



Fermi

Gamma-ray Space Telescope



Fundamental Physics / Dark Matter

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- **Mission Assumptions**
 - **MeV/GeV Space-Based**
- **Dark Matter**
 - **MeV and Light GeV range Dark Matter**
 - The WIMP (and not exactly a WIMP) story
 - Axion-like particles
 - **GeV range Dark Matter**
 - WIMPs
- **New/Fundamental Physics**
 - **Complementary detections, multi-wavelength/messenger**

fermi
Gamma-ray
Space Telescope

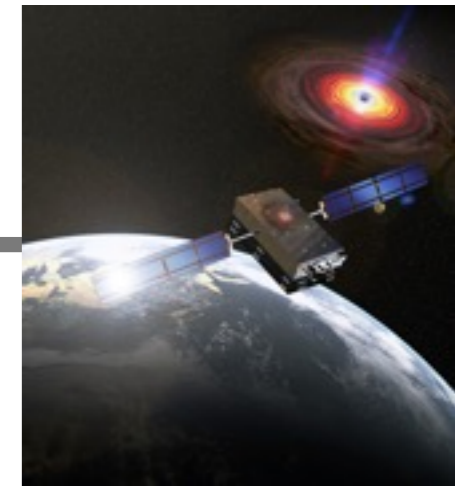


- An idea of mission capabilities (typically MIDEX class)

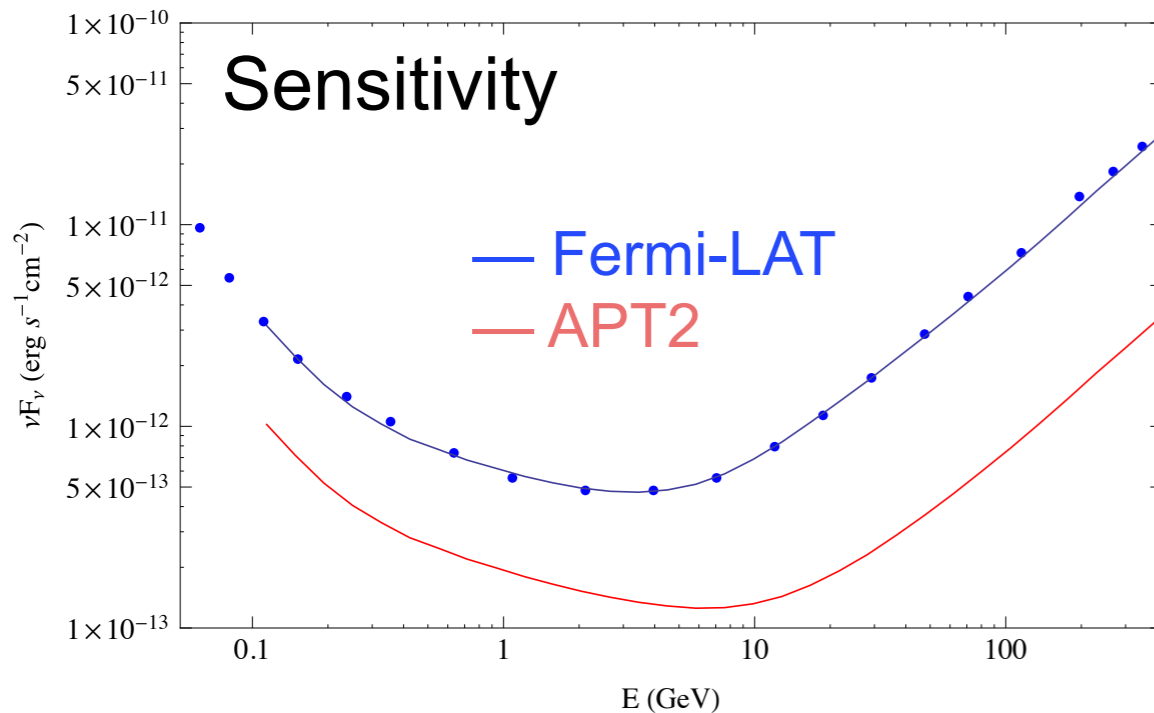
Mission	Energy Range [MeV]	Energy Resolution [$\Delta E/E$]	Angular Resolution	FOV	Flux Sensitivity [$\text{MeV cm}^{-2}\text{s}^{-1}$]
TPCs (polarimetry)					
AdEPT	5-200	$\sim 30\%$ at 70 MeV	$\sim 0.6^\circ$ at 70 MeV	3.14 m^2sr	$< 3 \times 10^{-5}$
LArGO	0.1 - 10^5	$\sim 3\%$ at 1 MeV	$\sim 1^\circ$ at 100 MeV	large (> 2.5 sr?)	
HARPO	1-100	6/15/30% at 1/10/100 MeV	$\sim 0.3^\circ$ at 40 MeV	$4\pi(?)$ sr	$< 10^{-6}$
Spectrometers/mappers					
GRX/COSI	0.2-few	1/0.1% at 0.2/1 MeV	$\sim 4^\circ$ at 1 MeV	3.14 m^2sr	$< 2 \times 10^{-5}$
Continuum/survey mapper					
ComPair	1-500	2/4/12% at 1/10/100 MeV	$\sim 7(1)^\circ$ at 1(100) MeV	3.5 sr	$< 2 \times 10^{-6}$
AstroGAM	0.3-100	1/7% at 1/10 MeV	$\sim 1^\circ$ at 100 MeV	~ 2.6 sr	$< 6 \times 10^{-6}$
Current					
Fermi-LAT	20- $> 3 \times 10^5$	18/7% at $10^2/10^3$ MeV	$\sim 3(0.04)^\circ$ at 100(10^5) MeV	~ 2.5 sr	$< 10^{-6}$

Benchmark: 1 MeV-1 GeV, E Res best at 1 MeV
 Large FOV, Flux sensitivity $\sim 10^{-6} \text{ MeV cm}^{-2}\text{s}^{-1}$

An attempt to get common parameters among missions
 Not meant to be exhaustive list - only to define parameter space for new physics searches

