Detector Issues in Heavy Ion collisions

Pieter David

UCLouvain-CP3

Heavy Ions and Hidden Sectors
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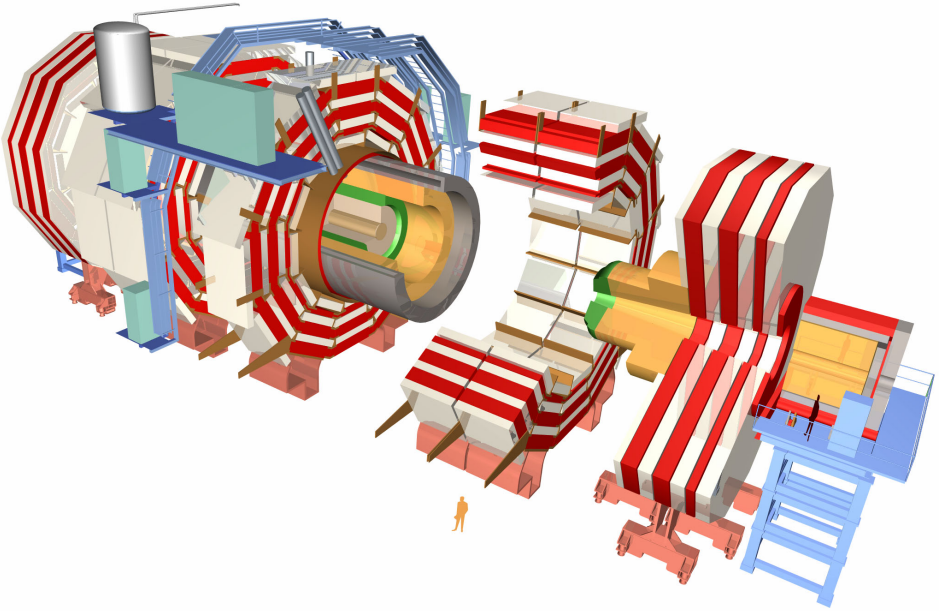
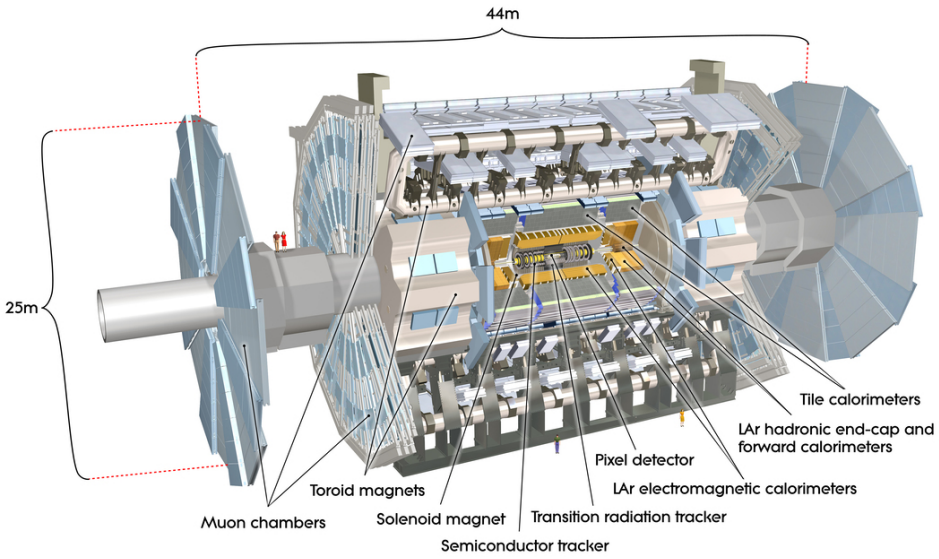
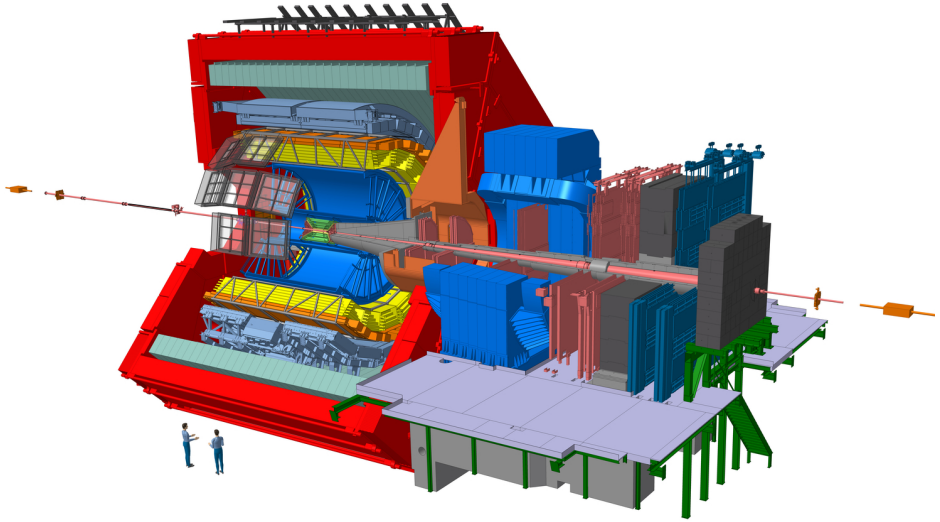
Outline

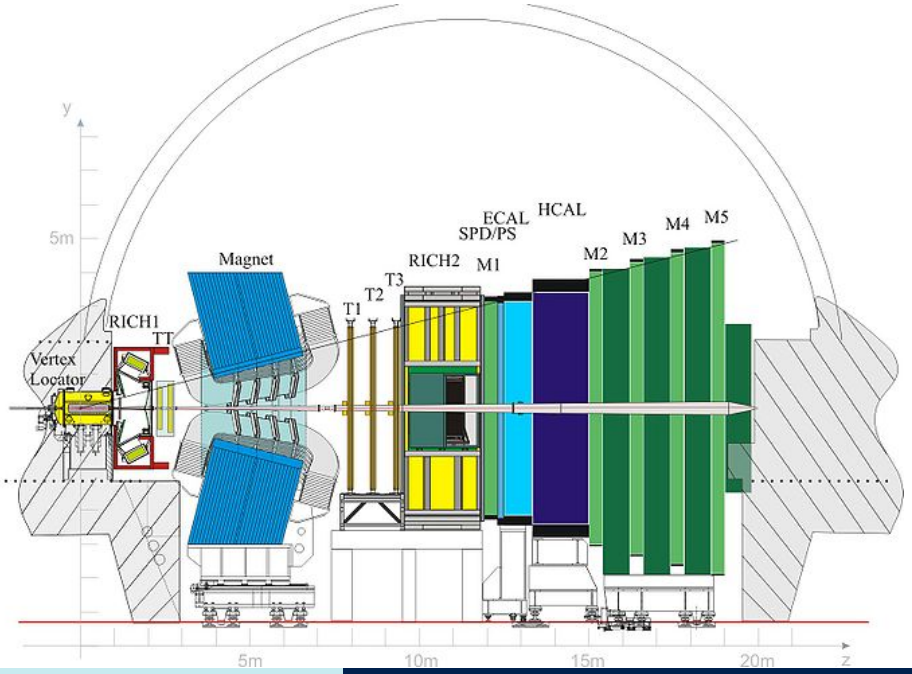
1. LHC detectors
2. (2018) heavy ion collisions (in CMS)
3. Detector limitations for long-lived particle searches
4. Detector upgrades

