A gamma ray line from the Sky ?

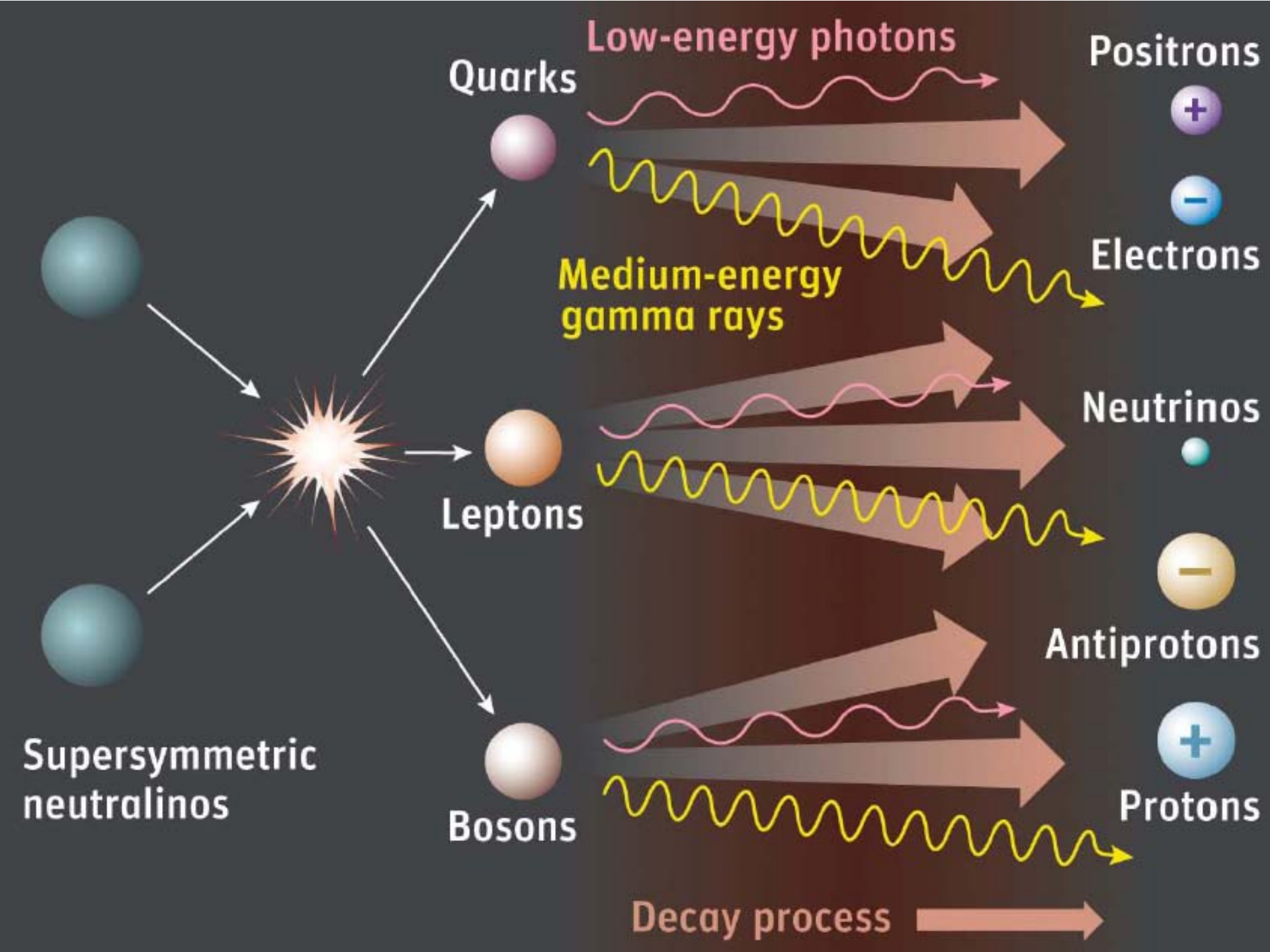
coll. with
Y. Mambrini, S. Pokorski and A. Romagnoni,
JHEP 0908:014,2009
and arXiv:1205.1520 [hep-ph]

GDR Terascale
Jussieu, nov. 7, 2012

A dark matter signature ?

- The existence of dark matter in the Universe is known for a long time. Its origin and properties are however still mysterious .
- We are maybe living the golden age of dark matter physics, due to the triple interpretation of the DM-DM ⇒ SM-SM interactions :

- DM annihilation into SM particles DM+DM → SM+SM : relic density (WMAP) and indirect DM detection
- DM scattering on nuclei DM+ N → DM+ N : direct detection
- DM production in colliders (LHC) SM + SM → DM + DM


Low-energy photons
Quarks
Positrons
Electrons
Medium-energy gamma rays
Neutrinos
Leptons
Antiprotons
Supersymmetric neutralinos
Bosons
Protons
Decay process

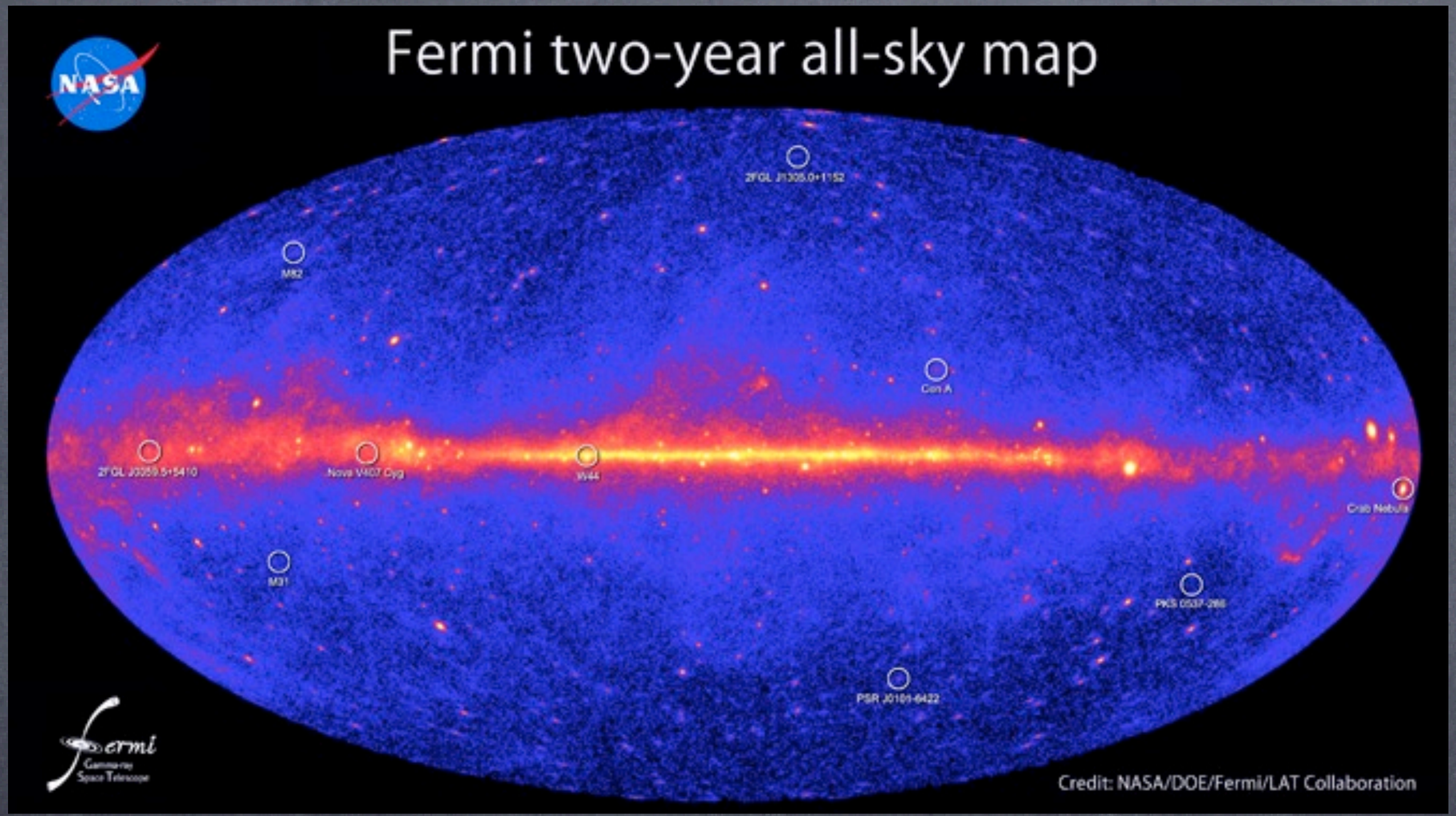
Of particular interest are the annihilations into photons

DM + DM → photon + X (anything)

In this case the photon is monochromatic (M_Z=M_X here)

$$E_\gamma = M_{DM}\left[1-(\frac{M_Z}{2M_{DM}})^2\right]$$

Observation of a line : Galactic Center



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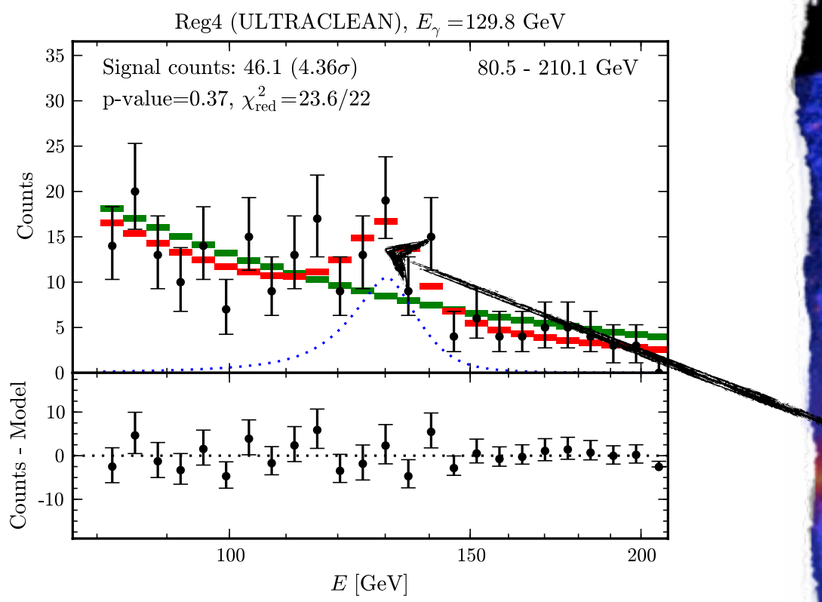
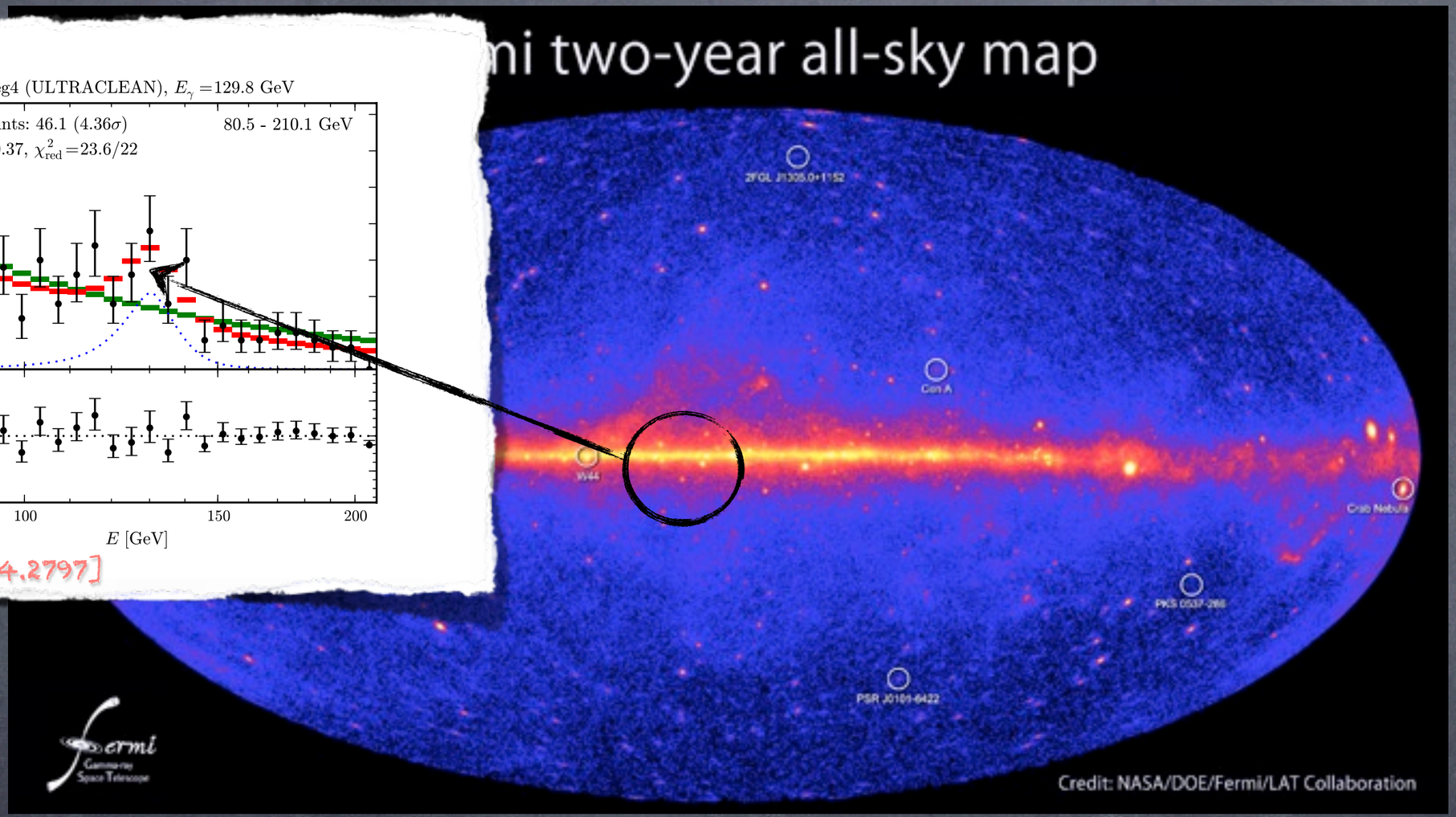


[Weniger, 1204.2797]



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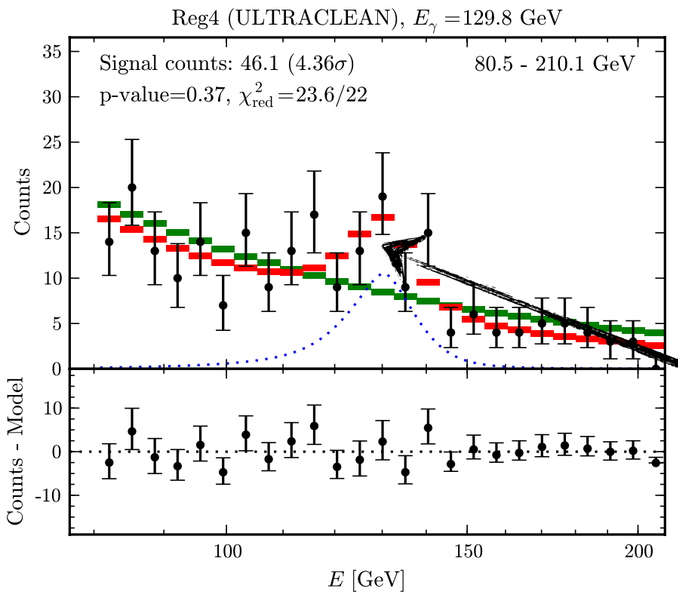

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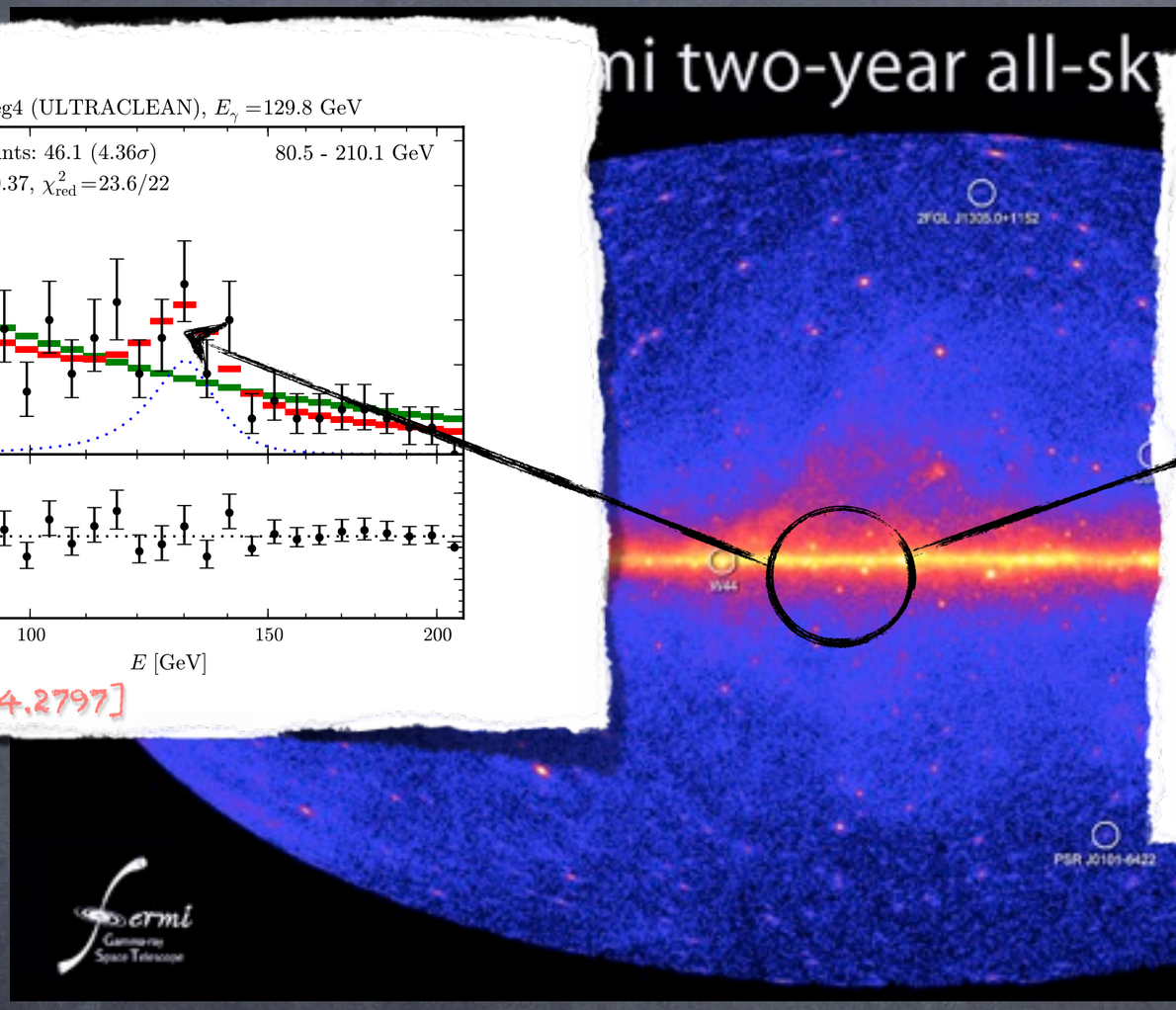

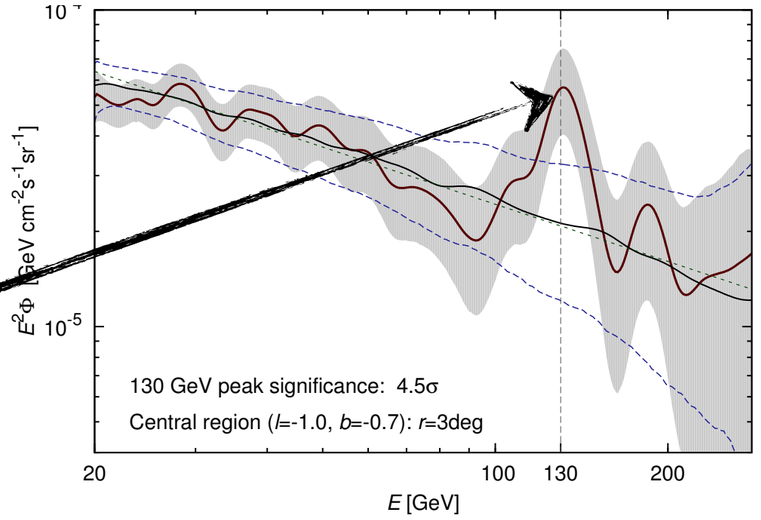

[Tempel, Hektor, Raidal, 1205.1045]

