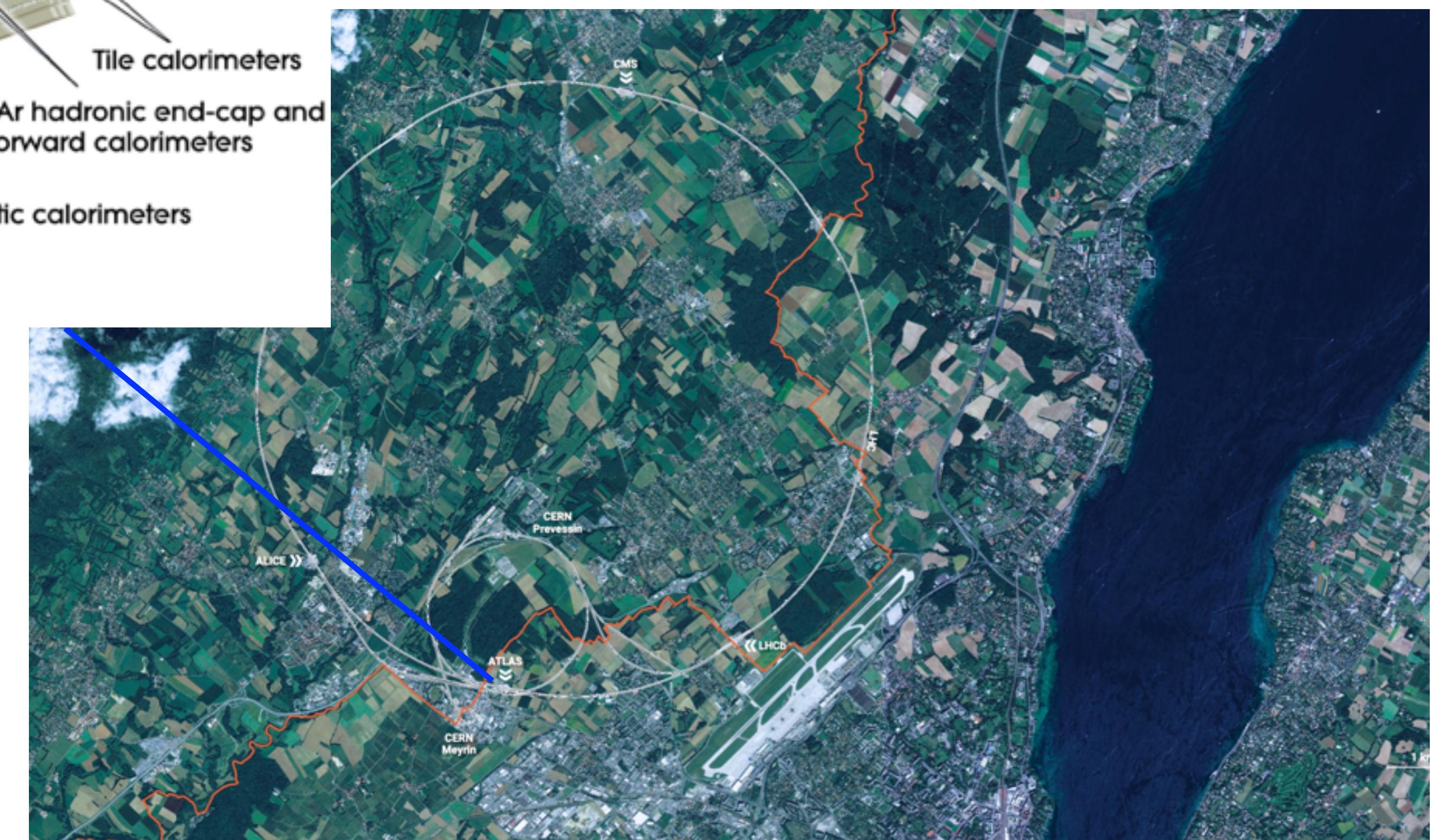
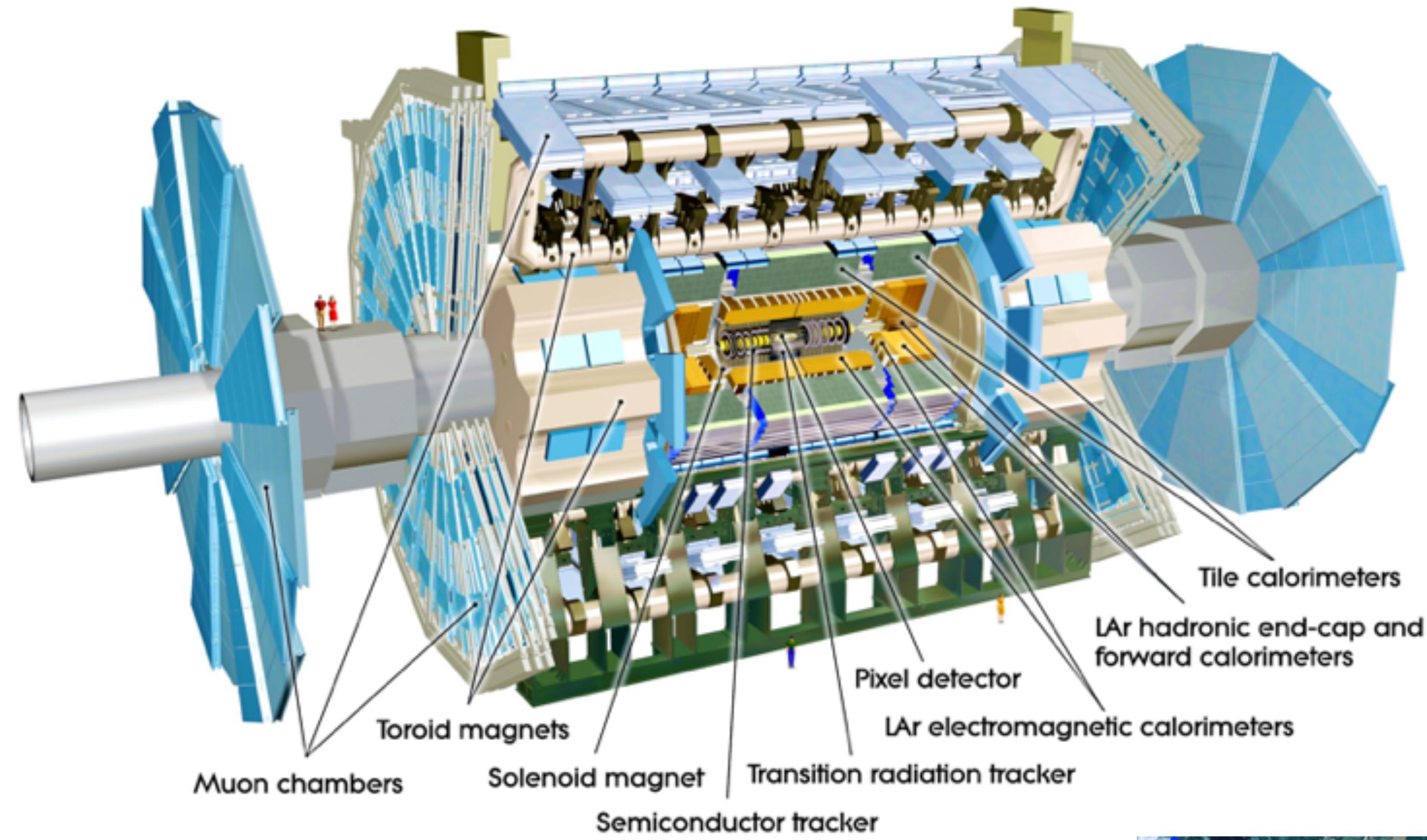


ATLAS Highlights

Guillaume Unal (CERN)
On behalf of the ATLAS Collaboration
ICHEP - Bologna July 11th, 2022

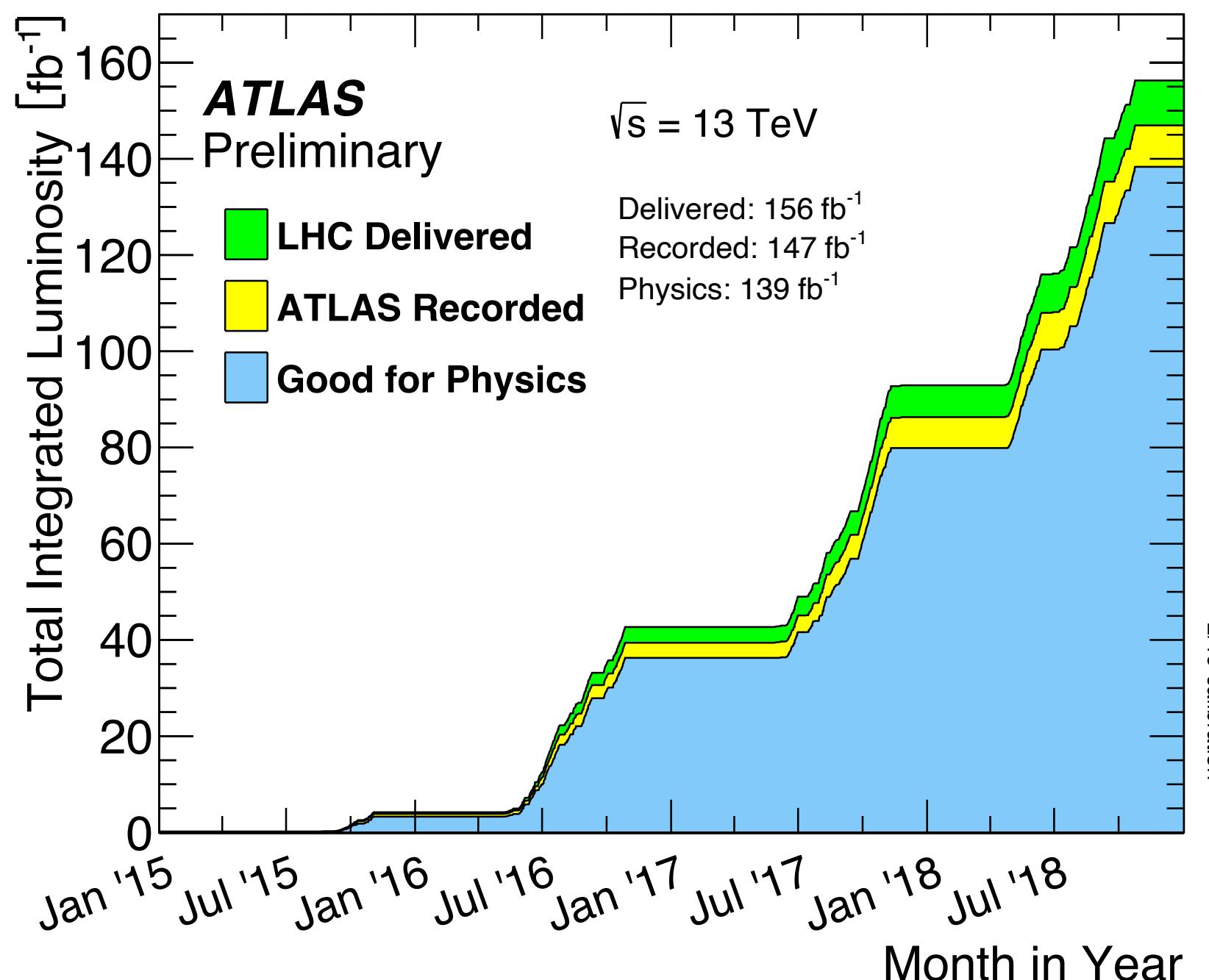




ATLAS experiment at the CERN LHC collider

Vast and rich physics program at the high energy frontier

- Understanding of electroweak symmetry breaking and of the BEH mechanism
- Broad search program at the \sim TeV scale addressing naturalness, dark matter, flavour
 - Also sensitive to feeble interactions
- Precise measurements of SM (EW, top, QCD) processes and heavy flavour properties
 - indirect probes to BSM physics
- Studies of the quark gluon plasma properties



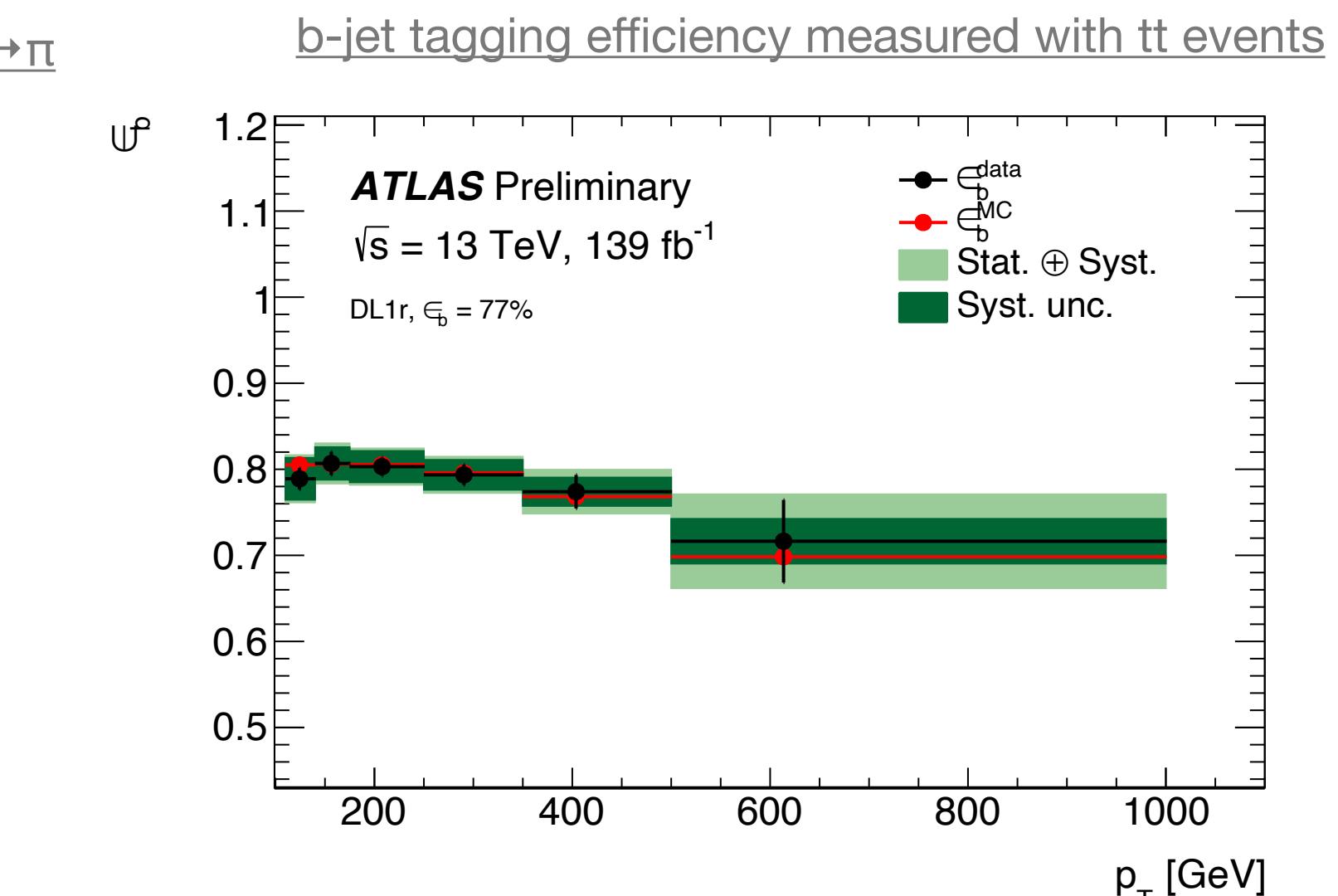
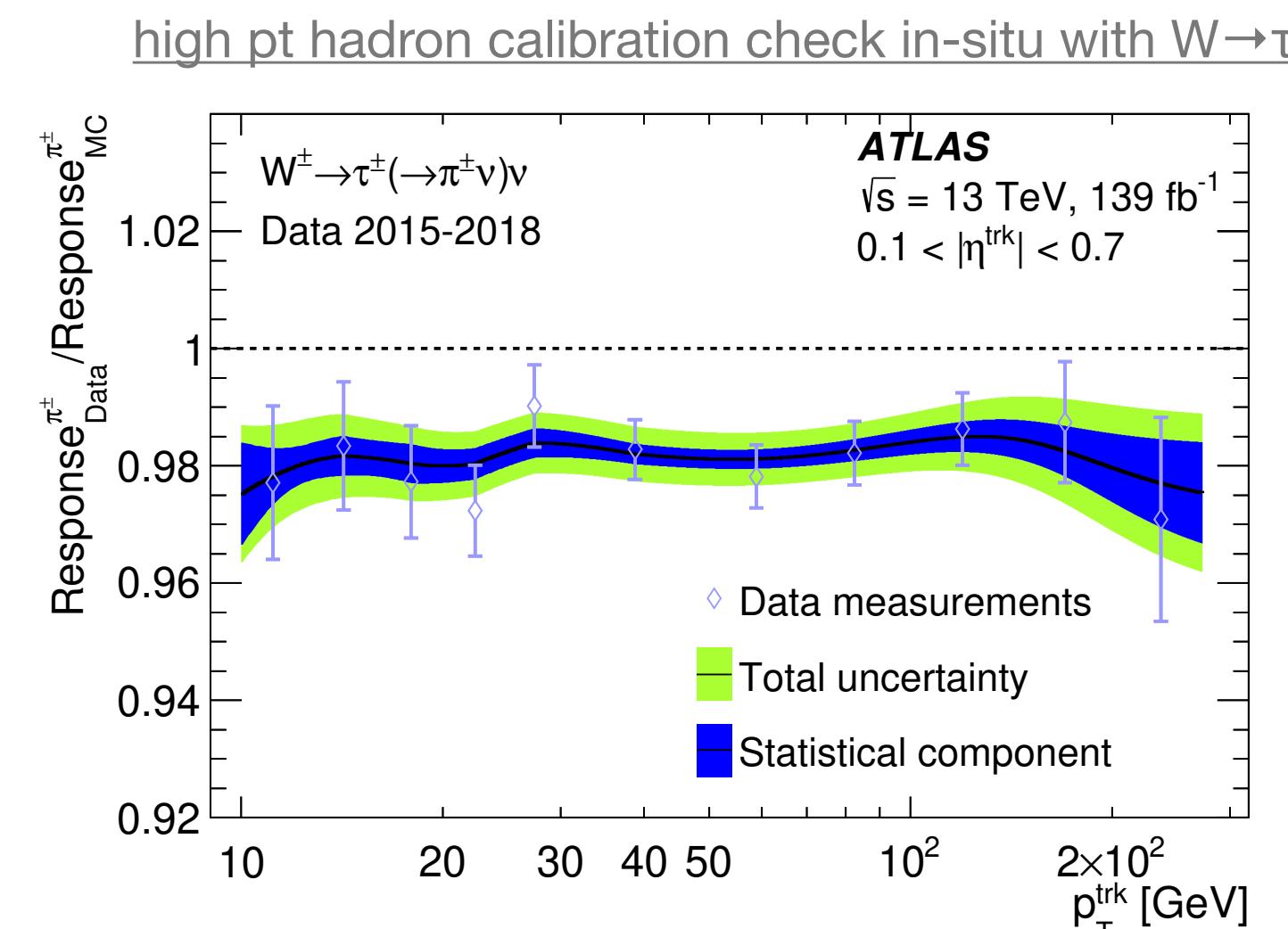
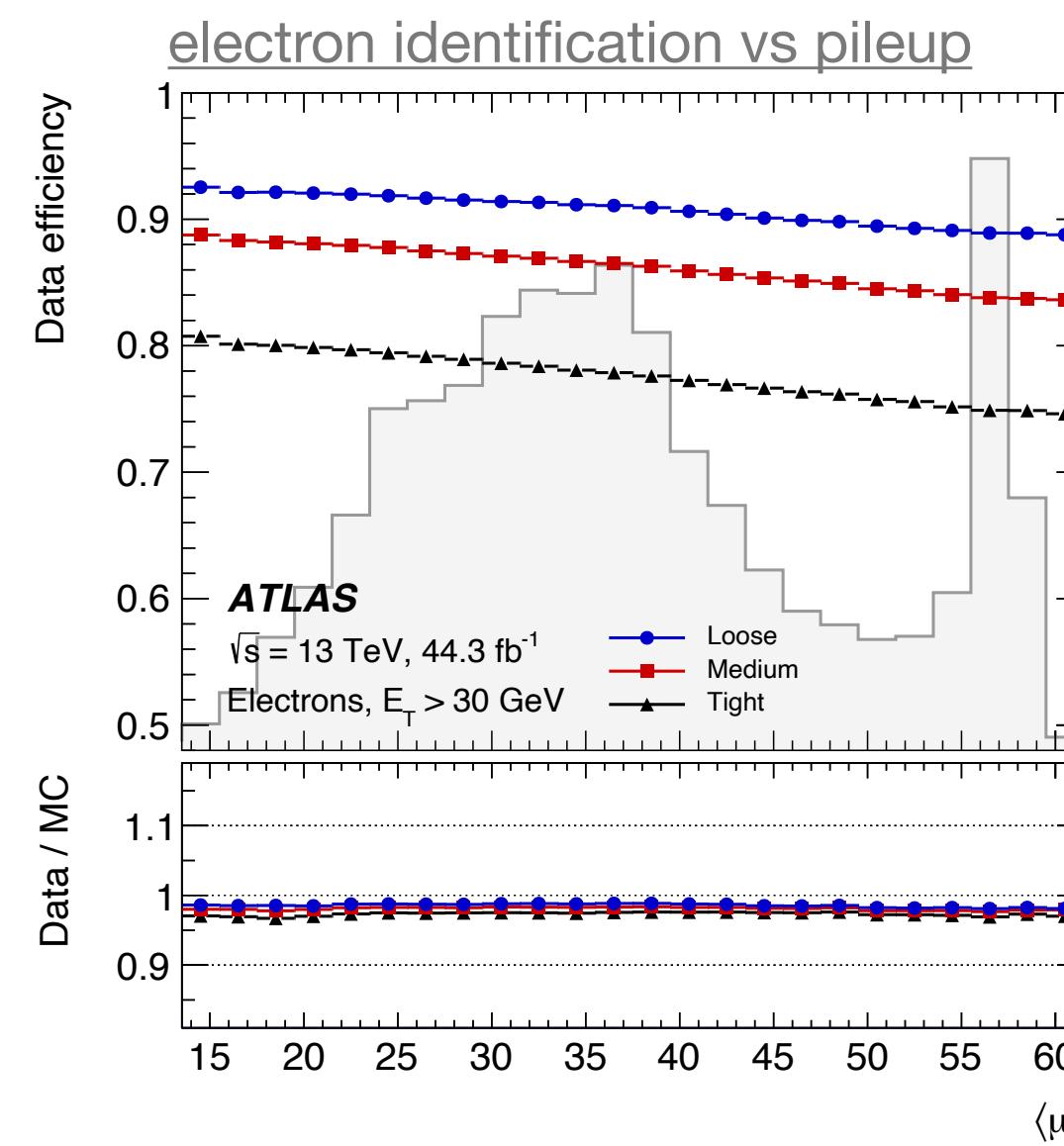
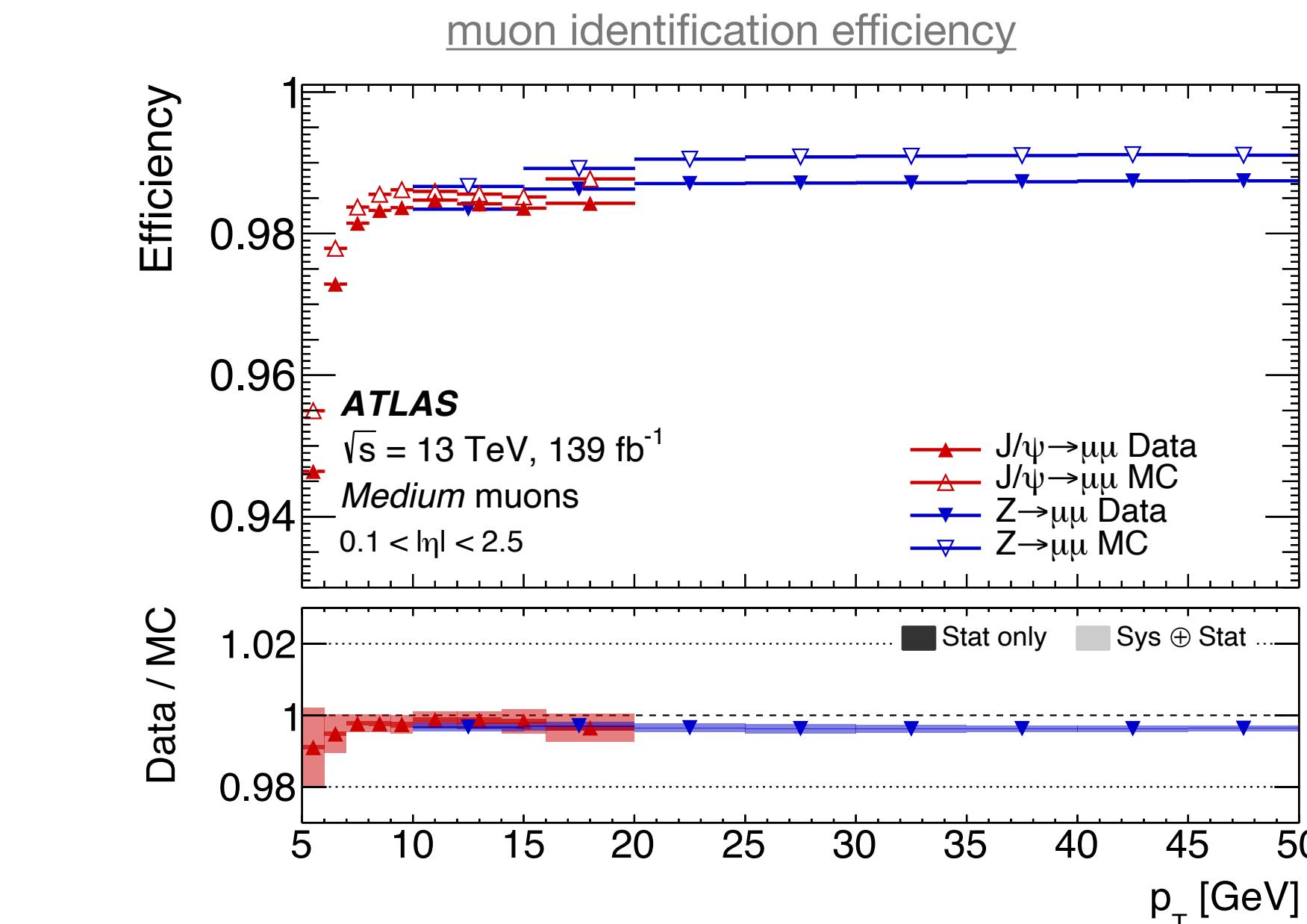
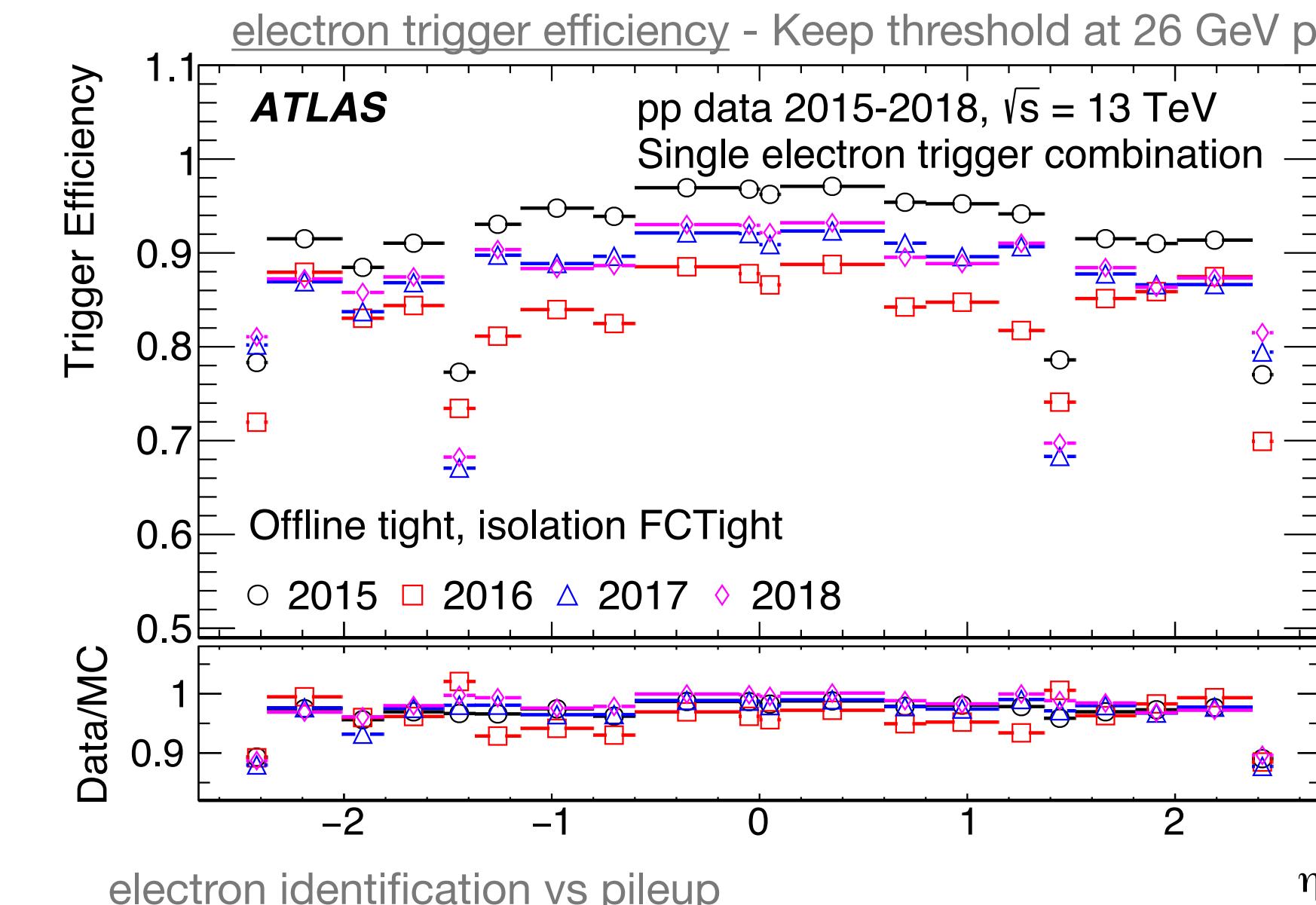
Fantastic dataset recorded in run 2 (2015-2018)
after the run 1 data set (2010-2012)
(incl. PbPb, XeXe and pPb collisions)

