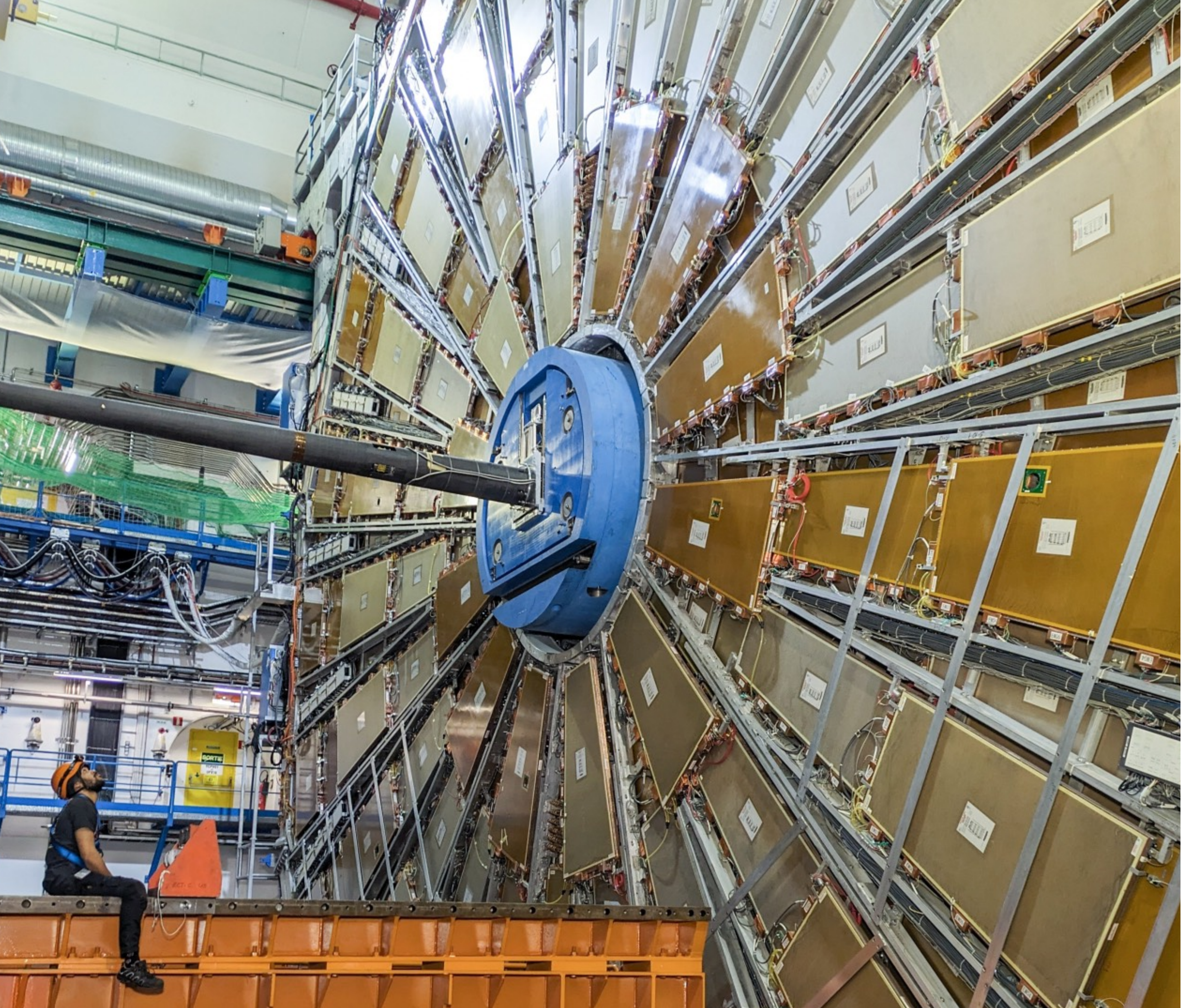

# ATLAS Status Report

**Dominique Trischuk**
Brandeis University
on behalf of the ATLAS Collaboration

LHCC Open Session
March 3, 2025

## Outline

- Data taking and performance
- Preparations for data taking in 2025 and beyond!
- Physics highlights
- Phase-II upgrades

Brandeis UNIVERSITY

# ATLAS Status Report

**Dominique Trischuk**
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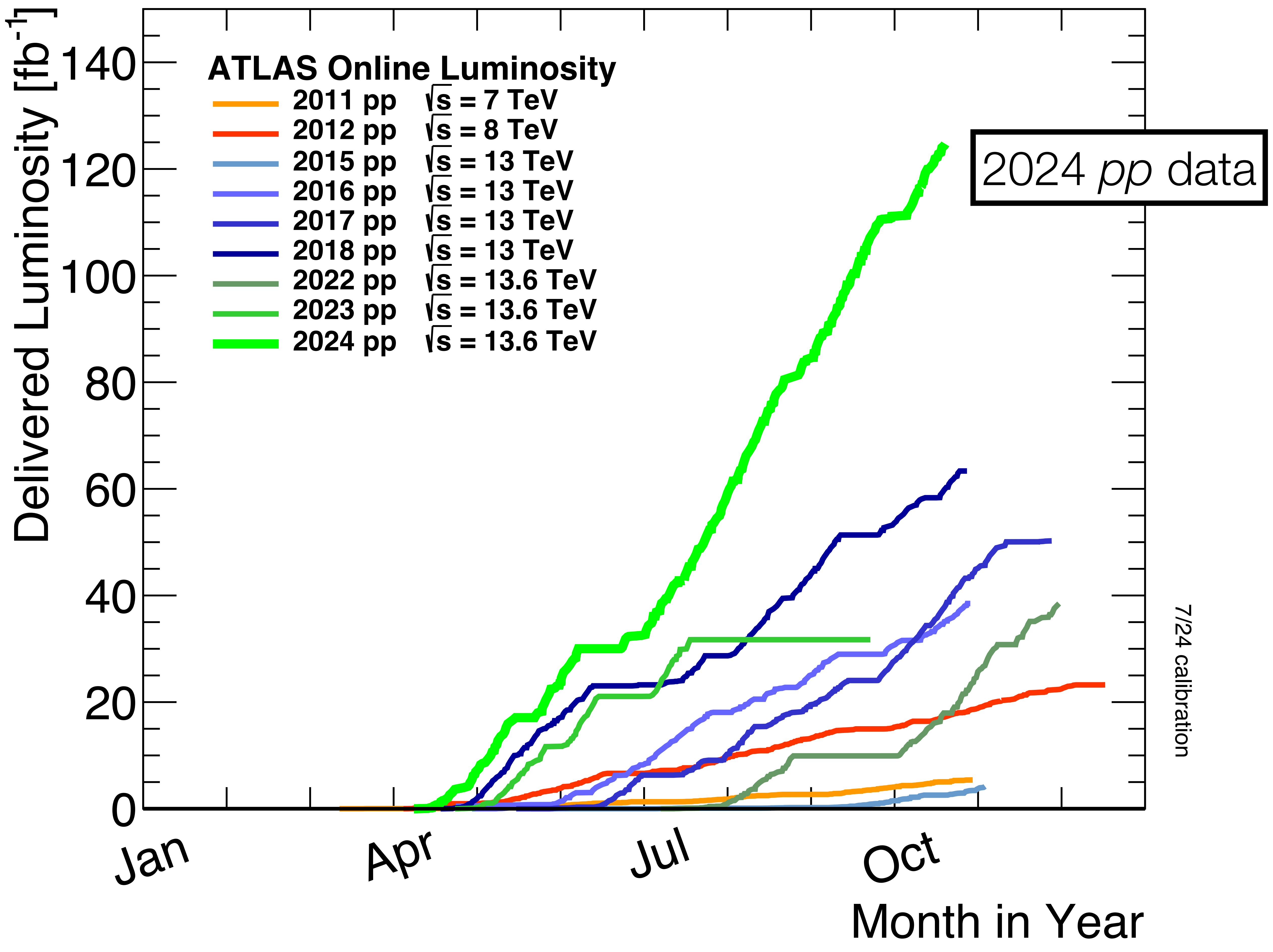
LHCC Open Session
March 3, 2025

ATLAS EXPERIMENT

# Proton-Proton Data Taking in 2024

- LHC and ATLAS luminosity above target — and smashed records in 2024
  - Highest integrated luminosity achieved so far: 2x best previous year (2018)
  - High recording efficiency (94%) despite of very high pileup conditions
  - Run 3 dataset, now at 195 (183) $fb^{-1}$ delivered (recorded)



# Proton-Proton Data Taking in 2024

- LHC and ATLAS luminosity above target — and smashed records in 2024
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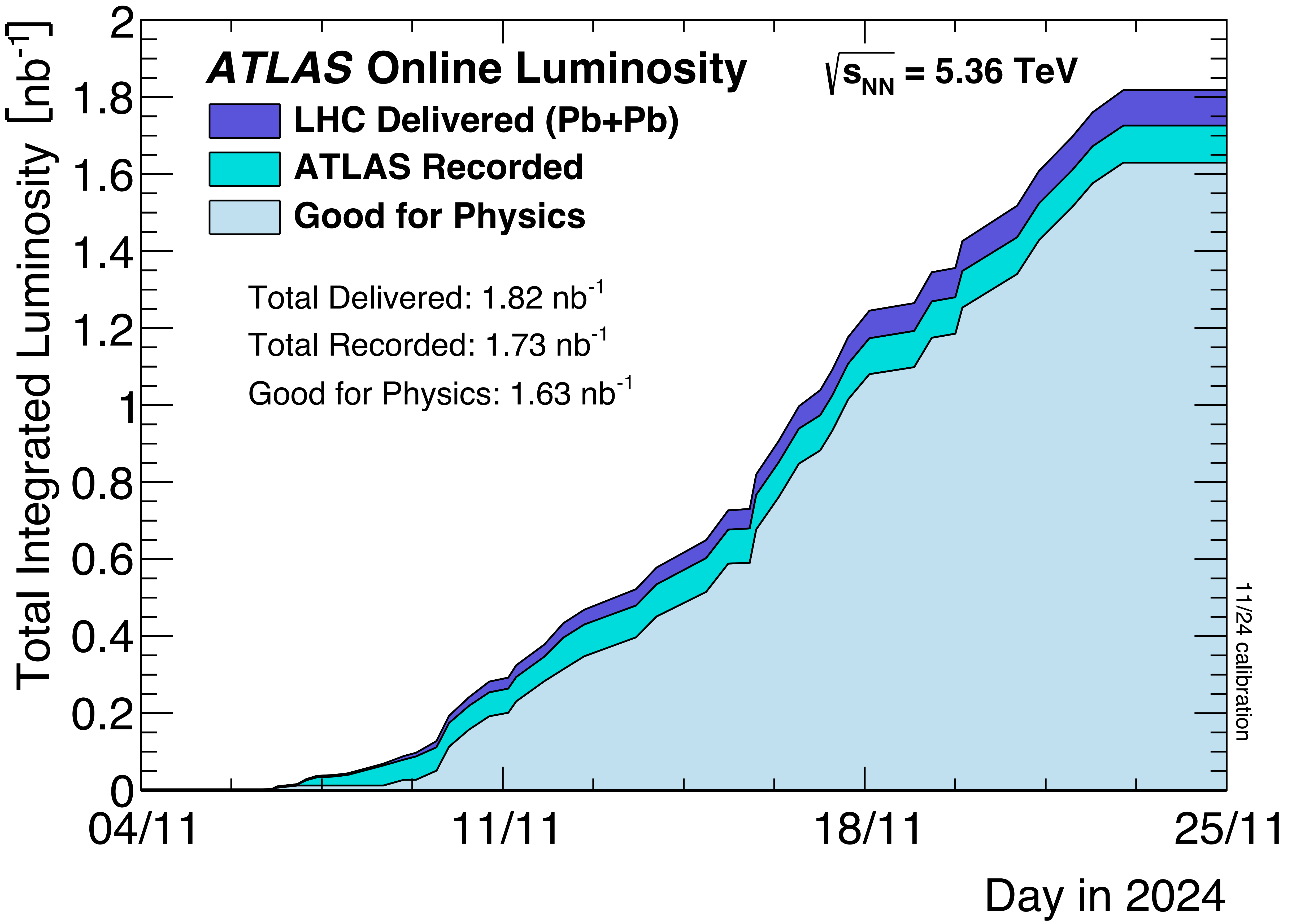
# 2024 Heavy Ion Run

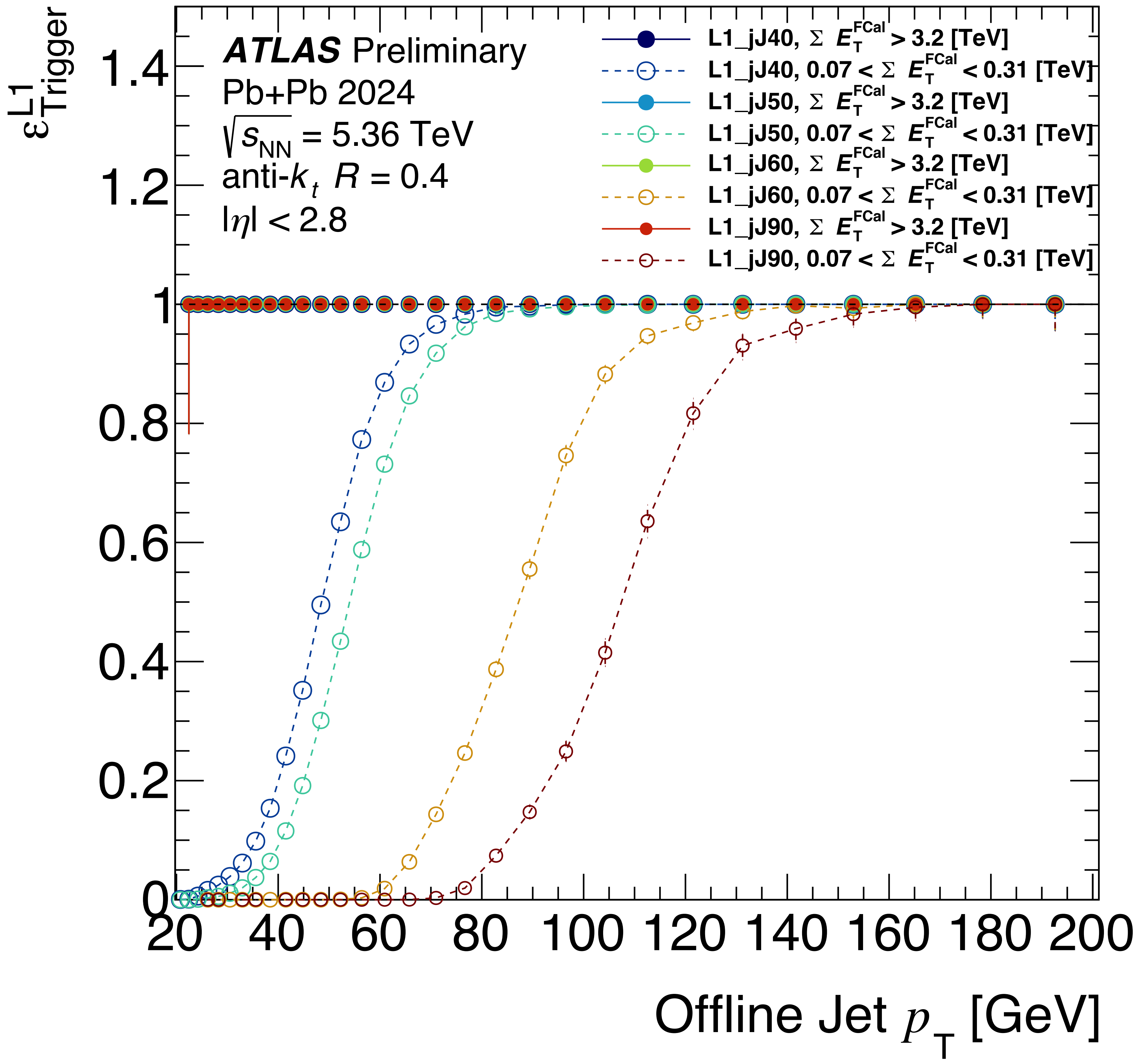



**PbPb run:**

- Total delivered integrated luminosity of 1.82 nb-1, recorded 1.73 nb$^{-1}$,
- Data quality efficiency for Pb-Pb data taking in 2024 was 97.7%
- First time exclusively triggering with only the Phase-I LAr + L1Calo system

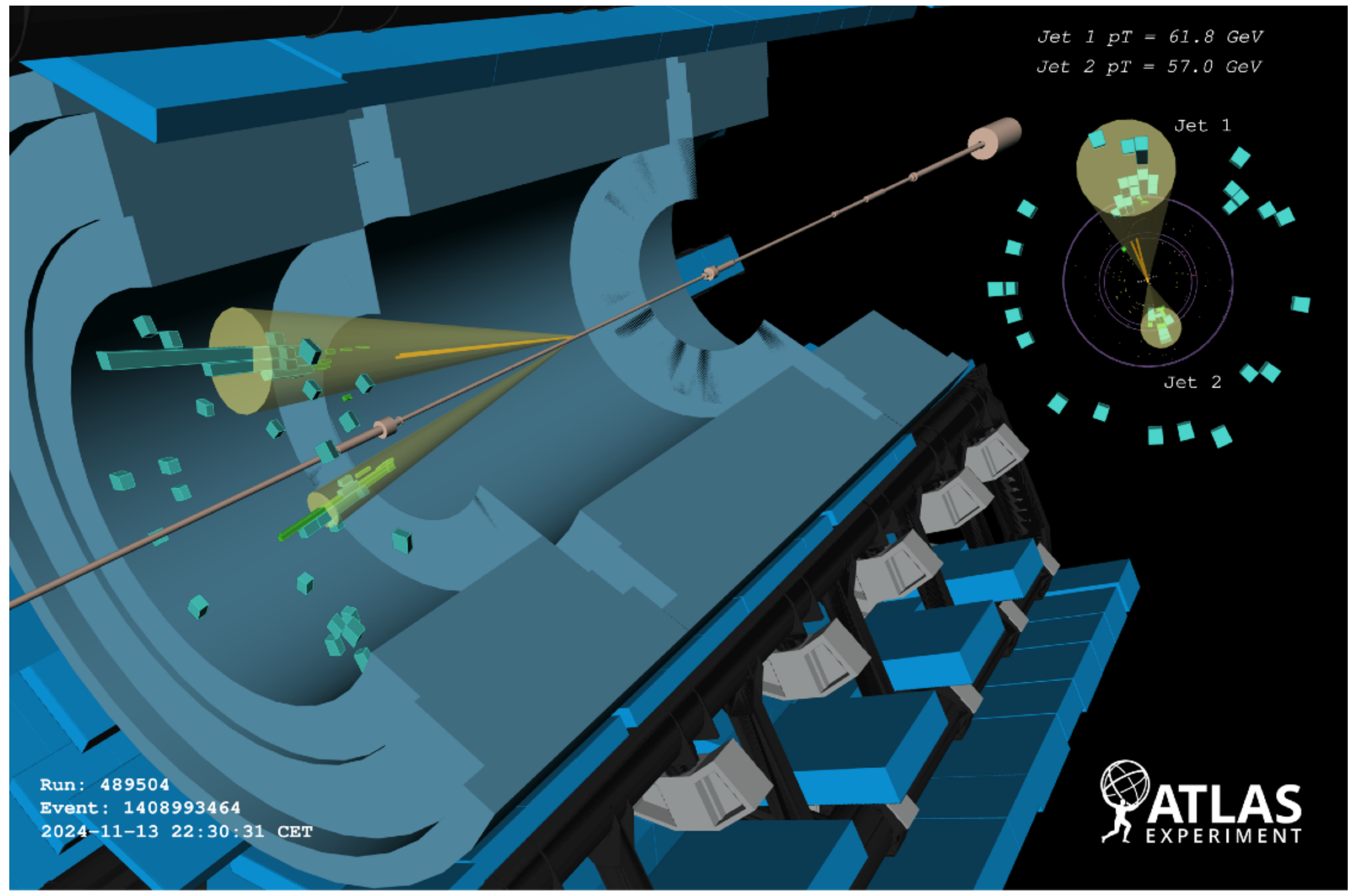
# New Triggers for Heavy Ion Runs

**Level 1 jet trigger efficiencies from the Phase-I L1Calo (jFEX)**

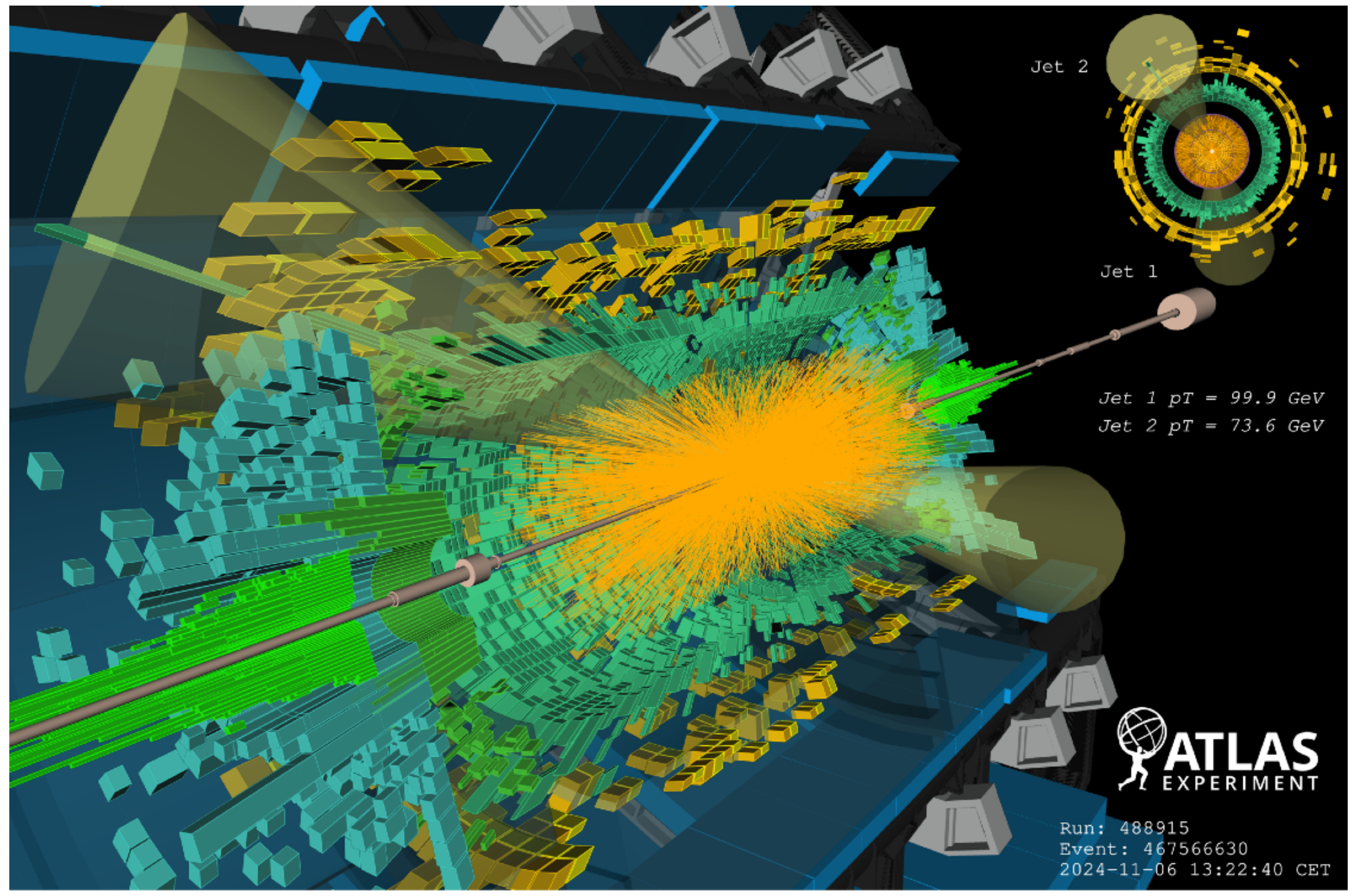



- Low-threshold triggers for ultra-peripheral collisions sensitive to noise & signal timings from Phase-I system – central collisions affected by dead time from early low-threshold triggers

Ultra-peripheral collision at 5.36 TeV




Ultra-central collision at 5.36 TeV




ATLAS Event Displays

Massive dynamic range that needs to be supported is the big challenge for the L1Calo trigger in Pb-Pb collisions!

# Operations Teams During Pb+Pb Run

ATLAS EXPERIMENT

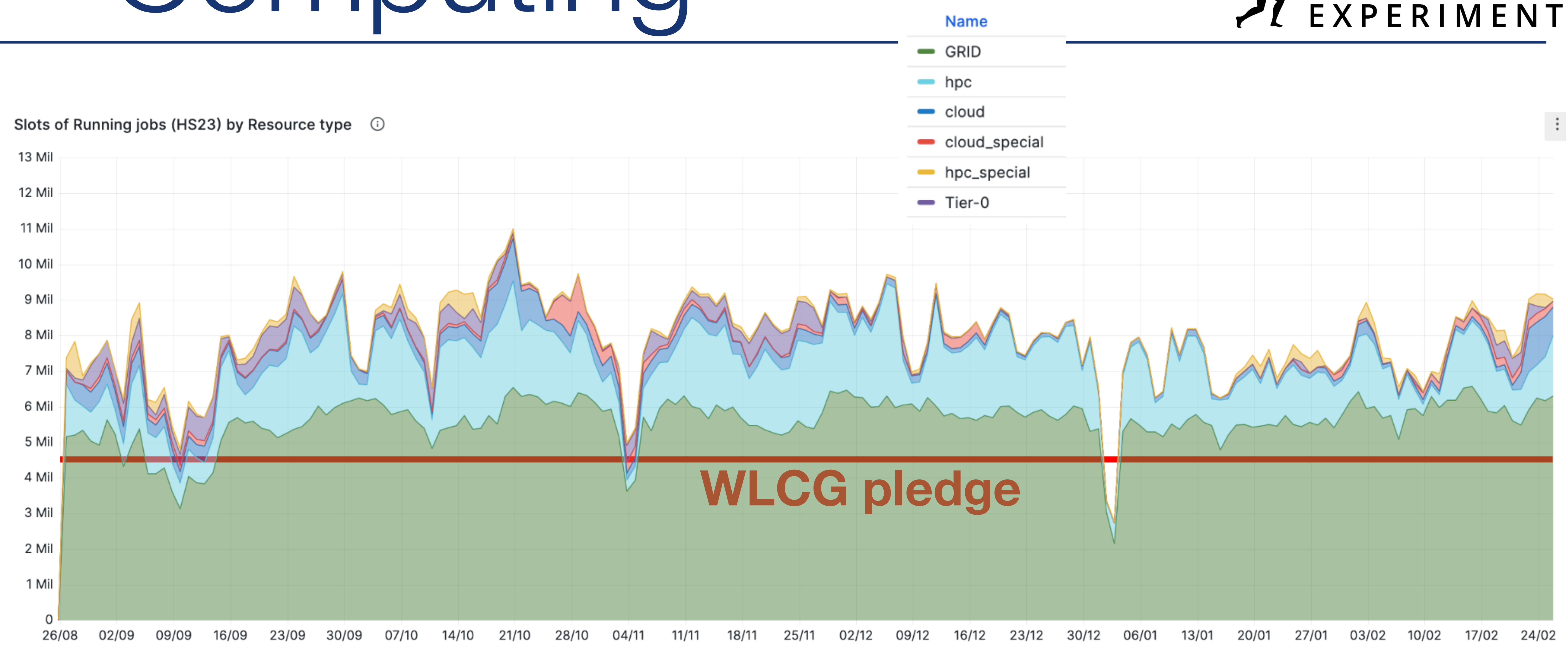
# Preparing for 2025 — Operations

- Operations workshop held to assess performance in 2024 and prepare for the rest of Run 3 and future operations
- **End of March**: 24/7 shift operation starts in the ACR with updated shift model
  - Shift leader and Data Quality as well as Trigger and Run Control desks have been merged reducing the shift crew from 8 to 6

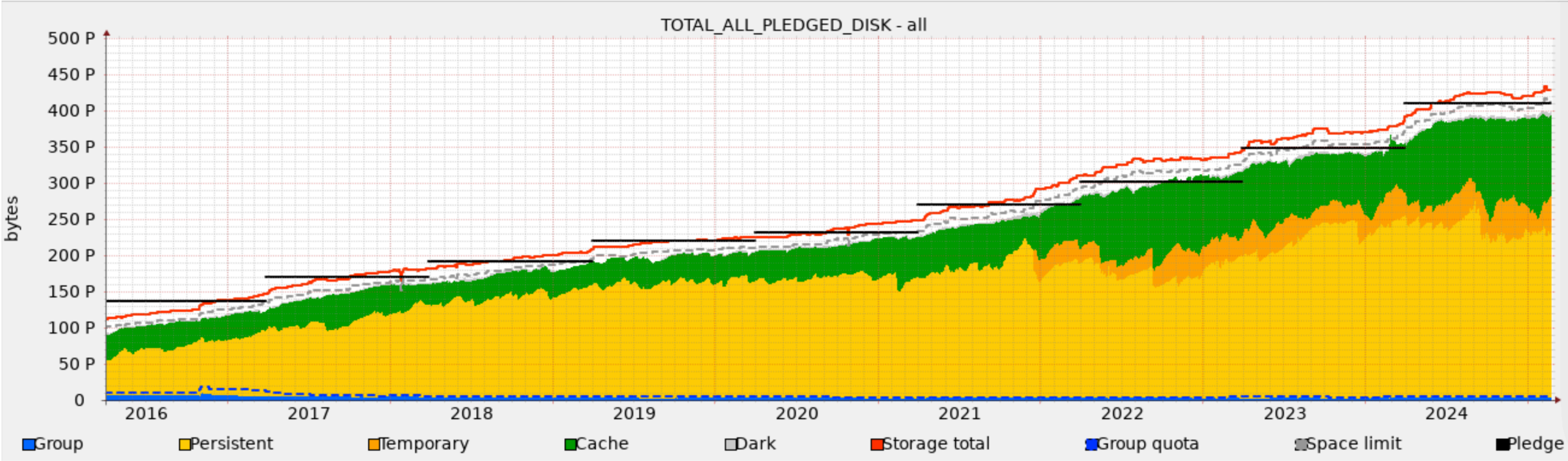
# Preparing for 2025 — Computing

**Smooth computing operations**

- Tier-0 cluster fully exploited by prompt and grid processing, no backlog
- Worldwide LHC computing grid (WLCG) sites continue to over deliver
- Regular deletions; largest persistent MC samples
- **Ready for data taking this year** with a RAW data size reduced from 1.8 to1.6 MB/event
- First ATLAS Heavy Ion Open Data release came in December

