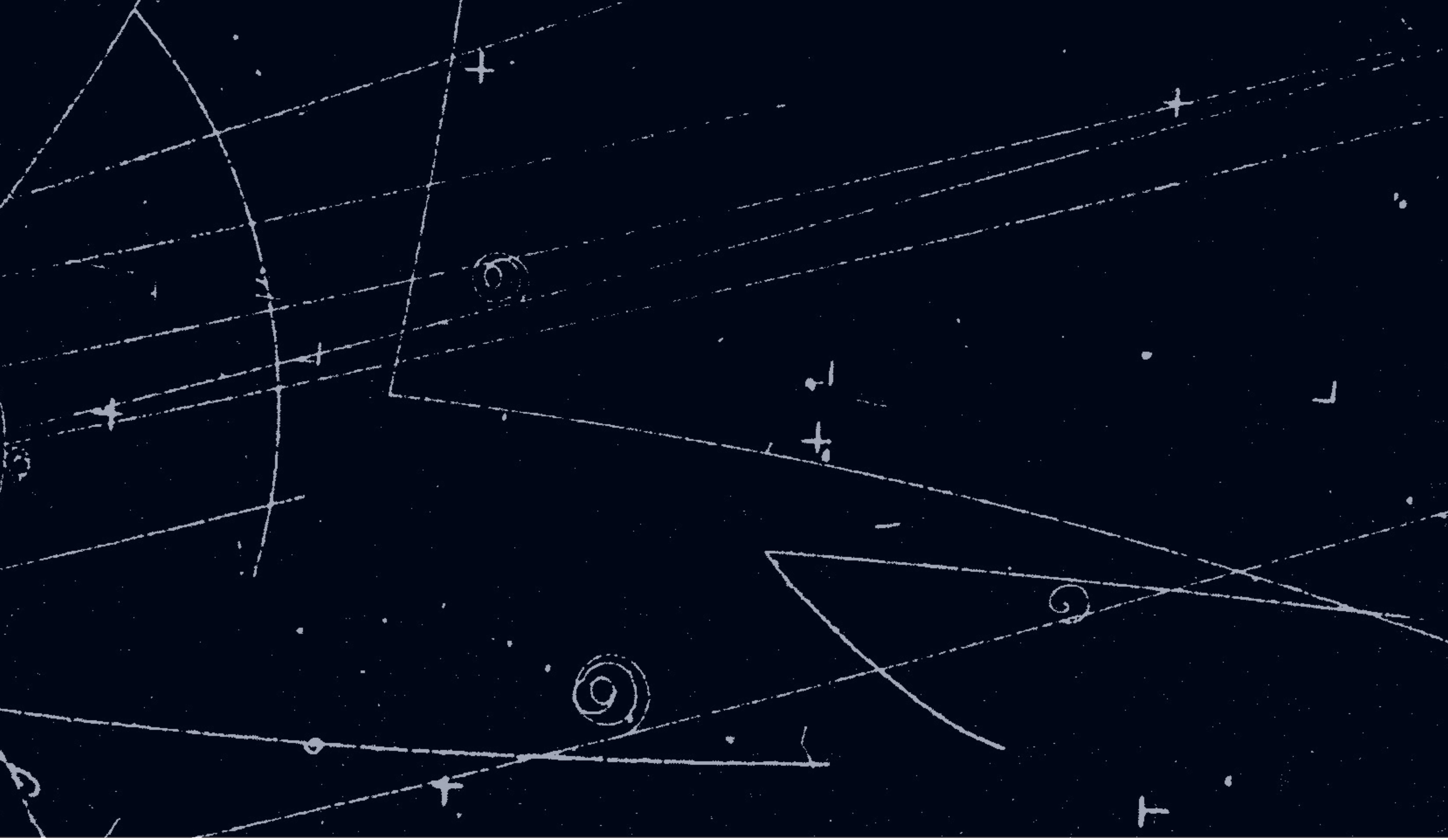
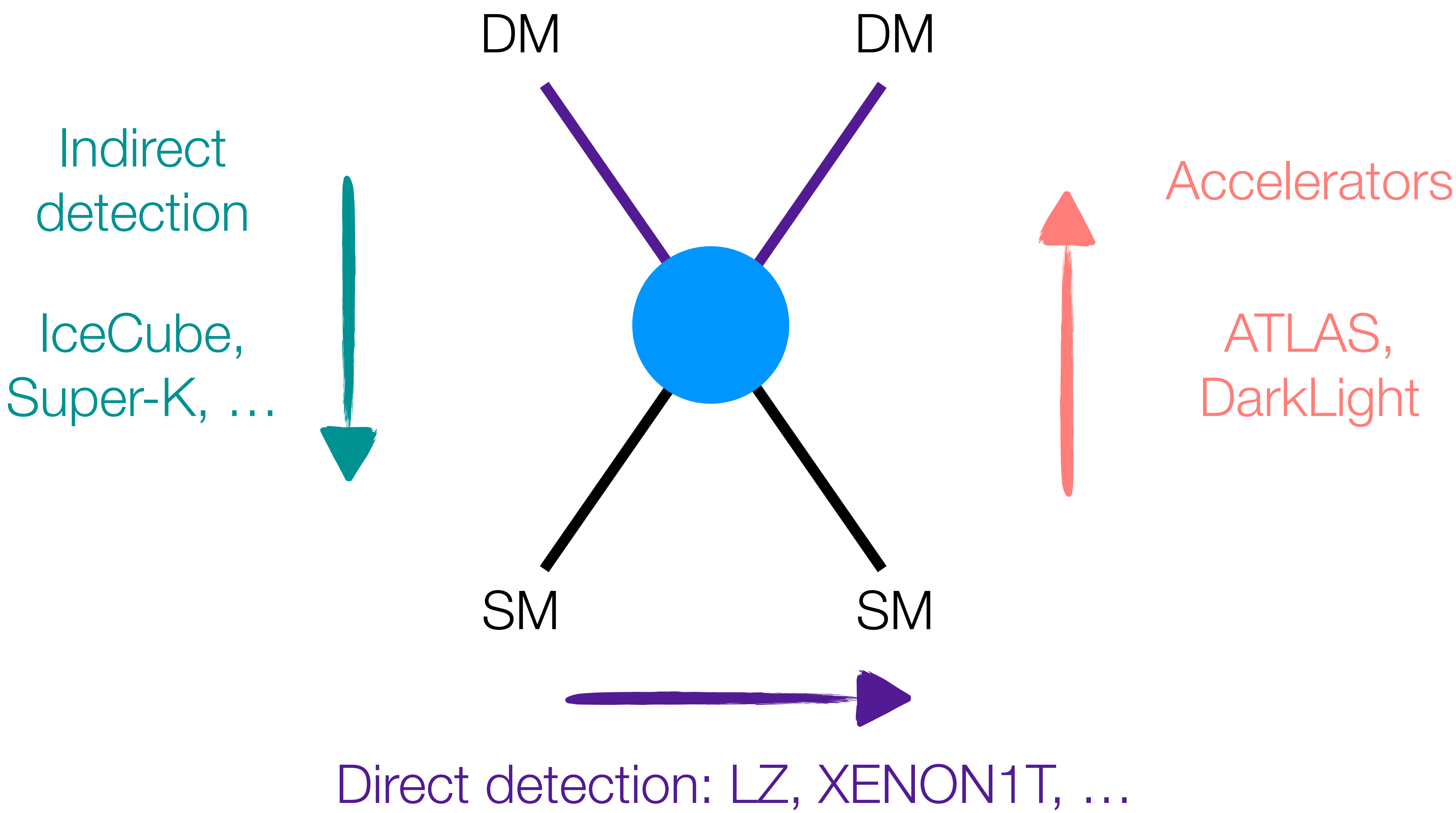


The DarkLight experiment at TRIUMF and the hunt for a new boson

Kate Pachal
TRIUMF

Looking for dark matter with experiments



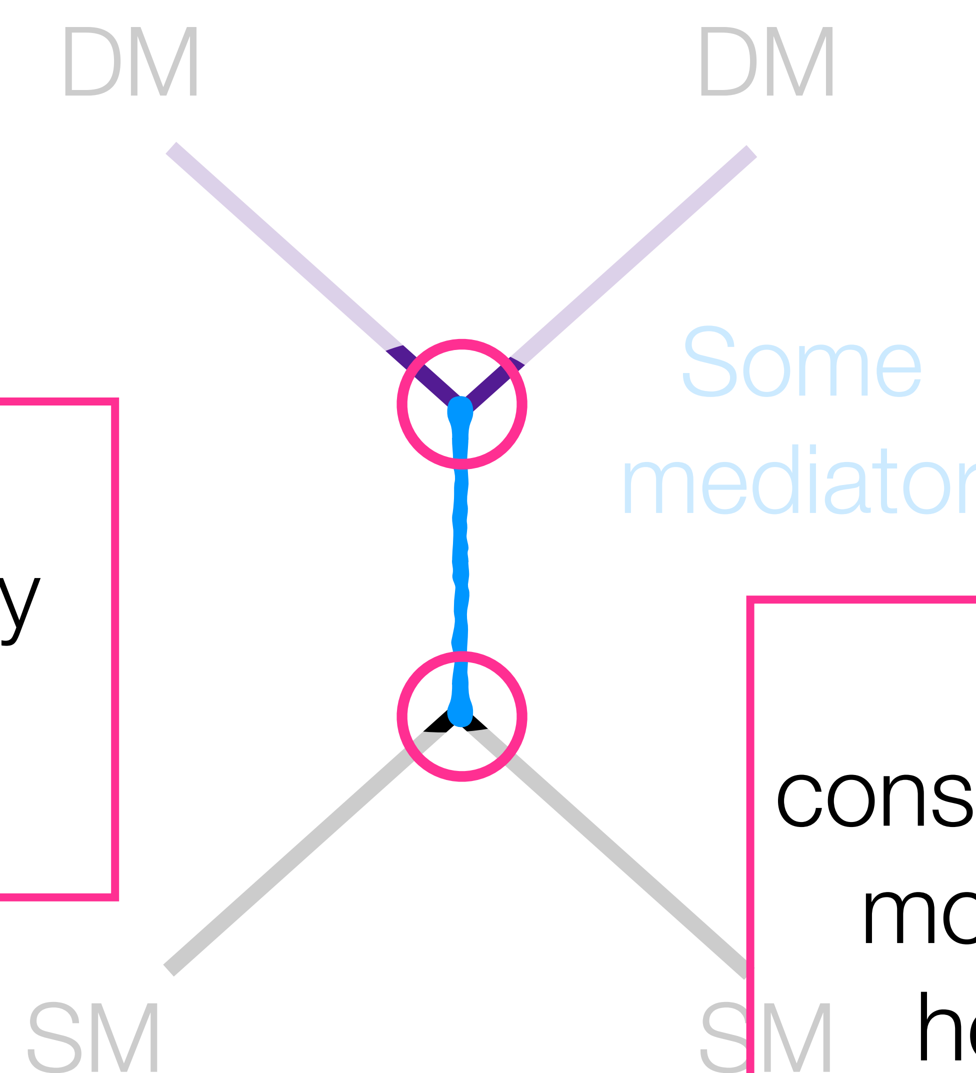
If there is some interaction with the Standard Model, and the energy scale isn't too high, → then we could we make it in the lab

Let’s build a very simple model….

What is this?

