First collaboration meeting on Physics and Experiments at a Muon Collider

Monday 27 Jul 2020, 13:30 → 18:30 Europe/Zurich

Physics Studies

Donatella Lucchesi

University of Padova And INFN

P. Andreetto, N. Bartosik, A. Bertolin, L. Buonincontri, M. Casarsa, F. Collamati, C. Curatolo, A. Ferrari, A. Ferrari, A. Gianelle, A. Mereghetti, N. Mokhov, M.Palmer, N. Pastrone, C. Riccardi, P. Sala, L. Sestini, I. Vai

For the International Muon Collider Collaboration

Università degli Studi di Padova

INFN Istituto Nazionale di Fisica Nucleare

Higgs $b\bar{b}$ Coupling Studies

With the full simulation, including the beam-induced background at $\sqrt{s}$= 1.5 TeV we evaluated:

- Jets reconstruction efficiency as function of transverse momentum
- Jet b-tagging efficiency as function of transverse momentum

Signal and physics background have been simulated and reconstructed at $\sqrt{s}$= 1.5 TeV, $\sqrt{s}$= 3 TeV and $\sqrt{s}$= 10 TeV by using the same detector and assuming the same beam-induced background.

The $\sqrt{s}$= 10 TeV was an exercise → we should discuss how to approach these studies.

Higgs $b\bar{b}$ Couplings Results

- The instantaneous luminosity, $\mathcal{L}$, at different √s is taken from MAP studies.
- The acceptance, A, the number of signal events, N, and background, B, determined with simulation.
- One detector and 4 Snowmass years are assumed.

$\sqrt{s}$ [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

	$\sqrt{s}$ [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

CLIC numbers are obtained with a model-independent multi-parameter fit performed in three stages, taking into account data obtained at the three different energies.

Results published on JINTST as Detector and Physics Performance at a Muon Collider

Physics Studies in the pipeline

- Optimization of jets reconstruction and b-jet identification.
- Tracks reconstruction improvements is more demanding

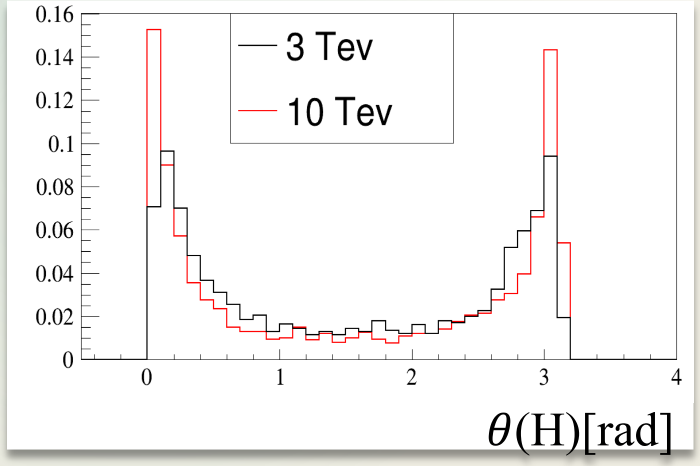
Re-evaluate

- $\mu^+\mu^- \rightarrow HX, H \rightarrow b\bar{b}$ at $\sqrt{s}$= 1.5 TeV, $\sqrt{s}$= 3 and $\sqrt{s}$= 10 TeV

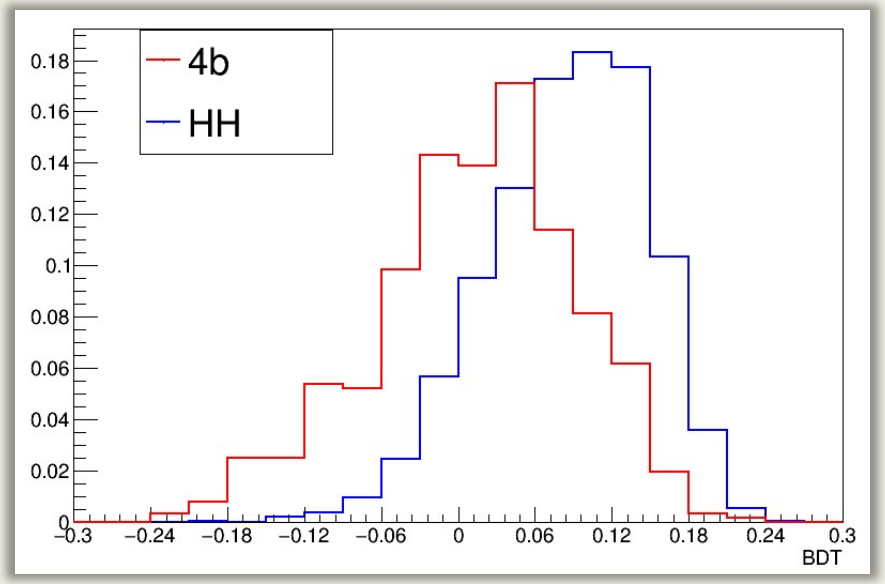
Measure Higgs trilinear coupling at $\sqrt{s}$= 3 and $\sqrt{s}$= 10 TeV

