



## *HIGGS BR*

Michael Spira (PSI)

Theory convenors: Sven Heinemeyer, Alexander Mück, Michael Spira

Exp. convenors: Ivica Puljak (CMS), Daniela Rebuszi (ATLAS)

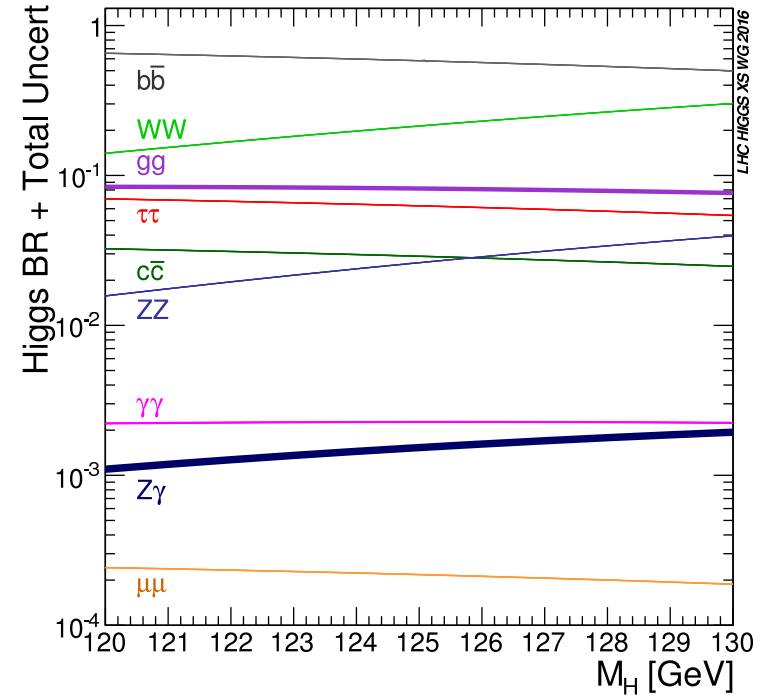
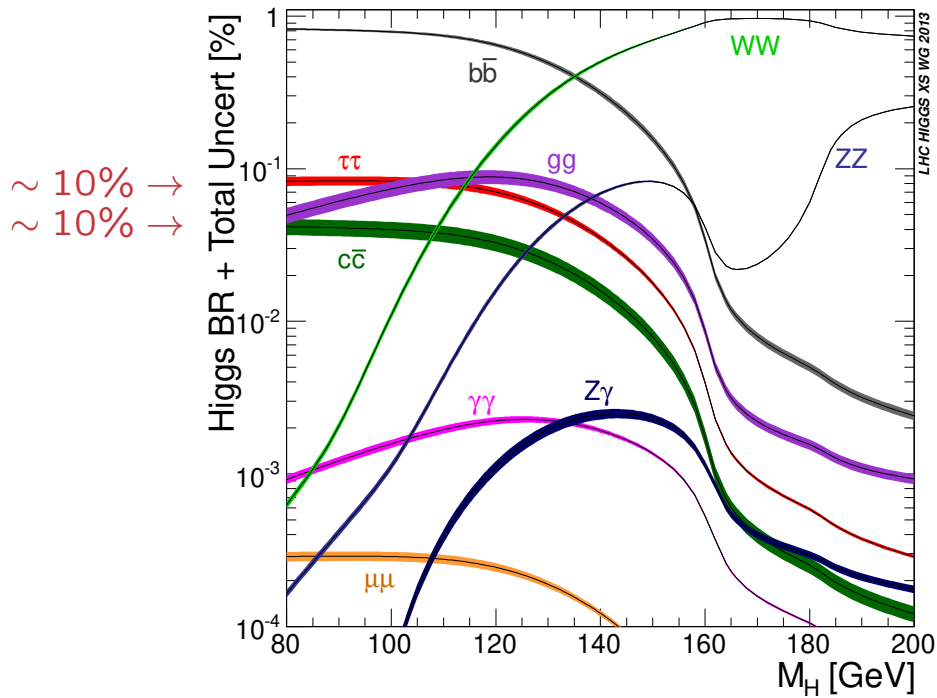
former convenor: Ansgar Denner

# Higgs Boson BRs

YR3 (2013)

HDECAY & Prophecy4f

YR4 (2016)



Denner, Heinemeyer, Puljak, Rebuszi, S.

