

Thoughts from lightDM in Israel

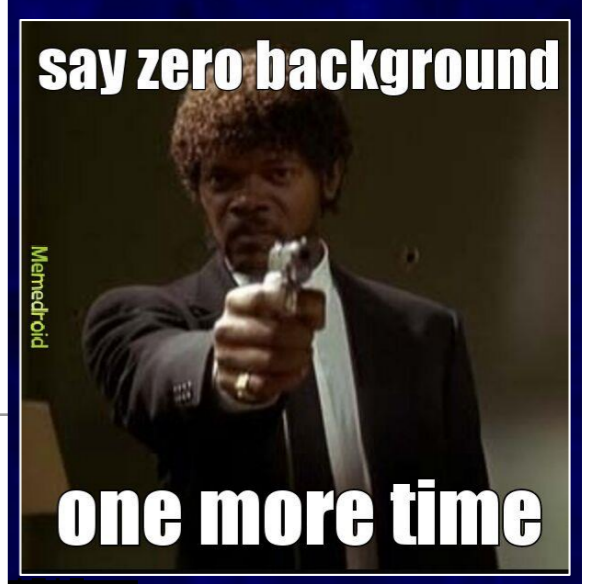
Tim Nelson

June 12, 2015



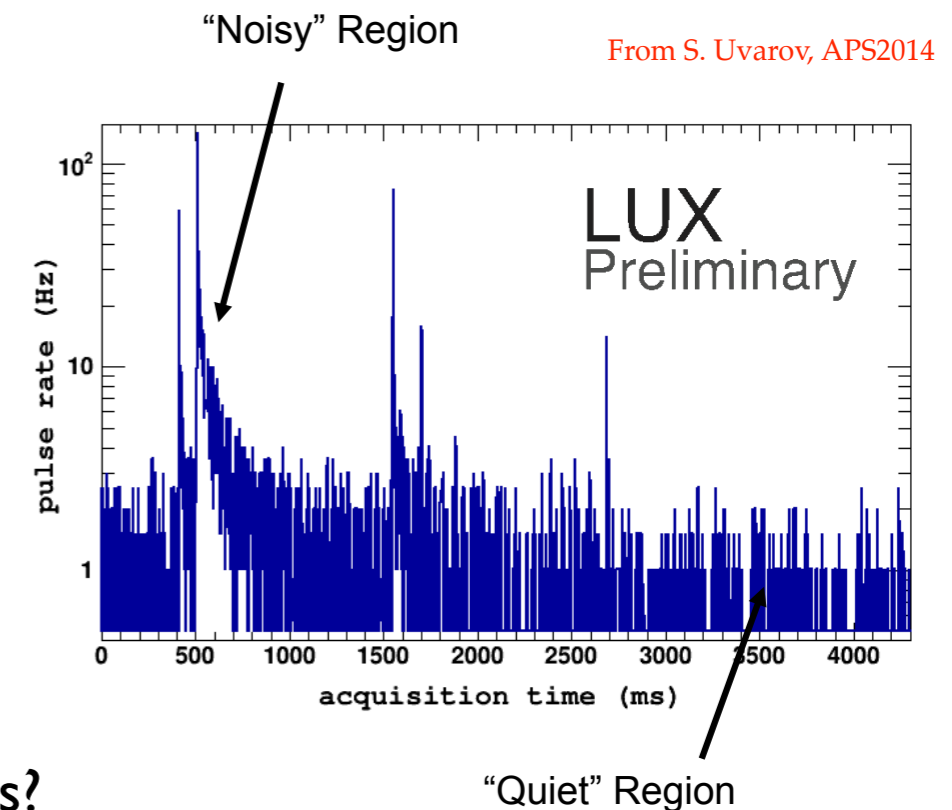
“Beyond WIMPs, from theory to detection”

- A comprehensive discussion of non-WIMP dark matter hosted by Tomer Volansky. Organizers include Rouven, Jeremy Mardon.
- Theory: virtually every talk invokes dark photons in one form or another. However, searches for visible decays are so mainstream (!) that they aren't really discussed to any significant extent.
- Experiment: Focus mostly on direct/indirect detection techniques.
 - technologies for direct detection of KeV - GeV DM
 - new analysis and interpretation of astrophysical data
- On dark forces, some interesting topics
 - invisible decays
 - light hidden photons as dark matter
 - millicharged particles
- Lots of other discussions and ideas generated during down-time



