Parallel Computing of SNiPER based on Intel TBB

Jiaheng Zou, IHEP, China

On behalf of the SNiPER framework working group

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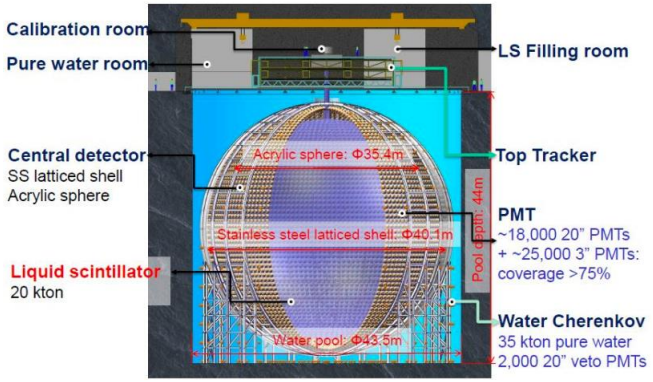
The SNiPER software framework

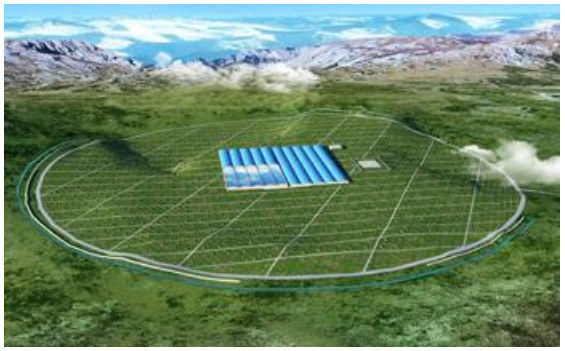
SNiPER: Software for Non-collider Physics Experiment

- a general purpose offline software framework
- lightweight and simple to use

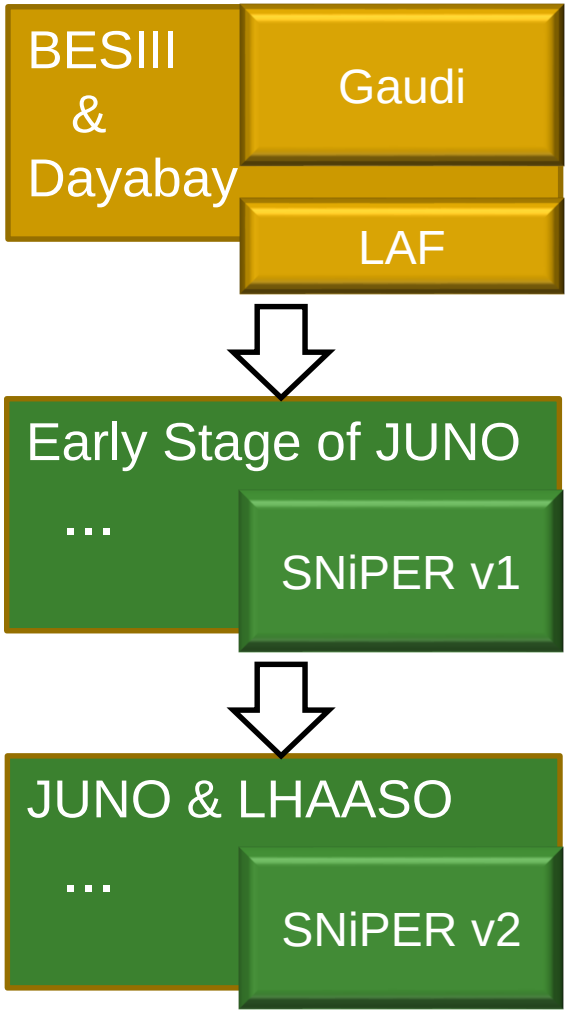
Current Status

- Performs well for JUNO and LHAASO experiments
- Other users or potential users, such as CSNS and CEPC





