

Trigger and DAQ System in ALEPH

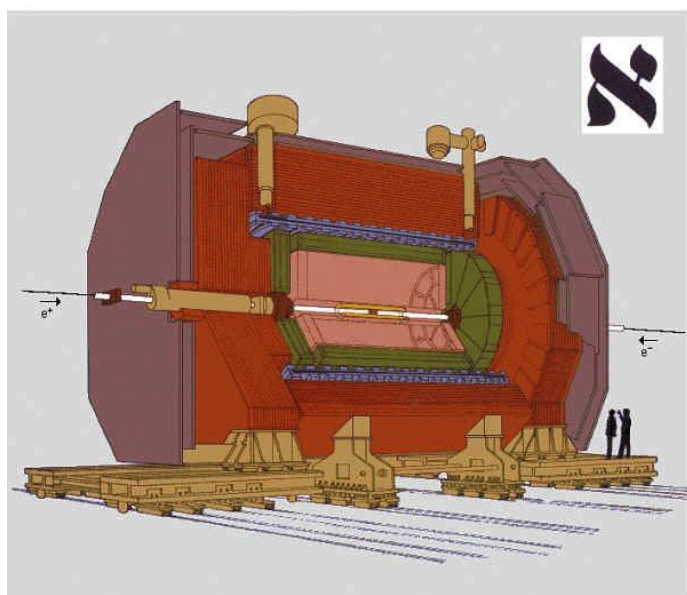
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The ALEPH Experiment/Detector

- ❑ Aleph was a general purpose detector at LEP
 - Operational from 1989-2000
 - Designed to study e^+e^- collisions at the Z pole and W^+W^- threshold and Higgs search (at highest possible energies)

❑ The Detector



- Vertex Detector
- Inner Tracking Chamber
- Time Projection Chamber
- Electromagnetic Calorimeter
- Superconducting Magnet Coil
- Hadron Calorimeter
- Muon Chambers
- Luminosity Monitors

Detectors used in Trigger System

A Few Numbers

- ❑ ~500'000 detector channels
- ❑ Bunch crossing rate 45 kHz (22 μ s bunch spacing)
- ❑ Readout Rate: ~4Hz
- ❑ Average Event Size (zero-suppressed): ~15 kB
- ❑ Readout System:
 - FastBus based
 - ~140 Crates holding mainly front-end electronics and digitizers
 - Hierarchical Event-Building to collect the data
 - ↳ Based on FastBus (later VME)
 - Readout Dead-Time: ~0.5%/Hz

Aleph Trigger System

- ❑ Two-stage hardware trigger and one level of SW trigger
 - In general, triggering on activity in the detector
- ❑ Level-1: Based on Calorimetry and Inner Tracking Chamber
 - Decision for every Bunch Crossing (45 kHz)
 - Latency $\sim 4\mu\text{s}$ ($\sim 6\mu\text{s}$ to clear front-end)
 - Trigger decision arrives at front-end electronics before next bunch crossing
 - ↳ no pipeline needed
 - ↳ No dead-time
 - Accept Rate: < 30 Hz (LEP was exceedingly clean)
- ❑ Level-2: Based on TPC tracking in the L1 triggered region
 - Confirmation of the ITC tracks
 - Decision upon positive Level-1 decision
 - Latency $\sim 50\mu\text{s}$ (has to wait for after the TPC drift time, $40\mu\text{s}$)
 - ↳ Miss next 2 bunch crossings
 - Accept Rate: ~ 4 -5 Hz
- ❑ Level-3: Software
 - Basically full TPC tracking and track matching (for charged triggers)
 - Accept Rate: 2-3 Hz
 - Not terribly interesting in this context

Pros and Cons of Hardware Triggers

- ❑ Hardware triggers make sense, when
 - Nothing of interest happens in general during a bunch-crossing
 - ↳ Typically true at e^+e^- colliders
 - Trigger decision 'easily' reached. 'Simple Algorithm'
 - ↳ In Aleph: significant activity in the calorimeter in a given solid-angle
 - The data rate higher than can be handled technologically (within reasonable cost)
 - ↳ In Aleph the data rate (raw) was ~ 500 MB/s.
 - Typical network speed (at the time): 10 Mb/s shared Ethernet!
- ❑ Disadvantages of (hardware) Triggers
 - More complex front-end electronics
 - ↳ Data have to be stored during the trigger formation (pipelines)
 - ↳ Complicated readout protocols
 - Find data belonging to the triggering bunch crossing
 - Extract data and send it out
 - ↳ Potentially radiation issues (less of an issue in e^+e^- colliders)
 - Separate data path for the trigger
 - ↳ Trigger data have to be split to feed the trigger logic

Pros and Cons of Trigger-Free Readout

□ Pros:

- Complete events every bunch crossing at the (SW)trigger
- Full algorithmic flexibility in the software trigger
 - ↳ Especially correlating different detectors (regions)
- No or very little trigger inefficiency
 - ↳ Only limited by output and storage capabilities

□ Cons:

- Zero-suppression on the detector
 - ↳ Fiber cost would otherwise go through the roof
 - Also material budget (by the way)...
 - ↳ Complication of the front-end electronics, e.g. common-mode suppression
- Large bandwidth readout network
 - ↳ Cost factor
 - ↳ Technology is on your side
 - At FCC timescale should surely not be a problem
- Power consumption/cooling at the front-end might be an issue

- ❑ Triggering in LHCb is difficult
 - To a lesser extent at low luminosity
- ❑ There is a (physics) interaction at every bunch crossing
- ❑ The signature of interesting events is not simple
 - Simple calorimetry (the easiest) is not sufficient
 - Need tracking across the entire detector and identification of detached vertices
- ❑ Thus, the entire detector needs to be considered
- ❑ The trigger efficiency based on (simple) hardware trigger (based on calorimetry) is getting exceedingly low (~25%) for some channels
 - Limited by maximum readout rate of 1.1 MHz

- ❑ Trigger-free readout is surely advantageous for the overall physics performance
 - If the trigger algorithm is 'complicated' and needs to correlate many detector regions
 - If one can afford it (readout system)
 - If one can do the zero-suppression on the detector (fibre cost, material budget)
 - If the bunch spacing is very small, e.g. CLICK (0.6 ns) it's mandatory
 - ↳ There is no way to trigger on an individual interaction
 - Sensor response much larger than bunch spacing
- ❑ A triggered readout is a preferred option
 - If the raw data rate is exceedingly high i.e. beyond technological reach
 - small amount of data can lead to a significant rate reduction at high efficiency