ILLUMINATING THE 130GEV γ LINE WITH CONTINUUM PHOTONS

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INTRODUCTION

Indirect Detection a promising channel for the discovery of Dark Matter

Two classes of signals:

Monochromatic Photons

Direct annihilation to photons

Continuum Photons

Photons from decay of other SM particles, e.g. jets

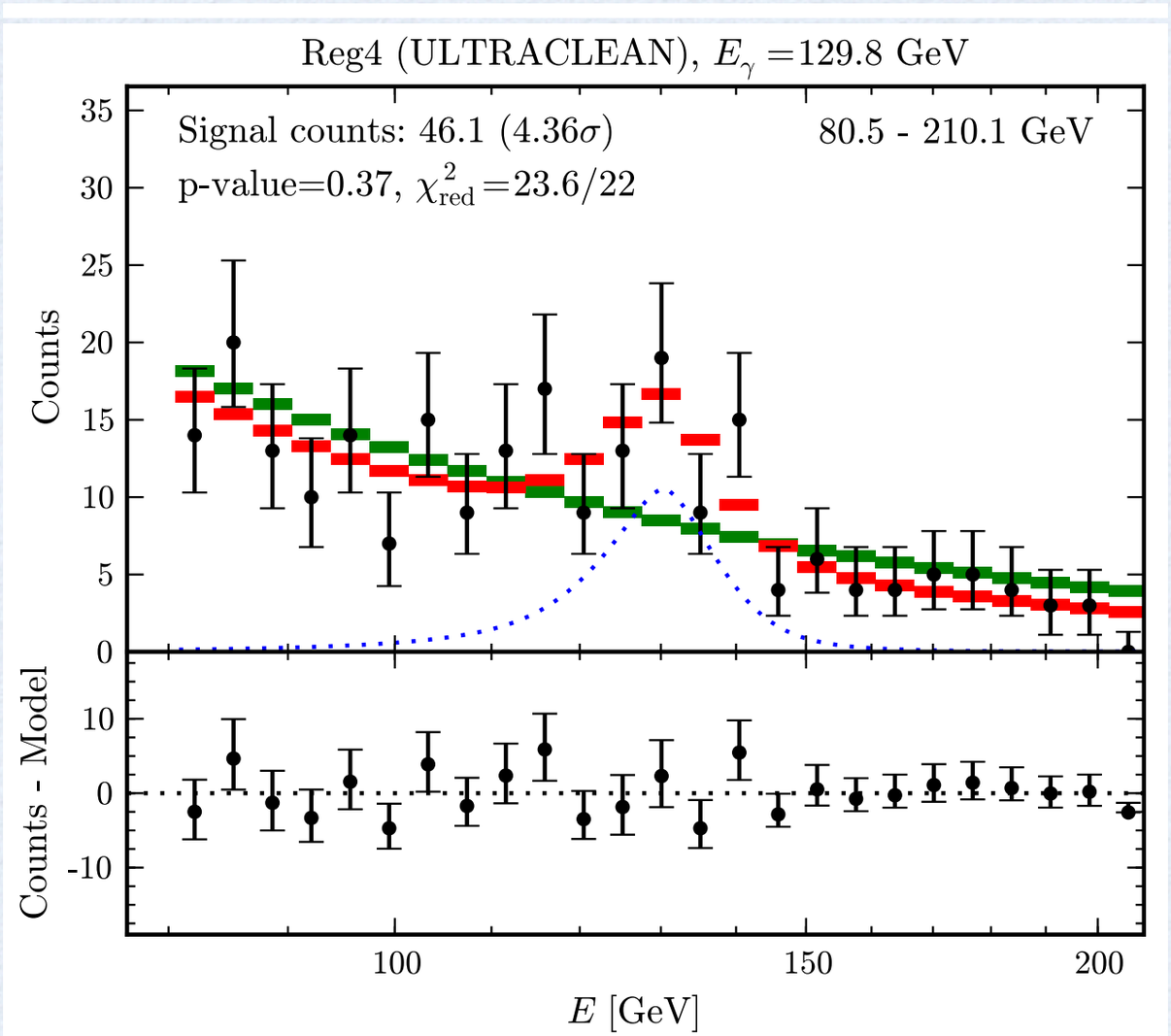
Fermi Gamma Ray Space Telescope

best observatory currently running

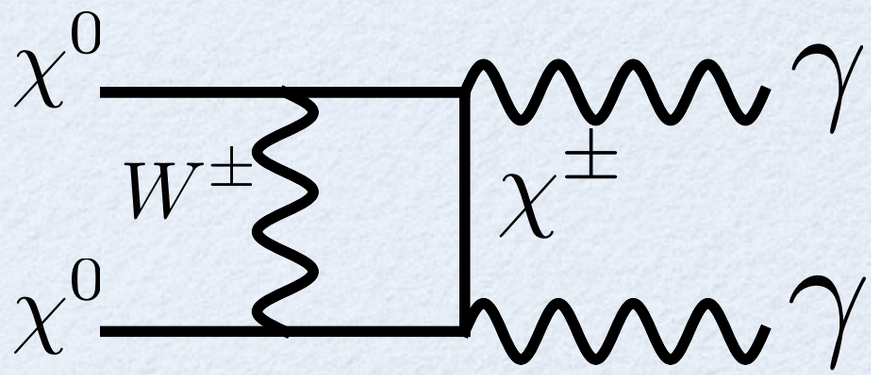
WENIGER SIGNAL

Observation of feature in γ spectrum at Fermi at galactic center

$$\langle \sigma v \rangle \sim 10^{-27}\ \mathrm{cm}^3/\mathrm{s} \qquad 3-5\sigma$$



