Center for Frontiers in Nuclear Science

Search for New Physics with an Invariant Mass of 10-20 MeV at ARIEL

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for the DARKLIGHT *Collaboration*

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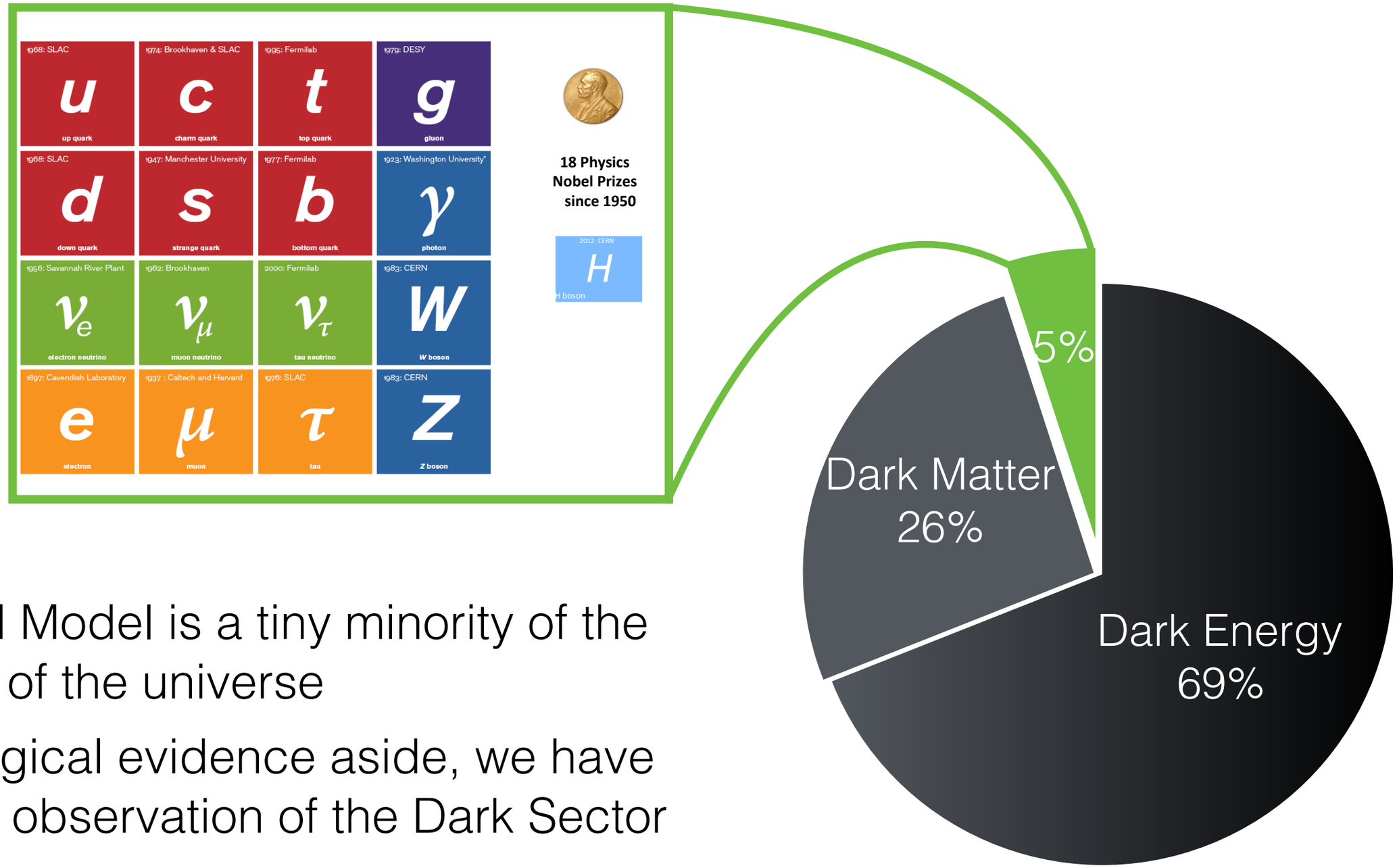
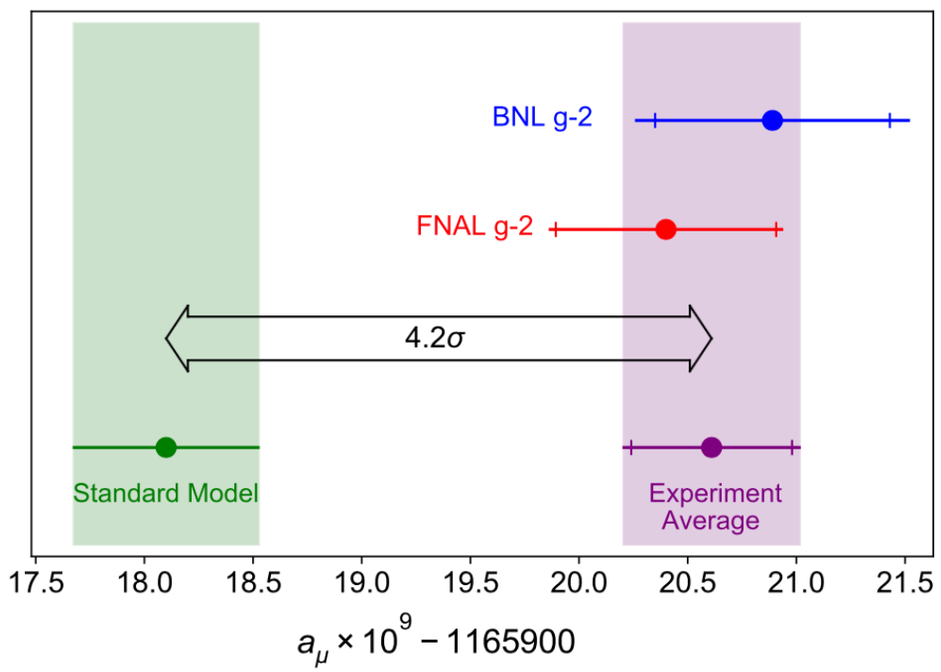
Dark Matter and Particle Physics



