Event building for free-streaming readout in the CBM experiment

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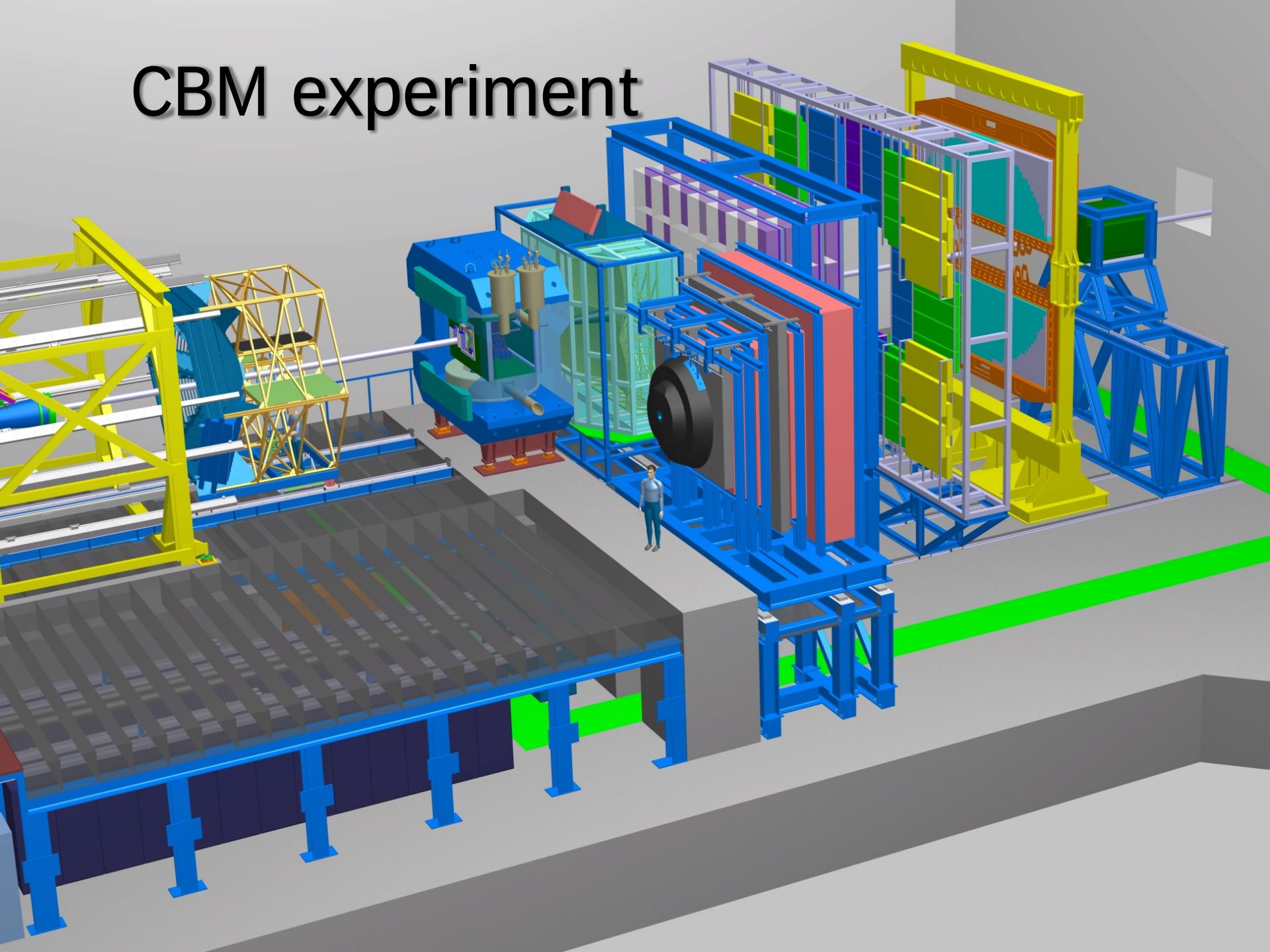
CBM experiment



