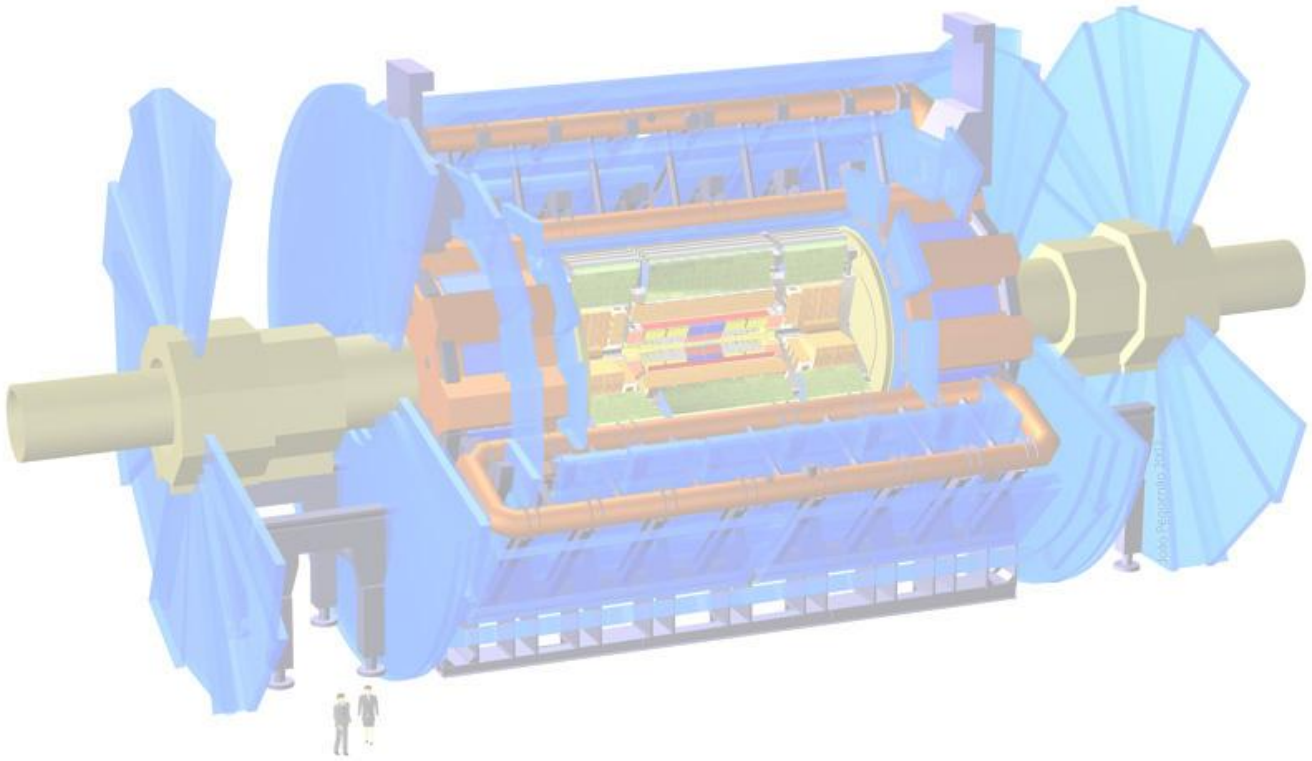
ATLAS highlights

92nd PRC meeting

Xingguo Li, on behalf of the DESY-ATLAS group
Hamburg, Nov 3-4, 2021



HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

ATLAS group (as the COVID-19 era continues)

DESY ATLAS group outing 2021

Overview of Group Activities

Leadership roles in many areas

Detector operation, tools and software

- Operation, monitoring and calibration of current silicon detector (SCT)
- Luminosity measurement

Detector upgrade - ITk

- Design, test and assembly of future detector

Physics Object performance & reconstruction

- Identification and calibration of jets, b-jets, electrons and photons
- Tracking for current and upgraded detector

Software and Computing

- Coordination of distributed computing
- Monte Carlo software and production

Data analysis

- From SM precision measurements to Dark Matter searches
- involvement in several analyses, relying on detector and object expertise

New ATLAS physics results

Since May 2021

The group is involved in many analyses, new public results in many sectors since the last PRC:

Standard Model:

- Observation of the electroweak production of $Z\gamma$ pair with two jets
- Measurement of 4 top-quark production including both one and two opposite sign leptons and multilepton channels

Beyond the Standard Model:

- Top-philic heavy resonance searches in four-top quark events
- Summary of constraints on dark matter in a two-Higgs-doublet model (2HDM) with a pseudoscalar mediator
- Search for Z(→ll)H(→invisible) and Z(→ll)+Dark Matter

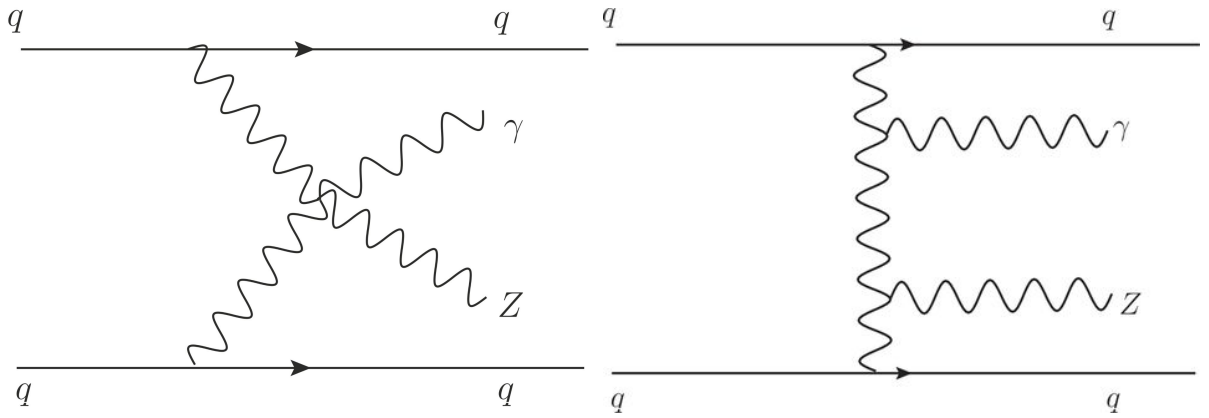
Observation of the electroweak production of Zγ pair with two jets

Observation of Vector Boson Scattering (VBS) Z(ll)γ

Motivation

ATLAS-CONF-2021-038

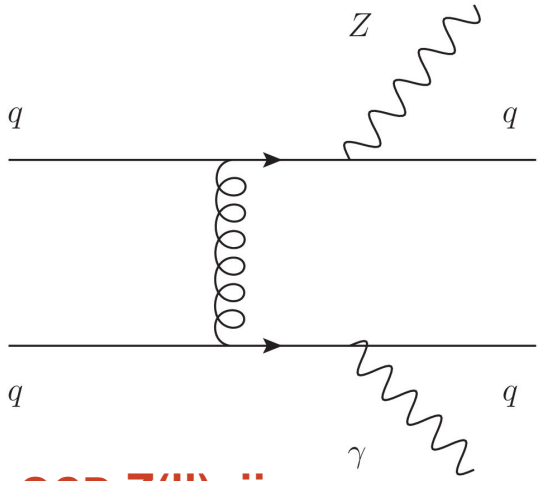
- Directly probe the **electroweak symmetry breaking** sector of Standard Model (SM) in the highest energy domain
- Sensitive to the neutral **quartic gauge couplings**
- Any deviations from the SM predictions are indications of new physics



VBS Z(ll)γjj

Signatures:

- Typically two jets present, one in the forward direction and the other in the backward direction
- **Large rapidity gap** between the two jets
- The **vector bosons** are **centrally** produced



