Title: Cosmic Rays Through the Higgs Portal

Date: Jun 05, 2008 03:00 PM

URL: http://pirsa.org/08060152

Abstract: An electroweak singlet coupling through the Higgs portal has a natural mass scale $m_Ssim m_h$. In this mass range its annihilation cross section is dominated by proximity to the W, Z and Higgs peaks. Analysis of the $gamma$ ray signal from electroweak singlet annihilation in the mass range $80,mathrm{GeV}<m_S<1,mathrm{TeV}$ indicates that it can reach the per mil level of the EGRET diffuse $gamma$ ray flux, providing a potential new test of dark matter.

Electroweak Singlets

$$\mathcal{L} = -\frac{1}{2}\partial_\mu S \partial^\mu S - \frac{1}{2}m_S^2 S^2 - D_\mu H^\dagger D^\mu H$$

$$-\frac{\eta}{2}S^2 H^\dagger H - \frac{\lambda}{4}\left(H^\dagger H - \frac{v_h^2}{2}\right)^2$$

Flux from the Galactic Halo

Majorana counting factor

number density

$$j = \int d^3\vec{r} \frac{\nu n^2(\vec{r})}{4\pi|\vec{r}_\odot - \vec{r}|^2} \times \frac{d\mathcal{N}(E, 2m_S)}{dE} \frac{\sigma v}{4\pi \text{ sr}}$$

$\sigma v \rightarrow$ annihilation cross-sect times relative speed

$$\frac{d\mathcal{N}(E, E_{in})}{dE} = \frac{1}{\sigma} \frac{d\sigma}{dE}$$ fragmentat function

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$$= \left(\frac{\text{TeV}}{m_S}\right)^2 \times \frac{d\mathcal{N}(E, 2m_S)}{dE} \frac{\sigma v}{\text{cm}^5 \text{ sr}}$$

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isothermal core

NFW profile

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σv → annihilation cross-sect times relative speed

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NFW profile

$$x = E/m_S \qquad \frac{d\mathcal{N}_\gamma(x)}{dx} = \frac{0.42 \exp(-8x)}{x^{1.5} + 0.00014}$$

photon fragmentation

Model-independent Bounds

Unitarity ⇒ $\sigma k^2 \leq 4\pi$

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EGRET
Diffuse photon background

$$j_{\gamma,E} = \frac{8.68 \times 10^{-11}}{\mathrm{GeV\,cm^2\,s\,sr}} \left(\frac{100\,\mathrm{GeV}}{E}\right)^{2.10}$$

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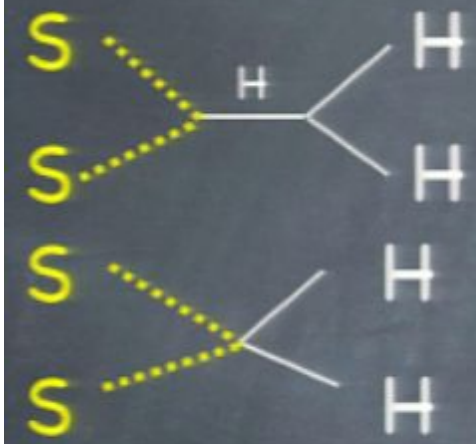
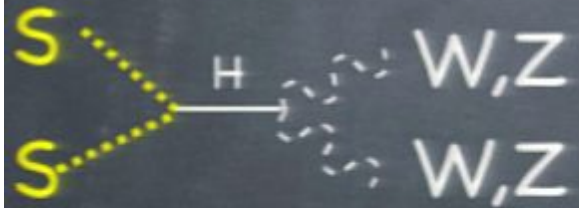
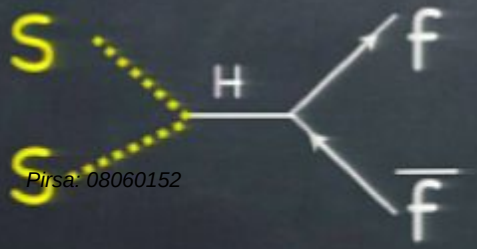
max of 0.05

$$\sigma v < 10^{-23} \frac{\mathrm{cm}^3}{\mathrm{s}} \times \left(\frac{m_S}{100\,\mathrm{GeV}}\right)^{0.9}$$

