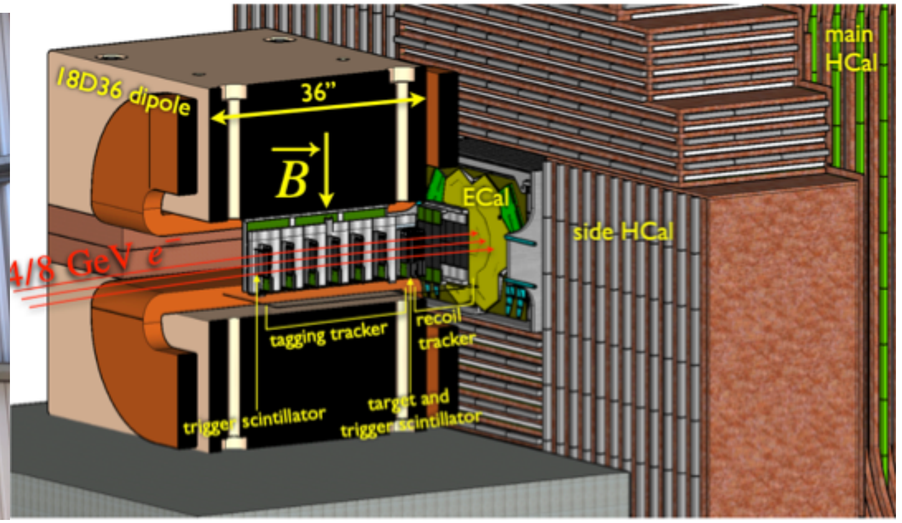
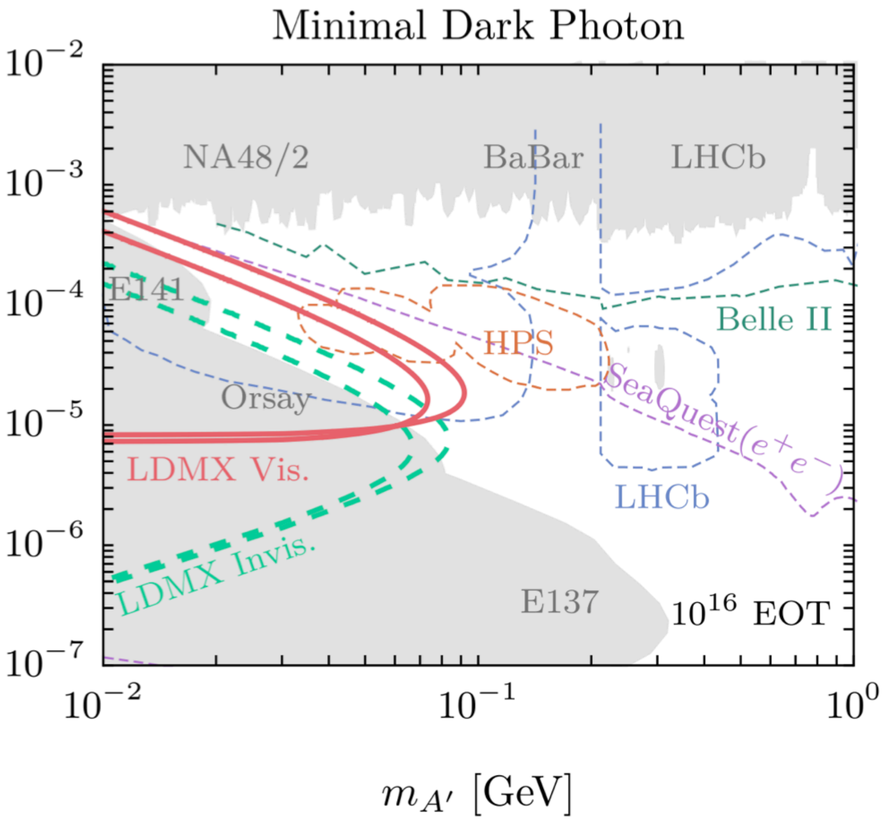
LDMX





- They have the magnet at SLAC -- needs refurbishing
- Mainly built for search via invisibles.
- Can do displaced vertices, but doesn't exhaust X17 -- even in high integrated luminosity assumption
- Starts in "2-3 years after establishing funding profile", several year run to reach full 10^{16} e.o.t. shown in plot

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arxiv:2203.08192

June 2023 status

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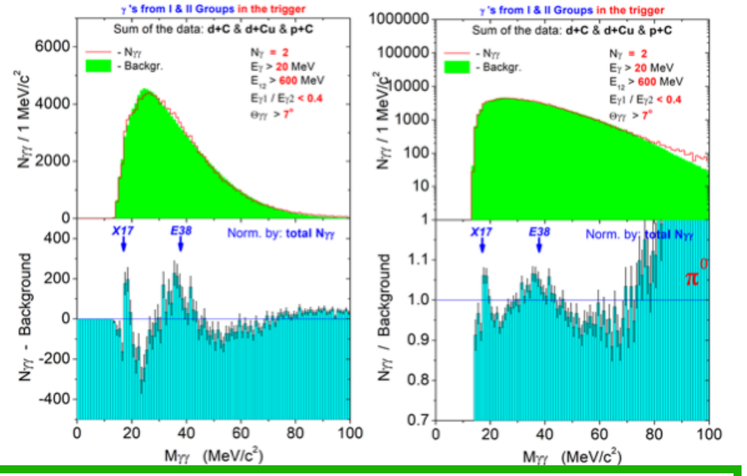
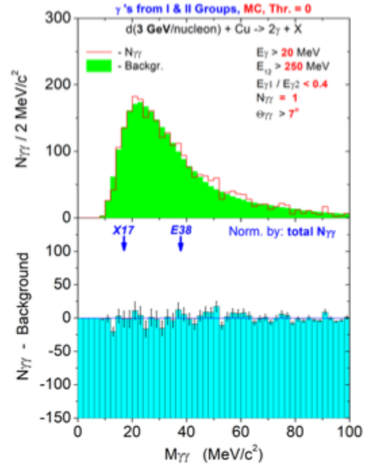
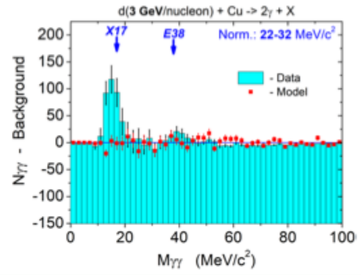
X17 at JINR

