
PPAP Meeting - CMS

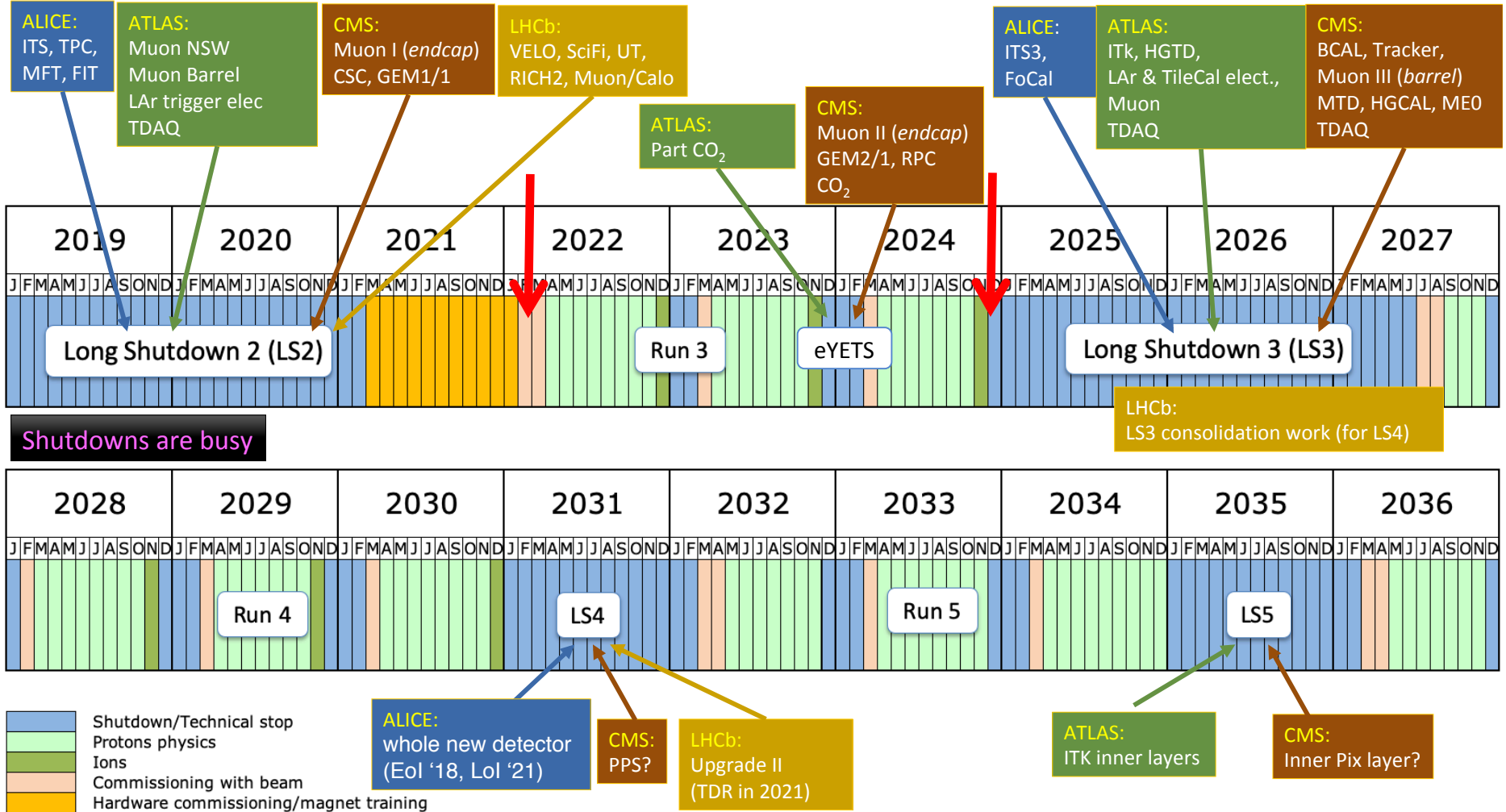
Claire Shepherd-Themistocleous (RAL)
on behalf of the CMSUK Collaboration

Outline

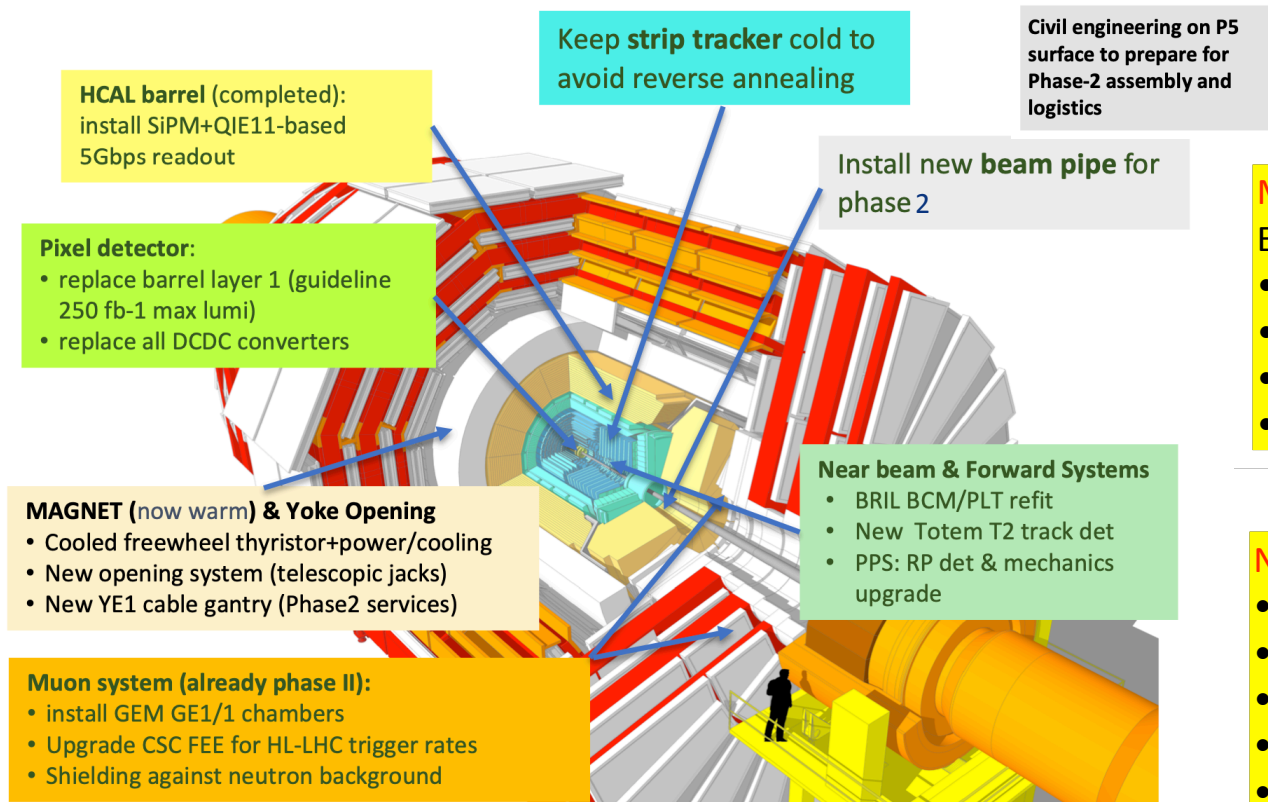
■ Outline

- Current status
- Physics recent UK highlights
- Upgrade programme and progress
- Computing – a word
- Future
- Summary

LHC Schedule



CMS LS2 activities



Muon activities in full swing.

Expect to complete by beginning of Dec:

- Install and commission new GEMs
- CSC cooling and front-end electronics
- DT repair, maintenance and shielding
- RPC gas leak & HV repair

Next major activities (time ordered):

- forward shielding (part 1)
- beam pipe
- pixel installation (new L1)
- yoke closing
- forward shielding (part 2)