- refinements input parameters
- full NLO elw. corrections to  $H \rightarrow f\bar{f}$
- NLO quark-mass effects in  $H \rightarrow gg$

Partial Width	QCD	Electroweak	Total	on-shell Higgs
$H \rightarrow b\bar{b}/c\bar{c}$	$\sim 0.2\%$	$\sim 0.5\%$	$\sim 0.5\%$	N <sup>4</sup> LO / NLO
$H \rightarrow \tau^+\tau^-/\mu^+\mu^-$		$\sim 0.5\%$	$\sim 0.5\%$	NLO
$H \rightarrow gg$	$\sim 3\%$	$\sim 1\%$	$\sim 3\%$	N <sup>3</sup> LO approx. / NLO
$H \rightarrow \gamma\gamma$	$< 1\%$	$< 1\%$	$\sim 1\%$	NLO / NLO
$H \rightarrow Z\gamma$	$< 1\%$	$\sim 5\%$	$\sim 5\%$	(N)LO / LO
$H \rightarrow WW/ZZ \rightarrow 4f$	$< 0.5\%$	$\sim 0.5\%$	$\sim 0.5\%$	(N)NLO

- parametric uncertainties:

$$m_t = 172.5 \pm 1 \text{ GeV}$$

$$\alpha_s(M_Z) = 0.118 \pm 0.0015$$

$$m_b(m_b) = 4.18 \pm 0.03 \text{ GeV}$$

$$m_c(3\text{GeV}) = 0.986 \pm 0.025 \text{ GeV}$$

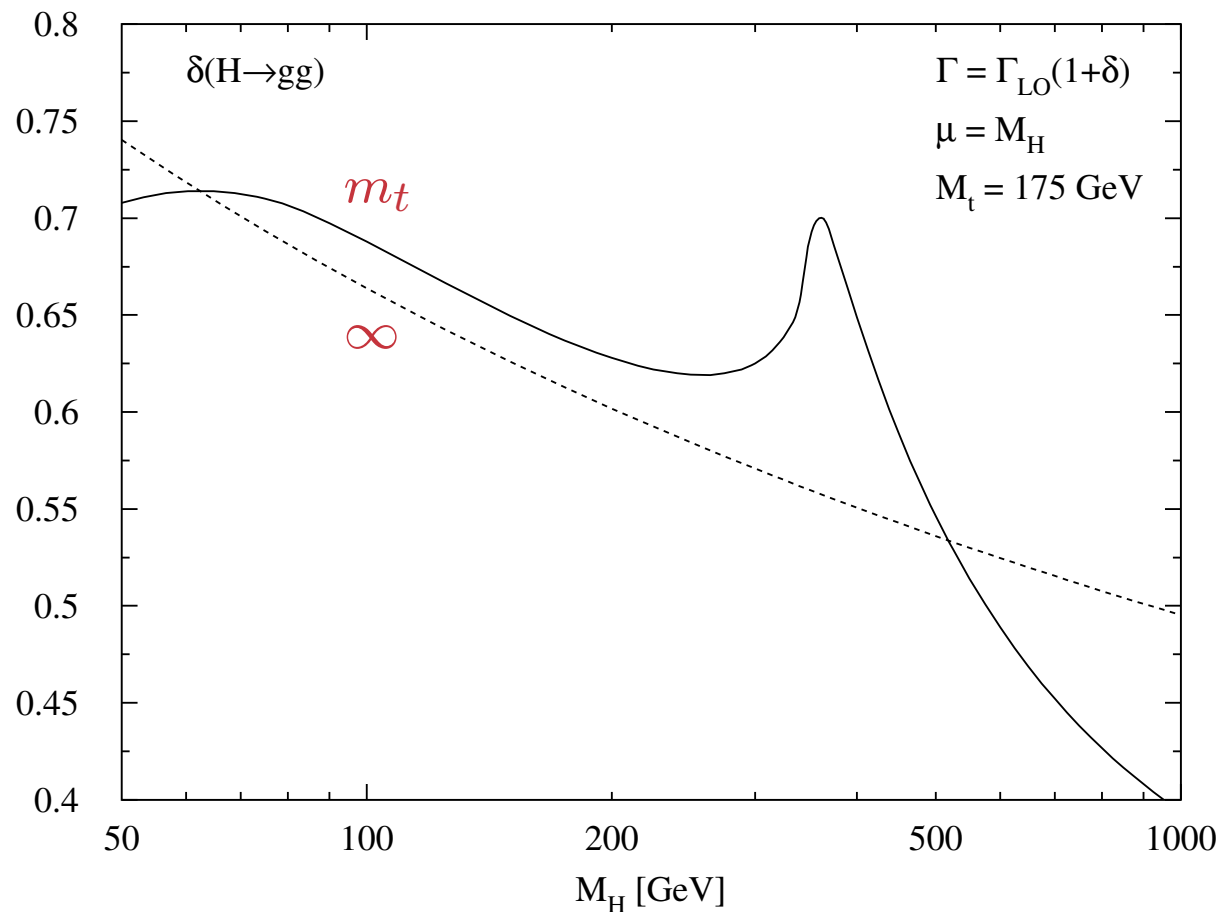
different uncertainties added quadratically for each channel

- total uncertainties: parametric & theor. uncertainties added linearly
- dominated by parametric uncertainties:  $m_b(b\bar{b}), \alpha_s(gg), m_c(c\bar{c})$
- parametric unc. from  $M_H$  small