Cross-Sections







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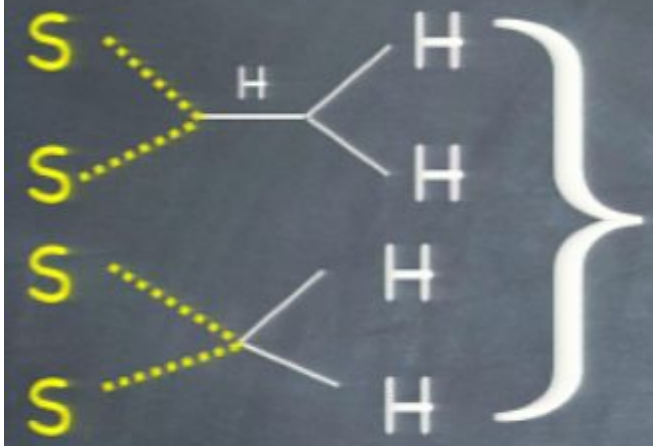
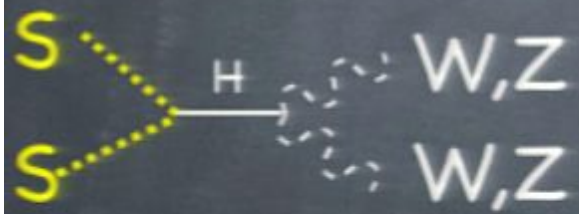
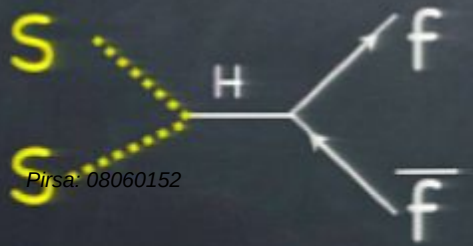


$$v\sigma_{SS\to hh} = \eta^2 \frac{\sqrt{{m_S}^2 - {m_h}^2}}{16\pi {m_S}^3} \times \frac{(2m_S^2 + m_h^2)^2}{(4{m_S}^2 - {m_h}^2)^2 + {m_h}^2{\Gamma_h}^2}$$





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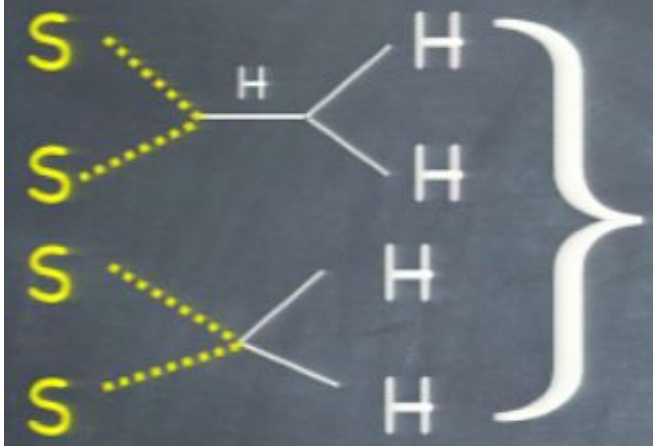

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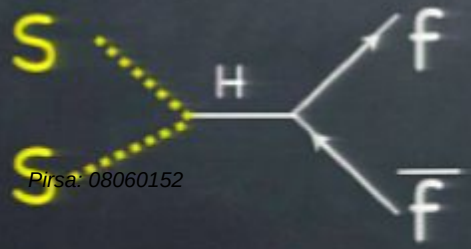

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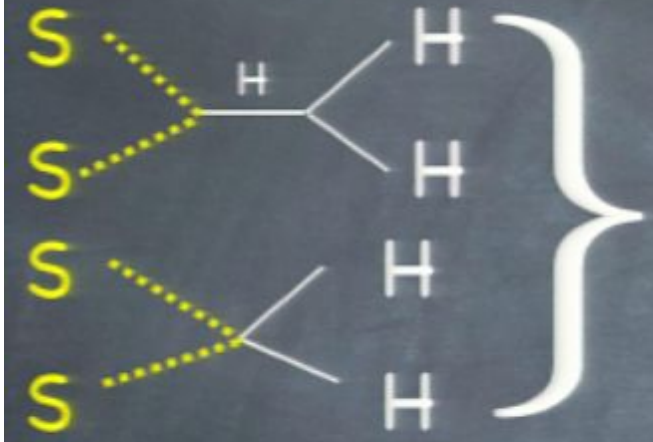

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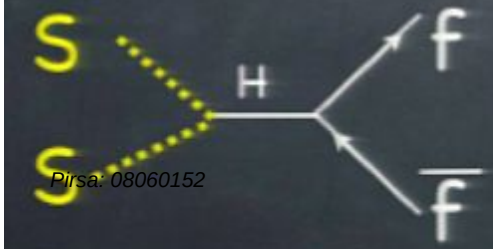

