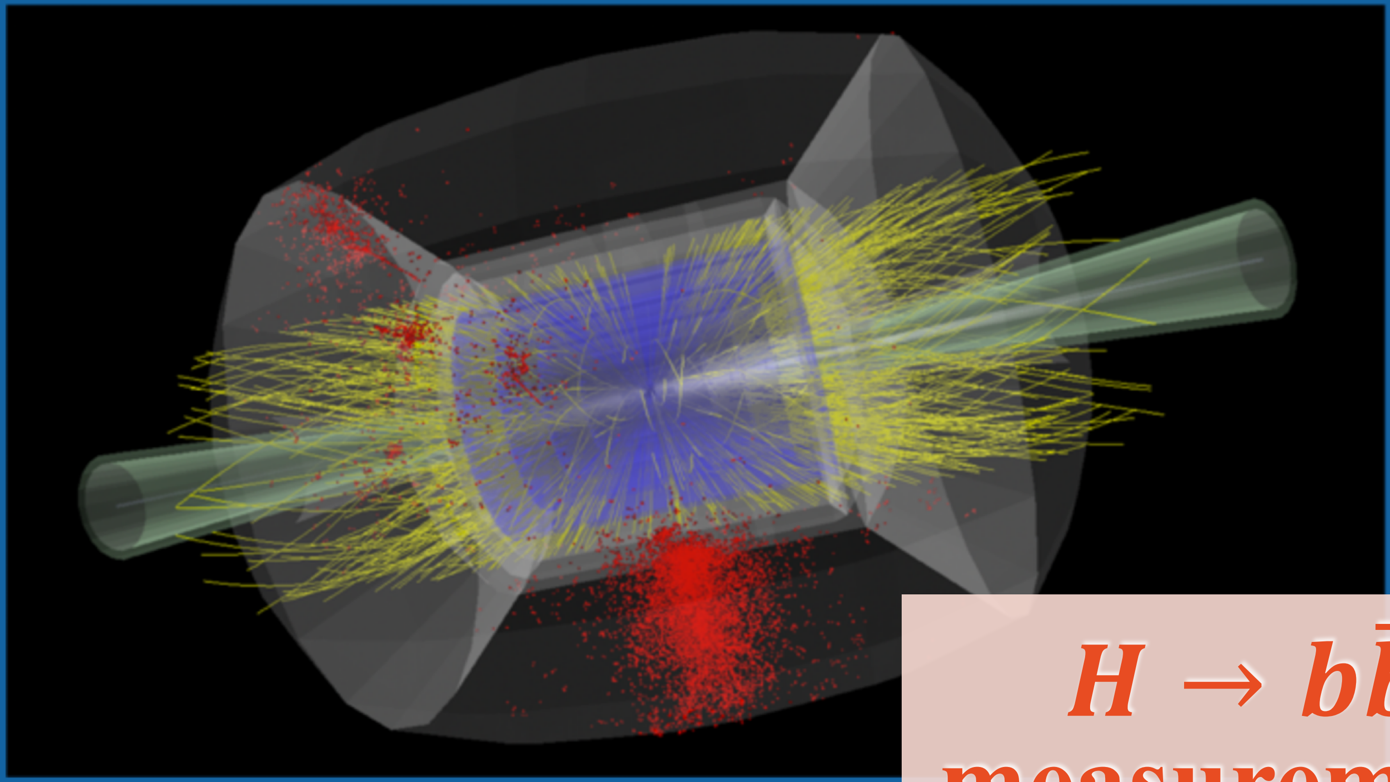

Muon Collider Meeting

31 March 2020 to 2 April 2020

Europe/Zurich timezone

$H \to b\bar{b}$ coupling precision measurement at a muon collider

Donatella Lucchesi INFN & University of Padova

for

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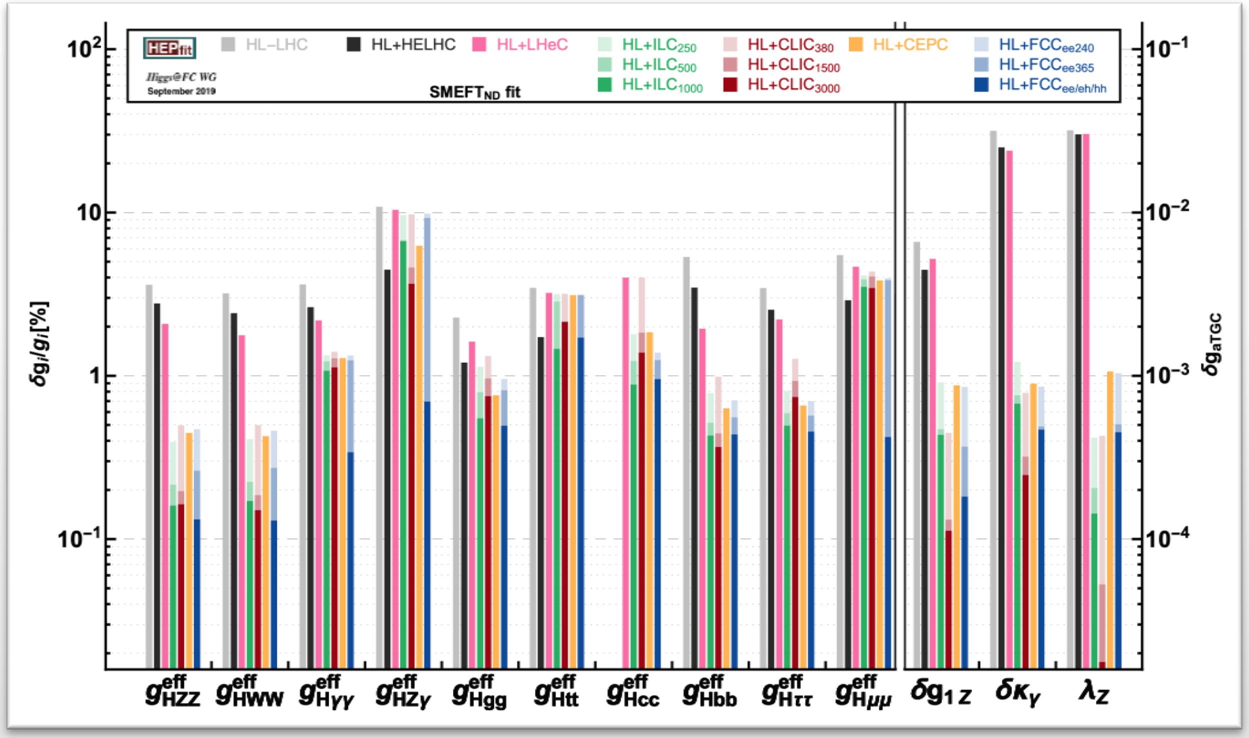
Università degli Studi di Padova