This mediator: *dark boson* (A’)

Let’s make a simplified model by taking easiest possible answer



Practical consequences for our model depend on how strong the couplings are at these vertices

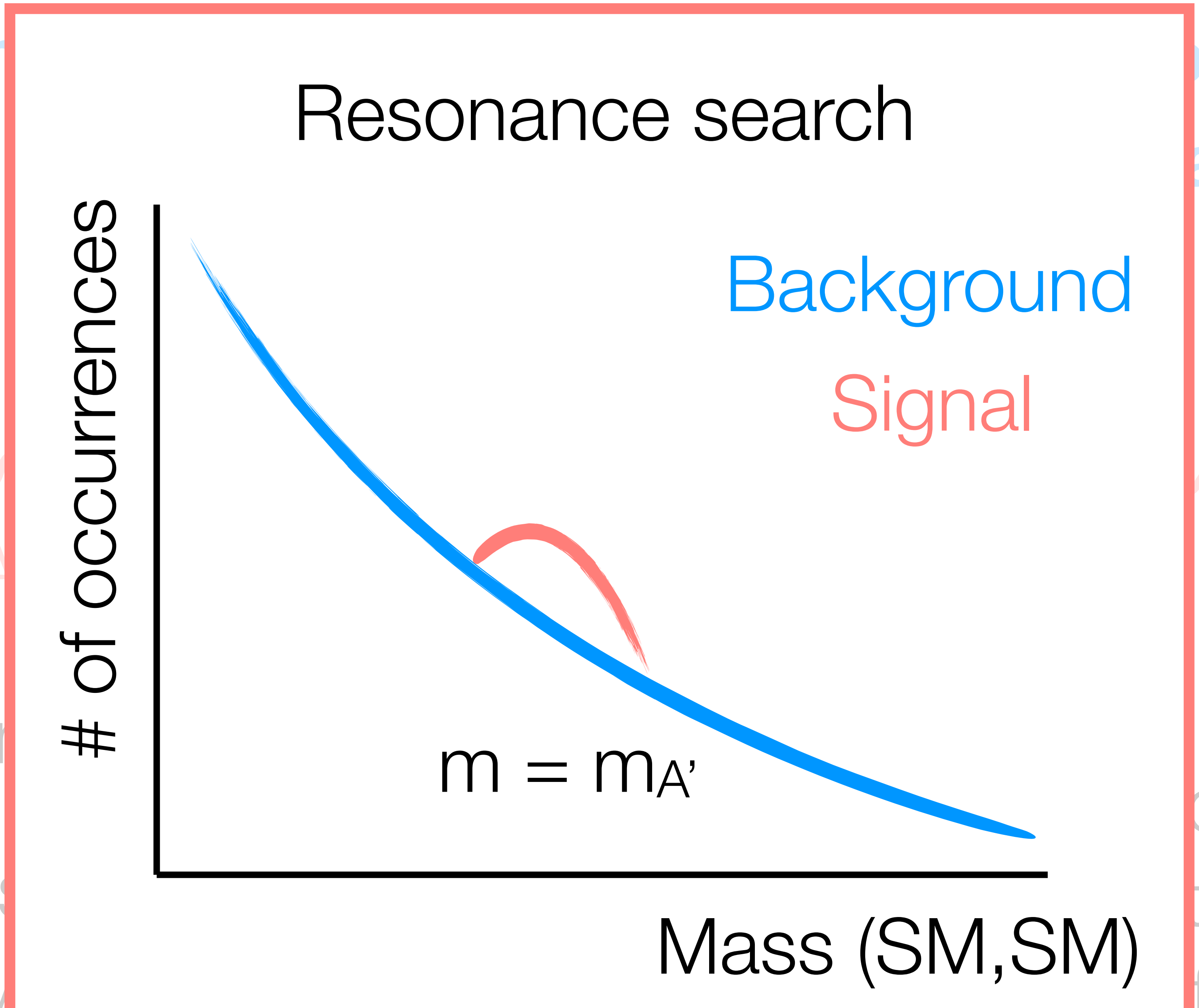
What does it look like in practice?

Experir … roduction
… article

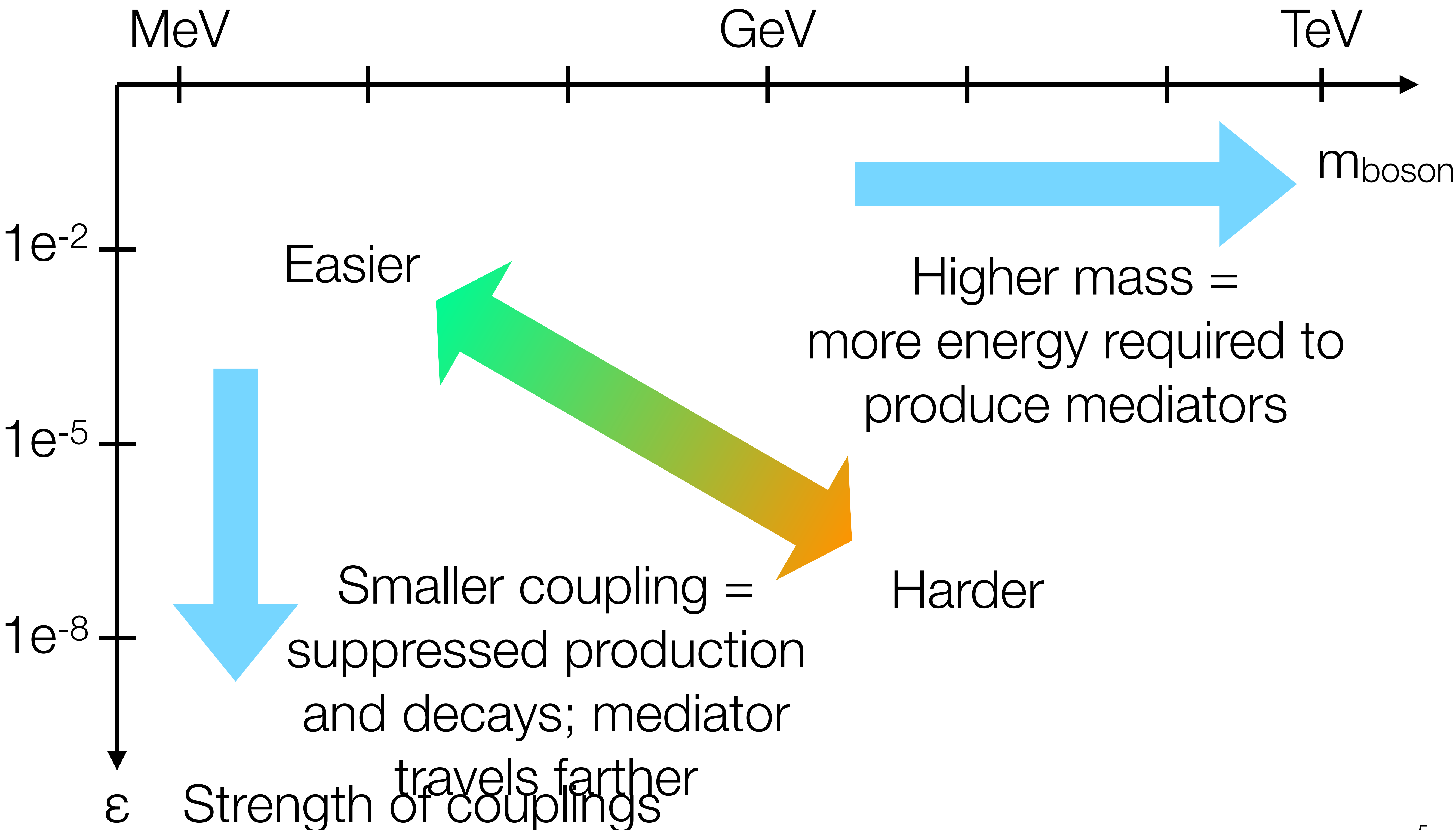
e+ e- … q/e/… q/e/…

Requires r … onance":

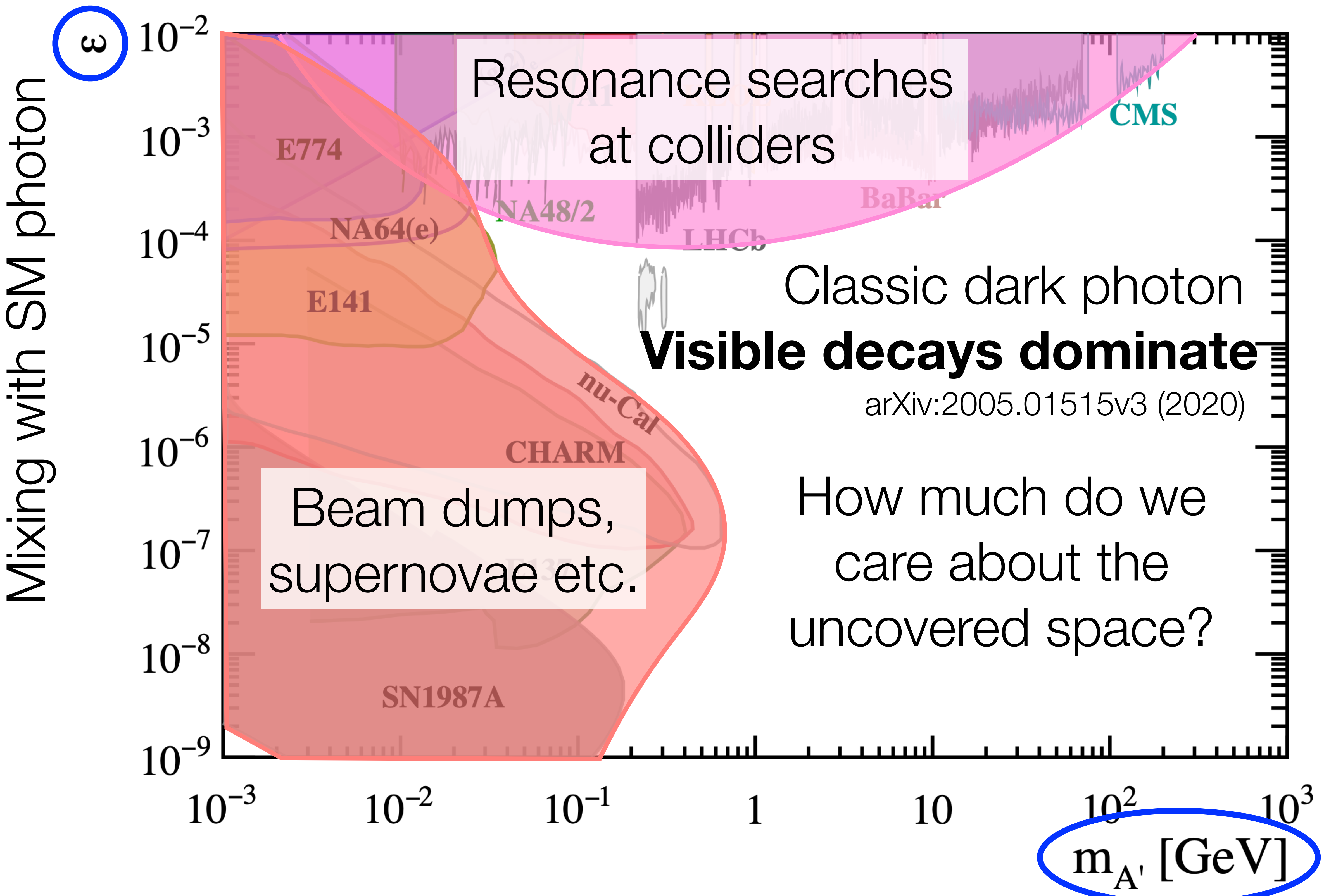
Signal i … ticles at
energy … f A'
reconstruct the DM



How are we looking for dark bosons?