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Annihilation Signals

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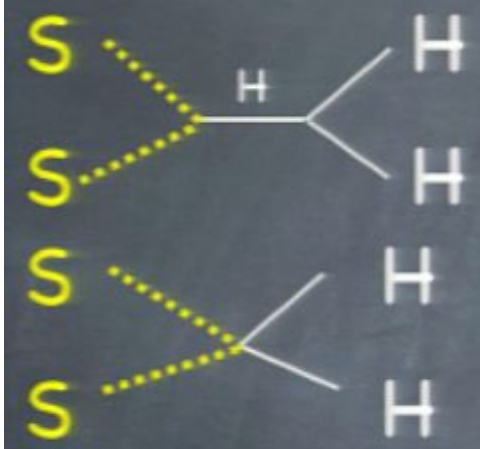

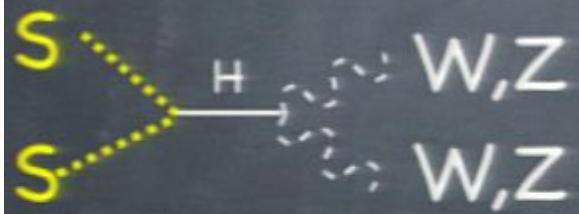

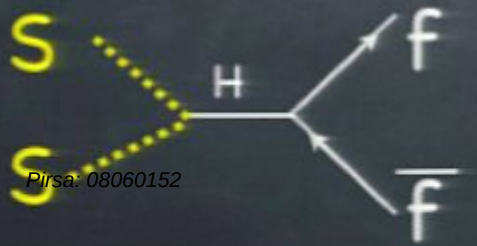

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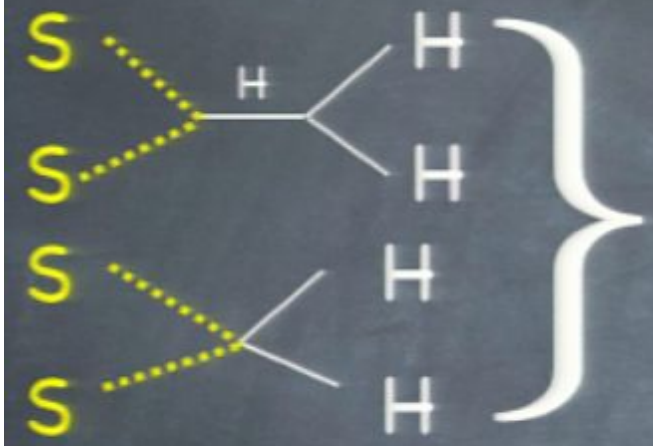

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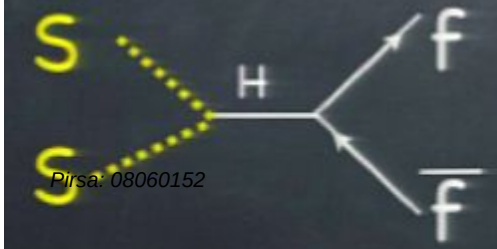

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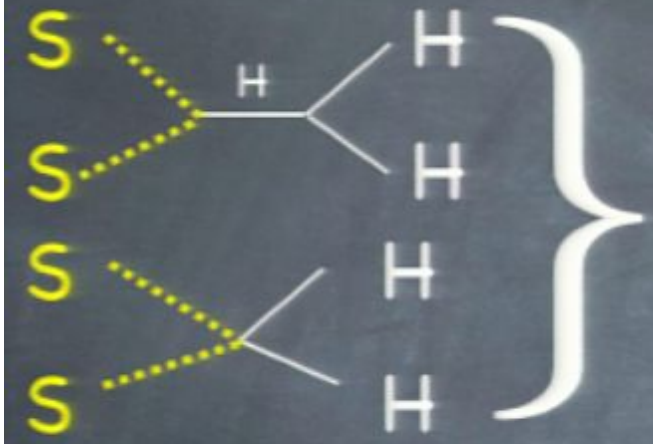

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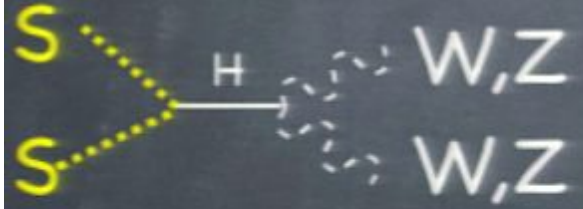