INFN Istituto Nazionale di Fisica Nucleare

Higgs Couplings

One of the main goals of future colliders is to measure with the highest possible precision all the Higgs couplings.



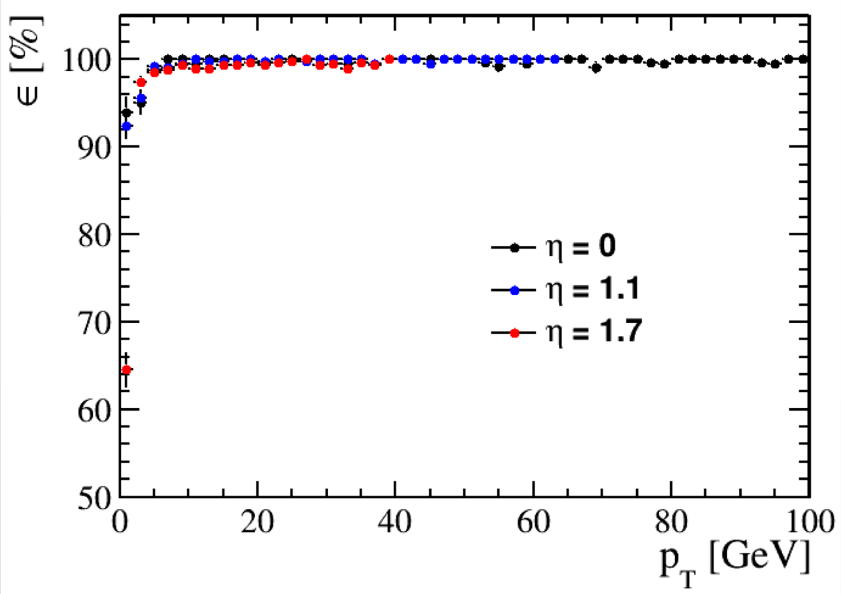
- Precisions achievable at muon collider are not yet evaluated to perform a comparison with other colliders
- We are entering the game with the first evaluation of the $H \to b\bar{b}$