QCD Z(ll)γjj

Observation of Vector Boson Scattering (VBS) Z(ll)γ

Analysis strategy

Selecting VBS Z(ll)γ

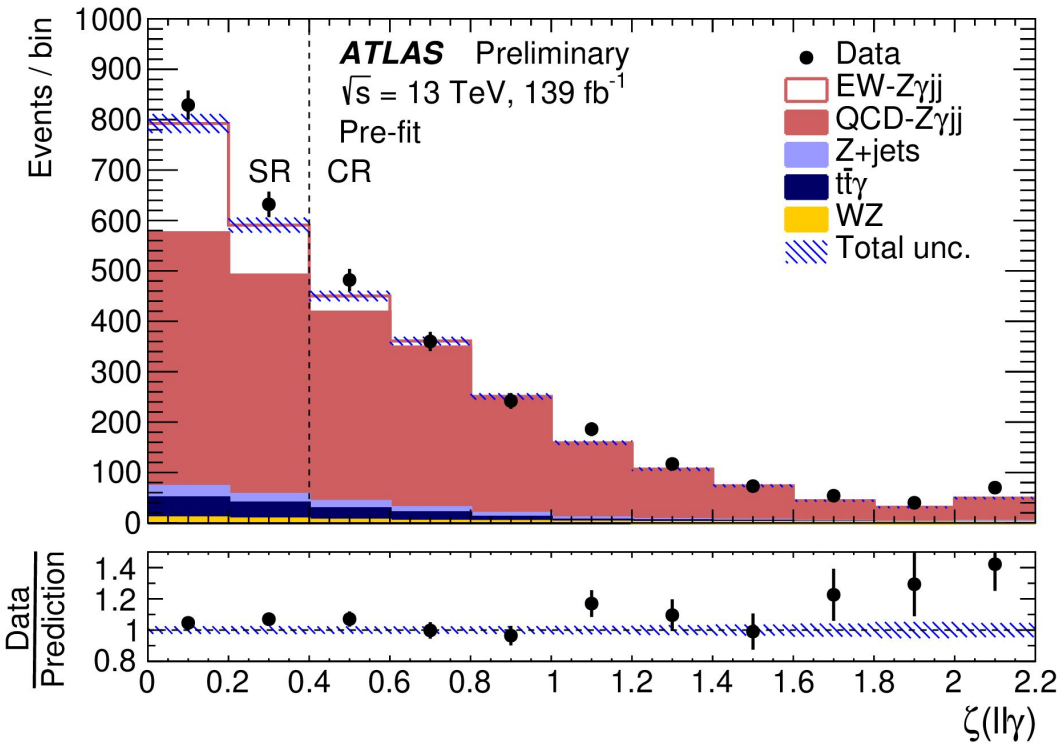
- $m_{ll\gamma}$ > 182 GeV to suppress photon final state radiations from leptons
- Large rapidity gap between the two leading jets $|\Delta y|>1$, m_{jj} > 150 GeV
- Vector bosons are centrally produced $\xi(ll\gamma)< 0.4$

QCD background Z(ll)γjj dominates:

- **Control region** selected using same selection as signal region except **$\xi(ll\gamma)>0.4$**
- Shape is estimated from simulation
- Normalisation is determined simultaneously from signal and control regions

$$\xi(ll\gamma)=|(y_{ll\gamma} - (y_{j1}+y_{j2})/2) /(y_{j1}-y_{j2})|$$

j1 (j2) are leading (sub-leading) jets

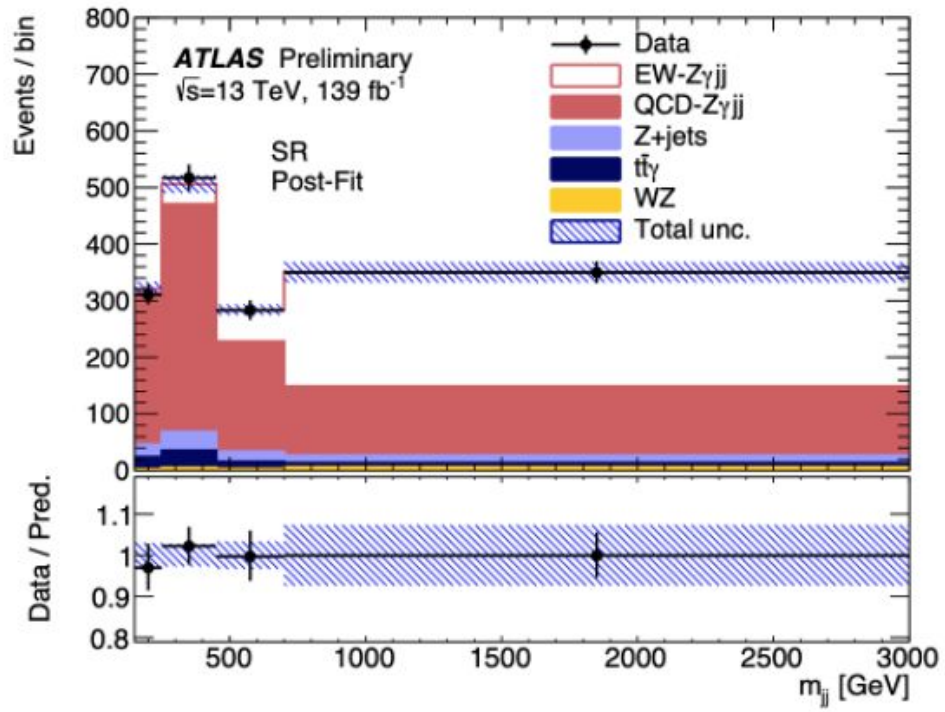


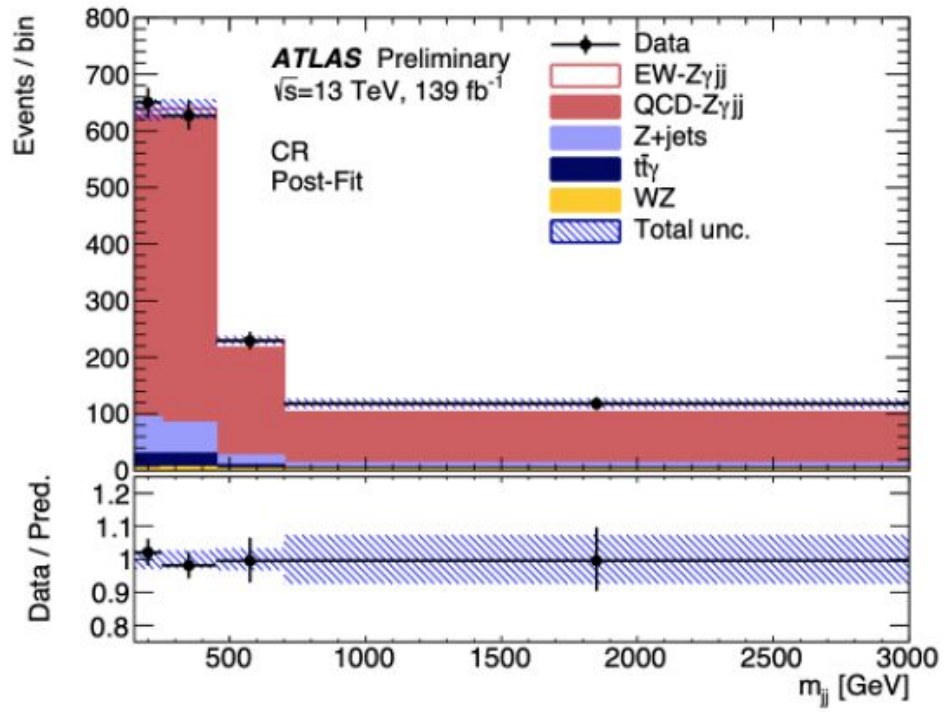
Observation of Vector Boson Scattering (VBS) Z(ll)γ

Results

Observation of VBS Z(ll)γ

- **Measured σ(VBS Zγjj) = 4.49 ± 0.40 (stat.) ± 0.42 (syst.) fb in agreement with SM predictions 4.47 ± 0.01 (stat.) ± 0.15 (PDF)$^{+0.23}_{-0.22}$ (scale)**
  - Systematic uncertainty dominated by **modelling of electroweak/QCD Z(ll)γjj** process and jet description





