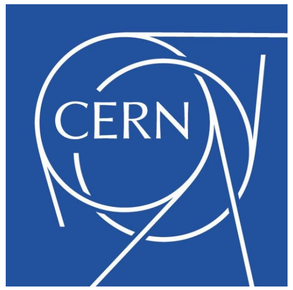
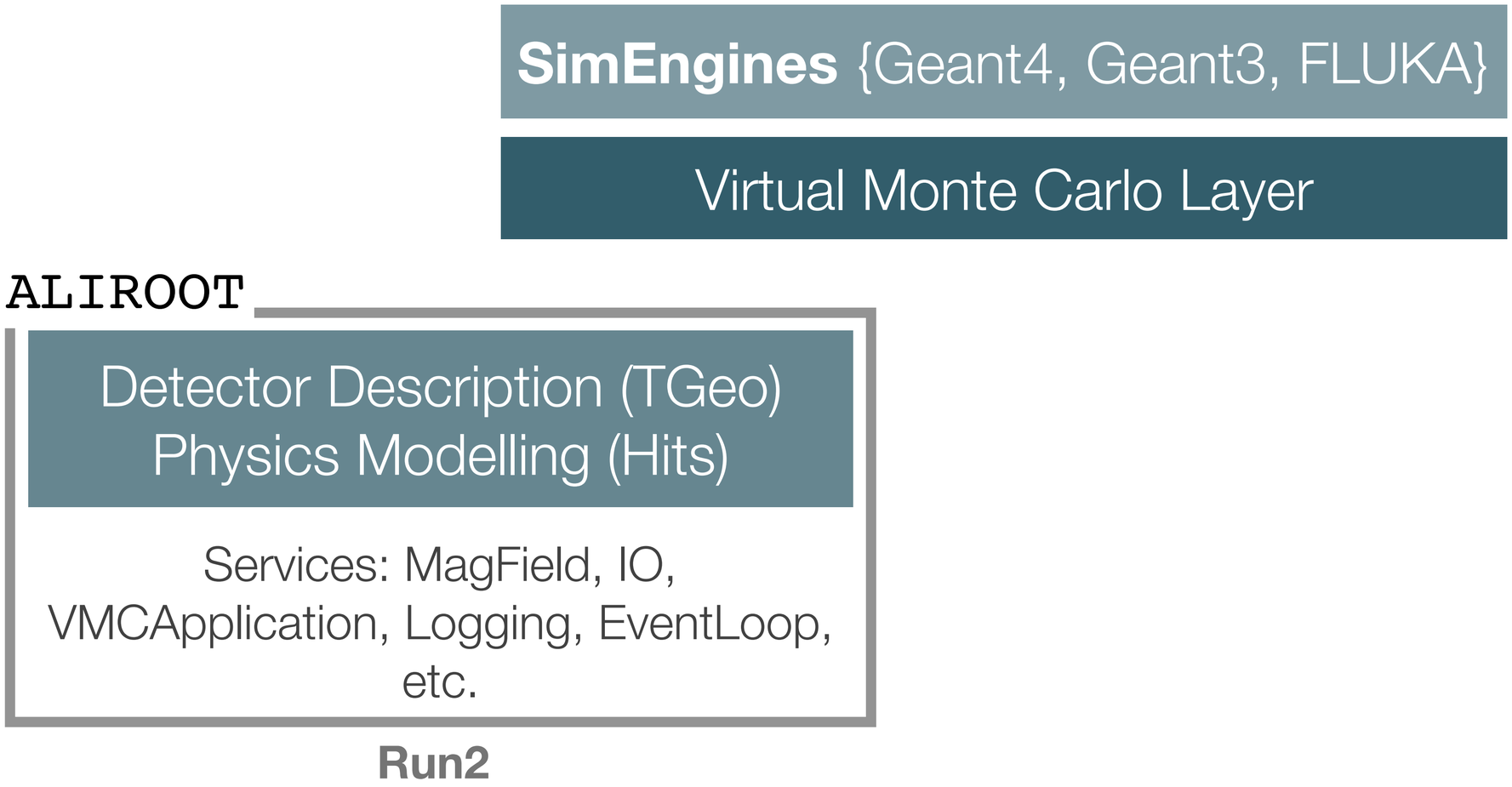
CHEP 2018
23RD INTERNATIONAL CONFERENCE ON
COMPUTING IN HIGH ENERGY AND NUCLEAR PHYSICS
9-13 July 2018
National Palace of Culture
Sofia, Bulgaria

A scalable and asynchronous detector simulation system based on ALFA (FairMQ)

Sandro Wenzel (CERN), for the ALICE collaboration



The ALICE simulation environment: From Run2 to Run3



see I. Hrivnacova talk (track2) for complementary info

The ALICE simulation environment: From Run2 to Run3

SimEngines {Geant4, Geant3, FLUKA}

Virtual Monte Carlo Layer

ALIROOT

Detector Description (TGeo)
Physics Modelling (Hits)

Services: MagField, IO, VMCApplication, Logging, EventLoop, etc.

