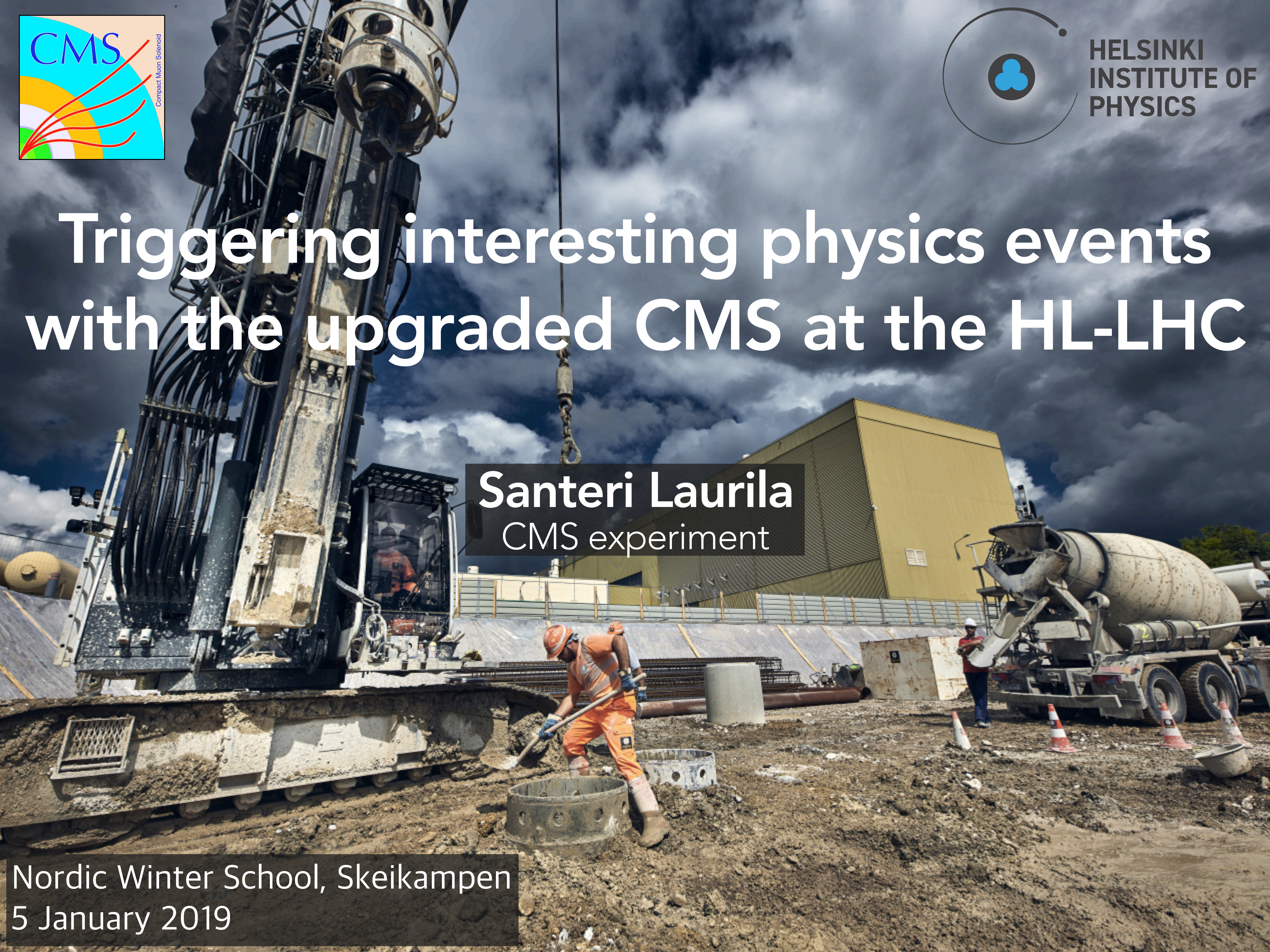
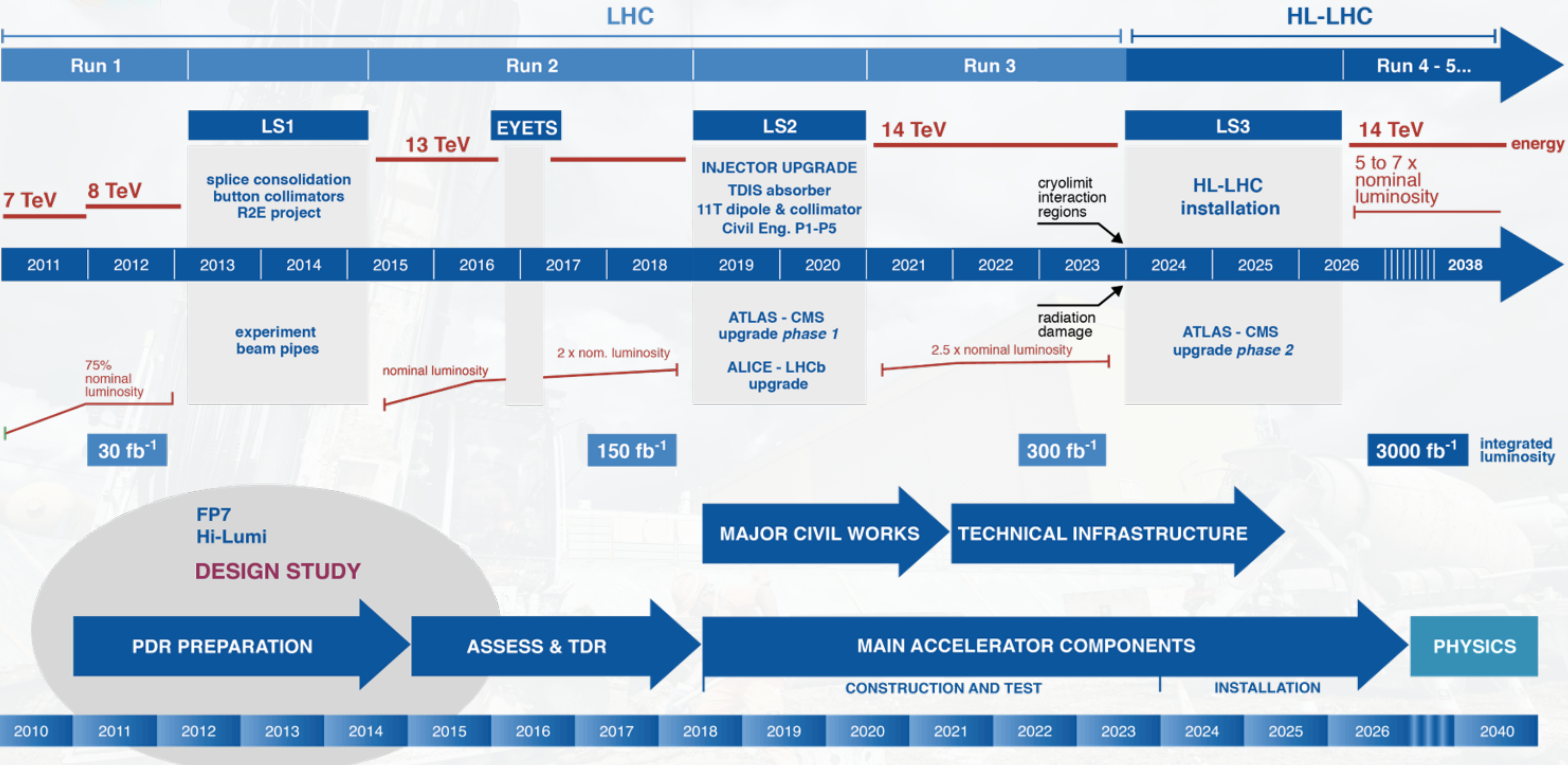


Triggering interesting physics events with the upgraded CMS at the HL-LHC

Santeri Laurila
CMS experiment
HELSINKI INSTITUTE OF PHYSICS

Nordic Winter School, Skeikampen
5 January 2019

Future of the LHC



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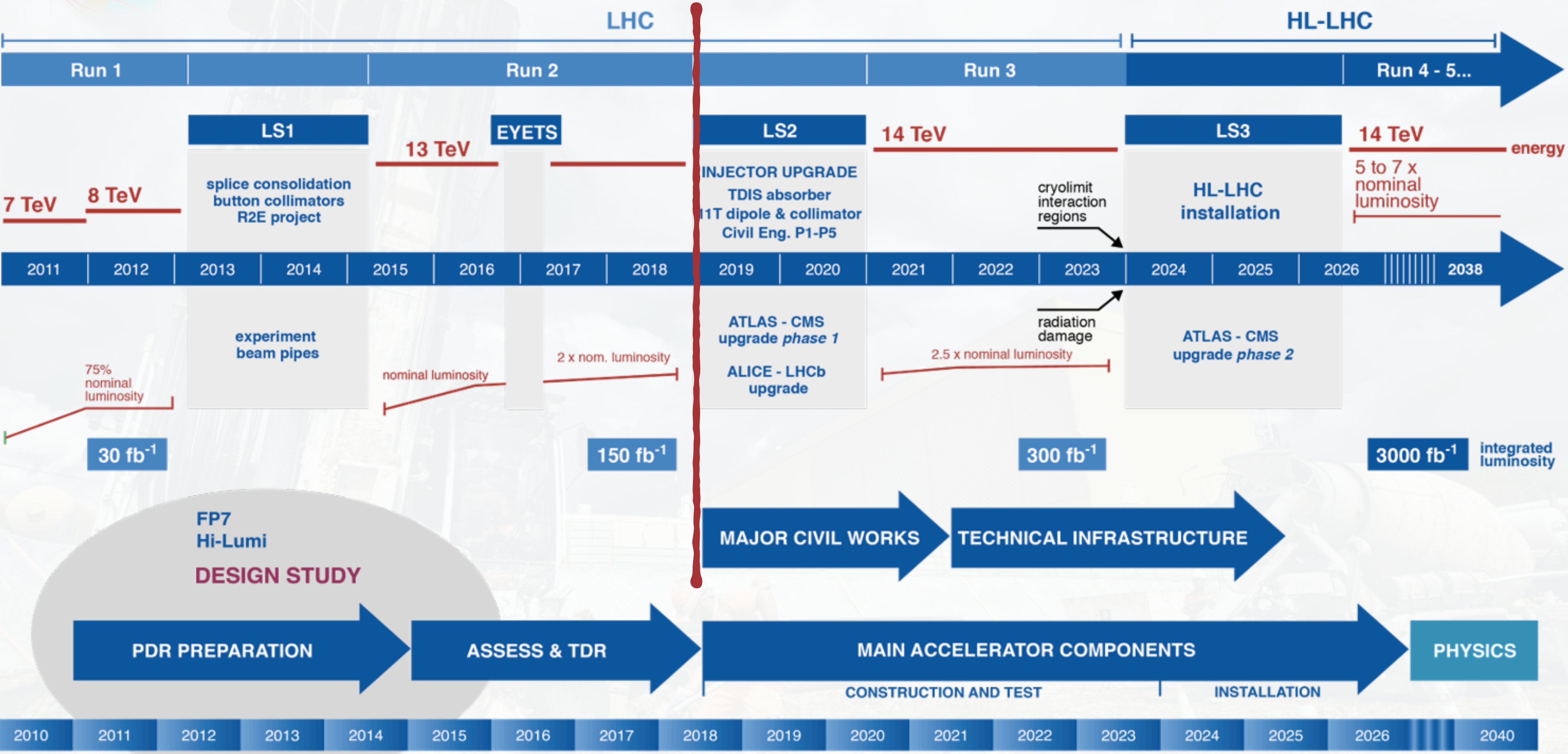

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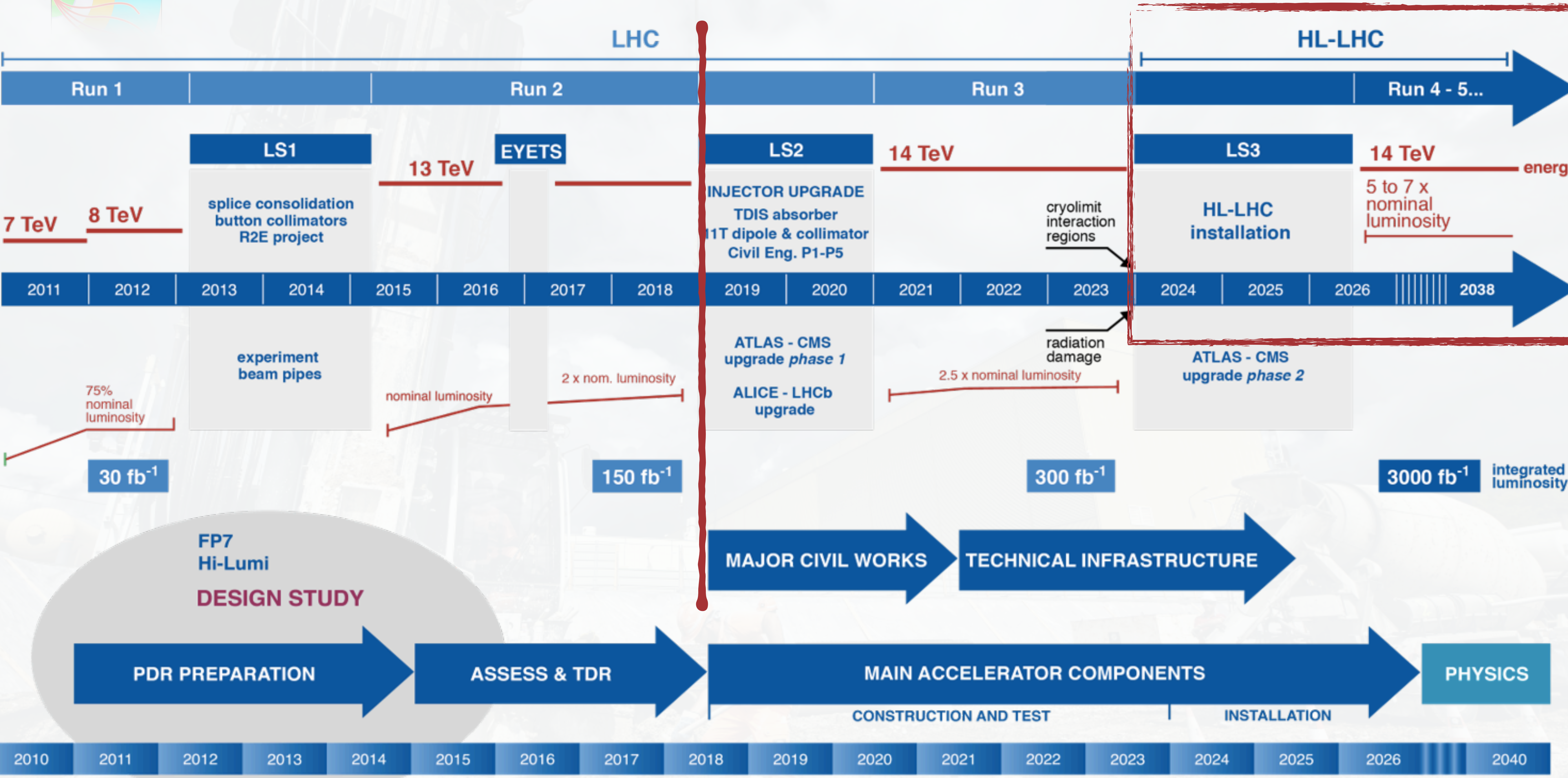

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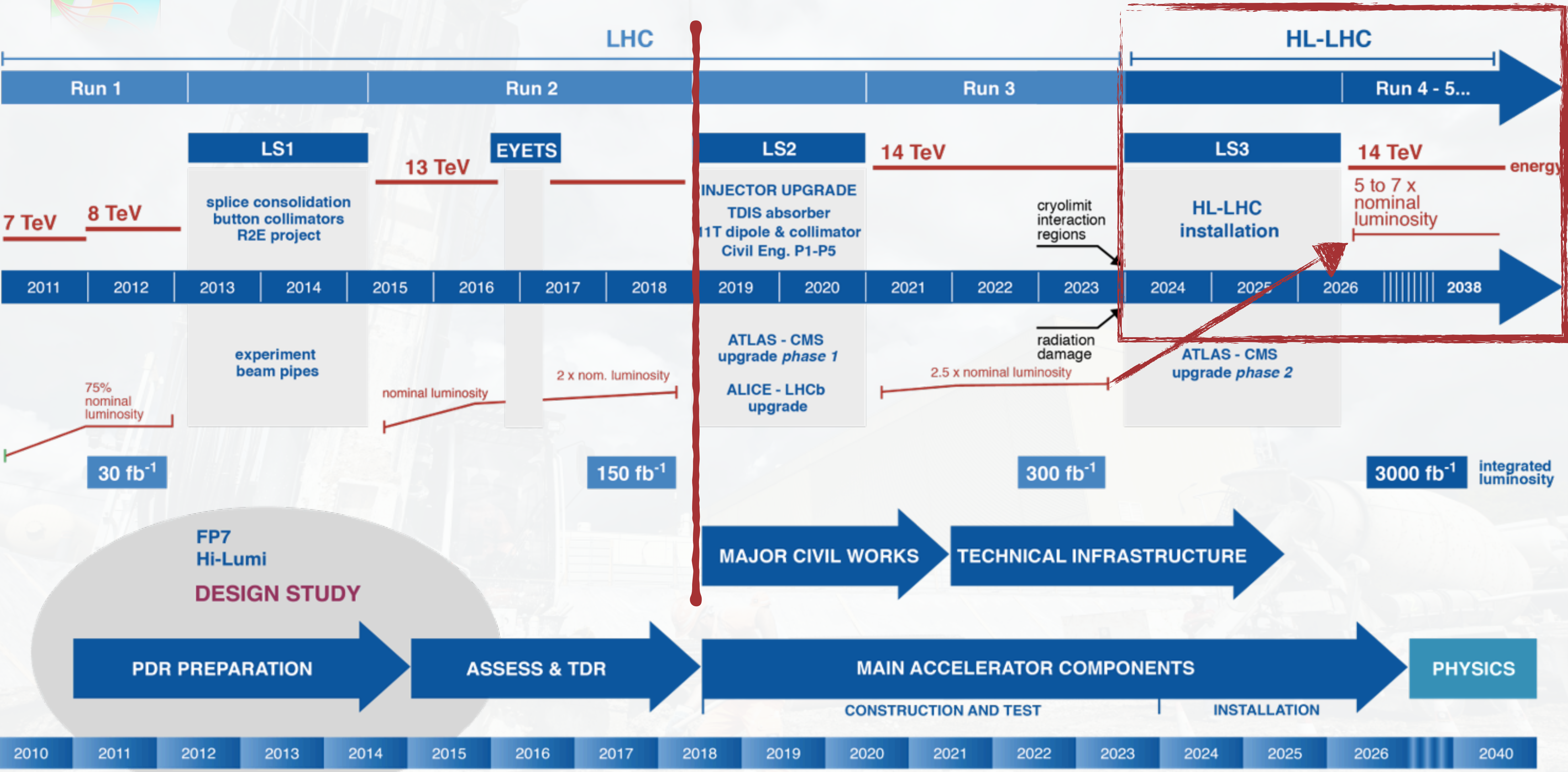

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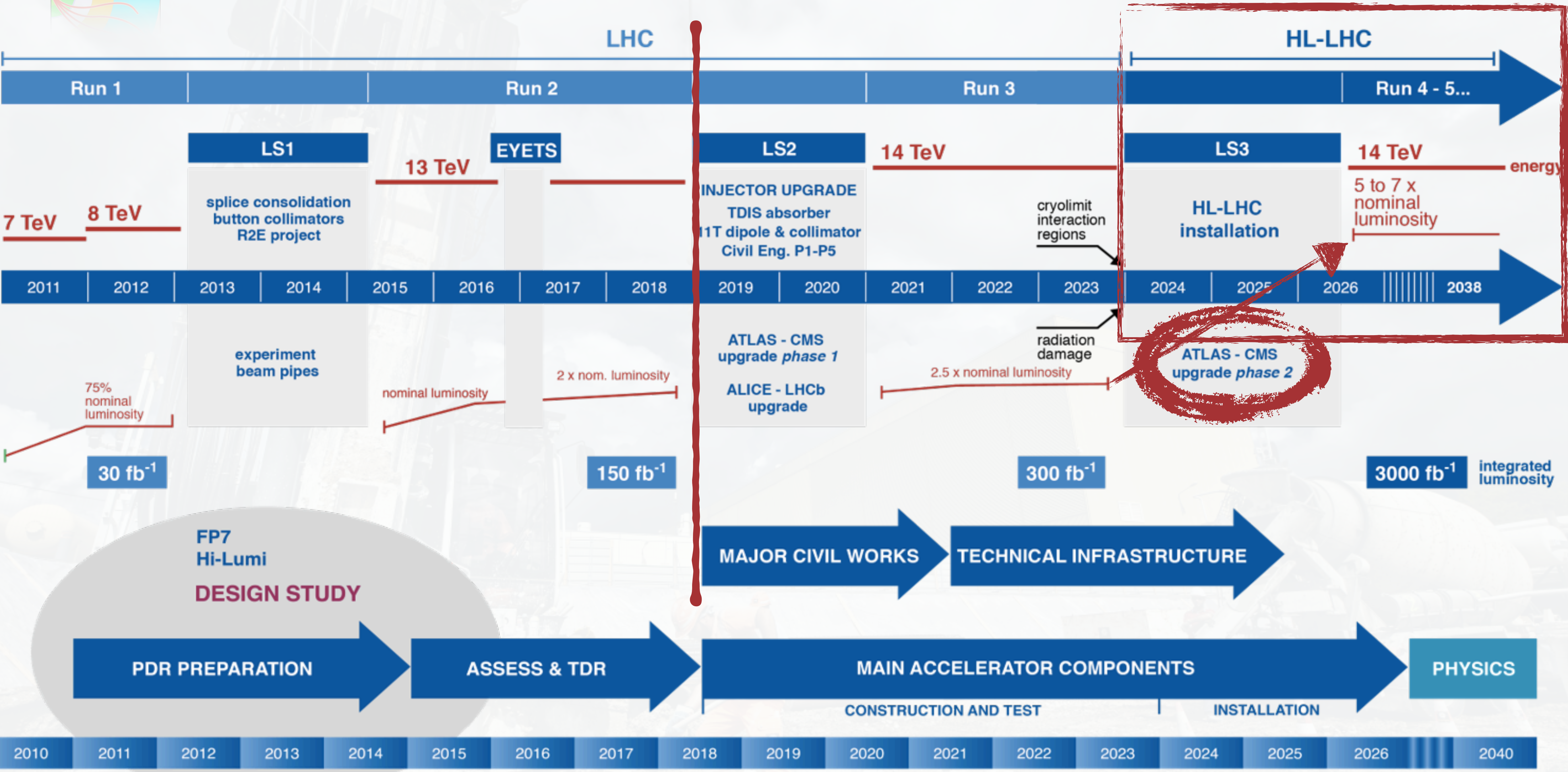