Direction Detection Down to $M_\chi \approx \text{KeV}$

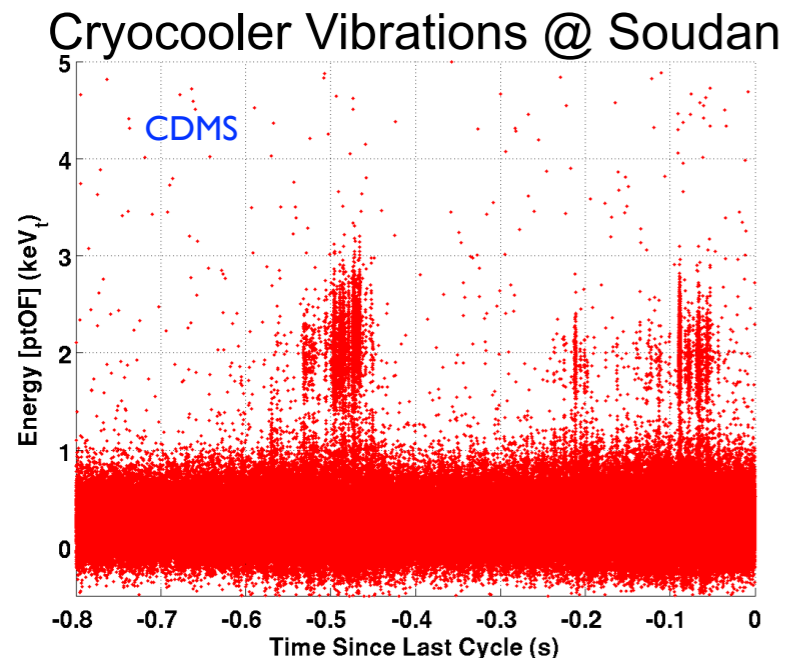
- Below KeV, generally too hot to be dominant DM.
- Detection of KeV DM requires sensitivity to $\text{meV}(!)$ recoils.
- Electron recoils (down to $M_\chi \sim \text{MeV}$)
 - Noble liquids: LXe “single electron” analyses
 - Semiconductors: CDMSLite, DAMIC, etc.
- Crazy ideas (below $M_\chi \sim \text{MeV}$)
 - Cooper pairs have meV binding energies. How do you amplify a quasiparticle signal? (<http://arxiv.org/abs/1504.07237>)
 - Molecular interactions: creation of color centers in crystals?
 - Single excitations in scintillators (RE’s idea... not discussed in a talk.)
- Theorists generally thinking that meV energy sensitivity with zero background is achievable in ~ 10 years. Experimenters trying to bring some realism to the table: *it’s another 30-year program.*
- How do we develop signatures that allow a good understanding of background with such small energy depositions? How valuable are experiments that can only set limits due to the qualitative nature of the signal?



Crazy Idea #1 (cooked up by Andrew Sonnenschein, Javier Tiffenburg, TN)

- Build on known techniques using HgCdTe sensors.
- Bandgap is adjustable between 0-1.5 eV. Mobility and mean free path are very high.
- Make thick drift sensors with very small collection/readout node (for low noise as with DAMIC).
- Run VERY cold (mK).
- In principle, \sim meV sensitivity may be possible without tackling entirely new techniques.

However, everything here is very, very difficult!!



There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we know we don't know. But there are also unknown unknowns. There are things we don't know we don't know.



