A dark photon search with JLab positron beam

Positron A' collaboration

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Dark matter is an elephant in the room

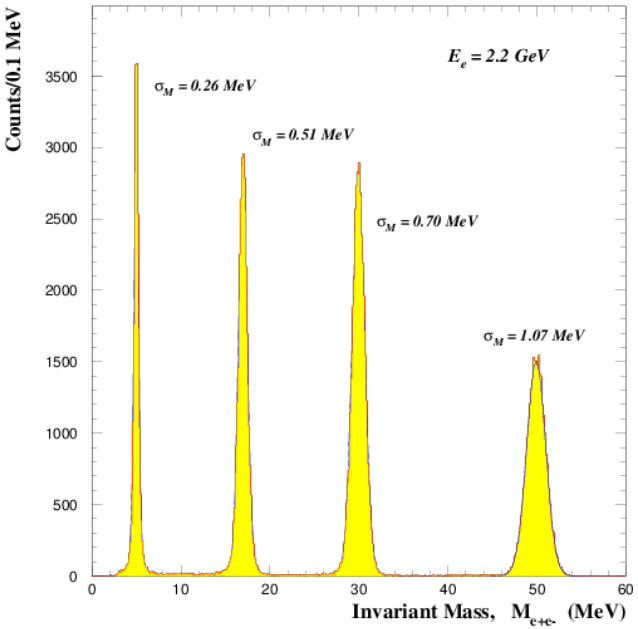
Motivation from 2006

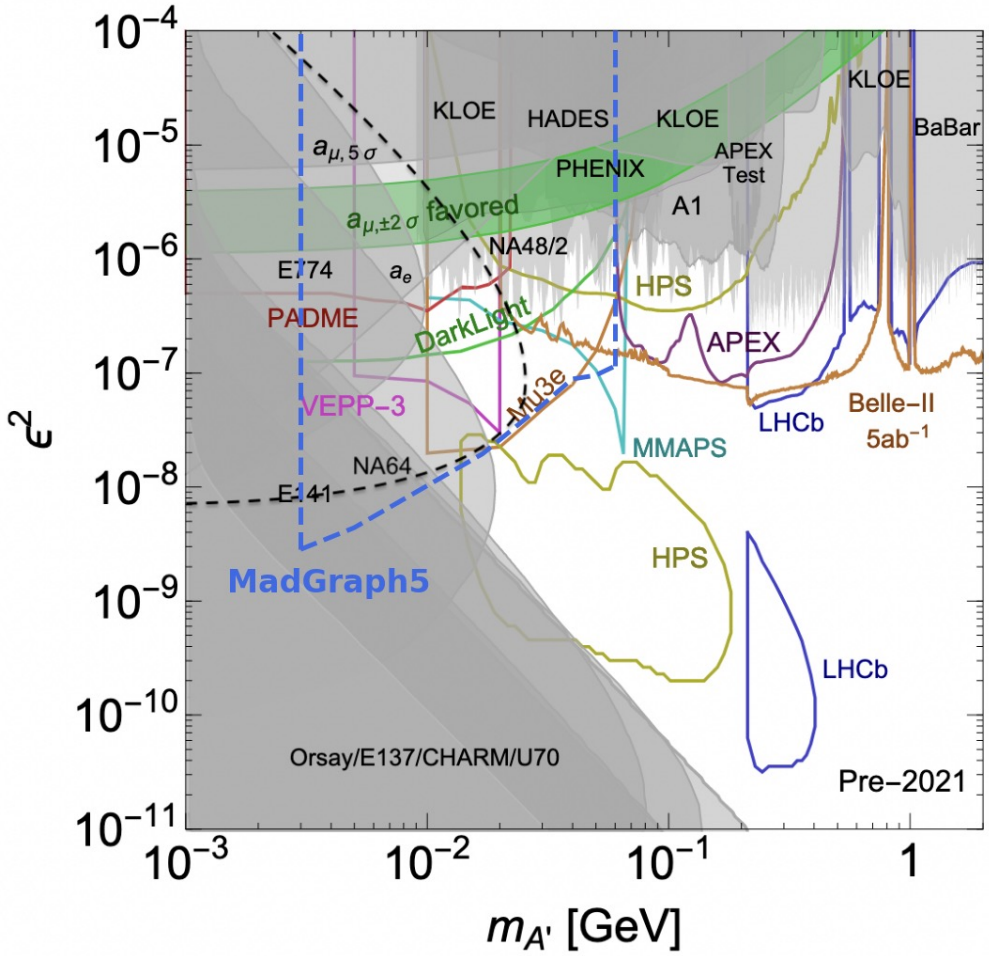
NASA Finds Direct Proof of Dark Matter

Credit: X-ray: NASA/CXC/CfA/M.Markevitch et al.; Optical: NASA/STScI; Magellan/U.Arizona/D.Clowe et al.; Lensing Map: NASA/STScI; ESO WFI; Magellan/U.Arizona/D.Clowe et al.

A Direct Detection Search for Hidden Sector New Particles in the 3-60 MeV Mass Range , X17 - E12-21-003