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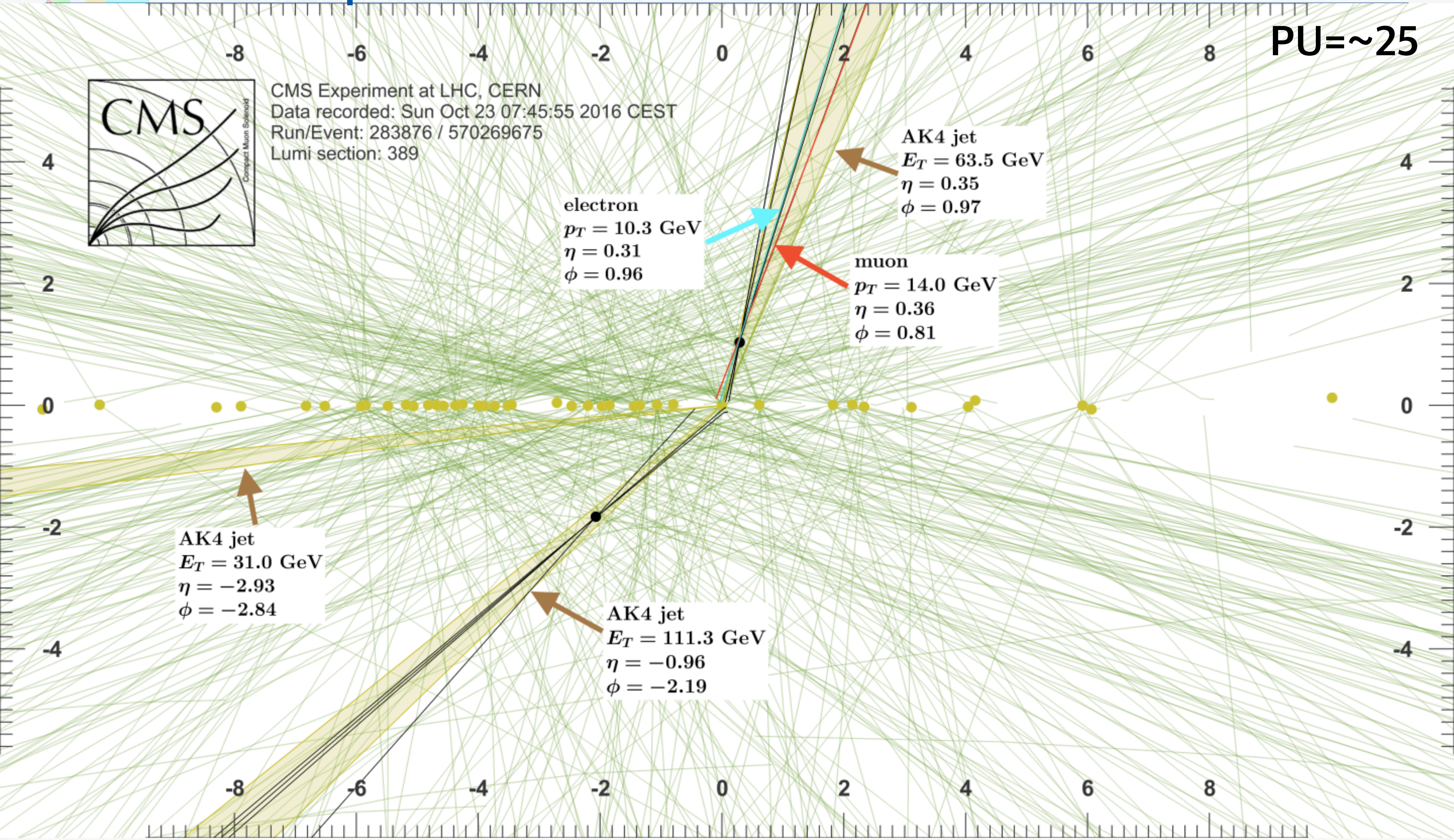
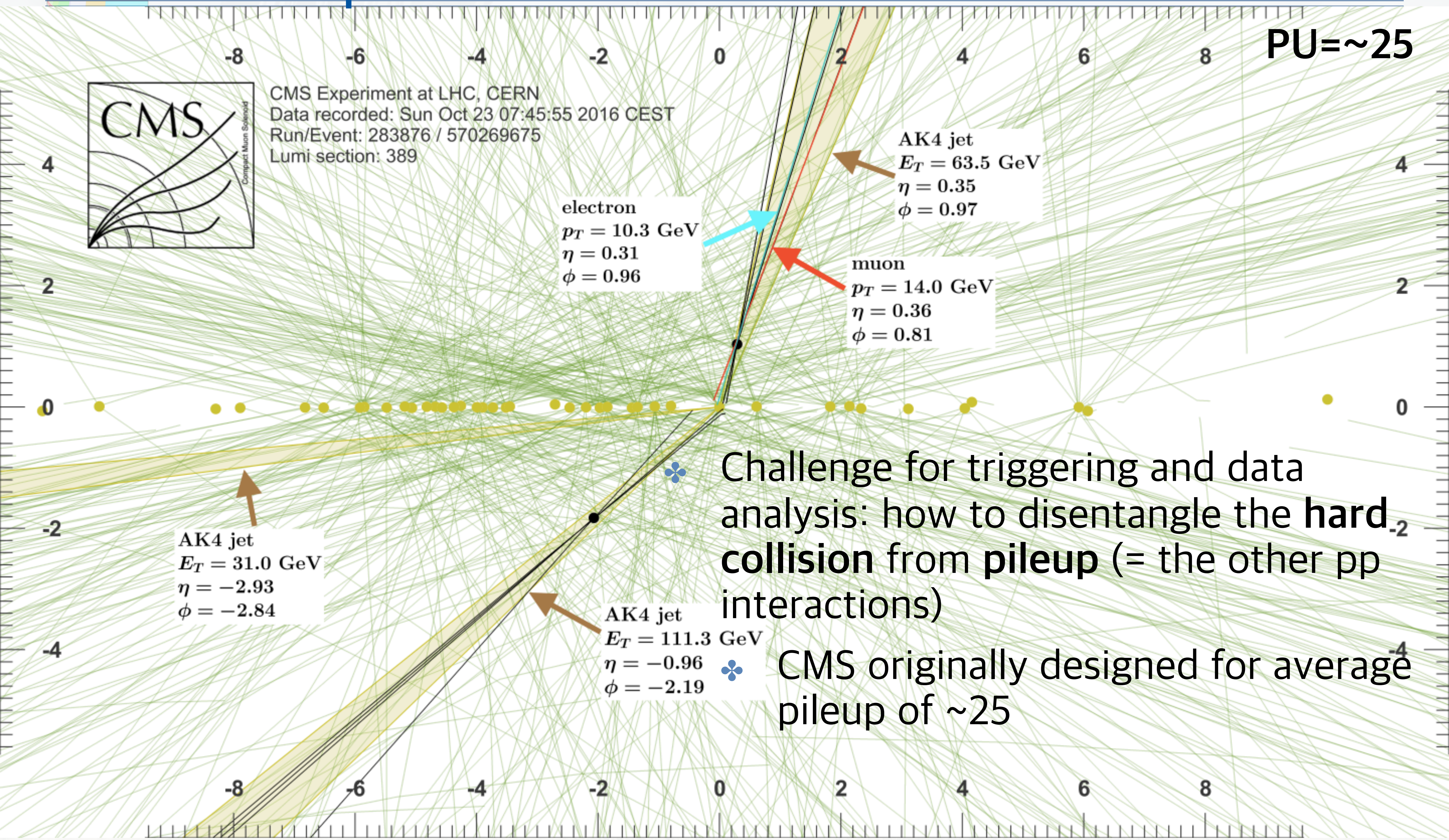
Pileup



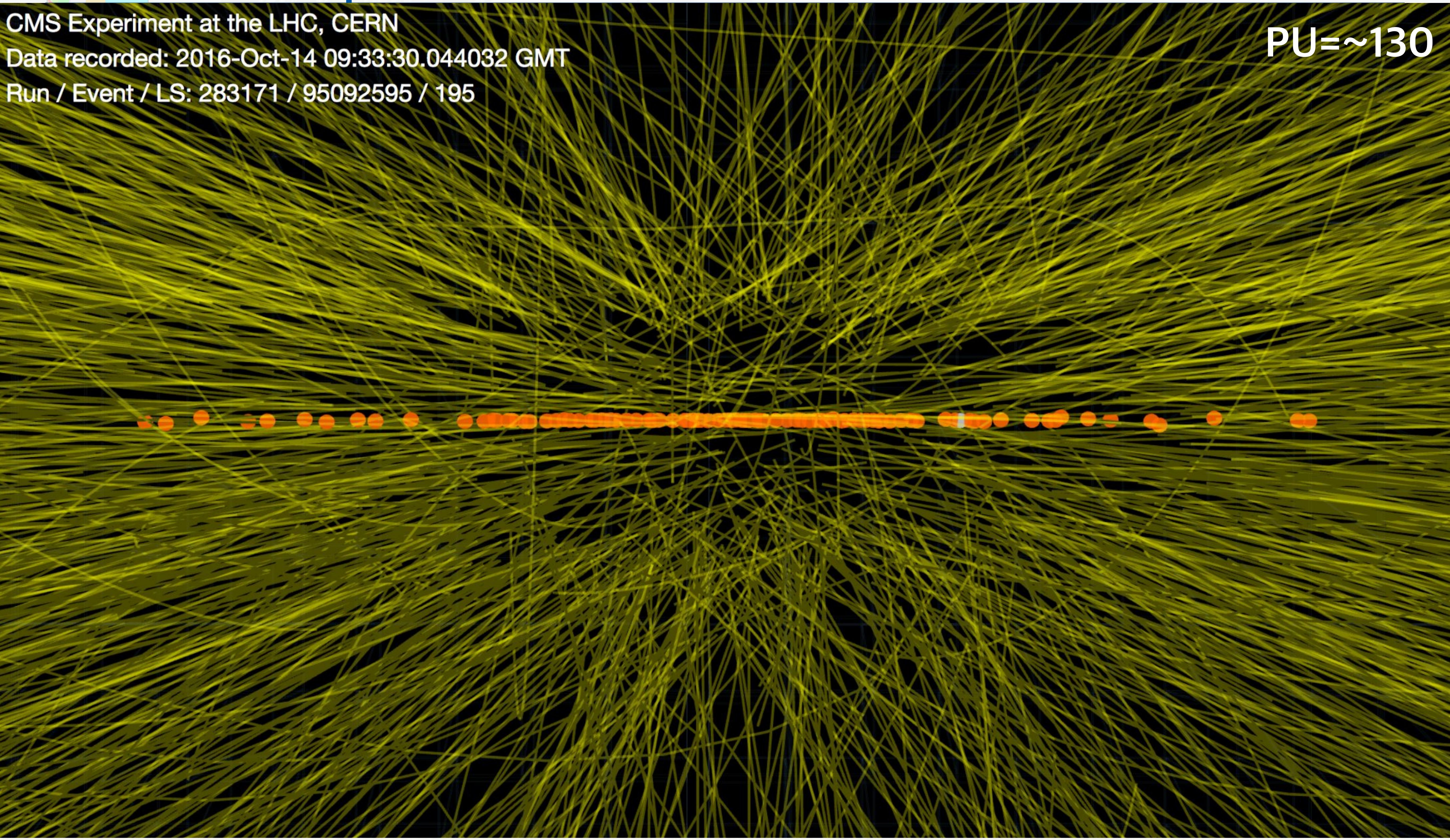
PU=~25
CMS Experiment at LHC, CERN
Data recorded: Sun Oct 23 07:45:55 2016 CEST
Run/Event: 283876 / 570269675
Lumi section: 389
AK4 jet
$E_T = 63.5$ GeV
$\eta = 0.35$
$\phi = 0.97$
electron
$p_T = 10.3$ GeV
$\eta = 0.31$
$\phi = 0.96$
muon
$p_T = 14.0$ GeV
$\eta = 0.36$
$\phi = 0.81$
AK4 jet
$E_T = 31.0$ GeV
$\eta = -2.93$
$\phi = -2.84$
AK4 jet
$E_T = 111.3$ GeV
$\eta = -0.96$
$\phi = -2.19$
-8
-6
-4
-2
0
2
4
6
8

Pileup

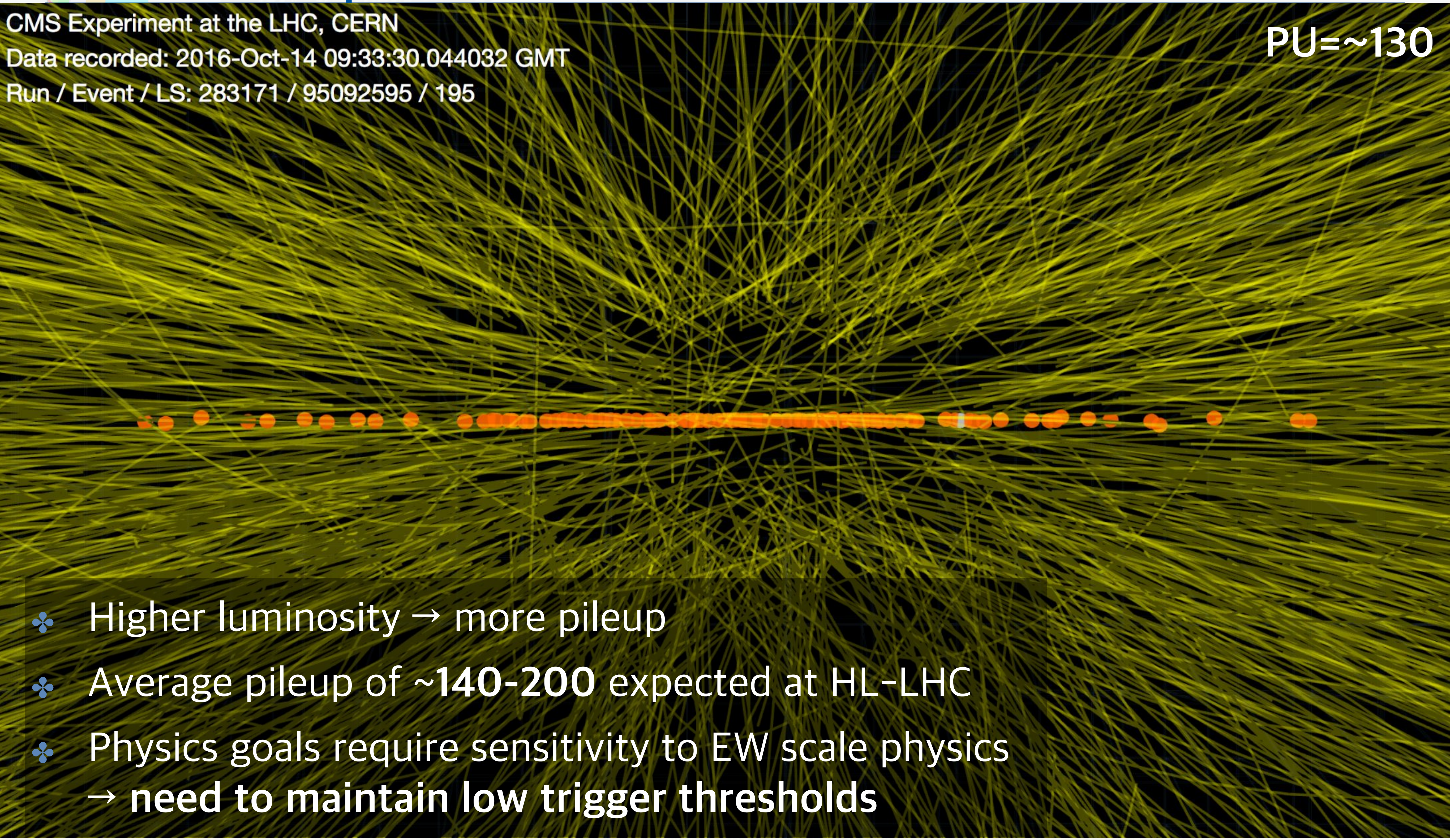


- Challenge for triggering and data analysis: how to disentangle the **hard collision** from **pileup** (= the other pp interactions)
  - CMS originally designed for average pileup of ~25

Pileup


CMS Experiment at the LHC, CERN
Data recorded: 2016-Oct-14 09:33:30.044032 GMT
Run / Event / LS: 283171 / 95092595 / 195
PU=~130

Pileup

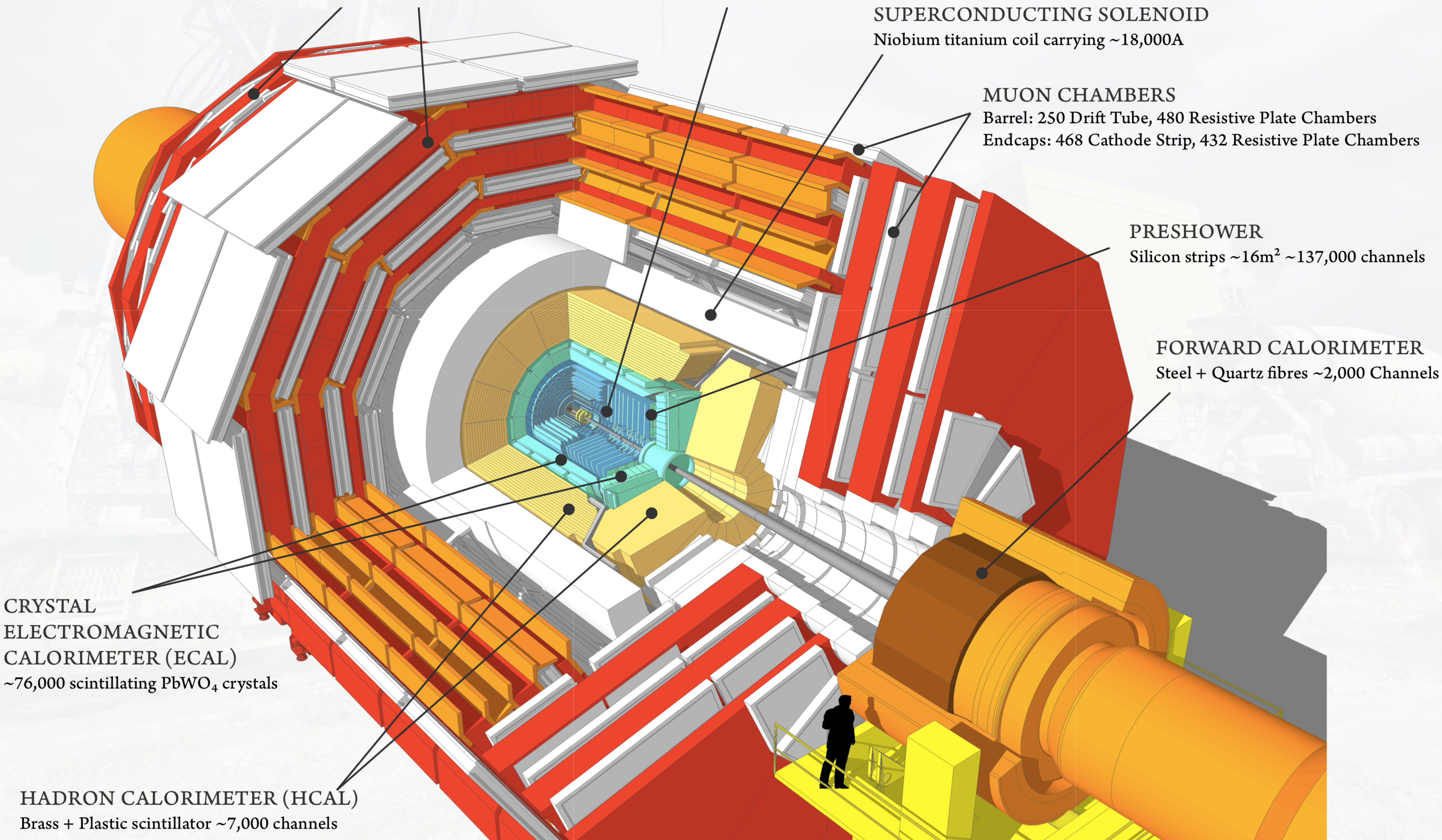


- Higher luminosity → more pileup
- Average pileup of ~**140-200** expected at HL-LHC
- Physics goals require sensitivity to EW scale physics
  → **need to maintain low trigger thresholds**

CMS Phase-2 Upgrade

- We need a **fast** and **radiation-hard** detector with **high-granularity readout**

