FastSim with Delphes

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on behalf of the Muon Collider Physics and Detector Group

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Outline

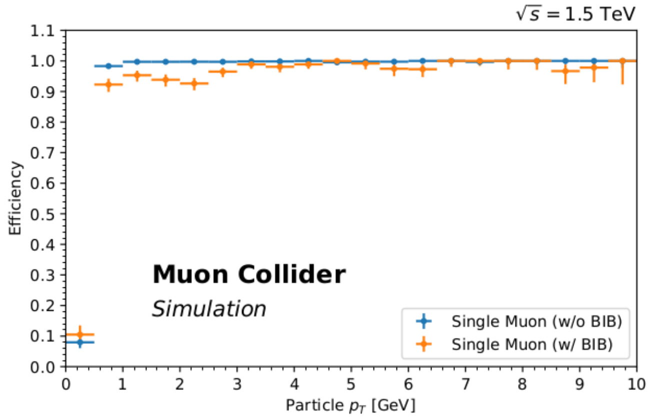
- Will summarize where we stand with the parametric detector simulation:
  - currently available Delphes card;
  - comparison to full simulation performance at 3 TeV.
- Ongoing work at 3 TeV.
- Plans for fast simulation at 3 TeV and 10 TeV.

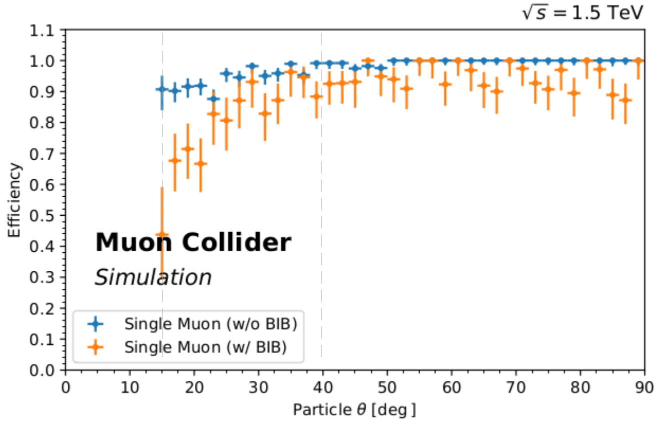
The status quo

- There is currently a Delphes card for the muon collider, written by M. Selvaggi in 2021 as an educated-guess hybrid between the FCC-hh and CLIC performance and intended as a target-performance card:
  - `delphes_card_MuonColliderDet.tcl`;
  - Michele's introductory talk on Delphes and the muon collider card.

