Indirect Dark Matter Searches with GRAMS (Gamma-Ray and Anti-Matter Survey)

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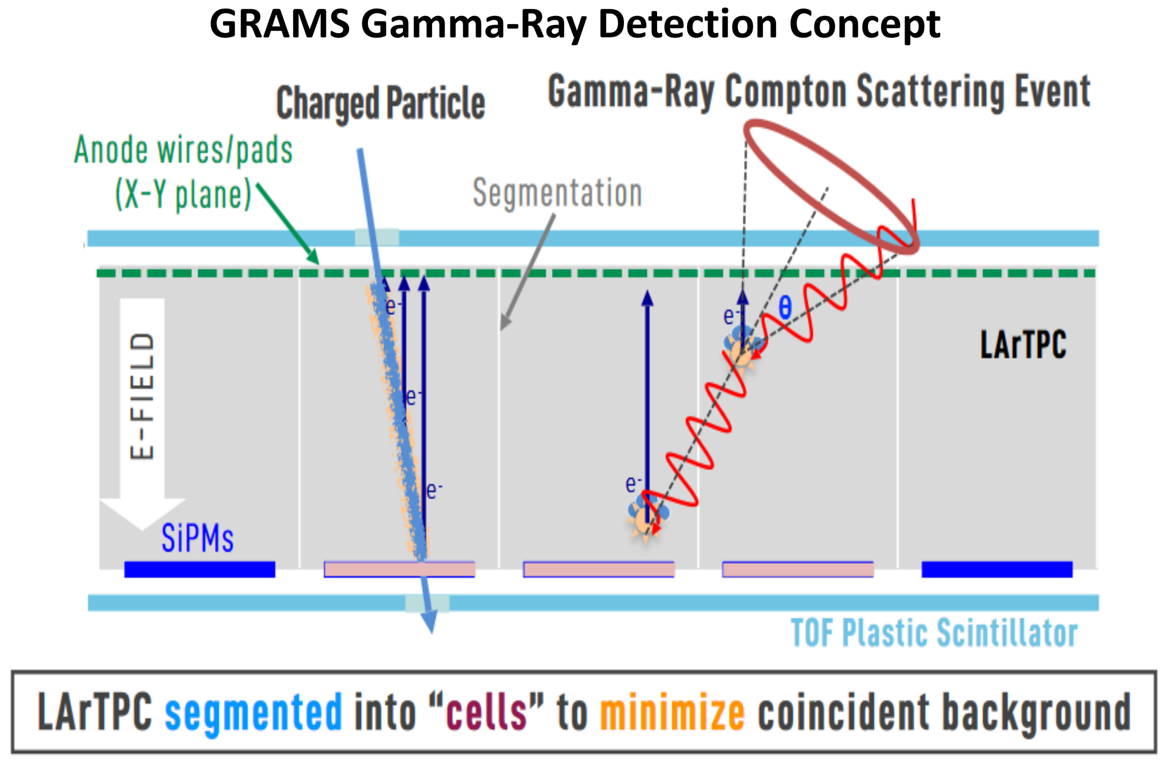
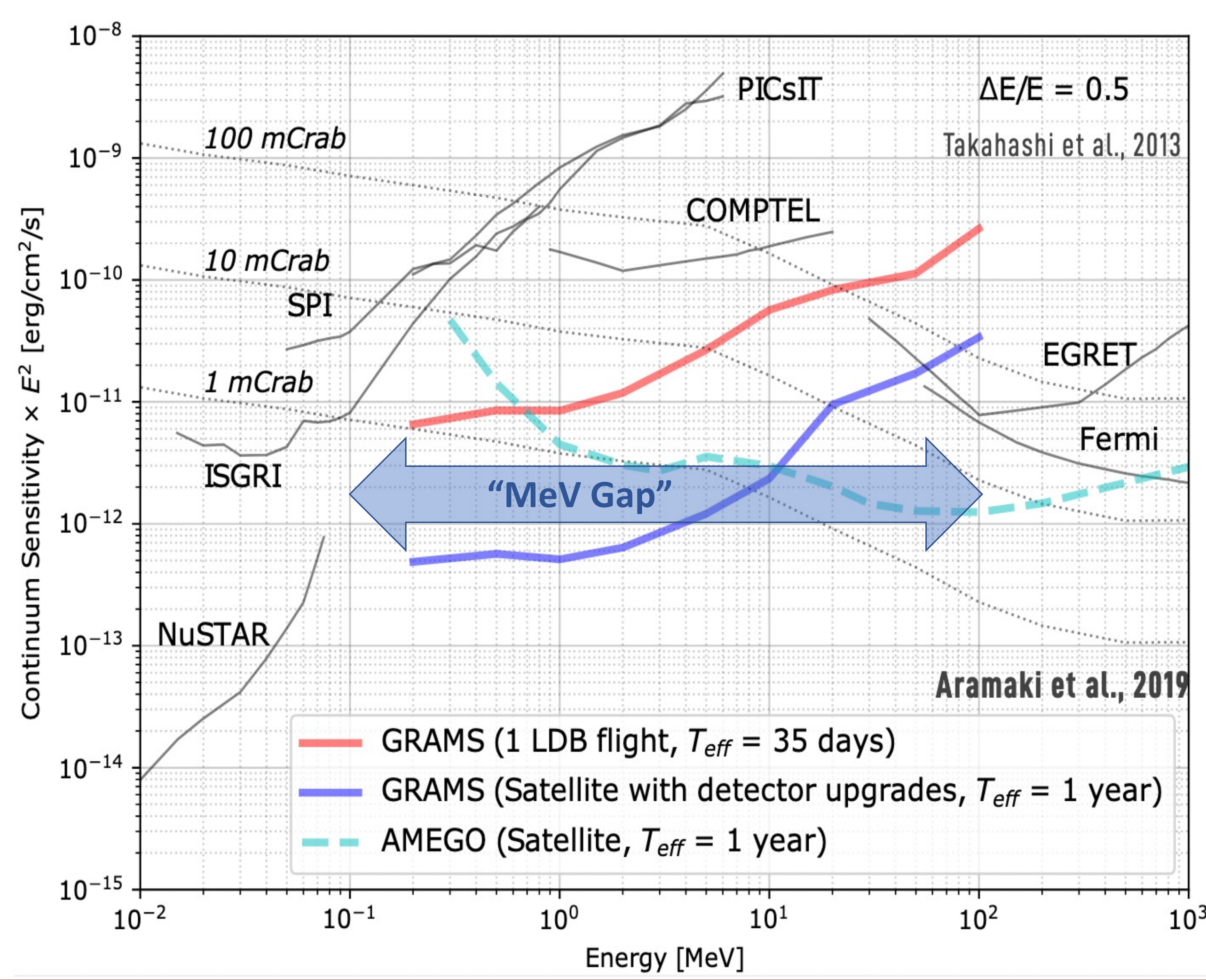
Introduction

