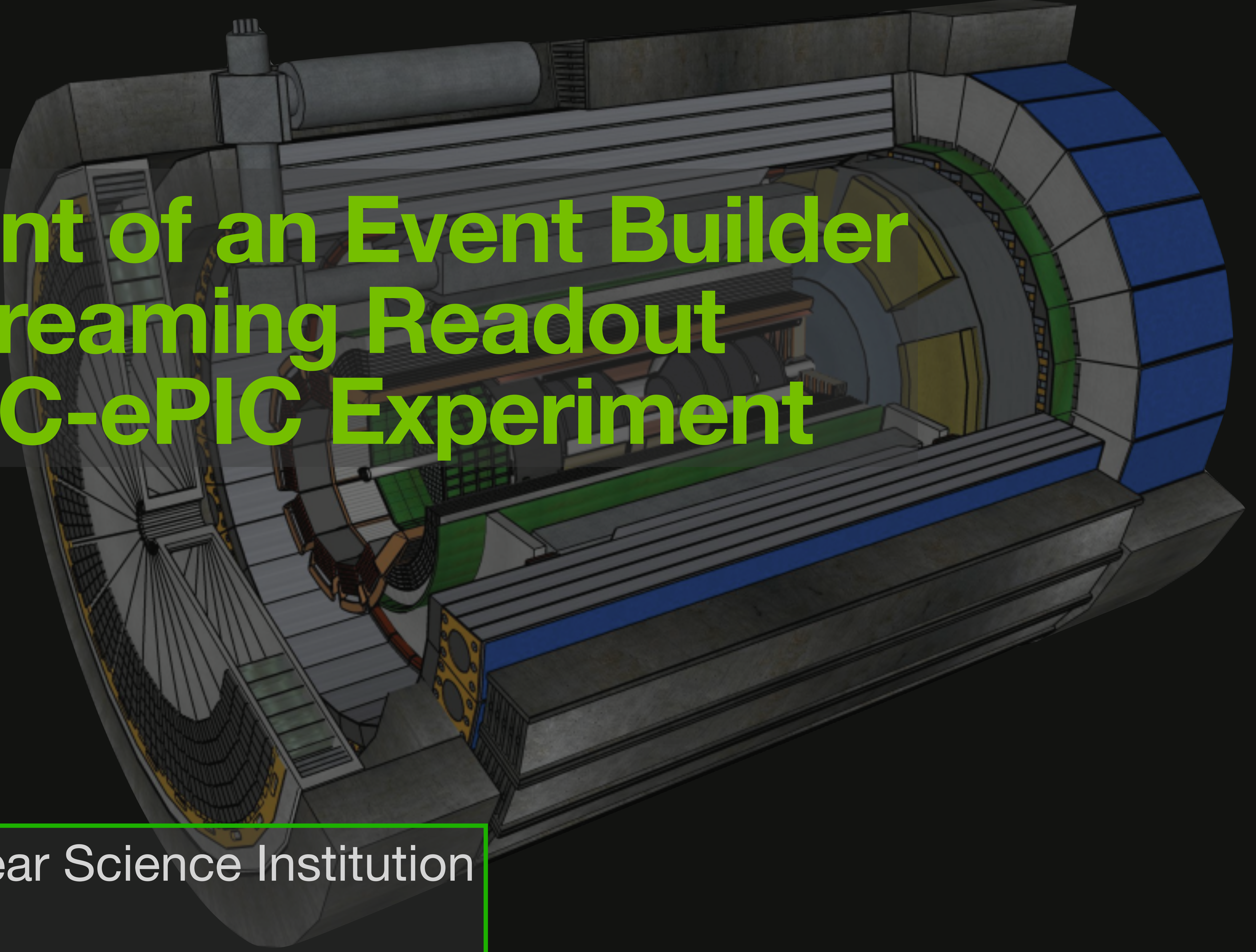

Development of an Event Builder with Streaming Readout for the EIC-ePIC Experiment

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Aim of My Work and Scope of This Presentation

My study aim

Development of an EICrecon algorithm to identify physics collisions within timeframes

Scope of this presentation

- Implementation of a base algorithm of event building in EICrecon
- Validation that the algorithm works through a blind analysis
- Performance test using primitive triggers

The algorithm will serve as a baseline for:

- Benchmarking other algorithms
- Validating future developments

Readout Data Flow

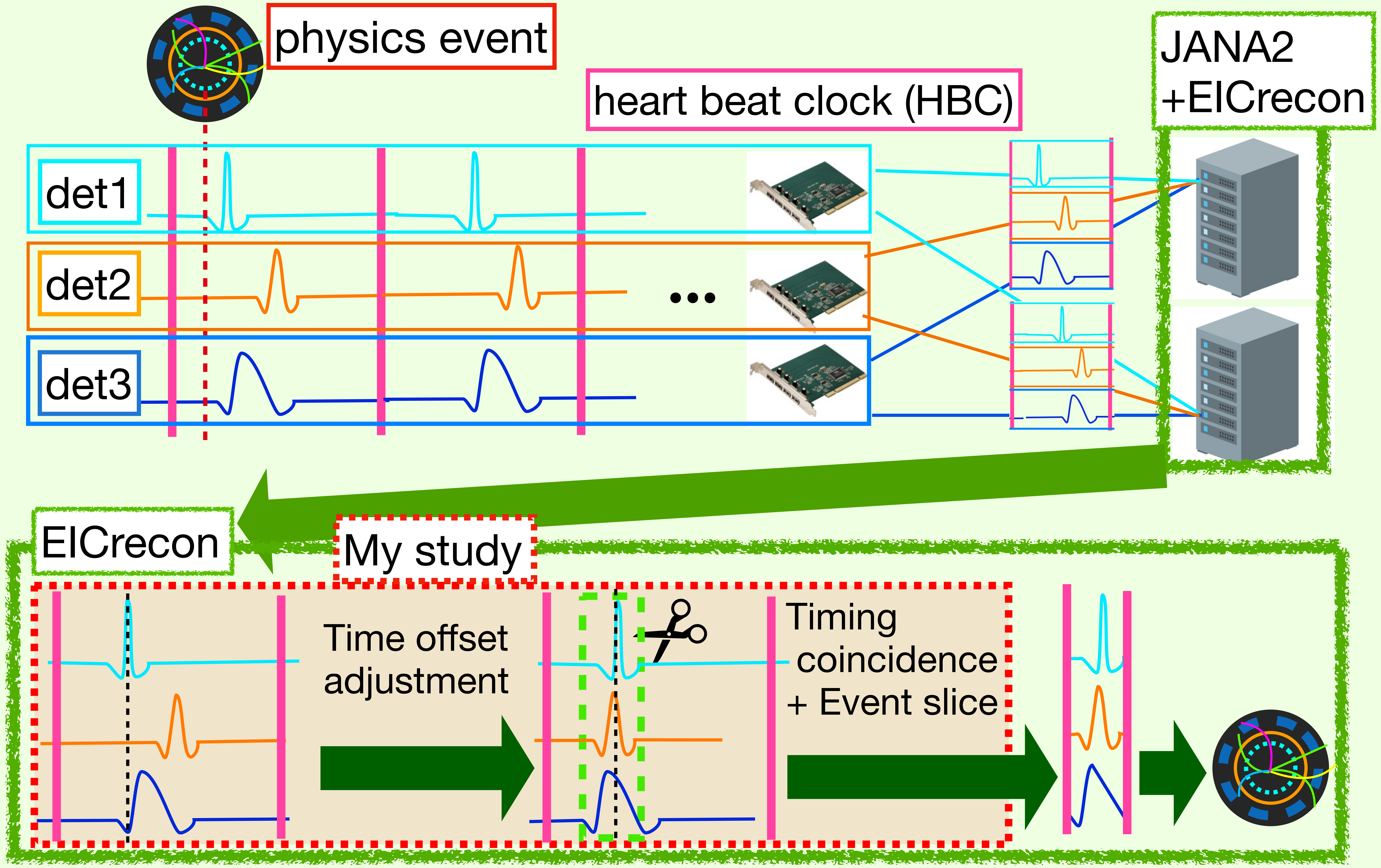
- The continuous signal is segmented by the Heart Beat Clock (common clock).

- The digital signals are sent to servers.

- Integrate all detector data.

- There are extraneous data.

- By building events, the data can be compact.



My study

Event extraction from streamed data and reconstruction into event data.

