Gamma-rays constraint on Higgs Production from Dark Matter Annihilation

Takashi Toma
IPPP Durham University

Based on arXiv:1211.2639 in collaboration with
N. Bernal, C. Boehm, S. Palomales-Ruiz and J. Silk

Higgs as a Probe of New Physics 2013 (HPNP2013)
February 13-16, 2013, University of Toyama, Japan

Outline

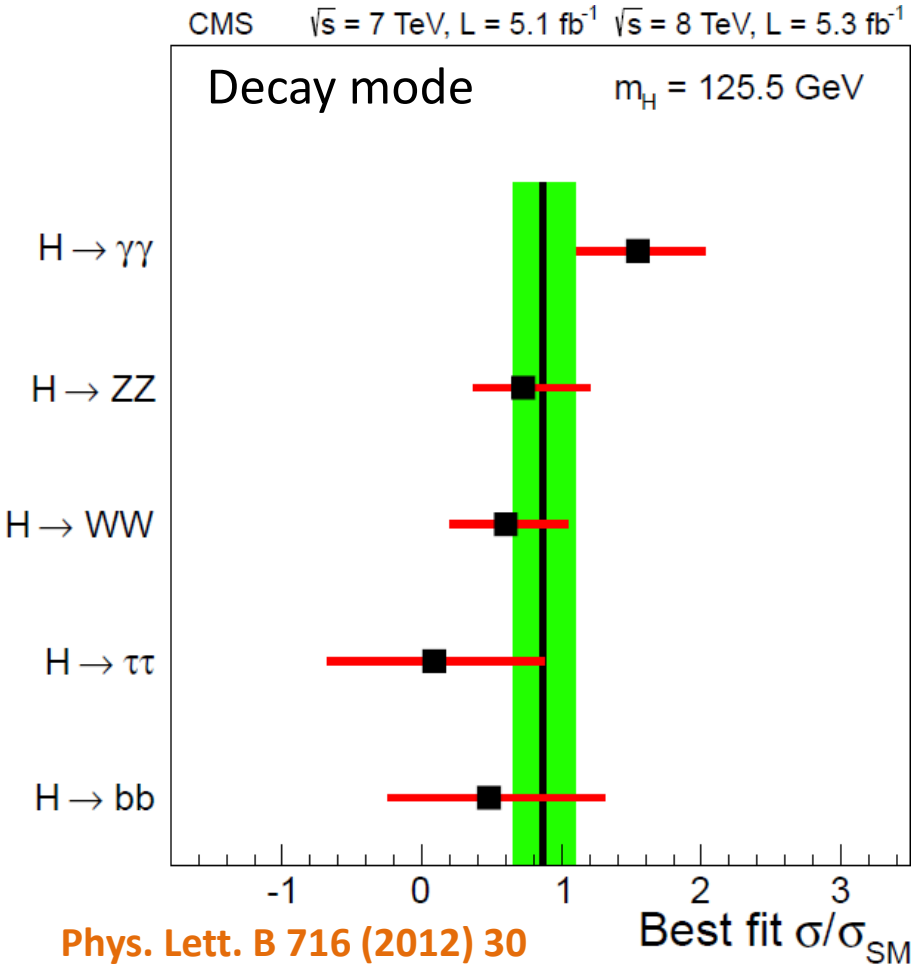
- Introduction
- Gamma-rays from Higgs decay

  DM mass of 63, 109, 126 GeV
- analysis
- Summary

Introduction

The SM-like Higgs boson was discovered at LHC.

The mass is $m_H \approx 126\ \mathrm{GeV}$



Phys. Lett. B 716 (2012) 30

- good agreement with SM

  SM? or BSM?