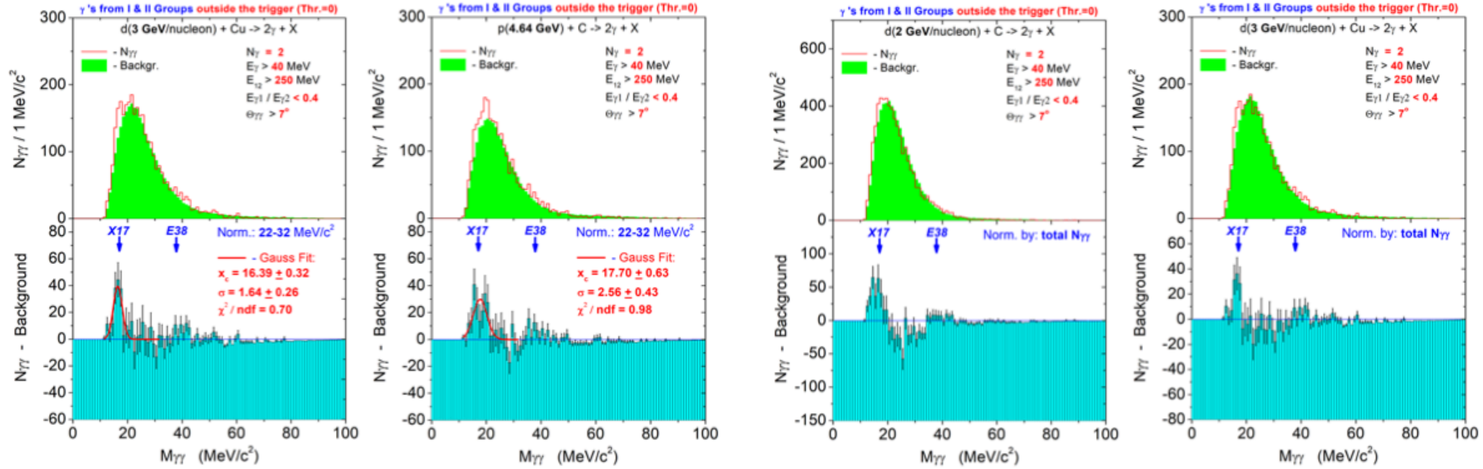
- A variety of datasets, cuts, and background normalizations...