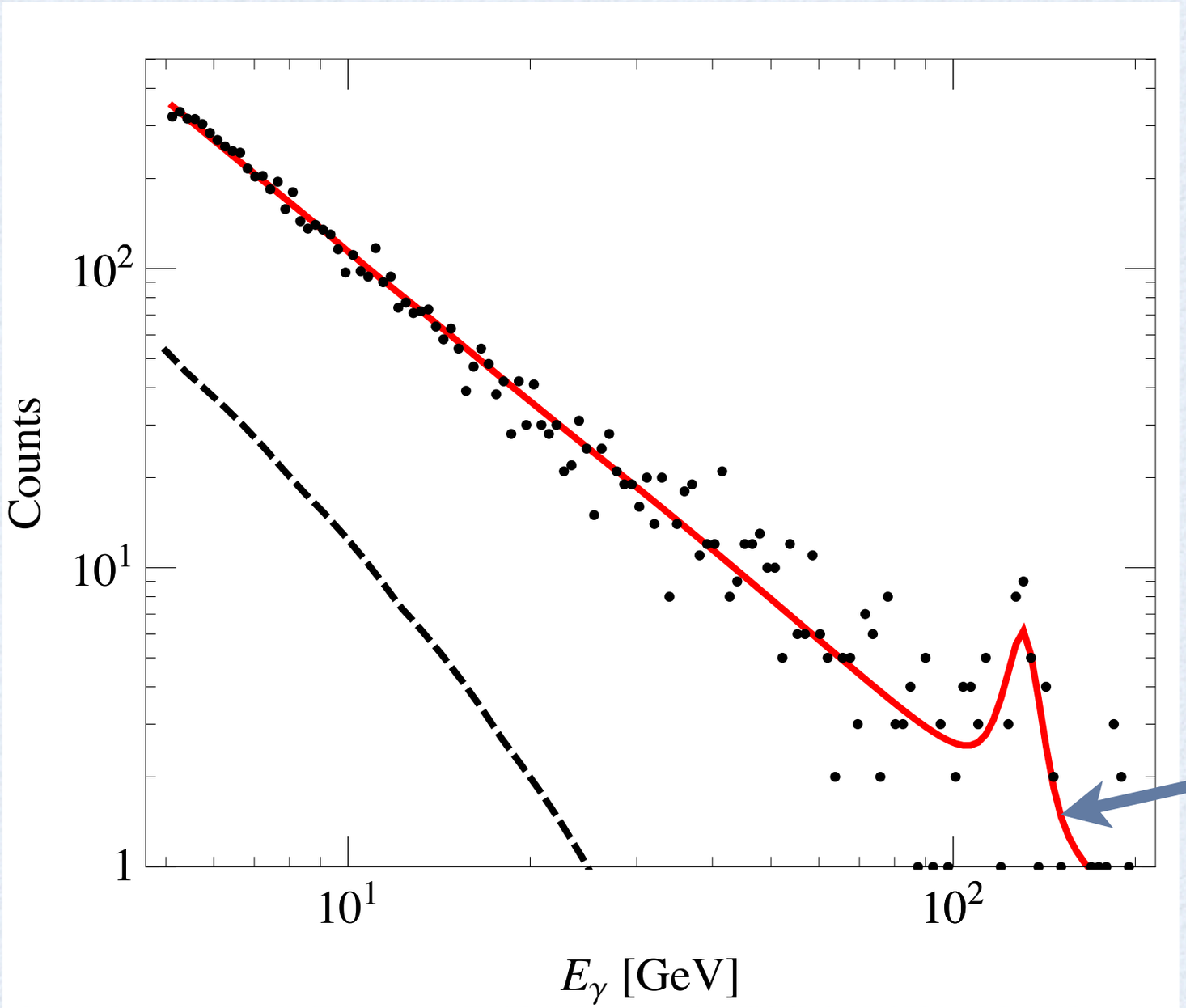
Plausible cross section for monochromatic photons



C. Weniger 1204.2797

SIGNAL

Performed our own extraction of 3° GC region



Pass 7v6 (3.7 years)

Ultraclean

Surprisingly clean
~10^4 counts

Power Law BG+ Line

Signal ~ 30 events

REALISTIC MODELS

What is the origin of this signal?

