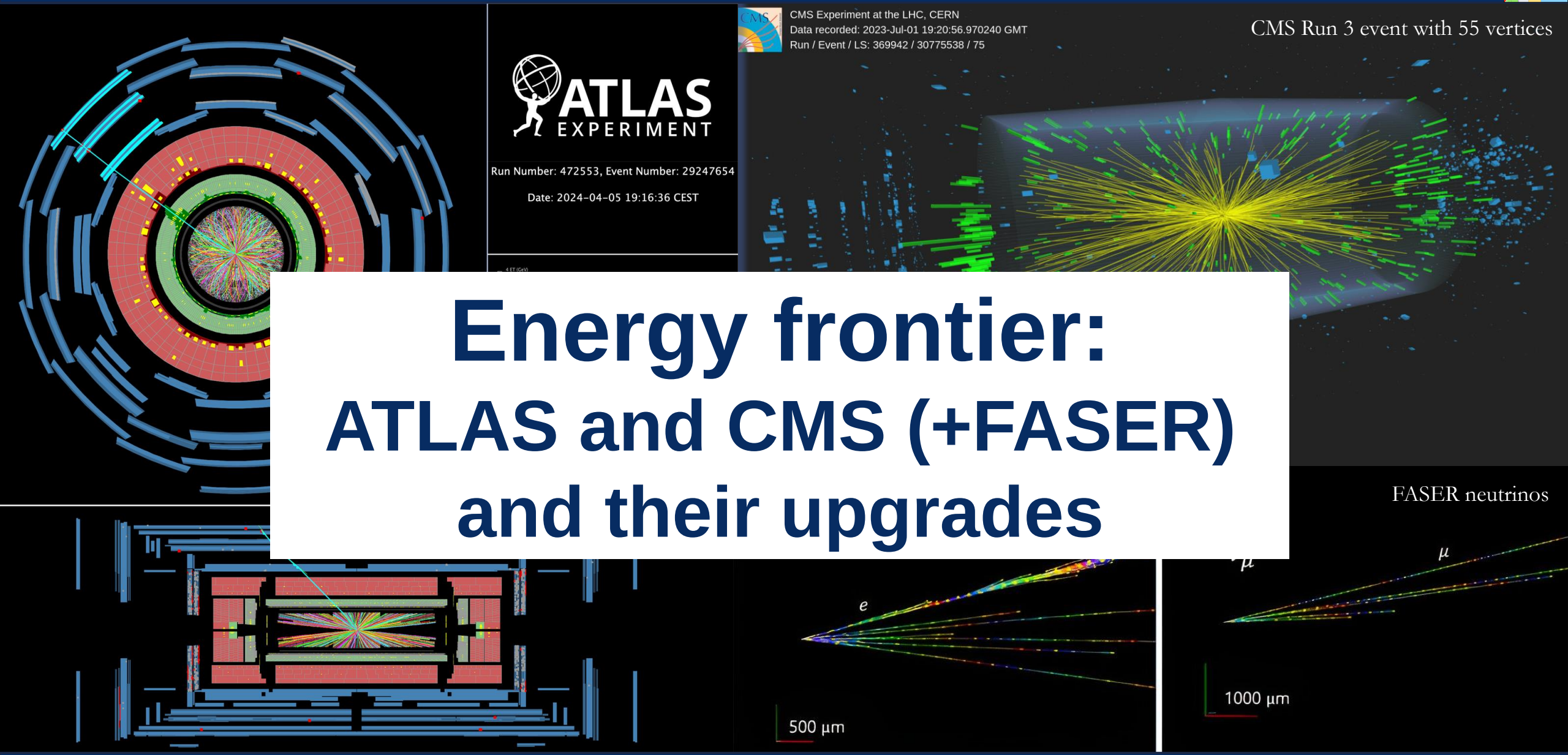


Energy frontier:
ATLAS and CMS (+FASER) and their upgrades

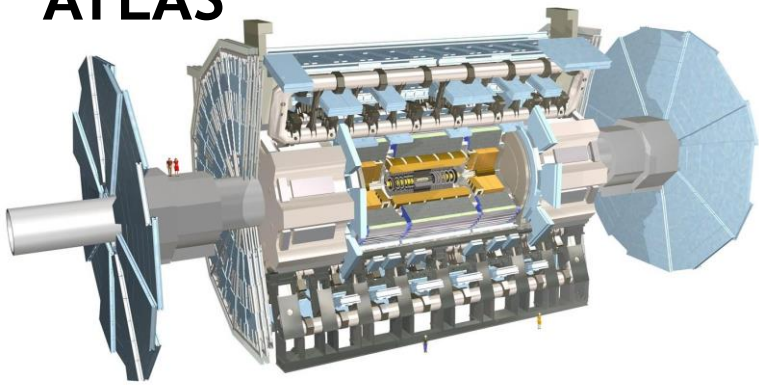
Outline

- **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

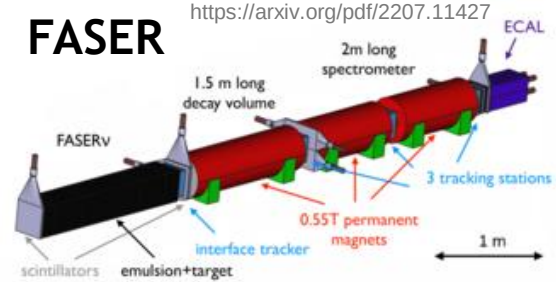
https://cds.cern.ch/record/1095924



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

FASER

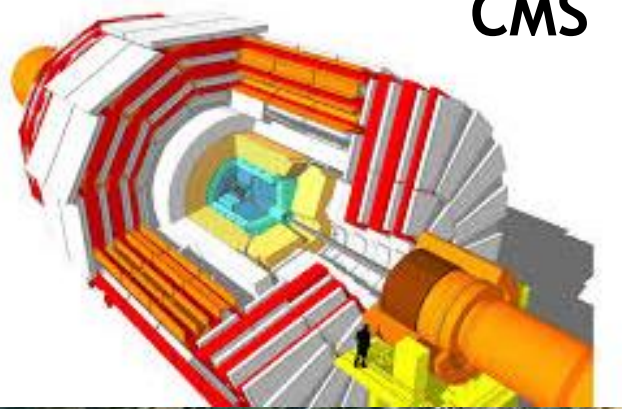
https://arxiv.org/pdf/2207.11427



102 active members
(27 Institutes)

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

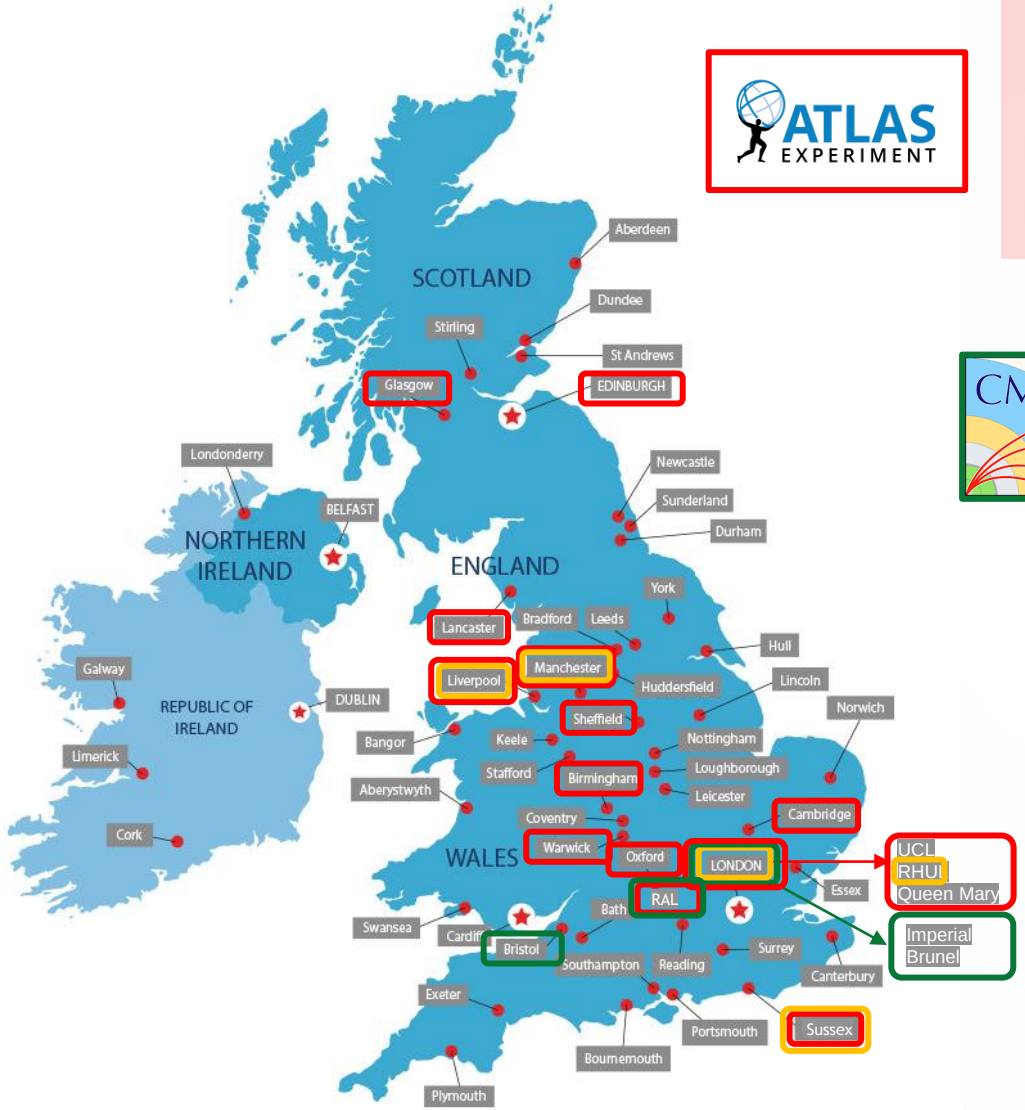
CMS



~ 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



ATLAS EXPERIMENT

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

CMS

- **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)

FASER

- **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
ATLAS	**Phase I:** hardware, firmware and software upgrades for L1Calo and HLT&DAQ systems **Operations:** Inner Tracker (SCT), L1 trigger, , HLT & DAQ systems, data quality, alignment, forward detector **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	ITk-Pixels ITk-Strips Calorimeter Trigger (eFEX & Global) High Level Triggering & DAQ Upgrade software
CMS	**Phase I:** L1 Trigger **Operations:** Silicon Strip tracker, ECAL, Calorimeter trigger system **Physics performance:** e/γ and τ reconstruction and ID, statistics tools, machine learning	ASICs for new tracking system Electronics and algorithms for trigger for: Tracker, ECAL, high granularity endcap calorimeter and L1 trigger
FASER	**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 **Operations and Physics performance:** Run coordinators, Track reco, e/γ reco/ID	

- **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

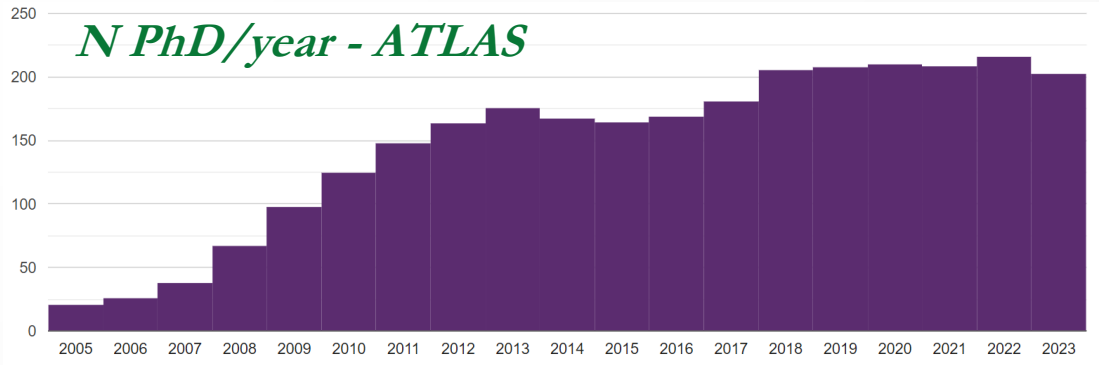
- **Major roles (management)**
  - **ATLAS:**
    - Spokesperson: Dave Charlton (2013-2017, deputy 2009-2013)
    - Physics Coordinator: Dan Tovey (2016-2017); Bill Murray (2014-2015); Dave Charlton (2008-2009)
    - Collaboration Board Chair: UK provided 3 out of the 14 CB Chairs, latest: Max Klein (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 Devies (2017-2019)
    - Project leaders for L1-Trigger, HLT, HGCAL, 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)
- **E**arly **C**areer **R**esearches are **essential for physics exploitation,** actively participate in operations and maintenance of the experiments, held regular physics meetings, dedicated workshops and fora:
  - Significant decline observed in number of postdocs funded for Energy Frontier exploitation in the past decade, partially mitigated by 2023 uplift on STFC-CGs → a threat if not adequately addressed
- **PhD students**: a healthy profile overall, to be watched-out closely
  - Number of PhD students enrolled in **ATLAS-UK** since 2005 → considering length of PhD of 3.5 yr, this corresponds to **~ 650 students** awarded PhD
  - **More than 110 PhD** students enrolled in CMS in the past decade
  - **6 PhD** enrolled in FASER students since 2020 (1 graduated, 1 finishing)

Some difficulties experienced in enrolling PhDs on Energy Frontier experiments → diverse possible reasons

Supported by STFC, CDTs, matched-funding partners (e.g. RAL, DESY, industry)



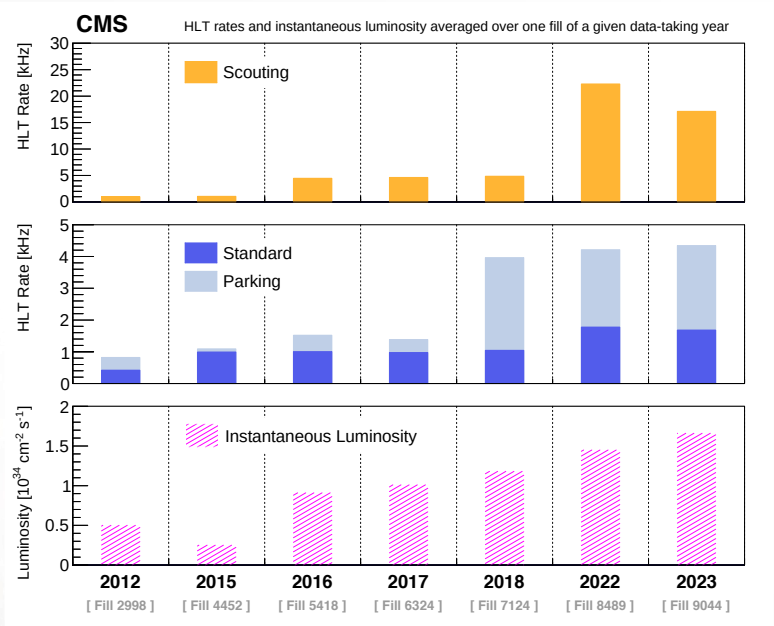
New ideas and cutting-edge technologies

- 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

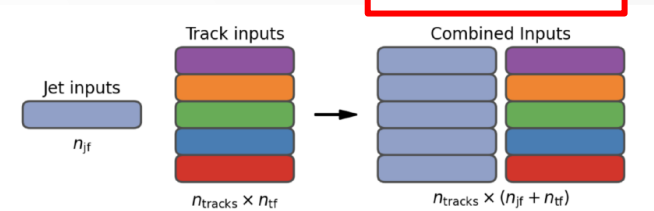


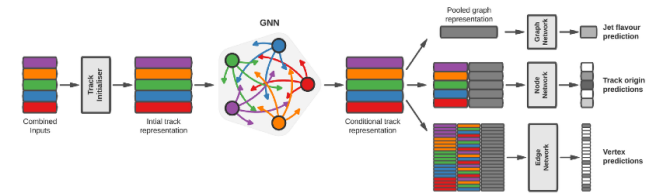
https://cms.cern/news/same-lhc-same-cms-more-physics

