Timeslices in JANA2

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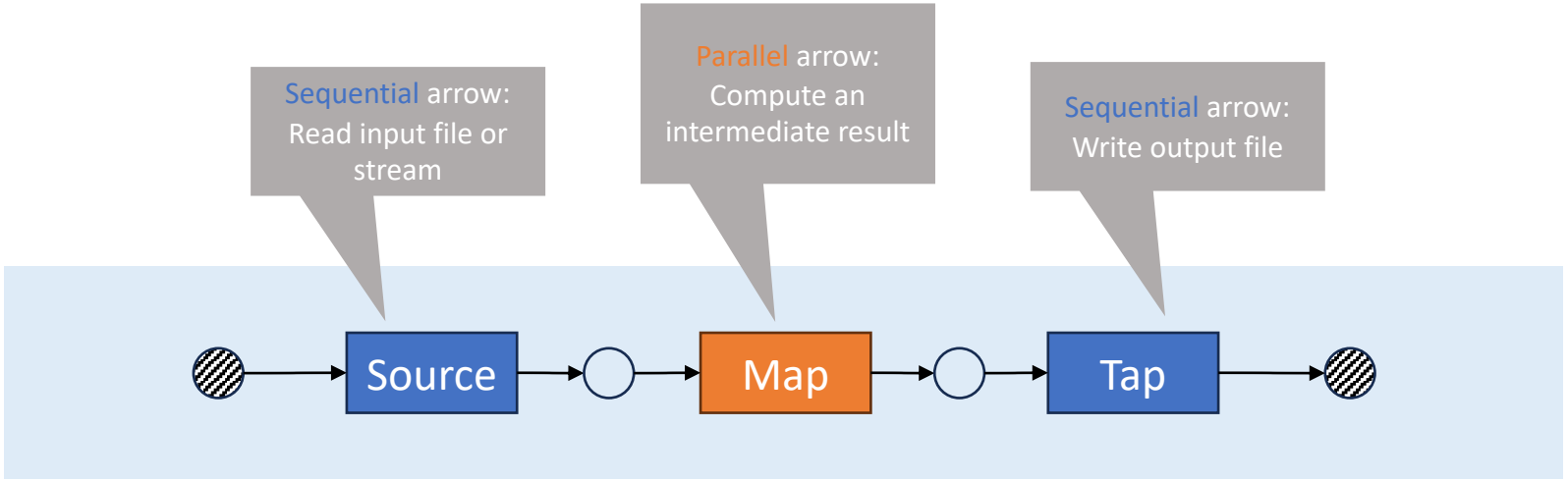
How JANA2 works internally – Formalism



- Dataflow-parallel **processing topology** consisting of **arrows, queues,** and **pools**
- Arrows represent fixed tasks which may be sequential or parallel
- Arrows may have multiple queues and pools for their inputs and outputs
- Queues allow asynchronous processing so that no thread is directly waiting for a computation to finish

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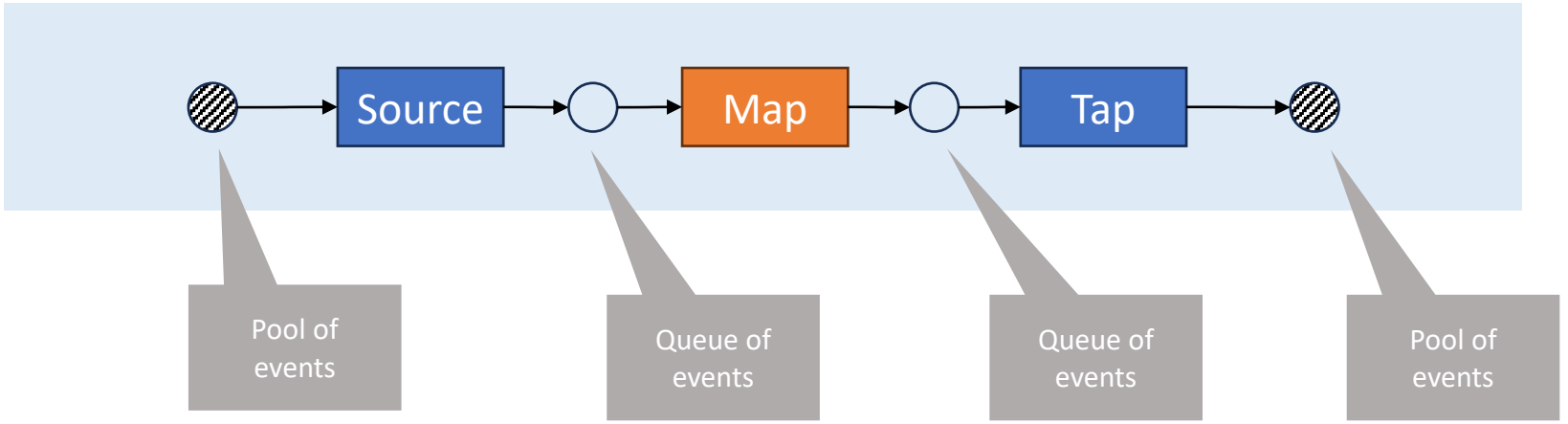