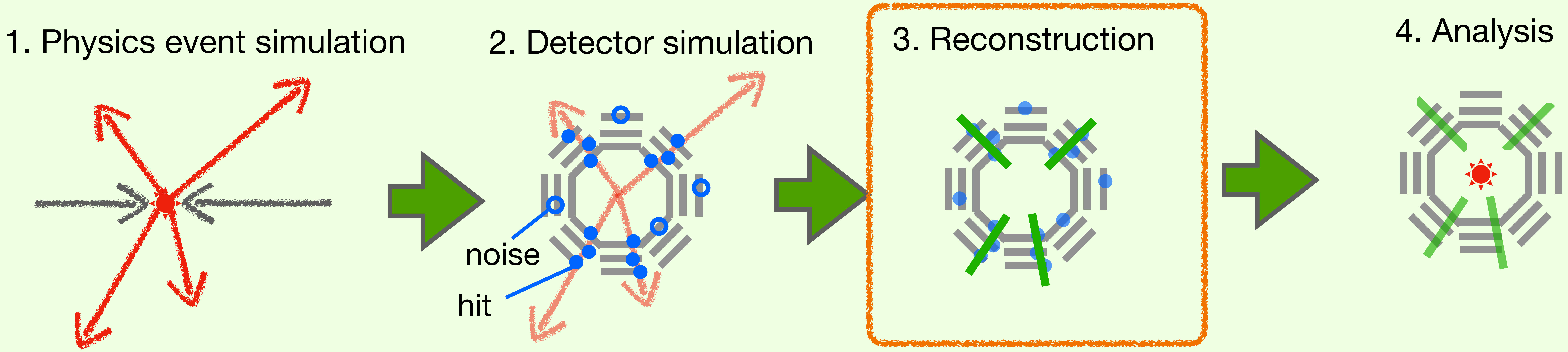
Simulation Flow

1. Event Generator (e.g. PYTHIA) → eventGene.hepmc

2. Detector simulation (npsim [Geant4 base]) → detSim.edm4hep.root

3. Reconstruction (eicrecon) → recon.edm4hep.root
   - Digitization
   - Event Selection ← My work
   - Reconstruction

4. Physics Analysis

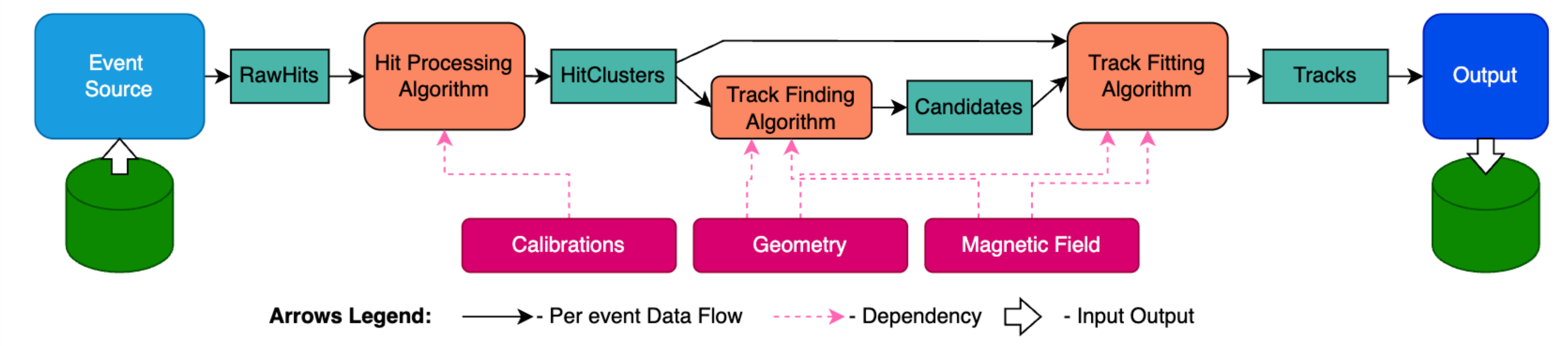


EICrecon Framework

Software for **reconstructing** particle information from simulations or real hit data for physics analysis based on JANA2.

- EICRecon Reference Page: (Main, git, tuto1, tuto2, tuto3).

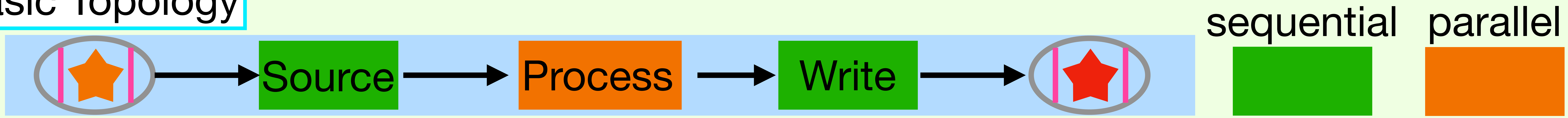
- Code structure: JANA2 (File reader, Reconstruction, File writer)



- Data Structure: edm4eic (git) ← edm4hep (git) ← podio (page)
  yaml → (compile w/ podio) → C++ class codes

JANA2 Data Flow

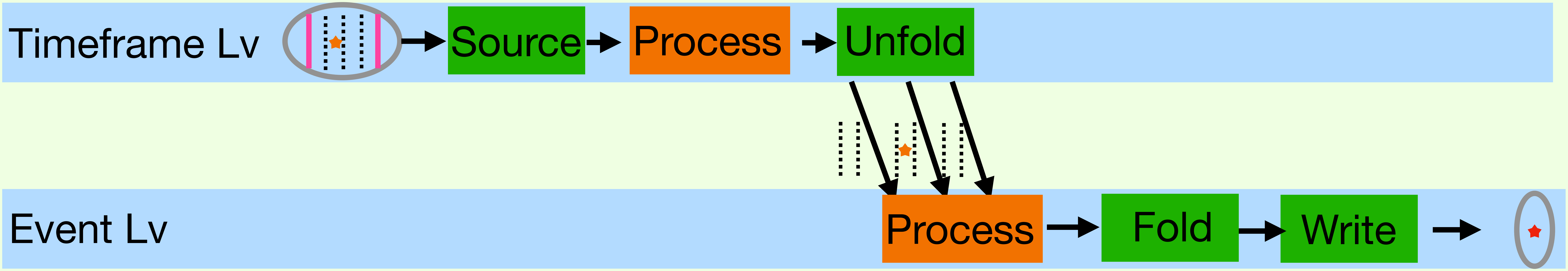
Basic Topology



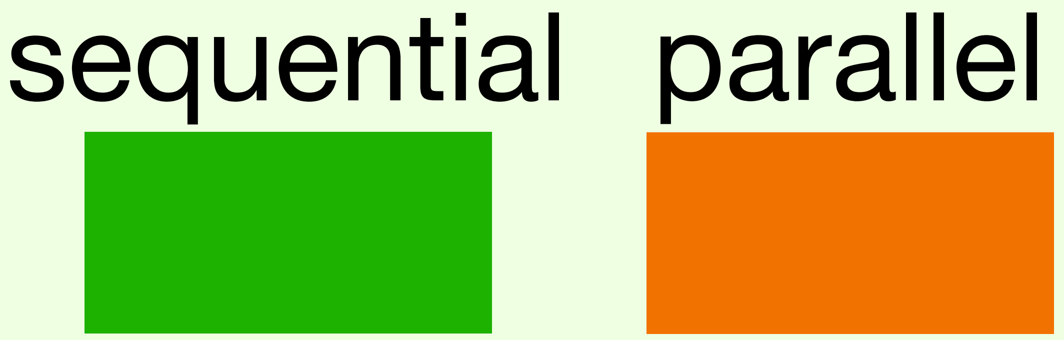
If the input data contains only one physics event, a single-level process is sufficient.

Timeslice Splitting Topology

※ Unfold: Split one frame into multi frames



A split time frame within a time slice needs to be processed.
→ It should be handled in parallel at the event level.



My Study Targets

Map of functions to be developed

Progress and Plan

1. Create a new factory to time alignment (**Done**)

2. Unfolding trivial test (**Done**)

3. Time splitting test (**Done**)

4. Timing Coincidence (**Done**)

This Presentation
※This study is still foundational stage.
→Concrete performance evaluations are future work.

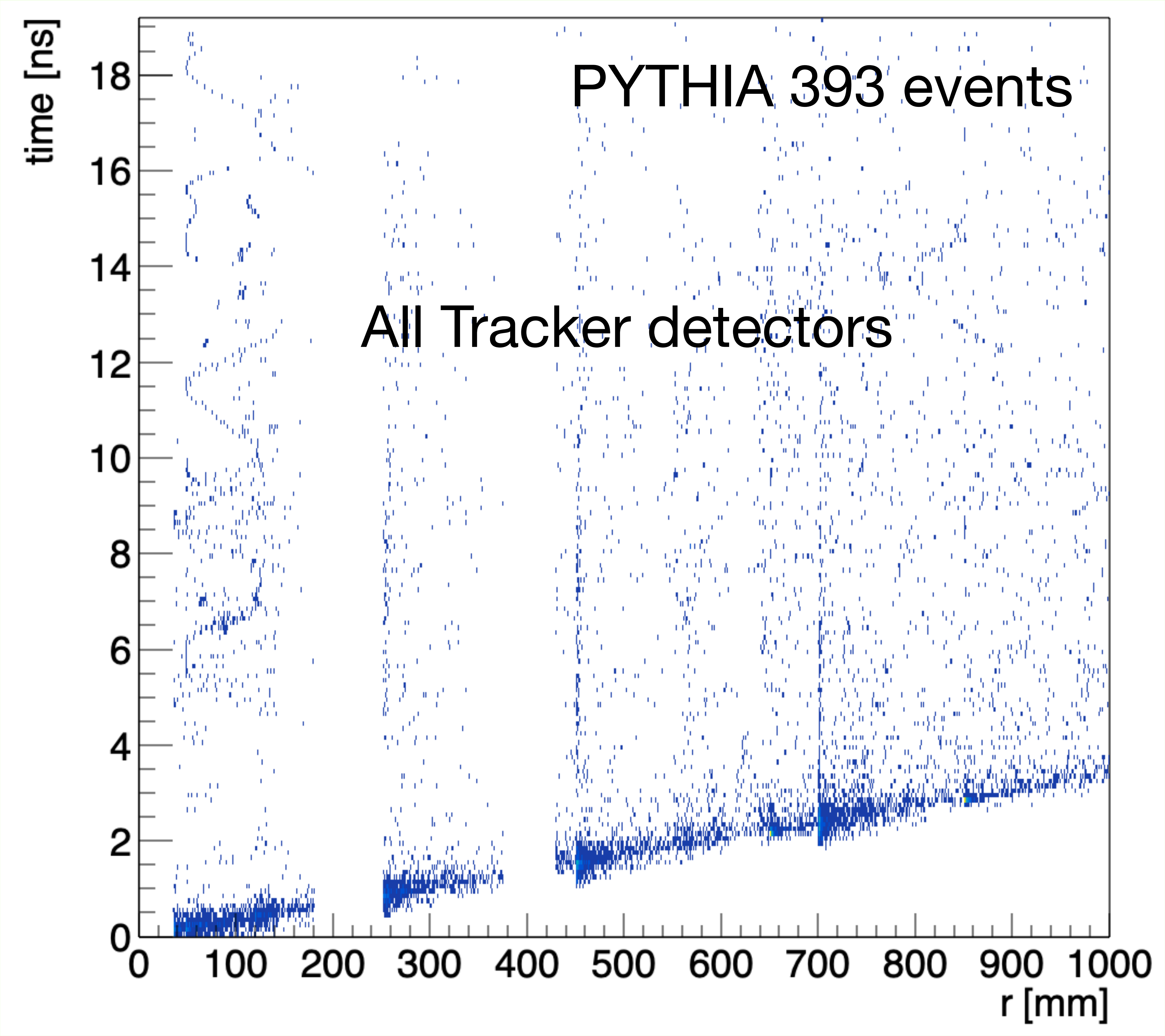
5. Injection of background events and detector noises and evaluation of timing coincidence (time windows vs. rejection, efficiency, primary tracking, etc) (**On going: Mid of August**)