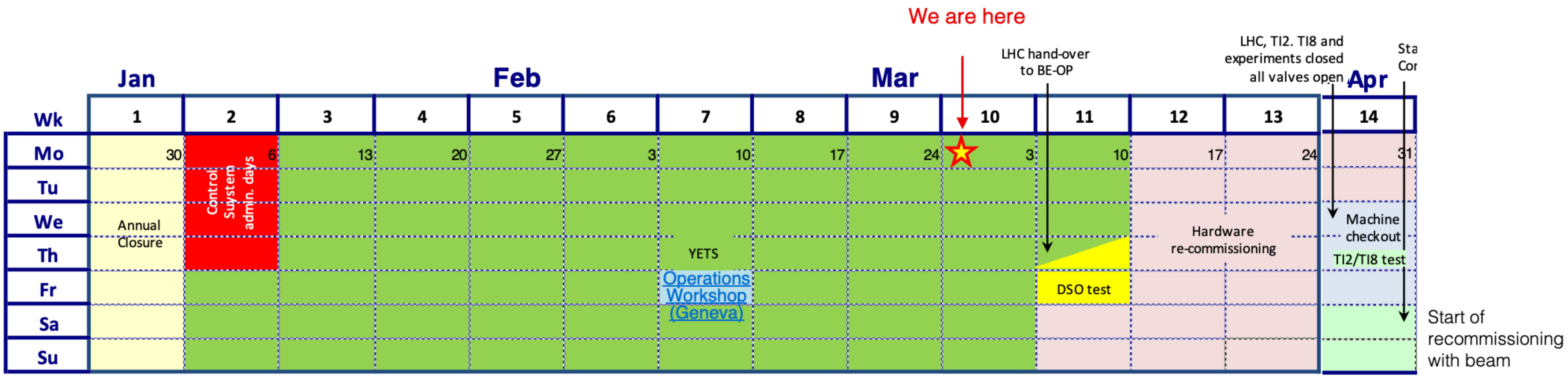



Disk space usage since 2016



# Preparing for 2025 — Maintenance

**EYETS - Extended Year-End Technical Stop**: 19 weeks beam-to-beam, P1 cavern to close up on April 4th




### Detector maintenance – main lines of work

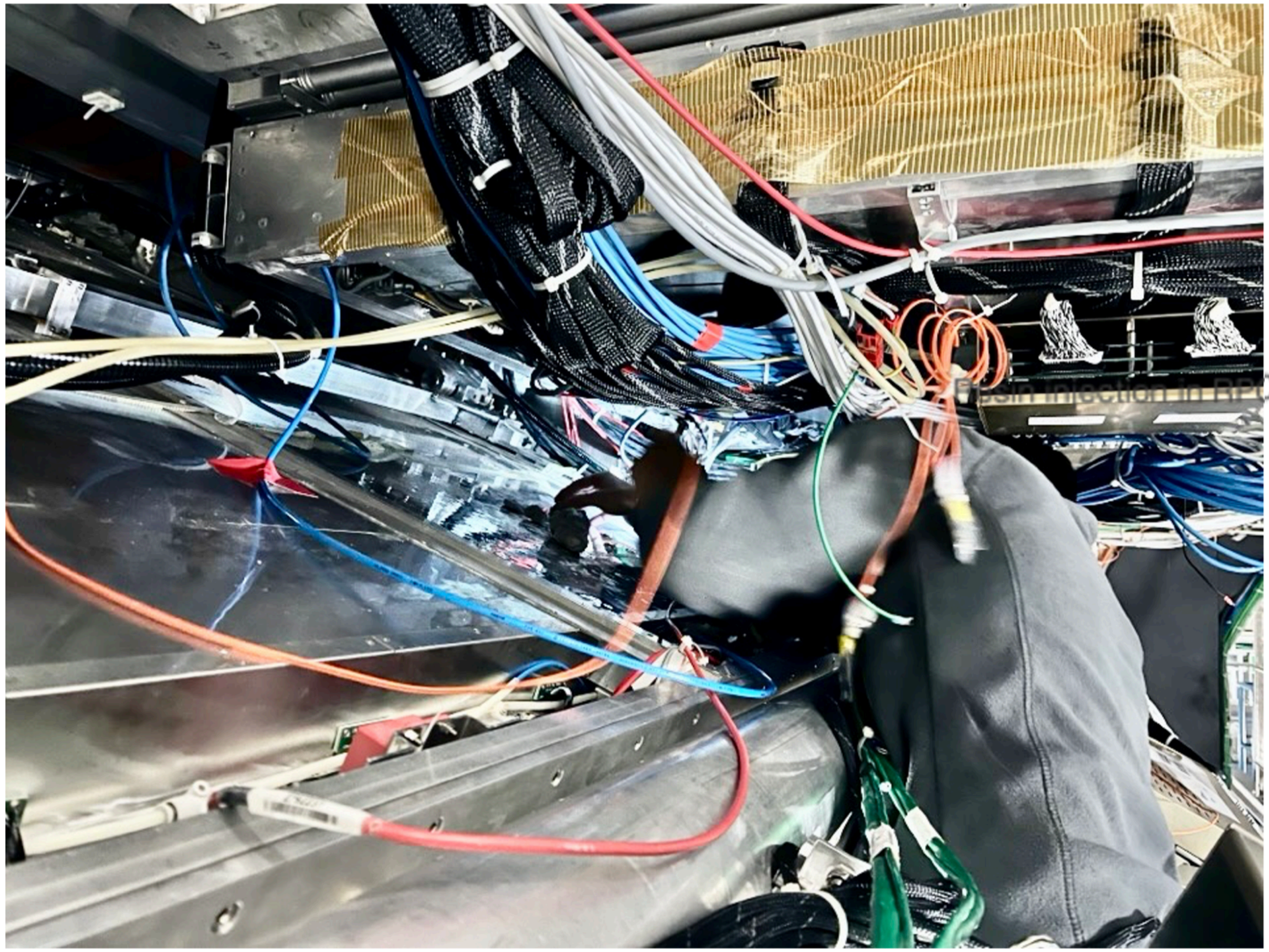
- **Tile Cal**: cooling valve replacement and leak fixing (14 leaks found)
- **RPC**: leak fixing and resin consolidation campaigns
- **TGC**: chamber replacement on side A incl. reconnection (completed)
- **sTGC**: understand HV problems; spotted a number of issues not to be “on-detector” failures
- **AFP**: studying electronics shielding improvements in the tunnel
- **Magnets**: Yearly maintenance and work on improving resilience

### Infrastructure work

- Primary and detector cooling, electrical circuits, magnets, muon gas
- $CO_2$ cooling for Run 4

# Preparing for 2025 — Maintenance

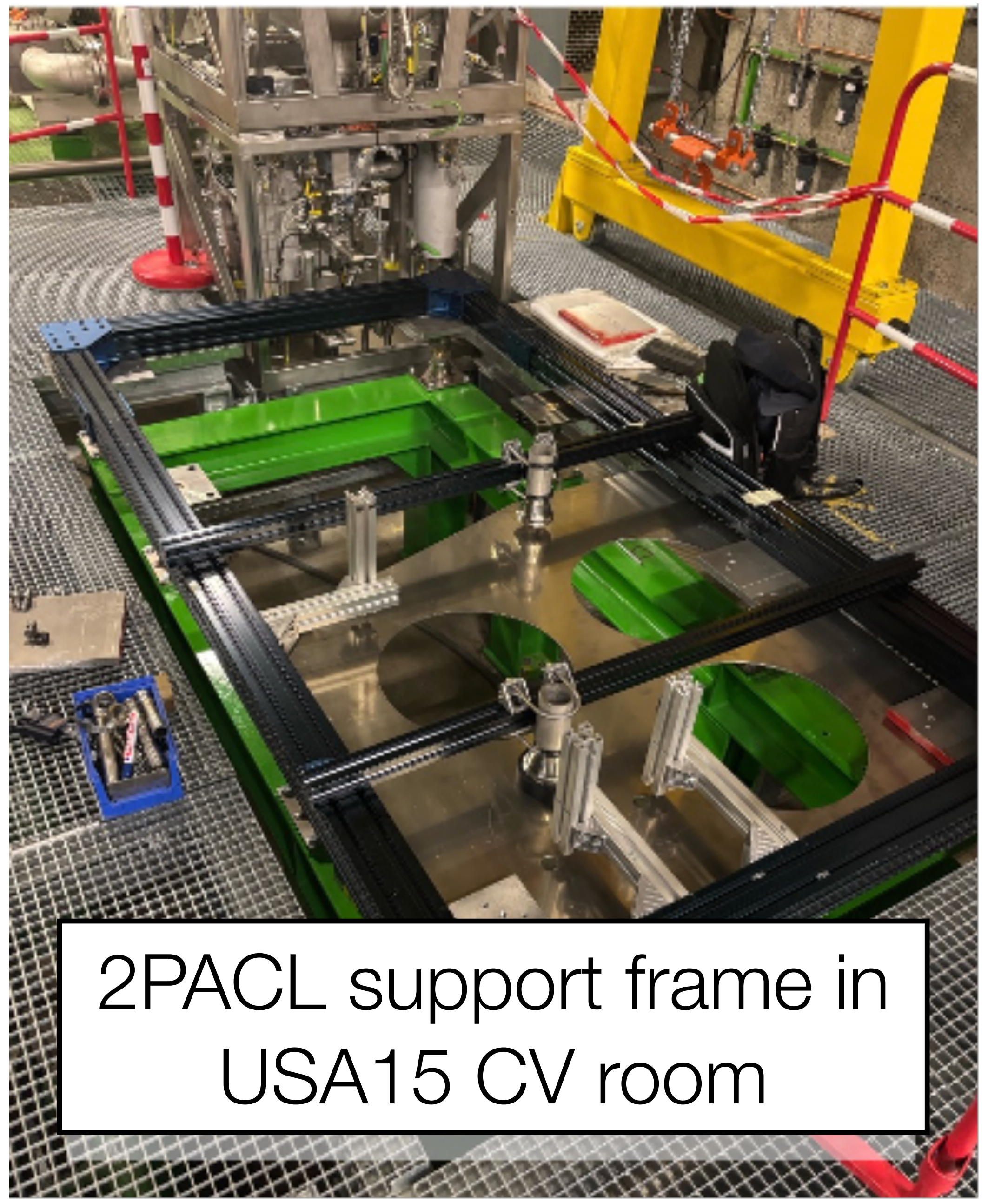
**EYETS - Extended Year-End Technical Stop**: 19 weeks beam-to-beam, P1 cavern to close up on April 4th



Resin injection in RPC sector 13A (very confined space!)

TileCal maintenance team exchanging valves in cavern

# Infrastructure Upgrades During EYETS

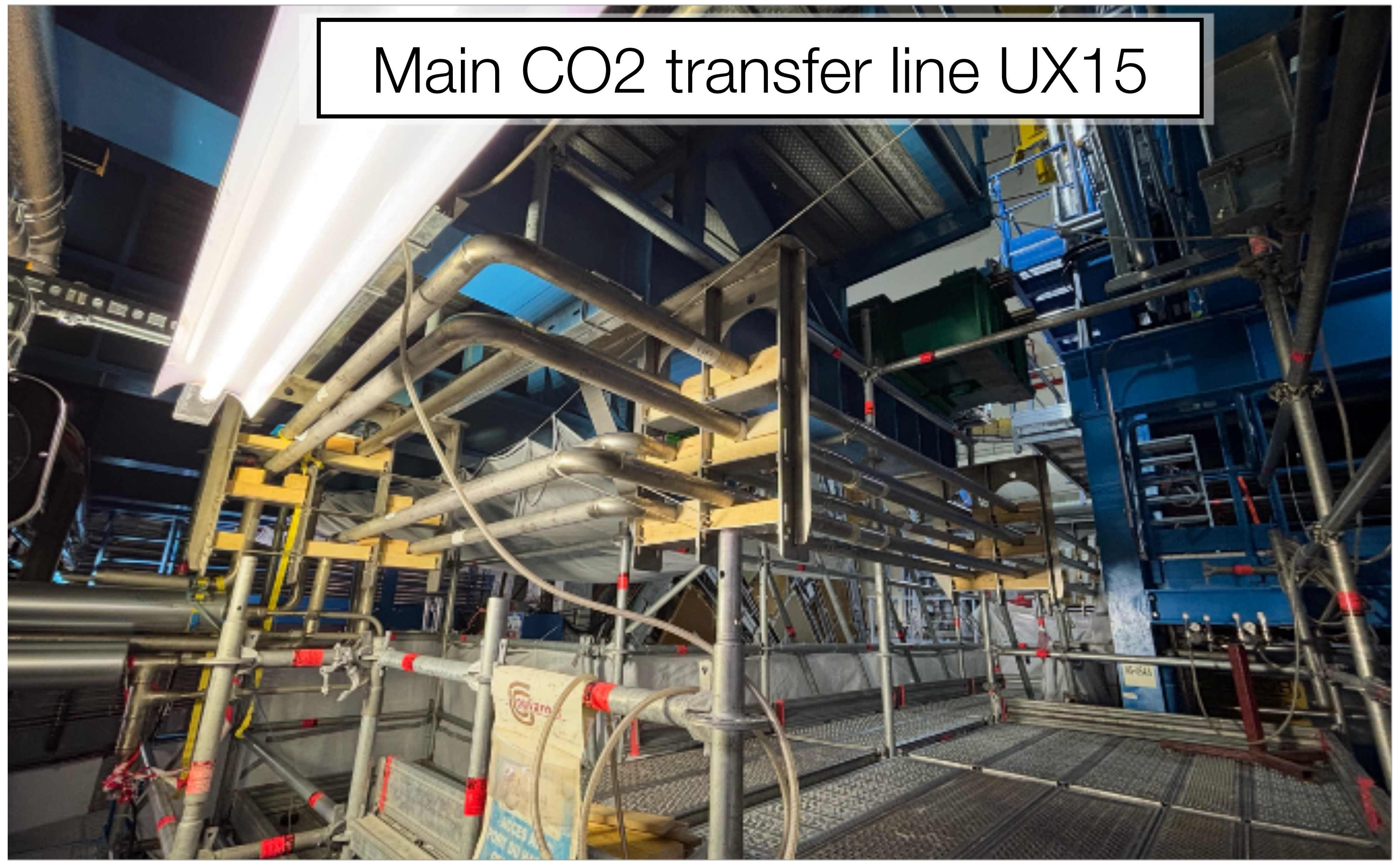

2PACL support frame in USA15 CV room


R744 units installed in SXSN1

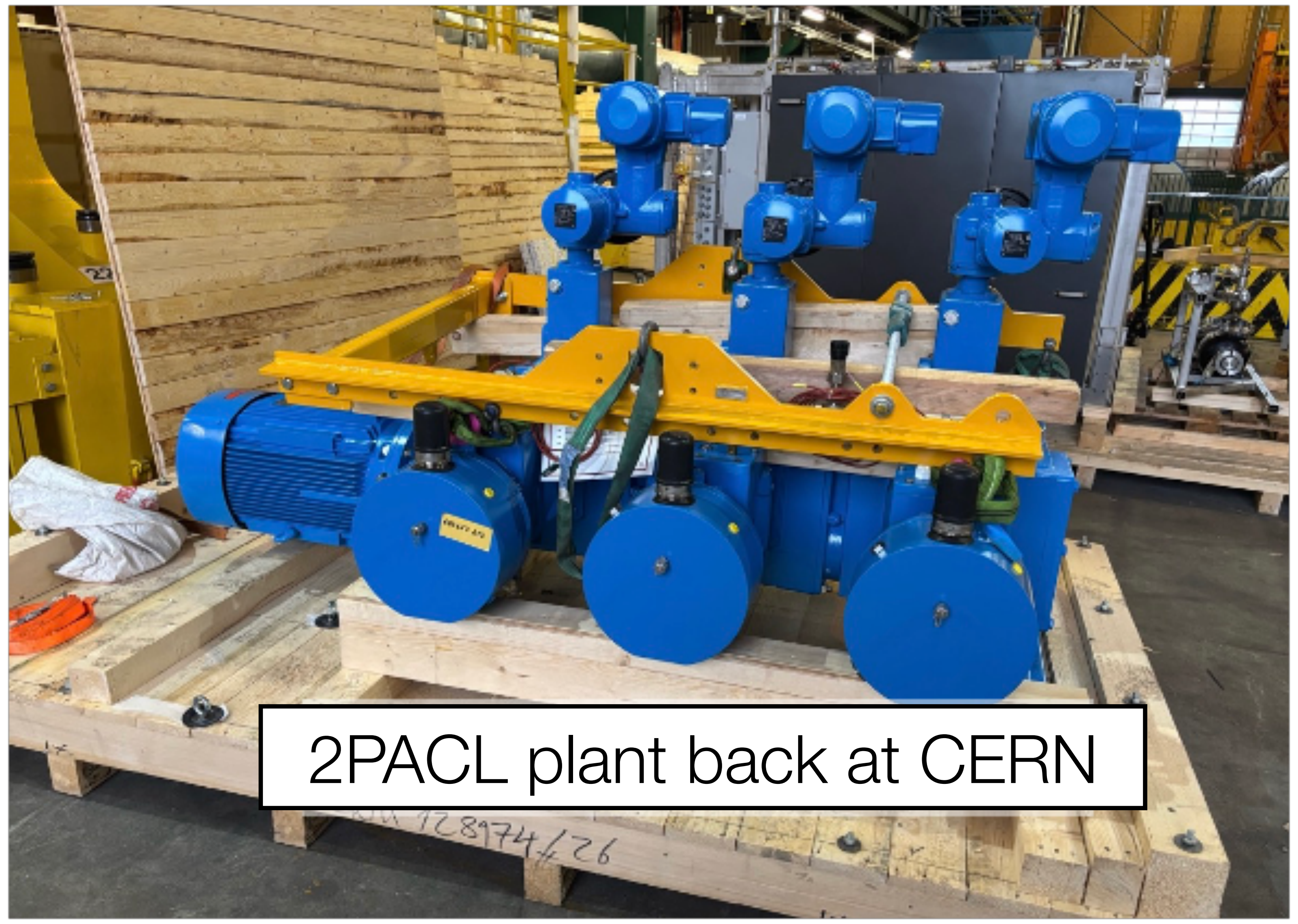

2PACL control cabinets in USA15 CV room

## $CO_2$ Cooling Upgrades

- **Phase Accumulator Controlled Loop (2PACL)**: delays with plant installation due to welding non-conformities; Welding of CO2 main trainer line in UX15 completed; Expect installation completed by the end of this EYETS, then commissioning with dummy loads
- **R744 primary cooling units** (SXSN1): cabling/piping almost completed, commissioning starts early March


Main CO2 transfer line UX15


Main CO2 transfer line USA15 - UX15


2PACL plant back at CERN

# Physics Highlights

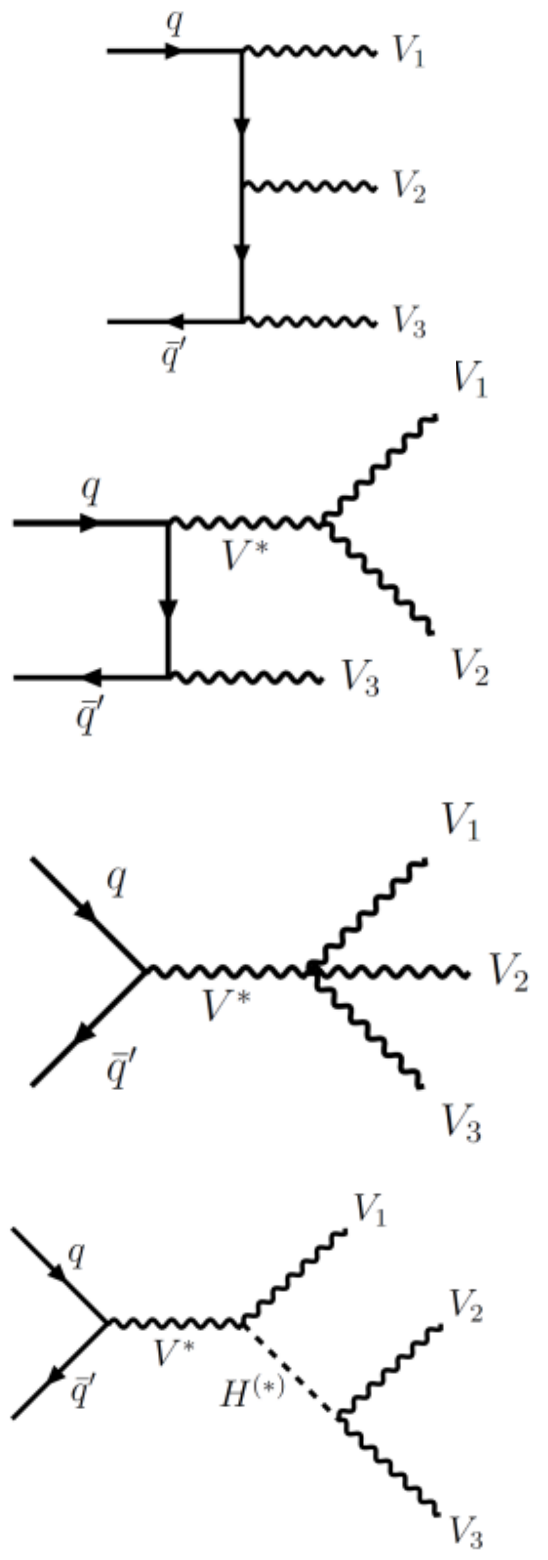

Publications in 2024: 127 papers and 14 public notes released
**In total**: 405 papers on full Run 2 and 14 on Run 3 dataset

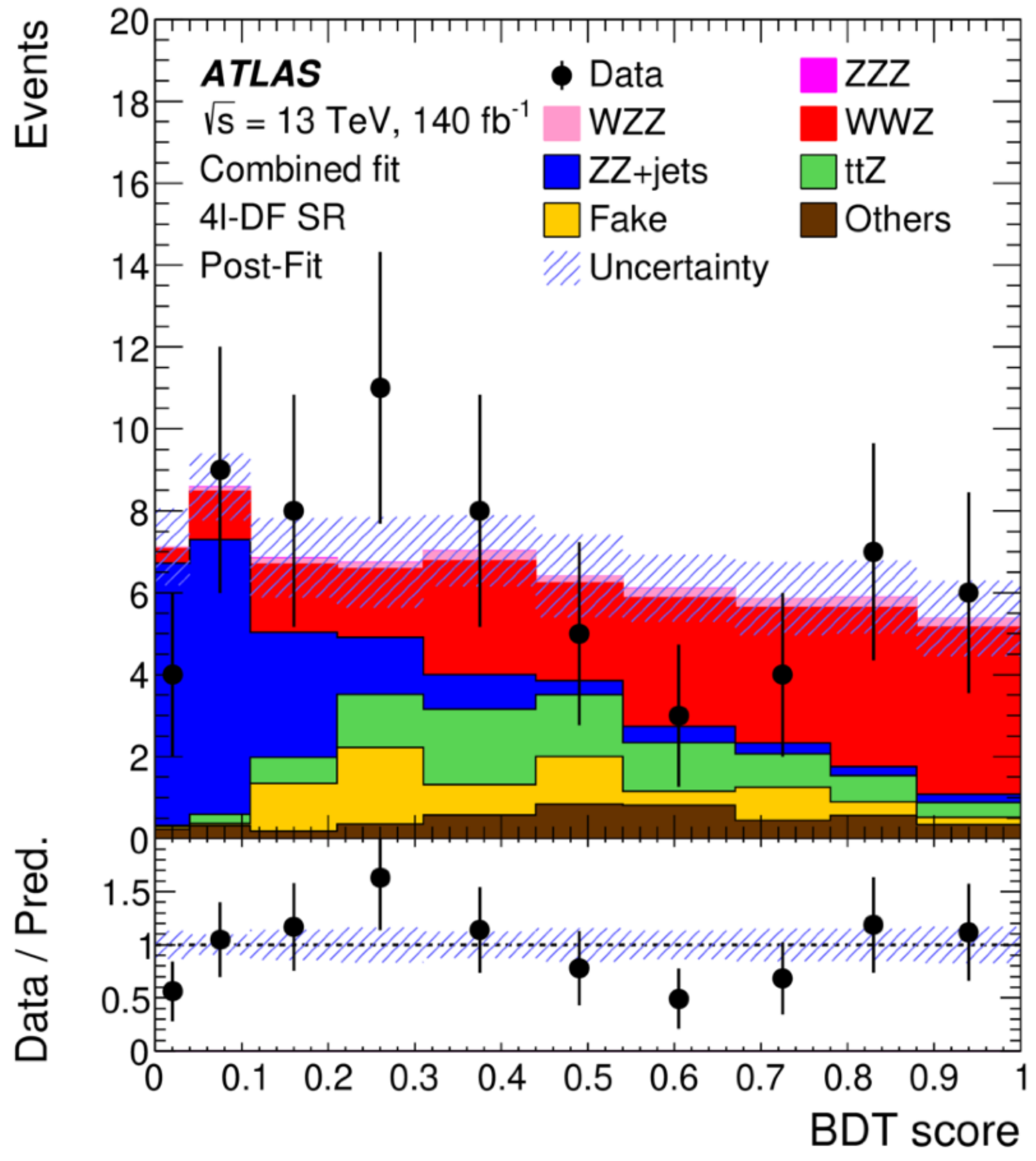
Since the last LHCC meeting in November, 22 new ATLAS papers

# Standard Model Measurements

## Observation of VVZ Production

[arXiv:2412.15123](#)
[Physics Briefing](#)

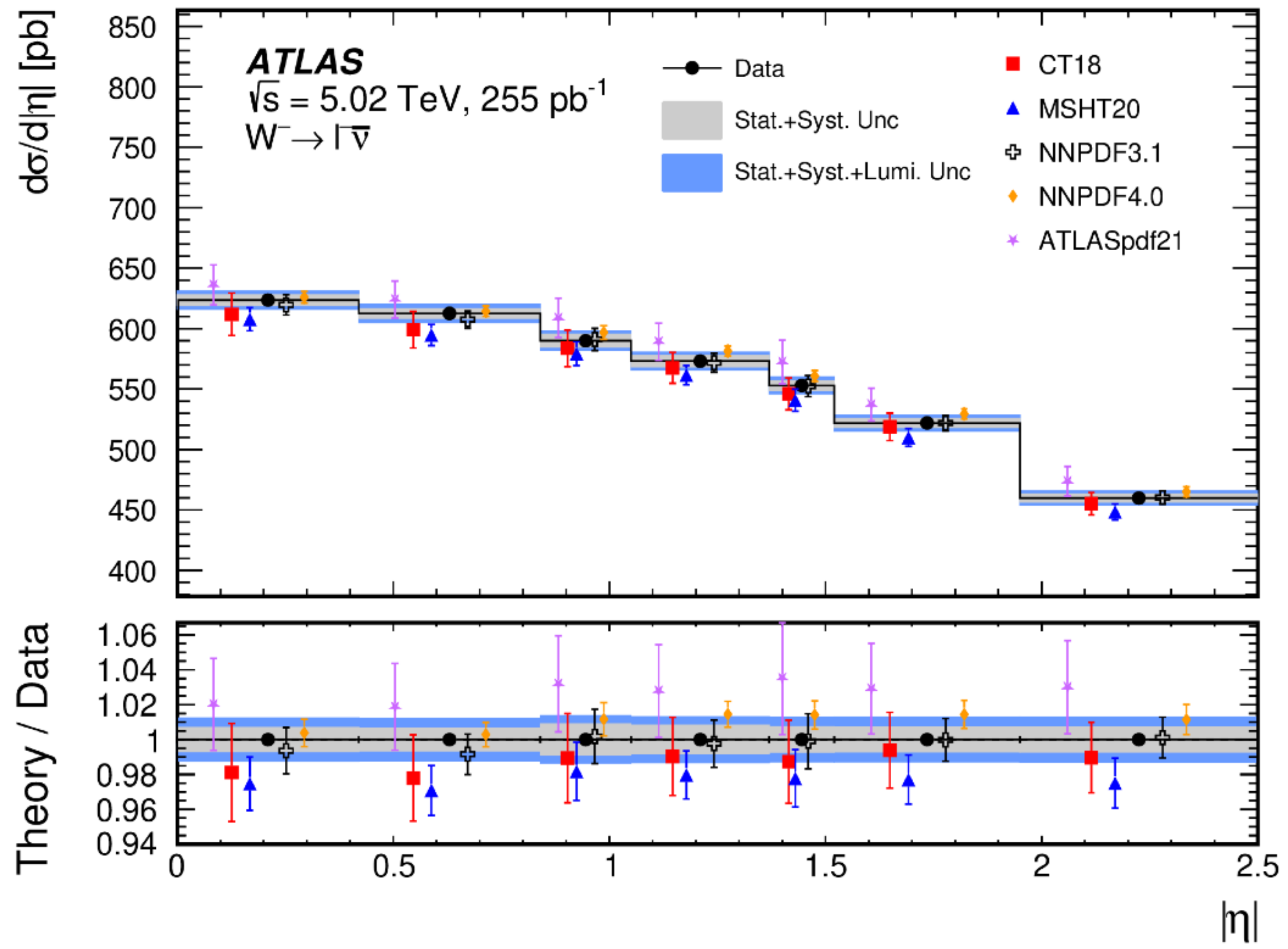


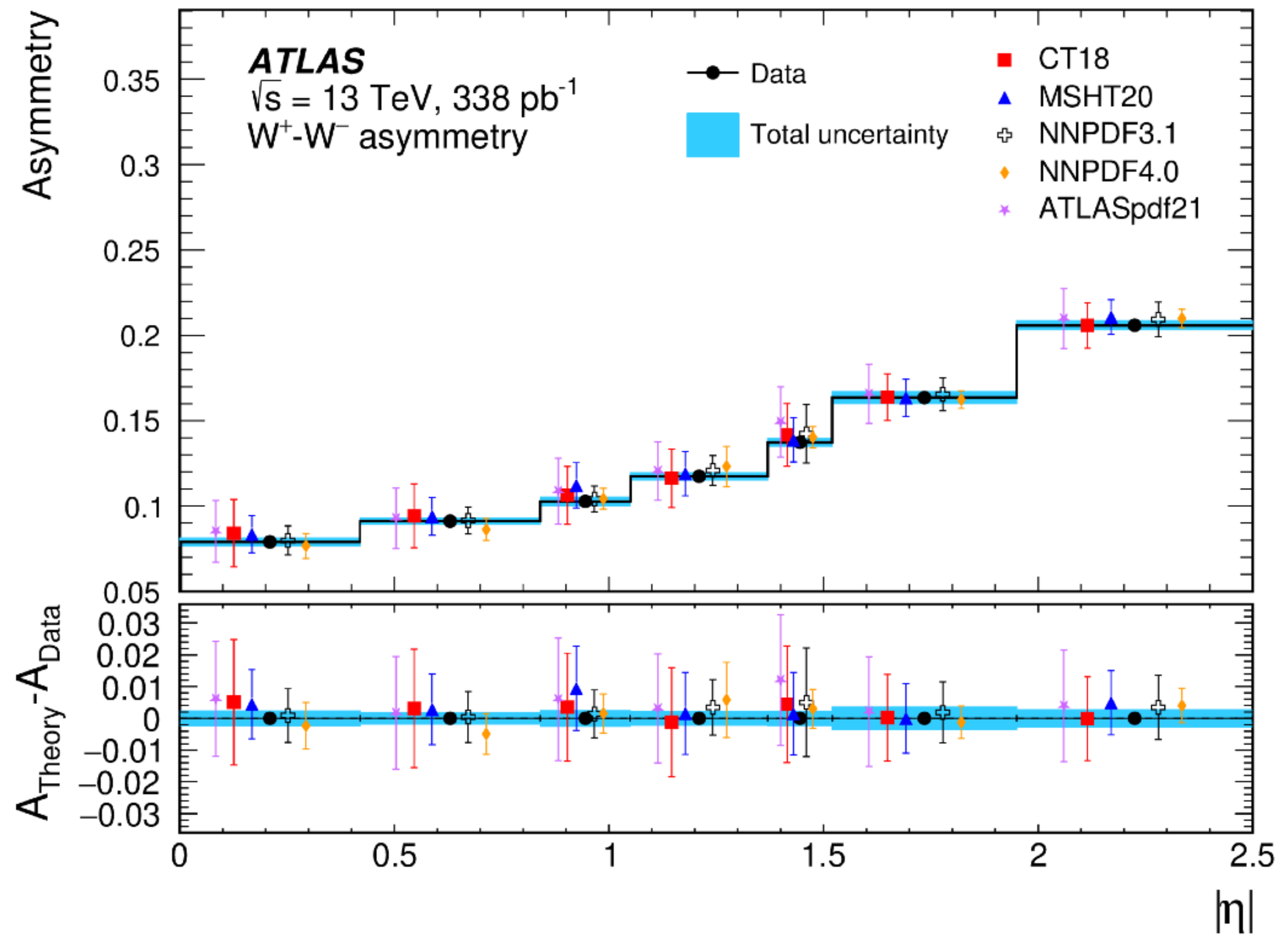




- First observation of VVZ production — rare combination of triplet massive vector bosons — with a statistical significance of **6.4 standard deviations**
- Seven decay channels probed and, in all cases, one $Z$ boson always decays into a pair of charged leptons

