A Search for Beyond the Standard Model Particles with the PHENIX detector at RHIC

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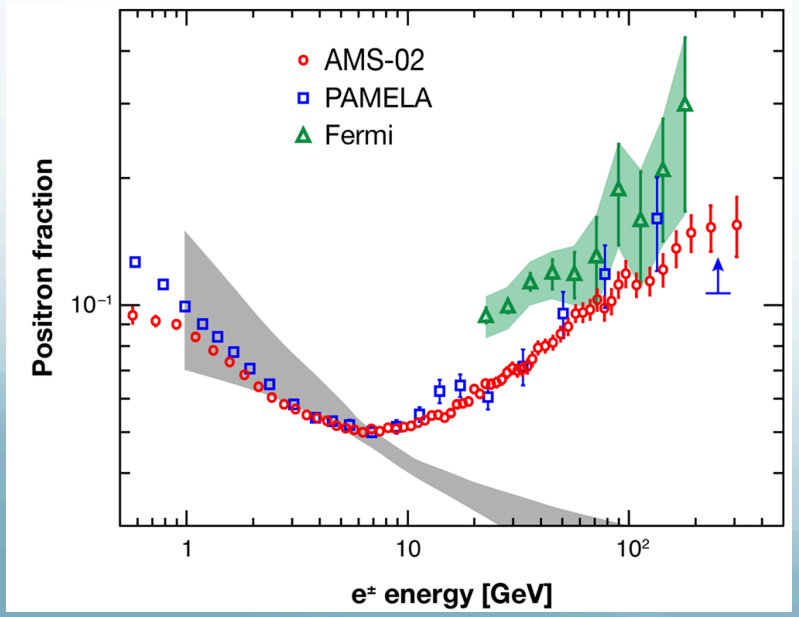
Introduction

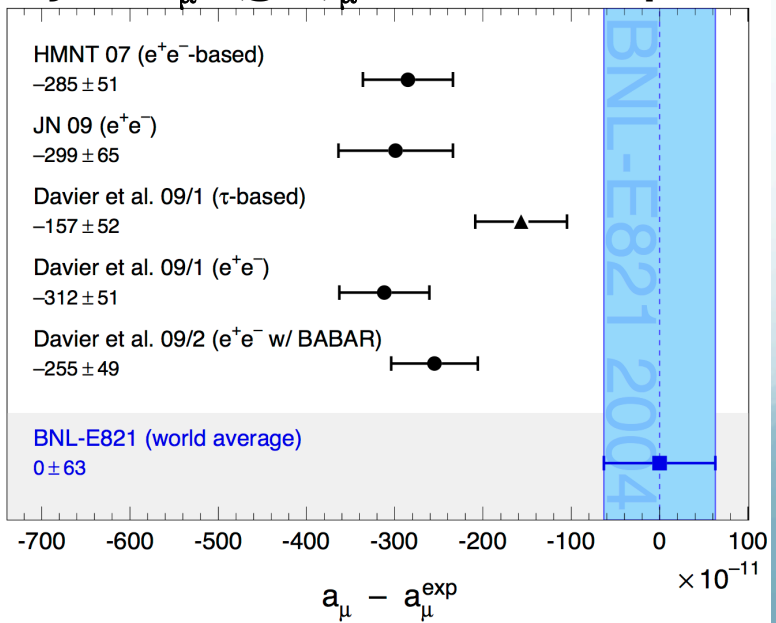
Dark photon, *U*

- *U*(1) gauge field of dark matters very weakly coupled with the Standard Model (SM) [N. Arkani-Hamed, et al., PRD79, 015014, 2009]
  - ✓ Mixing in the ordinary photons with the mixing parameter, ε^2
  - ✓ MeV ~ GeV mass scale
  - ✓ Explain the results which cannot be described by SM
    - Positron excess in the universe (PAMELLA & AMS)
    - Muon g-2 anomaly (E821@BNL)