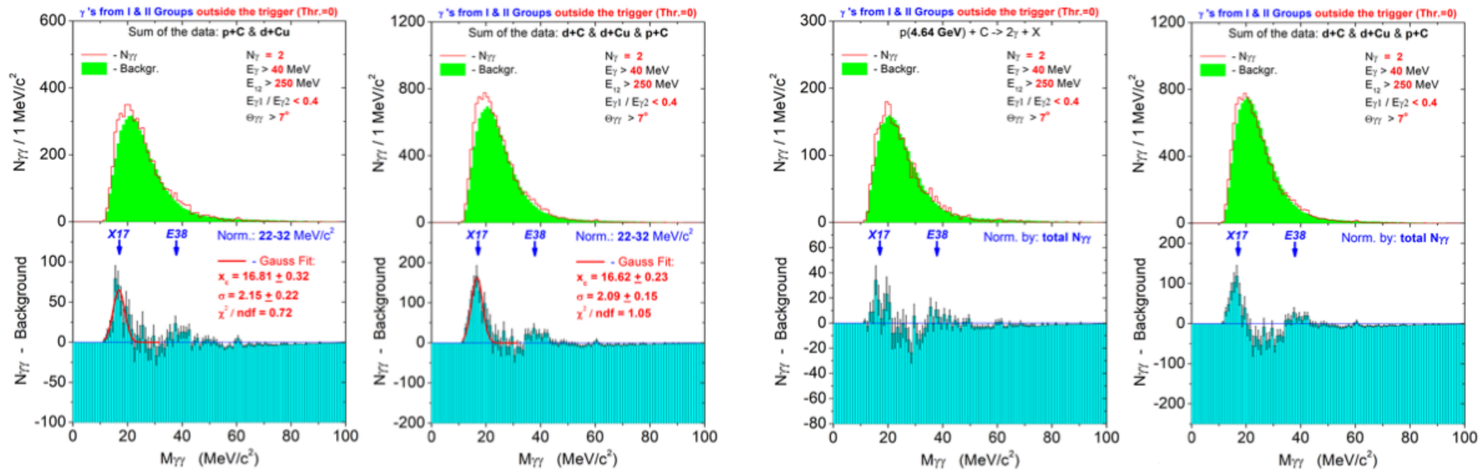




Monte Carlo and ratio to data







arxiv:2311.18632

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Older Experiments

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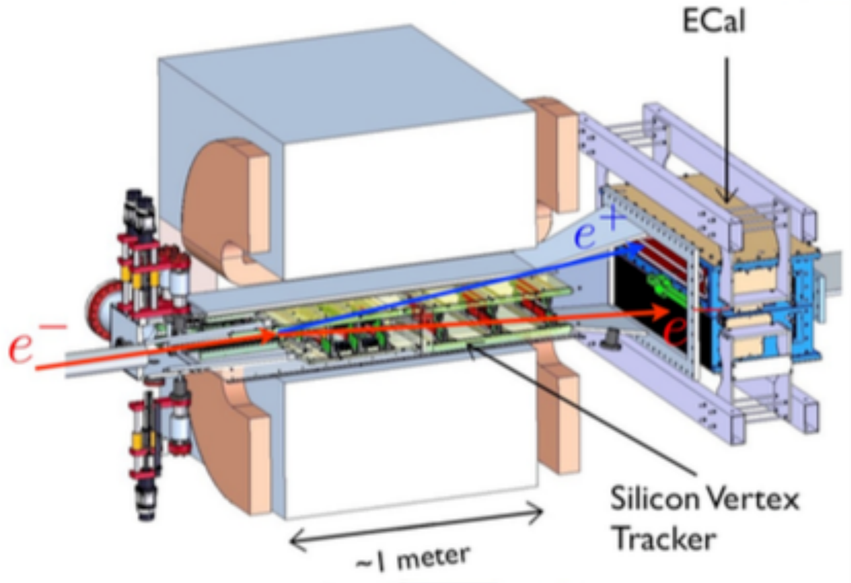
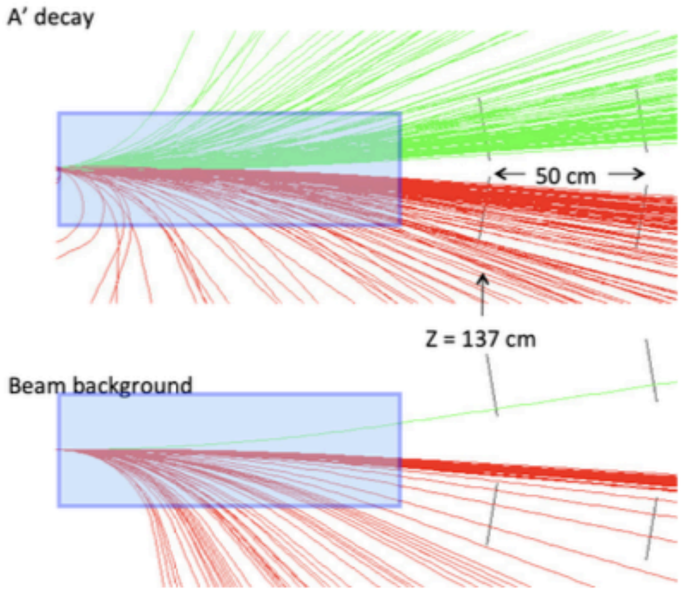
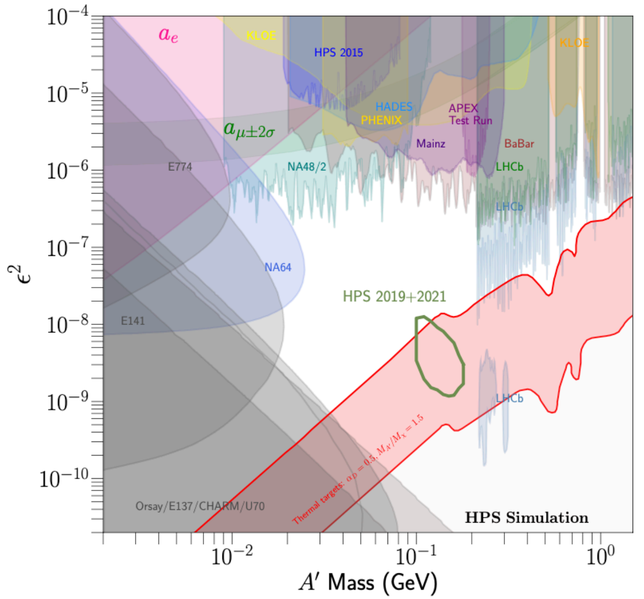
HPS



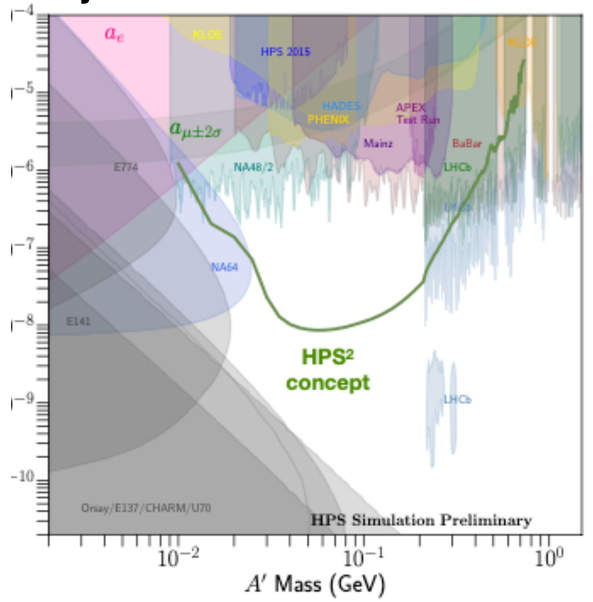
- Tracking very close to target+beam
- Prompt and displaced vertices for SM decay
- 107 of 180 run-days remaining.
- studying HPS^2 concept to reach low mass:
  - new trackers behind the magnet trade vertex resolution for mass resolution



Projected Exclusion w/ Existing Data



Projected Exclusion w/ 150d HPS^2



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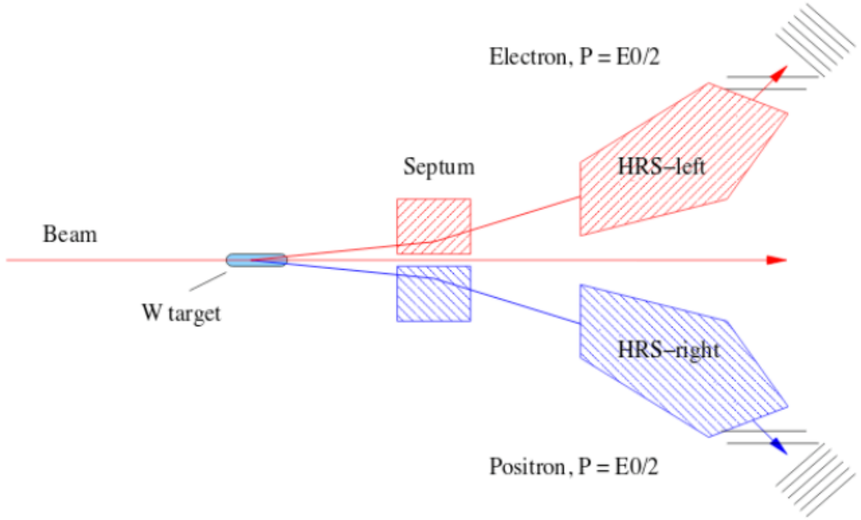
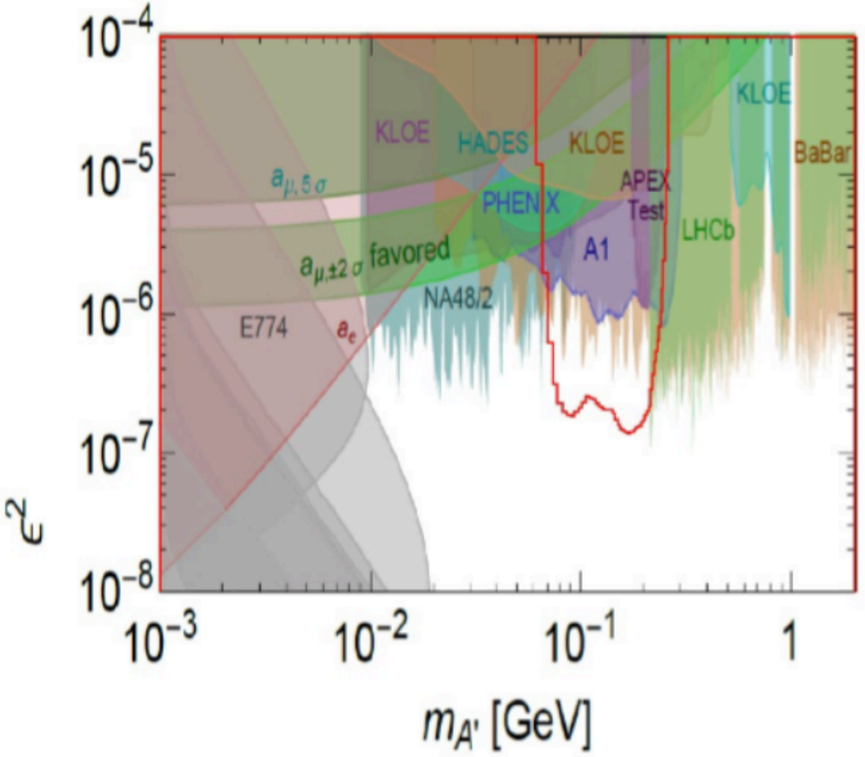
APEX





