Fermi Gamma-ray Space Telescope

Fundamental Physics / Dark Matter

R. Caputo
UCSC

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GammaSIG Session
HEAD meeting - Chicago

Overview

- 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

MeV Mission Assumptions

- **An idea of mission capabilities (typically MIDEX class)**

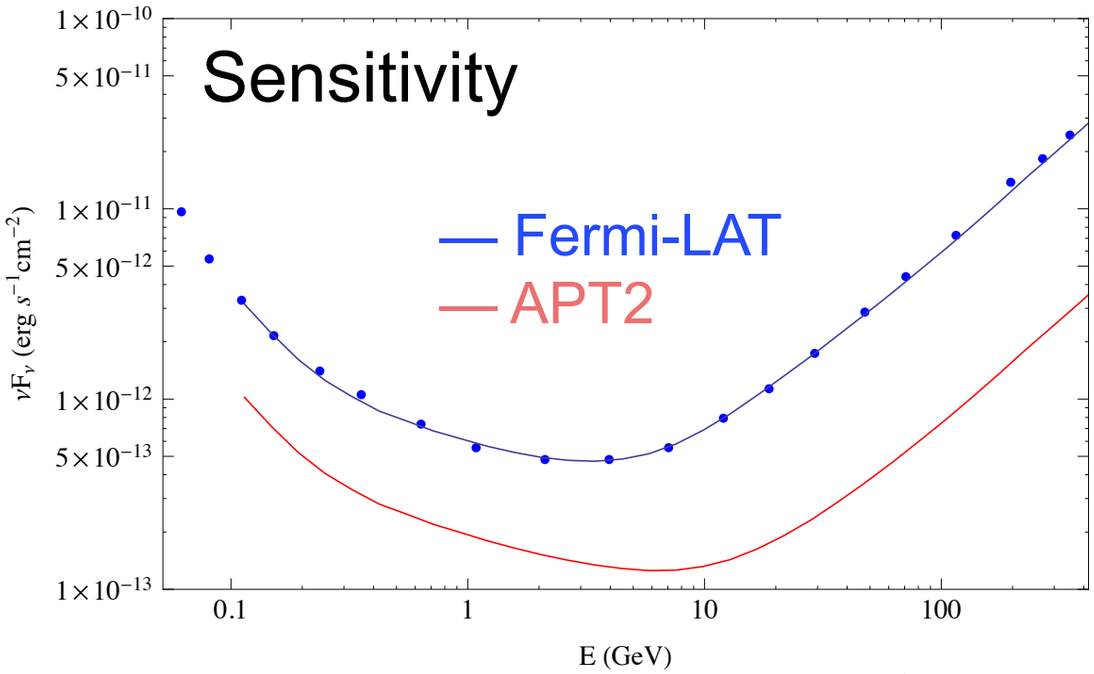
Mission	Energy Range [MeV]	Energy Resolution [$\Delta E/E$]	Angular Resolution	FOV	Flux Sensitivity [MeV cm^{-2}s^{-1}]
TPCs (polarimetry)					
AdEPT	5-200	~30% at 70 MeV	~0.6° at 70 MeV	3.14 m^{2}sr	<3×10^{-5}
LArGO	0.1 - 10^5	~3% at 1 MeV	~1° at 100 MeV	large (>2.5 sr?)	
HARPO	1-100	6/15/30% at 1/10/100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

GeV Mission Assumptions

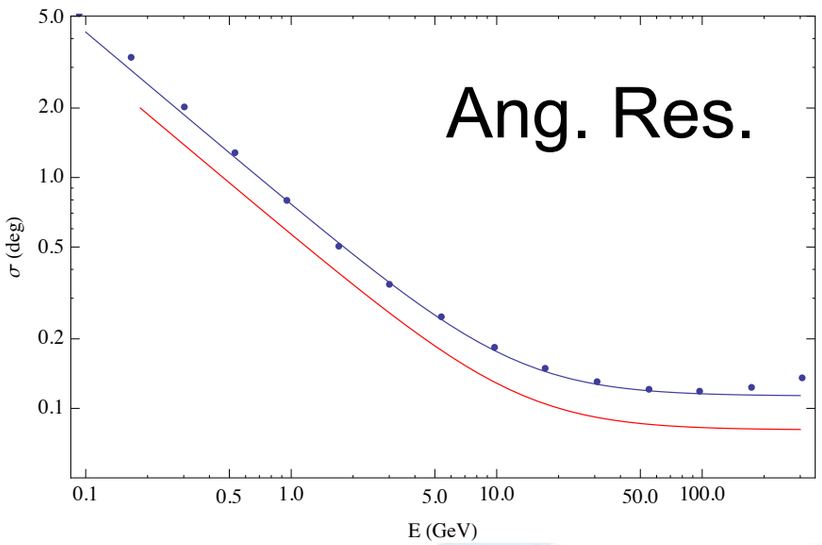
- **An idea of mission capabilities (Probe class)**

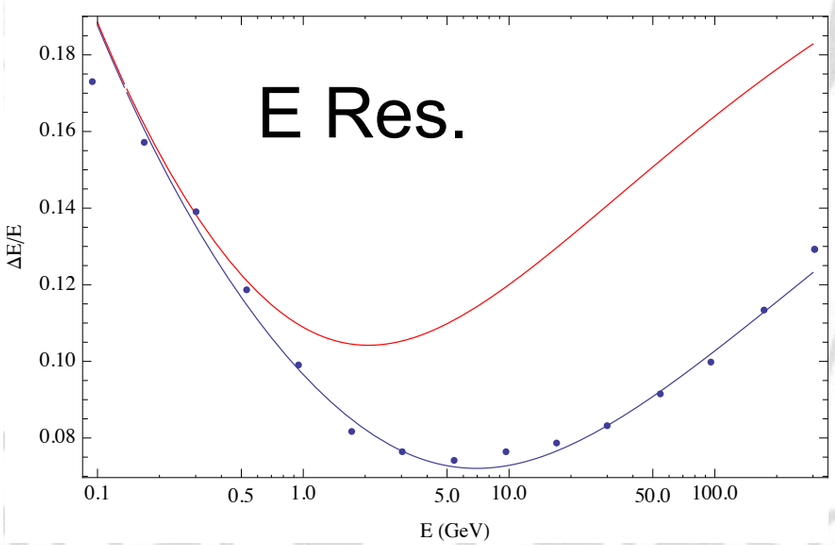


APT2

~1B$ instrument,

- 3mx5m scintillating fiber tracker,
- 3.5 times the mass of Fermi,
- 50 tracker layers,
- 5.5 radiation length calorimeter in LEO
- launched by a Falcon 9.