The upcoming GRAMS (Gamma-Ray and AntiMatter Survey) experiment aims to provide exceptional sensitivity to a poorly explored region of the cosmic gamma-ray spectrum from ~0.1-100 MeV, often referred to as the "MeV gap". A closer look at this energy range will likely uncover crucial details behind a variety of processes in multi-messenger astrophysics and lend to the indirect search for dark matter (DM). The focus of this work investigates the potential for GRAMS to place new constraints on particle (DM) by searching for anomalous gamma-ray signals that can theoretically be explained by the annihilation of DM or the Hawking radiation from evaporating primordial black holes (PBHs).

GRAMS Gamma-Ray Detection Concept



T. Aramaki, et al, 2021

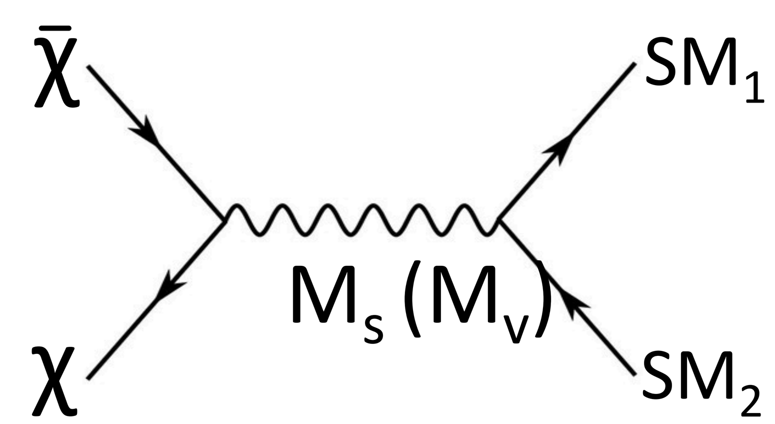


Dark Matter Signatures in Gamma Ray Spectrum

$$\left.\frac{dN}{dE_\gamma}\right|_{\bar{\chi}\chi} = \left.\frac{dN}{dE_\gamma}\right|_{\bar{\chi}\chi,\text{line}} + \left.\frac{dN}{dE_\gamma}\right|_{\bar{\chi}\chi,\text{dec.}} + \left.\frac{dN}{dE_\gamma}\right|_{\bar{\chi}\chi,\text{FSR}}$$

Prompt photon emission — Annihilation into light leptons

$$\left.\frac{d\Phi}{dE_\gamma}\right|_{\bar{\chi}\chi}(E) = \frac{\Delta\Omega}{4\pi}\cdot\frac{\langle\sigma v\rangle_{\bar{\chi}\chi}}{2 f_\chi m_\chi^2}\cdot J\cdot\left.\frac{dN}{dE_\gamma}\right|_{\bar{\chi}\chi}(E).$$