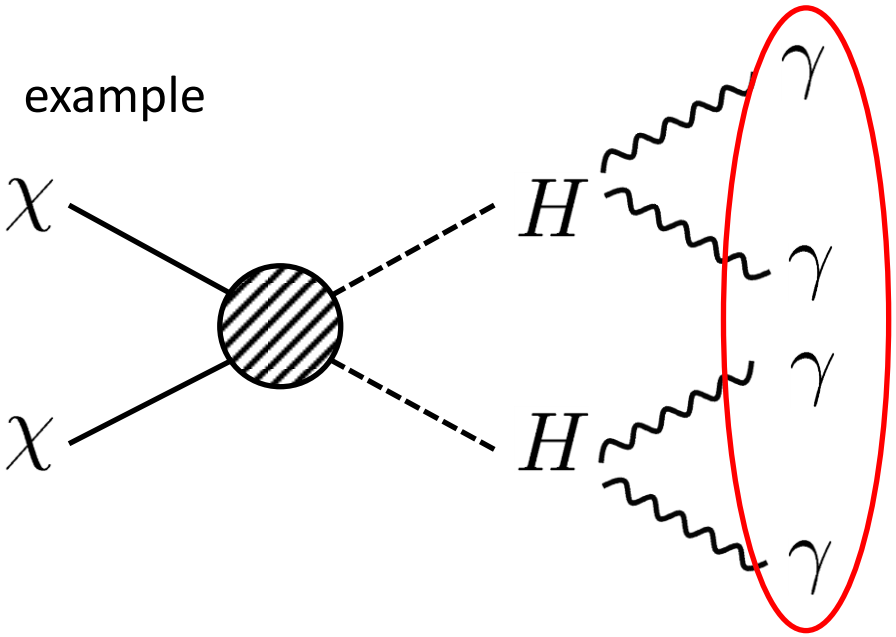
- we need more information

  One way:

  - examination of coupling between the Higgs and Dark Matter (DM) with astrophysical data

Introduction

The Higgs decays into gamma-rays and it may be observed.



line signal could be seen
if Higgs is produced at rest
or almost rest.

$E_\gamma \approx 63\ \mathrm{GeV}$

characteristic signal

- constraint on annihilation cross section into Higgs

→ coupling strength

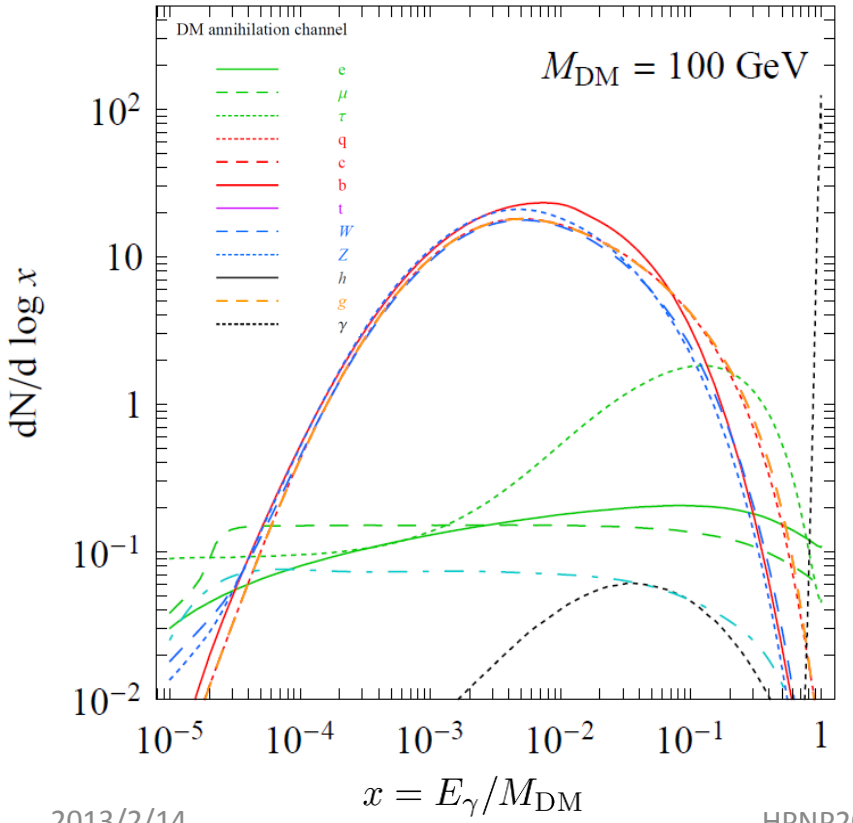
Gamma-rays from DM annihilation

- two types of gamma-rays

1. Continuum γ-ray

$$\chi\chi \to f\overline{f} \to \gamma$$

$$\chi\chi \to f\overline{f}\gamma \quad \text{(FSR)}$$



2. γ-ray line

- direct production

$$\chi\chi \to \gamma\gamma \; (E_\gamma = m_\chi)$$

Loop suppressed

- decay of Higgs

$$\chi\chi \to HH \; (m_\chi \approx 126 \text{ GeV})$$
$$\chi\chi \to HZ \; (m_\chi \approx 109 \text{ GeV})$$
$$\chi\chi \to H\gamma \; (m_\chi \approx 63 \text{ GeV})$$

(Spin = ½ or 1)