Goal: DM Dwarf sensitivity improved by x10

An attempt to get common parameters among missions
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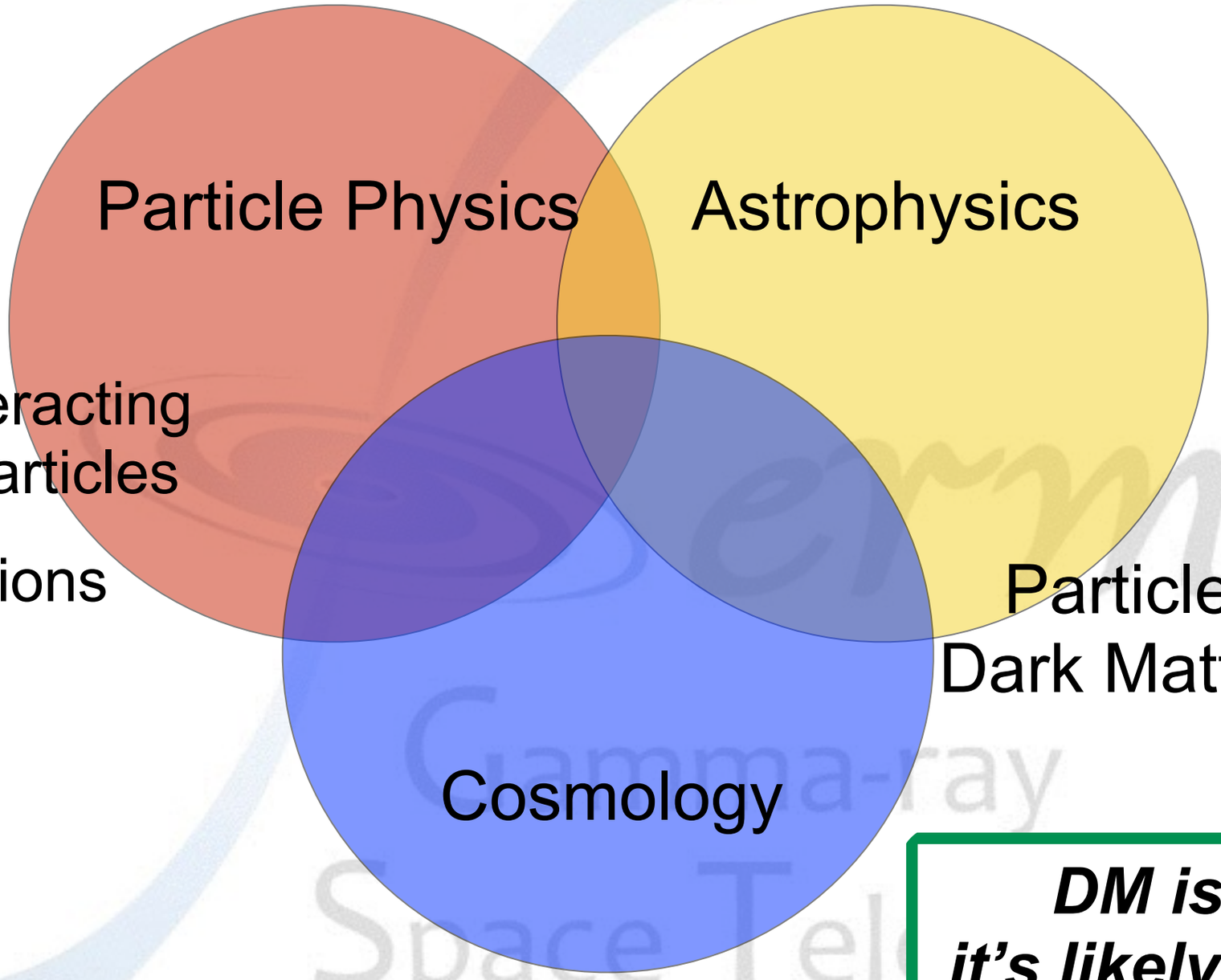
A brief history of Dark Matter