Run2

ALICE-O2

Detector Description (TGeo)
Physics Modelling (Hits)

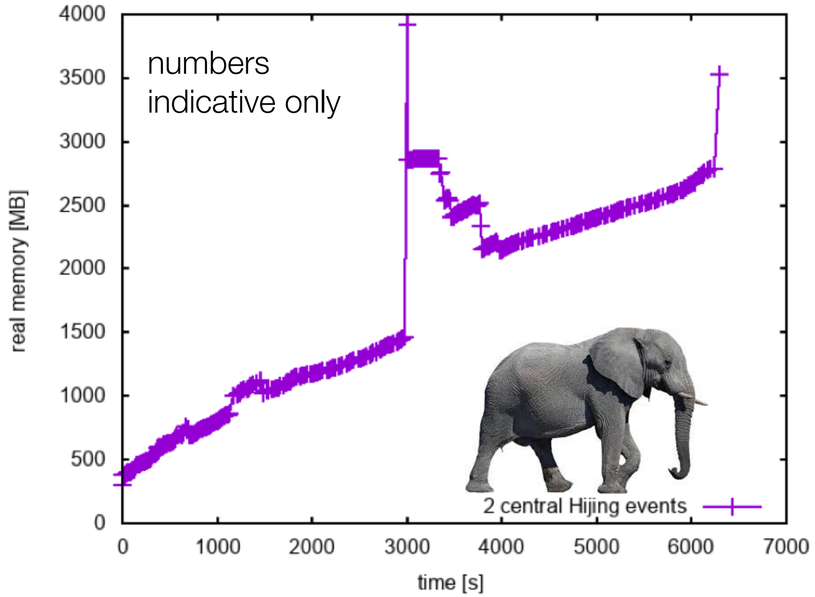
FairRoot | **FairMQ**

Run3

Keep the big picture; Make in-house code smaller;
Potentially benefit from new developments (e.g., FairMQ)

Motivation: The ALICE simulation scale

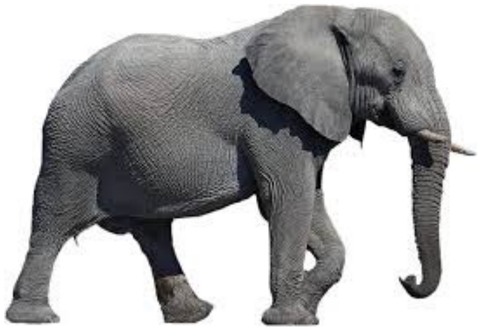
- **Simulating Pb-Pb collision** can be very demanding
  - may have up to 100k primaries in the collision to transport
- **Heavyweight resource utilization** using standard single-core event based simulation (FairRoot)
  - **~O(GBs) of memory / event**
  - **may be ~O(h) of CPU time / event**



- **Consequences:**
  - typically bad for scheduling and efficiently using given resource (packing problem)
  - prevents access to (opportunistic) HPC
  - sub-optimal user experience

The goal : Improve on this situation

- **Goal:** A simulation system running on anything from laptop to many-core and HPC facilities
  - get **result faster** (if resource available) for any given event
  - be able to **utilize smallest opportunistic resources**
  - **support VMC** (not relying on a particular simulation engine)
  - **user convenience** (same events; same output file regardless where and how run)

