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Interlude: a look at the muon collider beam-induced background

Muon Collider Simulation Framework Tutorial

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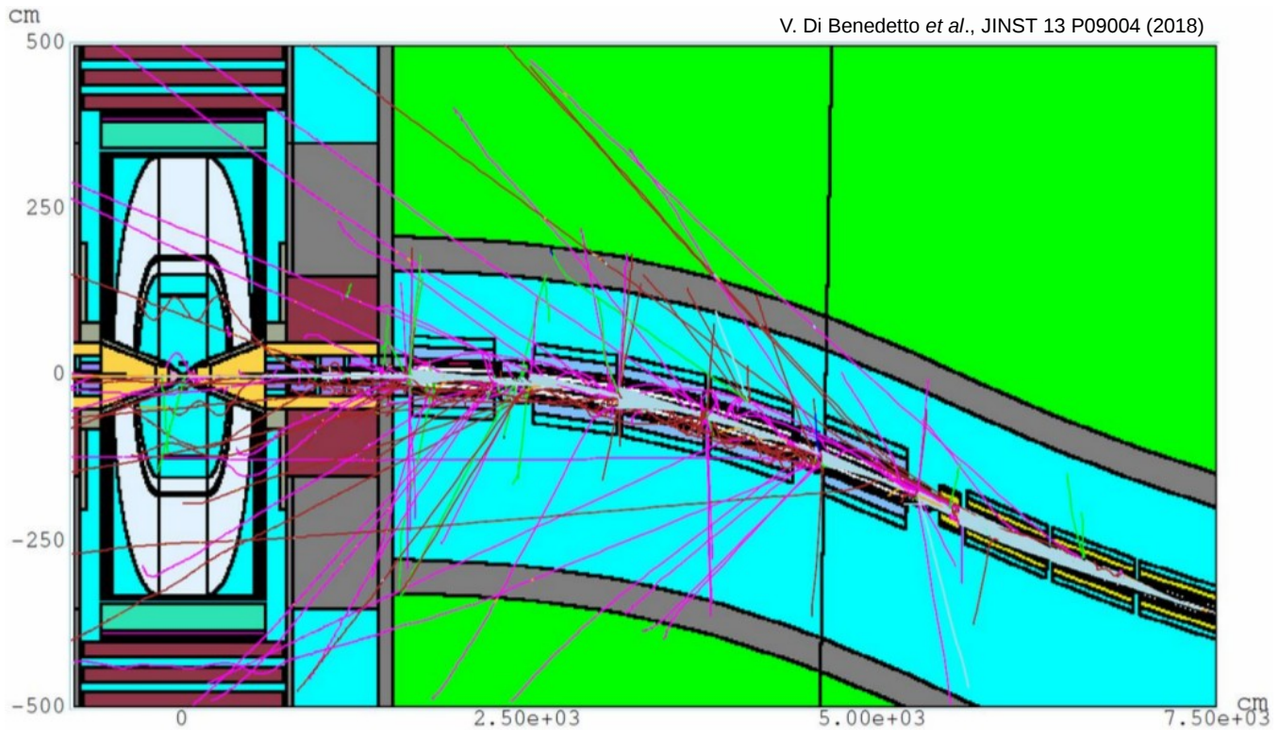
Introduction



V. Di Benedetto *et al*., JINST 13 P09004 (2018)

- Every aspect of a design of a muon collider presents unprecedented challenges.
- From the experiment point of view the main challenge is represented by the effects on the detector due to the decays of muons circulating in the beams.
- This brief interlude in the train of though of the tutorial aims at getting you acquainted with the beam-induced background (BIB).