Physics and interaction rates

- Some main physics observables
  - Charm: D-mesons, J/ψ , ψ' etc
  - Multistrange baryons: $\Xi^-(dss)$,$\Xi^+(\bar{d}\bar{s}\bar{s})$,$\Omega^-(sss)$,$\Omega^+(\bar{s}\bar{s}\bar{s})$
  - Rare QGP probes requiring the high interaction rate
  - Many of the probes are extremely difficult to trigger on
- CBM rate capability is limited by the setup not by the accelerator
  - 10^5 for MVD if precise vertex reconstruction is required
  - 10^6 for PSD if precise determination of event plane is needed
  - 10^7 for all other detectors

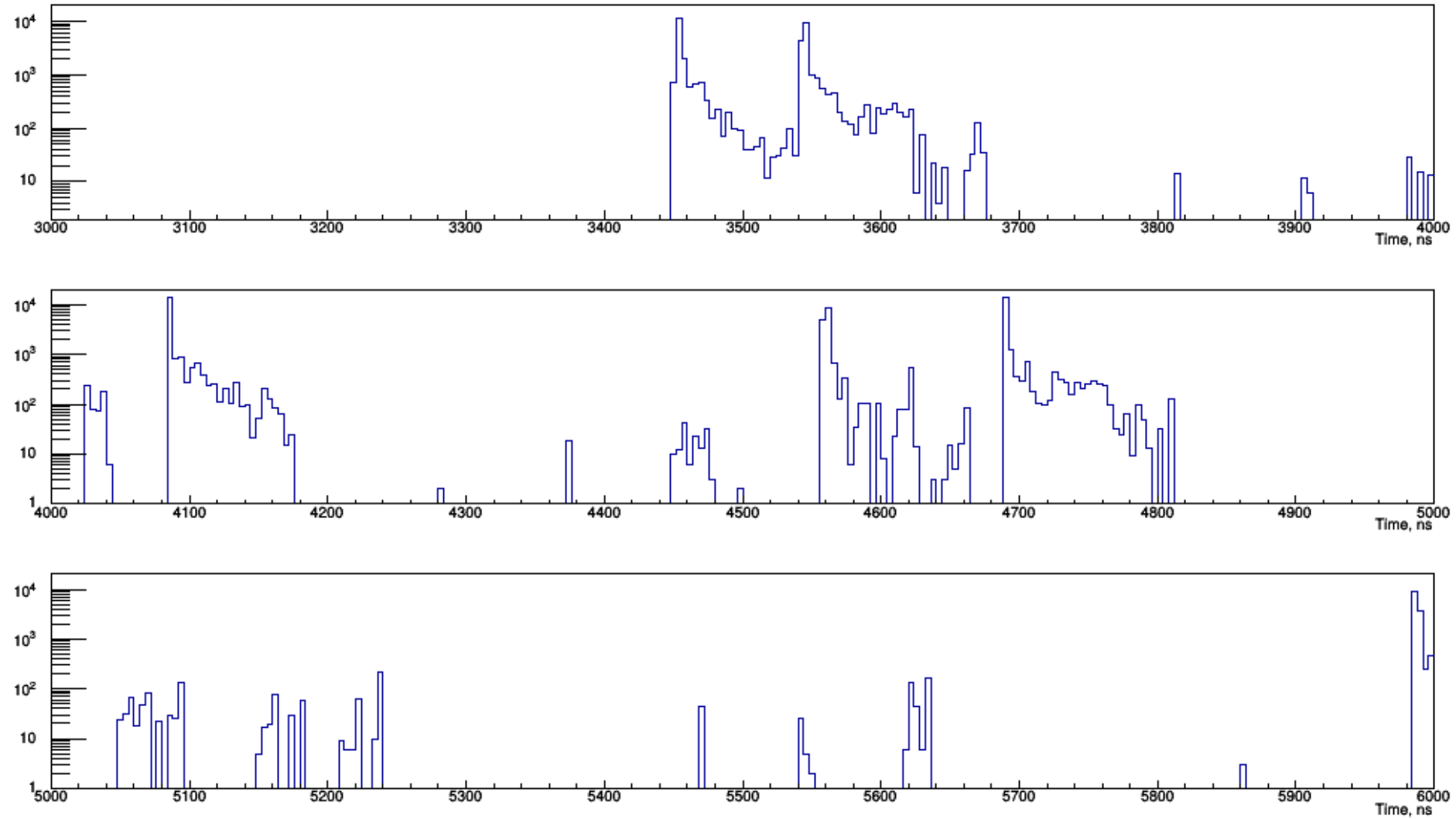
CBM readout concept

- CBM is the first high interaction rate experiment going to run in a free streaming mode without trigger
  - Readout electronics will be self-tiriggered and deliver time-stamped data
  - Timeslice is all data acquired in a given period of time (more than 1 μs)
  - Timeslices can be threated separately from each other
  - Full reconstruction of a timeslice should be performed at individual computing unit
    - Node, processor or core
  - Interesting data should be saved
- Full reconstruction of all acquired data is available = complex cuts (identification quality, event topology, etc.) can be used for data selection