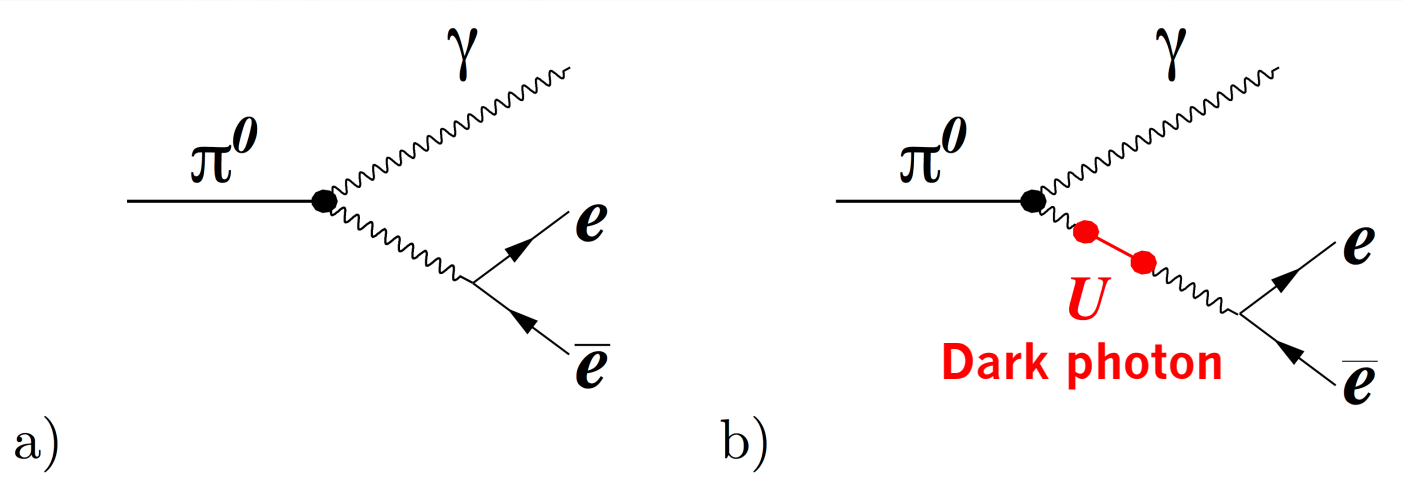
Positron excess in the universe



Discrepancy of $a_\mu=(g-2)_\mu/2$ from SM prediction



Search in π^0 Dalitz decays



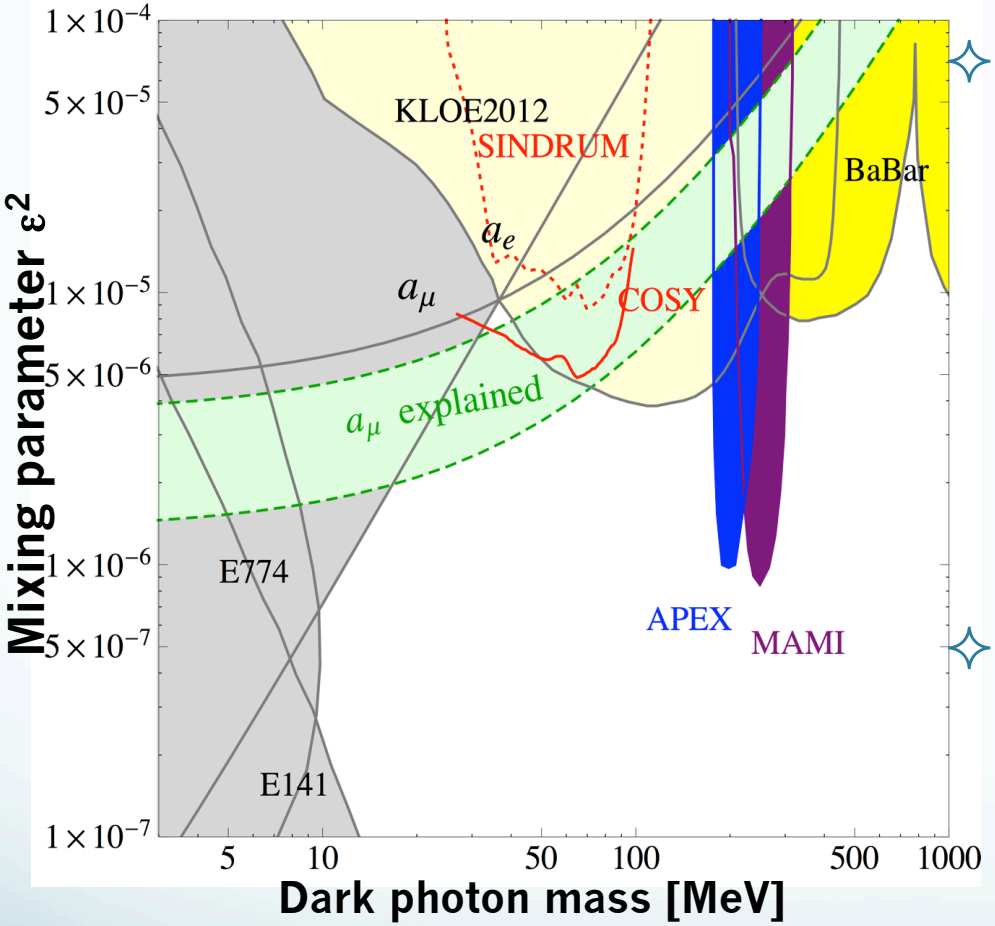
Measurement of $\pi^0 \to \gamma U \to \gamma e^+e^-$ in π^0 Dalitz decays

