Higgs boson decay width and couplings at Muon Collider

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The Muon Collider

- Advantages from lepton and hadron colliders:
  - all energy available in hard collision
  - no bremsstrahlung ➔ energy frontier machine
- Muons are unstable: decay products at high energy interact with machine elements producing a large flux of secondary particles: **Beam Induced Background (BIB)**
- BIB is mitigated with two cone-shaped tungsten shielding nozzles [1]. Nevertheless the Muon Collider environment is peculiar due to BIB presence: detailed simulation considering BIB is mandatory to assess realistic performance in physics measurements
- With $\sqrt{s}$ = 3 TeV and L = 1 ab^{-1} 500k Higgs are expected, enough statistics to aim at precision measurements

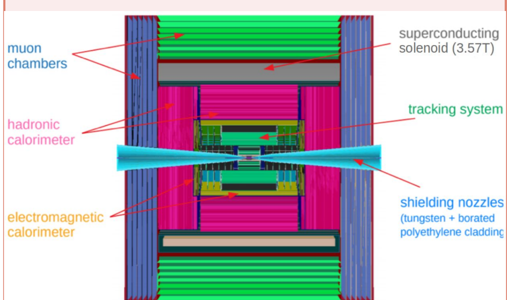


Figure 1: Representation of the Muon Collider Detector used in this study, with its main components and the shielding nozzles [2]

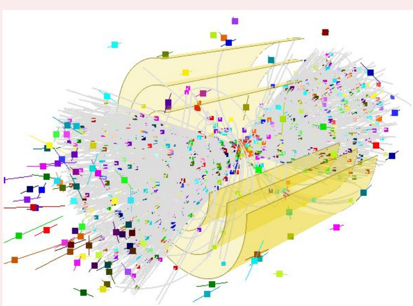


Figure 2: Event display showing reconstructed BIB tracks in the detector

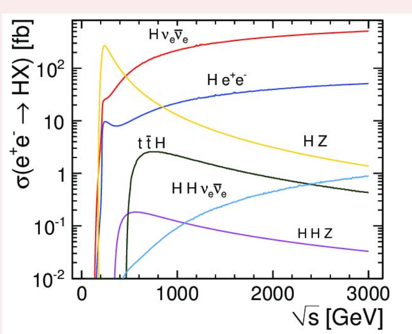


Figure 3: Higgs production cross-sections at a lepton collider

Analysis strategy

- Higgs width at a 3 TeV Muon Collider can be measured indirectly using **on-shell and off-shell Higgs** decaying to ZZ and W$^+$W$^-$, a technique already used by CMS [3]
  - On-shell ➔ on-shell Higgs decays to ZZ* and WW*
  - Off-shell ➔ VV produced through off-shell Higgs
  - Their **ratio** is **proportional only to Γ_H**
- Coupling g_{Hxx} can be obtained measuring $\sigma(\mu^+\mu^- \to H) \times BR(H \to xx)$, once Γ_H is known
- This study uses both **ZZ and W$^+$W$^-$ decay channels.** BIB events superimposed on physics events before event reconstruction is performed
- Candidate selection:
  - Max P_T muon(s)
  - Jets required not to contain selected muon(s)
  - In H ➔ W$^+$W$^-$ analysis missing transverse energy used as neutrino candidate
- Template fits to pseudo-experiments performed to determine uncertainties in event counts
- Finally couplings and Γ_H are fitted from event counts and their uncertainties