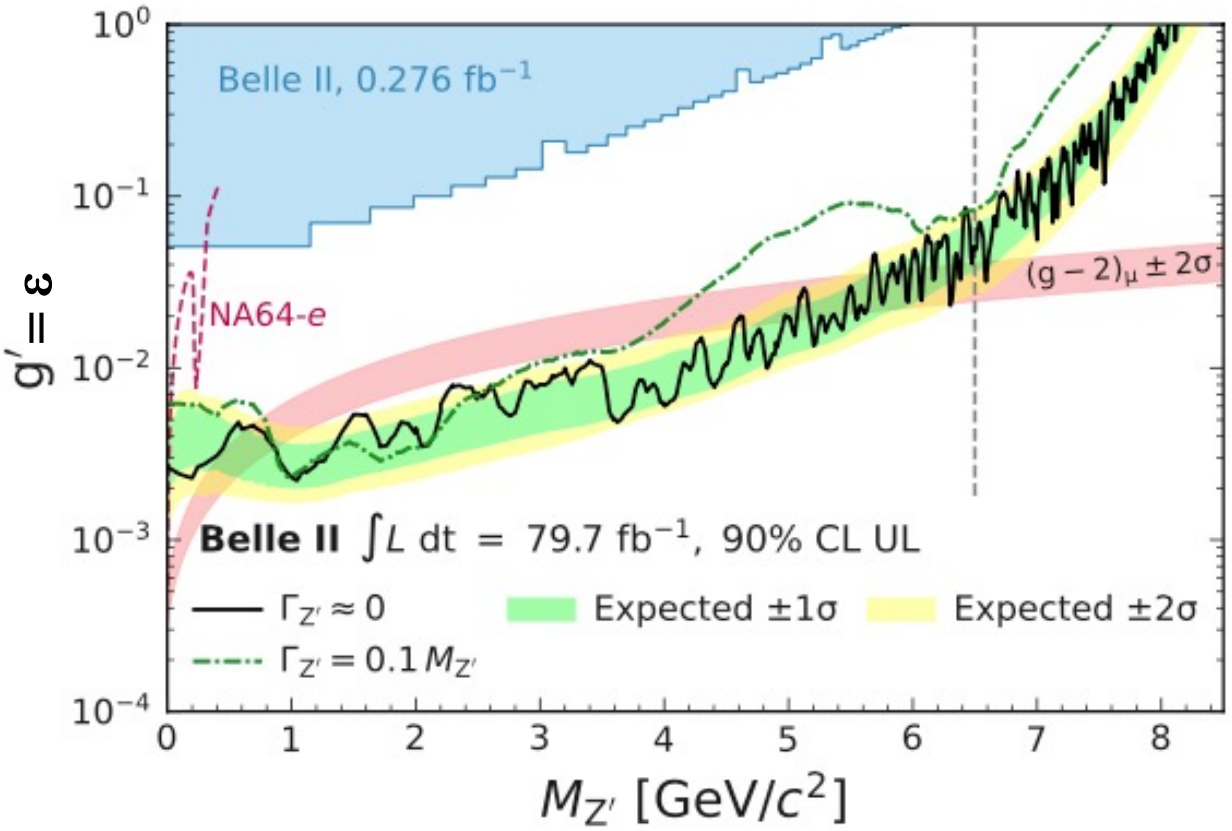
visible decay mode





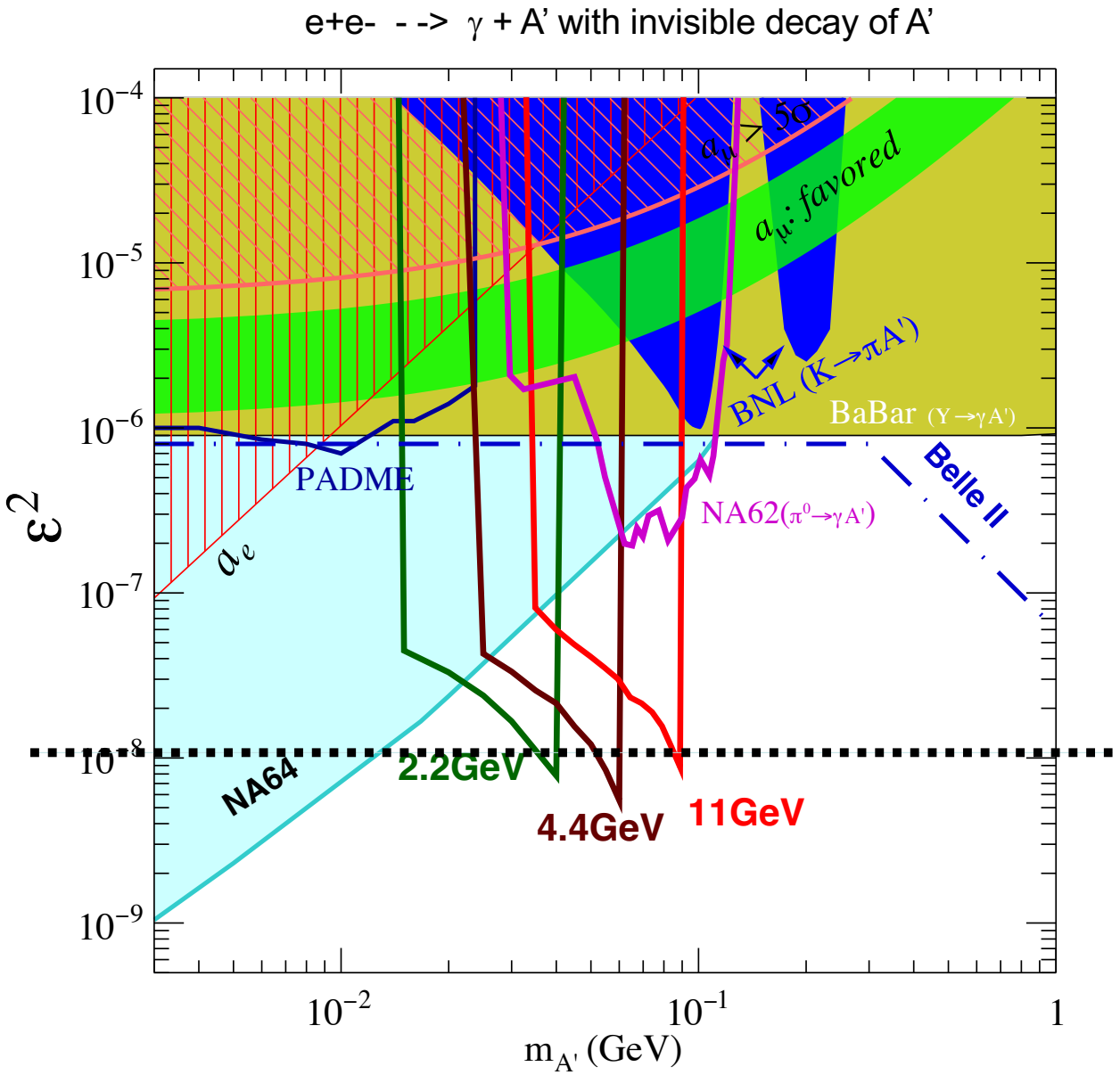
Belle-II recent analysis invisible decay

arXiv:2212.03066v3 e+e- - -> γ^* + Z' with invisible decay of Z'