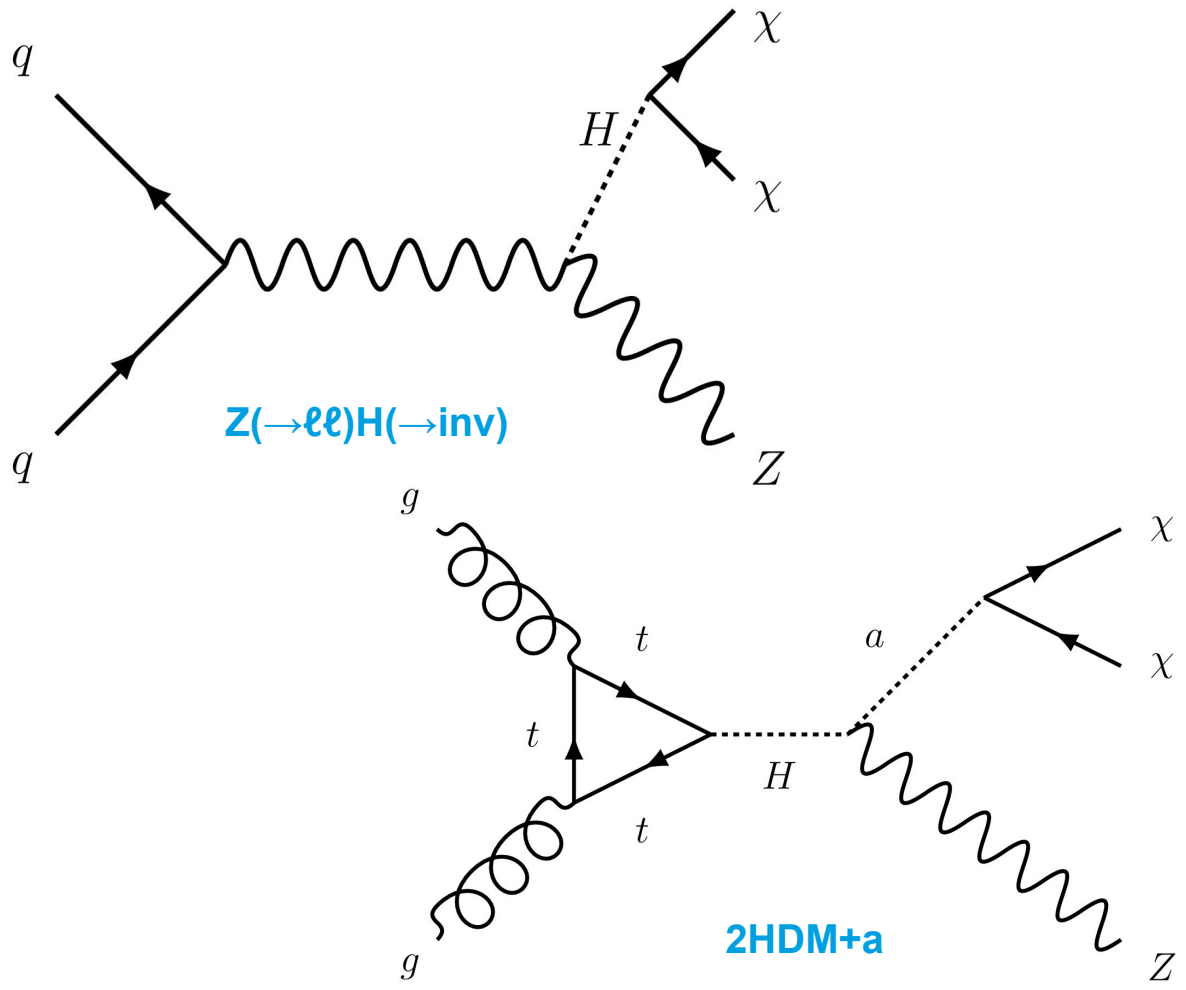
Search for Z(→ℓℓ)H(→inv) and Z(→ℓℓ)+Dark Matter

Search for Z(→ℓℓ)H(→inv) and Z(→ℓℓ)+Dark Matter

Motivation

ATLAS-CONF-2021-029

- One hypothetical set of dark matter candidates is the Weakly Interacting Massive Particles (WIMPs)
- **Complementary sensitivity** to search for dark matter
  - Dark matter can be produced in invisible decays of the Higgs boson in the right mass range, Z(→ll)H(→ inv)
    - Absence of significant excess allows us to constrain H→ invisible
  - Consider simplified dark matter model and two-Higgs-Doublet models plus an additional pseudoscalar mediator a (2HDM+a), Z(→ll)+Dark Matter
- **Distinct** signature in final states with Z→ℓℓ and missing transverse momentum



Search for Z(→ℓℓ)H(→inv) and Z(→ℓℓ)+Dark Matter

ATLAS-CONF-2021-029

Analysis strategy

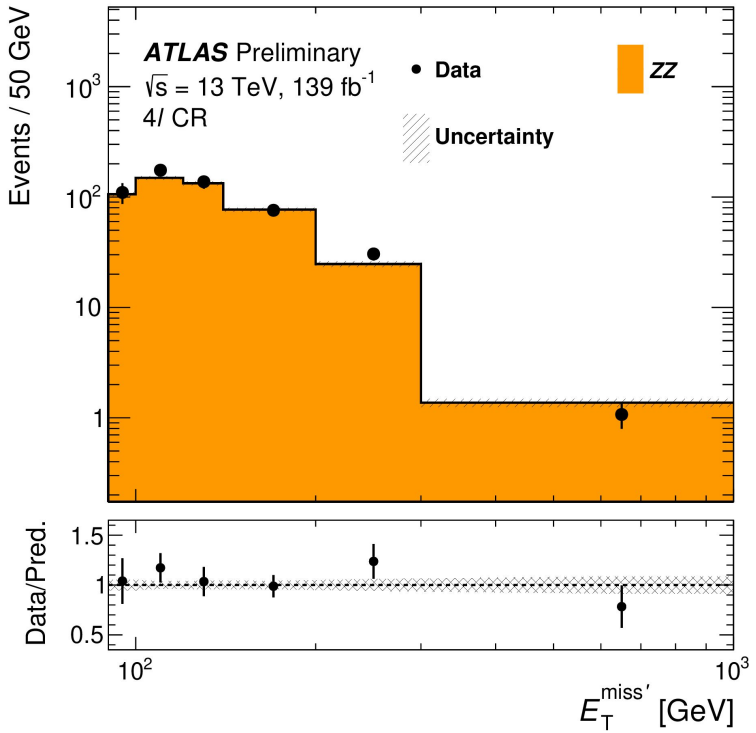
Signal Selection of Z→ℓℓ and missing transverse momentum (MET)

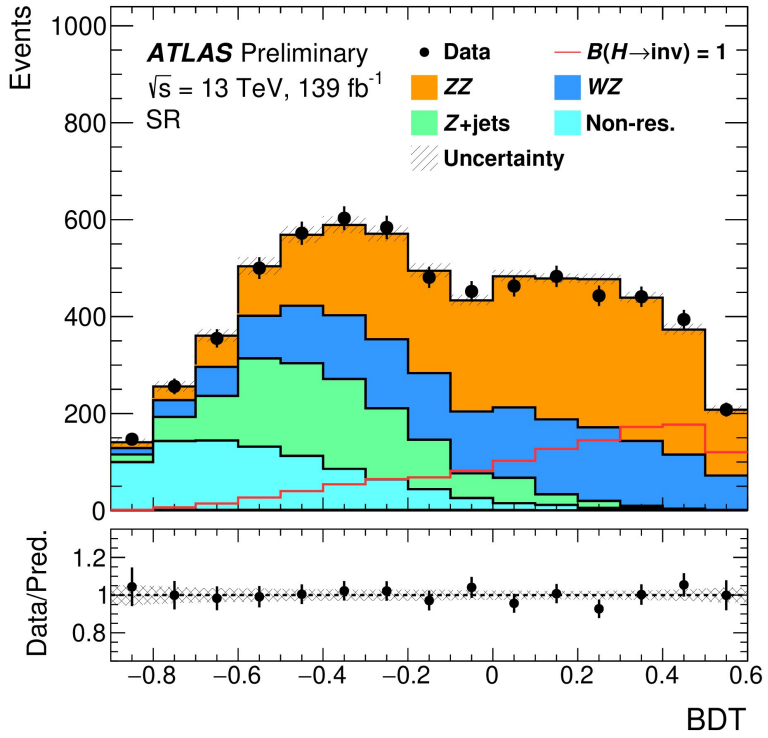
- E_T^{miss} > 90 GeV
- Use a single discriminant to search for signals

SM backgrounds **dominated by ZZ production**, use a control region to constrain this background

- Other backgrounds (**non-resonant**, **WZ**) also determined in control regions

A simultaneous fit in the signal and three background control regions to constrain systematic uncertainty and to determine the background normalisation for a subset of backgrounds