The Evolution of SNiPER



Usage of the famous Gaudi framework

- Offline software of BESIII and Dayabay exp.
- Learned a lot from Gaudi

Development of LAF (~2012)

- Lightweight Analysis Framework from scratch
- Fulfill specific requirements of Dayabay analysis

SNiPER v1 (~2013)

- Expanding of LAF in the early stage of JUNO

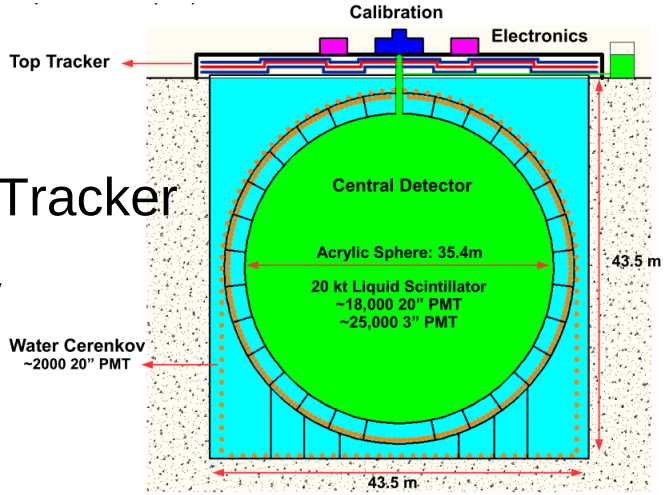
SNiPER v2

- More new features and enhanced utility
- Applied to more experiments besides LHAASO

Key Features

- Hybrid programming of C++ and Python (Boost.Python)
  - C++ for functional modules to ensure efficiency
  - Python for friendly and flexible configuration
- Dynamic loading and configuration
- Fundamental concepts
  - Algorithm and Service that learned from Gaudi
  - Task and Incident – flexible event processing controlling
  - Data Buffer – powerful memory management

Specific Requirements of JUNO



Three sub-detectors

- Central Detector, Water Cherenkov, Top Tracker
- Each sub-detector is triggered separately

Anti-neutrino Inverse Beta Decay

$$\bar{\nu}_e + p \rightarrow e^+ + n$$

$$e^+ + e^- \rightarrow 2\gamma$$

$$n + Gd \rightarrow Gd^* \rightarrow Gd + \gamma_s \ (8\mathrm{MeV})$$

- In Central Detector, e^+ and n are triggered separately, too

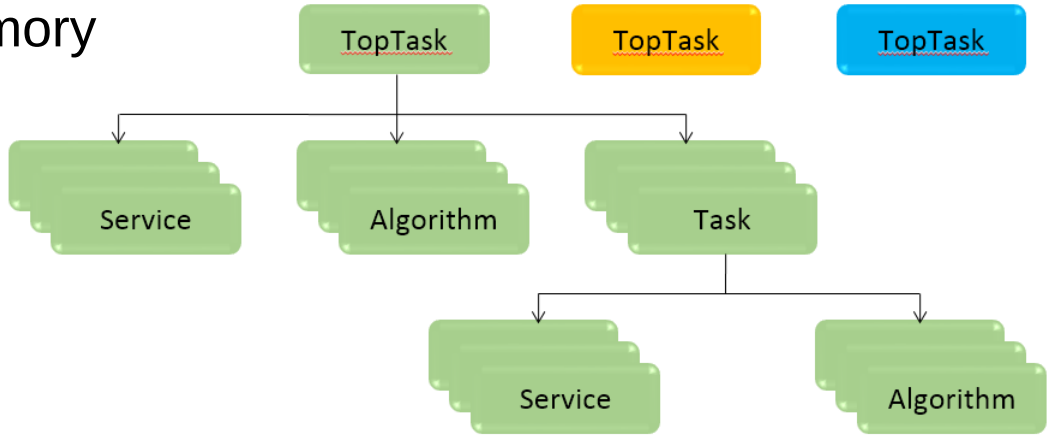
Two main challenges

- Physics events number is different from triggers (logical events) number
- It is mandatory to handle (logical) events correlations

