安定なヒッグスボソンのコライダー実験におけるシグナル

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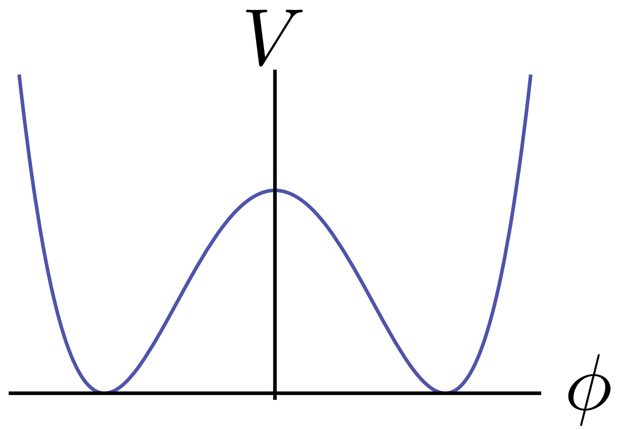
Introduction

Electro-Weak Symmetry Breaking

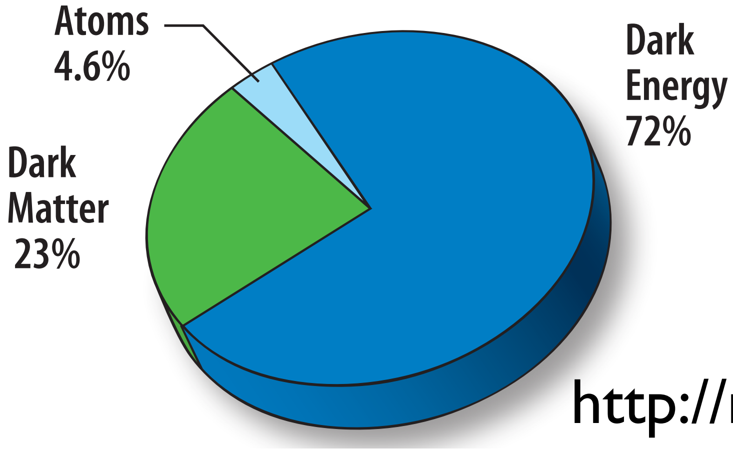


Higgs mechanism: Not seen yet.

Naturalness and hierarchy problem: New physics?

Dark Matter

WIMP?



http://map.gsfc.nasa.gov/

A possible solution: Dark Higgs scenario

Stable Higgs in gauge-Higgs unification

Model

Hosotani, Oda, Ohnuma, Sakamura, PRD78,096002(2008).

$SO(5) \times U(1)$ in 5D warped space-time.

EWSB by Hosotani mechanism.

4D Higgs field: Wilson line phase,

$$\hat{\theta}_H(x) = \theta_H + \frac{H(x)}{f_H}\,. \qquad f_H \simeq 246\,\mathrm{GeV}$$