  …and a smart trigger



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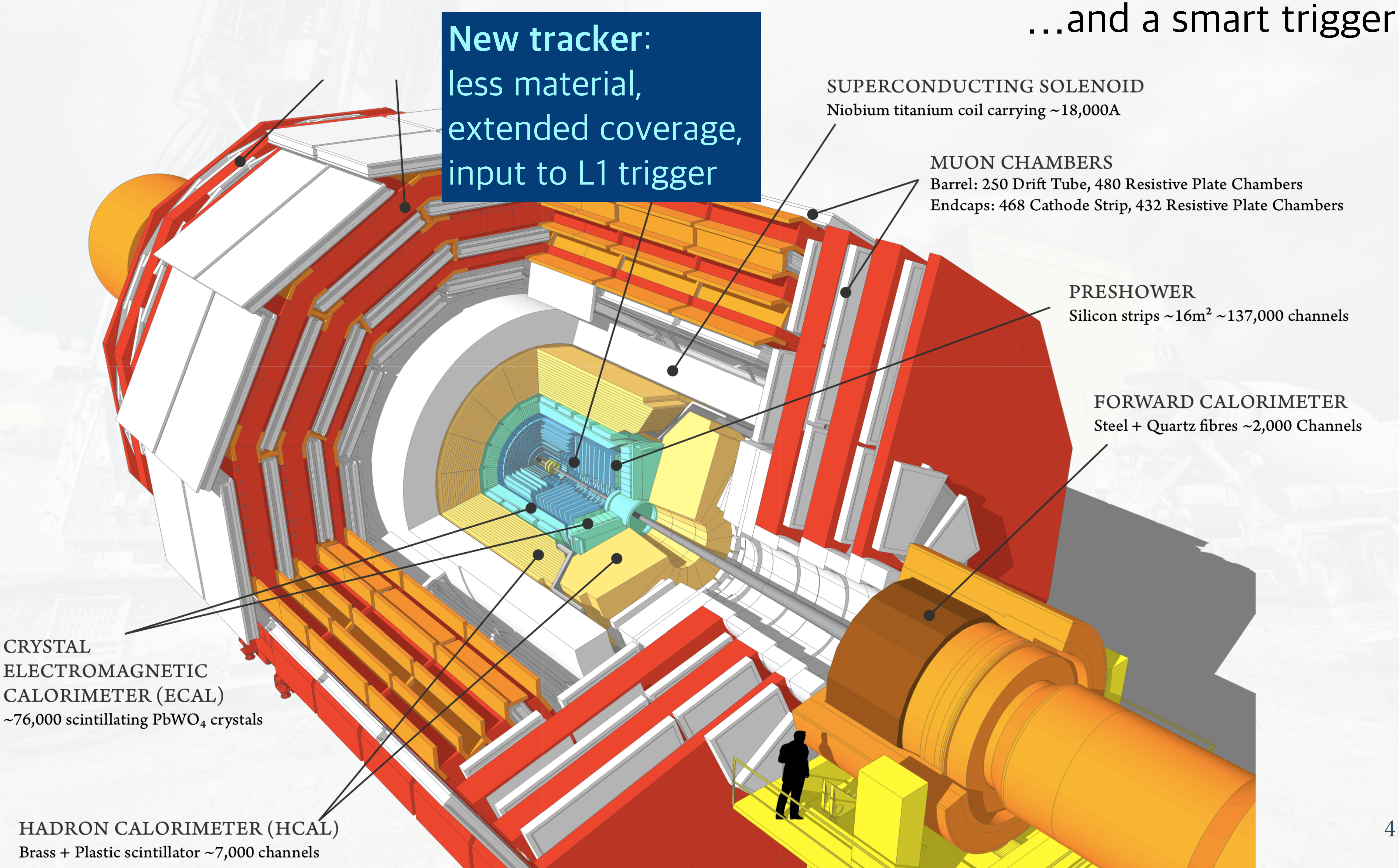

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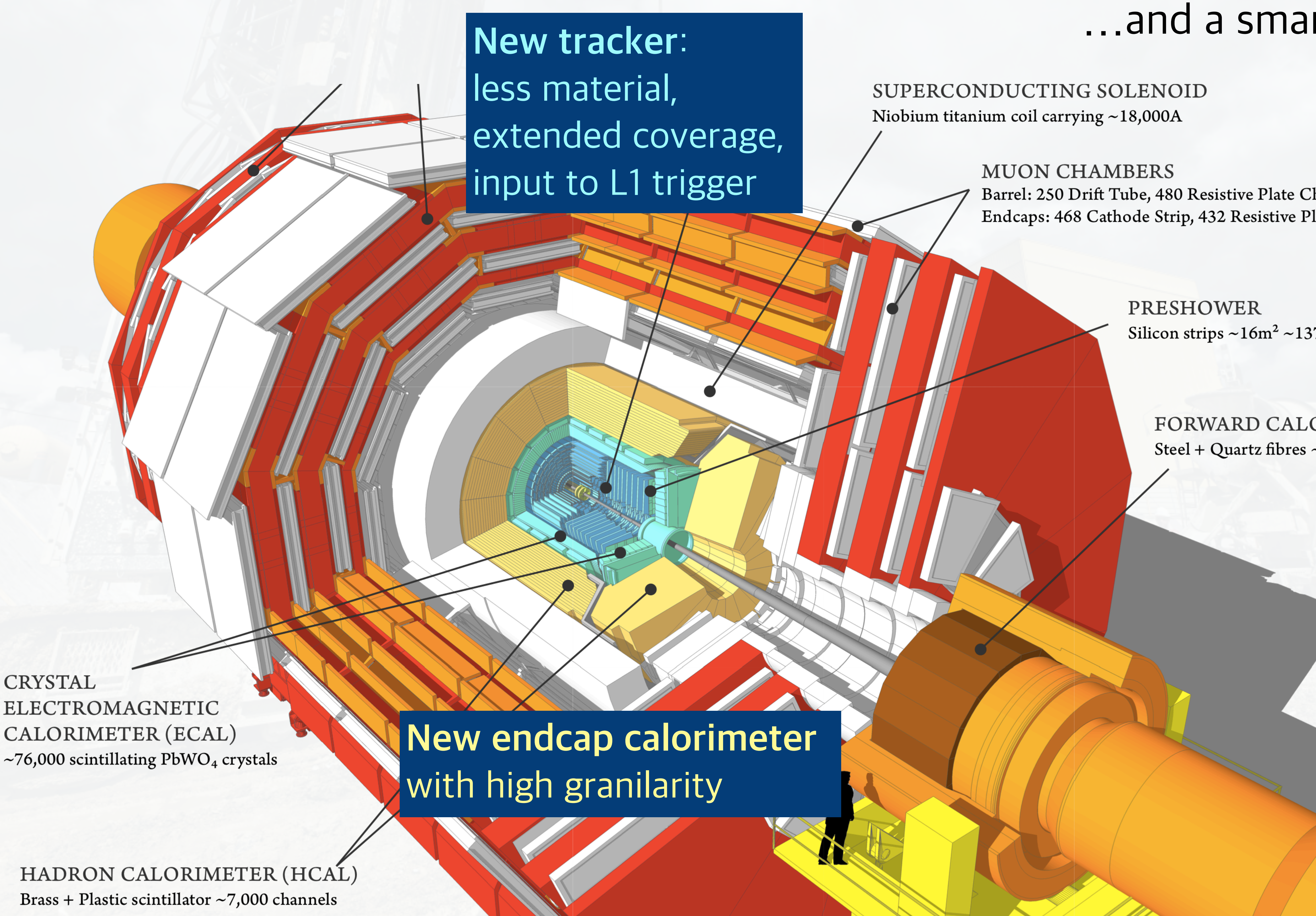

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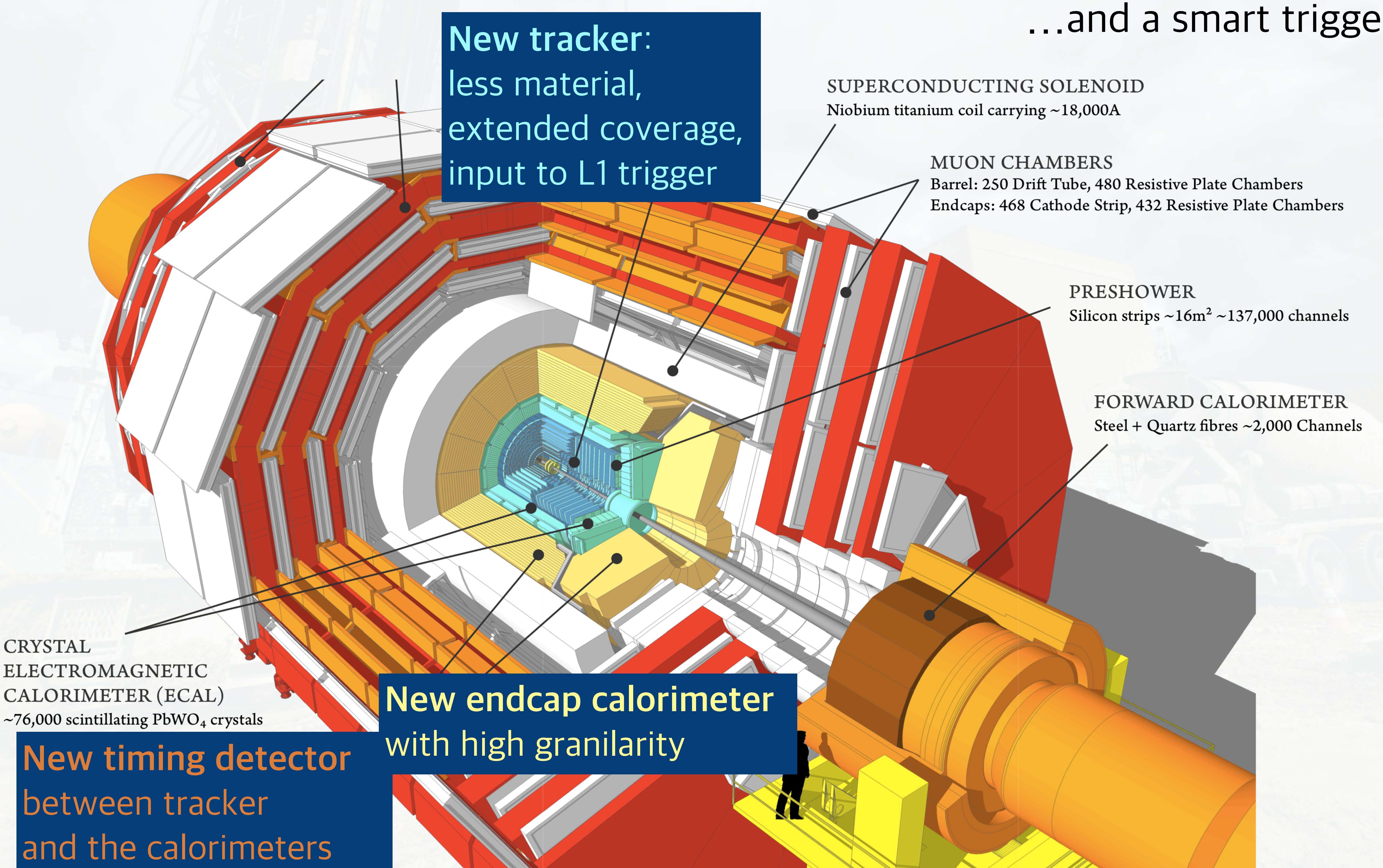

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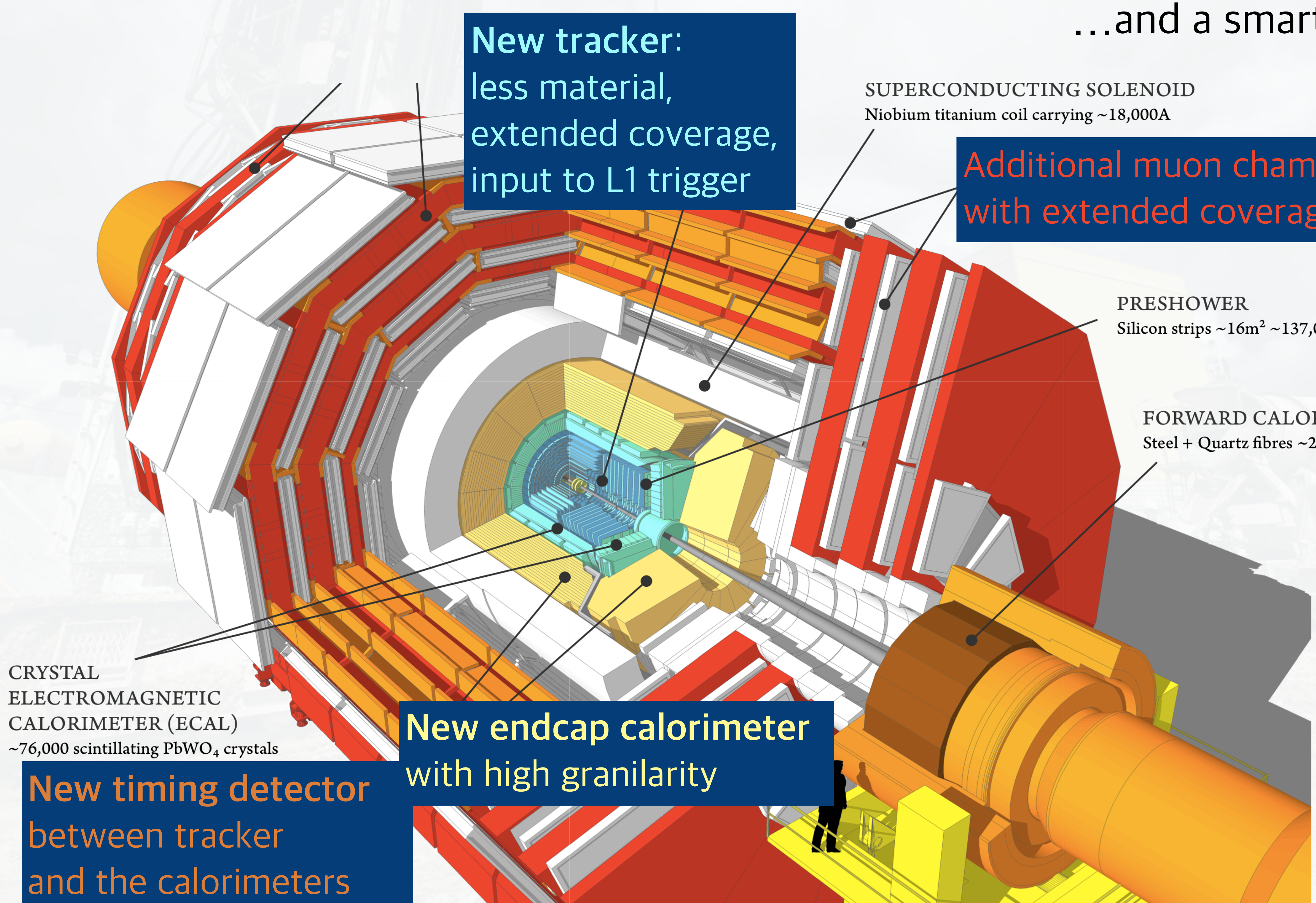

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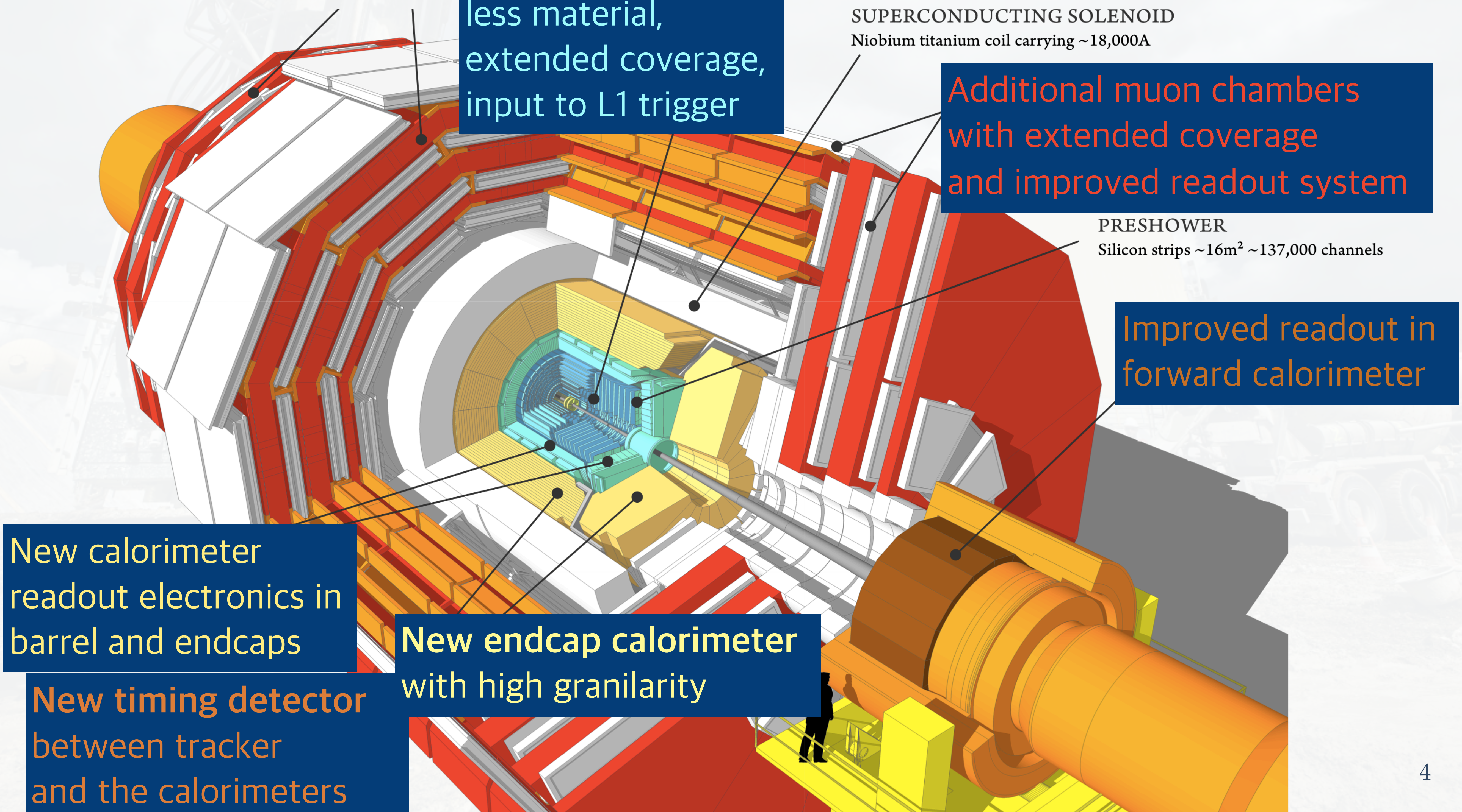

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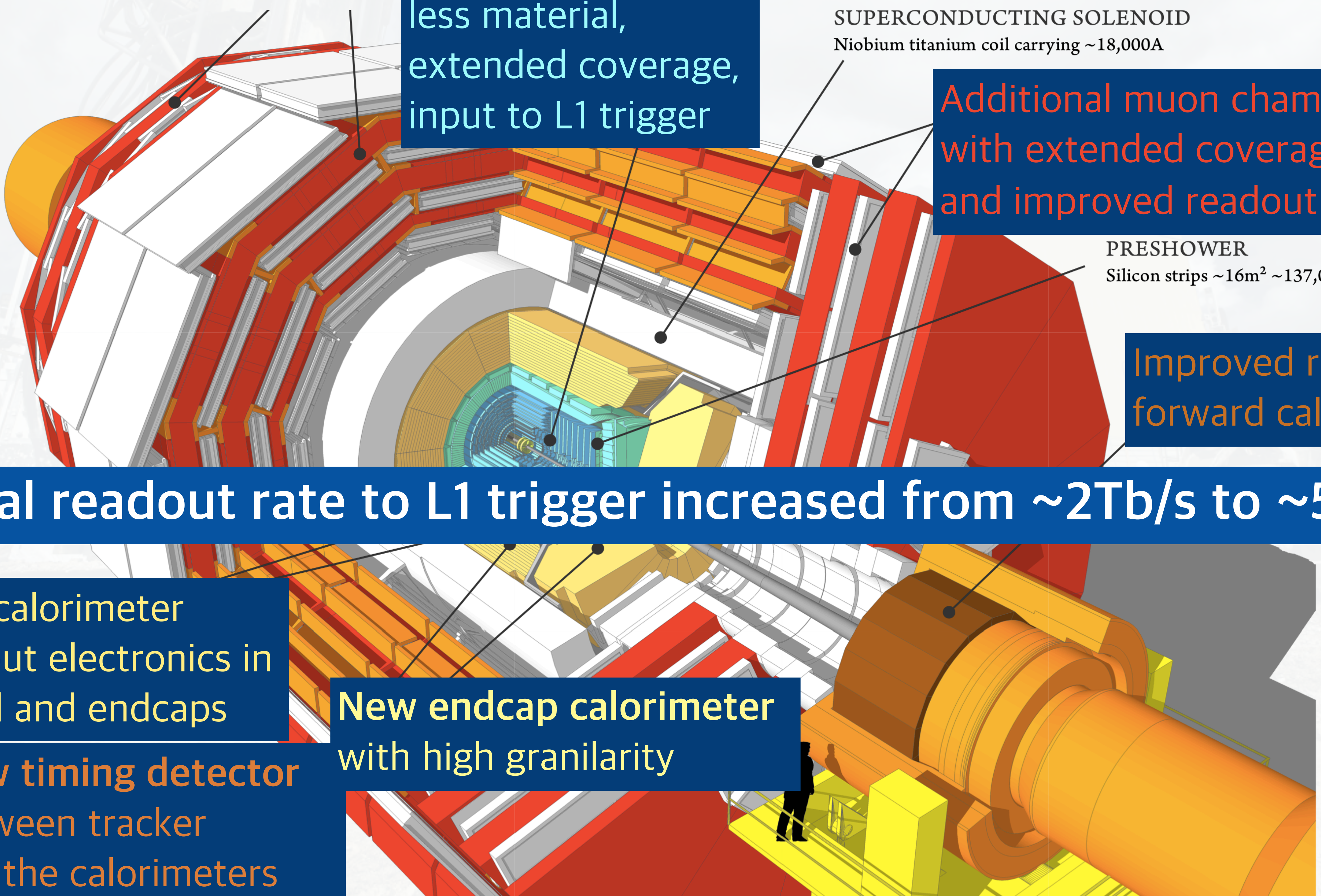
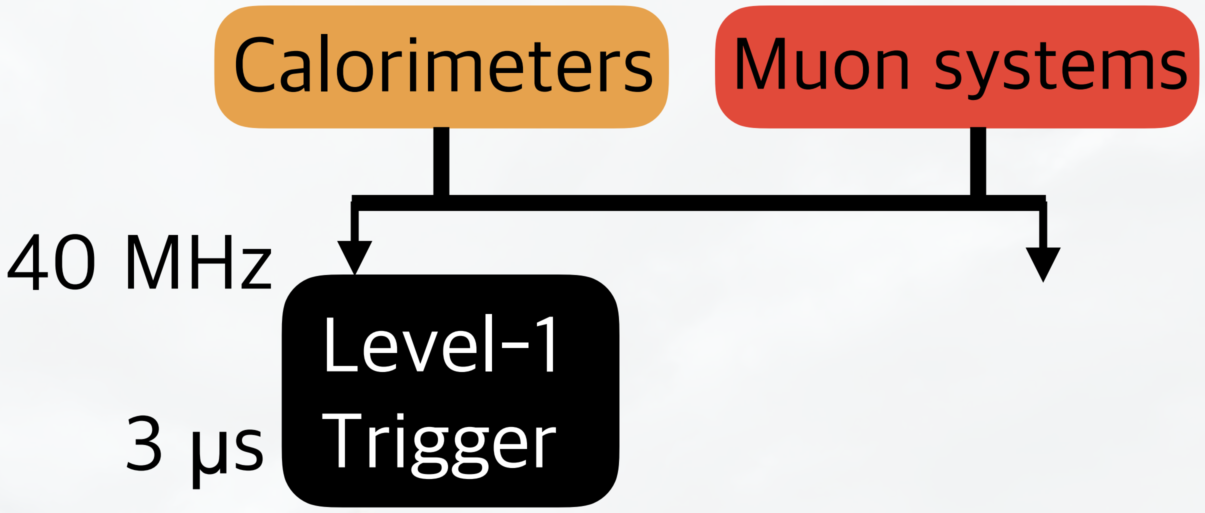