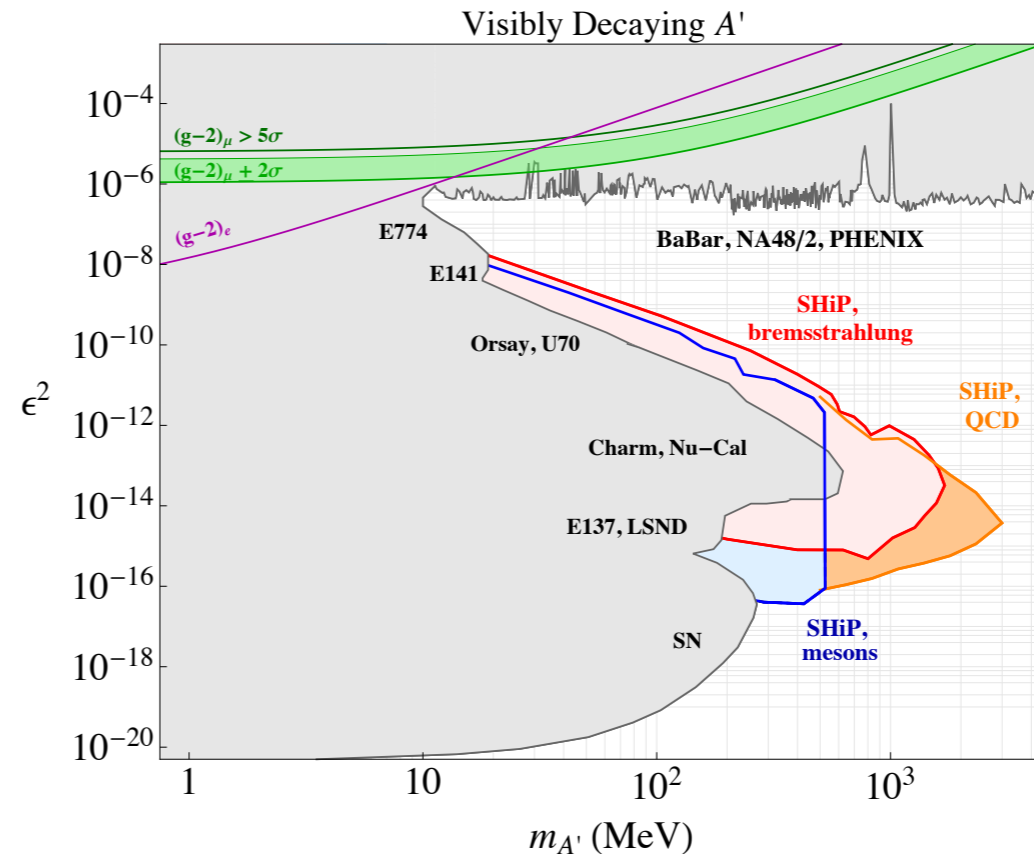
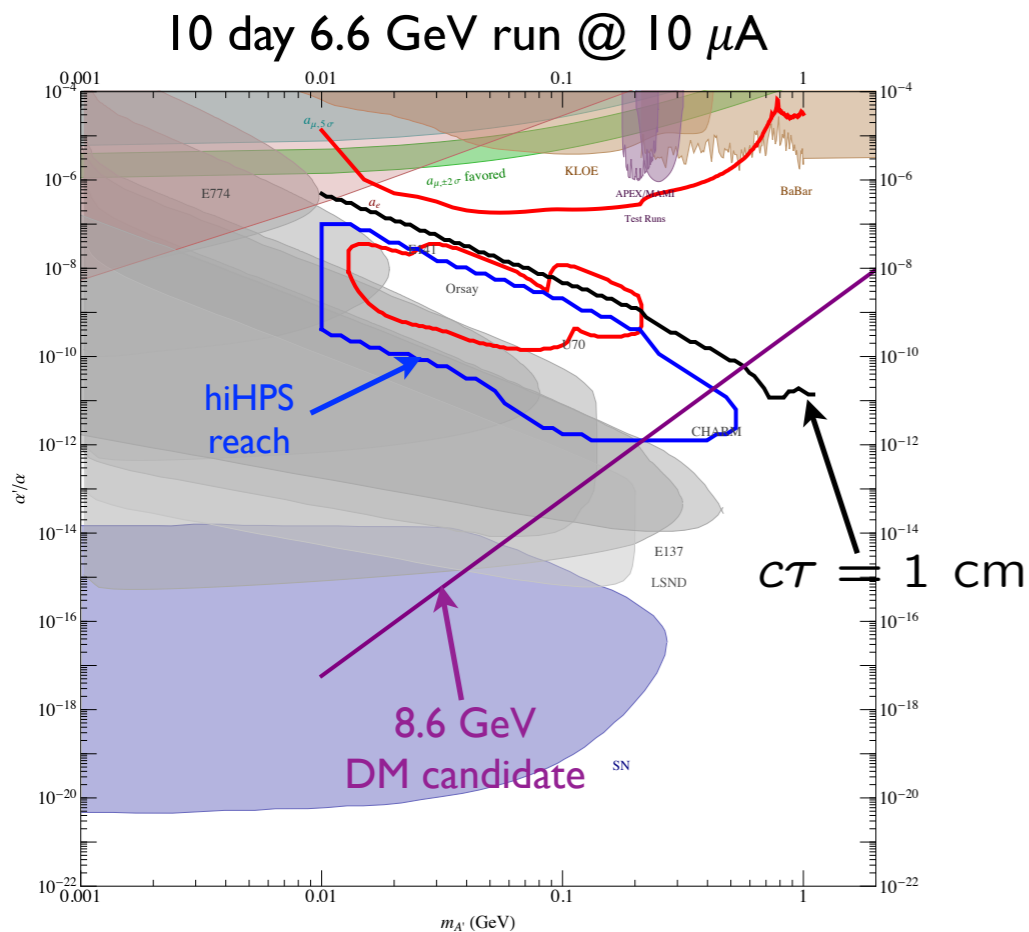
