Searching exotic decay channels of the SM Higgs boson at CEPC

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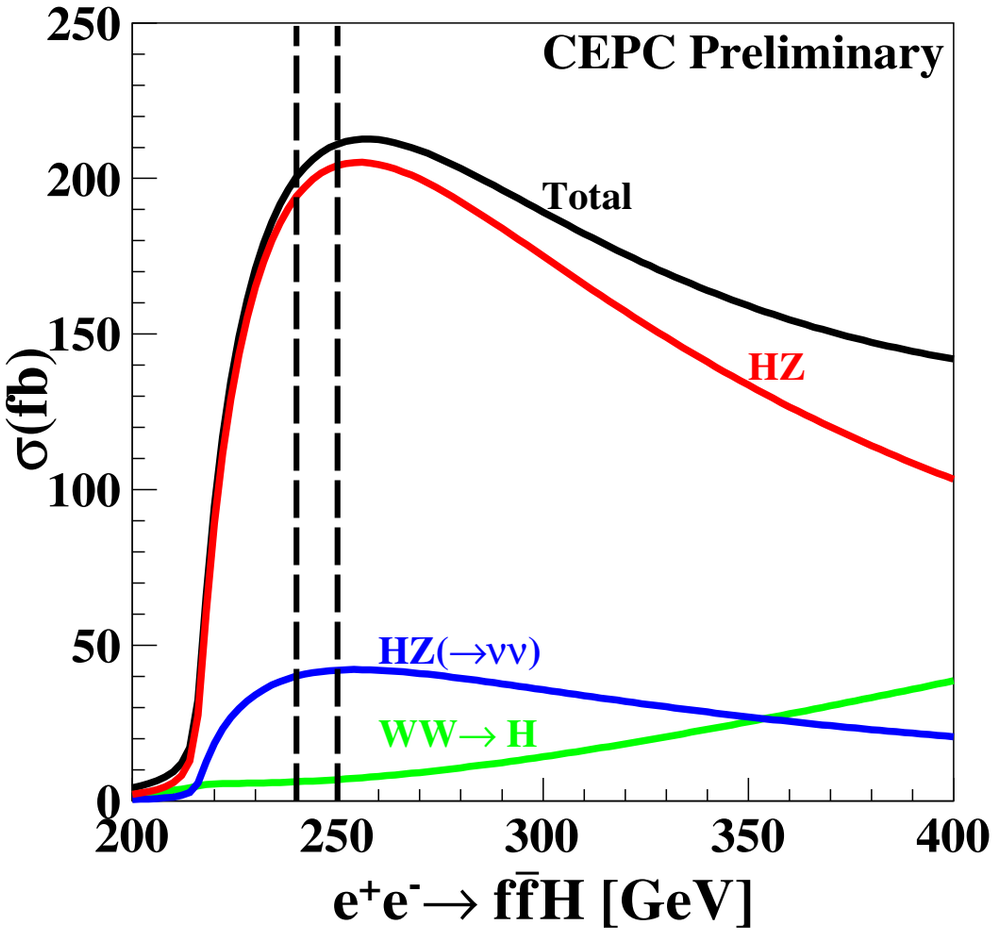
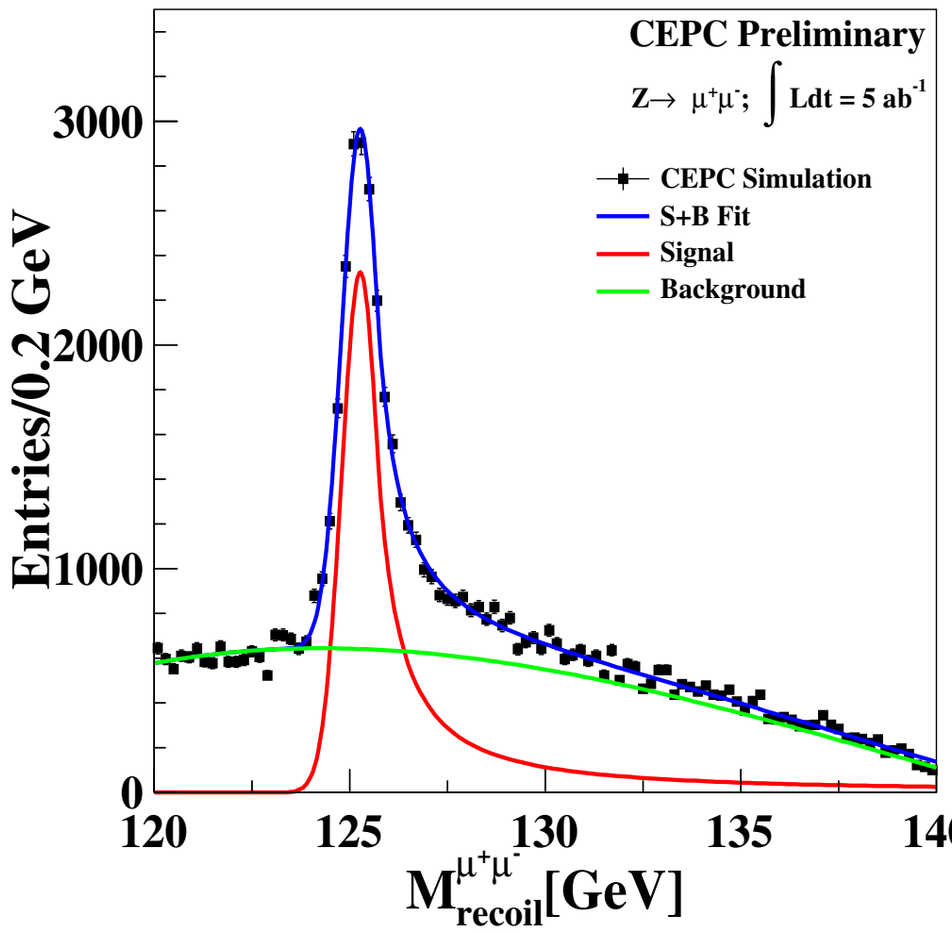
Base on the work in collaboration with Zhen Liu and Lian-Tao Wang.

CEPC: a Higgs factory

- More than 1,000,000 ZH signal events in the SM!



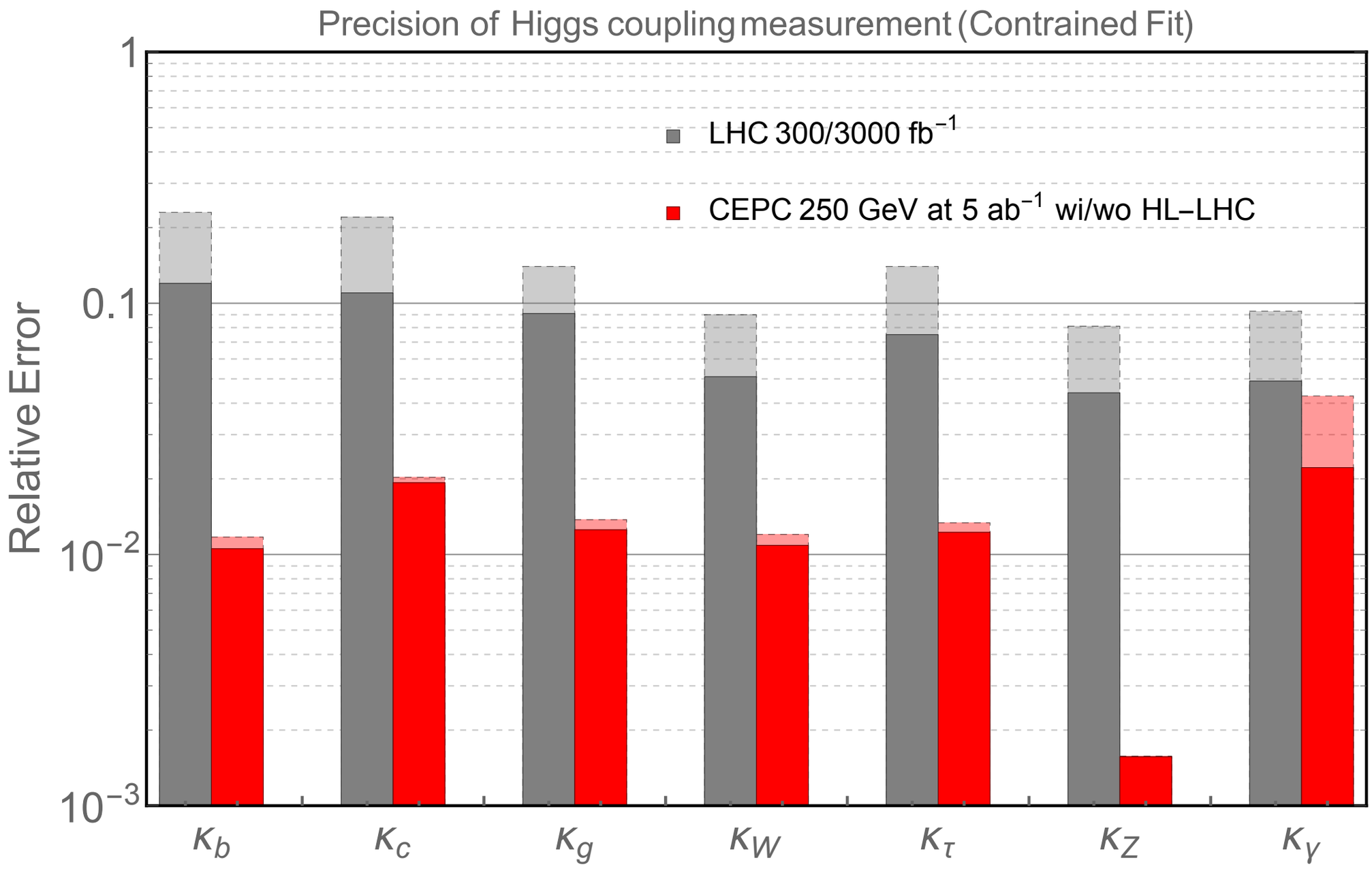


$$m^2_{\mathrm{recoil}} \equiv \left(\sqrt{s} - E_{f\bar{f}}\right)^2 - \overrightarrow{p}^2_{f\bar{f}} = s - 2E_{f\bar{f}}\sqrt{s} + m^2_{f\bar{f}}$$

CEPC-SPPC preCDR, Volume I-Physics & Detector, The CEPC-SPPC Study Group

CEPC: a Higgs factory

- The combination of different Z decay modes gives:



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CEPC: a Higgs factory

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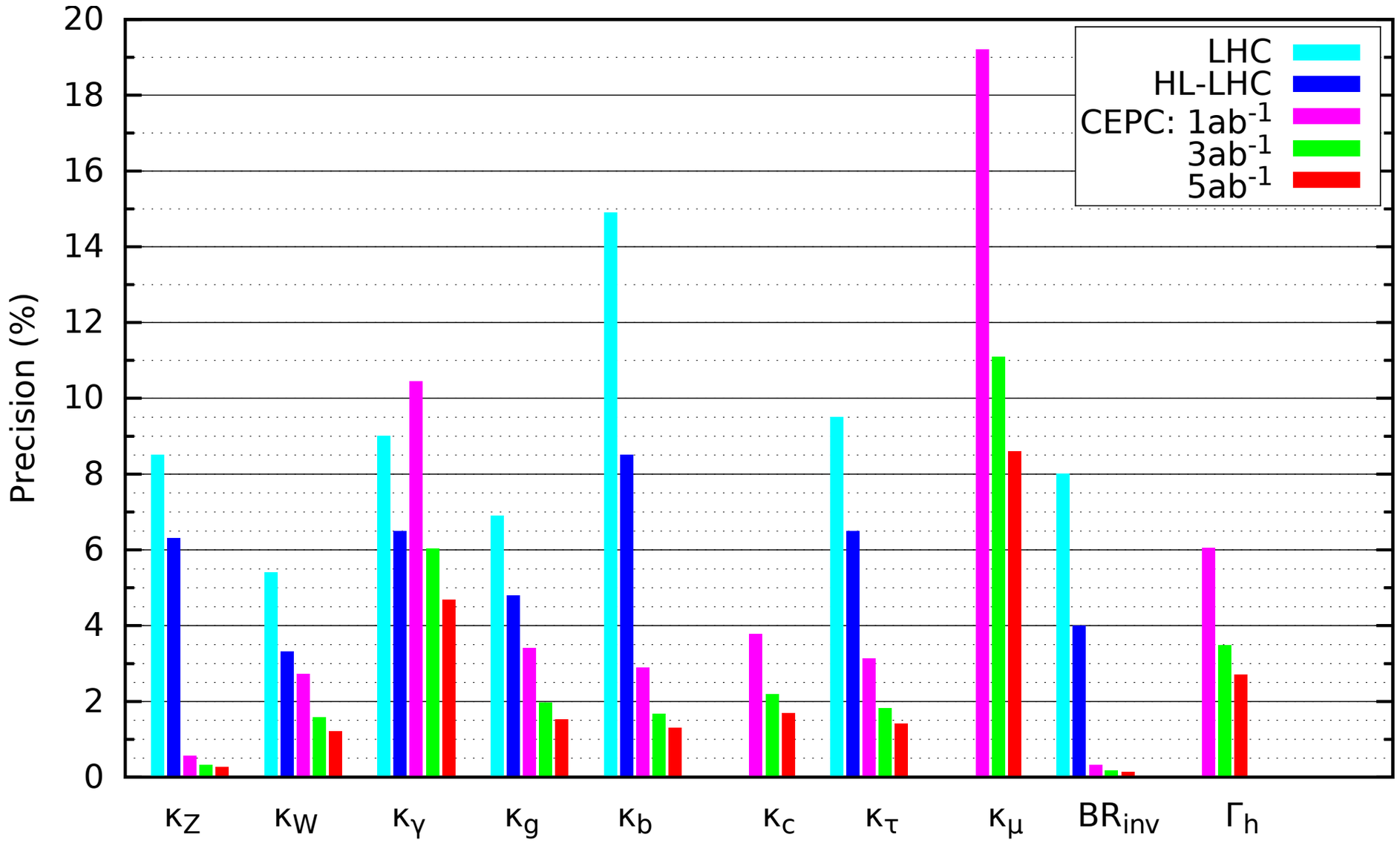

What can we do beyond the SM?

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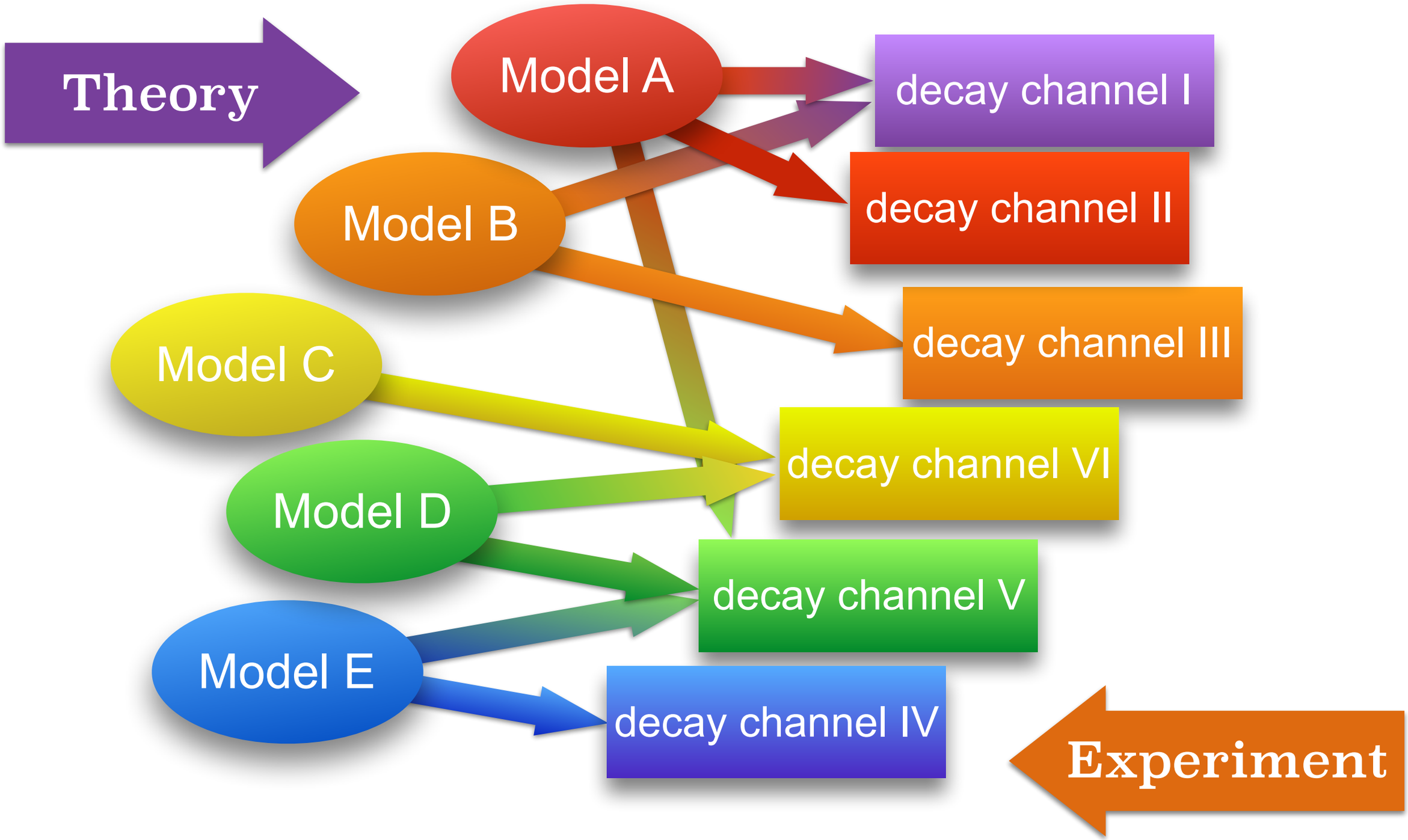
Exotic decay of the SM Higgs boson

- Light exotic particles weakly couple to the SM sector:
  - SUSY model: MSSM, NMSSM, …
  - Warped Extra Dimension model: light radion;
  - Hidden valley with Higgs boson as the mediator: “Higgs portal”;
  - Dark matter: dark force, …
  - Bayrogenesis: exotic light scalar;
  - Neutrino mass: *N*-loop radiative seasaw;
  - …

Exotic decay of the SM Higgs boson

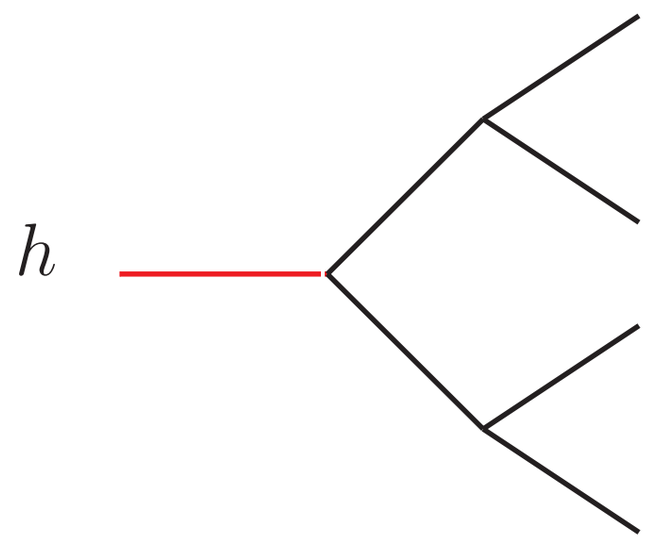


The dictionary links models and signals.

Exotic decay of the SM Higgs boson

- Phenomenology: investigate the detail of the signals.
- Topology ⇒ Insert fields ⇒ signals at CEPC.
- Example:

Topology



$$h \to 2 \to 4$$

Exotic decay of the SM Higgs boson

- Phenomenology: investigate the detail of the signals.
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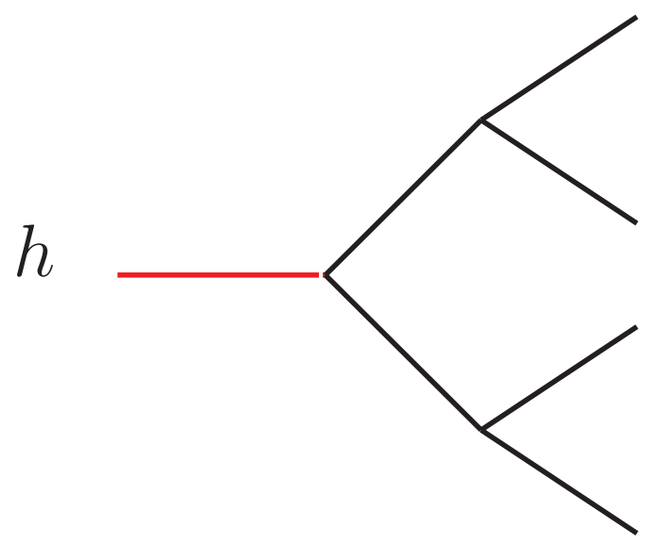

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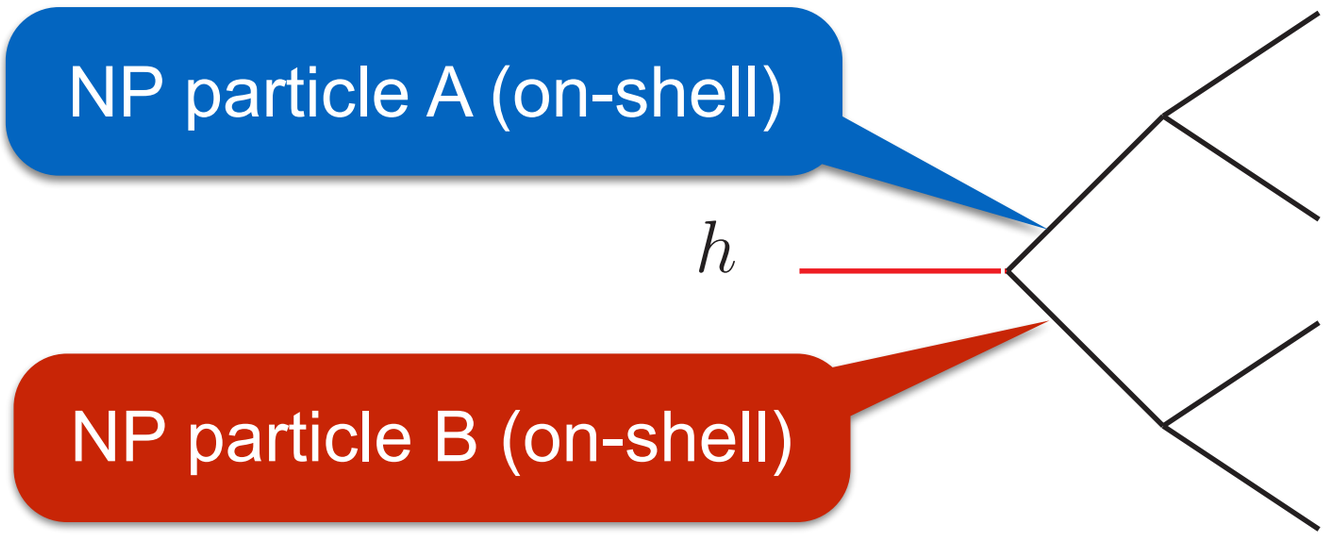

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Exotic decay of the SM Higgs boson

