Center for Frontiers in Nuclear Science

Prospects for Dark Photons at EIC

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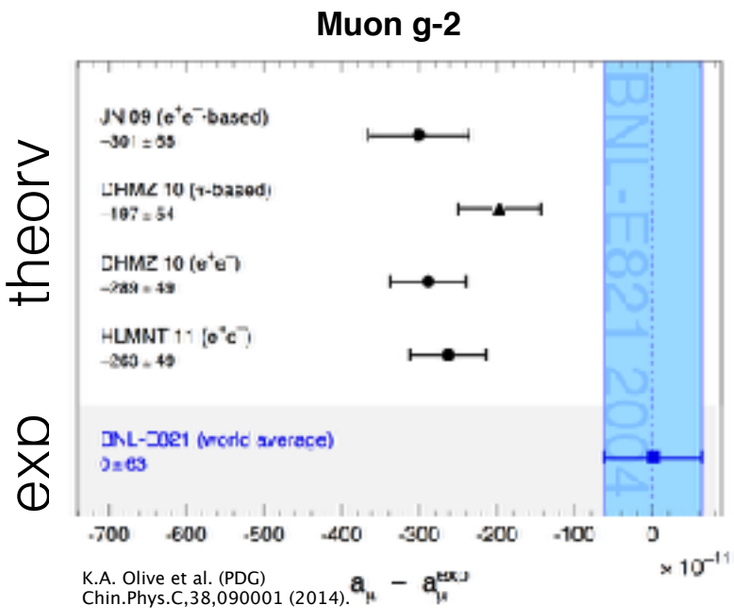
Motivation

- Dark Matter Decay Mechanism?
- Anomalies:



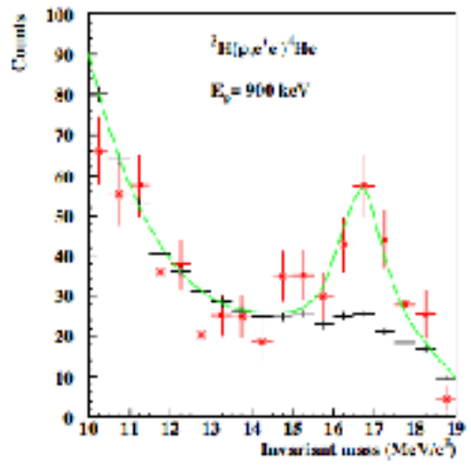
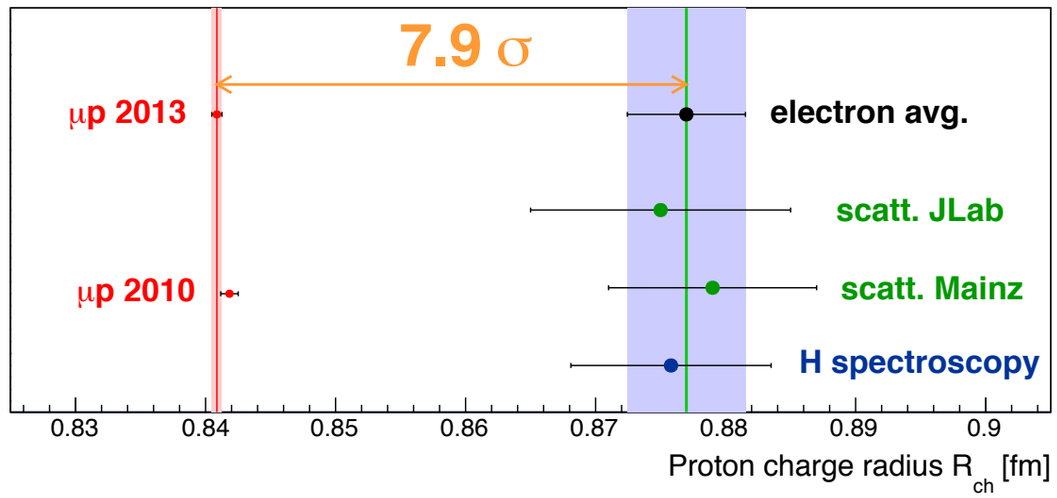


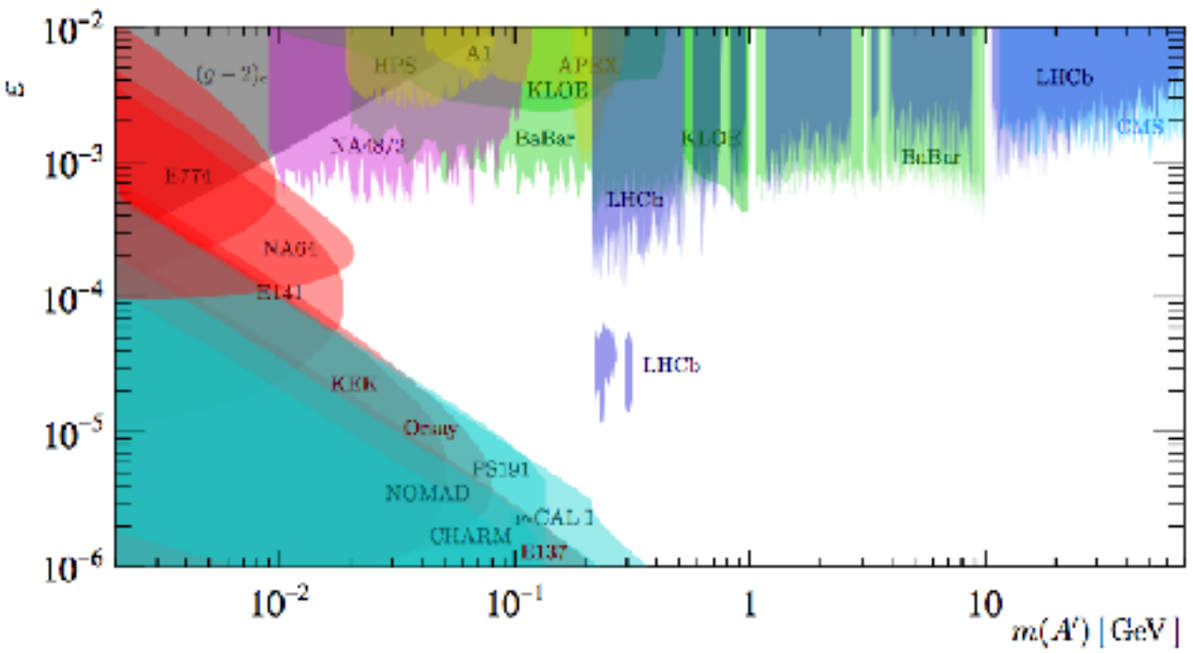
FIG. 3. Invariant mass distribution derived for the 20.49 MeV transition in ^{8}Be.

