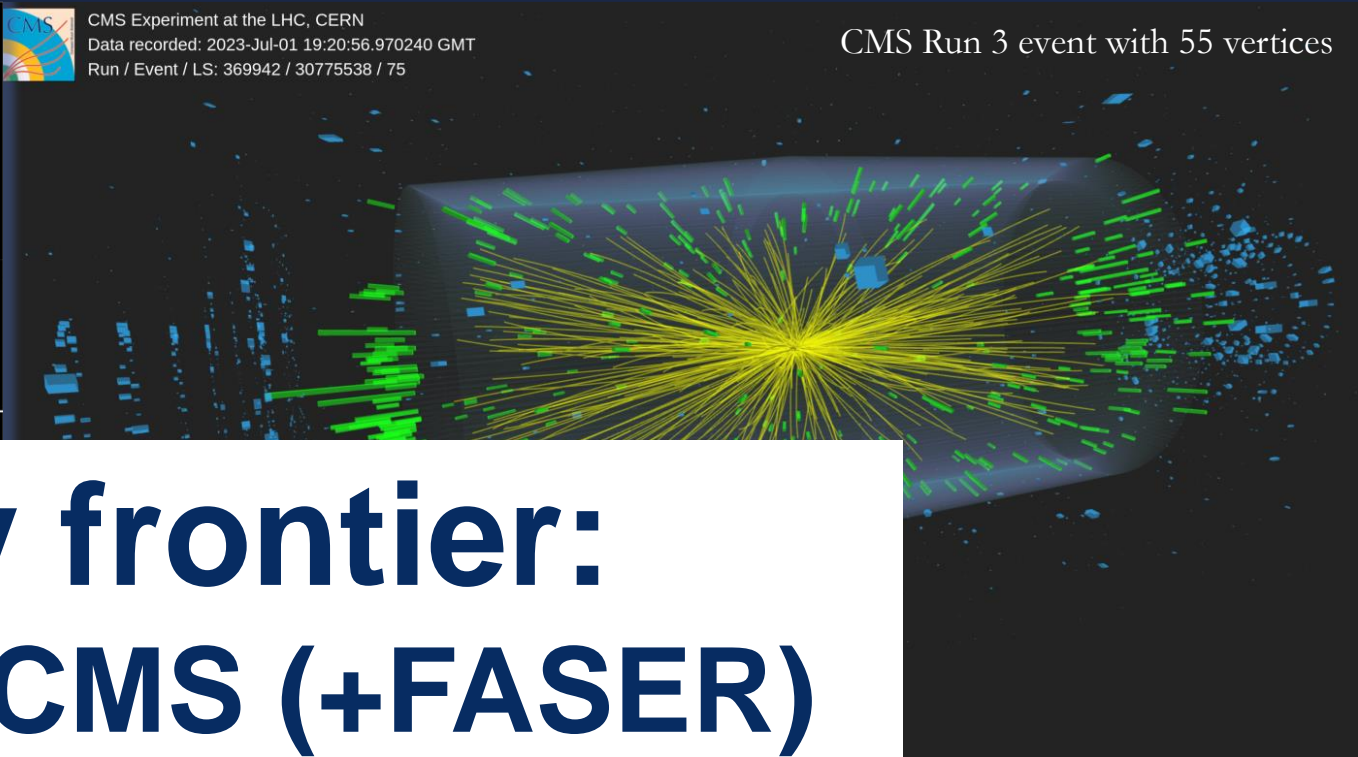
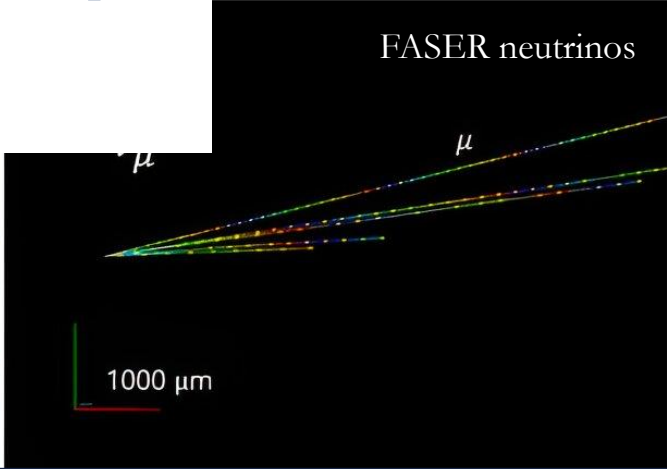
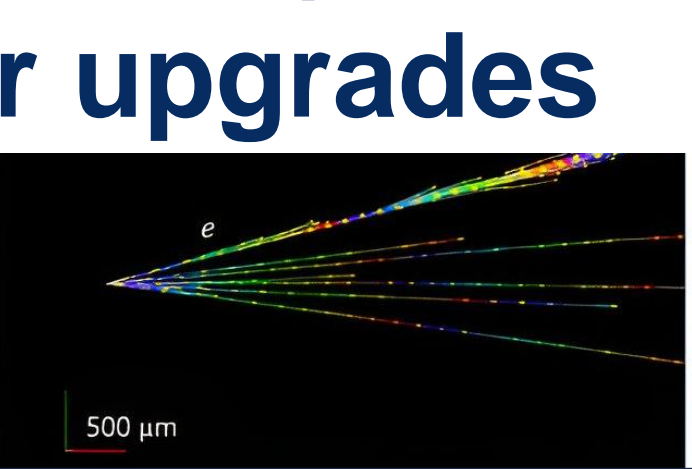
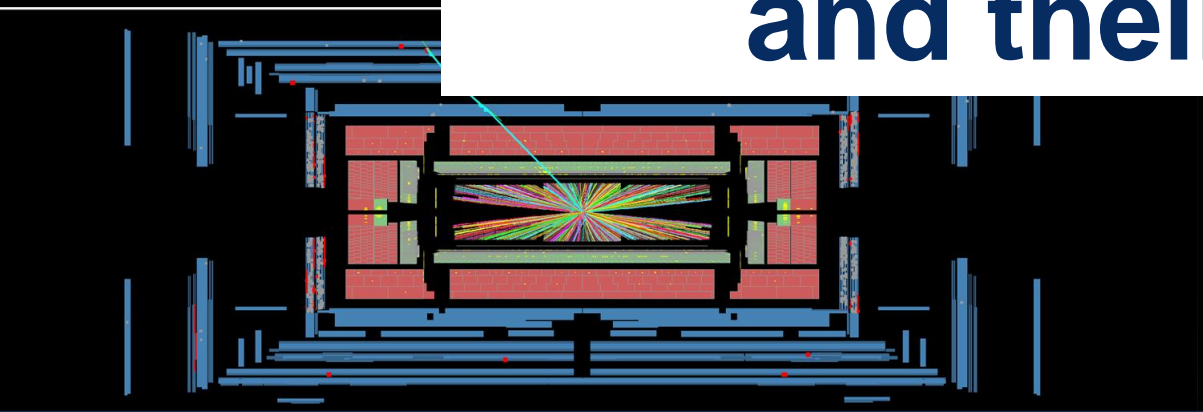




Run Number: 472553, Event Number: 29247654
Date: 2024-04-05 19:16:36 CEST



Energy frontier: ATLAS and CMS (+FASER) and their upgrades



FASER neutrinos

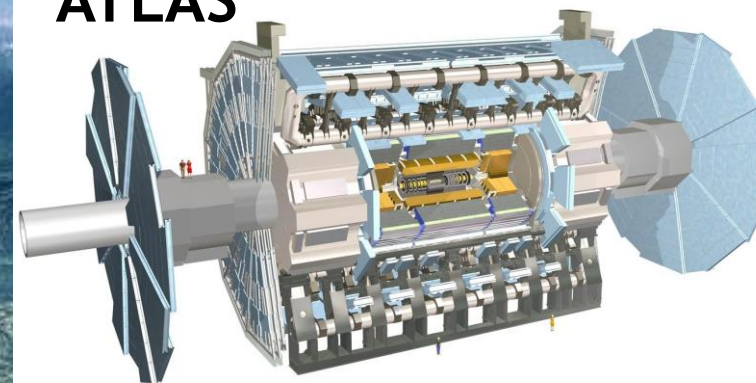
Outline

- **ATLAS, CMS** and **FASER** experiments in Run 3:
 - status and physics highlights
- Towards the HL-LHC:
 - exploitation of the physics potential
 - Phase II upgrades

with a detailed view of UK efforts and contributions

ATLAS

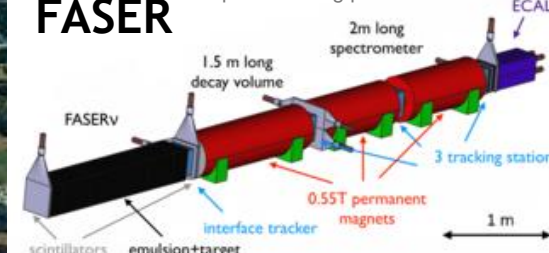
<https://cds.cern.ch/record/1095924>



~ **5900 active members**
(2870 scientific authors, **183 Institutes**)

FASER

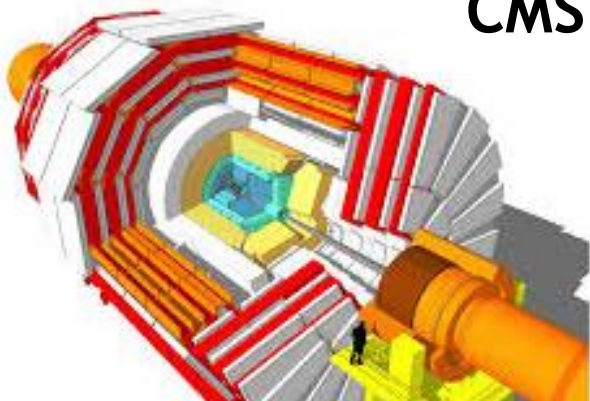
<https://arxiv.org/pdf/2207.11427>



102 active members
(**27 Institutes**)

2014 J. Phys.: Conf. Ser. 513 (2014) 022032

CMS



~ **6300 active members** (2166 scientific authors, **247 Institutes**)

The UK has also a small participation in SND@LHC (UCL, Imperial) - see W. Barter's talk

UK Institutions

- 14 universities + STFC Rutherford Lab
- 11.7% of ATLAS active authors
- 261 Physicists and 108 engineer/tech/admin
- 142 current doctoral students



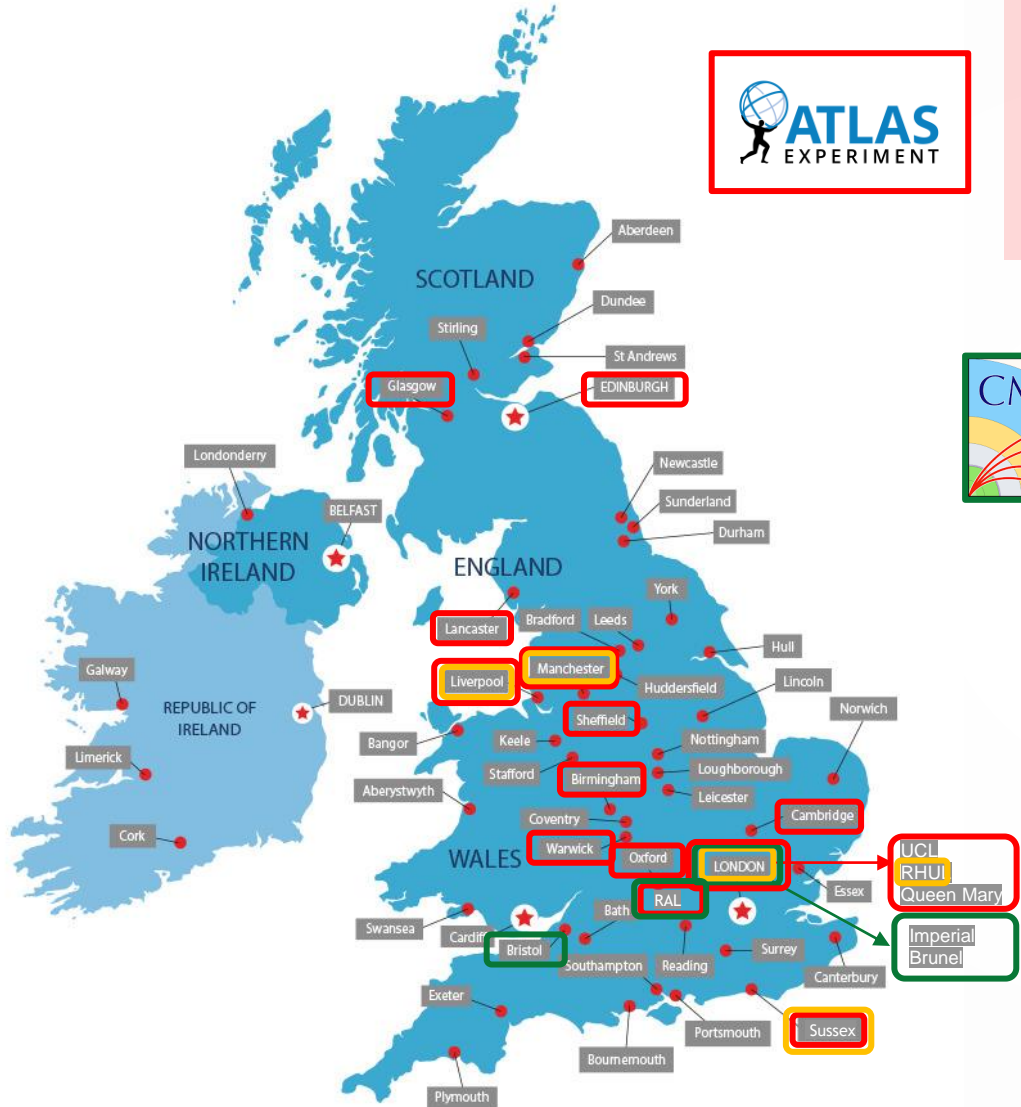
- 3 universities + STFC Rutherford Lab
- 3.6% of CMS active authors
- 82 Physicists and 38 engineer/tech/admin
- 21 current doctoral students

+ around 6-7 “associated” institutes (mostly CMS)

- 4 universities
- ~6.3% of FASER authors
- 5(6) Physicists, 5 current doctoral students



Project Funding: mainly from STFC
Additional funding: EPSRC, UKRI, Royal Society, ERC, Marie Curie, Schmidt Family Foundation, Leverhulme Trust



UK major commitments



	Run 3 Operations and performance (include Phase I upgrade)	Run 4: Phase II upgrade
	<p>Phase I: hardware, firmware and software upgrades for L1Calo and HLT&DAQ systems</p> <p>Operations: Inner Tracker (SCT), L1 trigger, , HLT & DAQ systems, data quality, alignment, forward detector</p> <p>Physics performance: luminosity, beam background, Monte Carlo generators, e/γ, μ, τ reco/ID, flavour tagging and b/c calibration, global particle flow, machine learning</p>	<p>ITk-Pixels ITk-Strips Calorimeter Trigger (eFEX & Global) High Level Triggering & DAQ Upgrade software</p>
	<p>Phase I: L1 Trigger</p> <p>Operations: Silicon Strip tracker, ECAL, Calorimeter trigger system</p> <p>Physics performance: e/γ and τ reconstruction and ID, statistics tools, machine learning</p>	<p>ASICs for new tracking system Electronics and algorithms for trigger for: Tracker, ECAL, high granularity endcap calorimeter and L1 trigger</p>
	<p>Commissioning and Run 3: test beam 2021-22, scintillator veto system for trigger, ECAL, tracking spectrometer, new pre-shower in preparation for 2025 → no major upgrades foreseen for Run 4</p> <p>Operations and Physics performance: Run coordinators, Track reco, e/γ reco/ID</p>	

- **Computing:** underpins all our research → Tier1 and Tier2 centers, core support, software development, also through coordinated projects relevant for HL-LHC and beyond (see D. Costanzo's talk)

Management and coordination roles

► Major roles (management)

► ATLAS:

- Spokesperson: Dave Charlton (2013-2017, deputy 2009-2013)
- Physics Coordinator: Dan Tovey (2016-2017); Bill Murray (2014-2015); Dave Charlton (2008-2009)
- Collaboration Board Chair: UK provided 3 out of the 14 CB Chairs, latest: Max Klein (2017-2020)
- Project leaders for Inner Tracker, ITK, Trigger and Run coordinators

► CMS:

- Spokesperson: Jim Virdee (2007-2009, deputy 1993-2006)
- Collaboration Board Deputy Chair: Claire Shepherd-Themistocleous (2014), Gavin Davies (2017-2019)
- Project leaders for L1-Trigger, HLT, HGAL, ECAL and Run coordinators

► FASER:

- Physics Coordinator: Carl Gwilliam (2022-2024)

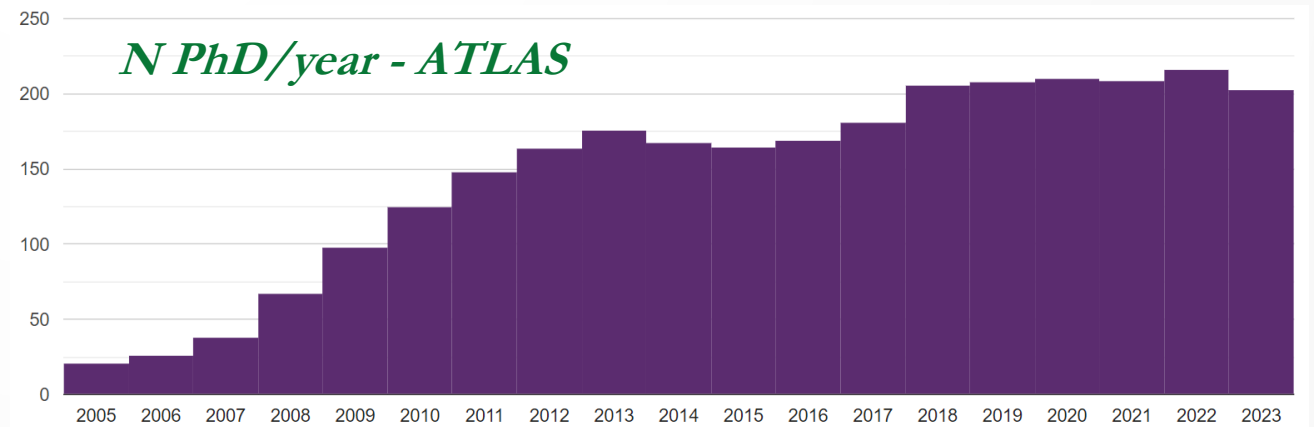
► Impact on international physics and upgrade activities through coordination:

- **Since 01/2021:** **ATLAS** counts 14 Level-1 coordinators, 15 Physics and Combined Performance group conveners (and >40 sub-group conveners) in diverse areas, ~55 Level-3 coordinators; **CMS** counts 2 Level-1 coordinators and 4 operations and physics group coordinators around trigger and searches for new physics, plus >10 L3 coordinators. In **FASER**, the UK counts 1 Run Coordinator, 2 Physics Analysis leads

Engagement, ECR and PhD students

- ▶ This is a very **dynamic** community, engaged in developing new ideas at all levels
 - ▶ Shown also through awarded European Research Council Advanced grants, individual fellowships from UKRI (Future Leader), STFC (ERF) and Royal Society (URF)
- ▶ **Early Career Researches** actively participate in operations and maintenance as well as in the physics programme: regular UK physics meetings, dedicated workshops etc.
- ▶ **PhD students**: a healthy profile overall
 - ▶ Number of PhD students enrolled in **ATLAS-UK** each year since 2005 → considering length of PhD of 3.5 yr, this corresponds to ~ **650 students** awarded PhD in the past decade
 - ▶ **More than 110 PhD** students enrolled in CMS in the past decade
 - ▶ **6 PhD** enrolled in FASER students since 2020 (1 graduated, 1 finishing)

Supported also through partnerships (e.g. RAL, DESY, industry) and STFC-CDT programmes



New ideas and cutting-edge technologies

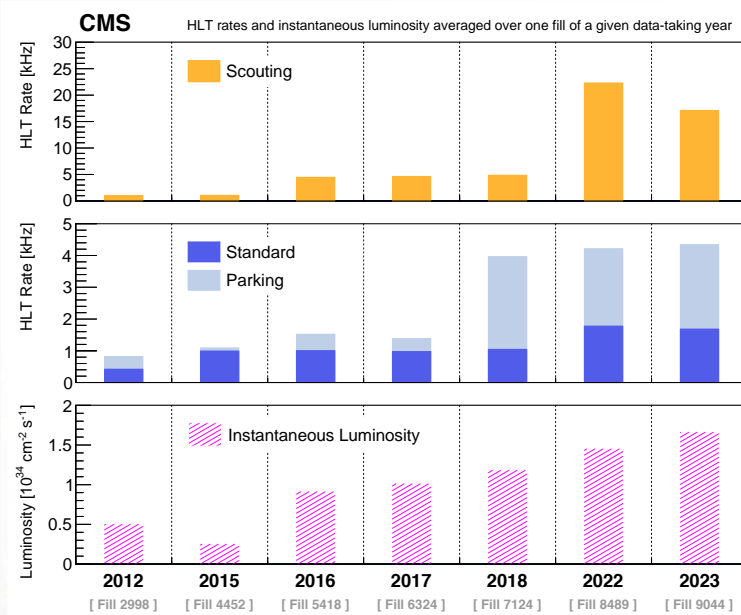
➔ Amazing results achieved thanks to deployment of new ideas of UK members, e.g.:

Data Scouting/Trigger Level Analysis



- Enhance sensitivity by pushing thresholds – **huge UK involvement**
- Respect bandwidth limits by only storing **reduced event content**
- Analysis performed with trigger-level objects

[arXiv:2403.16134](https://arxiv.org/abs/2403.16134)



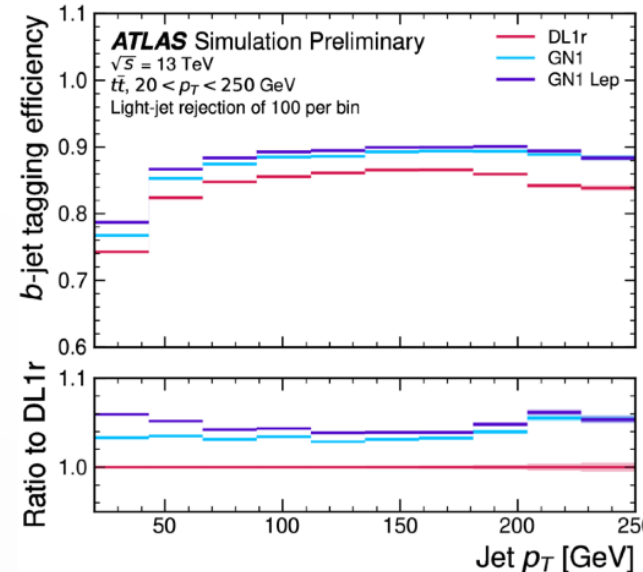
<https://cms.cern/news/same-lhc-same-cms-more-physics>

Bristol, Imperial, RAL

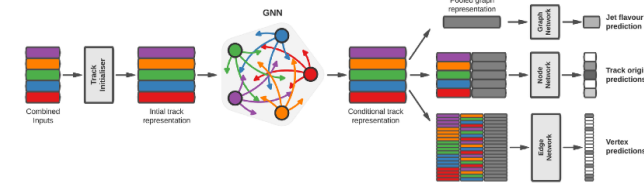
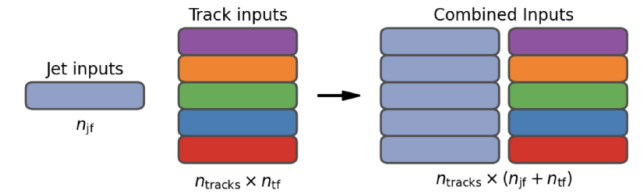
Flavour tagging: b and c jets

- Novel **Graph Neural Network approaches** → optimised all the discriminating information for b-/c-jets
- Auxiliary tasks: tracks classification and vertex association

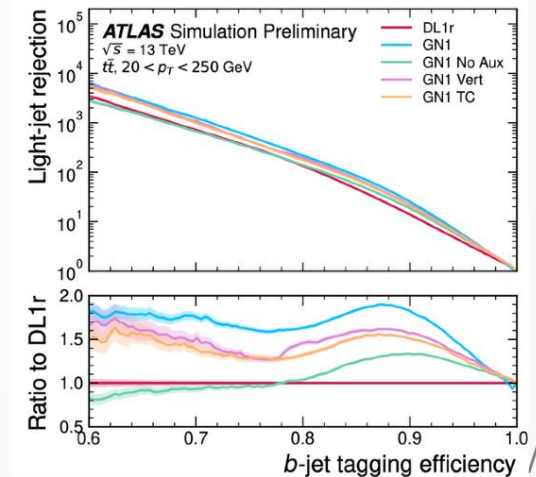
[ATL-PHYS-PUB-2022-027](https://arxiv.org/abs/2202.027)

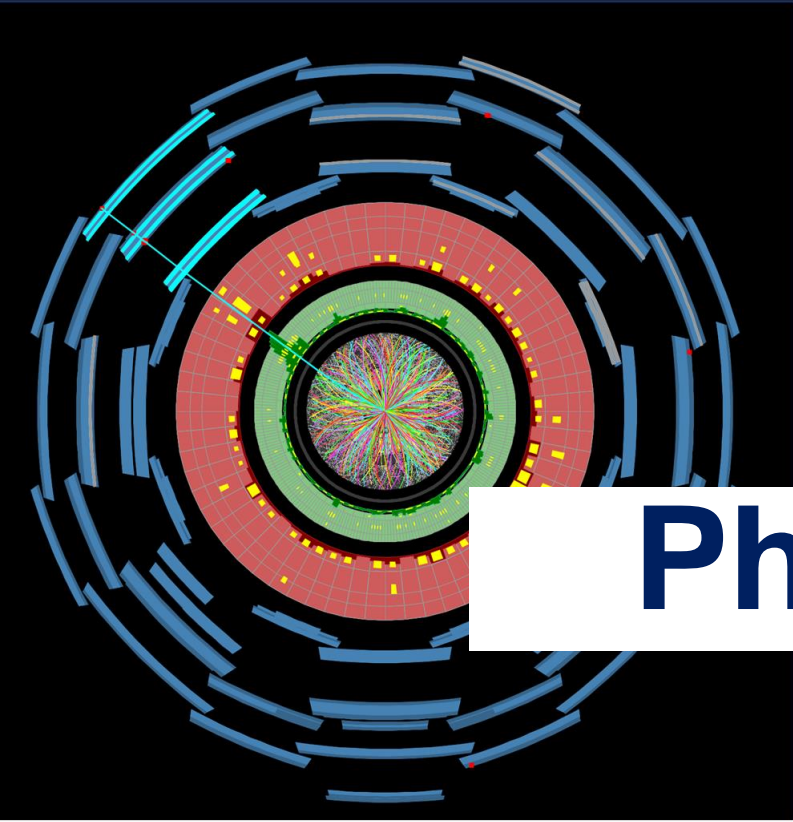


Liverpool, Oxford, UCL, Warwick



Significantly improved b-tag/c-tag efficiency and light-jet rejection

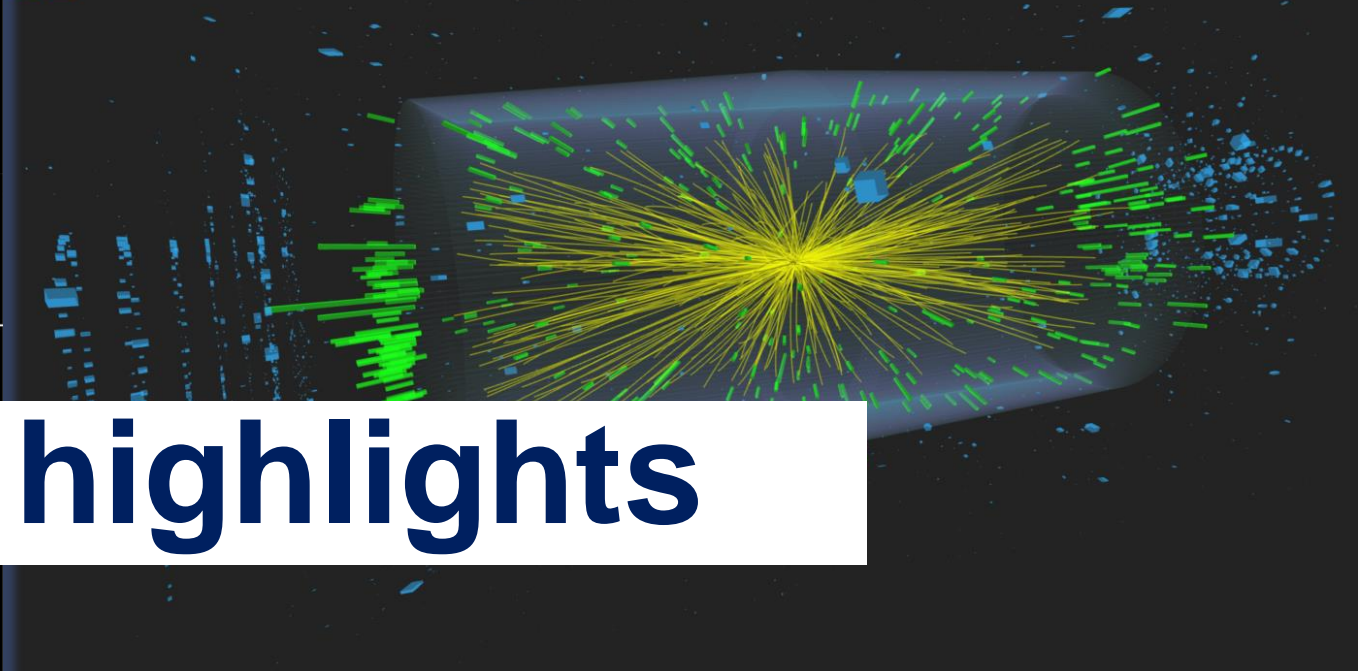




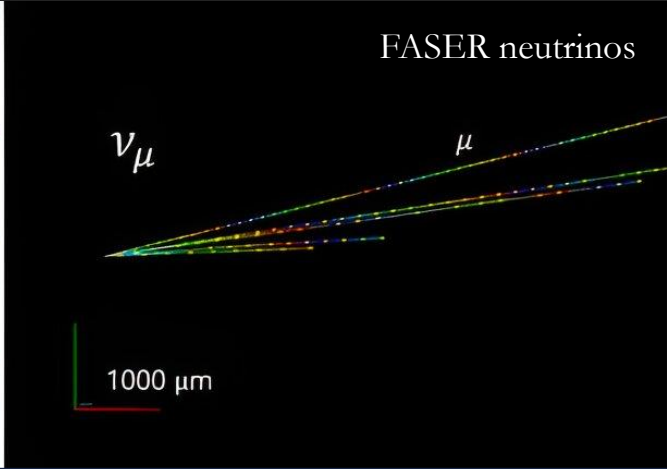
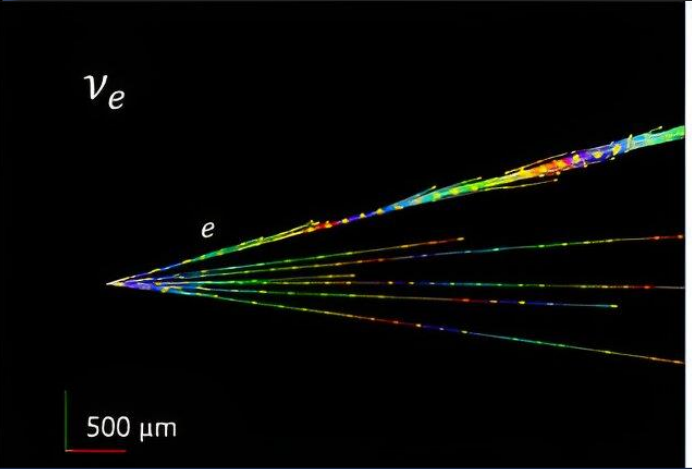
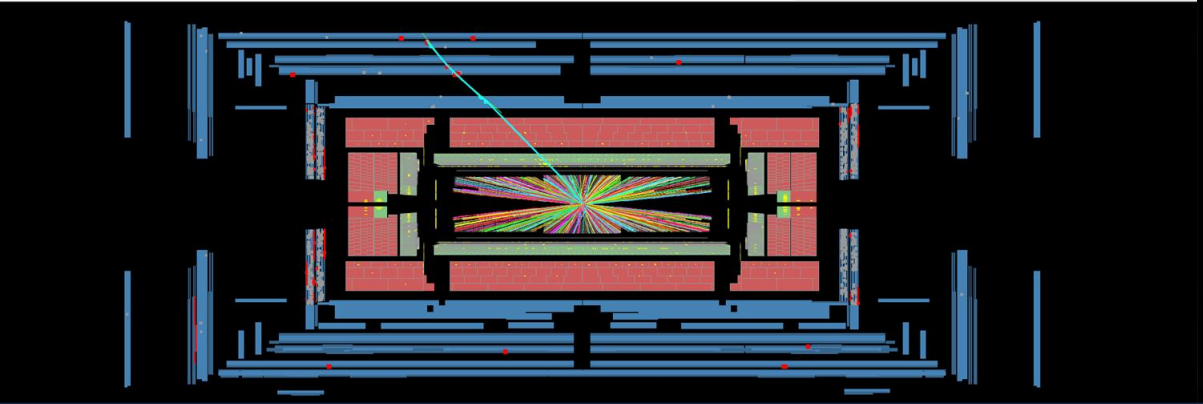
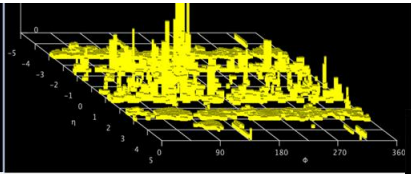
Run Number: 472553, Event Number: 29247654
Date: 2024-04-05 19:16:36 CEST

CMS Experiment at the LHC, CERN
Data recorded: 2023-Jul-01 19:20:56.970240 GMT
Run / Event / LS: 369942 / 30775538 / 75

CMS Run 3 event with 55 vertices



Physics highlights



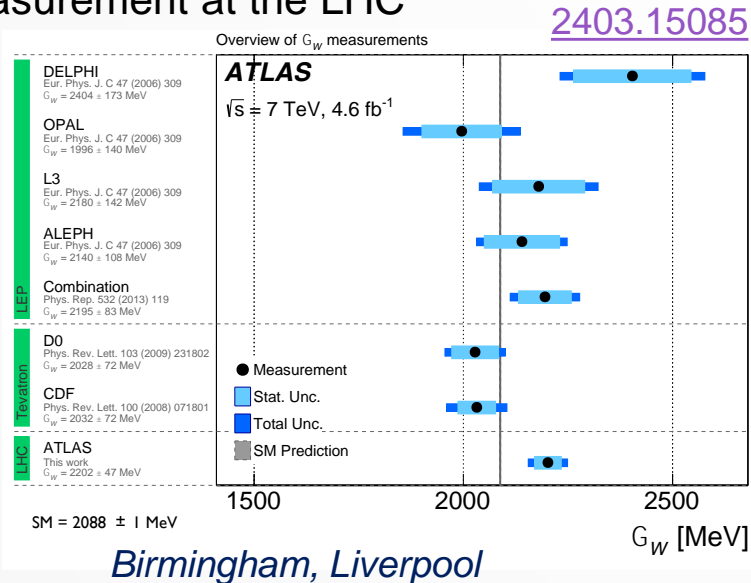
Physics strengths and highlights: ATLAS

► ATLAS-UK contributes to **all areas of the physics programme**, from SM precision measurements to Higgs studies and searches for new physics:

- Within the period 01/2021-12/2023, out of the 255 papers released by ATLAS, **50%** had UK members contributing, and **25%** had UK leadership ([source: glance](#)).
- Strong support to tasks crucial for optimising and measuring physics object performance and dedicated involvement in computing and software

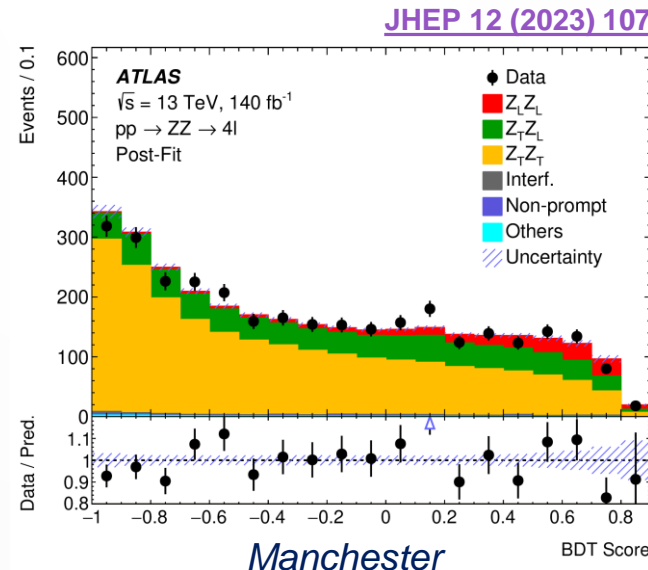
SM precision measurements

W boson mass, and first width measurement at the LHC

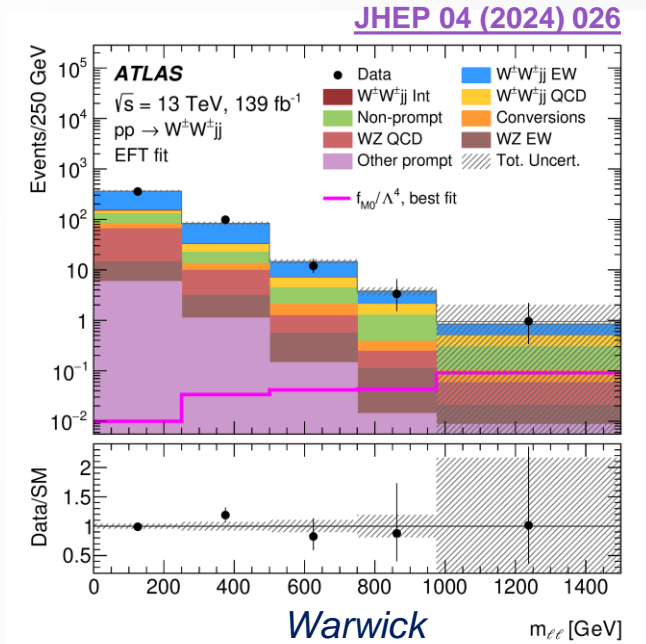


Multi-boson measurements

Evidence of longitudinally polarised vector bosons (ZZ to 4l)