Weakly Interacting Massive Particles

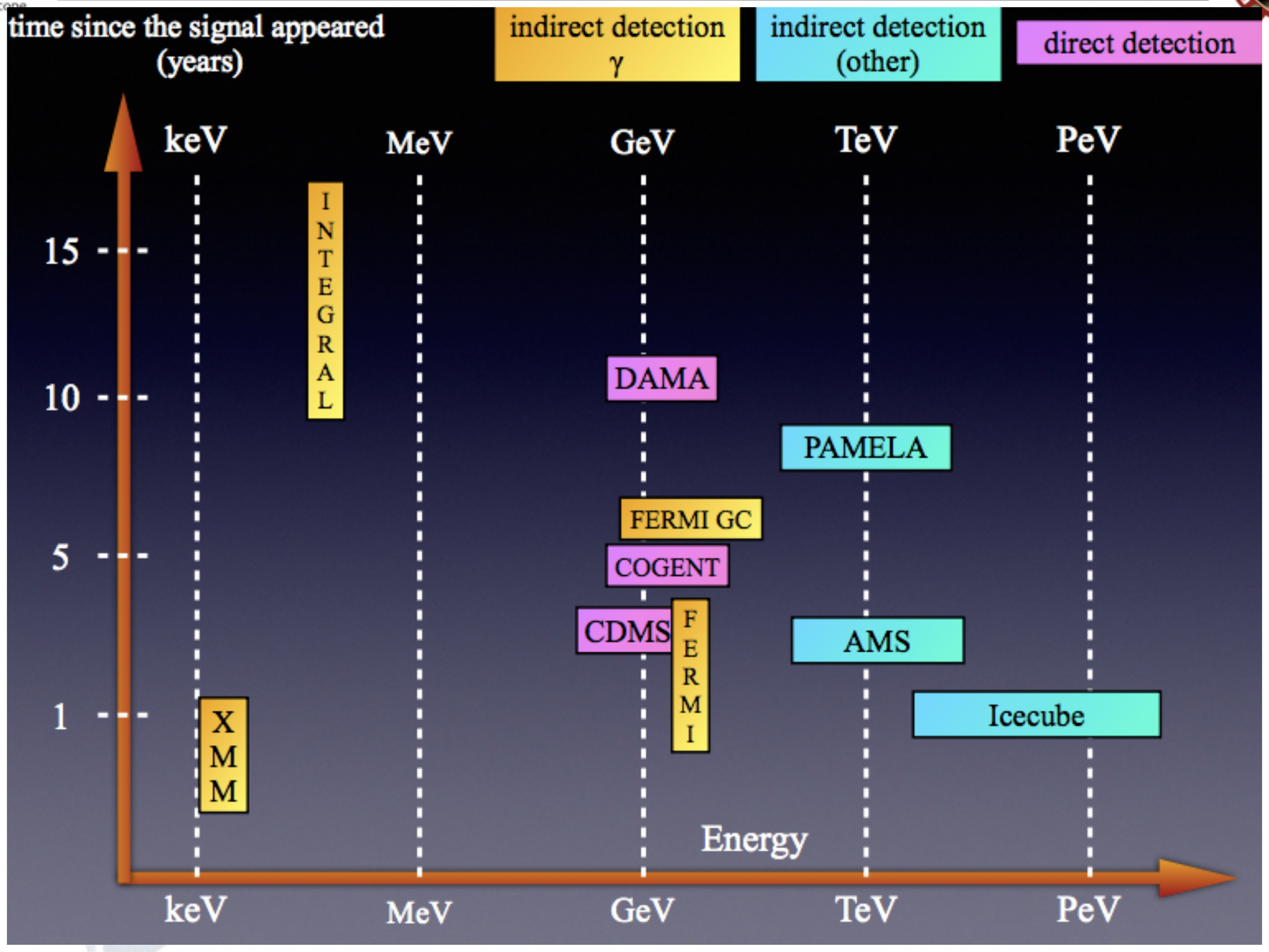
Axions

Particle Dark Matter

DM is there, it's likely a particle it could be many

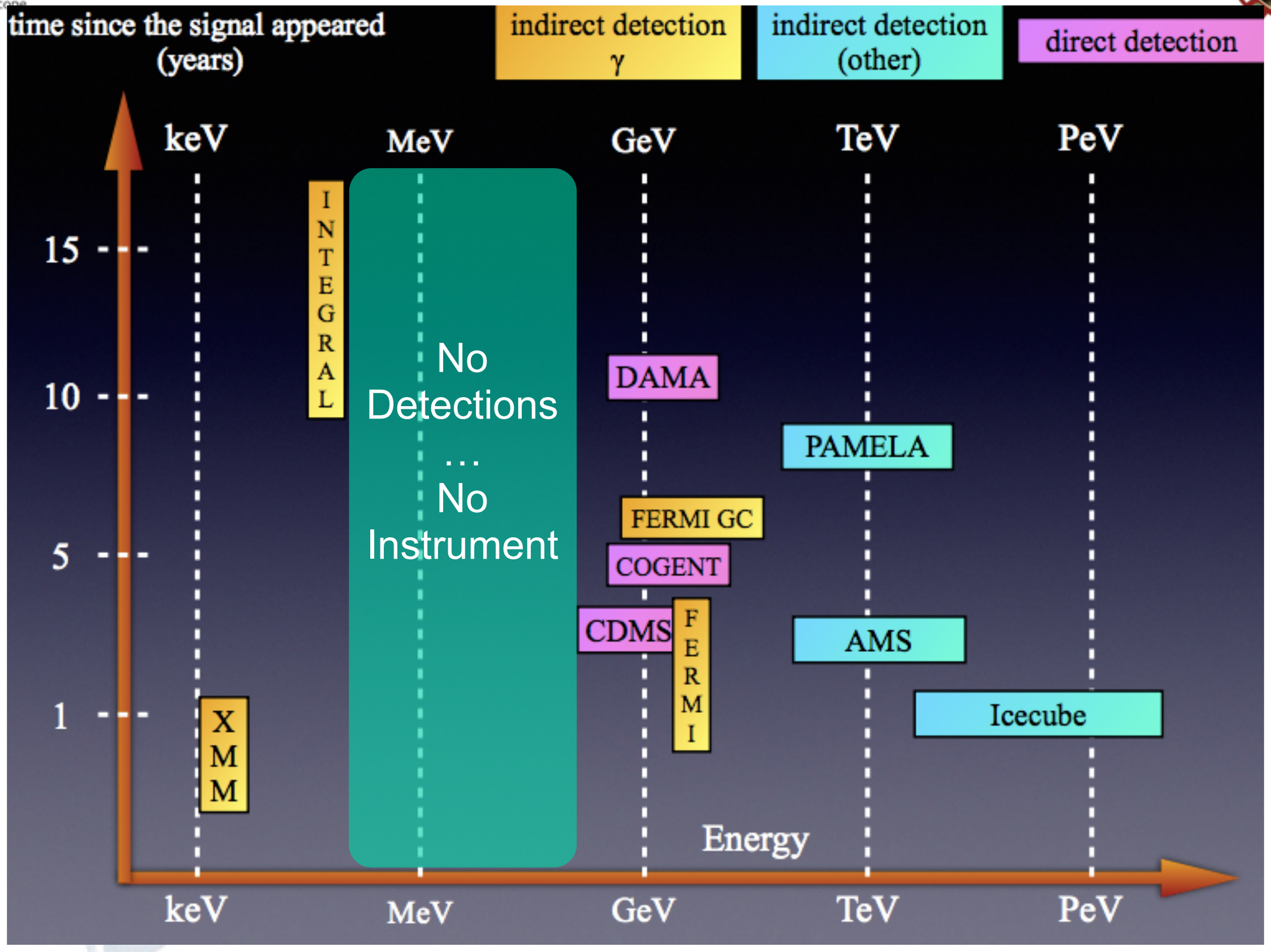
See J. McEnery's Talk from earlier today…