1070 papers submitted for publication
220 results with full run 2 p-p collision dataset

Thanks to the LHC

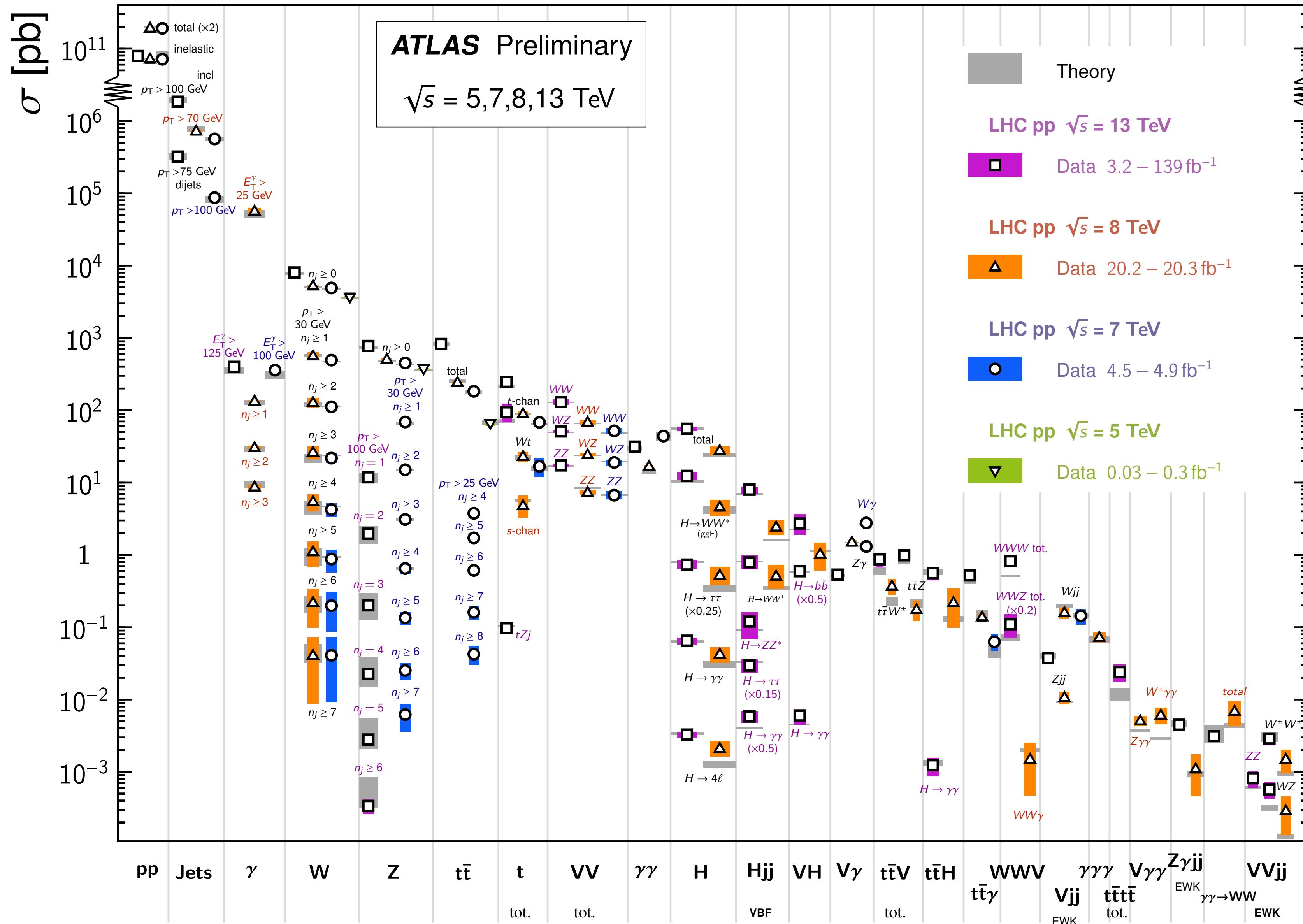
Very well understood detector performance with the full run 2 dataset

with run 2 pileup condition, ~35 pp interactions per bunch crossing
 continuous improvements of identification and calibration of reconstructed objects



Standard Model Production Cross Section Measurements

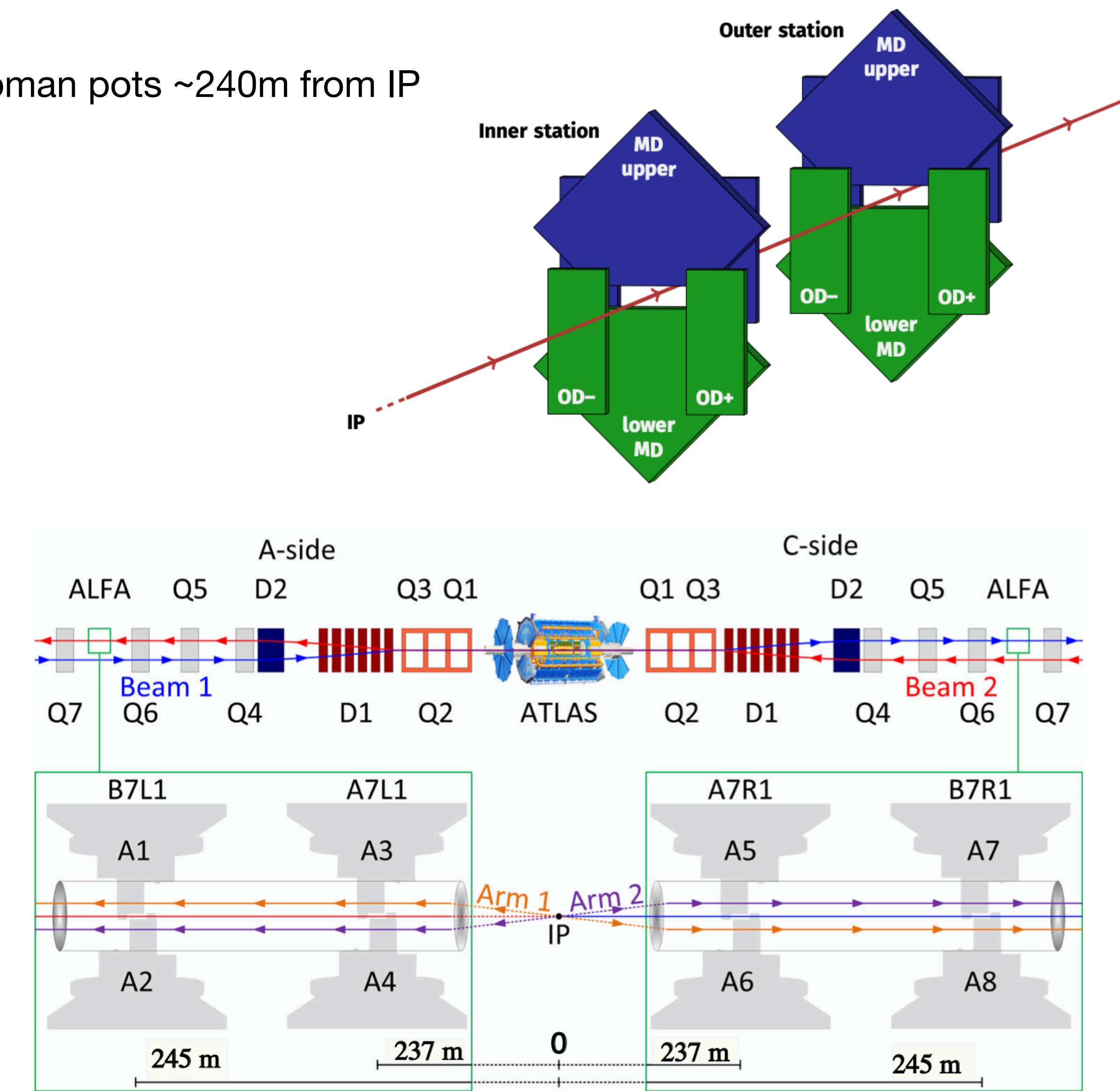
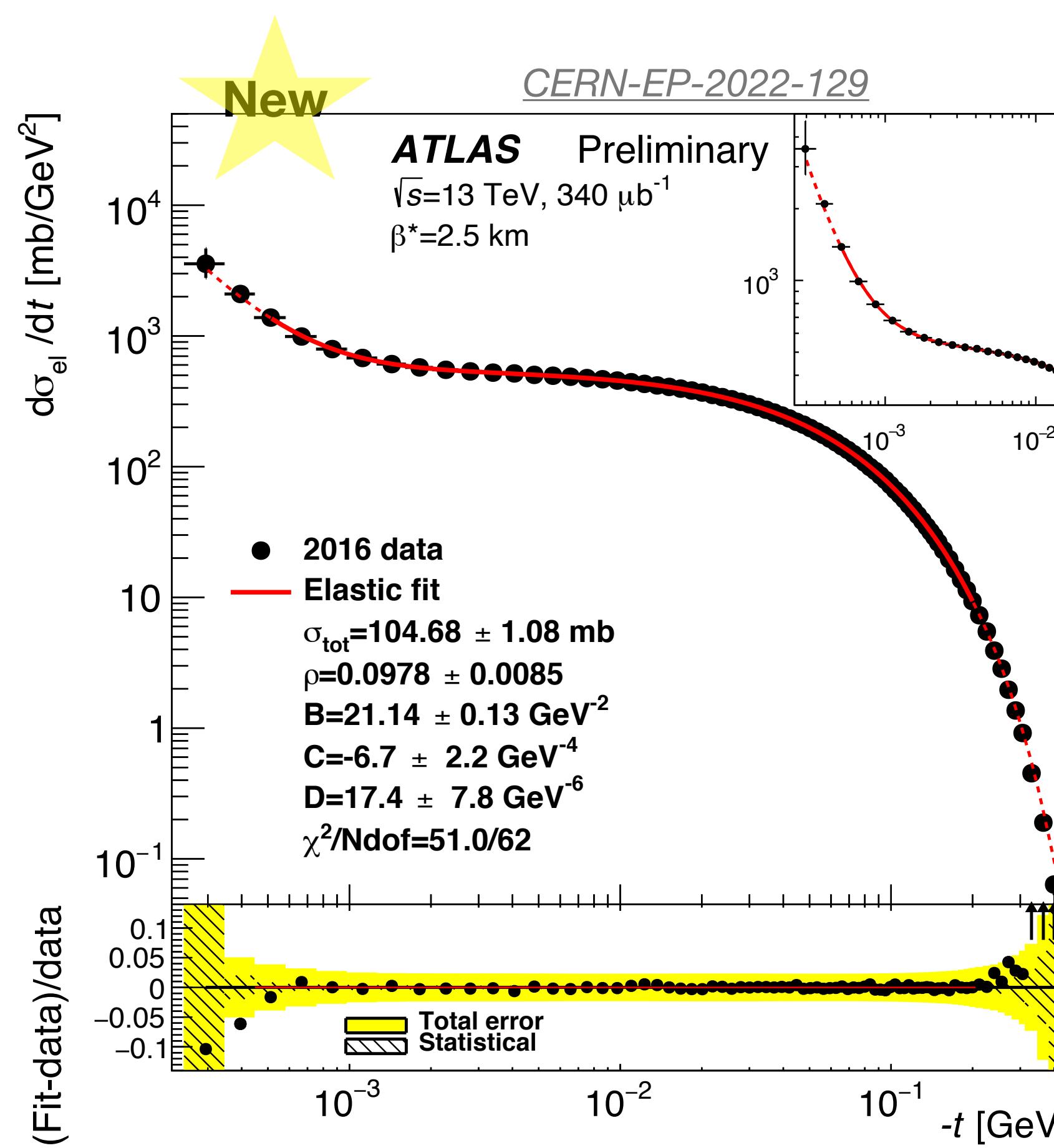
Status: February 2022



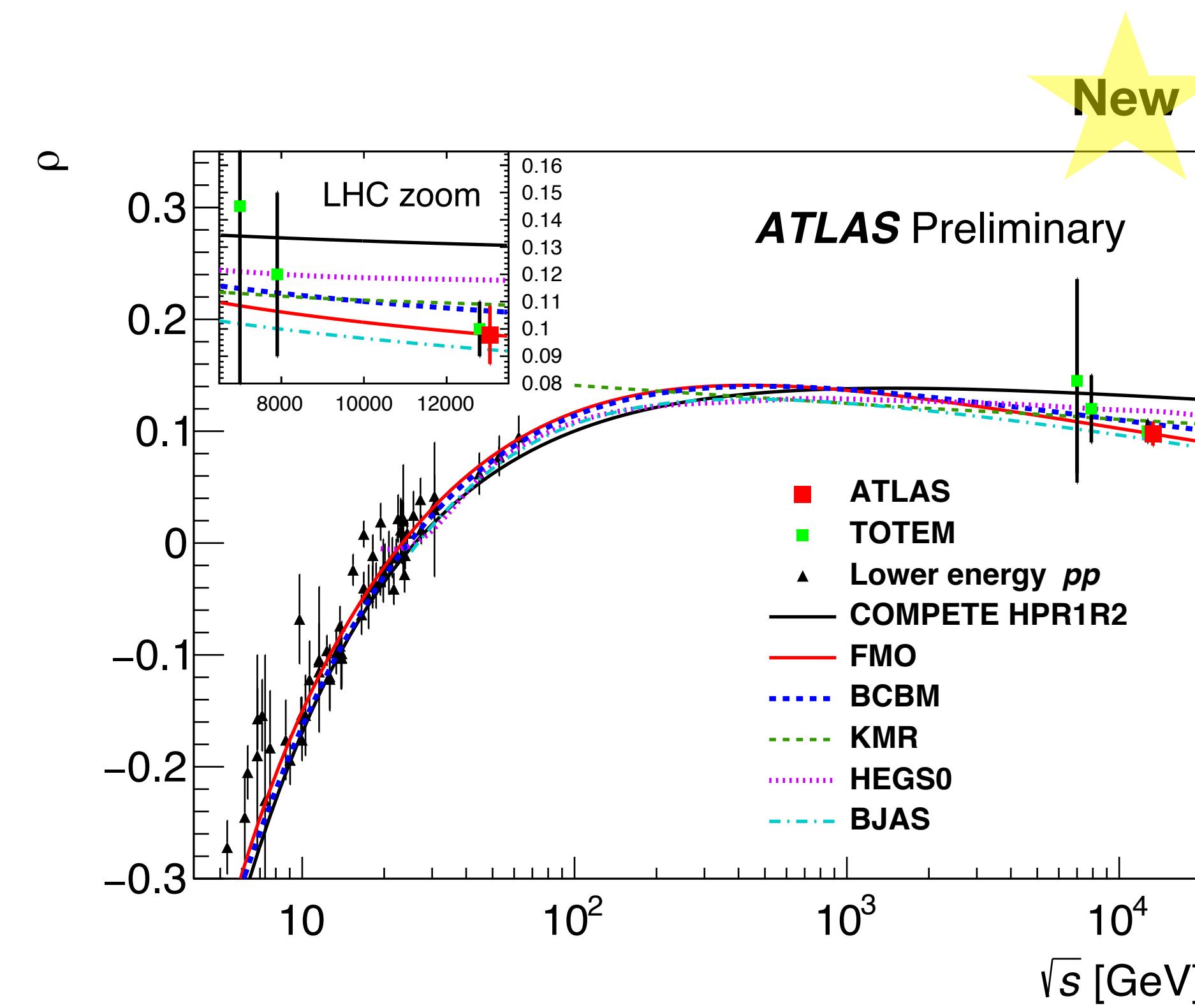
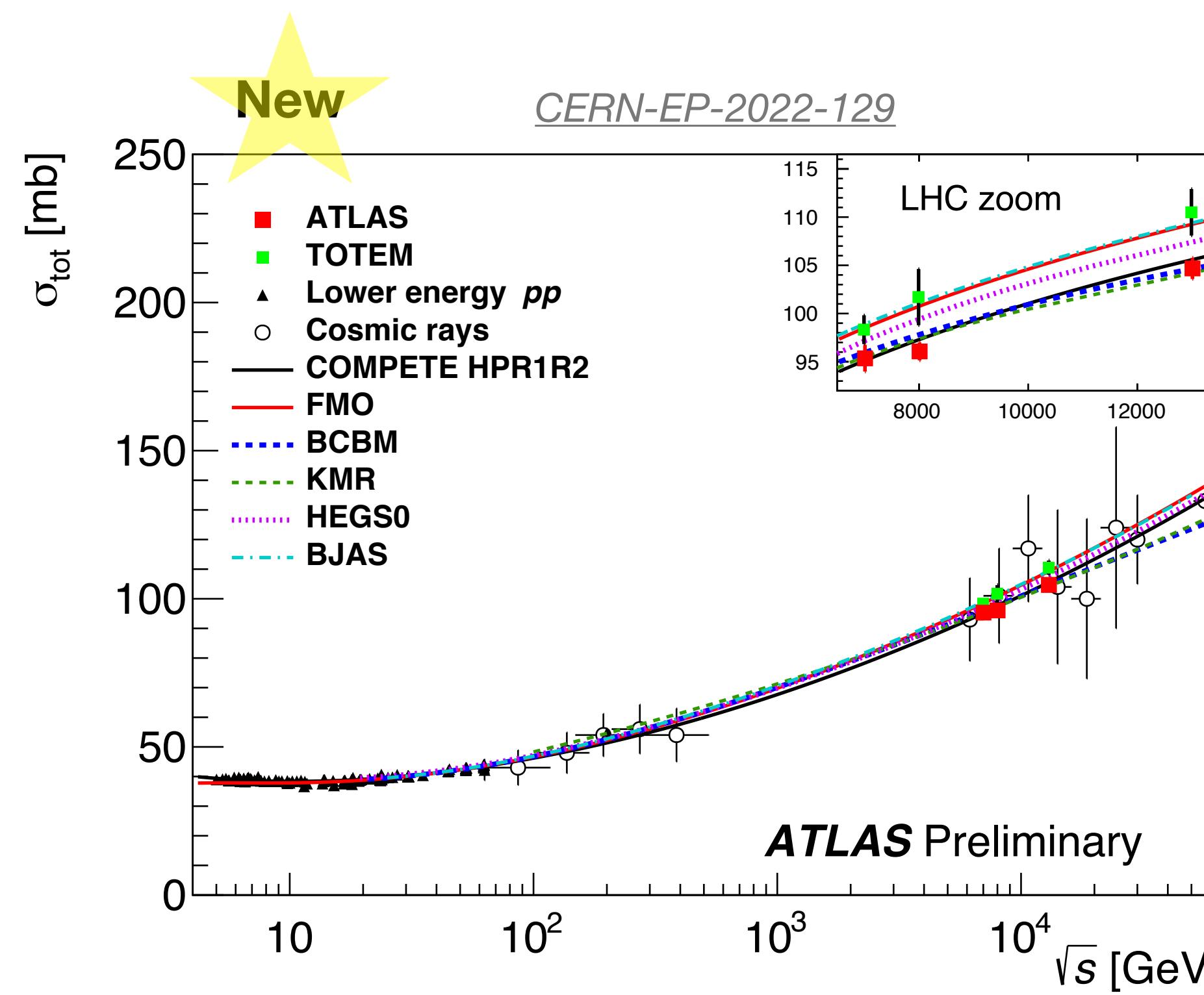
large benefit from recent theory developments and computation

Elastic cross-section measurement

- Differential $d\sigma/dt$ $pp \rightarrow pp$ elastic cross-section
 - Measure scattered protons with detectors located in roman pots $\sim 240m$ from IP
 - Special data taking with large β^* optics (2.5km)
 - Luminosity calibration from Van Der Meer scans



- From precise $d\sigma/dt$ measurement can extract
 - ρ (Real/Imaginary part of elastic amplitude for $t>0$) **0.0975 ± 0.0106**
 - Total cross-section (from optical theorem) **$104.68 \pm 1.08 \text{ mb}$**
- common models don't accommodate well both measurements at the same time

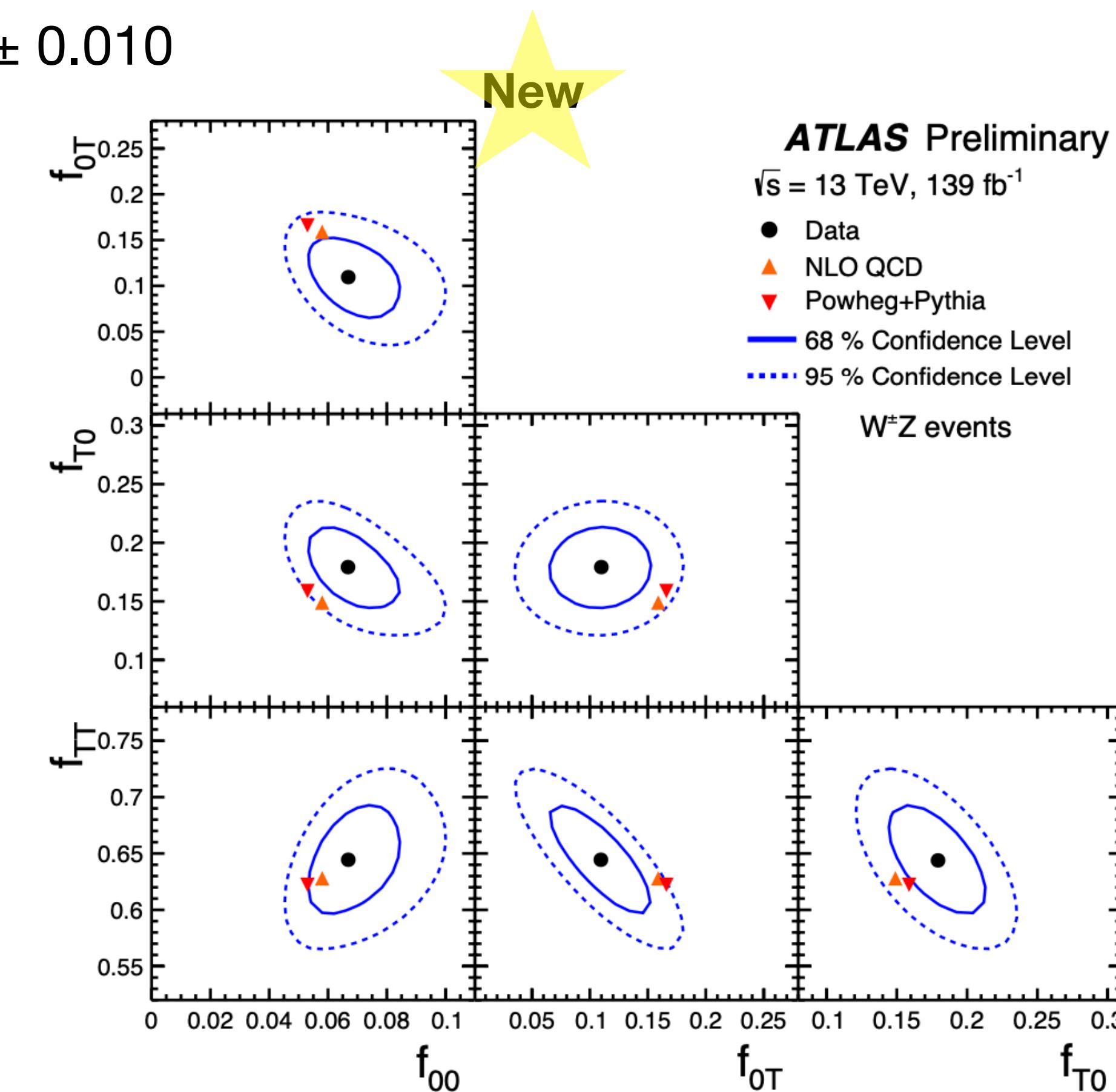
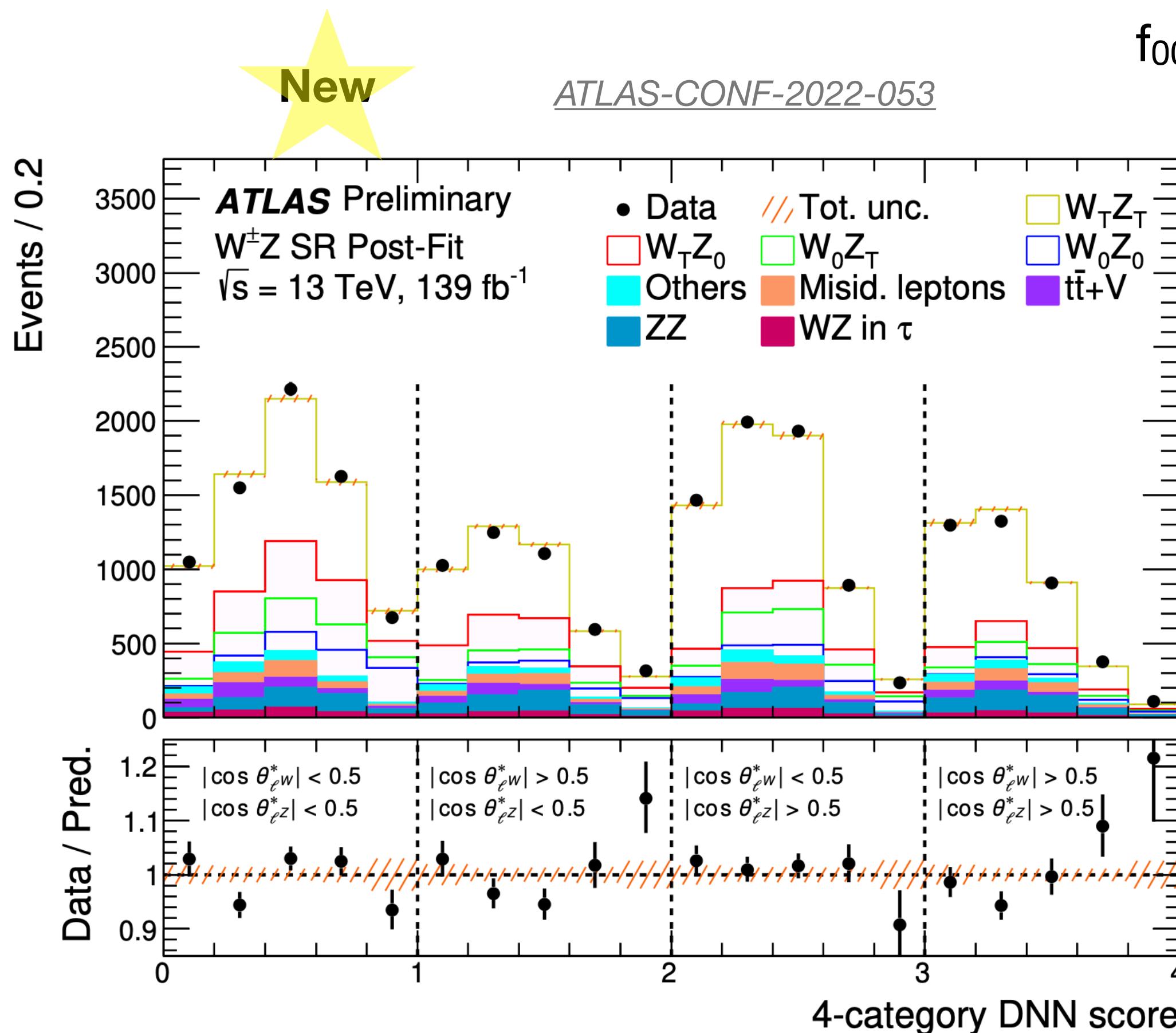
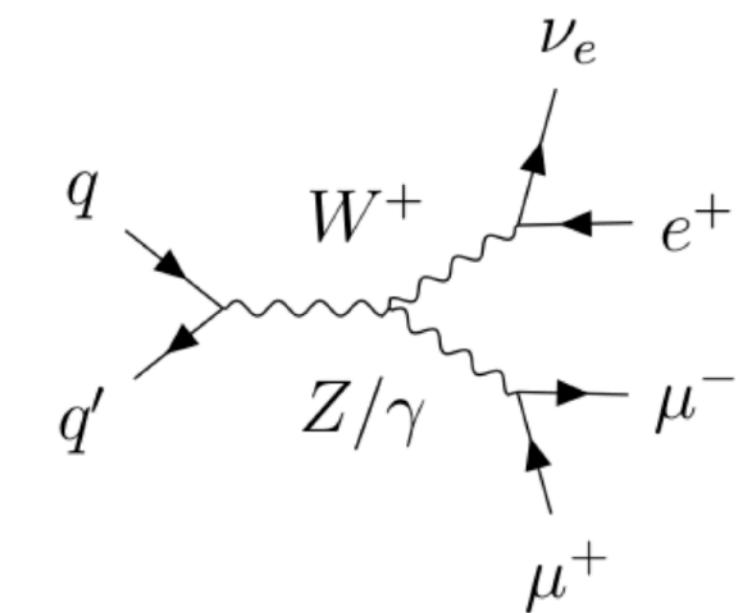