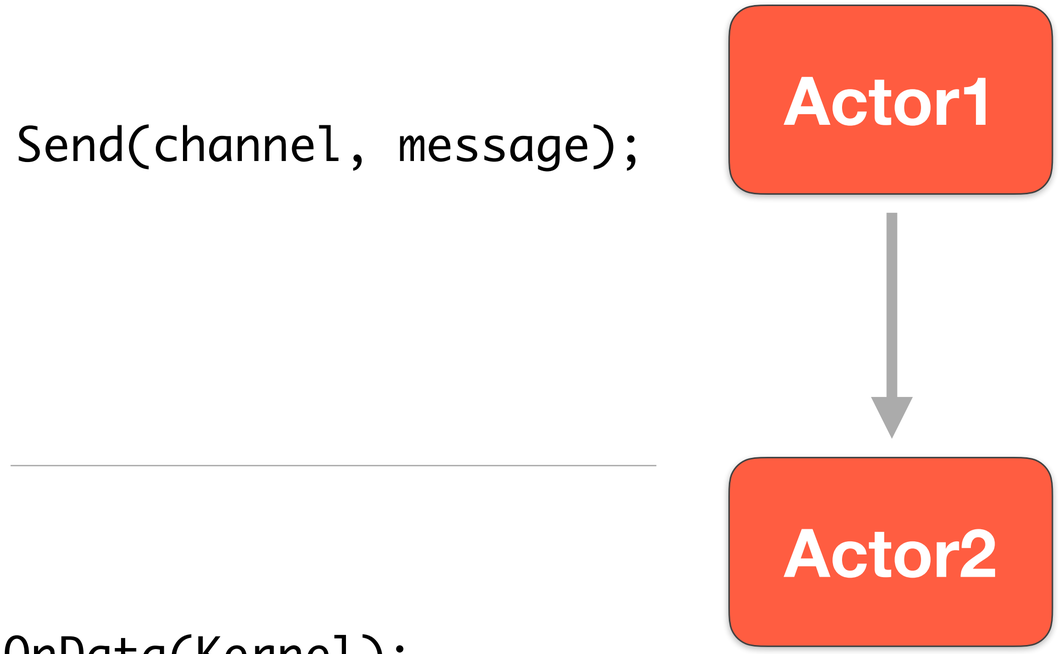


- **Ingredients put forward here:**
  - **independent actors** based on heterogenous multi-processing and message passing
  - **event splitting** and **collaborative simulation parallelism**

How? Use FairMQ as foundation

ALFA: ALICE-FAIR new message queuing based framework; Track 5

- **FairMQ** = Fair(MessageQueue) is an abstract messaging library for C++
- **Enables systems of heterogenous actors** which can be used to have
  - **asynchronous** and **parallel computing**
  - easy **scalability** from single node to complex cluster
- Does not replace multi-threading but complements it
- **Easy to use** … in particular to strip apart existing applications



Ingredient 1: Separation of concern with FairMQ

- **Break** existing monolithic simulation into **few actors with specialized concern**
  - deployed on same or different nodes
- **We gain:**
  - **Concurrent** event generation, particle transport and IO

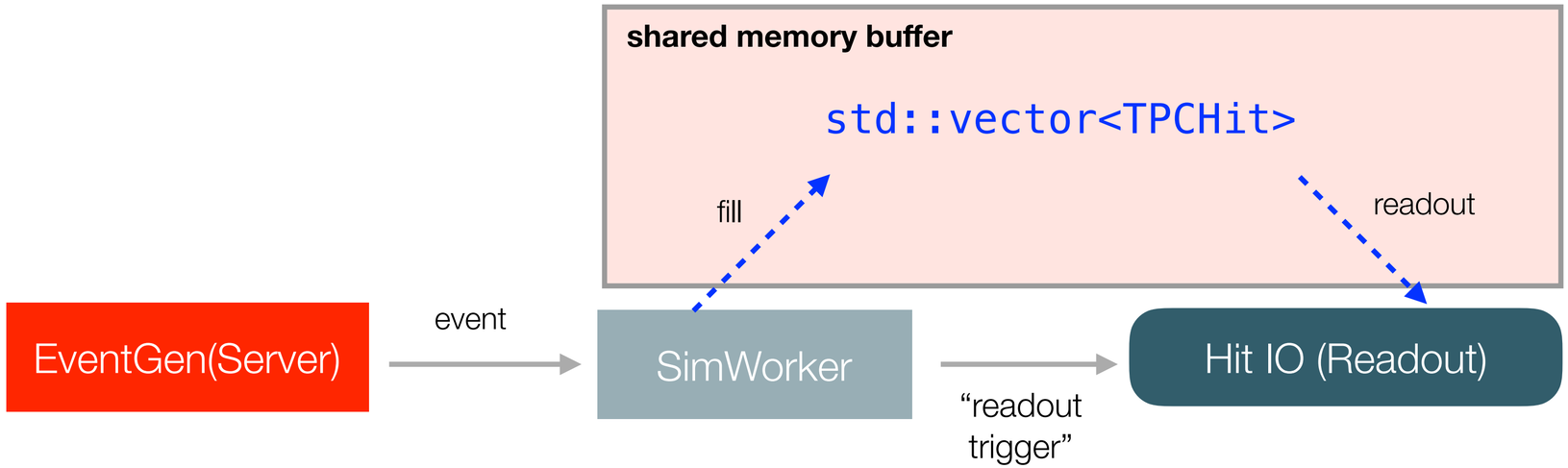
- **Is it easy? … Yes!**
  - Have actors and communication setup in a few lines of code with FairMQ
  - C++ object exchange trivial thanks to ROOT serialisation (in principle no special care needed)