→ A new dynamical parity, H-parity,

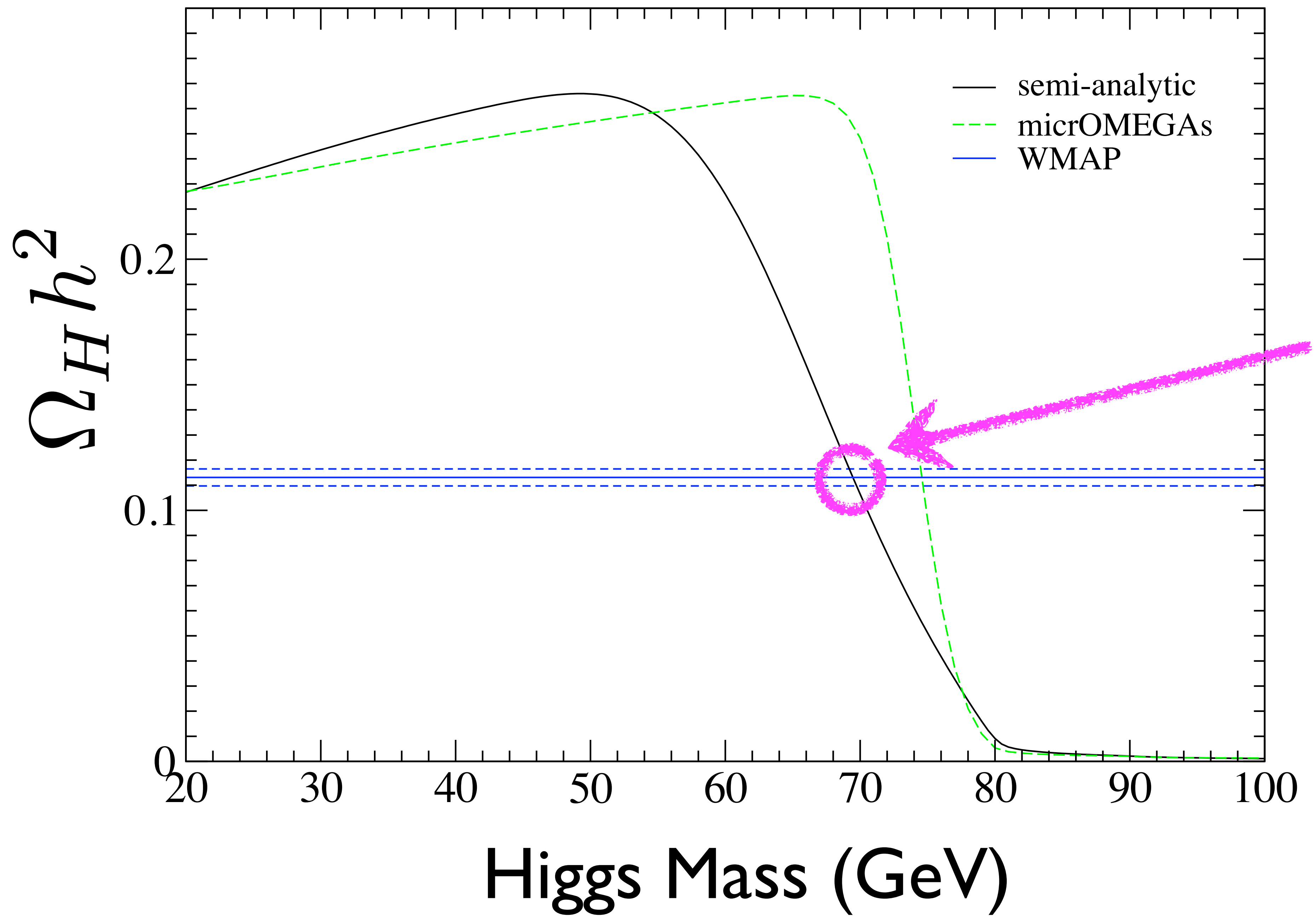
$$H(x) \to -H(x)\,.$$

Higgs is STABLE!

Dark Higgs

Y. Hosotani, P. Ko, MT (PLB680,179)

Relic Abundance



$m_H \sim 70\,\mathrm{GeV}$ favored.

Collider signals

Effective interactions

Integrating out KK modes,

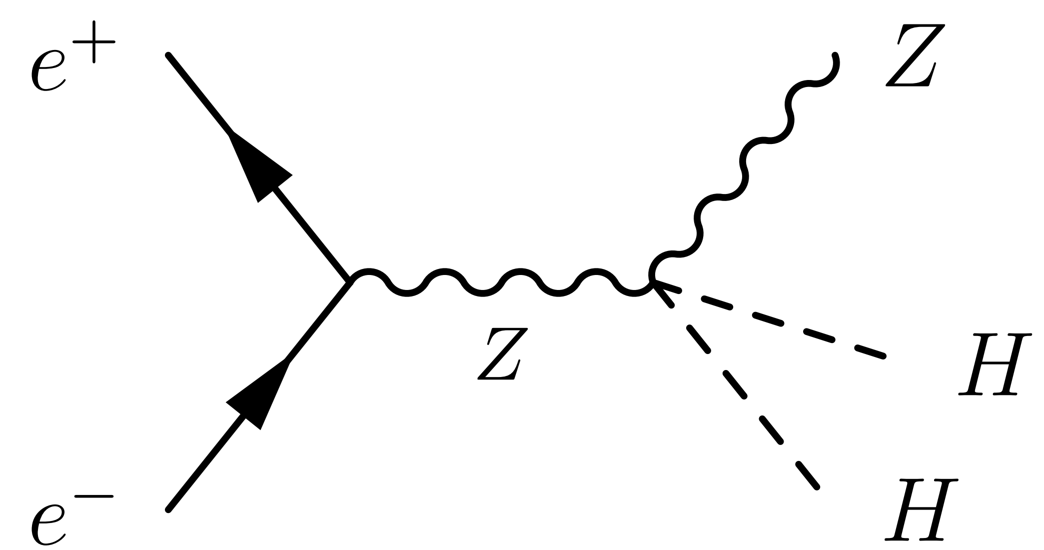
$$
\begin{aligned}
\mathcal{L}_{\rm int} \quad &= \quad -\frac{m_W^2}{f_H^2} H^2 W^{+\mu} W_\mu^- - \frac{m_Z^2}{2f_H^2} H^2 Z^\mu Z_\mu \\
&\quad +\sum_f \frac{m_f}{2f_H^2} H^2 \bar{f} f + \cdots \, .
\end{aligned}
$$

No odd powers of H .