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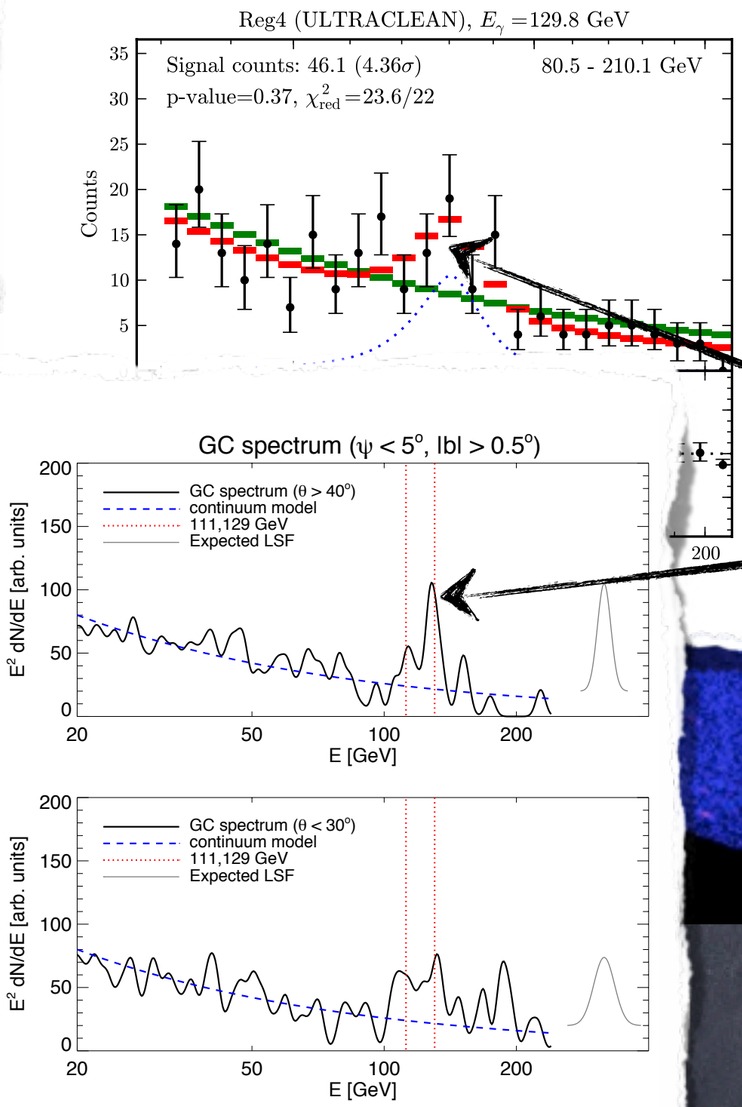

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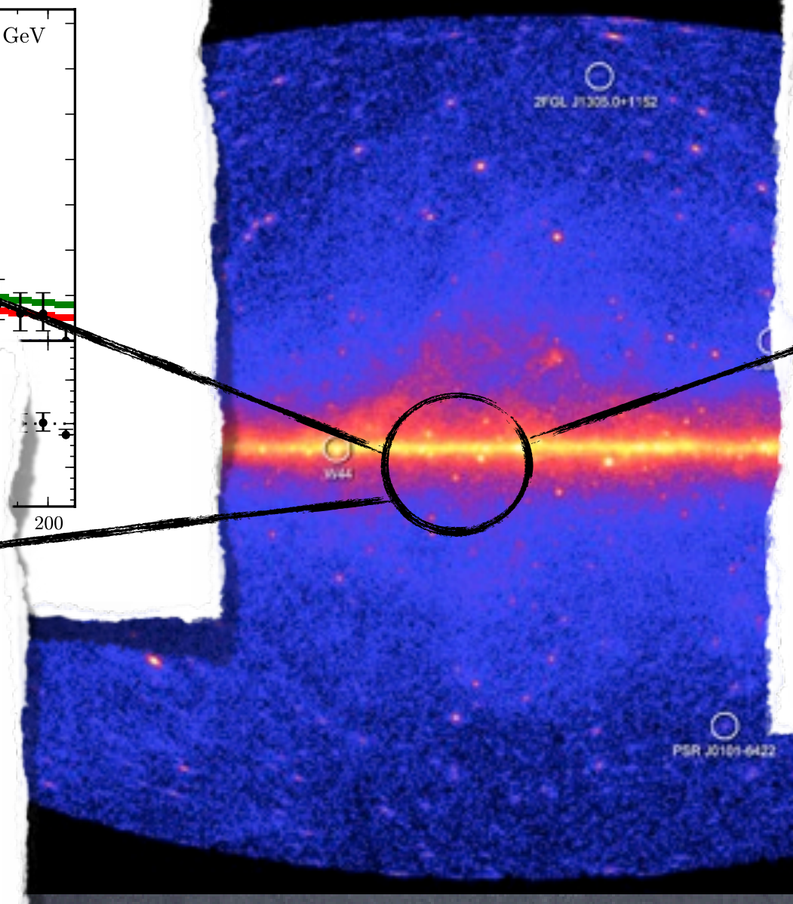

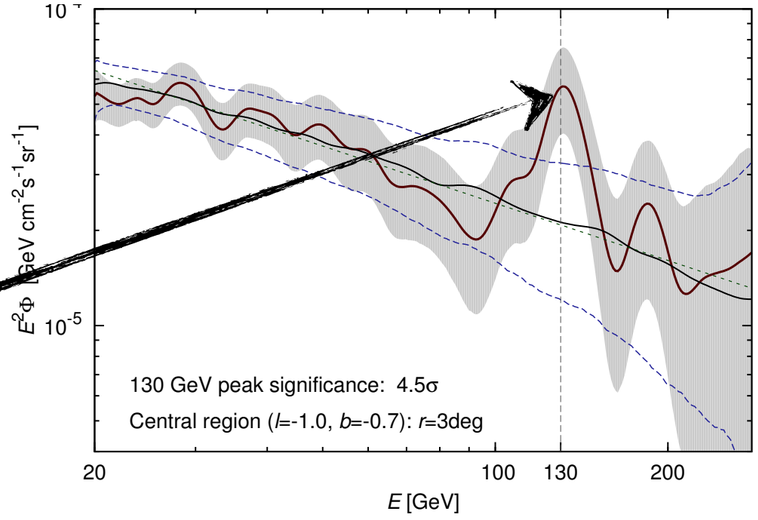

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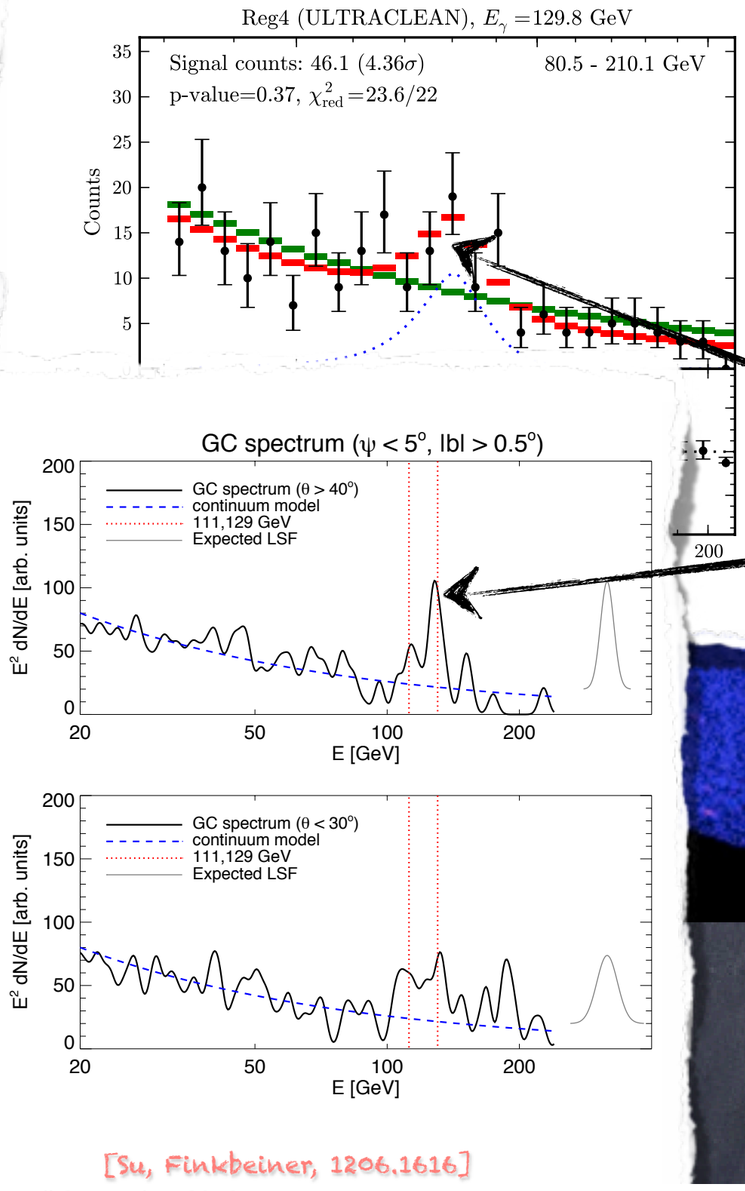

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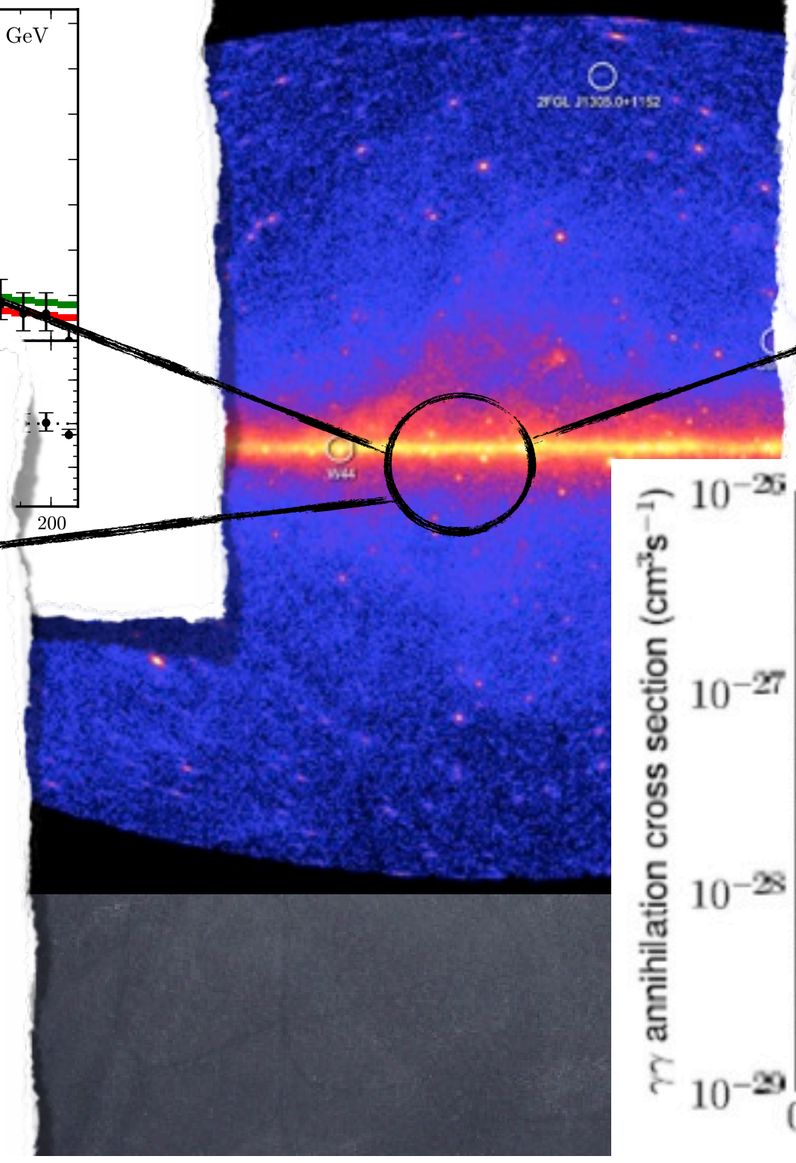

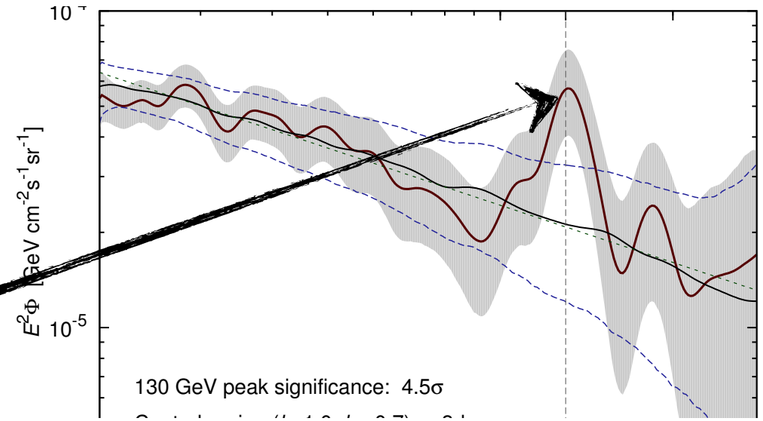

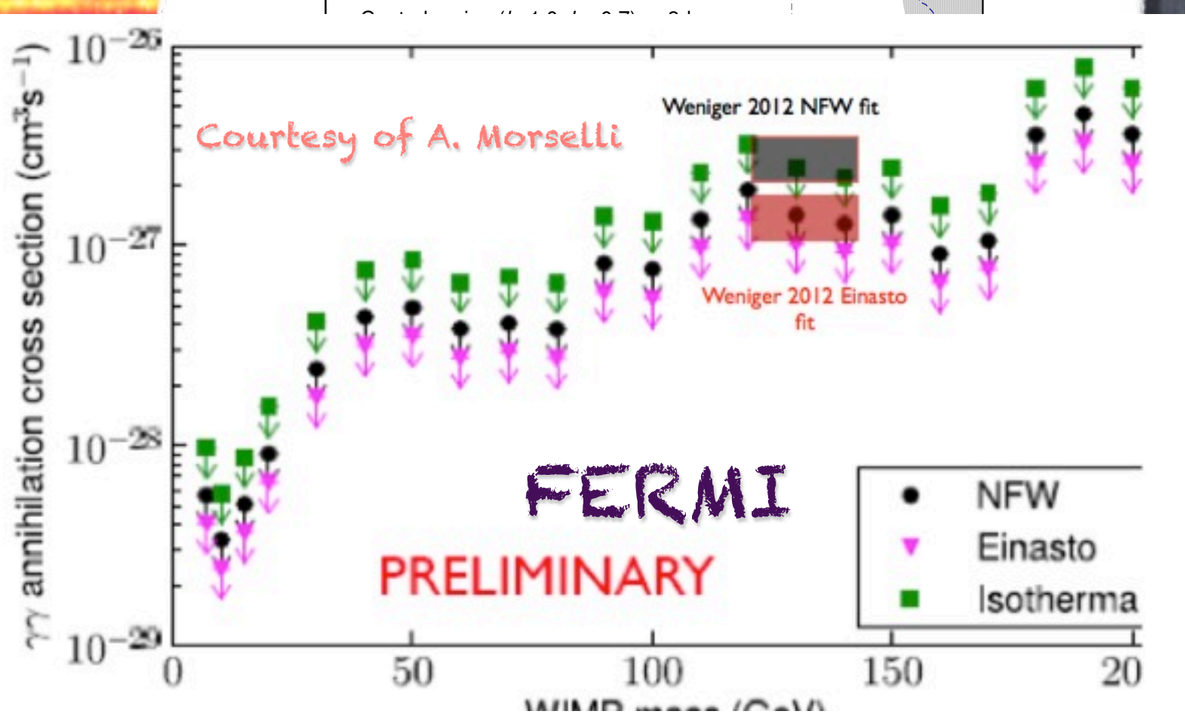

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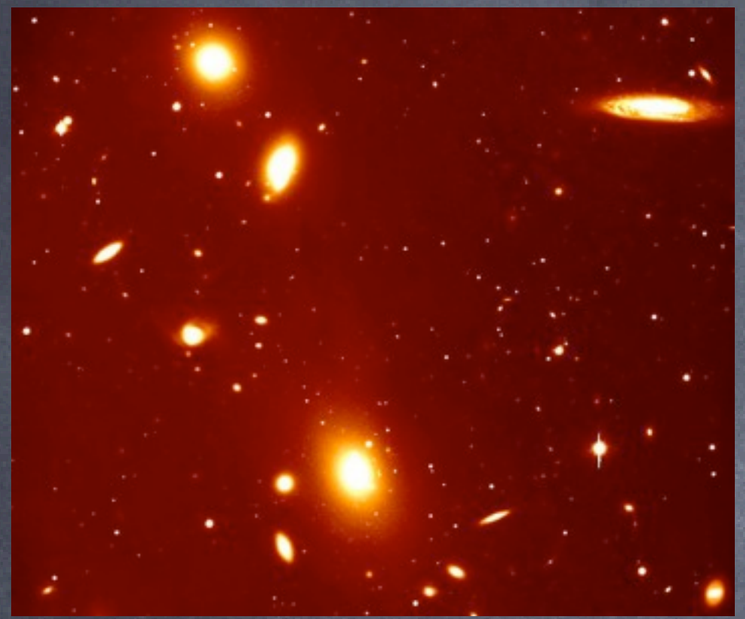
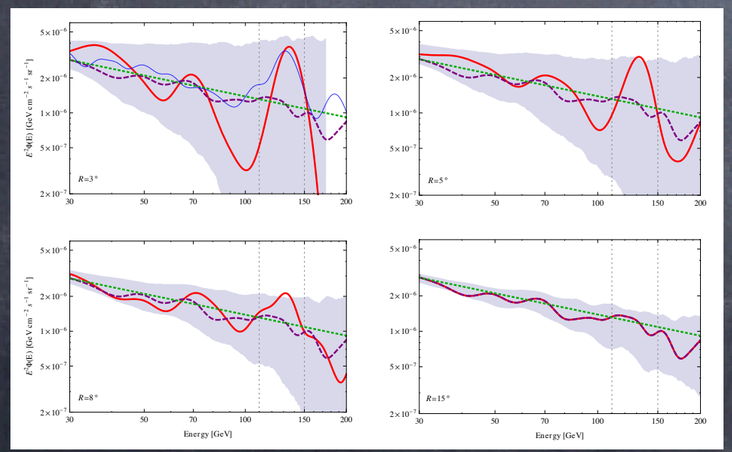


Clusters of Galaxies



Hektor, Raidal, Tempel 1207.4466

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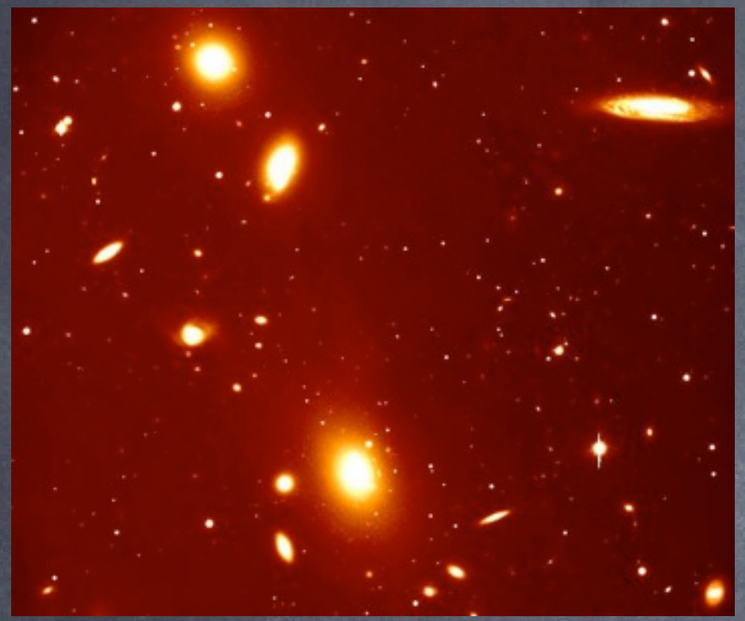

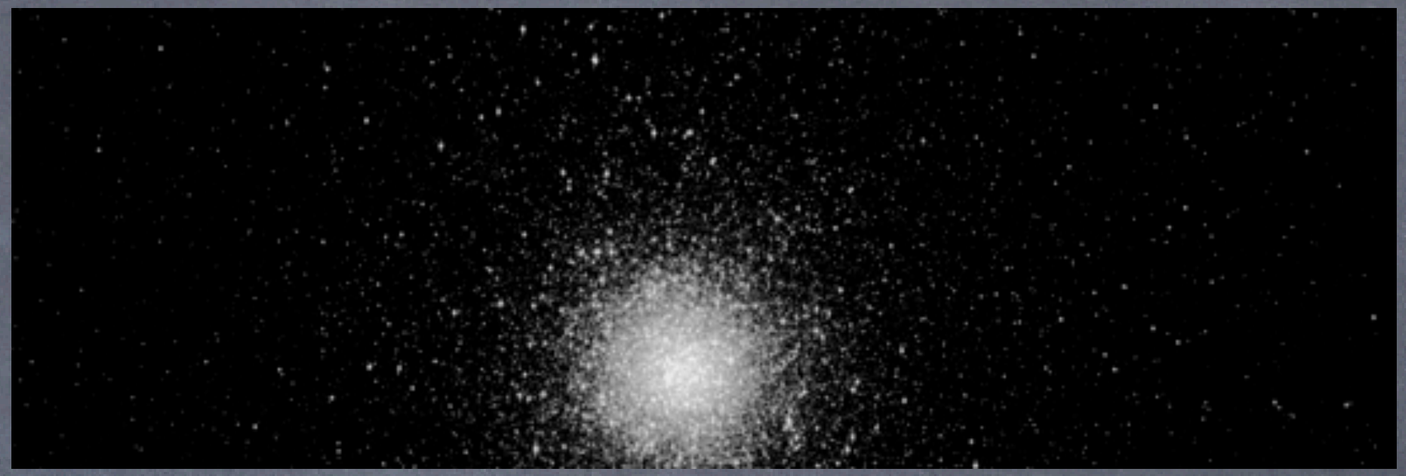

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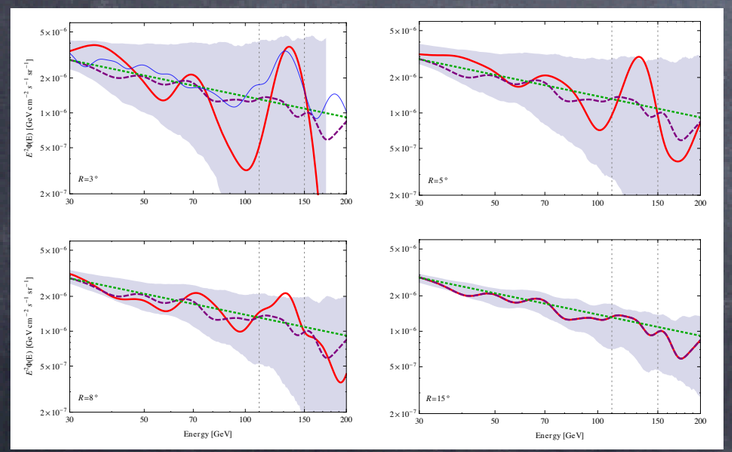

