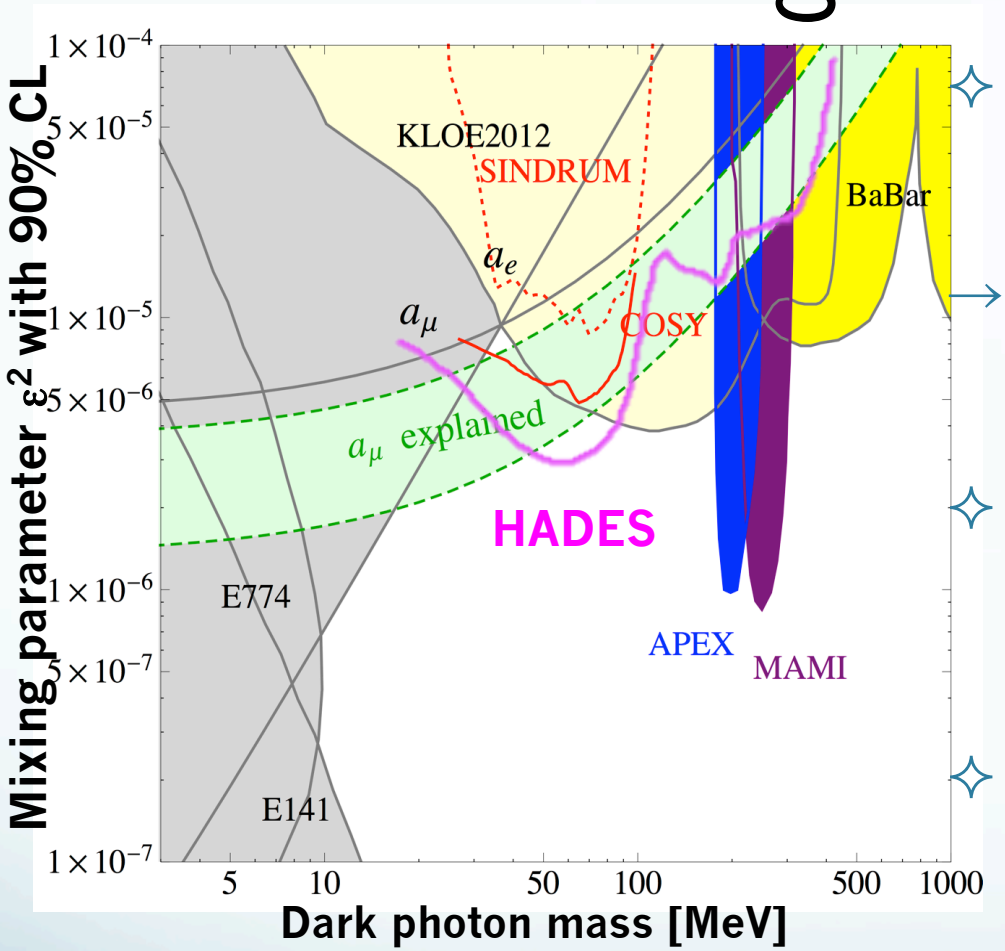
PHENIX Searches for Low Mass Dark Photons

Yorito Yamaguchi
for the PHENIX collaboration
Stony Brook University

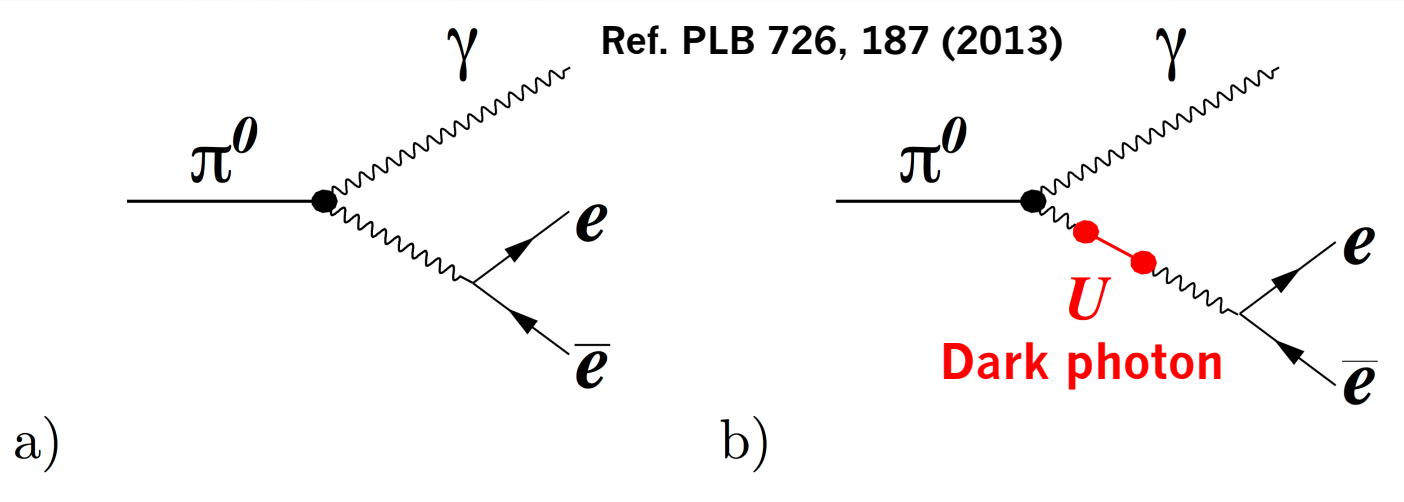
Muon g-2 anomaly



- Observed 3.6σ discrepancy from SM prediction is one of possible BSM phenomena
- → Dark photon can explain this discrepancy as well as other astrophysical anomalies.
- Many experiments contributed for the dark photon search.
  - ✓ Theory curves from Hye-Sung Lee & Bill Marciano
- Muon g-2 explainable band (90% CL) still survives for 30-50 MeV.

