Internal Bremsstrahlung Signatures from Dark Matter Annihilations in Light of Direct Detection and Collider Searches

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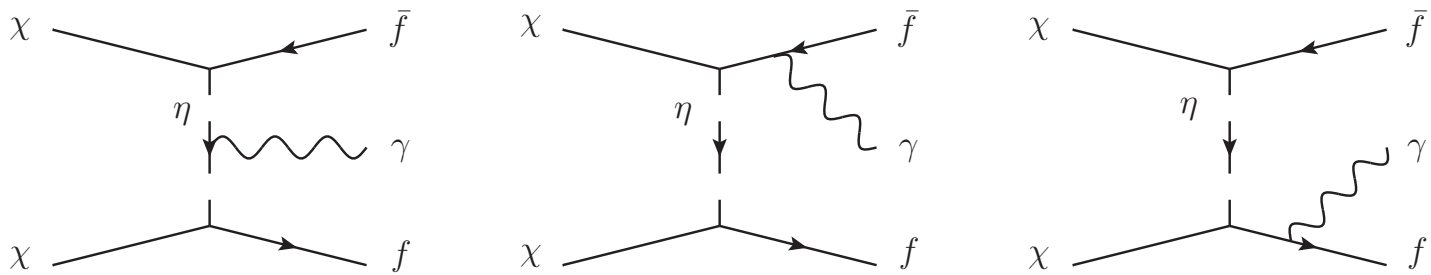
Outline

gamma-ray features

- gamma-ray features as smoking gun for dark matter detection
- numerous possibilities:
  - line
  - box
  - virtual internal bremsstrahlung
  - ...
- generically small cross section

$\hookrightarrow$ focus on internal bremsstrahlung

What is Internal Bremsstrahlung?



- hard gamma from a three-body process

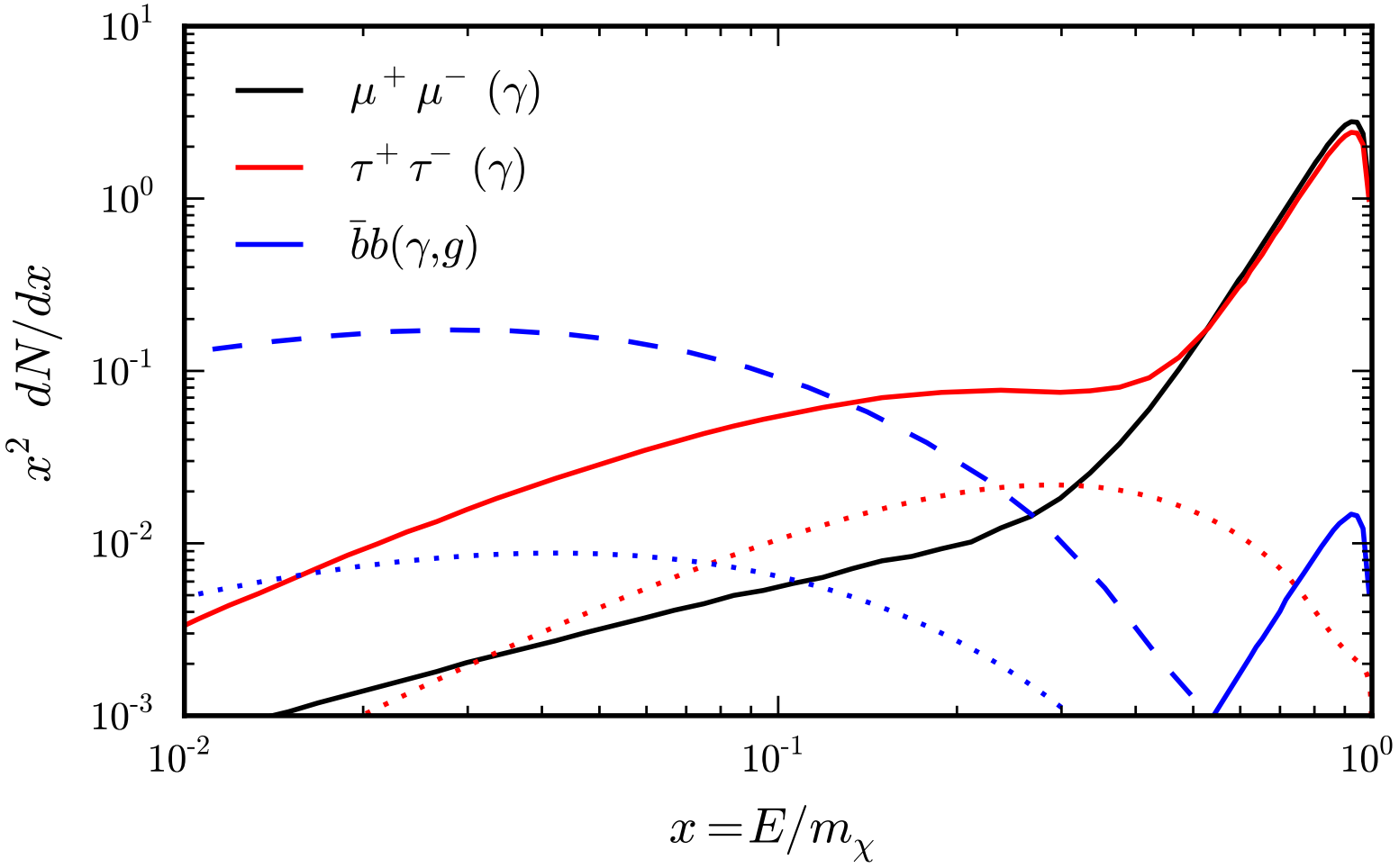
When does it happen?

