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

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**CENTER** for



NUCLEAR STUDY NIX

# Introduction

### Dark photon, U

- - $\checkmark$  Mixing in the ordinary photons with the mixing parameter,  $\epsilon^2$
  - ✓ 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 $\pi^0$ Dalitz decays

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#### <u>Measurement of $\pi^0 \rightarrow \gamma \cup \rightarrow \gamma e^+e^-$ in $\pi^0$ Dalitz decays</u>

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

#### Important requirements for the dark photon search

1. A large data samples of  $e^+e^-$  from  $\pi^0$  Dalitz decays

2. A very good mass resolution of e<sup>+</sup>e<sup>-</sup>

# Current dark photon mapping<sup>3/8</sup>



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 4/8



Originally designed for the study of Quark Gluon Plasma

✓ Good momentum resolution

✓ High precision for eID

→ High statistics of e<sup>+</sup>e<sup>-</sup> from π<sup>0</sup> Dalitz decays in p+p (2006) & d+Au (2008) at 200GeV

✓ 1.3M e<sup>+</sup>e<sup>-</sup> pairs



✓ Small background contribution in m<sub>ee</sub><100MeV</p>

- Data looks agreement with hadronic cocktail calculation.
- $\checkmark \sigma_{ee}$  is about 3MeV calculated from well-tuned simulation.

# Confidence level calculation <sup>6/8</sup>

- ✓ 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



# Dark photon limit



 $\sim$  1, 2 $\sigma$  statistical fluctuations of the expected reach

# Dark photon limit



♦ Expected reach with 1.3M events & 3MeV of σ<sub>ee</sub>
♦ 1, 2σ statistical fluctuations of the expected reach
♦ Observed upper limit with the PHENIX detector
✓ Including systematic errors from uncertainties on the Dalitz

continuum &  $\sigma_{ee}$ 

# Summary and outlooks

### **Current status**

- Dark photon search is being conducted at the PHENIX experiment.
  - $\checkmark$  Searching for the dark photon in  $\pi^0$  Dalitz decays
  - ✓ 1.3M pairs in p+p (2006) and d+Au (2008) datasets
  - ✓ Good mass resolution at PHENIX ~ 3MeV
  - $\rightarrow$  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