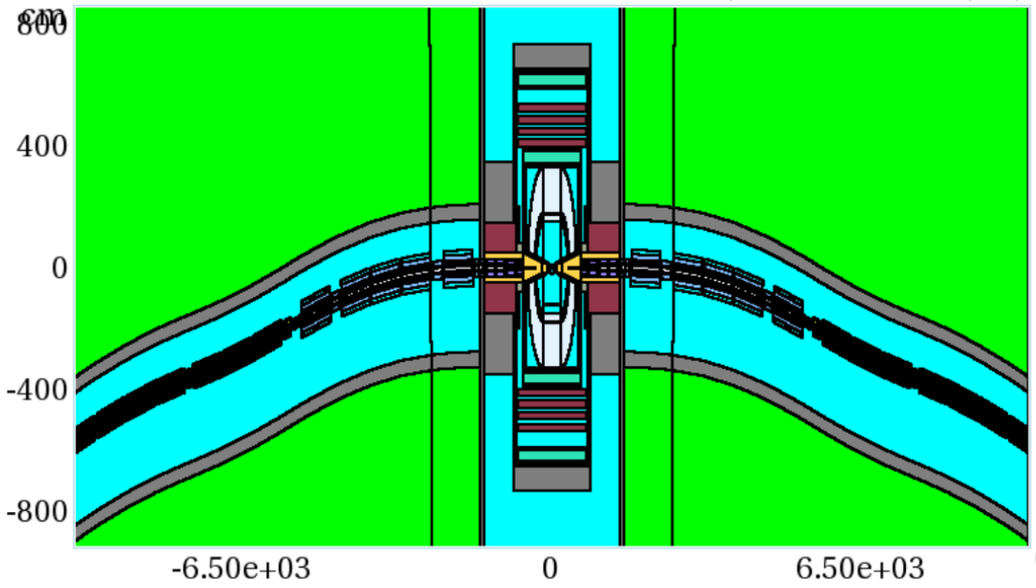
BIB generation

- The BIB sample we will be using was produced by N. Mokhov with MARS15, a simulation software that provides a realistic simulation of beam-induced backgrounds that reach the detector:

  - MARS15 implements a model of the tunnel ±200 m from the interaction point (with realistic geometry, materials distribution, machine lattice elements and magnetic fields), the experimental hall and the machine-detector interface (MDI);

  - $e^{\pm}$ from $\mu^{\pm}$ decays and synchrotron photons radiated by $e^{\pm}$ interact with the machine components producing hadrons, secondary muons, $e^{\pm}$ and γ; secondary particles are transported to the detector.

N.V. Mokhov and S.I. Stiganov, arXiv:1204.6721v1 (2012)



- Sample specs:

  - generation energy thresholds:
    - 100 keV for charged hadrons, muons, electrons, and photons,
    - 1×10^{-12} GeV for neutrons
  - simulated one bunch crossing of 750-GeV $\mu^{\pm}$ beams with 2×10^{12} μ/bunch.

BIB simulation

- The detector response to the BIB particles has been simulated with ILCSoft's ddsim.
- In order to speed up the simulation step, the generated particles of the whole bunch crossing have been equally distributed into 2993 "pseudo-events" and processed in 16 parallel jobs.
- A generation-level filter has been applied before the simulation to reject particles that would reach the detector out-of-time:
  - time of arrival w.r.t. bunch crossing < 25 ns;
  - neutron energy > 150 MeV.

BIB reconstruction

- The proper use of the BIB sample will be illustrated by L. Sestini in the next exercise: it is meant to be superimposed event-by-event to the μμ hard-scattering processes and reconstructed together.

- For the purpose of this exercise, the Marlin hit digitization and reconstruction have been run directly on the BIB sample and the REC output files have been ntuplized.

