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Research Interests

Electroweak Symmetry Breaking & Naturalness

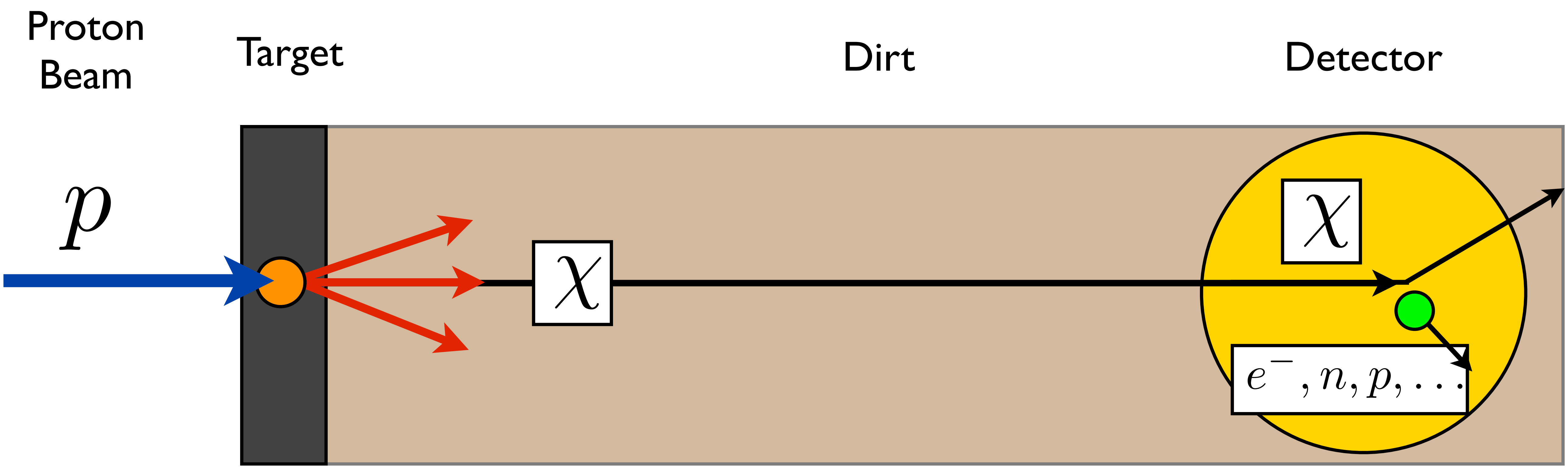
- SUSY, Composite Higgs, Extra Dimensions
- Collider Phenomenology, Higgs properties, Electroweak precision & Flavor

Dark Matter

- WIMPs (Collider, Direct Detection, Indirect detection)
- Alternative theories (e.g. hidden/dark sectors, new stabilization symmetries) and phenomenology

Dark Matter at Fixed Target Experiments

Relativistic Dark Matter Beam!



[BB, Pospelov Ritz, '09]

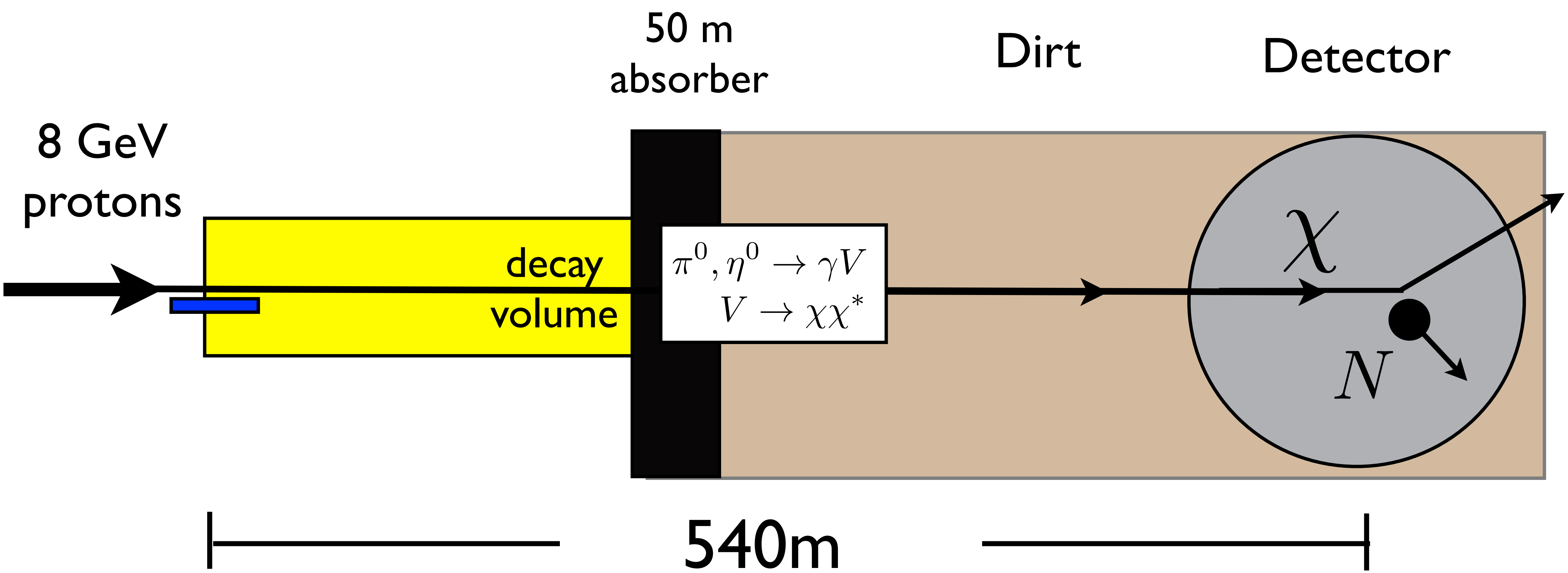
- Superior sensitivity for many models with light DM + light mediator
- Provides a strong motivation for intense proton sources like SPS
- Can also use fixed target experiments to probe a variety of light, weakly coupled exotics. See e.g. the proposed SHiP experiment at CERN http://ship.web.cern.ch/ship/