SNiPER Task

SNiPER Task seems like application manager

- manage its own algorithms and services
- manage its own data memory



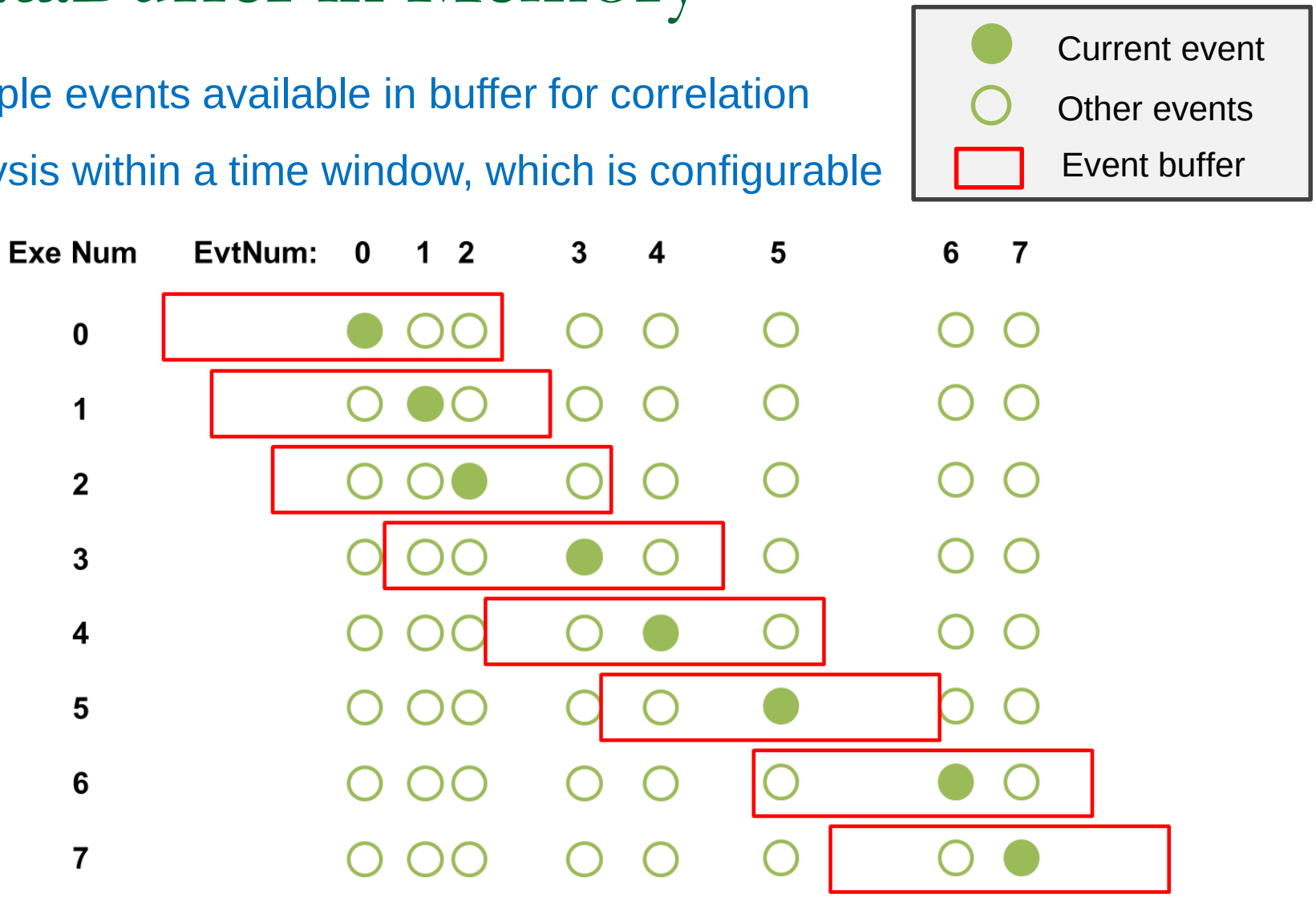
SNiPER Task is not application manager

- there can be more than 1 Task instances in a job
- a TopTask can own many (sub) Tasks
- Task instances can interact with each other via “Incidents”

