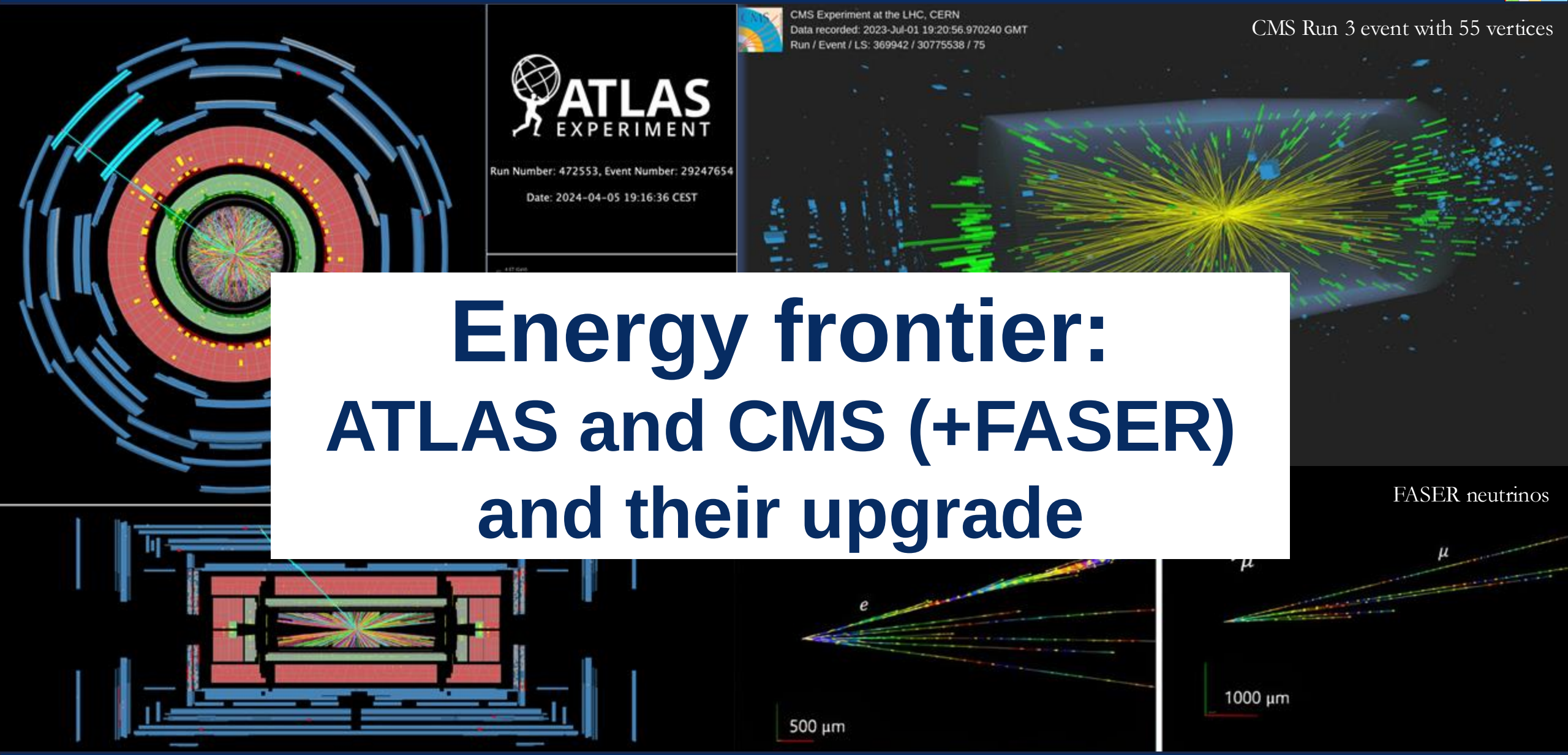
DISCLAIMER

- Some details are still being iterated upon (in red) – will fix before practice
- The talk is long (and dense) – idea is to cut at least 3-4 slides, or compress / reduce info
  - I have some ideas, but suggestions are welcome (note: some slides are repeated, with one plot or write up overlapping or changed, so those are ‘quick’)
- A couple of figures appearing ‘blurry’ – will be fixed

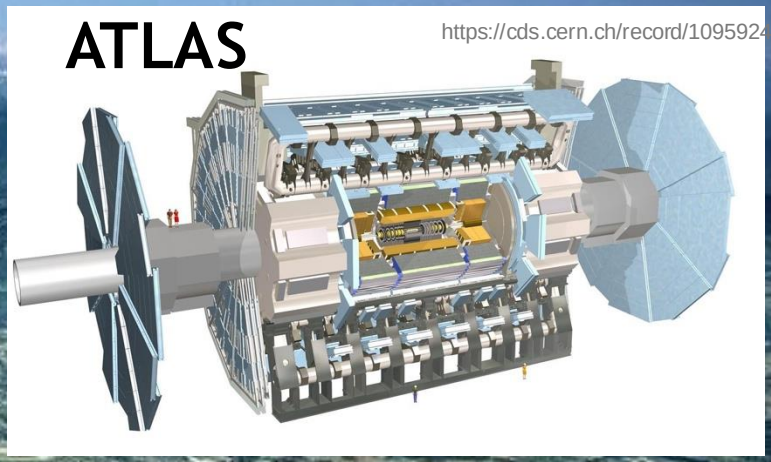


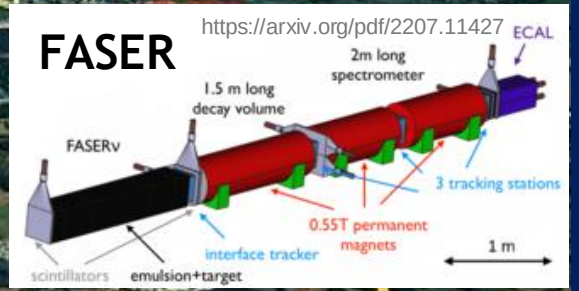
Energy frontier:
ATLAS and CMS (+FASER) and their upgrade

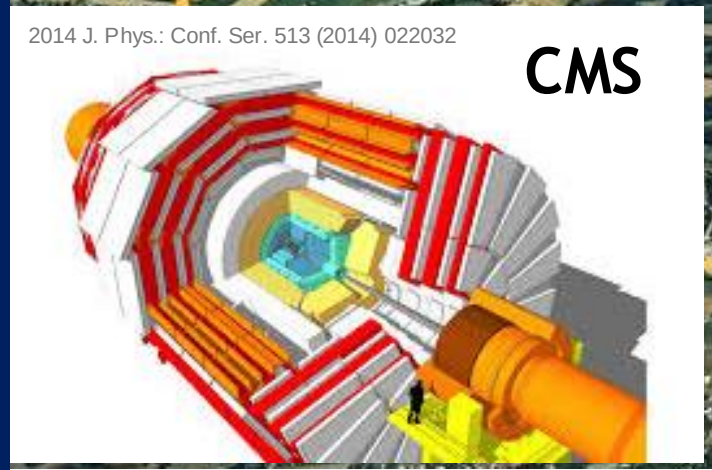
Outline

- **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

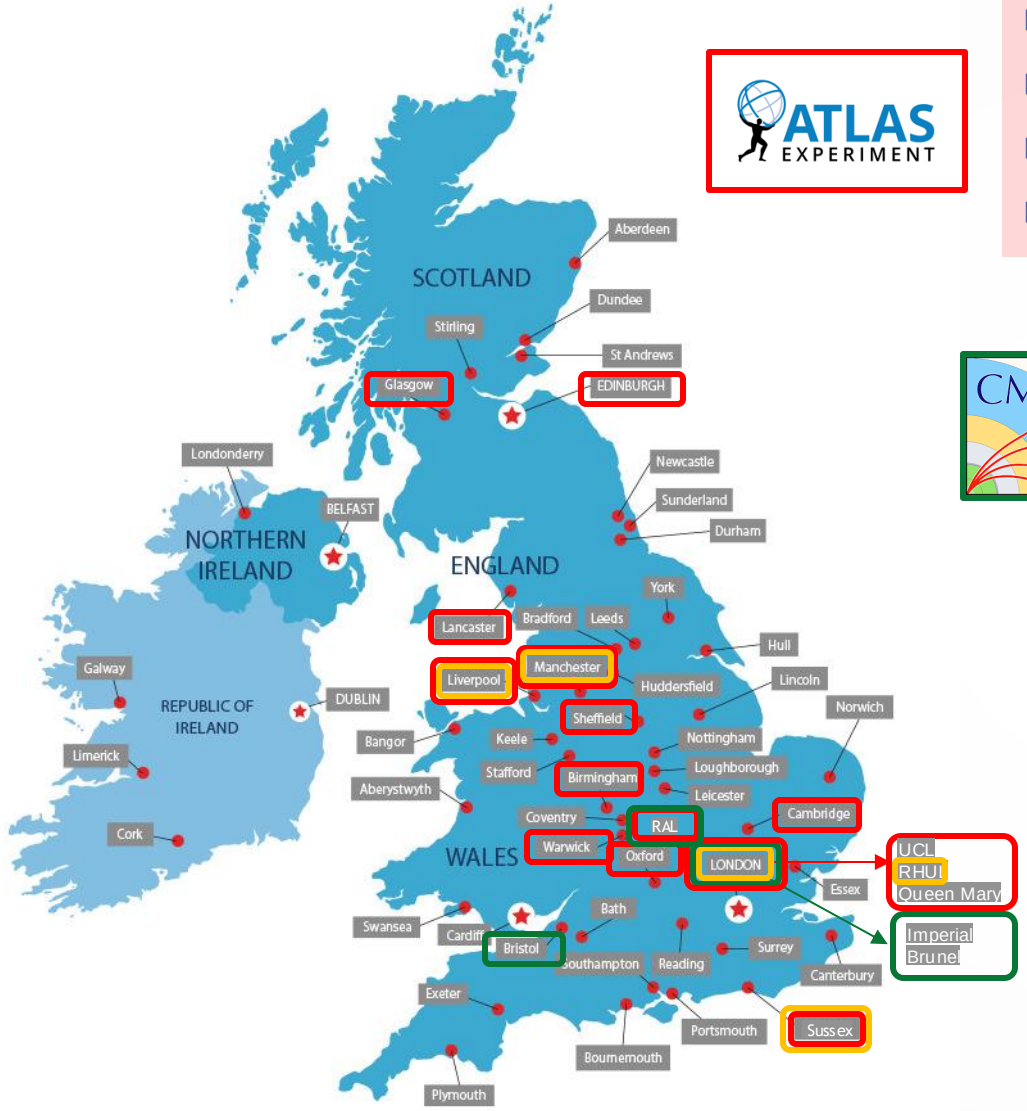






The UK has also a small participation in SND@LHC (UCL, Imperial) - see W. Barter's talk

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, Eric and Wendy Schmidt

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, 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 RPC activities (Cambridge funds through individual UKRI-funded fellowship)
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)

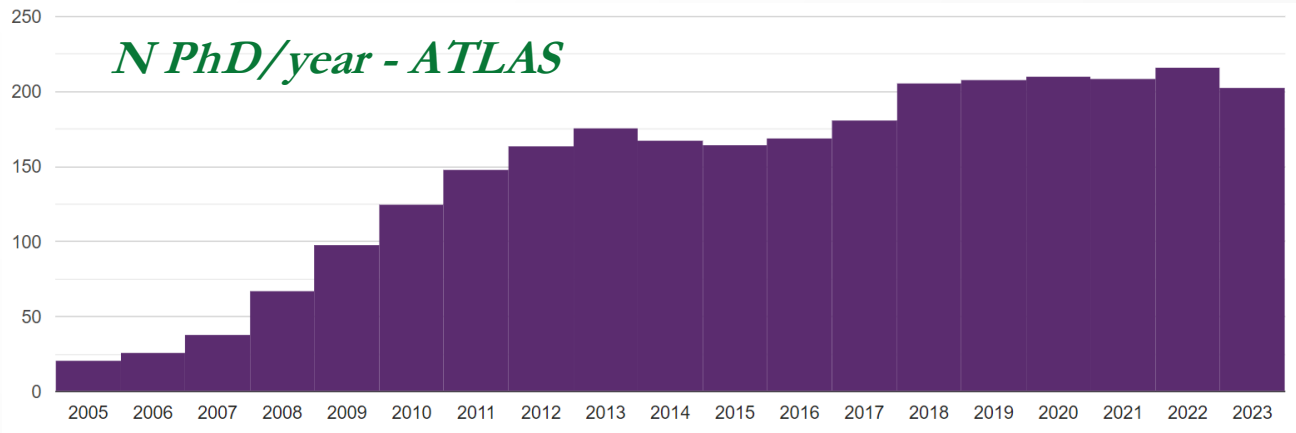
Management and coordination roles

- 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)
  - **CMS:**
    - Spokesperson: Jim Virdee (2007-2009)
    - Collaboration Board Deputy Chair: Claire Shepherd-Themistocleous (2014)
  - **FASER:**
    - Physics Coordinator: Carl Gwilliam (2022-2024)
- Impact on international physics and upgrade activities through coordination:
  - **Since 01/2021:** ATLAS counts 6(8 for upgrade) Level-1 coordinators including Inner Tracker PL for 6 years, 15 Physics and Combined Performance group conveners/coordinators (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, UK institutes have been Run coordinator (1) and physics analysis lead (2)

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 actively participate to operations and maintenance as well as to the physics programme: regular UK physics meetings, dedicated workshops..
- **PhD students**: a healthy profile overall
  - Number of PhD students enrolled by **ATLAS-UK** each year since 2005: ~ 200/yr → considering length of PhD of 3.5 yr, this corresponds to **~ 650 students** awarded PhD in the past decade
  - **CMS-UK** enrolled more than **110 PhD** students in the past decade
  - **FASER-UK** enrolled **6 PhD** students since 2020, 1 graduated, 1 finishing

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



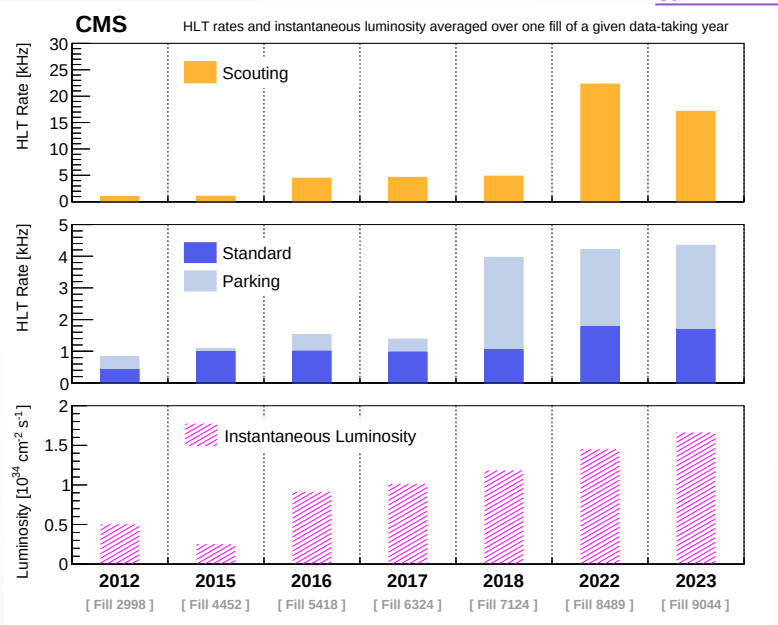
New ideas and cutting-edge technologies

- Amazing results achieved thanks to deployment of new ideas of UK members, i.e.

Data Scouting/Trigger Level Analysis

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

arXiv:2403.16134

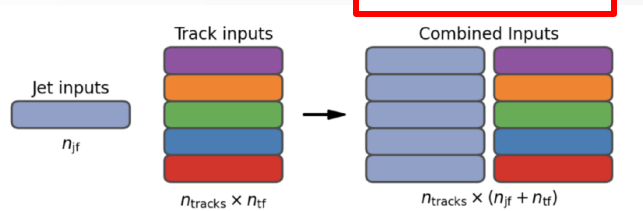


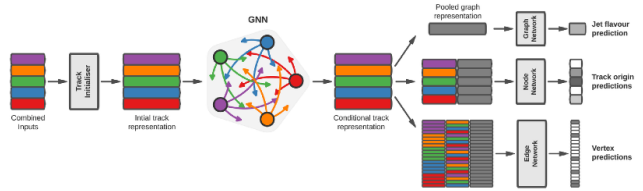
https://cms.cern/news/same-lhc-same-cms-more-physics

