Reconstructing muons at a Muon Collider

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Muon Collider

A Muon Collider is a promising proposal as multi-TeV high luminosity machine [1]. Lepton colliders allow to probe much higher energy scales than hadrons with higher precision; in addition, the usage of muons guarantees a much lower level of synchrotron radiation than the electron case.

However, a muon collider poses relevant technological challenges:

- the production of a large number of muons in low emittance bunches
- the need to deal with the Beam-Induced Background (BIB).

Figure 1 is a schematic view of the detector.

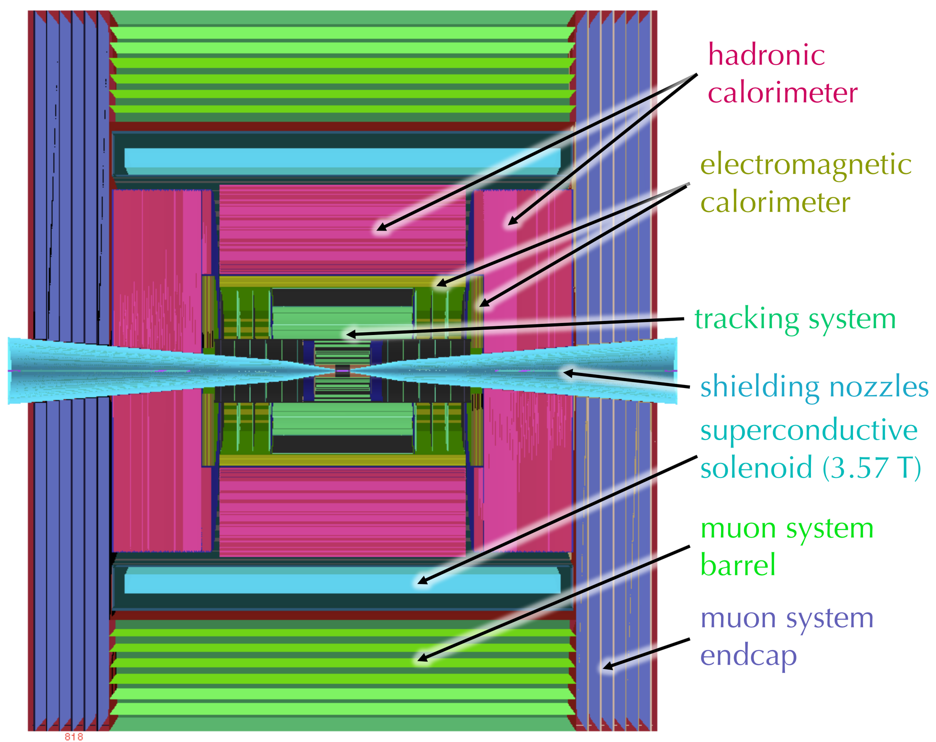

Figure 1: Schematic view of the detector.

Muon system

The muon system is mainly inherited by the CLIC design [2]. The iron yoke plates are instrumented with:

- 7 layers of detectors in the barrel
- 6 layers in the endcap.

The technology chosen is Glass Resistive Plate Chamber (GRPC) with $3 \times 3\,\mathrm{cm}^2$ cells.

A Geant4 standalone simulation has been developed to estimate the hit rate of neutrons and photons from the BIB for alternative MicroPattern Gaseous Detector technologies [3].

Preliminary results in Figs. 2-3 show that in the central region GRPCs are already at the limit of standard rate capability.