Bristol, Imperial, RAL

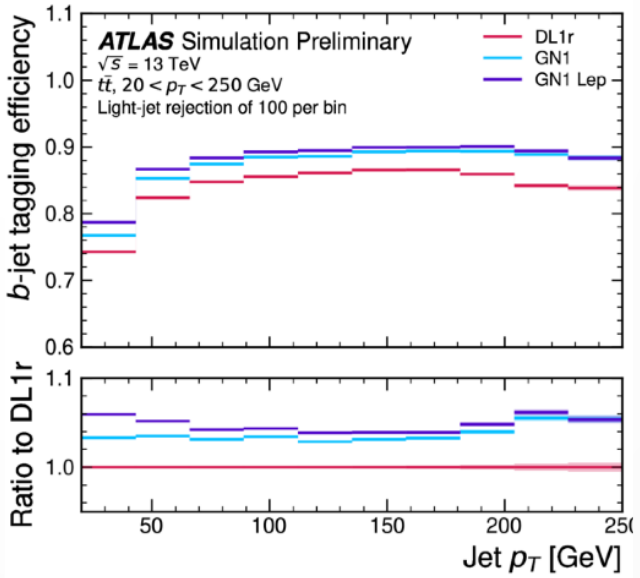
Flavour tagging: b and c jets

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

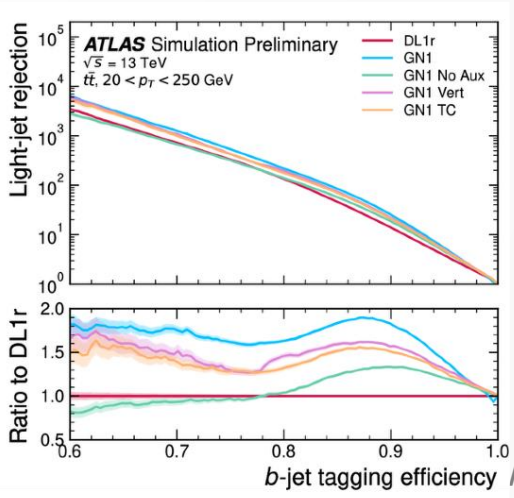




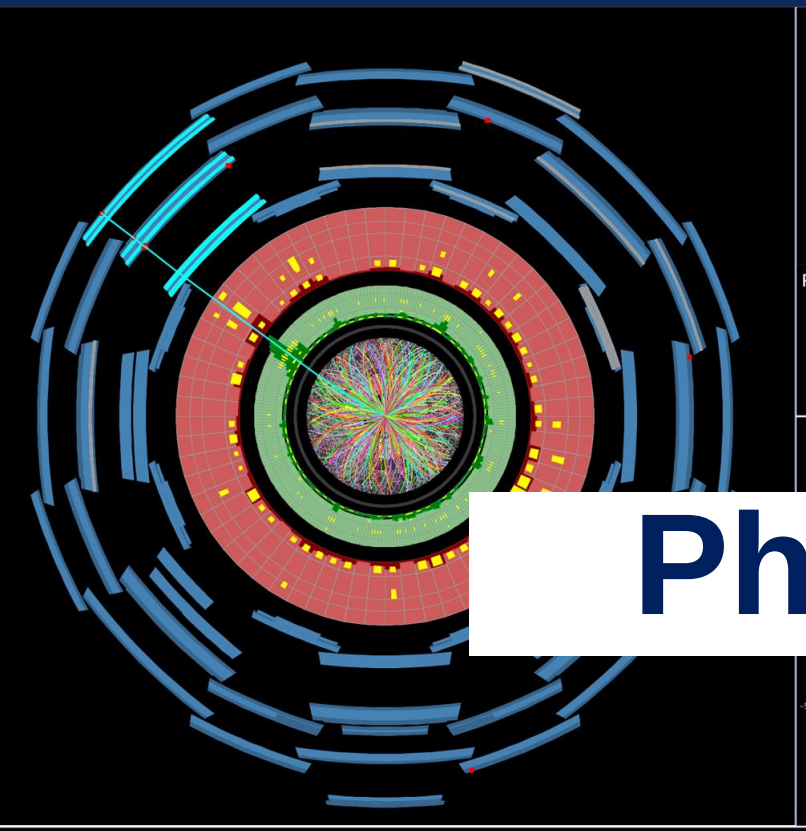
ATL-PHYS-PUB-2022-027

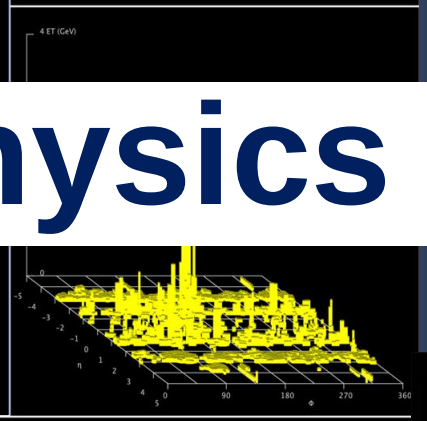


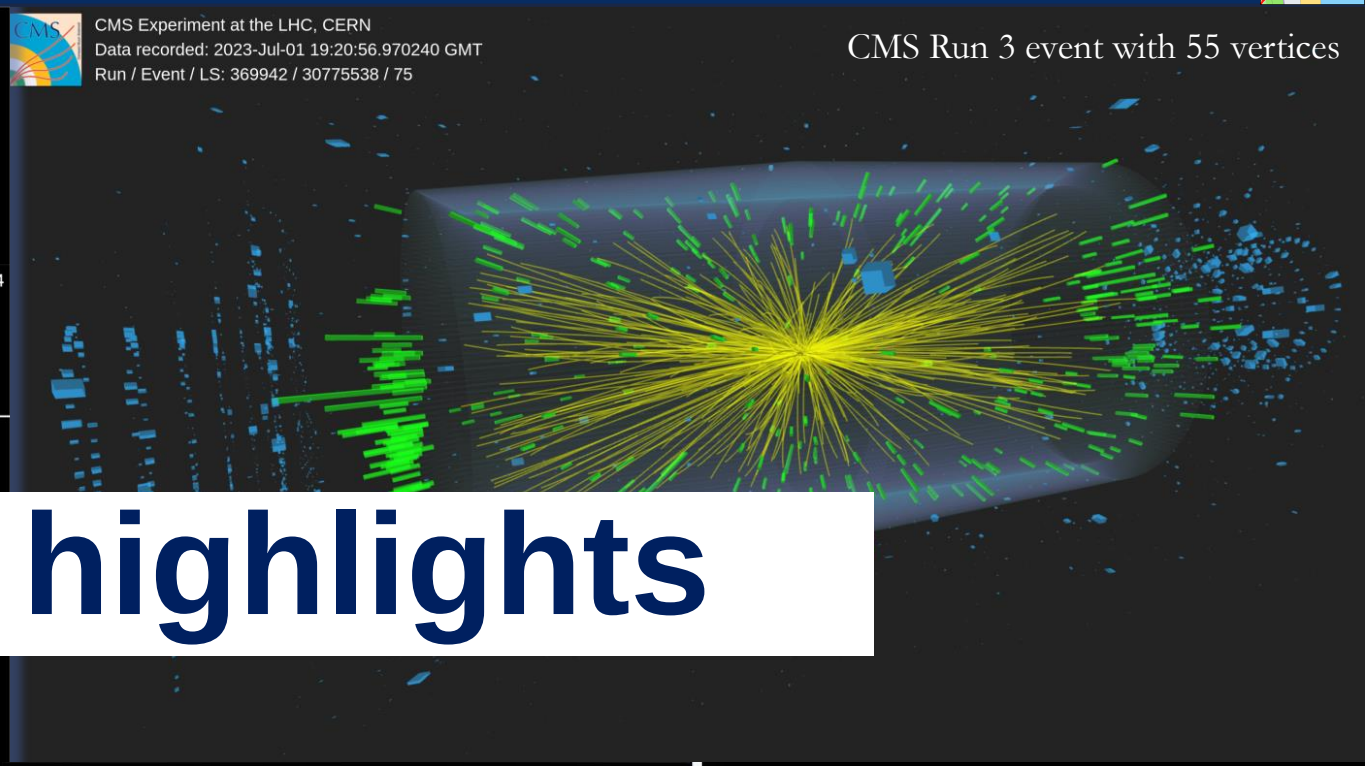
Significantly improved b-tag/c-tag efficiency and light-jet rejection



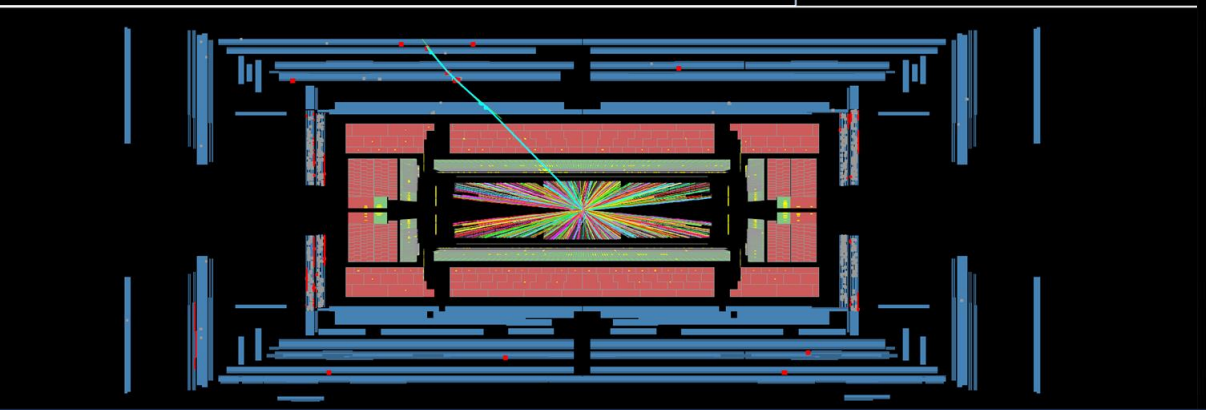
Liverpool, Oxford, UCL, Warwick

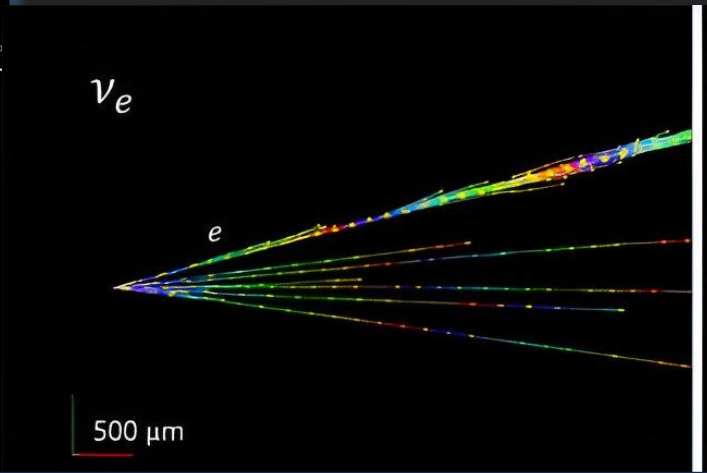


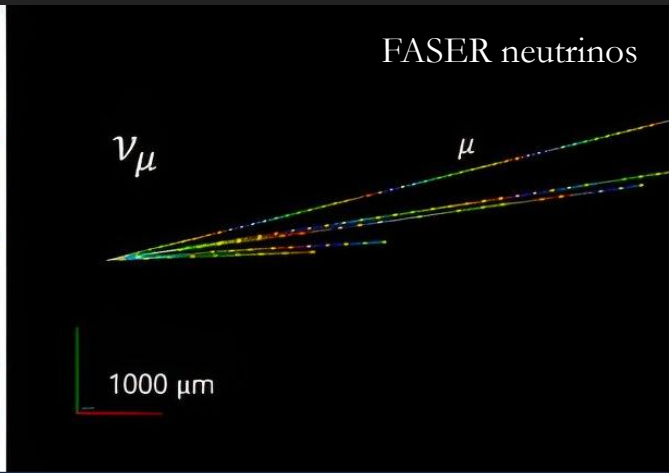




Physics highlights







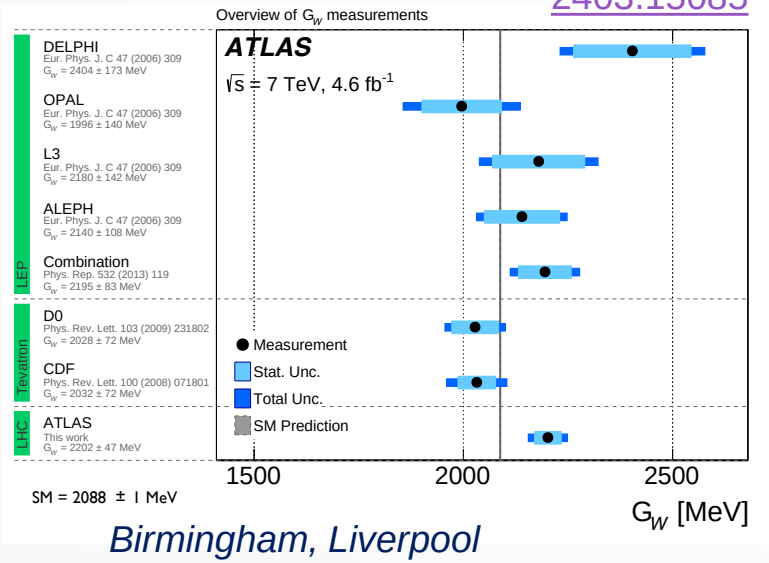
Physics strengths and highlights: ATLAS

- 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

2403.15085

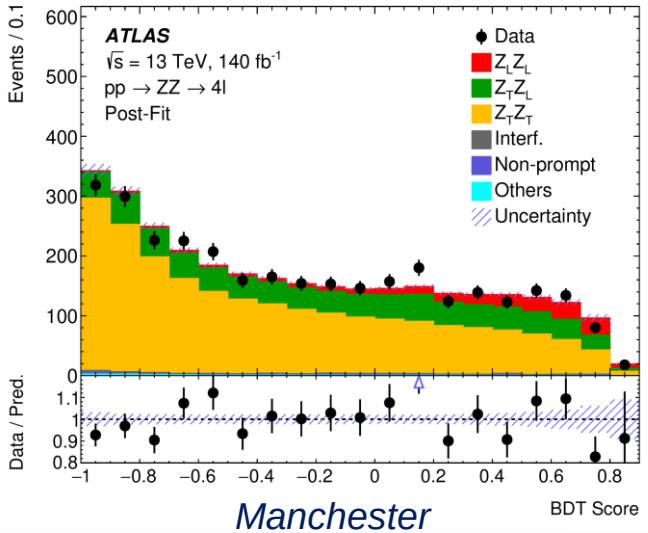


Birmingham, Liverpool

Multi-boson measurements

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

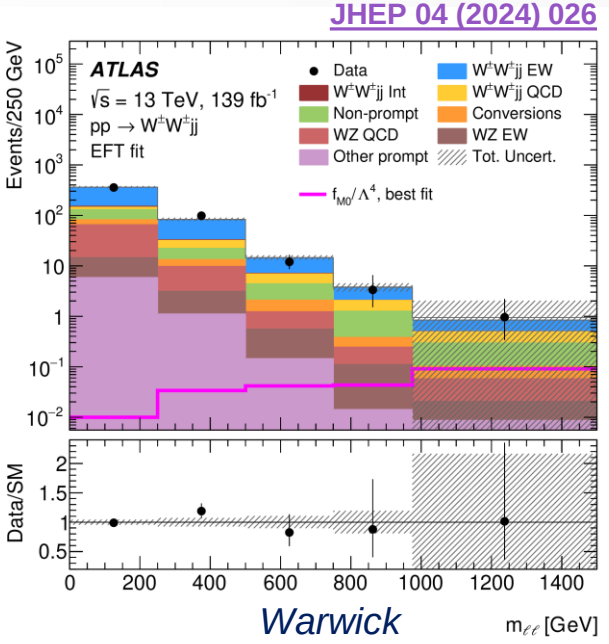
JHEP 12 (2023) 107



Manchester

Same-sign WWjj in VBF

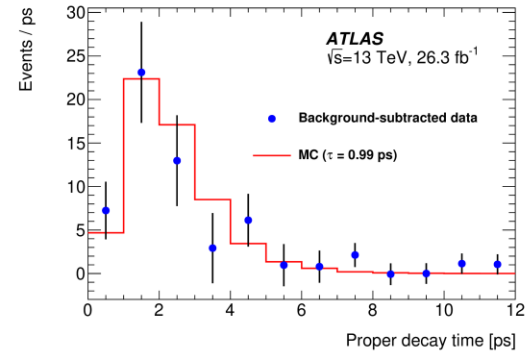
JHEP 04 (2024) 026



Warwick

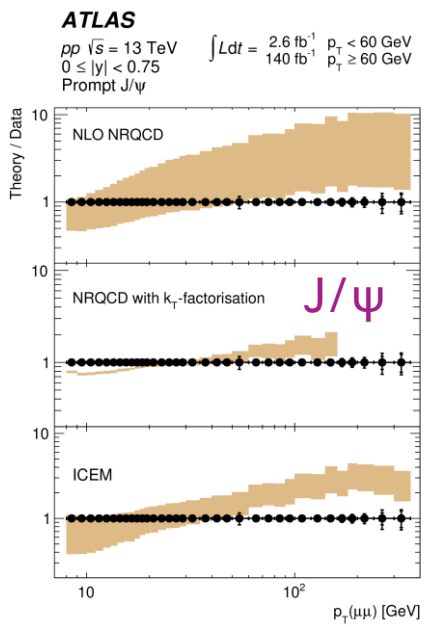
Highlights: ATLAS B and Top physics

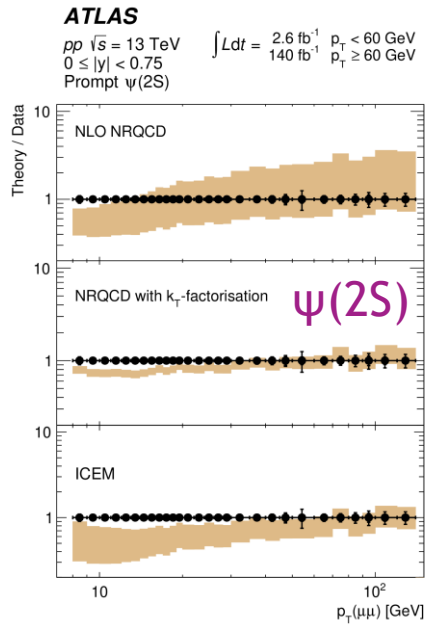
- **B physics:** UK-led flagship analyses such as **$B_s^0 \rightarrow \mu^+\mu^-$ effective lifetime** and measurements of the production cross-sections of **J/ψ** and **ψ(2S) mesons** (widest momenta range to date).