Precise studies of rare SM processes: polarization in WZ production

Study W and Z polarisation in WZ events reconstructed in 3l+v decay mode

Joint measurement of W and Z polarisation fraction, using deep neural network

First observation of simultaneous production of longitudinally polarised W and Z bosons with 7.1σ



Observation of di-charmonium excess in the 4μ final state

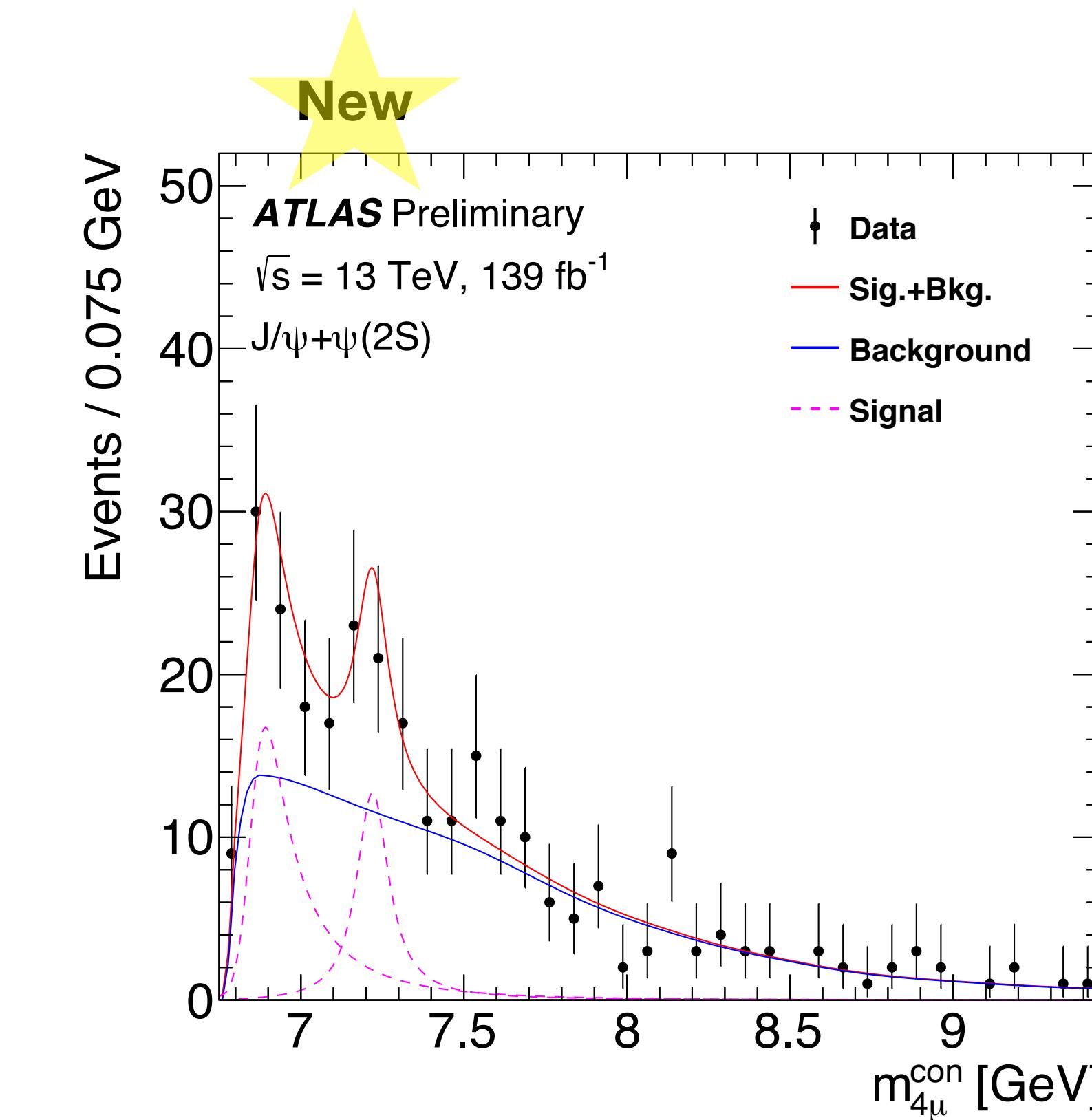
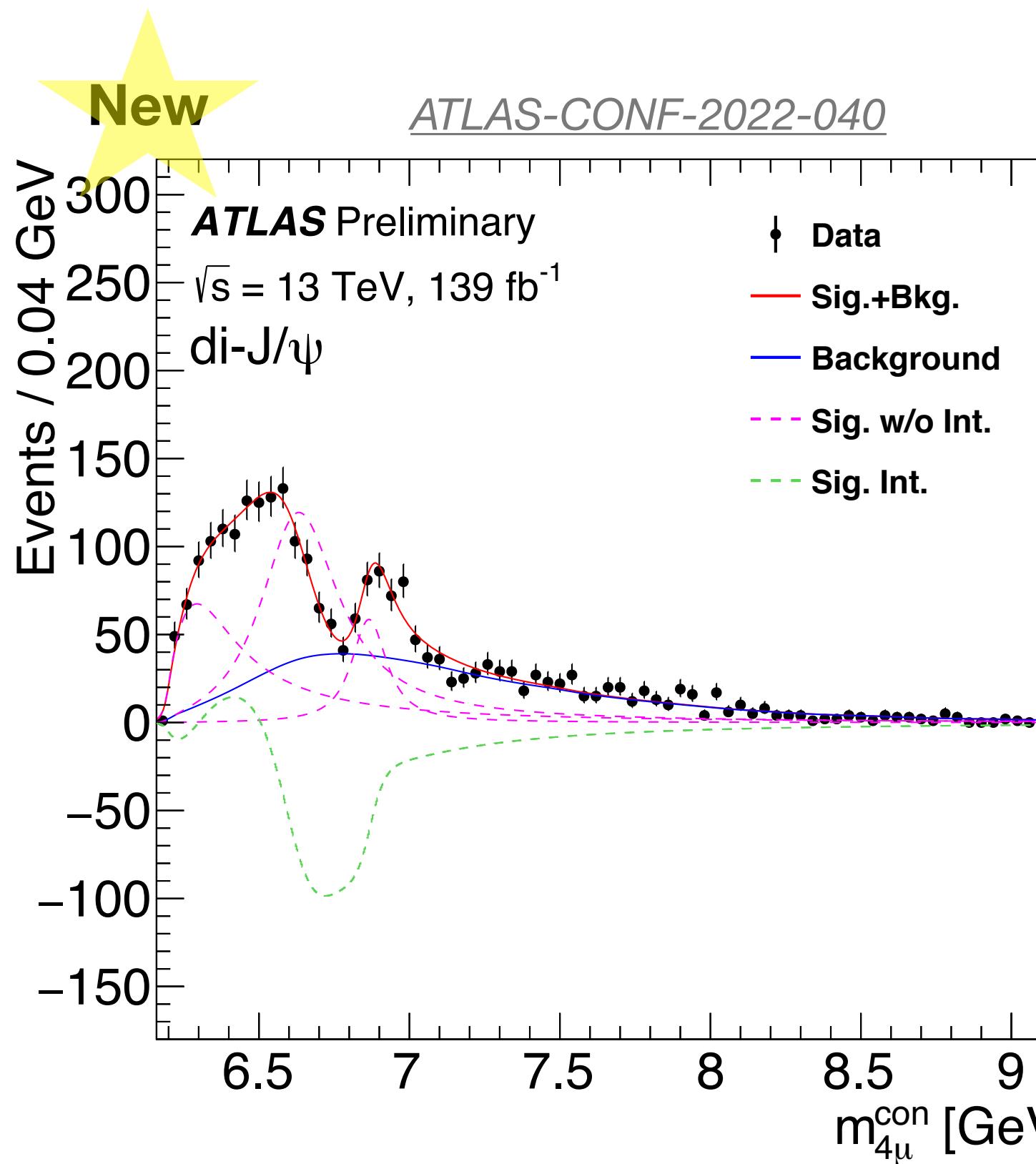
Motivated by Tetraquark

$$T_{cc\bar{c}\bar{c}} \rightarrow J/\psi \ J/\psi \rightarrow 4\mu$$

$$T_{cc\bar{c}\bar{c}} \rightarrow J/\psi \ \psi(2S) \rightarrow 4\mu$$

Background from single parton and double parton scattering

See large structures near threshold as well as narrow resonance at 6.9 GeV, confirming [LHCb observation](#)



Top quark measurements

Top pair production cross-section @ 5 TeV

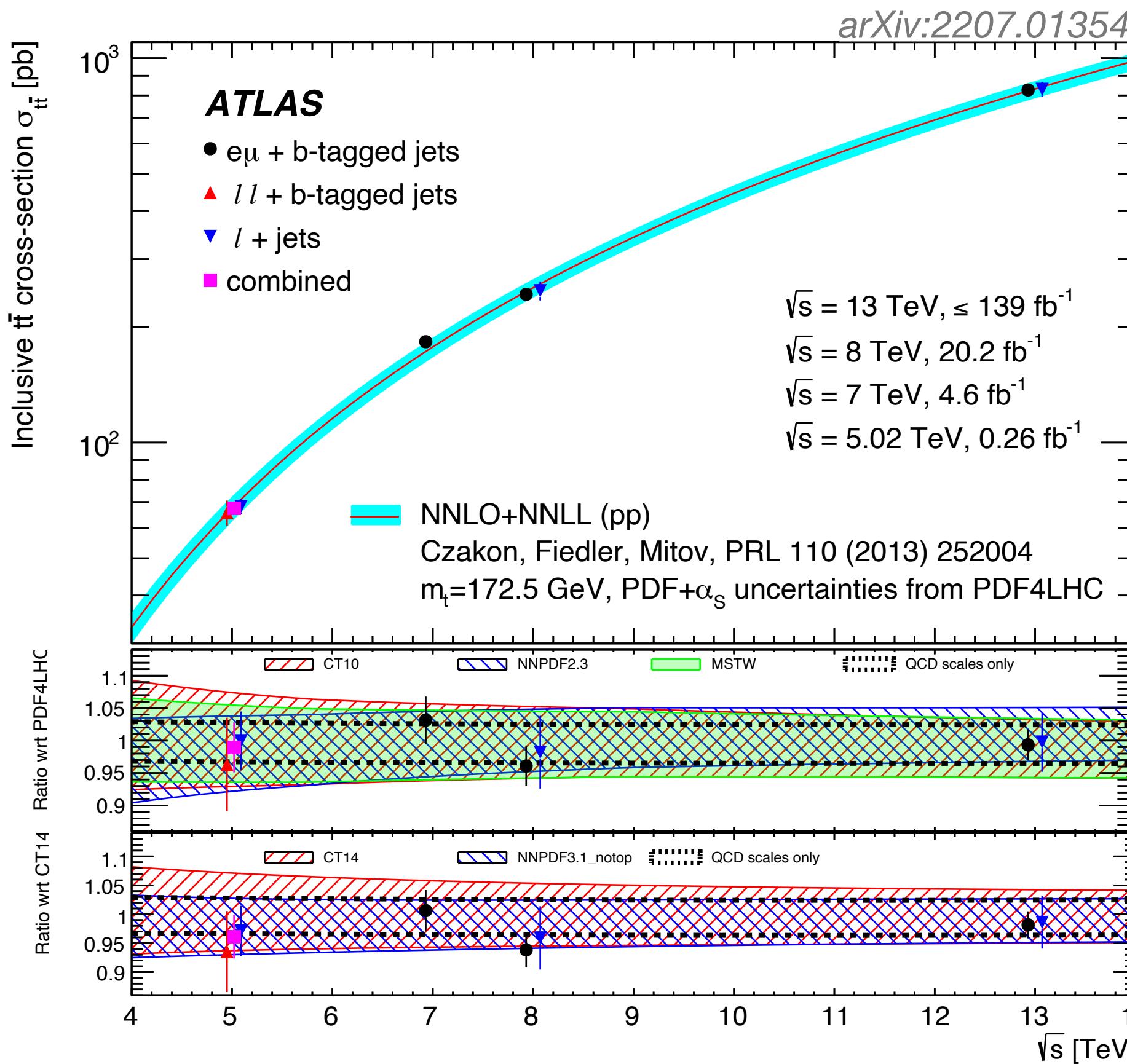
260 pb⁻¹ dataset recorded in run 2

Dilepton and lepton+jets final states

$$\sigma(t\bar{t}) = 67.5 \pm 0.9 \text{ (stat)} \pm 2.3 \text{ (syst)} \pm 1.1 \text{ (lumi)} \pm 0.2 \text{ (beam)} \text{ pb}$$

4% accuracy

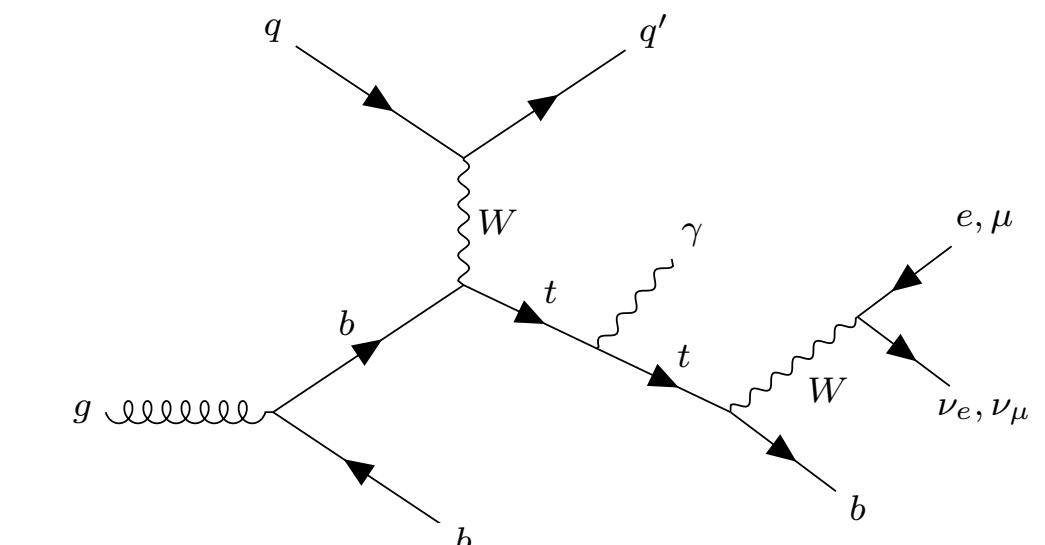
(prediction $68.2 \pm 4.8^{+1.9}_{-2.3}$ pb)



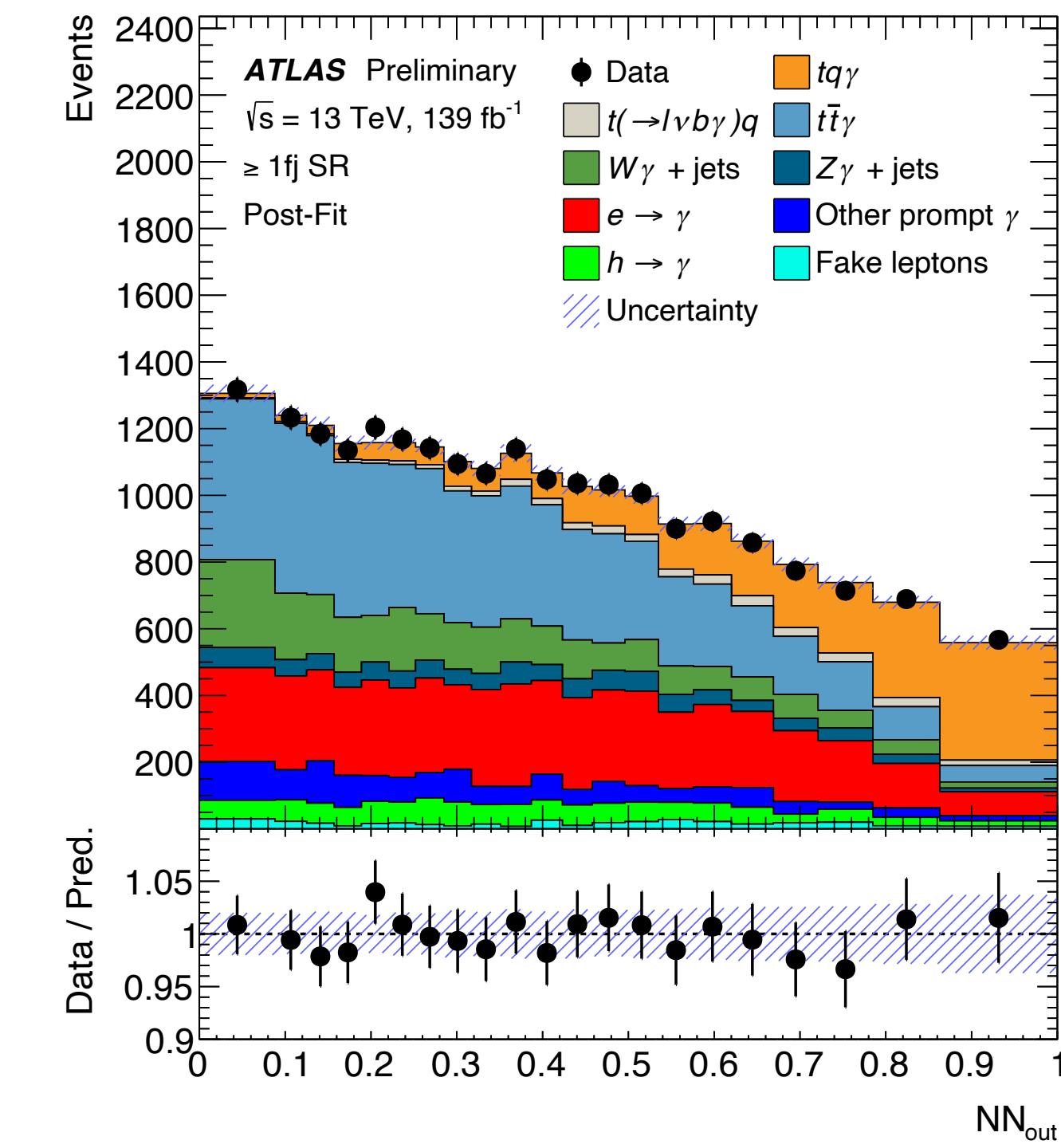
Single top + photon observation

$$\sigma_{\text{fid}} = 580 \pm 19 \pm 63 \text{ fb}$$

prediction: $406^{+25}_{-32} \text{ fb}$

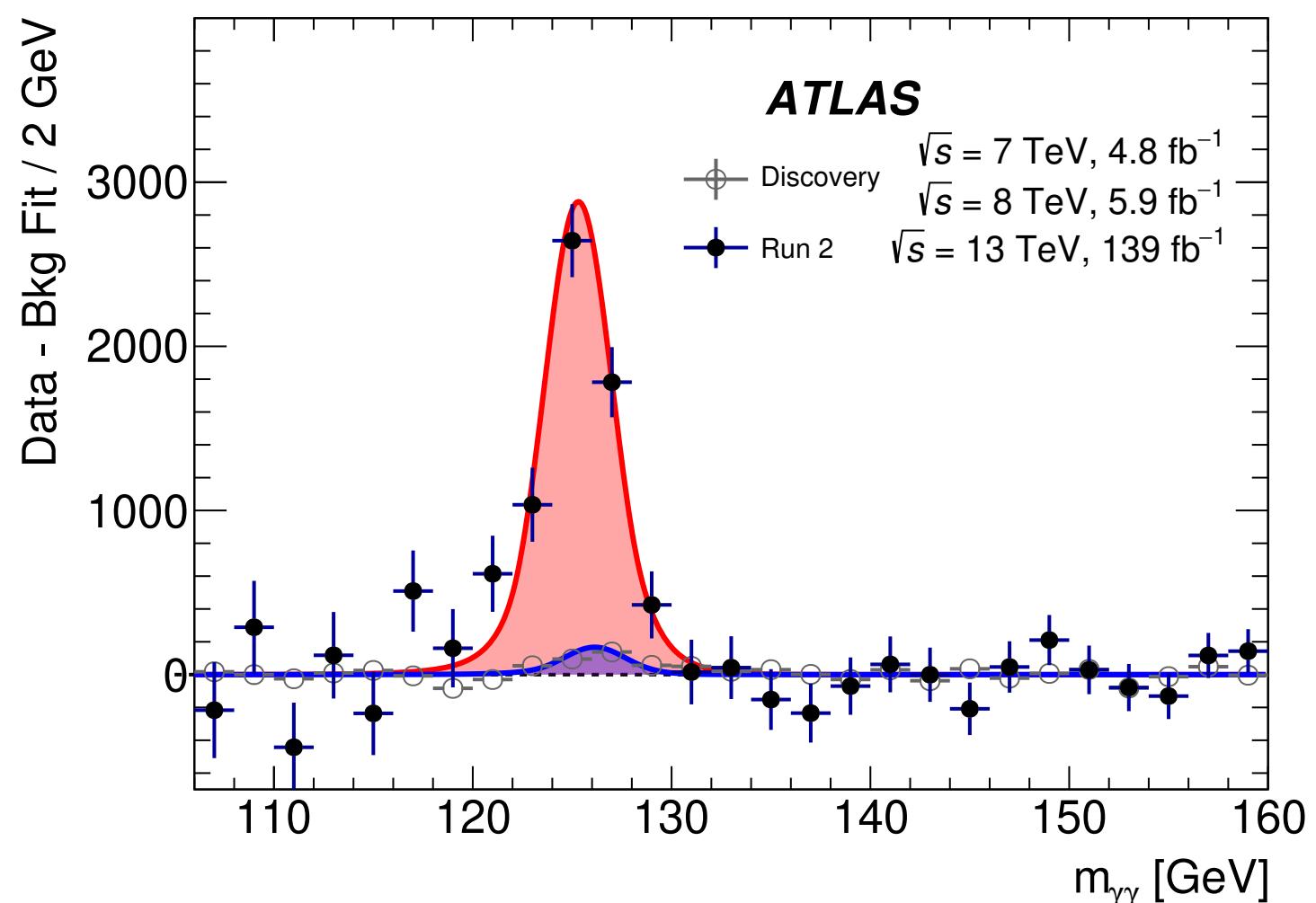
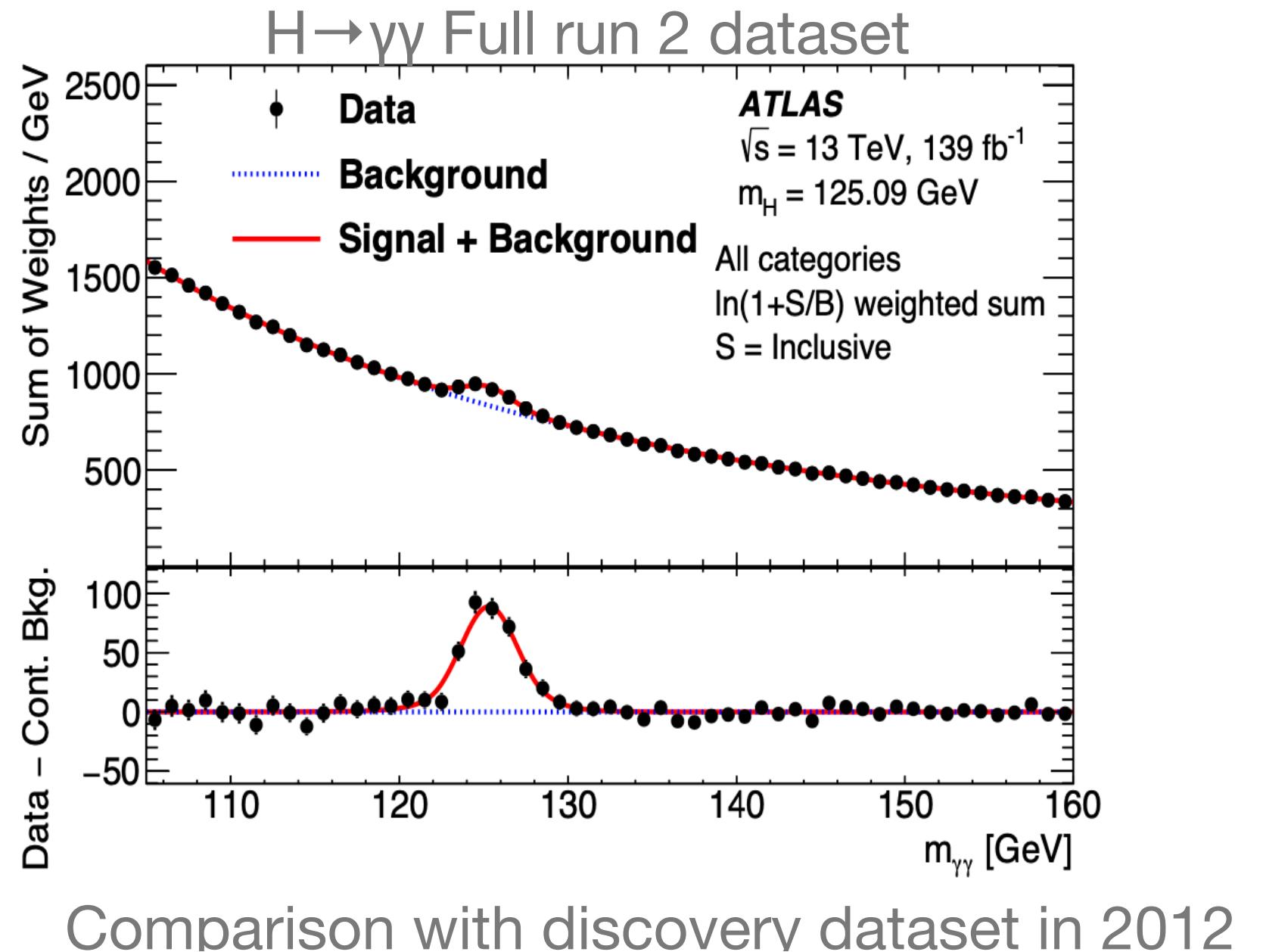


