

# Rich Dark Sectors

SLAC Dark Sectors Workshop  
April 30, 2016

# Rich Dark Sectors (RDS)

## 1. Dark Sector Masses and Naturalness

Thursday, 4:30pm-6:00pm

Where do light masses come from?

Are they natural? Are there additional states to discover?

## 2. Exotics

Friday, 10:00am-11:30am

What should we look for beyond the minimal portals?

Are we missing any experimental opportunities?

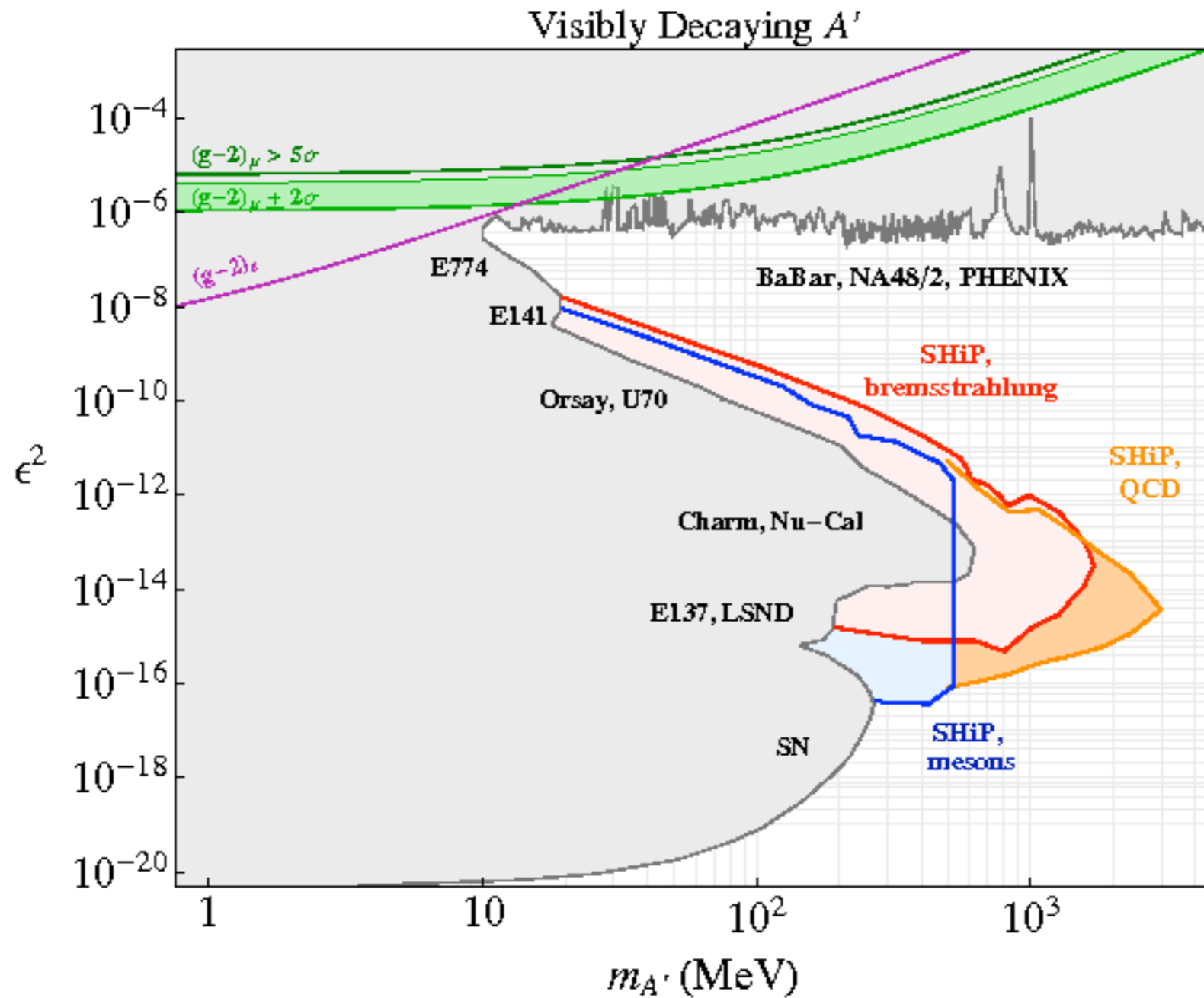
## 3. Non-Minimal Dark Matter

Friday, 1:30pm-3:00pm

Is DM self-interacting/inelastic/excitable/asymmetric/... ?