MiniBooNE Beam Dump Run

First dedicated dark matter search of its kind

Very similar to neutrino induced neutral current event!

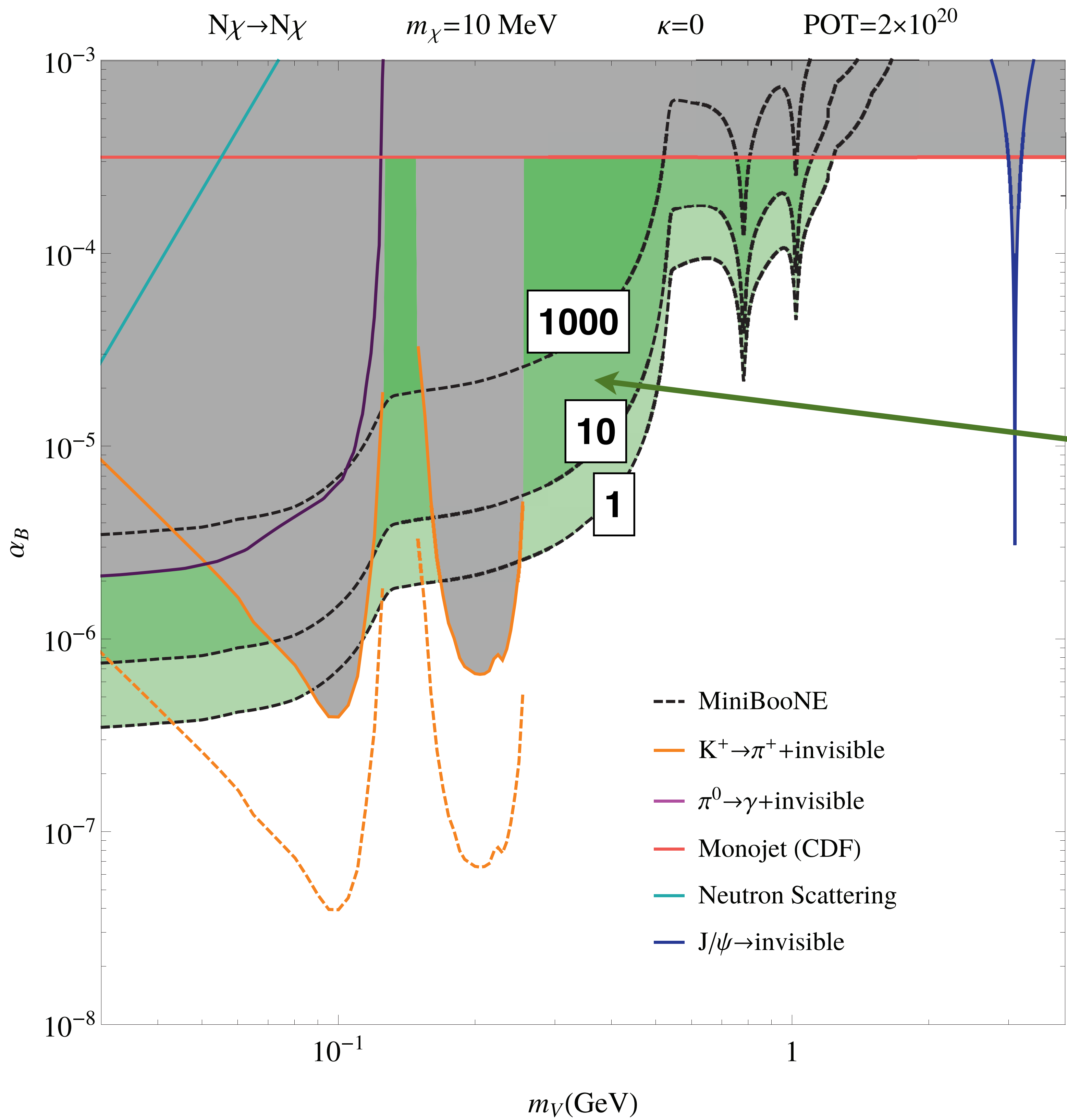
Focus protons onto the beam dump - charged pions absorbed or stopped



Neutrino background reduced by factor of ~ 50!

MiniBooNE sensitivity to leptophobic DM

[BB, deNiverville, McKeen,Pospelov, Ritz, '14]



MiniBooNE signal

Unique sensitivity over much of the parameter space!

