Lab Searches for WISP(ish)s @ Low(ish) Energies

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WISPs*

*Weakly interacting sub-eV particles

Coincidences?

- Neutrino masses: $m_\nu \sim \mathrm{meV}$
- Dark Energy scale: $\rho_\Lambda \sim (\mathrm{meV})^4$
- Energy density of the Universe:

$$\rho_{\mathrm{today}} \sim (\mathrm{meV})^4$$

Hints?

- Neutrino masses: $m_\nu \sim \mathrm{meV}$
- Dark Energy scale: $\rho_\Lambda \sim (\mathrm{meV})^4$
- Energy density of the Universe:

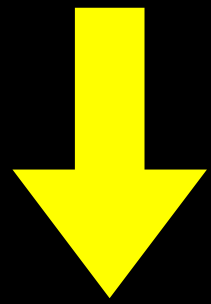
$$\rho_{\mathrm{today}} \sim (\mathrm{meV})^4$$

+

Some direct(ish) hints for WISP(ish)s

WD energy loss, (hidden) CMB, γ-transparency, Pamela, DAMA, CoGent…

Large scale



Small coupling

Example: Axion coupling

- Effective higher dimensional coupling

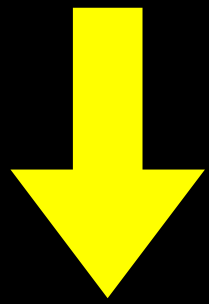
$$\mathcal{L}_{Int} = -\frac{1}{4} g a F^{\mu\nu} \tilde{F}_{\mu\nu} = -g a \mathbf{E} \cdot \mathbf{B}$$

$$g \sim \frac{1}{f_a}$$

- Small coupling for large axion scale:

Small → $g \sim \frac{\alpha}{2\pi f_a}$ ← Large

Large scale



Small mass

Example: Axion See-Saw

- The axion mass is small, too!

Small → $m_a \sim \frac{m_\pi f_\pi}{f_a}$ ← Large

Example: Axion See-Saw

- The axion mass is small, too!

Small → $m_a \sim \frac{m_\pi f_\pi}{f_a}$ ← Large

Pseudo-Goldstone Boson!

Example: Axion See-Saw

- The axion mass is small, too!

$$m_a \sim \frac{m_\pi f_\pi}{f_a}$$

$$\sim 0.6\,\mathrm{meV}\left(\frac{10^{10}\,\mathrm{GeV}}{f_a}\right)$$

Sub-eV mass

Large scale

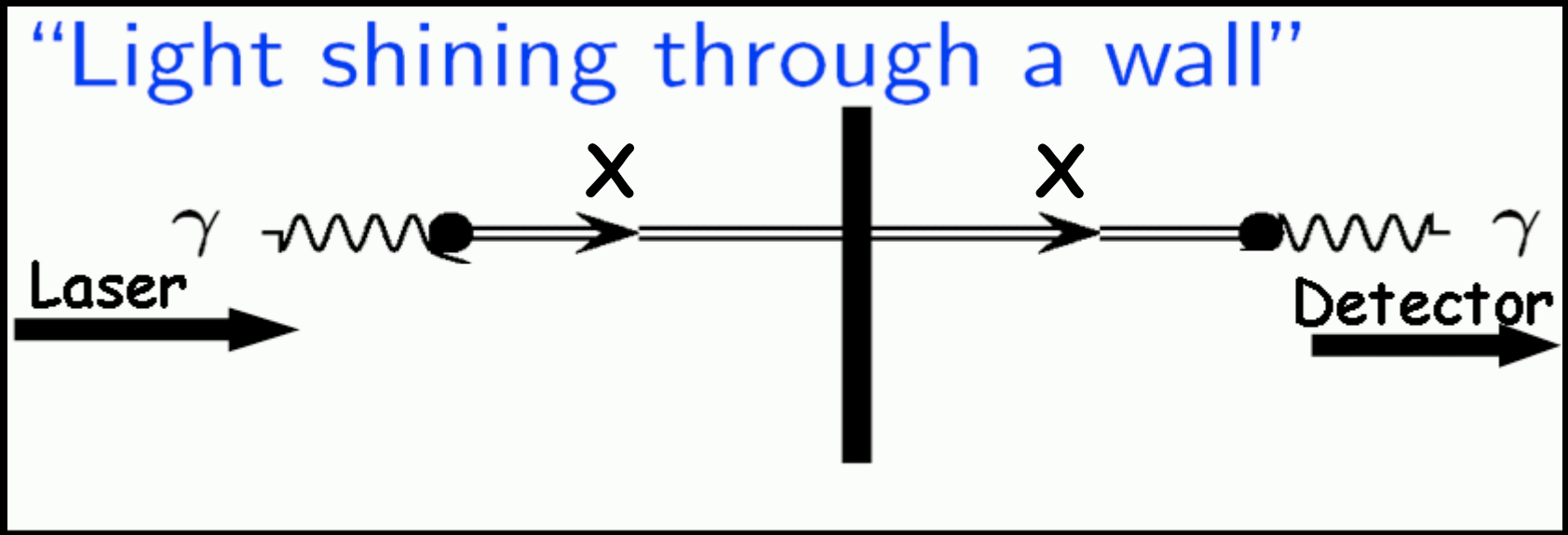
Experiments

Plenty of Experiments

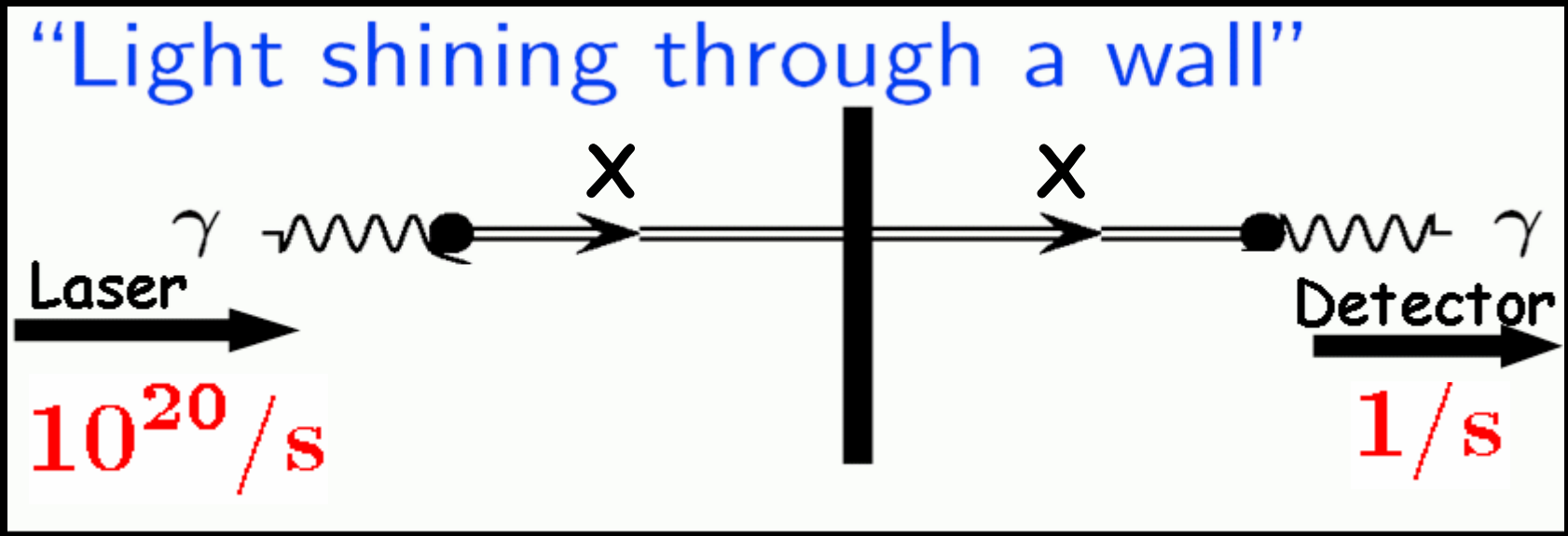
- The "classics"
  - Light shining through walls
  - Helioscopes
  - Axion dark matter searches (Haloscopes)
  - Polarization experiments
- Worth to revive: Tests of Coulomb's law
- 5^{th} Forces (see Seth Hoedl)
- Searching at higher Masses
  - Fixed Target experiments
  - Mesons experiments

Light shining through walls

Light shining through walls



Light shining through walls

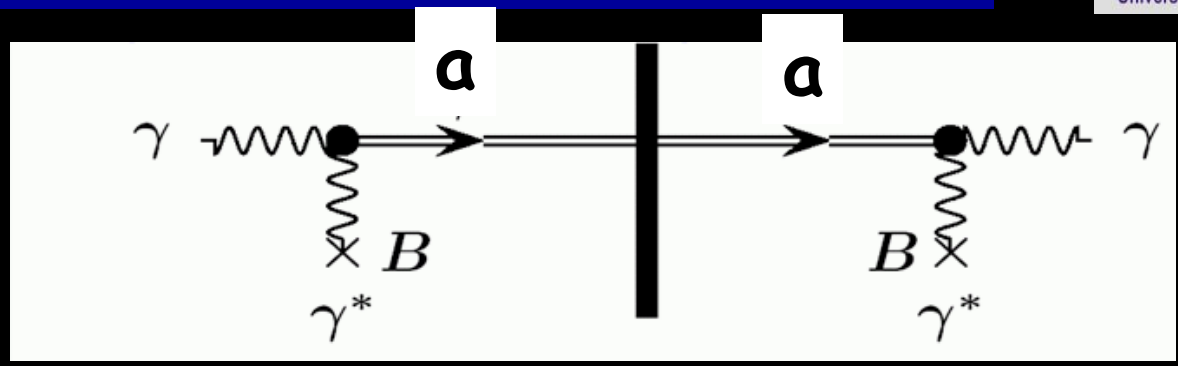


- Test $P_{\gamma \to X \to \gamma} \lesssim 10^{-20}$

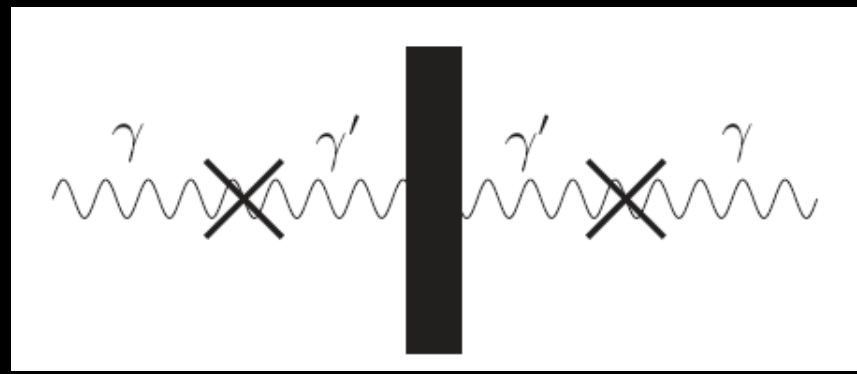
- Enormous precision!
- Study extremely weak couplings!