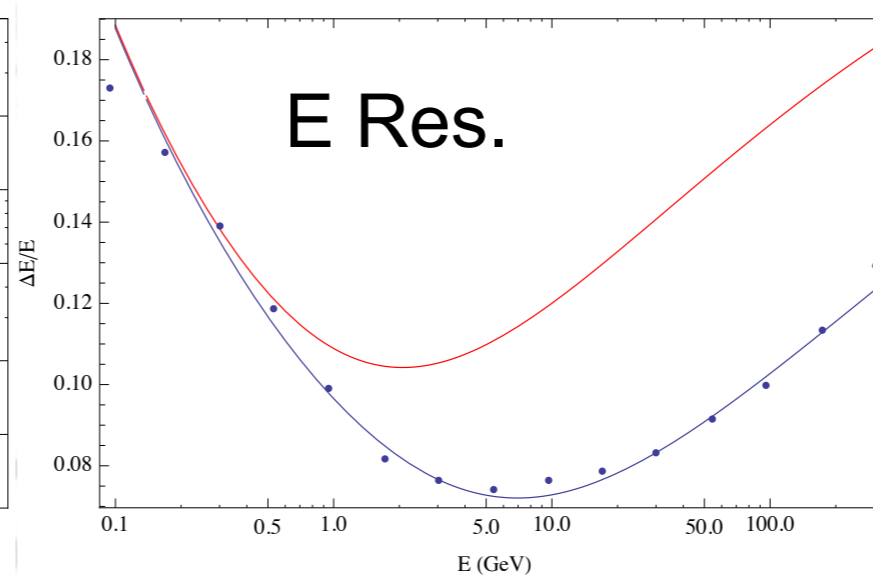
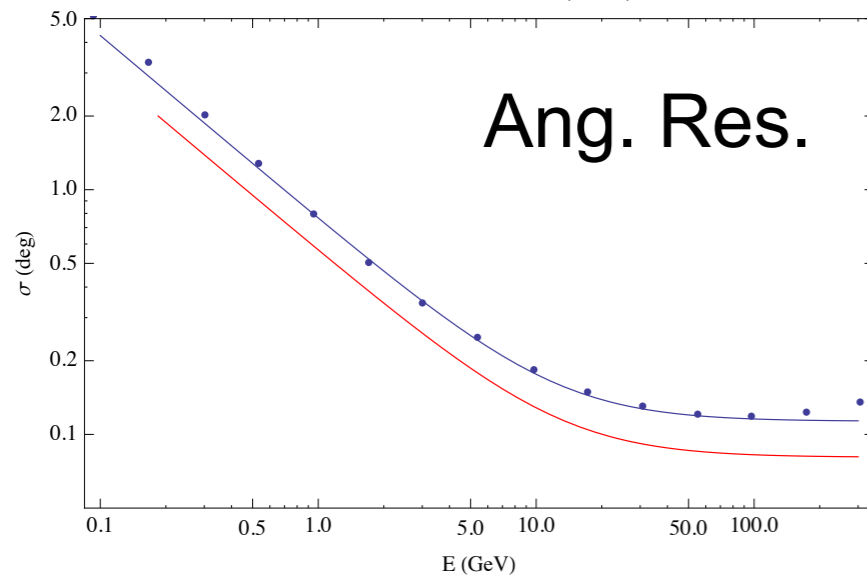


- An idea of mission capabilities (Probe class)



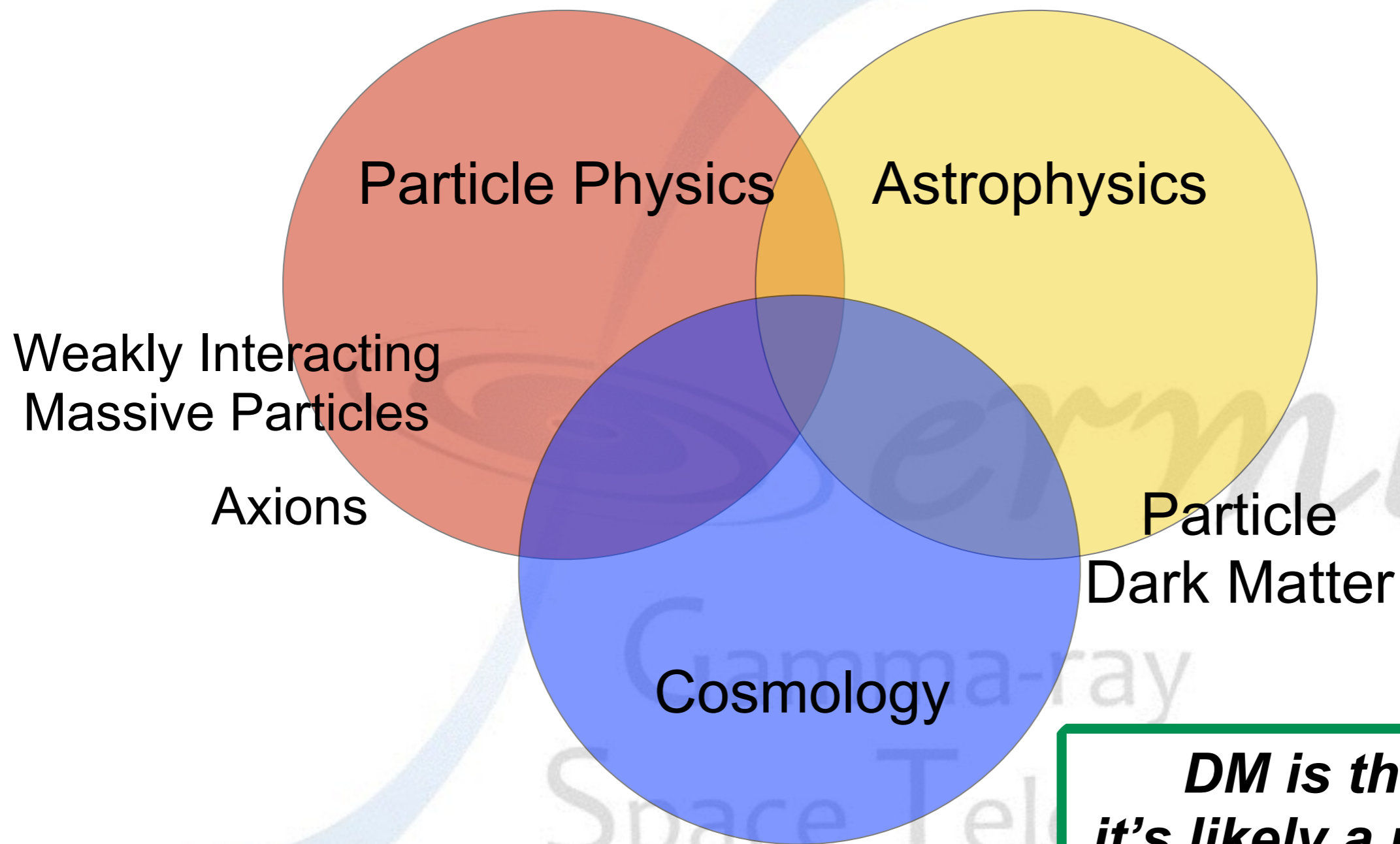
APT2

- ~1B\$ instrument, probe class (explorer?)
- scintillating fiber tracker
- larger (~3.5 times the mass) than Fermi,