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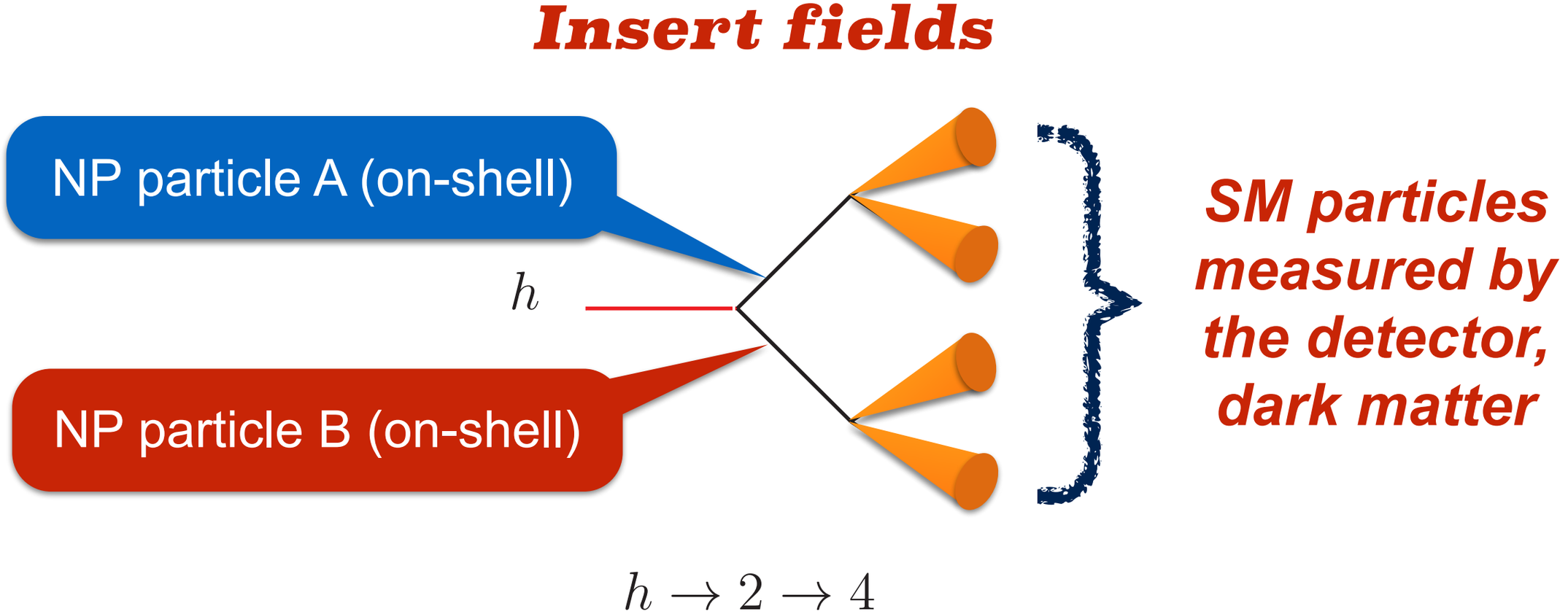
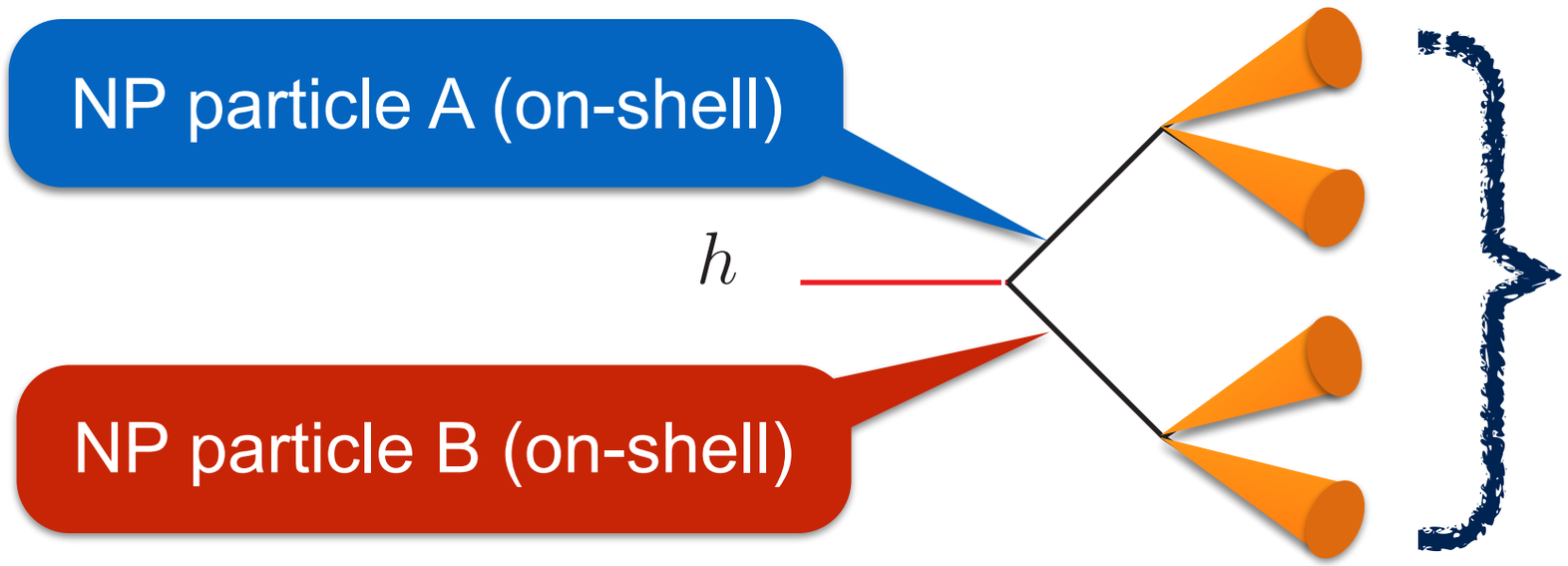


Exotic decay of the SM Higgs boson

- Some assumptions:
  - The first decay is two-body decay;
  - In the final state, there are only SM particles or missing energy.

Insert fields



SM particles measured by the detector, dark matter

$$h \to 2 \to 4$$

Exotic decay of the SM Higgs boson

- Some assumptions:
  - The first decay is two-body decay;
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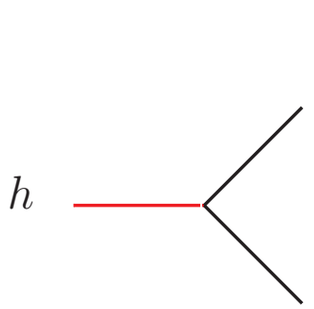
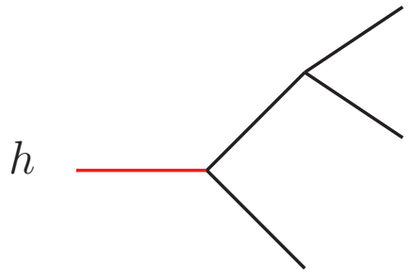
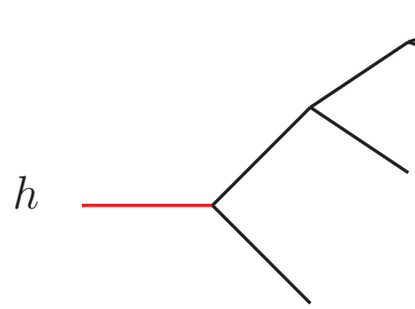


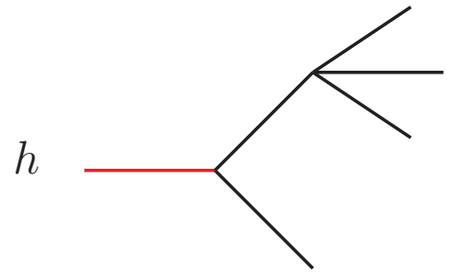
$h \to 2$



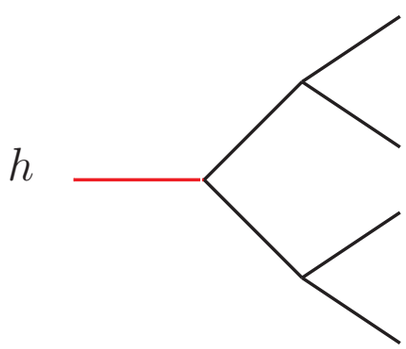
$h \to 2 \to 3$



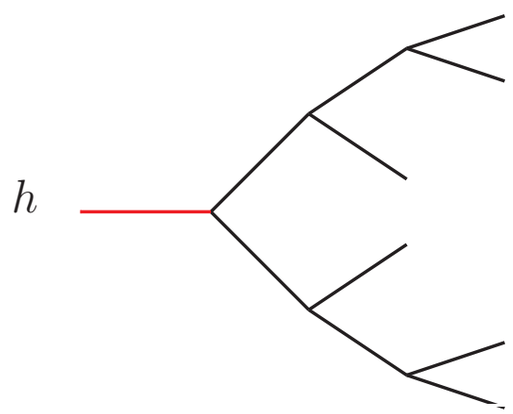
$h \to 2 \to 3 \to 4$



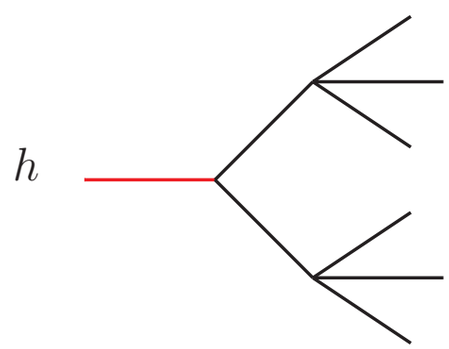
$h \to 2 \to (1+3)$



$h \to 2 \to 4$



$h \to 2 \to 4 \to 6$



$h \to 2 \to 6$

Exotic decay of the SM Higgs boson

- What can we do with HL-LHC?

PHYSICAL REVIEW D **90,** 075004 (2014)

Exotic decays of the 125 GeV Higgs boson

David Curtin,[1,a] Rouven Essig,[1,b] Stefania Gori,[2,3,4,c] Prerit Jaiswal,[5,d] Andrey Katz,[6,e] Tao Liu,[7,f] Zhen Liu,[8,g] David McKeen,[9,10,h] Jessie Shelton,[6,i] Matthew Strassler,[6,j] Ze'ev Surujon,[1,k] Brock Tweedie,[8,11,l] and Yi-Ming Zhong[1,m]

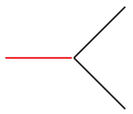
- For some channels the results are bad.

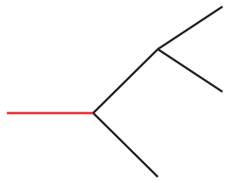
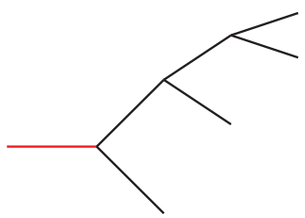
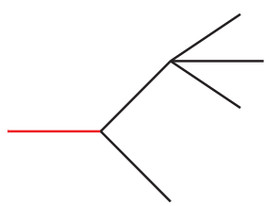
TABLE XIII. As in Table XII, estimates for various processes in $h \to aa$ if a decays only to SM gauge bosons through loops. The central columns show the case where the couplings are generated by initially degenerate $SU(5)$ multiplets; the right columns show the case where the $a \to \gamma\gamma$ rate is enhanced by a factor of 10. *An asterisk denotes that all 14 TeV estimates shown require* 300 fb^{-1} *of data.*

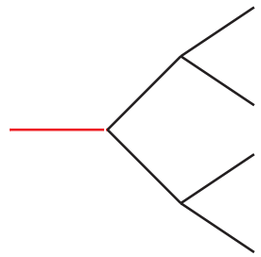
Decay mode $\mathcal{F}_i$	Projected/current 2σ limit on $\text{Br}(\mathcal{F}_i)$ $7+8$ [14] TeV	Production mode	$\text{Br}(a \to \gamma\gamma) \approx 0.004$		$\text{Br}(a \to \gamma\gamma) \approx 0.04$		Comments
			$\frac{\text{Br}(\mathcal{F}_i)}{\text{Br}(\text{non-SM})}$	Limit on $\frac{\sigma}{\sigma_{\text{SM}}} \cdot \text{Br}(\text{non-SM})$ $7+8$ [14] TeV	$\frac{\text{Br}(\mathcal{F}_i)}{\text{Br}(\text{non-SM})}$	Limit on $\frac{\sigma}{\sigma_{\text{SM}}} \cdot \text{Br}(\text{non-SM})$ $7+8$ [14] TeV	
$jjjj$	> 1 [0.1*]	W	0.99	> 1 [0.1*]	0.92	> 1 [0.1*]	Theory study [220,269], Sec. VII

Exotic decay of the SM Higgs boson

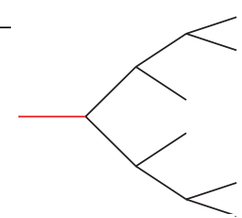
- There should be a list for CEPC.