27/10/2020

RRB Oct '20 - CMS Status report

8

CMS LS2 activities



27/10/2020

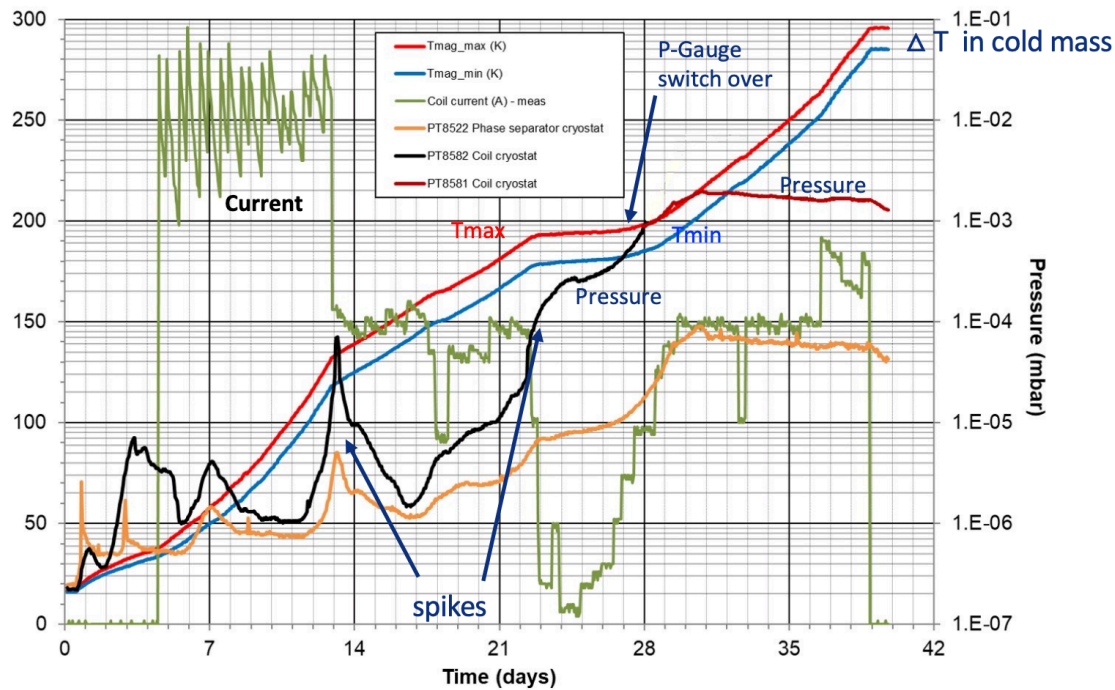
RRB Oct '20 - CMS Status report

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CMS Magnet Repairs

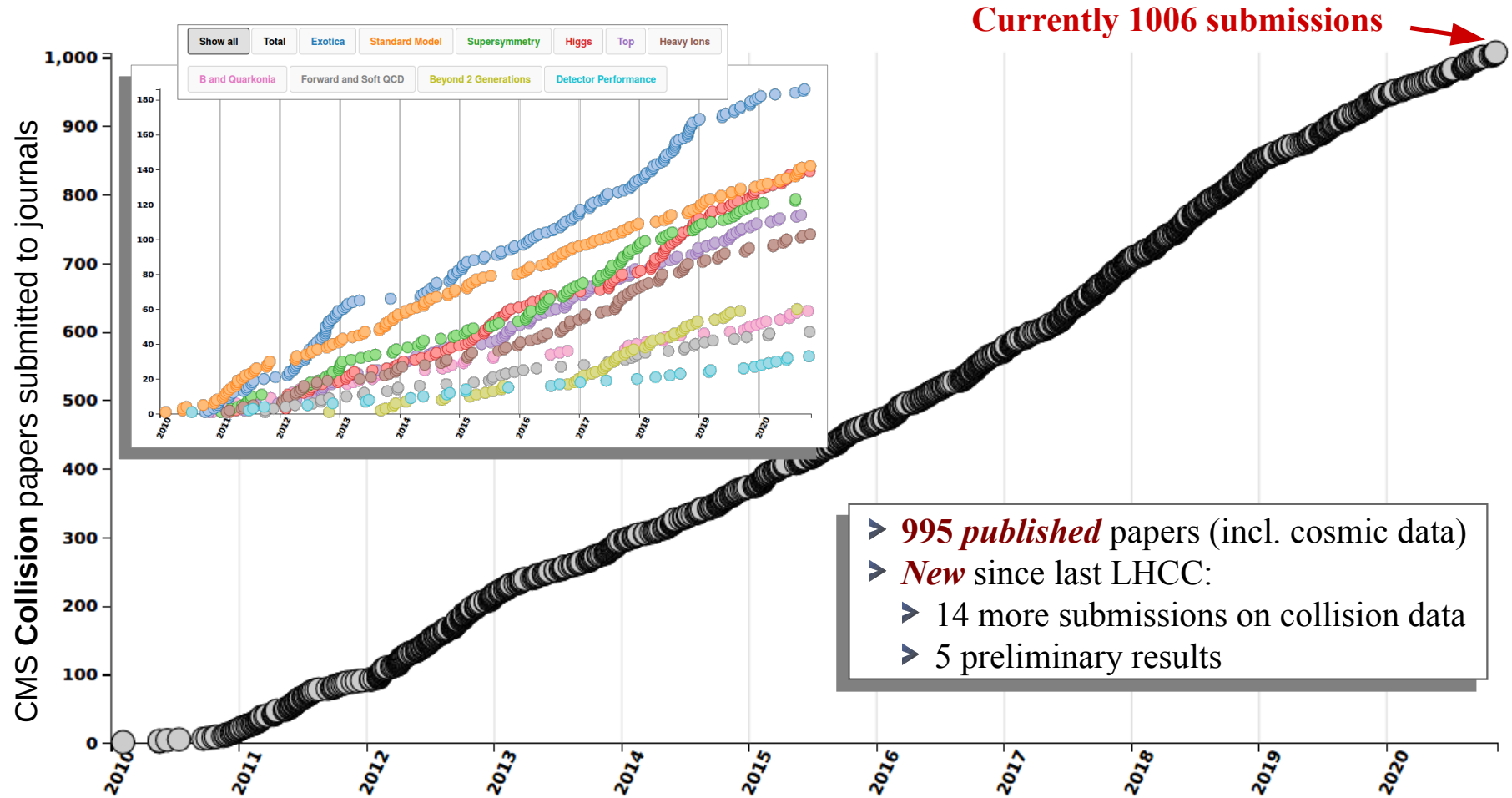
Needed to warm up magnet to replace broken pump

Procedure performed during lockdown

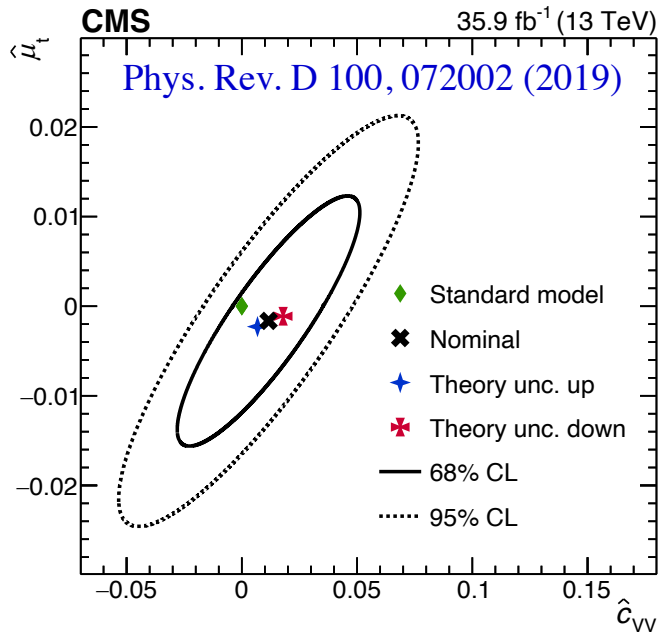


- Started 20th April
- Finished 24th May
- Temperature stable

CMS papers

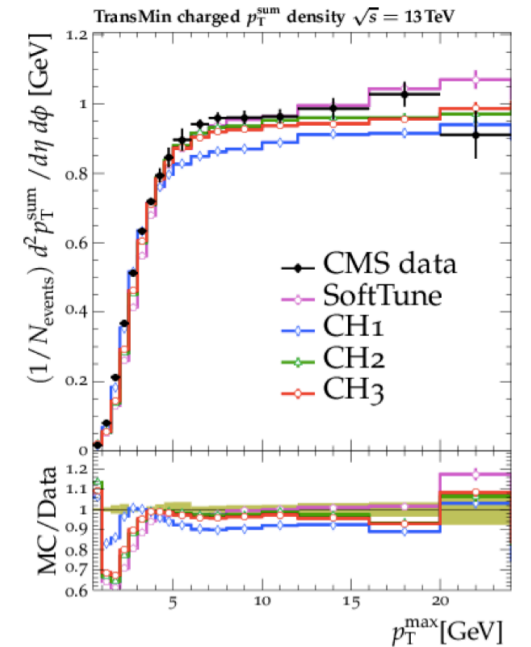
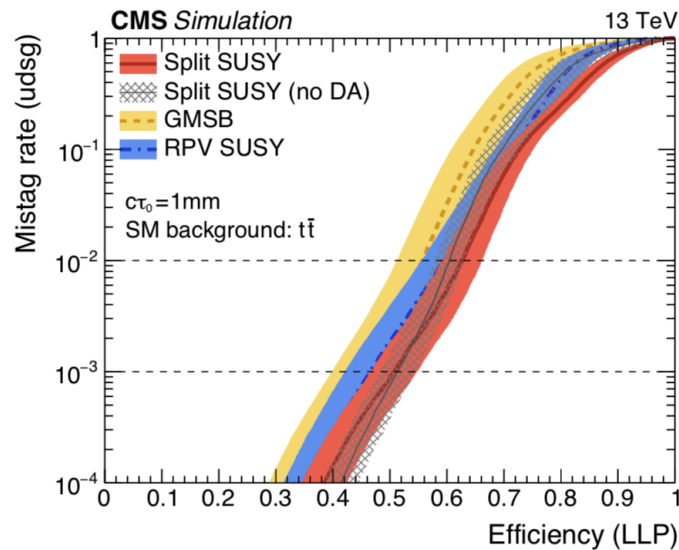


Recent UK Physics results



LLP tagger
using DNN
(CNN)

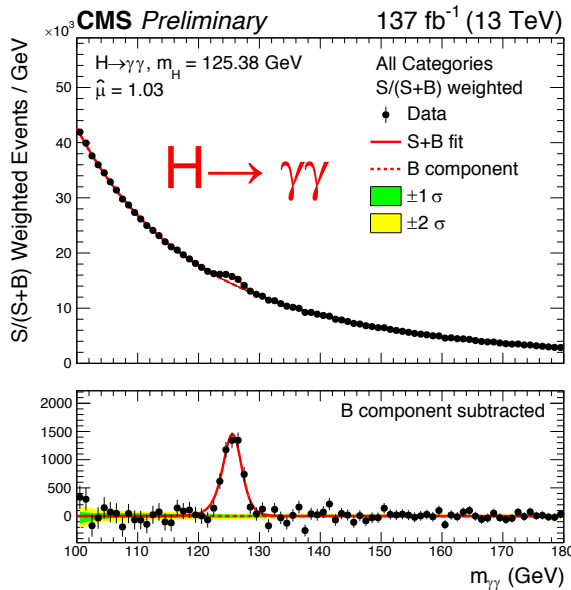
ttbar Spin Correlations
SMEFT Wilson coeff.
constraints



Herwig tune using
CMS underlying
events from 0.9, 7, 13
TeV data.

Recent UK Physics Results II

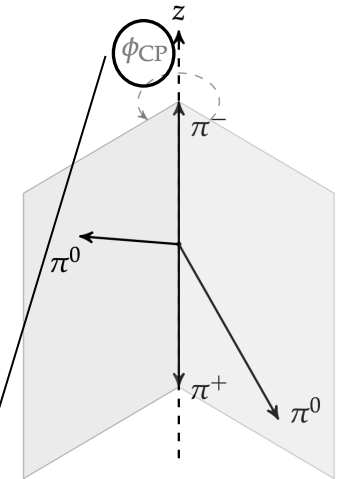
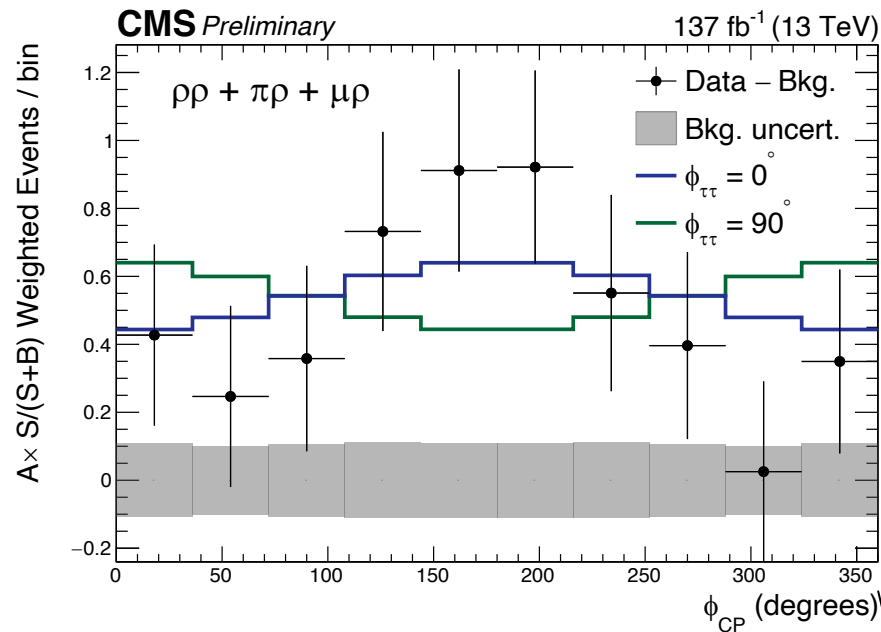
- Lots of Higgs SM and BSM analyses!