Bristol, Imperial, RAL

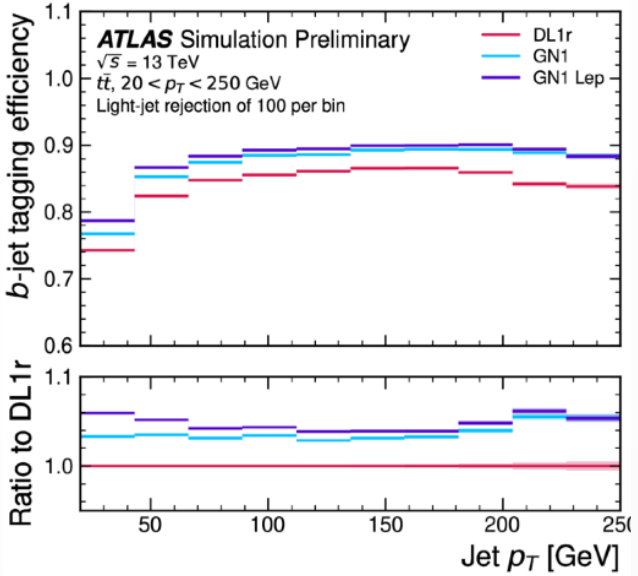
Flavour tagging: b and c jets

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

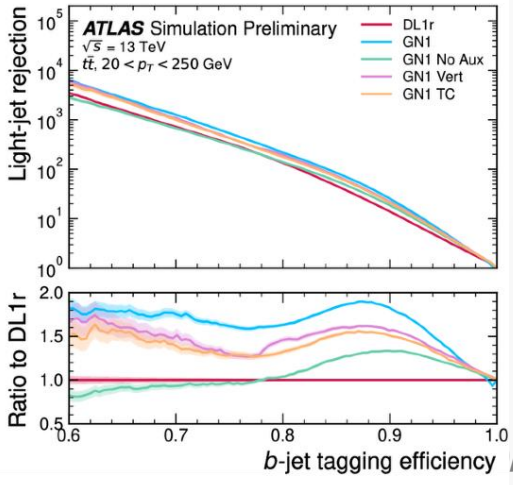




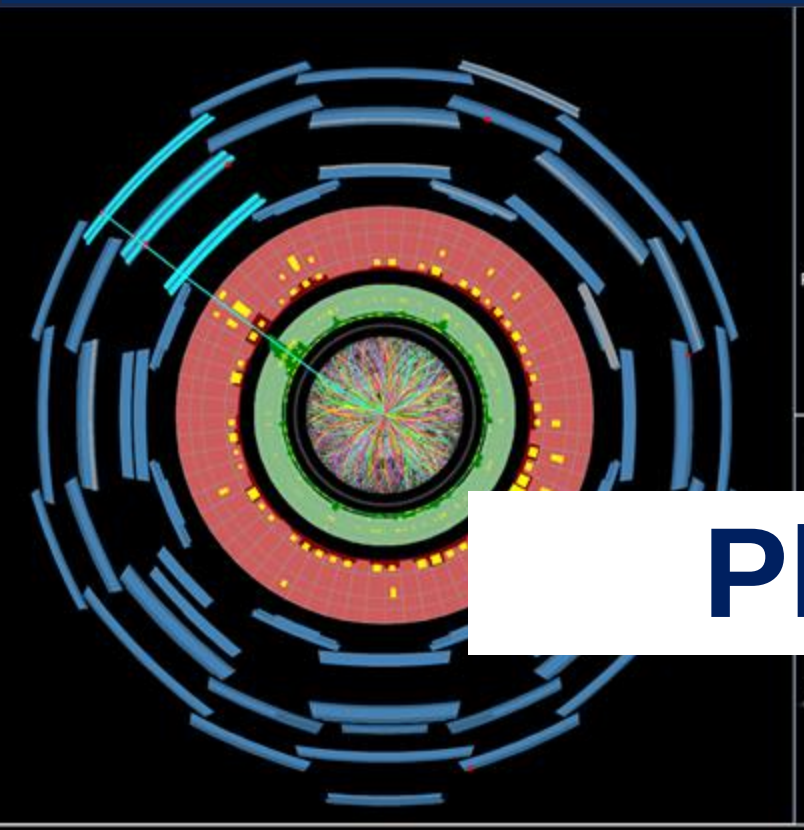
ATL-PHYS-PUB-2022-027

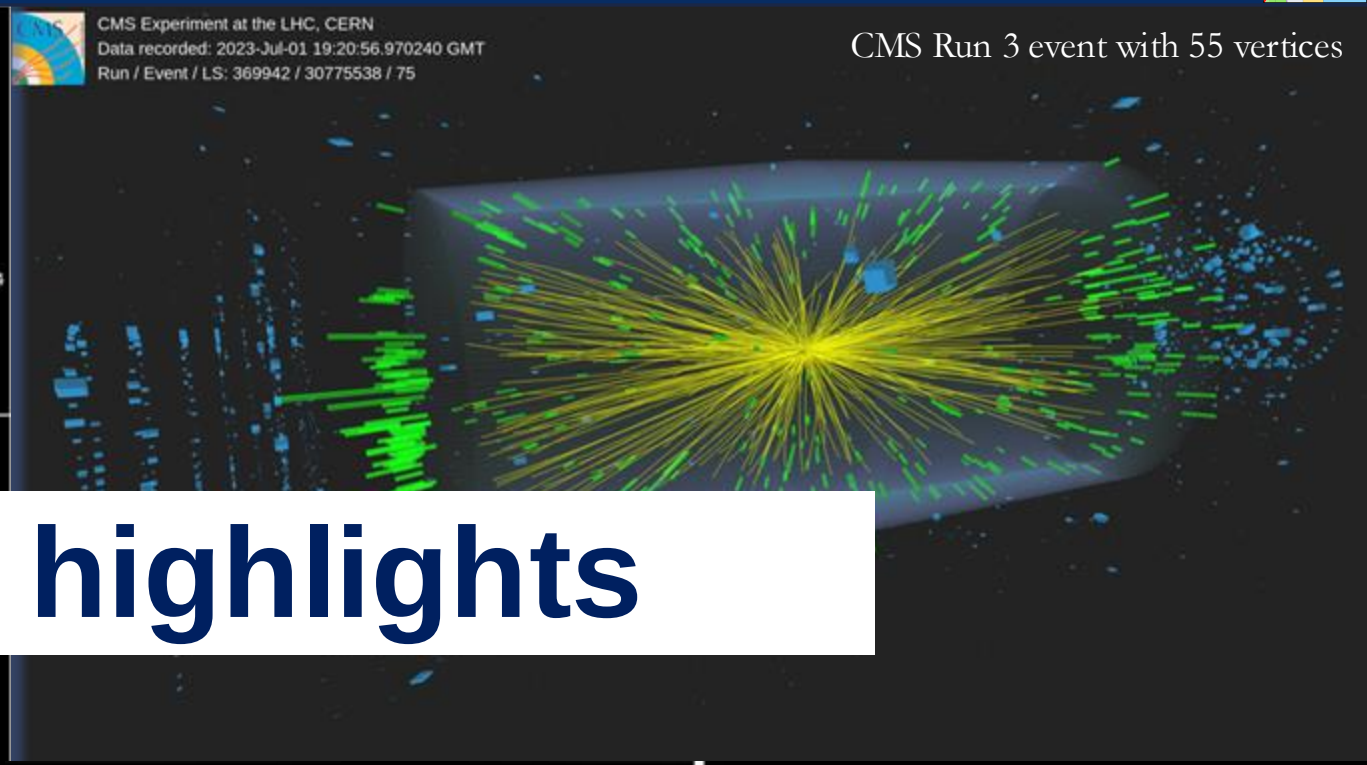


Significantly improved b-tag/c-tag efficiency and light-jet rejection



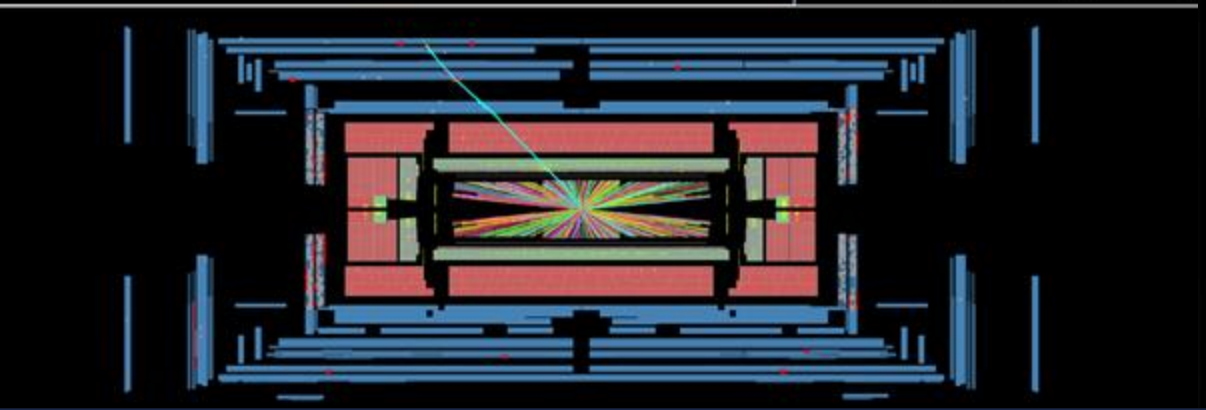
Liverpool, Oxford, UCL, Warwick

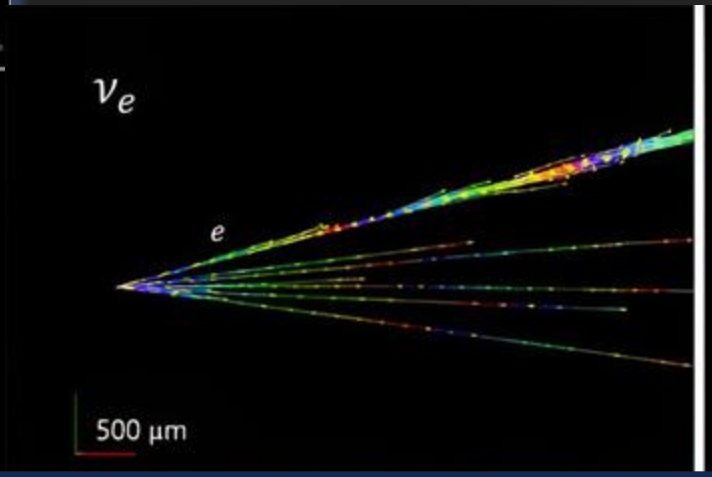


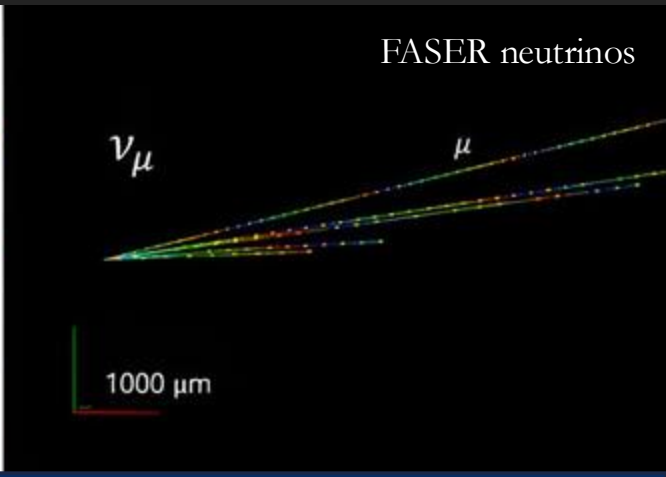


CMS Run 3 event with 55 vertices

Physics highlights







FASER neutrinos

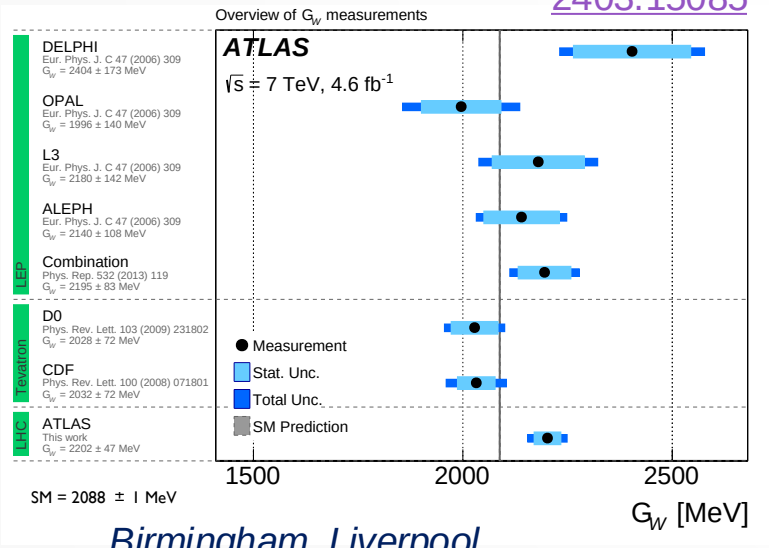
Physics strengths and highlights: ATLAS

- ATLAS-UK contributes to almost **all areas of the physics programme**, from SM precision measurements to 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

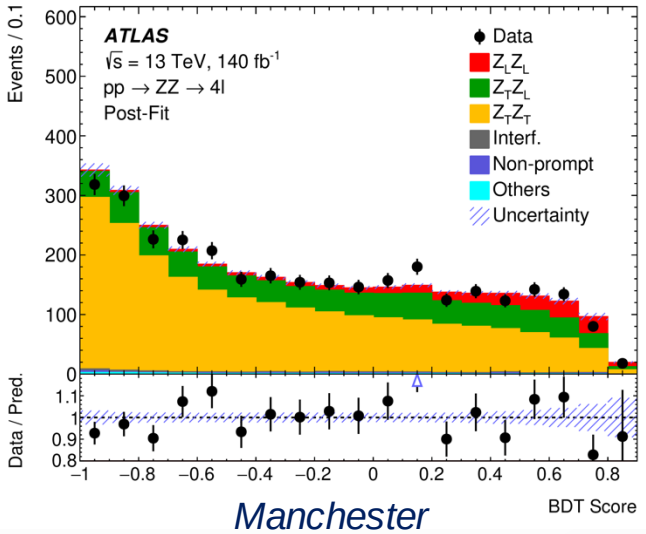


Birmingham, Liverpool

Multi-boson measurements

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

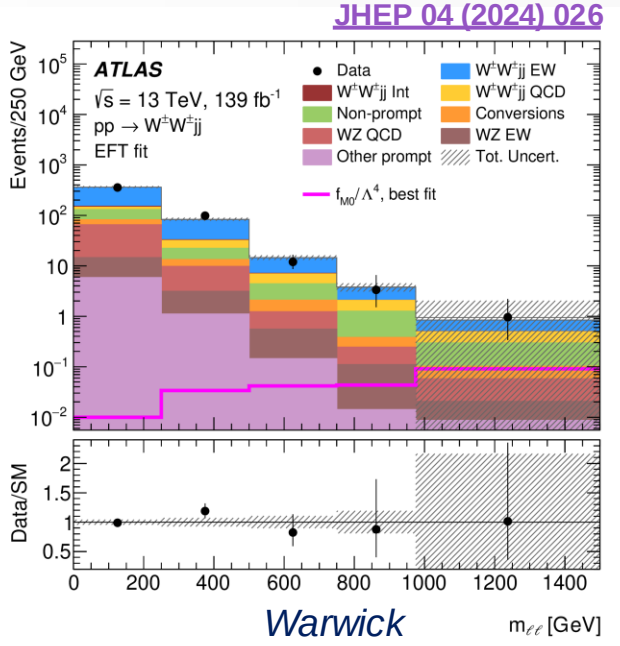
JHEP 12 (2023) 107



Manchester

Same-sign WWjj in VBF

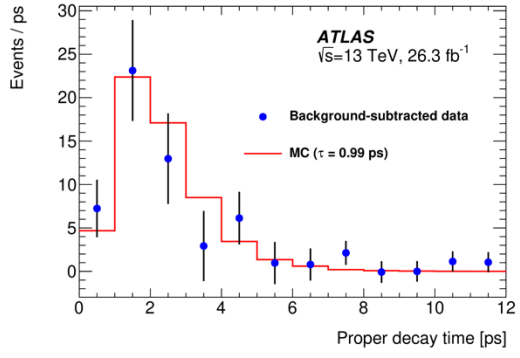
JHEP 04 (2024) 026



Warwick

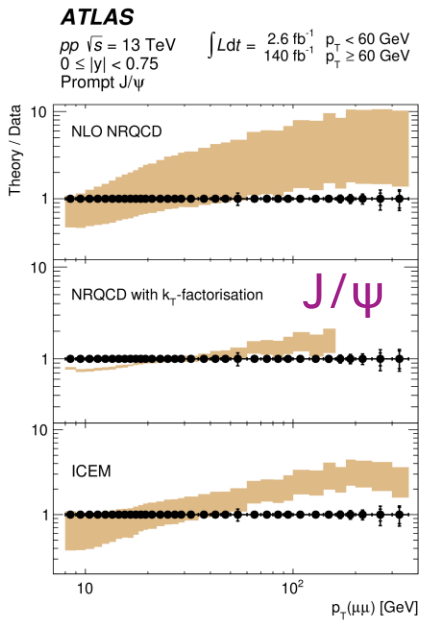
Highlights: ATLAS B and Top physics

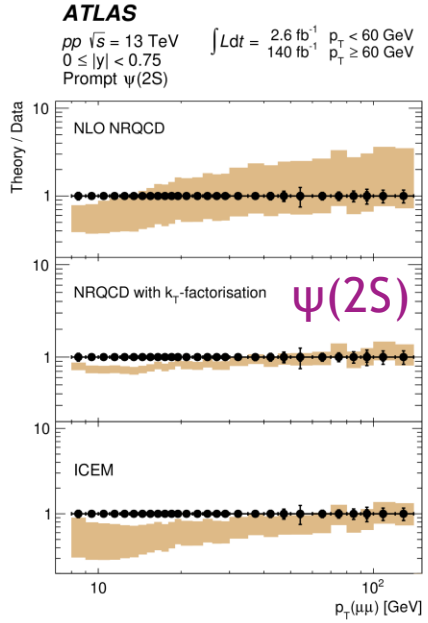
- **B physics:** UK-led flagship analyses such as **$B_s^0 \rightarrow \mu^+\mu^-$ effective lifetime** and measurements of the production cross-sections of **J/ψ** and **ψ(2S) mesons** (widest momenta range to date).



JHEP 09 (2023) 199

Sussex





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

Lancaster, RAL

- **Top physics:**

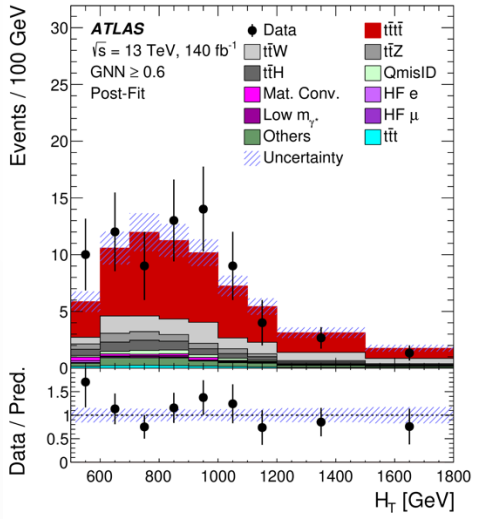
Strong involvement in top physics from the UK (UK sub-group and group conveners for long time).