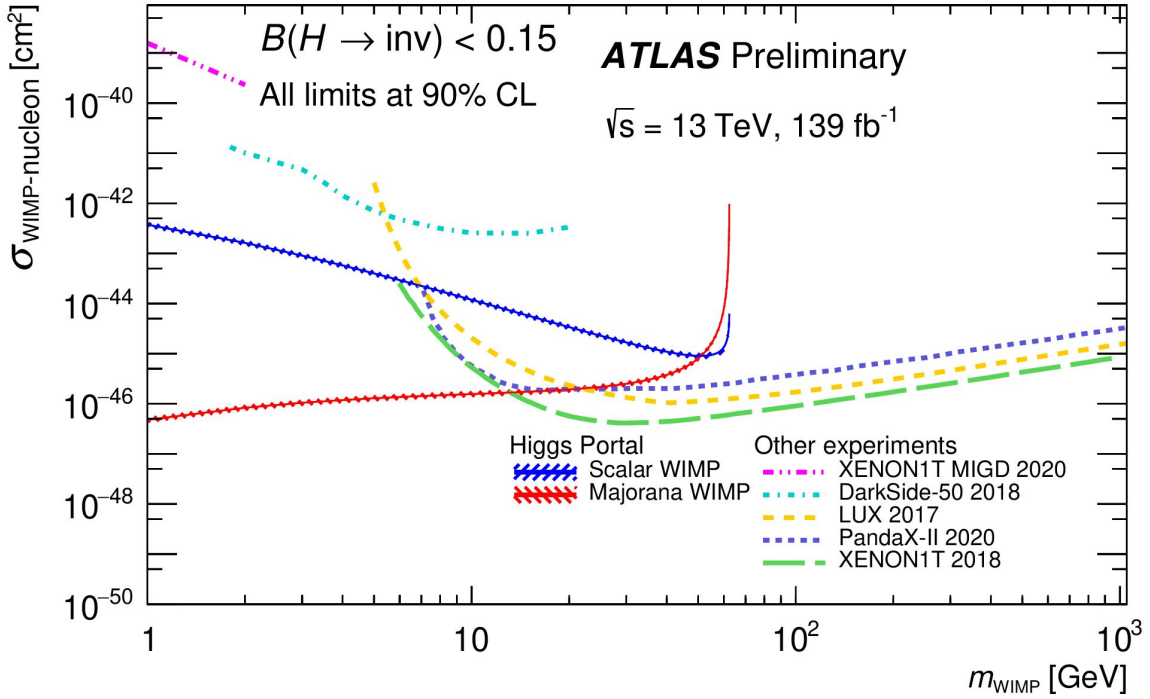
Search for Z(→ℓℓ)H(→inv) and Z(→ℓℓ)+Dark Matter

Results

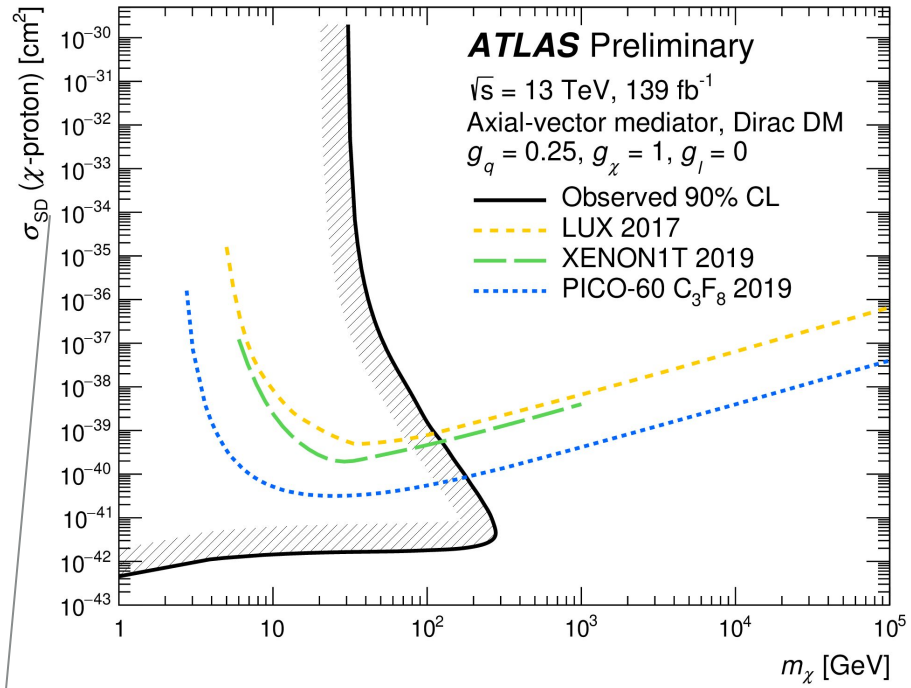
ATLAS-CONF-2021-029

No significant excess over SM is observed (limited by the ZZ modelling uncertainties/Jet, MET description)

- Z(→ll)H(→ inv) Branching ratio limit: < 0.18 (0.18) observed (expected) @ 95% C.L.
- Complementary sensitivity at low dark matter/WIMP masses compared to direct searches



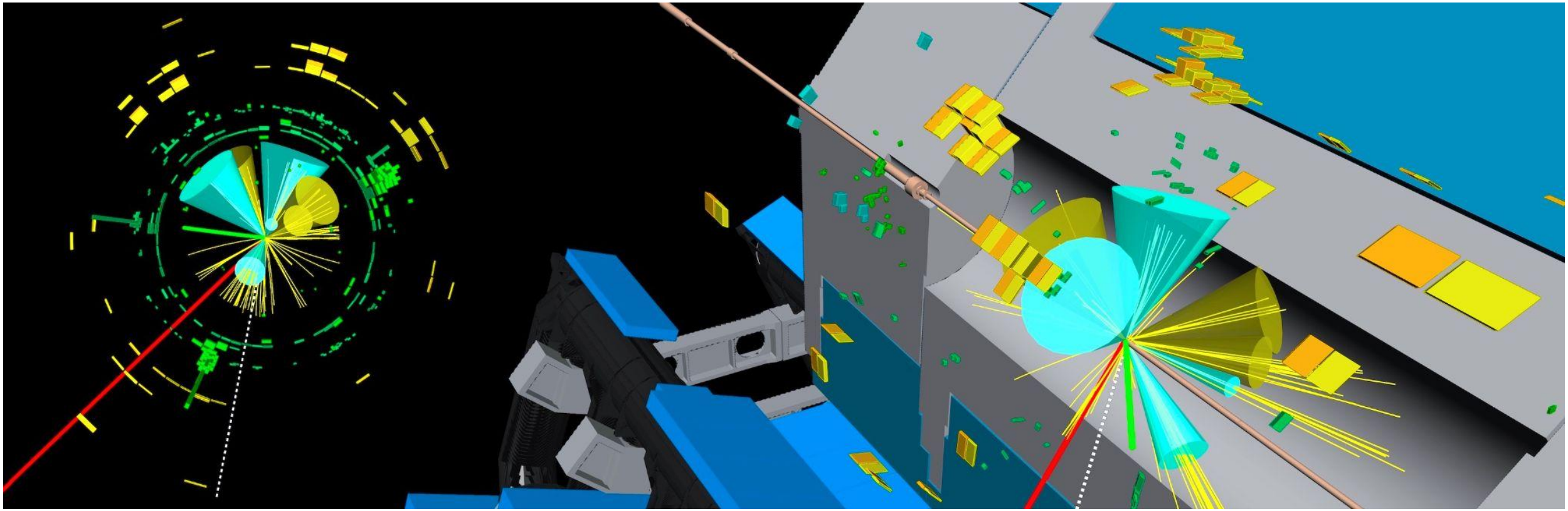
Reinterpretation in Higgs portal model, comparison to direct detection limits



Reinterpretation in dark matter simplified model, comparison to direct detection limits

Axial vector mediator couples to the nucleon spin, Spin Dependent (SD)
Vector mediator coupling increases with nucleon mass, Spin Independent (SI)

