Update on the displaced vertices issue

Muon Collider Tracking Meeting
23-02-2021

Recap

casarsa commented 5 days ago

Dear experts,

I am writing to report an issue we ran into and didn't manage to solve.

To perform b-tagging studies at a muon collider, we are running ddsim on different HepMC files
containing samples with b and c quarks. The samples were generated with both WIZARD and MadGraph + PYTHIA.

We noticed that some of the hadrons that are supposed to fly some distance before decaying do not
and have zero endpoints in the output SLCIO files. Not all of them, though: for example B0's are fine, while B+'s and B-'s are not.

In DDG4/src/Geant4InputAction.cpp the particles' endpoints seem to be correctly set and have non-zero values, but when the particles are written out in DDG4/lcio/Geant4Output2LCIO.cpp, Geant4Particle's vex, vey and vez velues are 0.

In our debugging, we ran ddsim on an old stdhep file and the output is fine for that. So, as a test, we made an attempt to convert our HepMC files to the stdhep format. In this case, the flight distances are OK, but we get this exception:

```
*** G4Exception : DECAY101
issued by : G4Decay::DecayIt
For B- decay probability exist but decay table is not defined - the particle will be killed;
isExtDecayer: 0; isPreAssigned: 0
*** This is just a warning message. ***
```

and the assignment of particles to the vertices looks weird. It seems that not only the first daughters are linked to the vertices, but all the descendants.

Hope you can help.

```
Massimo
```

https://github.com/AIDASoft/DD4hep/issues/785

Answ: The hepmc2 reader does not treat the vertex information correctly.

Can you make a test with HepMC3 reader?

Test 1

Test 1:

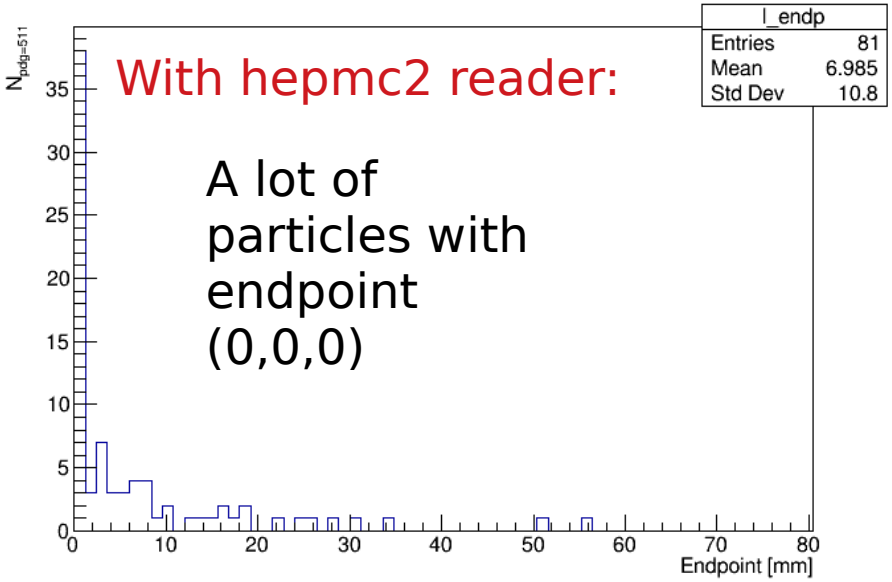
- $\mu^+\mu^- \rightarrow H\bar{\nu}\nu \rightarrow b\bar{b}\nu\bar{\nu}$ process
- 100 events generated with Pythia at 1.5 TeV center of mass energy

- First issues with hepmc3 reader: the run number is set to -1 (not defined in hepmc files)

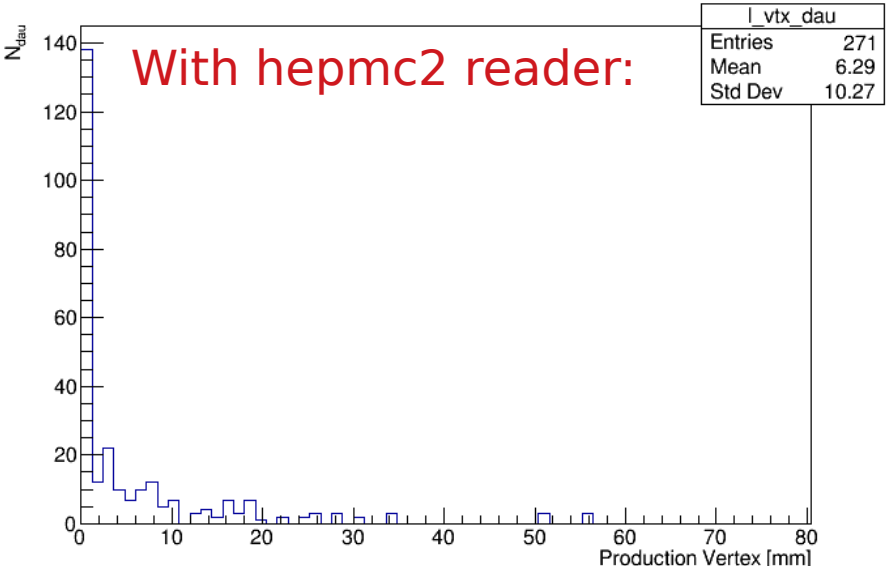
B^0 endpoint and daughter vtx production

With hepmc2 reader:

A lot of particles with endpoint (0,0,0)

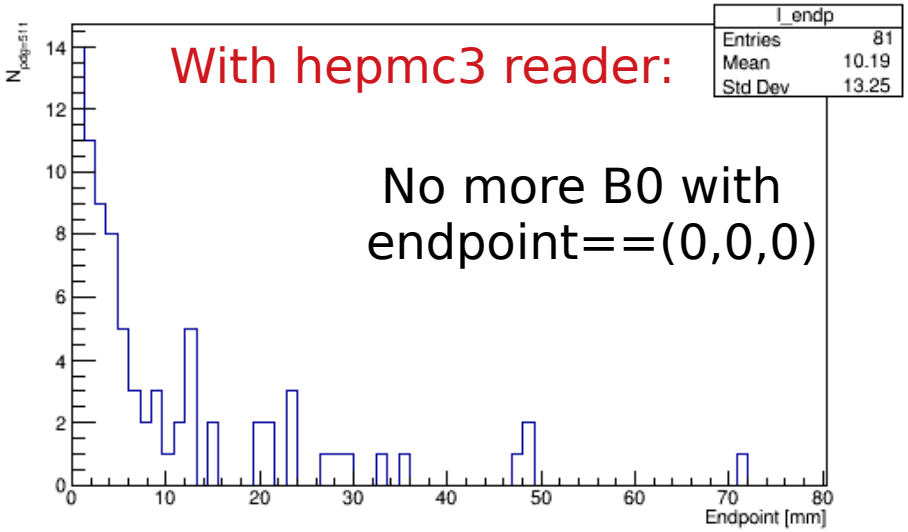


With hepmc2 reader:

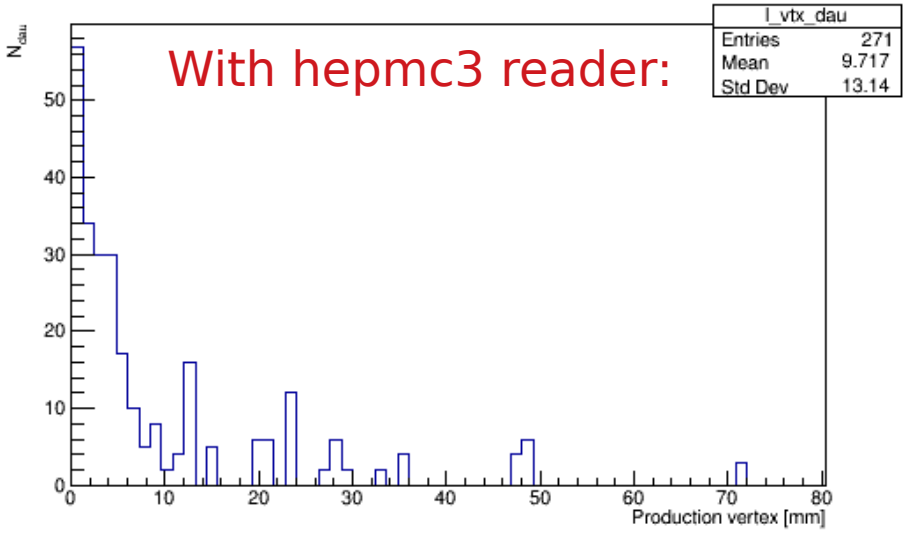


With hepmc3 reader:

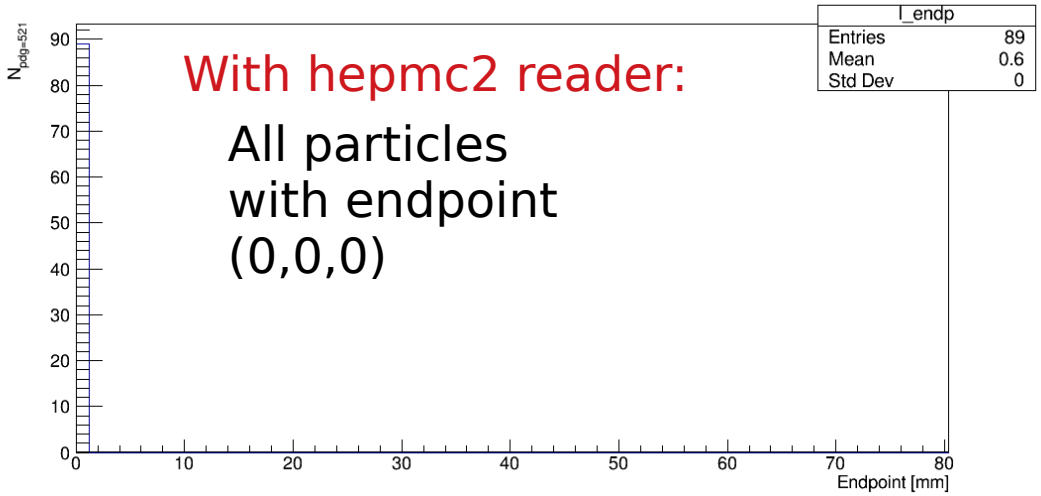
No more B0 with endpoint==(0,0,0)



With hepmc3 reader:

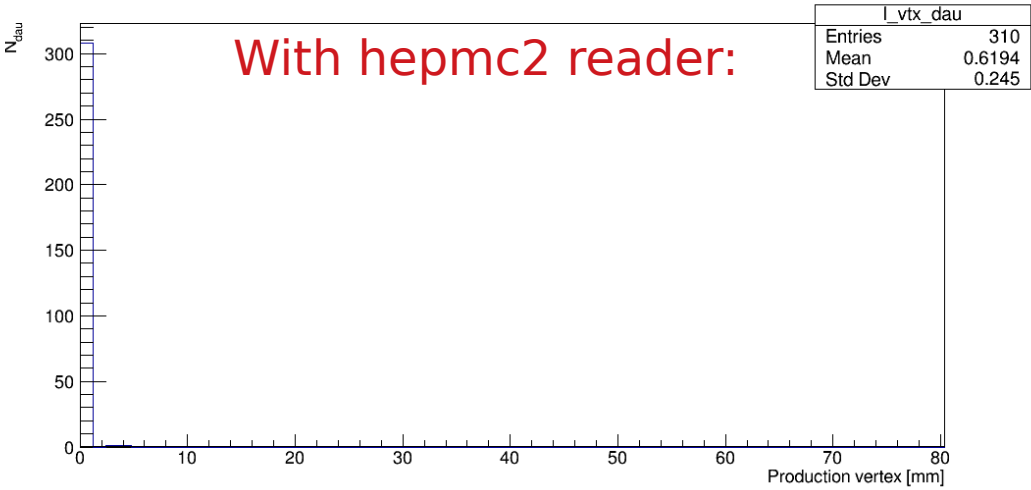


$B^{+/-}$ endpoint and daughter vtx production

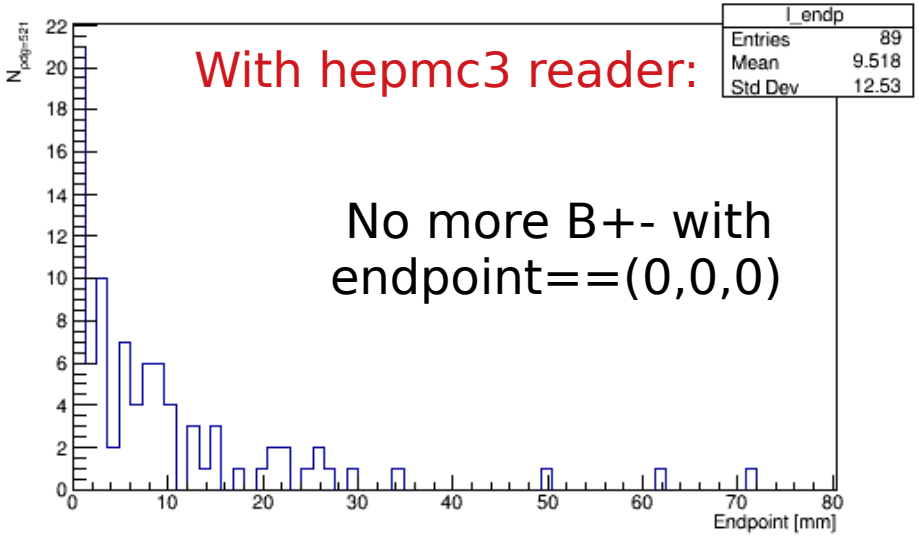


With hepmc2 reader:

All particles with endpoint (0,0,0)



With hepmc2 reader:



With hepmc3 reader:

No more B+- with endpoint==(0,0,0)

With hepmc3 reader:

Other particles included

CHARMED MESONS	
D^+	411
D^0	421
$\boldsymbol{D_0^*(2400)^+}$	10411
$\boldsymbol{D_0^*(2400)^0}$	10421
$D^*(2010)^+$	413
$D^*(2007)^0$	423
$D_1(2420)^+$	10413
$D_1(2420)^0$	10423
$D_1(H)^+$	20413
$\boldsymbol{D_1(2430)^0}$	20423
$D_2^*(2460)^+$	415
$D_2^*(2460)^0$	425
D_s^+	431
$D_{s0}^*(2317)^+$	10431
D_s^{*+}	433
$D_{s1}(2536)^+$	10433
$D_{s1}(2460)^+$	20433
$D_{s2}^*(2573)^+$	435

$c\bar{c}$ MESONS	
$\eta_c(1S)$	441
$\chi_{c0}(1P)$	10441
$\eta_c(2S)$	100441
$J/\psi(1S)$	443
$h_c(1P)$	10443
$\chi_{c1}(1P)$	20443
$\psi(2S)$	100443
$\psi(3770)$	30443
$\psi(4040)$	9000443
$\psi(4160)$	9010443
$\psi(4415)$	9020443
$\chi_{c2}(1P)$	445
$\boldsymbol{\chi_{c2}(2P)}$	**100445**

CHARMED BARYONS	
Λ_c^+	4122
Σ_c^{++}	4222
Σ_c^+	4212
Σ_c^0	4112
Σ_c^{*++}	4224
Σ_c^{*+}	4214
Σ_c^{*0}	4114
Ξ_c^+	4232
Ξ_c^0	4132
$\Xi_c'^+$	4322
$\Xi_c'^0$	4312
Ξ_c^{*+}	4324
Ξ_c^{*0}	4314
Ω_c^0	4332
Ω_c^{*0}	4334
Ξ_{cc}^+	4412
Ξ_{cc}^{++}	4422
Ξ_{cc}^{*+}	4414
Ξ_{cc}^{*++}	4424
Ω_{cc}^+	4432
Ω_{cc}^{*+}	4434
Ω_{ccc}^{++}	4444