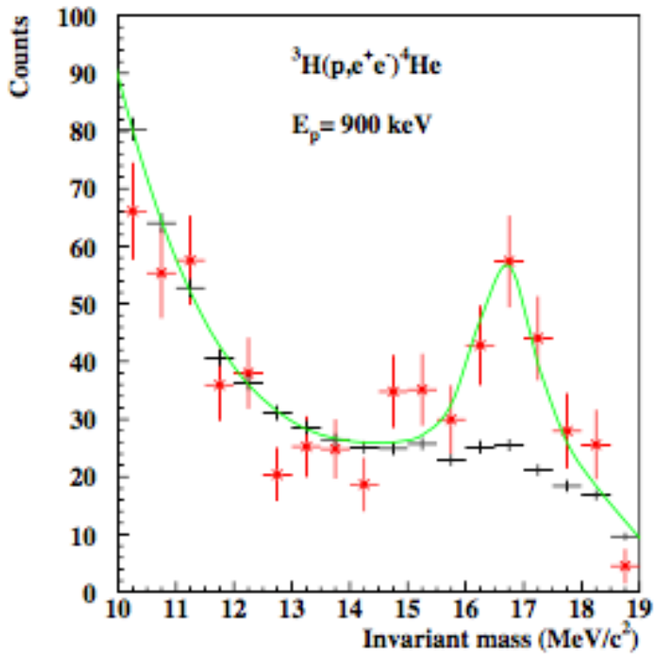
- Standard Model is a tiny minority of the contents of the universe
- Cosmological evidence aside, we have no direct observation of the Dark Sector
- We expect some connection to remain: a portal to the Dark Sector