Typically have both $\gamma\,\gamma$ & $\gamma\,Z^0$ signals

Similar Strengths

130 GeV $(\gamma\,\gamma)$ & 115 GeV $(\gamma\,Z^0)$ lines

130 GeV $(\gamma\,Z^0)$ & 145 GeV $(\gamma\,\gamma)$ lines

Usually $\sigma(\gamma\,Z^0) > \sigma\,(\gamma\,\gamma\,)$

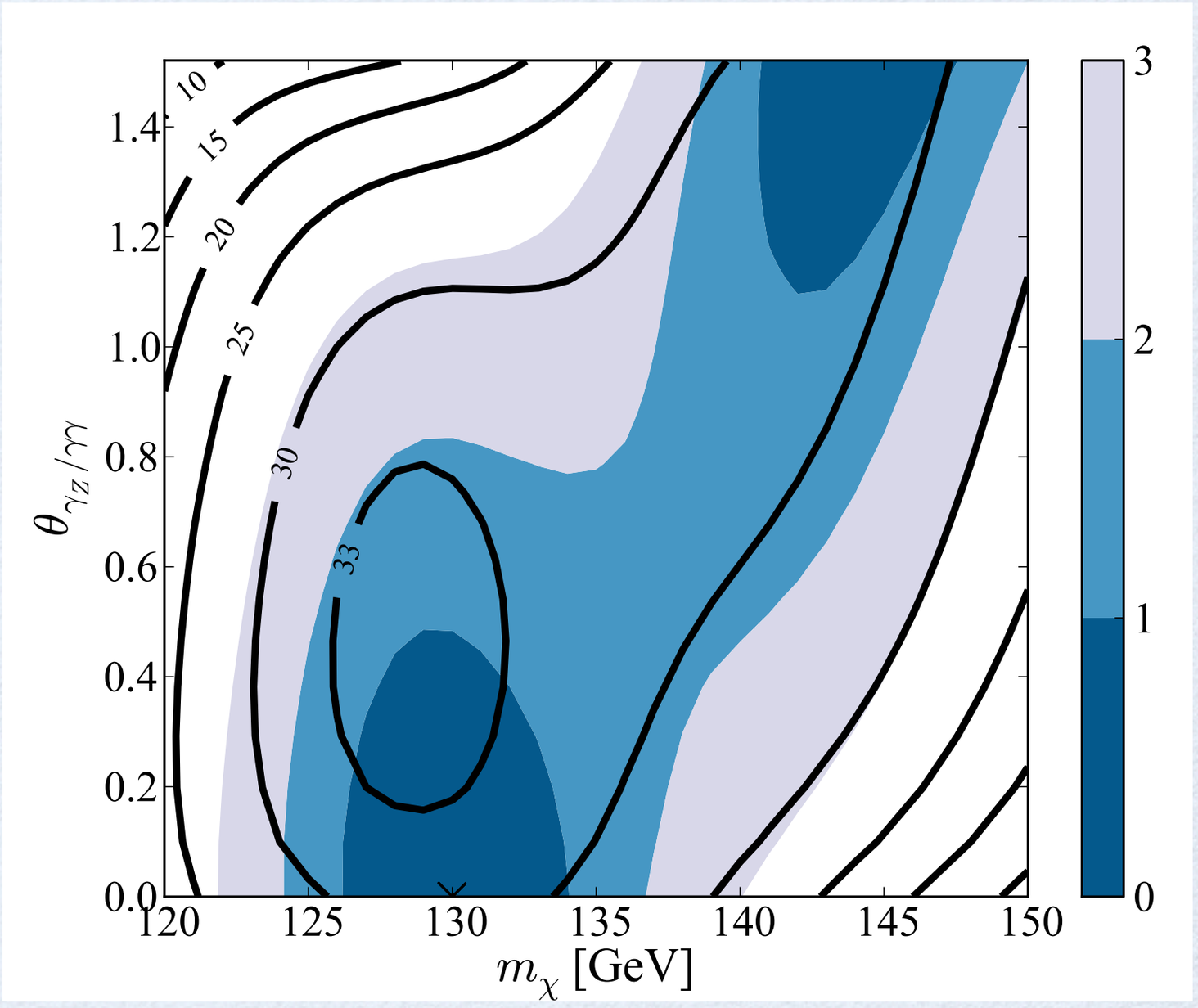
FITTING TO TWO LINES

Can do a fit to both lines

$$\theta_{\gamma Z/\gamma\gamma} \equiv \arctan \frac{N_{\gamma Z}}{N_{\gamma\gamma}},$$

Two lines work well

At 2σ, any ratio is allowed



CONTINUUM PHOTONS

Typically have annihilations to other SM states

$$\chi\chi \to WW, b\bar{b}, \tau\tau, \mu\mu$$

Often tree-level and much larger

Frequently produce many photons

For a specific final state can set a limit on

$$R^{\rm th} \equiv \frac{\sigma_{\rm ann}}{2\,\sigma_{\gamma\gamma} + \sigma_{\gamma Z}},$$