	FCC <sub>ee</sub>	current th.	current par.
$H \rightarrow b\bar{b}$	0.8%	0.5%	2.2%
$H \rightarrow c\bar{c}$	1.4%	0.5%	5.5%
$H \rightarrow \tau^+\tau^-$	1.1%	0.5%	< 0.1%
$H \rightarrow \mu^+\mu^-$	12%	0.5%	< 0.1%
$H \rightarrow gg$	1.6%	3.2%	3.0%
$H \rightarrow \gamma\gamma$	3.0%	1.0%	< 0.1%
$H \rightarrow Z\gamma$	???	5.0%	< 0.1%
$H \rightarrow WW$	0.4%	0.5%	< 0.1%
$H \rightarrow ZZ$	0.3%	0.5%	< 0.1%

## open issues in HDECAY:

- Dalitz decays ( $H \rightarrow \gamma\gamma \Leftrightarrow Z\gamma \Leftrightarrow l^+l^-\gamma$ )  $\Rightarrow$  refined def. of  $H \rightarrow Z\gamma$ ?  
Chen, Chen, Qiao, Zhu  
Sang, Feng, Jia
- NLO elw. corrections to  $H \rightarrow Z\gamma$
- numbers and uncertainties for Yukawa-induced  $H \rightarrow s\bar{s}$
- NLO mass effects in  $H \rightarrow gg$  up to  $M_H = 3$  TeV ( $\leftarrow$  BSM)

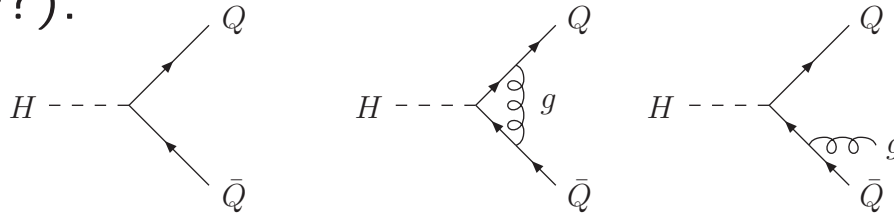


S., Djouadi, Graudenz, Zerwas

# HIGGS DALITZ DECAYS

(i) strong:

- $H \rightarrow b\bar{b}, c\bar{c}, (s\bar{s}?)$ :

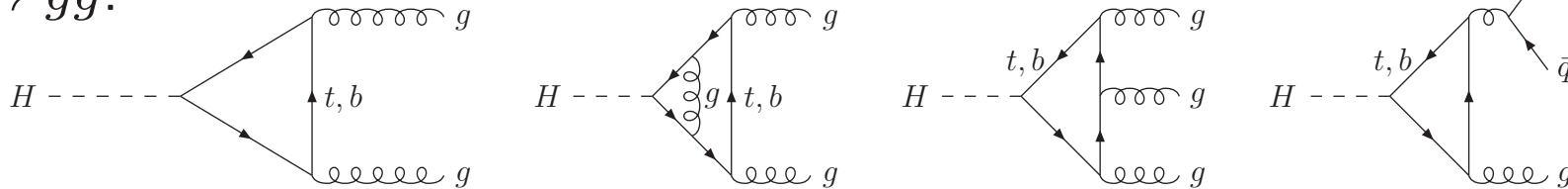


$$\Gamma = \Gamma_{LO}(1 + \delta)$$

$$\delta \sim 25\%$$

Braaten, Leveille  
Drees, Hikasa  
Gorishnii, Kataev, Larin, Surguladze  
Chetyrkin, Kwiatkowski, Steinhauser, Baikov

- $H \rightarrow gg$ :



$$\Gamma = \Gamma_{LO}(1 + \delta)$$

$$\delta \sim 100\%$$

Inami, Kubota, Okada  
S., Djouadi, Graudenz, Zerwas  
Chetyrkin, Kniehl, Steinhauser  
Baikov, Chetyrkin

$$\delta_{b,c,s} = \left\{ -\frac{7}{2} + \frac{1}{3} \left[ \log \frac{M_H^2}{m_b^2} + \log \frac{M_H^2}{m_c^2} + \log \frac{M_H^2}{m_s^2} \right] \right\} \frac{\alpha_s}{\pi}$$

- resummation of logs (inclusive decay width):