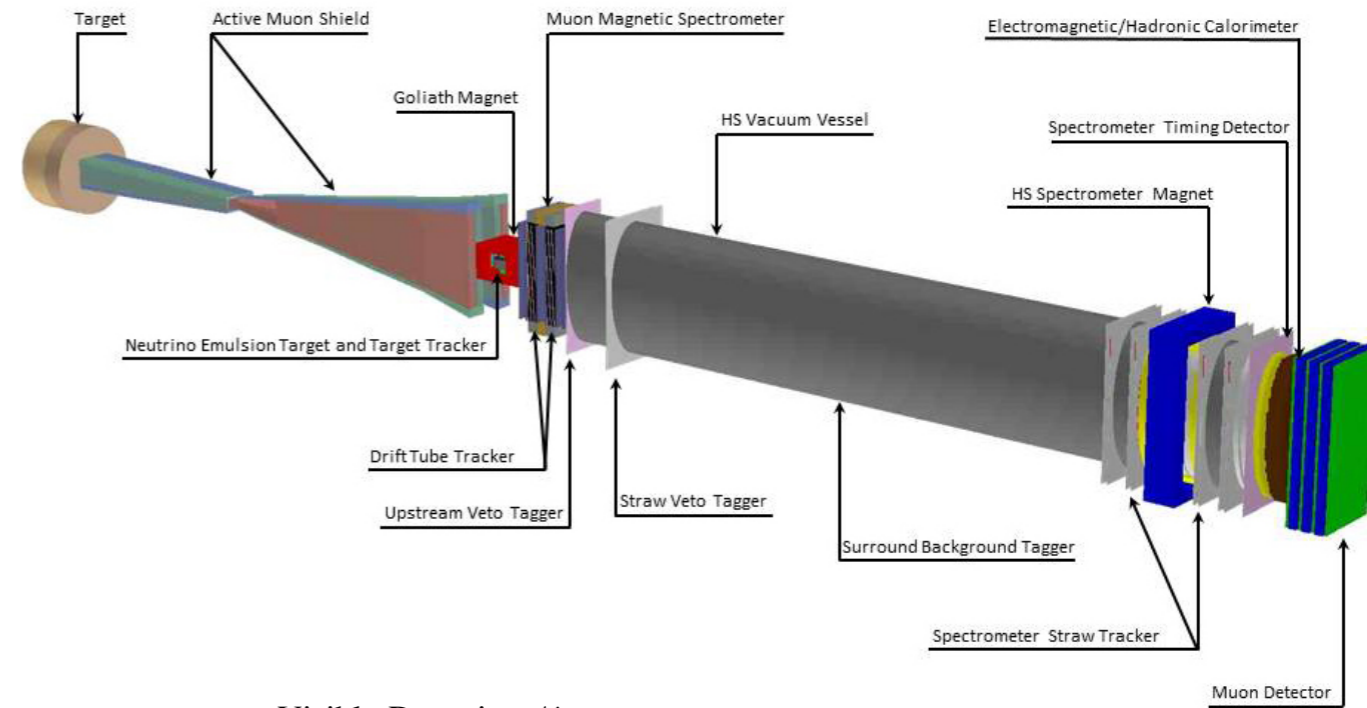
Indirect Detection / Astrophysics