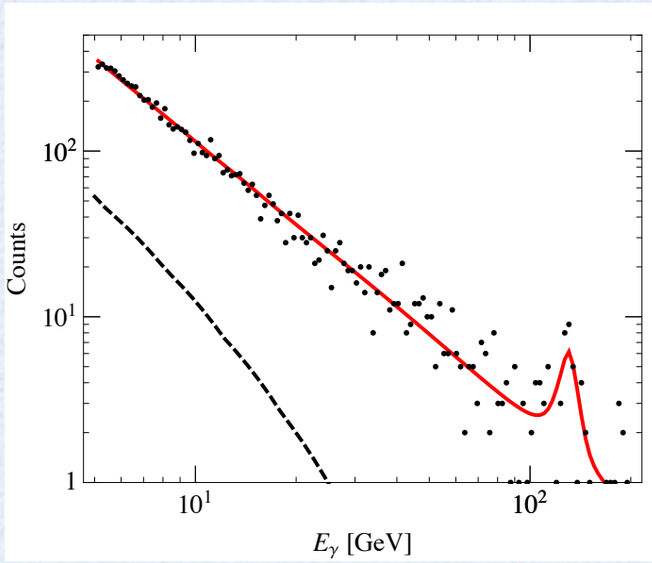
From the exact same region

no astrophysics uncertainty

SUPERSATURATION CONSTRAINT

Should over predict measured photons!

Very conservative constraint: allows signal to be 100% of measurement at 1 energy