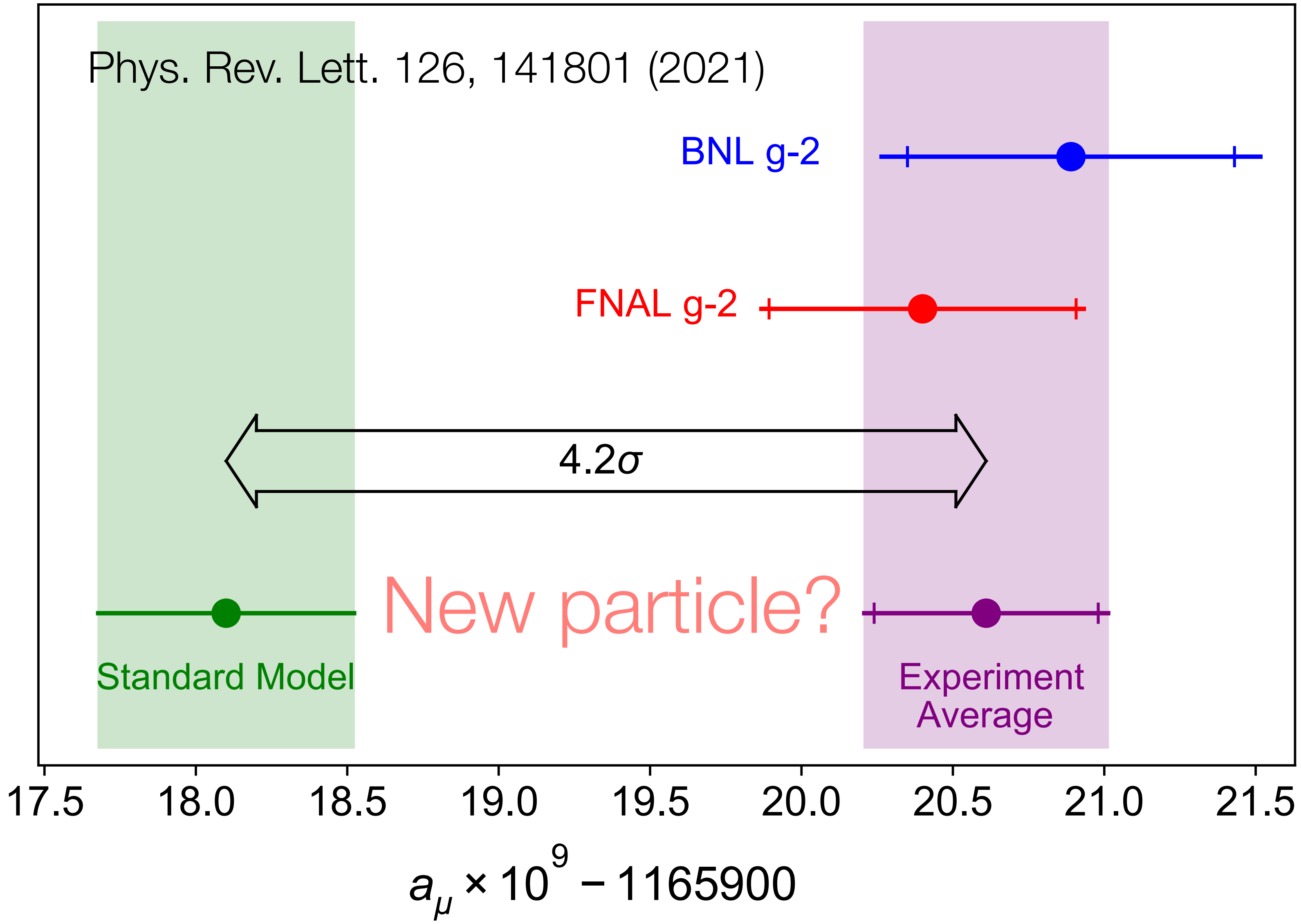
A real example

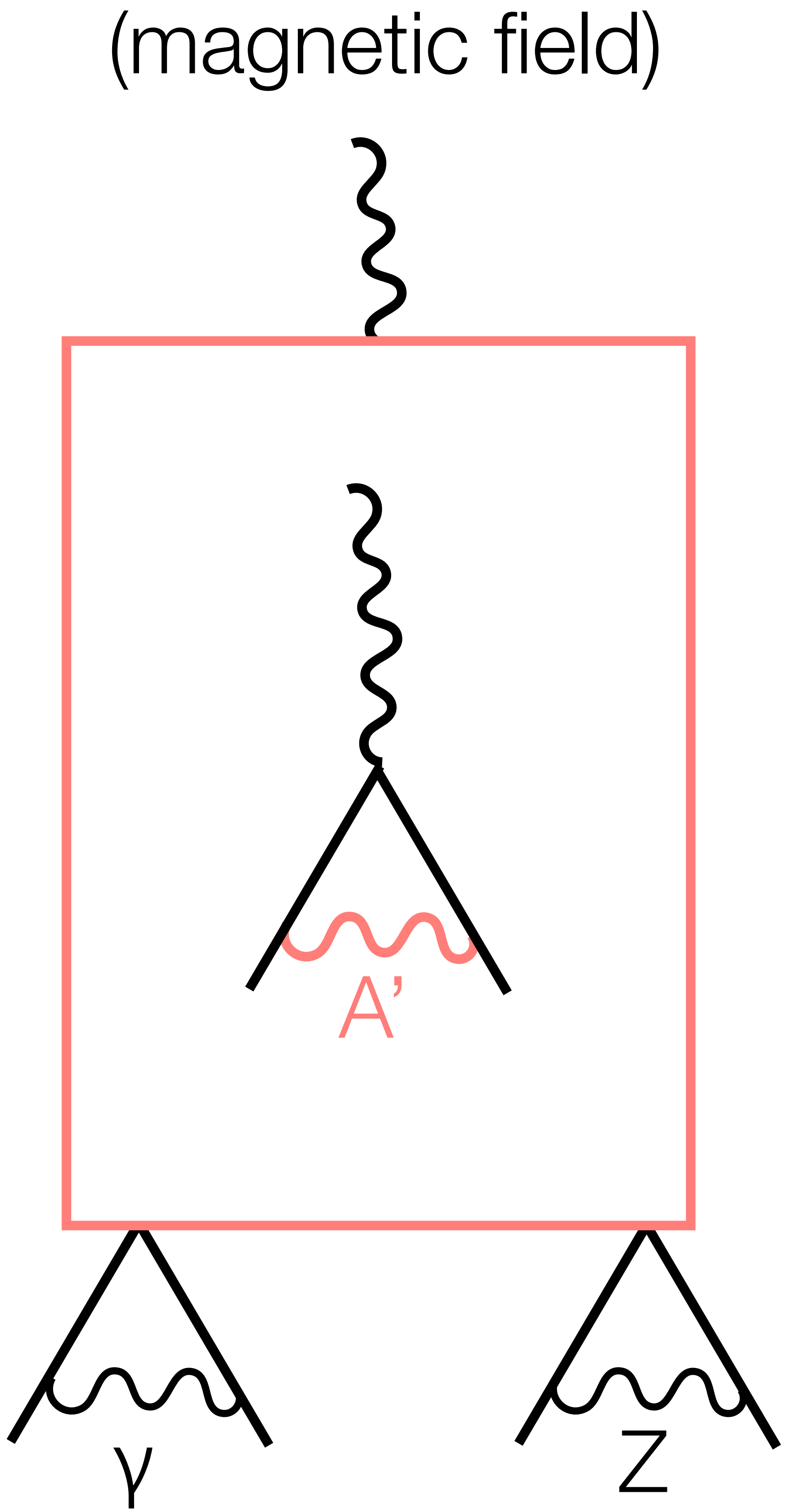


Muon g-2

"Spin" of a muon in a magnetic field **very precisely predicted**

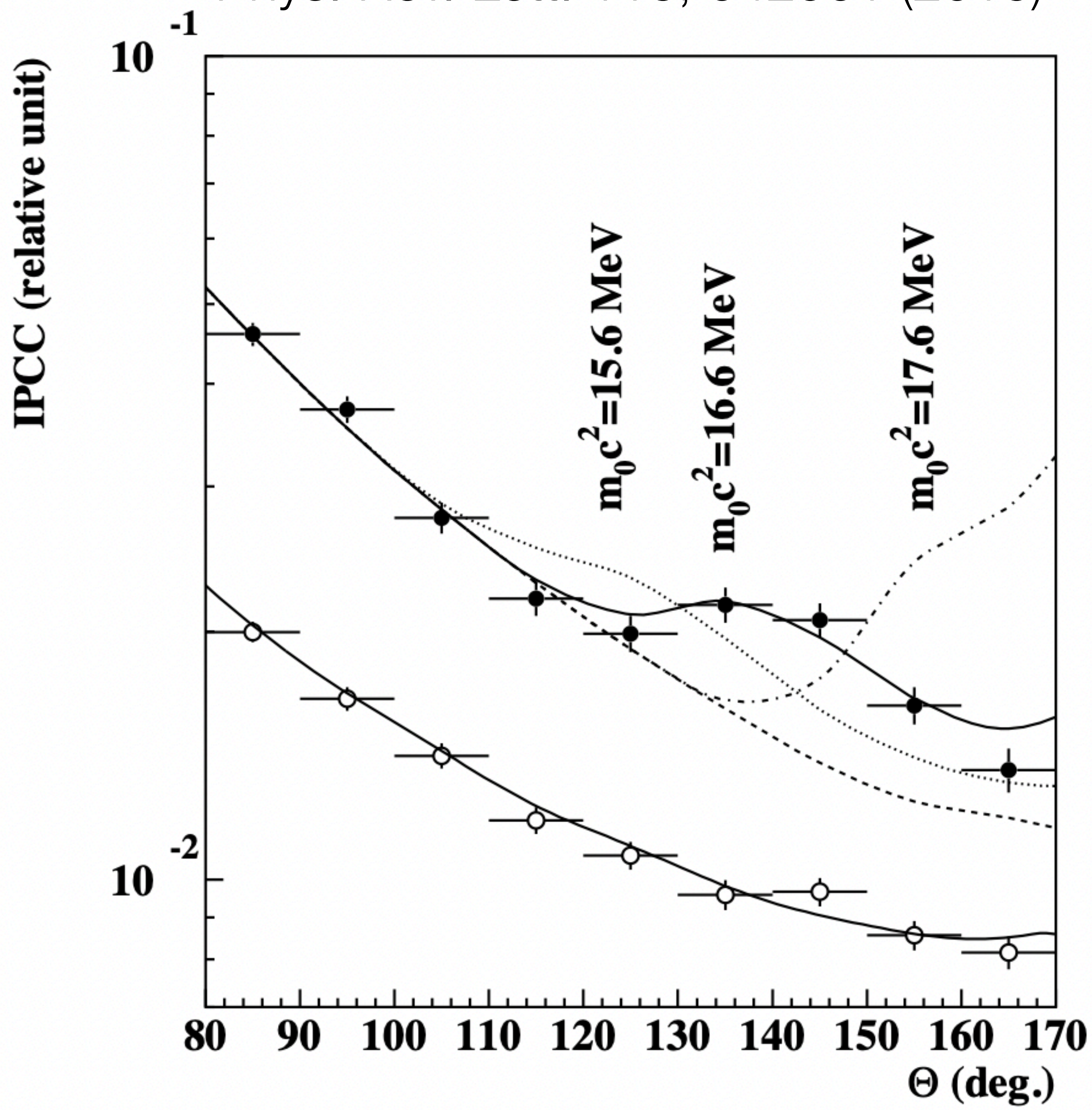
Measured value is significantly different



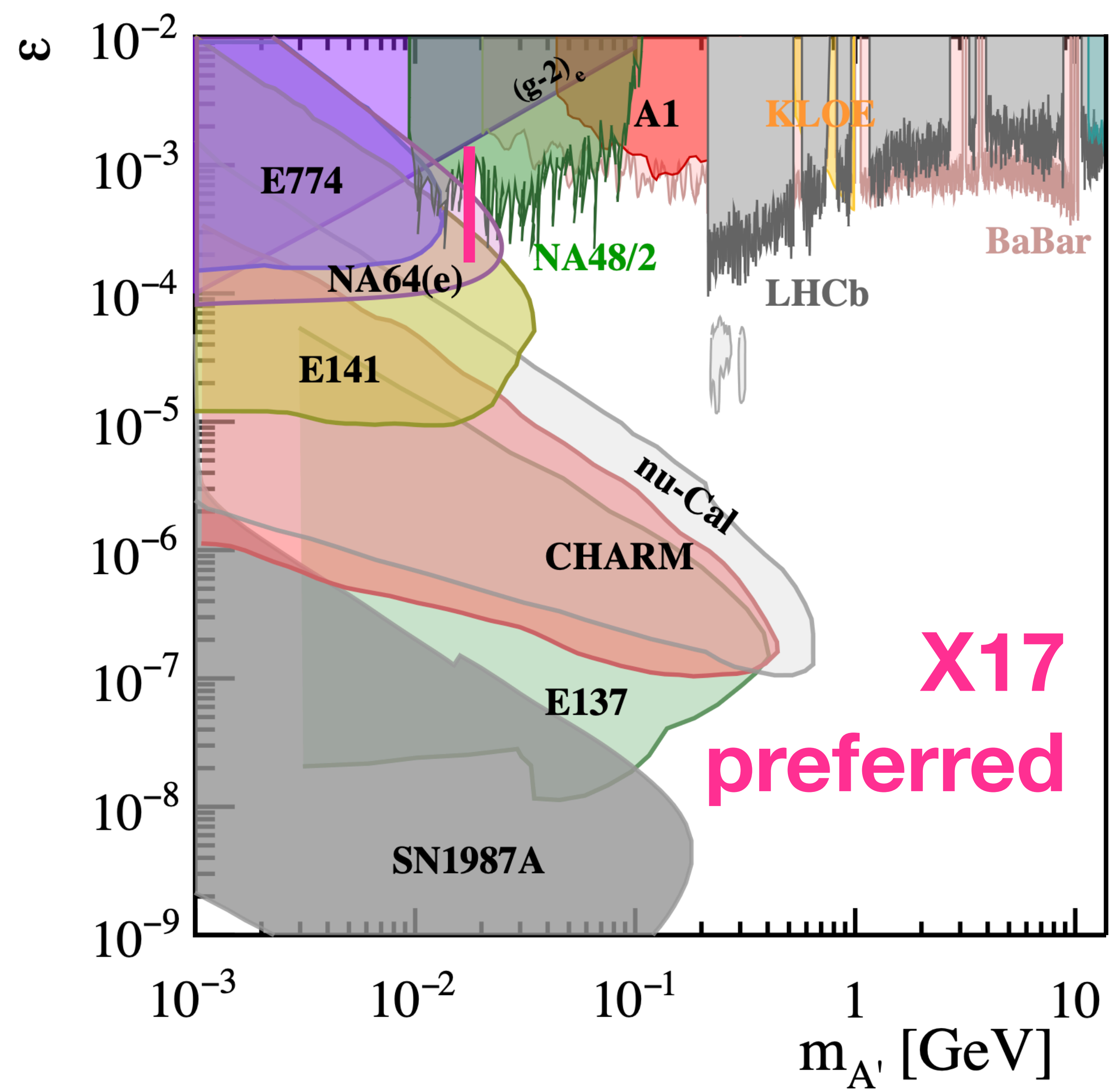


The “X17”

Phys. Rev. Lett. 116, 042501 (2016)