CMS Trigger System

- Without an efficient trigger, interesting data is wasted
- **Level-1 Trigger**
  - Hardware algorithms for a quick first decision



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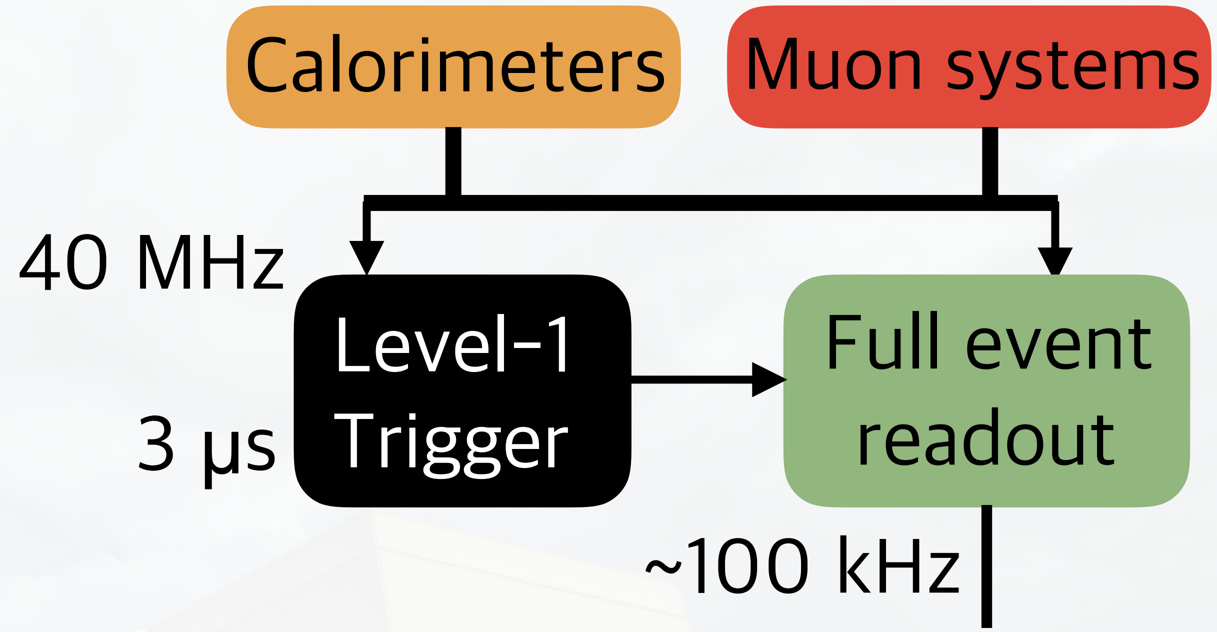

CMS Trigger System

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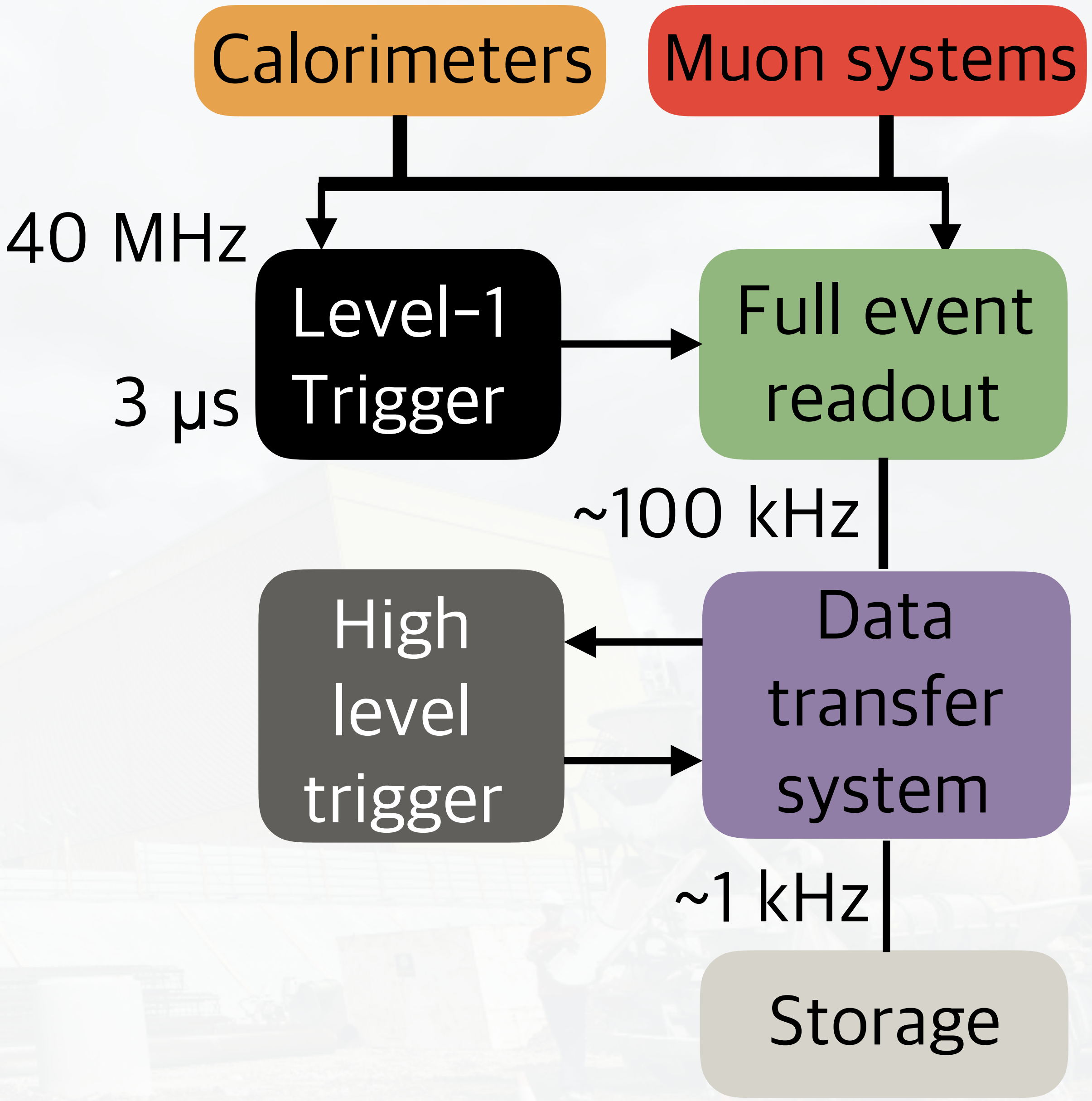
- **Level-1 Trigger**
  - Hardware algorithms for a quick first decision
- **High Level Trigger**
  - Fast software reconstruction using the full event information



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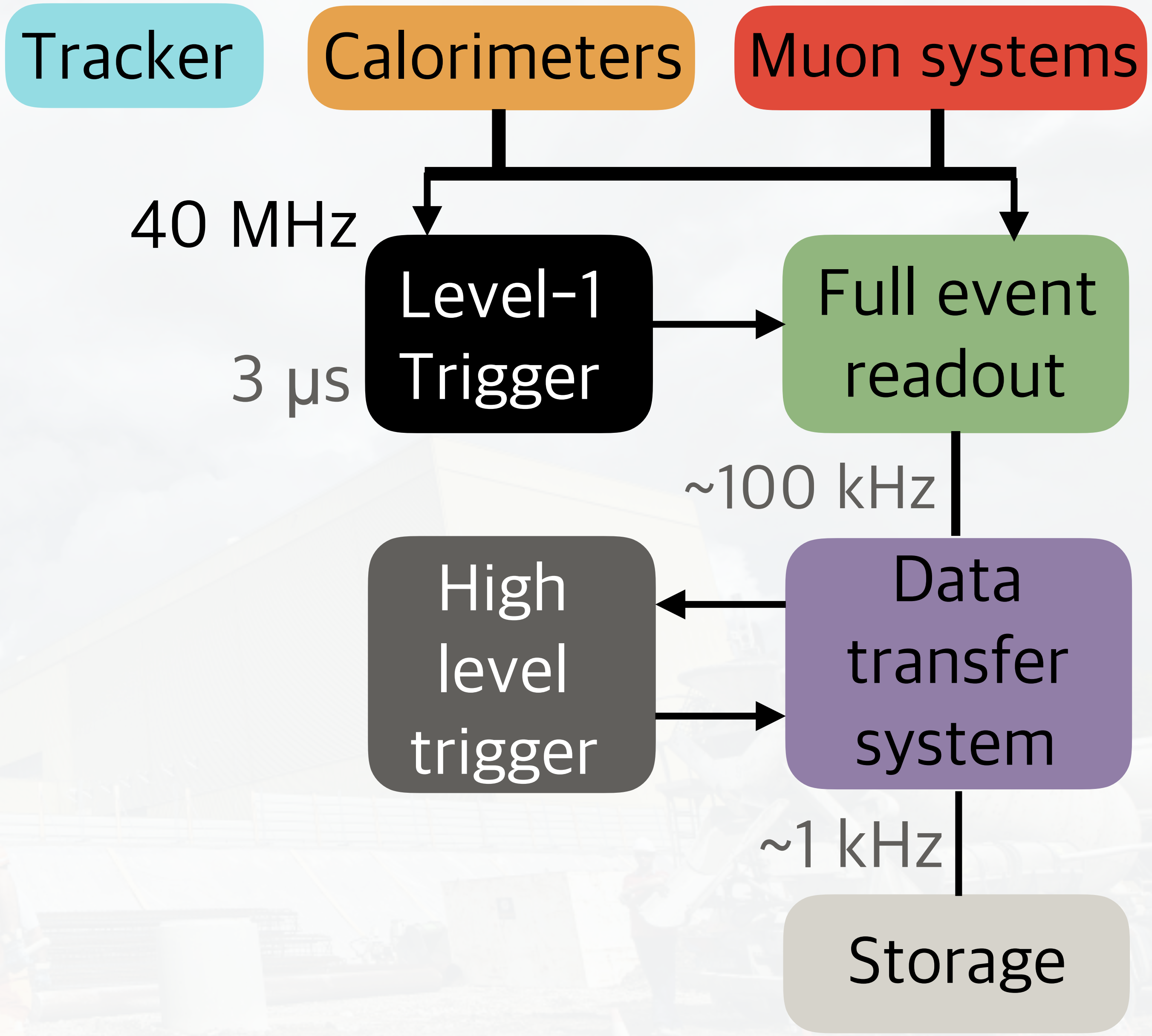

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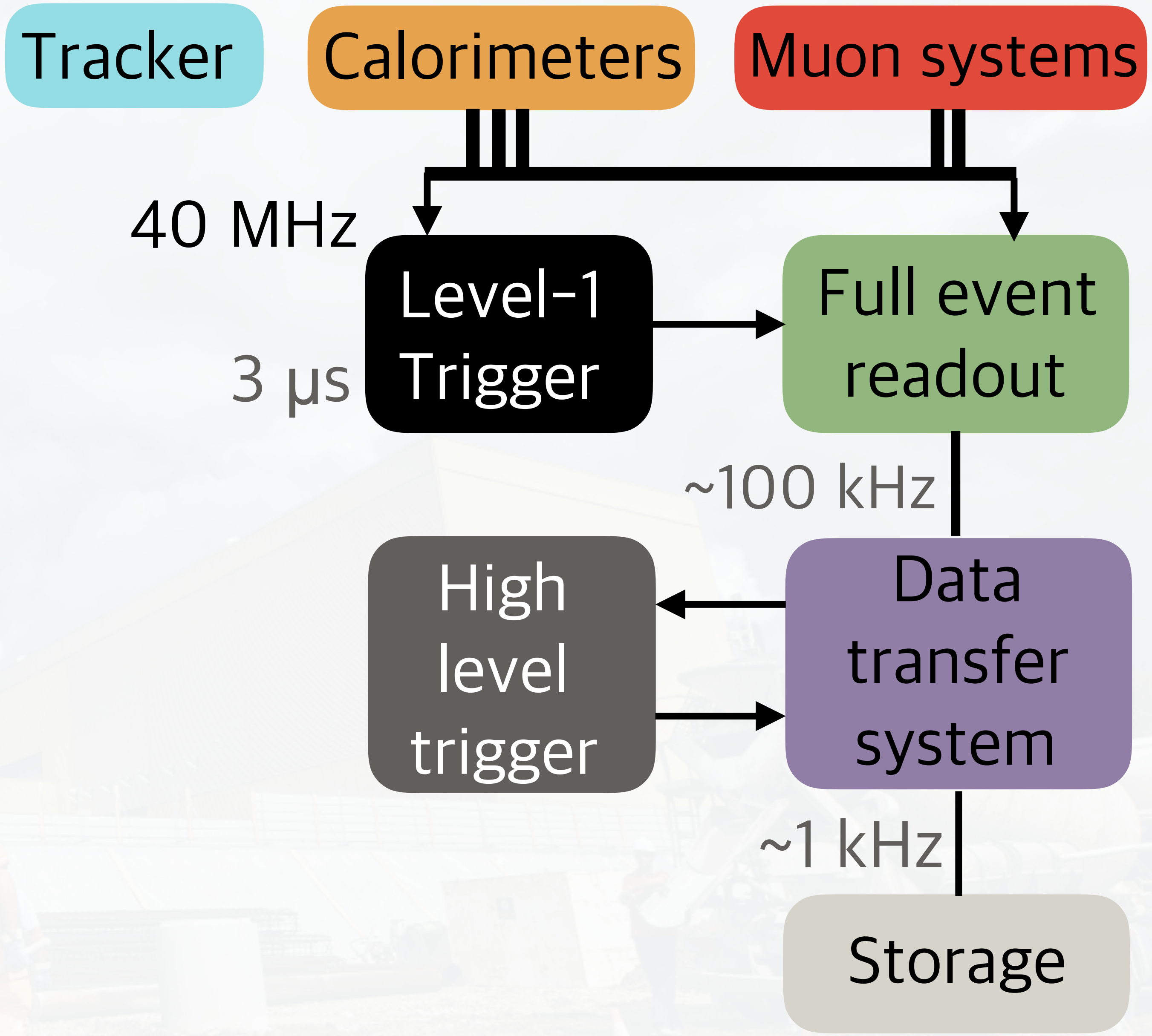

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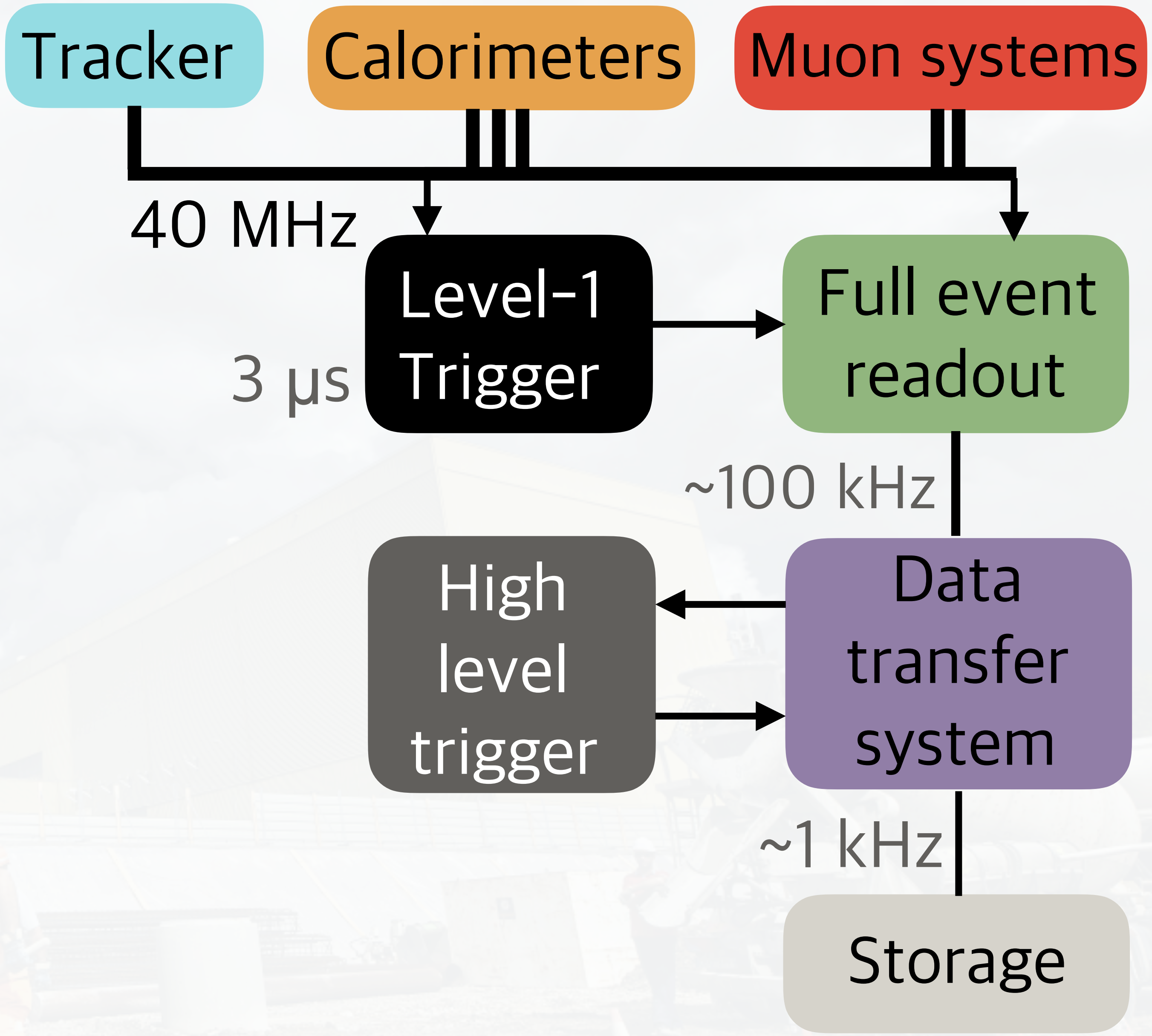

