Search for Muonic Dark Forces at BABAR

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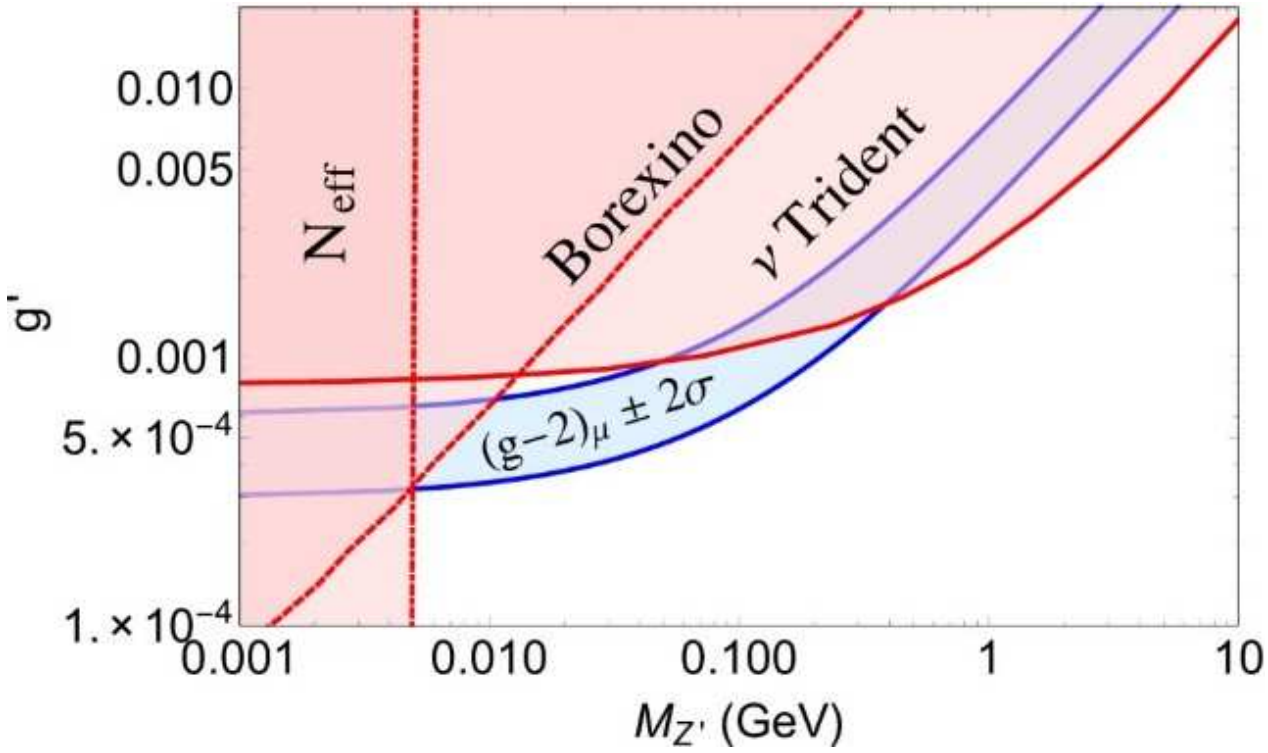
On Behalf of the BABAR Collaboration

Parameter Space of the $L_\mu - L_\tau$ Model

★ Current constraints



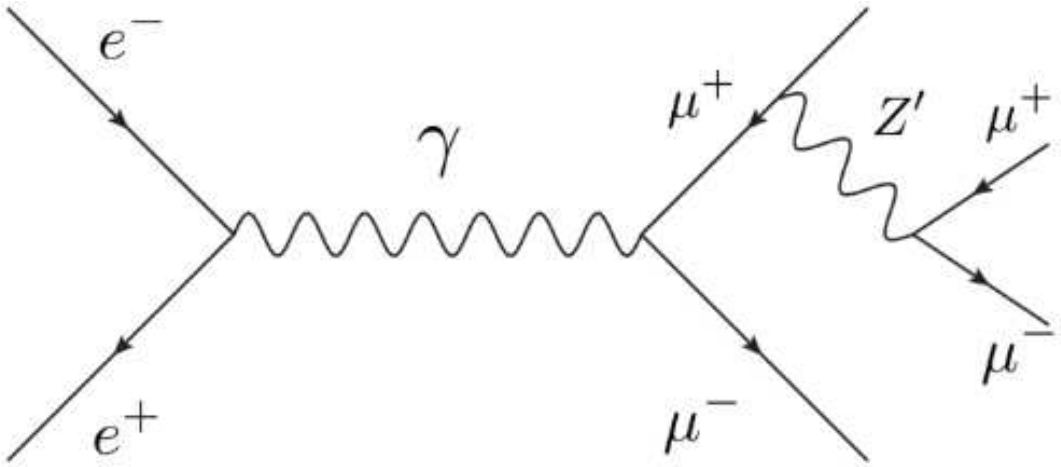
★ $L_\mu - L_\tau$ **Gauge Interaction:** New gauge boson, Z' is produced primarily from radiation of the heavy-flavor leptons

★ It can be parametrized by the mass of Z' ($M_{Z'}$) and the gauge coupling (g')

★ **Simplified Model:** Consisting of only the SM plus new gauge Z'