Dark Matter Detections



Slide from Y. Mambrini, 2nd AstroGAM workshop

Dark Matter Detections



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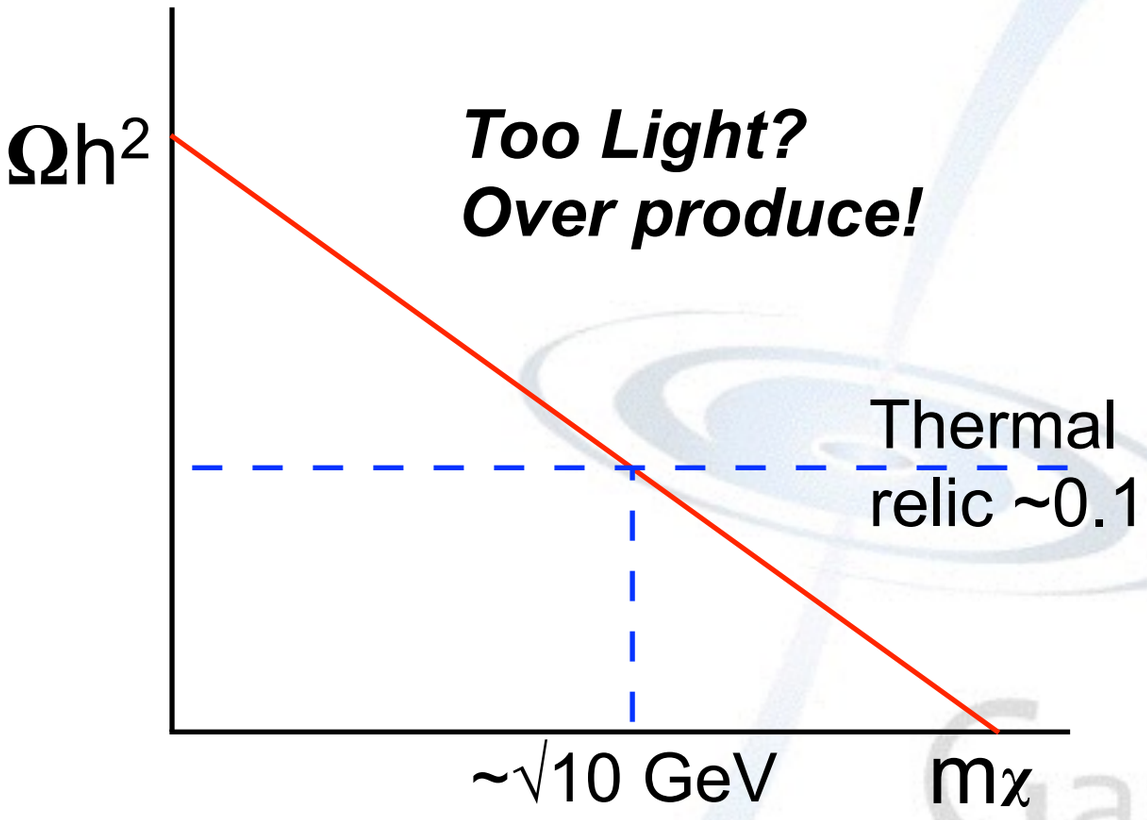
MeV Dark Matter

- **Why MeV (WIMP-ish) Dark Matter?**
  - **Lee-Weinberg: Cosmological lower bound on heavy neutrino mass (1977)**



Two Scenarios:

1. $G_F^2 m\chi^2 \Longrightarrow G'_F{}^2 m\chi^2$

   Non-SM interaction
   (not strictly Weakly Interacting)

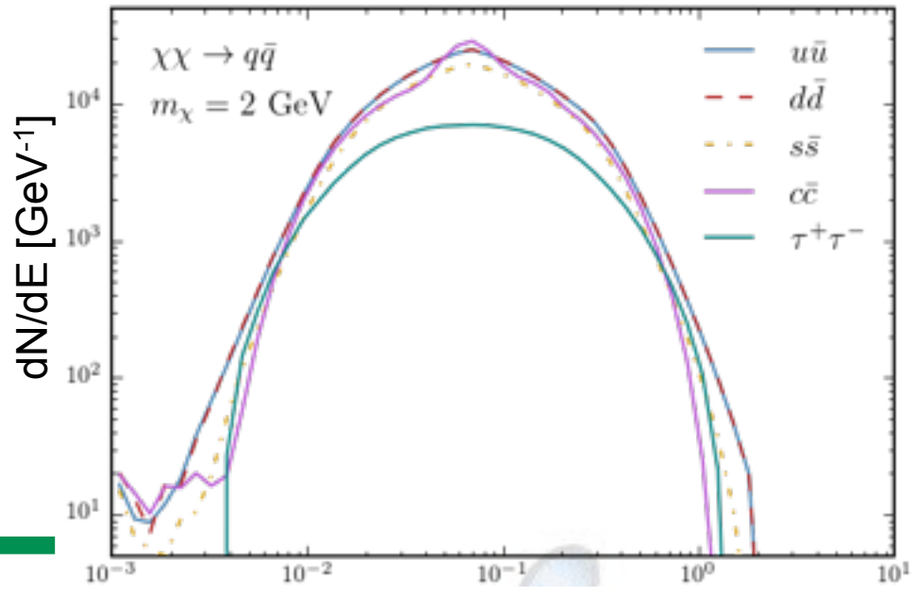
2. Or not strictly a thermal relic
   (bound by BBN ~1 MeV)

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

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	

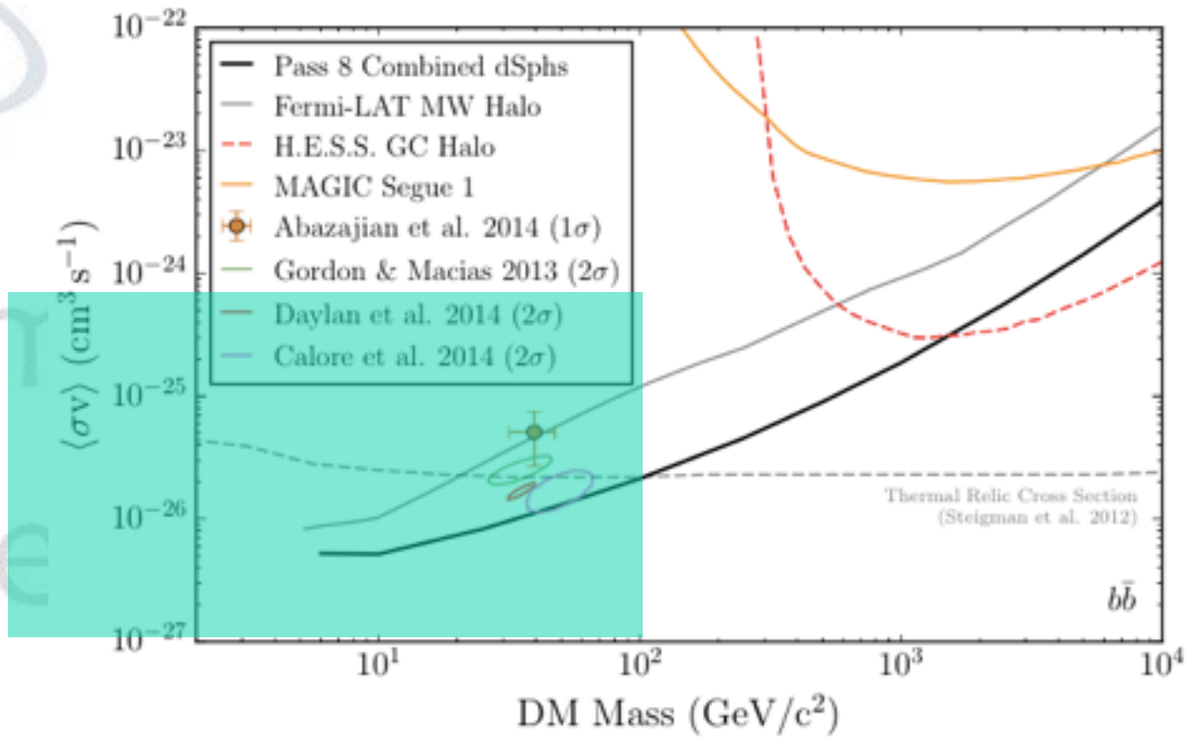
Scan new MeV DM parameter space to develop a gamma-ray spectrum