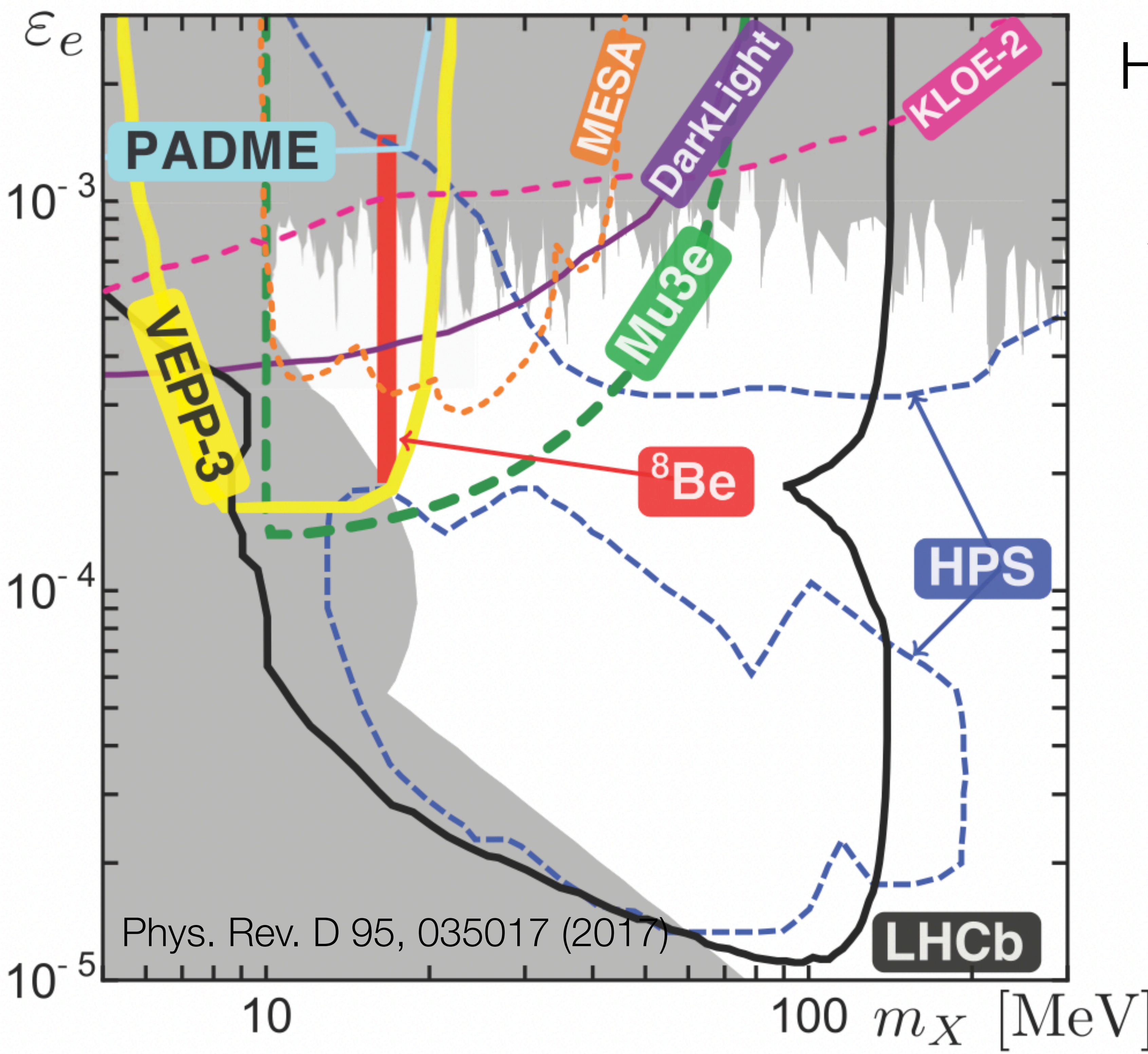


Phys. Rev. D 95, 035017 (2017)



If your new boson dislikes protons, this is workable

“Proto-phobic” limits around the X17



Here, the other extreme:

X/A’ couples **only** to e

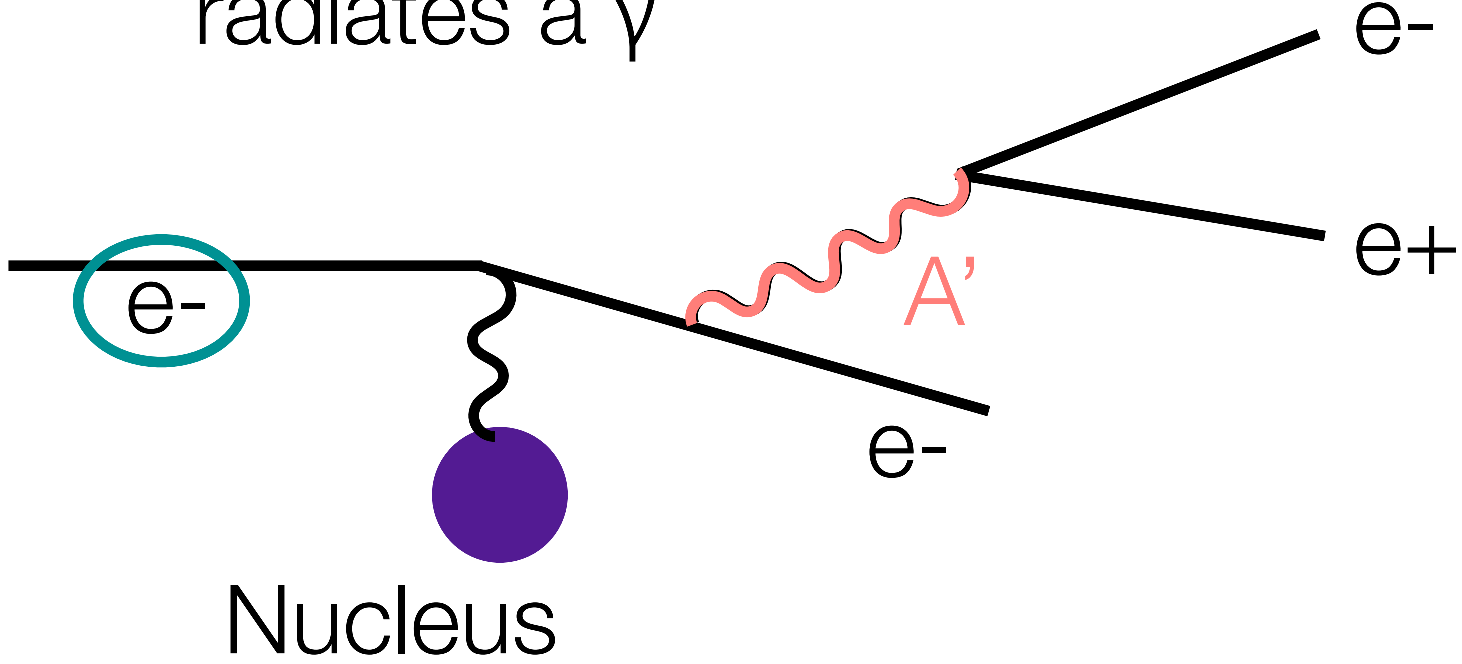
Grey = excluded

Open contours = projected limits from upcoming experiments/results

Not excluded here

Low-mass di-lepton resonances

Incoming electron interacts with target and radiates a γ



Photon can convert into an electron-positron pair

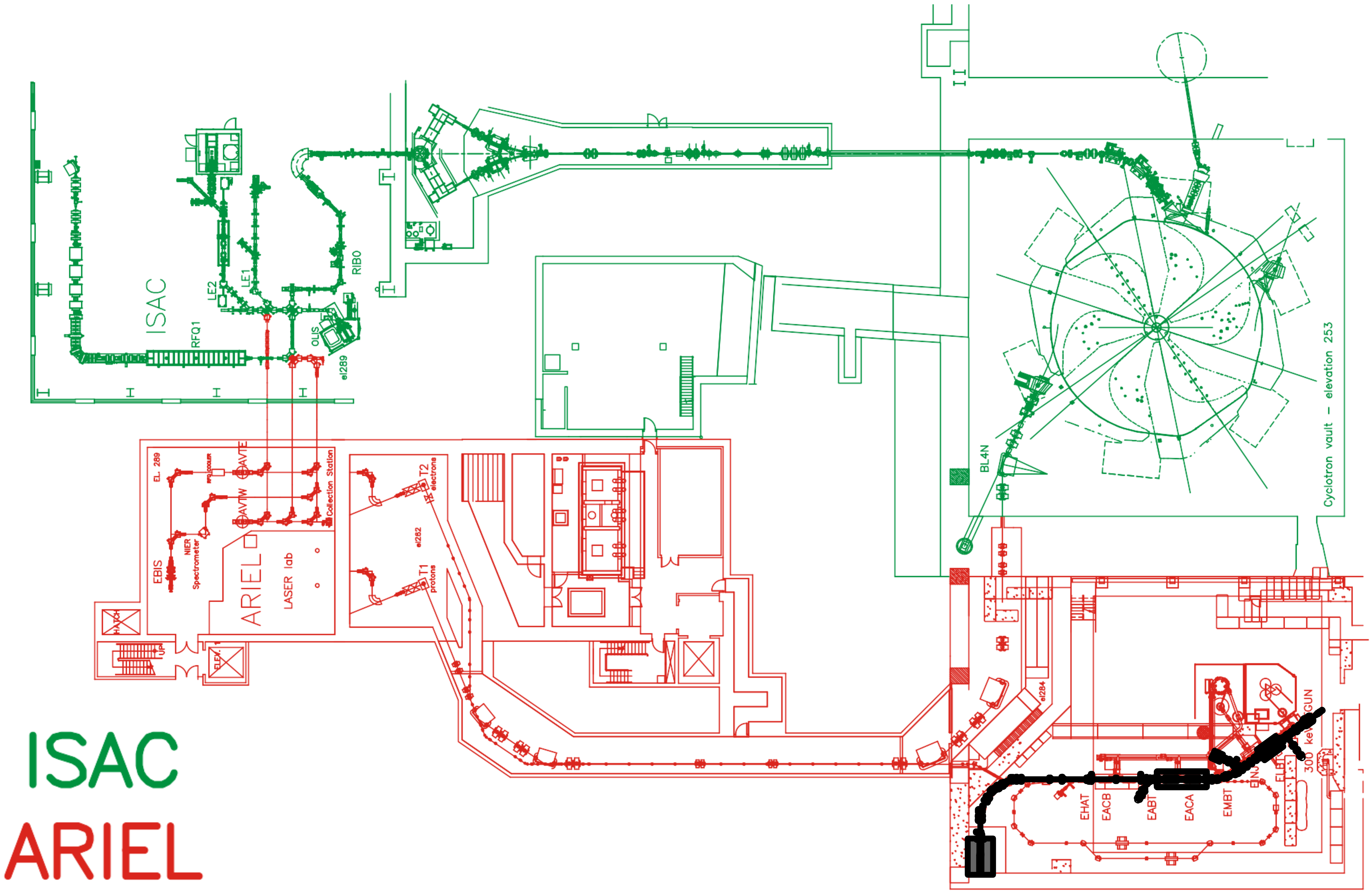
But if a **new boson** is in this energy range, e- could radiate that instead

New boson could decay to dark matter, or back to e+e- pair

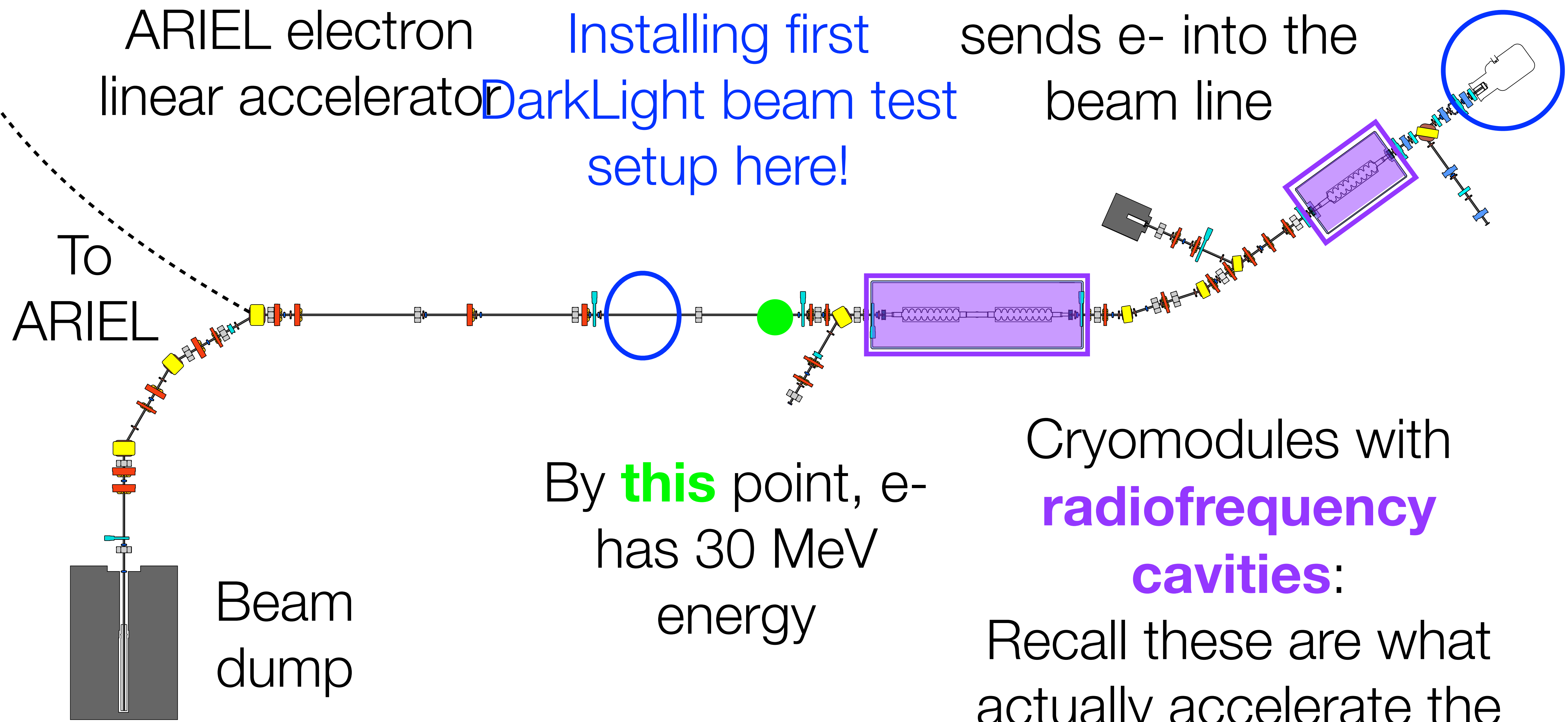
DarkLight experiment will look for this visible process

