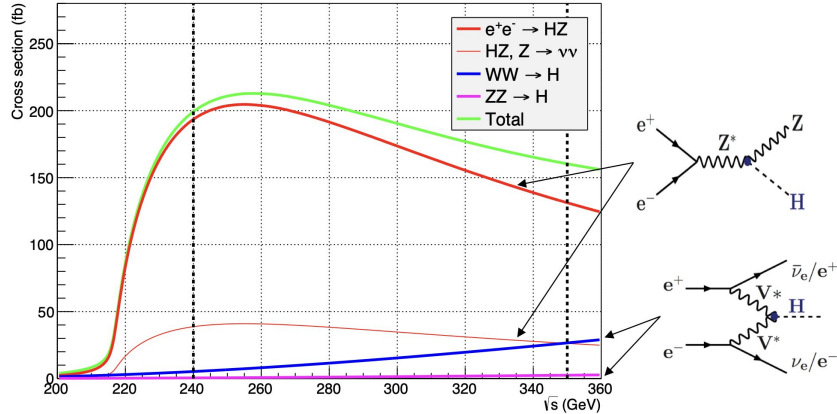# Higgs Yukawa couplings
Contributions from Dalitz diagrams

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(with input from Gavin Salam and Marco Zaro)

Intro
Physical Overview and Motivation

FCCee @ $\sqrt{s}$ = 240 GeV → Higgs factory

Measure Higgs couplings

Sensitivity on coupling strength modifiers $K_{b,c,s,g}$?

$\sigma(\nu\nu H)$ = 46.2 fb

BR(H→bb) = 0.582
BR(H→cc) = 0.0289
BR(H→ss) = 2.4e-04
BR(H→gg) = 0.819

BR(H→uu) = 1.2e-07
BR(H→dd) = 5.5e-07

Intro
Physical Overview and Motivation

Final state	upper limit BR(H→xx) 95% CL
H → dd	1.7e-03
H → uu	1.8e-03
H → bd	3.3e-04
H → bs	4.5e-04
H → cu	3.0e-04
H → sd	9.5e-04

Question:

How sensitive are we really to the Yukawa couplings?

Parameter	FCC-ee CDR	FCCee today
H→WW	1 %	2.0 %
H→ZZ	3.6 %	4.6 %
H→gg	1.6 %	0.78 %
H→γγ	7.5 %	3.5 %
H→cc	1.8 %	1.6 %
H→bb	0.25 %	0.18 %
H→μμ	15.8 %	19.5 %
H→$\tau\tau$	0.75 %	0.9%
H→Zγ		
H→ss	–	103 %
Invisible	< 0.25 %	< 0.18 %
m_H	5 MeV	4 MeV
Γ_H	1 %	4%
κ_λ	42 %	30%

Contamination from Dalitz decays

With first real emission, H→qqg receives contribution from
- Yukawa H→qq* → q (qg)
- Dalitz   H→gg* → g(qq)