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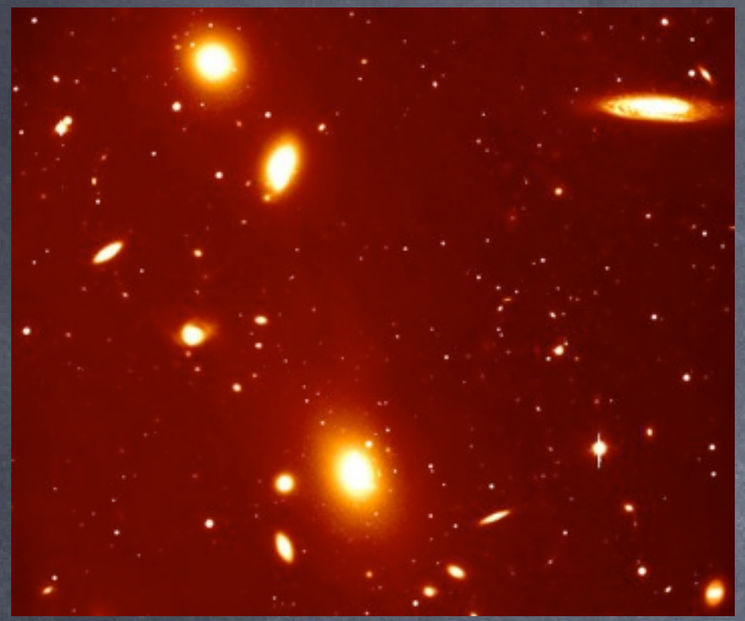

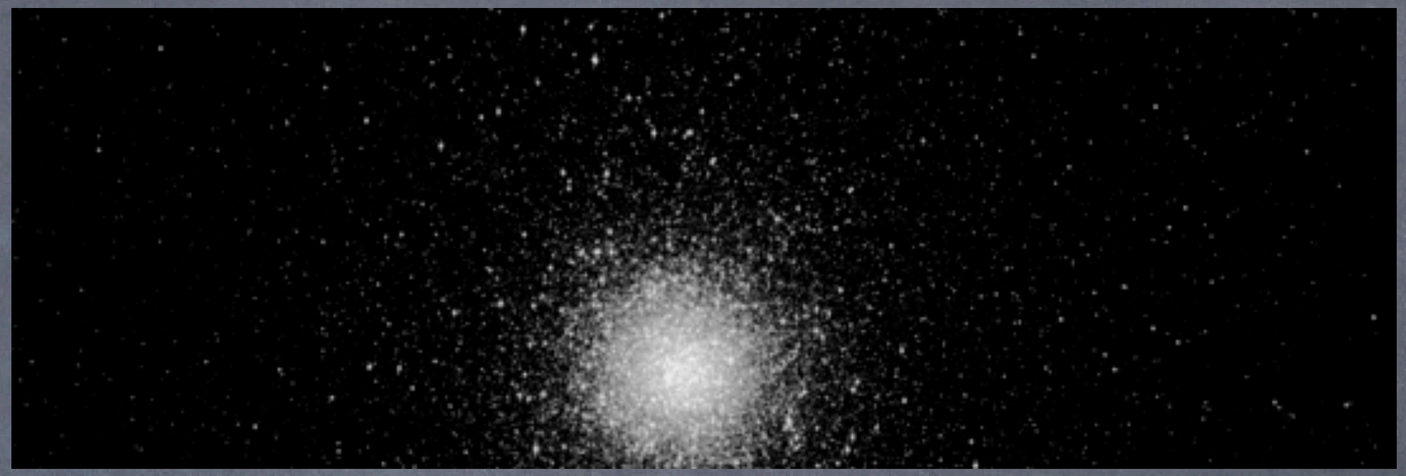

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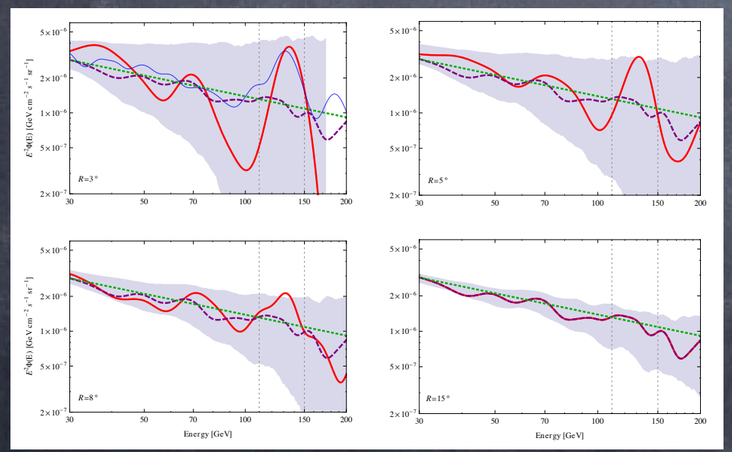

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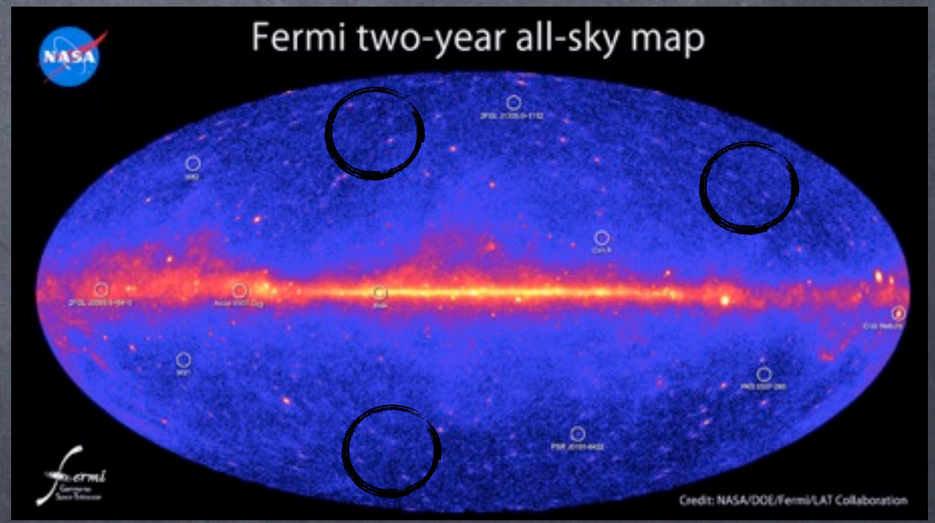

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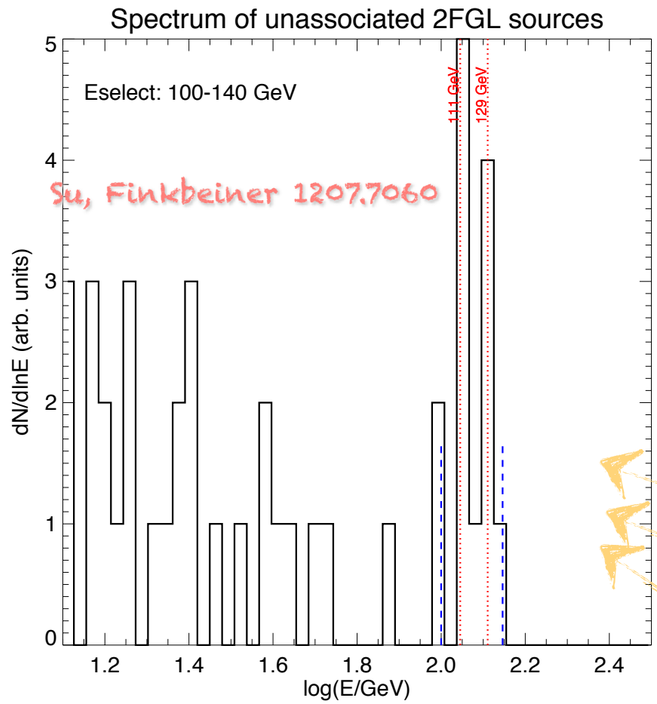

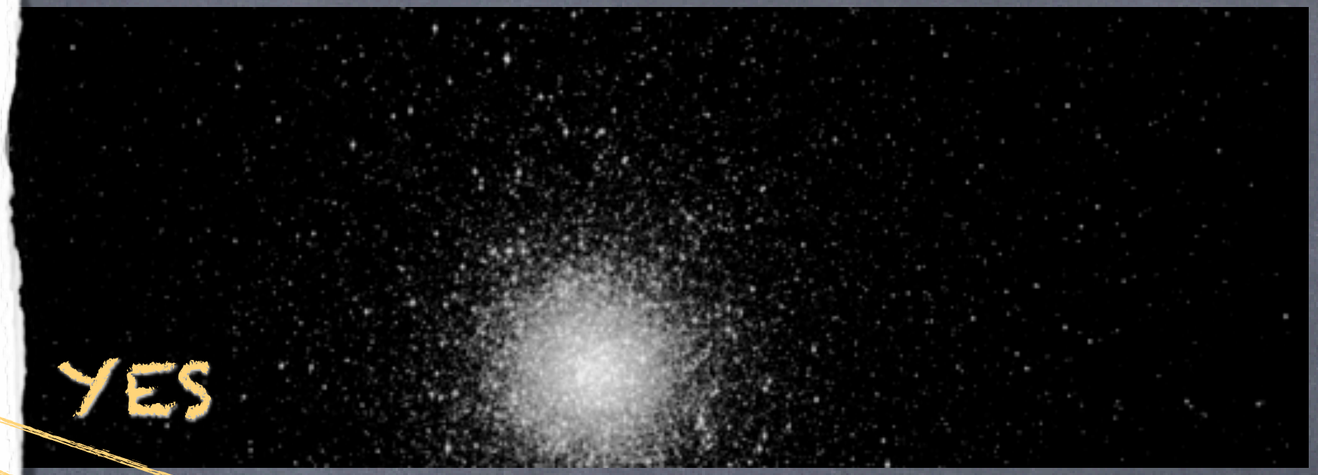

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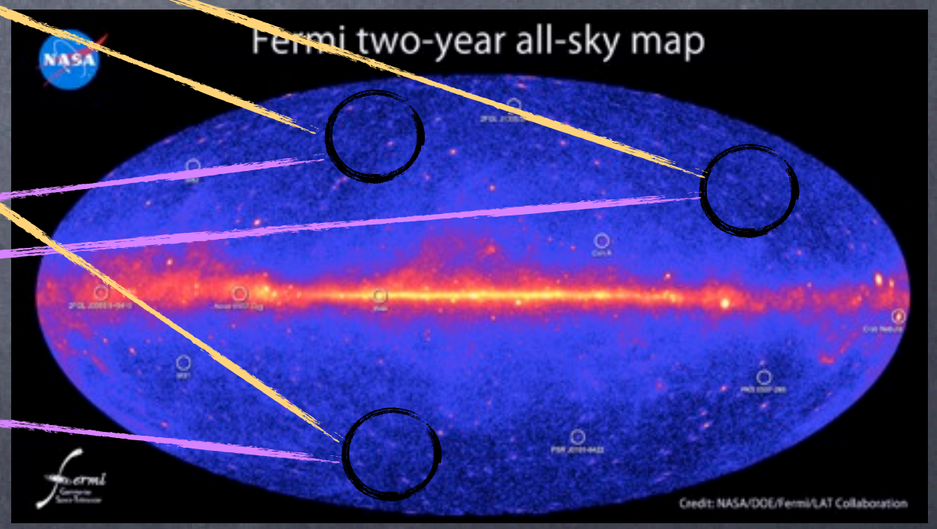
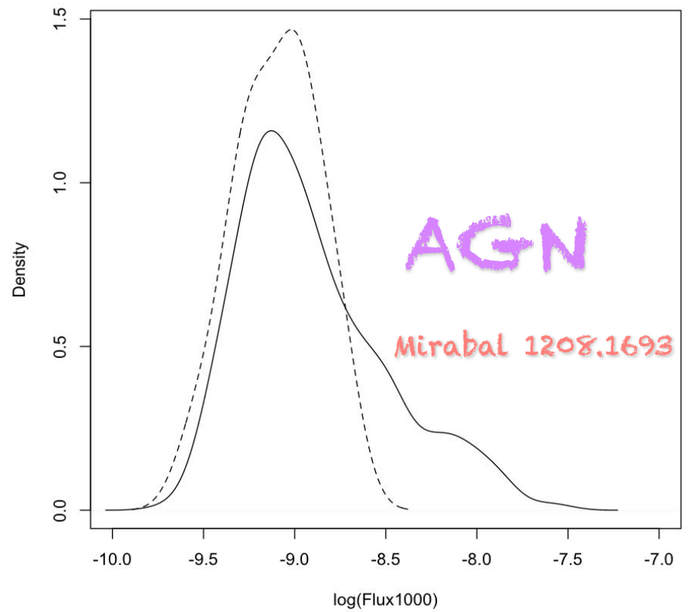
NO





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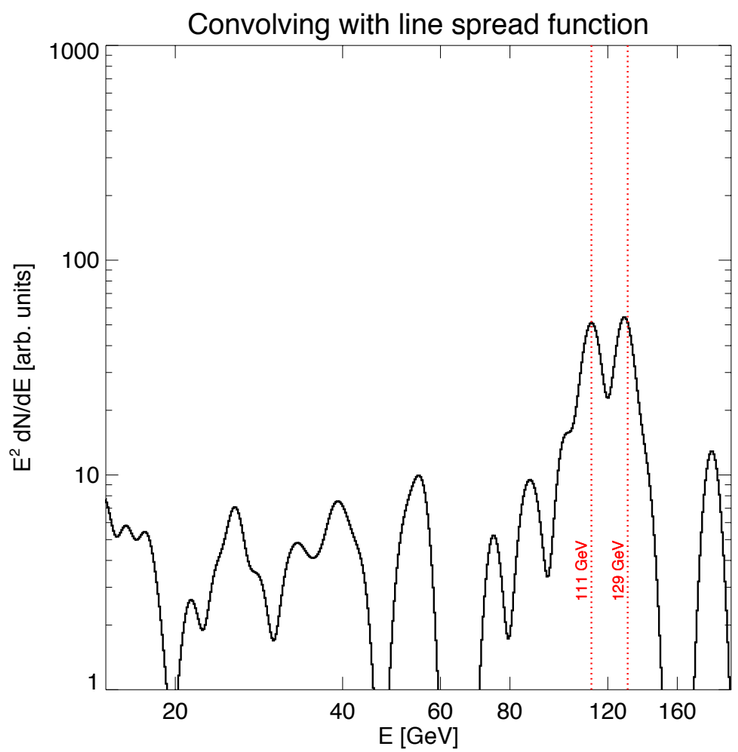

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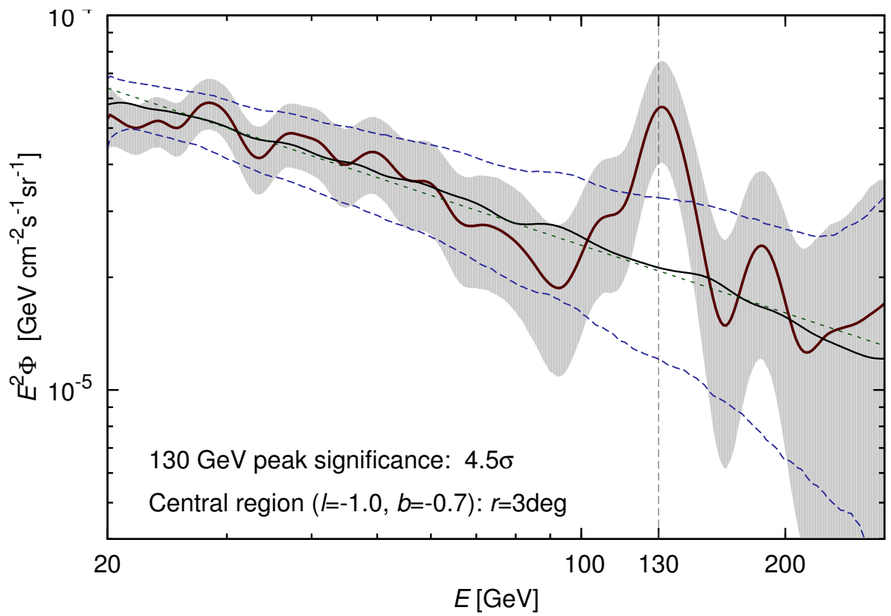

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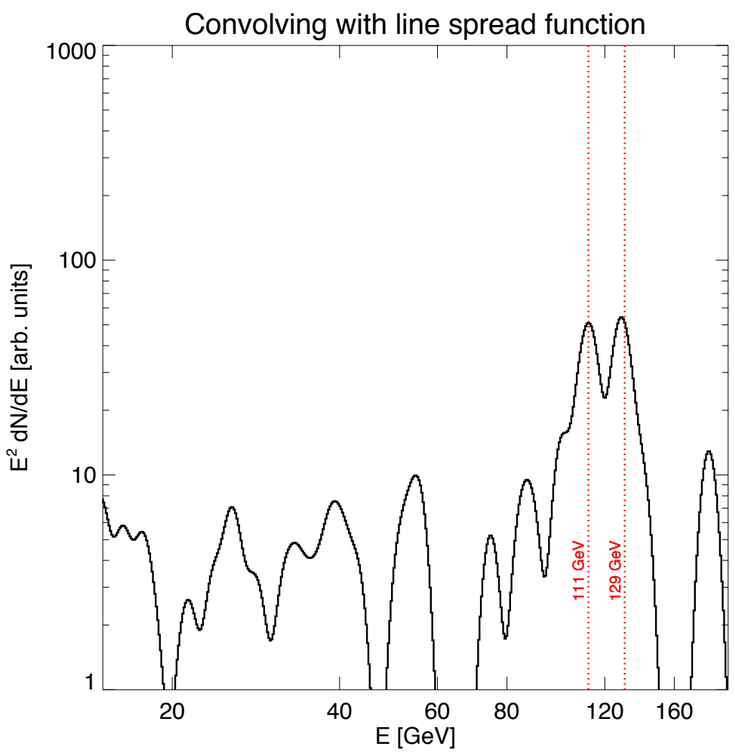

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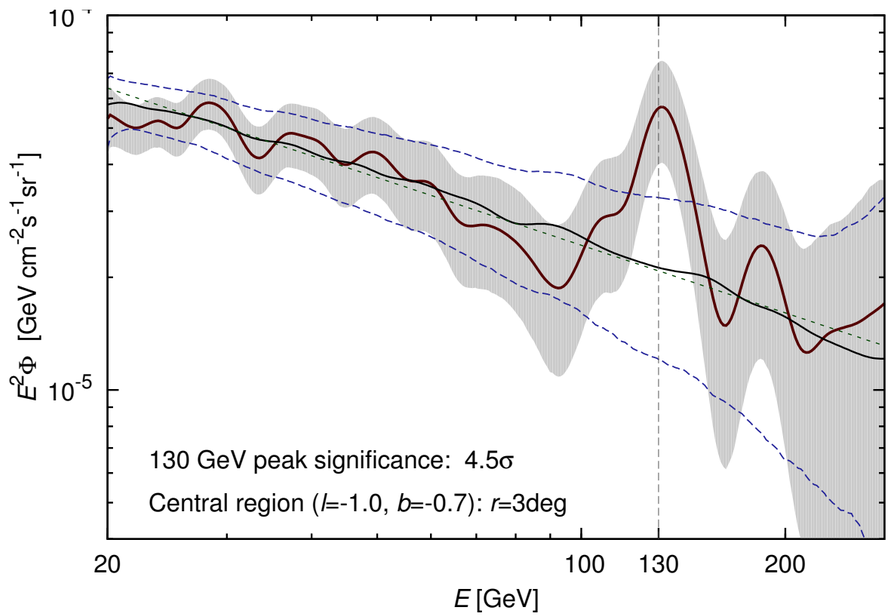

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FERMI resolution $\Delta E/E = 10\%$ not sufficient to distinguish 1 or 2 lines.