Flavored Dark Matter

Minimal Flavor Violation

[D'Ambrosio, Giudice, Isidori, Strumia '02]

$$-\mathcal{L} \supset \bar{Q}\, Y_d\, d_R\, H + \bar{Q}\, Y_u\, u_R\, H^\dagger + \bar{L}\, Y_e\, e_R\, H + \mathrm{h.c.}$$

In the limit $Y_{u,d,e} \to 0$ the SM exhibits large global flavor symmetry:

$$G_F = SU(3)_Q \times SU(3)_u \times SU(3)_d \times SU(3)_L \times SU(3)_e$$

MFV Hypothesis:

In the presence of new physics, the SM Yukawas are the only source of flavor breaking

⇒ Built-in protection against large FCNCs

Z_3 Flavor Triality

[BB, Pradler, Spannowsky '11]
[BB, Lin, Wang '13]

Consider the following element of
$SU(3)_c \times SU(3)_Q \times SU(3)_u \times SU(3)_d$:

$$U = (\omega^2)_c \times (\omega)_Q \times (\omega)_u \times (\omega)_d$$

with $\omega \equiv e^{2\pi i/3}$

	$SU(3)_c$	$SU(3)_Q$	$SU(3)_u$	$SU(3)_d$
Q	$\mathbf{3}$	$\mathbf{3}$	$\mathbf{1}$	$\mathbf{1}$
$\bar{u}$	$\bar{\mathbf{3}}$	$\mathbf{1}$	$\bar{\mathbf{3}}$	$\mathbf{1}$
$\bar{d}$	$\bar{\mathbf{3}}$	$\mathbf{1}$	$\bar{\mathbf{3}}$	$\mathbf{1}$
Y_u	$\mathbf{1}$	$\bar{\mathbf{3}}$	$\mathbf{3}$	$\mathbf{1}$
Y_d	$\mathbf{1}$	$\bar{\mathbf{3}}$	$\mathbf{1}$	$\mathbf{3}$
G	$\mathbf{8}$	$\mathbf{1}$	$\mathbf{1}$	$\mathbf{1}$

$$Q \to (\omega^2)_c(\omega)_Q\, Q = \omega^3 Q = Q$$

$$\bar{u} \to (\omega^{-2})_c(\omega^{-1})_u\, \bar{u} = \omega^{-3}\bar{u} = \bar{u}$$

$$\bar{d} \to (\omega^{-2})_c(\omega^{-1})_d\, \bar{d} = \omega^{-3}\bar{d} = \bar{d}$$

$$Y_u \to (\omega^{-1})_Q(\omega^1)_u\, Y_u = \omega^0\, Y_u = Y_u$$

$$Y_d \to (\omega^{-1})_Q(\omega^1)_d\, Y_d = \omega^0\, Y_d = Y_d$$

$$G \to (\omega^{-1+1})_c\, G = G$$

The quark fields, gluon field, and Yukawa spurions transform trivially under Flavor Triality!

Flavored Dark Matter

[BB, Pradler, Spannowsky]
[BB, Lin, Wang]

$$U = (\omega^2)_c \times (\omega)_Q \times (\omega)_u \times (\omega)_d$$

with $\omega \equiv e^{2\pi i/3}$

Example - color singlet, flavor triplet: $\chi \sim (\mathbf{3}, \mathbf{1}, \mathbf{1})_{G_q}$

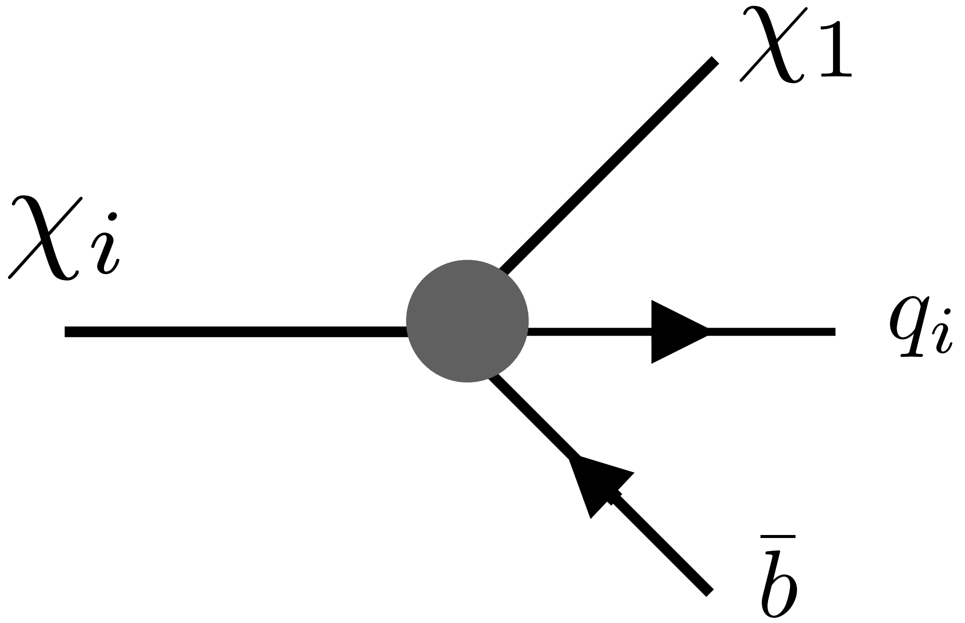
$$\chi \to (\omega)_Q \, \chi = \omega \chi \neq \chi$$

χ is charged under Flavor Triality and thus stable

Dark Matter candidate!

