CMS L1 Pixel Track Trigger for LHC Phase-II

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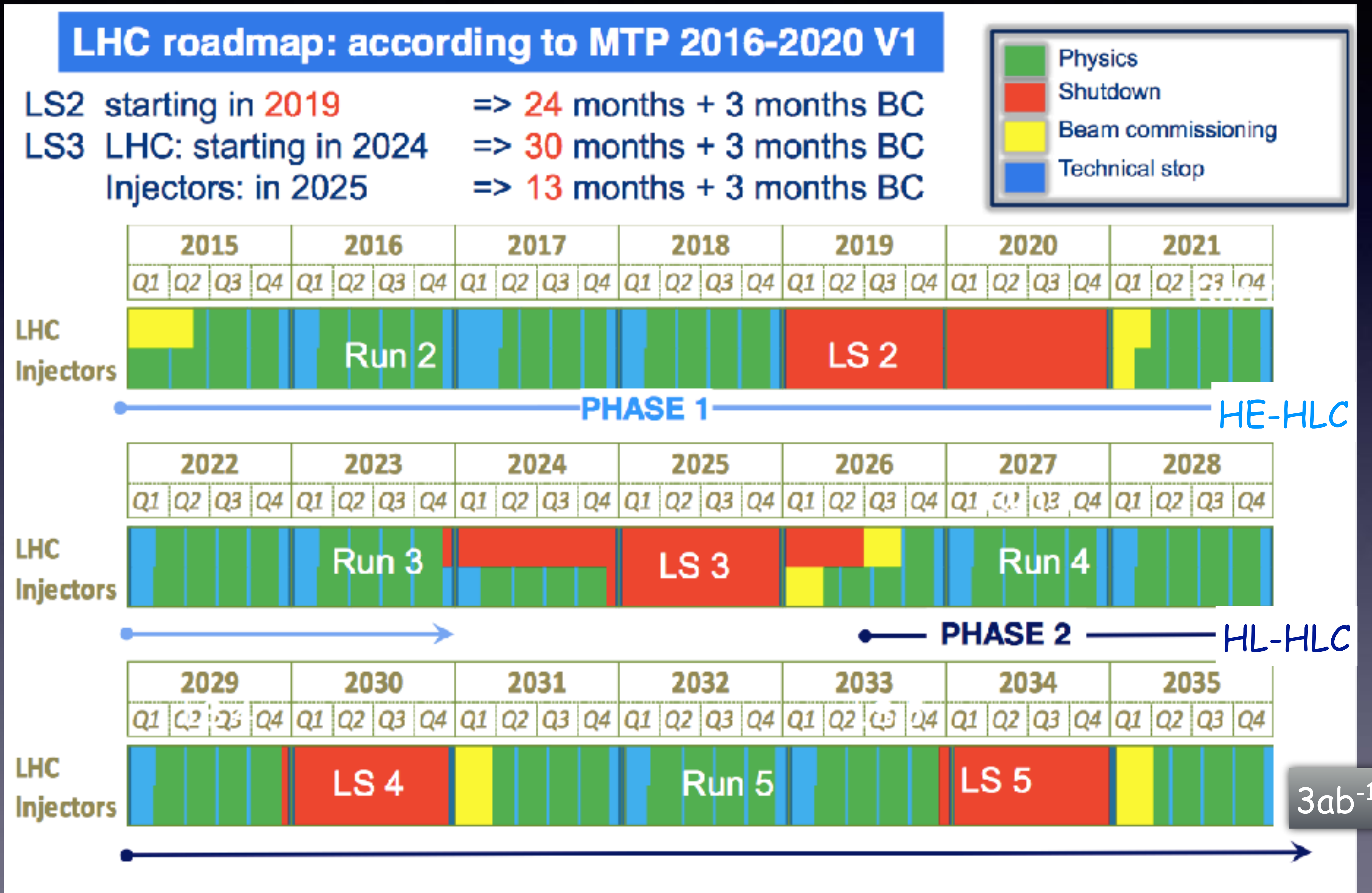
2nd BRL Workshop, 2017. 6. 17

2010-2012
Run1, 7-8TeV

LHC Comissioning



General Survival & Improvement Concepts

- pile-up 20 → 140...200
  - association of tracks and calorimeter energies to individual vertices (up to high eta)
  - particle flow reconstruction
- particle densities x5-10 (ATLAS+CMS: 6'000 primary tracks per event)
  - finer granularity → more channels
- data rates (particles per event) x5-10
  - higher band-width (analogue→digital links)
- increased trigger rates (at fixed thresholds) due to degraded resolution and ambiguities
  - improve resolution of pt and E measurement at trigger level
  - use topological information
  - provide tracking information to L1 trigger
  - increase latency and acceptable trigger rates (LHCb: no trigger at all: 40 MHz read-out)
- radiation damage x10
  - more radiation hard detection elements (silicon, crystals)
- increased front-end power consumption
  - ASIC technology scaling 250nm → 130 nm → 65 nm to reduce power per transistor
  - improved powering and cooling
- reduce material budget inside detector volume
- changes to a running system
  - test new systems as early as possible (e.g. run new triggers in parallel to old ones, run pilot systems inside detectors)

