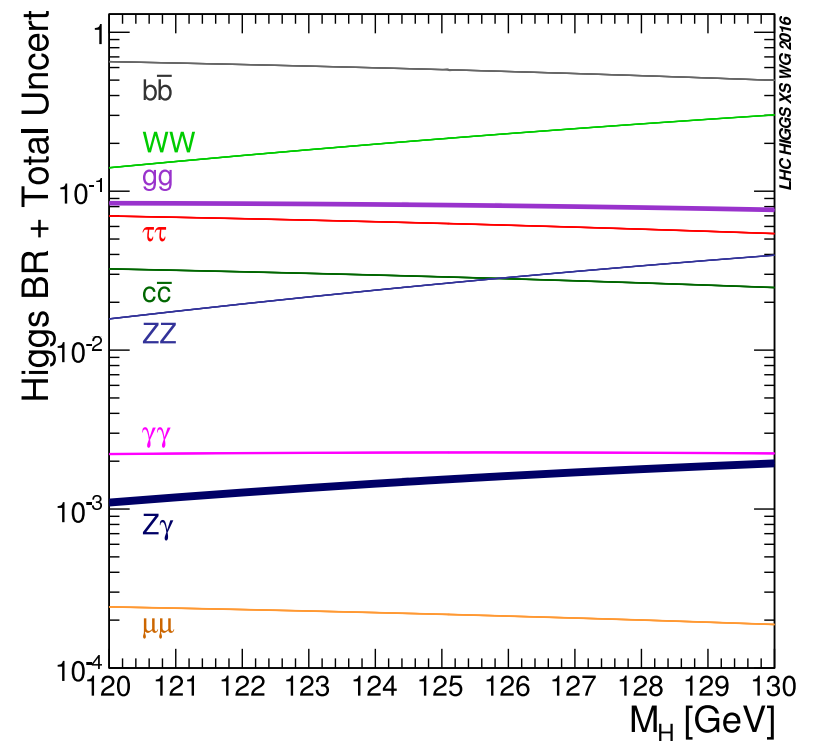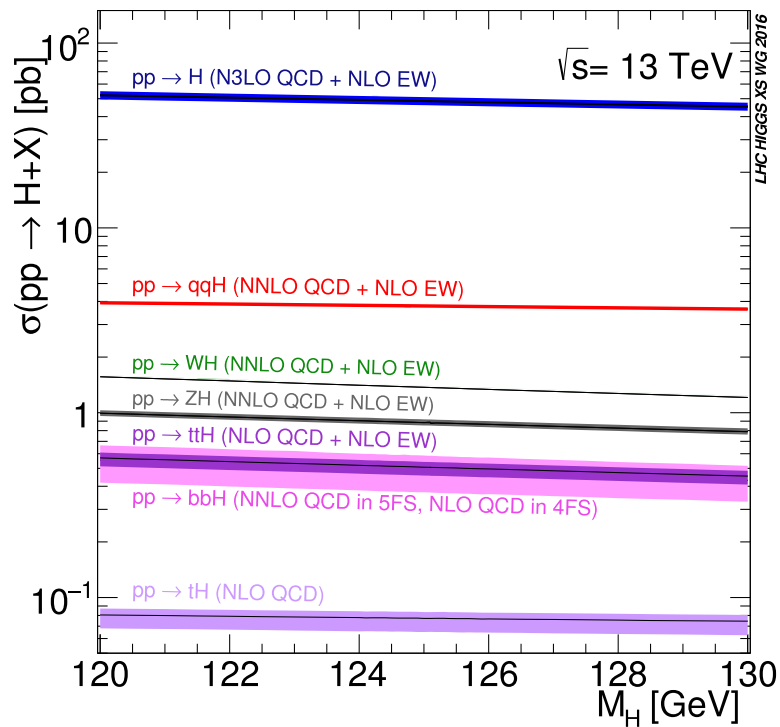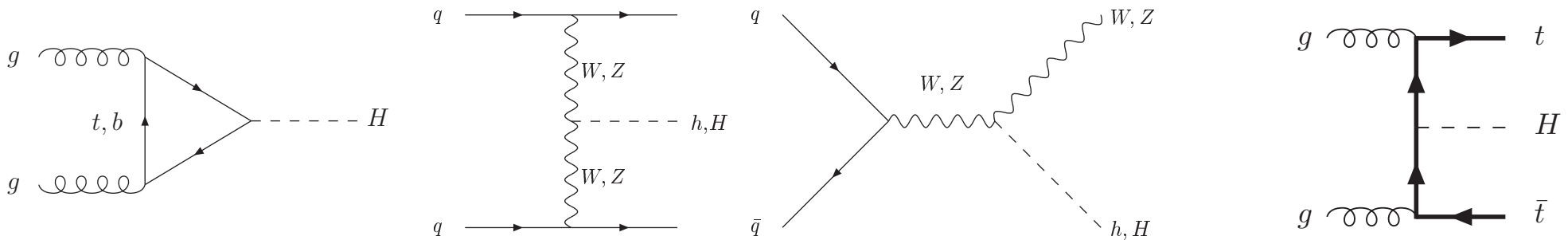# STRANGE HIGGS DECAYS : STRONG AND WEAK DALITZ DECAYS