Need **energetic e-** …

The accelerator

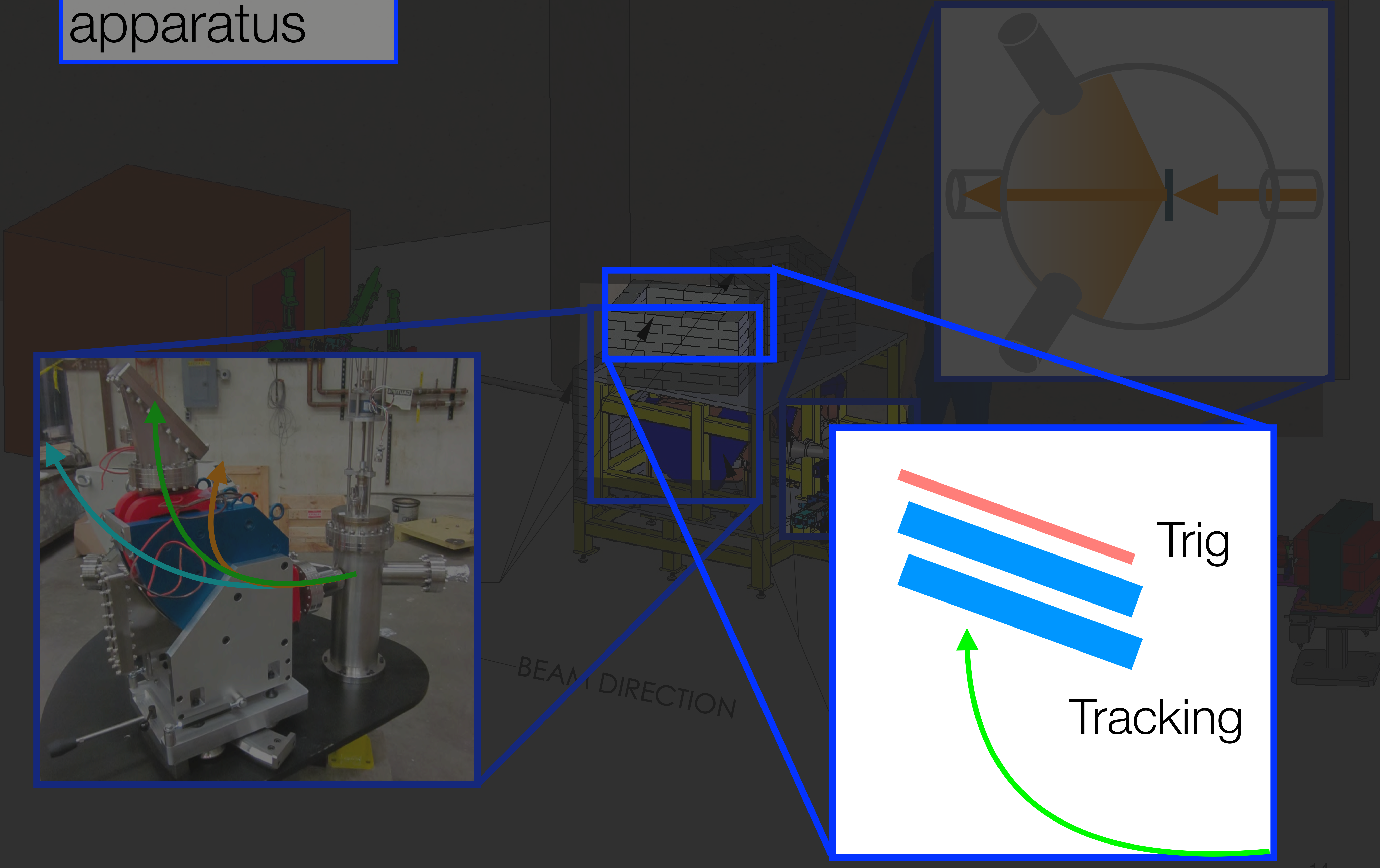


The accelerator

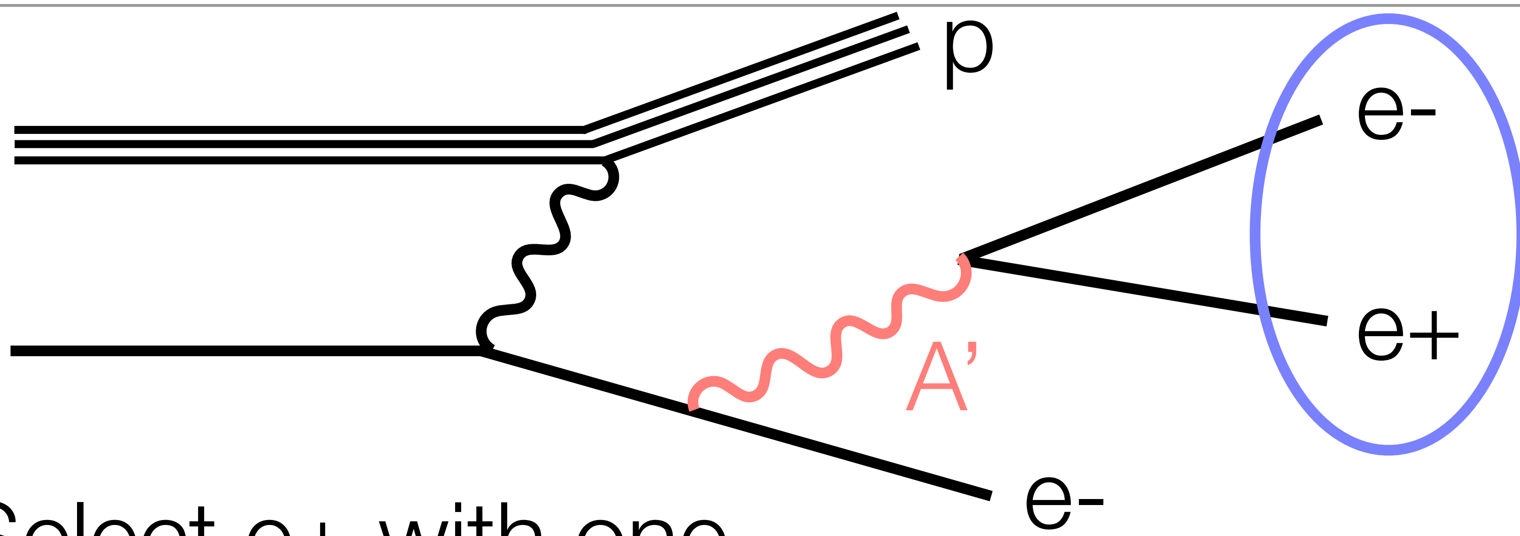



S.W.L. 1 TON
TRIUMF
CAUTION
HARD HATS
REQUIRED
NOTICE
WORK PERMIT

Experimental apparatus



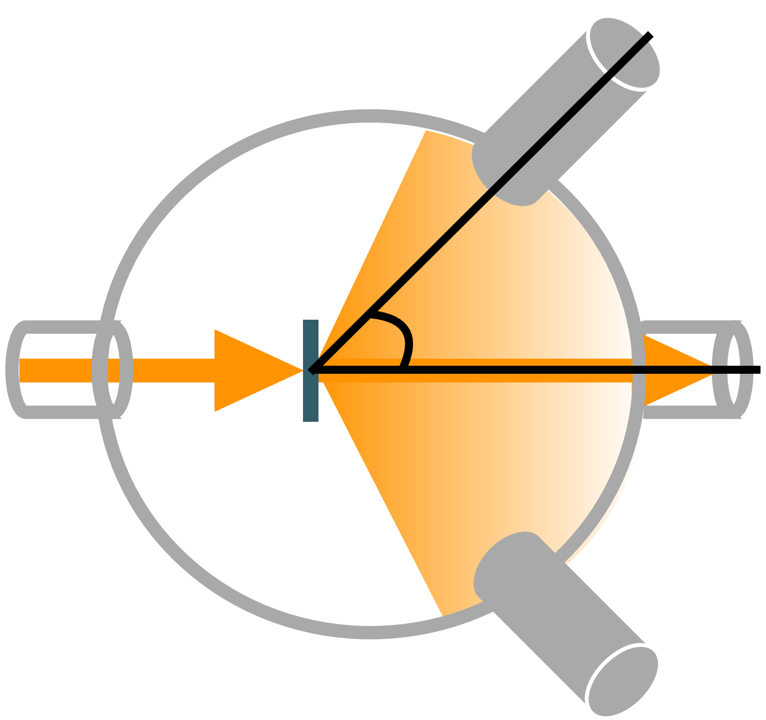
What are we actually measuring?



Three particle final state

But these are the ones we care about

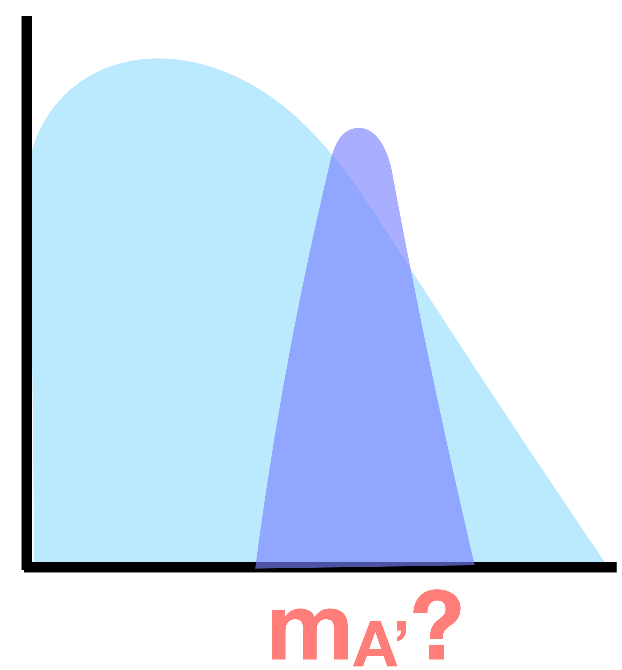
Select e+ with one spectrometer and e- with the other