Each Task, as a subroutine, can handle different number of events on demand

DataBuffer in Memory

Multiple events available in buffer for correlation analysis within a time window, which is configurable



- Only serial computing is supported in the original SNiPER
- We began parallel computing of SNiPER in 2017, the development and testing is ongoing

Goals of multi-threaded SNiPER

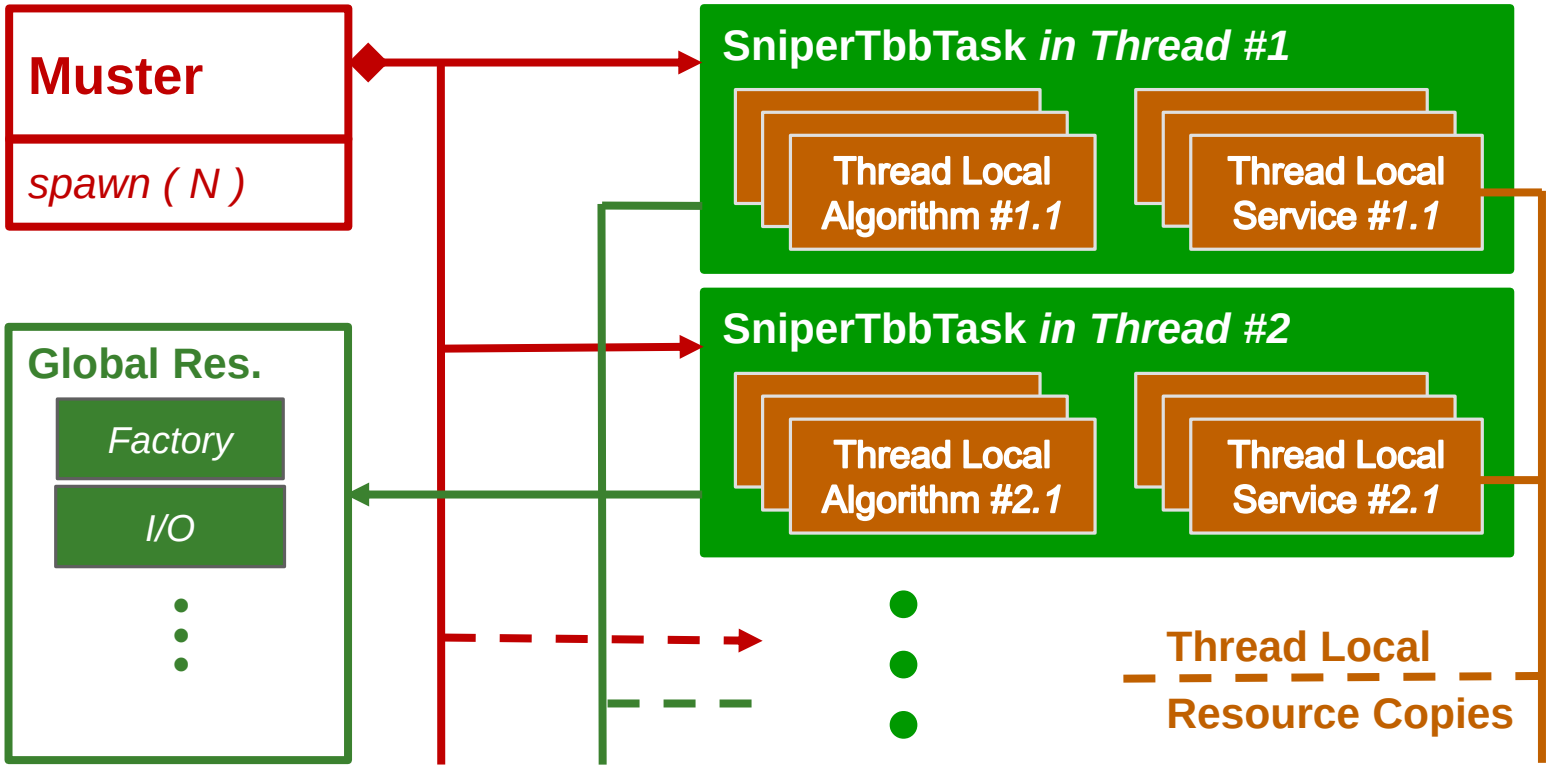
- (Almost) transparent to users
  - Very few constraints to user algorithms
  - Minimize the migration costs from serial to parallel computing
- Compatible with both serial and parallel user algorithms
  - Advanced users can implement parallel algorithms via TBB, OpenMP or Raw Threads
- Non-invasive to SNiPER kernel modules
  - Parallel features are implemented as a wrapper of the kernel
  - We can apply serial computing as before without the wrapper
  - Smoothly switch between serial and parallel mode