WISPS=Weakly interacting sub-eV particles

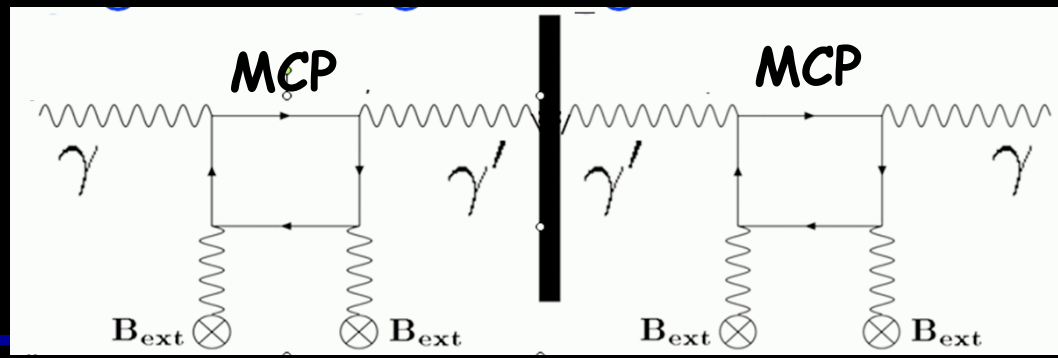
- Axions



- Massive hidden photons (without B-field) =analog ν-oscillations



- Hidden photon + minicharged particle (MCP)



Light Shining Through Walls

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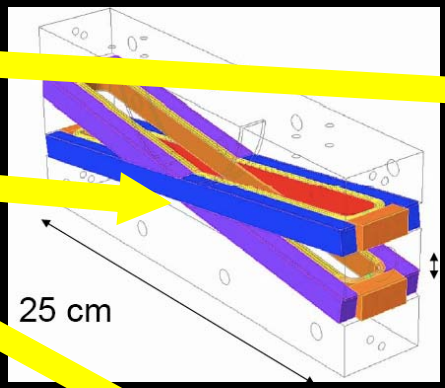
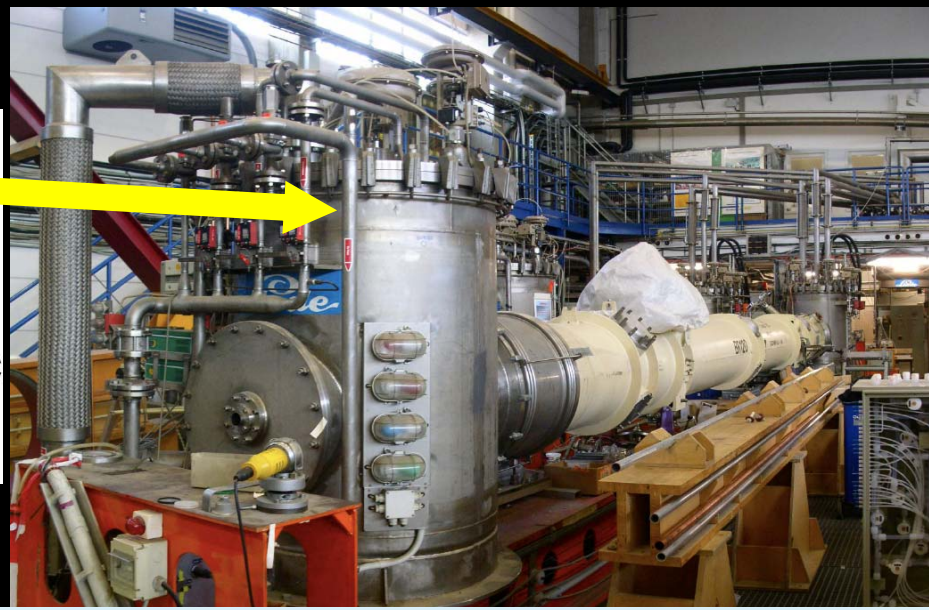
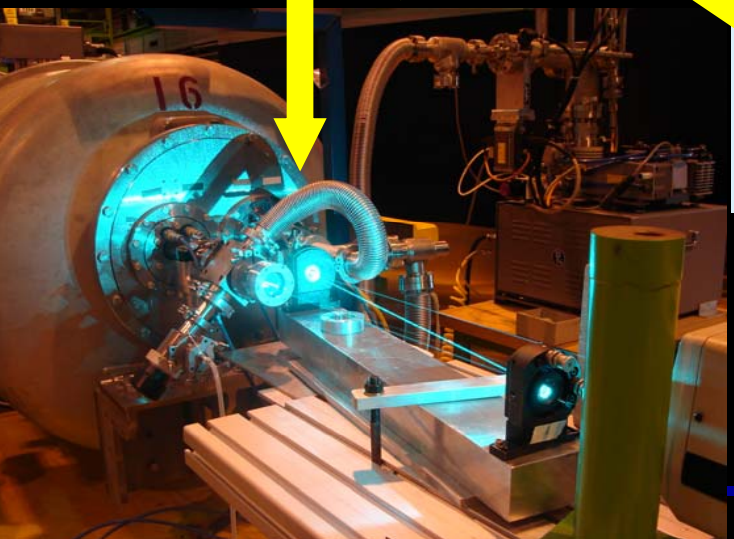
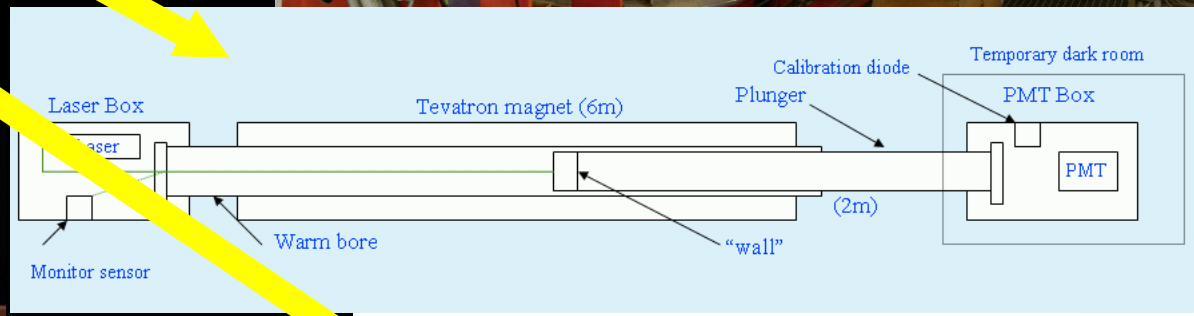
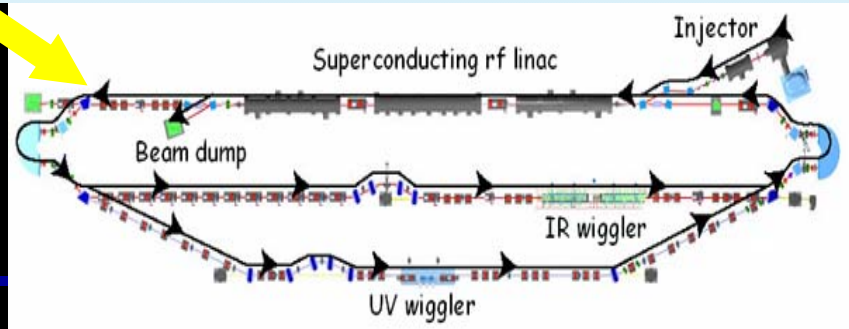
- A lot of activity
  - ALPS
  - BMV
  - GammeV
  - LIPPS
  - OSQAR



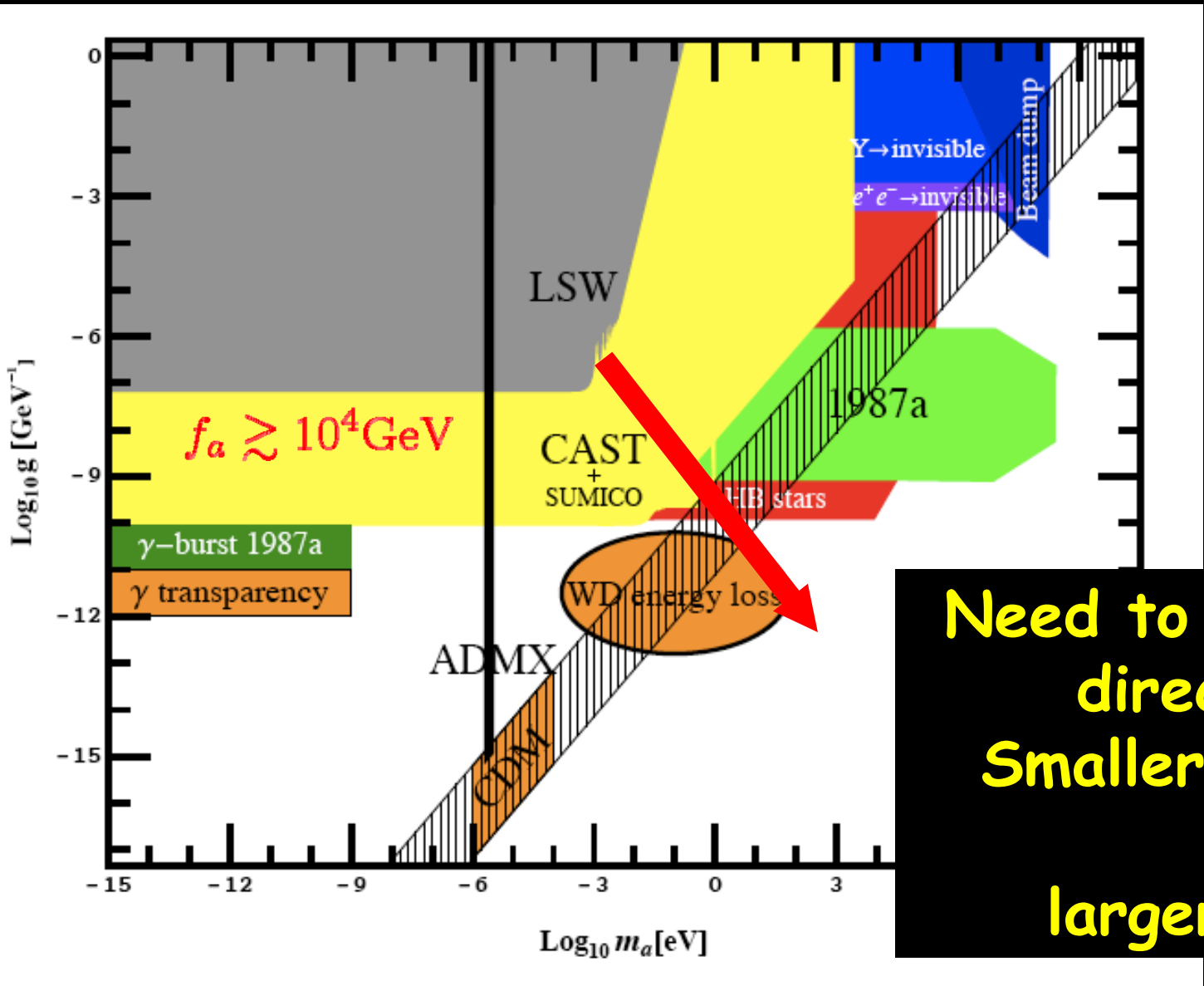








Current Status: Axion(-like particles)



