On new physics off the Z peak in $H \to \ell^+ \ell^- \gamma$

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Work done in collaboration with

Aliaksei Kachanovich[a], Jean Kimus & Steven Lowette

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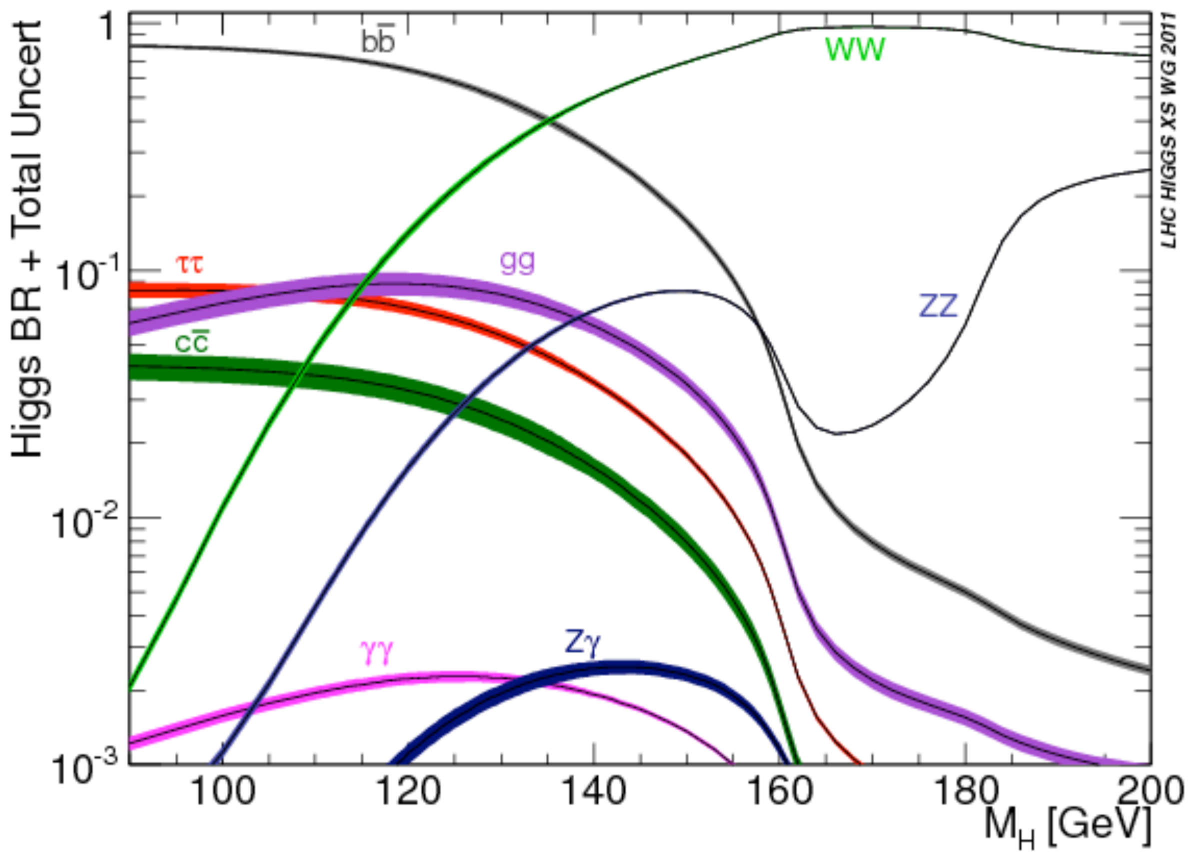
Scalars 2025 - University of Warsaw - September 22-25 2025



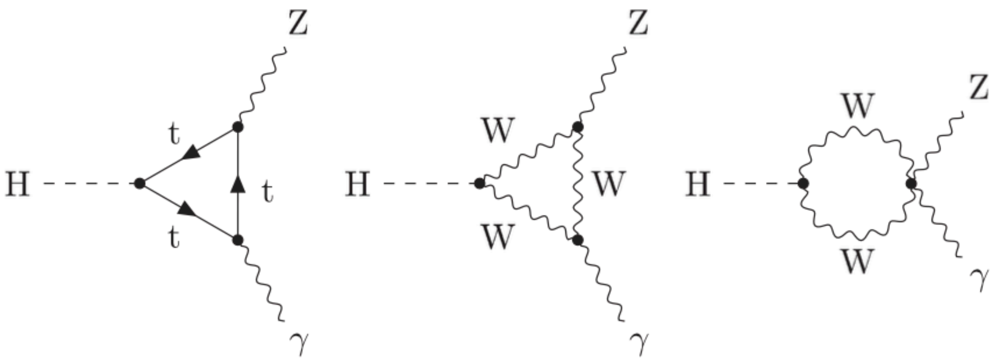


FIG. 1. Examples of Feynman diagrams for $H \to Z\gamma$ decay.

Cahn et al (1979); Bergstrom & Hulth (1985); Spira et al (1992); Kachanovich et al (2020);…

Branching almost as $H \to \gamma\gamma$ but $H \to \gamma Z^{(*)} \to \gamma f \bar{f}$

$f\bar{f} = l^+ l^-$ clean, but Z branching fraction only ~ 7 %

$\nu\bar{\nu}$ large missing E_T, hard to reconstruct

$q\bar{q}$ large, complex QCD background

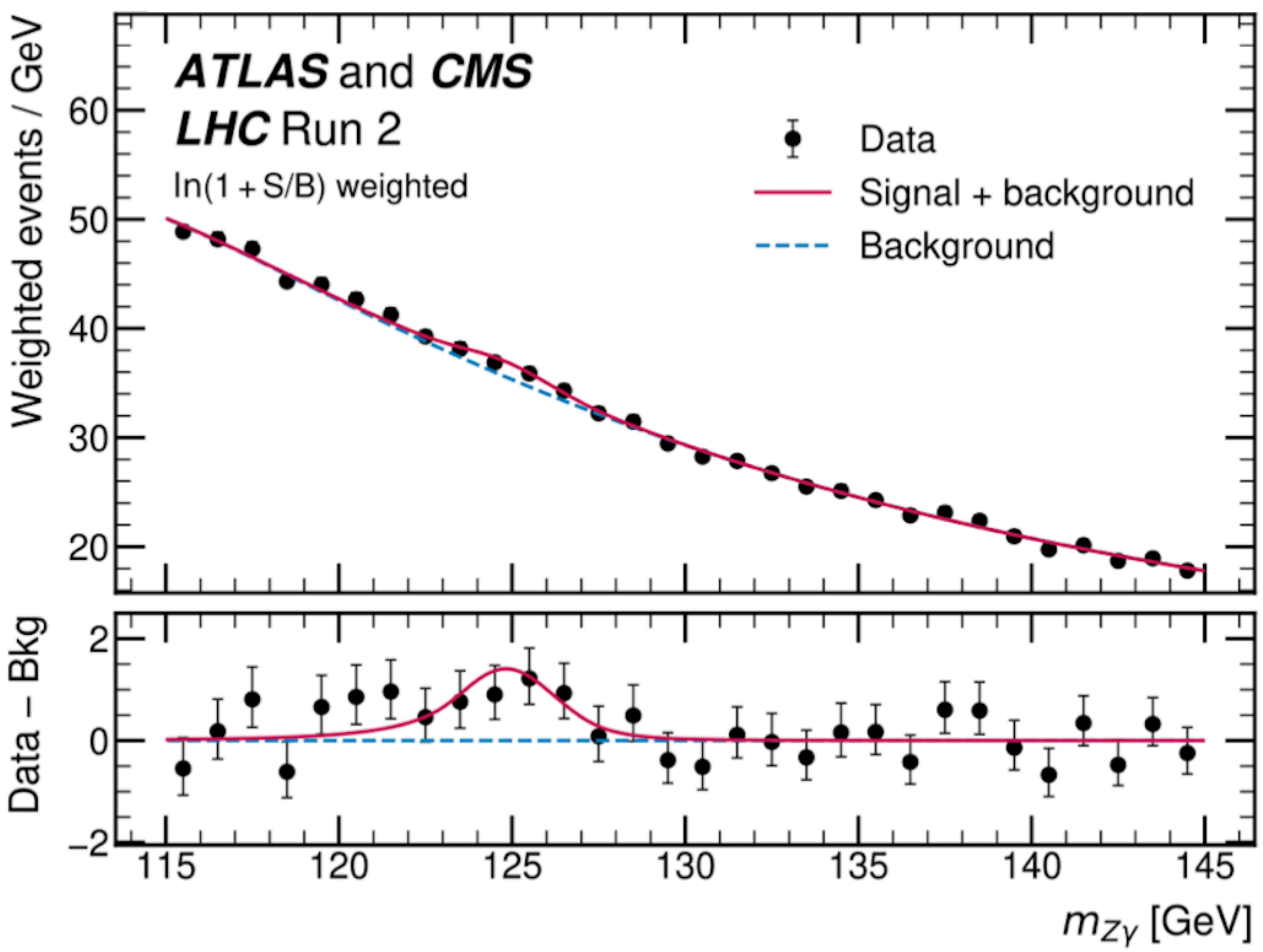
Evidence for the Higgs Boson Decay to a Z Boson and a Photon at the LHC

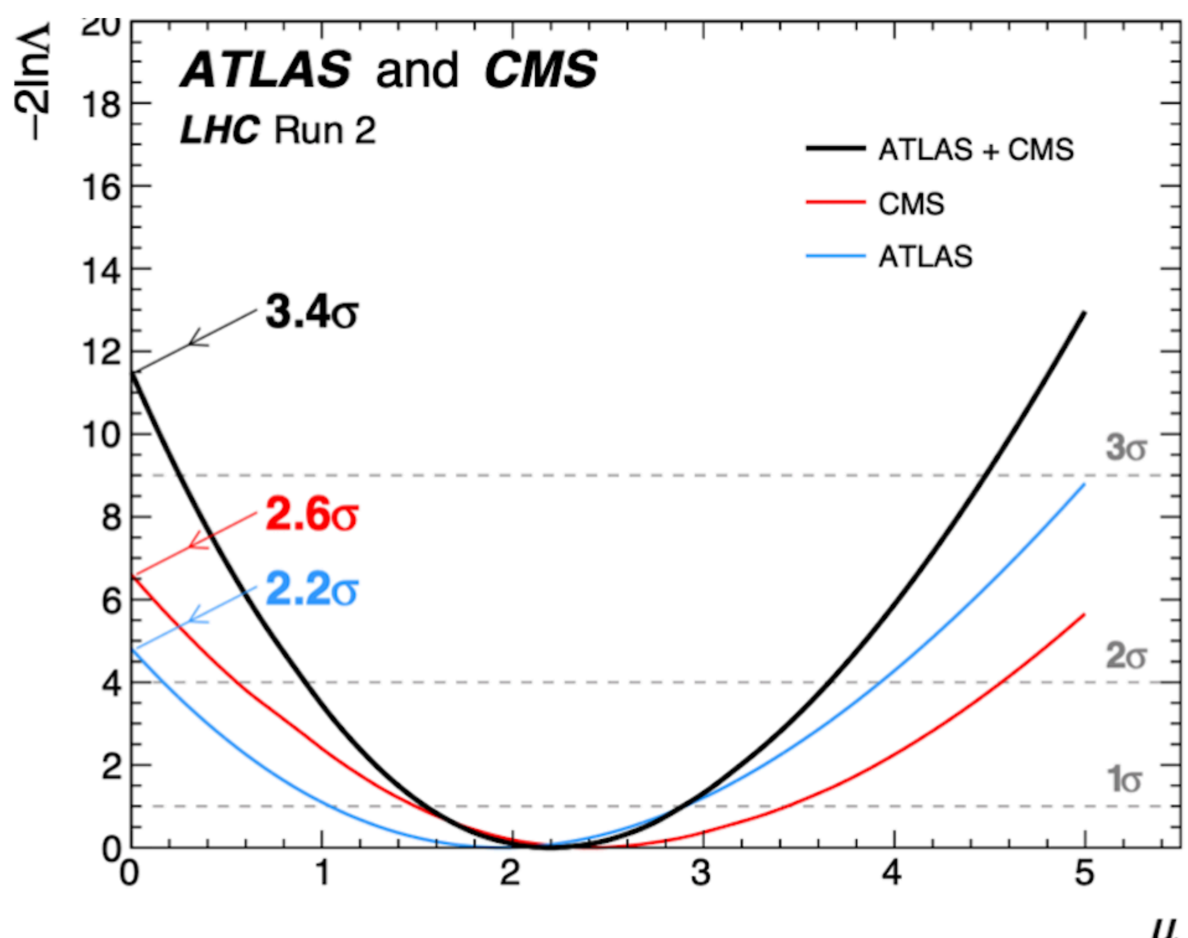
G. Aad *et al.*[*]
(ATLAS and CMS Collaborations)

(Received 8 September 2023; accepted 27 November 2023; published 11 January 2024)

The first evidence for the Higgs boson decay to a Z boson and a photon is presented, with a statistical significance of 3.4 standard deviations. The result is derived from a combined analysis of the searches performed by the ATLAS and CMS Collaborations with proton-proton collision datasets collected at the CERN Large Hadron Collider (LHC) from 2015 to 2018. These correspond to integrated luminosities of around 140 fb^{-1} for each experiment, at a center-of-mass energy of 13 TeV. The measured signal yield is 2.2 ± 0.7 times the standard model prediction, and agrees with the theoretical expectation within 1.9 standard deviations.

DOI: 10.1103/PhysRevLett.132.021803





$$\mu = \Gamma_{H\to Z\gamma}|_{\text{obs}} / \Gamma_{H\to Z\gamma}|_{\text{SM}}$$

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)

Submitted to: Phys. Lett. B.

CERN-EP-2025-155
18th July 2025

Search for the Higgs boson decay to a Z boson and a photon in pp collisions at $\sqrt{s}$ = 13 TeV and 13.6 TeV with the ATLAS detector

The ATLAS Collaboration

I'll come to that…

Standard Model considerations

Letter

Interference effects in $gg \to H \to Z\gamma$ beyond leading order

Federico Buccioni [a], Federica Devoto [b], Abdelhak Djouadi [c], John Ellis [d e], Jérémie Quevillon [f], Lorenzo Tancredi [a]

F. Buccioni, F. Devoto, A. Djouadi et al.

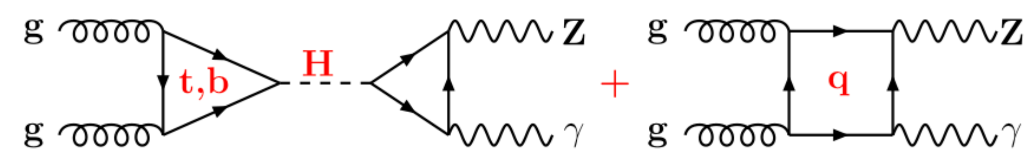


Fig. 1. Feynman diagrams at leading order for the signal (left) and the background (right) in the process $gg \to Z\gamma$.

Conclusions : small effect ☛ stat. fluctuation or new physics

Next-to-leading-order electroweak correction to $H \to Z^0\gamma$

Wen-Long Sang [1,*], Feng Feng [2,3,†] and Yu Jia [3,4,‡]

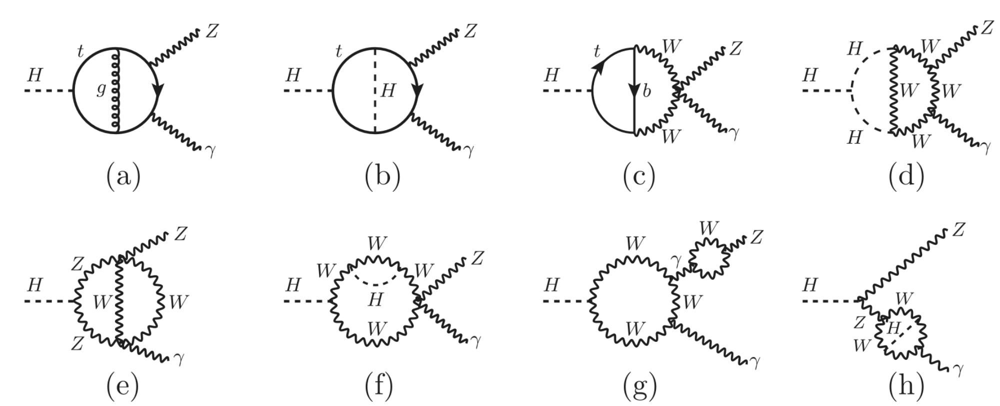


FIG. 2. Some representative two-loop diagrams for $H \to Z^0\gamma$. (a) Represents a sample diagram for NLO QCD correction, while (b)–(h) represent sample diagrams for NLO electroweak correction.

Conclusions:

NLO electroweak corrections are significant ~ few % ☛ increased theory prediction,

LO value $(1.40 – 1.71) \times 10^{-3}$ to NLO $(1.55 \pm 0.06) \times 10^{-3}$

BSM considerations (sample)

New physics interpretations for nonstandard values of $h \to Z\gamma$

Rafael Boto[1,*] Dipankar Das[2,†] Jorge C. Romão[1,‡] Ipsita Saha[3,§] and Joao P. Silva[1,‖]

Conclusions: challenge is to preserve $H \to \gamma\gamma$ …

New fermion singlets or doublets, charged scalars with off-diagonal couplings ☛ need large effect; scale must be accessible to the LHC; good for FCC.

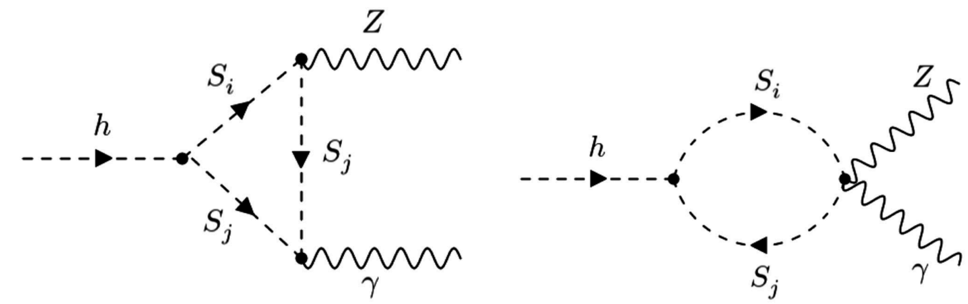


FIG. 1. Representative Feynman diagrams that give additional contributions to $\mu_{Z\gamma}$ exclusively.