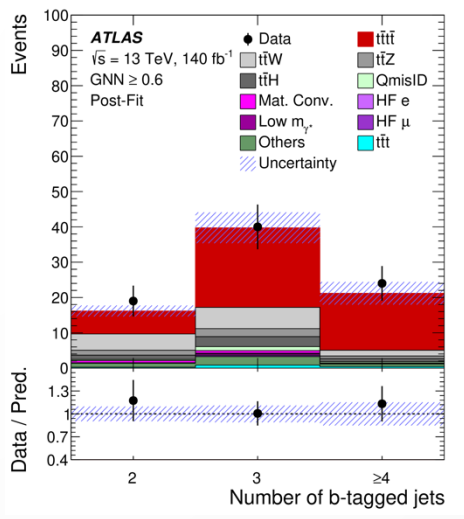
Birmingham, Glasgow, Manchester, RHUL

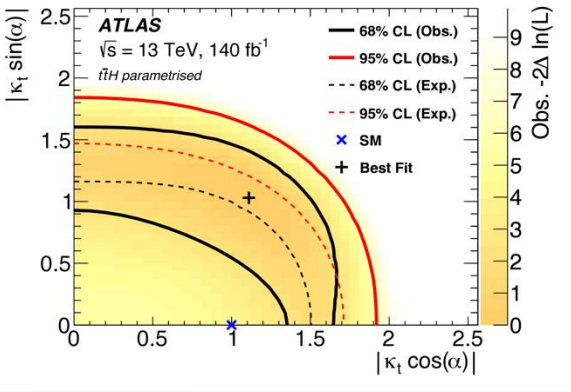
- I.e.: Observation of **4-top** (6.1σ)

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

Manchester



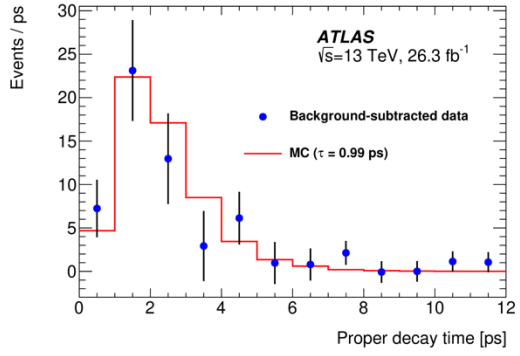




constrain of the top-Higgs Yukawa coupling

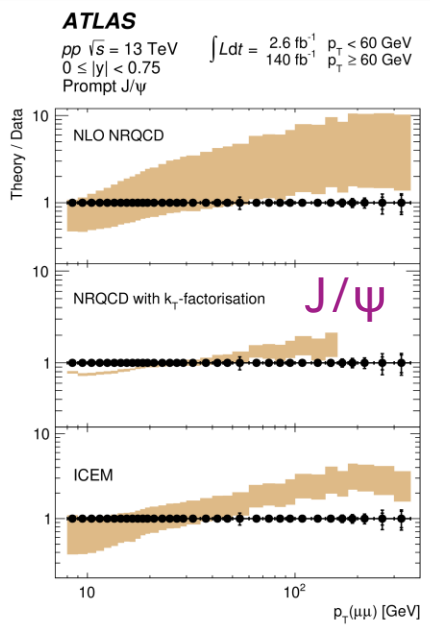
Highlights: ATLAS B and Top physics

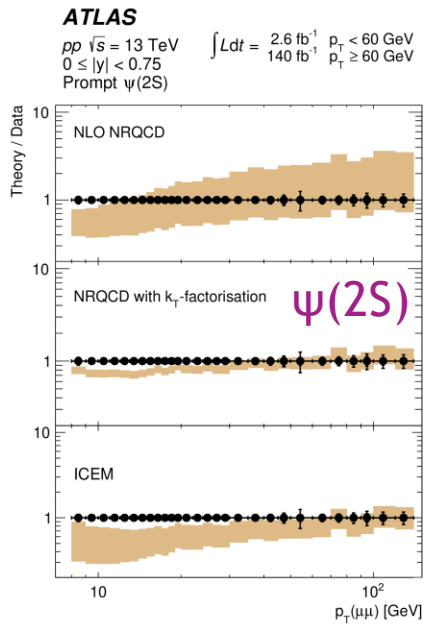
- **B physics:** UK-led flagship analyses such as **$B_s^0 \rightarrow \mu^+\mu^-$ effective lifetime** and measurements of the production cross-sections of **J/ψ** and **ψ(2S) mesons** (widest momenta range to date).



JHEP 09 (2023) 199

Sussex





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

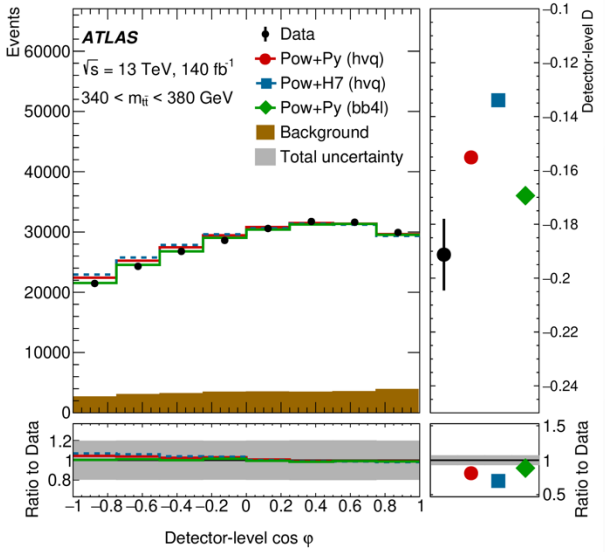
Lancaster, RAL

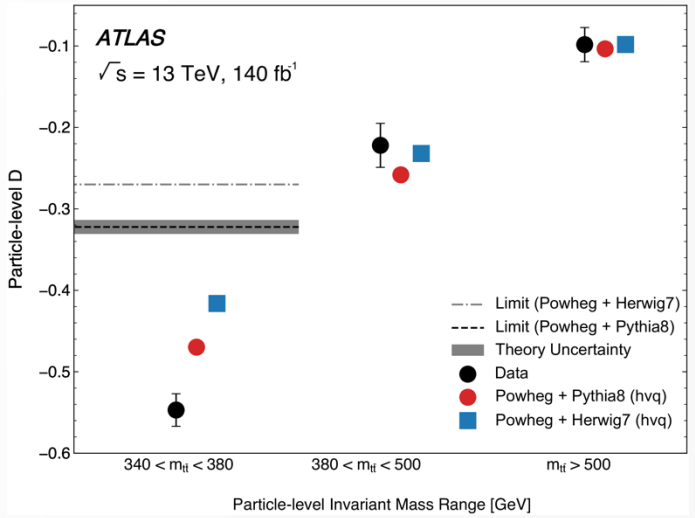
- **Top physics:**
  - Observation of **quantum entanglement** in top-quark pairs

arXiv:2311.07288

Spin entanglement detected from measurement of observable D, inferred from the angle between the charged leptons in their parent top- and antitop-quark rest frames.

Birmingham, Glasgow, Manchester



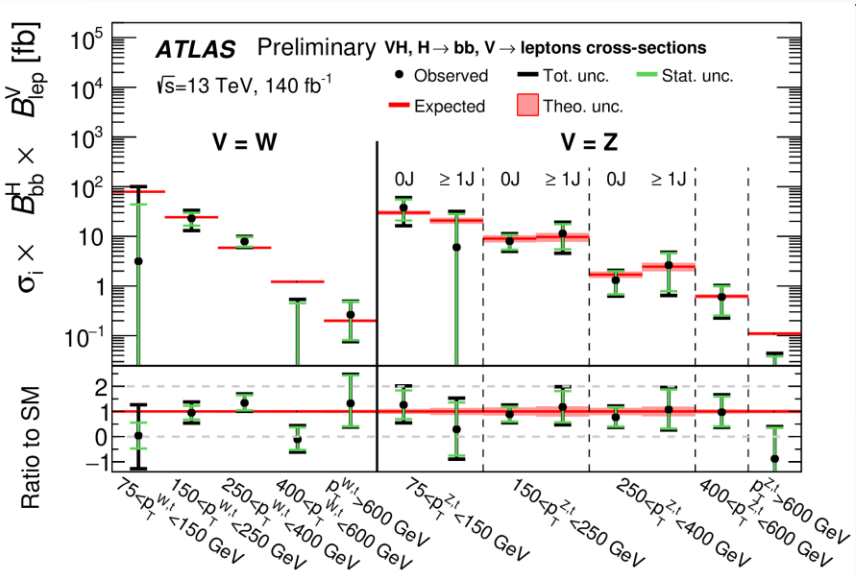


Physics highlights: Higgs physics

- 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

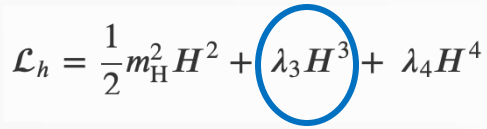
Birmingham, Glasgow, QHML, Oxford, Sheffield, UCL

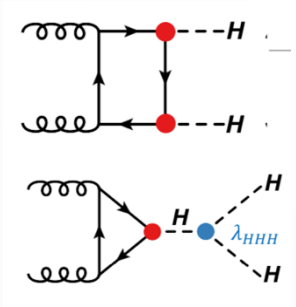
ATLAS-CONF-2024-010



- 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, Liverpool, Oxford, RHUL, UCL – more ??

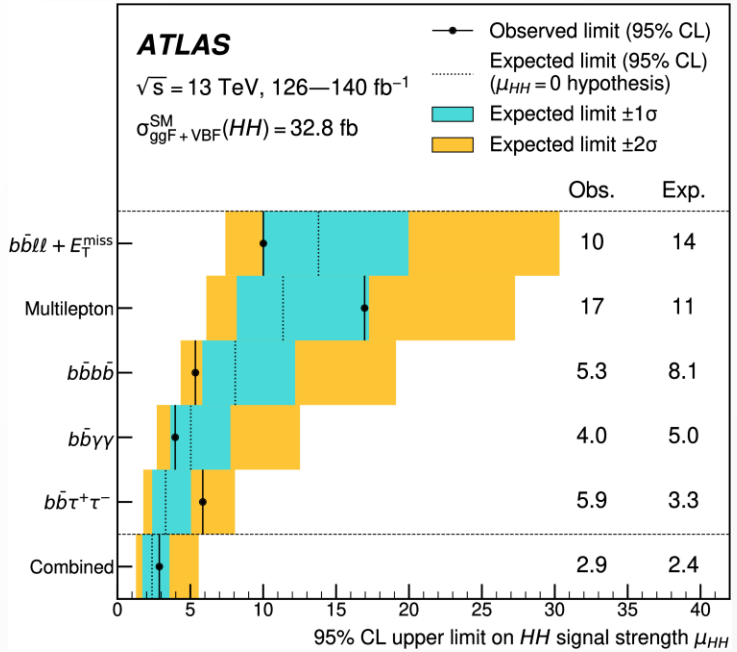




Self-coupling

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

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

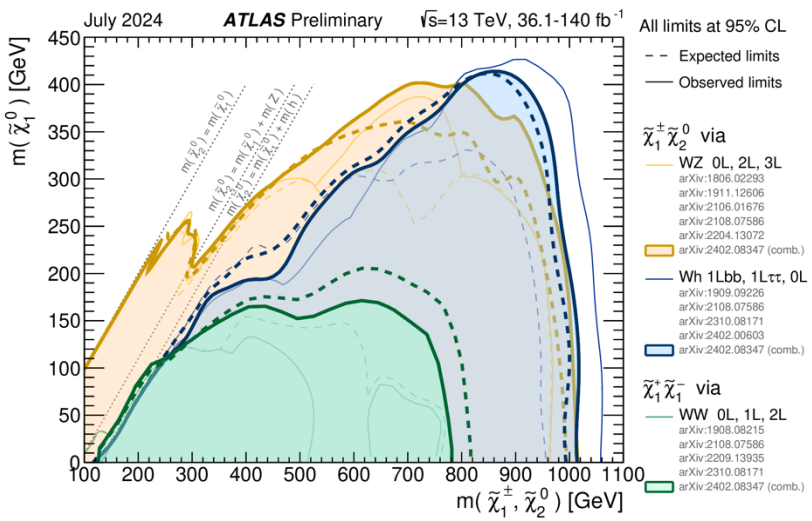


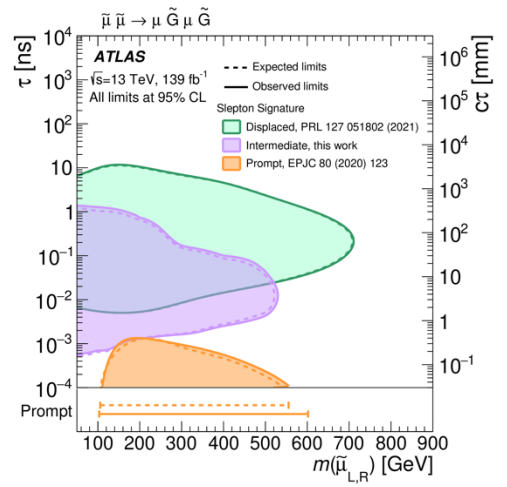
Highlights: ATLAS Searches for new physics

- 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, QHML, Sheffield



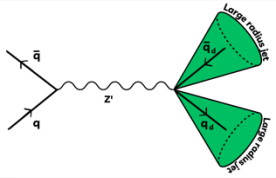


[Phys. Lett. B 846 (2023) 138172]

Lancaster

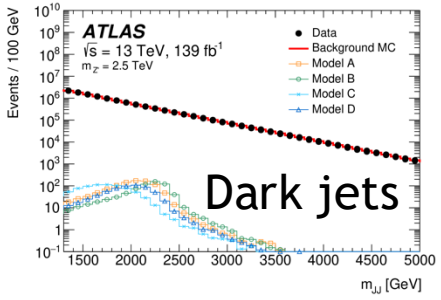
millimeter-displaced slepton

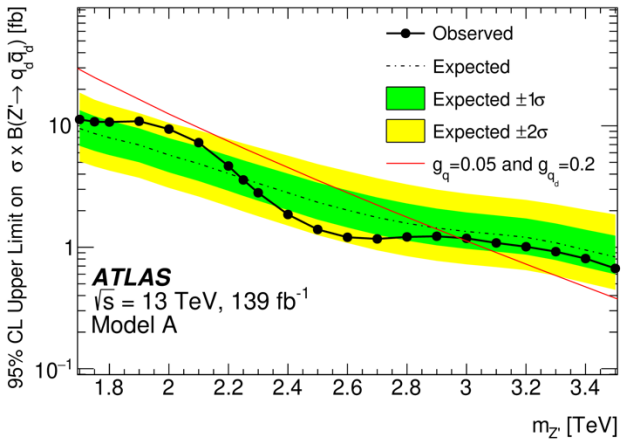
- **Dark-matter** and **hidden sectors → LLP**

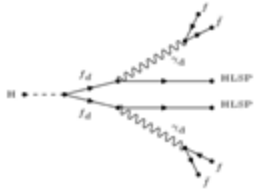


[JHEP 02 (2024) 128]

Manchester, QMUL



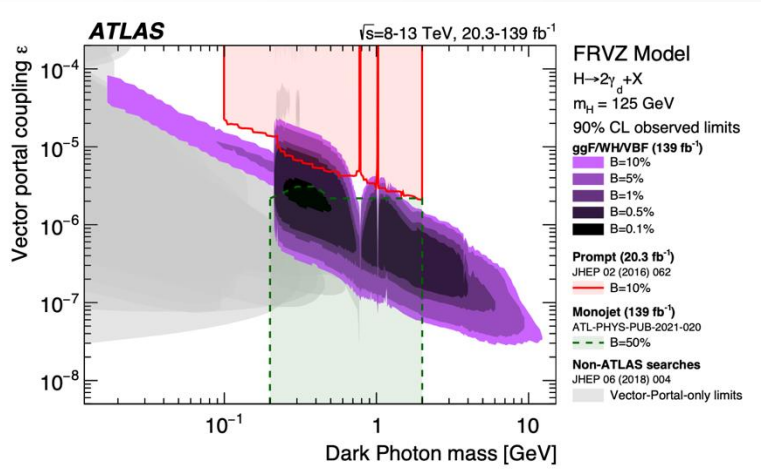




Higgs decaying through **dark photons**
→use lepton-jets

Edinburgh, Liverpool

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



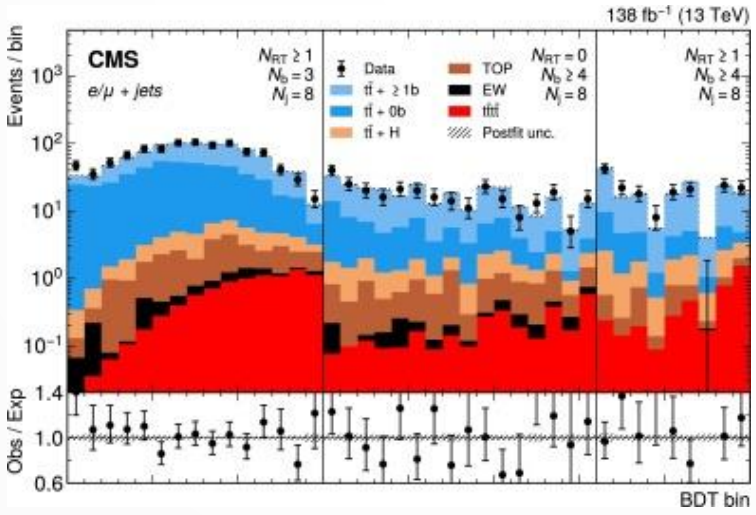
Physics strengths and highlights: CMS

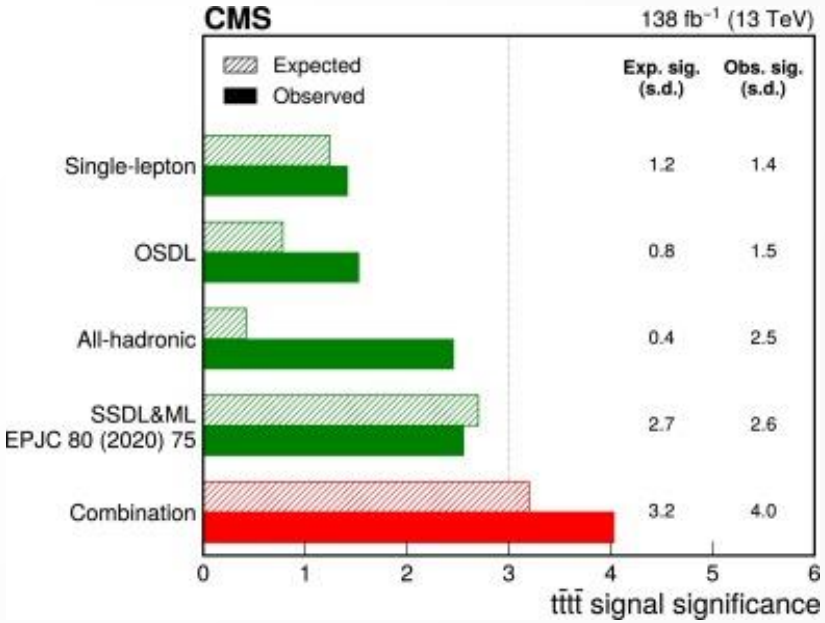
- UK-CMS is strongly engaged in top physics (Brunel, Bristol, RAL), Higgs physics (Imperial), and searches for new physics, including SUSY, dark matter, long-lived particles (Imperial) and new resonances as Z' (RAL)
- **Top physics**
  - Long-standing contributions on top-pair cross sections, single-top studies, top MC modelling etc.
  - Recent highlight – **four-top process**