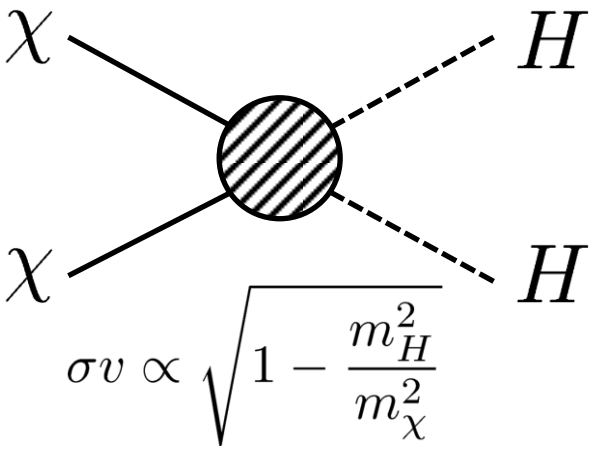
Tree or loop process

JCAP 1103 (2011) 051

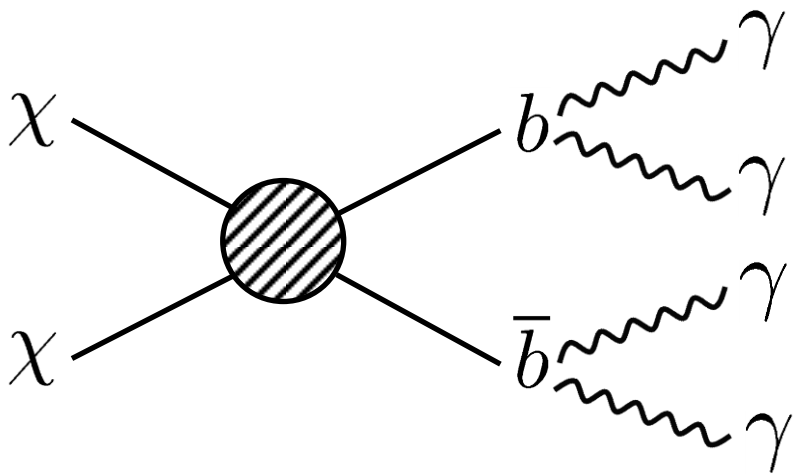
Gamma-rays from DM annihilation

However

- Phase space suppression



No suppression



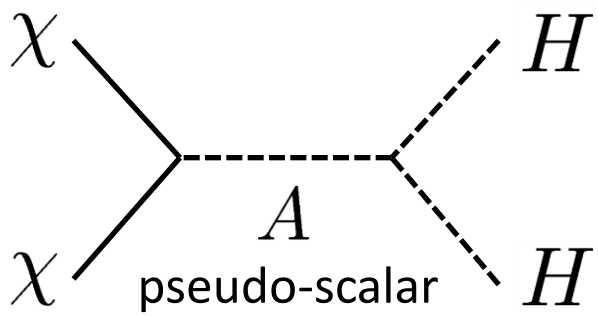
In addition

- Branching ratio $\dfrac{\mathrm{Br}(H \to \gamma\gamma)}{\mathrm{Br}(H \to b\bar{b})} \approx 4 \times 10^{-4}$ small

→ The γ-ray line from the Higgs decay might be swamped.

A wayout

In case of SUSY model

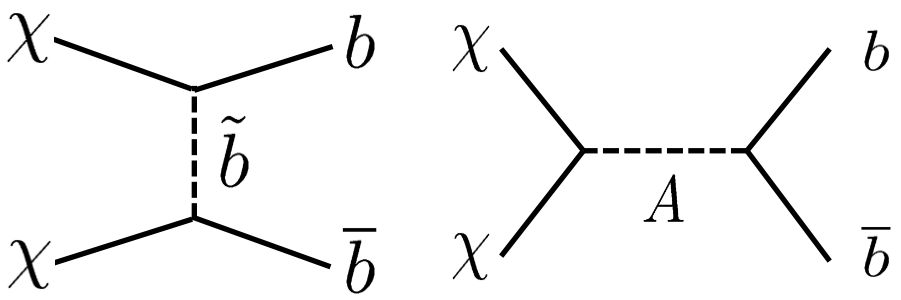


- phase space suppression
- small branching ratio

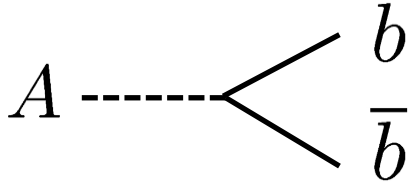
$$\frac{\mathrm{Br}(H \to \gamma\gamma)}{\mathrm{Br}(H \to b\bar{b})} \approx 4 \times 10^{-4}$$

