Muon Collider BIB studies

Updates

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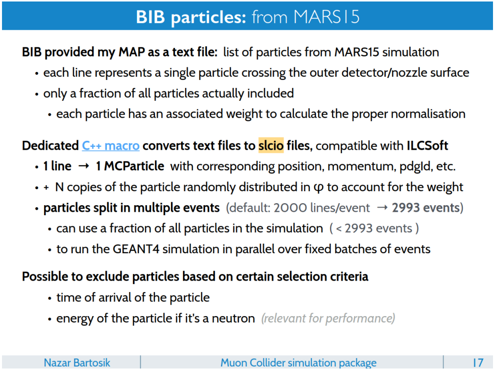
Outline

- BIB Simulation: understanding event distribution
- Occupancy plot of MCParticles
- Event Visualization example

Understanding BIB simulation steps



BIB particles: from MARS15

BIB provided my MAP as a text file: list of particles from MARS15 simulation

- each line represents a single particle crossing the outer detector/nozzle surface
- only a fraction of all particles actually included
  - each particle has an associated weight to calculate the proper normalisation

Dedicated C++ macro converts text files to slcio files, compatible with **ILCSoft**

- **1 line → 1 MCParticle** with corresponding position, momentum, pdgId, etc.
- + N copies of the particle randomly distributed in φ to account for the weight
- **particles split in multiple events** (default: 2000 lines/event → **2993 events**)
  - can use a fraction of all particles in the simulation (< 2993 events)
  - to run the GEANT4 simulation in parallel over fixed batches of events

Possible to exclude particles based on certain selection criteria

- time of arrival of the particle
- energy of the particle if it's a neutron *(relevant for performance)*

Nazar Bartosik | Muon Collider simulation package | 17

Figure: Talk by Nazar Bartosik on MC Simulation Package in Sept2020 [link]

These 2993 events are distributed in 16 files (8 each for μ^-, μ^+ beams)

sim_mumipl—1e3x500—26m—lowth-excl_j**1**.slcio

...

sim_mumipl—1e3x500—26m—lowth-excl_j**8**.slcio

Contents of BIB slcio file

- Simulation of detector response to incoming particles.
- Has MCParticle Collection, Tracker & Calorimeter SimHits Collections.

```
EVENT: 0
RUN: 0
DETECTOR: CLIC_o3_v14_mod4
COLLECTIONS: (see below)
///////////////////////////////////

---------------------------------------------------------------------------
COLLECTION NAME               COLLECTION TYPE          NUMBER OF ELEMENTS
===========================================================================
ECalBarrelCollection          SimCalorimeterHit              3211
ECalEndcapCollection          SimCalorimeterHit               480
HCalBarrelCollection          SimCalorimeterHit              2613
HCalEndcapCollection          SimCalorimeterHit              4200
HCalRingCollection            SimCalorimeterHit               494
InnerTrackerBarrelCollection  SimTrackerHit                   926
InnerTrackerEndcapCollection  SimTrackerHit                   218
MCParticle                    MCParticle                    24455
OuterTrackerBarrelCollection  SimTrackerHit                   798
OuterTrackerEndcapCollection  SimTrackerHit                   242
VertexBarrelCollection        SimTrackerHit                   430
VertexEndcapCollection        SimTrackerHit                   734
YokeBarrelCollection          SimCalorimeterHit                 0
YokeEndcapCollection          SimCalorimeterHit                 0
---------------------------------------------------------------------------
```