Bristol, Brunel

    - **UK-led** first evidence of this important process (later superseded by observation)
    - observed cross section of 17+/4(stat)+/3(syst) fb
    - BDT-based
    - 0/1/2(SS) leptons

PLB.2023.138076





Physics strengths and highlights: CMS

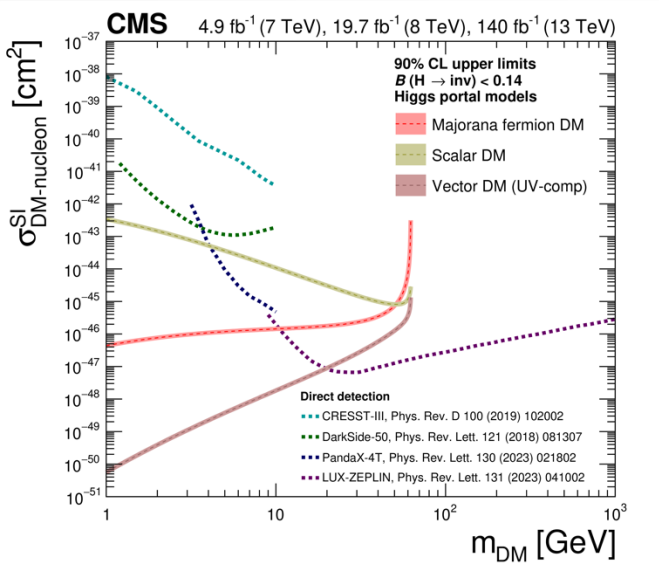
- UK-CMS is strongly engaged in top physics (Brunel, Bristol, RAL), Higgs physics (Imperial), and searches for new physics, including SUSY, dark matter, long-lived particles (Imperial) and new resonances as Z' (RAL)

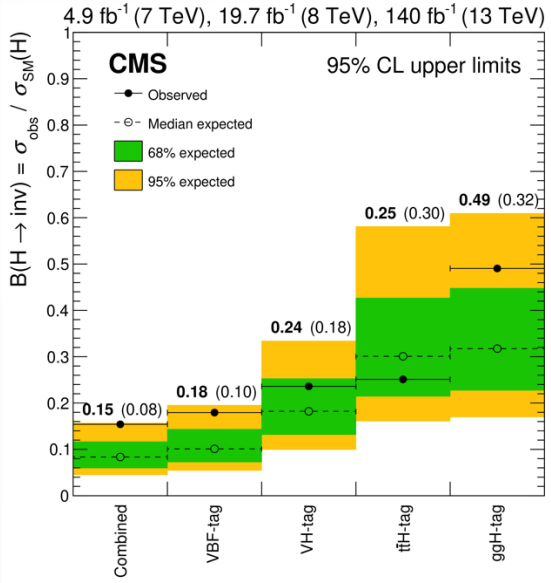
UK-led recent report on **Dark sector searches**: huge effort to map over 40 results and produce new interpretations

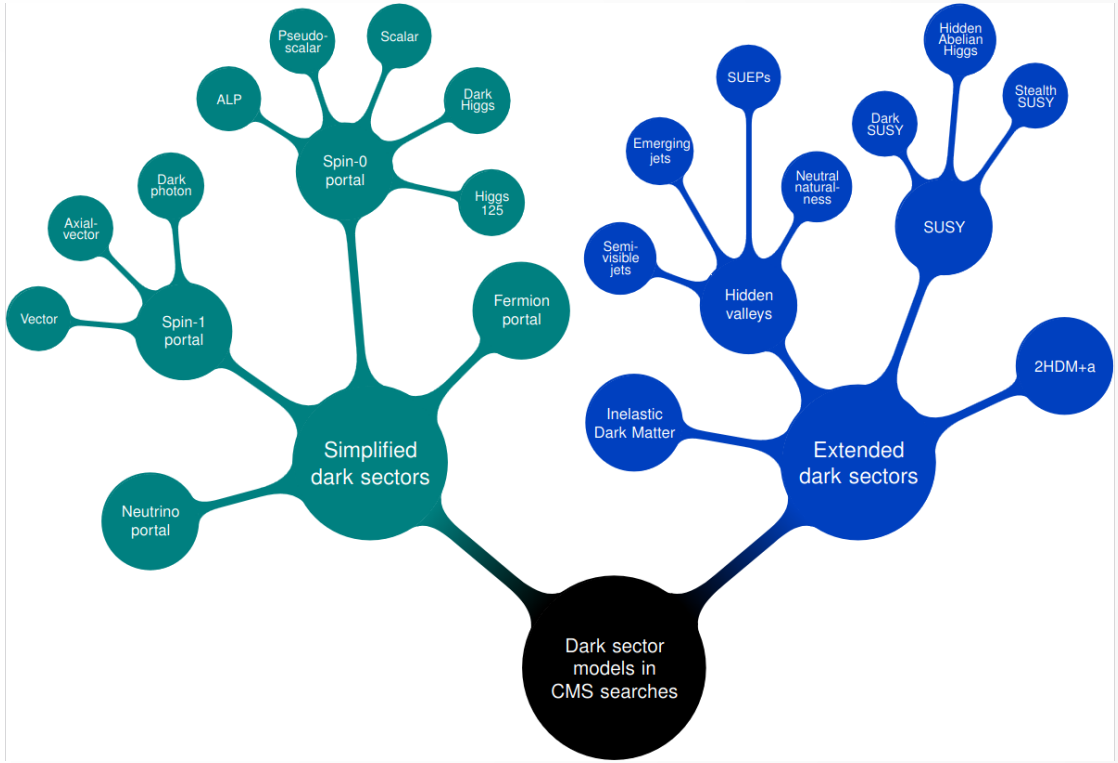
arXiv:2405.13778

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

Bristol, Imperial







Physics strengths and highlights: CMS

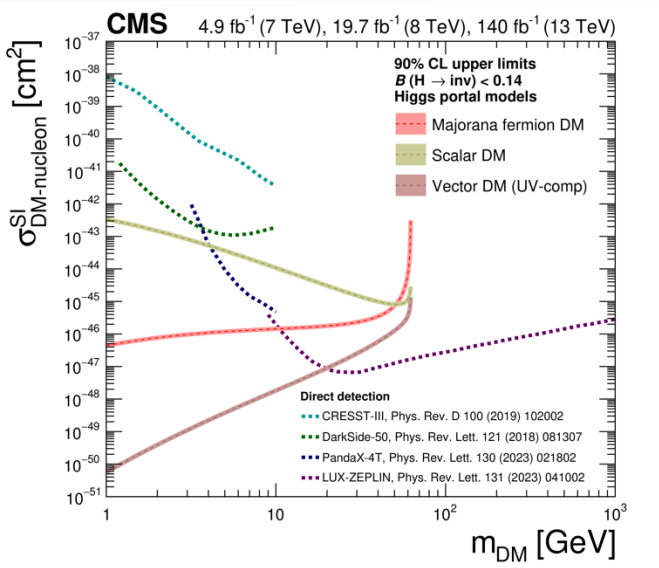
- UK-CMS is strongly engaged in top physics (Brunel, Bristol, RAL), Higgs physics (Imperial), and searches for new physics, including SUSY, dark matter, long-lived particles (Imperial) and new resonances as Z' (RAL)

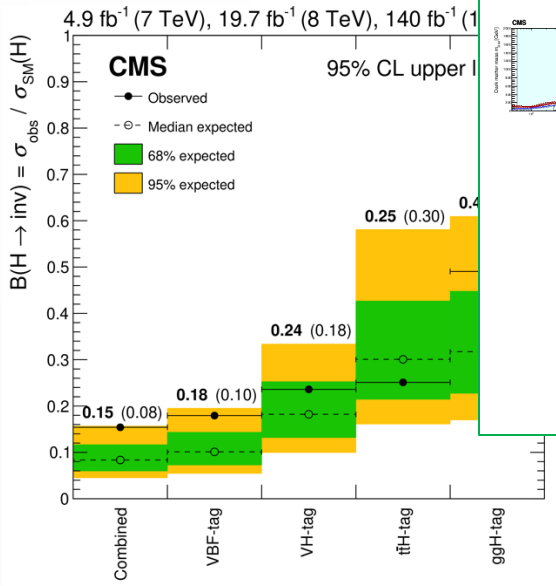
UK-led recent report on **Dark sector searches**: huge ef
to map over 40 results and produce new interpretations

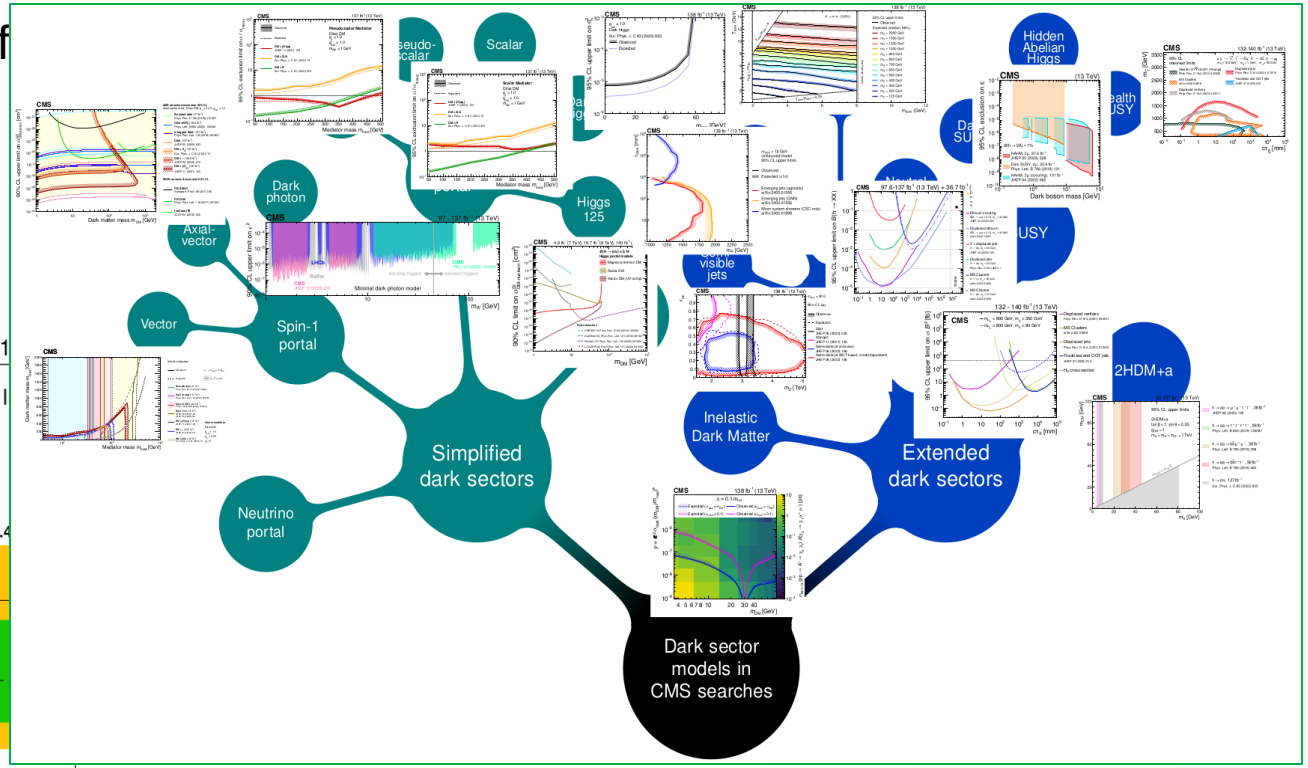
arXiv:2405.13778

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

Bristol, Imperial







Imperial

Physics strengths and highlights: CMS

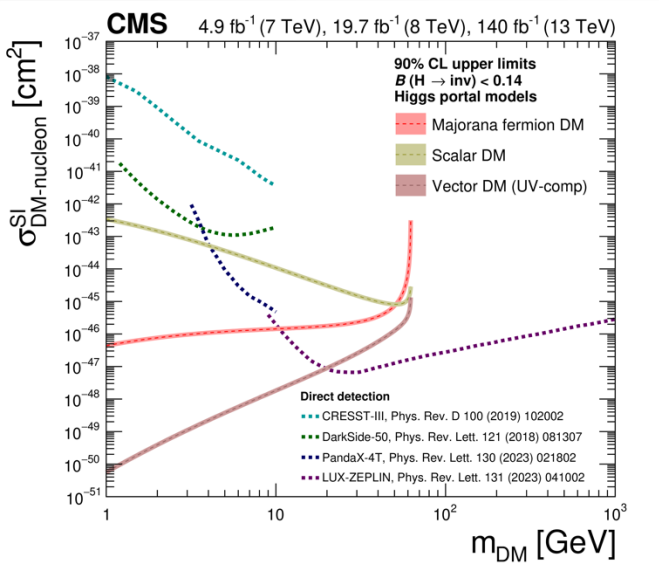
- UK-CMS is strongly engaged in top physics (Brunel, Bristol, RAL), Higgs physics (Imperial), and searches for new physics, including SUSY, dark matter, long-lived particles (Imperial) and new resonances as Z' (RAL)

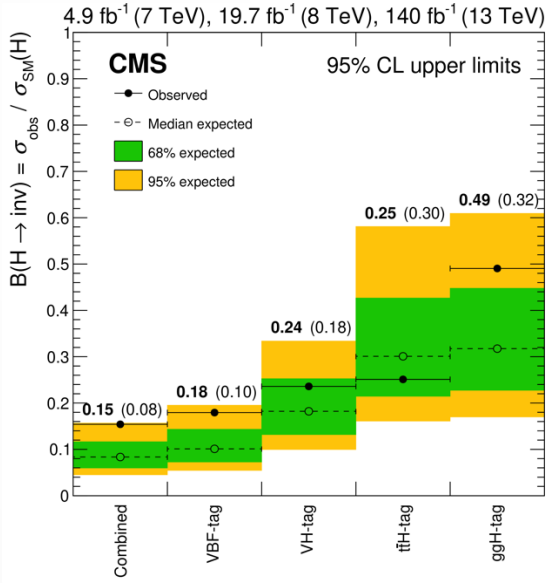
UK-led recent report on **Dark sector searches**: huge effort to map over 40 results and produce new interpretations

arXiv:2405.13778

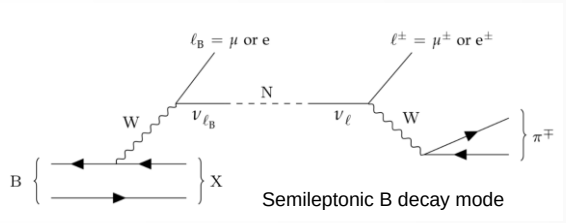
Include Higgs decaying in WIMP-like DM (**Higgs-portal**)

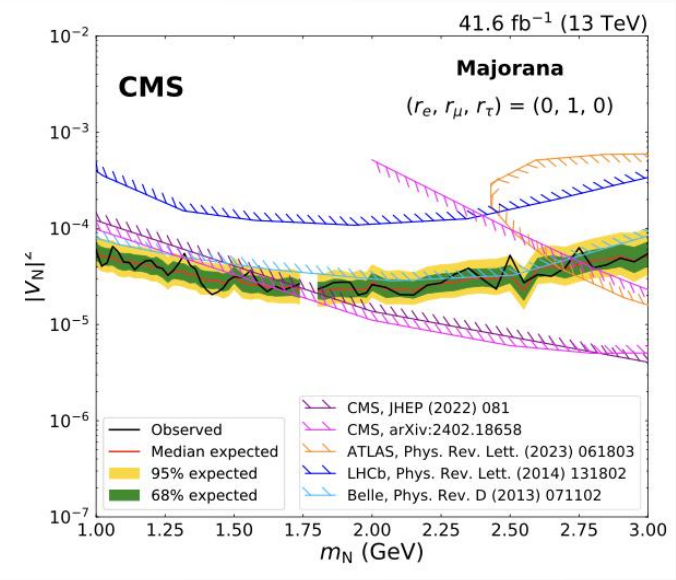
Bristol, Imperial





Heavy neutrinos (HNL) – long-lived





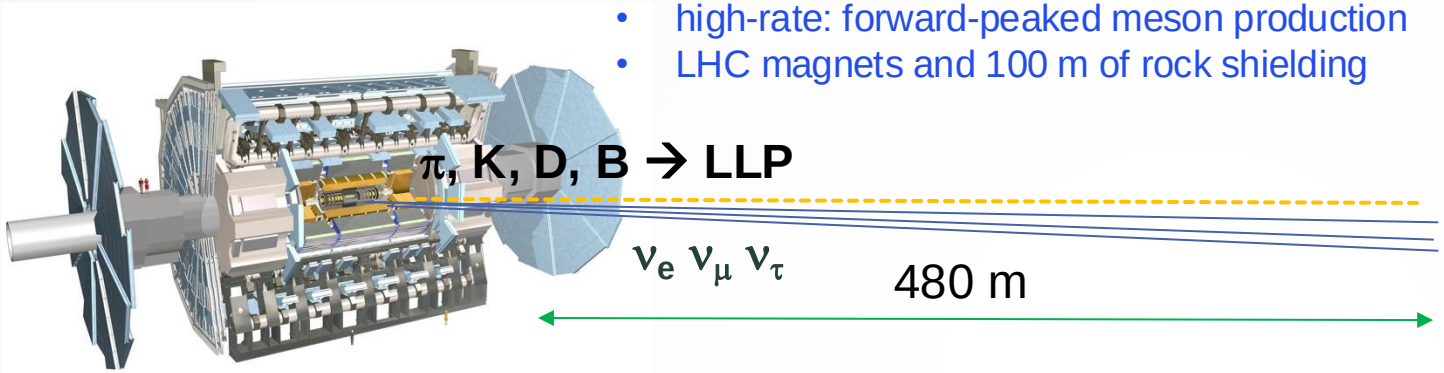
JHEP 03 (2024) 105

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

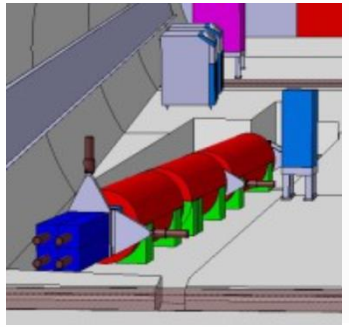
Imperial

Physics highlights: FASER

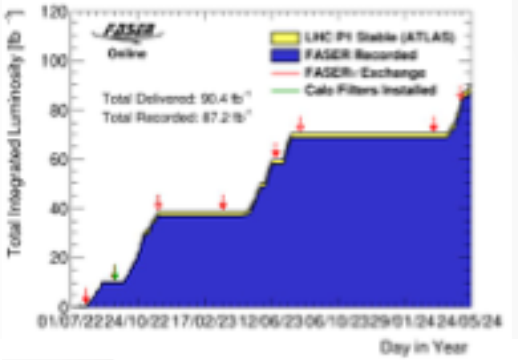
- Built in 2021, in operation since 2022 Run 3 start, FASER targets new light, weakly interactive particles and high-energy neutrinos produced at the ATLAS collision point