Two missing Higgs bosons

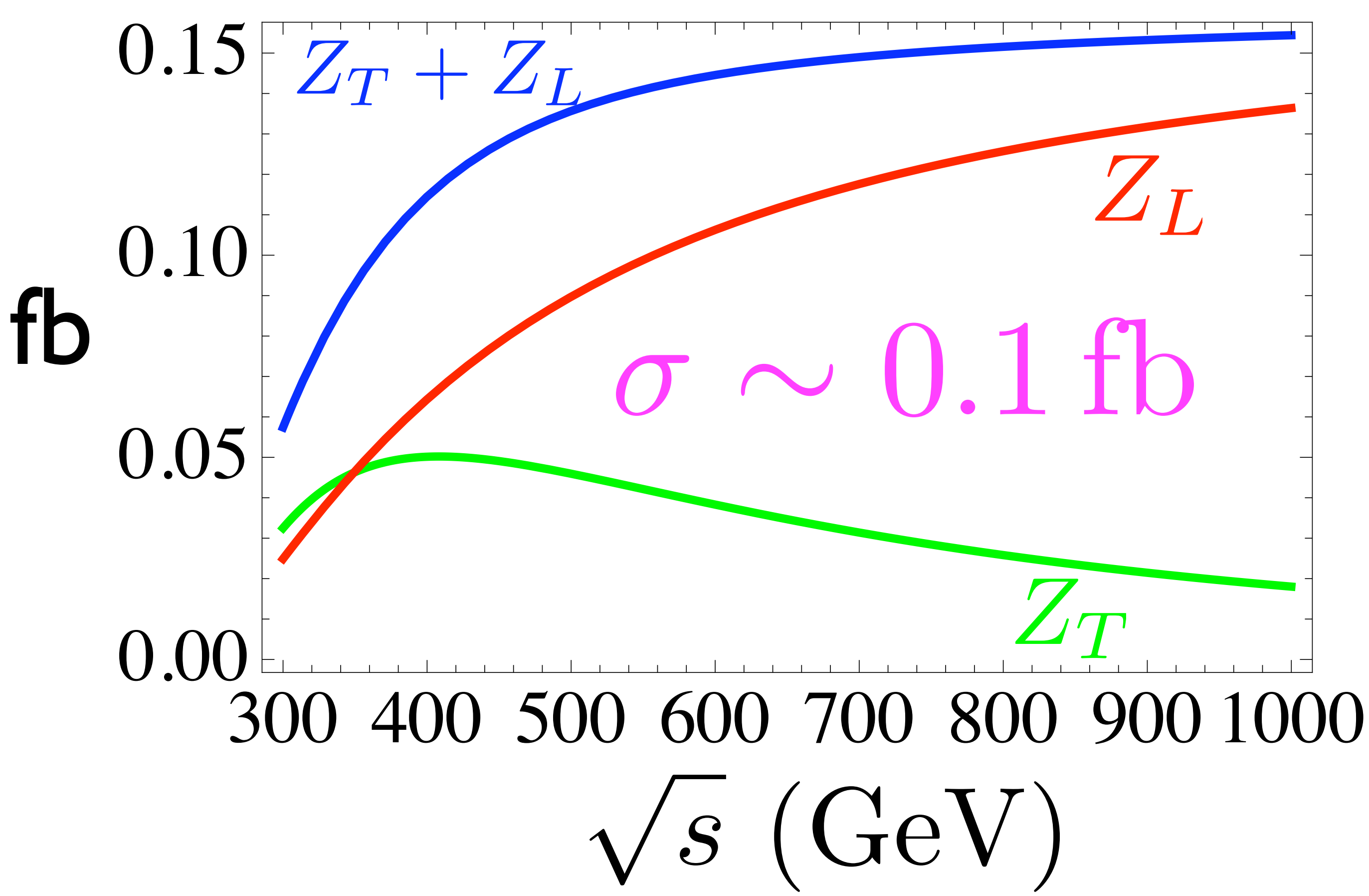
Linear Collider

Signal: $e^+e^- \to ZHH$



H's are missing.