- dark matter χ is a Majorana fermion
- scalar η couples to Standard Model
- $\mathcal{L}_{\text{int}} = -y\bar{\chi}\Psi_R\eta + \text{h.c.}$

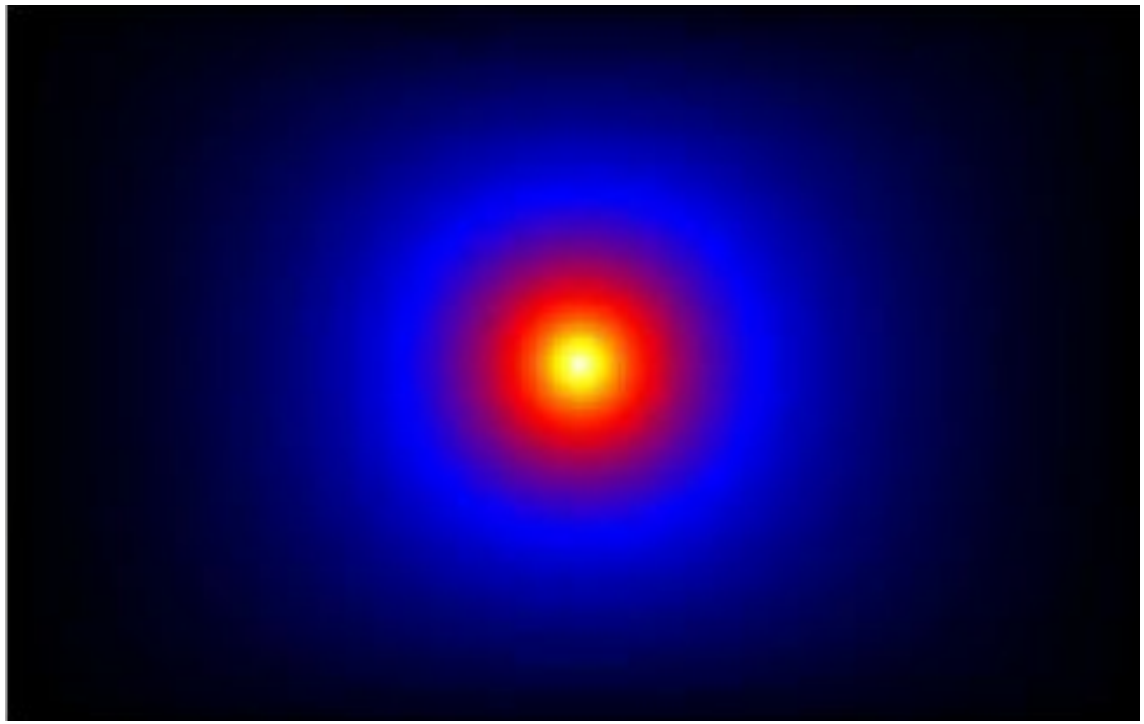
  $\Rightarrow$ chirality suppression

- suppression is lifted by emission of hard gamma
- strong enhancement for $\Delta m = m_\eta - m_\chi$ small
- Examples:
  - slepton or squark coannihilation in MSSM
  - right handed neutrino DM [Bergstrom 2012]