Michael Spira (PSI)

I   Introduction

II   Strong Dalitz Decays

III Weak Dalitz Decays

IV   Conclusions

I *INTRODUCTION*
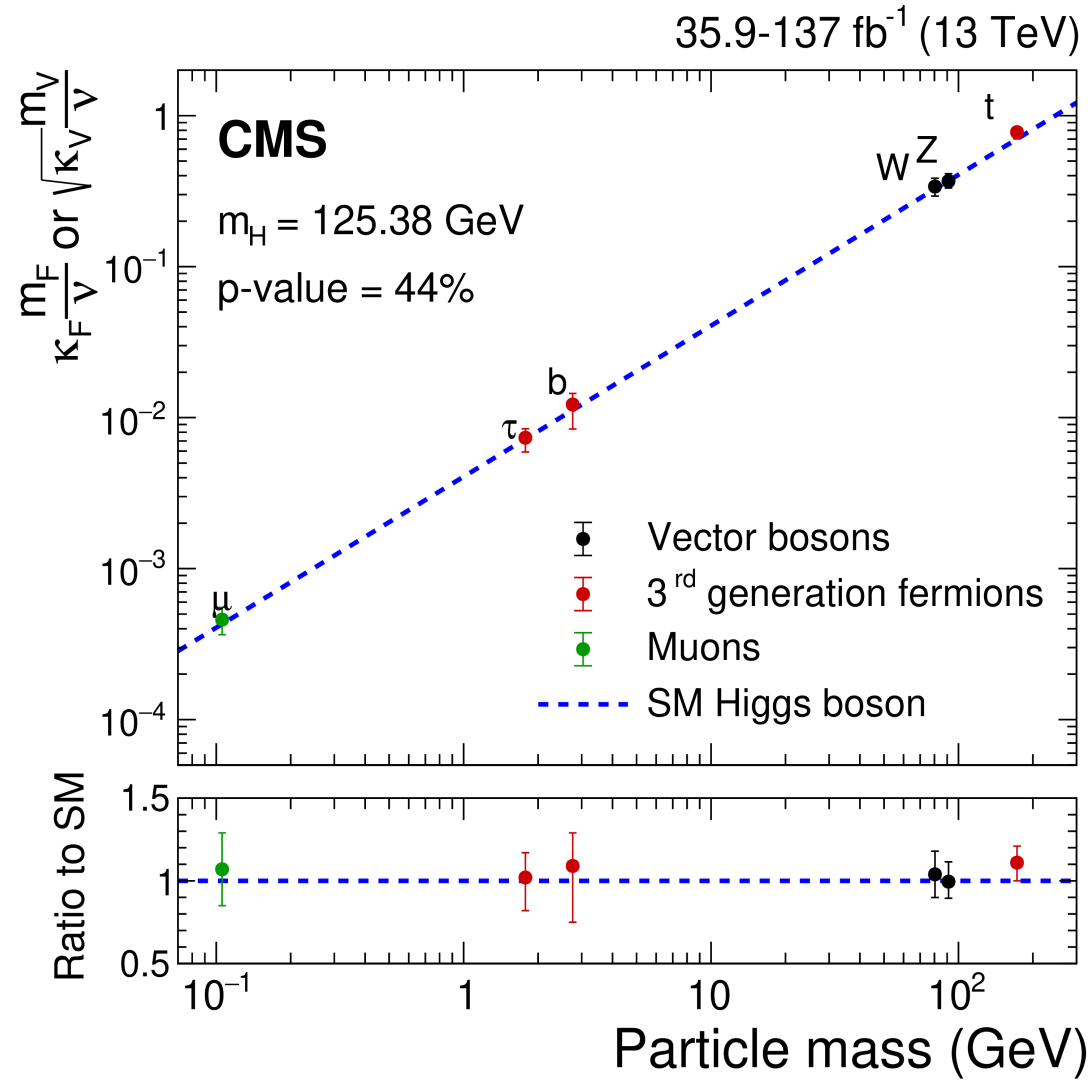
- ## Higgs Boson Production

- Discovery: LHC [Tevatron]
  → Higgs mass
  couplings
  spin
  $\mathcal{CP}$
  λ ?