Choose the Optimal Bin For Each Final State

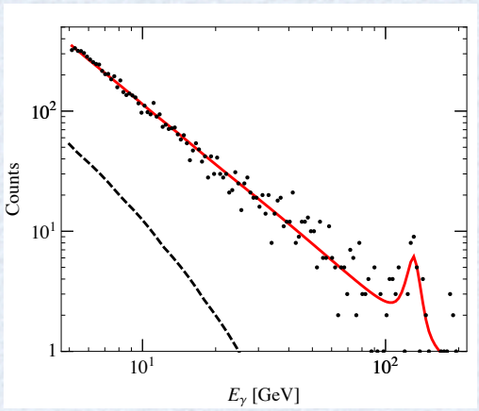
WW, ZZ ~ 10-20 GeV

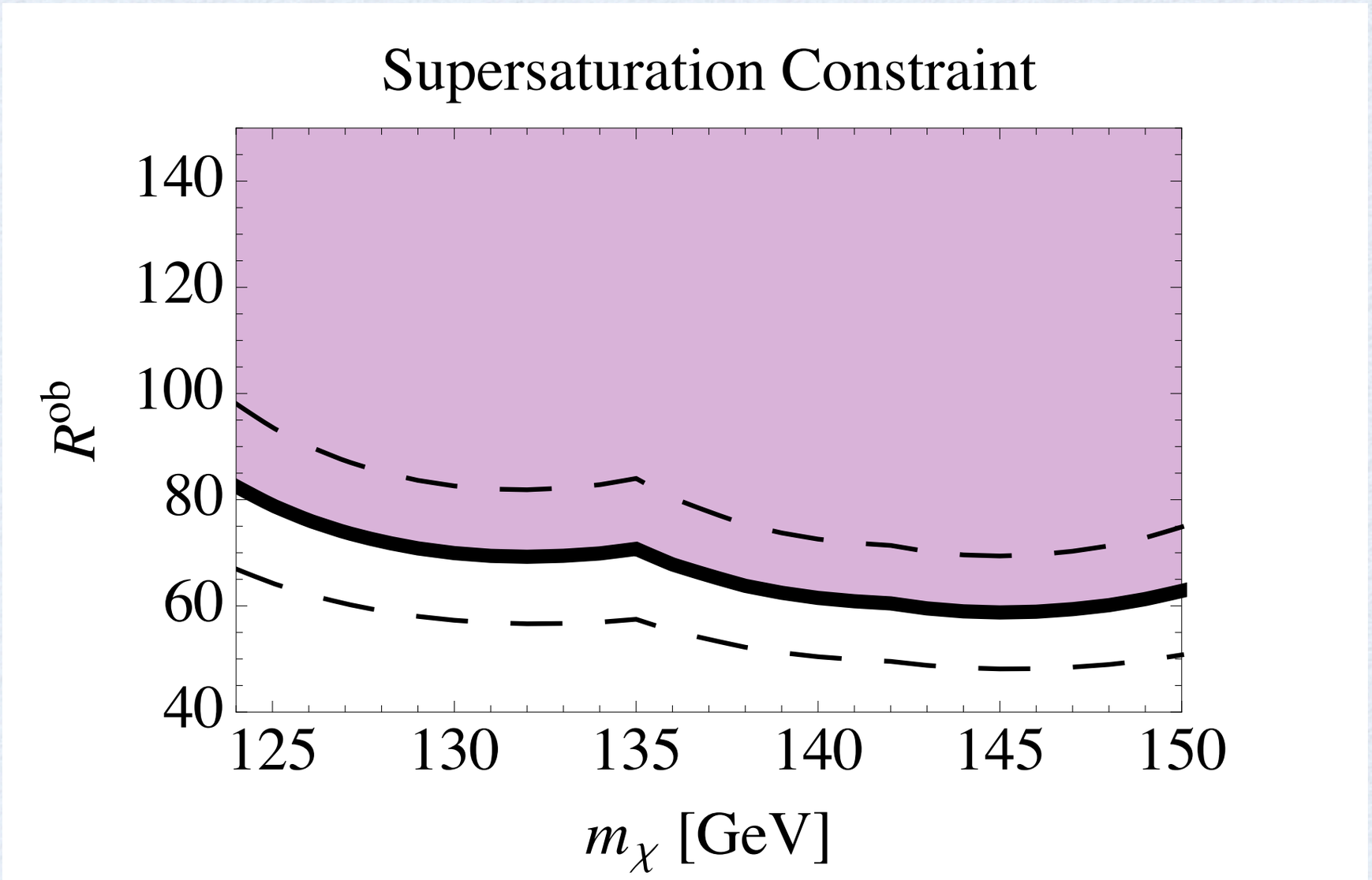
b b ~ 5-15 GeV

ττ~ 55-65 GeV

μμ~ 85-94 GeV

SUPERSATURATION LIMIT





Excludes tree-level continuum annihilations with loop-level monochromatic annihilations

TYPICAL NEUTRALINO SIGNALS

Wino:
$$\sigma_{\gamma\gamma} v \simeq 2.5 \times 10^{-27}\ \mathrm{cm}^3/\mathrm{s}$$
$$\sigma_{\gamma Z} v \simeq 1.4 \times 10^{-26}\ \mathrm{cm}^3/\mathrm{s} \qquad \Longrightarrow \quad R^{\mathrm{th}} = 210;$$