JHEP 09 (2023) 199

Sussex





Eur. Phys. J. C 84 (2024) 169

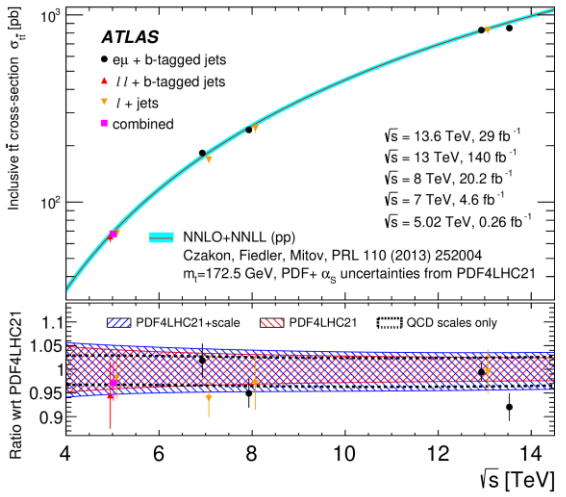
Lancaster, RAL

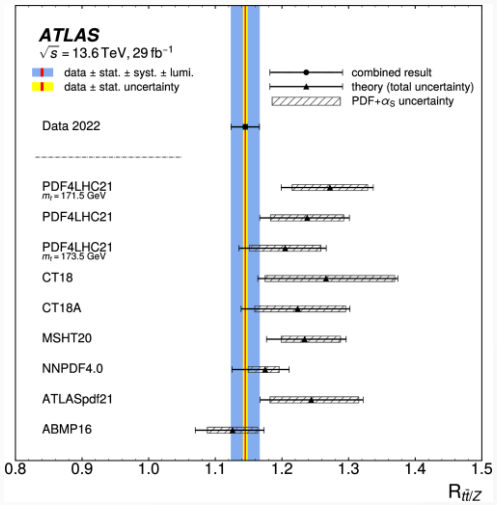
- **Top physics:**

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



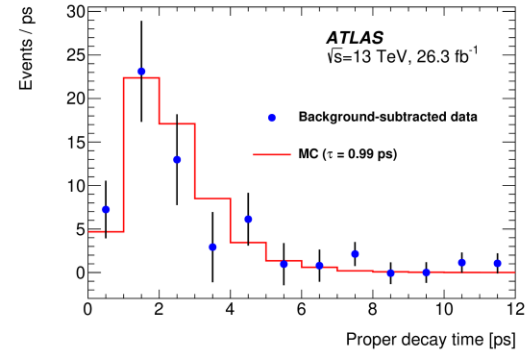


Phys. Lett. B 848 (2024) 138376

Birmingham, Edinburgh, Lancaster, QMUL, Sussex

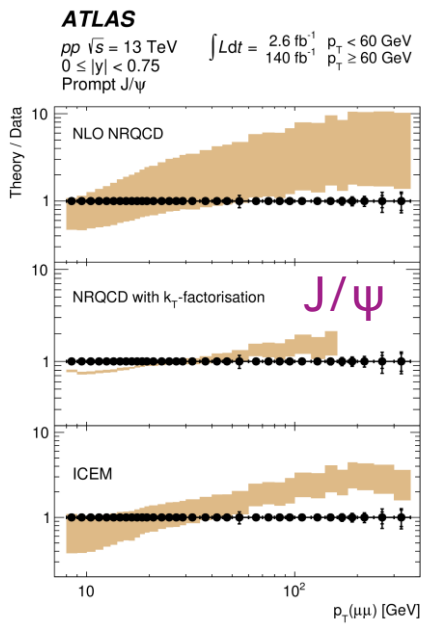
Highlights: ATLAS B and Top physics

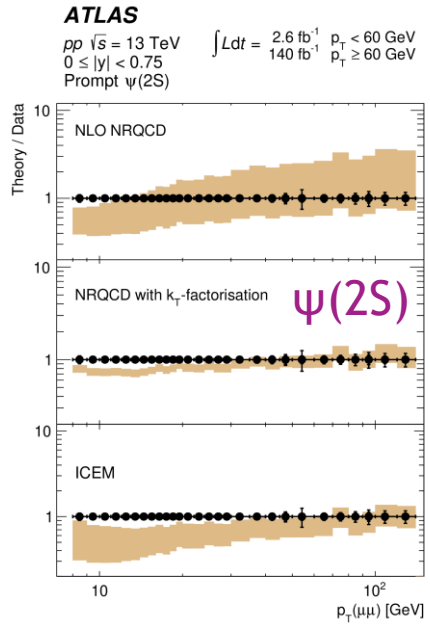
- **B physics:** UK-led flagship analyses such as **$B_s^0 \rightarrow \mu^+\mu^-$ effective lifetime** and measurements of the production cross-sections of **J/ψ** and **ψ(2S) mesons** (widest momenta range to date).



JHEP 09 (2023) 199

Sussex



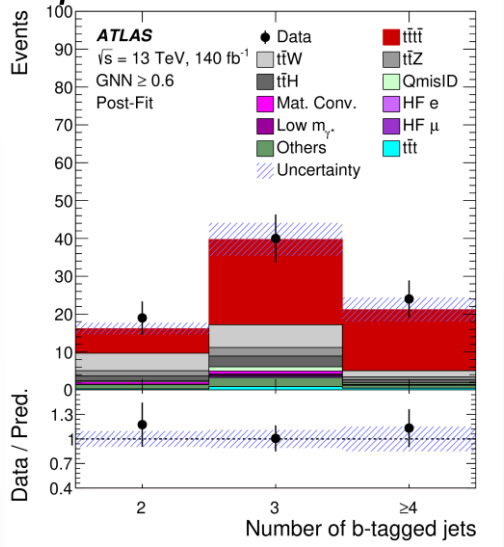


Eur. Phys. J. C 84 (2024) 169

Lancaster, RAL

- **Top physics:**
  - Observation of **4-top process**

4-top

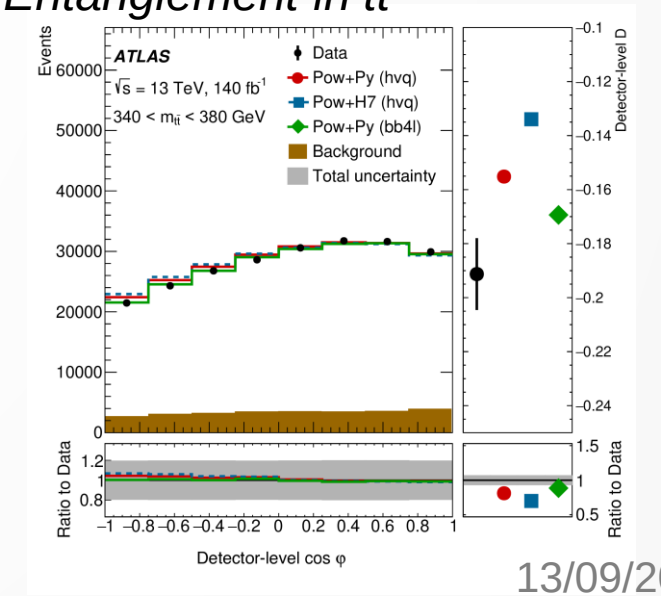


Eur. Phys. J. C 83 (2023) 496

Manchester

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

Entanglement in tt



arXiv:2311.07288

Birmingham, Glasgow, Manchester

Physics highlights: Higgs physics

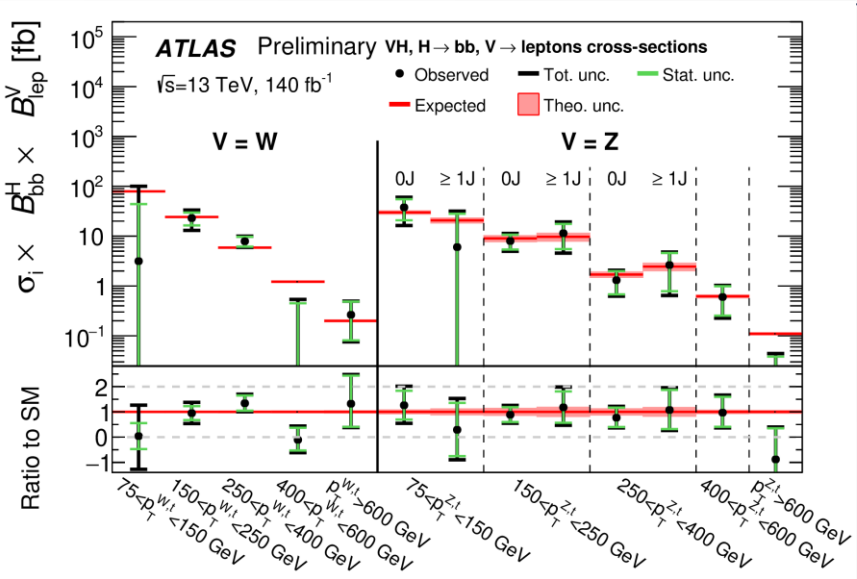
- Simultaneous measurement of **WH/ZH with Higgs to cc/bb**

  → legacy of Run 2 results:

  - H→bb improved by **15%,** H→cc by **a factor of 3**.
  - Cross section measurements in bins of p_T boson

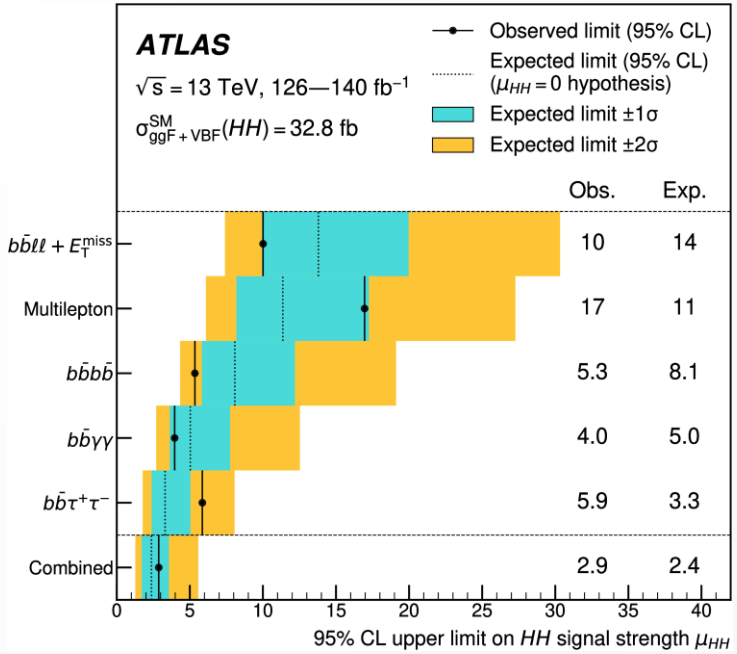
ATLAS-CONF-2024-010

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

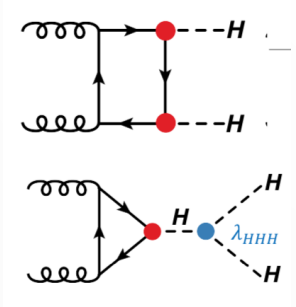


- UK leadership also in ttH; H → ττ, rare H decays
- **EWSB and Higgs-self coupling:** a flagship analysis, with strong commitment from UK institutes in Run 2 and now in Run 3 → **Focus mostly on Run-3 bb and ττ decays (4b, bbττ,bbll)**

Birmingham, Cambridge, Glasgow, Liverpool, Oxford, RHUL, UCL, Warwick



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



Self-coupling

- $\kappa_\lambda \in [-1.2, 7.2]$ ($\kappa_\lambda \in [-1.6, 7.2]$)
- $\kappa_{2V} \in [0.57, 1.48]$ ($\kappa_{2V} \in [0.4, 1.6]$)

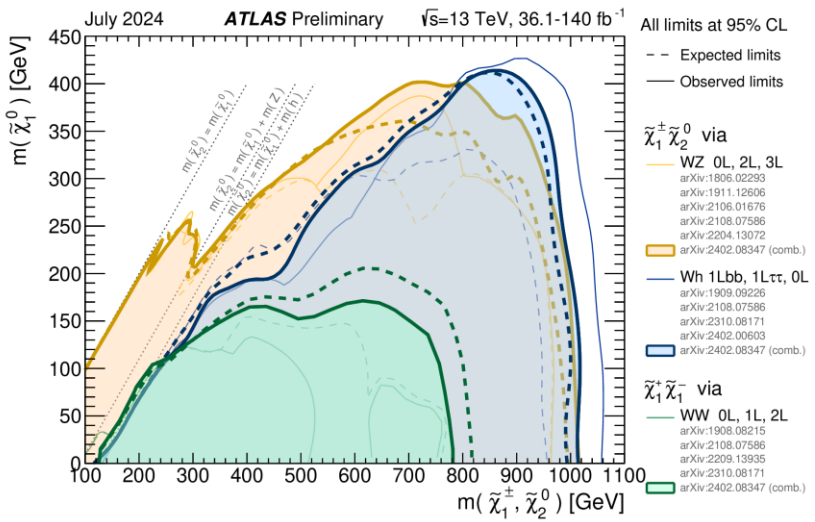
$\kappa_j^2 = \sigma_j / \sigma_j^{\mathrm{SM}}$ coupling modifier parameters

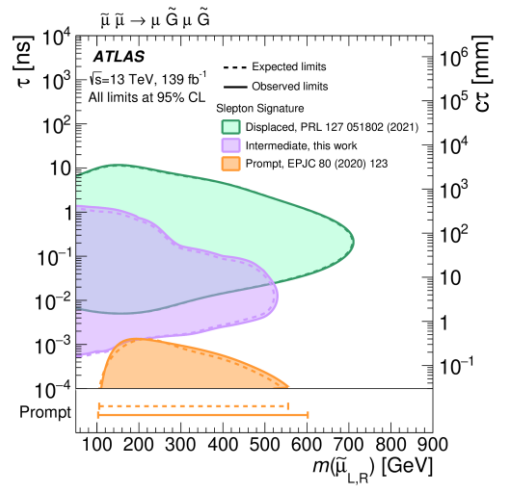
Highlights: ATLAS Searches for new physics

- 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



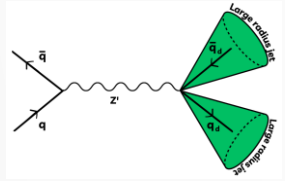


[Phys. Lett. B 846 (2023) 138172](#)

Lancaster

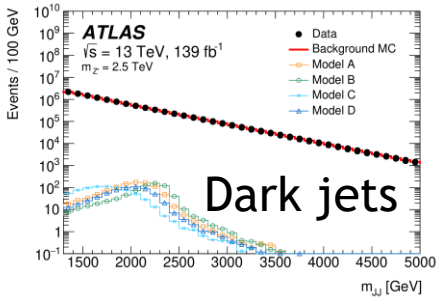
millimeter-displaced slepton

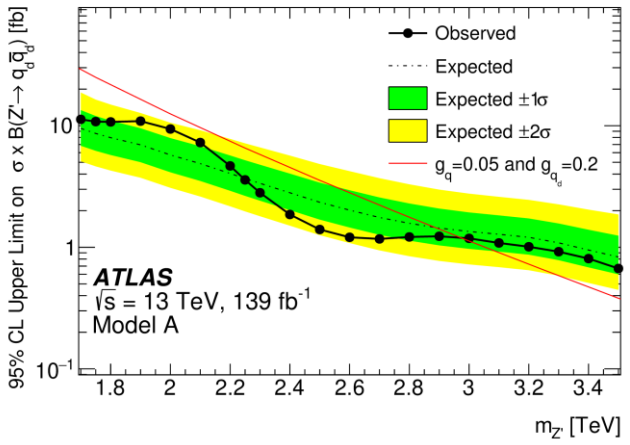
- **Dark-matter** and **hidden sectors → LLP**

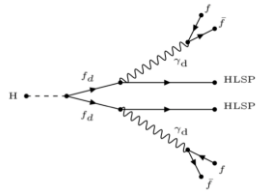


[JHEP 02 (2024) 128](#)

