# PANDA Software Trigger

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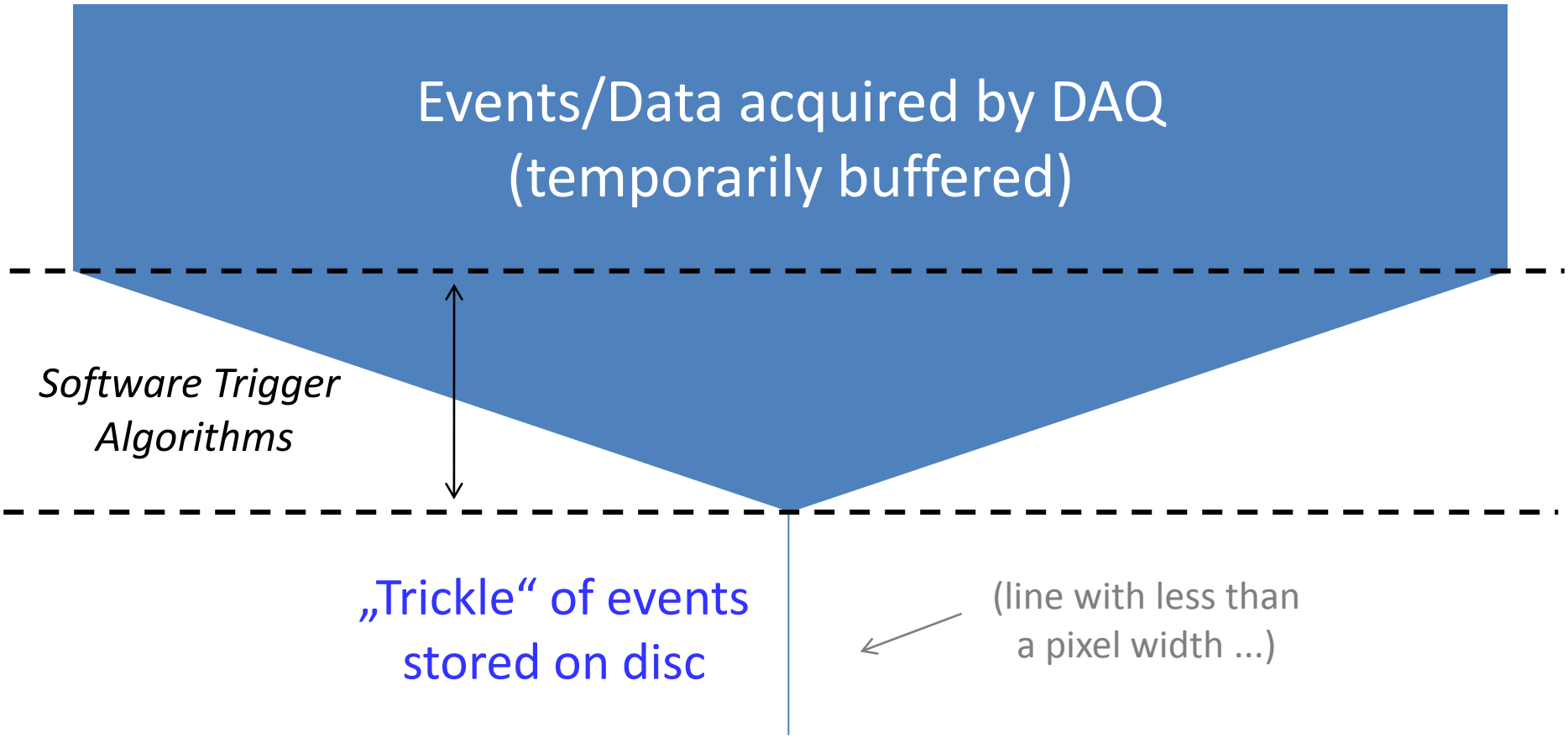
# Why Software Trigger at all?