H to gg large statistics
 Allow exclusive modes
 e.g. rare modes tH and tH (use DNN)

Probing CP structure of Higgs to tau coupling

Angle between tau decay planes sensitive to CP structure



Upgrade of CMS for HL-LHC

L1-Trigger/HLT/DAQ

<https://cds.cern.ch/record/2714892>

<https://cds.cern.ch/record/2283193>

- Tracks in L1-Trigger at 40 MHz
- PFlow selection 750 kHz L1 output
 - HLT output 7.5 kHz
 - 40 MHz data scouting

Calorimeter Endcap

<https://cds.cern.ch/record/2293646>

- 3D showers and precise timing
- Si, Scint+SiPM in Pb/W-SS

Tracker <https://cds.cern.ch/record/2272264>

- Si-Strip and Pixels increased granularity
 - Design for tracking in L1-Trigger
 - Extended coverage to $\eta \approx 3.8$

Barrel Calorimeters

<https://cds.cern.ch/record/2283187>

- ECAL crystal granularity readout at 40 MHz with precise timing for e/γ at 30 GeV
- ECAL and HCAL new Back-End boards

Muon systems

<https://cds.cern.ch/record/2283189>

- DT & CSC new FE/BE readout
- RPC back-end electronics
- New GEM/RPC $1.6 < \eta < 2.4$
- Extended coverage to $\eta \approx 3$

Beam Radiation Instr. and Luminosity

<http://cds.cern.ch/record/002706512>

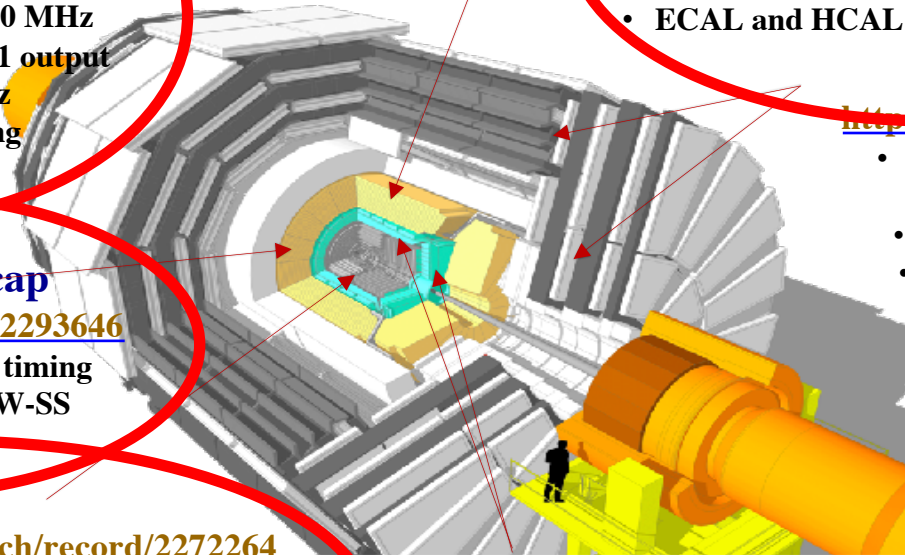
- Bunch-by-bunch luminosity measurement: 1% offline, 2% online

MIP Timing Detector

<https://cds.cern.ch/record/2667167>

Precision timing with:

- Barrel layer: Crystals + SiPMs
- Endcap layer: Low Gain Avalanche Diodes



Upgrade of CMS for HL-LHC

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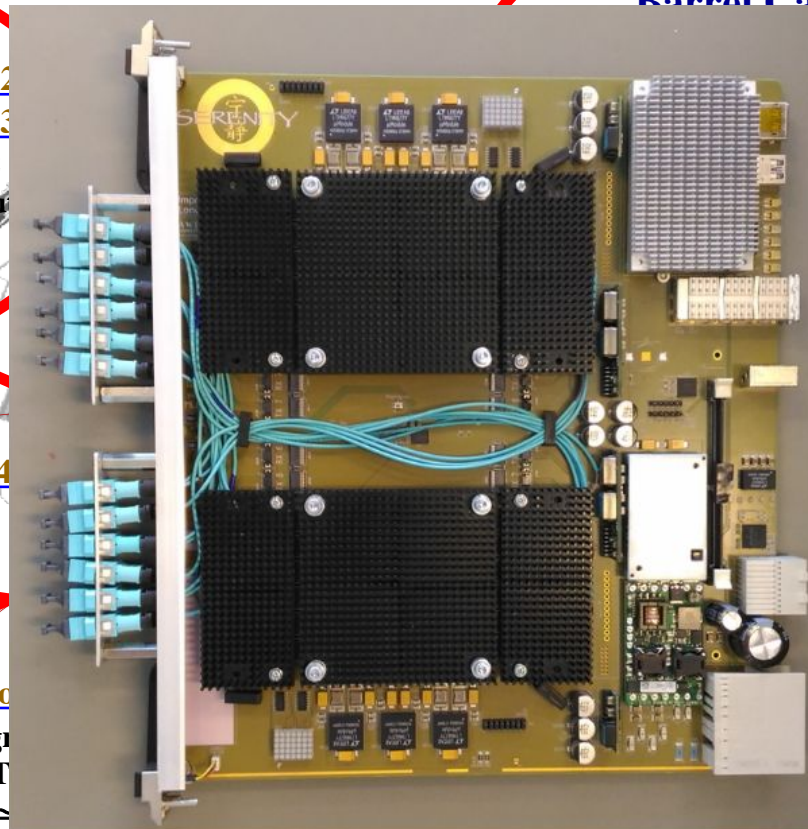
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Barrel Calorimeters

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• High rate readout at 40 MHz with
• High rate readout for e/γ at 30 GeV
• New Back-End boards

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• DT & CSC new FE/BE readout
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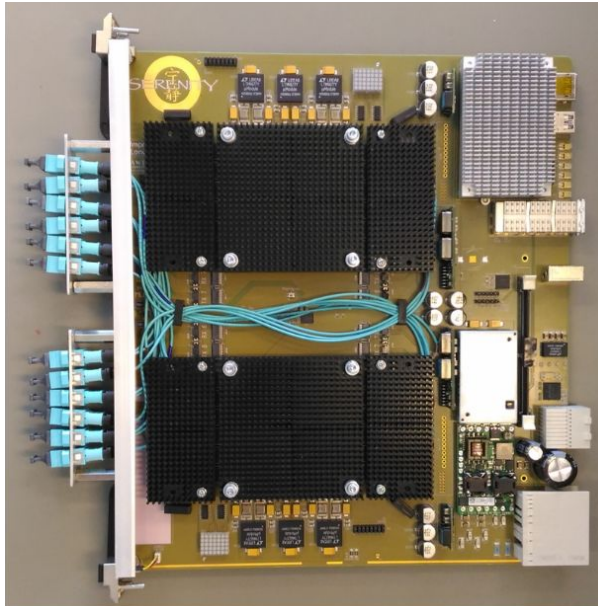
Endcap Detector

<https://cds.cern.ch/record/2667167>

• Working with:

- Barrel layer: Crystals + SiPMs
- Endcap layer: Low Gain Avalanche Diodes

Common electronics



ATCA board with up to 2 FPGAs (pluggable)

288 optical fibres @ 25Gb/s (~ 7Tb/s)

Comes with infrastructure firmware & software

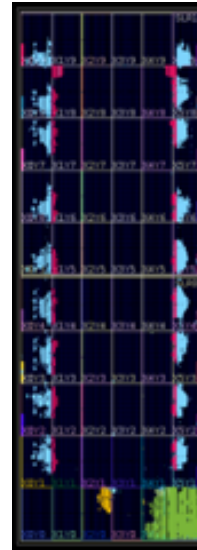
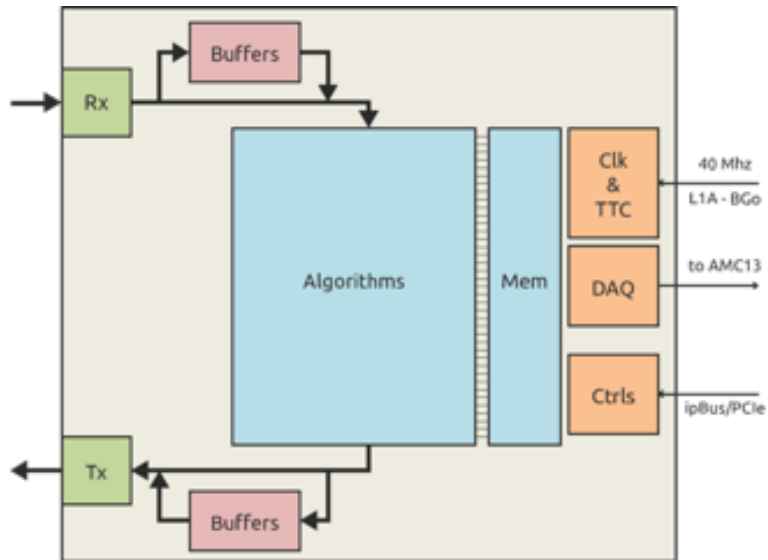
- Board management
- Control & feedback to system (trigger, timing, throttle)
- I/O links and buffering
- Path to DAQ
- Board monitoring (e.g. optics, power regulators)

Now producing version 1.2 of board. Boards in use at CERN and in variety of labs.

Framework firmware and software well advanced.