- 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**

Search in π^0/η Dalitz decays



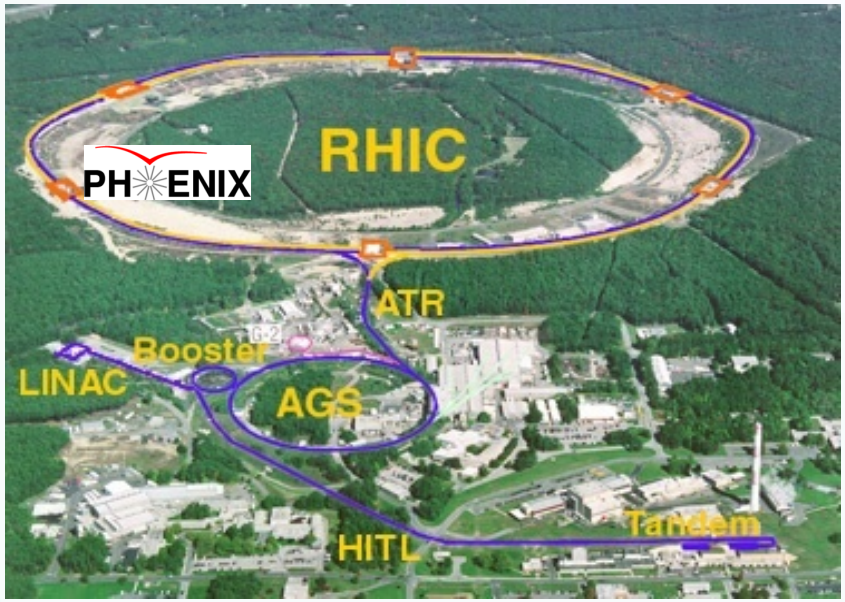
Measurement of $\pi^0/\eta \to \gamma U \to \gamma e^+e^-$ in Dalitz decays

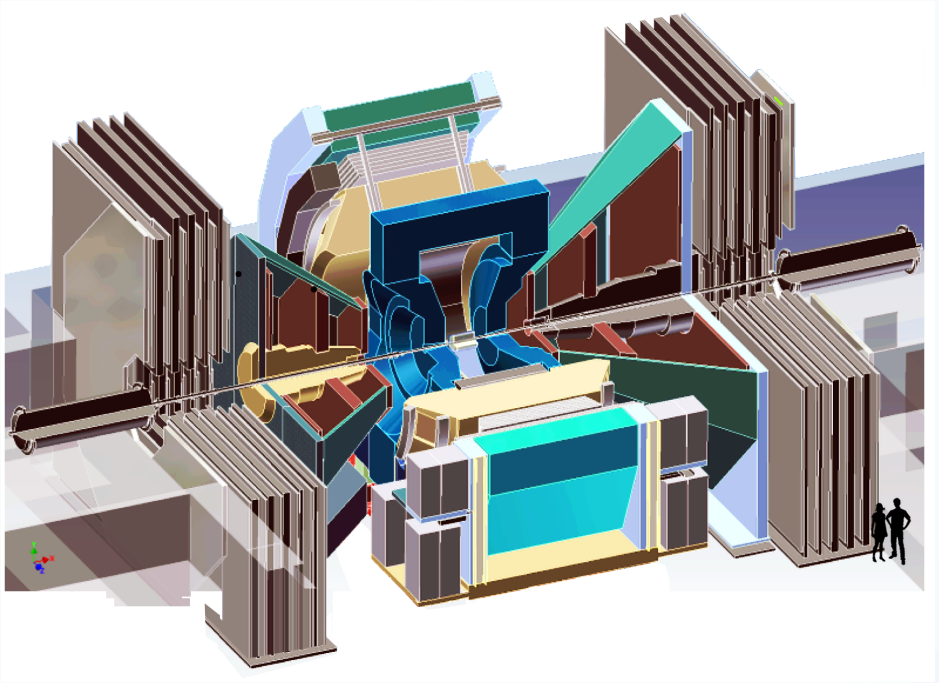
- Aim to detect possible e^+e^- pairs from the dark photons in the π^0/η Dalitz decayed e^+e^- pairs
  - ✓ The dark photon exclusively decays into e^+e^- pair.
  - ✓ Its natural width is very narrow.
    - Expected peak width = detector mass resolution
  - ✓ Same approach with COSY-WASA & HADES