- e+e- mass resonance, very low opening angles
- Plot includes 2020 data and future proposed settings -- current design can't reach X17

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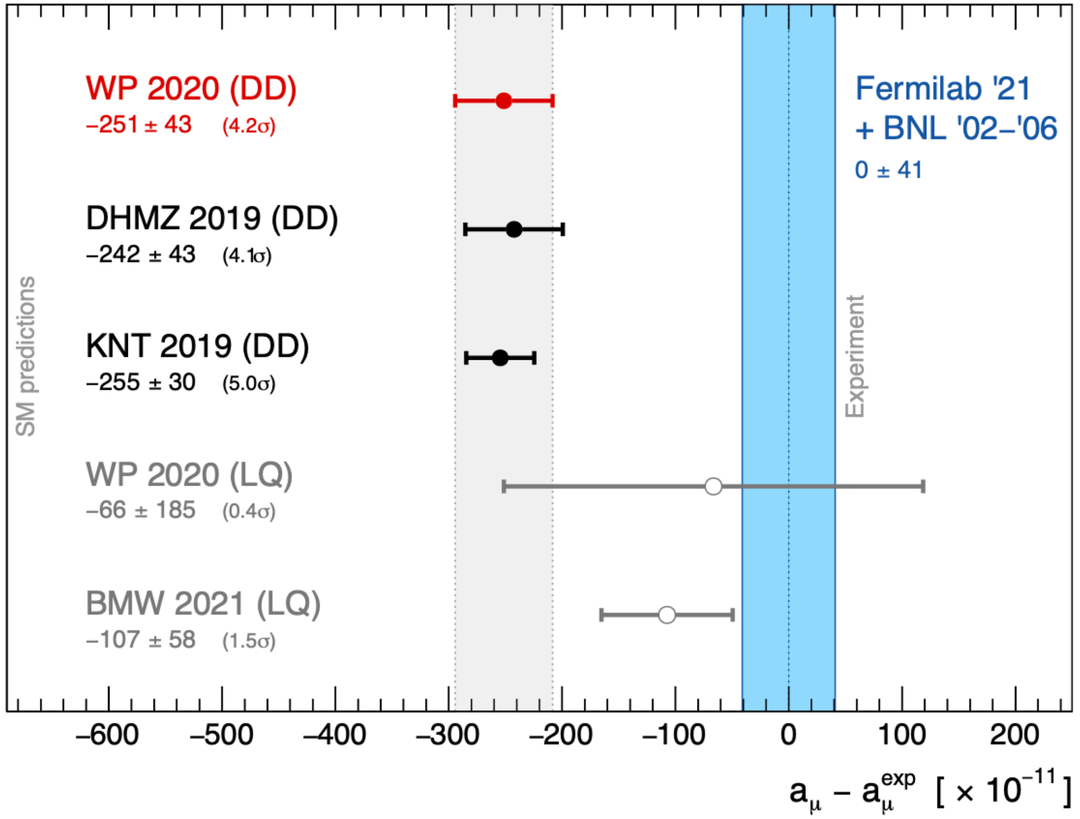
g-2 Lattice Issues

- Data-driven calculations suggest smaller hadronic contribution to magnetic anomaly
- Lattice QCD suggests larger, but caveats. Hence not used in PDG average



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Inferring X17 properties

- 8Be 18.15 MeV 1+ -> 0+:
  - If J_X=0, then L=1 and P=-1 ==> X can be a **pseudoscalar** produced in P-wave.
  - If J_X=1, then L=0,1,2 and P=+1,-1,+1 respectively ==> X can be ~~vector in P-wave~~ or **axial vector** in S- or D-wave.
- 4He 20.21 MeV 0- -> 0+:
  - If J_X=0, then L=0 and P=-1 ==> X can be a **pseudoscalar** produced in S-wave.
  - If J_X=1, then L=1 and P=+1 ==> X can be an **axial vector** in P-wave.

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from Daniel Firak (SBU)

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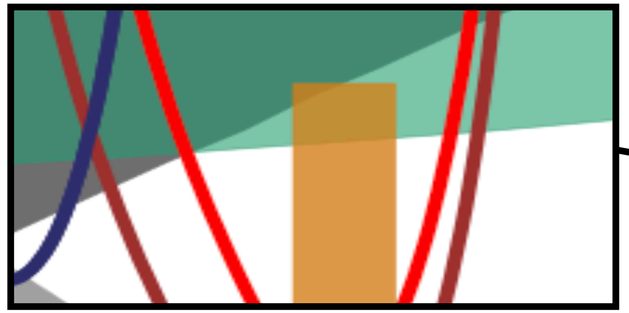
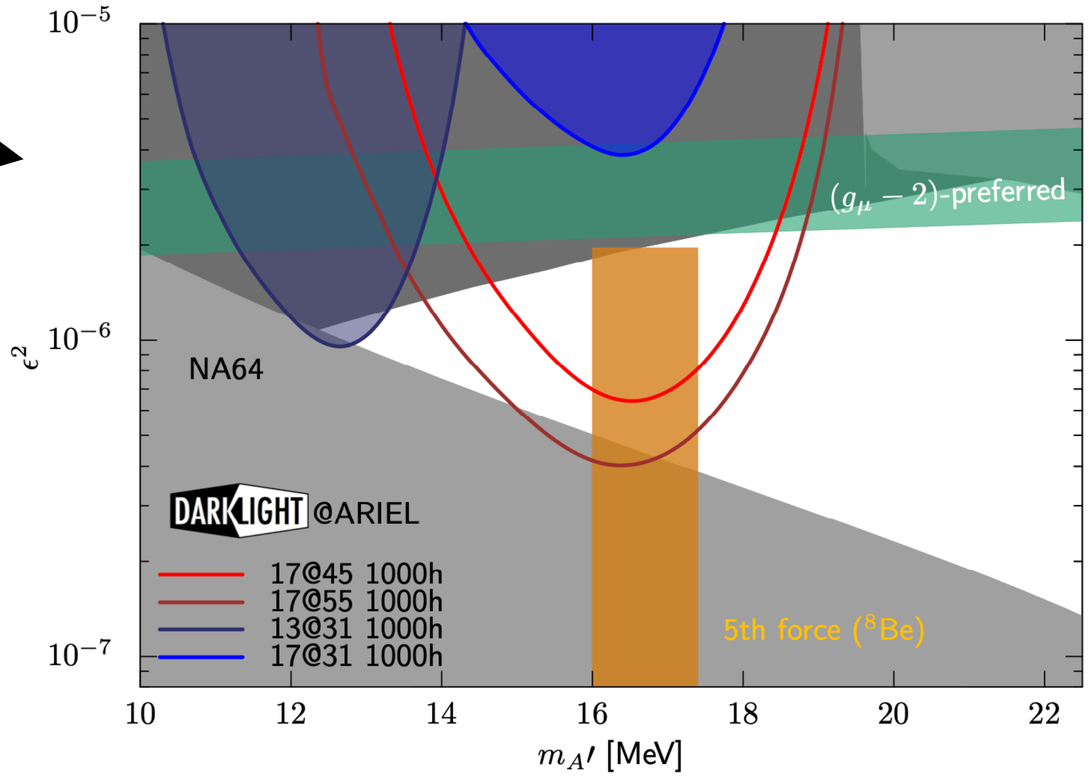
Revised g-2 region