<http://cern.ch/serenity>

Common electronics



Serenity - A collaboration agreement

Context:

Providing back-end electronics for CMS is a large complex project of significant value, spanning ~5 years and requiring at least another decade of support. As sub-detectors begin to specify their back-end systems it is essential that the limited time available for final R&D is used as constructively as possible. Beyond the R&D phase, previous experience has shown that there is no substitute for extensive testing before full production, and it is therefore important to ensure adequate long-term planning, both in terms of technological decisions to be made and in the distribution of effort and resources for testing, exploitation and support. As a result of these arguments CMS has stated the need for an open and shared hardware platform(s), incorporating a comprehensive firmware and software ecosystem, in order to provide support for multiple sub-detector and physics developments leading up to LS3 and beyond. During its R&D phase the Serenity group has targeted this common approach, however given the scale and complexity of systems to be built it is critical that we make the best use of the limited time available so that:

- different technological choices can be thoroughly investigated, minimising future schedule and cost risk.
- the development effort is coherent and suitably organised, from the initial prototyping phase through to pre-production, production and commissioning.
- there is a clear way forward for all, allowing colleagues to collaborate effectively in a constructive environment.

Proposed Applications in CMS:

At present the common platform is targeted towards the following sub-detectors, however it is open to other sub-detectors joining.

- Tracker DTC
- HGCal TPG (both stages) and DAQ
- Parts of the Level-1 Trigger, Muon & Timing Systems

Flexible board many users:

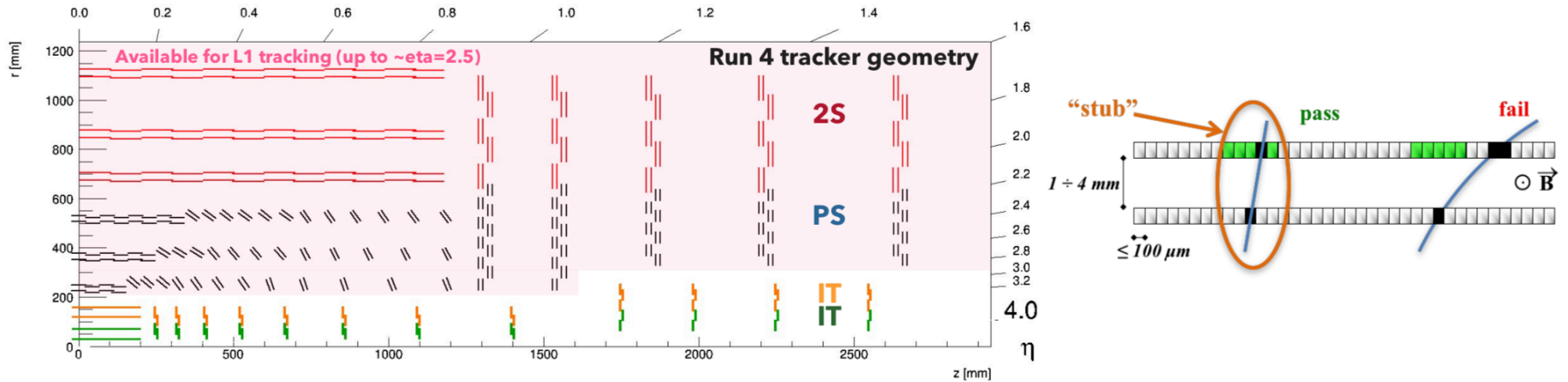
- UK projects (Tracker, HGC, L1 trigger)
- non-UK (muons, timing det)

Set up Serenity Consortium within CMS:

UK, Germany, France, Italy, India, ++?

7 Groups

Tracker



Si tracker to be completely replaced.

UK developed idea of "pt" modules enabling use of tracks at L1.

UK developed frontend ASIC (CBC)

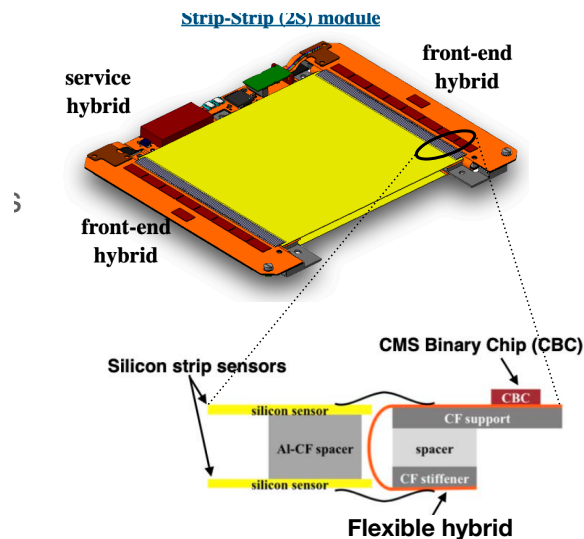
UK led development of all FPGA track reconstruction

Outer module ASIC (CBC)

CBC is the readout ASIC for the 2S tracker modules

Major Milestone Procurement Readiness Review (PRR) passed March 2020

A good example of a successful ASIC project.



Wafer test stand at
IC complete and
ready for testing
once bulk
purchasing begins

Tracker – Off detector processing

DTC (Data, Trigger, Control)

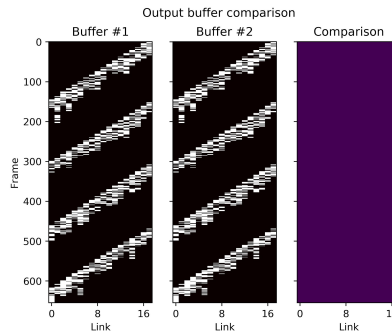
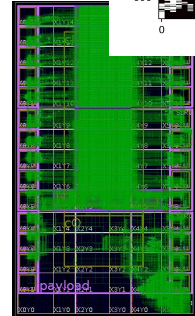
Stub sorting and routing to Track Finding boards

TF Finds and fits tracks

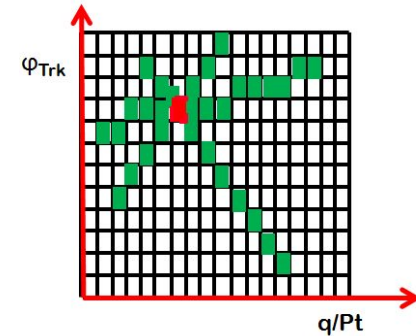
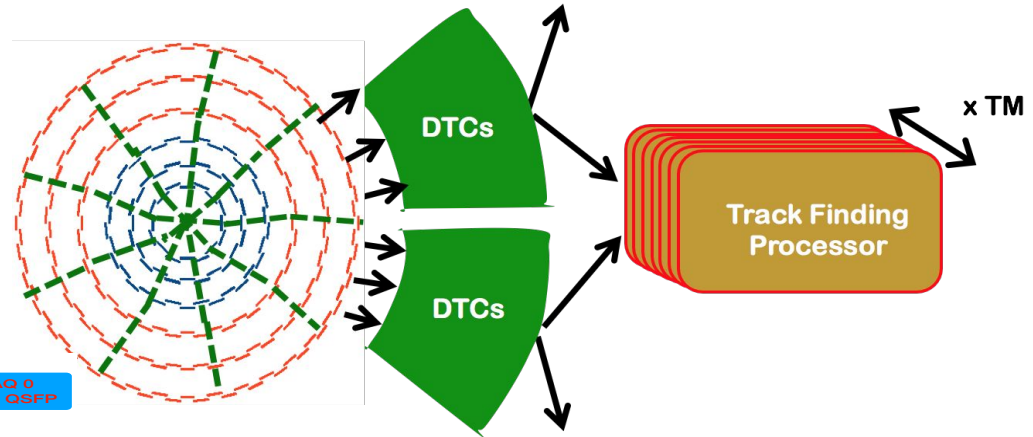


Serenity and Apollo boards at TIF at CERN

VU9P 360MHz

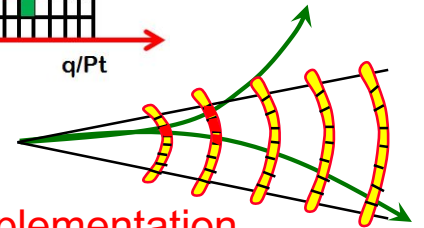


Hardware simulation comparison

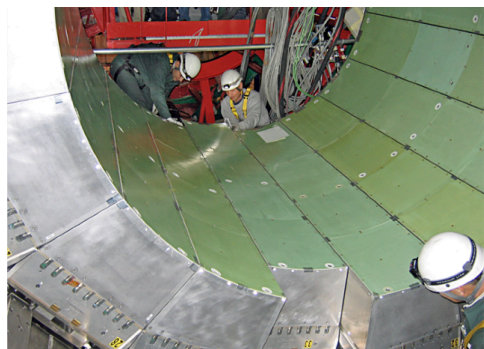


TMTT Algorithm latency < 2.5us

Algorithm implementation and comparison



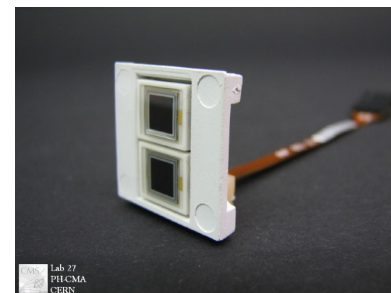
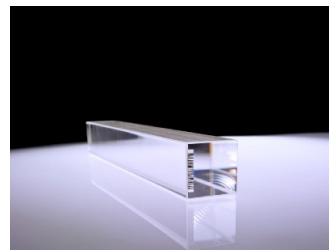
ECAL Barrel



Replace all on and off detector readout



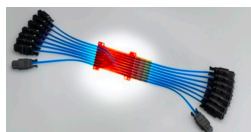
Keep crystals and APDs



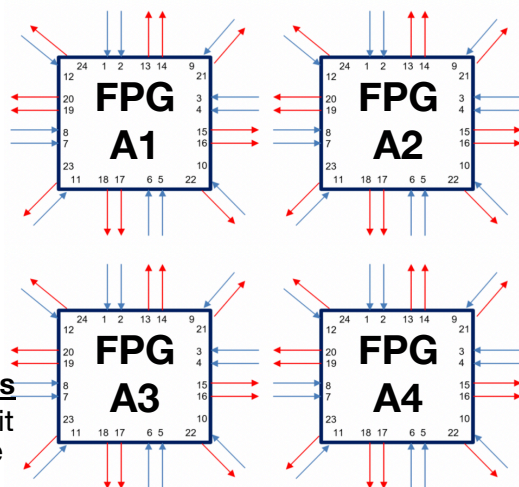
Trigger firmware/software (UK)

Optical Fibre router (UK)

