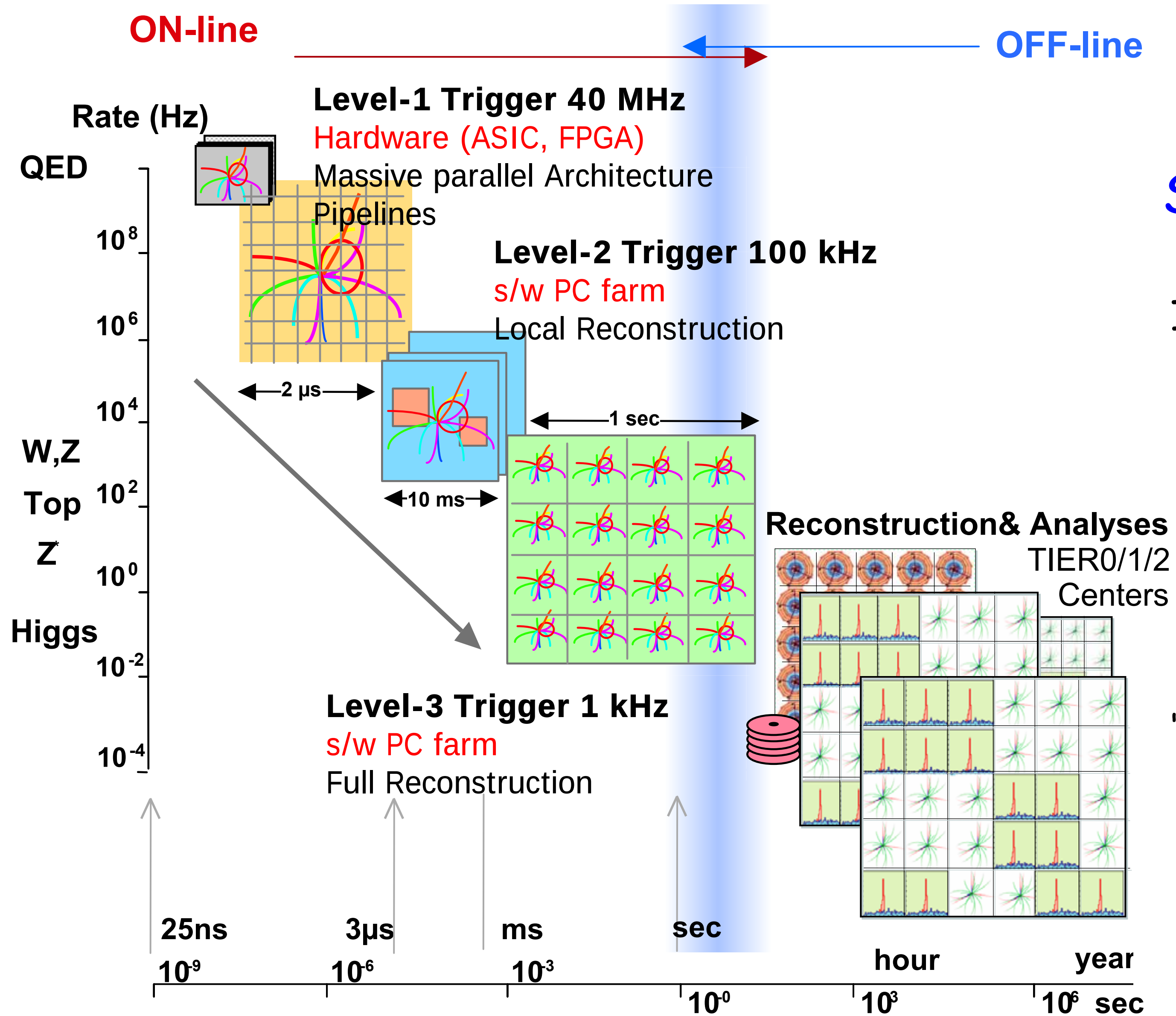
Trigger at SLHC

PHYSICS AT THE TERA SCALE
Helmholtz Alliance



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1st Detector Workshop of the HGF Alliance 'Physics at the Terascale'

