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Memory usage crisis in MicroBooNE

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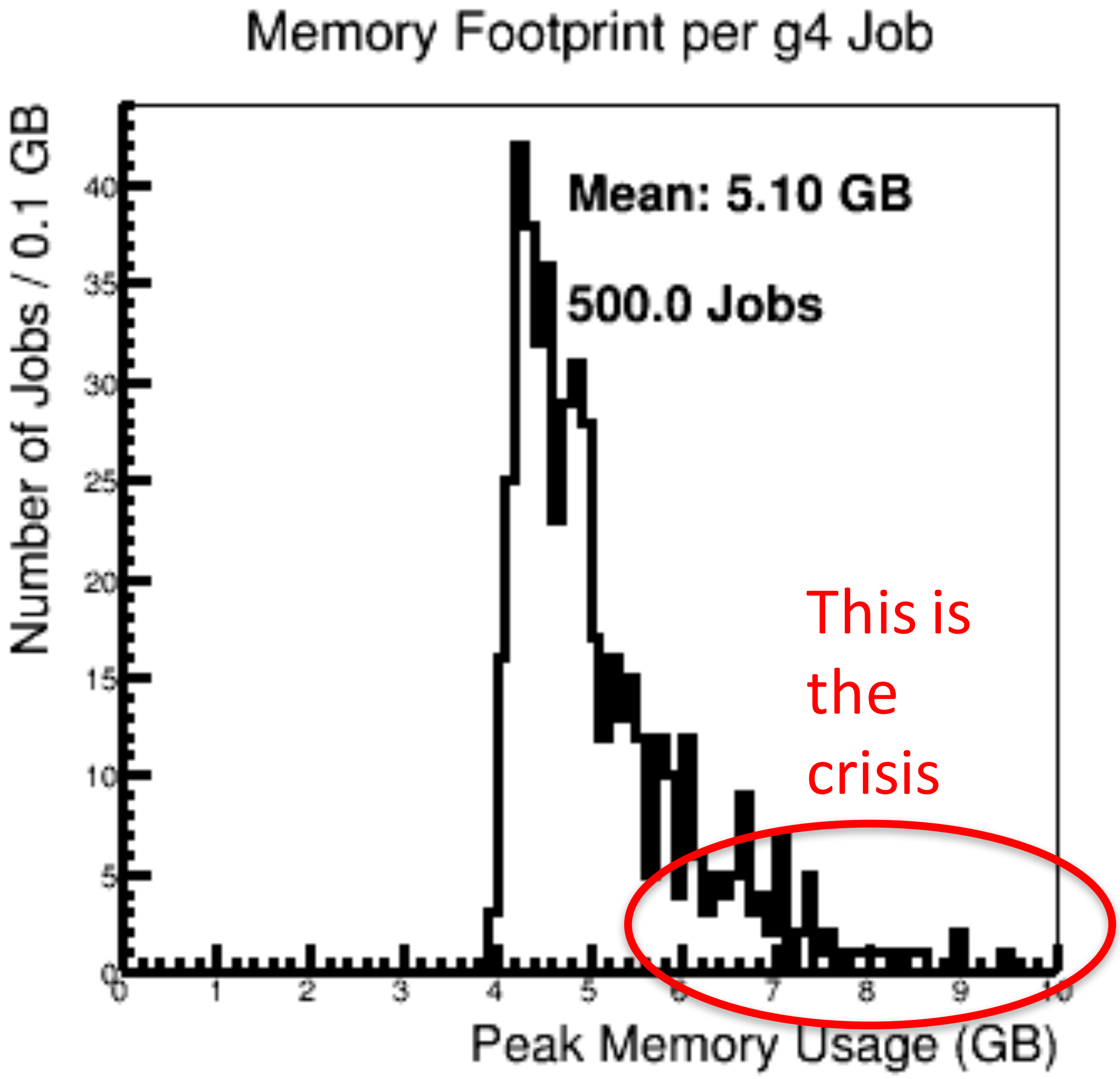
LArSoft Steering Group Meeting

4/8/2016

Problem



- Memory in the MC workflow jumped significantly.
- Seems to have appeared when shower generation with CORSIKA was turned on
- uboonecode version: v04_36_00_01
- LArSoft version: v04_36_00

Addressing the problem - procedure

- Locate workflow
- Perform Initial tests
- Produce memory profile
- Analyze results
- Implement recommendations
- Produce report