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

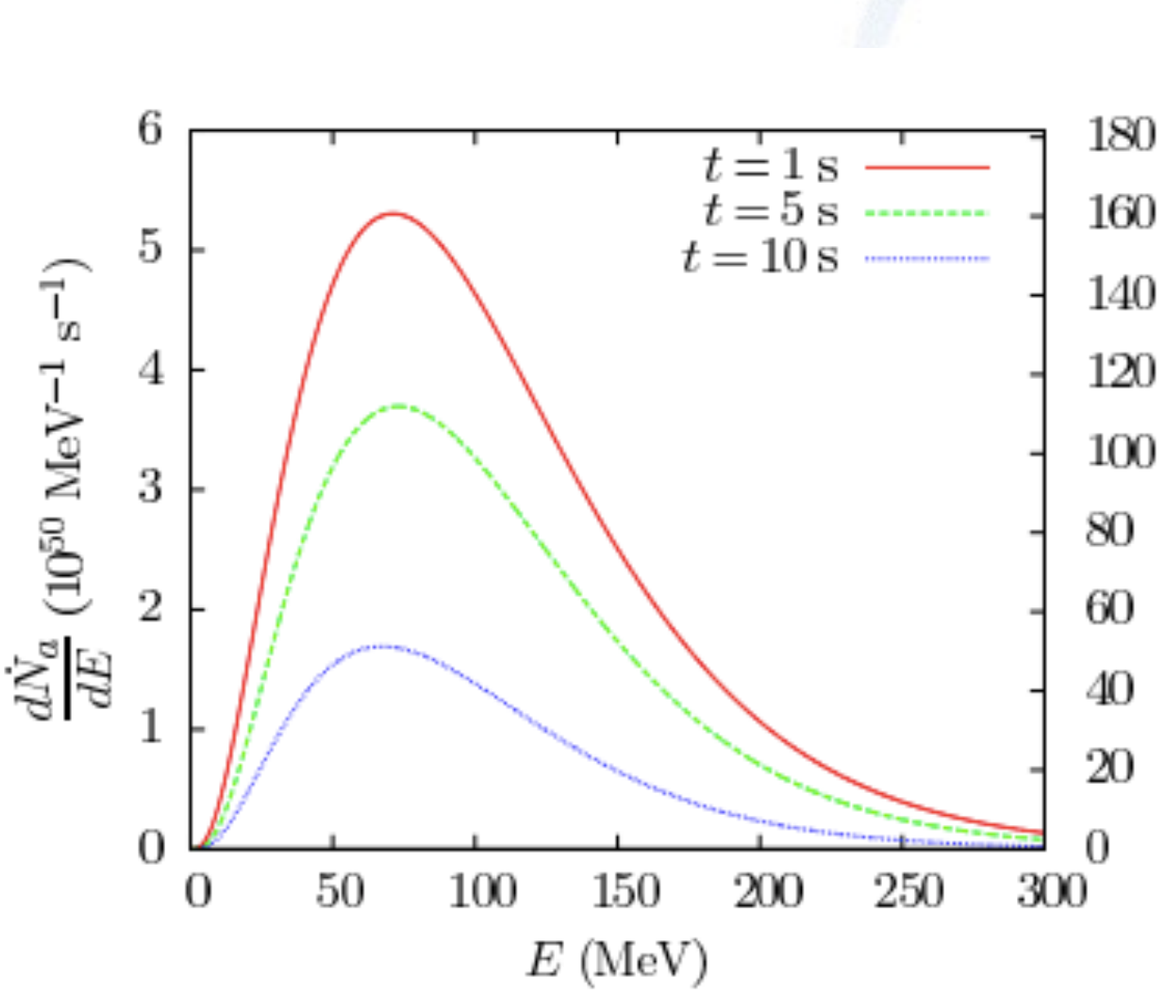
Complement current parameter space…

gamma-rays ~order(-1) DM mass

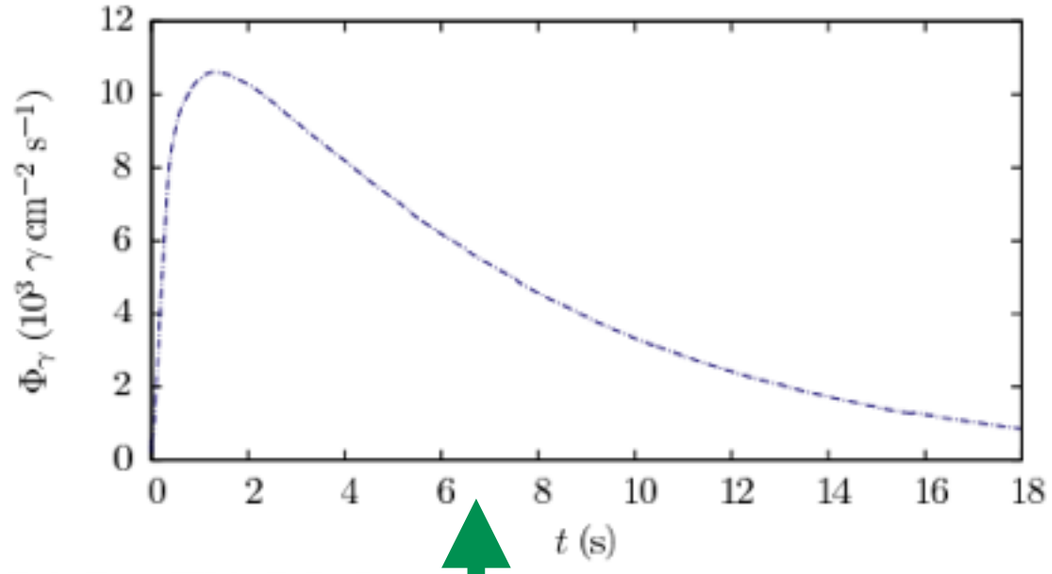