- Positron excess
 - DM annihilation has finally been declared dead.
 - DM decay not completely ruled out but definitely disfavored.
- Fermi GeV Excess
 - Very interesting analysis by Mariangela Lisanti and Tracy Slayter of spatial granularity of signal to determine whether more consistent with a diffuse source (DM) or unresolved point sources. Not complete (slides not posted) but case for unresolved point sources looked compelling.
- Many discussions of open questions in cosmology, structure formation, DM halos, galactic dynamics, etc. Clearly a big struggle with unknowns there too. What are the effects of having a component of self-interacting dark matter?

Dark Forces - Visible Decays

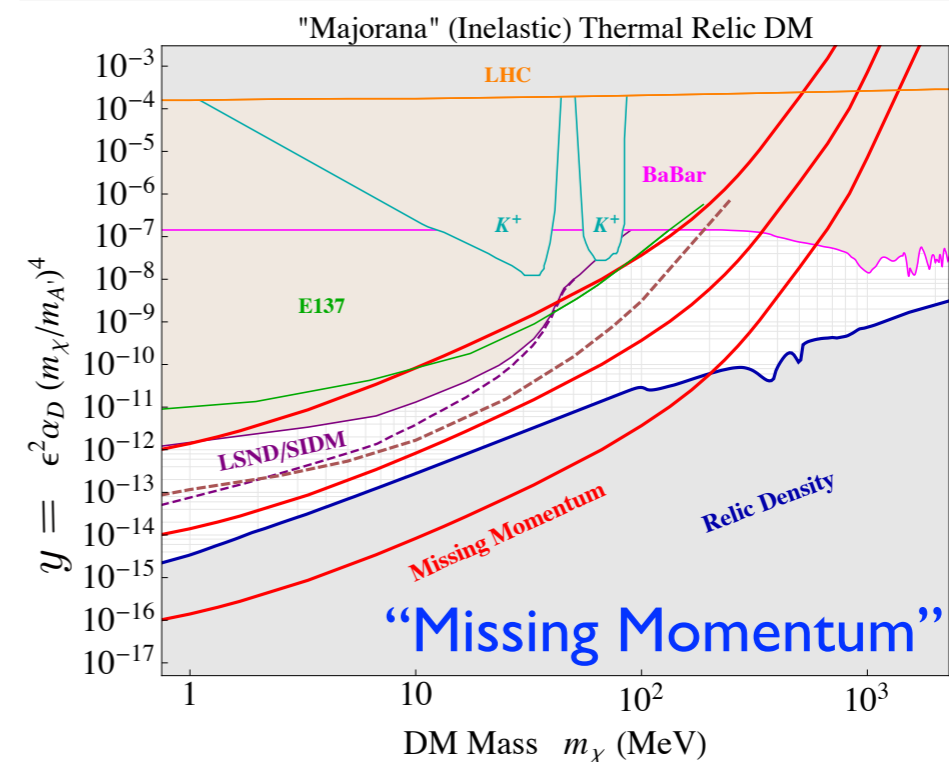
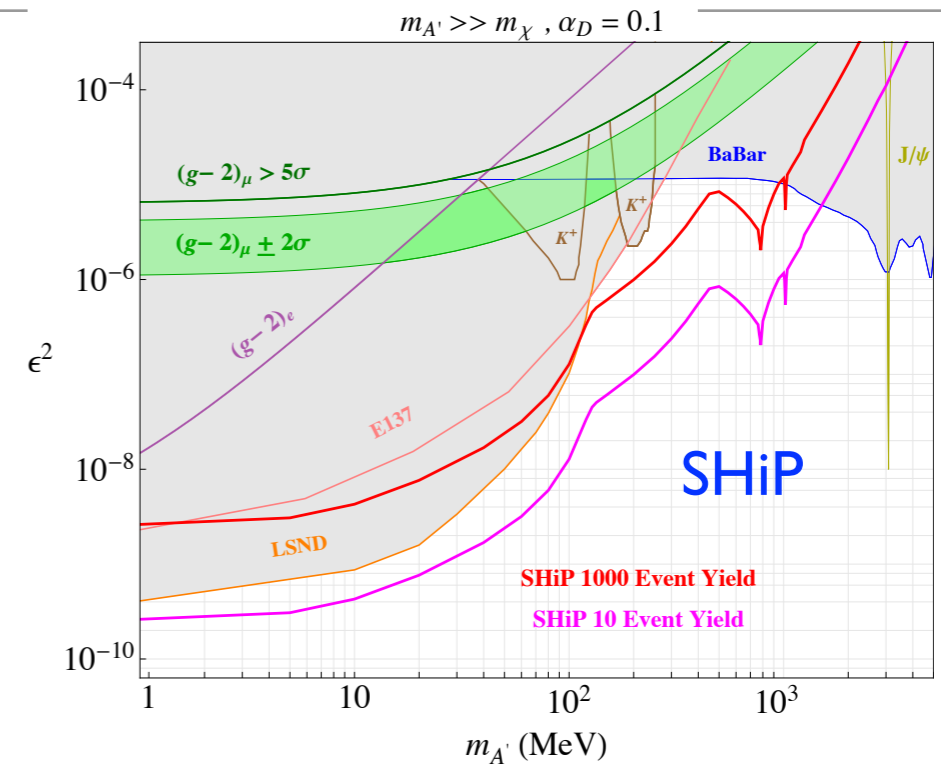
CERN SHiP Proposal: <http://ship.web.cern.ch/>

- Reach similar to HPS dump concept studied for Snowmass.
- Designed for sensitivity to broader set of portals (also scalar, neutrino).



Dark Forces - *Invisible* Decays

- Gordon Krnjaic reviewed main efforts: B-factories, dump experiments, missing momentum.
- Not going to branch off into discussion of the missing momentum experiment here: that's another entire meeting. Despite many open questions, it still appears feasible.
- SHiP wasn't discussed (and I haven't looked into it much yet) but clearly could be a key player. Anecdotally, it's a major investment (>\$100M) so it's not going to happen overnight.
- Maxim Pospelov: Build small particle accelerator next to an existing deep underground detector?