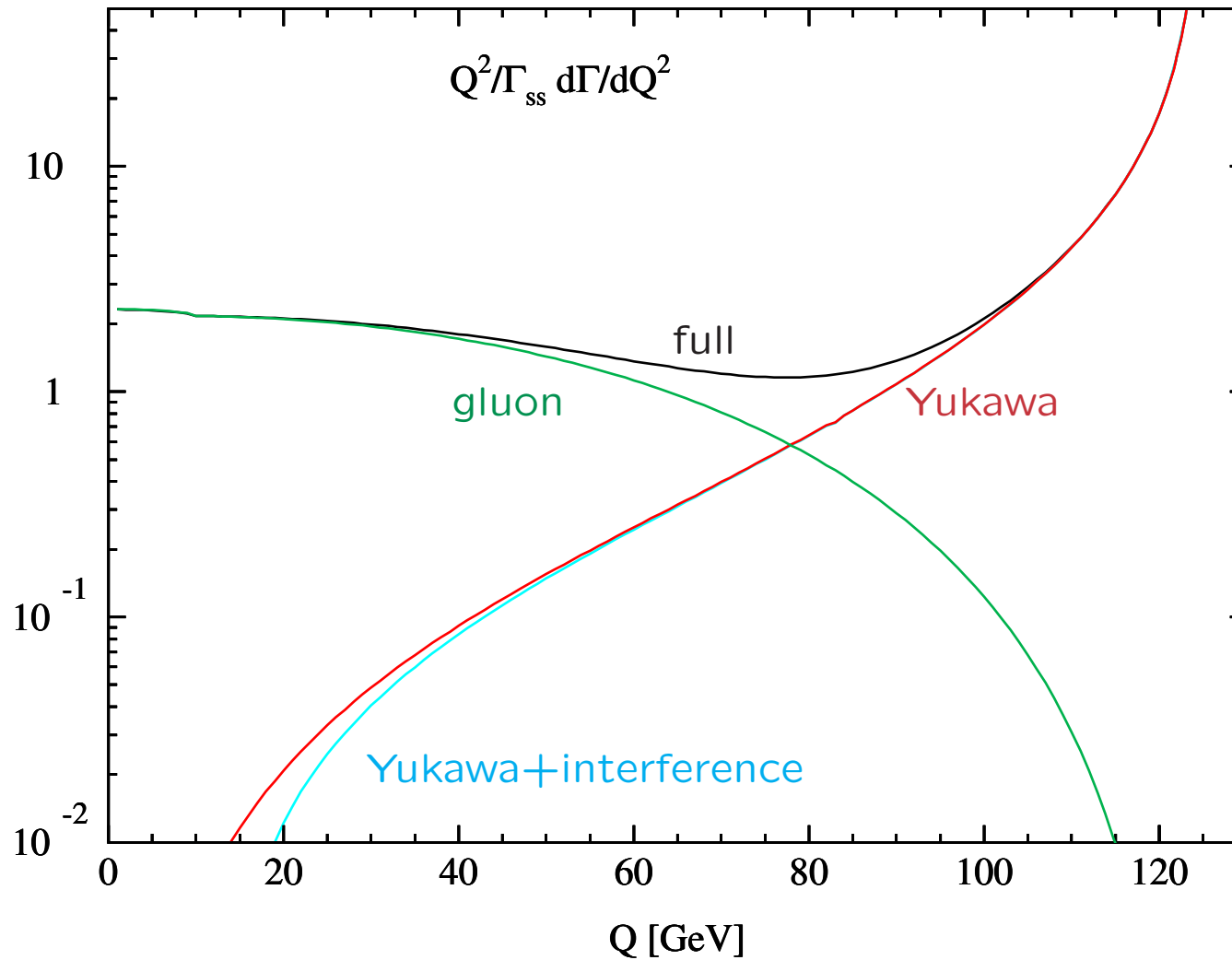
$$\begin{aligned}
 \Gamma[H \rightarrow gg] &= \Gamma^{3FS} \\
 \delta\Gamma[H \rightarrow b\bar{b} + \dots] &= \Gamma^{5FS} - \Gamma^{4FS} \\
 \delta\Gamma[H \rightarrow c\bar{c} + \dots] &= \Gamma^{4FS} - \Gamma^{3FS} \\
 \delta\Gamma[H \rightarrow s\bar{s} + \dots] &= \Gamma^{3FS} - \Gamma^{2FS} \quad ?? \quad \text{Djouadi, S., Zerwas}
 \end{aligned}$$

$$H \rightarrow b\bar{b} : 1\% \quad [BR(H \rightarrow b\bar{b}) \approx 58\% \rightarrow 0.6\%]$$

$$H \rightarrow c\bar{c} : 27\% \quad [BR(H \rightarrow c\bar{c}) \approx 2.9\% \rightarrow 0.8\%]$$

- $BR(H \rightarrow s\bar{s})_{Yuk} \sim 0.022\%$  ( $\overline{MS}$  mass)
- exclusive? impact of cuts? matching scale for 2FS?