ATLAS-CONF-2022-013



- + evidence of single top s-channel production at 13 TeV
- + charge asymmetry in $t\bar{t} + \text{photon}$ events
- + several searches probing all possible top FCNC couplings

Higgs boson measurements

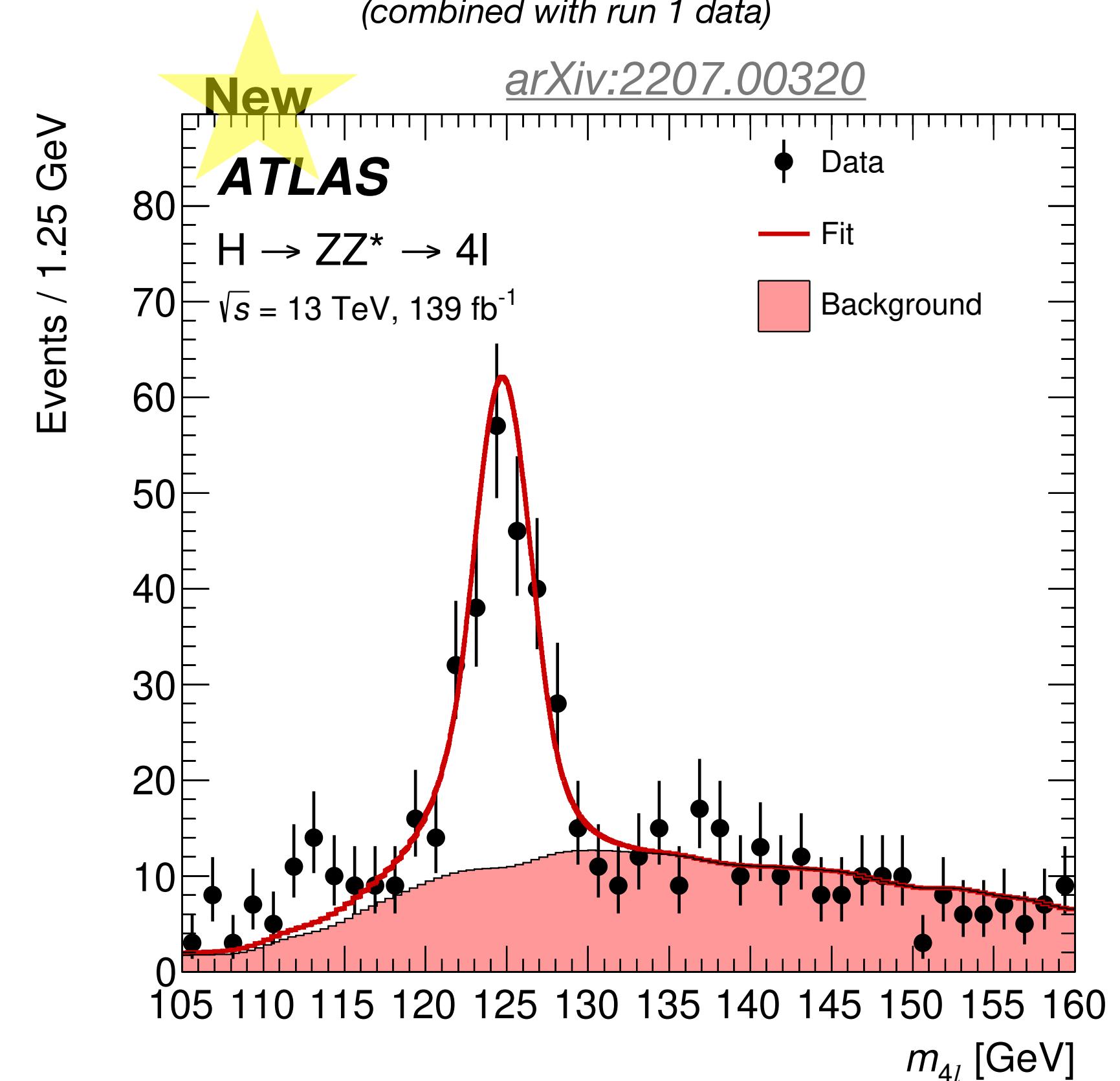


Precise mass measurement using H \rightarrow 4l

Event-by-event resolution, DNN for S/B separation,
precise muon and electron momentum calibration

$$m_H = 124.94 \pm 0.17(\text{stat.}) \pm 0.03(\text{syst.}) \text{ GeV}$$

(combined with run 1 data)

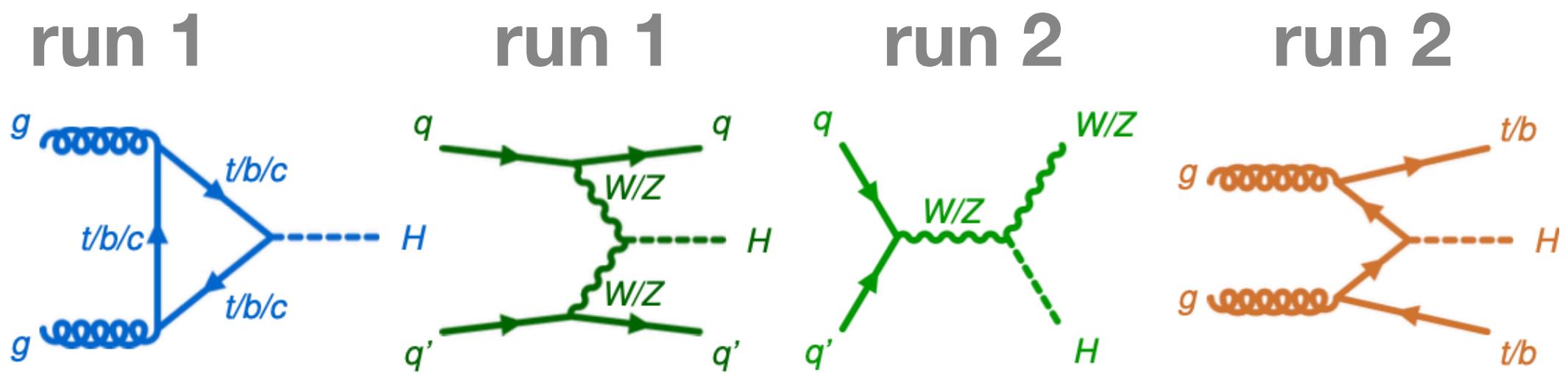


Higgs boson coupling measurements

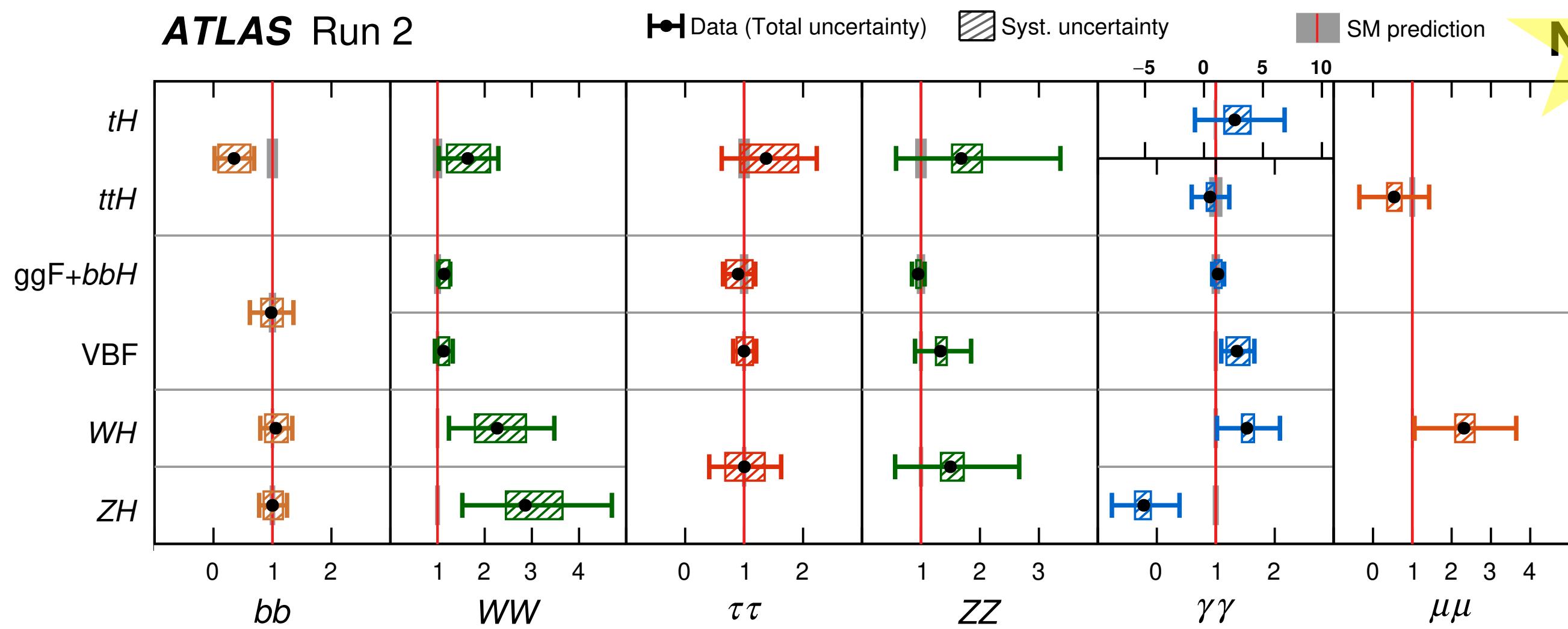
Total cross-section / Standard Model prediction

$$\mu = 1.05 \pm 0.06 = 1.05 \pm 0.03 \text{ (stat.)} \pm 0.03 \text{ (exp.)} \pm 0.04 \text{ (sig. th.)} \pm 0.02 \text{ (bkg. th.)}.$$

(benefits also from reduced theory uncertainty)



Measurements per production mode * decay channel:

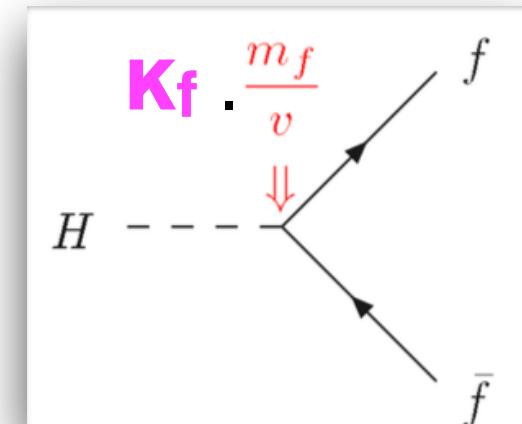
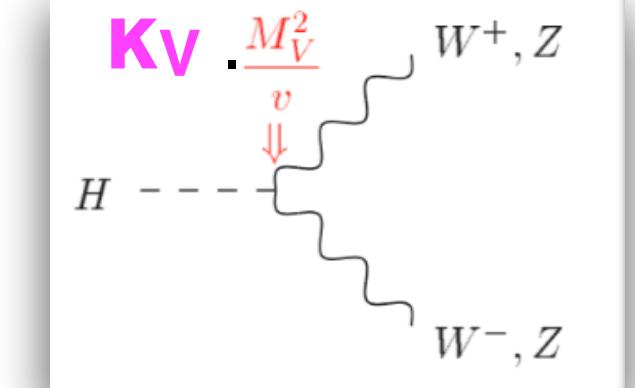


Nature 607 (2022) 52

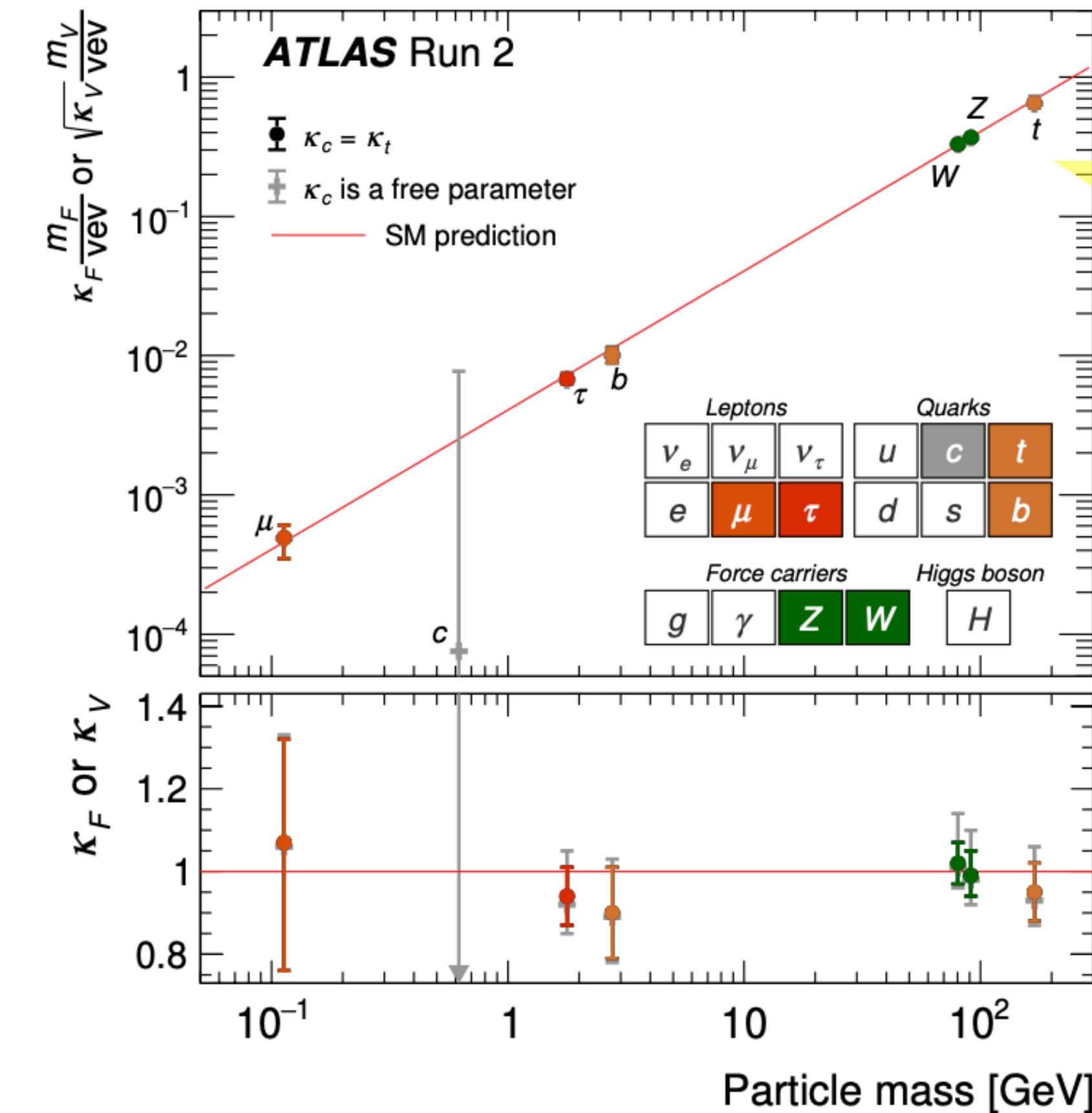
$\sigma \times B$ normalized to SM prediction

12

Coupling modifier interpretation



$$\sigma(i \rightarrow H \rightarrow f) = \sigma_i B_f = \frac{\sigma_i(\kappa) \Gamma_f(\kappa)}{\Gamma_H(\kappa, B_{\text{inv.}}, B_{\text{u.}})}$$

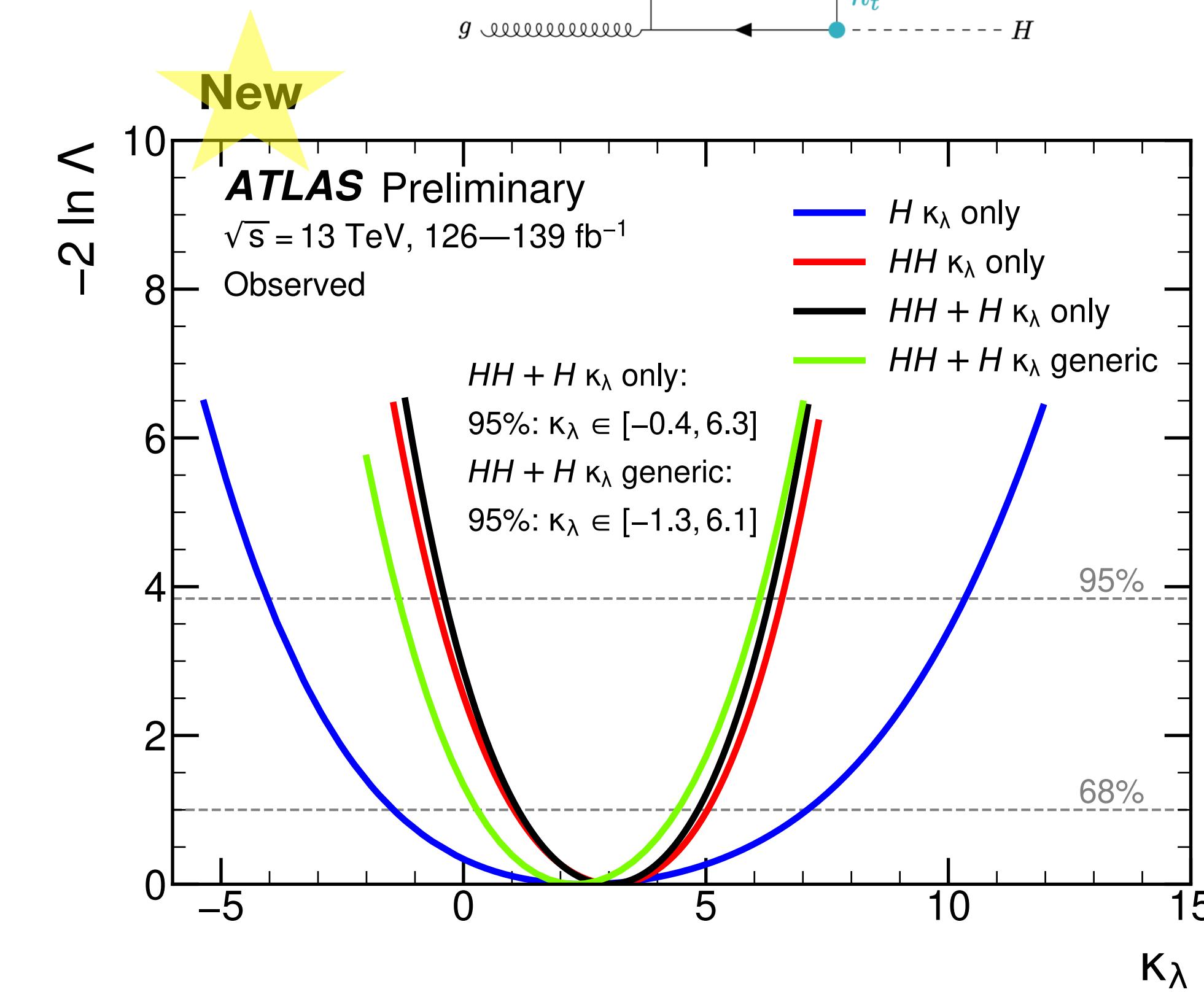
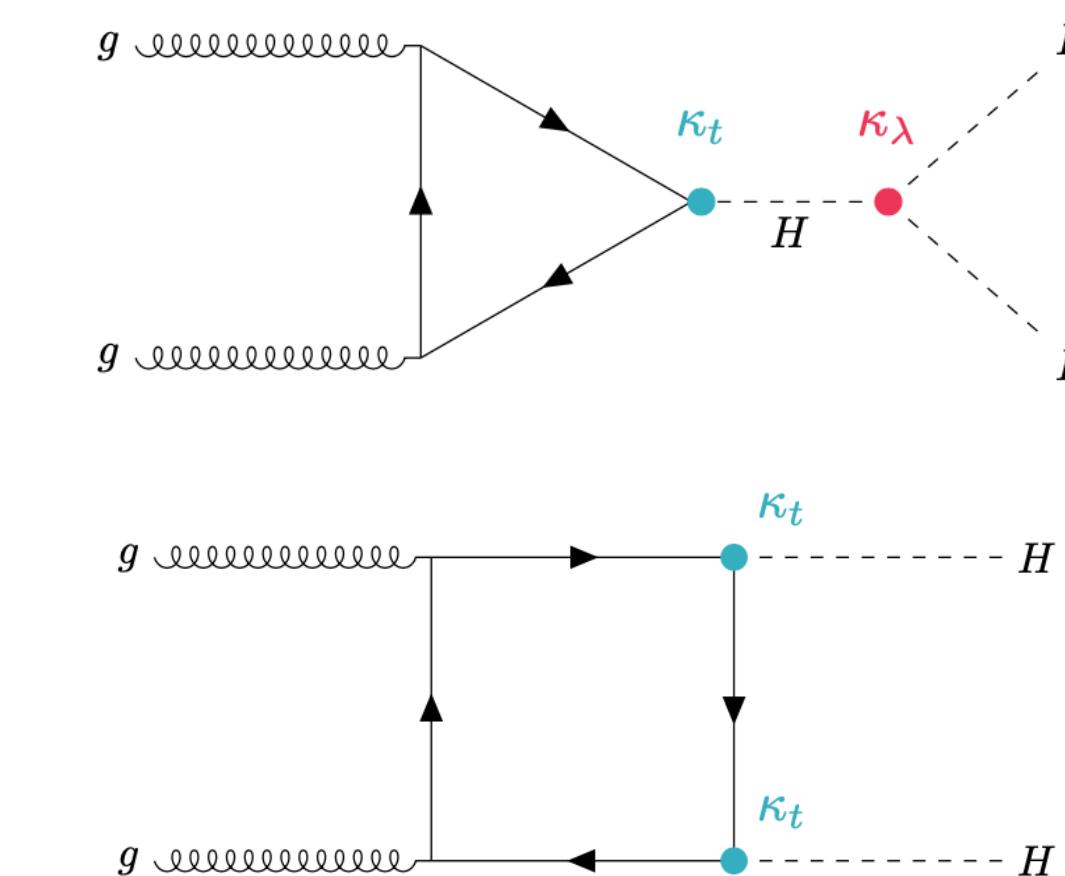
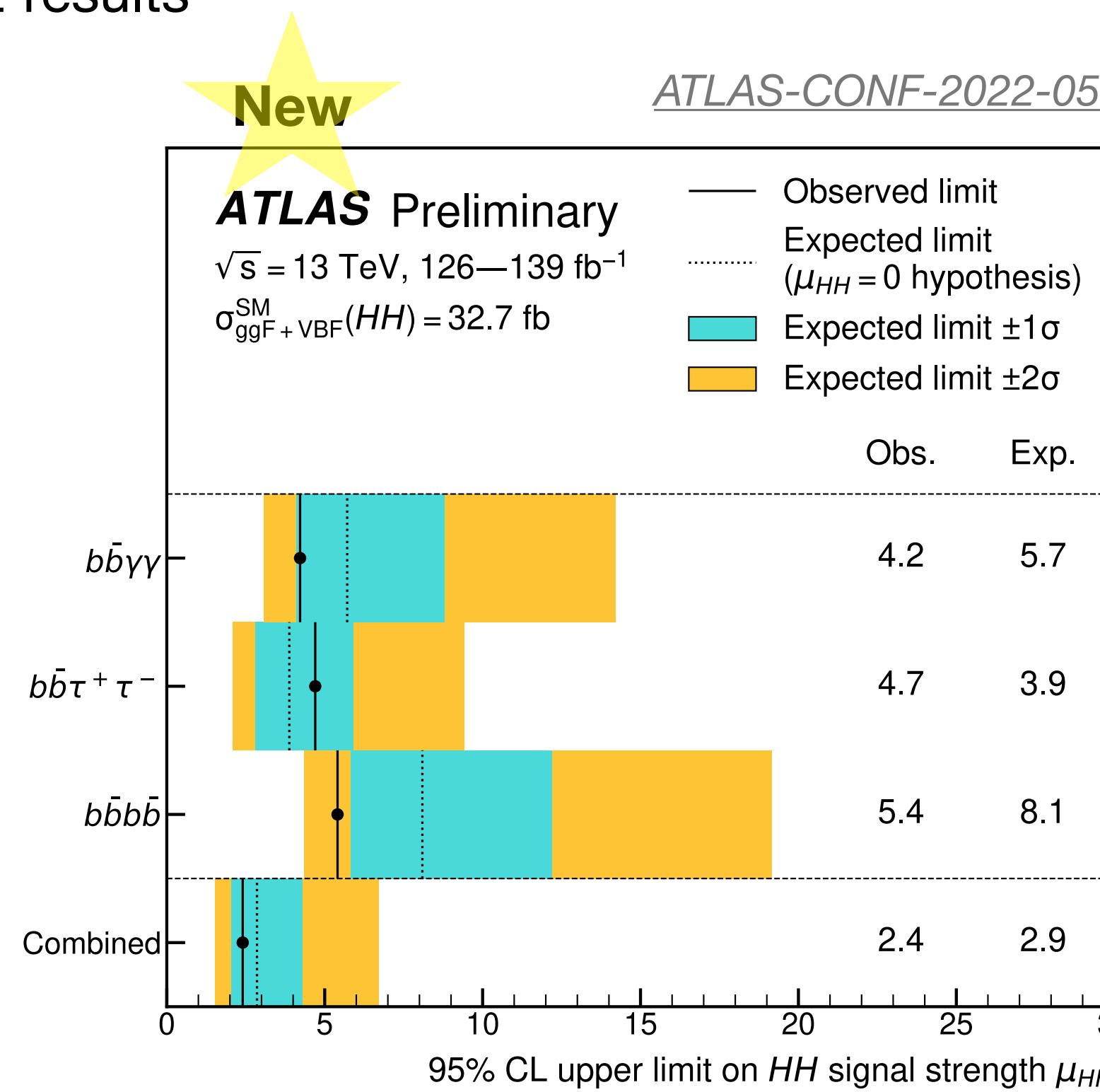


New

New

Searching for Higgs pair production

- Probe Higgs self-interaction and Higgs potential
- Main challenges
 - Very small cross-section 32.7 fb ($<1/1000$ of single H)
 - Negative interference between main contributions
- Compromise between statistics and S/B:
 $(H \rightarrow b\bar{b}).(H \rightarrow \gamma\gamma \text{ or } \tau\tau \text{ or } b\bar{b})$
- Sensitivity with full run 2 data set significantly improved over partial run 2 results

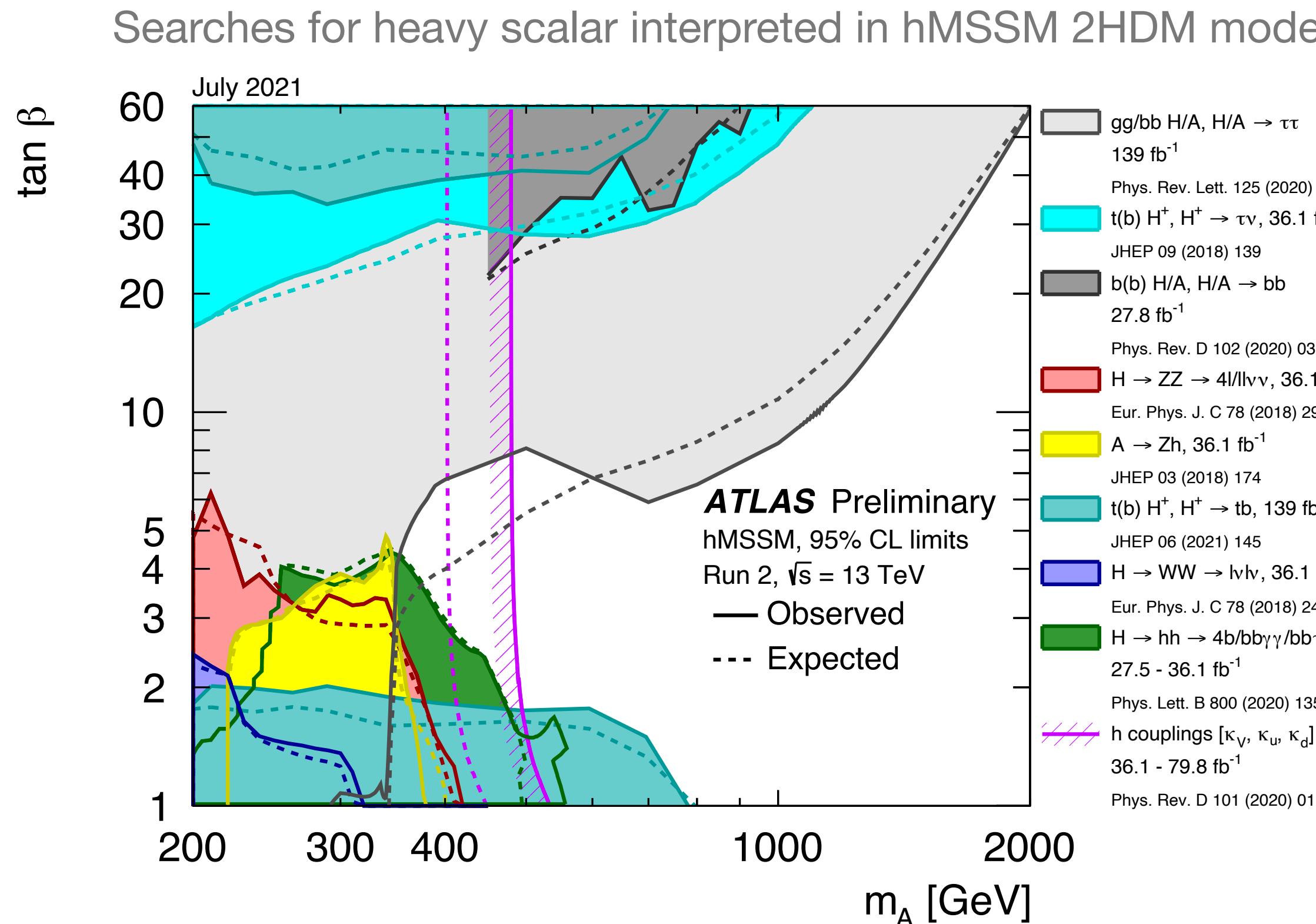


Searches for extended scalar sector

Motivated in many BSM models (SUSY,...)