Analysis Strategy

Cleanest channel at BABAR: $e^+e^- \to \mu^+\mu^- Z', Z' \to \mu^+\mu^-$



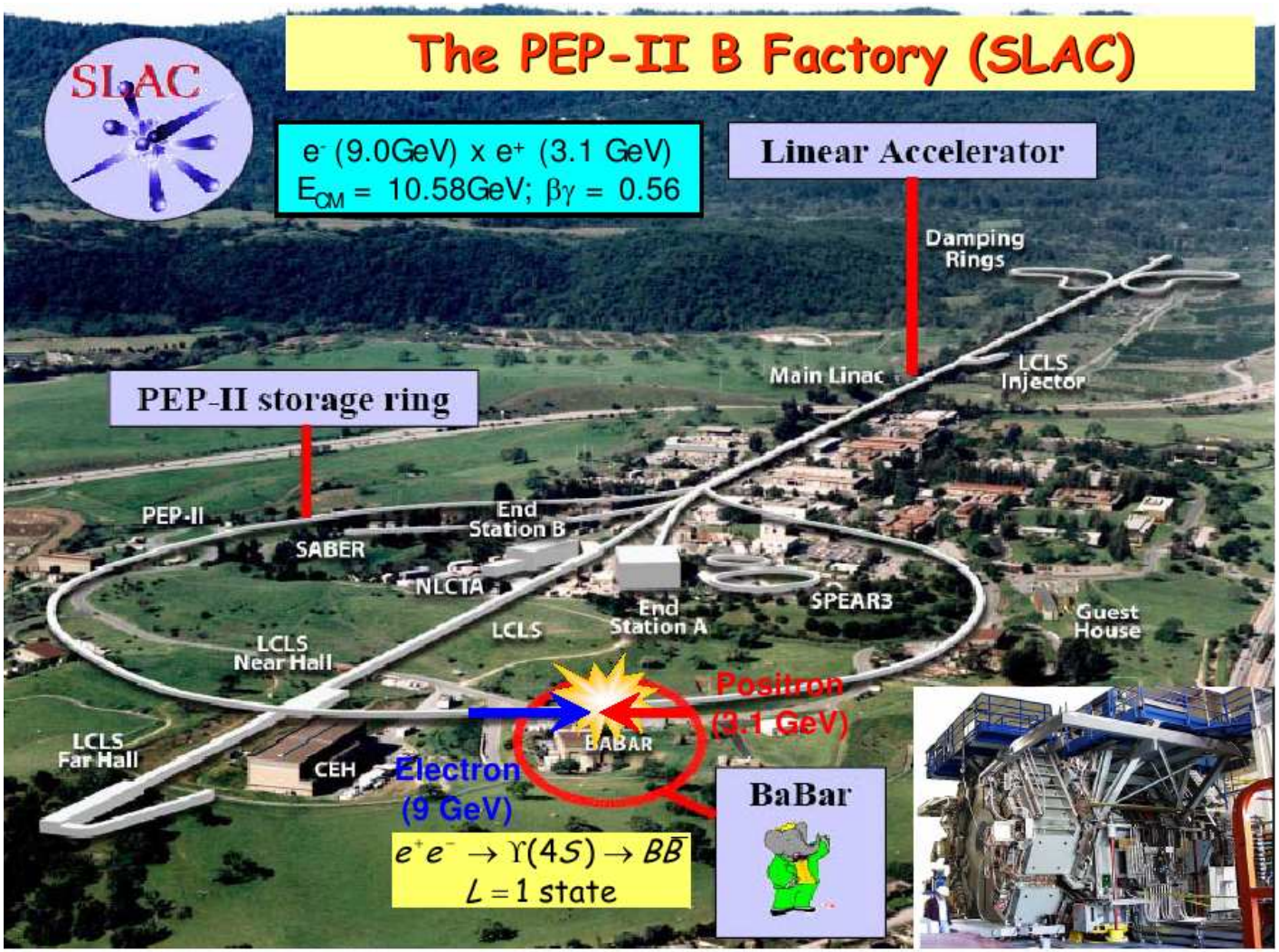
★ Search for dark bosons Z' with vector couplings only to the second and third generation of leptons

Ratio between fraction of the total cross-section:

$$F = \frac{1}{\sigma_0} \int_{X_0}^{1} \frac{d\sigma_{e^+e^- \to \gamma X(s,x)}}{dx}$$