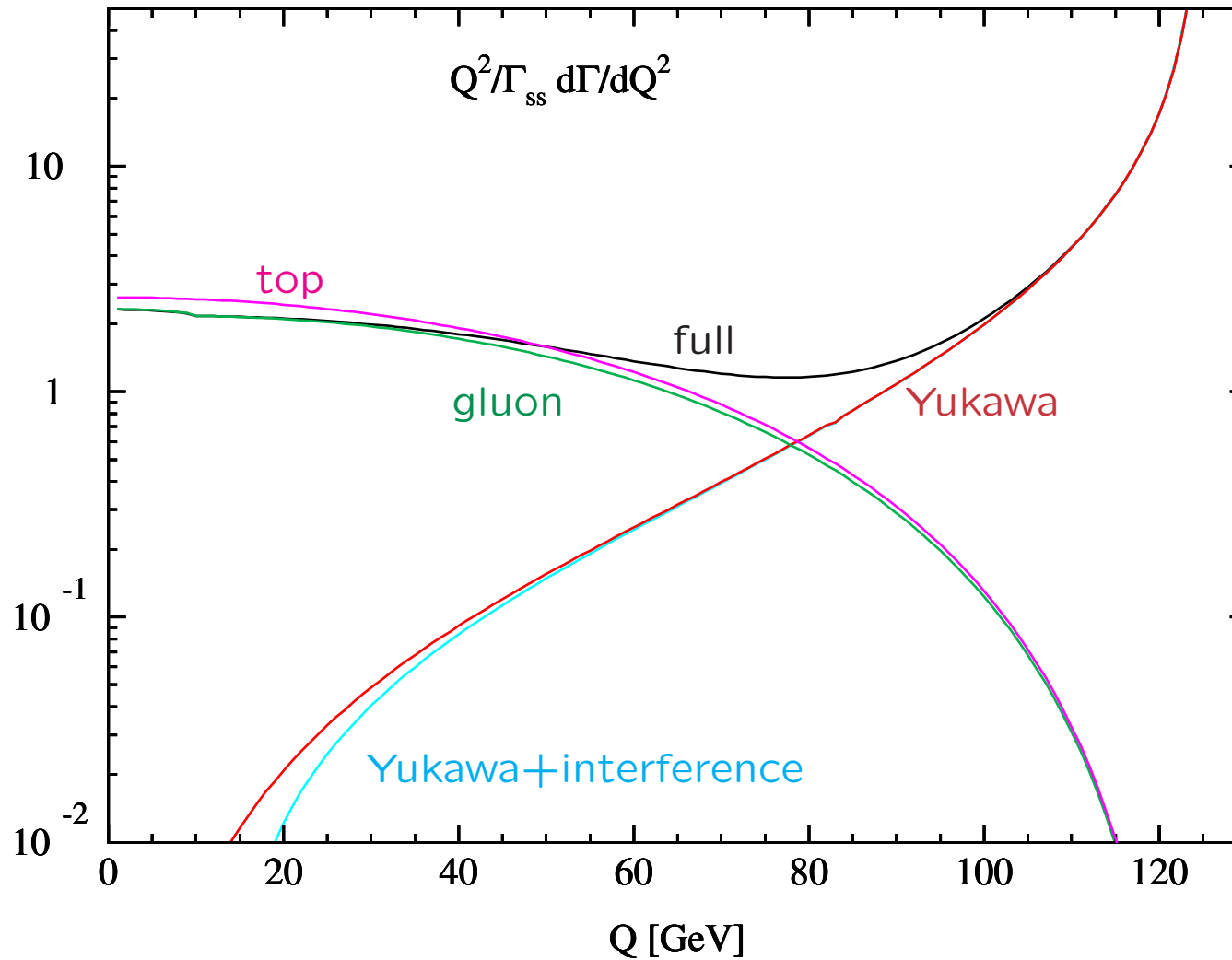
$H \rightarrow s\bar{s}g$



- using  $\bar{m}_s(M_H)$  (neglecting regular mass effects)
- no resummation towards the end-point