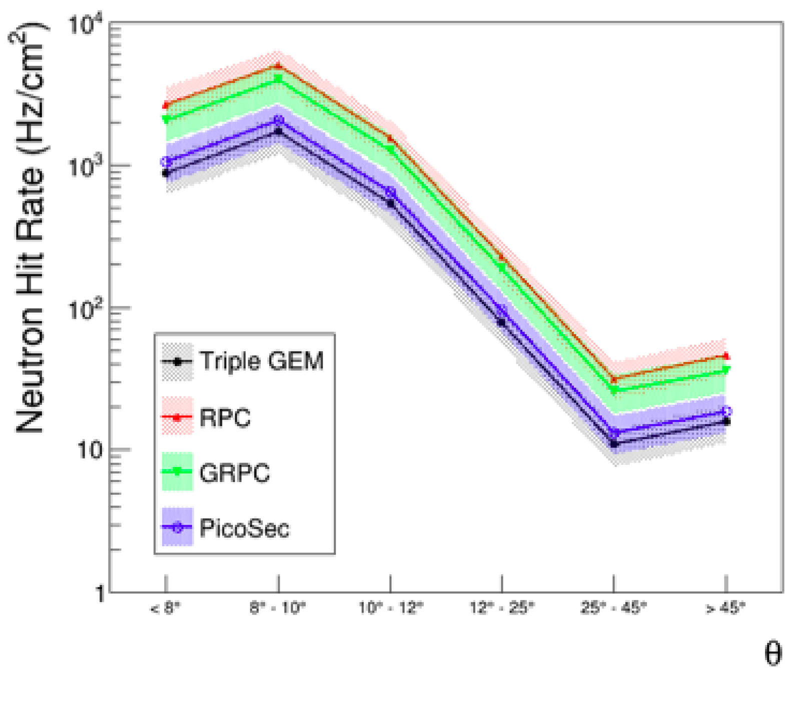

Figure 2: Neutron hit rate vs polar angle θ.

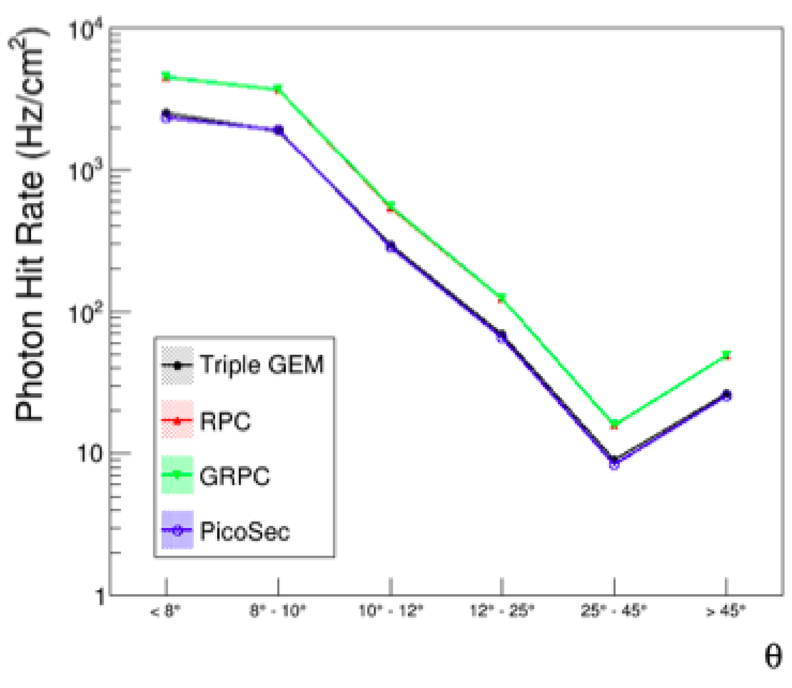

Figure 3: Photon hit rate vs polar angle θ.

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Beam-induced Background (BIB)

BIB is mainly due to electrons and positrons from muon decay interacting with the machine components. Since it may degrade detector performance, a proper detector design has to be considered [4].

In the muon system the BIB is mainly composed by neutrons and photons [3]. Hits are concentrated around the beam axis in the endcaps in a region small with respect to the whole layer region of 500×500 cells (Fig. 4).

A geometrical cut, combined with some other cuts, allows to reject almost all BIB hits (Fig. 5).

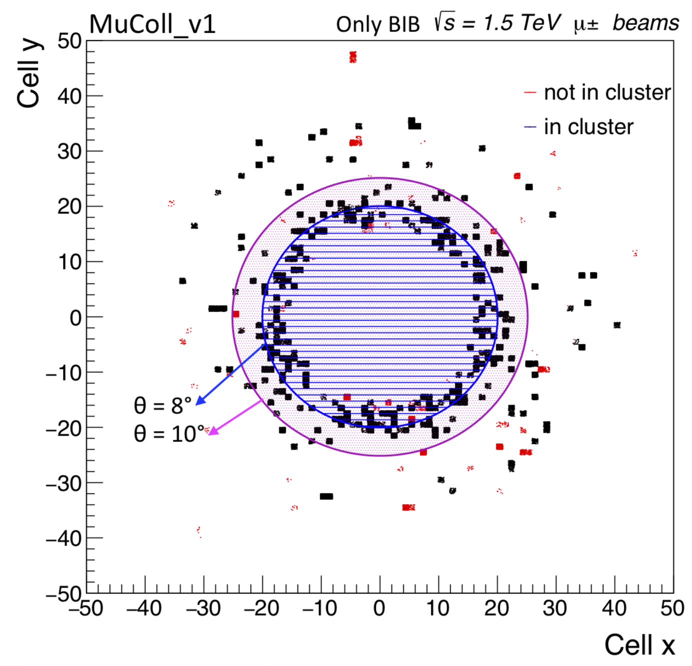

Figure 4: BIB hits distribution in the muon endcap [5].