Interpretation of excess in $H \to Z\gamma$ using a light axionlike particle

Kingman Cheung[1,2,3,*] and C. J. Ouseph[1,2,†]

Conclusions: the challenge is to preserve $H \to \gamma\gamma$ …

A light ALP, m ~ 0.05–0.1 GeV, produced on-shell and decaying into a pair of highly collimated photons would do. ☛ 2 for the price of 1; good for FCC

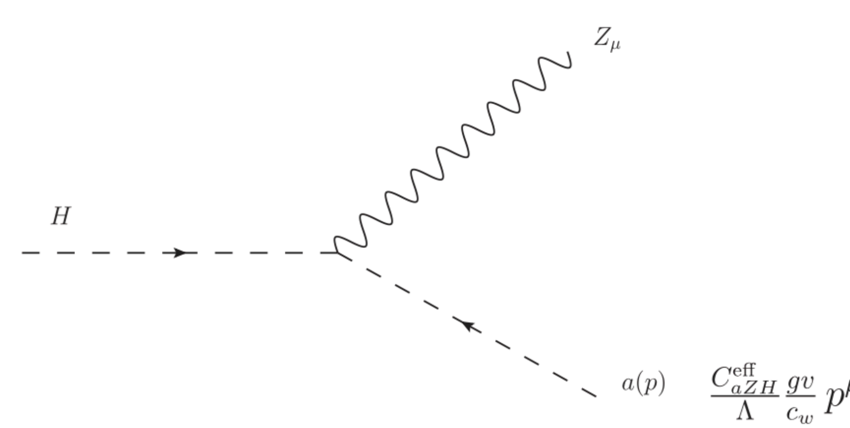


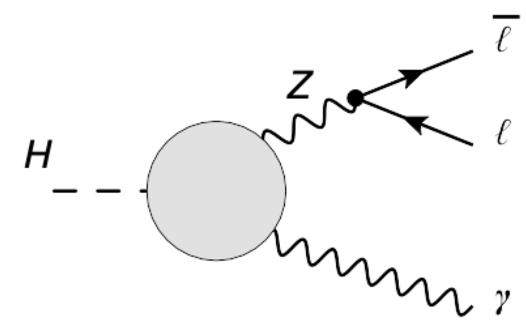
FIG. 2. Feynman rule for the vertex of aZH, which p_μ is the momentum of the incoming axion.

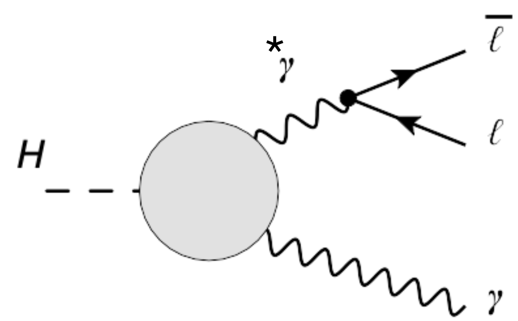
And that's basically it…

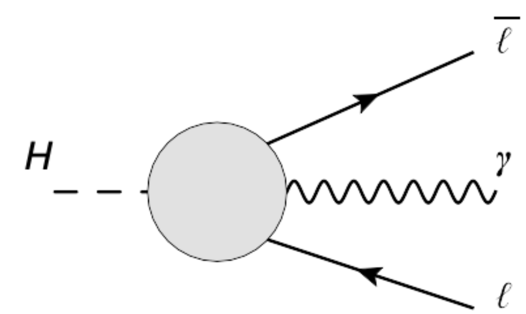
$H \to l^+ l^- \gamma$ (SM)

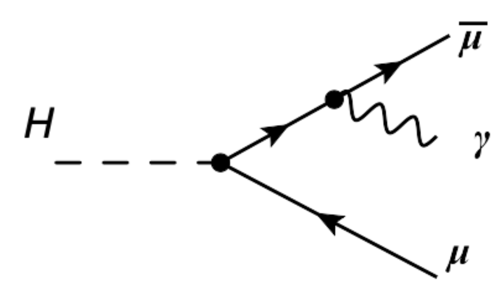
signal

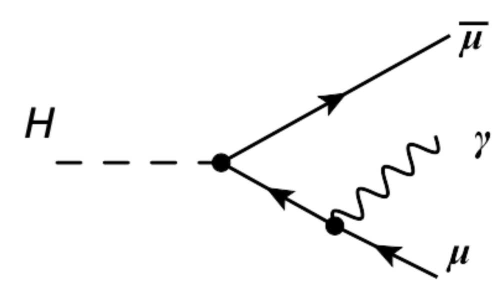
background







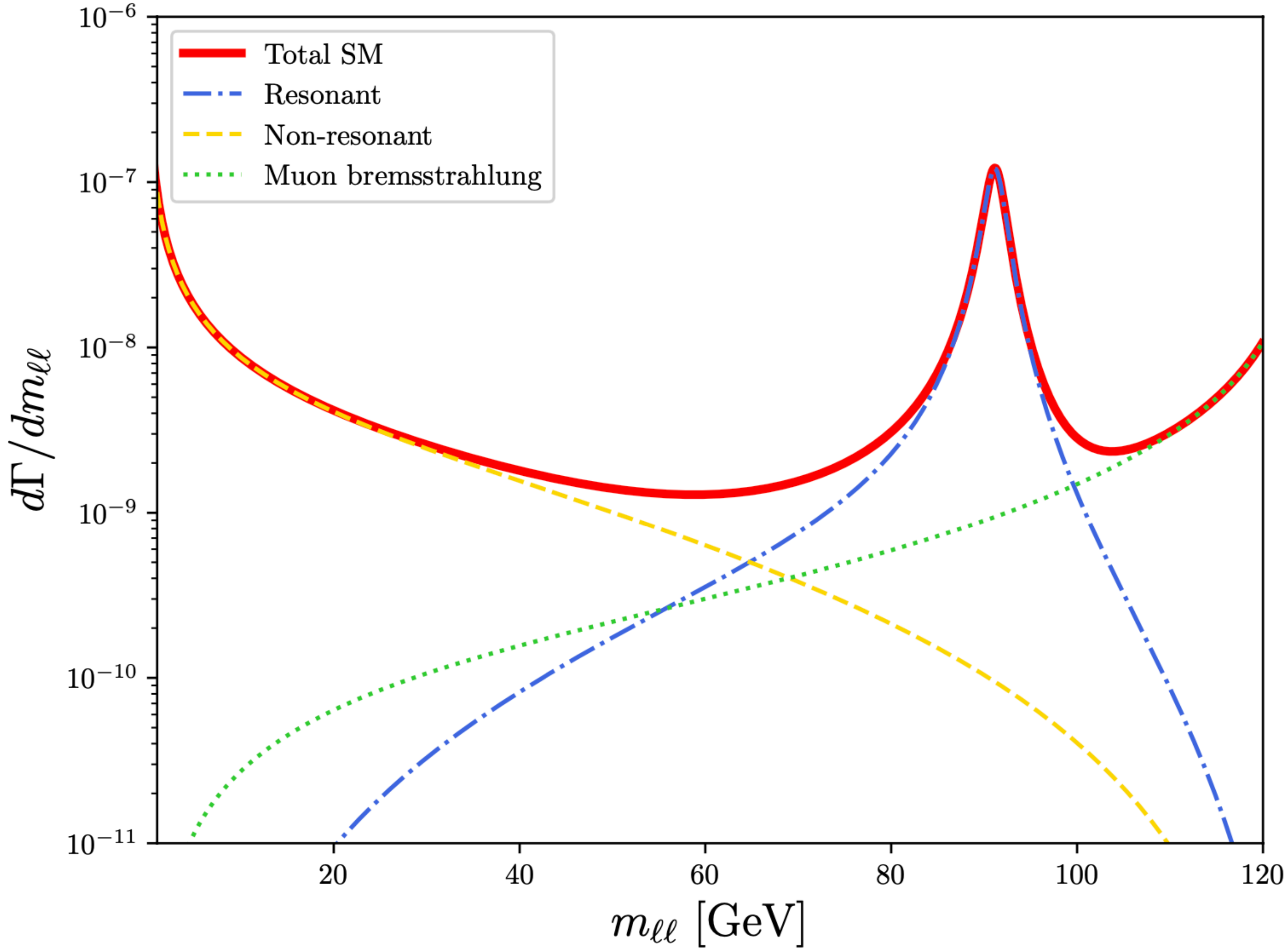




resonant

non-resonant

$H \to l^+ l^- \gamma$ (SM)

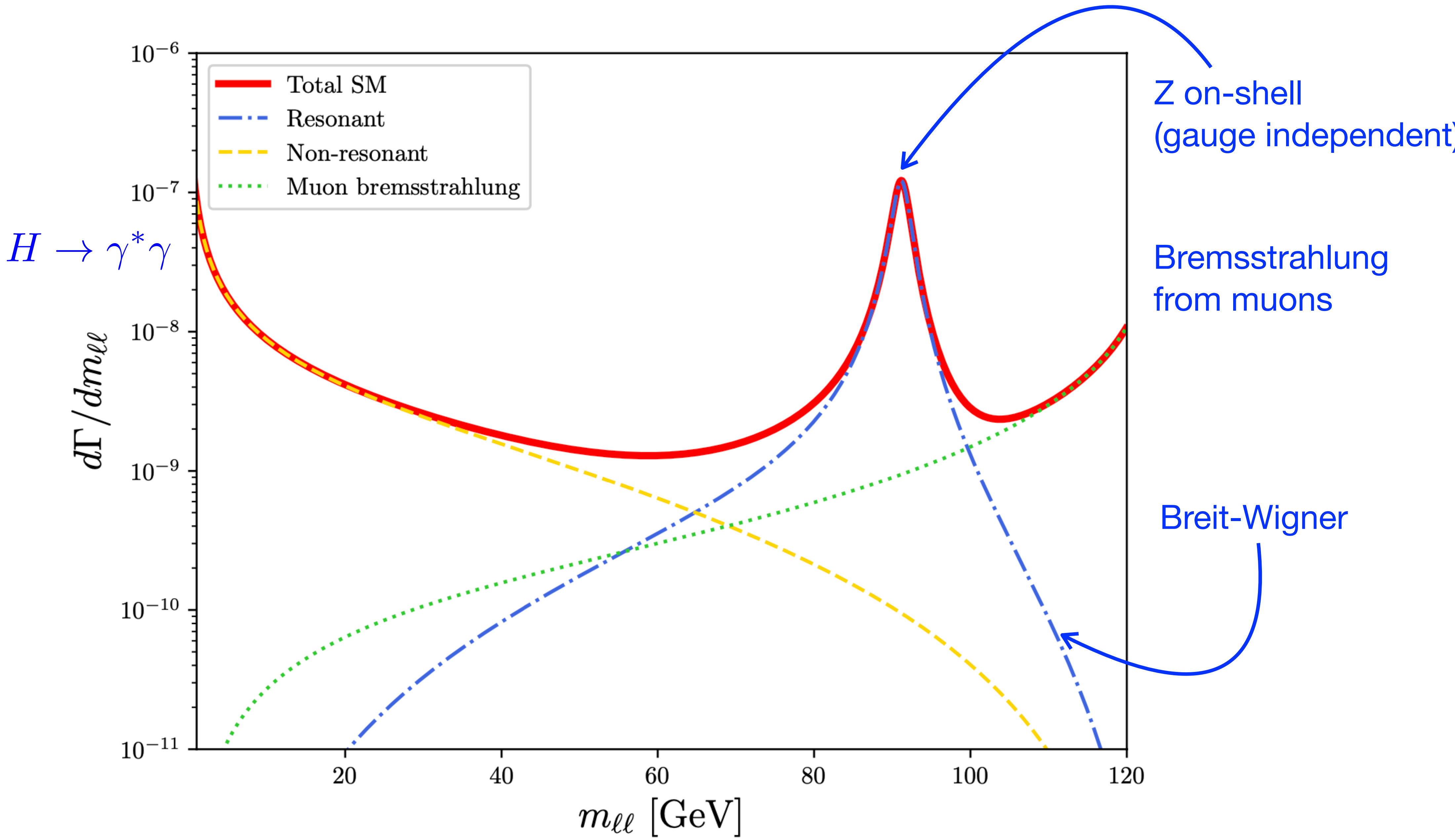


Theory !
No cuts

FIG. 3. Differential decay rate $d\Gamma/dm_{\ell\ell}$ for $H \to \ell^+\ell^-\gamma$ as function of the dilepton inviariant mass, summed (solid red line) for electron and muon pairs. The blue dot-dashed curve corresponds to the resonant Z contribution, see the text. The dotted green curve corresponds to Bremsstrahlung from muon pairs. The dashed yellow curve corresponds to the non-resonant contributions, which include $H \to \gamma^*\gamma$ and the contribution from box diagrams. We emphasize that this curve is theoretical as it assumes no cuts on the energy of the leptons and of the photon.

Kachanovich, Kimus, Lowette, MT (2025)

$H \to l^+ l^- \gamma$ (SM)



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Modified $H \to Z\gamma$?

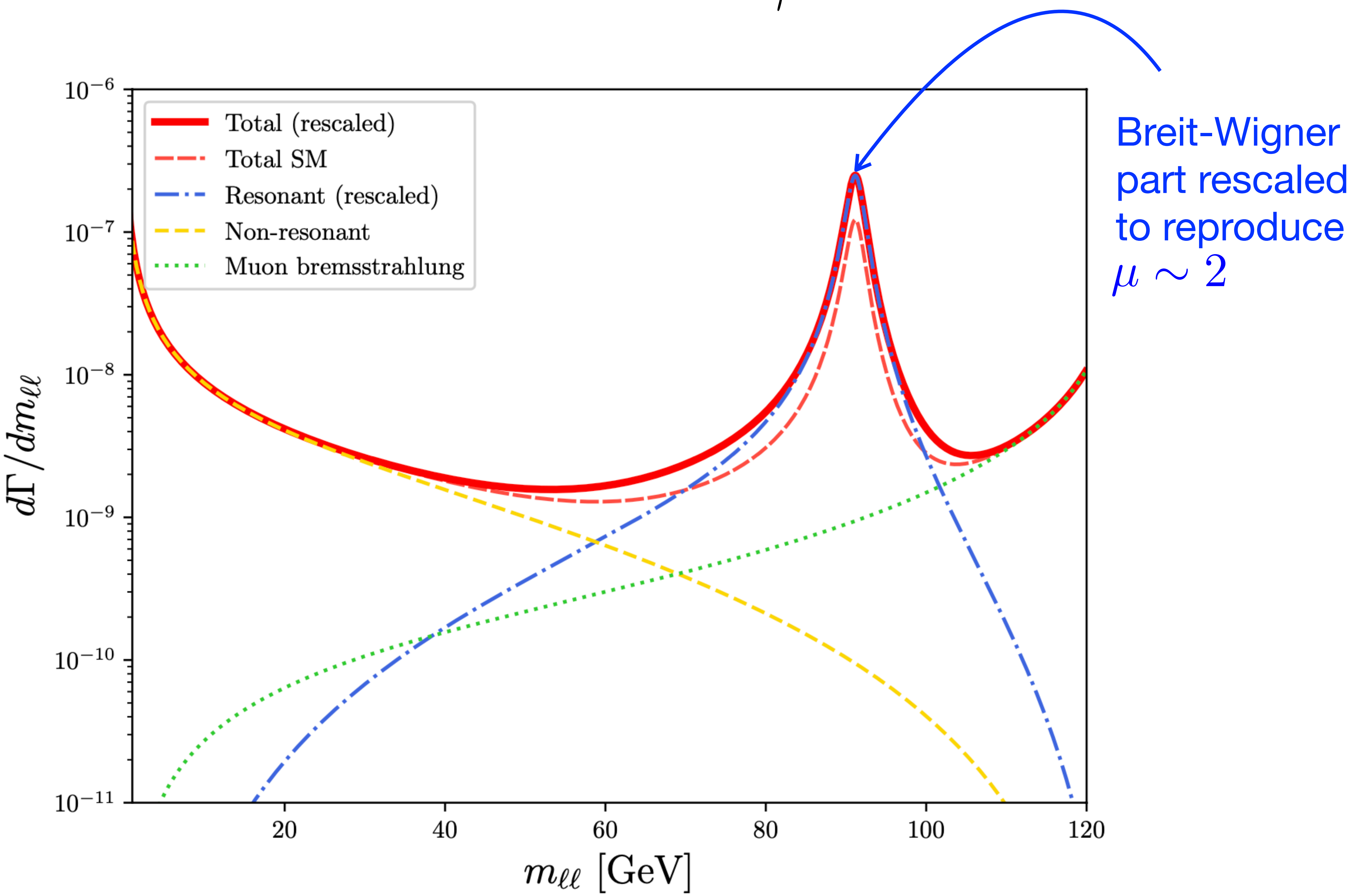
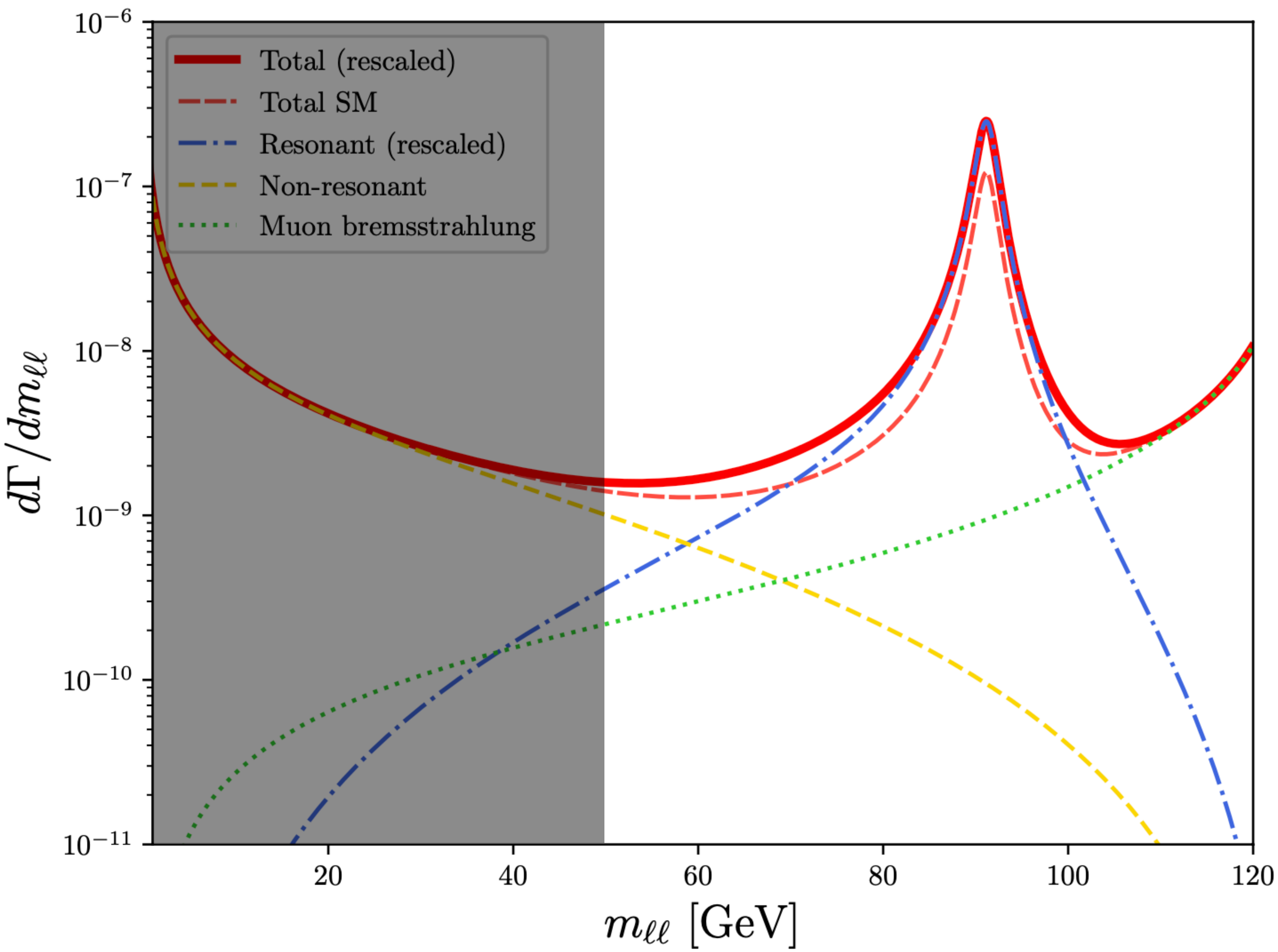