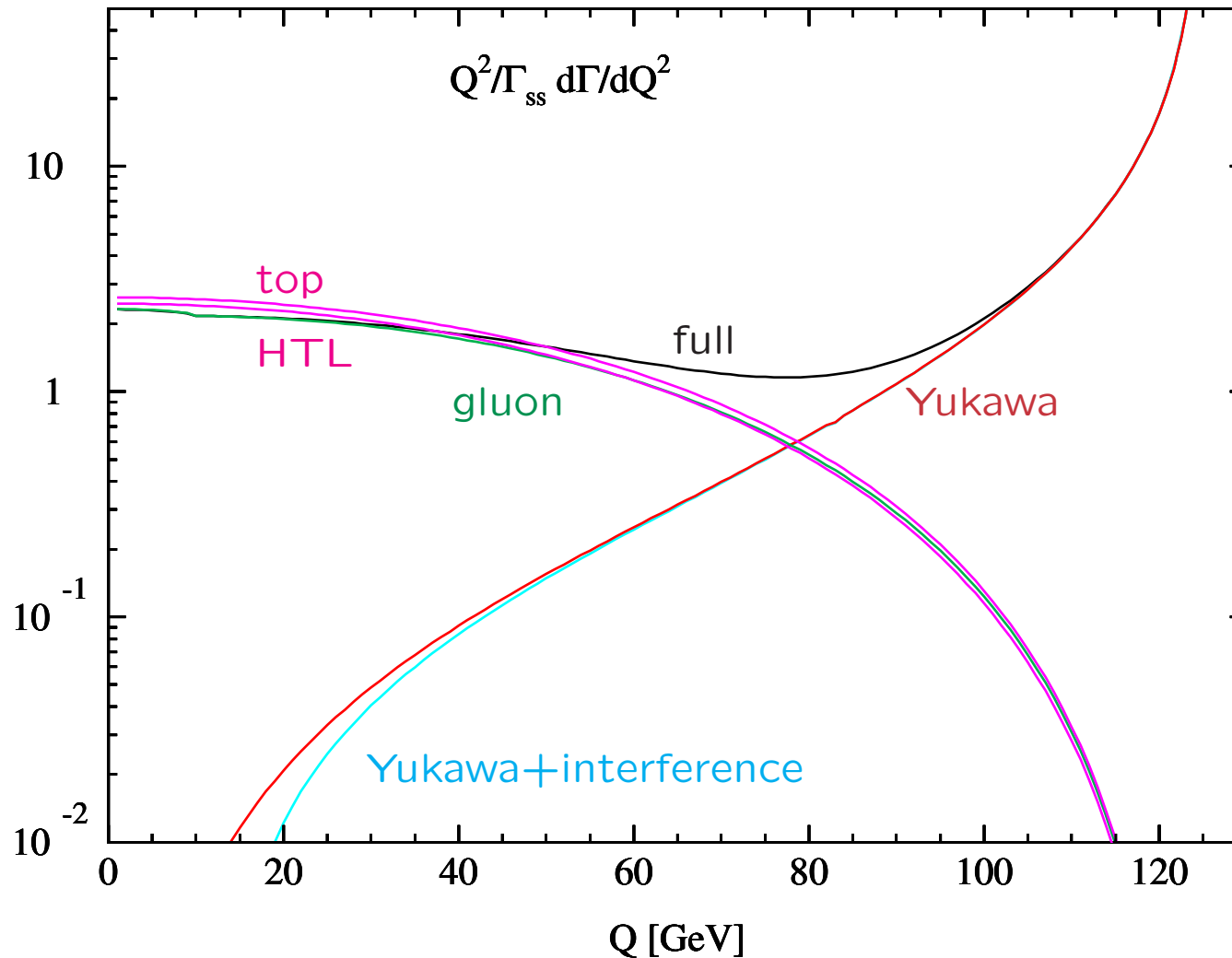


$H \rightarrow s\bar{s}g$



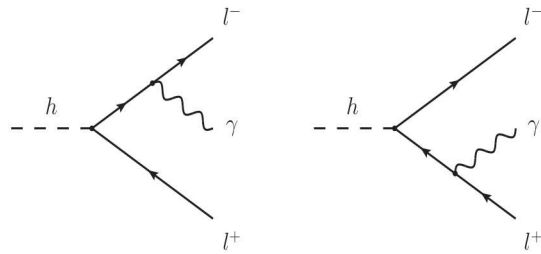
- using  $\bar{m}_s(M_H)$  (neglecting regular mass effects)
- no resummation towards the end-point

$H \rightarrow s\bar{s}g$

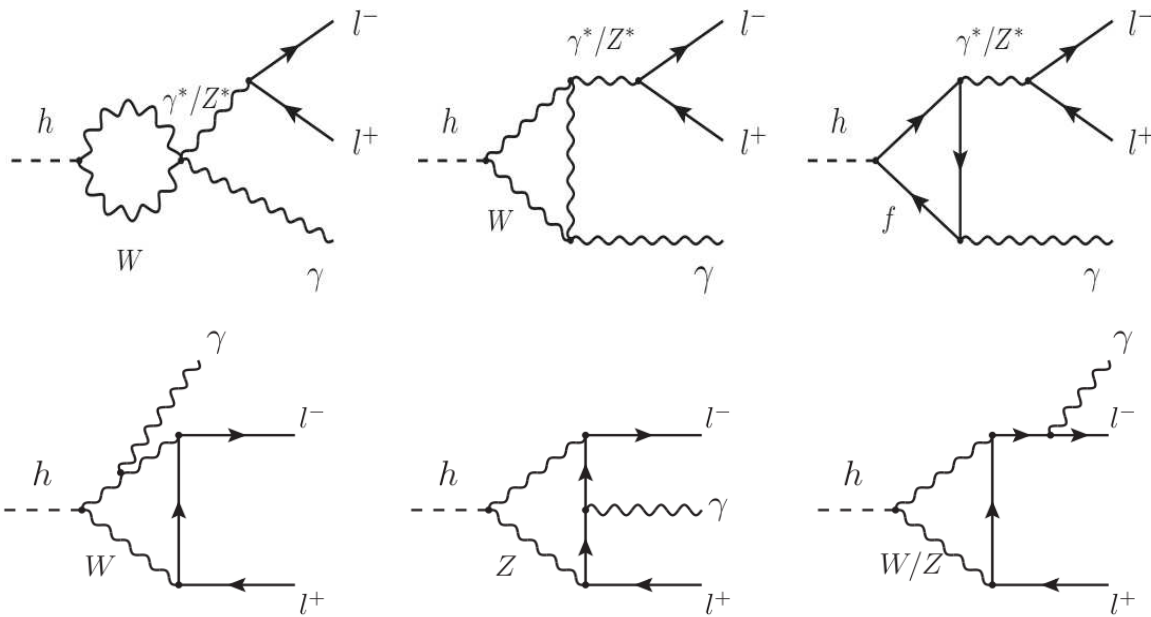


- using  $\bar{m}_s(M_H)$  (neglecting regular mass effects)
- no resummation towards the end-point
- QCD/elw. corrections?

