

Muon Collider BIB studies

Updates

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Oct 27, 2022

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

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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_muonipl-1e3x500-26m-lowth-excl.j1.slcio

...

sim_muonipl-1e3x500-26m-lowth-excl.j8.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	SimCalorimeterHtt	3211
ECalEndcapCollection	SimCalorimeterHtt	480
HCalBarrelCollection	SimCalorimeterHtt	2613
HCalEndcapCollection	SimCalorimeterHtt	4280
HCalRingCollection	SimCalorimeterHtt	494
InnerTrackerBarrelCollection	SimTrackerHtt	926
InnerTrackerEndcapCollection	SimTrackerHtt	218
MCParticle	MCParticle	24455
OuterTrackerBarrelCollection	SimTrackerHtt	798
OuterTrackerEndcapCollection	SimTrackerHtt	742
VertexBarrelCollection	SimTrackerHtt	430
VertexEndcapCollection	SimTrackerHtt	734
YokeBarrelCollection	SimCalorimeterHtt	0
YokeEndcapCollection	SimCalorimeterHtt	0

```
Event : 0 - run: 0 - timestep 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 SimCalorimeterHtt collection -----
Flag: 0x00000000
parameter CellIDEncoding [string]: system:0;side:5;2,module:7;0,stage:15;4,layer:19;9,submodule:28;4,x:32;-16,y:48;-16,
-> LCIO::OEMT_LONG : 1
LCIO::OEMT_MODULE : 0
LCIO::OEMT_ID1 : 1
LCIO::OEMT_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]-540780+9.020e-05+1.251e+03,-8.578e+02,-2.703e+02 | +3
id-Fields: (system:20,side:8,module:1,stage: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]-542650+4.542e-05+1.251e+03,-8.578e+02,-2.652e+02 | +8
id-Fields: (system:20,side:8,module:1,stage:0,layer:2,submodule:0,x:-23,y:52)
->
-> +22+1.311e-05+4.975e+00+4.182e-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+2.856e-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,+1.252e+03,-8.578e+02,-2.675e+02)
```

```
collection name : MCParticle
parameters:
```

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

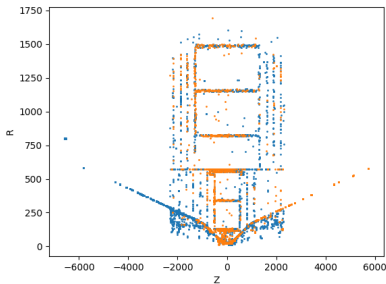
```
Flag: 0x0
simulator status bits: [sbvts] s: created in simulation b: backscatter v: vertex is not endpoint of parent t: decayed in tracker c: decayed in calorimeter l: has left detector st: stopped o: overlap
```

[id]	[index]	[PDG]	[px]	[py]	[pz]	[px_err]	[py_err]	[pz_err]	[energy]	[gen]	[sinstat]	[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	1.1	c	s	3.06e+02,-1.86e+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	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(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	1.1	c	s	3.30e+02,1.36e+03,2.74e+03	3.68e+02,1.31e+01,2.77e+03	9.40e-01	0.00e+00,0.00e+00,0.00e+00	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	
[00012175]	2	2112	-2.79e-01,-1.70e-01,2.12e-01	0.00e+00,-0.00e+00,0.00e+00	1.02e+00	1.1	c	s	-2.63e+02,-1.08e+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	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(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	1.1	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	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(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	1.1	c	s	2.56e+02,1.97e+02,2.74e+03	3.25e+02,2.49e+02,2.79e+03	9.40e-01	0.00e+00,0.00e+00,0.00e+00	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(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	1.1	c	s	-2.36e+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	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(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	1.1	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	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(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	1.1	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	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	(0,0)	

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

Occupancy (R vs Z) of a fraction of MCParticles

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



hadronic calorimeter

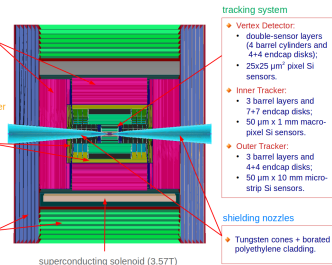
- 60 layers of 19-mm steel absorber + plastic scintillating tiles;
- 30x30 mm² cell size;
- 7.5 λ_p .

electromagnetic calorimeter

- 40 layers of 1.9-mm W absorber + silicon pad sensors;
- 5x5 mm² cell granularity;
- 22 $X_0 + 1 \lambda_p$.

muon detectors

- 7-barrel, 6-endcap RPC layers interleaved in the magnet's iron yoke;
- 30x30 mm² cell size.