Look for coincidence: e+ and e- arrive simultaneously

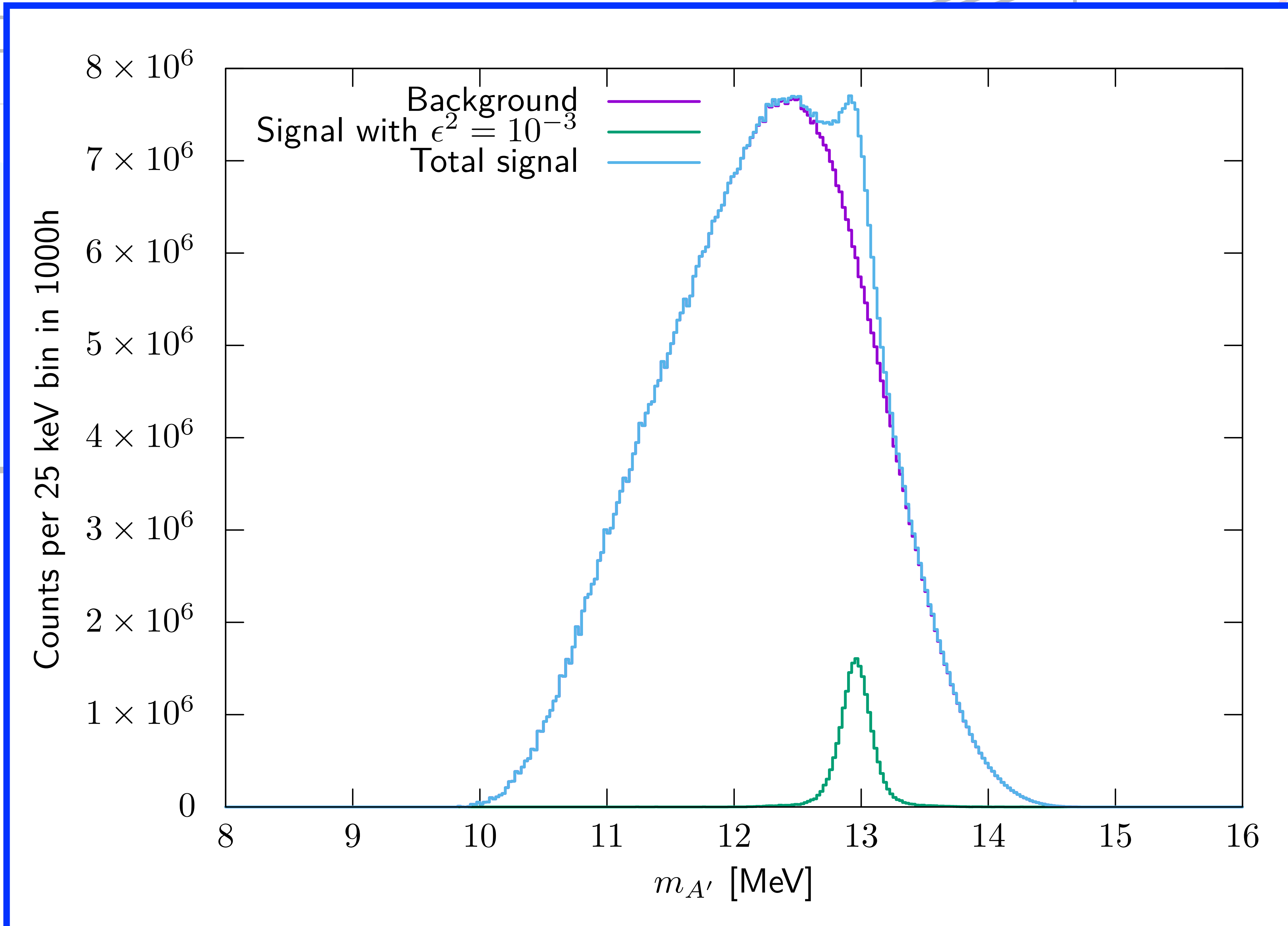
Bump hunt!

Look in invariant mass of e+ e- pair



Irreducible

Bac



p

e-

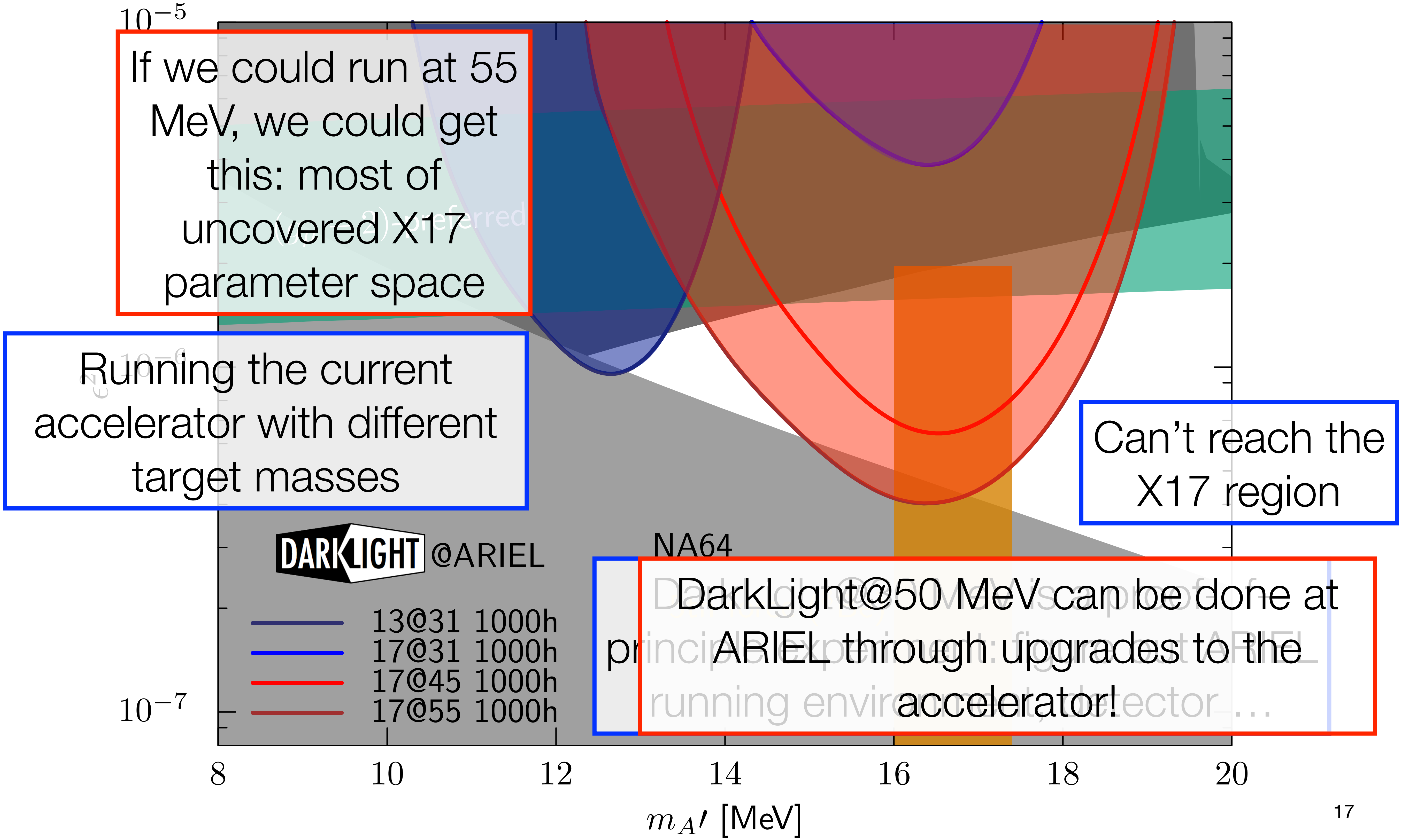
e+

e-

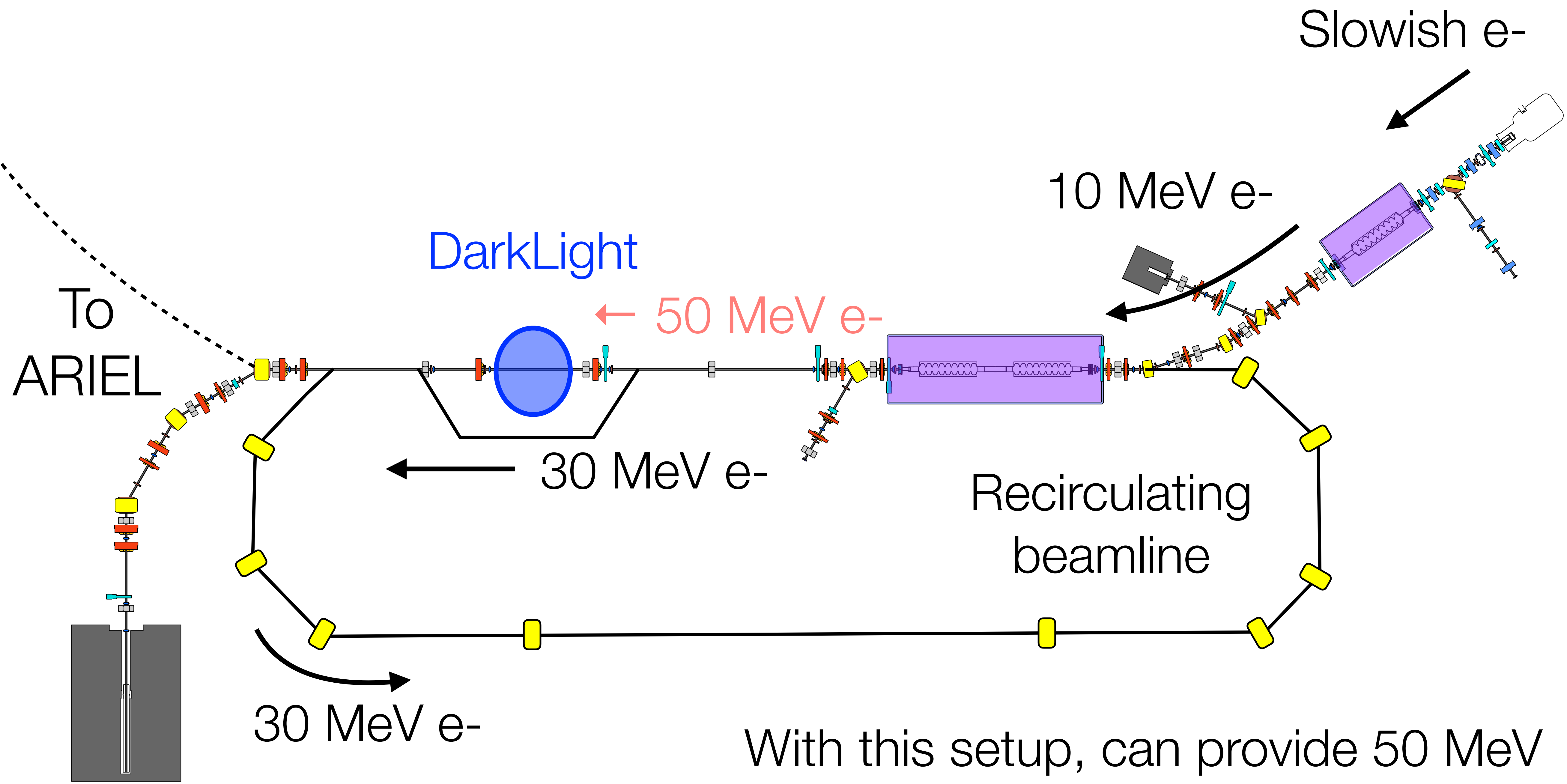
collisions in neighbouring bunches

DarkLight exclusion reach

Good overlap with g-2 but only in already-excluded regions

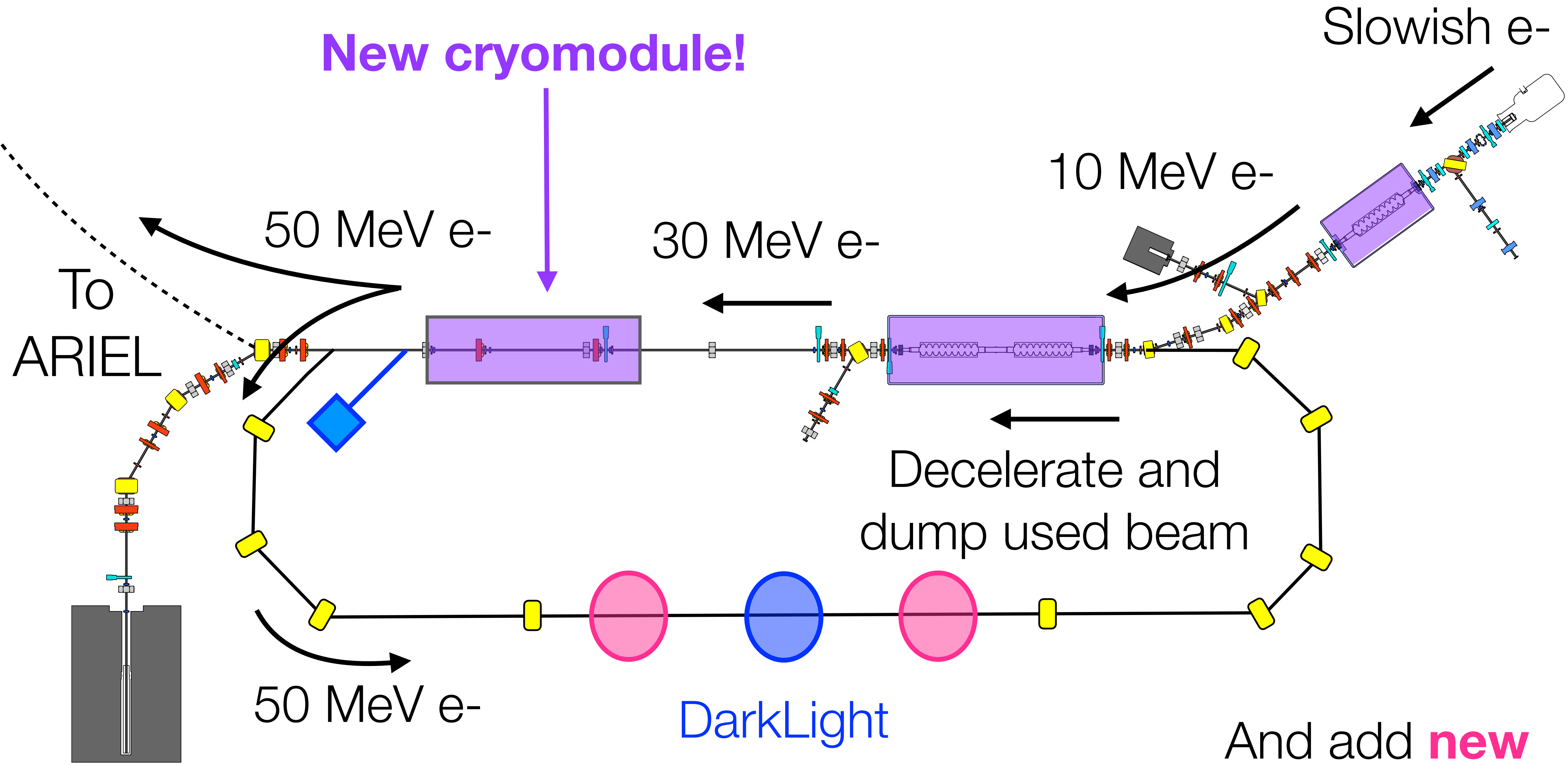


The next phase: 50 MeV single-user mode



With this setup, can provide 50 MeV beam to DarkLight or ARIEL, but not both

The long-term plan: 50 MeV parallel delivery



With this mode, deliver beam to ARIEL and DarkLight **at the same time**

And add **new experiments** in future!