- resonance $2m_\chi \approx m_A$

We have to suppress



- suppression by heavy sbottom
- small coupling between bottom and pseudo-scalar

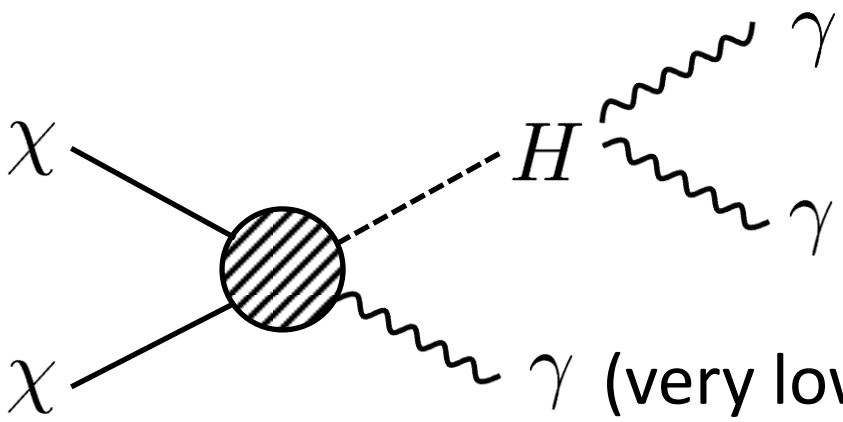


→ it is possible to see a line signal

gamma-rays from 63 GeV DM

In case of $m_H = 63\ \mathrm{GeV}$

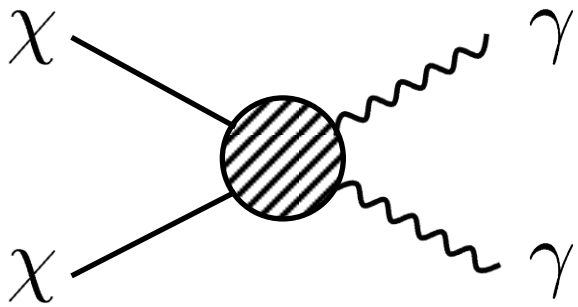
channel: $\chi\chi \to H\gamma$ (DM spin = ½ or 1)



$E_\gamma = 63\ \mathrm{GeV}$

(very low energy) $E_\gamma = \dfrac{4m_\chi^2 - m_H^2}{4m_\chi}$

But confused with



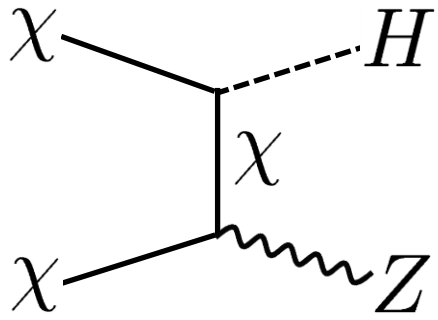
$E_\gamma = 63\ \mathrm{GeV}$

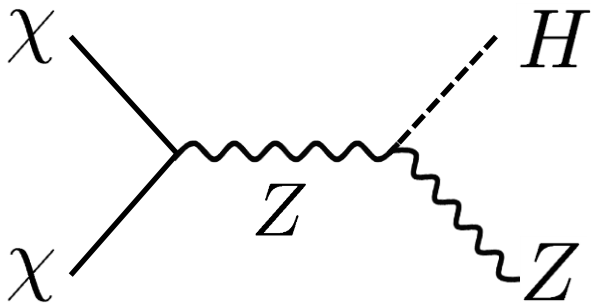
Which is dominant?