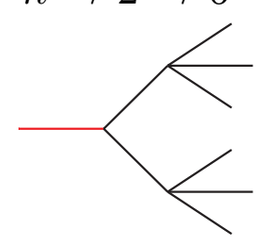


Decay Topologies	Decay mode $\mathcal{F}_i$
$h \to 2$	$h \to \not{E}_{\rm T}$
$h \to 2 \to 3$	$h \to \gamma + \not{E}_{\rm T}$
	$h \to (b\bar{b}) + \not{E}_{\rm T}$
	$h \to (jj) + \not{E}_{\rm T}$
	$h \to (\tau^+\tau^-) + \not{E}_{\rm T}$
	$h \to (\gamma\gamma) + \not{E}_{\rm T}$
	$h \to (\ell^+\ell^-) + \not{E}_{\rm T}$
$h \to 2 \to 3 \to 4$	$h \to (b\bar{b}) + \not{E}_{\rm T}$
	$h \to (jj) + \not{E}_{\rm T}$
	$h \to (\tau^+\tau^-) + \not{E}_{\rm T}$
	$h \to (\gamma\gamma) + \not{E}_{\rm T}$
	$h \to (\ell^+\ell^-) + \not{E}_{\rm T}$
	$h \to (\mu^+\mu^-) + \not{E}_{\rm T}$
$h \to 2 \to (1+3)$	$h \to b\bar{b} + \not{E}_{\rm T}$
	$h \to jj + \not{E}_{\rm T}$
	$h \to \tau^+\tau^- + \not{E}_{\rm T}$
	$h \to \gamma\gamma + \not{E}_{\rm T}$
	$h \to \ell^+\ell^- + \not{E}_{\rm T}$



Decay Topologies	Decay mode $\mathcal{F}_i$
$h \to 2 \to 4$	$h \to (b\bar{b})(b\bar{b})$
	$h \to (b\bar{b})(\tau^+\tau^-)$
	$h \to (b\bar{b})(\mu^+\mu^-)$
	$h \to (\tau^+\tau^-)(\tau^+\tau^-)$
	$h \to (\tau^+\tau^-)(\mu^+\mu^-)$
	$h \to (jj)(jj)$
	$h \to (jj)(\gamma\gamma)$
	$h \to (jj)(\mu^+\mu^-)$
	$h \to (\ell^+\ell^-)(\ell^+\ell^-)$
	$h \to (\ell^+\ell^-)(\mu^+\mu^-)$
	$h \to (\mu^+\mu^-)(\mu^+\mu^-)$
	$h \to (\gamma\gamma)(\gamma\gamma)$
	$h \to \gamma\gamma + \not{E}_{\rm T}$
$h \to 2 \to 4 \to 6$	$h \to (\ell^+\ell^-)(\ell^+\ell^-) + \not{E}_{\rm T}$
	$h \to (\ell^+\ell^-) + \not{E}_{\rm T} + X$
$h \to 2 \to 6$	$h \to \ell^+\ell^-\ell^+\ell^- + \not{E}_{\rm T}$
	$h \to \ell^+\ell^- + \not{E}_{\rm T} + X$





Exotic decay of the SM Higgs boson

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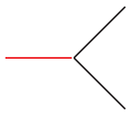

Decay Topologies	Decay mode $\mathcal{F}_i$
$h \to 2$	$h \to \not{E}_{\rm T}$
$h \to 2 \to 3$	$h \to \gamma + \not{E}_{\rm T}$
	$h \to (b\bar{b}) + \not{E}_{\rm T}$
	$h \to (jj) + \not{E}_{\rm T}$
	$h \to (\tau^+\tau^-) + \not{E}_{\rm T}$
	$h \to (\gamma\gamma) + \not{E}_{\rm T}$
	$h \to (\ell^+\ell^-) + \not{E}_{\rm T}$
$h \to 2 \to 3 \to 4$	$h \to (b\bar{b}) + \not{E}_{\rm T}$
	$h \to (jj) + \not{E}_{\rm T}$
	$h \to (\tau^+\tau^-) + \not{E}_{\rm T}$
	$h \to (\gamma\gamma) + \not{E}_{\rm T}$
	$h \to (\ell^+\ell^-) + \not{E}_{\rm T}$
	$h \to (\mu^+\mu^-) + \not{E}_{\rm T}$
$h \to 2 \to (1+3)$	$h \to b\bar{b} + \not{E}_{\rm T}$
	$h \to jj + \not{E}_{\rm T}$
	$h \to \tau^+\tau^- + \not{E}_{\rm T}$
	$h \to \gamma\gamma + \not{E}_{\rm T}$
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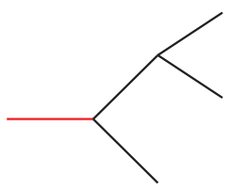
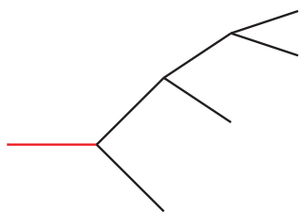
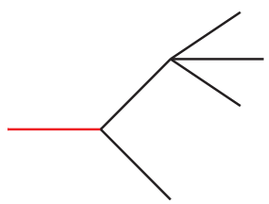
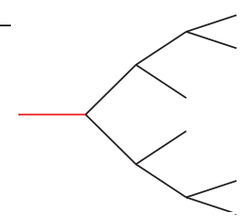
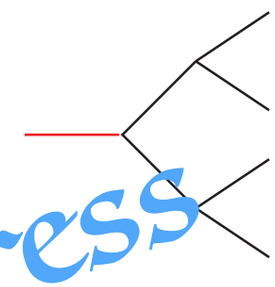


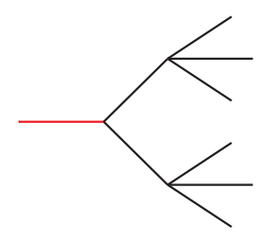




Decay Topologies	Decay mode $\mathcal{F}_i$
$h \to 2 \to 4$	$h \to (b\bar{b})(b\bar{b})$
	$h \to (b\bar{b})(\tau^+\tau^-)$
	$h \to (b\bar{b})(\mu^+\mu^-)$
	$h \to (\tau^+\tau^-)(\tau^+\tau^-)$
	$h \to (\tau^+\tau^-)(\mu^+\mu^-)$
	$h \to (jj)(jj)$
	$h \to (jj)(\gamma\gamma)$
	$h \to (jj)(\mu^+\mu^-)$
	$h \to (\ell^+\ell^-)(\ell^+\ell^-)$
	$h \to (\ell^+\ell^-)(\mu^+\mu^-)$
	$h \to (\mu^+\mu^-)(\mu^+\mu^-)$
	$h \to (\gamma\gamma)(\gamma\gamma)$
	$h \to \gamma\gamma + \not{E}_{\rm T}$
$h \to 2 \to 4 \to 6$	$h \to (\ell^+\ell^-)(\ell^+\ell^-) + \not{E}_{\rm T}$
	$h \to (\ell^+\ell^-) + \not{E}_{\rm T} + X$
$h \to 2 \to 6$	$h \to \ell^+\ell^-\ell^+\ell^- + \not{E}_{\rm T}$
	$h \to \ell^+\ell^- + \not{E}_{\rm T} + X$







Exotic decay of the SM Higgs boson

- An example:
  - $h \to 2 \to 4$
  - Insert light (pseudo)scalar (a, s) or vector boson (Z').
  - $h \to ss(aa) \to (jj)(jj)$, $h \to Z'Z' \to (jj)(jj)$.
  - Effective Lagrangian:

$$\begin{aligned}\mathcal{L}_{\text{eff}} =& \sqrt{2}\varepsilon_s v h s s + \sqrt{2}\varepsilon_a v h a a + \varepsilon_1 g_1' v h Z'_{1\mu} Z_1'^{\mu} + \varepsilon_2 g_2' v h Z'_{2\mu} Z_2'^{\mu} \\ &+ y_s s \bar{f} f + i y_a a \bar{f} \gamma_5 f + \frac{\alpha_s c_s}{\Lambda_s} s G_{\mu\nu} G^{\mu\nu} + \frac{\alpha_s c_a}{\Lambda_a} a G_{\mu\nu} \tilde{G}^{\mu\nu} \\ &+ g_1' Z'_{1\mu} \bar{f} \gamma^{\mu} f + g_2' Z'_{2\mu} \bar{f} \gamma^{\mu} P_R f\end{aligned}$$

Spin correlations are kept for model distinguishing.

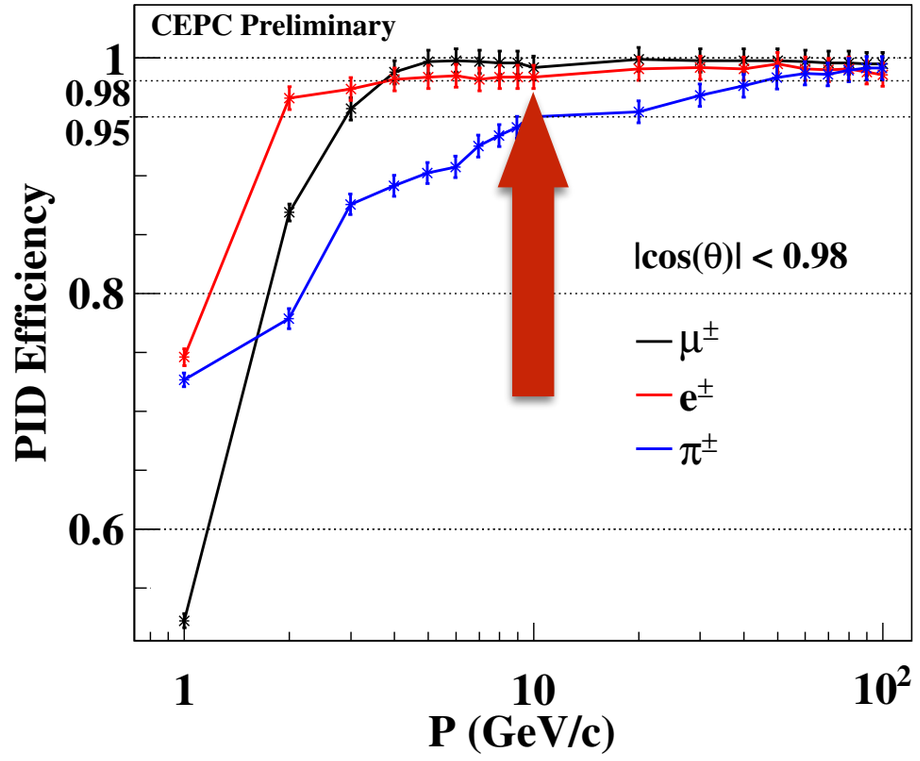
Exotic decay of the SM Higgs boson

- An example:
  - Parton level simulation.
  - Detector effects (energy resolution, PID efficiency):

$$\frac{\delta E_j}{E_j} = \frac{0.3}{\sqrt{E_j/\mathrm{GeV}}} \oplus 0.02$$

$$\frac{\delta E_\gamma}{E_\gamma} = \frac{0.16}{\sqrt{E_\gamma/\mathrm{GeV}}} \oplus 0.01$$

$$\Delta\left(\frac{1}{p_{\mathrm{T},\ell}}\right) = 2\times10^{-5} \oplus \frac{10^{-3}}{p_{\mathrm{T},\ell}\sin\theta_\ell}$$



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Exotic decay of the SM Higgs boson

- An example:
  - Parton level simulation.
  - Main SM backgrounds: $e^+e^- \rightarrow Zjjjj + X$.
  - Systematic error of the simulation due to the ISR effect. (We thank M.-Q Ruan for helpful discussion.)
  - A parton level simulation which could give a reasonable estimation of the significance with clearly error estimation is acceptable in current study.