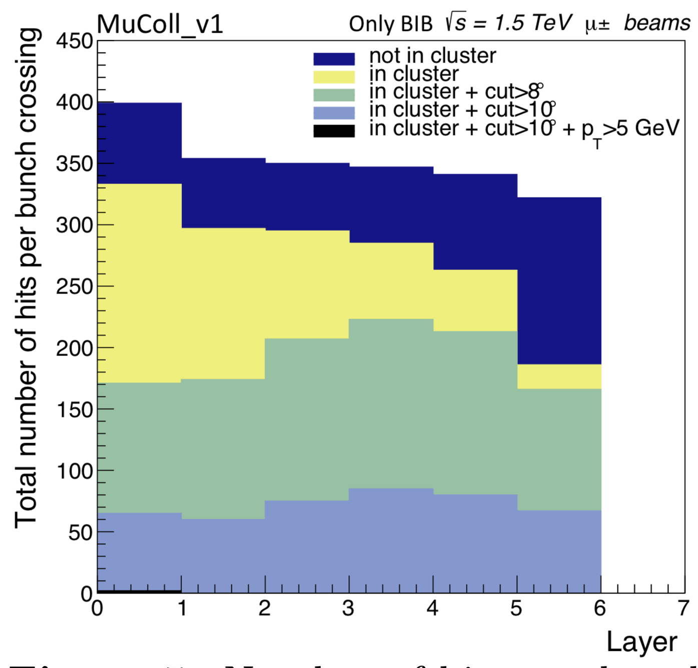

Figure 5: Number of hits per bunch crossing in muon system layers [5].

Muon reconstruction performance

Pandora reconstruction for single muon

Muon reconstruction has been performed within PANDORA PFA framework, that allows to investigate cluster topologies [6]. A cluster is a combination of hits inside a cone and on neighbouring layers.

The single muon efficiency, i.e. the ratio between generated particles associated to a cluster and total generated particles, is higher than 99% for $p_T > 10\,\mathrm{GeV}$.

The resolution is less than 10^{-4} if $p_T > 30\,\mathrm{GeV}$. Δp_T is the difference between the generated muon p_T and the p_T of the corresponding Pandora reconstructed track.

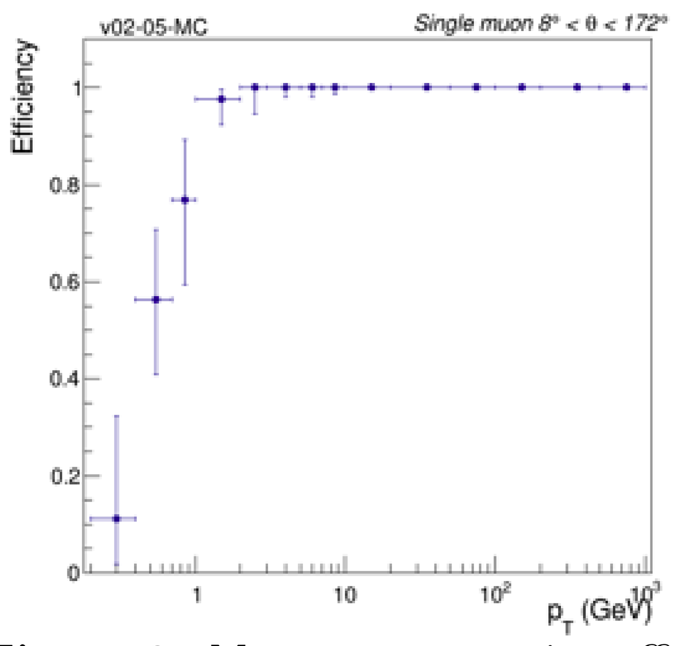

Figure 6: Muon reconstruction efficiency as a function of the transverse momentum [7].