gamma-rays from 109 GeV DM

channel: $\chi\chi \to HZ$

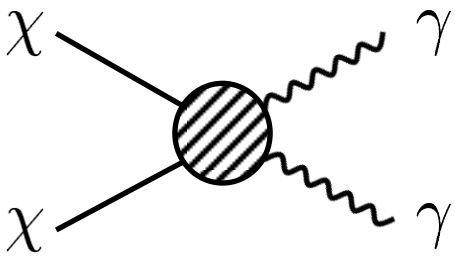
for example



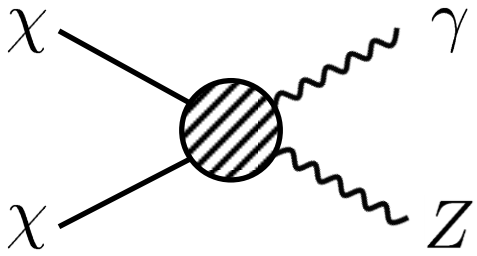


63 GeV gamma

In addition to the Higgs decay



109 GeV gamma

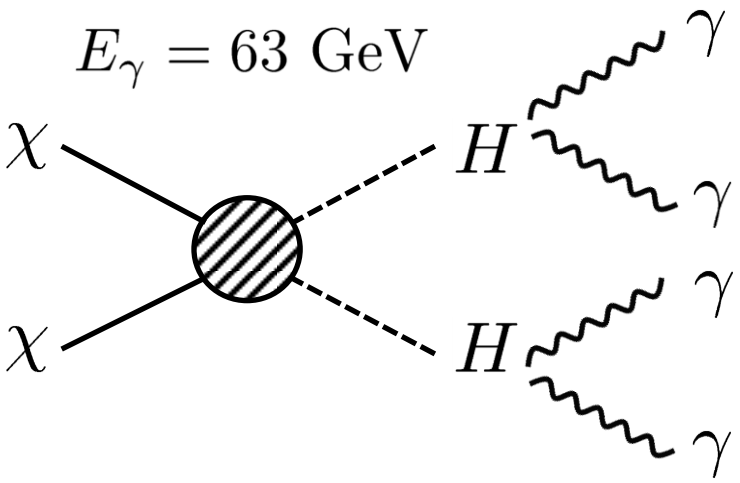


72 GeV gamma

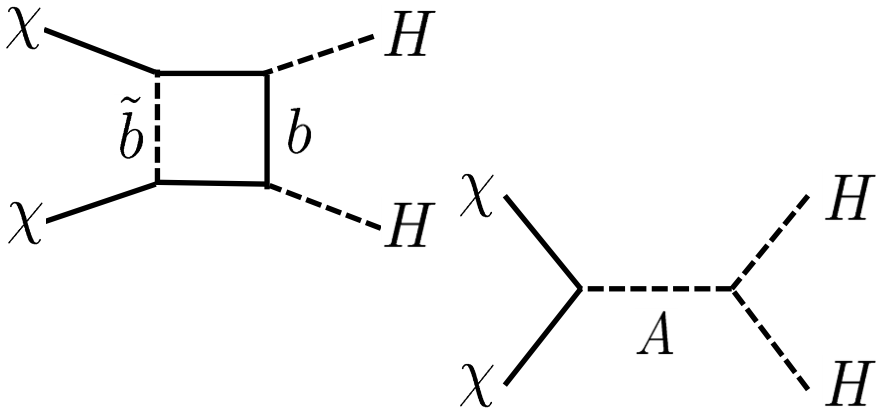
They are not relative with Higgs.

gamma-rays from 126 GeV DM

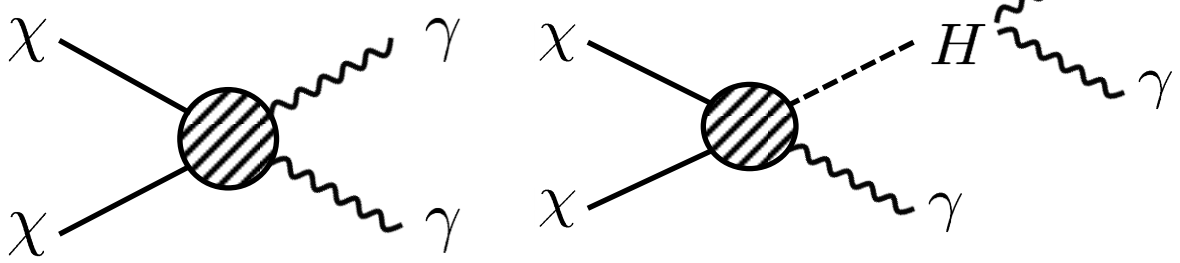
channel: $\chi\chi \to HH$



In SUSY models



Can we disentangle it with the following?



$E_\gamma = 63$ GeV

for 63 GeV DM

Analysis for gamma-rays flux

Differential flux

$$\frac{d\Phi_\gamma}{dE_\gamma} = \eta \frac{\langle \sigma v \rangle}{m_\chi^2} \frac{dN_\gamma}{dE_\gamma} \frac{1}{8\pi} \int_{\Delta\Omega} d\Omega \int_{\mathrm{los}} \rho^2 \left(r\left(s, \Omega\right)\right) ds$$