Dark Forces - Millicharges

- Eder Izaguirre & Itay Yavin with Chris Hill (CMS) & Andy Haas (ATLAS)
- Build simple detector in cavern adjacent to CMS and ATLAS IPs
- Runs parasitically with LHC program.

Why not deploy a similar version of the mQ detector in the counting (or control) room?

Deploy 10 cm x 5cm x 140 cm scintillating bars
Need 200 to cover 1m²

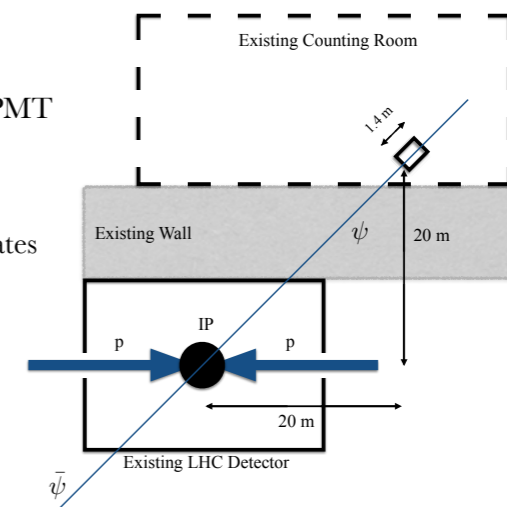
High detection efficiency
mCP with $Q = 10^{-3}e$ gives ~ 1 PE in one PMT
(Assuming a 10% det. efficiency)

The problem
Not a pulsed beam. Large dark current rates

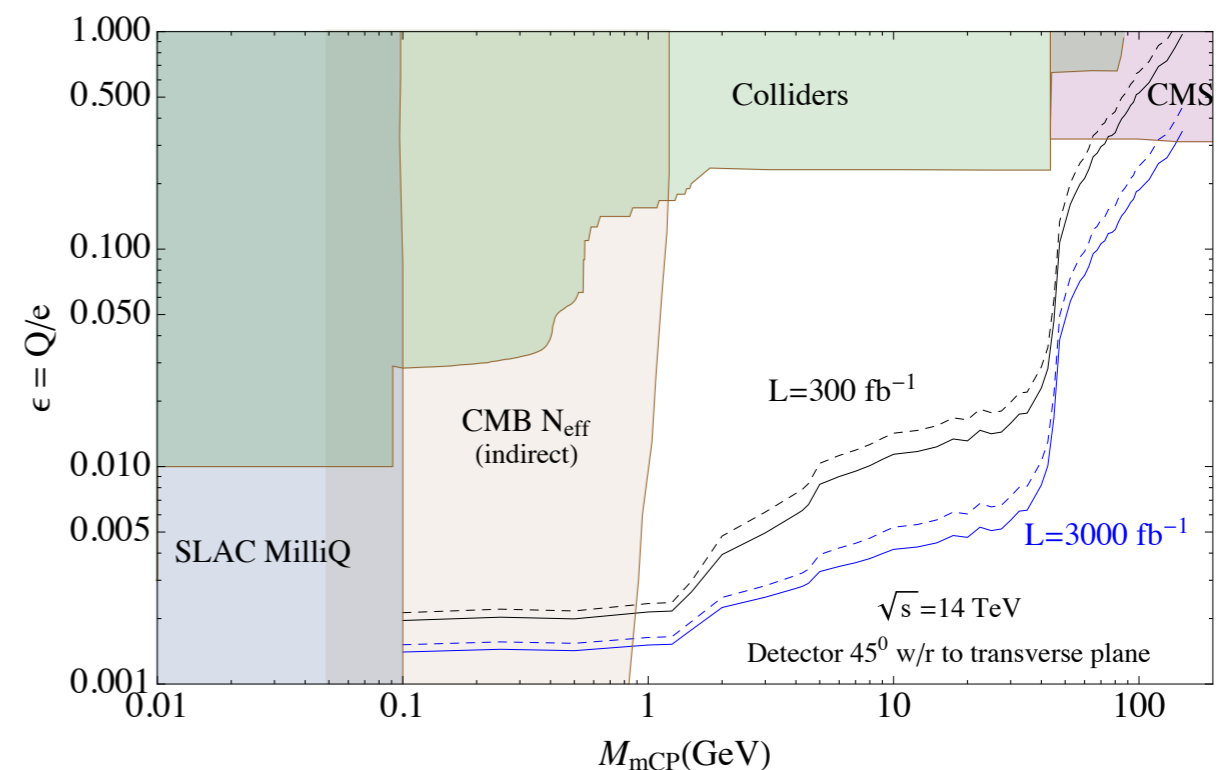
From PMT Handbook
Rate (1 PE) ~ 500 Hz

Lifetime ~ 1 year

Background = 10^{10} events



Model-independent (direct) bounds on mCPs



Dark Forces - Dark Photons as Dark Matter

Jeremy Mardon gave a very nice exposition on low-mass dark photons as a DM candidate: existing constraints, new ideas, and potential cosmological origins.