Spectrum

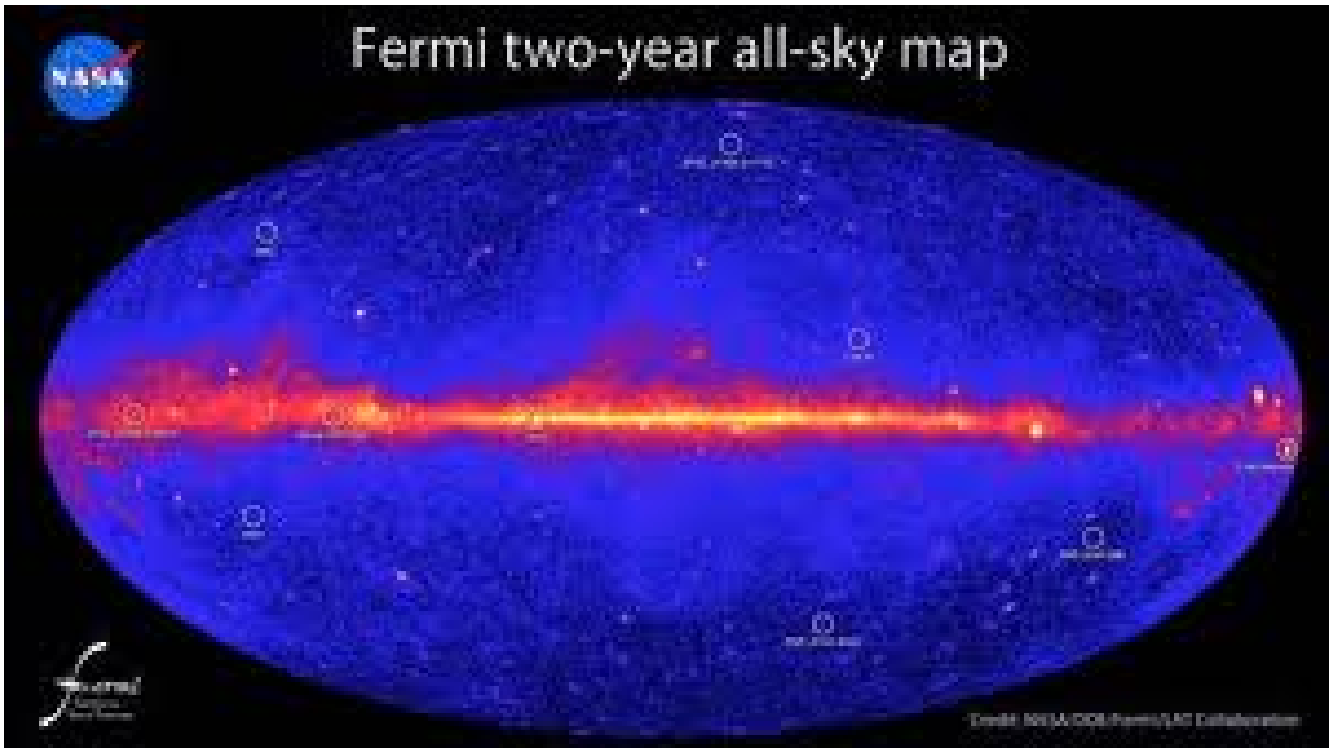

$\mu^+\mu^-\ (\gamma)$
$\tau^+\tau^-\ (\gamma)$
$\bar{b}b(\gamma,g)$
$x^2\ dN/dx$
$x = E/m_\chi$
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-2}
10^{-1}
10^0

Where to look for DM?



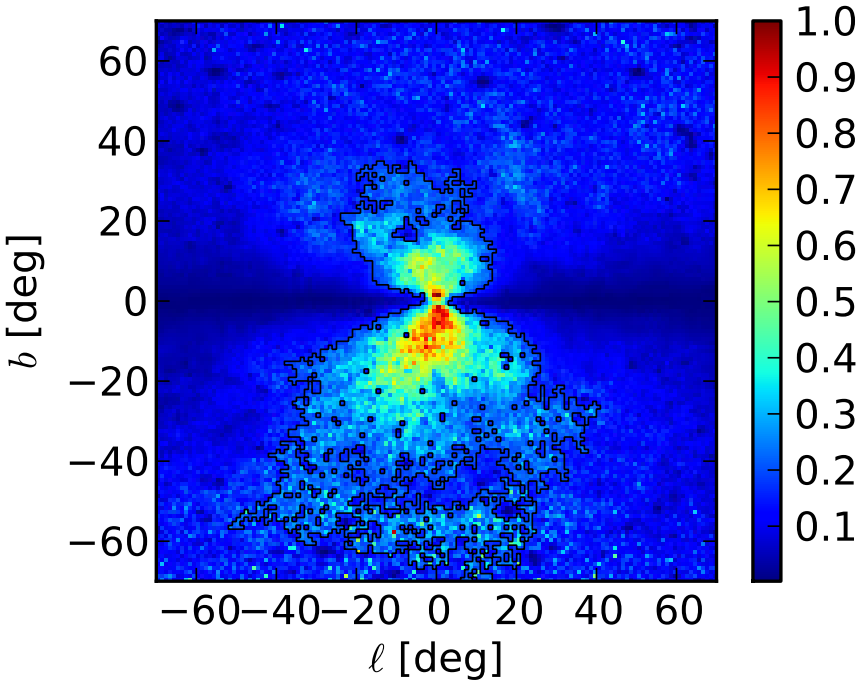
$$\text{Flux} \sim J = \int_{l} \int_{\Delta\Omega} \rho^2_{DM}(l, \Omega) dl \, d\Omega$$