total cross section for $m_H = 70\,\mathrm{GeV}$



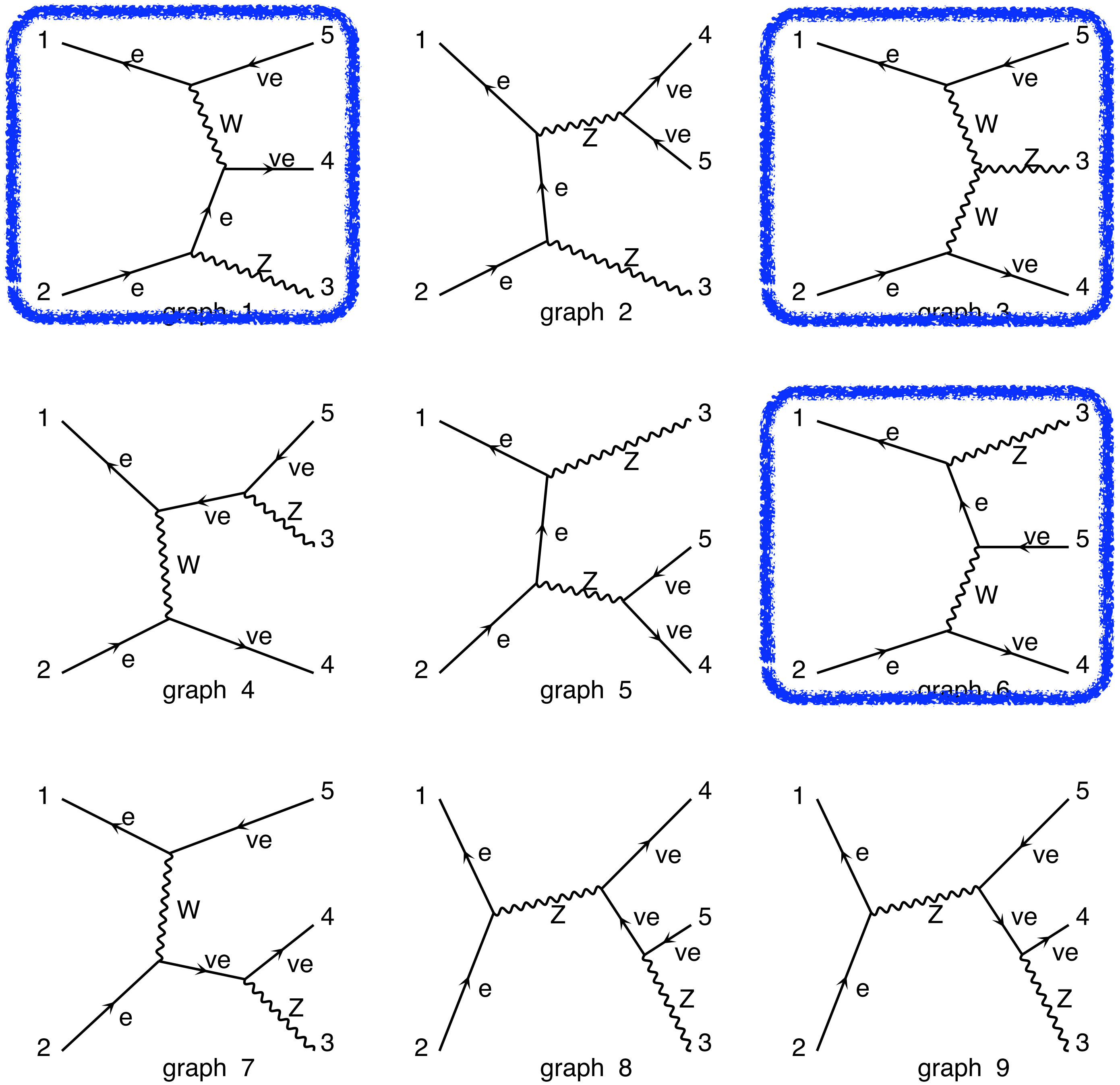
Z_L violates the unitarity unless $s/m_{\mathrm{KK}}^2 \ll 1$.

$m_{\mathrm{KK}} \sim 1\,\mathrm{TeV}$

$\sqrt{s} = 500\,\mathrm{GeV}$ in the following.

LC background $e^+e^- \to Z\nu\bar{\nu}$

Diagrams by MadGraph



BG cross section with $M_{\rm miss} \geq 120\,{\rm GeV}$

$\sigma_{\rm BG} \simeq 311\,{\rm fb}$

Need polarizations!

beams and Z

LC with polarizations

Ideal case: $e_L^+ e_R^- \to Z_L H H\,,\ Z_L \nu\bar{\nu}$

$\sigma_{\rm signal} \simeq 0.12\,{\rm fb}$ vs $\sigma_{\rm BG} \simeq 0.42\,{\rm fb}$

$|\cos\theta| < 0.6$ is applied.