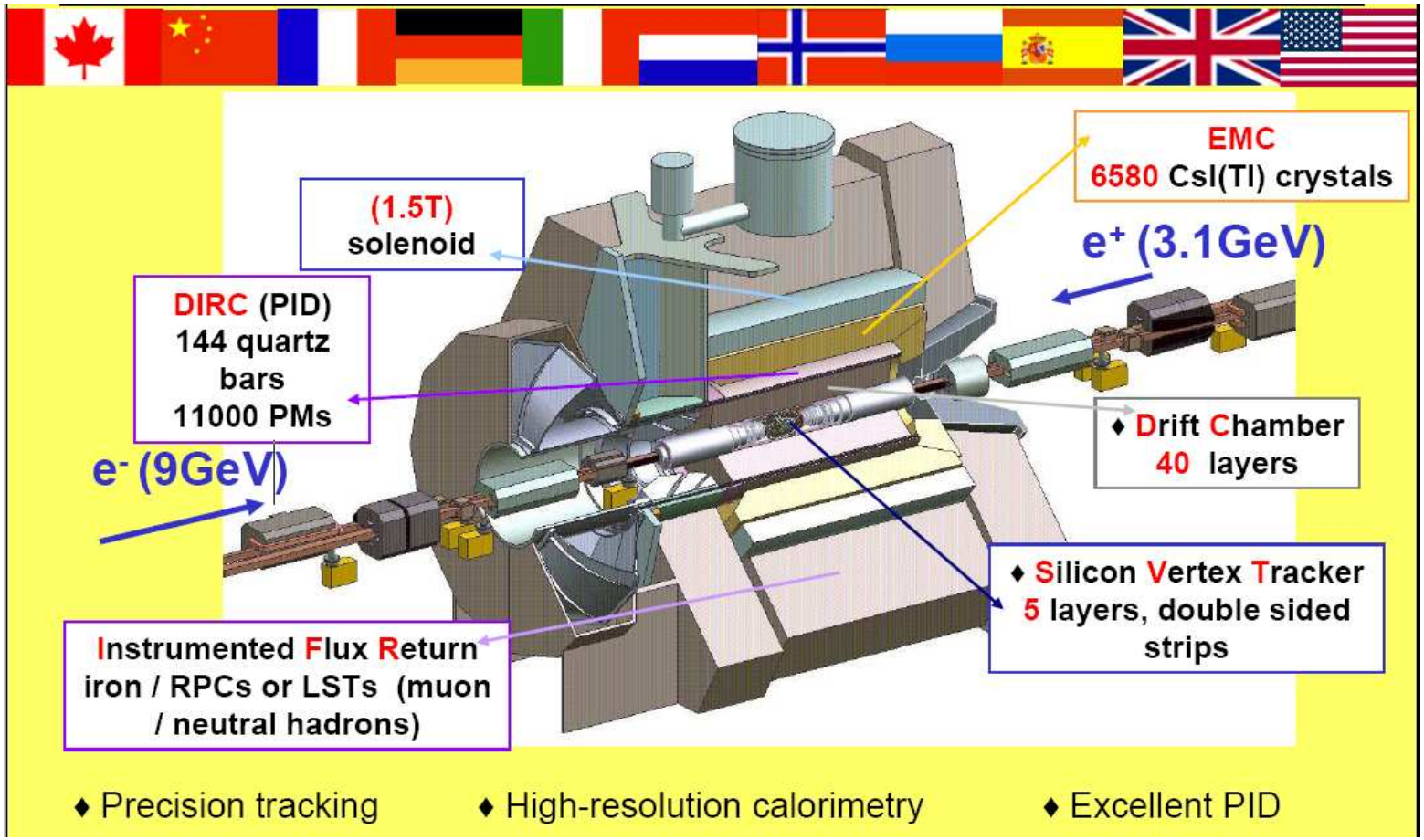
The B Meson Factories

- BABAR at Stanford Linear Accelerator Center (SLAC), California



- Another B-factory machine is at KEKB, Tsukuba, Japan

BABAR Detector



- Collides (9 GeV) $e^- \bowtie e^+$ (3.1 GeV) $\hookrightarrow \Upsilon(4S)$ with $E_{CM} = 10.58$ GeV
- Peak luminosity : $\sim 1.21 \times 10^{34}\ cm^{-2}s^{-1}$, $B^0\overline{B}^0$ production $\sim$ 12 Hz
- Boost $\beta\gamma = 0.56$ allows to measure B decay times

Data and Selection

★ **BABAR Data:**

- ★ Int. luminosity at $\Upsilon(4S)$ + $\Upsilon(3S)$ + $\Upsilon(2S)$: 514 fb^{-1}
- ★ Int. Luminosity off peak: 47.9 fb^{-1} (40 MeV below peak)

