Search for $\mathrm{H} \rightarrow c\bar{c}$ at a Multi-Tev Muon Collider

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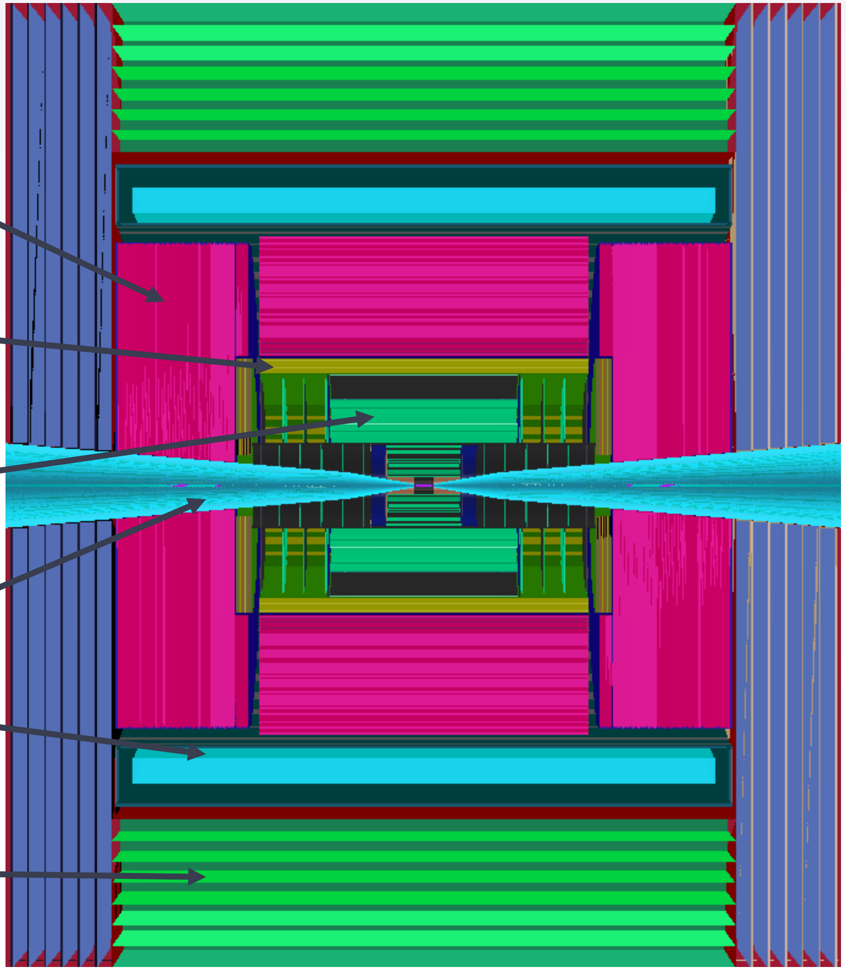
A Muon Collider would represent a powerful machine for the future exploration in Particle Physics

Access to high energy frontier + **Precise measurements of Higgs couplings**

- **Advantage wrt hadron machines (HL-LHC, FCC-hh)**: Whole center of mass energy $\sqrt{s}$ available for interactions.
- **Advantage wrt e^+e^- machines (FCC-ee, CLIC, ILC)**: Negligible beamstrahlung → storage rings + tens of TeV collisions.

❖ Higgs-to-c-quark coupling (g_{Hcc}) not accessible experimentally at LHC / HL-LHC.

❖ Feasibility study aiming to determine the **precision achievable at Muon Collider on g_{Hcc}** (by now w/o BIB overlay, because computationally high demanding)



*for mitigation of Beam Induced Background (BIB) main issue at Muon Collider.

Flavour Tagging:
c jet identification at the Muon Collider

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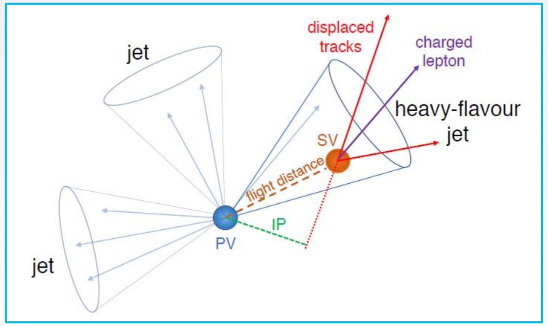


Goal: reject the dominant $H \to b\bar{b}$ and $H \to gg$ bkg, kinematically indistinguishable from $H \to c\bar{c}$.
Method: exploit variables connected to c hadrons present in jets.
Two independent taggers implemented (inspired to the CMS ones) through a Boosted Decision Tree:

- **CvsB** → to separate c jets from b jets
- **CvsL** → to separate c jets from light-flavour jets

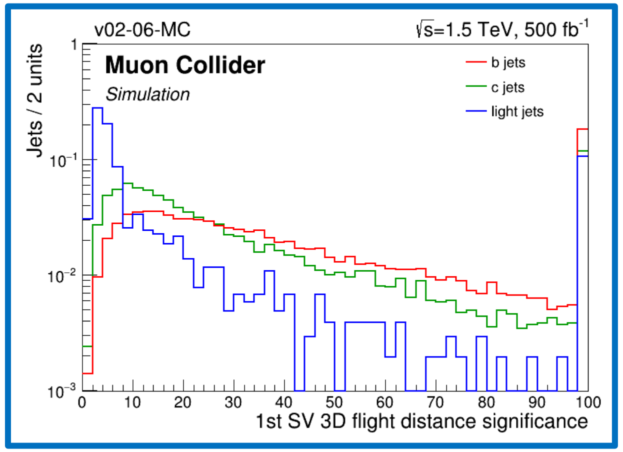
The tagger performance is compatible to the CLIC one without BIB overlay.

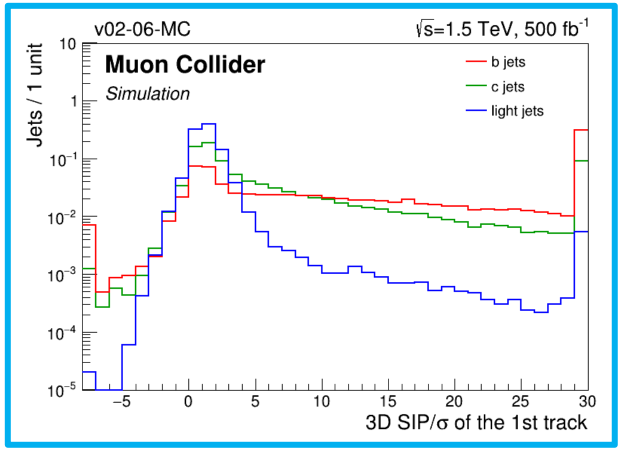
Features (few examples)

Track variables
Signed Impact Parameter (SIP) significance, pT_{jaxis}, …

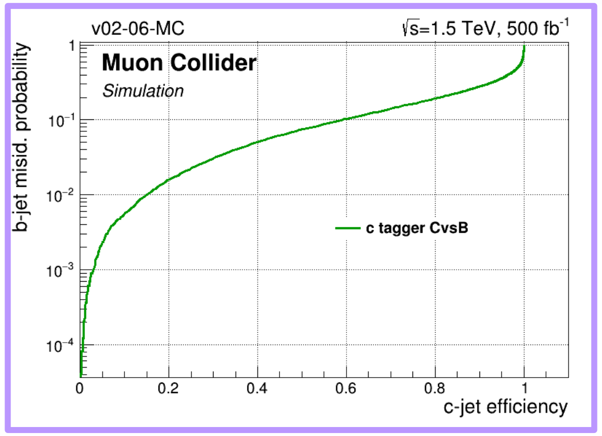
Secondary vertex variables
Flight distance significance, mass, …

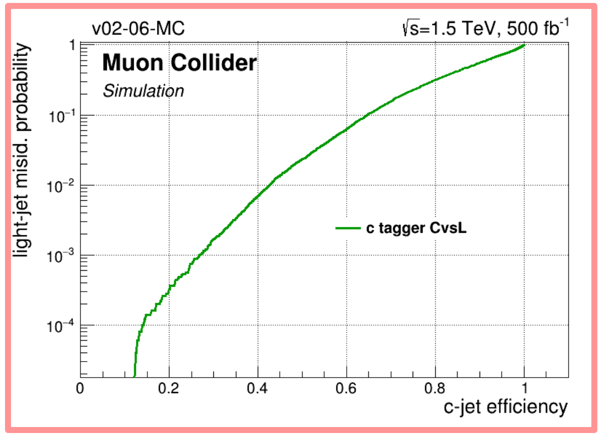
Soft lepton variables
Muon and electron pT_{jaxis}, $\mathrm{pT/pT_j}$, …