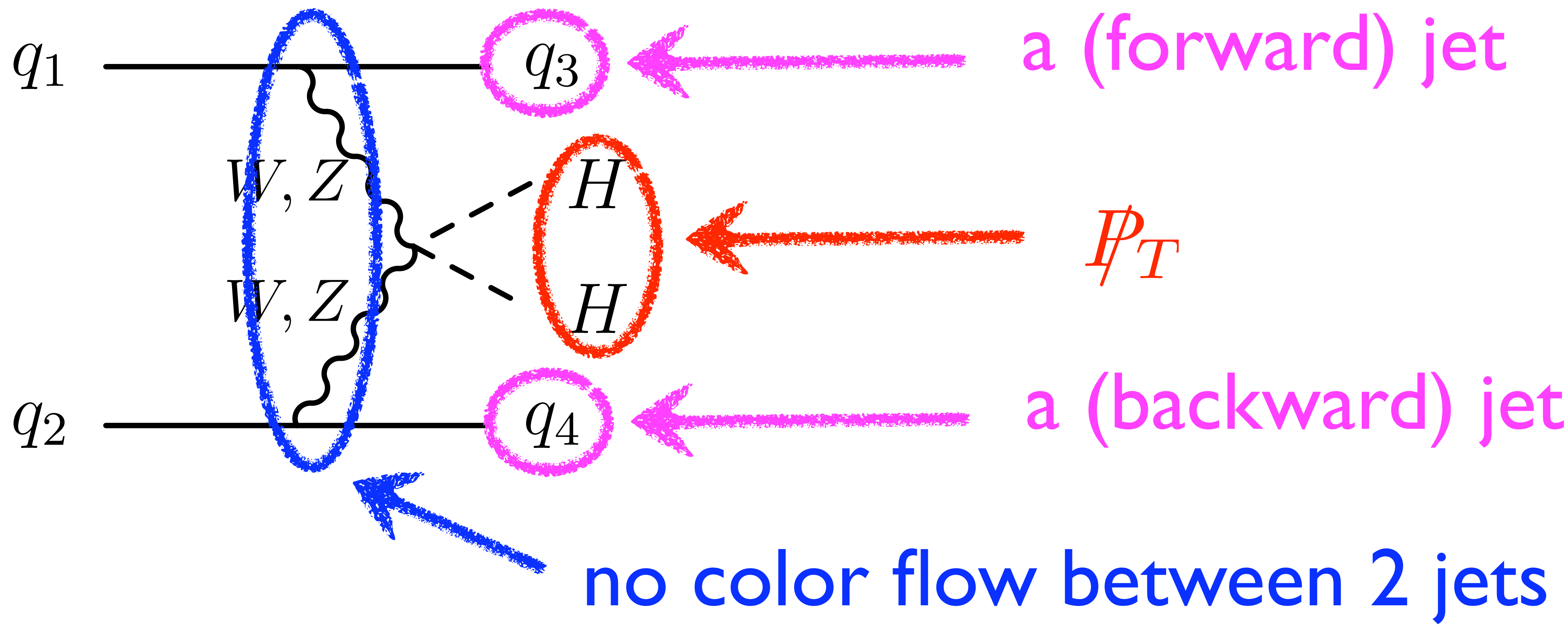
Significance: $\mathcal{S} \equiv \dfrac{N_{\rm signal}}{\sqrt{N_{\rm signal} + N_{\rm BG}}}$

$$\mathcal{S} = 1.4\sqrt{L/100\,{\rm fb}^{-1}}$$

A few (or more) ${\rm ab}^{-1}$ is required!

