G4Stage1 memory usage tests with trajectory sparsification

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Simulation Task Force

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06/29/20 Update

- Added a fhicl parameter **SparsifyTrajectories** (false by default) to the *ParticleListActionService* configuration
- This allows for *simb::MCParticle::SparsifyTrajectory()* optional method to be called on each particle within the *ParticleListActionService::endOfEventAction* function
  - The approach is to iteratively check if a point $\mathbf{x}_n \in (\mathbf{x}_{n-1}, \mathbf{x}_{n+1})$ can be removed when linear interpolation is good enough (within epsilon) to approximate $\mathbf{x}_n$
- This helps reduce the number of trajectory points stored in the *MCParticle* objects

Tests, larsoft suite v08_55_01*

- Ten, 7GeV beam events, **keepOnlyPrimaryFullTrajectories** : false
  - Store full trajectories for all particles (including background particles) from the beam generator and their descendants
  - Without **SparsifyTrajectories** option : VmHWM = 4025.17 MB
  - With **SparsifyTrajectories** option : VmHWM = 3815.8 MB
- Ten, 7GeV beam events, **keepOnlyPrimaryFullTrajectories** : true
  - Store full trajectories only for the primary beam particle and its descendants
  - Without **SparsifyTrajectories** option : VmHWM = 3514.35 MB
  - With **SparsifyTrajectories** option : VmHWM = 3678.47 MB

keepOnlyPrimaryFullTrajectories: false, SparsifyTrajectories: false

```
Details for branch: Events

     Size in bytes   Fraction Data Product Name
        1063088562      0.525 simb::MCParticles_largeant__G4Stage1.
         941538004      0.465 sim::SimEnergyDeposits_largeant_LArG4DetectorServicevolTPCActive_G4Stage1.
          13751244      0.007 simb::MCParticlesimb::MCTruthsim::GeneratedParticleInfoart::Assns_largeant__G4Stage1.
           3320243      0.002 sim::SimEnergyDeposits_largeant_LArG4DetectorServicevolTPCActiveOuter_G4Stage1.
           1527476      0.001 simb::MCTruths_ar39__SinglesGen.
            488194      0.000 simb::MCTruths_cosmicgenerator__SinglesGen.
            202463      0.000 sim::AuxDetHits_largeant_LArG4DetectorServicevolAuxDetSensitiveCRTPaddle_G4Stage1.
            196127      0.000 simb::MCTruths_kr85__SinglesGen.
            136042      0.000 simb::MCTruths_generator__SinglesGen.
             20581      0.000 simb::MCTruths_rn222__SinglesGen.
             13394      0.000 simb::MCTruths_ar42__SinglesGen.
             12382      0.000 beam::ProtoDUNEBeamEvents_generator__SinglesGen.
              4330      0.000 sim::ProtoDUNEbeamsims_generator__SinglesGen.
              1234      0.000 art::TriggerResults_TriggerResults__SinglesGen.
              1221      0.000 art::TriggerResults_TriggerResults__G4Stage1.
               580      0.000 EventAuxiliary
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        2024302077      1.000 Total
```

keepOnlyPrimaryFullTrajectories: true, SparsifyTrajectories: false

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Details for branch: Events

     Size in bytes   Fraction Data Product Name
         941537985      0.525 sim::SimEnergyDeposits_largeant_LArG4DetectorServicevolTPCActive_G4Stage1.
         831380409      0.464 simb::MCParticles_largeant__G4Stage1.
          13751244      0.008 simb::MCParticlesimb::MCTruthsim::GeneratedParticleInfoart::Assns_largeant__G4Stage1.
           3320234      0.002 sim::SimEnergyDeposits_largeant_LArG4DetectorServicevolTPCActiveOuter_G4Stage1.
           1527476      0.001 simb::MCTruths_ar39__SinglesGen.
            488194      0.000 simb::MCTruths_cosmicgenerator__SinglesGen.
            202459      0.000 sim::AuxDetHits_largeant_LArG4DetectorServicevolAuxDetSensitiveCRTPaddle_G4Stage1.
            196127      0.000 simb::MCTruths_kr85__SinglesGen.
            136042      0.000 simb::MCTruths_generator__SinglesGen.
             20581      0.000 simb::MCTruths_rn222__SinglesGen.
             13394      0.000 simb::MCTruths_ar42__SinglesGen.
             12382      0.000 beam::ProtoDUNEBeamEvents_generator__SinglesGen.
              4330      0.000 sim::ProtoDUNEbeamsims_generator__SinglesGen.
              1234      0.000 art::TriggerResults_TriggerResults__SinglesGen.
              1222      0.000 art::TriggerResults_TriggerResults__G4Stage1.
               580      0.000 EventAuxiliary
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        1792593893      1.000 Total
```

keepOnlyPrimaryFullTrajectories: false, SparsifyTrajectories: true

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Details for branch: Events

     Size in bytes   Fraction Data Product Name
         941538029      0.524 sim::SimEnergyDeposits_largeant_LArG4DetectorServicevolTPCActive_G4Stage1.
         835200151      0.465 simb::MCParticles_largeant__G4Stage1.
          13751241      0.008 simb::MCParticlesimb::MCTruthsim::GeneratedParticleInfoart::Assns_largeant__G4Stage1.
           3320223      0.002 sim::SimEnergyDeposits_largeant_LArG4DetectorServicevolTPCActiveOuter_G4Stage1.
           1527476      0.001 simb::MCTruths_ar39__SinglesGen.
            488194      0.000 simb::MCTruths_cosmicgenerator__SinglesGen.
            202471      0.000 sim::AuxDetHits_largeant_LArG4DetectorServicevolAuxDetSensitiveCRTPaddle_G4Stage1.
            196127      0.000 simb::MCTruths_kr85__SinglesGen.
            136042      0.000 simb::MCTruths_generator__SinglesGen.
             20581      0.000 simb::MCTruths_rn222__SinglesGen.
             13394      0.000 simb::MCTruths_ar42__SinglesGen.
             12382      0.000 beam::ProtoDUNEBeamEvents_generator__SinglesGen.
              4330      0.000 sim::ProtoDUNEbeamsims_generator__SinglesGen.
              1234      0.000 art::TriggerResults_TriggerResults__SinglesGen.
              1220      0.000 art::TriggerResults_TriggerResults__G4Stage1.
               580      0.000 EventAuxiliary
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        1796413675      1.000 Total
```