Manchester, QMUL



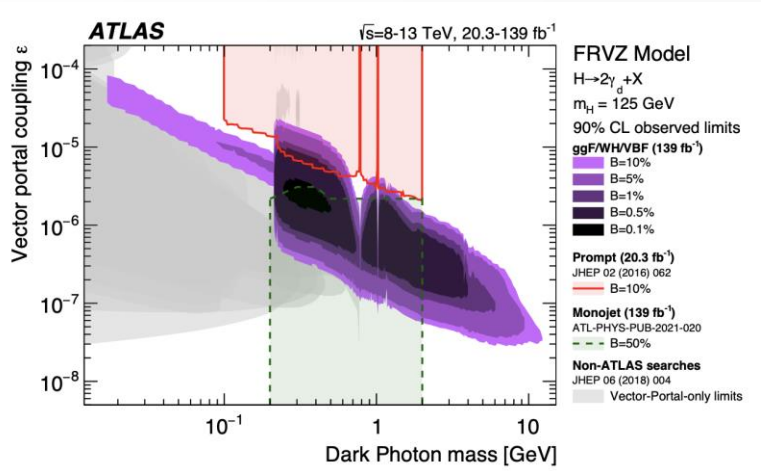




Higgs decaying through **dark photons**
→use lepton-jets

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

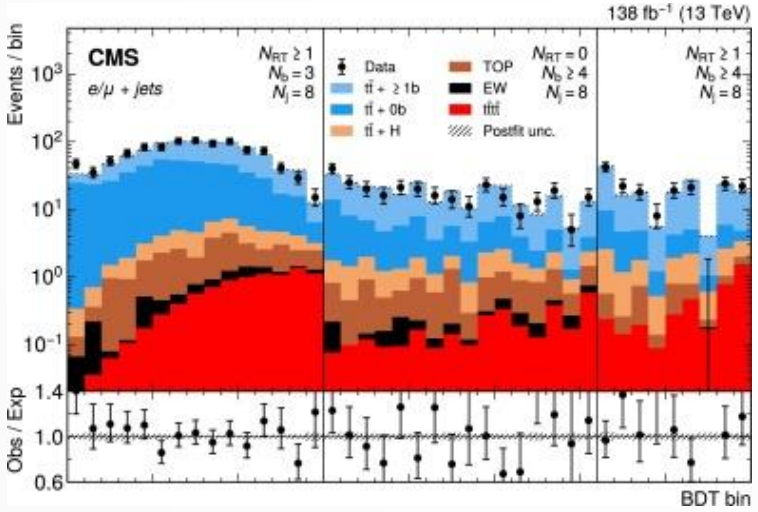
Top physics: long-standing contributions on top-pair and single-top cross sections, top MC modelling etc.

- Recent highlight – **4-top process**
  - **UK** part of first evidence of this important process (later superseded by observation)

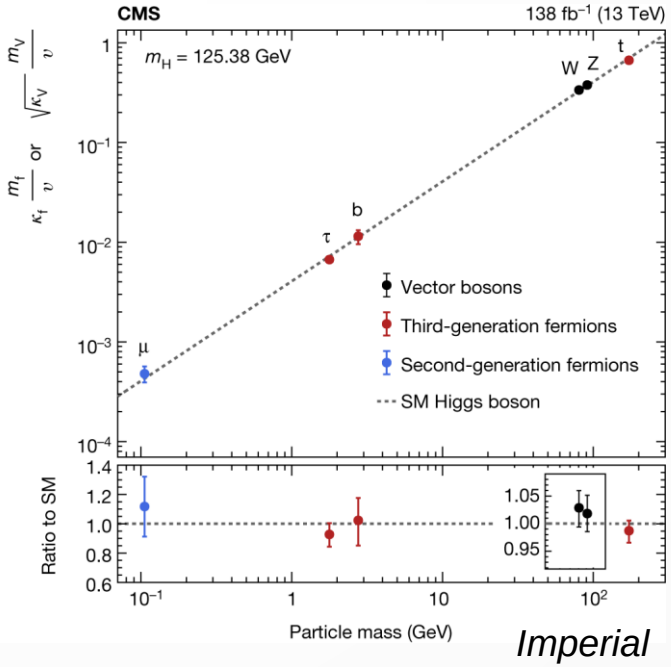
PLB.2023.138076

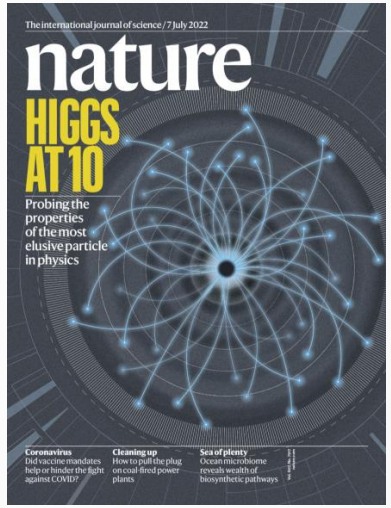
Bristol, Brunel

observed σ
17±4(stat)± 3(syst) fb



Higgs physics: strongly engaged in H→γγ, ττ, e^+e^-, the UK has also led every **single-Higgs combination** effort since Higgs discovery





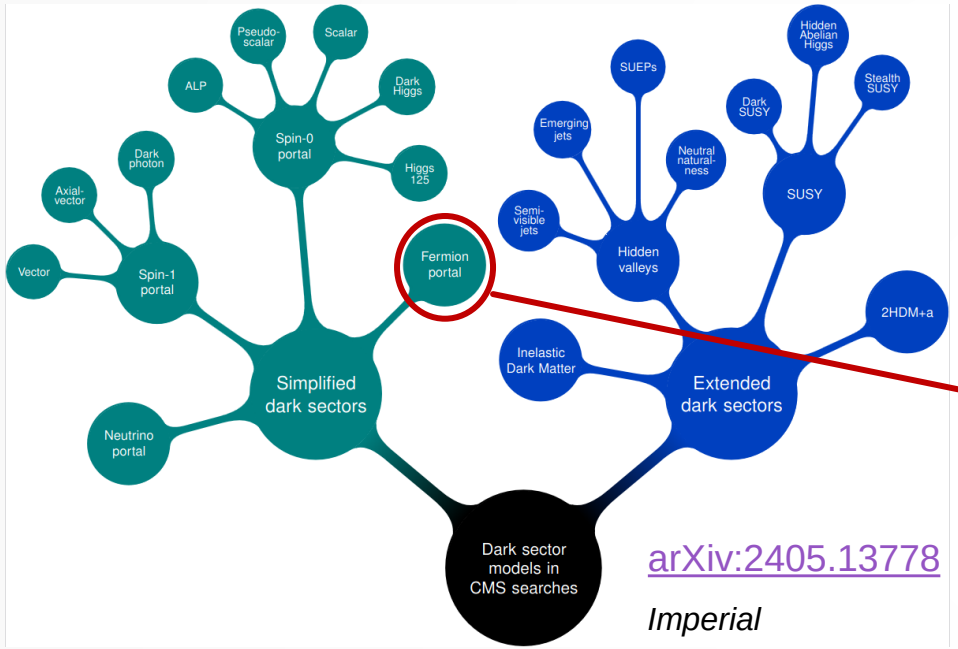
Nature 607, pages60–68 (2022)

(featuring with ATLAS)

Imperial

Physics strengths and highlights: CMS

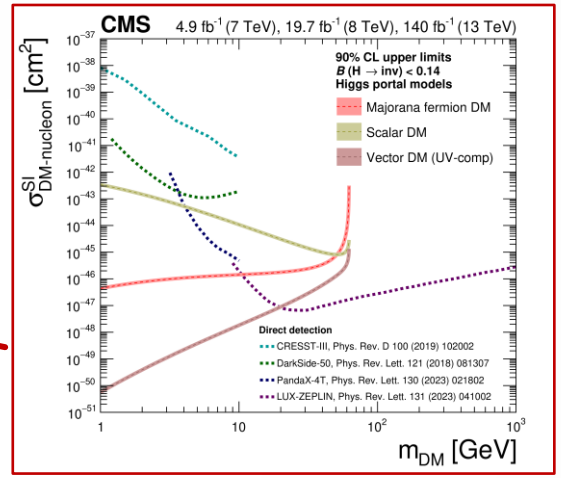
- Among **searches for new physics**, the UK led recent report on **dark sectors** → huge effort to map over 40 results and produce new interpretations

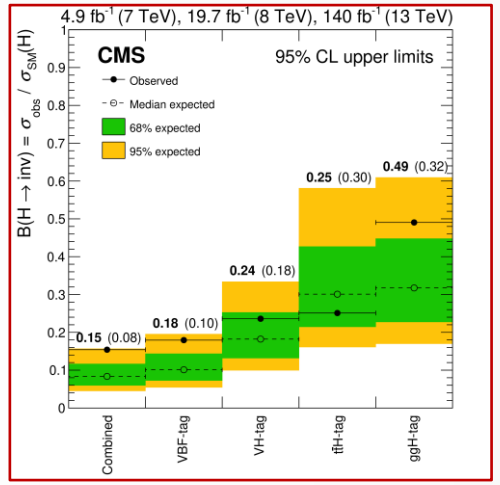


arXiv:2405.13778

Imperial

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





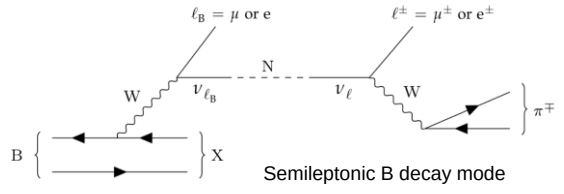
Bristol, Imperial

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

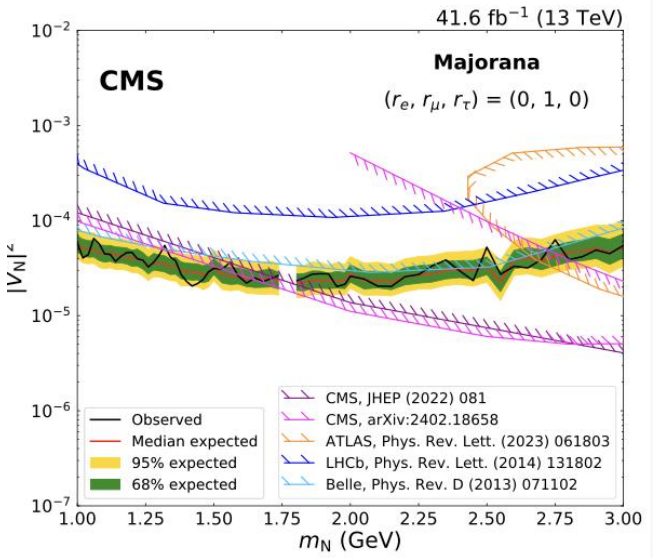
→ based on a special "parked data" stream collected in 2018

JHEP 03 (2024) 105

Imperial

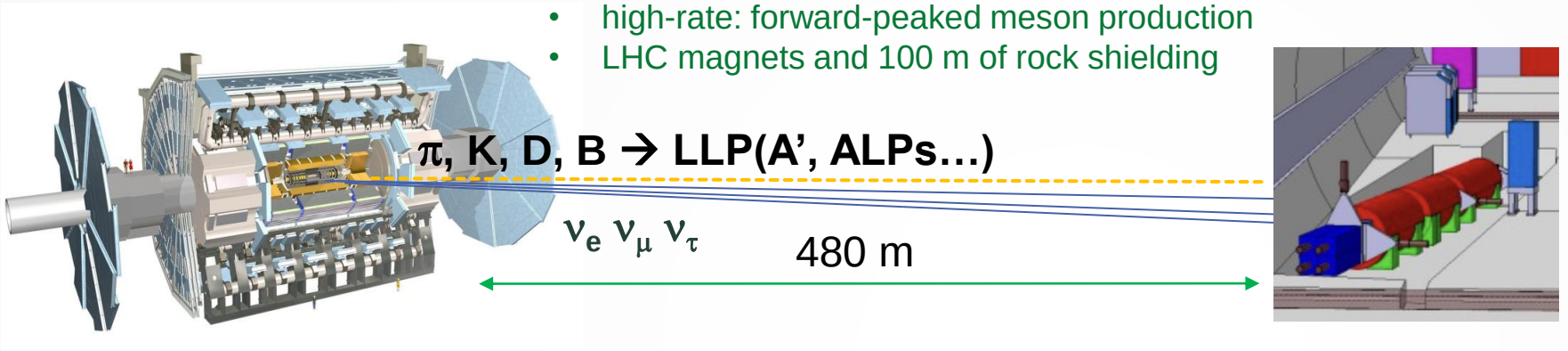


N long-lived, constraints depending on couplings and mass



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



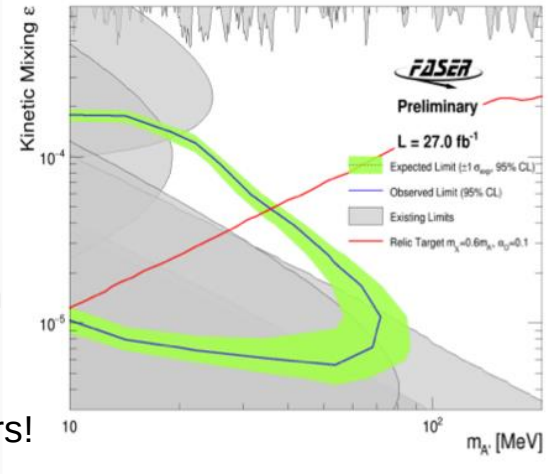
Built with left-over, e.g. ATLAS SCT modules for tracker

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

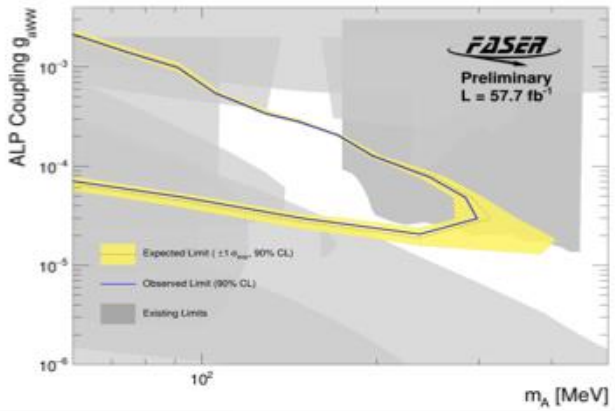
Liverpool, Manchester, Sussex



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



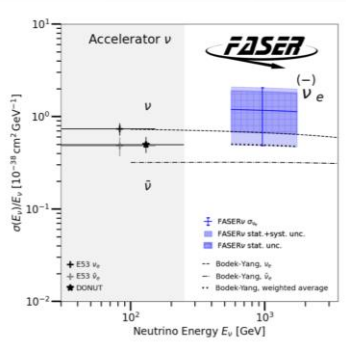
Access very challenging region

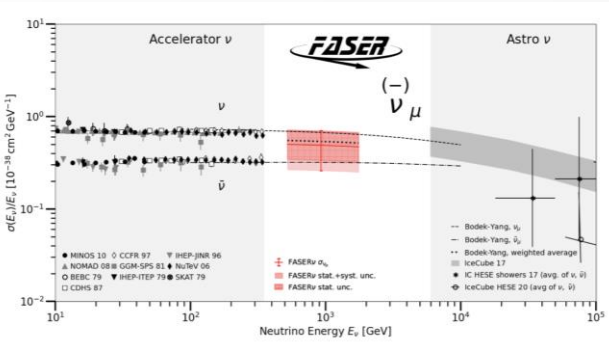
- First **direct observation of ν and ν_e and ν_μ** interaction measurements

PRL 131 (2023) 3, 031801

PRL. 133, 021802 (2024)

Liverpool, Manchester, RHUL, Sussex





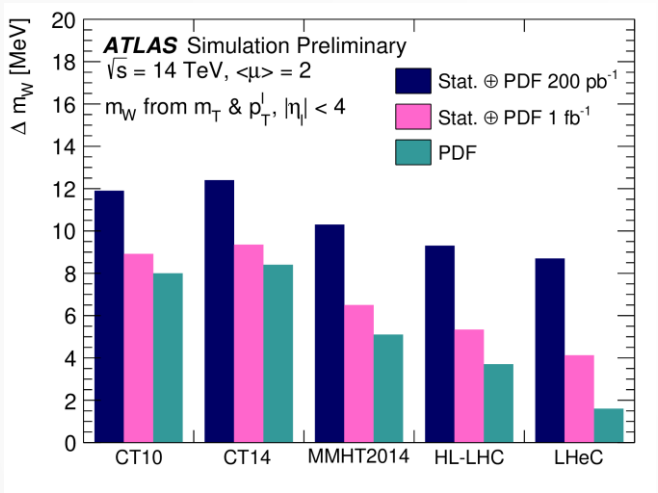
$4\nu_e$ and $8\nu_\mu$ candidates observed in TeV range