$$\sigma_{\mathrm{ann}} v \simeq \sigma_{WW} v \simeq 4.0 \times 10^{-24}\ \mathrm{cm}^3/\mathrm{s}$$

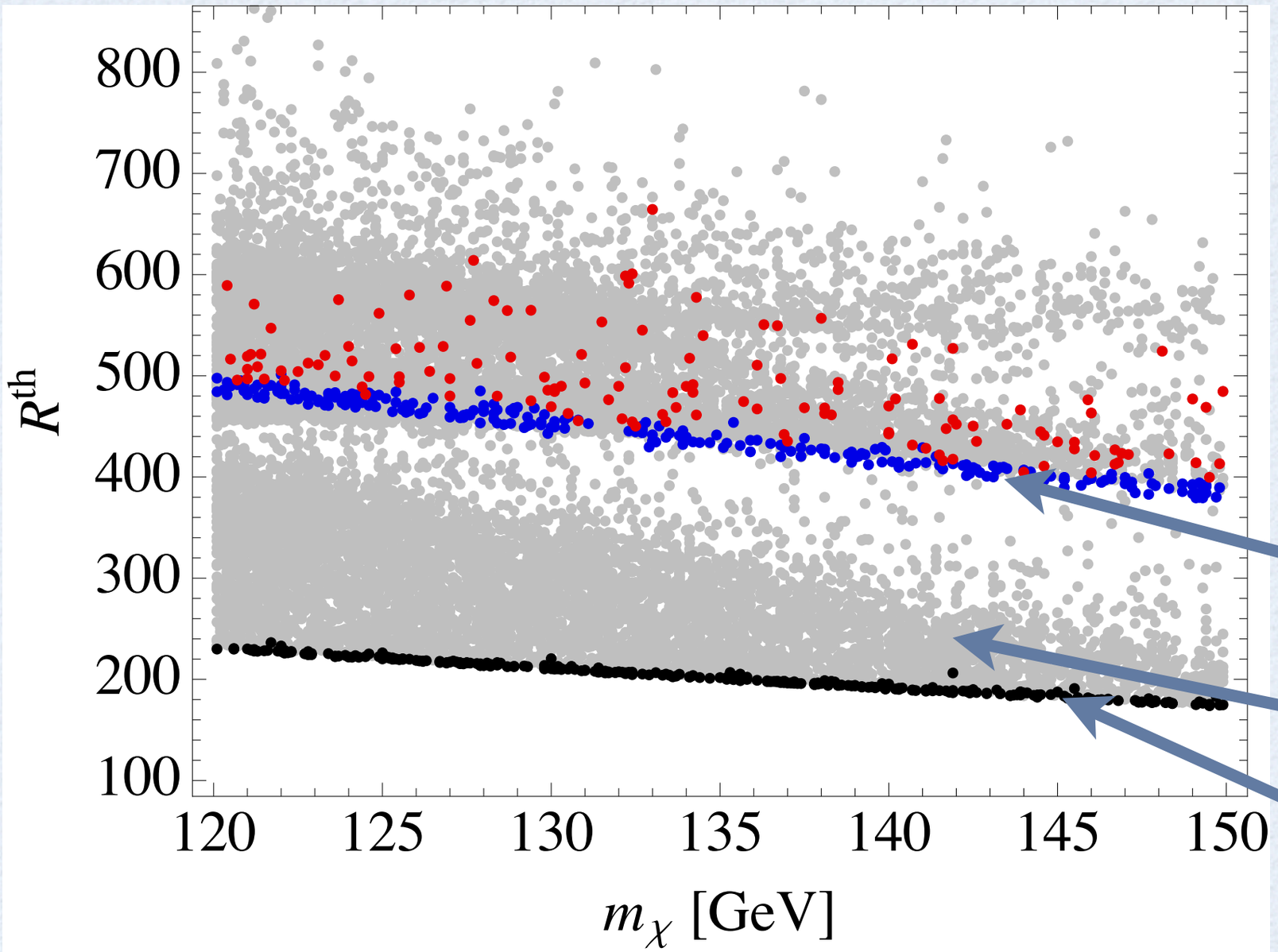
Higgsino:
$$\sigma_{\gamma\gamma} v \simeq 1.1 \times 10^{-28}\ \mathrm{cm}^3/\mathrm{s}$$
$$\sigma_{\gamma Z} v \simeq 3.7 \times 10^{-28}\ \mathrm{cm}^3/\mathrm{s} \qquad \Longrightarrow \quad R^{\mathrm{th}} = 710.$$
$$\sigma_{\mathrm{ann}} v \simeq \sigma_{WW} v + \sigma_{ZZ} v \simeq 4.2 \times 10^{-25}\ \mathrm{cm}^3/\mathrm{s}$$