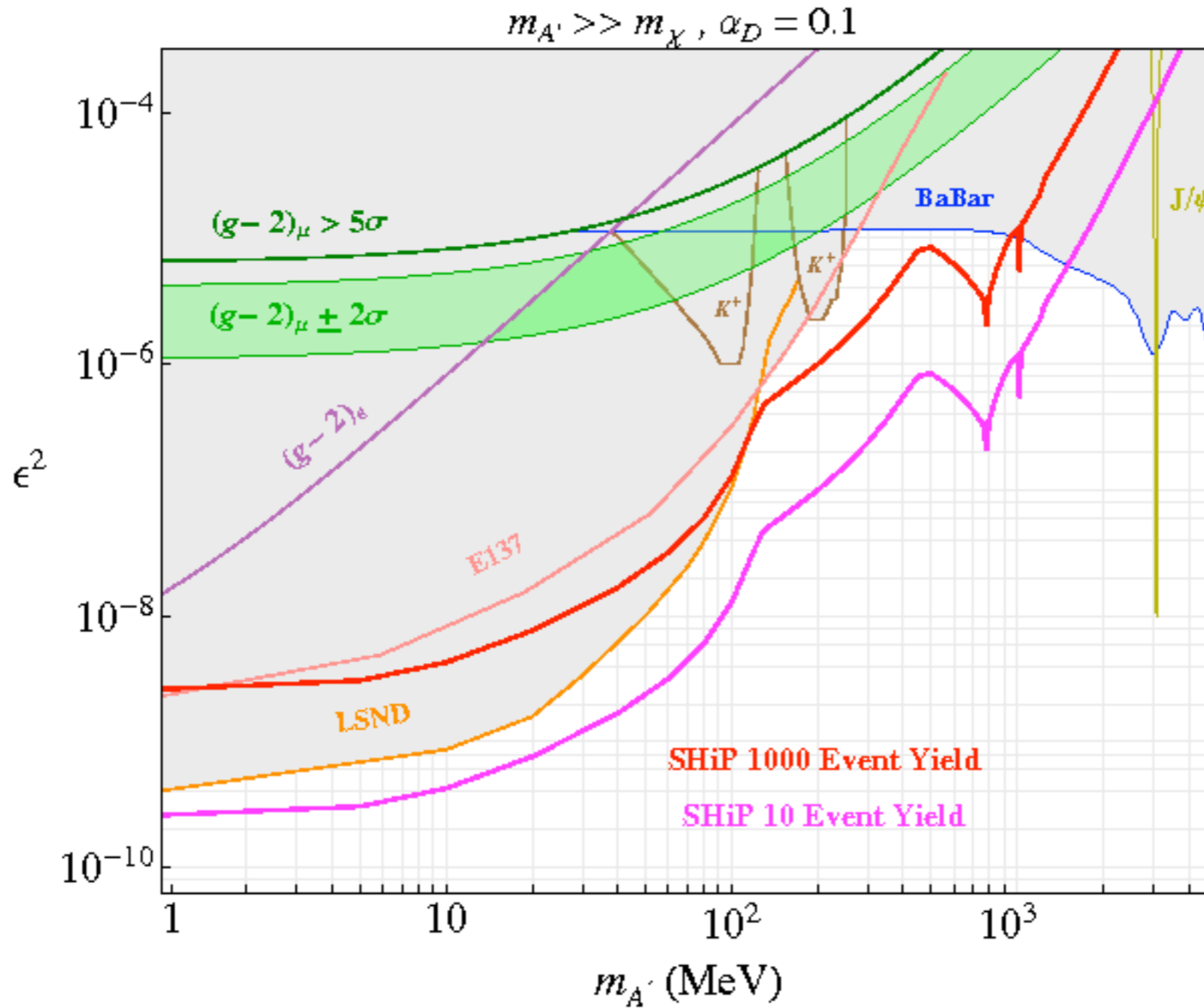
Are there ways to combine DM and other searches?