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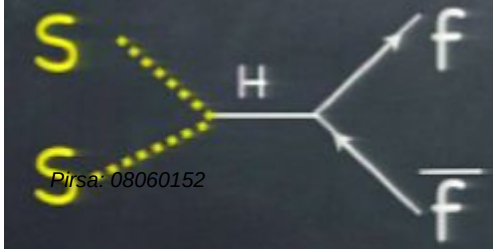

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$80\,\mathrm{GeV} < m_S < 1\,\mathrm{TeV}$

Enhancement of Signal due to

a) W,Z channels

b) Proximity to Higgs mass

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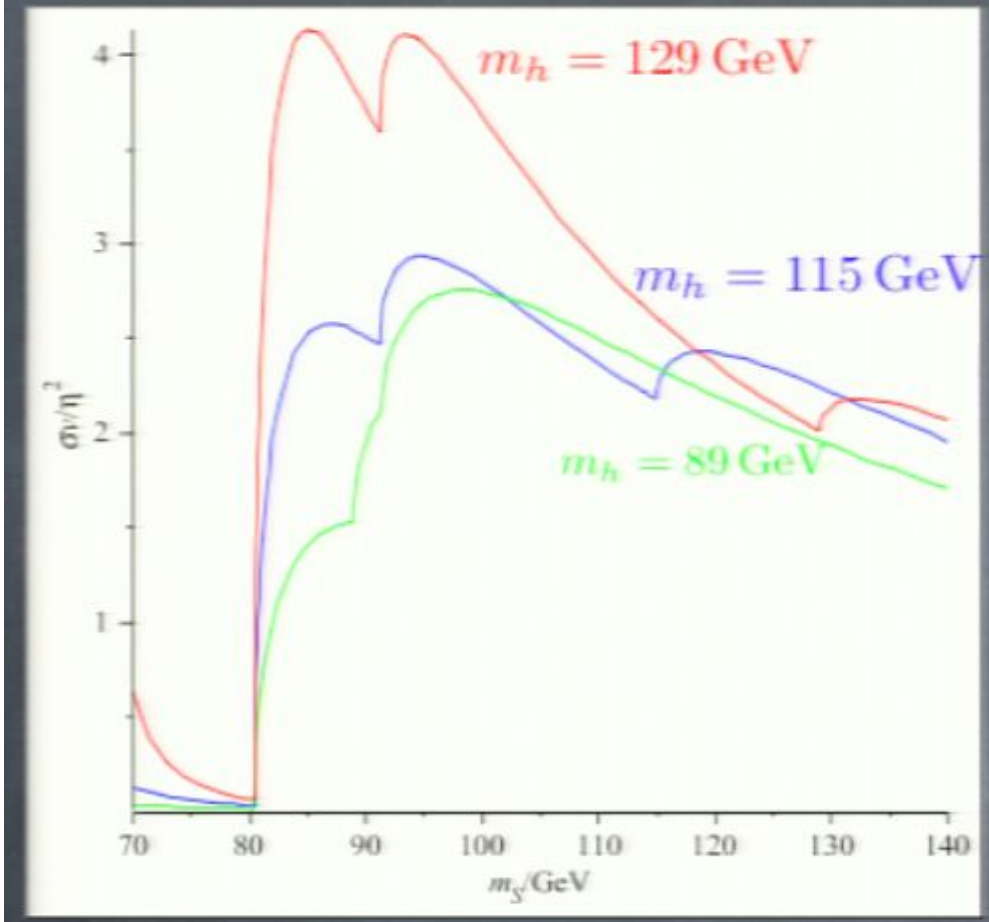
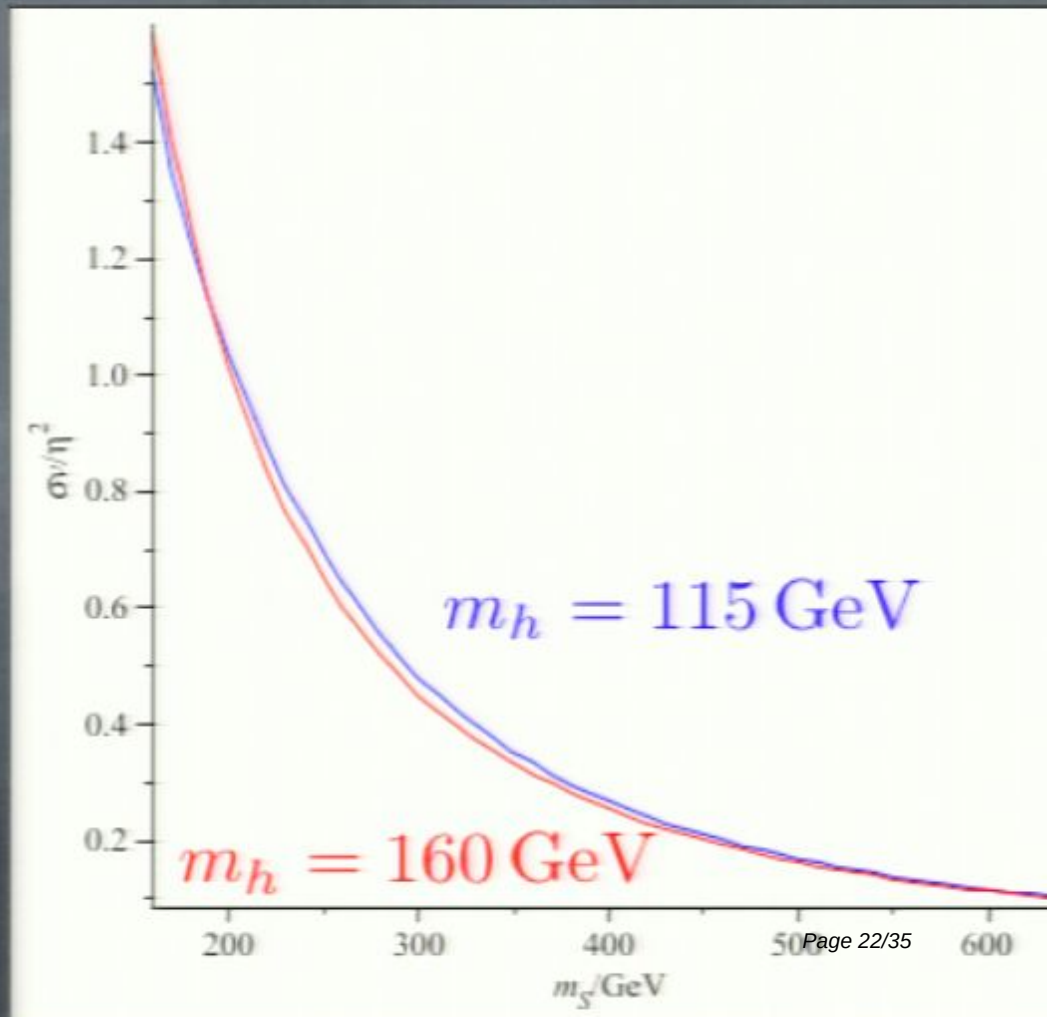
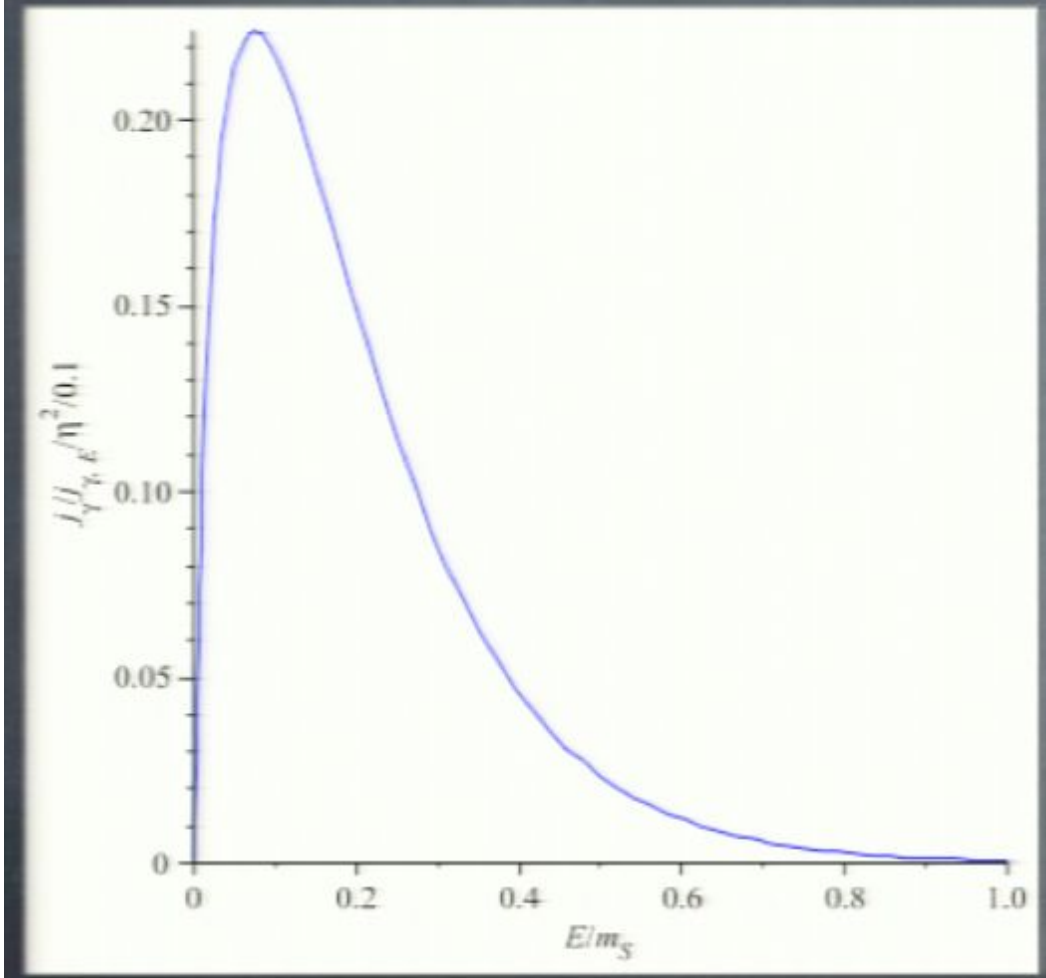