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



Luminosity so far

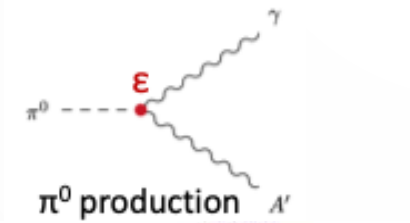


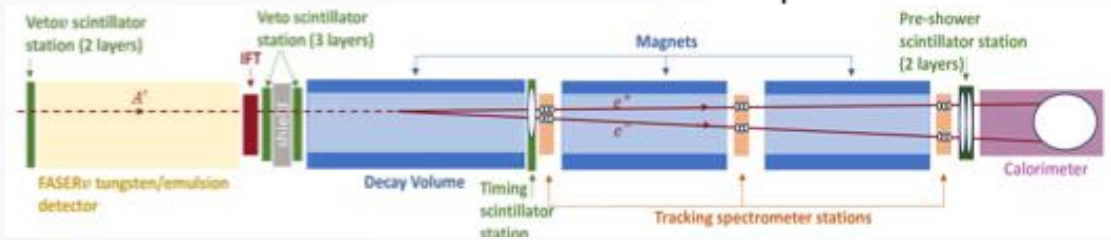
- Strong UK contributions with STFC-funding through PhDs (no MoU involved, cheap experiment built with left-over…):

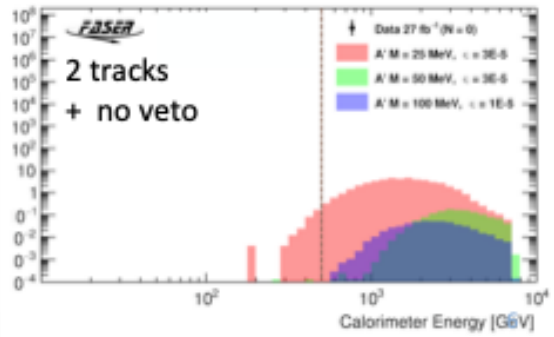
Dark Photon search

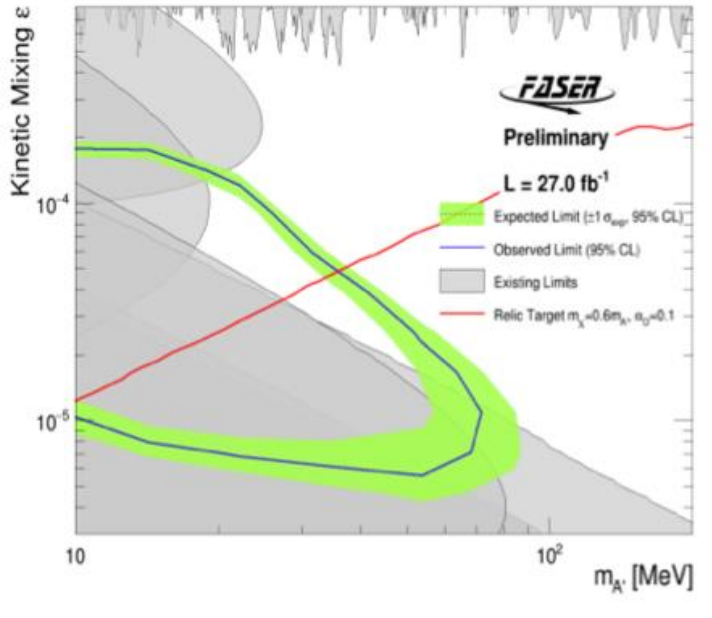
Phys. Lett. B 848 (2024) 138378

Liverpool, Manchester, Sussex









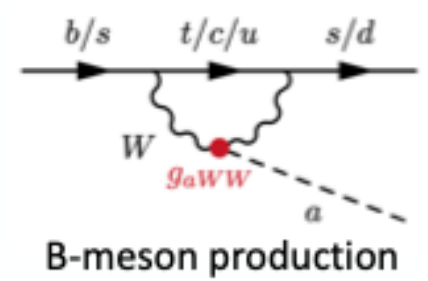
First constraint in thermal relic region @ low coupling for 30 yrs!

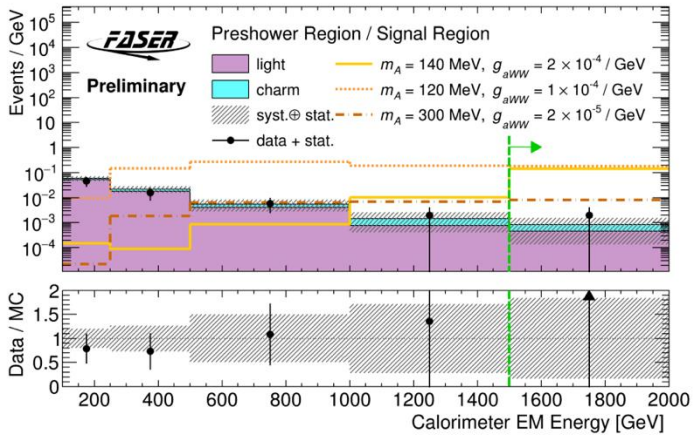
Physics highlights: FASER (2)

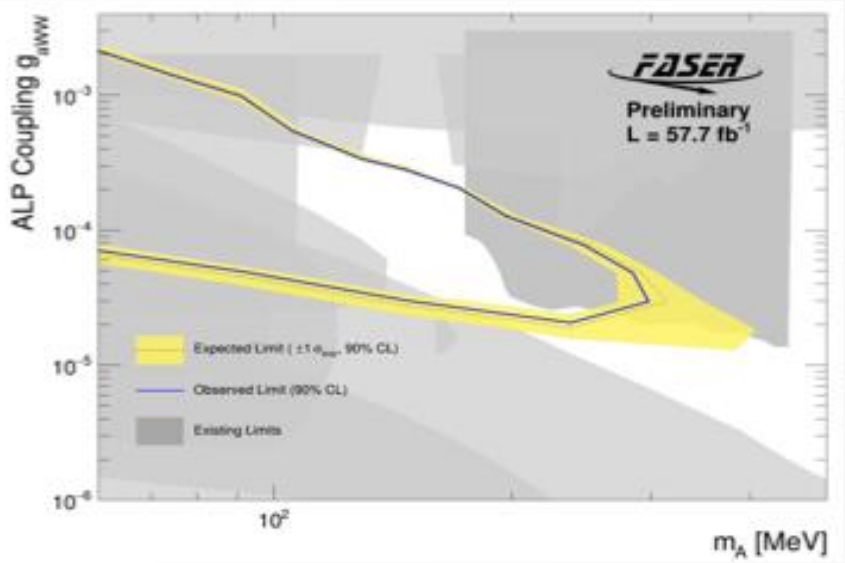
- Search for **axion-like particles (ALPs)** in $\gamma\gamma$

CERN-FASER-CONF-2024-001

Liverpool

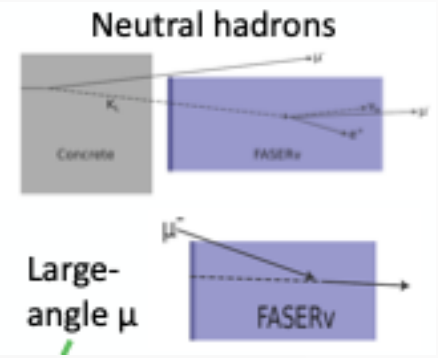


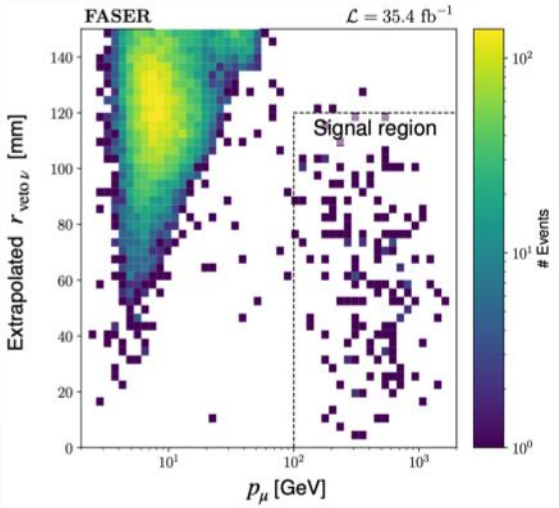




- First direct observation of neutrinos and measurement of ν_e **and** ν_μ interactions

PRL 131 (2023) 3, 031801



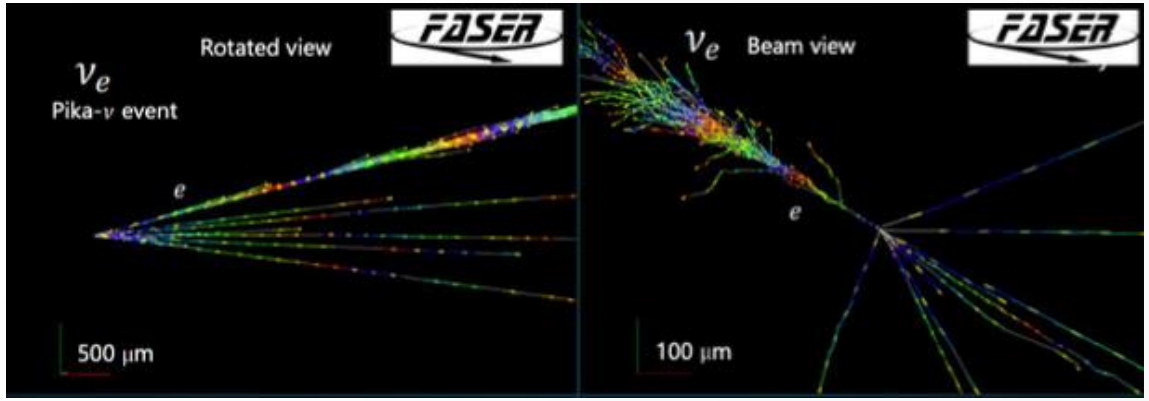


Liverpool, Manchester, RHUL, Sussex

PRL. 133, 021802 (2024)

Observed: 153+12-13 ν_m interactions

Interactions in emulsion detectors (FASERν)



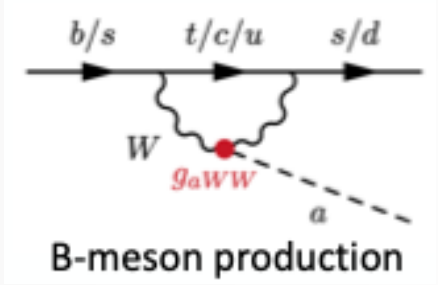
4ν_e and 8ν_μ candidates observed, also in TeV range

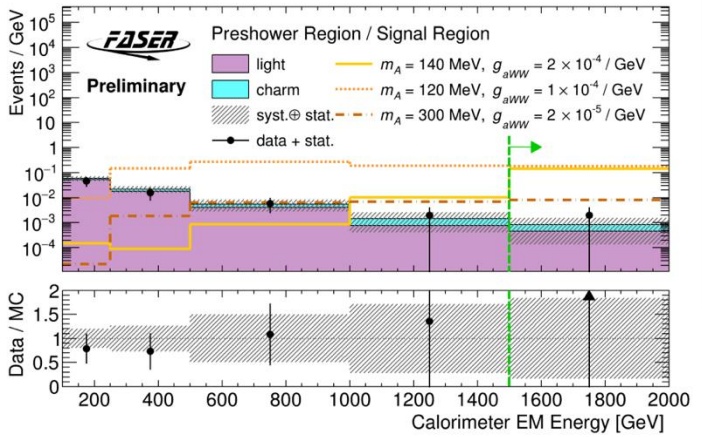
Physics highlights: FASER (2)

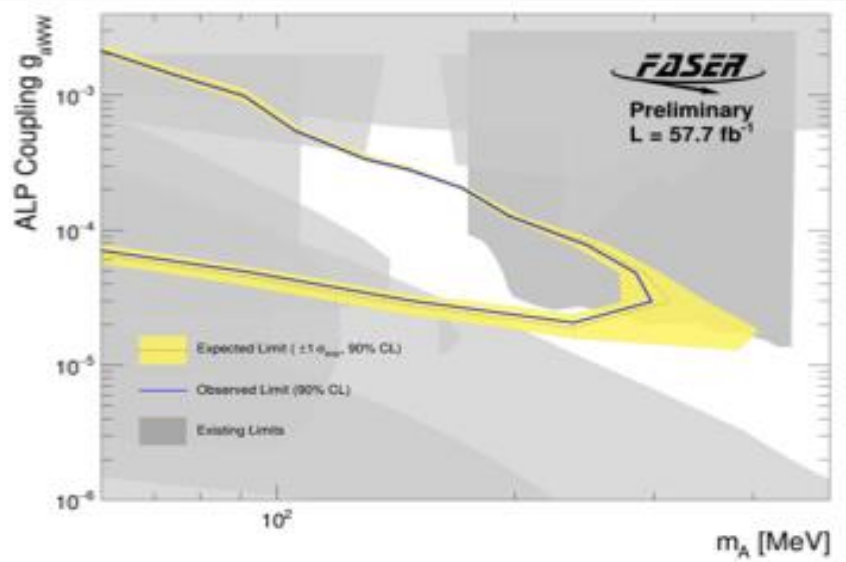
- Search for **axion-like particles (ALPs)** in $\gamma\gamma$

CERN-FASER-CONF-2024-001

Liverpool

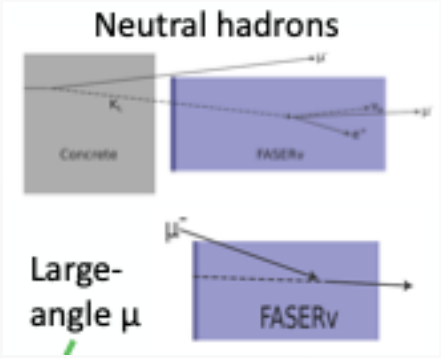


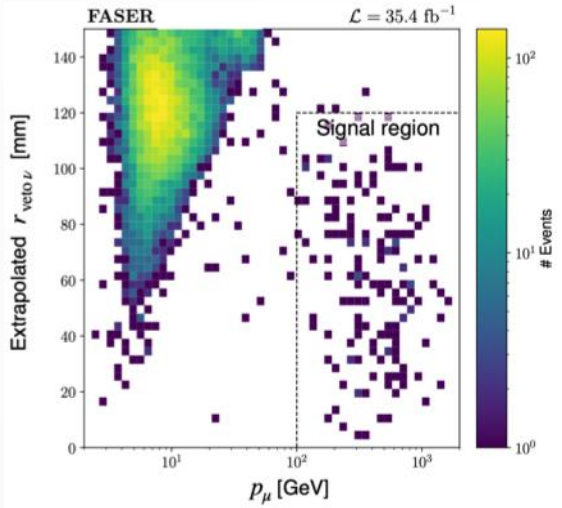




- First direct observation of neutrinos and measurement of ν_e **and** ν_μ interactions

PRL 131 (2023) 3, 031801

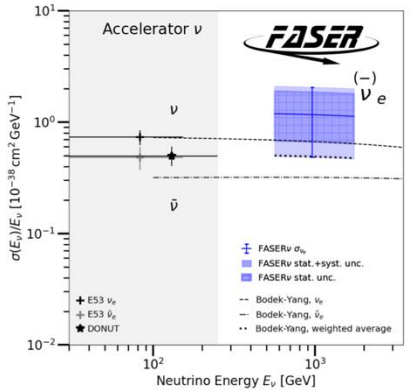


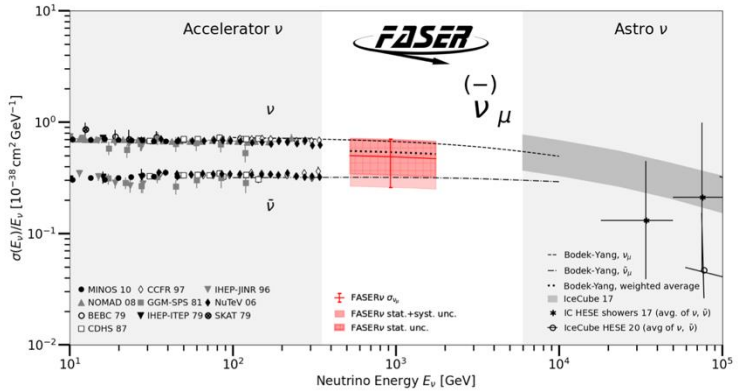


Liverpool, Manchester, RHUL, Sussex

PRL. 133, 021802 (2024)