Bino:
$$\sigma_{\gamma\gamma} v \simeq \mathrm{few} \times 10^{-30}\ \mathrm{cm}^3/\mathrm{s};$$
$$\sigma_{\gamma Z} v \simeq \mathrm{few} \times 10^{-31}\ \mathrm{cm}^3/\mathrm{s}; \qquad \Longrightarrow \quad R^{\mathrm{th}} \sim 10^3.$$
$$\sigma_{\mathrm{ann}} v \simeq \sigma_{\ell\bar{\ell}} v \simeq \mathrm{few} \times 10^{-27}\ \mathrm{cm}^3/\mathrm{s}.$$

Dead dead dead from this modest constraint

More thorough study

Scanning throughout MSSM parameter space



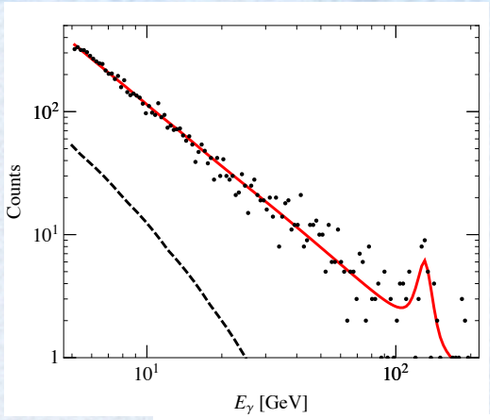
$R^{\rm th} \gtrsim 200$

Higgsino

Mixed

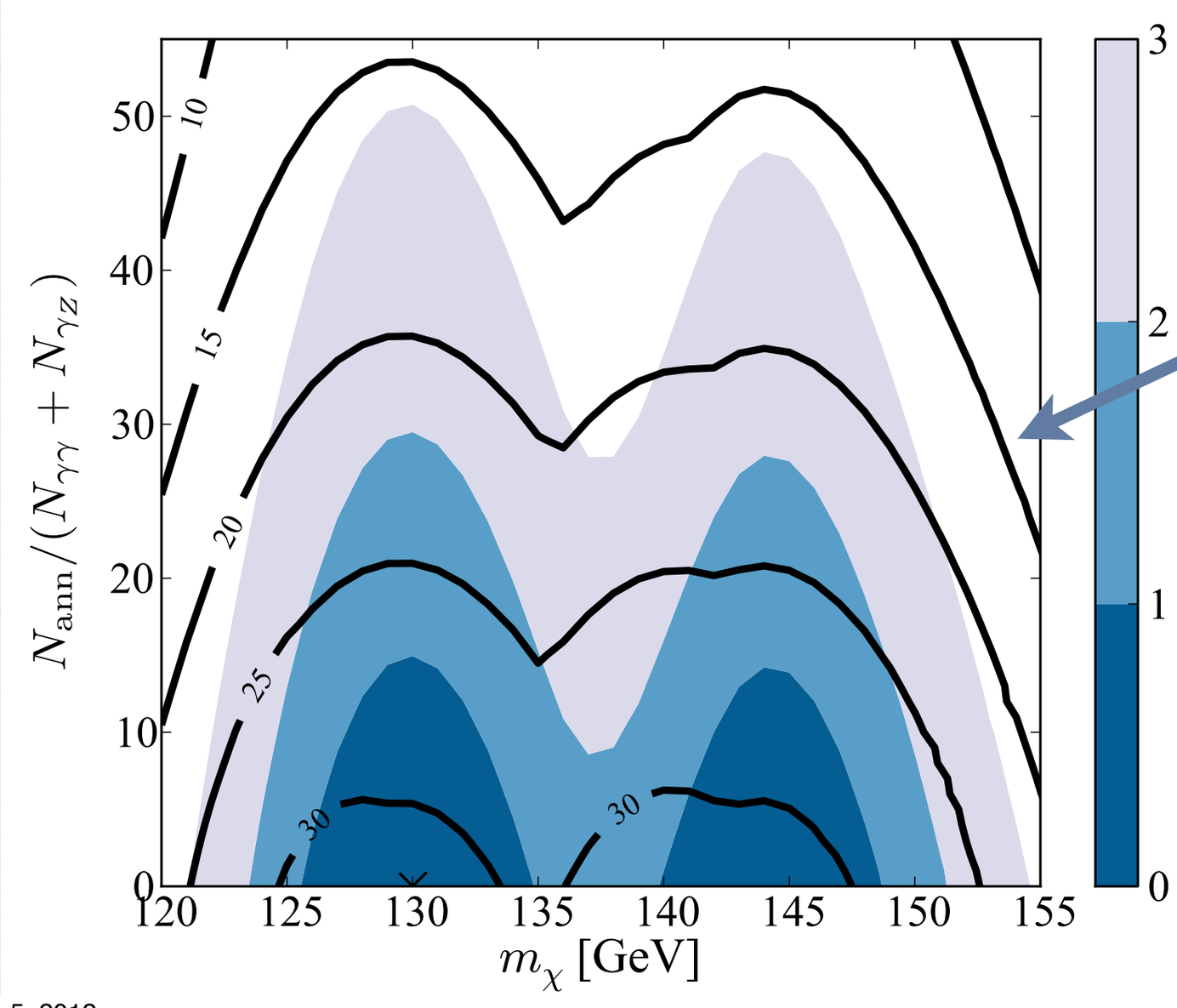
Wino

USING THE CONTINUUM



Very flat spectrum, no features

Tighter constraints possible



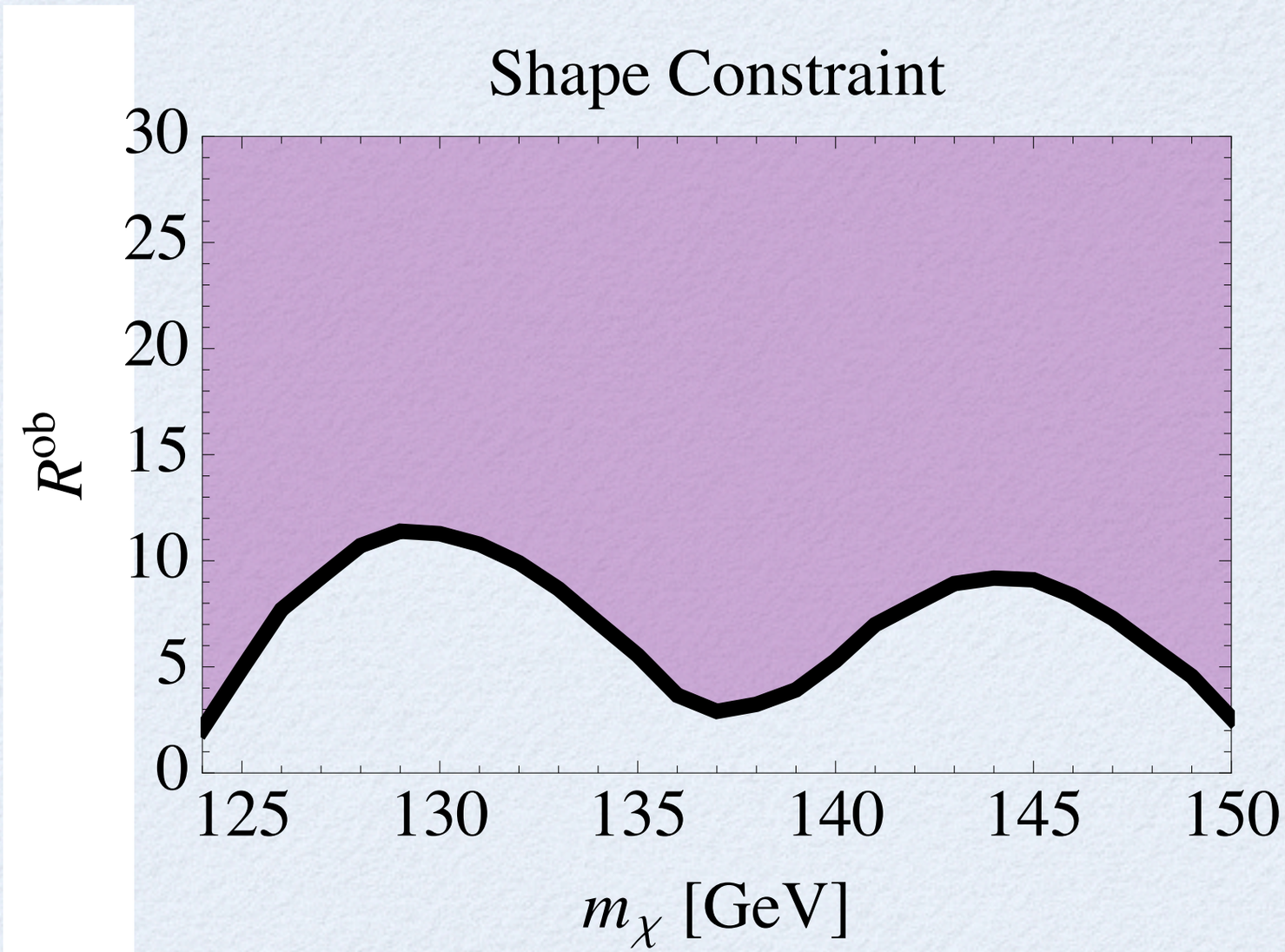
Number of γ in bump

If R>10, signal bump drops in size proportionately