LHC detectors

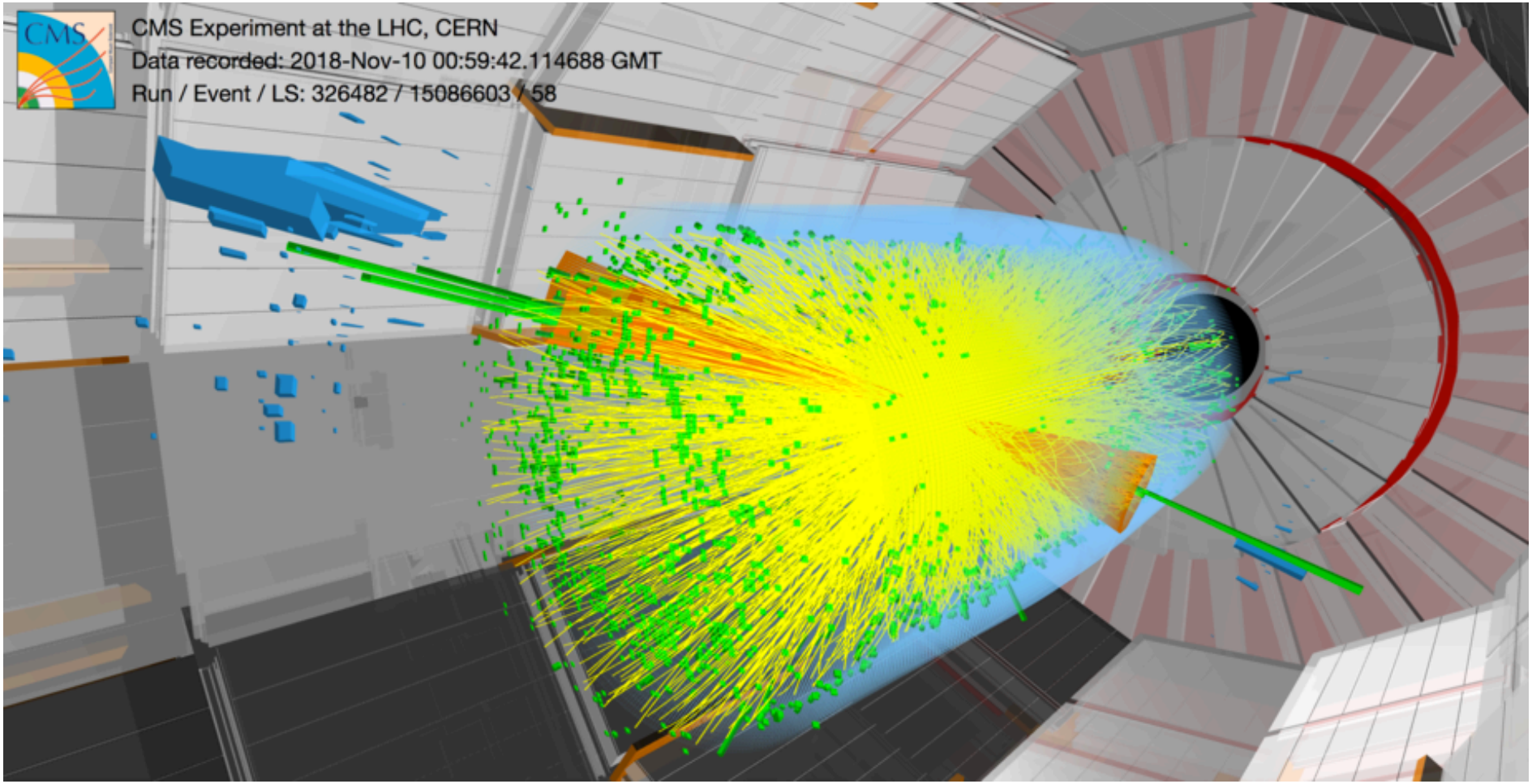




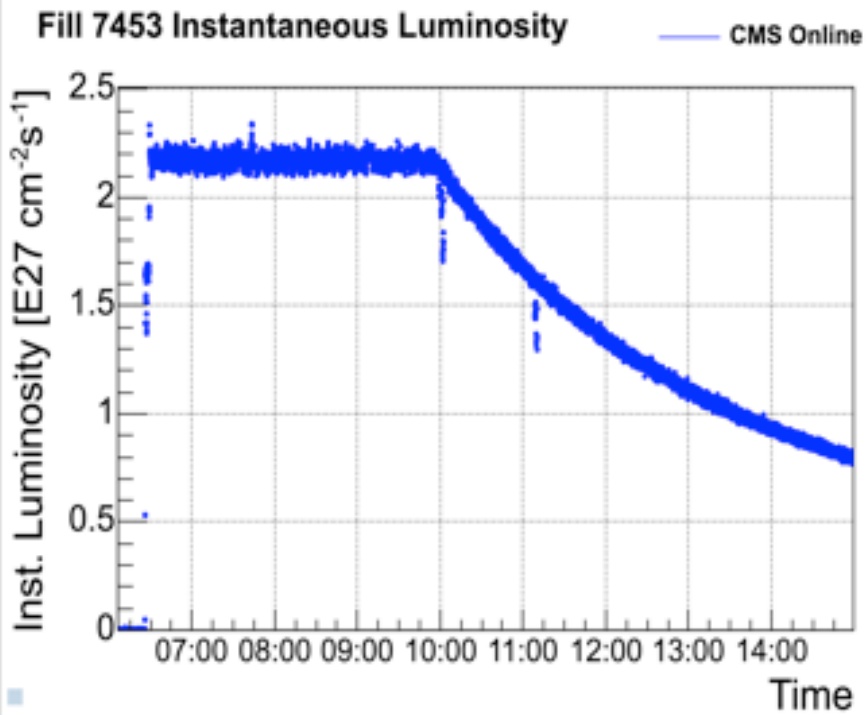


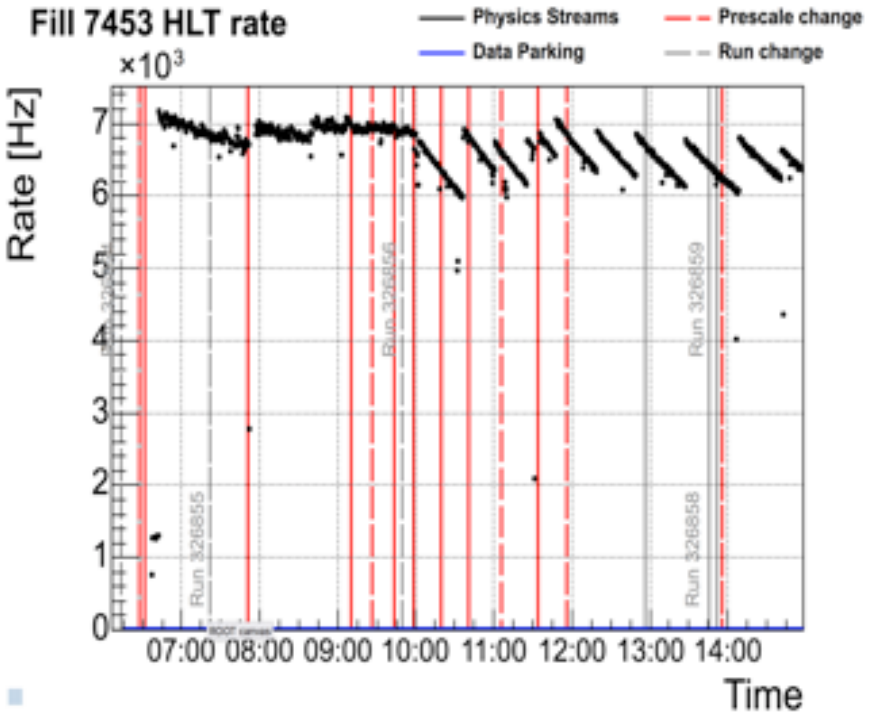


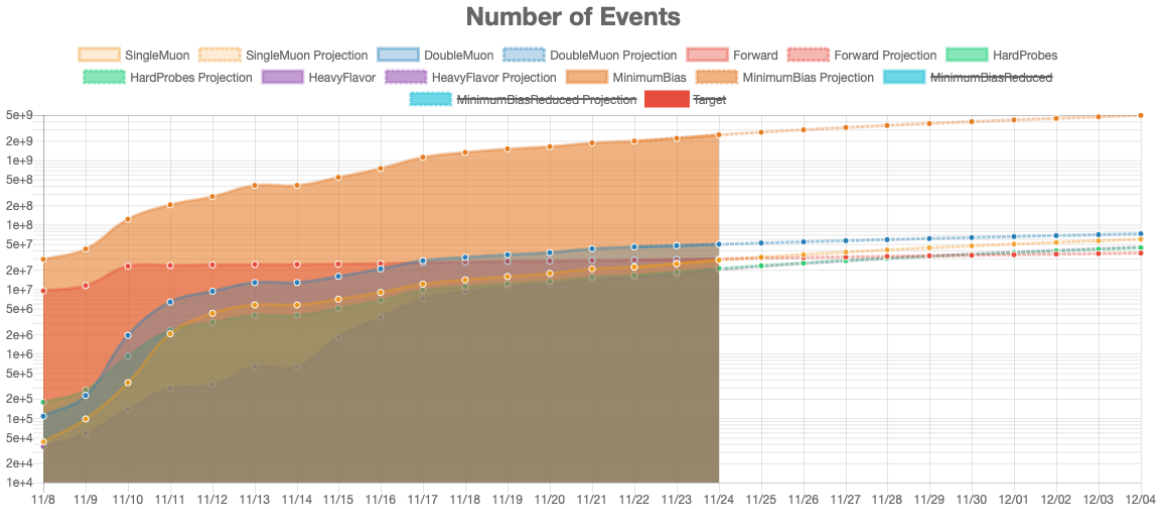
A heavy ion collisions event in CMS

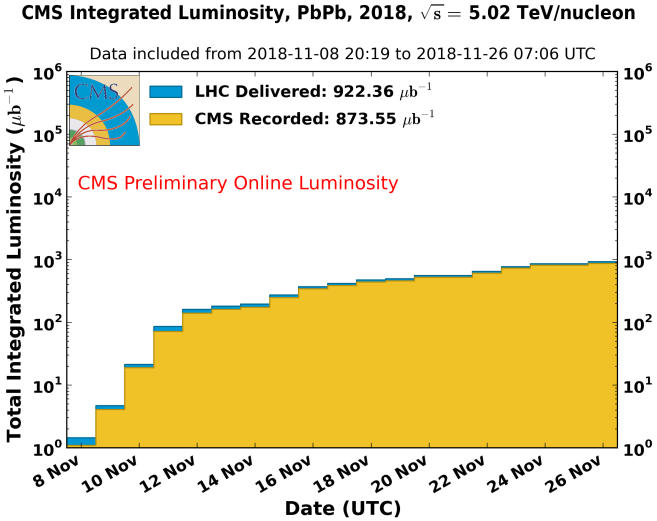


2018 HI trigger







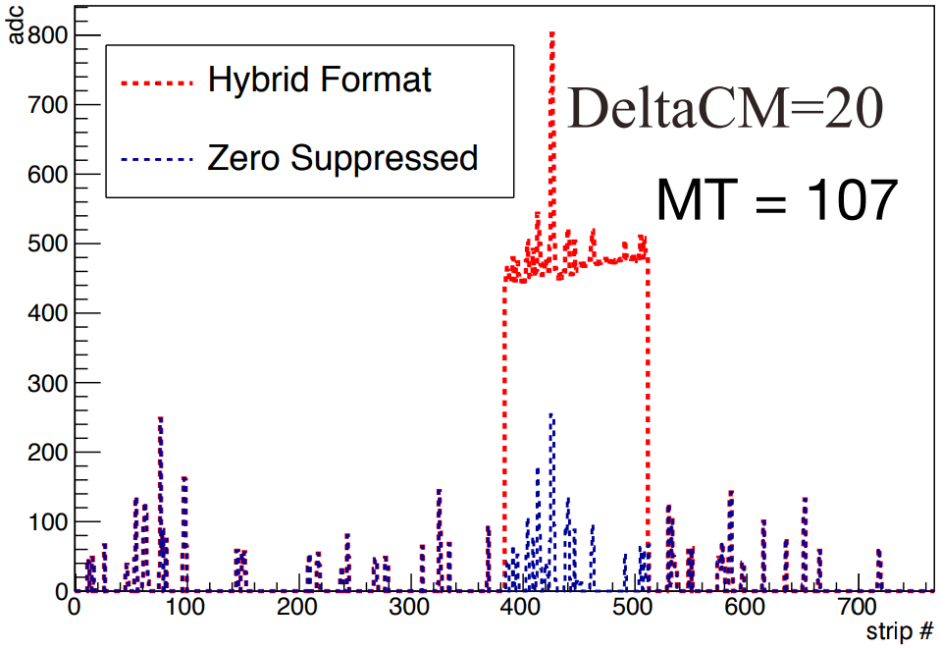


2018 HI pushing the CMS detector to (some) limits

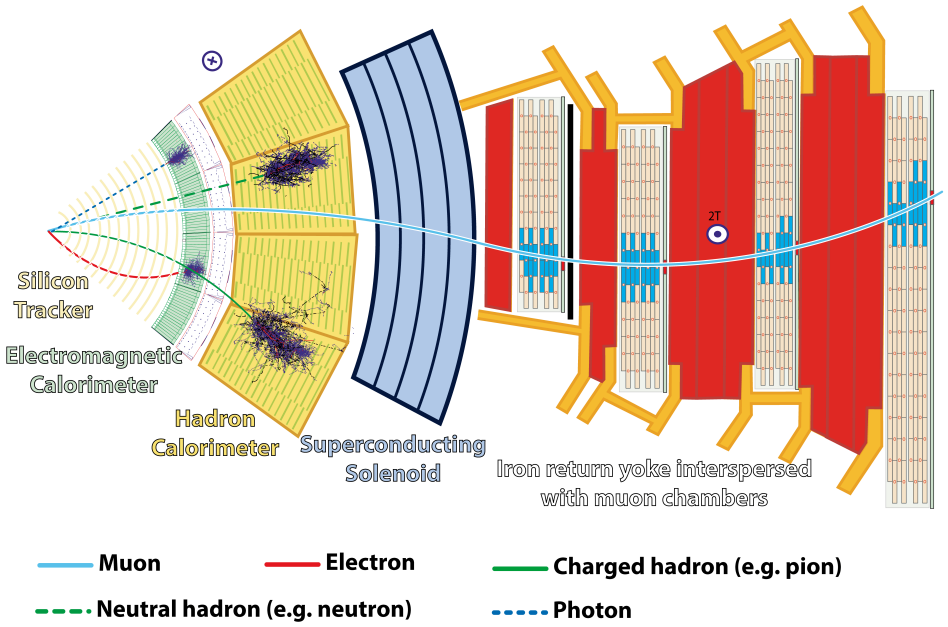