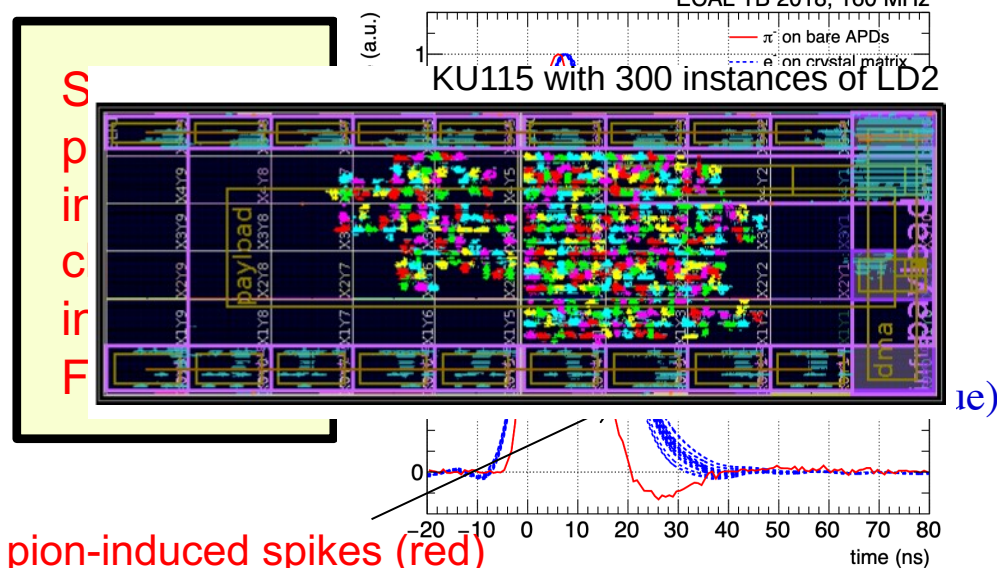
Design exploits UK expertise from Phase 1 upgrade



Optical links
 → Transmit
 ← Receive



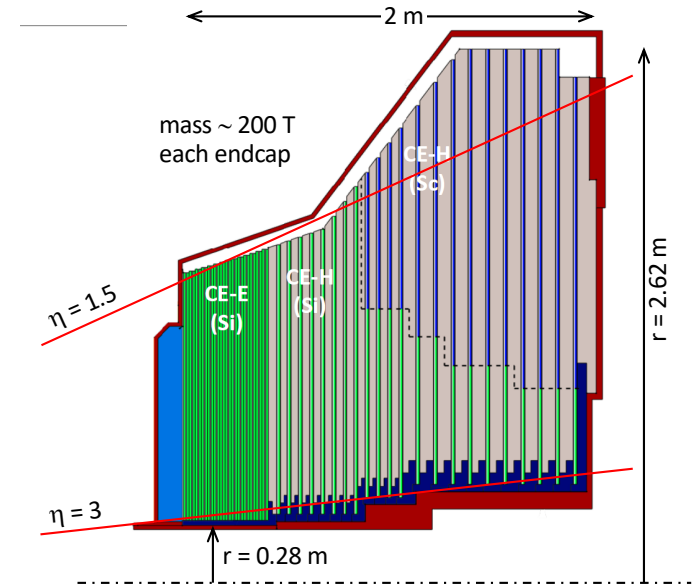
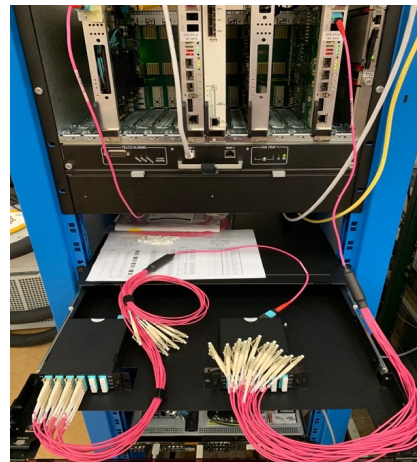
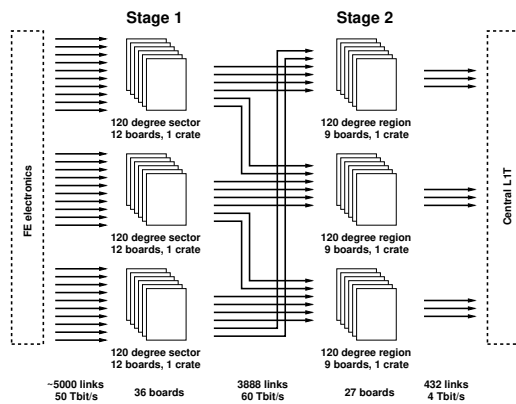
Link sharing between FPGAs pion-induced spikes (red)



Trigger primitive development and electronics, and simulation (UK)

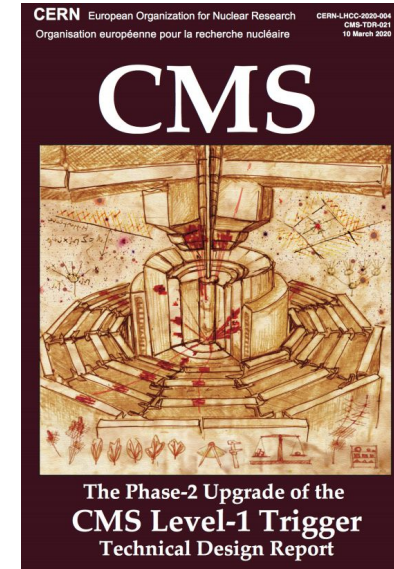
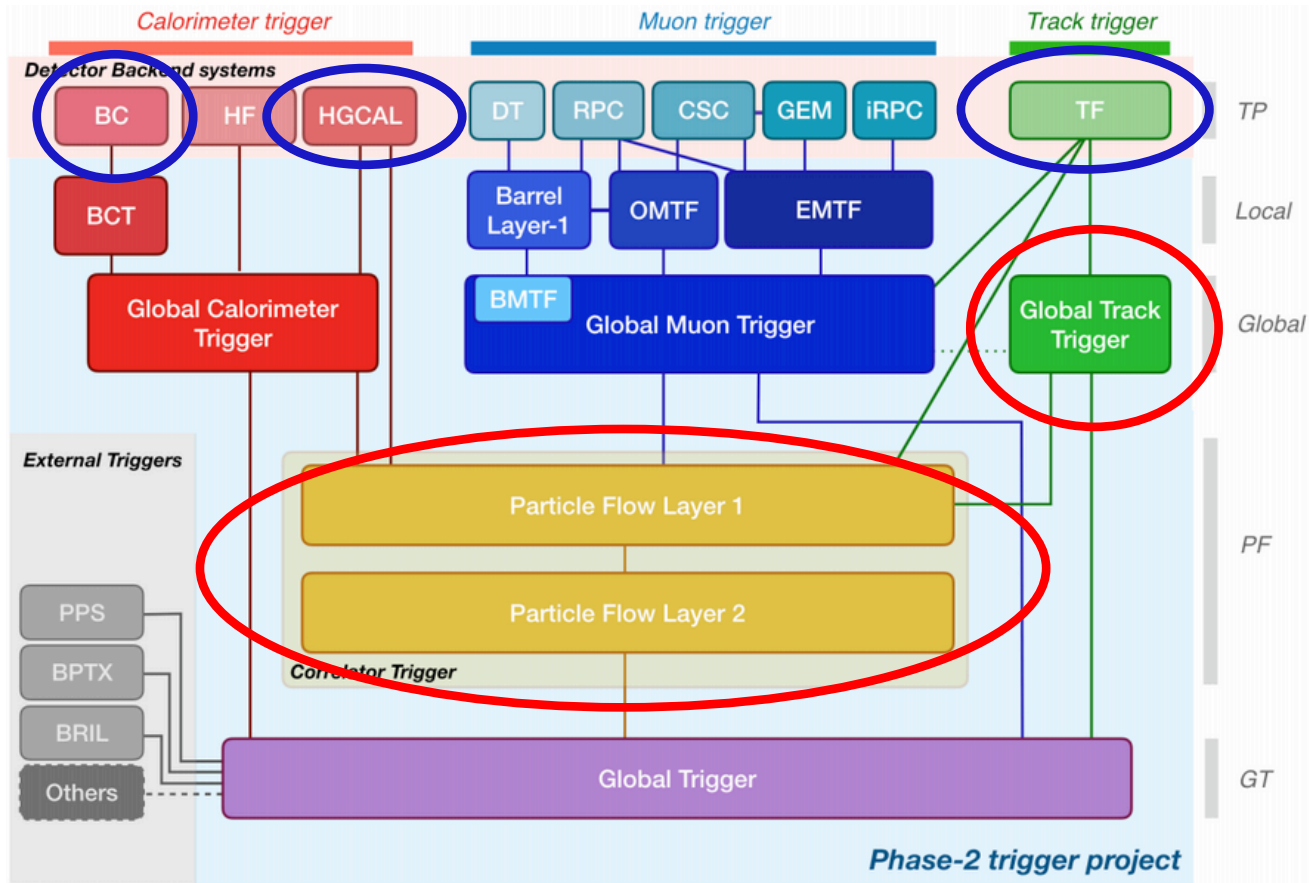
Firmware development and detector performance simulation underway

TP Architecture for one end-cap



Communication tests
with Serenity Board

L1 Trigger

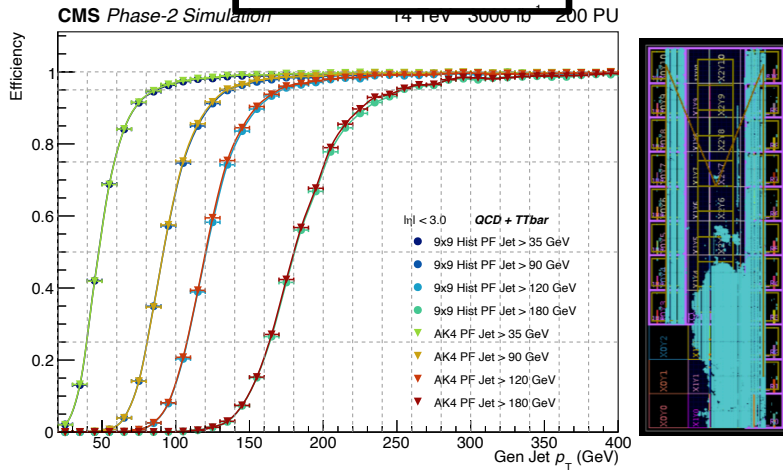


Approved June 2020

Standalone muon, calorimeter, track triggers
Correlator enables Particle Flow reconstruction.

