LHCb workloads
in the benchmarking suite

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https://indico.cern.ch/event/739897

Current LHCb workload: gen-sim

- **A typical LHCb "MC simulation job"**
  - Including both event generation and detector simulation
  - Single-threaded and single-process
  - This type of job represents ~90% of CPU consumed by LHCb in WLCG

- Extremely easy to run
  - It takes around 30 minutes to process 5 events

- Current metric: score is #events per (wall-time) 1000 seconds
  - In the past:
    - One score including both generation and simulation
    - Including the first event (slower due to I/O)
  - In the latest versions:
    - Two new separate score for generation and simulation, excluding first event
    - Old gen-sim score is still measured and recorded

LHCb gen-sim workload metrics

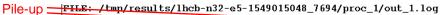- In the past: parse the total event loop for generation and simulation

One of 32 job logs:

```
INFO Algorithm          (millisec) |   <user> |   <clock> |      min      max | entries | total (s) |
INFO -----------------------------------------------------------------------------------------------
INFO EVENT LOOP                     | 350681.855 | 351971.374 | 226829.970  587473.2 |      5 |  1759.857 |
```

In this job: average 352s (= 1760 / 5) per event – i.e. 2.84 events per 1000s

Benchmarking score:
```
{"score": 91.1255, "avg": 2.8477, "median": 2.8431, "min": 2.8102, "max": 2.9122}
{"copies":32 , "threads_x_copy":1 , "events_x_thread" : 5 , "througput_score": {"s
```

Across 32 jobs: average 2.85 events per 1000s – i.e. 91.1 events per 1000s node throughput (= 2.85 x 32)

- Now: separately parse generation and simulation, skip the first event

```
2019-02-01 10:17:12 UTC GaussGen            INFO Evt 8803,  Run 7140089,  Nr. in job = 3 with seeds [7140089, 8803, 117214431, 0]
  PYTHIA Warning in SpaceShower::pT2nextQCD: small daughter PDF
2019-02-01 10:19:53 UTC GaussGenPrevPrev    INFO Evt 8803,  Run 7140089,  Nr. in job = 3 with seeds [7140089, 8803, 935330033, 0]
2019-02-01 10:19:53 UTC GaussGenPrev        INFO Evt 8803,  Run 7140089,  Nr. in job = 3 with seeds [7140089, 8803, 1199519958, 0]
2019-02-01 10:19:53 UTC GaussGenNext        INFO Evt 8803,  Run 7140089,  Nr. in job = 3 with seeds [7140089, 8803, 233623463, 0]
  PYTHIA Error in BeamRemnants::setKinematics: kinematics construction failed
2019-02-01 10:19:53 UTC GaussGenNextNext    INFO Evt 8803,  Run 7140089,  Nr. in job = 3 with seeds [7140089, 8803, 1707412442, 0]
2019-02-01 10:19:53 UTC MainEventGaussSim   INFO Evt 8803,  Run 7140089,  Nr. in job = 3 with seeds [7140089, 8803, 2073811835, 0]
2019-02-01 10:20:35 UTC GiGaGetMainEvent    INFO Number of extracted MCParticles 'MC/Particles'    1406
2019-02-01 10:20:35 UTC GiGaGetMainEvent    INFO Number of extracted MCVertices  'MC/Vertices'     1510
2019-02-01 10:20:35 UTC PrevPrevEventGa...   INFO Evt 8803,  Run 7140089,  Nr. in job = 3 with seeds [7140089, 8803, 1184460771, 0]
2019-02-01 10:20:35 UTC PrevEventGaussSim   INFO Evt 8803,  Run 7140089,  Nr. in job = 3 with seeds [7140089, 8803, 549931932, 0]
2019-02-01 10:20:35 UTC NextEventGaussSim   INFO Evt 8803,  Run 7140089,  Nr. in job = 3 with seeds [7140089, 8803, 17447920, 0]
2019-02-01 10:20:59 UTC GiGaGetNextEvent    INFO Number of extracted MCParticles 'MC/Particles'     742
2019-02-01 10:20:59 UTC GiGaGetNextEvent    INFO Number of extracted MCVertices  'MC/Vertices'      895
2019-02-01 10:20:59 UTC NextNextEventGa...   INFO Evt 8803,  Run 7140089,  Nr. in job = 3 with seeds [7140089, 8803, 1401020779, 0]
2019-02-01 10:20:59 UTC GaussGen            INFO Evt 8804,  Run 7140089,  Nr. in job = 4 with seeds [7140089, 8804, 195401829, 0]
```