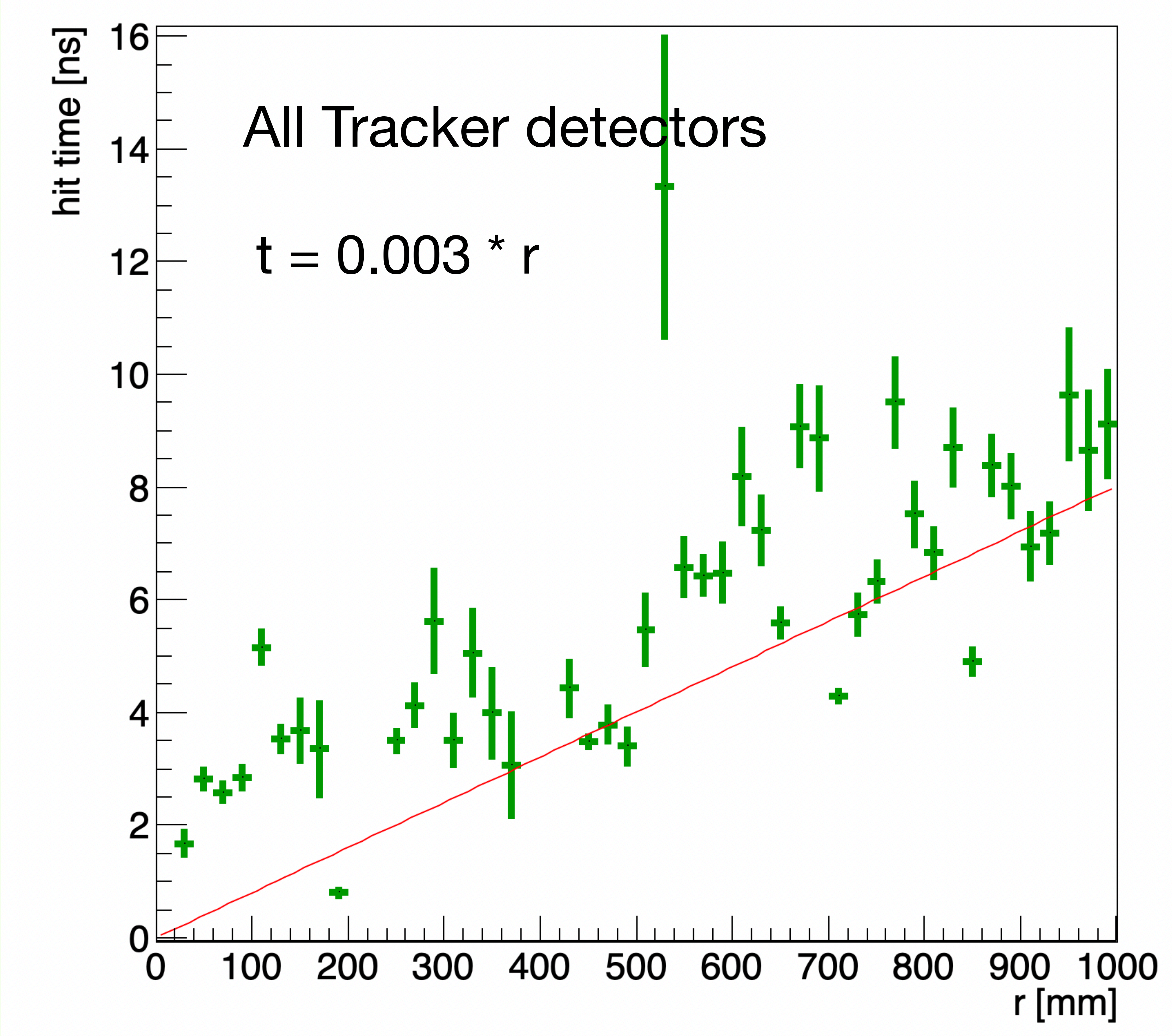
6. Apply detector response (September?)

7. Optimize time window, Time alignment, Interval selection (October?)

1.1 Hit time vs Hit position (Time Alignment)

These plots show the relation between hit time vs hit position to alignment hit time.





→A correlation between distance and hit time is observed.
However, since we are looking at MC hits, this result is expected (W/O detector response).

1.2 Time Alignment

Create Factory to do time alignment

Original input data

```
HitChecker: Event 188640 Hits in: 13.1356, 1.12963, 1.2371, 1.03809, 1.02581, 24.2638, 10.5798, 9.64017, 1.77883, 1.93878, 1.63005, 1.61152
```

↓

Sort + time alignment ($t' = t$ - 0.003 [ns/mm] * R [mm])

```
HitChecker: Event 188640 Hits in: 0.863942, 0.867679, 0.889219, 0.943039, 1.06582, 1.37656, 1.41053, 1.49302, 1.5067, 1.66467, 1.68391, 1.76771
```

It seems work well.

→ **Future plan: Time response of detectors will be included.**

2.0 Create Unfold Code

JEventUnfolder (JANA2) Nathan's work:
Base of unfold code. It handles to IDs of a time frame (parent) and events (child).

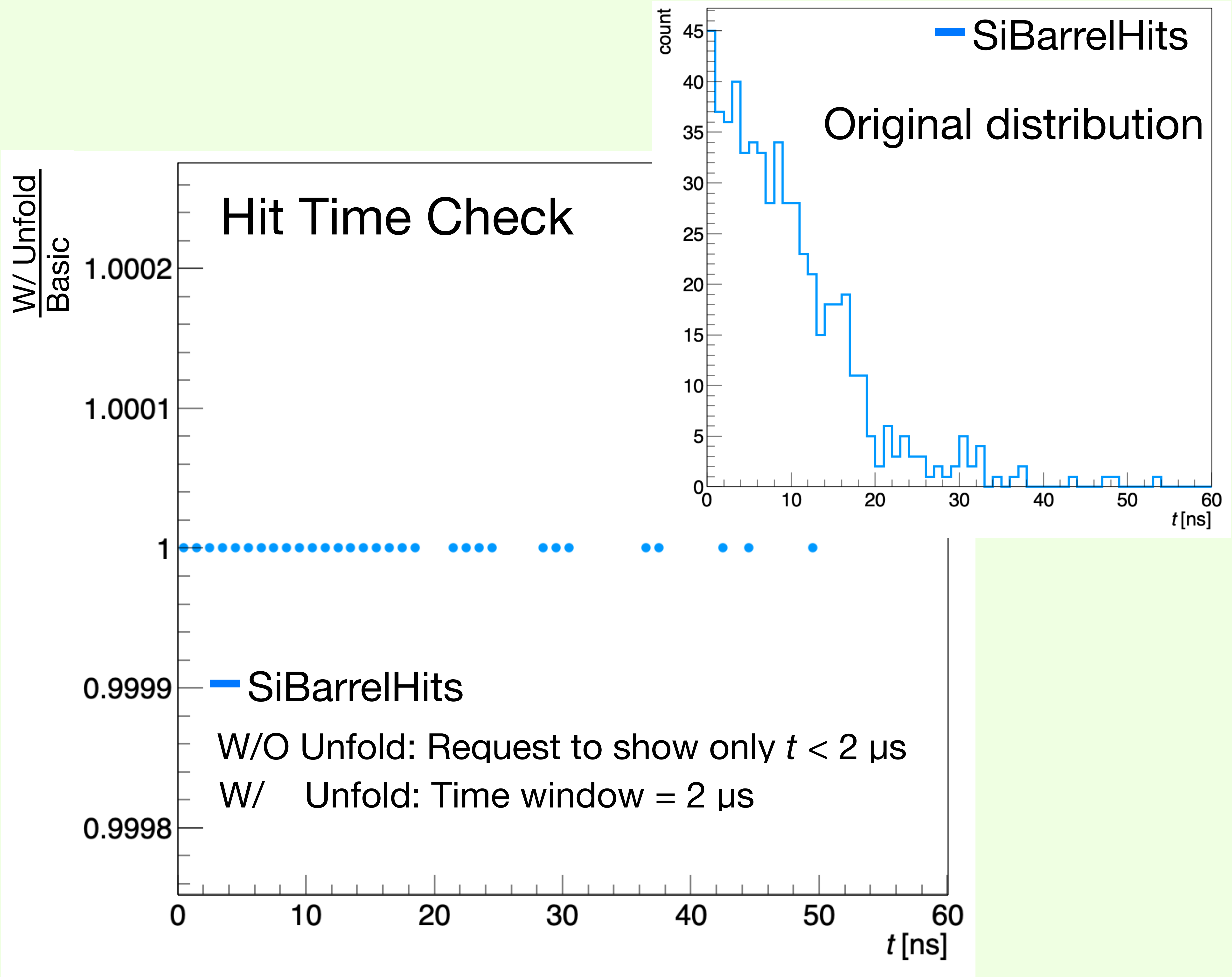
MyTimesliceSplitter (JANA2, unfolding tutorial) Nathan's work:
This code is to test JEventUnfolder.
It deparses each time region as event level.
However, it cannot be used in EICrecon directly.