## W Boson Cross Sections with Low Pileup Data

[arXiv:2502.09403](#)



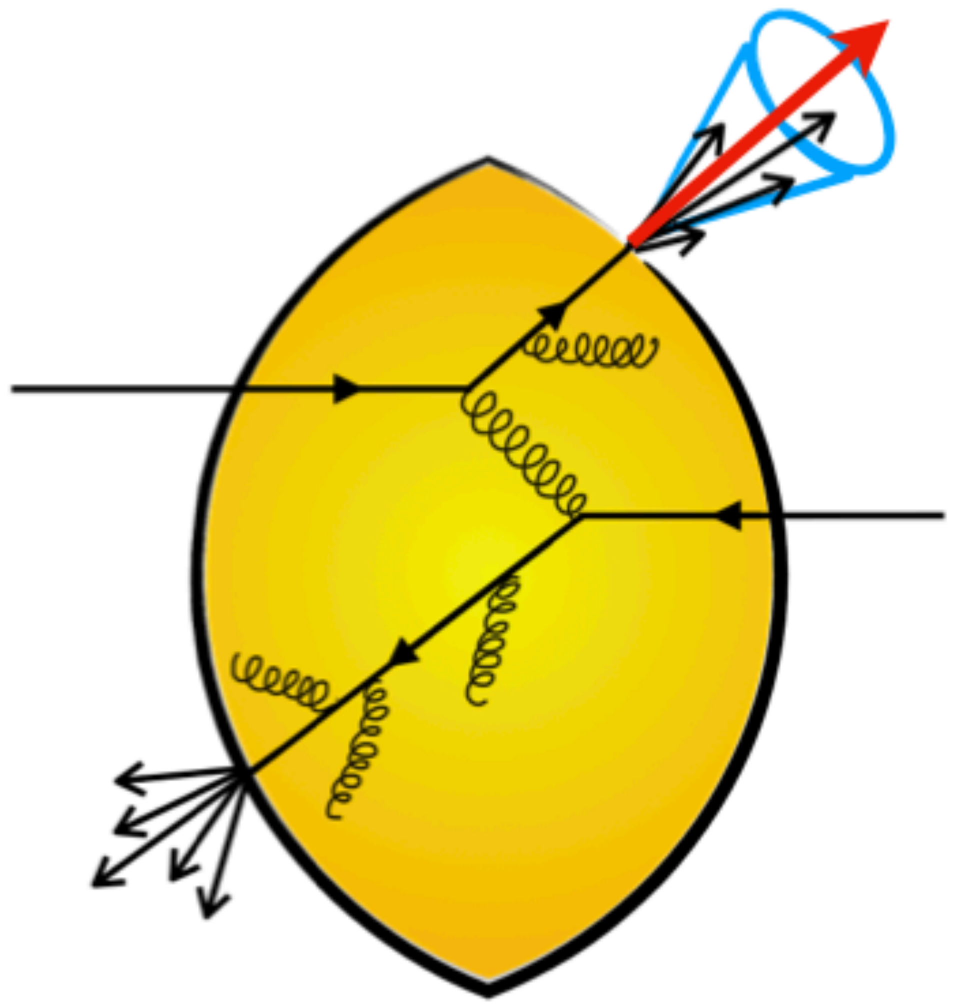




- W boson cross section measured at 5 and 13 TeV using low pileup ( $<\mu> < 2$) data collected between 2017 and 2018
- High precision single and double differential measurements performed: $\frac{d\sigma}{dp_T}, \frac{d\sigma}{d|\eta|}, \frac{d\sigma}{d|\eta|dp_T}$
- Per-mille precision measurement of $W^{\pm}$ charge asymmetry

# Azimuthal Anisotropies of Charged Particles

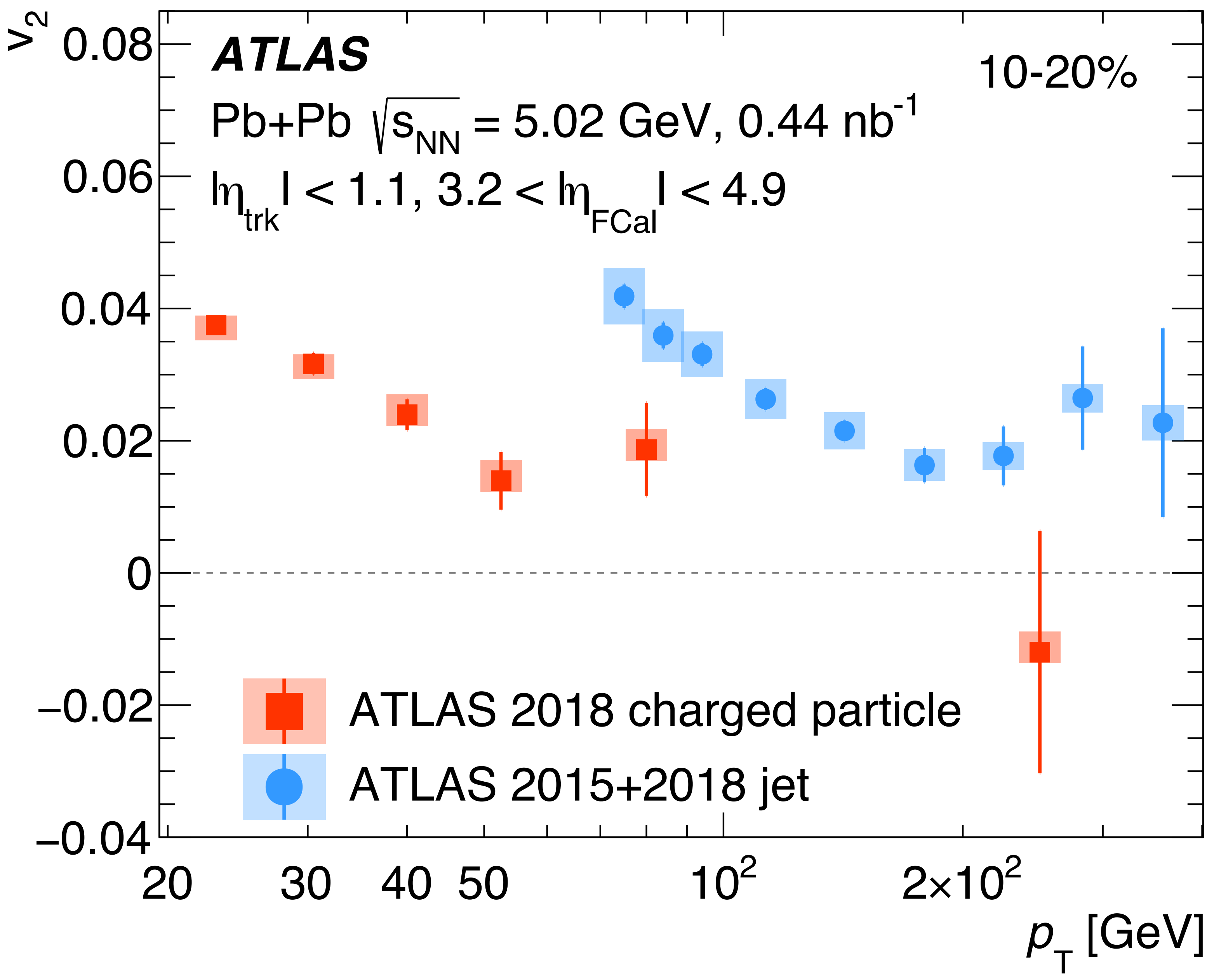
arXiv:2412.15658

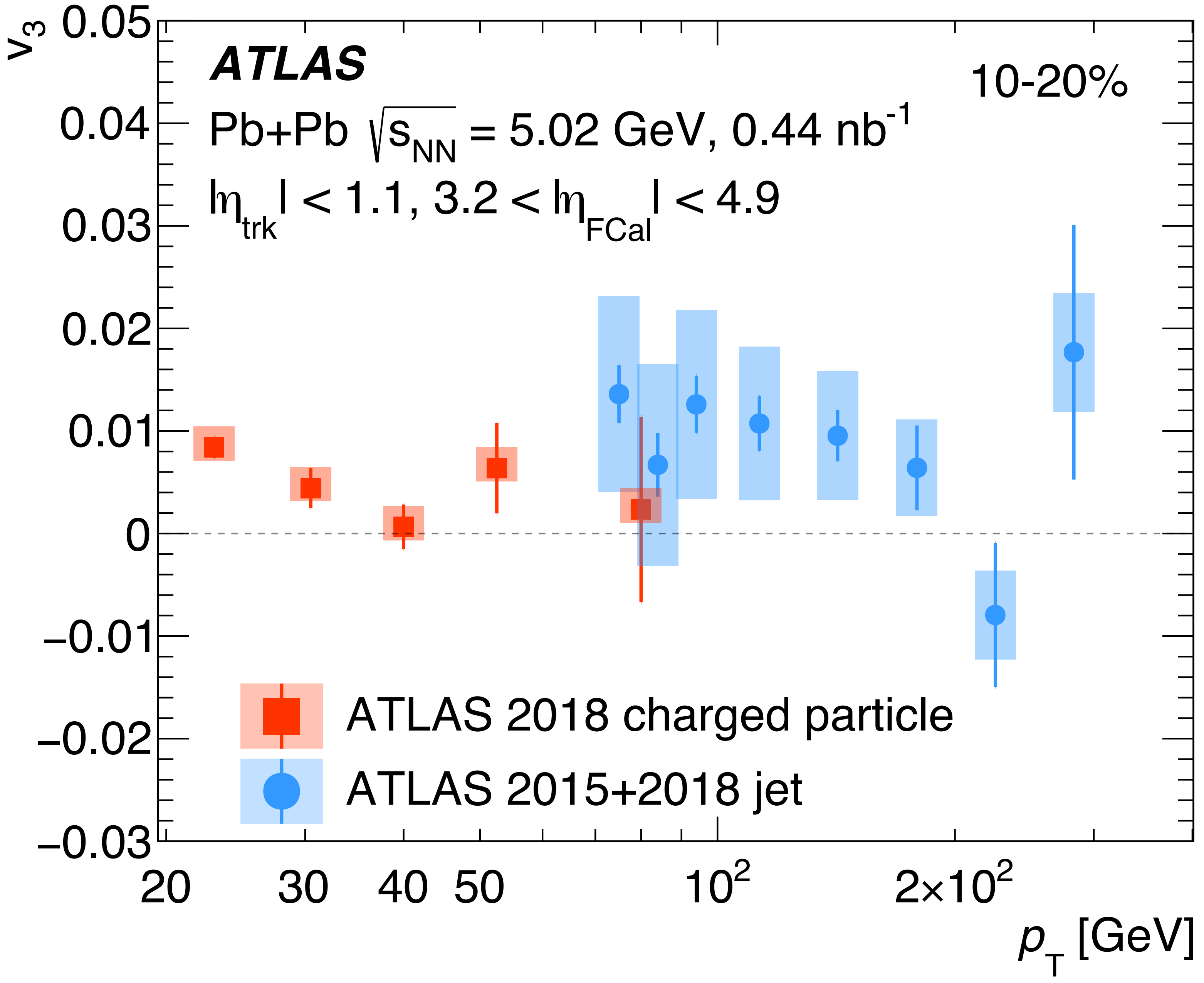
ATLAS EXPERIMENT



- Measurement of high $p_T$ flow in heavy ion (Pb-Pb) collisions
- Measuring flow (v2, v3) is useful to study collective dynamics as well as **energy loss in quark gluon plasma and its fluctuations**
- New result tests different techniques to **access fluctuations in energy loss** via **charged particles** or **jets**

$v_2$ → Access to bulk properties + energy loss + fluctuations




$v_3$ → Access to fluctuations in the geometry

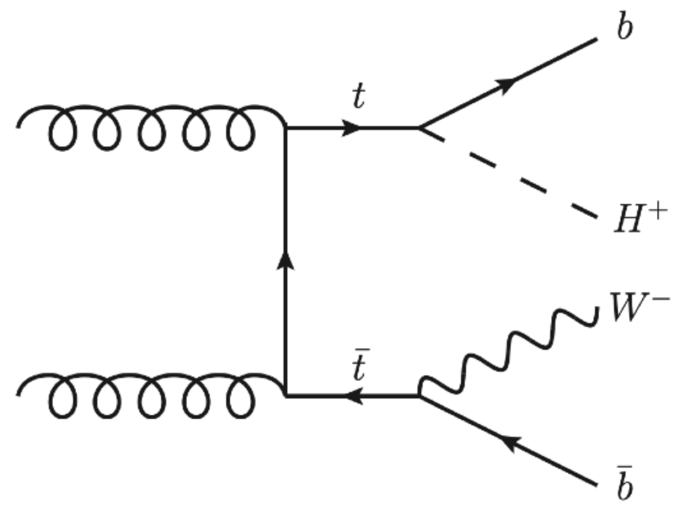
# Search for H+ → τν

arXiv:2412.17584

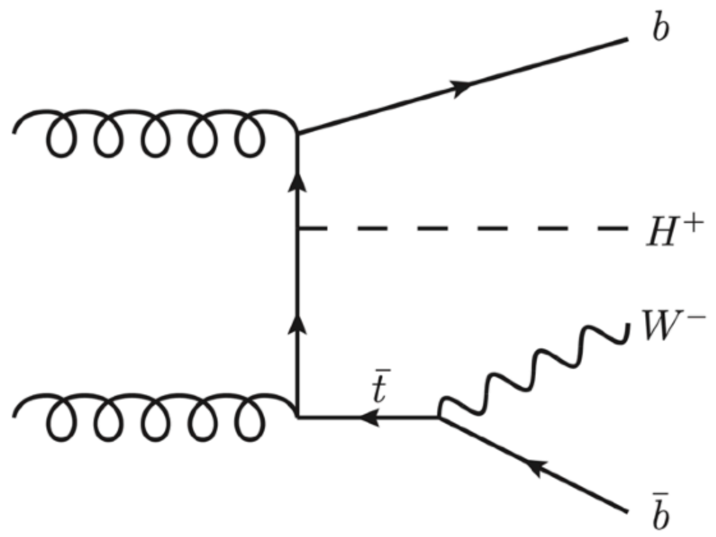
ATLAS EXPERIMENT

Search for **charged Higgs (H+)** produced in association with a top-quark using **$\tau$ + lepton** and **$\tau$ + jets** final states

**low**-mass ($m_{H+} < m_{top}$)




**high**-mass ($m_{H+} > m_{top}$)




**$\tau$+leptons**

leptonic $W$ boson decay
Single lepton trigger

**$\tau$ + jets**

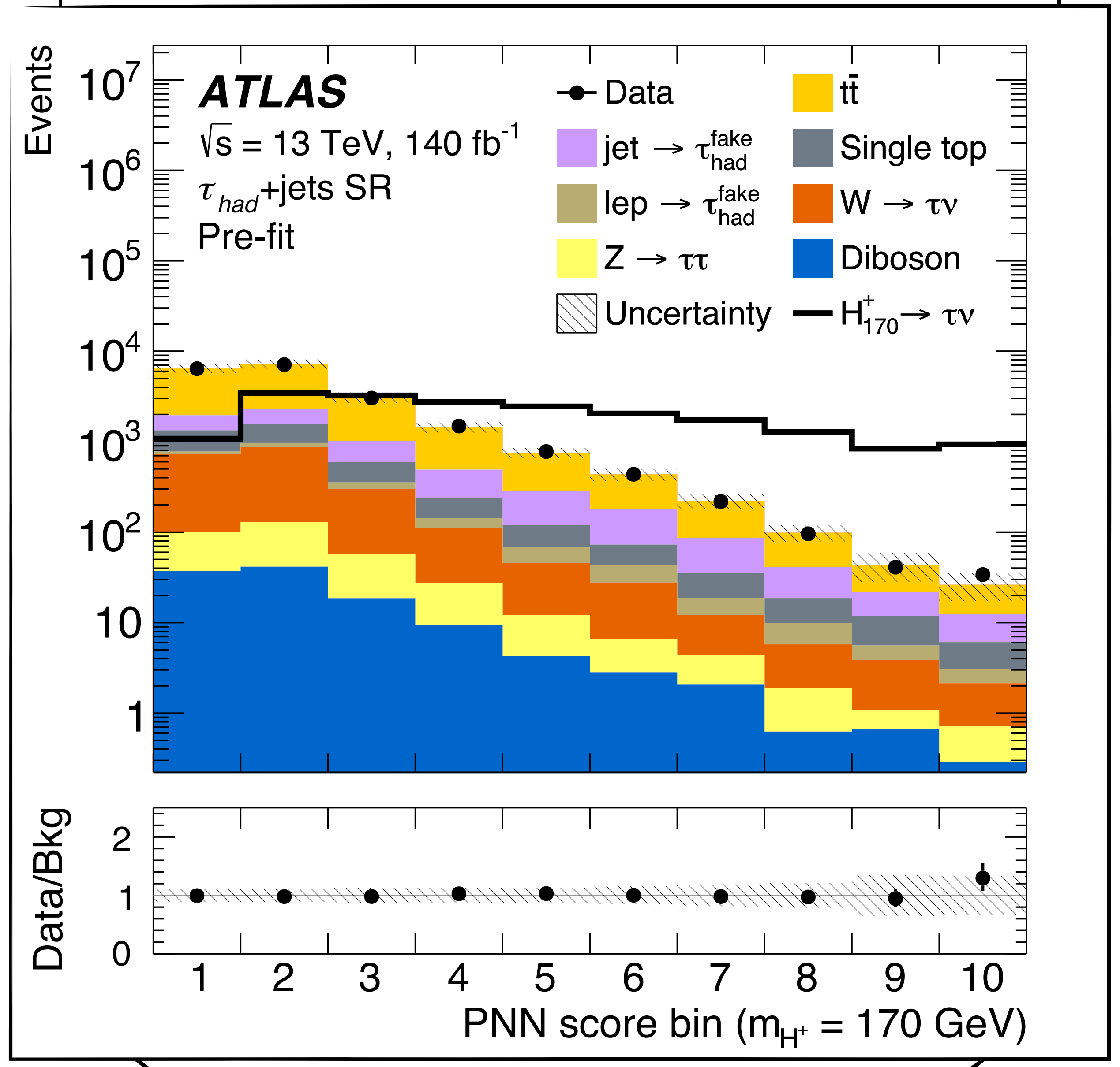
hadronic $W$ boson decay
Missing energy trigger

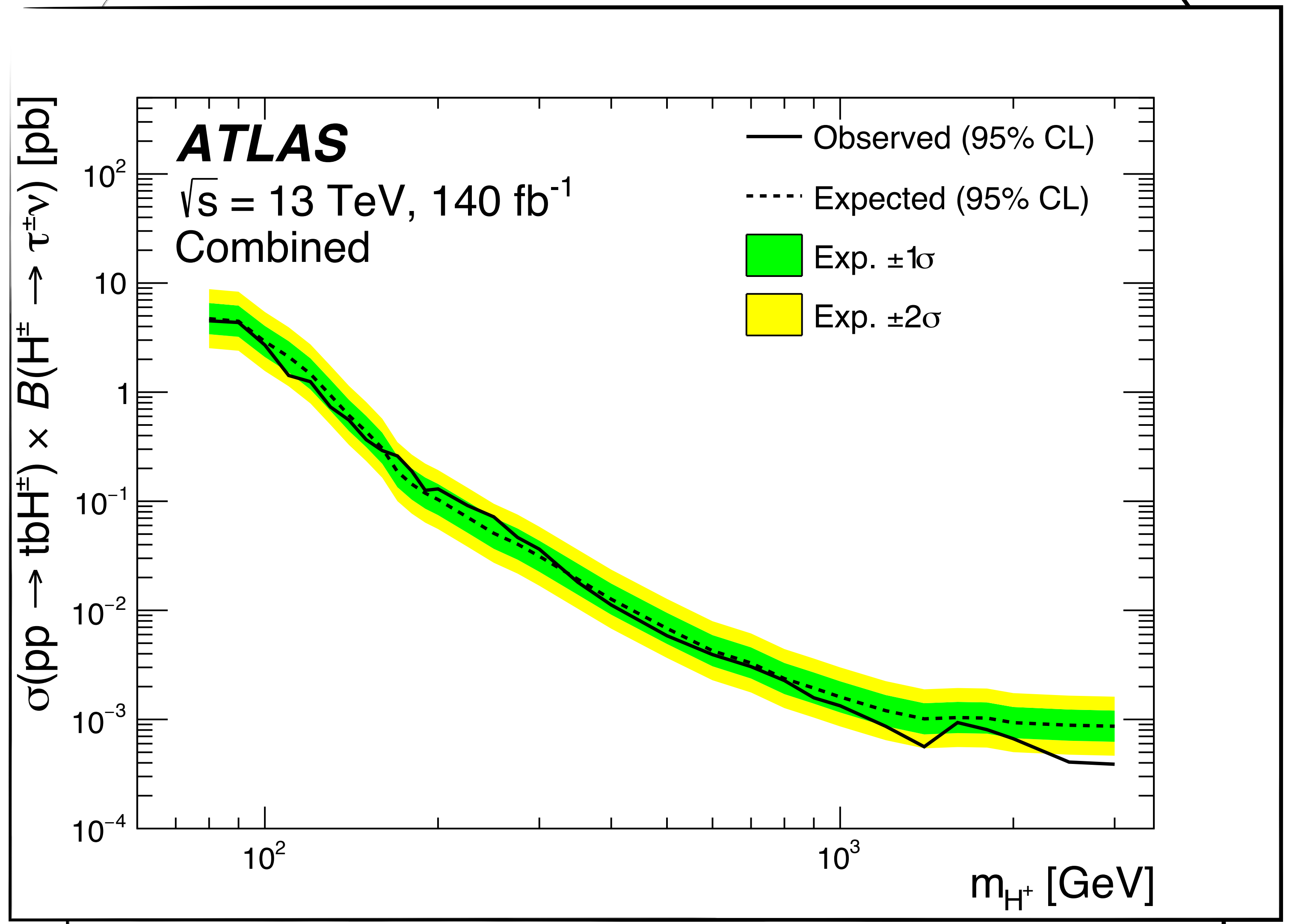
Both regions require ≥ 1 b-jet

Object Selection

Event categorization

Parametrized neutral network (PNN): trained on kinematic variables of the tau, lepton and jets, and parametrized with the generator-level H+ mass




95% CL upper limit set on H+ production cross section x branching ratio ranging from 4.5 pb to 0.4 fb for:

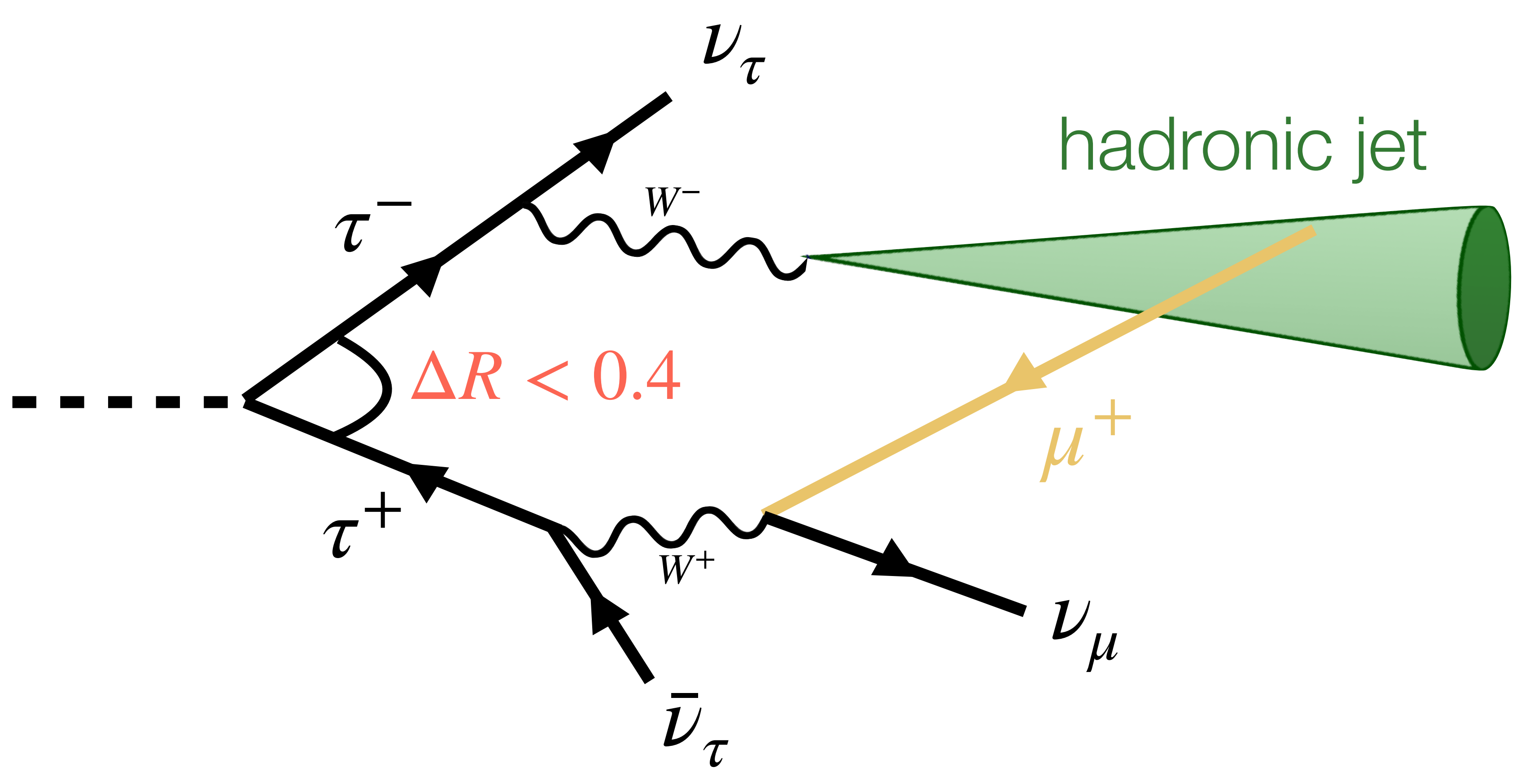
$$80\ \text{GeV} \leq m_{H^\pm} \leq 3000\ \text{GeV}$$

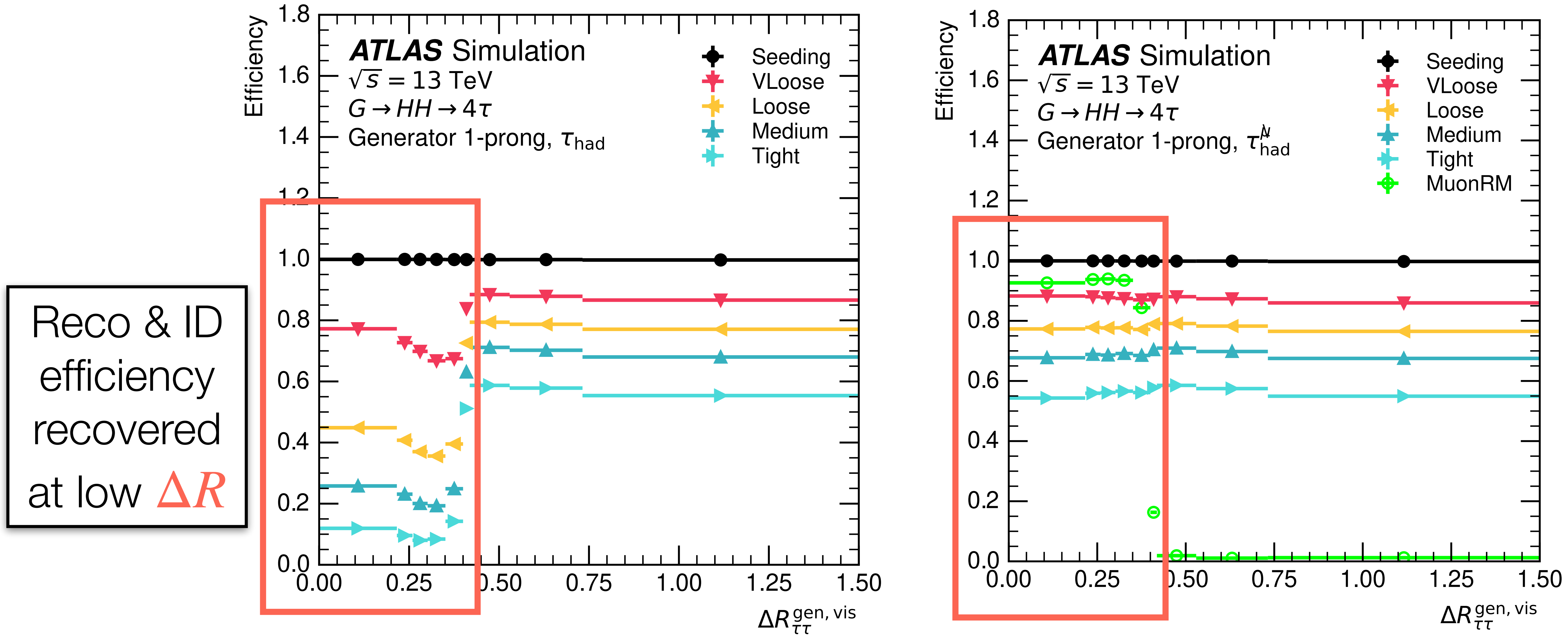
Most restrictive limits in this production and decay mode!