- Detection of e^+e^- pairs from the dark photons in the π^0 Dalitz decayed e^+e^- pairs
  - ✓ The dark photon exclusively decays into e^+e^- pair.
  - ✓ Its natural width is practically zero.
    - Expected peak width = mass resolution

Important requirements for the dark photon search

1. Large data samples of e^+e^- from π^0 Dalitz decays
2. A very good mass resolution of e^+e^-

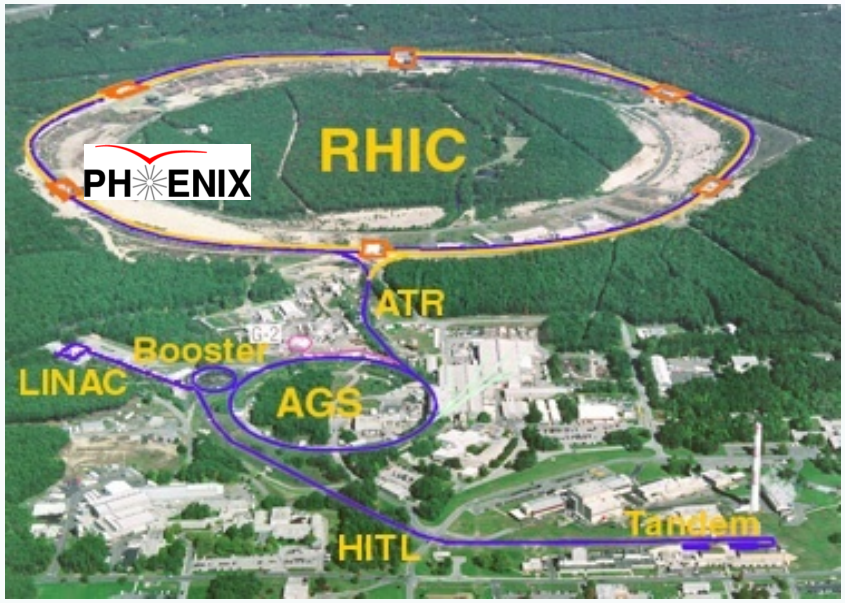
Current dark photon mapping

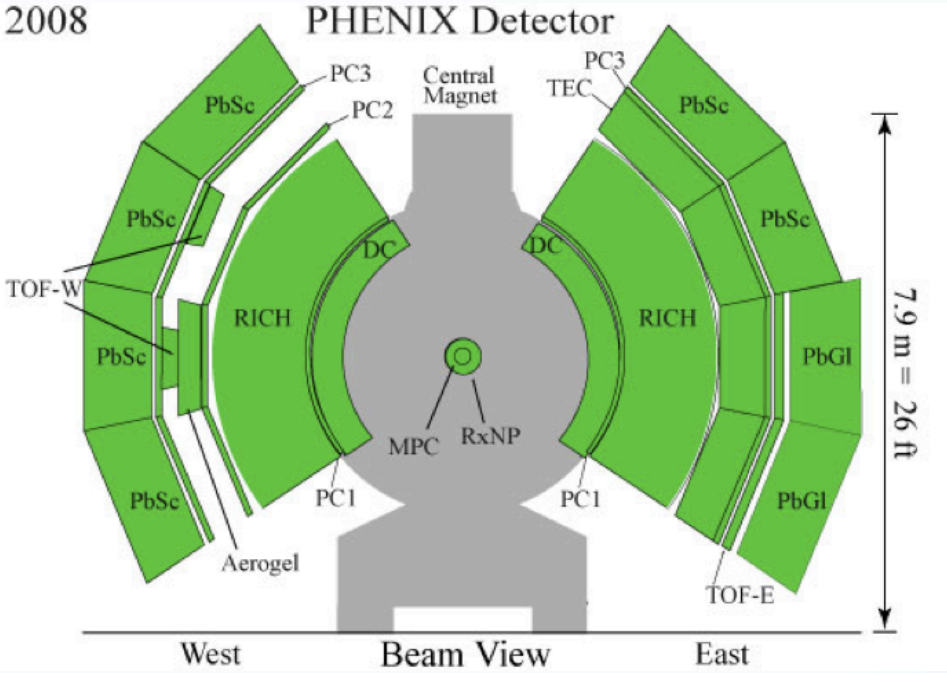


- Many experiments contributed for the dark photon search.
  - ✓ Theory curves from Hye-Sung Lee & Bill Marciano [PRL 109, 031802 (2012)]