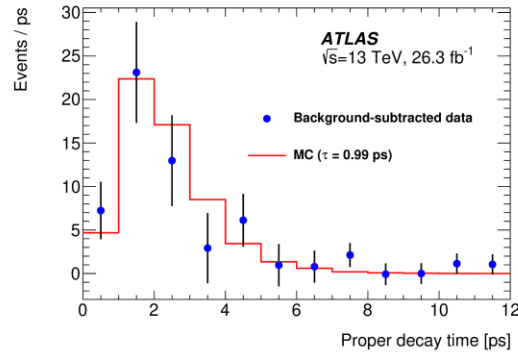


Same-sign WWjj in VBF



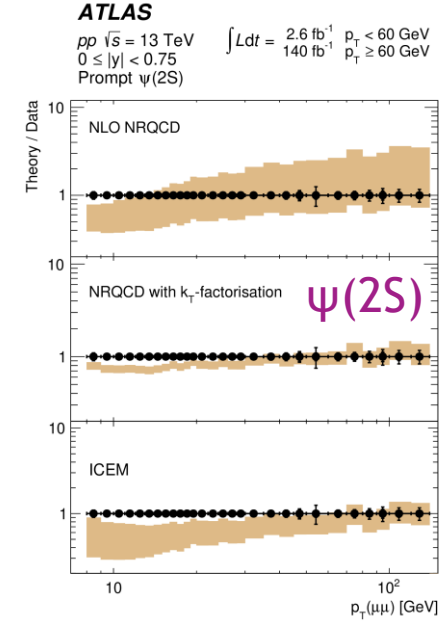
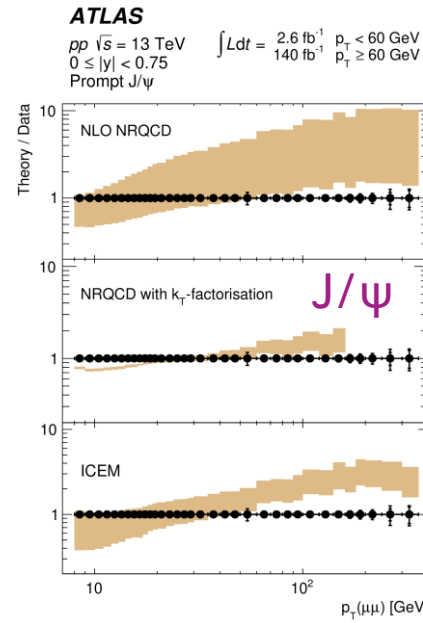
Highlights: ATLAS B and Top physics

- **B physics:** UK-led flagship analyses such as $B_s^0 \rightarrow \mu+\mu^-$ **effective lifetime** and measurements of the production cross-sections of **J/ψ** and **ψ(2S) mesons** (widest momenta range to date).



[JHEP 09 \(2023\) 199](#)

Sussex



[Eur. Phys. J. C 84 \(2024\) 169](#)

Lancaster, RAL

- **Top physics:**

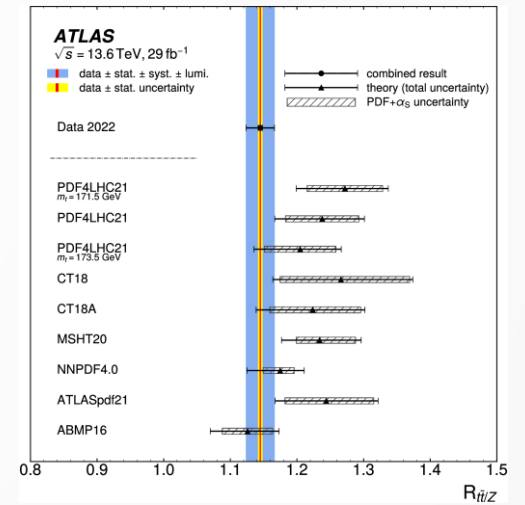
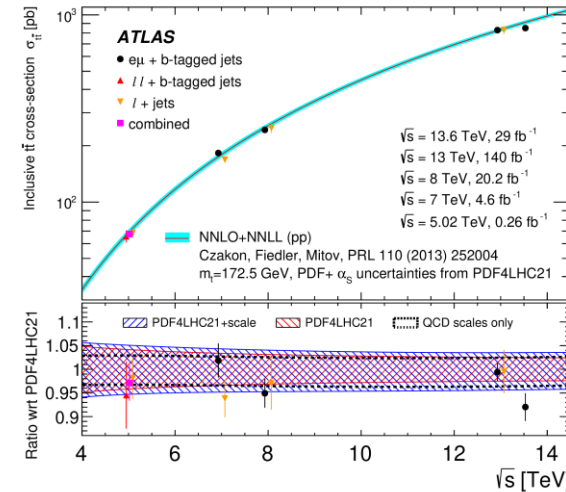
Strong involvement in top physics from the UK (UK sub-group and group conveners for long time)

Birmingham, Edinburgh, Lancaster, QMUL, Manchester, RHUL, Sussex

- **Run 3 top-pair cross section and ratio with Z production cross section**

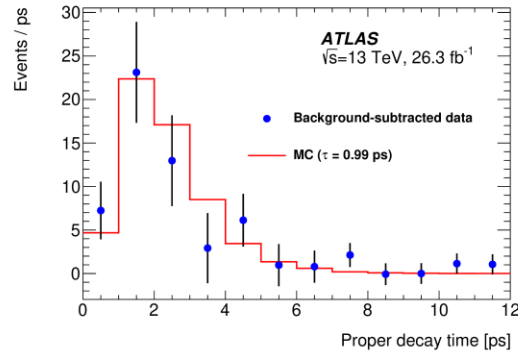
[Phys. Lett. B 848 \(2024\) 138376](#)

Birmingham, Edinburgh, Lancaster, QMUL, Sussex

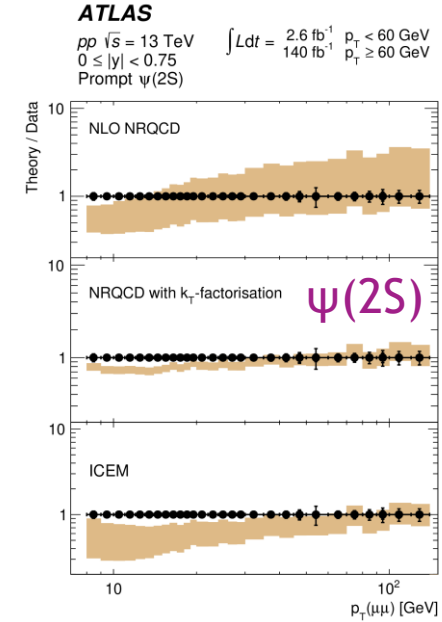
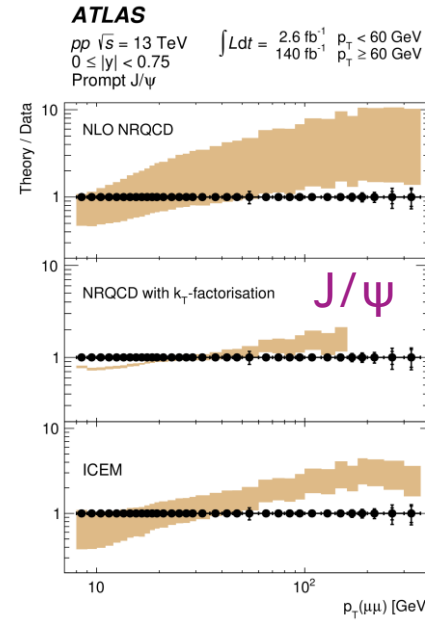


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[JHEP 09 \(2023\) 199](#)
Sussex



[Eur. Phys. J. C 84 \(2024\) 169](#)

Lancaster, RAL

- **Top physics:**

- Observation of **4-top process**

[Eur. Phys. J. C 83 \(2023\) 496](#)

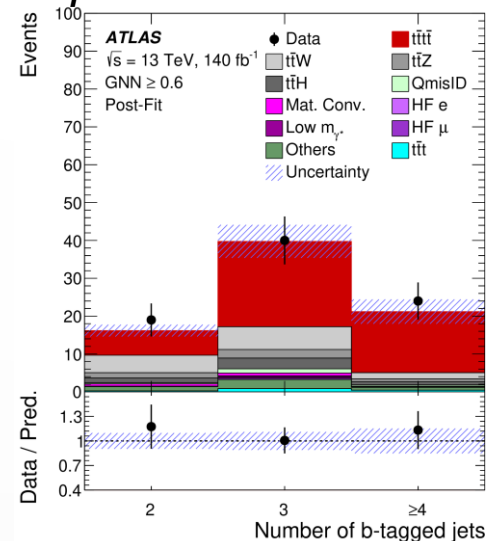
Manchester

- Observation of **quantum entanglement** in top-quark pairs

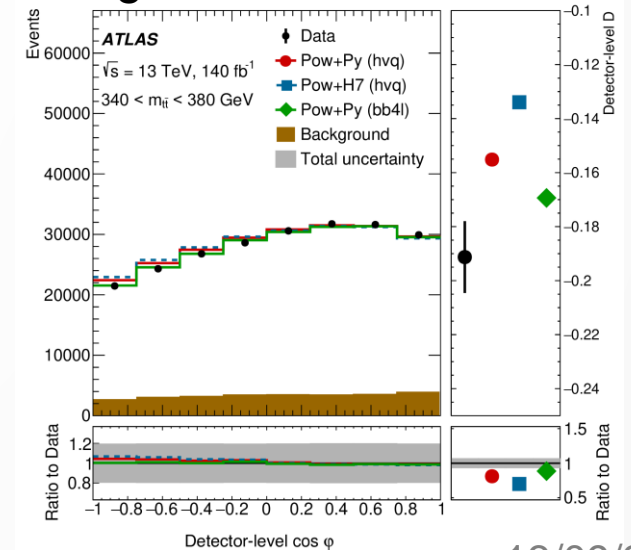
[arXiv:2311.07288](#)

Birmingham, Glasgow, Manchester

4-top



Entanglement in $t\bar{t}$



Physics highlights: Higgs physics

- ▶ Simultaneous measurement of **WH/ZH with Higgs to cc/bb**
 → legacy of Run 2 results exploiting new tagging techniques:
 - ▶ H→bb improved by **15%**, H→cc by **a factor of 3**.
 - ▶ Cross section measurements in bins of p_T boson

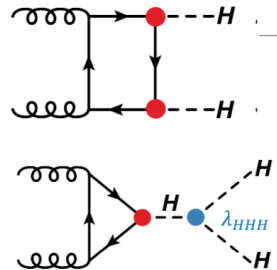
[ATLAS-CONF-2024-010](#)

*Birmingham, Glasgow, Liverpool,
 QMUL, Oxford, Sheffield, UCL*

- ▶ UK leadership also in ttH; H → ττ, rare H decays
- ▶ **EWSB and Higgs-self coupling:** a flagship analysis, with strong commitment from UK institutes in Run 2 and now in Run 3 → **Focus mostly on Run-3 bb and ττ decays (4b, bbττ)**

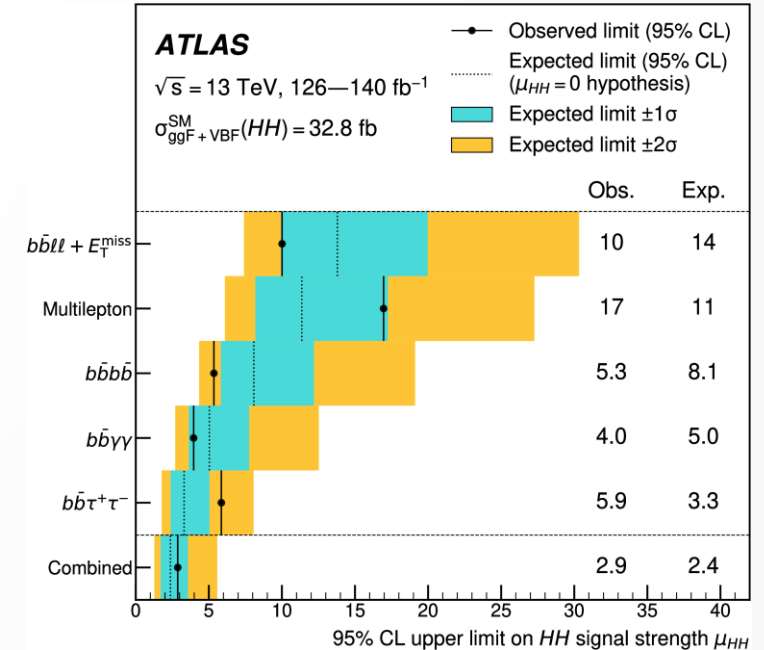
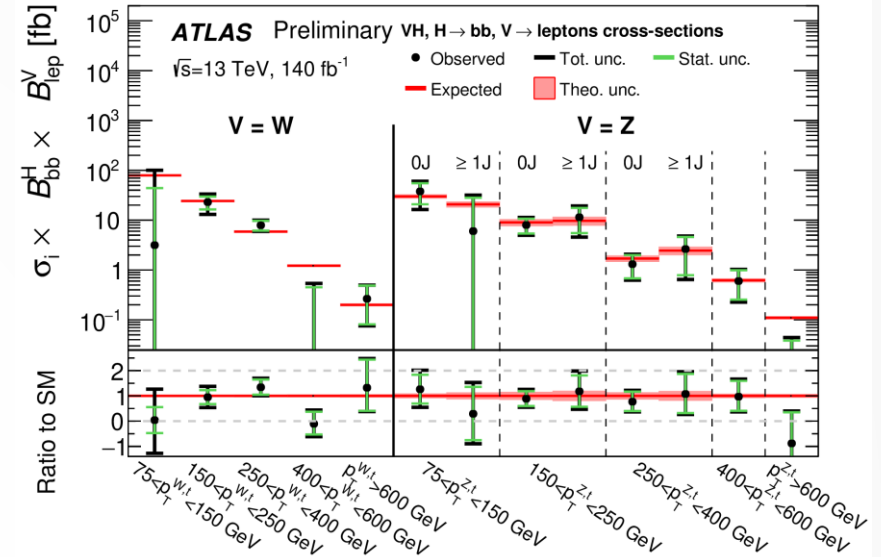
*Birmingham, Cambridge,
 Liverpool, Oxford, RHUL, UCL*

$$\mathcal{L}_h = \frac{1}{2} m_H^2 H^2 + \lambda_3 H^3 + \lambda_4 H^4$$



Self-coupling

- $\kappa_\lambda \in [-1.2, 7.2]$ ($\kappa_\lambda \in [-1.6, 7.2]$)
 - $\kappa_{2V} \in [0.57, 1.48]$ ($\kappa_{2V} \in [0.4, 1.6]$)
- $\kappa_j^2 = \sigma_j / \sigma_j^{\text{SM}}$ coupling modifier parameters



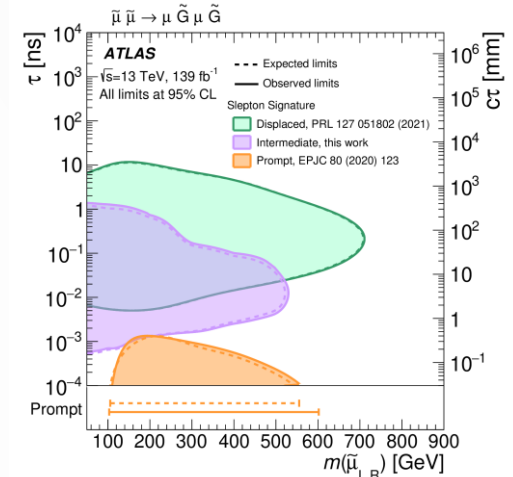
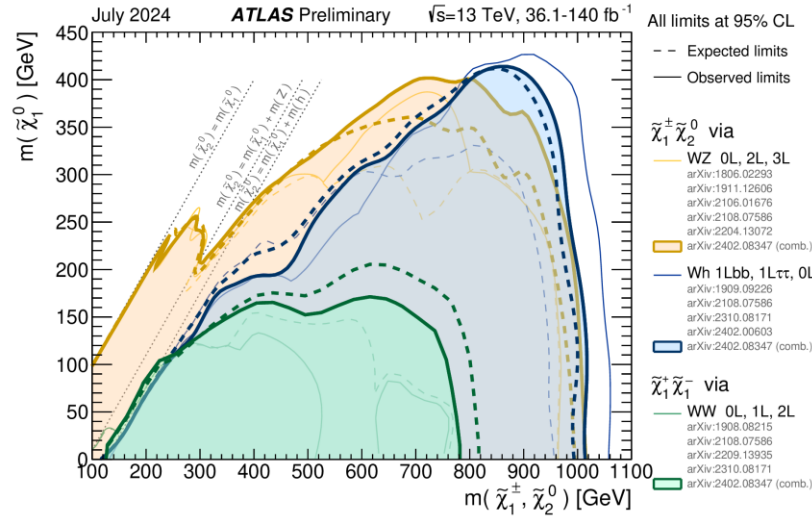
Highlights: ATLAS Searches for new physics

► Vast programme of BSM searches for supersymmetry, leptoquarks, exotic Higgs boson decays, long-lived particles (LLP) and other unconventional signatures ('dark jets' or 'lepton-jets') predicted in dark-sectors.

