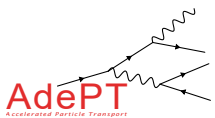
AdePT implementation overview

HSF Detector Simulation on GPU Community Meeting

AdePT Developers

May 3, 2022



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- GEANT4 tracks one particle at a time
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- AdePT steps all active tracks at once
  - Much higher degree of parallelism & more uniform work for GPU
- Different properties than simulation workflow of GEANT4
  - No "thread-local" state, everything associated with a track
  - At the same time: track must be as lightweight as possible
  - Data structures must not create bottlenecks (prefer atomics)

Track storage

- Properties stored per track: (see code for TestEm3)
  - Random number generator state
  - Kinetic energy
  - Position, direction, and current navigation state (volume)
  - State to be preserved across steps (number-of-interaction-left, MSC properties)

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- Pre-allocate arrays of tracks per particle type (array of structures)
  - One for electrons, one for positrons, one for gammas
  - Advantage: can call spezialized kernels, potentially specialize stored properties
  - Atomic counter to hand out "slots" (recent addition to allow compaction)

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- Properties *not* stored per track:
  - Particle type / PDG number (instead implicit from array)
  - Charge, mass (can be inferred from particle type)

Random number generator: RANLUX++

- Based on the well-known RANLUX generator
  - Uses the equivalent LCG and therefore faster
  - Excellent statistical properties: inherited from RANLUX, only shared by MIXMAX (XORWOW used by default in cuRAND known to fail some statistical tests)

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  - See J. Hahnfeld, L. Moneta: A Portable Implementation of RANLUX++
- Advantage over MIXMAX: smaller state
  - Even for `N = 17`, the default generator in GEANT4 (148 bytes of state)
  - Compared to 80 bytes for RANLUX++

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- For reproducibility, RNG state associated with each track
  - Identical results no matter the parallel execution order / kernel configuration
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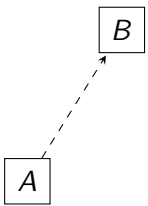

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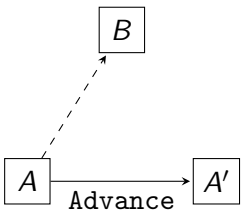

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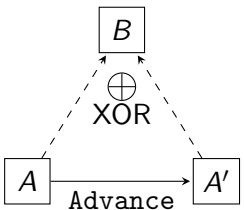

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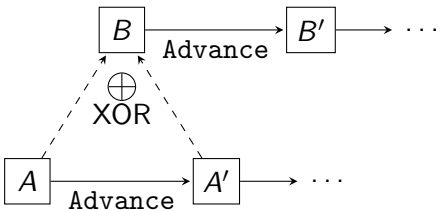

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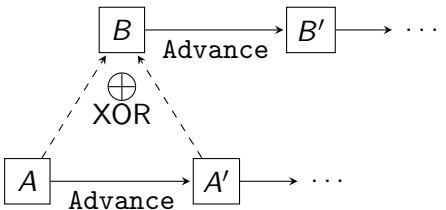
  - However, can re-use RNG state of dying track (annihilation, conversion)



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Arrays of active and next tracks

track #0
track #1
track #2
track #3
track #4
track #5
track #6
track #7

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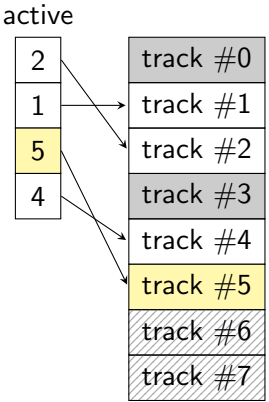
- Store indices of active tracks (per particle type)
  - For transportation, parallelize over these indices
  - Based on the index, locate the track and its state



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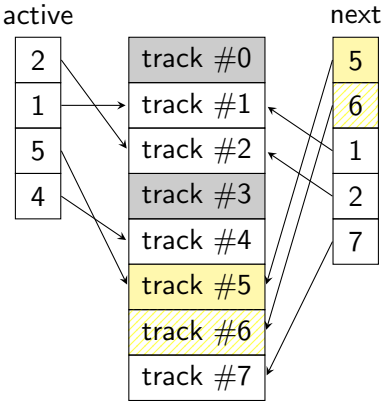
  - Implemented with atomic counter



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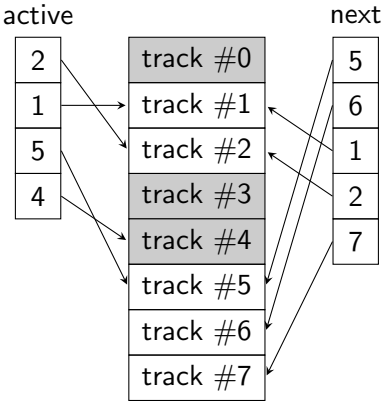

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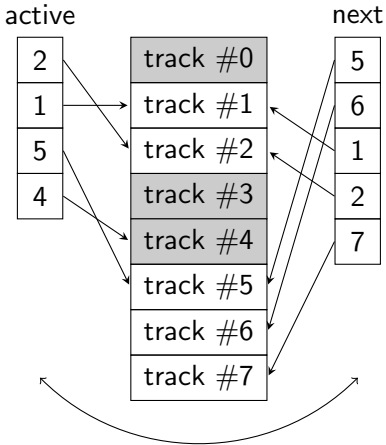
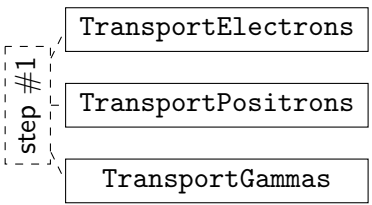
- After each step, swap the two arrays
  - And clear the array of "next next" active tracks



Overview of stepping workflow

- Transport of all particle types and active tracks is independent!
  - Can start kernels for particle types in parallel



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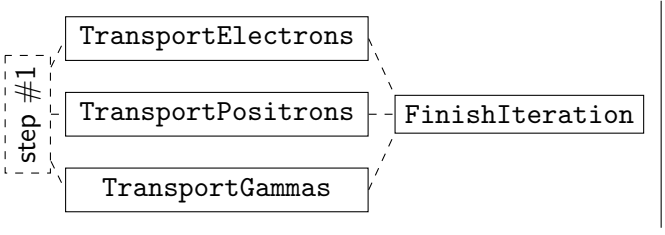

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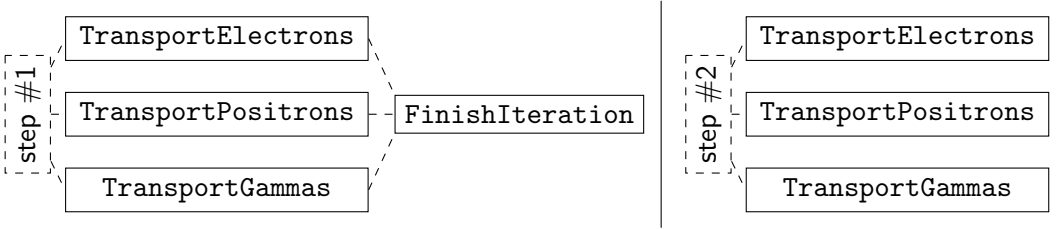

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  - In particular RNG state per track for reproducibility
- Active tracks managed via arrays of indices
- Transport kernels started in parallel, only synchronized once per step