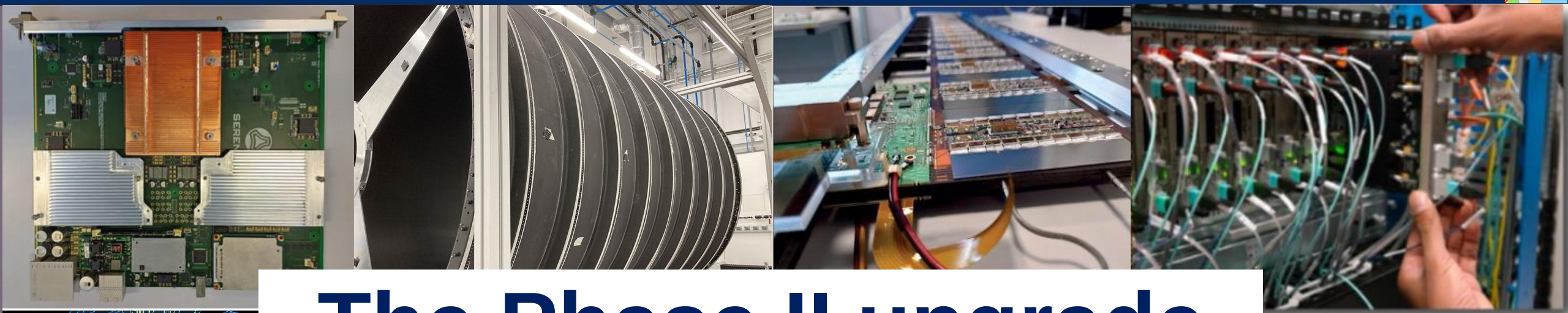
Interactions in emulsion detectors (FASERν)



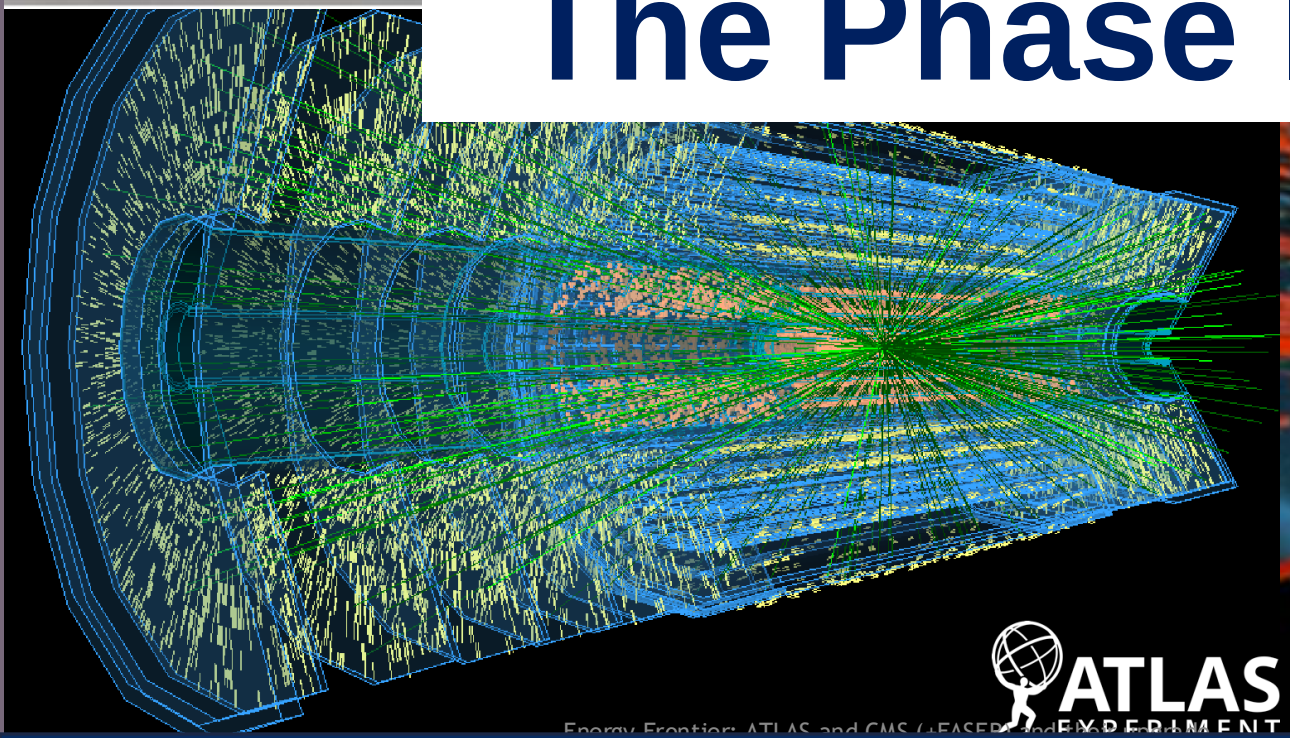


Observed: 153+12-13 ν_m interactions

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



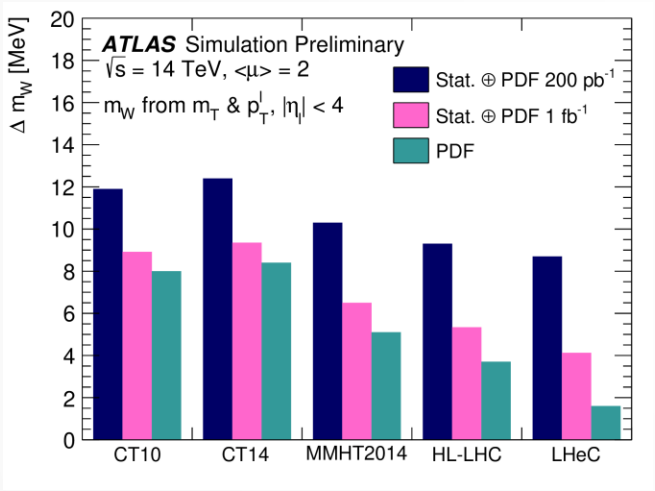
The Phase II upgrade



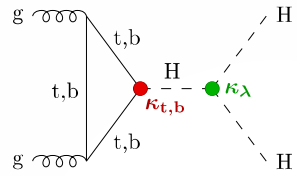
Pushing towards the energy frontier: HL-LHC

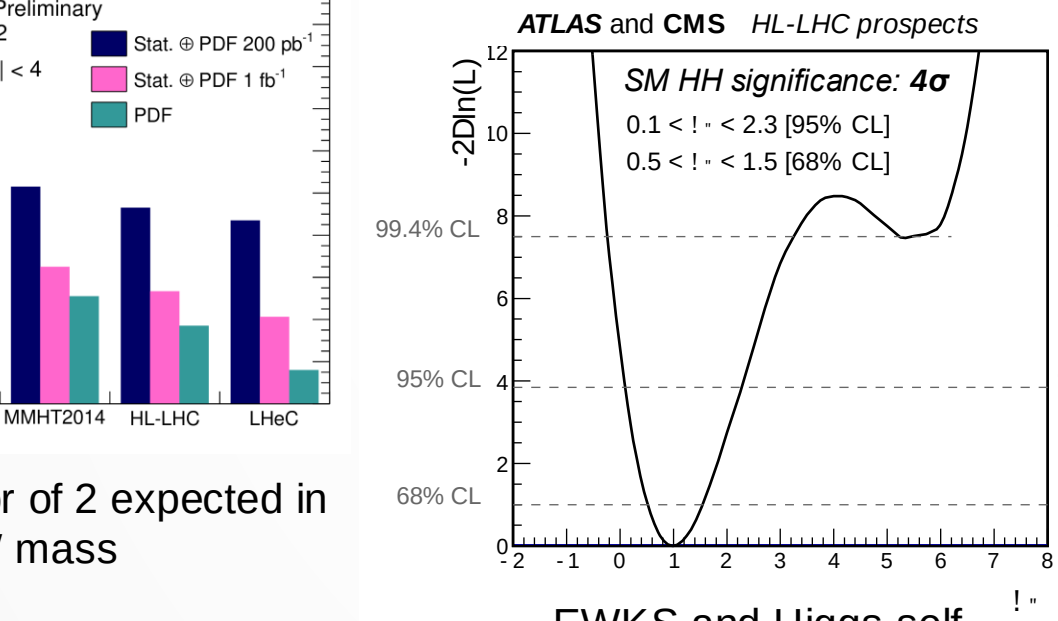
- **HL-LHC prospect studies**, done also to understand the impact of the detectors' performance → strong engagement of **UK-ATLAS** and **UK-CMS** for the Yellow Book reports (2017-19)
  - From SM precision measurements to di-Higgs and new physics searches, huge potential

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

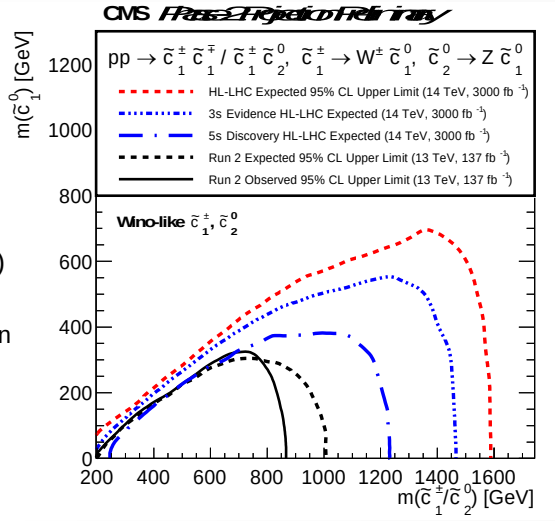


At least a factor of 2 expected in precision for W mass

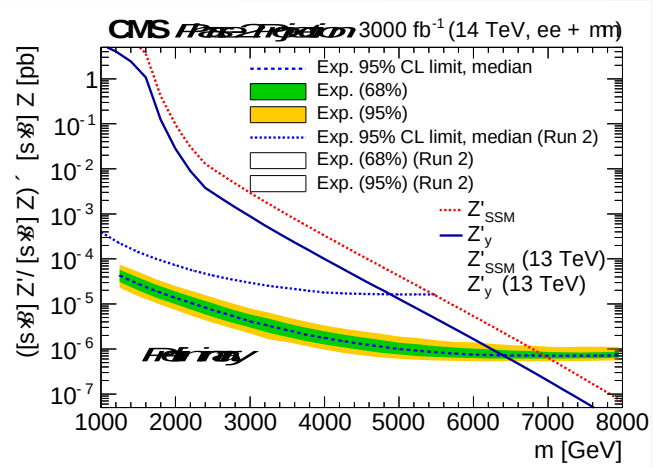




EWKS and Higgs-self coupling evidence



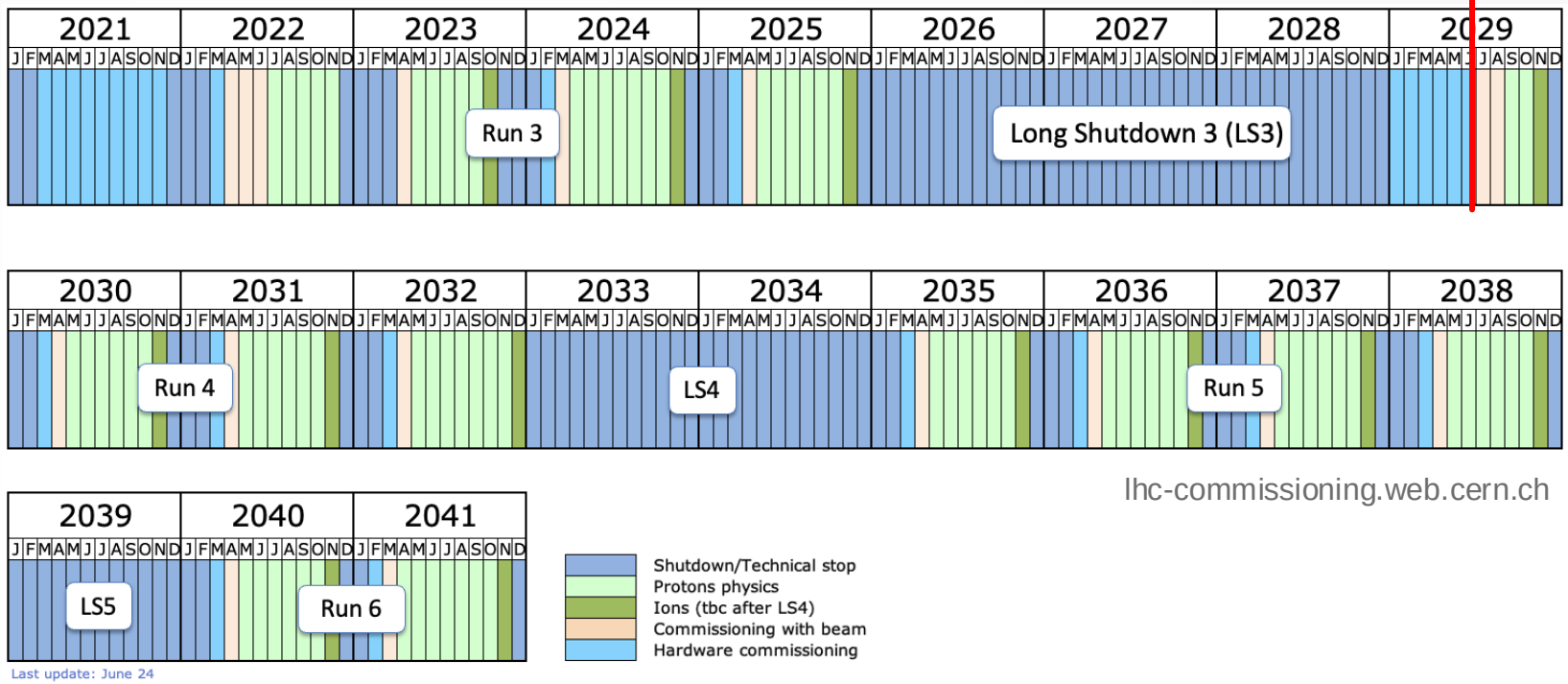
For NP, increase the present reach in mass and coupling by 20-50%

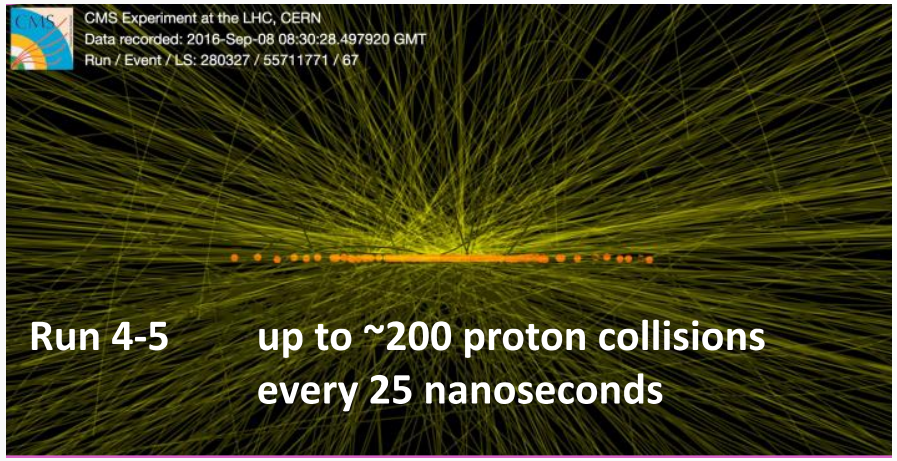


Contribution of many institutes…

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}**
  - **3-4 ab^{-1} / experiment expected**
- **14 TeV** collisions

