MC Streaming

Scope of project
Hardware emulation: FADC
Streaming Readout Unit (SRU)
From geant4 identifiers to SRU
From geant4 event-centric to data streaming

Streaming Simulations Scope

Continuous DATA Stream

TCP
10/40GbE

Data Subscribers, Analyzers

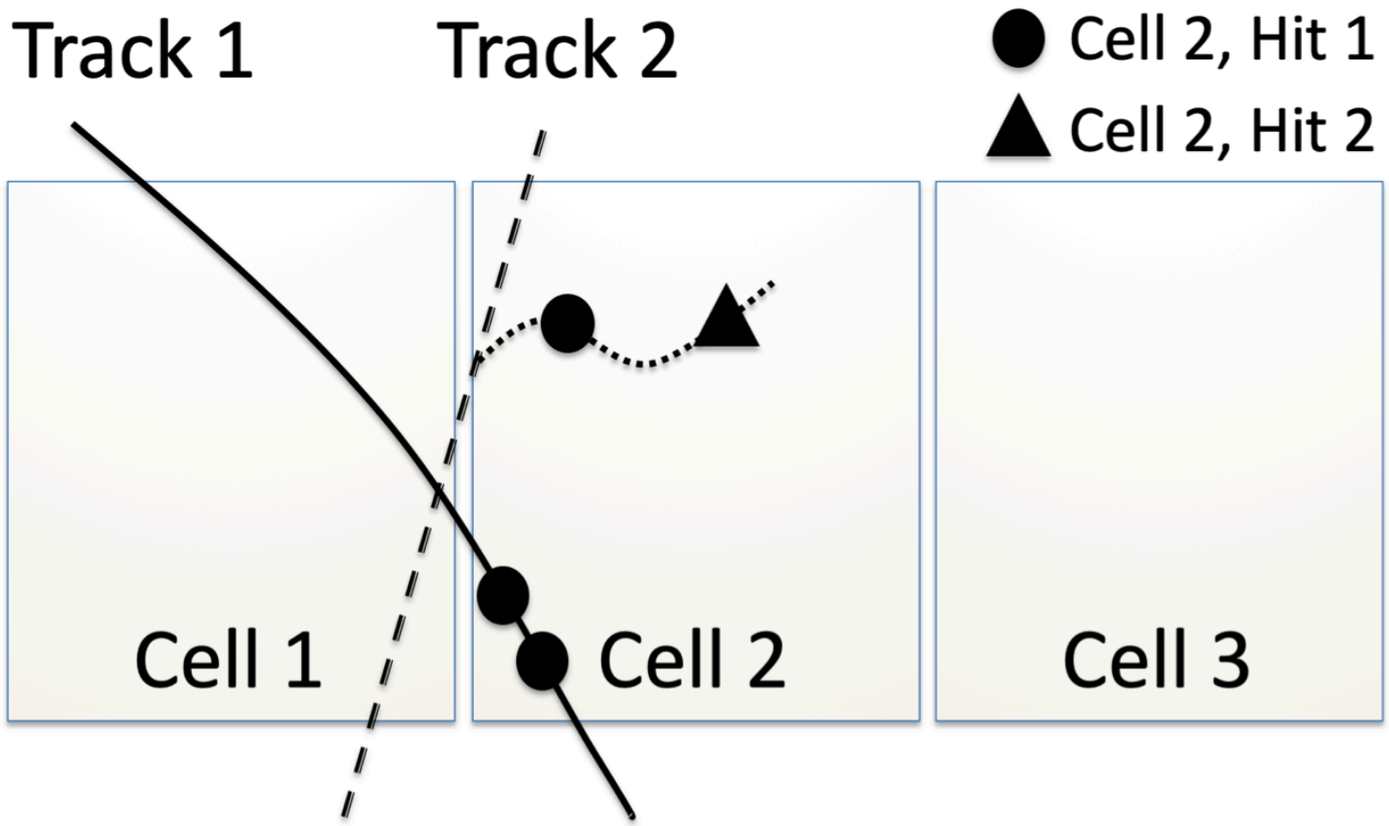
GOAL: Having simulated data stream on network indistinguishable from real data

Streaming protocols / analysis systems should be transparent to the data source: experiment or simulation

Define and address challenges on hardware, communications and software issues

Intrinsic Time-Window of readout electronic.

and energy sharing mechanism



Geant4 steps are analyzed and grouped into hits based on their timing.

This mechanism is used to account for signals pile-up, time coordinate of hits.

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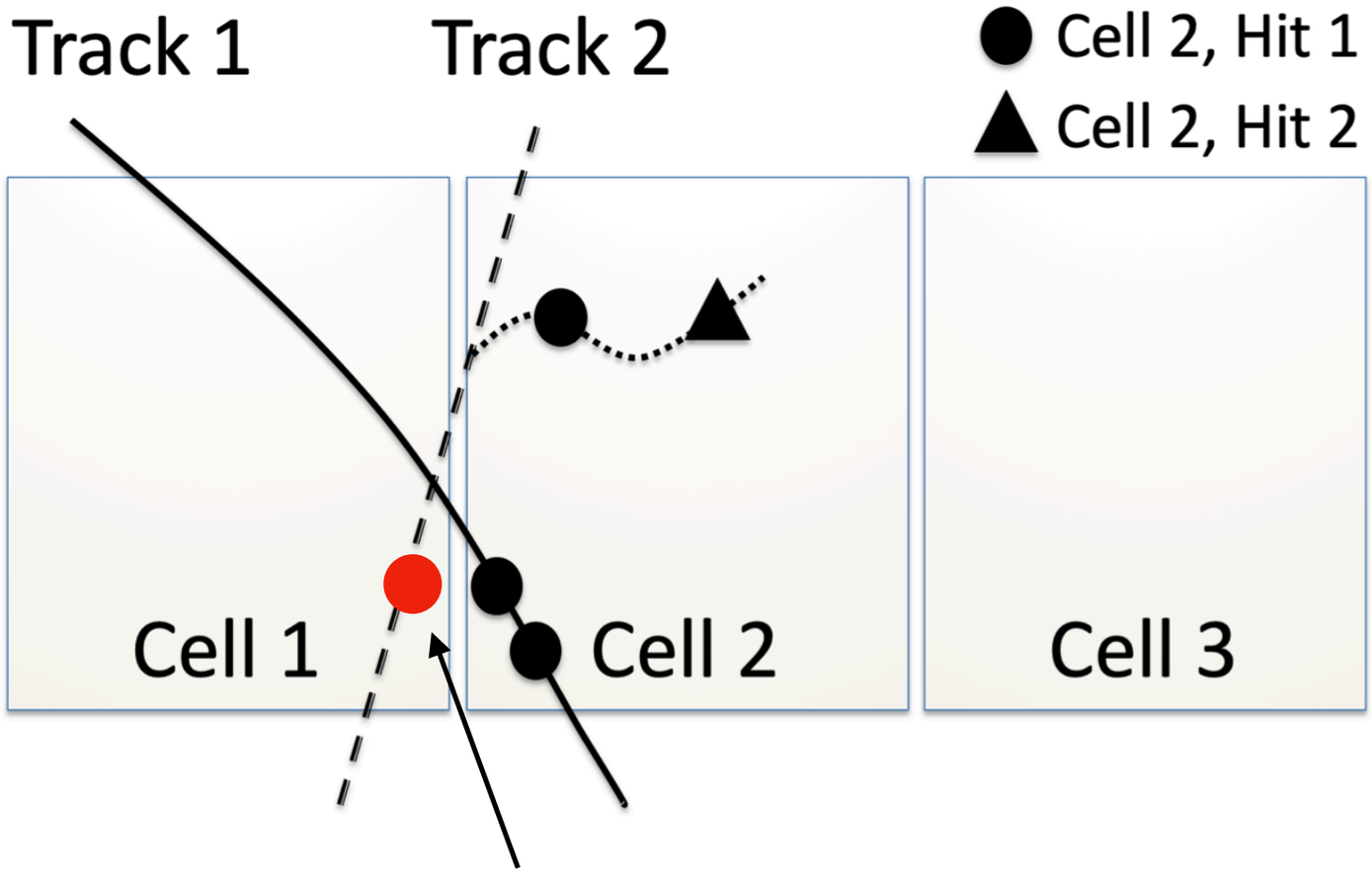

energy shared mechanism: red step with different identifier is created dynamically based on existing geant4 step properties
Examples: silicon vertex detectors, paddle that have PMTs on both ends.