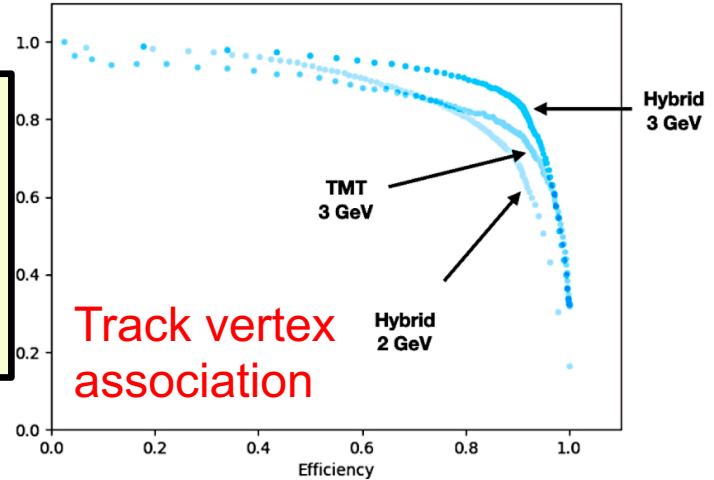
L1 Trigger – Algorithms

Jet finding



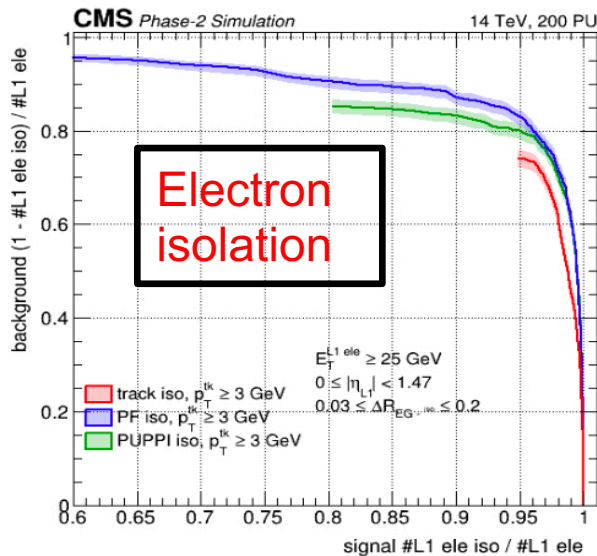
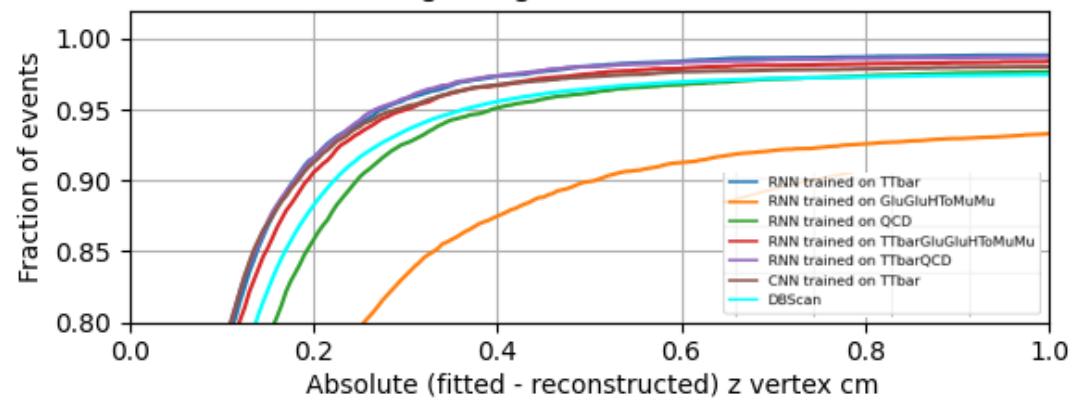
Implementation
in FPGAs and
on Serenity
cards

Efficiency vs Purity ROC for association (Conv_pt500_7feat_invpt)



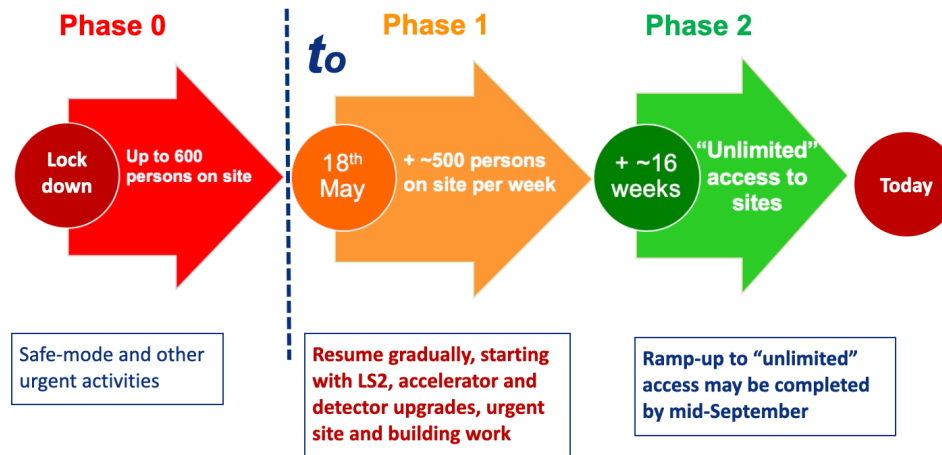
Vertex Reconstruction

Vertex finding using Neural Nets with $TTbar$ MC



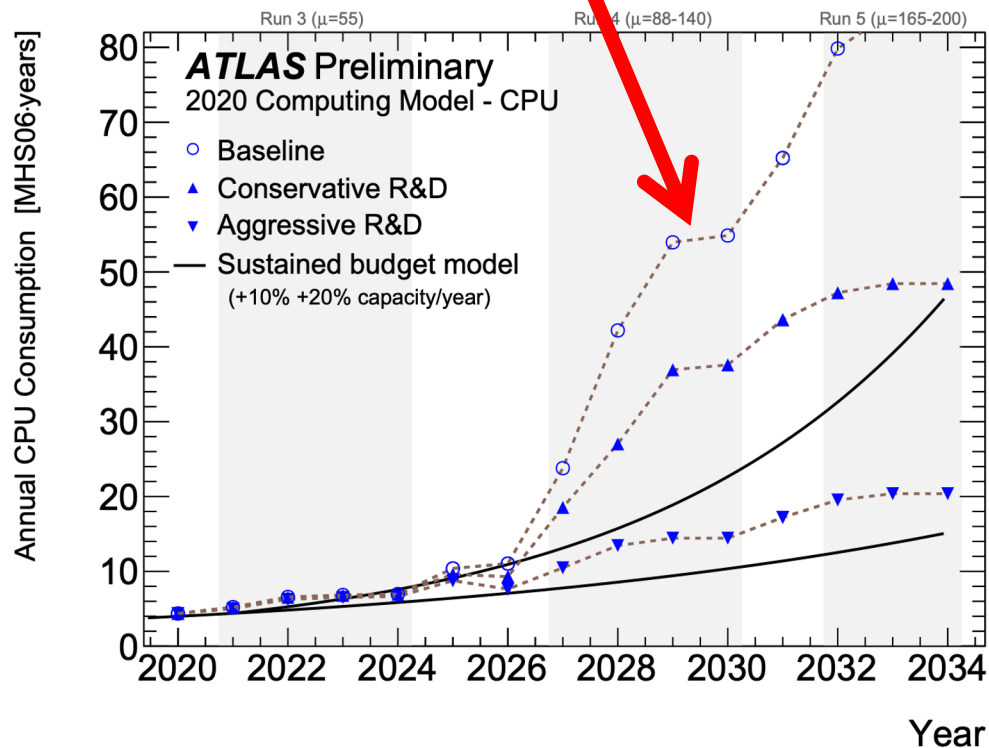
CMS and Coronavirus

- L2 activities on CMS progressing well. Covid impact order of 3 months delay.
 - Resident community vital for work done since March.
- Impact on upgrades being evaluated. Estimate 3-5 months.
- Small number of cases for people working at CMS pit.



Computing Challenge

- UK new initiative. (Swift-HEP, Excalibur)
- HL-LHC computing demands can't be met by current CPU based systems.



CMS participation

Data management (IC, Brunel)

FPGA acceleration. (RAL, IC)

Data accessibility and analysis speed. (Bristol)

GPUs in CMS HLT

CMS already piloting the use of GPUs in the HLT for Run 3



GPU deployment @HLT



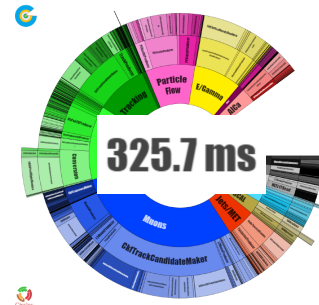
- Planning to move to heterogeneous architecture in High Level

Next major TDR for HLT

UK leads through Trigger Coordinator

- Proposal approved at last CB. Final configuration to be decided when approaching purchasing time.

current timing of representative



27/10/2020

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Future

- Major next run period Run 3.
- Upgrade to start of run 4
 - Procurement of hardware
 - System development and realization
 - Integration and commissioning
- Major undertaking: operation, exploitation and upgrades.
 - Operation and exploitation ability considerably reduced by successive reductions in funded effort. European strategy top priority **exploitation of full physics potential of LHC & HL-LHC**
- ...and then to Run 4
 - Will be a new detector. Commissioning will extend into running & operation and exploitation will require that effort levels remain similar to current totals.