Important requirements for this measurement

1. A large data sample of e^+e^- from π^0/η Dalitz decays
2. A very good mass resolution of e^+e^-

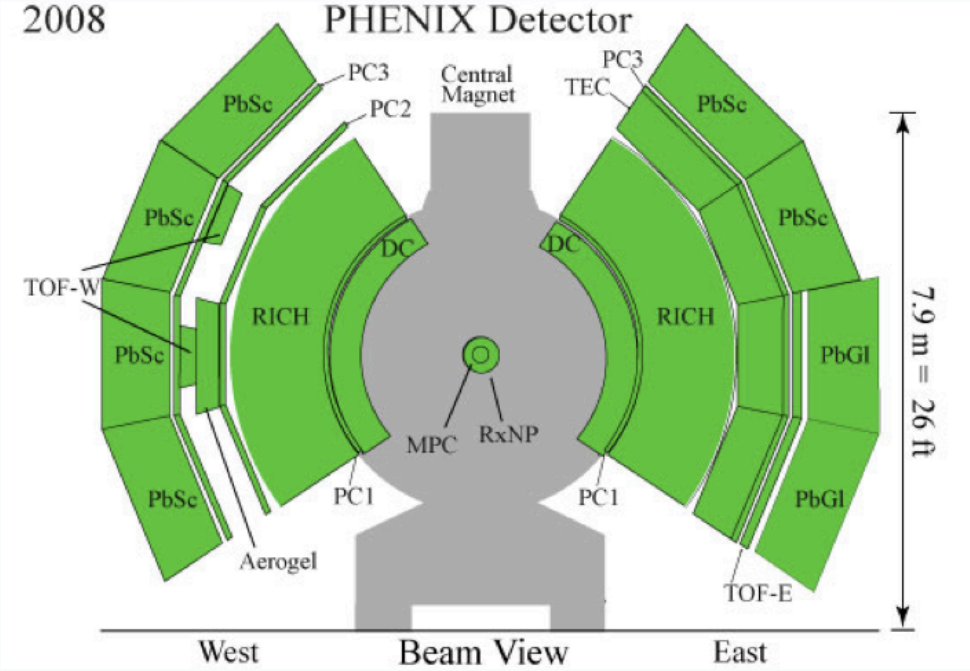
PHENIX experiment at RHIC





- Relativistic Heavy Ion Collider at BNL
  - ✓ Collision species: p+p, d+Au, Au+Au, Cu+Cu, U+U, …
  - ✓ Maximum collision energy: 200 (for HI),500 (for p+p) GeV
  - ✓ Running since 2001
- PHENIX experiment is originally designed for the study of Quark Gluon Plasma.
  - ✓ Excellent capability for e^+e^- measurements

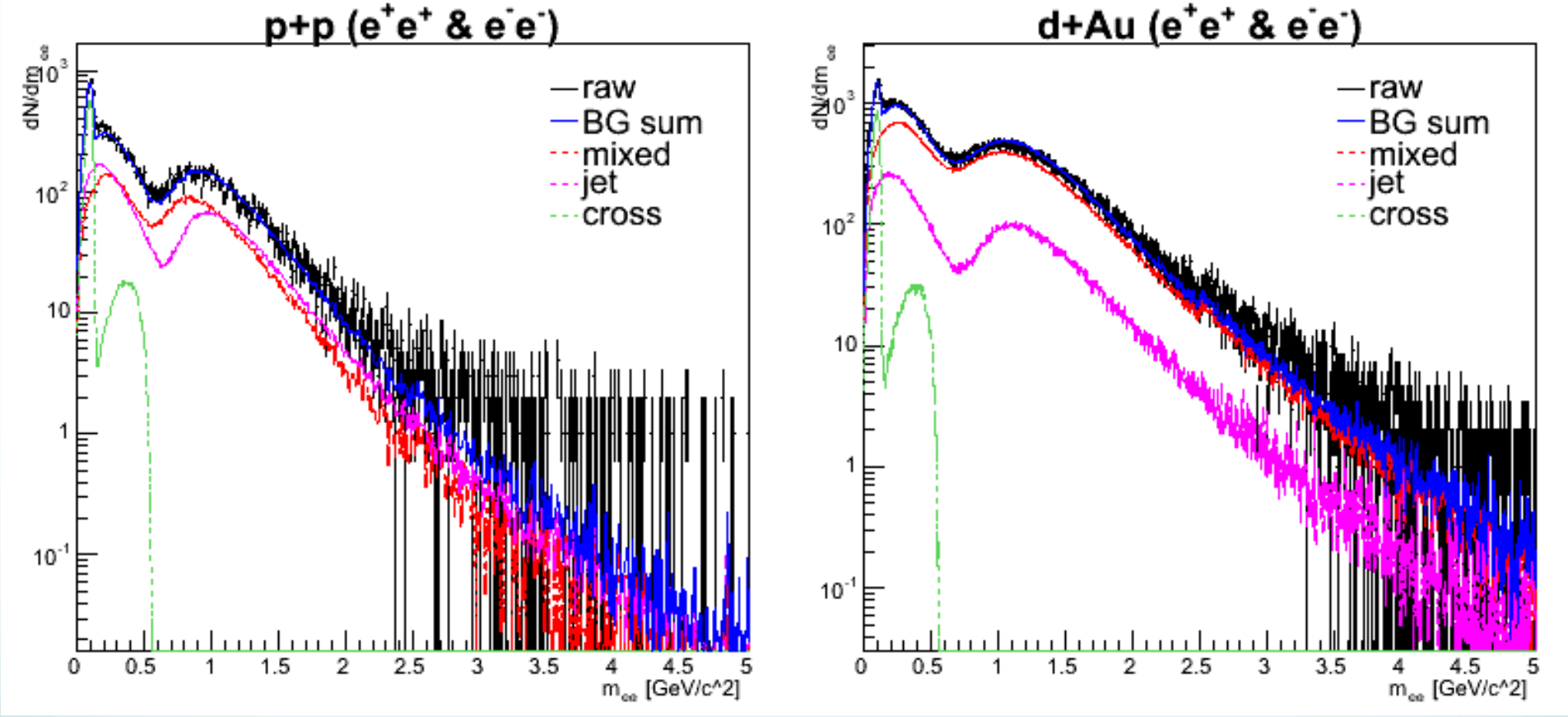
How to measure electrons



- Central arm at mid-rapidity: $|\eta|<0.35$
- Momentum measurement of charged tracks by DC & PC
  - ✓ $\delta p/p = 1\% \oplus 1.1\% \times p$ [GeV/c]
- Electron identification by RICH & E/p matching
  - ✓ Charged hadron rejection power ~ 10^3
  - ✓ Electron trigger requires with a coincidence of a RICH hit & correlated EMCal energy deposit