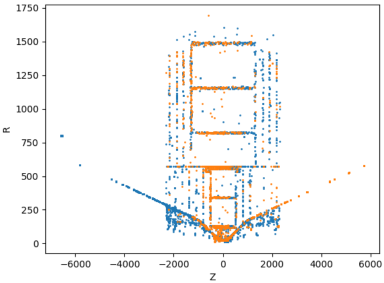
```
===========================================================================
       Event  : 0 - run:  0 - timestamp 0 - weight 1
===========================================================================
date:      01.01.1970  00:00:00.000000000
detector : CLIC_o3_v14_mod4
event parameters:

collection name : ECalBarrelCollection
parameters:

-------------- print out of SimCalorimeterHit collection --------------

 flag:  0xb0000000
parameter CellIDEncoding [string]: system:0:5,side:5:-2,module:7:8,stave:15:4,layer:19:9,submodule:28:4,x:32:-16,y:48:-16,
 -> LCIO::CHBIT_LONG   : 1
    LCIO::CHBIT_BARREL : 0
    LCIO::CHBIT_ID1    : 1
    LCIO::CHBIT_STEP   : 1

[   id   ] |cellId0 |cellId1 |  energy  |        position (x,y,z)          | nMCParticles
          -> MC contribution: prim. PDG |  energy  |   time   | length  | sec. PDG | stepPosition (x,y,z)
-----------|--------|--------|----------|----------------------------------|--------------
[00000031] |01048724|-3407895|+9.821e-05|+1.251e+03, -8.578e+02, -2.703e+02|          +3
       id-fields: (system:20,side:0,module:1,stave:0,layer:2,submodule:0,x:-23,y:-53)
          ->                          +22|+4.079e-05|+4.974e+00|+1.146e-01| (+11, +1.252e+03, -8.575e+02, -2.678e+02)
          ->                          +22|+3.075e-05|+4.974e+00|+7.244e-02| (+11, +1.252e+03, -8.576e+02, -2.678e+02)
          ->                          +22|+2.667e-05|+4.975e+00|+4.099e-02| (+11, +1.252e+03, -8.576e+02, -2.678e+02)
[00000032] |01048724|-3342359|+6.542e-05|+1.251e+03, -8.578e+02, -2.652e+02|          +8
       id-fields: (system:20,side:0,module:1,stave:0,layer:2,submodule:0,x:-23,y:-52)
          ->                          +22|+1.311e-05|+4.975e+00|+4.102e-02| (+11, +1.252e+03, -8.576e+02, -2.677e+02)
          ->                          +22|+1.348e-05|+4.975e+00|+3.588e-02| (+11, +1.252e+03, -8.576e+02, -2.677e+02)
          ->                          +22|+2.056e-06|+4.975e+00|+1.154e-02| (+11, +1.252e+03, -8.576e+02, -2.677e+02)
          ->                          +22|+1.482e-05|+4.977e+00|+1.762e-02| (+11, +1.252e+03, -8.578e+02, -2.675e+02)
          ->                          +22|+2.954e-06|+4.977e+00|+1.378e-02| (+11, +1.251e+03, -8.578e+02, -2.675e+02)
```

```
collection name : MCParticle
parameters:

-------------- print out of MCParticle collection --------------

  flag:  0x0
  simulator status bits: [sbvtcls]  s: created in simulation b: backscatter v: vertex is not endpoint of parent t: decayed in tracker c: decayed in calorimeter l: has left detector s: stopped o: overlay

[   id   ]index|      PDG |    px,     py,        pz    | px_ep,   py_ep , pz_ep      | energy  |gen|[simstat ]| vertex x,     y   ,   z     | endpoint x,    y  ,   z     |    mass |  charge |            spin             | colorflow | [parents] - [dau

[00012173]    0|      2112| 3.06e-01,-1.24e-01, 2.12e-01| 0.00e+00,-0.00e+00, 0.00e+00| 1.02e+00| 1 |[    c s ]| 3.06e+02,-1.06e+02, 2.74e+03| 3.52e+02,-1.25e+02, 2.77e+03| 9.40e-01| 0.00e+00| 0.00e+00, 0.00e+00, 0.00e+00|  (0, 0)   | [] - []
[00012174]    1|      2112| 3.30e-01,-3.57e-03, 2.12e-01| 0.00e+00,-0.00e+00, 0.00e+00| 1.02e+00| 1 |[    c s ]| 3.23e+02, 1.36e+01, 2.74e+03| 3.68e+02, 1.31e+01, 2.77e+03| 9.40e-01| 0.00e+00| 0.00e+00, 0.00e+00, 0.00e+00|  (0, 0)   | [] - []
[00012175]    2|      2112|-2.79e-01,-1.78e-01, 2.12e-01|-0.00e+00,-0.00e+00, 0.00e+00| 1.02e+00| 1 |[    c s ]|-2.63e+02,-1.88e+02, 2.74e+03|-3.03e+02,-2.13e+02, 2.77e+03| 9.40e-01| 0.00e+00| 0.00e+00, 0.00e+00, 0.00e+00|  (0, 0)   | [] - []
[00012176]    3|      2112| 1.56e-01,-2.91e-01, 2.12e-01| 0.00e+00,-0.00e+00, 0.00e+00| 1.02e+00| 1 |[    c s ]| 1.67e+02,-2.77e+02, 2.74e+03| 4.36e+02,-4.65e+02, 2.81e+03| 9.40e-01| 0.00e+00| 0.00e+00, 0.00e+00, 0.00e+00|  (0, 0)   | [] - []
[00012177]    4|      2112| 2.72e-01, 1.87e-01, 2.12e-01| 0.00e+00, 0.00e+00, 0.00e+00| 1.02e+00| 1 |[    c s ]| 2.56e+02, 1.97e+02, 2.74e+03| 3.29e+02, 2.48e+02, 2.79e+03| 9.40e-01| 0.00e+00| 0.00e+00, 0.00e+00, 0.00e+00|  (0, 0)   | [] - []
[00012178]    5|      2112|-2.44e-01, 2.23e-01, 2.12e-01|-0.00e+00, 0.00e+00, 0.00e+00| 1.02e+00| 1 |[    c s ]|-2.50e+02, 2.05e+02, 2.74e+03|-3.14e+02, 2.78e+02, 2.81e+03| 9.40e-01| 0.00e+00| 0.00e+00, 0.00e+00, 0.00e+00|  (0, 0)   | [] - []
[00012179]    6|      2112| 2.41e-01, 2.26e-01, 2.12e-01| 0.00e+00, 0.00e+00, 0.00e+00| 1.02e+00| 1 |[    c s ]| 2.24e+02, 2.33e+02, 2.74e+03| 3.94e+02, 3.51e+02, 2.84e+03| 9.40e-01| 0.00e+00| 0.00e+00, 0.00e+00, 0.00e+00|  (0, 0)   | [] - []
[00012180]    7|      2112| 1.58e-01, 2.90e-01, 2.12e-01| 0.00e+00, 0.00e+00, 0.00e+00| 1.02e+00| 1 |[    c s ]| 1.40e+02, 2.92e+02, 2.74e+03| 1.64e+02, 3.36e+02, 2.77e+03| 9.40e-01| 0.00e+00| 0.00e+00, 0.00e+00, 0.00e+00|  (0, 0)   | [] - []
```