$\boxed{N=\sigma\times\mathscr{L}}$

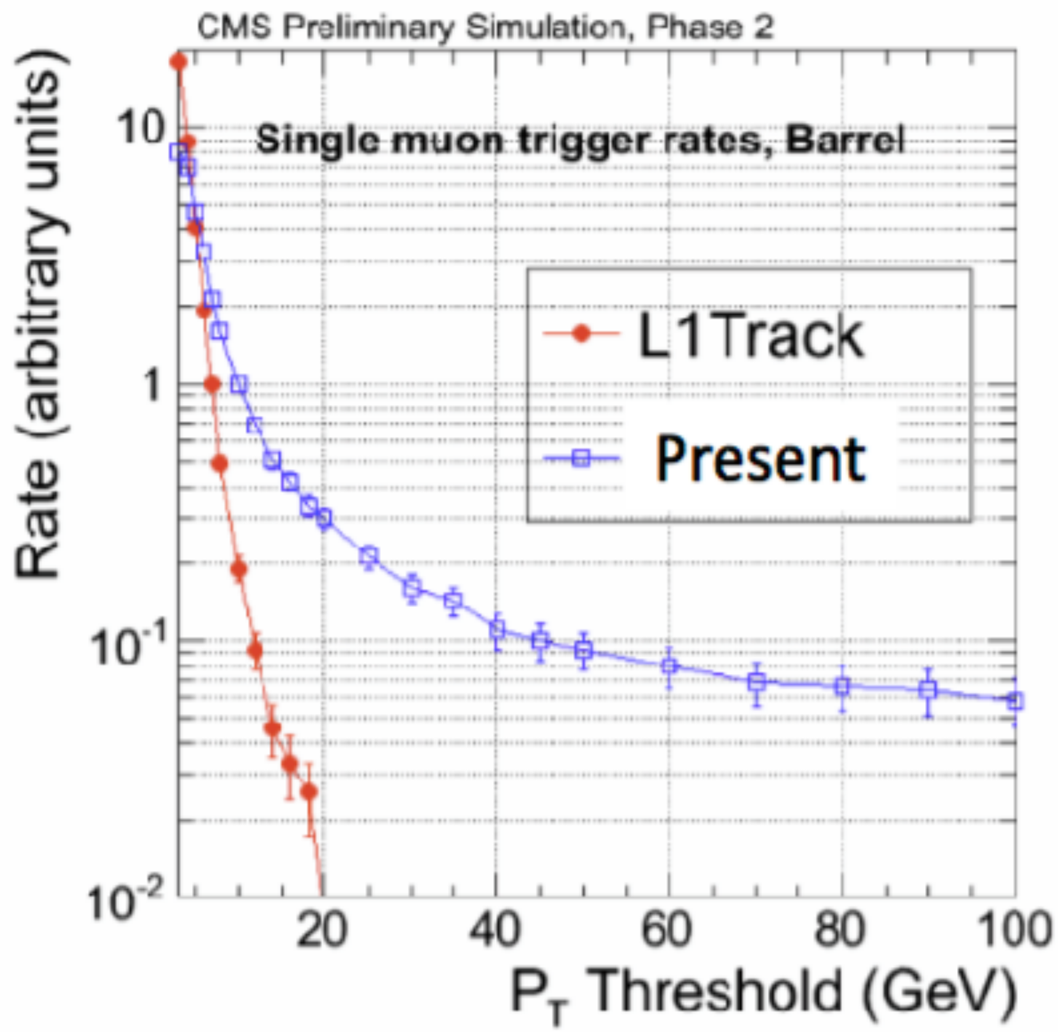
Lutz Feld, Phase-II upgrade, Aachen (2013)

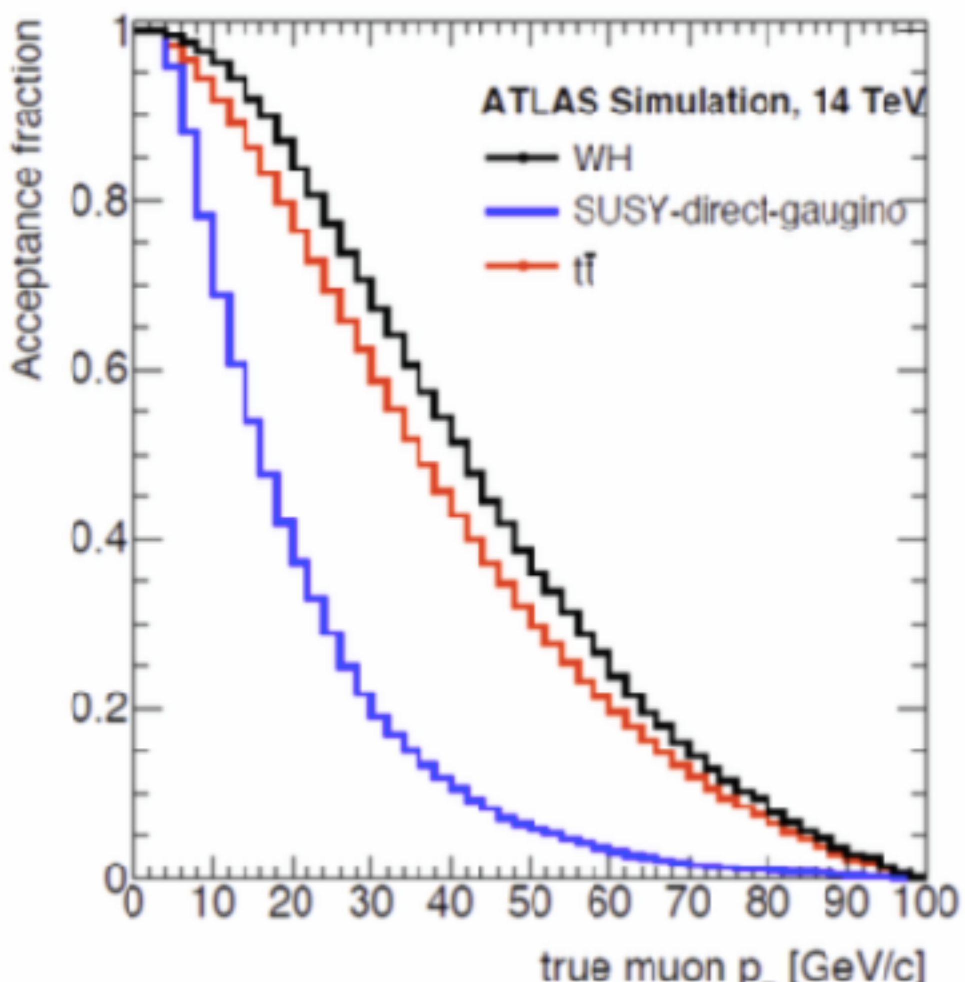
new technologies needed
+ keep what works well
+ cost-effective solutions
+ keep logistics in mind (ALARA)

Need a smart trigger!