- Many benchmark channels (no ‚golden' channel)
- Channels consist purely/predominantly of hadrons
- Signal and background events look quite similar in terms of
  - Multiplicity tracks/neutrals
  - kinematic distributions
  - event shape, ...
- *Many, many, many* more background events ($\times 10^6$)
- No ‚simple' hardware trigger can cope with that situation
- Need sophisticated algorithms with high selectivity
- Only possible with online reco + a lot computing power

# Challenge




- Required reduction factor: 1/1000 (all triggers in total)
- e.g. 50 algorithms → factor 1/50000 in average

# Goals

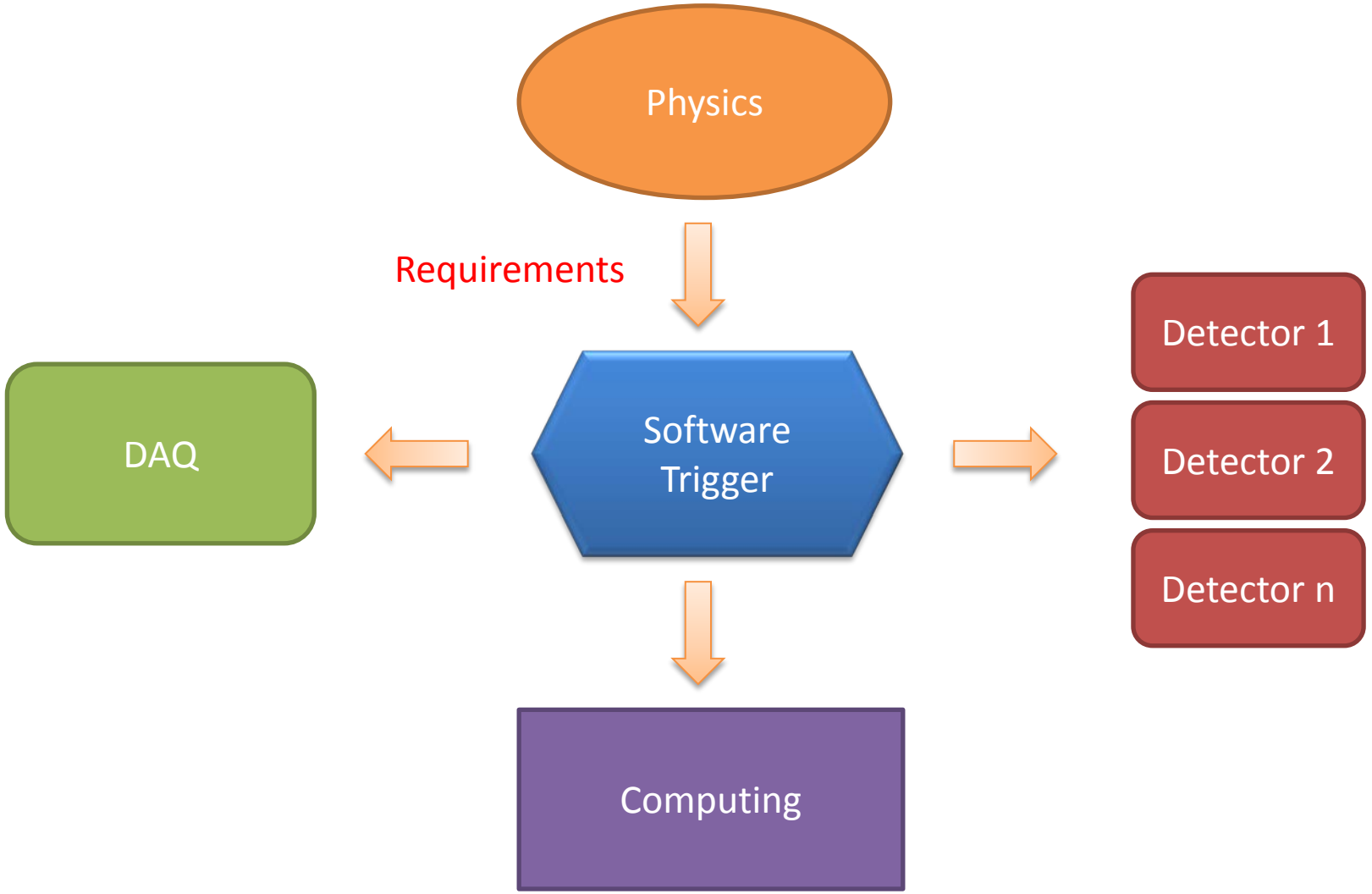
- Identify tiny fraction of interesting physics events
- Reject major part of uninteresting background events
- Reduce the stored data rate to 1/1000 of the initial one