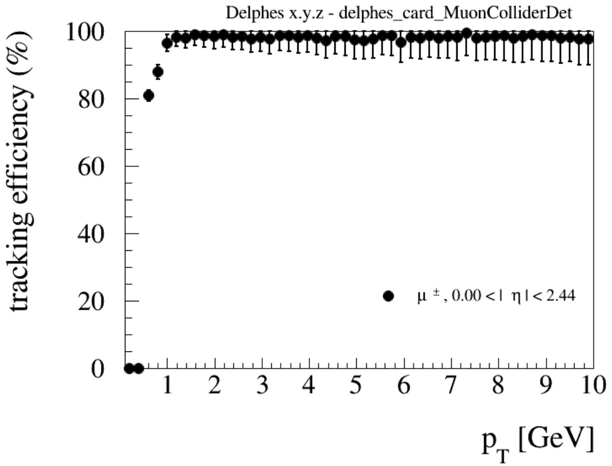
Track reconstruction efficiency

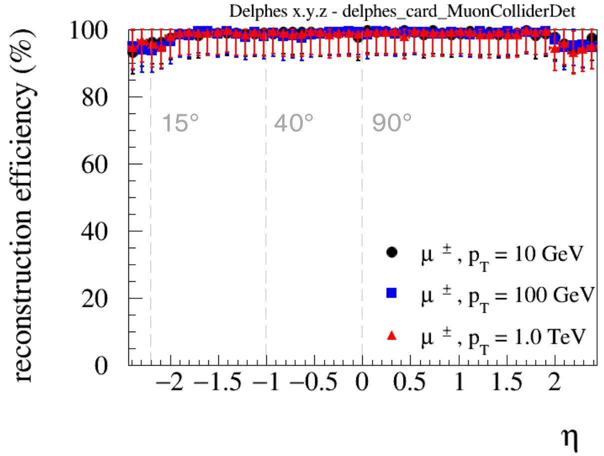
FULL SIMULATION





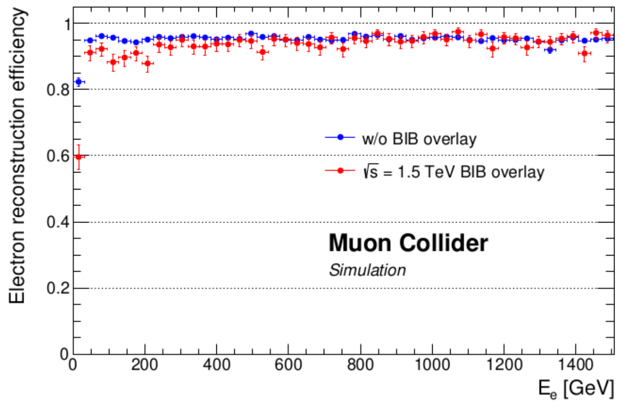
FAST SIMULATION

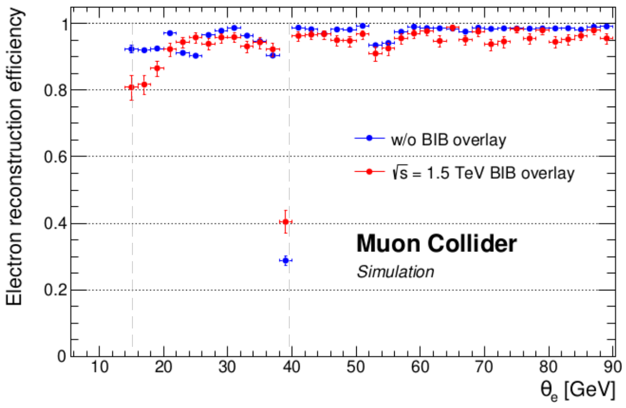




Electron reconstruction efficiency

FULL SIMULATION





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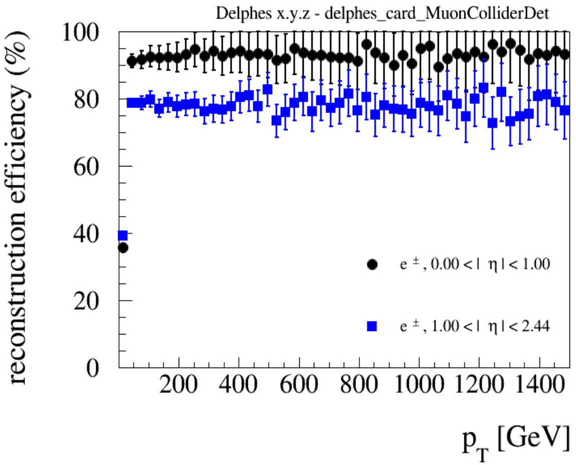
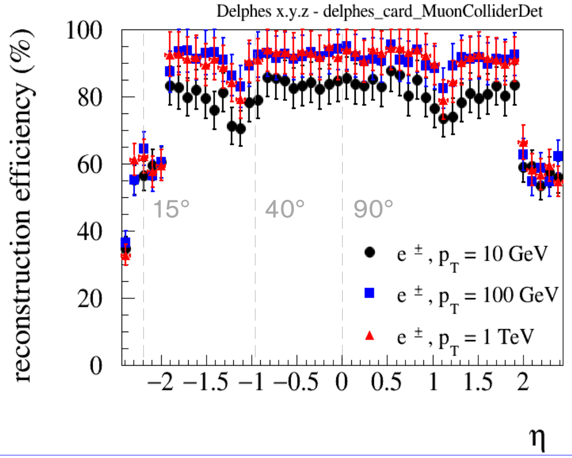
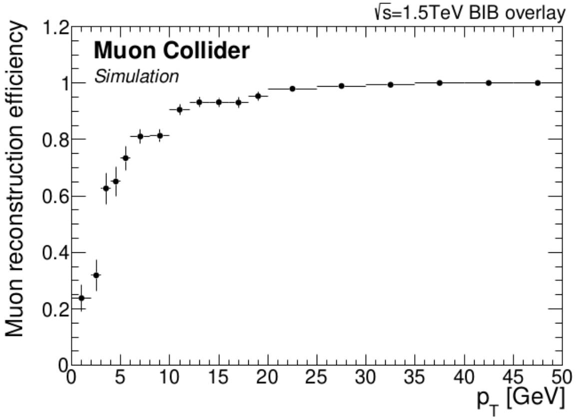
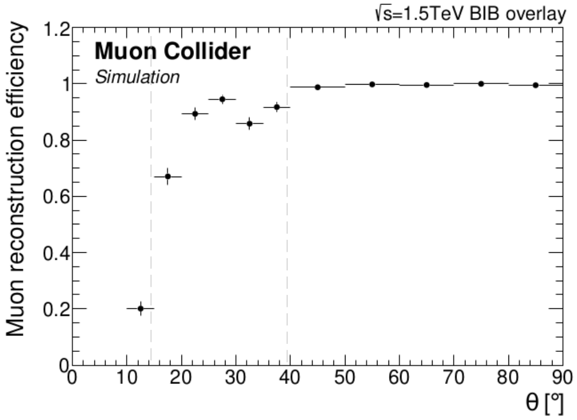