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 $\mu\text{m} \times 1 \text{ mm}$ macro-pixel Si sensors.
- Outer Tracker:**
 - 3 barrel layers and 4+4 endcap disks;
 - 50 $\mu\text{m} \times 10 \text{ mm}$ micro-strip Si sensors.

shielding nozzles

- Tungsten cones + borated polyethylene cladding.

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
```

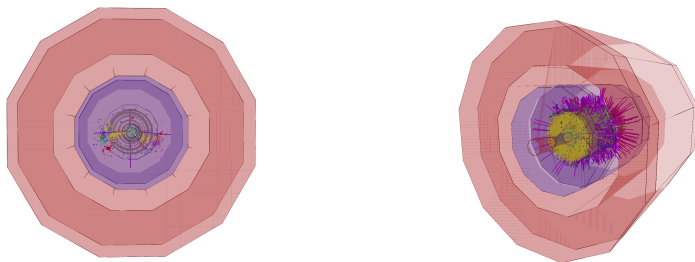


Figure: Hbb event (left) and BIB (1/2993 event) (right).

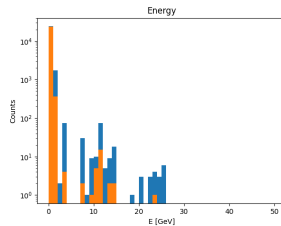
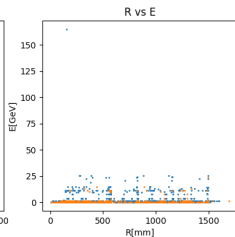
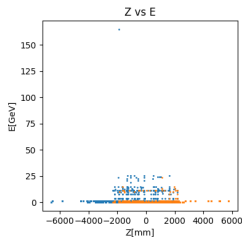
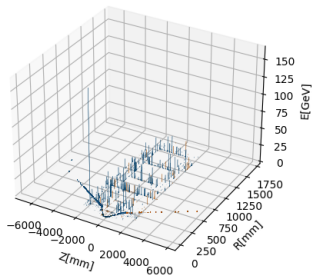
Interesting toolkit to study BIB patterns

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

MC Particle Z_R_E (for 2/2993evts)

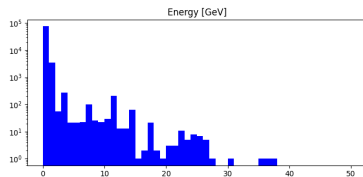
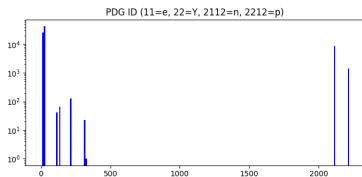


Updates: Dec 1

- 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

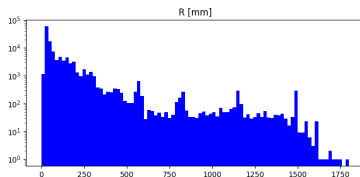
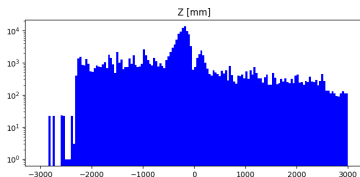
μ^- beam with 570/1494 pseudoevents (38%)



Mostly photons, electrons and neutrons

MCParticle distributions: Z and R

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

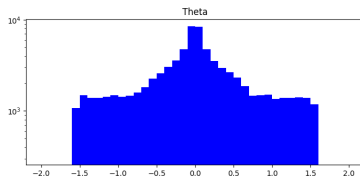
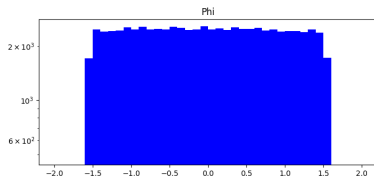


μ^- beam is headed in -z direction

MCParticle distributions

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

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



- uniform in Φ as expected
- MCParticles have high longitudinal momentum