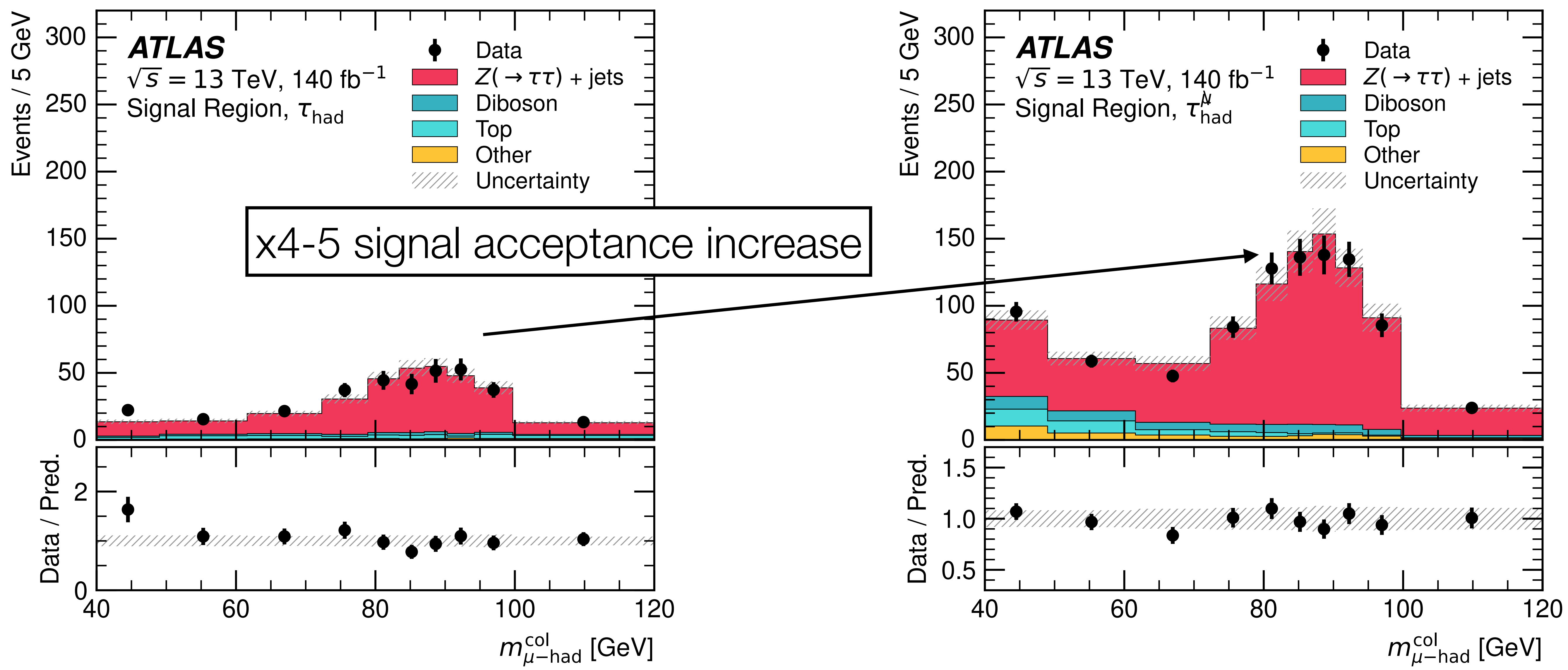
Results

# Highly Boosted Tau Pairs

arXiv:2412.14937




- Boosted topology results in overlapping signatures from both $\tau$ decays affecting the $\tau_{had}$ reconstruction and identification efficiency
- Recovered by removing **muon track/assoc. calorimeter clusters** from $\tau_{had}$ **decay products**
- Validation performed using $Z \to \tau\tau$ signal

# Boosted Top Mass

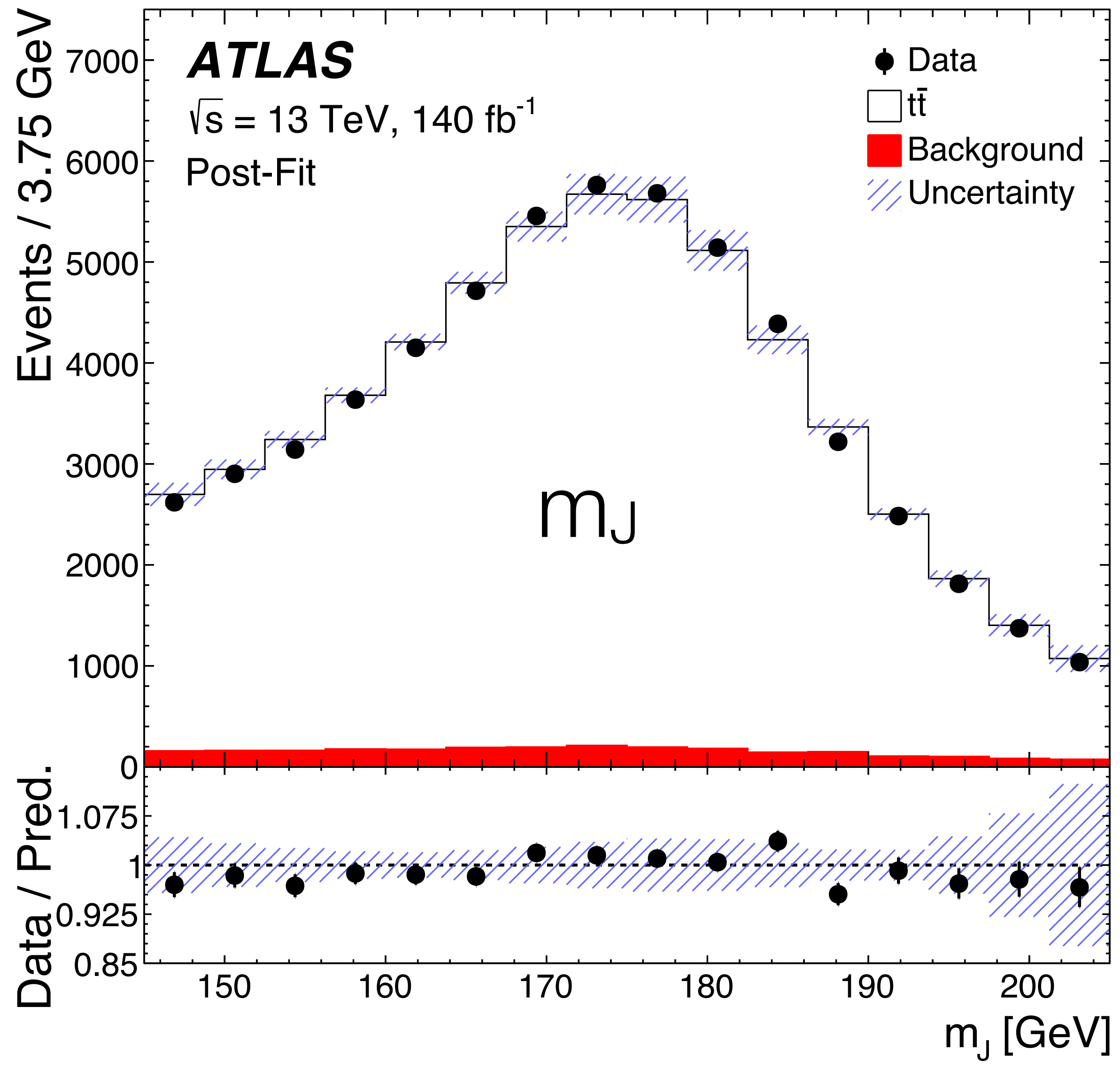
[arXiv:2502.18216]

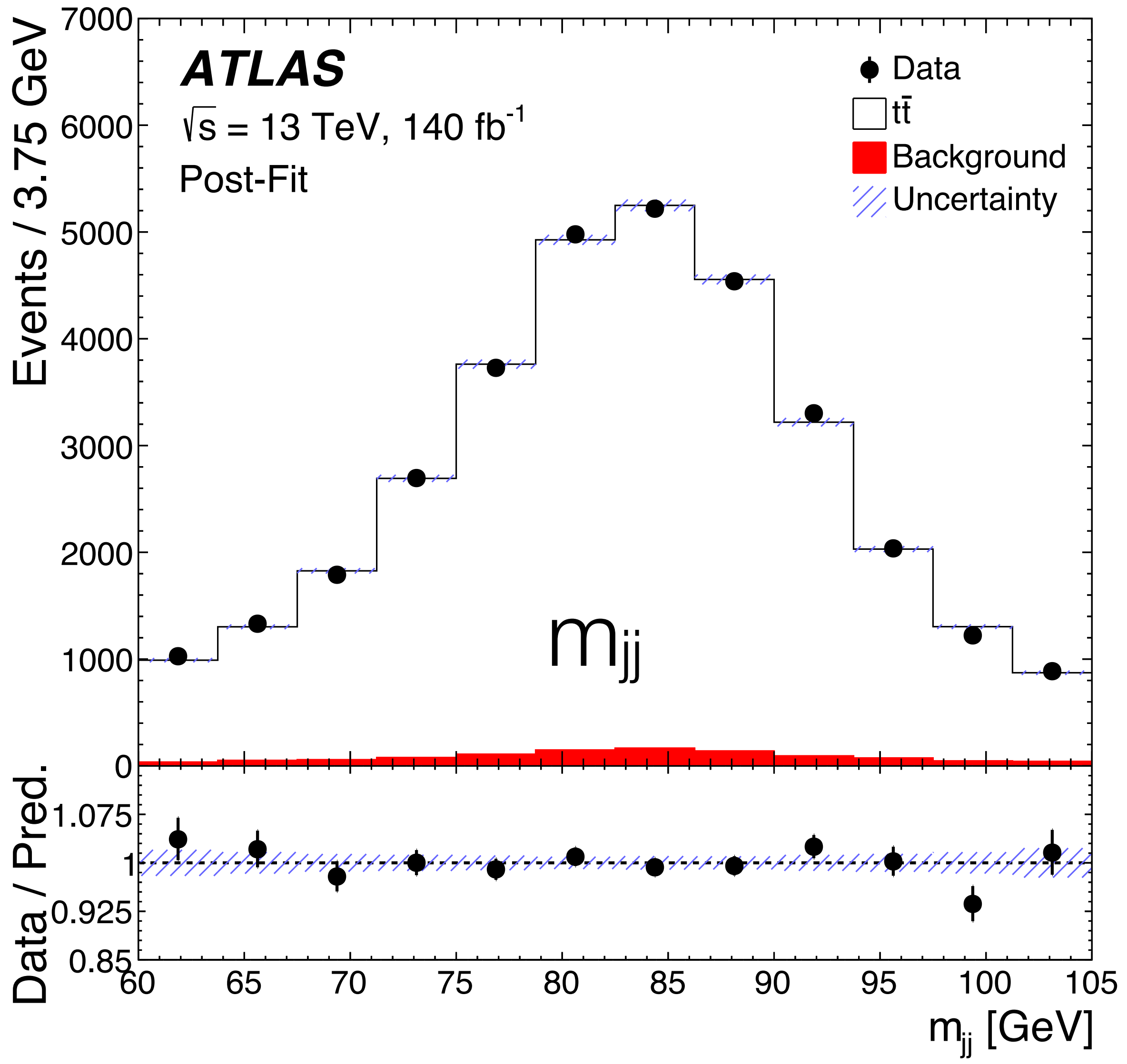
- Measurement of the **top mass in boosted top** (l+jets) events using large- and small-radius jets simultaneously:
  - Average large-radius jet as top mass estimate: $\mathbf{m_J}$
  - Add observables that can constrain the experimental+modelling uncertainties: $\mathbf{m_{jj}}$ **and** $\mathbf{m_{tj}}$

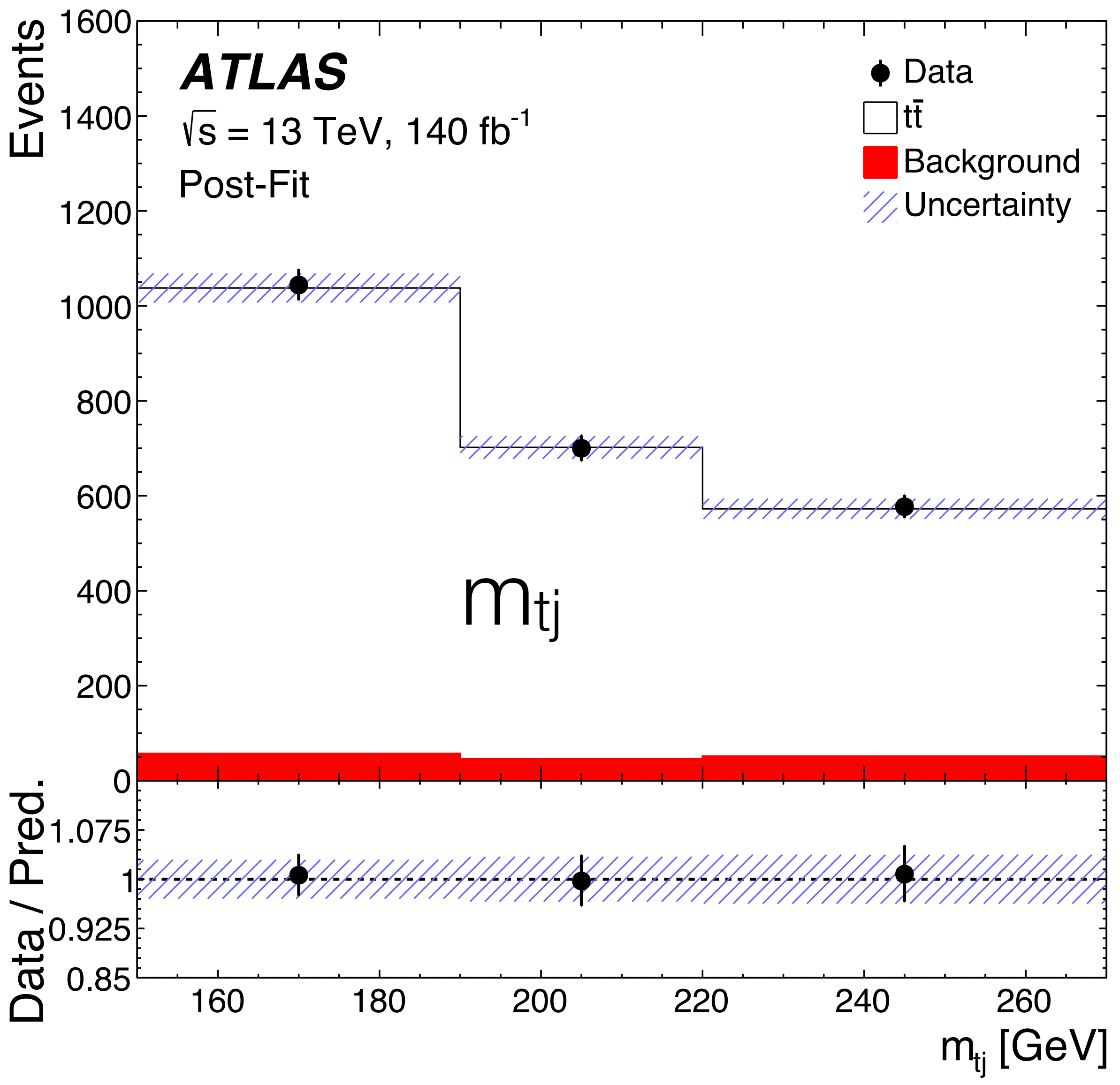
$$L\left(\overline{m_J}^d, \boldsymbol{n}_{\boldsymbol{m}_{jj}}, \boldsymbol{n}_{\boldsymbol{m}_{tj}} | m_t, \mu, \boldsymbol{\theta}\right) = G\left[\overline{m_J}^d | \overline{m_J}(m_t, \mu, \boldsymbol{\theta}), \sigma_{\overline{m_J}}\right] \times \prod_i P\left[n_{m_{jj},i} | \nu_i(\mu, \boldsymbol{\theta})\right] \times \prod_k P\left[n_{m_{tj},k} | \rho_k(\mu, \boldsymbol{\theta})\right] \times \prod_s G\left[\beta_s | \theta_s, 1\right],$$

- **Most precise** single-channel ATLAS top-mass measurement:

$m_t = 172.95 \pm 0.53$ GeV

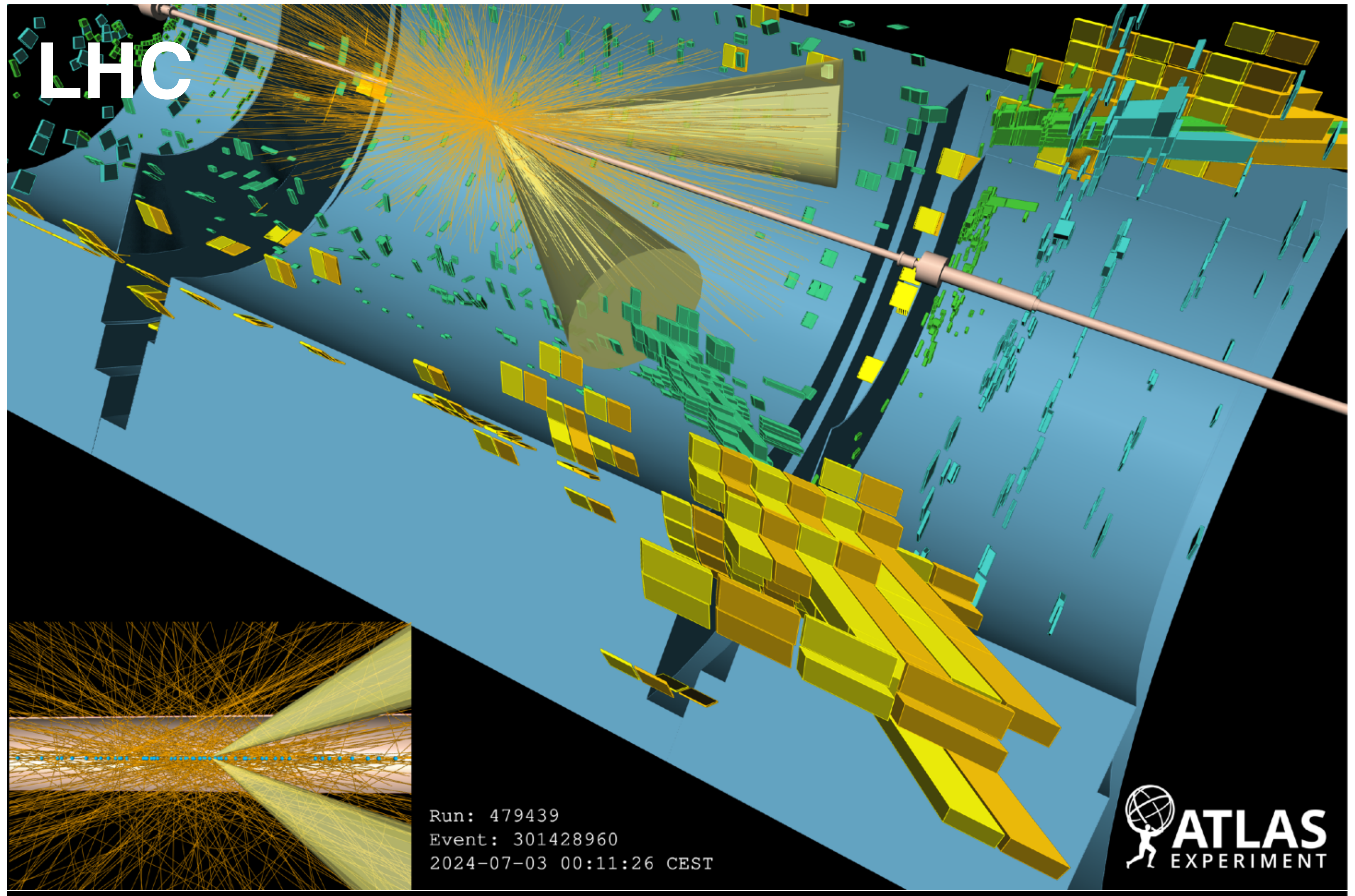


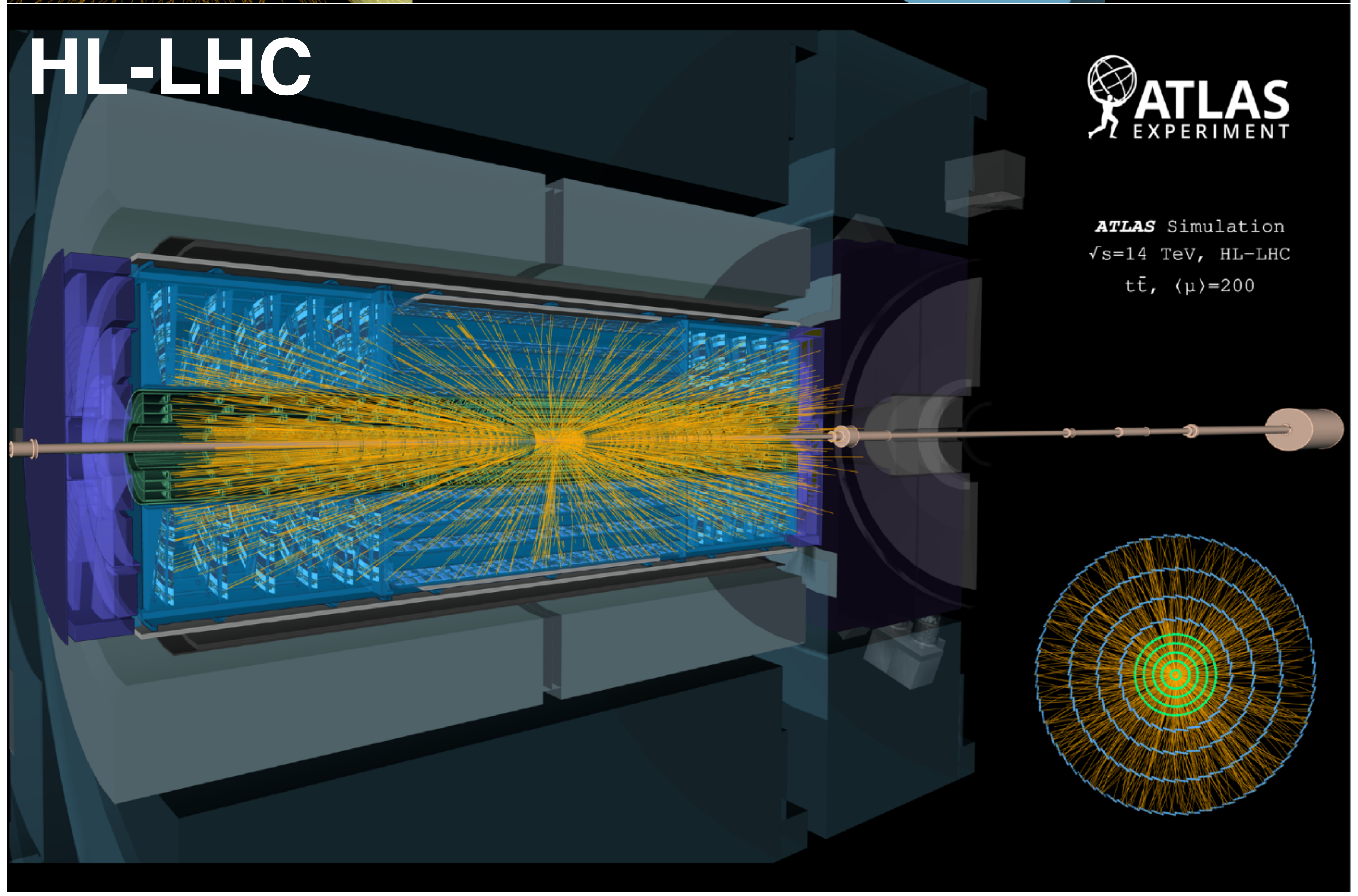



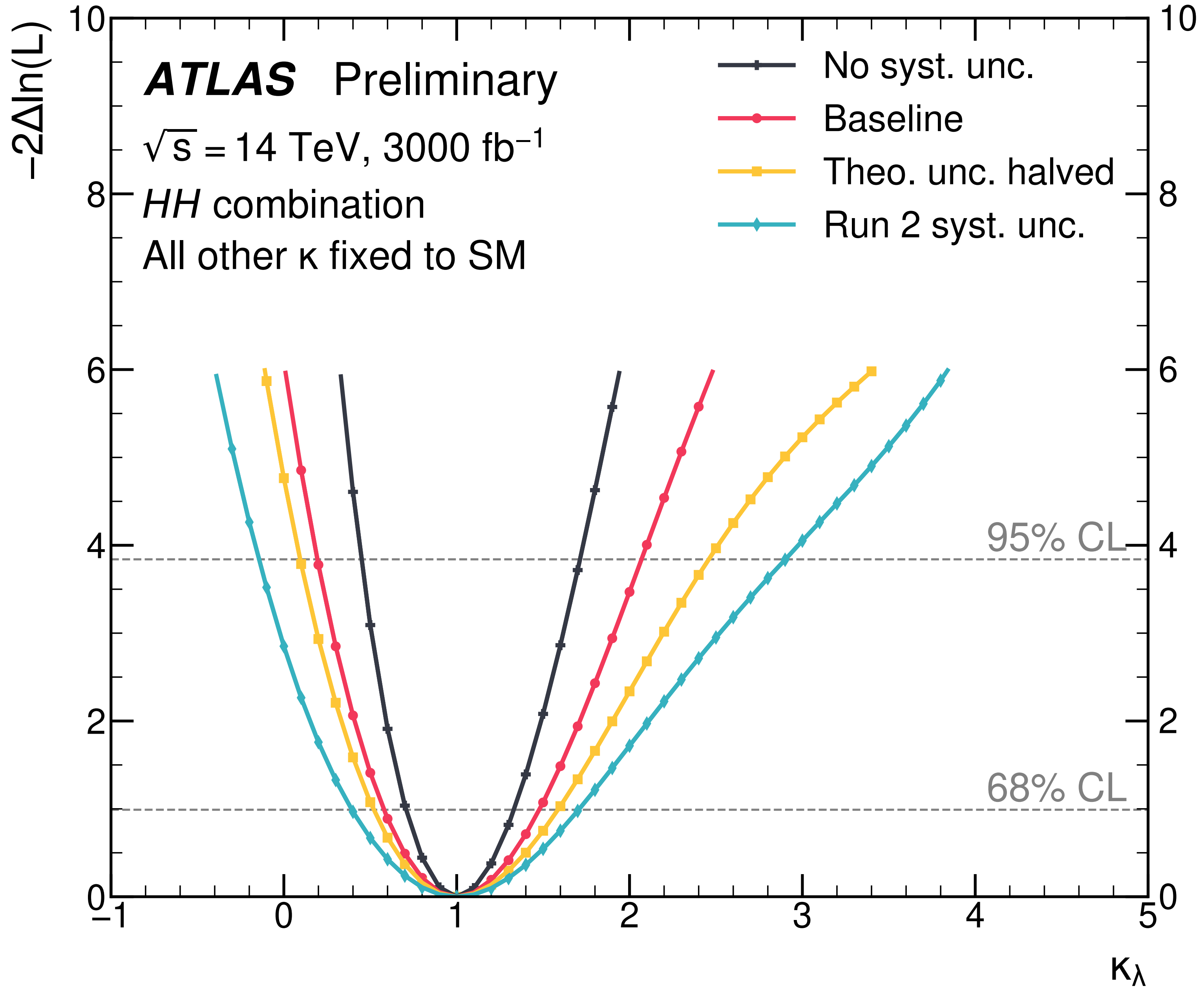
# High-Luminosity LHC

**NEW** note to appear soon on the
Higgs and Di-Higgs Public Results page

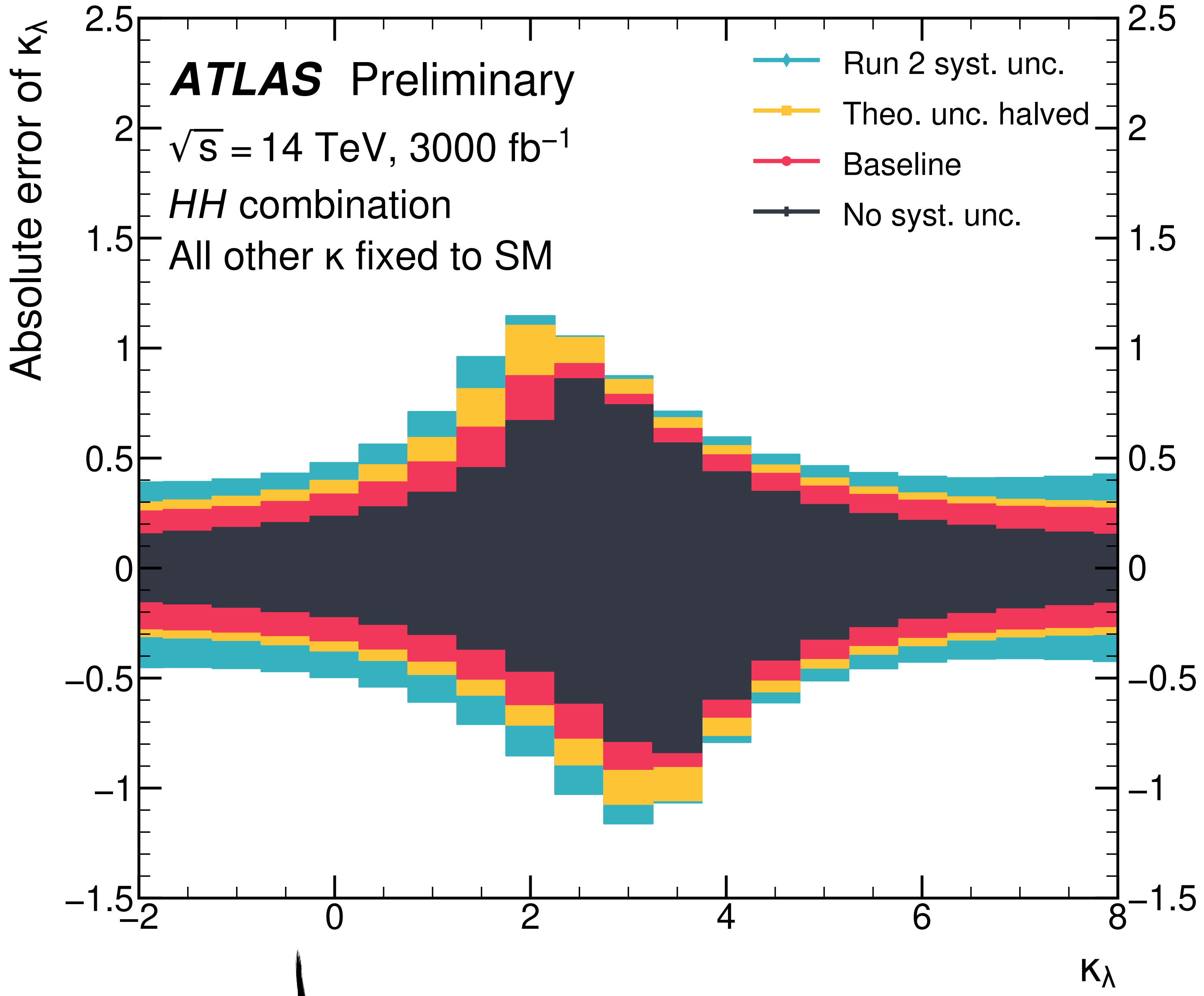



Higgs factory for precise Higgs coupling measurements, **access to Higgs self interaction** and longitudinal vector boson scattering, and increased overall rare & new physics sensitivity