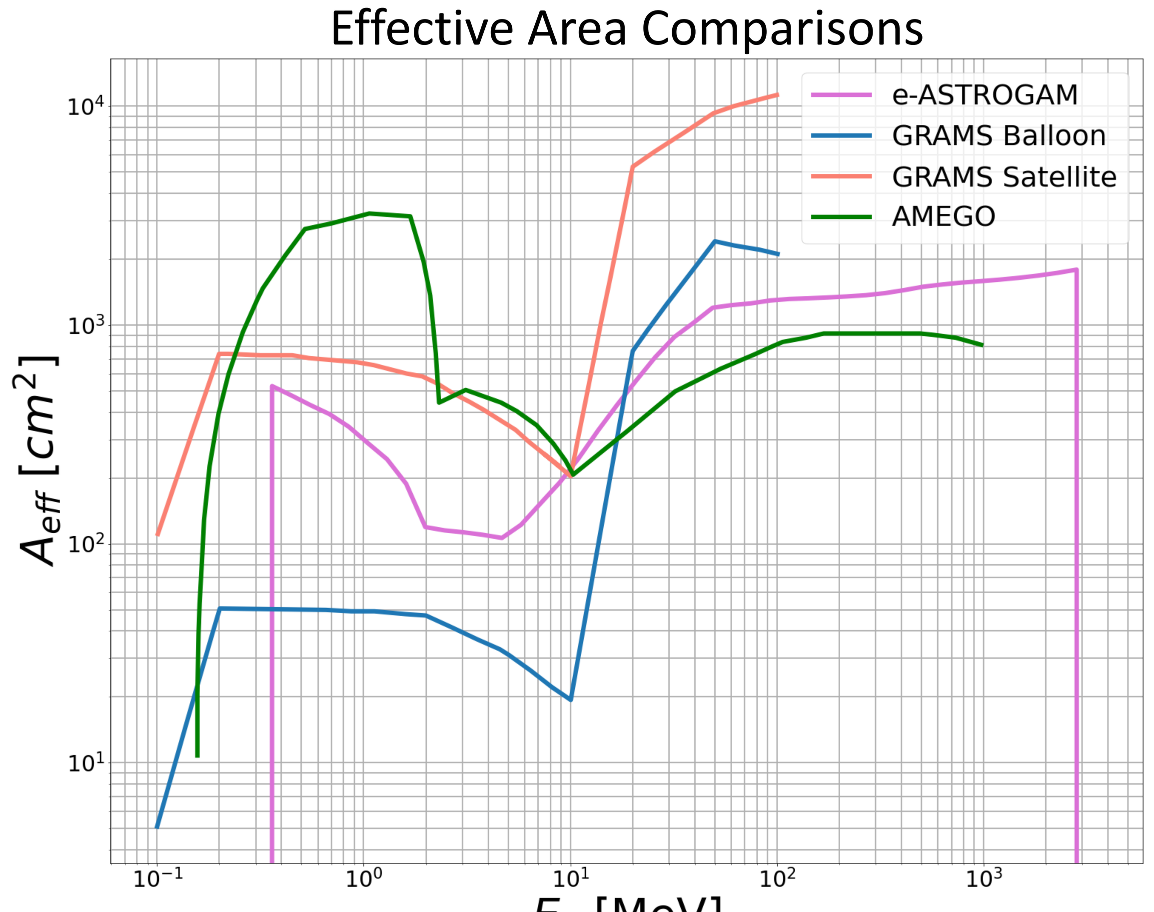


Bosonic channels:
χχ → γγ
χχ → π⁰γ

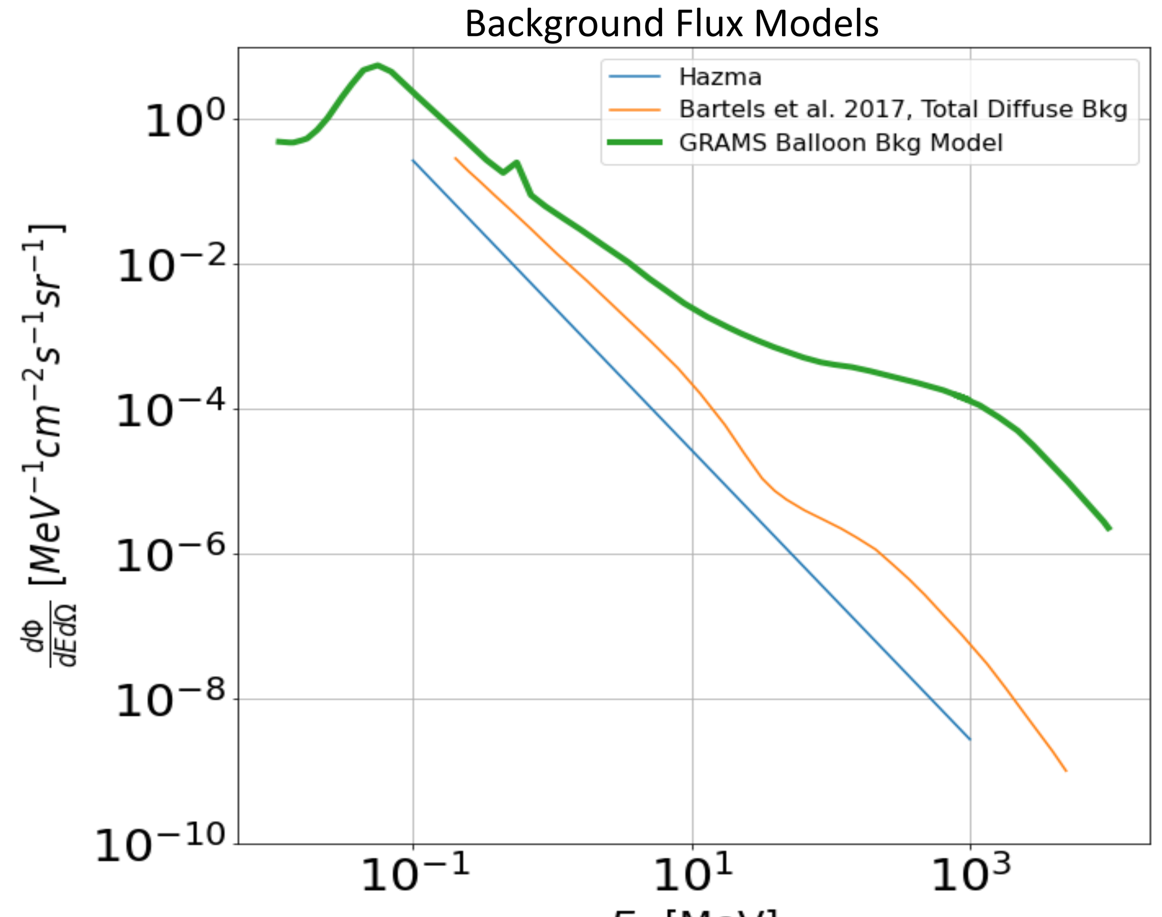
Leptonic Channels:
χχ → e⁺e⁻
χχ → μ⁺μ⁻

Effective Area and Background Models