Event #3 GEN

One of 32 job logs:

Event #3 SIM

Pile-up

```
FILE: /tmp/results/lhcb-n32-e5-1549015048_7694/proc_1/out_1.log

iCPU=xx [      time,    evt,   #part, ##,   #vert, ##, G/S]  time/k#part

iCPU=00 [    32.000,   8801,      0,  0,       0,  0, GEN]      ---
iCPU=00 [    14.000,   8802,      0,  0,       0,  0, GEN]      ---
iCPU=00 [   161.000,   8803,      0,  0,       0,  0, GEN]      ---
iCPU=00 [    82.000,   8804,      0,  0,       0,  0, GEN]      ---
iCPU=00 [    11.000,   8805,      0,  0,       0,  0, GEN]      ---

iCPU=00 [   365.000,   8801,   9638,  5,   10387,  5, SIM]   37.87093
iCPU=00 [   573.000,   8802,  19742,  5,   21208,  5, SIM]   29.02441
iCPU=00 [    66.000,   8803,   2148,  2,    2405,  2, SIM]   30.72626
iCPU=00 [   151.000,   8804,   5443,  3,    5901,  3, SIM]   27.74205
iCPU=00 [   305.000,   8805,  12255,  5,   12933,  5, SIM]   24.88780

[FIRSTEVENT] Total time in magnetic field SIM initialization 45.0
```

Metrics for this job:

Event #1 SIM: includes slow initialization (e.g. magnetic field, conditions)

Comments:
- GEN and SIM time ~uncorrelated
- SIM time ~proportional to #particles (but first event SIM is slower)
- SIM time / particle more stable as a throughput metric than time / event

Trident analysis

- Servesh ran the bmk on a node with 16 virtual processors (8 cores 2xHT)
  - 16 identical jobs executed in parallel, i.e. roughly ~ at the same time
  - Trident plot shows all 16 jobs
  - Correlated with timing info from a single log of one of these 16 jobs

- Summary of results:
  - *GEN slightly more efficient than SIM (visible as higher IPC regions)*
  - Initialization of GEN and SIM clearly visible, before and during 1st event
    - Should skip 1st event for benchmarking steady-state GEN and SIM
  - Some patterns to be better understood (memory peak in a GEN event)

[START OF JOB] Time 0s
ApplicationMgr   INFO Application Manager Configured successfully
2019-02-28 16:14:13.471 UTC DetectorPersist... INFO Added successfully Conversion service:XmlCnvSvc
...

[SIGNAL GENERATOR INITIALIZATION] Time 10s
2019-02-28 16:14:23.337 UTC GaussGen   SUCCESS Requested to process 5 events
2019-02-28 16:14:23.462 UTC GaussGen   INFO Create BeamForInitialization
[photos splash]
[pythia splash]
[tauola splash]
2019-02-28 16:14:41.023 UTC Generation.Sign... INFO Generating **Signal events of D*(2010)- D*(2010)+**
2019-02-28 16:14:24.379 UTC Generation.Sign...SUCCESS Using as production engine Pythia8Production
2019-02-28 16:14:41.024 UTC Generation   SUCCESS Requested to generate EventType 27163076
...

[MINBIAS GENERATOR INITIALIZATION - PILEUP #1/4] Time 30s
2019-02-28 16:14:41.089 UTC GaussGenPrevPrev SUCCESS Requested to process 5 events
2019-02-28 16:14:41.089 UTC GenerationPrevP... INFO Generating **Minimum Bias events.**
2019-02-28 16:14:41.089 UTC GenerationPrevP...SUCCESS Using as production engine Pythia8Production
2019-02-28 16:14:57.589 UTC GenerationPrevPrevSUCCESS Requested to generate EventType 30000000
...