Need to go in this direction:
Smaller coupling
+
larger mass

Current status: Hidden Photons

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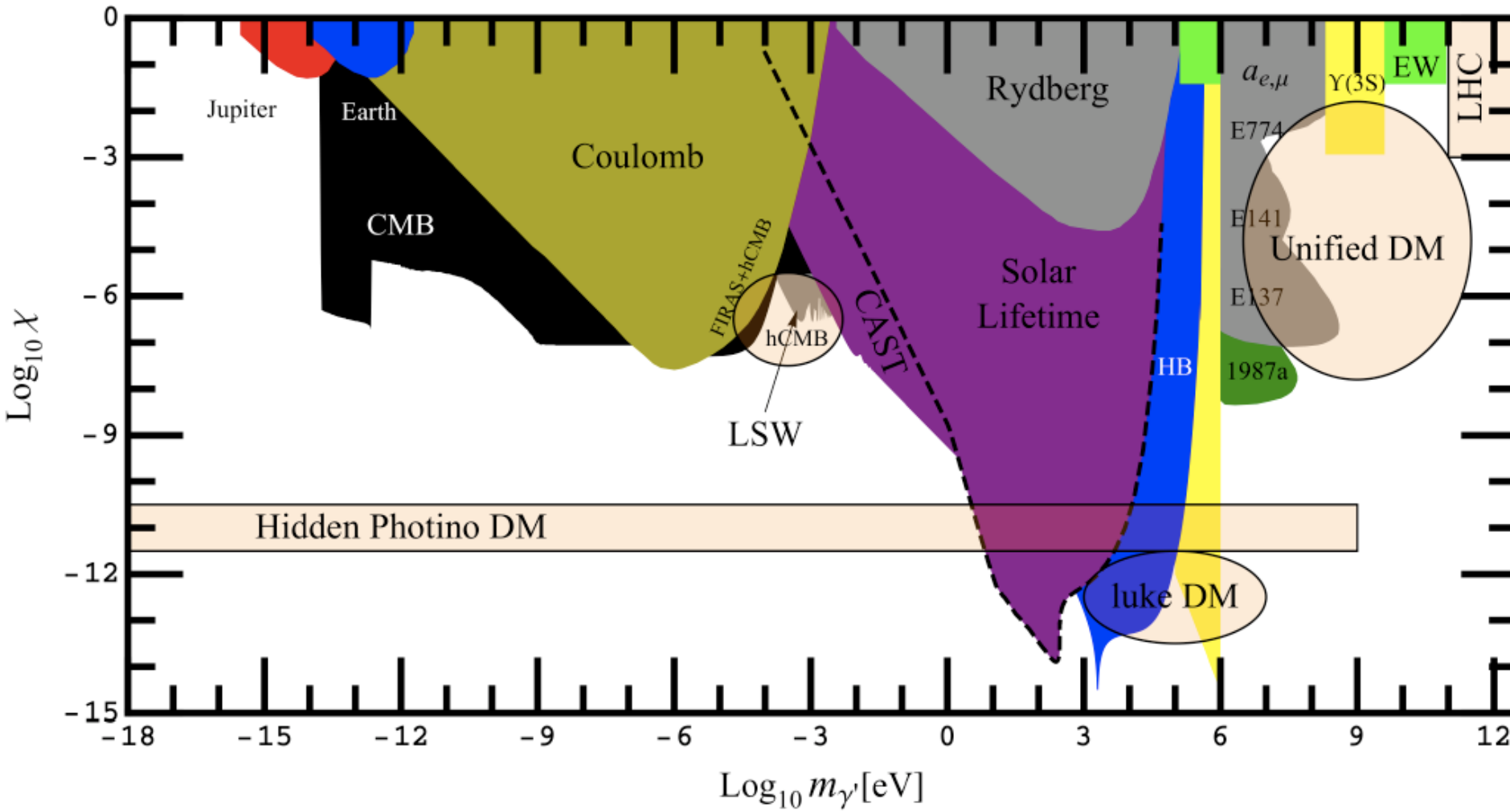
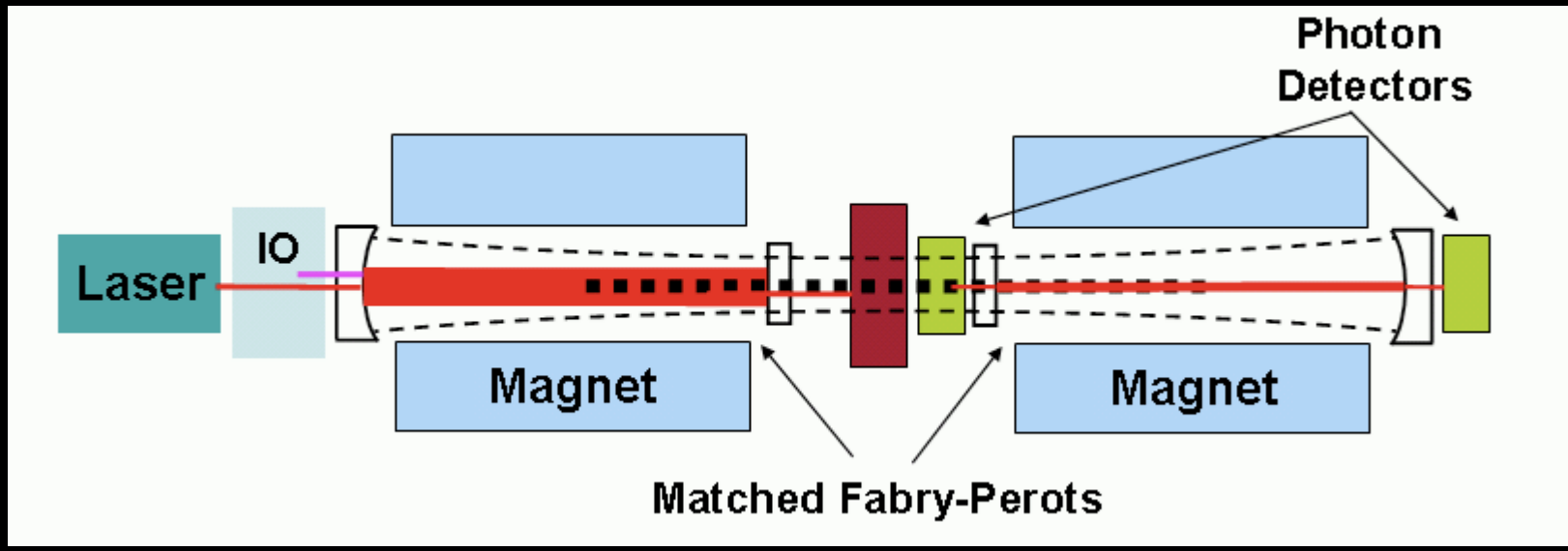
- Already competitive + testing interesting area



Future Improvements

- Resonant regeneration



$$P_{\gamma \to X \to \gamma} \sim N_{pass,1} N_{pass,2} P_{\gamma \to X \to \gamma}(1\,pass)$$

- Huge improvements possible $N_{pass} \sim 10^5$ possible

First/2 Implementation

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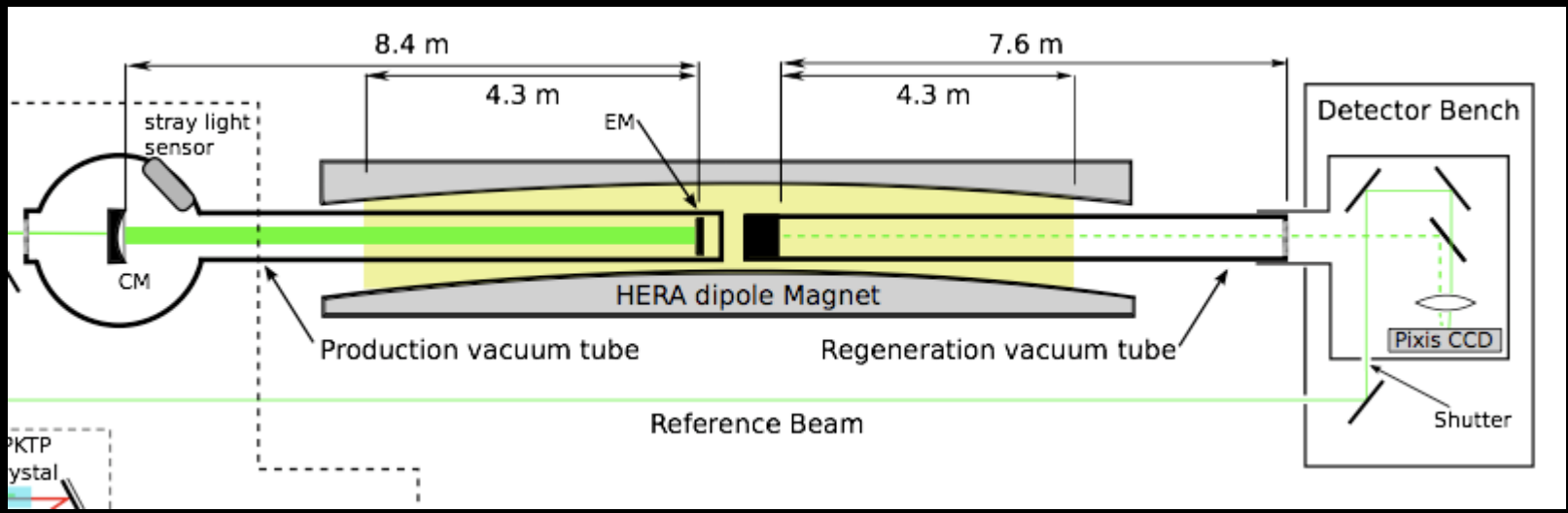
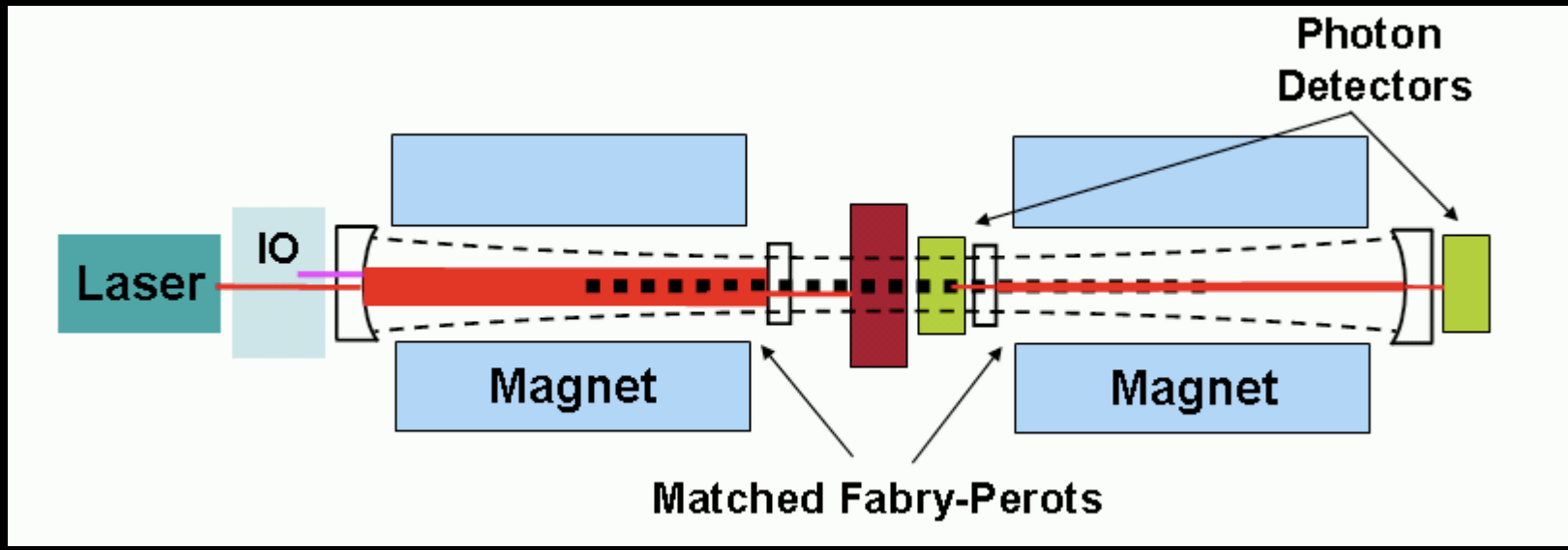
- ALPS has optical cavity in production region



(see talk by Klaus Ehret)