Fast communication / shared memory

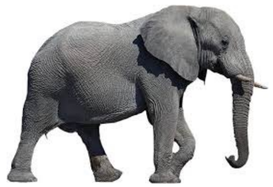
see posters 305 (A. Rybalchenko) and 366 (D. Klein)

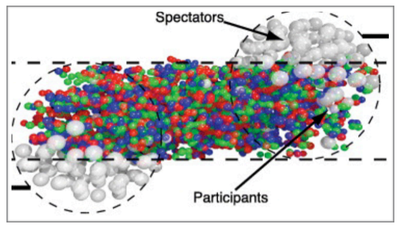
- **Some overhead when sending C++ structures**
  - need to copy/serialize/deserialize
- **Fast alternatives** such as shared memory transport within one node are **possible and supported by FairMQ**

- **Implemented a scheme similar to data acquisition:**
  - The sim workers directly put their C++ hits data into a shared buffer
  - Readout process streams directly from shared memory
  - Not a single copy; not a single pack/unpack; …. but some need for synchronization



Ingredient 2: Event splitting



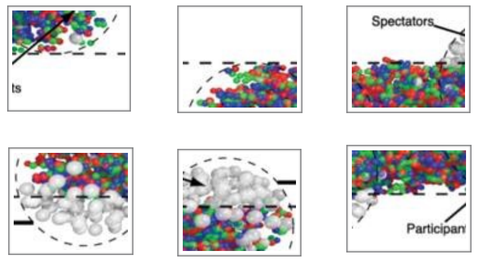


full event

EventGen(Server) → **SimWorker**

sub-events

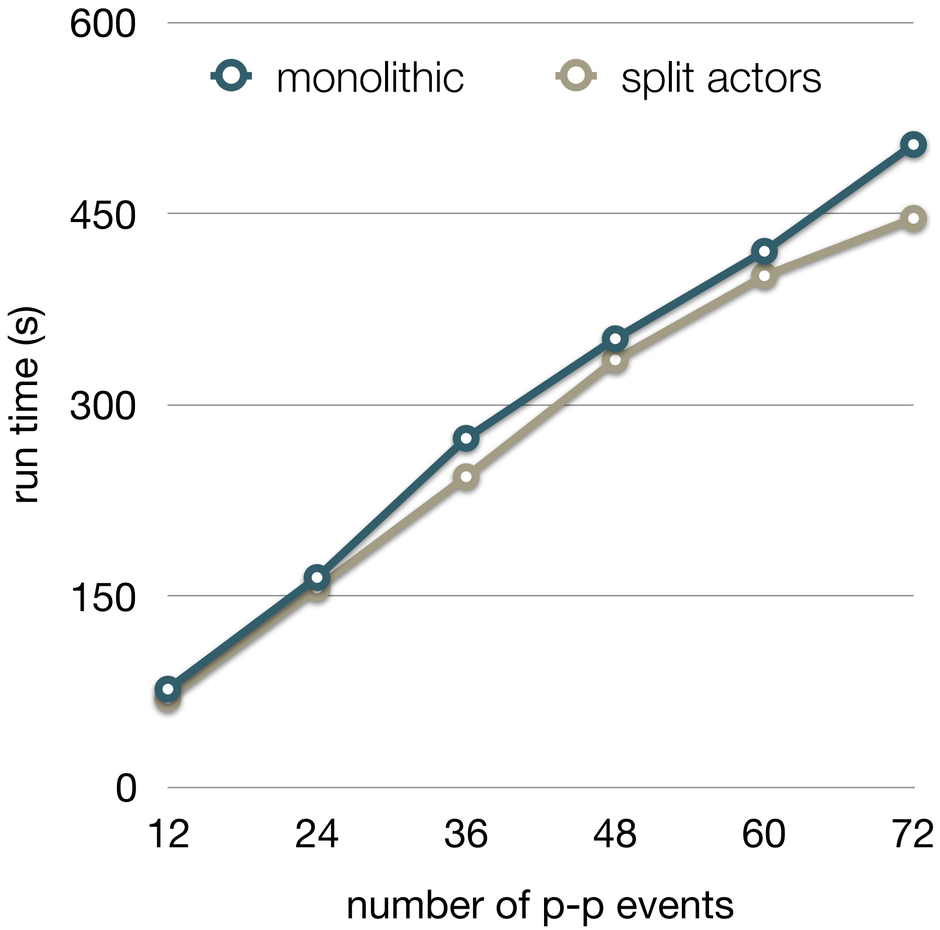
(one at a time)