BOTTOM MESONS	
B^0	511
B^+	521
B_0^{*0}	10511
B_0^{*+}	10521
B^{*0}	513
B^{*+}	523
$B_1(L)^0$	10513
$B_1(L)^+$	10523
$B_1(H)^0$	20513
$B_1(H)^+$	20523
B_2^{*0}	515
B_2^{*+}	525
B_s^0	531
B_{s0}^{*0}	10531
B_s^{*0}	533
$B_{s1}(L)^0$	10533
$B_{s1}(H)^0$	20533
B_{s2}^{*0}	535
B_c^+	541
B_{c0}^{*+}	10541
B_c^{*+}	543
$B_{c1}(L)^+$	10543
$B_{c1}(H)^+$	20543
B_{c2}^{*+}	545

$b\bar{b}$ MESONS	
$\eta_b(1S)$	551
$\chi_{b0}(1P)$	10551
$\eta_b(2S)$	100551
$\chi_{b0}(2P)$	110551
$\eta_b(3S)$	200551
$\chi_{b0}(3P)$	210551
$\Upsilon(1S)$	553
$h_b(1P)$	10553
$\chi_{b1}(1P)$	20553
$\Upsilon_1(1D)$	30553
$\Upsilon(2S)$	100553
$h_b(2P)$	110553
$\chi_{b1}(2P)$	120553
$\Upsilon_1(2D)$	130553
$\Upsilon(3S)$	200553
$h_b(3P)$	210553
$\chi_{b1}(3P)$	220553
$\Upsilon(4S)$	300553
$\Upsilon(10860)$	9000553
$\Upsilon(11020)$	9010553
$\chi_{b2}(1P)$	555
$\eta_{b2}(1D)$	10555
$\Upsilon_2(1D)$	20555
$\chi_{b2}(2P)$	100555
$\eta_{b2}(2D)$	110555
$\Upsilon_2(2D)$	120555
$\chi_{b2}(3P)$	200555
$\Upsilon_3(1D)$	557
$\Upsilon_3(2D)$	100557

BOTTOM BARYONS	
Λ_b^0	5122
Σ_b^-	5112
Σ_b^0	5212
Σ_b^+	5222
Σ_b^{*-}	5114
Σ_b^{*0}	5214
Σ_b^{*+}	5224
Ξ_b^-	5132
Ξ_b^0	5232
$\Xi_b'^-$	5312
$\Xi_b'^0$	5322
Ξ_b^{*-}	5314
Ξ_b^{*0}	5324
Ω_b^-	5332
Ω_b^{*-}	5334
Ξ_{bc}^0	5142
Ξ_{bc}^+	5242
$\Xi_{bc}'^0$	5412
$\Xi_{bc}'^+$	5422
Ξ_{bc}^{*0}	5414
Ξ_{bc}^{*+}	5424
Ω_{bc}^0	5342

Ω_{bc}^{*0}	5432
Ω_{bc}^{*0}	5434
Ω_{bcc}^+	5442
Ω_{bcc}^{*+}	5444
Ξ_{bb}^-	5512
Ξ_{bb}^0	5522
Ξ_{bb}^{*-}	5514
Ξ_{bb}^{*0}	5524
Ω_{bb}^-	5532
Ω_{bb}^{*-}	5534
Ω_{bbc}^0	5542
Ω_{bbc}^{*0}	5544
Ω_{bbb}^-	5554

PDG: 523 (x63)

- **Hepmc (Generator):**

  B^{*+} 523

  ID: 83 PDG-id: 523

  Momentum [MeV]:(-1.883e+04, -3988, 3.768e+04)

  Vertex [mm] :(-8.572e-12 4.248e-12 1.218e-11)

  Endpoint [mm]:(-8.572e-12 4.248e-12 1.218e-11)

  Daughters prod. vertex [mm]: (-8.572e-12 4.248e-12 1.218e-11)

- **After ddsim:**

  ID: 99 PDG-id: 523

  Momentum [GeV]: (-18.8283, -3.98772, 37.6769)

  Vertex [mm]: (-8.572e-12, 4.248e-12, 1.218e-11)

  Endpoint [mm]: (-8.572e-12, 4.248e-12, 1.218e-11)

  Daughters prod. vertex [mm]: (0,0,0)

PDG: 533 (x15)

- **Hepmc (Generator):** B_s^{*0} 533
- ID: 38 PDG-id: 533

  Momentum [MeV]:(5.952e+04, -2.88e+04, 5.67e+04)

  Vertex [mm]:(7.235e-13 -1.458e-12 3.898e-12)

  Endpoint [mm]:(7.235e-13 -1.458e-12 3.898e-12)

  Daughters prod. vertex [mm]: (7.235e-13 -1.458e-12 3.898e-12)
- **After ddsim:**

  ID: 41 PDG-id: 533

  Momentum [GeV]: (59.5233,-28.8032,56.7003)

  Vertex [mm]: (0,0,0)

  Endpoint [mm]: (0,0,0)

  Daughters prod. vertex [mm]: (0,0,0)

Endpoint and daughters production vertices at zero

PDG: 513 (x51)

B^{*0} 513

- **Hepmc (Generator):**

  ID: 21 PDG-id: -513

  Momentum [MeV]:(5.308e+04,-1.056e+05,-5.361e+04)

  Vertex [mm]:(1.031e-10 -8.553e-11 -6.920e-11)