Dark Matter, Anomalies, and New Physics

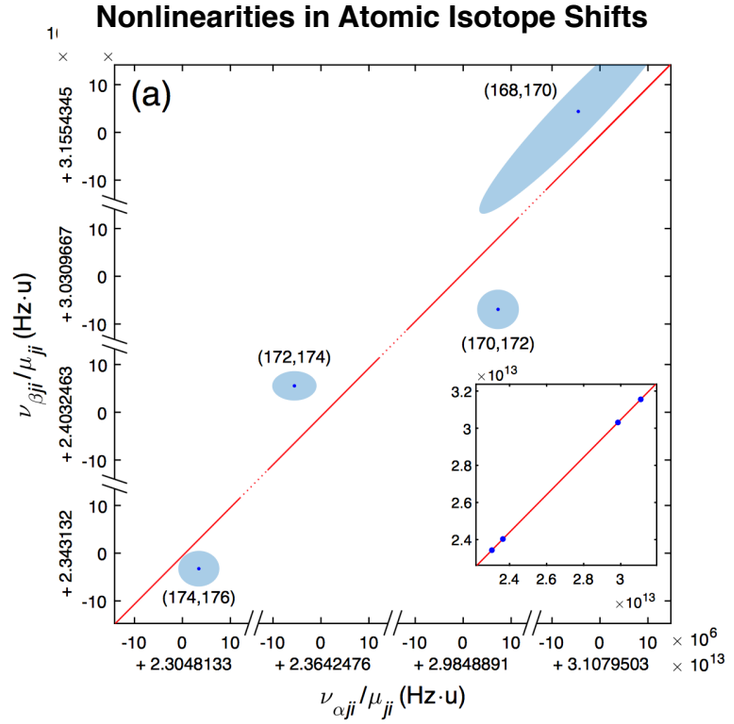
Muon g-2 Discrepancy



X17 in 4He and 8Be

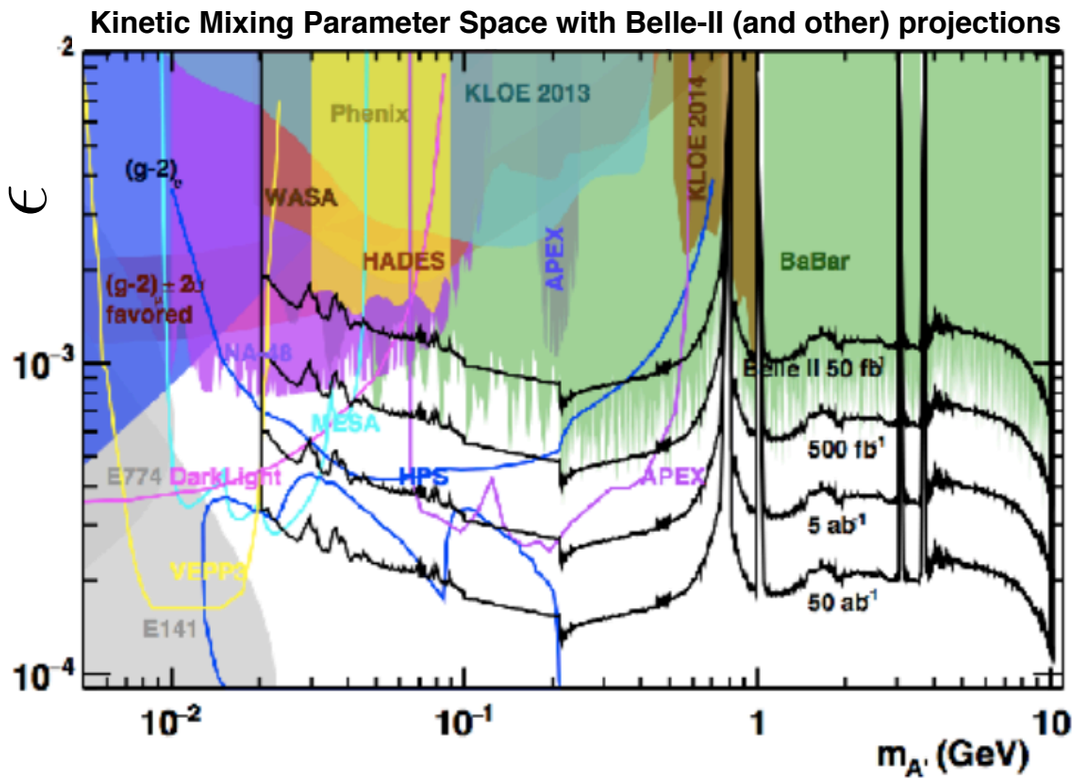


Nonlinearities in Atomic Isotope Shifts

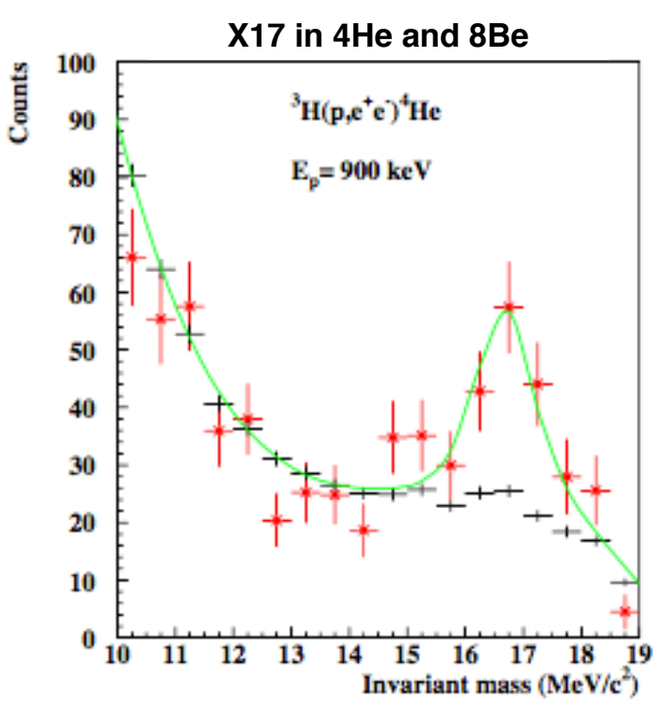


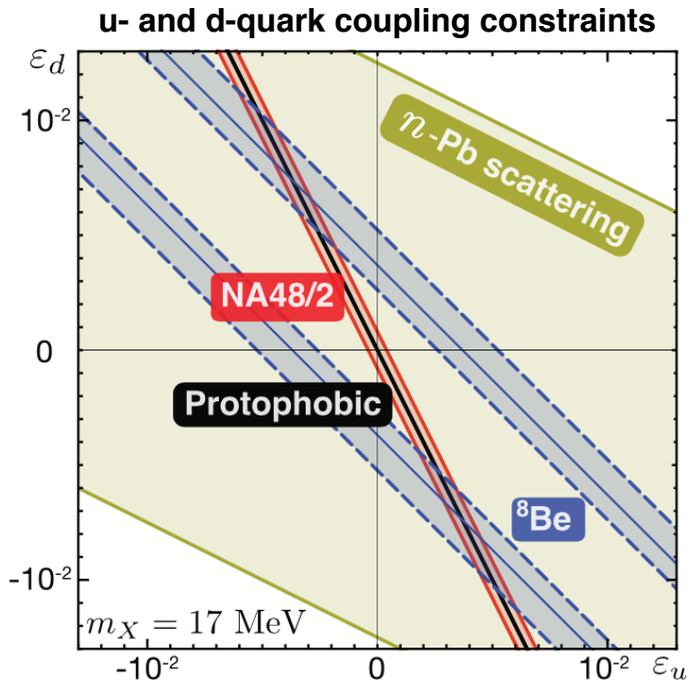
- Anomalies could be the signature of such a connection - a fifth force
- Parameterize by coupling (ϵ_f) and mass
- Existing experiments rule out simple model for g-2

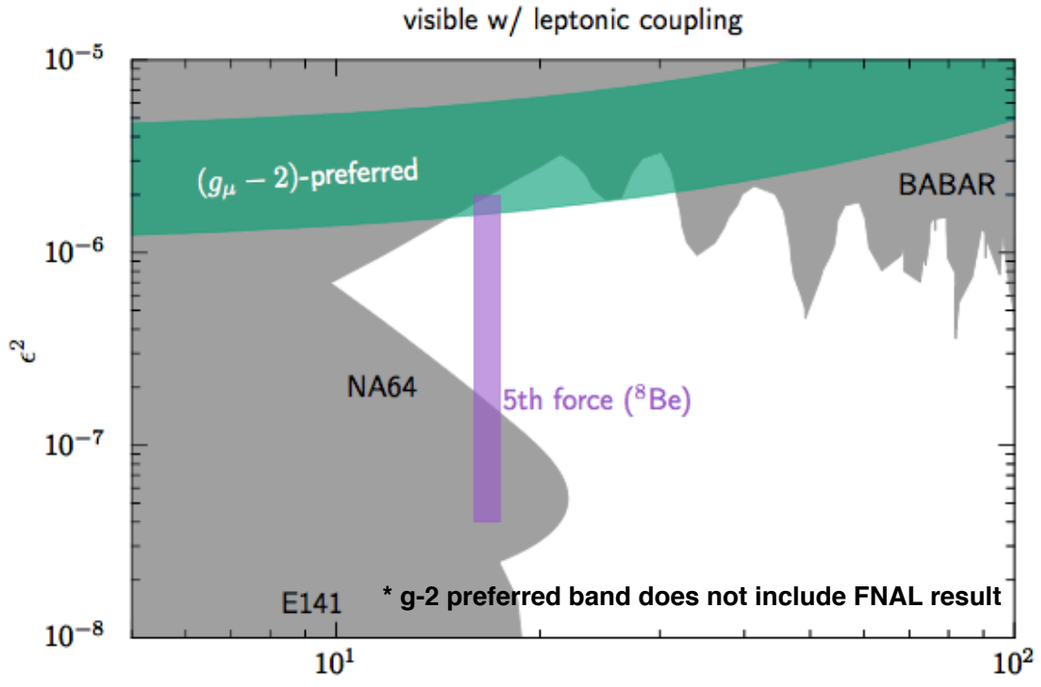
Kinetic Mixing Parameter Space with Belle-II (and other) projections



Looking for the X17

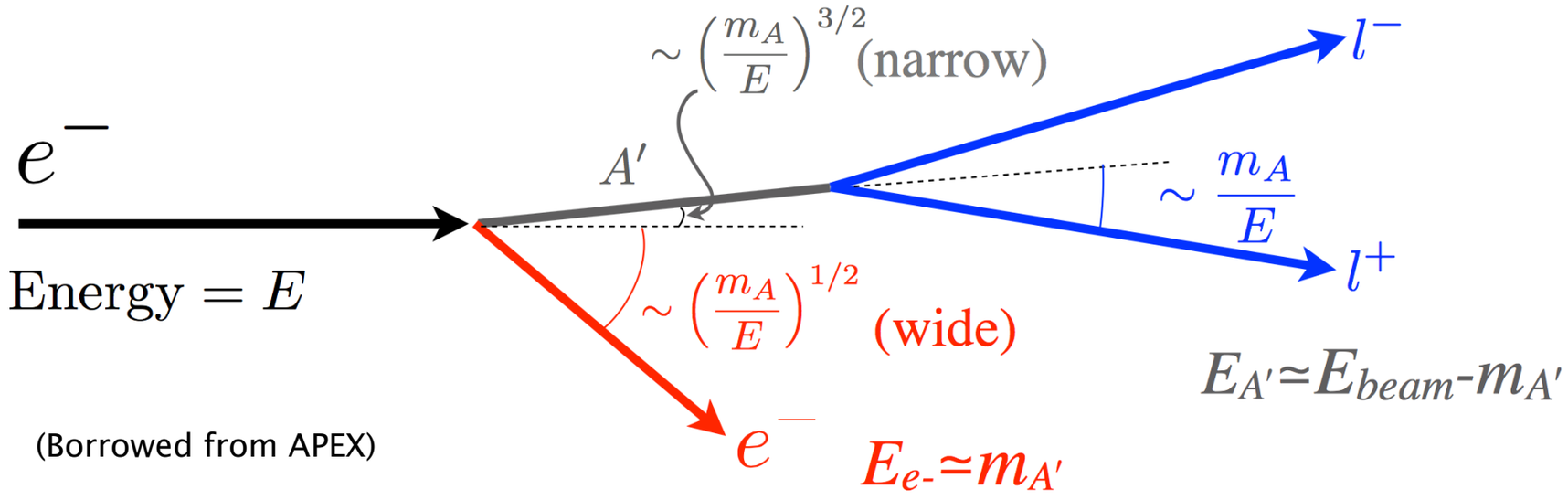






- X17 signal is large -- should have been seen in existing hadronic searches
- Unless flavor-dependent couplings suppress it there ⇒ 'protophobic'
- ***Purely leptonic production*** key aspect of expanded search for this new particle
- X17 region can be reached with **low beam energy**