# Steps

- Define the physics requirements (min. efficiency, S/N, etc..)
- Identify the criteria to separate signal from background
- Determine minimum quality of online quantities (p, E, PID, ...)
- Define selection algorithms for various physics channels
- Port algorithms to appropriate hardware (FPGA, GPU,...)
- Test the hardware performance under realistic conditions

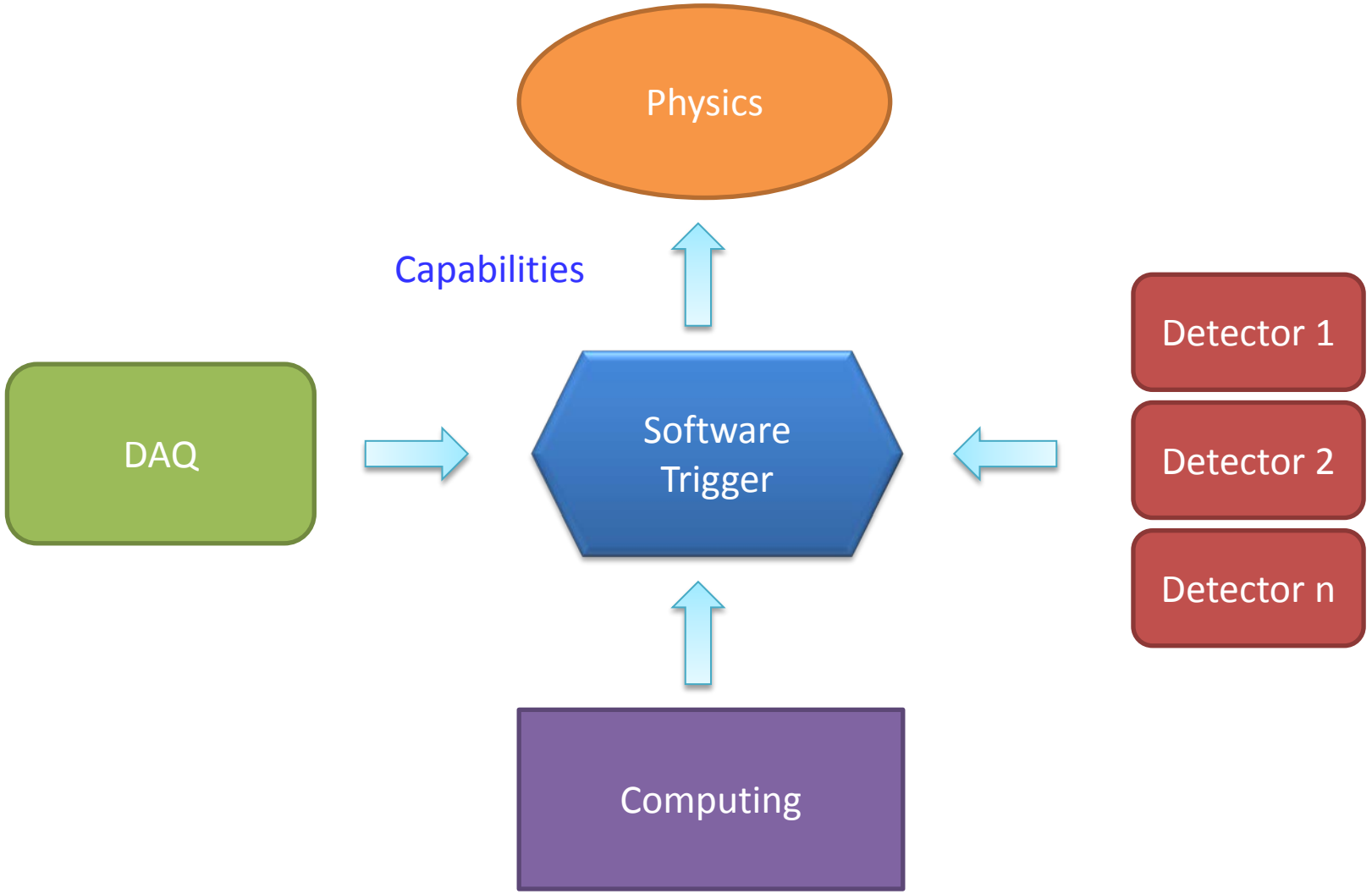
# Positioning of ST Project

Software Trigger mediates between physics requirements...