Trigger Challenges

- more luminosity → more interesting events but also more background
- only useful if interesting events can still be triggered and read-out
- high pile-up and particle densities lead to decreased resolution at trigger level
  → trigger rates increase beyond capacity of trigger/DAQ system

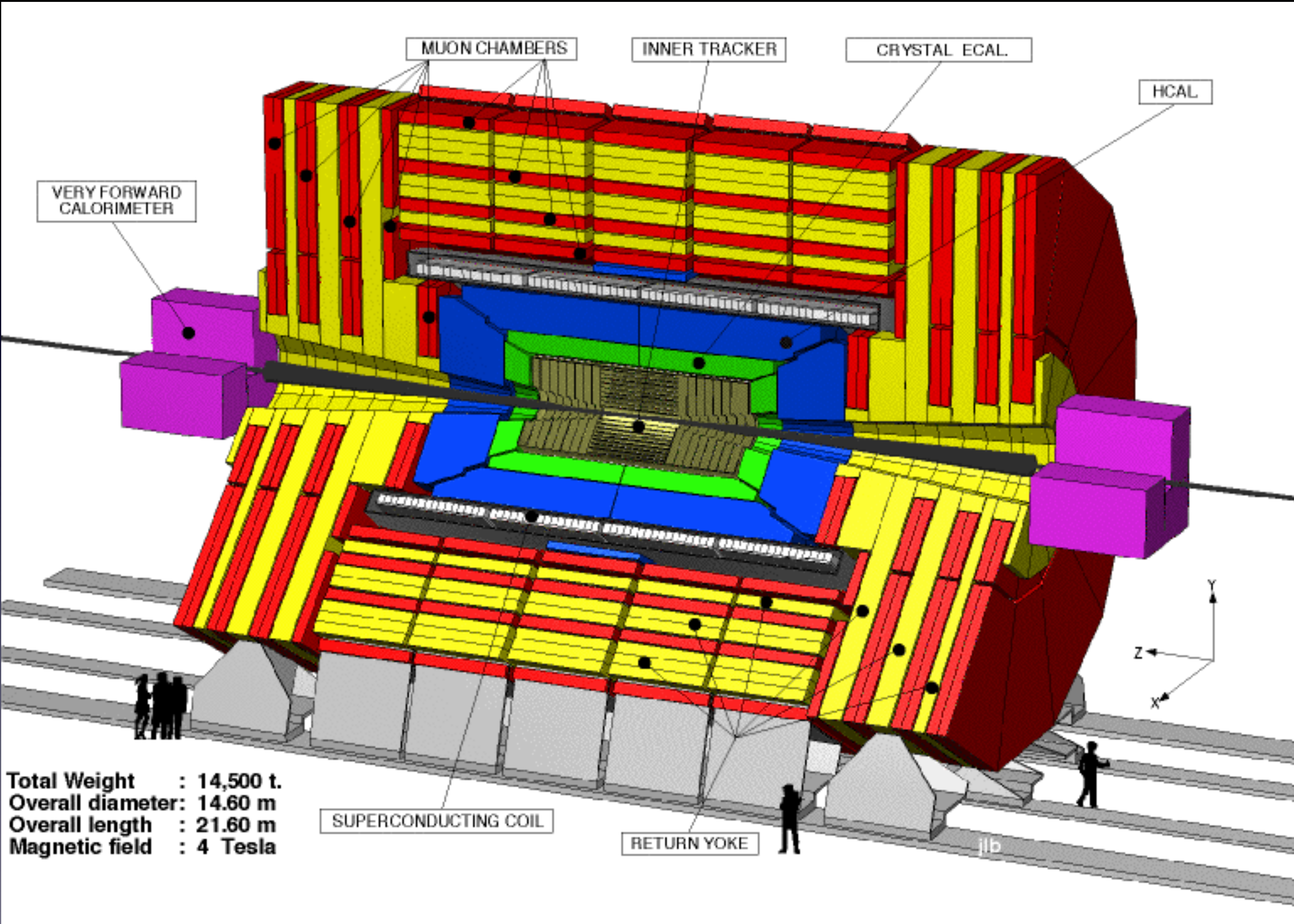


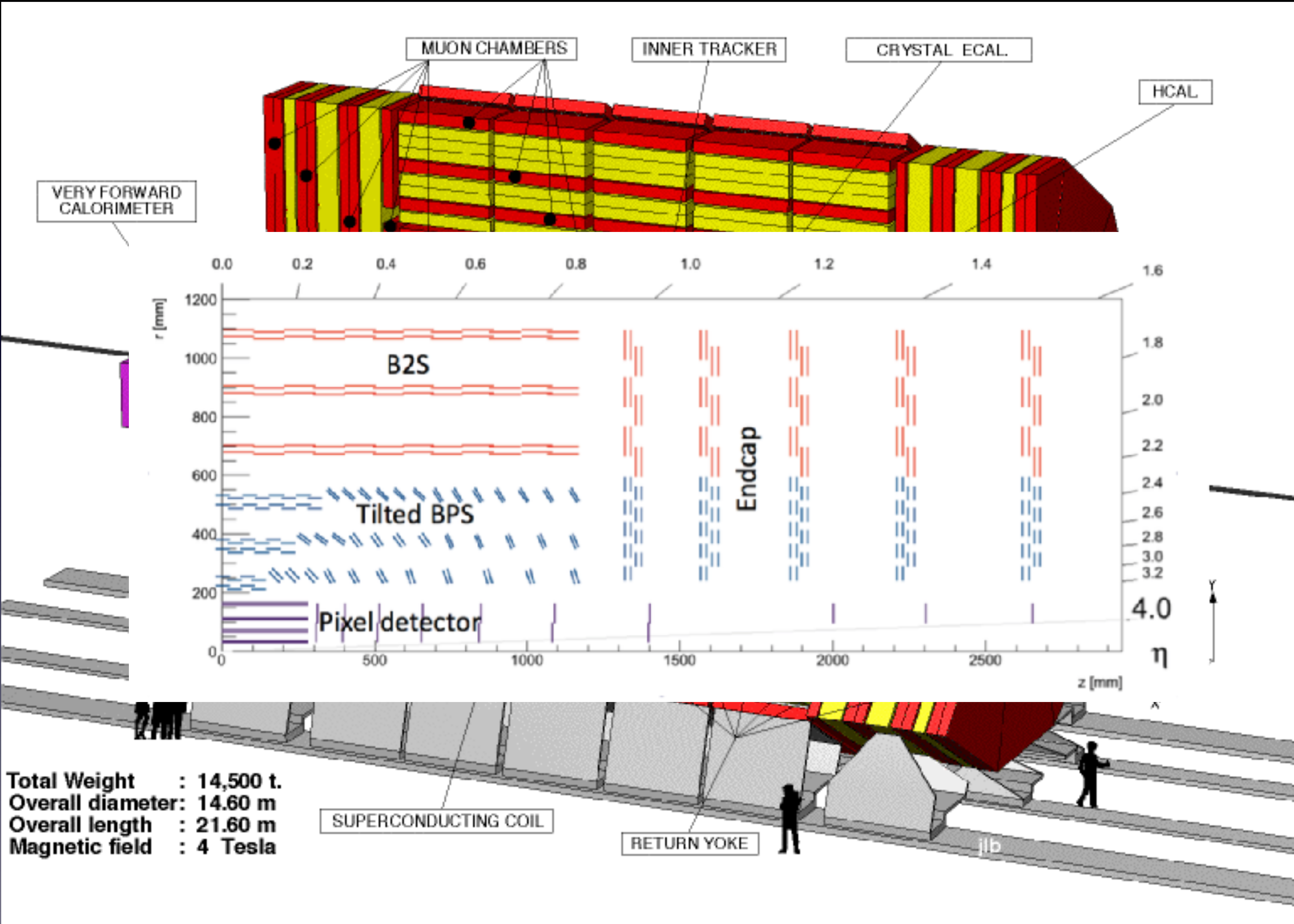


matching of muon system tracks with tracker tracks
→ improved precision of pt measurement at trigger level
→ large rate reduction

simply increasing trigger thresholds would kill the signal

Lutz Feld, Phase-II upgrade. Aachen (2013)