(ii) weak:



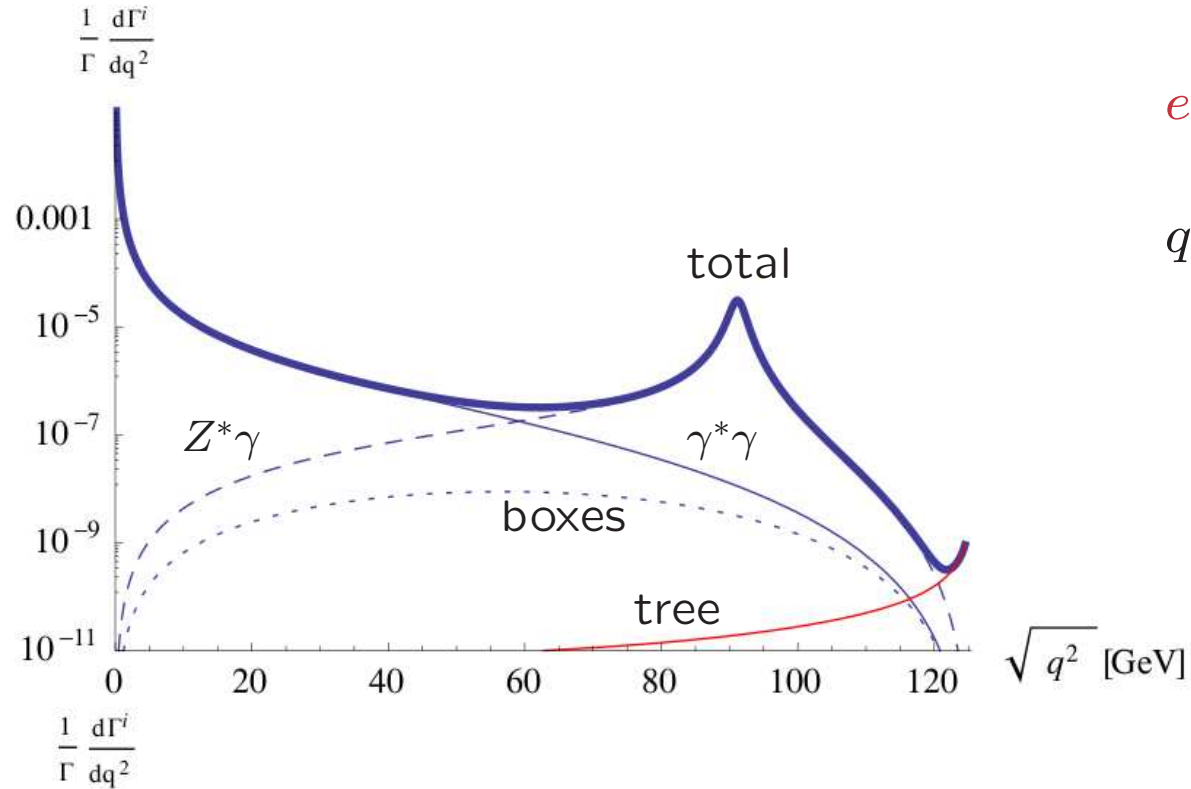
tree



off-shell

boxes

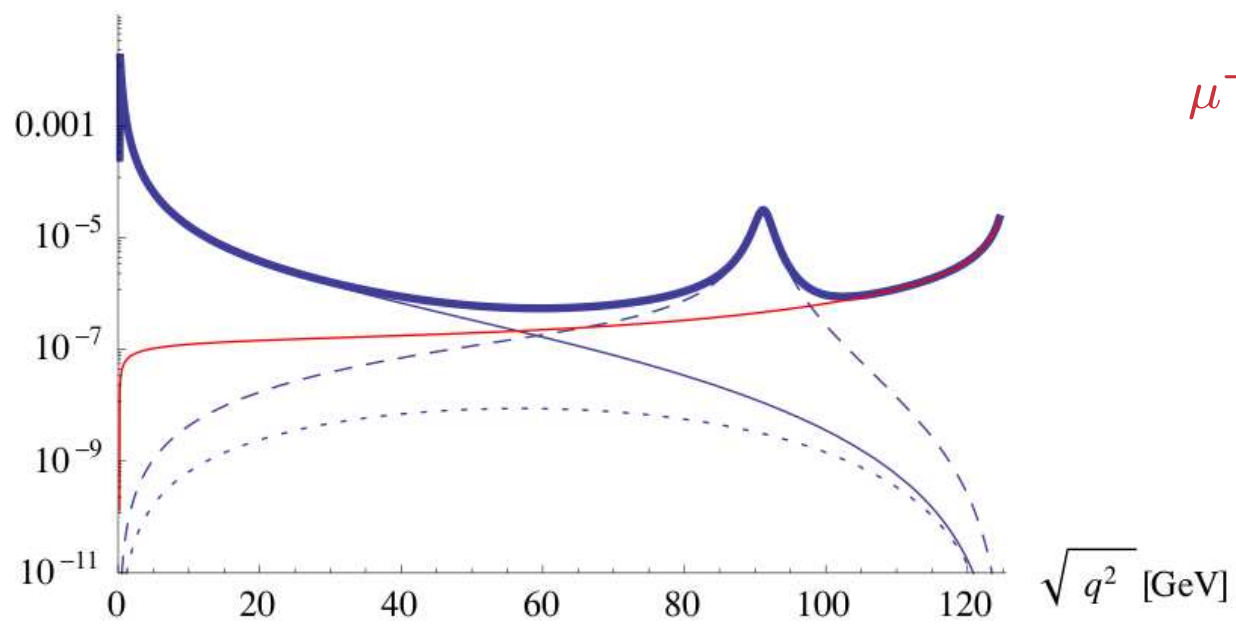
Abbasabadi, Bowser-Chao, Dicus, Repko  
Sun, Chang, Gao  
Passarino