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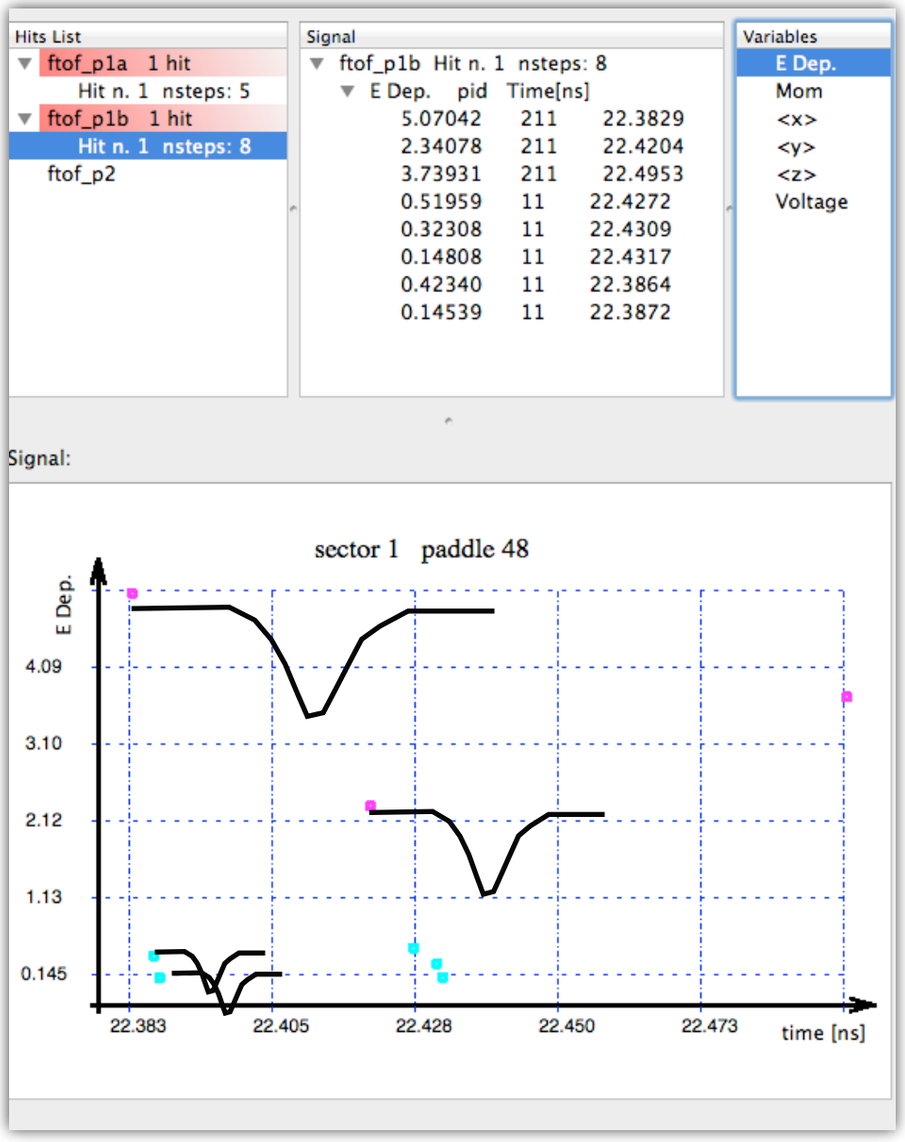
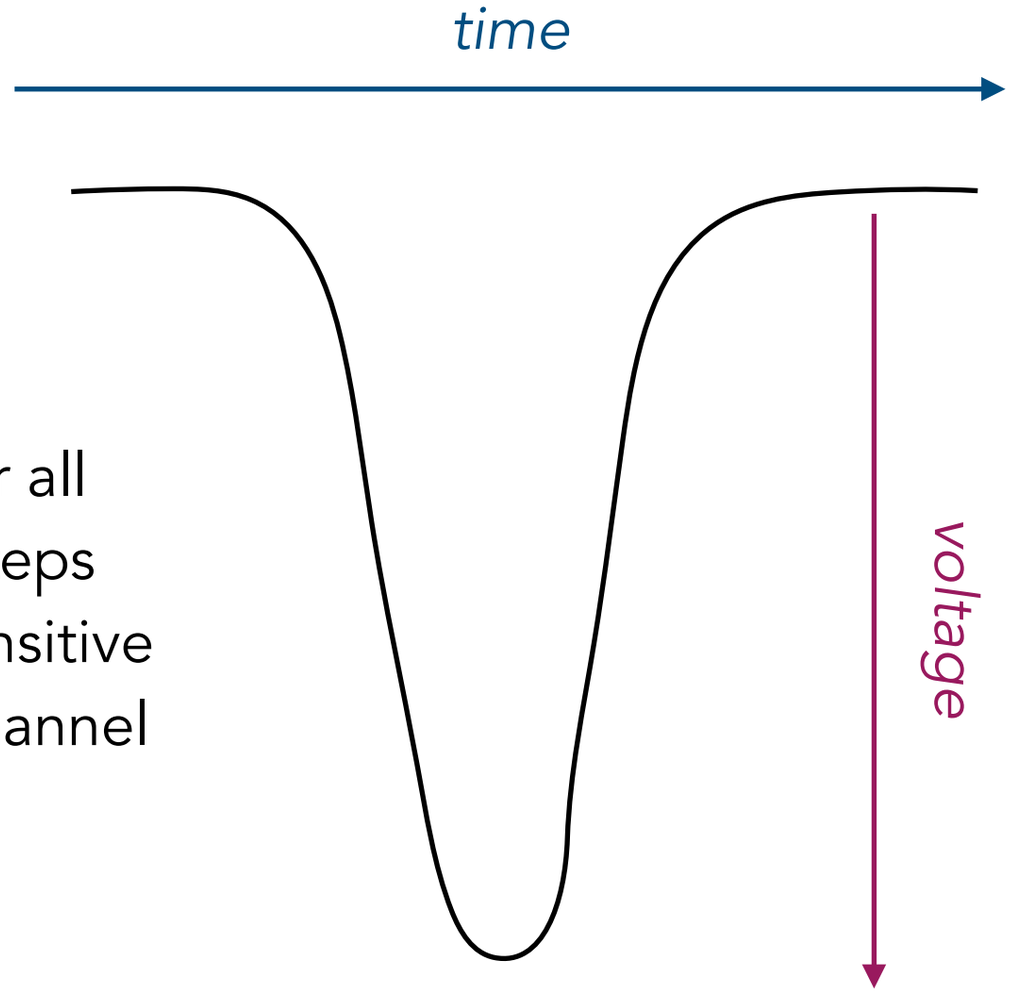
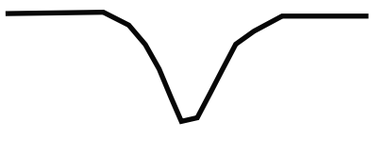
Hardware emulation: FADC