η : Symmetry factor

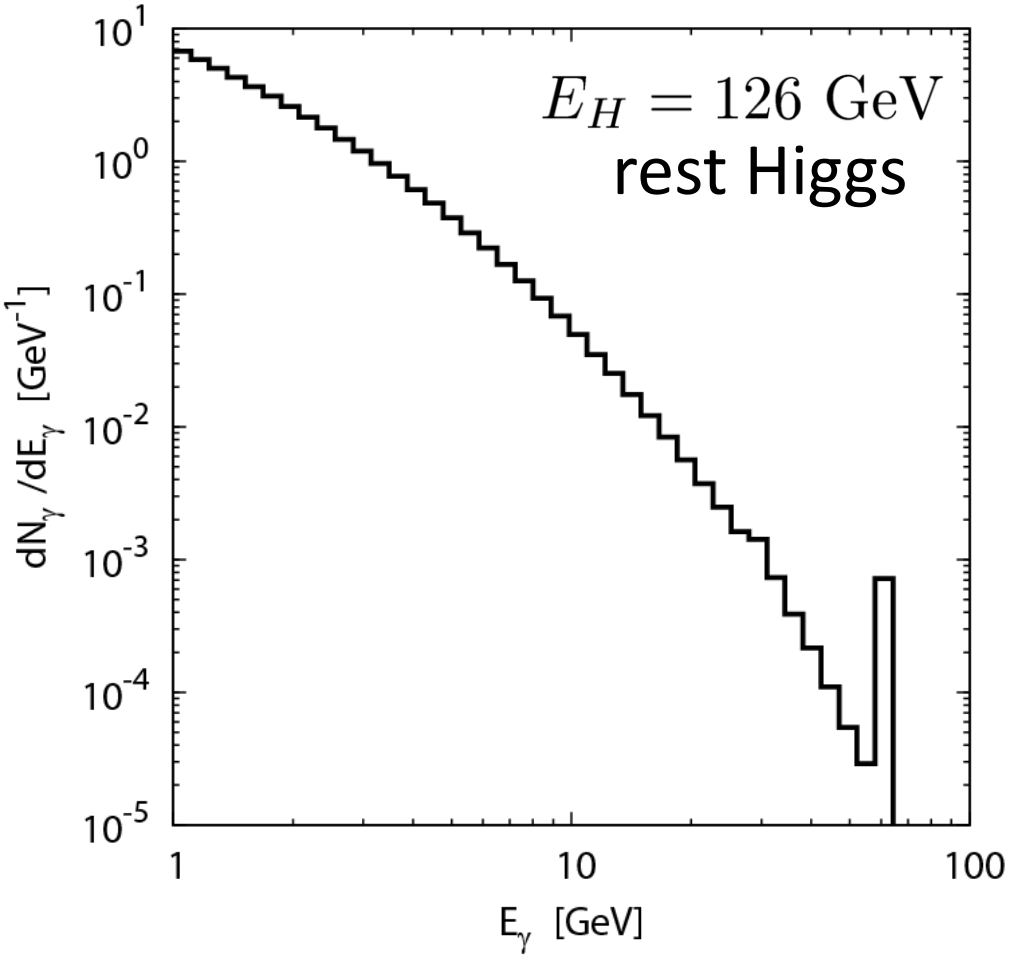
(1 for Majorana particle, ½ for not a self-conjugate particle)

$\frac{dN_\gamma}{dE_\gamma}$: energy spectrum

DM profile : $\rho(r) = 0.193 \rho_\odot \exp\left[-\frac{2}{\alpha} \left(\left(\frac{r}{r_s} \right)^\alpha - 1 \right) \right]$

$\alpha = 0.17$

Energy spectrum from the rest Higgs



used PYTHIA 6.4

Higgs decays into 2 gamma
→ peak at 63 GeV

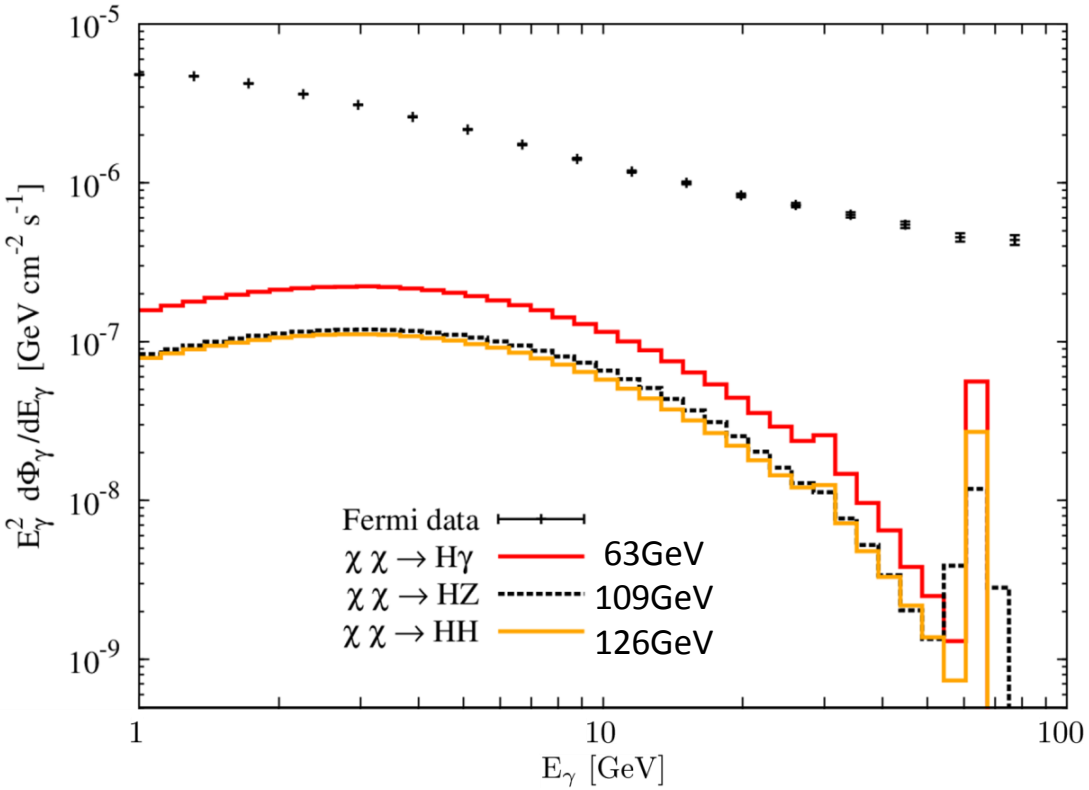
Higgs decays into Z gamma
→ small peak at 30 GeV