- **Event-Splitting:**
  - provide less resource demanding work items
- **What do we gain?**
  - lower memory profile; **potential for collaboration**; fit work to small time windows
- **Is it easy?**
  - yes, since primaries are independent
  - previous experience also by ATLAS with customized G4
  - might just complicate bookkeeping (MC truth)

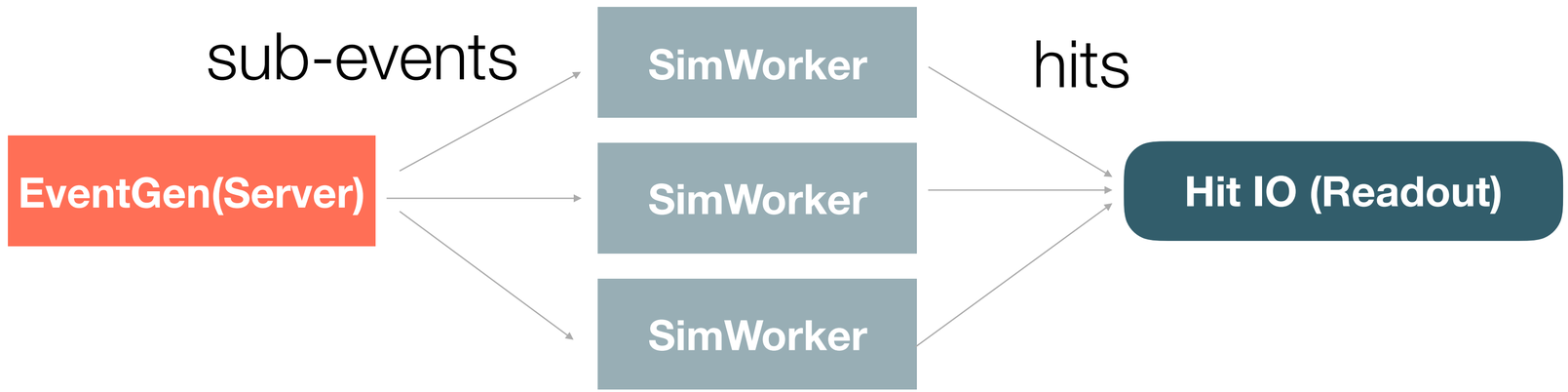
Benchmark single worker

- Is this **beneficial straight away** or is there an **overhead**?
- **Works well** with typical 14TeV p-p events:
  - gain few percent from split asynchronous components
  - gain higher than transport cost
  - essentially no additional gain from shared memory in this scenario
- A different test with large Pb-Pb also shows **no negative impact due to sub-event splitting.**



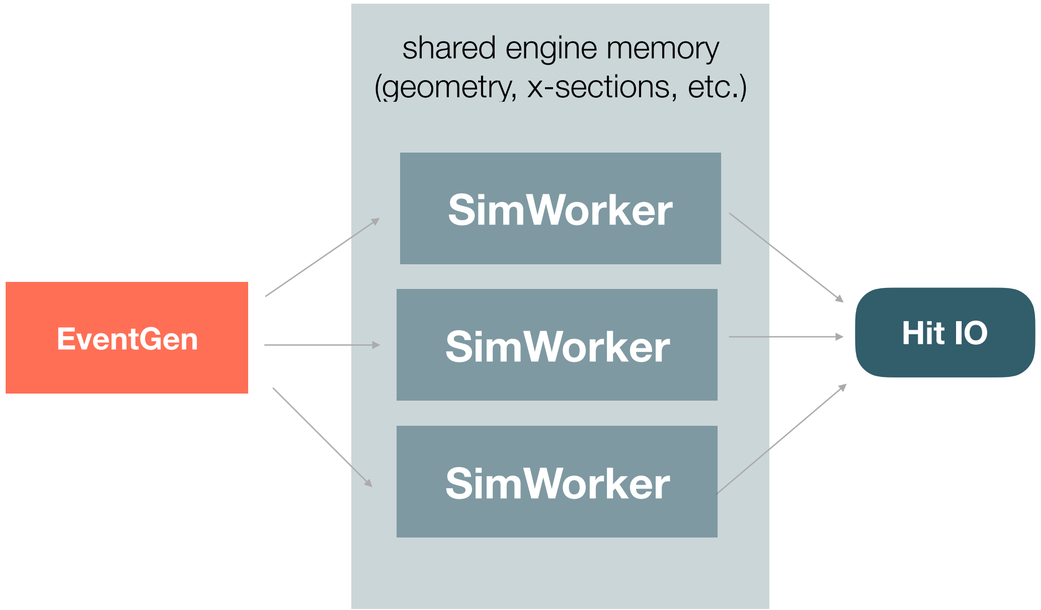
Ingredient 3: Collaborative Parallel Simulation