Models & Phenomenology

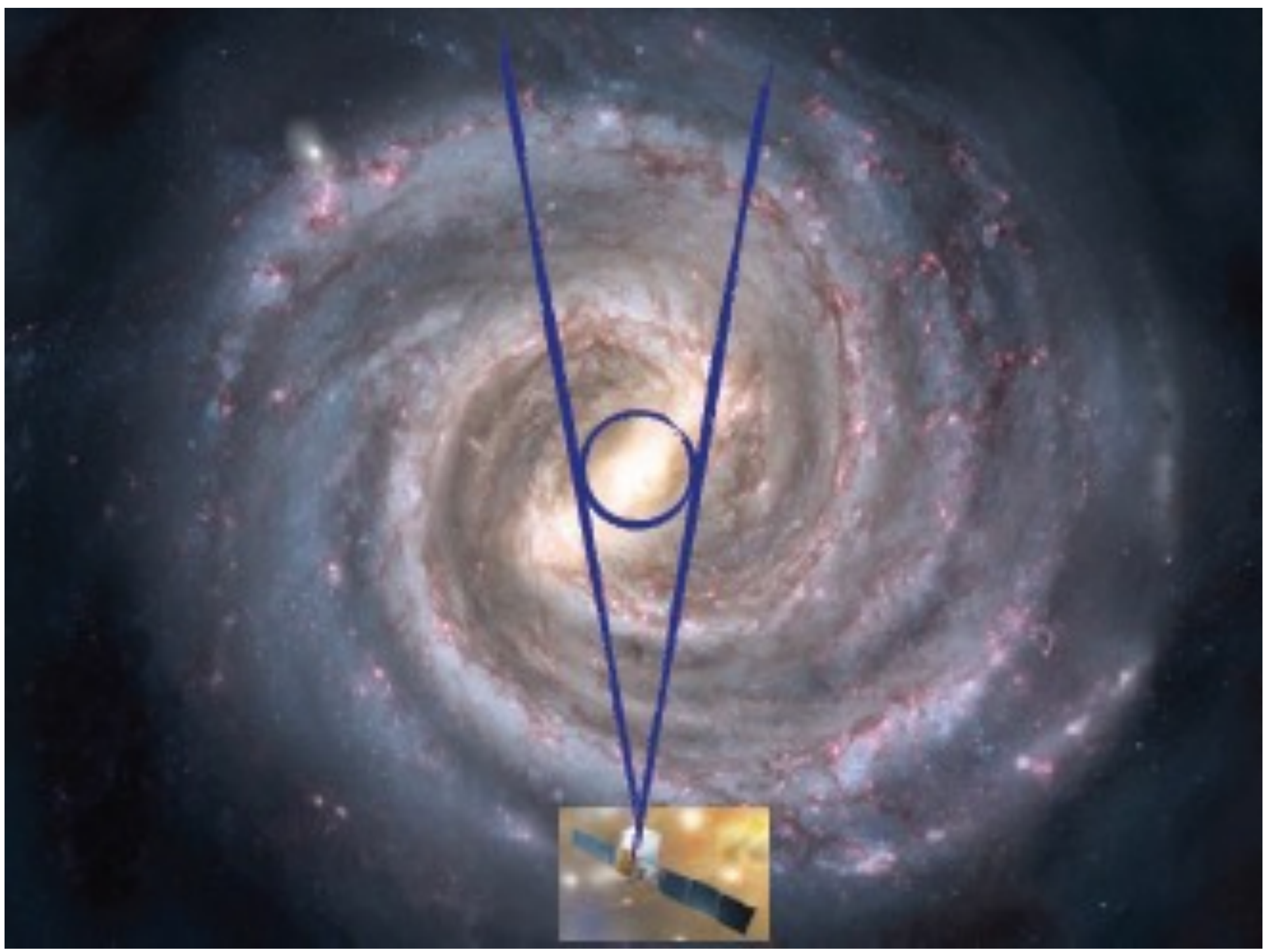
- Many models possible (flavor triplets, sextets...)
- SUSY with RPV - MFV can explain proton stability and DM stability
- Generic prediction is presence of heavy "dark" flavors