# Minimal Visible Dark Photon



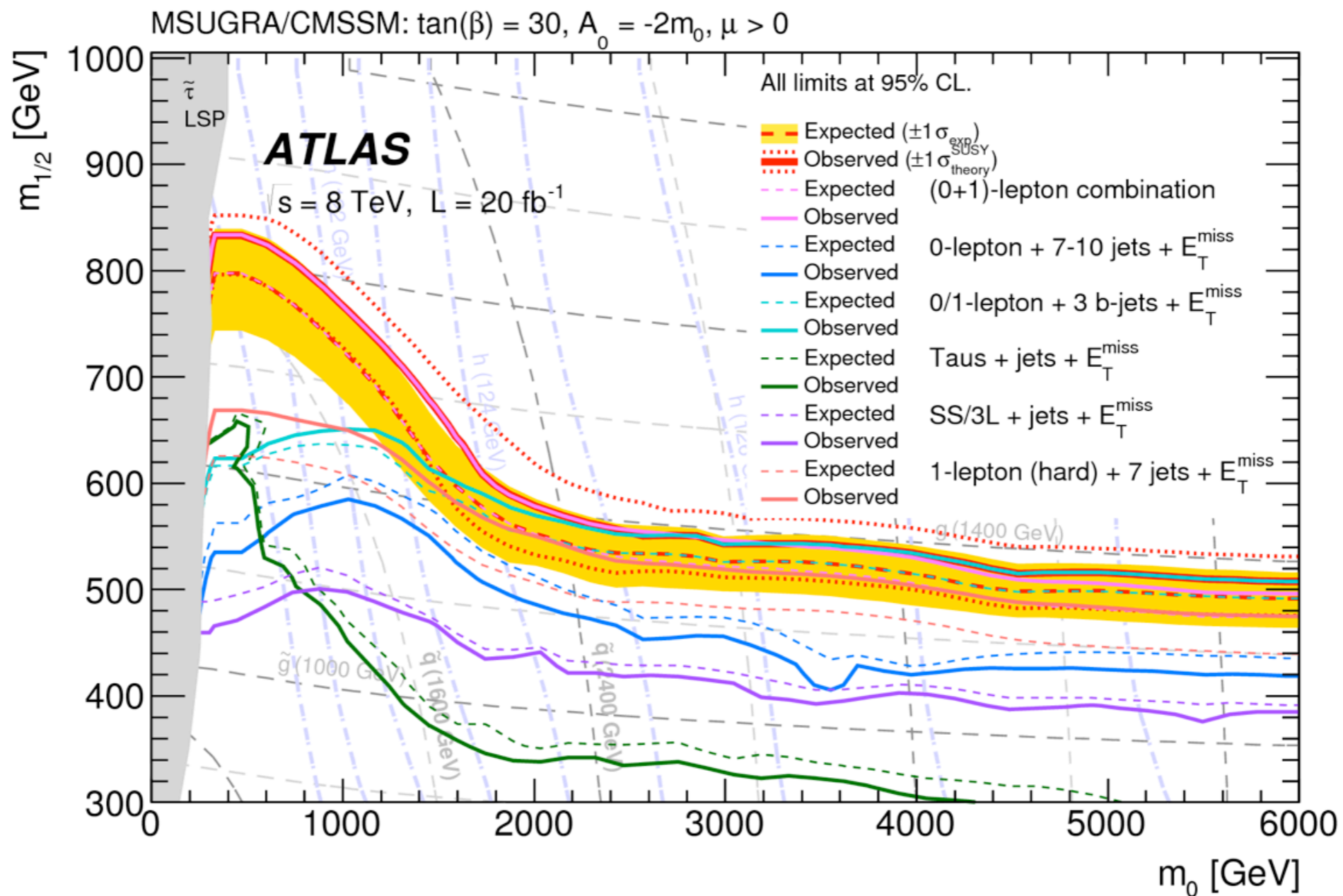
Is this all there is to (dark) life?