# Positioning of ST Projekt

... and available hardware/software capabilities

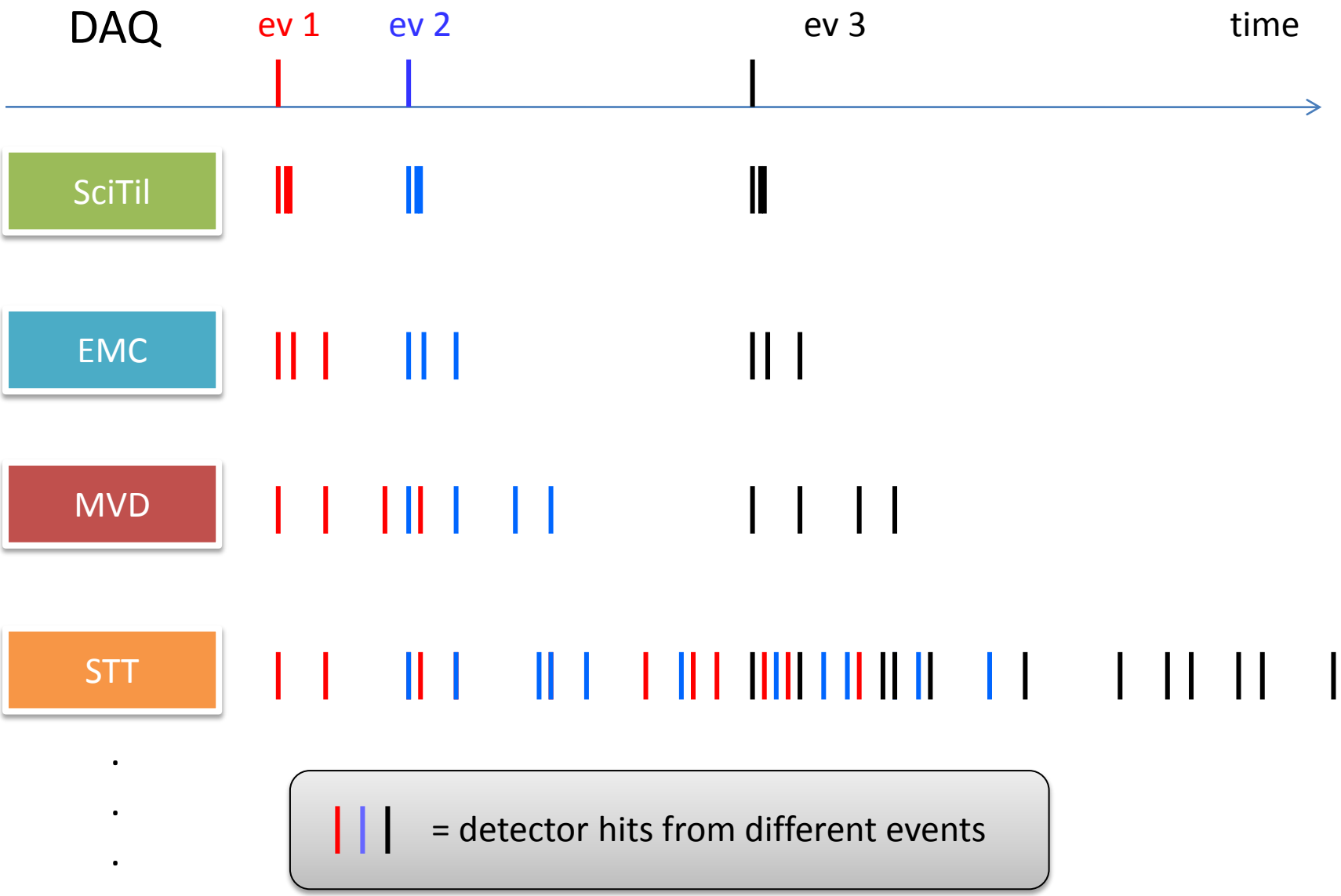


# Positioning of ST Project

The two directions are:

- „Top down“
  - Analysis experts tell, what it required to study all channels
  - Online experts provide the required information
- „Bottom up “
  - Online experts tell, what can be reconstructed in time
  - Analysis experts determine resulting limitations to the planned physics program
- Will be a mixture of both to converge...