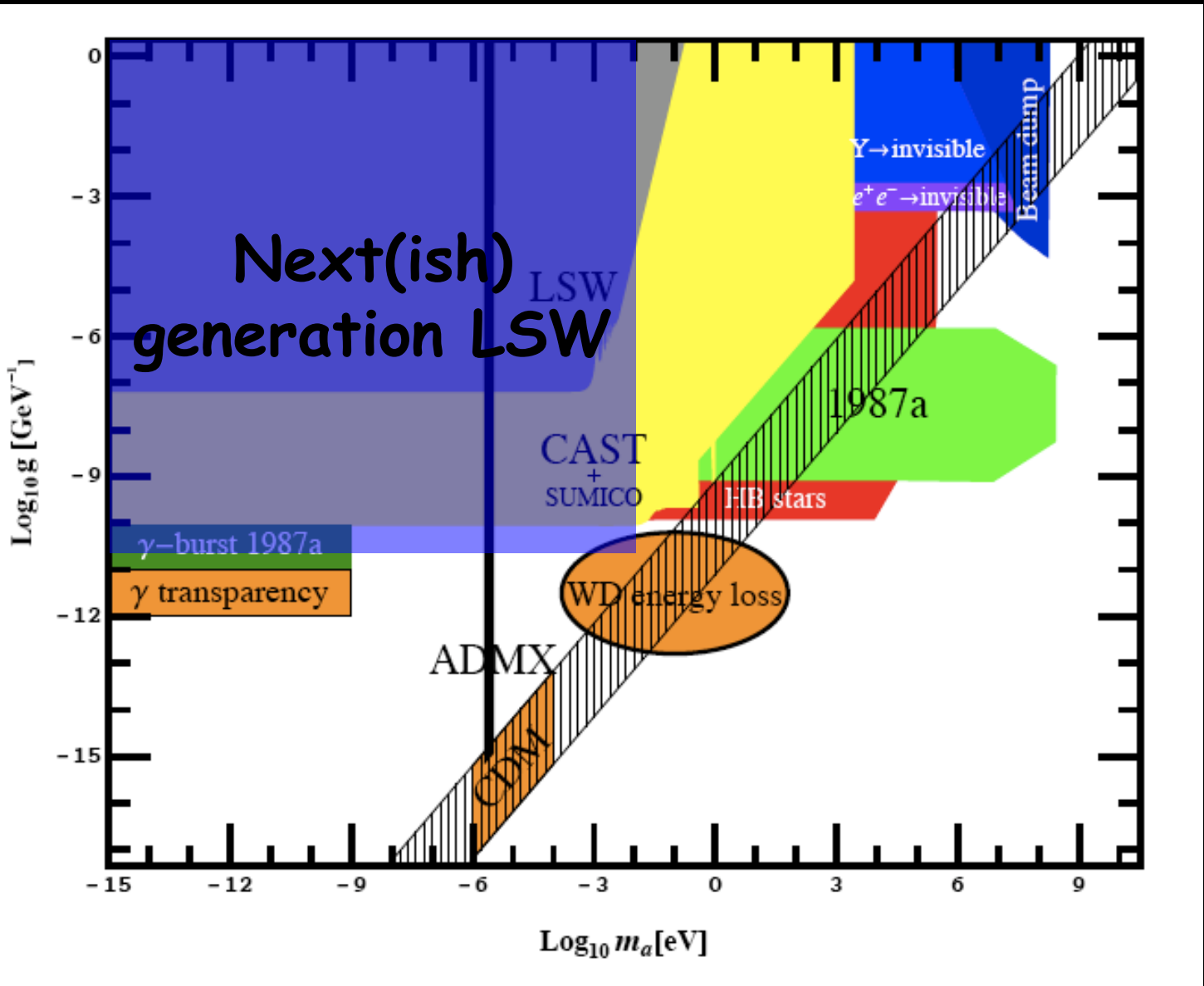
Future Improvements

- Resonant regeneration

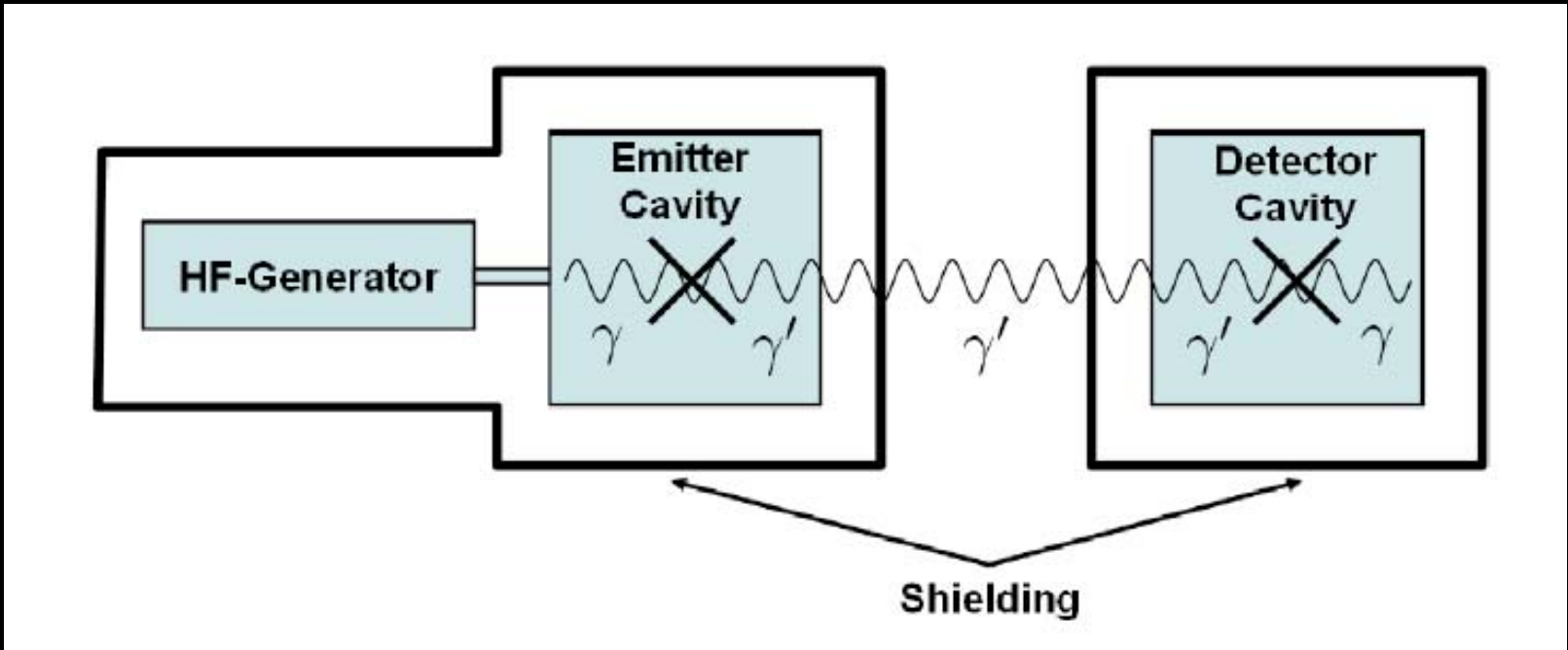


- More and stronger magnets
  (see talk by Paola Arias)
- Better detectors
  (see A. Engel and G. Cantatore)

We might get there, soon ;-)



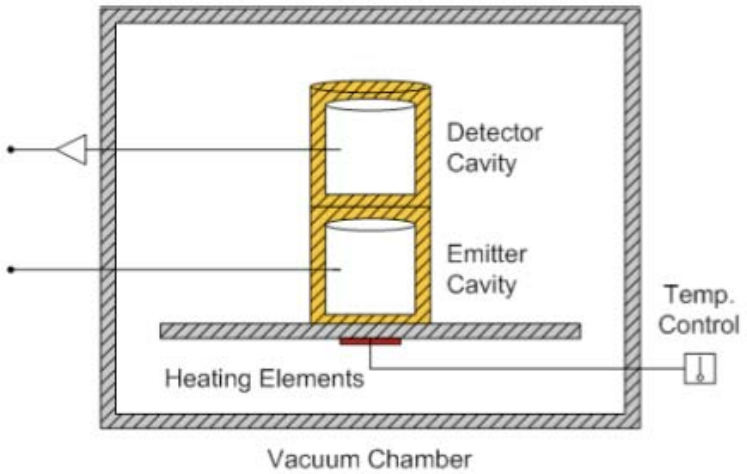
Microwave LSW



- Super-resonant $N_{pass} \sim 10^{11}$ possible

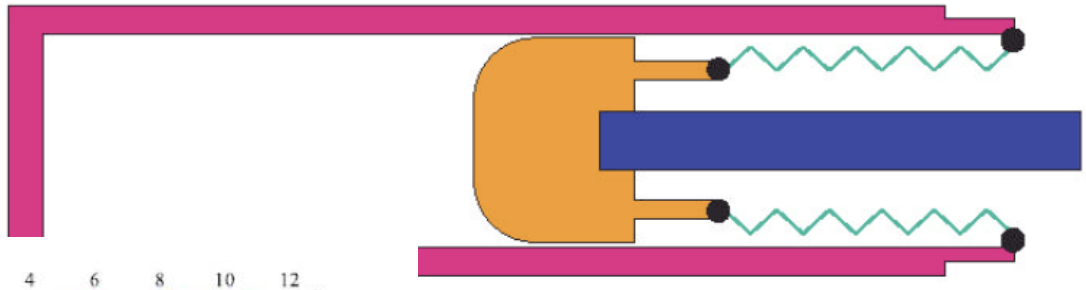
It's underway: Australia + Yale Cavity Exp.

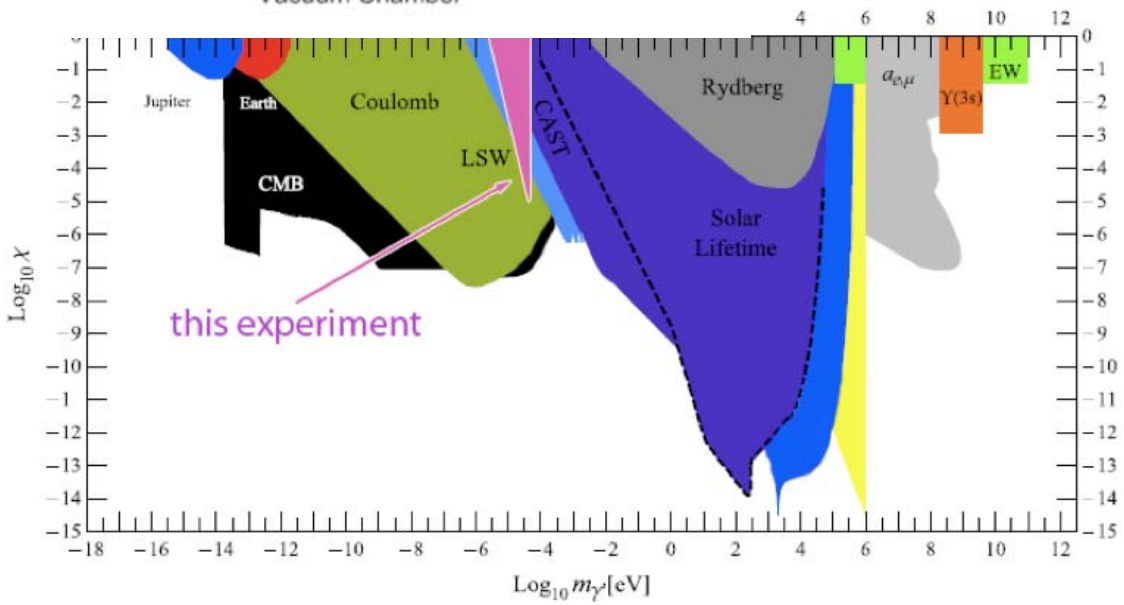
+ @CERN (Fritz Caspers) + @Daresbury (Peter Williams)