(Oda, 1207.1537)

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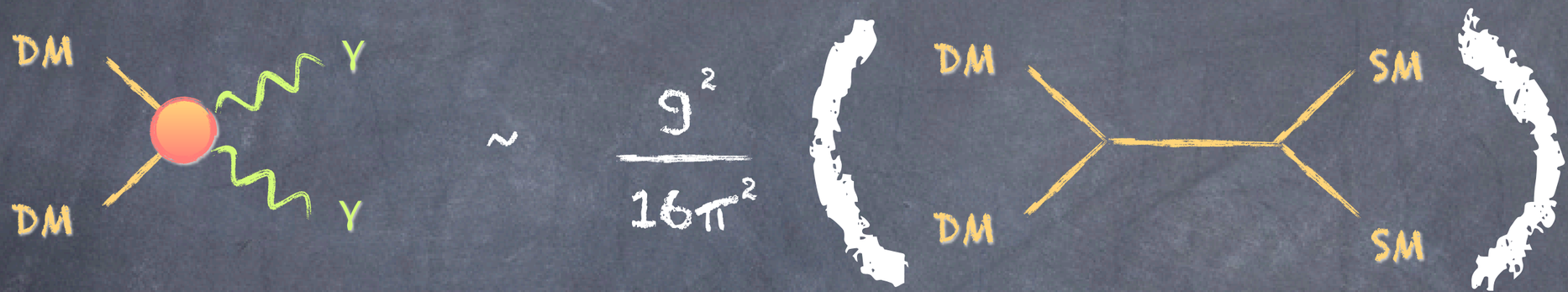

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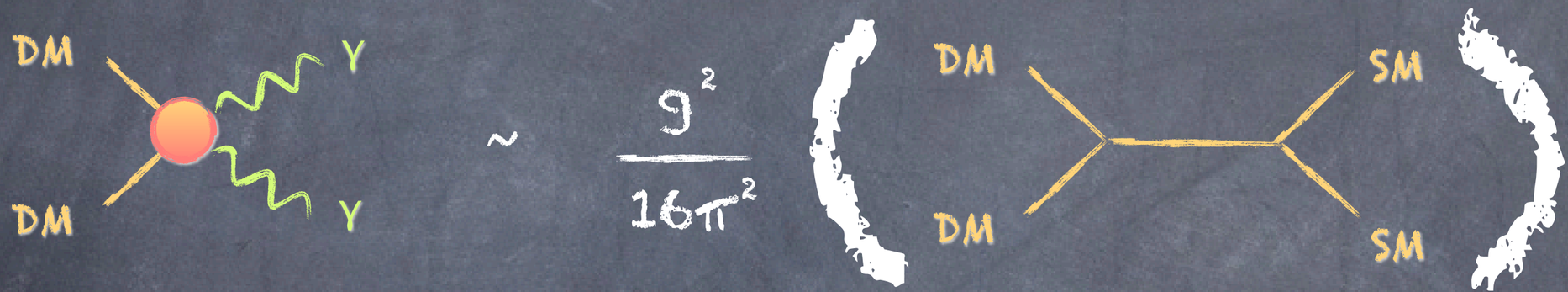

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Models type 1 : resonance channel(s)

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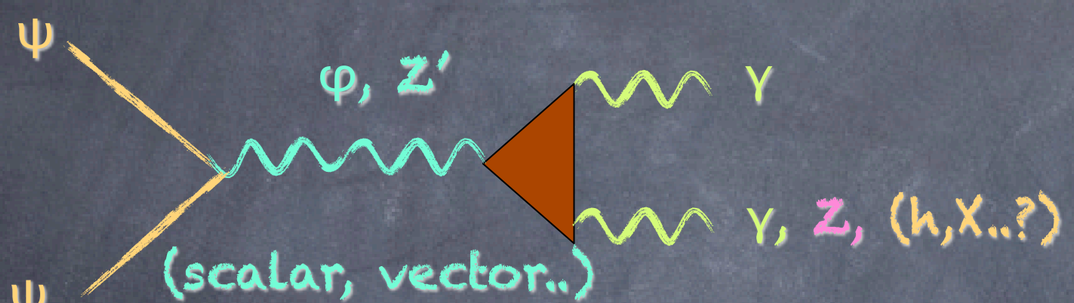

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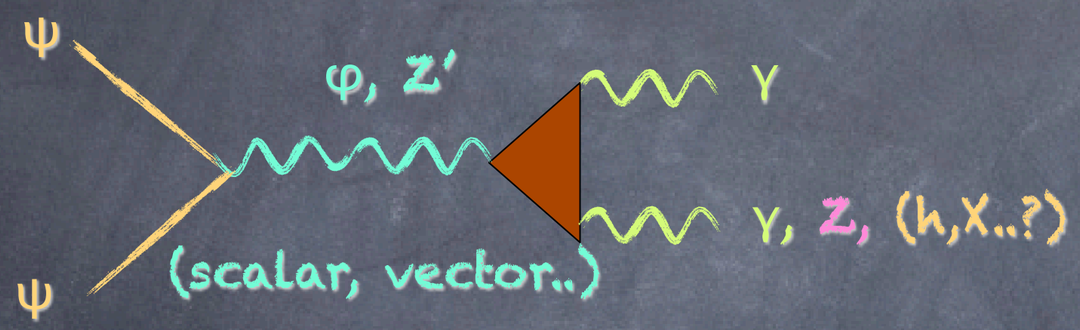

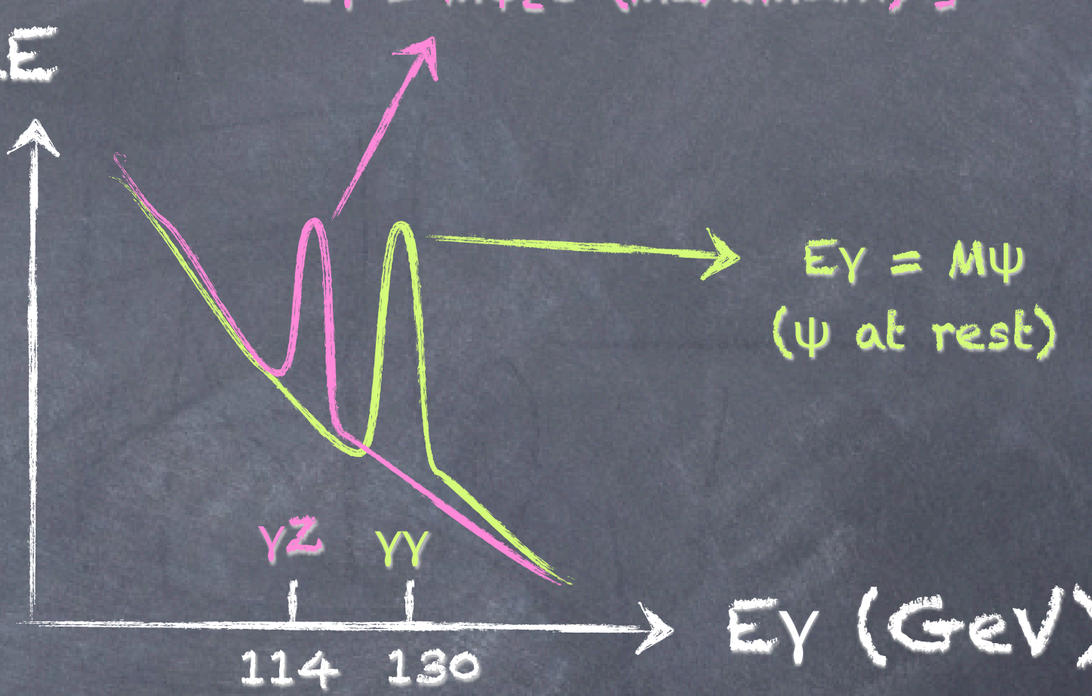

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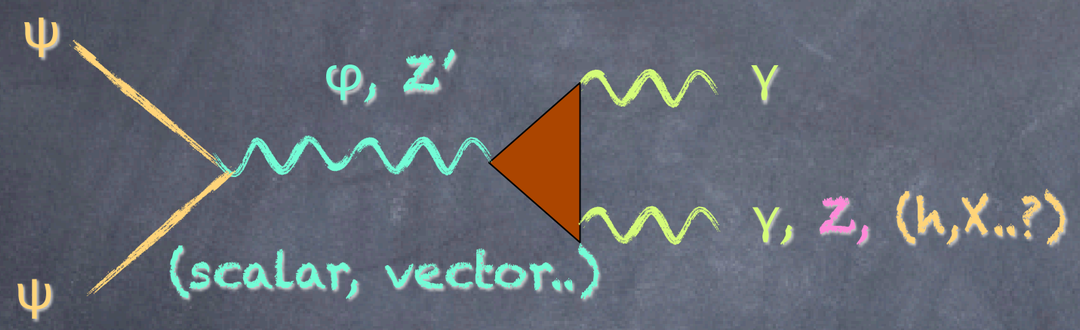

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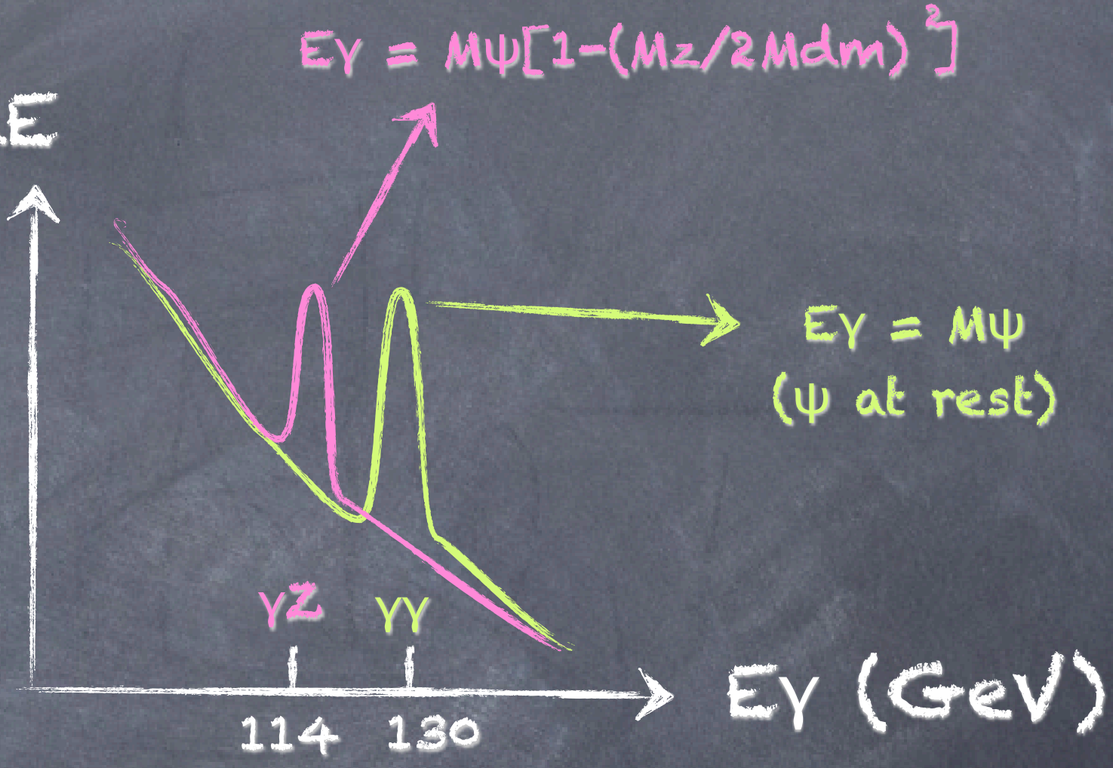

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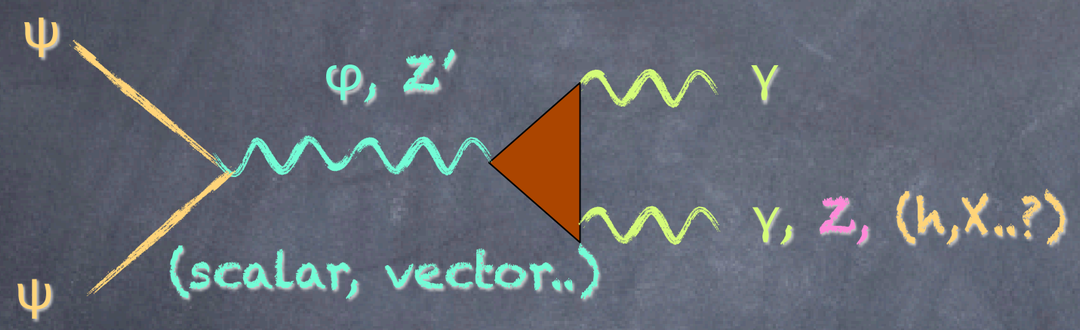

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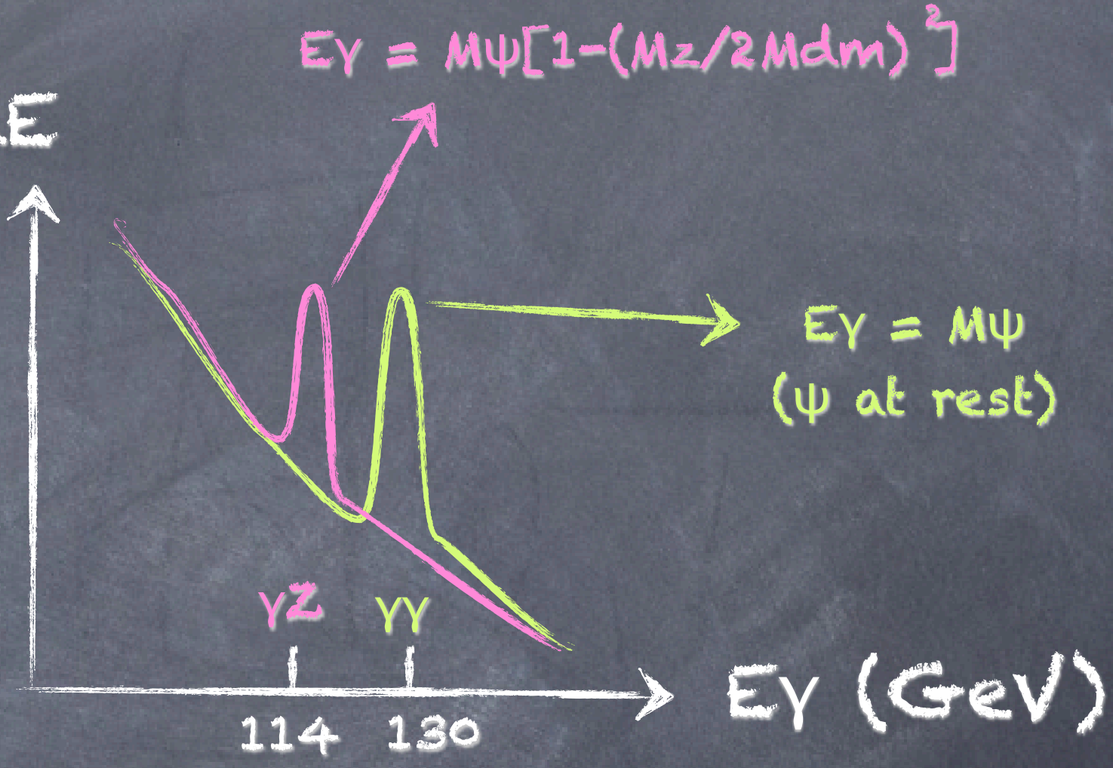

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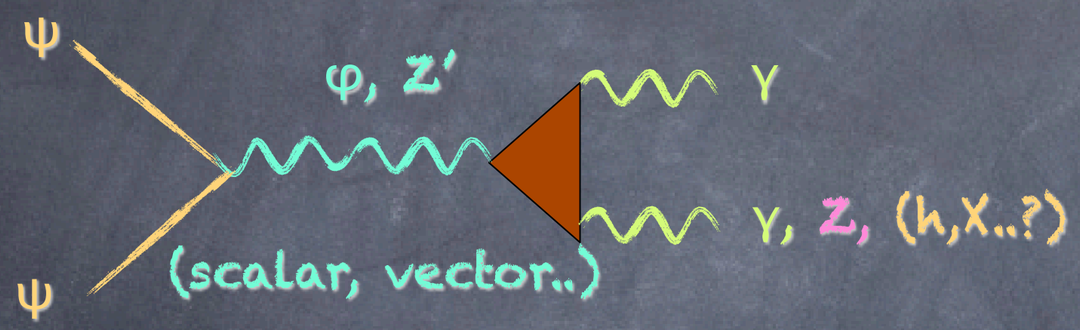

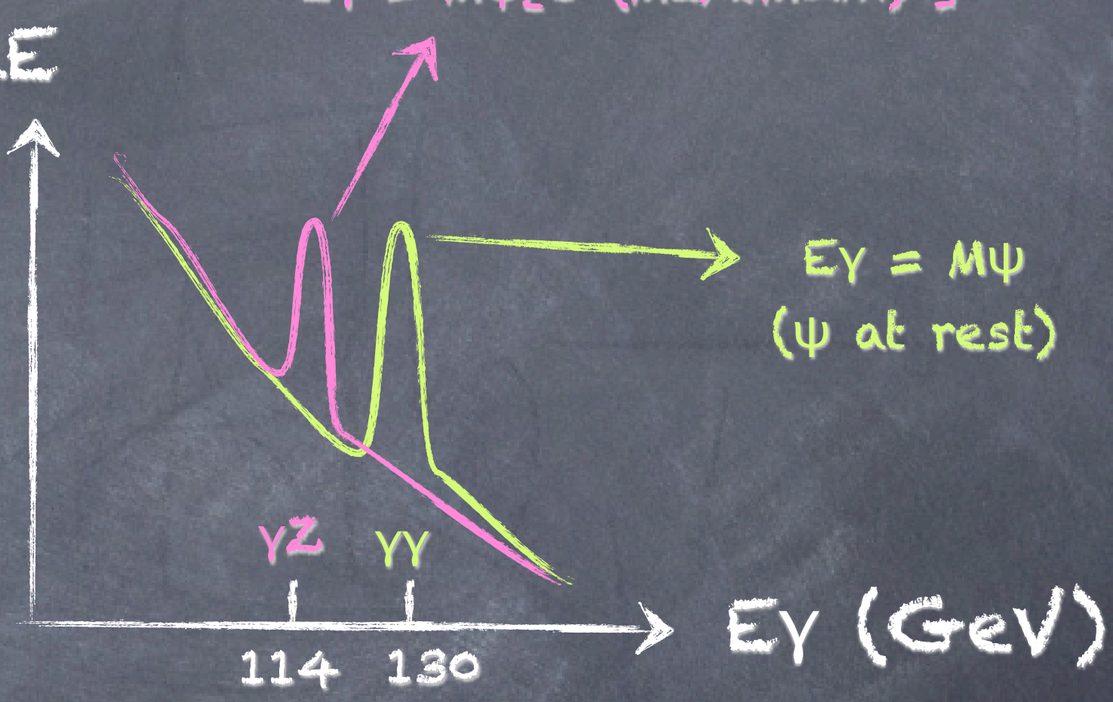

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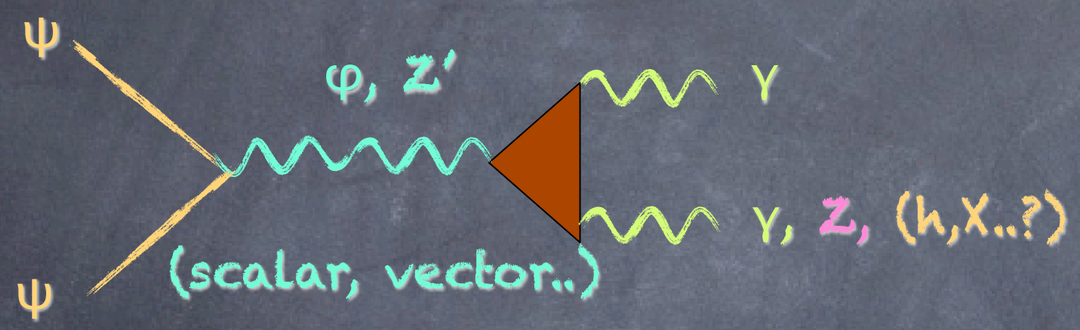

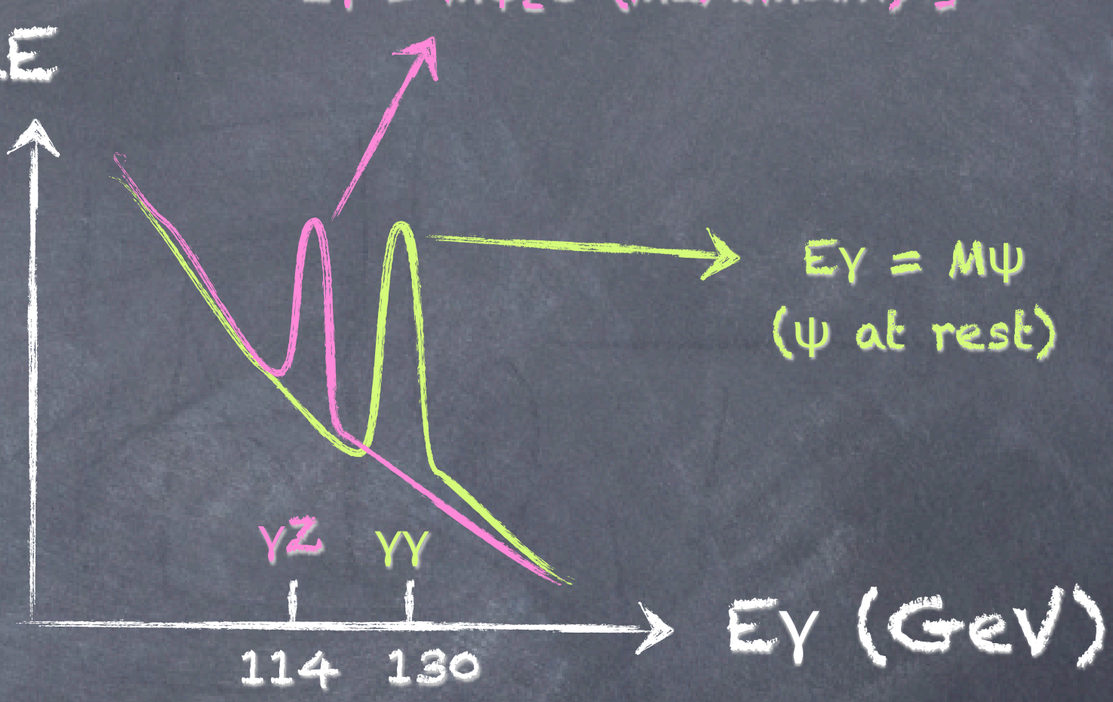

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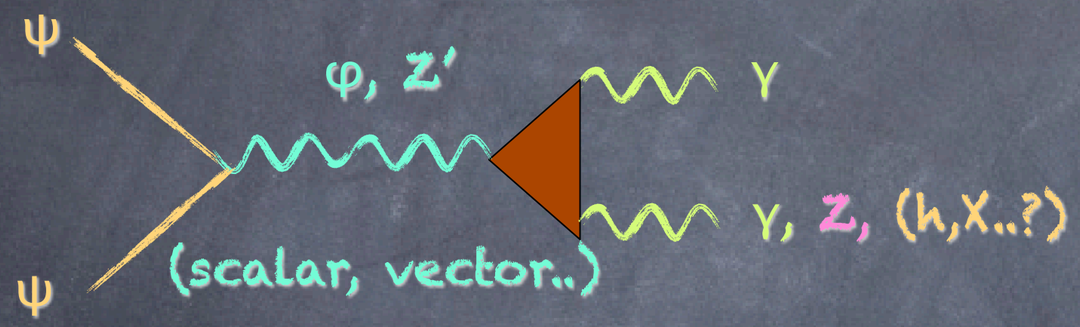