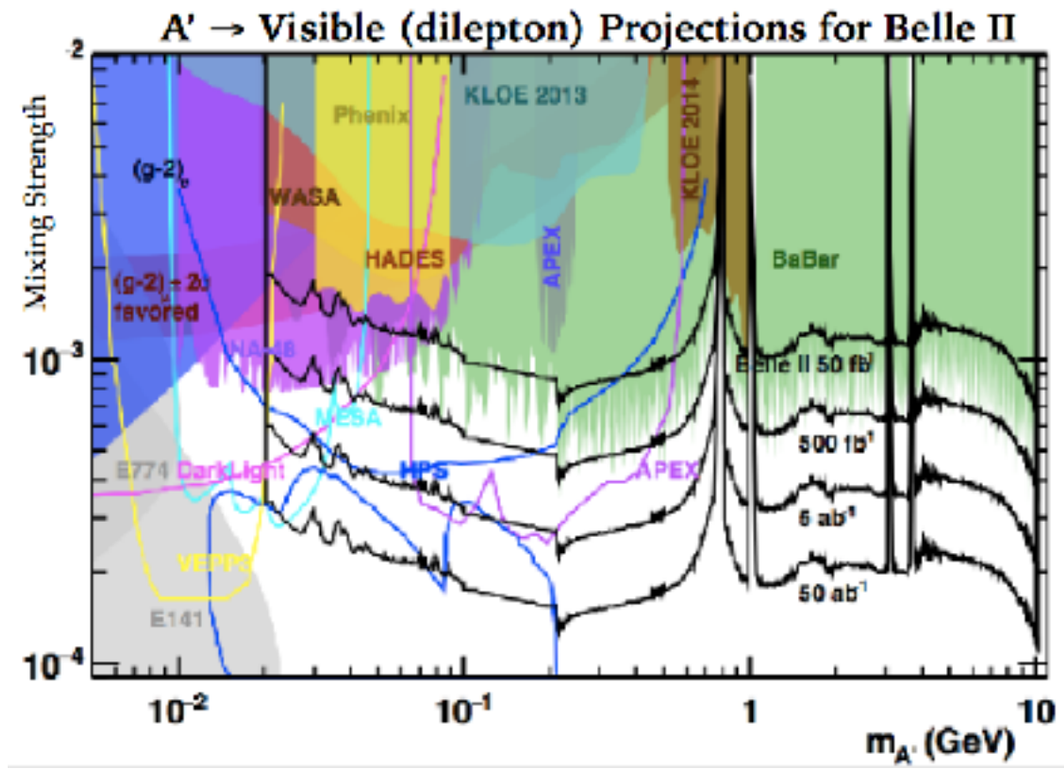


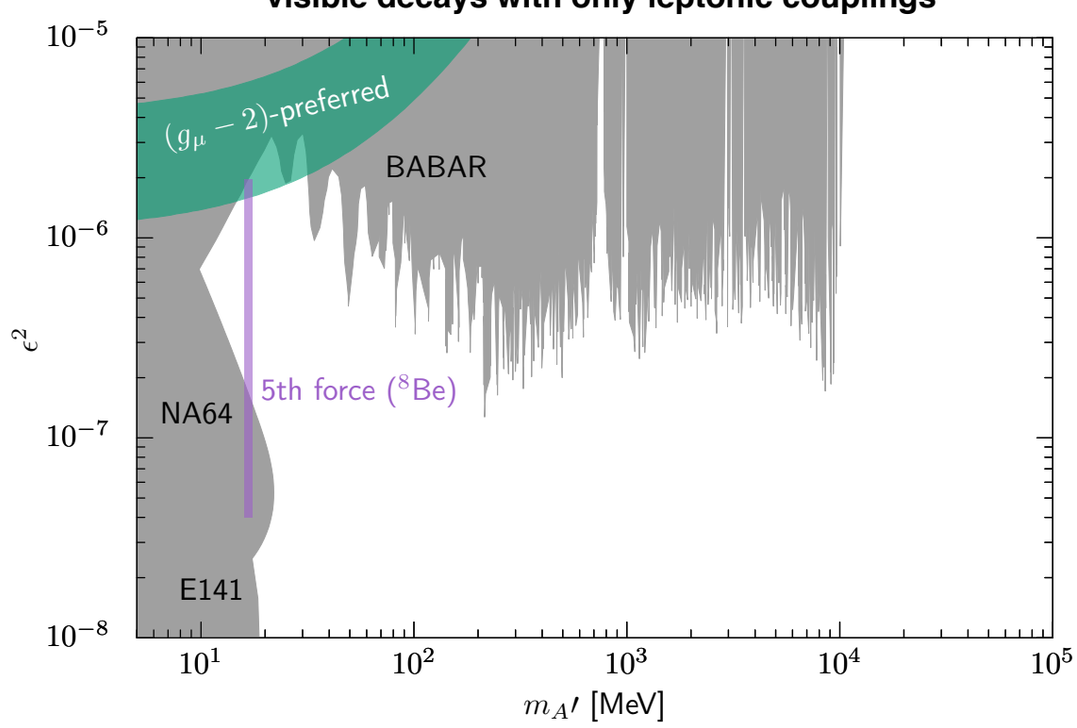
- Because we can write it:

$$L \supset \frac{\epsilon}{2} F_{\mu\nu} F'^{\mu\nu}$$

Existing Limits and Projections







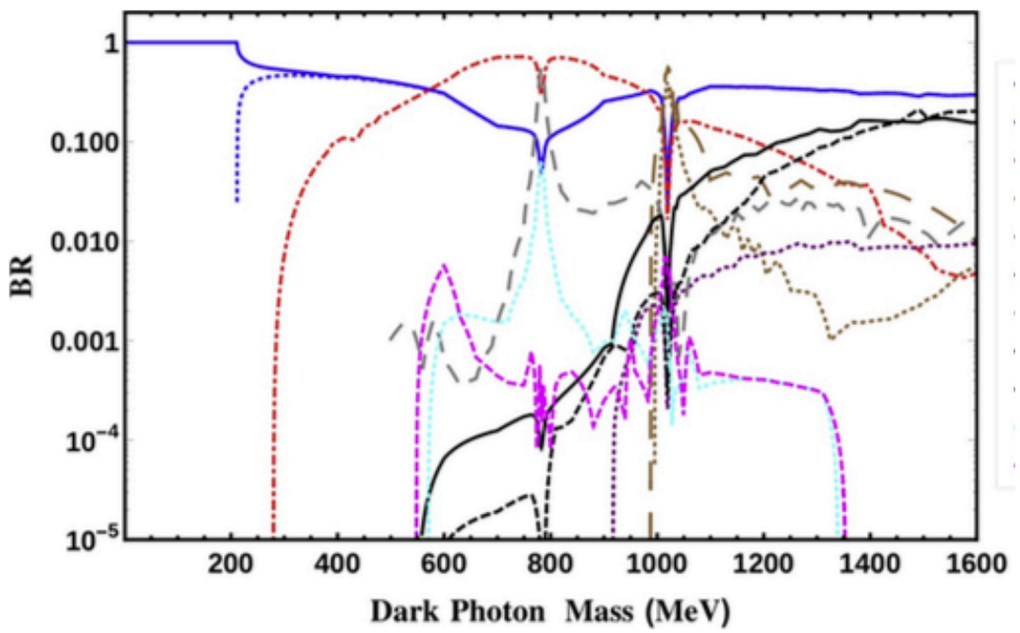
- In simple Kinetic Mixing Model:

$$\alpha_D = \epsilon^2 \alpha_{EM}$$

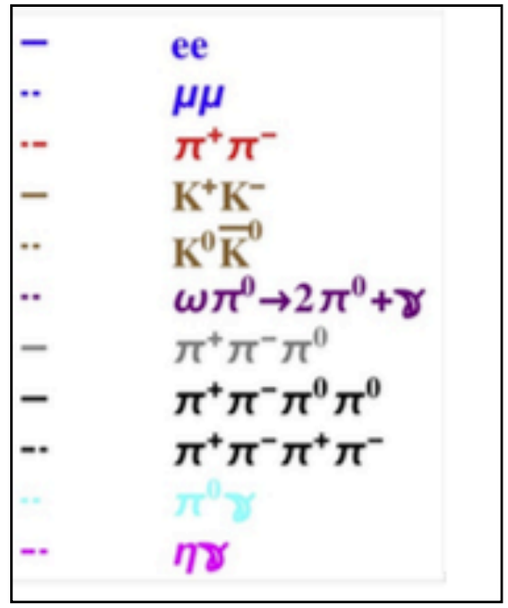
- Most searches hadronic / other model dependent
- Want to explore the parameter space with **purely leptonic** couplings as well!
- (But keep the notation and name)

A' Channels

- Production:
  - **ISR (A'-strahlung from e- beam) ($m_A < \sqrt{s}$))**
  - Decay (on-shell A' replaces photon in decay chain) (m_A < parent)
- Final States (model-dependent):
  - **e+ e- pair ($m_A > 2m_e$)**
  - μ+ μ- pair ($m_A > 2m_\mu$, cleaner signal)
  - hadronic pair(s) (messier, harder)
  - invisible (much harder)
  - displaced vertices (cleaner, much harder)

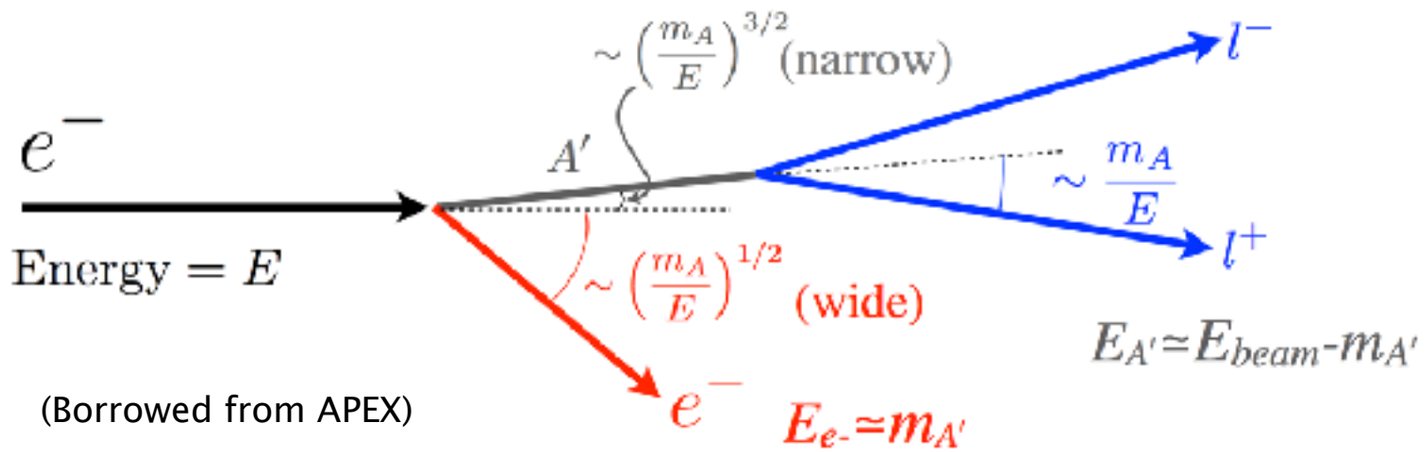


Branching to:



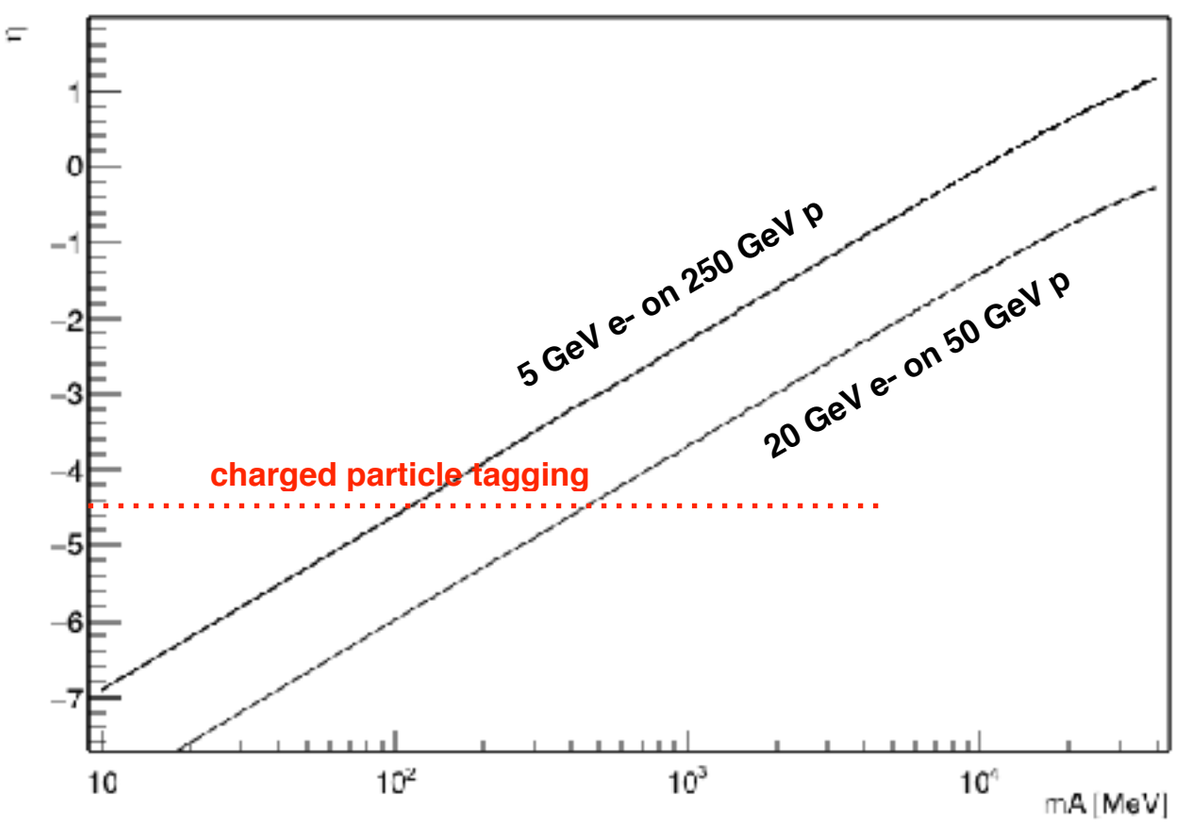
Kinematics

- Fixed target but boost opens decay in our favor:

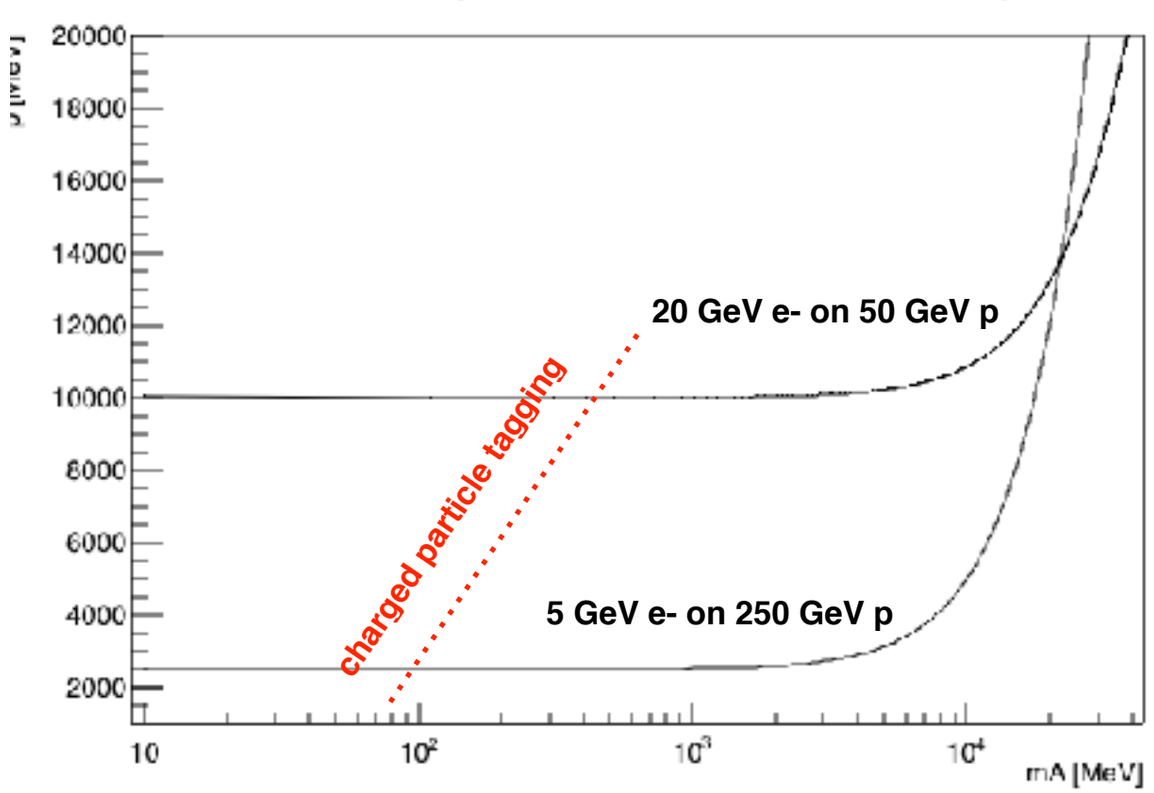


(Borrowed from APEX)