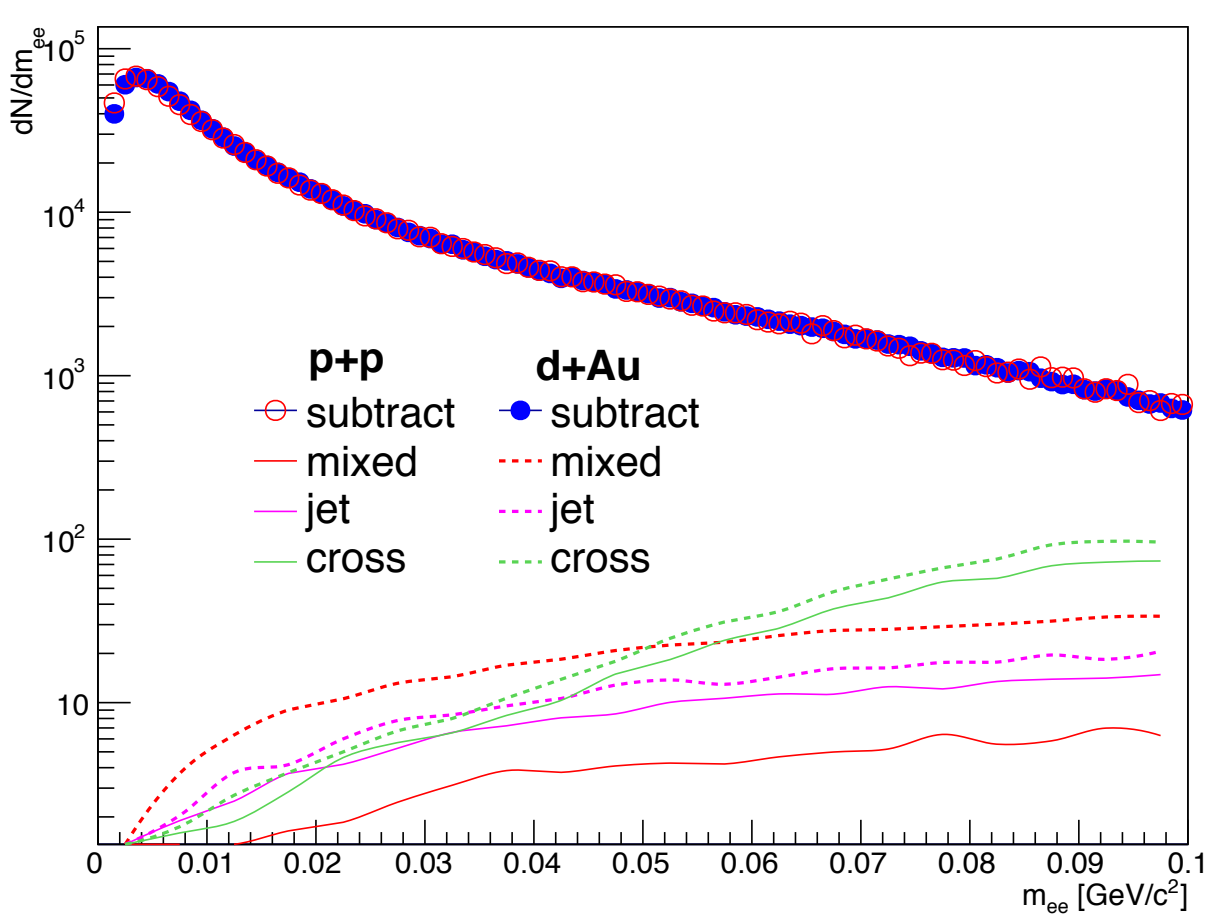
→ Promising measurements of e^+e^- with high statistics

Background pairs



- 2006 p+p & 2008 d+Au datasets were analyzed.
  - ✓ Background pairs: **combinatorial** pairs, **semi-correlated jet** pairs, **cross** pairs from double Dalitz decays
  - ✓ Each BG contribution was evaluated using Like-sign pairs.

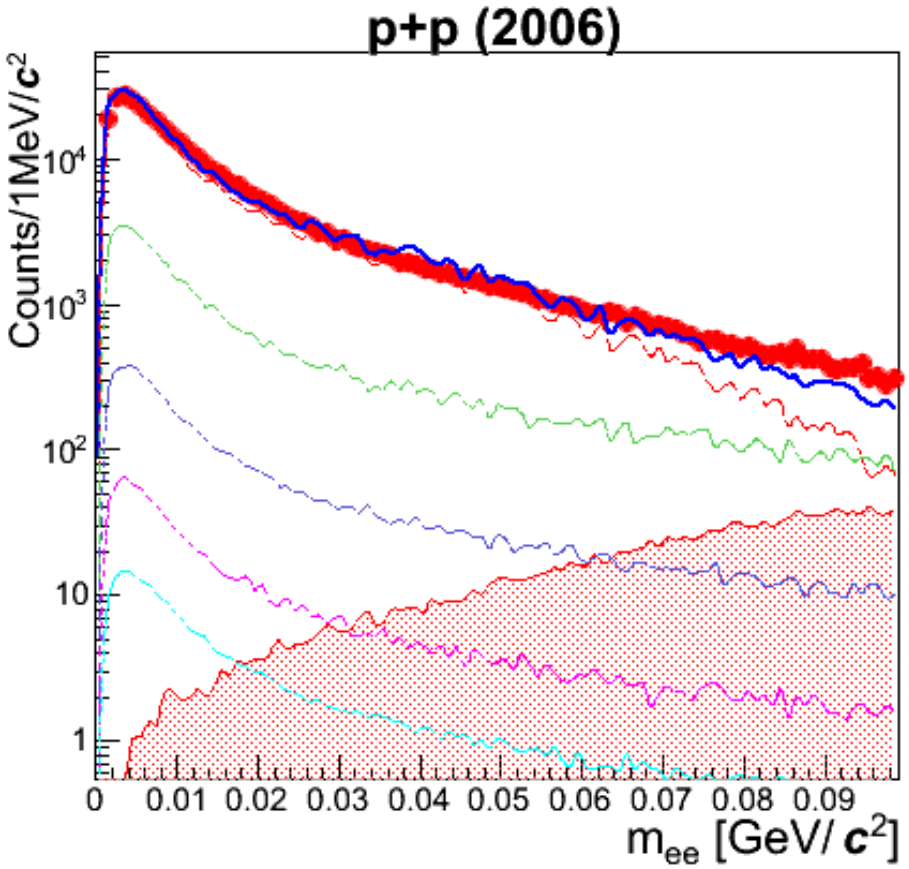
Background pairs (cont.)