MUON CHAMBERS
INNER TRACKER
CRYSTAL ECAL.
HCAL
VERY FORWARD CALORIMETER
SUPERCONDUCTING COIL
RETURN YOKE
Y
Z
X
Total Weight : 14,500 t.
Overall diameter: 14.60 m
Overall length : 21.60 m
Magnetic field : 4 Tesla


MUON CHAMBERS
INNER TRACKER
CRYSTAL ECAL
HCAL
VERY FORWARD CALORIMETER
B2S
Tilted BPS
Endcap
Pixel detector
r [mm]
z [mm]
η
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
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2.4
2.6
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1200
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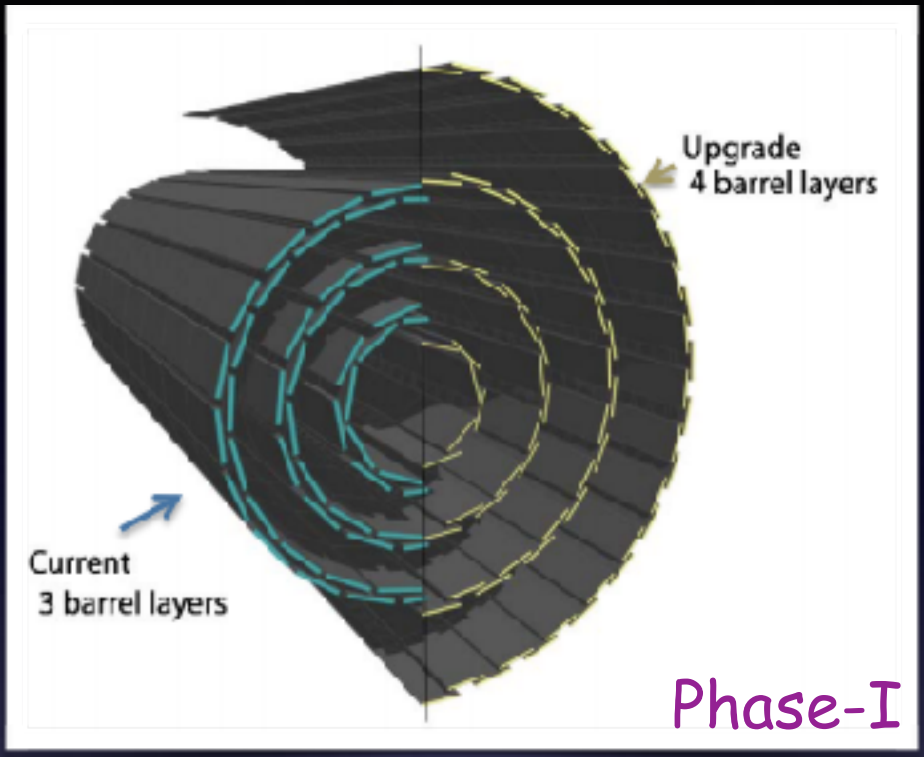
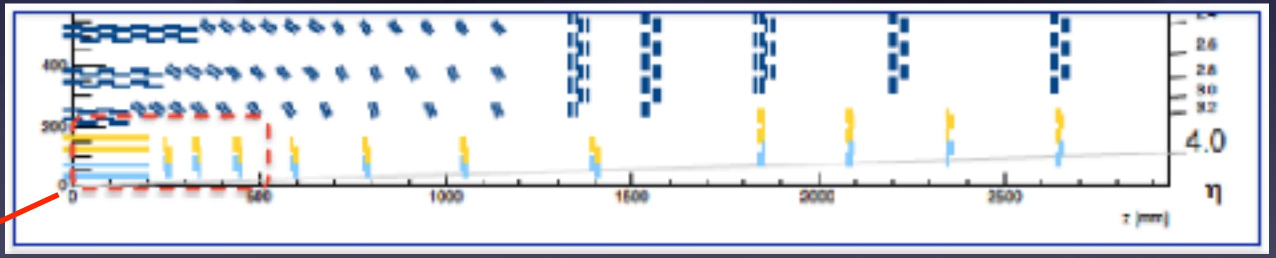
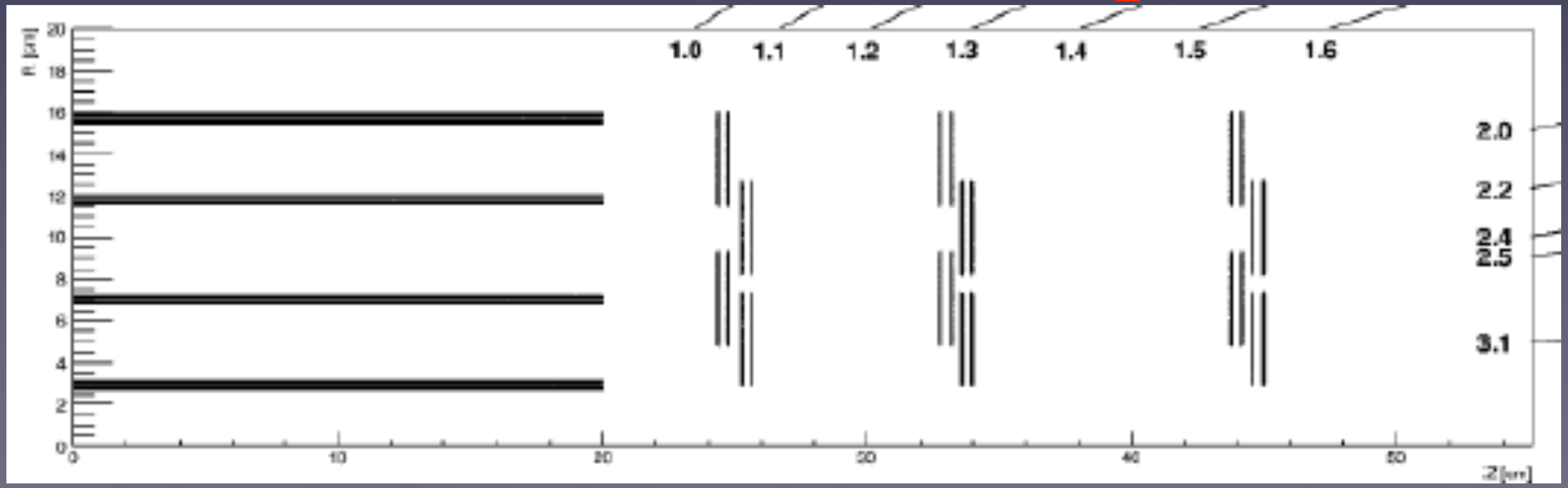
SUPERCONDUCTING COIL
RETURN YOKE
Total Weight : 14,500 t.
Overall diameter: 14.60 m
Overall length : 21.60 m
Magnetic field : 4 Tesla