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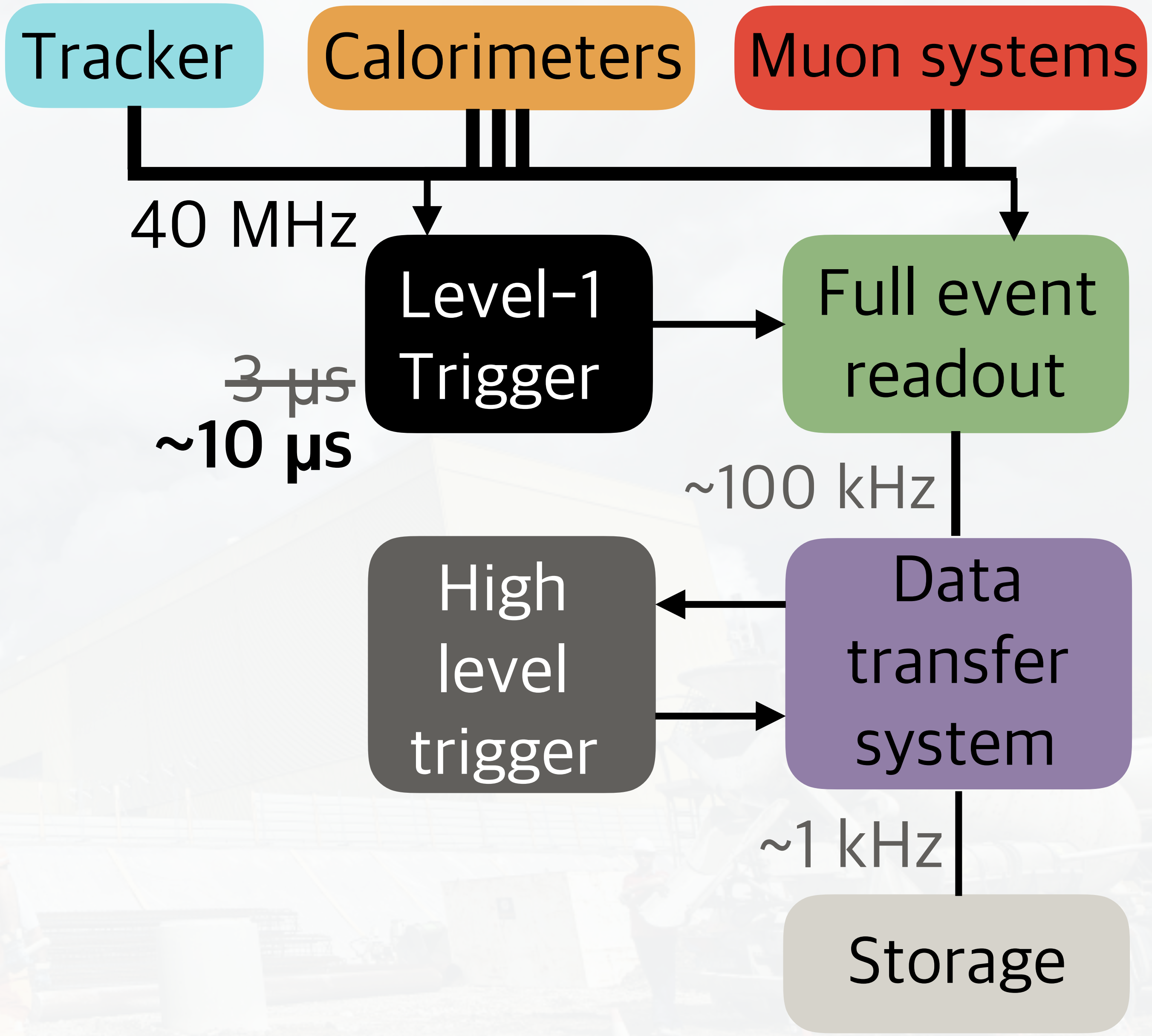

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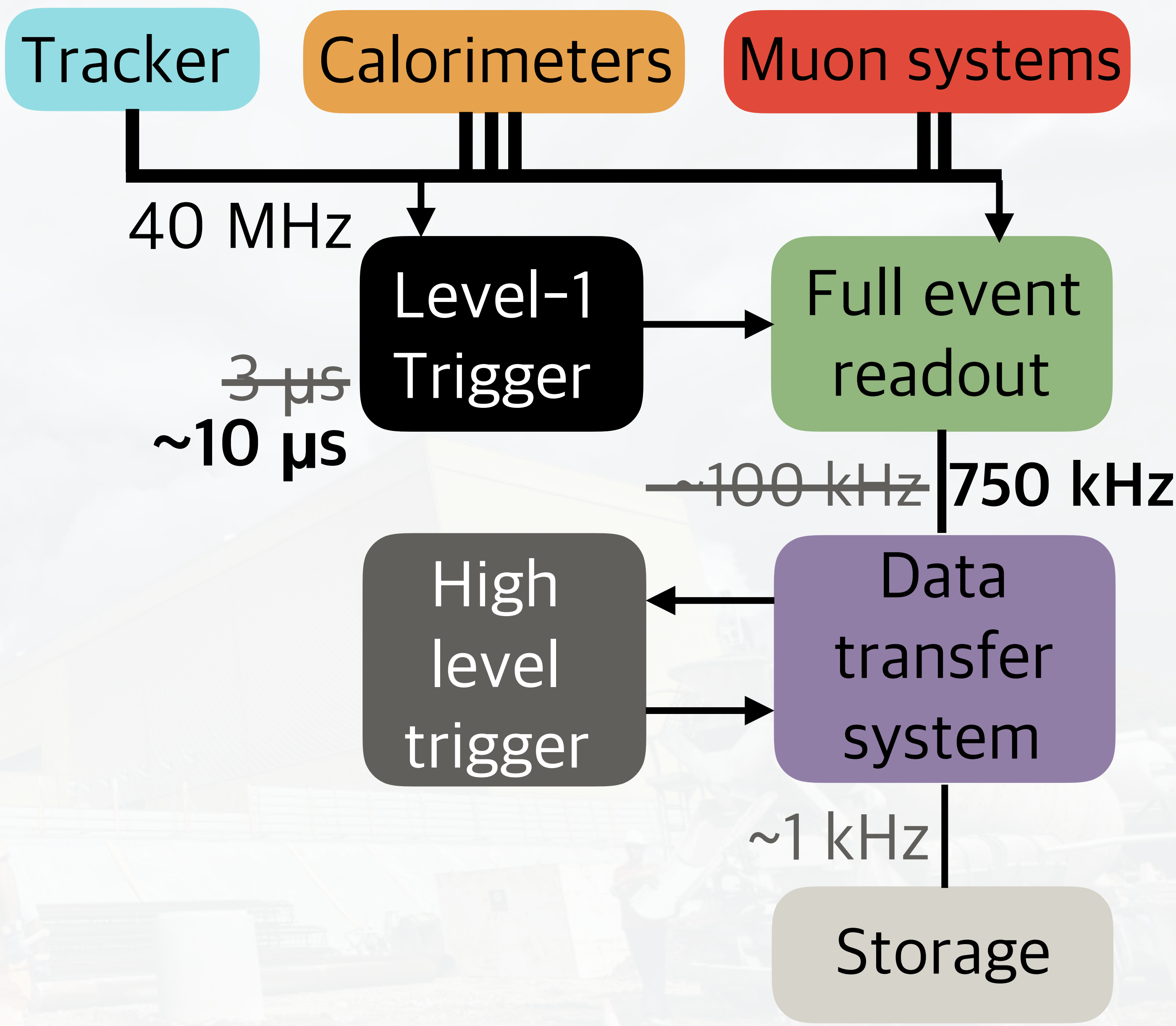

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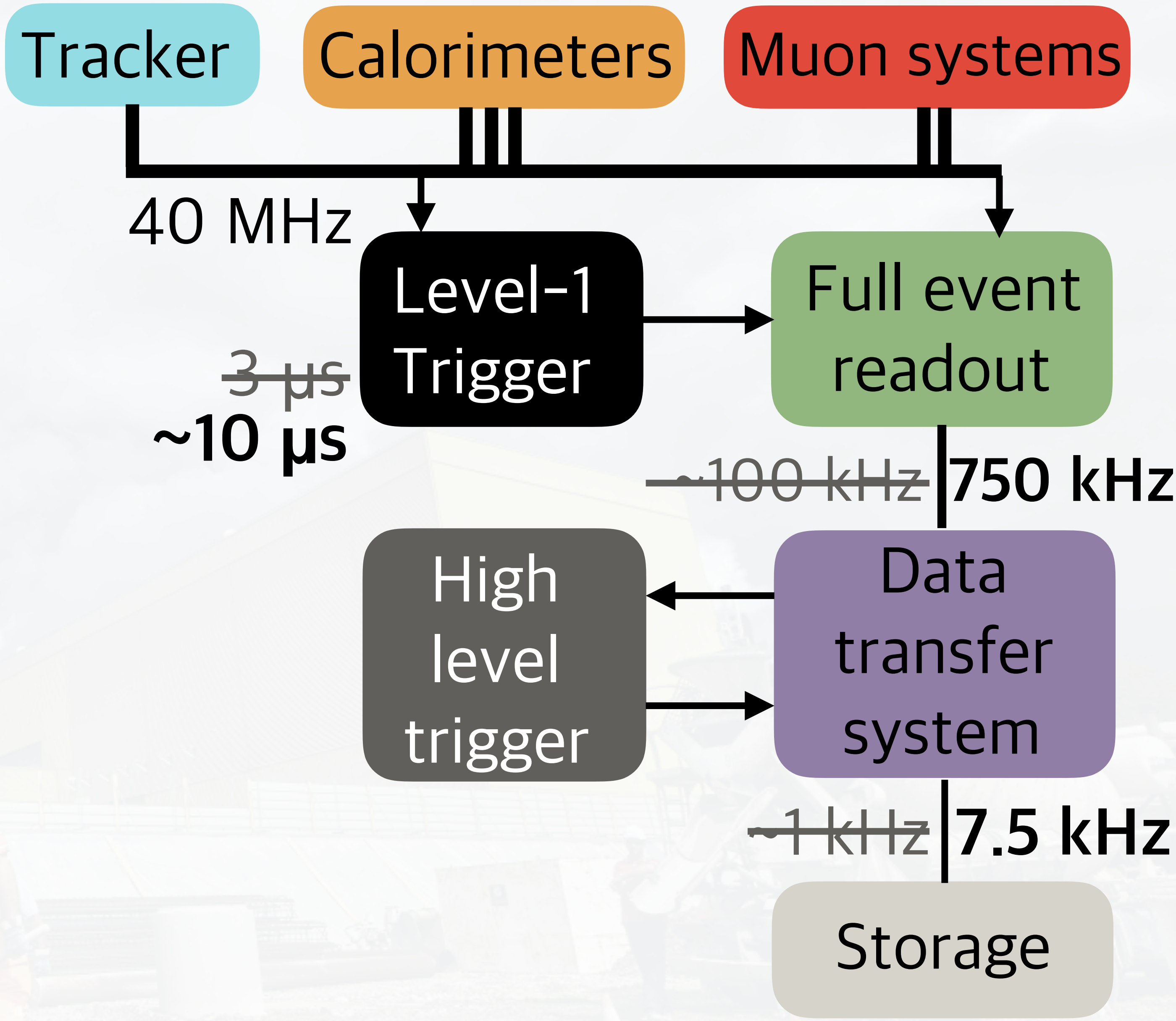

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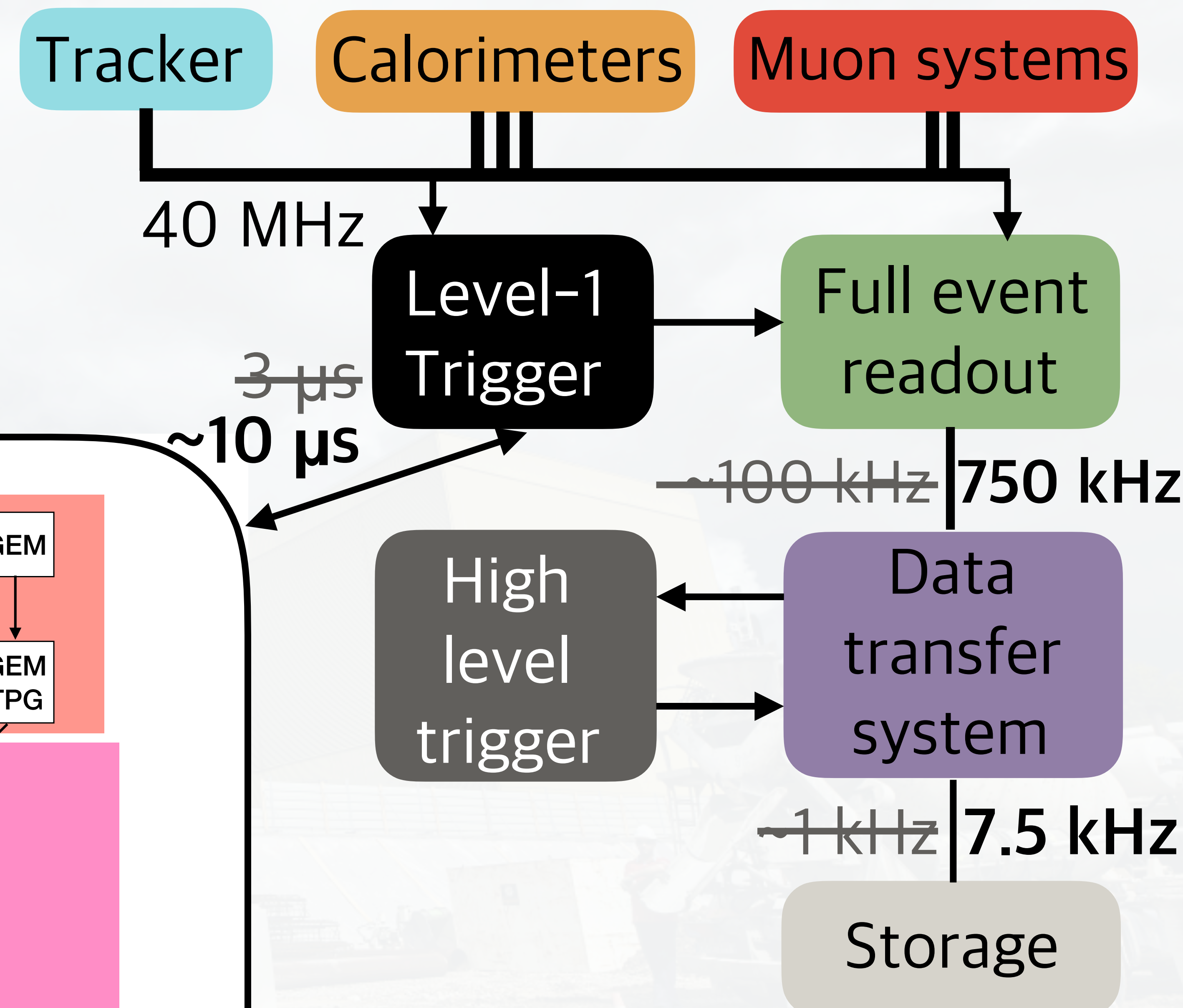

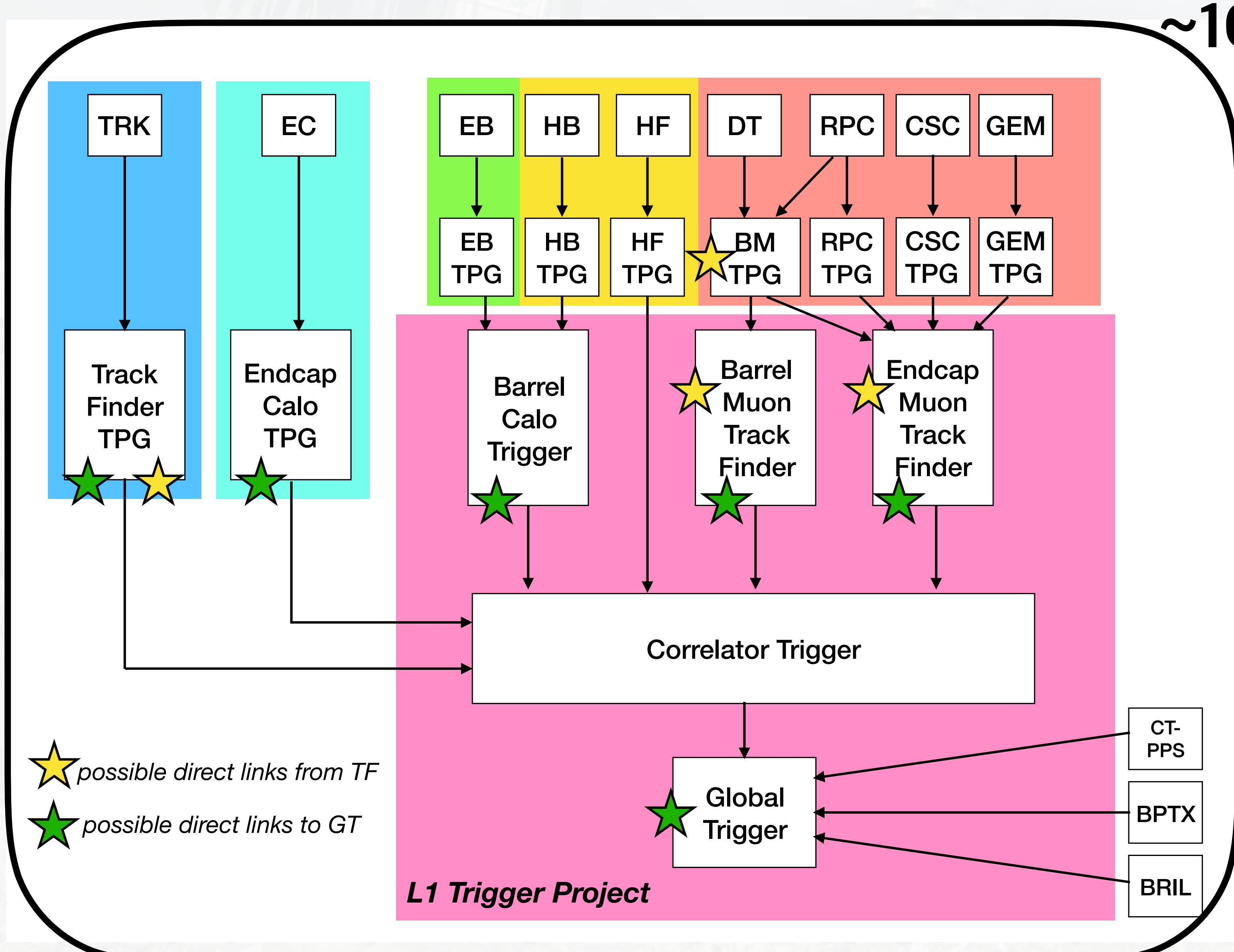

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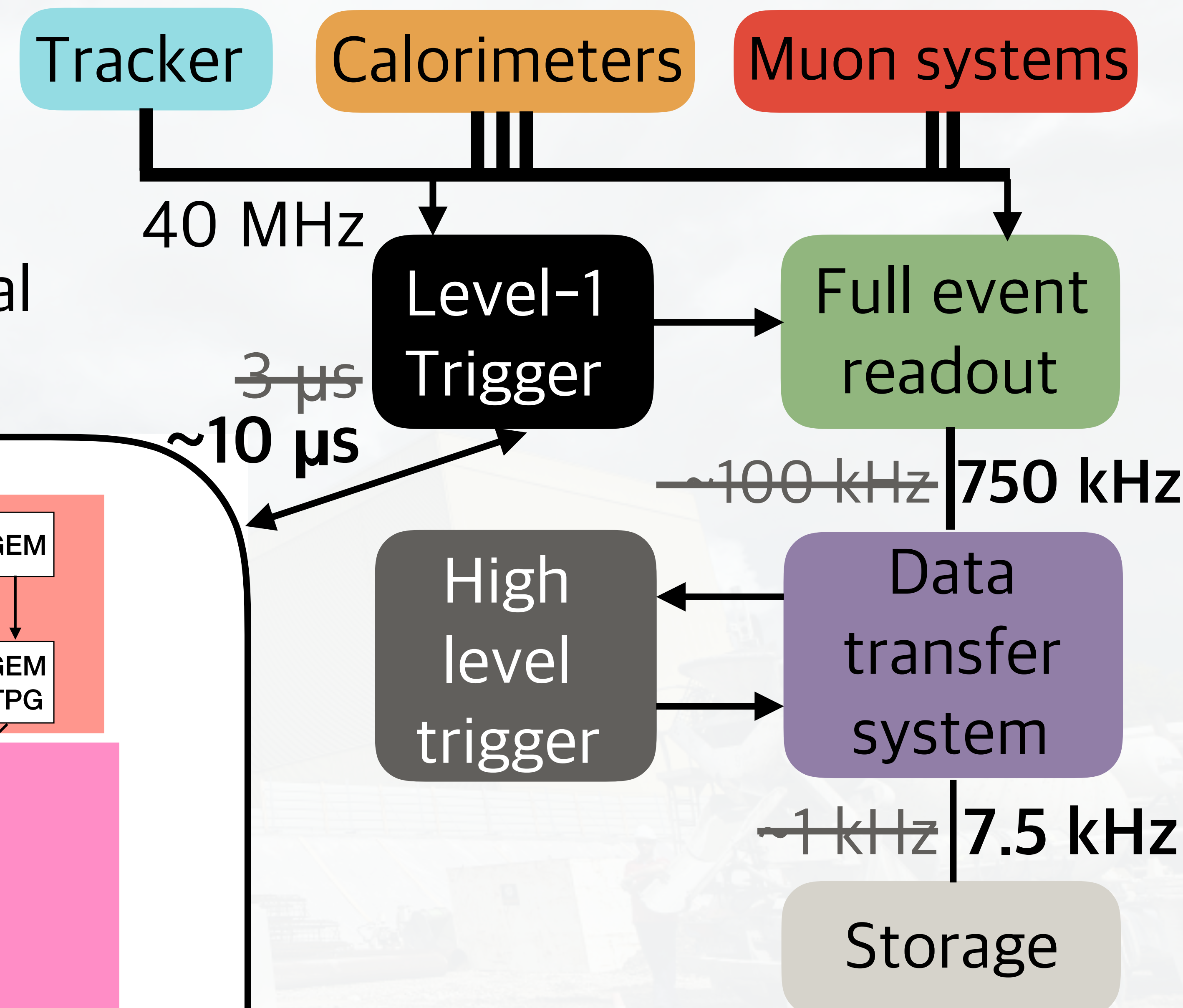
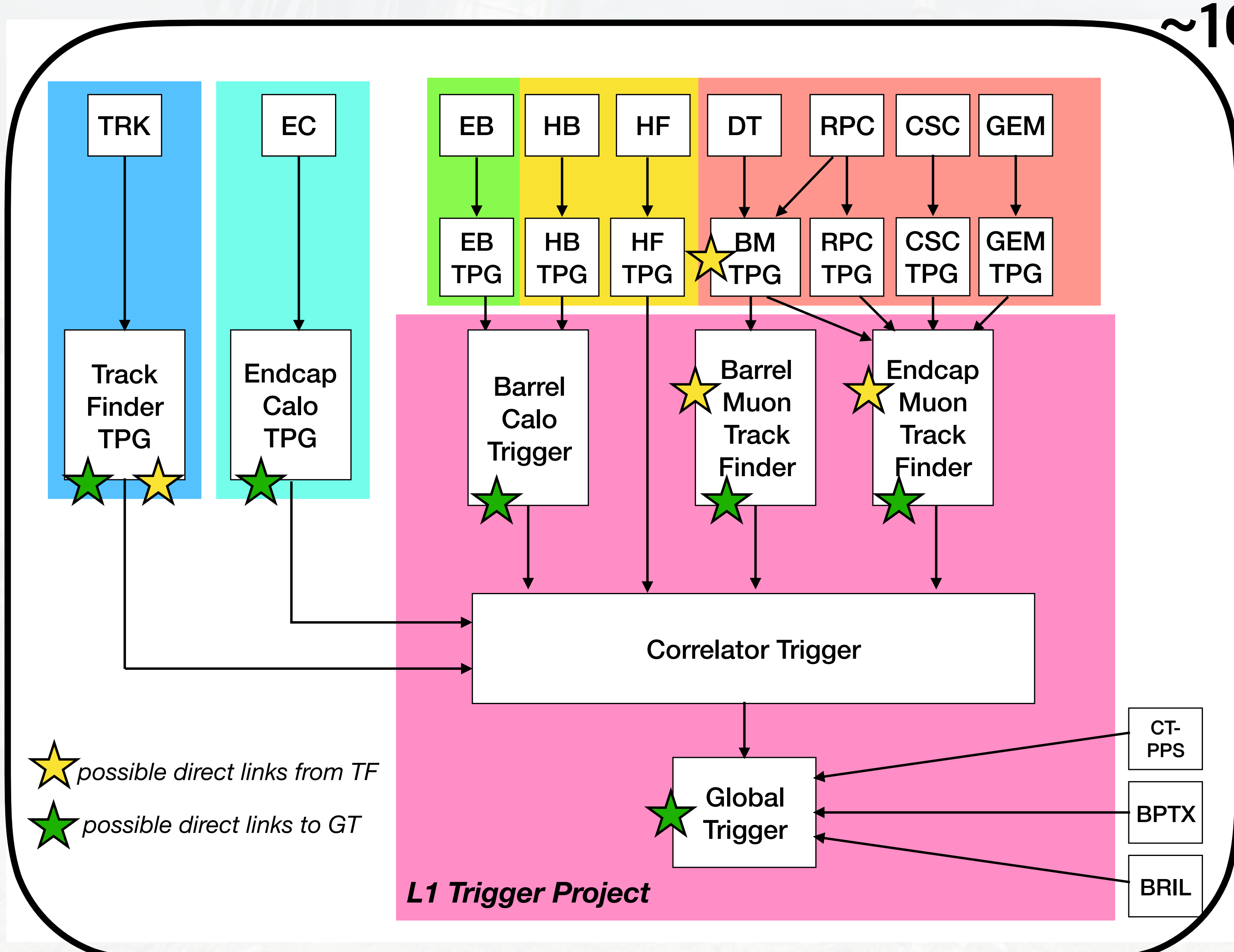
- Inputs from **Trigger Primitive Generators** (TPGs) and **track finders** are combined in a **correlator** module before the final decision by the **Global Trigger**