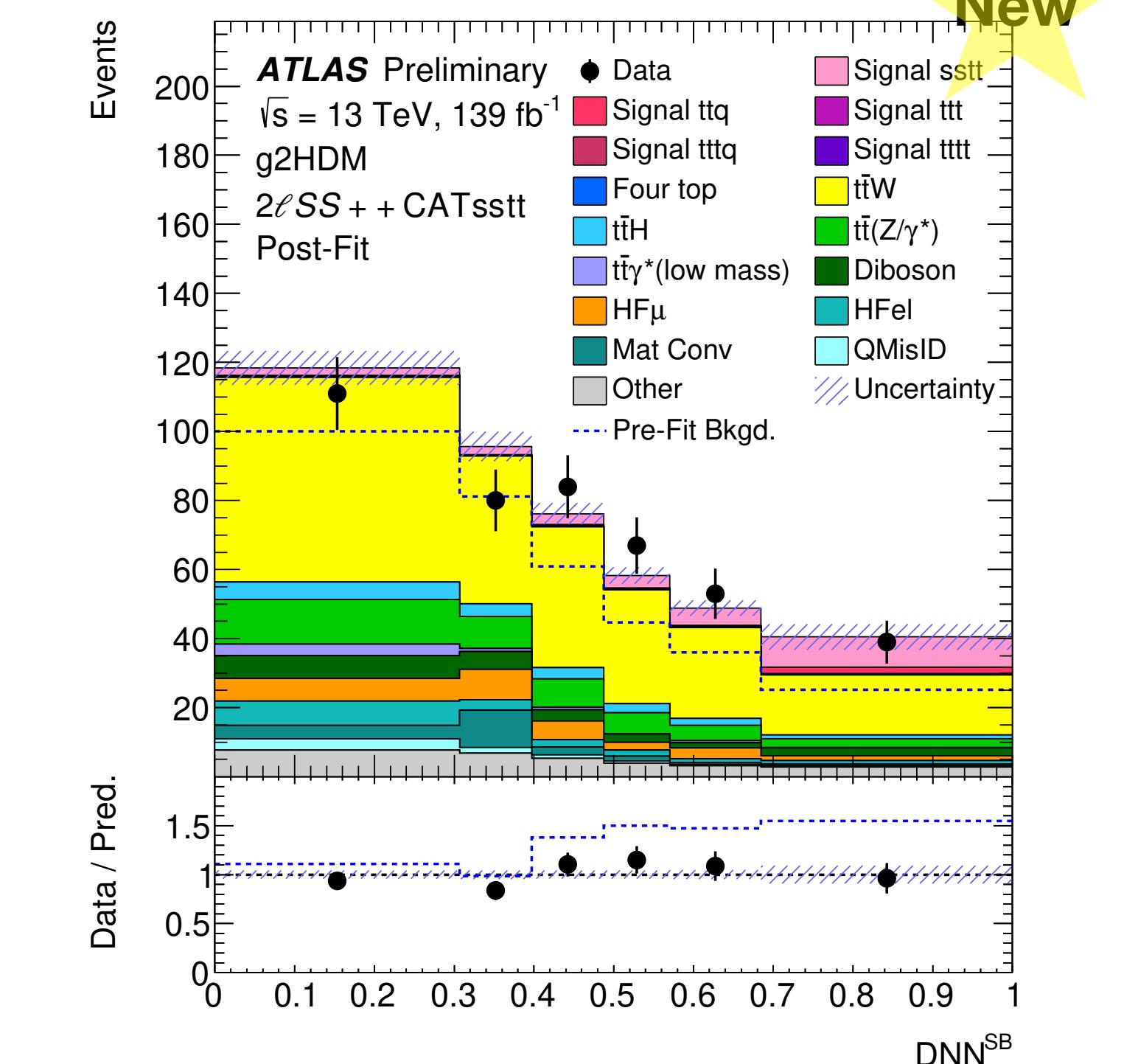
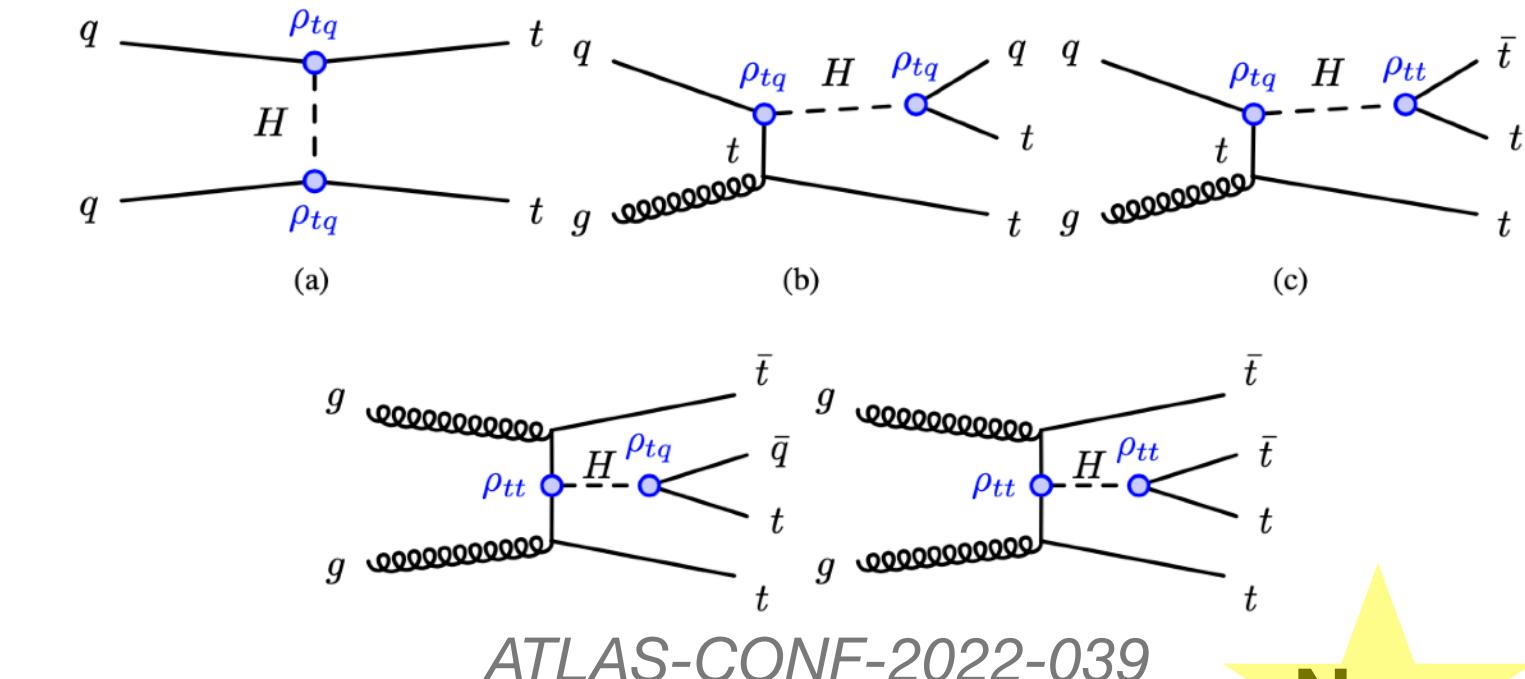
Benchmark: 2 Higgs double model \Rightarrow 5 states

one identified with $h(125)$ and quasi SM like



Also searches for light scalar produced in $h(125)$ decay (NMSSM)

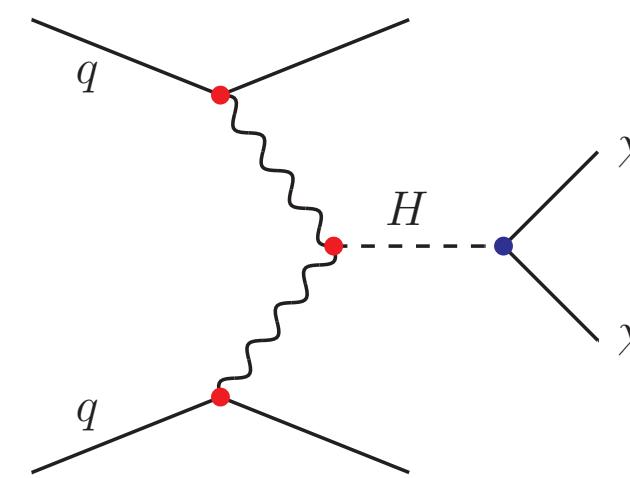
generic 2HDM model
Scan ρ_{tt} , ρ_{tc} , ρ_{tu} couplings
for heavy Higgs masses $200 \text{ GeV} < m_H < 1000 \text{ GeV}$
(largest deviation 2.8σ local)



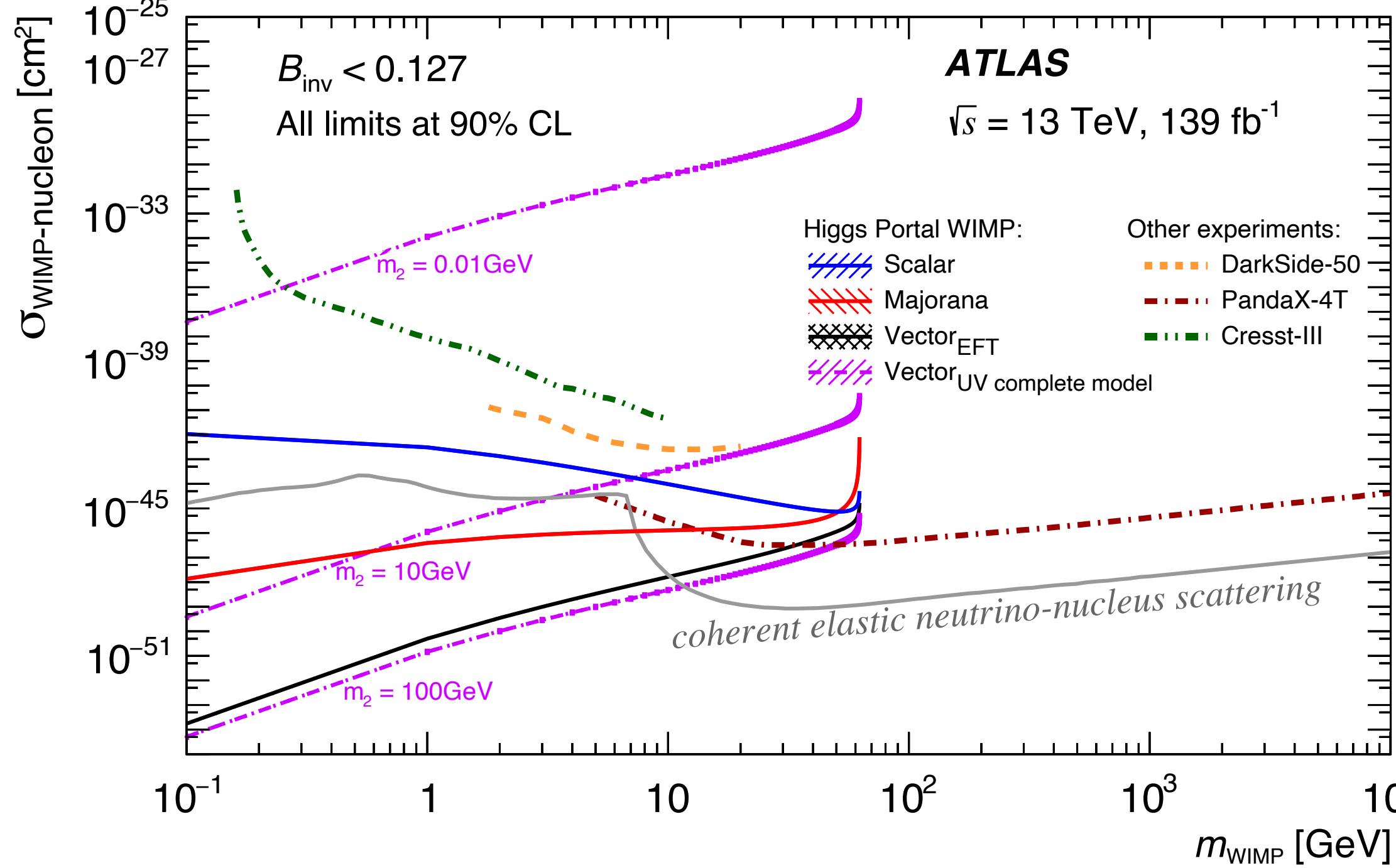
Searches motivated by Dark Matter

Search for $H \rightarrow$ Dark matter (invisible)

$\text{BR}(H \rightarrow \text{invisible}) < 14.5\% \text{ (obs)} \quad (10.3\% \text{ exp.})$
 from search with VBF topology
 (13% limit when combined with Higgs coupling measurements)

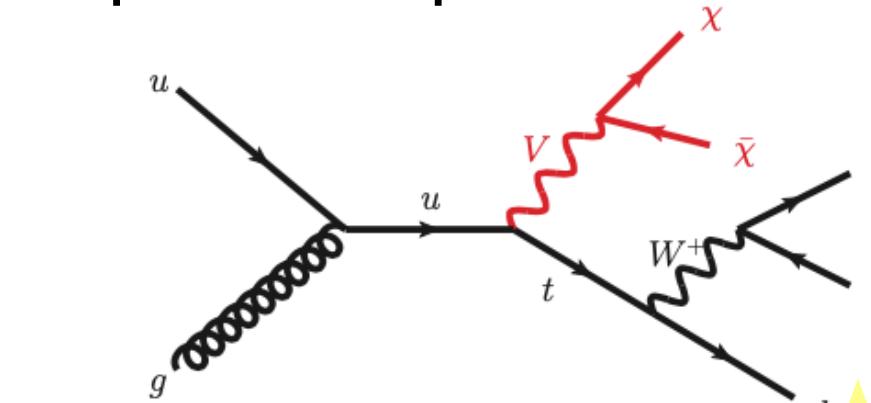


arXiv:2202.07953



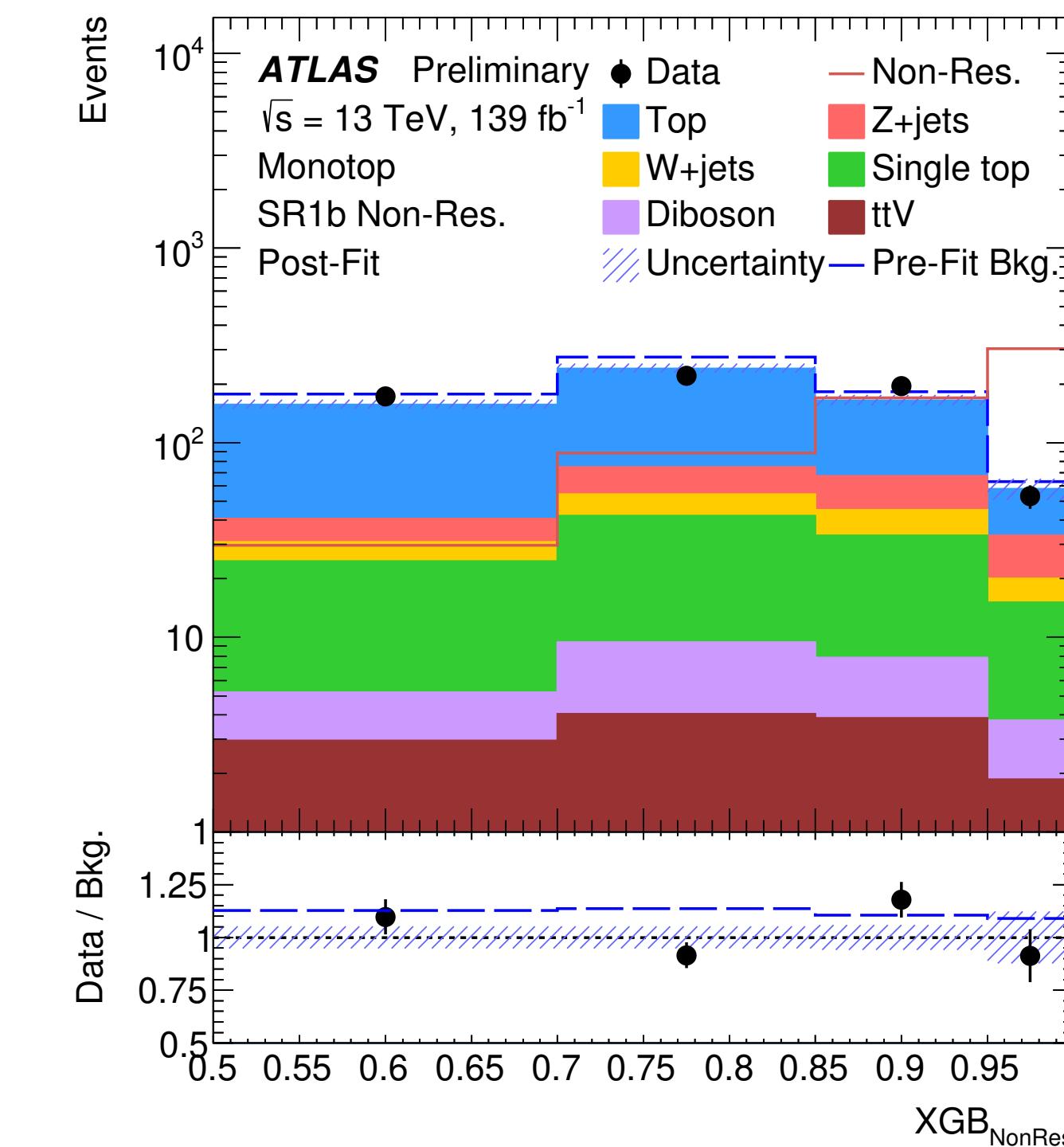
Searches for mono-top production

Part of wide mono-X searches (X=SM particles) + missingEt
 fully hadronic final state
 mass reach for V mediator $\sim 2.5 \text{ TeV}$
 probe also non-resonant model
 Large increase of sensitivity compared to partial run-2 result