diagram 1   HIG=0, HIW=0, QCD=1, QED=1

diagram 2   HIG=0, HIW=0, QCD=1, QED=1

diagram 1   HIG=1, HIW=0, QCD=1, QED=0
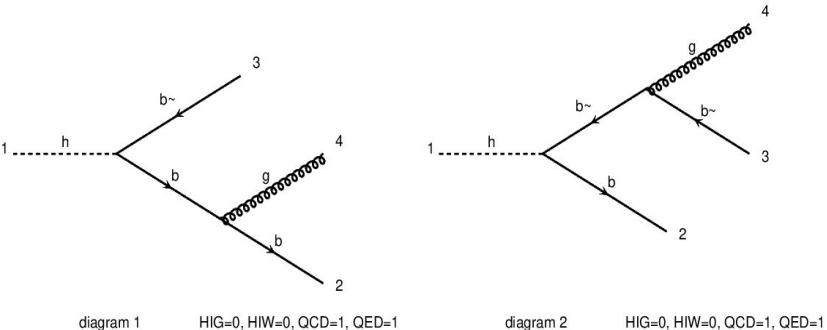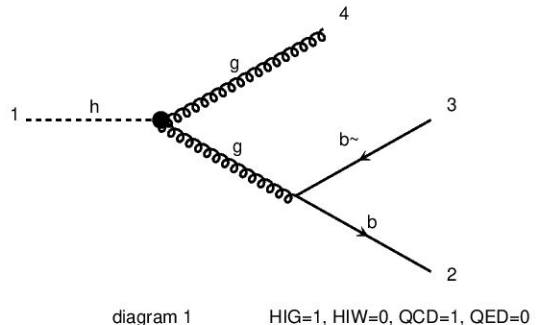
Yukawa
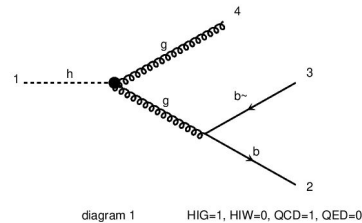
Dalitz

Event generation

```
import model heft
generate h > b b~ g


Full sample
Yukawa: HIG=0
Dalitz: QED=0
```

- parton level study with MG5
- model H →gg vertex with mt →∞ approx
- generate full, Yukawa, Dalitz
  - Interference = Full - Yukawa - Dalitz
- rescale m_b/y_b to obtain result for charm, strange, up and down
  - Dalitz ~ log(m)
  - Yukawa ~ m^2