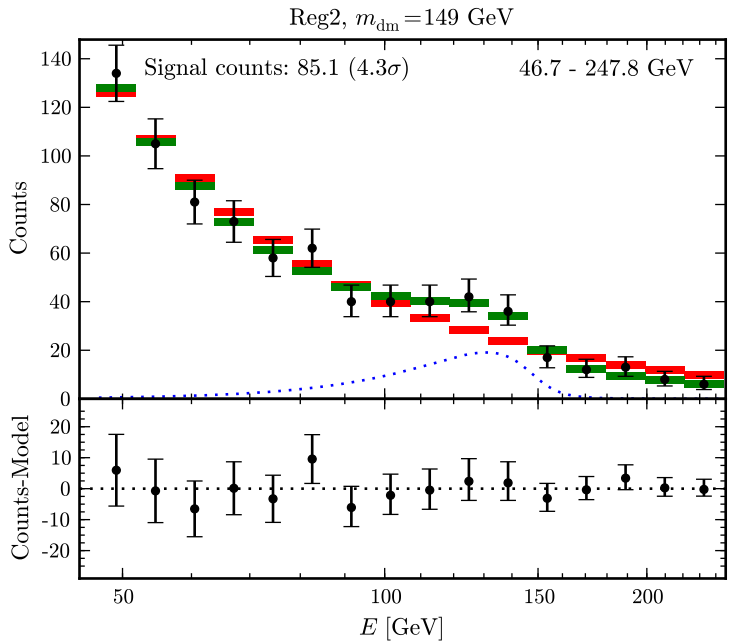
Look at the Galactic Center?



- pro: highest J-factor
- con: huge background in the Galactic Center
- but: characteristic signature

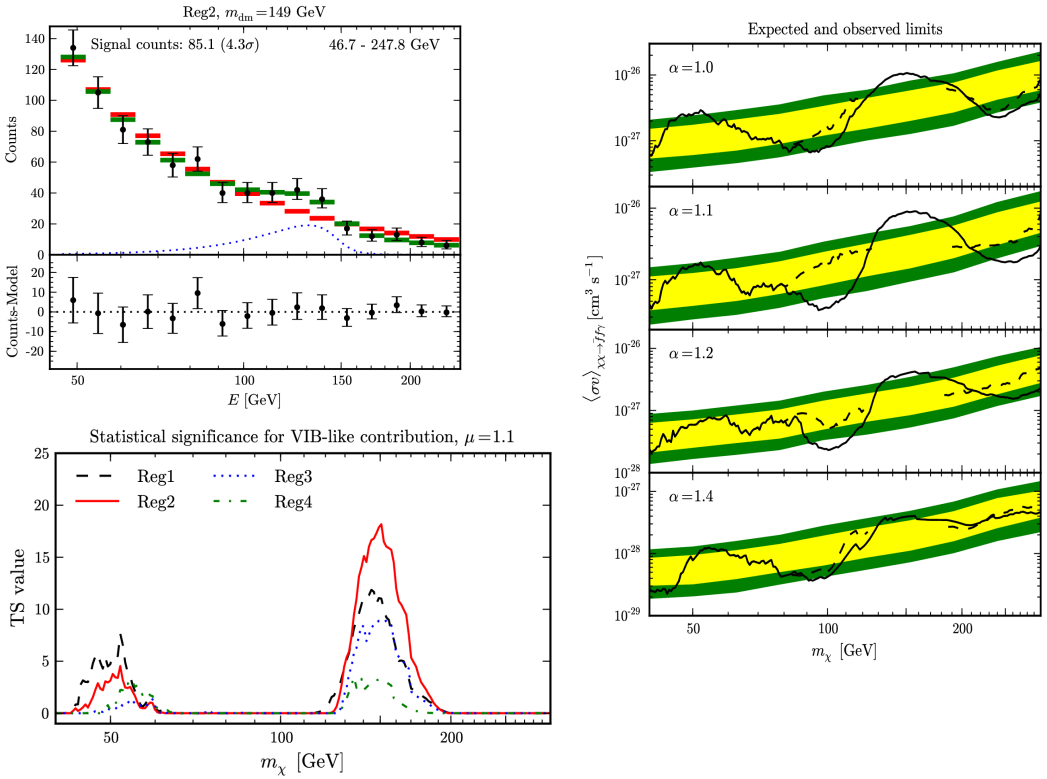
$\Rightarrow$ look at the center





select region of interest → analyse spectrum

Fermi 130 GeV excess



- internal bremsstrahlung is a good fit for the 130 GeV excess
- global (local) significance 3.1 (4.3) sigma