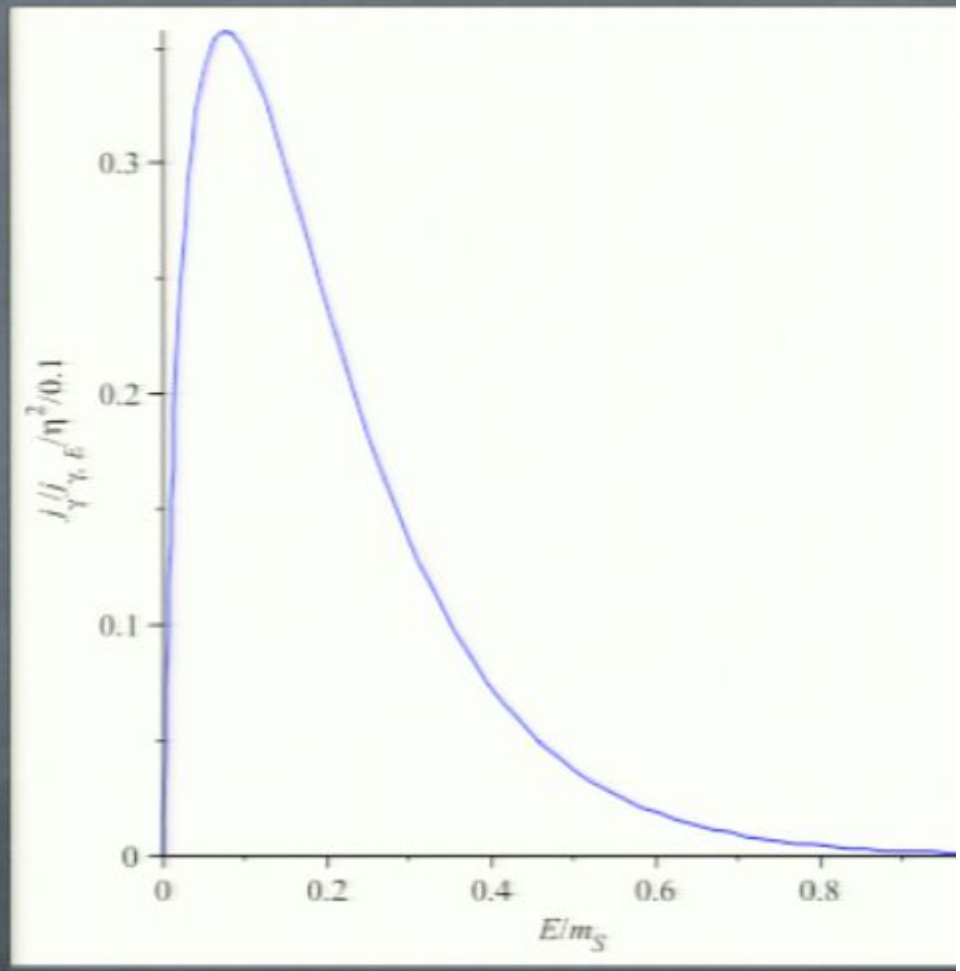
Small m_S

Large m_S



Photon Flux
in units of EGRET Flux





$m_S = 120$ GeV, $m_h = 115$ GeV

$m_S = 120$ GeV, $m_h = 160$ GeV

Thermal Creation

$$\frac{d}{dt}(na^3) = \dot{N}_{thermal} - \langle \sigma v \rangle n^2 a^3$$

Lee/Weinberg

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Assume equilibrium ($\frac{d}{dt}(na^3) = 0$)