Top-philic resonance searches in 4-top quark events

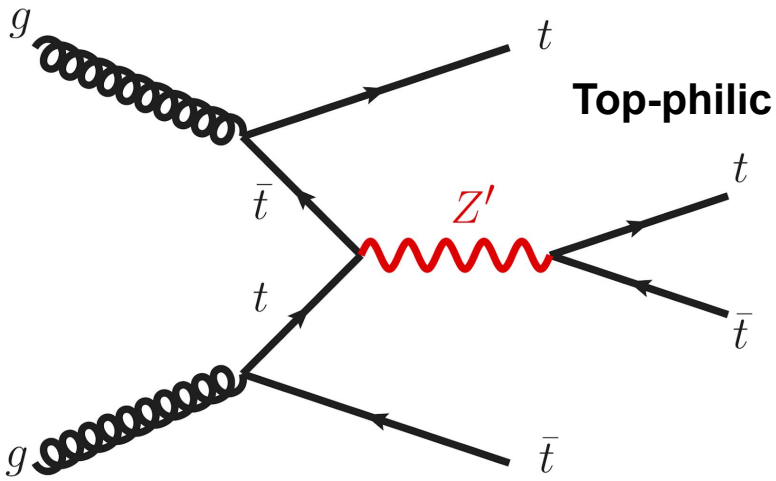


Top-philic heavy resonance searches: 4-top events

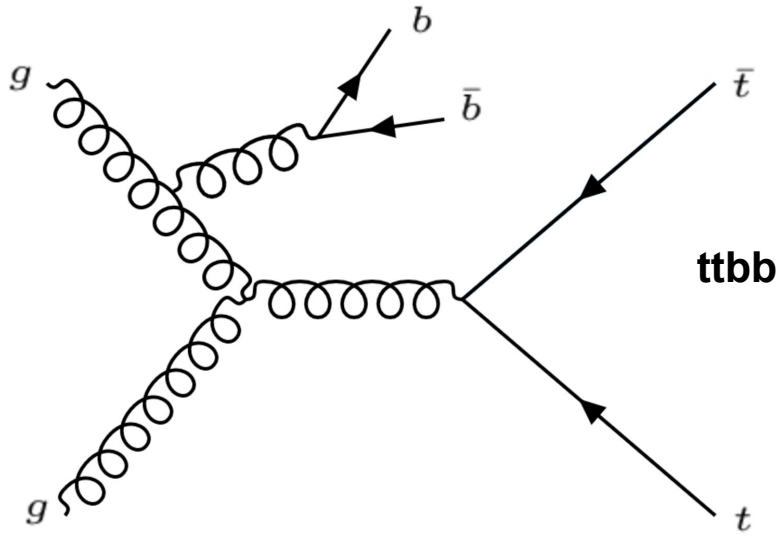
Motivation

ATLAS-CONF-2021-048

- The **heaviest** elementary particle, the top quark, **couples strongest** to the Higgs boson
- The **large top-Higgs coupling i.e., top Yukawa,** motivates many top-quark based resonance searches
- **New top-philic resonances** are predicted in Beyond SM theories such as composite Higgs scenarios
  - Associated production ttZ' is favoured over qqbar annihilation
  - Z' mass from 1 TeV to 3 TeV
- **First search of its kind in the spectacular 4-top final state**



Top-philic resonance

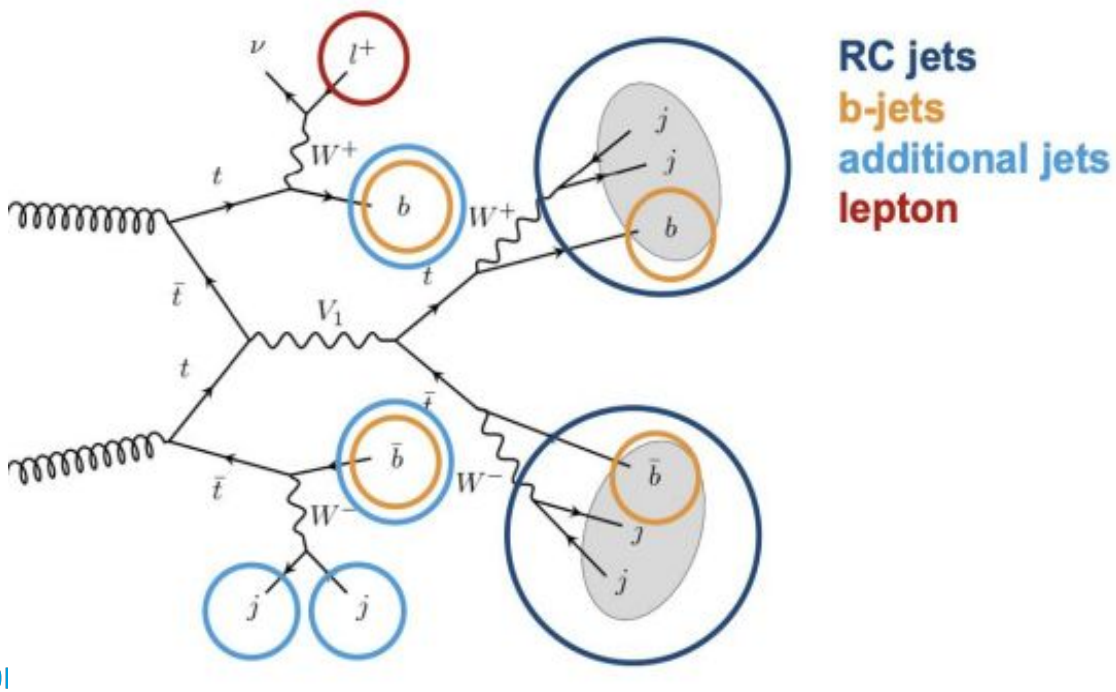


ttbb background

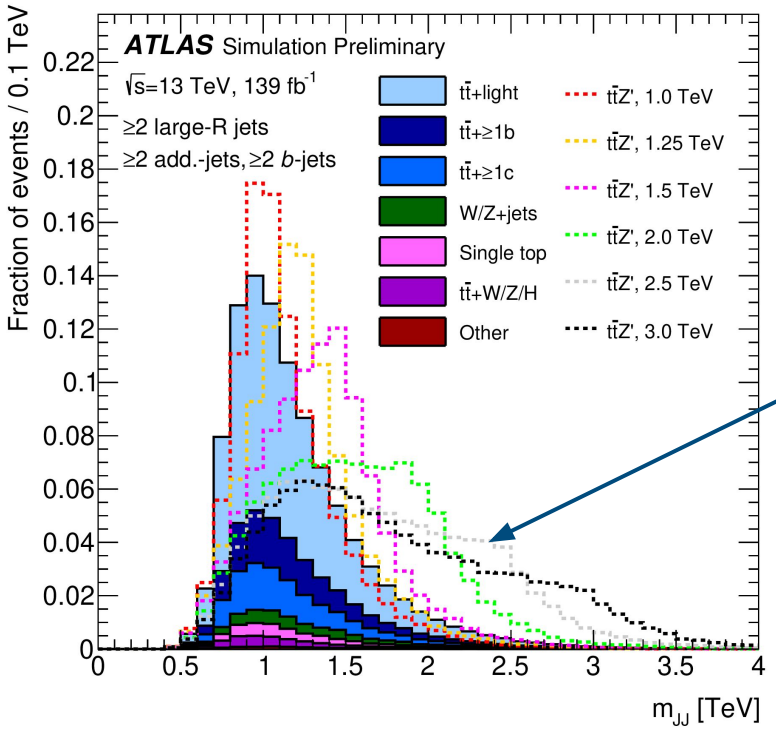
Top-philic heavy resonance searches: 4-top events

Analysis Strategy

- **Targeting** exactly **1 lepton** channel and the resonance decays into boosted hadronic tops
  - ≥ 2 **re-clustered (RC) R=1.0 jets** with p_T>300 GeV
  - ≥ 2 jets outside the RC jets ("**additional jets**")
  - ≥ 2 **b-tagged jets**



- SM backgrounds **dominated** by tt+jets
  - **Data-driven** technique assisted with simulations is developed to overcome the mismodelling of the background