Muon reconstruction efficiency

FULL SIMULATION





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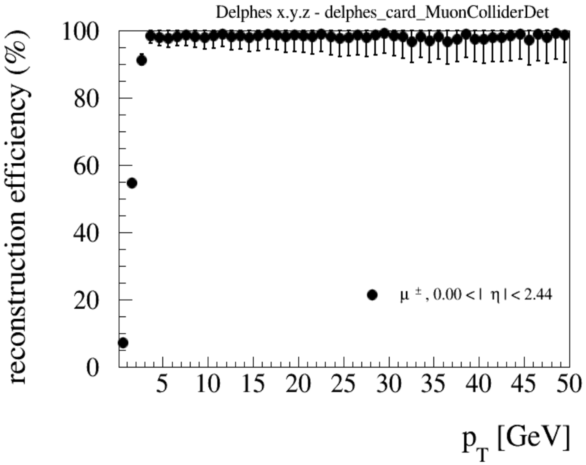
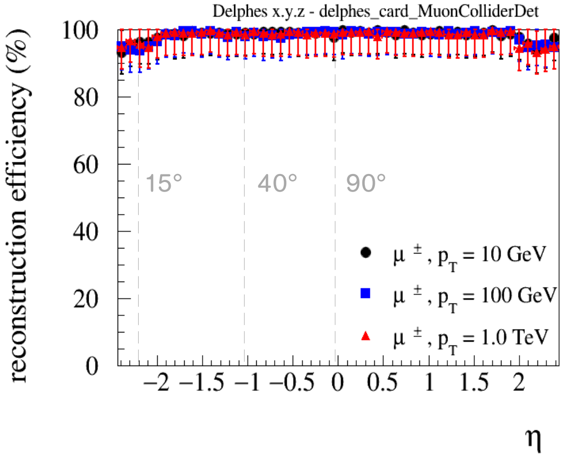
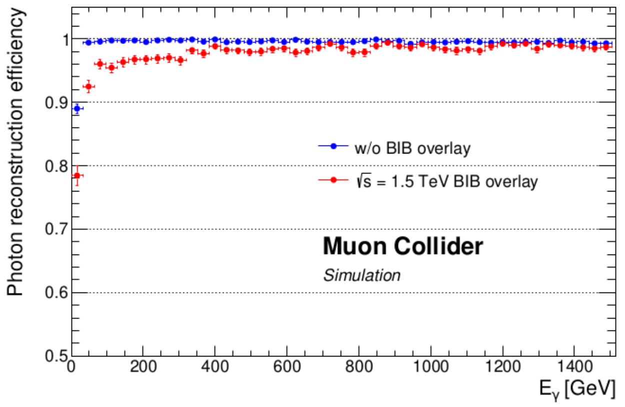
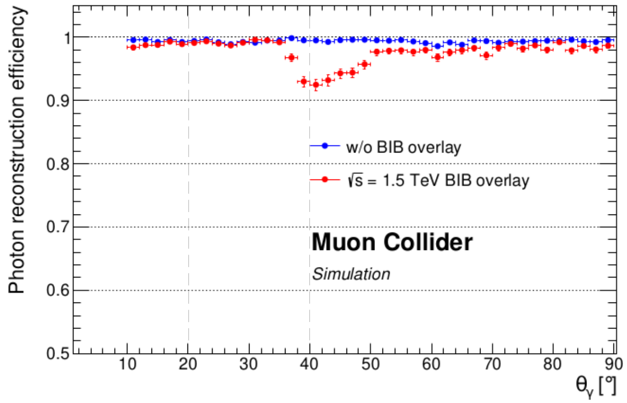