Top Level Concept Design

- Feasibility
  - Event level parallel processing
  - Create “thread local” SNiPER Task copies to suppress conflicts
  - Based on the Intel TBB library
- A coincidence: SNiPER Task and Intel TBB task
  - Bind a TBB task with a SNiPER Task
  - Appoint each event to a TBB task
  - Events are processed simultaneously in different SNiPER Task copies that invoked by TBB tasks

Muster: the multi-threaded wrapper

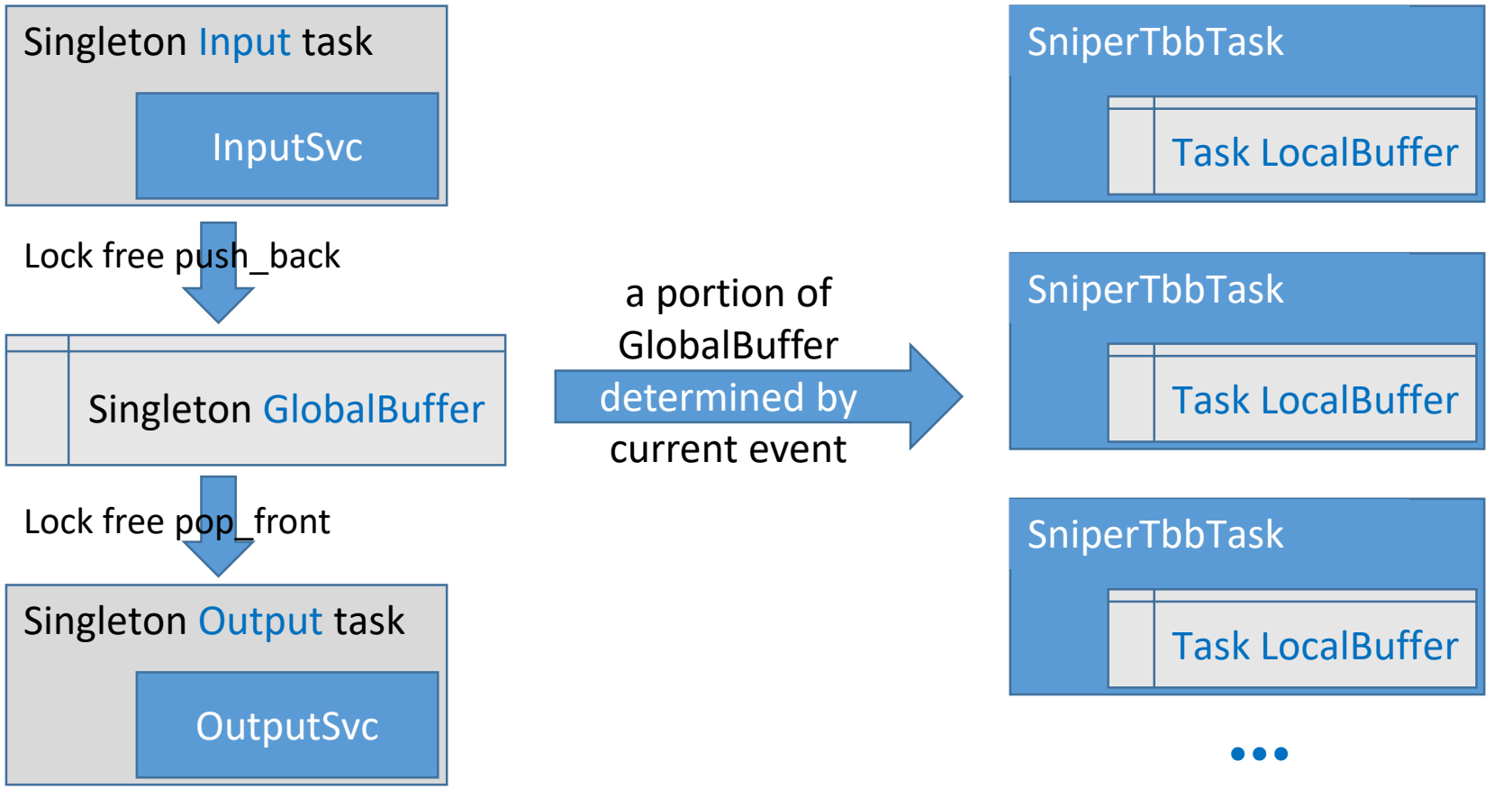
- Muster — Multiple SNiPER Task Scheduler
- SniperTbbTask — Binding of a SNiPER Task to a TBB task