- $\mu^+\mu^- \rightarrow HHX, H \rightarrow b\bar{b},\ H \rightarrow b\bar{b}$ and $\mu^+\mu^- \rightarrow b\bar{b}b\bar{b}\nu\bar{\nu}$ inclusive generated at $\sqrt{s}$= 3 with WHIZARD 2.8.2
- Detector acceptance and MDI of $\sqrt{s}$=1.5 TeV
- Detector performance determined at $\sqrt{s}$=1.5 TeV events weighted to take into account for the different energy.

Laura Buonincontri master thesis.



News results will be presented at ICHEP2020 by Lorenzo Sestini.



Possible Roadmap for Physics Study

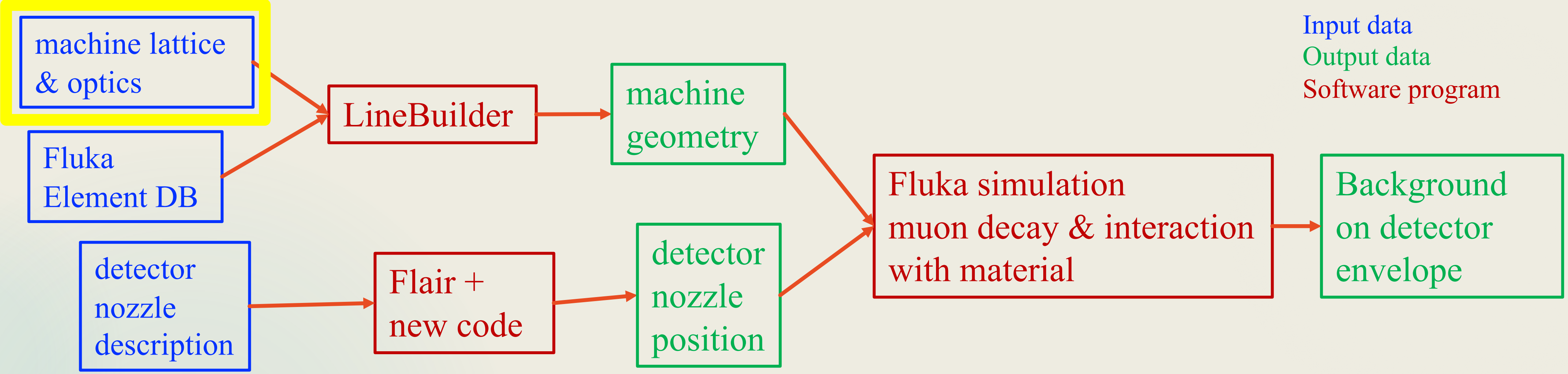
We have to create a list of physics benchmark processes in concertation with the theoretical community. Our experience so far tell us that we can follow two different paths:

1) Identify the physics process for which the full simulation is mandatory and study them including the beam-induced background.

2) Use efficiencies and resolutions “à la Delphes”, whenever it is possible but “cum grano salis” to make sure biases are not created.

1) Identify the physics process for which the full simulation is mandatory and study them including the beam-induced background.

The code for beam-induced background generation is available



Machine IR needed:

- We may have $\sqrt{s}$= 3 TeV from MAP. When?
- What do we do for $\sqrt{s}$= 10 TeV?

Latest results will be presented at ICHEP2020 by Francesco Collamati.

1) Identify the physics process for which the full simulation is mandatory and study them including the beam-induced background.

A full list of in J. de Blas Snowmass EF workshop talk

- Electroweak precise determination of observables: $M_Z, \Gamma_Z, \sin\theta_W$, asymmetries
- Full study of $\mu^+\mu^- \rightarrow W^+W^-$
- Vector boson scattering