**Goal: DM Dwarf
sensitivity
improved by x10**

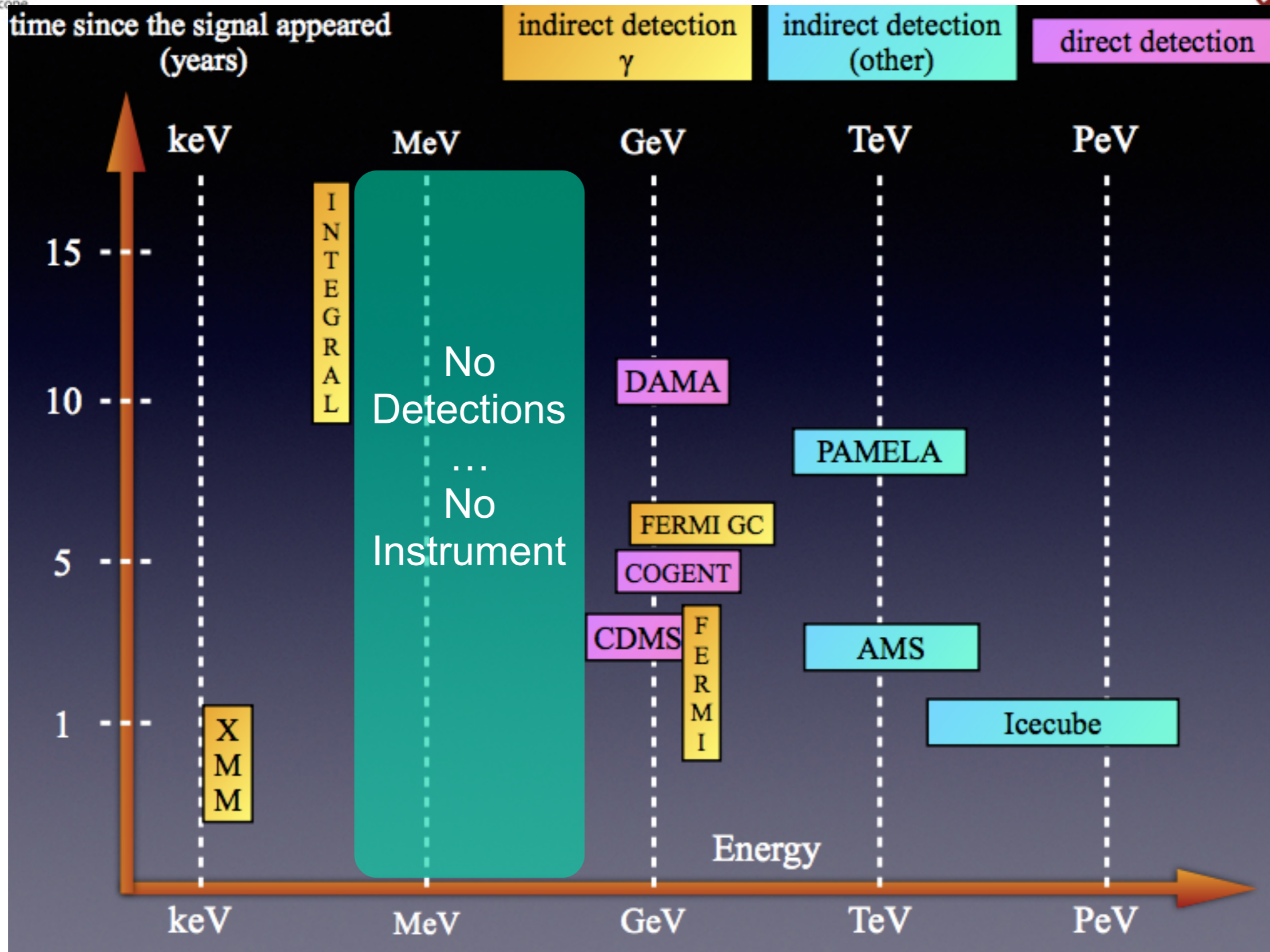
An attempt to get common parameters among missions
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***DM is there,
it's likely a particle
it could be many***