Karlsruhe

April 3rd, 2008

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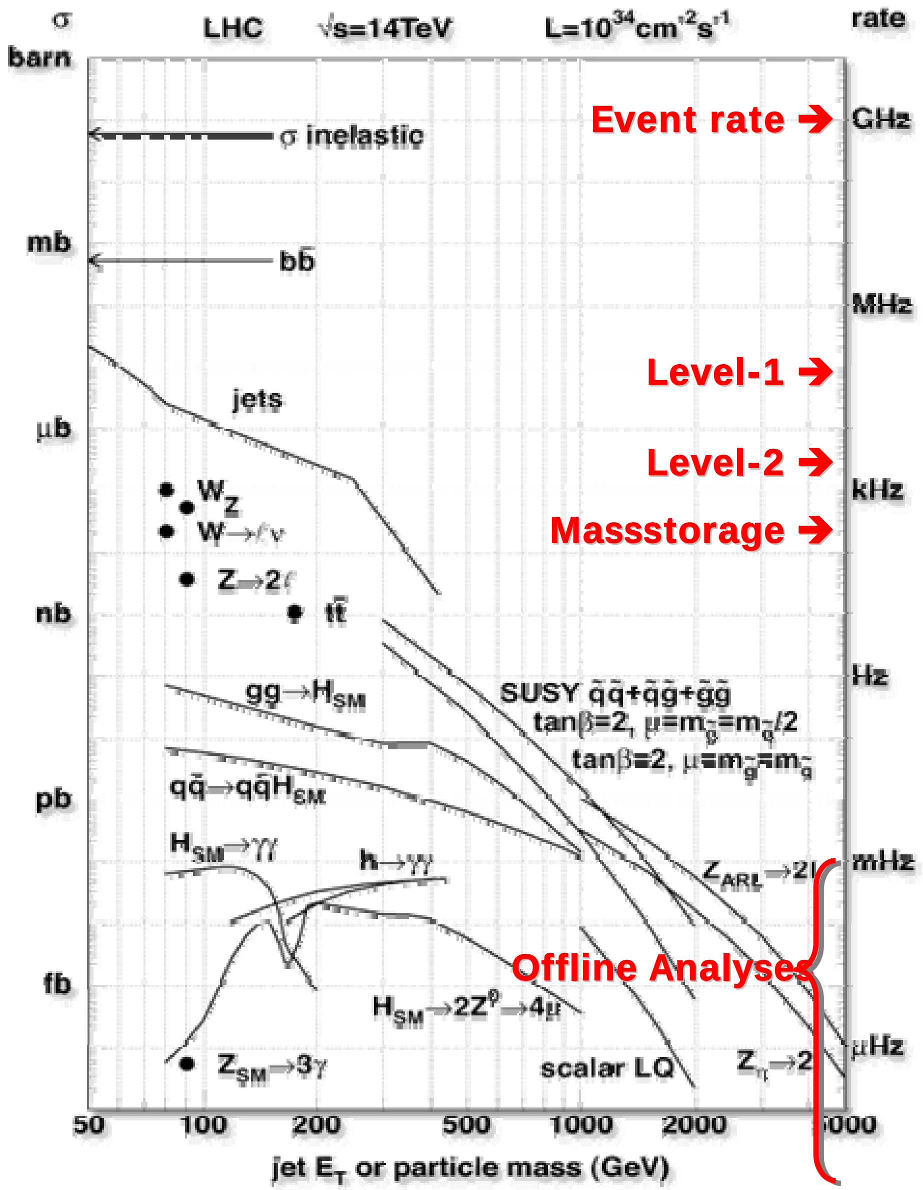
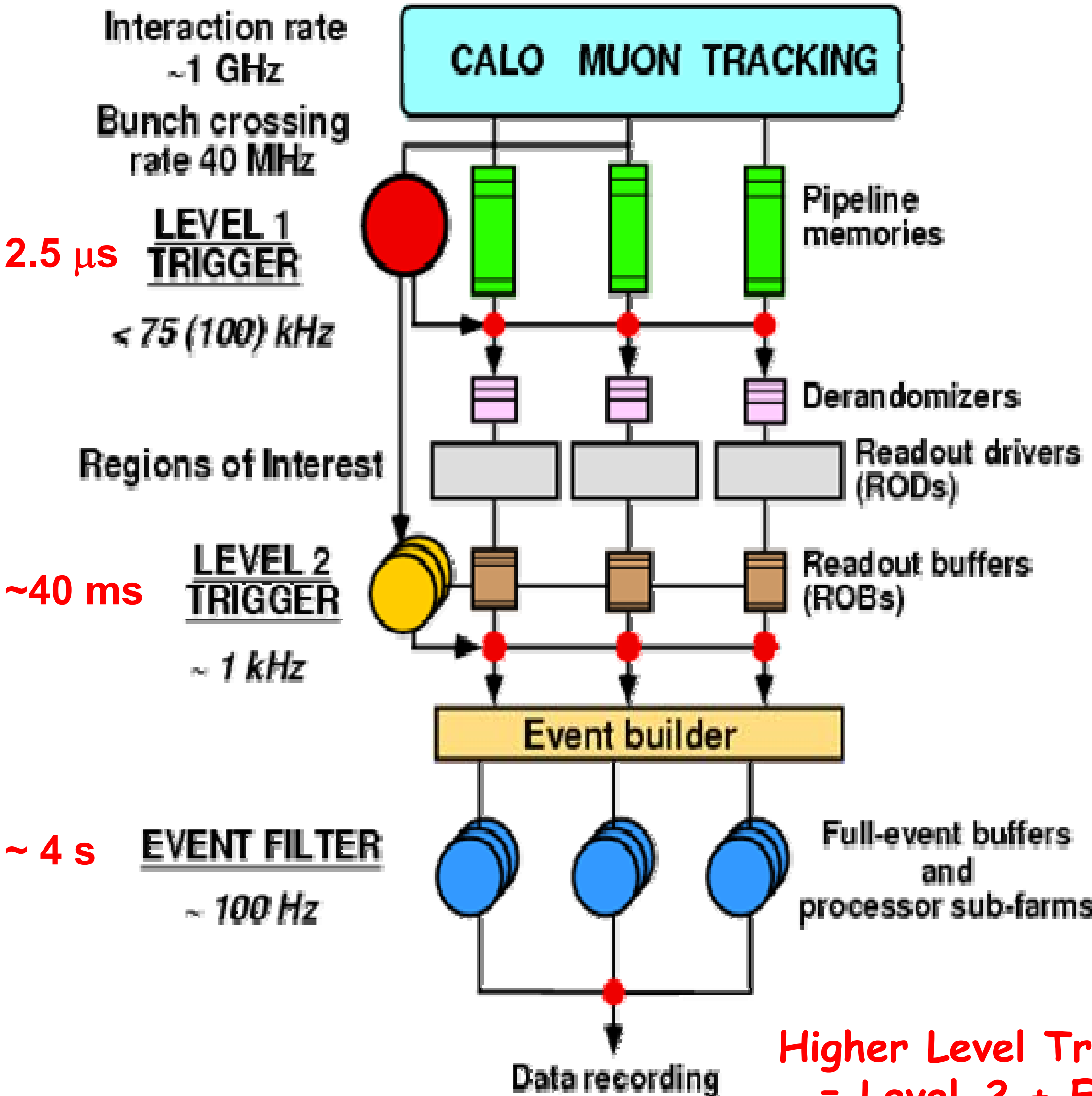
- Summary

LHC: the challenge(s)



- extremely high interaction rates
  - → mostly uninteresting background
- many physics processes of interest happen only rarely
  - → very efficient selection needed
- complex detectors
  - → 10^8 electronic channels
- many simultaneous pp interactions
  - → at design luminosity
- constraints from available latency, computing resources, network bandwidth, …
- solution
  - → multi-level trigger systems