- Sensitivity in direct detection experiments.
- “Radio in a Box”: Peter Graham, Kent Irwin, Jeremy Mardon, et. al

DETECTING HIDDEN PHOTON DM

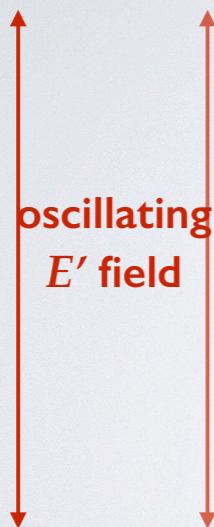
3. Resonant searches

A “hidden electric field” that penetrates shielding
 — $E' \approx \sqrt{\rho_{DM}} \approx 2000 \text{ V/m}$
 Has fixed frequency
 — $\omega = m_{\gamma'}$, $\delta\omega/\omega = 10^{-6}$
 Can excite an electromagnetic resonator

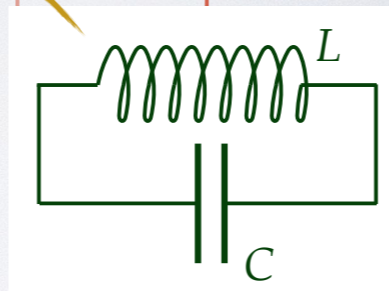
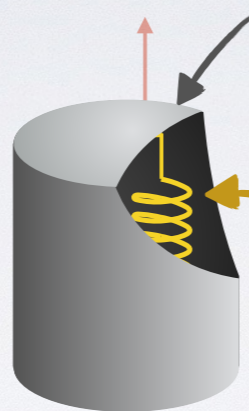
electromagnetic cavities

- ADMX is automatically sensitive!
Redondo et al 1201.5902
- cavity size restricts mass range