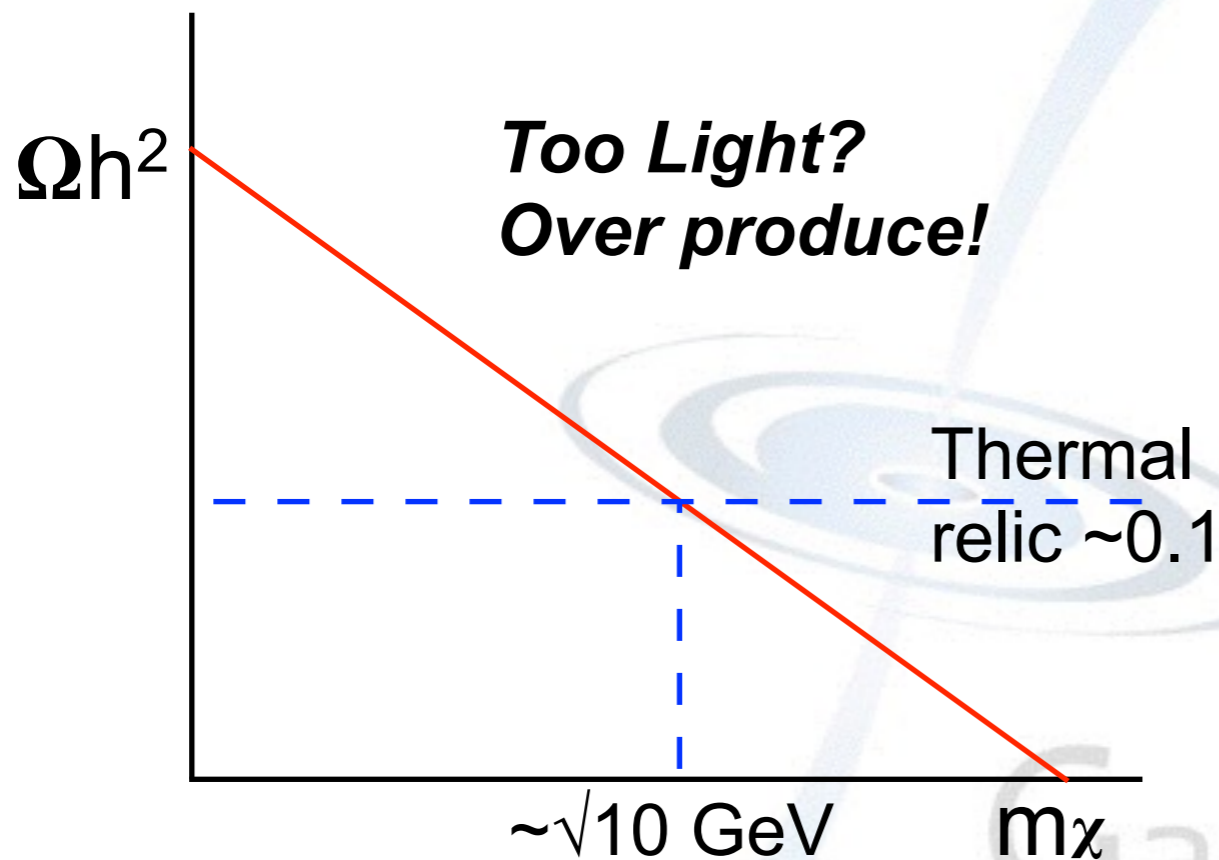
Dark Matter Detections





- **Why MeV (WIMP-ish) Dark Matter?**

- **Lee-Weinberg: Cosmological lower bound on heavy neutrino mass (1977)**



Two Scenarios:

1. $G_F^2 m_\chi^2 \implies G'^2 m_\chi^2$
Non-SM interaction
(not strictly Weakly Interacting)

2. Or not strictly a thermal relic
(bound by BBN $\sim 1 \text{ MeV}$)

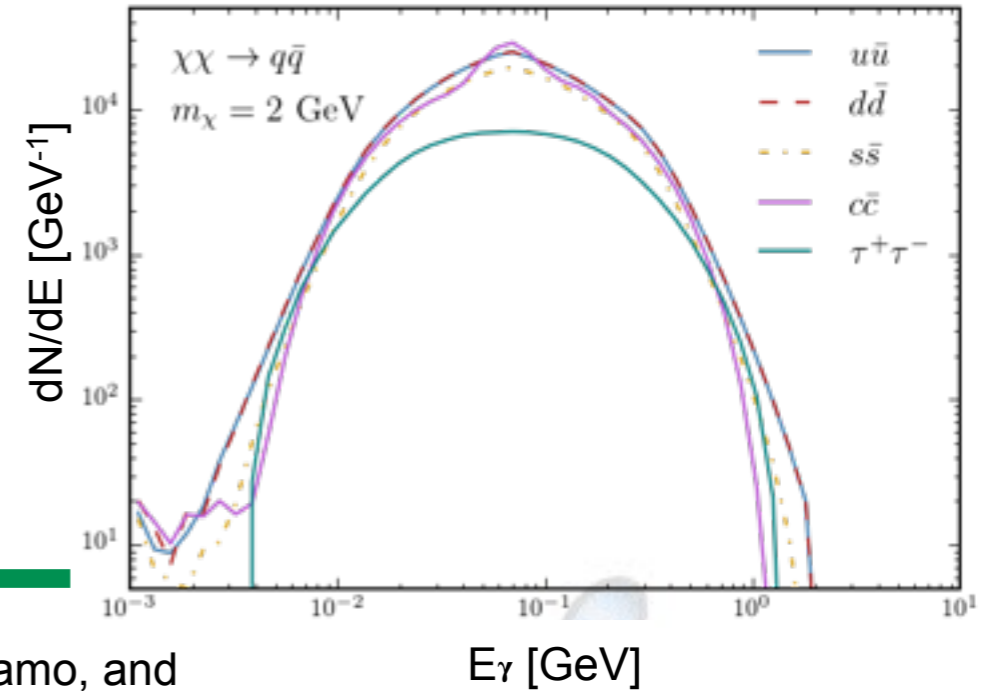
$$\Omega h^2 \propto \langle \sigma v \rangle = G_F^2 m_\chi^2 > 10^{-9} \text{ GeV}^{-2}$$

MeV Dark Matter



Model Name	DM Particle Mass [MeV]	Final State BR (%)	Notes
A1	2,000	τ, μ, e, c, u, d, s	Univ. Fermions
A2	2,000	τ, μ, e	Univ. Leptons
A3	2,000	τ (67%), c (33%)	p-wave supp. fermions
A4	2,000	τ	p-wave supp. leptons
B1	200	μ, e, u, d, s	Univ. Fermions
B2	200	μ, e	Univ. Leptons
B3	200	μ (55%), s (45%)	p-wave supp. fermions
B4	200	μ	p-wave supp. leptons
C	100	e	(any, no γ 's)
D	20	e	(any, no γ 's)
E	1	e (80%), γ (20%)	
F	0.2	γ	