ATLAS trigger & DAQ architecture



- **Level-1**
  - → coarse calorimeter data and muon trigger chambers
    - buffering on detector
- **Level-2**
  - → Region-of-Interest data (~2% only)
  - → full granularity
  - → all detectors
  - → fast rejection
    - buffering in ROBs
- **EF (Event Filter)**
  - → refines selection
  - → latest calibration, alignment

Higher Level Trigger = Level-2 + EF

SLHC physics requirements

- to exploit physics potential of SLHC, need
  - → triggers for discovery physics
    - (very) high p_T objects (thresholds increased wrt LHC)
    - as inclusive as possible (also inclusive W/Z selection ?)
  - → triggers for precision measurements
    - high p_T objects (with similar thresholds as for LHC)
    - use more exclusive / multi-object selection to control rate
  - → monitor and calibration triggers
    - low to high p_T thresholds (will be pre-scaled)

- conditions at 10^{35} $cm^{-2}s^{-1}$ will impact trigger rates
  - → higher rate for fixed threshold and efficiency
    - trivial increase by corresponding increase in luminosity
    - further increase due to less effective isolation criteria, increase in fake rate, …
      - → up to 400 inelastic pp interactions per crossing (on average)

TDAQ upgrade parameter space

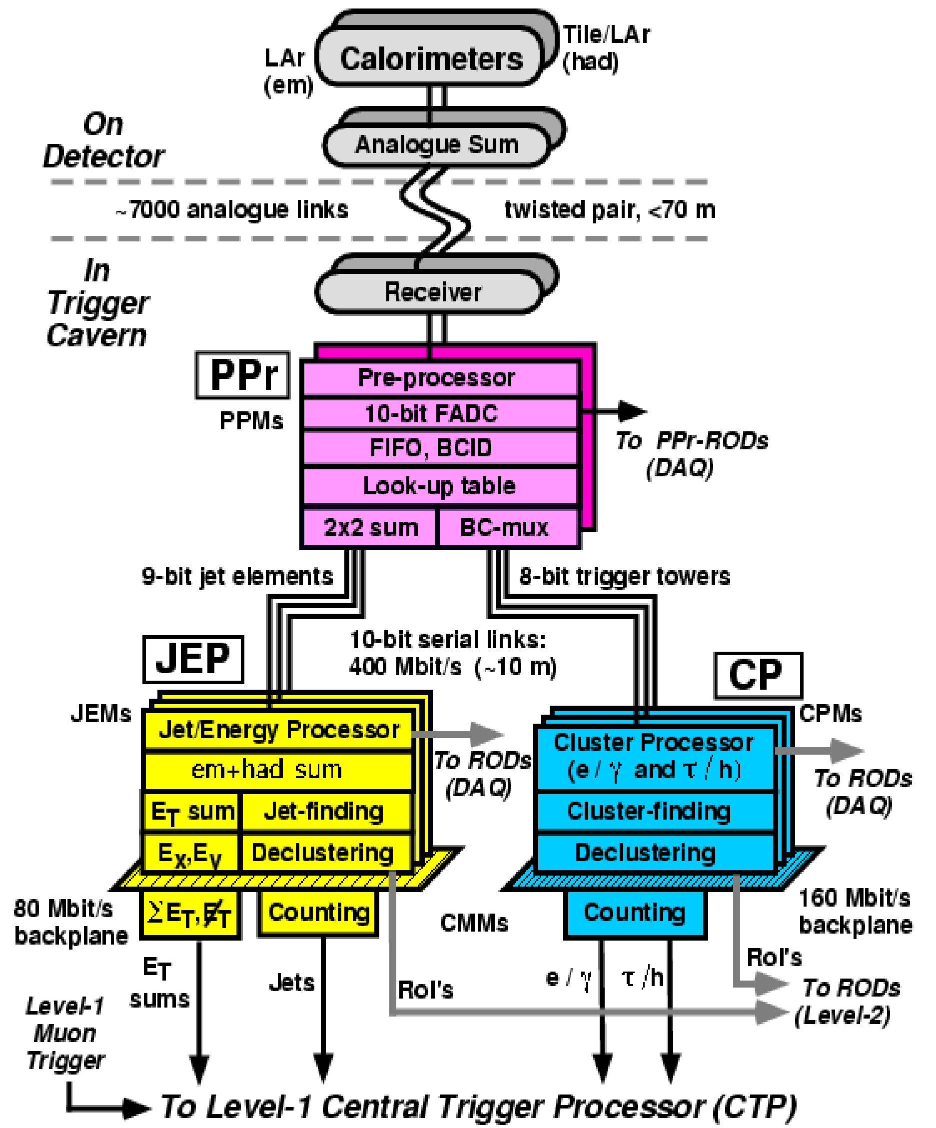
- upgrades of the trigger and DAQ system are influenced (driven) by several constraints and requirements, from
  - → physics goals
    - objects, algorithms, p_T thresholds, …
  - → machine parameters
    - bunch crossing frequency,
      # of simultaneous inelastic pp interactions, …
  - → sub-detector changes
    - number of channels, occupancy,
      signal formats for LVL1 (analog vs. digital), …
  - → technology evolution
    - availability of performing commodity items, …

Upgrade plans/ideas

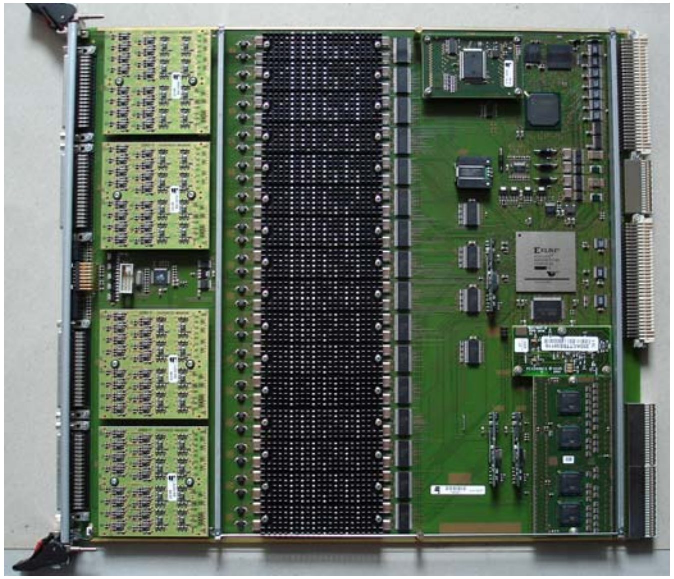
- CMS
  - → increase Level-1 latency to 6.4 μs
  - → muon and calorimeter trigger at Level-1 with finer granularity
  - → introduce Level-1 track trigger (see later)
  - → regional correlation at Level-1 with track, muon and calo trigger information (before global trigger)
- ATLAS
  - → discussion on new concepts have started
    - example Level-1 calorimeter trigger (see later)
  - → need/use of Level-1 track trigger to be determined
- boundary Level-1 to Higher Level trigger likely to be kept
  - → no change in Level-1 accept rate
- mostly focusing on Level-1 issues right now
  - → DAQ and Higher Level trigger to profit from technology advancements (bandwidth/processing demands will increase)