  - Example: high efficiency for D-mesons
- Timeslice should be sectioned into individual collisions (events) during the reconstruction
  - Event building problem

Event building

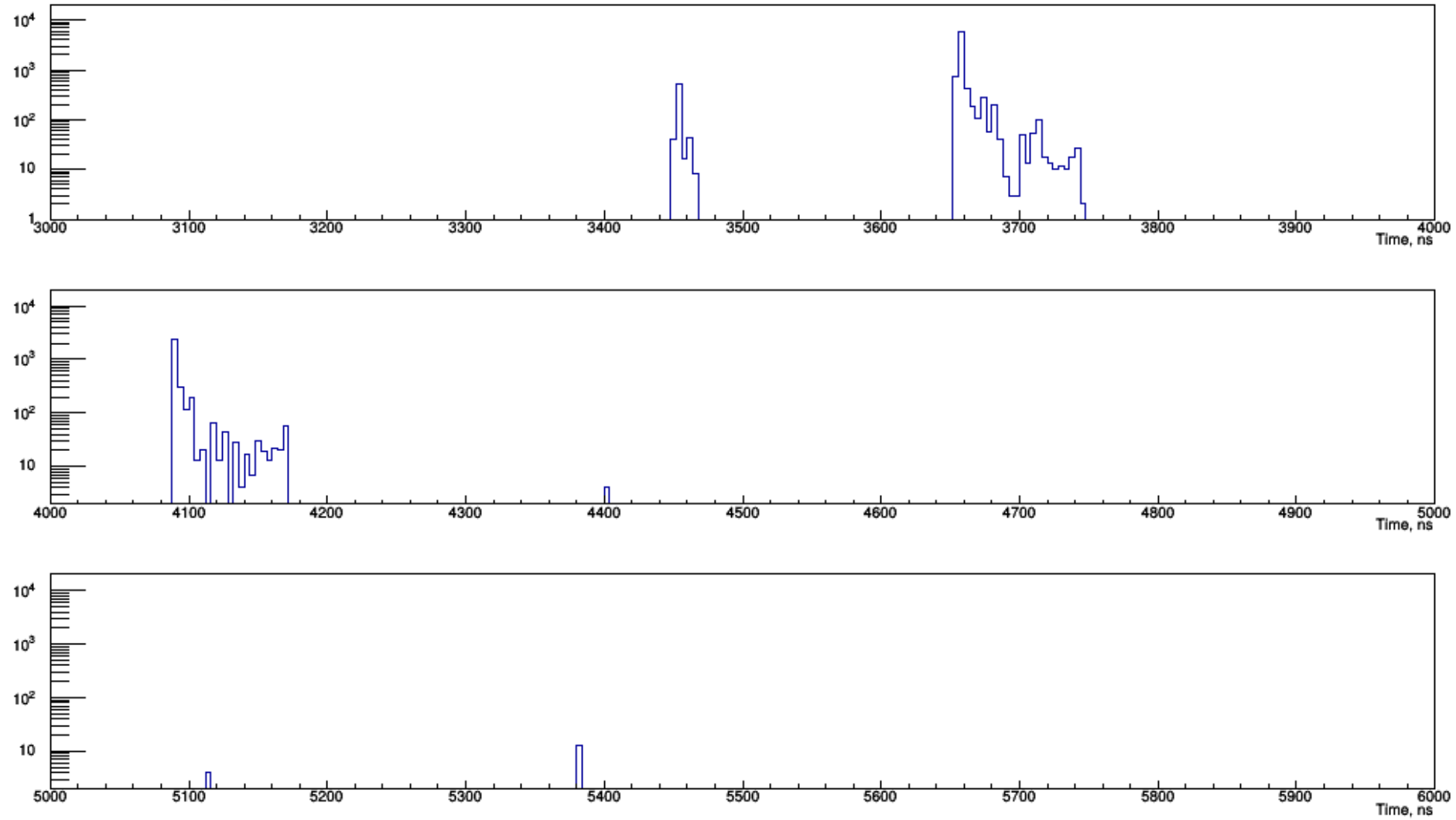
- Event building is a software algorithm in the CBM reconstruction chain
  - Different implementations for different colliding systems and energies
  - Physical objects (tracks, vertexes etc.) must be associated with events
    - Event association is not required for individual activated electronic channels (digis).
- Two approaches:
  - Digis for event building (simple method)
    - All event based reconstruction methods will work
    - Experience from previous experiments easily adopted
    - Can handle limited interaction rate (goal: up to 1 MHz)
    - Fallback solution
  - Track and vertex information for event building
    - Dedicated reconstruction algorithms for timeslices (e.g. 4D tracking)
    - A lot of affords to develop
    - Should work for high interaction rate
    - Final solution
- Only STS detector for simplicity
  - Include information from other subdetectors after getting some experience