Lab frame symmetric η for A' decay

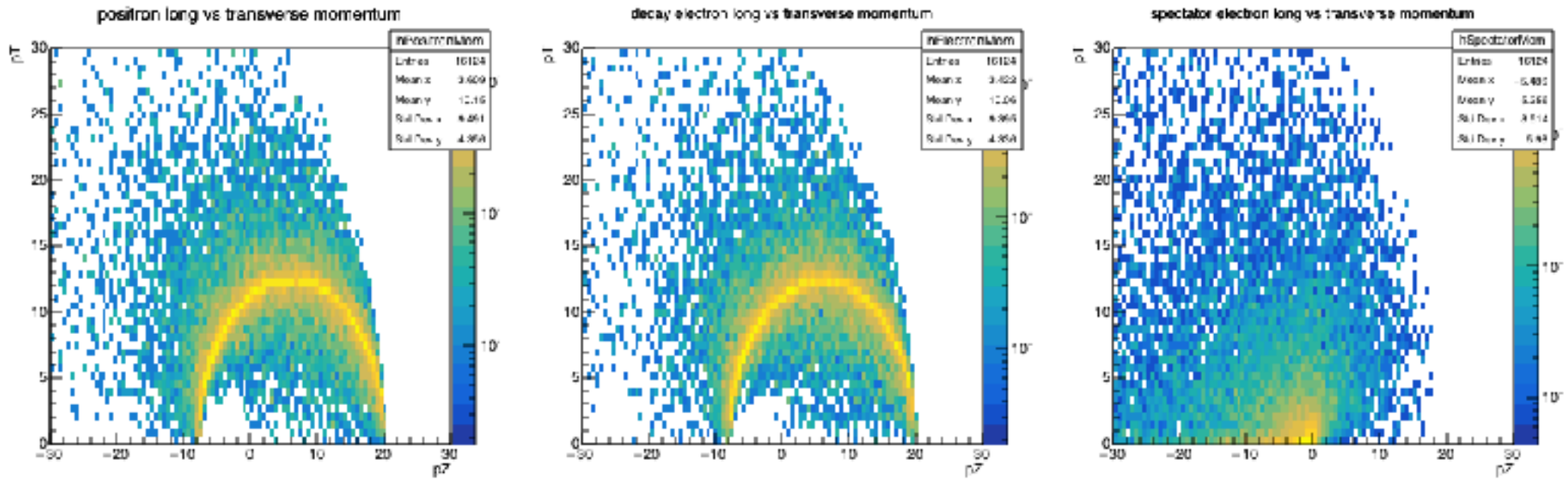


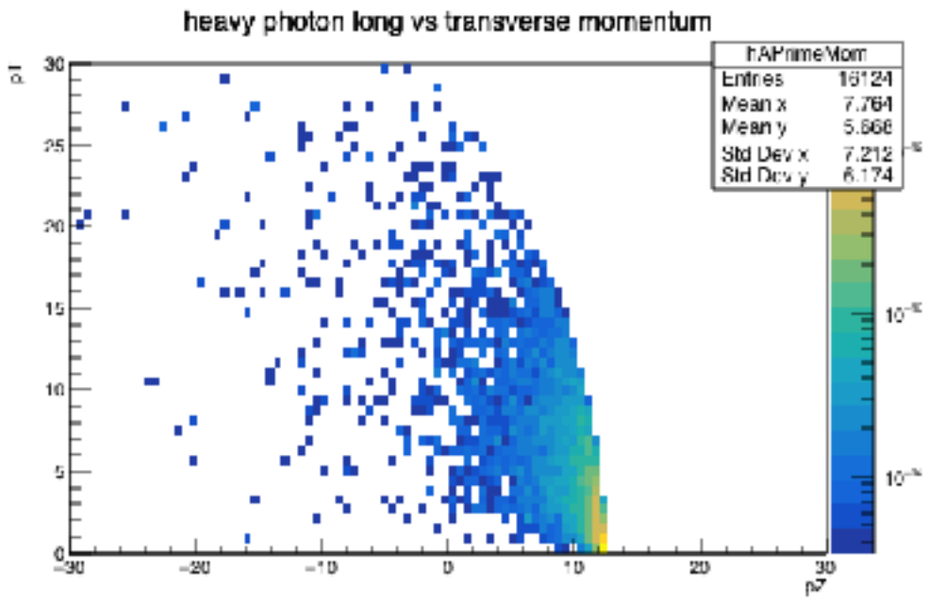
Lab frame symmetric momentum for A' decay

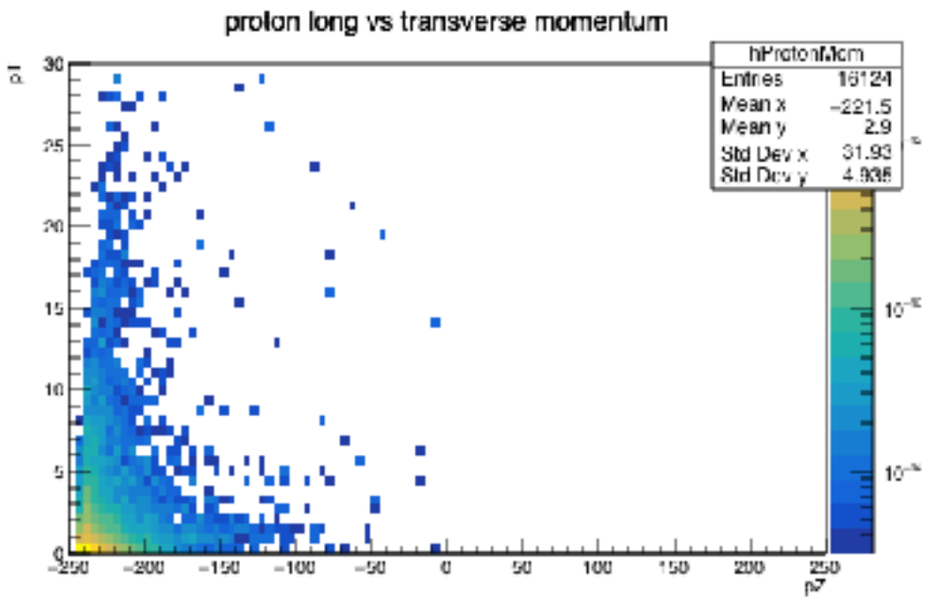