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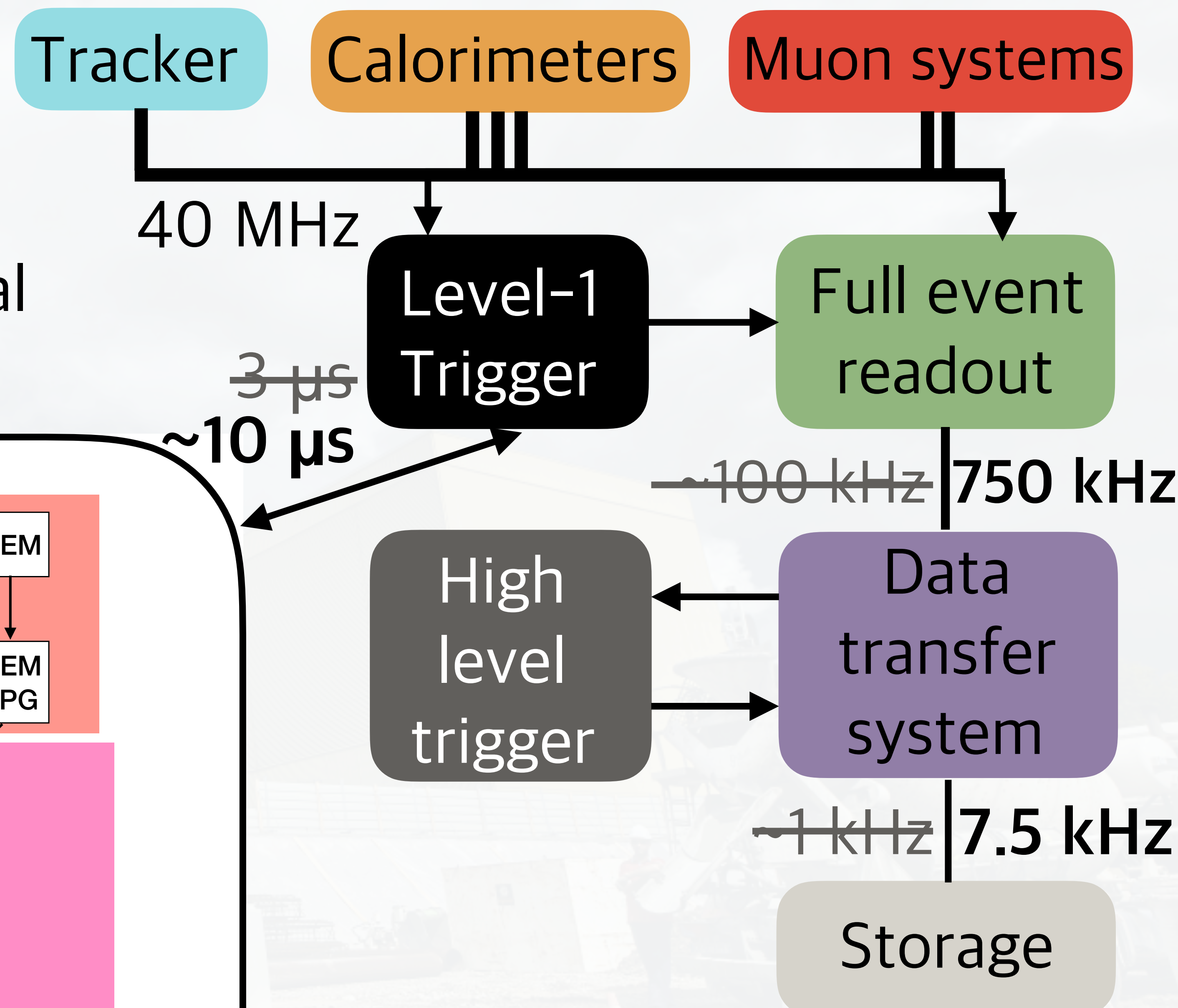
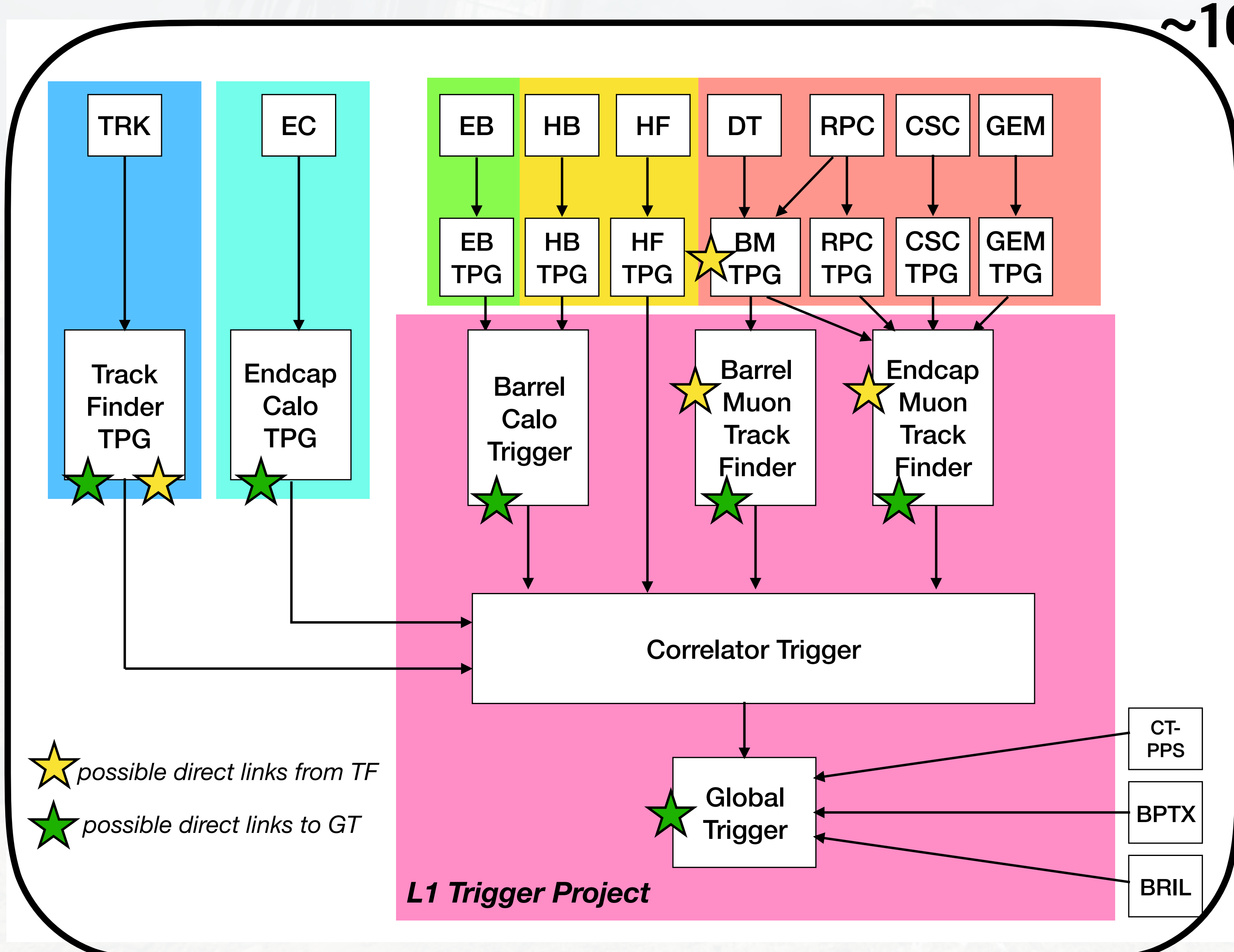
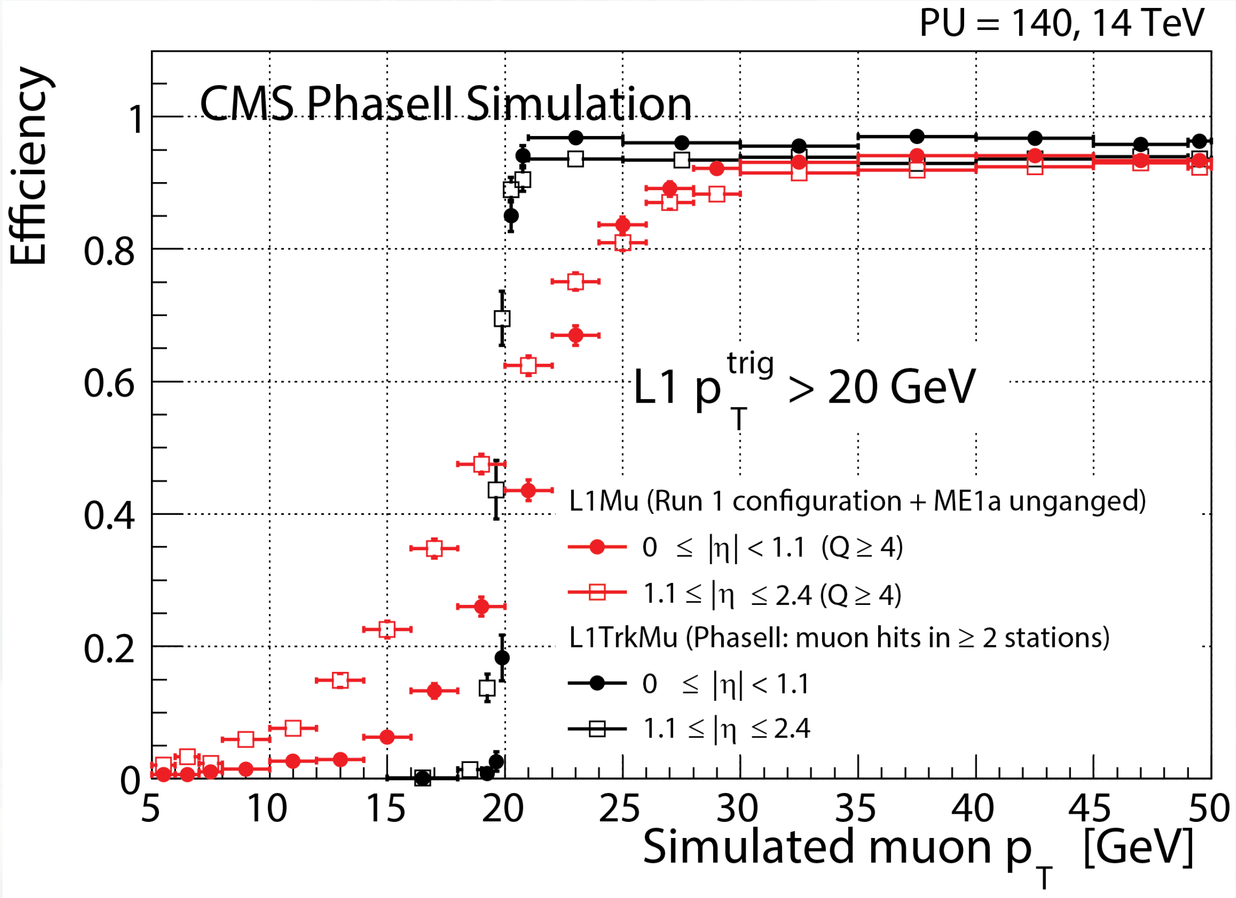
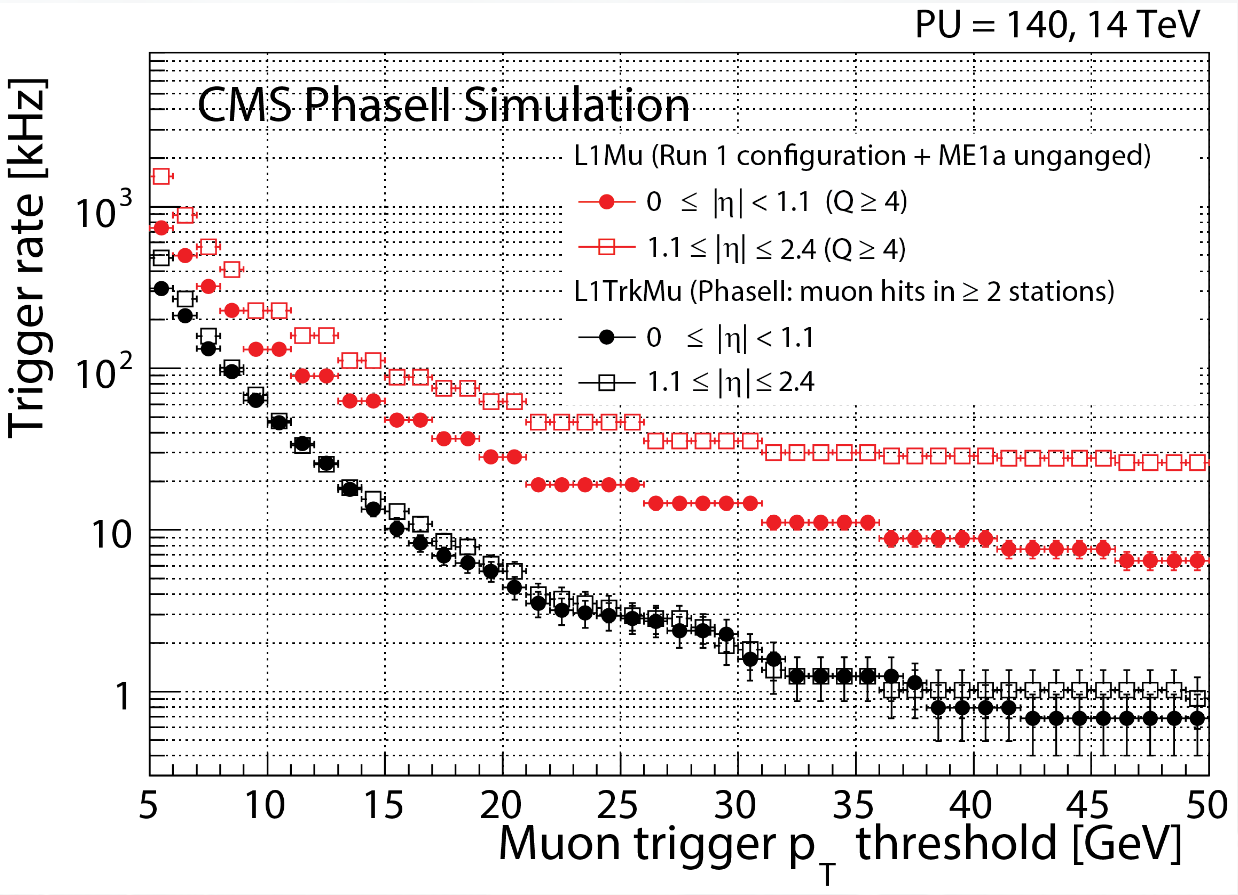




- **New algorithms** are being developed and tested to take advantage of this new architecture