Let's look at MC Particles vertex (x, y, z) corrdinates

Occupancy (R vs Z) of a fraction of MCParticles

2/2993 events, 1 from μ^- and μ^+ beam each.



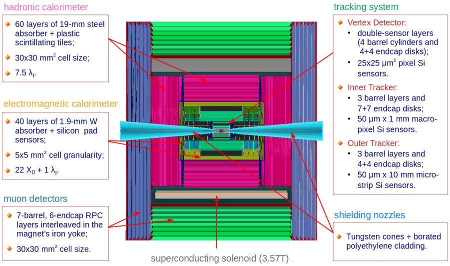


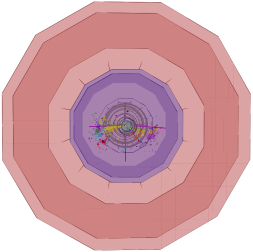
Figure: Left: MCParticles from μ^- beam and μ^+ beam

Next: check SimHits distribution

Event Display

Can visualize event with simplified geometry rendering

$ced2go -d geometry.xml sim_mumi−1e3x500−26m−lowth-excl_j1.slcio



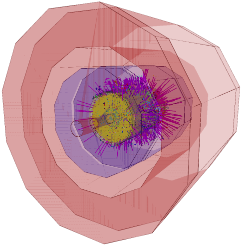


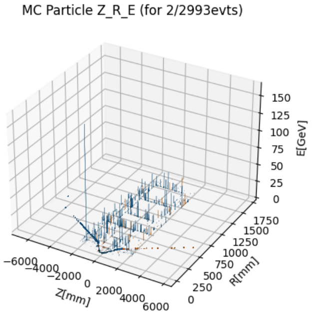
Figure: Hbb event (left) and BIB (1/2993 event) (right).

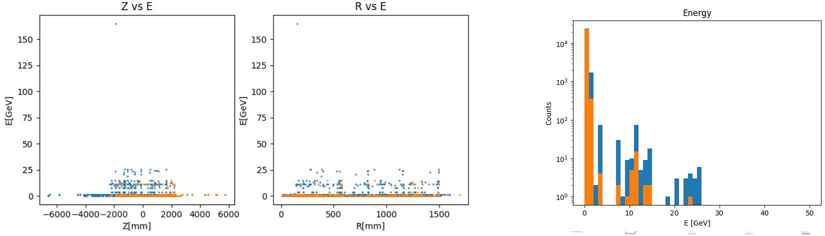
Interesting toolkit to study BIB patterns

Nov 3rd: Updates

- 3d plot: Z vs R vs E
- Energy distribution (plot multiple pseudo-events to see a pattern)
- Write a script to read all .slcio BIB files and write out MCParticle collection to a branch or TTree

Z vs R vs Energy



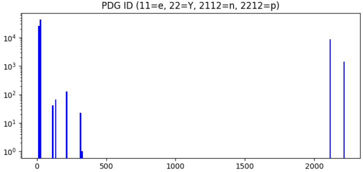


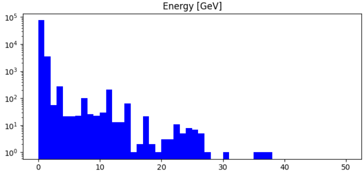
Updates: Dec 1

- MCParticle distributions
- next: generate more events using these distributions
- looking at code that converts MARS output to slcio format, to how to structure the MCParticles info.