Cu Cavity with Tuning Plunger

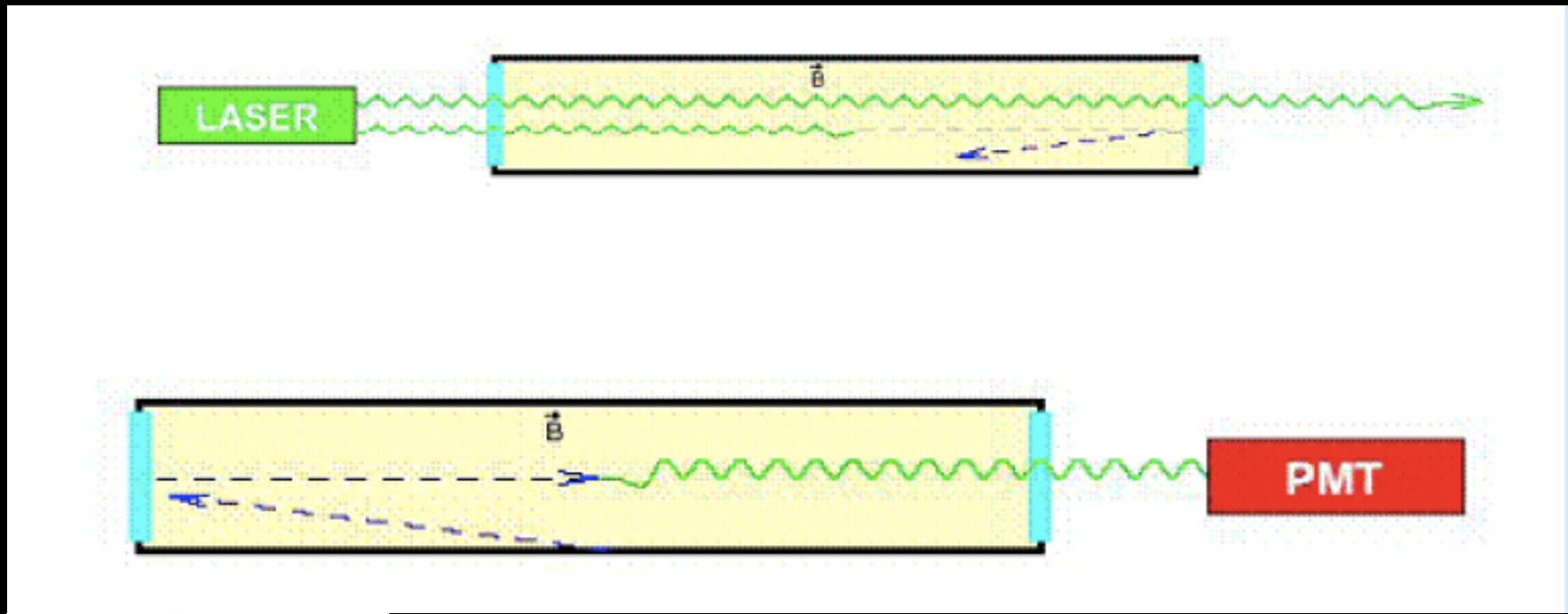
See talk by Penny Slocum





WISPs connected to Dark Energy…

- Testing Chameleons
- Afterglow Experiment

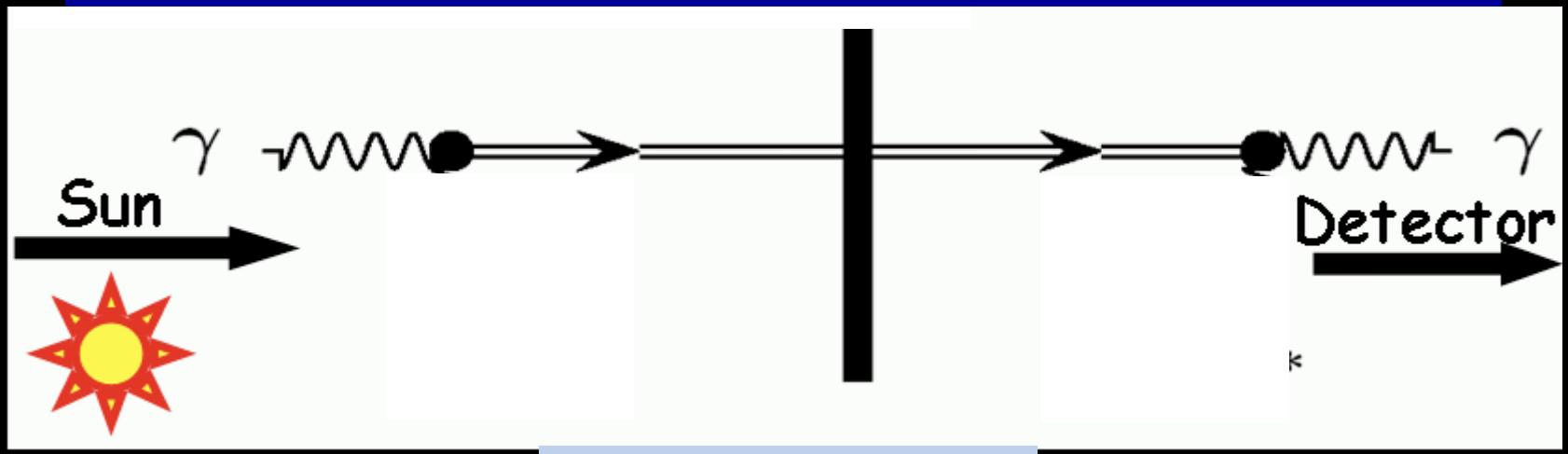


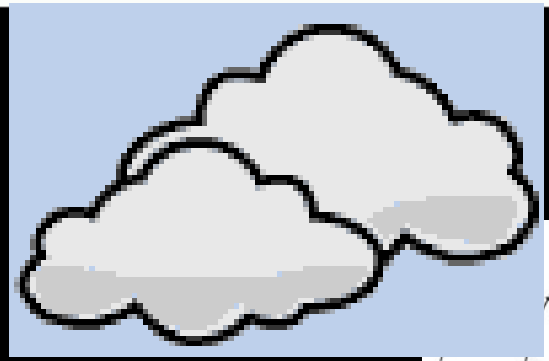
GammeV

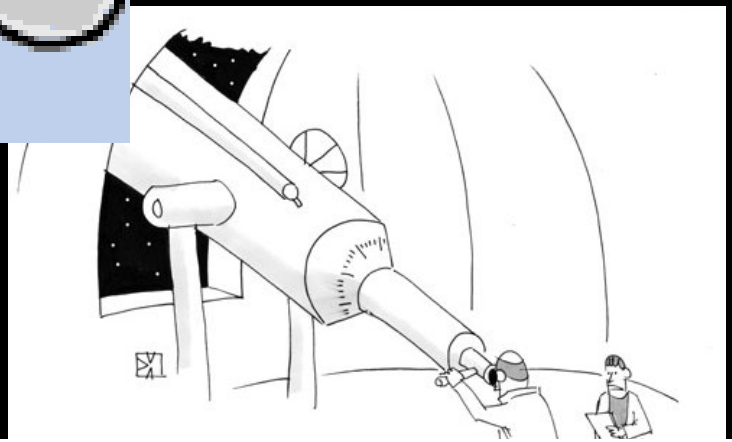
See talk by William Wester

Helioscopes

Principle







This isn't Dark matter,

I just forgot to take off the lens cap

Helioscopes

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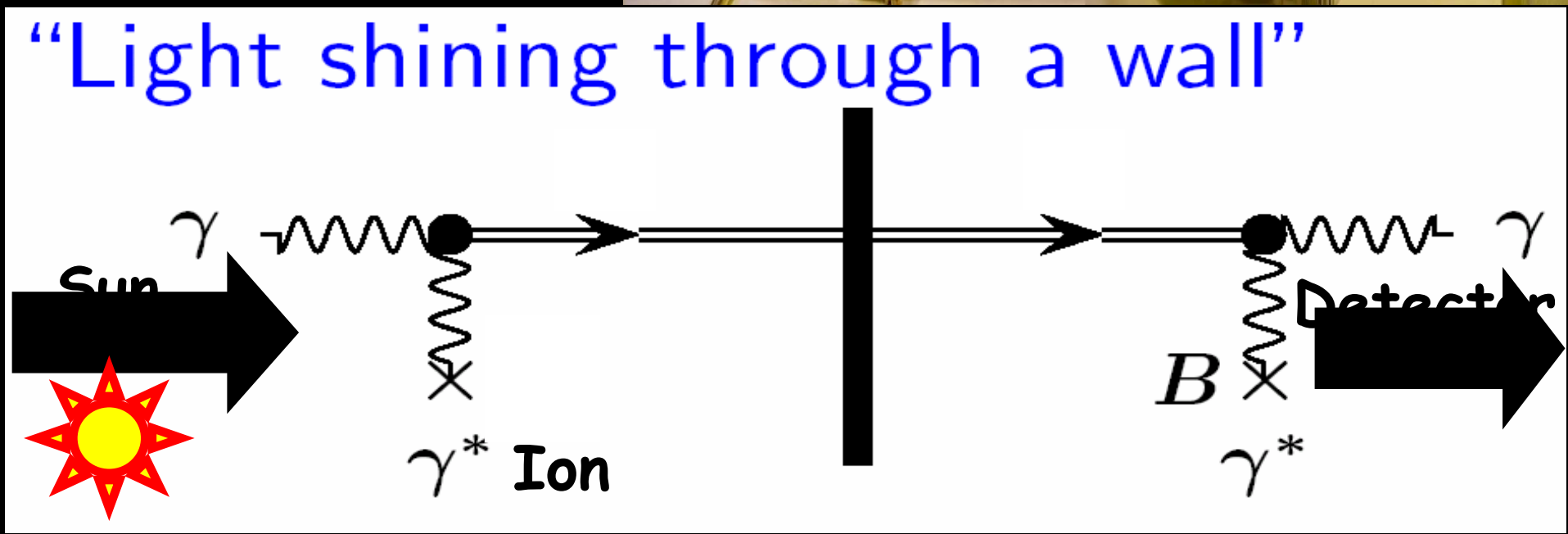
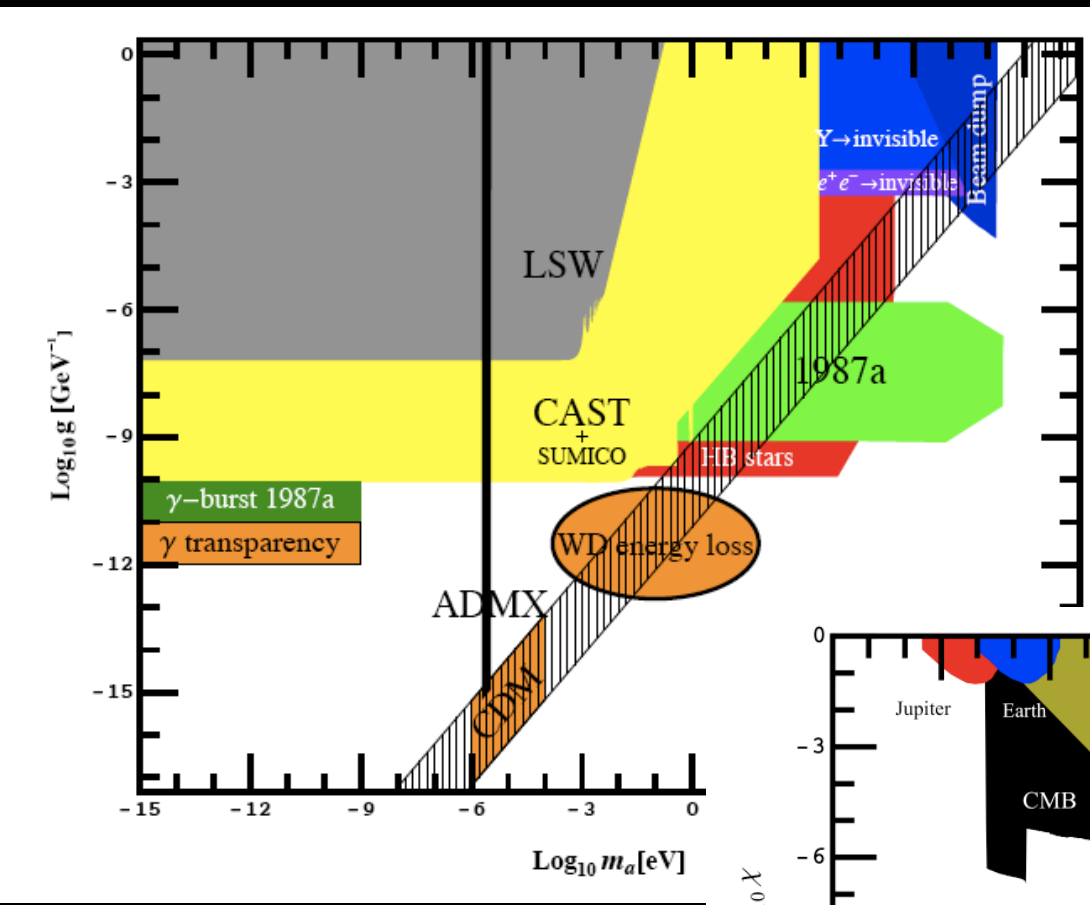
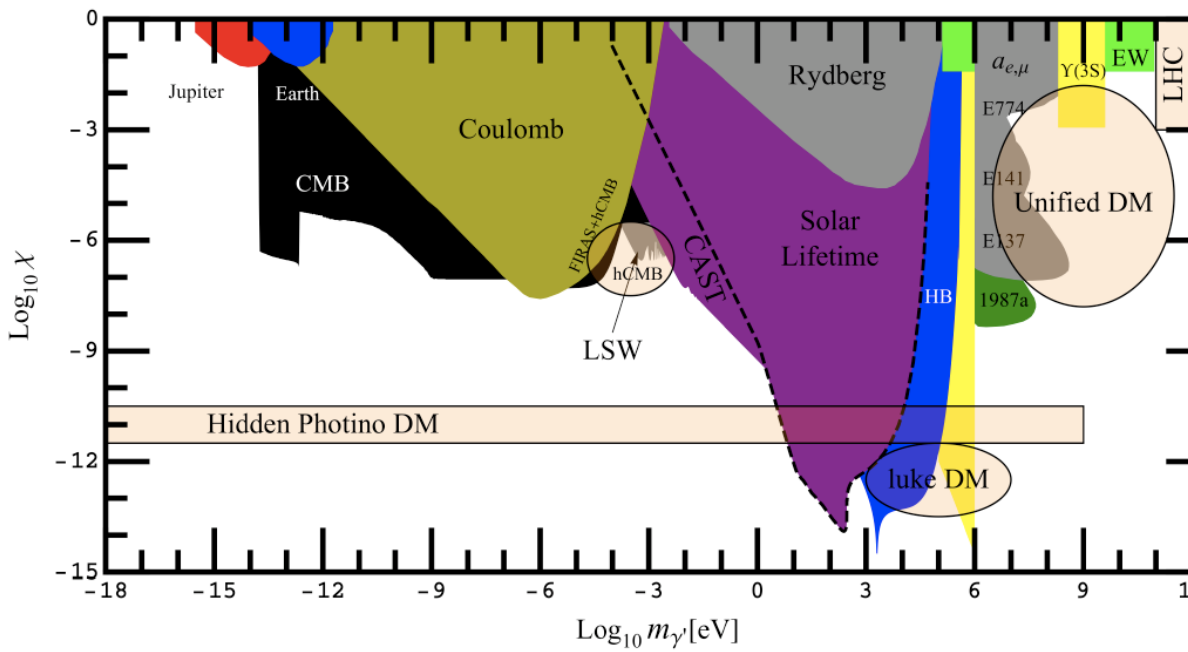
CAST@CERN
SUMICO@Tokyo