keepOnlyPrimaryFullTrajectories: true, SparsifyTrajectories: true

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Details for branch: Events

     Size in bytes   Fraction Data Product Name
         941538027      0.538 sim::SimEnergyDeposits_largeant_LArG4DetectorServicevolTPCActive_G4Stage1.
         788419557      0.451 simb::MCParticles_largeant__G4Stage1.
          13751244      0.008 simb::MCParticlesimb::MCTruthsim::GeneratedParticleInfoart::Assns_largeant__G4Stage1.
           3320222      0.002 sim::SimEnergyDeposits_largeant_LArG4DetectorServicevolTPCActiveOuter_G4Stage1.
           1527476      0.001 simb::MCTruths_ar39__SinglesGen.
            488194      0.000 simb::MCTruths_cosmicgenerator__SinglesGen.
            202471      0.000 sim::AuxDetHits_largeant_LArG4DetectorServicevolAuxDetSensitiveCRTPaddle_G4Stage1.
            196127      0.000 simb::MCTruths_kr85__SinglesGen.
            136042      0.000 simb::MCTruths_generator__SinglesGen.
             20581      0.000 simb::MCTruths_rn222__SinglesGen.
             13394      0.000 simb::MCTruths_ar42__SinglesGen.
             12382      0.000 beam::ProtoDUNEBeamEvents_generator__SinglesGen.
              4330      0.000 sim::ProtoDUNEbeamsims_generator__SinglesGen.
              1234      0.000 art::TriggerResults_TriggerResults__SinglesGen.
              1219      0.000 art::TriggerResults_TriggerResults__G4Stage1.
               580      0.000 EventAuxiliary
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        1749633080      1.000 Total
```

Beam primary only	SparsifyTrajectories	VmHWM
False	False	4025 MB
False	True	3816 MB
True	False	3514 MB
True	True	3678 MB

Notes

- If only the primary and its descendants have full trajectories, then calling the *SparsifyTrajectory()* method on *every* particle is superfluous
  - Most particles already only have a start and an end point -> nothing to remove
  - Most likely cause of increased memory usage
- As a test, I moved the check for the **SparsifyTrajectories** parameter to the *ParticleListActionService::postTrackingAction()* where a check of whether a particle has a full trajectory or not already exists
  - Minimal added complexity
  - The method is called only on particles with full trajectories
- The previous 4 tests were repeated (see next slides) after this change

Tests, larsoft suite v08_55_01*

- Ten, 7GeV beam events, **keepOnlyPrimaryFullTrajectories** : false
  - Store full trajectories for all particles (including background particles) from the beam generator and their descendants
  - Without **SparsifyTrajectories** option : VmHWM = 3949.7 (4027.38) MB
  - With **SparsifyTrajectories** option : VmHWM = 3708.7 (3632.84) (3713.69) (3681.3) (3708.53) (3624.54) MB
- Ten, 7GeV beam events, **keepOnlyPrimaryFullTrajectories** : true
  - Store full trajectories only for the primary beam particle and its descendants
  - Without **SparsifyTrajectories** option : VmHWM = 3623.37 (3638.17) (3653.71) MB
  - With **SparsifyTrajectories** option : VmHWM = 3728.9 (3727.86) (3610.37) (3552.3) (3636.7) (3615.58) MB

Call SparsifyTrajectory() on all particles when SparsifyTrajectories==True

Beam primary only	SparsifyTrajectories	VmHWM
False	False	4025 MB
False	True	3816 MB
True	False	3514 MB
True	True	3678 MB

Call SparsifyTrajectory() only on particles with full trajectories when SparsifyTrajectories==True

Beam primary only	SparsifyTrajectories	VmHWM
False	False	3989 MB
False	True	3703 MB
True	False	3646 MB
True	True	3626 MB

Conclusions

- Don’t gain much by storing only the primary beam particle full trajectories on top of sparsifying (~75MB)
- Calling the SparsifyTrajectory() method on particles with full trajectories only is more efficient, as expected

BACKUP

Sparsify called on beam primary and descendants only

- **keepOnlyPrimaryFullTrajectories**: true, **SparsifyTrajectories**: true
  - VmHWM = 3610.37 (3552.3) MB

Sparsify called on all beam and beam bkg particles and their descendants

- **keepOnlyPrimaryFullTrajectories**: false, **SparsifyTrajectories**: true
  - VmHWM = 3616.36 (3632.84) MB