FIG. 4. Same as Figure 3, together with a decay rate with the Z-peak contribution rescaled to match the measured excess of events (solid red curve) compared with the SM prediction (short-dashed red curve).

$$\mu = \Gamma_{H\to Z\gamma}\big|_{\text{obs}} / \Gamma_{H\to Z\gamma}\big|_{\text{SM}}$$

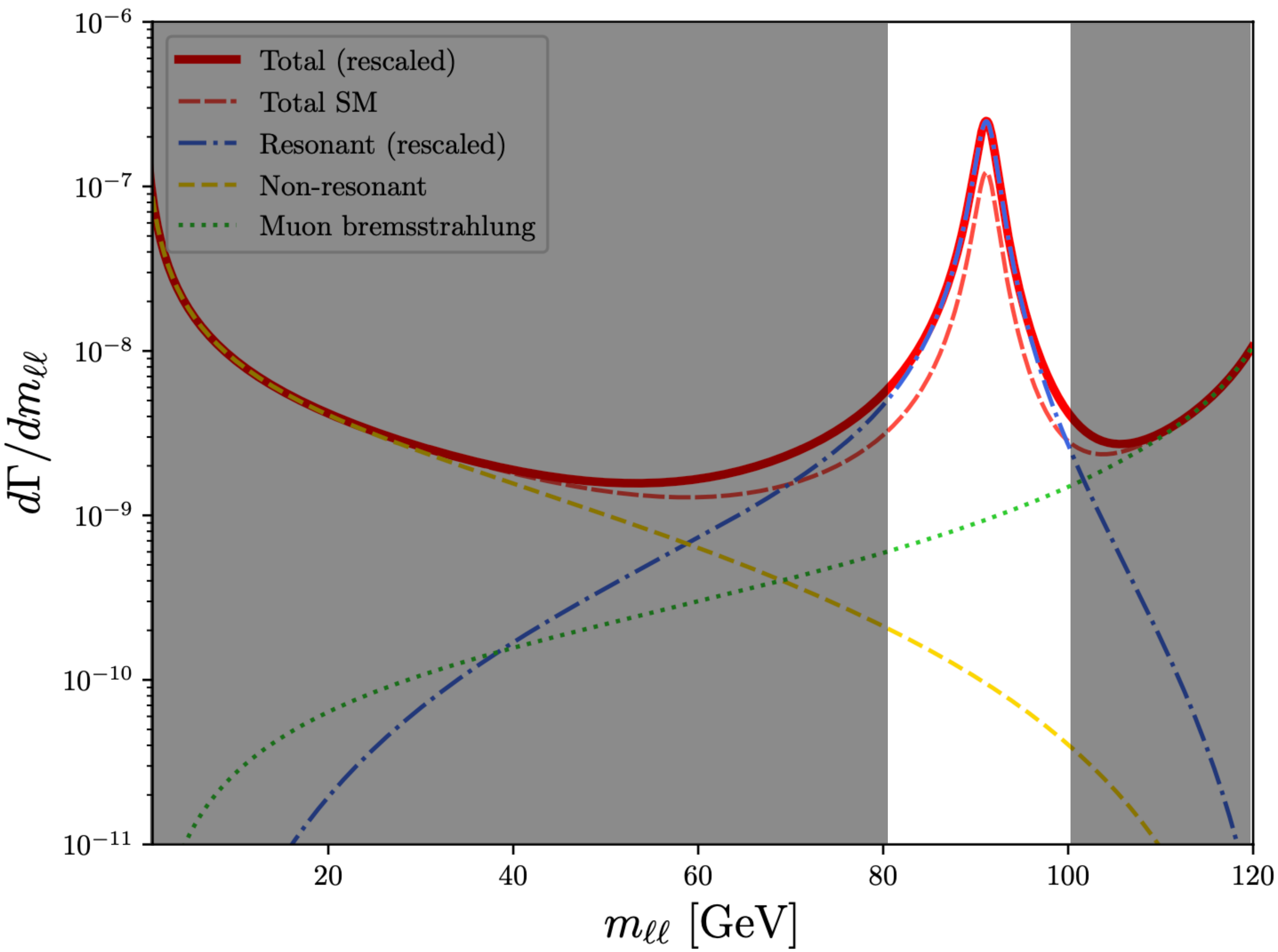
Modified $H \to Z\gamma$?



CMS cuts (similar for ATLAS) : $50\,\text{GeV} \leq m_{\ell\ell} \leq 125\,\text{GeV}$

$E_1 \geq 7$ GeV $\quad E_2 \geq 25$ GeV $\quad E_\gamma \geq 15$ GeV

Changing cuts ?



Changing cuts ?

#	Cuts	$m_{\ell\ell}^{min}$[GeV]	$m_{\ell\ell}^{max}$[GeV]	$\mu_{\rm resc}$
3	CMS	40	125	2.1
4	**CMS**	**50**	**125**	**2.1**
5	CMS	70	125	2.1
6	CMS	70	100	2.1
7	CMS	80	100	2.1

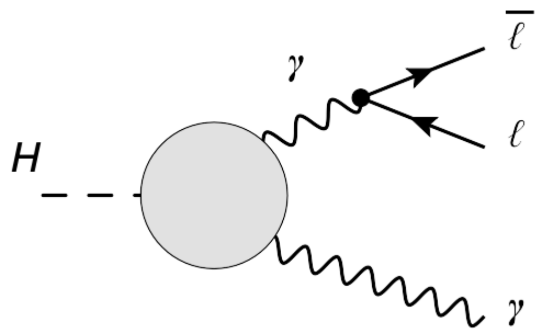
CMS : $E_1 \geq 7$ GeV $E_2 \geq 25$ GeV $E_\gamma \geq 15$ GeV

Non-resonant (off the Z peak) new physics?

- $H \to \gamma^* \gamma$

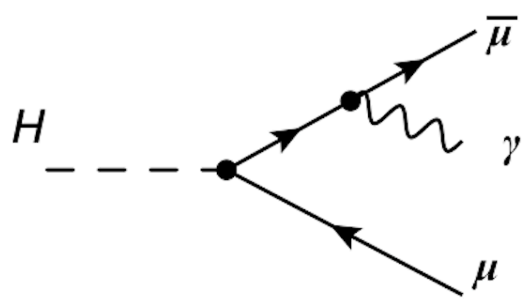
  same problem as modifying $H \to Z\gamma$

  hard gamma ~ small m_{ll}



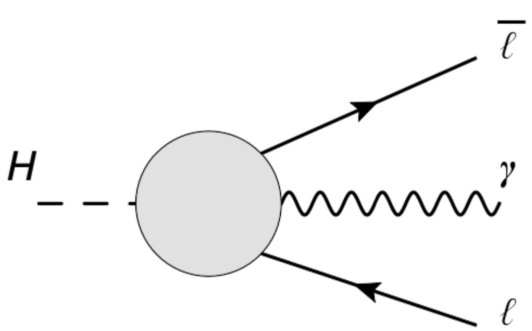
- Bremsstrahlung (muons) ?

  soft gammas ~ large m_{ll}



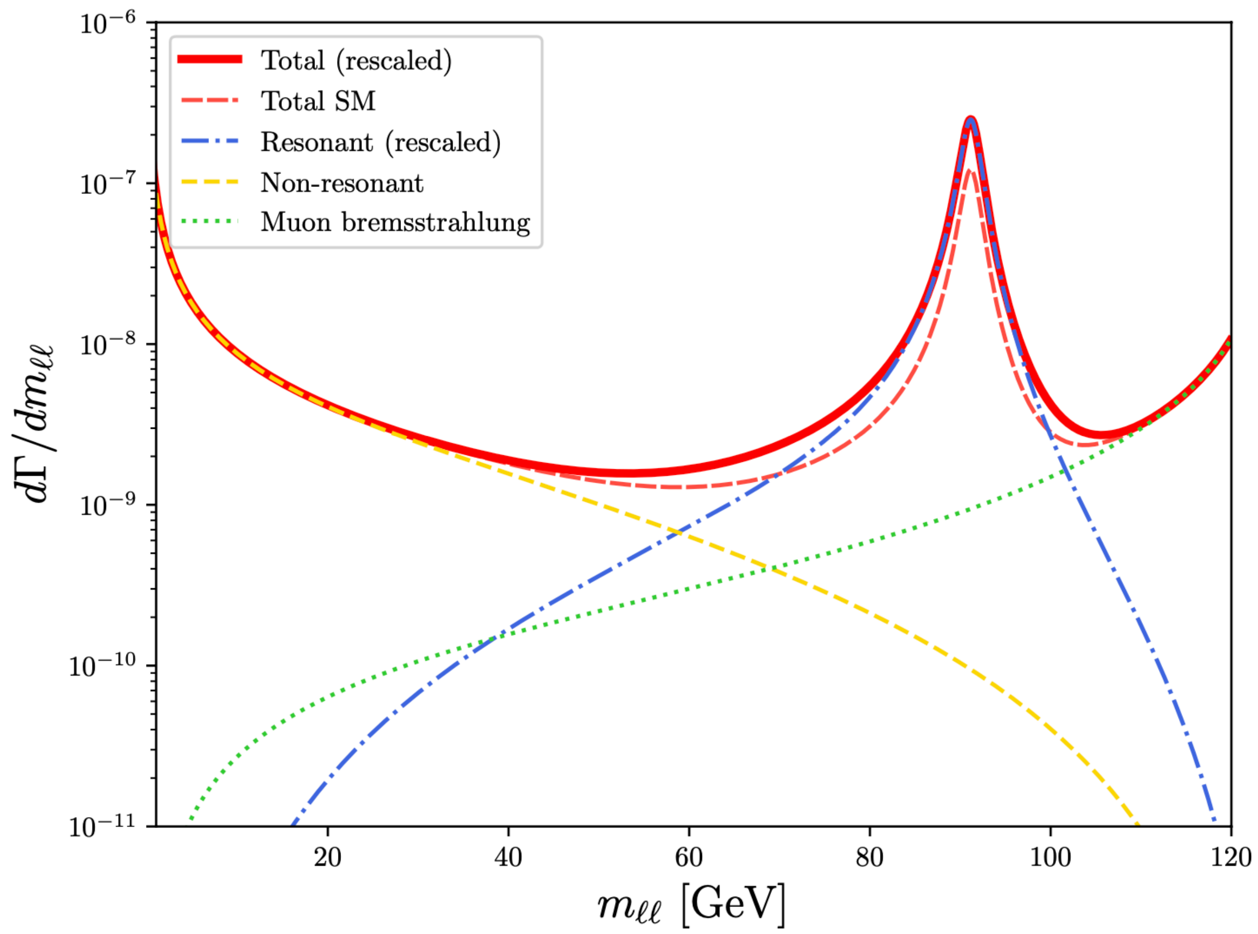
- Direct contribution to $H \to l^+ l^- \gamma$?

  ~ box diagrams

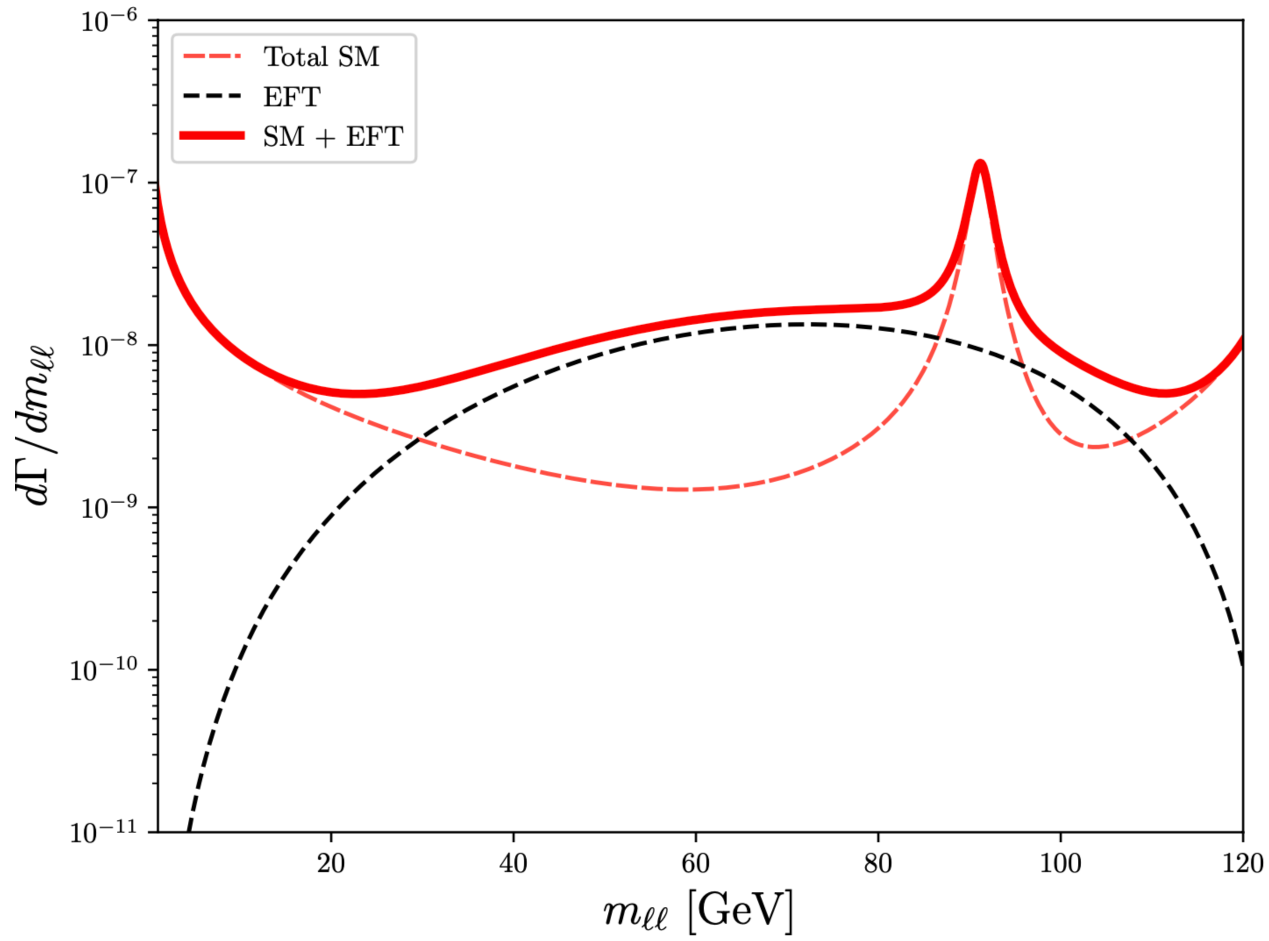


Resonant or non-resonant (off the Z peak) new physics?

Resonant ?

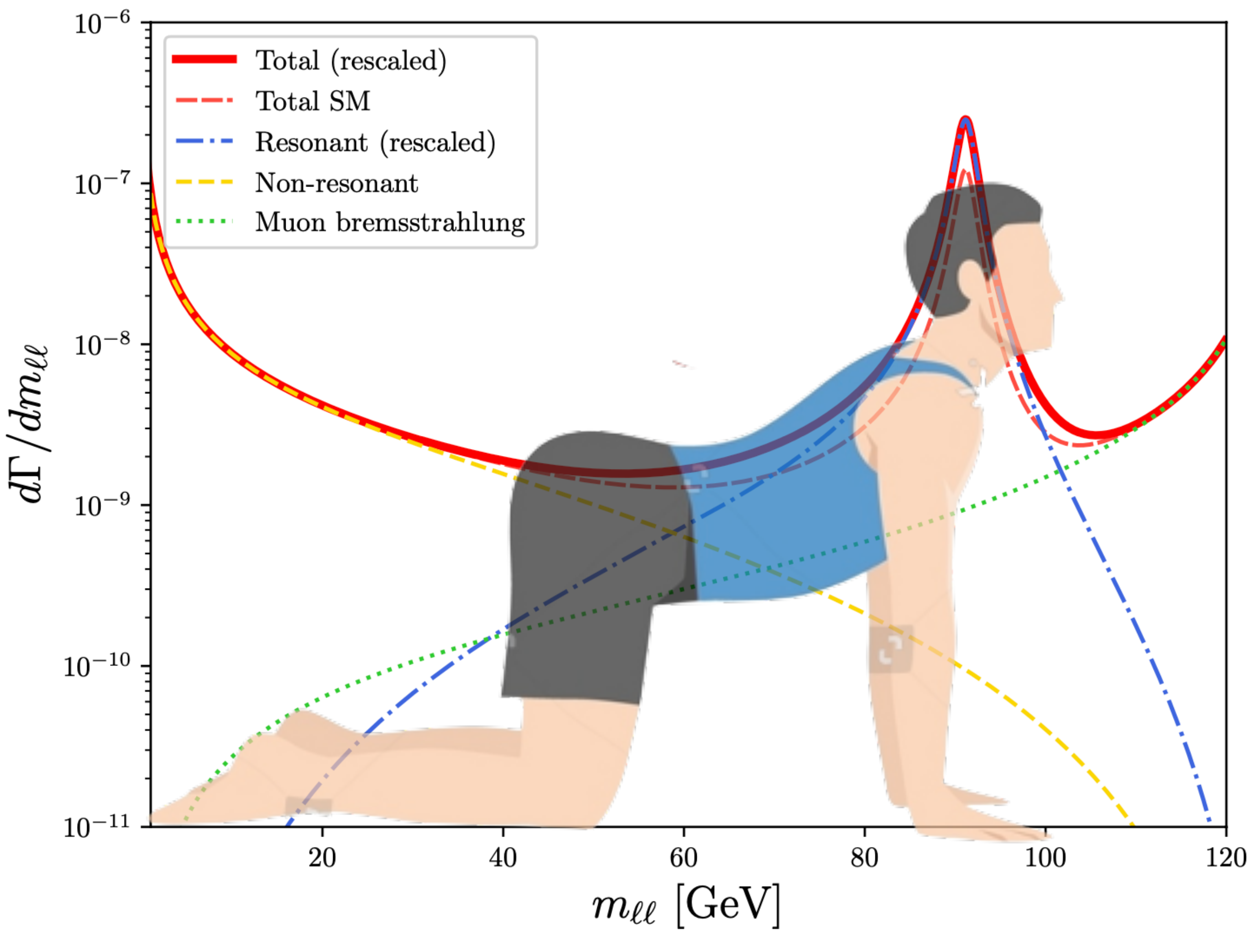


Non-resonant ?