Current Status: Very good





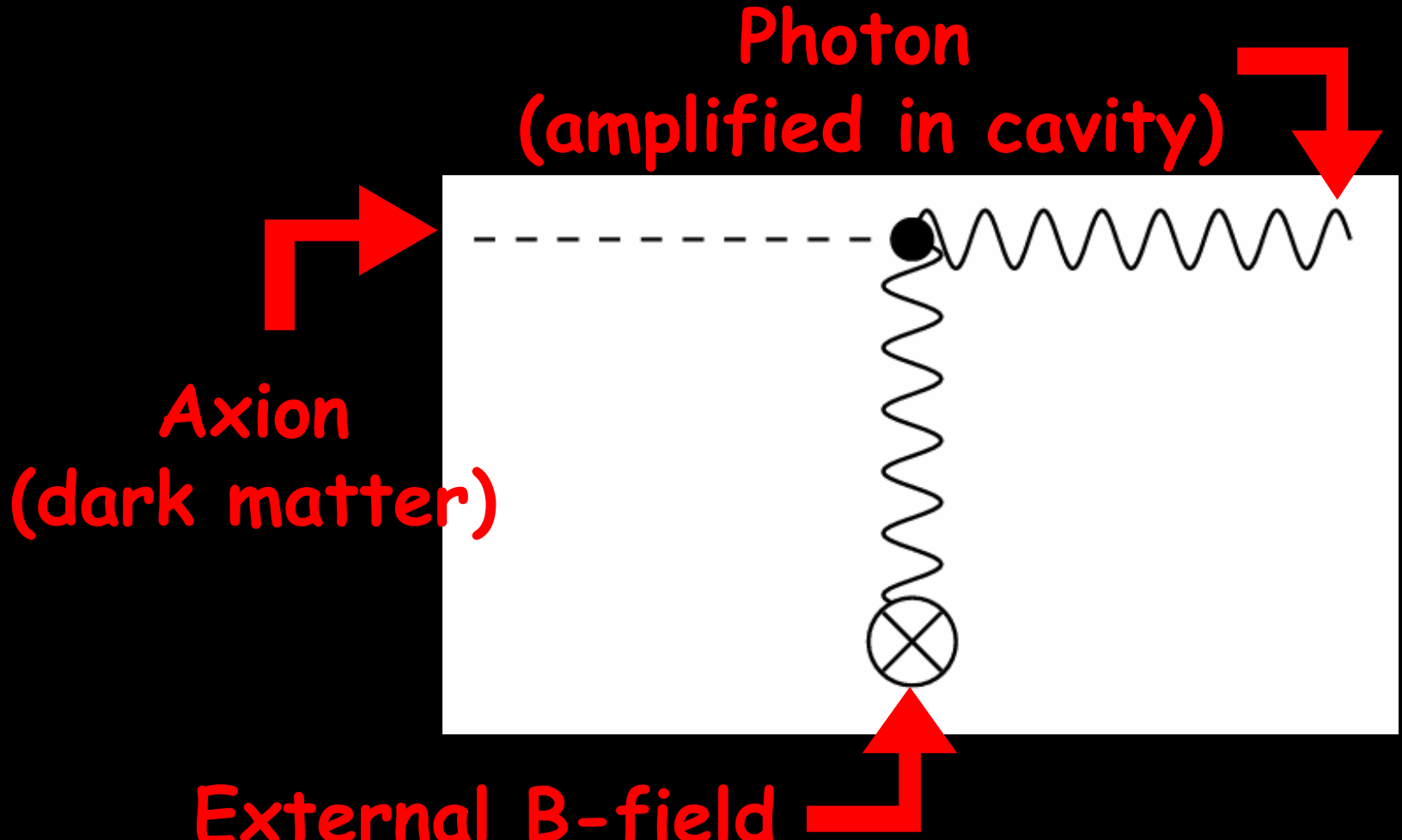
Future

- Stronger magnet + wider aperture
- More gas => touch axion line

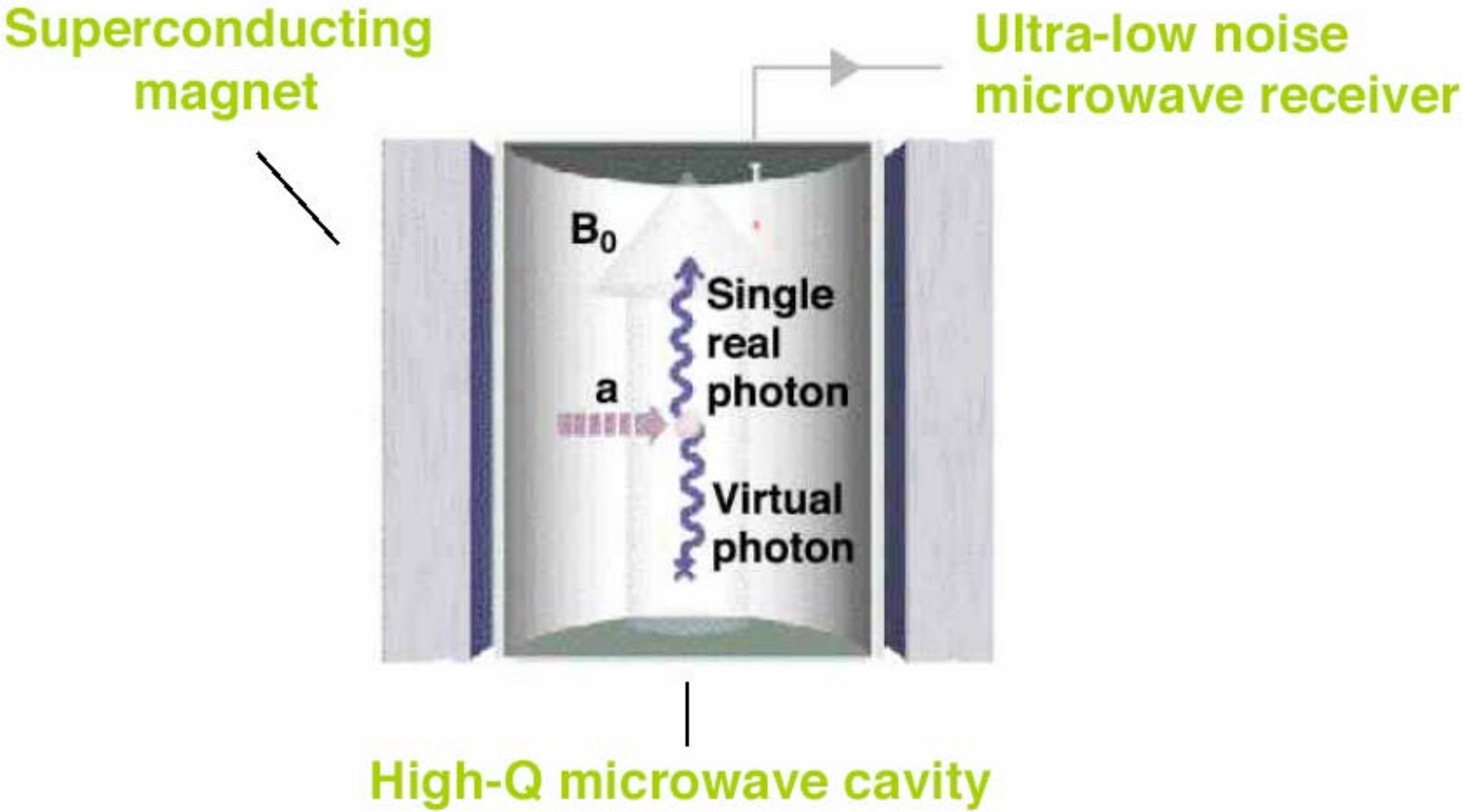
Searching Axion Dark Matter: Haloscopes

Two photon coupling

- Photon generation from axions!

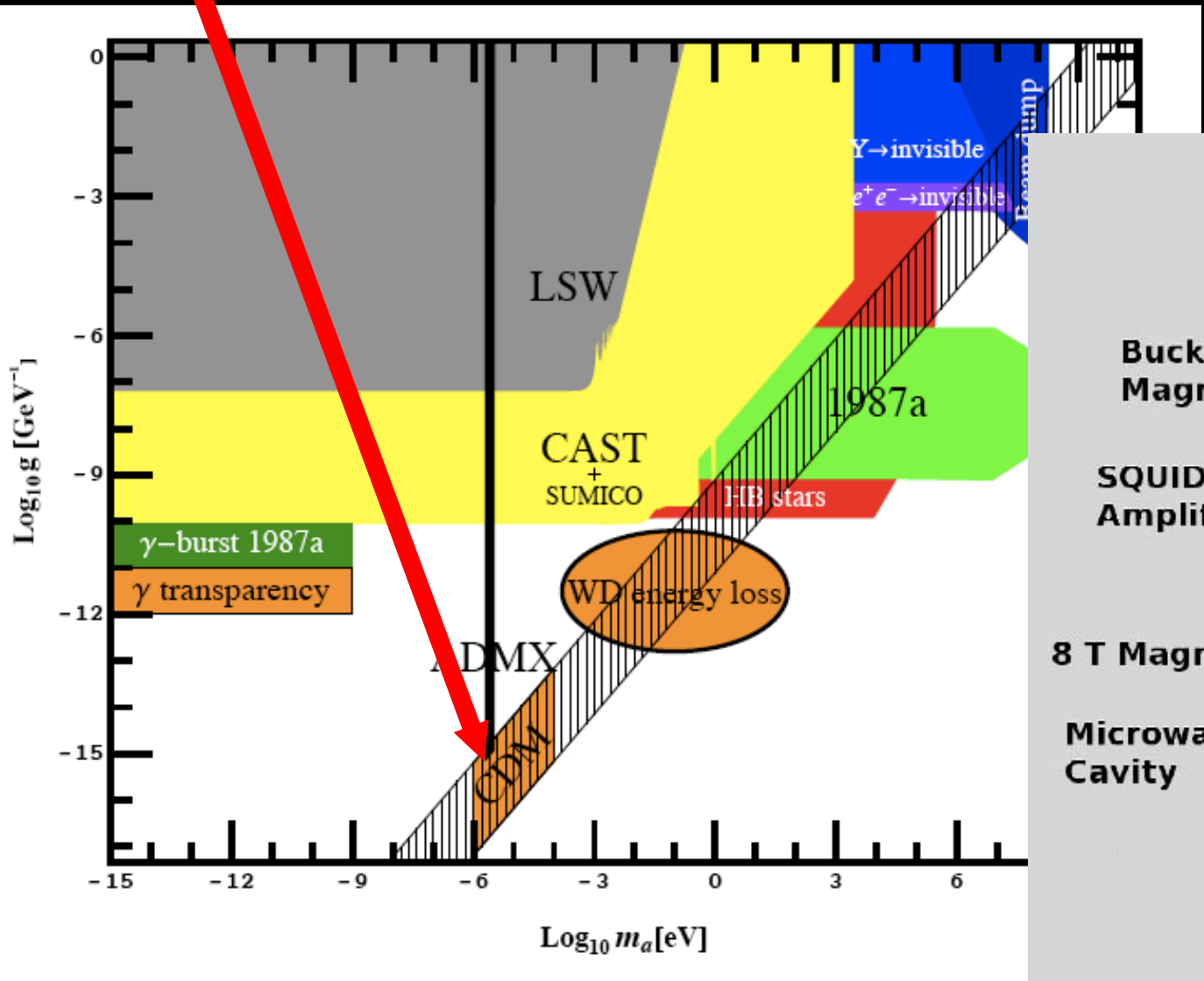


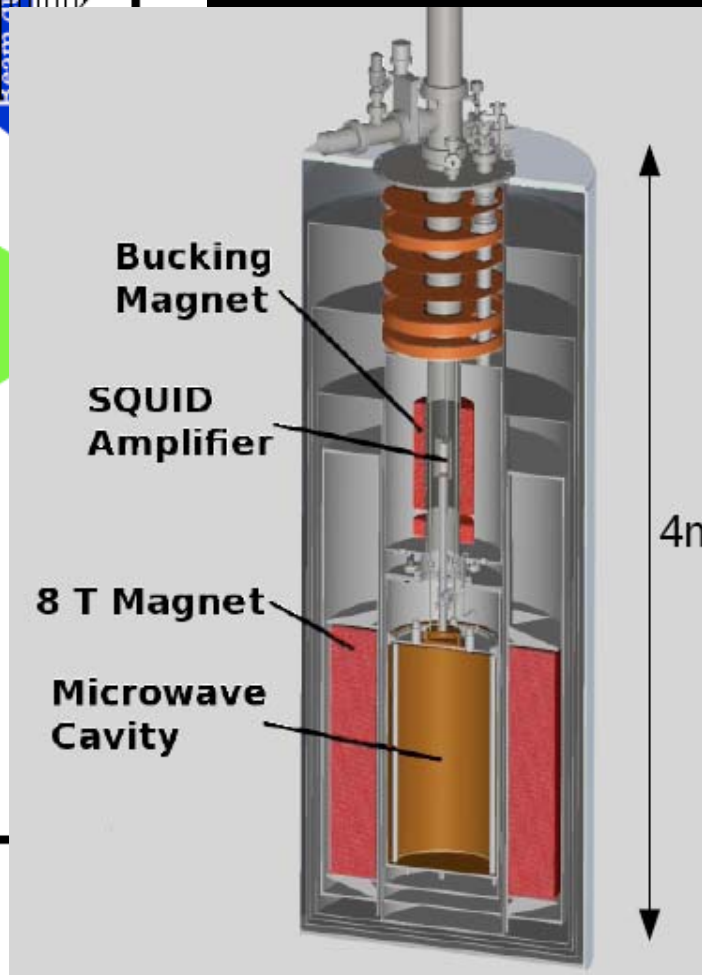
Axions in Cavity



Really testing axions!!!