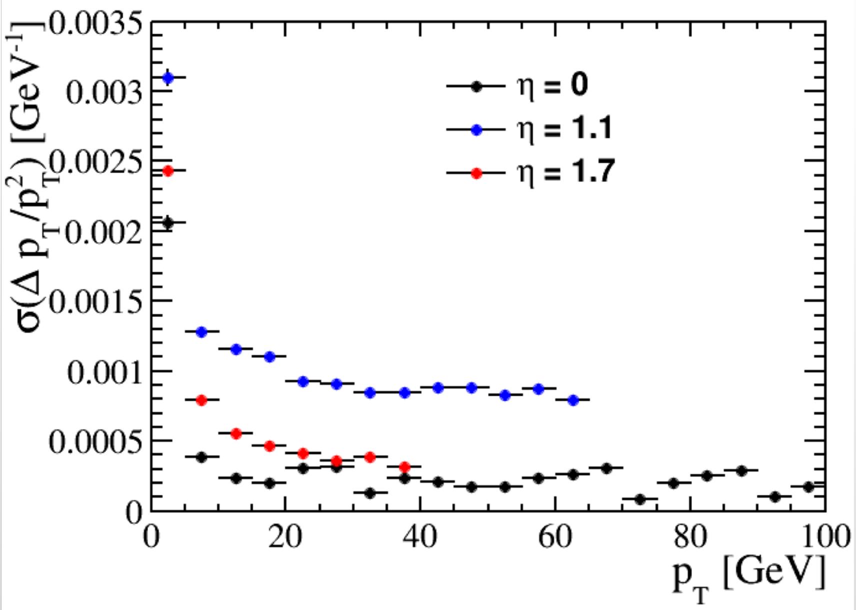
Results published
Detector and Physics Performance at a Muon Collider
Accepted for publication JINST

Detector Performance at $\sqrt{s}$ =1.5 TeV

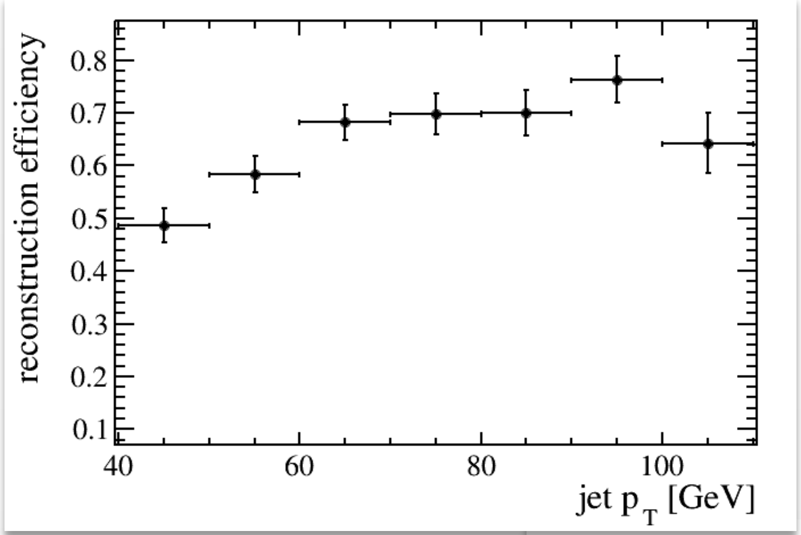
- Use of ILCRoot framework to simulate and reconstruct events and the beam-induced background provided by MAP collaboration
- Developed some of the missing tools, muon reconstruction not performed