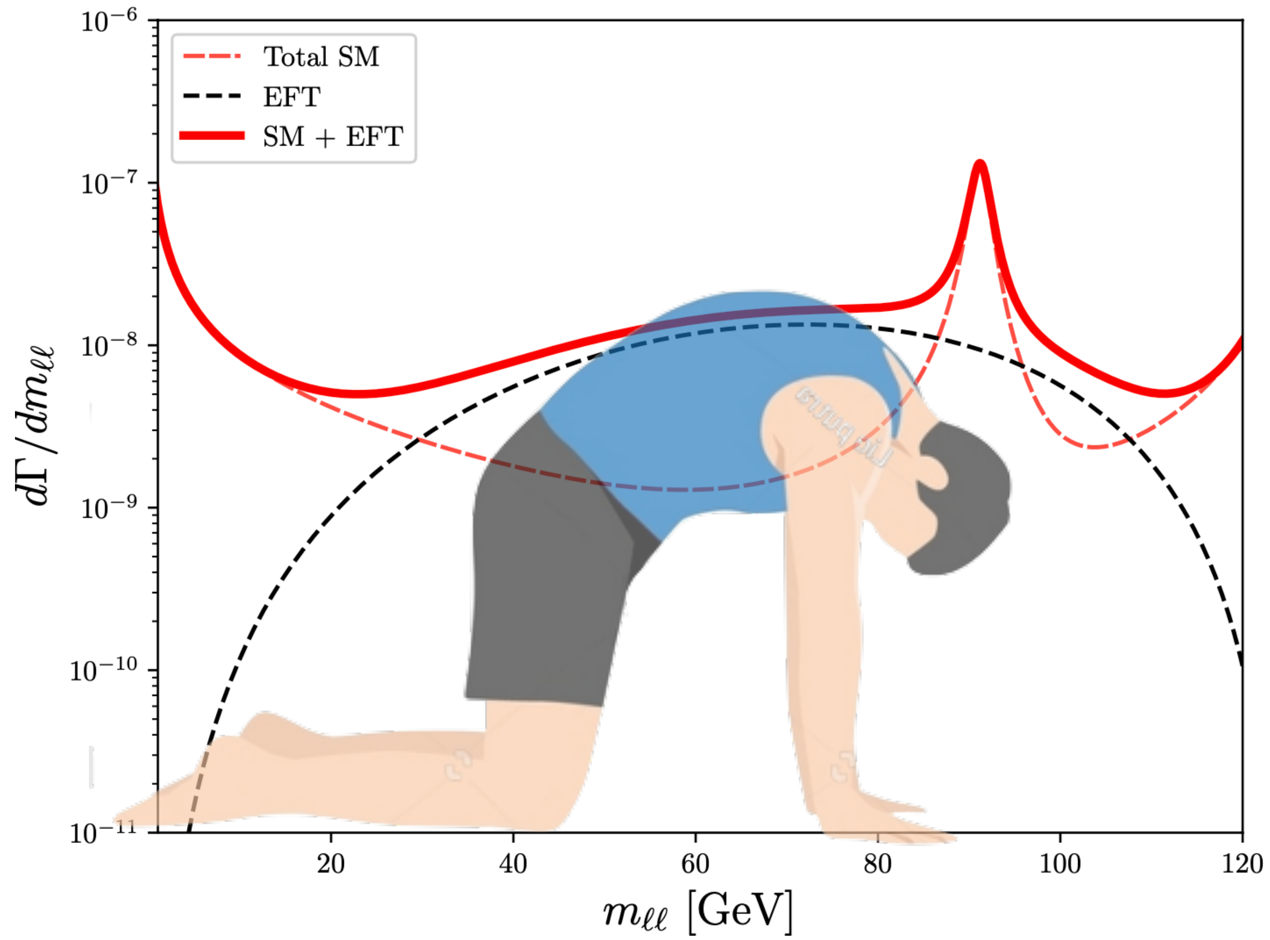
Resonant or non-resonant (off the Z peak) new physics?

Resonant ?



Cow ?

Non-resonant ?



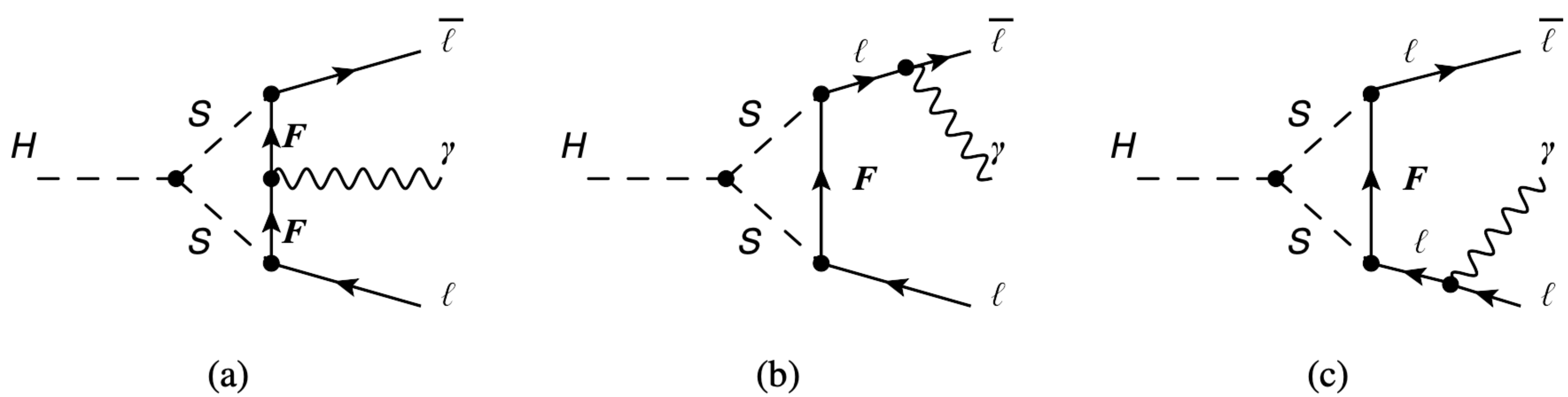
Cat ?

A toy model, with dark matter ?

$$\mathcal{L} \supset \frac{1}{2}\partial_\mu S \partial^\mu S - \frac{1}{2}m_S^2 S^2 + \bar{F}(i\not{D} - m_F)F - \sum_\ell (y_\ell S \bar{F}\ell_R + h.c.) - \frac{\lambda_{hs}}{2} S^2 |\Phi|^2$$

	S	F	SM
Z_2	-	-	+
Q	0	1	Q_{SM}

$\langle S \rangle = 0$ { no S-h or F-l mixing; $m_S < m_F$, S stable }

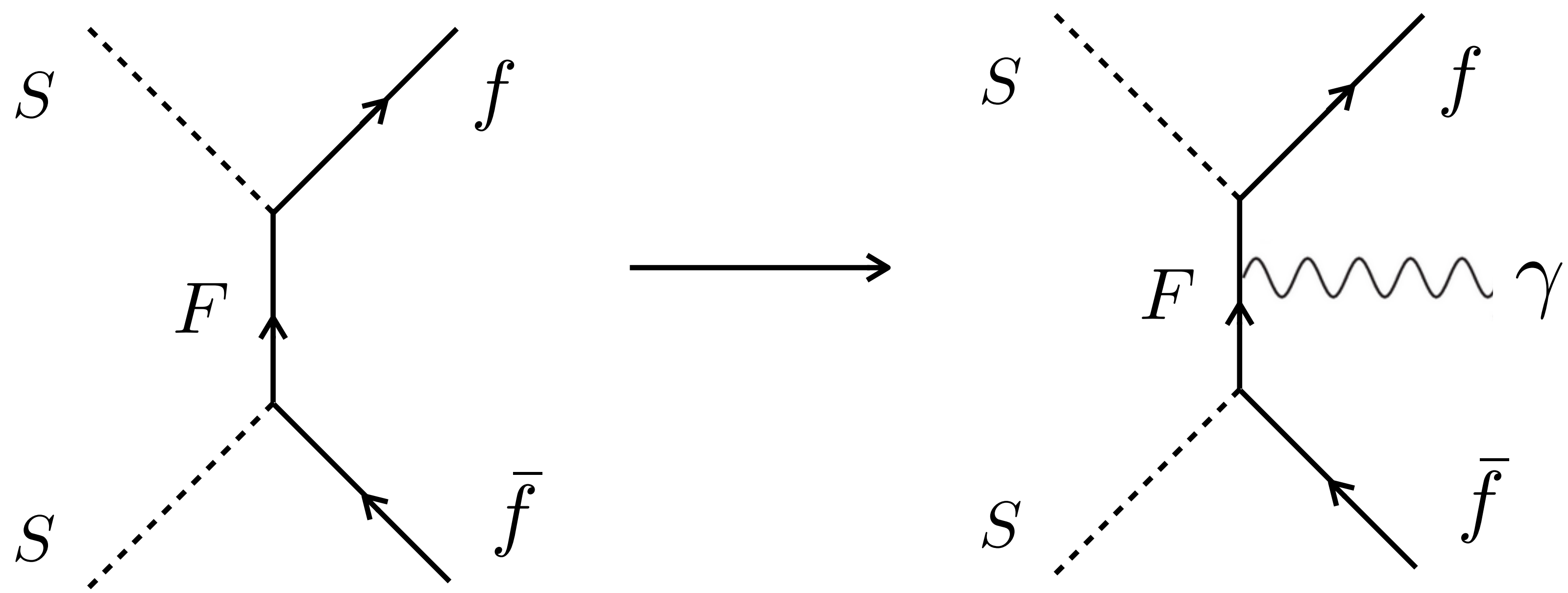


(no contribution to $H\gamma\gamma$ or $H\gamma Z$ at 1-loop)

DIGRESSION

$$\mathcal{L} \supset \frac{1}{2}\partial_\mu S \partial^\mu S - \frac{1}{2}m_S^2 S^2 + \bar{F}(i\not{D} - m_F)F - \sum_\ell (y_\ell S \bar{F} \ell_R + h.c.) - \frac{\lambda_{hs}}{2} S^2 |\Phi|^2$$

An instance of t-channel dark matter



$$\sigma v \sim y_f^4 \frac{m_f^2}{M_S^4}$$

helicity suppressed

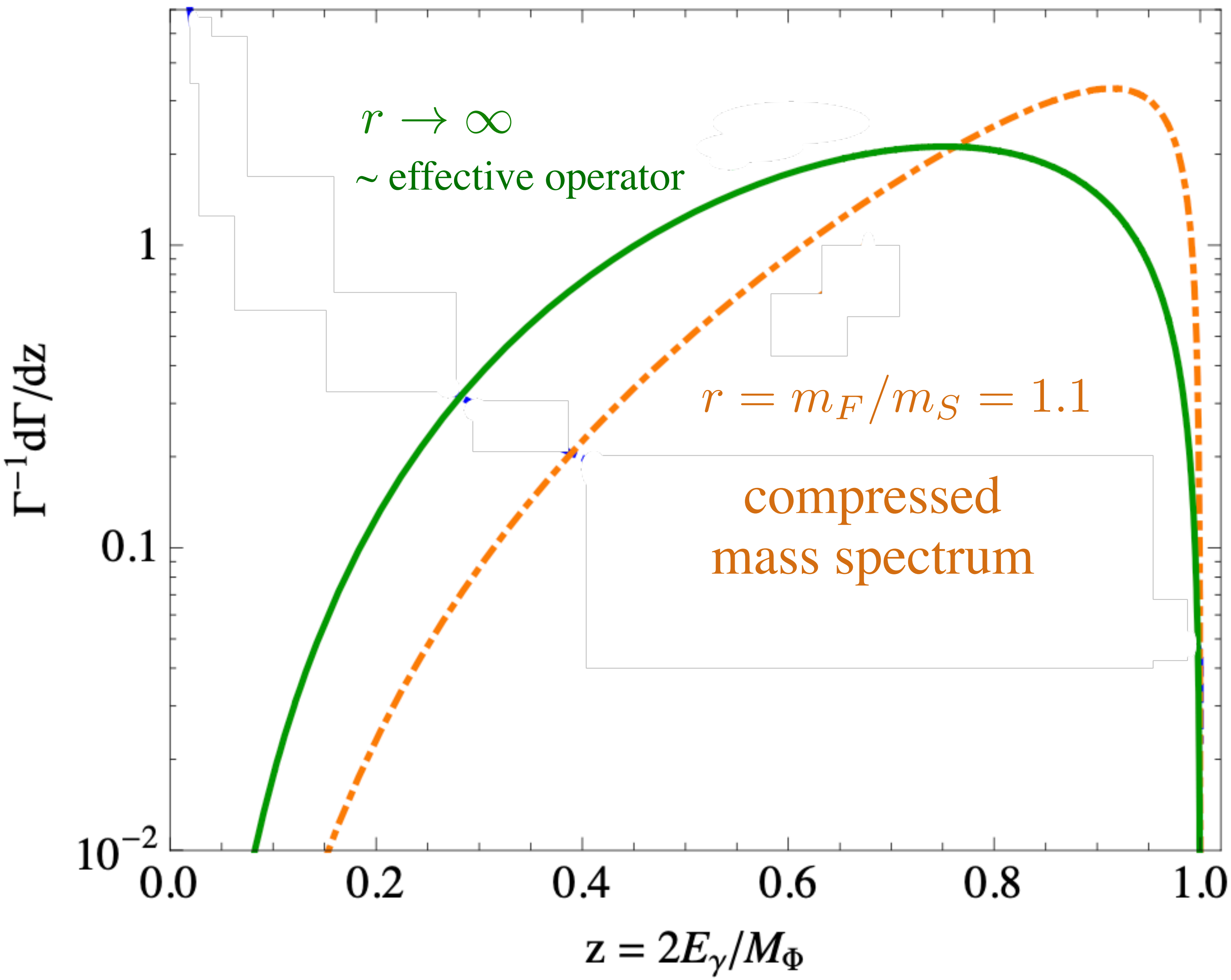
$$\sigma v \sim y_f^4 \frac{\alpha}{M_S^2}$$

virtual internal bremsstrahlung

Giachino, Lopez Honorez, MT; Toma (2013)

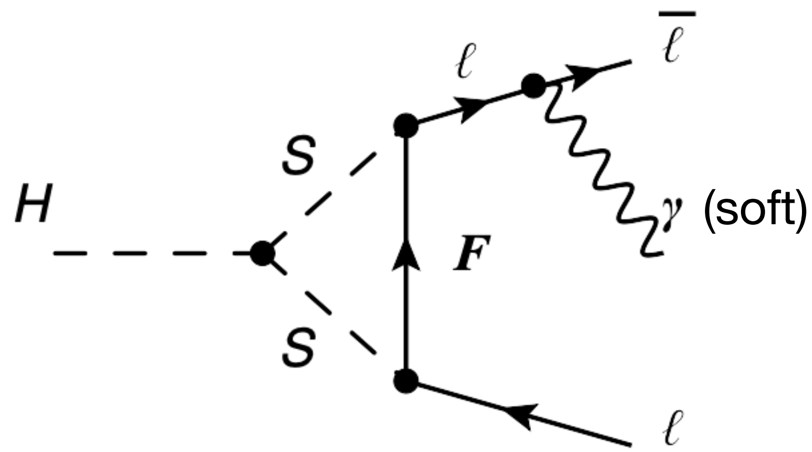
Gamma-ray spectrum features a peak

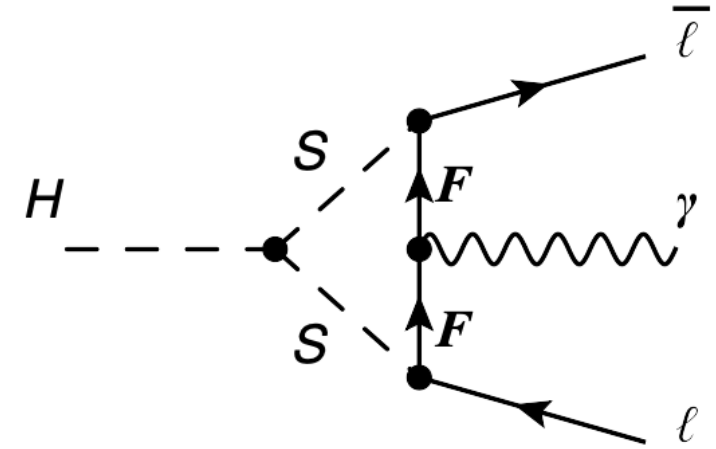
$$SS \to f\bar{f}\gamma$$

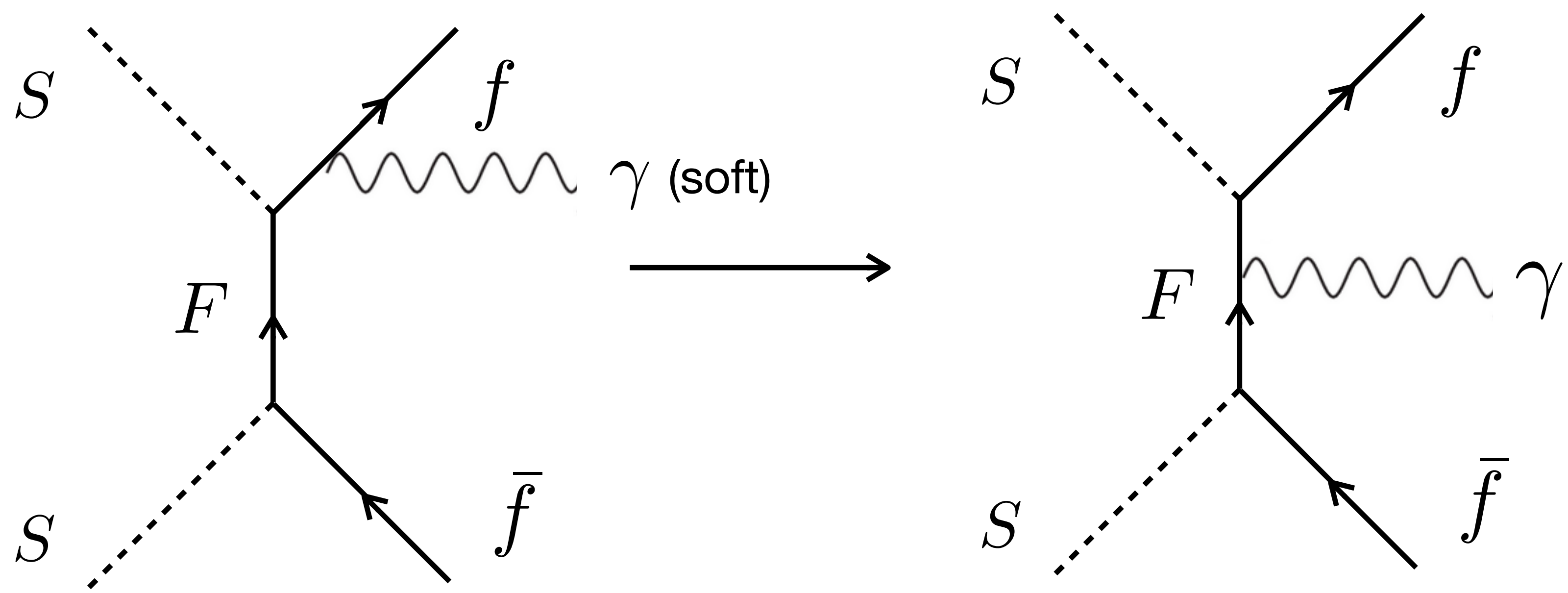


Barger, Gao, Keung, Marfatia (2009)