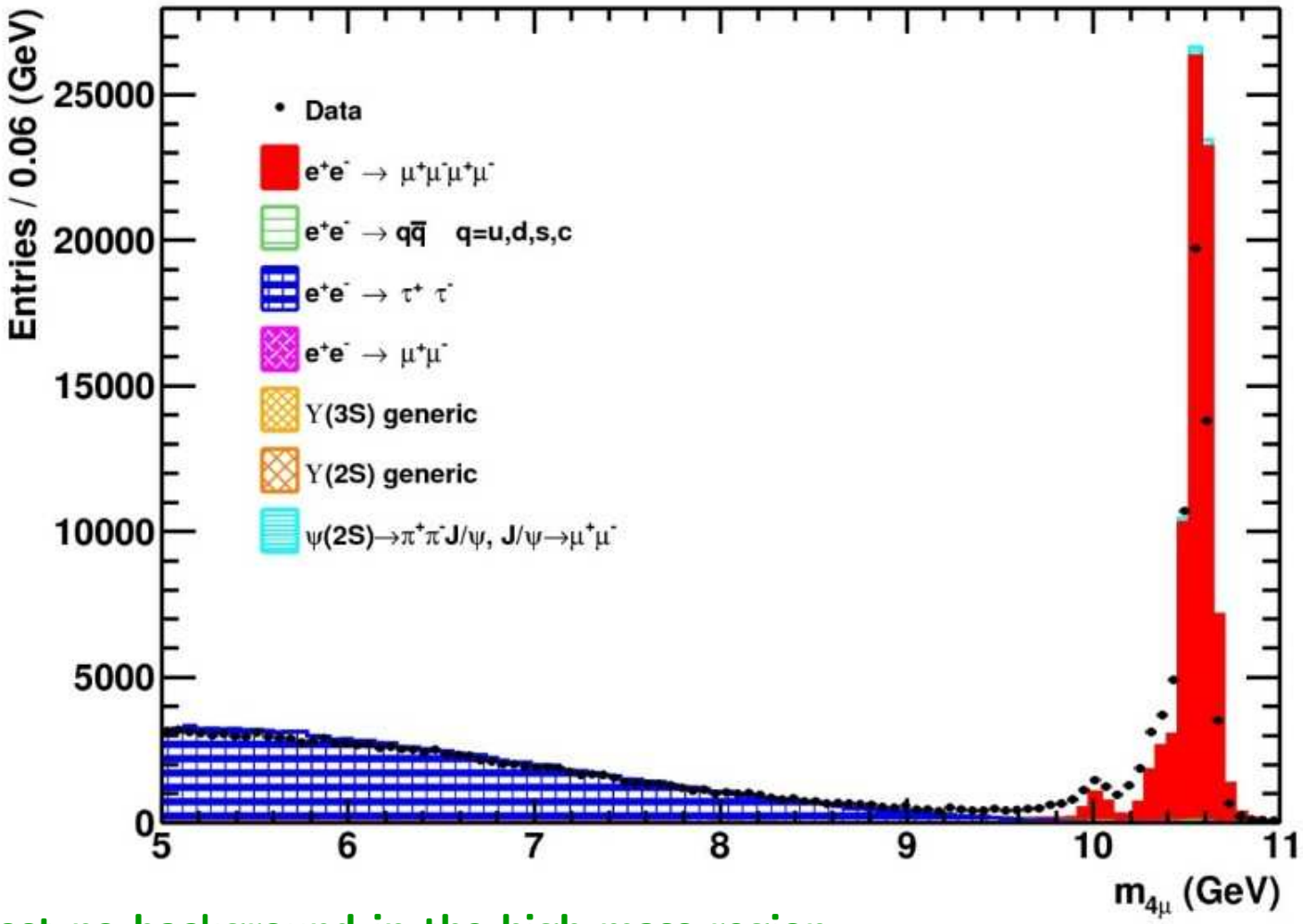
★ **Selection:**

- ★ Exactly final 4 tracks
- ★ Extra neutral energy $<$ 200 MeV
- ★ Two same-sign tracks identified as muons
- ★ Four muon invariant mass within 500 MeV of CM-energy
- ★ Veto events with a dimuon candidate within

  10 MeV of the $\Upsilon(1S)$ for $\Upsilon(2S)$ and $\Upsilon(3S)$ dataset

  to reject $\Upsilon(2S, 3S) \to \pi\pi\Upsilon(1S)$, $\Upsilon(1S) \to \mu\mu$

Four-Muon Invariant Mass

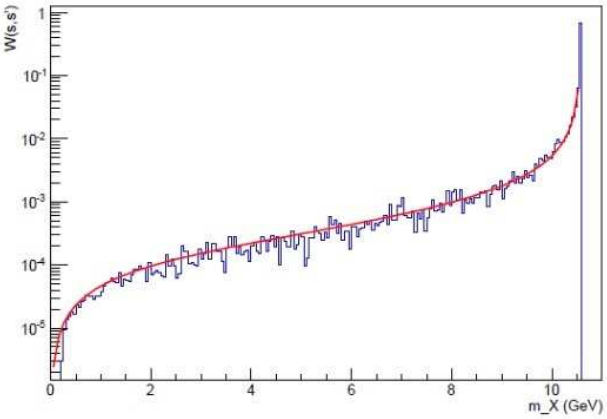


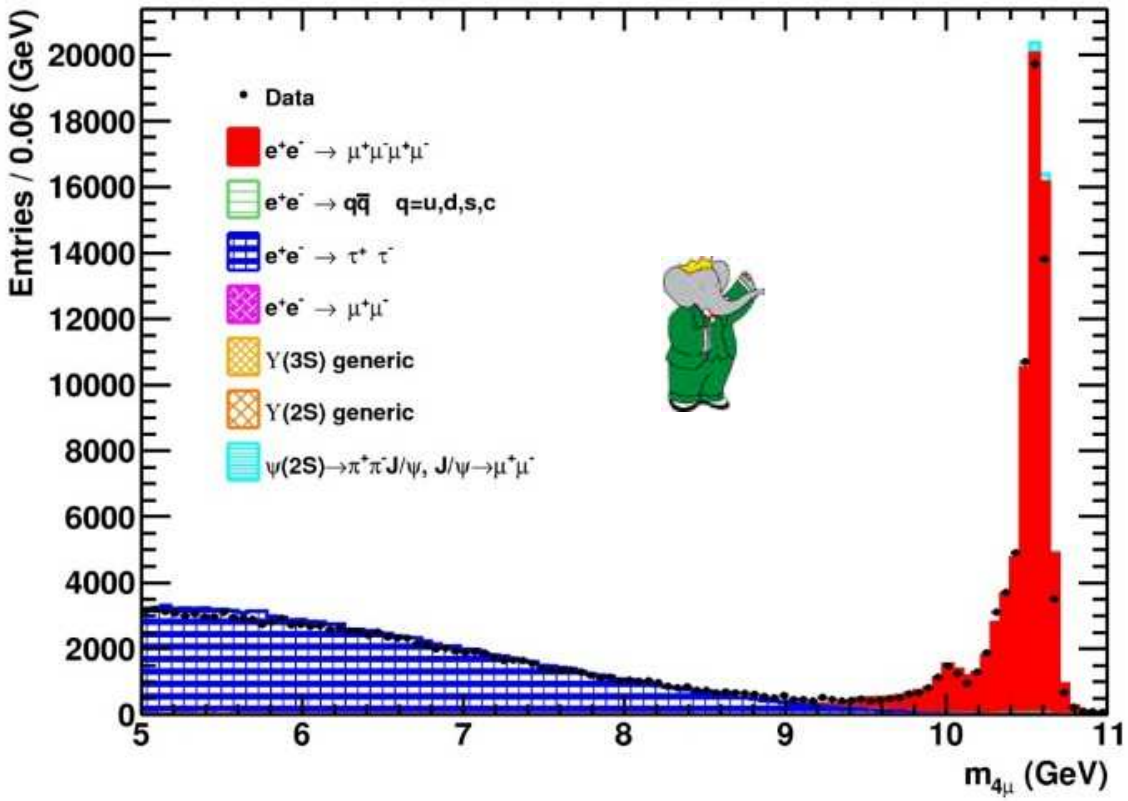
★ **Almost no background in the high mass region**