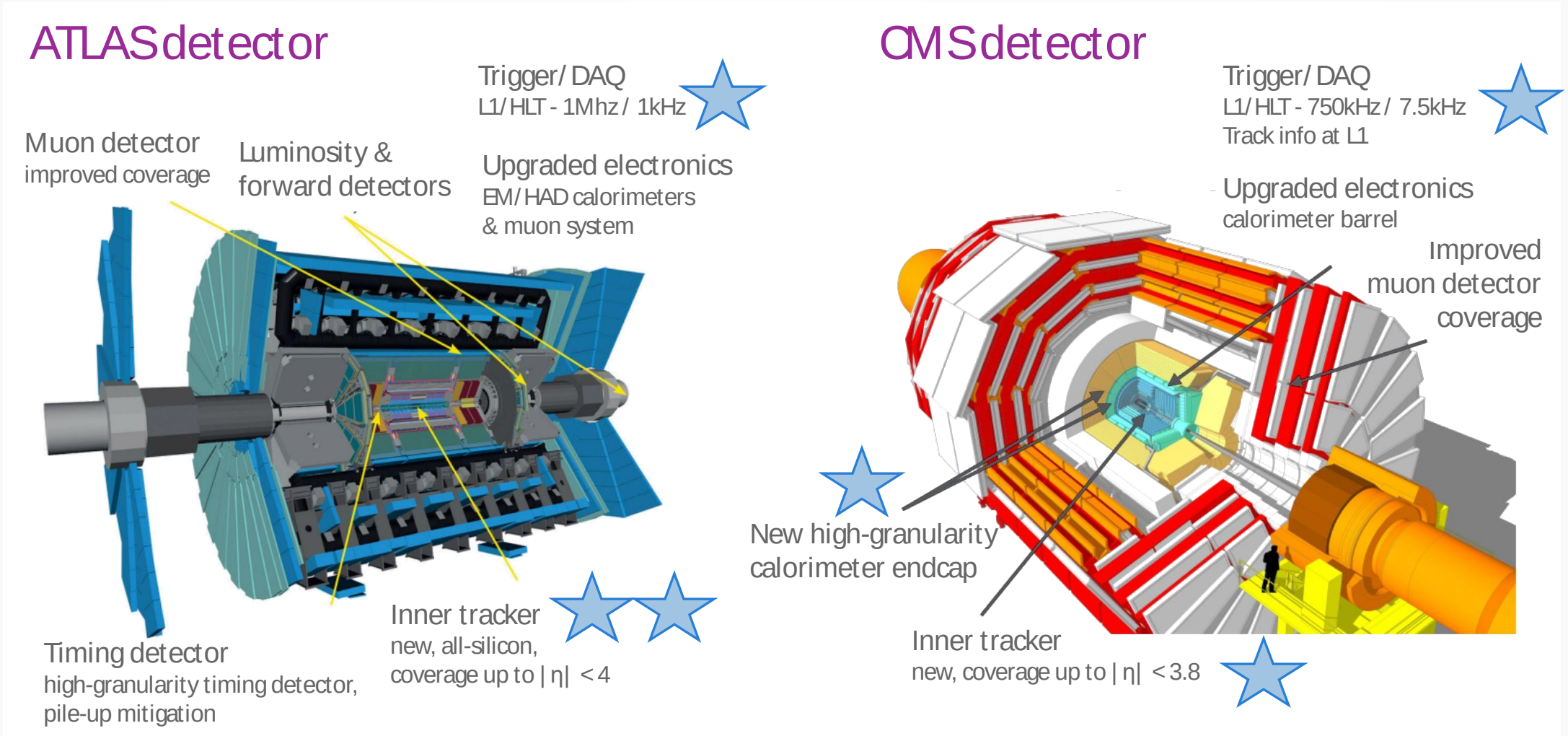




Challenges and solutions

- 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

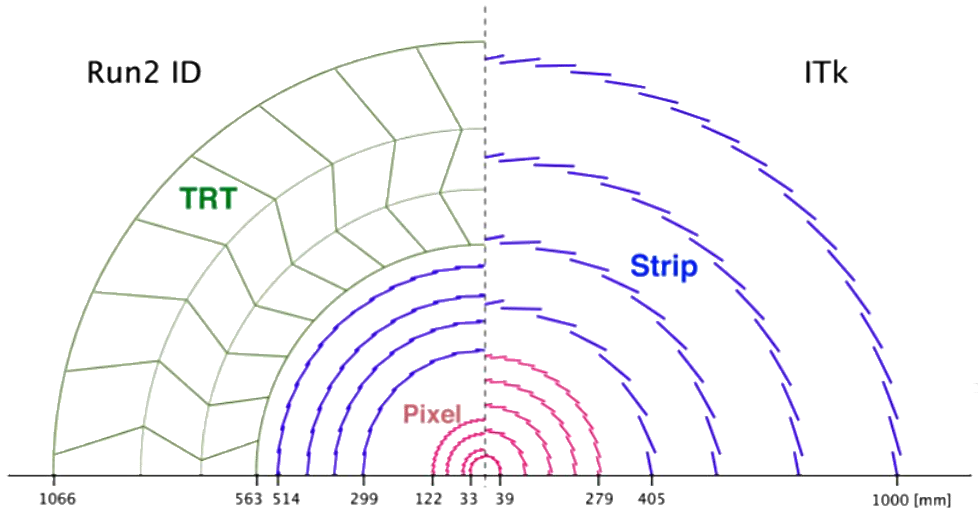
GPDs upgrade programs at glance

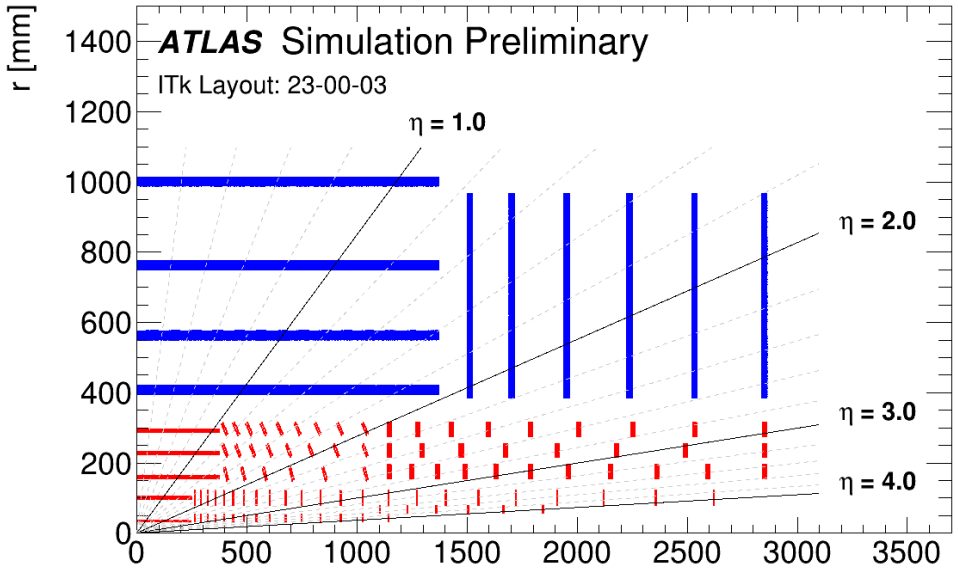


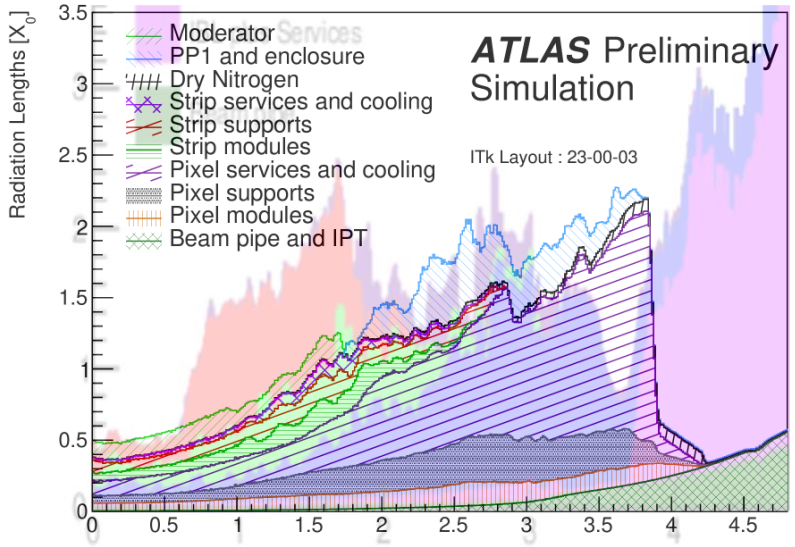
- **Funding**: mainly STFC, capital contribution to upgrade in line with fair share. Current (being extended):
  - **ATLAS**: £128M for 12 years (2014-2026)
  - **CMS**: £13.6M for 6 years (2019-2025)

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







Material comparison between current ID and 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

    - Institutes ready for production – highlight to be included in 1 sentence
    - huge work to understand and solve sensors problems in collaboration with US and other institutes

"Interposer" solution, module design modified

Cold tests (-70 deg) on-going

  - **ITK pixels:**

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

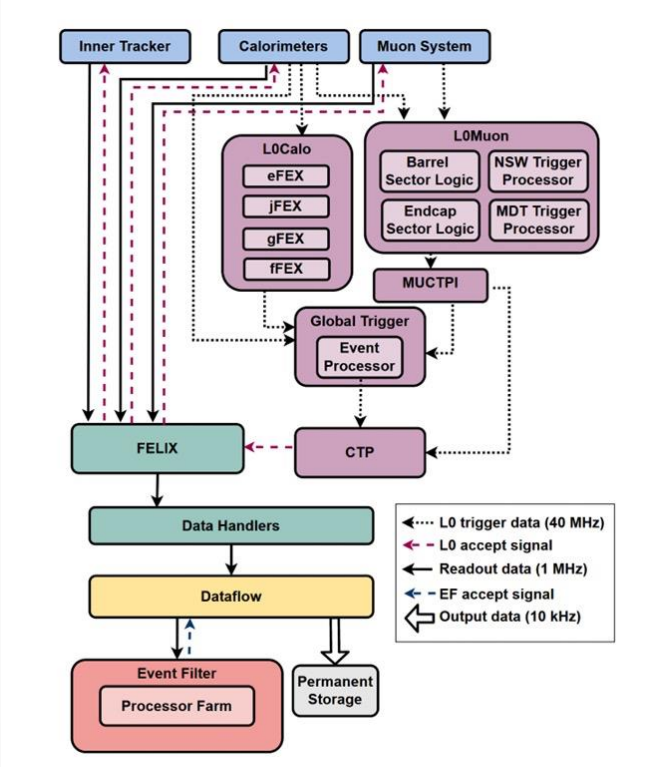
    - Assembly site, construction processes and quality insurance tests in place at all sites
    - Joint task force ATLAS-CMS expert for ASICs to study challenges in hybridization process and ASICs
- Preparation in SR1 in full progress with deliverables from UK getting to CERN…

Preparation for I&C in SR1

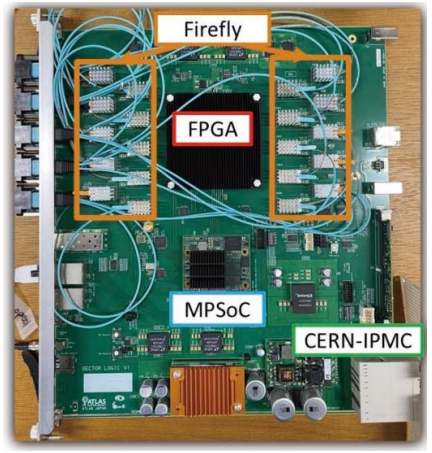
ATLAS upgrade: Trigger and DAQ

- Another **important 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, Edinburgh (to be checked)



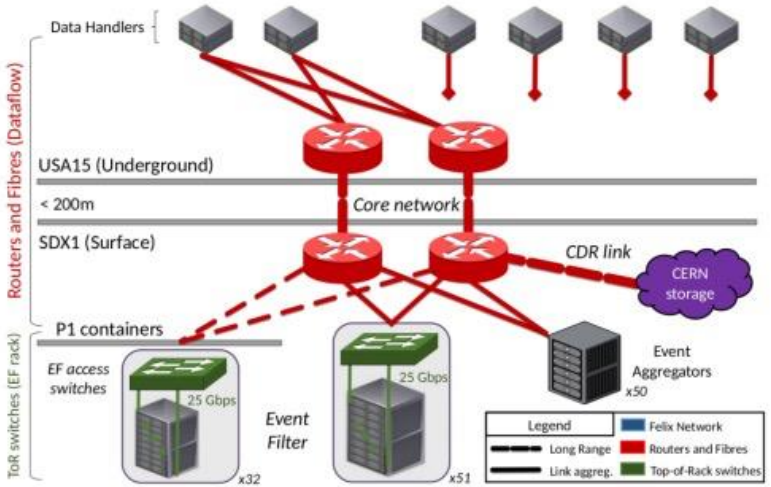
L0 Trigger: prototyping and testing



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

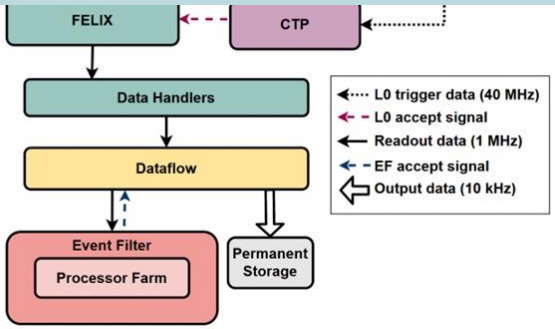
- Another **important UK deliverable**
- Phase II TDAQ specifications are challenging:
  - L0 rate 1 MHz with 10us latency
  - EF output rate 10 KHz

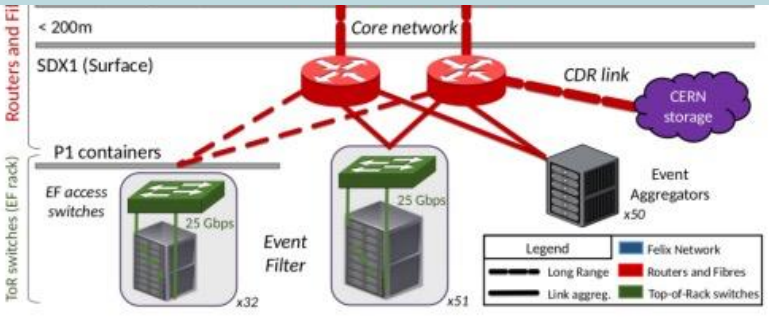
Birmingham, RHUL, UCL, RAL

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

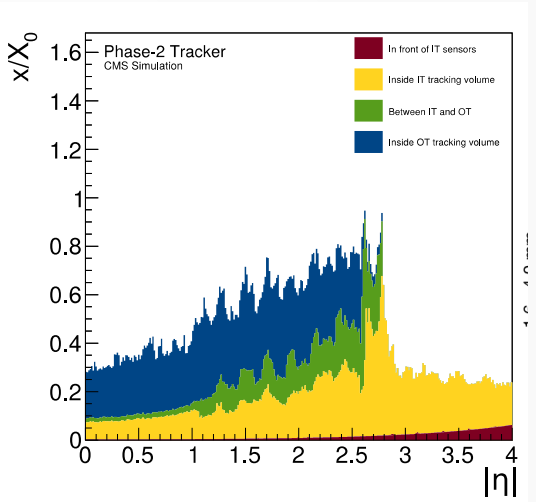
- **Overall:** ALTAS-Phase II upgrade work is also relevant for
  - **training of qualified personnel:** 55 PhD students have graduated in the past 5 years with activities on upgrade, apprenticeship programs for technical staff, research and development spin-off..
  - **Industry engagement:** collaborations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

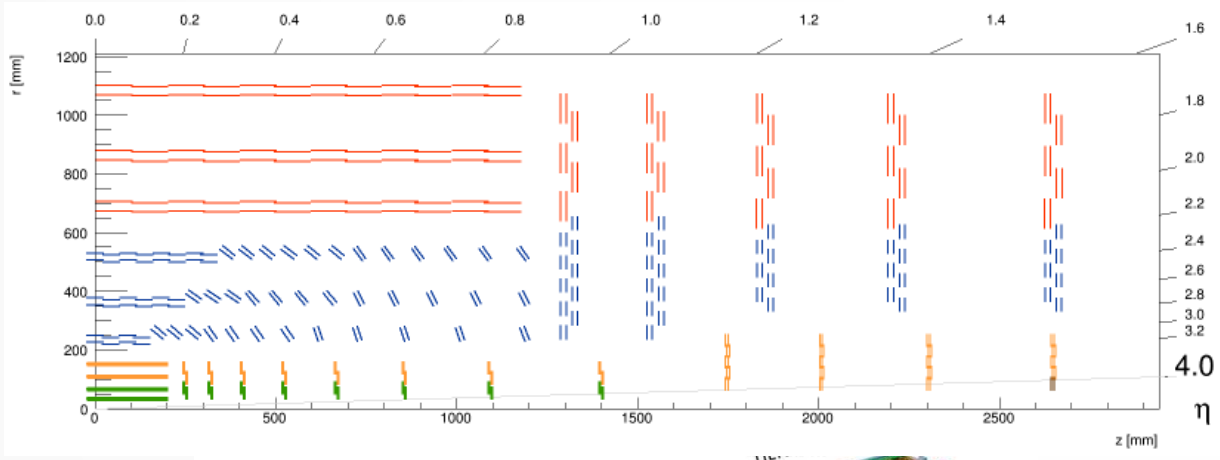


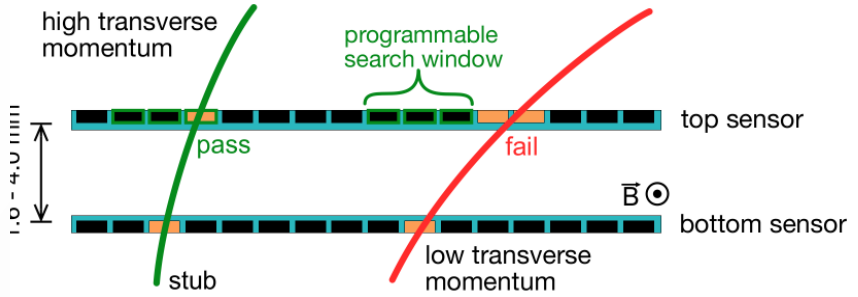


CMS upgrade: Tracker

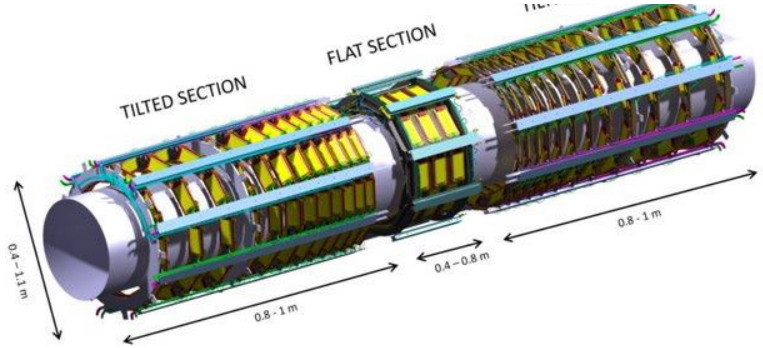
- **Main UK-deliverable:** common electronics platform contributing to tracker, calorimetry and trigger
- CMS also going through a total replacement of its tracking system
  - Increased granularity (~1200 tracks / unit of pseudorapidity)
  - Reduced material to preserve calorimetric resolution
  - Contribution to the L1 trigger (outer tracker tracks identification)







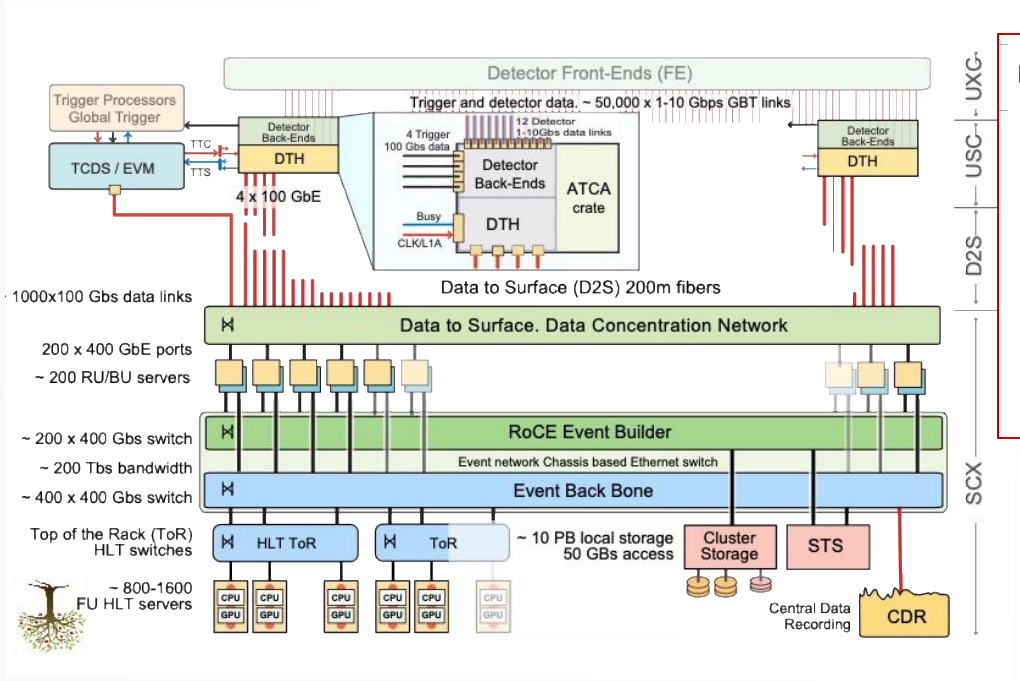
Outer tracker



UK: electronics and algorithms for track trigger, and ASICs → progressing well, with **ASICs completed**