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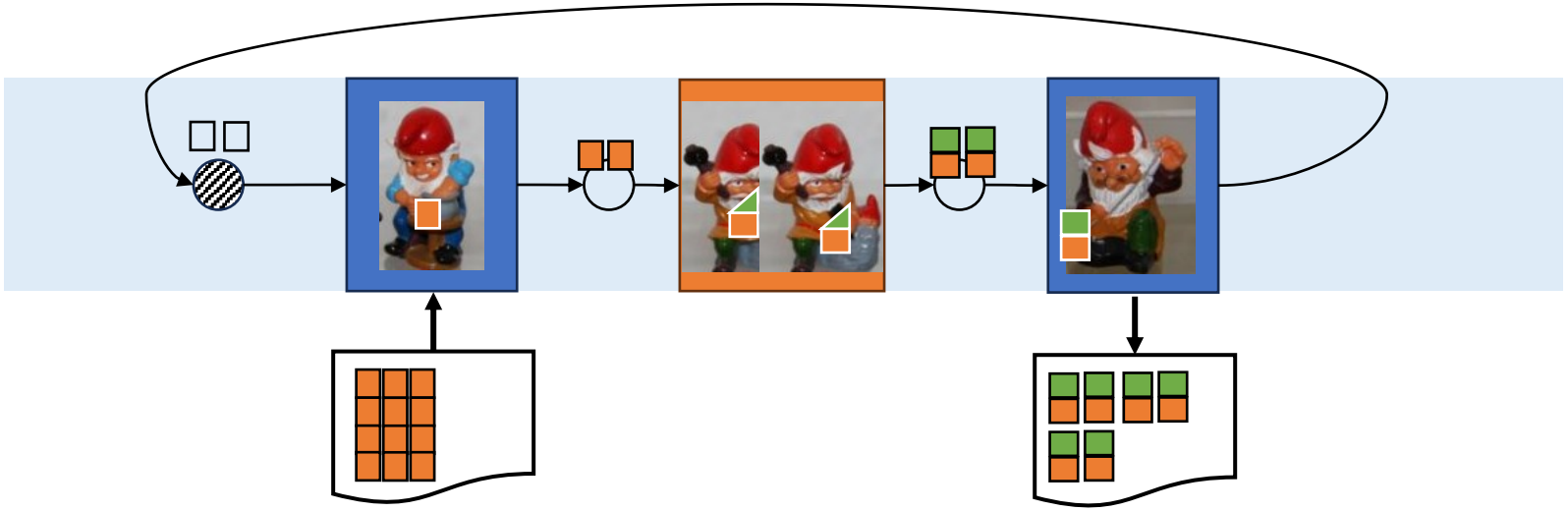
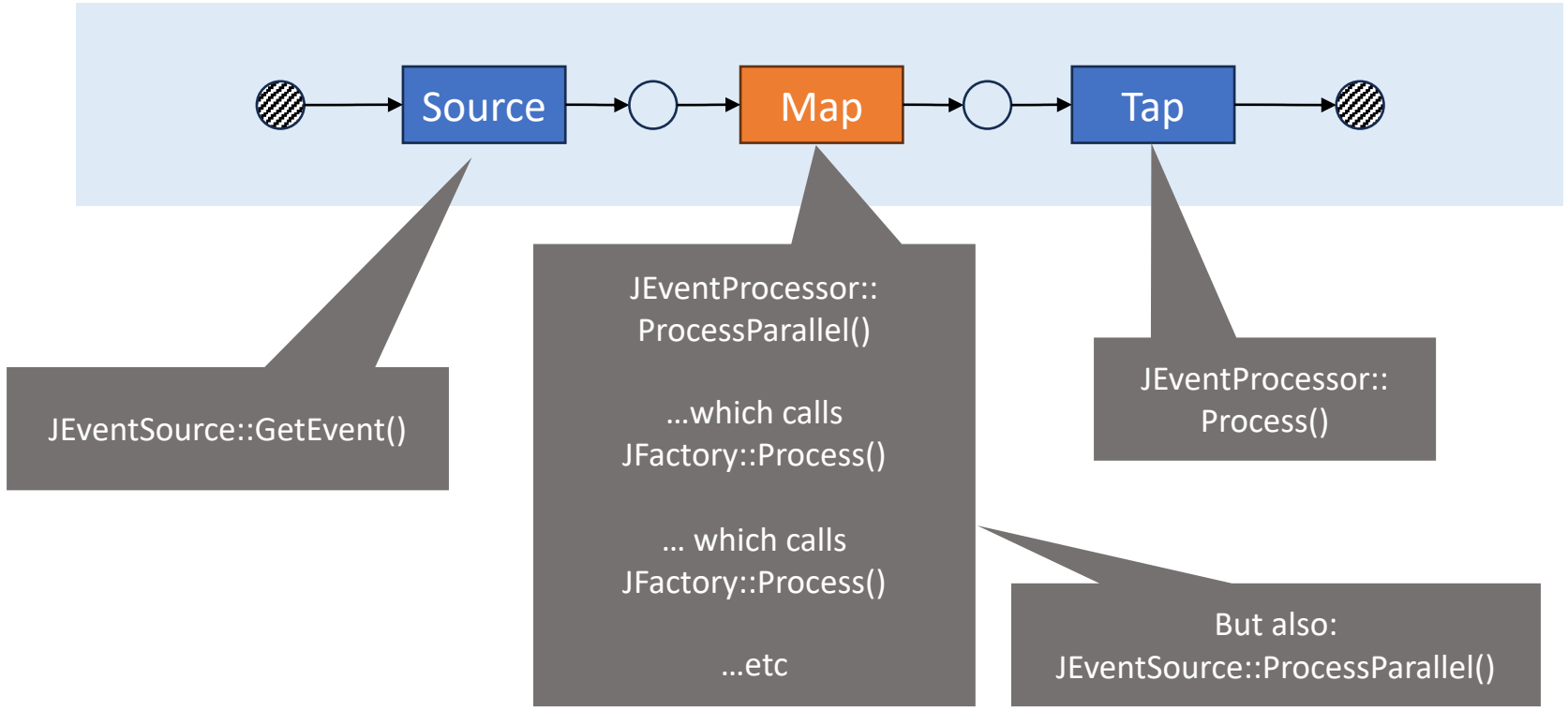
How JANA2 works internally – Cartoon



How JANA2 Components map to Arrows

- The user doesn't interact with topologies or arrows directly
- Instead, the user provides JANA with components such as JEventSources, JEventProcessors, JFactories
- Components are **decoupled** from each other. "**Only communicate through the data model**"
- JANA2 assigns the components' callbacks to arrows in the processing topology