$t = \frac{b}{T^2}$

until freeze-out ⇒ $\left. \frac{d}{dT} \frac{n_0(T)}{T^3} \right|_{T=T_f} = 2b\langle \sigma v \rangle \frac{n_0^2(T_f)}{T_f^6}$

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$t = \frac{b}{T^2}$

$\xi = m_S c^2/k_B T_f$

$$\exp(\xi) = 4.182\times 10^{11}\,\frac{\langle\sigma v\rangle}{10^{-24}\,\mathrm{cm}^3/\mathrm{s}}\,\frac{m_S}{100\,\mathrm{GeV}}\,\frac{\sqrt{\xi}}{\xi - 1.5}$$

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Conside N specie

Freeze-out Criteria

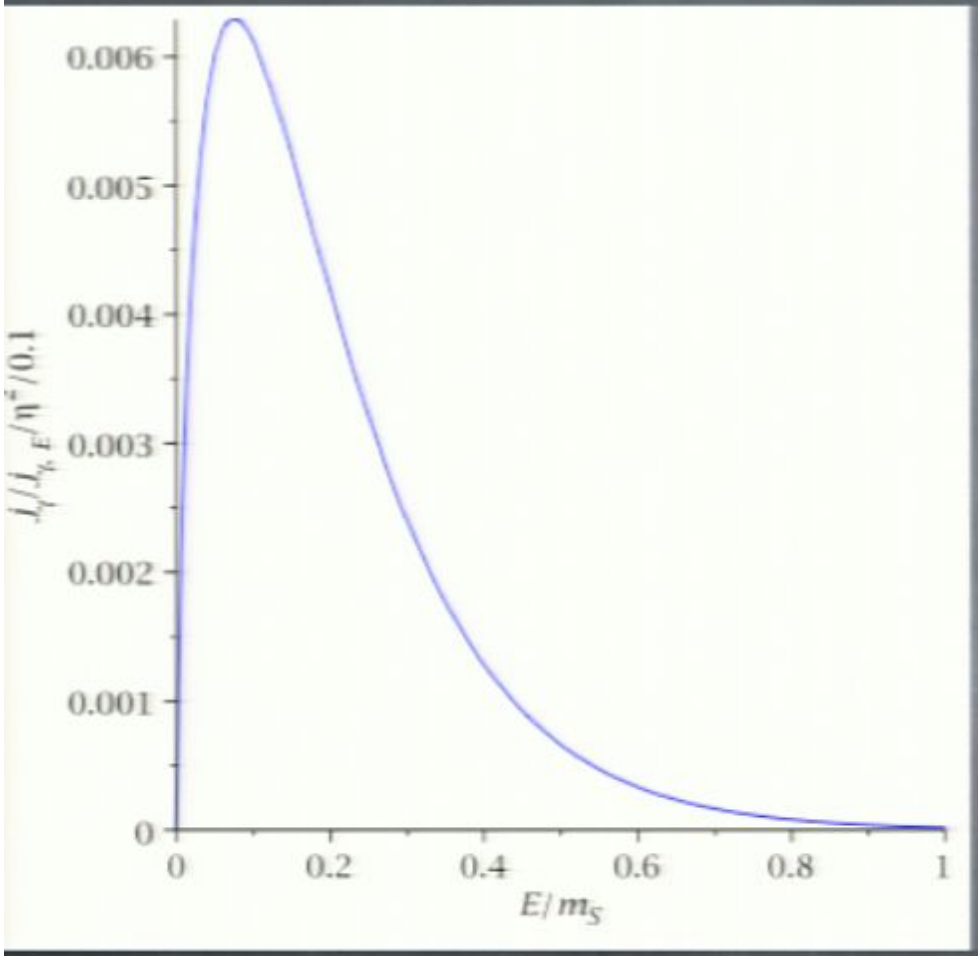
$$\varrho_S \simeq \frac{2\xi - 3}{2\xi - 1}\xi \times \frac{N \times 2.51\,\mathrm{eV/cm^3}}{\langle\sigma v\rangle/10^{-24}\,\mathrm{cm^3/s}}$$

$$\exp(\xi) = 4.182 \times 10^{11} \frac{\langle\sigma v\rangle}{10^{-24}\,\mathrm{cm^3/s}} \frac{m_S}{100\,\mathrm{GeV}} \frac{\sqrt{\xi}}{\xi - 1.5}$$