[MINBIAS GENERATOR INITIALIZATION - PILEUP #2/4] Time 45s
2019-02-28 16:14:57.591 UTC GaussGenPrev   SUCCESS Requested to process 5 events
2019-02-28 16:14:57.591 UTC GenerationPrev.... INFO Generating **Minimum Bias events.**
2019-02-28 16:14:57.591 UTC GenerationPrev....SUCCESS Using as production engine Pythia8Production
2019-02-28 16:15:14.066 UTC GenerationPrev   SUCCESS Requested to generate EventType 30000000
...

[MINBIAS GENERATOR INITIALIZATION - PILEUP #3/4] Time 60s
2019-02-28 16:15:14.067 UTC GaussGenNext   SUCCESS Requested to process 5 events
2019-02-28 16:15:14.068 UTC GenerationNext.... INFO Generating **Minimum Bias events.**
2019-02-28 16:15:14.068 UTC GenerationNext....SUCCESS Using as production engine Pythia8Production
2019-02-28 16:15:30.561 UTC GenerationNext   SUCCESS Requested to generate EventType 30000000
...

[MINBIAS GENERATOR INITIALIZATION - PILEUP #4/4] Time 75s
2019-02-28 16:15:30.563 UTC GaussGenNextNext SUCCESS Requested to process 5 events
2019-02-28 16:15:30.563 UTC GenerationNextN... INFO Generating **Minimum Bias events.**
2019-02-28 16:15:30.564 UTC GenerationNextN...SUCCESS Using as production engine Pythia8Production
2019-02-28 16:15:47.279 UTC GenerationNextNextSUCCESS Requested to generate EventType 30000000
...

[SIGNAL SIMULATION INITIALIZATION] Time 90s
2019-02-28 16:15:47.282 UTC MainEventGaussSim SUCCESS Requested to process 5 events
...

[MINBIAS SIMULATION INITIALIZATION - PILEUP #1/4] Time 115s
2019-02-28 16:16:09.422 UTC PrevPrevEventGa...SUCCESS Requested to process 5 events
...

[MINBIAS SIMULATION INITIALIZATION - PILEUP #2/4] Time 115s
2019-02-28 16:16:09.434 UTC PrevEventGaussSim SUCCESS Requested to process 5 events
...

[MINBIAS SIMULATION INITIALIZATION - PILEUP #3/4] Time 115s
2019-02-28 16:16:09.446 UTC NextEventGaussSim SUCCESS Requested to process 5 events
...

[MINBIAS SIMULATION INITIALIZATION - PILEUP #4/4] Time 115s
2019-02-28 16:16:09.457 UTC NextNextEventGa...SUCCESS Requested to process 5 events
...

[GENERATE EVENT #1/5 - SIGNAL AND MINBIAS PILEUP] Time 115s
2019-02-28 16:16:09.471 UTC ApplicationMgr   INFO Application Manager Started successfully
2019-02-28 16:16:09.490 UTC GaussGen   INFO Evt 8801, Run 7140089, Nr. in job = 1 with seeds [7140089, 8801, 516570798, 0]
PYTHIA Warning in SpaceShower::pT2nextQCD: weight above unity
PYTHIA Error in BeamRemnants::setKinematics: kinematics construction failed
2019-02-28 16:16:28.813 UTC GaussGenPrevPrev INFO Evt 8801, Run 7140089, Nr. in job = 1 with seeds [7140089, 8801, 1161403360, 0]
2019-02-28 16:16:28.816 UTC GaussGenPrev   INFO Evt 8801, Run 7140089, Nr. in job = 1 with seeds [7140089, 8801, 281376746, 0]
2019-02-28 16:16:28.846 UTC GaussGenNext   INFO Evt 8801, Run 7140089, Nr. in job = 1 with seeds [7140089, 8801, 209151265, 0]
2019-02-28 16:16:28.912 UTC GaussGenNextNext INFO Evt 8801, Run 7140089, Nr. in job = 1 with seeds [7140089, 8801, 1073365045, 0]

[SIMULATE EVENT #1/5 - INITIALIZATION OF MAGNETIC FIELD] Time 135s
--- Warning from G4Material::G4Material() define a material with density=0 is not allowed.
 The material /dd/Materials/Vacuum will be constructed with the default minimal density: 1e-25g/cm3
2019-02-28 16:16:29.342 UTC MagneticFieldSvc   INFO **Opened magnetic field file :**
/cvmfs/lhcb.cern.ch/lib/lhcb/DBASE/FieldMap/v5r7/cdf/field.v5r0.c1.down.cdf
...