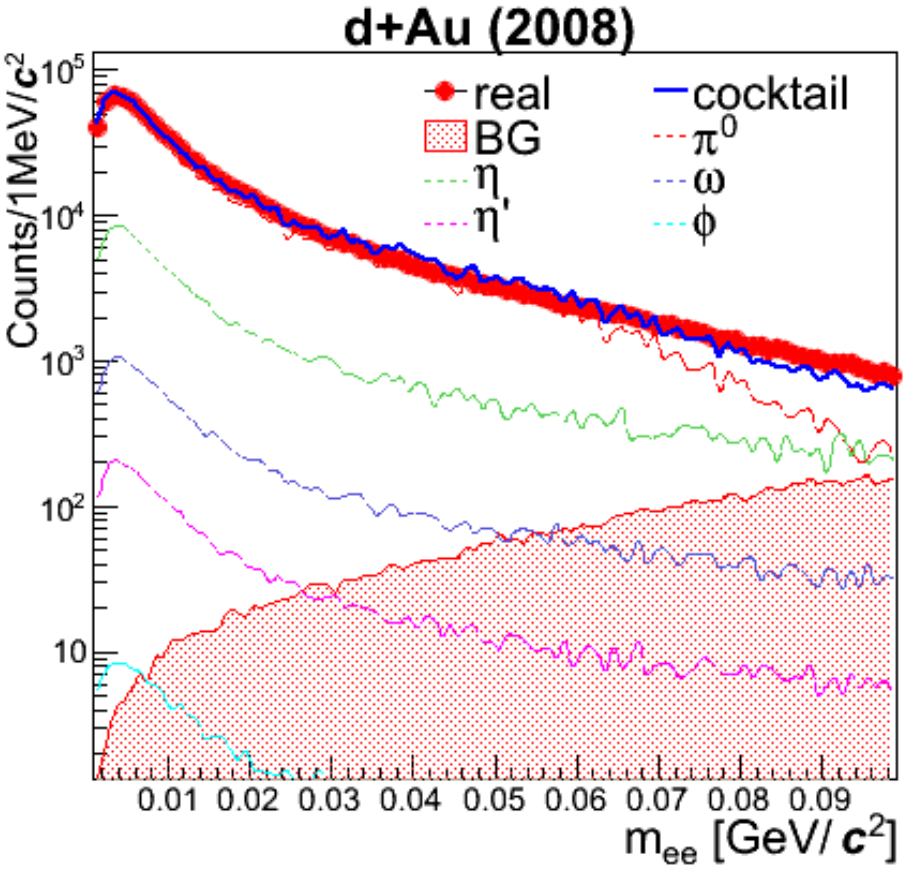


- **Jet** & **cross** pair contributions are consistent for both p+p and d+Au as expected
  - ✓ p+p & d+Au datasets are normalized in m_{ee}<30 MeV

→ Background contributions are very well understood.