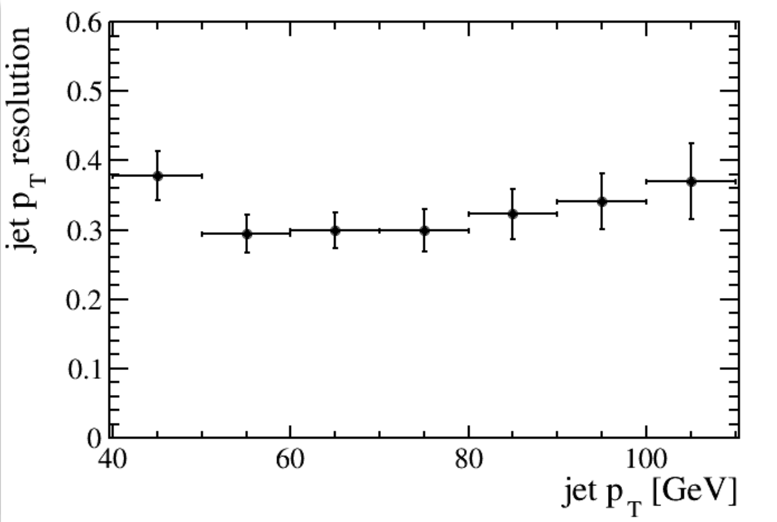
Tracking performance



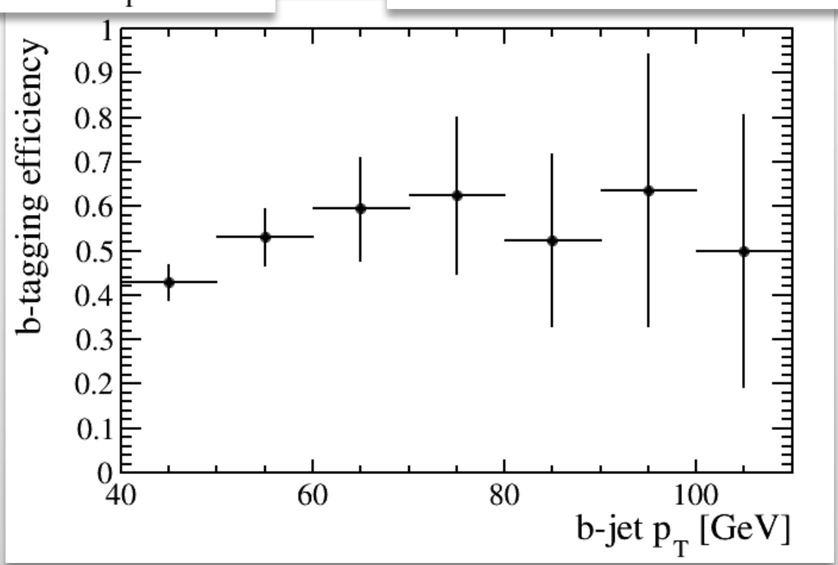


Detector Performance at $\sqrt{s}$ =1.5 TeV: Jets





Fake jets ~25%

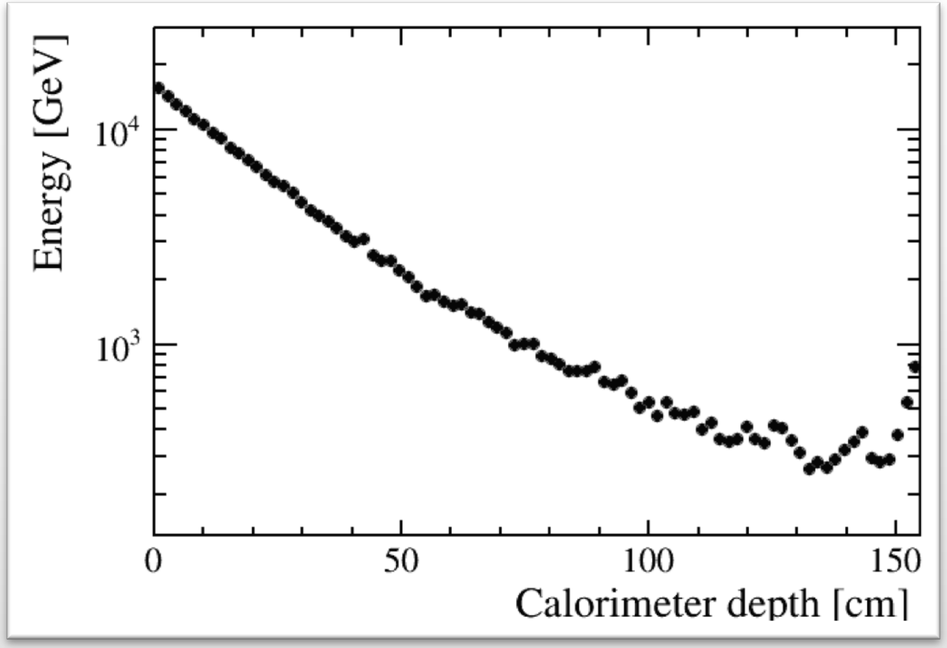


Background tagging:
- Low statistics when all clean-up cuts are applied
- fake rate: 1 ÷ 3 %

Tests done so far show fake rate is manageable.

Detector Performance at $\sqrt{s}$ =1.5 TeV: Muons Reconstruction

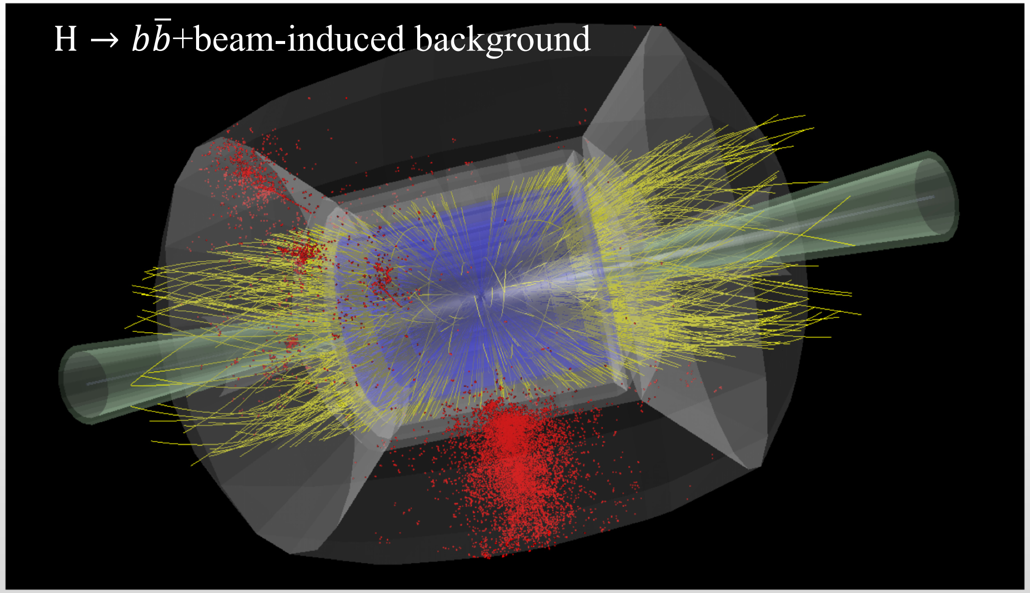
- The current software package does not include muon detector simulation nor muon reconstruction.
- The same performance obtained by CLIC in muon reconstruction and identification are assumed:
  - beam-induced background particles are not fully contained before the muon detector, but the released energy is reduced by roughly a factor 20 from the first to the last calorimeter layers
  - The residual energy flux can be easily reduced by an absorber in front of the muon detector.
  - the presence of the magnet coil in this design is not yet included in the present simulation.