Voltage vs time signal shape from geant4 steps



Sum over all geant4 steps for each sensitive detector channel



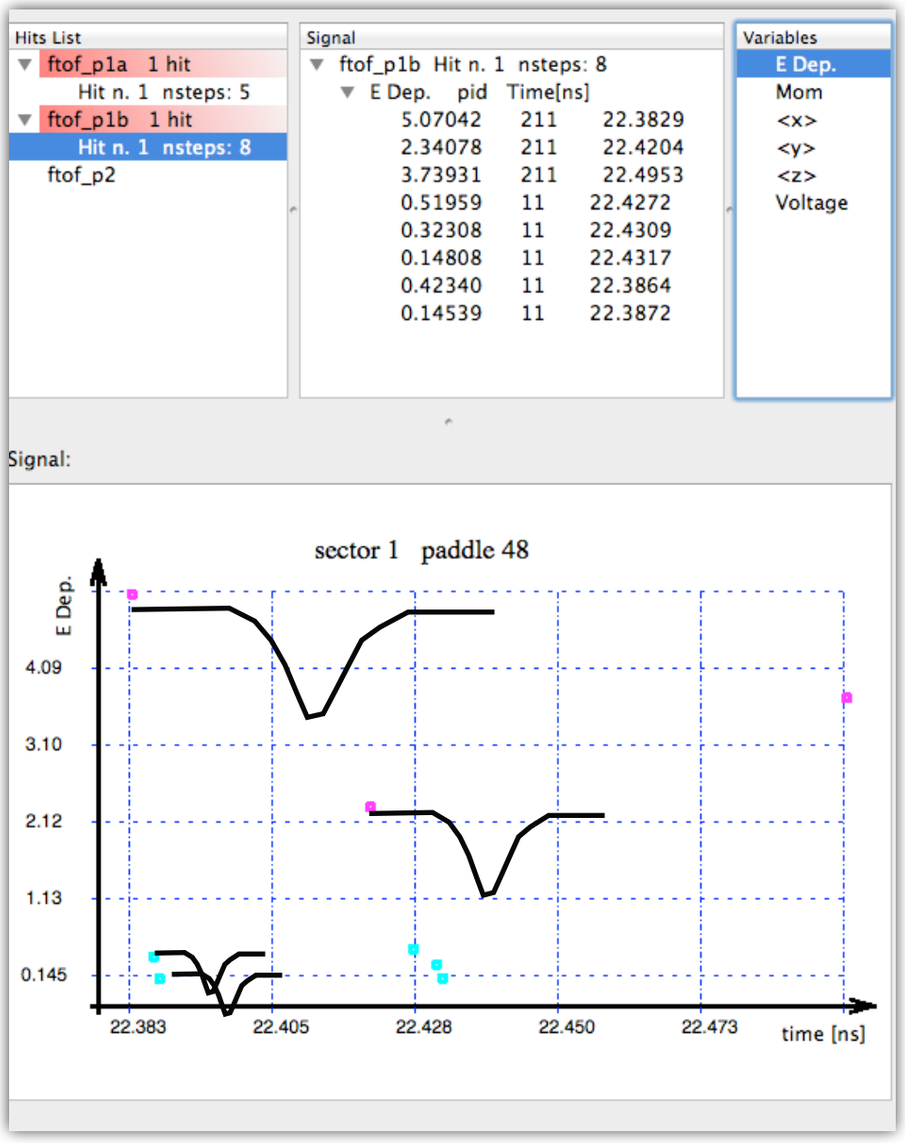


User defined function $f(t, Edep_i)$

$$F(t) = \Sigma\, f(Edep_i)$$

Hardware emulation: FADC

Voltage vs time signal shape from geant4 steps



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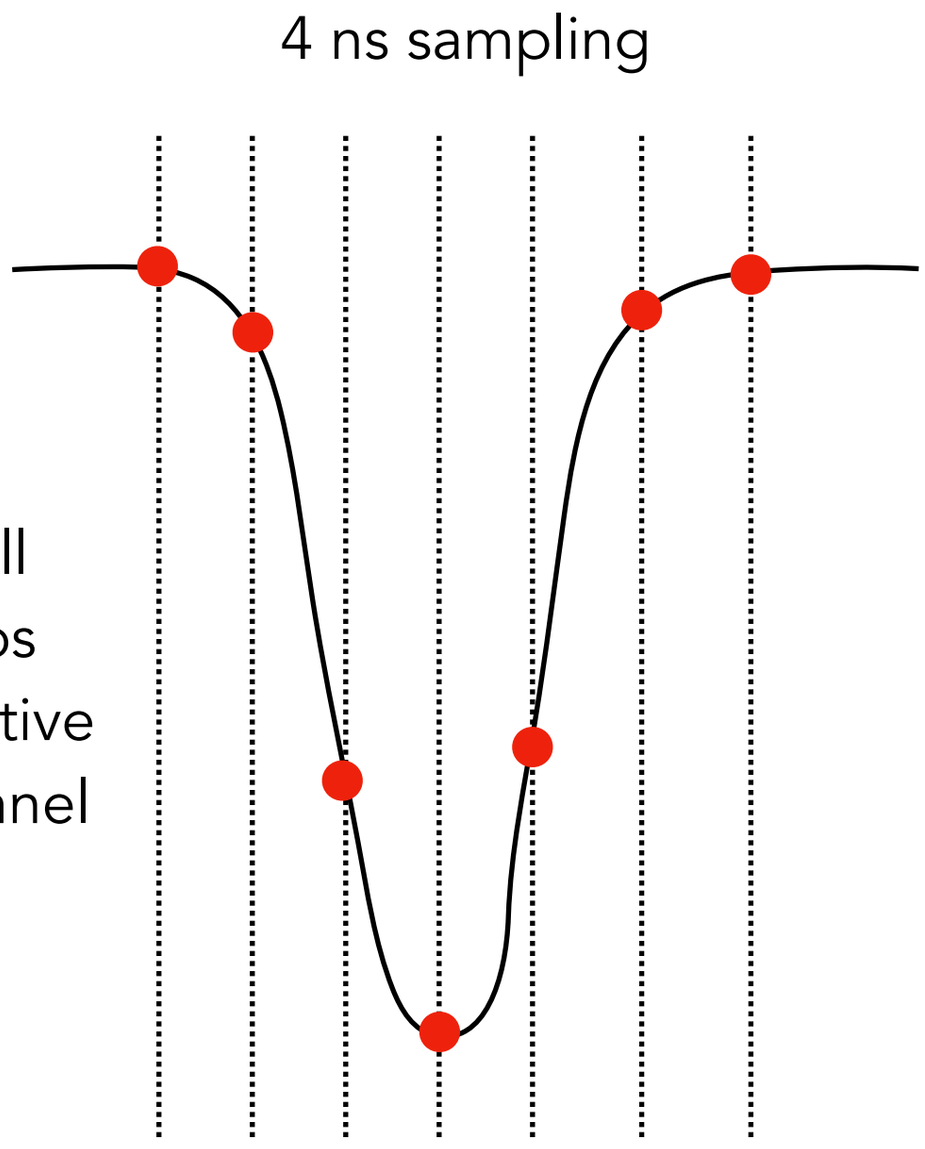

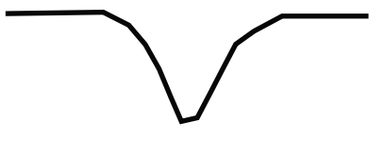

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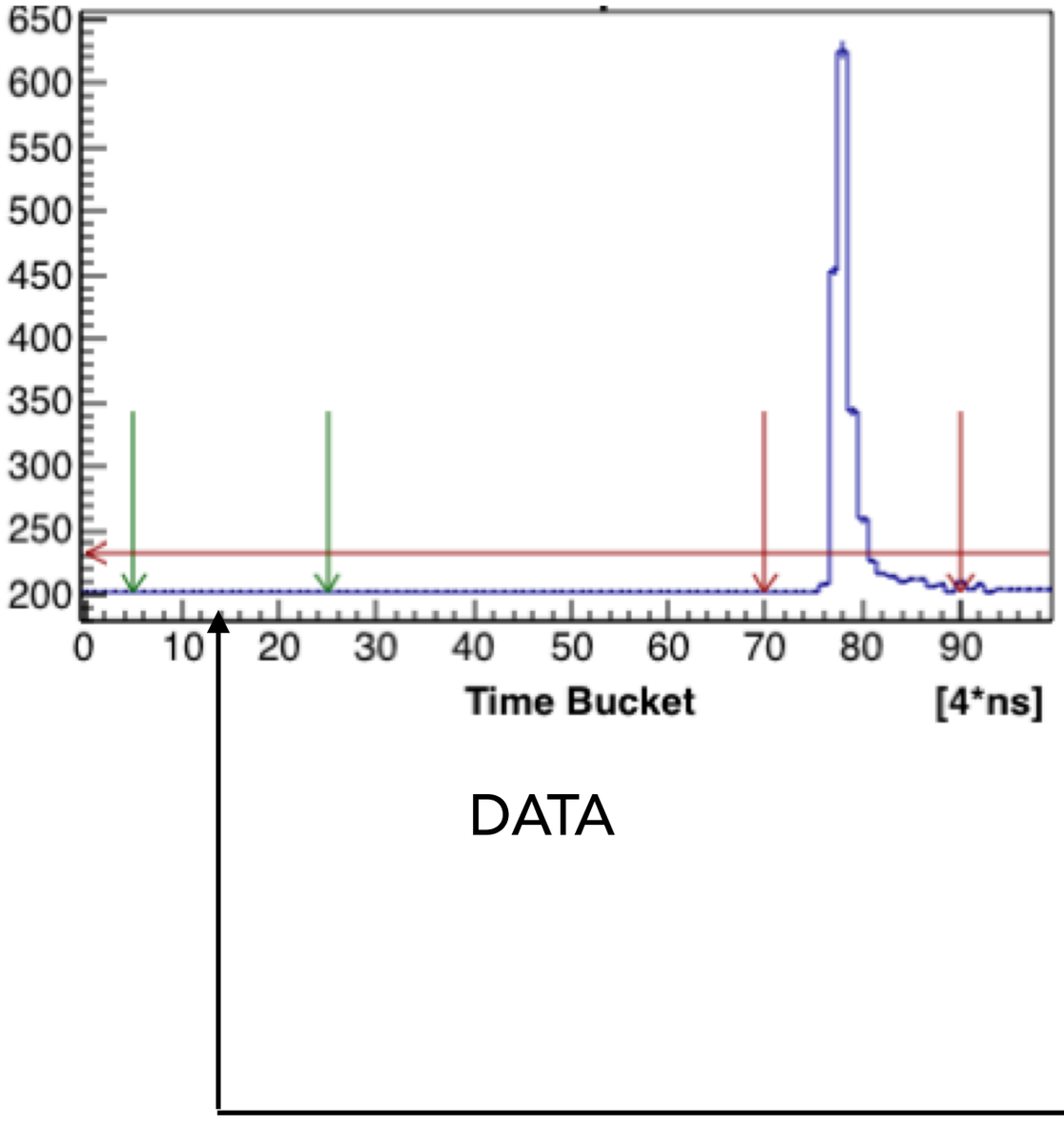
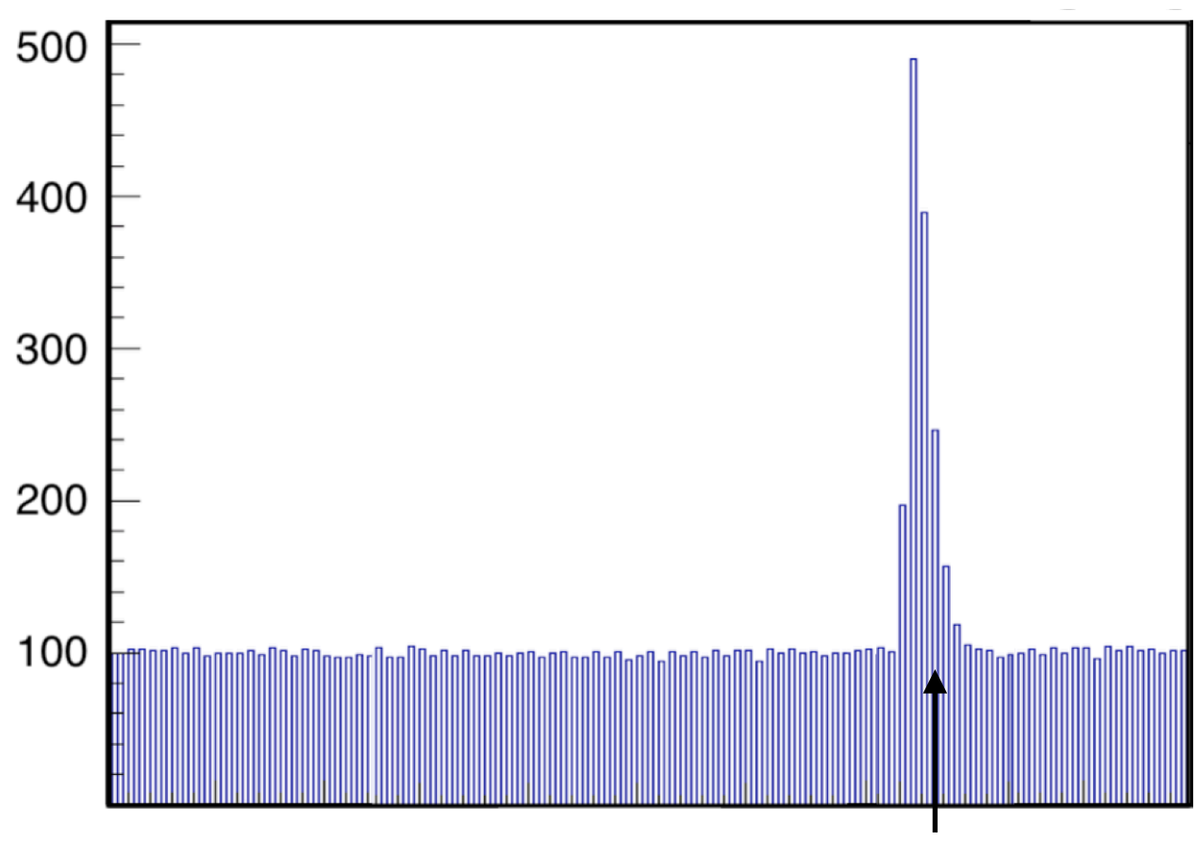