Effective Area Comparisons



Background Flux Models

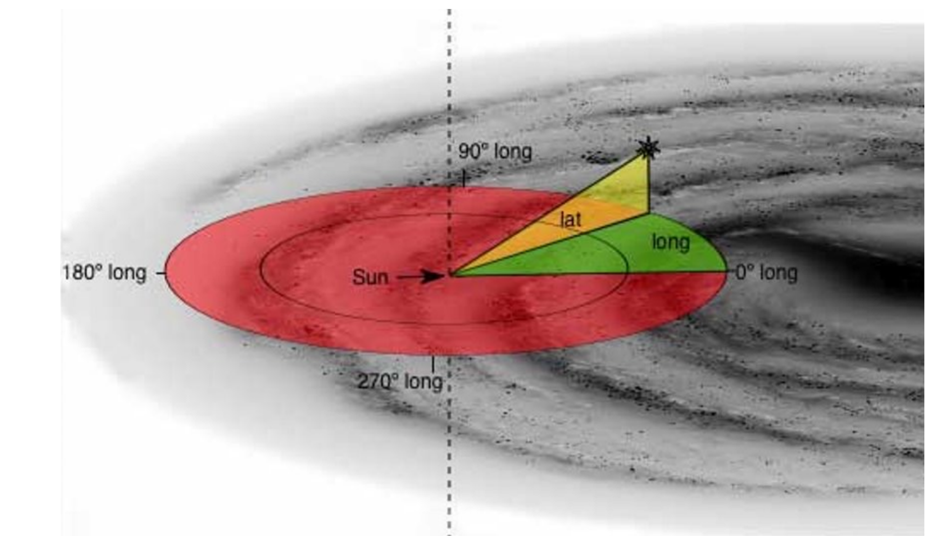


Assumptions for Sensitivity Projections

- Considering Navarro-Frenk-White DM density profile