  - ✓ The latest result: COSY-WASA [PLB 726, 187 (2013)]
    - 550k π^0 Dalitz events = World largest samples
- The muon g-2 explainable band (90%-CL) still survives for 30-70MeV.

- Getting more important as a candidate of the cause for the muon g-2 anomaly due to the recent SUSY result at LHC
- Short-term aim: **Covering the entire region of the muon g-2 explainable band**

PHENIX experiment at RHIC



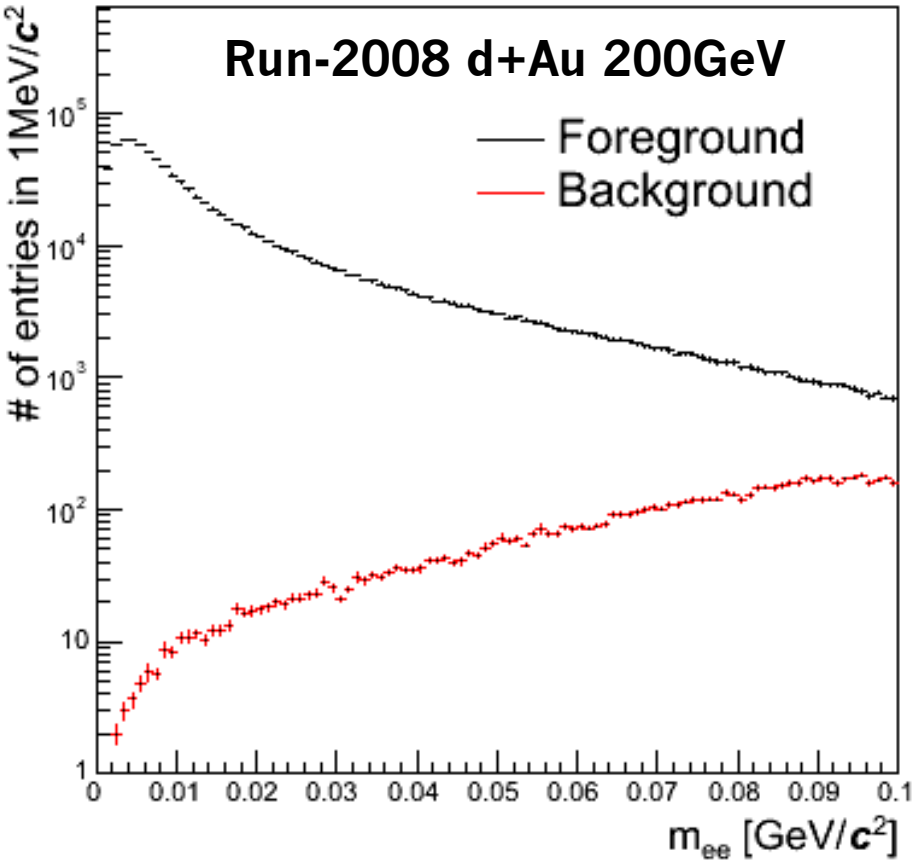


- Originally designed for the study of Quark Gluon Plasma
- Excellent capability for the measurement of e^+e^- pairs
  - ✓ Good momentum resolution
  - ✓ High precision for eID