Exotic decay of the SM Higgs boson

- An example:

  - Preselection cuts: $|\cos\theta_{j,\ell}| < 0.98, E_{j,\ell} > 10\mathrm{GeV},$

$$y_{ij} \equiv \frac{2\min\left(E_i^2, E_j^2\right)(1-\cos\theta_{ij})}{E_{vis}^2} > y_{\mathrm{cut}},$$

$$\text{a pair of OSSF leptons, } \theta_{\ell\ell} > 80^\circ$$

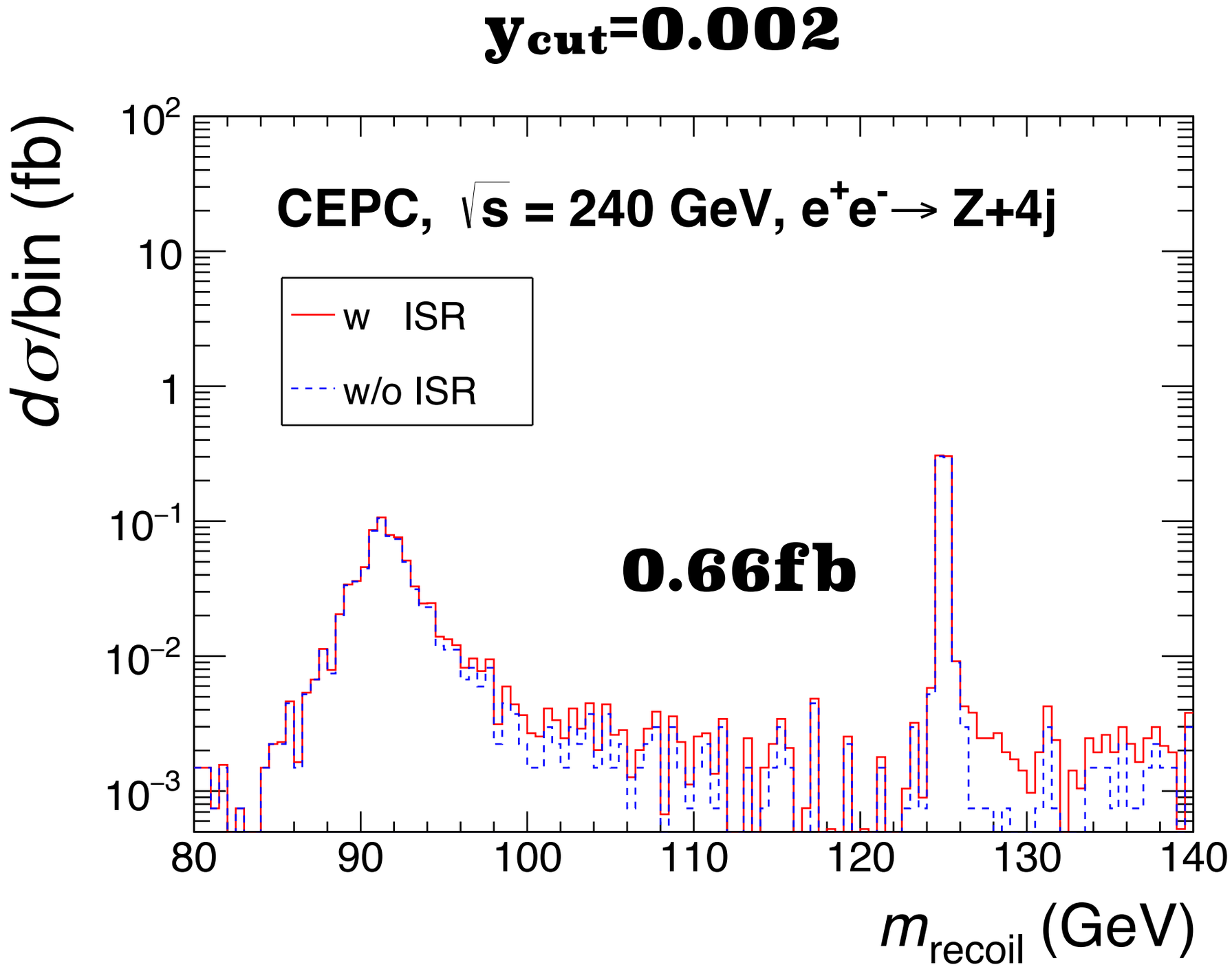
$$|m_{\ell\ell} - m_Z| < 10\mathrm{GeV}, |m_{\mathrm{recoil}} - m_h| < 5\mathrm{GeV}.$$

  - MadGraph5_aMC@NLO.

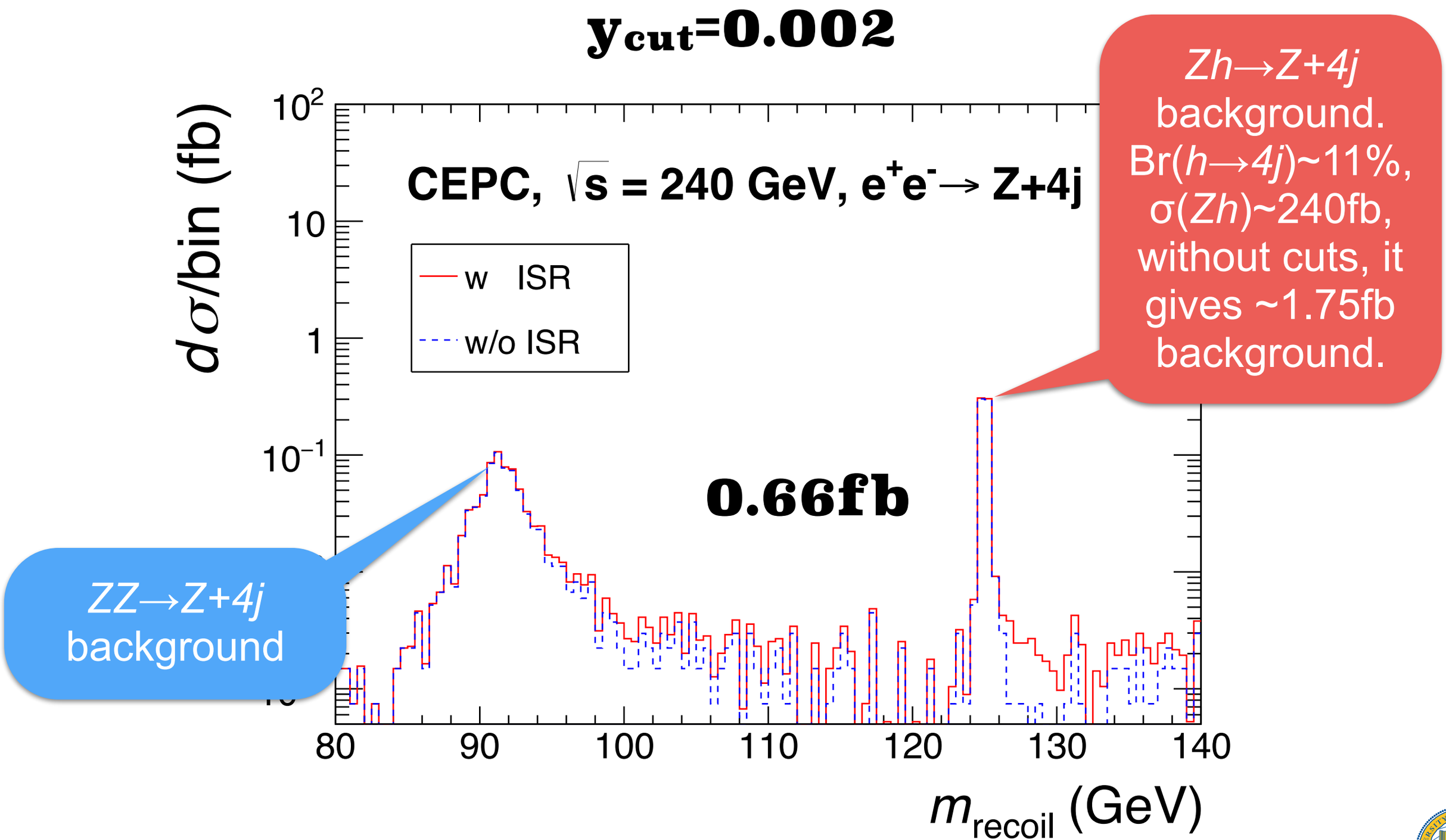
  - The ISR effect of the background is roughly mimicked by generating events with 1 additional photon (with pT>1GeV to avoid the IR divergence). (No ISR for signal events!)