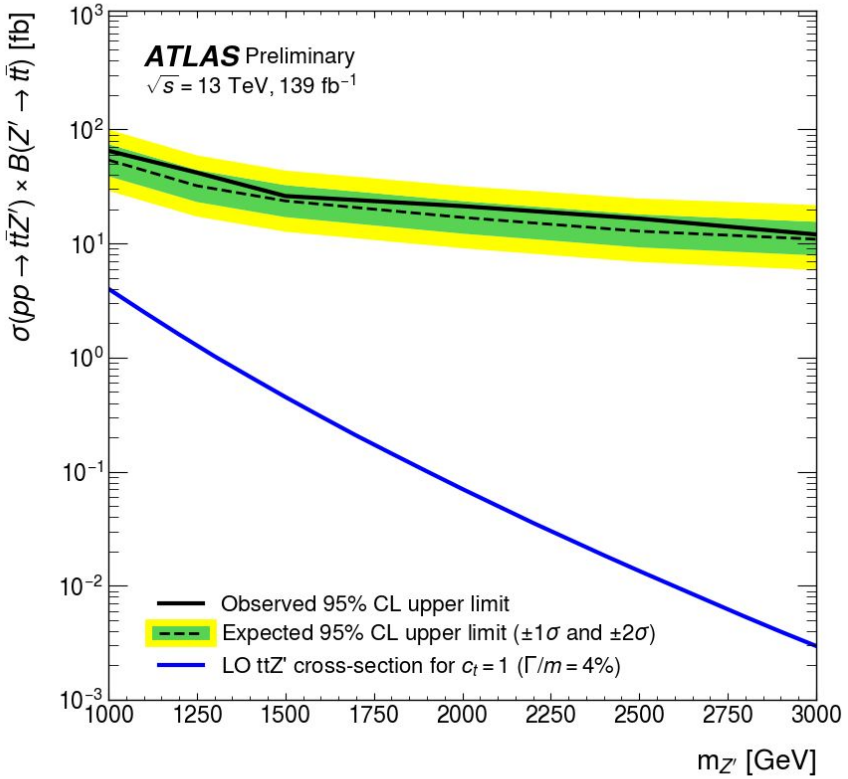
Invariant mass of the two leading RC jets

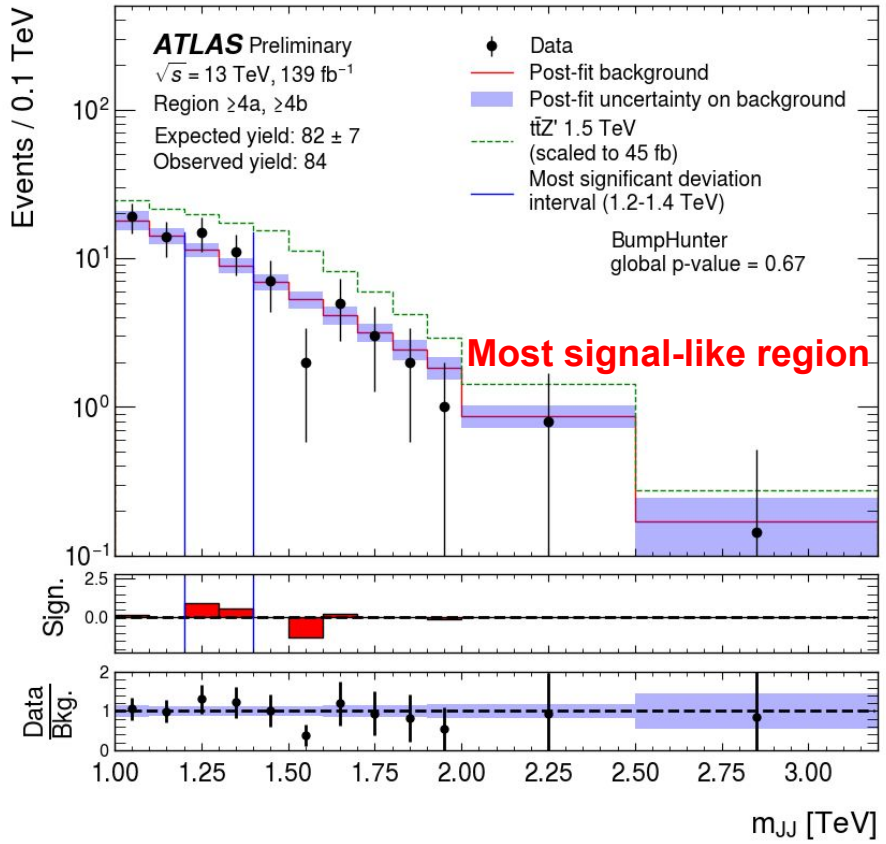
Top-philic heavy resonance searches: 4-top events

Result

Systematic dominated by
tt+jets and signal modellings

- No significant excess over the background expectation
- Observed limits range from 65 fb to 12 fb for Z' masses between 1.0 and 3.0 TeV

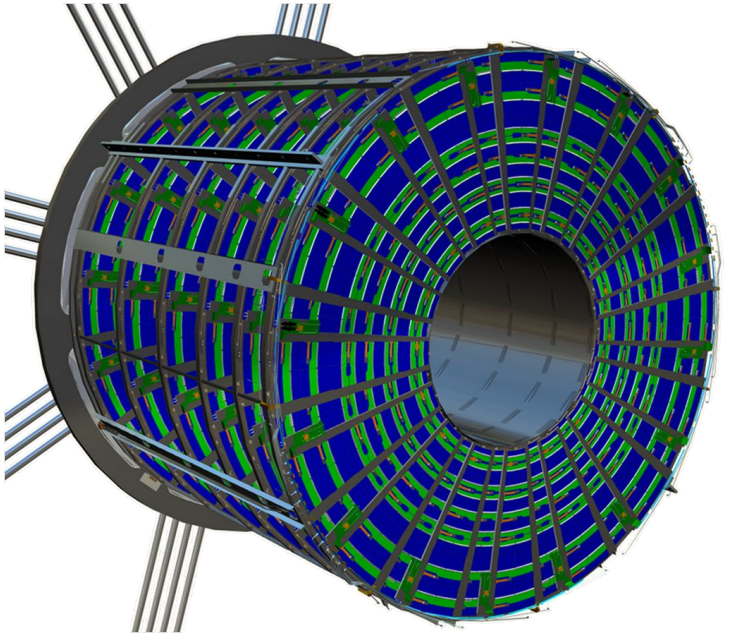




Detector Upgrade Activities

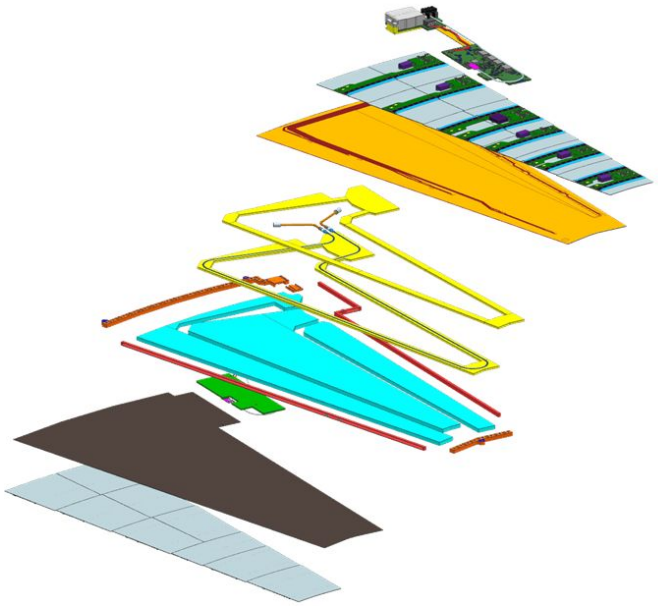
Overview of activities

ATLAS Detector Upgrade - Inner Tracker (ITk) for the HL-LHC



- DESY ATLAS is working on the realisation of one full end-cap of the ITk
- In Germany: Strong collaboration with HU Berlin, TU Dortmund and Uni Freiburg

- **At DESY:**
  - Sensor studies and quality control testing
  - Hybrid quality control
  - Module development, building and testing
  - Petal core development, production and testing
  - Module loading onto petal cores
  - End of substructure (EoS) card
  - Endcap integration at DESY and CERN
  - CO_2 cooling
  - ITk Strip testbeam
  - And many other tasks…