- L1 rate of 30 kHz (3× more than 2015), HLT output of around 7 GB/s

- Example detector complication: Strip tracker "baselines" often not flat in heavy ion

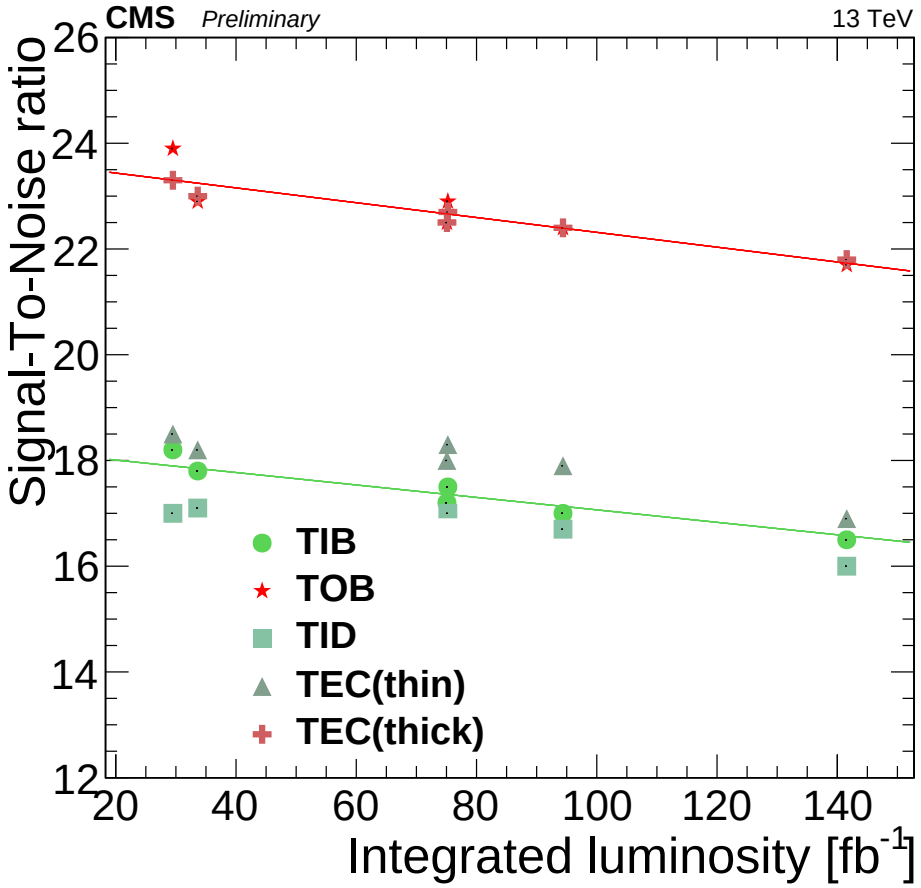
- zero-suppression in the detector frontend electronics (as in proton-proton) would reduce efficiency
- 2015 solution: no zero-suppression (big events limiting trigger rate)
- 2018 hybrid readout: zero-suppression only when baseline as expected