Photon reconstruction efficiency

FULL SIMULATION





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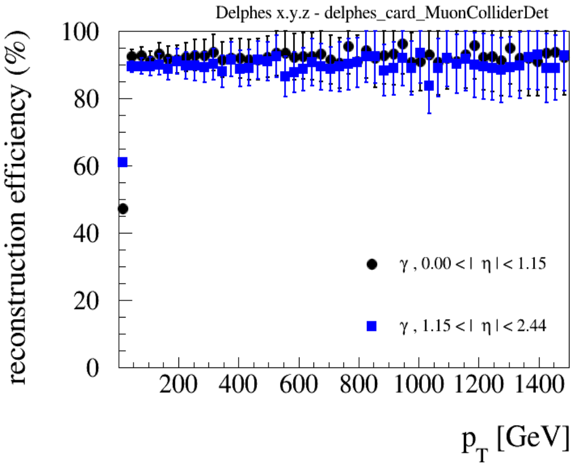
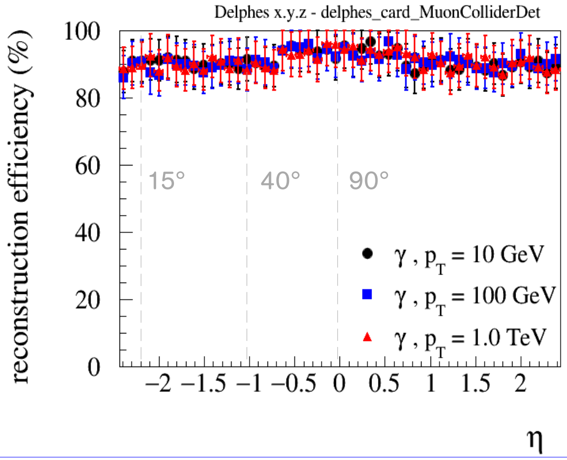
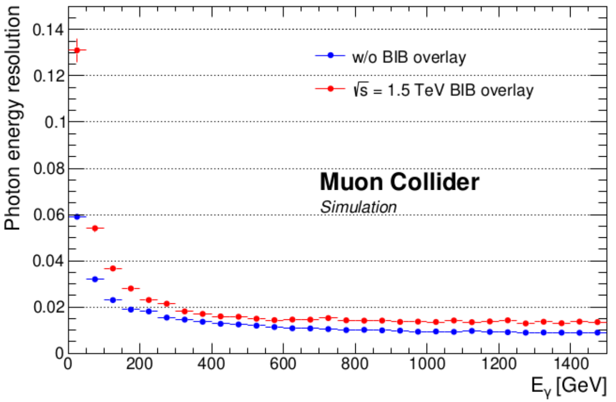
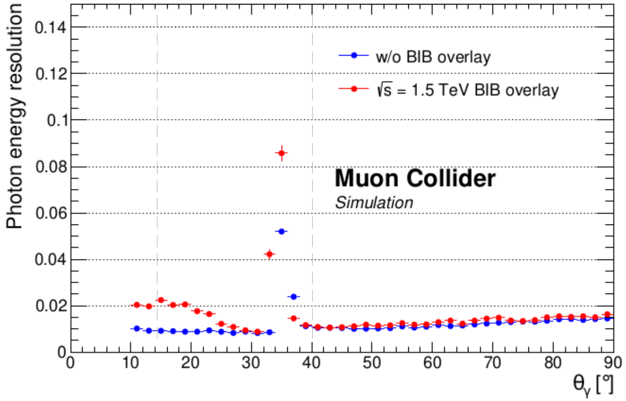