What to do about the excess?

be patient and wait for more data

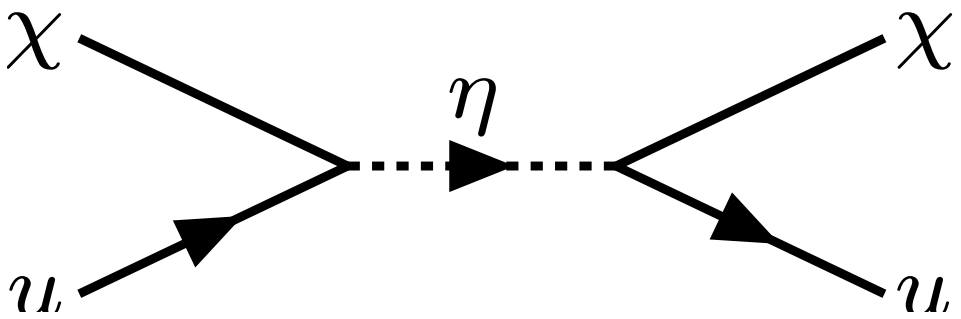
Going beyond the 130 GeV excess

- What else can be said about these models?
- Can we extend the range of gamma ray searches?
- Are there other observables predicted?

other gamma ray searches

- Fermi dwarf observations (continuum photons)
- line search by HESS, 500 GeV - 20 TeV [A. Abramowski et al. '13]
- principles similar to those described above, different background