LHC

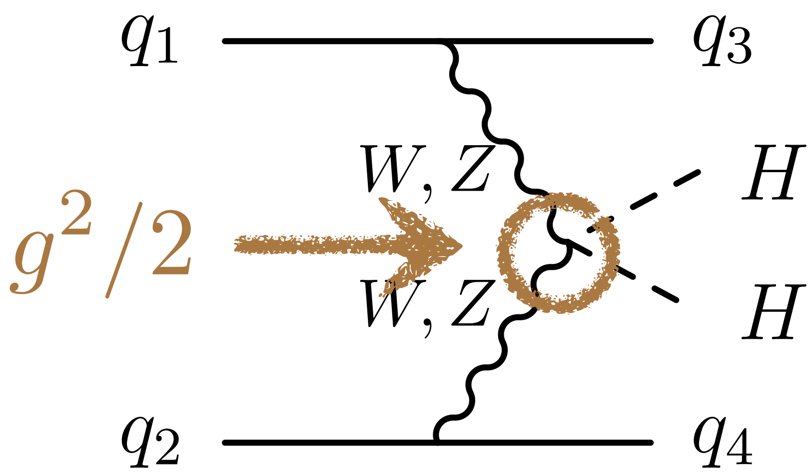
Signal: Weak boson fusion

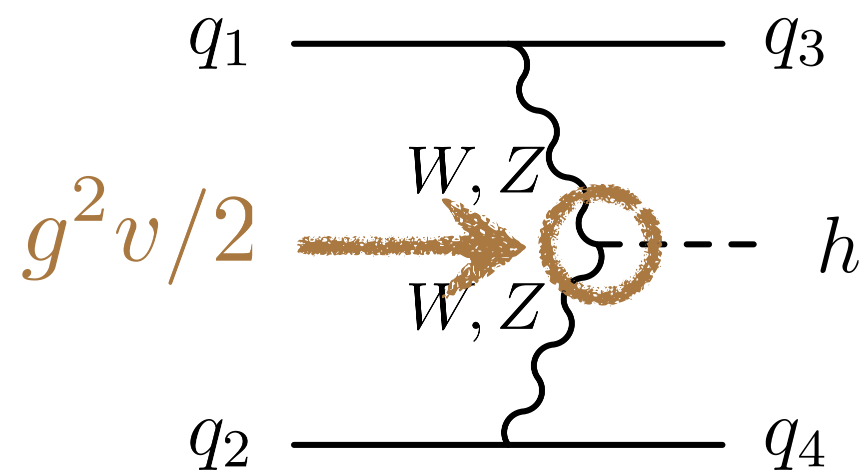


Background: Wjj, Zjj, jjj

→ Similar as invisible Higgs search

Signal cross section at LHC





$$\frac{d\sigma_{HH}}{dm_{HH}^2} = \frac{\bar{\beta}_f}{32\pi^2 v^2} \sigma_h \Big|_{m_h^2 = m_{HH}^2}$$

in the SM

$$\sigma_{HH} \sim 1.5\,\mathrm{fb}$$

$$\sigma_{BG} \simeq 167\,\mathrm{fb}$$

$$\mathcal{S} \sim 1.2\sqrt{L/100\,\mathrm{fb}^{-1}}$$

Éboli, Zeppenfeld

$p_T^j > 40$ GeV, $\quad |\eta_j| < 5.0,$

$|\eta_{j1} - \eta_{j2}| > 4.4, \quad \eta_{j1} \cdot \eta_{j2} < 0,$

$\not{p}_T > 100$ GeV.

$M_{jj} > 1200$ GeV, $\quad \phi_{jj} < 1.$

Summary

- Stable Higgs in gauge-Higgs unifiction is a viable candidate of dark matter.

  Dark Higgs scenario

- $m_H \sim 70\,\mathrm{GeV}$ is predicted.

- We need a few ab^{-1} or more.

  both for LHC and LC.

- Signals in KK mode production should be studied.