e^+e^- Mass spectra

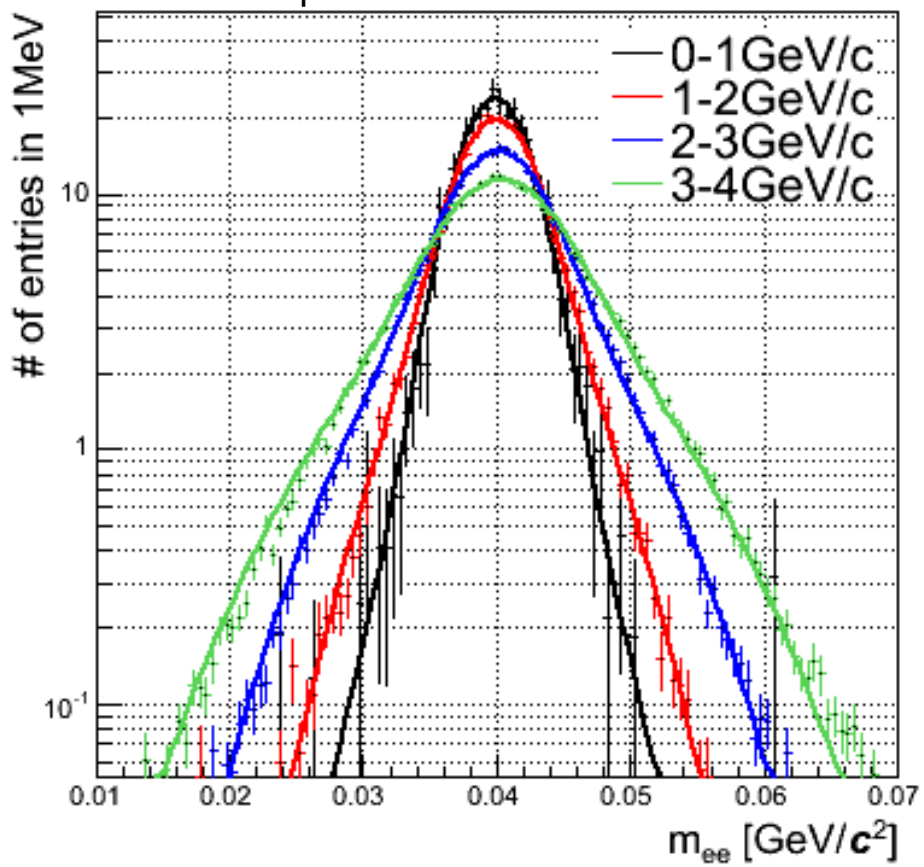




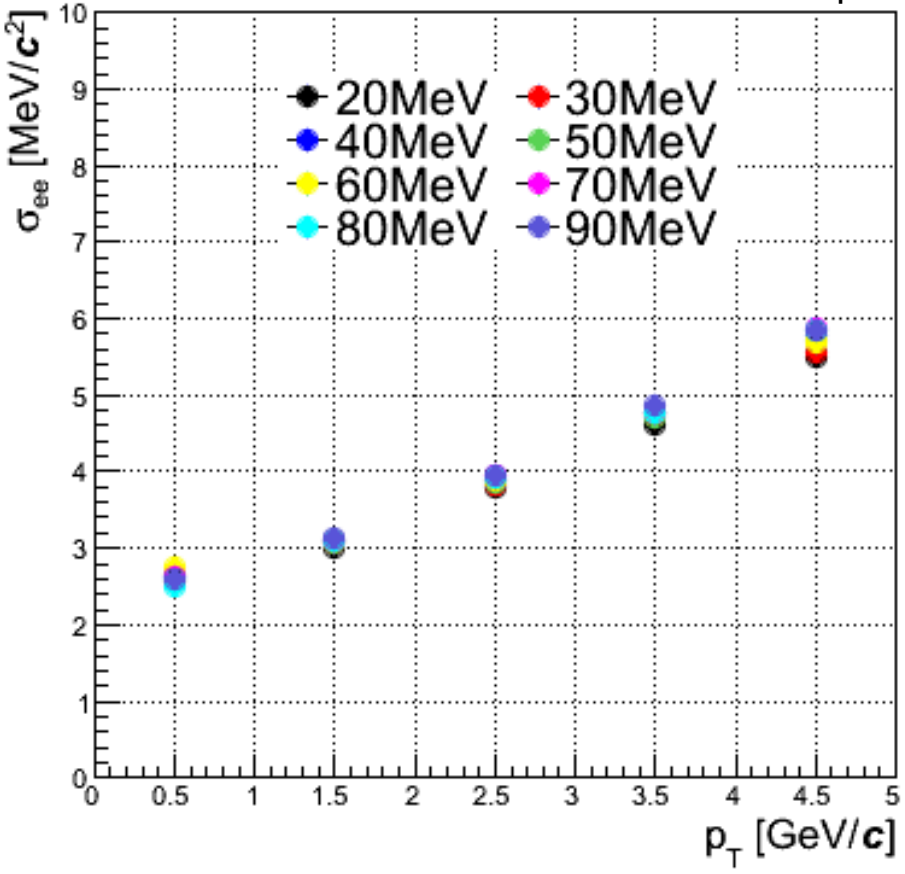
- Measured e^+e^- spectra can be well described by a "cocktail" of hadron decays + BG.
  - ✓ 400k (p+p) + 1.0M (d+Au) = total 1.4M e^+e^- Dalitz pairs
  - ✓ No significant dark photon signal

Mass resolution

Dark photon mass = 40MeV



Mass resolution as a function of pT

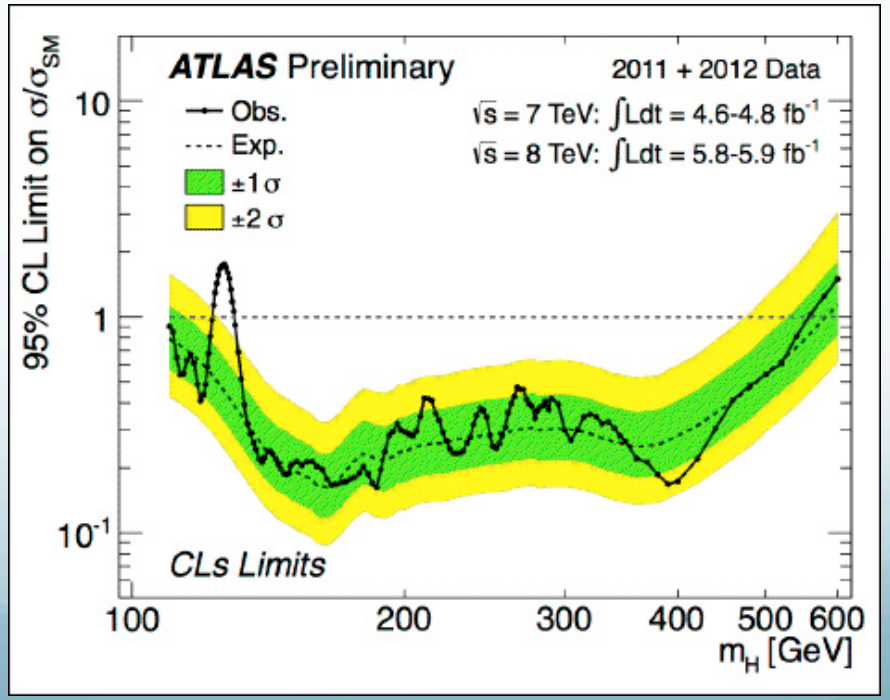


- Mass resolution of the PHENIX detector was calculated by the GEANT-based simulation tuned to match the real data.
  - ✓ Considering the real e^+e^- p_T spectrum, an expected dark photon peak width is about 3 MeV (for inclusive pT).