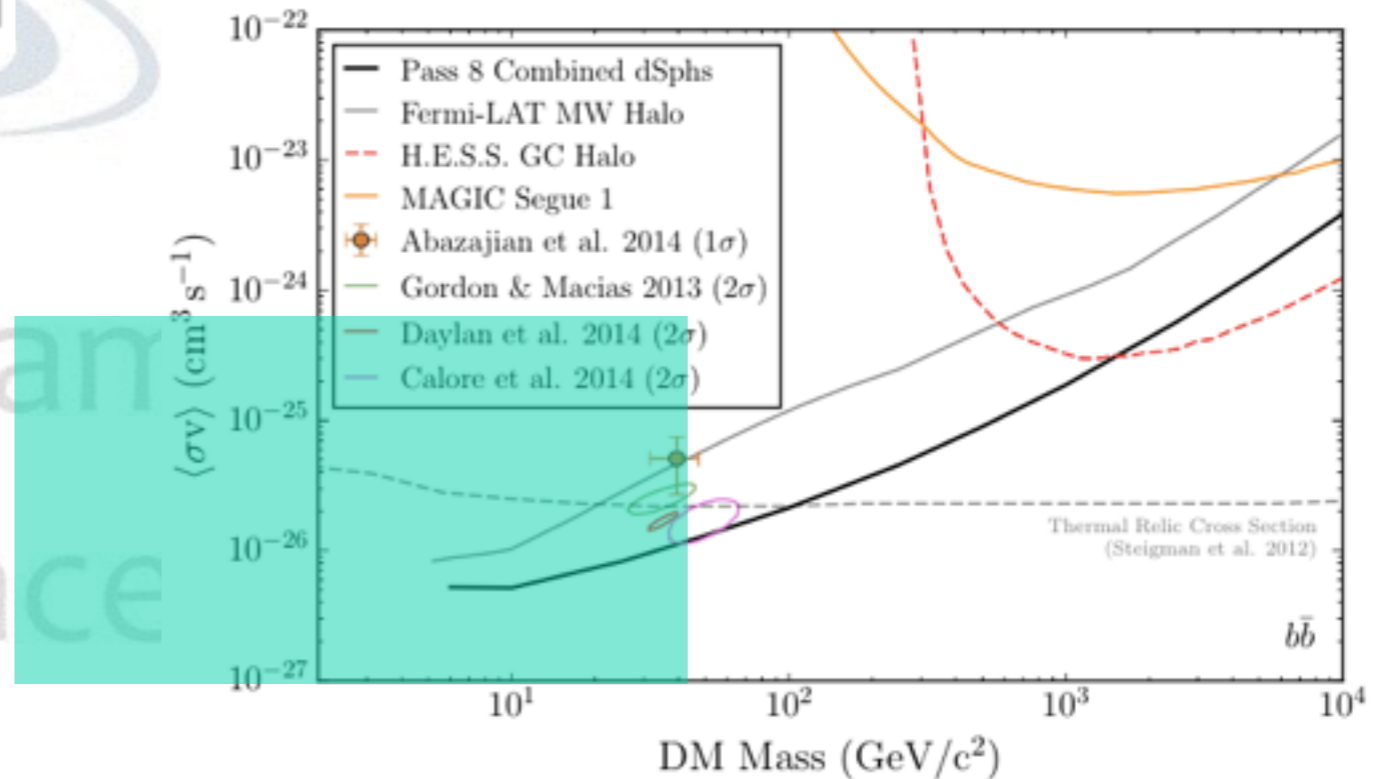
Scan new MeV DM parameter space to develop a gamma-ray spectrum



RC, E. Carlson, F. D'Eramo, and