DATA

pedestal mean and sigma

Geant4 Simulation



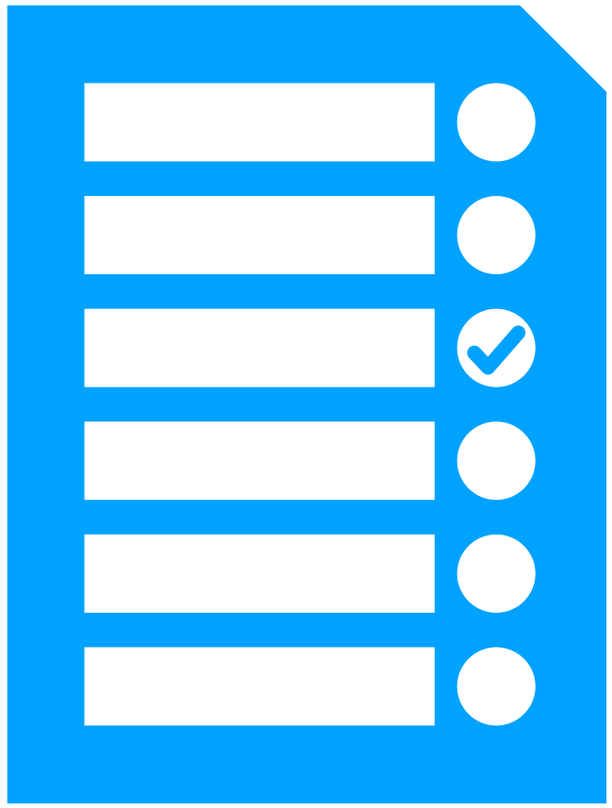
shape and width depends on user defined function

$f(Edep_i)$

Streaming Readout Unit (SRU)

CLASS Object with (organized) buffer of hits

example electronic address:
crate / slot / channel



- FADC board
- VTP,
- DC Readout Board
- …

The SRU data contains channels, time-ordered:

- Wave packets raw data
- Integrated values (for example, mode 7 FADC)

The buffers include the physics / electronic noise, either Geant4 produced or merged from actual data.

From geant4 identifiers to SRU

Link between geant4 sensitive identifiers and hardware address (e.g. crate/slot/channel)

```
string “drift chamber”
     int sector 2
     int region 3
      int layer 5
      int wire 7
```

→ “Real”Translation Table database

```
vector <int>
   crate 2
   slot 8
  channel 11
```

From geant4 identifiers to SRU

Link between geant4 sensitive identifiers and hardware address (e.g. crate/slot/channel)

```
<composite data_type="0xf" tag="57602" padding="0" num="19" length="92" ndata="91">
  <comp>
      <format  data_type="0x3" tag="65" length="6" ndata="1">
         c,i,l,N(c,N(s,i,s,s))
      </format>
      <data  tag="66" num="67">
         <row num="1">
            <uint8 count="1"> 0x04  </uint8>
            <uint32 count="1"> 0x00000001  </uint32>
            <uint64 count="1"> 0x0000000000000001  </uint64>
            <repeat  n="4">
               <paren>
                  <uint8 count="1"> 0x03  </uint8>
                  <repeat  n="1">
                     <paren>
                        <uint16 count="1"> 0x0002  </uint16>
                        <uint32 count="1"> 0x00000003  </uint32>
                        <uint16 count="1"> 0x0004  </uint16>
                        <uint16 count="1"> 0x0005  </uint16>
               </paren>
      </repeat>
</paren>
<paren>
   <uint8 count="1"> 0x04  </uint8>
   <repeat  n="1">
      <paren>
         <uint16 count="1"> 0x0002  </uint16>
         <uint32 count="1"> 0x00000003  </uint32>
         <uint16 count="1"> 0x0004  </uint16>
         <uint16 count="1"> 0x0005  </uint16>
      </paren>
   </repeat>
</paren>
```