MeV Dark Matter

- **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)**



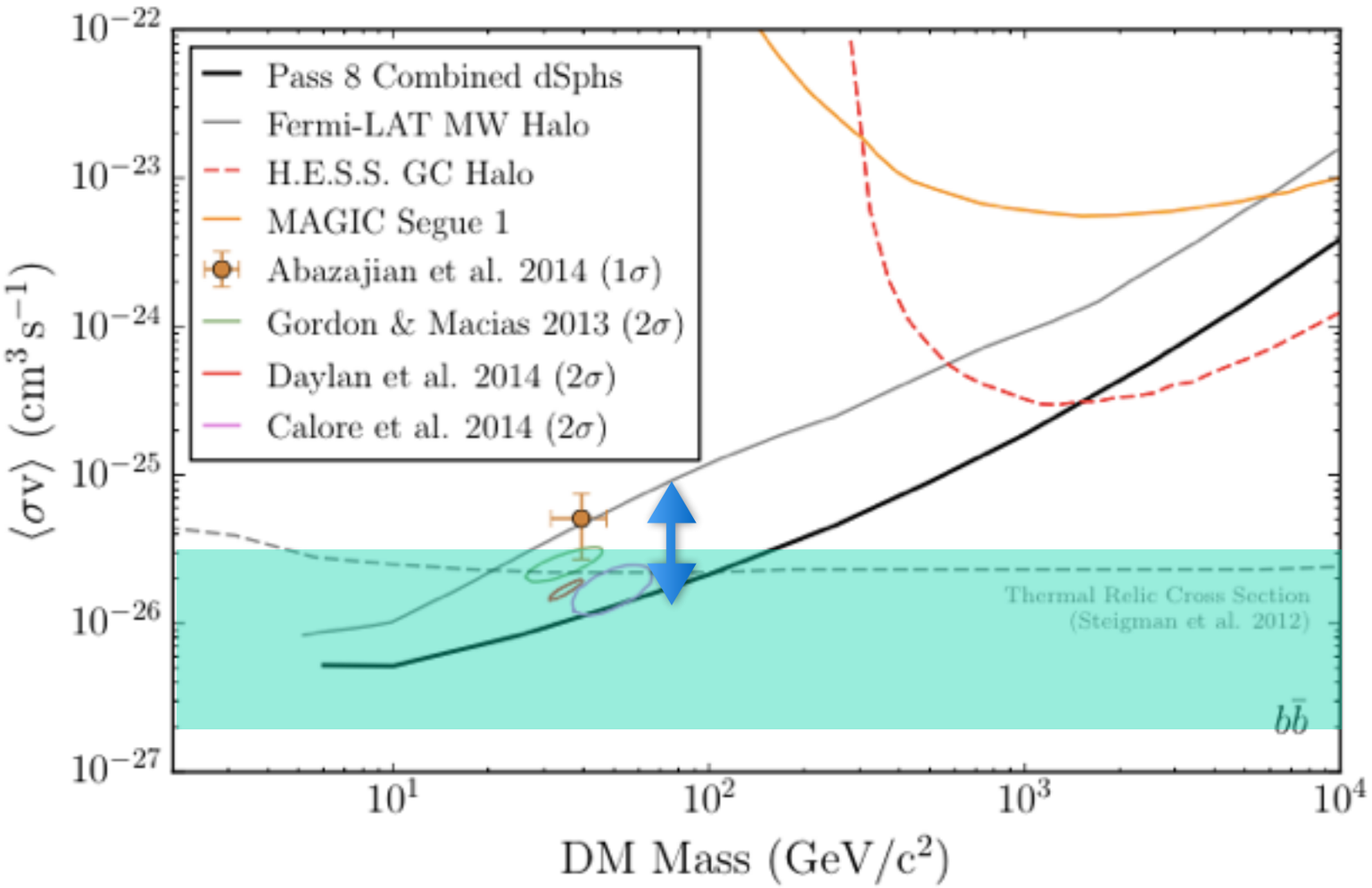
massless ALP
(m_a~10^{-11} eV)
with $g_{a\gamma} = 10^{-10}$ GeV^{-1}
18 M_{sol} progenitor