# Minimal Invisible Dark Photon



Is this all there is to (dark) life?

# Provocative Example: “Minimal” SUSY



Not the whole story for SUSY searches!

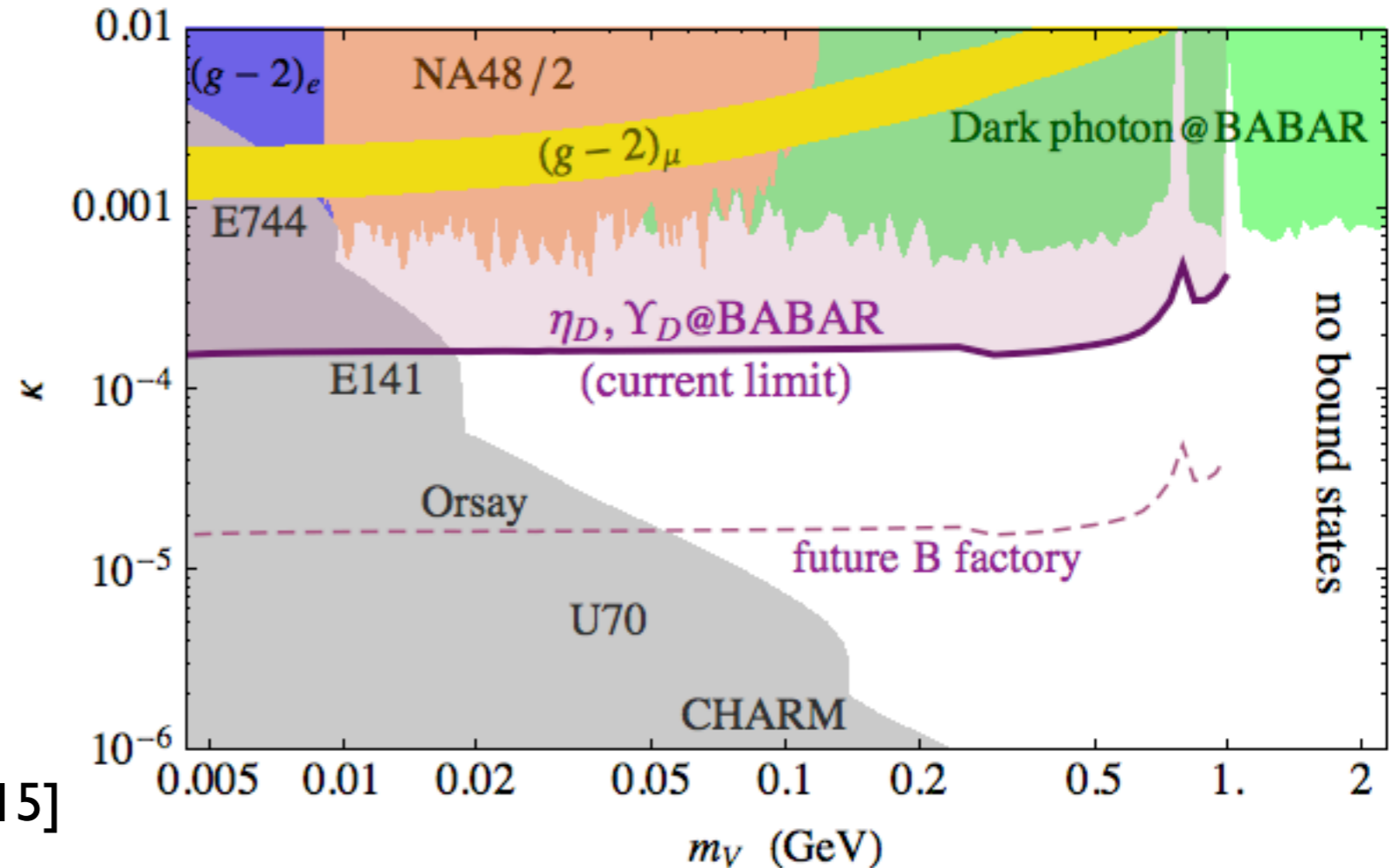
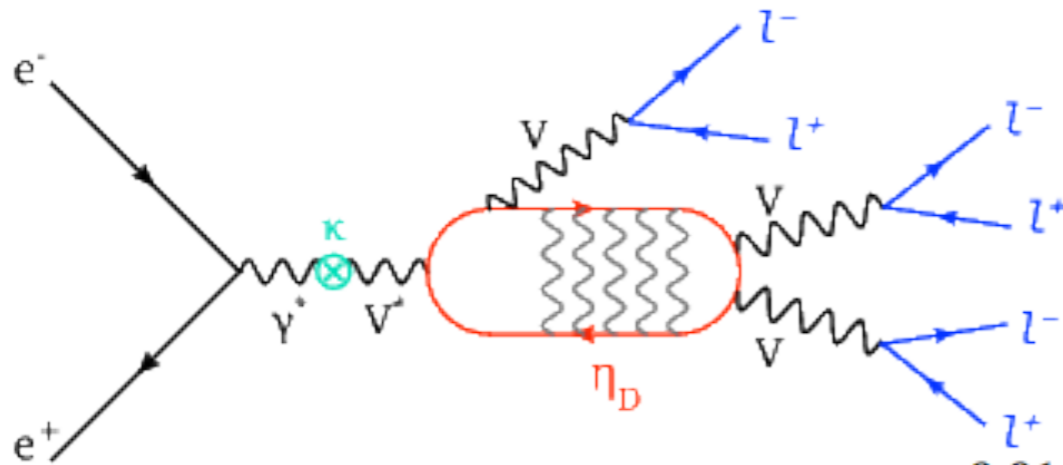
# Going Beyond the Minimal Pictures