Searching at an e- Accelerator



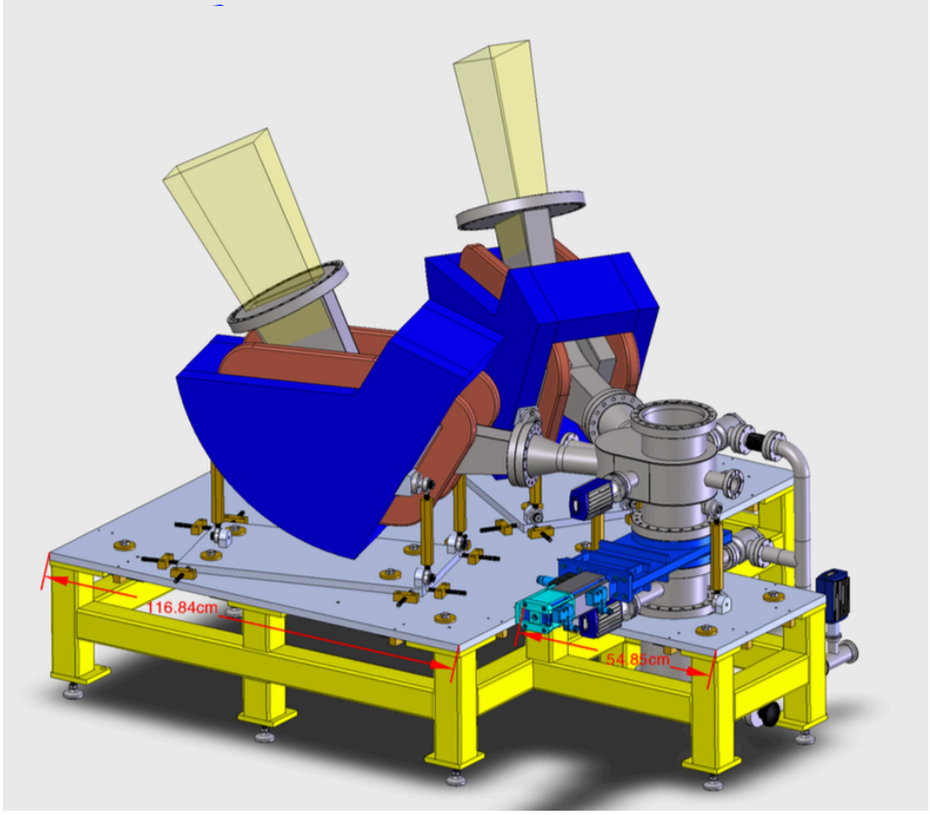
(Borrowed from APEX)

- Radiative production:

$$e^- + \mathrm{Ta} \rightarrow e^- + \mathrm{Ta} + A'$$

$$A' \rightarrow e^+ + e^-$$

- Detect decay products in spectrometers:
- Wide decay angle ⇒ Beam energy ~ M_A
- Preserve narrow intrinsic width ⇒ Thin target
- Maximize integrated luminosity ⇒ High beam current



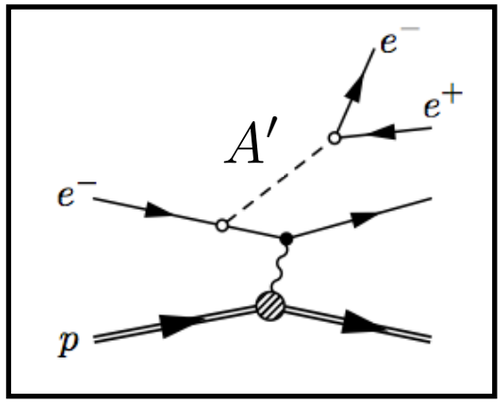
Backgrounds

- Irreducible QED background is smooth, shaped by acceptance
- Reducible coincidence background dominates at high $\mathcal{L}$: single e+ far more likely than complete e+e- pair ⇒ elastic e- from same bunch acts as missing partner!

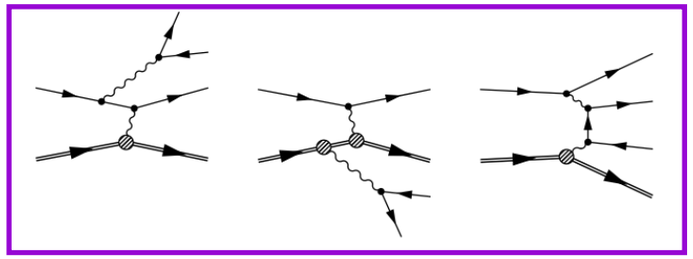
$$S \sim \mathcal{L} \qquad B \sim \mathcal{L}^2 \qquad \mathrm{FOM} \sim \frac{S}{\sqrt{B}}$$

- At high $\mathcal{L}$, FOM scales with **rep rate** and wall clock, not beam current