Pixel Upgrade

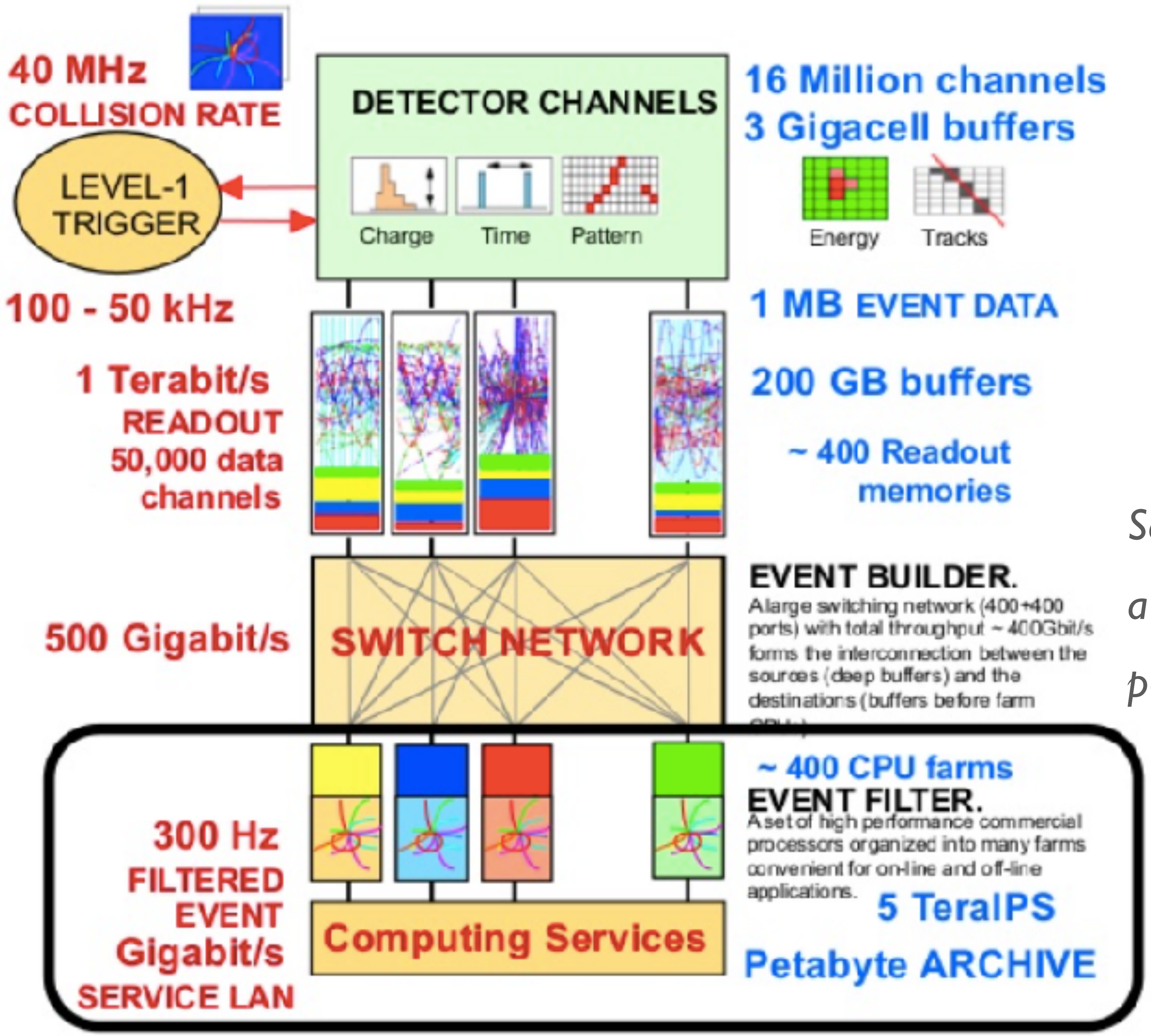
- Radiation tolerant
- Thin sensors ~100 μm
- Smaller pixels 30×100 μm
- Position resolution 2~3 μm
- Coverage up to η~4
    - Only first three disks used for trigger







The CMS Data Acquisition System



L1 gives a simple information passing the threshold & region of interest (seed)

HLT combines L1 information from several detector parts

Save events satisfying

a specific cut (ex. $\mu(p_T)>24$GeV)

per prescale (ex. 1 in 100 events)