# Online reco schematic



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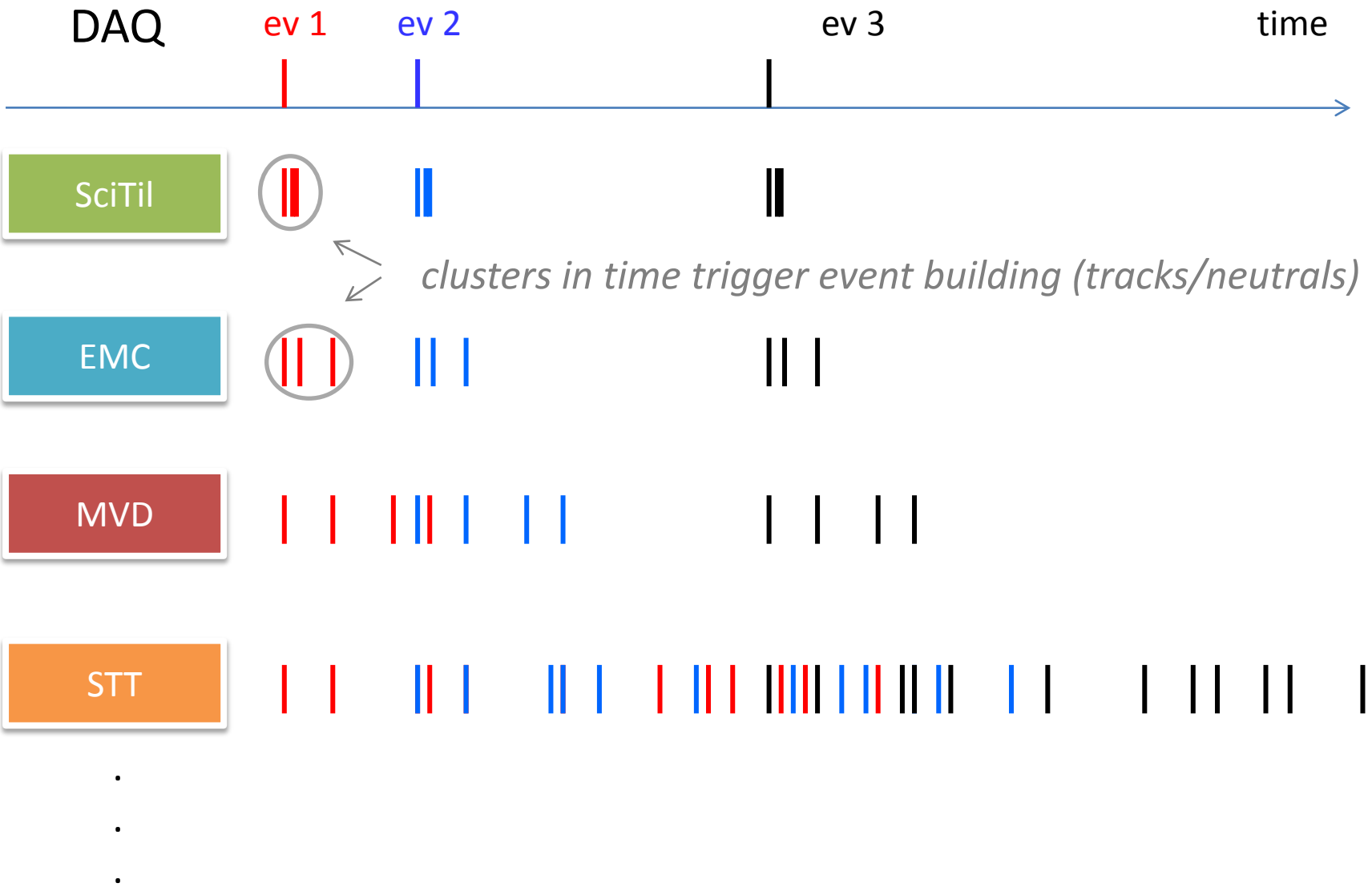