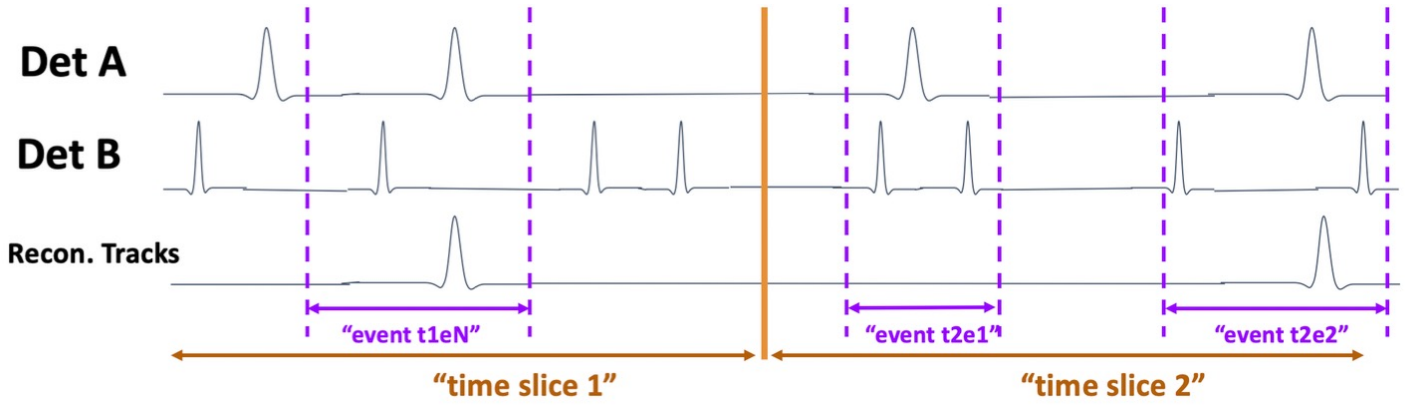


Event levels

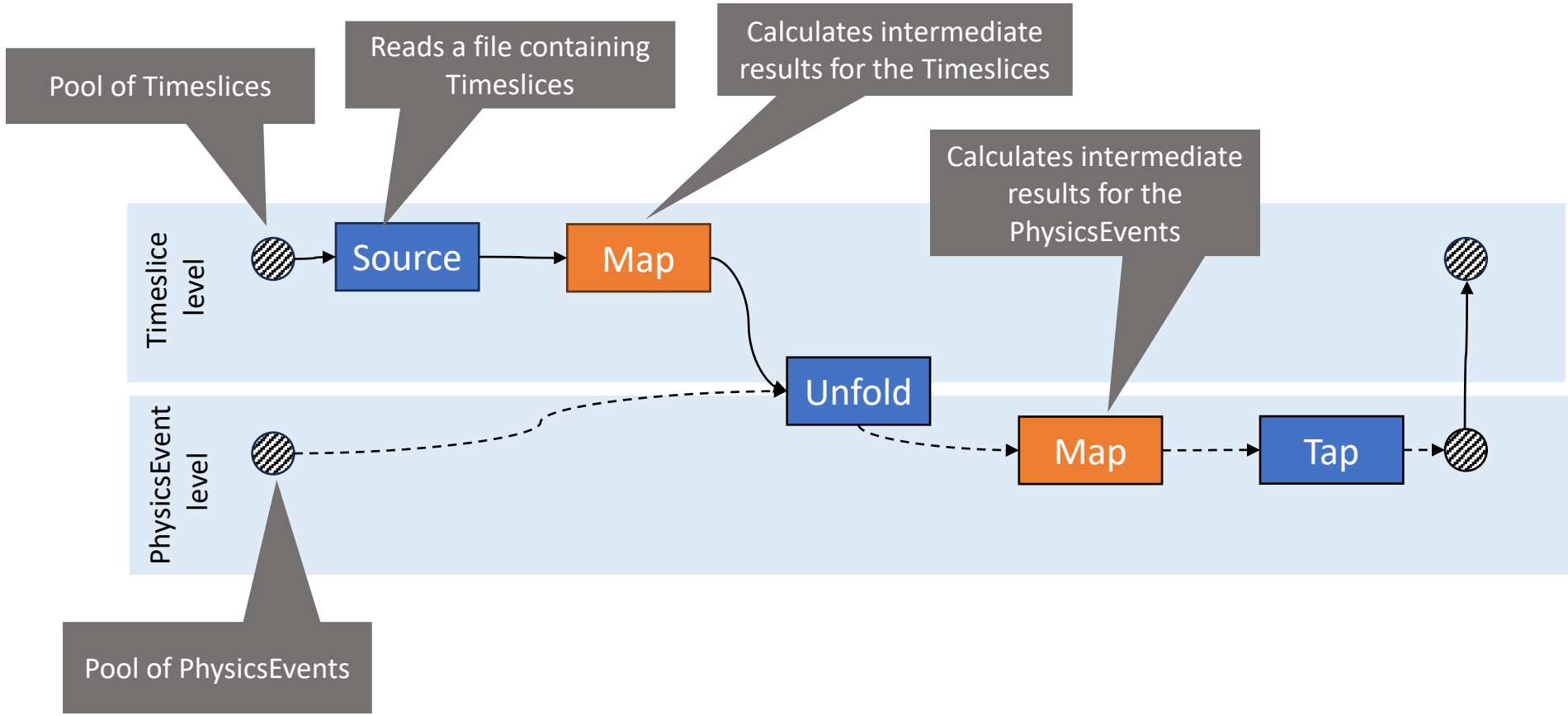
- JANA2 has a JEvent abstraction which previously meant both
  1. A container of intermediate data that is used as JANA's unit of parallelism
  2. A physics event
- Now, JEvent strictly means (1).

- Each JEvent is *tagged* (not typed!) as belonging to some JEventLevel.
- For now, JEventLevel is an enum, although user-definable event levels may be supported in the future.
- JANA2 doesn't assume that all event levels are hierarchical, e.g. that one physics event fits inside exactly one block, or even fully ordered. Instead, users establish that relationship explicitly.

```
enum class JEventLevel {
    Run,
    Subrun,
    Timeslice,
    Block,
    SlowControls,
    PhysicsEvent,
    Subevent,
    Task,
    None
};
```



Generalizing to two event levels



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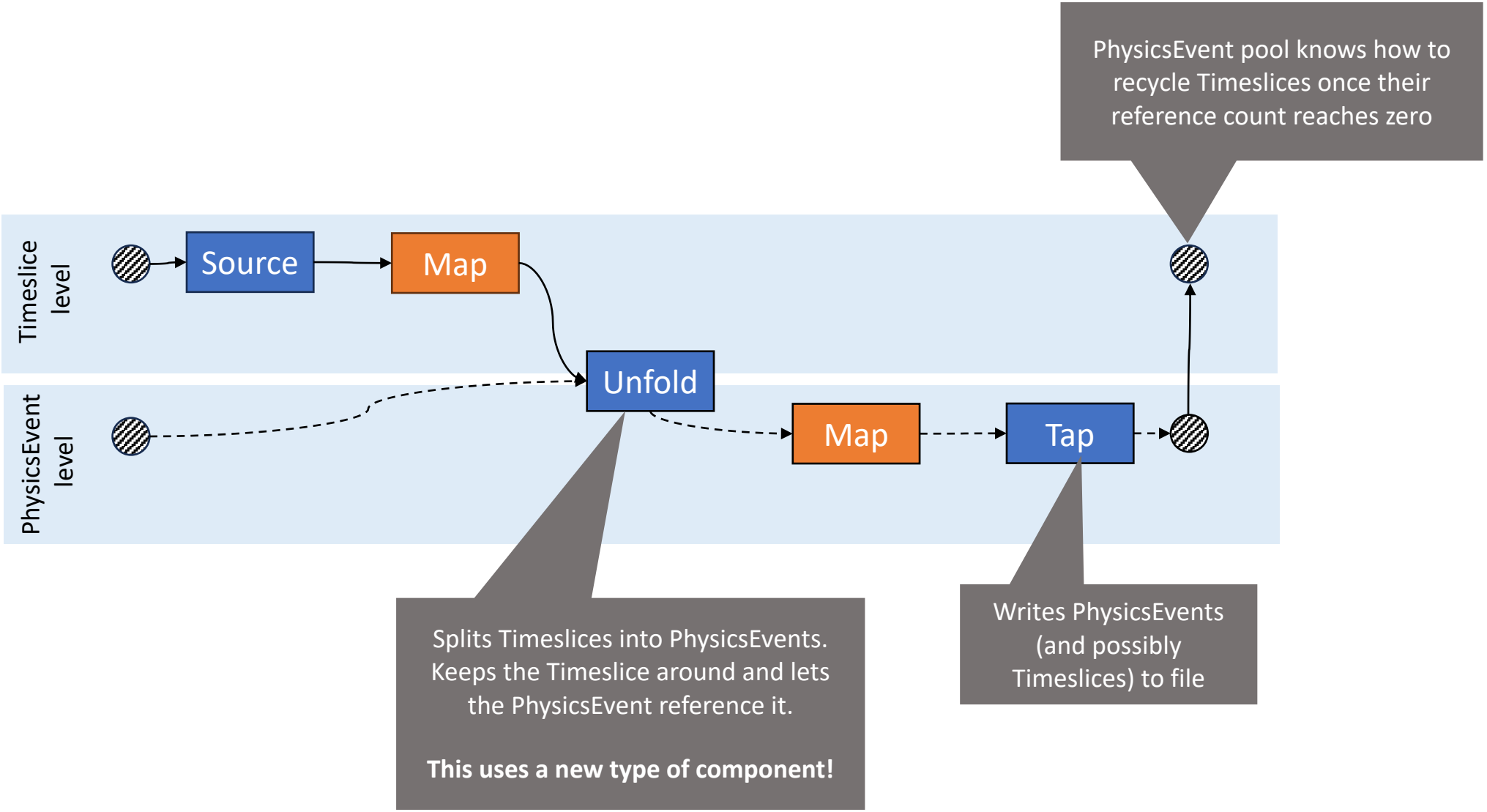