Electromagnetic energy resolution

FULL SIMULATION





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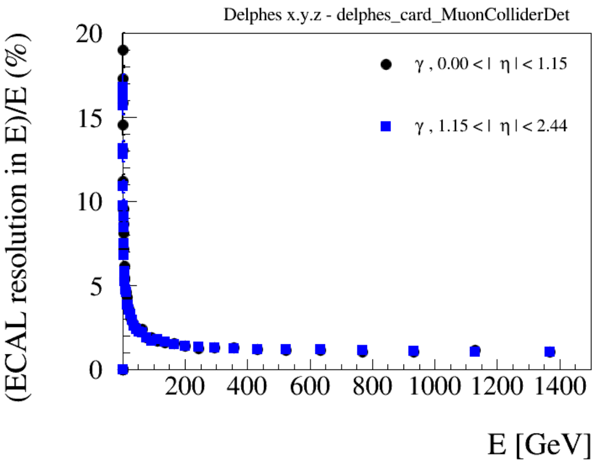
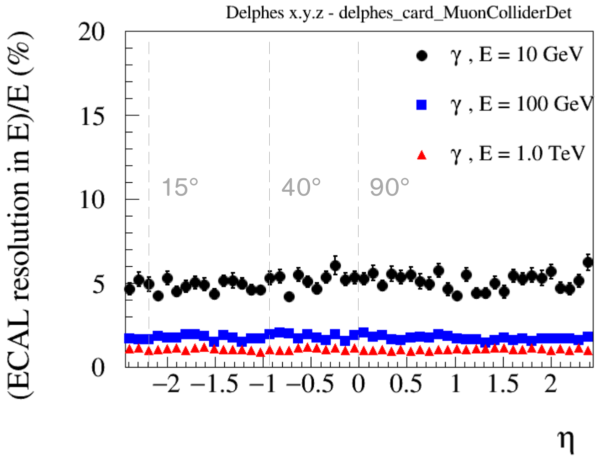
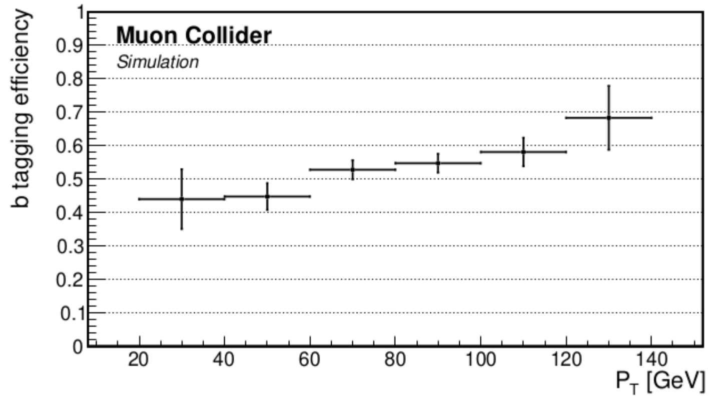
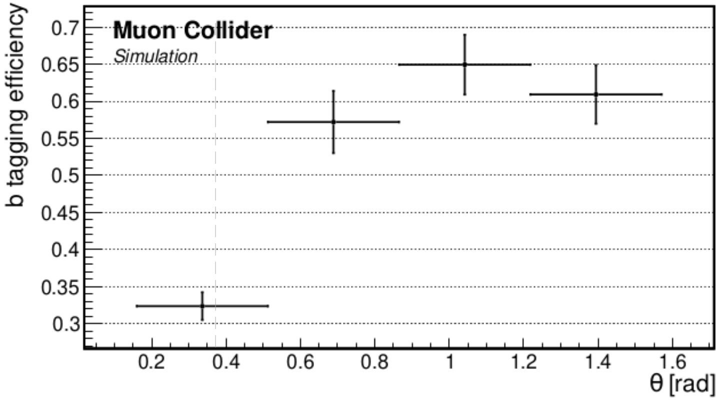