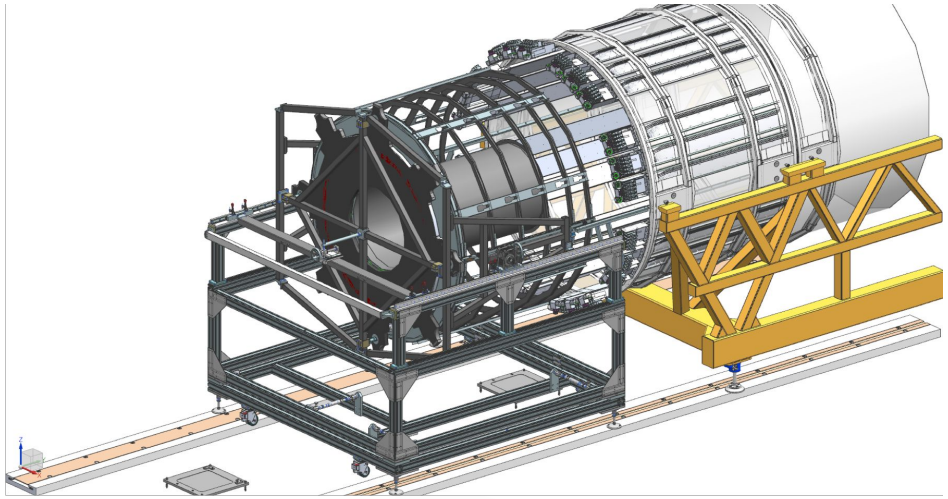


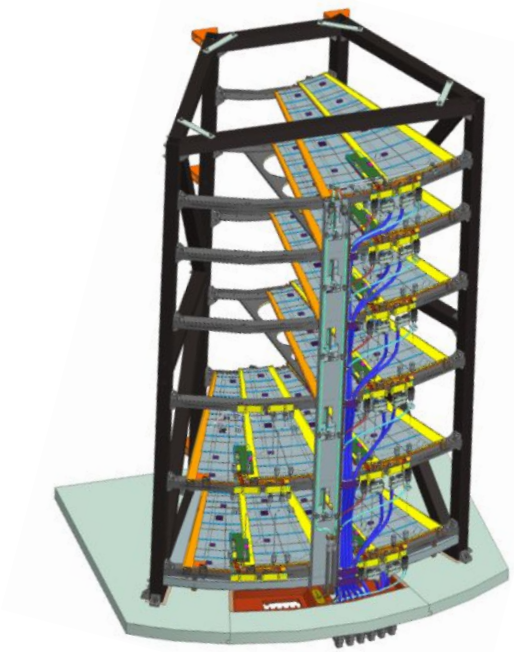
- **Now: Getting ready for the end-cap**
  - Moved from single module production and testing to more complete systems
  - Prepared for site qualification for the ITk module production
  - Tools for integration finalised and will be built now

Increasing the scale

From modules and petals to larger detector structures

- As ITk production approaches, the focus should also shift to **larger scale deliverables and setups**
  - Production of end-cap mechanical structures already started at collaborating institutes (Nikhef)
    - DESY providing structural carbon fiber-based components
  - End-cap integration tools maturing into final design stage
  - End-cap system test: a crucial setup of the ITk end-cap
  - High capacity CO_2 cooling setups near completion at DESY
    - Required for most large scale setups across the collaboration

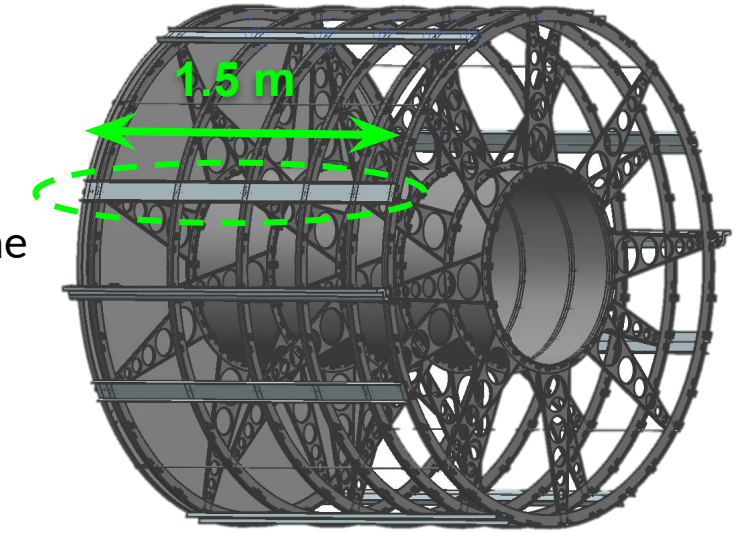




Real thing: Service trays

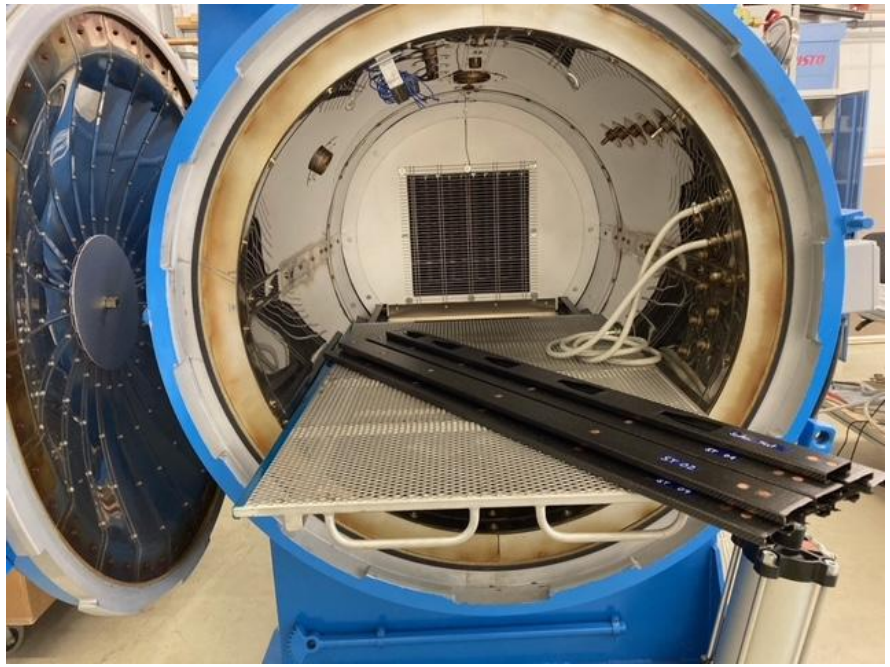
Developed, prototyped and manufactured

- Host cooling and electrical services along the End-cap, add structural stiffness to the End-cap structure
- Electrical link between each End-cap wheel and bulkhead via tray + cooling service
- 16 trays in total (8 per end-cap structure) + an additional tray for system test setup (see next slides)



All 17 service trays have already been co-cured at DESY autoclave

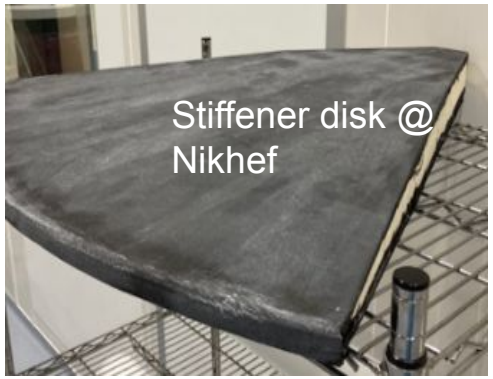
First **production deliverable** produced at DESY!