  - Additional cut to suppress the ISR effect: $E_{vis} > 225\mathrm{GeV}.$

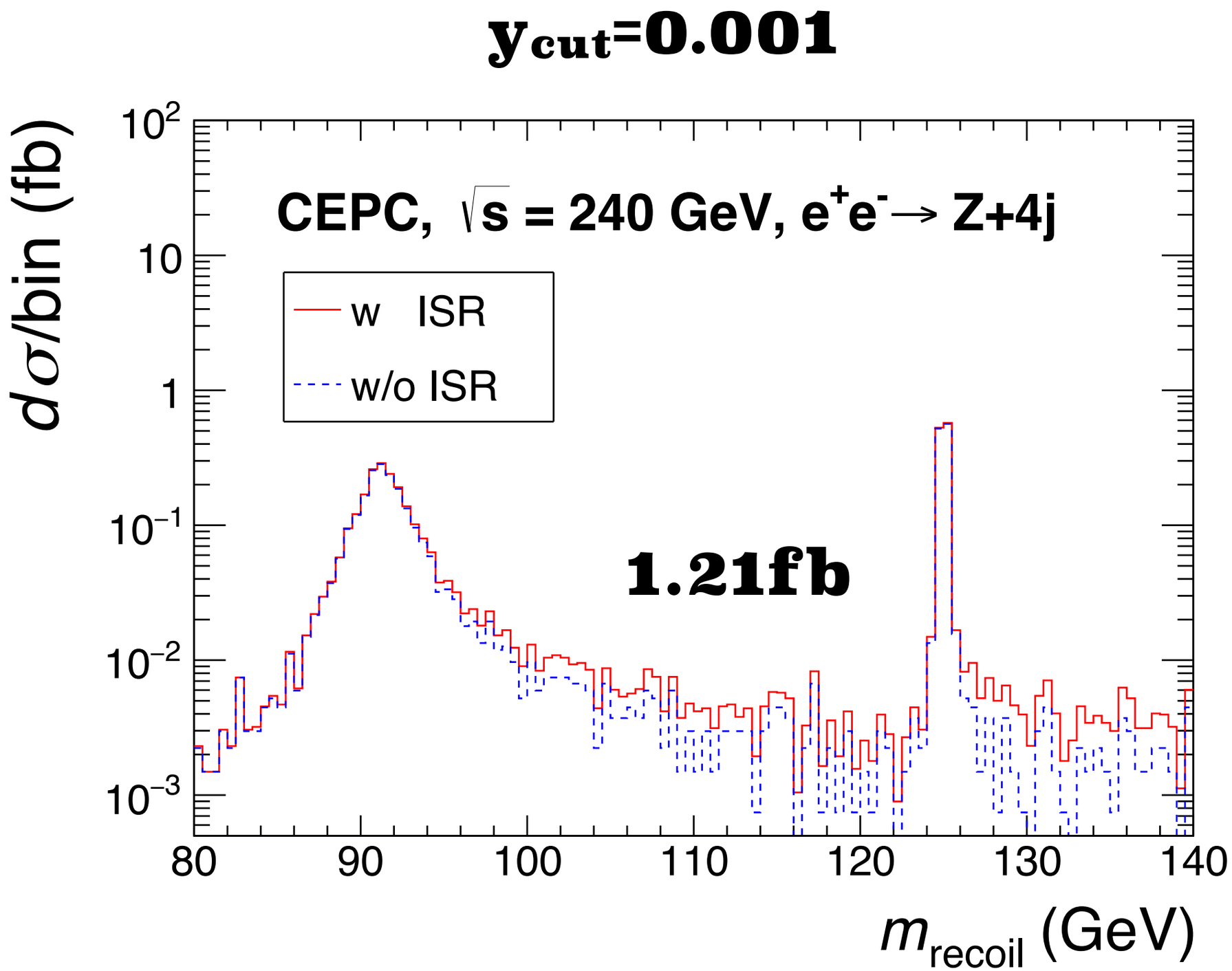
Exotic decay of the SM Higgs boson



Exotic decay of the SM Higgs boson

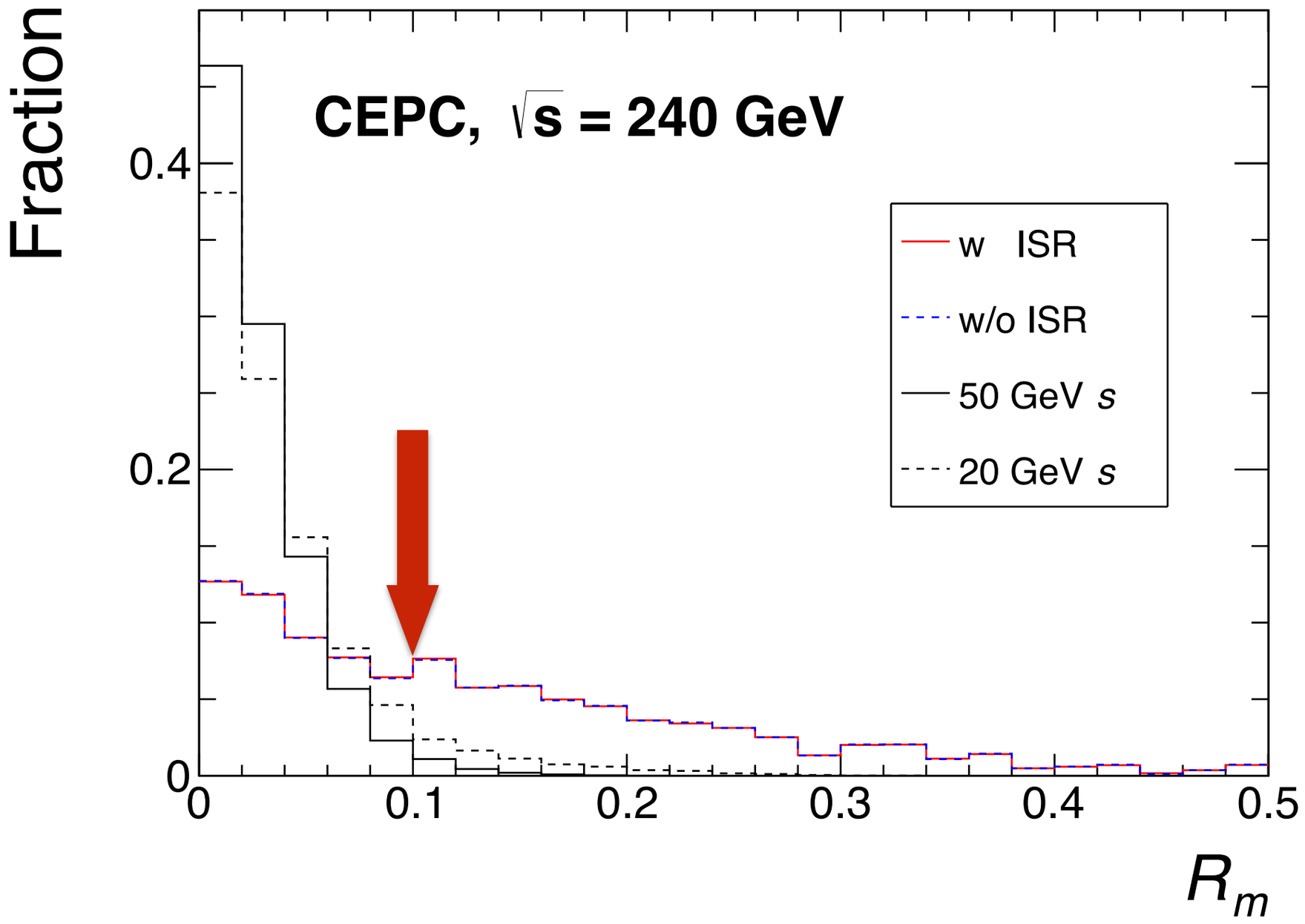


Exotic decay of the SM Higgs boson



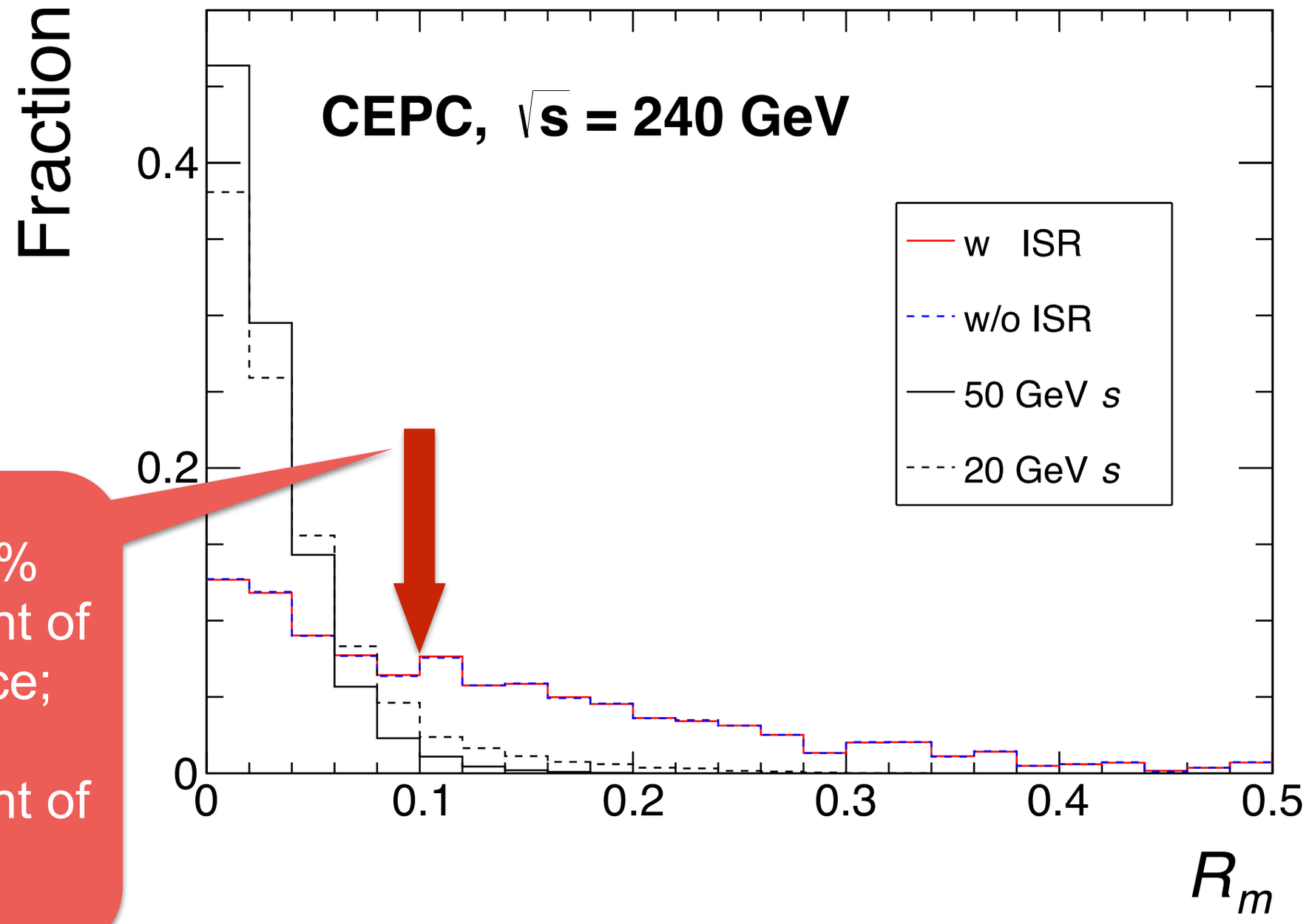
Exotic decay of the SM Higgs boson

- Additional cut: $R_m \equiv \min_{\sigma \in S_4} \left(\frac{\left| m_{j_{\sigma(1)} j_{\sigma(2)}} - m_{j_{\sigma(3)} j_{\sigma(4)}} \right|}{m_{j_{\sigma(1)} j_{\sigma(2)}} + m_{j_{\sigma(3)} j_{\sigma(4)}}} \right)$.



Exotic decay of the SM Higgs boson

- Additional cut: $R_m \equiv \min_{\sigma \in S_4} \left(\frac{\left| m_{j_{\sigma(1)} j_{\sigma(2)}} - m_{j_{\sigma(3)} j_{\sigma(4)}} \right|}{m_{j_{\sigma(1)} j_{\sigma(2)}} + m_{j_{\sigma(3)} j_{\sigma(4)}}} \right)$.