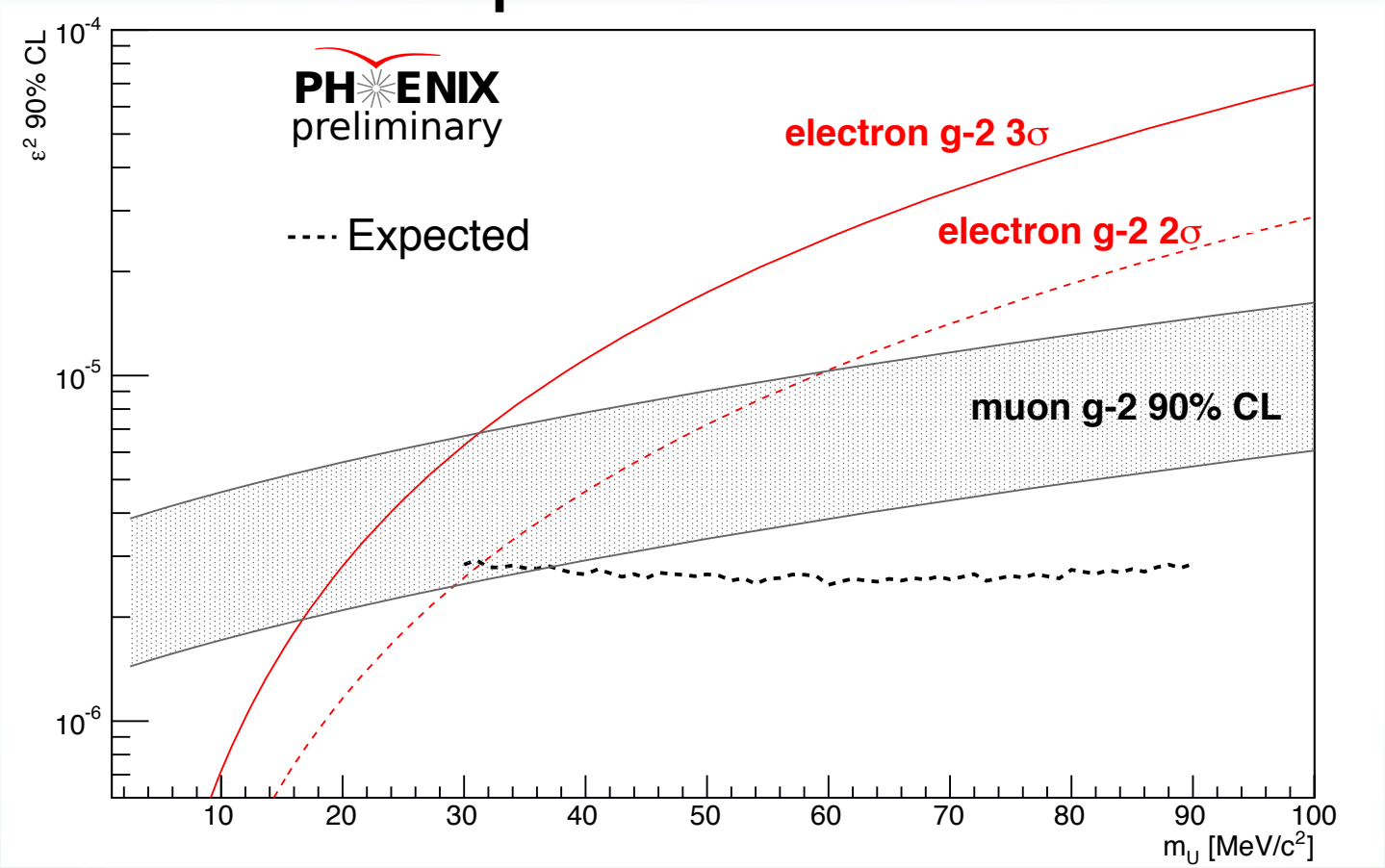
Confidence level calculation

- **CLs approach**
  - ✓ 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 1.4M events & 3 MeV of σ_{ee}

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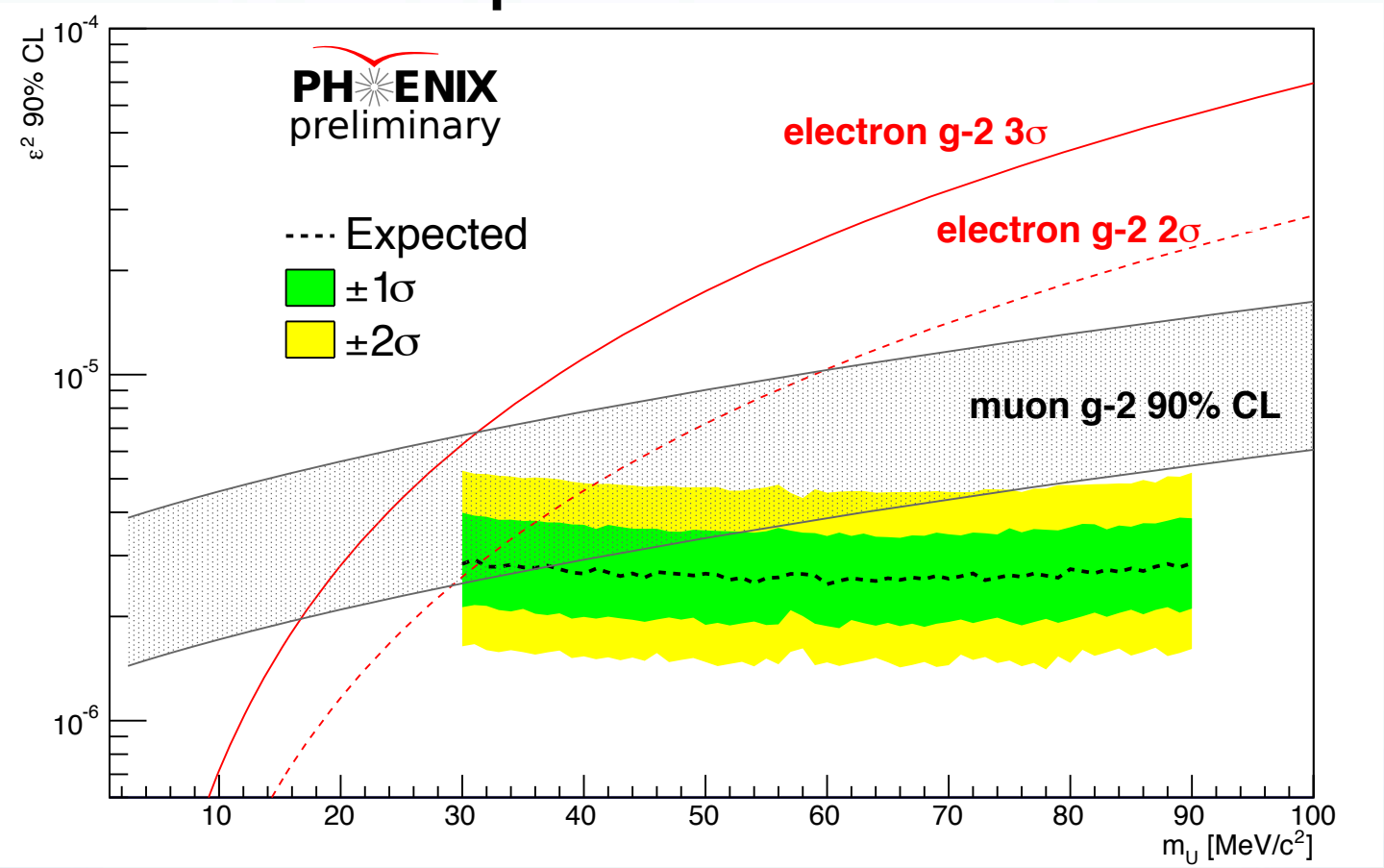