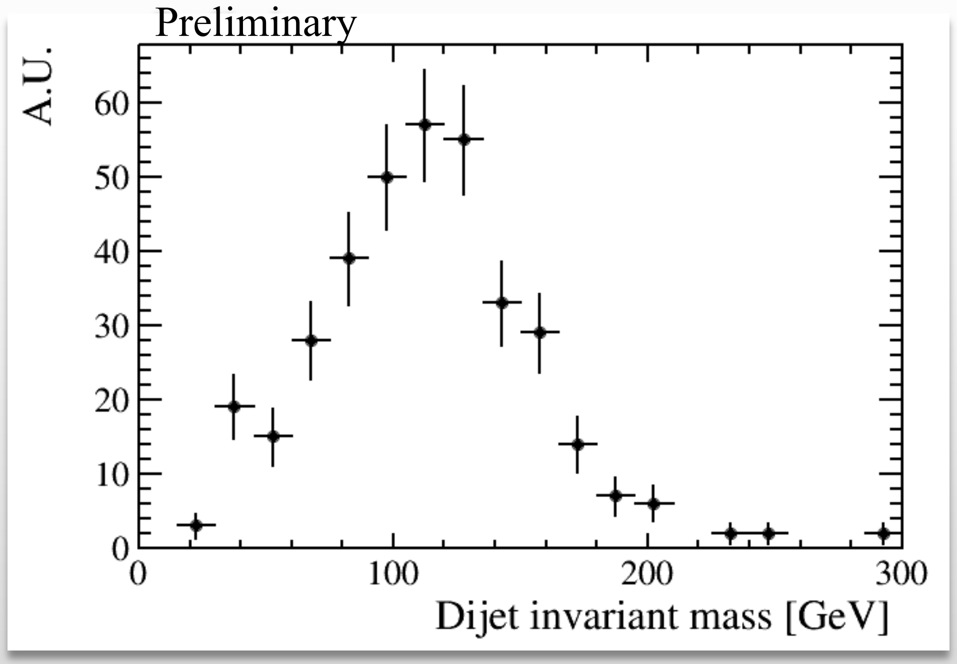
$b\bar{b}$ Studies at $\sqrt{s}$ =1.5 TeV

Events $\mu^+\mu^- \rightarrow b\bar{b}X$ $@\sqrt{s} = 1.5\ TeV$ are generated with PYTHIA 8

Process	cross section [pb]
$\mu^+\mu^- \to \gamma^*/Z \to b\bar{b}$	0.046
$\mu^+\mu^- \to \gamma^*/Z\gamma^*/Z \to b\bar{b}$ +X	0.029
$\mu^+\mu^- \to \gamma^*/Z\gamma \to b\bar{b}\gamma$	0.12
$\mu^+\mu^- \to HZ \to b\bar{b}$ +X	0.004
$\mu^+\mu^- \to \mu^+\mu^- H\ H \to b\bar{b}$ (ZZ fusion)	0.018
$\mu^+\mu^- \to \nu_\mu\nu_\mu H\ H \to b\bar{b}$ (WW fusion)	0.18



$\mu^+\mu^- \rightarrow H\nu\bar{\nu} \rightarrow b\bar{b}\nu\bar{\nu}$ + beam-induced background fully simulated



Higgs $b\bar{b}$ Couplings: Assumptions

$$\sigma(\mu^+\mu^- \to H\nu\bar{\nu}) \cdot BR(H \to b\bar{b}) \propto \frac{g_{HWW}^2 g_{Hbb}^2}{\Gamma_H}$$

$$\sigma(\mu^+\mu^- \to H\nu\bar{\nu}) \cdot BR(H \to b\bar{b}) = \frac{N_s}{A\varepsilon\mathcal{L}T}$$

$$\frac{\Delta\sigma}{\sigma} \simeq \frac{\sqrt{N_s + B}}{N_s}$$

$$4\left(\frac{\Delta g_{Hbb}}{g_{Hbb}}\right)^2 = \left(\frac{\Delta\sigma}{\sigma}\right)^2 + \left(\frac{\Delta(g^2{}_{HWW}/\Gamma_H)}{g^2{}_{HWW}/\Gamma_H}\right)^2$$

Obtained, with several approximations, from e^+e^-: 2% @1.4TeV and 1.8% @ 3TeV arXiv:1608.07538v2

N_s : number of signal events.