The Phase II upgrades

Pushing towards the energy frontier: HL-LHC

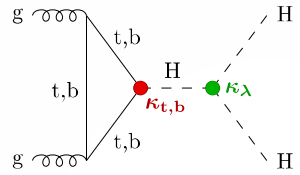
- **HL-LHC prospect studies**, done also to understand the impact of the detectors' performance → strong engagement of **UK-ATLAS** and **UK-CMS** for the Yellow Book reports (2017-19)
  - From SM precision measurements to di-Higgs and new physics searches, huge potential

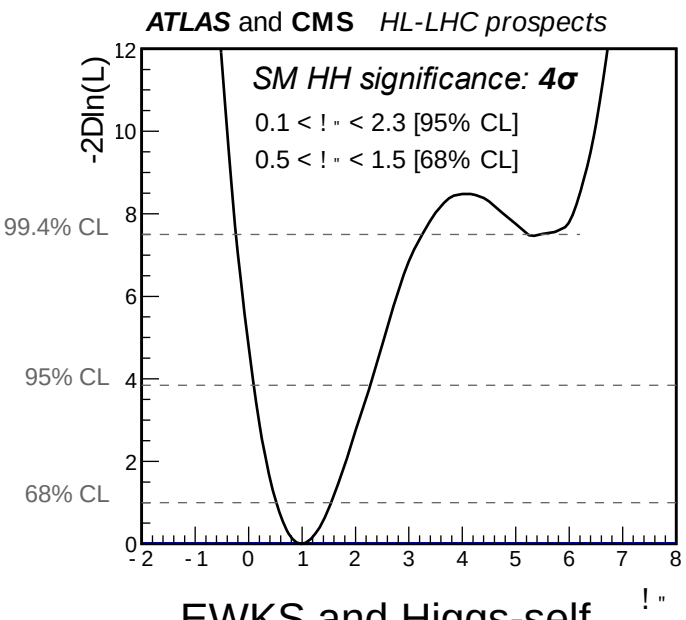
Report on the Physics at the HL-LHC, and Perspectives for the HE-LHC

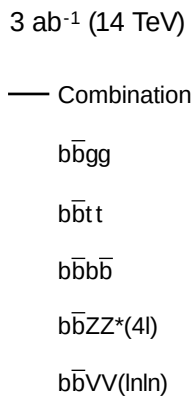


At least a factor of 2 expected in precision for W mass

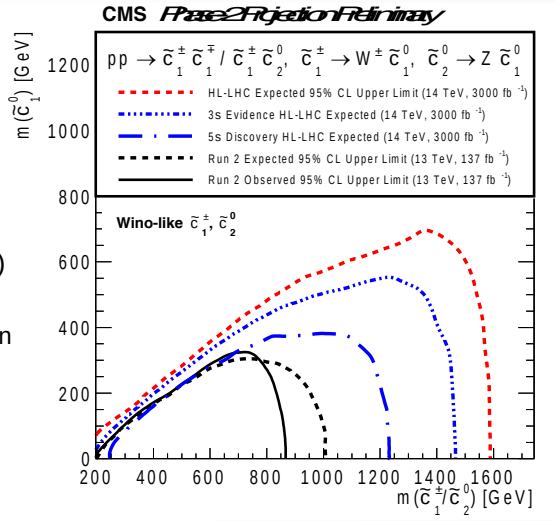
Contribution of many UK institutes…



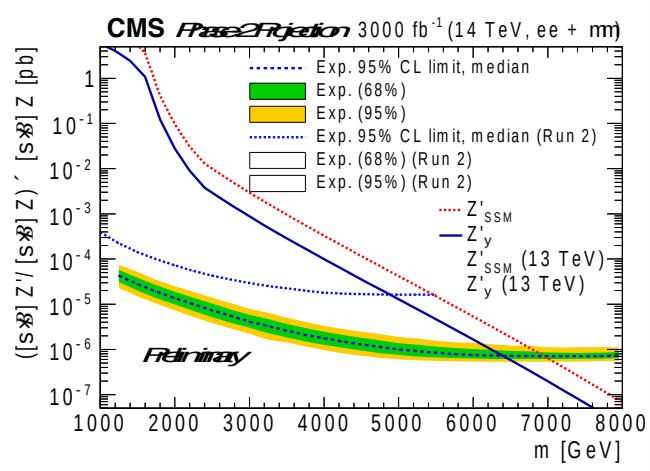




EWKS and Higgs-self coupling evidence

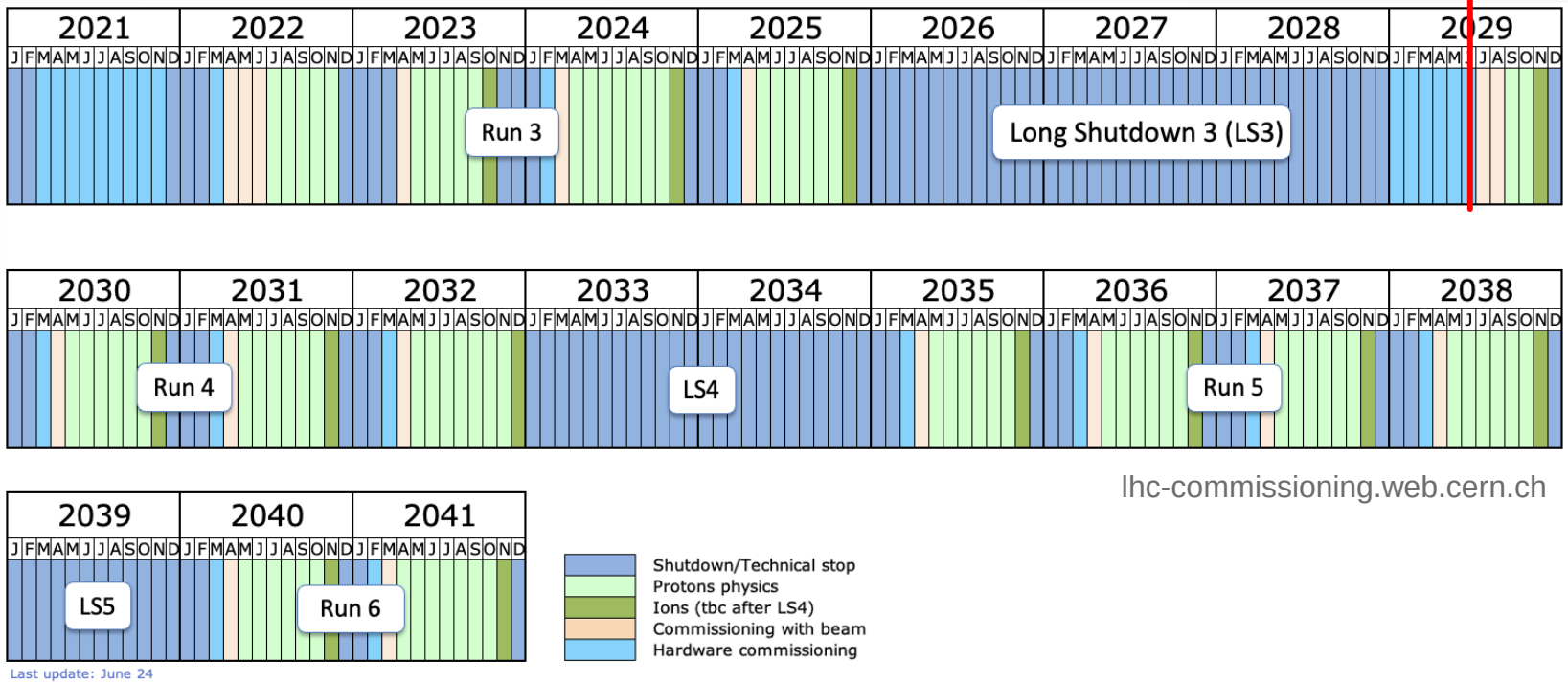


For NP, increase the present reach in mass and coupling by 20-50%

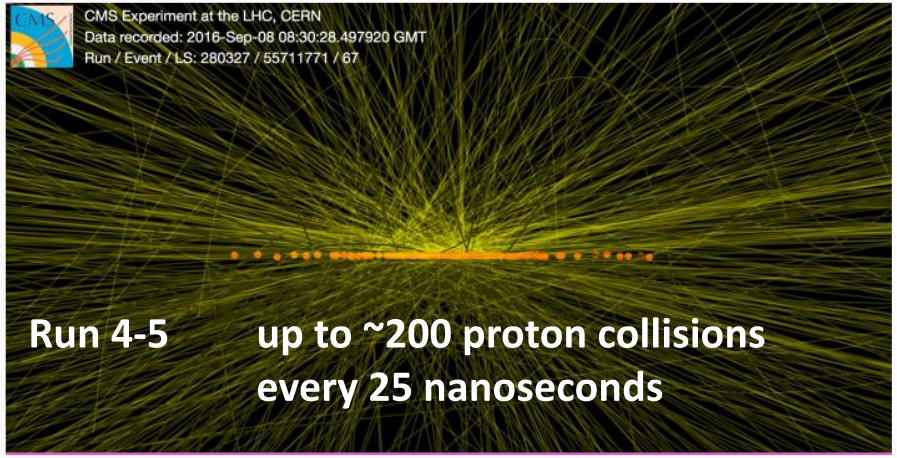


The Phase II upgrades timeline

- 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 x 10^{34} cm^{-2} s^{-1}**
  - **3 ab^{-1} / exp. of integrated lumi @ $\sqrt{s}$ =14 TeV expected**



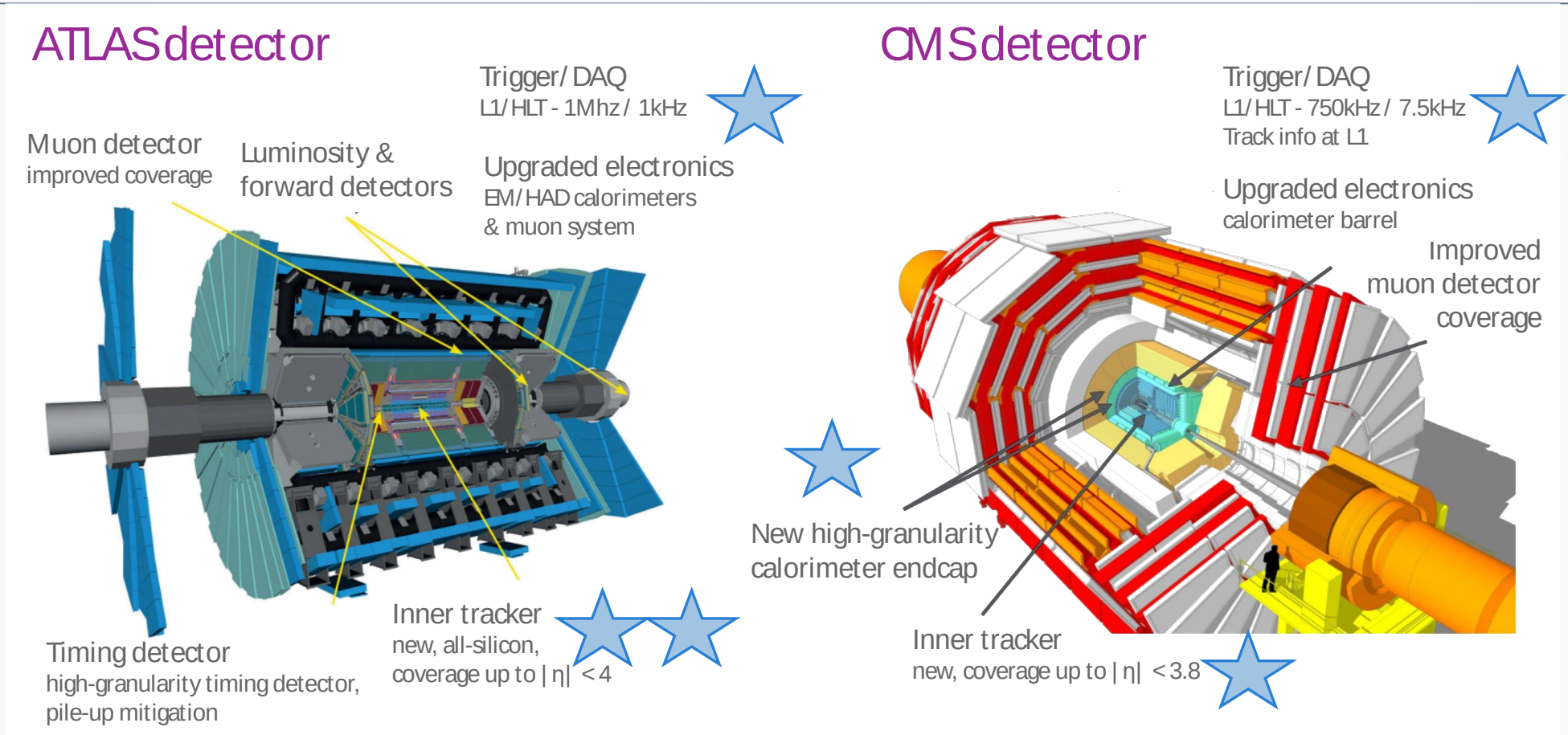
lhc-commissioning.web.cern.ch



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

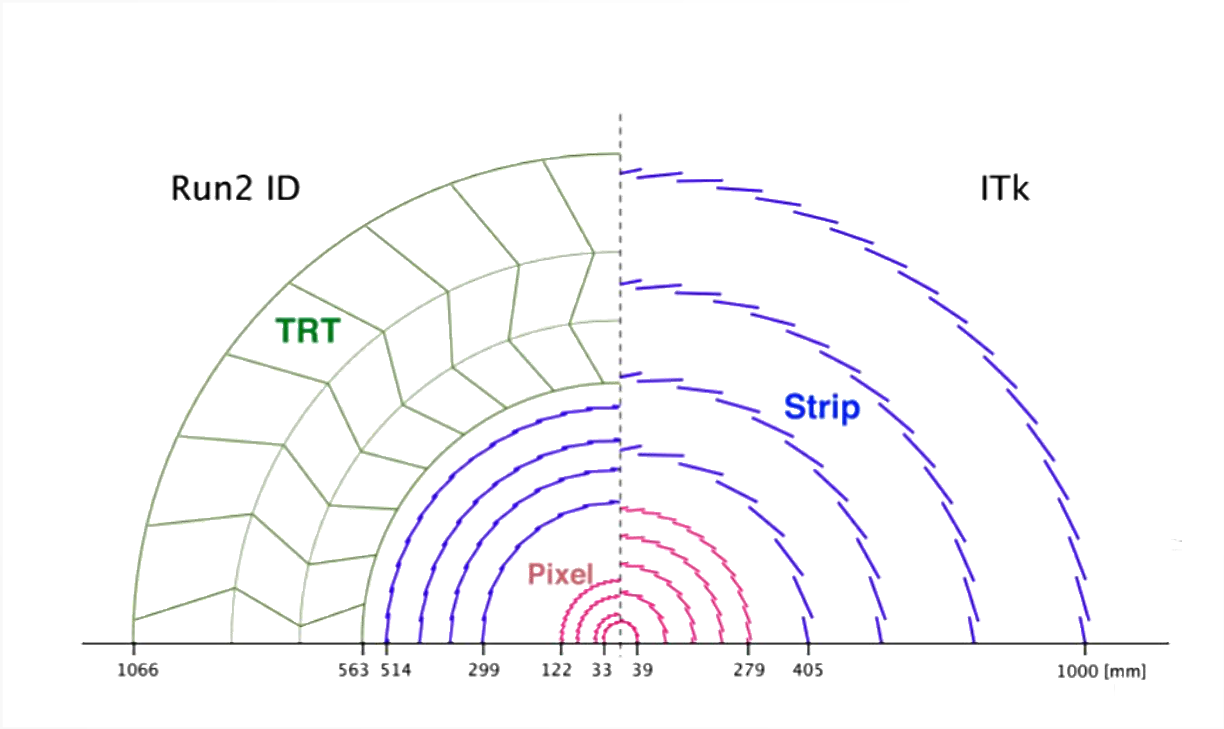
GPDs upgrade programs at glance

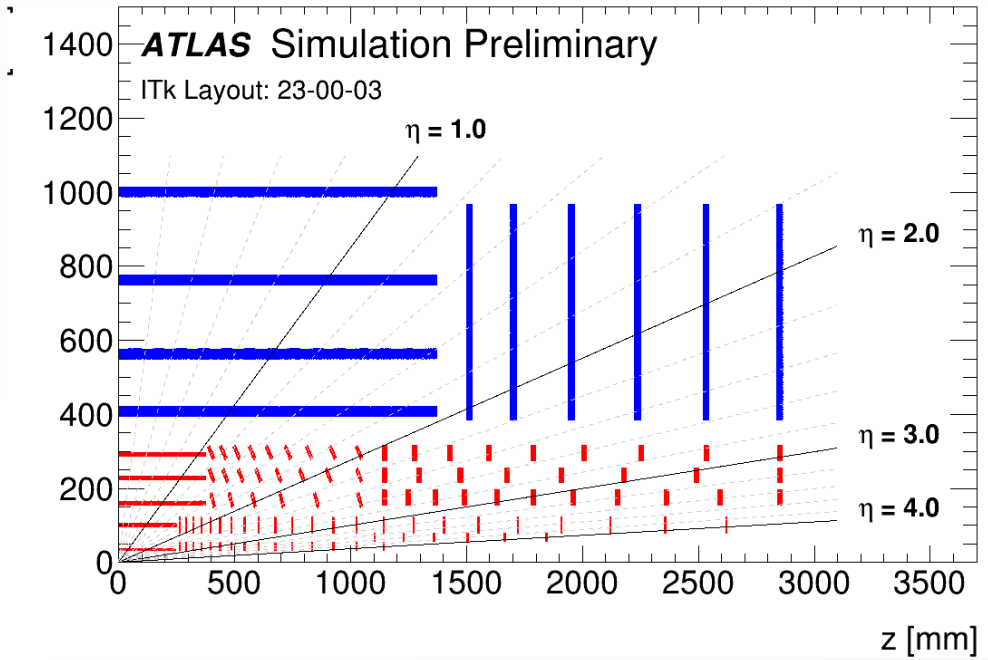


- **Funding**: mainly STFC, capital contribution to upgrade in line with fair share. Current:
  - **ATLAS**: £128M for 12 years (2014-**2026**)
  - **CMS**: £13.6M for 6 years (2019-**2025**)
- Still have to secure funding for the completion of the projects
- Retention of expert personnel **crucial** (technicians, engineers, detector experts)