Locate workflow

- Obtain workflow: MC Production workflow is the culprit
- Establish test environment
  - FNAL GPVM machines worked for this
  - Access to ancillary files made easy here
  - Easy to get up and running quickly
- Configure and run
  - gen: prodgenie_bnb_nu_cosmic_uboone.fcl
  - g4: standard_g4_uboone.fcl
  - detsim: standard_detsim_uboone.fcl
- Establish scope of exploration
  - Data structures within code
  - Experiment can handle run-time configuration changes

Perform initial tests

- Test software infrastructure configuration (art) under this workflow
  - Rule in or out the ROOT I/O module and its configuration
  - Option combinations investigated
    - splitLevel : 0 # no splitting (no column-wise n-tuple)
    - splitLevel : default # full
    - saveMemoryObjectThreshold : <reduced_value>
    - treeMaxVirtualSize : <reduced value>
    - physics.end_paths:[] # No output module with this configuration
  - Utilize memory tracking service (built into art)
  - **Result**: output module not the key area to explore
- Isolate problem stage in workflow using memory tracker
  - G4 stage found
  - Geant4 (LArG4), creation of MC tracks and showers (MCReco)

Produce profile

- Vito Di Benedetto drafted to help with all this
- Obtain compute resources for evaluation and testing
  - larsoftdev6 commandeered
- Generate test data sample
  - Turned off auto-seeding procedure!
- Select, install, and configure tools
  - massif (valgrind),
  - igprof
- Perform profiling run
  - Really long to do 20 events under massif (>16 hours!)

Analyze results

- Gather team for profile review
  - Developers: Saba Sehrish, Gianluca Petrillo, Vito Di Benedetto
  - Analysts: Chris Jones, Marc Paterno, me
- Produce list of candidate functions and data structures from profile (see next slide)
- Produce testing plans
- **Analysis sessions required all of these people to be present**
  - Required expertise with the tools, the application and domain, the language
  - A lot of dedicated hours working together
  - Experts on the team have been doing this for >20 years!
- Need access to appropriate resources: experiment people, computing facilities

Massif – high power tool

- Valgrind tool that tracks memory use across the application
  - Emulates x86 instruction sequences so it is very very slow! (>10x)
  - Require big machine run – memory footprint large
- Points directly to functions with stack trace:
  - 21.14% (528,938,544B) 0x25A200EA: **sim**::**MCRecoEdep::MakeMCEdep**(std::vector<sim::SimChannel, std::allocator<sim::SimChannel> > const&)
  - 38.26% (522,945,536B) 0x1ADDBB7A: **larg4**::**ParticleListAction::SteppingAction**(G4Step const*) (vector.tcc:101)|| ->38.26% (522,945,536B) 0x1B4A603F: g4b::UserActionManager::UserSteppingAction(G4Step const*)
- *Does not imply that the problem is easy to fix!*
- Requires good test sample

Implement recommendations

- Gianluca and Saba implemented all of the code improvements
- From Saba's MicroBooNE report: We looked at the design and use of data structures
  - Some data structures in MCReco are merged and compacted
  - MCReco no longer holds memory between events
  - Particles are dropped ASAP when filtering by volume
- Testing
  - Gianluca Petrillo provided data product dumping modules for detailed results comparisons after code changes
    - DumpMCParticles, DumpMCTracks and DumpMCShowers
  - No observed change in physics results
  - Results available in the MicroBooNE 4.36 production branch.