Detector(-related) limitations



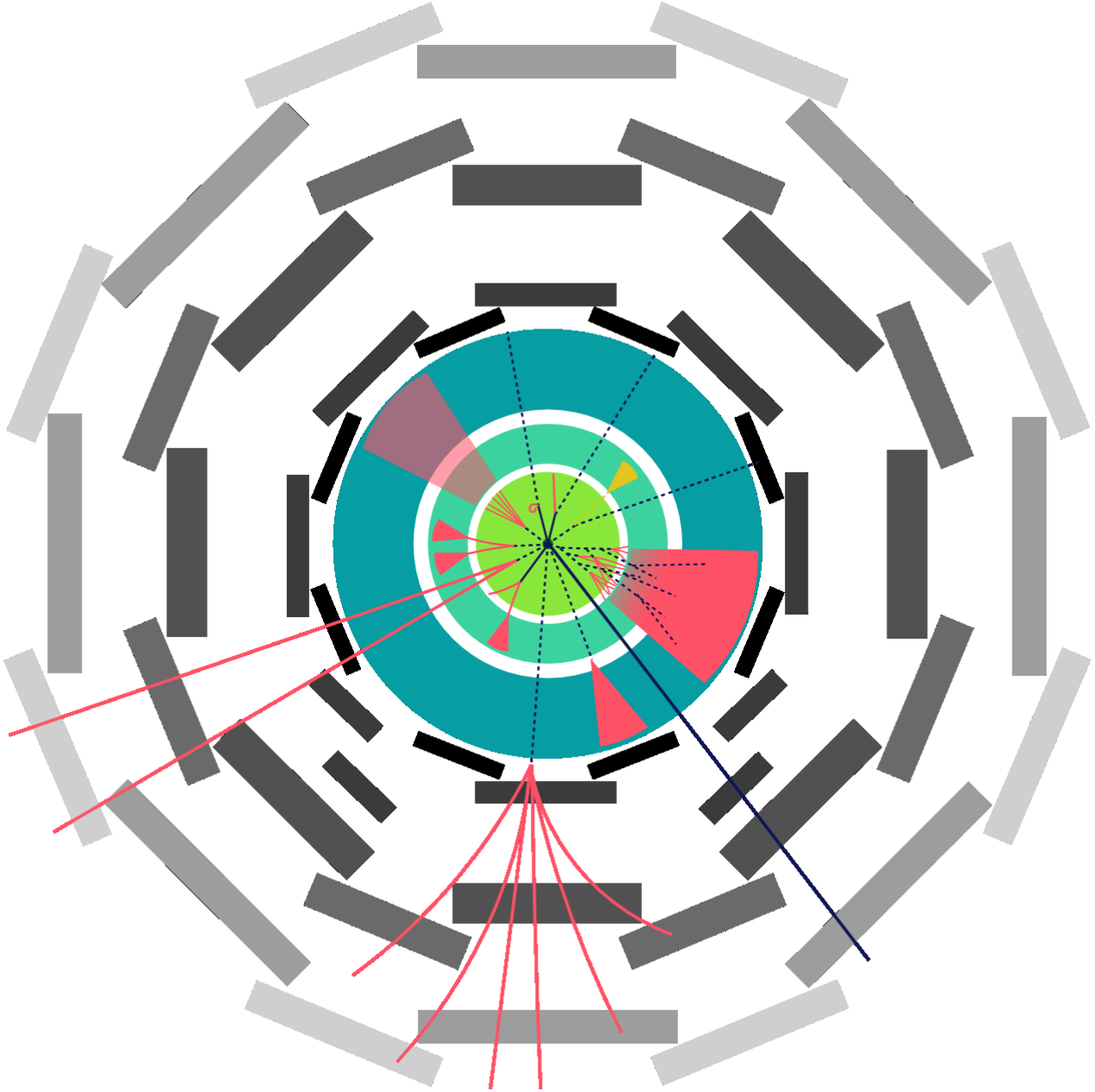
An example: ageing of the CMS strip tracker (relevant for HSCP searches)



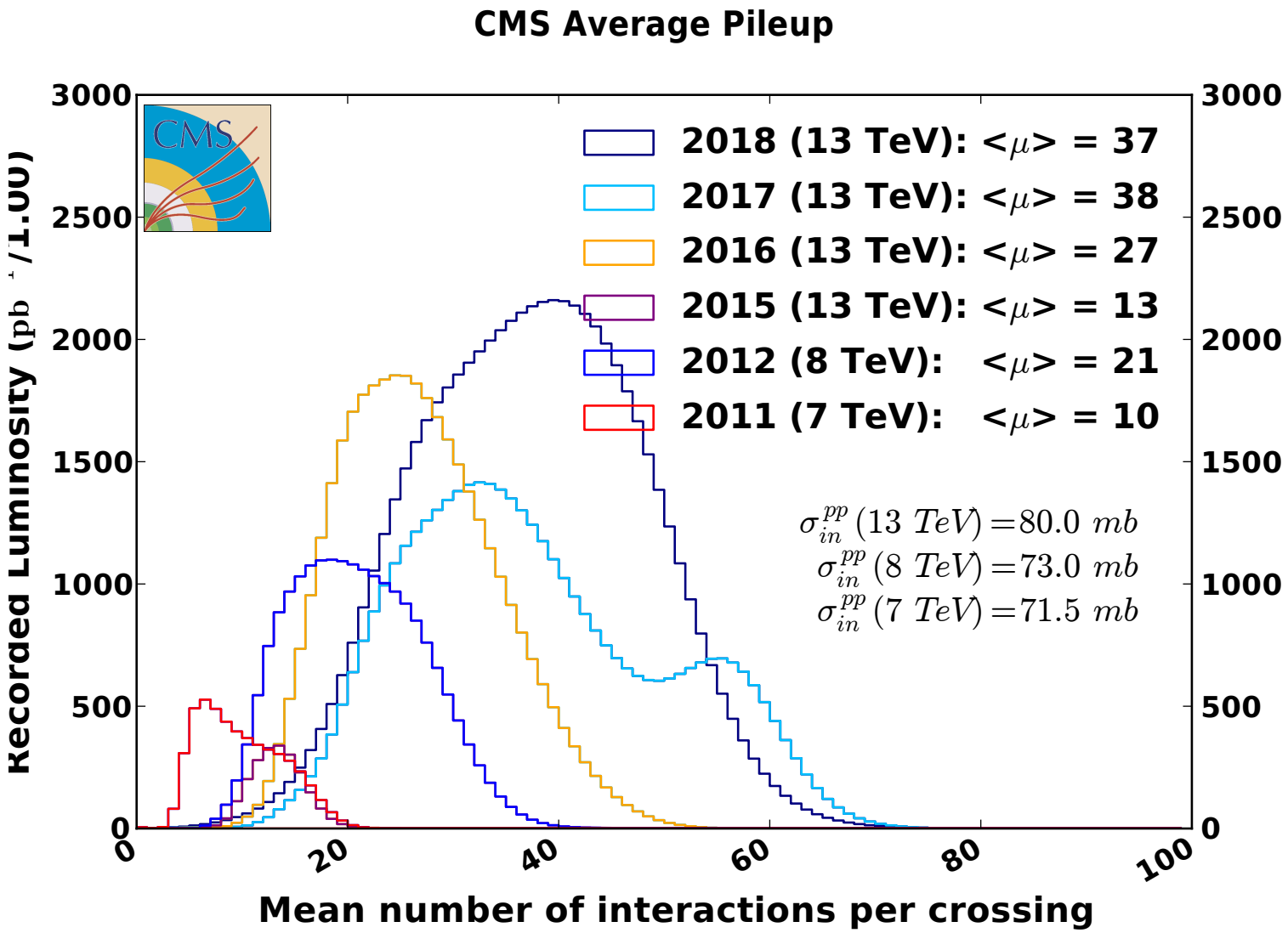
Also

- hardware trigger / readout
- high-level trigger (online reconstruction)
- offline reconstruction (computing resources)