Experimental timeline

November 2021	Install first test targets in ARIEL e-linac.

Getting started now!

Backup

Why ARIEL?

- Low energy, high intensity beam.
  - Energy not much above the production threshold is nice because it gives an opening angle that we can easily pick up with spectrometers
  - Peak intensity of 3 mA gives us plenty of instantaneous luminosity - don’t need to run forever
- Finally, because the e-linac is available! No need to share beam time with any other targets until ~phase 2, at which point parasitic running will be an option

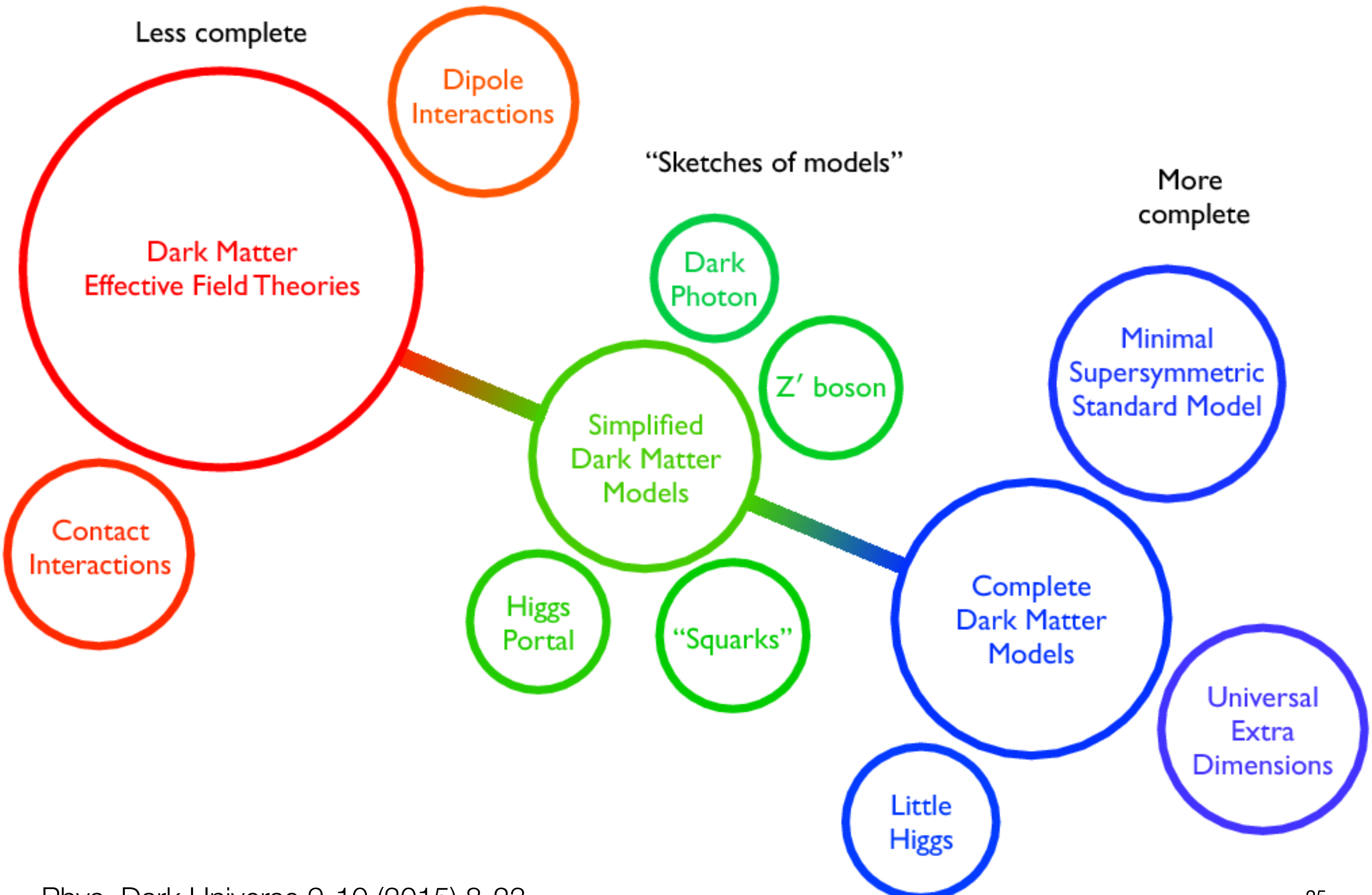
Are we sensitive to anything else?

- Given the e+e- selection, we are sensitive only to resonances at masses relatively close to the selected target mass

- In general, lots of new physics models give resonances with this type of decay. E.g. doesn’t have to be spin 1 like the target model discussed. But sensitivity != motivation: a more complete question would be “what might isn’t yet excluded in this mass range that results in a dilepton final state.” And I am not sure!

- What we do know: if we see something, there will be lots more study from a more complex detector required to determine what it actually is

Was in intro after wordy slide

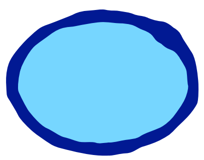


Phys. Dark Universe 9-10 (2015) 8-23

Anastasiou, Baudis, Chiochia
University of Sydney

Why you need high energies for small scales

We can see an object with **light** as long as the object is ~ the size of the wavelength or larger



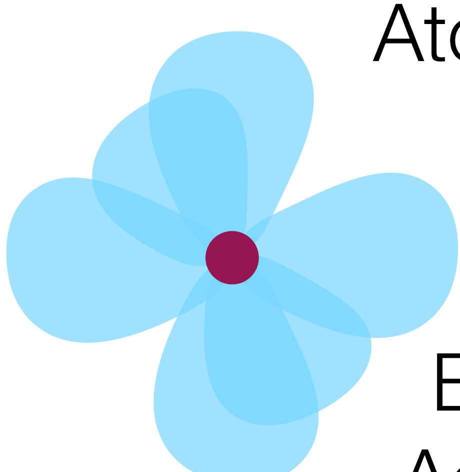
Cell: width ~10^{-5} m

Can probe with visible light

Below ~10^{-7} m is outside visible light range

Use particle-wave duality:

$$\lambda = \frac{h}{p}$$

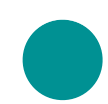


Atom: width ~ 10^{-10} m

$$p = \frac{h}{10^{-10}} = 10^4 eV$$

Electron microscope! Accelerate electrons to ~10-100 keV, see atoms!

Nucleus?



Proton?

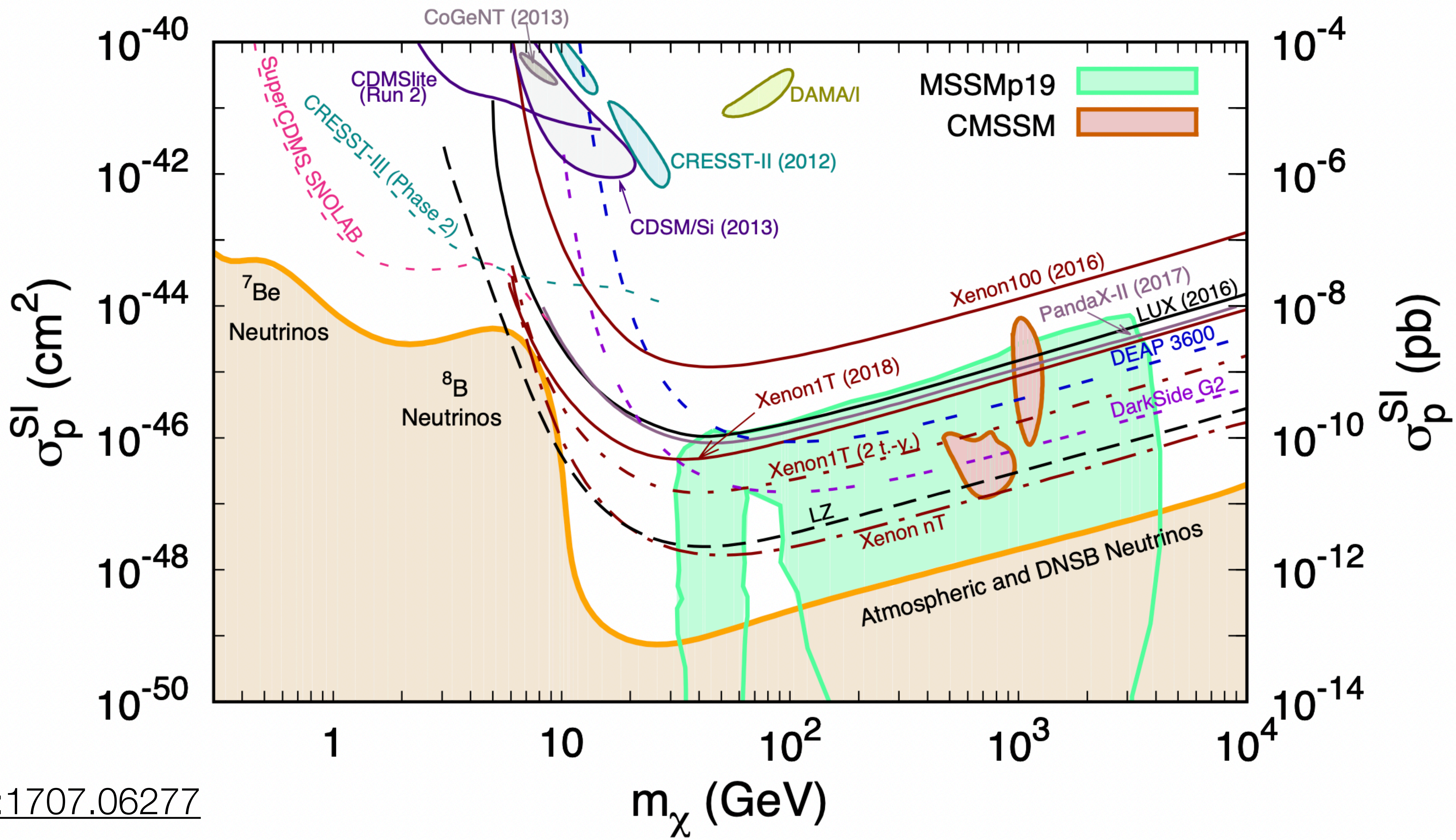
… quarks?

$$p > \frac{h}{10^{-15}} \sim 1 \text{ MeV}$$

Need a particle collider!

Aren't WIMPs basically excluded by direct detection?

- Reminder about WIMP models: make up relic density with a single particle, order GeV to TeV mass, couplings are order of weak scale.