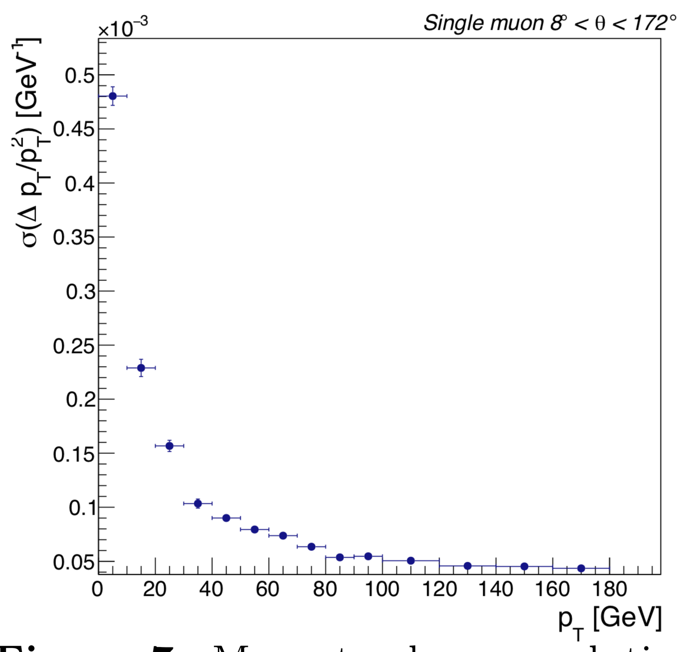

Figure 7: Muon track p_T resolution as a function of transverse momentum [7].

Stand-alone muon reconstruction

The low BIB occupancy suggests to use standalone muon objects to seed the global muon track reconstruction. A processor that clusterizes muon hits inside a cone with angular aperture ΔR ($\Delta R = \sqrt{\Delta\phi^2 + \Delta\eta^2}$) has been developed. The cluster of muon hits represents a stand-alone (SA) muon segment.

Figure 8 shows the number of reconstructed SA muon for different samples: single muon, single muon+BIB, dark-SUSY channel with eight muons in the final state, and two Z bosons decaying in four muons. An aperture of ΔR=0.02 allows to reconstruct the single muon without other tracks from the BIB.

For the SA muon purity, i.e. the number of cluster hits that are associated with the generated muon, has been evaluated. The efficiency for SA muons with purity > 80% is reported in Figs. 9-10 as a function of trasnsverse momentum for two multi-muon final state samples: Higgs + Z boson (six muons) and dark SUSY channel (eight muons). It is higher than 90%. The lower efficiency in the p_T range 300-600 GeV (Fig. 9) is due to muons in the barrel.

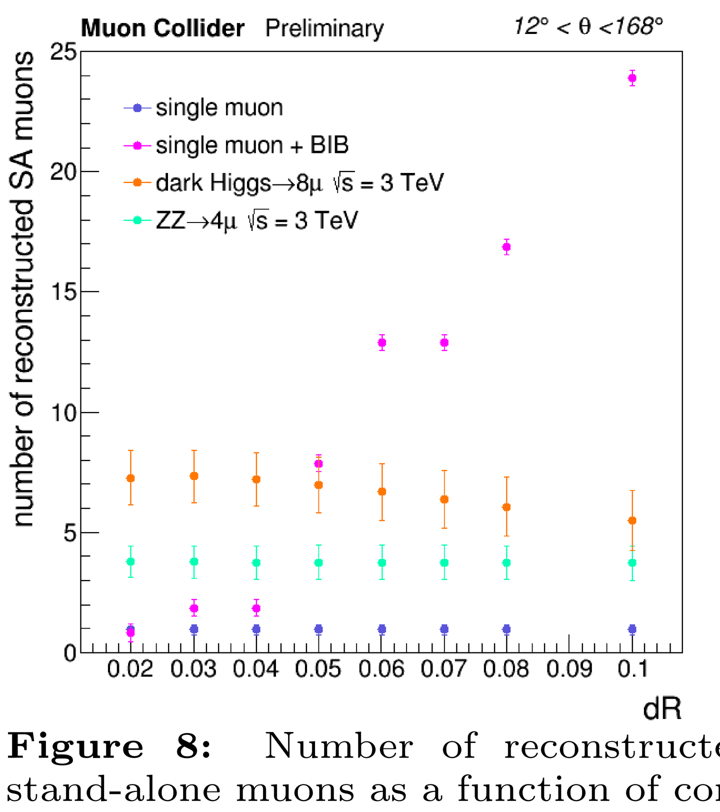

Figure 8: Number of reconstructed stand-alone muons as a function of cone aperture ΔR.