**4.3σ expected significance**
for HH production



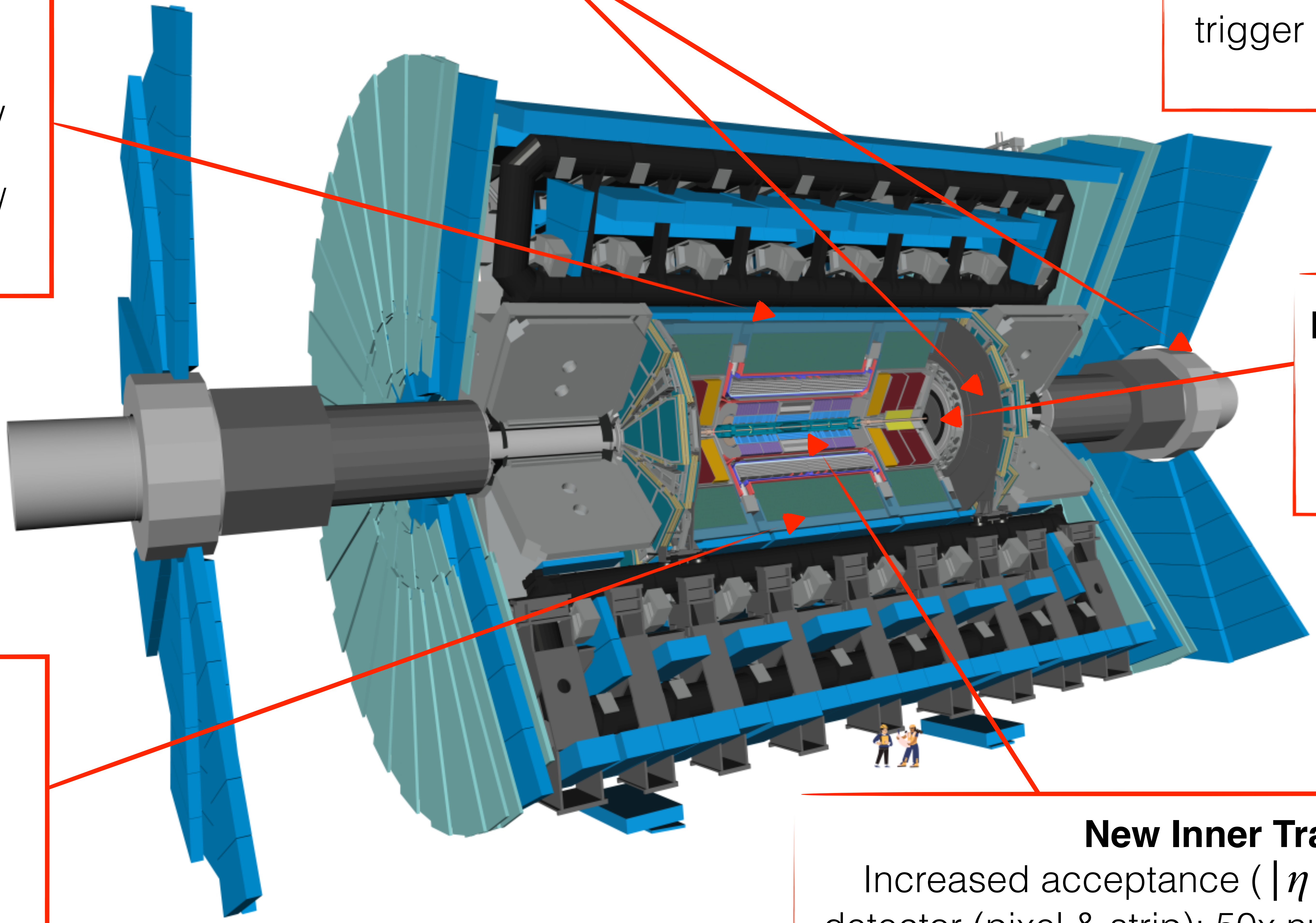

With 3ab-1 ATLAS alone will get to 45% accuracy on Higgs self-coupling (for $k_\lambda$=1), with conservative assumptions!

# ATLAS Phase-II Upgrades

New upgraded forward and luminosity detectors

**Trigger & DAQ Upgrade:**
First level trigger @ 1 MHz; High level trigger @ 10 kHz (150 kHz full tracking event filter)

**New Muon Chambers & Electronics**
Inner barrel region with new RPC and sMDT detectors; Improve trigger momentum/ efficiency, reduce fakes

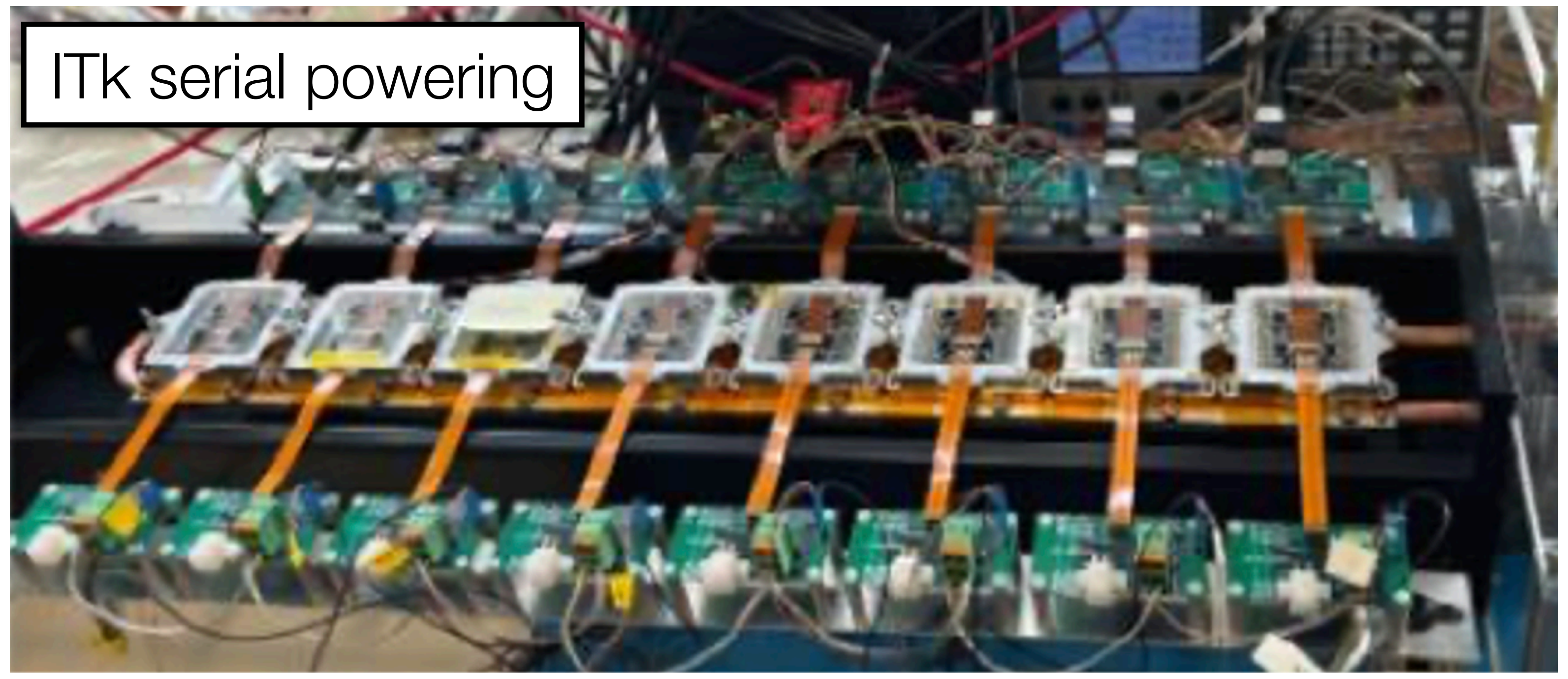


**High Granularity Timing Detector (HGTD):**
Fast timing (30-50 ps) detector for pileup rejection $2.4 < |\eta| < 4$

**Calorimeter Electronics Upgrade:**
Upgrade of LAr and Tile calorimeter electronics

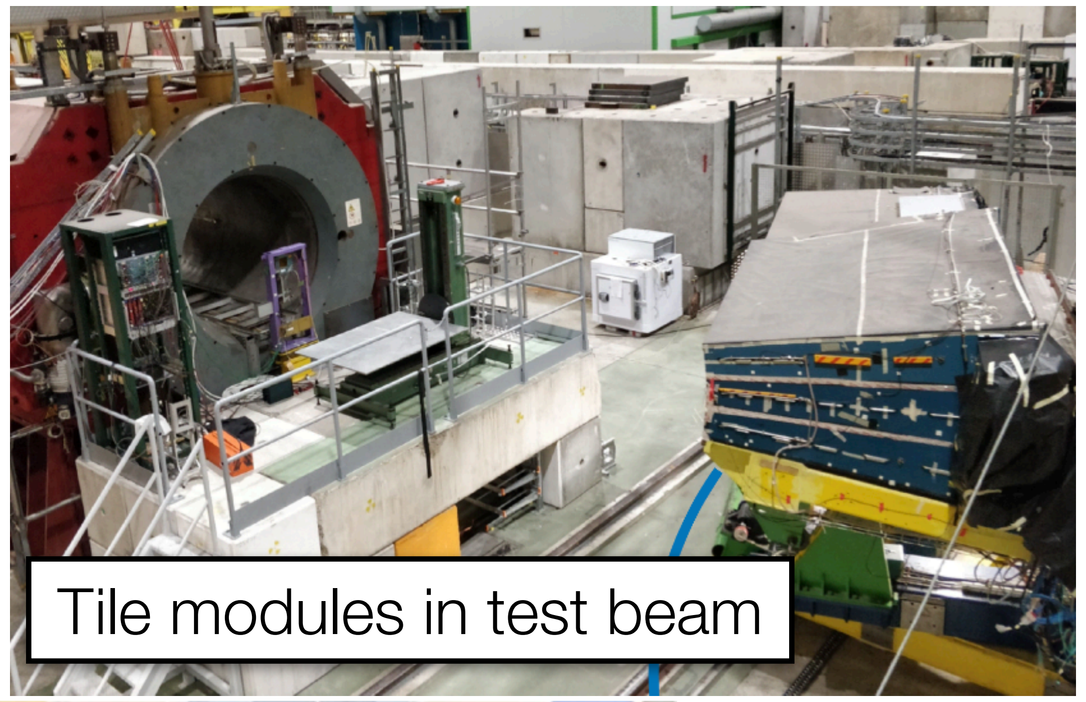
**New Inner Tracker (ITk)**
Increased acceptance ($|\eta| < 4$) with an all-silicon detector (pixel & strip); 50x number of channels to cope with detector occupancy increase