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

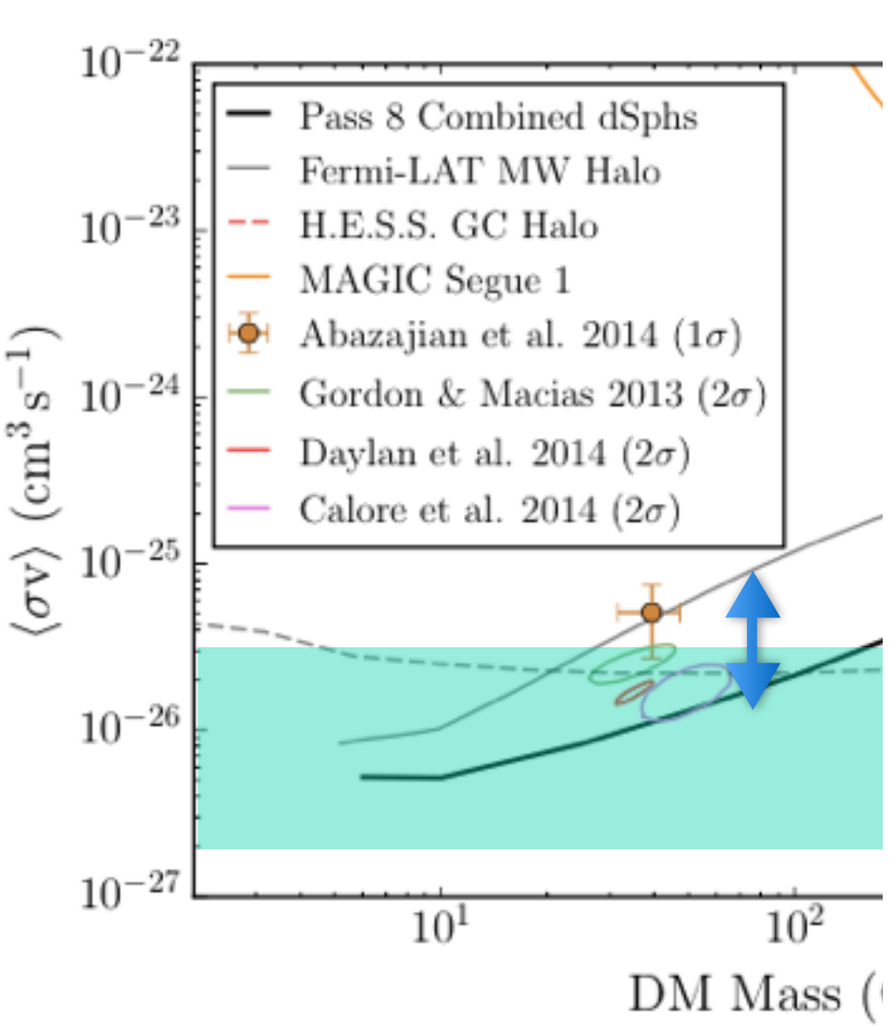
GeV Dark Matter

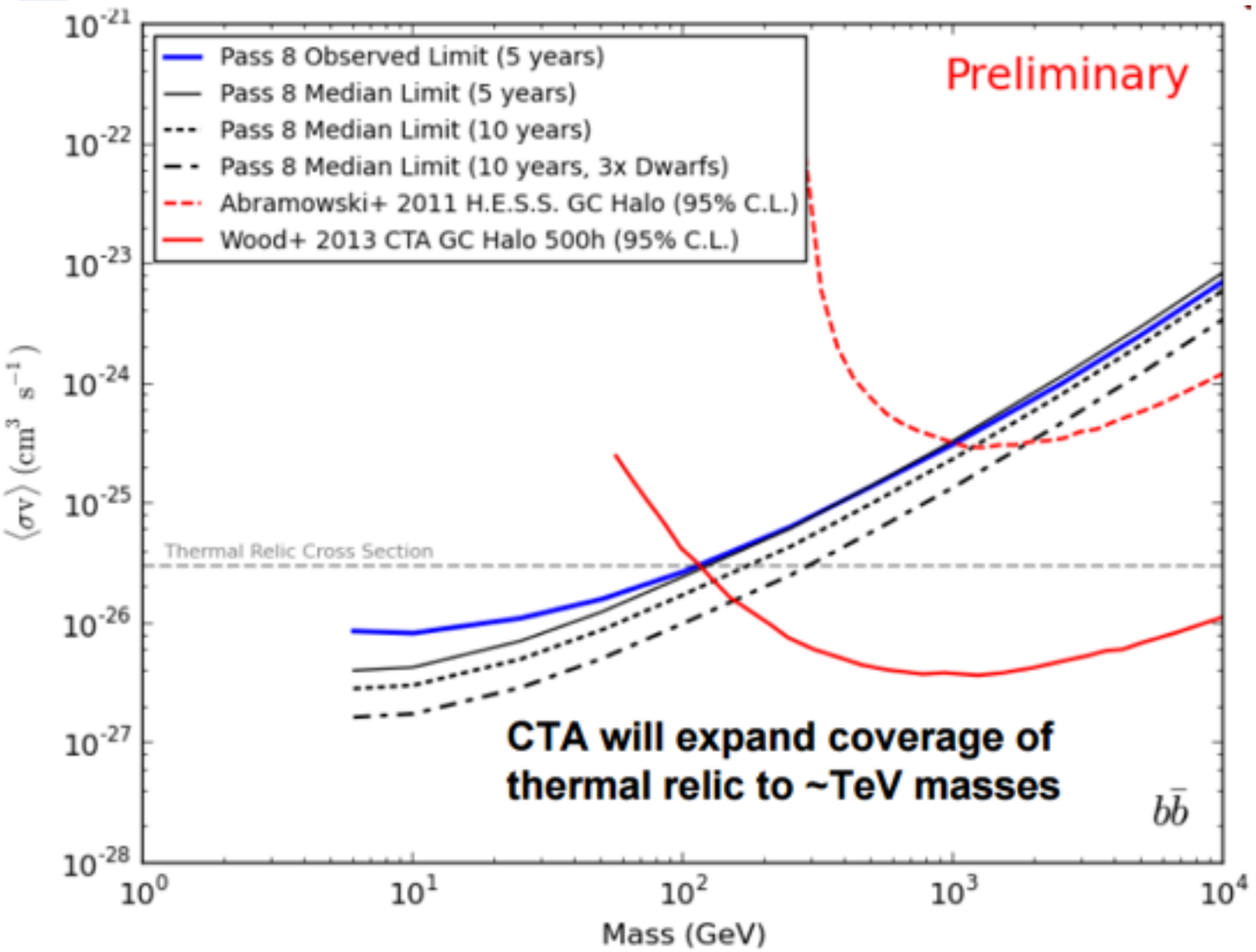
- GeV DM candidate is standard WIMP picture
  - Theoretically Motivated
- To cover thermal relic OM sensitivity needed