Giachino, Lopez Honorez, MT; Toma (2013)







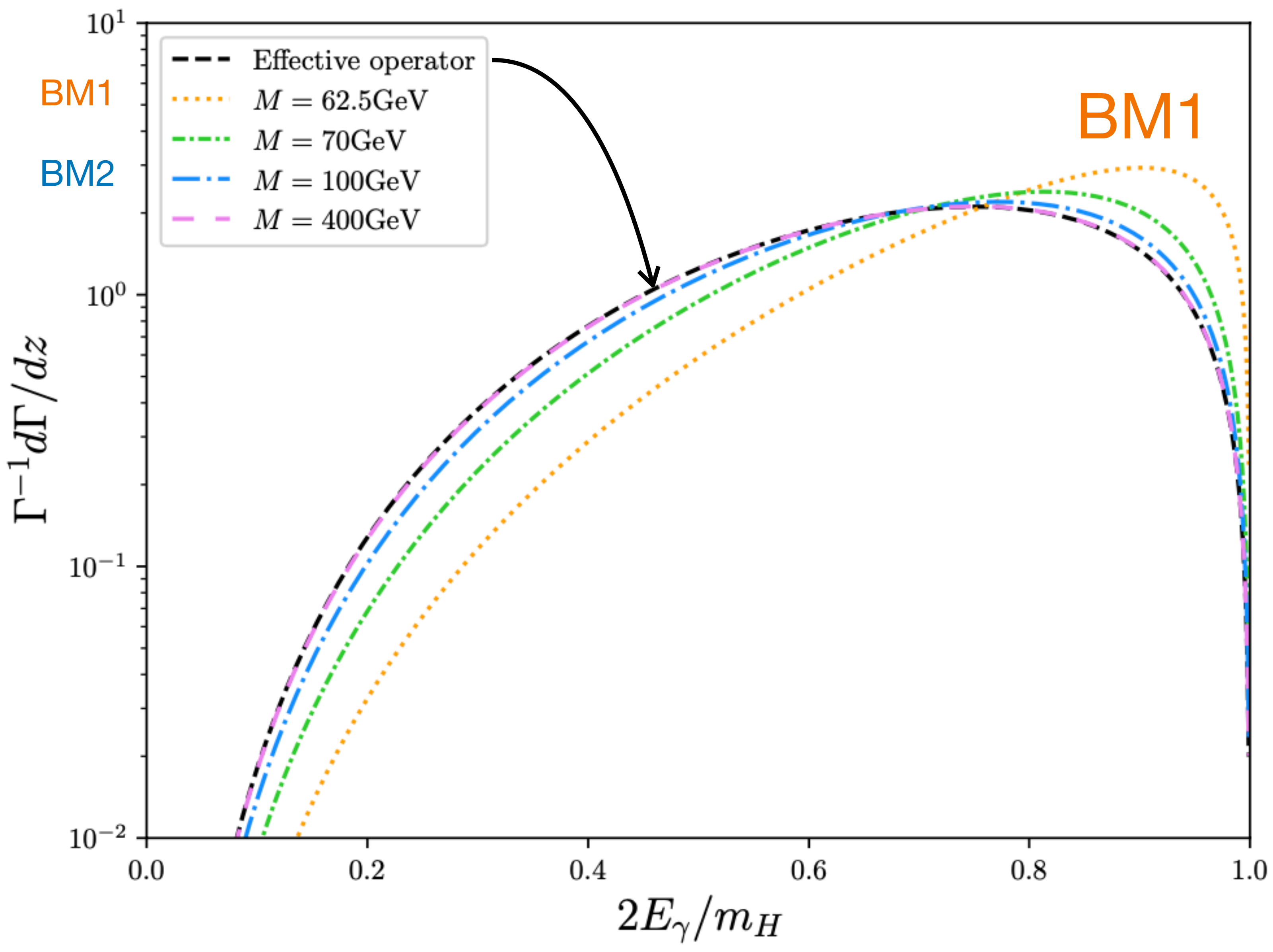
$$\sigma v \sim y_f^4 \frac{m_f^2}{M_S^4}$$

helicity suppressed

$$\sigma v \sim y_f^4 \frac{\alpha}{M_S^2}$$

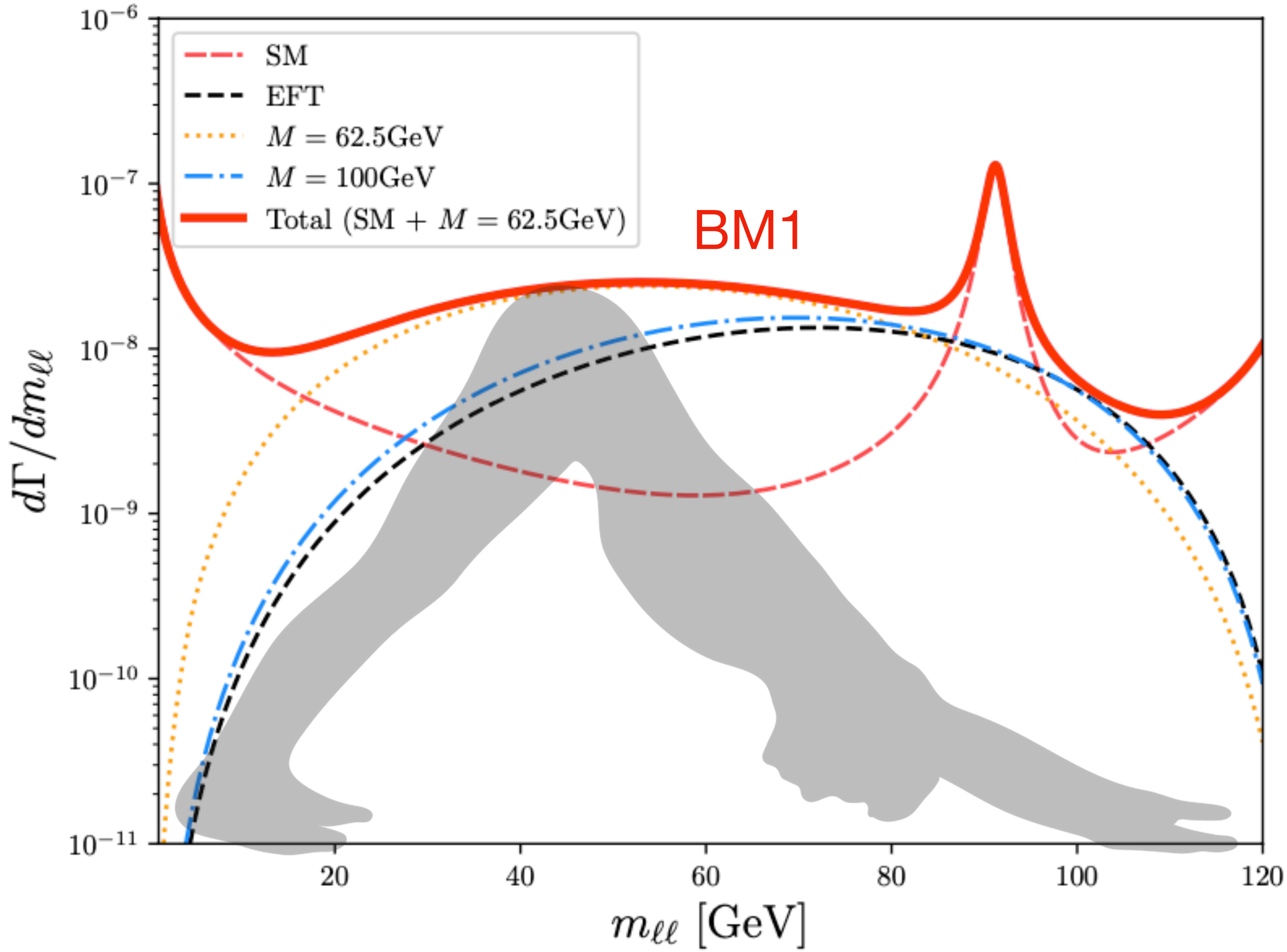
virtual internal bremsstrahlung

$H \to l^+ l^- \gamma$: gamma ray



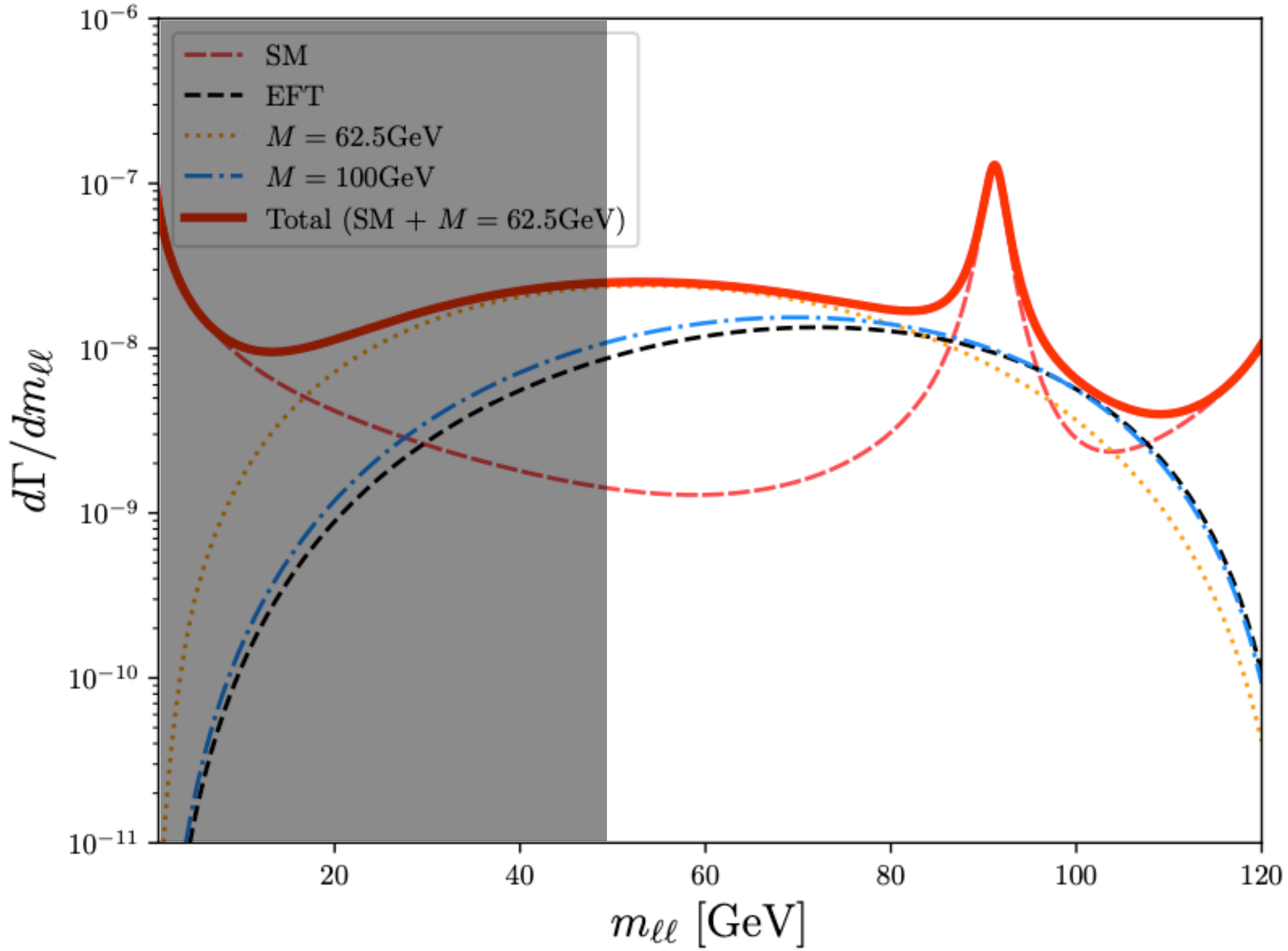
Kachanovich, Kimus, Lowette, MT (2025)

$H \to l^+ l^- \gamma$: dileptons

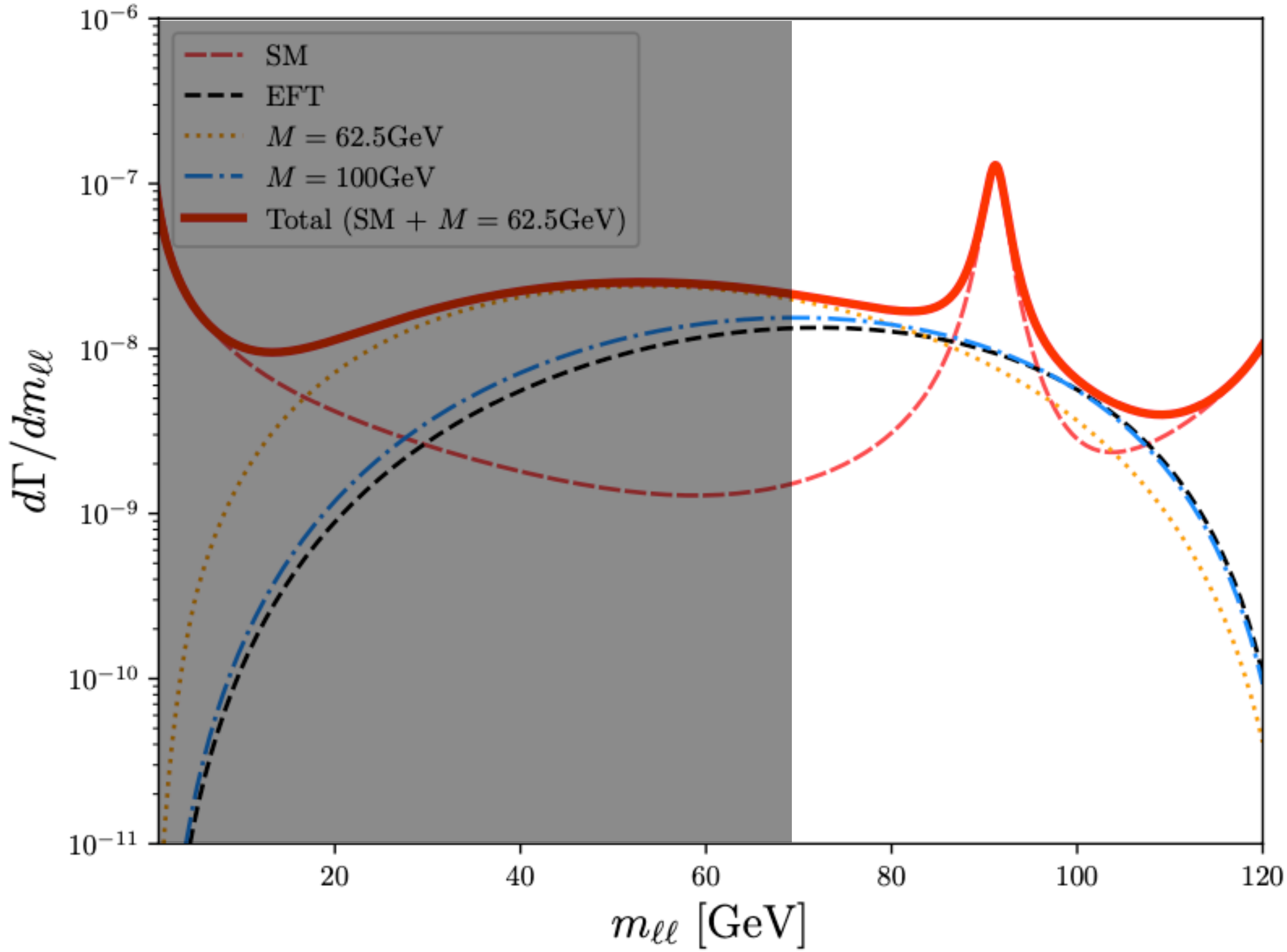


(downward dog)

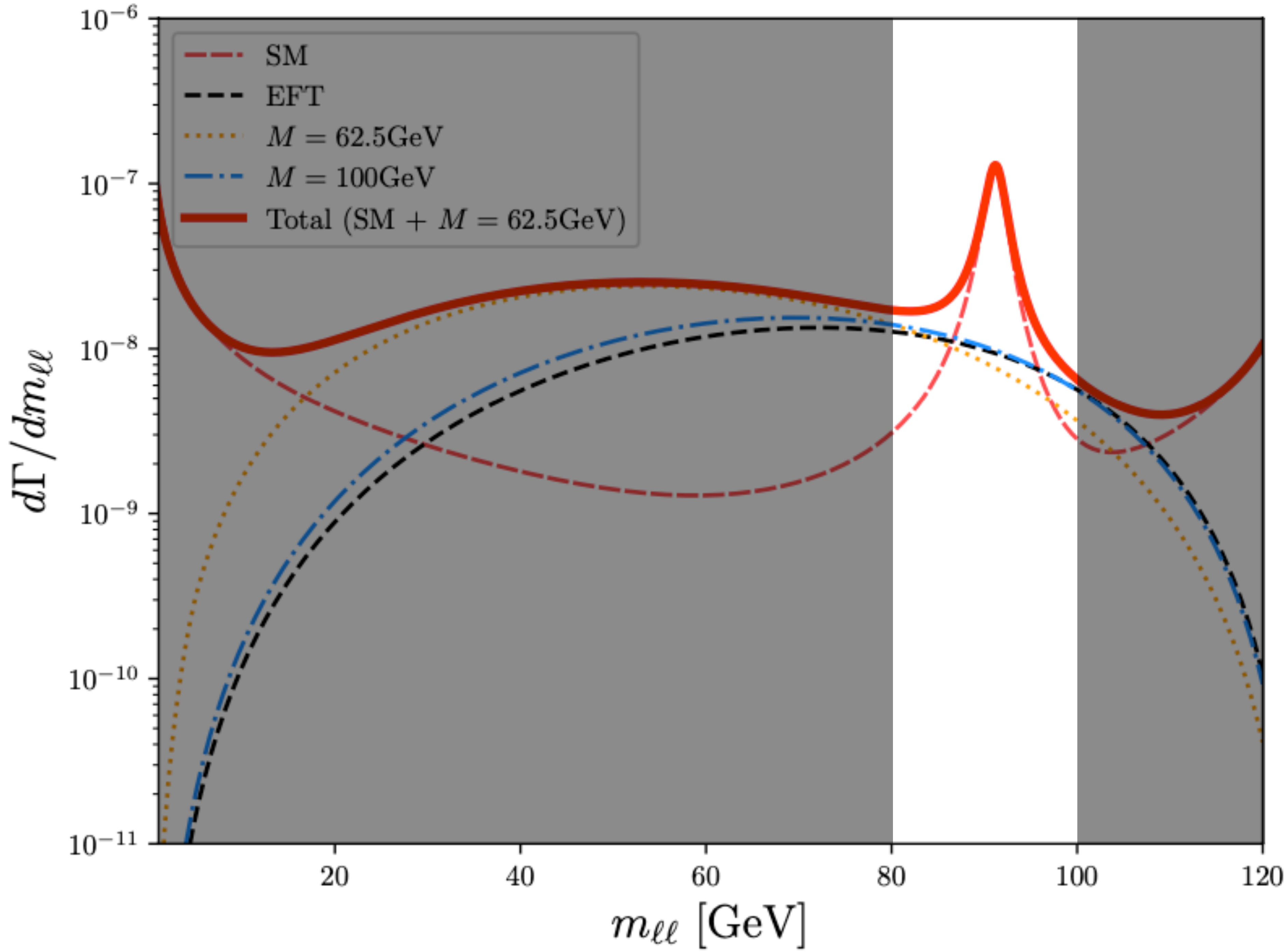
$H \to l^+l^-\gamma$: dileptons



$H \to l^+ l^- \gamma$: dileptons



$H \to l^+ l^- \gamma$: dileptons



Changing cuts ?