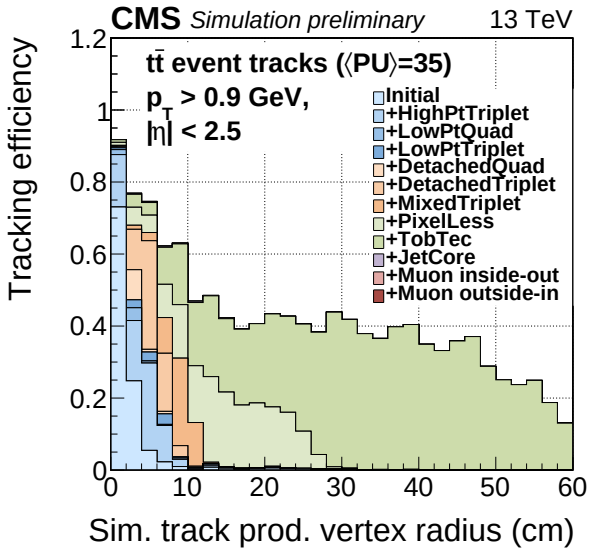
Which long-lived particles?

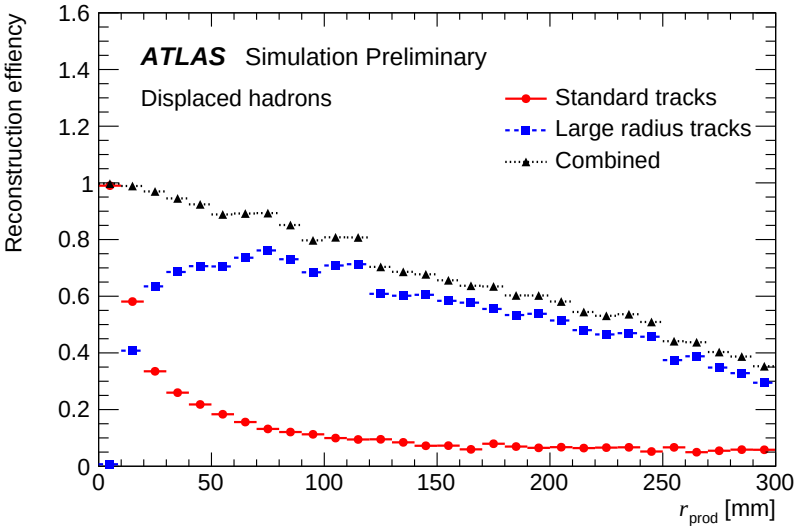


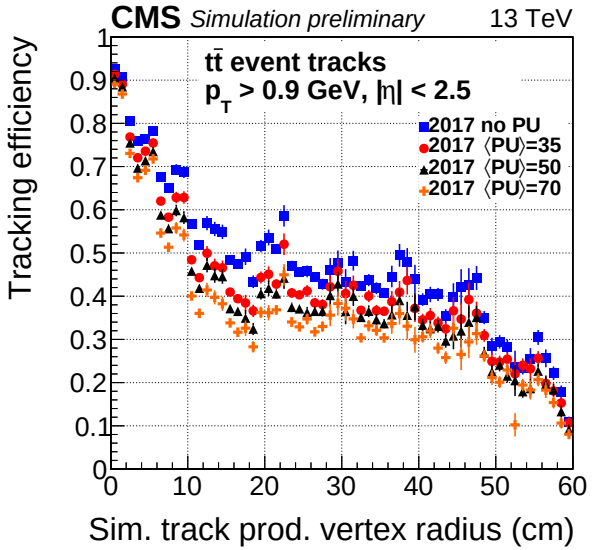
Pileup in proton-proton collisions

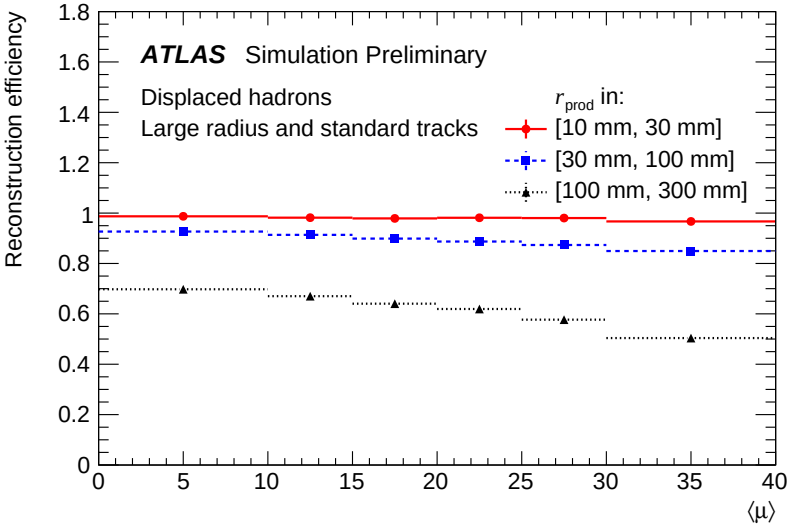


Displaced track reconstruction





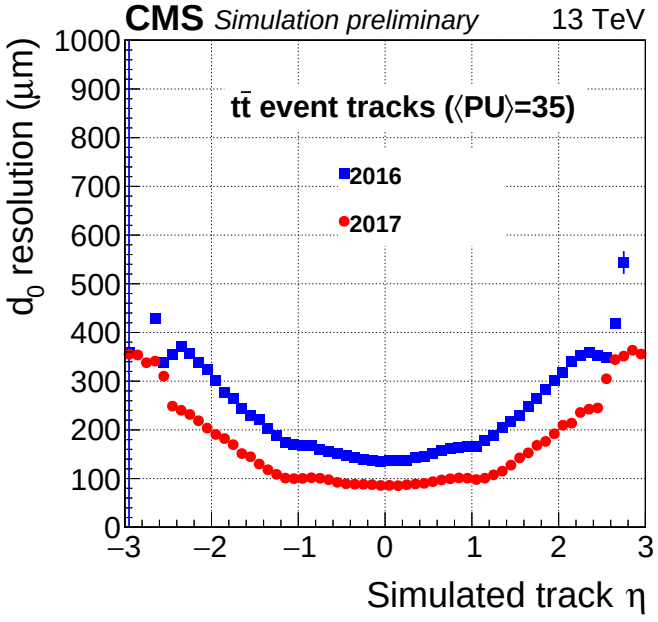


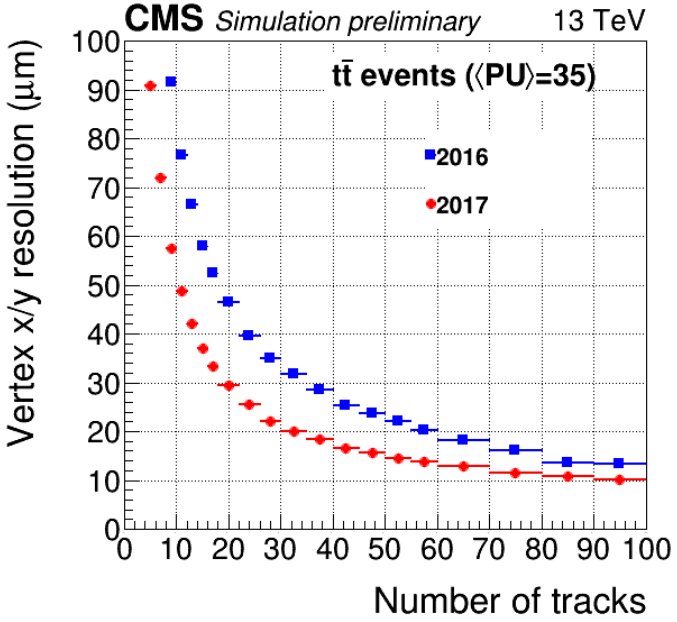


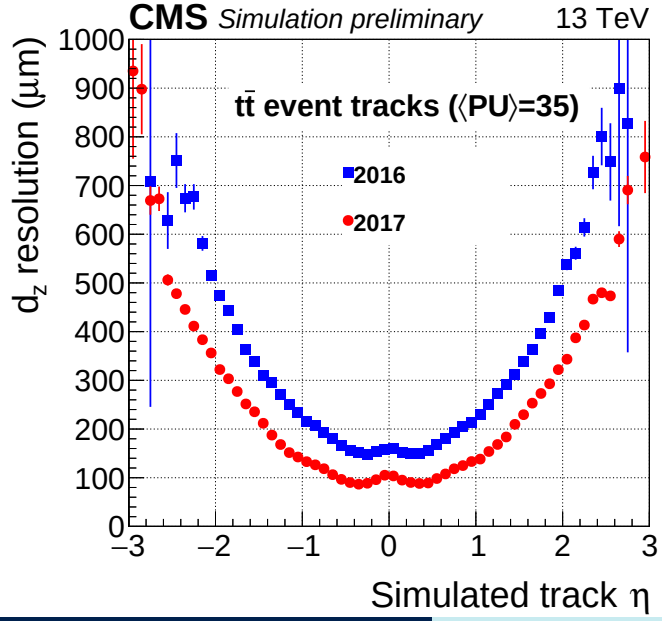
CMS tracking performance page

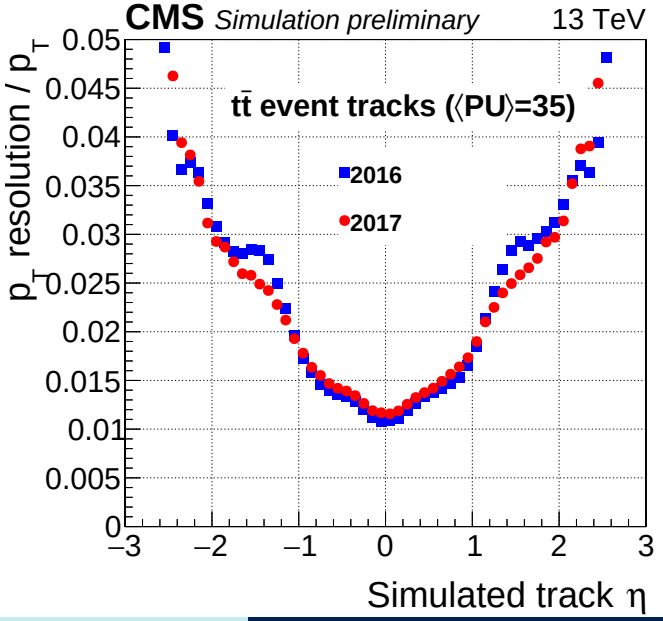
ATL-PHYS-PUB-2017-014

Vertex and track resolution





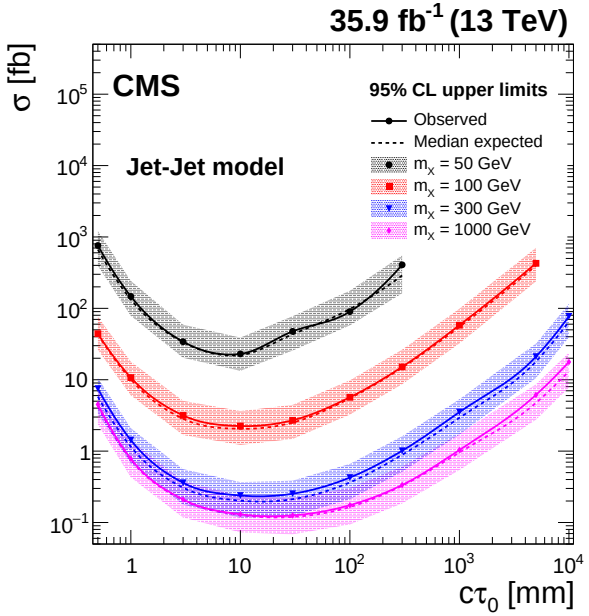


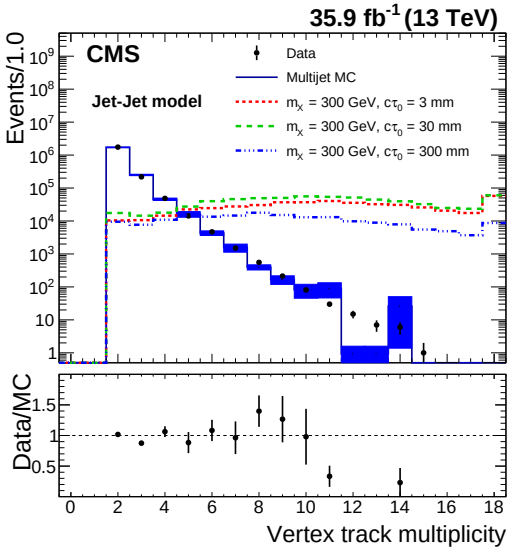


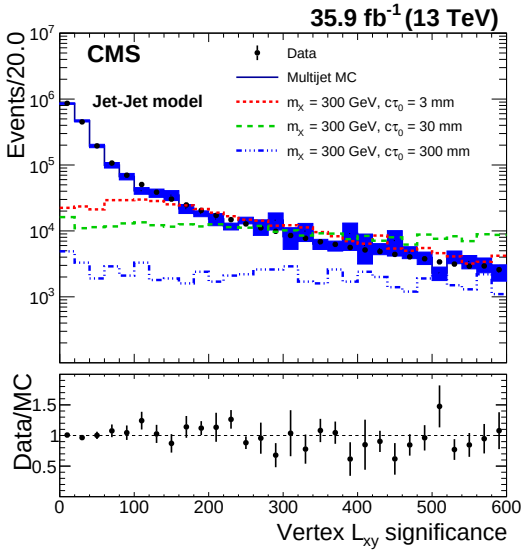
Example: displaced dijets in CMS

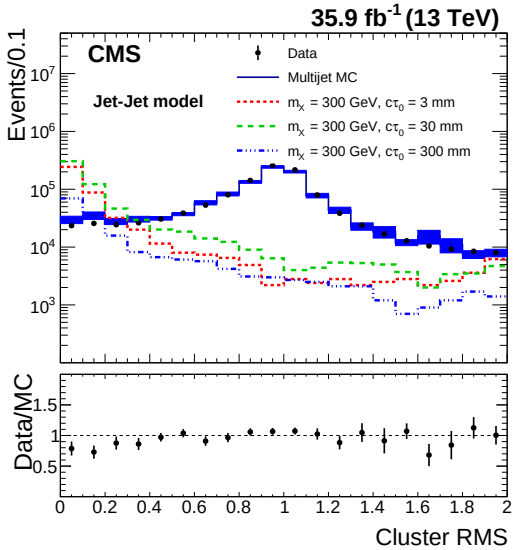
arχiv:1811.07991 submitted to Phys.Rev.D

- Simplified model: pair-produced long-lived particles, both decaying to two jets (also sensitive to 1jet)
- 35.9 fb^{-1} of proton-proton data at $\sqrt{s} = 13\,\mathrm{TeV}$ (2016)
- Dedicated high-level trigger selection for displaced dijets
- Up to 55 cm transverse displacement









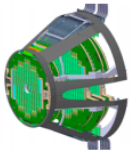
ALICE upgrade

A Large Ion Collider Experiment

ALICE Detector Upgrades

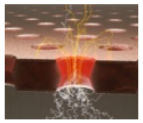
New Inner Tracking System (ITS)

-CMOS pixel, MAPS technology
-Improved resolution, less material, faster readout



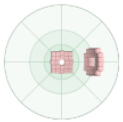
New Muon Forward Tracker (MFT)

-CMOS Pixels, MAPS technology
-Vertex tracker at forward rapidity



New TPC Readout Chambers (ROCs)

-Gas Electron Multiplier (GEM) technology
-New electronics (SAMPA), continuous readout