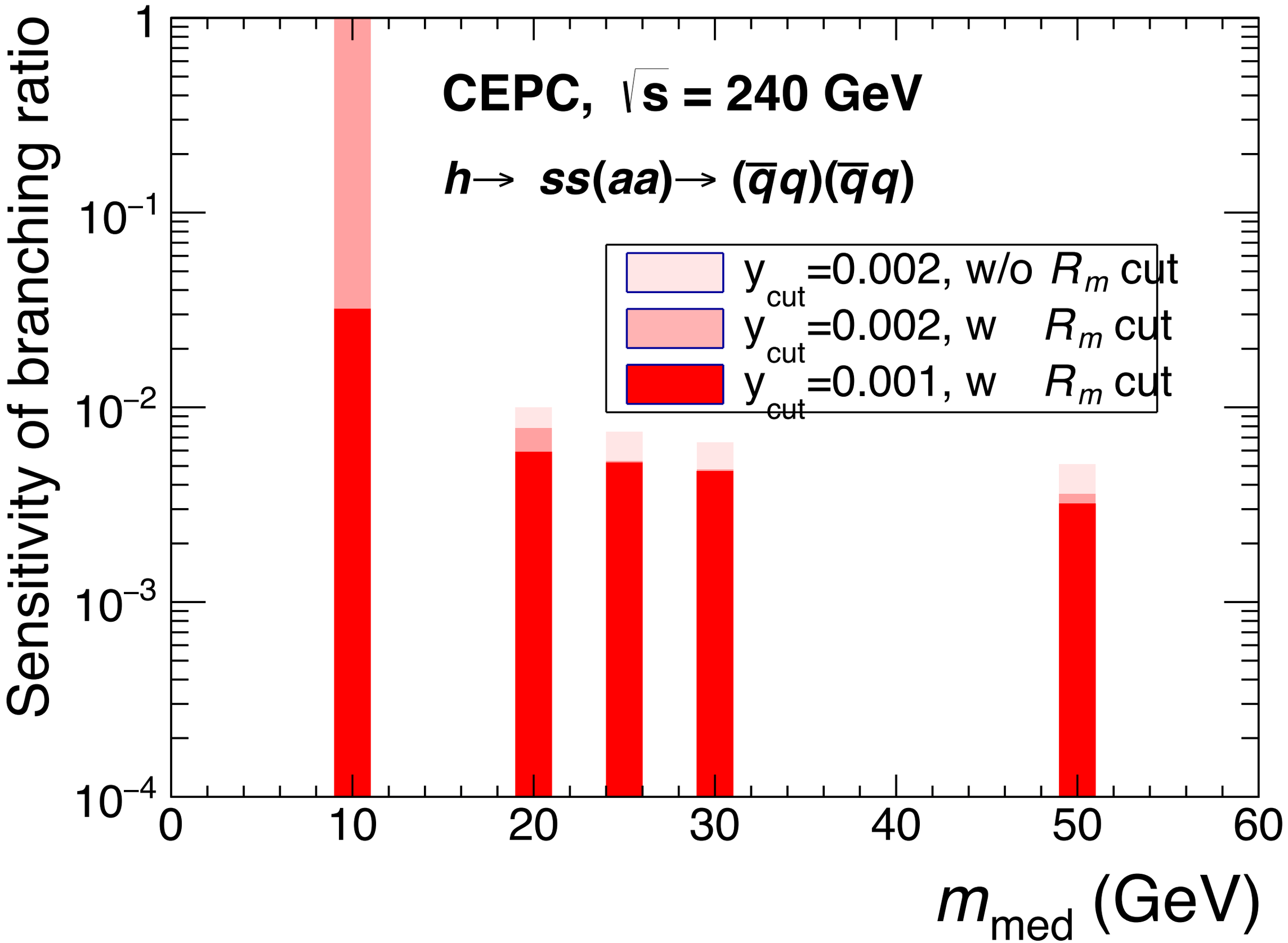


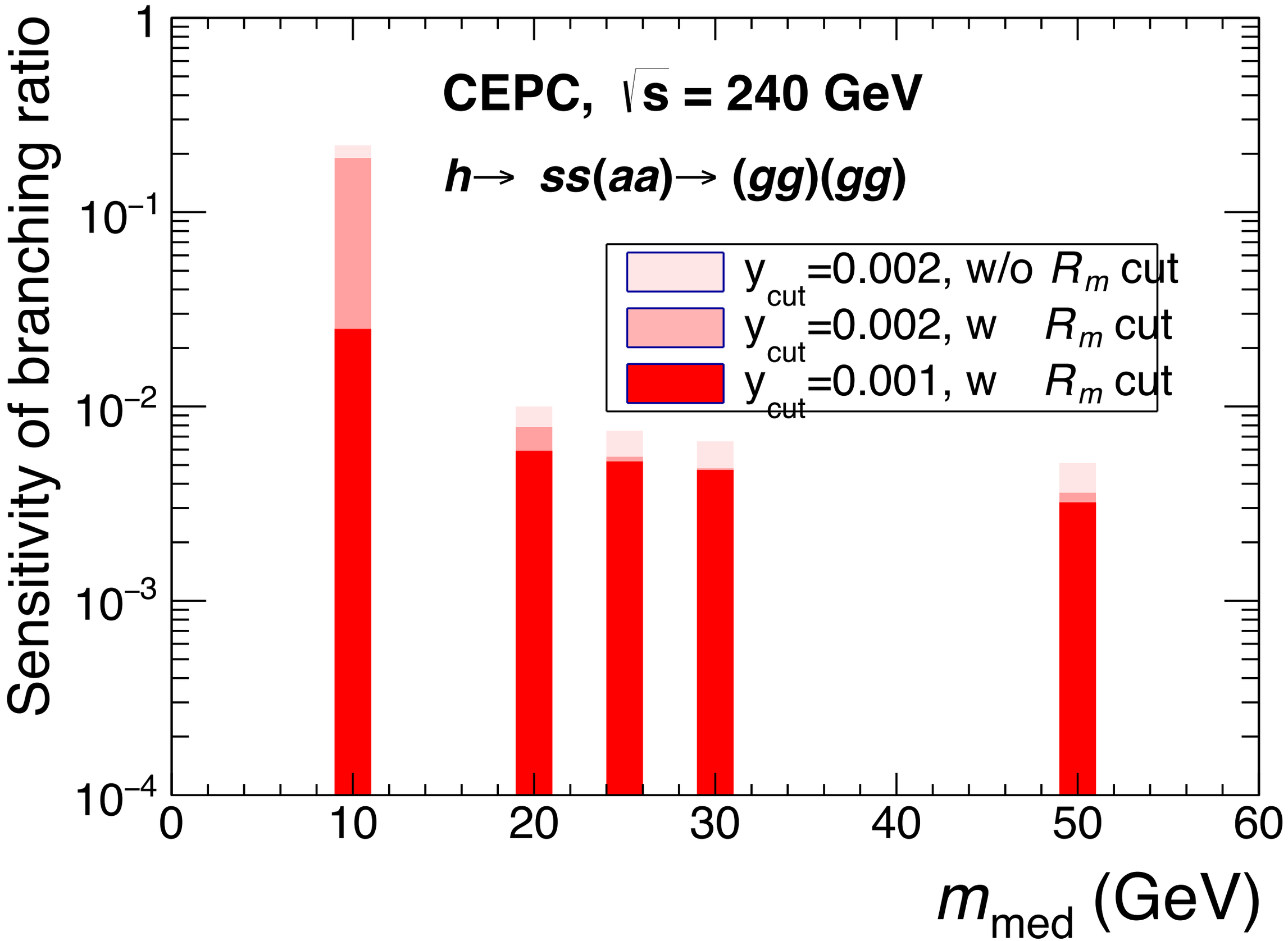
~20%-30% improvement of significance; ~100% improvement of S/B.

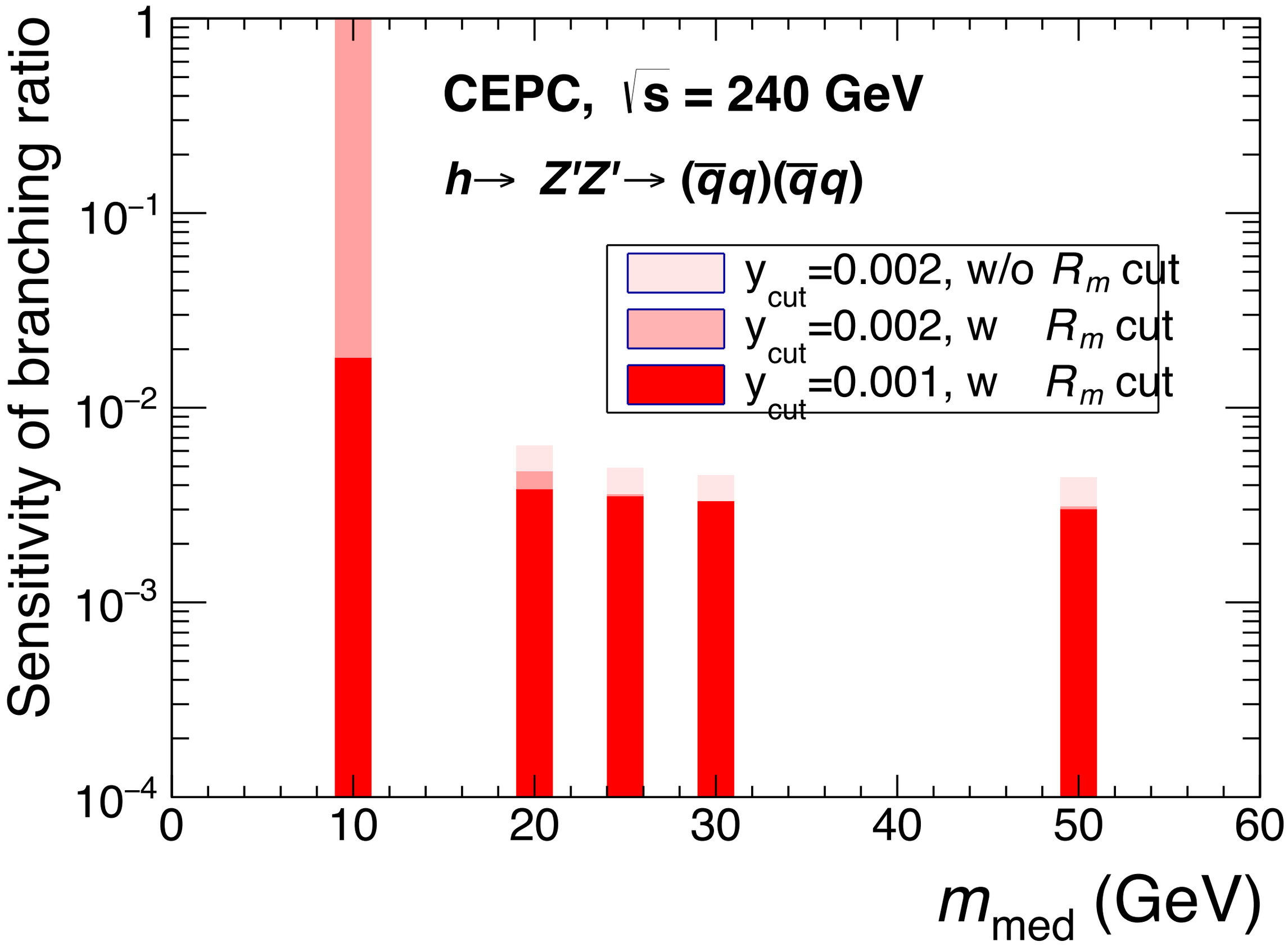
Exotic decay of the SM Higgs boson

- 3σ sensitivity at 5ab^{-1} CEPC.

	$m_{\rm med}$ (GeV)	10	20	25	30	50
$s\bar{f}f, a\bar{f}\gamma_5 f$	$y_{\rm cut} = 0.002$	>100%	0.78%	0.53%	0.48%	0.36%
	$y_{\rm cut} = 0.001$	3.2%	0.59%	0.52%	0.47%	0.32%
$sG_{\mu\nu}G^{\mu\nu}, aG_{\mu\nu}\tilde{G}^{\mu\nu}$	$y_{\rm cut} = 0.002$	19%	0.78%	0.55%	0.48%	0.36%
	$y_{\rm cut} = 0.001$	2.5%	0.59%	0.52%	0.47%	0.32%
$V_\mu\bar{f}\gamma^\mu f, V_\mu\bar{f}\gamma^\mu P_R f$	$y_{\rm cut} = 0.002$	>100%	0.47%	0.36%	0.32%	0.31%
	$y_{\rm cut} = 0.001$	1.8%	0.38%	0.35%	0.33%	0.30%


CEPC, $\sqrt{s}$ = 240 GeV
$h \to ss(aa) \to (\bar{q}q)(\bar{q}q)$
y_{cut}=0.002, w/o R_m cut
y_{cut}=0.002, w R_m cut
y_{cut}=0.001, w R_m cut
Sensitivity of branching ratio
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0
10
20
30
40
50
60
m_{med} (GeV)


CEPC, √s = 240 GeV
h→ ss(aa)→ (gg)(gg)
y_cut=0.002, w/o R_m cut
y_cut=0.002, w R_m cut
y_cut=0.001, w R_m cut
Sensitivity of branching ratio
1
10^−1
10^−2
10^−3
10^−4
0
10
20
30
40
50
60
m_med (GeV)


CEPC, √s = 240 GeV
h→ Z′Z′→ (q̄q)(q̄q)
y_cut=0.002, w/o R_m cut
y_cut=0.002, w R_m cut
y_cut=0.001, w R_m cut
Sensitivity of branching ratio
1
10^−1
10^−2
10^−3
10^−4
0
10
20
30
40
50
60
m_med (GeV)

Exotic decay of the SM Higgs boson

- 3σ sensitivity at 5ab^{-1} CEPC.

	$m_{\rm med}$ (GeV)	10	20	25	30	50
$s\bar{f}f, a\bar{f}\gamma_5 f$	$y_{\rm cut} = 0.002$	>100%	0.78%	0.53%	0.48%	0.36%
	$y_{\rm cut} = 0.001$	3.2%	0.59%	0.52%	0.47%	0.32%
$sG_{\mu\nu}G^{\mu\nu}, aG_{\mu\nu}\tilde{G}^{\mu\nu}$	$y_{\rm cut} = 0.002$	19%	0.78%	0.55%	0.48%	0.36%
	$y_{\rm cut} = 0.001$	2.5%	0.59%	0.52%	0.47%	0.32%
$V_\mu\bar{f}\gamma^\mu f, V_\mu\bar{f}\gamma^\mu P_R f$	$y_{\rm cut} = 0.002$	>100%	0.47%	0.36%	0.32%	0.31%
	$y_{\rm cut} = 0.001$	1.8%	0.38%	0.35%	0.33%	0.30%

- HL-LHC? Four jets, very difficult!

TABLE XIII. As in Table XII, estimates for various processes in $h \to aa$ if a decays only to SM gauge bosons through loops. The central columns show the case where the couplings are generated by initially degenerate $SU(5)$ multiplets; the right columns show the case where the $a \to \gamma\gamma$ rate is enhanced by a factor of 10. *An asterisk denotes that all 14 TeV estimates shown require* 300 fb^{-1} *of data*.