# Overall Status of Phase-II Upgrades

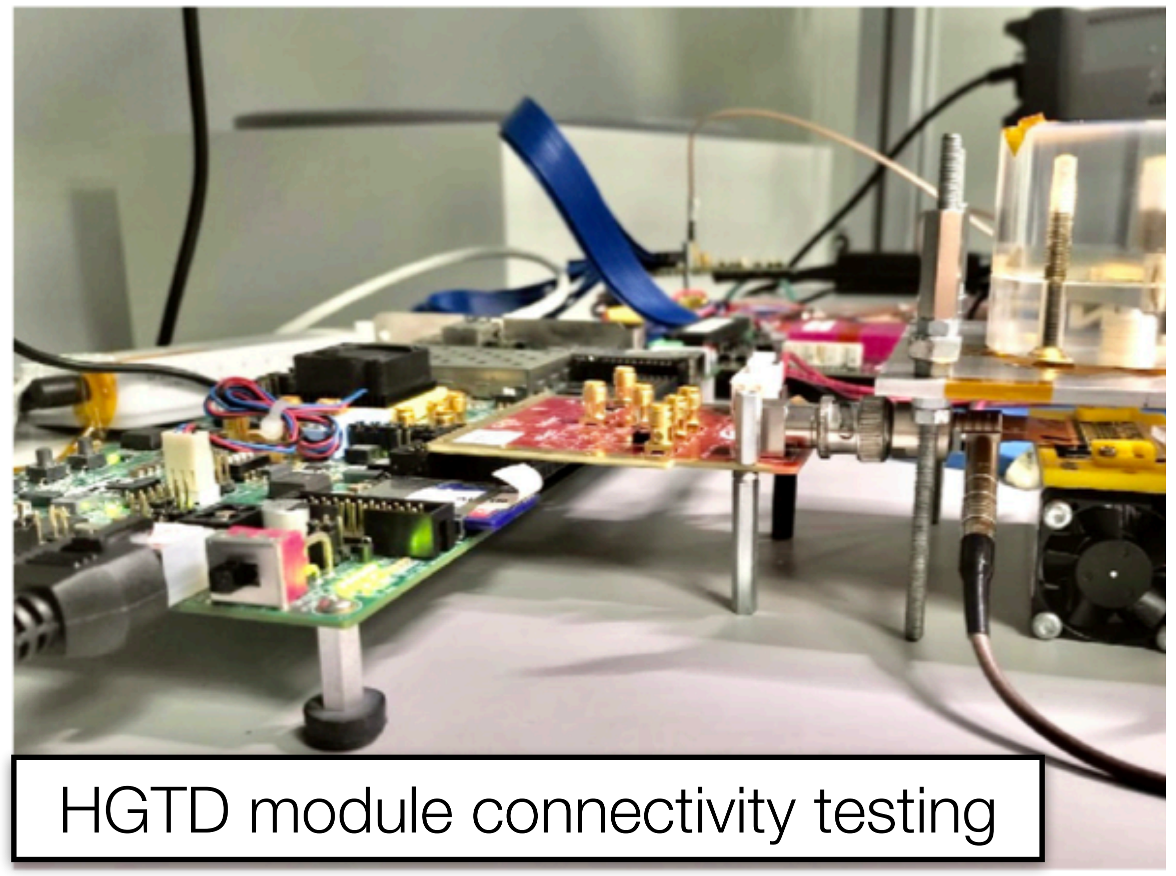

ITk serial powering


Tile PMT tests

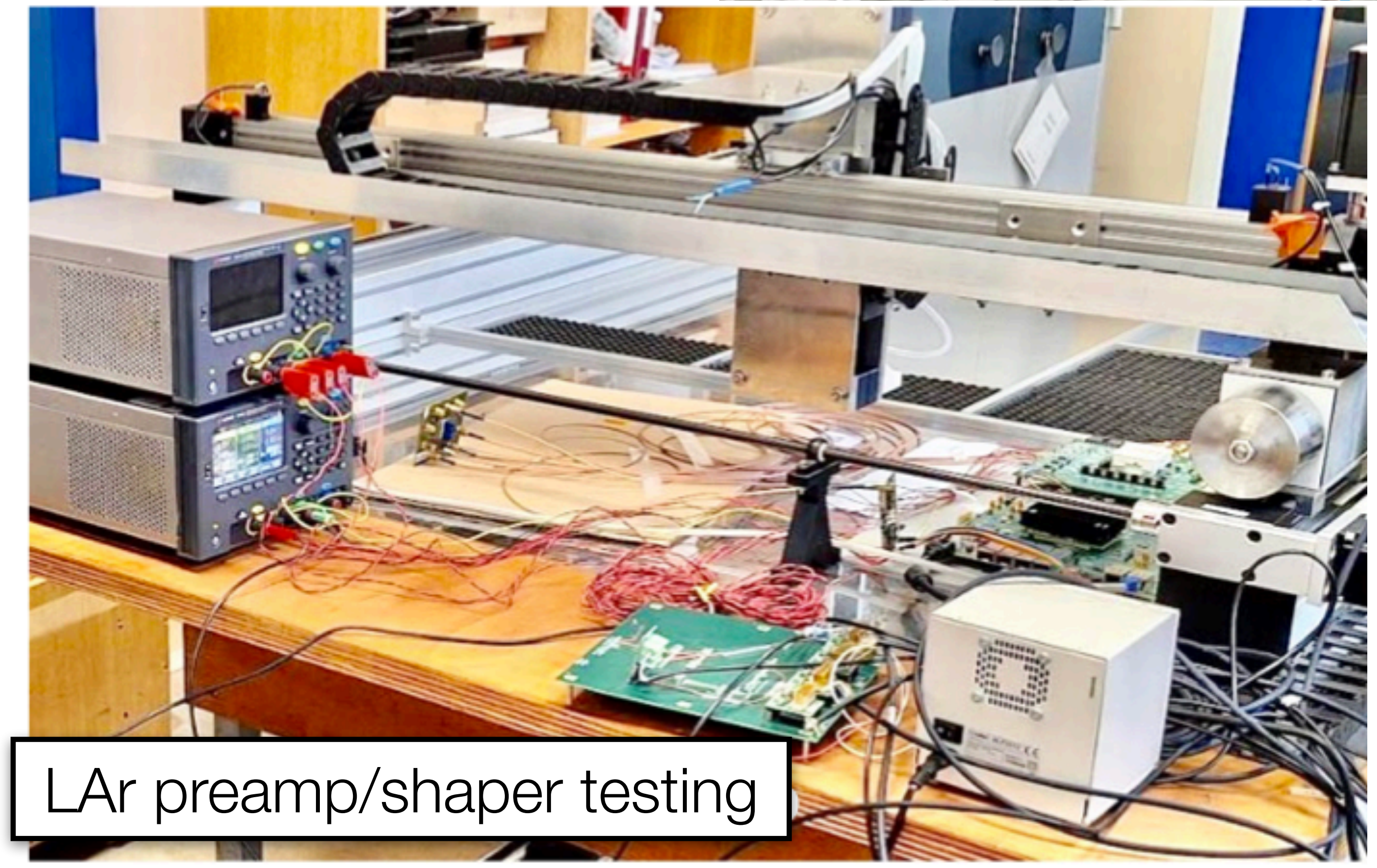

ITk module production

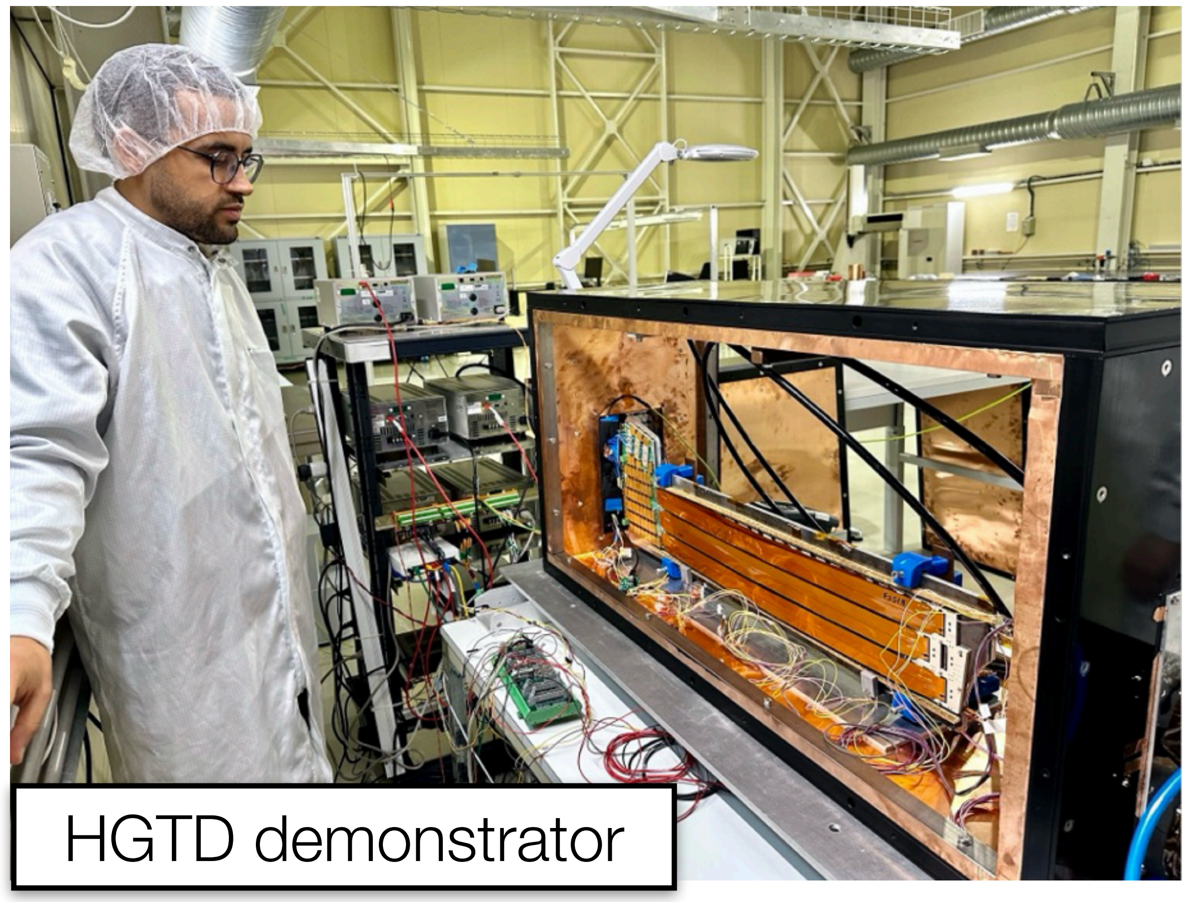

Tile modules in test beam

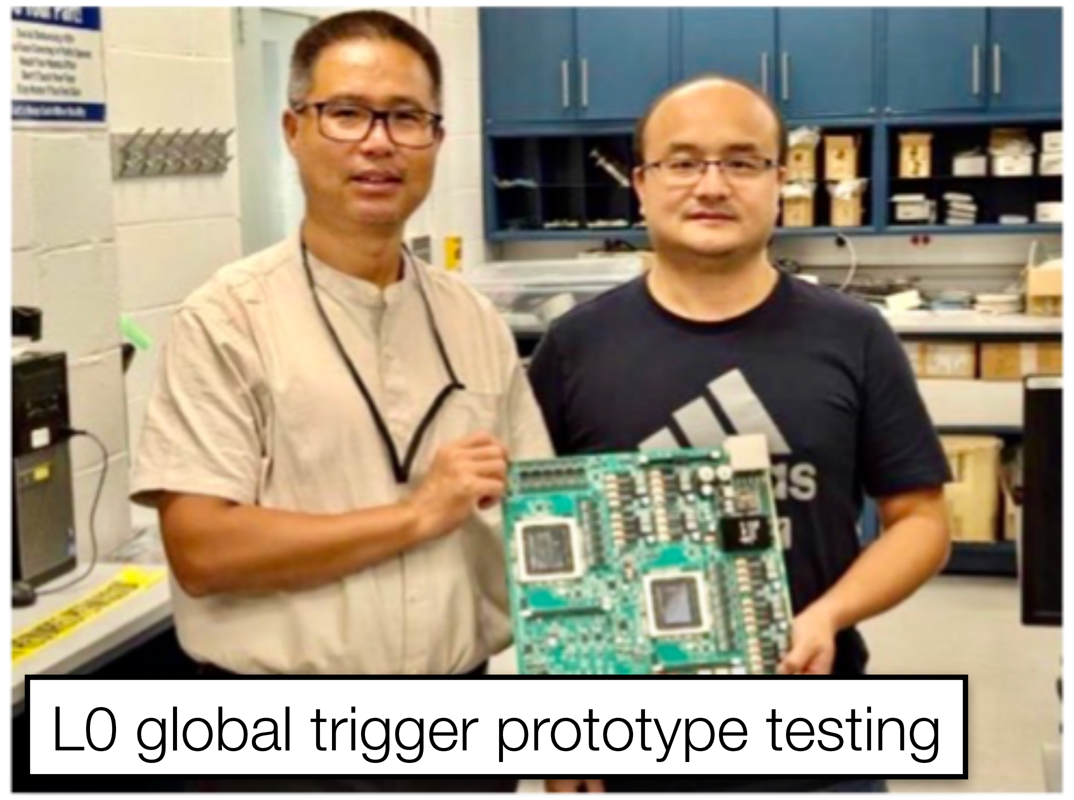

ITk system tests

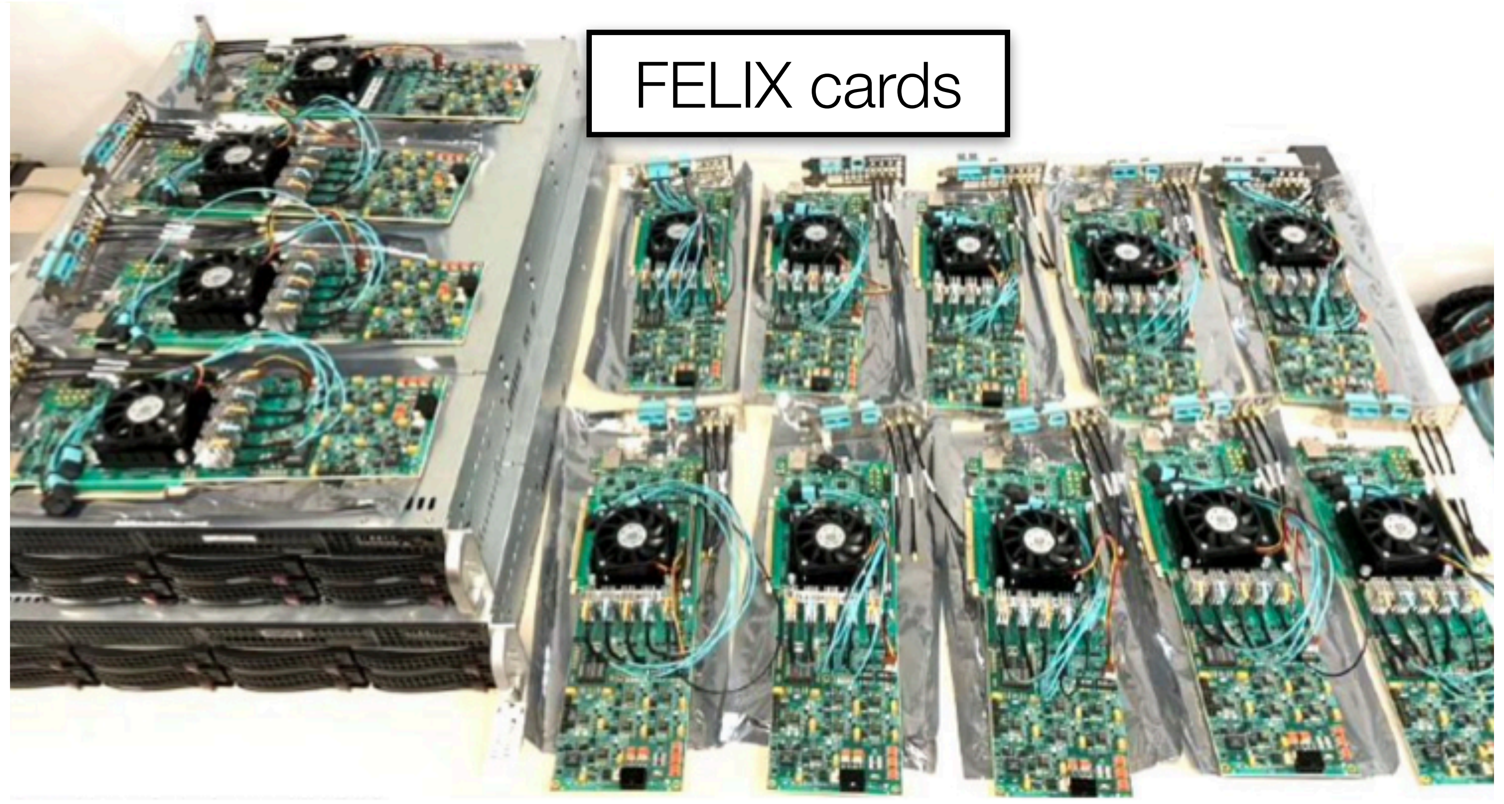

HGTD module connectivity testing


Visit to Phase-II upgrade sites


LAr preamp/shaper testing

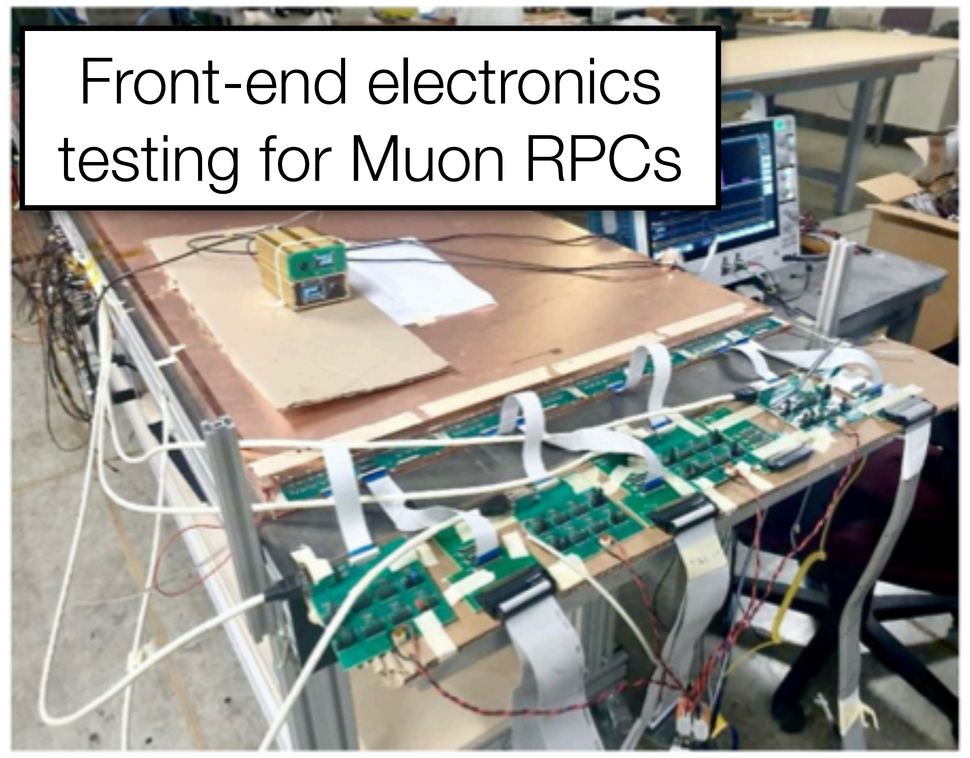

HGTD demonstrator


L0 global trigger prototype testing

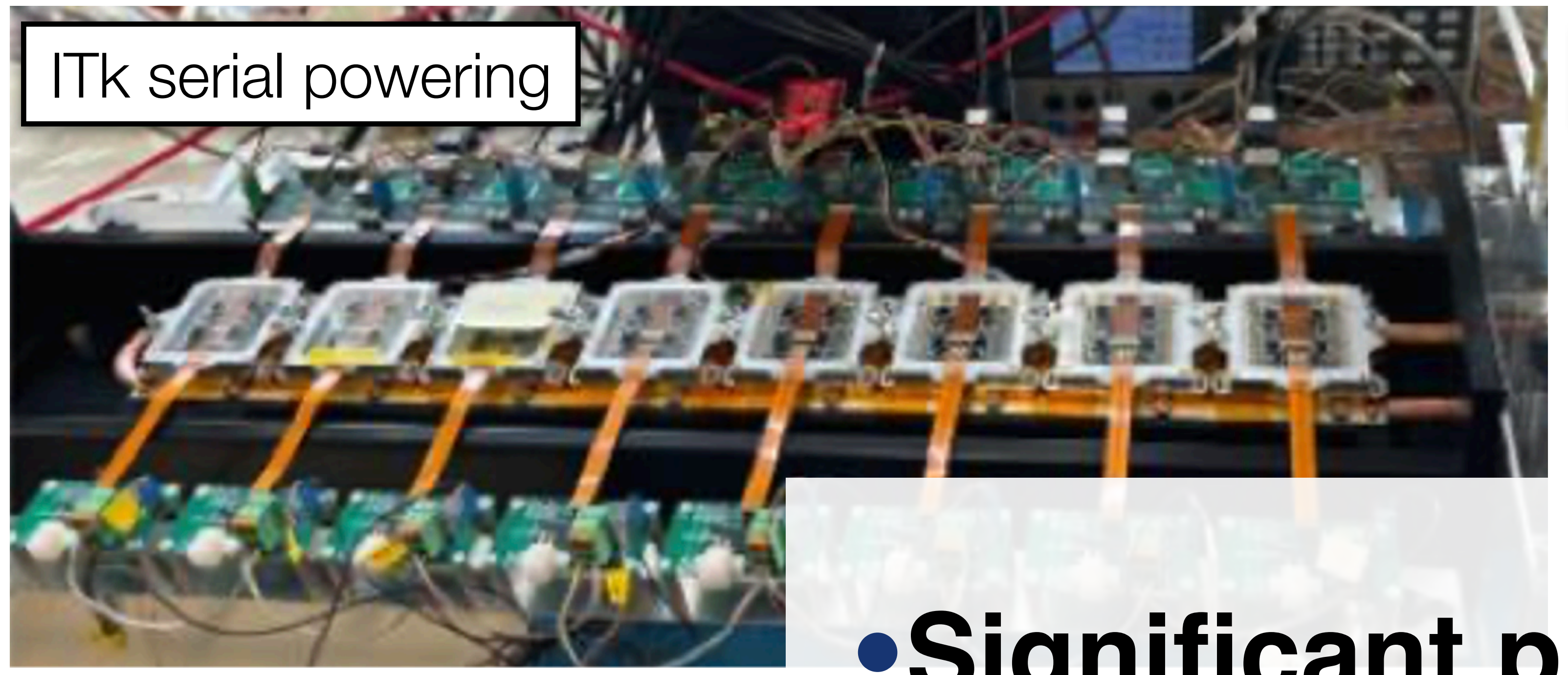

FELIX cards


Muon RPC readout panels


Muon RPC production


Front-end electronics testing for Muon RPCs

# Overall Status of Phase-II Upgrades



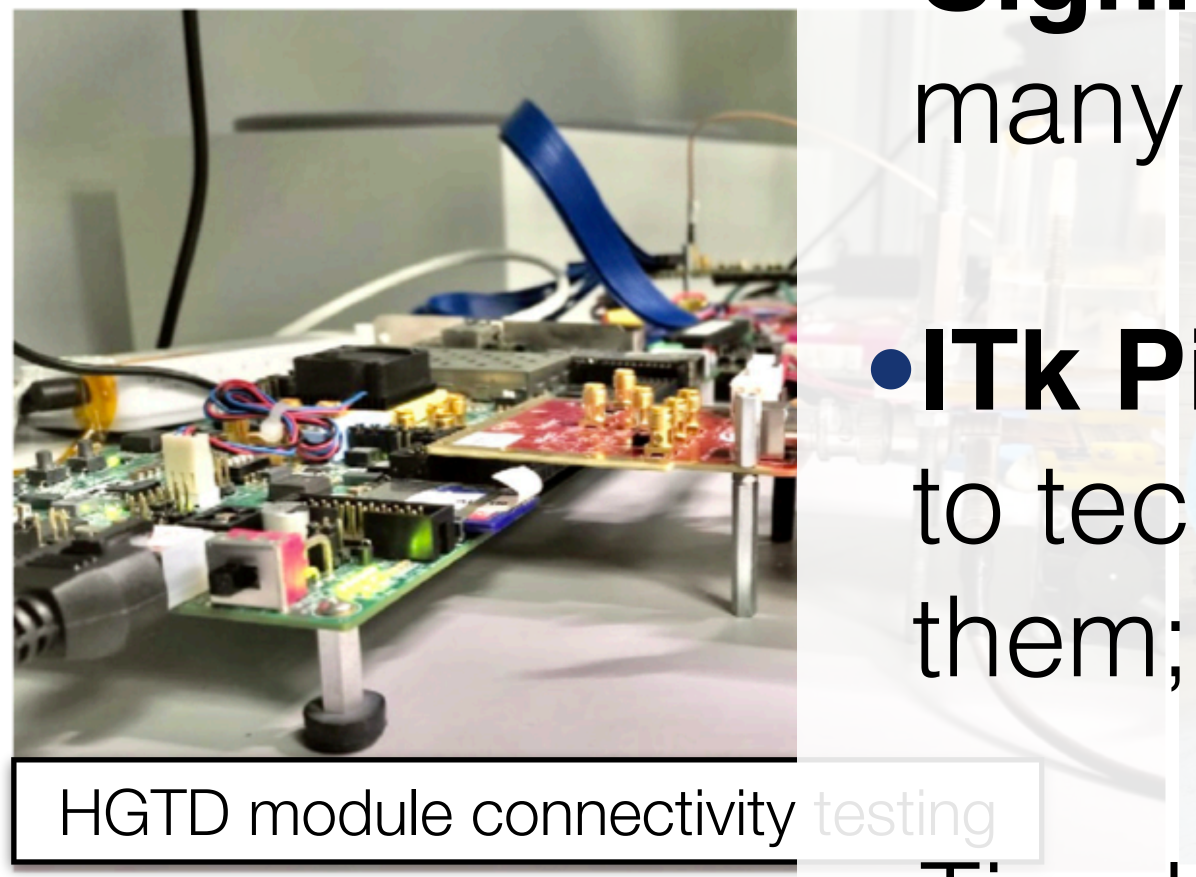


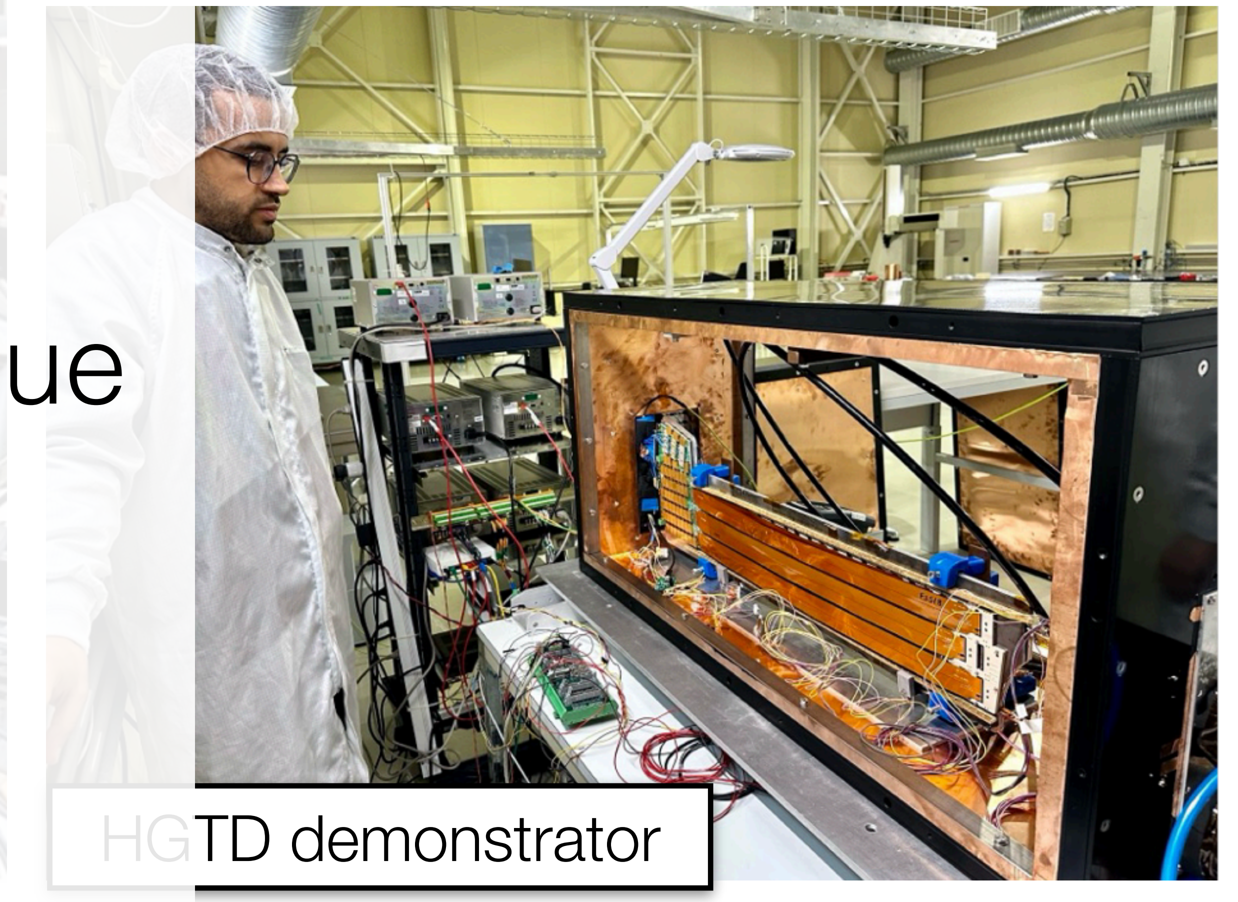


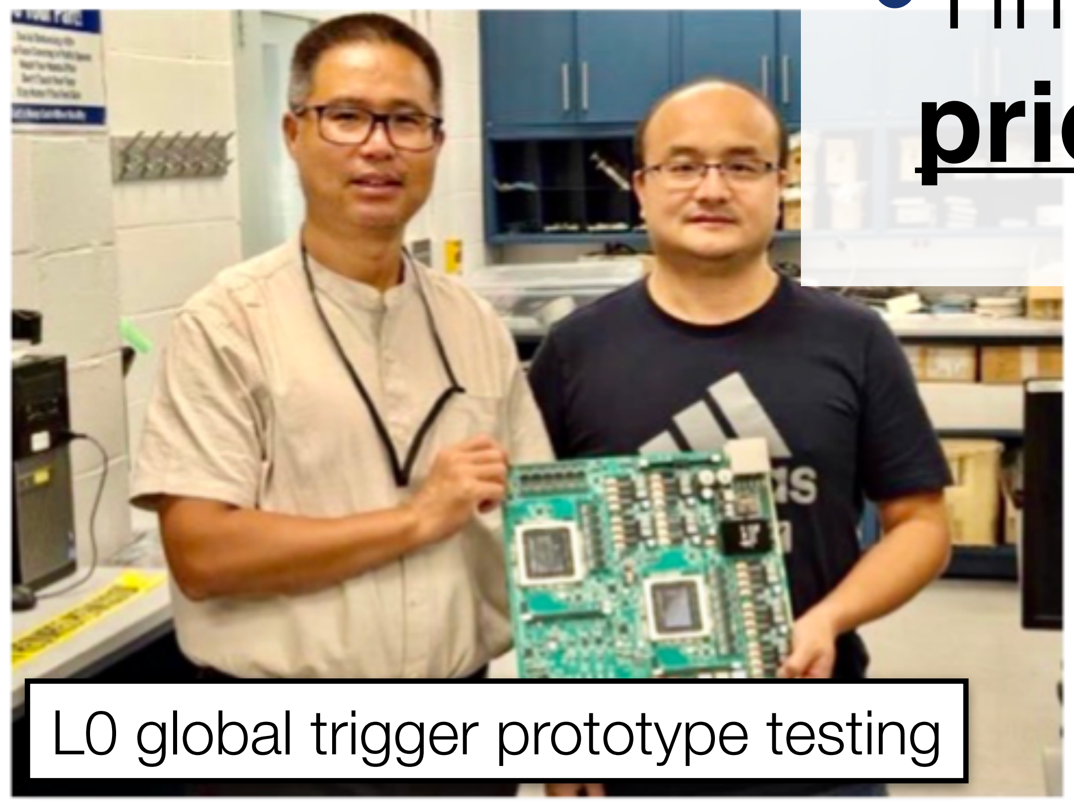
- **Significant progress made in all upgrade activities** with many components in production, some completing!

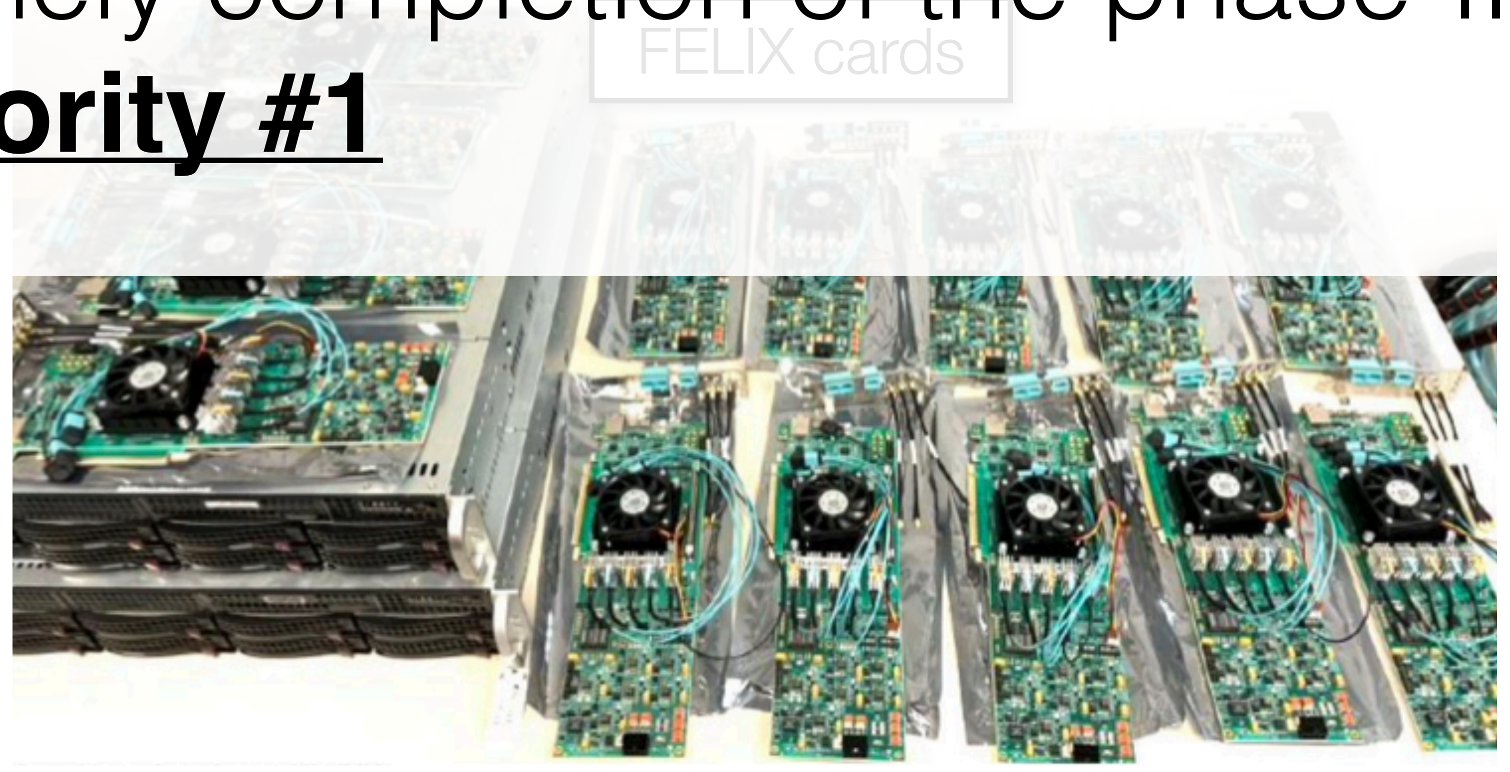
- **ITk Pixel and Strip define critical path of the schedule** due to technical challenges, but good progress in addressing them; 2025 marks the **start of module production**!

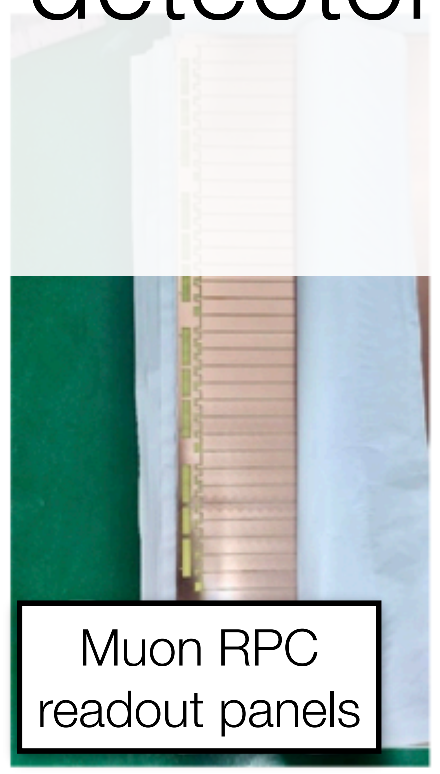
- Timely completion of the phase-II detector upgrades is **<u>priority #1</u>**