- Expected reach with 1.4M events & 3 MeV of σ_{ee}
- 1, 2σ statistical fluctuations of the expected reach

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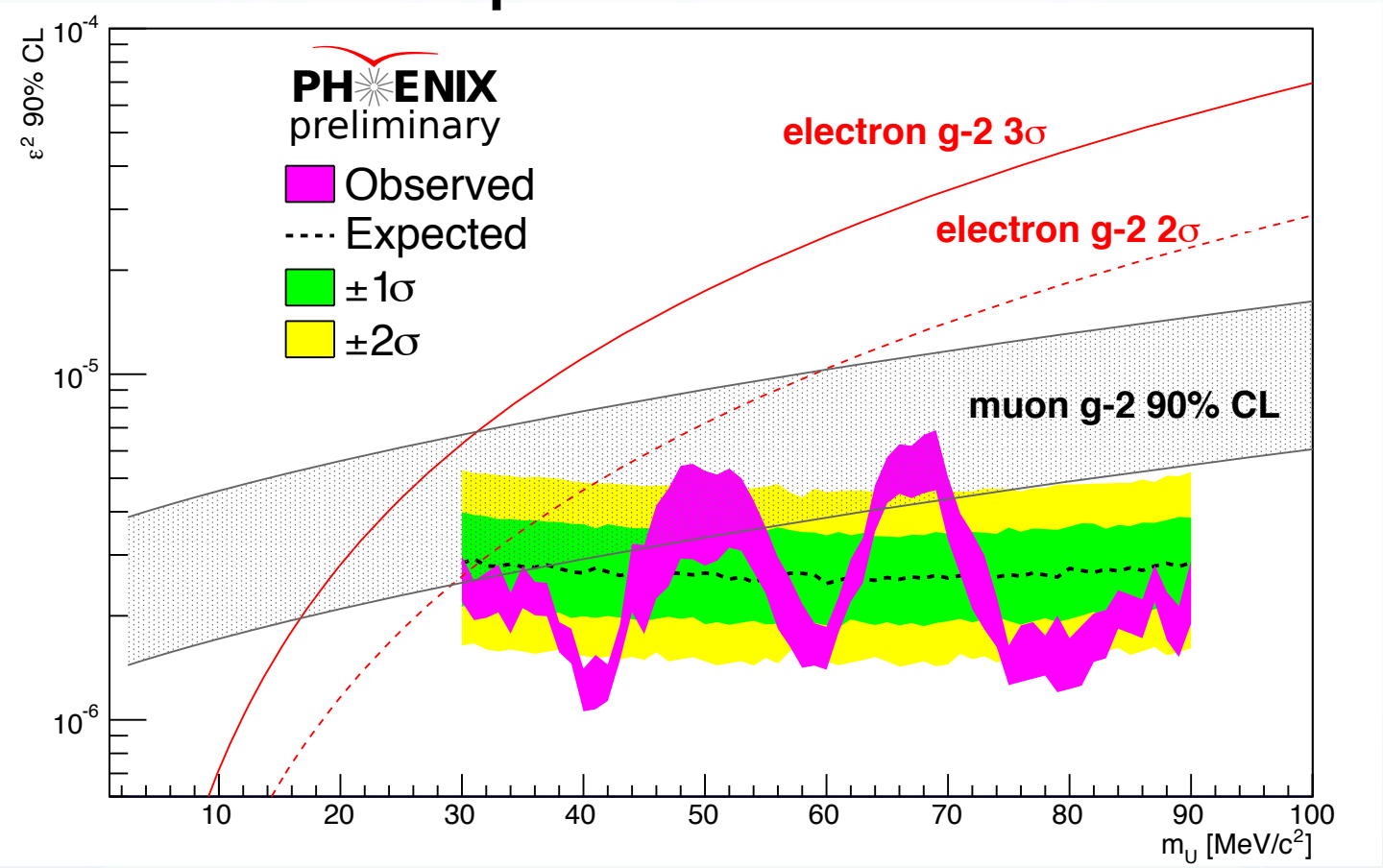

- Expected reach with 1.4M events & 3 MeV of σ_{ee}
- 1, 2σ statistical fluctuations of the expected reach
- Observed upper limit with the PHENIX detector
  - ✓ Including systematic errors from uncertainties on the Dalitz continuum & σ_{ee}

Summary and outlooks

- Dark photon search is being conducted at the PHENIX experiment.
  - ✓ Searching for the dark photon in π^0/η Dalitz decays
  - ✓ 1.4M pairs in p+p (2006) and d+Au (2008) datasets
  - ✓ Good mass resolution at PHENIX ~ 3MeV
  - → Improved upper limits of the dark photon in 30-90MeV, but a small region in the muon g-2 explainable band still survives.

- Future plan of the dark photon search at PHENIX
  - ✓ Increase of statistics by adding the 2009 p+p data
    - Comparable statistics to the 2006 p+p data & an additional detector installed near the beam pipe
    - Paper preparation is now ongoing, and we hope to submit the paper soon.
  - ✓ Long-lived dark photon search with the 2014 Au+Au data
    - Secondary vertex measurement by VTX