#	Cuts	$m_{\ell\ell}^{min}$[GeV]	$m_{\ell\ell}^{max}$[GeV]	$\frac{Br_{\rm resc}}{Br_{\rm SM}}$	$\frac{Br_{\rm EFT}}{Br_{\rm SM}}$	$\frac{Br_{\rm UV}}{Br_{\rm SM}}$
3	CMS	40	125	2.0	2.1	2.1
4	**CMS**	**50**	**125**	**2.1**	**2.1**	**2.1**
5	CMS	70	125	2.1	1.8	1.7
7	CMS	80	100	2.1	1.5	1.4

Tighter cuts
decrease
signal strength

CMS : $E_1 \geq 7$ GeV $E_2 \geq 25$ GeV $E_\gamma \geq 15$ GeV

Submitted to: Phys. Lett. B.

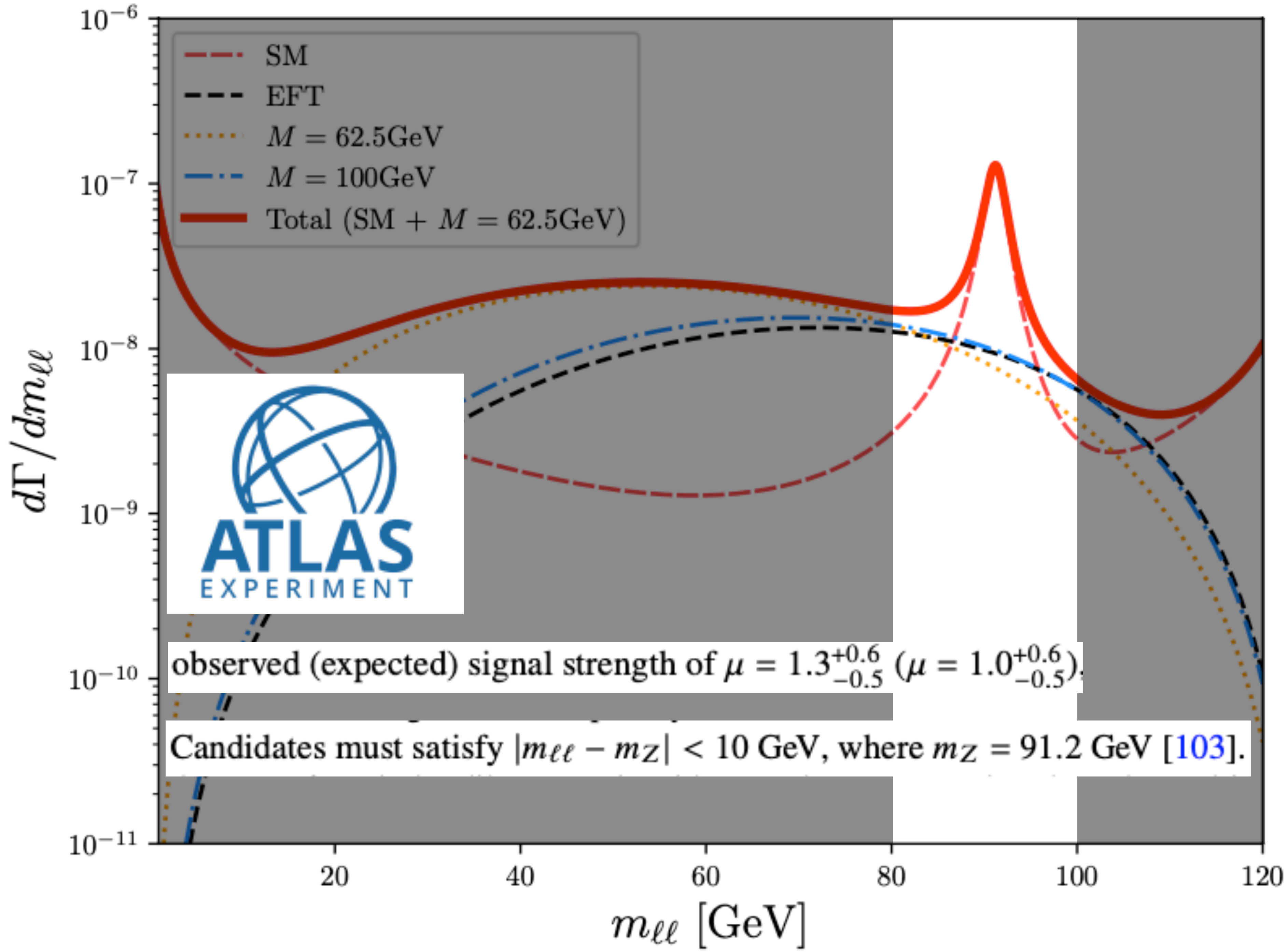
CERN-EP-2025-155
18th July 2025

Search for the Higgs boson decay to a Z boson and a photon in pp collisions at $\sqrt{s} = 13$ TeV and 13.6 TeV with the ATLAS detector

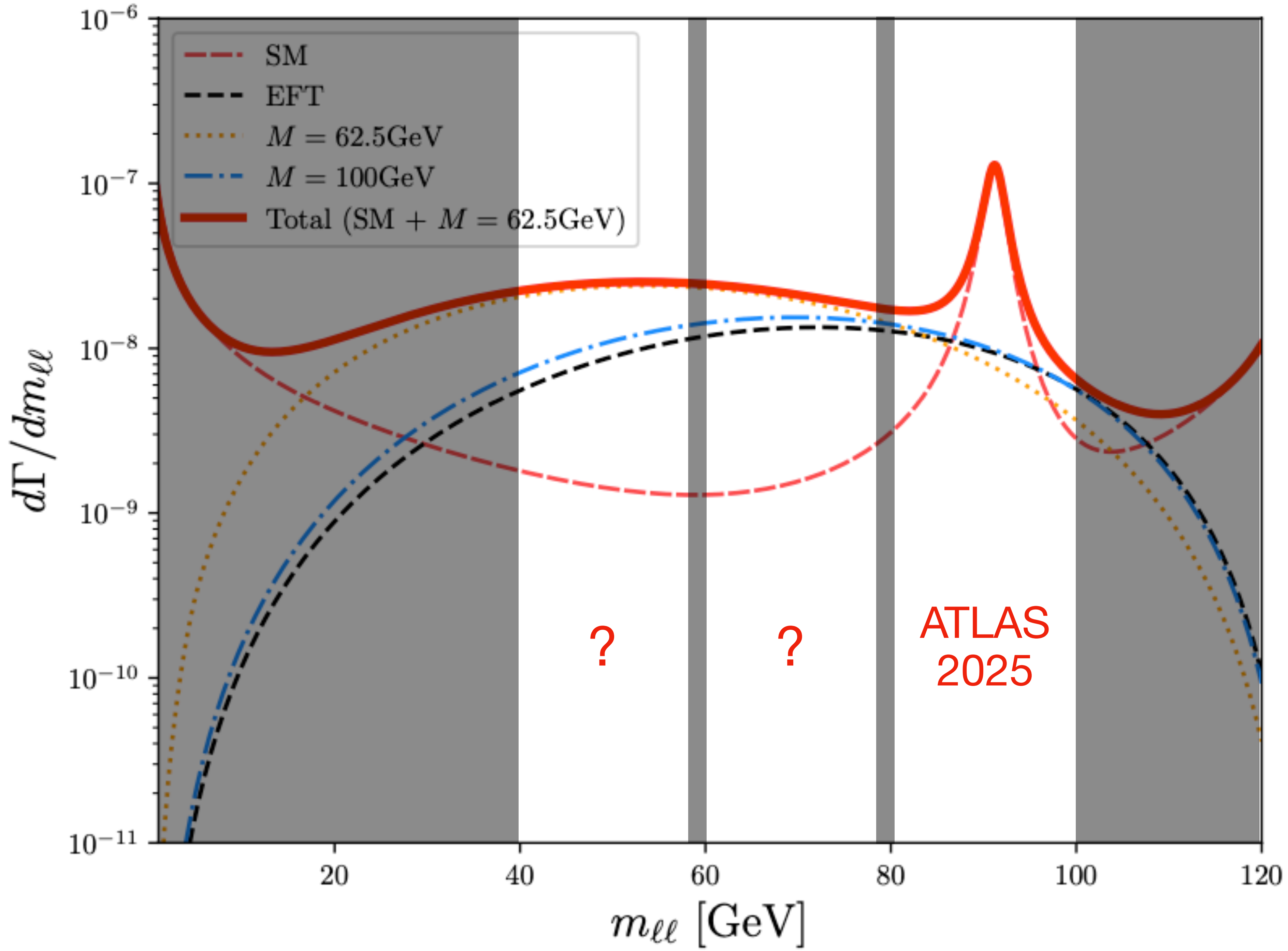
The ATLAS Collaboration

A search for the Higgs boson decay to a Z boson and a photon in the $\ell\ell\gamma$ ($\ell = e, \mu$) final state is performed using pp collisions at $\sqrt{s} = 13.6$ TeV recorded with the ATLAS detector at the Large Hadron Collider during 2022–2024, corresponding to an integrated luminosity of 165 fb^{-1}. The signal yield, normalised to the Standard Model prediction, is measured to be $\mu = 0.9^{+0.7}_{-0.6}$, compared to an expected value of $\mu = 1.0 \pm 0.7$. This corresponds to an observed (expected) signal significance of 1.4 (1.5) standard deviations for the background-only hypothesis. This result is combined with that of a similar search performed with 140 fb^{-1} of $\sqrt{s} = 13$ TeV pp collisions to provide the most stringent expected sensitivity to date to this rare decay, namely an observed (expected) signal strength of $\mu = 1.3^{+0.6}_{-0.5}$ ($\mu = 1.0^{+0.6}_{-0.5}$), corresponding to an observed (expected) significance of 2.5 (1.9) standard deviations. The measurement is consistent with the Standard Model expectation.

$H \to l^+ l^- \gamma$: dilepton invariant mass



Binning ?

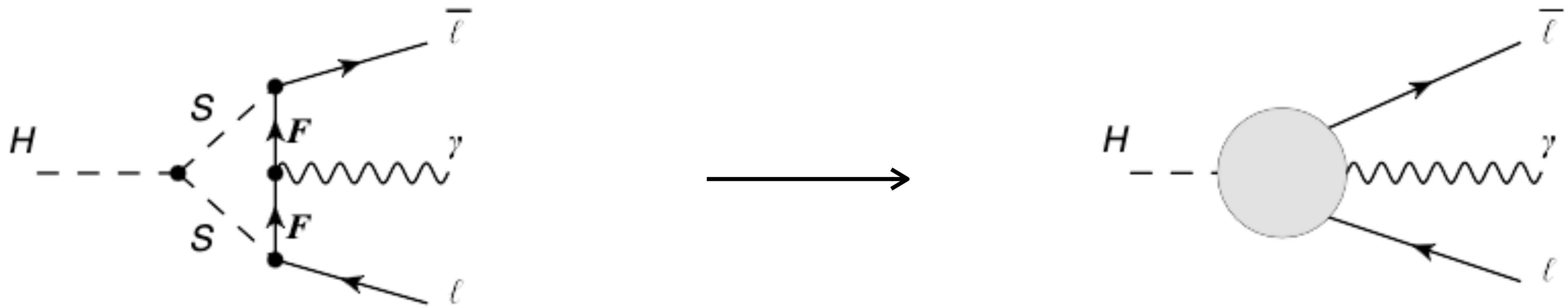


SM
EFT
$M = 62.5\text{GeV}$
$M = 100\text{GeV}$
Total (SM + $M = 62.5\text{GeV}$)
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
$d\Gamma/dm_{\ell\ell}$
20
40
60
80
100
120
$m_{\ell\ell}$ [GeV]
?
?
ATLAS
2025

Thank you for the message…

But what does it take ?

Toy model vs EFT



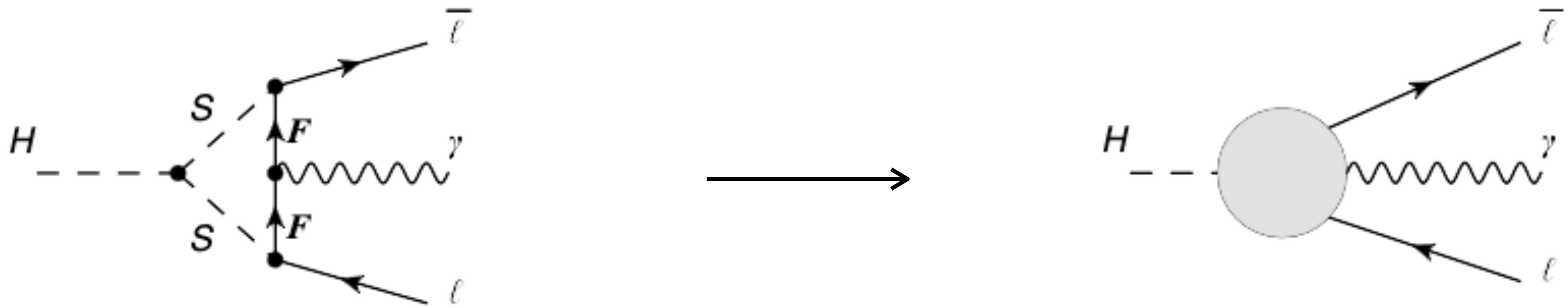
$$\mathcal{L} \supset \frac{1}{2}\partial_\mu S \partial^\mu S - \frac{1}{2} m_S^2 S^2 + \bar{F}(i\not{D} - m_F)F - \sum_\ell (y_\ell S \bar{F} \ell_R + h.c.) - \frac{\lambda_{hs}}{2} S^2 |\Phi|^2$$

$\longrightarrow$ $$\mathcal{L}_{\text{eff}} \supset \frac{g'}{\Lambda_R^4} |\Phi|^2 \partial_\nu (\bar{\ell}_R \gamma_\mu \ell_R) B^{\mu\nu}$$ dim 8 operator

$\longrightarrow$ $$\Delta \mathcal{M} = \frac{g' v}{\Lambda_R^4} \left[(q_\mu p_{1\nu} - g_{\mu\nu}\, q \cdot p_1) - (q_\mu p_{2\nu} - g_{\mu\nu}\, q \cdot p_2) \right] \bar{u}(p_2) \gamma^\mu P_R v(p_1) \varepsilon^{*\nu}(q)$$

$\longrightarrow$ $\Lambda_R \approx 260 \text{ GeV}$ for $\mu = 2.1$

Toy model vs EFT



$$\mathcal{L} \supset \frac{1}{2}\partial_\mu S \partial^\mu S - \frac{1}{2} m_S^2 S^2 + \bar{F}(i\not{D} - m_F)F - \sum_\ell (y_\ell S \bar{F} \ell_R + h.c.) - \frac{\lambda_{hs}}{2} S^2 |\Phi|^2$$

$\longrightarrow$ $$\mathcal{L}_{\text{eff}} \supset \frac{g'}{\Lambda_R^4} |\Phi|^2 \partial_\nu (\bar{\ell}_R \gamma_\mu \ell_R) B^{\mu\nu}$$ dim 8 operator

$\longrightarrow$ $$\Delta\mathcal{M} = \frac{g' v}{\Lambda_R^4}\left[(q_\mu p_{1\nu} - g_{\mu\nu}\, q \cdot p_1) - (q_\mu p_{2\nu} - g_{\mu\nu}\, q \cdot p_2)\right] \bar{u}(p_2)\gamma^\mu P_R v(p_1) \varepsilon^{*\nu}(q)$$

$\longrightarrow$ $\Lambda_R \approx 260$ GeV

No lepton flavour violation
Λ_R same for
electrons and muons…

Toy model point of view ?

1. $H \to l^+ l^- \gamma$ excess :

(BM2)

- $\frac{1}{\Lambda_R^4} \sim \frac{y_l^2 \lambda_{hs}}{16\pi^2 M^4}$ with $\Lambda_R \approx 260$ GeV $\begin{cases} m_{F,S} = \mathcal{O}(100) \text{ GeV} \\ y_l, \lambda_{\text{hs}} = \mathcal{O}(1) \end{cases}$

- no invisible Higgs decay : $m_S \gtrsim m_H/2$

- compressed mass spectrum : $m_F \gtrsim m_S$

- no lepton flavour violation : $y_e = y_\mu$ 🤮

Don’t know if this has a name

Constraints ?