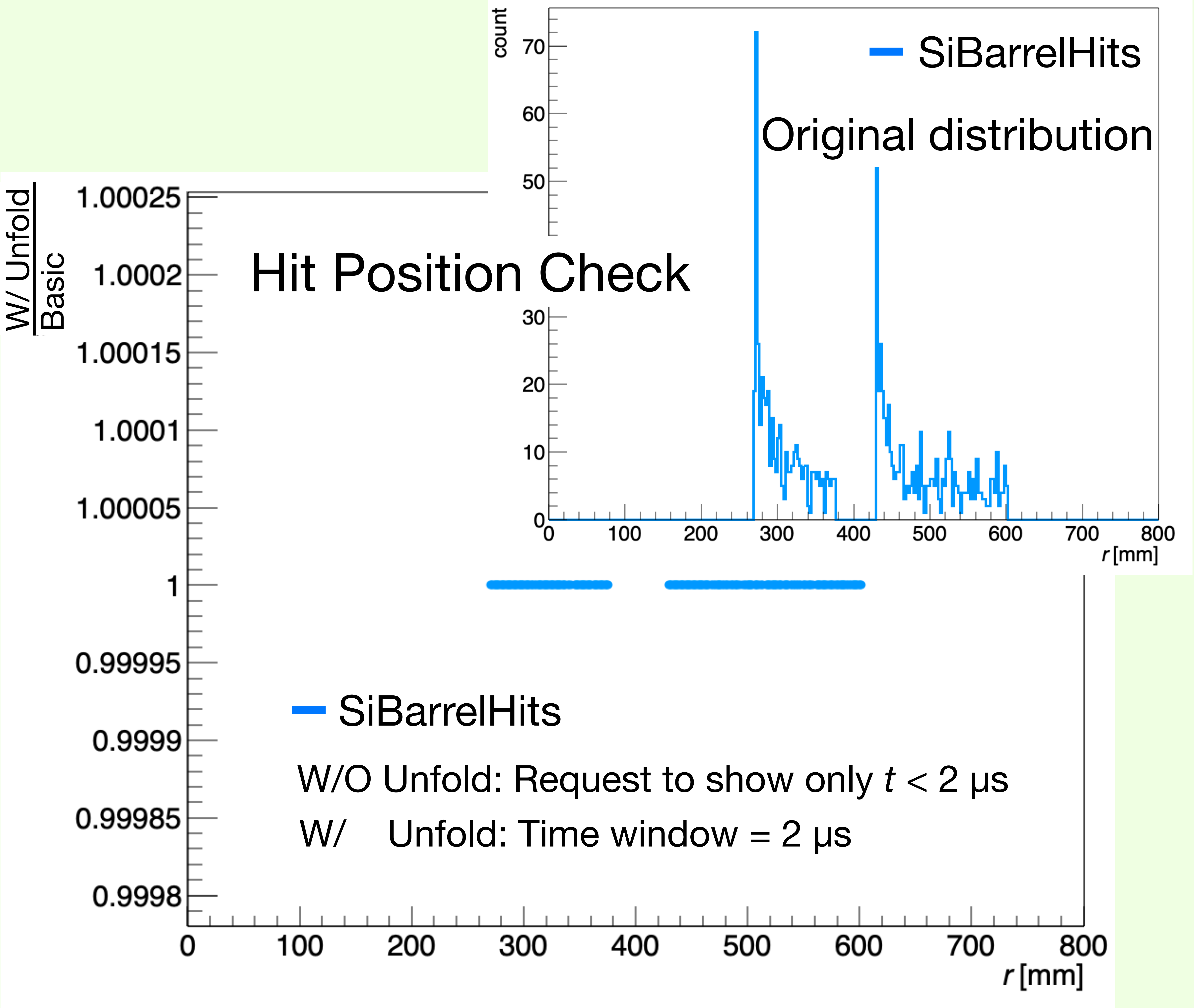
TimeframeSplitter (EICrecon):
This code performs the actual time frame splitting based on JEventUnfolder.

Need to implement time-splitting function without losing physics events.

2.1 Compare Original or W/ Unfolding for Position and Energy

Trivial test: Compare the outputs between the basic topology and the unfold topology

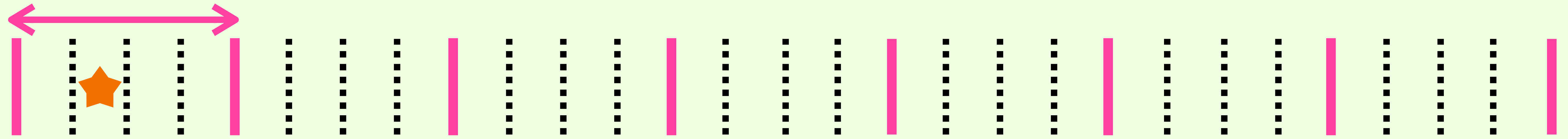




The results show a complete match between cases W/O and W/ unfolding.
These results are reasonable.

3. Time Splitting results

2 μs (500 kHz)



time frame

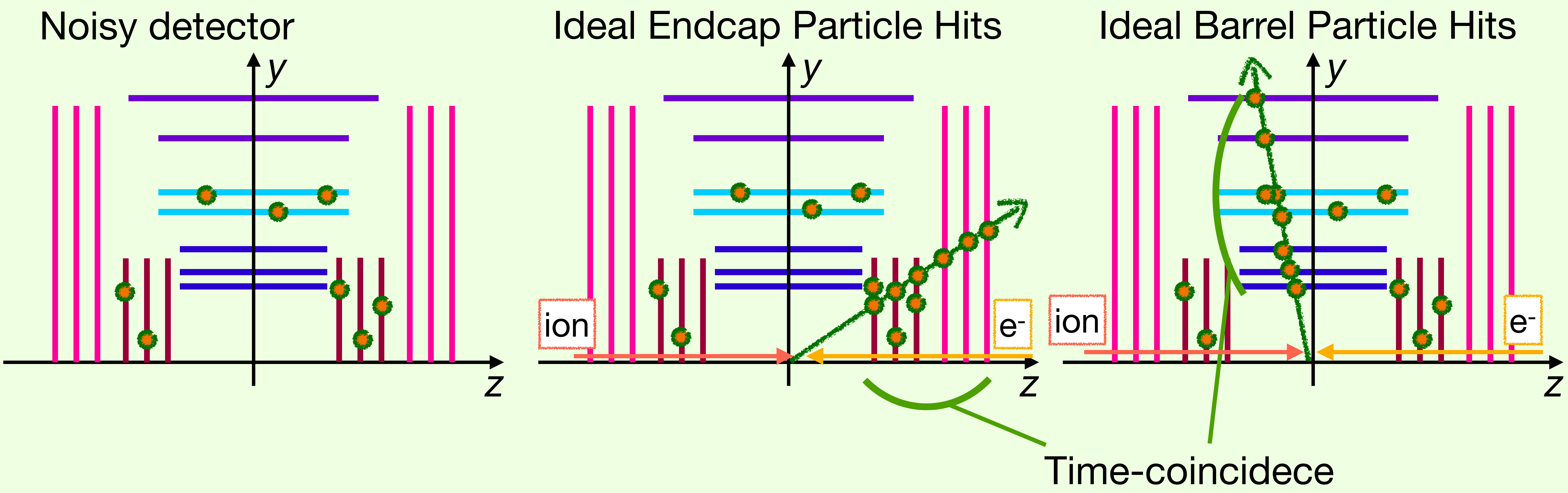
```
23:44:23.426  [info] Timeslice
HitChecker: Event 188640 Hits in: , 1.02581, 1.03809, 1.12963, 1.2371, 1.61152, 1.63005, 1.77883, 1.93878, 9.64017, 10.5798, 13.1356, 24.2638

child_idx = 0:: TimeframeSplitter: timeslice 188640 iTimeSlice 0 eTimeSlice 4
23:44:23.426  [info] PhysicsEvent
HitChecker: Event 188640 Hits in: , 1.02581, 1.03809, 1.12963, 1.2371, 1.61152, 1.63005, 1.77883, 1.93878

child_idx = 1:: TimeframeSplitter: timeslice 188640 iTimeSlice 4 eTimeSlice 8
23:44:23.925  [info] PhysicsEvent
HitChecker: Event 188640 Hits in:

child_idx = 2:: TimeframeSplitter: timeslice 188640 iTimeSlice 8 eTimeSlice 12
23:44:24.267  [info] PhysicsEvent
HitChecker: Event 188640 Hits in: , 9.64017, 10.5798

child_idx = 3:: TimeframeSplitter: timeslice 188640 iTimeSlice 12 eTimeSlice 16
23:44:24.590  [info] PhysicsEvent
HitChecker: Event 188640 Hits in: , 13.1356

child_idx = 4:: TimeframeSplitter: timeslice 188640 iTimeSlice 16 eTimeSlice 20
23:44:24.889  [info] PhysicsEvent
HitChecker: Event 188640 Hits in:
```

Input data in one time frame

separate into 4 ns
→This value itself has no meaning now.
It should be determined by hit time distributions.