“Occam’s Razor does not apply to the dark sector”  
- BJ Bjorken

- Multiple motivators for non-minimal dark sectors:
  - origin of dark photon masses and naturalness
  - astrophysical hints of non-minimal dark matter
  - other “anomalies”
  - the visible sector is definitely not minimal
- But what should experiments look for?  
LOTS of theories...

Point #1: minimal searches can be sensitive to non-min.

e.g. Bound-State Dark DM

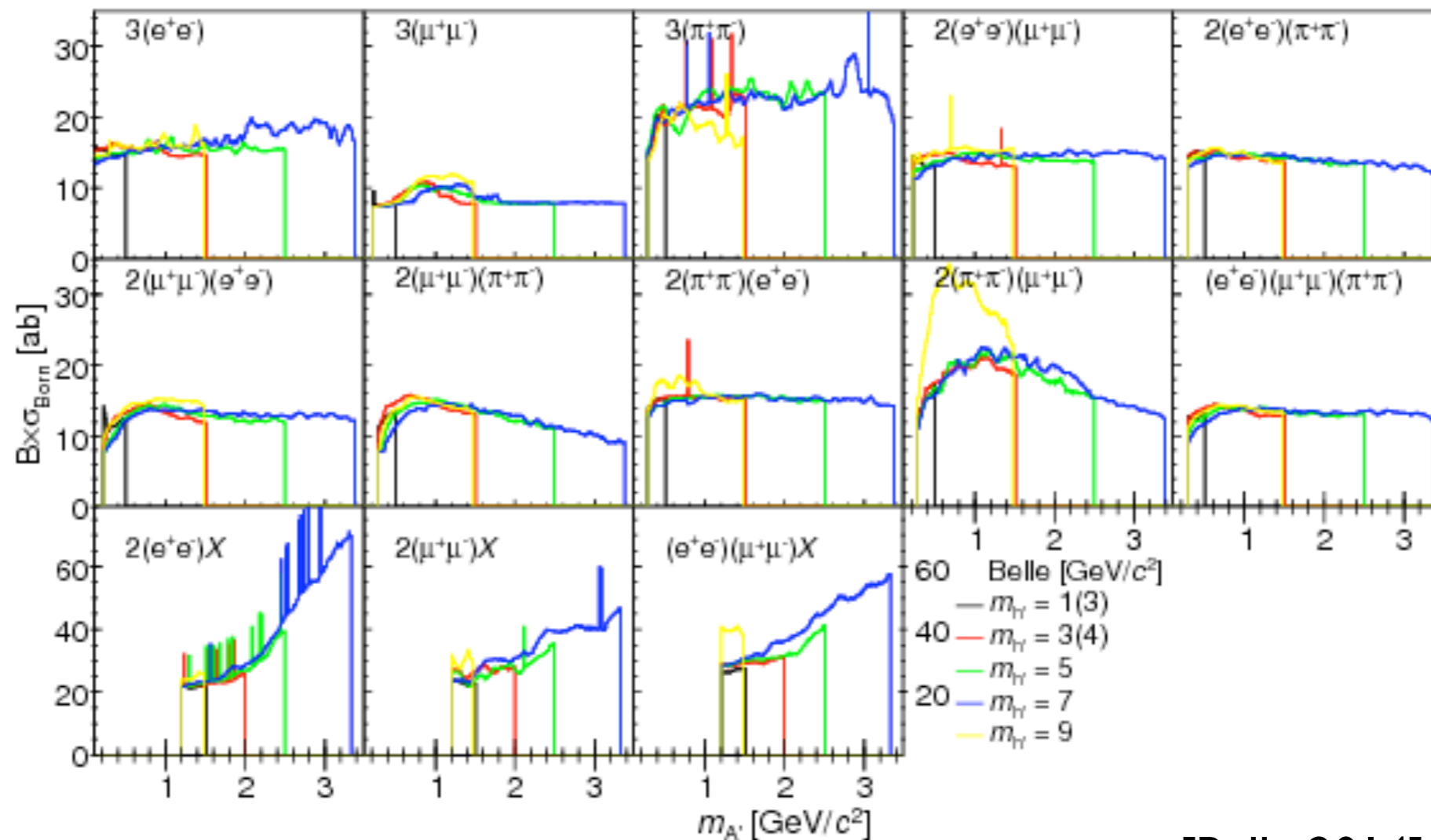


[An, Echenard, Pospelov, Zhang 2015]

Point #2: sometimes new searches are needed.

e.g. Dark Higgs for Dark Photon Mass

$$e^+e^- \rightarrow A'h' \rightarrow 6\ell \text{ (or } 2\ell + MET)$$



[Belle 2014]