- ROI: Milky Way galactic center, b < 10°, l < 10° window

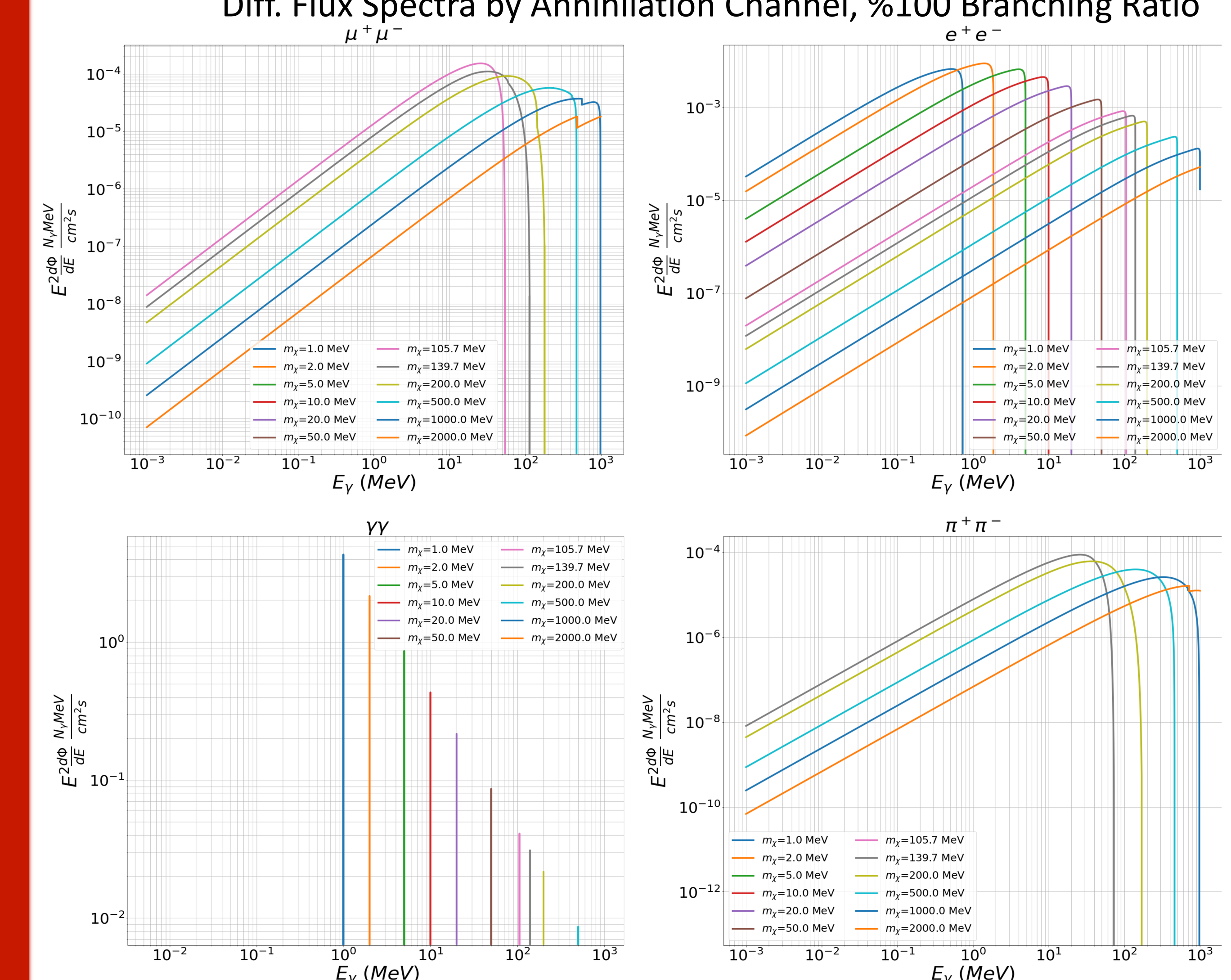
$$N_{\gamma BG} = \int_{ROI}\int_{E_{min}}^{E_{max}} T_{obs} A_{eff}(E) \left.\frac{d\Phi}{dE}\right|_{BG}(E)\cdot dE\, d\Omega$$