- No selection is applied on the reconstructed hits.

```
<execute>

  <!-- ========== setup  ========== -->
  <processor name="MyAIDAProcessor"/>
  <processor name="EventNumber" />
  <processor name="InitDD4hep"/>

  <!-- ========== digitisation  ========== -->
  <processor name="VXDBarrelDigitiser"/>
  <processor name="VXDEndcapDigitiser"/>
  <processor name="InnerPlanarDigiProcessor"/>
  <processor name="InnerEndcapPlanarDigiProcessor"/>
  <processor name="OuterPlanarDigiProcessor"/>
  <processor name="OuterEndcapPlanarDigiProcessor"/>

  <!-- === calorimeter digitization and pandora reco === -->
  <processor name="MyDDCaloDigi"/>
  <processor name="MyDDSimpleMuonDigi"/>
  <processor name="MyDDMarlinPandora"/>

  <!-- ========== output  ========== -->
  <processor name="Output_REC"/>

</execute>

<global>
  <parameter name="LCIOInputFiles">
    /data/samples/BIB/sim_mumi-1e3x500-26m-lowth-excl_j1.slcio

                                  .
                                  .
                                  .

    /data/samples/BIB/sim_mupl-1e3x500-26m-lowth-excl_j8.slcio
  </parameter>
  <!-- Limit the number of processed records (run+evt): -->
  <parameter name="MaxRecordNumber" value="-1" />
  <parameter name="SkipNEvents" value="0" />
  <parameter name="SupressCheck" value="false" />
  <parameter name="RandomSeed" value="1234567890" />
</global>
```

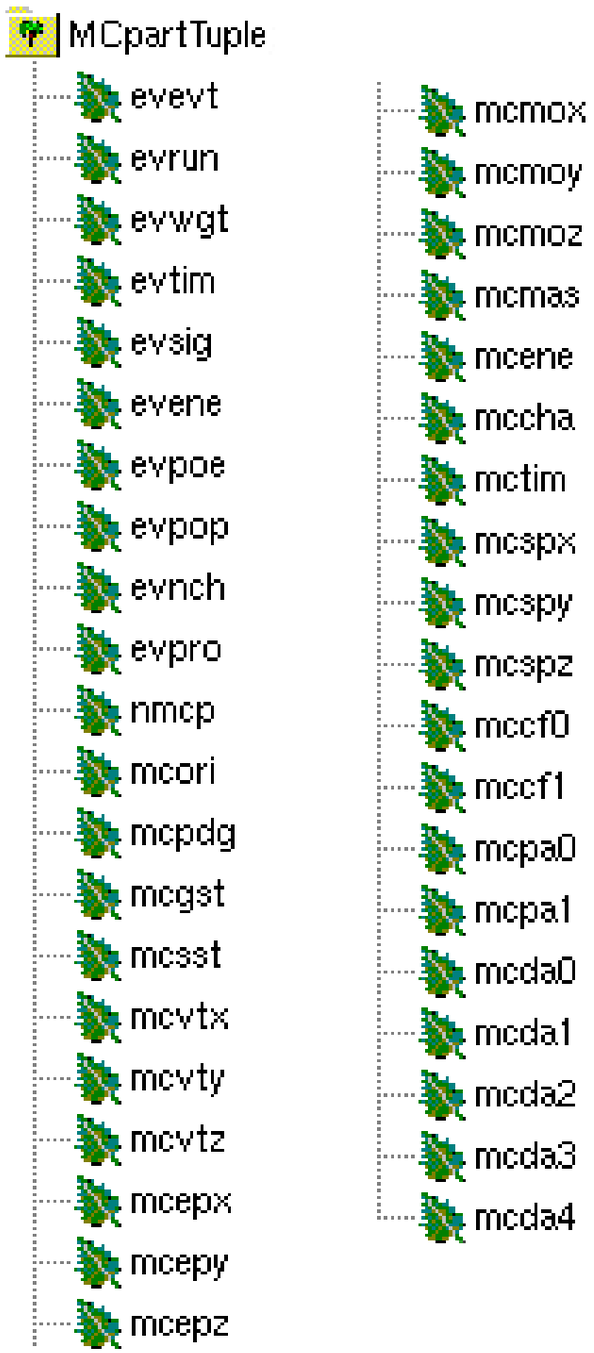
Tutorial practical info

- To have a look at the characteristics of the beam-induced background, two ROOT files have been prepared:
  - `/data/ntuples/BIB/mcParts_ntuple_BIB.root` ➔ contains a TTree with the BIB Monte Carlo particles (MCpartTuple);
  - `/data/ntuples/BIB/allHits_ntuple_BIB.root` ➔ contains TTrees with the reconstructed hits of the tracker, the ECAL and HCAL calorimeters, and the muon detercors (TrackerHitsTuple, CaloHitsTuple, MuonHitsTuple).