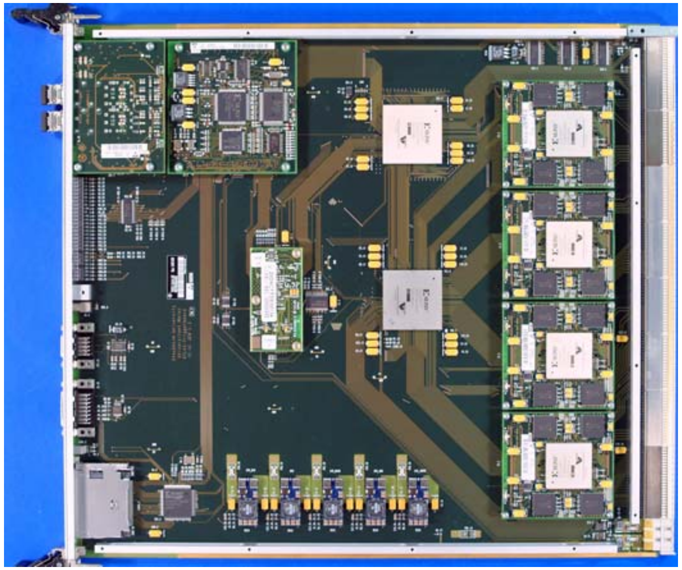
ATLAS LVL1 calorimeter trigger

- analogue electronics on detector sums signals → trigger towers
- signals received and digitised
  - → digital data measure E_T per tower for each BC
    - ❍ E_T matrix for ECAL and HCAL
- tower data transmitted to processors (4+2 crates in total)
  - → fan out values needed in more than one crate
    - ❍ Motivation for very compact design of processor
- within crates, values need to be fanned out between electronic modules, and between processing elements on the modules
- Connectivity and data-movement issues drive the design



ATLAS calorimeter trigger: installed





- limitations on input/output
  - → stability and reliability of cable plants
- first stage (preprocessor)
  - → mixed signal design
- data duplication in processor systems
  - → backplane limitations

ATLAS Level-1 calorimeter trigger

- present areas for initial upgrade studies
  - brainstorming meeting Jan. 2008 in Heidelberg

→ critical assessment of present system (lessons learnt)
  - to be continued during first data taking

→ granularity of input data
  - relation to upgrades of calorimeter f/e electronics

→ improvement of trigger algorithms
  - transfer part of Higher Level rejection to Level-1

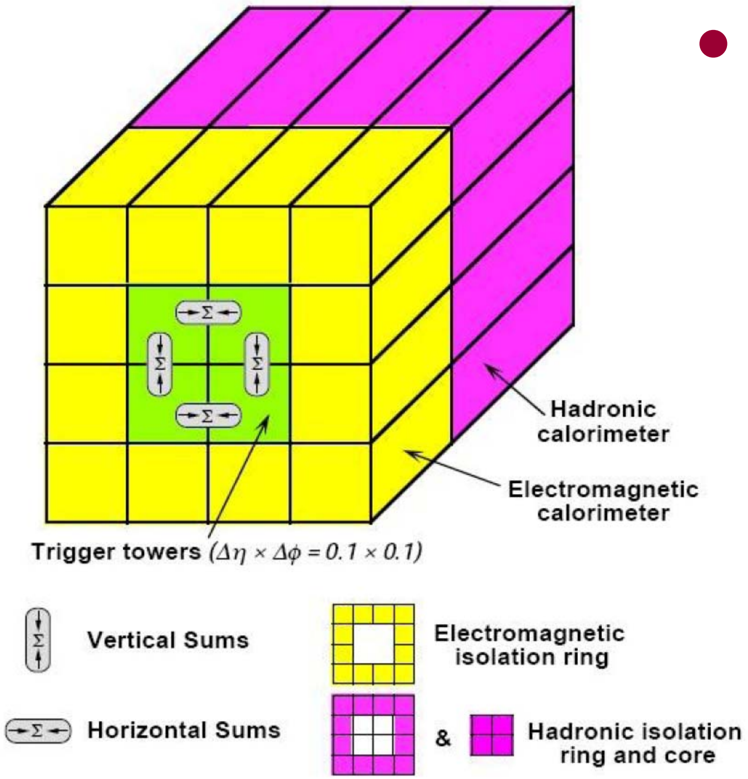
→ architecture studies
  - possibilities to reduce/avoid data duplication (backplanes)