crate number

slot

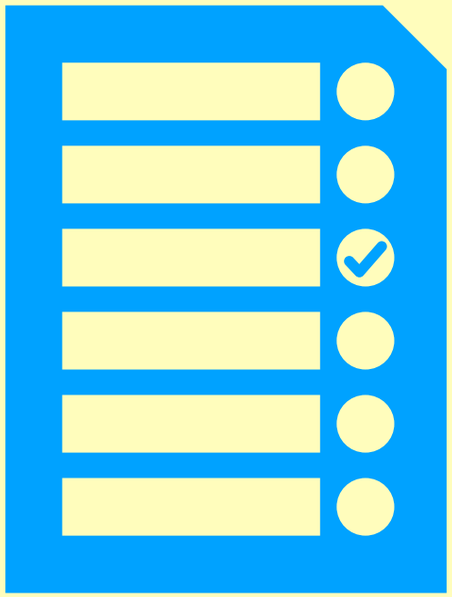
channels

XML Representation of CLAS12 simulated data hardware addresses

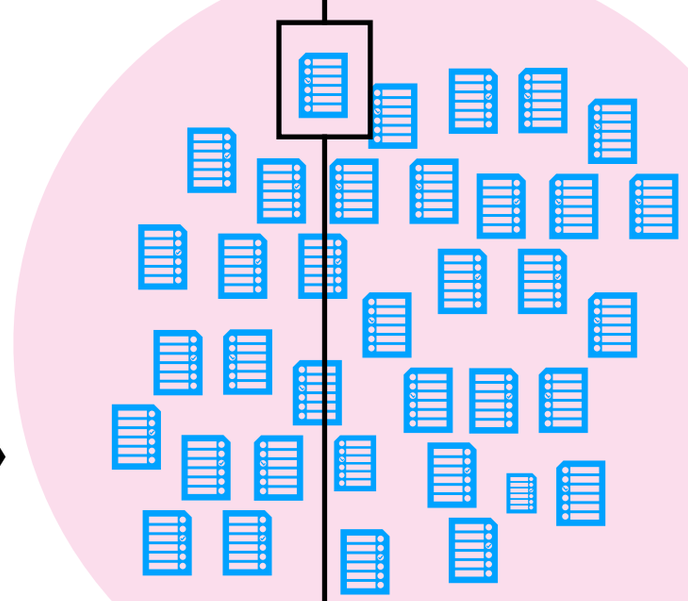
Streaming Simulations

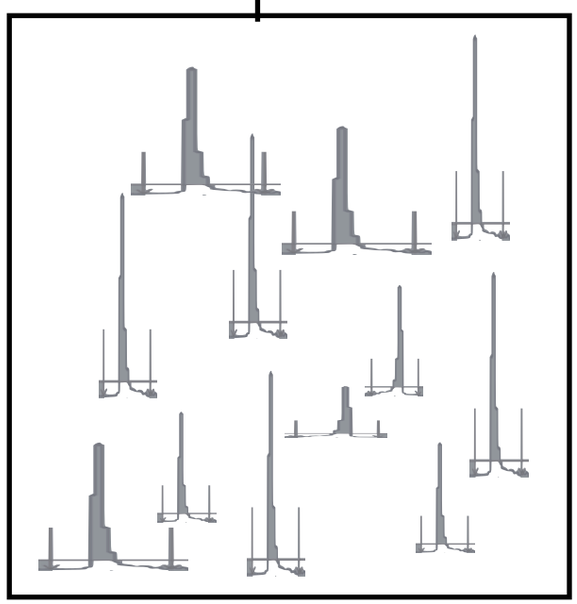
Streaming Readout Unit (SRU):
- FADC: one board or one crate TP
- DC Readout Board
- etc

electronic address:
crate / slot / channel



Streaming Readout Unit





problem: this is a buffer of data, not a collection of geant4 events

Simulation produce 1 file / SRU

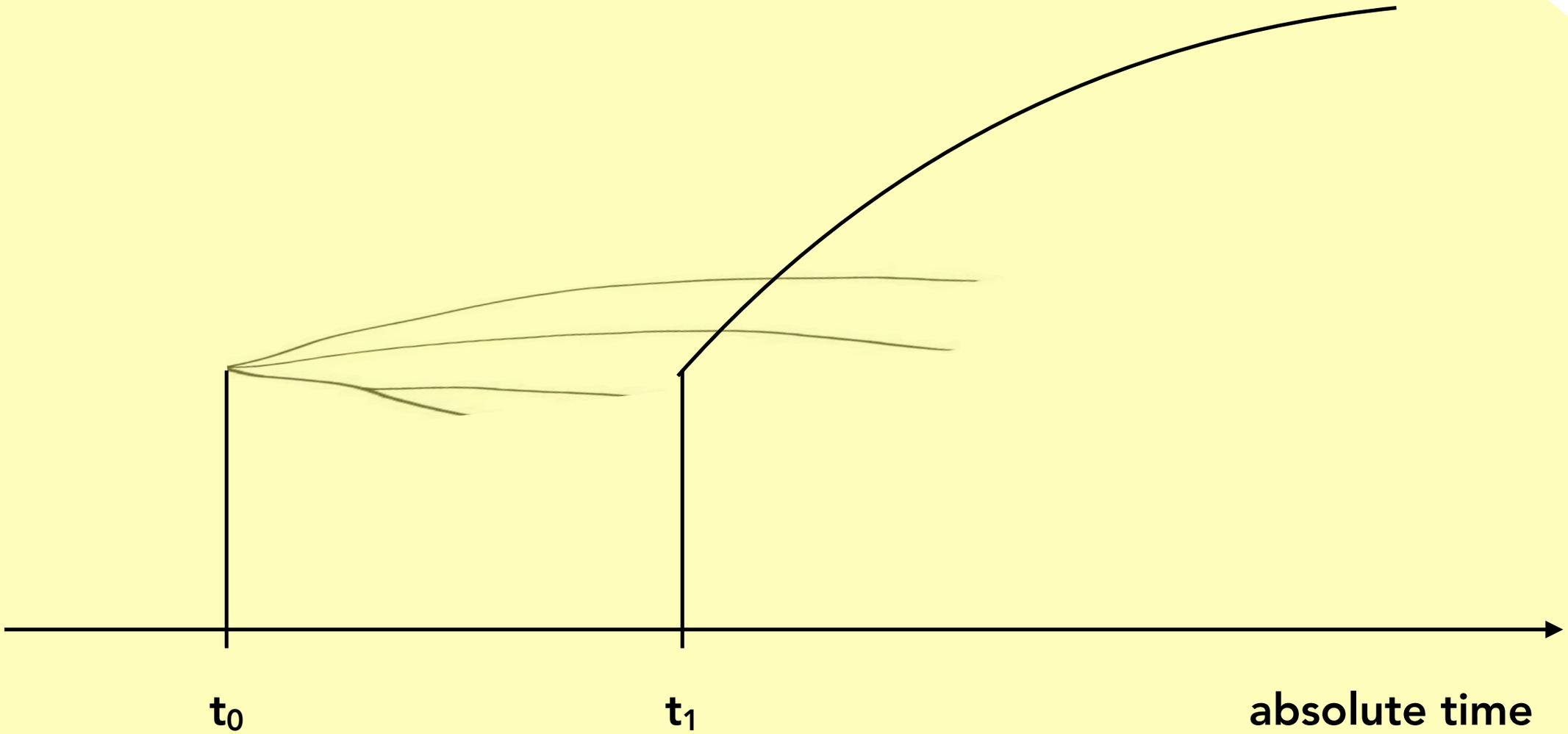
Data Subscribers, Analyzers

Streaming protocols / analysis systems should be transparent to the data source: experiment or simulation