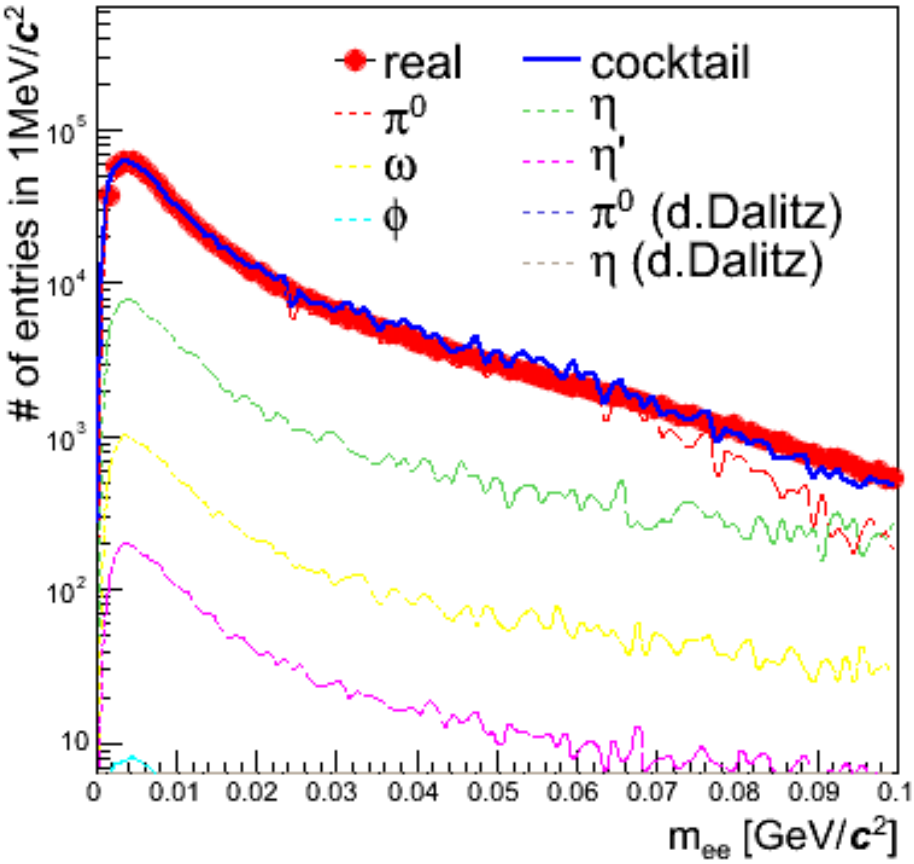
→ High statistics of e^+e^- from π^0 Dalitz decays in p+p (2006) & d+Au (2008) at 200GeV
  - ✓ 1.3M e^+e^- pairs

e^+e^- Mass spectrum

Before BG subtraction



After BG subtraction

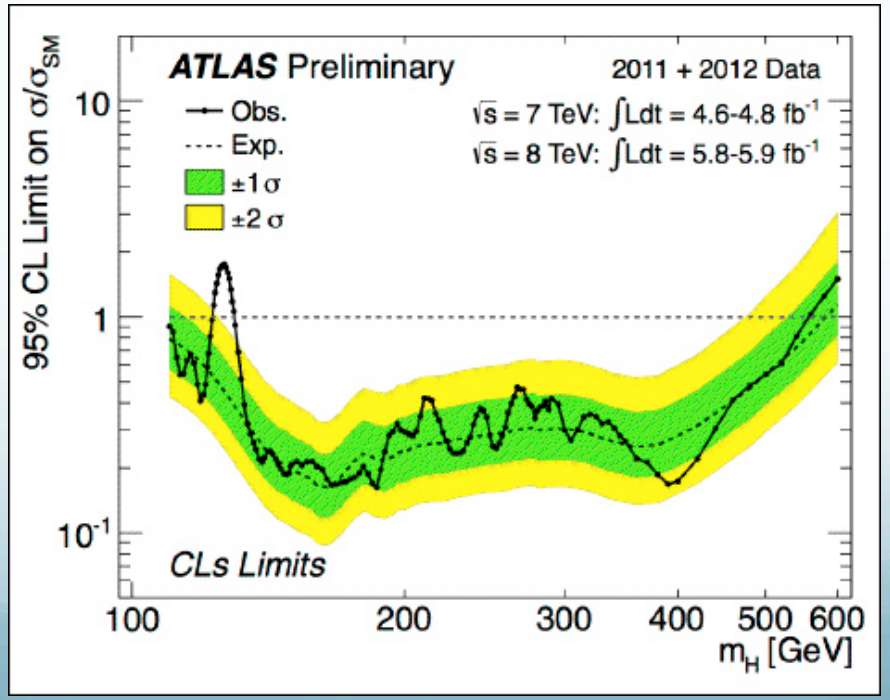


- Successful measurement of e^+e^- pairs at PHENIX
  - ✓ Small background contribution in m_{ee}<100MeV
  - ✓ Data looks agreement with hadronic cocktail calculation.
  - ✓ σ_{ee} is about 3MeV calculated from well-tuned simulation.