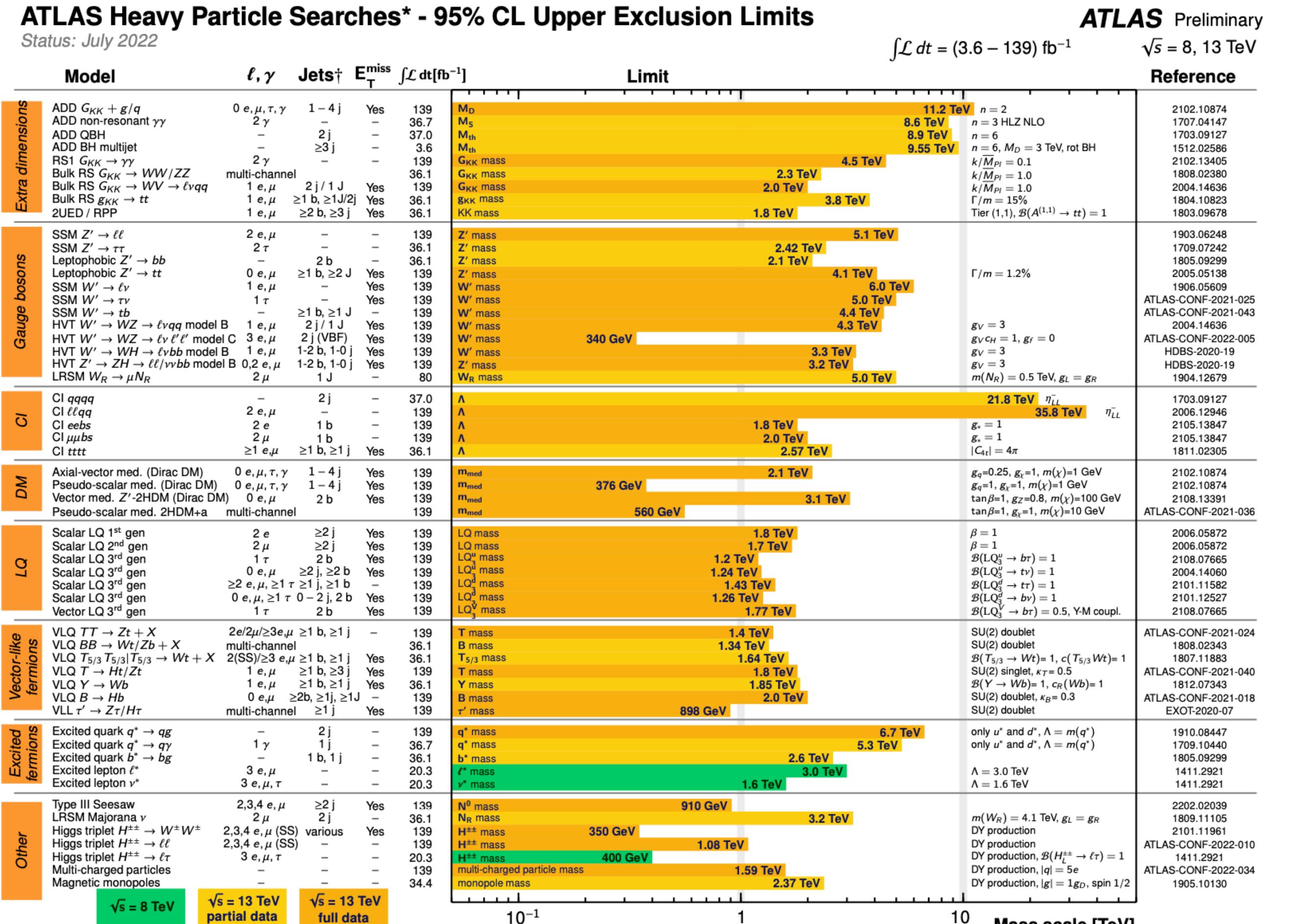
ATLAS-CONF-2022-036

New

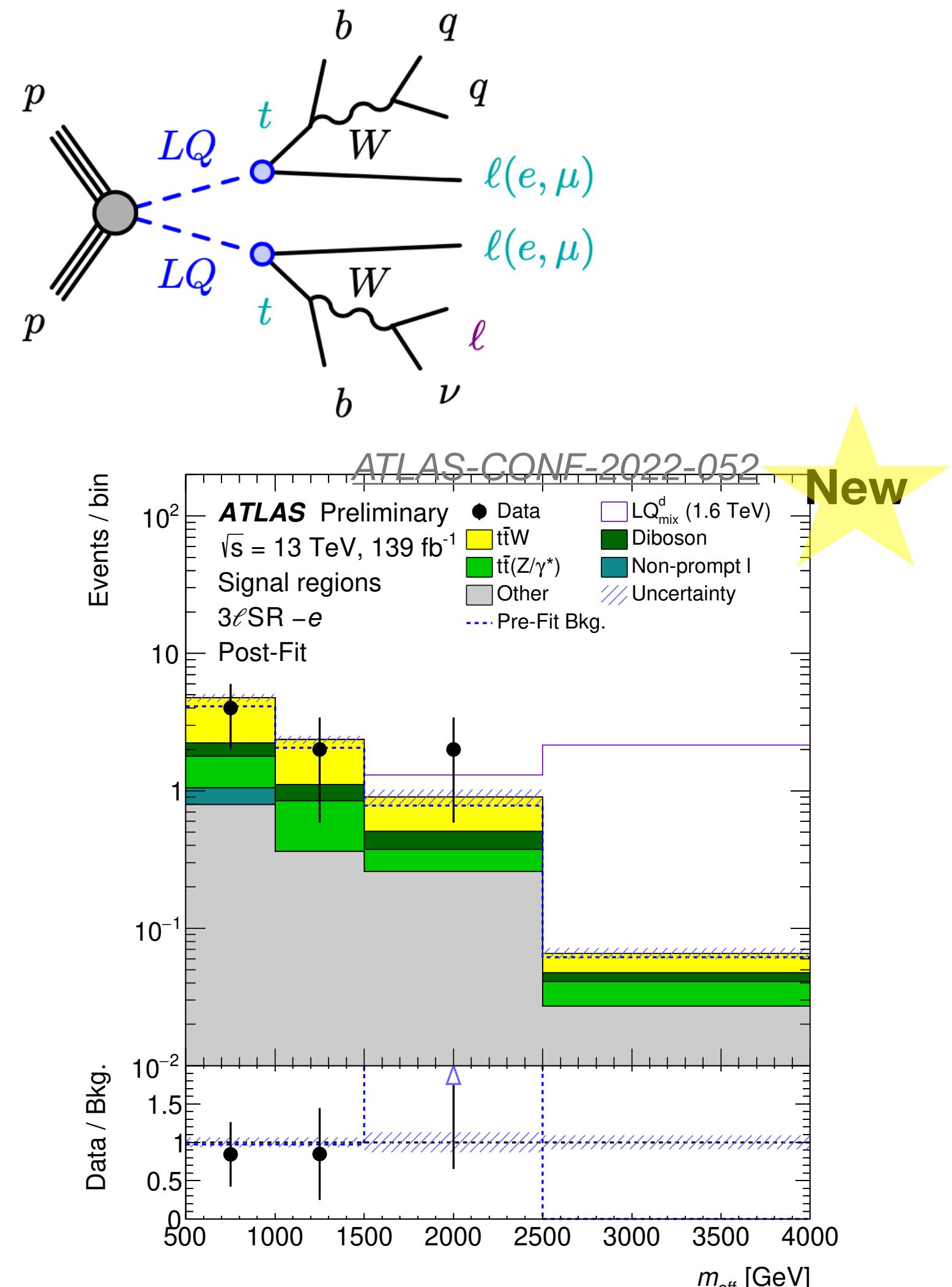


Searches for heavy resonances

Many searches reaching few TeV sensitivity in mass



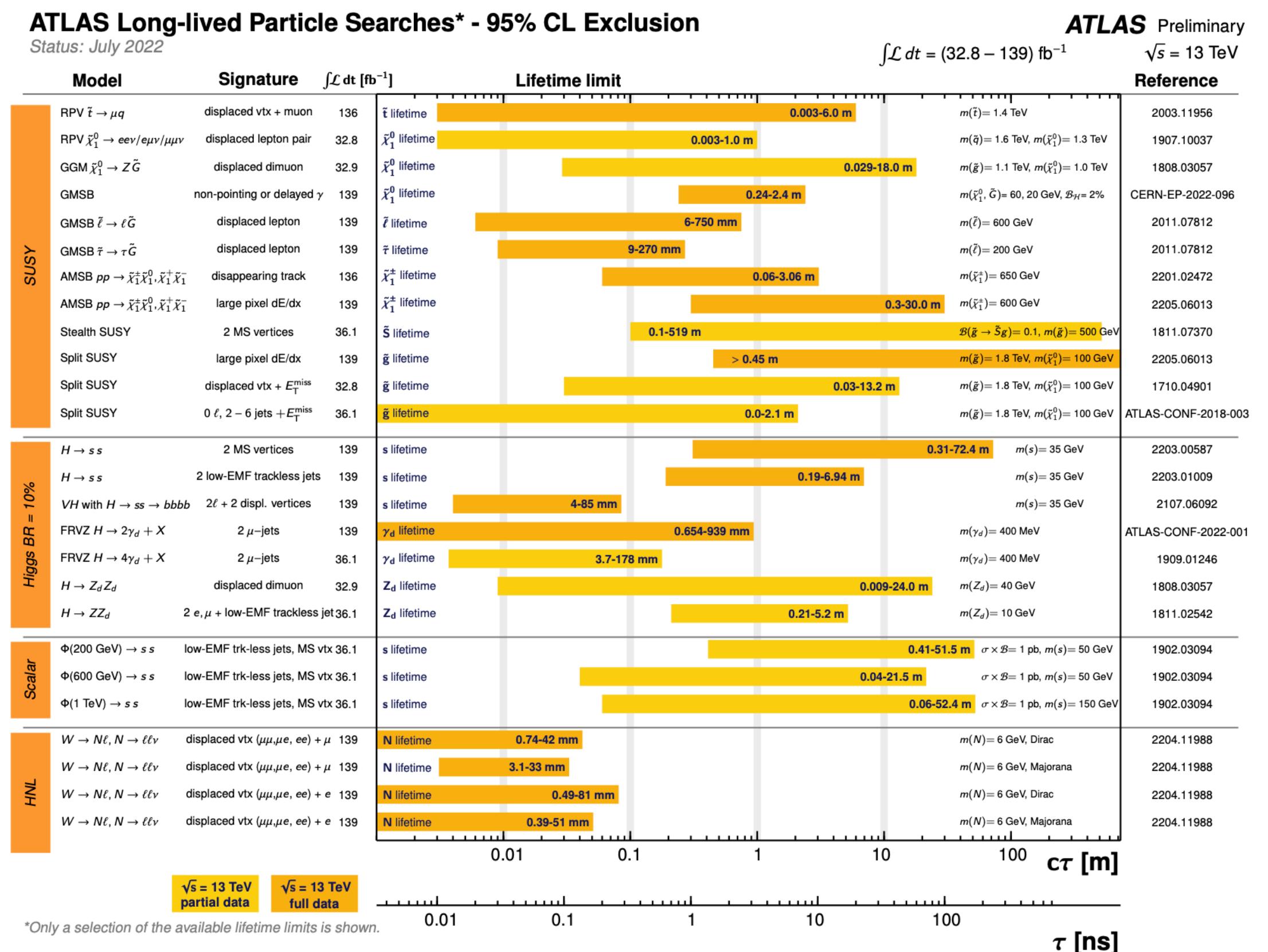
Leptoquark pair production, $LQ \rightarrow t e$ or $t \mu$
 mass reach $\sim 1.6 \text{ TeV}$ (scalar LQ), $\sim 2 \text{ TeV}$ (vector LQ)



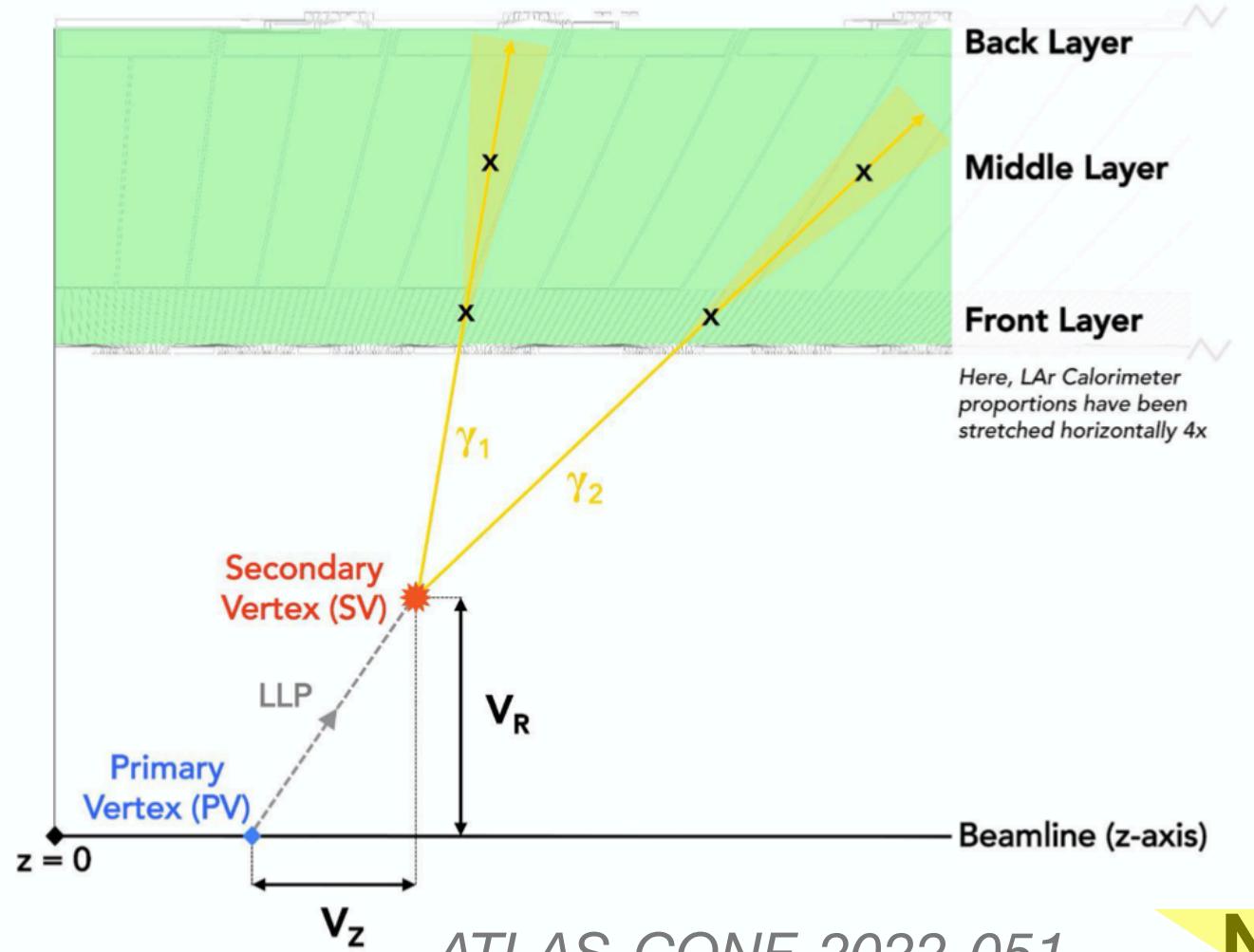
Searches for long-lived particles

Large program to search for long-lived particles exploiting a comprehensive set signatures:

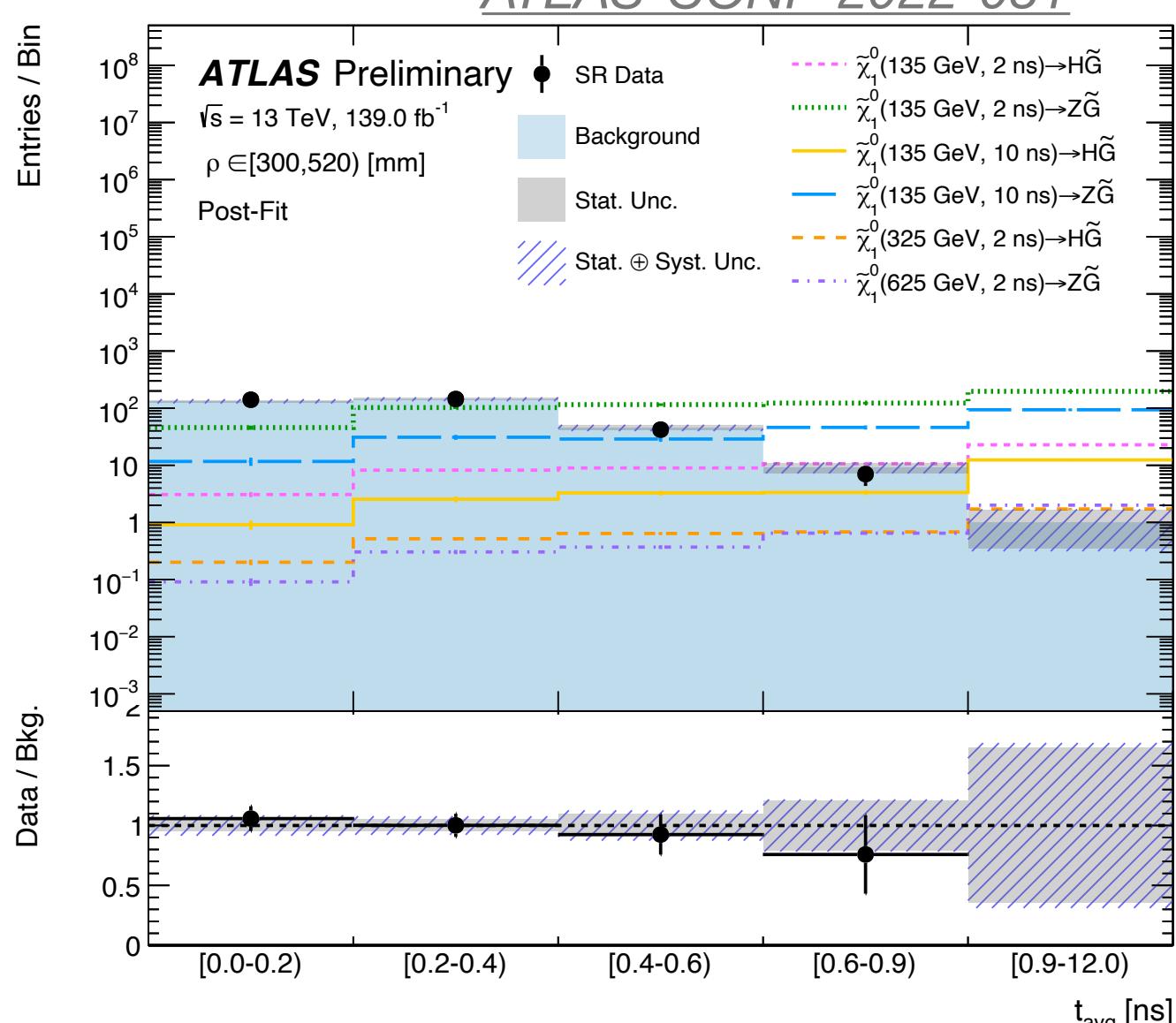
- displaced vertices in inner tracking detector
- lepton not consistent with originating from pp vertex
- decay in the calorimeter or muon spectrometer
- dE/dx measurement for charged metastable particles + multi charge



Search for H or Z produced far from interaction point
exploiting shower pointing and time measurements



New



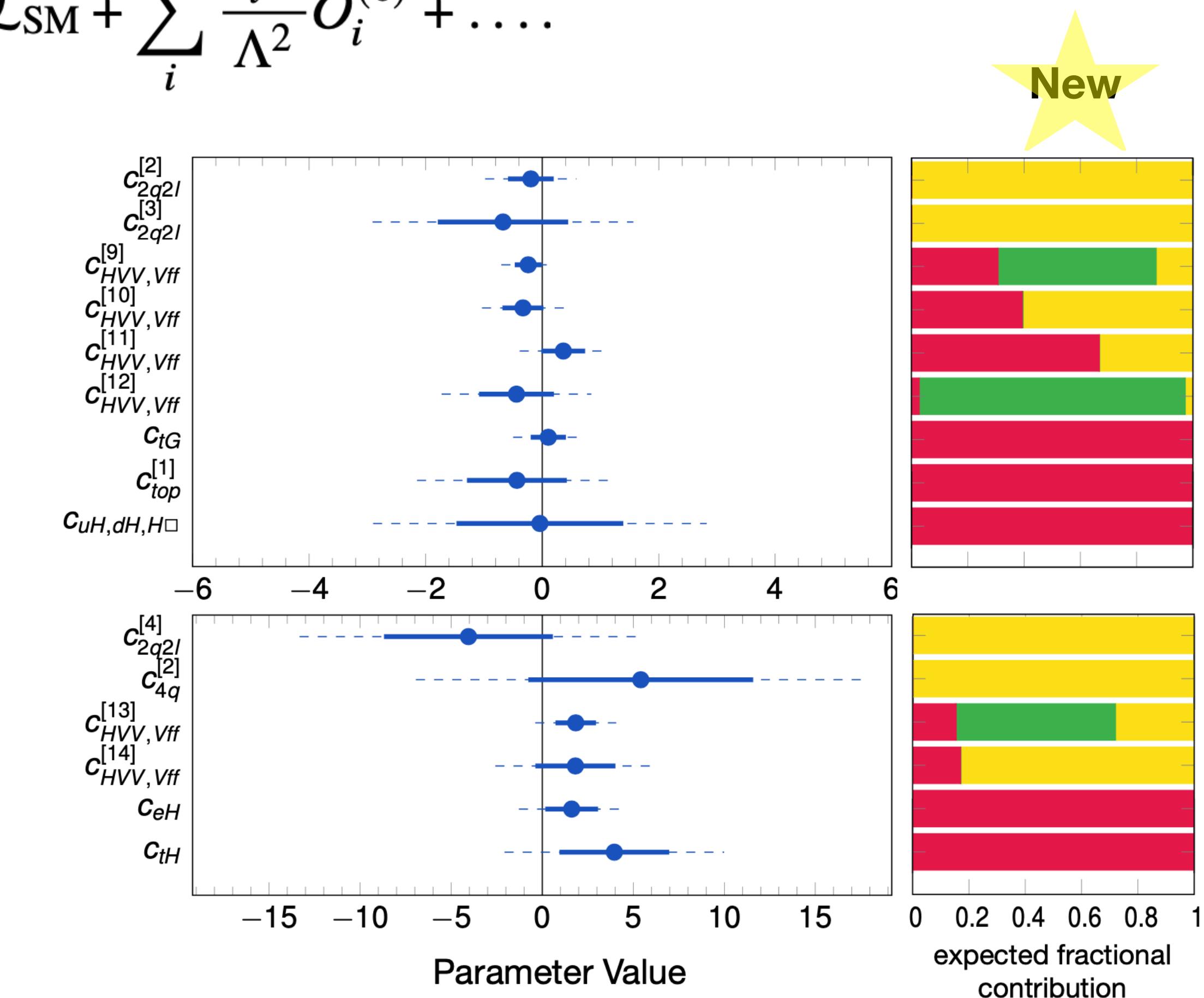
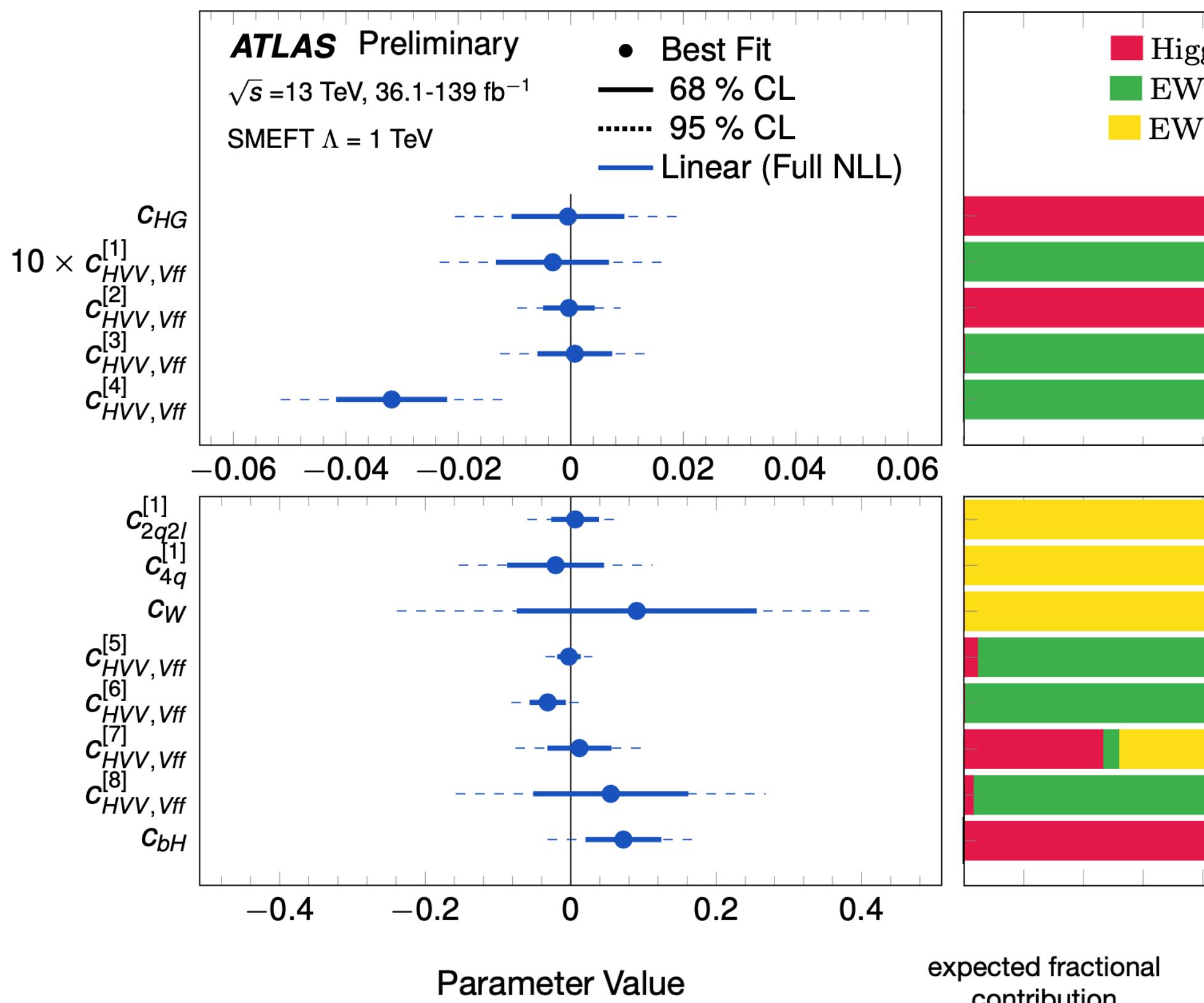
Effective Field Theory

Systematics expansion of SM Lagrangian to look for BSM physics at higher energy scale

Combine Higgs boson measurements, electroweak (di) boson measurements
and constraints on electroweak parameters (from LEP/SLD)

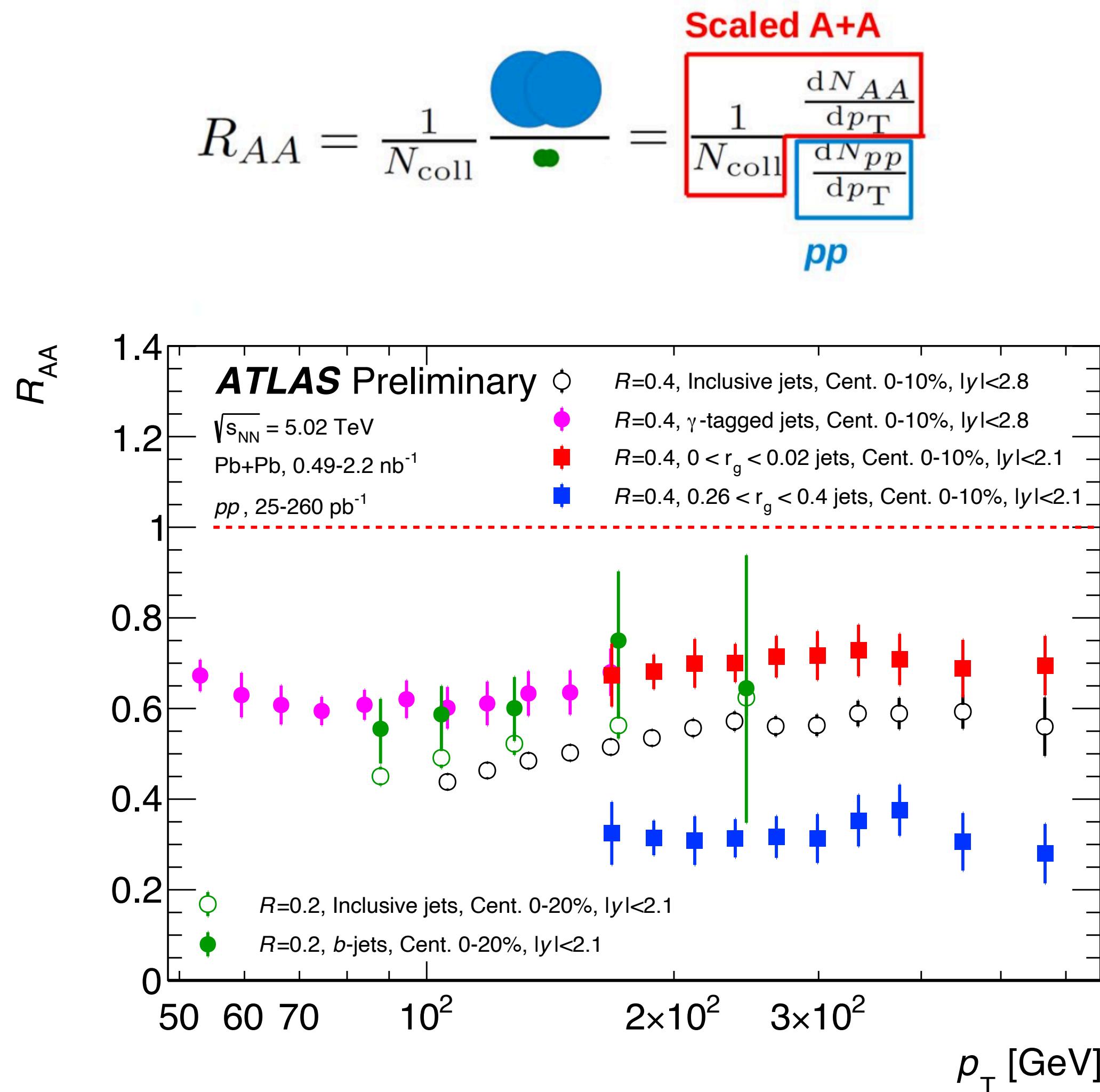
$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_i \frac{c_i^{(6)}}{\Lambda^2} O_i^{(6)} + \dots$$

ATL-PHYS-PUB-2022-037

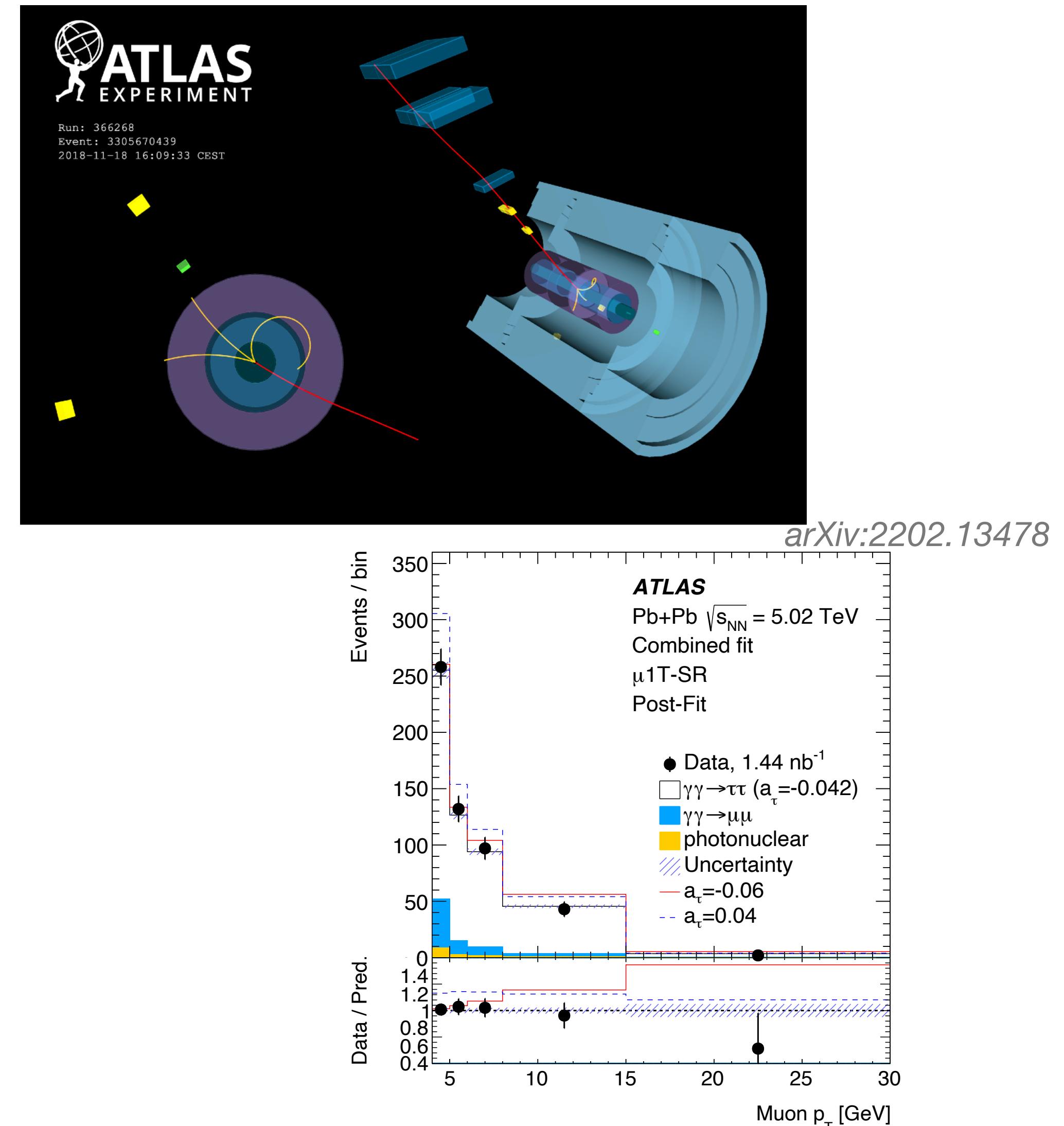


Physics with Pb Pb collisions

studies of jet quenching in quark-gluon plasma



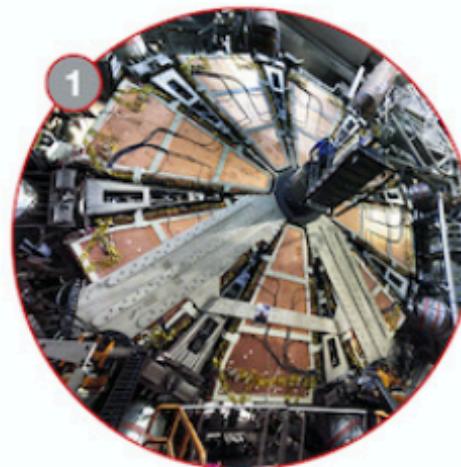
$\gamma\gamma \rightarrow \tau\tau$ process in ultra peripheral collisions



ATLAS for run 3

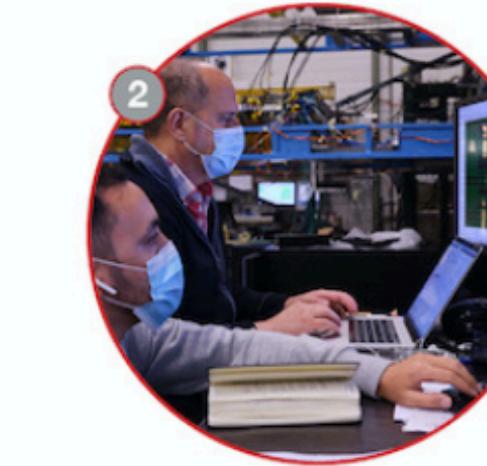
MUON NEW SMALL WHEELS (NSW)

Installed new muon detectors with precision tracking and muon selection capabilities. Key preparation for the HL-LHC.