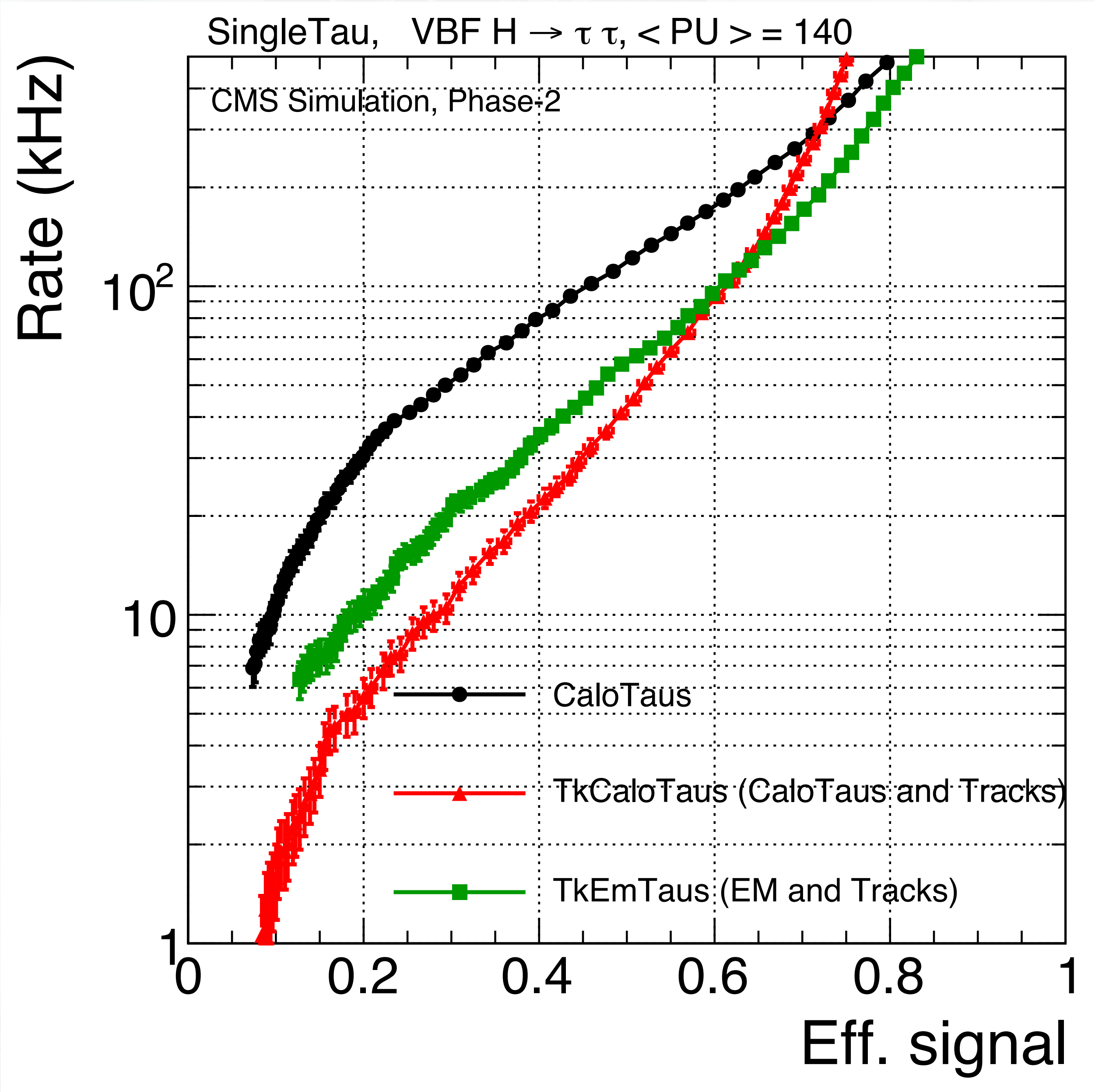
Expected Performance: Muons

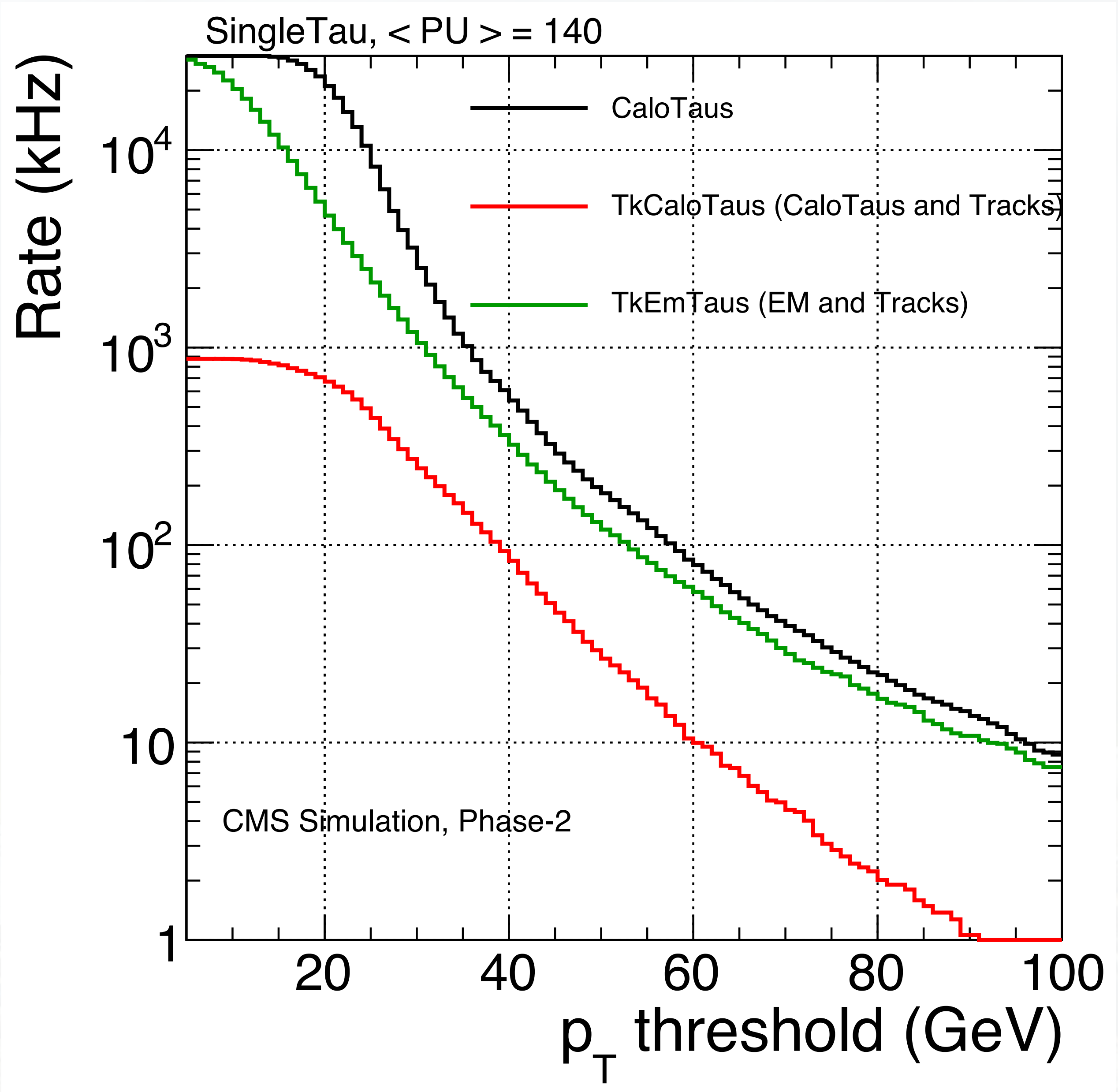




- Combining tracker and muon chamber signals leads to **sharper turn-on** (left) and **lower rates** (right) w.r.t. old configuration

Expected Performance: Taus





- New algorithms matching tracks and calorimeter deposits outperform the old configuration, providing lower rates for a given **efficiency** (left) or **threshold** (right)


Groundbreaking(!) upgrade work will continue,
HL-LHC results to be discussed
at Winter School 2029!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Back-up slides

HL-LHC Physics Goals

- **15M Higgs bosons / year** (2017: 3M)
  - More precise **Higgs couplings** (probe for BSM!)
  - Higgs **pair production** → self-coupling (120K events)
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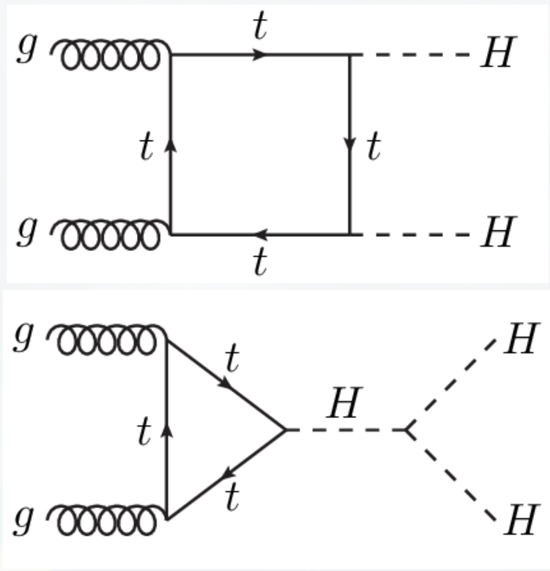

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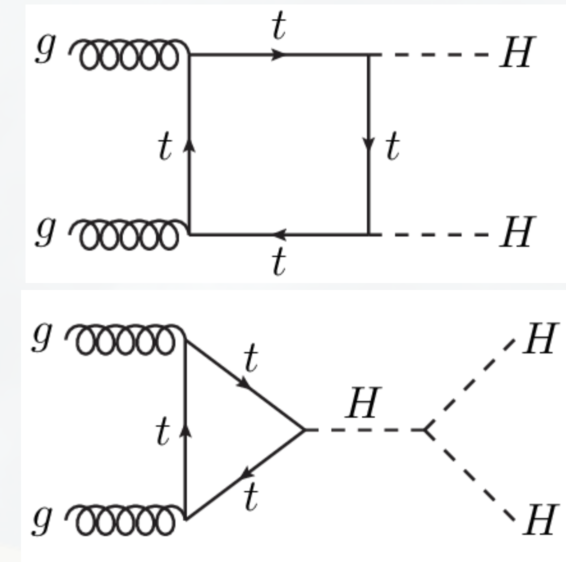

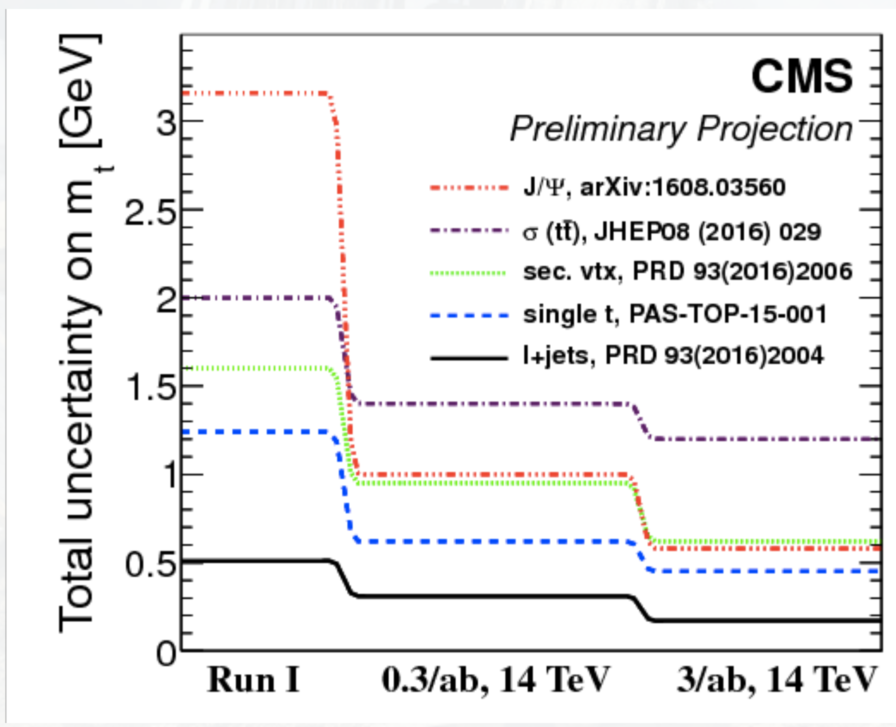

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  - **Top quark mass** resolution of ~0.1 GeV (currently ~1 GeV)
  - Vector boson scattering, triple-gauge couplings…

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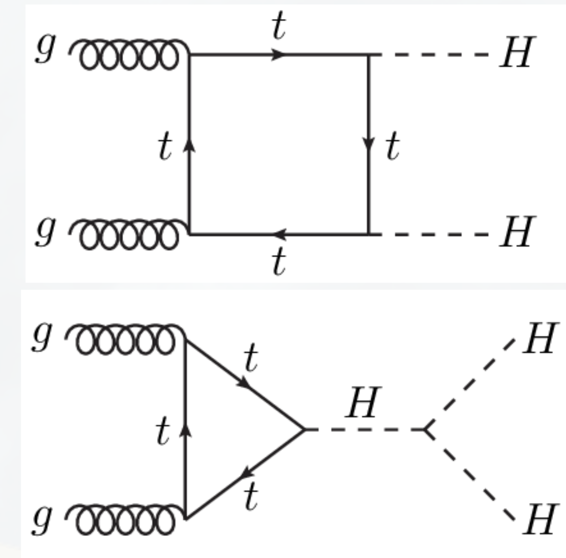

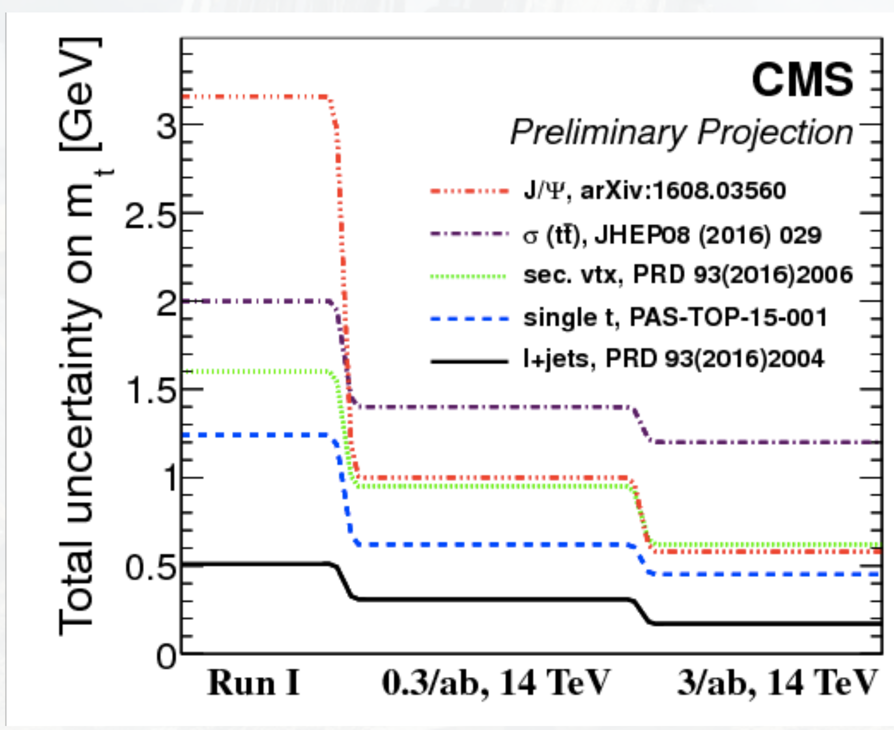

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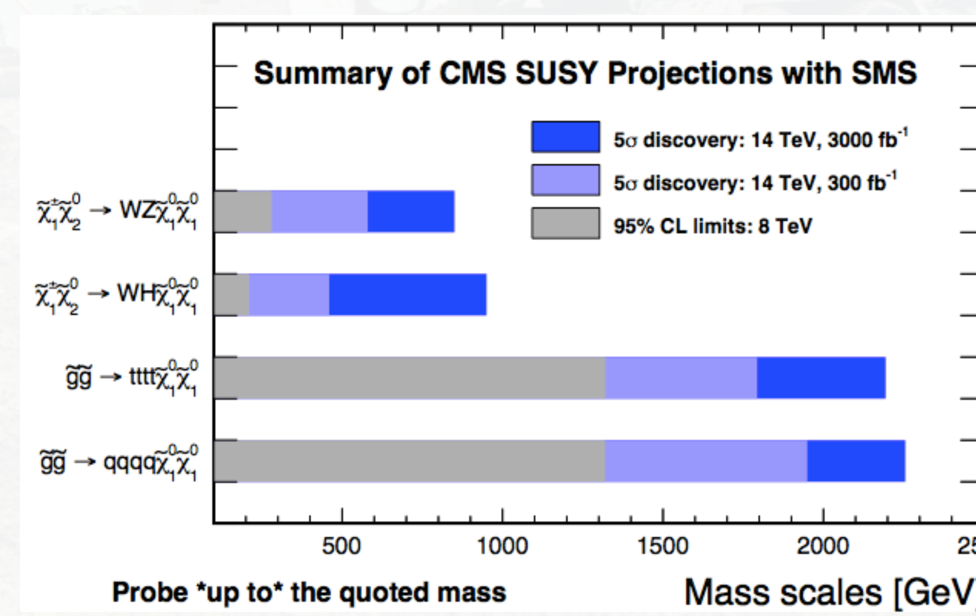
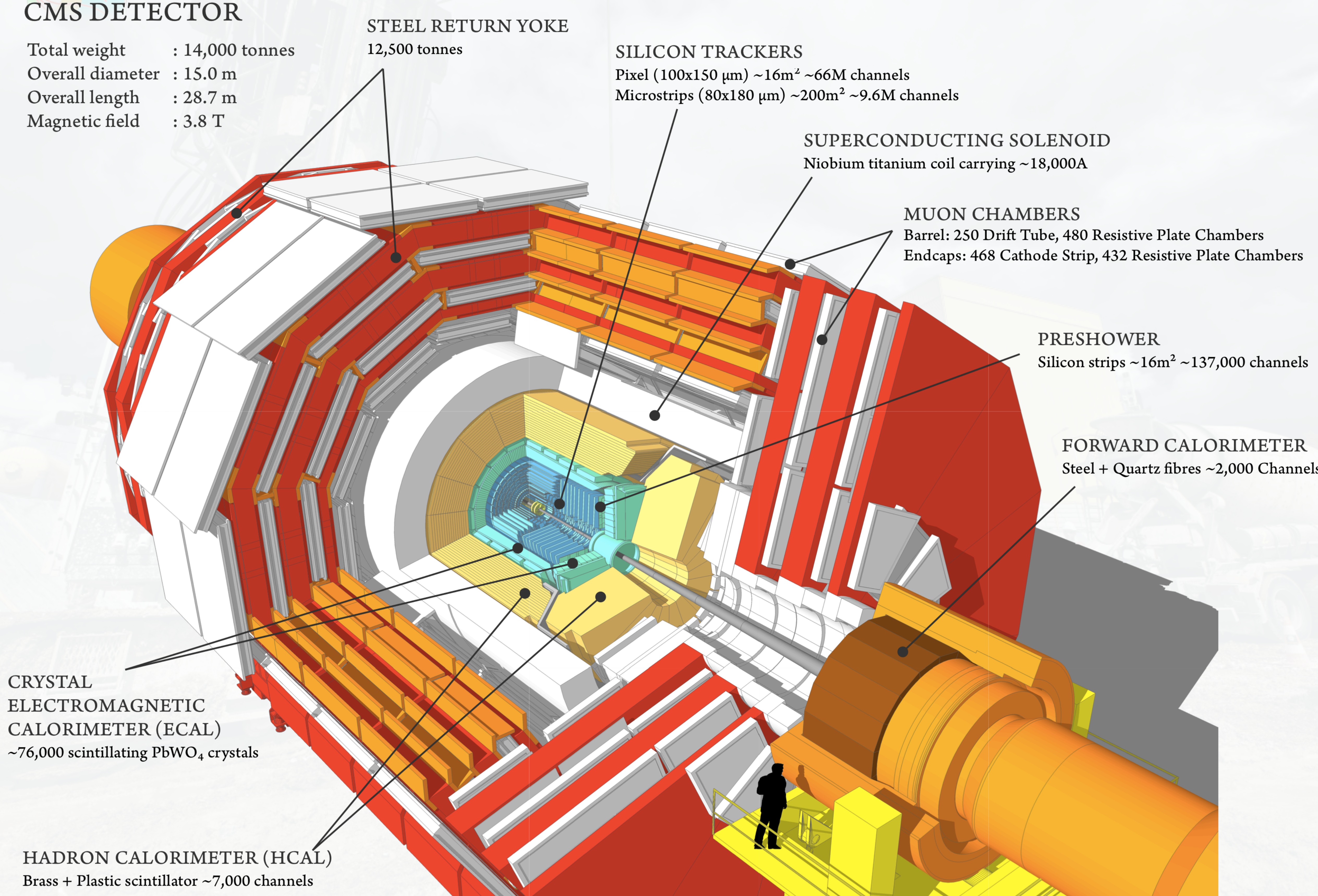