★ **Monte Carlo $e^+e^- \to \mu^+\mu^-\mu^+\mu^-$ lacks radiative corrections (disagreement in high mass region)**

Four-Muon Invariant Mass (ISR Corrected)

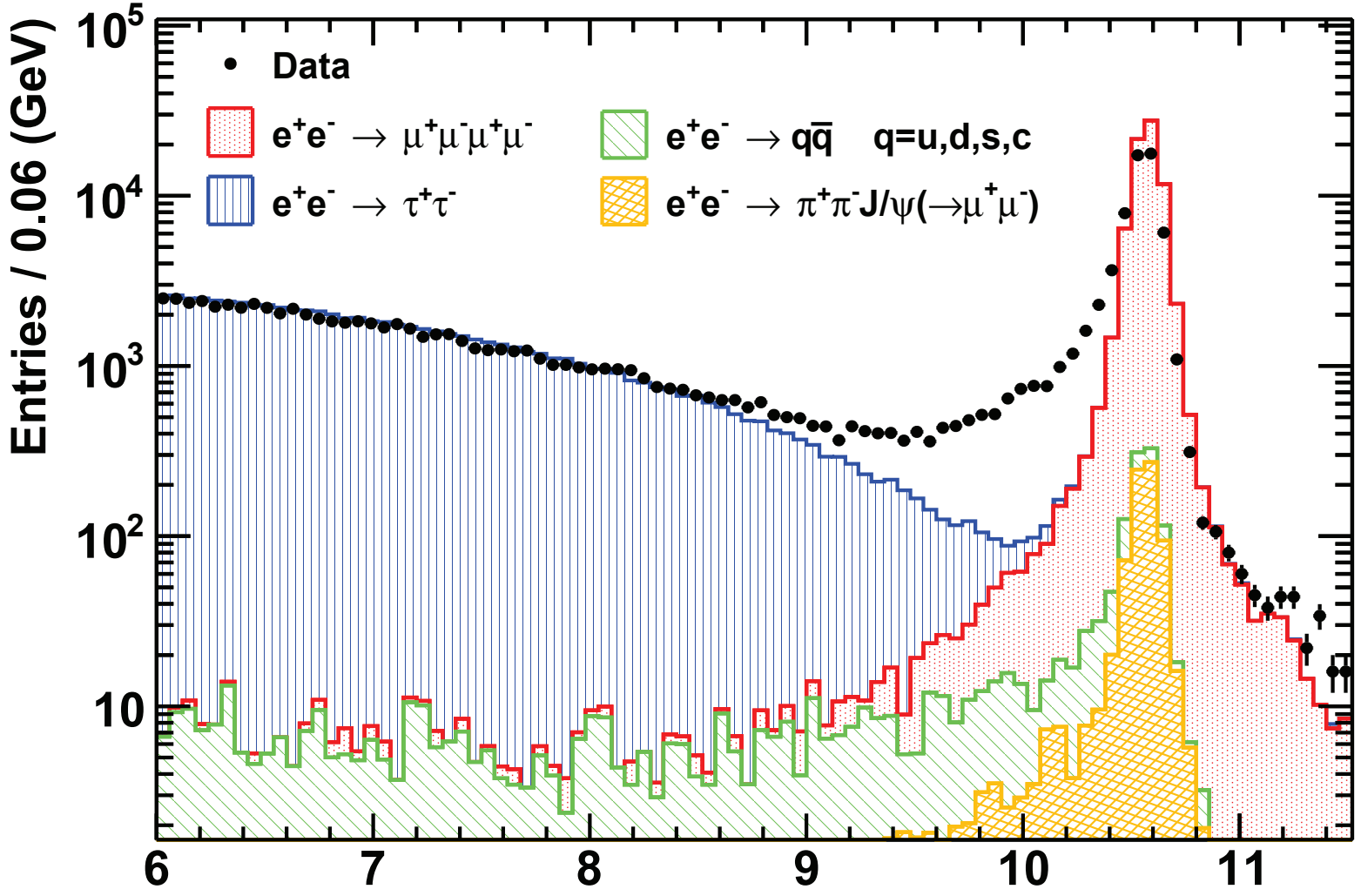
★ **QED radiator (ISR emission probability)**





★ **We convolve the mass spectrum with the QED radiator to correct the ISR:** $e^+e^- \longrightarrow \mu^+\mu^-\mu^+\mu^-$