$$\frac{N_\gamma}{\sqrt{N_{BG}+N_\gamma}} \geq n_\sigma$$, where n_σ = significance level

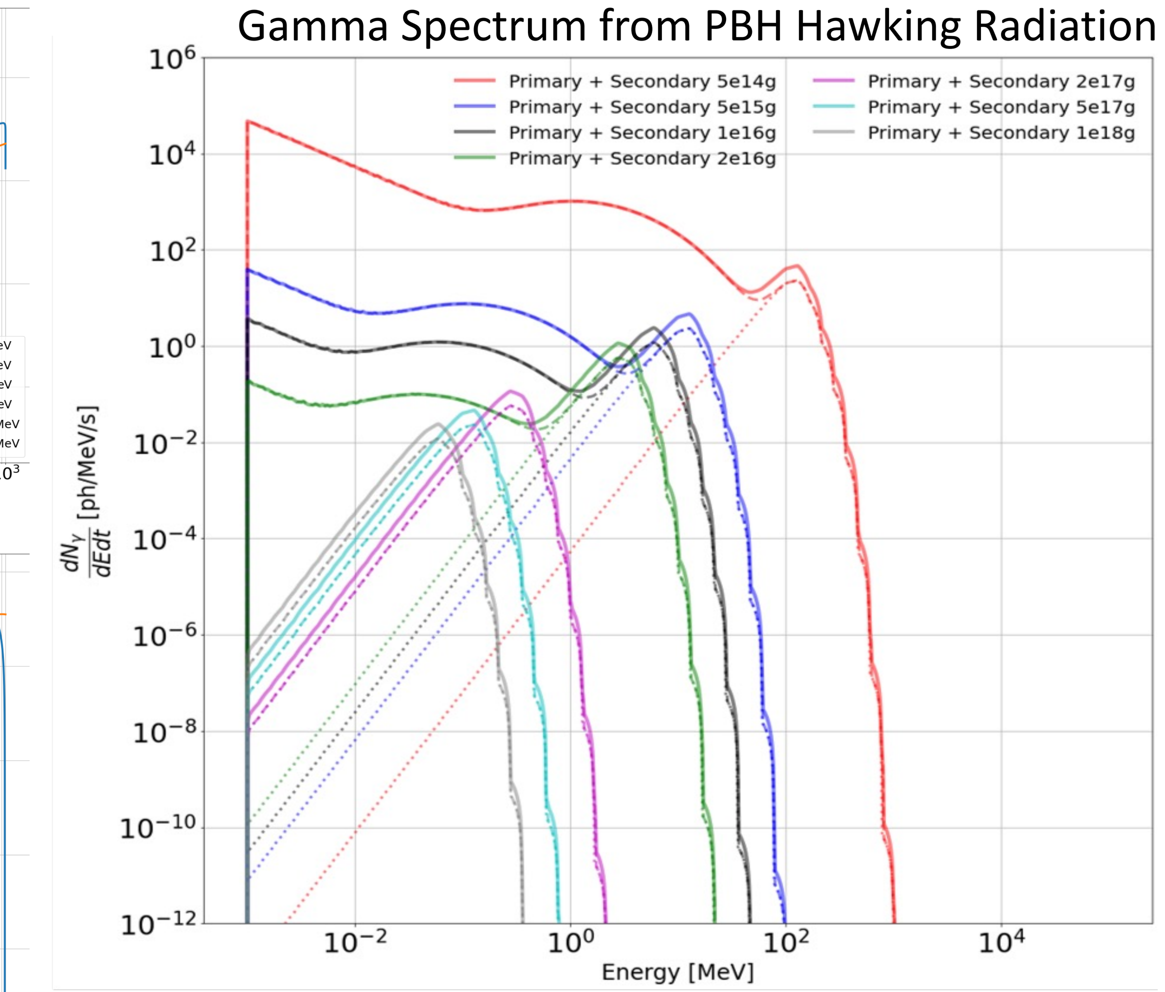


Differential Flux Spectra from DM Annihilation and PBH Evaporation

Diff. Flux Spectra by Annihilation Channel, %100 Branching Ratio