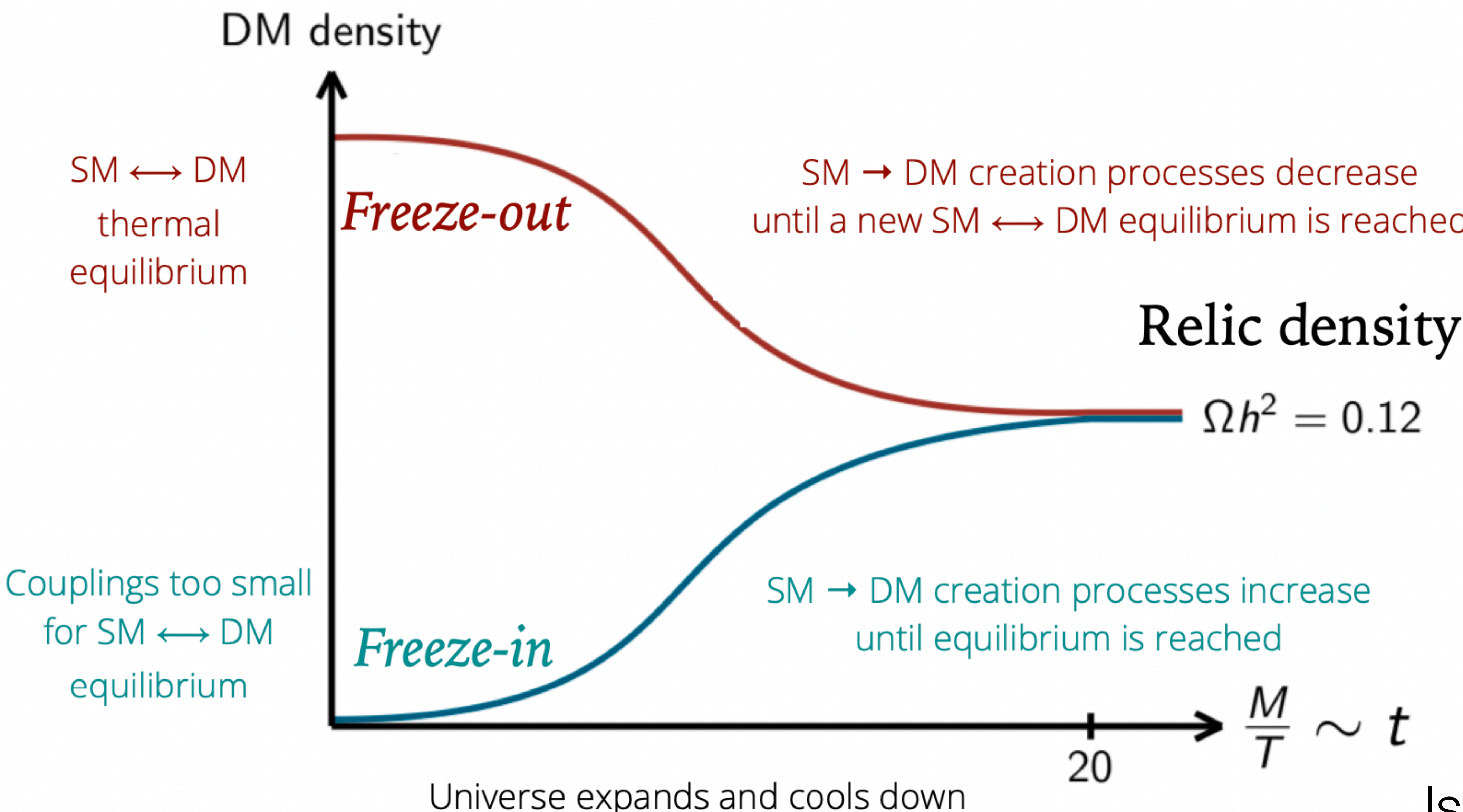
arXiv:1707.06277

What does this plot tell us?

- Interpreted in a contact interaction (EFT) framework: applicable for these experiments but need to convert from other models to make a 1-to-1 equivalence
    - Different models have very different interactions (e.g. spin-dependent versus spin-independent)
- Freeze-in and other wimp paradigms can give very different probable coupling ranges
- Note that the neutrino floor is not a forbidden region, it’s a hard to search region.

Freeze-in and freeze-out

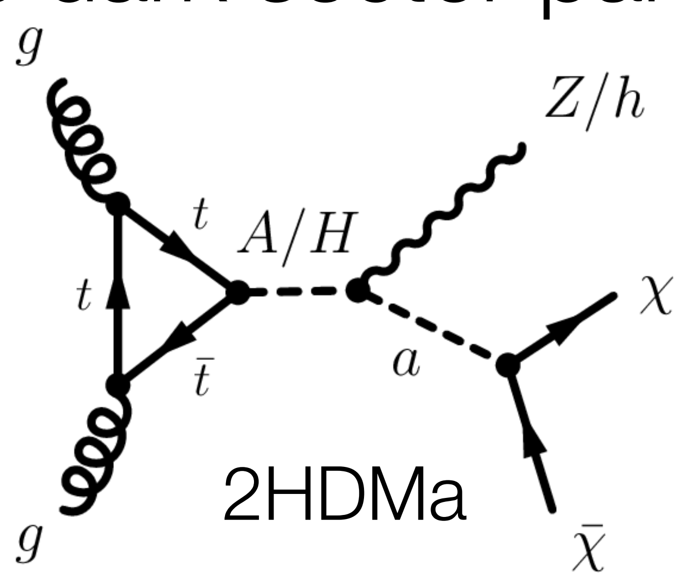
Usually think about freeze-in with WIMPs, but freeze-out and other interactions can give you exact same relic density with very different (smaller) couplings



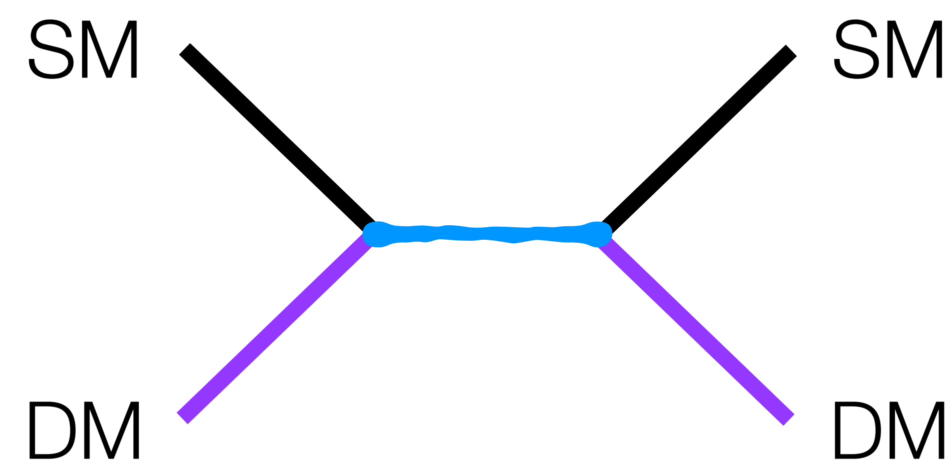
Isabelle John

When you said that model “really is simplified”…

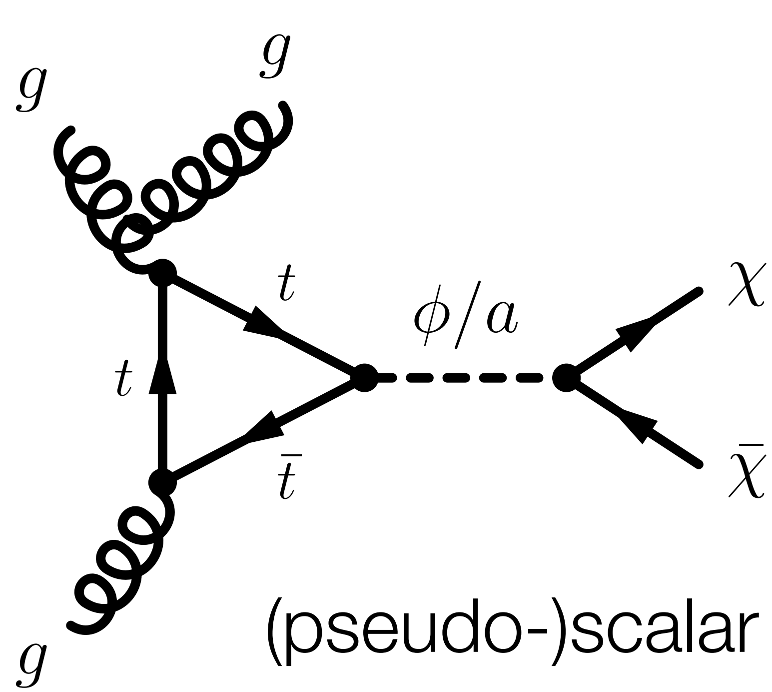
More dark sector particles



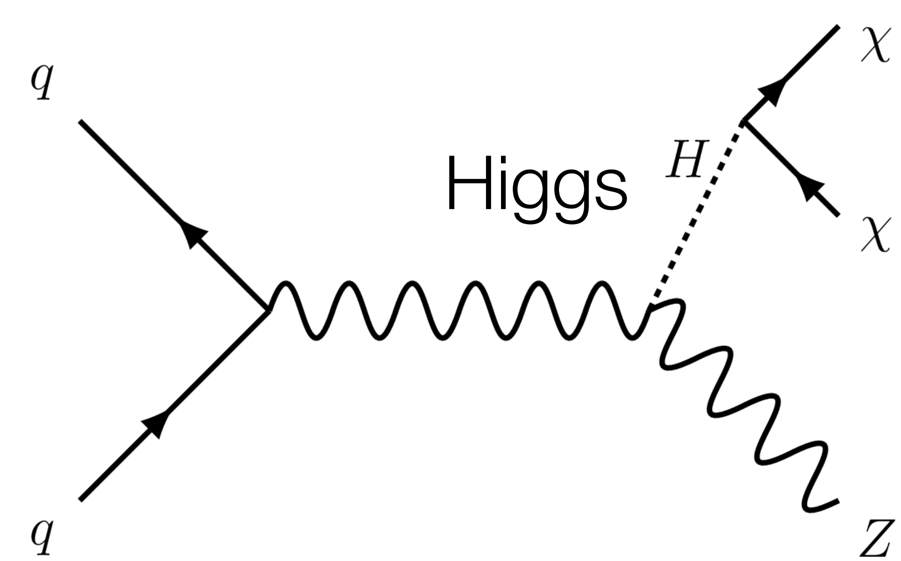
Not s-channel couplings



Not a vector mediator

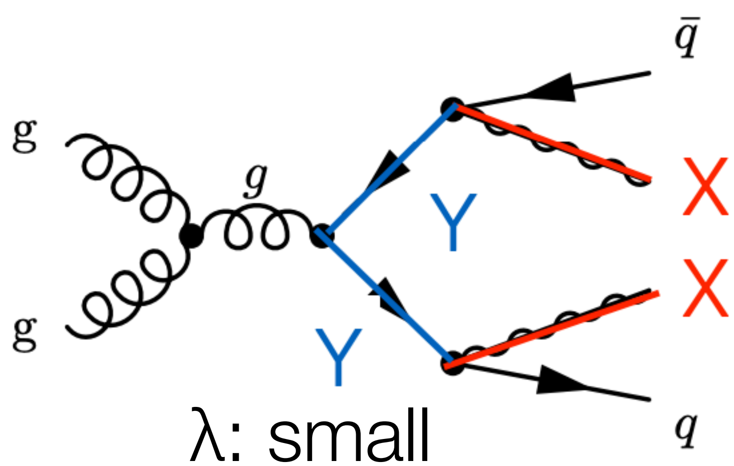


No BSM mediator



When you said that model "really is simplified"…

Not prompt



λ: small coupling

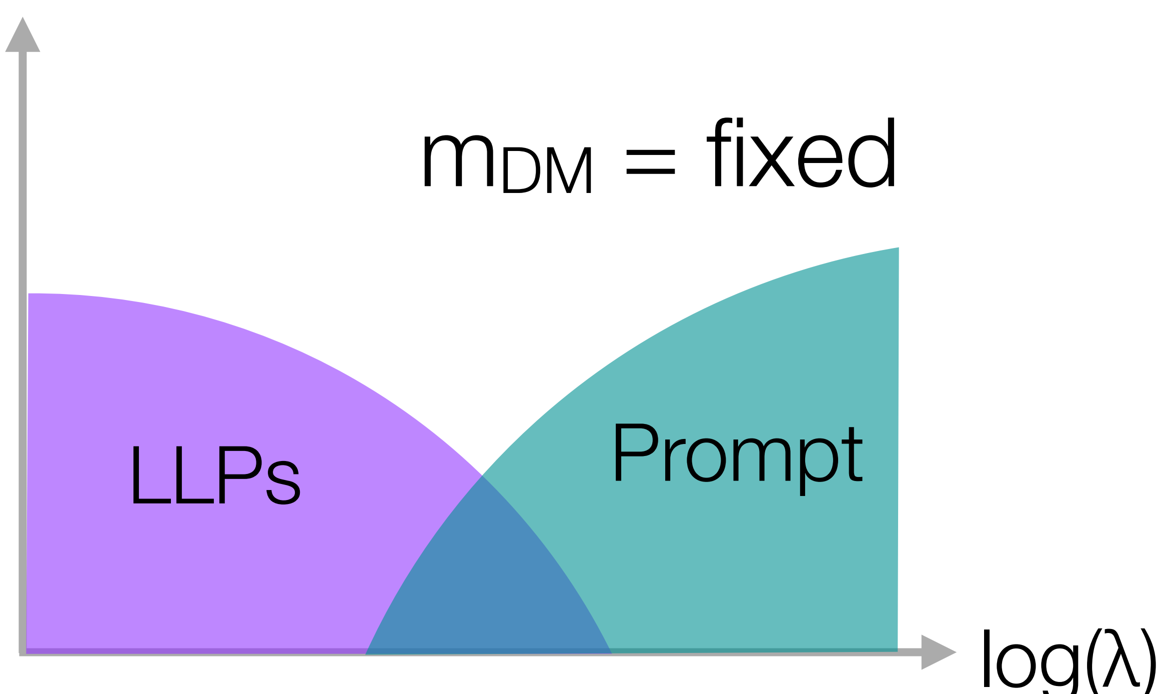


Diagram from C. Arina

Not a WIMP

Axions, asymmetric dark matter, sterile neutrinos, non-WIMP SUSY candidates

(Not a particle)

How does an energy recovery LINAC work?