GeV Dark Matter

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



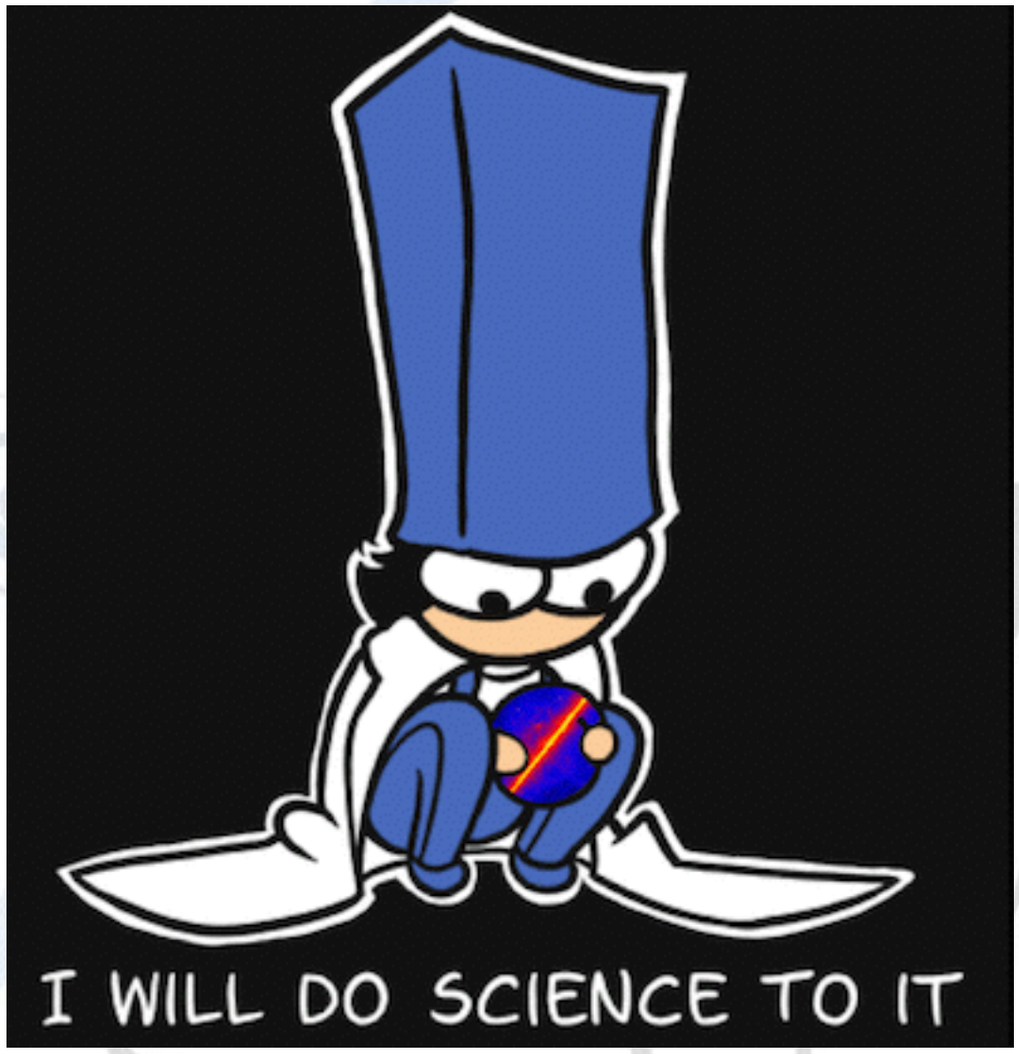


New/Fundamental Physics

- 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

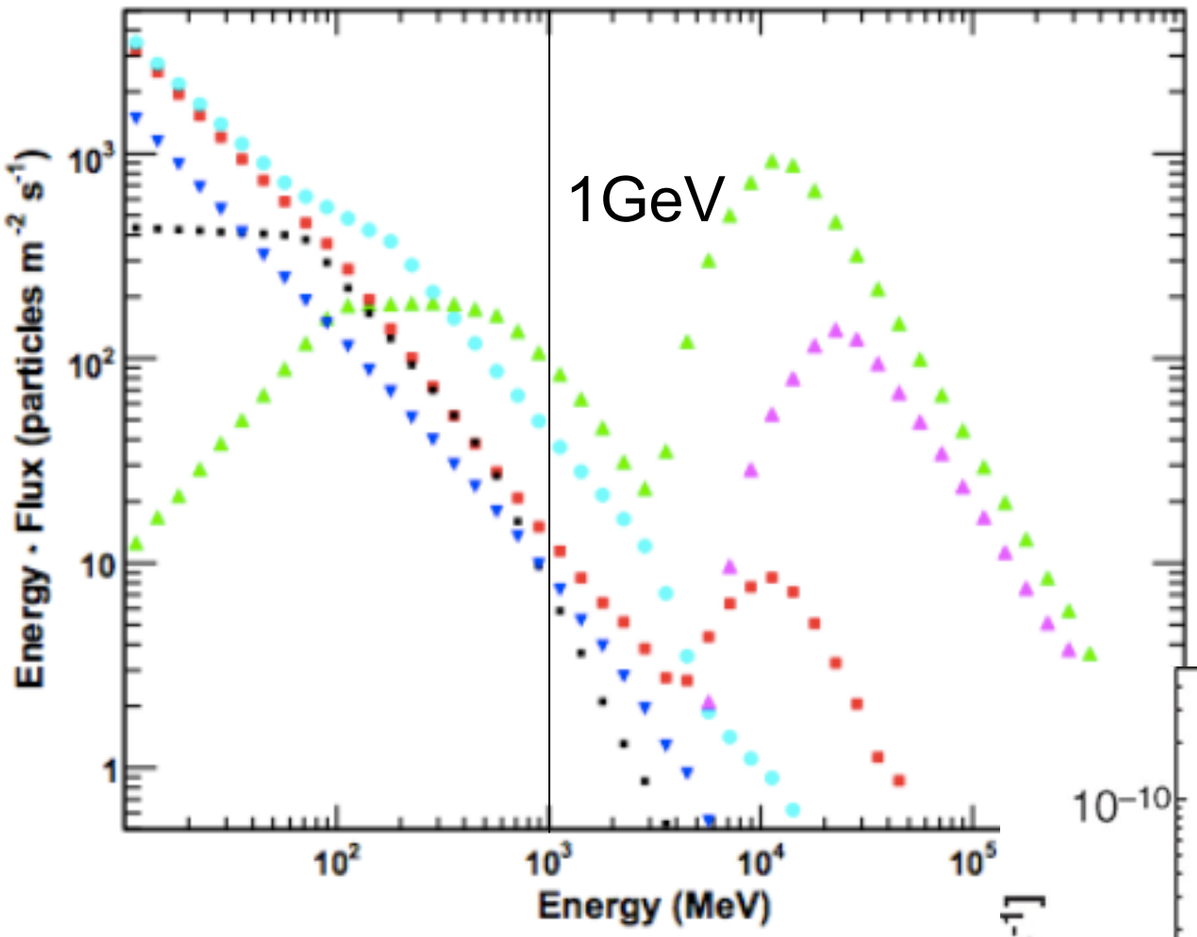
http://astrogam.iaps.inaf.it/Program_Astrogam2.html

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