Introducing JEventUnfolder component

```
Result Unfold(
    const JEvent& parent,
    JEvent& child,
    int child_index) override;
```

```
enum class Result {
    NextChildNextParent,
    NextChildKeepParent,
    KeepChildNextParent
};
```

- JEventUnfolder looks and feels very similar to a JOmniFactory
- Users may declare Parameters, Services, Resources, Inputs, Outputs, or access everything through JApplication/JEvent
- No Generator needed as there will only be one instance active for any given level, same as JEventProcessors

- Provides an **Unfold** callback
  - Name comes from functional programming and stream processing
  - Unfold handles both “splitting” and “merging” streams
  - Returns a Result code indicating whether the parent and child belong together
  - We never need to have all PhysicsEvents corresponding to one Timeslice in memory at once

- Inputs come from the parent event (e.g. Timeslice)
- Outputs are inserted into the child event (e.g. PhysicsEvent)
- The child event keeps a pointer to the parent event around, so that any factory can access Timeslice-level data

What does this mean for our Factories?

- OmniFactories look almost exactly the same as before
- OmniFactories each belong to a particular event level. All of their outputs belong to that level.
- OmniFactory::Input helper now takes event level as an optional parameter
- Event level information can be applied **entirely** at the JOmniFactoryGenerator level
- The same algorithm and factory can be wired and reconfigured for different event levels

```
struct MyProtoclusterFactory
  : public JOmniFactory<MyProtoclusterFactory> {

PodioInput<ExampleHit> hits_in {this};
PodioOutput<ExampleCluster> clusters_out {this};

void Configure() {
}

void ChangeRun(int32_t run_nr) {
}

void Execute(int32_t run_nr, uint64_t evt_nr) {
    ...
}
```

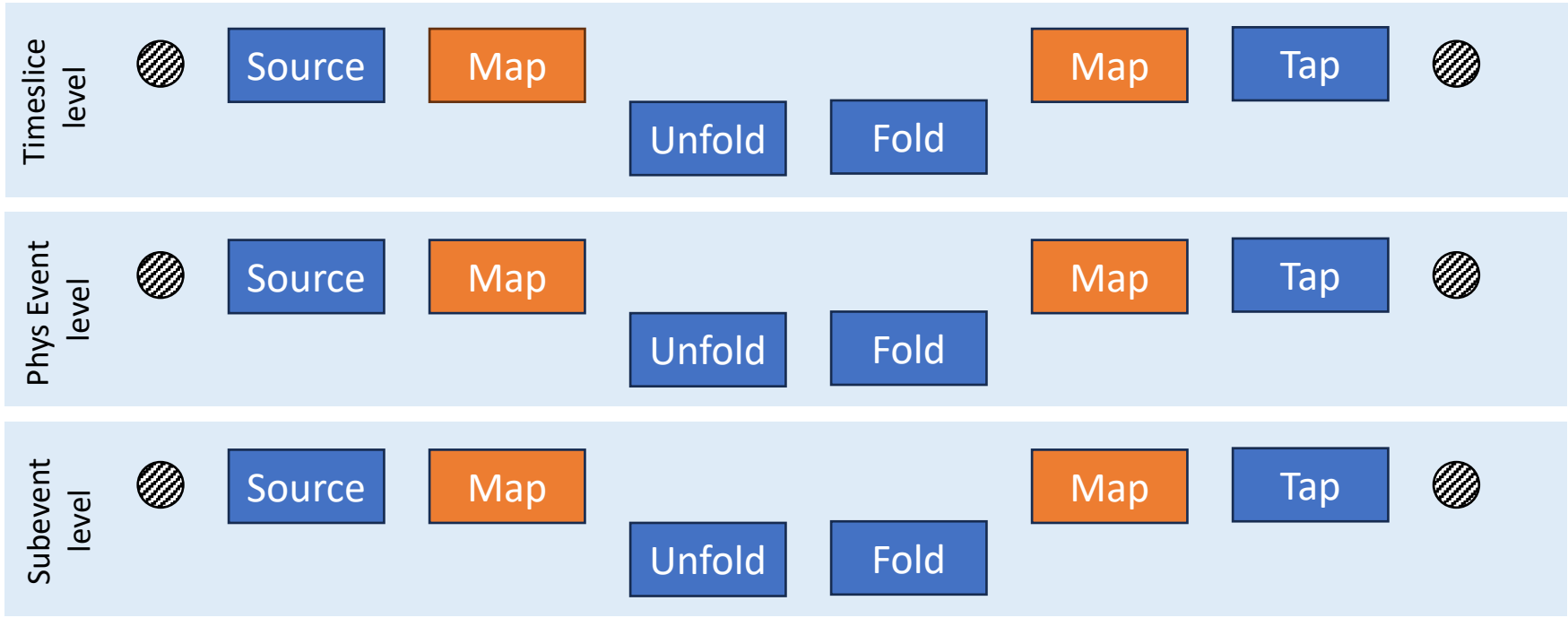
```
// Factory that produces timeslice-level protoclusters
// from timeslice-level hits
app->Add(new JOmniFactoryGeneratorT<MyProtoclusterFactory>(
    { .tag = "timeslice_protoclusterizer",
      .level = JEventLevel::Timeslice,
      .input_names = {"hits"},
      .output_names = {"ts_protoclusters"}
    }));

// Factory that produces event-level protoclusters
// from event-level hits
app->Add(new JOmniFactoryGeneratorT<MyProtoclusterFactory>(
    { .tag = "event_protoclusterizer",
      .input_names = {"hits"},
      .output_names = {"evt_protoclusters"}
    }));
```