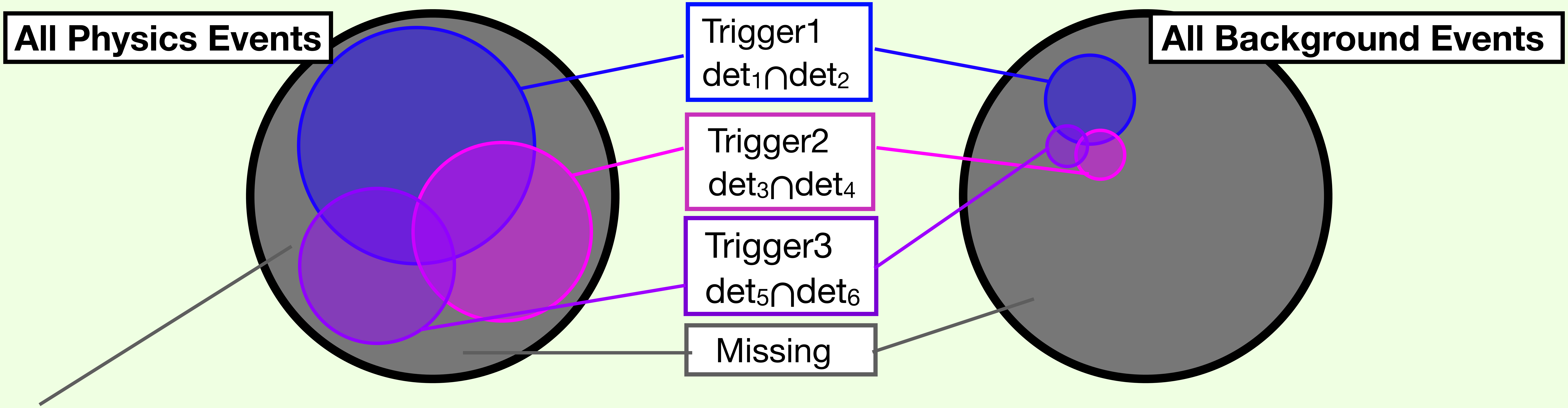
As the time split test, it works well.

Next: Develop algorithms to decline the intervals of empty or small hits.



Even if a detector can capture physics events with high efficiency, it must still be time-coincident with other detectors when there is significant noise.

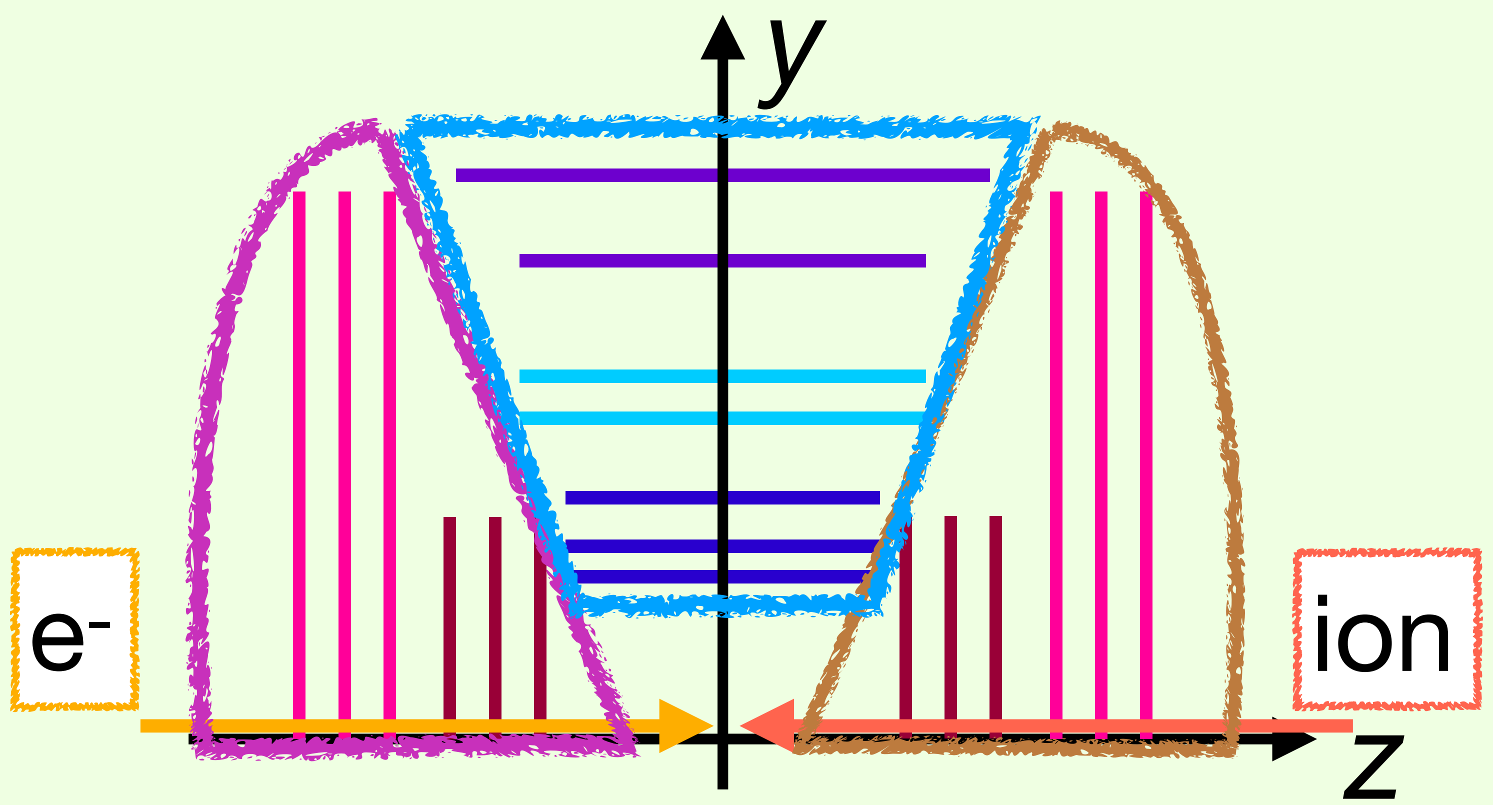
4.2 Trigger Combination



Search for the detector the combination which can capture the remaining physics events

Reduce wrong triggers
→ Strong requirement (number of hits, hit timing, number of detectors)