B tagging efficiency

FULL SIMULATION





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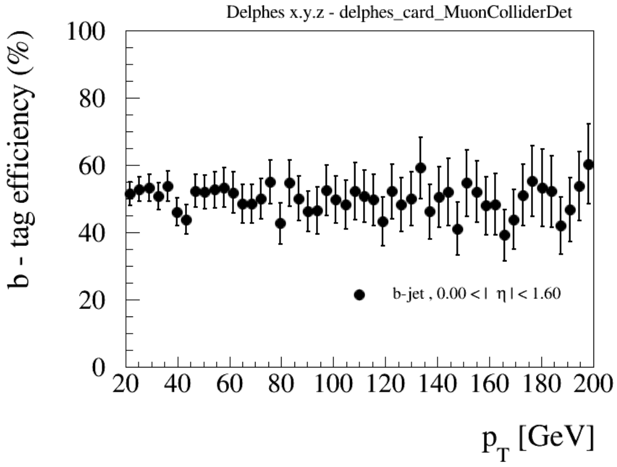
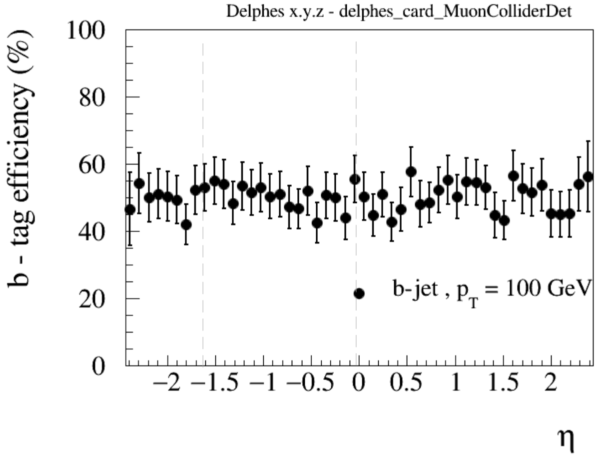


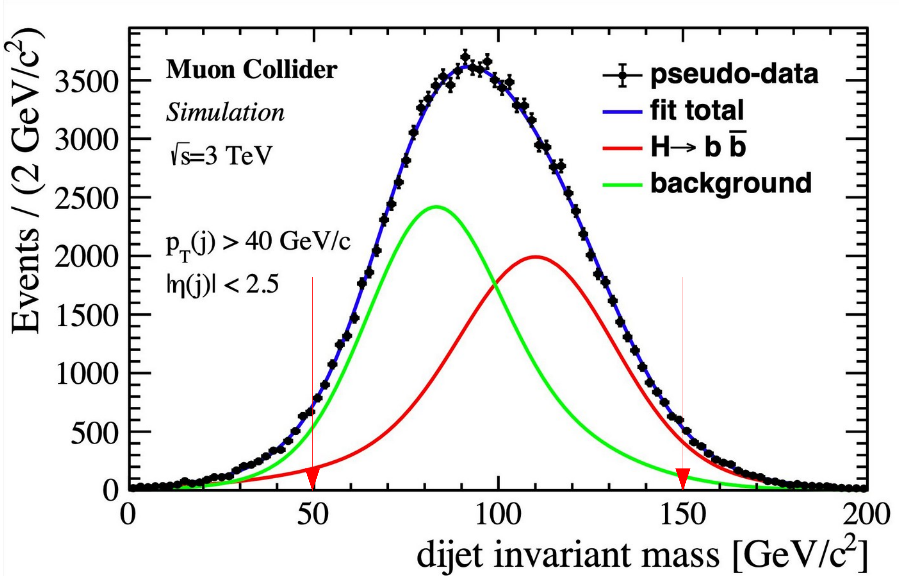


Fast simulation vs full simulation

- At the last IMCC meeting, L. Giambastiani presented a comparison of our Higgs sensitivity studies carried out with the detector detailed simulation and the corresponding fast simulation results from M. Forslund and P. Maede's paper (arXiv:2203.09425):
  - Luca's talk.
- Fast simulation analyses:
  - samples generated at 3 TeV with MadGraph 5 + Pythia and normalized to an integrated luminosity of 1 ab^{-1};
  - simple cut-based analyses;
  - signal sensitivity estimated as $\frac{\Delta\sigma}{\sigma} = \frac{\sqrt{S+B}}{S}$.