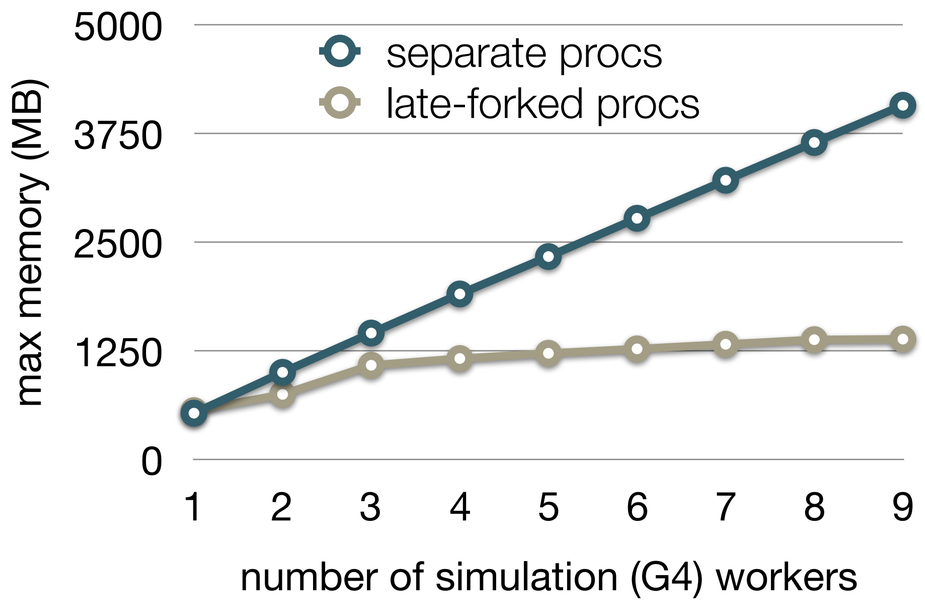
- Based on the previous steps, the idea is to **fan out the number of simulation workers**
- Target a diamond workflow for user-experience (but easy to change)
- **Scenario, where workers collaborate on transport/simulation**
  - given set of events
  - even on same event via (sub-events)



A scaling study : Memory

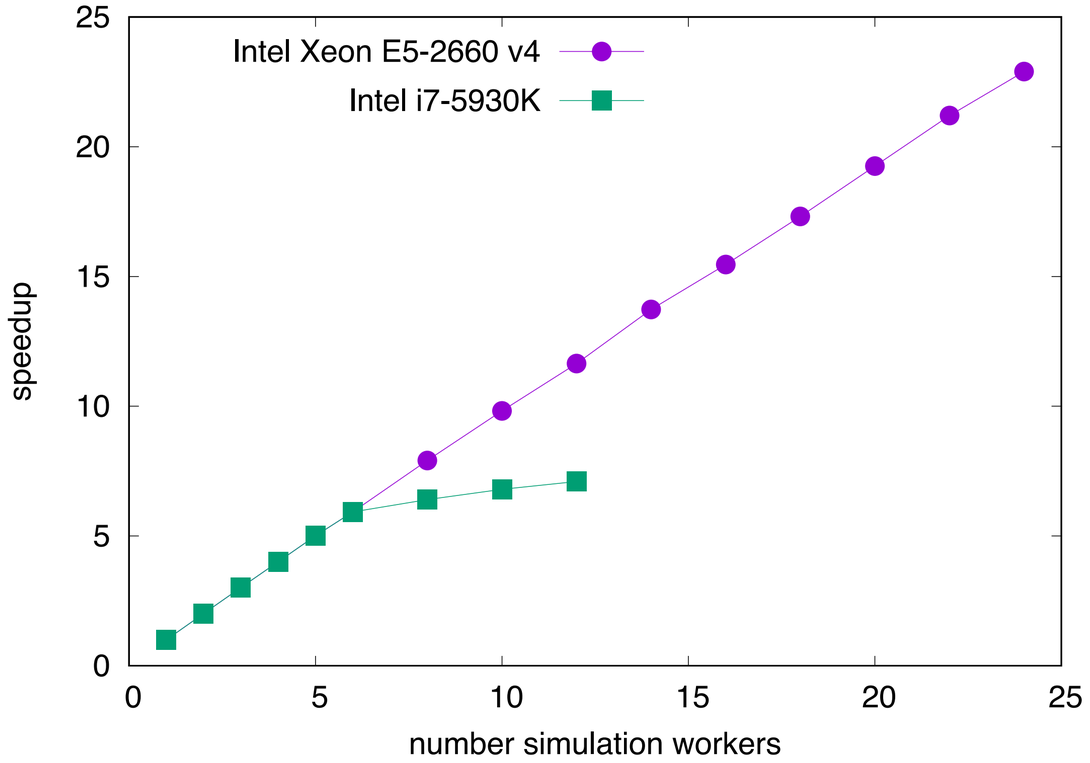
- **Isn't there a memory problem with too many workers?**
  - after all a single G4 worker has ~500MB of initial memory usage (before run-stage)
- **Absolutely not!**
  - implemented **mechanism** based on **late forking**
    - letting all simulation workers share the same simulation setup (geometry, x-sections) with "copy-on-write"
  - **works exceptionally well**
    - comparison of max memory consumption demonstrates superior scaling for forked version