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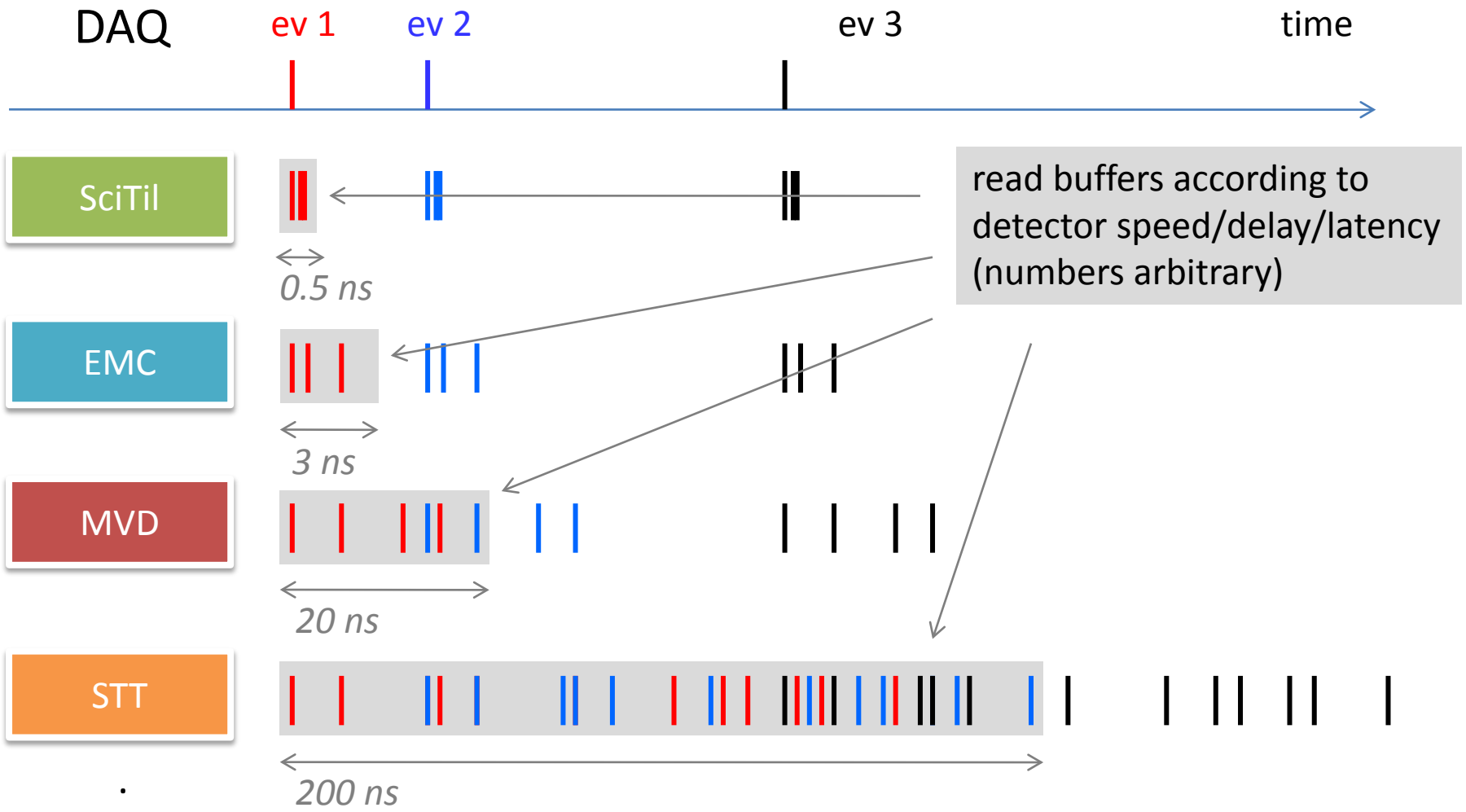
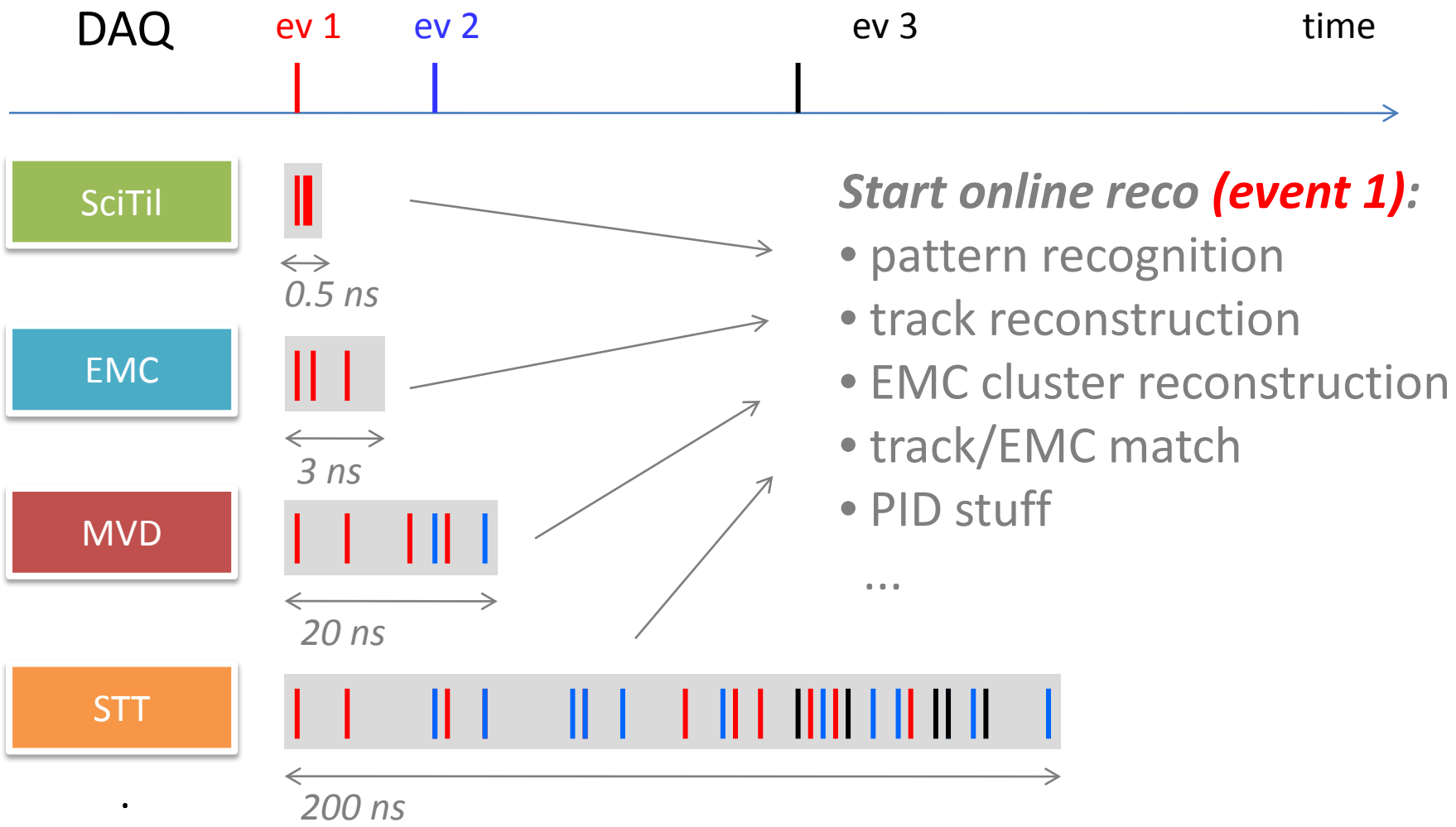