	$m_h = 115$ GeV	$m_h = 160$ GeV
$N = 1$	$m_S = 881$ GeV $x_\sigma = 0.0531$	$m_S = 885$ GeV $x_\sigma = 0.0531$
$N = 24$	$m_S = 170$ GeV $x_\sigma = 1.36$	$m_S = 188$ GeV $x_\sigma = 1.37$
$N = 45$	$m_S = 105$ GeV $x_\sigma = 2.57$	$m_S = 135$ GeV $x_\sigma = 2.59$
$N = 78$	n/a	$m_S = 115$ GeV $x_\sigma = 4.56$

Singlet masses satisfying the freeze-out condition for $\eta^2 = 0.1$, $m_h = 115$ GeV

Photon Flux
in units of EGRET Flux



$m_h = 115\,\mathrm{GeV}$

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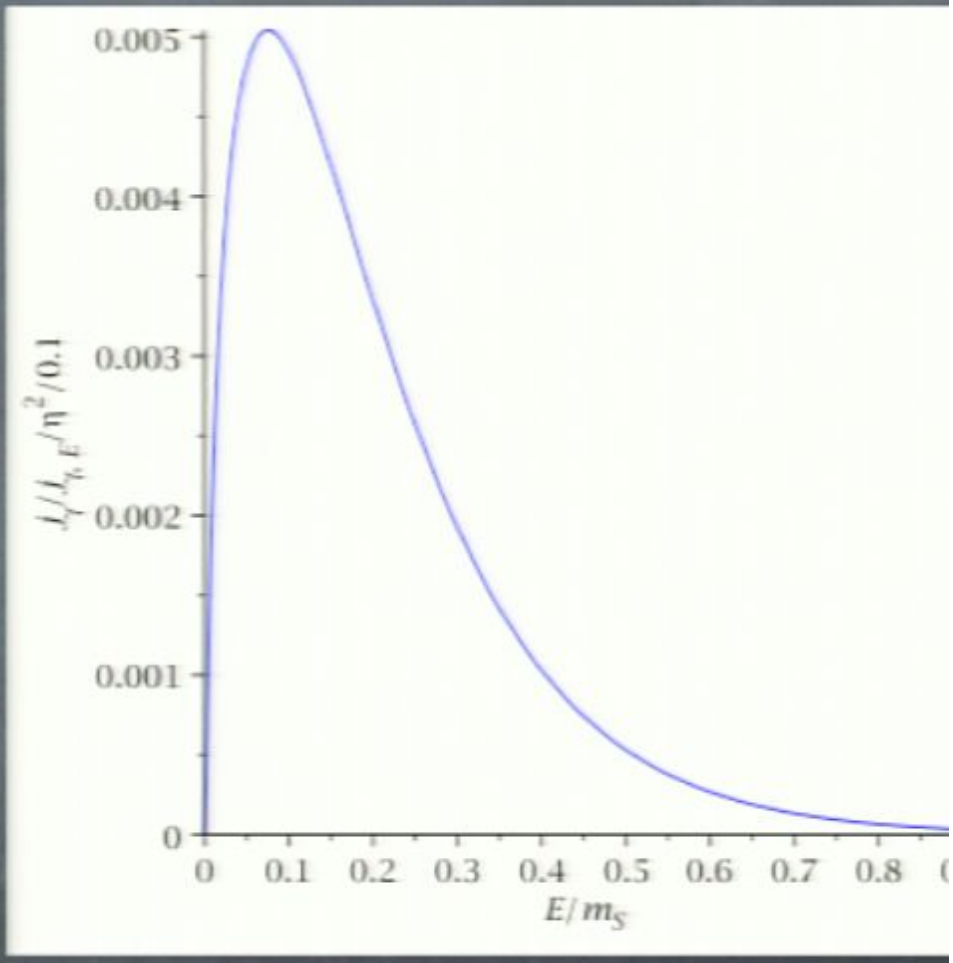

$m_h = 160\,\mathrm{GeV}$

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Summary

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