Direct Detection

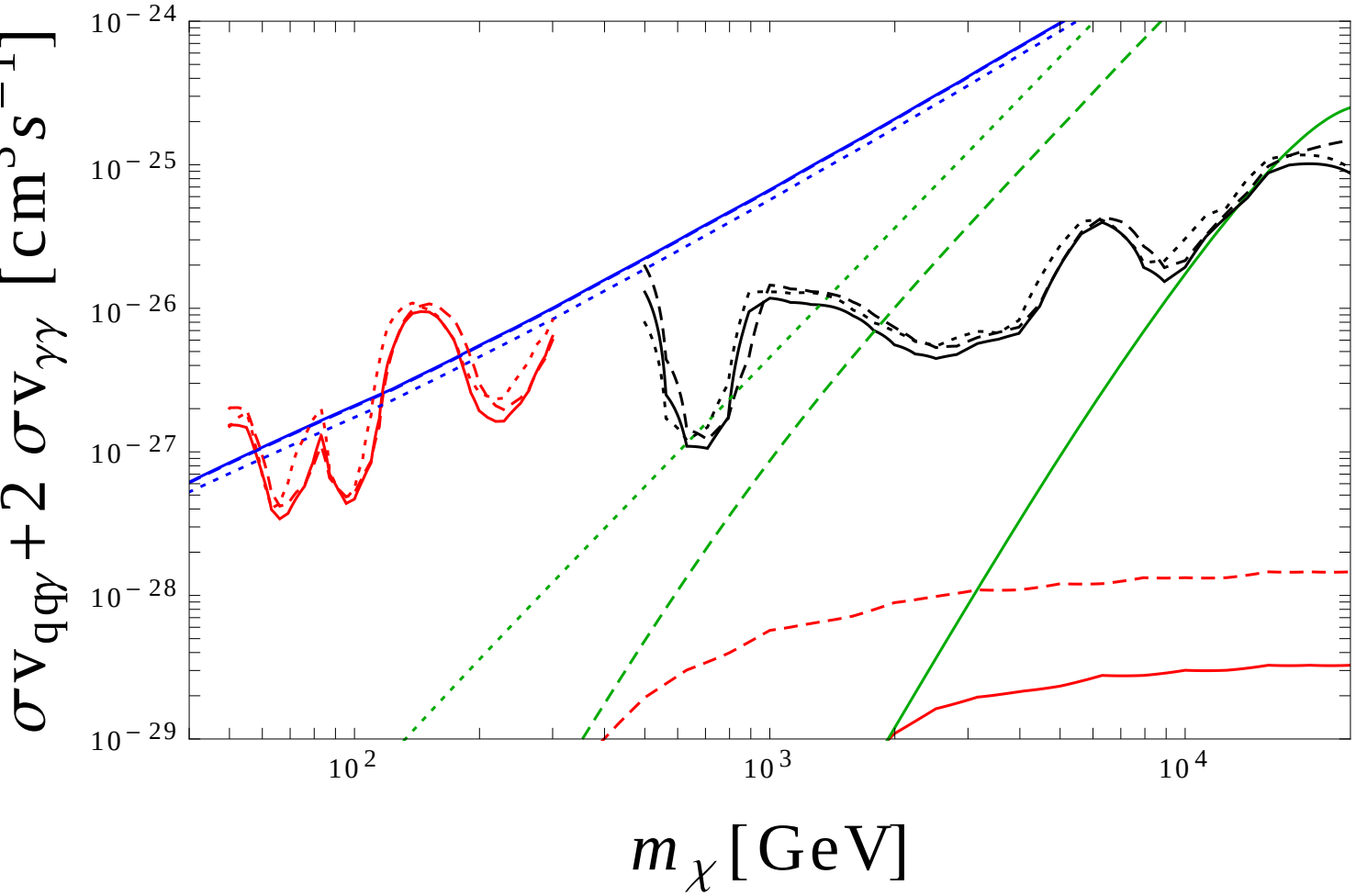


- scattering of quarks and gluon in the nucleus
- heavy quarks flavour suppressed compared to valence quarks
- enhancement for small Δm