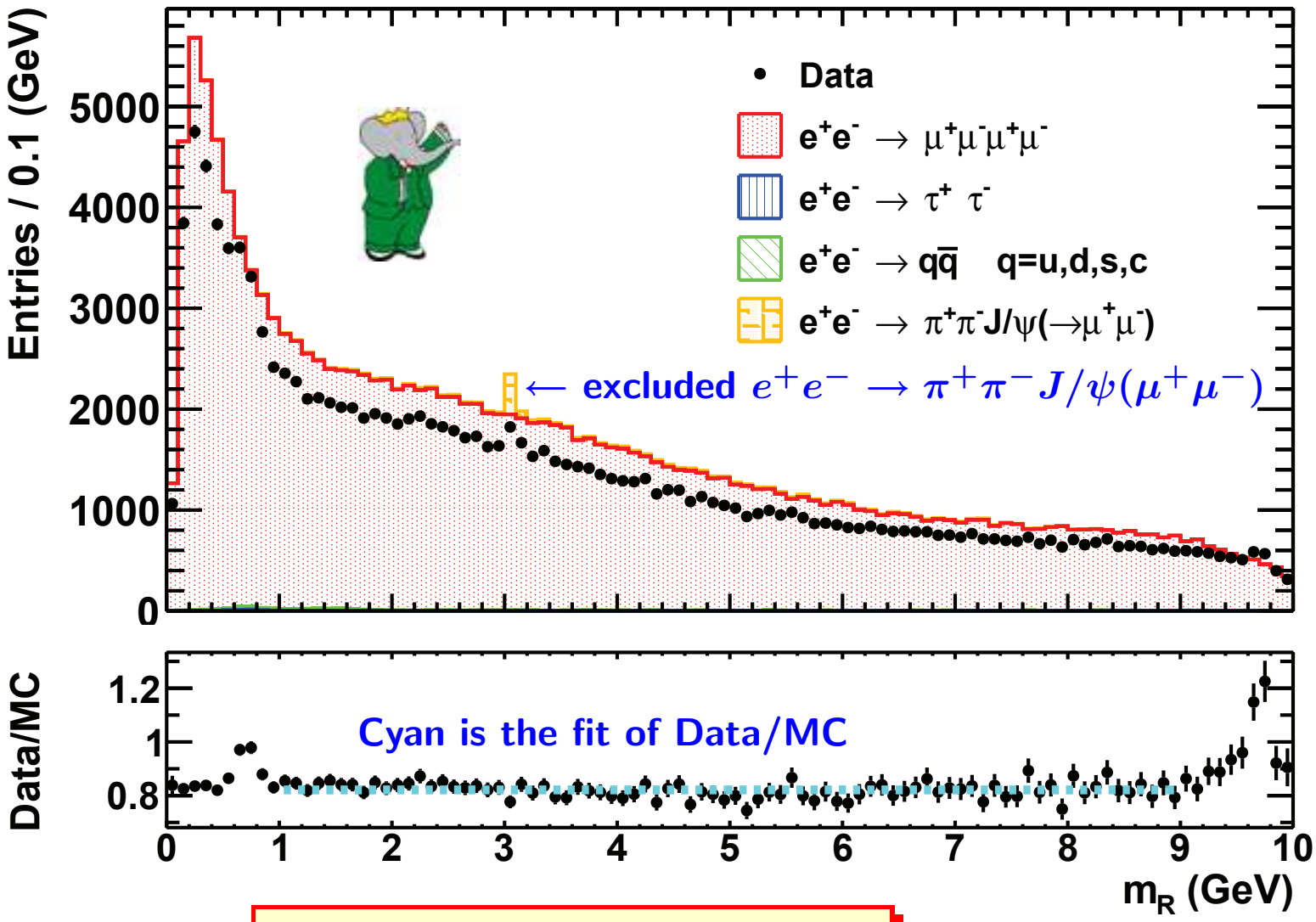
Four-Muon Invariant Mass



★ **Four-muon invariant mass:** $e^+e^- \to \mu^+\mu^-\mu^+\mu^-$

★ **MC** $e^+e^- \to \mu^+\mu^-\mu^+\mu^-$ **does not include ISR corrections**

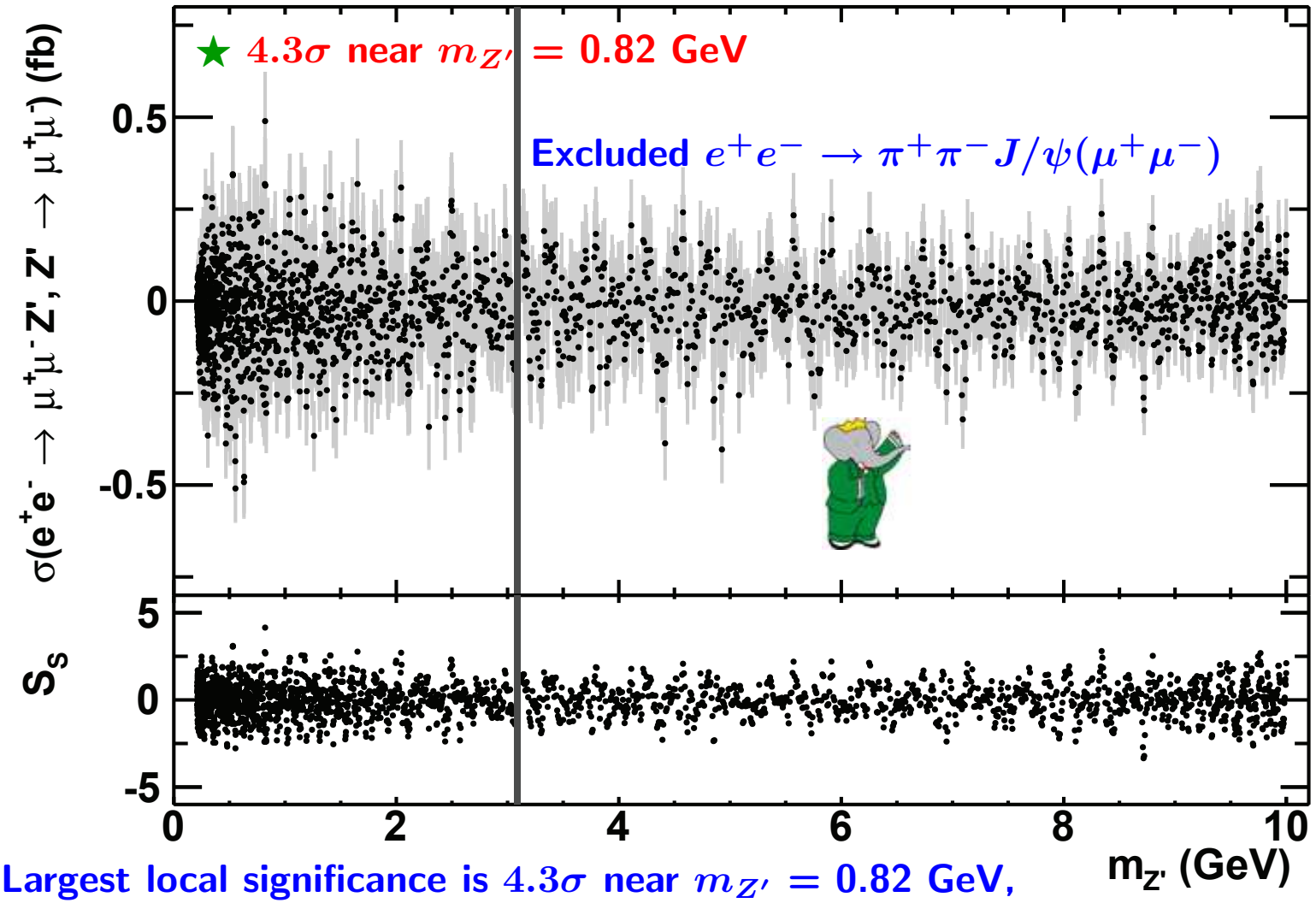
Reduced Dimuon Mass