A scaling study : Speedup

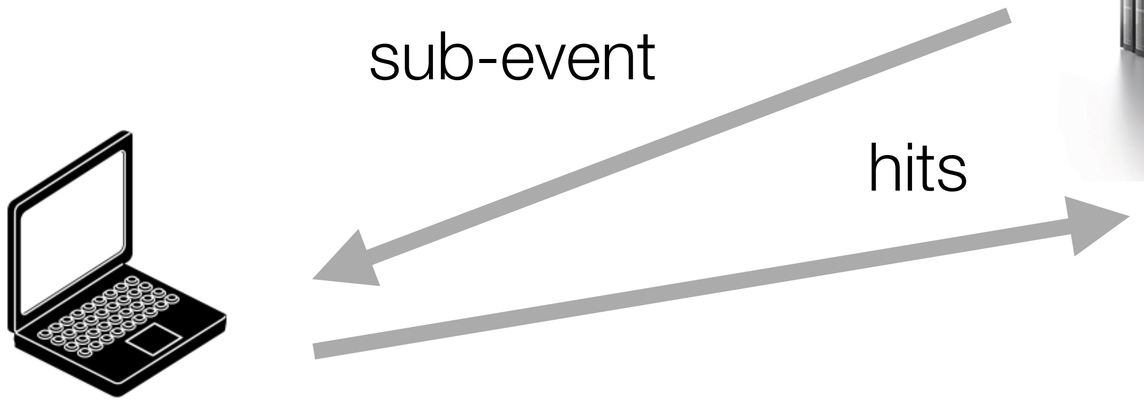
- **So what about the speedup?**
- Tested system collaborating on few large Pb-Pb event (60K primaries each) as a function of the number of workers
- **Very good (strong) scaling** up to number of physical cores
- Big Pb-Pb **events are now accessible in a few minutes**
- Together with good memory behaviour, this enables **scheduling on (opportunistic) HPC resources**



- preliminary
- sub-event size of 500
- turbo boost disabled
- zmq transport (no shared memory)
- IO merger becomes a bottleneck for ~26 worker jobs

Elastic (and Volunteer) Computing

- Architecture is the typical foundation for **elastic computing which we get as free lunch (really!!)**
- The number of workers can **dynamically change at any time**
- **Volunteer workers** can attach **anywhere** to a running production
- Probably not a primary goal but nice to have




```
“o2sim_join -eventserverIP xxx -hitmergerIP yyy"
```

Conclusions

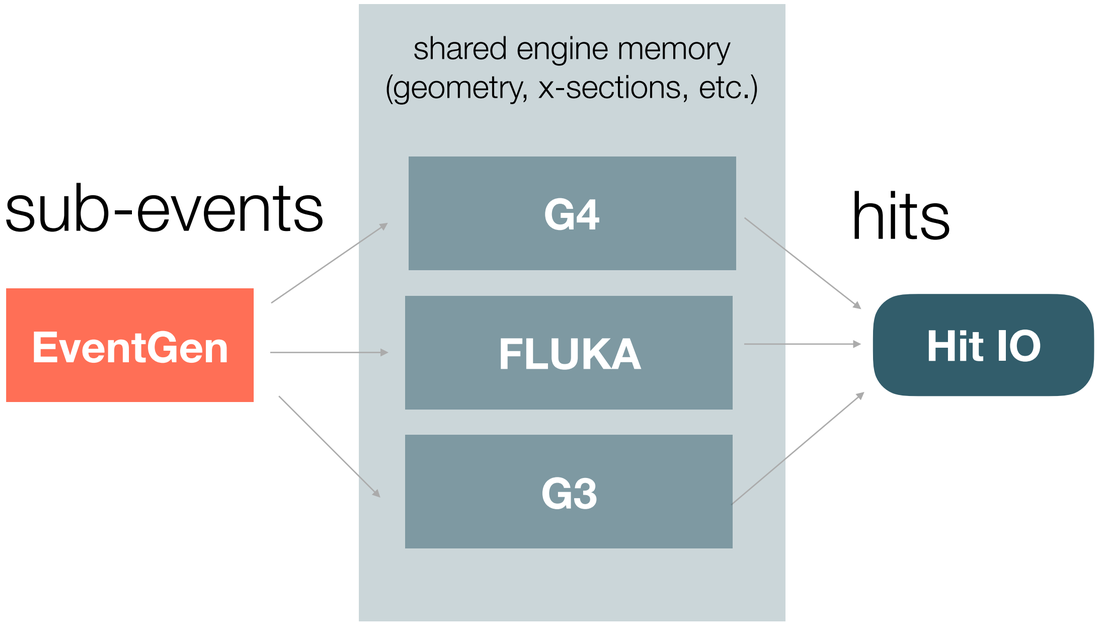
In the **Run3 ALICE simulation** based on **FairMQ …**