Tagger Performance (evaluated separately)





c eff.	*b* eff.
30 %	3.0 %
50 %	7.5 %
70 %	14 %
90 %	28 %

c eff.	*light* eff.
30 %	0.2 %
50 %	2.3 %
70 %	16 %
90 %	55 %

$H \to c\bar{c}$ search strategy

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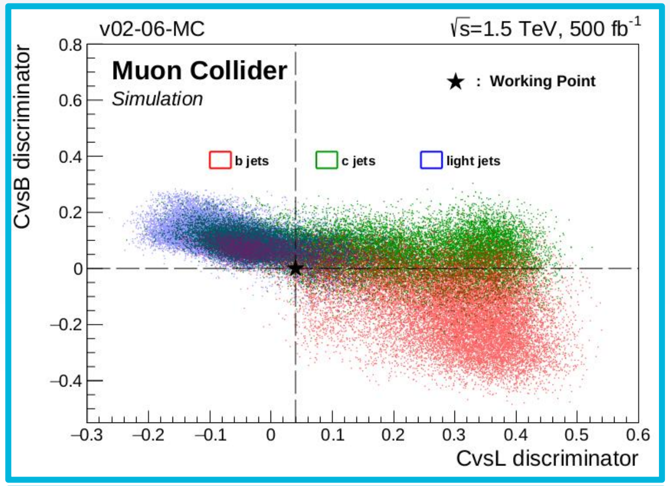
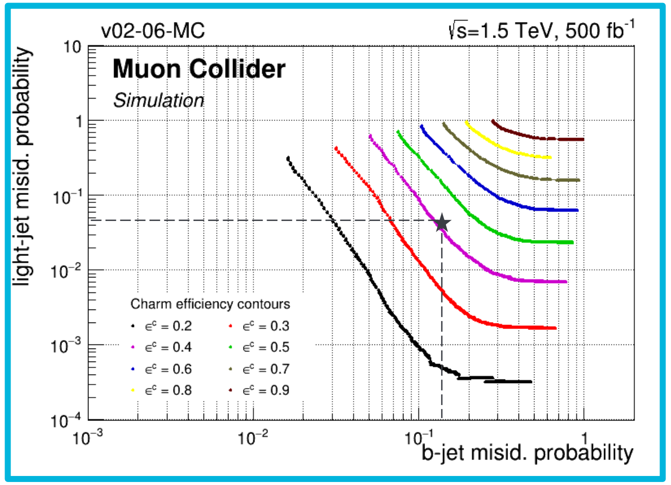
Choice of the tagger working point (the combined efficiencies are shown)

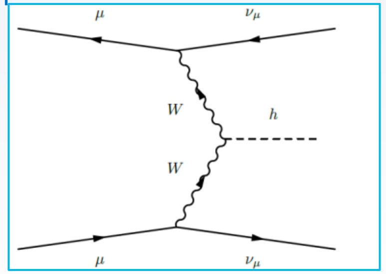




$(CvsL, CvsB)$	c eff.	b eff.	lf eff.
(0.04, 0.00)	40 %	13 %	5 %

WW fusion:

Here dominant higgs production mechanism



Samples simulated and reconstructed at $\sqrt{s} = 1.5$ TeV

Signal process

$\mu^+\mu^- \to H\nu\bar{\nu} \to c\bar{c}\,\nu\bar{\nu}$

Higgs background

$\mu^+\mu^- \to H\nu\bar{\nu} \to b\bar{b}\,\nu\bar{\nu}$

$\mu^+\mu^- \to H\nu\bar{\nu} \to gg\,\nu\bar{\nu}$

Non-Higgs background

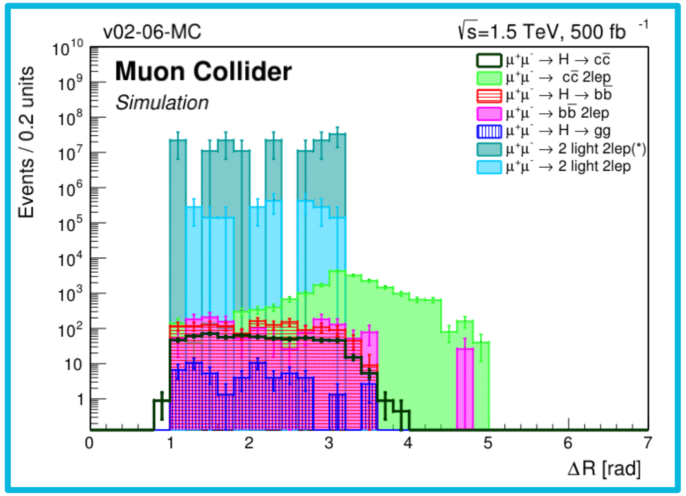
$\mu^+\mu^- \to c\bar{c}$ 2leptons

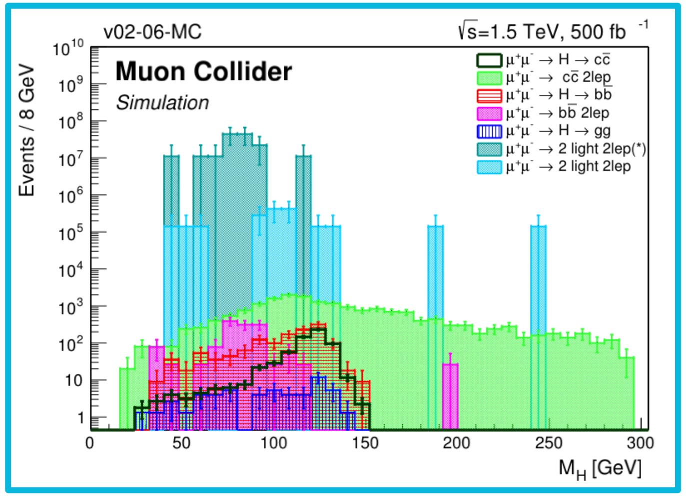
$\mu^+\mu^- \to b\bar{b}$ 2leptons

$\mu^+\mu^- \to$ 2light 2leptons

Only jets with CvsB and CvsL score higher then the working point are selected → Higgs candidates are built using the two highest pT jets → Requirements on Higgs:

- $E_H > 130$ GeV
- $pT_H > 30$ GeV
- $\Delta R(j_1, j_2) < 3$
- $m_H \in [110, 130]$ GeV





Results

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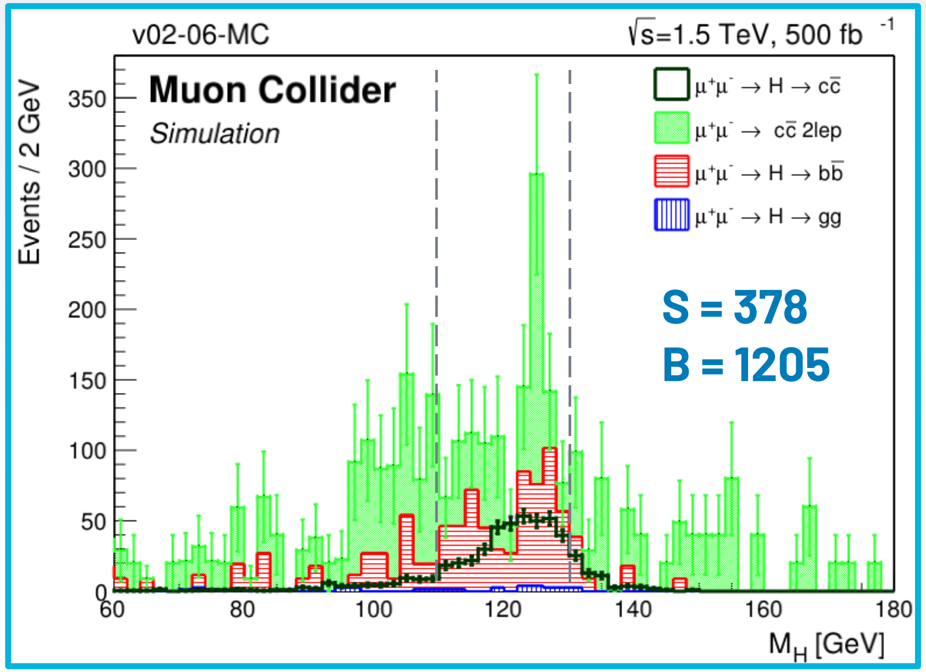

*not reported processes are completely suppressed by the selections

$S/\sqrt{S+B}$ signal significance	$\Delta\sigma/\sigma$ rel. uncertainty on signal cross section	$\Delta g_{Hcc}/g_{Hcc}$ rel. uncertainty on Hcc coupling
Preliminary Muon Collider results at $\sqrt{s}$ = 1.5 TeV, 500 fb^{-1} (no BIB overlay)		
9.5	10.5 %	**5.5 %**
Projection at $\sqrt{s}$ = 3 TeV, 1300 fb^{-1} (assuming same selection efficiencies)		
20.4	4.9 %	**2.6%**

Conclusions

- A Flavour tagging algorithm based on MVA techniques has been developed and applied in the estimation of Hcc coupling at a future Muon Collider experiment, using fully simulated and reconstructed signal and background samples.
- The precision reachable is 5.5 % at $\sqrt{s}$ = 1.5 TeV and 2.6 % at $\sqrt{s}$ = 3 TeV
- Future developments: optimization of reconstruction and analysis, full BIB overlay, search at $\sqrt{s}$ = 10 TeV.