→ prototype/emulation board development
  - firmware development for algorithms

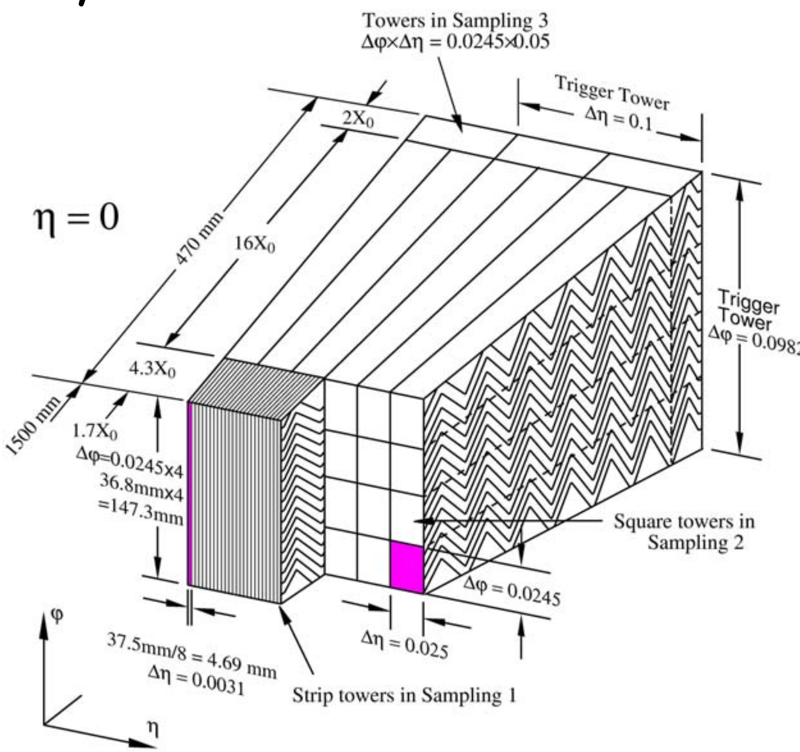
→ assessment of multi-Gbit link technologies

→ timing distribution
  - TTC inadequate for multi-Gbit links

Calorimeter trigger algorithm



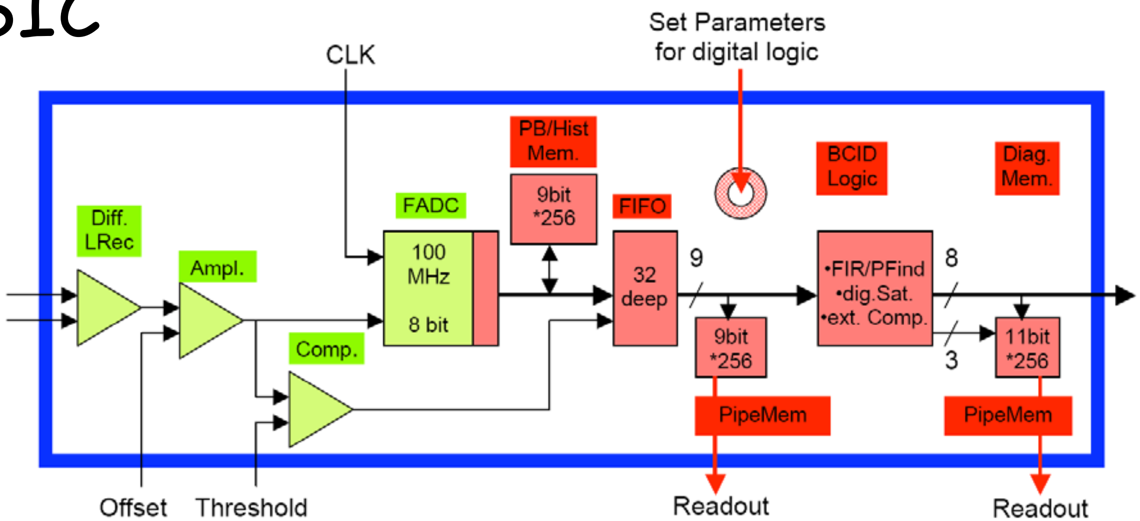
- much finer granularity of cells in liquid argon calorimeter
  - → additional rejection power (Higher Level trigger with calorimeter only)
  - → investigate possibilities of using finer granularity for Level-1



- example: EM trigger
  - → select e/γ at Level-1
    - narrow shower shape
    - no longitudinal leakage
    - transverse isolation
  - → input: 'trigger towers'
    - summed energies of ≤ 60 cells

Calorimeter trigger upgrade: plans

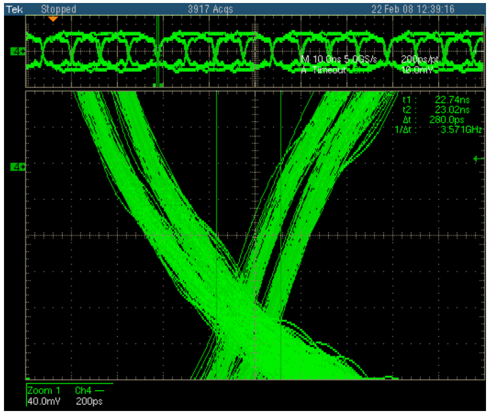
- Heidelberg
  - → integrate pre-processor functionality into higher density
  - → mixed signal ASIC
    - analog signal conditioning
    - digitisation (FADC)
    - bunch crossing identification



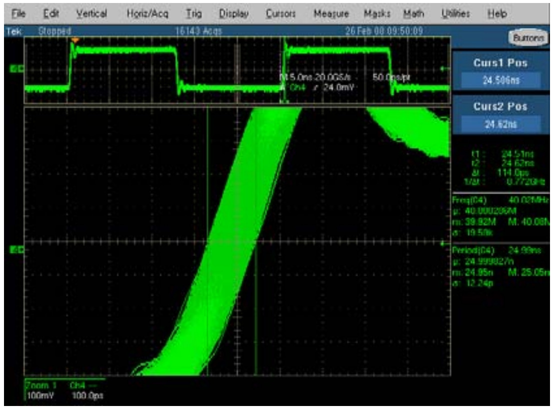
  - → implement prototype channel in MPW-run
    - 180 nm UMC process

Calorimeter trigger upgrade: plans

- Mainz
  - → investigate clock jitter / data integrity of high speed data links
    - ➔ using Xilinx demonstrator boards
    - ❍ develop jitter cleaner card
    - ❍ synchronous vs. asynchronous transmission



