Dark Matter via Higgs portal

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Standard model with DM particles

- Simplest SM extended to contain only one new particle DM state
- Minimal Higgs sector is unchanged, contains a unique Higgs boson 125 GeV
- DM particle interact only with H state and their annihilation into SM particles
  - e.g. only through H boson exchange in the s-channel

The minimal model in an effective approach

- The SM Higgs sector

$$\Phi = \begin{pmatrix} \Phi^+ \\ \Phi^0 \end{pmatrix} \qquad V(\Phi) = \mu^2 \Phi^\dagger \Phi + \lambda (\Phi^\dagger \Phi)^2$$

$$\Phi \to \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ v + H \end{pmatrix} \qquad v = \sqrt{-\mu^2/\lambda} = 1/(\sqrt{2} G_F)^{1/2} = 246\,\text{GeV}$$

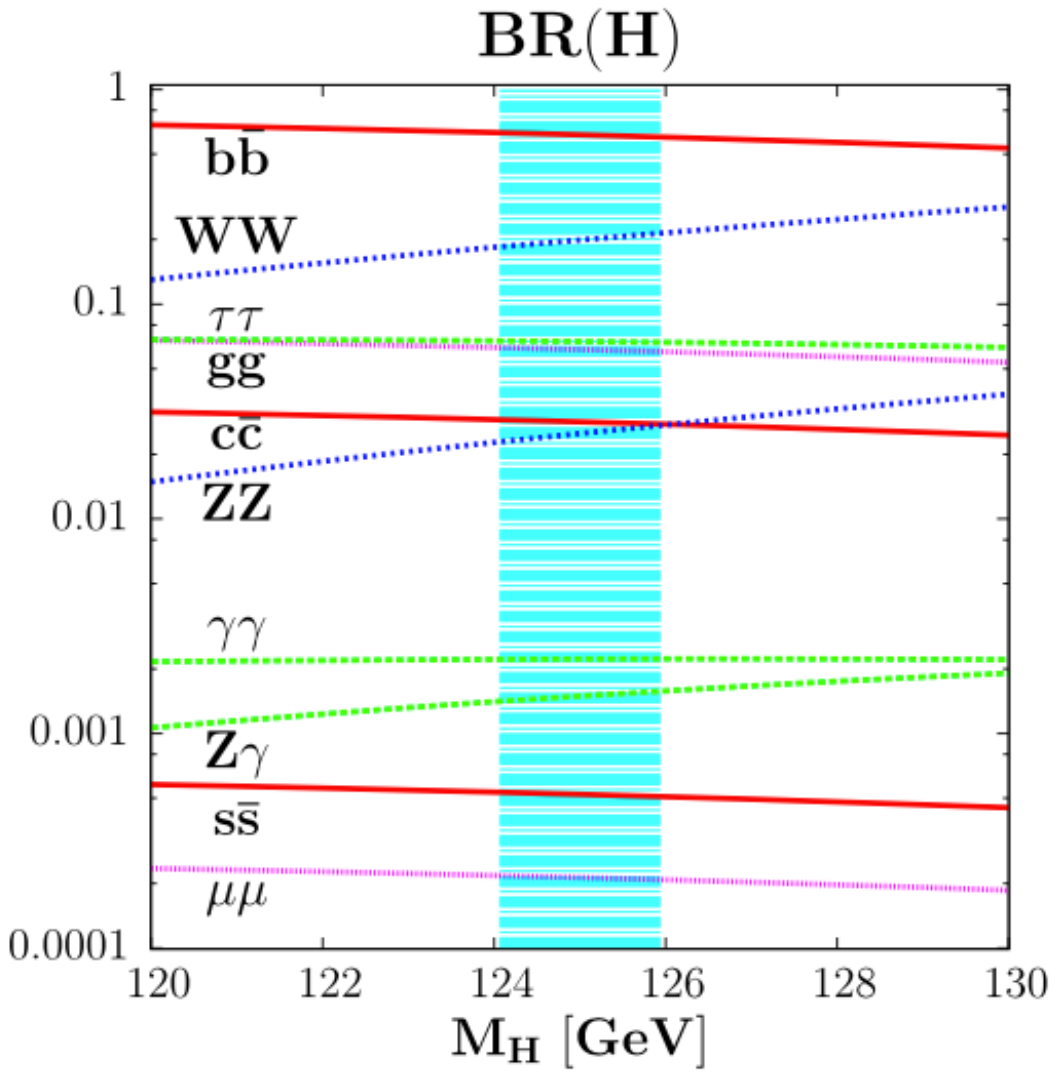
- The DM sector

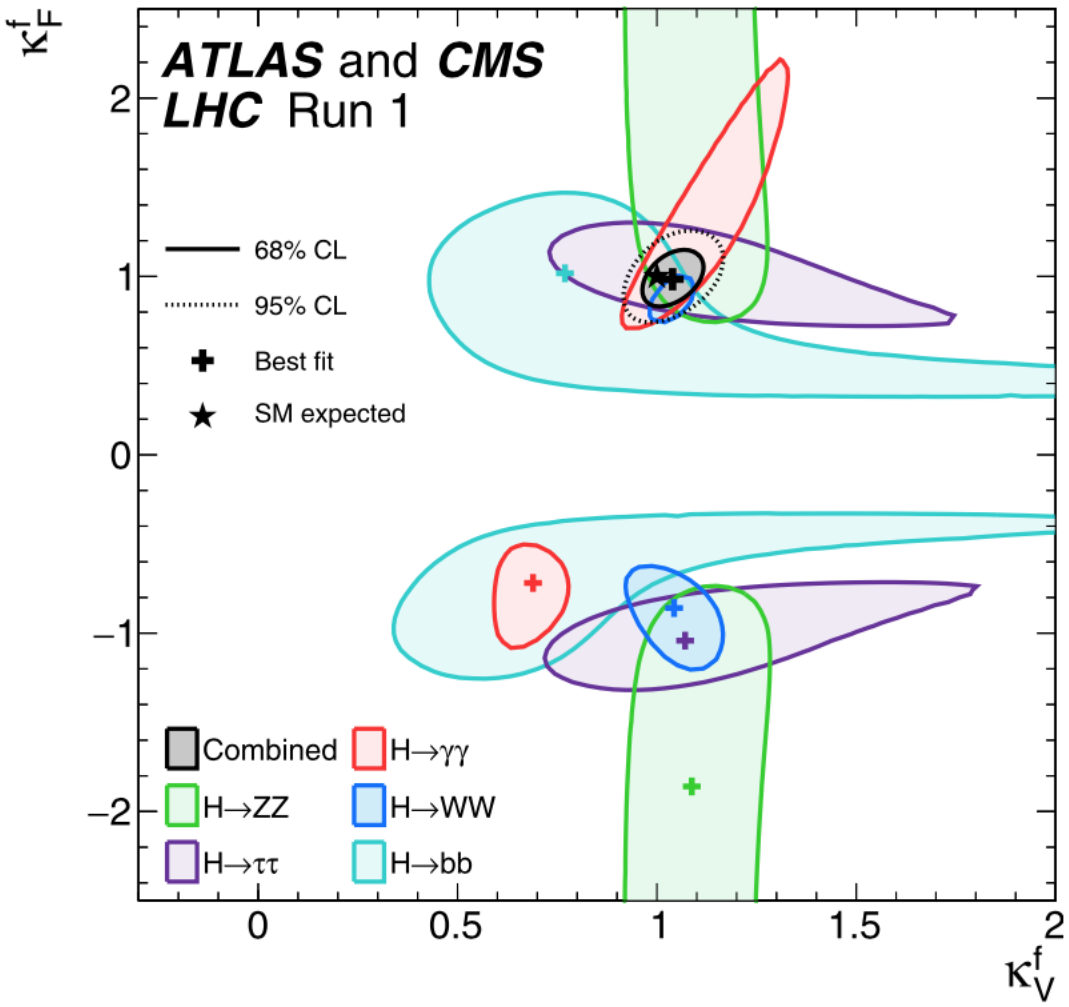
$$\Delta\mathcal{L}_S = -\frac{1}{2} M_S^2 S^2 - \frac{1}{4} \lambda_S S^4 - \frac{1}{4} \lambda_{HSS} \Phi^\dagger \Phi S^2 \,,$$

$$\Delta\mathcal{L}_V = \frac{1}{2} M_V^2 V_\mu V^\mu + \frac{1}{4} \lambda_V (V_\mu V^\mu)^2 + \frac{1}{4} \lambda_{HVV} \Phi^\dagger \Phi V_\mu V^\mu ,$$

$$\Delta\mathcal{L}_\chi = -\frac{1}{2} M_\chi \bar{\chi} \chi - \frac{1}{4} \frac{\lambda_{H\chi\chi}}{\Lambda} \Phi^\dagger \Phi \bar{\chi} \chi \,.$$