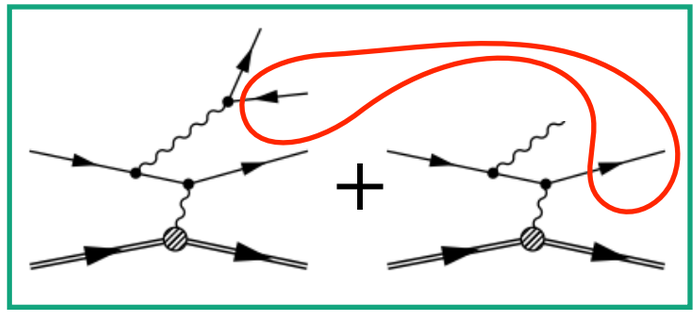
Signal

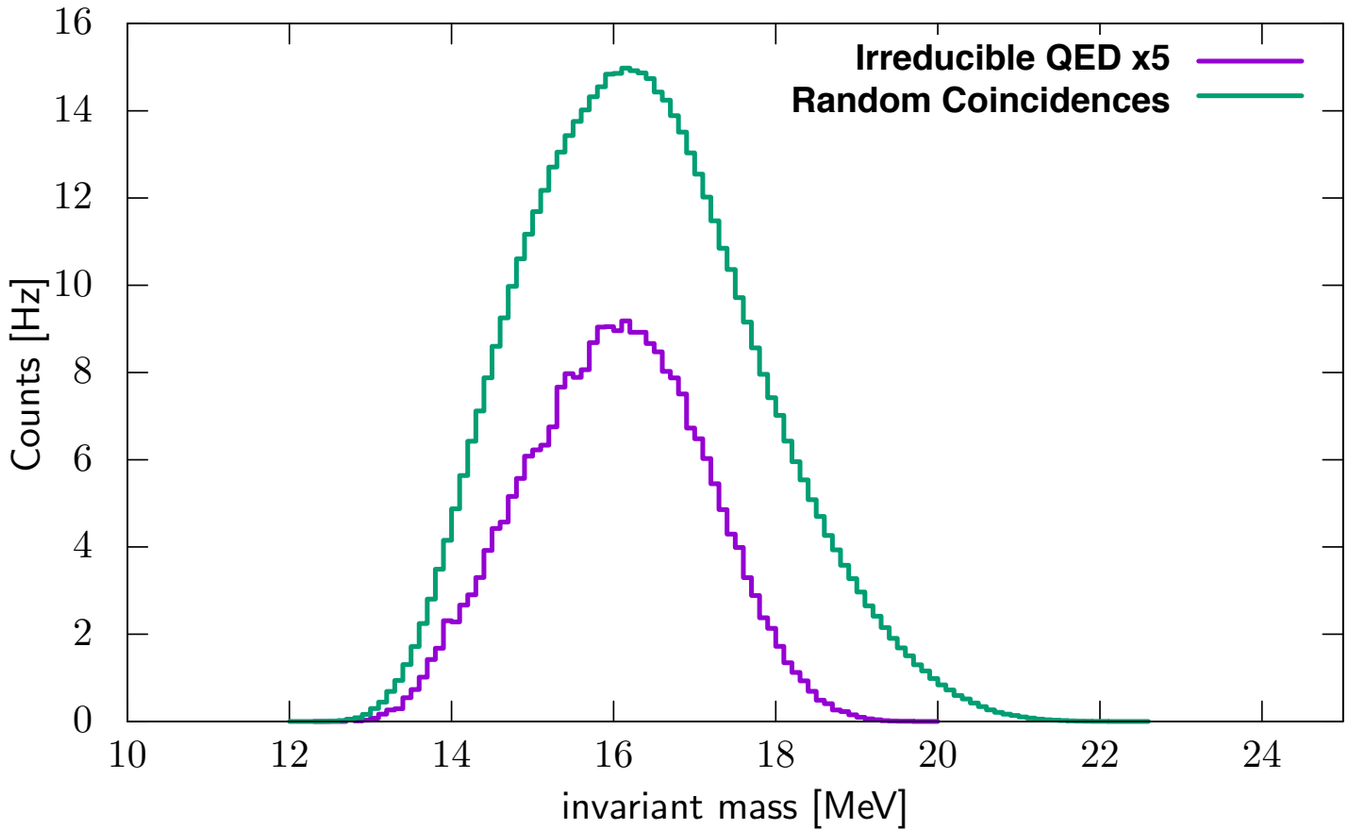


Irreducible QED Background



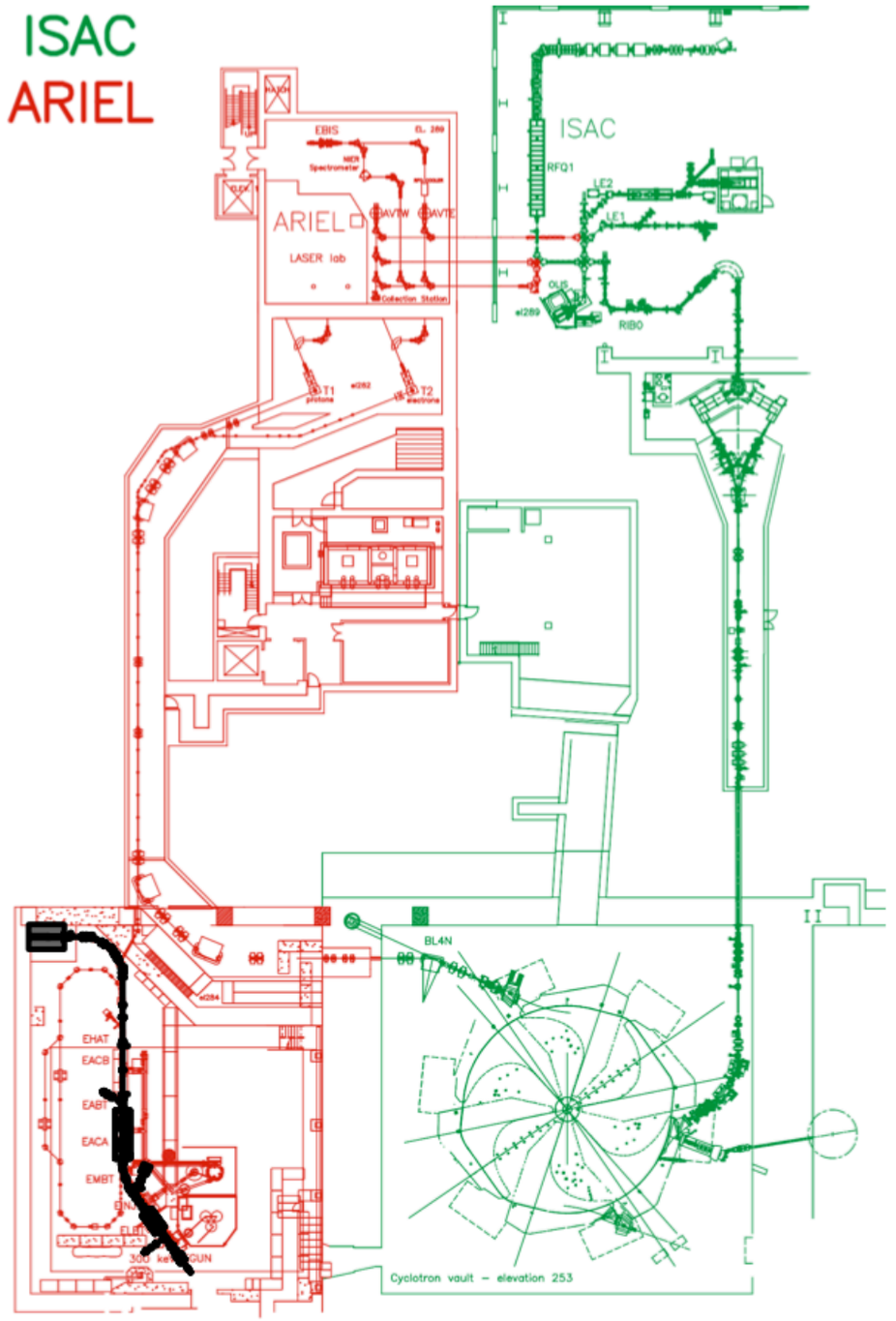
Combinatoric Background





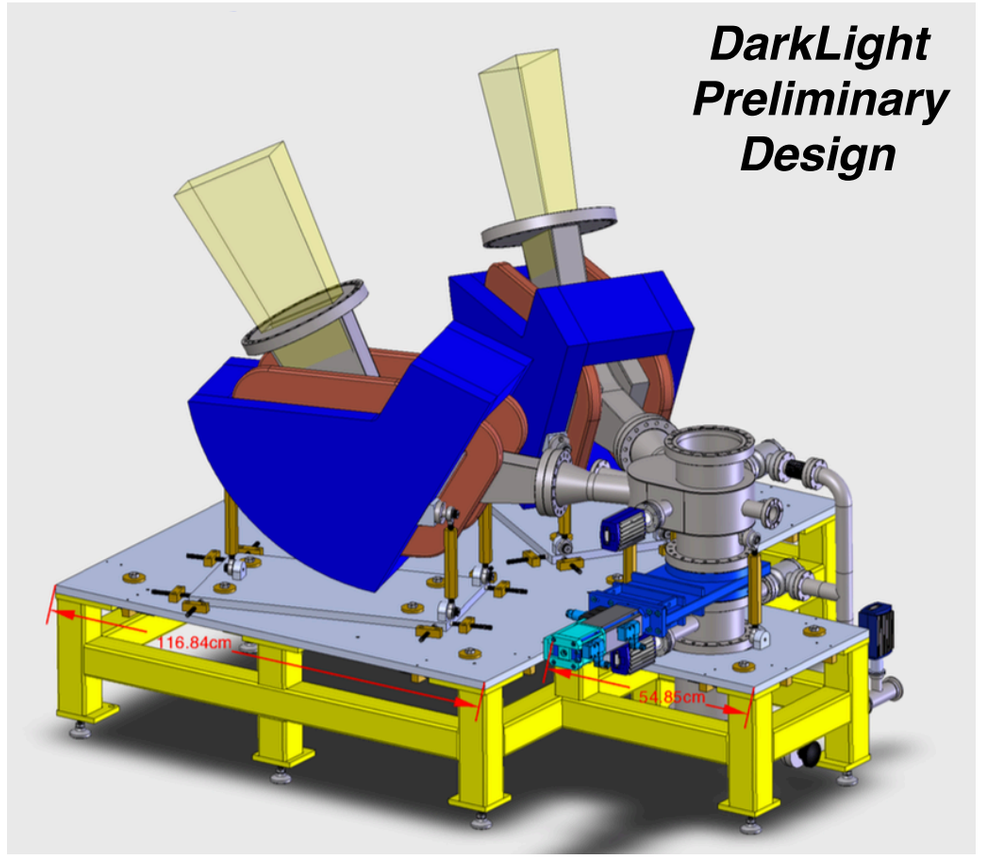
ARIEL

- **A**dvanced **R**are **I**sotop**E** **L**ab being built at TRIUMF:
  - Optics designed for up to 75 MeV
    - 650MHz gun, peak current up to 10 mA
- First stage built: 31 MeV beam