Digi dynamics in time



UrQMD 10 AGeV Au+Au central collisions at 1 MHz. No delta from beam particles.
All events generate approximately the same number of digis.
Delta electrons can produce digis up to 1 μs after the collision of origin.

Digi dynamics in time

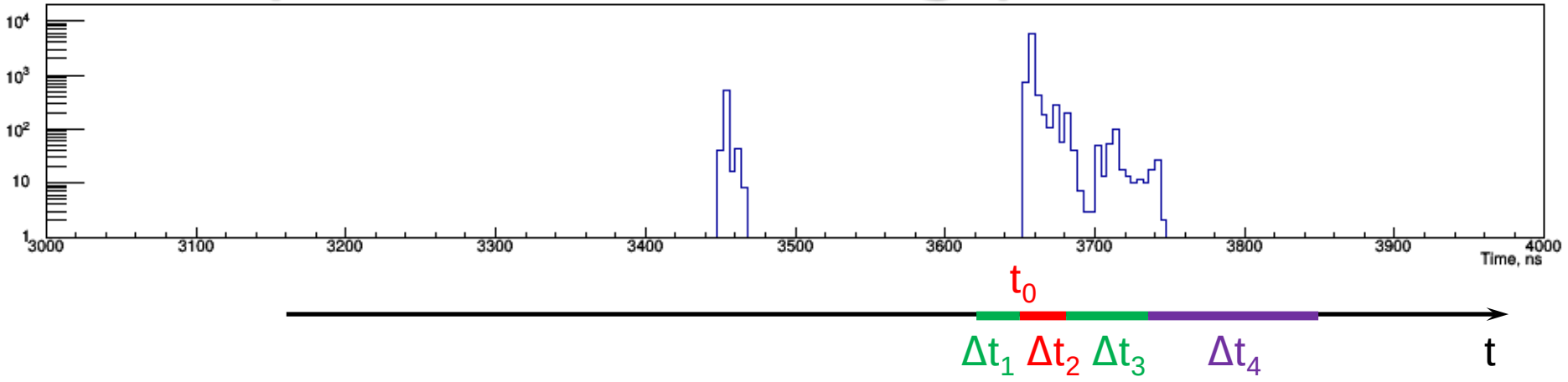


UrQMD 10 AGeV Au+Au mbias collisions at 1 MHz. No delta from beam particles.
Same random seed in digitizer = same event positions.
Different number of digits per collision, some collisions don`t produce digis at all!!!

Simple event builder

- Mbias gold-gold collisions is the worst case for simple event builder
  - Low number of tracks in peripheral collisions
  - Large number of digis produced by delta electrons tails from central collisions
  - Can’t control collision centrality in the experiment
  - ... but can measure it after the collision.
- There is a possibility that modeled UrQMD collision can’t be reconstructed
  - It produce no tracks in the detector acceptance ...
  - ... or just a few tracks, without possibility to reconstruct primary vertex and detect a collision for physical analysis.
  - Generator data alone is not enough to calculate denominator for event building efficiency for min. bias collisions.
  - First guess: At least 5 tracks in the detector acceptance is required for primary vertex reconstruction.