$35.9\text{-}137\ \text{fb}^{-1}\ (13\ \text{TeV})$

CMS

$m_H = 125.38$ GeV

p-value = 44%

- Vector bosons
- 3rd generation fermions
- Muons
- SM Higgs boson

Ratio to SM

Particle mass (GeV)

HIGGS BOSON DECAYS

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

- QCD: variation $\mu_R = [1/2, 2]\mu_0$
  elw: missing HO estimated from known structure at NLO
  different uncertainties added linearly for each channel
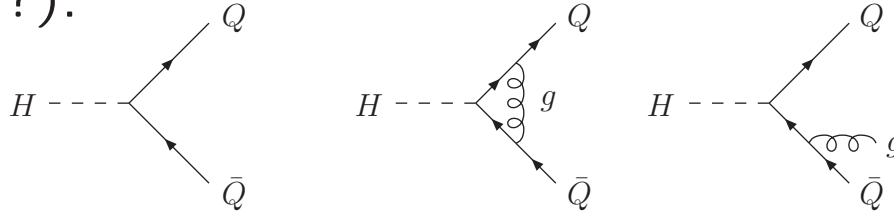
- parametric uncertainties:
  $m_t = 172.5 \pm 1$ GeV $\qquad\qquad \alpha_s(M_Z) = 0.118 \pm 0.0015$
  $m_b(m_b) = 4.18 \pm 0.03$ GeV $\qquad m_c(3\text{GeV}) = 0.986 \pm 0.025$ GeV
  different uncertainties added quadratically for each channel

- total uncertainties: parametric & theor. uncertainties added linearly

II *STRONG DALITZ DECAYS*

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

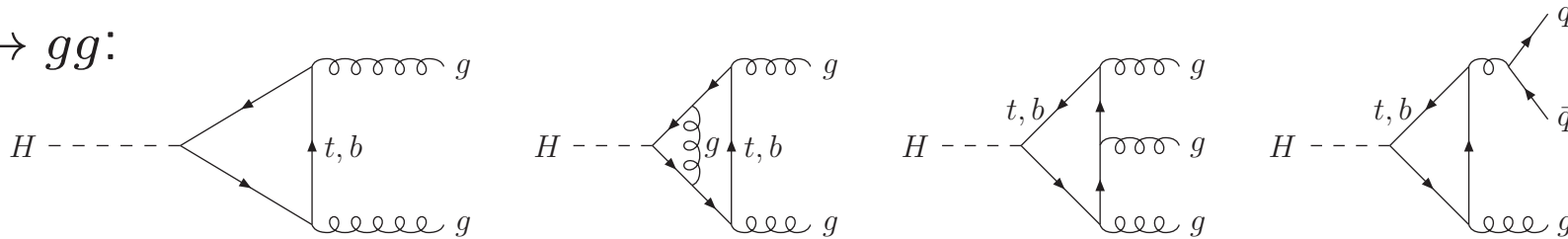Braaten, Leveille
Drees, Hikasa
Gorishnii, Kataev, Larin, Surguladze
Chetyrkin, Kwiatkowski, Steinhauser, Baikov
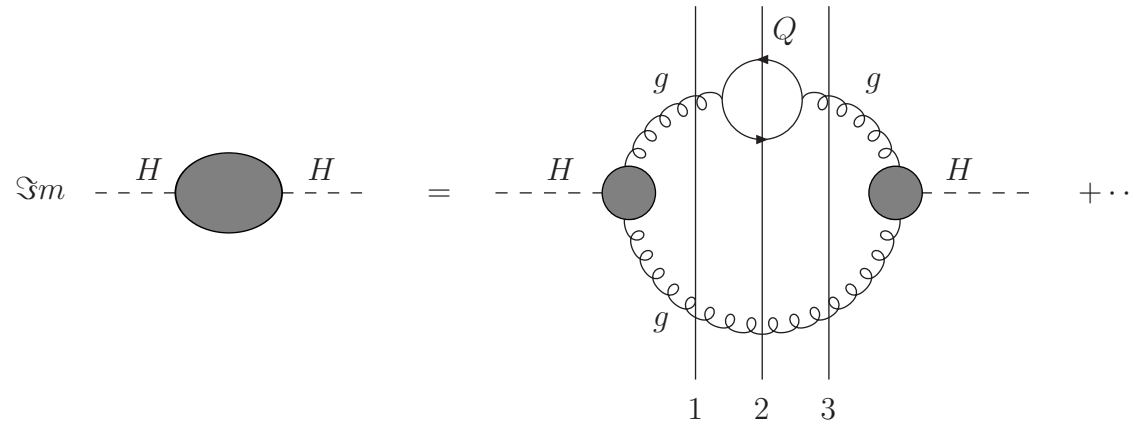
$$\Gamma = \Gamma_{LO}(1 + \delta) \qquad \delta \sim 25\%$$

- $H \to gg$:

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

$$\Gamma = \Gamma_{LO}(1 + \delta) \qquad \delta \sim 100\%$$

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

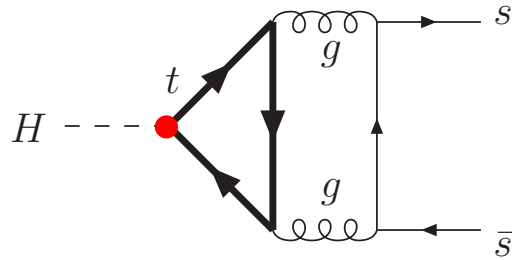- resummation of logs (inclusive decay width):

$$\Gamma[H \to gg] = \Gamma^{3FS}$$
$$\delta\Gamma[H \to b\bar{b} + \ldots] = \Gamma^{5FS} - \Gamma^{4FS}$$
$$\delta\Gamma[H \to c\bar{c} + \ldots] = \Gamma^{4FS} - \Gamma^{3FS}$$
$$\delta\Gamma[H \to s\bar{s} + \ldots] = \Gamma^{3FS} - \Gamma^{2FS} \quad ?? \quad \text{Djouadi, S., Zerwas}$$

$$H \to b\bar{b} : 1\% \quad [BR(H \to b\bar{b}) \approx 58\% \to 0.6\%]$$
$$H \to c\bar{c} : 27\% \quad [BR(H \to c\bar{c}) \approx 2.9\% \to 0.8\%]$$
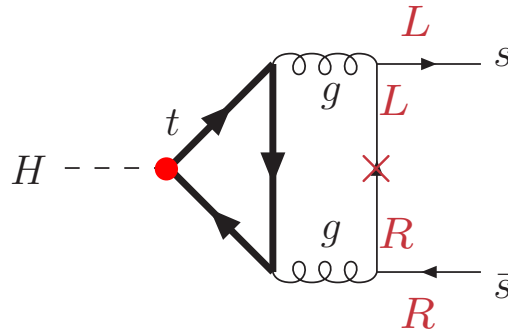
- exclusive? impact of cuts? matching scale for 2FS?
- BR$(H \to s\bar{s})_{Yuk} \sim 0.022\%$ ($\overline{\text{MS}}$ mass)