ex)
trig1: Backward
trig2: Barrel
trig3: Forward



4.3 Trigger Evaluation

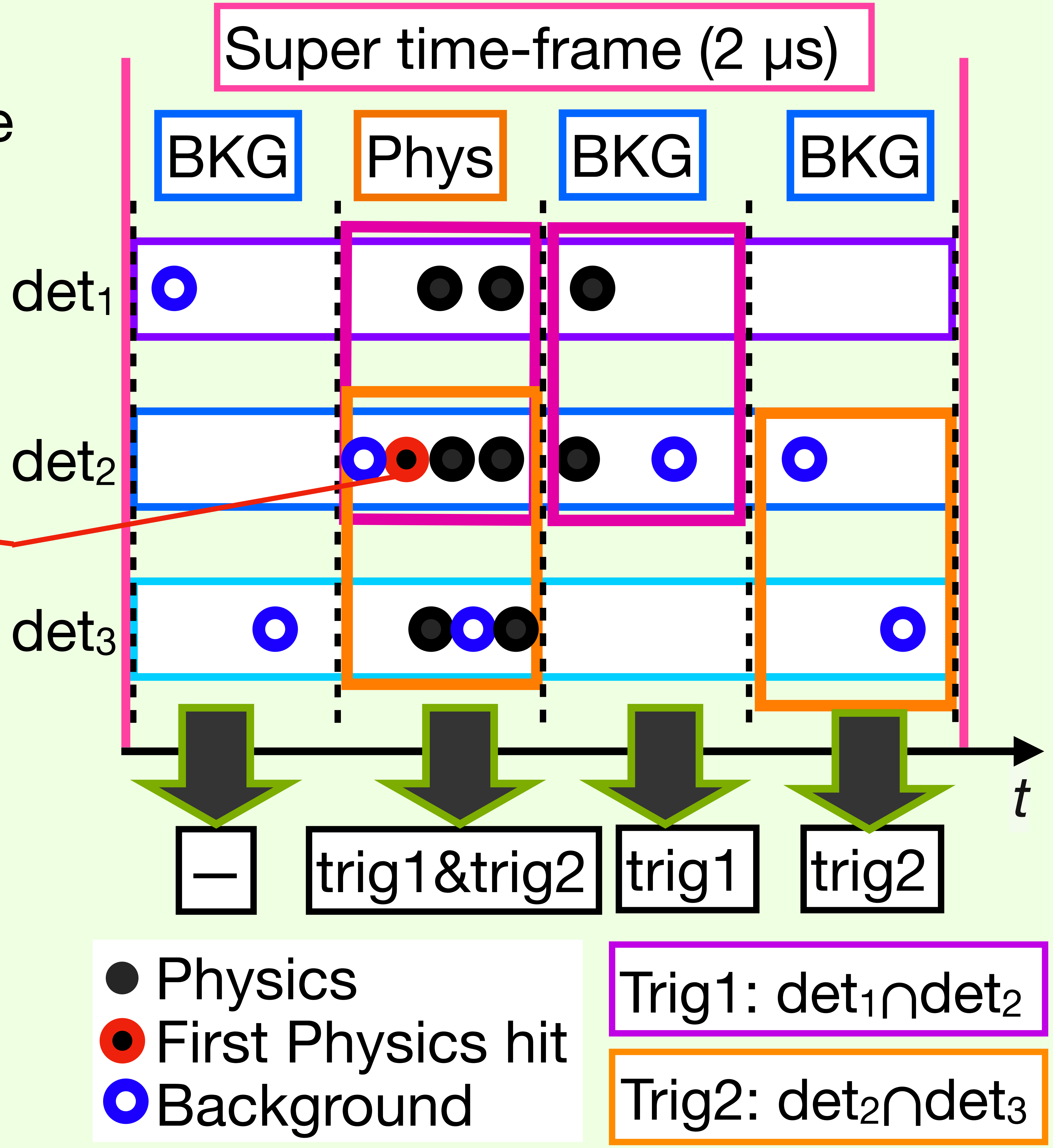
In physics simulations, where the event properties (time, number of hits, etc.) are known, we can define physics and noise regions within each time-frame.

- Separate a time-frame by arbitrary-width time slices (e.g., 20 ns).

- Regard the timeslice containing the first hit from the collision origin as a physics event.

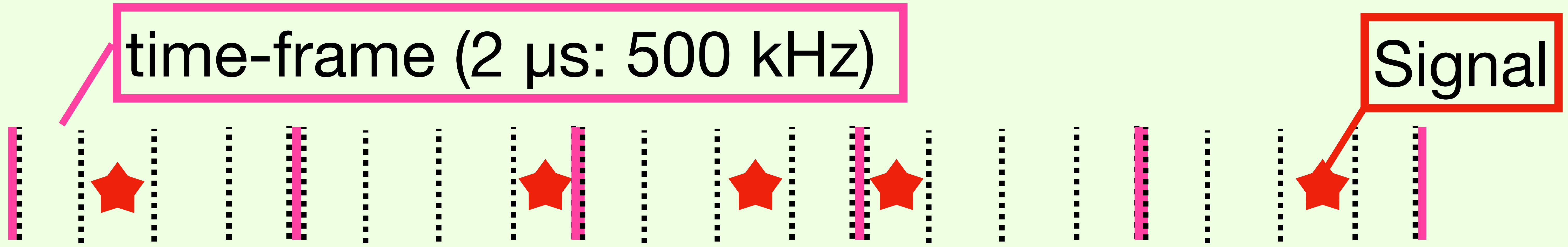
- Other timeslices are regarded as background regions, even if they include hits from the collision.

- Find triggers fired with sub-detector combinations.
(Currently, we do not require the number of hits, hit positions, hit timing correlations, etc.)



4.4 Simulation Data

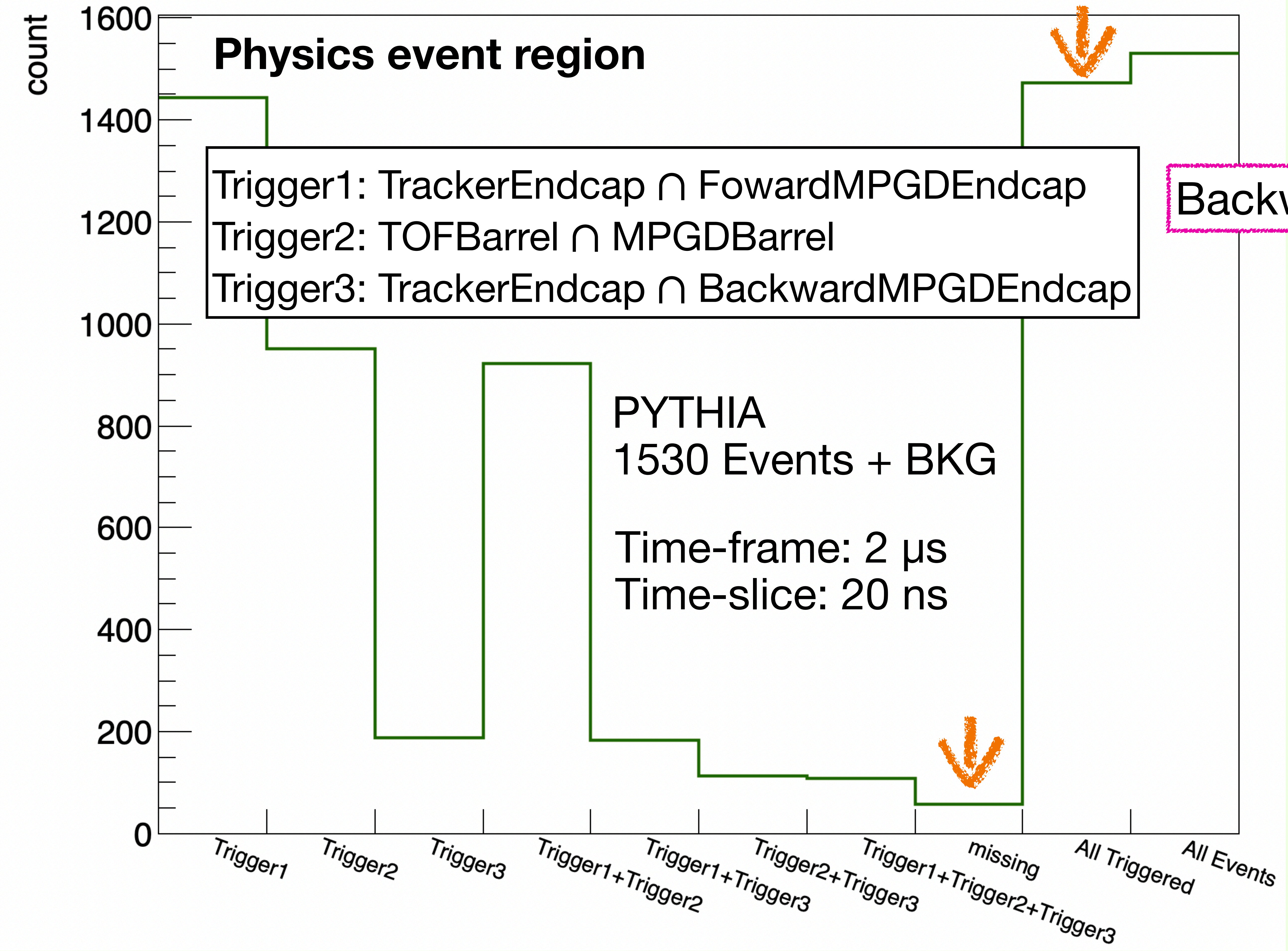
Input simulation file setting (1530 events) (**Root file page**)