  Endpoint [mm]:(1.031e-10 -8.553e-11 -6.920e-11)

  Daughters prod. vertex [mm]: 1.031e-10 -8.553e-11 -6.920e-11

- **From ddsim:**

  ID: 23 PDG-id: -513

  Momentum [GeV] : (53.0815,-105.607,-53.612)

  Vertex [mm]: (0,0,0)

  Endpoint [mm]: (0,0,0)

  Daughters prod. vertex [mm]: (0,0,0)

Endpoint and daughters production vertices at zero

PDG: 5222 (x1)

- **Hepmc (Generator)**: Σ_b^+ 5222

  ID: 24 PDG-id: -5222

  Momentum [MeV]:(3.698e+04, 6.475e+04, 1.326e+05)

  Vertex [mm]:(6.362e-12 1.819e-11 4.376e-11)

  Endpoint [mm]:(6.362e-12 1.819e-11 4.376e-11)

  Daughters prod. vertex [mm]: 6.362e-12 1.819e-11 4.376e-11

- **After ddsim:**

  ID: 27 PDG-id: -5222

  Momentum [GeV]: (36.9823,64.7479,132.601)

  Vertex [mm]: (0,0,0)

  Endpoint [mm]: (0,0,0)

  Daughters prod. vertex [mm]: (0,0,0)

Endpoint and daughters production vertices at zero

PDG: 5112 (x1)

- **Hepmc (Generator):**

  Σ_b^- 5112

  ID: 23 PDG-id: 5112

  Momentum [MeV]:(-3.654e+04,-1.611e+04,-7.355e+04)

  Vertex [mm]:(8.955e-12 -4.799e-11 -4.130e-10)

  Endpoint [mm]:(8.955e-12 -4.799e-11 -4.130e-10)

  Daughters prod. vertex [mm]: (8.955e-12 -4.799e-11 -4.130e-10)

- **After ddsim:**

  ID: 23 PDG-id: 5112

  Momentum [GeV]: (-36.5377,-16.1104,-73.5526)

  Vertex [mm]: (0,0,0)

  Endpoint [mm]: (0,0,0)

  Daughters prod. vertex [mm]: (0,0,0)

Endpoint and daughters production vertices at zero

PDG: 5224 (x1)

- **Hepmc (Generator):**

  Σ_b^{*+} 5224

  ID: 90 PDG-id: -5224

  Momentum [MeV]:(-1.815e+04, 4.723e+04, 6.804e+04)

  Vertex [mm]:(3.415e-12 7.113e-12 2.714e-11)

  Endpoint [mm]:(3.415e-12 7.113e-12 2.714e-11)

  Daughters prod. vertex [mm]: (3.415e-12 7.113e-12 2.714e-11)

- **After ddsim:**

  ID: 97 PDG-id: -5224

  Momentum [GeV]: (-18.1482,47.2288,68.0377)

  Vertex [mm]: (0,0,0)

  Endpoint [mm]: (0,0,0)

- Daughters prod. vertex [mm]: (0,0,0)

Endpoint and daughters production vertices at zero

PDG: 5334 (x1)

- **Hepmc (Generator):**

  Ω_b^{*-} 5334

  ID: 68 PDG-id: 5334

  Momentum [MeV]:(-7892, 1.542e+04,-1.239e+05)

  Vertex [mm]:(1.417e-11 -2.6467e-11 -1.821e-10)

  Endpoint [mm]:(1.417e-11 -2.646e-11 -1.821e-10)

  Daughters prod. vertex [mm]: (1.417e-11 -2.646e-11 -1.821e-10)

- **After ddsim:**

  ID: 82 PDG-id: 5334

  Momentum [GeV]: (-7.89239,15.4221,-123.938)

  Vertex [mm]: (0,0,0)

  Endpoint [mm]: (0,0,0)

- Daughters prod. vertex [mm]: (0,0,0)

Endpoint and daughters production vertices at zero

PDG: 5122

- **Hepmc (Generator):** Λ_b^0 5122

  ID: 120 PDG-id: -5122

  Momentum [MeV]:(-1.711e+01 4.488e+01 6.452e+01)

  Vertex [mm]:(3.415e-12, 7.113e-12, 2.714e-11)

  Endpoint [mm]:(-1.070e+00, 2.807e+00, 4.035e+00)

  Daughters prod. vertex [mm]: (-1.070e+00, 2.807e+00, 4.035e+00)
- **After ddsim:**

  ID: 120 PDG-id: -5122

  Momentum [GeV]: (-17.1147,44.8821,64.5212)

  Vertex [mm]: (0,0,0)

  Endpoint [mm]: (-1.0704 2.80705 4.03533)
- Daughters prod. vertex [mm]: (-1.0704 2.80705 4.03533)

PDG:413 (x47)

There are 48 pgd=413 particles (the 48th is in the next slide)

- **Hepmc (Generator):**

  ID: 28 PDG-id: -413

  Momentum [MeV]:(-1298, 2044, -2620)

  Vertex [mm]:(-5.026e-11 -2.056e-11 -1.285e-11)

  Endpoint [mm]:(-1.435e-09 2.161e-09 -2.808e-09)
- Daughters prod. vertex [mm]: (-1.435e-09 2.161e-09 -2.808e-09)
- **After ddsim:**

  ID: 30 PDG-id: -413

  Momentum [GeV]: (-1.29776,2.04449,-2.62008)

  Vertex [mm]: (0,0,0)

  Endpoint [mm]: (-1.38466e-09,2.18139e-09,-2.79552e-09)

  Daughters prod. vertex [mm]: (-1.38466e-09 2.18139e-09 -2.79552e-09)

PDG: 413 (II) (x1)

This is the only 413 with endpoint at zero after ddsim.