SUSY:

► Since Run-1, several UK-led searches for **top and bottom squarks, charginos and neutralinos, and sleptons**

Cambridge, Edinburgh, Liverpool, Oxford, QMUL, Sheffield, Sussex

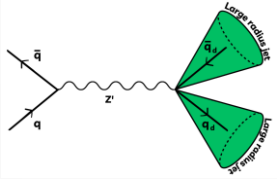


millimeter-displaced slepton

[Phys. Lett. B 846 \(2023\) 138172](#)

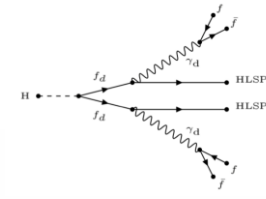
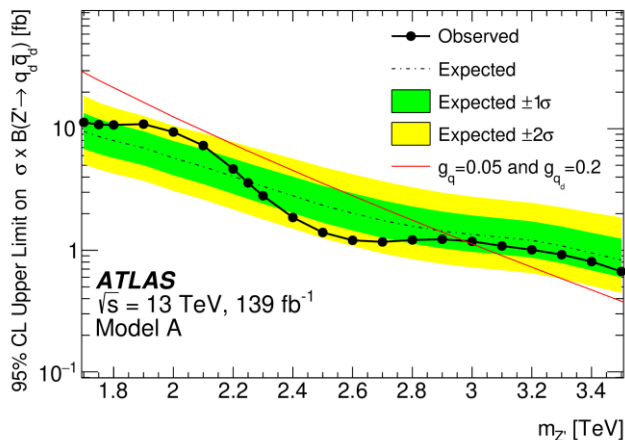
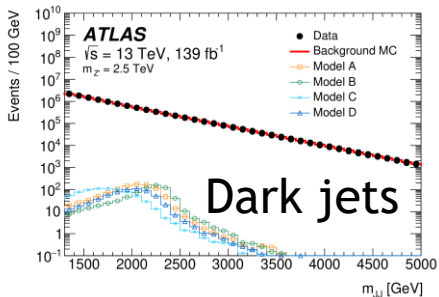
Lancaster

Dark-matter and hidden sectors → LLP



[JHEP 02 \(2024\) 128](#)

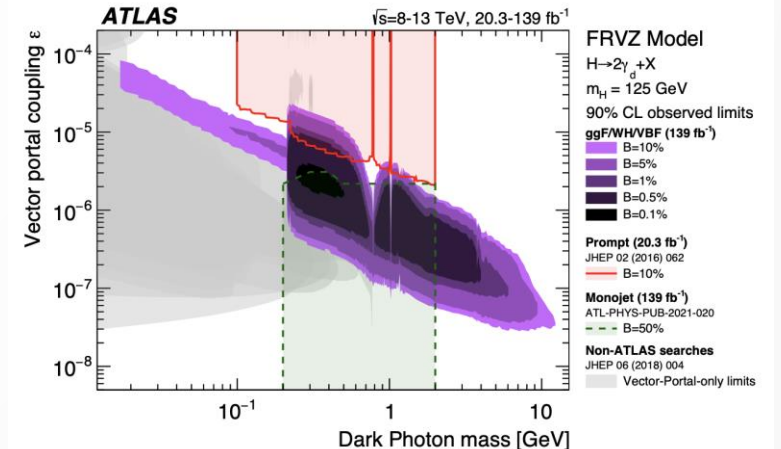
Manchester, QMUL



Higgs decaying through **dark photons**
 → use lepton-jets

Edinburgh, Liverpool

[Eur. Phys. J. C 84 \(2024\) 719](#)



Physics strengths and highlights: CMS

► UK-CMS is strongly engaged in top physics (Brunel, Bristol, RAL), Higgs physics (Imperial), and searches for new physics (Bristol, Imperial, RAL) including SUSY, dark matter, extended Higgs-sectors, long-lived particles and new resonances

► Thanks also to huge advancement in techniques and close collaboration with UK phenomenologists

Top physics: long-standing contributions on top-pair and single-top cross sections, top MC modelling etc.

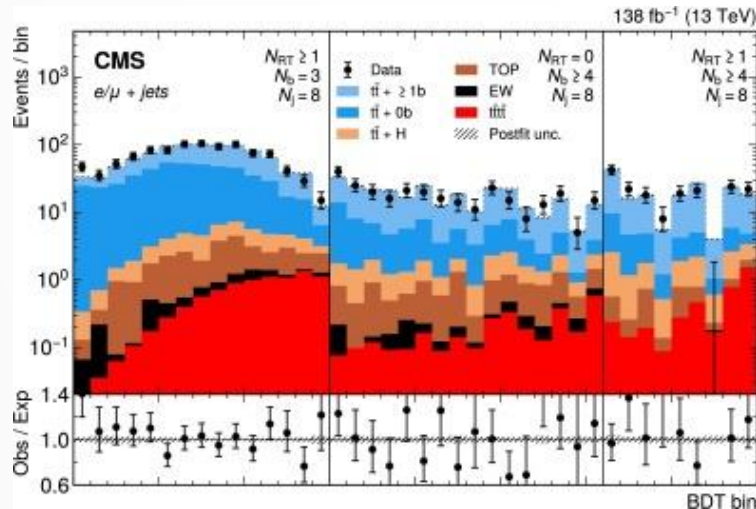
► Recent highlight – **4-top process**

► **UK-led** first evidence of this important process (later superseded by observation)

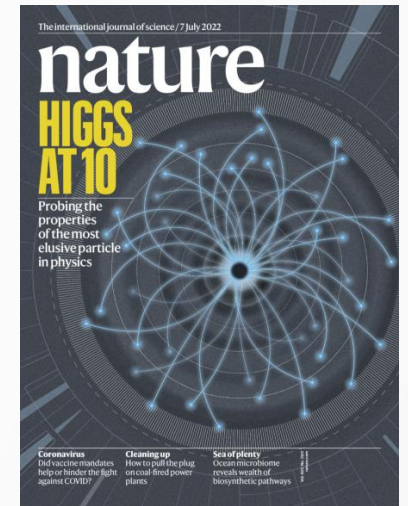
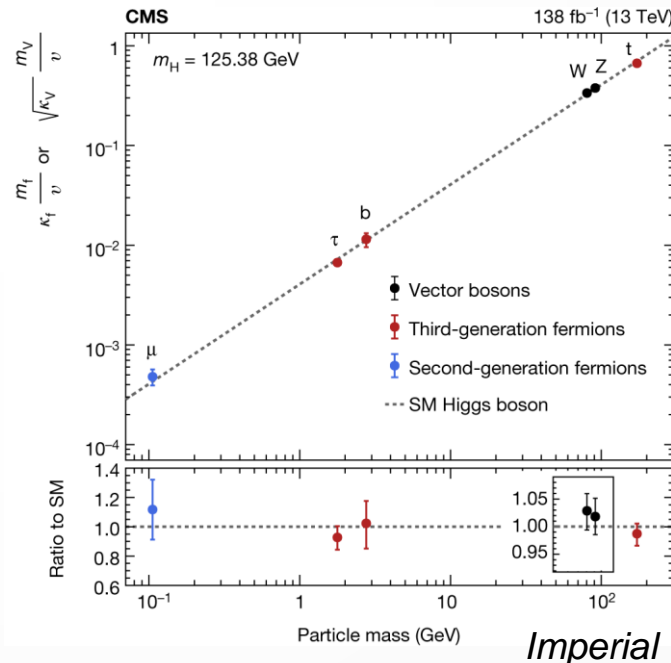
[PLB.2023.138076](https://arxiv.org/abs/2302.01231)

Bristol, Brunel

observed σ
 $17 \pm 4(\text{stat}) \pm 3(\text{syst}) \text{ fb}$



Higgs physics: strongly engaged in $H \rightarrow \gamma\gamma, \tau\tau, e^+e^-$, the UK has also led every **single-Higgs combination** effort since Higgs discovery



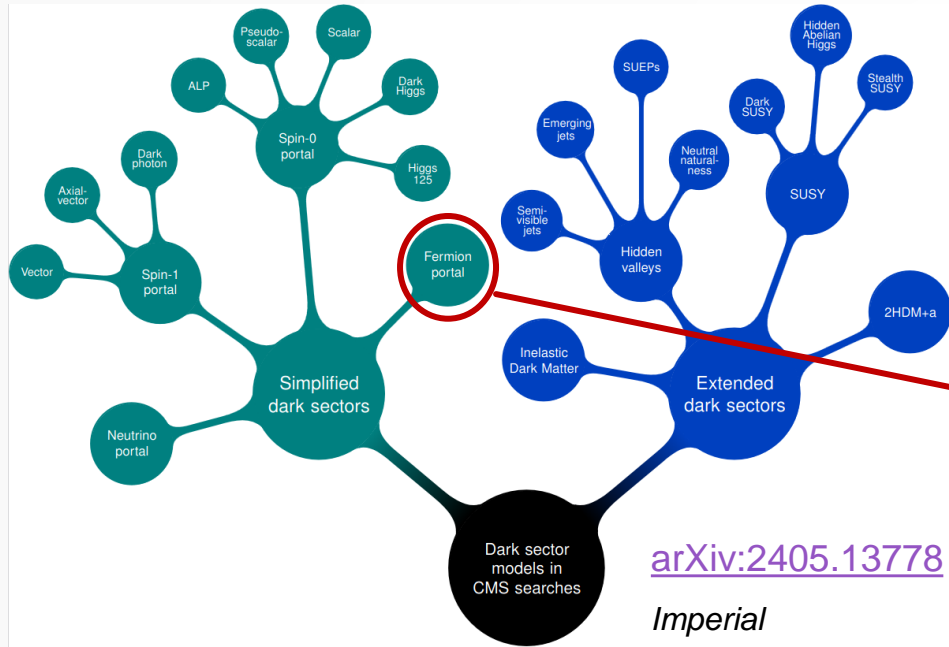
[Nature 607, pages60–68 \(2022\)](https://www.nature.com/articles/60760a)

(featuring with ATLAS)

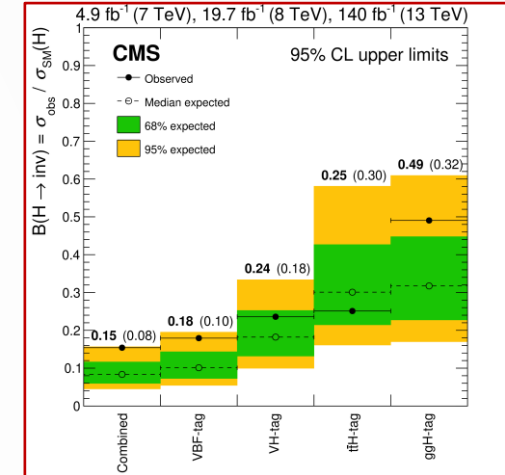
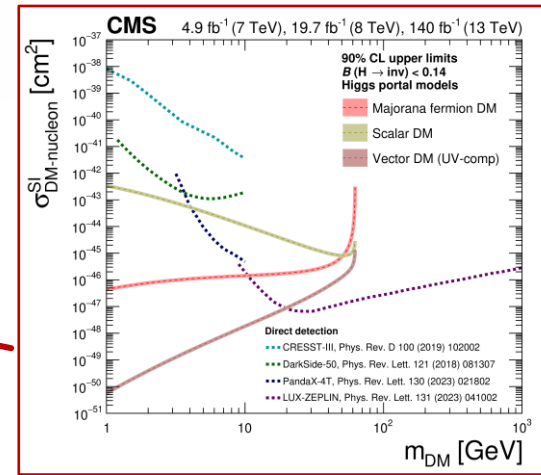
Imperial

Physics strengths and highlights: CMS

- Among **searches for new physics**, the UK led recent report on **dark sectors** → huge effort to map over 40 results and produce new interpretations



Include Higgs decaying in WIMP-like DM (**Higgs-portal**)



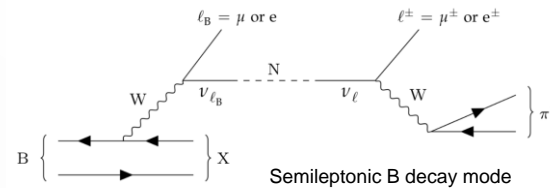
Bristol,
Imperial

- Other searches include e.g. **Heavy neutrinos (HNL)**

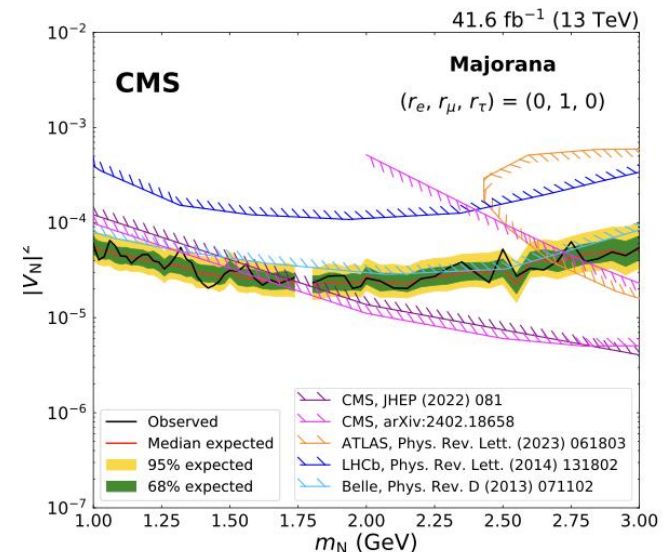
→ based on a special “parked data” stream collected in 2018

[JHEP 03 \(2024\) 105](#)

Imperial

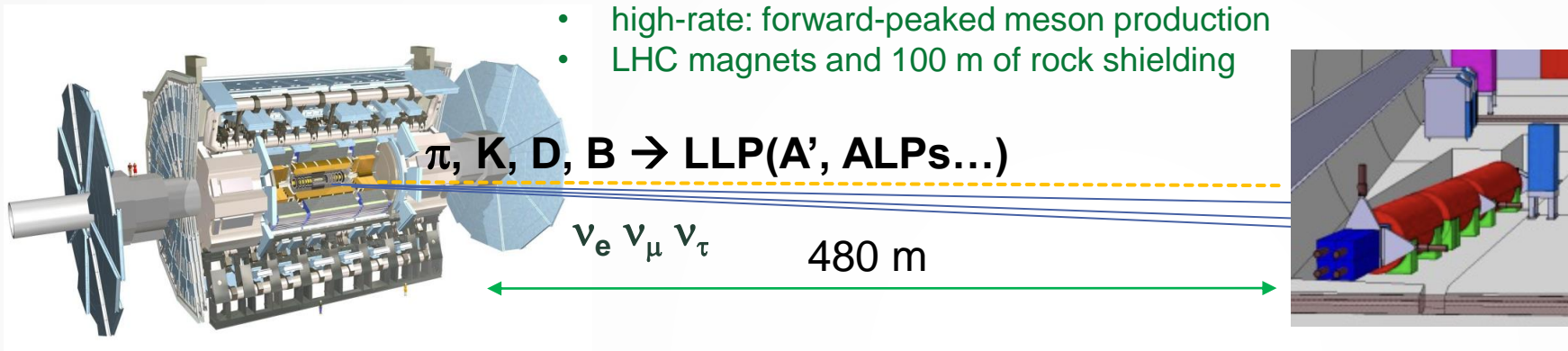


N long-lived, constraints depending on couplings and mass



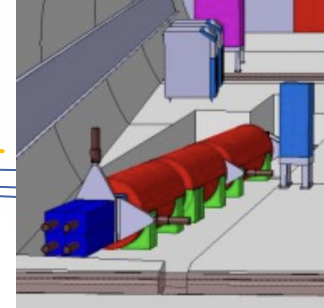
Physics highlights: FASER

- Built in 2021, in operation since 2022 Run 3 start, FASER targets new light, weakly interactive particles and high-energy neutrinos produced at the ATLAS collision point



- high-rate: forward-peaked meson production
- LHC magnets and 100 m of rock shielding

Built with left-over, e.g. ATLAS SCT modules for tracker

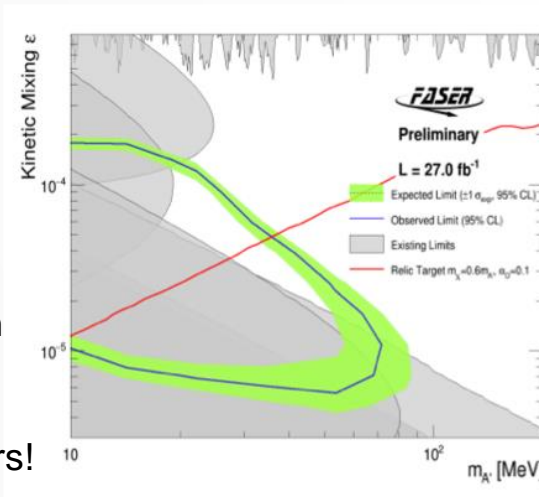


Strong UK contributions

- STFC-funding PhDs
- UK institutes also on ATLAS

- Search for **dark photon (A') in e^+e^-**
[Phys. Lett. B 848 \(2024\) 138378](https://arxiv.org/abs/2403.13837)

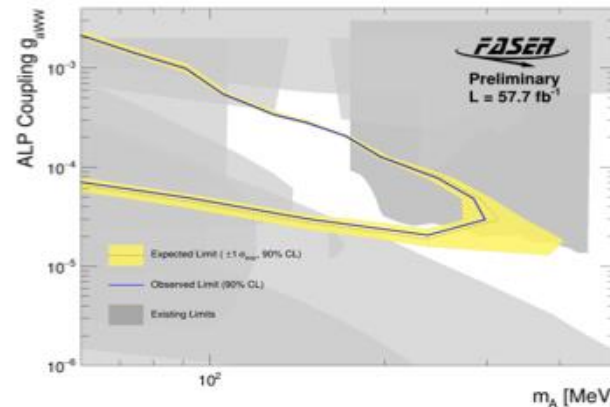
Liverpool,
Manchester,
Sussex



First constraint in DM thermal relic region @ low coupling for 30 yrs!