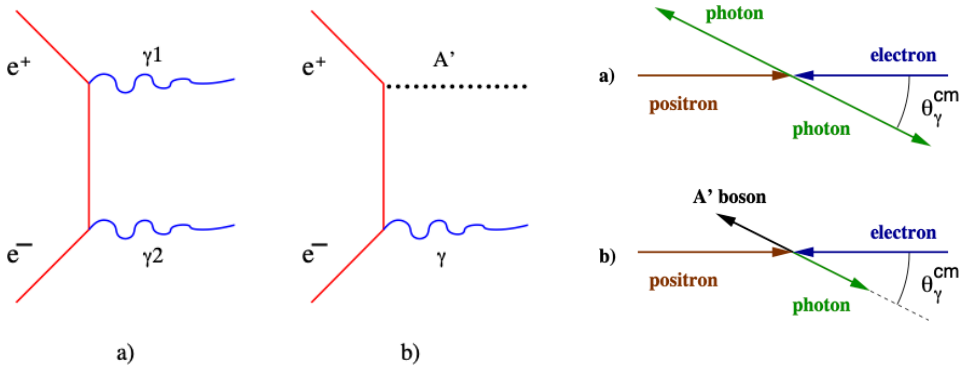


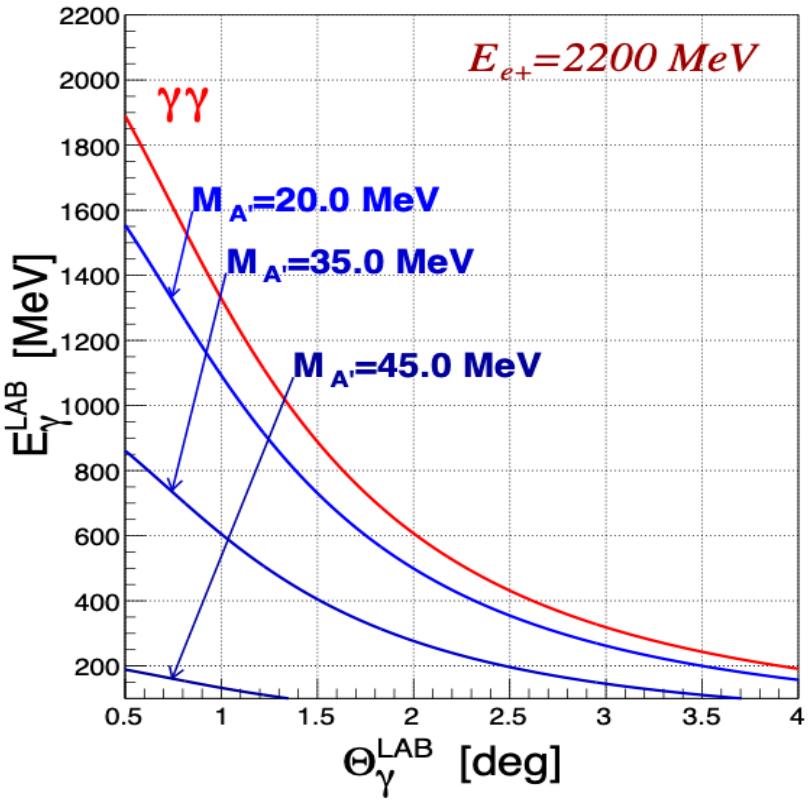
Good mass resolution for $m_{Z'} < 0.1$ GeV is hard to get