I/O Concept Design

Each I/O stream is handled by a separate Input/Output task

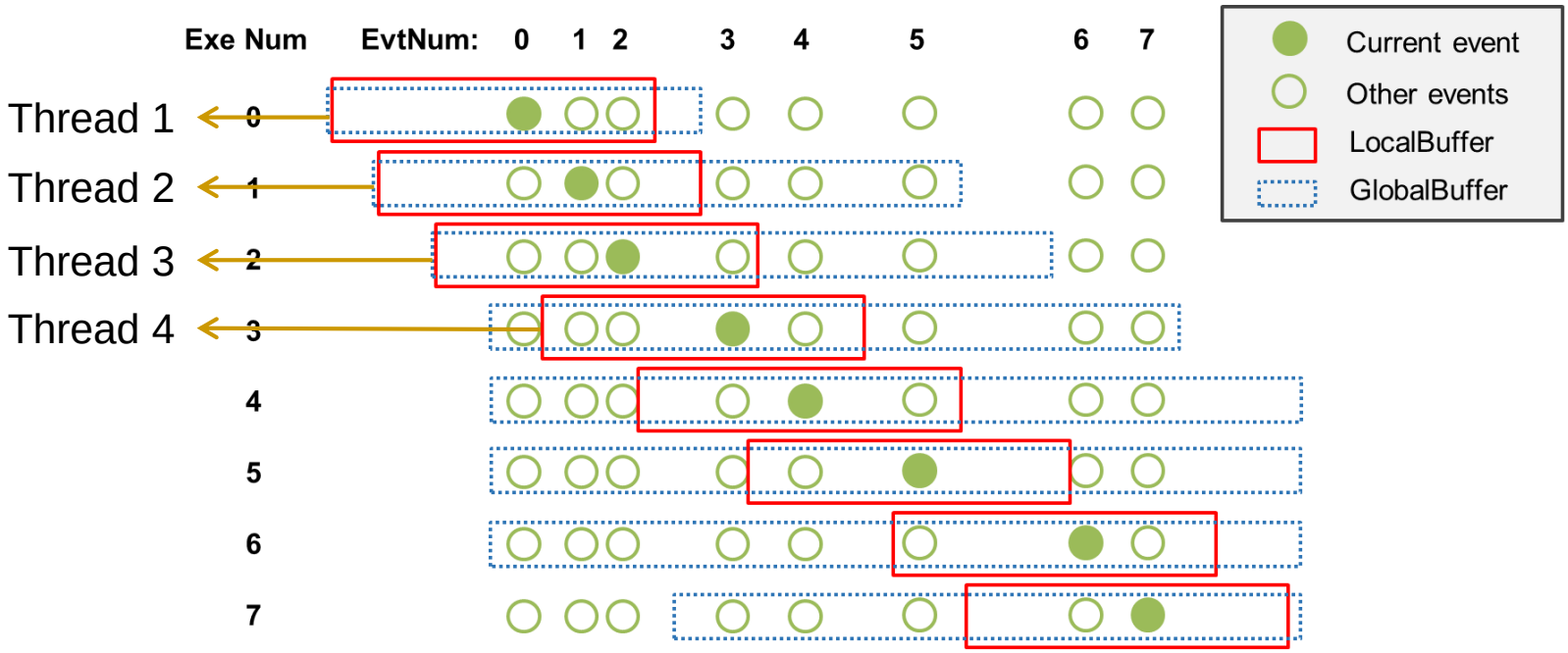
Data processing tasks are decoupled from I/O streams