- Search for **axion-like particles (ALPs) in $\gamma\gamma$**

Liverpool [CERN-FASER-CONF-2024-001](https://arxiv.org/abs/2403.001)

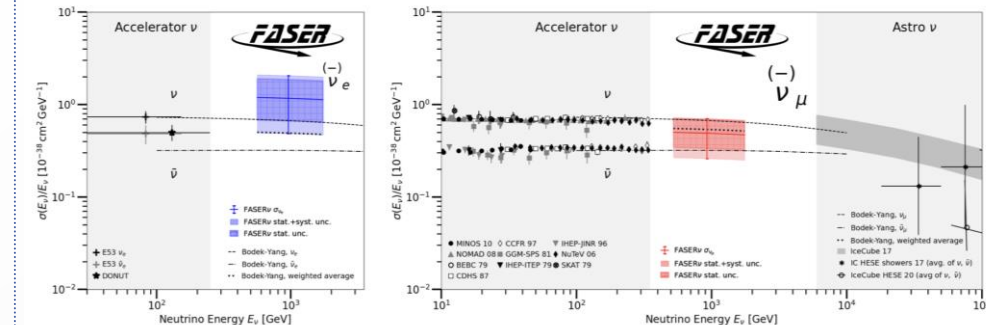


Access very challenging region

- First **direct observation of ν and ν_e and ν_μ** interaction measurements

[PRL 131 \(2023\) 3, 031801](https://arxiv.org/abs/2303.031801)
[PRL. 133, 021802 \(2024\)](https://arxiv.org/abs/2402.021802)

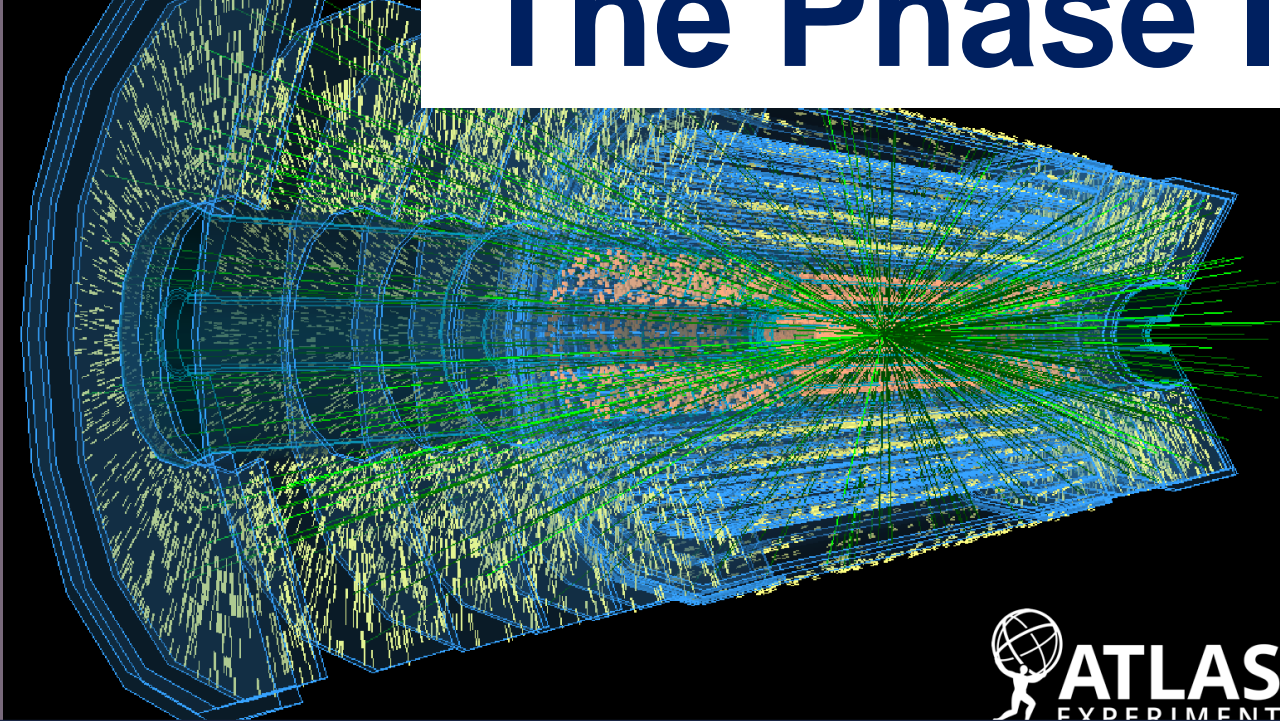
Liverpool, Manchester,
RHUL, Sussex



$4\nu_e$ and $8\nu_\mu$ candidates observed in TeV range



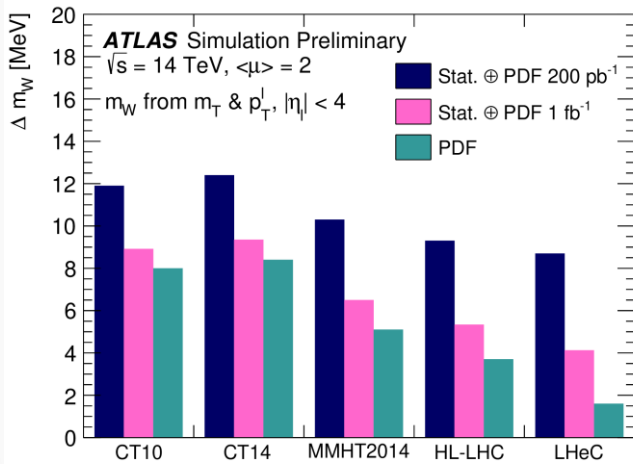
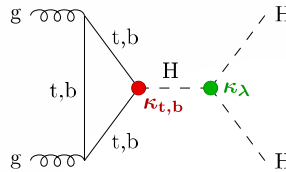
The Phase II upgrades



Pushing towards the energy frontier: HL-LHC

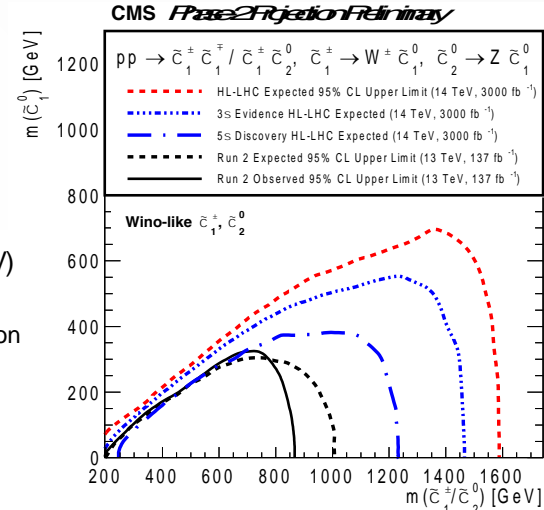
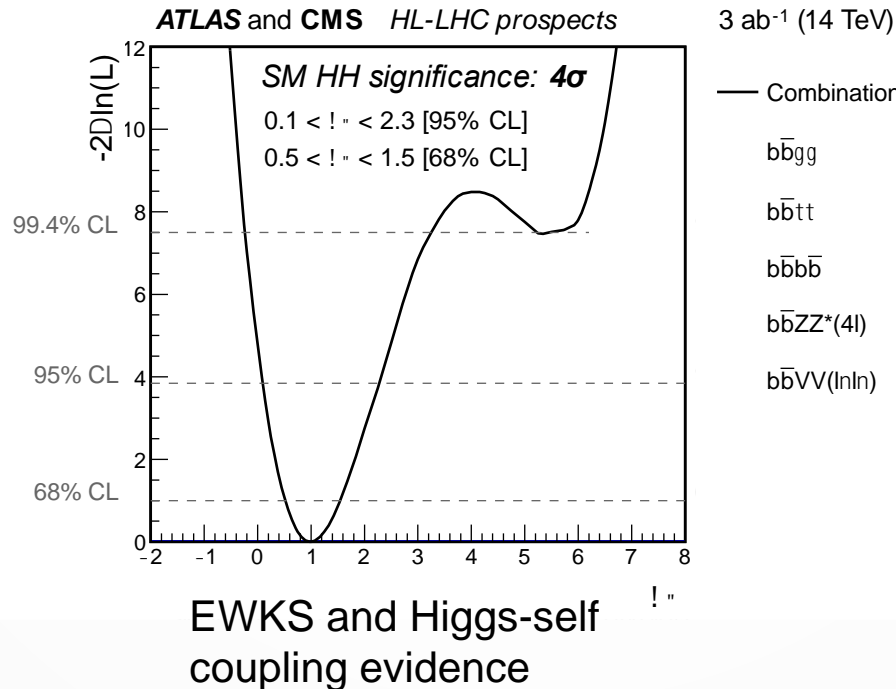
- **HL-LHC prospect studies**, done also to understand the impact of the detectors' performance → strong engagement of **UK-ATLAS** and **UK-CMS** for the Yellow Book reports (2017-19)
 - From SM precision measurements to di-Higgs and new physics searches, huge potential

[Report on the Physics at the HL-LHC, and Perspectives for the HE-LHC](#)

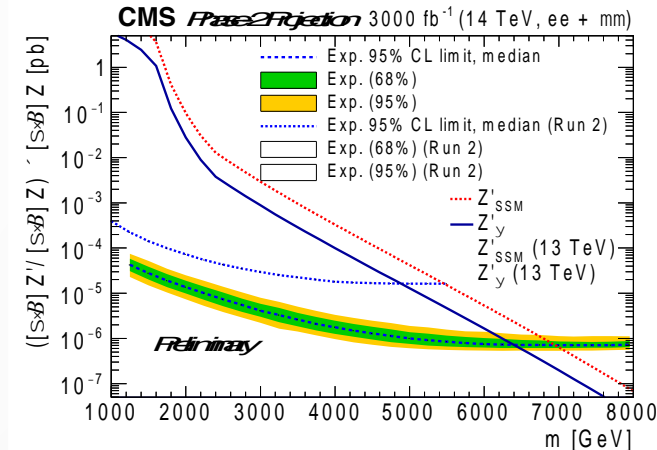


At least a factor of 2 expected in precision for W mass

Contribution of many UK institutes...



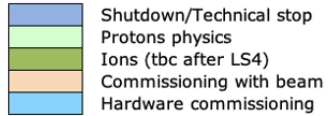
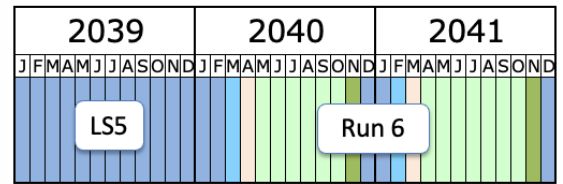
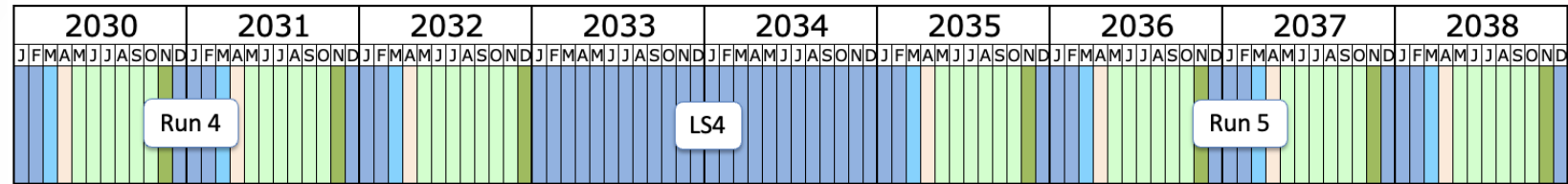
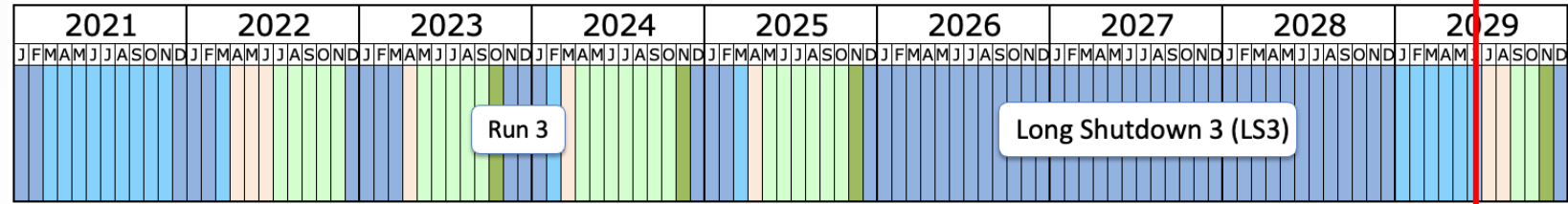
For NP, increase the present reach in mass and coupling by 20-50%



The Phase II upgrades timeline

HL-LHC

- ▶ LS3 (2025-2029) – could shift by 6-9 months
- ▶ Run 4 and beyond (HL-LHC): ~10 years programme with an LS4 shutdown in 2033+
 - ▶ Inst lumi: $5-7.5 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$
 - ▶ 3 ab^{-1} / exp. of integrated lumi @ $\sqrt{s} = 14 \text{ TeV}$ expected

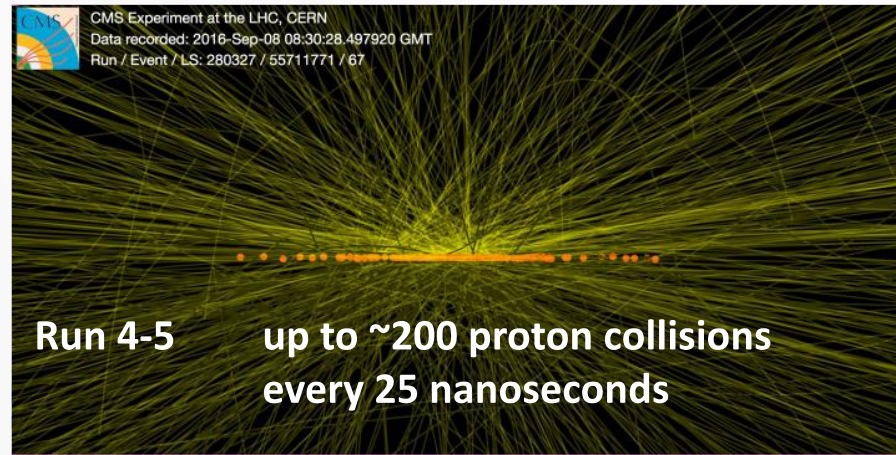


lhccommissioning.web.cern.ch

Last update: June 24

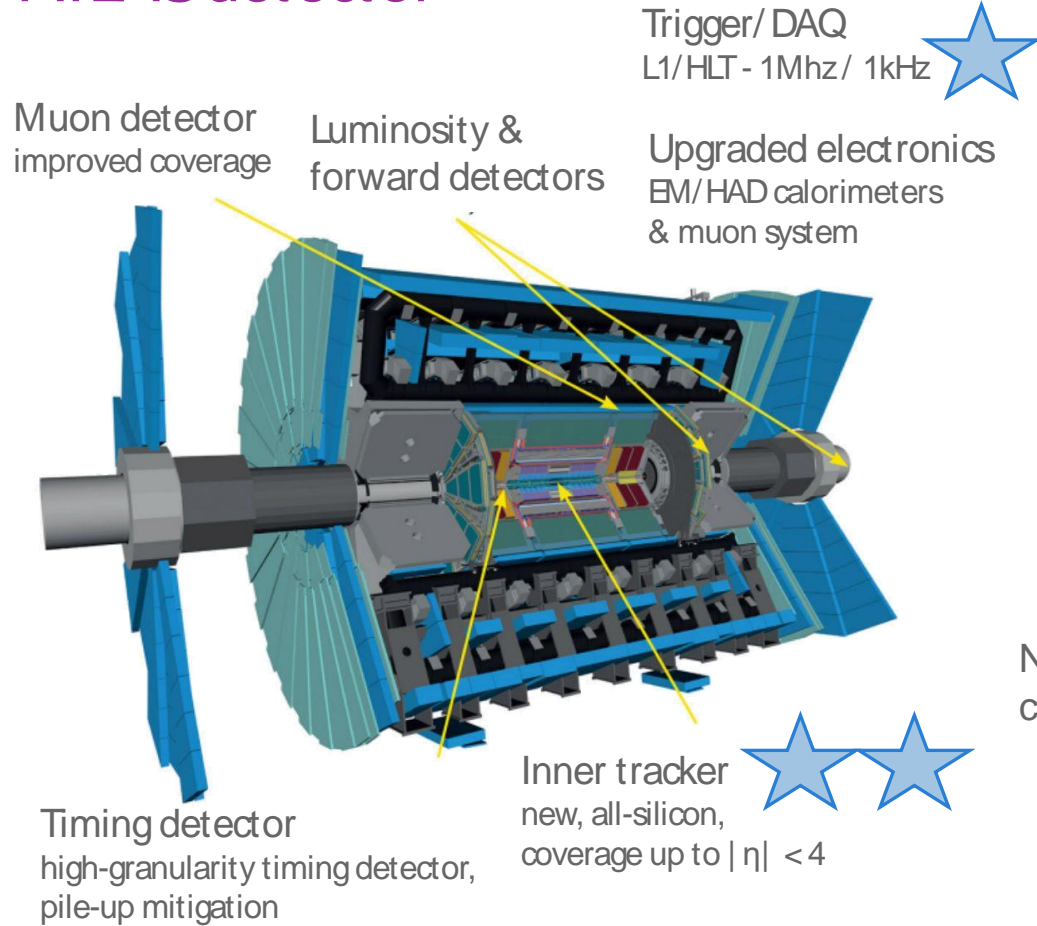
Challenges and solutions

- High instantaneous lumi (pileup) → improve **granularity** and **timing** information
- High integrated lumi = high radiation environment → replacement of **tracker** and **endcap calorimeter**
- Huge amount of data (computing, storage) → **new trigger & DAQ** systems

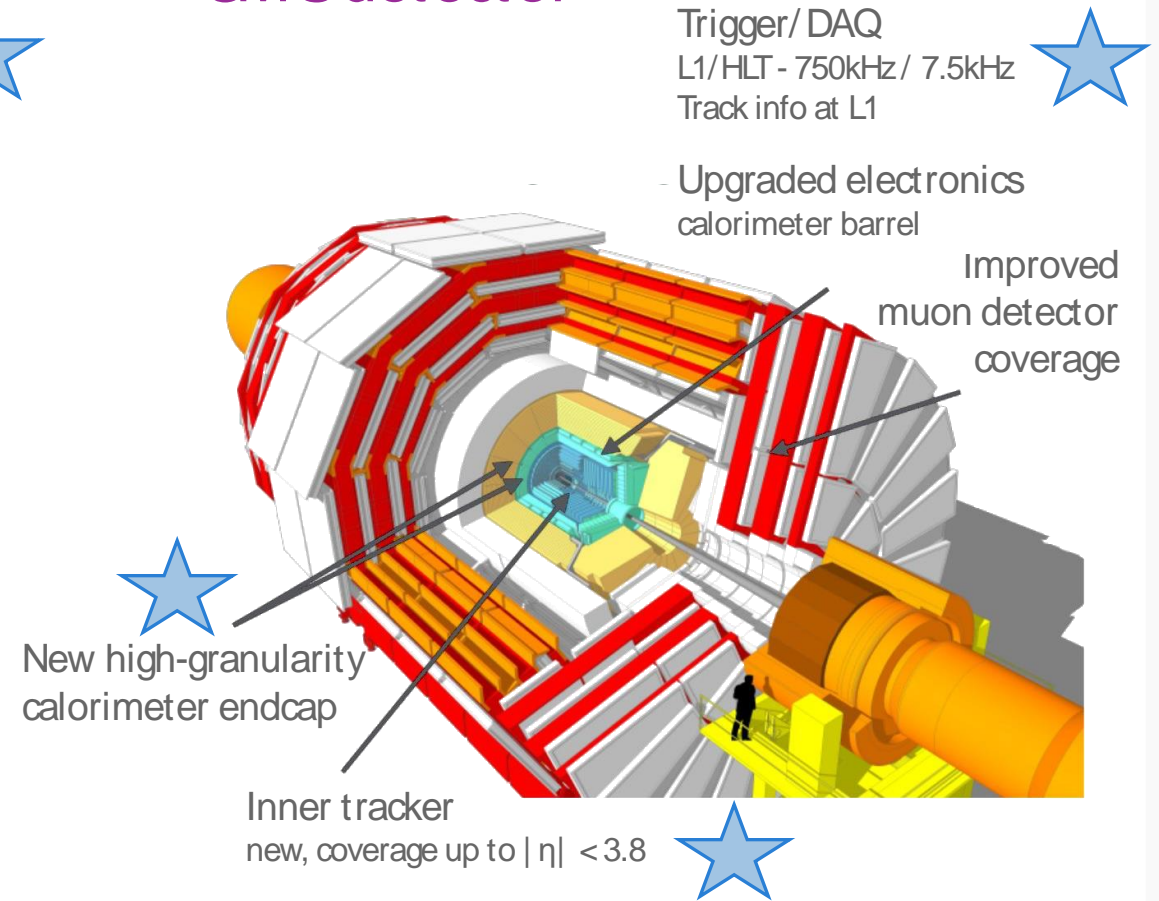


GPDs upgrade programs at glance

ATLAS detector



CMS detector



► **Funding:** mainly STFC, capital contribution to upgrade in line with fair share. Current (being extended):