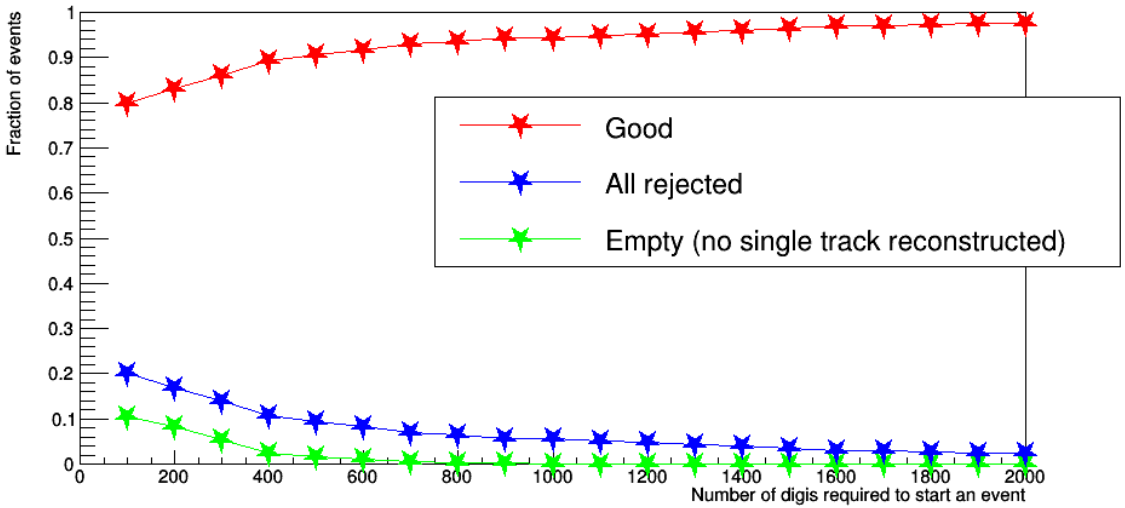
Simple event building procedure

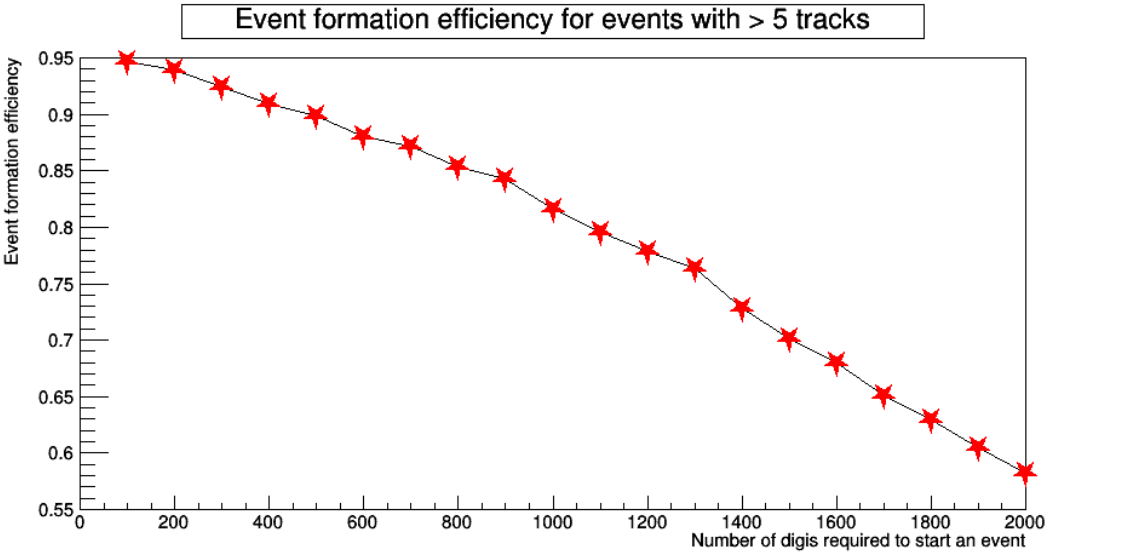


- Event found:
  - Number of digis in a given period of time $[t_0, t_0+\Delta t_2]$ (2 ns) is more than a threshold
  - All STS stations in the same period of time produced at least one digi
- All digis in period $[t_0-\Delta t_1, t_0+\Delta t_2+\Delta t_3]$ are associated with found event
- Algorithm does not search events in $[t_0+\Delta t_2+\Delta t_3, t_0+\Delta t_2+\Delta t_3+\Delta t_4]$ time period
- Δt_1=2 ns, Δt_2=2 ns, Δt_3=5 ns, Δt_4=8 ns
- Initial guess for threshold is 2000 digis per 2 ns
  - Works perfect for central events

Mbias events. Event building efficiency

- Good reconstructed event:
  - More than 5 reconstructed tracks in event based reconstruction
  - Difference between number of reconstructed long (>4 hits in STS) tracks in event based and real case less than 10 and 5%
  - No single long track from other events
- Good reconstructable event contain at least 5 long tracks found in event based reconstruction.
- Threshold of 500 for 90% fraction of good events and 90% event formation efficiency for good events





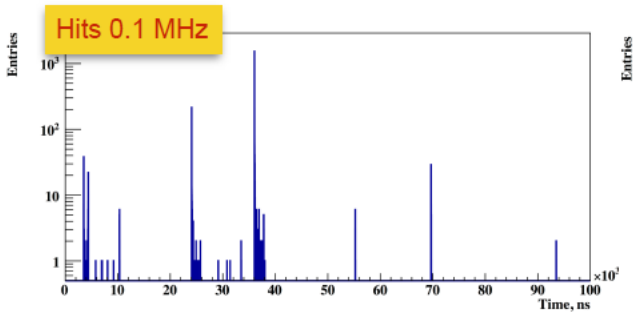
Track and vertex information for event building