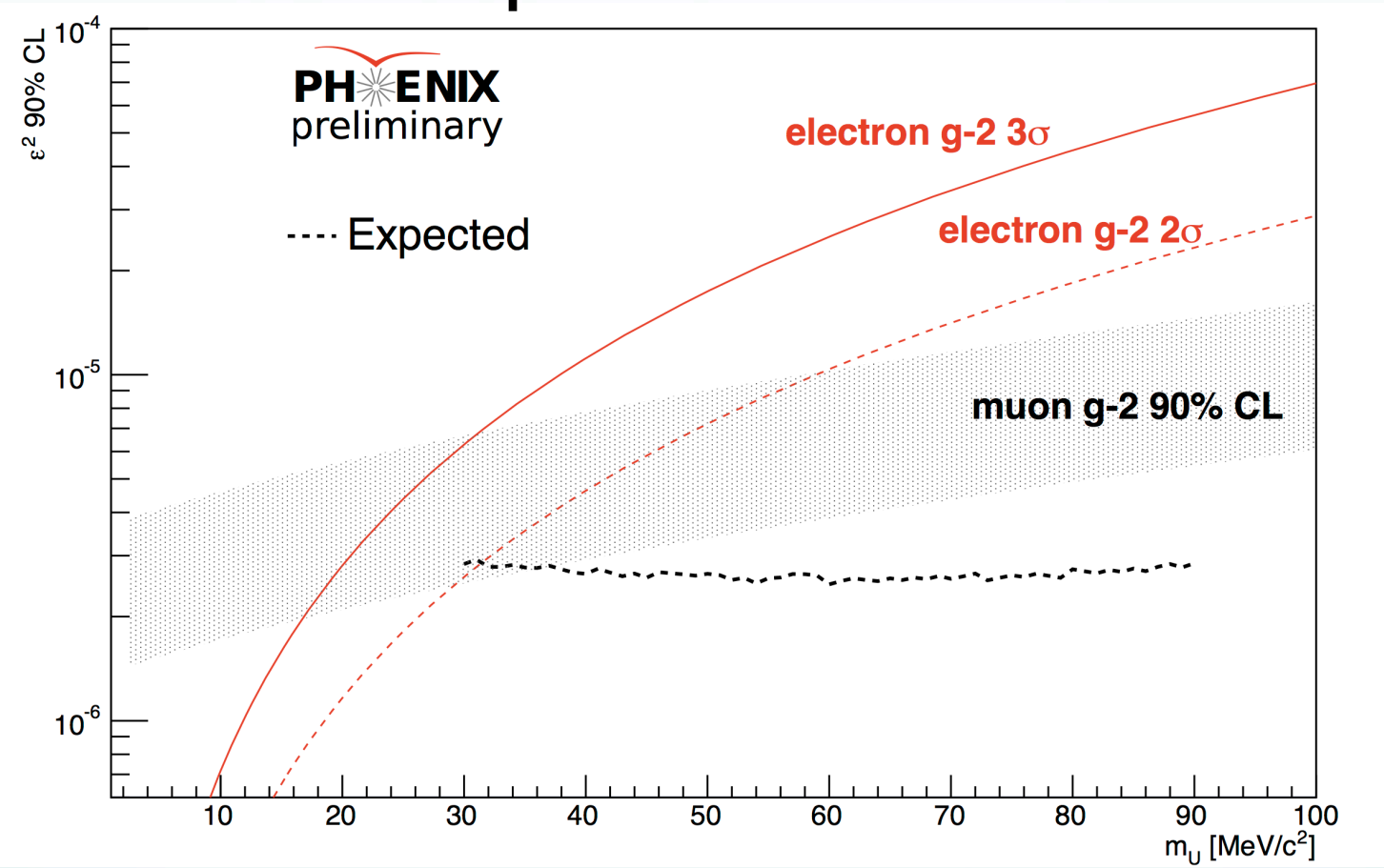
Confidence level calculation

- **CLs method**
  - ✓ Widely accepted way to compute confidence levels for hypotheses with limited signal sensitivities
    - Famous "Brazil band plot" for Higgs search at LHC
  - ✓ Relative likelihoods of how well the data is described by:
    a. Only background (Dalitz continuum)
    b. Signal (dark photon) + Background