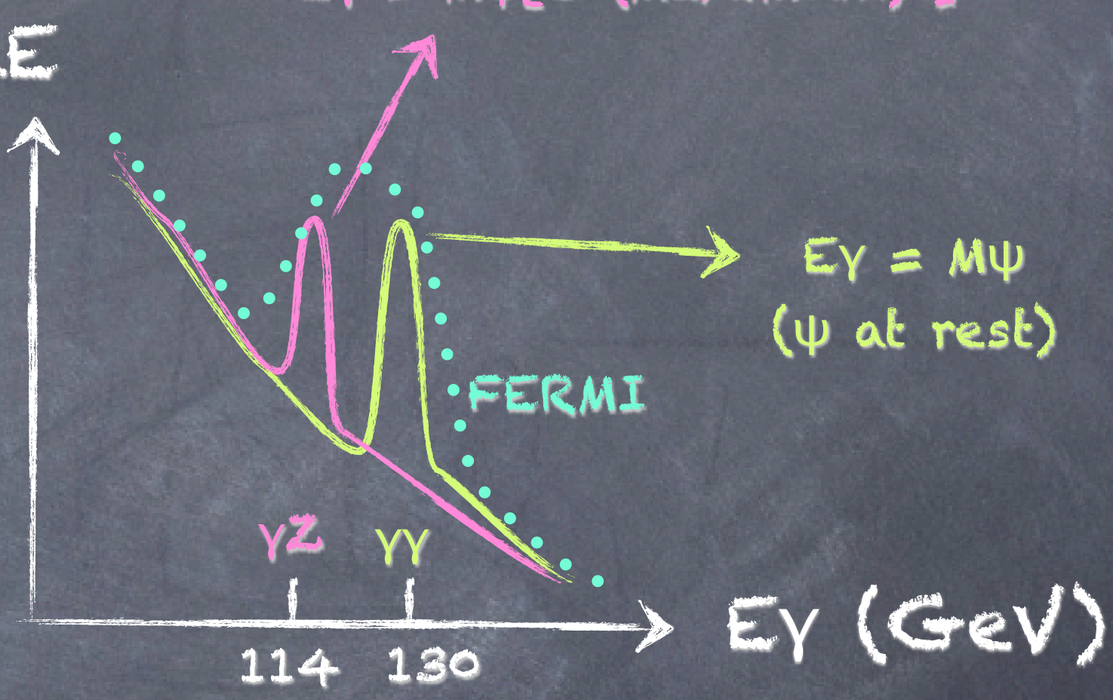

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J. Cline 2012

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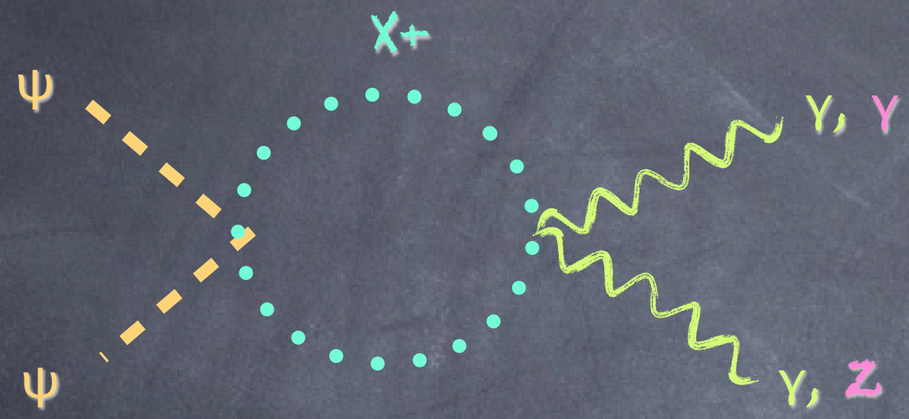

$$\mathcal{L}_{int} = \frac{\lambda_X}{2}|\psi|^2|X|^2 + \lambda_h|H|^2|X|^2 + \frac{\lambda_{h\psi}}{2}|H|^2|\psi|^2$$

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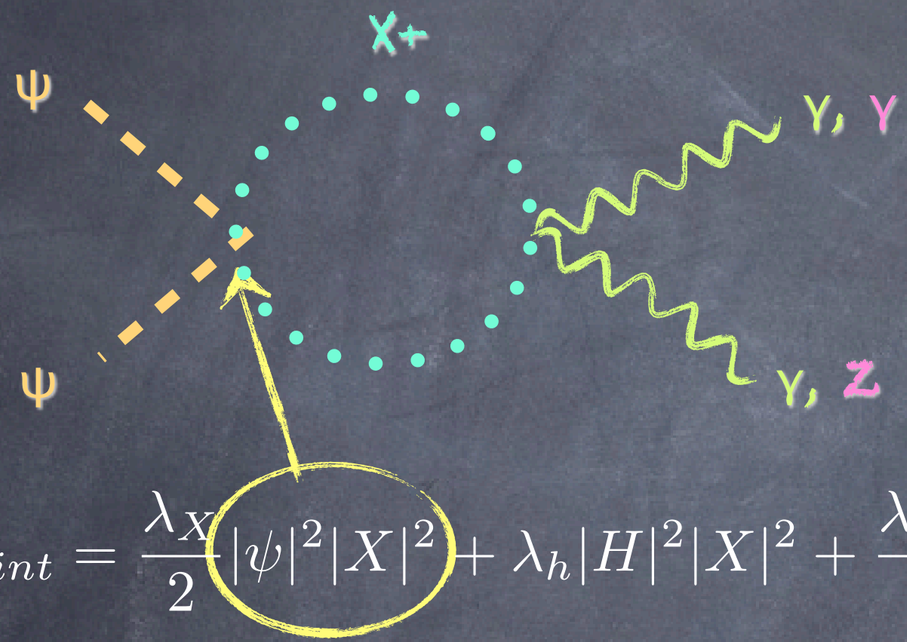
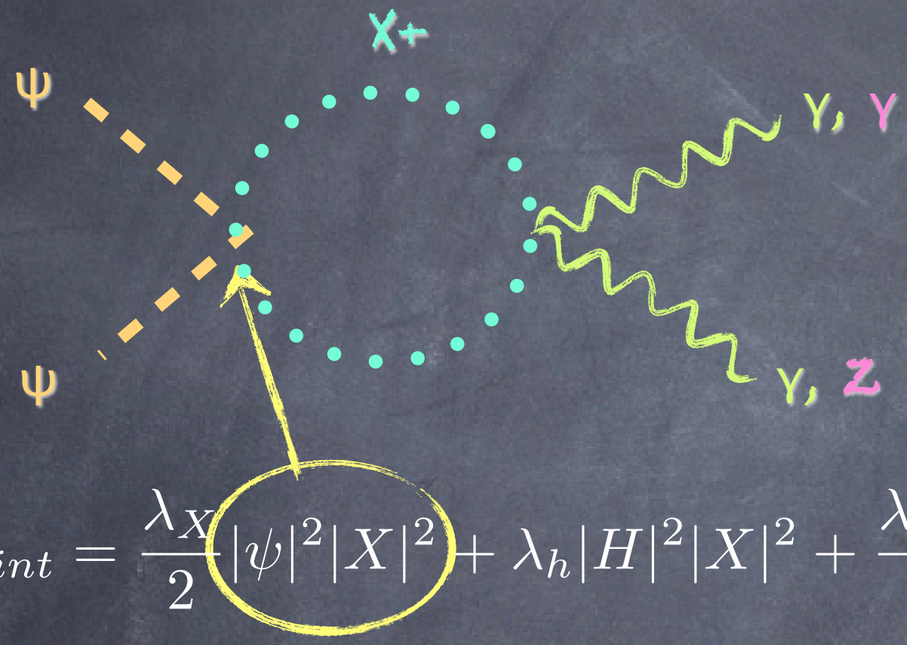


$$\mathcal{L}_{int} = \frac{\lambda_X}{2}|\psi|^2|X|^2 + \lambda_h|H|^2|X|^2 + \frac{\lambda_{h\psi}}{2}|H|^2|\psi|^2$$

J. Cline 2012

Models type 2 : internal loops

ψ= DM candidate



WMAP

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J. Cline 2012

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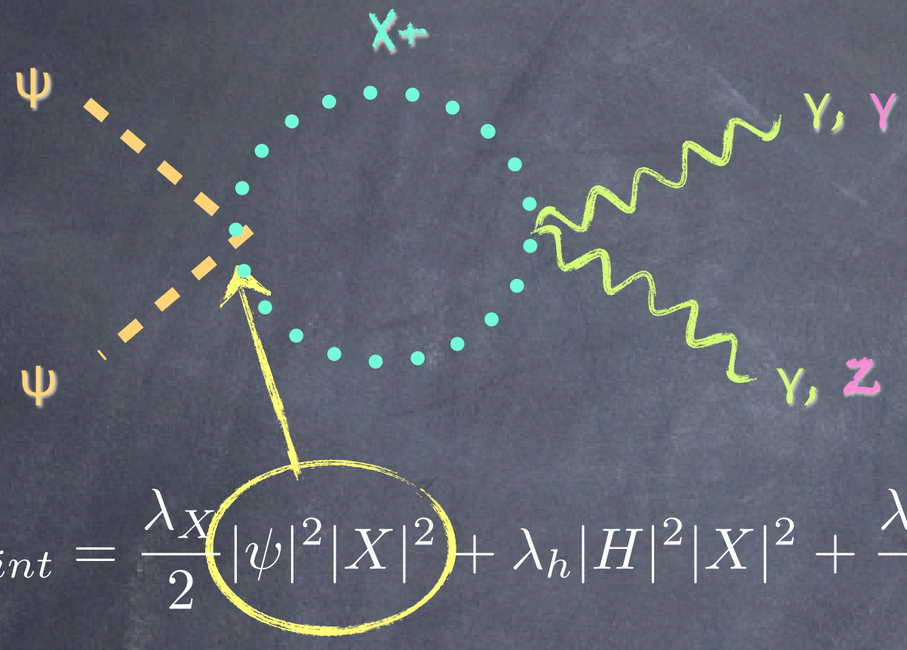

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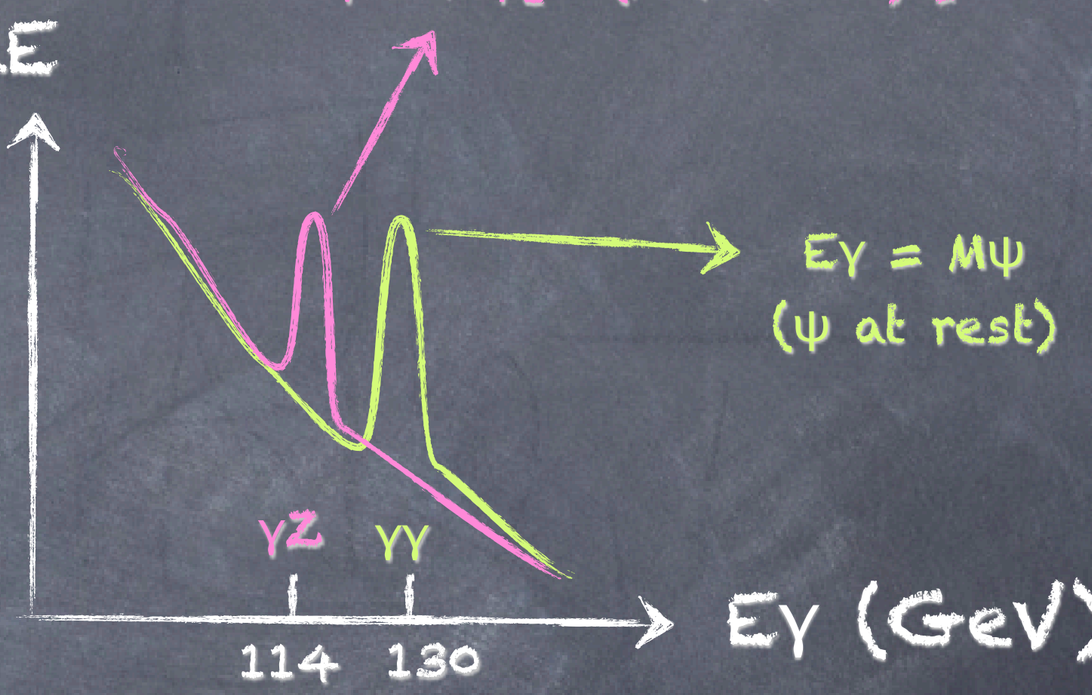

J. Cline 2012

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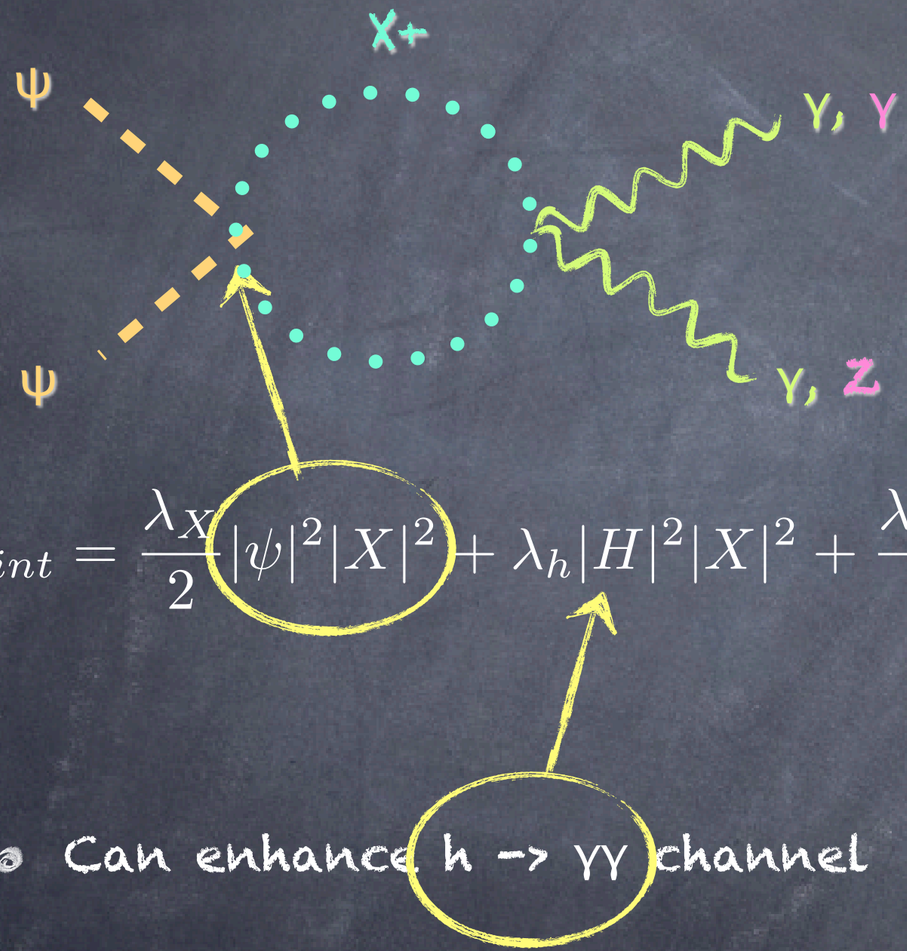

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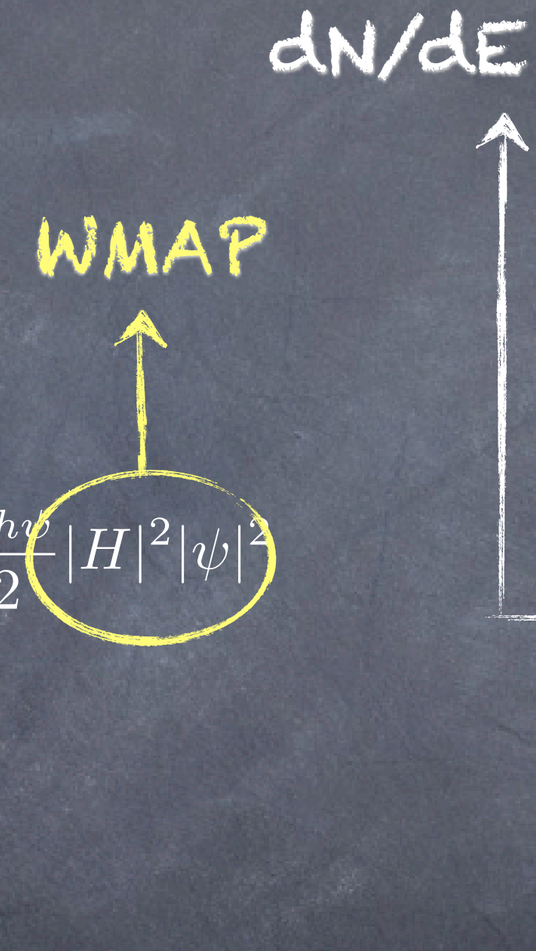

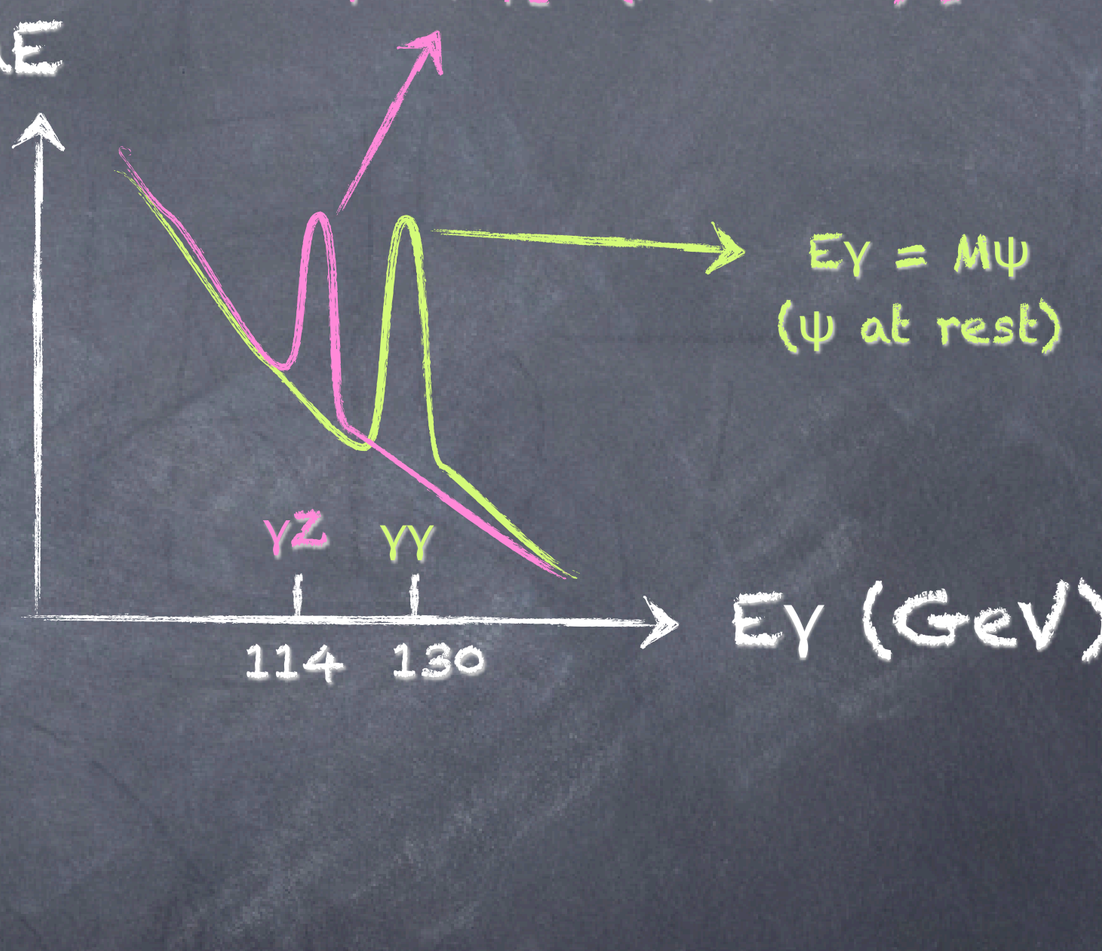

- Can enhance h -> γγ channel

J. Cline 2012

Models type 2 : internal loops

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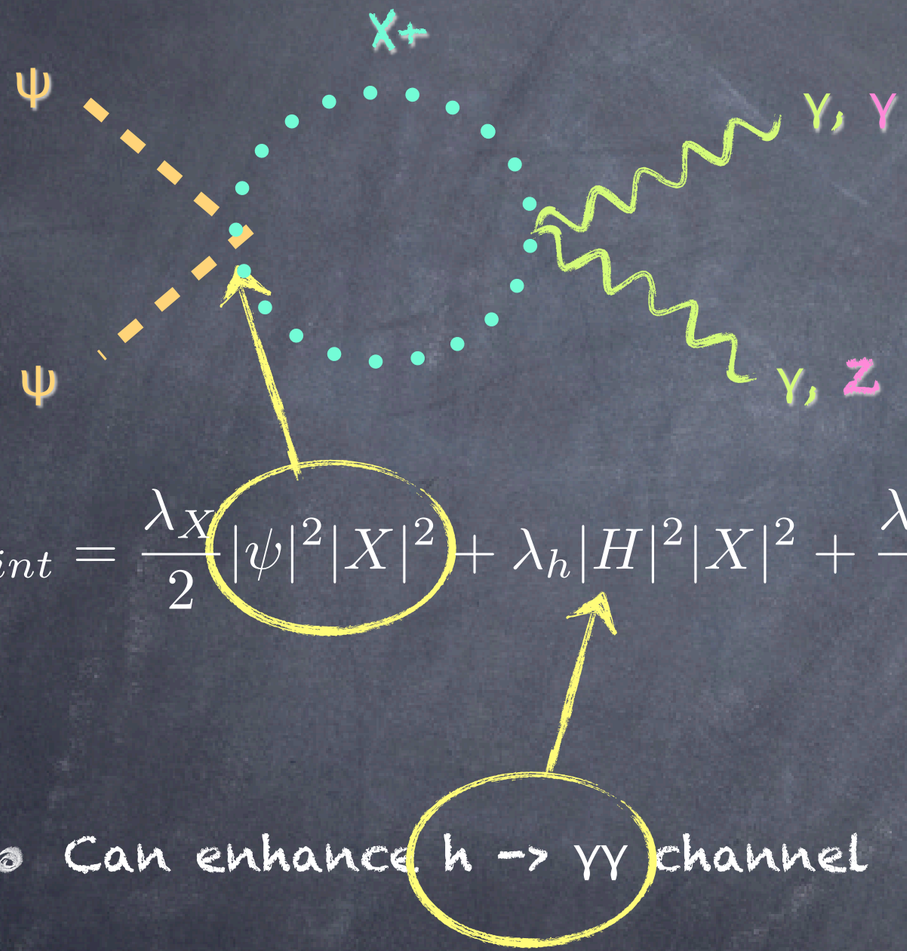