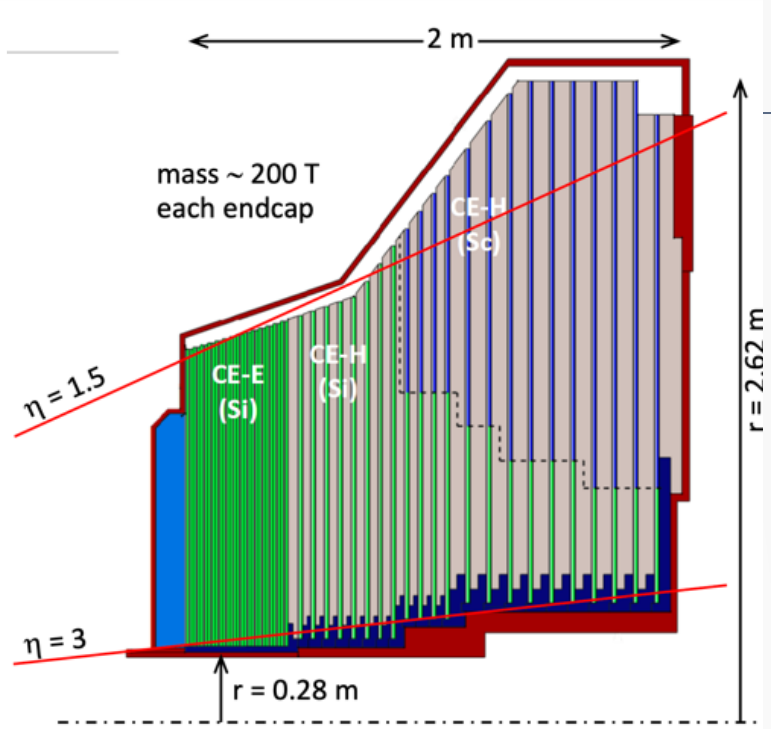
CMS upgrade: Calorimeter and DAQ

- **CMS calorimeter (ECAL)** system fully upgraded
  - Radiation tolerant, shower lateral compactness, fine granularity
  - Resolution 20 ps /channel and contribution to the L1 trigger
- **DAQ:**
  - 50k high-speed front-end optical links
  - Up to 60 Tb/s data rate, total event size 7-10 MB



Highlights

- Unified detector readout
  - ATCA form-factor for detector backend
- Dual-function board DTH-400
  - DAQ data aggregation
  - Timing and Trigger Control and Distribution
- Event Network
  - RDMA over Converged Ethernet
- Heterogeneous HLT nodes
  - GPU-equipped servers



UK deliverables:

electronics and algorithms for trigger for both ECAL and HGCAL

→ progressing!

Recent achievements: test beam

- Common technology: off-detector electronics board Serenity
  - Complete hardware production including QA
  - Complete software and firmware

Large UK involvement including students

SERENITY

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

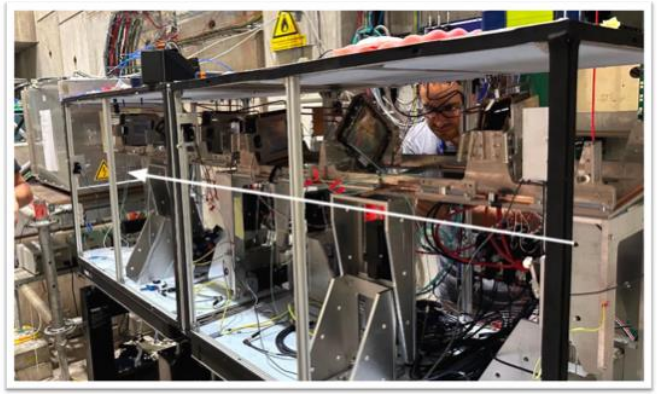
Successful ASIC work
Collaboration with Serenity

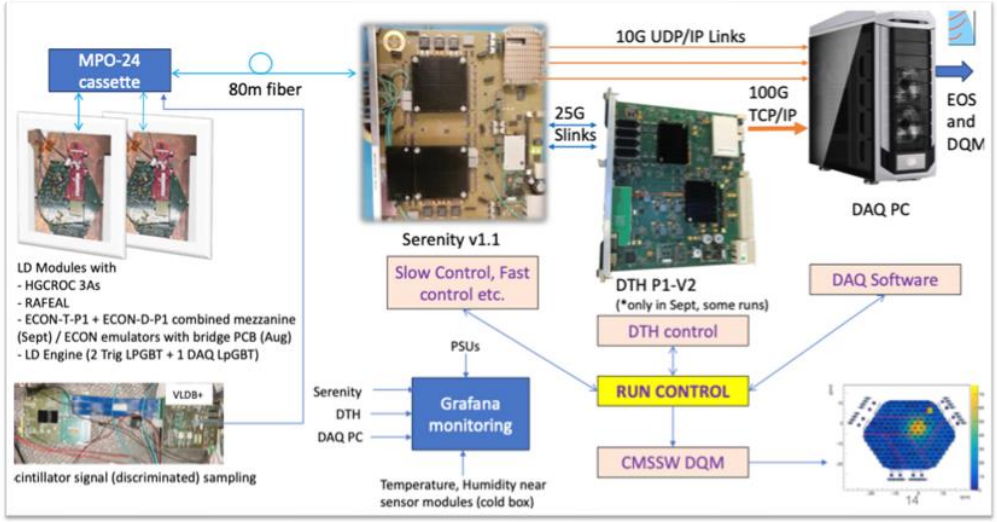
Tracker test beam

Muons @ 160 GeV

12x 2S tracker modules (each with 16 CBC ASICs)

Readout via Serenity prototype (triggerless)





HGCAL test beam

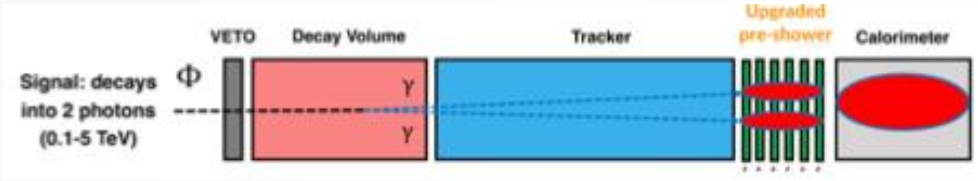
Muons, electrons and pions

Serenity readout (self-triggering)

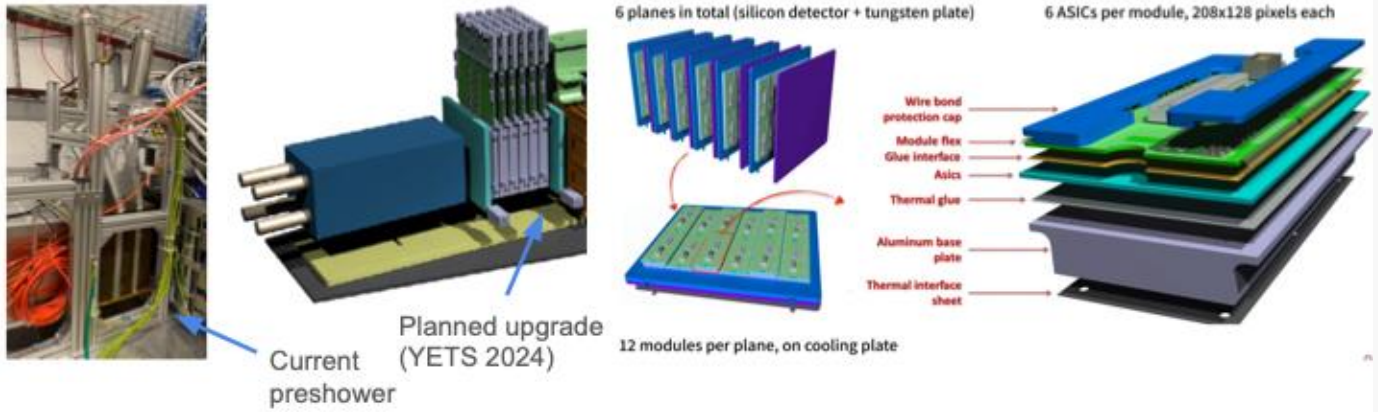
Billions of events recorded at up to 100 kHz

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)*

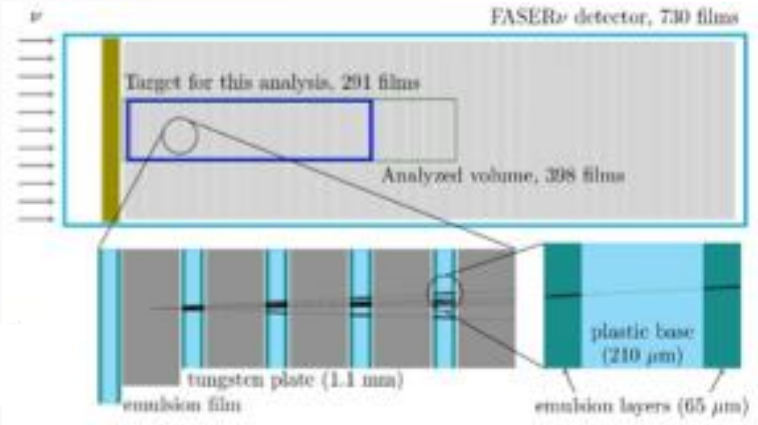


- Resolve diphoton events
- Improve sensitivity for searches of LLP→γγ



  - FASERν emulsion detector not as efficient – discussions about replacements/alternatives in progress

Current emulsion detector



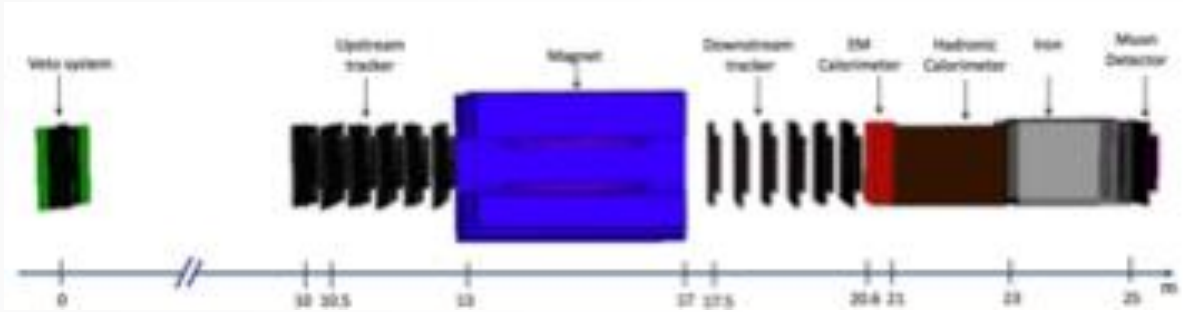
Several ideas from UK groups, in particular the possibility of a **silicon/tungsten emulsion detector** using uninstalled SCT modules

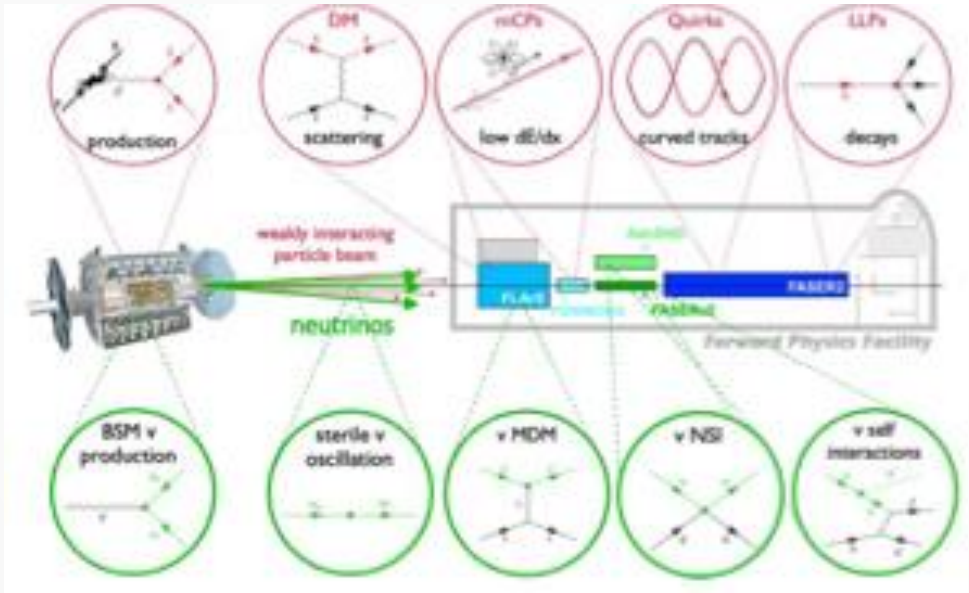
(being studied by *Manchester*)

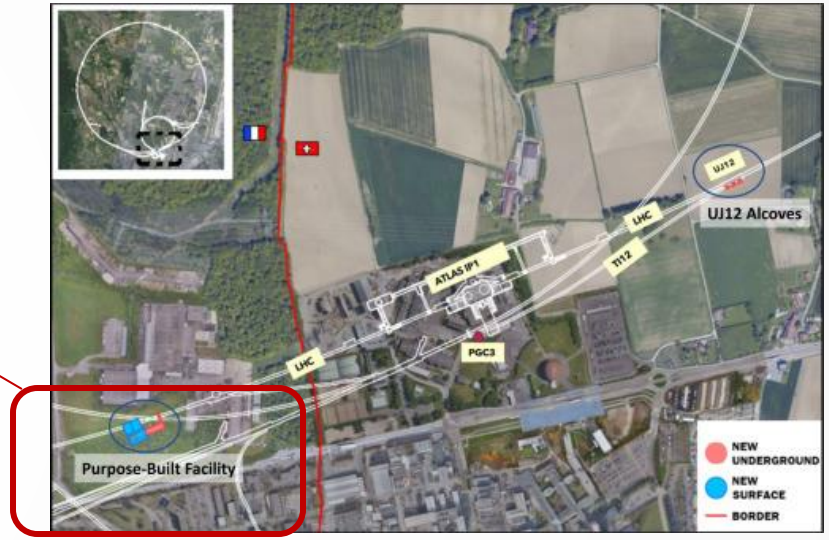
FASER @ HL-LHC: a totally different scenario

- 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







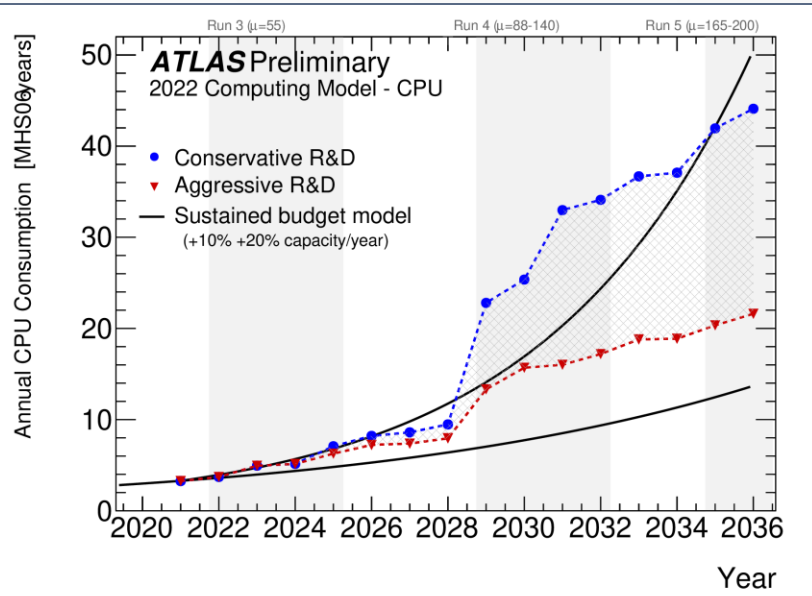
FASER-2 as part of a suite of experiments host at the FPF

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

Phase-II Computing

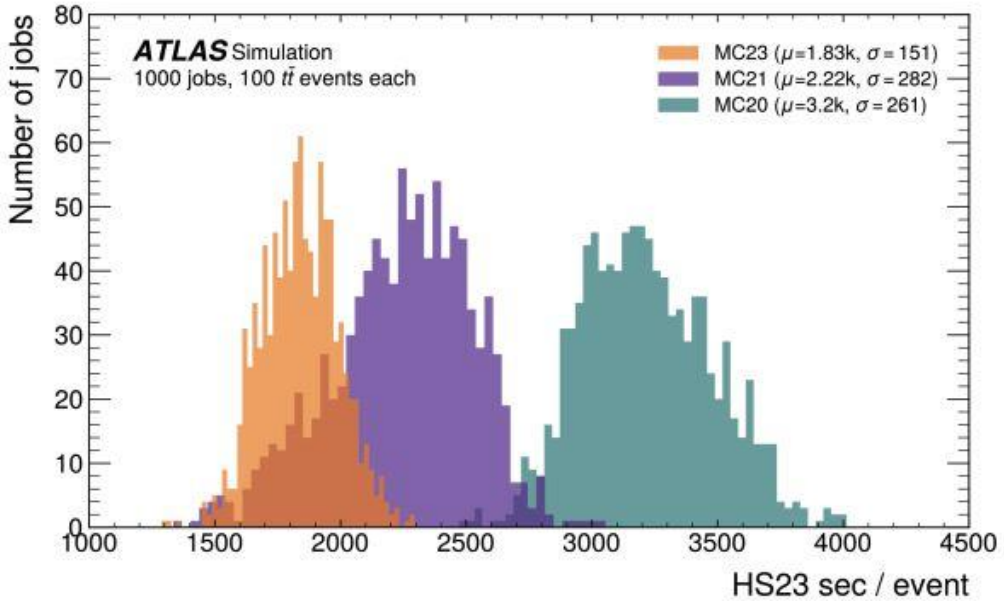
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/UPGRADE/CERN-LHCC-2022-005/

- The HL-LHC presents significant computing challenge
  - A lot of work on-going to cope with that → 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 perspective → 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 thanks 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 many, in particular to Steve McMahon, Alex Tapper and Joel Goldstein

Back up