Memory Management in Threads

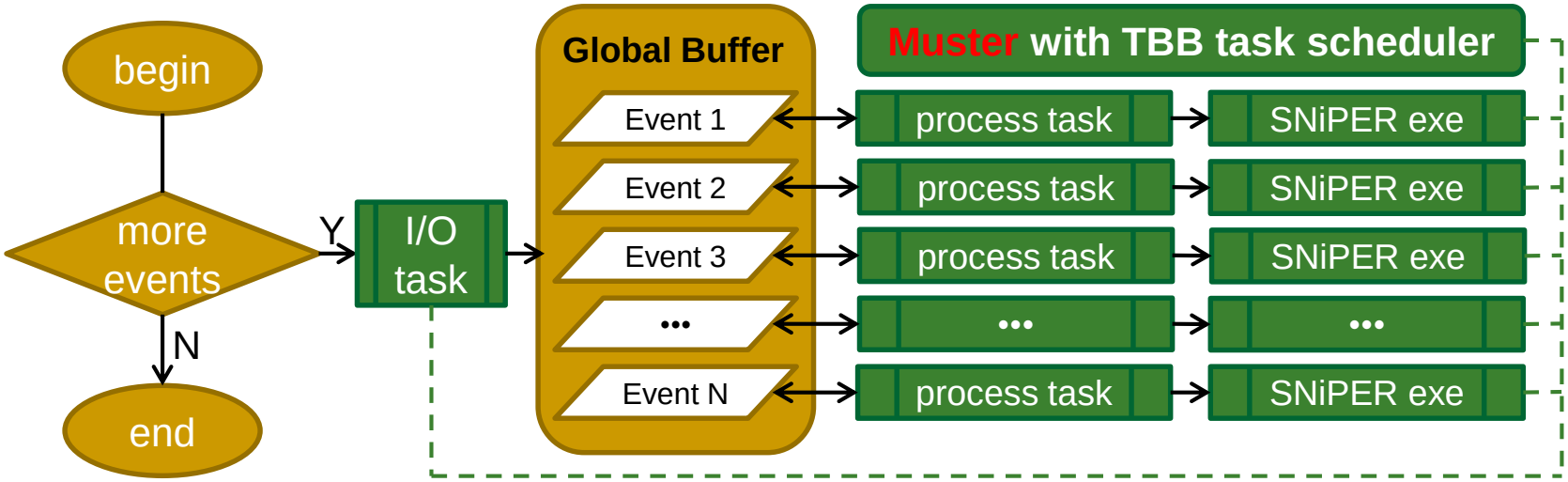
Global Buffer – bind to I/O streams, cache all events in memory, keep events in right order for output

