CMS Simulation Status

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Geant4 Technical Forum

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Geant4 in Run2 and start of Run-3

- **For Run-2 legacy MC production**
  - Geant4 10.4.p03 + private patches is used
  - VecGeom was used for the first time

- **For start of Run-3 in 2022**
  - The production platform slc7_amd64_gcc10
  - Geant4 10.7.2 + private patches
  - VecGeom 1.1.17
  - DD4hep 1.19
  - CLHEP 2.4.5.1

- **Updates for 2023 Run-3 MC production**
  - The production platform el8_amd64_gcc11
  - G4GammaGeneralProcess is enabled
  - LTO method to build executable

- **In preparation for 2024**
  - The current platform el8_amd64_gcc11
  - Geant4 11.1.1
  - DD4hep 1.23
  - VecGeom 1.2.1
  - CLHEP 2.4.6.0
  - We would expect from Geant4 an extra patch to 11.1 before summer
    - There were significant number of warning for stack tracks in the initial Geant4 11.1
    - Most part of warnings are fixed in 11.1.p01
  - Today talk is focused on discussion on current known problems with 11.1.p01

CPU performance of CMS production

Ratio of Run3/Run2 CPU per event for different WFs	QCD	Z->e+e-	ttbar	T1tttt
2022 GEN-SIM production	0.70	0.75	0.79	0.83
2023 GEN-SIM production	0.62	0.71	0.71	0.74

- T1tttt is pp →gluino +gluino, gluino → ttbar + lightest neutralino
- Significant speed-up came from
  - Geant4 version
  - Computing platform
  - LTO method

Warnings in CMSSW with Geant4 11.1.p01 (1/2)

```
-------- WWWW ------- G4Exception-START -------- WWWW -------
*** G4Exception : Transport-001-ExcessSteps
      issued by : G4Transportation::AlongStepDoIt
 Transportation is killing track that is looping or stuck.
   Track is proton and has 122.996 MeV energy  ( pre-Step = 122.996 )
   momentum = (-472.647,132.748,-70.1384) mag= 495.92
   position = (-9586.47,1453.77,-12162.4) is in volume 'WallAir',
   its material is 'Air' with density = 0.001214 g/cm^3
 Total number of Steps by this track: 31
 Length of this step = 0.320436 mm
 Number of propagation trials = 1 ( vs maximum = 10 for 'important' particles)
 CMS info: TrackID=1447263 ParentID=1446990  proton; Ekin(MeV)=122.996;
 time(ns)=104.212; status=0
   position(mm): (-9586.47,1453.77,-12162.4);
   direction: (-0.953071,0.26768,-0.141431)
   PhysicalVolume: WallAir; material: Air
   stepNumber=31; stepLength(mm)=0.320436; weight=1; creatorProcess:
   pi+Inelastic; modelID=23000
*** This is just a warning message. ***
-------- WWWW -------- G4Exception-END --------- WWWW -------
```

Warnings in CMSSW with Geant4 11.1.p01 (2/2)

```
--------- wwww -------- G4Exception-START --------- wwww --------
*** G4Exception : HAD_FANCY3DNUCLEUS_001
      issued by : G4Fancy3DNucleus::ChooseFermiMomenta():
      difficulty finding proton momentum, set it to (0,0,0)
      Nucleus_Z A_6 12 proton with eMax=938.061

 CMS info: TrackID=138 ParentID=0  pi-; Ekin(MeV)=13198.6;
   time(ns)=7.33126; status=0
   position(mm): (-232.793,-117.467,2360.79);
   direction: (-0.0982354,-0.0614322,0.993265)
   PhysicalVolume: serviceR259Z2505; material: servicecompositeR259Z2505
   stepNumber=147; stepLength(mm)=8.15646; weight=1
*** This is just a warning message. ***
--------- wwww --------- G4Exception-END --------- wwww --------
```

General comment on tracking in magnetic field

- Magnetic field driver G4DormandPrince745
    - both for Run-2 legacy processing and Run-3
- A smart configuration of Geant4 parameters for tracking in field is implemented with 3 sets of parameters
    - set 1 - for central detector region R < 8 m, |Z| < 11 m, and E > 200 MeV;
    - set 2 - for low-energy particles E < 15 MeV;
    - set 3 - for the rest.
- Dynamic switch between these 3 sets during tracking is performed
    - Providing accuracy for tracking of relativistic particle
    - Reducing tracking problems for low-energy sparing e^{+-}

Magnetic field parameters	Parameter set 1	Parameter set 2	Parameters set 3
DeltaIntersection (mm)	10^{-6}	0.01	10^{-4}
DeltaOneStep (mm)	10^{-4}	0.1	10^{-3}
DeltaChord (mm)	10^{-3}	0.1	$2 \cdot 10^{-3}$
MaxStep (cm)	150	150	50

- CMS set of parameters for simulation of high energy track propagation guarantee accuracy 0.1 um inside the trackers
- Having 3 set of parameters for provides robustness of tracking
- It is not obvious that a discrete approach when we have several sets is the best what can be done
- Most part of warnings relate to tracking of low-energy e+- in air

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Summary

- CMS production for 2022/2023 is based on Geant4 10.7.p02
  - 2022 production has been going well
- CMS plan migration to Geant4 11.1
  - The target 2024 production
  - Geant4 11.1.p01 demonstrates a good performance
    - Rare warnings may be addressed
  - CMS expecting 11.1.p02 before the summer
- CMS has started R&D to use new approaches
  - G4HepEm, Adept, and Celeritas are considered
  - It is not too early to show preliminary results