- ADMX

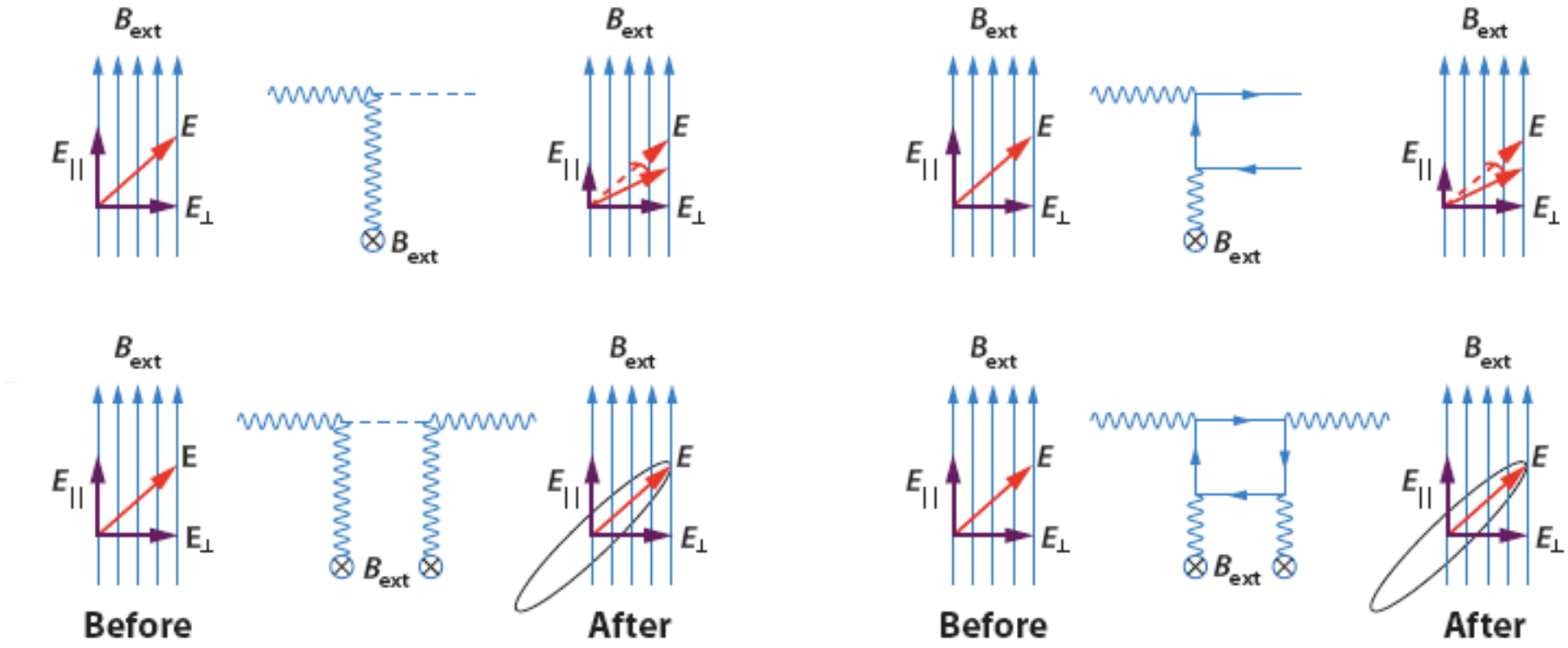




Laser Polarization Experiments

Principle

- Search for changes in Polarization

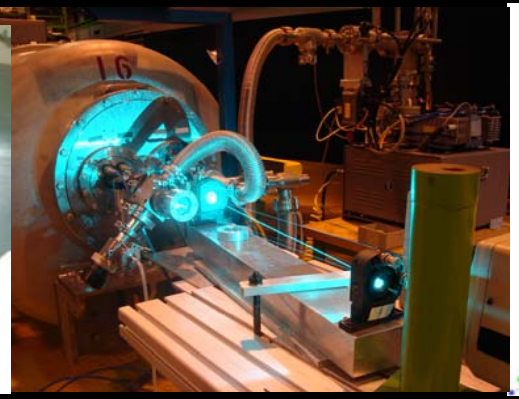
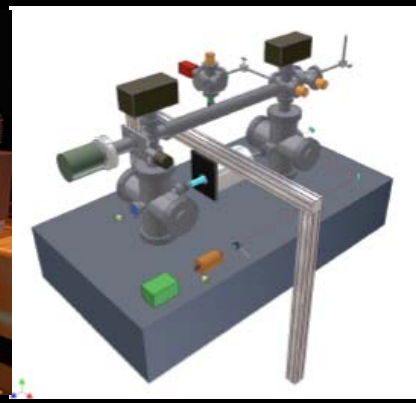


Axions

Minicharged particles
+
Always QED

Currently BMV, Q&A, OSQAR, PVLAS II



- Not quite as sensitive
- But: Develop Cavity Technology
  Test QED effect!

Something to Revive?!?

Tests of Coulomb's law

Test for hidden photons and MCPs

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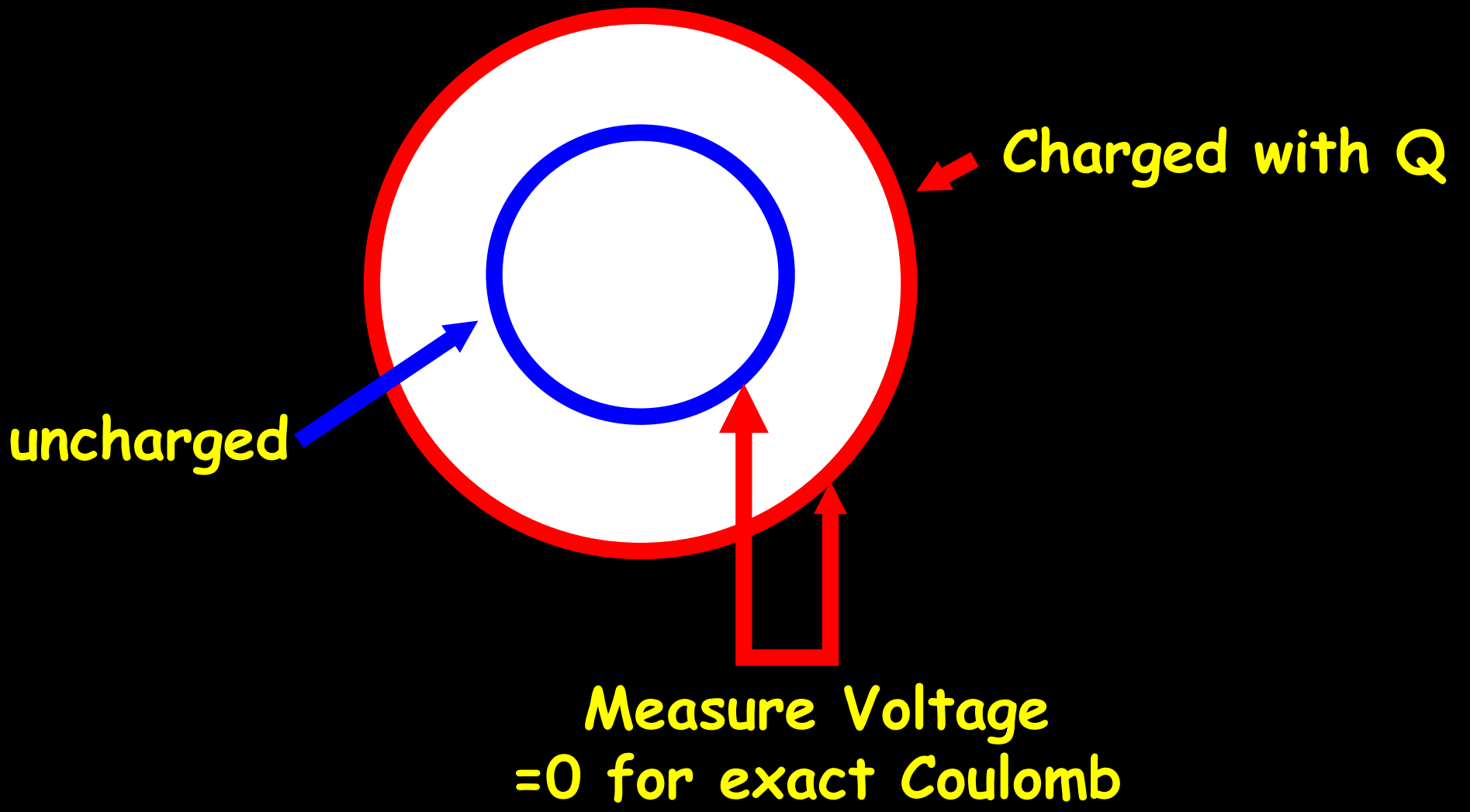
- WISPs modify Coulomb's law
- Hidden photons:

$$\delta V \sim \alpha q^2 \chi^2 \frac{\exp(-m_{\gamma'} r)}{r}$$

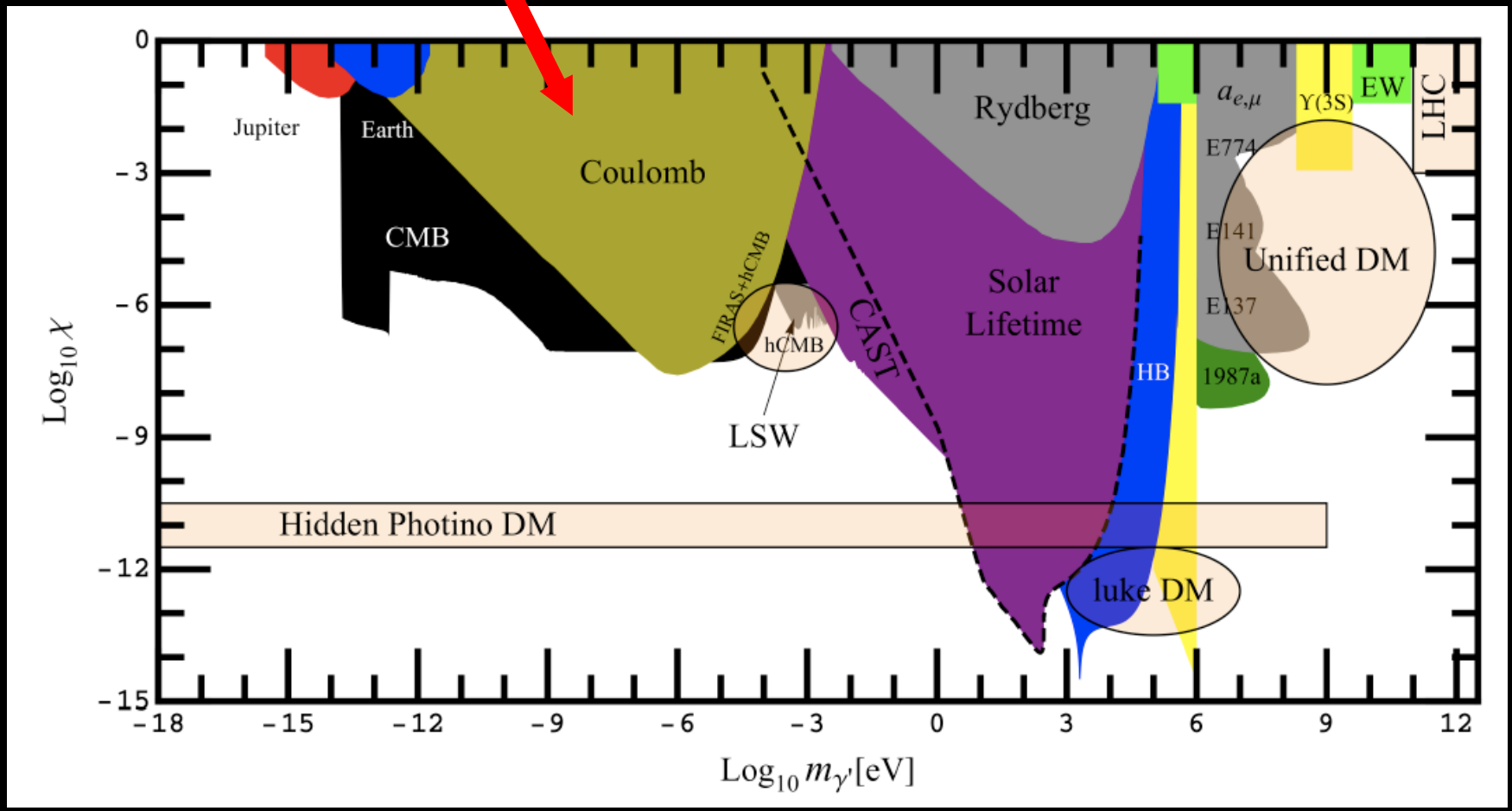
- Minicharged particles

$$\delta V(r) \approx \frac{Q\alpha}{r}\left[\frac{\alpha\epsilon^2}{4\sqrt{\pi}}\frac{\exp(-2mr)}{(mr)^{\frac{3}{2}}}\right.$$