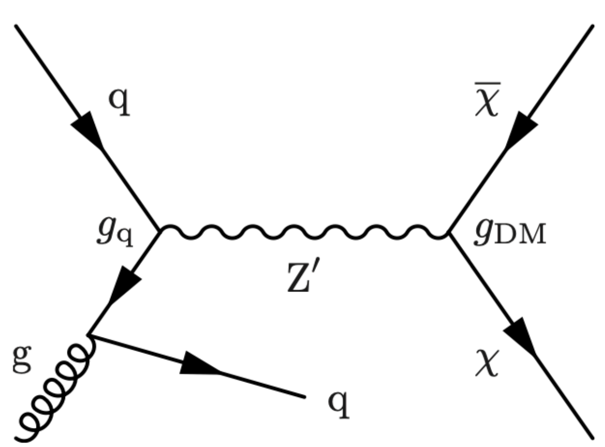
2. Other collider constraints

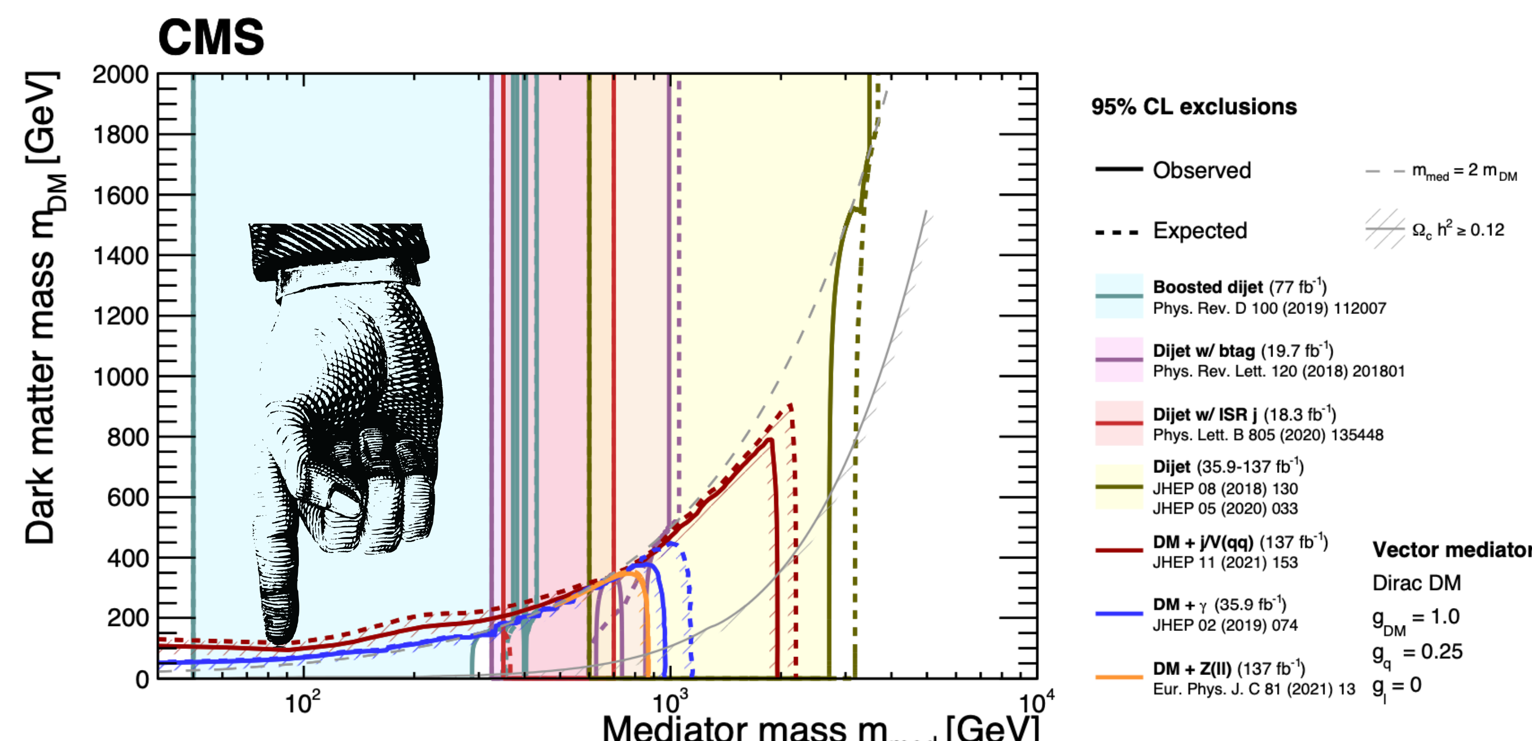
Compressed mass spectrum $m_F \gtrsim m_S$ and $y_l, \lambda_{\rm hs} = \mathcal{O}(1)$

$$pp \underset{\gamma/Z}{\longrightarrow} F + \bar{F} + \ldots \to l\,S + \bar{l}\,S + \ldots$$

soft leptons & S ~ missing E_T

Recasting CMS limits $m_\chi \gtrsim 108$ GeV $\to$ $m_F \gtrsim 67$ GeV





Constraints ?

3. Electroweak precision tests (in brief, no problem) 😮‍💨

$$F \sim (1, 1, -1) \longrightarrow \text{oblique parameters}$$

but $m_F \lesssim m_Z$ $\quad (S, \cancel{T}, U) \quad \rightarrow \quad (S, \cancel{T}, U, V, W, X)$

Maksymyk, Burgess & London (1994)

BM1 (BM2)

$$\left.\frac{\Delta\Gamma}{\Gamma}\right|_{\rm inv} = 0.0078\,|V| = 0.0002\,(0.00005) \;< 0.003$$

$$\left.\frac{\Delta\Gamma}{\Gamma}\right|_{\ell\ell} = |-0.0021\,S - 0.0044\,X + 0.0078\,V| = 0.0002\,(0.00006) \;< 0.001$$

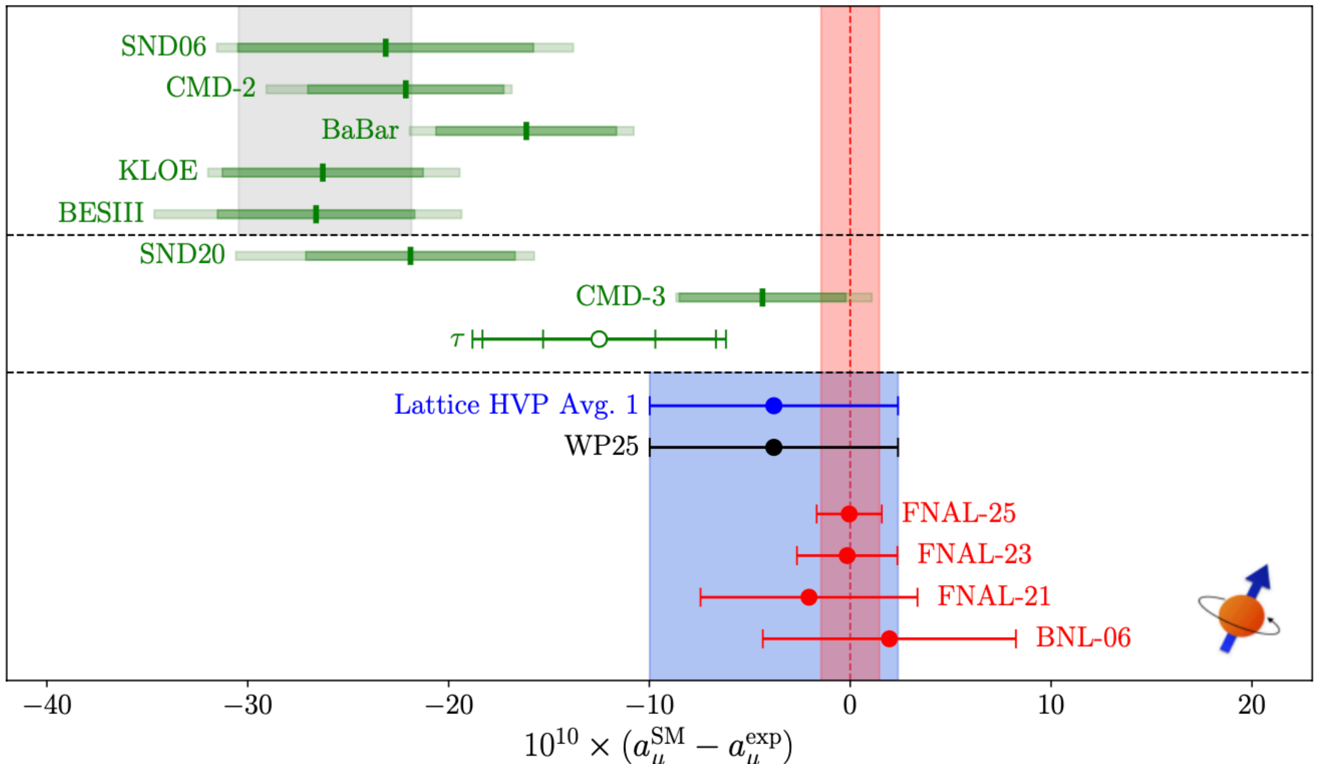
$$\Delta m_W = (-0.29\,S + 0.34\,U)\,\textbf{GeV} = 0.0082\,(0.0026)\,\textbf{GeV} \;< 0.013\,\textbf{GeV}$$

Albergaria, Jurciukonis & Lavoura (2024)

Moreno & MT (1994)

Constraints ?

4. Muon g-2



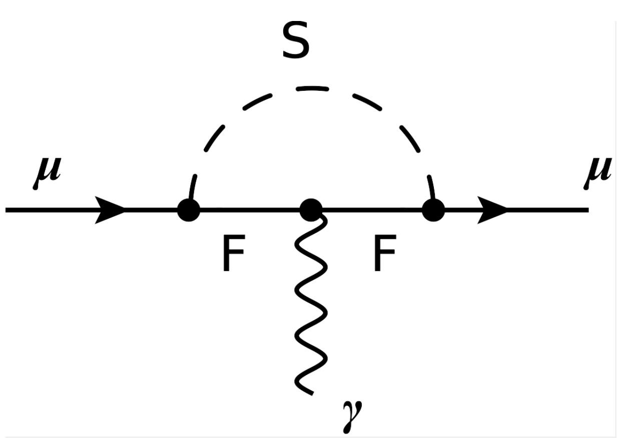
arXiv:2505.21476

Final result (runs 1-6) of Muon g-2 experiment @ FNAL

+ Lattice + CMD-3, etc

$$a_\mu^{exp} - a_\mu^{SM} = 38(63) \times 10^{-11}$$

Since September 2025, officially consistent with SM, so I put a constraint



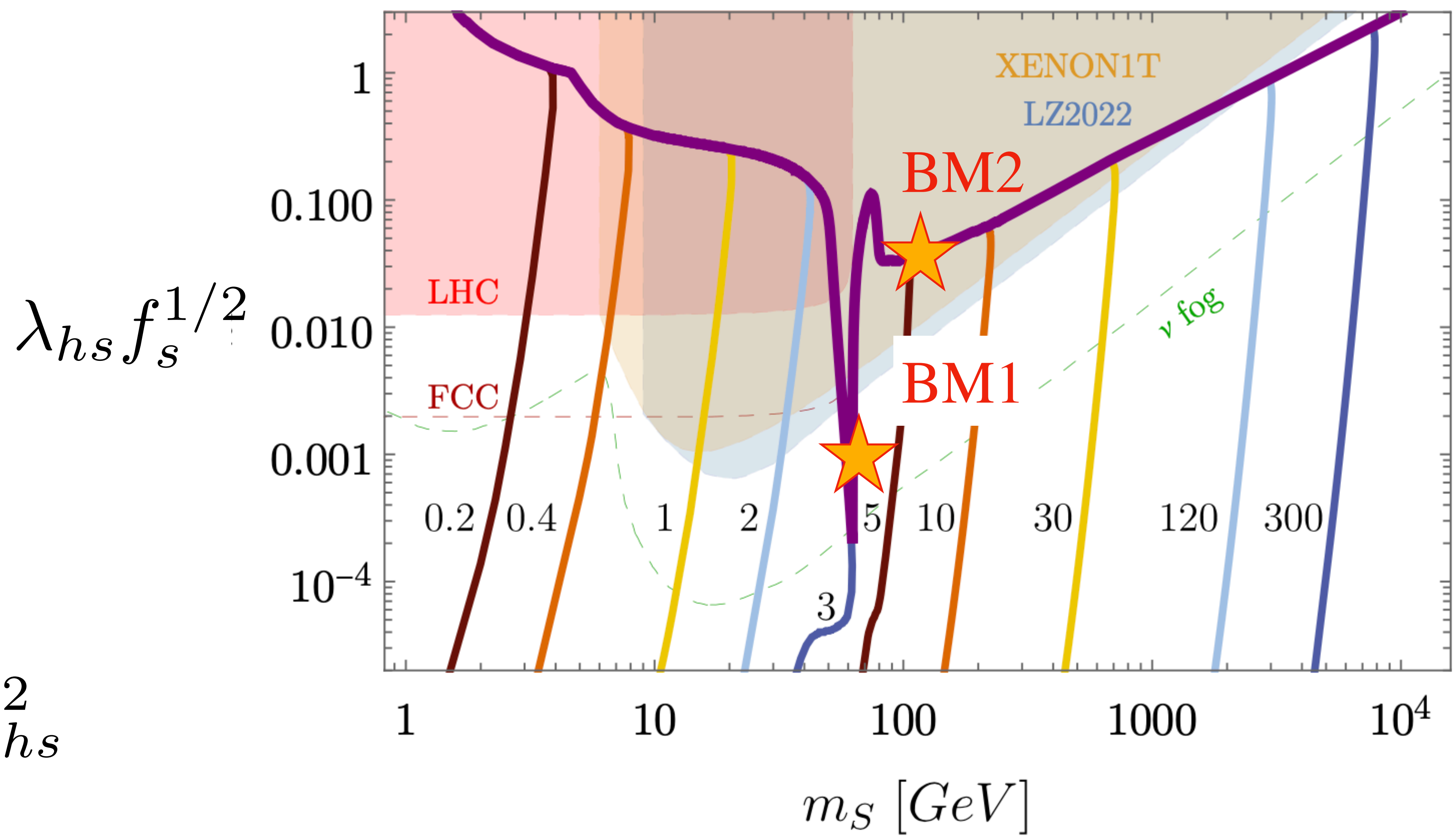
$$\Delta F_2(0) \hat{=} \Delta \left(\frac{g_\mu - 2}{2} \right) \hat{=} \Delta a_\mu = \frac{y_l^2}{192\pi^2} \frac{m_\mu^2}{M^2}$$

$$= 4\ 10^{-10}$$

for $y_\mu = 0.5$ and $m_S = 62.5$ GeV

Constraints ?

5. Dark matter ?



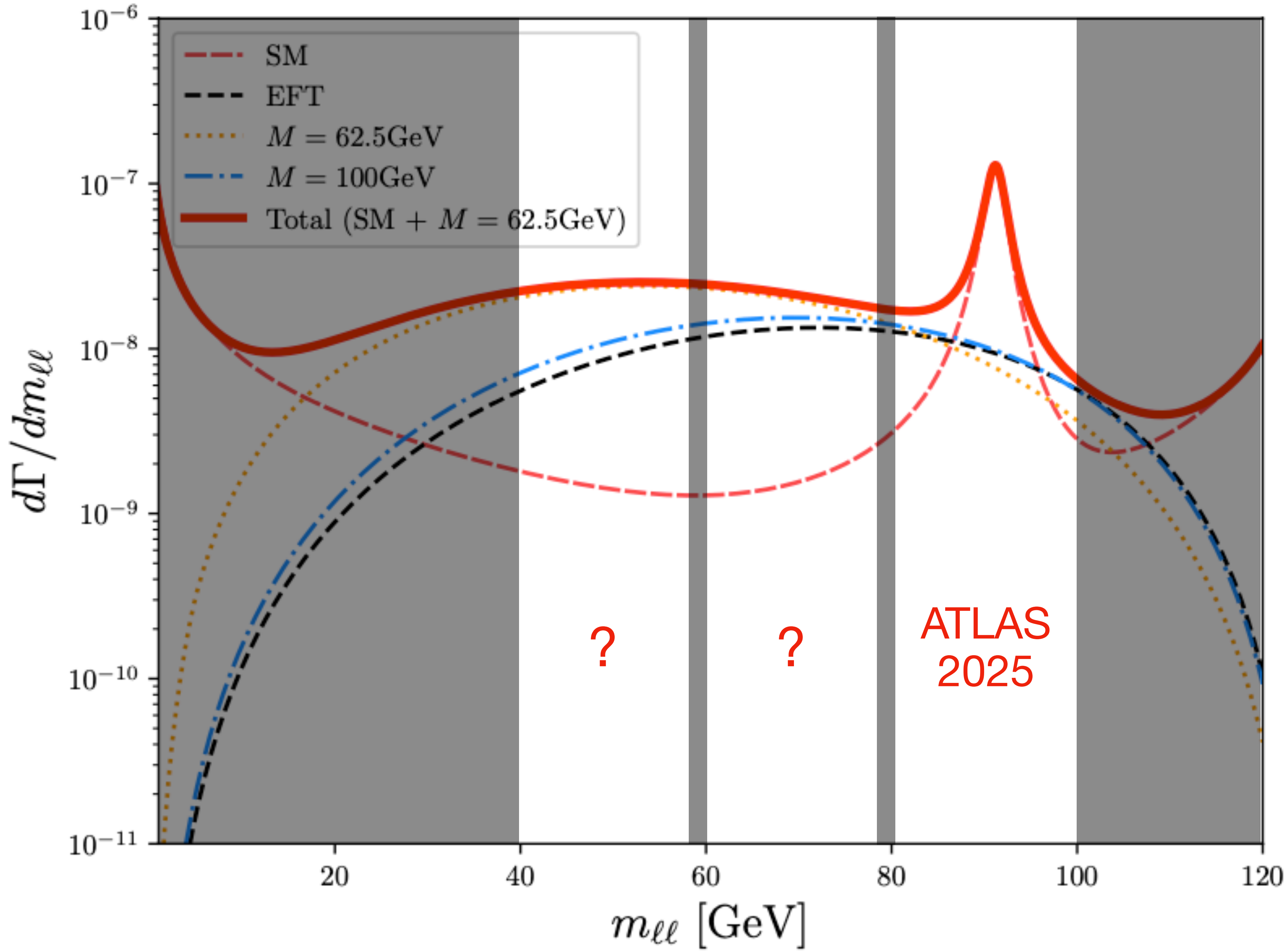
$$n_S \propto 1/\lambda_{hs}^2$$
$$\sigma_D \propto \lambda_{hs}^2$$
$$f_s = n_s/n_{dm}$$