New Fast Interaction Trigger (FIT) Detector

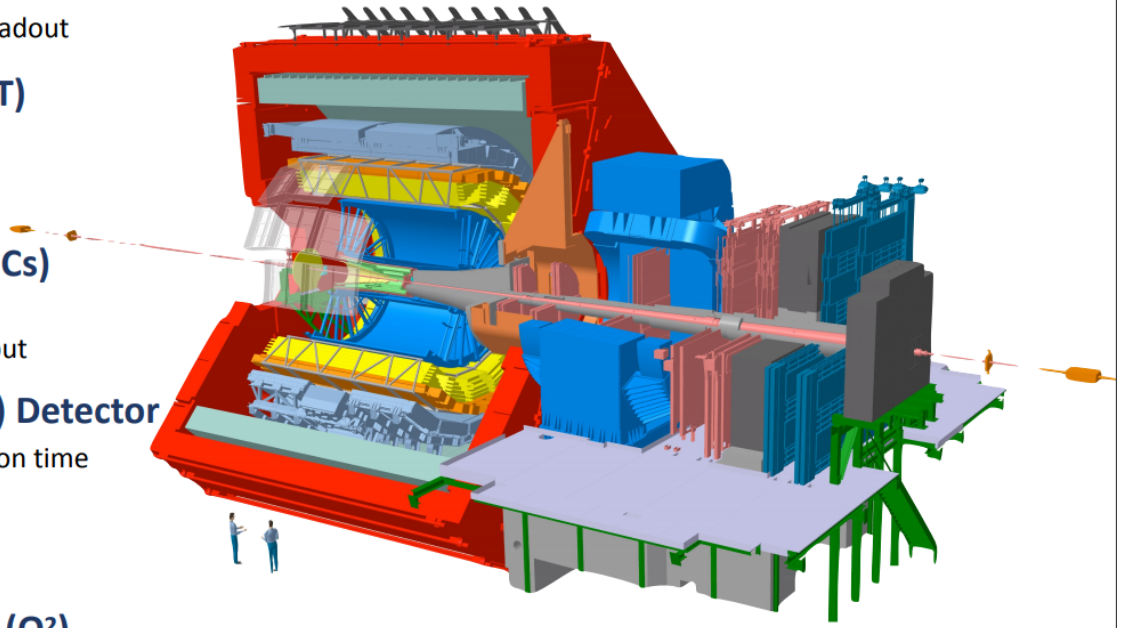
-Centrality, event plane, luminosity, interaction time

Readout upgrade

-TOF, TRD, MUON, ZDC, Calorimeters

Integrated Online-Offline system (O^2)

-Record Minimum-Bias Pb-Pb data at 50 kHz

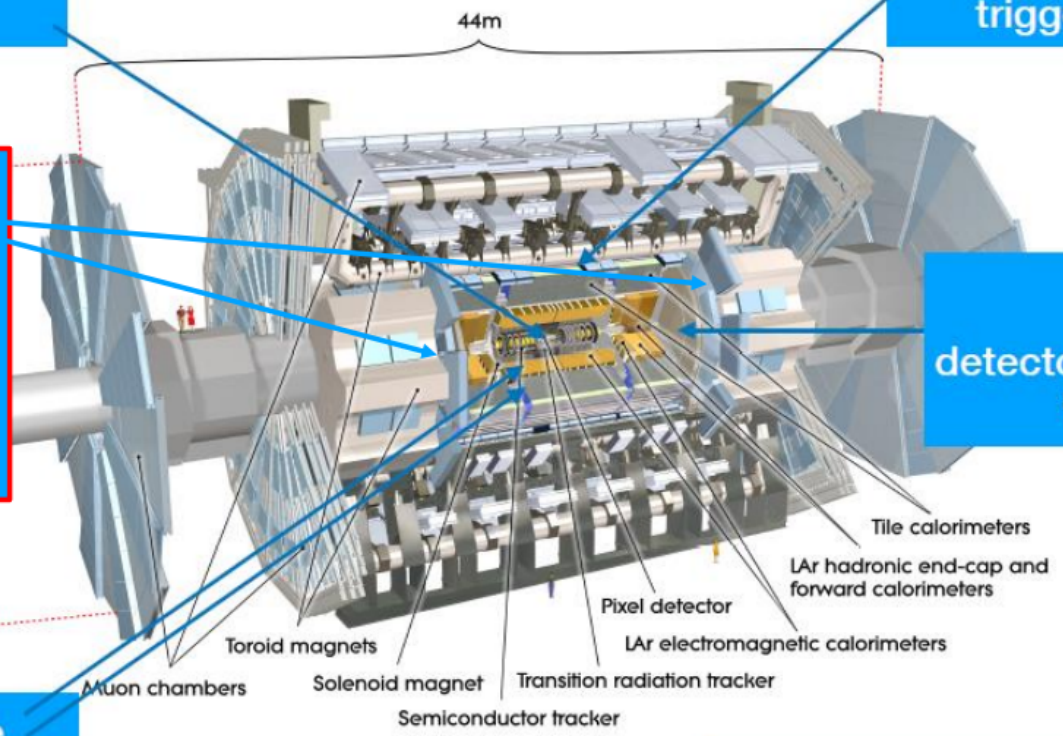


ATLAS upgrade

Complete replacement of the tracker

New inner muon trigger system

Muon system **Phase-I:**
(1) New Small Wheels
(2) BIS 7+8
Phase-II:
(1) BI system
(2) MDT incl. in trigger

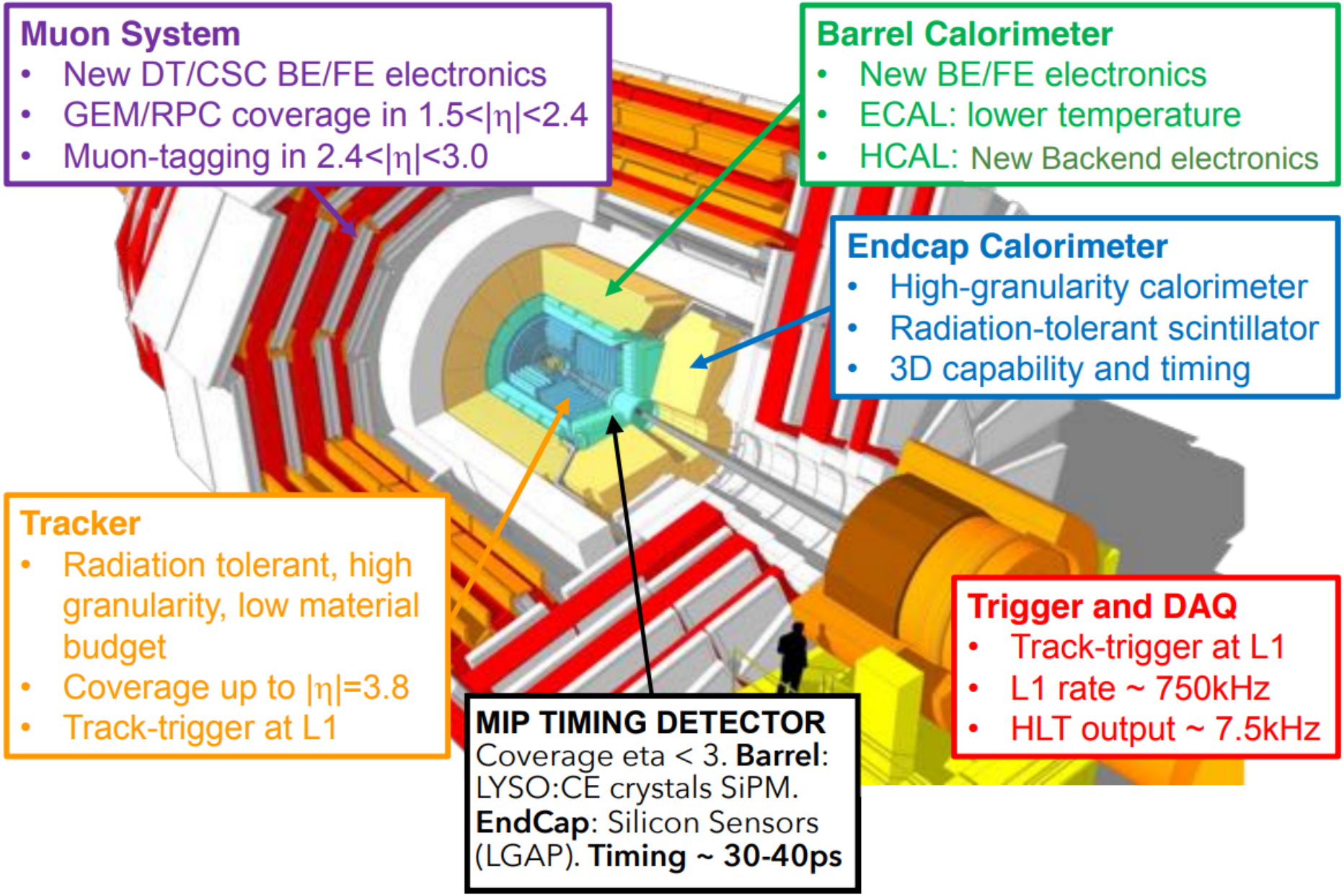


timing detector: High Granularity Timing Detector (HGTD)