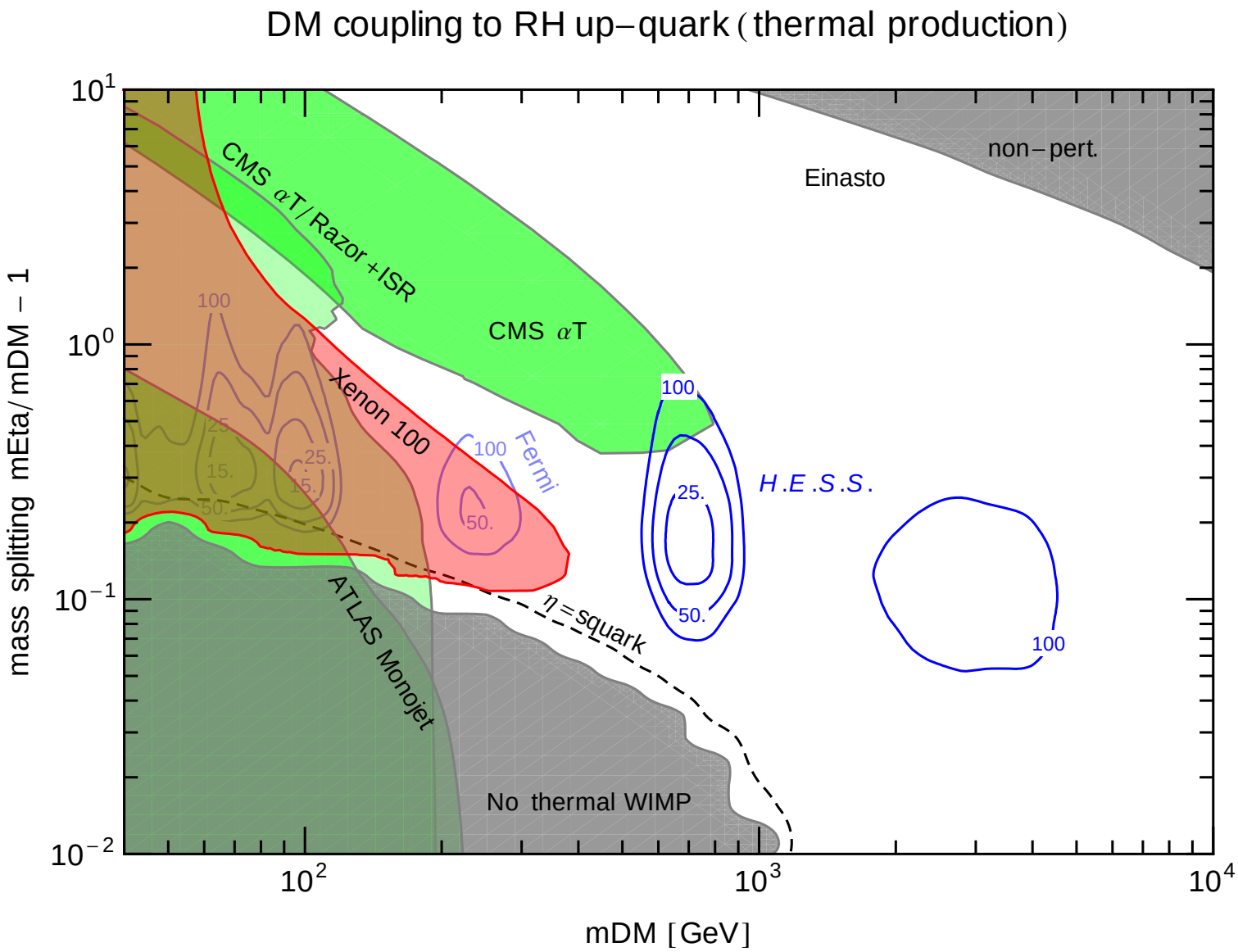
Collider

- production of coloured η due to strong interaction
- signature at collider: 1,2 jets plus missing E_T
- efficincy depends on $m_\eta - m_\chi$
- for $m_\eta - m_\chi \lesssim 100$ GeV rely on ISR [Dreiner, Kramer, Tattersall '12]
- $m_\eta \gtrsim 200$ GeV

Collecting the constraints



How about thermal dark matter?