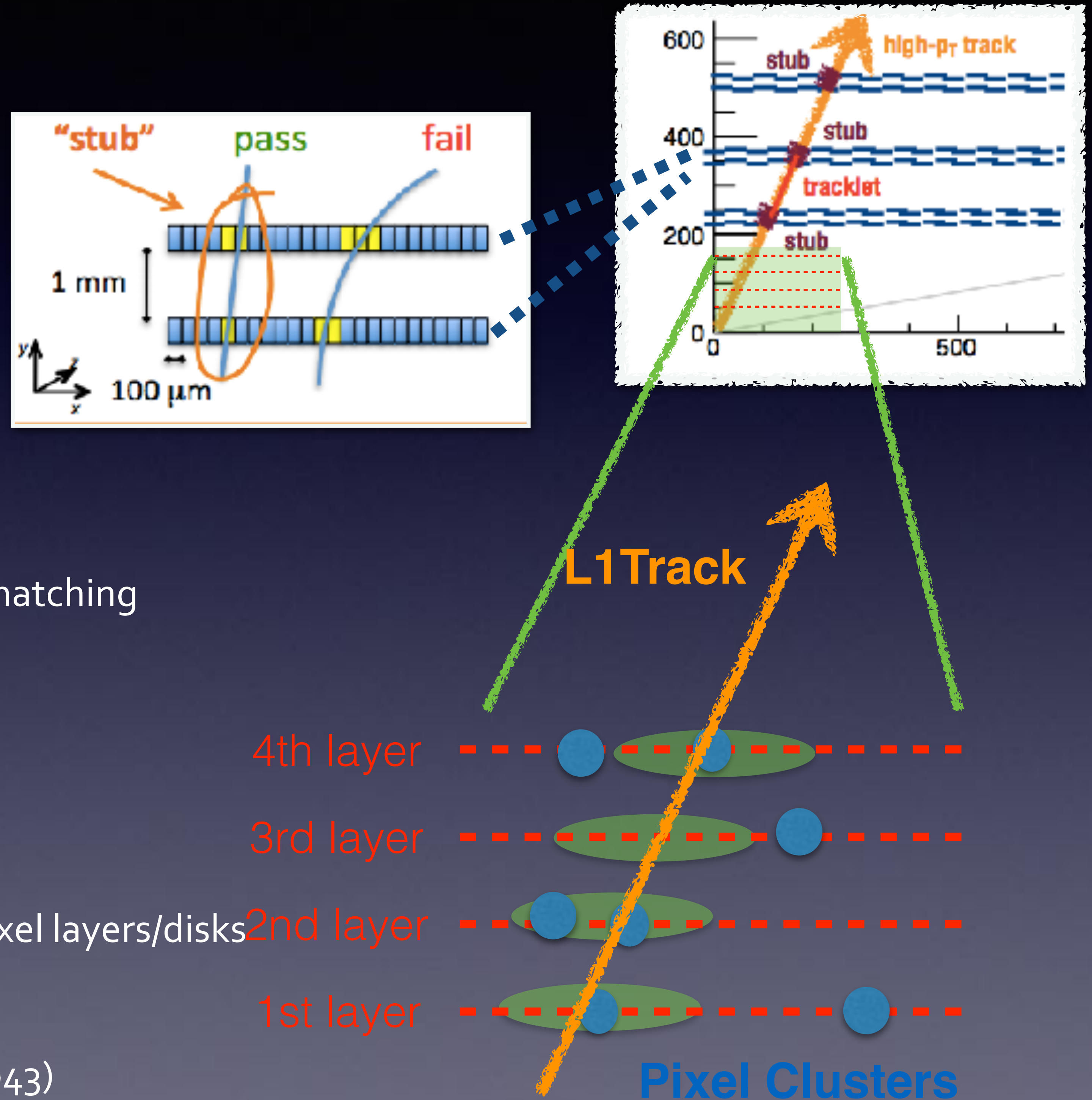
Cluster with ~1300 computers doing event filtering

New in Phase-II

L1 (Pixel) Track

L1 Track

- Self-seeded L1 track from silicon strip tracker
- L1 Track: Full efficiency at 2.2 GeV/c & track parameters (zo, do, phi, eta, p_T)



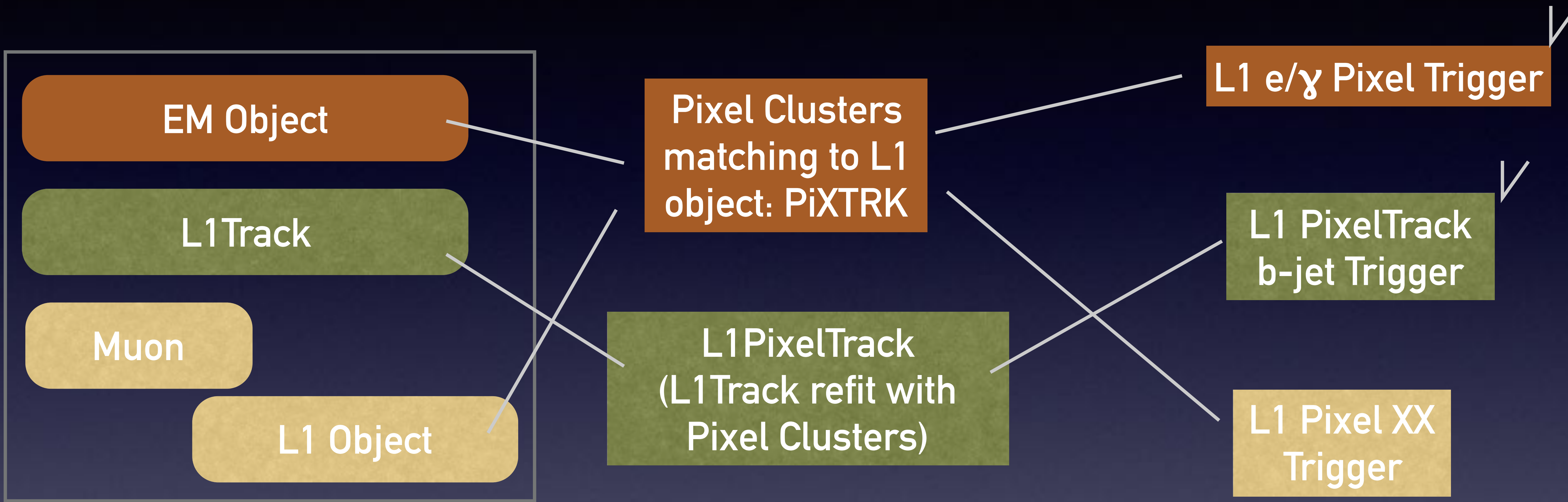
L1 Pixel Track

- Refit the L1 track with pixel clusters with following matching condition:
  - Barrel layers: $|r\Delta\phi| < 3$ mm, $|\Delta z| < 5$ mm
  - Endcap disks: $|\Delta r| < 5$mm
  - Require pixel clusters from at least 3 different pixel layers/disks on the track
  - Use linearized χ^2 fit (CMS Detector Note 2014-043)
- Adding pixel clusters improves track resolution !!