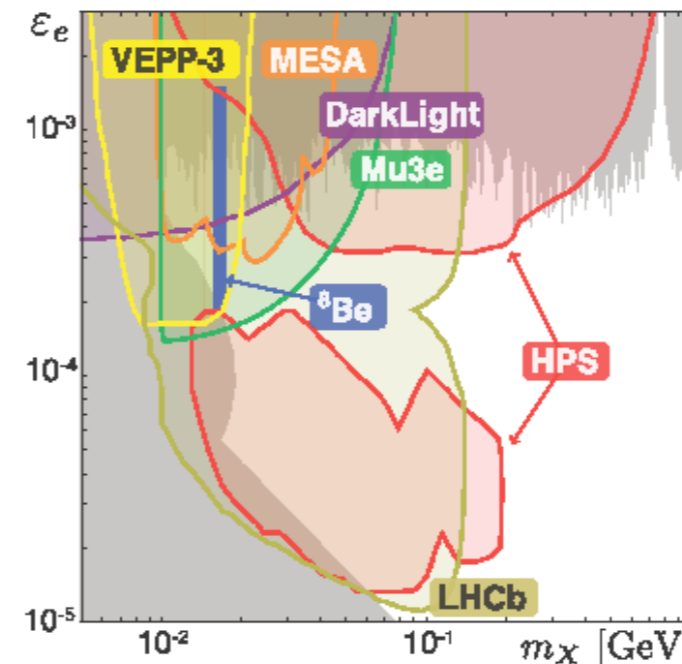
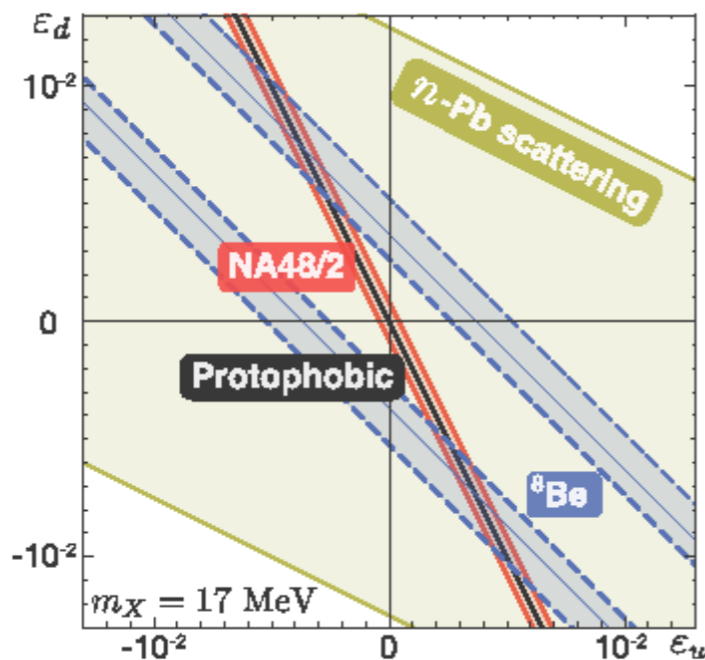
## Point #3: theory experiment communication is key!

- But how?
- For theorists:
  - MC tools needed for experimental signal simulation
  - specific motivated benchmarks, experimental searches
- For experimentalists:
  - report results in general way  
(e.g. model-independent, detector efficiencies, ...)
  - consider more general final states, beyond  $\epsilon - m_A$ .
- Forum for sharing ideas? (wiki?)

## Point #4: Complementarity is Complicated

- Many experimental/astrophysical/cosmological limits.
- Connecting them is model-dependent.
- A central repository of relevant searches would be useful.
- Exclusions in minimal models may not apply to more general theories.

e.g. protophobic avoids NA48 due to couplings



# Rich Dark Sectors Goals

- Many theories, but how best to connect to experiment?
- How can searches for minimal dark sectors be applied to more general scenarios?
- Complementarity of different search methods?  
Constraints on minimal scenarios may not apply.
- Do minimal searches miss interesting, testable physics?
- New experiments to probe motivated RDS scenarios?

# Dark Sector Masses and Naturalness

- Where do light dark sector masses come from?
  - Stueckelberg?
  - Dark sector Higgs mechanism? Strong coupling?
- Are the masses natural?
  - SUSY? Strong coupling/warping? Dark Anthropics?
  - Is there a connection to SM Higgs naturalness (and decays)?
- What does this imply for experimental searches?
  - Are there additional states to discover?
  - What can existing/planned experiments do?

# Exotics

- What should we consider beyond the standard portals?
  - Non-abelian dark forces? Direct coupling with small charges?
  - Connections through higher-dimensional operators?
  - ???
- What does this imply for experimental searches?
  - Are there additional states to discover?
  - What can existing/planned experiments do?
  - Can the LHC/ILC/FCC help?

# Non-Minimal Dark Matter

- Is DM self-interacting/inelastic/excitable/asymmetric/... ?
  - What does astrophysics suggest?
  - Hints from indirect/indirect detection, LHC searches?
- What does this imply for experimental searches?
  - Are there additional states to discover?
  - What can existing/planned experiments do?
  - How can laboratory searches be related to DM searches?