MC Kinematics

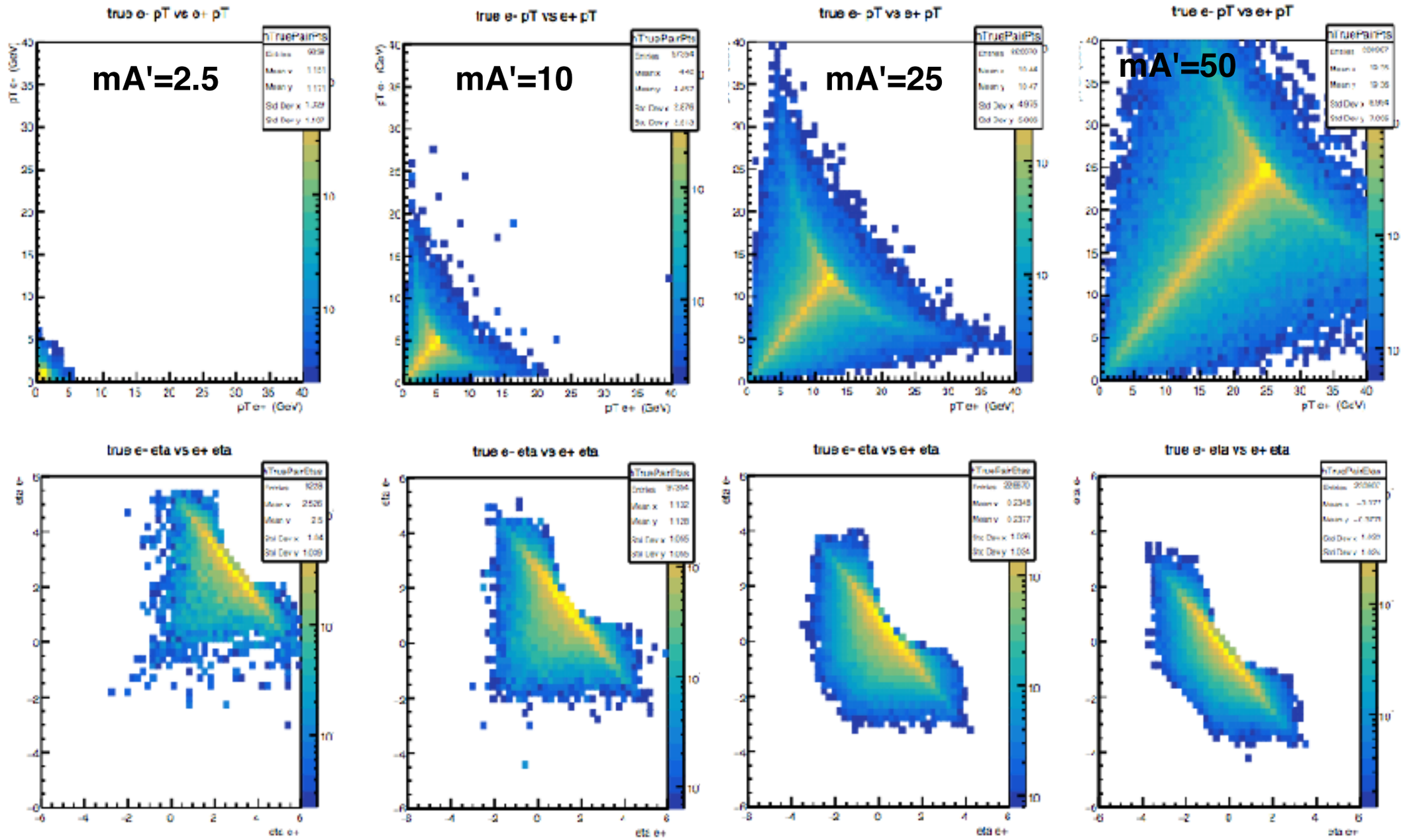
- Spectator prefers to lose all its momentum
- A' prefers to carry forward momentum
- Low boost of A' produces relatively low boost e+e- decay pair.