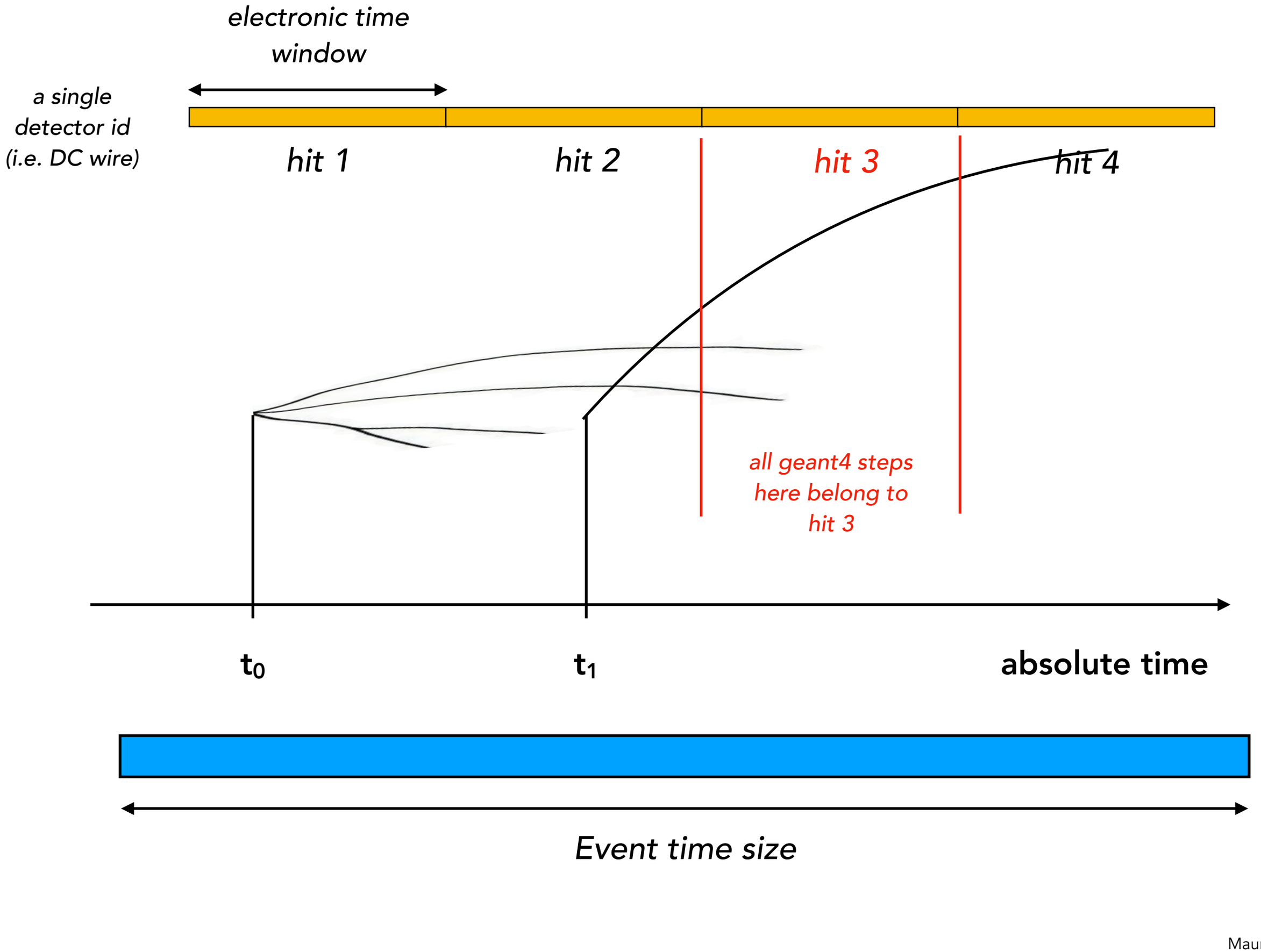
Maurizio Ungaro

Event Time Dimension in Geant4

One geant4 event: several tracks at t_0 and one track at t_1

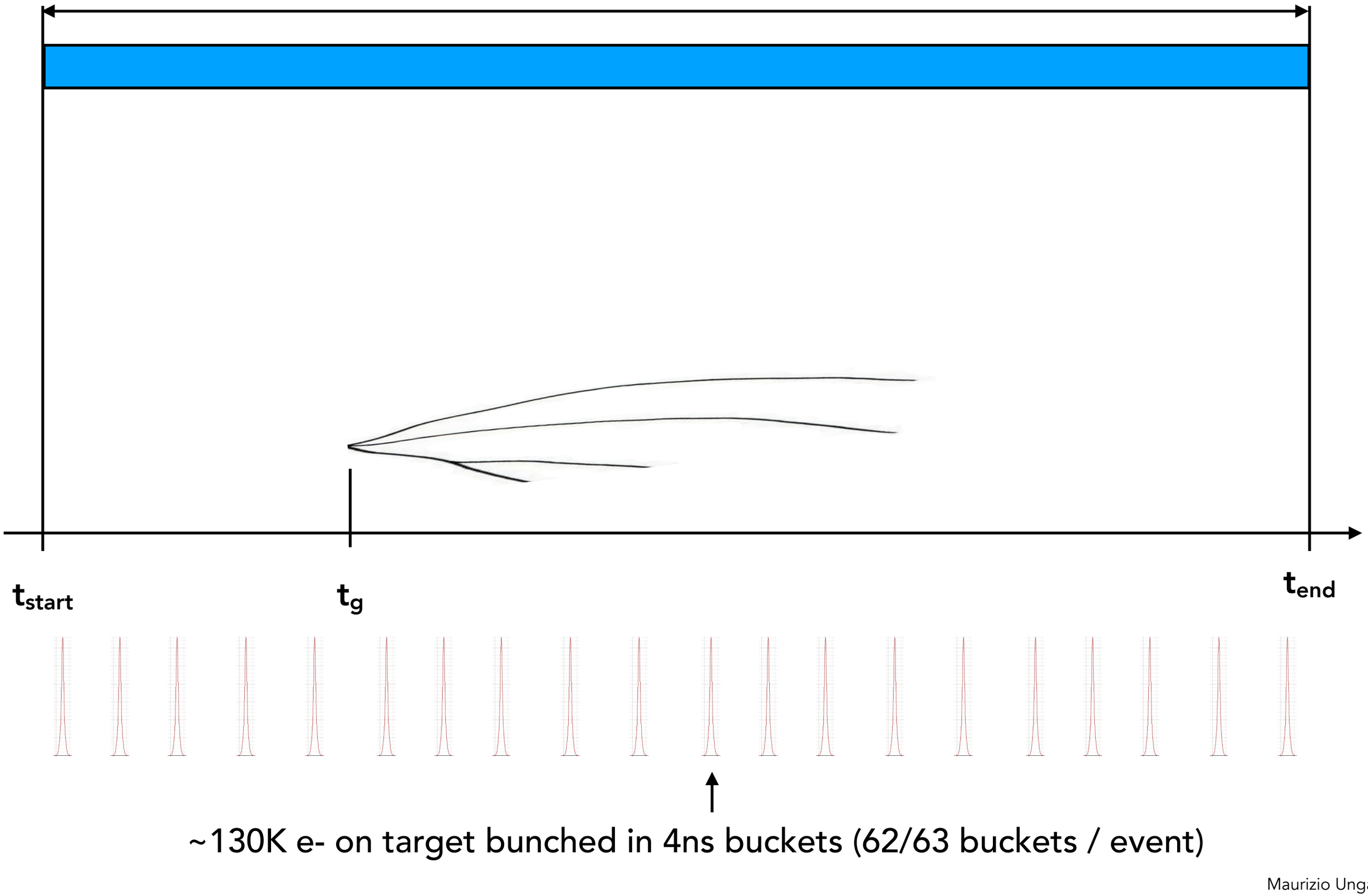


Event Time Dimension in Geant4



Event Time Dimension in Geant4

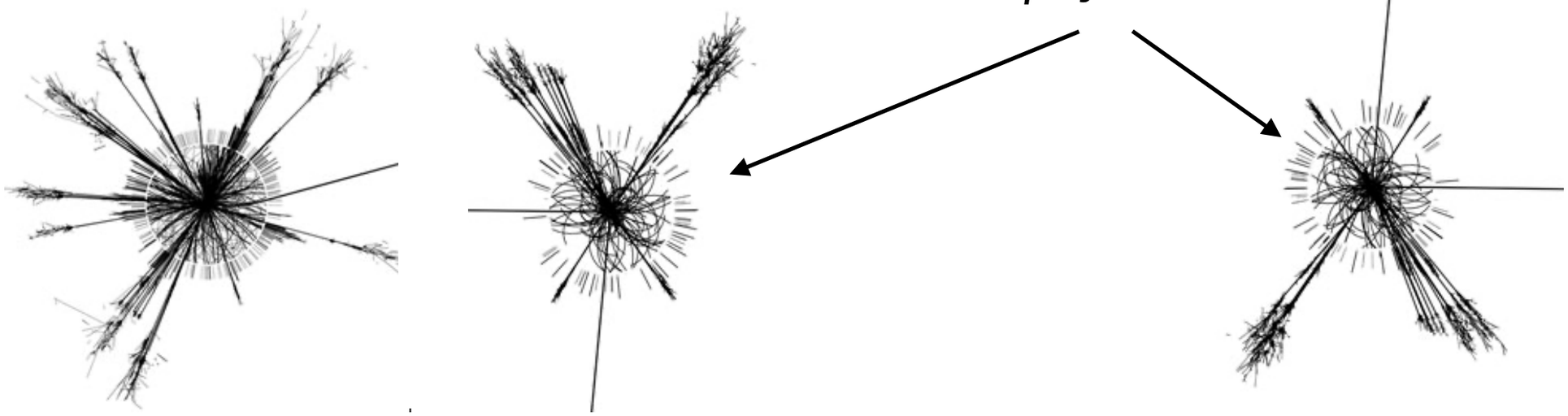
Event time size: typical CLAS12: 1 event = 250 ns

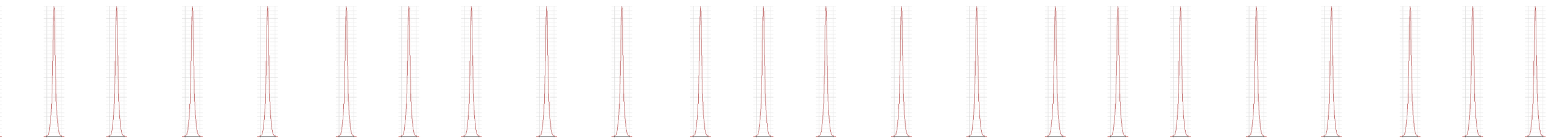


~130K e- on target bunched in 4ns buckets (62/63 buckets / event)