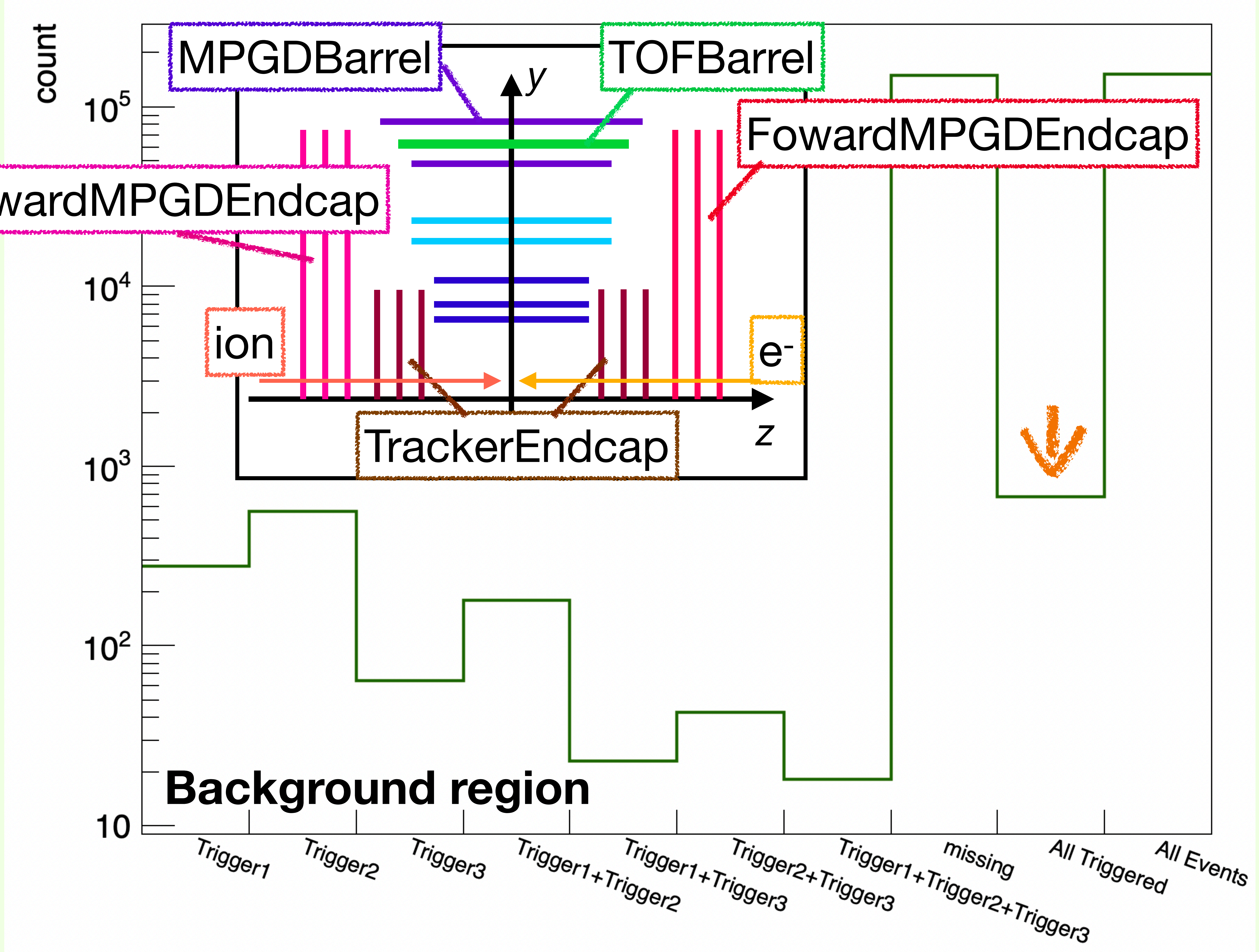


Symbol	Process	Description	Sampling Frequency (kHz)	Status Code Shift
🔴	signal	DIS NC 18x275 $Q^2>1$ (Deep inelastic scattering neutral current)	500	0
⚪	synrad	Synchrotron Radiation	14000	2000
🔵	ebrems	Electron bremsstrahlung radiation	316.94	3000
🟢	etouschek	Electron Touschek scattering (intrabeam scattering)	1.3	4000
🟡	ecoulomb	Electron Coulomb scattering processes	0.72	5000
🟣	p.b.gas	Proton beam gas interactions	22.5	6000

4.5 Results of Trigger Contributions

Trigger ratio for the physics event region and background region

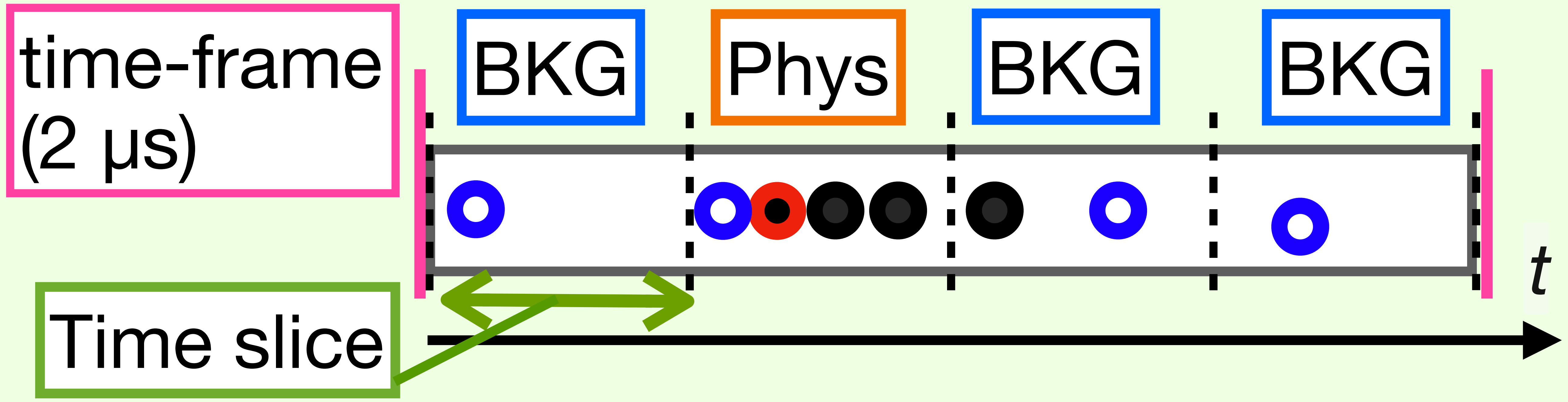




Physics event: The triggers can capture over 96% (1473/1530)
Background: The rejection ratio is about 99% (73/15300)

4.6 Trigger Efficiency for each Time-slice Width.

- All time slice width could capture over 90% physics events.
- The background reduction rates for all setting are not significantly changed.



※1 This simulation uses a 500 kHz physics rate; however, in realistic simulation (83 kHz), it is expected that the number of backgrounds increase fivefold.
→ **Next: Need more strong constrain.**

※2 This test does not consider the track reconstruction quality.
→ **Next: Evaluate how the time window affects the track reconstruction quality.**

trigger/time slice width [ns]	**5**	**10**	**20**	**200**
Physics trigger rate (trigger/all events)	1389/1530 = 90.8%	1441/1530 = 94.2%	1473/1530 = 96.3%	1512/1530 = 98.8%
BKG trigger rate (trigger/all events)	1700/612000 = 0.3%	1100/306000 = 0.4%	674/153000 = 0.4%	173/15300 = 1.1%

Progress and Plan

1. Create a new factory to time alignment (**Done**)

2. Unfolding trivial test (**Done**)

3. Time splitting test (**Done**)

4. Timing Coincidence (**Done**)

5. Injection of background events and evaluation of timing coincidence
   → time windows vs. rejection, efficiency, primary tracking, etc

   → Recently created root files including background by the background group.

   (**On going: Mid of August**)

6. Apply detector response and detector noises (September?)

7. Optimize time window, Time alignment, Interval selection (October?)

Discussion with other groups (1. Detector response)

Now we have only truth hit information.

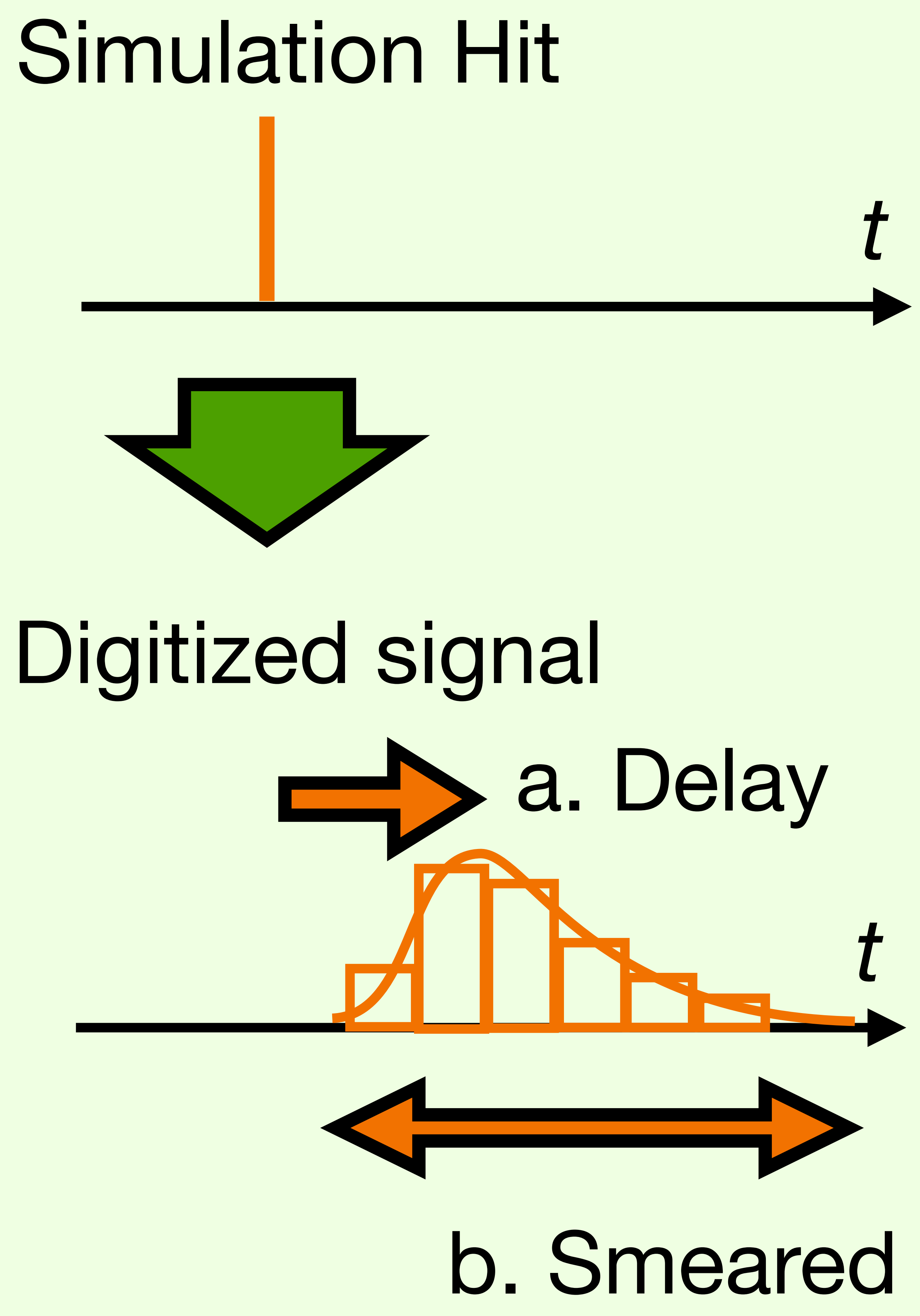
→ To evaluate the streaming readout quality, the detector response is essential.