Dijet invariant mass

FULL SIMULATION



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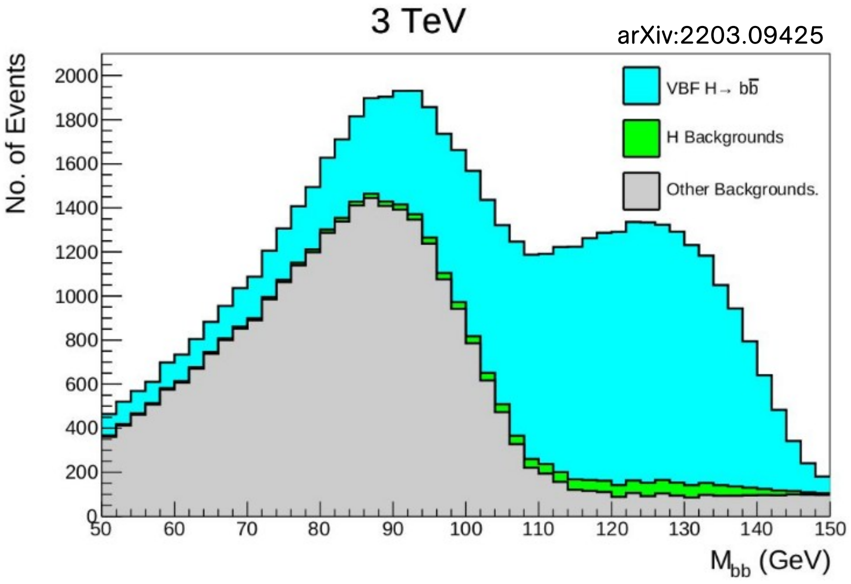


Preliminary full sim vs fast sim analyses

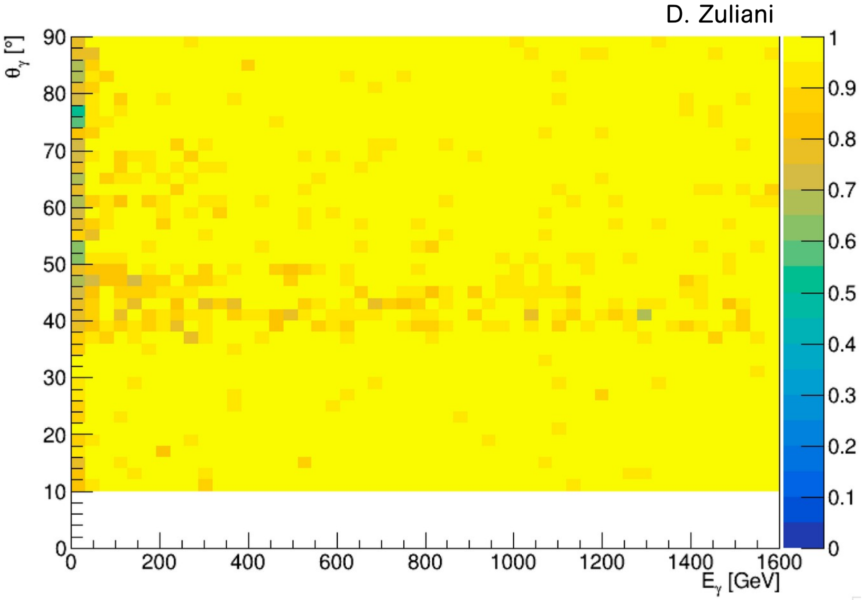
	Full sim		Fast sim	
Cross sections resolution →	H->WW	2.9%	H->WW	1.7%
	H->ZZ	17%	H->ZZ	11%
	H->bb	0.75%	H->bb	0.76%
	H->μμ	38%	H->μμ	40%
	H->γγ	8.9%	H->γγ	6.1%
	HH->4b	30%		
Couplings resolution →	g_{HWW}	0.9%	g_{HWW}	0.55%
	g_{HZZ}	8.2%	g_{HZZ}	5.1%
	g_{Hbb}	0.8%	g_{Hbb}	0.97%
	$g_{H\mu\mu}$	19%	$g_{H\mu\mu}$	20%
	$g_{H\gamma\gamma}$	4.5%	$g_{H\gamma\gamma}$	3.2%
	λ_3	20%	λ_3 (95% CL)	25%

Plans for 3 TeV

- Ongoing work to prepare a “working” Delphes card, based on the full simulation studies, to be kept up-to-date with future improvements in the physical objects reconstruction.