Higgs production at LHC





Collider constraints on invisible higgs decays

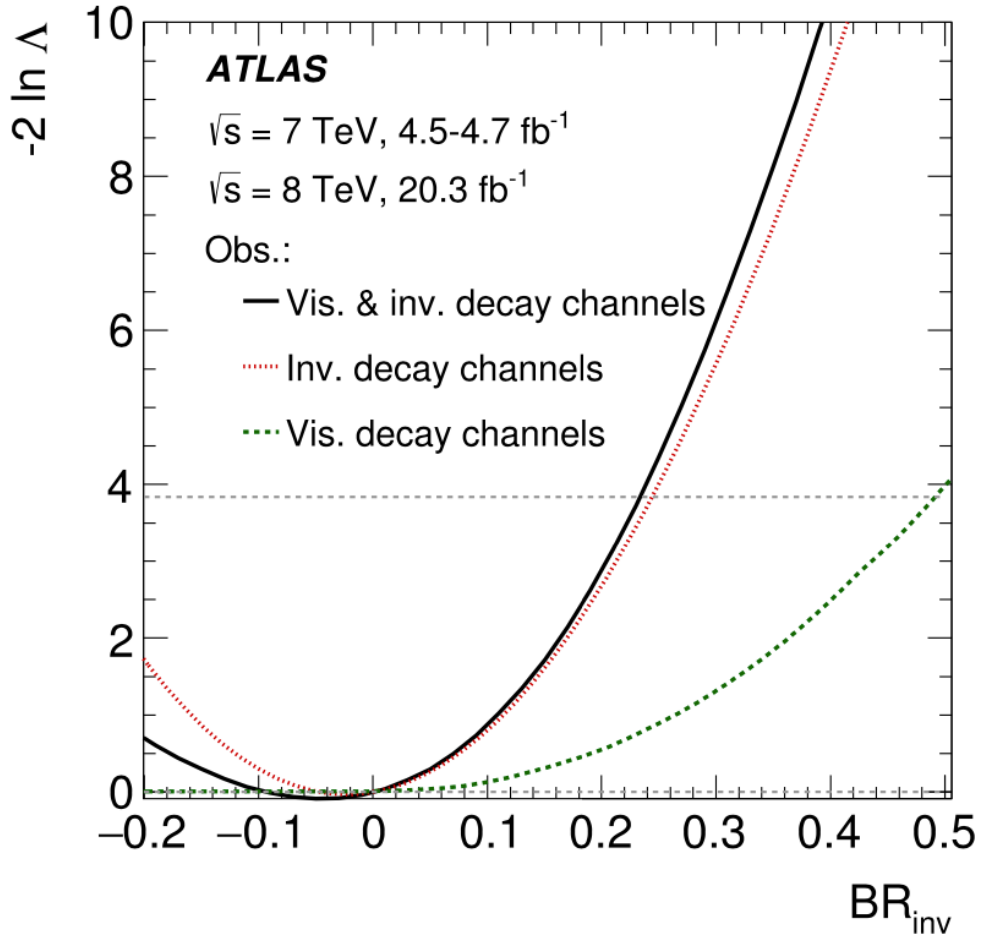
- If DM particles X are light, less than half of the mass of Higgs

$$\Gamma_{\text{inv}}(H \to SS) = \frac{\lambda_{HSS}^2 v^2 \beta_S}{64\pi M_H},$$