$$\lambda_{hs} = \mathcal{O}(1) \longrightarrow f_s < 1$$

See Lebedev's talk

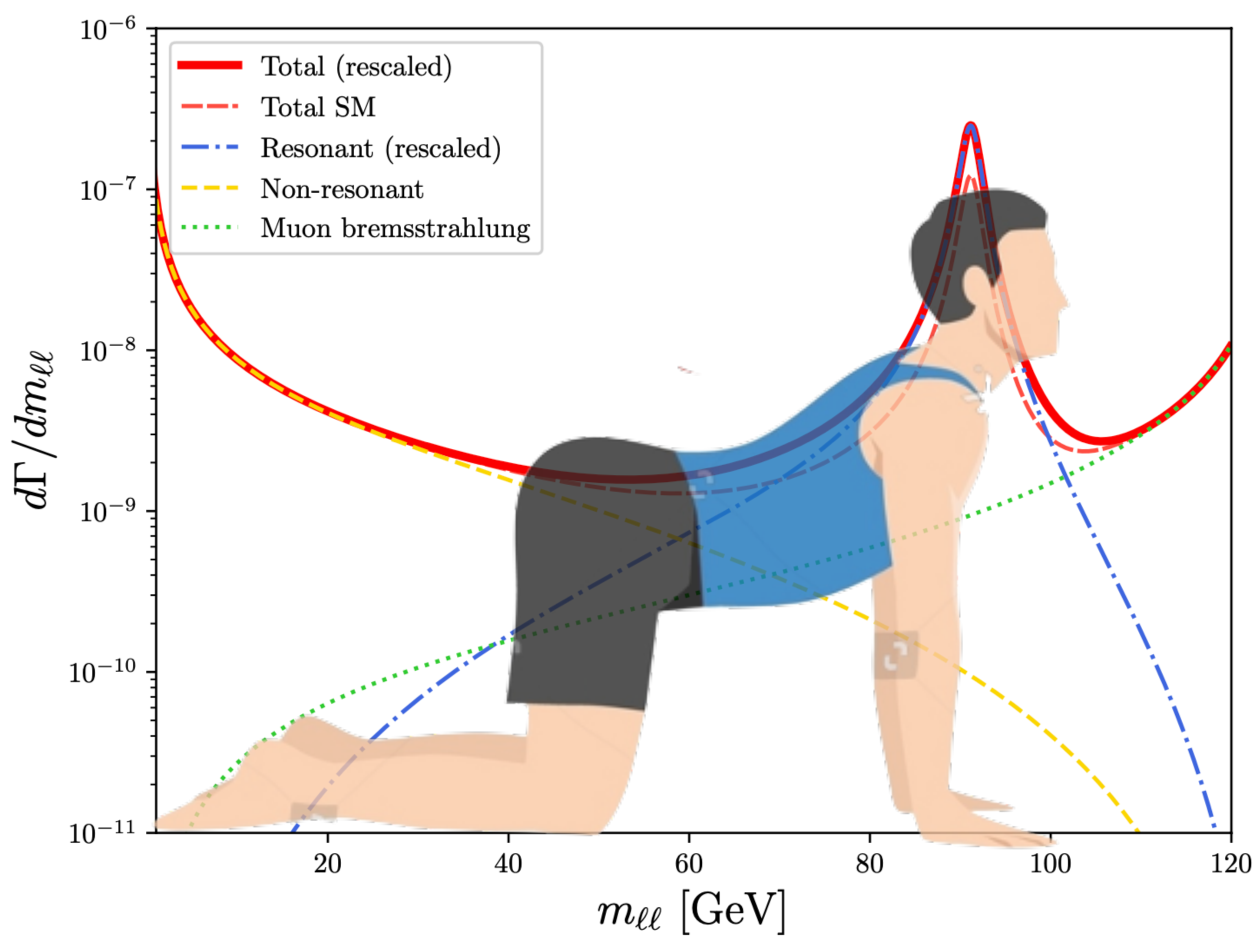
Conclusions

Conclusions



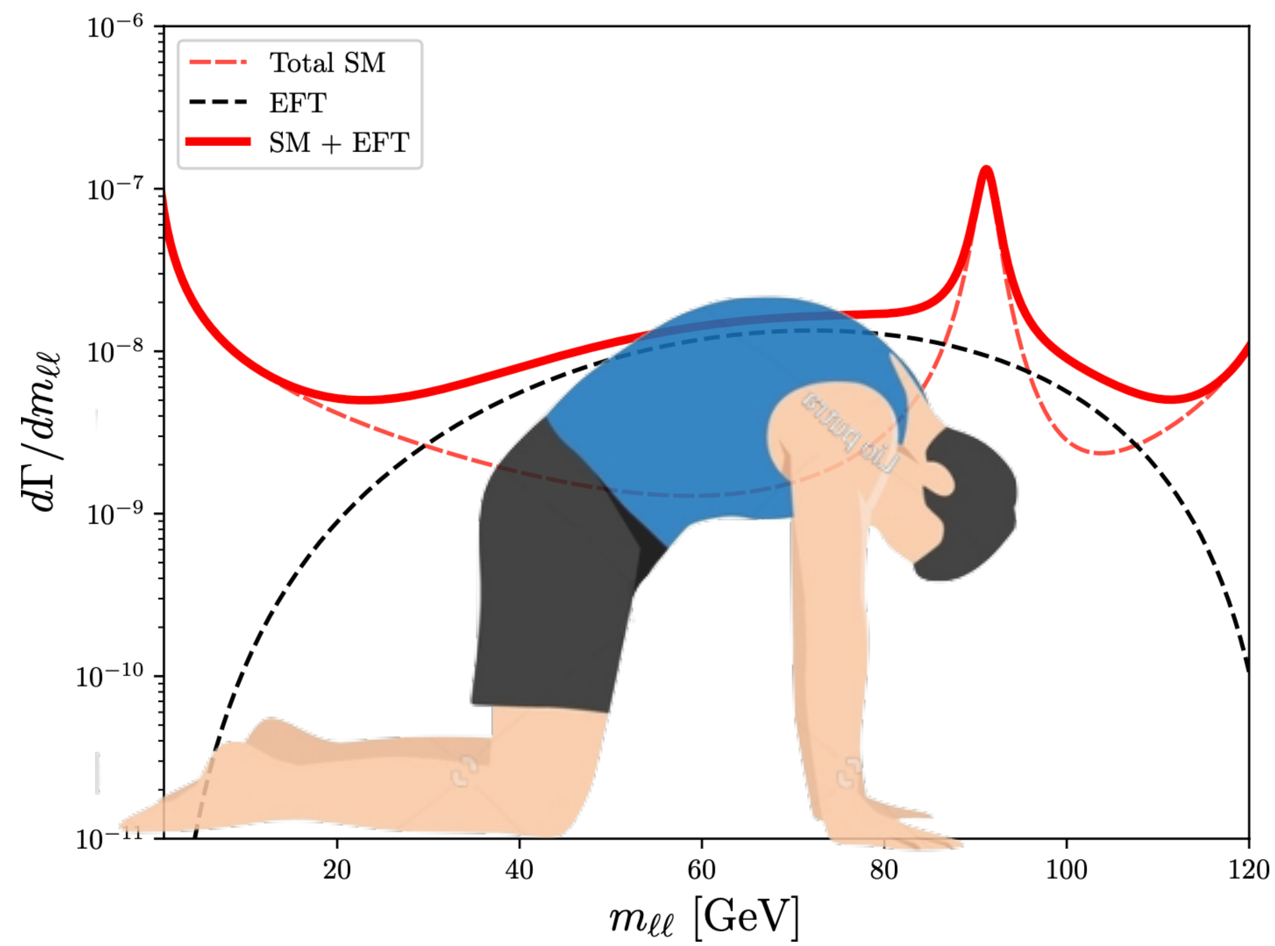
Conclusions

cow ?



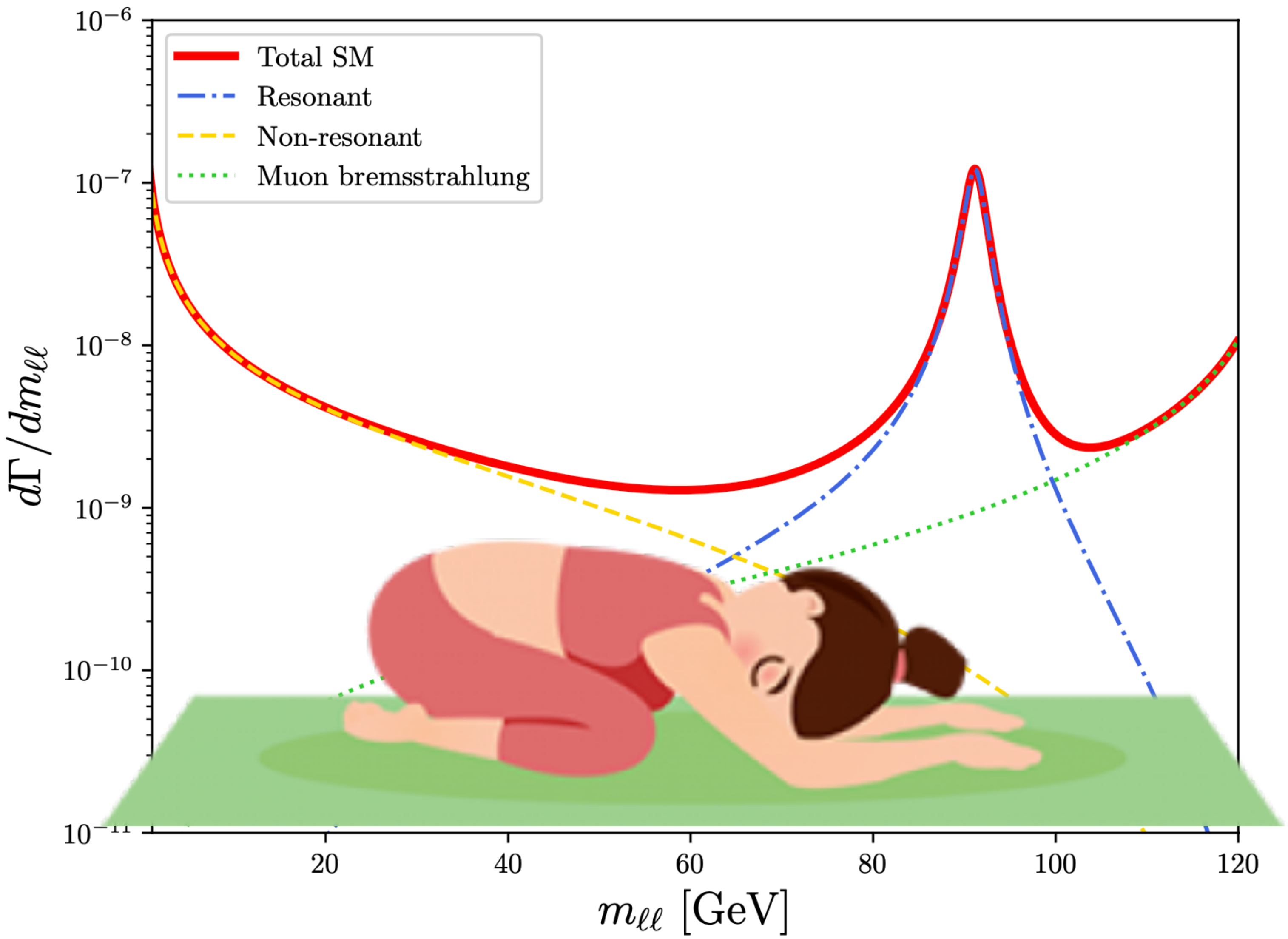
No, according to ATLAS 2025
Still, curious to see the CMS update

or cat ?



A matter of experimental analysis
Model building, while good for the back,
is, say, unconvincing

Conclusions



Very likely a mouse

(child or mouse pose, perfect for resting)

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Rencontres de Moriond

1966 - 2026

60 years discussing physics

15 - 22 March

EW - Electroweak Interactions & Unified Theories

VHEPU - Very High Energy Phenomena in the Universe

22 - 29 March

Cosmology

QCD and High Energy Interactions

Some backup slides

$H \to l^+ l^- \gamma$ in the SM

$$\mathcal{M}_{H\to f\bar{f}\gamma} = \left[q_\mu p_1 \cdot \varepsilon^*(q) - \varepsilon^*_\mu(q)\, q\cdot p_1\right] \bar{u}(p_2)\big(A_1\gamma^\mu P_R + B_1 \gamma^\mu P_L\big) v(p_1)$$
$$+ \left[q_\mu p_2 \cdot \varepsilon^*(q) - \varepsilon^*_\mu(q)\, q\cdot p_2\right] \bar{u}(p_2)\big(A_2\gamma^\mu P_R + B_2 \gamma^\mu P_L\big) v(p_1)$$

gauge-invariant

$q \to \epsilon^*(q)$

$$s = (p_1+p_2)^2, t = (p_1+q)^2, u = (p_2+q)^2$$
$$s+t+u = m_H^2 + 2m_l^2 \approx m_H^2$$
$A_2(s,u) = A_1(s, t\to u)$, etc

Gauge invariant separation of form factors $A_{1,2}$ & $B_{1,2}$

e.g.

$$A_1(s,t) = A_1^{res}(s) + A_1^{nr}(s,t)$$

with

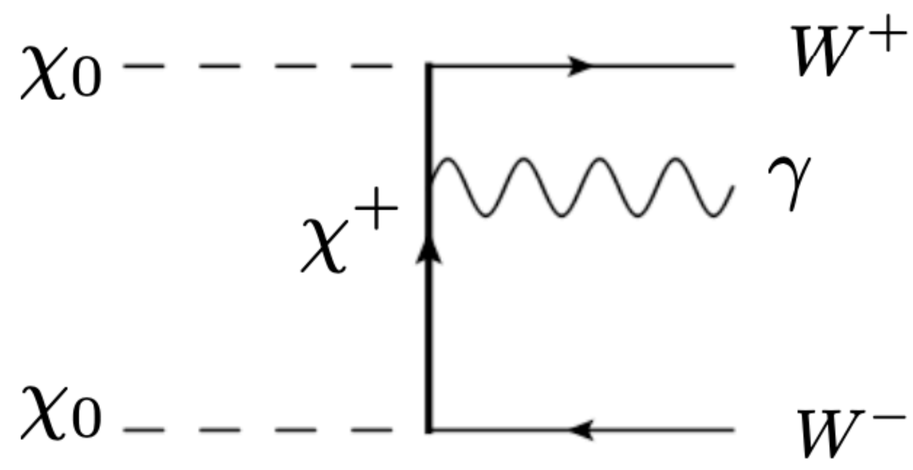
$$A_1^{res}(s) \equiv \frac{\alpha_1(m_Z^2)}{s - m_Z^2 + i m_Z \Gamma_Z} \qquad \text{and} \qquad A_1^{nr}(s,t) \equiv \tilde{A}_1(s,t) + \frac{\alpha_1(s) - \alpha_1(m_Z^2)}{s - m_Z^2 + i m_Z\Gamma_Z}$$

Kachanovich, Nierste & Nisandzic (2022)

$$
\begin{aligned}
\mathcal{M}_{H\to f\bar{f}\gamma} = \quad & \big[q_\mu p_1\cdot\varepsilon^*(q) - \varepsilon^*_\mu(q)\, q\cdot p_1\big]\,\bar{u}(p_2)\big(A_1\gamma^\mu P_R + B_1\gamma^\mu P_L\big)v(p_1) \\
+ \quad & \big[q_\mu p_2\cdot\varepsilon^*(q) - \varepsilon^*_\mu(q)\, q\cdot p_2\big]\,\bar{u}(p_2)\big(A_2\gamma^\mu P_R + B_2\gamma^\mu P_L\big)v(p_1)
\end{aligned}
$$

$$
\begin{aligned}
\Delta B_1 \;=\;& \frac{3\pi^2 e^2 Y^2 m_H^2}{4 m_W \sin\theta_W} \\
\times\;& \Bigg\{ \frac{3}{t\,(s+t)}\Big[B_0(t,m_F^2,m_S^2) - B_0(m_H^2,m_S^2,m_S^2)\Big] \\
& -\frac{2(m_F^2-m_S^2)}{s\,t^2(s+t)}\Big[(s^2+2s\,t+t^2)C_0(0,m_H^2,u,m_F^2,m_S^2,m_S^2) \\
& \quad +(s+t)\big(u\,C_0(0,0,u,m_F^2,m_F^2,m_S^2)-(s+u)C_0(0,t,m_H^2,m_S^2,m_F^2,m_S^2)\big) \\
& \quad +t\,(s+t)C_0(0,0,t,m_F^2,m_F^2,m_S^2)\Big] \\
& -\frac{2}{s\,t^2}\Big[2m_F^2m_S^2m_H^2 - m_F^4m_H^2 - m_F^2m_H^2t - m_S^4m_H^2 + m_S^2m_H^2t \\
& \quad +m_F^4s - 2m_F^2m_S^2s - m_F^2s\,t + m_F^2t^2 + m_S^4s - m_S^2s\,t - m_S^2t^2\Big] \\
& \times D_0(0,0,0,m_H^2,t,u,m_S^2,m_F^2,m_F^2,m_S^2)\Bigg\}
\end{aligned}
$$

VIRTUAL INTERNAL BREMSSTRAHLUNG



2 circumstances in which emission from a virtual state may be dominant compared to FSR:

A. Charged bosons in final state, e.g. W±, provided $M_{\chi_0} \gg M_W$ and $M_{\chi_0} \sim M_{\chi^+}$

$$\mathcal{M} \propto ((p_{\chi_0} - p_W)^2 - M^2_{\chi^\pm})^{-1} \sim (M^2_{\chi_0} - 2E_W M_{\chi_0} - M^2_{\chi^\pm})^{-1}$$

Potentially large enhancement for soft W emission, corresponding to $E_\gamma \sim M_{\chi_0}$

Bergstrom, Bringmann, Eriksson and Gustafsson
Phys.Rev.Lett. 95 (2005) 241301

Binning ?

	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-125
$\Gamma_{\rm SM}$	0.004	0.004	0.006	0.014	0.119	0.295	0.008	0.000
$\Gamma_{\rm tree}$	0.000	0.000	0.000	0.001	0.002	0.003	0.004	0.000
$\Gamma_{\rm NR}$	0.004	0.003	0.003	0.001	0.001	0.001	0.000	0.000
$\Gamma_{\rm resc}$	0.001	0.002	0.006	0.023	0.242	0.621	0.008	0.000
$\Gamma_{\rm EFT}$	0.024	0.046	0.078	0.119	0.118	0.079	0.035	0.000
$\Gamma_{\rm UV62}$	0.040	0.067	0.098	0.129	0.103	0.053	0.017	0.000
$\Gamma_{\rm UV100}$	0.027	0.048	0.080	0.121	0.117	0.074	0.031	0.000

TABLE II. Binned decay rates (in keV), using CMS cuts, for different intervals of dilepton invariant mass $m_{\ell\ell}$ (in GeV). The first 3 lines correspond to the SM. Γ_{SM} is the total SM contribution, $\Gamma_{\rm tree}$ the contribution from Bremsstrahlung and $\Gamma_{\rm NR}$ the one from the SM non-resonant contributions. The separation between the various processes is explained in Section II. The four last lines correspond to possible new physics. Line 4 is the contribution of the rescaled Z peak, essentially as reported by the ATLAS and CMS collaborations, see Section III A; Γ_{EFT} the contribution from the effective operator, Section III B; Γ_{UV62} the UV model with masses $m_F = m_S = 62.5$ GeV; Γ_{UV100} the same with $m_F = m_S = 100$ GeV.