$$\chi^2_{pixel} = \sum_i \frac{(f_i(\vec{\eta}) - m_i)^2)}{\sigma_i^2}$$

A. Ryd, L. Skinnari

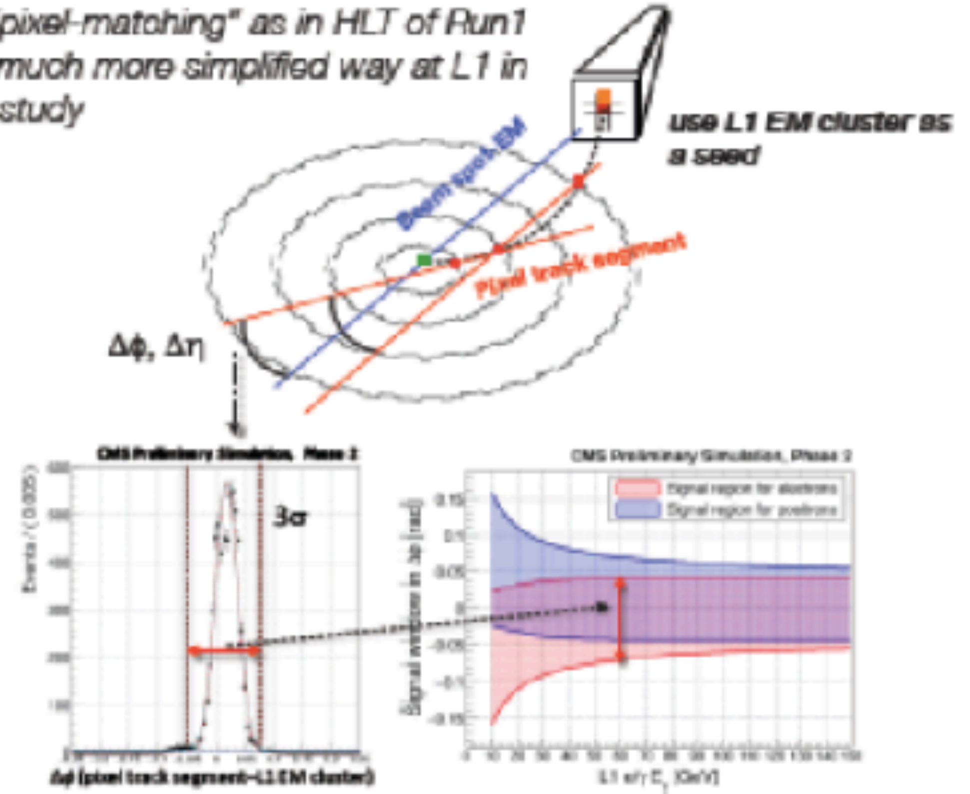
L1 Pixel Track Triggers

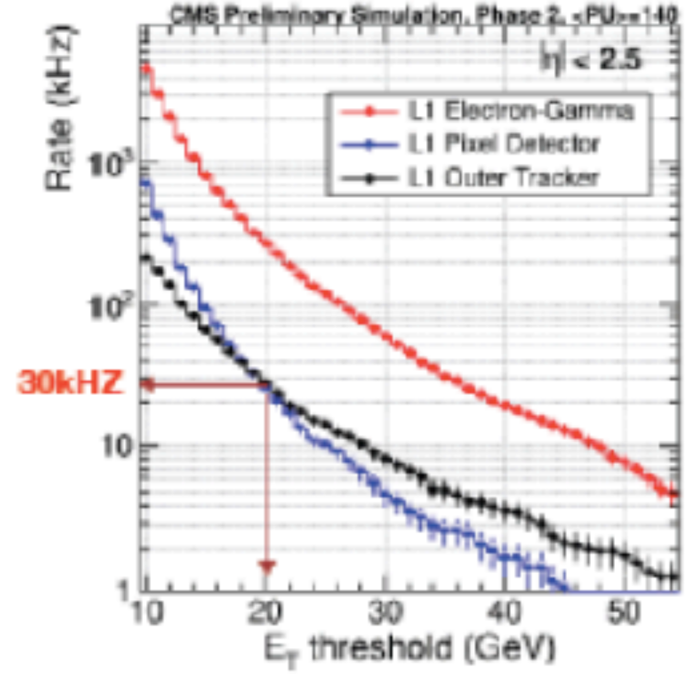


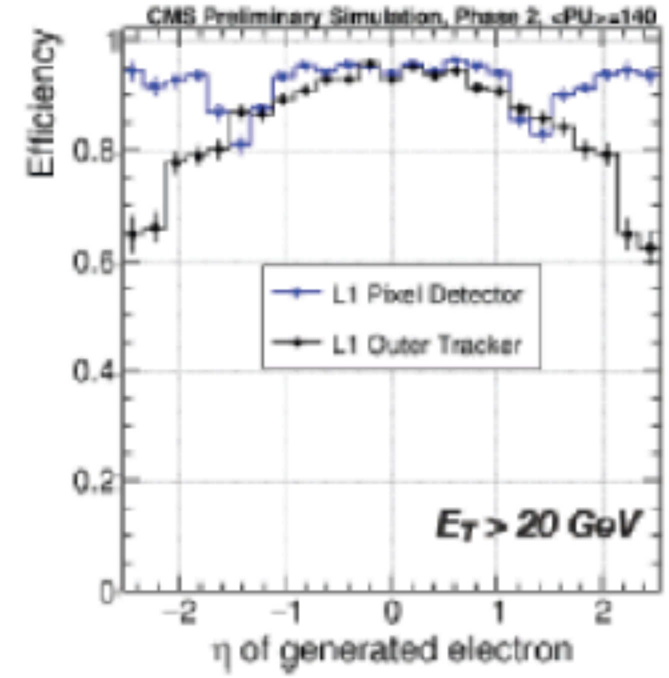
- Two main challenges
  - **Bandwidth** is overcome by a seed trigger (eg L1EMcluster)
  - **L1 latency** needs a study of possible implementation of L1 fast trigger in the pixel FE readout architecture

L1 pixel trigger for electron

do "pixel-matching" as in HLT of Run1 but much more simplified way at L1 in this study