S. Profumo: in preparation

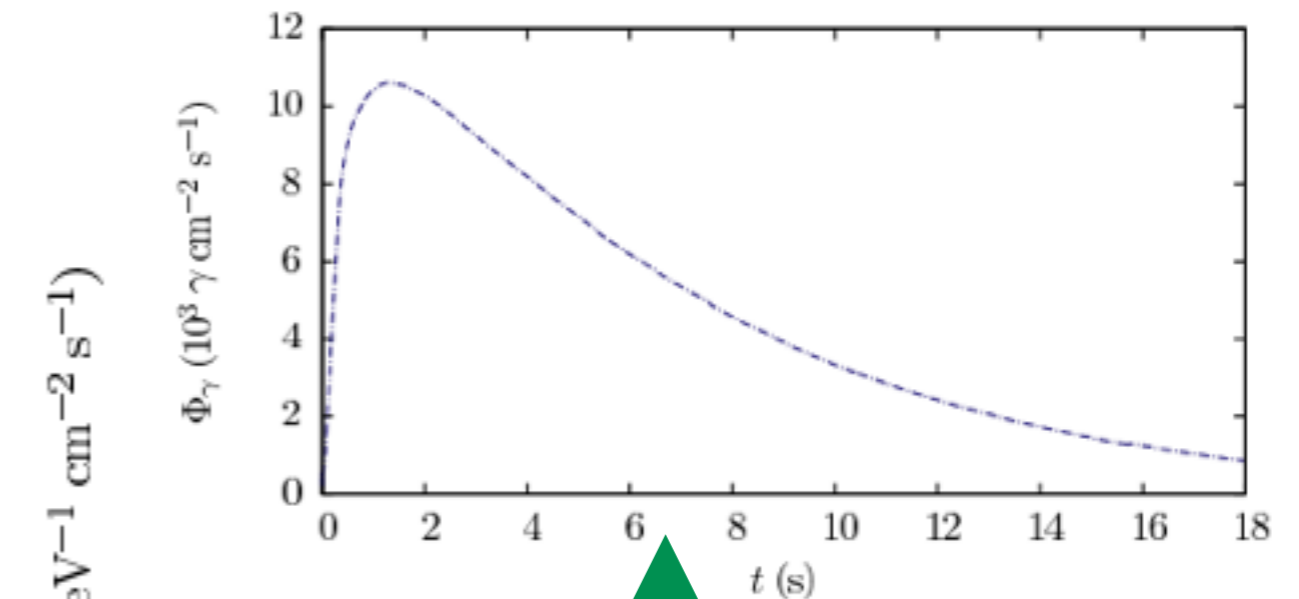
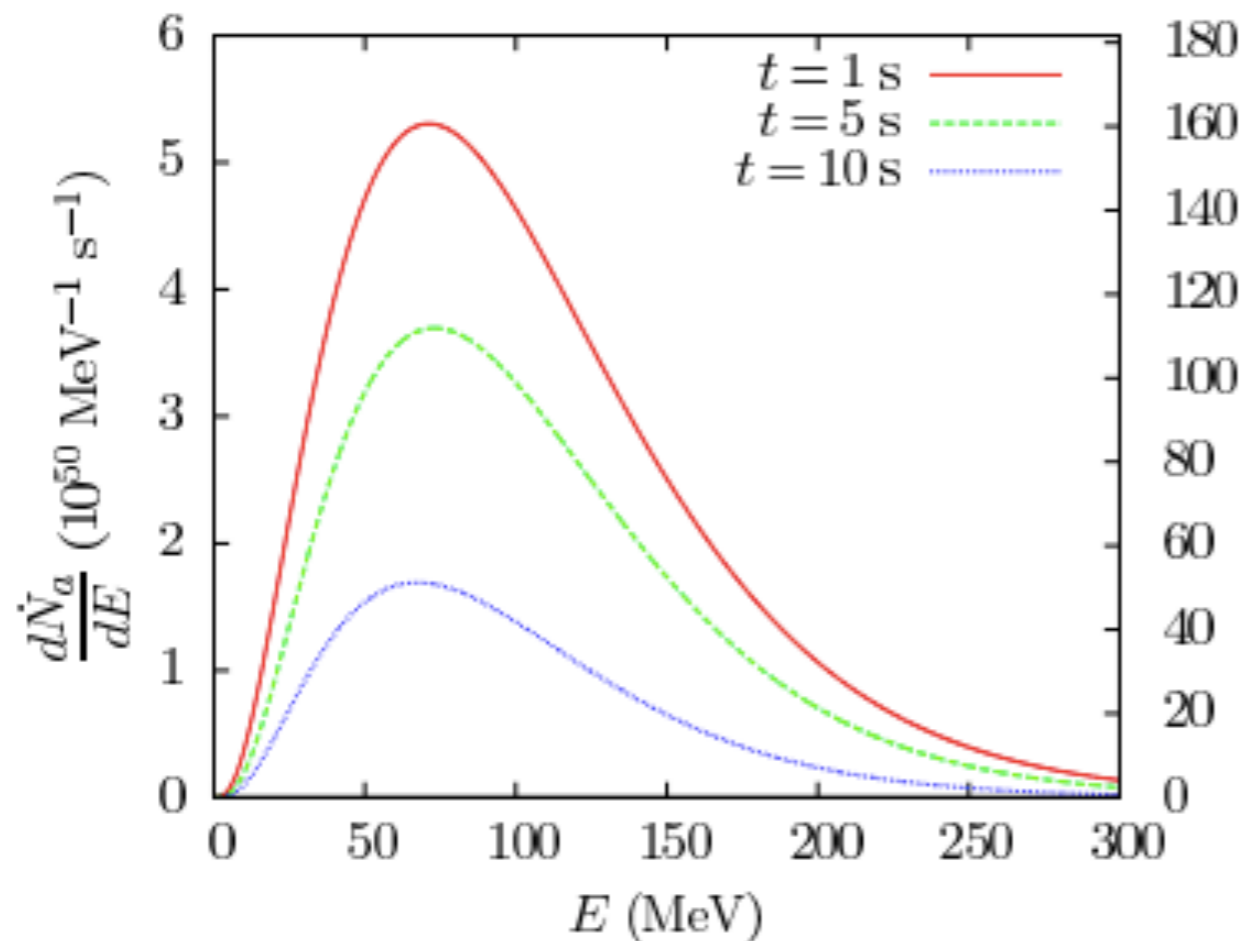
Complement current parameter space...