# Online reco schematic




***Start online reco (event 1):***

- pattern recognition
- track reconstruction
- EMC cluster reconstruction
- track/EMC match
- PID stuff

...

# Approach

- Information for the trigger can be
  - direct hit information (perhaps SciTil hits, EMC hits)
  - higher reconstructed information (tracks, clusters, inv. mass, angles, ...)

- Two (not complementary!) scenarios:
  - Inclusive trigger before event building
    - e.g. 2 electron cand. (J/psi)
      → start event building on selected buffered data
  - Exclusive trigger with reco‘d events
    - reconstruct every event (candidate)
    - run event based trigger algorithm

# Physics Report

## Selection criteria used in the Physics Report Analyses

| Channel | TRK | NEUT | Excl. | mult | PID | p | E | ang. | inv M | dist cut | veto | 4C | Vtx C | Mass C | Sig Eff[%] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| J/psi pi+ pi- | 4 | 0 | x | | e, pi | | | | x | | | | J/psi pi+ pi- | | ***30*** |
| J/psi pi0 pi0 | 2 | 4 | x | | e | | g | | x | | J/psi eta pi0 | x | J/psi | | ***17*** |
| chi_c1,2 gam | 2 | 2 | x | | e | | g | | x | | | x | J/psi | | ***30*** |
| J/psi gam | 2 | 1 | x | | e | | | | x | | | x | J/psi | | ***40*** |
| J/psi eta | 2 | 2 | x | | e | | | | x | | | x | J/psi | | ***40*** |
| h_c -> 3gam | 0 | 3 | x | 3n | | | g | h_c | x | | | x | | | ***8*** |
| h_c -> 2phi gam | 4 | 1 | x | | K | | g | | x | | pi0 | x | | | ***8*** |
| D+ D- | 6 | 0 | x | | ? | D | | | x | z(D) | | x | D+- | | ***8*** |
| D*+ D*- | 6 | 0 | x | | ? | D* | | | x | z(D*) | | x | D0 | D0 | ***14*** |
| eta_c1 eta | 2 | 7 | x | | e | | | | x | | | x | | chi, pi0, eta | ***7*** |
| eta_c1 eta | 4 | 8 | x | | K, pi | | | | x | | >1 comb/ev | x | K pi | D0, D0*, eta, pi0 | ***5*** |
| J/psi omega | 4 | 2 | x | | e, pi | | | | x | | | x | J/psi pi+pi- | J/psi, pi0 | ***15*** |
| f2(2230) -> 2phi | 4 | 0 | x | | K | | | | x | | | x | phi | | ***20*** |
| Ds Ds(2317) | 3 | 0 | | | K, pi | | | K | x | | | | Ds, phi | | ***20*** |
| Xi- Xi+ pi0 | 6 | 2 | x | | p, pi | | g | | x | d(IP-Xi) | >1 comb/ev | x | Lam,Xi+- | Xi Xi pi0 | ***16*** |
| Lam Lam | 6 | 0 | x | | p, pi | | | | x | d(IP-Xi) | | | Lam | | ***11 ... 23*** |
| Xi- Xi+ | 6 | 0 | x | | p, pi | | | | x | | | | Lam, Lam pi | | ***19*** |

**no multiplicity cuts**

**PID!**

**few kinematic cuts (except mass)**

**a lot of fitting!**

# Ingredients for Algorithms

Studying the *Physics Book* (offline scenario) gives idea about necessary information, e.g.

- J/psi (→ base for many charmonia)
  - Invariant Mass: Tracking/Momentum
  - Electron ID: Tracking, cluster energy, track/cluster match
  - Muon ID: Tracking, Muon detector information
  - Vertex: Tracking
- D/Ds Mesons
  - Pi0s: EMC clusters
  - Inv. Mass: Tracking
  - Kaon, Pion ID: dE/dx, DIRC info (w/ track match), ToF (track match)
  - Vertex: Tracking
- Baryons
  - Inv. Mass: Tracking
  - proton, pion ID: DIRC info (w/ track match)
  - Vertex: Tracking
- Full events: 4C fitting

Track and momentum reconstruction is key ingredient for almost everything!

# Some comments to Physics Book results

- Some of the benchmark channels reported in Physics Book seemed to be at the limit concerning
  - signal/noise ratio
  - signal statistics (due to low cross section and/or limited integrated luminosity/beam time)

- For proper efficiency determination
  - trigger efficiency
  - event building efficiency
    have to be taken into account

*which might make the situation even more challenging...*

# Quality of Online Reco

- How different will be algorithms for online/offline reco?
- How will the reconstruction quality differ?
- Assumption: Online quality will be worse, i.e.
  - worse track finding/reco. efficiency
  - worse momentum resolution *(→ inv. mass resolution)*
  - worse EMC energy resolution *(→ mass res. of pi0, eta, …)*
  - less precise PID information *(→ worse PID efficiency)*
  - no fitting (4C, vertex, mass) available

# To be investigated

- Which information are mandatory for full physics program?

- What is required precision for

  – momentum resolution
  – energy resolution
  – track finding efficiency (maybe momentum dependent)
  – event building efficiency
  – PID information

  to achieve the required trigger efficiencies & purities?

# To Do

- Implementation of time based simulation, pattern recognition and reconstruction for all detectors
- Determination of selectivity of various selection criteria (full MC)
- Resolution/efficiency dependence of trigger algo‘s (perhaps sufficient with toy MC)
- Event building efficiency as function of event rate (+ impact of possible event bursts from pellet target)