Clock recovery



Δt ~300 ps

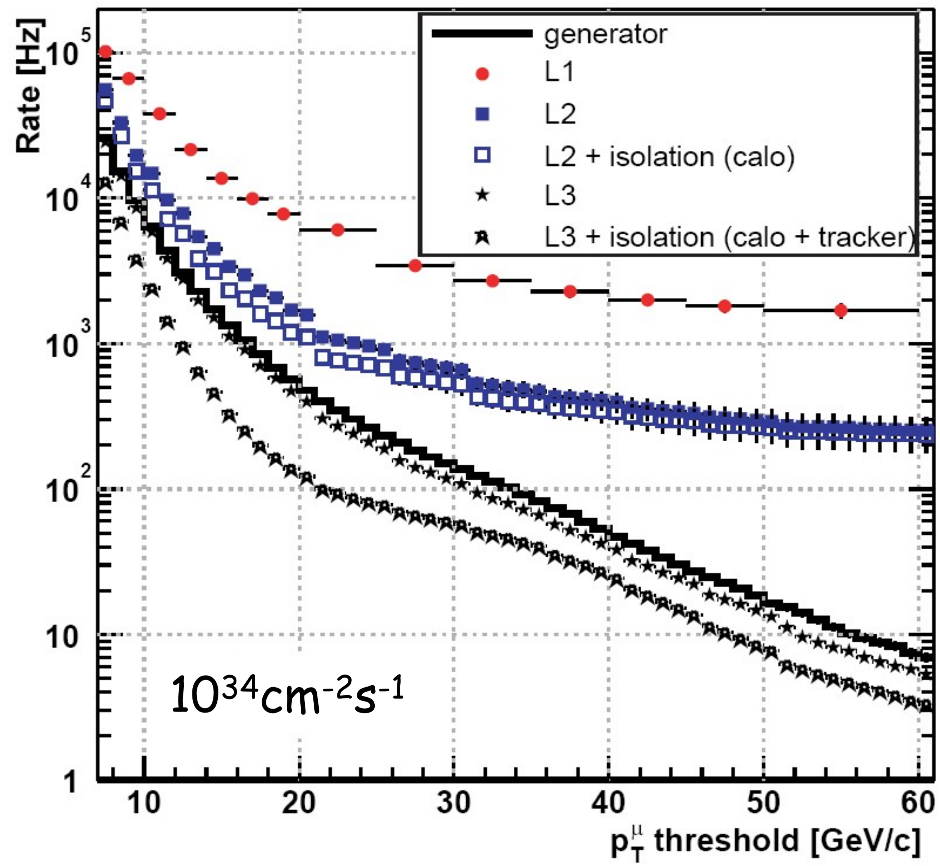
Δt ~120 ps

  - → develop demonstrator board for jet-energy sum-processor
    - ❍ firmware developments for signal deserialisation and algorithmic processing in single FPGA
      - ➔ spread over several parts presently
    - ❍ integrate into present system for detailed tests

CMS: track trigger at Level-1

- motivation
  - → need to sufficiently reduce trigger rates at SLHC
  - → allow for increased algorithm complexity

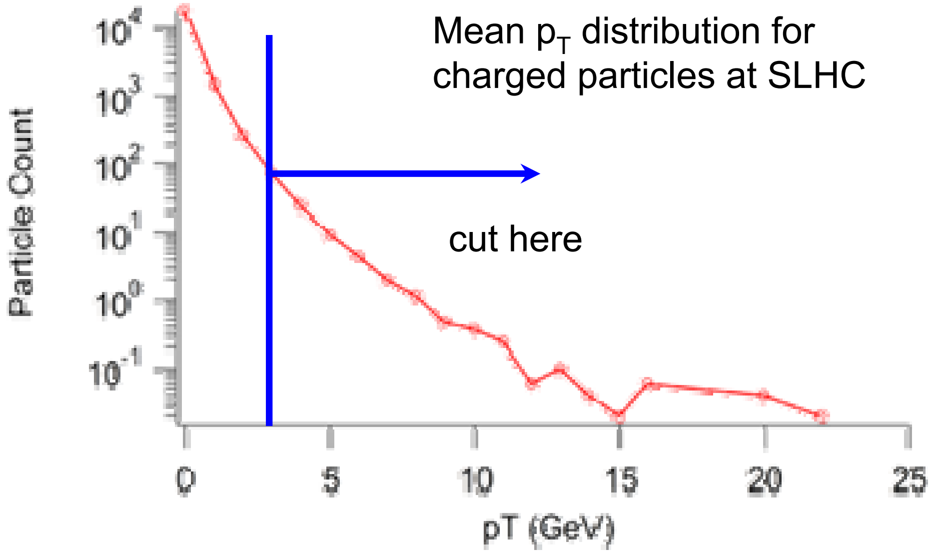
- examples
  - → improve muon momentum measurement
  - → increase rejection of fake e/γ objects
  - → refine isolation criteria (track based)
  - → disentangle different primary vertex contributions



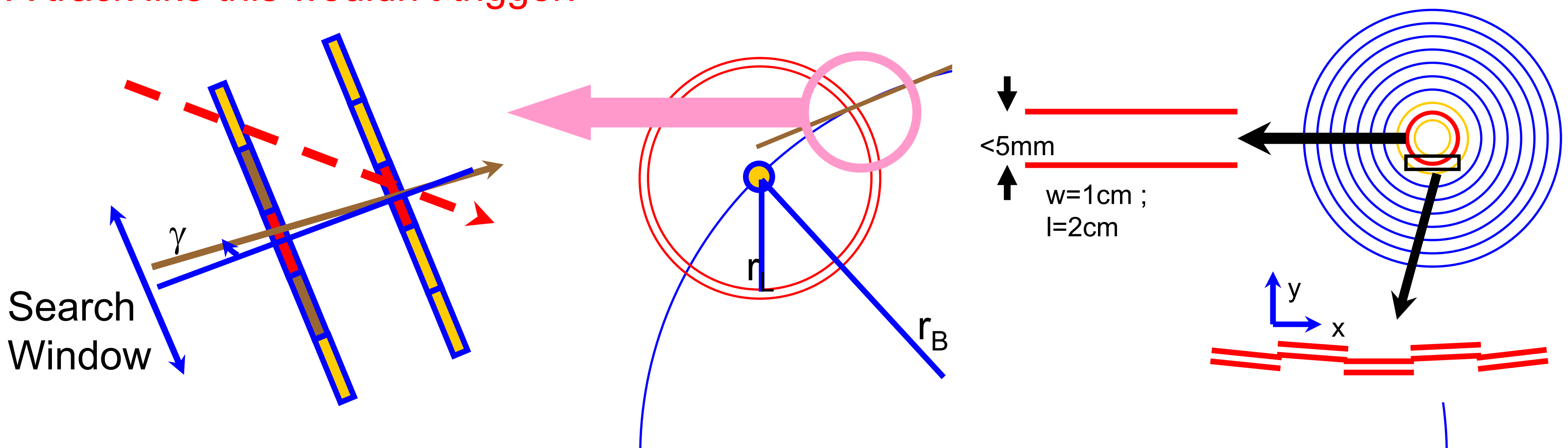
- muon trigger rate
  - → limited rejection power at high p_T