Jeremy Mardon, SITP, Stanford

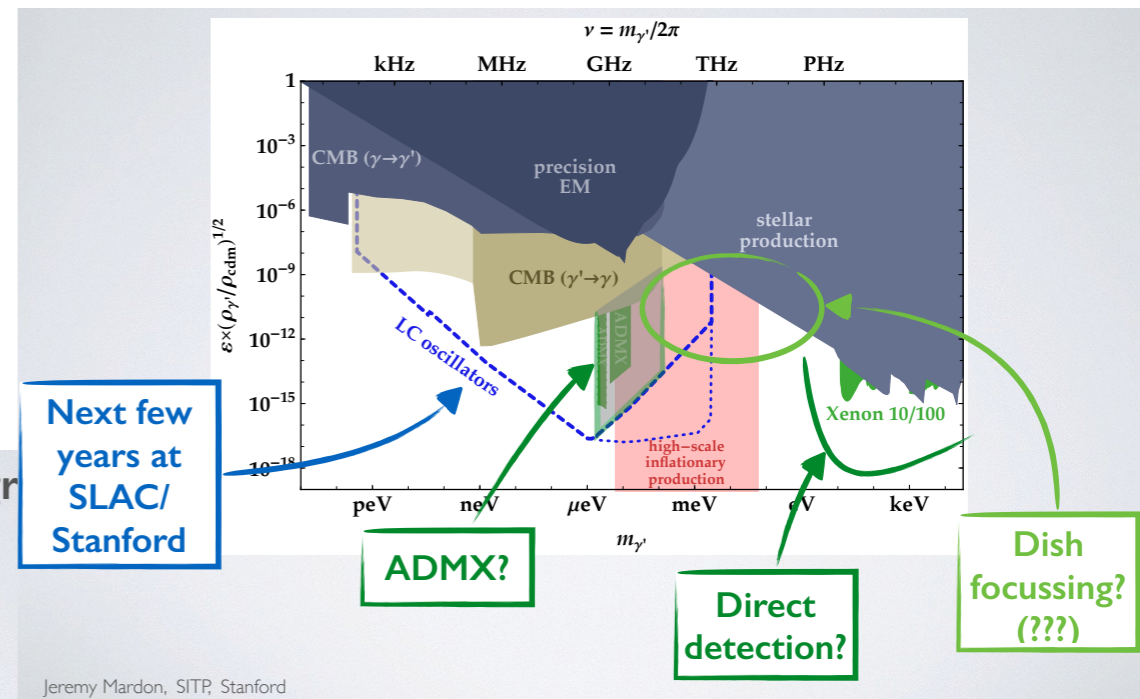


Metal box to shield background



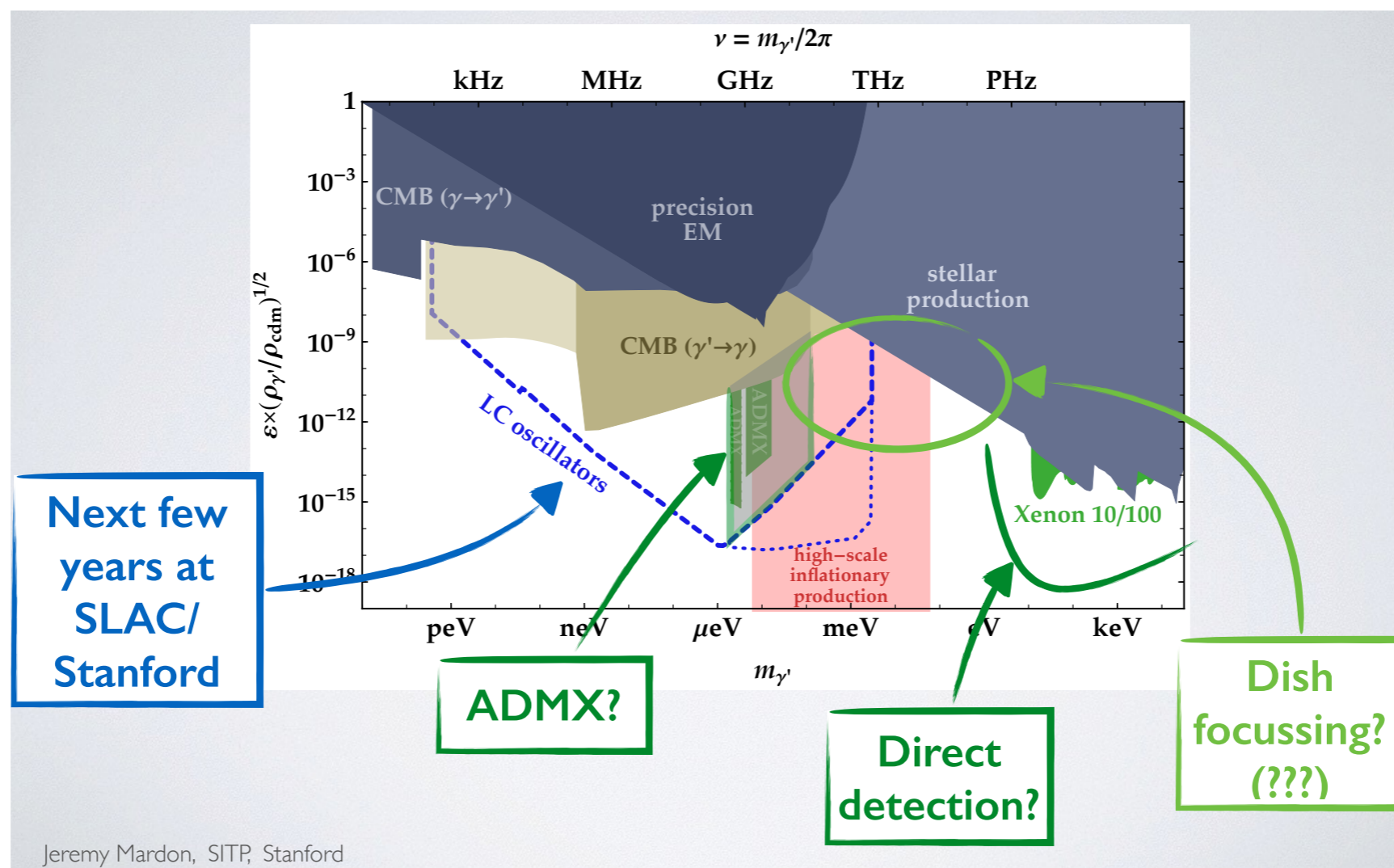
Tunable resonant LC circuit
 Read out with SQUID

Jeremy Mardon, SITP, Stanford



Crazy Idea #2 (stupidity here is all mine)

- LCLS II will produce $\sim 10^{21} \sim 1 \text{ KeV}$ photons / second.
- Won't LCLS undulators produce low-mass ($\ll 1 \text{ KeV}$) hidden photons relatively copiously?
- Place a detector alongside LCLS undulators to observe ultra-light DM or hidden photon interactions?



And much, much more!

- Really too many interesting ideas to list
- Go have a look for yourself. Time to start using a few CPU cycles on new ideas.

<http://tomerv.wix.com/lightdm#!sessions/c3kh>