Famous ATLAS Brazil band plot

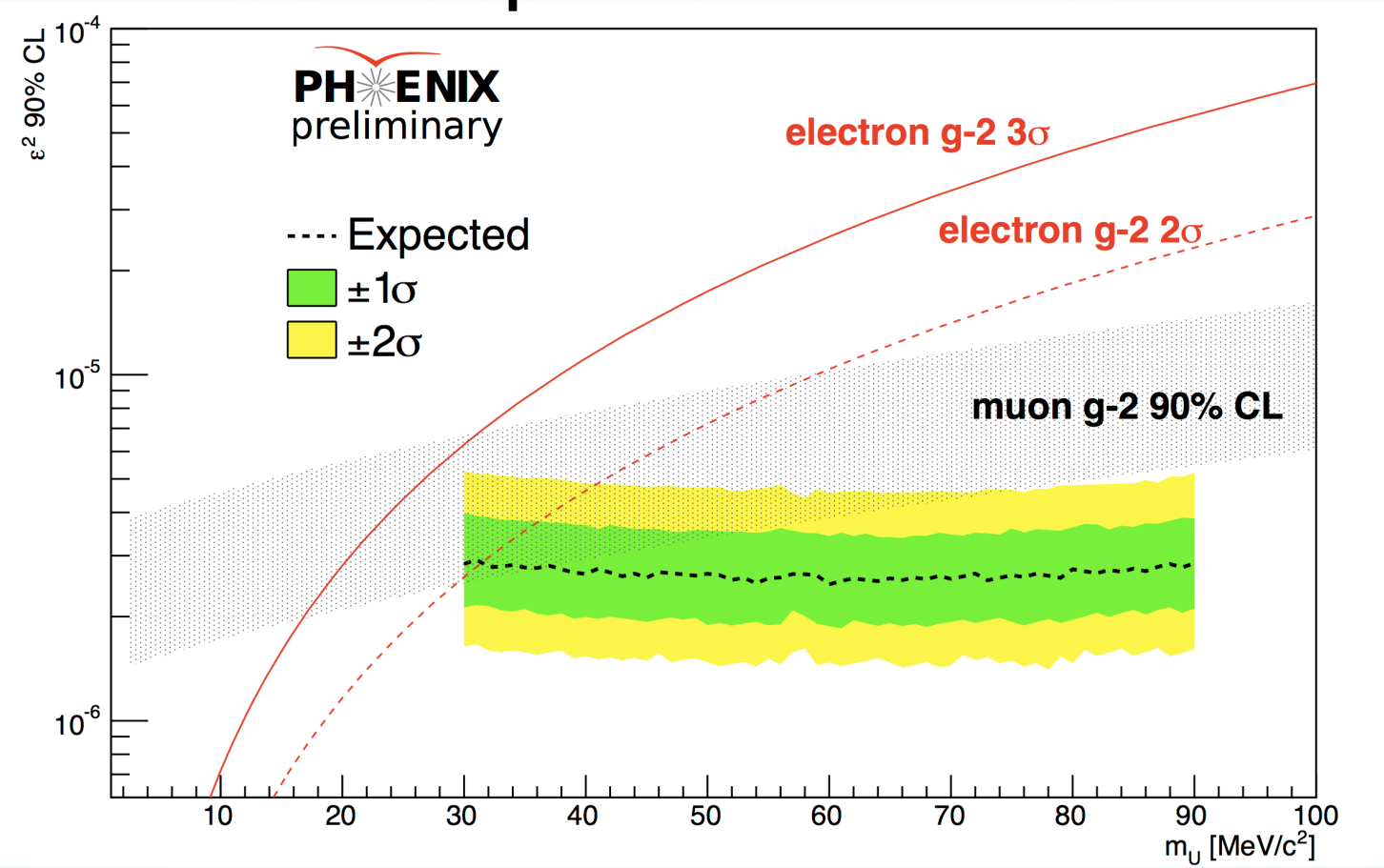


Dark photon limit



- Expected reach with 1.3M events & 3MeV of σ_{ee}

Dark photon limit



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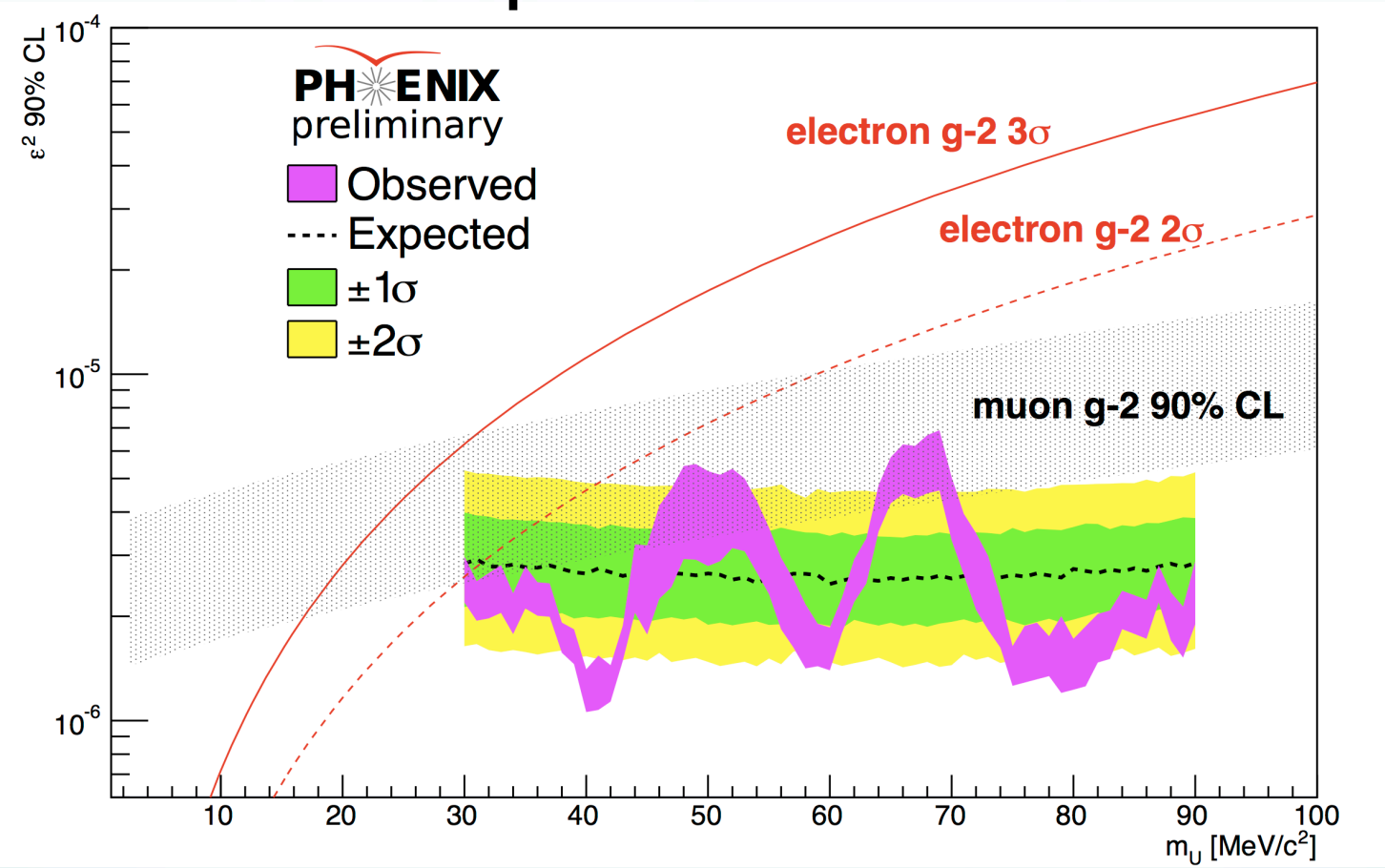
- 1, 2σ statistical fluctuations of the expected reach

Dark photon limit



- Expected reach with 1.3M events & 3MeV of σ_{ee}
- 1, 2σ statistical fluctuations of the expected reach
- Observed upper limit with the PHENIX detector
  - ✓ Including systematic errors from uncertainties on the Dalitz continuum & σ_{ee}

Summary and outlooks

Current status

- Dark photon search is being conducted at the PHENIX experiment.
  - ✓ Searching for the dark photon in π^0 Dalitz decays
  - ✓ 1.3M pairs in p+p (2006) and d+Au (2008) datasets
  - ✓ Good mass resolution at PHENIX ~ 3MeV
  - → Improved upper limit of the dark photon in 30-90MeV
    - Addition of statistics from the 2009 p+p data is ongoing.

Outlooks

- Possibility to search for long-lived dark photons with smaller mixing parameter
  - ✓ Expected Dalitz statistics in the 2014 Au+Au data = more than 15M events
  - ✓ Background-less measurement with secondary vertex requirement