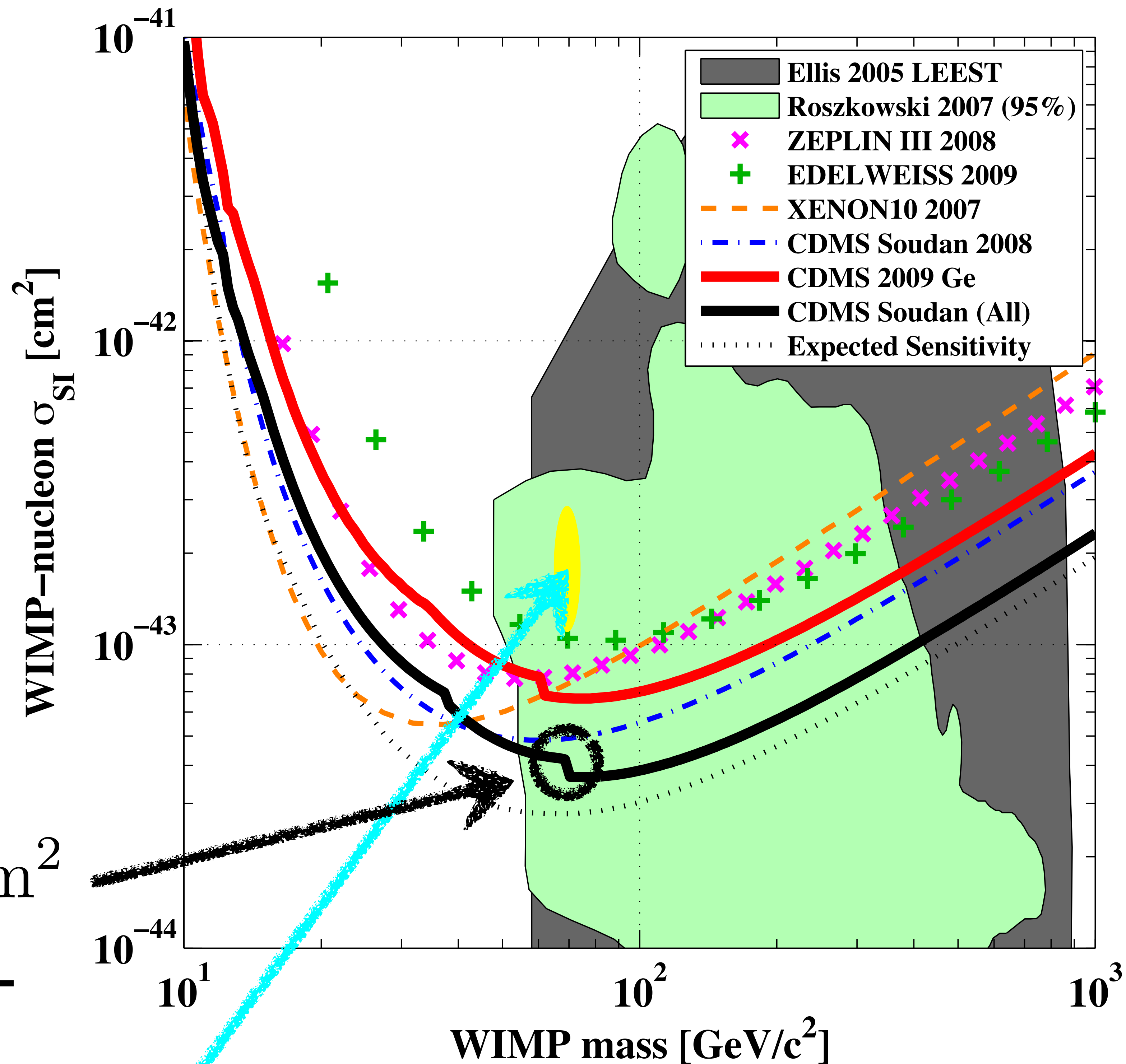
  $m_{\mathrm{KK}} \lesssim 1\,\mathrm{TeV}$

Backup Slides

Spin-Independent Cross Section

CDMS II

arXiv:0912.3592



Local DM density

$$\rho_0 = 0.3\,\mathrm{GeV/cm^3}$$

assumed in exps.

For $m_H = 70\,\mathrm{GeV}$

Exp. bound:

$$\sigma_{\rm SI} \lesssim 3.8\times 10^{-44}\,\mathrm{cm^2}$$

90% CL

Dark Higgs

Prediction: $\sigma_{\rm SI} \simeq (1.2-2.7)\times 10^{-43}\,\mathrm{cm^2}$

Uncertainties in the direct detection

Local density of CDM (not measured)

$\rho_0 = 0.3\,\mathrm{GeV/cm^3}$

assumed in the experiments.

$\rho_0 = 0.2 \sim 0.6\,\mathrm{GeV/cm^3}$

reasonable for smooth halo.

$\rho_0 \sim 0.04\,\mathrm{GeV/cm^3}$ (Kamionkowski and Koushiappas)

possible for non-smooth halo.

Effective Higgs coupling $HH\bar{f}f$

may be altered in more general models.