- $p_T(g) > 1$ GeV, else Yukawa is not finite

diagram 1   HIG=0, HIW=0, QCD=1, QED=1   diagram 2   HIG=0, HIW=0, QCD=1, QED=1
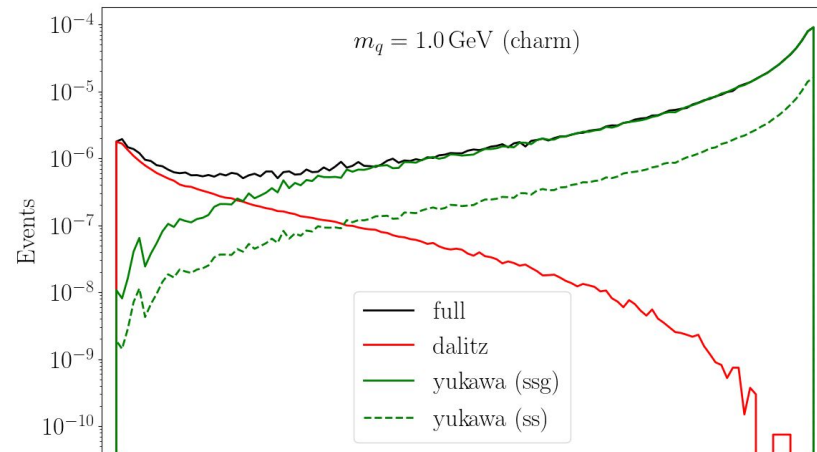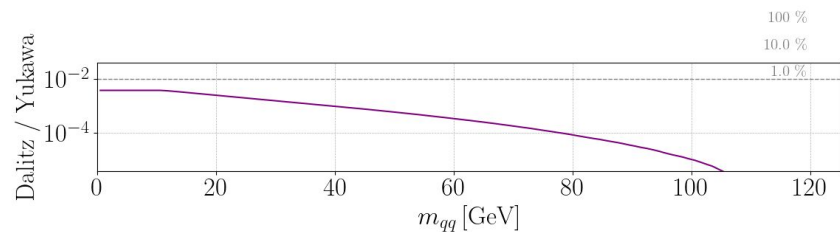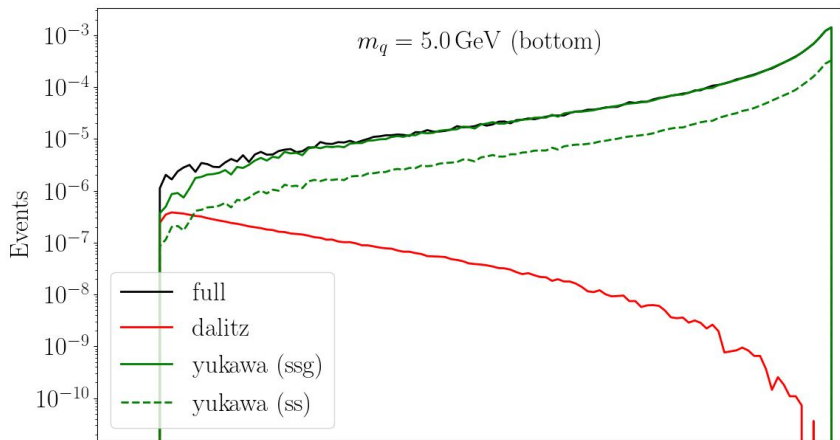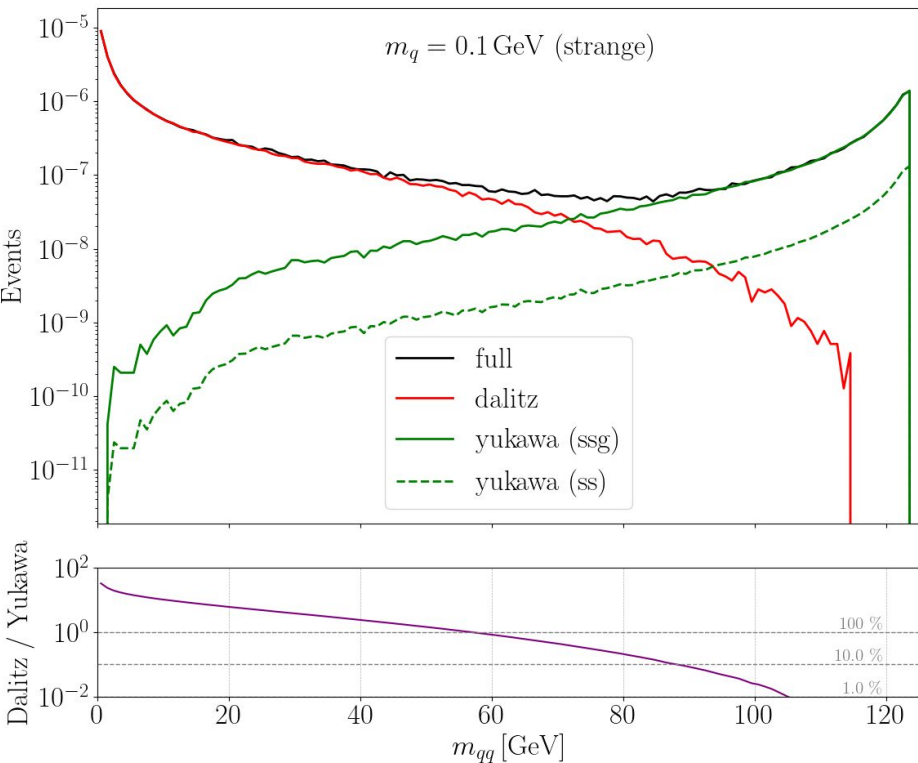
Yukawa

diagram 1   HIG=1, HIW=0, QCD=1, QED=0
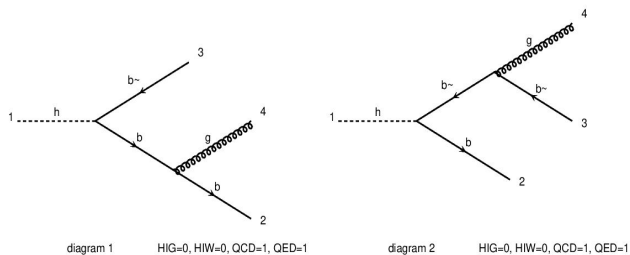
Dalitz