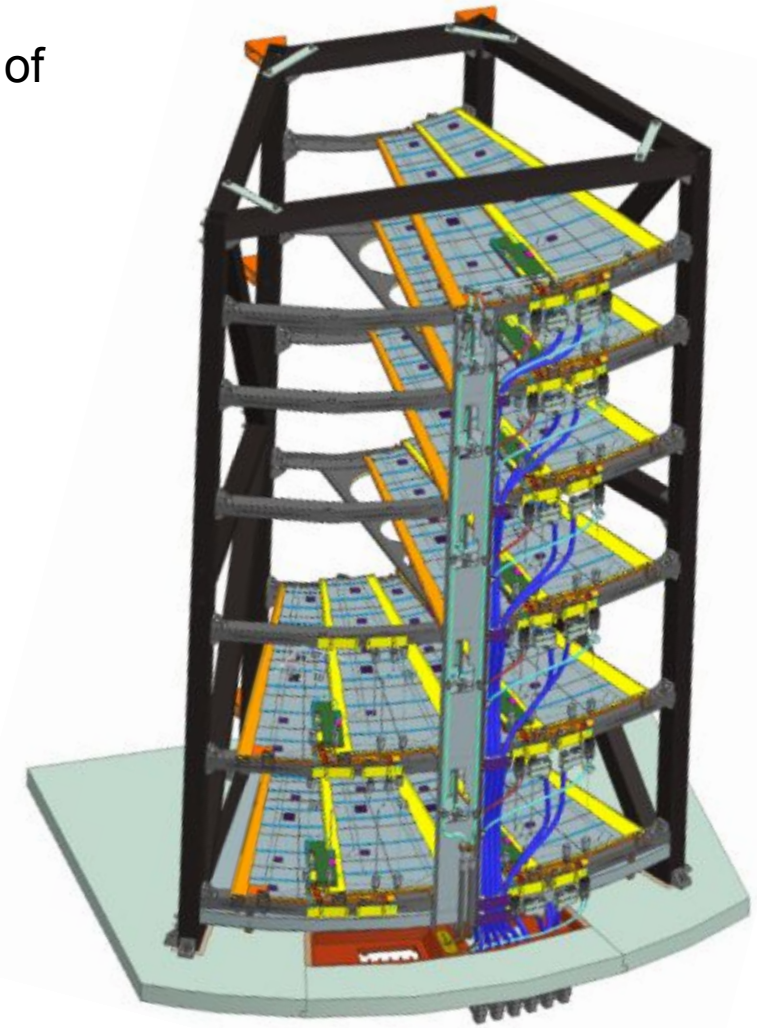


End-cap system test

Design and production of setup

- System test will consists of up to 12 petals mounted into a 1/8th slice of the End-cap
  - realistic test environment to study electrical performance of petals
  - will be located at DESY and moved afterwards to CERN for full strips system test
- Status of system test structure
  - overall design completed, first parts currently under construction
  - very close collaboration between all End-cap institutes -> important for end-cap assembly and segment tests

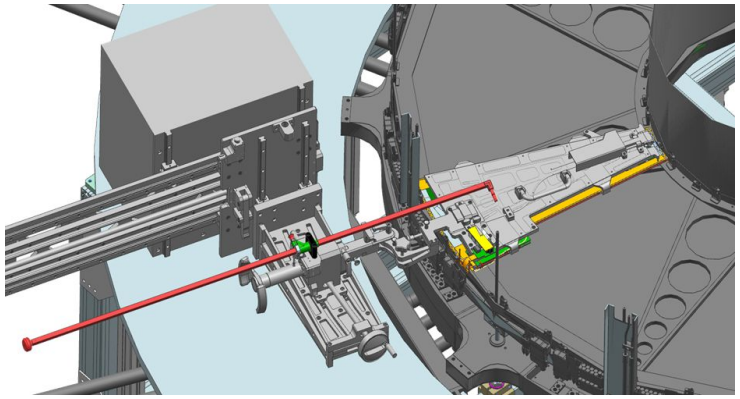




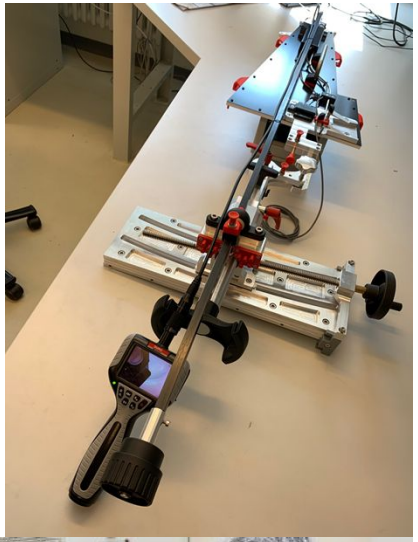
End-cap Integration

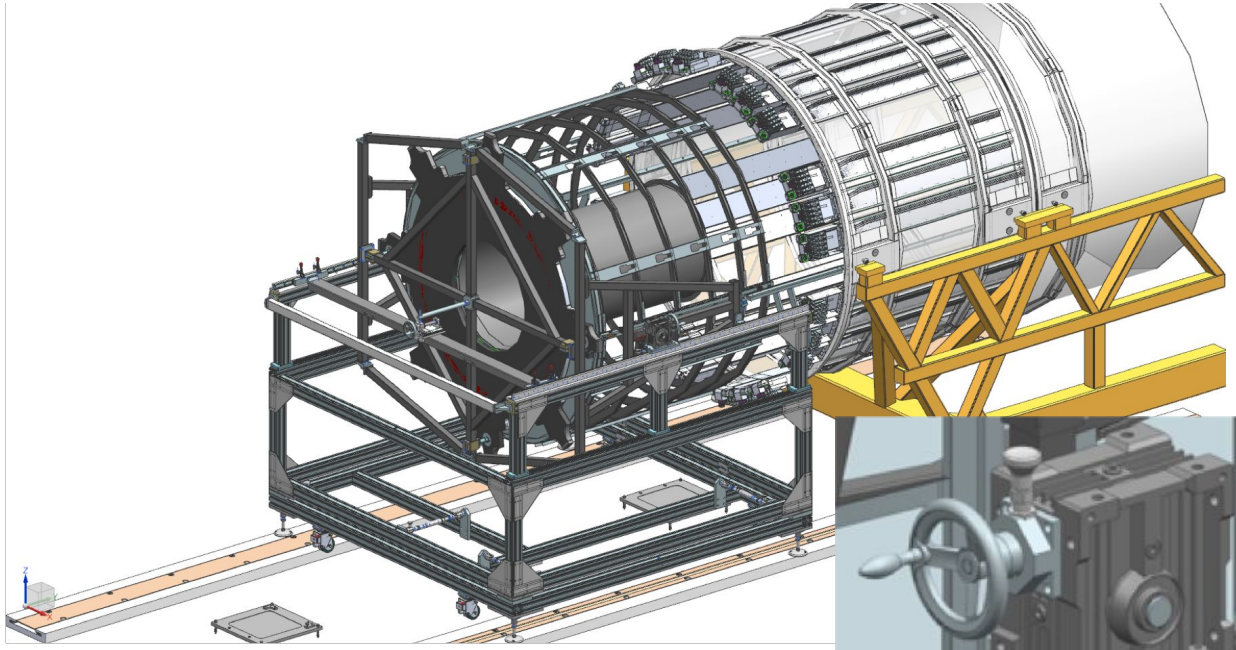
Getting tools ready for assembling the end-cap

- Super-frame: holding end-caps during transport, petal insertion, installation of fully instrumented endcaps into ITk at CERN
- Received go-ahead for construction after review, pending final design details
- Petal insertion successfully demonstrated and passed review successfully

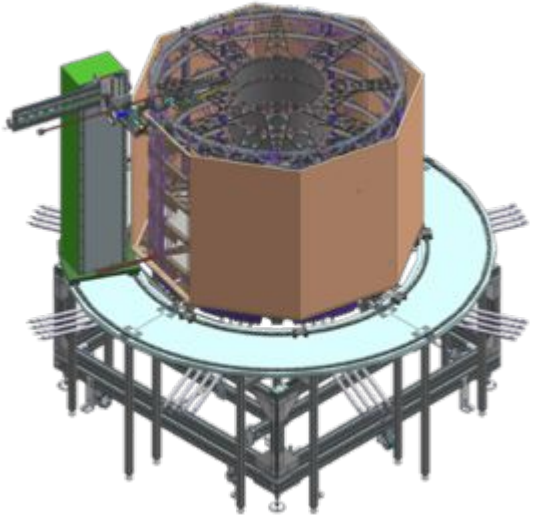


Petal insertion tool tested with end-cap mock-up





End-cap installation at CERN using super-frame



Petal insertion at DESY using insertion tool and super-frame

Worm-gear for end-cap rotation.

CO_2 Cooling Systems

Four copies of a high performance cooling machine

CO_2 cooling systems for system test and end-cap segment testing are being worked on/with:

- **LUCASZ**: Manufacturing of four cooling machines (CERN, DESY, Nikhef, INFN)
  - one machine **commissioned at CERN**
  - second one in process at DESY
  - Nikhef and INFN machines will be commissioned at DESY before the end of the year

Assembly of LUCASZ machines

First LUCASZ at CERN

Conclusion

Summary

- ATLAS DESY group continues to play an important role in ATLAS detector operation, ITk project, computing, simulation, measurements and searches for new phenomena
- New public results in many sectors with a strong DESY contribution released since last PRC
- ATLAS highlights presented today illustrating:
  - Leading roles in Run 2 physics measurements and searches covering a wide range of physics
  - Excellent progress towards constructing an ITk strip end-cap for HL-LHC