Before Fermilab 2021





- 2021 Fermilab+BNL reduces preferred band somewhat: no longer touches X17
- *Some* increase from LQCD and CMD-3 would move this substantially (or all the way to zero)

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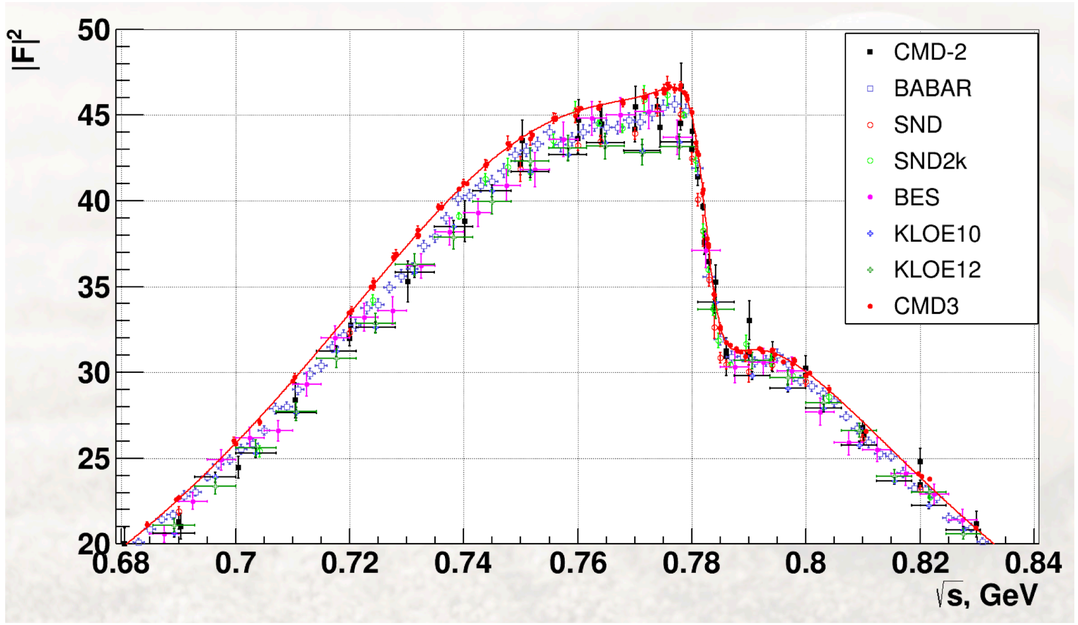
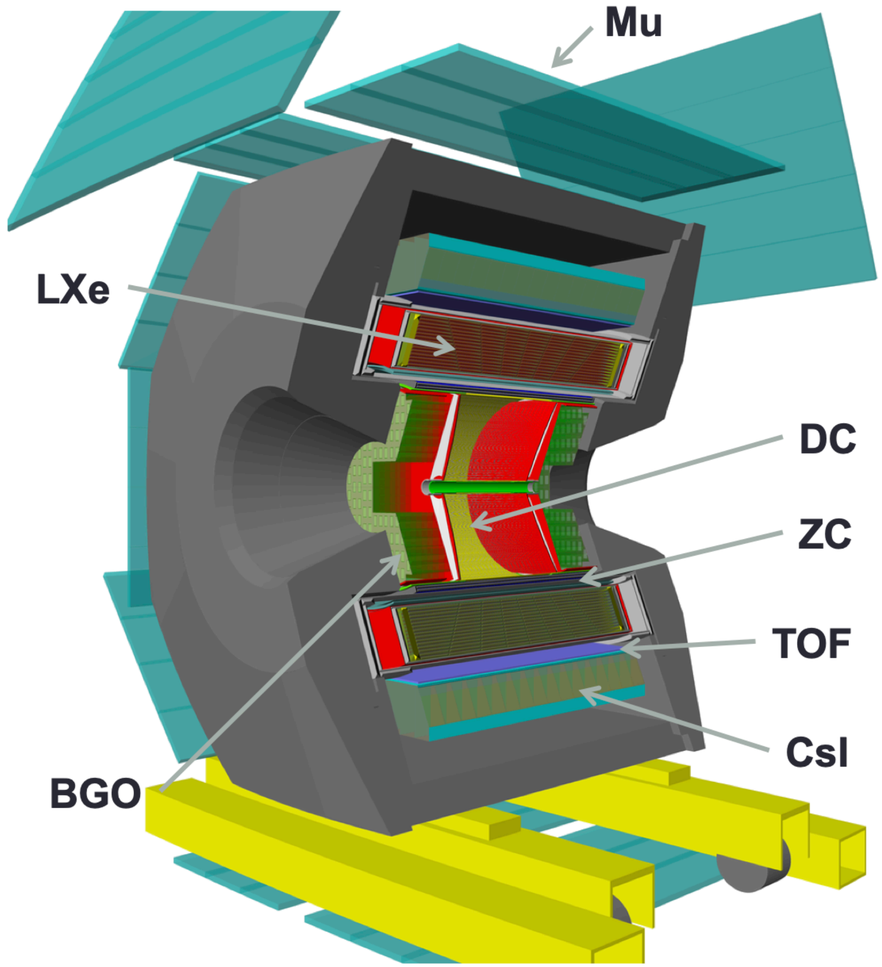
CMD-3

- VEPP-2000
- Program to measure $e^+e^- \rightarrow$ hadrons
- $e+e- \rightarrow \pi+\pi-$ form factor disagrees with all prior results





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Other Nuclear Excitement

- **N_Tof**: Proposal at EAR2/CERN to look for X17 in $^{3}He(n, X17)^{4}He$. Peak height vs beam energy can distinguish quantum numbers
- **NUCLEX: ΔE-E detectors for 12C and 8Be at INFN Legnaro**: Studying 5-fold layout like ATOMKI, but 1% mass resolution. If peak does not sharpen, then it has the wrong intrinsic width to be the assumed particle. Still in early stages as of Nov, 2023.