→ Particularly, the delay and smear effects might affect the event build efficiency.

→ And each effect is different for each sub-detector.

Timeline ?

- Estimation of realistic detector response for each sub-detectors
- Implement these effects



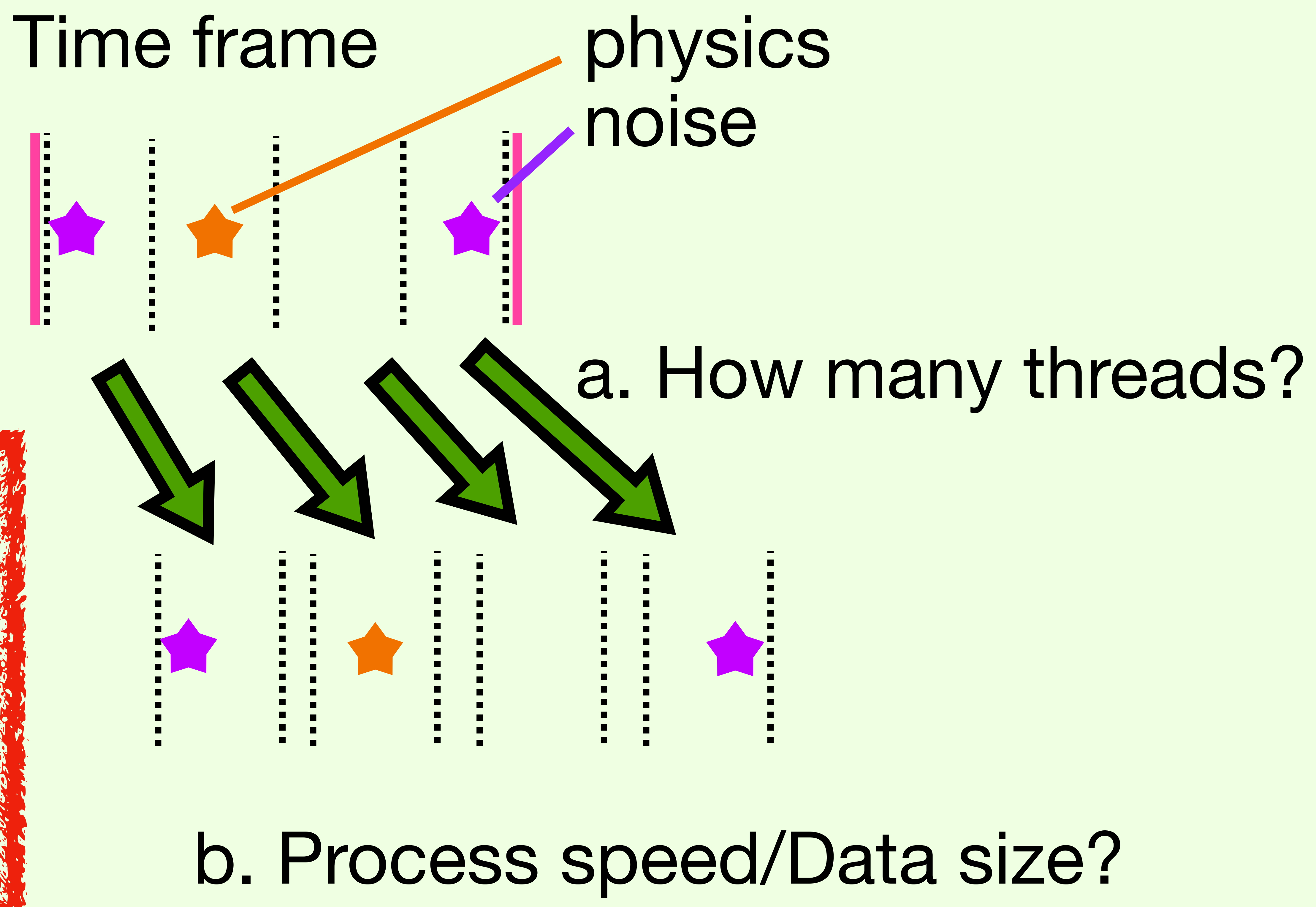
Discussion with other groups (2. Hardware performance limit)

The streaming readout performance depends on computing resource.

- Number of threads
- Process speed
- Data size

Timeline ?

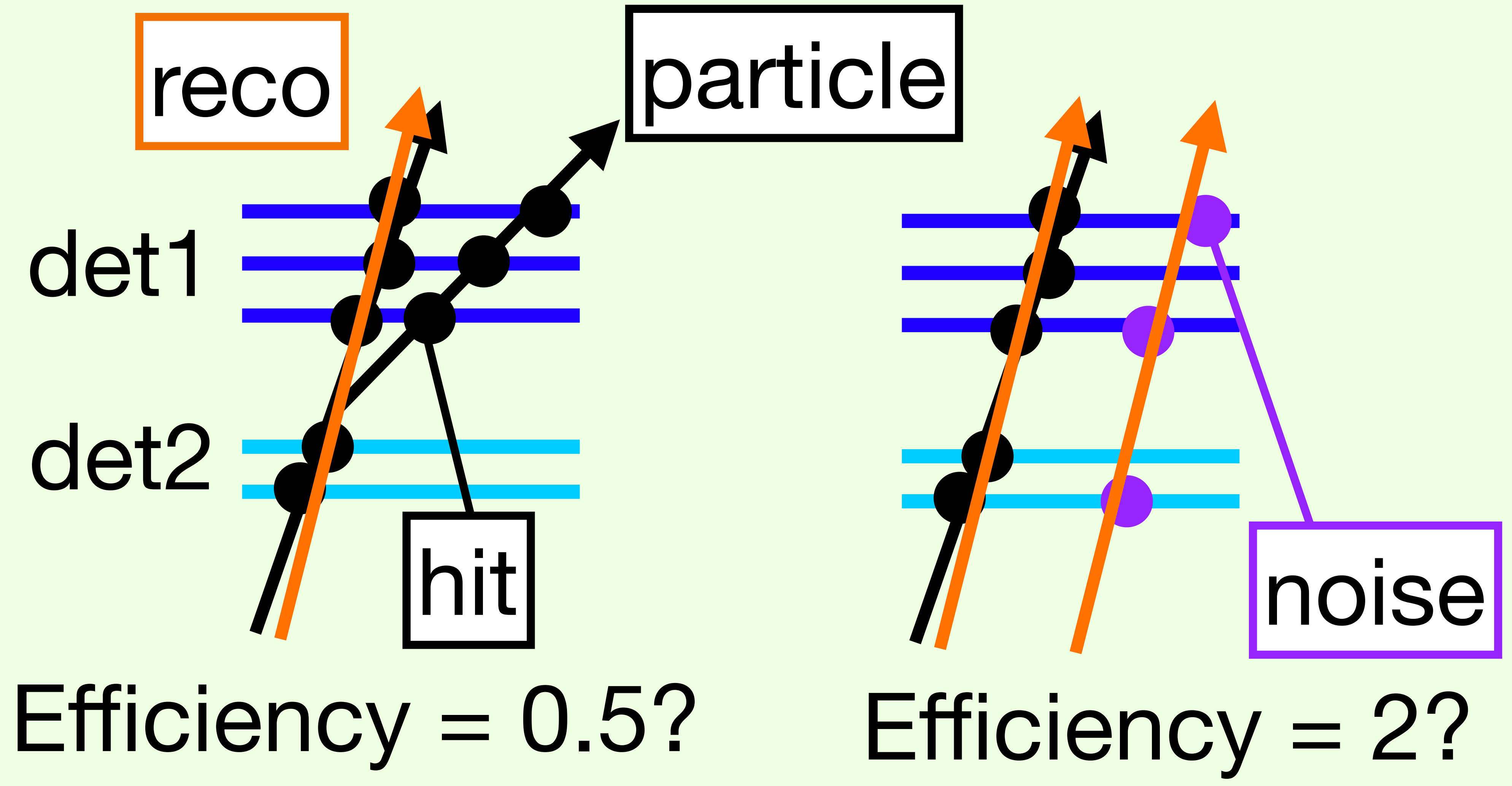
- Determine the computing power
- Run EICrecon using simulation with a test environment



Discussion with other groups (3. Track Reconstruction)

1. How to estimate reconstruction quality.
   - Efficiency
   - Resolution

→ How to match simulation particles and reconstruction tracks.
→ What type of particle should we compare? Final state? Original particle?



2. Track reconstruction requirement
   - Number of hits for each sub-detectors
   - Hit position, hit timing