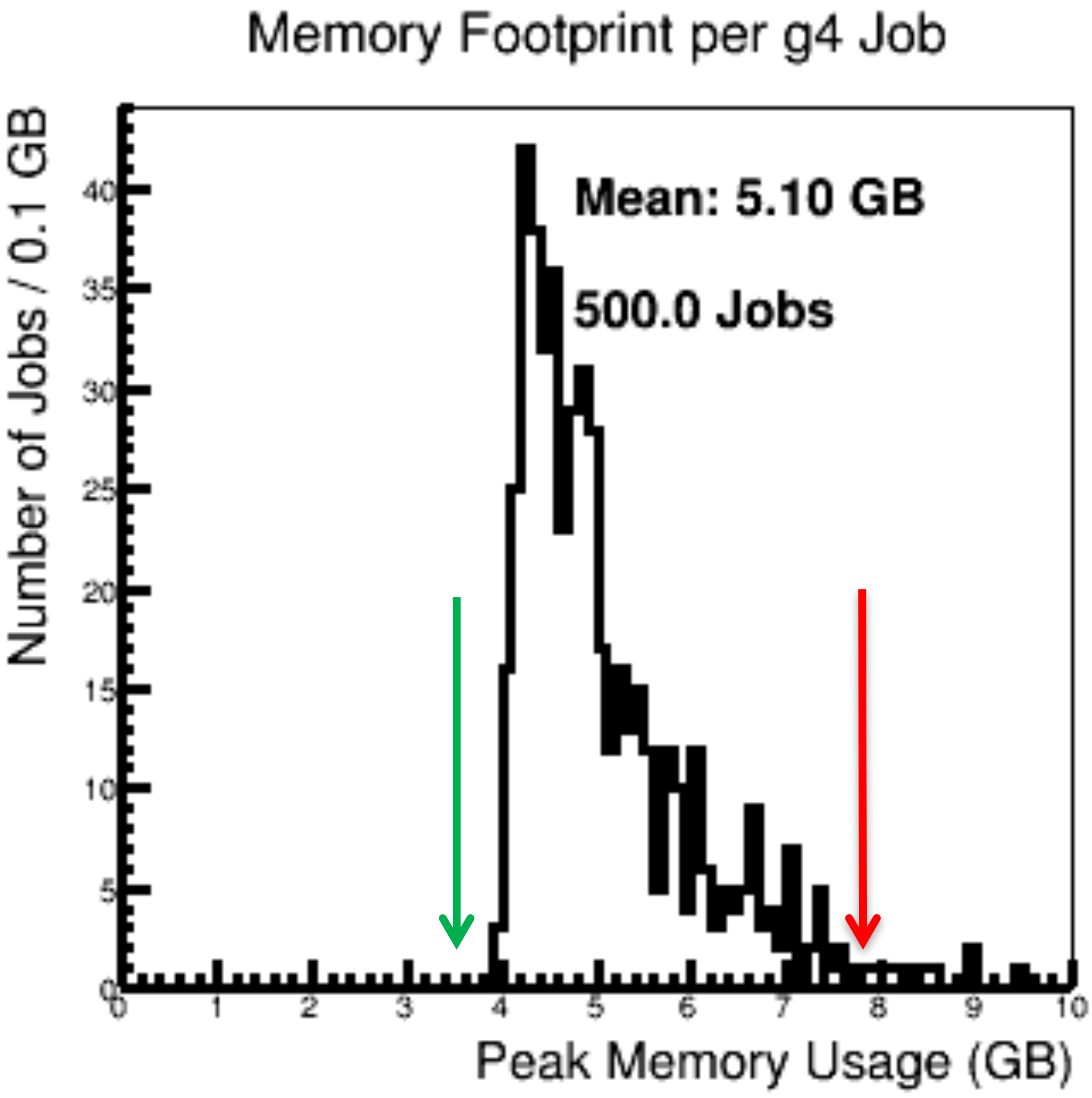
Summary - remarks

- A written report has been produced and is being finalized
- Recommended next steps
  - Continue with other memory hot spots at a normal pace (quite slow) instead of in crisis mode
  - Continue performance work in this mode
    - demonstrate fixes and document (my opinion).
    - *Reviews are not enough*. Learning through example is more effective.
- Outcome
  - MicroBooNE discussing integration and final testing already
    - Code also being moved to the development branch
  - Sample events added to CI infrastructure
    - to be used in test suite to report changes in memory use across releases.
    - Memory tracker service is enough to measure changes

Lessons learned

- Don't clear memory at the front of calls into member functions that cache data.
  - Clear out the cache as soon as the data is not needed
  - Clearing at the front causes the previous event's data to be retained
  - Recommended practice: don't cache data in algorithmic objects
- Complex data structures used for small look-ups cost memory
  - Maps of numbers to vectors
  - Vectors of maps
  - Vectors or vectors
  - Maps when hash tables or simple linear structures will do
  - Maps and vectors as data members of simple structs
- All of these hurt when the number of live instances goes way up, and this is what happened with the additional particle flux (latent data structure problems)
- Request for recommended practices and exercises
  - To be added to any future art / LArSoft course
  - To be given at collaboration meetings
  - This way of making performance improvements motivates people

Summary - performance



- Sample events originally had ~8 GB memory footprint
- After changes, footprint reduced to ~3.6 GB
- Larger scale run needed to reproduce this distribution
- Expected to shift and compress, unclear where that new peak will be
- Would be nice to catch the data structure design issues earlier to avoid a crisis: better communications during design