Current summary of A' invisible decay



The experimental method

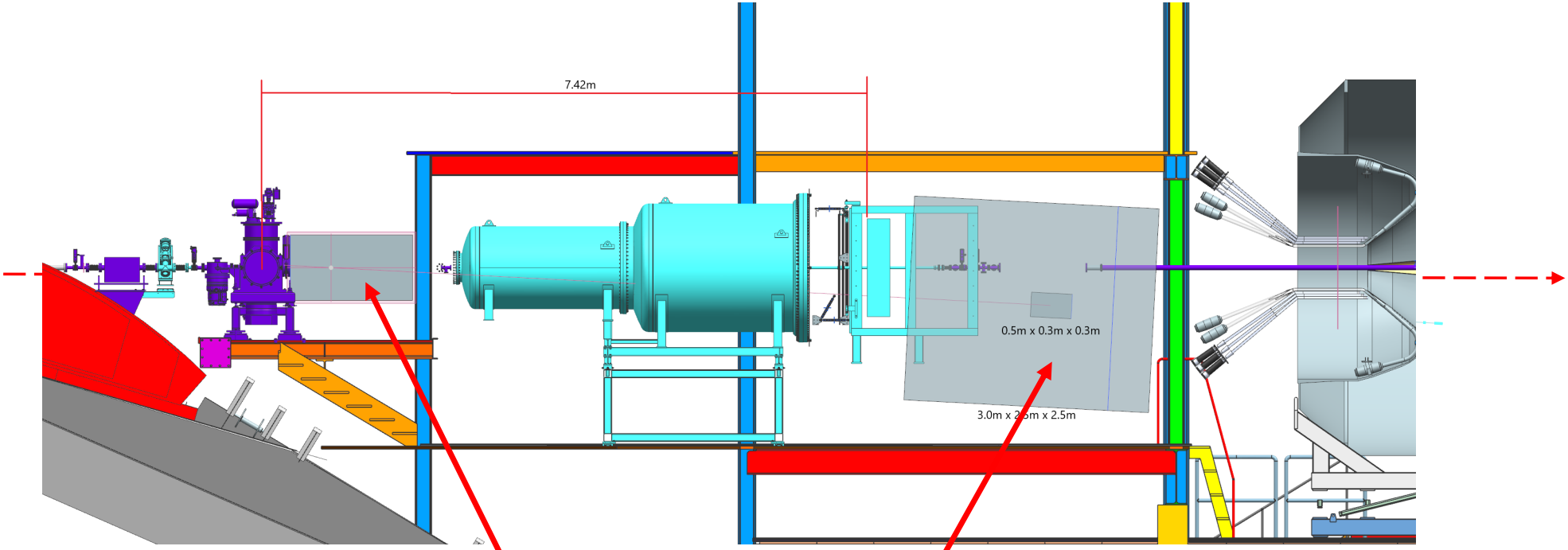


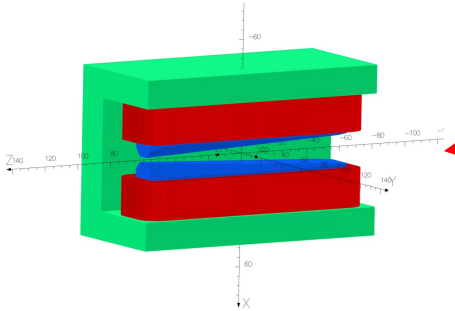


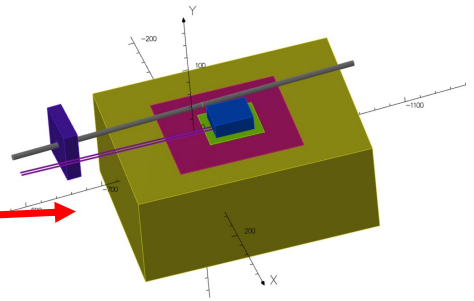
- A positron beam on a hydrogen target (e^+e^- annihilation)
- Selection of the one-photon final state events
- Search for a bump in the missing mass spectrum
- Connection between A' and the dark matter is not essential for the proposed study

$$M_{A'}^2 = 2m_e^2 + 2m_e * (E_+ - E_\gamma) - 4E_+ * E_\gamma * \sin^2(\frac{\theta_\gamma}{2})$$