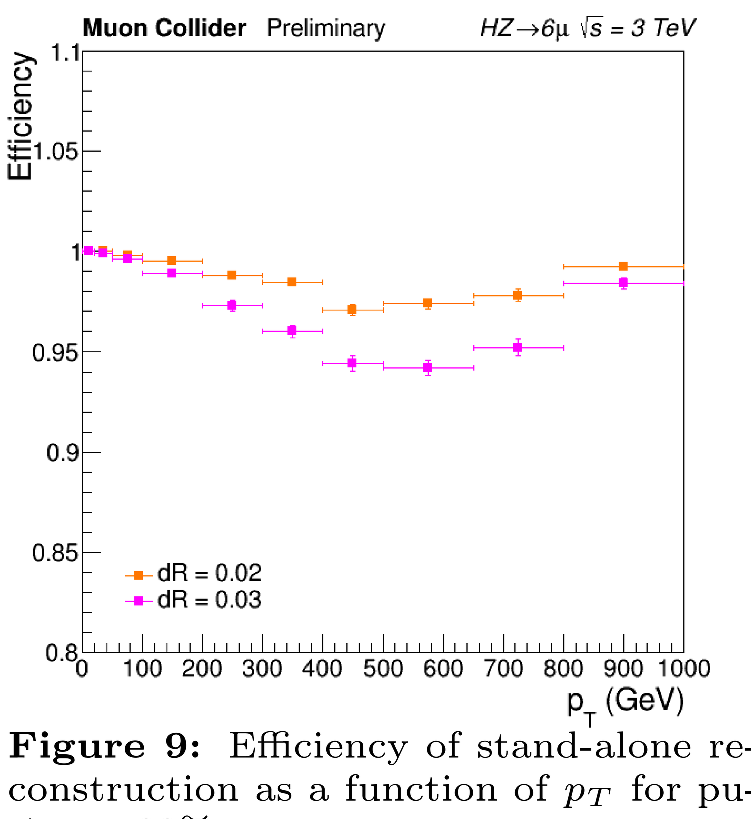

Figure 9: Efficiency of stand-alone reconstruction as a function of p_T for purity > 80%.

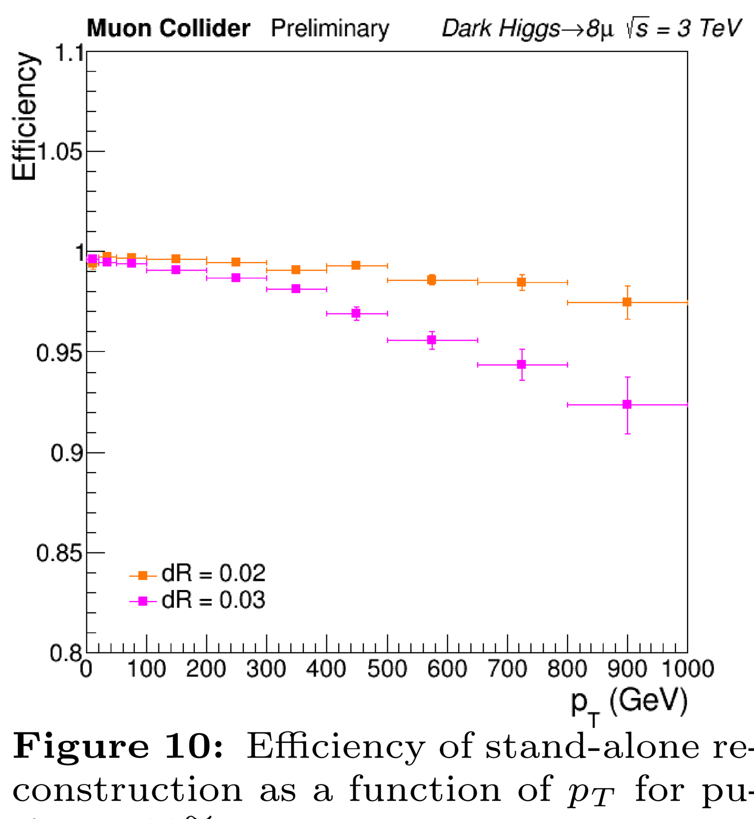

Figure 10: Efficiency of stand-alone reconstruction as a function of p_T for purity > 80%.

References

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