Event Time Dimension in Geant4

physics events at absolute times t_i



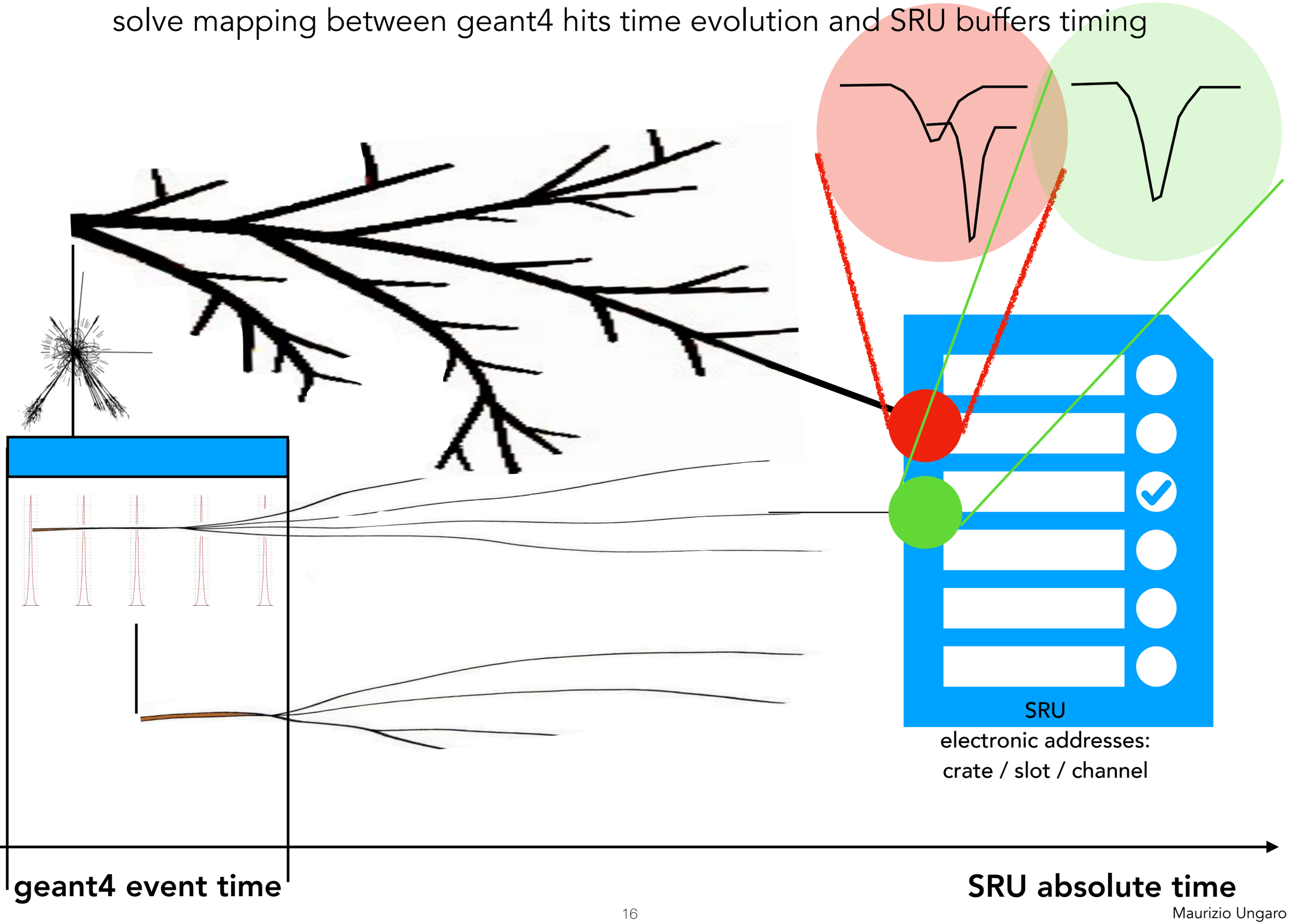


Natural mapping between absolute stream time and event number

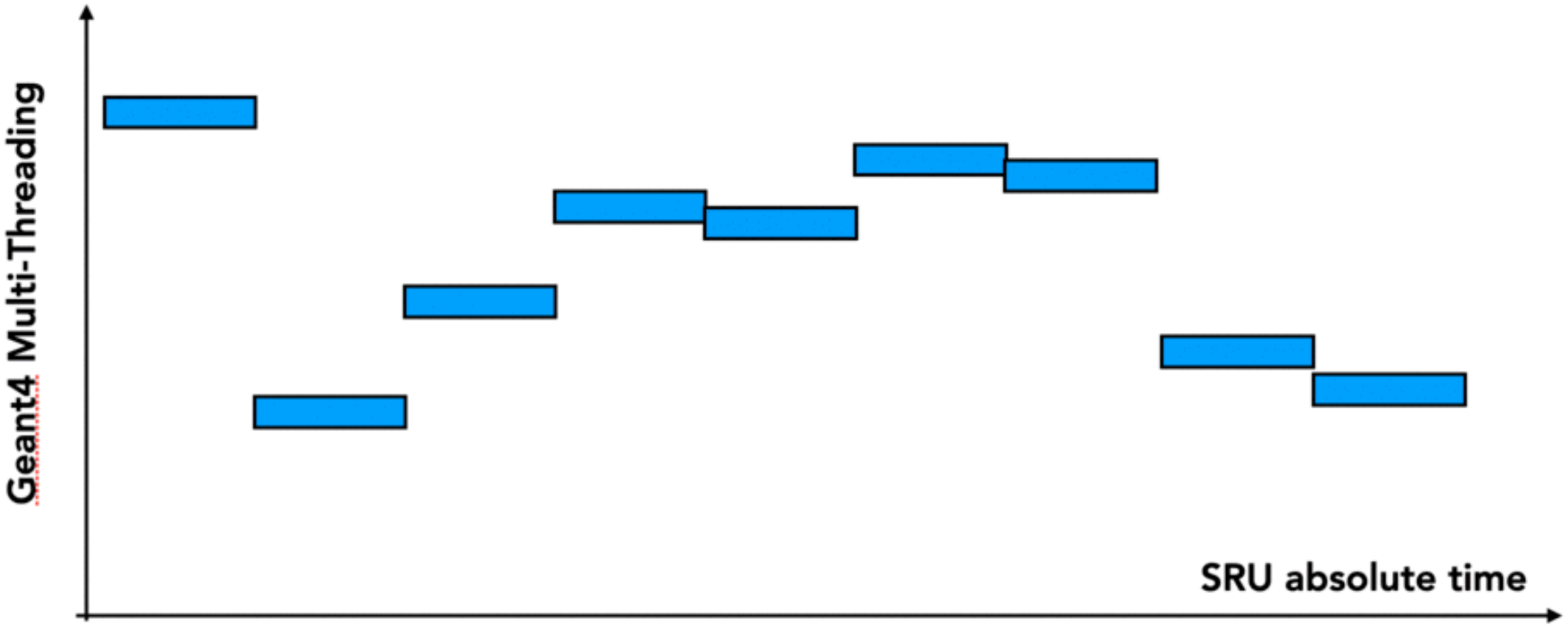
we're still limited by geant4 event centric framework: hits could "spill" into next event hits!

hits in geant4 events must be accumulated in SRU buffer

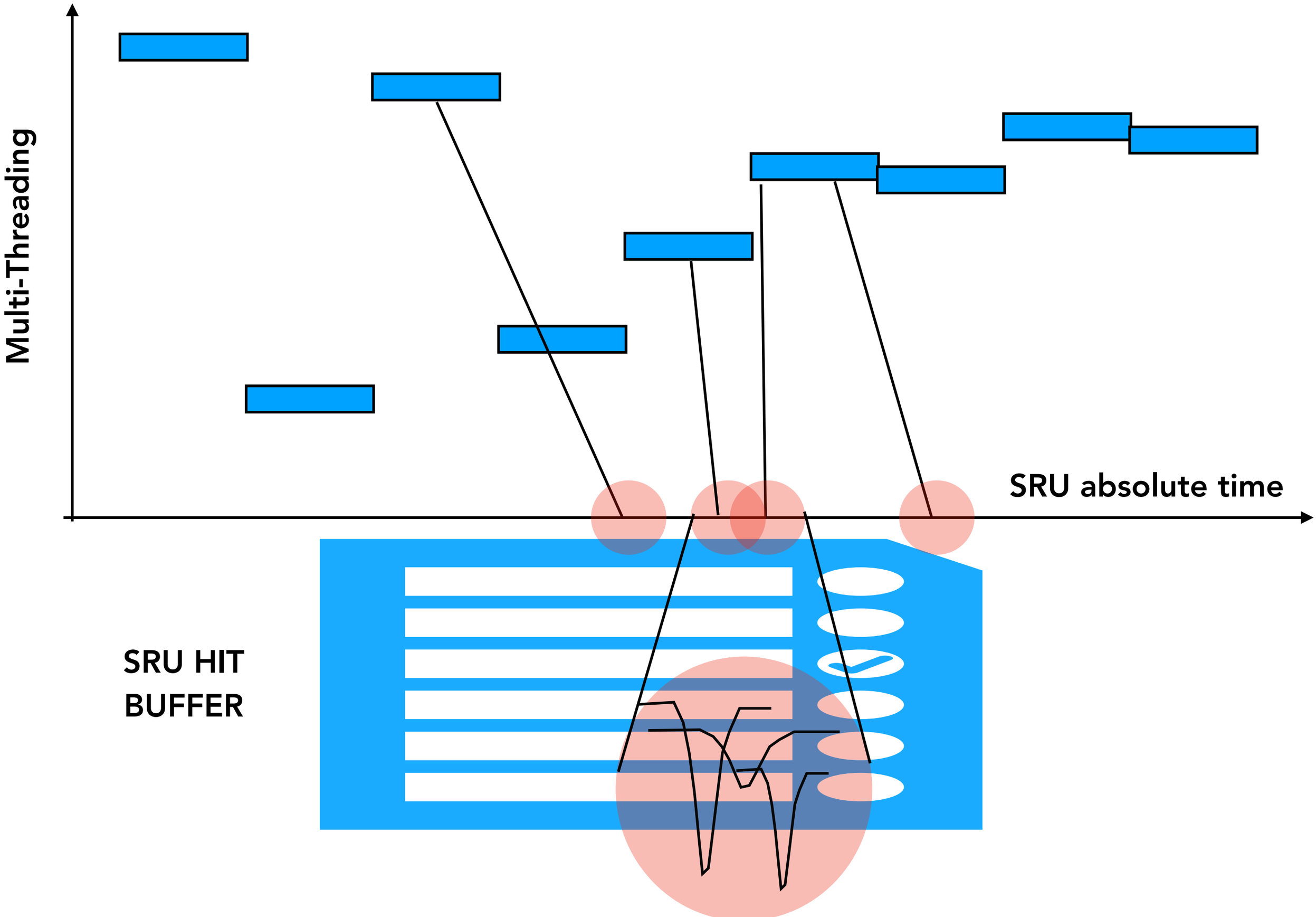
solve mapping between geant4 hits time evolution and SRU buffers timing