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 → 4)
    - High radiation tolerance (up to 1 x 10^{16} neq/cm^2)
    - 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:**

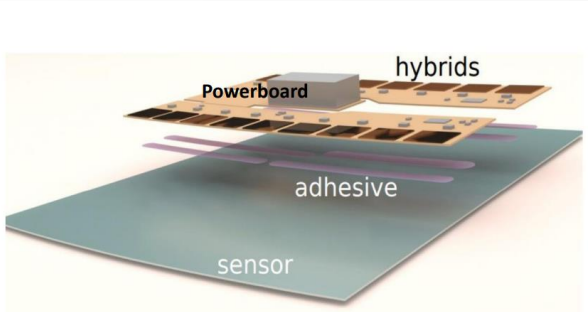
Birmingham, Cambridge, Glasgow, Lancaster, Liverpool, Oxford, QMUL, RAL PP, RAL TD, Sheffield, UCL, Warwick

    - 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

"Interposer" solution, module design modified

Interposers fabricated in the UK

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



  - **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

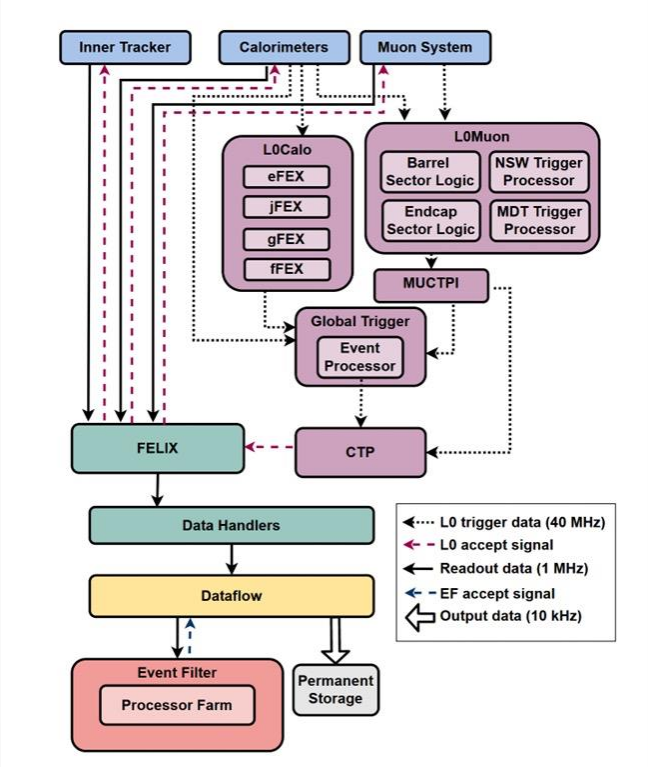
Left Cylinders made in US dressed in UK, sent to CERN

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

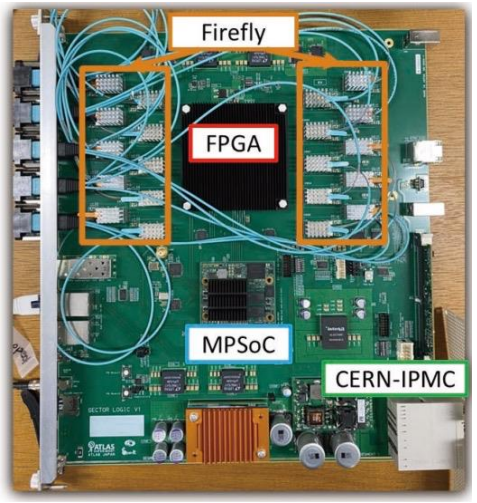
ATLAS upgrade: Trigger and DAQ

- 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



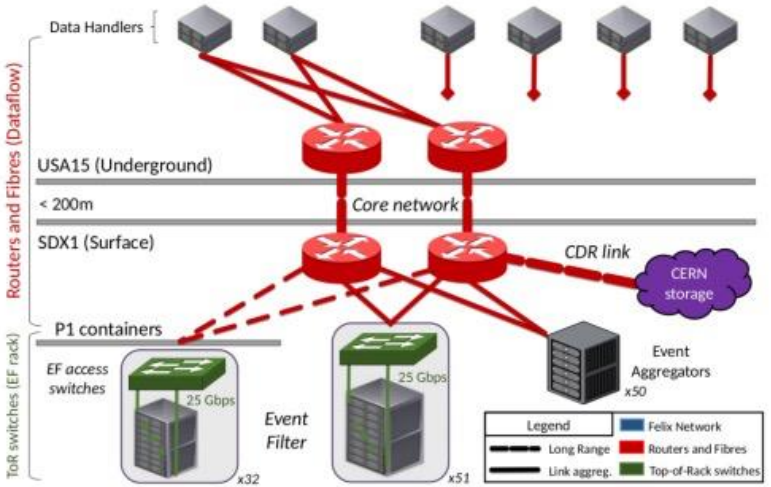
L0 Trigger: prototyping and testing



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

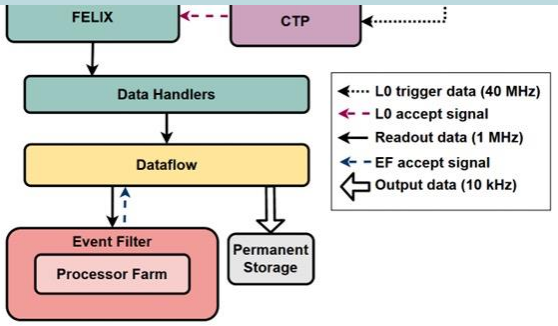
- Another **major UK deliverable**
- Phase II TDAQ specifications are challenging:
  - L0 rate 1 MHz with 10us latency
  - EF output rate 10 kHz

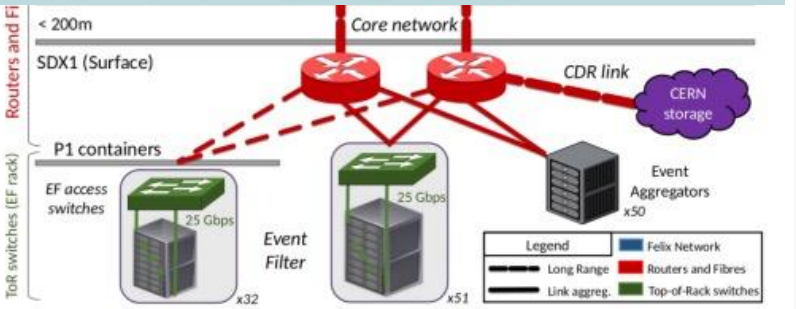
Birmingham, RHUL, UCL, RAL

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

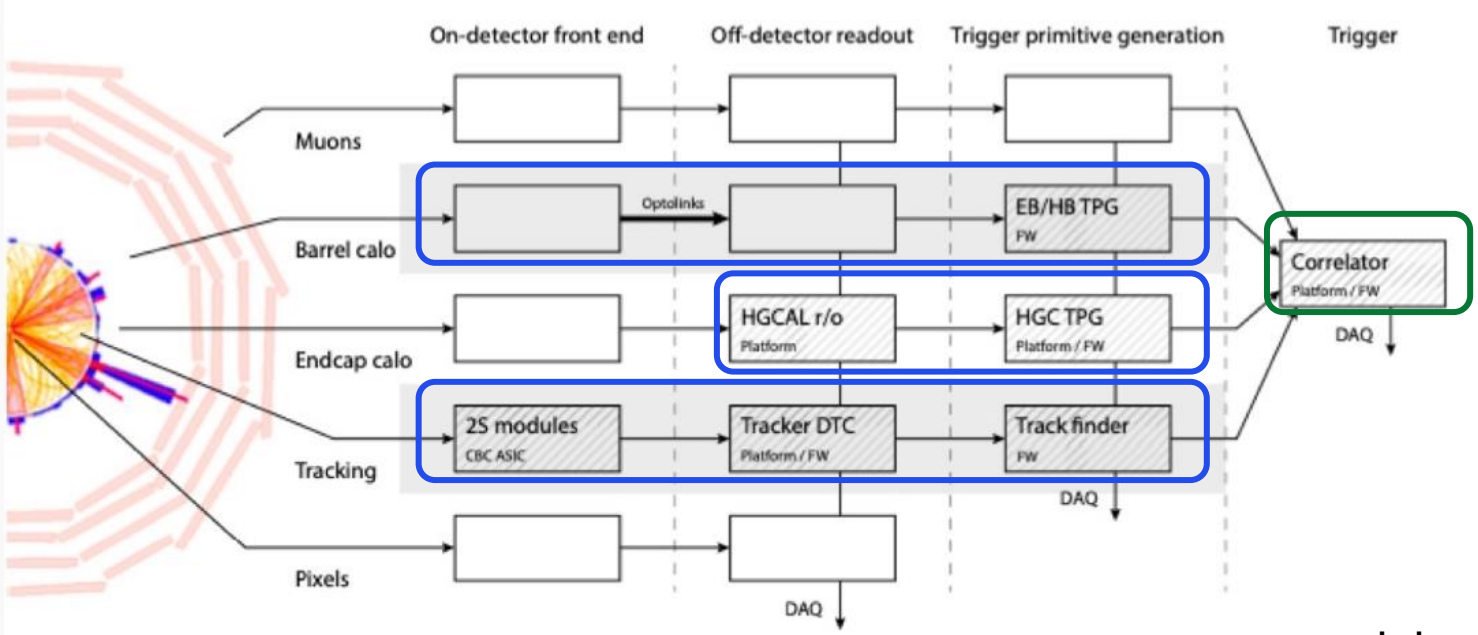
- **Overall:** ALTAS-Phase II upgrade work is also relevant for
  - **training of qualified personnel:** 55 PhD students have graduated in the past 5 years with activities on upgrade, apprenticeship programs for technical staff, research and development spin-off..
  - **Industry engagement:** collaborations 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

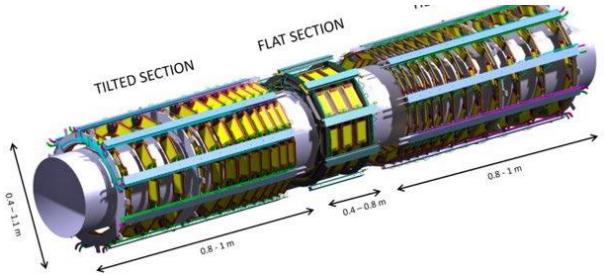
Successfully UK-delivered "building-blocks"

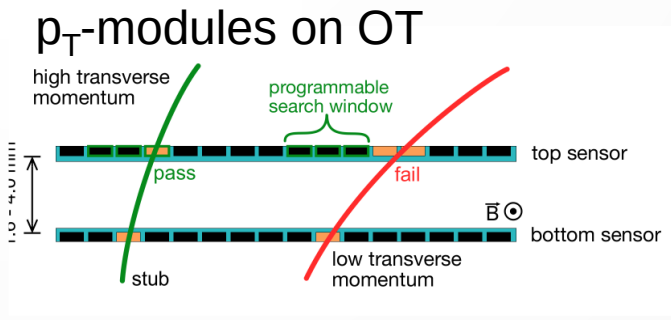
- MP7 processor board (Phase I)
- New time-multiplexed trigger Architecture
- **FPGA-based track finding**

JINST **12** P12019

Bristol,Brunel, Imperial, RAL

Outer tracker

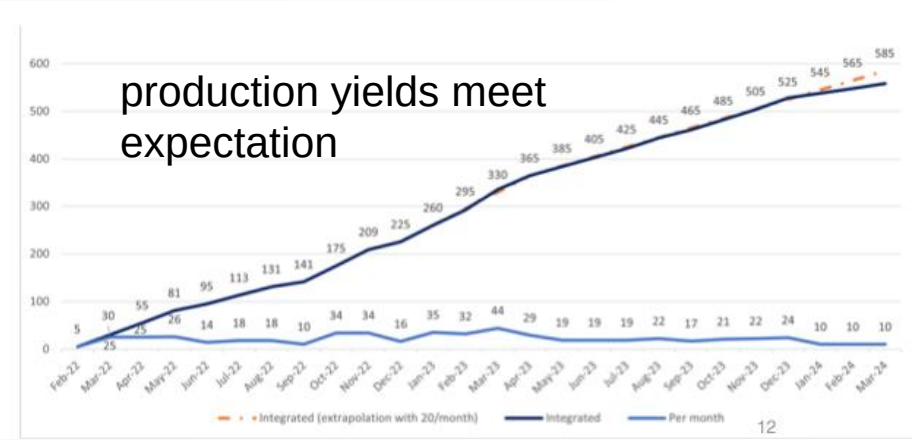


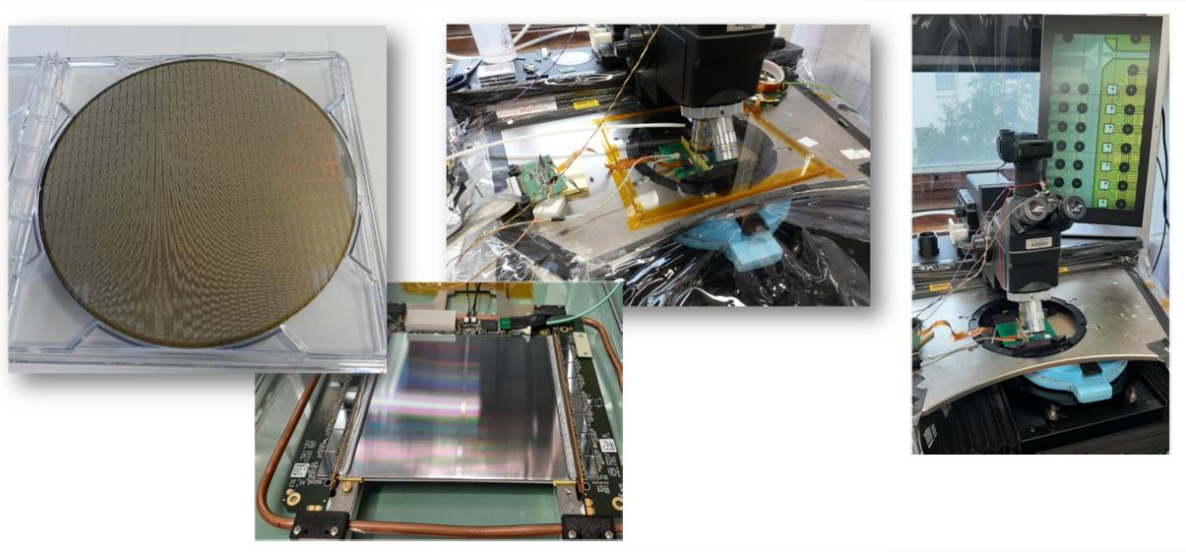


shown to work in 2017!
Since then ..