gamma-rays ~order(-1) DM mass





- Axions in neutron stars (hep-ph/0505090)
 - emission process for axions with mass up to a few MeV
 - production in Gamma Ray Bursts
- Axions produced in supernovae (arXiv:1410.3747)
 - core collapse supernova (SN1987A)

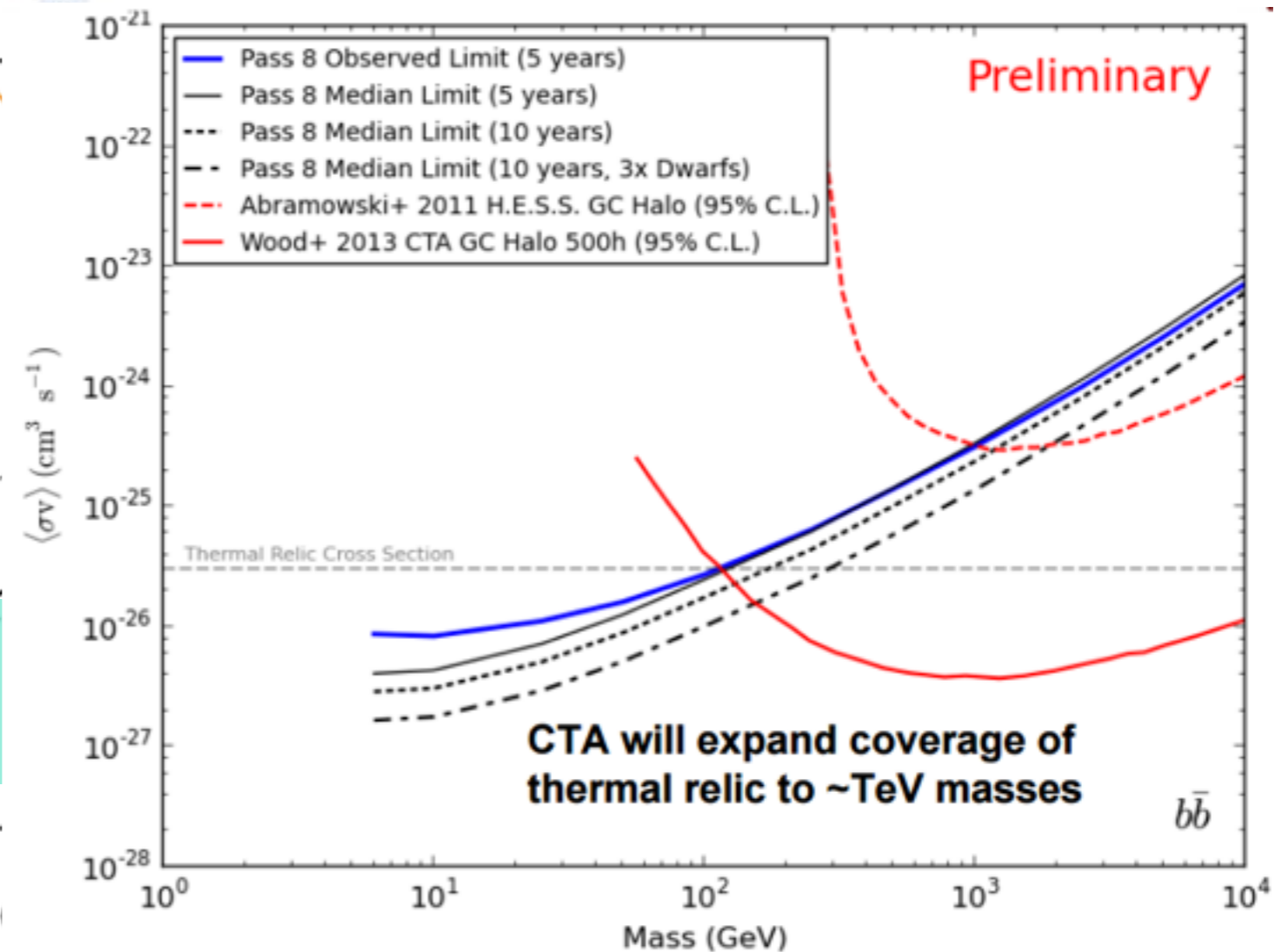
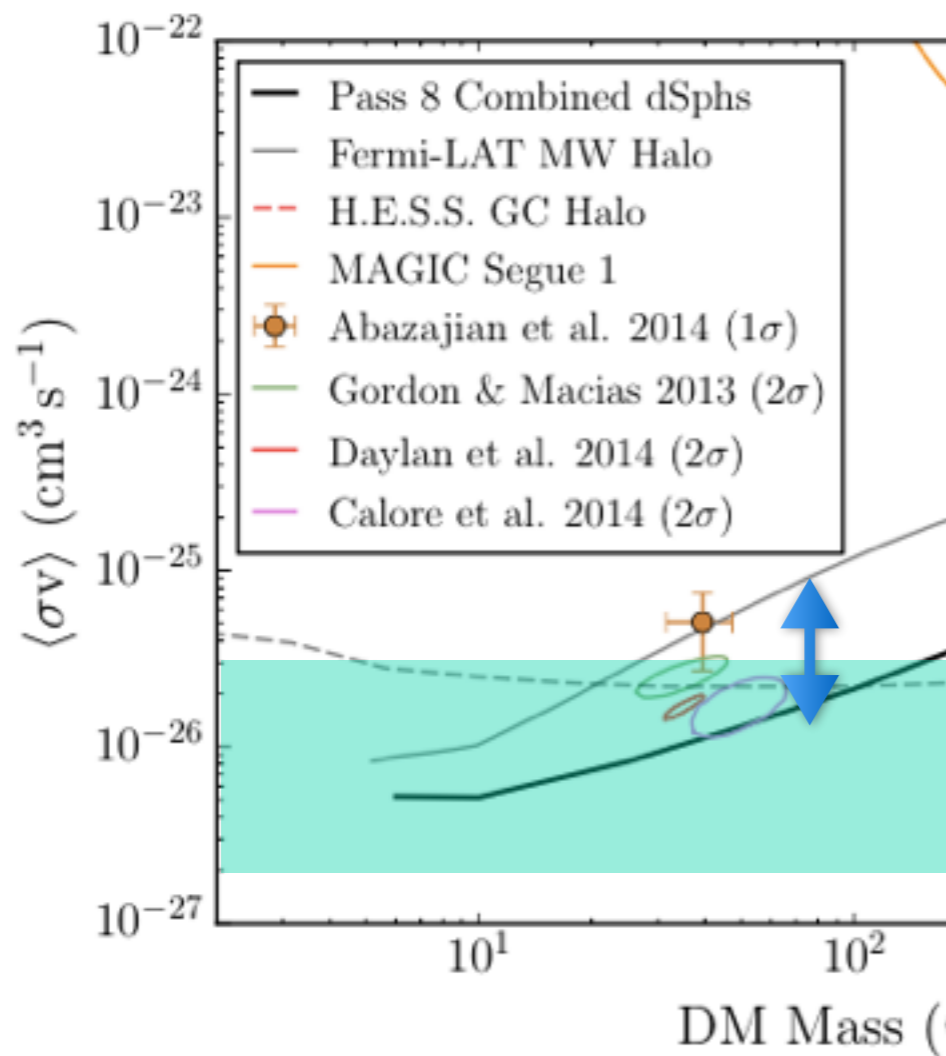


massless ALP
 ($m_a \sim 10^{-11} \text{ eV}$)
 with $g_{a\gamma} = 10^{-10} \text{ GeV}^{-1}$
 18 M_{sol} progenitor

timing of
 photons between
 (25-100 MeV)
 with $g_{a\gamma} = 10^{-10} \text{ GeV}^{-1}$
 18 M_{sol} progenitor



- GeV DM candidate is standard WIMP picture
 - Theoretically Motivated
- To cover thermal relic OM sensitivity needed