QCD corrections

- involves top Yukawa coupling, part of the NNLO QCD corrections

QCD corrections
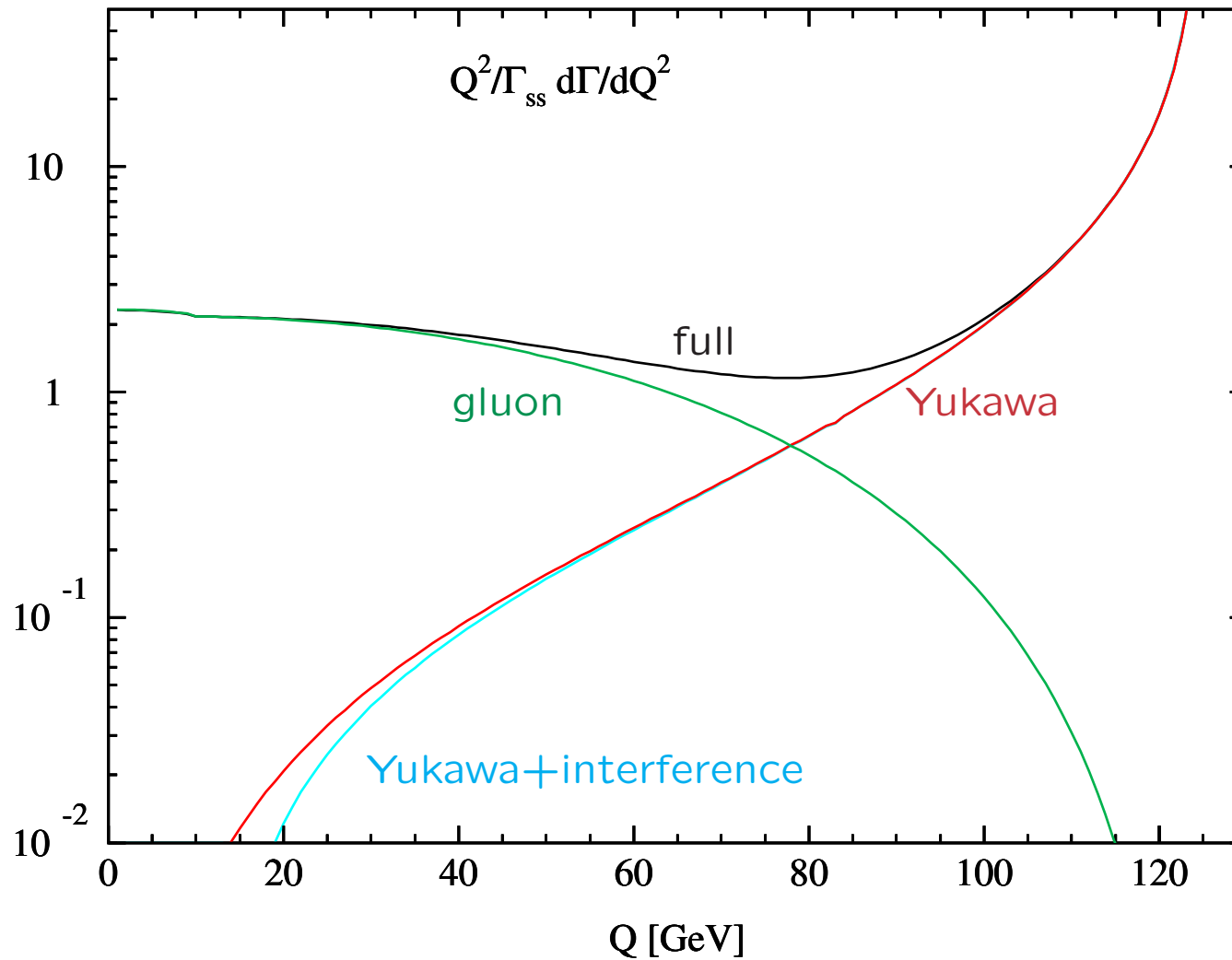

- involves top Yukawa coupling, part of the NNLO QCD corrections

- helicity flip $\Rightarrow$ develops factor $m_s \to$ small correction ($\sim 3\%$)