- Two example macros are provided to run over the TTrees and fill some significant histograms (available in the `MuonColliderSoft github repository`) :
  - `~/MuC-Tutorial/tutorial/2-BIB/make_mcPartPlots_BIB.C`;
  - `~/MuC-Tutorial/tutorial/2-BIB/make_recoHitPlots_BIB.C`.

- To get ready:
  - `cd ~/MuC-Tutorial/tutorial/2-BIB/`
  - detailed instructions are in the `readme.txt` file.

BIB MC particles: ntuple content

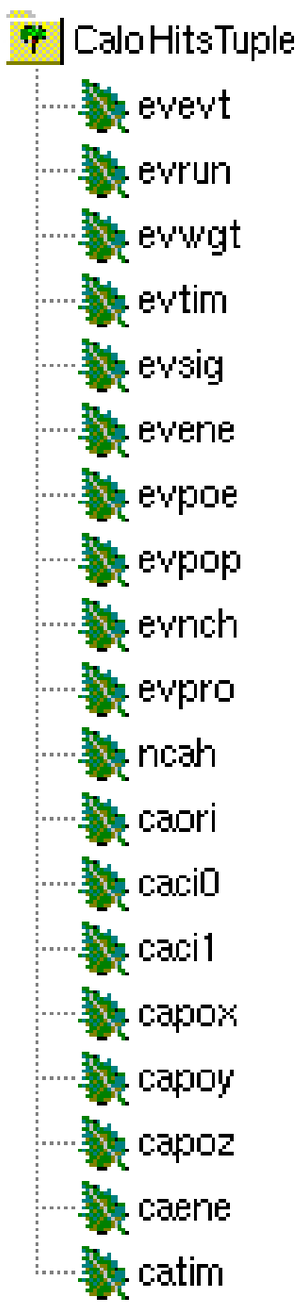


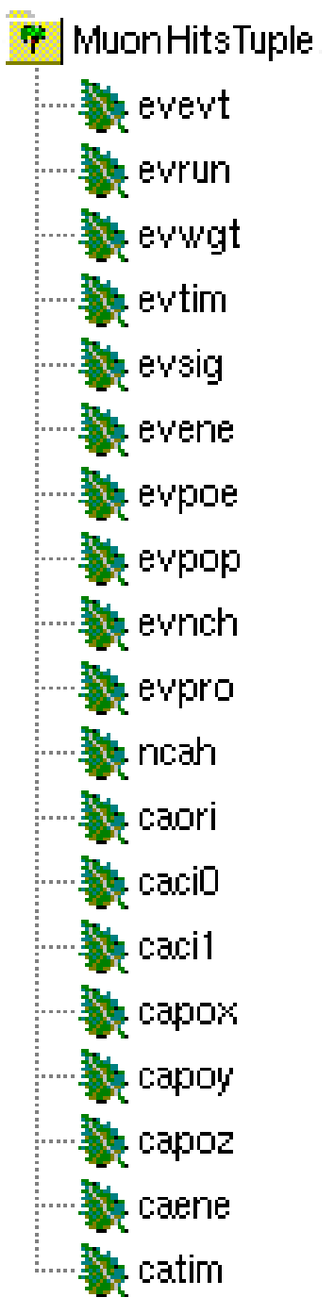
- The Monte Carlo information of the BIB generated particles is in the mcxxx leaves.

- The quickest way to decode the variable names is to go directly to the `source code`.

- `This` represents a convenient source of information about the objects saved in the collections (in particular the EVENT namespace).

BIB reco hits: ntuple content





- Tracker hits ➔ thxxx
- calorimeter hits ➔ caxxx
- muon detector hits ➔ caxxx