[SIMULATE EVENT #1/5 - INITIALIZATION OF GEOMETRY AND PHYSICS] Time 150s
2019-02-28 16:16:42.507 UTC GiGaLVCnv   WARNING GiGaVolConv Misalignment: Multiple indistinguishable misalignable detector elements
found inside /dd/Geometry/AfterMagnetRegion/T/IT/lvITV_410_1to4_ShortLayer . Please Check Geometry DB
2019-02-28 16:16:52.397 UTC MainEventGaussSim   INFO Evt 8801, Run 7140089, Nr. in job = 1 with seeds [7140089, 8801, 1637558138, 0]
2019-02-28 16:16:52.400 UTC GiGa.GiGaMgr   INFO GiGaRunManager:: Geometry will be extracted from GiGaGeo
[LHCb detector info printouts]
[HADRONIC PROCESSES SUMMARY splash]

[SIMULATE EVENT #1/5 - SIMULATE SIGNAL AND MINBIAS PILEUP] Time 180s
2019-02-28 16:17:17.528 UTC RichG4HistoSet2   INFO Now Booking Rich G4 Histo Set2
...
2019-02-28 16:18:28.753 UTC GiGaGetMainEvent   INFO Number of extracted MCParticles 'MC/Particles' 3991
2019-02-28 16:18:28.754 UTC GiGaGetMainEvent   INFO Number of extracted MCVertices 'MC/Vertices' 4354
...
2019-02-28 16:19:56.208 UTC NextNextEventGa... INFO Evt 8801, Run 7140089, Nr. in job = 1 with seeds [7140089, 8801, 143414944, 0]
2019-02-28 16:19:56.230 UTC GiGaGetNext... INFO Number of extracted MCParticles 'MC/Particles' 2
2019-02-28 16:19:56.230 UTC GiGaGetNext... INFO Number of extracted MCVertices 'MC/Vertices' 3
2019-02-28 16:19:56.236 UTC IODataManager   INFO Referring to dataset 00071400_00000089_1.sim by its file ID:F626C0AF-743B-E911-AC75-0242AC110002

[GENERATE EVENT #2/5 - SIGNAL AND MINBIAS PILEUP] Time 340s
2019-02-28 16:19:56.705 UTC GaussGen   INFO Evt 8802, Run 7140089, Nr. in job = 2 with seeds [7140089, 8802,
...
2019-02-28 16:20:05.663 UTC GaussGenNextNext INFO Evt 8802, Run 7140089, Nr. in job = 2 with seeds [7140089, 8802, 1456434655, 0]

[SIMULATE EVENT #2/5 - SIGNAL AND MINBIAS PILEUP] Time 350s
2019-02-28 16:20:05.667 UTC MainEventGaussSim   INFO Evt 8802, Run 7140089, Nr. in job = 2 with seeds [7140089, 8802, 1360117217
...
2019-02-28 16:25:30.401 UTC NextNextEventGa... INFO Evt 8802, Run 7140089, Nr. in job = 2 with seeds [7140089, 8802, 618267676, 0]
2019-02-28 16:25:32.805 UTC GiGaGetNext... INFO Number of extracted MCParticles 'MC/Particles' 275
2019-02-28 16:25:32.805 UTC GiGaGetNext... INFO Number of extracted MCVertices 'MC/Vertices' 261

[GENERATE EVENT #3/5 - SIGNAL AND MINBIAS PILEUP] Time 680s
2019-02-28 16:25:33.255 UTC GaussGen   INFO Evt 8803, Run 7140089, Nr. in job = 3 with seeds [7140089, 8803, 117214431, 0]
PYTHIA Warning in SpaceShower::pT2nextQCD: **small daughter PDF**
....
2019-02-28 16:27:14.261 UTC GaussGenPrevPrev   INFO Evt 8803, Run 7140089, Nr. in job = 3 with seeds [7140089, 8803, 935330033, 0]
...