$$m_R = (m^2_{\mu\mu} - 4m^2_{\mu})^{1/2}$$

Measured Cross Section

★ **Measured $\sigma(e^+e^- \to \mu^+\mu^- Z', Z' \to \mu^+\mu^-)$**

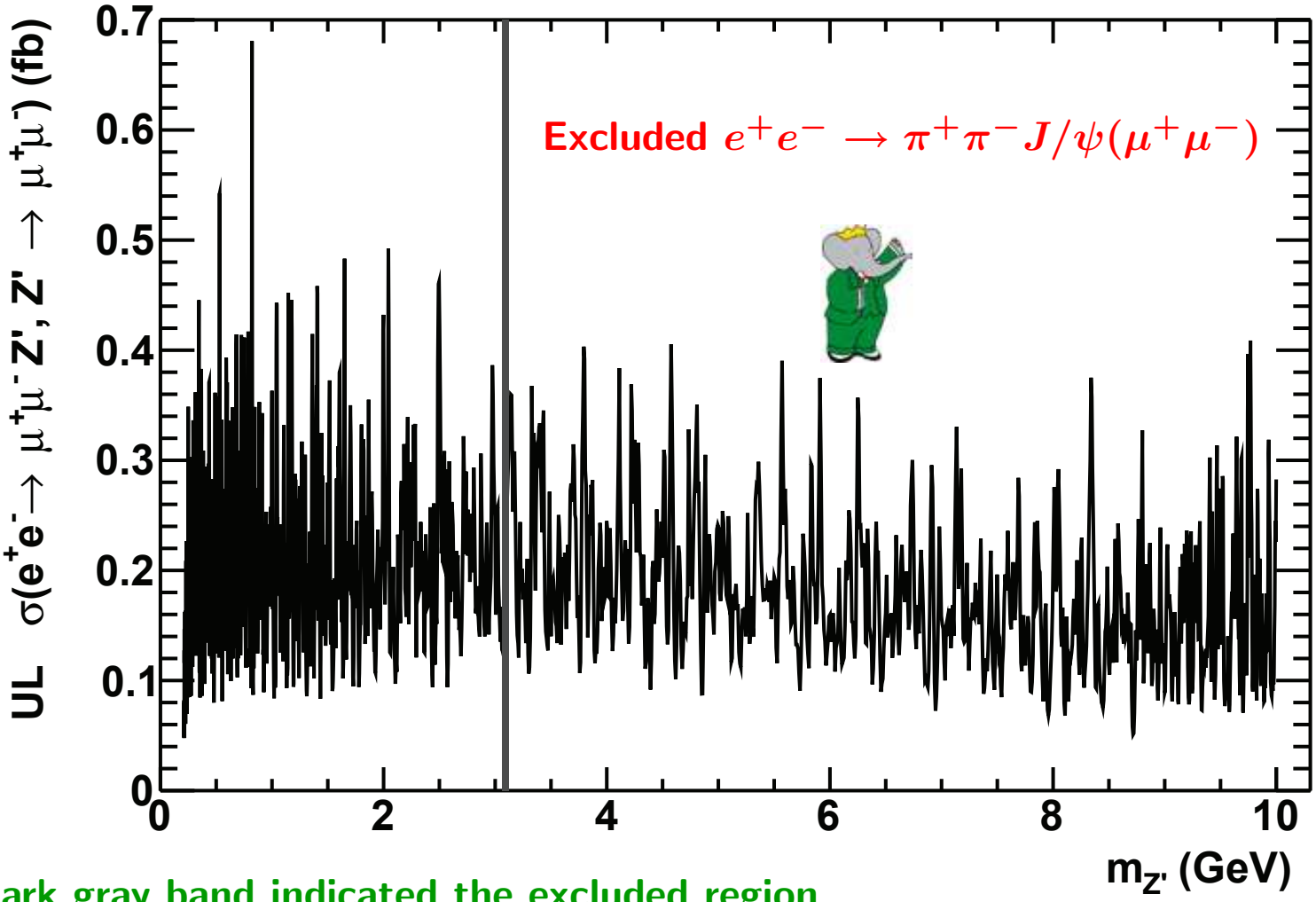


★ **Largest local significance is 4.3σ near $m_{Z'} = 0.82$ GeV,**

corresponding to a global significance of 1.6σ (null hypothesis)