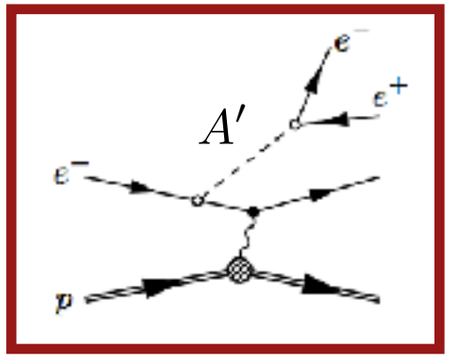


Decay Pair Evolution

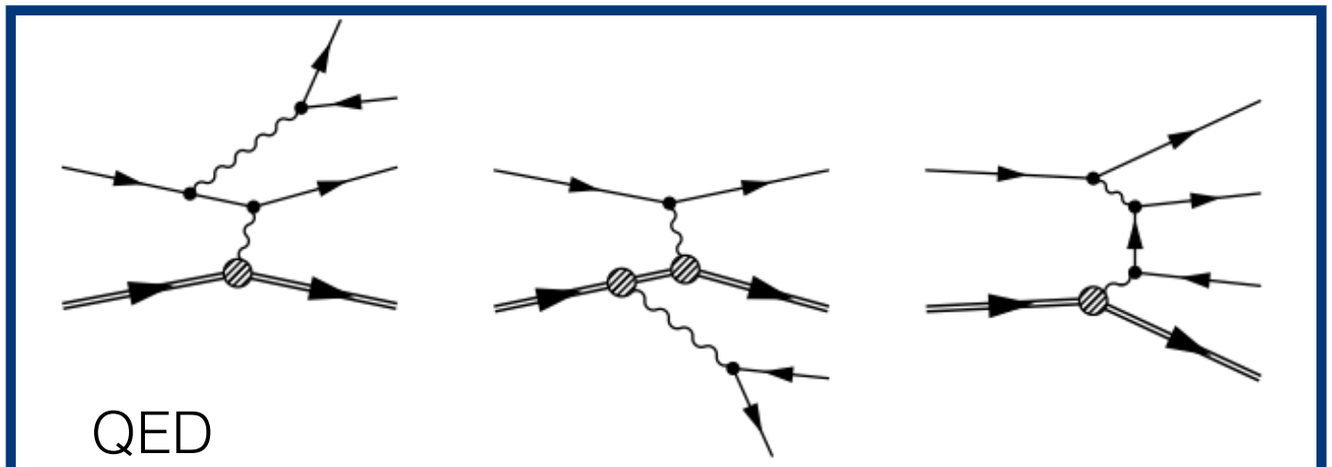


Backgrounds

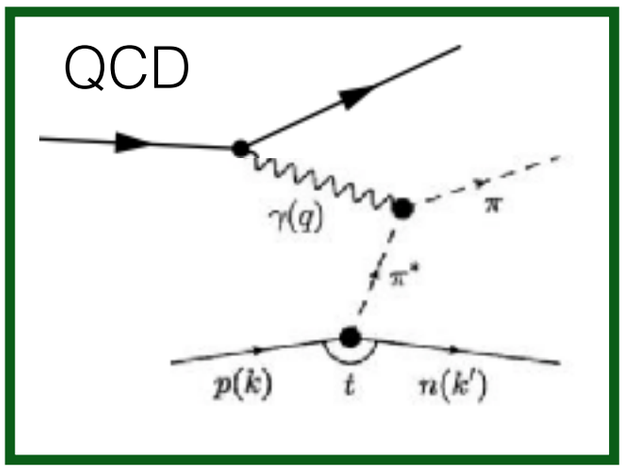
A' Signal



- Irreducible QCD: two genuine leptons from virtual photon

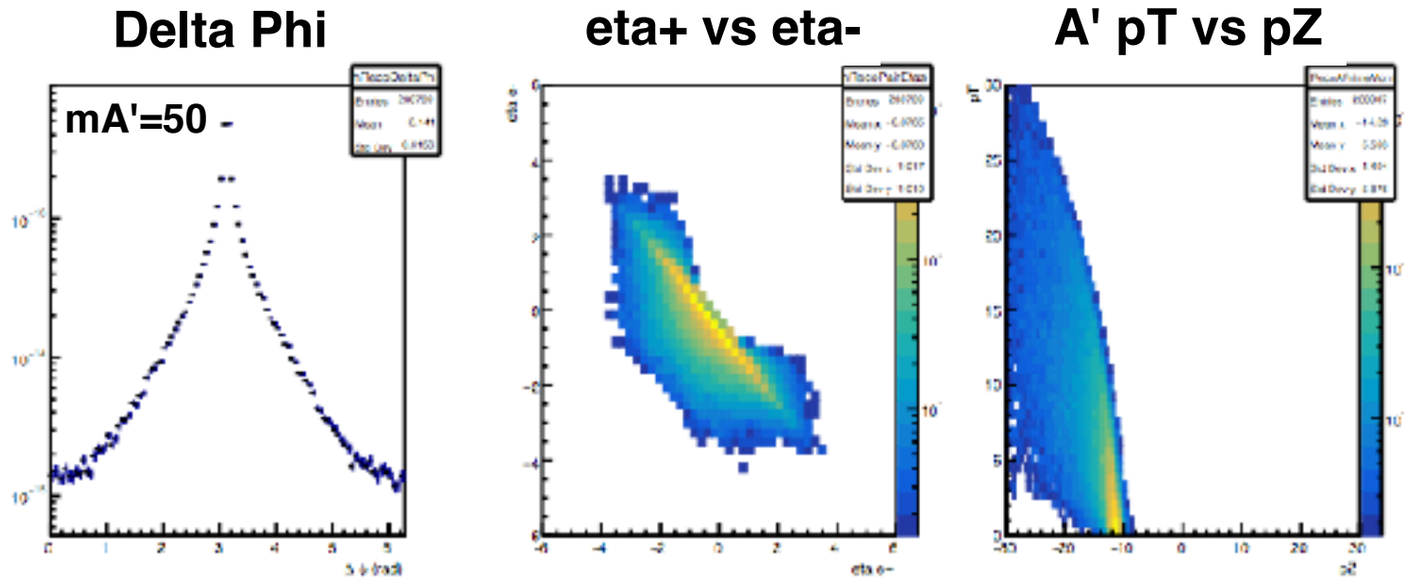


- Other hadronic processes (eg pion scattering) that fake a lepton or pair



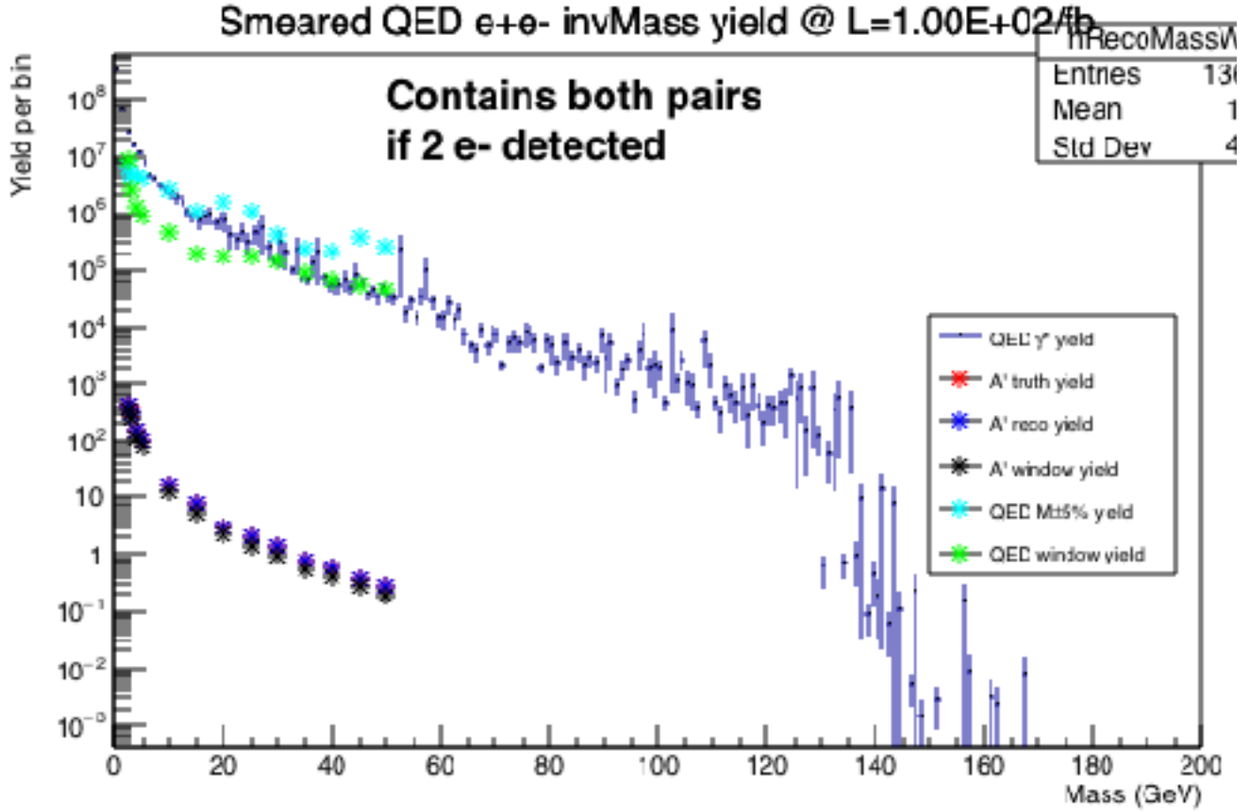
Background Suppression

- *(50 GeV A' Sample)*
- QED:
  - Phi and Eta Correlations
- QCD:
  - Isolation (not embedded in jets)
    - PID or Muon channel
- Accidentals:
  - Phi and Eta Correlations