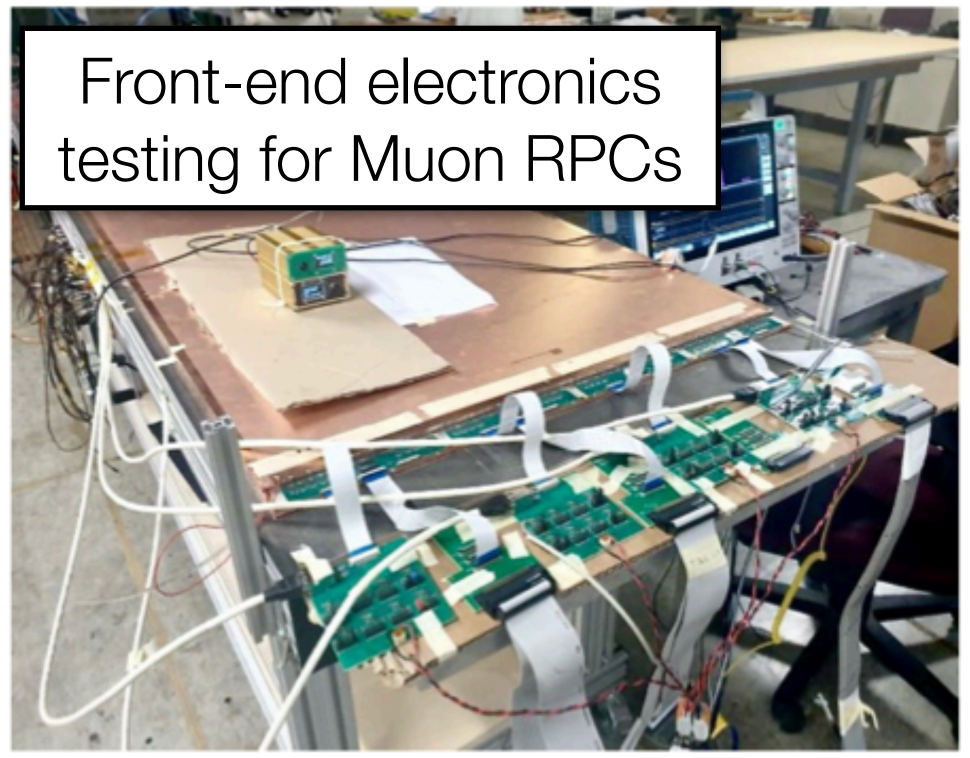



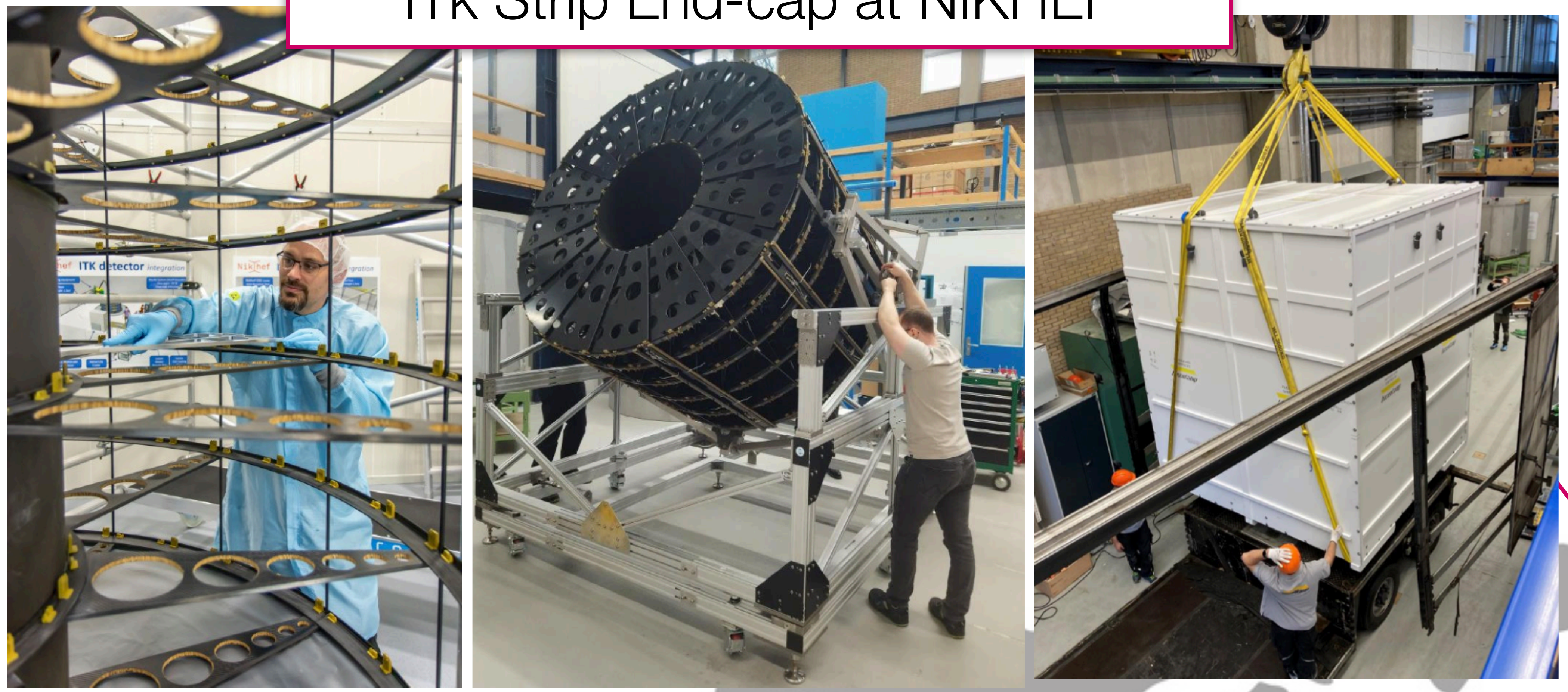




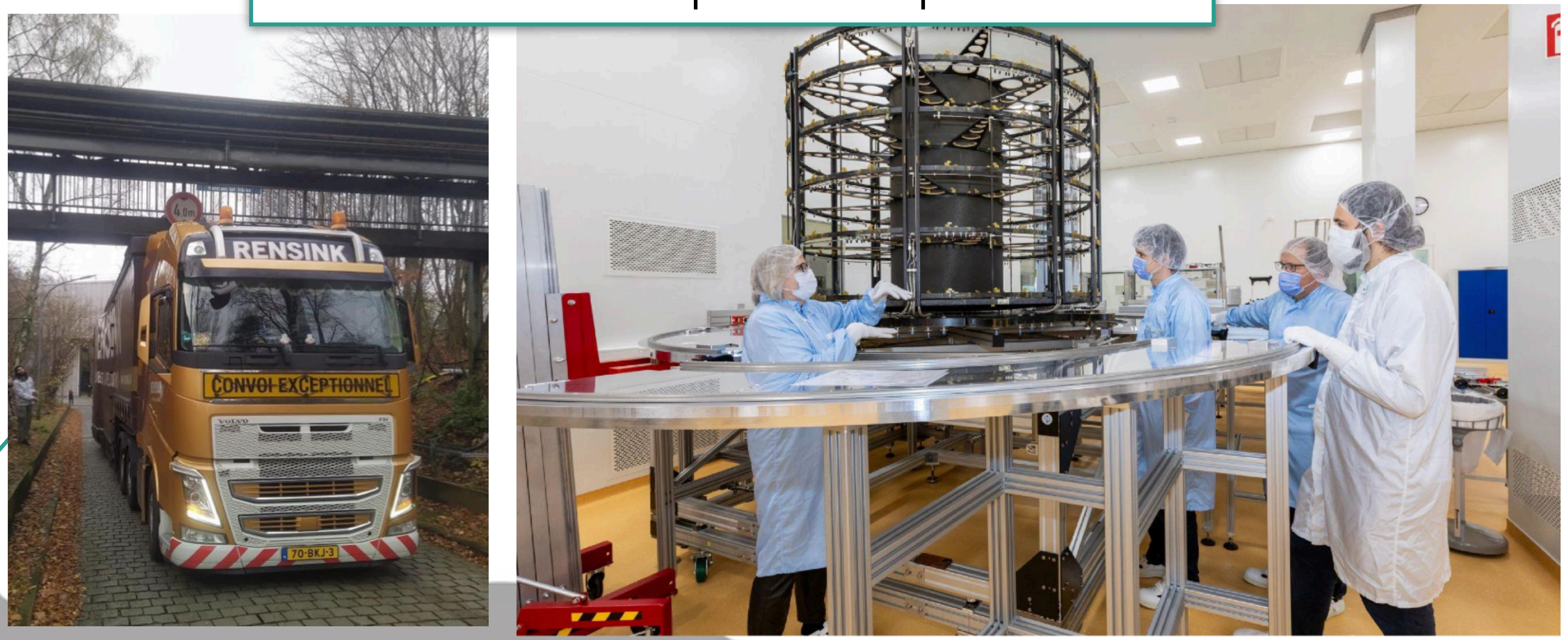


# ITk Highlights — Mechanics

ITk Strip End-cap at NIKHEF



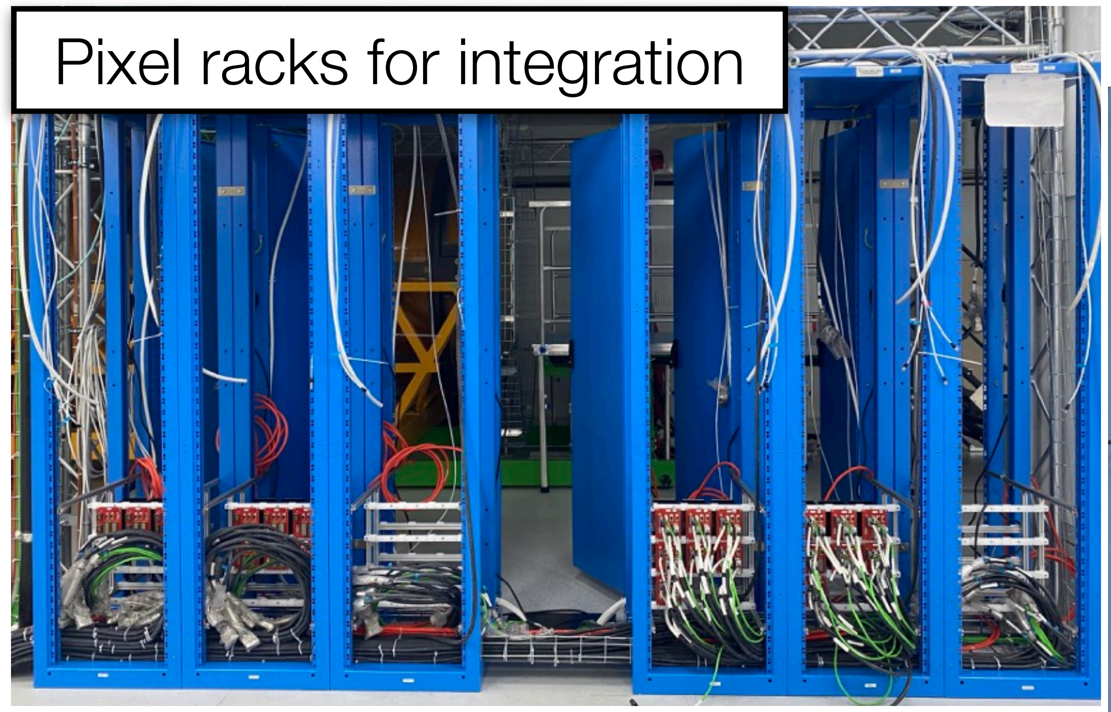
Arrival of ITk Strip End-cap at DESY

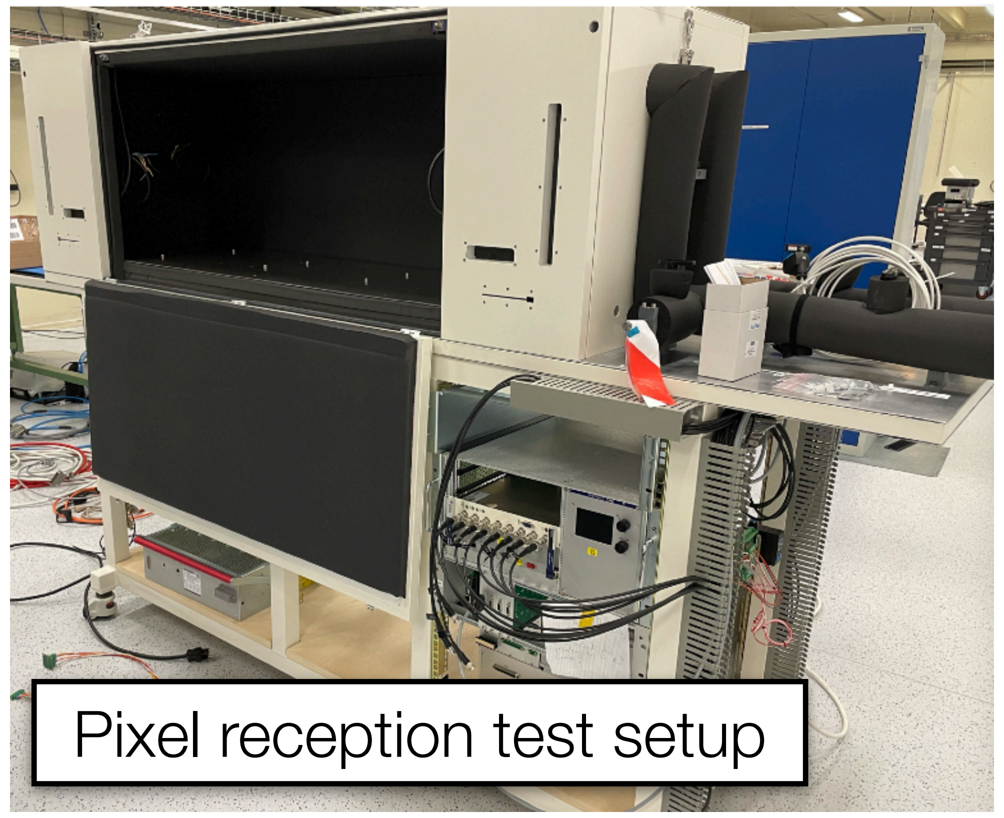


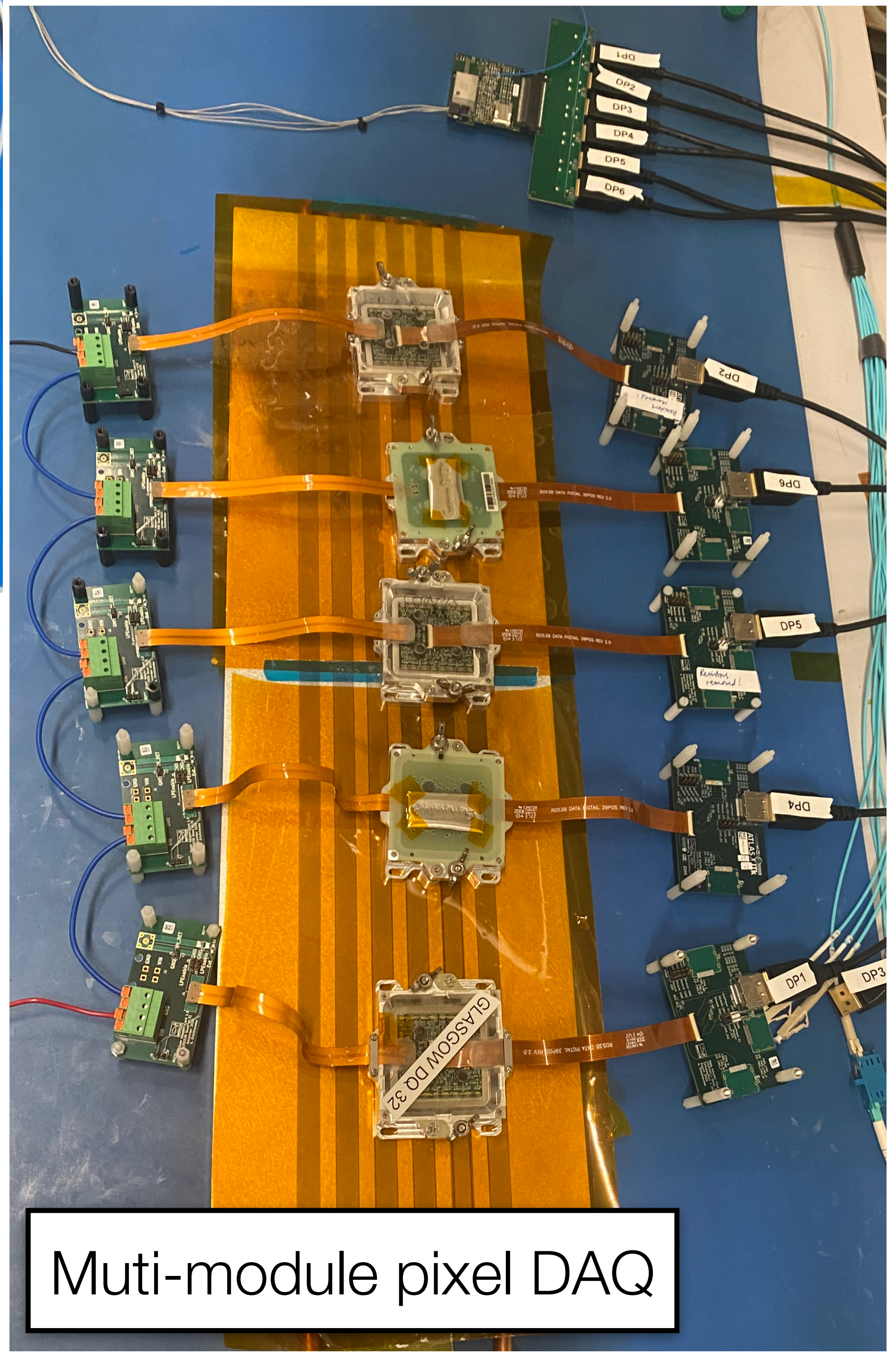

**Many delicate shipments over the past year!**

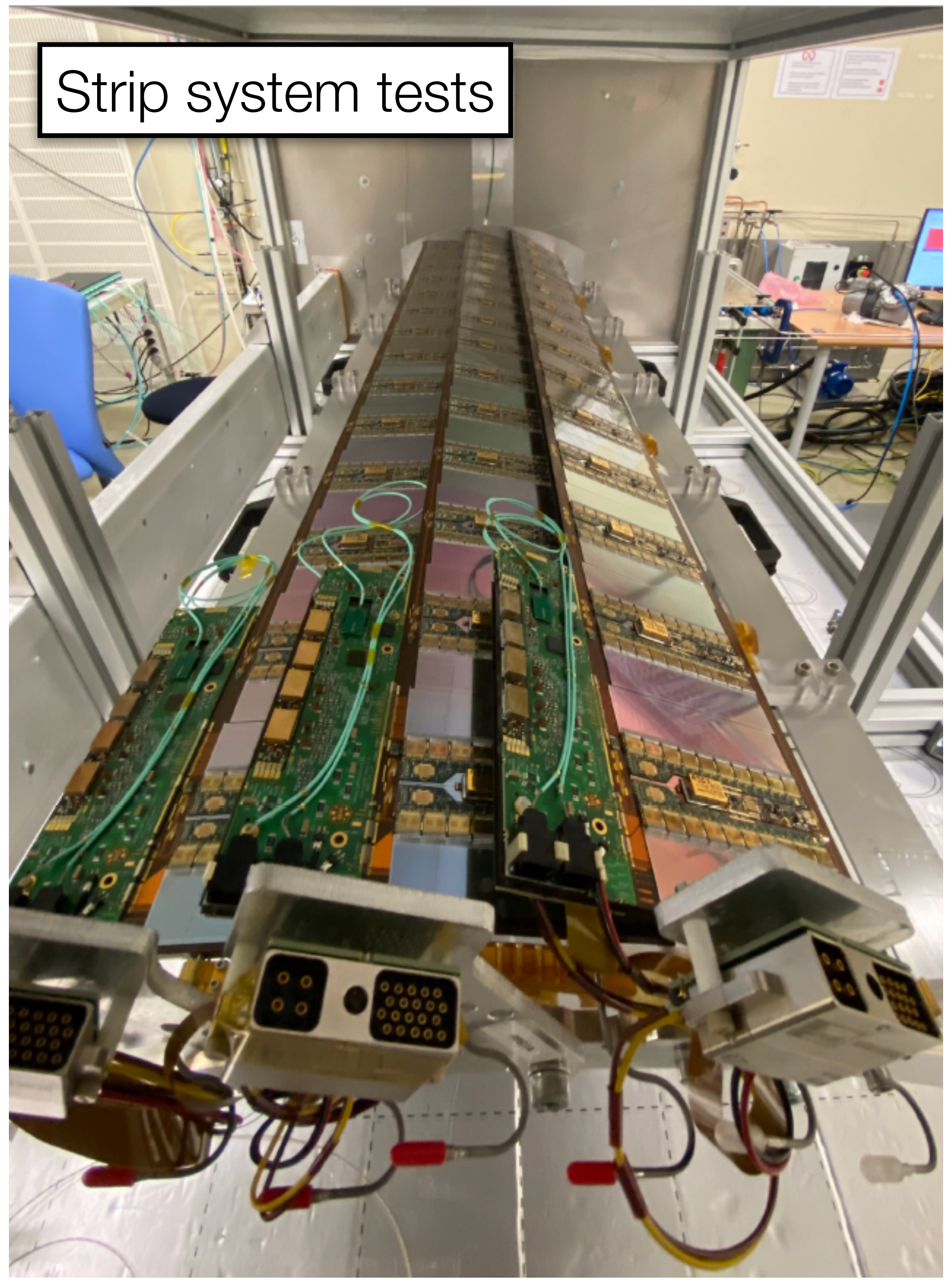
# ITk Highlights — Mechanics

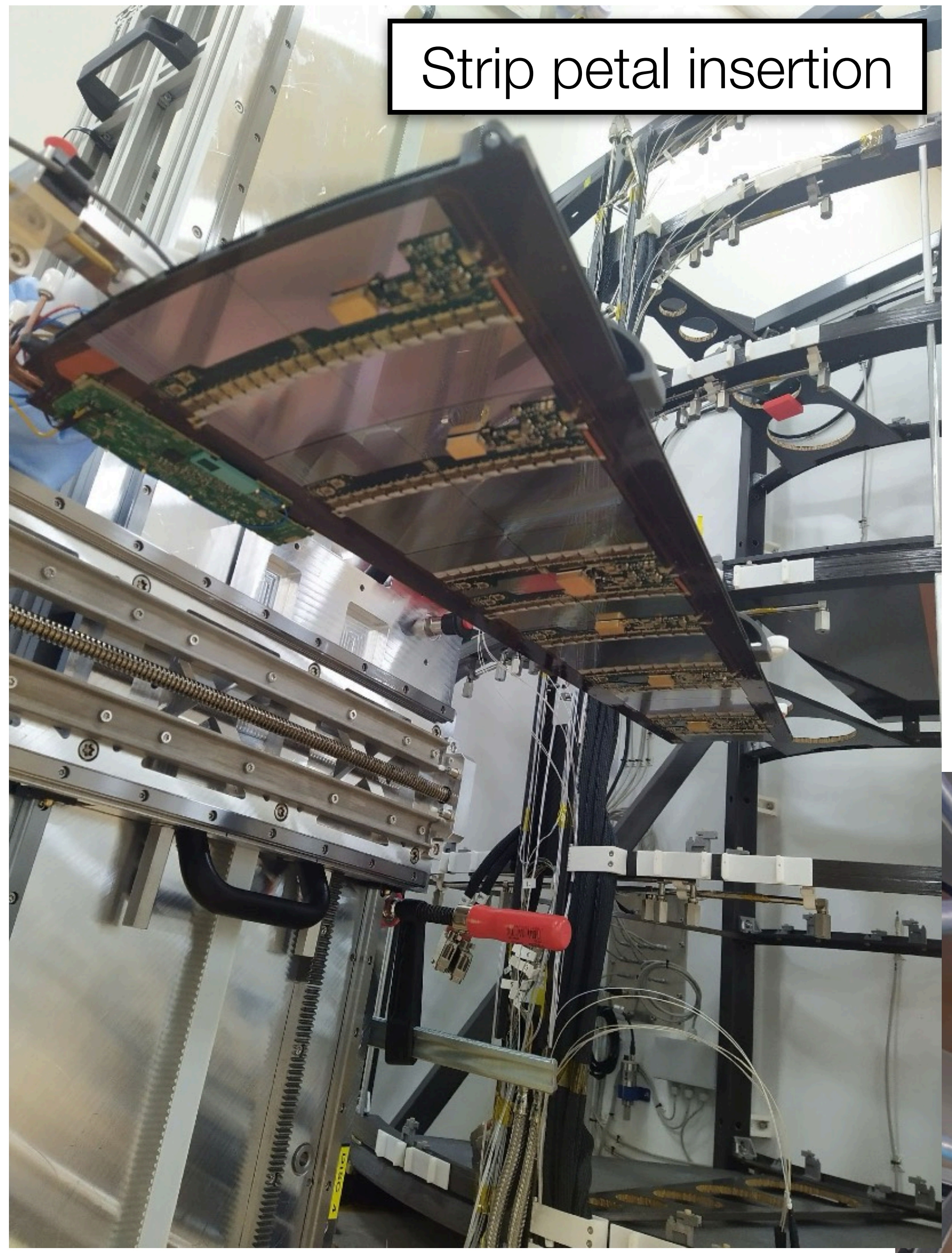
# ITk Highlights — Integration & Commissioning

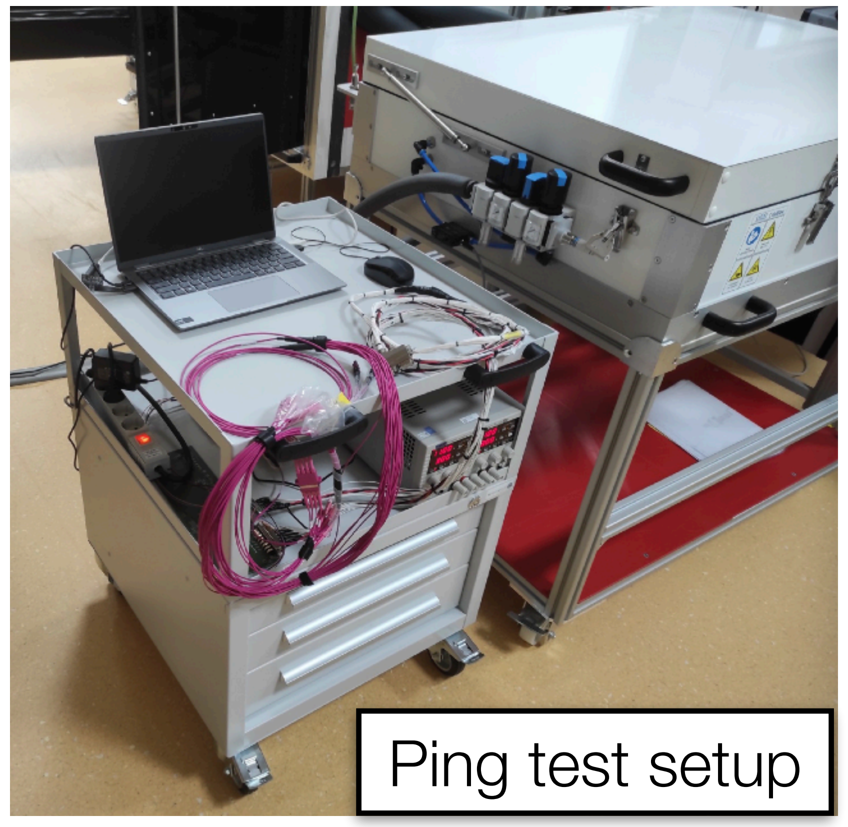

Pixel racks for integration

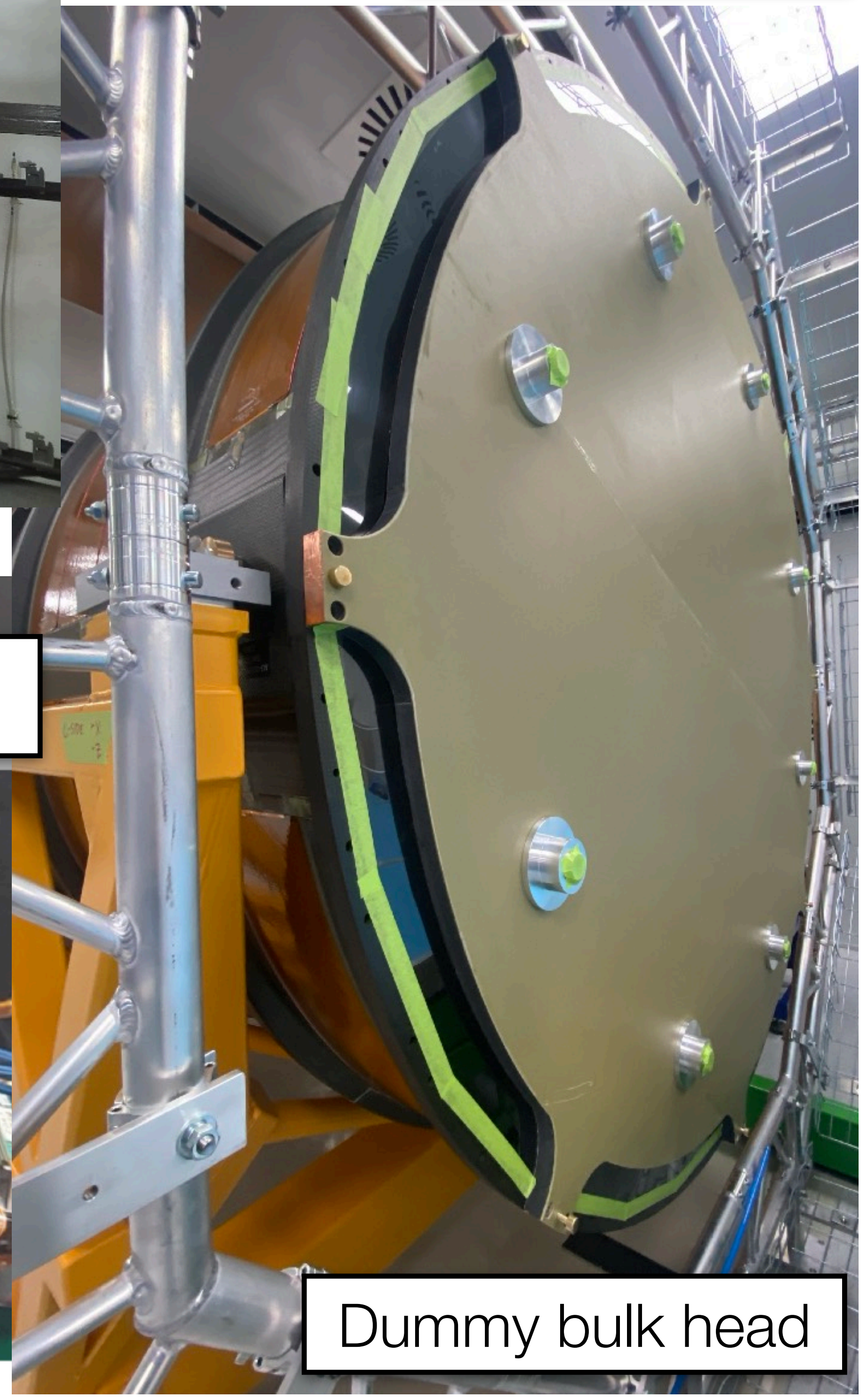

Pixel reception test setup

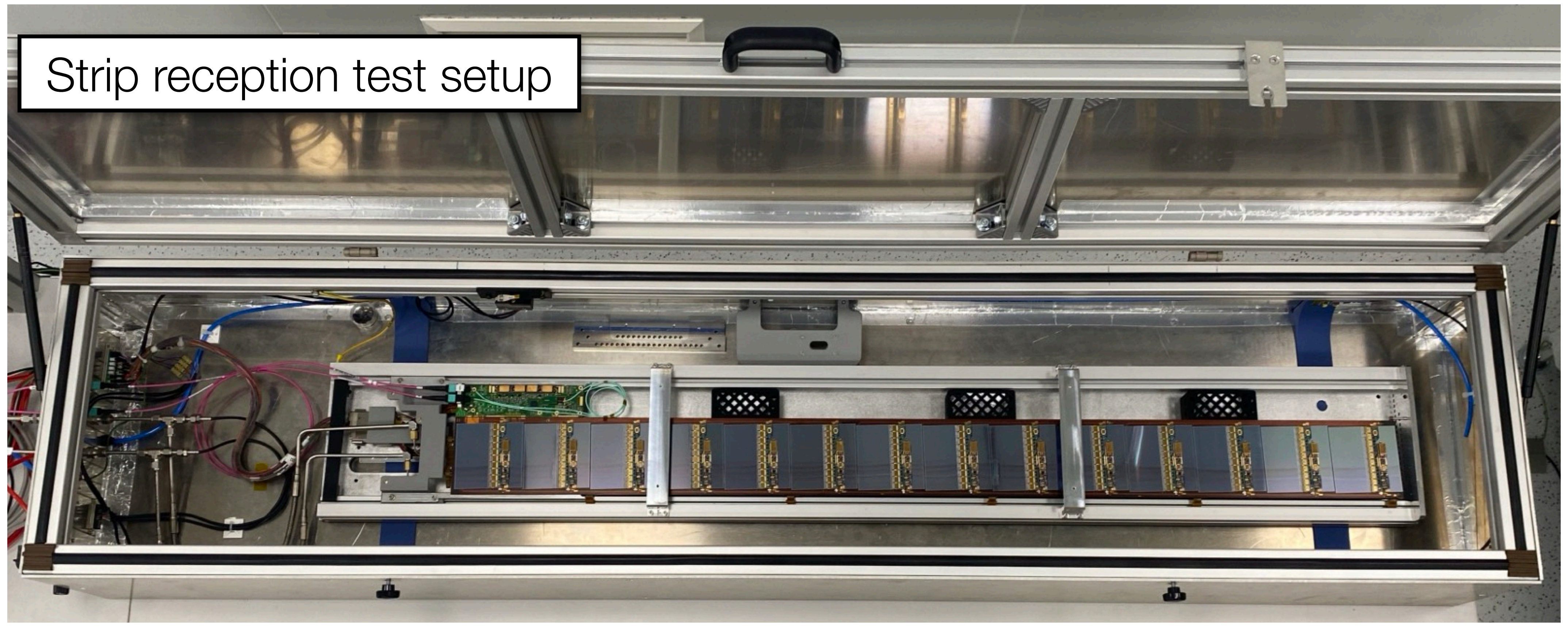

Muti-module pixel DAQ

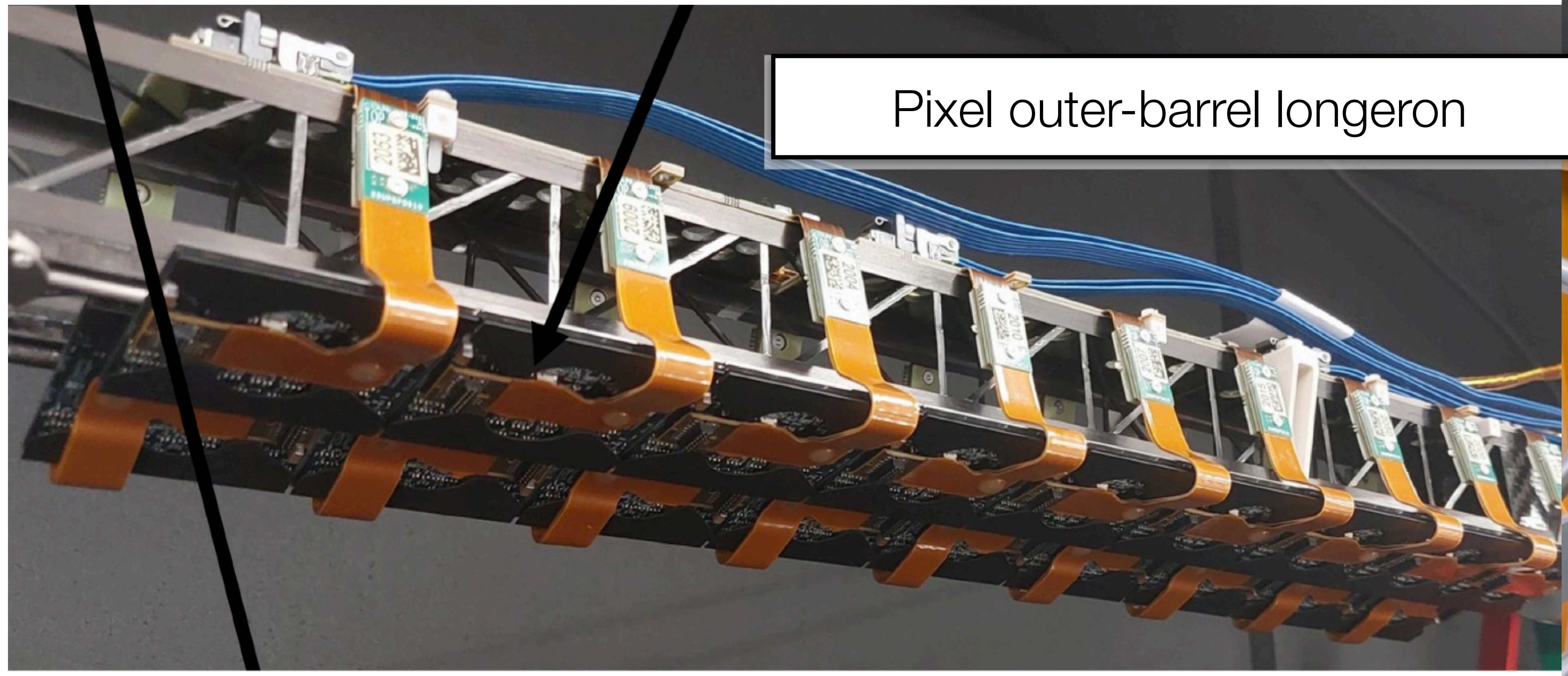

Strip system tests


Strip petal insertion


Ping test setup


Dummy bulk head


Strip reception test setup


Pixel outer-barrel longeron

# ITk Strip

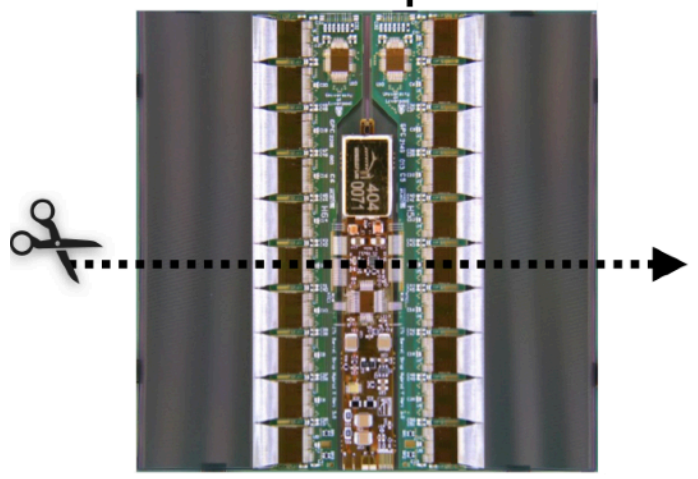
- Many areas (sensors, ASICs, EOS, bustapes, cores, etc.) in production; some close to completion

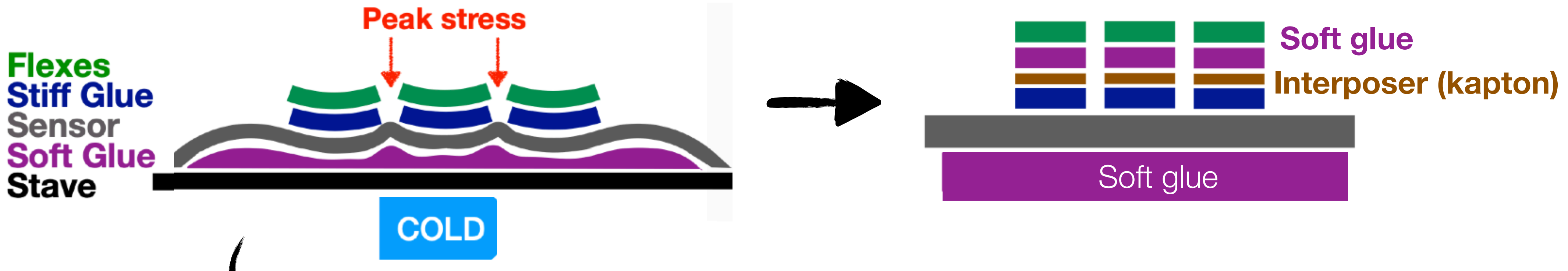
- Module production start impeded by technical challenges (cold noise, sensor cracking)
  - Barrel module production starting with **interposer layer** between **flexes** and **sensor**
  - End-cap design pending technical discussion; decision imminent

- Plan has been decided to cope with lpGBT v1 bug for ~10% of barrel and 5% of end-cap end-of-substructure (EOS) cards
  - Rest of the detector will use lpGBT v2
  - Thanks for the prompt action from ESE to mitigate this problem!