NEW READOUT SYSTEM FOR THE NSWs

The NSW system includes two million micromega readout channels and 350 000 small strip thin-gap chambers (sTGC) electronic readout channels.



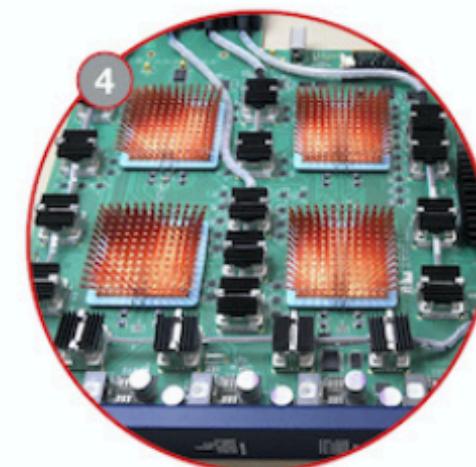
LIQUID ARGON CALORIMETER

New electronics boards installed, increasing the granularity of signals used in event selection and improving trigger performance at higher luminosity.



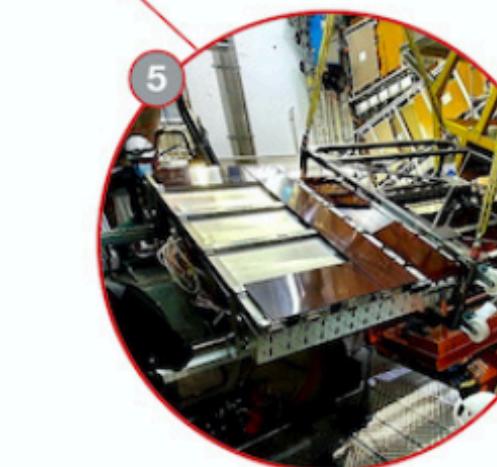
TRIGGER AND DATA ACQUISITION SYSTEM (TDAQ)

Upgraded hardware and software allowing the trigger to spot a wider range of collision events while maintaining the same acceptance rate.



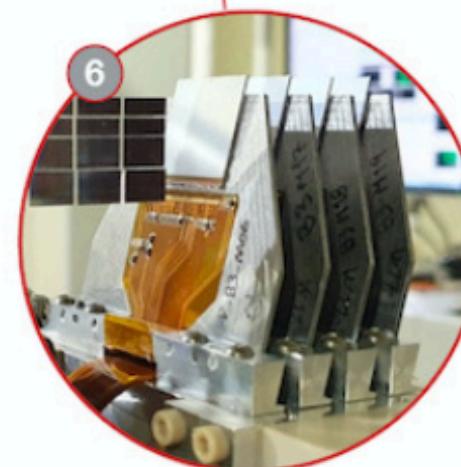
NEW MUON CHAMBERS IN THE CENTRE OF ATLAS

Installed small monitored drift tube (sMDT) detectors alongside a new generation of resistive plate chamber (RPC) detectors, extending the trigger coverage in preparation for the HL-LHC.

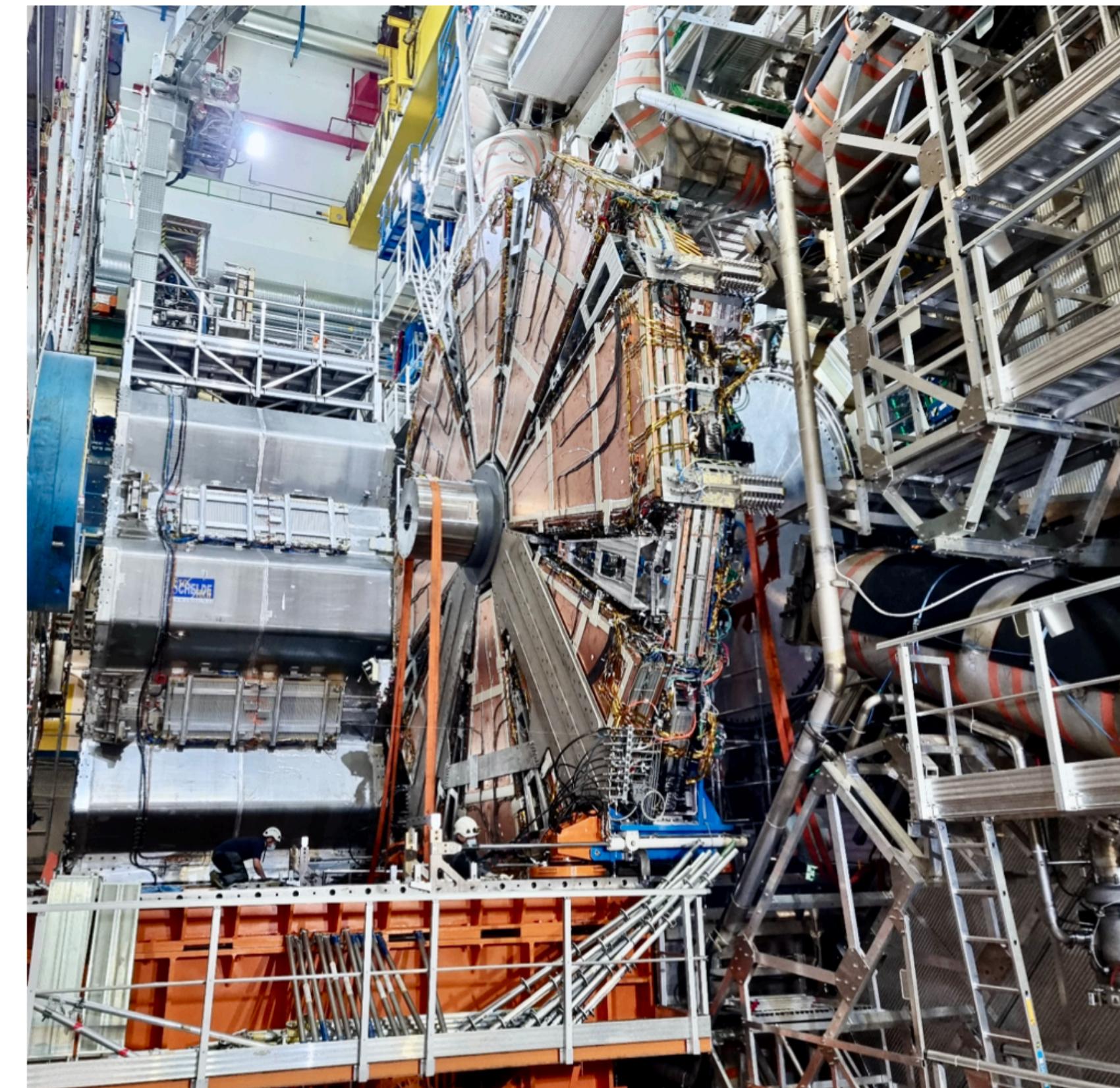
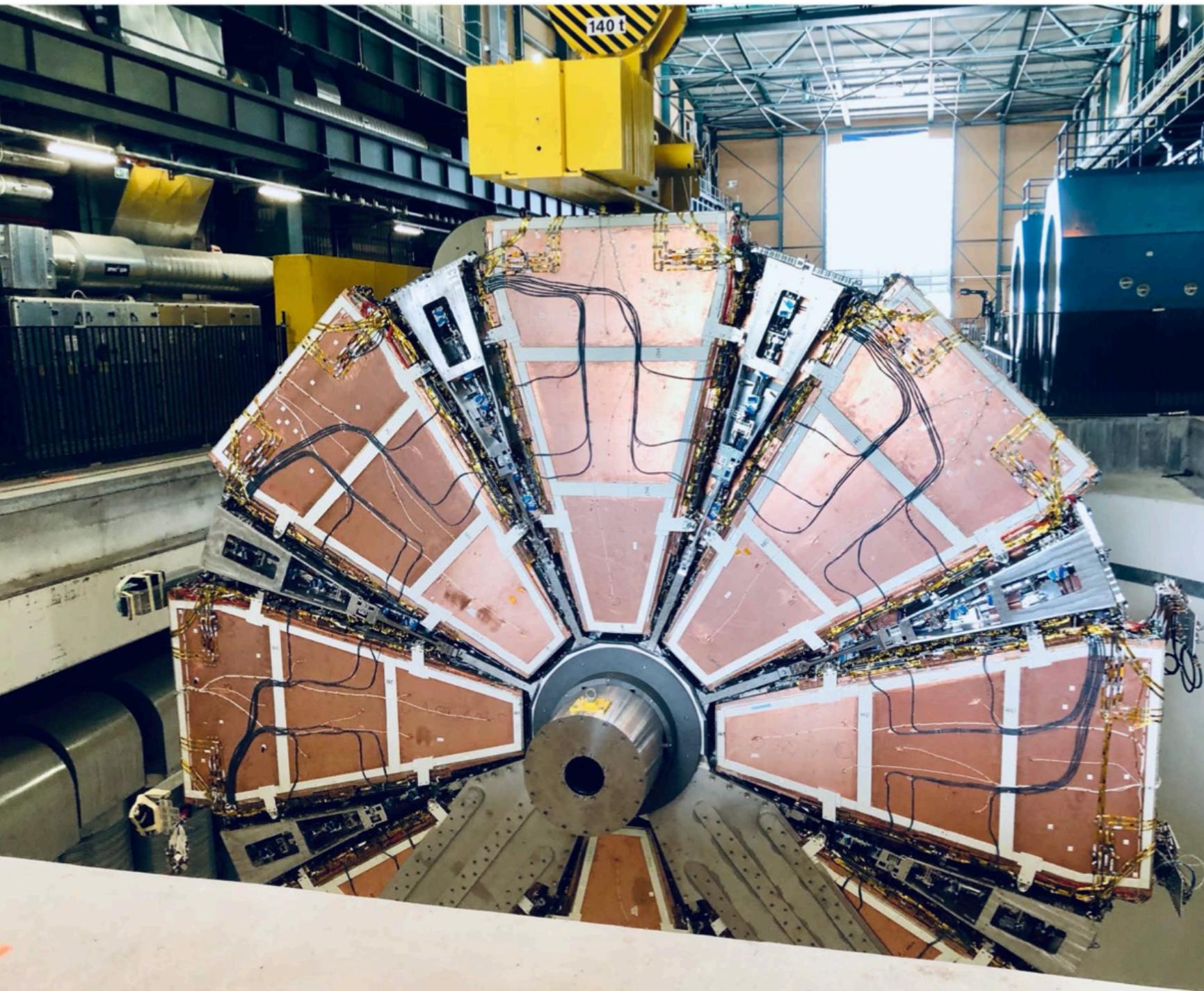


ATLAS FORWARD PROTON (AFP)

Re-designed AFP time-of-flight detector, allowing insertion into the LHC beamline with a new “out-of-vacuum” solution.



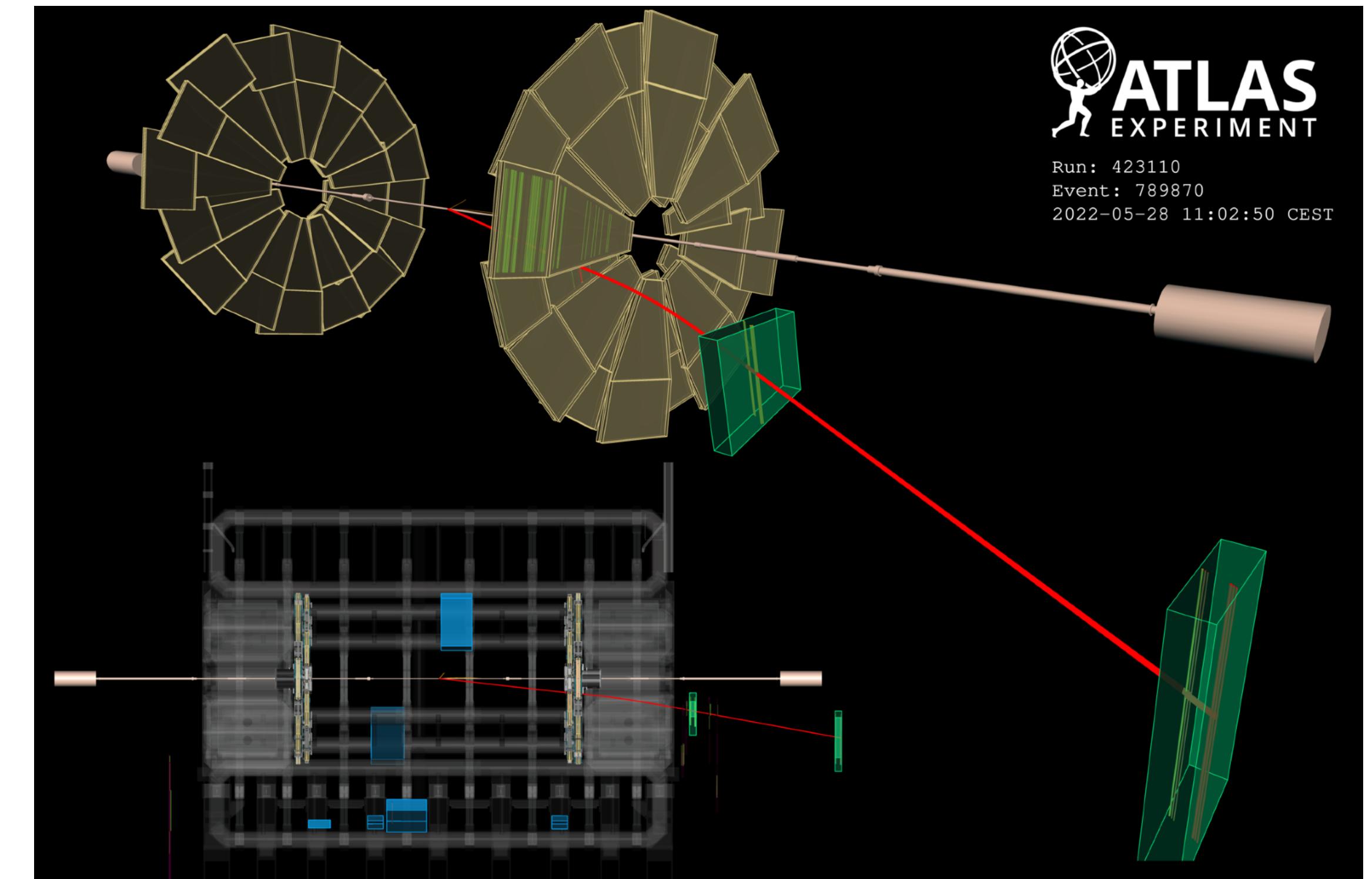
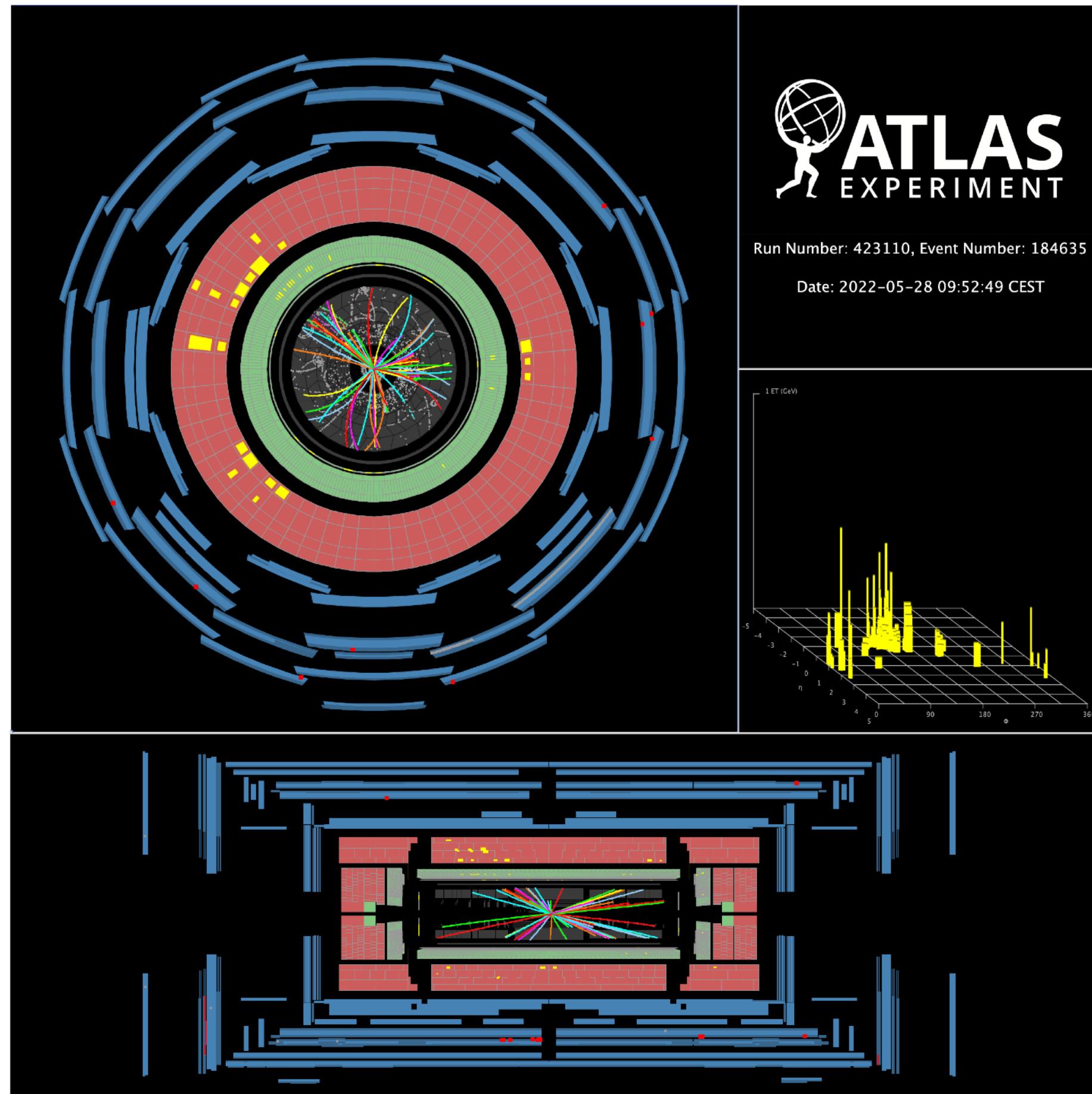
New Small Wheel for muon trigger+measurement



NSW being positioned

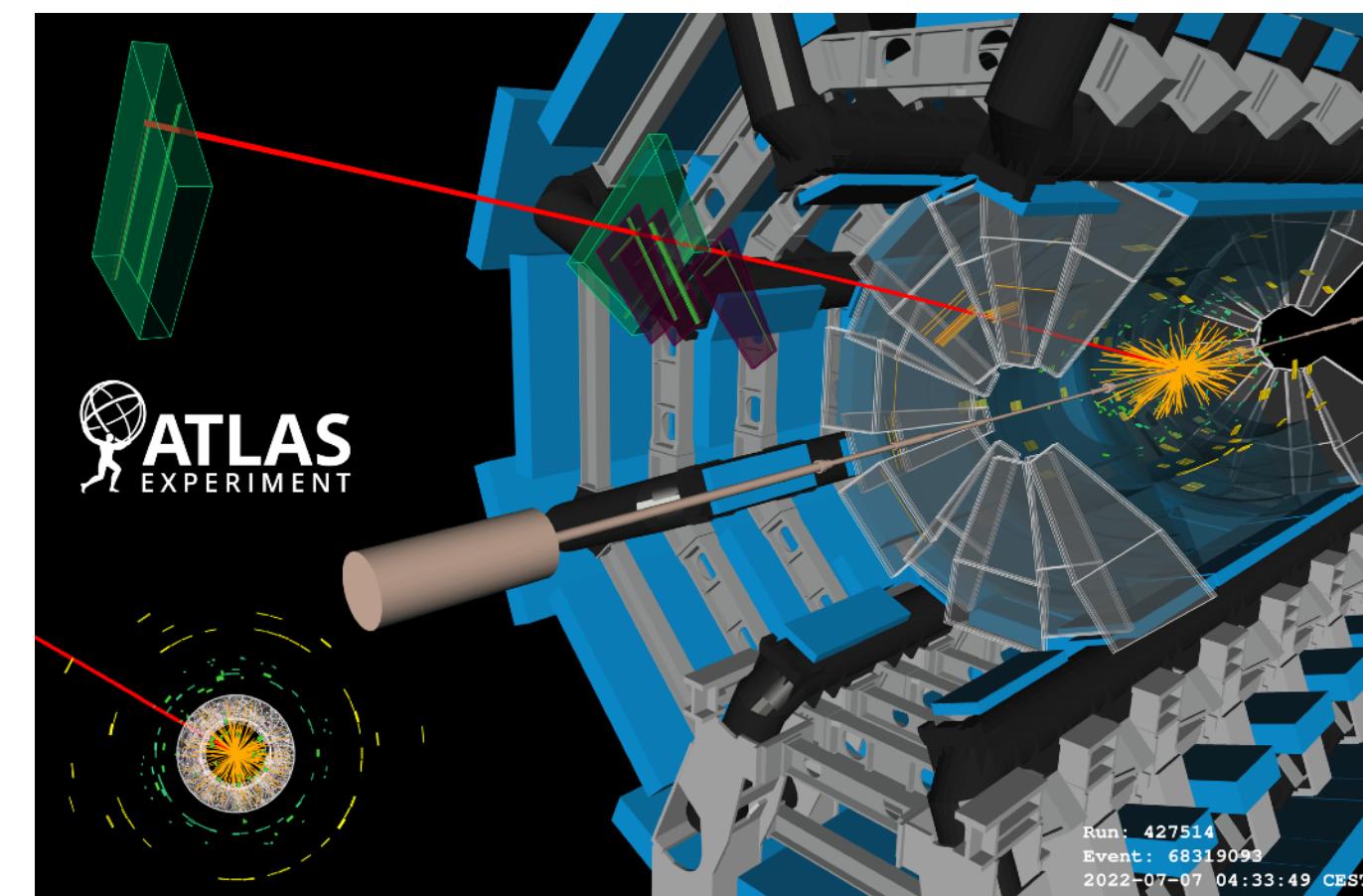
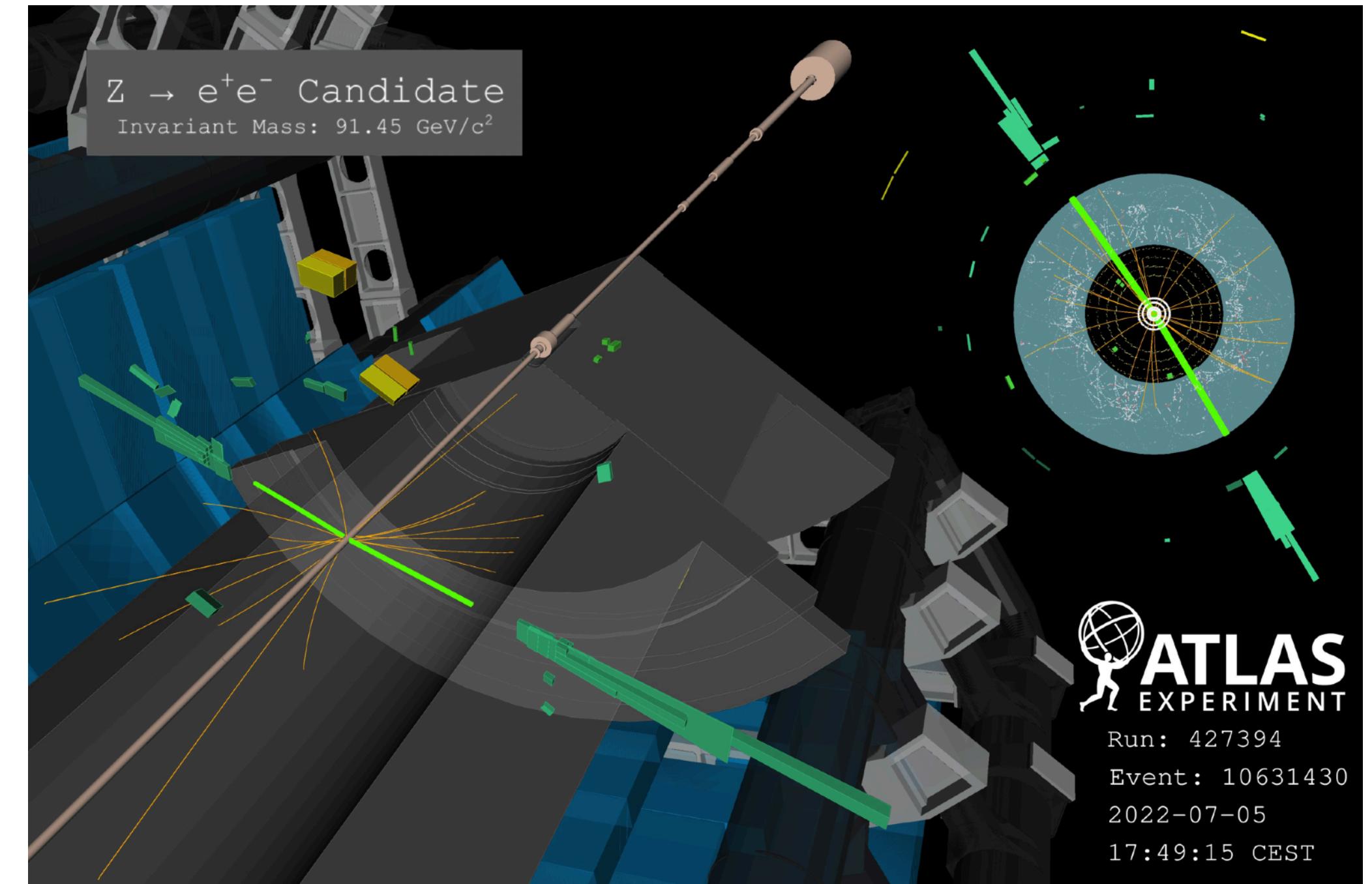
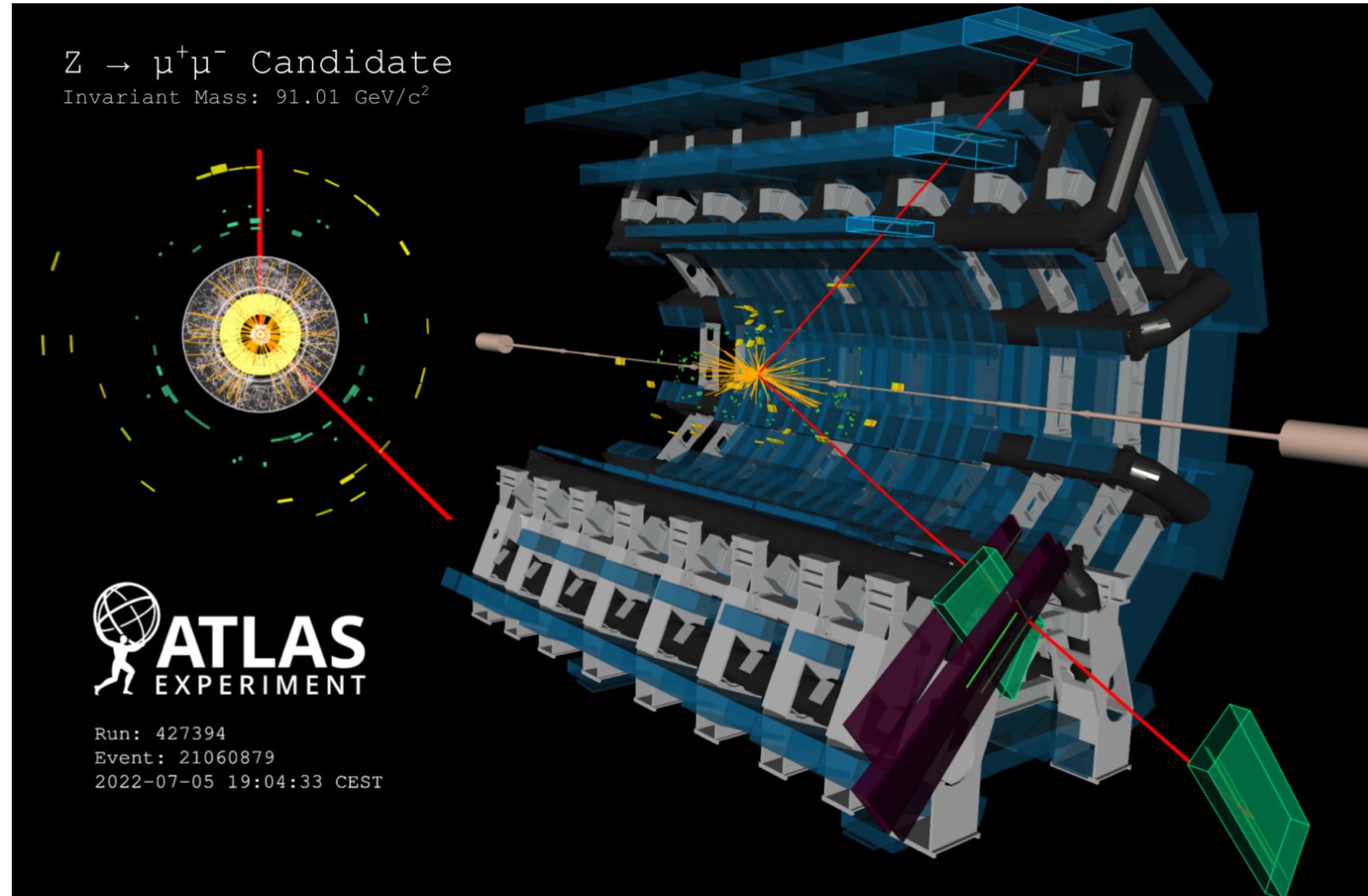
900 GeV pp collision data

recorded in May during stable-beam periods provided by the LHC during its commissioning