- Planned recirculation upgrade will enable 50+ MeV beam



Spectrometer Design

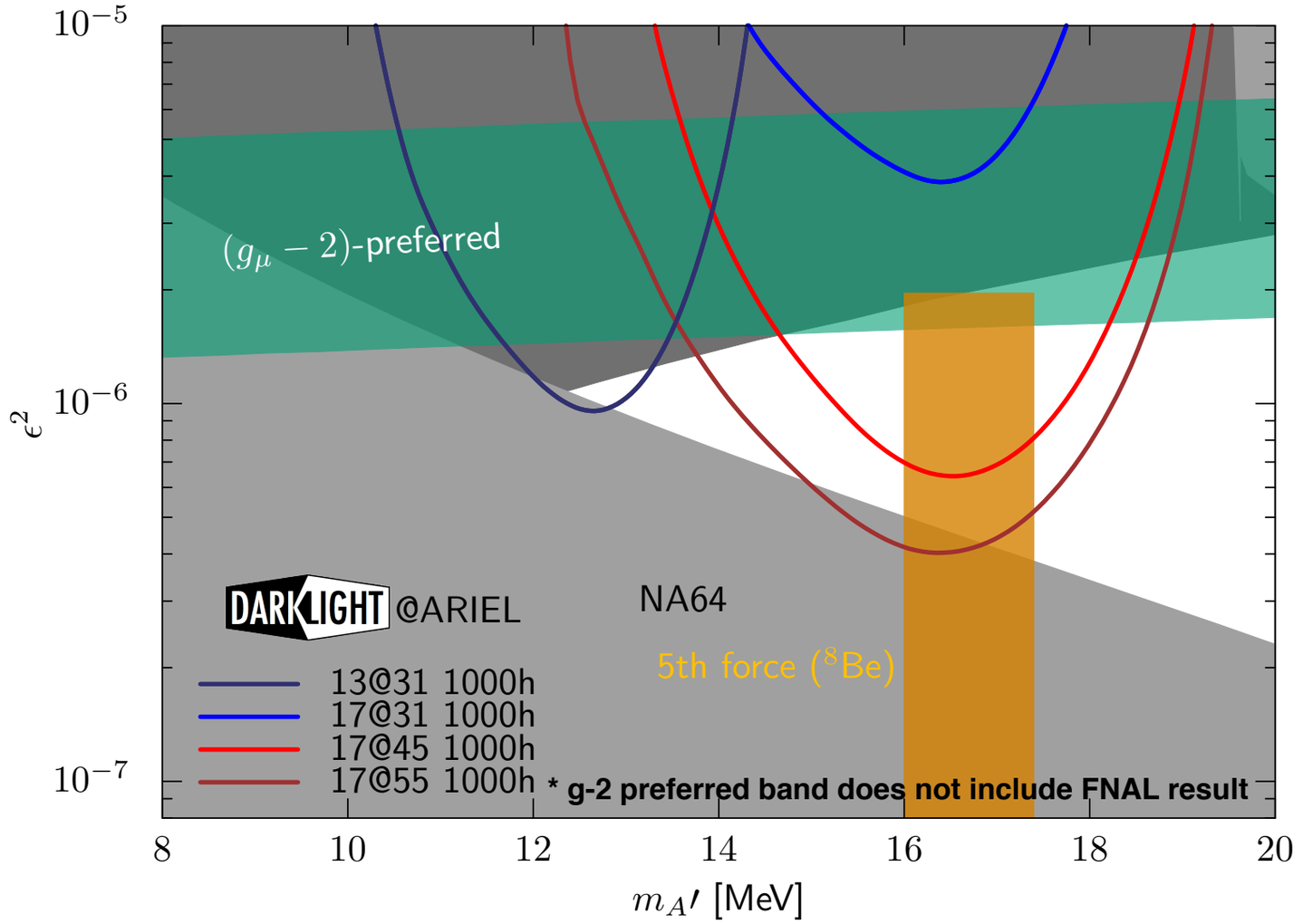
- Retractable tantalum foil target
- Twin-arm spectrometer
  - Asymmetric angles to maximize S/√B
  - Adjustable for different M_A and beam energy
- GEM focal plane detectors
- Plastic scintillator trigger hodoscopes
- Precise timing to distinguish individual e^- bunches