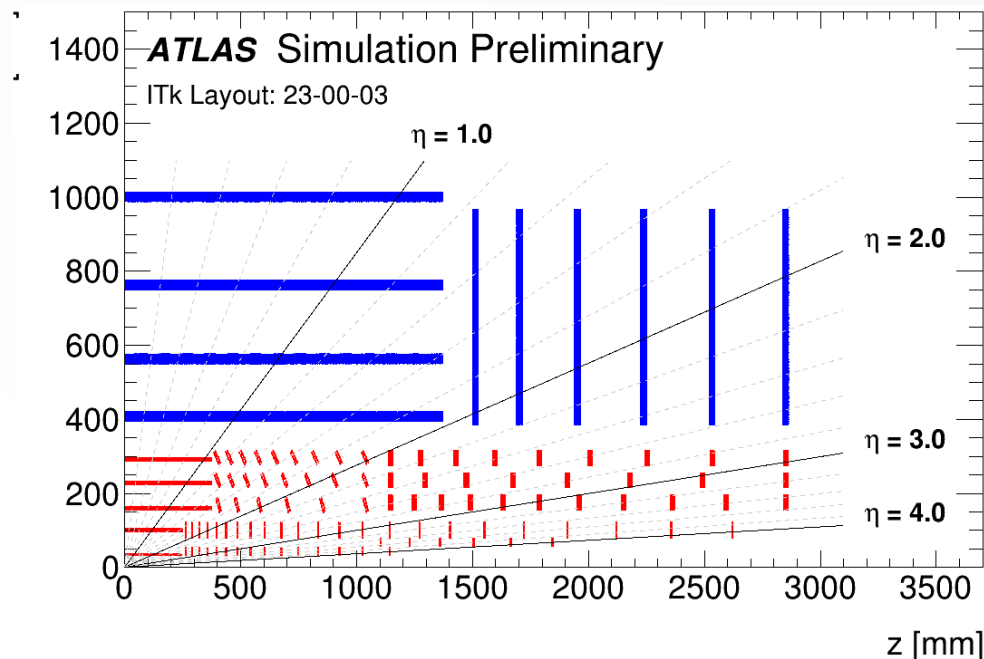
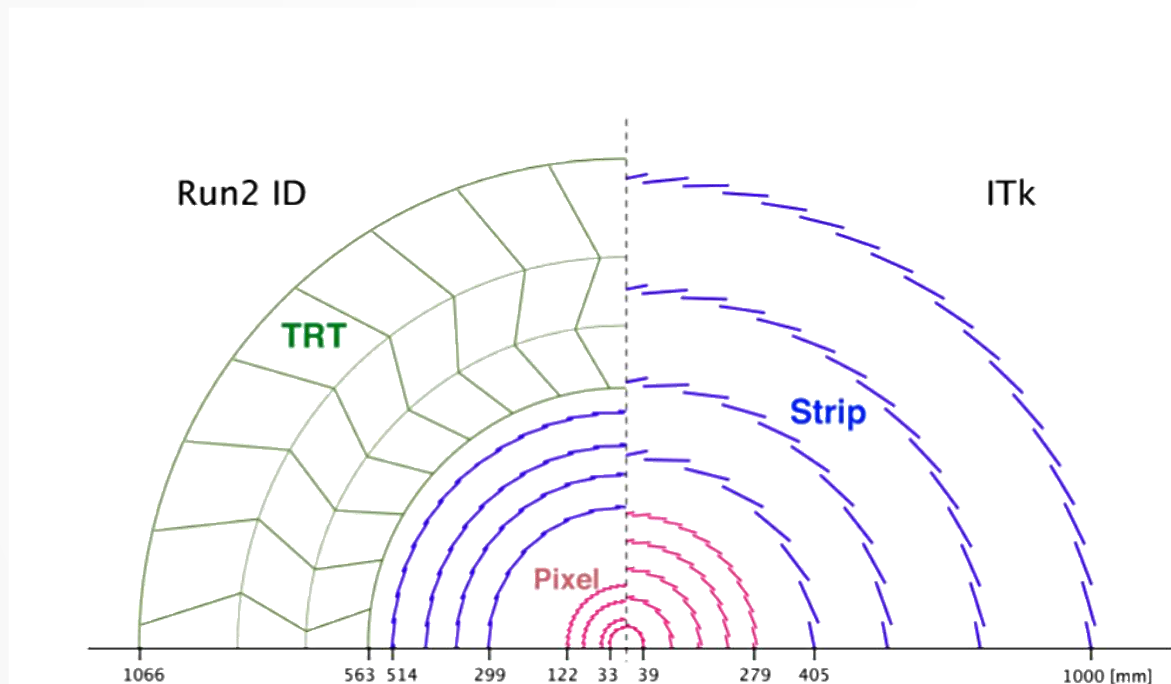
► **ATLAS:** £128M for 12 years (2014-2026)

► **CMS:** £13.6M for 6 years (2019-2025)

ATLAS upgrade: Inner Tracking Detector (ITk)

► One of the **main UK deliverables for ATLAS**

- Complete replacement of the current inner detector
 - Larger angular coverage (η : 2.5 \rightarrow 4)
 - High radiation tolerance (up to 1×10^{16} neq/cm²)
 - Reduced material budget
- Very large total surface for Pixel and Strip sensors



- UK is responsible to build **40% of the strip modules** and **50% of the strip local supports** (cores) + strip service modules
- UK deliverables in pixel include assemble and test **20% of ATLAS Pixel modules** and build **one endcap**
- **UK providing a lot of the leadership in the ITk**

Inner Tracking Detector (ITk): status

- Schedule remains challenging, but lot of good progress has been made

- **ITK strips:**

- huge work to understand and solve module cracking problems in collaboration with US and other institutes
 - UK Institutes ready for production – **now on track to start bulk production before the end of 2024**

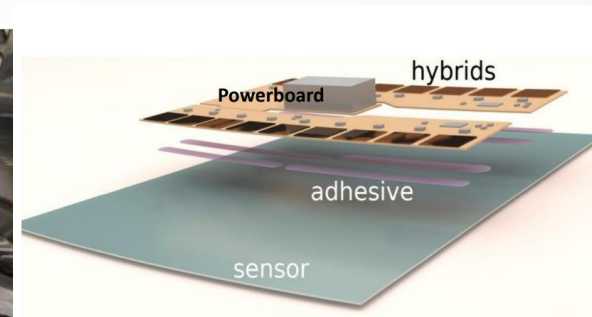
Birmingham, Cambridge, Glasgow, Lancaster, Liverpool, Oxford, QMUL, RAL PP, RAL TD, Sheffield, UCL, Warwick

“Interposer” solution, module design modified

Interposers fabricated in the UK

14 interposed modules on stave under Cold tests in UK (-70°C)

Lightning recap: SE4445+kapton cut & roll method



- **ITK pixels:**

Edinburgh, Glasgow, Lancaster, Liverpool, Manchester, Oxford, QMUL, RAL PP, RAL TD, Sheffield, UCL, Warwick

- Assembly site, construction processes and quality insurance tests in place at all sites - PRR November
 - Joint task force ATLAS-CMS expert for ASICs to study challenges in hybridization process and ASICs

- Preparation in SR1 in full progress with deliverables from UK getting to CERN...

Preparation for I&C in SR1



Left Cylinders made in US dressed in UK, sent to CERN

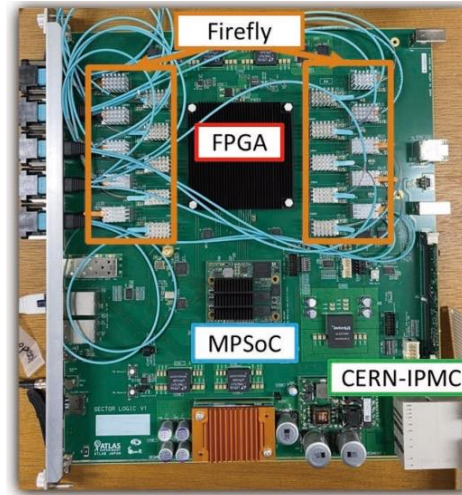
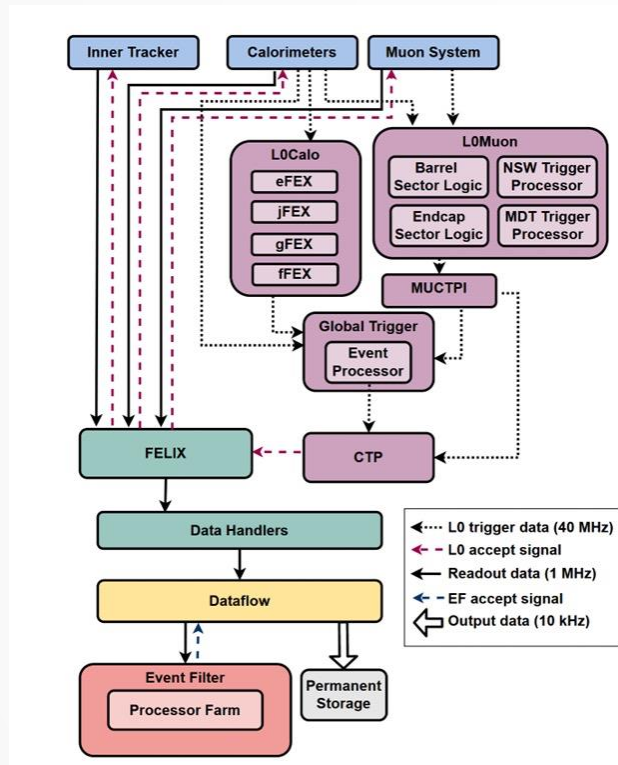
Above stave loading into cylinders in the UK
Sent to CERN end of 2024
Loading starts in Q1-2025
UK provide service modules

ATLAS upgrade: Trigger and DAQ

- ▶ Another **major UK deliverable**
- ▶ Phase II TDAQ specifications are challenging:
 - ▶ L0 rate 1 MHz with 10us latency
 - ▶ EF output rate 10 kHz
 - ▶ Estimate event size of 4.6 MB

Birmingham, RHUL, UCL, RAL, QMUL

L0 Trigger: prototyping and testing

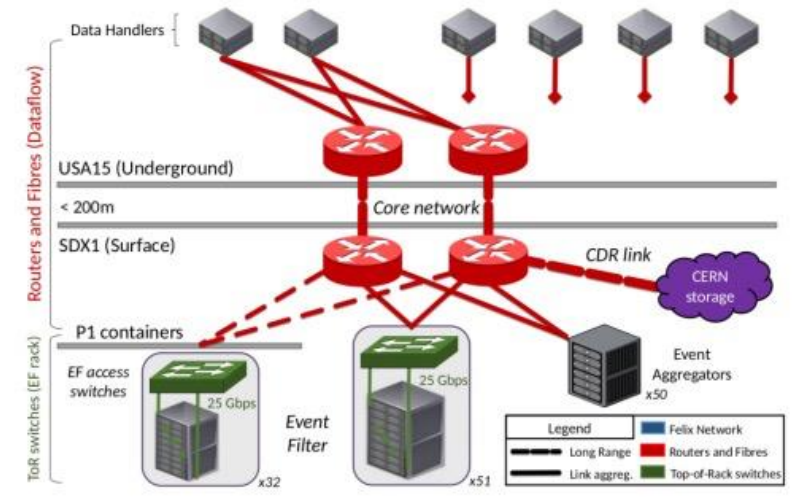


DAQ: FELIX prototype testing on-going

Event filter: demonstrators progressing well and on track, very good progress on GPU and FPGA support in ATLAS software



Phase-II FELIX prototype II



ATLAS upgrade: Trigger and DAQ

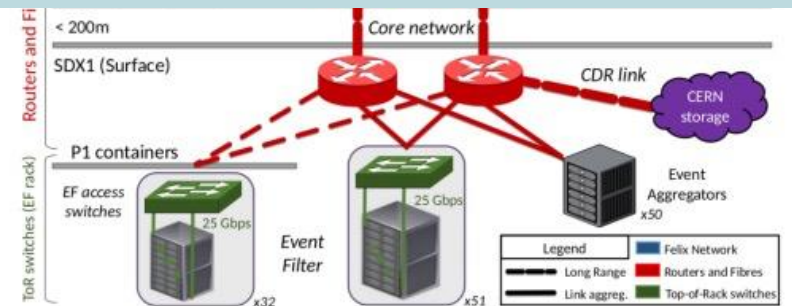
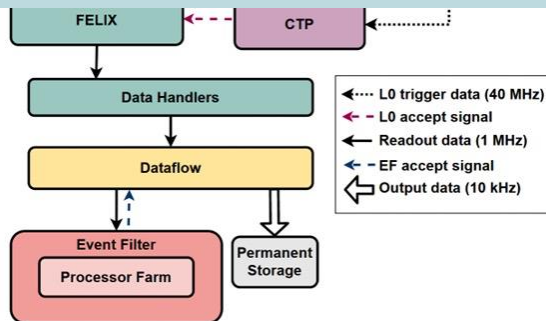
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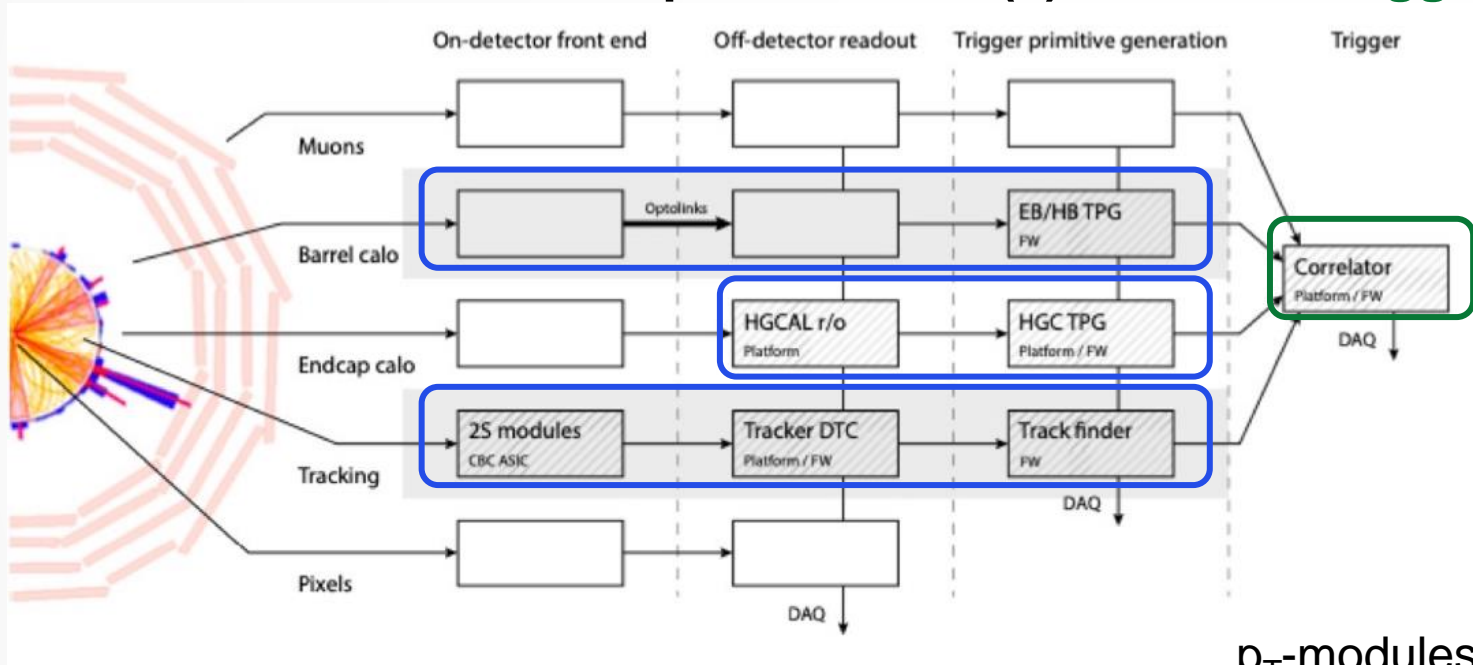
▶ **Overall:** ATLAS-Phase II upgrade work is also relevant for

- ▶ **training of qualified personnel:** 55 PhD students have graduated in the past 5 years with activities on upgrade, apprenticeship programs for technical staff, research and development spin-off..
- ▶ **Industry engagement:** collaborations with national and international partners, including Micron Superconductor, ZOT, Graphic, INTEL ...