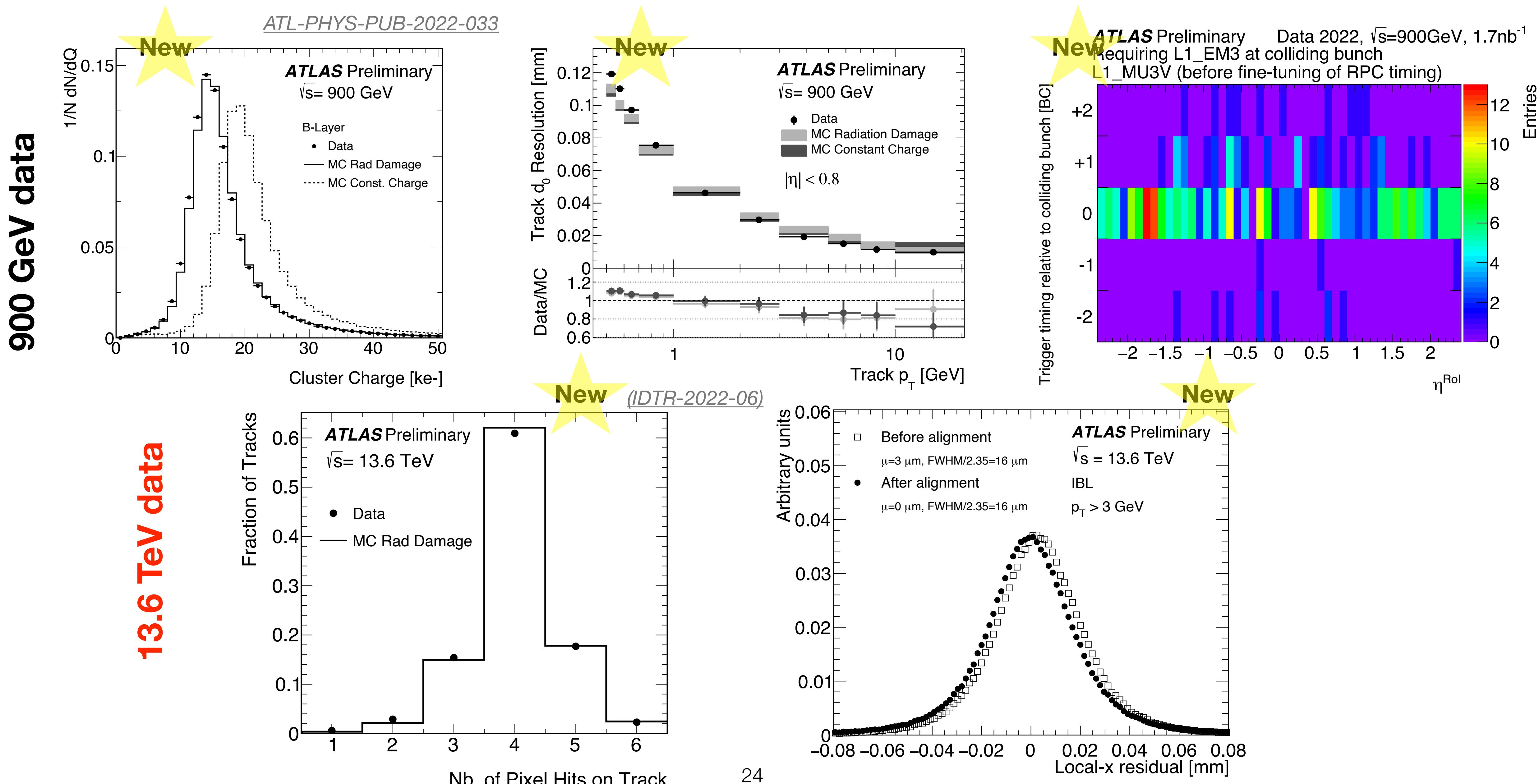


13.6 TeV pp collision data

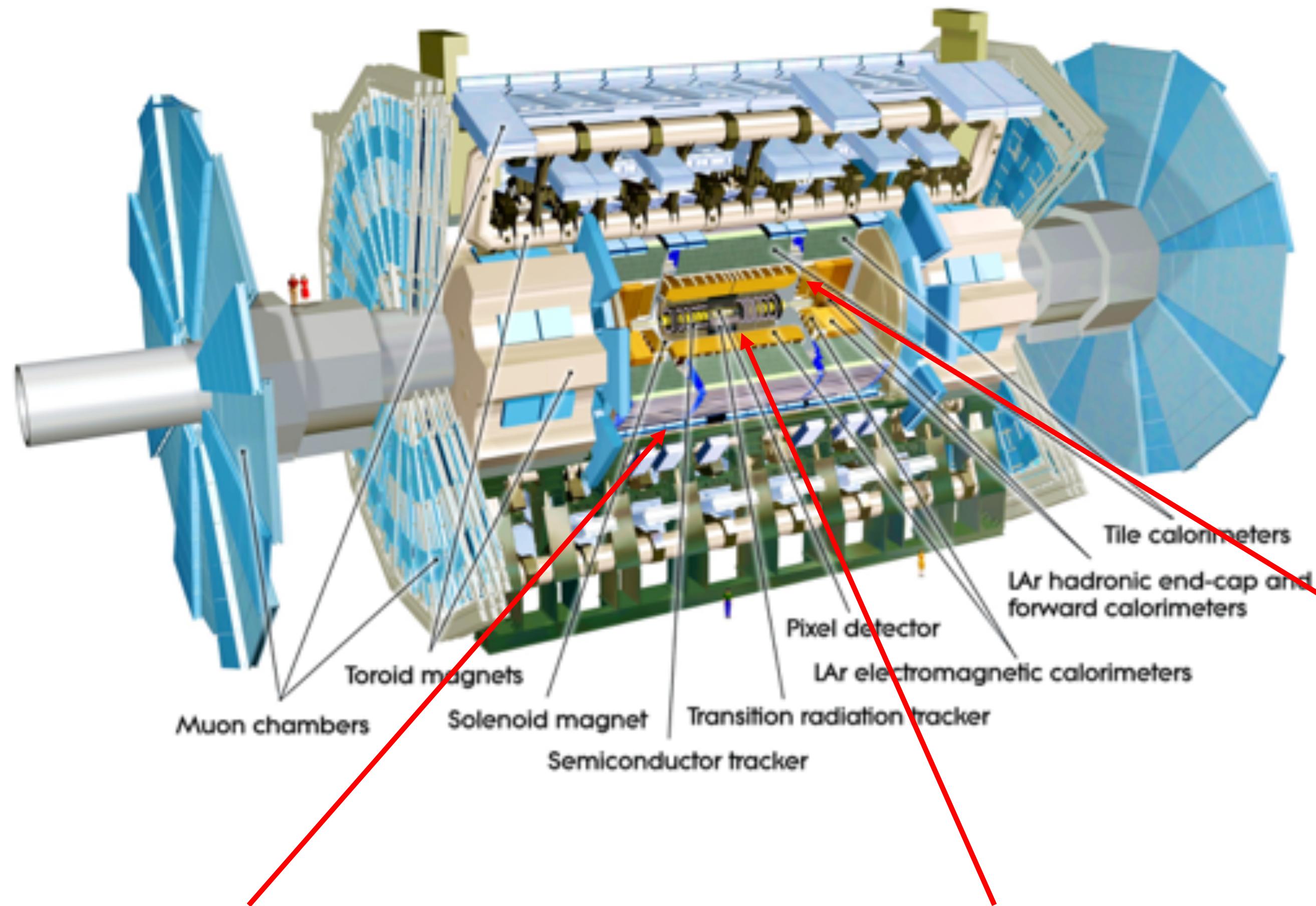
started July 5th



First look at detector performance with 2022 collision data



ATLAS Phase-2 Upgrade for HL-LHC



New Muon Chambers

Inner barrel region with new
RPC and sMDT detectors

New Inner Tracking Detector (ITk)

All silicon, up to $|\eta| = 4$

Detailed scope described in 7 TDRs approved by the CERN Research Board in 2017, 2018, 2020

Upgraded Trigger and Data Acquisition system

Level-0 Trigger at 1 MHz

Improved High-Level Trigger
(150 kHz full-scan tracking)

Electronics Upgrades

LAr Calorimeter

Tile Calorimeter

Muon system

High Granularity Timing Detector (HGTD)

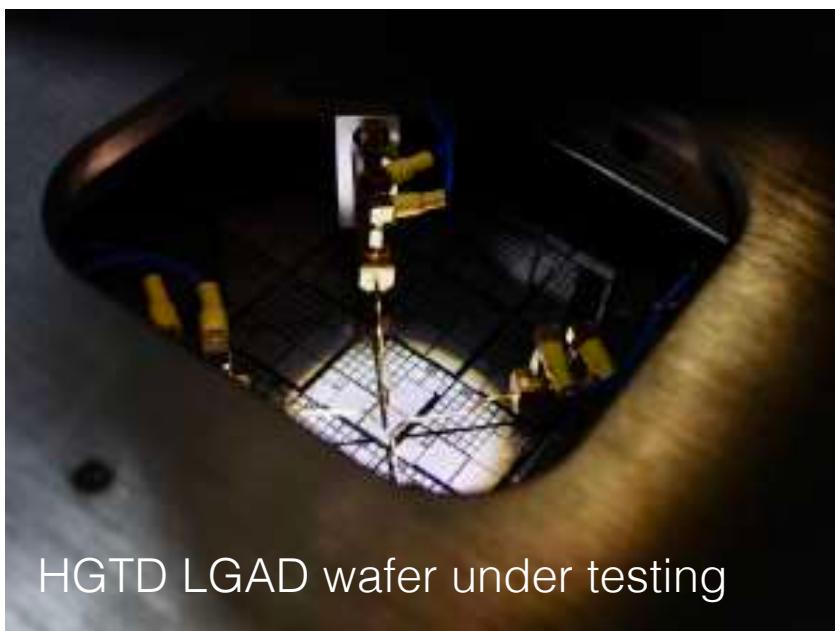
Forward region ($2.4 < |\eta| < 4.0$)

Low-Gain Avalanche Detectors (LGAD)
with 30 ps track resolution

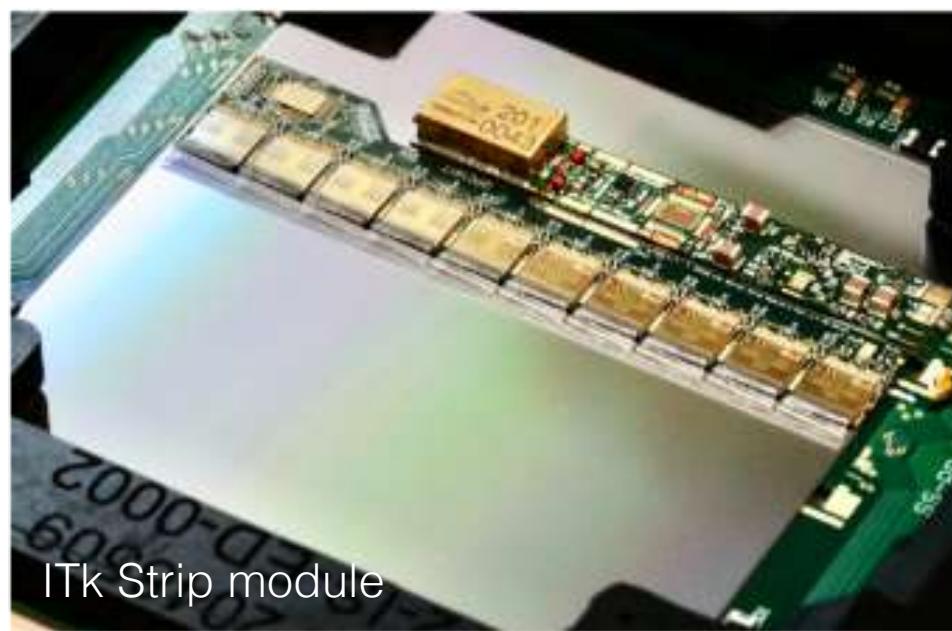
Additional small upgrades

Luminosity detectors (1% precision goal)

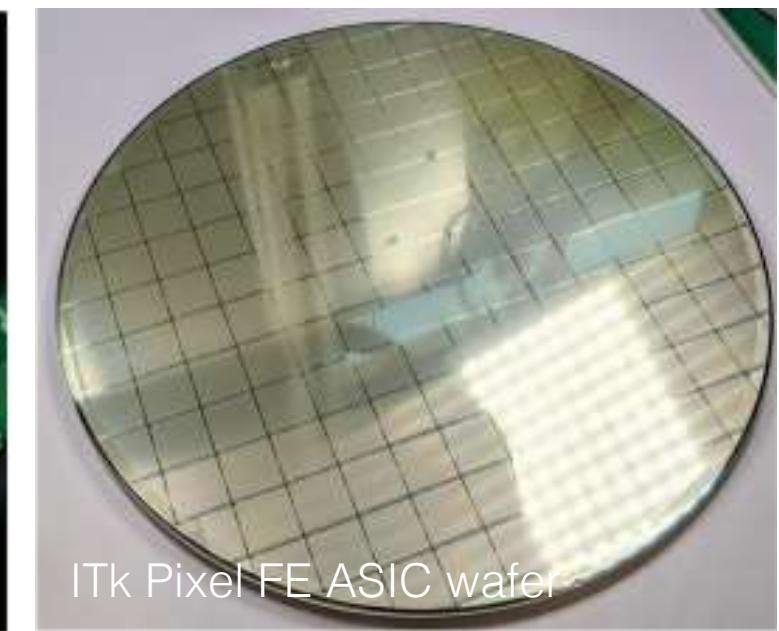
HL-ZDC



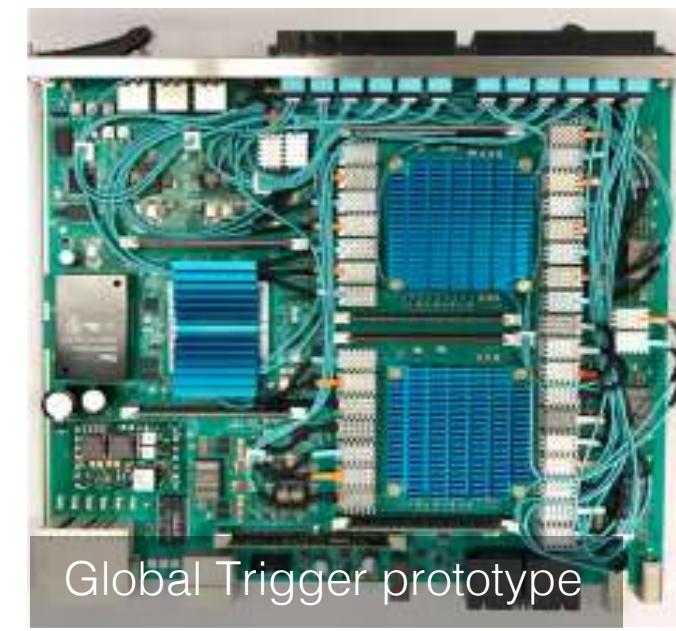
HGTD LGAD wafer under testing



ITk Strip module



ITk Pixel FE ASIC wafer



Global Trigger prototype



Tile MiniDrawer mechanics



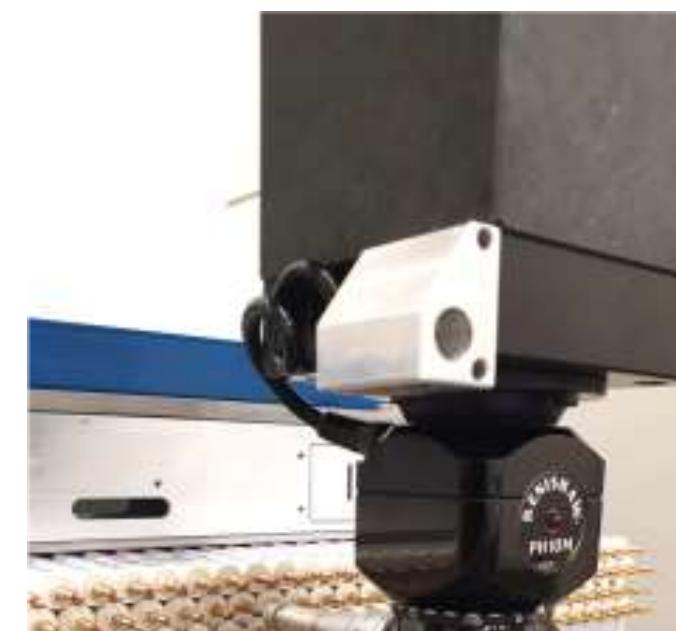
ITk Pixel module loading



ITk Strip FE ASIC in test beam



ITk Strip endcap petal



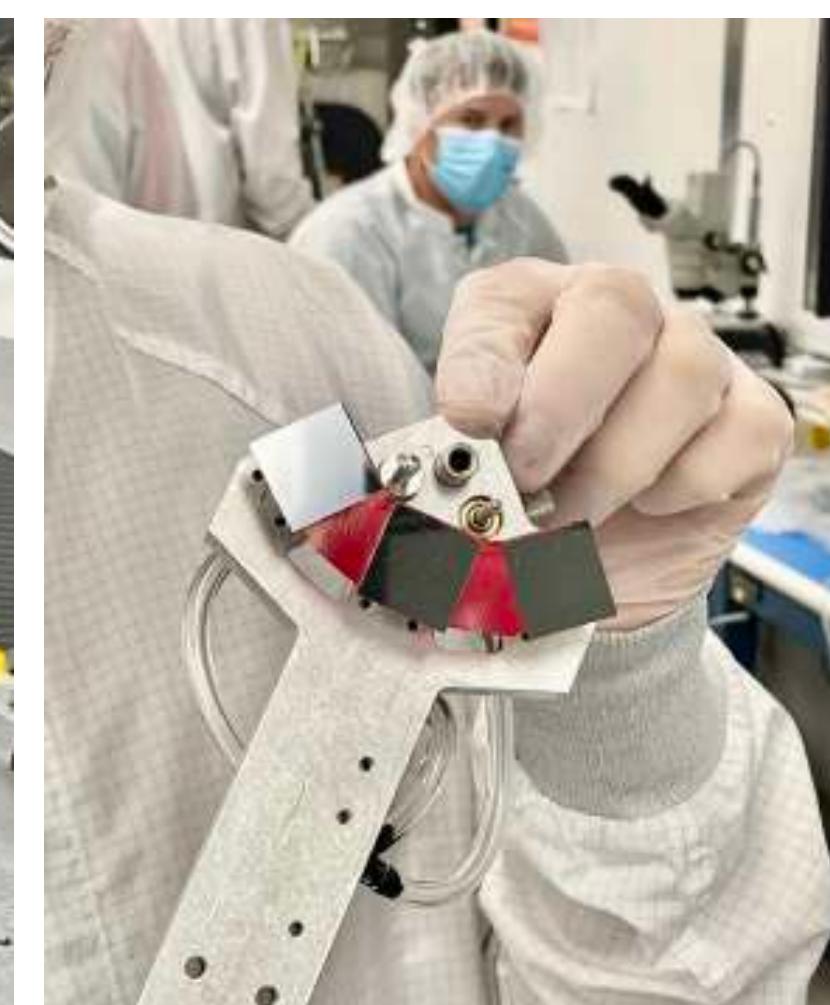
sMDT geometry measurements



HGTD testbeam at DESY



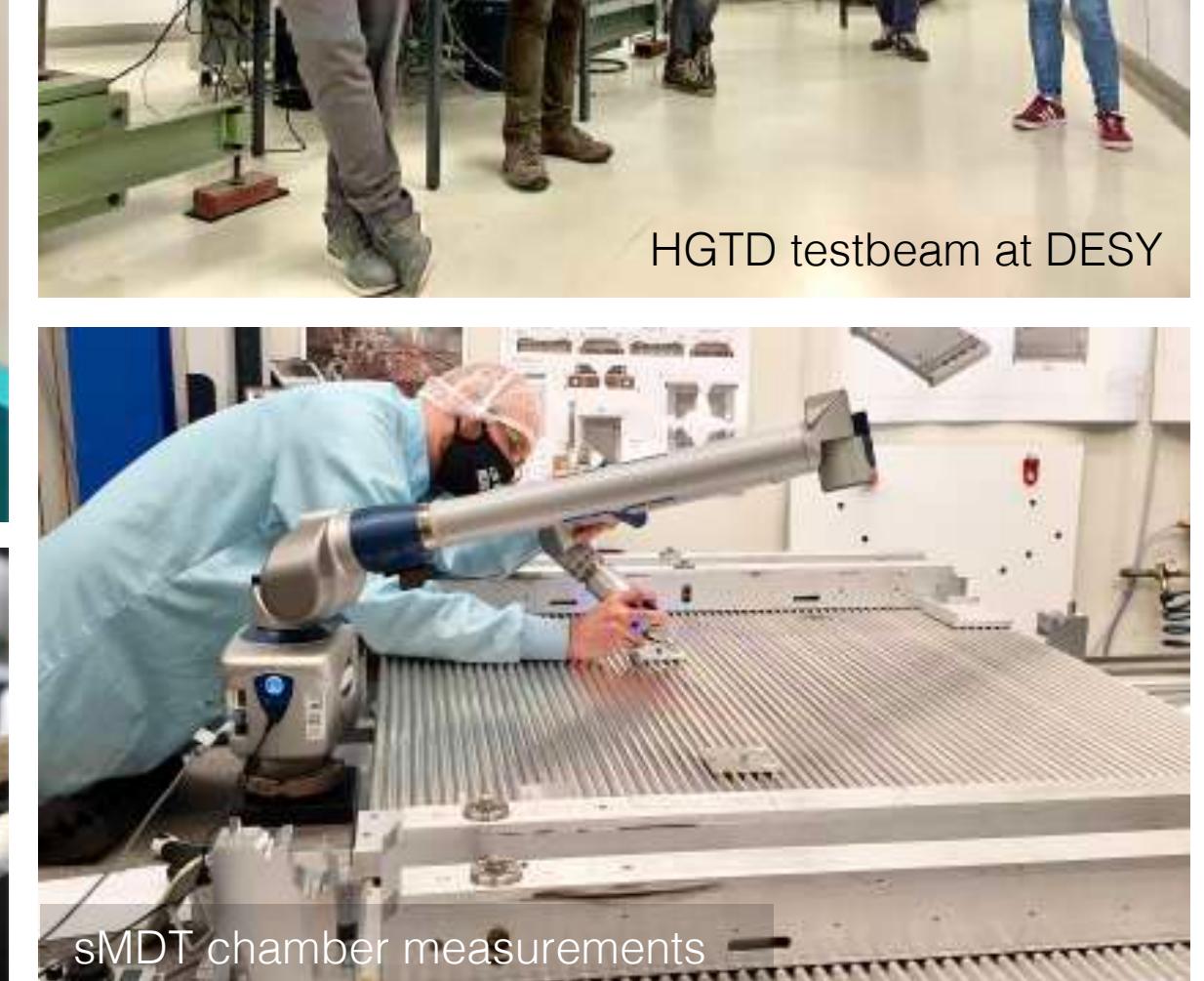
ITk Pixel Inner System ring with modules



Pixel bare module probing ...



... and module metrology



sMDT chamber measurements

71 parallel session talks and 59 posters presented by members of the ATLAS Collaboration at this conference

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[G] Projected sensitivity of Higgs boson pair production combining the bbyy and bbtauau decay channels at the HL-LHC with the ATLAS detector | Abstract 06 Jul 2022 Janice Andree Pearce SLAC Higgs & Diboson searches Poster

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[G] Search for heavy resonances decaying into a Z or W boson and a Higgs boson in final states with leptons and b-jets | Abstract 06 Jul 2022 Tong Qiu London QMUL Higgs & Diboson searches Poster

[G] Search for new physics in multi-body invariant masses in dijet events with an isolated lepton using sqrt(s)=13 TeV proton-proton | Abstract 06 Jul 2022 Huan Yu Meng Toronto

Conclusions

- Many results under production with the run-2 dataset
 - 30 new results released for this conference
 - Standard Model measurements over a wide range of phase space
 - reaching 5-10% constraints on main Higgs boson coupling
 - wide program for BSM physics search
- Run-3 is starting now
 - expect to collect a large dataset until 2025, ~double of run-2 dataset
- Very significant effort to prepare detector upgrades for HL-LHC
 - precision measurement of Higgs boson, rare decays and sensitivity to HH production
 - and many other measurements and searches