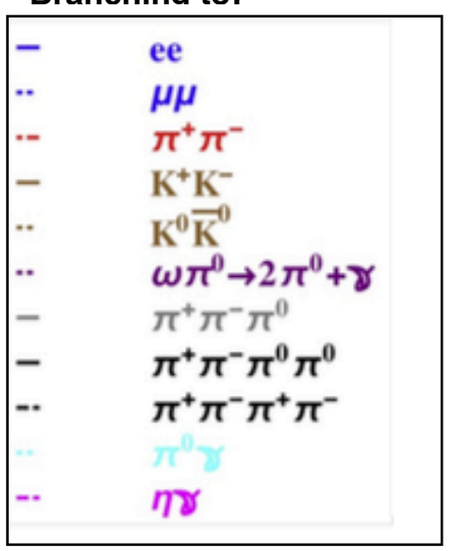


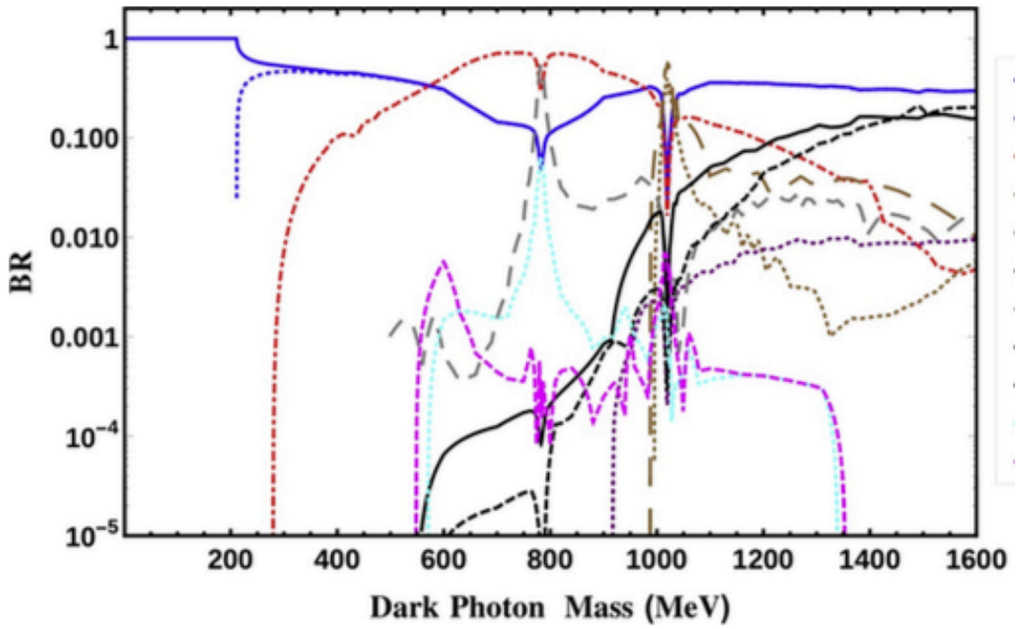
Performance vs QED at 100fb^{-1}

- Yield (arb) with caveats:
  - Weighting of QED background ambiguous in some regions (FF correction)
  - Resonances ignored
  - Detector resolutions applied, but PID limits etc not applied
  - Cuts deliberately loose (require back-to-back in phi)
  - Assumes 100% BR (factor of ~few, model):



Branching to:

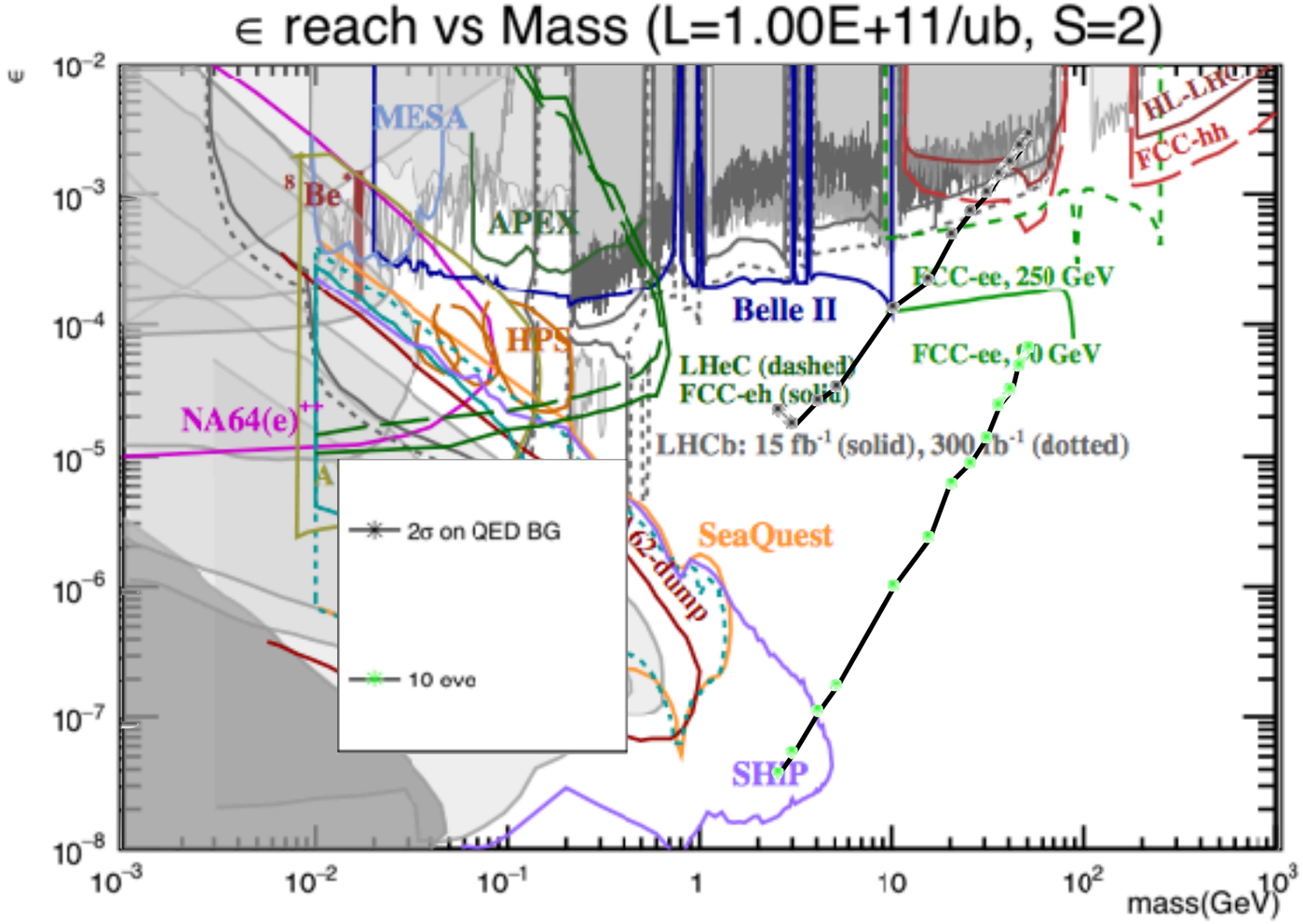




Performance vs QED at 100fb^{-1}

$$S = \frac{\sigma_A L}{\sqrt{\sigma_{QED} L}}$$

$$\alpha_D = S \frac{\alpha_{D0}}{\sqrt{L}} \frac{\sqrt{\sigma_{QED}}}{\sigma_{A0}}$$



- Naive model promising across broad range (with caveats!)
- Expect gains from cuts
- Expect losses from hadronic backgrounds
- Reach somewhat reduced if BR to hadrons is large.

Summary

- Dark Photons leptonic couplings can be directly probed at EIC
- Asymmetric beams provide a favorable boost to ISR production
- Most competitive in few-10 GeV range, may reach above as well
- Hadronic backgrounds require further study
  - Calorimeter and topological e(mu)/pi discrimination important

- Additional notes:
  - Higher-z ion beams enhance ISR production
  - Other production modes (intermediate decay to A') can help reach lower mass

MC reweighting

- MadGraph MC sample does not have proton form factor built-in
- Can reconstruct Q2 of elastic e*p->ep (or ep->e*p) scatter from proton record
- Scattering angle is not uniquely determined, but both favor small scattering angles.
- Signal has unique A' mass, so intermediate state can be identified
- BG diagrams do not all have this feature -- needs different approach (generator?)