- **… we sub-event parallelized Geant4, Geant3 and FLUKA** at the same time
- … **may collaborate** on a **single event**
- **… are HPC ready**
- … do event generation, transport and IO **asynchronously**
- … **provide user convenience**: single merged file, single source of events
- … **have elasticity** and **are agile** (can change deployment easily and scale across nodes)

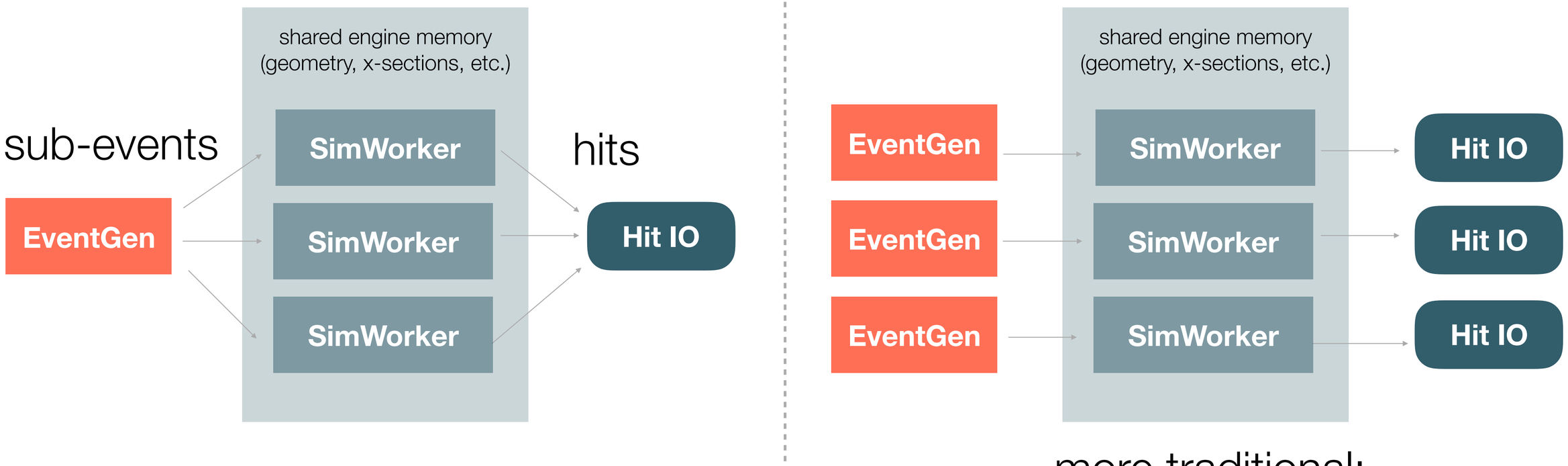
BACKUP SECTION

Heterogeneous Simulation

- An interesting extension is heterogenous computing: simulation workers can take different flavours
  - G3 / G4 / Fluka collaborate on same event
    - (e.g., as a function of particle type, energy)
  - Attach workers doing fast simulation kernels



Collaborative Parallel Workers or Trivial Parallelism?



collaborative; user friendly; better to transport large events quickly

easy switch

more traditional; might be better in certain situations such as small events

Coupling to Data Processing

see G. Eulisse: Evolution of the ALICE Software Framework for LHC Run 3

- Messaging architecture allows direct forwarding of simulation products to the data processing (on a different node) without need for intermediate storage

- possible fully asynchronous simulation, digitization, reconstruction, etc.