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

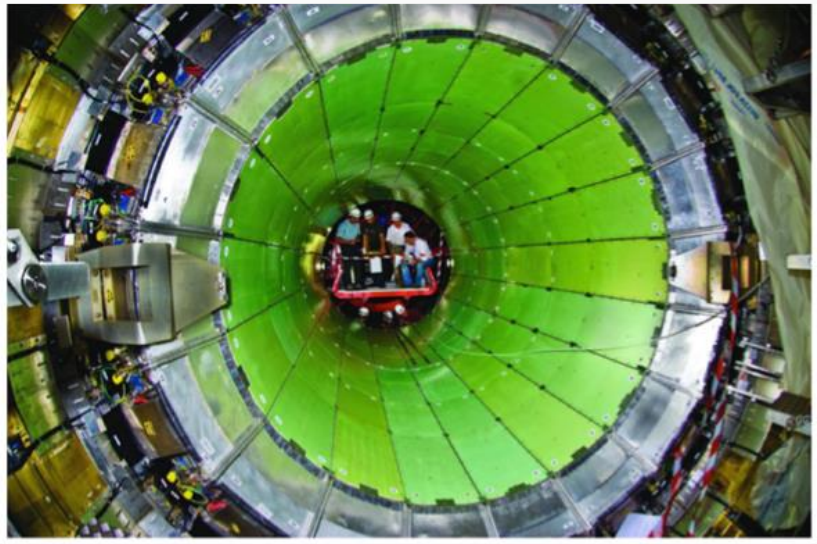
SERENITY

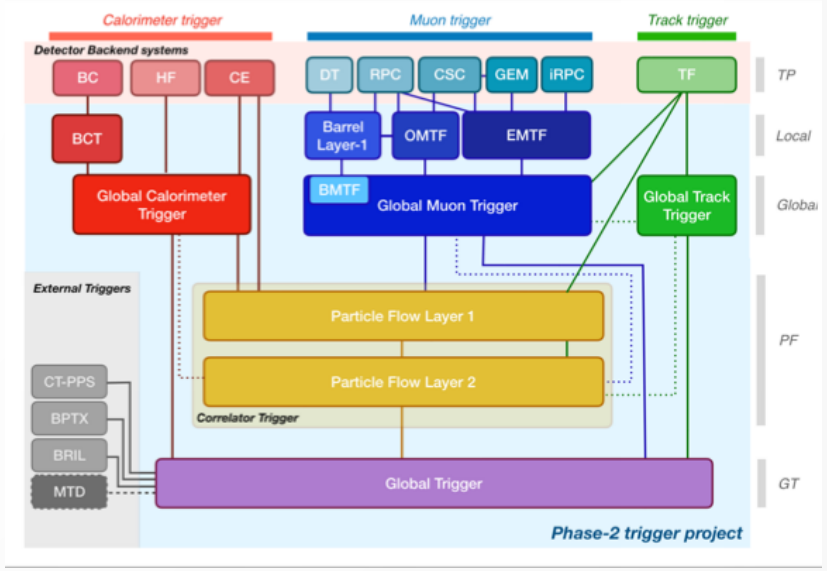
https://serenity.web.cern.ch/serenity/

Large UK involvement including students

CMS upgrade UK contributions: work ahead

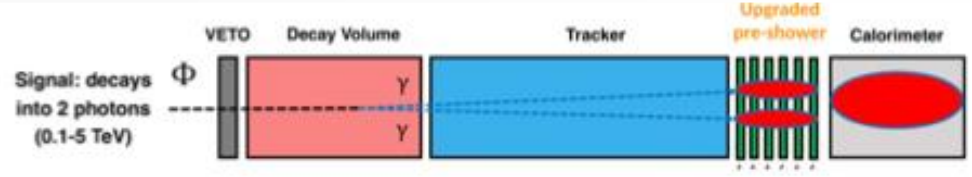
- Complete delivery of common off-detector electronic board Serenity
- For **Tracker:**
  - Install back-end system, complete development and validation for the Trigger Primitive Generator systems
  - Complete development and validation of the online software needed to coordinate, commission and operate 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

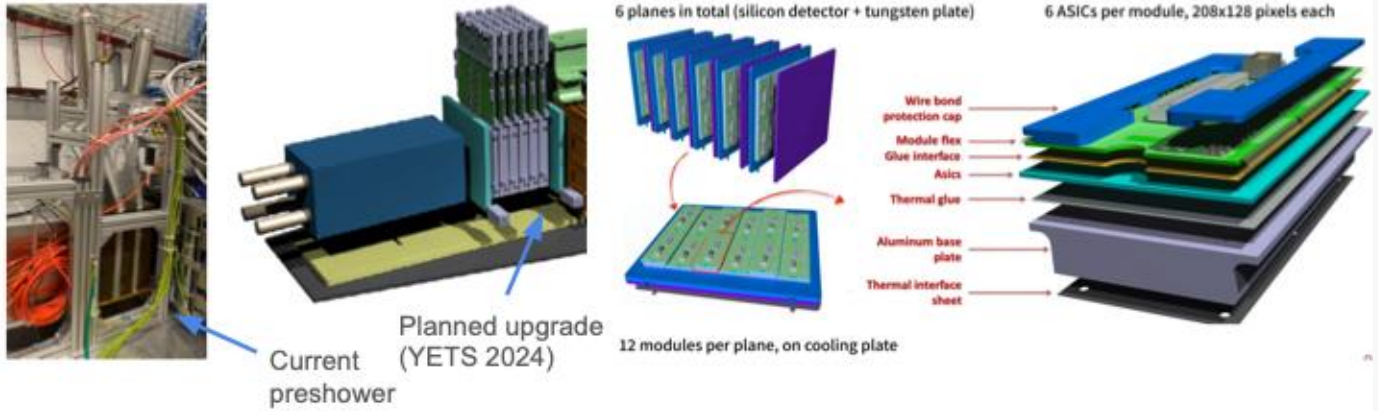




FASER @ HL-LHC

- 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)*

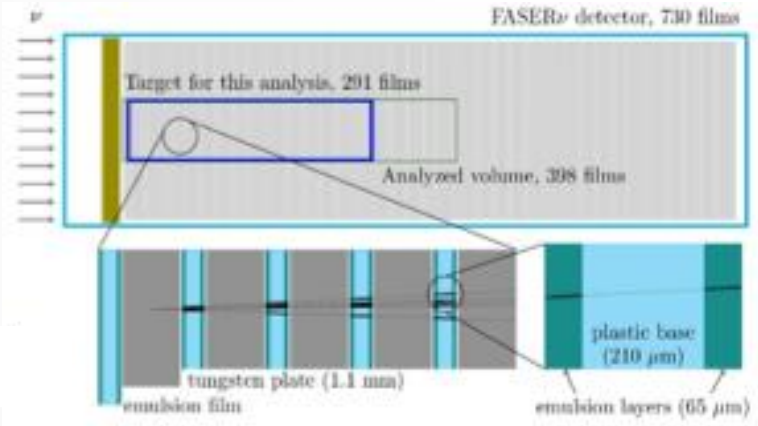




- Resolve diphoton events
- Improve sensitivity for searches of LLP→γγ

  - FASERν 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)*

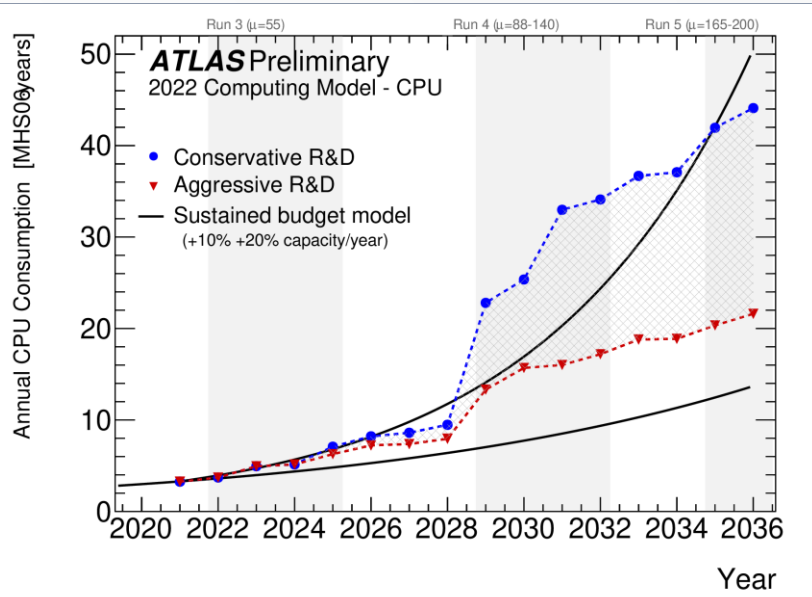
A different scenario **if** the **Forward Physics Facility (FPF)** will be supported → **FASER-2** *(see back-up)*

Liverpool, Manchester, Oxford, RAL, RHUL, Sussex

Phase-II Computing

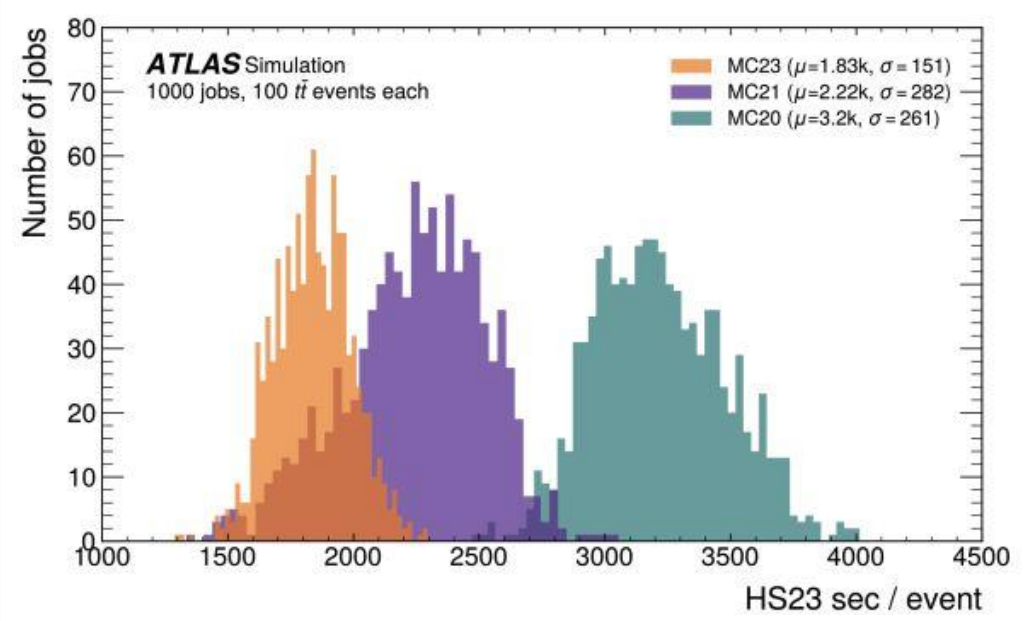
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/UPGRADE/CERN-LHCC-2022-005/

- 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)
  - The **UK** play a key role within the international LHC community with coordinated efforts (i.e. within the **SWIFT-HEP** project)



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**. Limited investments on strategic areas (e.g. AI/ML) and limited support for qualified personnel are considerable threats

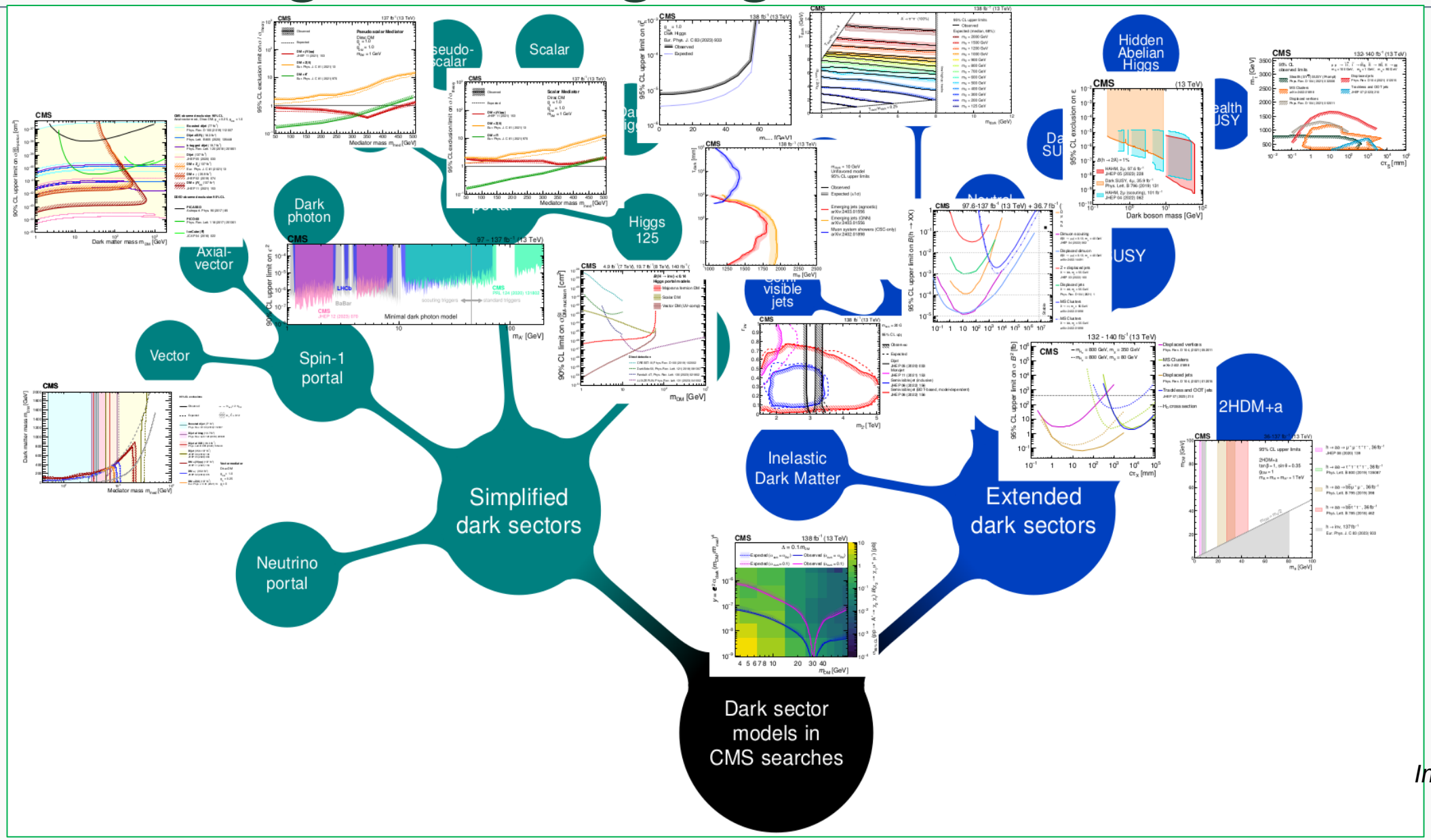
Summary & Outlook

- 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 – it is crucial to maintain/uplift physics exploitation support
- *[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 and well on-track, but still facing challenges in funding and expertise retention; strong engagement of UK institutes also on FASER @ HL-LHC
  - Computing is a key enabler for all we do, which the UK is targeting also 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 strengths and highlights: CMS dark sectors



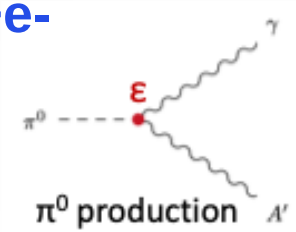
Imperial

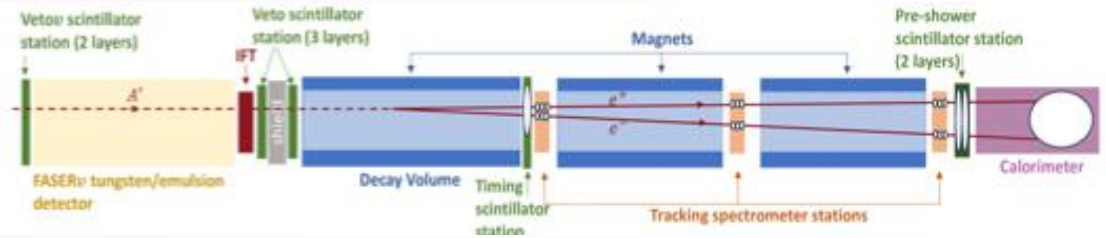
Physics highlights: FASER searches

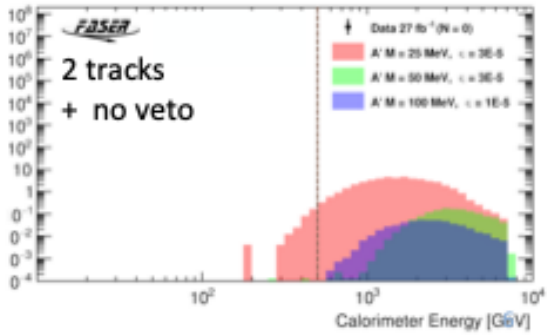
- Search for **Dark Photon (A') in e+e-**

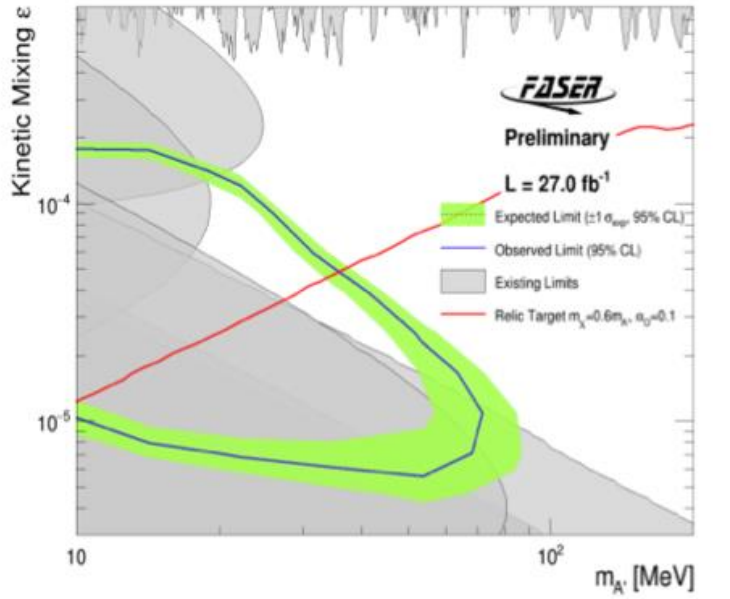
  Phys. Lett. B 848 (2024) 138378

  Liverpool, Manchester, Sussex







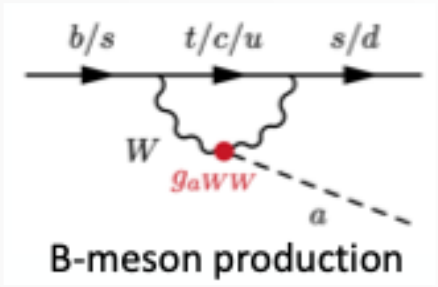


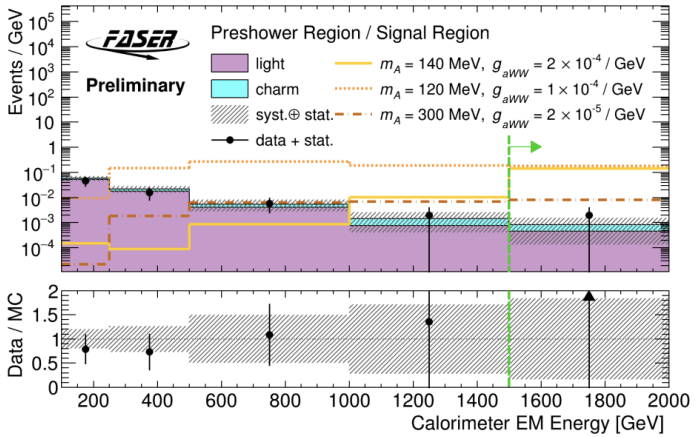
First constraint in thermal relic region @ low coupling for 30 yrs!