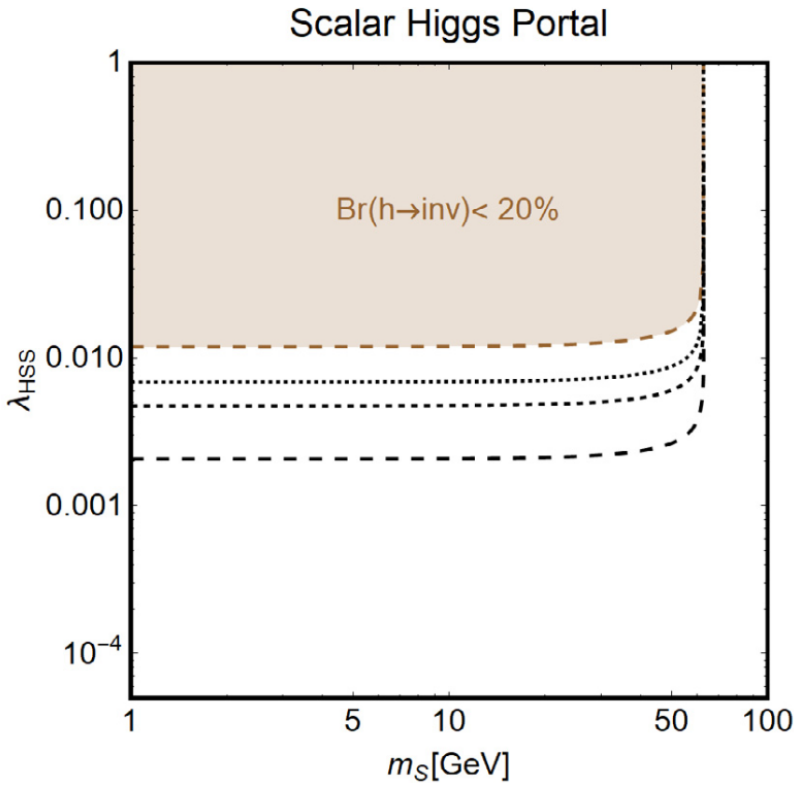
$$\Gamma_{\text{inv}}(H \to VV) = \frac{\lambda_{HVV}^2 v^2 M_H^3 \beta_V}{256\pi M_V^4}\left(1 - 4\frac{M_V^2}{M_H^2} + 12\frac{M_V^4}{M_H^4}\right),$$

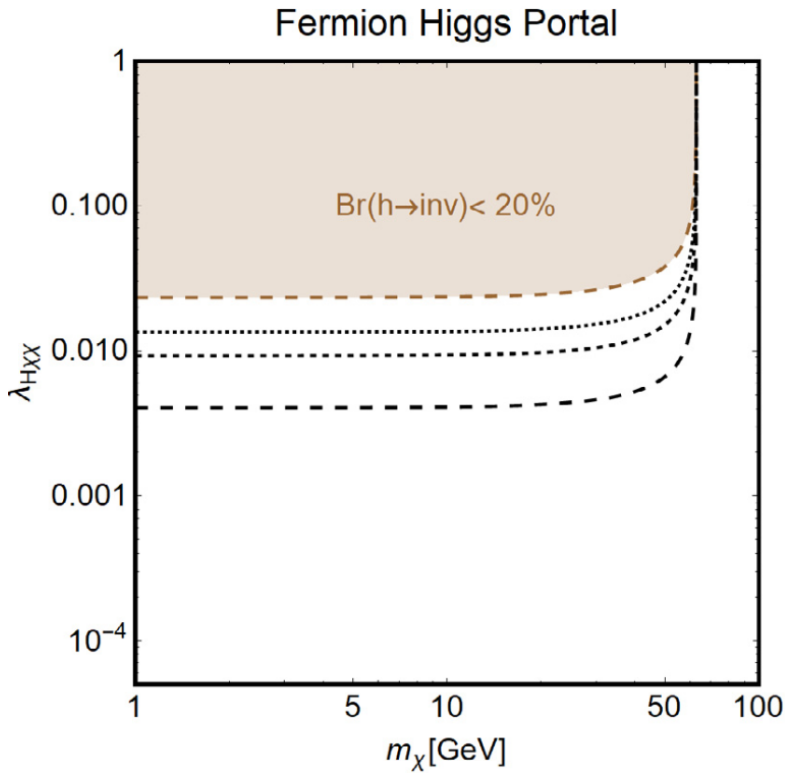
$$\Gamma_{\text{inv}}(H \to ff) = \frac{\lambda_{Hff}^2 v^2 M_H \beta_f^3}{32\pi \Lambda^2},$$