What does this mean for JEventSources?

```
#include <JANA/JEventSourceGenerator.h>
#include "MyFileReader.h"

class MyFileReaderGenerator : public JEventSourceGenerator {

    double CheckOpenable(std::string resource_name) override {
        if (resource_name.find(".root") != std::string::npos) {
            return 0.01;
        }
        return 0;
    }

    JEventSource* MakeJEventSource(std::string resource_name) override {

        auto source = new MyFileReader;

        if (resource_name.find("timeslices") != std::string::npos) {
            source->SetLevel(JEventLevel::Timeslice);
        }
        else {
            source->SetLevel(JEventLevel::PhysicsEvent);
        }
        return source;
    }
};
```

- JANA2 can figure out that the input file contains timeslices from inside the JEventSourceGenerator
- This means that this critical information is already known before the time of topology construction
- The topology builder is able to decide what topology to build based off what components were provided.
- The same PODIO event source class can be reused for files containing timeslices vs physics events with minimal modification

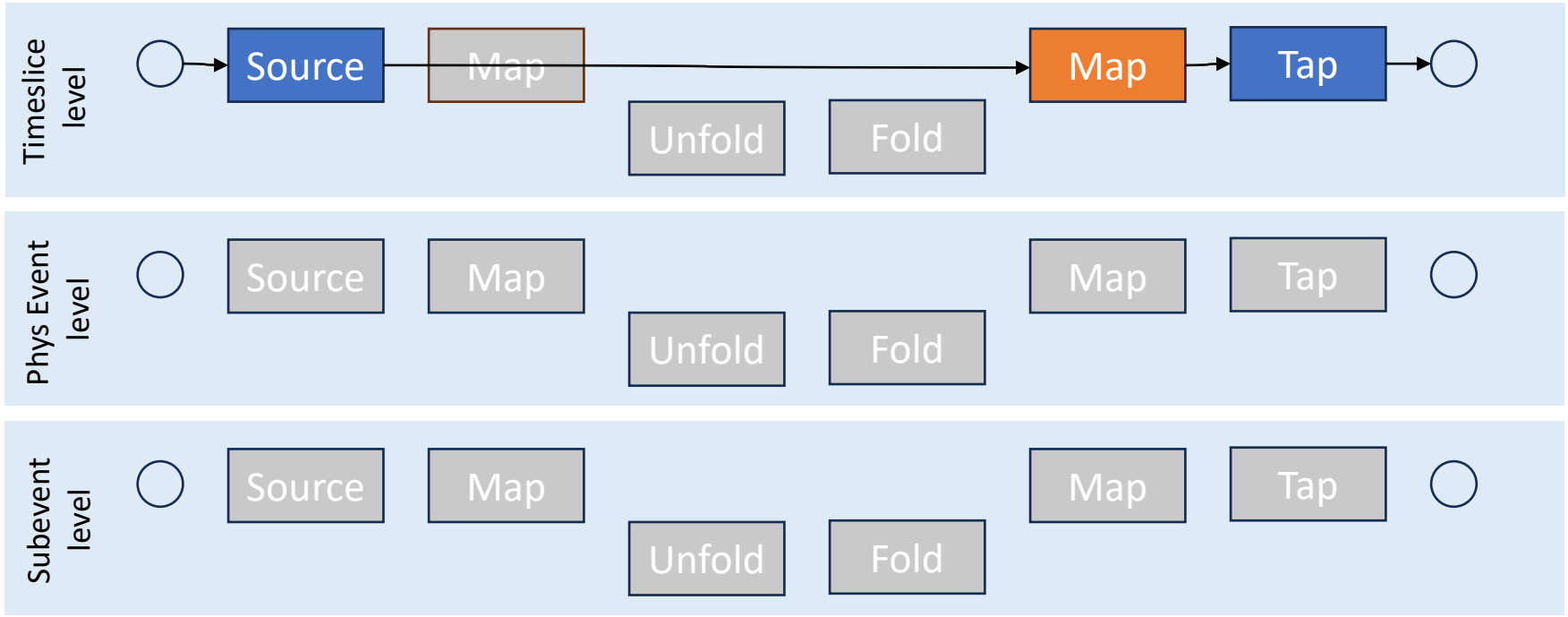
Generalizing further



- Source calls
  - JEventSource::GetEvent()
- Map calls
  - JOmniFactory::Process()
  - JEventProcessor::ProcessParallel()
  - JEventSource:: ProcessParallel()
  - JEventUnfolder:: ProcessParallel()
  - JEventFolder:: ProcessParallel()
- Tap calls
  - JEventProcessor::Process()
- Unfold calls
  - JEventUnfolder::Unfold()
- Fold calls
  - JEventFolder::Fold()

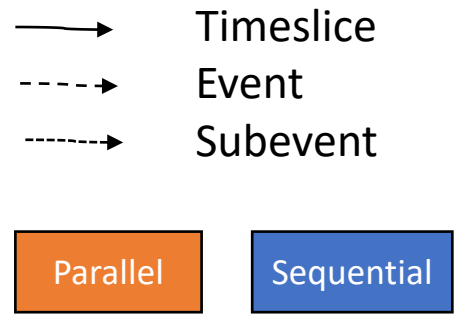
- The arrows in the further generalized topology (abstractly) form a grid:
  `{Source, Map1, Unfold, Fold, Map2, Tap} x {Timeslice, PhysicsEvent, Subevent,…}`
- Depending on which components the user provides, JANA2 can activate and wire the arrows automatically
- This wiring could also be specified manually