Summary

- Physics analysis increasingly benefiting from large stats enabling high precision and differential measurements. Increasingly entering the high precision era
- Upgrade work progressing well. UK and CMS globally broadly on schedule.
- Intense work over next few years. Tackling operations, exploitation and upgrades simultaneously a major challenge.
- CMS and LHC has a very long term programme. The completion and exploitation of the upgrades is a headline goal in the European Strategy update.
- Computing capability a major challenge and CMSUK engaging strongly with UK initiative

Backup slides

HGCAL Parameters

Key Parameters (updated from the TDR):

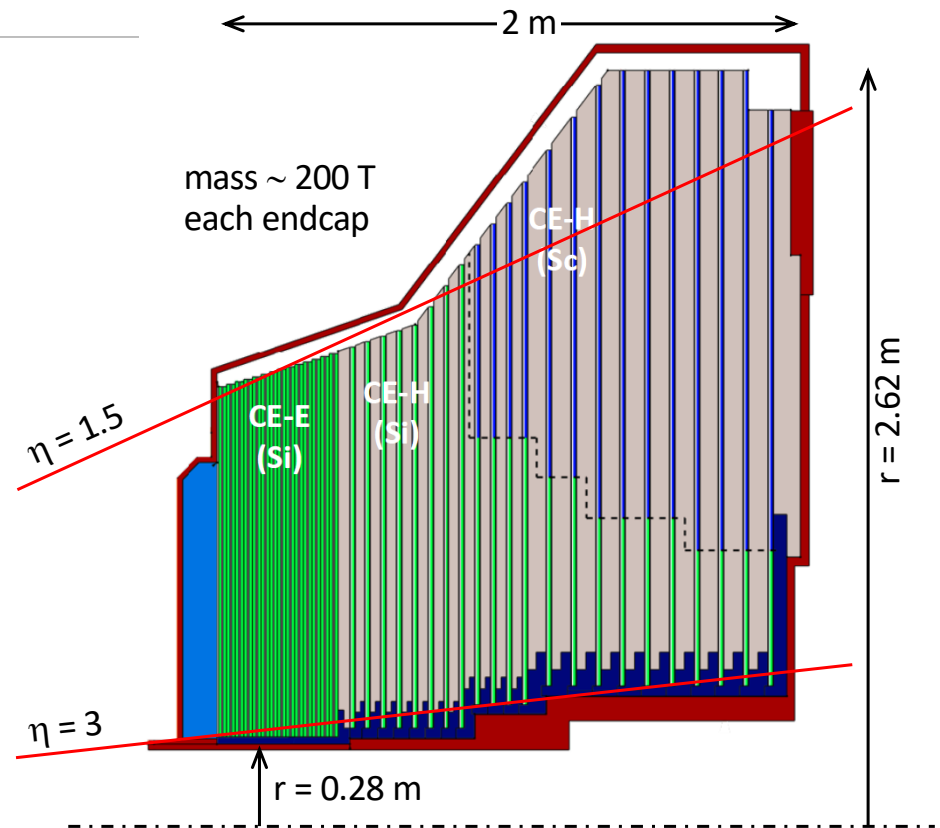
- HGCAL covers $1.5 < \eta < 3.0$
- **Full system maintained at -30°C**
- **$\sim 640 \text{ m}^2$** of silicon sensors
- **$\sim 370 \text{ m}^2$** of scintillators
- 6.1M Si channels, 0.5 or 1.1 cm^2 cell size (6M)
240k scint-tile channels ($\eta-\phi$)
 - Data readout from all layers
 - Trigger readout from alternate layers in CE-E and all in CE-H
- ~ 31000 Si modules (incl. spares)

Active Elements:

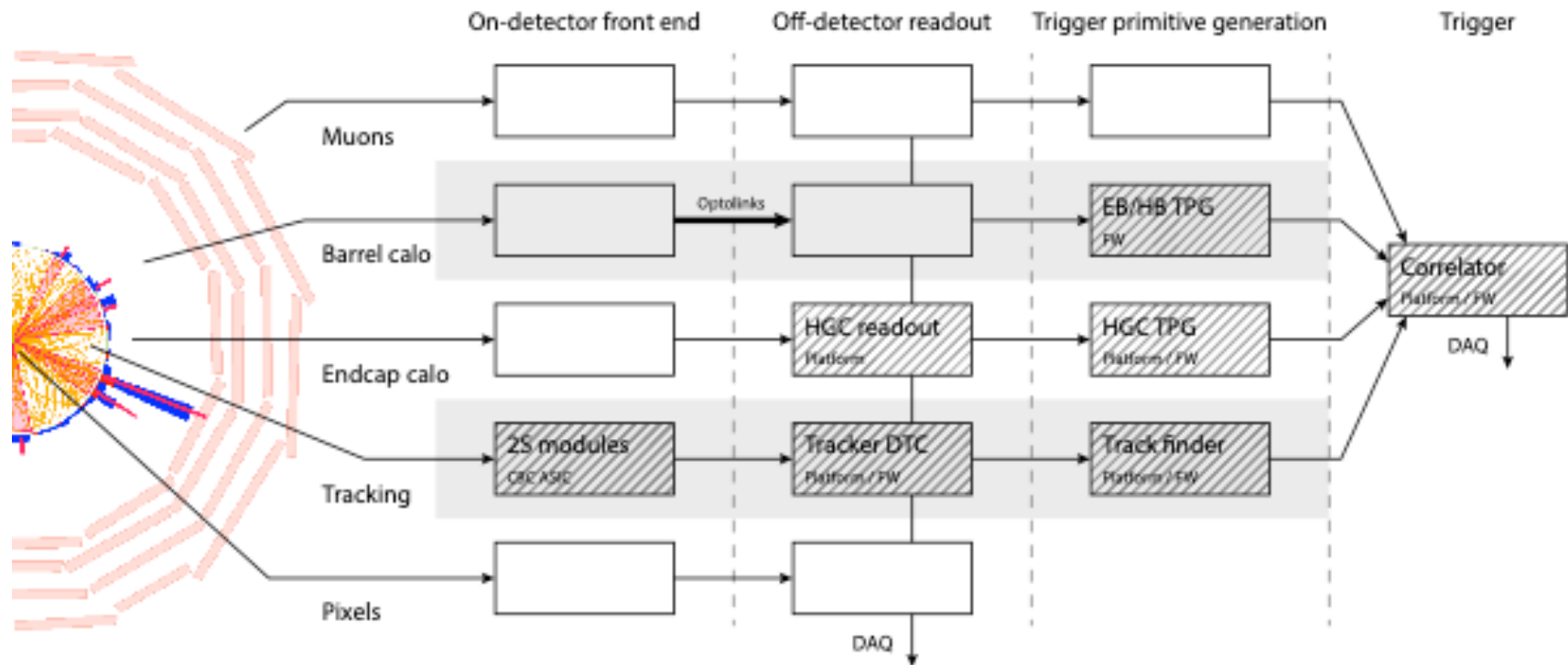
- Si sensors (full and partial hexagons) in CE-E and high-radiation region of CE-H
- SiPM-on-Scintillating tiles in low-radiation region of CE-H

Electromagnetic calorimeter (**CE-E**): **Si**, Cu/CuW/Pb absorbers, 28 layers, $25.5 X_0$ & $\sim 1.7\lambda$

Hadronic calorimeter (**CE-H**): **Si & scintillator**, steel absorbers, 22 layers, $\sim 9.5\lambda$ (including CE-E)



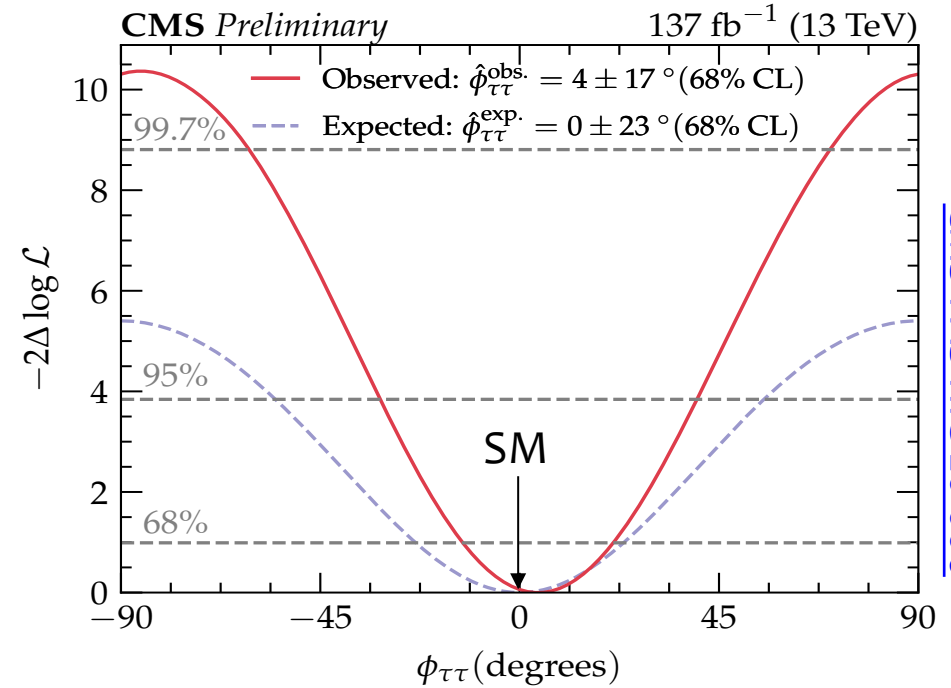
CMS UK Upgrade Activities



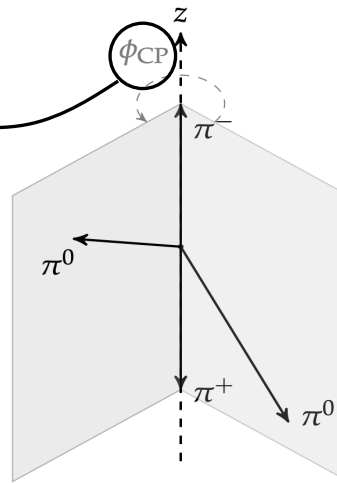
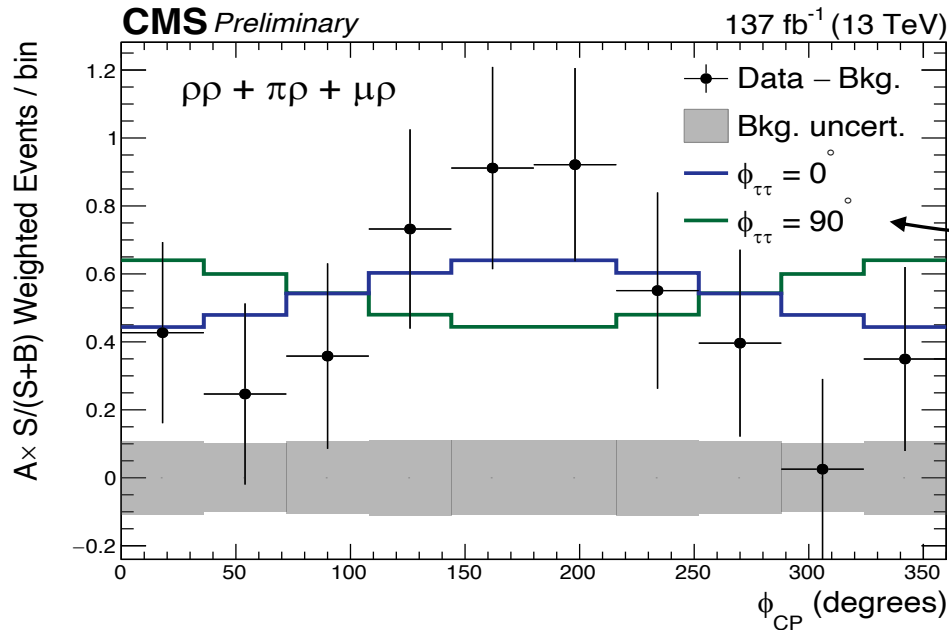
CP properties of fermion couplings with $H \rightarrow \tau\tau$