CMS upgrade UK contributions

- ▶ The CMS detector upgrade for HL-LHC comprises a totally new tracking system with hardware trigger capability and a new High-granularity calorimetry (HGCal)
- ▶ **Main UK-deliverable:** common **electronics platform** contributing to **tracker, barrel electromagnetic calorimeter, and endcap calorimeter(s), and to L1 trigger**



Based on **8 years** of R&D activities

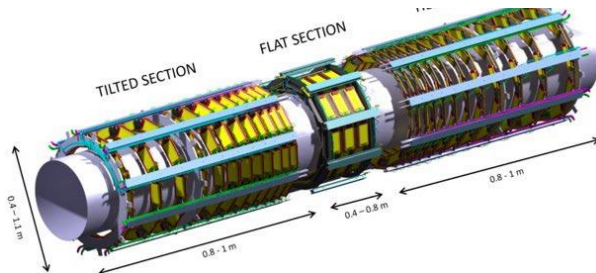
Successfully UK-delivered “building-blocks”

- MP7 processor board (Phase I)
- New time-multiplexed trigger Architecture
- **FPGA-based track finding**

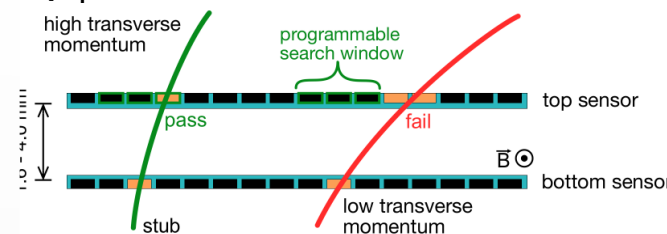
[JINST 12 P12019](#)

Bristol, Brunel, Imperial, RAL

Outer tracker



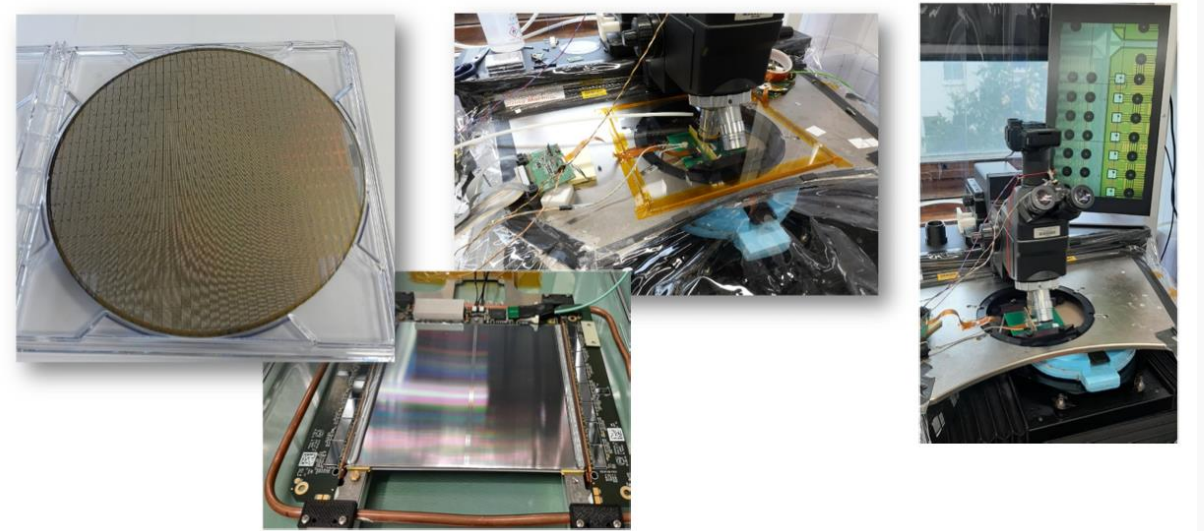
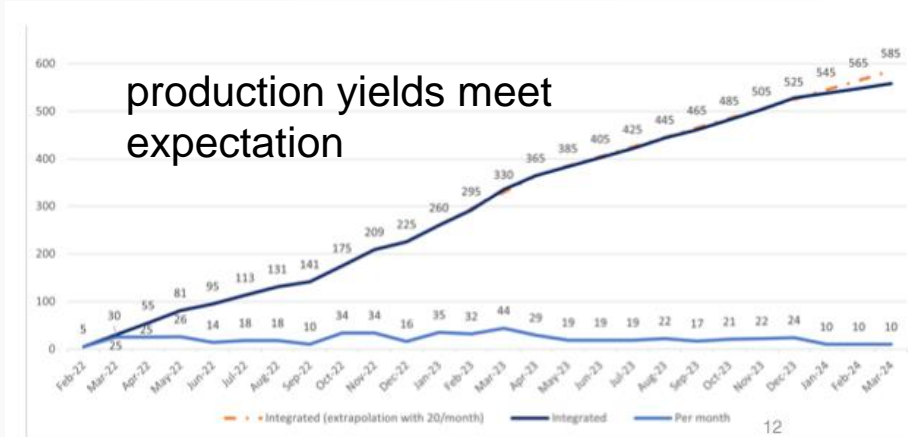
p_T -modules on OT



shown to work in 2017!
Since then ..

CMS upgrade UK contributions: ASICs and board

- ▶ ASICs successfully delivered by UK
 - ▶ QA of all wafers completed



- ▶ Common technology: off-detector electronics board

- ▶ Founded **Serenity** Collaboration (UK-led)
- ▶ **Serenity board** can be used in different capacities across many sub-detectors
- ▶ Produced 27 prototypes with partners, currently in pre-production
- ▶ Used in test-beam for **tracker** and **HGCAL**
- ▶ Being integrated with detector components

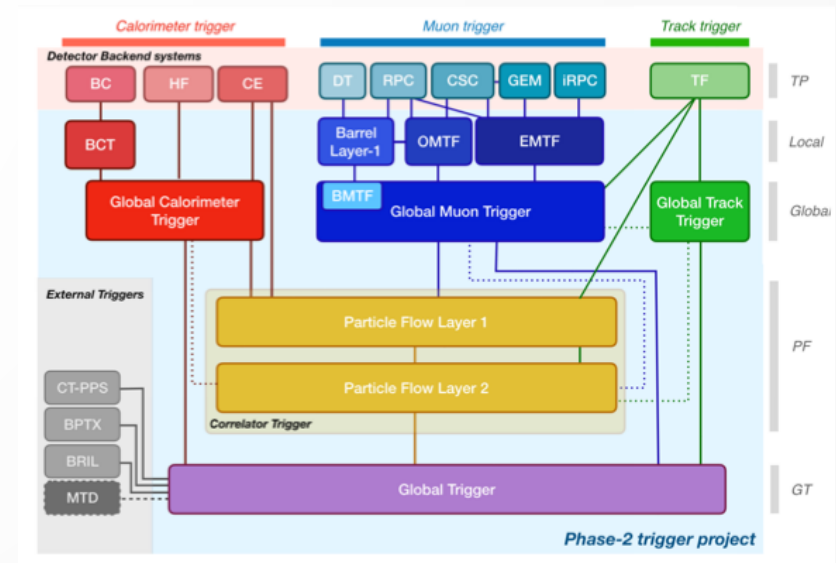
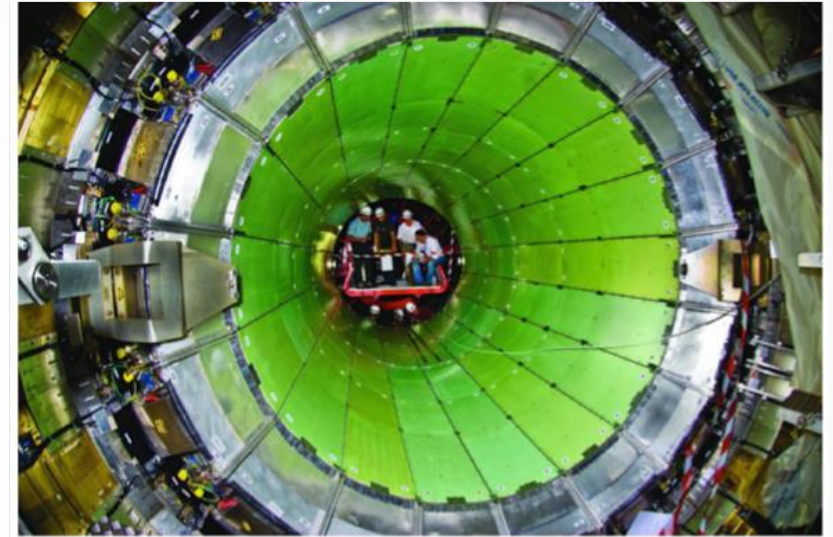
Large UK involvement including students



<https://serenity.web.cern.ch/serenity/>

CMS upgrade UK contributions: work ahead

- Complete delivery of common off-detector electronic board Serenity
- For **Tracker**:
 - Install back-end system, complete development and validation for the Trigger Primitive Generator systems
 - Complete development and validation of the online software needed to coordinate, commission and operate the systems
 - Testing and commissioning before/after installation
- For **ECAL**
 - Algorithm firmware → key UK-deliverables to reject APD spikes at L1
 - Installation of new readout electronics and associated service (2026-27)
 - Installation and commissioning of optical fibre router to transmit crystal data between off-detector boards
- For **HGCAL**
 - Install the Trigger Primitive Generator system in final location
 - Test and commission the full system thoroughly
- For **L1 Trigger**
 - Fully test, install and commission the 36 Serenity boards for the Global Track Trigger and Correlator L1T subsystems
 - Operate and commission system and algorithms ready for beam

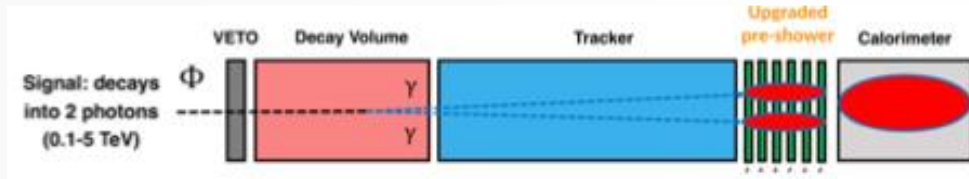


FASER @ HL-LHC

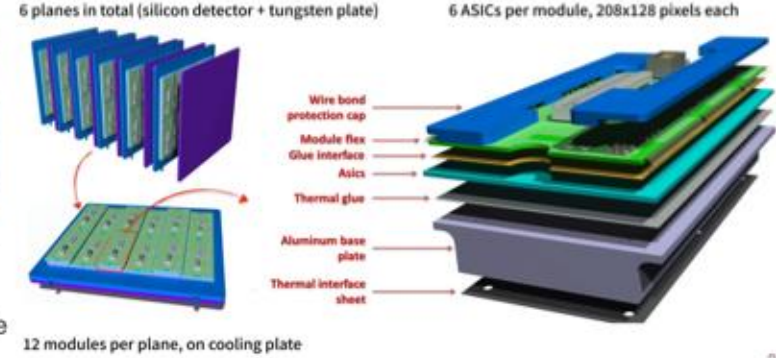
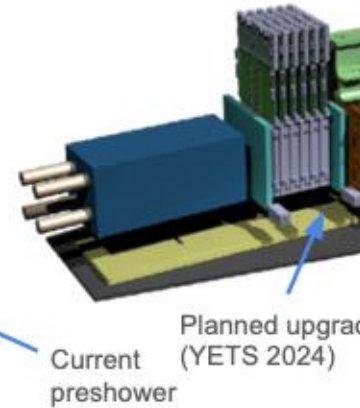
► FASER has been recently approved to run in Run 4 **as is**. Great additional physics potential in studies of hidden sectors and measurements of high-energy neutrino. **No major upgrades foreseen BUT:**

► New **pre-shower system** would have been operational since 2025 by then

Liverpool supporting Geneva (Lead)

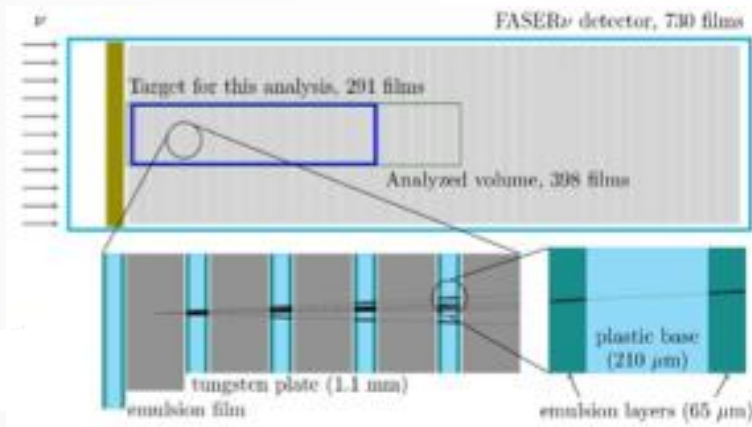


- Resolve diphoton events
- Improve sensitivity for searches of LLP $\rightarrow \gamma\gamma$



► FASER_v emulsion detector not as efficient – discussions about replacements/alternatives in progress

Current emulsion detector



Several ideas from UK groups, in particular the possibility of a **silicon/tungsten emulsion detector** using uninstalled SCT modules *(being studied by Manchester)*

A different scenario if the **Forward Physics Facility (FPF)** will be supported \rightarrow **FASER-2** (see *back-up*)

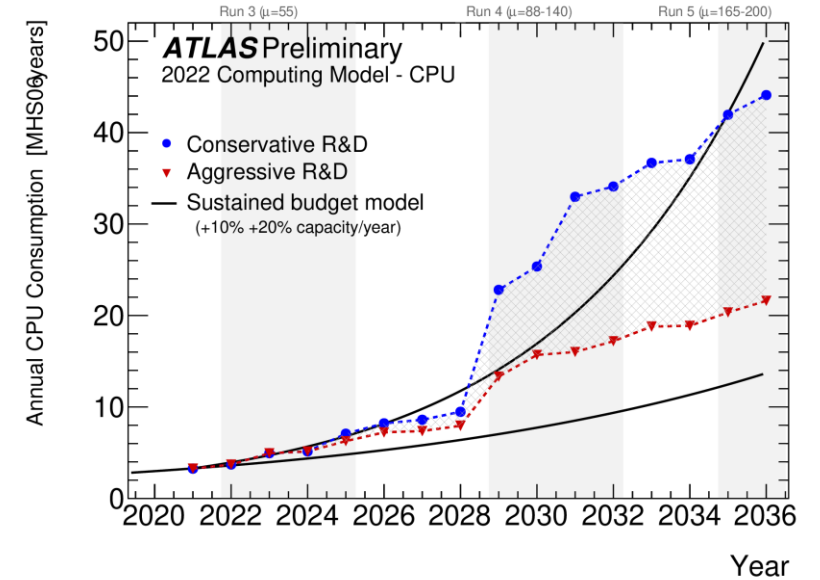
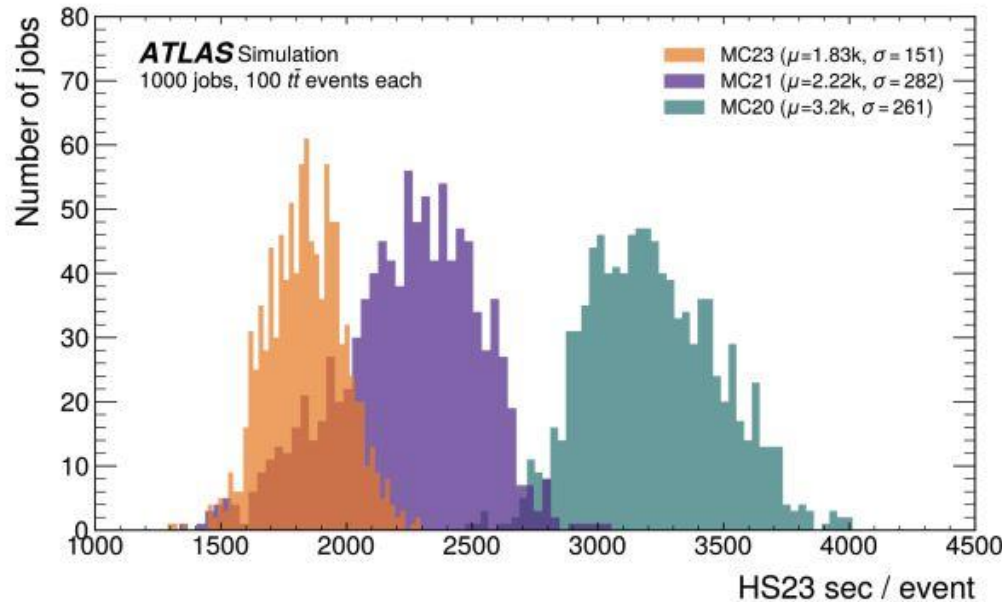
Liverpool, Manchester, Oxford, RAL, RHUL, Sussex

Phase-II Computing

- ▶ The HL-LHC presents significant computing challenge
 - ▶ A lot of work on-going to address this → manageable, exploiting rapidly changing technology landscape (see Davide's talk)
 - ▶ In UK, coordinated efforts (i.e. within the **SWIFT-HEP** project) to address challenges from various perspectives → efficient MC production, efficient analysis software etc.