Basic topology

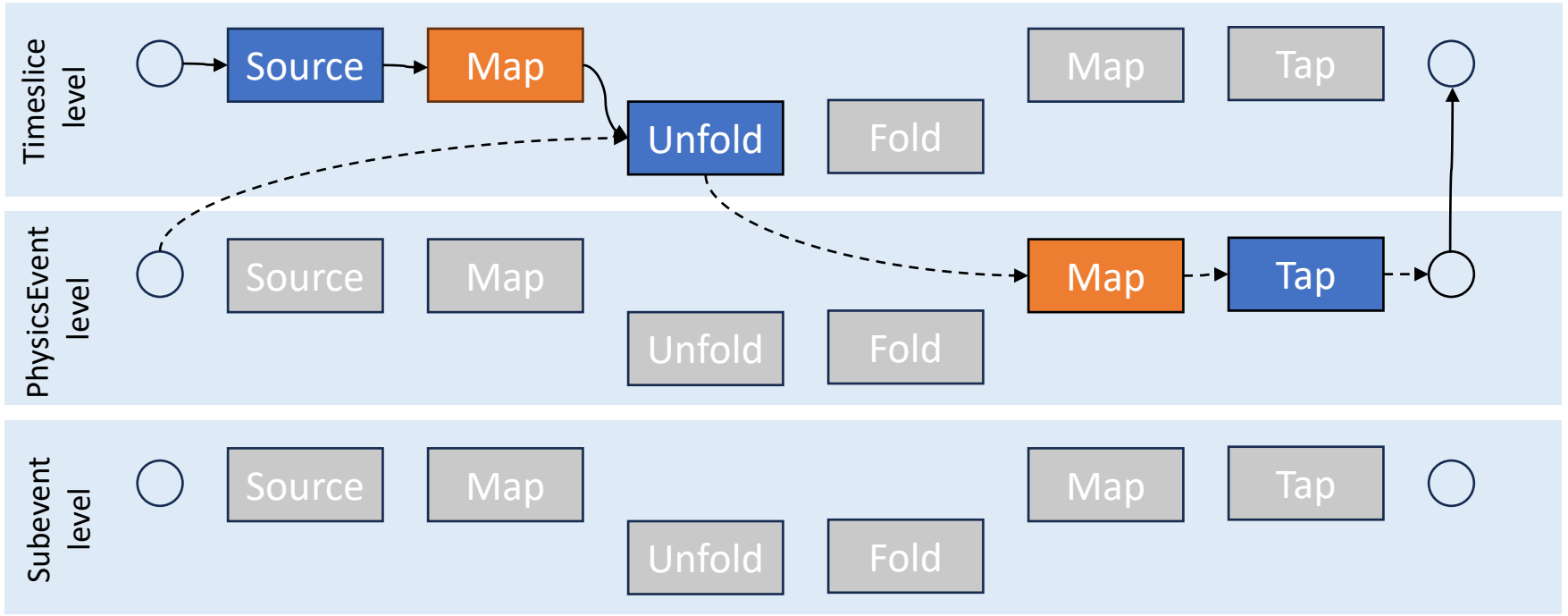


User provides:

- JEventSource [Timeslice]
- JEventProcessor [Timeslice]
- JFactory [Timeslice]



Timeslice splitting topology



User provides:

- JEventSource [T]
- JFactory [T]
- JEventUnfolder [T -> P]
- JEventProcessor [P]
- JFactory [P]

Timeslice

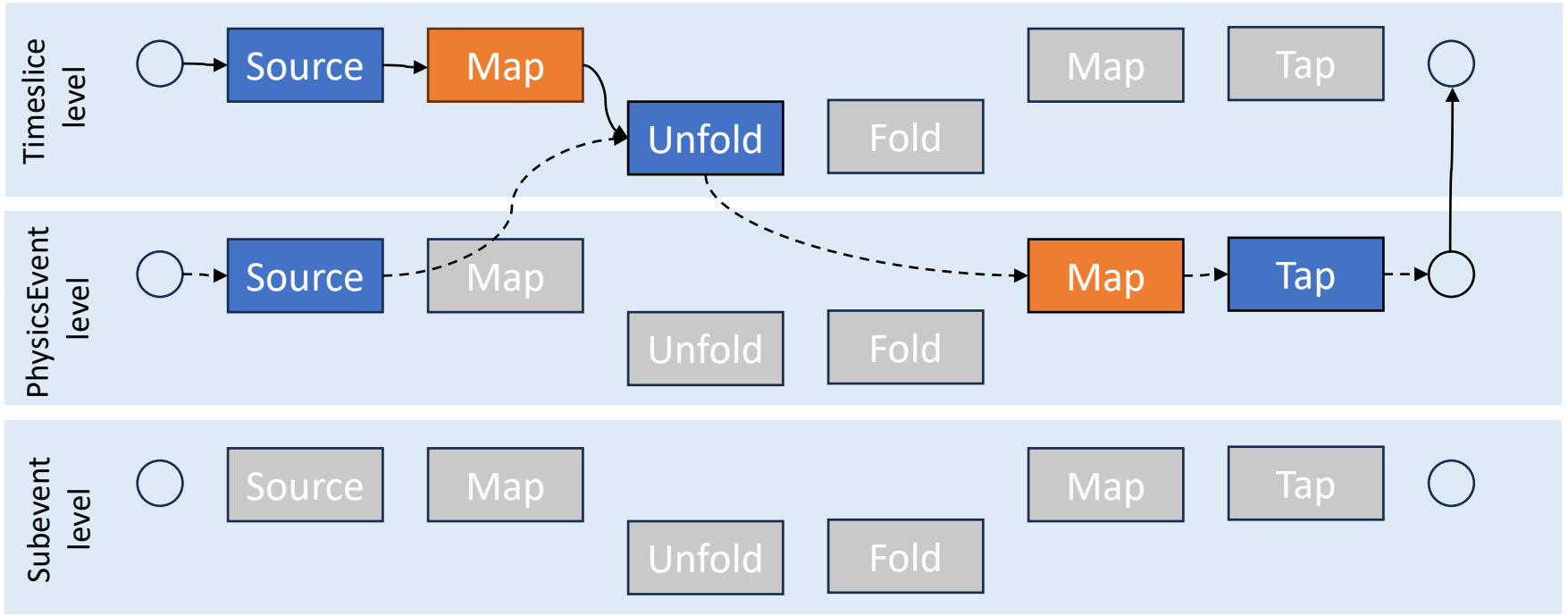
Event

Subevent

Parallel

Sequential

Slow/fast event merging topology



User provides:

- JEventSource [T]
- JEventSource [P]
- JEventProcessor [P]

- JEventUnfolder [T -> P]

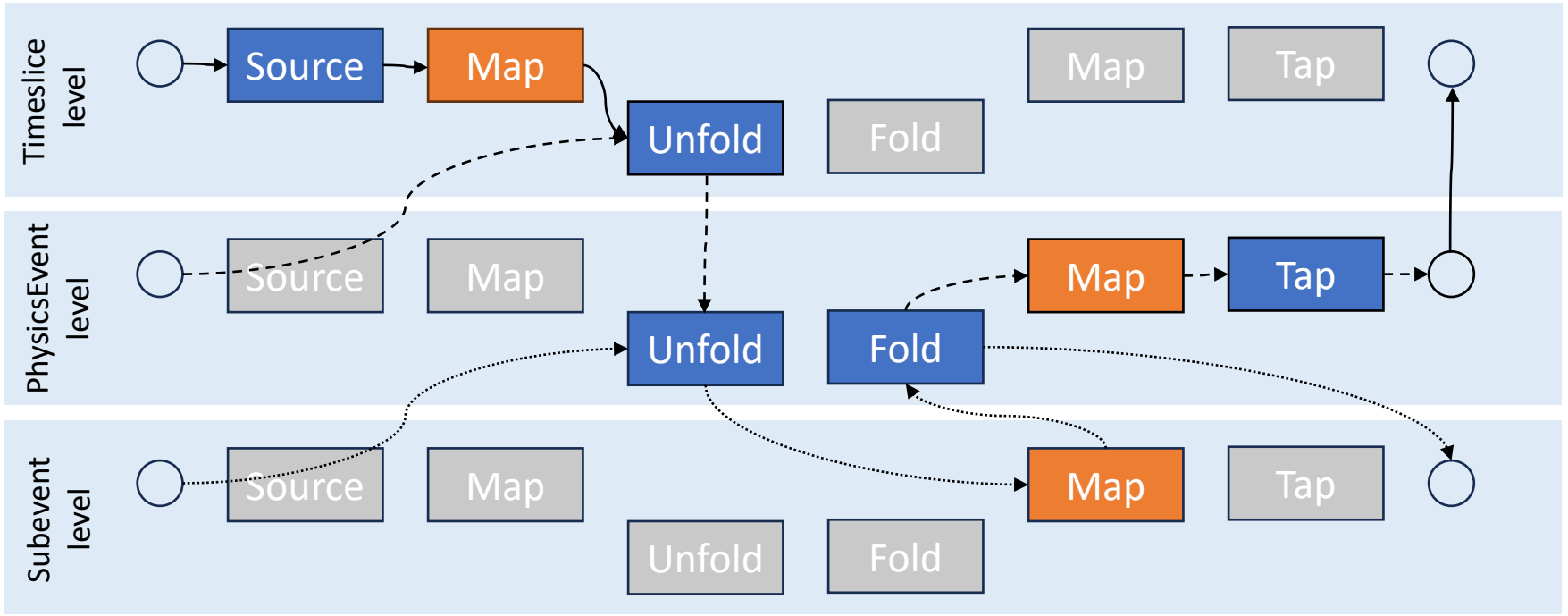
- JFactory [T]
- JFactory [P]