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Other Anomalies

- KTeV π^0 -> e^+e^- enhancement (arxiv:2212.06453v3)
- Neutron lifetime (PT Du et al 2020 J. Phys.: Conf. Ser. 1506 012004)
- Isotope Shifts (King Plots) (arxiv:2111.01429)
  (But recent studies match ab-initio calcs) (arxiv:2403.07792)
- Cosmic ^{7}Li underabundance (arxiv:1510.08858)
  ($1<M_X<20$MeV, but wants $\tau \gtrsim 100$s)

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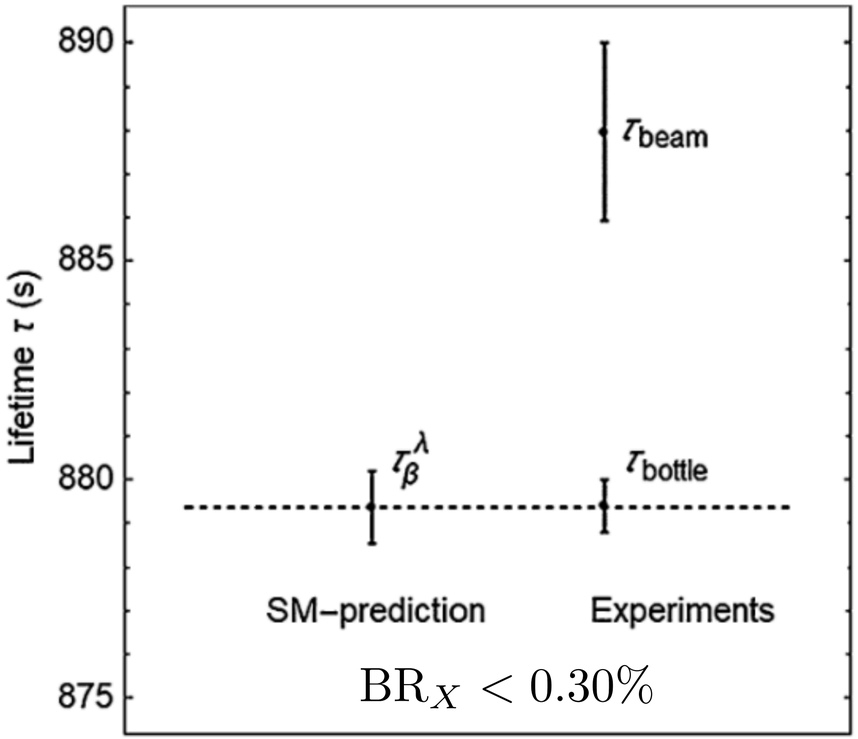
Neutron Lifetime

- Bottle lifetime: 879.4s±0.6 (look at survival ratio)
- Beam lifetime: 888.0s±2 (count decay protons)
- Can reconcile if neutron can decay to something other than a proton with BR~1%:

$$\tau_{\mathrm{beam}}^{-1} = \tau_{\beta}^{-1} \qquad \tau_{\mathrm{bottle}}^{-1} = \tau_{\beta}^{-1} + \tau_{X}^{-1}$$

- In principle mediated by light virtual boson (into some dark final state)
- *But* Dubbers et al. calculation of SM (e- decay only) prediction matches the *bottle* value.



https://doi.org/10.1016/j.physletb.2019.02.013

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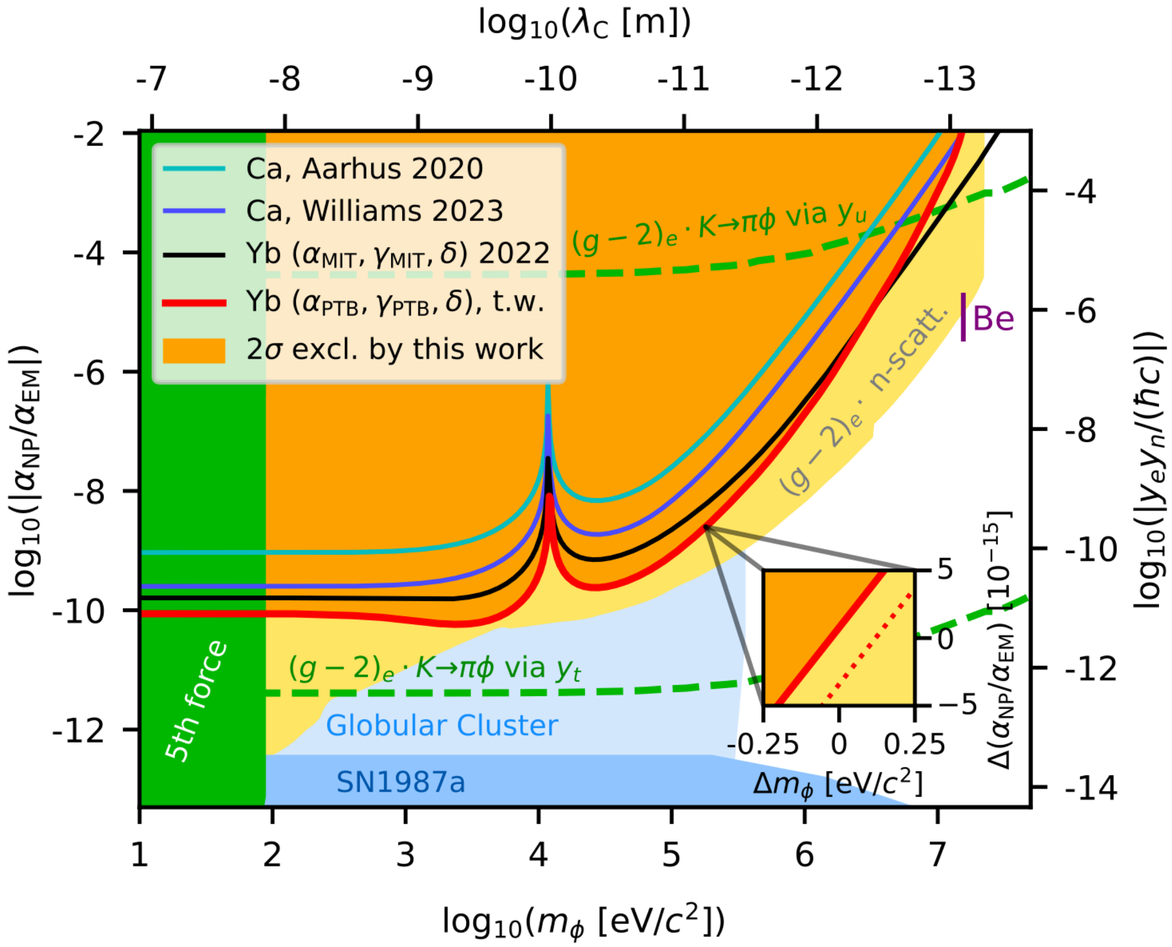
Isotope Shifts