MCParticle distributions: Particle ID and Energy

μ^- beam with 570/1494 pseudoevents (38%)

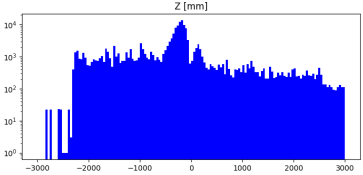


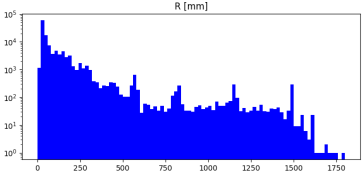


Mostly photons, electrons and neutrons

MCParticle distributions: Z and R

$$R = \sqrt{x^2 + y^2}$$

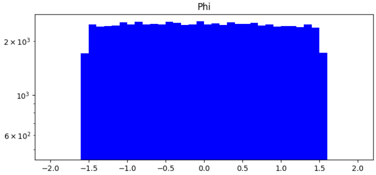


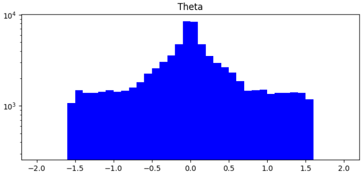


μ^- beam is headed in -z direction

MCParticle distributions

$Phi = tan^{-1}(P_y/P_x)$
$Theta = tan^{-1}(P_y/P_z)$





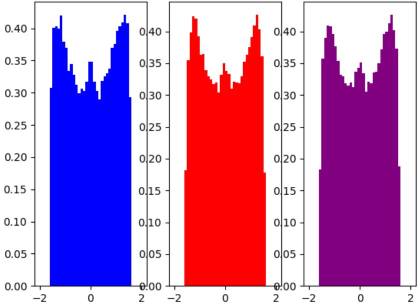
- uniform in Phi as expected
- MCParticles have high longitunal momentum

Updates: Dec 22

- Using gaussian kernal density estimation (KDE) to generate distributions given an input histogram. Started with theta distribution as example.
- Working on 2D correlated variables like Z and R coordinates.
- Recap: Njets and Mbb with BIB
- Working on changing E threshold depending on depth into ECal barrel.

Theta distributions (normalized)

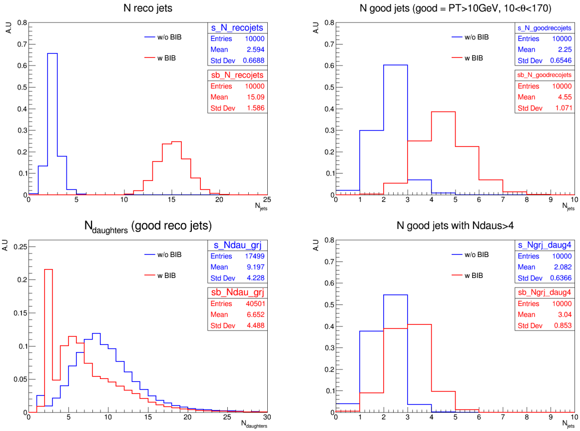
Using 6/2993 pseudoevents hits only for testing.
Blue is original one, and others generated using KDE.



Q. Should we randomize N MCParticles within a range?

Recap: Jet reconstruction in presence of BIB

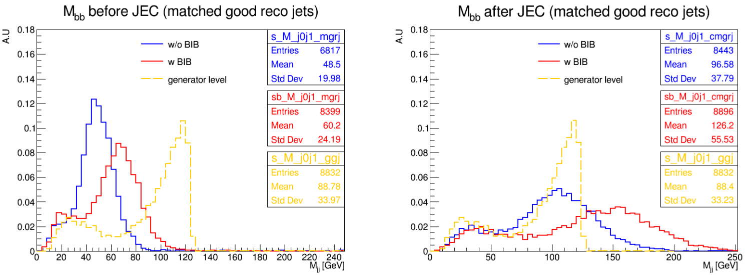
Signal Process: $\mu^+\mu^- \to \nu\bar{\nu}H, H \to b\bar{b}$ overlaid with BIB at 1.5TeV.
Anti-k_T jet with R=0.5 used.



Acceptance cut (pT and theta) - good to reduce fake jets from BIB.

Higgs reconstruction in presence of BIB

Jet energy correction (JEC) applied to account for lost energy due to tight E_{th}=**2 MeV** cut on reco hits in ECal, along with timing cut of **250ps**.



- BIB hits increase energy of b-jets, need BIB mitigation.
- Need a jet cleaning strategy to improve mass resolution.

Plan for winter break and Spring semester

- Finish up bib generation through parametrization for Delphes implementation.
- Continue with jet cleaning and bib mitigation strategy.