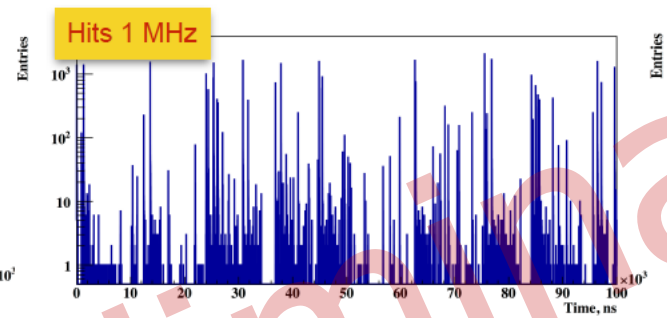
- Reconstruction of tracks and vertexes at timeslice level
  - 4D (x, y, z, t) tracking
  - Use extended state vector for track fitting

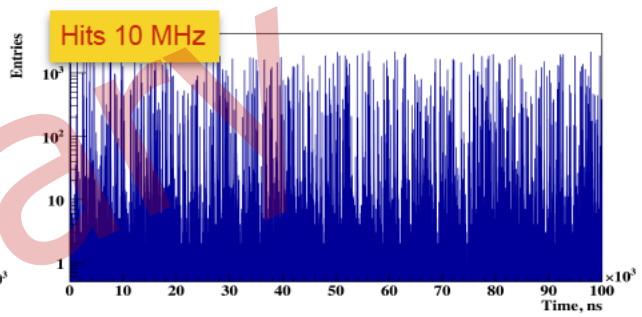
    $(x, y, t_x, t_y, q/p) \rightarrow (x, y, t_x, t_y, q/p, t)$
  - 4D vertex location
  - Fast! Need online reconstruction of Au+Au collisions at 10 MHz rate.
- All tracks born in the same location and the same time form a collision
  - Secondary vertexes require special care