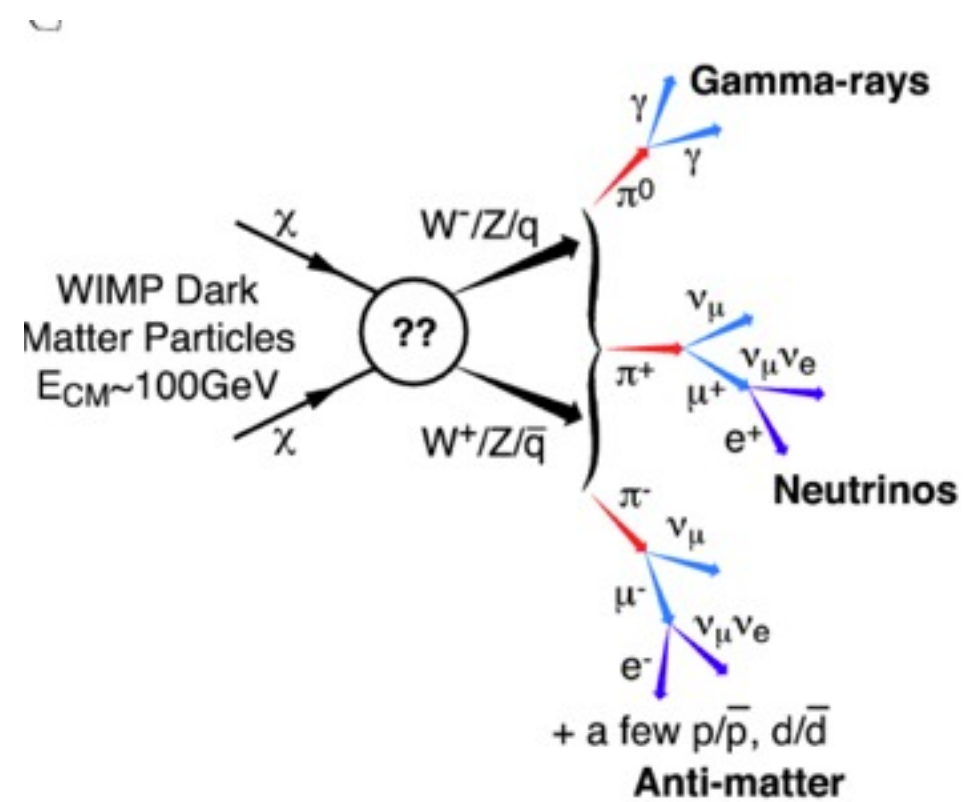


The Galactic Center Gamma Ray Excess

Fermi studies gamma rays from space, including those from the center of the Milky Way

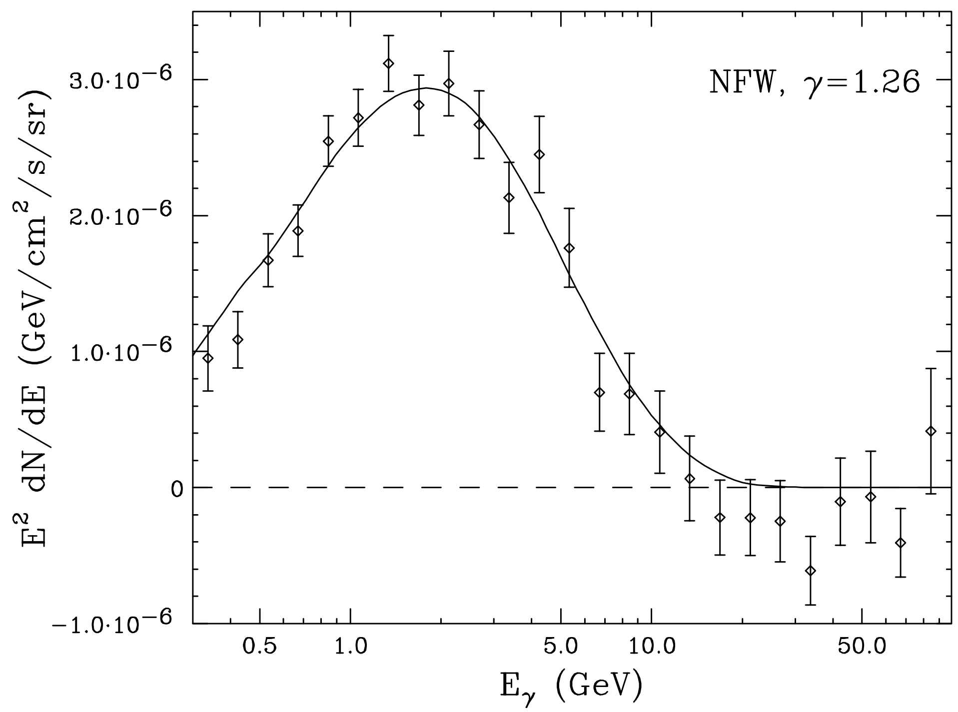
Some of these gamma-rays may come from Dark Matter annihilation!