CMS: trigger capable tracker modules

- Use close spaced stacked pixel layers
- Geometrical p_T cut on data (e.g. ~ GeV):
- Angle (γ) of track bisecting sensor layers defines p_T ($\Rightarrow$ window)
- For a stacked system (sepn. ~1mm), this is ~1 pixel
- Use simple coincidence in stacked sensor pair to find tracklets

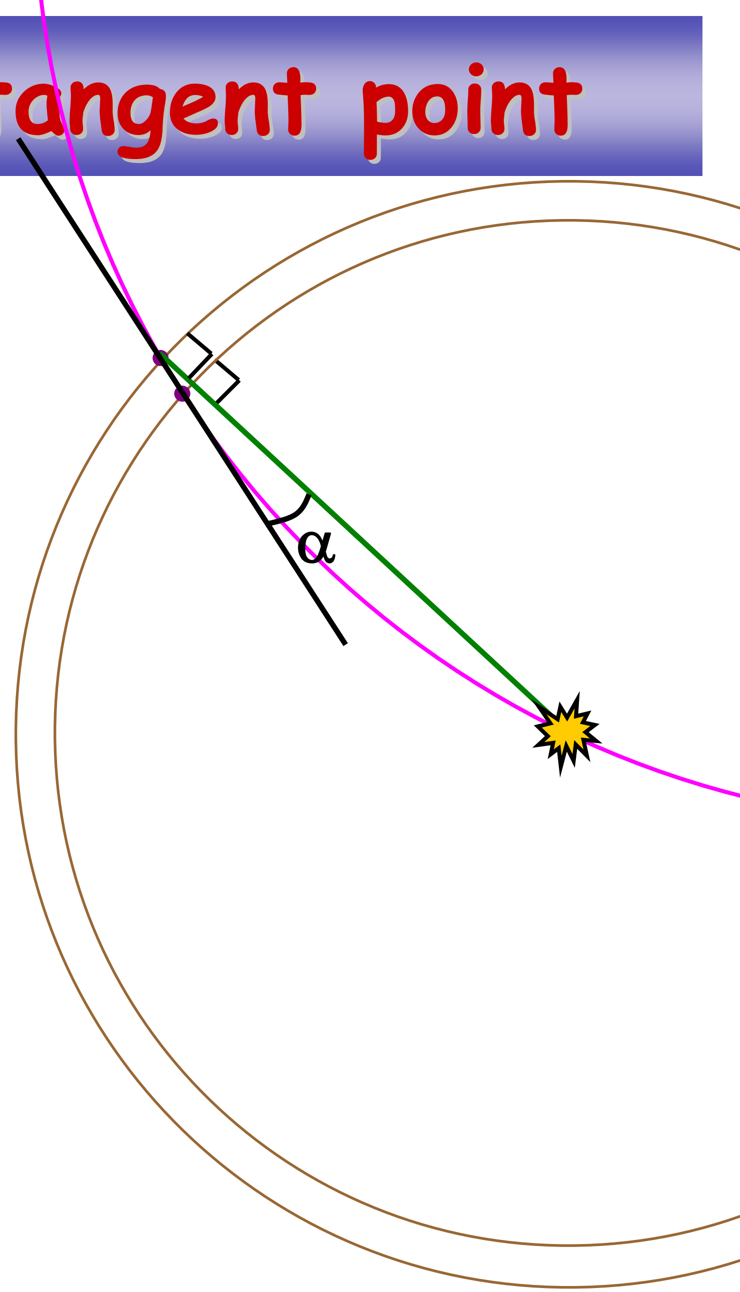


A track like this wouldn't trigger:

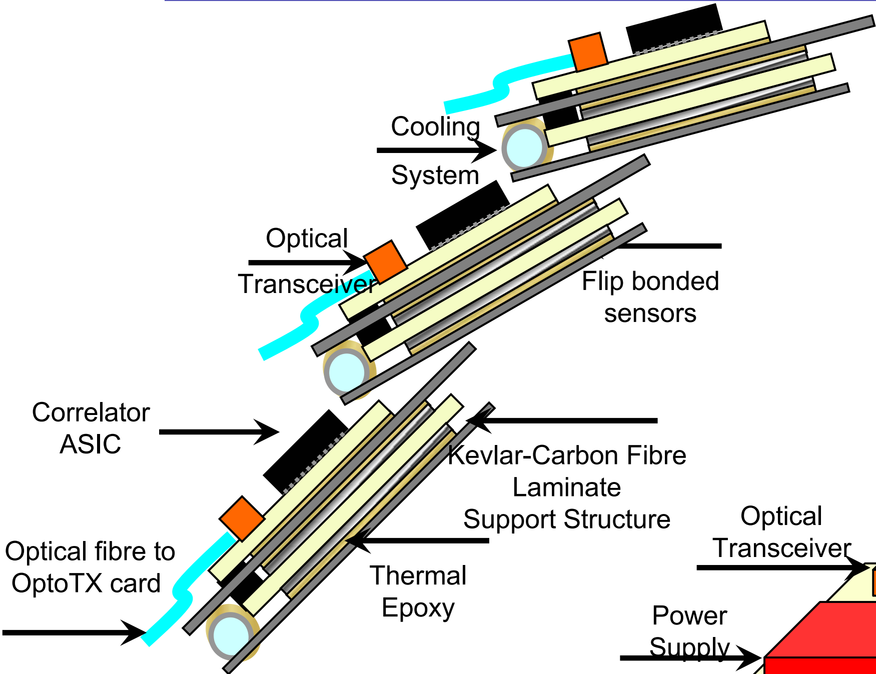


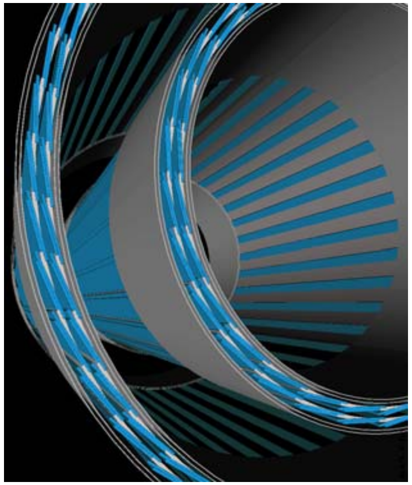
Reconstruction of tangent point

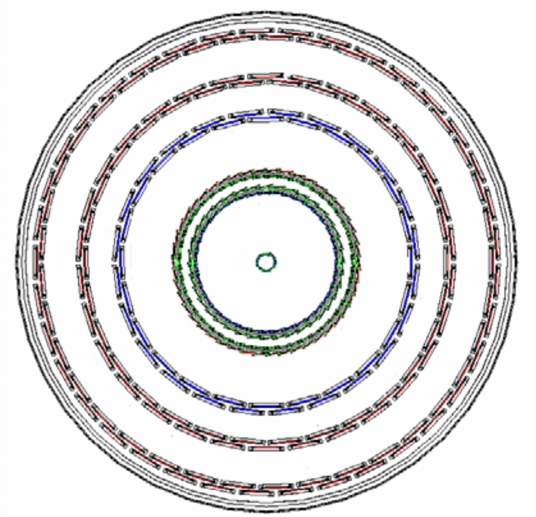
- → assume IP r=0
- → angle α determines p_T of track
- smaller α = greater p_T
  - → can find high-p_T tracks by looking for small angular separation of hits in the two layers
  - → correlation is fairly 'pure' provided separation is small and pixel pitch is small
- matching hits tend to be from the same track
  - → if sensors are precisely aligned, column number for hit pixels in each layer can be compared
  - → finding high-p_T tracks becomes a relatively simple difference analysis

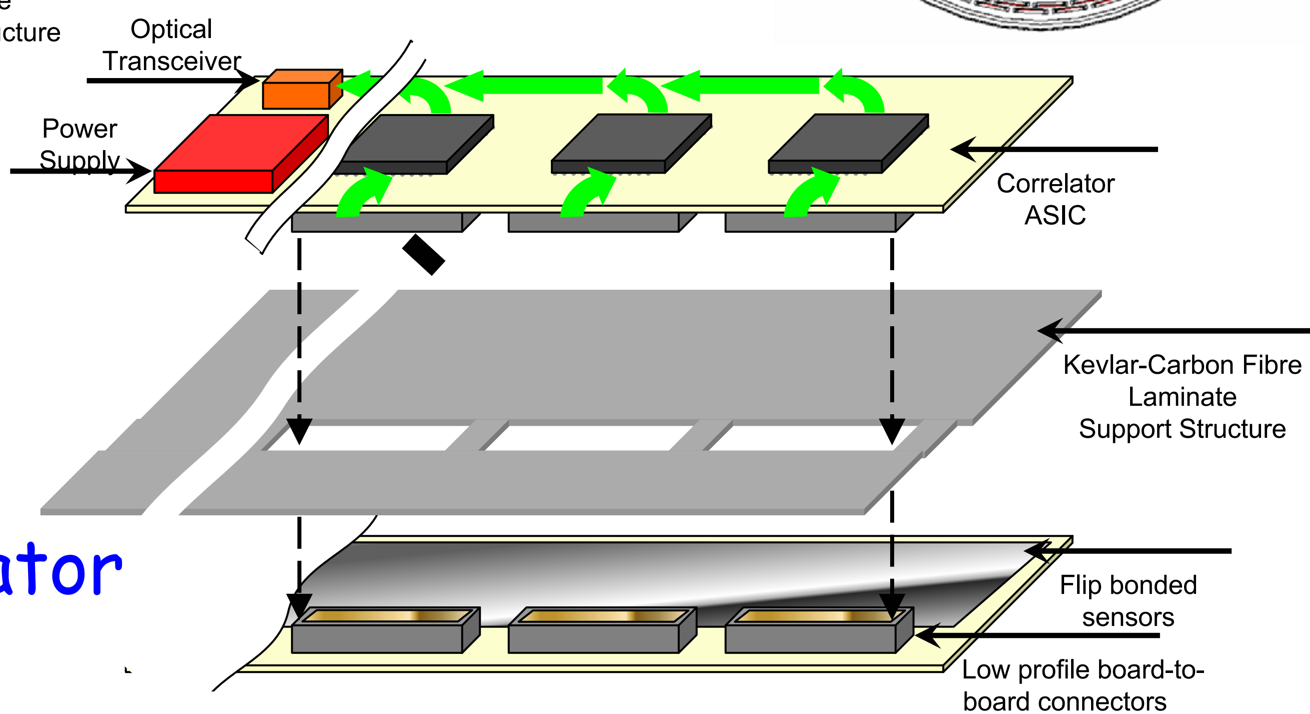


CMS: conceptual design









- correlator PCB

Summary

- trigger upgrade for SLHC depends on
  - → physics requirements (not yet really known)
  - → machine parameters (might change again)
  - → detector upgrades
- challenges at SLHC might/will be even larger than the ones for LHC
  - → triggering will be a really tough job
- present activities with HGF alliance
  - → Heidelberg and Mainz on Level-1 calo trigger