[You cannot perturbatively generate a Yukawa coupling for a massless fermion]
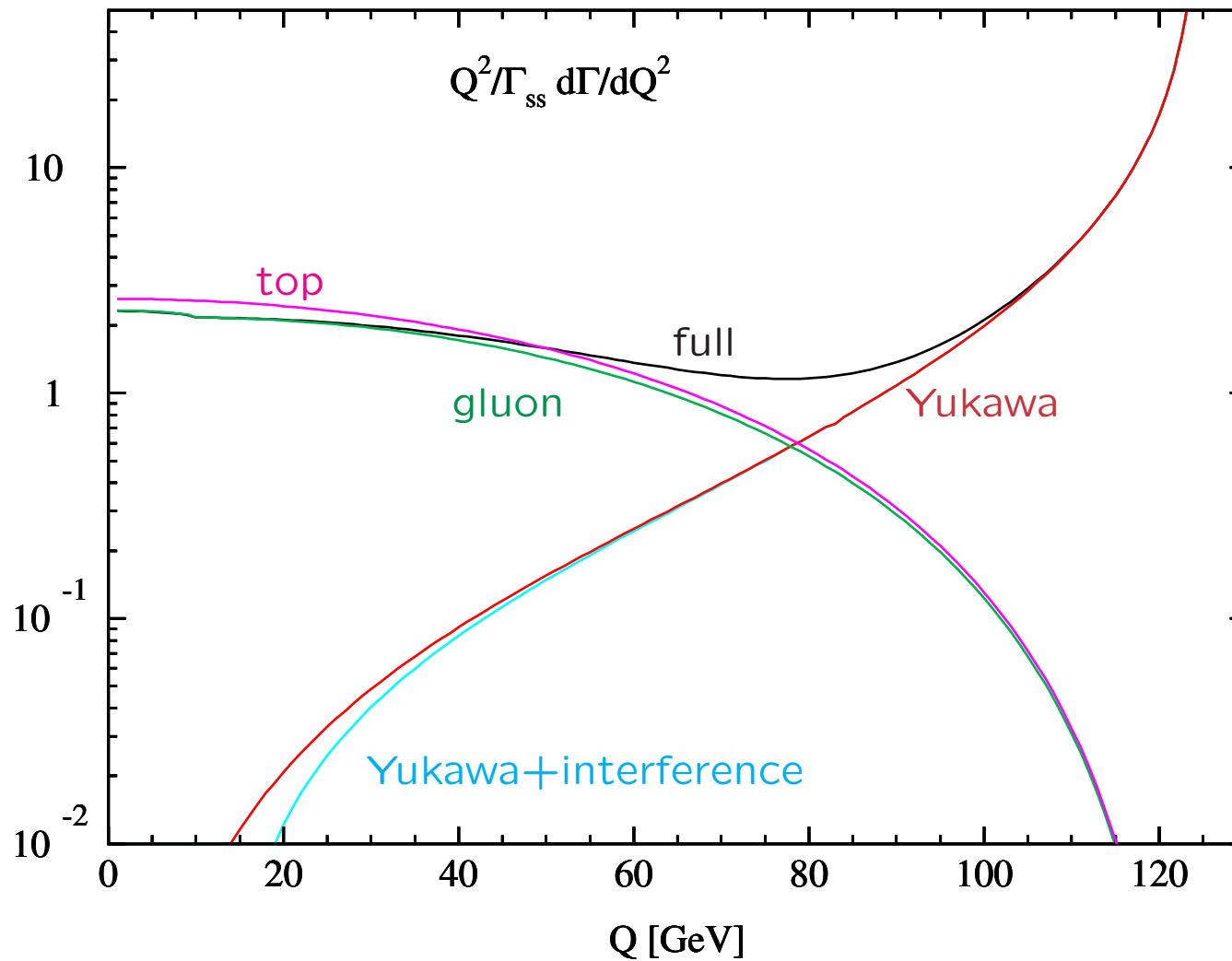
- weak and strong Dalitz decays: **no** helicity flip!
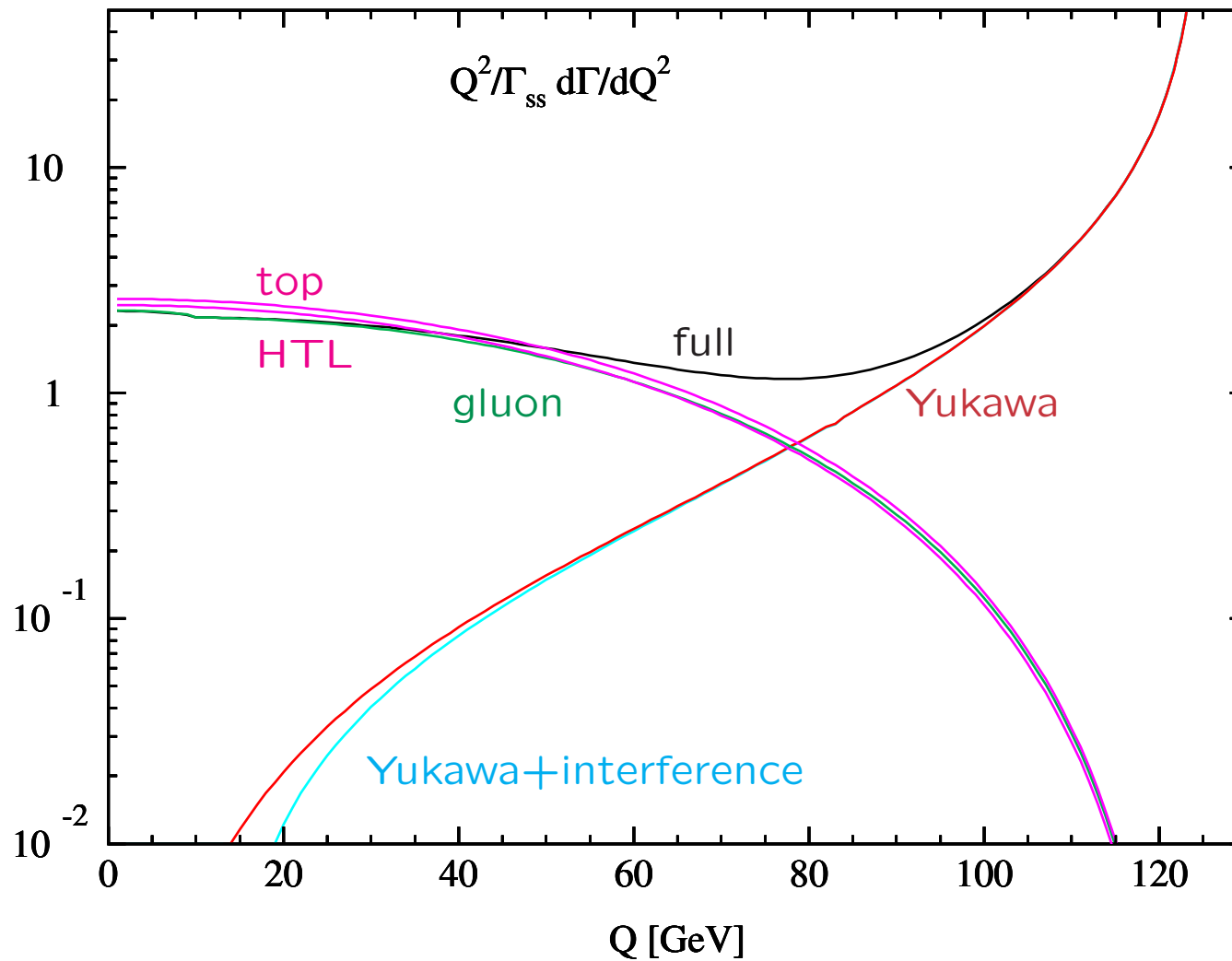
$H \rightarrow s\bar{s}g$