- **BSM searches**
  - Discoveries or further exclusion of models

CMS detector



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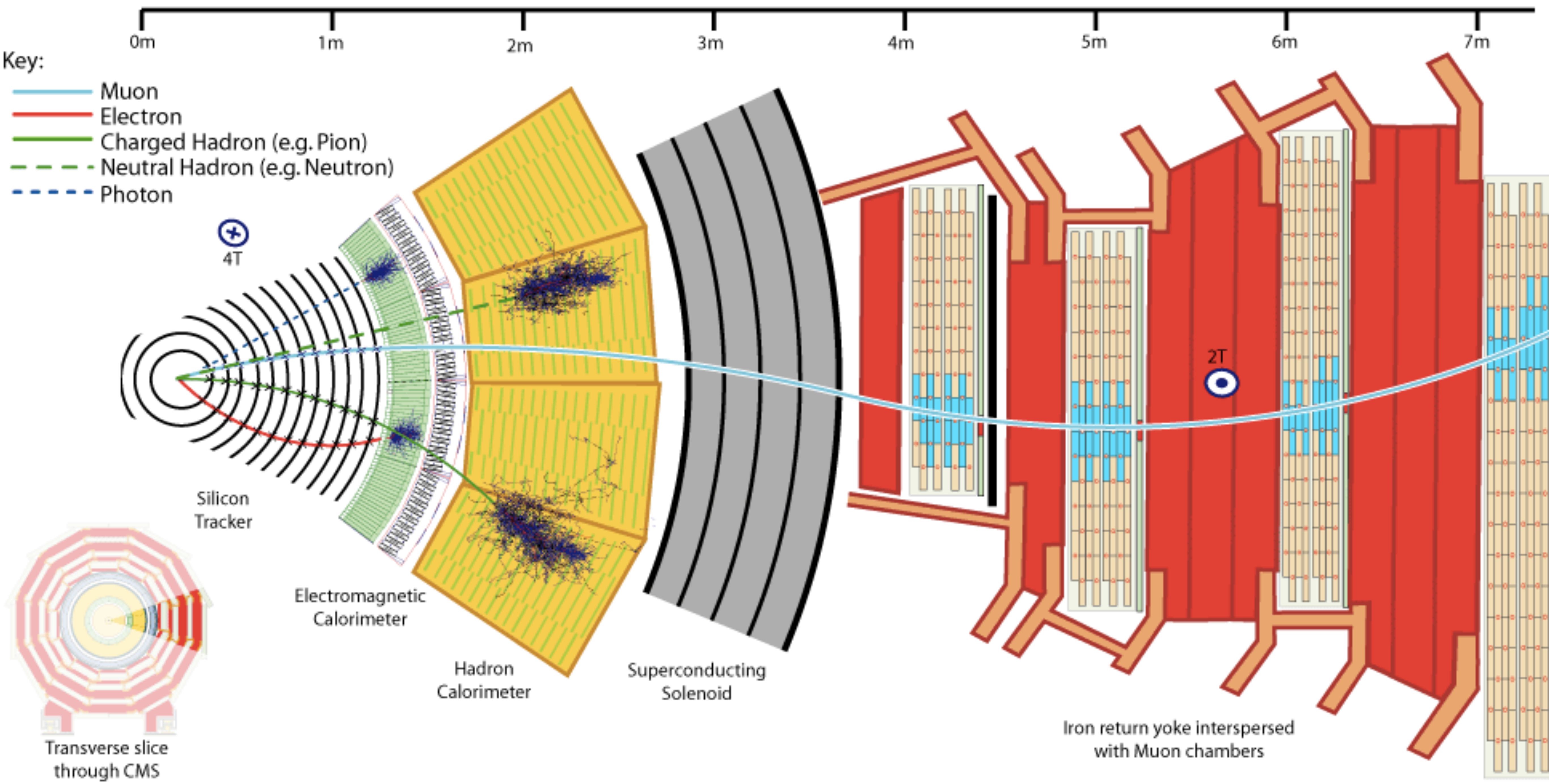
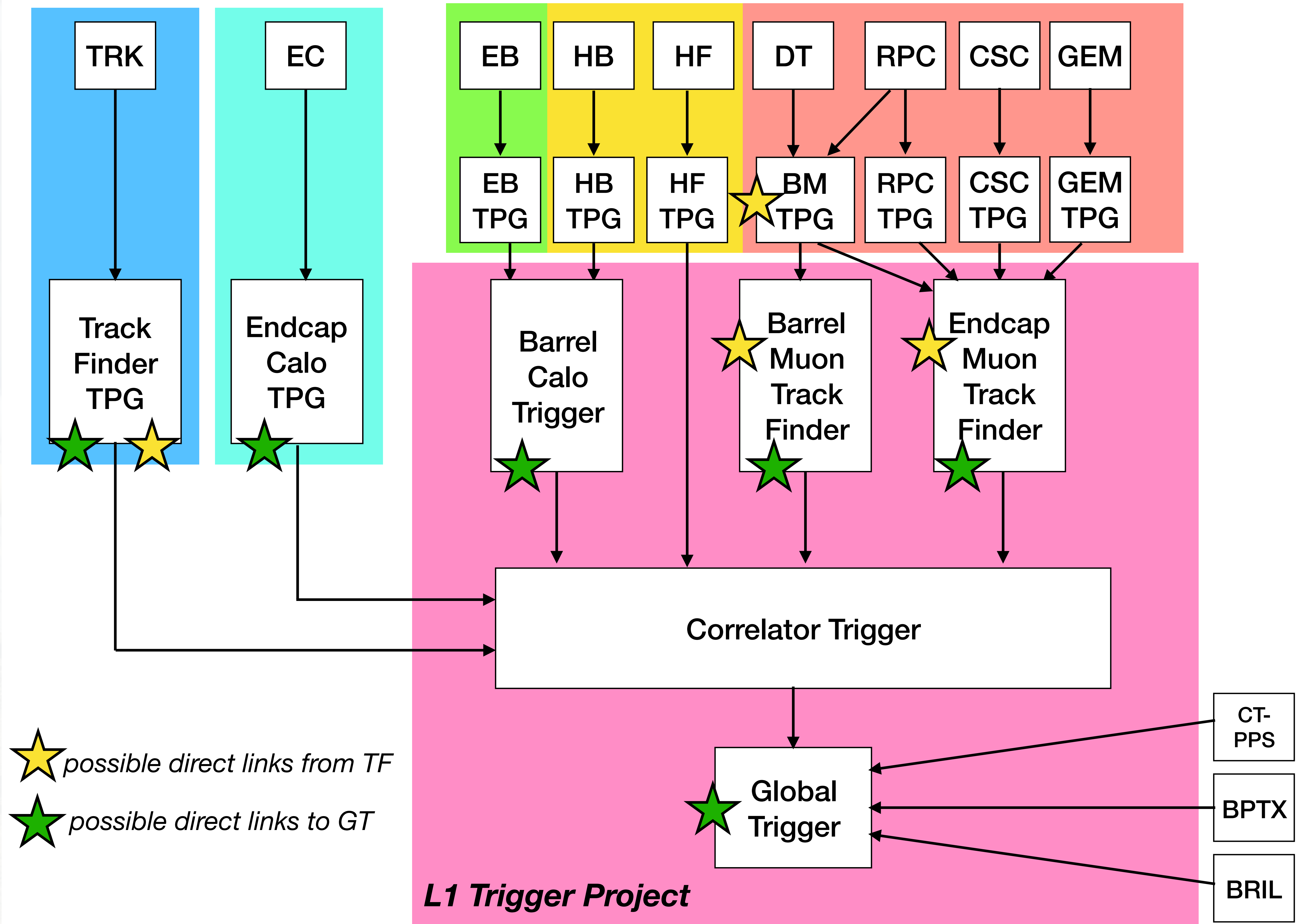
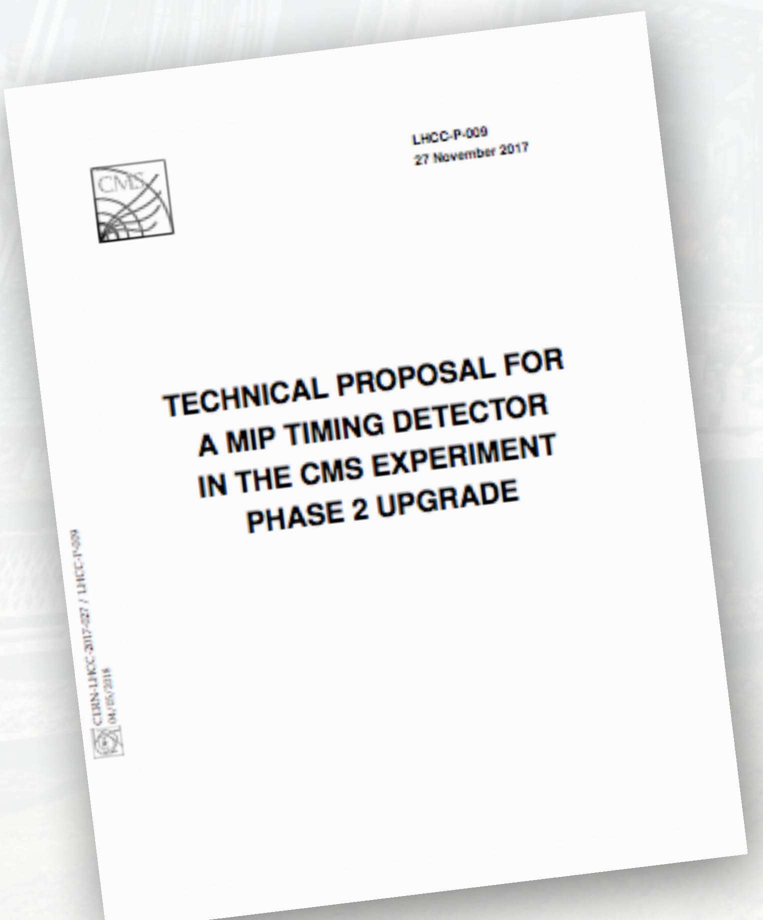


Upgraded Level-1 Trigger

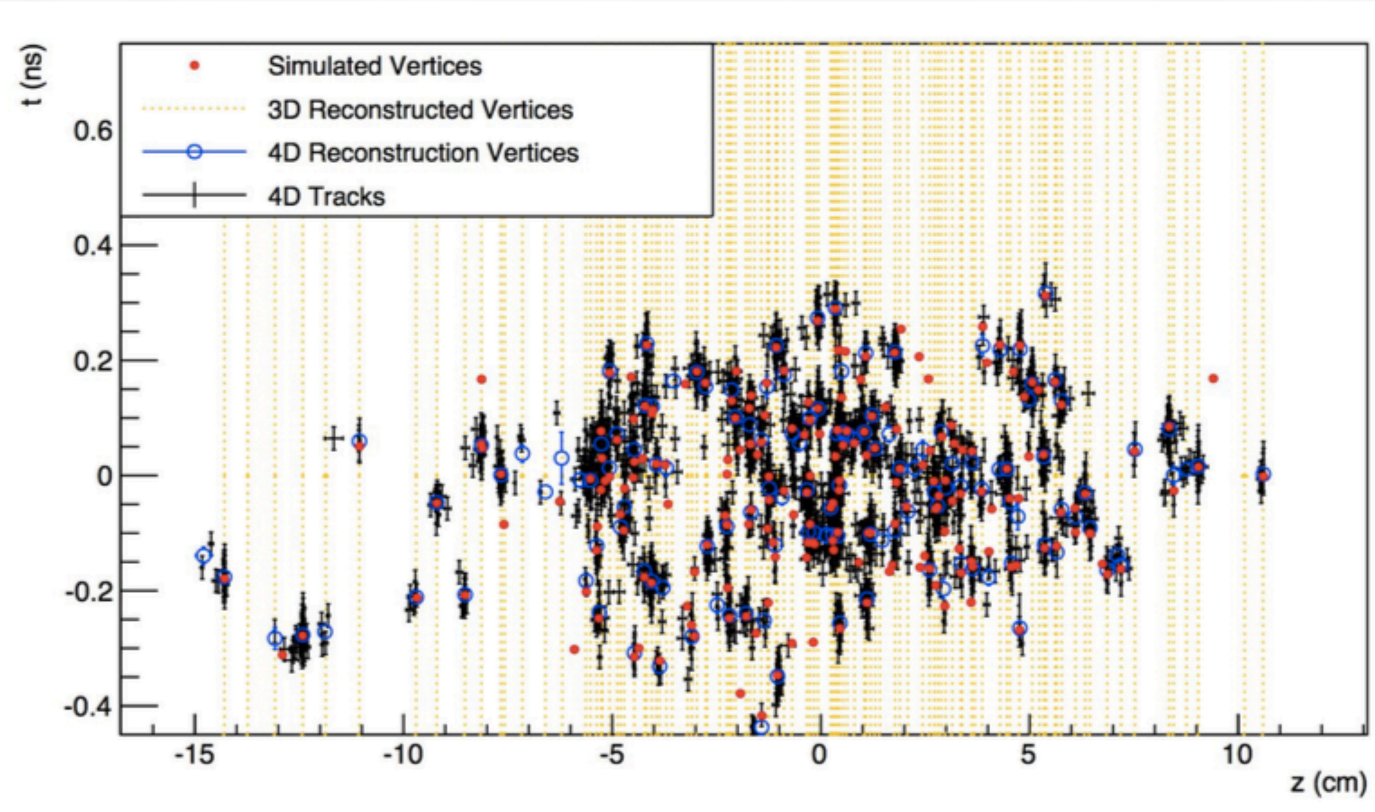


MTD: MIP Timing Detector

- Thin layer between tracker and calorimeters, covering |η|<3
- Time-of-arrival measurement with time resolution of ~30 ps
- Read more:


LHCC-P-009
27 November 2017

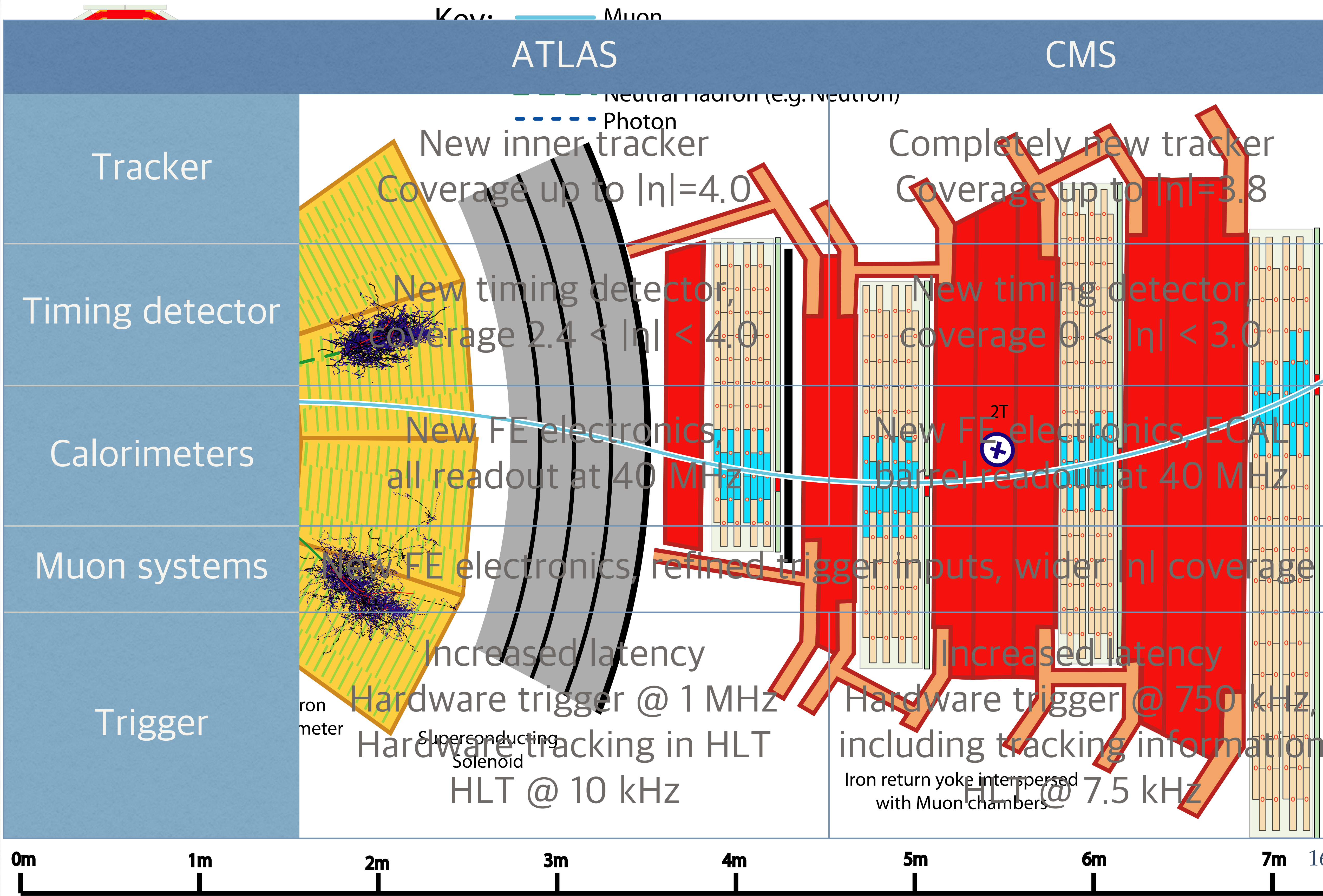
TECHNICAL PROPOSAL FOR
A MIP TIMING DETECTOR
IN THE CMS EXPERIMENT
PHASE 2 UPGRADE



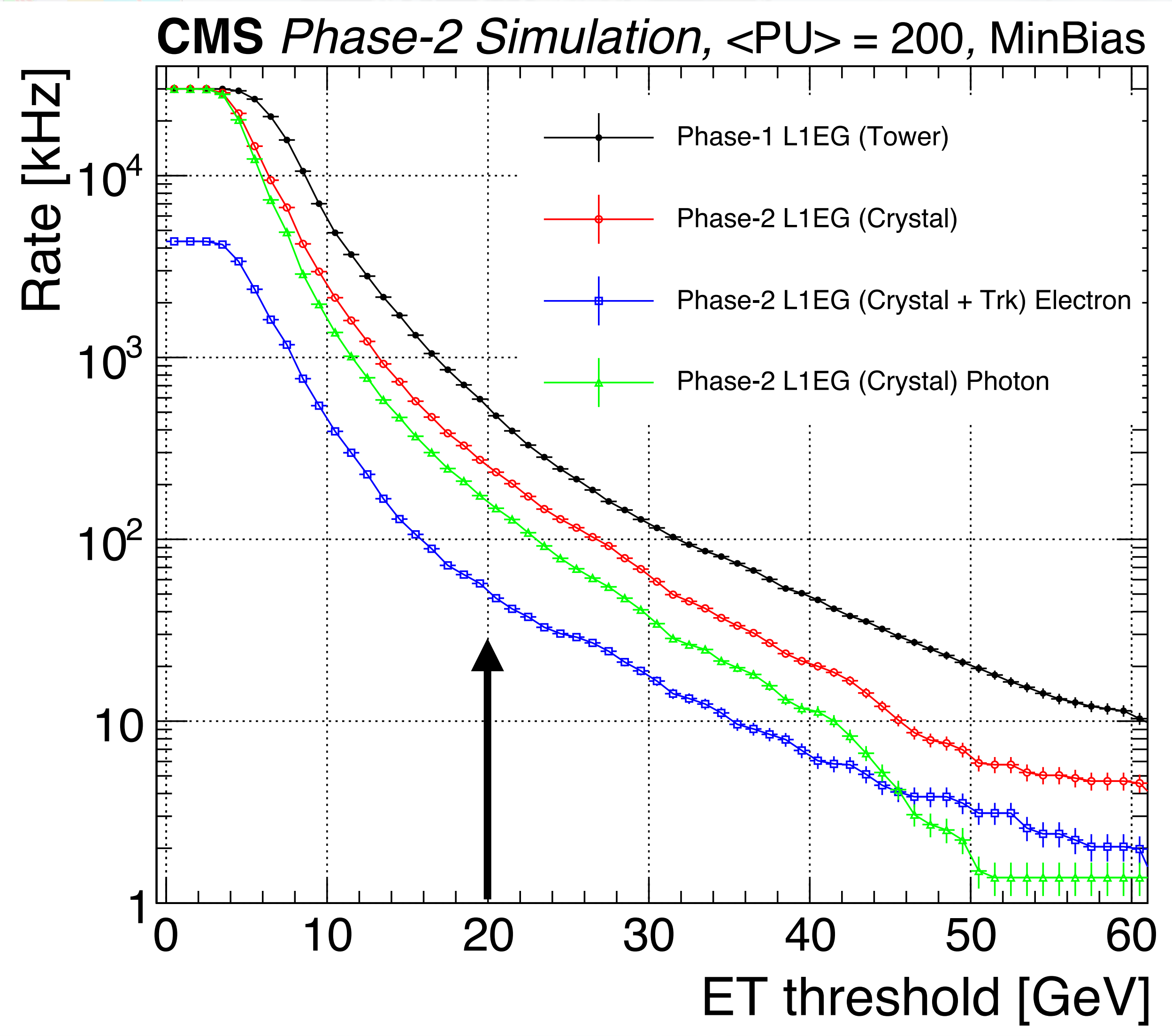
- Physics case:
  - Improved vertexing
  - Better lepton/photon isolation → Smaller fake backgrounds
  - Enhanced pileup jet subtraction → Improved VBS sensitivity and jet mass resolution
  - More efficient b jet tagging

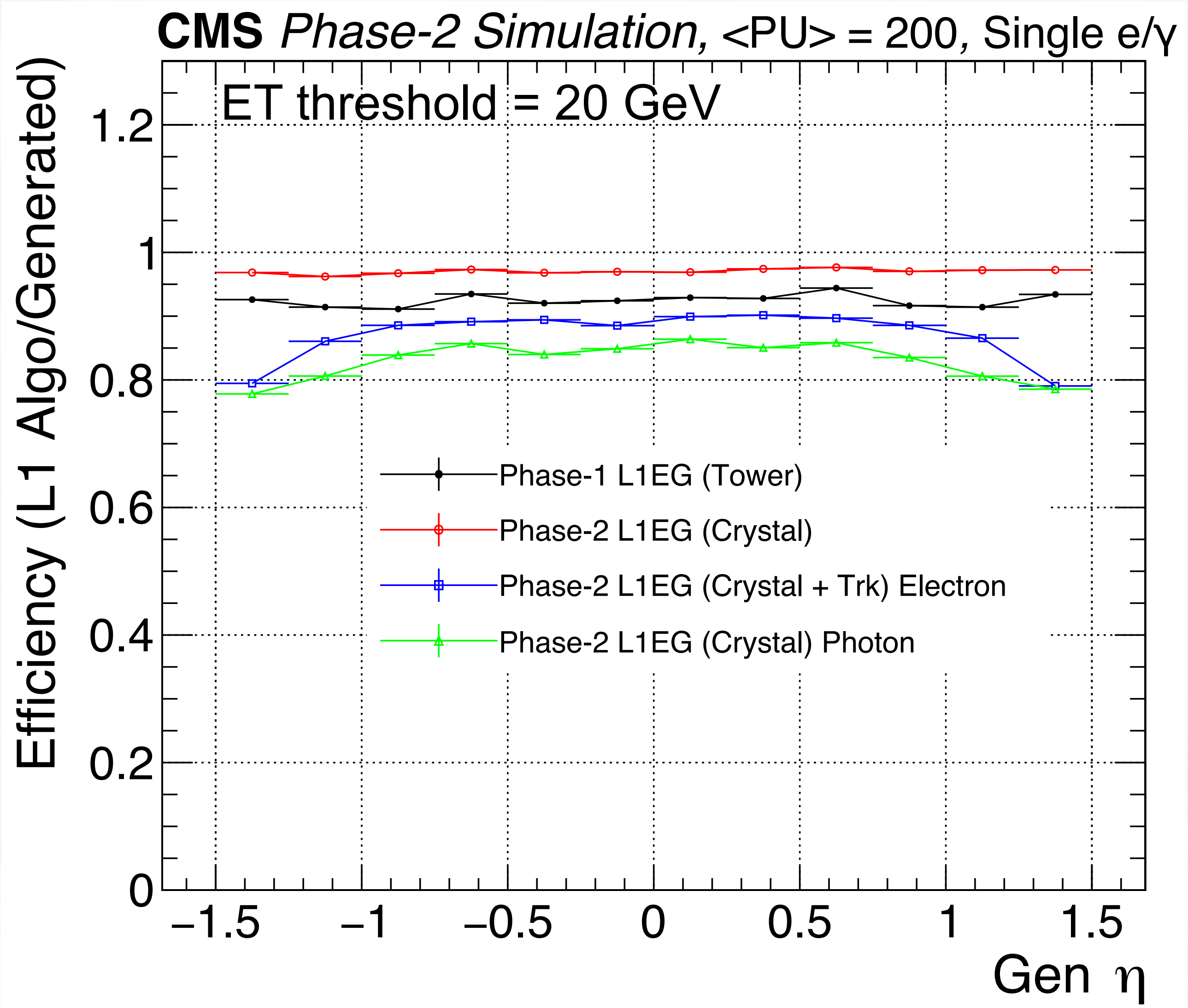
ATLAS vs. CMS upgrades for HL-LHC

	ATLAS	CMS
Tracker	New inner tracker Coverage up to |η|=4.0	Completely new tracker Coverage up to |η|=3.8
Timing detector	New timing detector, coverage 2.4 < |η| < 4.0	New timing detector, coverage 0 < |η| < 3.0
Calorimeters	New FE electronics, all readout at 40 MHz	New FE electronics, ECAL barrel readout at 40 MHz
Muon systems	New FE electronics, refined trigger inputs, wider |η| coverage	
Trigger	Increased latency Hardware trigger @ 1 MHz Hardware tracking in HLT HLT @ 10 kHz	Increased latency Hardware trigger @ 750 kHz, including tracking information HLT @ 7.5 kHz



Expected Performance: e/γ





- New global electron and photon algorithms reduce the **rate** by a factor of ~10 (left) while the **efficiency** decreases only ~10% (right)
- Fine-grained calorimeter input improves performance alone