$e^+e^- \gamma$

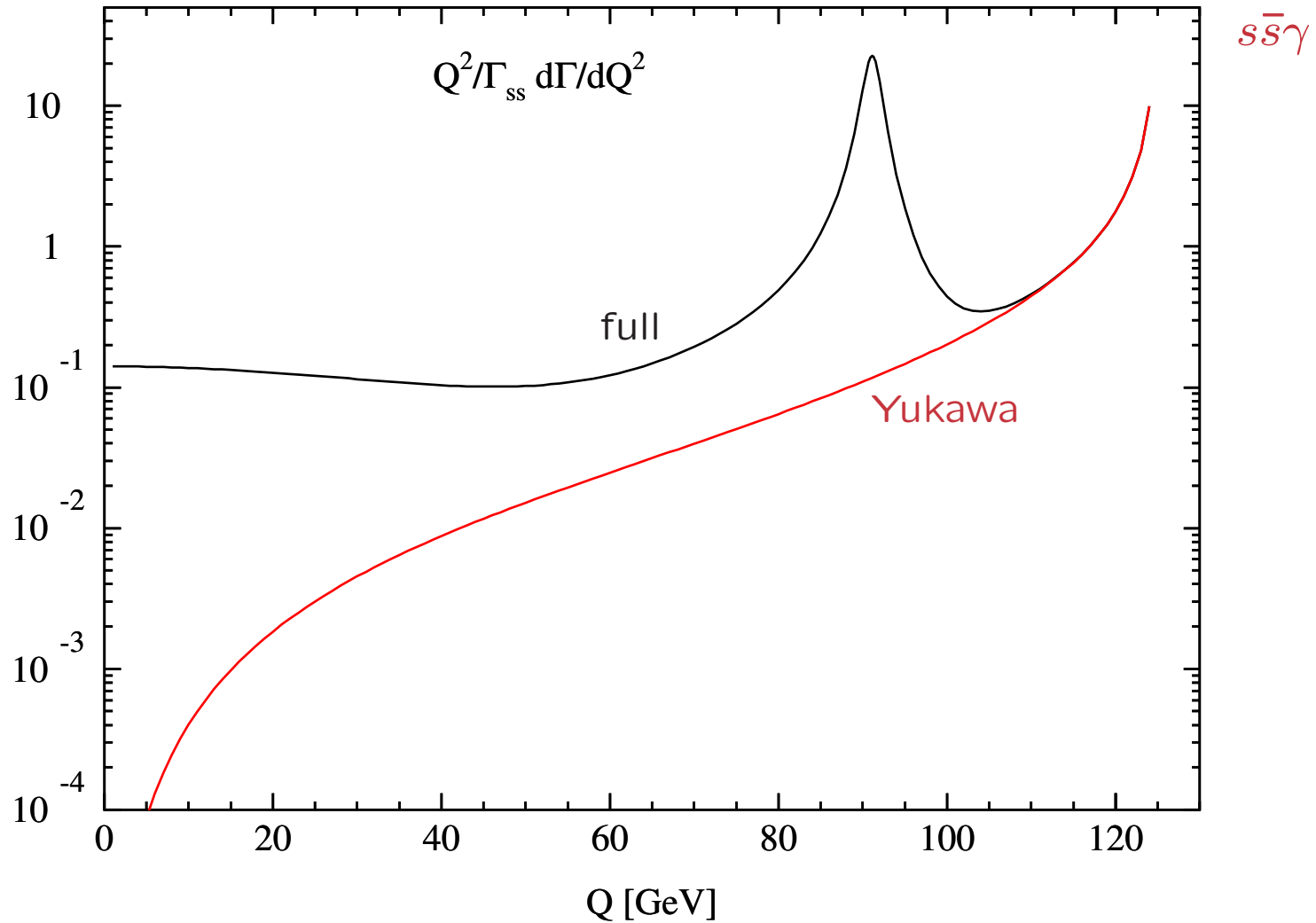
$$q^2 = M_{l^+l^-}^2$$

Sun, Chang, Gao



$\mu^+\mu^- \gamma$

- Dalitz dec. ( $H \rightarrow Z\gamma \Leftrightarrow H \rightarrow l^+l^-\gamma \Leftrightarrow H \rightarrow \gamma\gamma$ )  $\leftarrow$  QCD/elw. corrs?



- using  $\bar{m}_s(M_H)$  (neglecting regular mass effects)
- no resummation towards the end-point
- QCD/elw. corrections?

*BACKUP SLIDES*

# • Higgs Boson Production & Decay