$$E_\gamma = \frac{m_H^2 - m_Z^2}{2m_H}$$

all channels are included.

The line signal is visible.

Gamma-ray flux from the rest Higgs



The limits are obtained from the line rather than the continuum gamma.

- channel: $\chi\chi \to H\gamma$ most visible because of small DM mass

We obtain a limit:

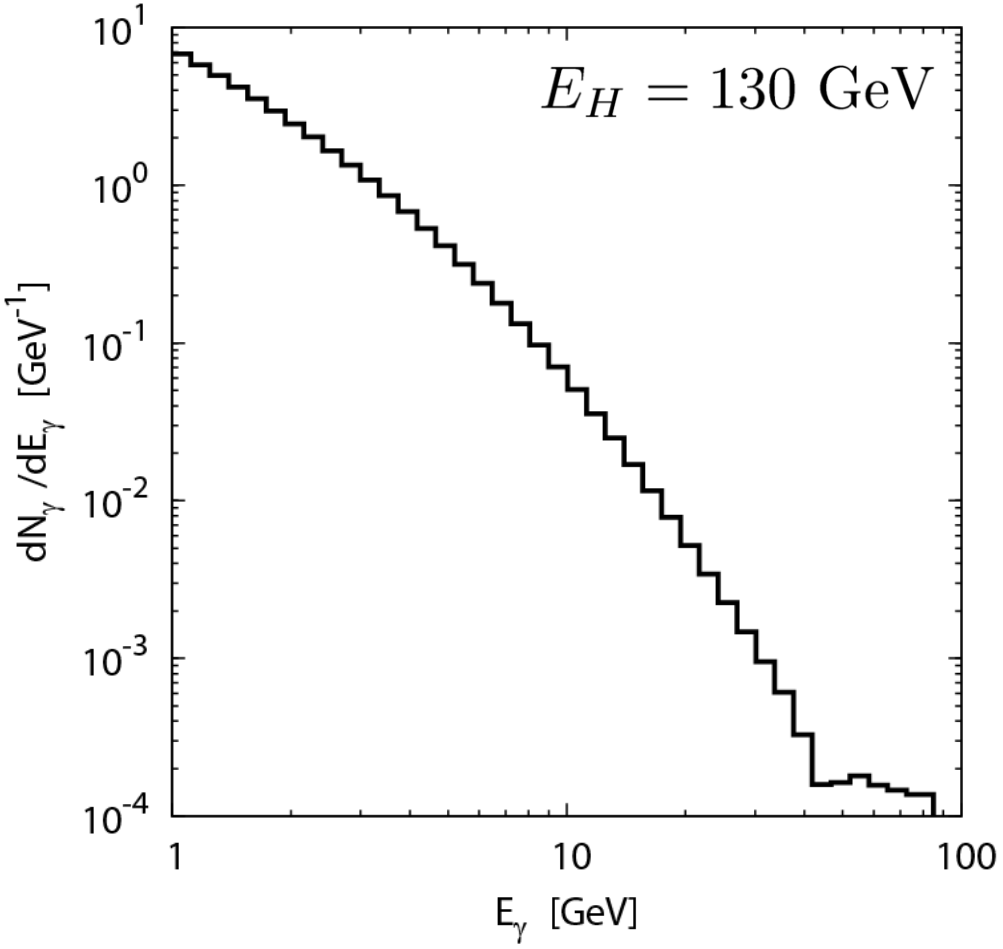
$\langle\sigma v\rangle \sim 2.5 \times 10^{-25}\ \mathrm{cm}^3/\mathrm{s}$ for 63GeV

$\langle\sigma v\rangle \sim 5.0 \times 10^{-25}\ \mathrm{cm}^3/\mathrm{s}$ for 109GeV

$\langle\sigma v\rangle \sim 6.0 \times 10^{-25}\ \mathrm{cm}^3/\mathrm{s}$ for 126GeV