Several input from M. Carena Snowmass EF workshop talk

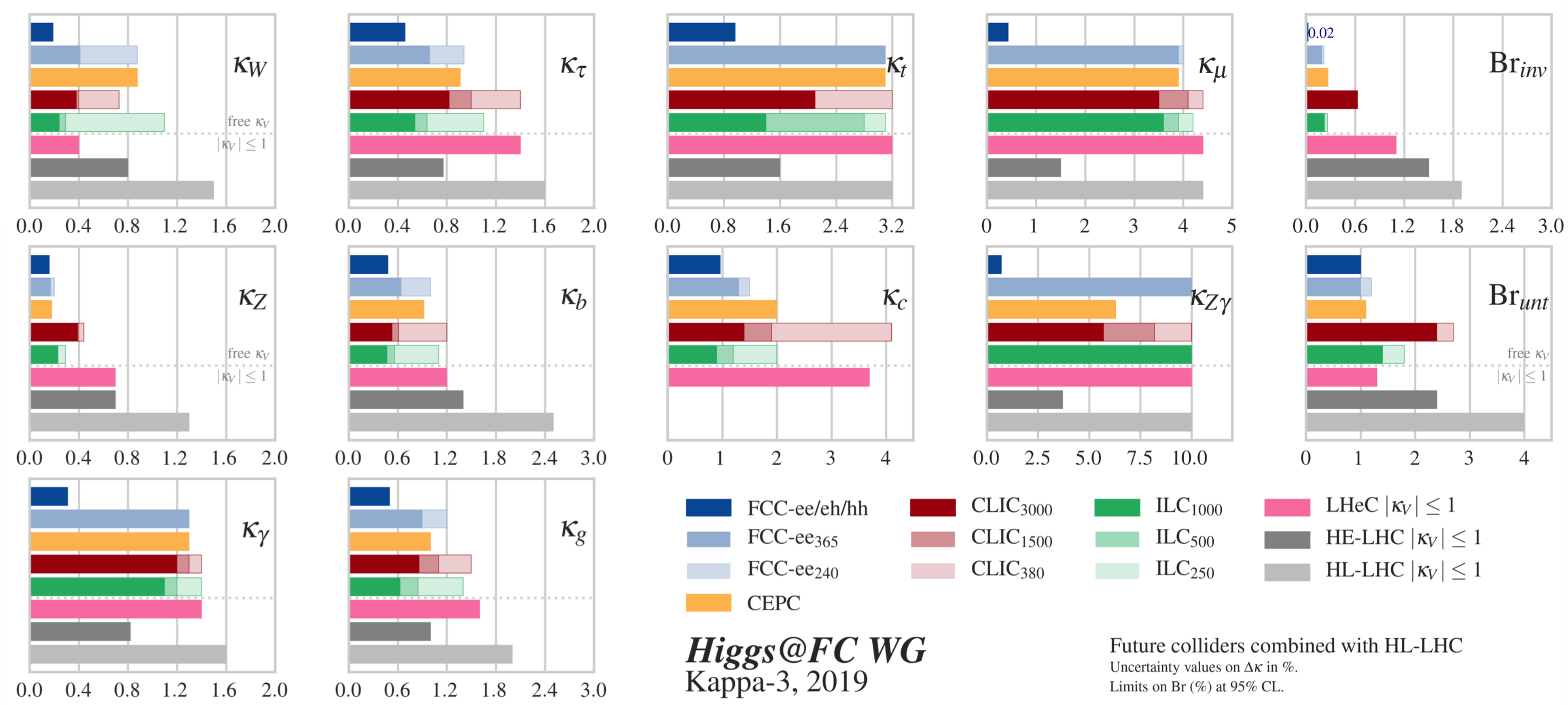
- Dark sector and mediators:
  - dark photon,
  - dark Higgs,
  - heavy neutrino,
  - axions

Detector optimization can heavily impact on forward tracks reconstruction, short tracks, etc

New detailed results will be presented at ICHEP2020 by Massimo Casarsa.

2) Use efficiencies and resolutions “à la Delphes”, whenever it is possible but “cum grano salis” to make sure biases are not created.

a. Higgs Couplings to bosons and fermions



Plan is to add the muon collider row

2) Use efficiencies and resolutions "à la Delphes", whenever it is possible but "cum grano salis" to make sure biases are not created.

b. Higgs self-couplings

- $\mu^+\mu^- \to HHX, H \to b\bar{b},\ H \to b\bar{b}$ and $\mu^+\mu^- \to b\bar{b}b\bar{b}\nu\bar{\nu}$ in progress at √s= 3 TeV

- $\mu^+\mu^- \to HHHX, H \to b\bar{b},\ H \to b\bar{b}, H \to b\bar{b}$ signal
  $\mu^+\mu^- \to b\bar{b}b\bar{b}b\bar{b}\nu\bar{\nu}$ how to efficiently generate it?

Should we start meeting among the interested people to organize the Higgs studies?

To summarize

- Create a priority list for physics tstudies at $\sqrt{s}$= 3 TeV for 1) full simulation and 2) parametric, à la Delphes.

- Agree on how to proceed to address the $\sqrt{s}$= 10 TeV studies if we will not have idea of the beam-induced background