- Compare atomic transition frequencies between different isotopes
- control effects due to mass and nucleus size by measuring super ratios of frequencies
- BSM electron-nucleus interactions would appear as frequency shifts beyond these effects
- 2021: Significant apparent nonlinearities might be BSM effect
- Recently: Recent Yb measurements fit well to SM nuclear deformation model. Cannot exclude all of X17 allowed region.
- *But if remaining nonlinearities are all due to new physics, mass and coupling would lie between solid and dotted red*



arxiv:2403.07792

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See backup slides for more on King Plots

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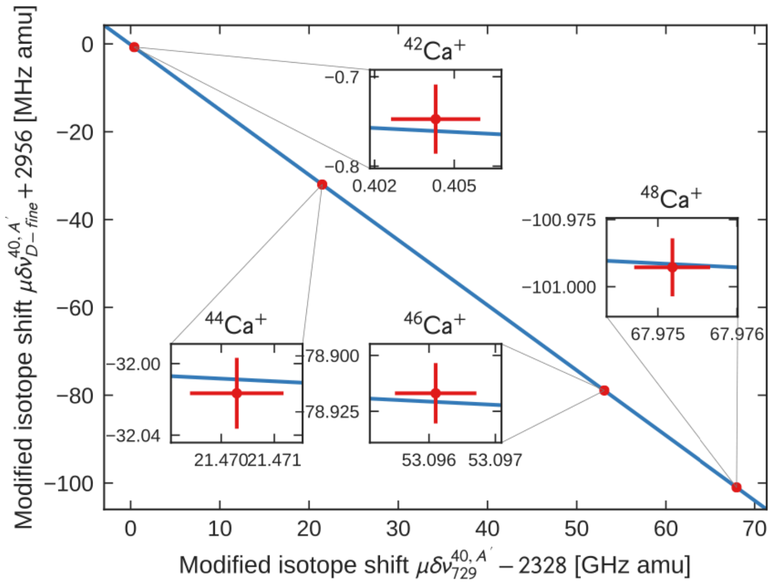
King Plots Explained

- Frequency difference between the same transition in two different isotopes (A, A') has two terms: Mass shift (nucleus recoil) and Field shift (nucleus size)
- 'Modified mass shift', $\mu\delta\nu_i^{AA'}$, divides out the mass dependence
- If we have two shifts (i,j) for the same isotope, we can factor out the nucleus size
- Field shift ratio and mass shift constants extracted from slope and intercept ... *if it's linear*
- nonlinearity=additional interaction with nucleus.

$$\delta\nu^{A,A'} = k_{\mathrm{MS}}\left(\frac{1}{m_A} - \frac{1}{m_{A'}}\right) + F\delta\left\langle r^2\right\rangle^{A,A'}$$

$$\mu\delta\nu_i^{AA'} = K_i + F_i\,\mu\,\delta\left\langle r_c^2\right\rangle^{AA'}$$

$$\mu\delta\nu_i^{AA'} = K_i - \frac{F_i}{F_j}K_j + \frac{F_i}{F_j}\,\mu\,\delta\nu_j^{AA'}$$



from Steffen Meyer's thesis ('17)

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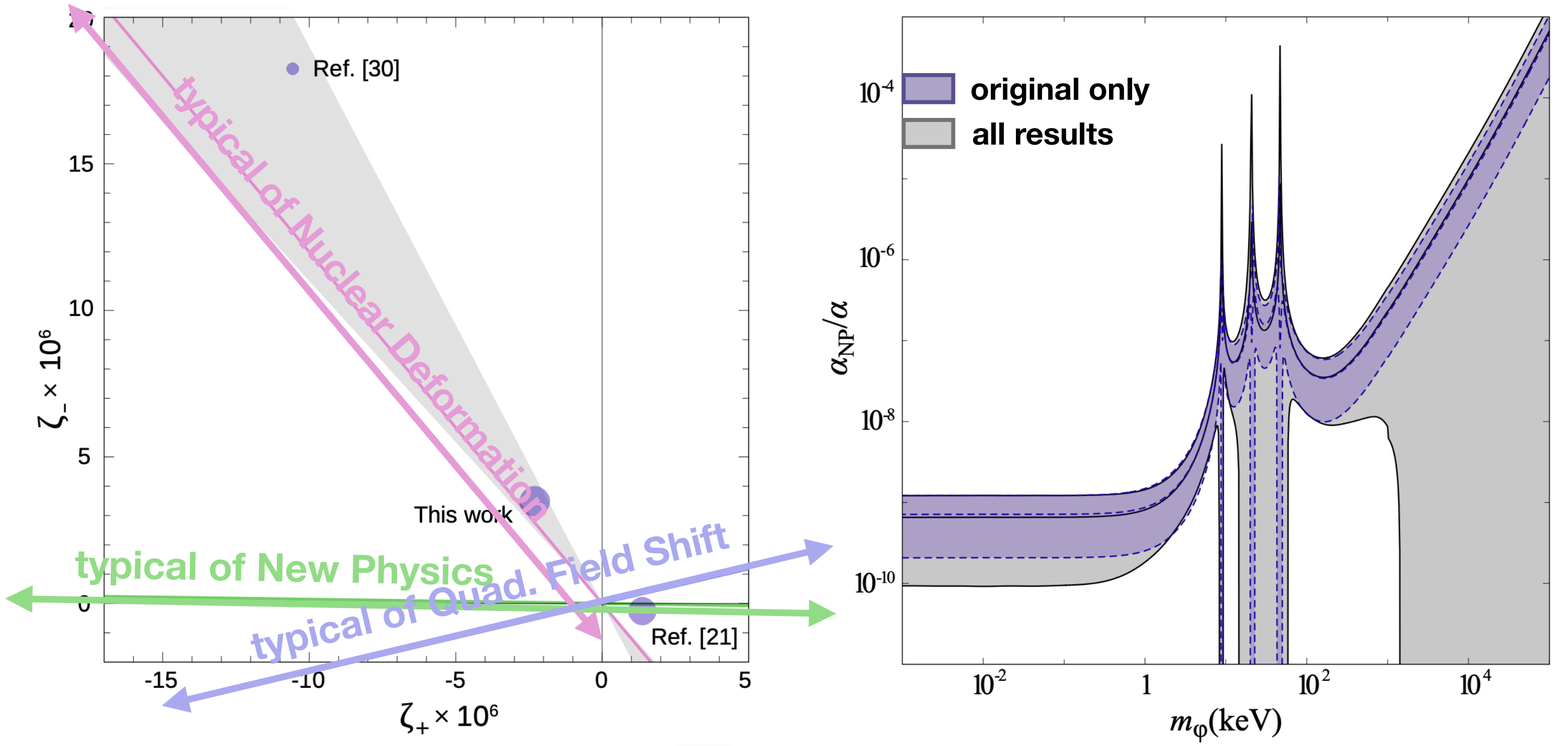
Nonlinear King Plots

