

ORANGE: surface-based GPU geometry

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ORANGE Oak Ridge Advanced Nested Geometry Engine

- Designed for deeply nested reactor models
- Portable (CUDA/HIP) geometry implementation for testing
- Tracking based on CSG tree of surfaces comprising volumes
- Maximize run-time performance
 by preprocessing



ORANGE surface-based tracking methodology



	Position	Volume	Surface+Sense
(input)	A	_	
Initialize	A	1	—
Find step	A	1	—
Move internal	В	1	_
Move to bdy	С	1	a inside ү
Cross bdy	С	2	a outside
Move internal	D	2	—



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*exact handling of direction changes on boundaries

ORANGE surface/volume construction



Only **partially** implemented in Celeritas ORANGE



Memory requirements (geometry model/parameters)

- Surfaces: type (byte), representation (1–10 reals)
 - *Must* be deduplicated across multiple adjacent shapes
 - Can be reused across multiple universes
- Volumes: linearized CSG tree (2–4 \times #faces \times ints) and surface IDs
- Surface→volume connectivity
- Acceleration structures (BVH, "voxelized" grid, etc.)



Memory requirements (track state)

- Multiply by number of tracks in flight for total memory usage
- Per-level data (multiply by maximum number of levels)
 - Physical state: position, direction
 - Logical state: volume, surface, sense, reentrant boundary flag, level
 - max levels × (6 × sizeof(real) + 2 × sizeof(int) + sizeof(bool)) + sizeof(bool) + sizeof(int)
 - Geant4-specific representation could remove "level" multiplication factor
- Scratch space
 - Initialization and intersection: max faces per volume × sizeof(bool)
 - Intersection: max intersections per volume × (sizeof(real) + 2 × sizeof(int))

Key tracking algorithms

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Opportunities for inter-thread cooperation

- Current Celeritas/ORANGE model is CPU-like
- Single thread corresponds to single track
- No inter-thread cooperation for geometry
- ExaSMR code has shown performance improvements by launching more threads with several threads contributing to a single track
- ORANGE can do the same for key parallelizable algorithms that are now "serial" loops





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