time evolution of geant4 events in MT mode



Each SRU hit buffer accumulates hits from several events



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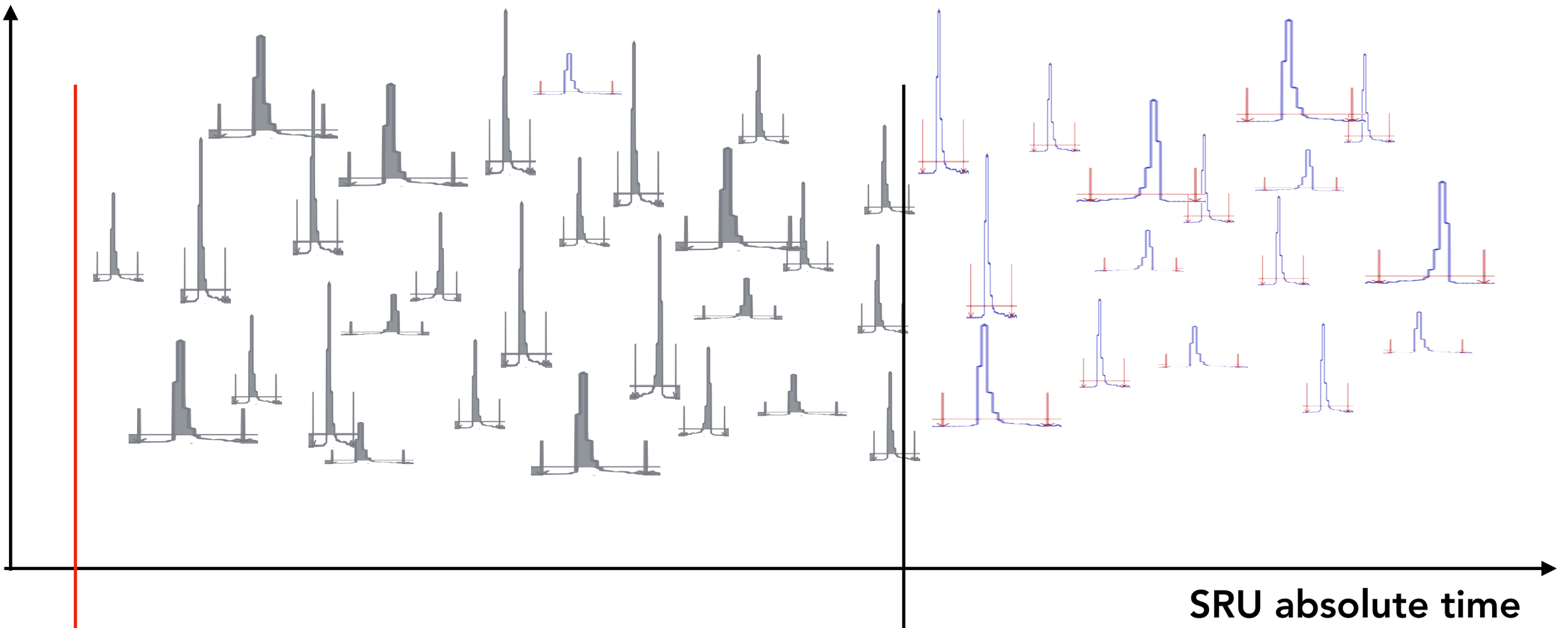


present

future

65 µs

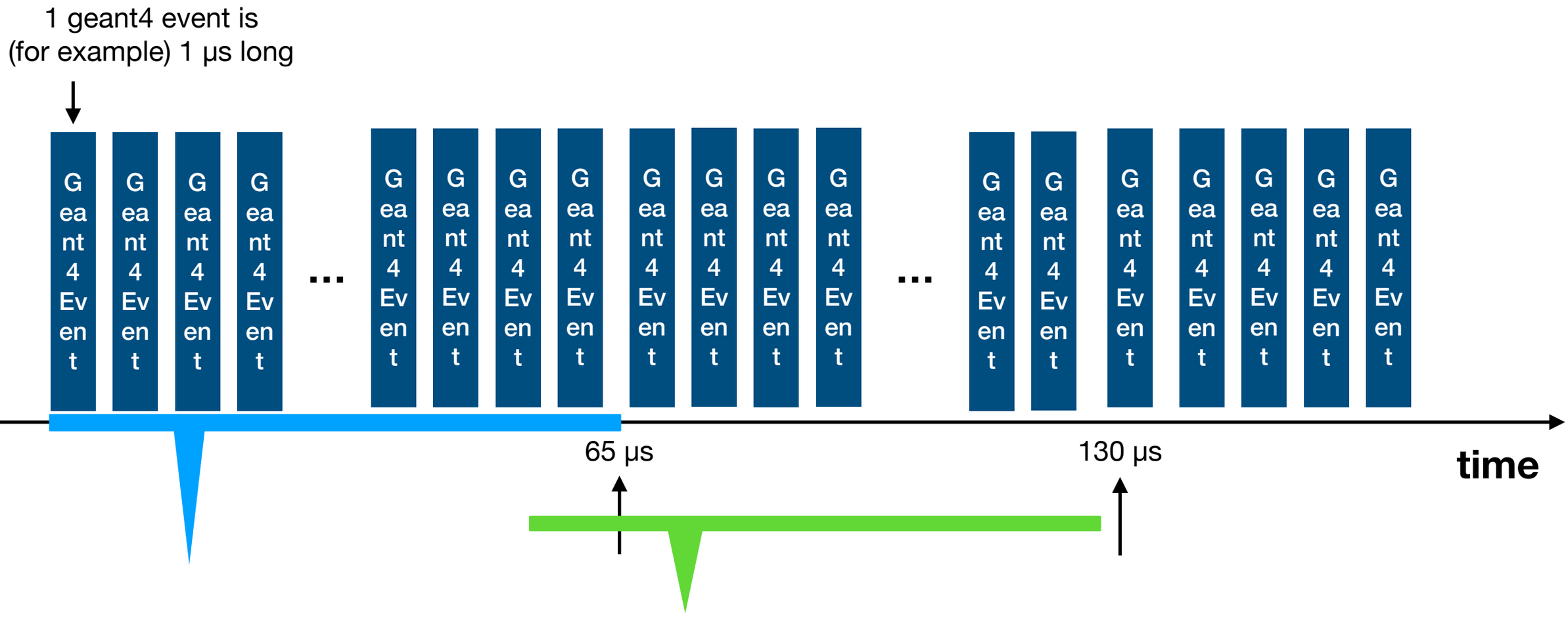
each 1 MHz data / crate
yields a buffer of 65 hits

Stream to SRU file behind this line

NOW

No hits left behind mechanism

Multiple Events / SRU Hits Buffer Scenario



- Hits from a geant4 event can end on different buffers (propagation time, etc)
- Pile-ups are intrinsic in this scenario

Outlook and Future Plan

- Most of the concepts described here are implemented in existing code used for CLAS12/Solid simulations (GEMC, https://www.sciencedirect.com/science/article/pii/S0168900220300279). New stand-alone libraries are being written and could be used in any c++ based geant4 simulations.

- Next step: use a simple, existing detector geometry and demo buffer stream feasibility by replacing a real small detector (one SRU) source with simulation.

- Add multiples crates, simultaneous buffers streams. One buffer = 1 file on disk = 1 network stream.

- Simulate challenges of large scale detectors:

  - ➡ buffer synchronizations issues
  - ➡ network glitches
  - ➡ large amount of data
  - ➡ crates / boards malfunctions
  - ➡ timing in respect to signal shapes

- Event generators and SRO: time- (and not event-) based generators