$Q^2/\Gamma_{ss} \, d\Gamma/dQ^2$

full

gluon

Yukawa

Yukawa+interference

Q [GeV]

- using $\overline{m}_s(M_H)$ (neglecting regular mass effects)

- no resummation towards the end-point

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

- using $\overline{m}_s(M_H)$ (neglecting regular mass effects)

- no resummation towards the end-point

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

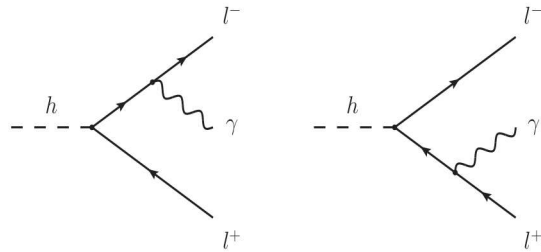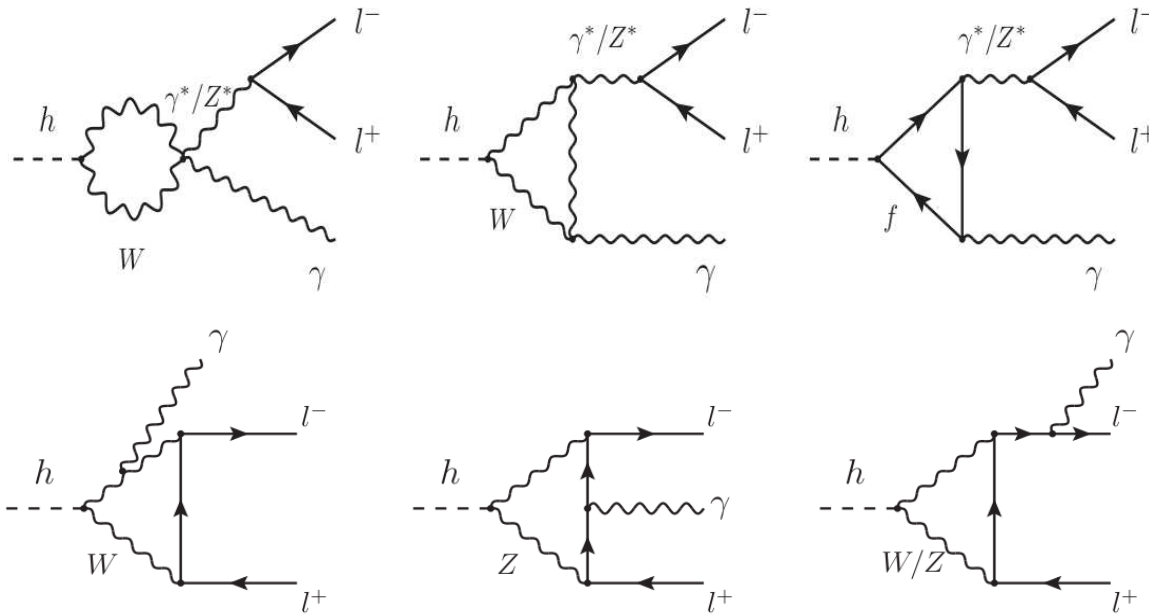- using $\overline{m}_s(M_H)$ (neglecting regular mass effects)

- no resummation towards the end-point
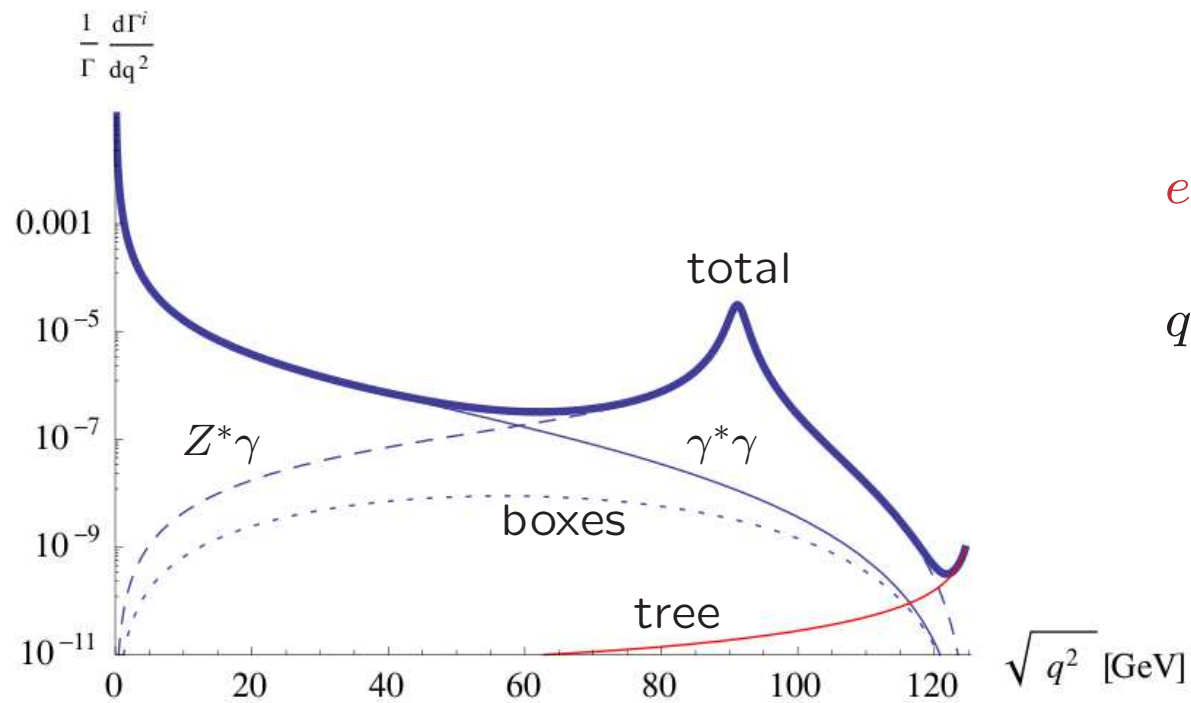
III *WEAK DALITZ DECAYS*