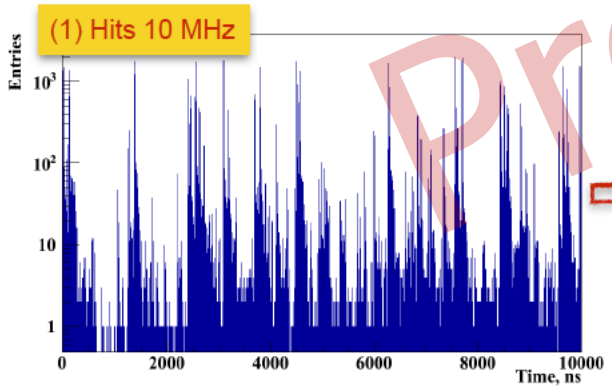
Time-based Track Reconstruction

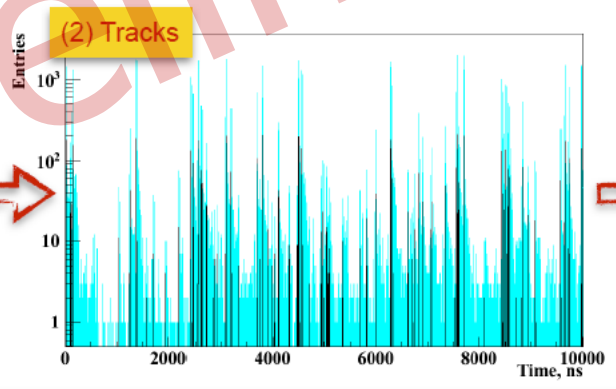
Slide by V. Akishina

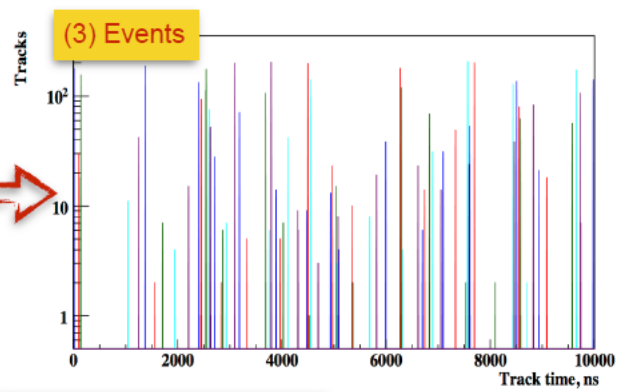












Event Building at IR = 10 MHz

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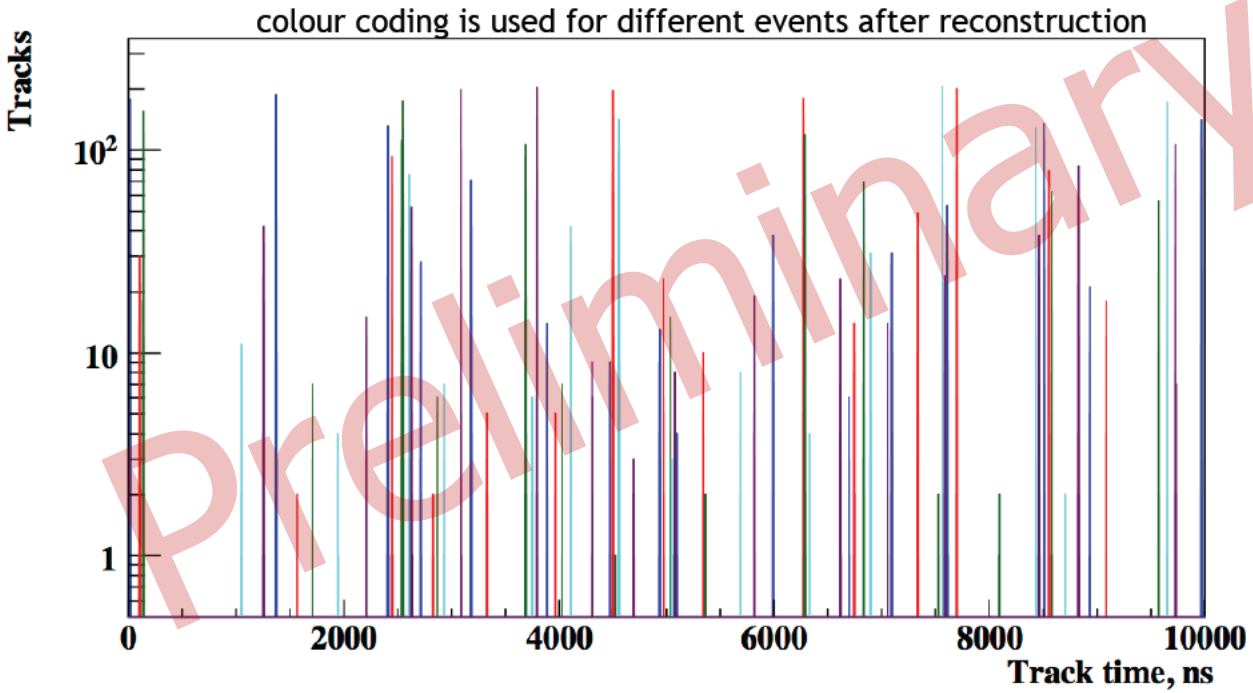
Reconstructed tracks are grouped in events using histogramming:

- all tracks are filled in a time histogram with bin width of 1 ns
- neighbouring not empty bins are called an event
- gap of a 4 empty bins is a sign for event end



- 70 reco events are reconstructed one-to-one, 7 reco events are merged together.
- Primary tracks can be separated using primary vertex information.
- Search of only one primary vertex per event using KF Particle Finder package is currently implemented.
- Multi-vertex reconstruction is in progress.

Conclusions

- CBM is the first high interaction rate experiment going to run in a free streaming mode without trigger
- The readout electronics will work in self triggering mode
- Event building is a software procedure in CBM
- Simple event building based on digi dynamics in time should be up to 1 MHz interaction rate
  - The procedure will be updated to include information from other subdetectors
  - Include delta electrons produced by beam particle in target
- More complex algorithms rely on 4D track and vertex reconstruction are under development
  - Very preliminary results are presented