- **Hepmc (Generator)**

  ID: 52 PDG-id: -413

  Momentum [MeV]:(-197.2, 562.7, -77.44)

  Vertex [mm]:(-6.393e-12 1.292e-11 -5.567e-12)

  Endpoint [mm]:(-2.251e-10 6.369e-10 -9.144e-11)

  Daughters prod. vertex [mm]: (-2.251e-10 6.369e-10 -9.144e-11)

- **After ddsim**

  ID: 55 PDG-id: -413

  Momentum [GeV]: (-0.197188,0.562684,-0.0774353)

  Vertex [mm]: (0,0,0)

  Endpoint [mm]: (0,0,0)

  Daughters prod. vertex [mm]: (0 0 0)

Endpoint at zero

Double Higgs sample

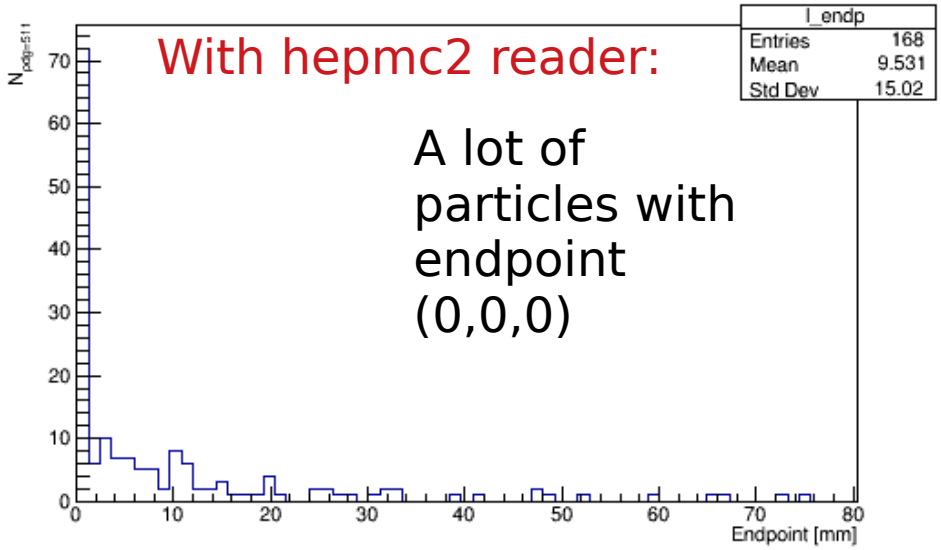
Test 2:

- $\mu^+\mu^- \rightarrow HH\bar{\nu}\nu \rightarrow b\bar{b}b\bar{b}\nu\bar{\nu}$ process
- 100 events generated with Whizard at 3 TeV center of mass energy

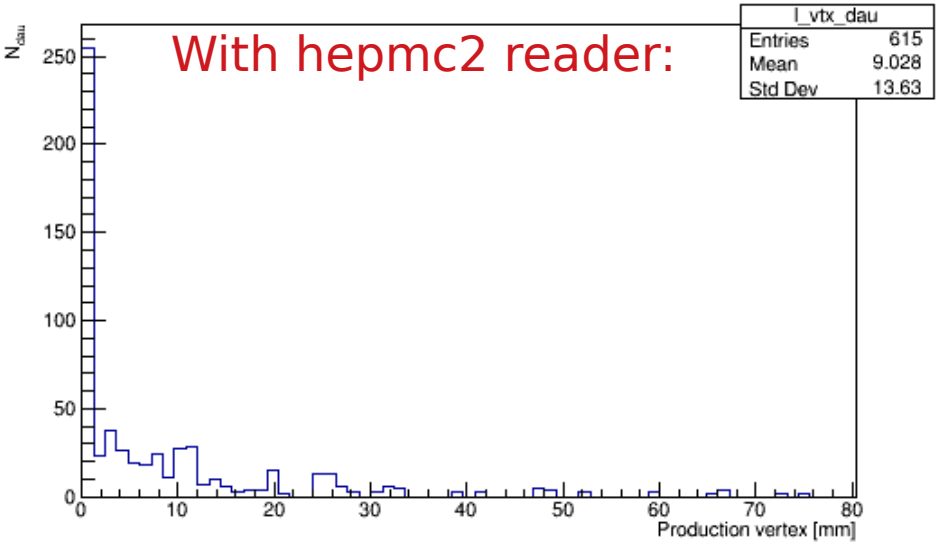
B^0 endpoint and daughter vtx production

With hepmc2 reader:

A lot of particles with endpoint (0,0,0)