- Yb isotope deviations from linearity, plotted as $\zeta_{\pm}$

$$\zeta_{\pm} \equiv d_{168} - d_{170} \pm (d_{172} - d_{174})$$

- (d_{168} is vertical deviation from straight-line fit for frequencies of isotope pair (168,170) with the same transition pair)
- Still prefers new physics, but newer results reduce overall significance at M_A>1MeV



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arxiv:2111.01429

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Options for the future @ LNF

Expected performance vs. impact

	BTF	Extend LINAC RF flat-top	Extraction from main ring		Extraction from damping ring	
			Resonant, RF off	RF knock-out	Resonant, RF off	RF knock-out
Beam max. E	500 MeV	320 MeV	400 MeV		400 MeV	
Pulse length	250 ns	2-3 μs	0.25→1 ms	O(10 ms)	100→300 μs	O(ms)
Repetition rate	49 Hz	49 Hz	2 Hz 49 Hz		2 Hz 49 Hz	
				Crystal		Crystal
Infrastructure		De-tune or by-pass SLED's	Direct injection line to DAFNE hall Electrostatic septum	Vacuum goniometer	Separated injection, extraction lines and new hole to BTF-1 Electrostatic septum	Vacuum goniometer
Gain factor	1	10	40→160 $10^3 \rightarrow 4 \cdot 10^3$ $10^3 \rightarrow 10^4$		16→50 $400 \rightarrow 1.2 \cdot 10^3$ $10^2 \rightarrow 10^3$	
Comments		Small hardware modifications No need to run a ring No new beam-lines Marginal on maximum energy Use BTF target or directly adjust LINAC energy	Need to run large infrastructure Even for 1 ring only, no wiggler, no RF, several 100 kW Electrostatic septum or cystal require vacuum installation on the ring RF knock-out gives good performance even at 2 Hz Adjusting extracted beam energy requires target + spectrometer		RF knock-out can be implemented with kickers Crystal requires simpler vacuum installation than electrostatic septum	

P. VALENTE

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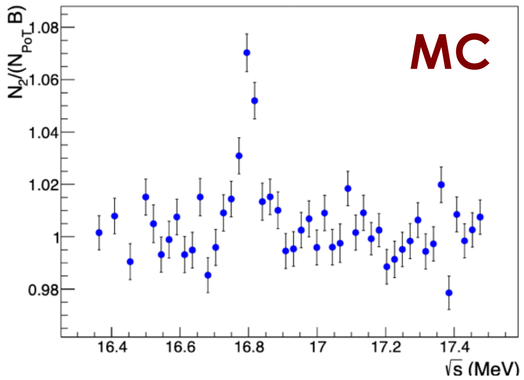
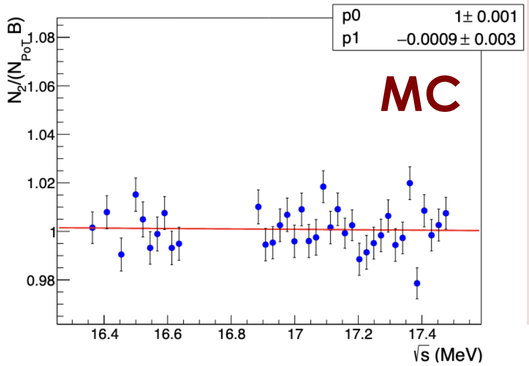
The "blind unblinding" procedure

ECT2026 Presentation: Mauro Raggi





To validate the error estimate, in presence of signal in any region of the mass scan [JHEP06(2025)040]

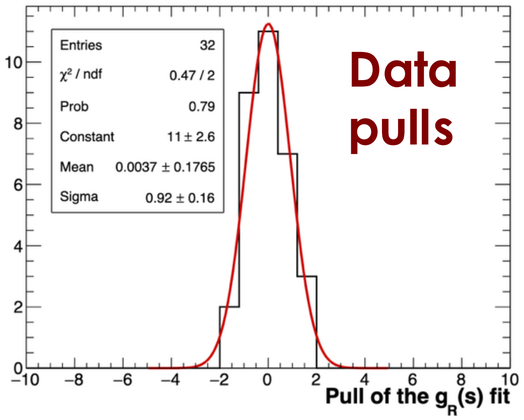
Aim to blindly define a side-band in $g_R(s)$, excluding 10 periods of the scan

Define the masked periods by minimizing χ^2 of a linear fit in $s^{1/2}$

1. Threshold on the χ^2 fit in **side-band is P(χ^2) = 20%,** corresponding to reject 10% of the times
2. If passed, check if the **fit pulls are gaussian**
3. If passed, check if a **straight-line fit of the pulls has no slope in $s^{1/2}$** (within 2 sigma)
4. If passed, check if constant term and slope of the linear fit for K(s) are within two sigma of the expectations, i.e.: ± 4% for the constant, ± 2% MeV^{-1} for the slope

Successfully applied, details in [JHEP06(2025)040]:

1. **P(χ^2) = 74%**
2. **Pulls gaussian fit probability 60%**
3. **Slope of pulls consistent with zero**
4. **Constant term = 1.0116(16), Slope = (-0.010 +- 0.005) MeV^{-1}**



Therefore, proceed with box opening

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