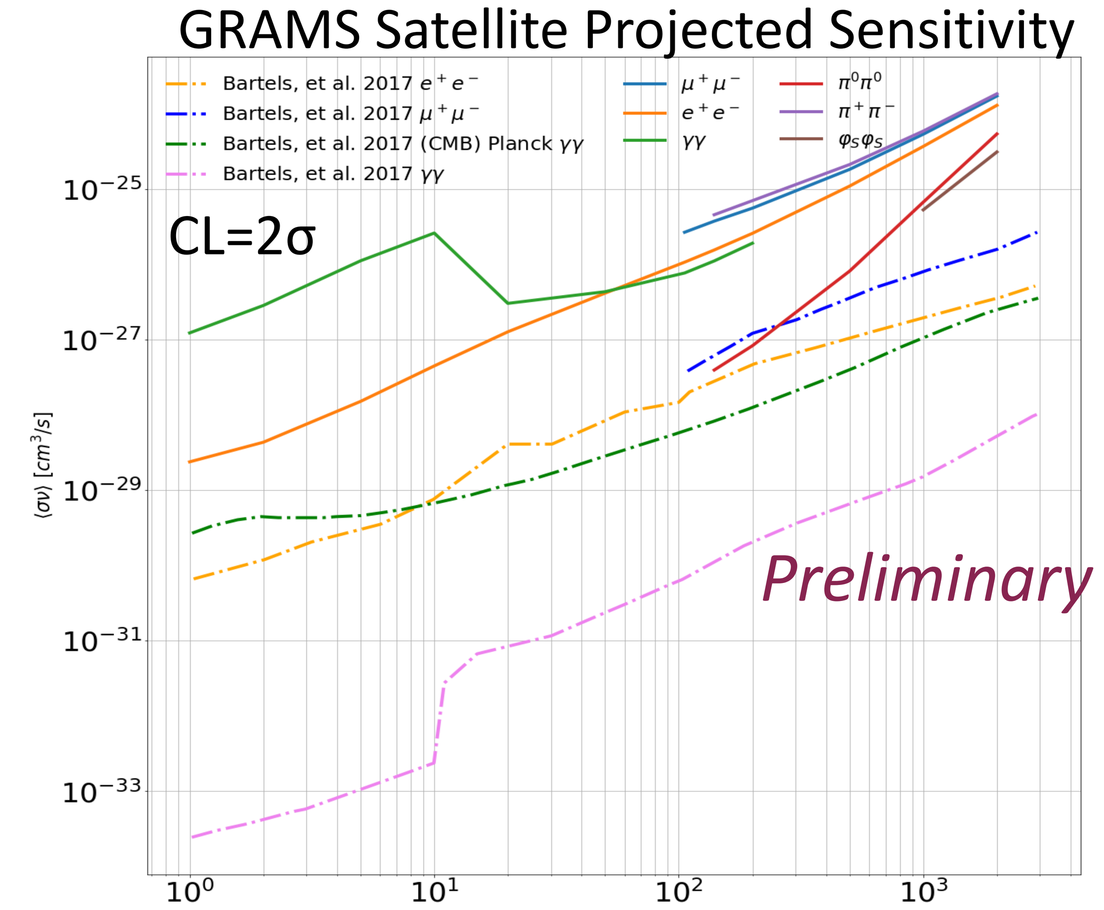


Gamma Spectrum from PBH Hawking Radiation

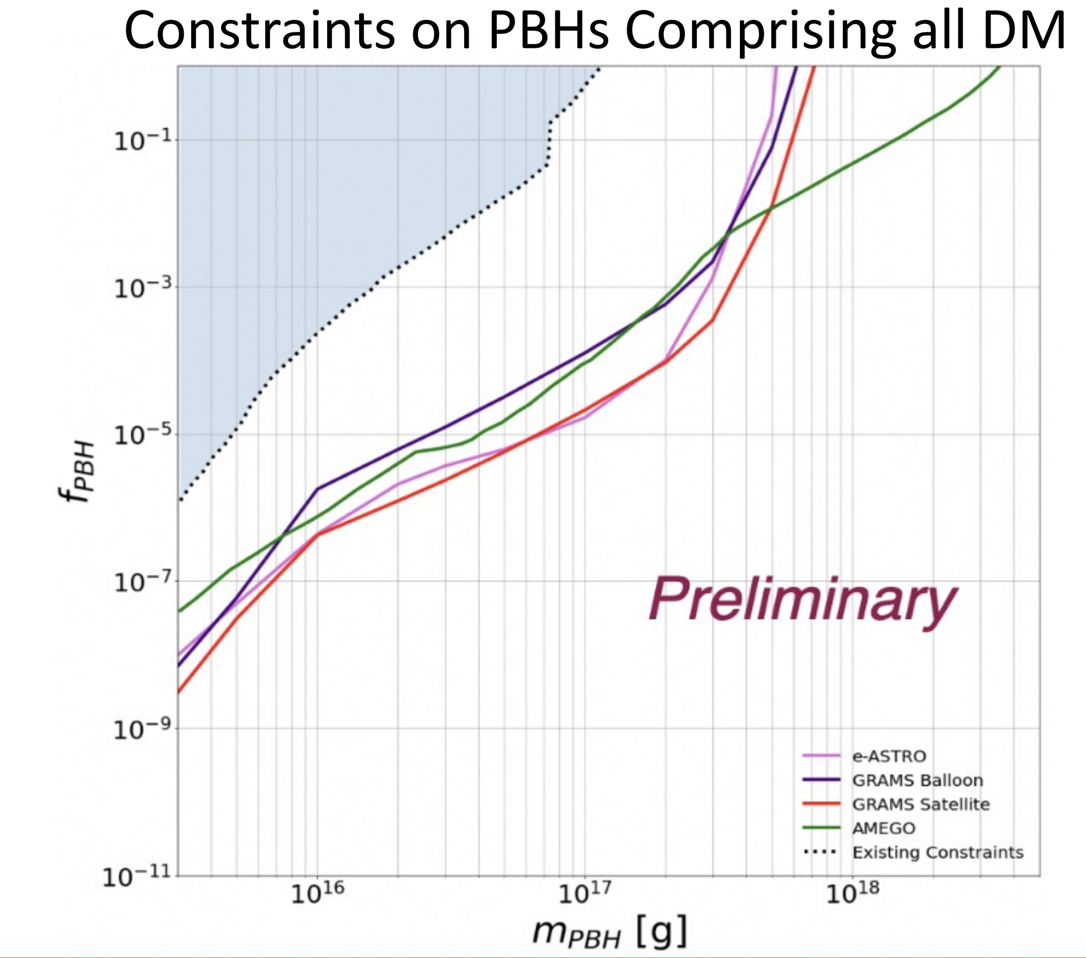


Projected Sensitivities and Summary

GRAMS Satellite Projected Sensitivity



Constraints on PBHs Comprising all DM



References

[1] T. Aramaki, P. Adrian, G. Karagiorgi, et al. Astroparticle Physics, 2020, 114: 107-114.
[2] A. Coogan, L. Morrison, S. Profumo, arXiv:1907.11846, 2019
[3] R. Bartels et al., arXiv:1703.02546, 2017