- Review and update the current “target” card to improve consistency with the full simulation studies:
  - same definitions of efficiencies (vs η or vs θ) and resolutions ($\Delta p_T/p_T$ or $\Delta p_T/p_T^2$ for tracks), same jet clustering and b-tagging algorithms, ...

photon reconstruction efficiency from full sim



Plans for 10 TeV

- We don't have a detector model for 10-TeV collisions yet.
- Define a baseline detector configuration from first principles (size, magnetic field intensity, ...).
- Use the parametric simulation to design the detector specifications:
  - a Delphes card has been implemented for FCC-ee that includes an analytic parameterization of the track parameter resolution as a function of a given tracker model;
  - use advanced machine-learning techniques (e.g. MODE).
- Once an optimal detector configuration is established, a "target" Delphes card will be prepared and a "working" Delphes card, based on the latest full simulation results, will follow.

Summary

- Given the unique and peculiar features of the beam-induced background at a muon collider, initial detector performance and physics studies were based on a detailed detector simulation and aimed at assessing the BIB effects and putting in place the necessary mitigation measures.

- Comparisons of the full simulation and fast simulation results allowed to identify the current working performance of the present detector design and the target one.

- Two new Delphes cards are in preparation for 3 TeV.

- The same strategy is going to be followed for 10 TeV.

Backup

Detector model at 3 TeV

hadronic calorimeter

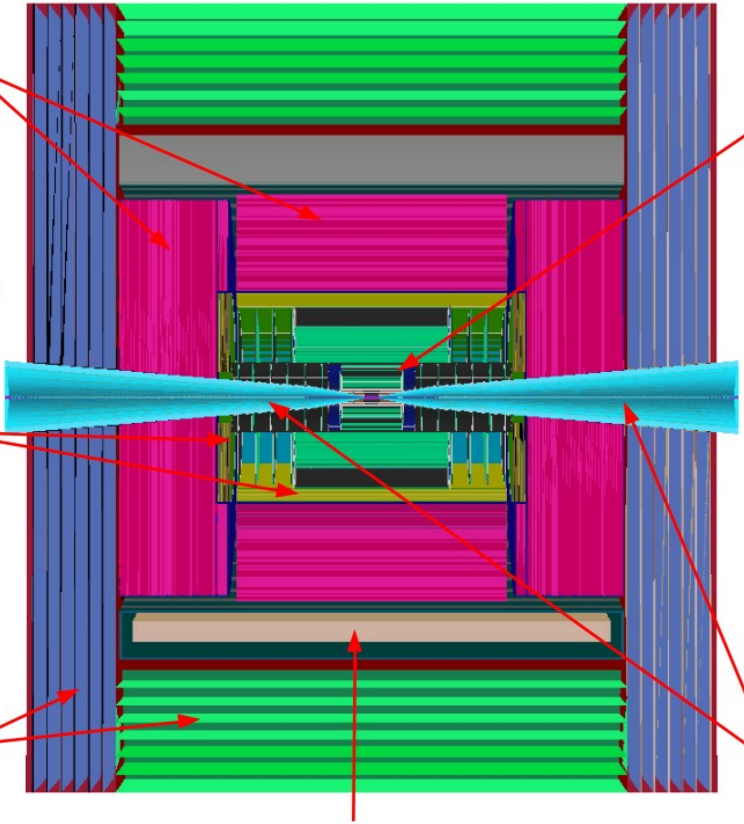
- 60 layers of 19-mm steel absorber + plastic scintillating tiles;
- 30x30 mm^2 cell size;
- 7.5 λ_I.

electromagnetic calorimeter

- 40 layers of 1.9-mm W absorber + silicon pad sensors;
- 5x5 mm^2 cell granularity;
- 22 X_0 + 1 λ_I.

muon detectors

- 7-barrel, 6-endcap RPC layers interleaved in the magnet's iron yoke;
- 30x30 mm^2 cell size.



superconducting solenoid (3.57T)

tracking system

- Vertex Detector:
  - double-sensor layers (4 barrel cylinders and 4+4 endcap disks);
  - 25x25 μm^2 pixel Si sensors.
- Inner Tracker:
  - 3 barrel layers and 7+7 endcap disks;
  - 50 μm x 1 mm macro-pixel Si sensors.
- Outer Tracker:
  - 3 barrel layers and 4+4 endcap disks;
  - 50 μm x 10 mm micro-strip Si sensors.

shielding nozzles

- Tungsten cones + borated polyethylene cladding.