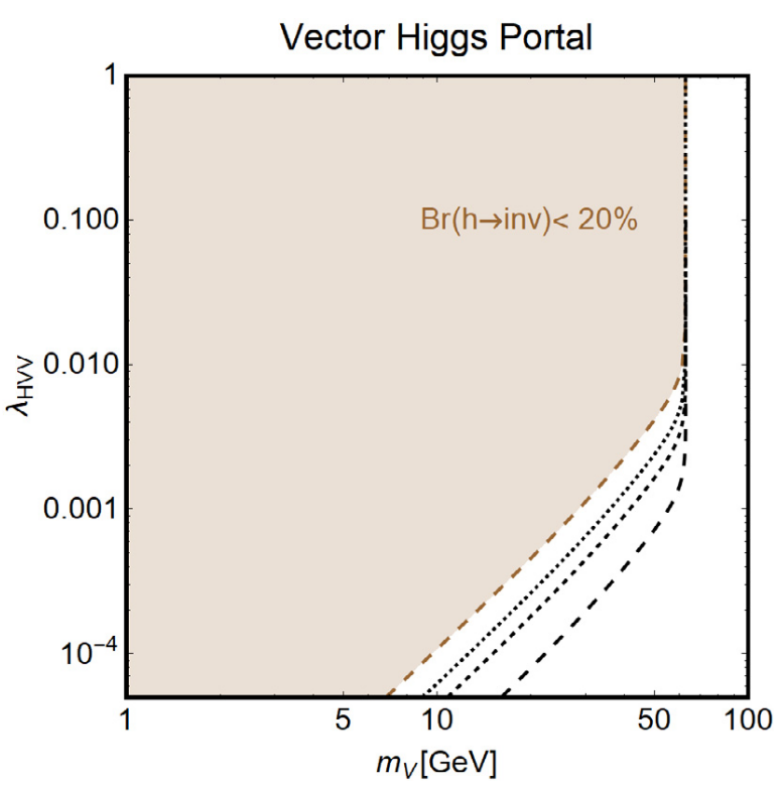
$$\text{BR}(H \to \text{inv}) < 20\%$$



Prospects for future measurements







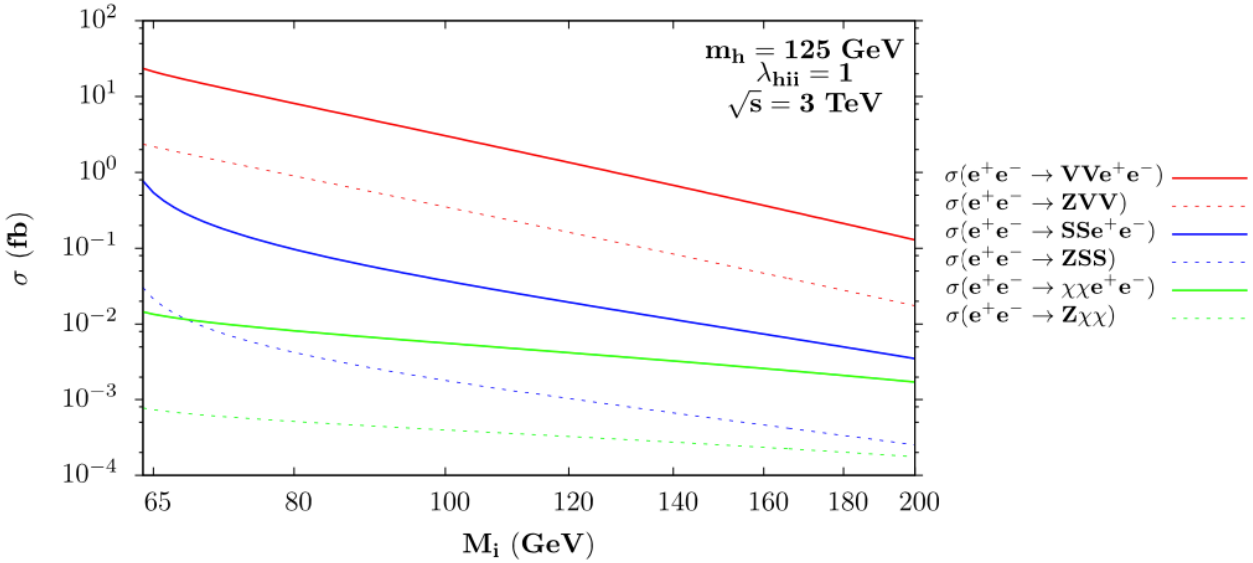
DM production through off-shell Higgs

- DM particles larger than half the Higgs mass
  - double production in Higgs-strahlung
  - vector boson fusion
  - gluon fusion mechanism

- Observation on e+e- colliders

$$e^+e^- \to ZXX$$

$$e^+e^- \to Z^*Z^* \to e^+e^-XX$$



Summary and Plan

- Dark Matter search via Higgs portal is a unique channel on collider
- Concentrate on the standard model with DM particles

- Next
  - Constrains from astroparticle experiments
  - Opertunities and perspective for CEPC
  - Look for special feature with certain new sub-detector component, e.g. ultra-fast timing layer between tracker and calorimeter