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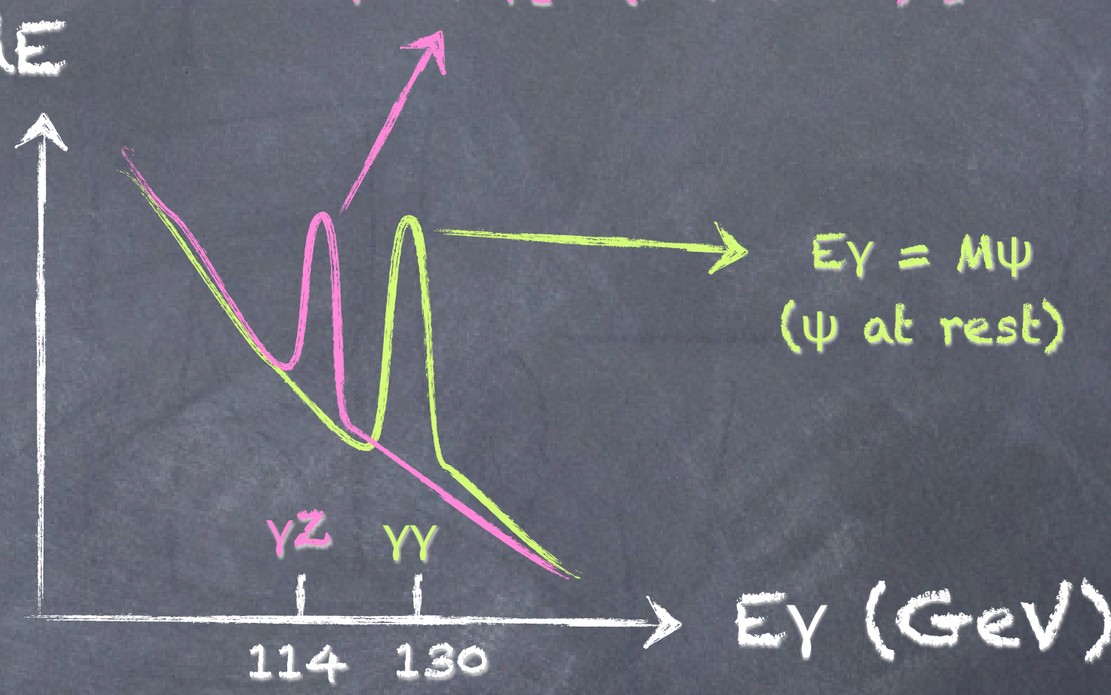

- Can enhance h -> γγ channel
- «issue» : line => λx ~10 and Mx ~ 130 GeV

Fortin, Shelton, Thomas, Zhao
2009
Ibarra, Lopez Gehler, Pato
2012
Fan, Reece
2012

Models type 3 : intermediate state

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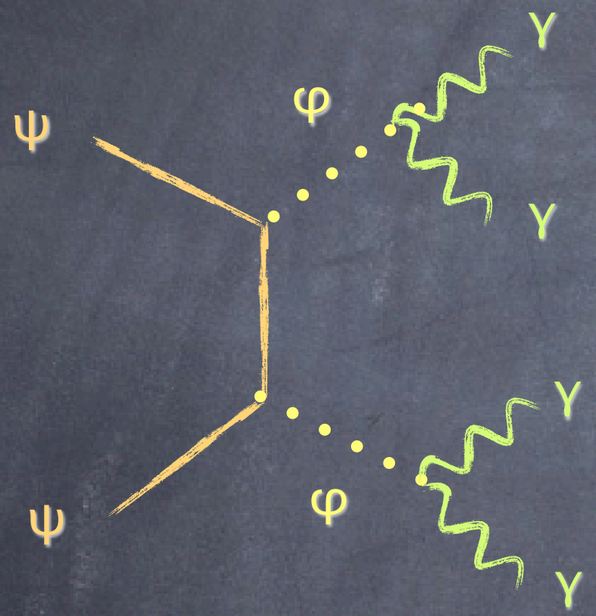

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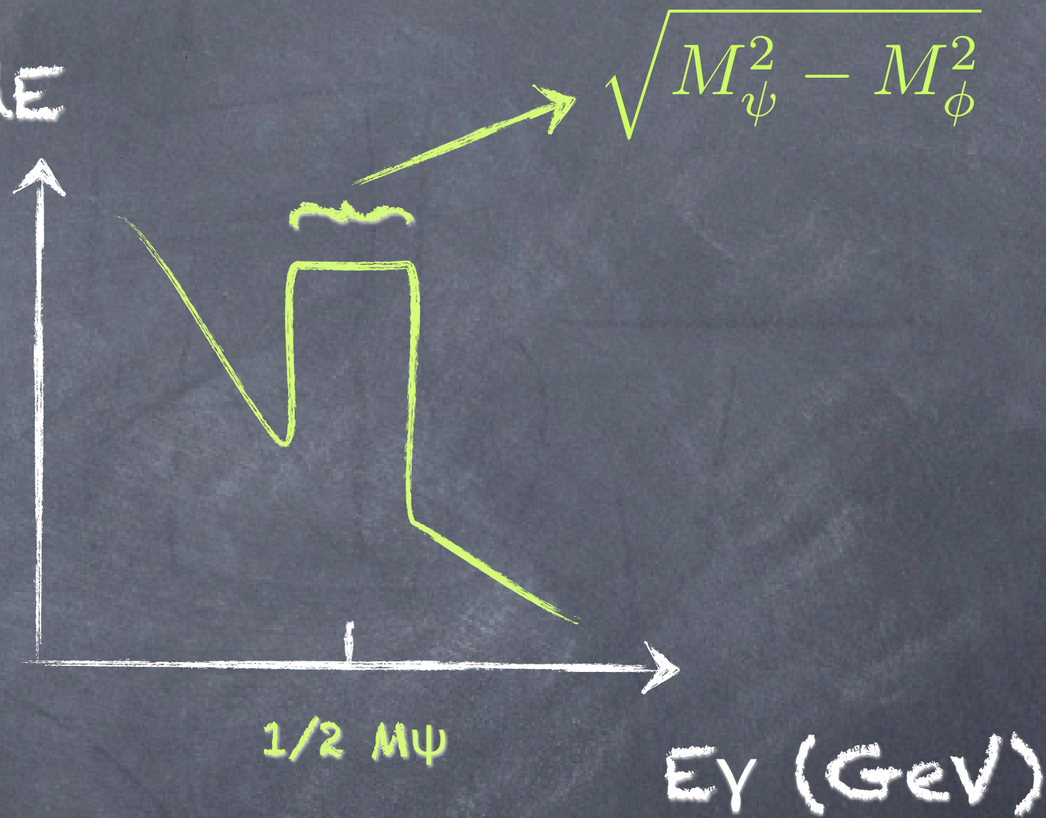

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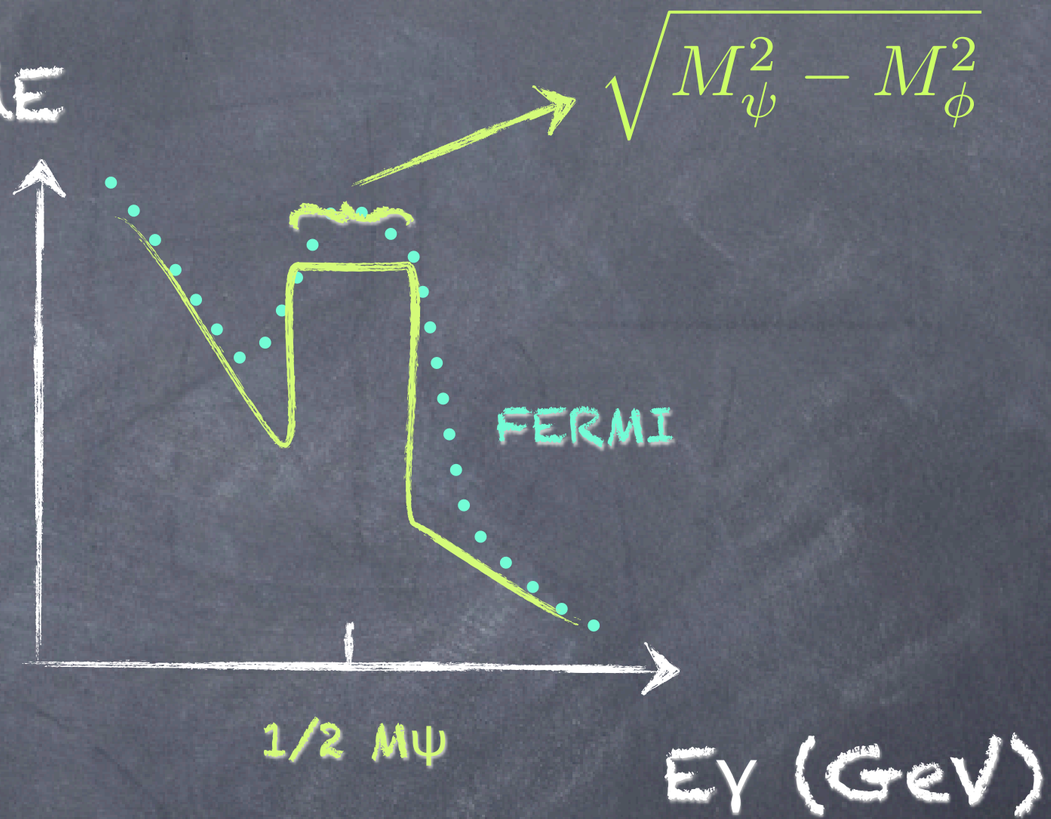

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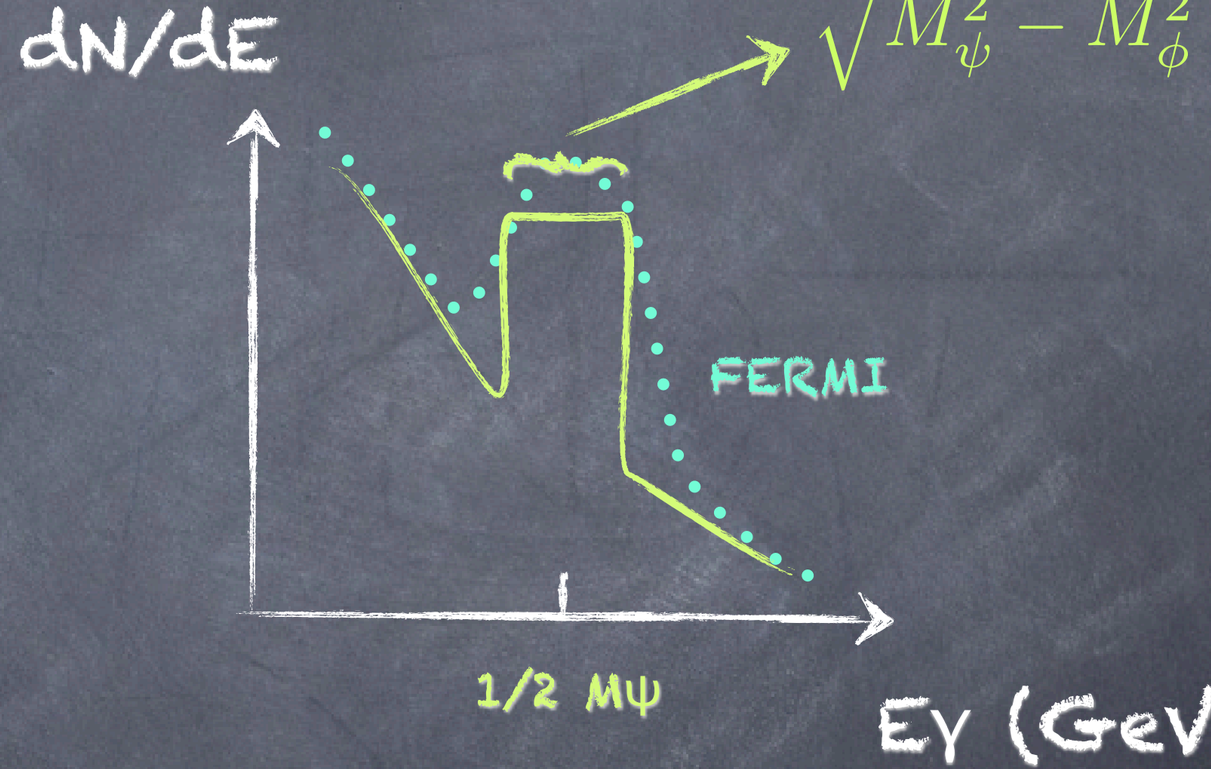

- Eγ=130 GeV => Mψ = 260 GeV.

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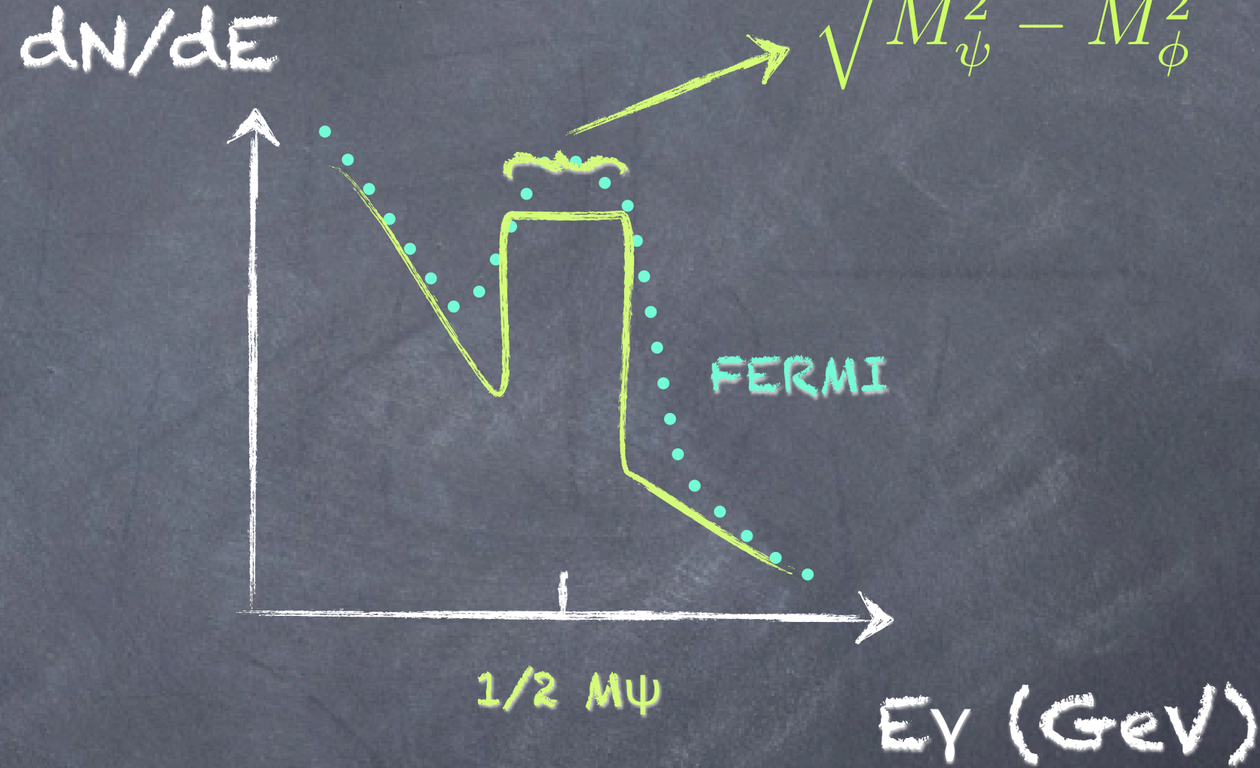
Ibarra, Lopez Gehler, Pato
2012
Fan, Reece
2012

Models type 3 : intermediate state



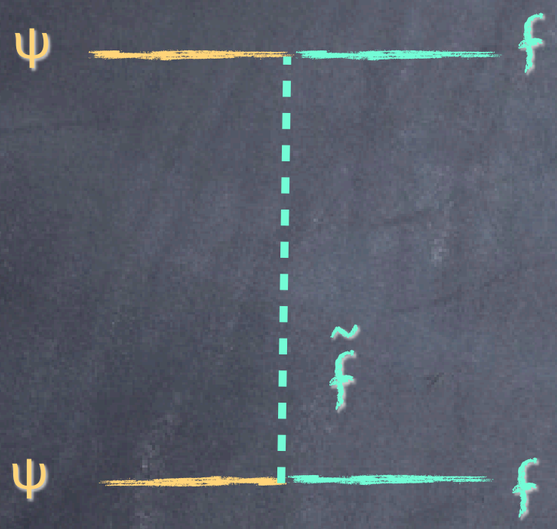
- Eγ=130 GeV => Mψ = 260 GeV.
- Seems like a mo,ochromatic line if Mψ ~Mφ.