tree

off-shell

boxes

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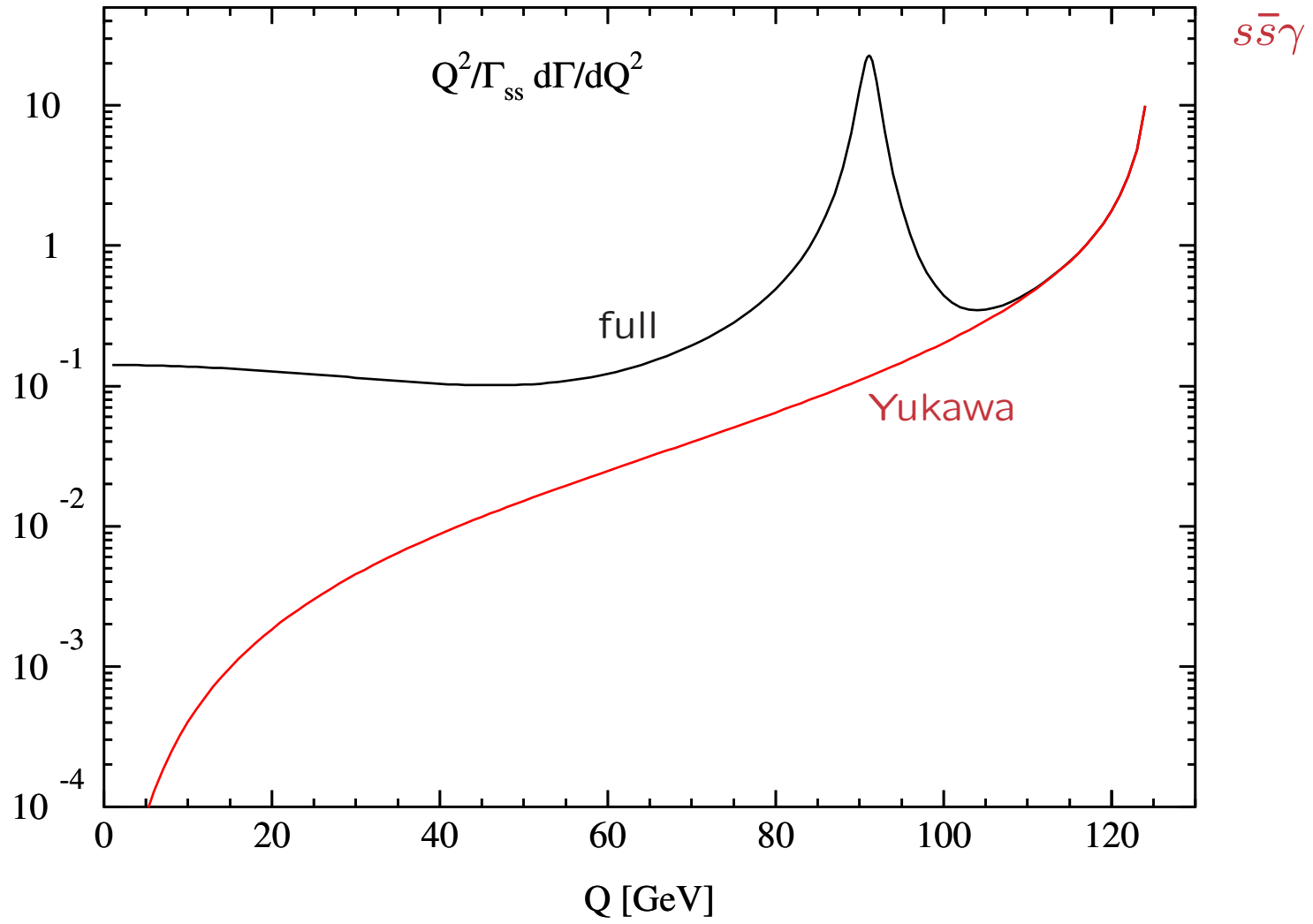Sun, Chang, Gao
Passarino

$e^+e^-\gamma$

$q^2 = M^2_{\ell^+\ell^-}$

Sun, Chang, Gao

- normalized to $\Gamma = \Gamma(H \to \gamma\gamma)$

- Dalitz decays ($H \to Z\gamma \Leftrightarrow H \to \ell^+\ell^-\gamma \Leftrightarrow H \to \ell^+\ell^- \Leftrightarrow H \to \gamma\gamma$)

- using $\overline{m}_s(M_H)$ (neglecting regular mass effects)

- no resummation towards the end-point

IV CONCLUSIONS

- strong and weak Dalitz decays do not pose a severe problem on the determination of the strange Yukawa coupling

- definition of strange mass?

- fragmentation effects? ($\Leftarrow H \to b\bar{b}, c\bar{c}$)

- necessity to define BR($H \to s\bar{s}$) on the TH side $\Rightarrow$ LHCHWG

BACKUP SLIDES