Bottom and charm
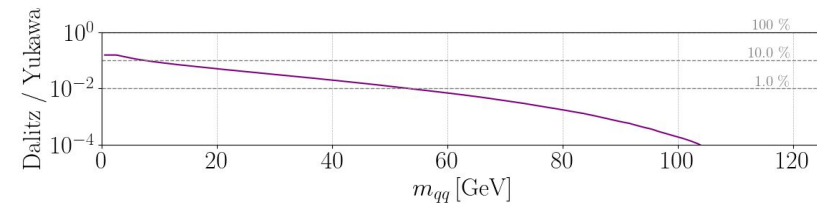
Overall Dalitz contribution seems small
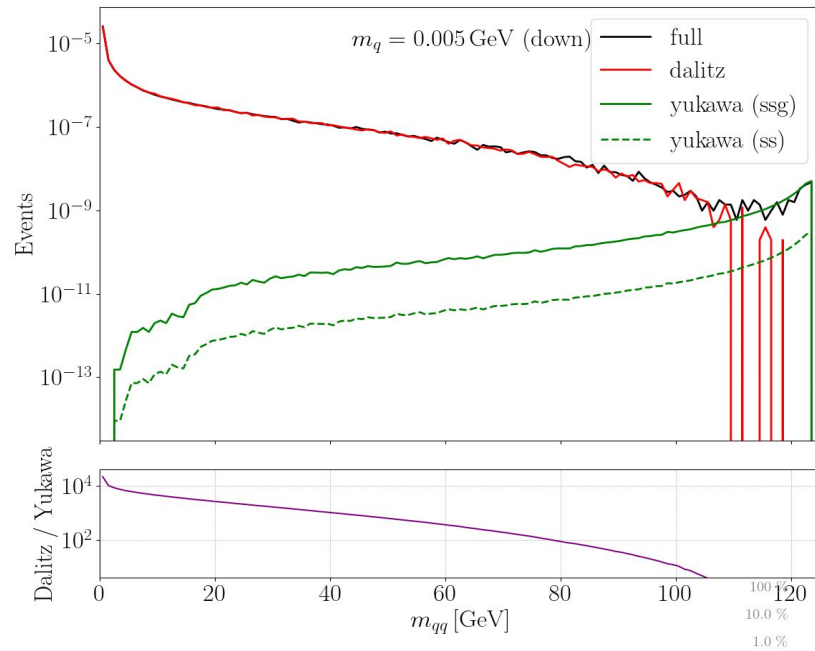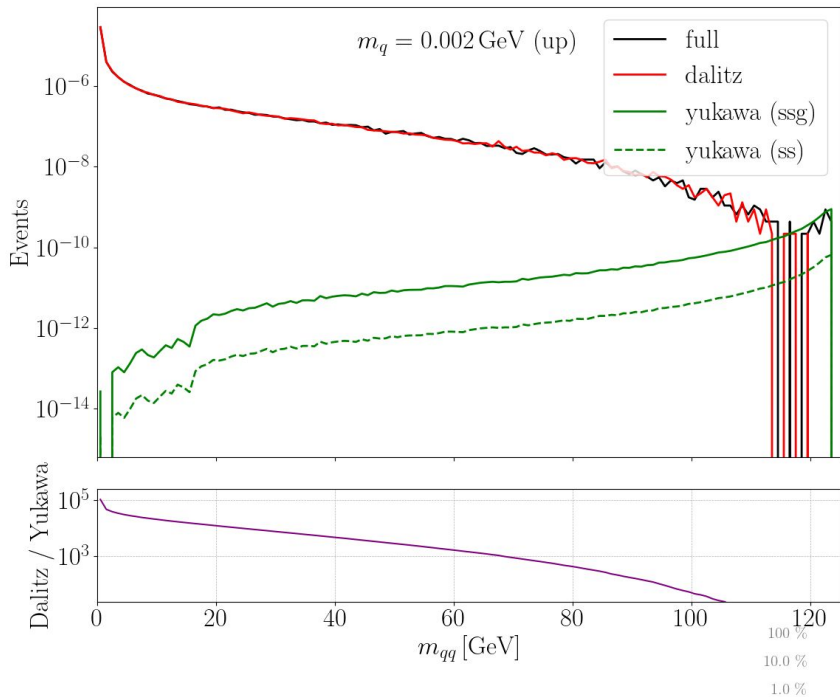- 10% inclusively for charm, but negligible at large m_{qq}