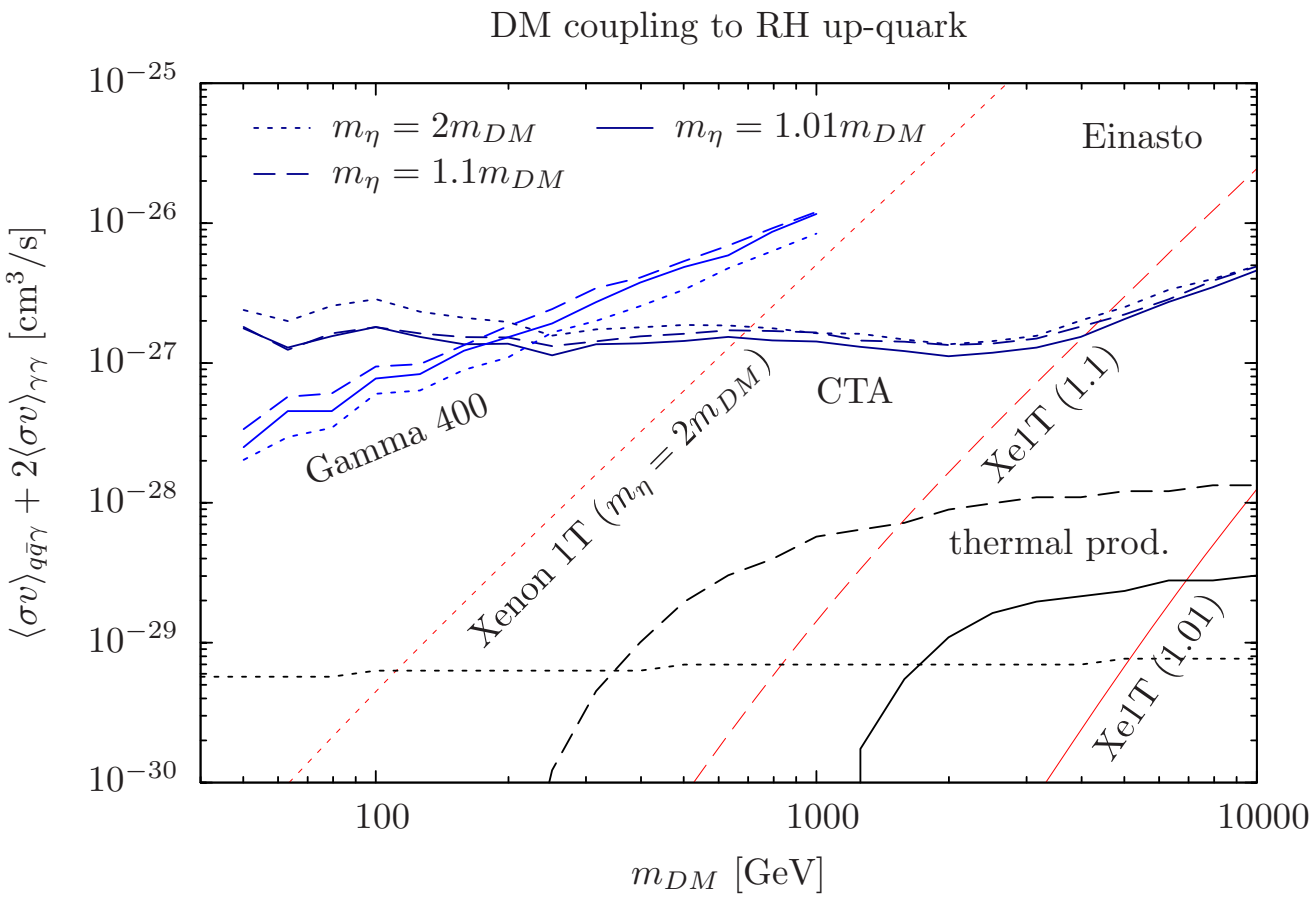
Leptons

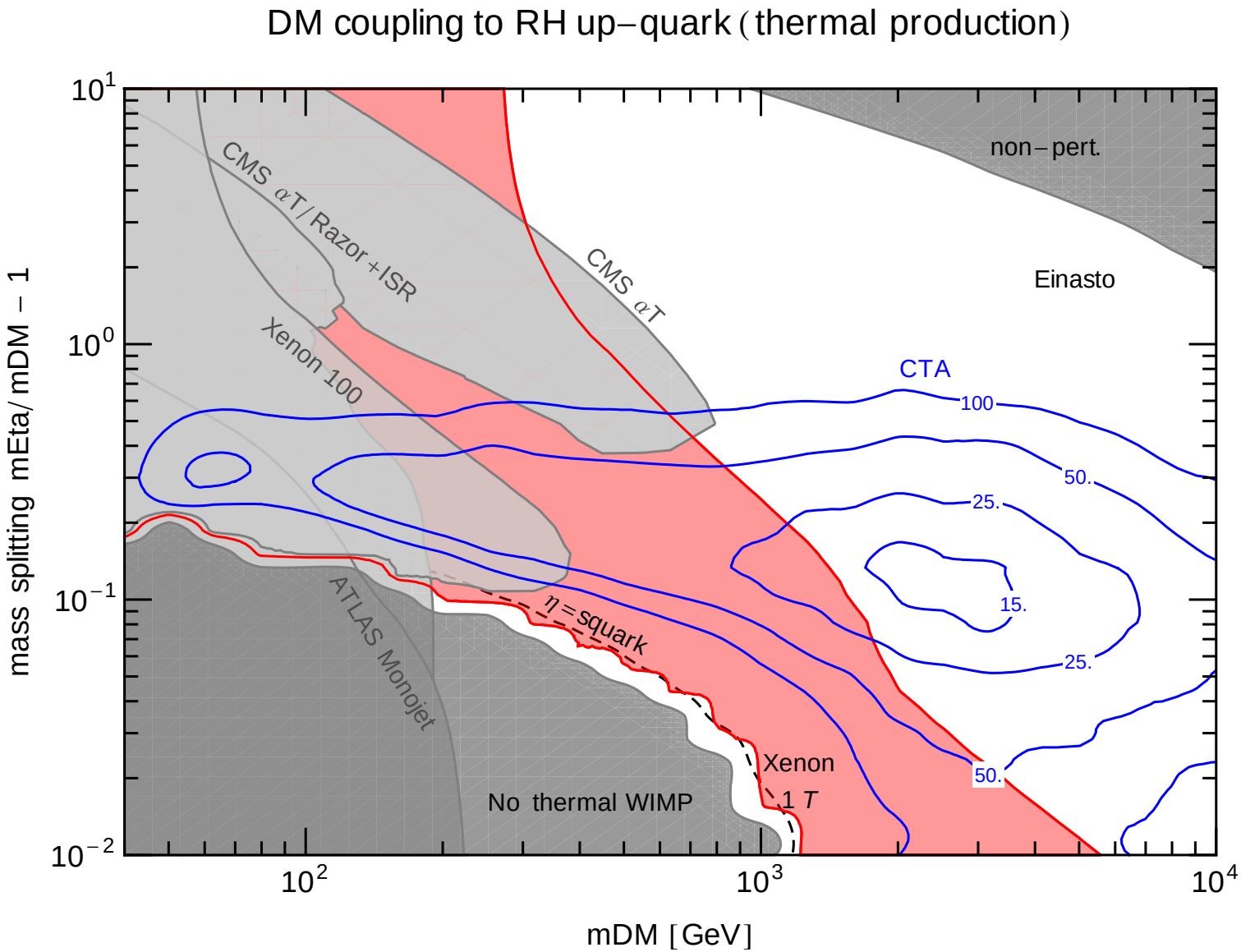
- LEP: $m_\eta \gtrsim 90$ GeV
- only electroweak production $\Rightarrow$ no LHC bound
- no direct detection
- reduced branching ratio to continuum photons

Conclusion

- spectral features provide save information from Galactic Center
- IB can account for line like gamma ray feature
- more data necessary
- coupling to light quarks constrained
- coupling to heavy quarks or leptons rather free

Collecting the prospects




DM coupling to RH up−quark (thermal production)
mass splitting mEta/ mDM − 1
mDM [GeV]
10^1
10^0
10^{-1}
10^{-2}
10^2
10^3
10^4
non − pert.
Einasto
CMS αT / Razor+ISR
CMS αT
Xenon 100
CTA
100
50.
25.
15.
25.
50.
ATLAS Monojet
η = squark
Xenon
1 T
No thermal WIMP