B: number of background events, $\mu^+\mu^- \to q\bar{q}$ from Pythia + beam-induced background

σ: cross section times BR

A: acceptance; removed nozzle region for $\sqrt{s}$ =1.5 TeV, 2 jets $|\eta| < 2.5$, and $p_T > 40$ GeV

for $\sqrt{s} = 3, 10$ TeV same nozzle angle is conservatively assumed

ε: measured with the full simulation at $\sqrt{s}$ =1.5 TeV, used the same at $\sqrt{s} = 3, 10$ TeV (conservative)

$t = 4 \cdot 10^7$ s

One detector

Higgs $b\bar{b}$ Couplings: Assumptions for $\sqrt{s} = 3, 10$ TeV cases

- nozzles and interaction region are not optimized for the higher energies, nor is the detector.
- efficiencies obtained with the full simulation at √s = 1.5 TeV used for the higher center-of-mass energy cases, with the proper scaling to take into account the different kinematic region.
- At higher √s the tracking and the calorimeter detectors are expected to perform significantly better since the yield of the beam-induced background decreases with √s
- The uncertainty on $\frac{\Delta(g^2{}_{HWW}/\Gamma_H)}{(g^2{}_{HWW}/\Gamma_H)}$ is taken from the CLIC at √s = 3 TeV and used at √s = 10 TeV

⬇

Conservative Assumptions

Higgs $b\bar{b}$ Couplings Results

- The instantaneous luminosity, $\mathcal{L}$, at different √s is taken from MAP
- The acceptance, A, the number of signal events, N, and background, B, are determined with simulation

$\sqrt{s}$ [TeV]	A [%]	ϵ [%]	$\mathcal{L}$ [cm^{-2}s^{-1}]	$\mathcal{L}_{int}$ [ab^{-1}]	σ [fb]	N	B	$\frac{\Delta\sigma}{\sigma}$ [%]	$\frac{\Delta g_{Hbb}}{g_{Hbb}}$ [%]
1.5	35	15	$1.25 \cdot 10^{34}$	0.5	203	5500	6700	2.0	1.9
3.0	37	15	$4.4 \cdot 10^{34}$	1.3	324	33000	7700	0.60	1.0
10	39	16	$2 \cdot 10^{35}$	8.0	549	270000	4400	0.20	0.91

Higgs $b\bar{b}$ Couplings Comparison to CLIC

- CLIC numbers are obtained with a model-independent multi-parameter fit.
- CLIC fit is performed in three stages, taking the statistical uncertainties obtainable at the three considered energies successively into account.

	$\sqrt{s}$ [TeV]	$\mathcal{L}_{int}$ [ab^{-1}]	$\frac{\Delta g_{Hbb}}{g_{Hbb}}$ [%]
Muon Collider	1.5	0.5	1.9
	3.0	1.3	1.0
	10	8.0	0.91
CLIC	0.35	0.5	3.0
	1.4	+1.5	1.0
	3.0	+2.0	0.9

Summary and Next Steps

- By using the MAP framework and simulated beam-induced background, it has been evaluated the precision on $H \rightarrow b\bar{b}$ coupling for the first time @$\sqrt{s} = 1.5\ TeV$ with full detectors and beam-induced background simulation.
- Extrapolation @$\sqrt{s} = 3, 10\ TeV$ have been determined
- After the new framework will be fully validated other couplings will be evaluated
- First performance studies in the next presentations by M. Casarsa, N. Bartosik and L. Sestini