[SIMULATE EVENT #3/5 - SIGNAL AND MINBIAS PILEUP] Time 780s
2019-02-28 16:27:14.264 UTC MainEventGaussSim   INFO Evt 8803, Run 7140089, Nr. in job = 3 with seeds [7140089, 8803, 2073811835, 0]
2019-02-28 16:27:41.809 UTC /dd/Structure/L... ERROR Gap not found!
2019-02-28 16:27:41.813 UTC GiGaGetMainEvent   INFO Number of extracted MCParticles 'MC/Particles' 1419
2019-02-28 16:27:41.813 UTC GiGaGetMainEvent   INFO Number of extracted MCVertices 'MC/Vertices' 1501
...

[GENERATE EVENT #4/5 - SIGNAL AND MINBIAS PILEUP] Time 820s
2019-02-28 16:27:55.174 UTC GaussGen   INFO Evt 8804, Run 7140089, Nr. in job = 4 with seeds [7140089, 8804, 195401829, 0]
 PYTHIA Warning in MultipartonInteractions::pTnext: weight above unity
 PYTHIA Error in Pythia::check: charge not conserved
 PYTHIA Abort from Pythia::forceHadronLevel: check of event revealed problems
 PYTHIA Warning in TauDecays::decay: unknown tau production, assuming unpolarized and uncorrelated
2019-02-28 16:28:45.095 UTC GaussGenPrevPrev   INFO Evt 8804, Run 7140089, Nr. in job = 4 with seeds [7140089, 8804, 1305292043, 0]
...

[SIMULATE EVENT #4/5 - SIGNAL AND MINBIAS PILEUP] Time 870s
2019-02-28 16:28:45.125 UTC MainEventGaussSim   INFO Evt 8804, Run 7140089, Nr. in job = 4 with seeds [7140089, 8804, 1348109561, 0]
...
2019-02-28 16:30:00.626 UTC NextNextEventGa... INFO Evt 8804, Run 7140089, Nr. in job = 4 with seeds [7140089, 8804, 185454740, 0]

[GENERATE EVENT #5/5 - SIGNAL AND MINBIAS PILEUP] Time 945s
2019-02-28 16:30:00.755 UTC GaussGen   INFO Evt 8805, Run 7140089, Nr. in job = 5 with seeds [7140089, 8805, 974091012, 0]
...

[SIMULATE EVENT #5/5 - SIGNAL AND MINBIAS PILEUP] Time 950s
2019-02-28 16:30:06.773 UTC MainEventGaussSim   INFO Evt 8805, Run 7140089, Nr. in job = 5 with seeds [7140089, 8805, 379163024, 0]
...
2019-02-28 16:32:56.143 UTC GiGaGetNextNext... INFO Number of extracted MCParticles 'MC/Particles' 2242
2019-02-28 16:32:56.143 UTC GiGaGetNextNext... INFO Number of extracted MCVertices 'MC/Vertices' 2293

[JOB FINALIZATION AND END] Time 1120s
2019-02-28 16:32:56.411 UTC ApplicationMgr   INFO Application Manager Stopped successfully
2019-02-28 16:32:56.411 UTC GaussGen   SUCCESS 5 events processed
...
2019-02-28 16:32:57.569 UTC ApplicationMgr   INFO Application Manager Finalized successfully
2019-02-28 16:32:57.570 UTC ApplicationMgr   INFO Application Manager Terminated successfully

- Correlation of log file and Trident timeline was long and tedious
  - Suggestion for BMK: extract the timeline info during log parsing (done for benchmark calculation anyway) to make Trident correlation easier
  - Suggestion for Trident: allow user-defined time start (t_0) and time scale

Future LHCb workloads?

- Include multi-process or multi-threaded MC simulation?
  - WIP in LHCb on multi process simulation (GaussMP)
    - Plan is launch first productions within ~weeks on KNL HPC at CINECA
  - WIP in LHCb on multi-threaded simulation (Gaussino)
    - Expected to reach full production quality next year
  - Reminder: MC sim is and will remain ~90% of LHCb CPU in WLCG!

- Include reconstruction workloads from the HLT?
  - Most active area of WIP in LHCb in view of Run3
  - Both CPU and GPU implementations are being worked on
  - These workloads are relevant for procurement for the LHCb trigger farm