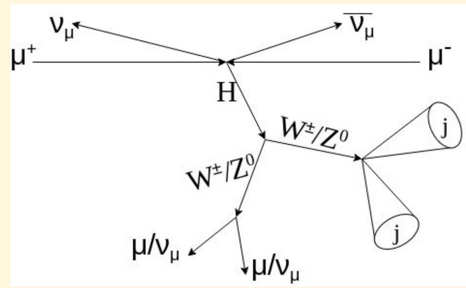


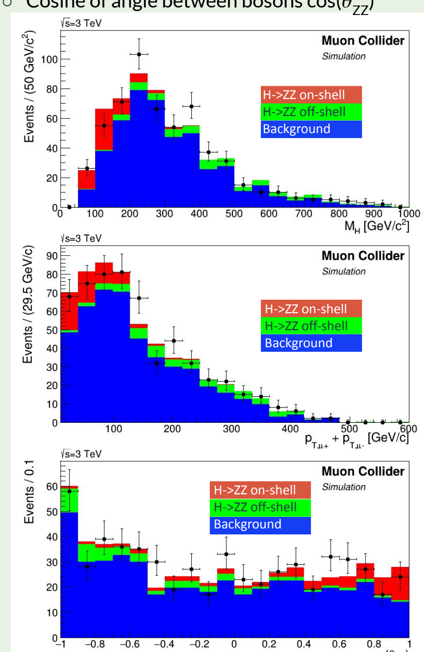
Figure 4: Sketch showing events topology

Process	Expected events
On-shell $H \to ZZ \to \mu^+\mu^- jj$	38.2
Off-shell $H \to ZZ \to \mu^+\mu^- jj$	56.0
$\nu\bar{\nu}\mu^+\mu^- jj$ background	458.3
On-shell $H \to W^+W^- \to \mu\nu_\mu jj$	1803.4
Off-shell $H \to W^+W^- \to \mu\nu_\mu jj$	411.4
$\nu\bar{\nu}\mu\nu_\mu jj$ background	2520.3

Table 1: Expected event counts for each signal and background sample used

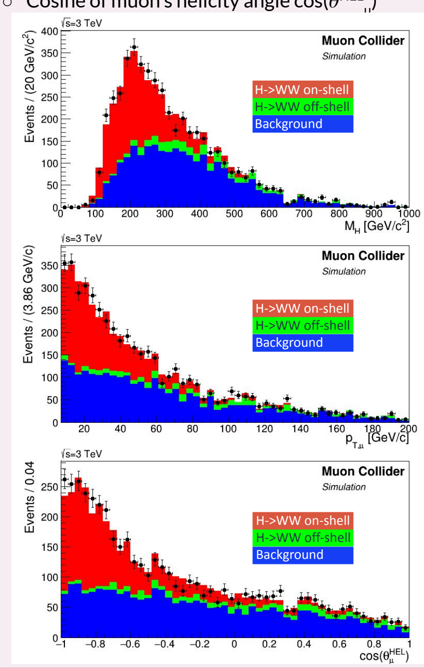
H ➔ ZZ template fit

- 3D template fit to pseudo-experiments on:
  - Reconstructed Higgs mass M_H
  - Sum of muon's transverse momenta $P_{T,\mu+}+P_{T,\mu-}$
  - Cosine of angle between bosons $\cos(\theta_{ZZ})$



H ➔ WW template fit

- 3D template fit to pseudo-experiments on:
  - Reconstructed Higgs mass M_H
  - Muon transverse momentum $P_{T,\mu}$
  - Cosine of muon's helicity angle $\cos(\theta^{HEL}_{\mu})$



Couplings and width fit

- All fitted signal yields, together with results of H ➔ *bb*[4] and H ➔ $\mu^+\mu^-$ [5] analyzes, are inputs of the final fit
- Results compared with CLIC, a proposed e$^+$e$^-$ linear collider, which takes advantage of multiple energy stages and larger luminosity
  - 25 yrs of CLIC operation vs 5 yrs of Muon Collider

	Muon Collider 1 ab^{-1} @ 3 TeV	CLIC 0.5 ab^{-1} @ 350 GeV + 1.5 ab^{-1} @ 1.4 TeV + 2 ab^{-1} @ 3 TeV
Γ_H	5.4%	3.5%
g_{HZZ}	6.1%	0.8%
g_{HWW}	1.4%	0.9%
g_{Hbb}	1.7%	0.9%
$g_{H\mu\mu}$	19.2%	7.8%

Table 2: Expected resolutions on Higgs width and its couplings to Z, W, *b* and μ, compared between Muon Collider and CLIC, a proposed linear e$^+$e$^-$ collider [6]

References
[1] Phys. Procedia 37 (2012) 2015
[2] https://confluence.infn.it/display/muoncollider/Muon+Collider+Detector
[3] Phys.Rev.D 99 (2019) 11, 112003
[4] See L. Buonincontri's poster
[5] See A. Montella's poster
[6] Eur. Phys. J. C 77, 475 (2017)