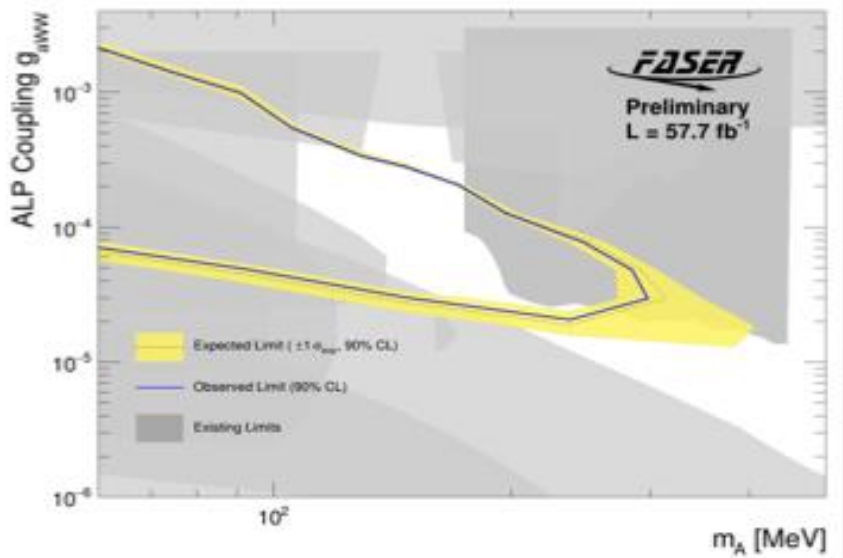
- Search for **axion-like particles (ALPs)** in γγ

CERN-FASER-CONF-2024-001

Liverpool



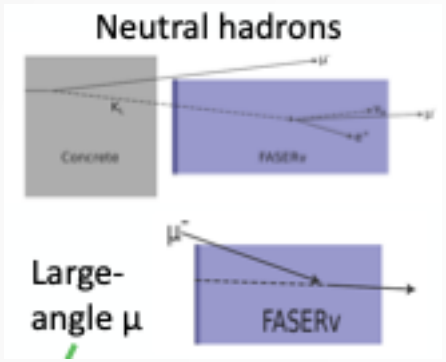


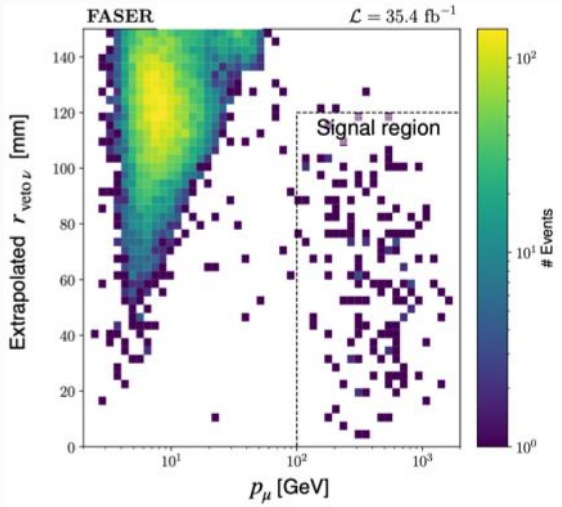


Physics highlights: FASER (2)

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

PRL 131 (2023) 3, 031801



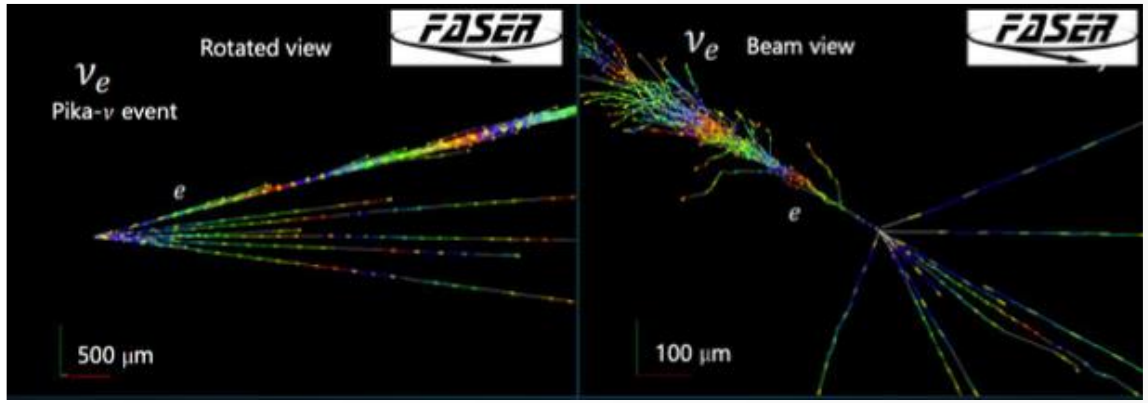


Liverpool, Manchester, RHUL, Sussex

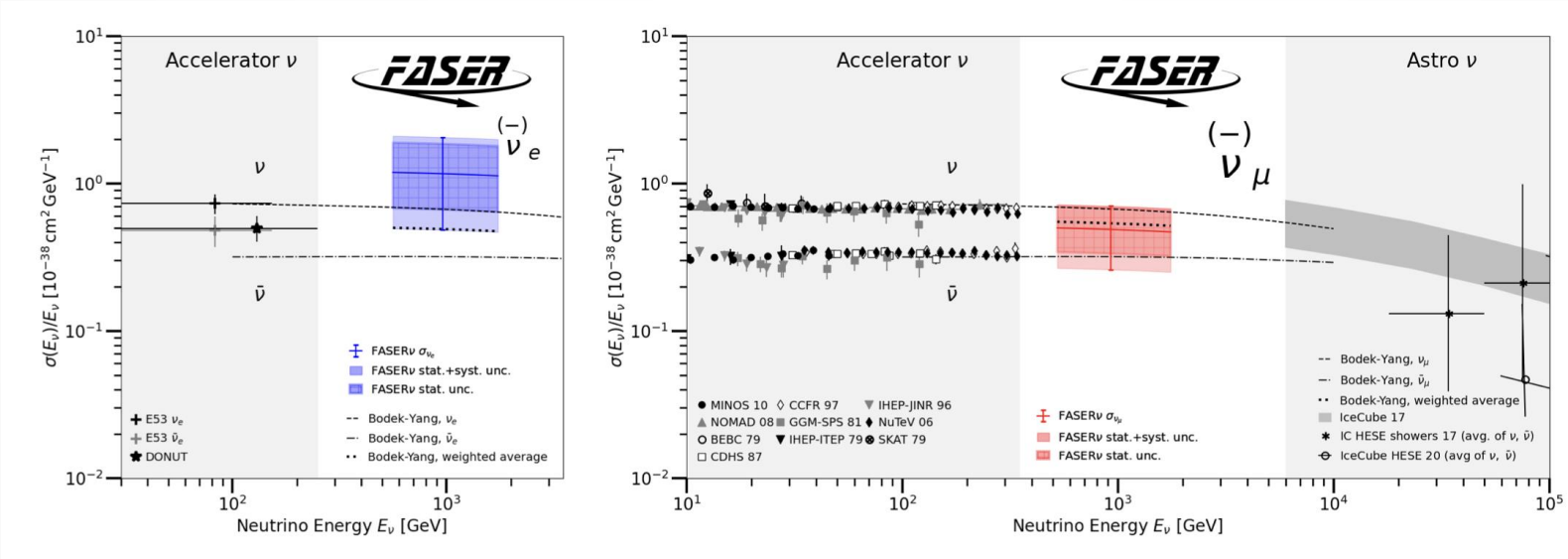
PRL. 133, 021802 (2024)

Observed: 153+12-13 ν_m interactions

Interactions in emulsion detectors (FASERν)



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

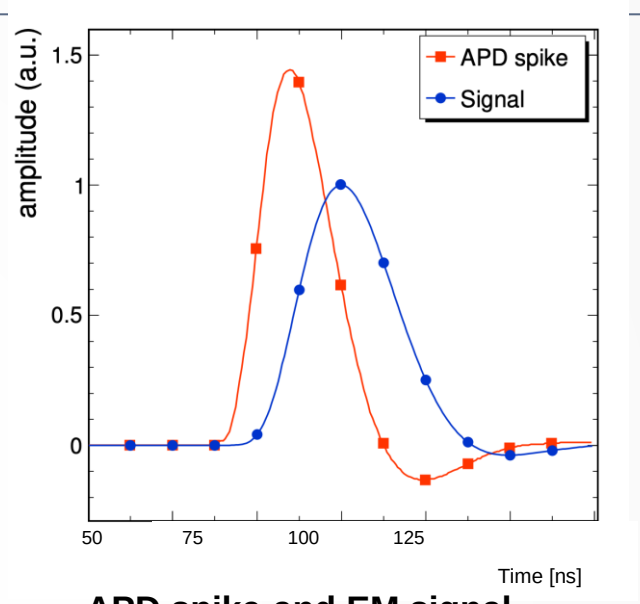


First cross section measurements in the TeV range

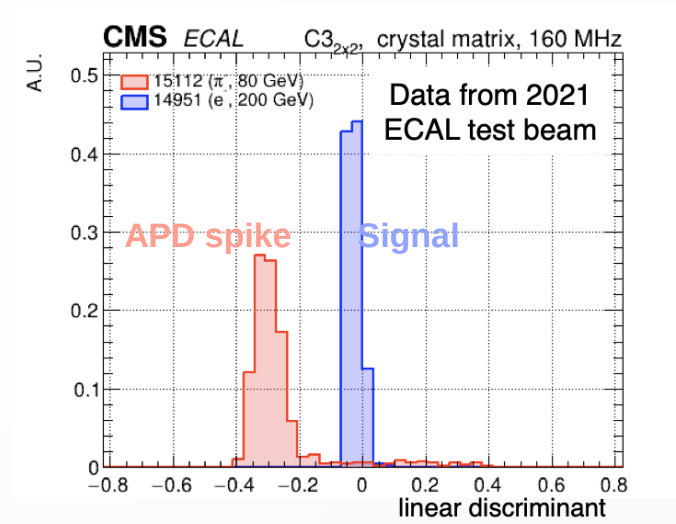
CMS ECAL upgrade

- **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 $\sigma_t \sim 30$ps for H$\square\gamma\gamma$ 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

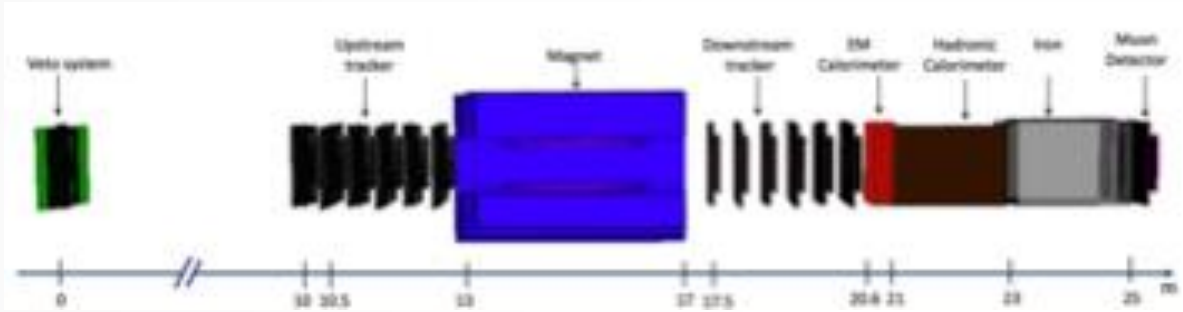


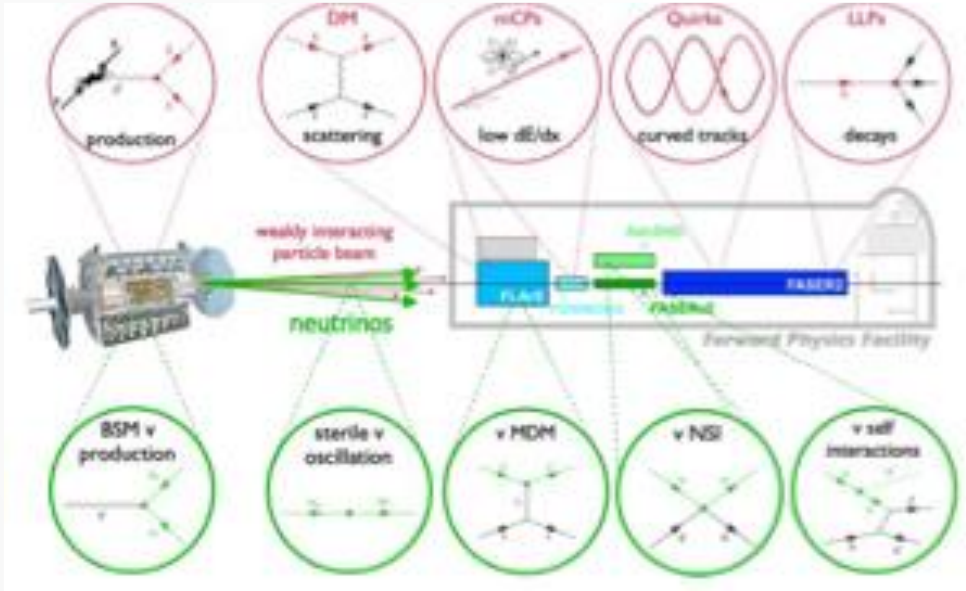
Spike rejection via pulse shape discrimination

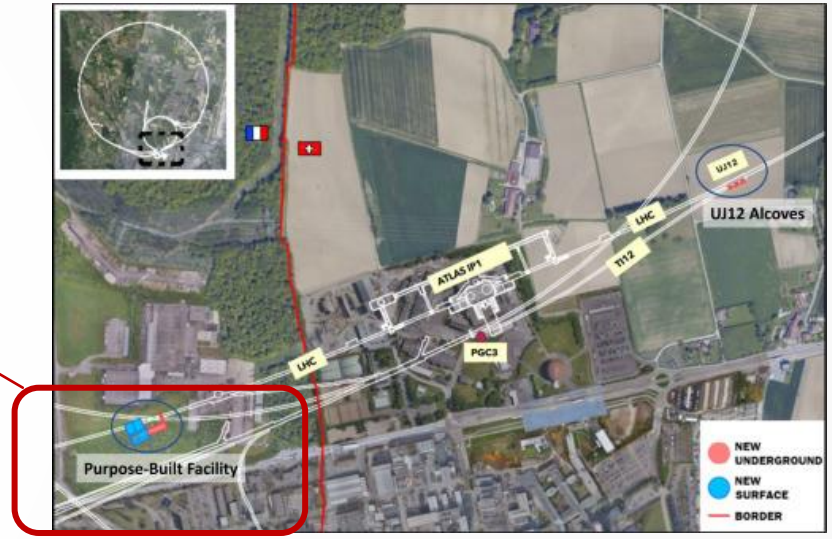
FASER @ HL-LHC: a totally different scenario

- 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.