E.g.: **MC simulation improvement (for Run 3)**

[CERN courier article](#)



But also: extensive use of GPUs needed for development and deployment of new AI-based approaches for trigger and analysis

- e.g.: **CMS:** improved computing capabilities of the HLT system exploiting GPUs → **crucial** for **UK-led data scouting approach**

Computing (infrastructure/software) is essential to exploit future experiments and UK play a key role within the international LHC community

Summary & Outlook

- UK community contributes crucially to ATLAS, CMS and FASER, in operations and maintenance, and producing many results key to understand the SM and explore beyond
- The UK is a very dynamic community, with ECR fora and initiatives, exploitation of cutting-edge techniques
- *[not discussed here]* Scientific outcomes can be 'enriched' with additional small experiments 'using' GPDs, with UK-initiatives such as ANUBIS
- Physics prospects for HL-LHC offer incredible opportunities:
 - Upgrades of the ATLAS and CMS detectors progressing, UK-deliverables substantial but well on-track; strong engagement of UK institutes also on FASER @ HL-LHC
 - Computing is a challenge which the UK is targeting through collaborative efforts

Huge thanks to (alphabetic order) Joel Goldstein, Steve McMahon, Claire Shepherd-Themistocleous, Alex Tapper, Pedro Teixeira-Dias, Sarah Williams

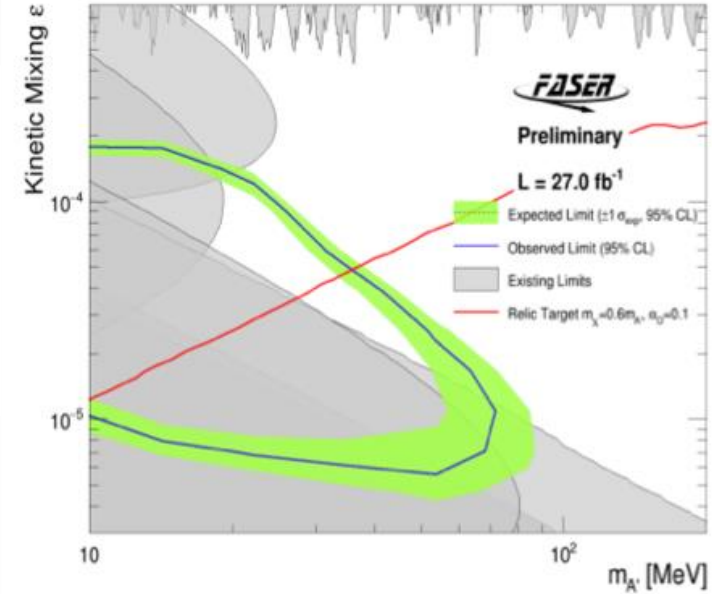
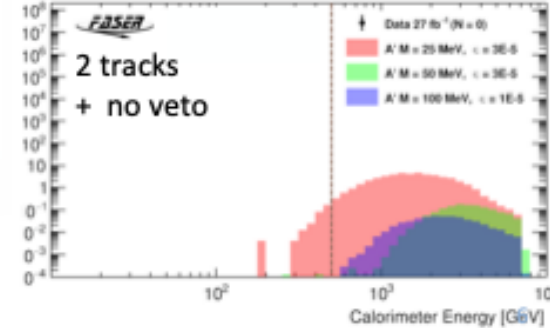
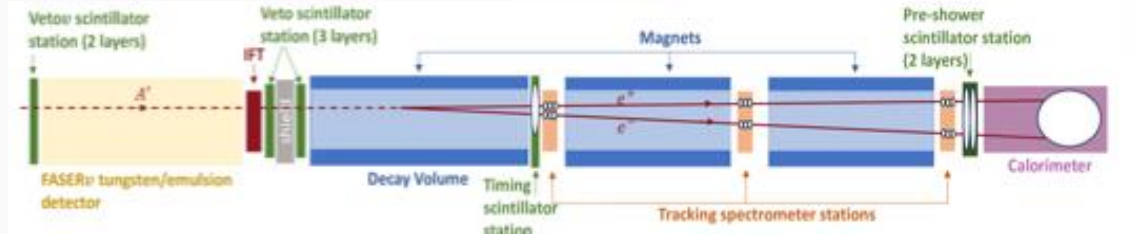
Back up

Physics highlights: FASER searches

Search for Dark Photon (A') in e^+e^-

[Phys. Lett. B 848 \(2024\) 138378](#)

Liverpool, Manchester, Sussex

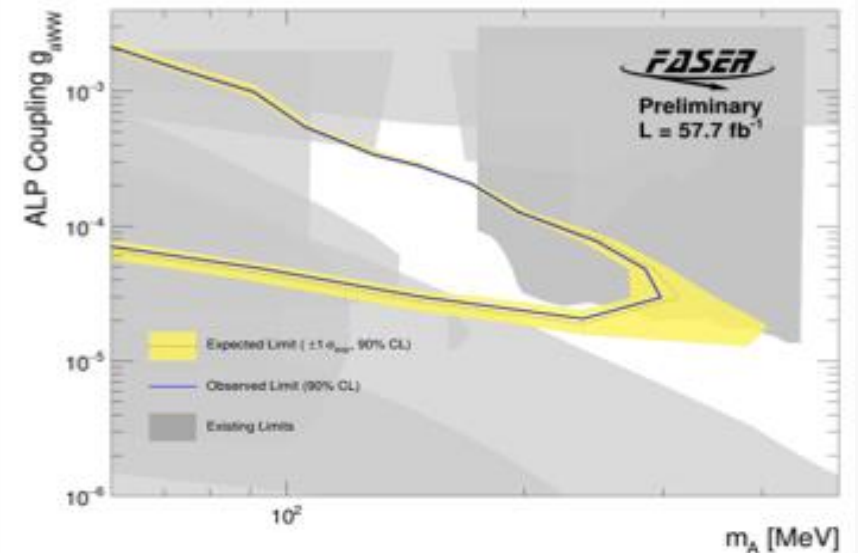
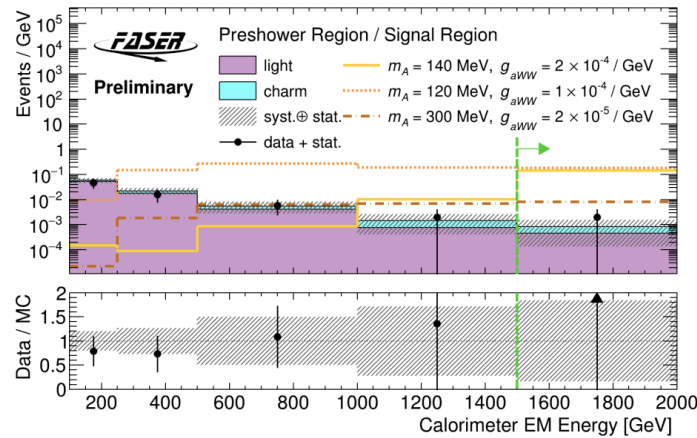
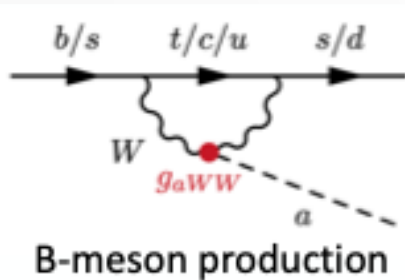


First constraint in thermal relic region @ low coupling for 30 yrs!

Search for axion-like particles (ALPs) in $\gamma\gamma$

[CERN-FASER-CONF-2024-001](#)

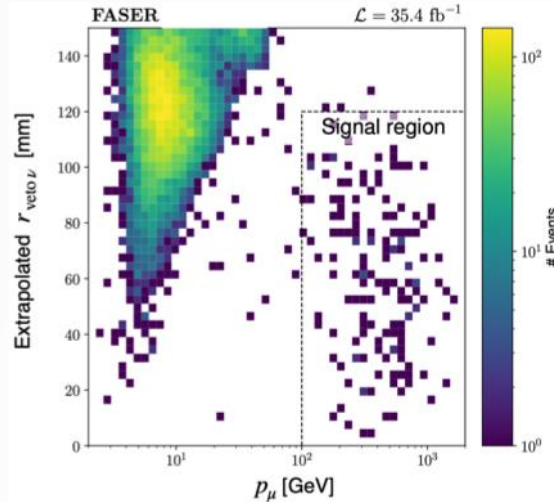
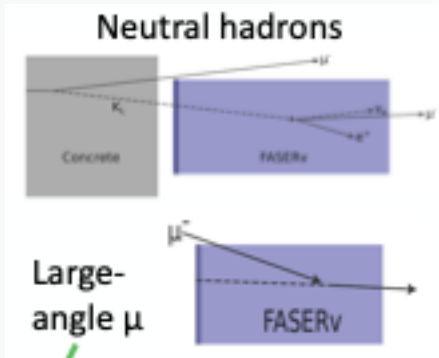
Liverpool



Physics highlights: FASER (2)

► First direct observation of neutrinos and measurement of ν_e and ν_μ interactions

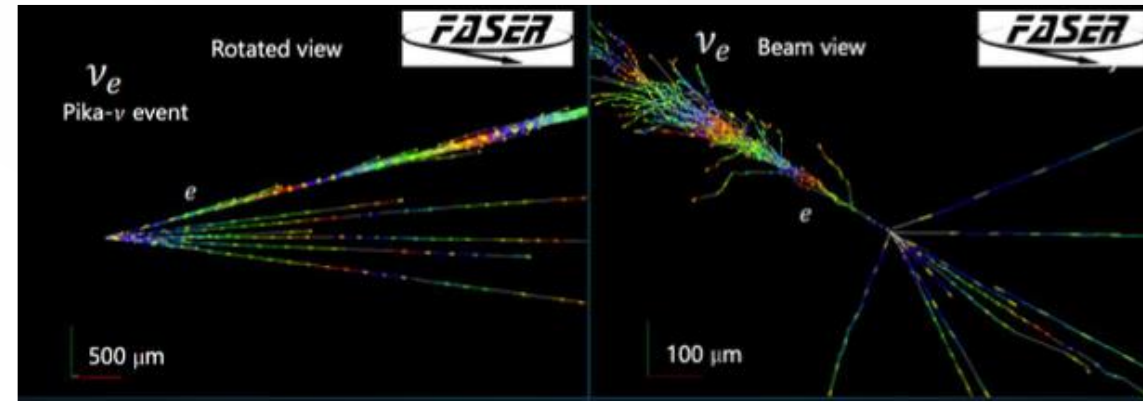
[PRL 131 \(2023\) 3, 031801](#)



Liverpool,
Manchester,
RHUL, Sussex

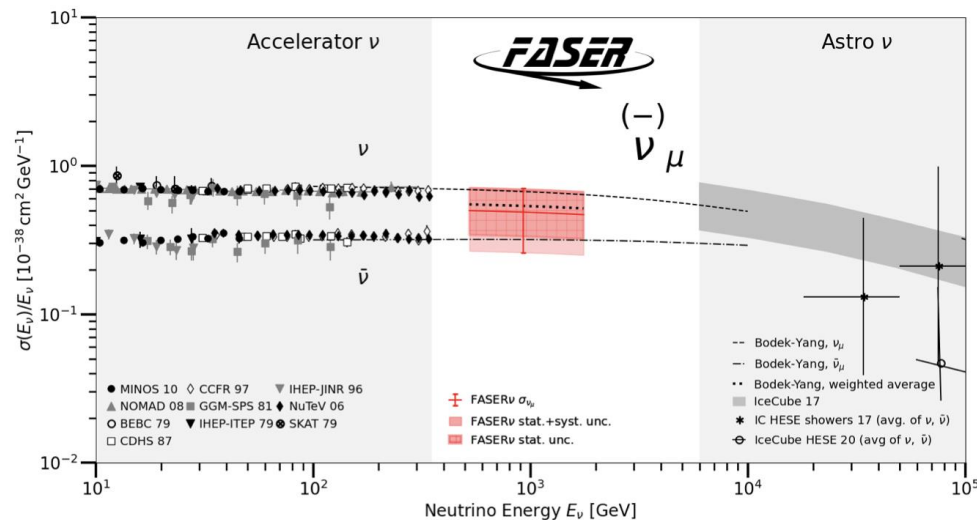
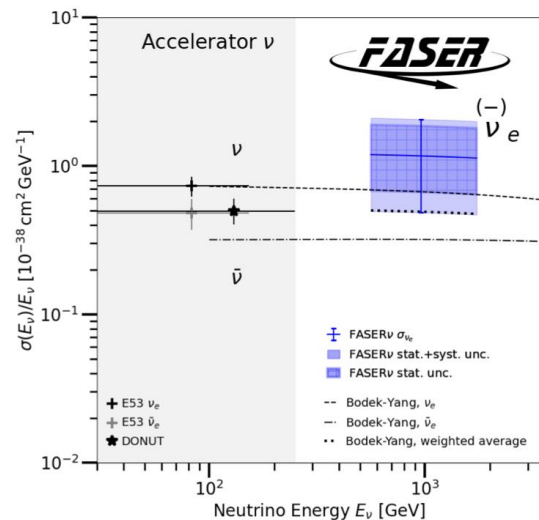
[PRL. 133,
021802 \(2024\)](#)

Interactions in emulsion detectors (FASER ν)



Observed: 153+12-13 ν_m interactions

4 ν_e and 8 ν_μ candidates observed, also in TeV range



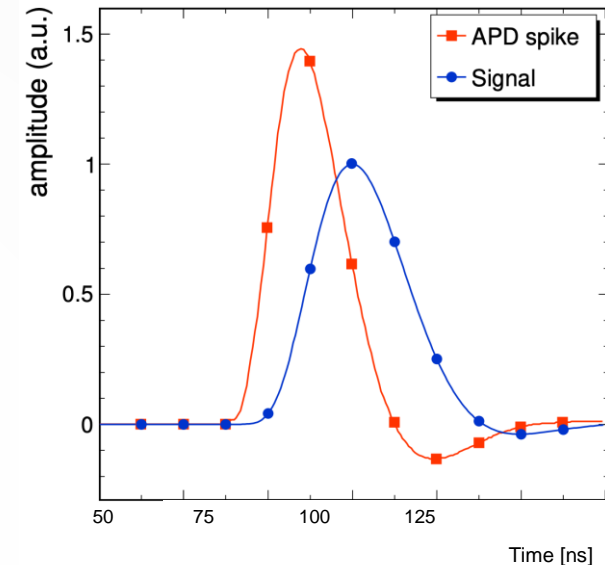
First cross section measurements in the TeV range

CMS ECAL upgrade

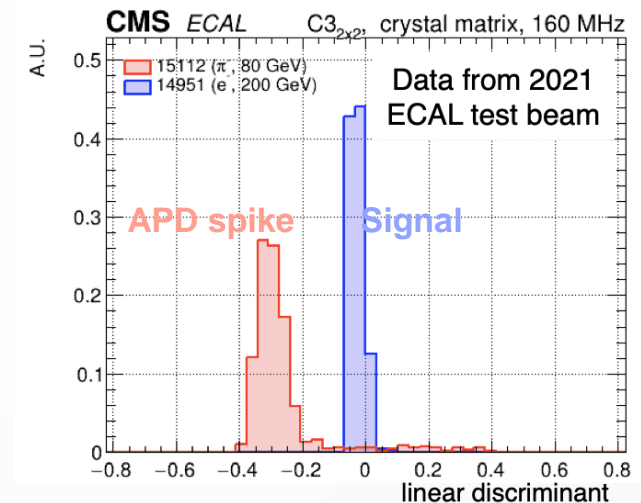
- ← **ECAL Barrel upgrade for Phase 2**
 - ← **New on-detector and off-detector electronics**
 - ← **shorter pulse shaping and faster sampling**
 - ← improved pileup suppression and precise timing measurements, targeting $\sigma_t \sim 30\text{ps}$ for $H \rightarrow \gamma\gamma$ photons
 - ← much improved rejection of APD spikes
 - ← **finer granularity information available at L1**
 - ← allows for improved algorithms in more powerful FPGA boards

← UK contributions

- ← **Algorithm firmware to reject APD spikes at L1**
 - ← using improved pulse shape discrimination
- ← **Optical fibre router to transmit crystal data between off-detector boards**
 - ← to allow for the computation of more advanced shower-shape/cluster variables at L1



APD spike and EM signal pulse shapes

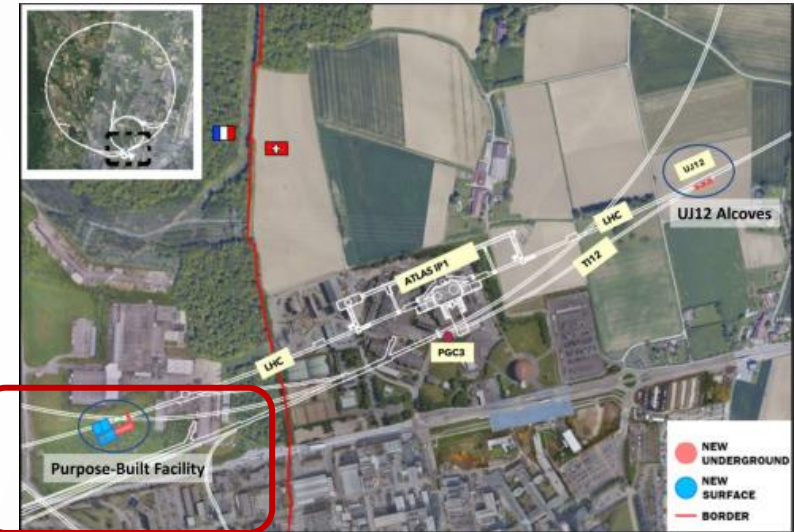
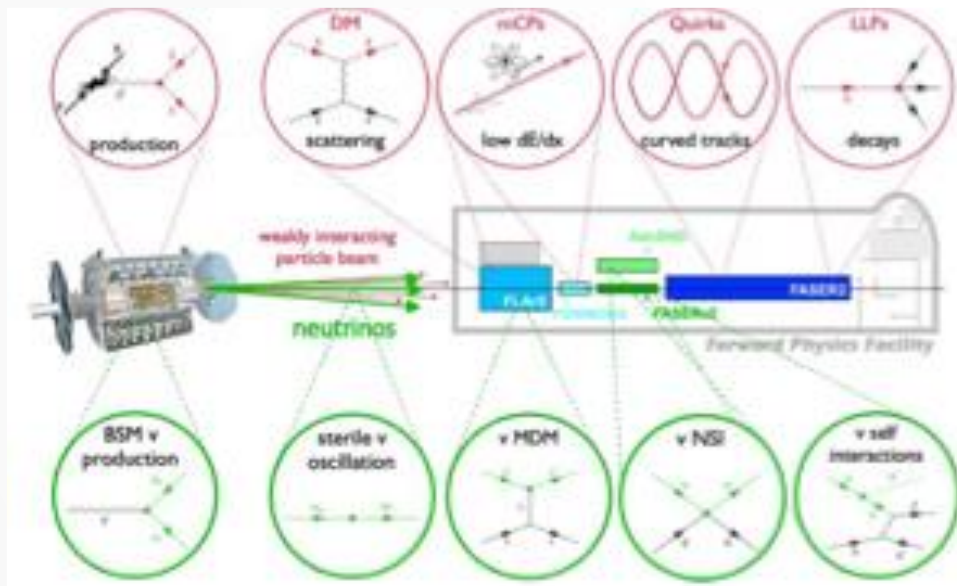
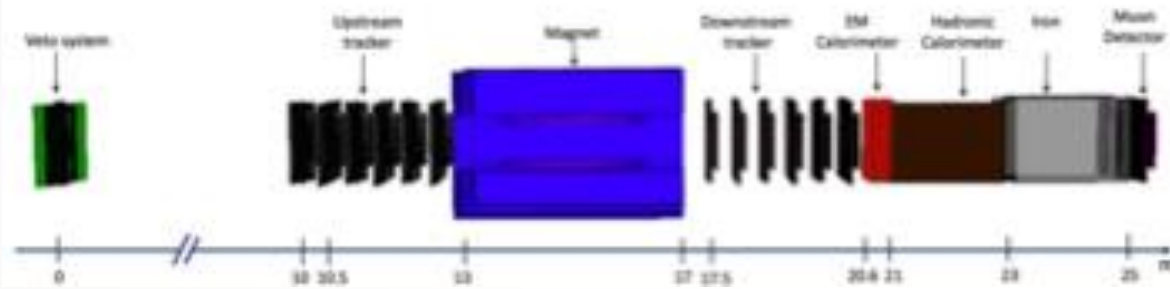


Spike rejection via pulse shape discrimination

FASER @ HL-LHC: a totally different scenario

- ▶ FASER has been recently approved to run in Run 4 **as is**. Nonetheless:
- ▶ In the assumption that a totally new facility, the Forward Physics Facility, is supported and goes ahead, a totally new, different scenario of opportunities arise

FASER-2



FASER-2 as part of a suite of experiments host at the FPF

Feasibility and potential detector layout studies carried out by UK-FASER institutes, Oxford, RAL.