Probe CP nature of tau Yukawa by measuring mixing between **CP-even** to **CP-odd** coupling

$$\mathcal{L}_Y = -\frac{m_\tau H}{v} \left(\kappa_\tau \bar{\tau}\tau + \tilde{\kappa}_\tau \bar{\tau}i\gamma_5\tau \right)$$



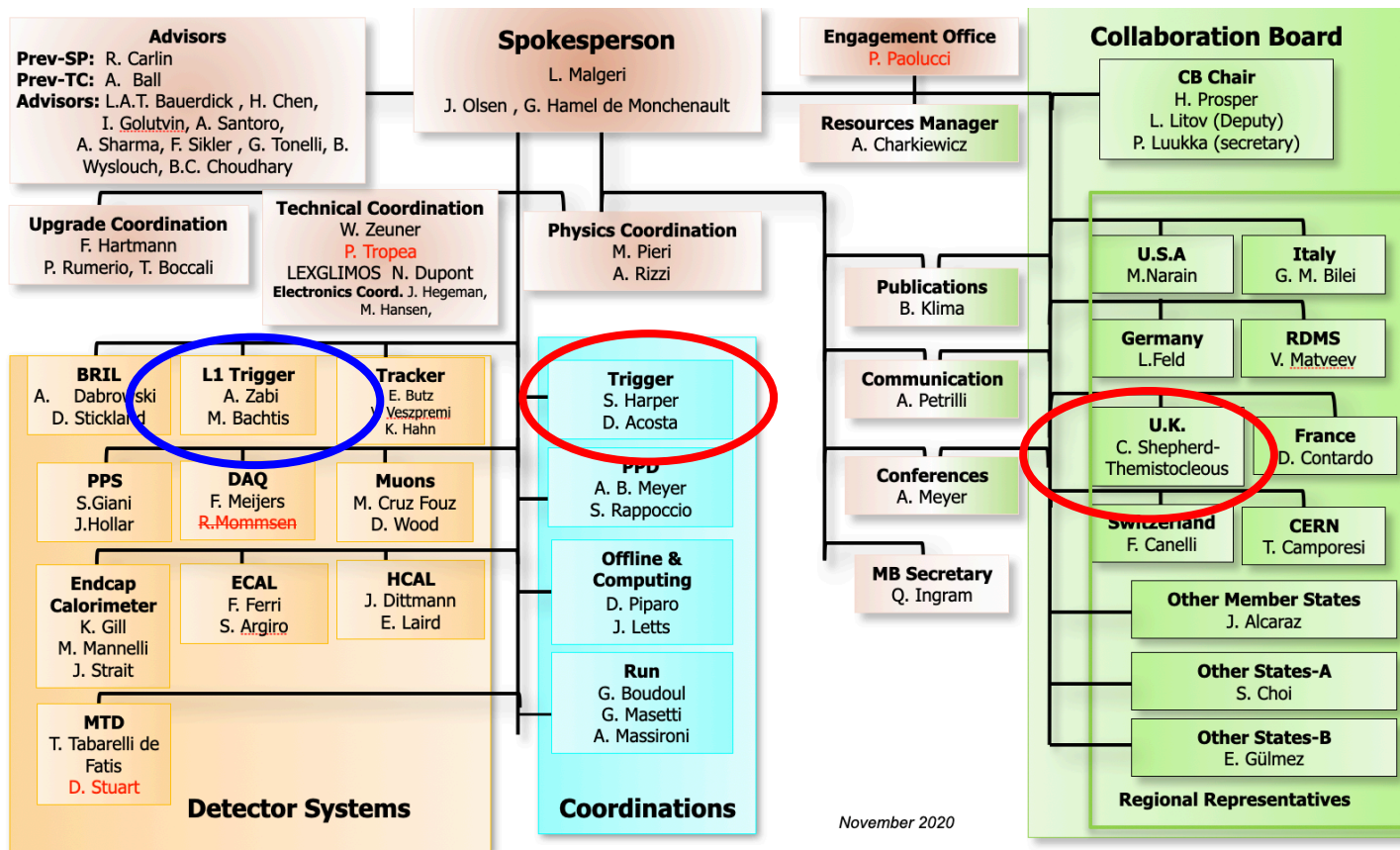
CMS-PAS-HIG-20-006



$$\tan(\phi_{\tau\tau}) = \frac{\tilde{\kappa}_\tau}{\kappa_\tau}$$

Sensitivity to mixing angle from angular distribution of hadronic τ decay products.

CMS Management



Higgs Convenor
 Nick Wardle

L1 Trigger DPG
 Aaron Bundock

Computing - Data
 workflow
 Katy Ellis

ECAL trigger coord
 David Petyt

Generators
 Gurpreet Singh

Upgrade of CMS for HL-LHC

Sudan Paramesvaran
(Tech Coord)

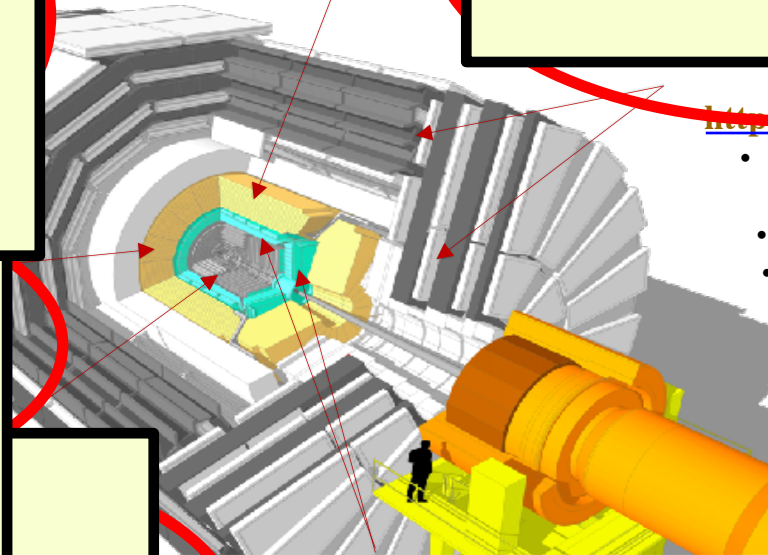
Tom Williams
(online software)

Thomas Reis
(reconstruction software)

Paul Dauncey
(TDAQ)
Chris Seez
(DPG)

Ian Tomalin
(Online Tracking)

Sarah Storey
(DAQ)



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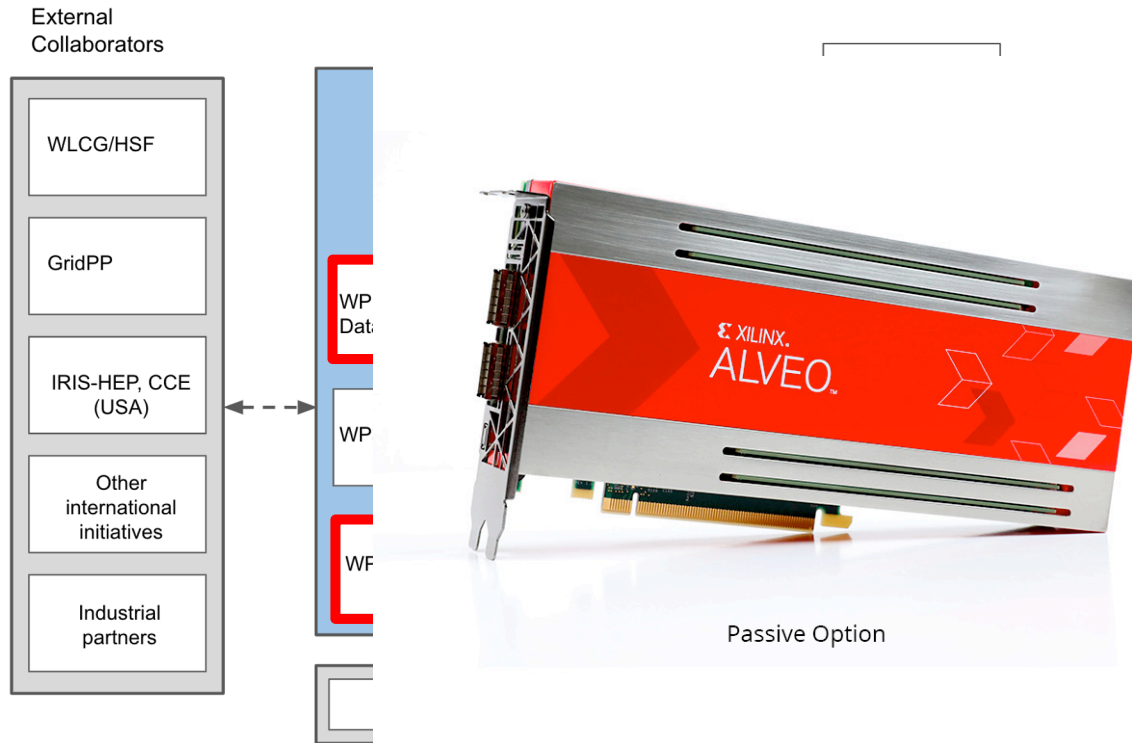
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Swift-HEP



S participation

WP1: (IC, Brunel) GridPP

WP4: (RAL) FPGA acceleration.

WP5: (Bristol) Data accessibility and analysis speed.

A lot of interest in UK. Good prospects for area and grant funding to grow. Currently 3 years
Excalibur UKRI funded similar programme. Current pilot project

Swift-HEP: International picture

	Entity	Scope	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	
Infrastructure	LHC	Global	Run-2	LS2		Run-3			LS3		Run-4			
	WLCG	Global	Global coordination of requirements, resources, policies, networking, security, etc.											
	GridPP	UK	GridPP5		GridPP6			?						
	IRIS-UK	UK	UKTO	IRIS 4yr x £4m			Support of non-LHC STFC communities?							
Experiments	ATLAS-CMS	Global	S&C Conceptual Design		S&C Technical Design			S&C deployment		Operation				
	LHCb	Global	S&C TDR	S&C deployment		Operation and Upgrade 2 preparation								
	DUNE	Global	Protodune	S&C CDR	ProtoDUNE Comp model	DUNE implementation and deployment				Operation				
	Others	Global	Experiments common software infrastructure design and development (neutrino, dark matter, etc)											
Software	HSF	Global	HEP Software Forum: White Paper --> Working Groups --> Community Meetings --->											
	IRIS-HEP	USA	S2I2	IRIS-HEP: 5yr x 5m USD				?						
	ECHEP	UK	£50k		ECHEP									
	Excalibur	UK	£240k		Excalibur			?						
	HSUK	UK					SWIFTHEP-1: 3 x £400k			SWIFTHEP-2: n x £2m?				