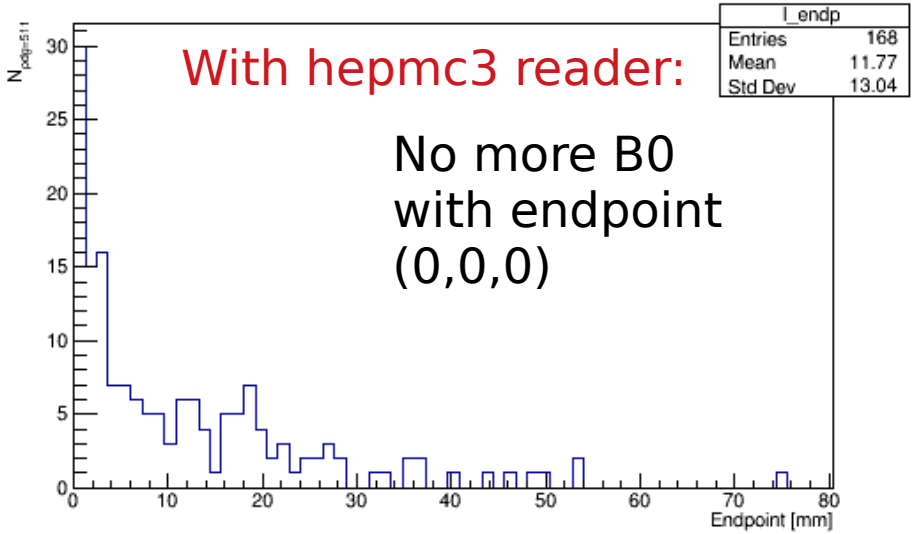


With hepmc2 reader:

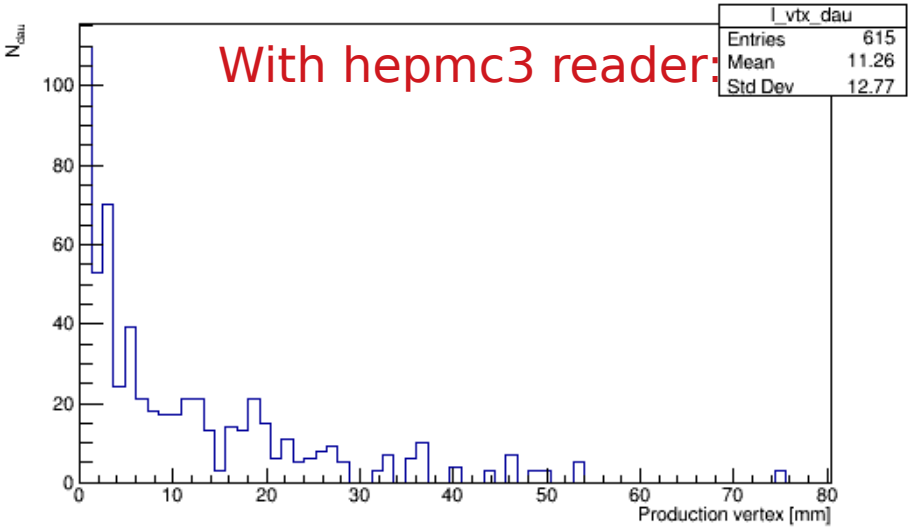


With hepmc3 reader:

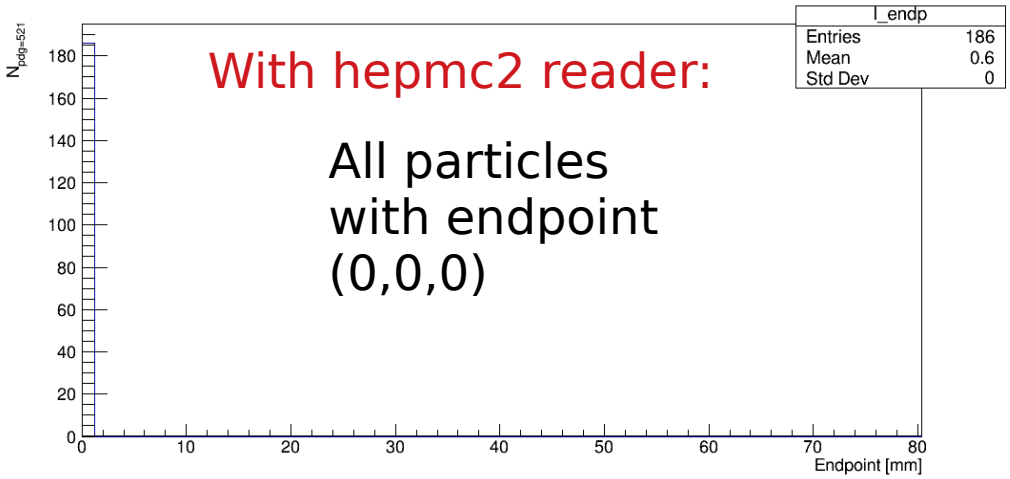
No more B0 with endpoint (0,0,0)