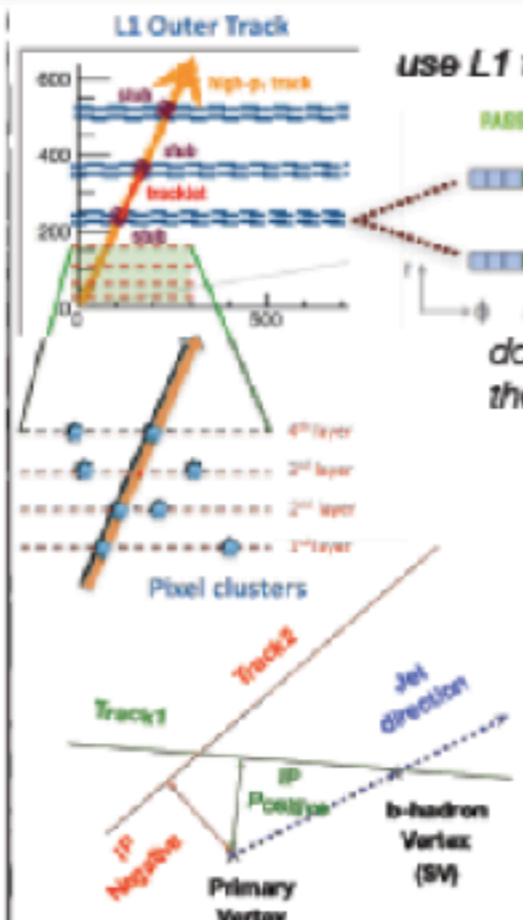




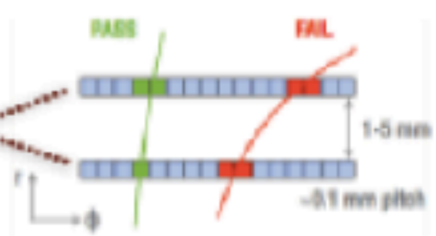


- *electron trigger efficiency improved in high η region (|η|>1.6) up to 20% while keeping the same level of single electron trigger rate at E_T > 20 GeV*

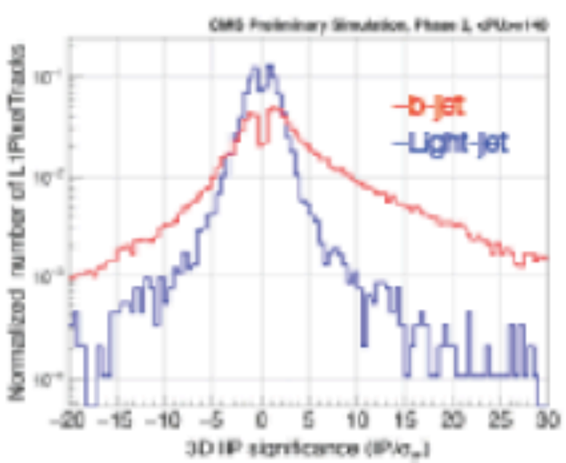
L1 pixel trigger for b-tagging

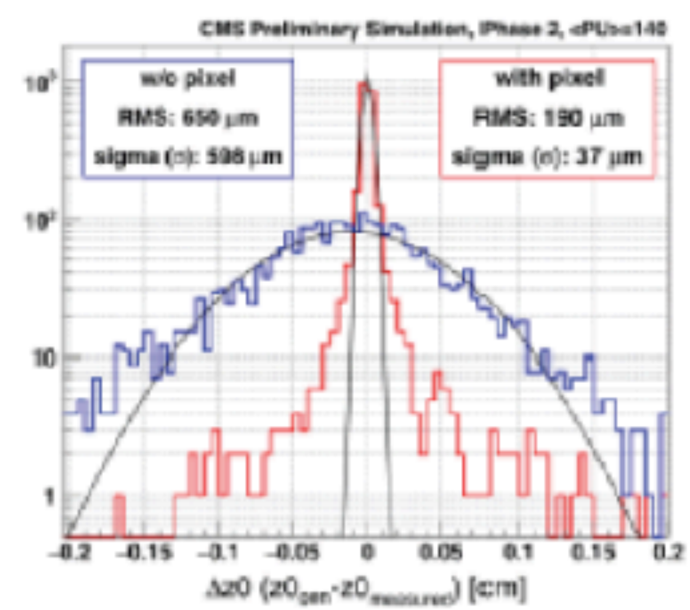


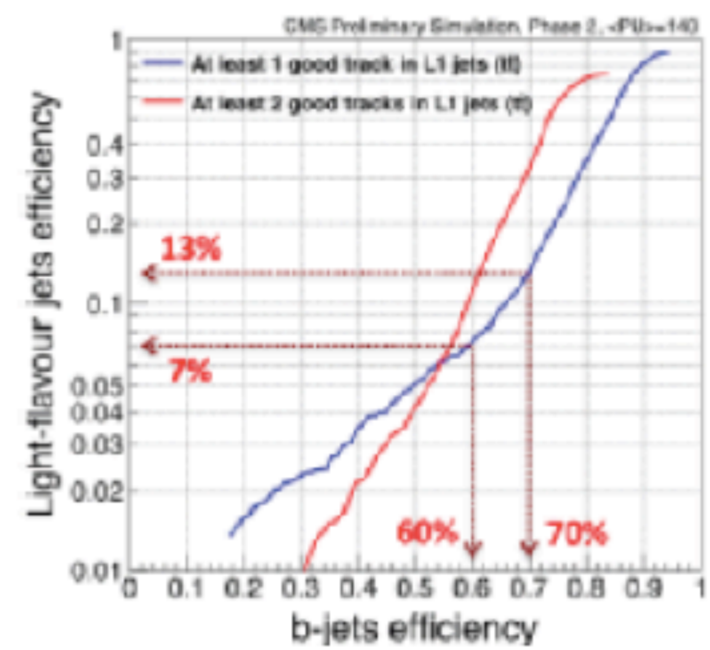
use L1 track as a seed



do matching pixel clusters with L1 tracks then repeating the linearized track fit to







- *jet vertex resolution improved from 600 μm (without pixel) to 40 μm*
- *~65% b-tagging efficiency for a light jet missing rate of ~10% at p_T > 20 GeV*

$$3DIP = \sqrt{(2DIP)^2 + (\Delta z0)^2_{L1jet-L1PixelTrack}}$$

L1 PIXEL TT: RECAP IN A NUTSHELL

Summary & Status

- Feasibility studies show the potential of the pixel inner tracker for improving performances of the L1 trigger

- Exploiting the forward tracking potential of the inner pixel tracker down to η of 4 opens a unique physics opportunity (eg very forward muon trigger, Bs→ϕϕ by S. Sarkar et al.)

- CMS software framework migration ongoing

  - Phase-II pixel detector design change

  - Update pixel trigger studies using migrated framework and new MC samples under progress