Bringmann, Bergstrom, Edsjo
2007
Shakya
2012

Model type 4 : internal bremstrahlung

Bringmann, Bergstrom, Edsjo
2007
Shakya
2012

Model type 4 : internal bremstrahlung



$\langle \sigma v \rangle_{ff} \sim (m_f/m_\psi)^2$ helicity suppressed

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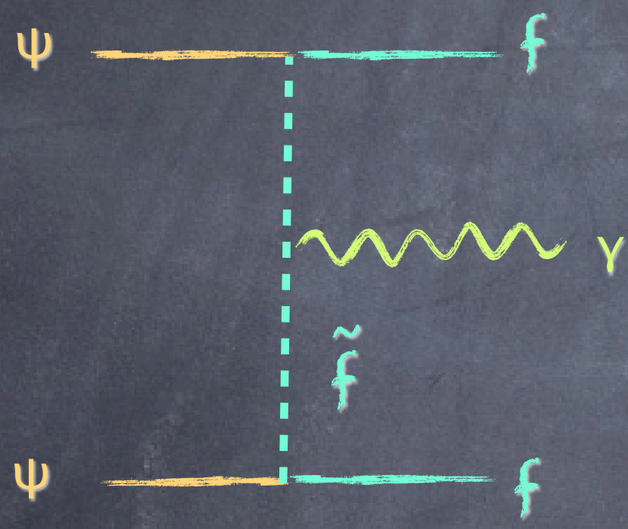
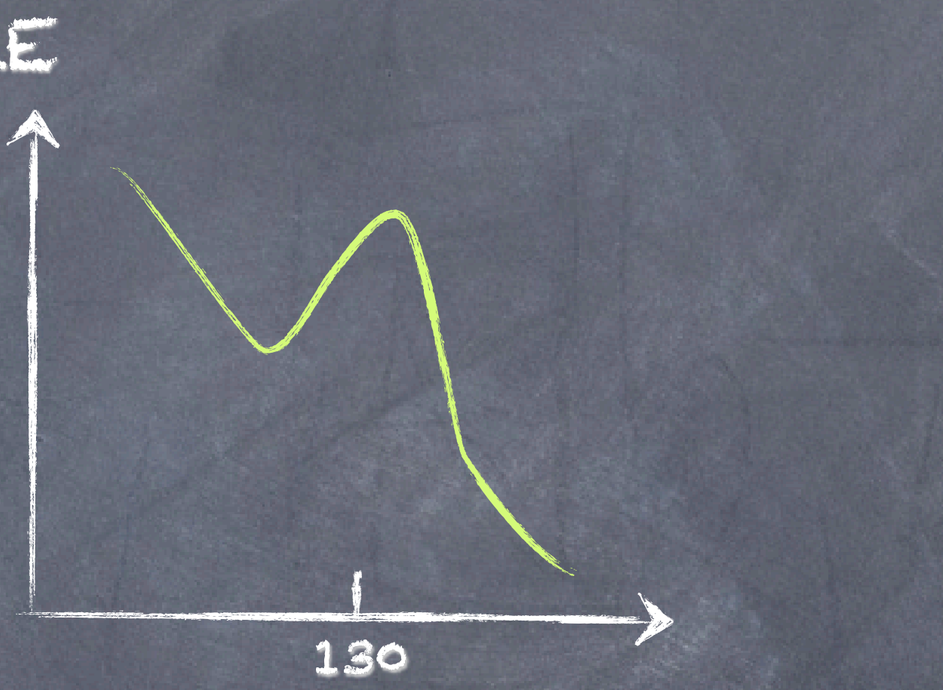
Model type 4 : internal bremstrahlung





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if $M_{\tilde{f}} \sim M_\psi$, $\langle\sigma v\rangle_{ff\gamma} \sim \langle\sigma v\rangle_{ff}$

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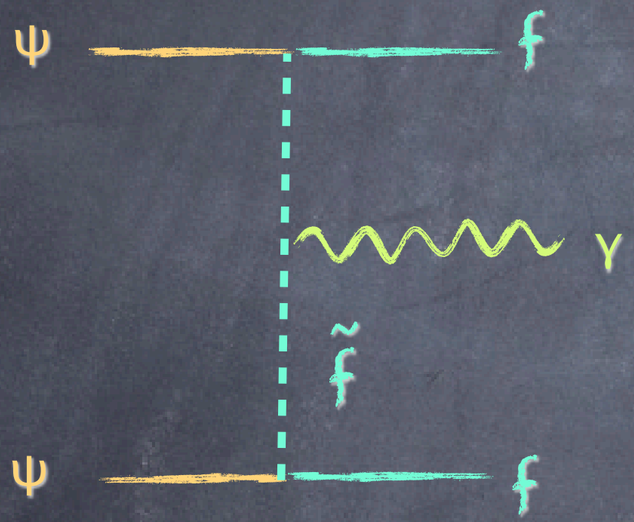

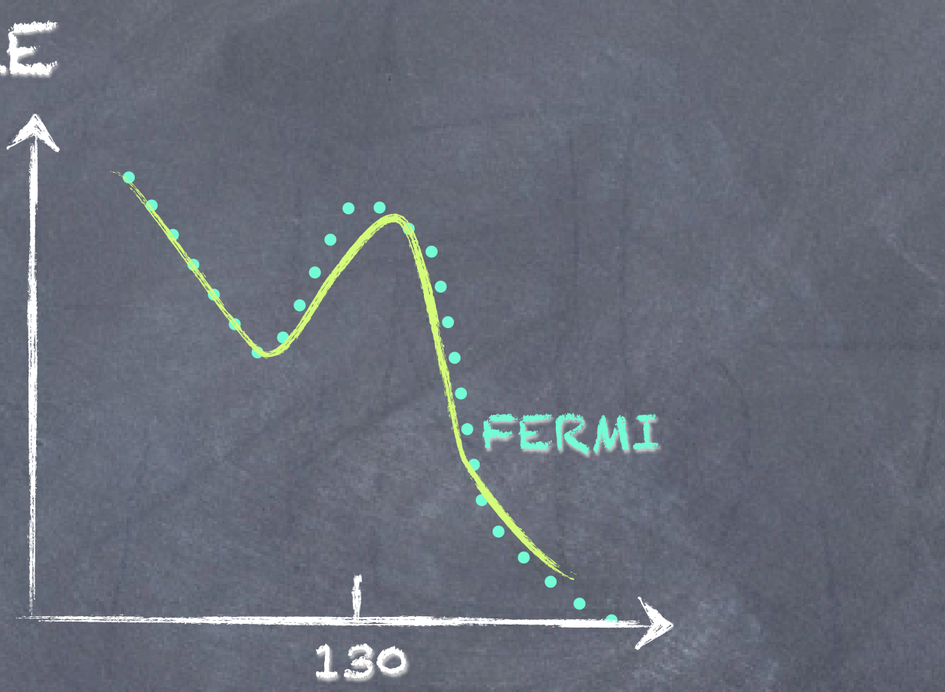

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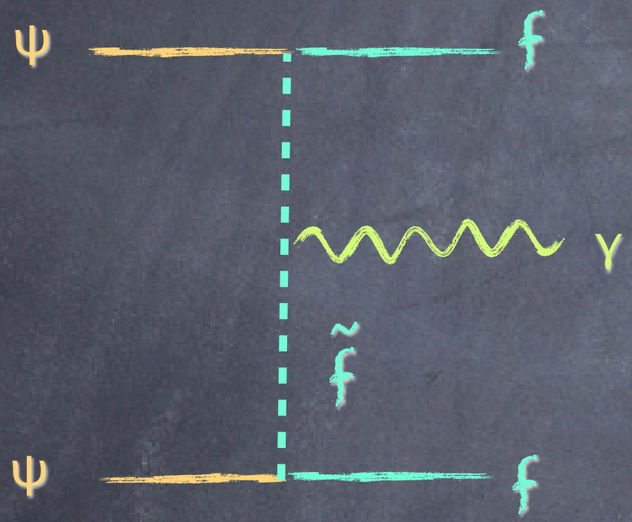

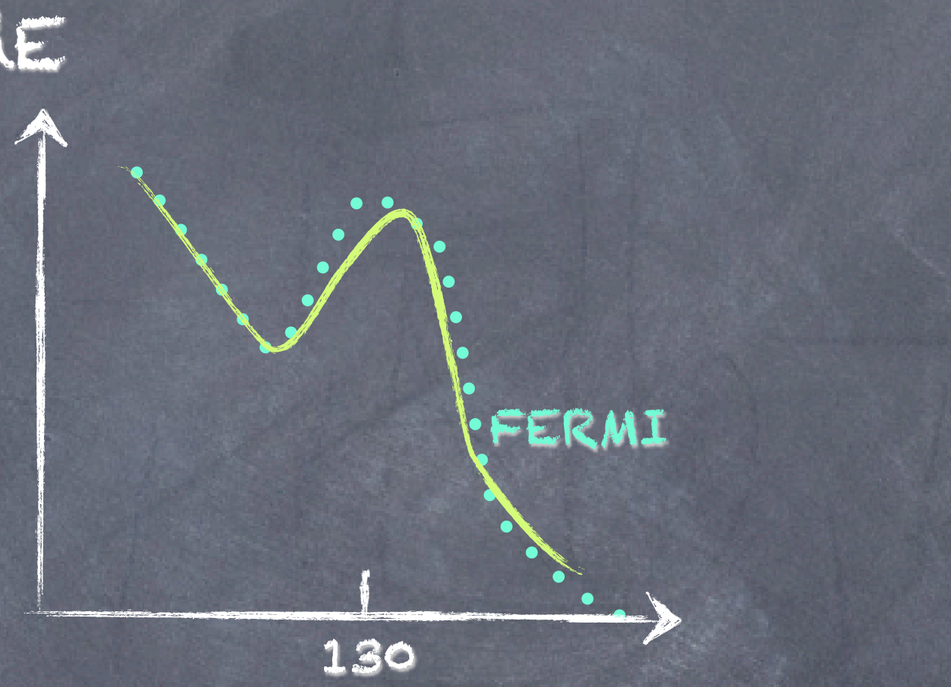

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- Less favored by FERMI (2.7σ)

Bringmann, Bergstrom, Edsjo
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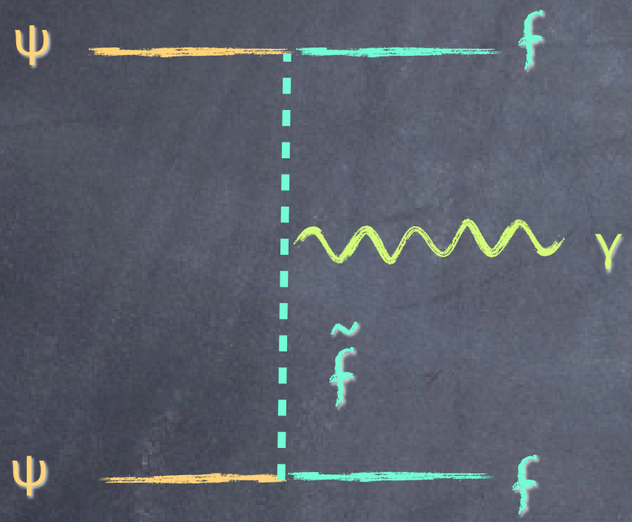
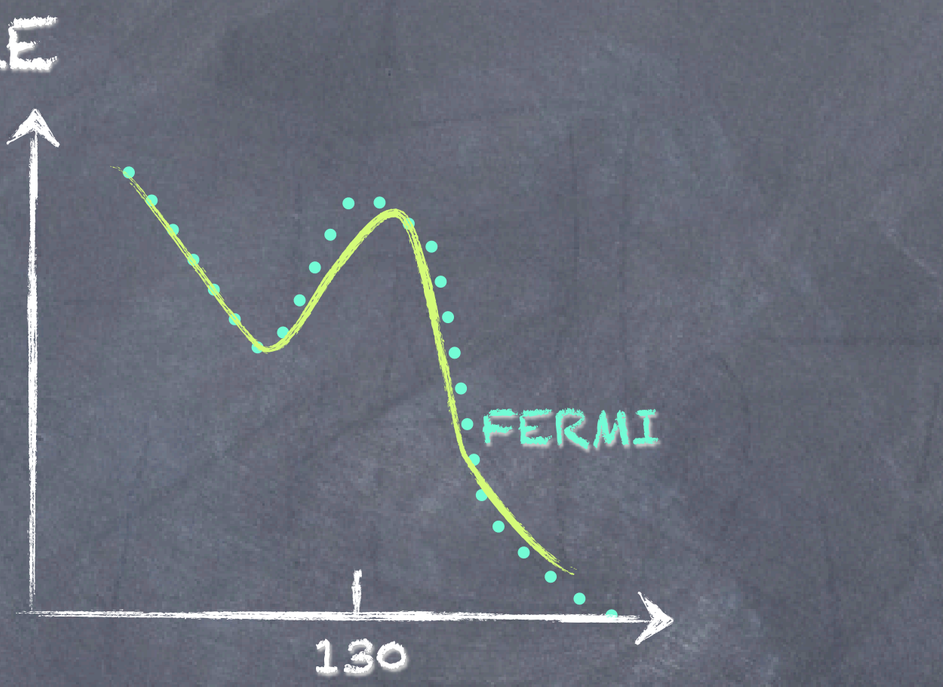
Shakya
2012

Model type 4 : internal bremstrahlung





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if $M_{\tilde{f}} \sim M_\psi$, $\langle\sigma v\rangle_{ff\gamma} \sim \langle\sigma v\rangle_{ff}$

- Less favored by FERMI (2.7σ)
- To fit a «monochromatic» line, Msfermion ~ 140 GeV

Hidden Z' DM models

Additional neutral gauge bosons can be light if hidden from SM. Natural communication between hidden U(1) and SM sectors

- kinetic mixing $\mathcal{L}_{\text{mix}} = \epsilon\, F^{Y}_{mn}\, F^{Z'}_{mn}$

- Chern-Simons terms (loop of heavy fermions or Green-Schwarz mechanism in string theory)

$$\mathcal{L}_{\text{CS}} = \alpha_1\, \epsilon^{mnpr}\, Z'_m\, Z_n\, F^{Y}_{pr}$$

If the mass of heavy fermions mostly generated by U(1)_X breaking, then effective operators should respect SM gauge symmetry. The Chern-Simons operator comes from

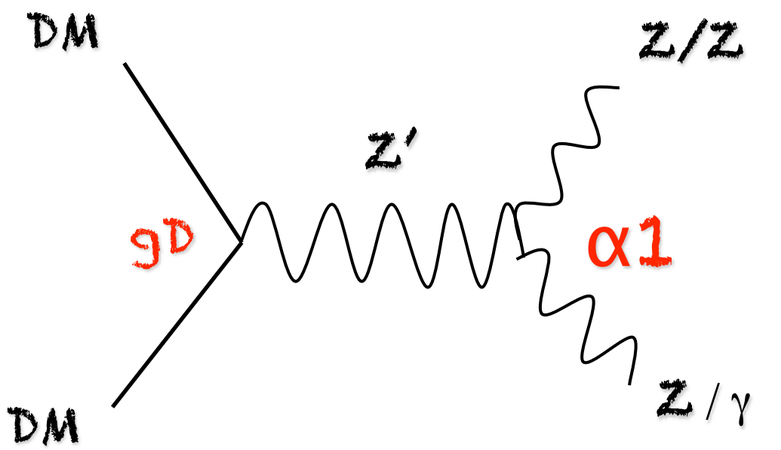
- $$\frac{1}{\Lambda^2}\,\epsilon^{\mu\nu\rho\sigma}\; D_\mu\theta_X\; (H^+ D_\nu H - D_\nu H^+ H)\; F^Y_{\rho\sigma}$$

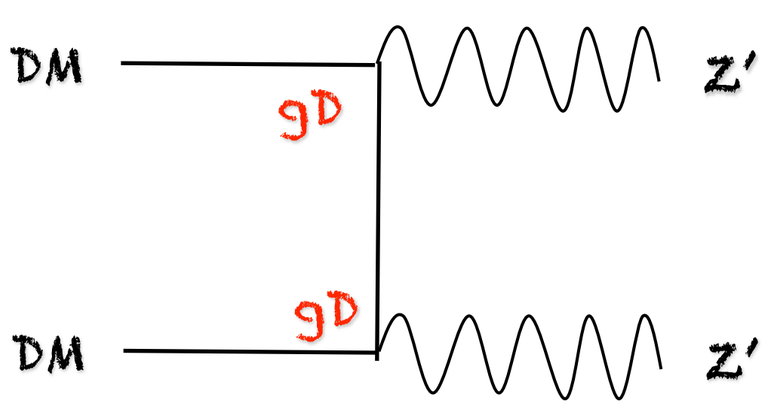
$$\rightarrow \quad \frac{v^2}{\Lambda^2}\,\epsilon^{\mu\nu\rho\sigma}\; (Z'_\mu - \frac{\partial_\mu a'_Z}{V})\; (B_\nu - \frac{\partial_\mu a_Y}{v})\; F^Y_{\rho\sigma}$$

where θ_X is the axion absorbed by Z' and

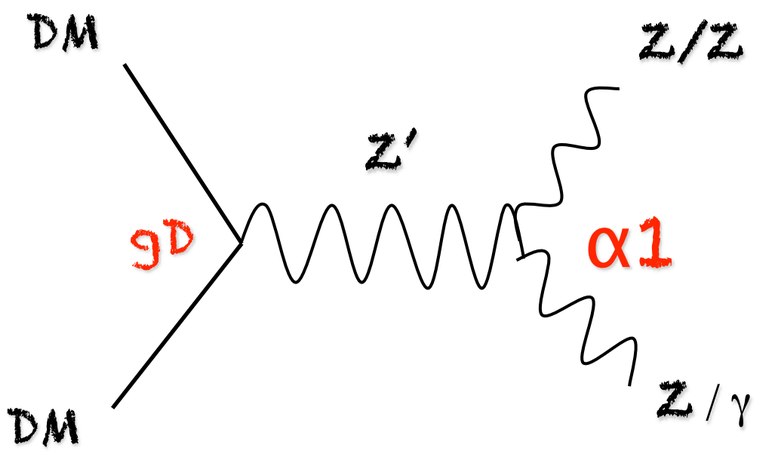
$$\theta_X \equiv \frac{a_X}{V} \quad , \qquad \mathcal{D}_\mu\theta_X \equiv \partial_\mu\theta_X - g_X Z'_\mu$$

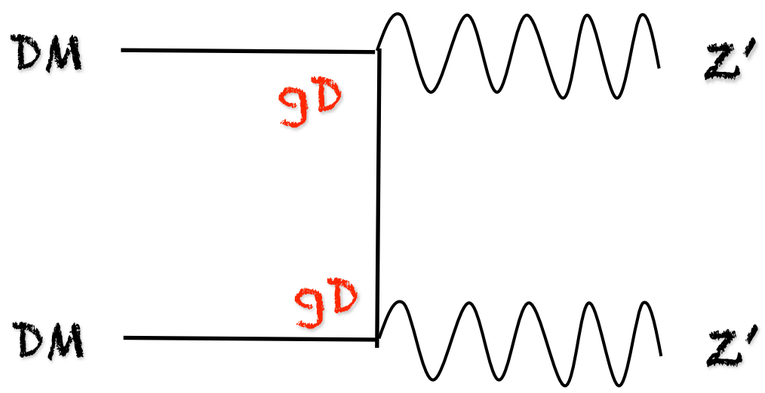
Results



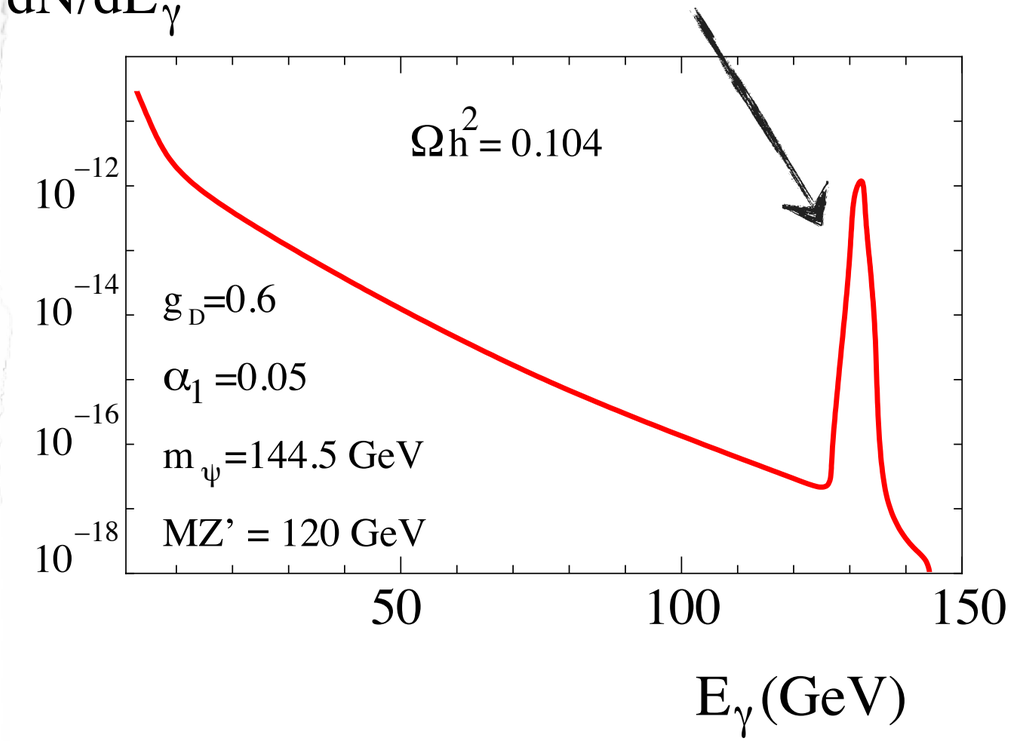


Results





$E_\gamma = M_X\,[1 - (M_Z/2M_X)^2]$



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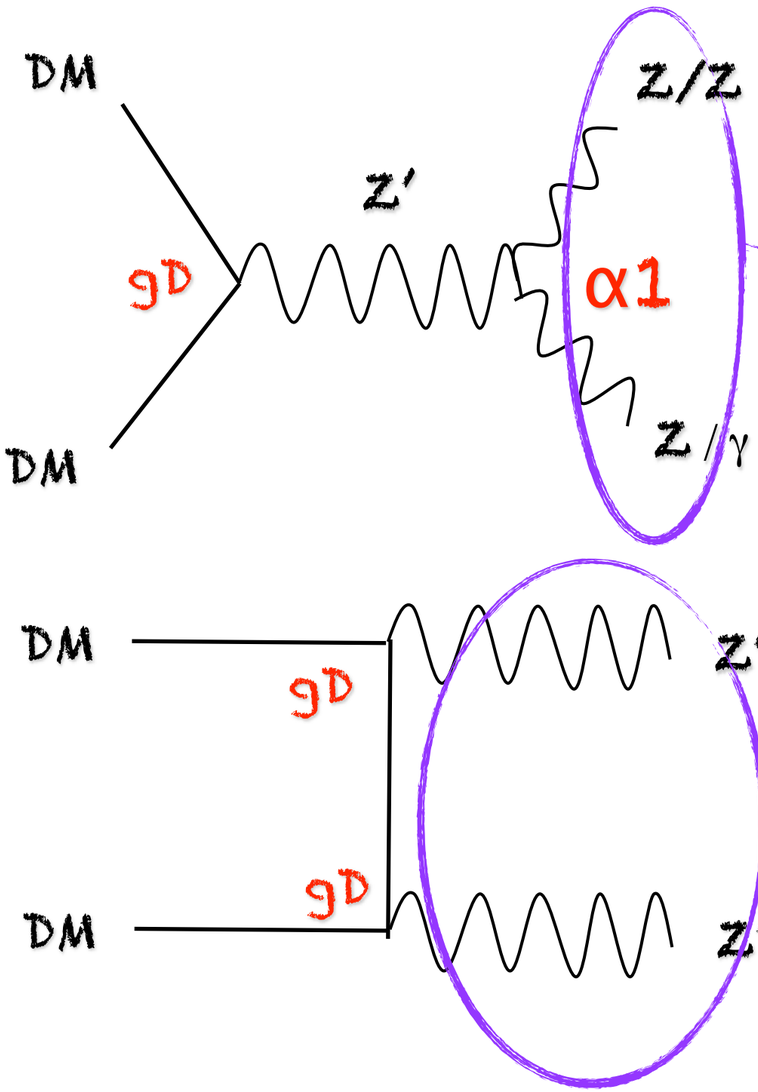