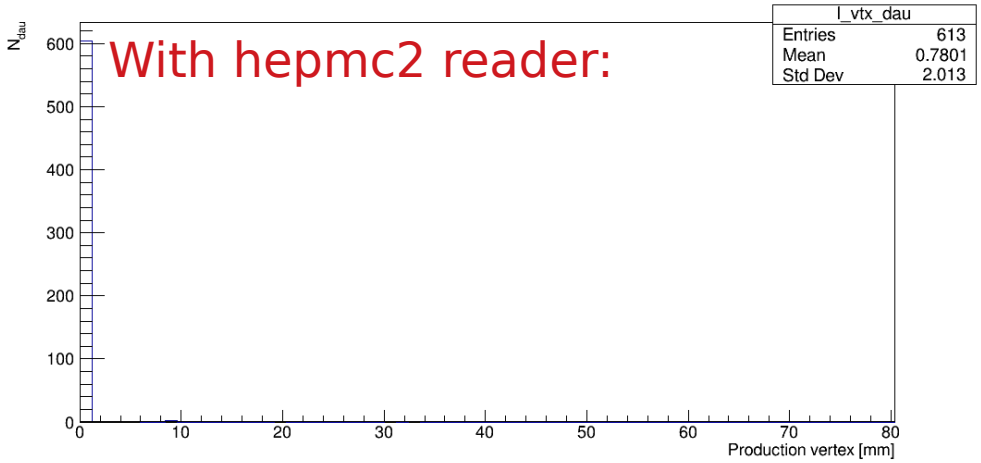


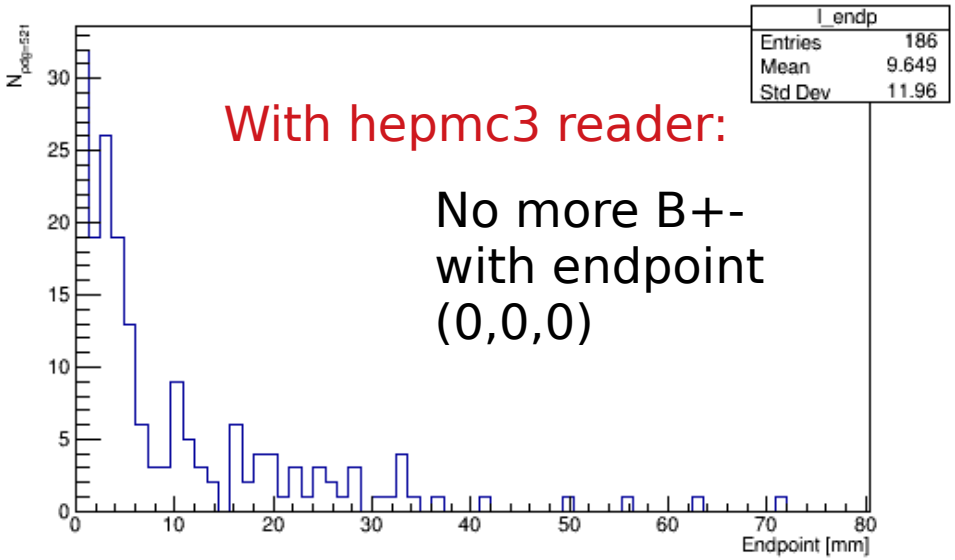
With hepmc3 reader:

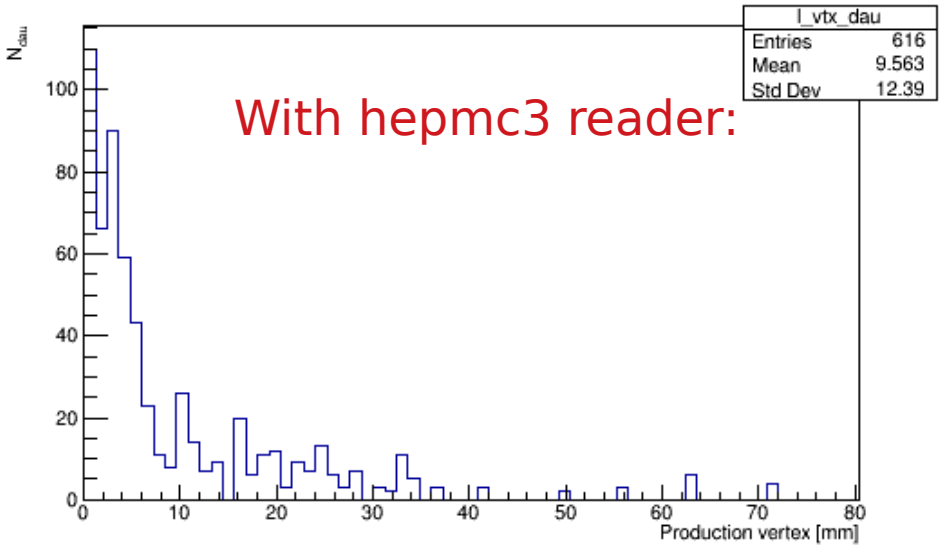


$B^{+/-}$ endpoint and daughter vtx production









Summary

- With the hepmc3 reader the endpoint of B^0 and B^+/B^- mesons is correctly set

There are still problems with some particles:

- The endpoint after ddsim is different from the generator one
- The production vertex of the mother is sometimes set to zero
- The production vertex of the daughters is different from the generator one

PDG: 533 (x15)

Hepmc

B_s^{*0} 533

- ID: 38 PDG-id: 533

  Momentum [MeV]:(5.952e+04, -2.88e+04, 5.67e+04)

  Vertex [mm]:(7.234949759081689 1e-13 -1.457579053551945 7e-12 3.897766319946904 5e-12)

  Endpoint [mm]:(7.234949759081689 1e-13 -1.457579053551945 7e-12 3.897766319946904 5e-12)

  Daughters prod. vertex [mm]: (7.234949759081689 1e-13 -1.457579053551945 7e-12 3.897766319946904 5e-12)

- **After ddsim:**

  ID: 41 PDG-id: 533

  Momentum [GeV]: (59.5233,-28.8032,56.7003)

  Vertex [mm]: (0,0,0)

  Endpoint [mm]: (0,0,0)

  Daughters prod. vertex [mm]: (0,0,0)

Endpoint and daughters production vertices at zero