$10^{-27\sim-28}\ \mathrm{cm}^3/\mathrm{s}$ for γ-production

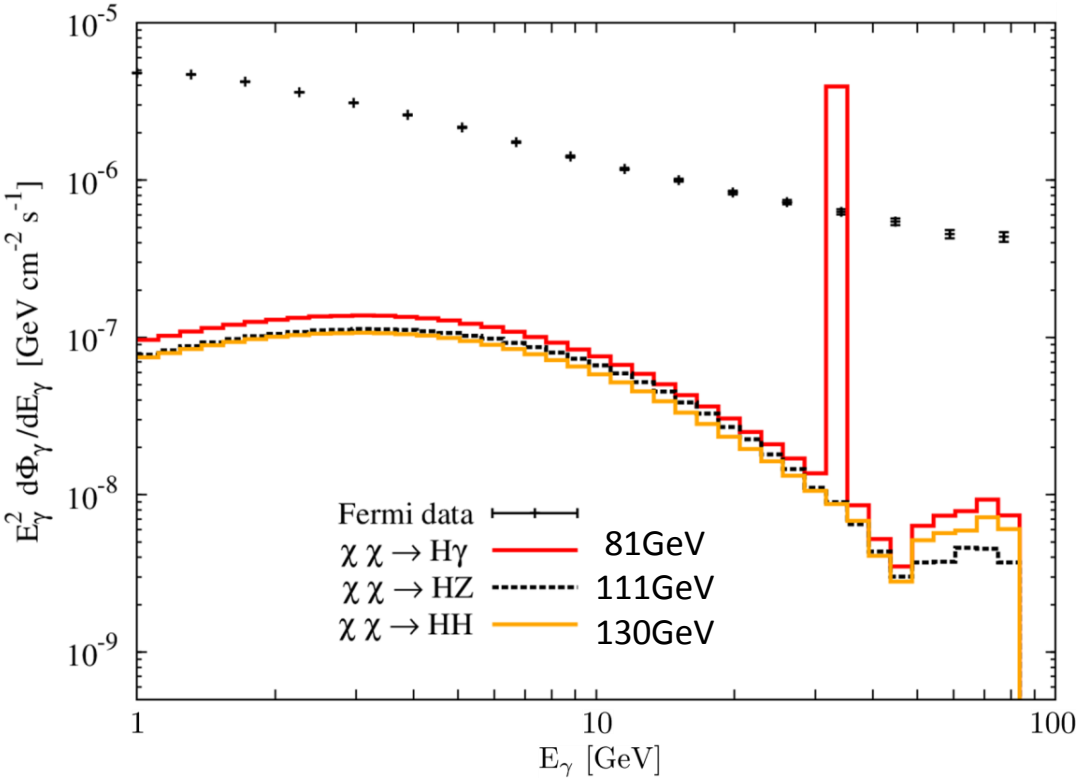
Energy spectrum for boosted Higgs

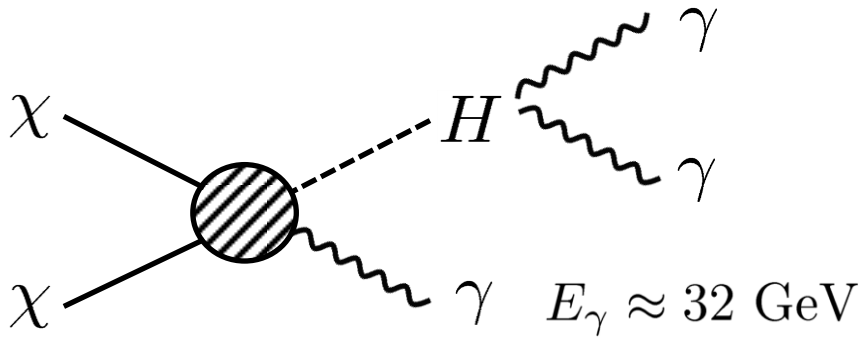


- Higgs decays into 2 gamma a tiny peak at 63 GeV
- No small excess around 30 GeV
- Several order of magnitude is different.

A limit is obtained from the continuum gamma rather than the line signal?

Gamma-ray flux for boosted Higgs





- limit from continuum : $HH,\ HZ$ processes

$$\langle \sigma v \rangle \sim 5 \times 10^{-25}\ \mathrm{cm}^3/\mathrm{s}$$

- intense line at 32 GeV for $H\gamma$ process

The limit :

$$\langle \sigma v \rangle \sim 4 \times 10^{-27}\ \mathrm{cm}^3/\mathrm{s}$$

Summary

- The SM-like Higgs boson was discovered at LHC.
- Using the decay property of the SM-like Higgs, we obtained the constraint on the cross section of DM into the SM-like Higgs for some DM masses.

  Higgs production: $\langle \sigma v \rangle \sim 10^{-25}\ \mathrm{cm}^3/\mathrm{s}$

The limit will be important when an enhancement mechanism of cross section is working.