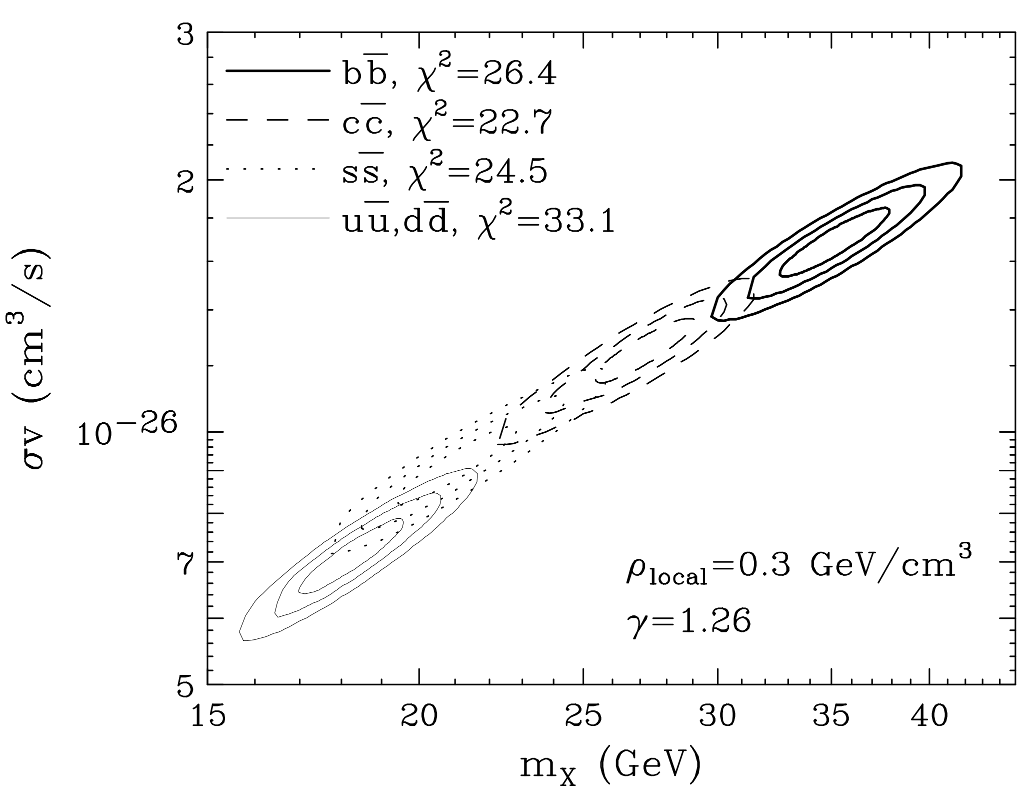


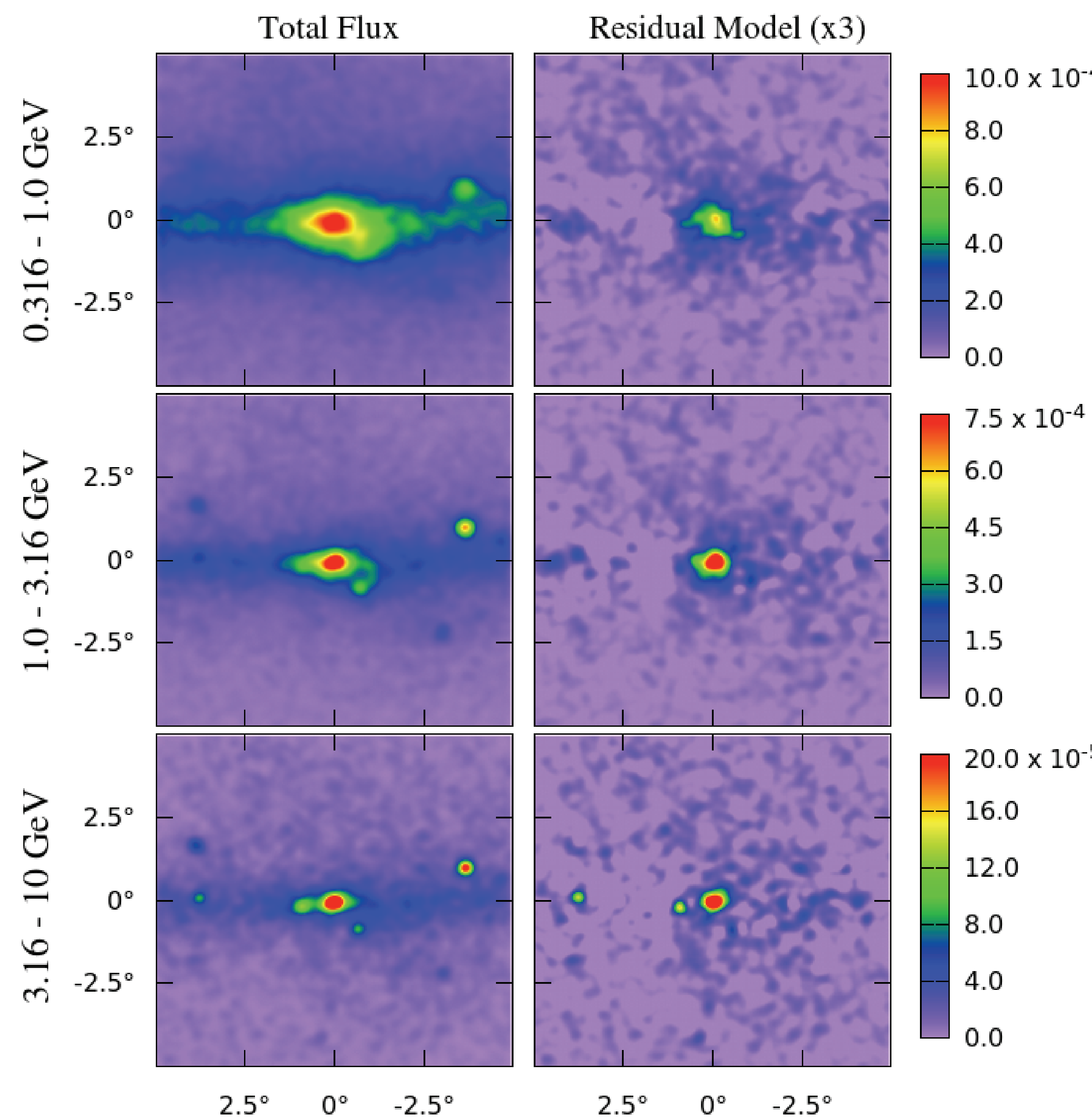


Gamma Rays from the Galactic Center

Goodenough, Hooper '09
Hooper, Goodenough '10
Hooper, Linden '11
Abazajian, Kaplinghat '12
Hooper, Slatyer '13
Gordon, Macias '13
Huang, Urbano, Xue '13
Abazajian et al, '14
Daylan et al, '14