Cavendish Experiments



Quite sensitive



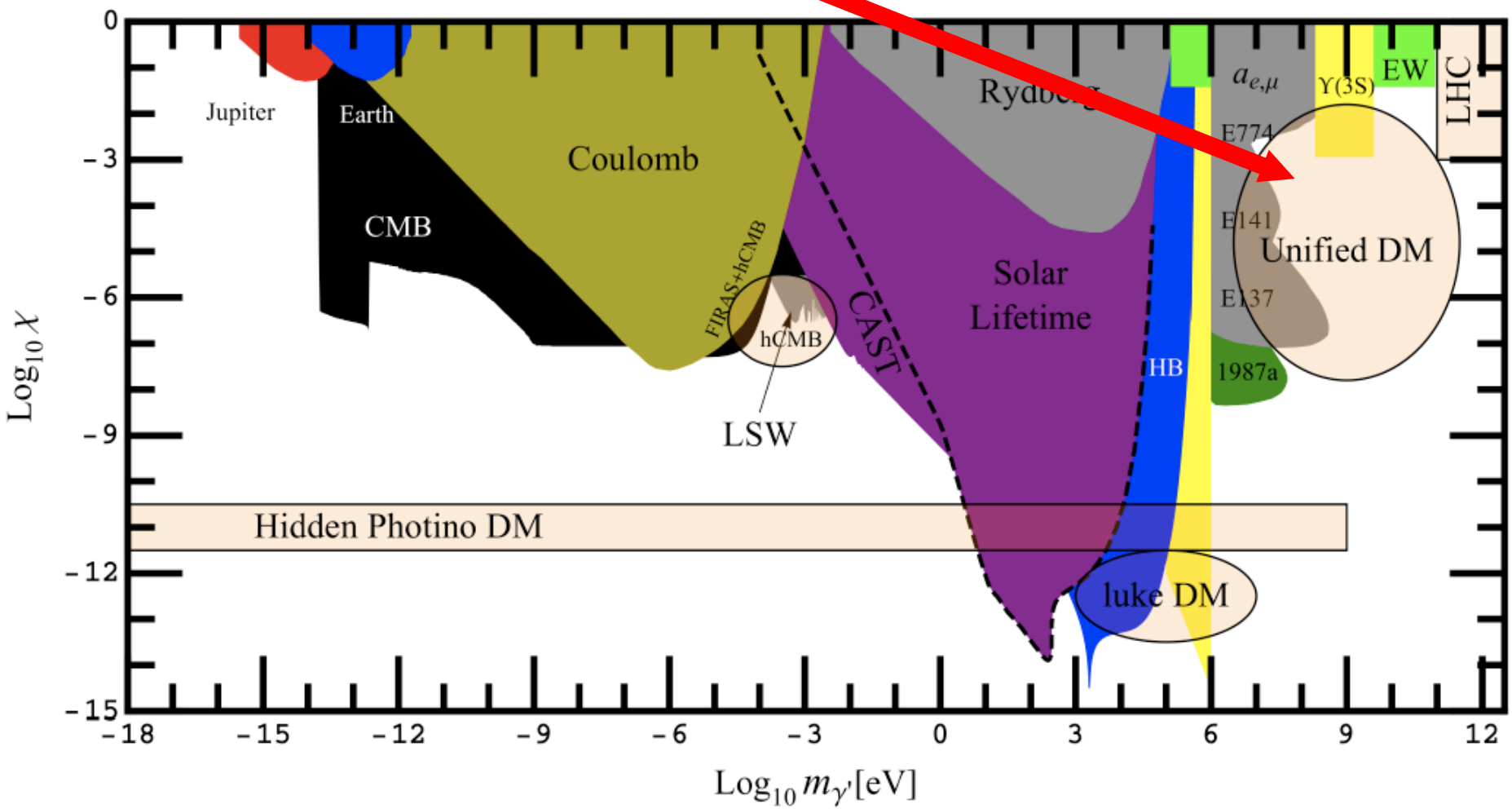
- Best experiment 39 years old!!!!

WISPishs*

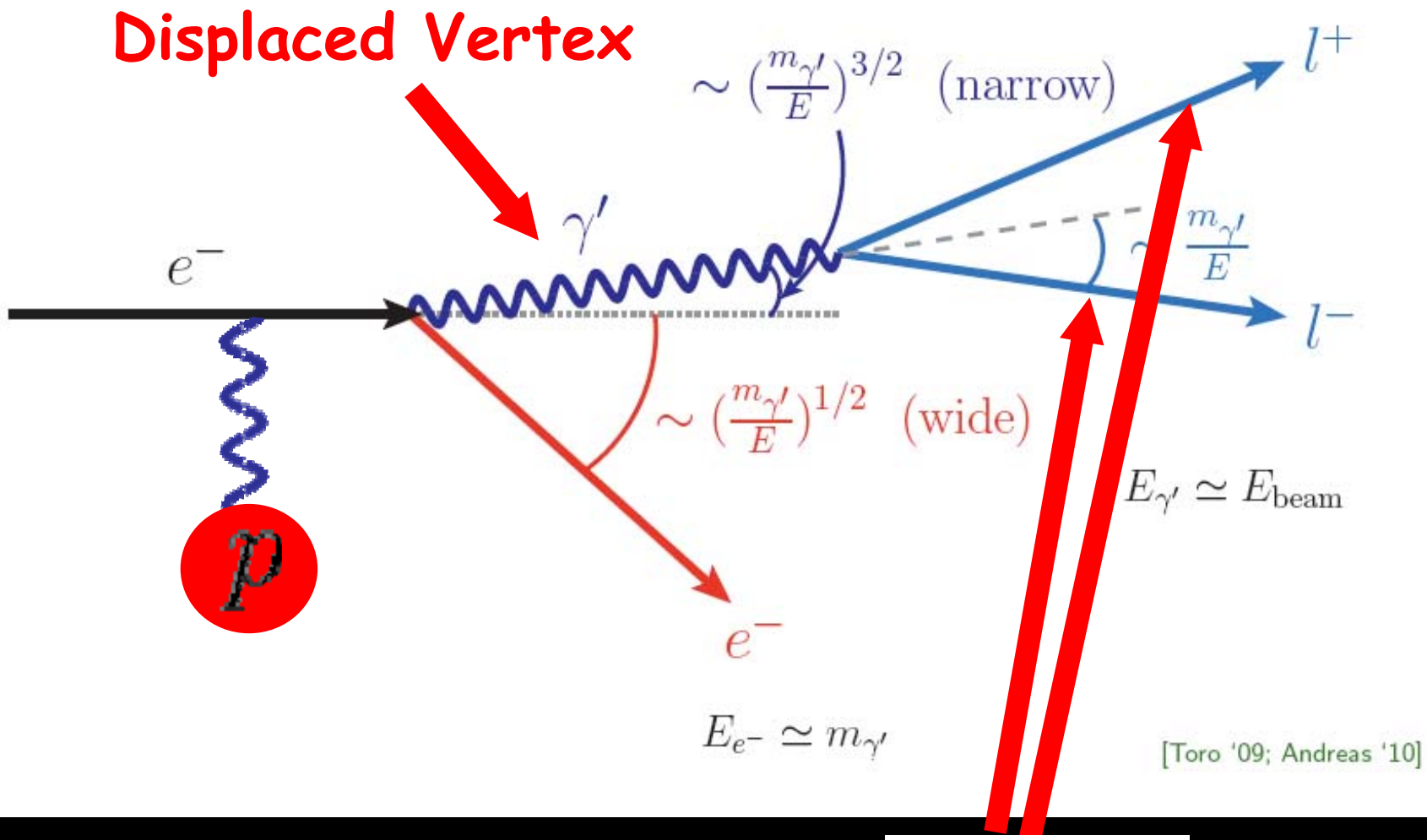
*Weakly interacting sub-TeV particles

Why?

- Lots of interest from astrophysics
- Pamela, DAMA, CoGent..



Fixed targets



Medium energy, high current

- Medium energies of beam 100 MeV-50 GeV
- BUT: High current → Test weak interactions

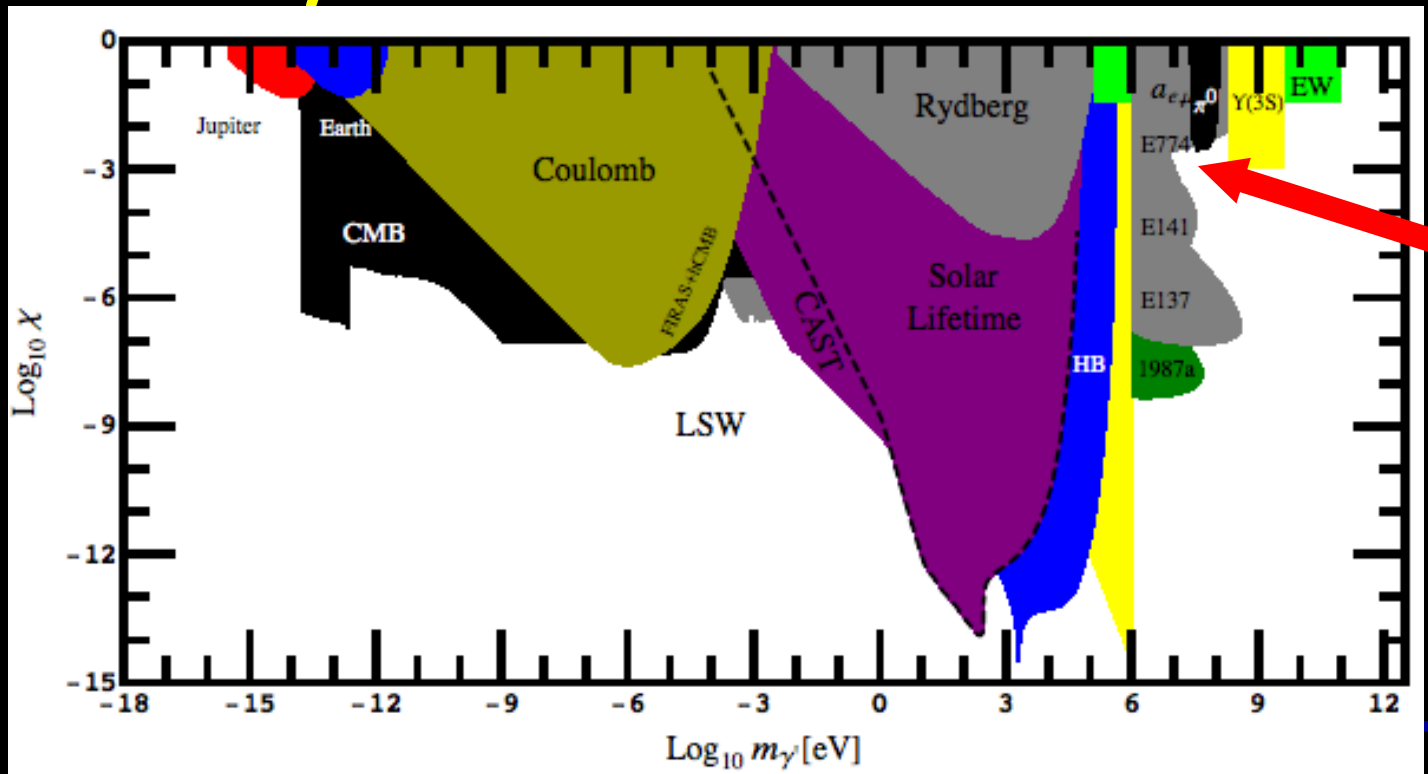
Many beams, many chances…

- DESY (see Sarah Andreas)
- Jefferson Lab (see Andrei Afanasev)
- Mainz Microtron
- …

Towards another idea…

- Study $\pi^0 \rightarrow \gamma + \gamma' \rightarrow \gamma + e^+e^-$

- Peak in the invariant mass at $m_{\gamma'}$
- Displaced vertex
- Currently bound from BR~$4*10^{-6}$



Fill the gap

Conclusions

Conclusions

- Good Physics Case for Axions and WISP(ish)s
  → explore `The Low Energy Frontier'
- Low energy experiments test energy scales much higher than accelerators
  → Complementary!
- Many O(20)!!!
  Experiments are running or in planning!

↓

HUGE discovery potential in the near future!

Discover the WISP Islands