Layout of the experiment in Hall B

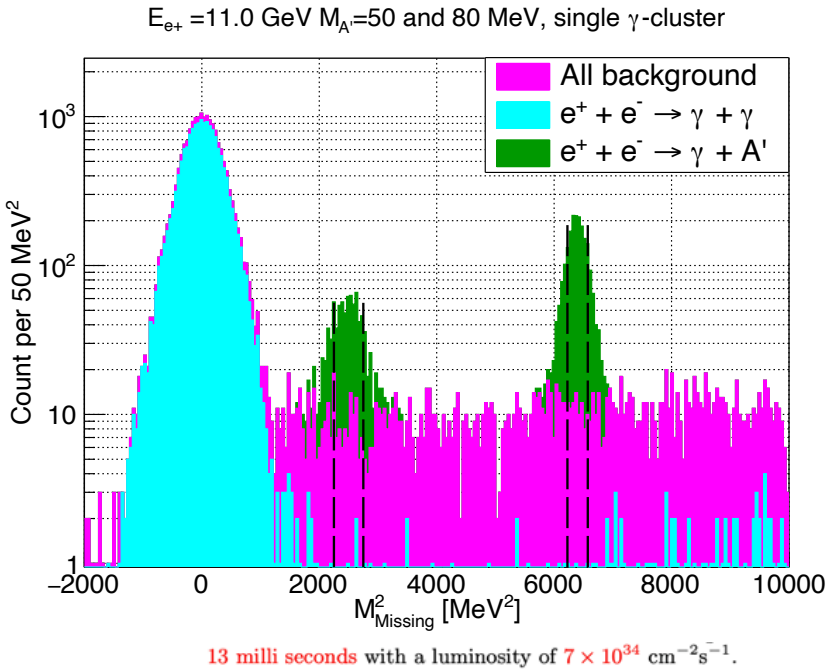


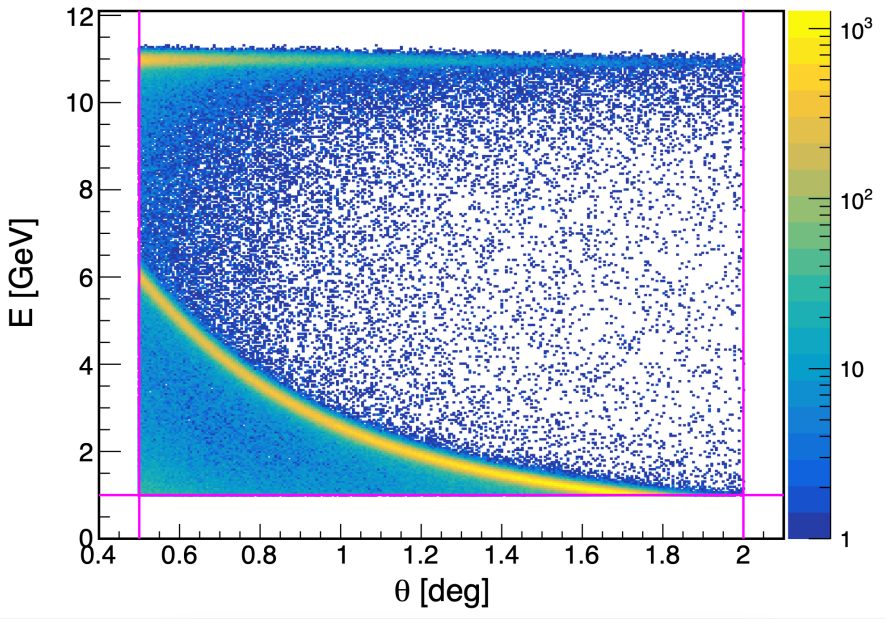




- NEW for PAC52 –
  - Geant4-based MC
  - sweeper
  - dump
- 50 nA positron beam on 5 cm long LH2
- High resolution part of PRIMEX HyCal calorimeter
- fADC - based DAQ with programmable trigger, 20 MHz

Detector non-uniformity estimation-I





$$M^2_{A'} = 2m_e^2 + 2m_e * (E_+ - E_\gamma) - 4E_+ * E_\gamma * \sin^2(\frac{\theta_\gamma}{2})$$

Mass spectrum quality contributions:

- Photon angle, θ - calibrated using GEM chamber with 1x10^{-6} radian steps
- Detector efficiency - calibrated using e^+-e^- rate and the photon angle, 10^{-6}
- Photon energy - calibrated using e^+-p and e^+-e^- elastic locus/band and θ

Some observations

- The search for a new particle, the U/A′-boson, by measuring the missing mass spectra is unique.
- The Belle-II is only other existing option but projected sensitivity is much lower.
- The decay to e+e- could be very small, extra ε^2, so an additional 10^8 level of statistics.
- Positron beam at INFN can do great job, just need Poseidon (P. Valente's project).
- Positron beams are running at KEK, BINP, Cornell in the rings, DESY has pulsed beam.
- Design study e+ at Mainz:EPJ D, H. Backe et al, 2022: 500 MeV, 1 MeV, 0.5 uA
- The 120 MeV stage will be great step forward at JLab.

Summary

1. This experiment will be sensitive to the A' coupling constant ε^2 on the level of 2×10^{-8} in the 15-90 MeV mass range.

2. The experiment will based on the existing PRAD experimental setup in Hall B. Required beam line development is well understood.

3. JLab positron project with stages will have better chance.