SHAPE RESULTS

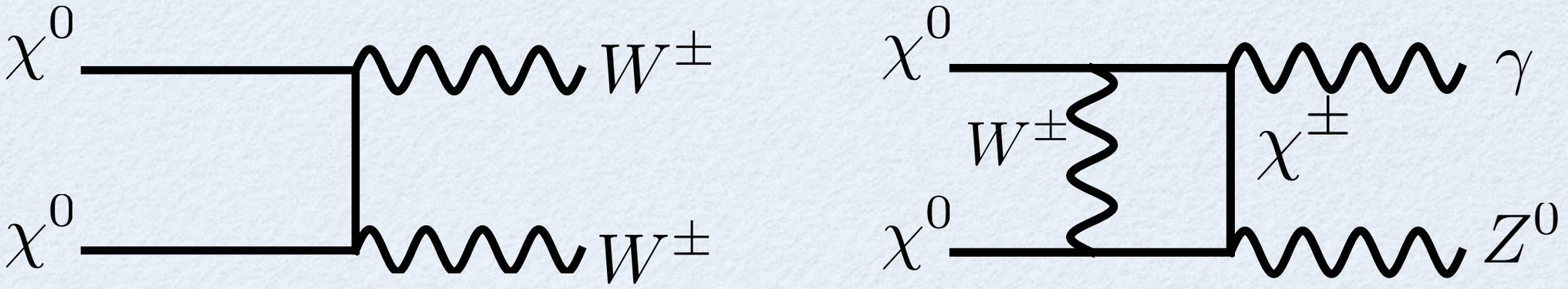
Places tight constraints!

Prefers R<10!



GENERAL IMPLICATIONS

Anything of the form



is dead on arrival...

A lot of WIMP models are of this ilk

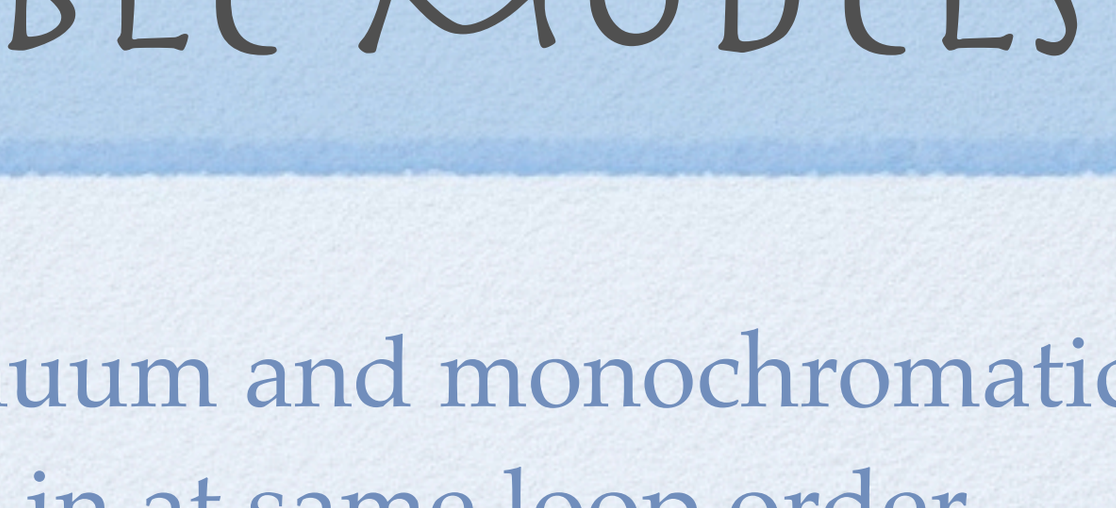
Need more designer models

POSSIBLE MODELS

Need to have continuum and monochromatic photons coming in at same loop order

Since DM is neutral, means most models will require all annihilations to occur at loop-level

J. Cline
1205.2688



$$m_X < m_S$$

CONCLUSIONS

The Fermi γ line Weniger discovered is a plausible signal of DM annihilation

Can comfortably accommodate both a $\gamma\gamma$ & γZ^0 line

Continuum photons from the same galactic region rule out simplest models of dark matter conclusively

Using shape of background can constrain even more models