Limits on Cross Section

★ **Cross section $\sigma(e^+e^- \to \mu^+\mu^- Z',\ Z' \to \mu^+\mu^-)$ as a function of Z' mass**



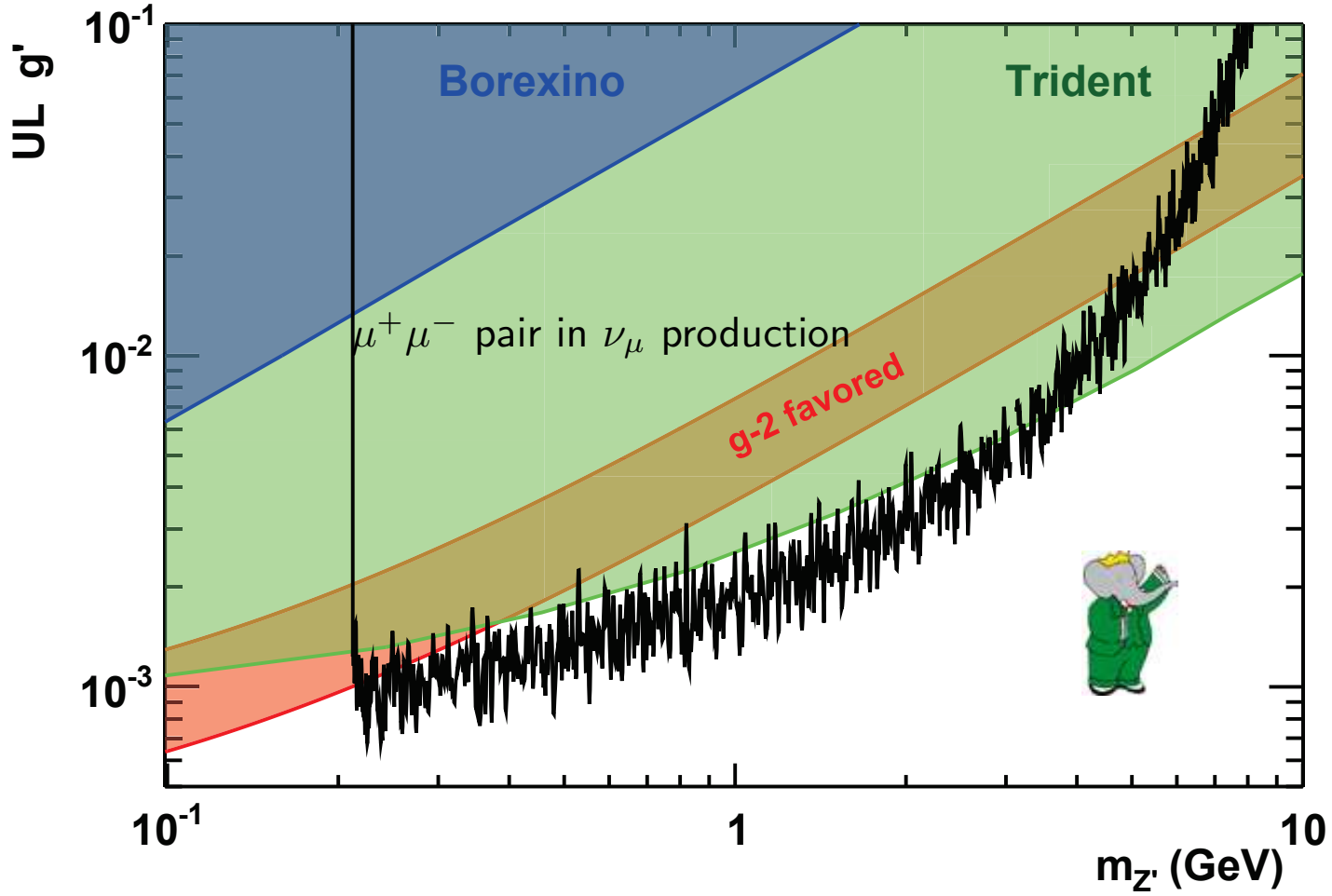
★ **Dark gray band indicated the excluded region**

★ **Derive 90% confidence level Bayesian upper limit (UL) on cross section**

Limits on New Gauge

★ New gauge coupling g' as a function of Z' mass

★ Upper limits down to 7×10^{-4} near dimuon threshold are set



★ Shaded red is the consistent region between calculated and measured anomalous magnetic moment of muon (g-2) within 2σ

Summary

★ First search for the direct production of a new muonic dark force boson coupled to muons

★ No significant signal is observed for Z' mass in range 0.212 - 10 GeV

★ Exclude almost all parameter space preferred by the discrepancy between calculated and measured anomalous magnetic moment of muon

★ It can be interpreted as a powerful constraint on new vectors that interact exclusively with muons

★ Published in Phys. Rev. D. 94, 011102 2016