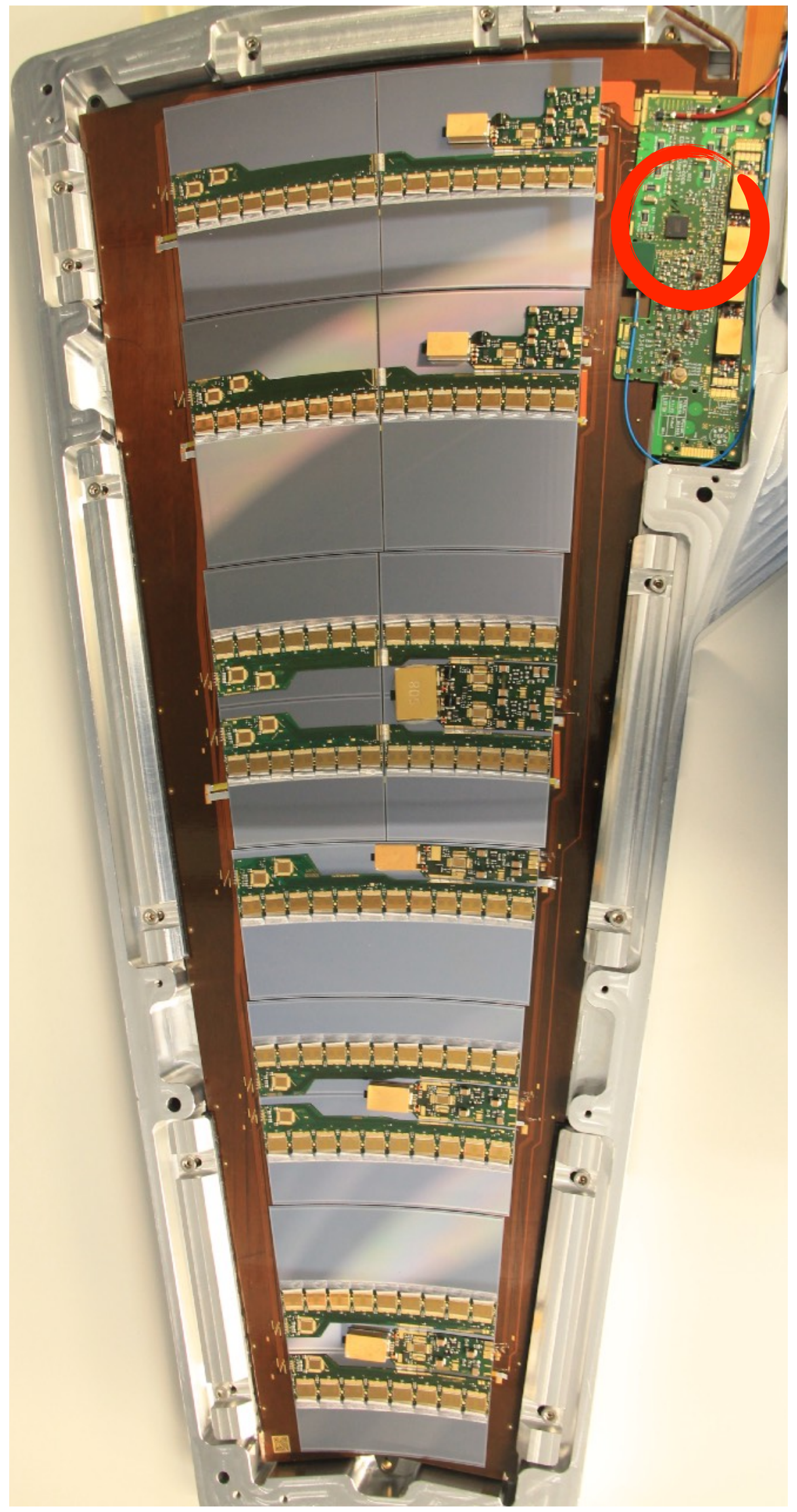
- Integration & DAQ workshops held earlier this year!

A barrel strip module






Sensor cracking driven by increase in stress when loaded **modules on cores go cold**

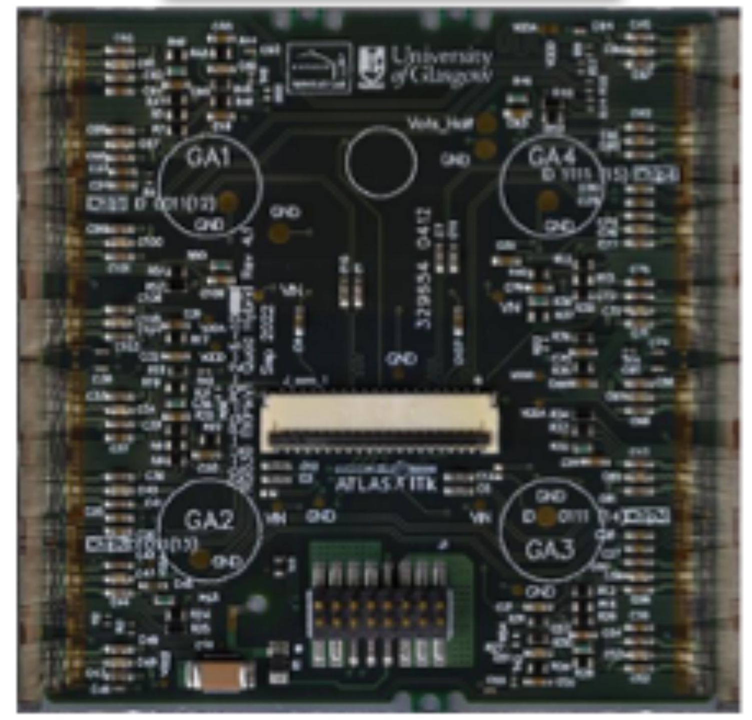


lpGBTs on EOSs inside the cold volume

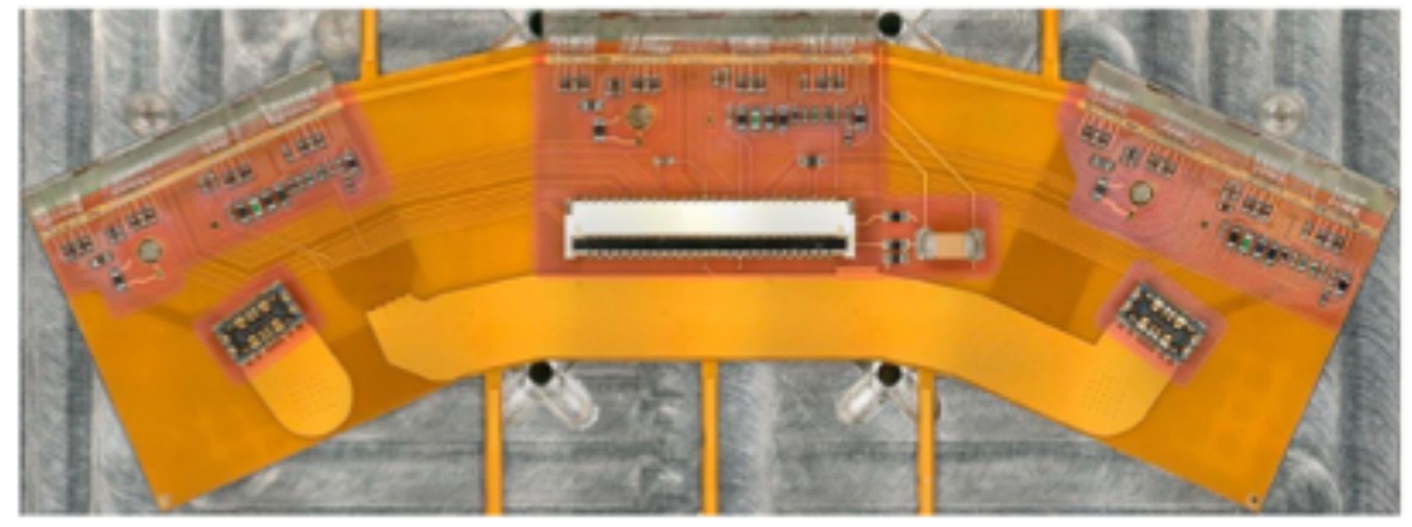

# ITk Pixel

- Many parts in pre-production and production (On-detector local supports, sensors etc.)
- ASIC (ITkPixV2) production well advanced
  - >21k chips probed with excellent yield (~90%)
- Pixel modules production started in one site
  - Other sites expected to start towards end of the month
- Ramp up module hybridization
  - Still need to qualify remaining 2 our of 4 vendors
  - **Essential to reach module production rates**
- Loading of modules onto structures proceeding
  - Outer barrel pre-production layer-3 longeron loaded
  - Inner barrel pre-production layer-0 stave loaded

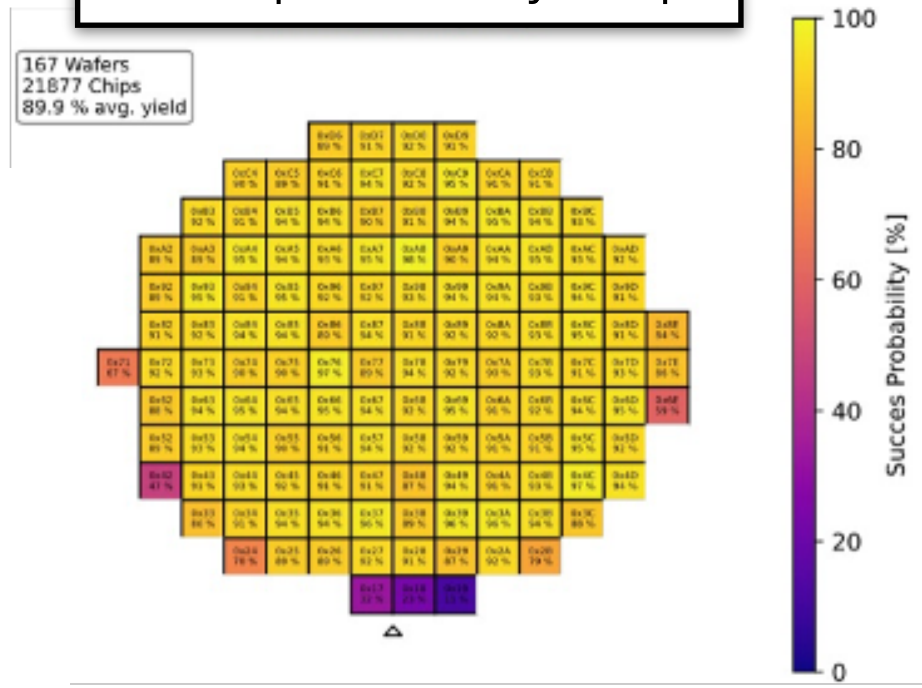
Quad module

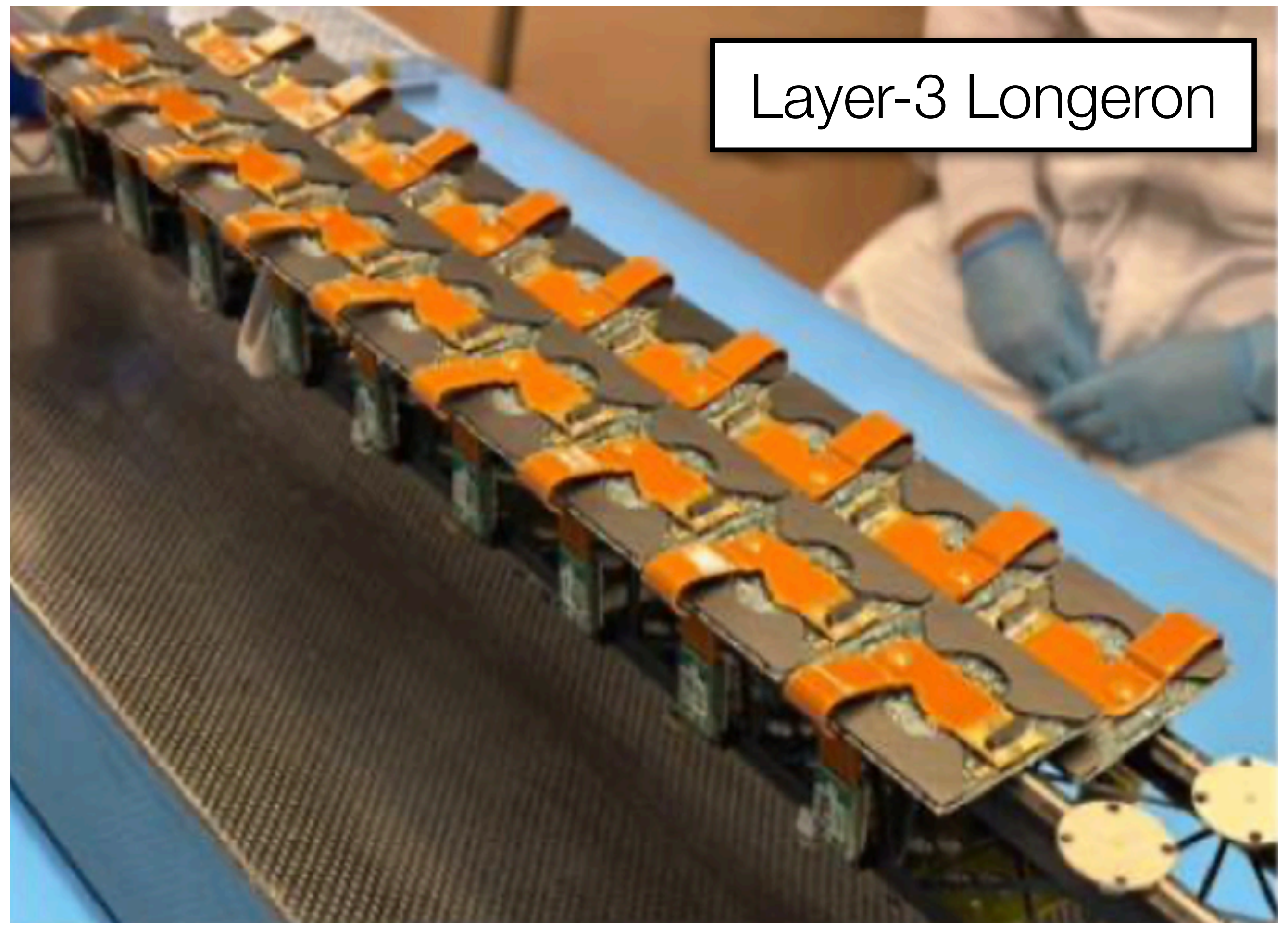


Triplet module (layer 0.5)

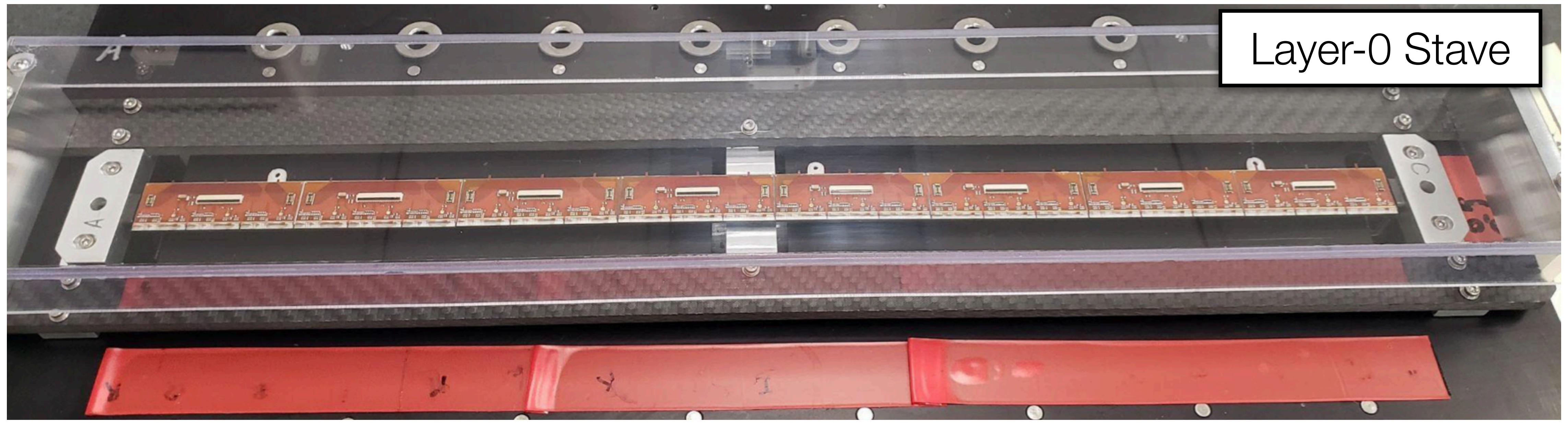


Yield probability map



Layer-3 Longeron



Layer-0 Stave

# Recent Other Phase-II Highlights

**HGTD**
- LGAD sensor production has started, along with large-scale system demonstration with 54 modules
- Need to address limited ASIC probing capability

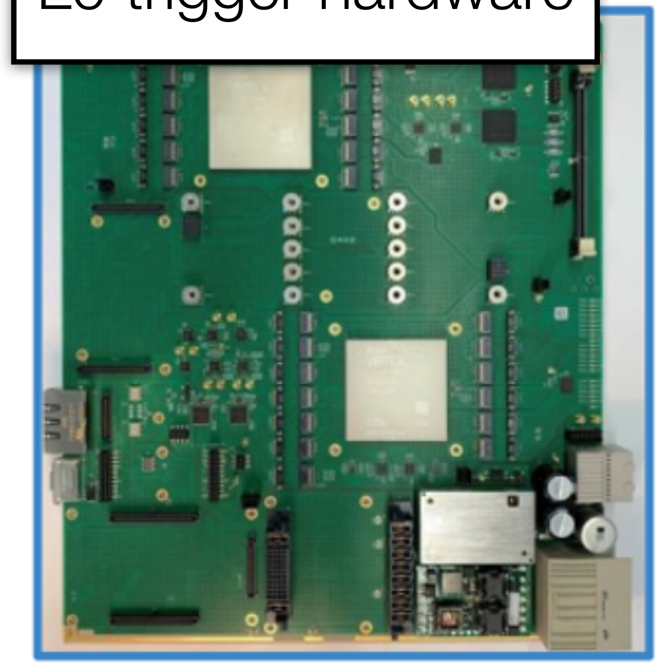
**LAr**
- First integration tests performed for a loaded LAr crate, including successful readout of two front-end boards in parallel
- Need to scale up the system to study the collective effects

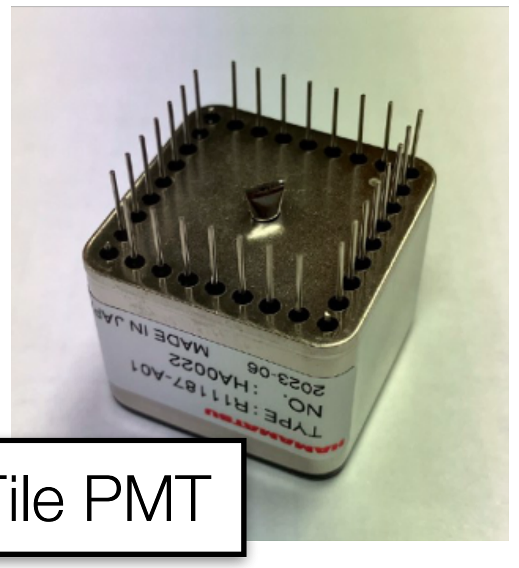
**Tile**
- Good overall progress, comfortable contingency

**Muons**
- sMDT production compete; Restructured RPC production chain to cope with export restrictions to China
- High priority to complete design and test RPC readout chain

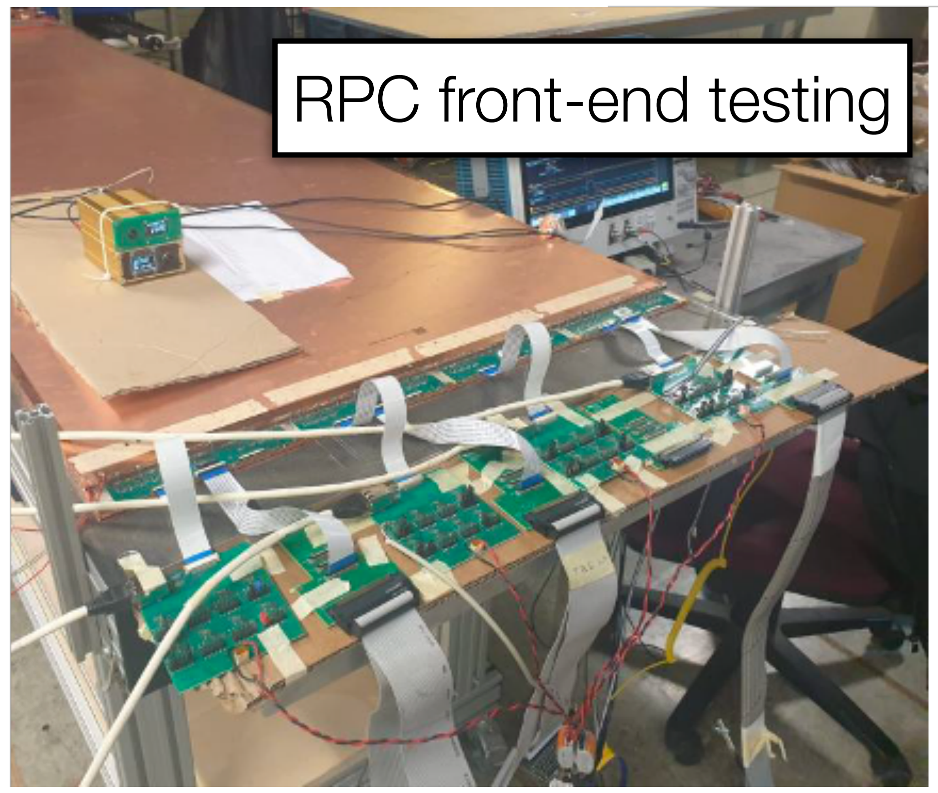
**TDAQ**
- Good progress in many areas including online software, L0 trigger hardware, dataflow, event-filter tacking technology choice, etc.)
- High priority to validate the detector to global trigger data transfer


HGTD demonstrator


L0 trigger hardware


Tile PMT


LAr FEC system


RPC front-end testing

# Conclusions

**Run 3 status**

- Excellent LHC and ATLAS performance in 2024
- Activities ramping up for exciting year of data-taking ahead in 2025 and beyond!

**Sustaining rich physics production**

- Continuing high-pace paper output across a wide range of themes with new and improved results

**Phase-II upgrades for the HL-LHC — *our highest priority!***

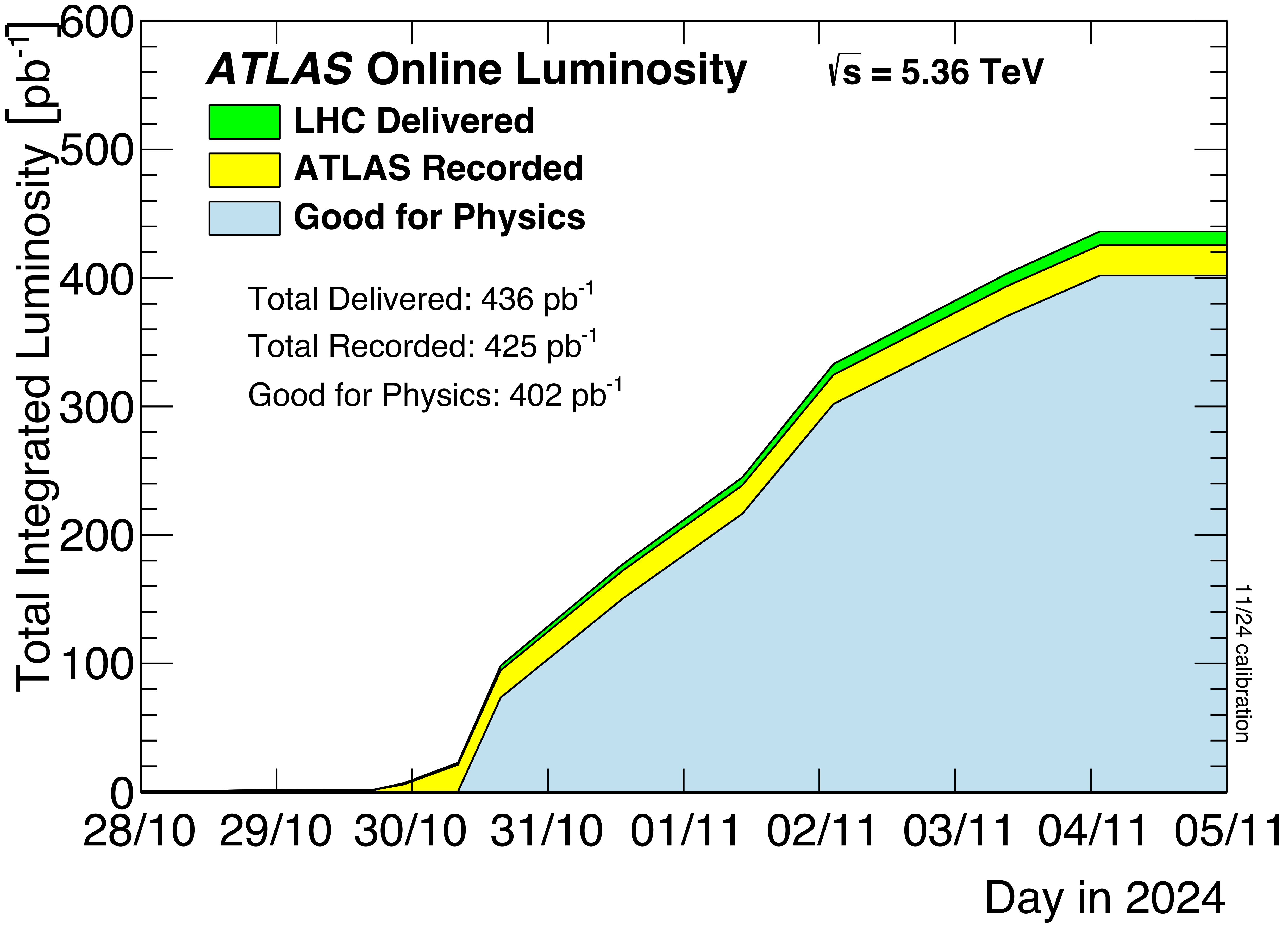
- Series production has started for many components, including ITk modules; remaining technical challenges are being addressed

ATLAS Collaboration Group Photo Dec 2024


3162
SCX1
ATLAS Collaboration Group Photo Dec 2024

# Backups

# 2024 *pp* Reference




**pp reference run:**

- Total delivered integrated luminosity of 436 $pb^{-1}$, recorded 425 $pb^{-1}$, exceeding the desired target of 300 $pb^{-1}$
- Data-taking efficiency of 98.3 %

# Data Quality Efficiencies 2024

ATLAS EXPERIMENT

| ATLAS PbPb Run-3: 2024 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Trigger | Inner Tracker | | | Calorimeters | | Muon Spectrometer | | | | | Magnets | | Global | |
| L1+HLT | Pixel | SCT | TRT | LAr | Tile | MDT | RPC | TGC | MM | sTGC | Solenoid | Toroid | Lumi. calib. | Other |
| 99.7 | 100 | 100 | 100 | 100 | 100 | 100 | 98.3 | 99.9 | 100 | 100 | 100 | 100 | 99.9 | 100 |

**Good for physics: 97.7% (1.63 nb$^{-1}$)**

Luminosity weighted good data quality efficiencies (in %) in 2024 during stable beam operations in HI collision physics runs at $\sqrt{s} = 5.36$ TeV/$NN$, corresponding to an integrated luminosity of 1.63 nb$^{-1}$, for 1.67 nb$^{-1}$ HI data recorded. Technical runs such as luminosity calibration scans totalling 58 $\mu$b$^{-1}$ recorded are not accounted for in the efficiencies.
When the stable beam flag is raised, the tracking detectors initiate a "warm start", which involves ramping up the high-voltage and activating the pre-amplifiers for the Pixel and SCT systems. The inefficiency due to this, as well as the DAQ inefficiency, are not included in the table above, but accounted for in the ATLAS recording efficiency.
The good-for-physics luminosity is 1.63 nb$^{-1}$ for all analyses, except those relying on $b$-jet triggers, where the data quality efficiency is slightly lower (95.7%) due to the brief time needed to measure the online beamspot at the start of a run.

| ATLAS $\sqrt{s} = 5.36$ TeV pp reference Run-3: 2024 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Trigger | Inner Tracker | | | Calorimeters | | Muon Spectrometer | | | | | Magnets | | Global | |
| L1+HLT | Pixel | SCT | TRT | LAr | Tile | MDT | RPC | TGC | MM | sTGC | Solenoid | Toroid | Lumi. calib. | Other |
| 100 | 99.0 | 100 | 100 | 100 | 100 | 100 | 100 | 99.7 | 100 | 100 | 100 | 100 | 99.6 | 99.7 |

**Good for physics: 98.3% (402 pb$^{-1}$)**

Luminosity weighted good data quality efficiencies (in %) in 2024 during stable beam operations in pp collision physics runs at $\sqrt{s} = 5.36$ TeV, corresponding to an integrated luminosity of 402 pb$^{-1}$, for 409 pb$^{-1}$ pp data recorded. Technical runs such as luminosity calibration scans totalling 17 pb$^{-1}$ recorded are not accounted for in the efficiencies.
When the stable beam flag is raised, the tracking detectors initiate a "warm start", which involves ramping up the high-voltage and activating the pre-amplifiers for the Pixel and SCT systems. The inefficiency due to this, as well as the DAQ inefficiency, are not included in the table above, but accounted for in the ATLAS recording efficiency.
The brief time needed to measure the online beamspot at the start of a run leads to a data loss of 1.2 pb$^{-1}$, corresponding to an efficiency loss of 0.3%. This inefficiency is accounted for under "Global".
The good-for-physics luminosity is 402 pb$^{-1}$ for all analyses.