Local Buffer – same as the serial version of DataBuffer



Execution with Muster

- Break the serial event loop into concurrent TBB tasks
- I/O is handled in separated TBB task
- There is no change for the processing procedure of each event in a TBB task
- Transparent to most users (algorithm developers)



Optimization with TBB features

- Recycling of TBB task objects
  - Event processing tasks can be recycled all the time
  - The number of processing tasks equal the number of threads
  - These tasks are allocated/released at the beginning/ending
- Scheduler Bypass
  - We are able to switch processing tasks and I/O task manually within rich context information

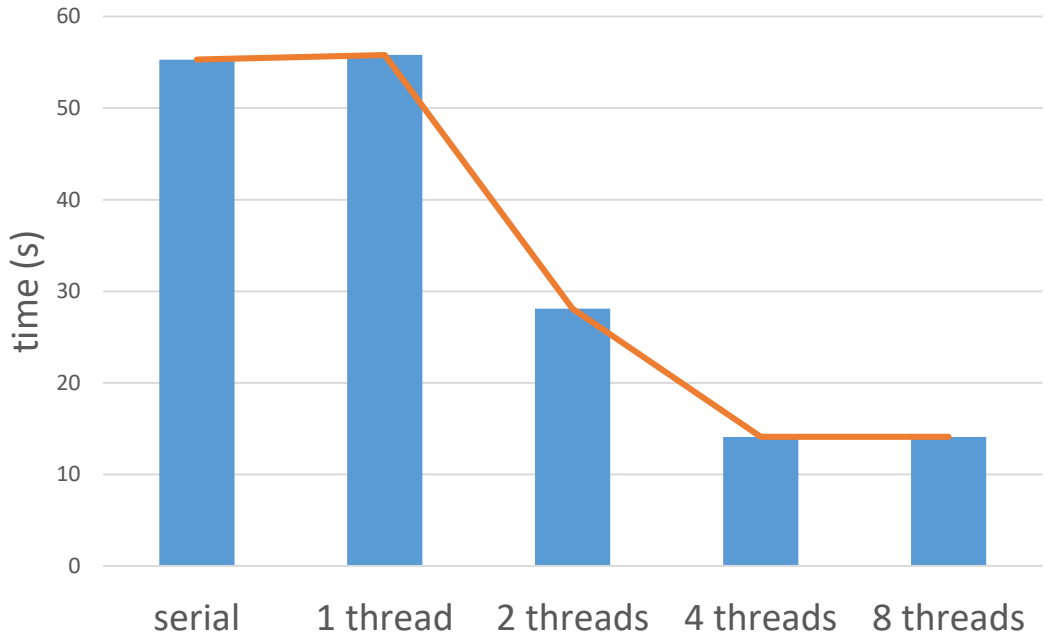
Current Status

- SNiPER Kernel
  - Revised potential conflicts in multi-threads
  - Keep APIs unchanged
- SNiPER Muster
  - Implemented as a non-invasive wrapper
  - Event level parallel processing with TBB tasks
- I/O problems, we are still using ROOT5 (will move to ROOT6)
  - Conflicts for concurrent reading and writing
  - Conflicts with our data lazy loading scheme

Performance Test

For the I/O issue, a dummy algorithm without I/O is used

4-cores CPU: Intel(R) Core(TM) i7-6700HQ



Summary

- SNiPER has been successfully applied to several non-collider experiments
- SNiPER Muster is implemented based on Intel TBB for multi-threaded parallel computing
  - More @ Poster #70 by Tao: Parallelized JUNO simulation software based on SNiPER
- We are pushing the I/O features according to our design

Thanks !