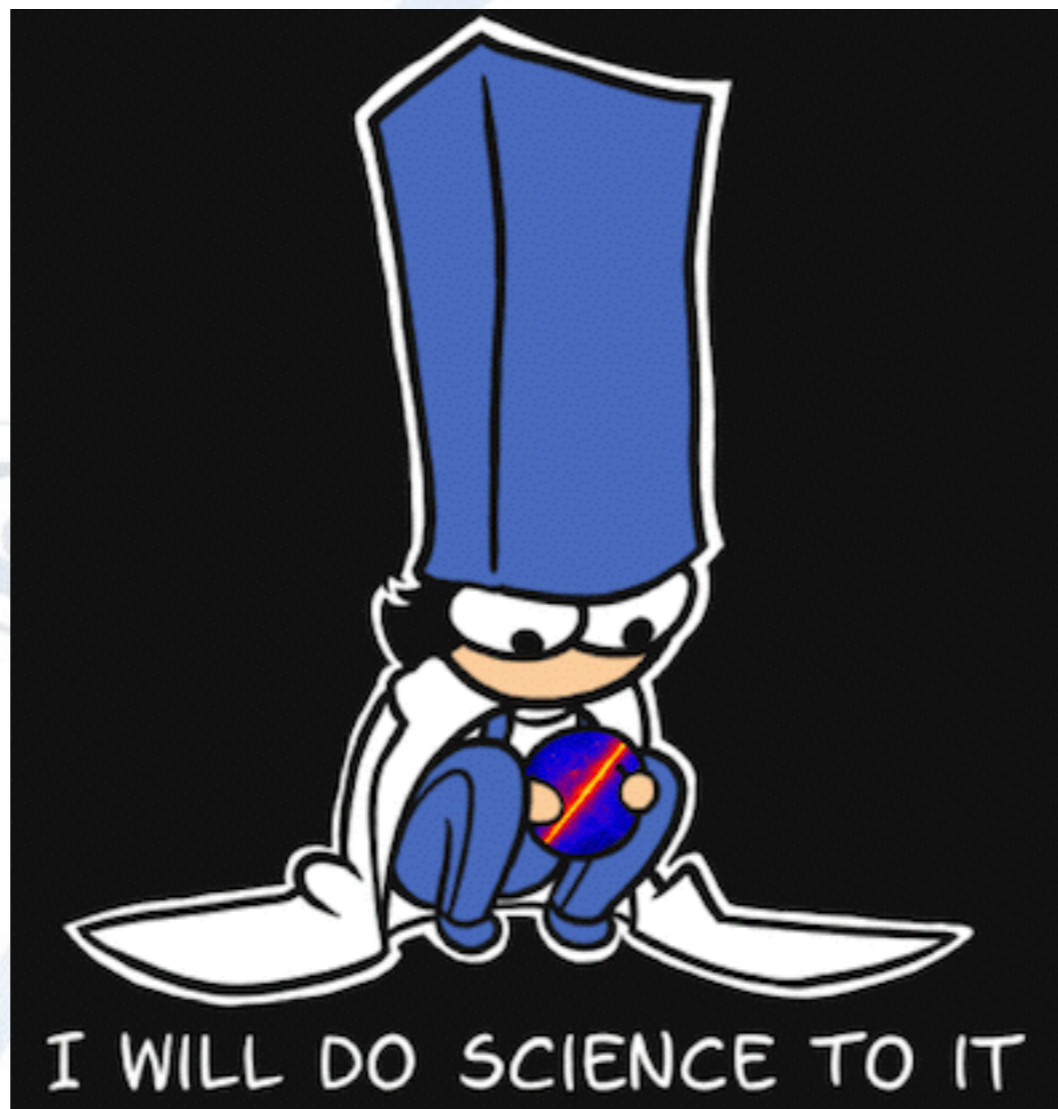




- **Complementary detections with other messengers**
- **Gravitational wave detectors**
 - 2nd generation coming online 2016-ish (LIGO, VIRGO)
 - GRBs are a GW signal (~50 SHB/year) (E. Chassande-Mottin)
- **Neutrino detectors**
 - **Complementary: sources of particle acceleration**
- **Understanding the Galactic Center**
 - **Point sources and pulsars**
 - good angular resolution
 - diffuse from ICS (more isotropic), less from π^0
- **Open to ideas for physics to add**
- **Discussion**

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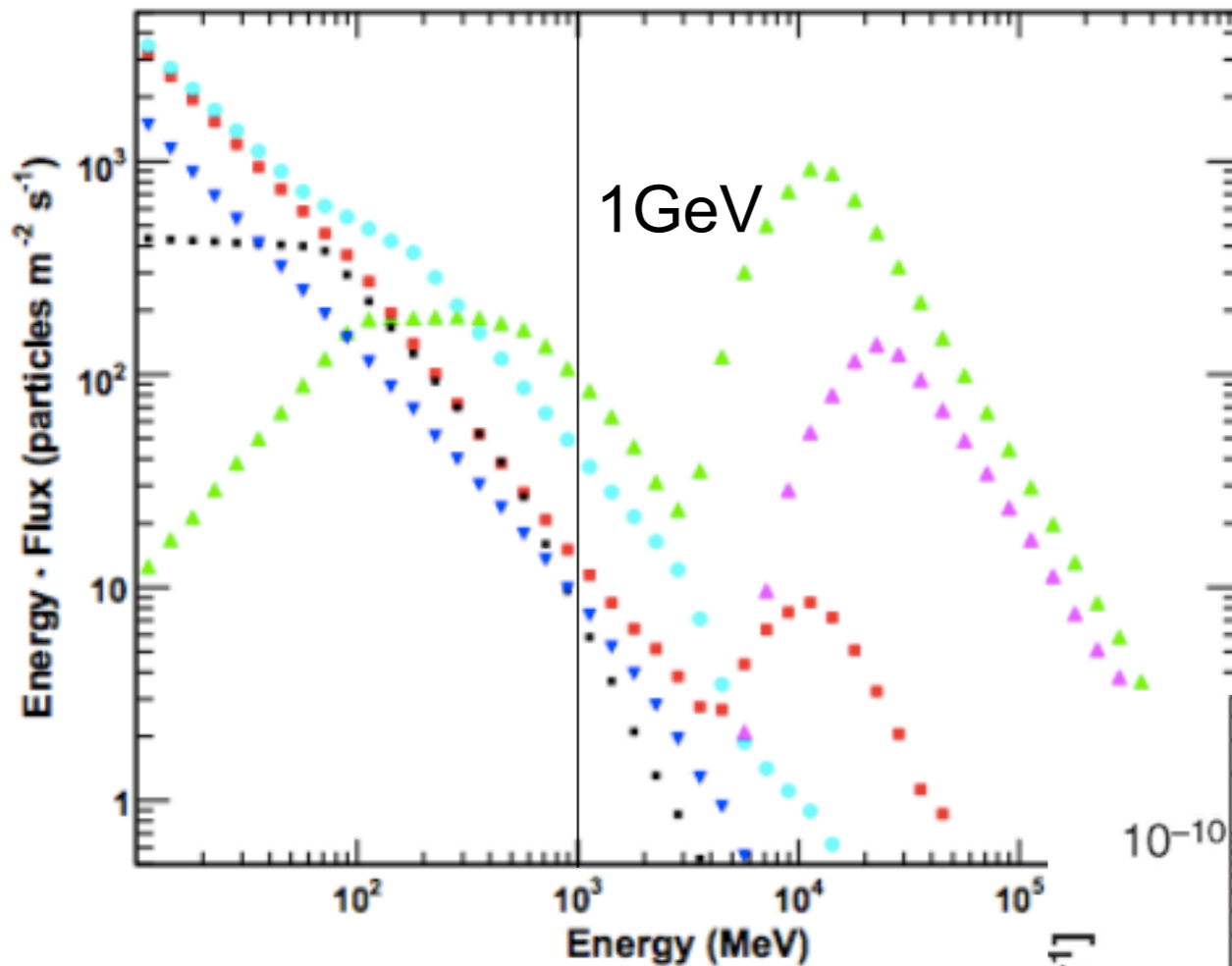
Backups



What Happens at the MeV scale?



- Fluxes shown as a function of total kinetic energy of particles



Backgrounds:

protons (green filled triangles up),
He (purple filled triangles up),
electrons (filled red squares),
positrons (light blue squares),
Earth albedo neutrons (black squares), and
Earth albedo γ -rays (dark blue filled triangles down).

Gamma-Ray production:
below 100 MeV gammas from π^0 decay drops