Timeslice
Event
Subevent

Parallel

Sequential

Timeslices + subevents topology



User provides:

- JEventSource [T]
- JEventProcessor [P]

- JEventUnfolder [T -> P]
- JEventUnfolder [P -> S]
- JEventFolder[S -> P]

- JFactory [T]
- JFactory [P]
- JFactory [S]

Timeslice
Event
Subevent

Parallel
Sequential

Memory management – Concept

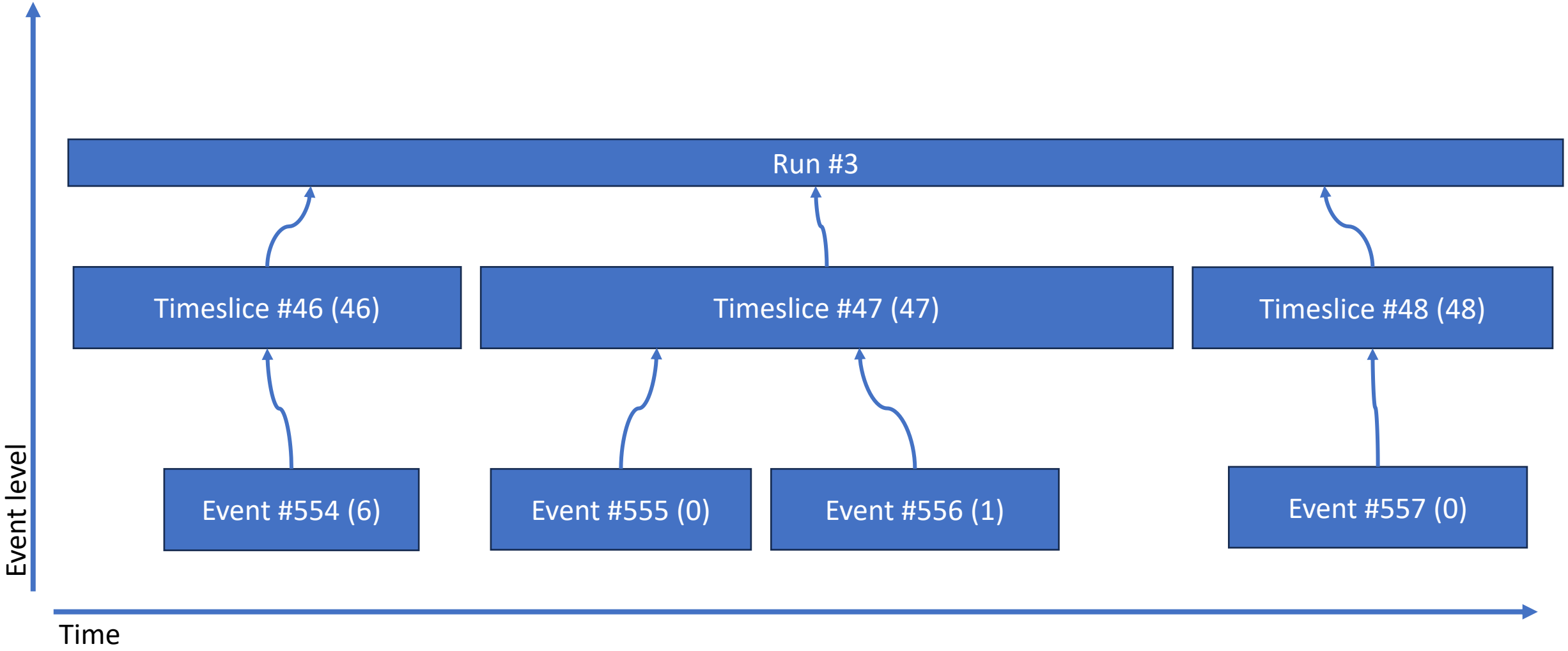
As of right now:

- Parents have shared-ptr-like semantics (except they are recycled to a pool)
- Parents always outlive their children
- Events can have multiple parents
- Parents are uniquely identified by their event level: “Diamond inheritance” not permitted
- To get data from a parent, you have to ask for the parent explicitly (no searching or “importing into the global namespace”)

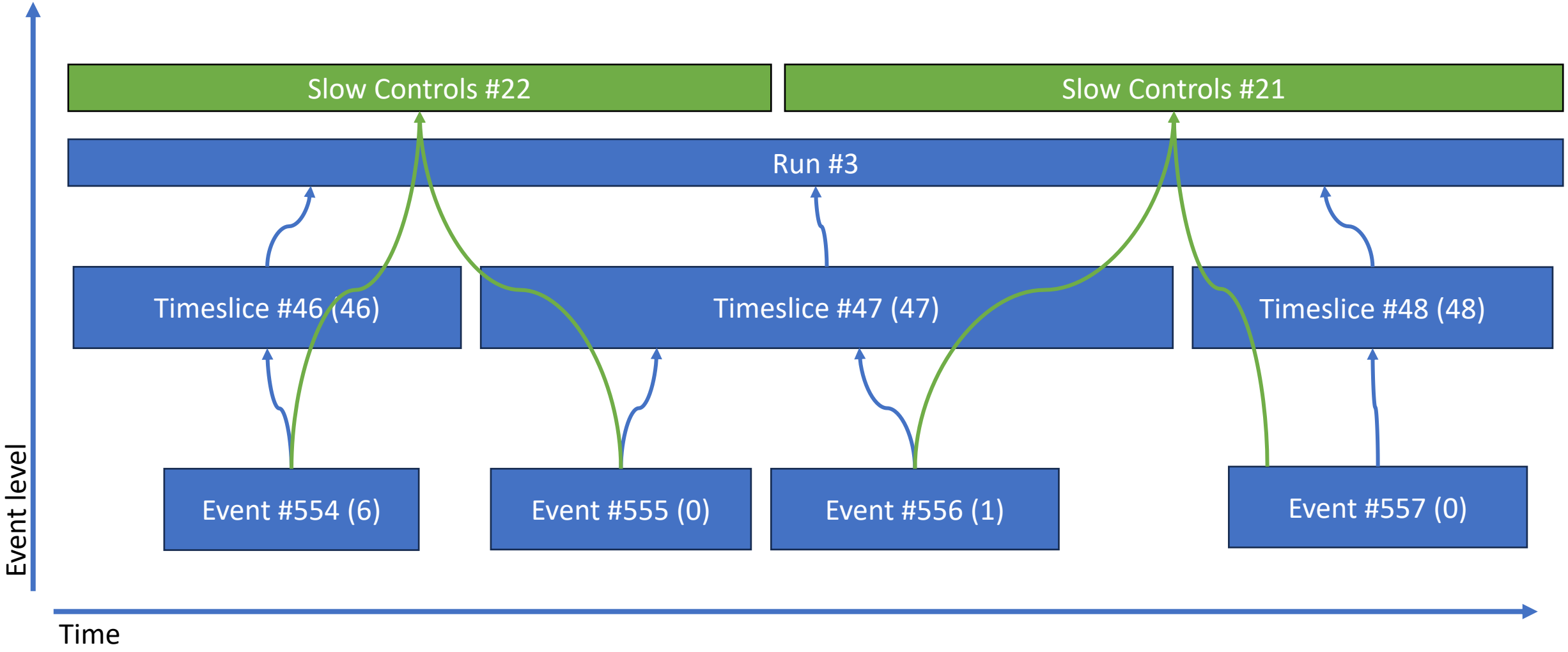
Future improvements:

- Event sources will eventually be able to emit events that already have parents
- Data in adjacent timeslices will be accessible via a ‘sibling’ reference, analogous to parents except weak-ptr-like

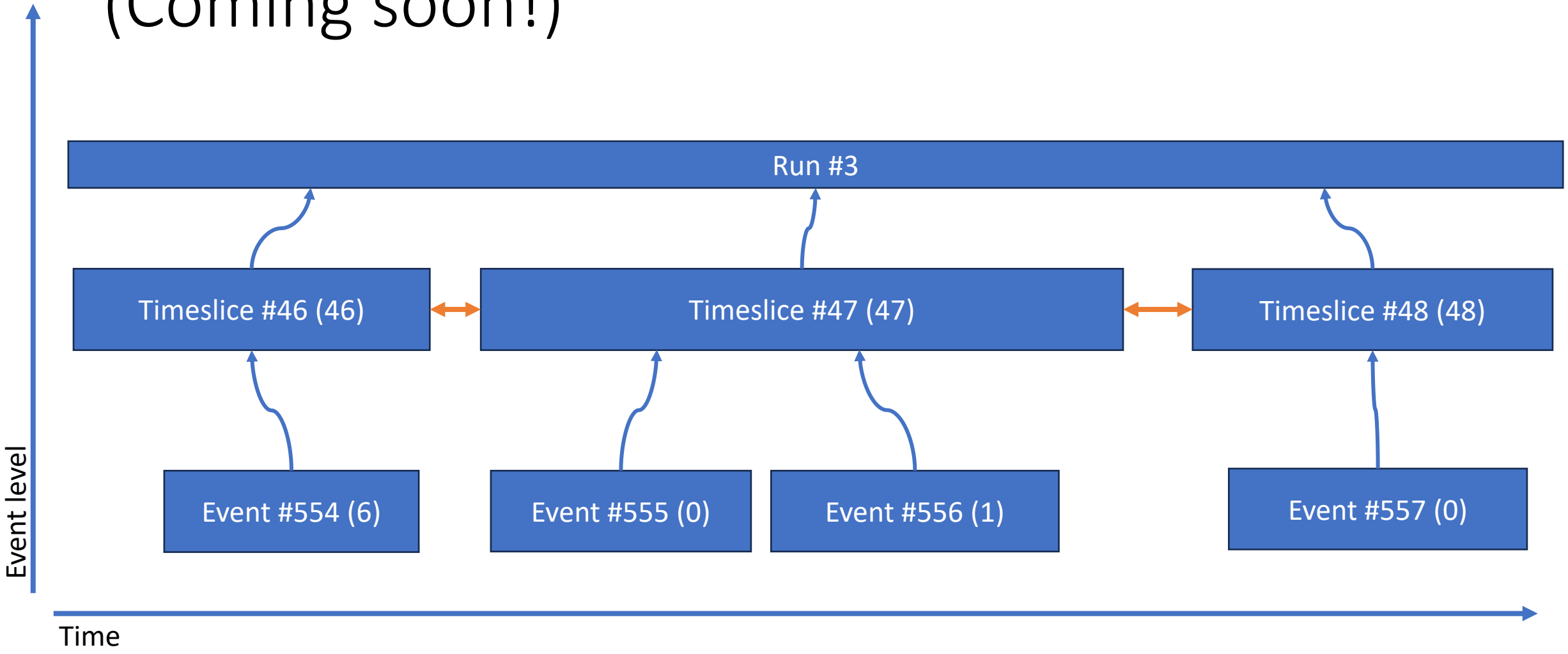
Memory management – Parent relation



Memory management – Multiple parents



Memory management – Sibling relations (Coming soon!)



Event key

- Generalizes the concept of event and run number to streaming scenarios
- Will eventually replace the awkward arguments to JOmniFactory::Execute

- Event number: For each level **inside** our unfold/fold hierarchy, we have:
  - Absolute number: Starts at 0, increments by 1
  - Relative number: Starts at 0 for each parent, increments by 1
  - User key: Could be anything, bunch crossing number in practice

- Run number: Separate numbers for each parent level **outside** of the unfold/fold hierarchy
  - Goal: Take advantage of the symmetry between “side-loading data from a database” and “retrieving data from events that live at a different level but were intermingled in the event stream”, e.g. BOR, slow controls
  - Might all end up being intervals of bunch crossing numbers in practice
  - Challenge: Getting JEventSource to emit events that already have parents

Summary

- JEvents and components can all be tagged with an **event level** := {…, Timeslice, PhysicsEvent, Subevent, …}
- We introduce a `JEventUnfolder` which lets us **split** a timeslice into events, and also **merge** two independent streams
- Components at any level (e.g. PhysicsEvent) are able to safely and easily reference the data at higher levels (e.g. Timeslice)
- We extend the **OmniFactory** interface patterns to JEventUnfolder
- JANA2 is now able to automatically build a complex topology from different components at different event levels.
- EICrecon will be able to tell just from the input file what topology needs to be built and how to build it => Smoother transition

Next steps

- A working prototype is already in master
  - src/examples/TimesliceExample
  - https://github.com/JeffersonLab/JANA2/

- Create timeslice data file
- Implement logic for splitting timeslice into physics events
- Ironing out small details
  - Recycling parents via an EventFolder vs directly to event pool
  - Improving the JEventKey to better generalize event and run numbers