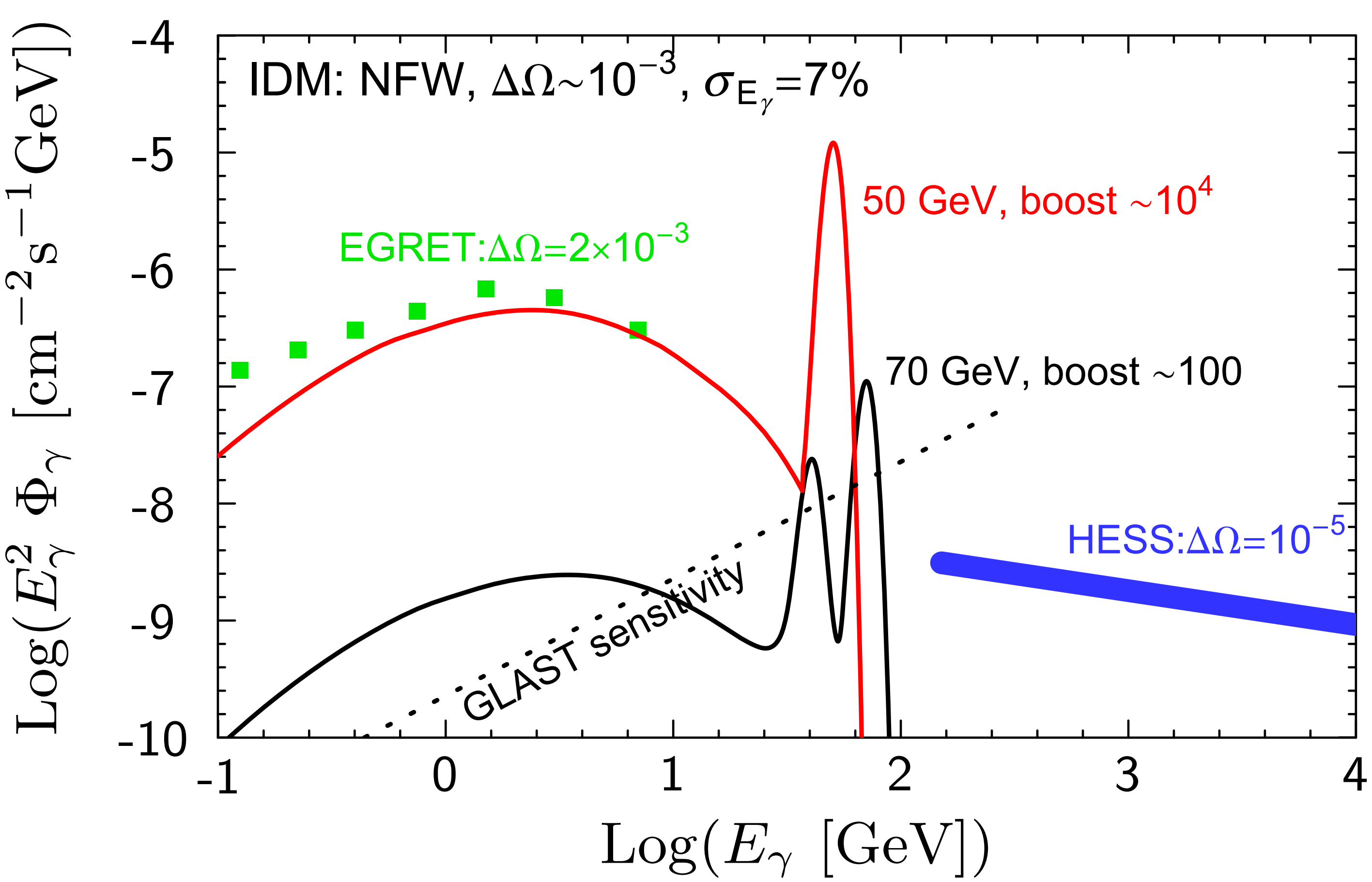
Astrophysical Signals

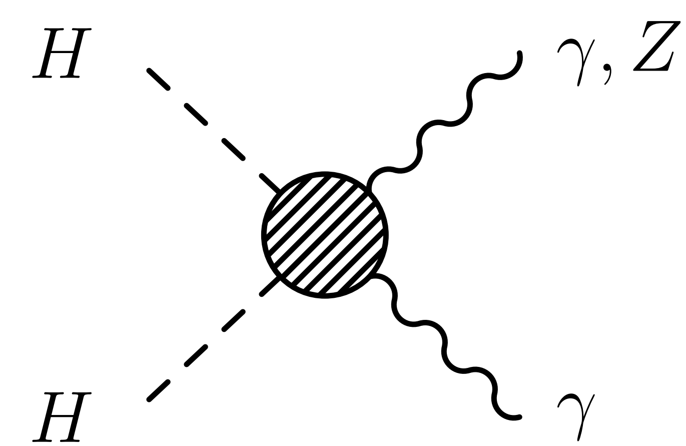
$HH \to \gamma\gamma,\ \gamma Z$ in the Galactic halo.

Two (nearly) monochromatic gamma lines.

$$E_\gamma = m_H (\simeq 70\mathrm{GeV})\,, m_H - m_Z^2/(4m_H)(\simeq 40\mathrm{GeV})$$

$$\sigma_{\gamma\gamma(\gamma Z)}\, v|_{v\to 0} \simeq 4.3(5.4)\times 10^{-29}\mathrm{cm}^3/\mathrm{s}$$





cf. Inert Doublet Model

← Gustafsson et al.