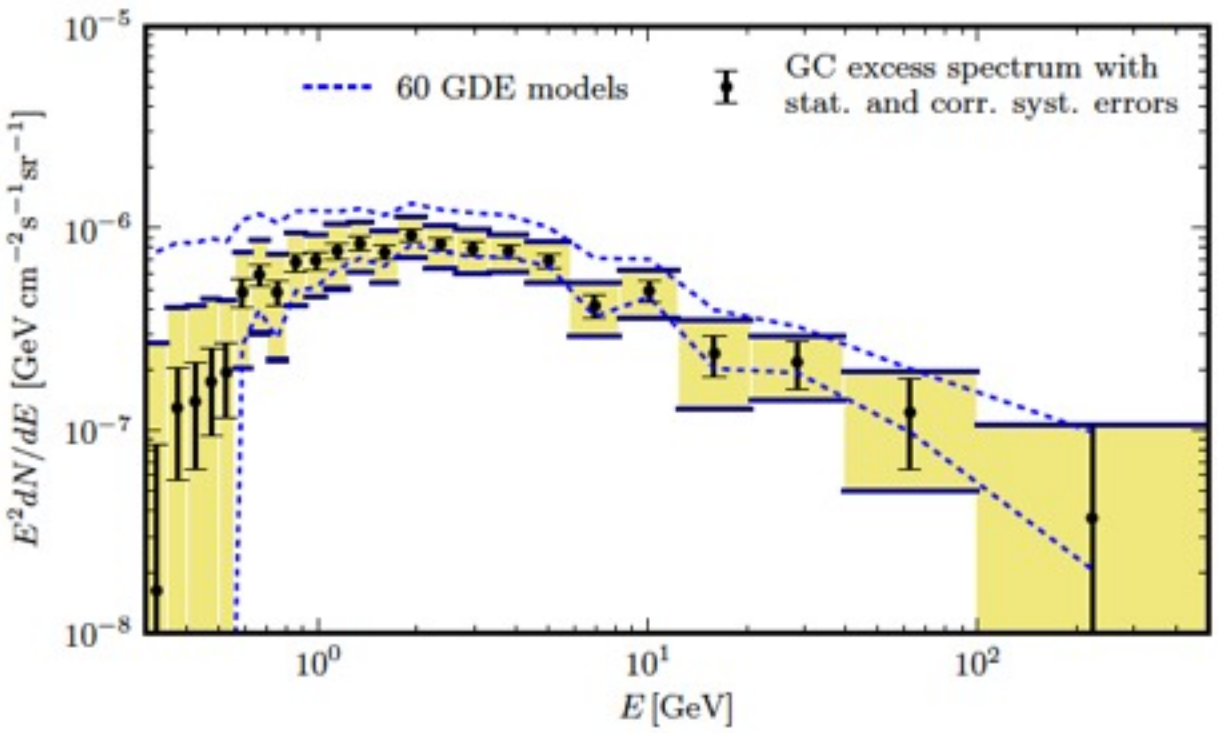




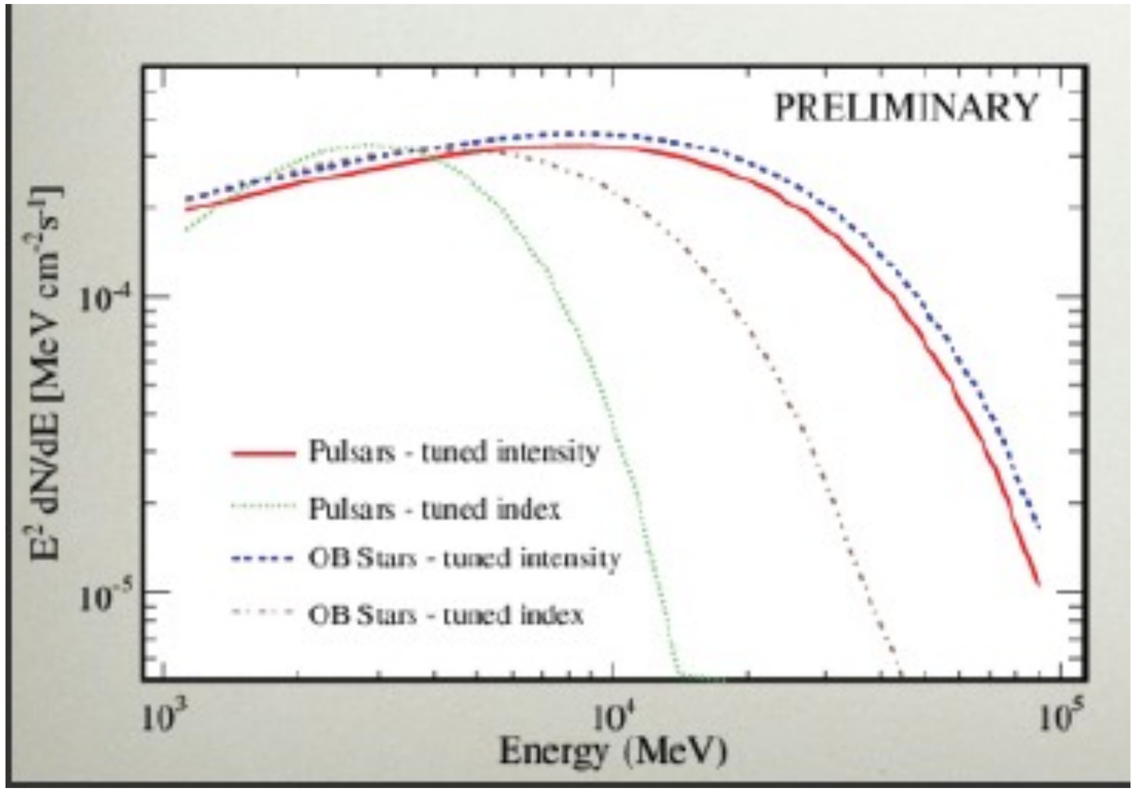


from Daylan et al, '14

Estimates of background model systematics



Calore, Cholis, Weniger, '14

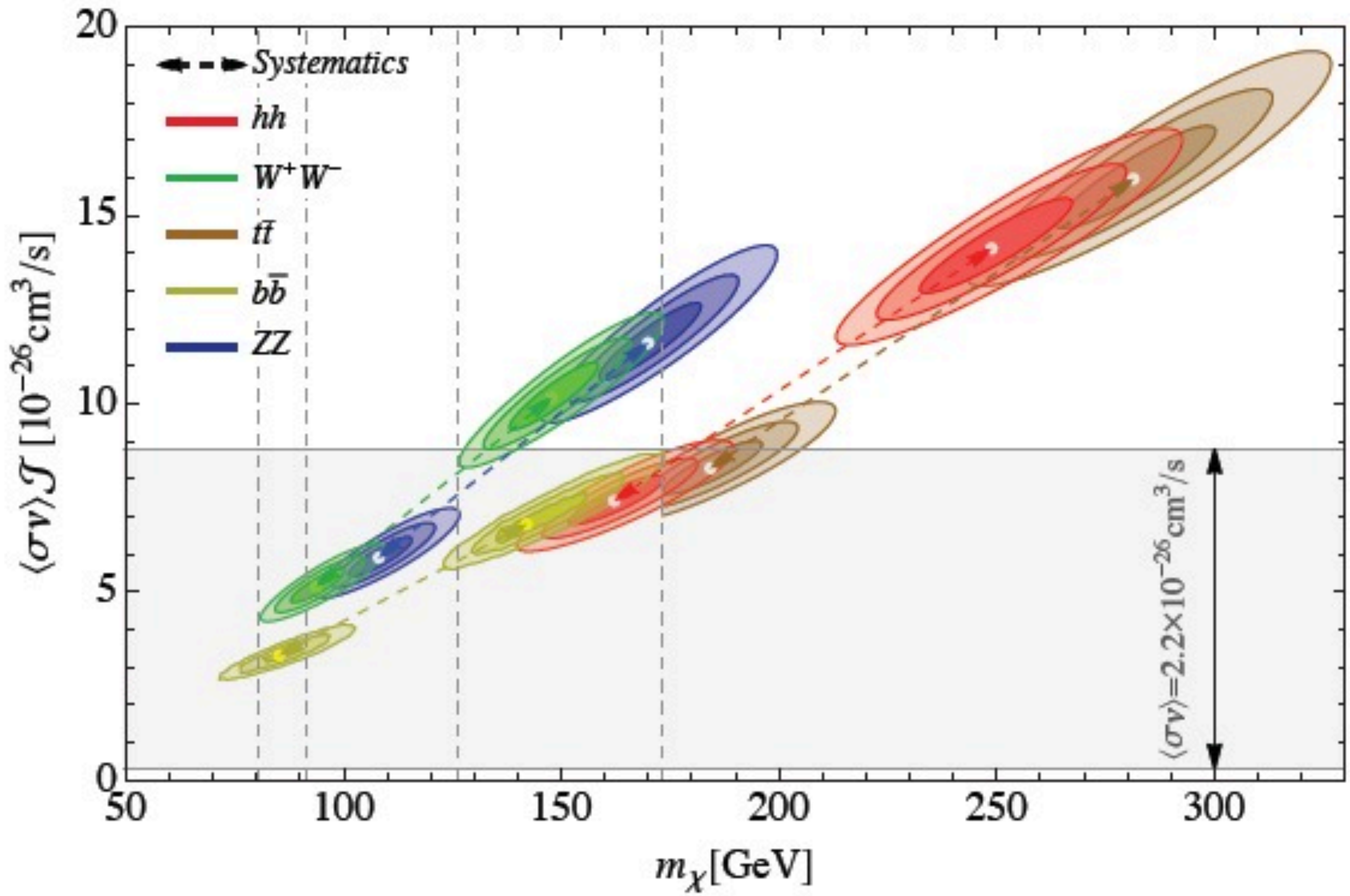


From talk by S. Murgia on behalf of Fermi collaboration (October '14)

Spectrum could be is significantly harder than previously considered

WIMPs at the Galactic Center

P. Agrawal, BB, P. J. Fox, R. Harnik, to appear



O(100 GeV) DM can explain the excess!

E.g. MSSM neutralino (mixed Bino/Wino annihilating to W bosons)

P. Agrawal, BB, P. J. Fox, R. Harnik, to appear