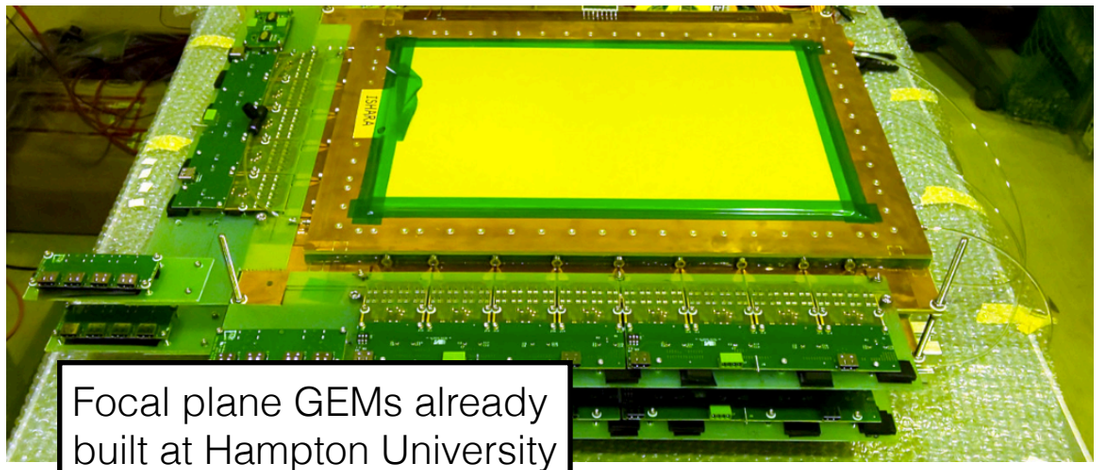
In-place acc.	±2°
Out-of-plane acc.	±5°
Momentum acc.	±20%
Min. central angle	16°
Max. central mom.	28 MeV
Field strength	0.32 T
Nom. bend radius	30 cm
Pole gap	4 cm

Projected Reach

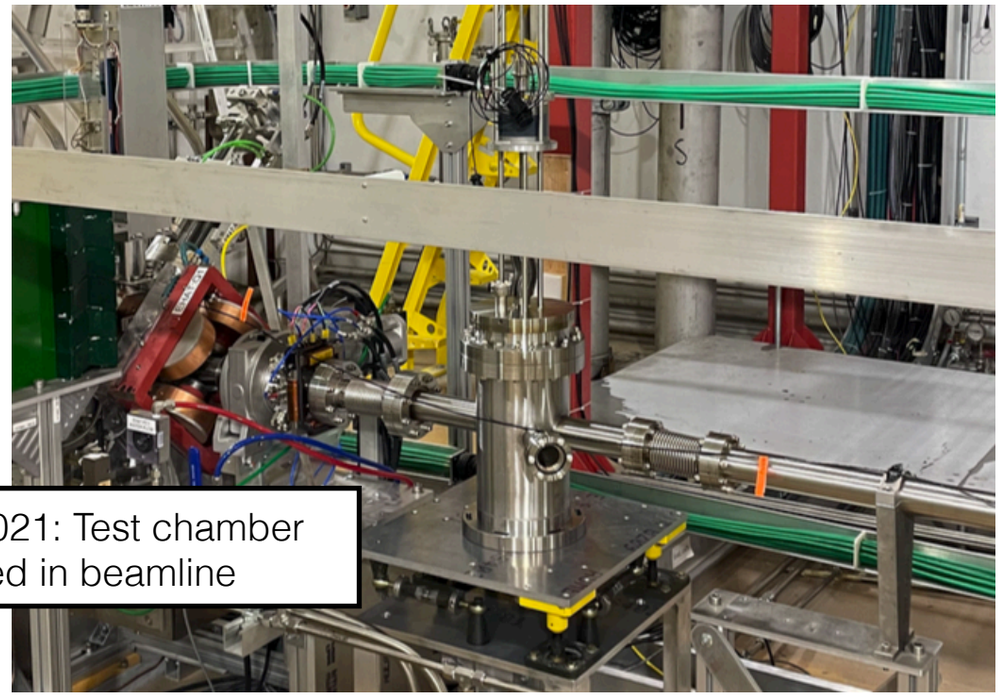
- Current ARIEL config: commissioning and pilot searches @ 31 MeV
- With ARIEL upgrades: deeper search in X17 region possible



DarkLight Timeline



Focal plane GEMs already built at Hampton University



Dec 2021: Test chamber installed in beamline

2021

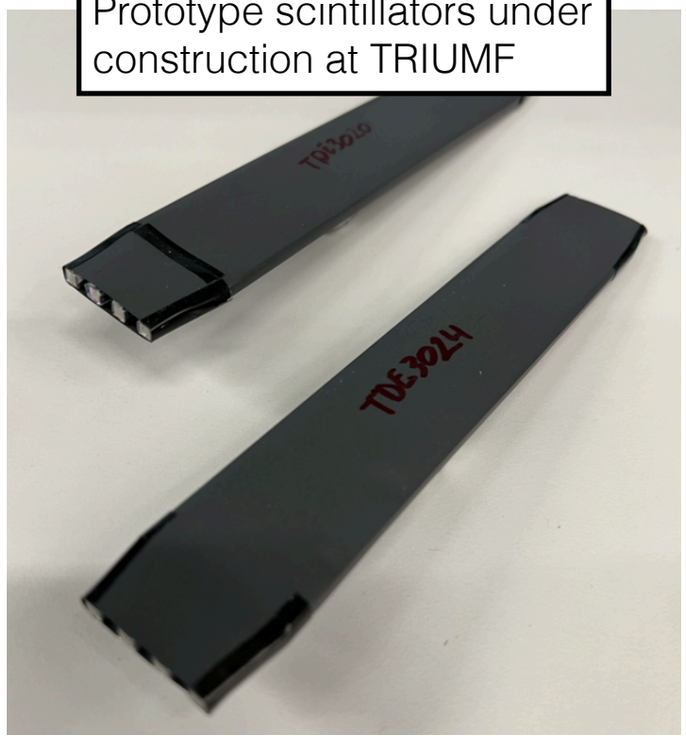
Fall 2021: 1300 hour beam time approved by TRIUMF