Strange

$m_q = 0.1\,\mathrm{GeV}$ (strange)

full
dalitz
yukawa (ssg)
yukawa (ss)

- Dalitz ~ 30 x Yukawa
- But:
  - m_{qq} > 90 GeV : Dalitz ~ 10%
  - m_{qq} > 100 GeV : Dalitz ~ 3%

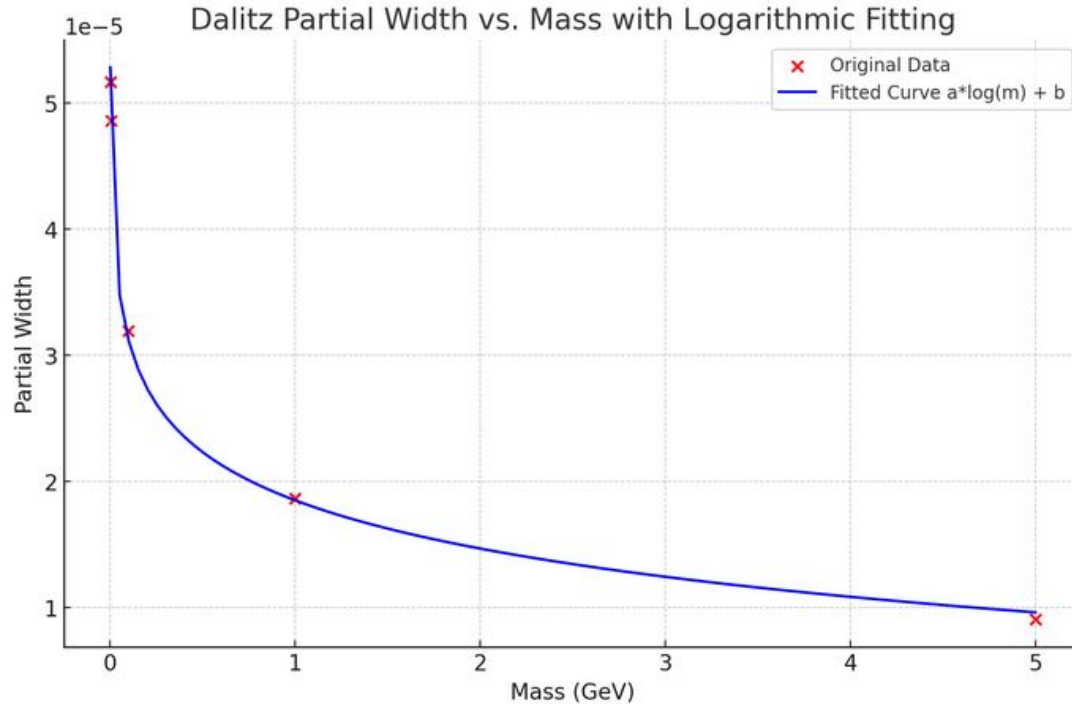- With few GeV expected hadronic mass resolution no issue seems

Up and down

Dalitz contribution overwhelming for up and down
- Dalitz ~ 10x Yukawa under Higgs peak

(Very) Preliminary conclusions

- Naive parton level study seems to indicate that Dalitz contribution under Higgs peak will be small for ≥ 2nd generation
    - Not the case for 1st generation
- Preliminary study with H->ss (shower) and H->gg (FO) and jet clustering (Gavin)
    - ~ 15% Dalitz contamination (vs 3% here), t.b.c
    - from TH perspective is shower analysis consistent with H→qqg calculation at NLO?
- Fragmentation/Hadronization effects neglected, are they going to be important?
- Detector effects to be included

Backup

Dalitz scaling with mass

Dalitz Partial Width vs. Mass with Logarithmic Fitting

expect scaling as $\log(m_H^2/m_q^2)$: OK