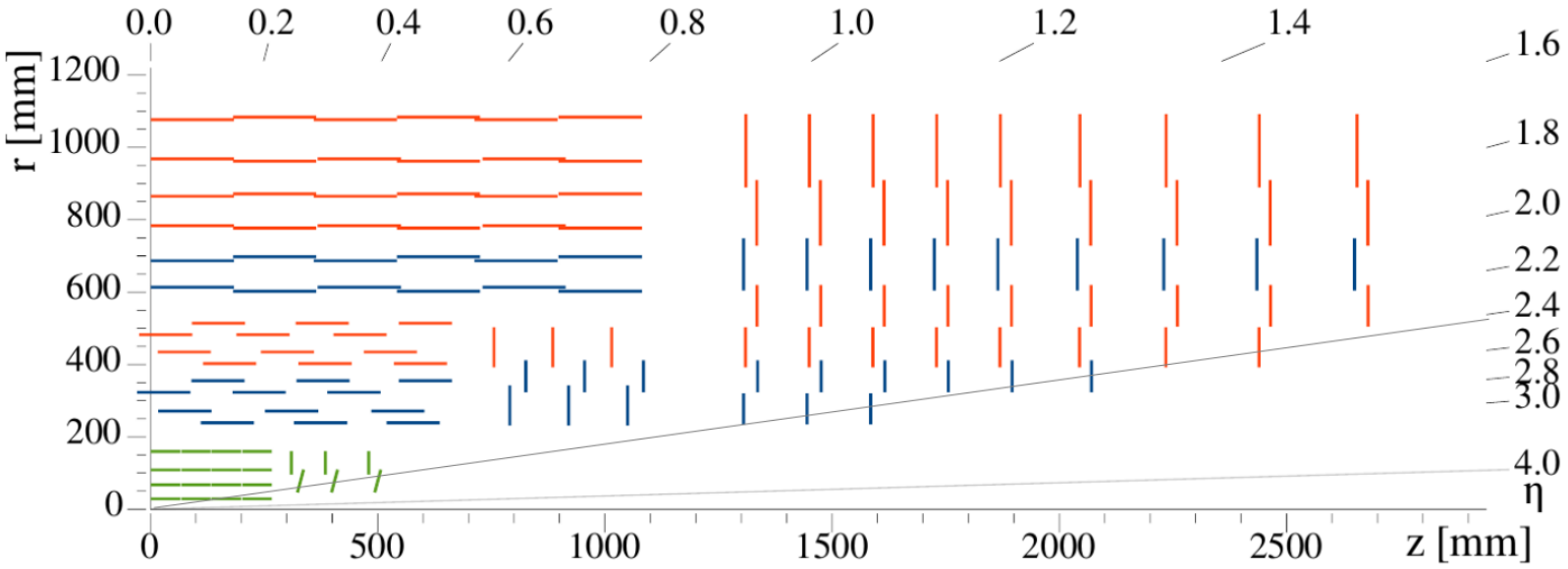
Calorimeter to replace electronics, readouts and power supplies
Allow for higher resolution objects at the lowest trigger level

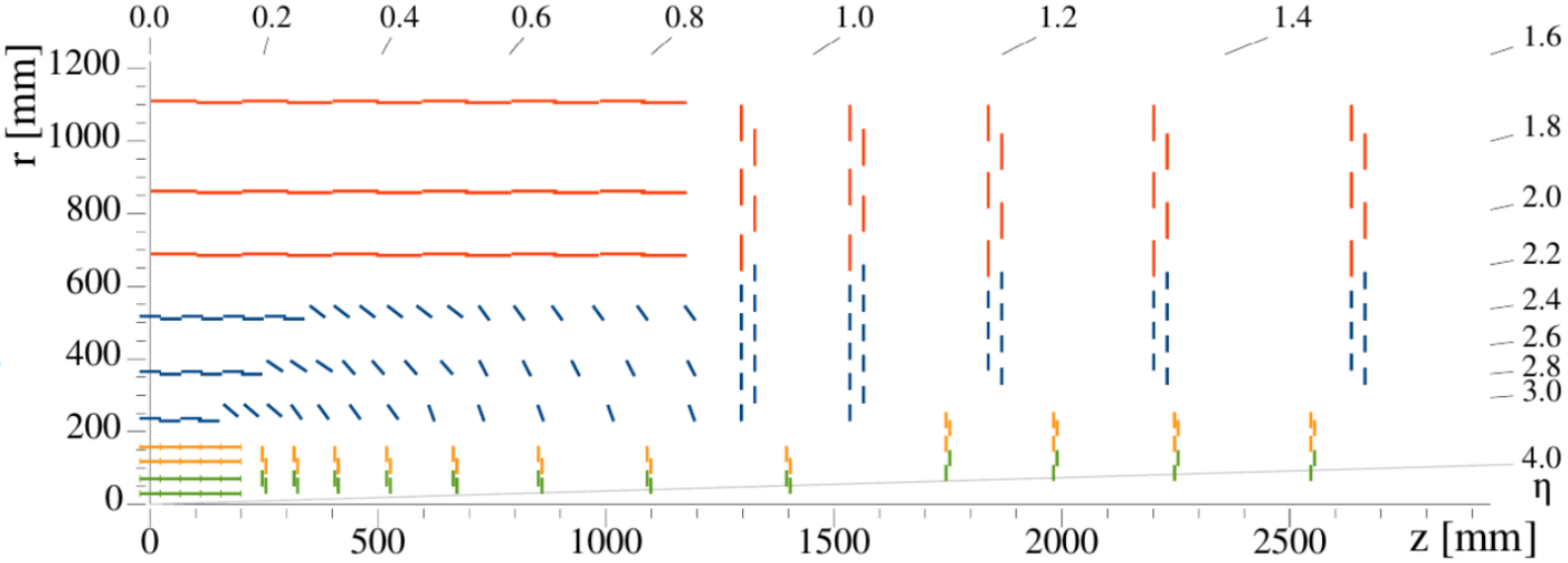
New trigger system

CMS upgrade


Muon System
• New DT/CSC BE/FE electronics
• GEM/RPC coverage in 1.5<|η|<2.4
• Muon-tagging in 2.4<|η|<3.0
Barrel Calorimeter
• New BE/FE electronics
• ECAL: lower temperature
• HCAL: New Backend electronics
Endcap Calorimeter
• High-granularity calorimeter
• Radiation-tolerant scintillator
• 3D capability and timing
Tracker
• Radiation tolerant, high granularity, low material budget
• Coverage up to |η|=3.8
• Track-trigger at L1
MIP TIMING DETECTOR
Coverage eta < 3. Barrel: LYSO:CE crystals SiPM. EndCap: Silicon Sensors (LGAP). Timing ~ 30-40ps
Trigger and DAQ
• Track-trigger at L1
• L1 rate ~ 750kHz
• HLT output ~ 7.5kHz

CMS tracker upgrade





Conclusions

- Heavy ion runs so far focussed on collecting “minimum bias” datasets
- From the detector side: mostly challenges related to readout and reconstruction (tracking) of busy events
- In some ways similar to the challenges in proton-proton (pileup), in some ways very different (radiation)
- There is a lot of room between LHC proton-proton (large luminosity, tight triggers) and heavy ion collisions (low luminosity, almost no trigger)
- Triggers are highly final-state dependent, so one size does not fit all
- Displaced decays remain challenging (but a lot of effort is ongoing)