2022

Feb 2022: Passed CFI funding selection round and TRIUMF Gate 1

APS April meeting

Prototype scintillators under construction at TRIUMF



Summer 2022: Install spectrometer arm, study backgrounds

April 2022: First beam on target, study beam performance

2023

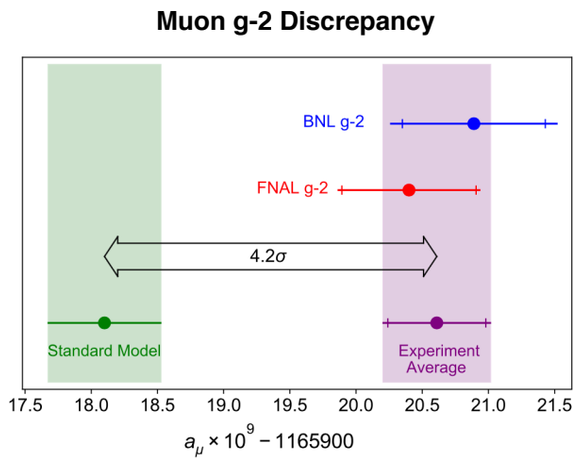
2024

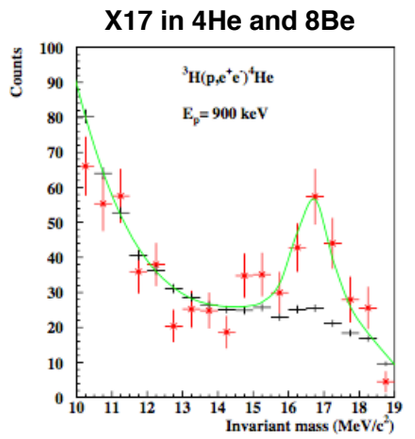
2023: Install and run full experiment at 31 MeV

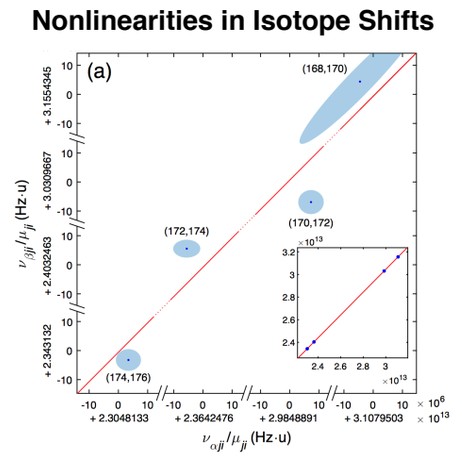
2024: Install recirculating beamline and run at 50 MeV

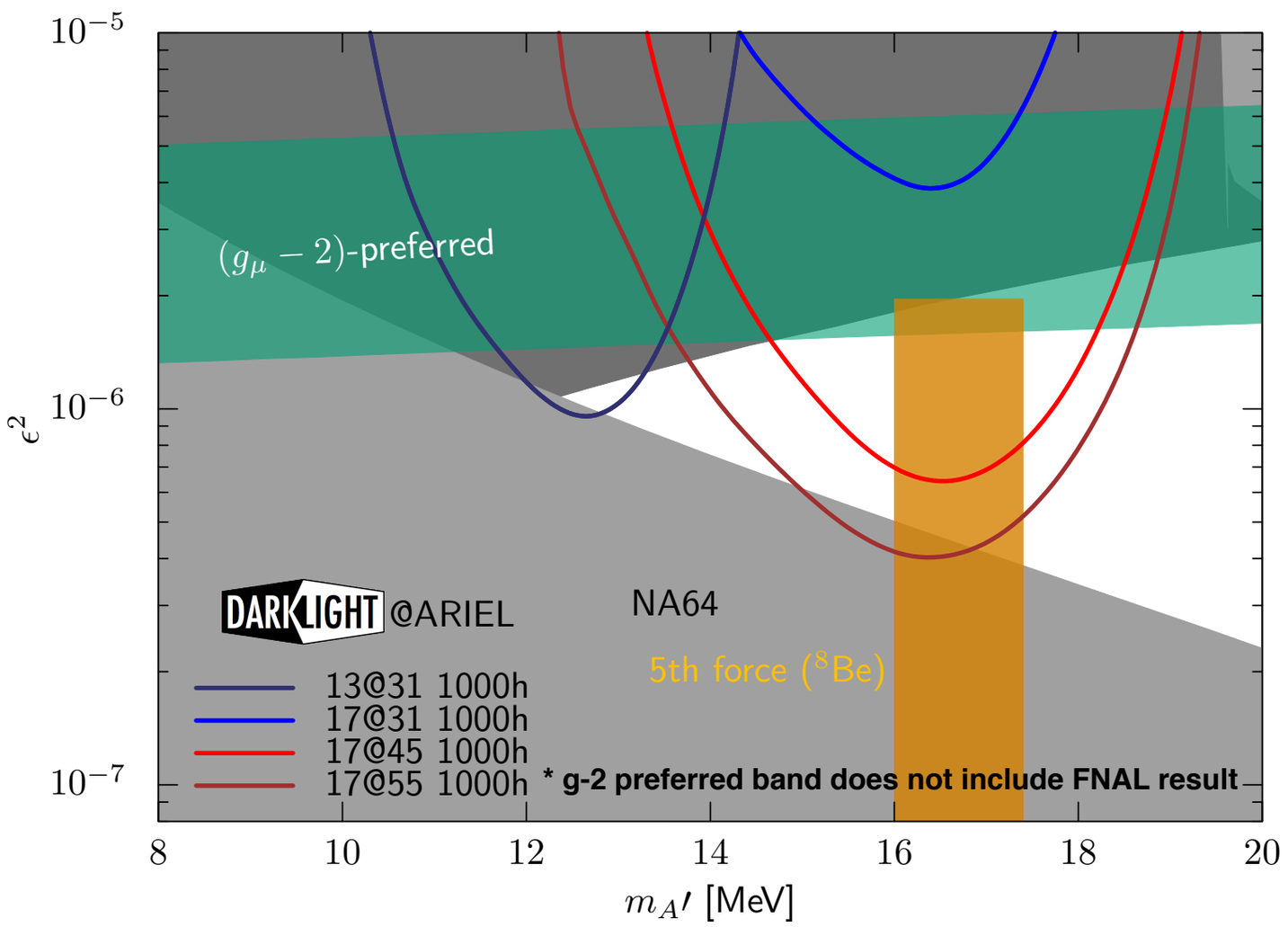
Outlook

- g-2 and other anomalies are compatible with low-mass, nearly-protophobic force -- can't probe effectively with pions
- Beamtests underway at TRIUMF now
- 31 MeV Pilot run planned for 2023
- Expected ARIEL upgrades in give access to higher masses starting in 2024
- On similar time scale, mixed-hadronic (LHCb etc) + pure-leptonic (this proposal) could provide complementary coverage of X17 region









The DarkLight Collaboration

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