Decay mode $\mathcal{F}_i$	Projected/current 2σ limit on Br($\mathcal{F}_i$) $7+8$ [14] TeV	Production mode	Br($a \to \gamma\gamma$) ≈ 0.004		Br($a \to \gamma\gamma$) ≈ 0.04		Comments
			$\frac{\text{Br}(\mathcal{F}_i)}{\text{Br(non-SM)}}$	Limit on $\frac{\sigma}{\sigma_{\rm SM}} \cdot$ Br(non-SM) $7+8$ [14] TeV	$\frac{\text{Br}(\mathcal{F}_i)}{\text{Br(non-SM)}}$	Limit on $\frac{\sigma}{\sigma_{\rm SM}} \cdot$ Br(non-SM) $7+8$ [14] TeV	
$jjjj$	> 1 [0.1*]	W	0.99	> 1 [0.1*]	0.92	> 1 [0.1*]	Theory study [220,269], Sec. VII

Exotic decay of the SM Higgs boson

- 3σ sensitivity at 5ab^{-1} CEPC.

	$m_{\rm med}$ (GeV)	10	20	25	30	50
$s\bar{f}f, a\bar{f}\gamma_5 f$	$y_{\rm cut} = 0.002$	>100%	0.78%	0.53%	0.48%	0.36%
	$y_{\rm cut} = 0.001$	3.2%	0.59%	0.52%	0.47%	0.32%
$sG_{\mu\nu}G^{\mu\nu}, aG_{\mu\nu}\tilde{G}^{\mu\nu}$	$y_{\rm cut} = 0.002$	19%	0.78%	0.55%	0.48%	0.36%
	$y_{\rm cut} = 0.001$	2.5%	0.59%	0.52%	0.47%	0.32%
$V_\mu\bar{f}\gamma^\mu f, V_\mu\bar{f}\gamma^\mu P_R f$	$y_{\rm cut} = 0.002$	>100%	0.47%	0.36%	0.32%	0.31%
	$y_{\rm cut} = 0.001$	1.8%	0.38%	0.35%	0.33%	0.30%

- HL-LHC? Four jets, very difficult!

TABLE XIV. As in Table XII, estimates for various processes in $h \to Z_D Z_D$ if $m_{Z_D} > 2m_b$ and couplings are proportional to electric charges. $\ell = e, \mu$ and all numbers represent the *sum* of processes involving e and μ; j represents all jets except b quarks. An asterisk indicates that 300 fb^{-1} was assumed; otherwise all estimates for 14 TeV assume 100 fb^{-1}.

Decay mode $\mathcal{F}_i$	Projected/current 2σ limit on Br($\mathcal{F}_i$) $7+8$ [14] TeV	Production mode	$\frac{\text{Br}(\mathcal{F}_i)}{\text{Br(non-SM)}}$	Limit on $\frac{\sigma}{\sigma_{\rm SM}} \cdot$ Br(non-SM) $7+8$ [14] TeV	Comments
$jjjj$	> 1 [0.1*]	W	0.25	> 1 [0.4*]	Theory study [220,269], Sec. VII

Exotic decay of the SM Higgs boson

- 3σ sensitivity at 5ab^{-1} CEPC.

	$m_{\rm med}$ (GeV)	10	20	25	30	50
$s\bar{f}f, a\bar{f}\gamma_5 f$	$y_{\rm cut} = 0.002$	>100%	0.78%	0.53%	0.48%	0.36%
	$y_{\rm cut} = 0.001$	3.2%	0.59%	0.52%	0.47%	0.32%
$sG_{\mu\nu}G^{\mu\nu}, aG_{\mu\nu}\tilde{G}^{\mu\nu}$	$y_{\rm cut} = 0.002$	19%	0.78%	0.55%	0.48%	0.36%
	$y_{\rm cut} = 0.001$	2.5%	0.59%	0.52%	0.47%	0.32%
$V_\mu\bar{f}\gamma^\mu f, V_\mu\bar{f}\gamma^\mu P_R f$	$y_{\rm cut} = 0.002$	>100%	0.47%	0.36%	0.32%	0.31%
	$y_{\rm cut} = 0.001$	1.8%	0.38%	0.35%	0.33%	0.30%

- HL-LHC? Four jets, very difficult!

TABLE XIV. As in Table XII, estimates for various processes in $h \to Z_D Z_D$ if $m_{Z_D} > 2m_b$ and couplings are proportional to electric charges. $\ell = e, \mu$ and all numbers represent the *sum* of processes involving e and μ; j represents all jets except b quarks. An asterisk indicates that 300 fb^{-1} was assumed; otherwise all estimates for 14 TeV assume 100 fb^{-1}.

Decay mode $\mathcal{F}_i$	Projected/current 2σ limit on Br($\mathcal{F}_i$) $7+8$ [14] TeV	Production mode	$\frac{\mathrm{Br}(\mathcal{F}_i)}{\mathrm{Br}(\text{non-SM})}$	$\frac{\sigma}{\sigma_{\rm SM}}$	Limit on Br(non-SM) $7+8$ [14] TeV	Comments
$jjjj$	>1 [0.1*]	W	0.25		> 1 [0.4*]	Theory study [220,269], Sec. VII

10% at HL-LHC? Only for very light mediator (jet-substructure)!

Exotic decay of the SM Higgs boson

- 3σ sensitivity of $h \to ss(aa) \to (bb)(bb)$, $h \to Z'Z' \to (bb)(bb)$.

	mass of the mediator (GeV)	20	25	30	50
$s\bar{f}f, a\bar{f}\gamma_5 f$	$y_{\rm cut} = 0.002, \epsilon_b = 70\%$	0.23%	0.13%	0.11%	0.089%
	$y_{\rm cut} = 0.002, \epsilon_b = 80\%$	0.13%	0.072%	0.061%	0.049%
	$y_{\rm cut} = 0.001, \epsilon_b = 70\%$	0.097%	0.080%	0.077%	0.057%
	$y_{\rm cut} = 0.001, \epsilon_b = 80\%$	0.079%	0.069%	0.064%	0.048%
$V_\mu \bar{f}\gamma^\mu f, V_\mu \bar{f}\gamma^\mu P_R f$	$y_{\rm cut} = 0.002, \epsilon_b = 70\%$	0.15%	0.097%	0.082%	0.079%
	$y_{\rm cut} = 0.002, \epsilon_b = 80\%$	0.084%	0.052%	0.046%	0.043%
	$y_{\rm cut} = 0.001, \epsilon_b = 70\%$	0.072%	0.062%	0.060%	0.054%
	$y_{\rm cut} = 0.001, \epsilon_b = 80\%$	0.061%	0.053%	0.051%	0.045%

- HL-LHC? Four *b*-jets, also difficult!

Decay mode $\mathcal{F}_i$	Projected/ current 2σ limit on $\mathrm{Br}(\mathcal{F}_i)$ $7+8$ [14] TeV	Production mode	Quarks allowed		Qua
			$\frac{\mathrm{Br}(\mathcal{F}_i)}{\mathrm{Br}(\text{non-SM})}$	Limit on $\frac{\sigma}{\sigma_{\rm SM}} \cdot \mathrm{Br}(\text{non-SM})$ $7+8$ [14] TeV	$\frac{\mathrm{Br}(\mathcal{F}_i)}{\mathrm{Br}(\text{non-SM})}$
$b\bar{b}b\bar{b}$	0.7 [0.2]	W	0.8	0.9 [0.2]	0

CEPC, $\sqrt{s}$ = 240 GeV

$h \to ss(aa) \to (\bar{b}b)(\bar{b}b)$

y_{cut}=0.002, ε_b=70%

y_{cut}=0.001, ε_b=70%

y_{cut}=0.001, ε_b=80%

Sensitivity of branching ratio

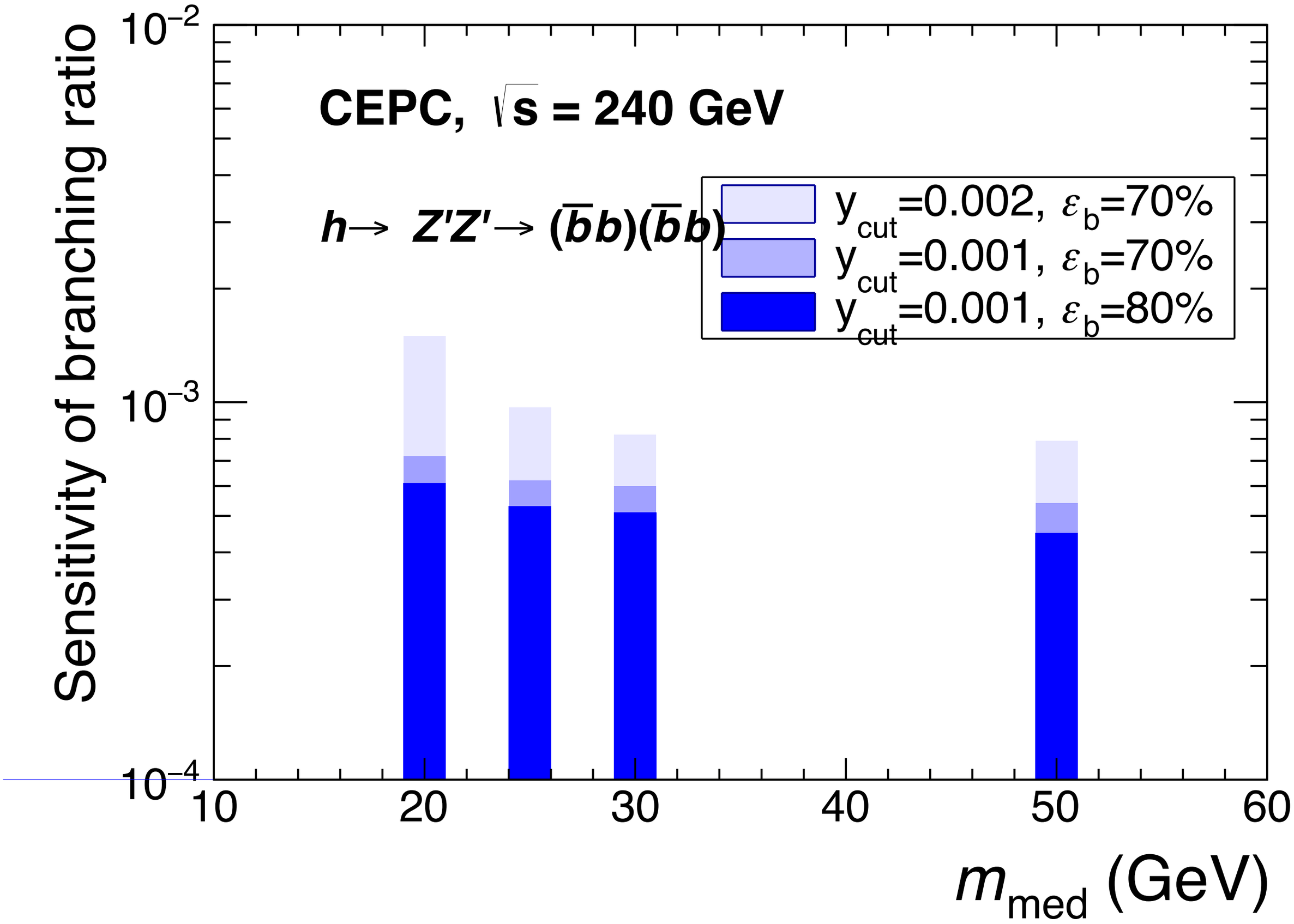
10^{-2}

10^{-3}

10^{-4}

10 20 30 40 50 60

m_{med} (GeV)


CEPC, √s = 240 GeV
h→ Z′Z′→ (b̄b)(b̄b)
y_cut=0.002, ε_b=70%
y_cut=0.001, ε_b=70%
y_cut=0.001, ε_b=80%
Sensitivity of branching ratio
10^−2
10^−3
10^−4
10
20
30
40
50
60
m_med (GeV)

Summary and outlook

- CEPC is a Higgs factory. 1,000,000 Higgs events with $5ab^{-1}$.
- Precisely measurement of the properties of the SM Higgs boson.
- A ideal machine for studying the exotic Higgs decay channels.
- As an example, the detail of the $h \rightarrow (jj)(jj)$ channel is shown.
- More than an order of magnitude improvement can be achieved without any advanced technology.
- More channels are in progress.

Thank you!