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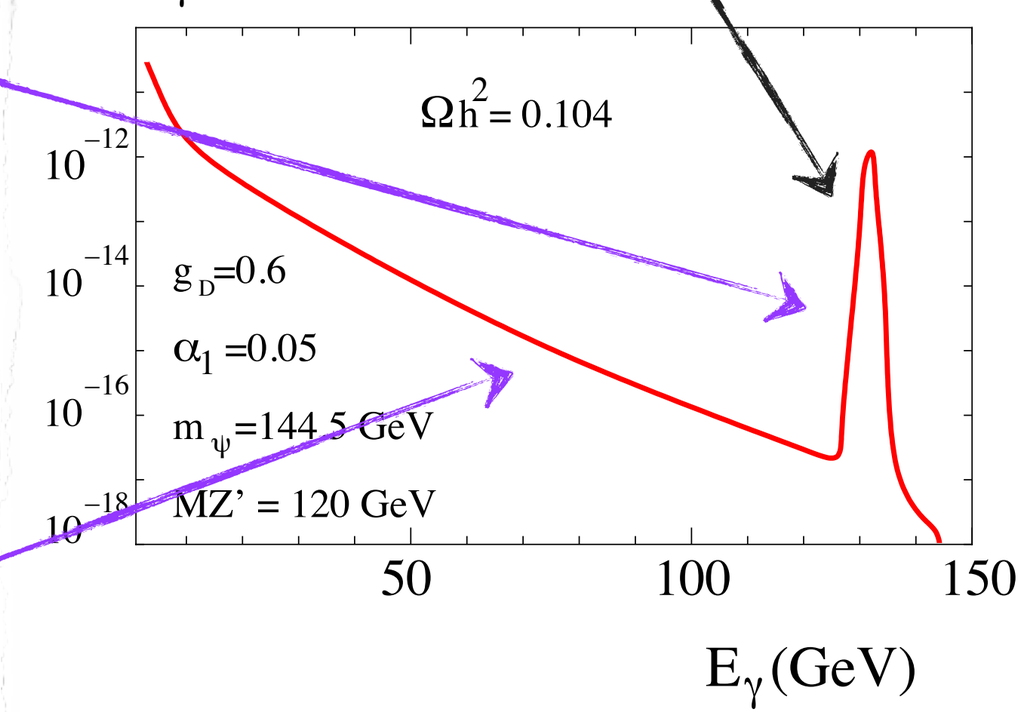

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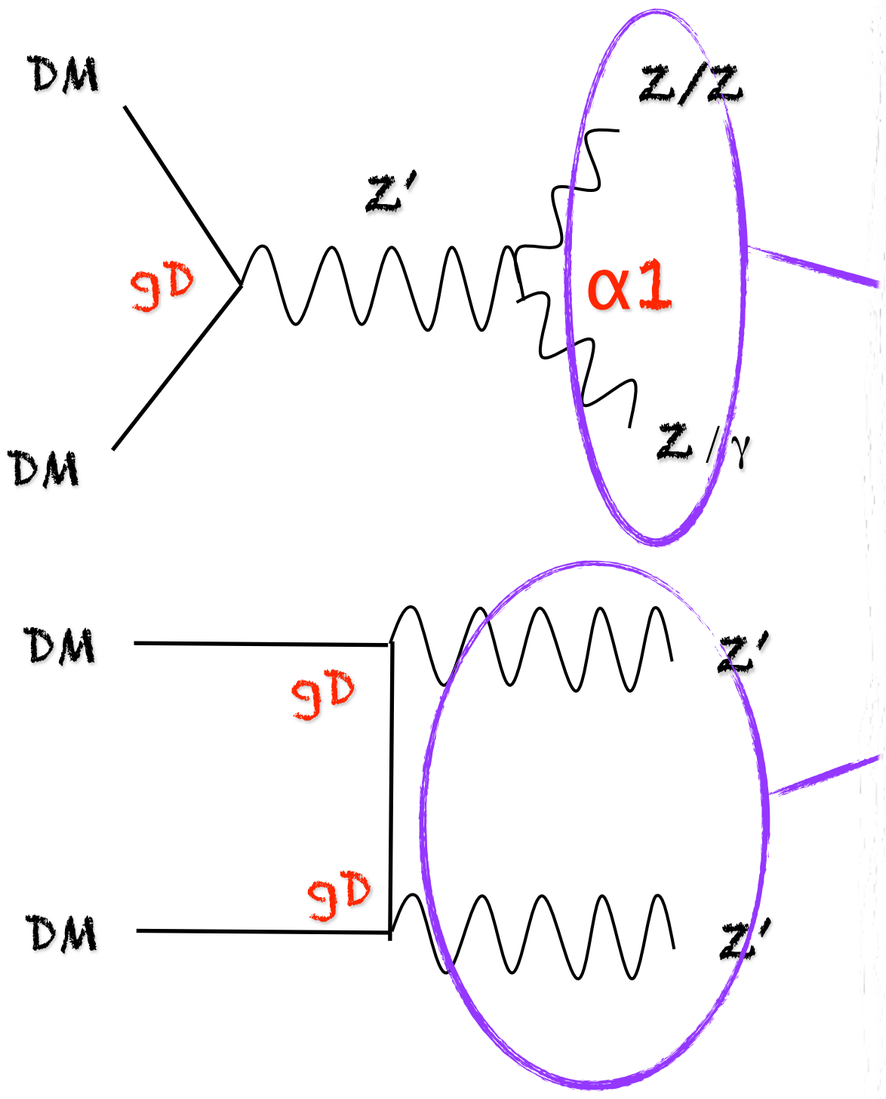
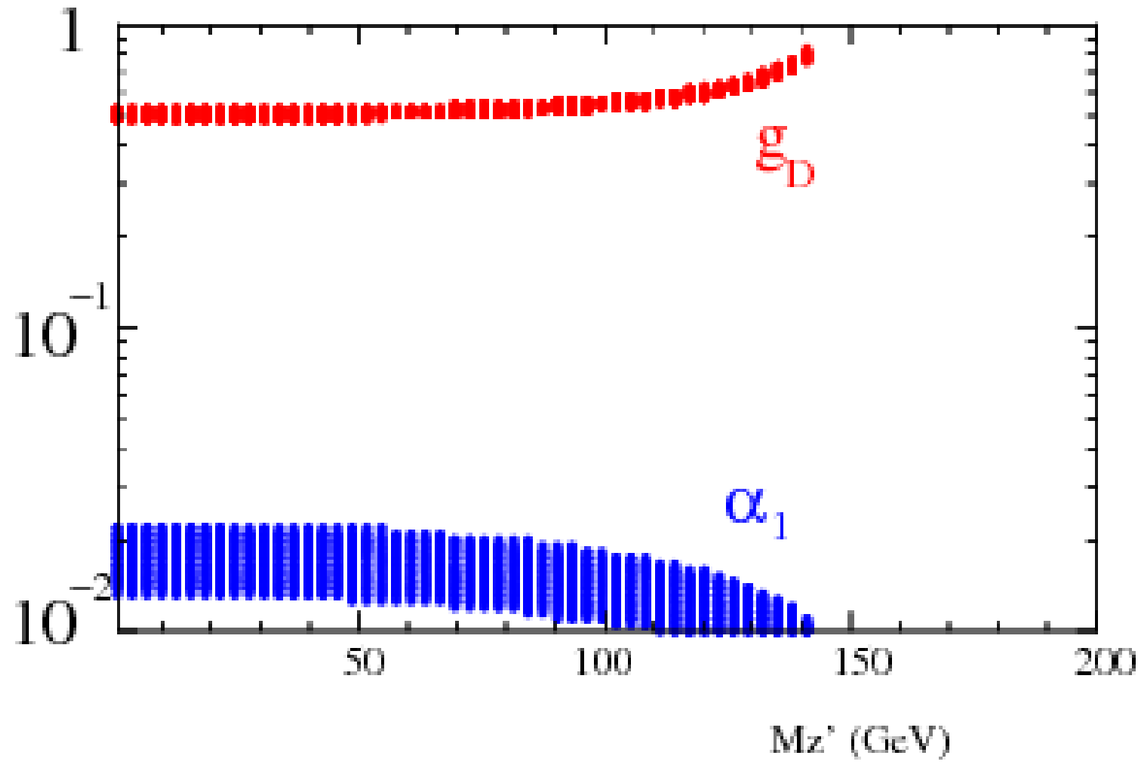


WMAP + fitting monochromatic line



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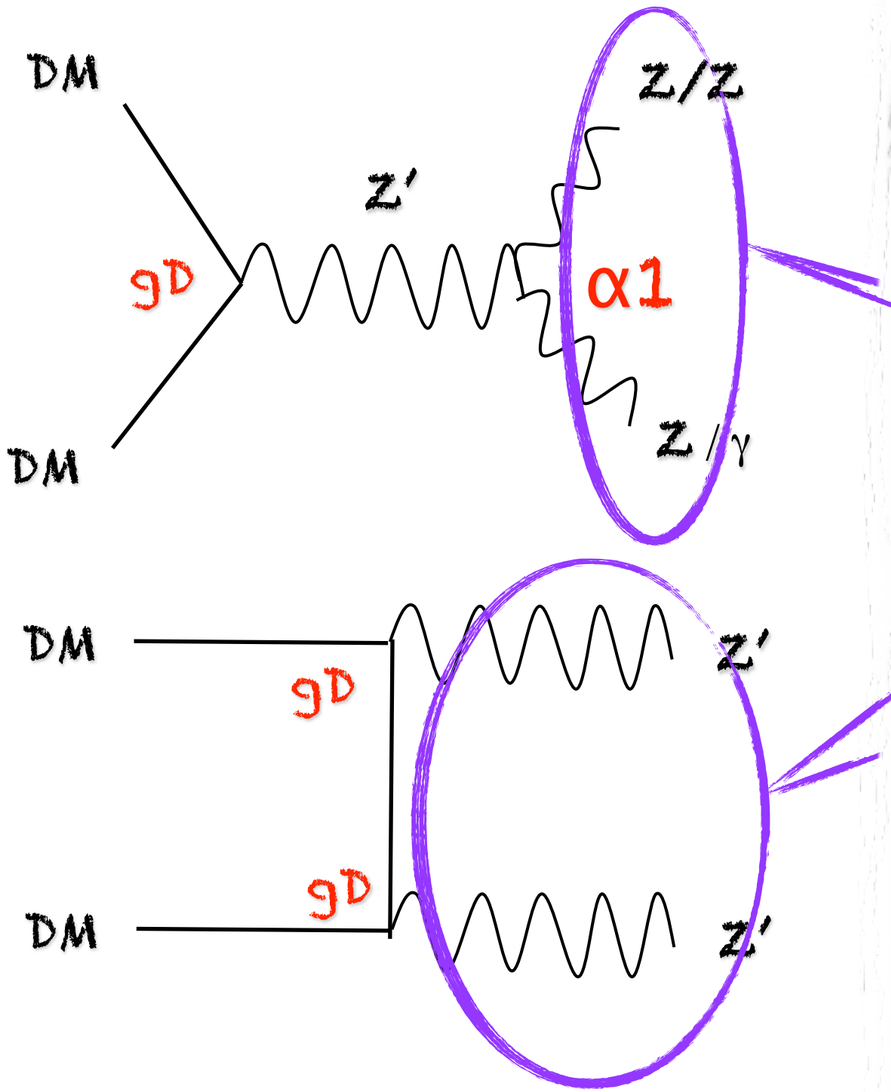

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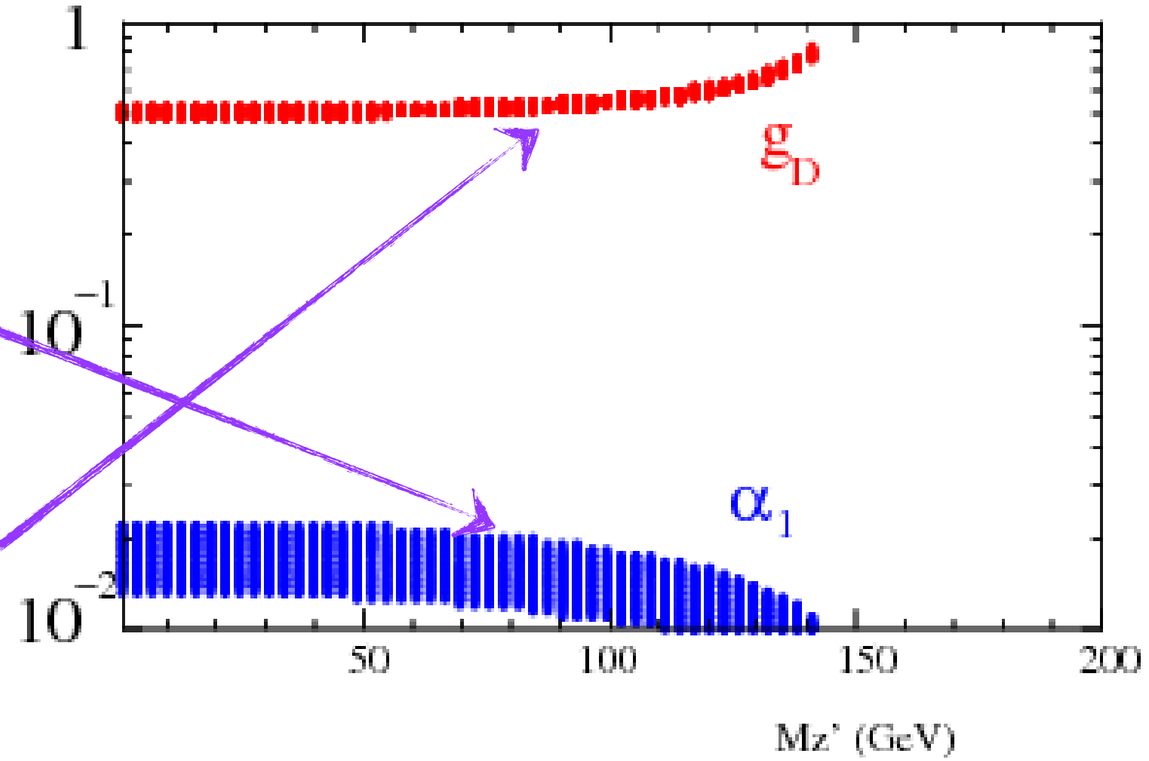

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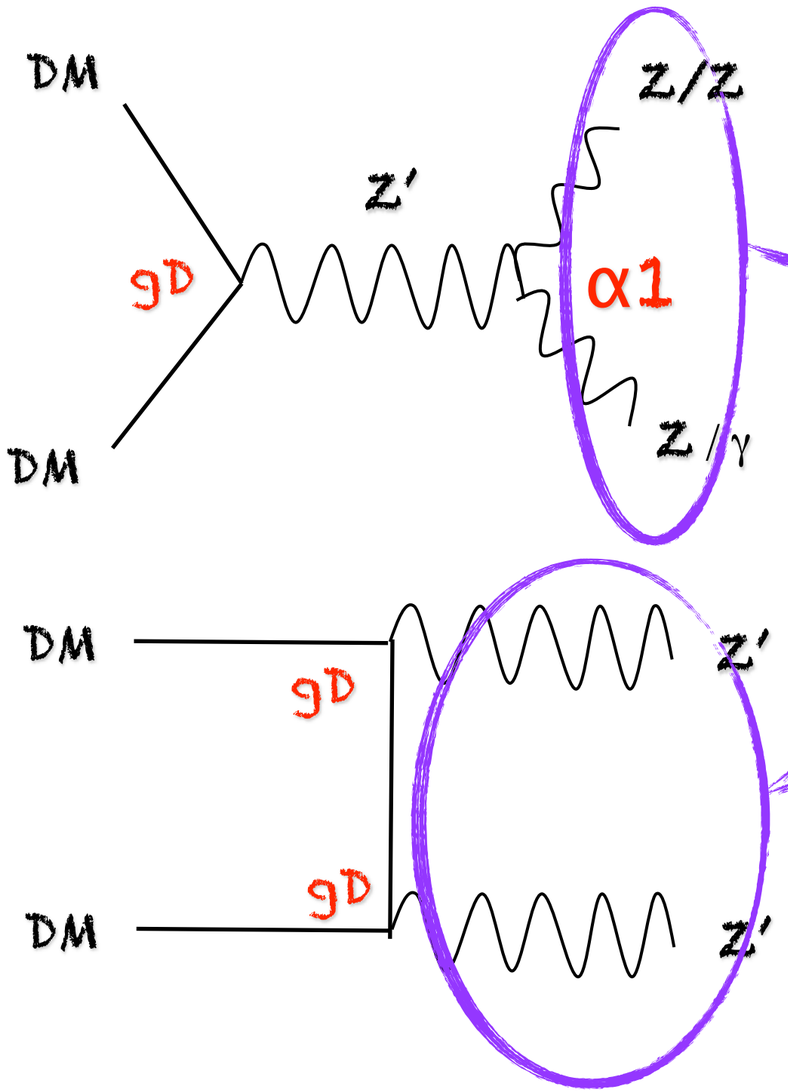

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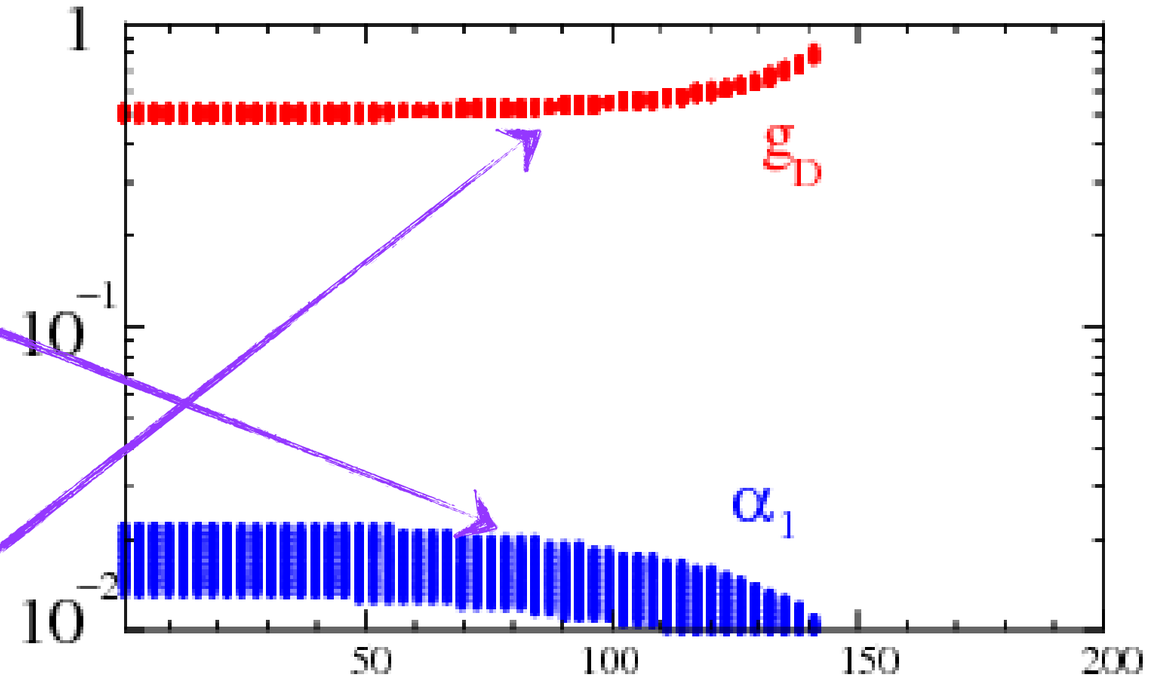
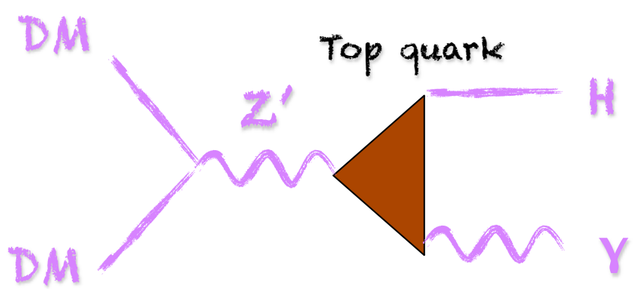


Higgs in Space



[Jackson, Servant, Shaughnessz, Tait, Taoso 09]

Conclusions

- Is it a real line or instrumental effect ? The effect is based on 50 photons…
- One or two (or even three) lines will discriminate among different models.
- Have to wait for more data; hopefully within two years the DM interpretation of the signal will be disproved or confirmed. Waiting also for HESS (CTA) results.
- Hidden Z' models are interesting since generic in field and string theory