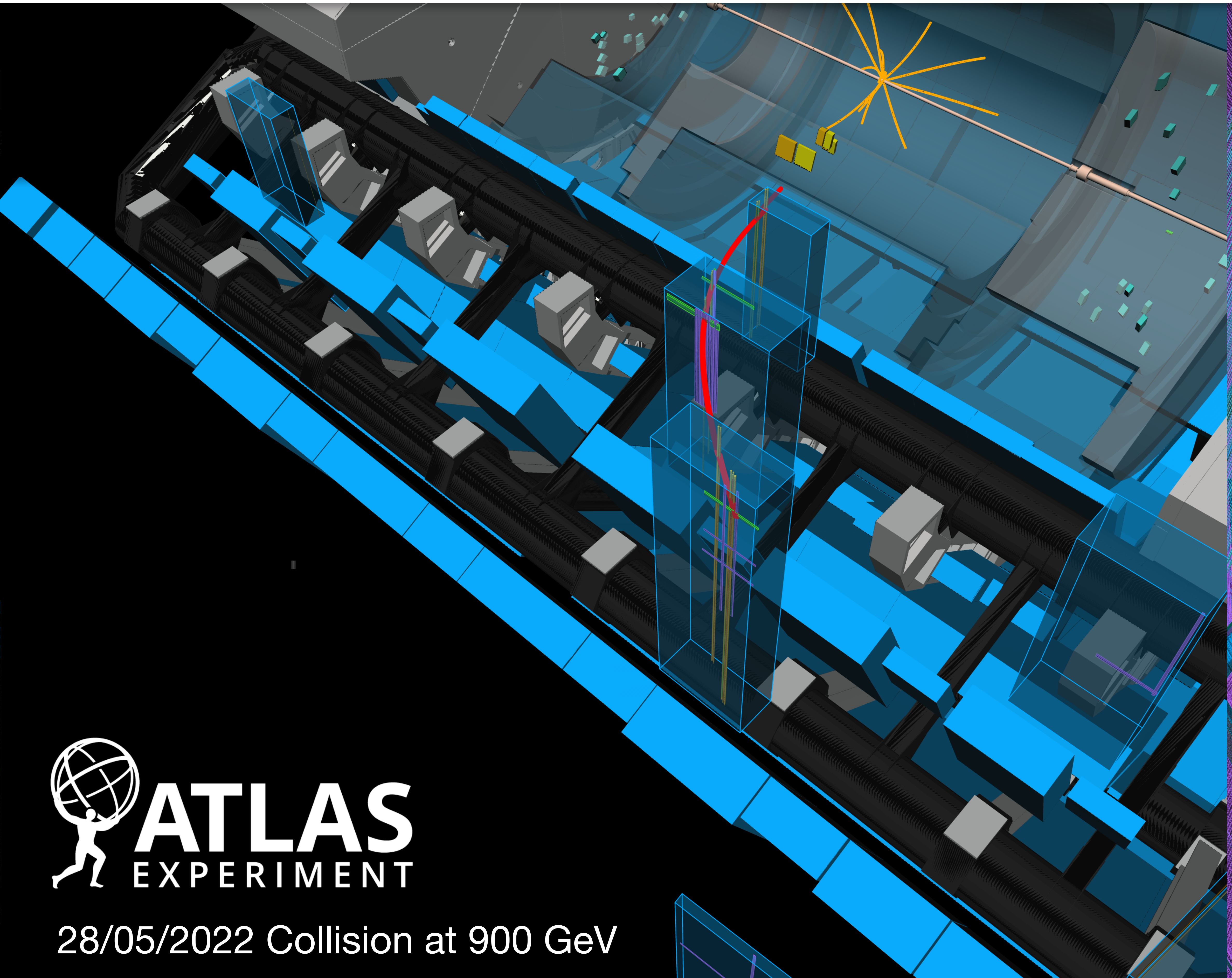
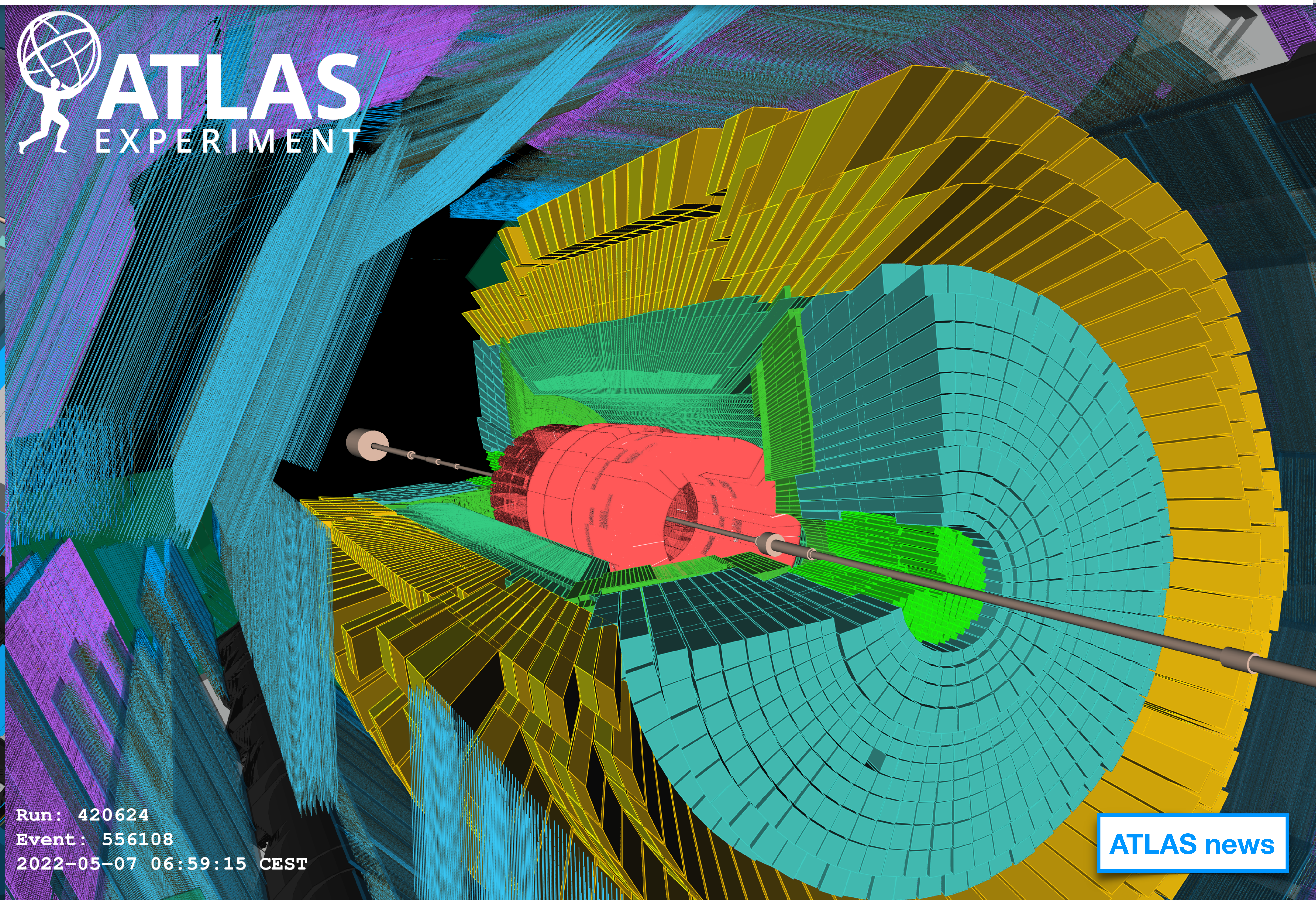
ATLAS Status and Overview - Highlights

HEP 2022 - 39th Conference on Recent Developments in High Energy Physics and Cosmology - 15-18 June, 2022
Thessaloniki, Greece

Marumi Kado
On Behalf of the **ATLAS Collaboration**
Università di Roma, Sapienza, CERN and IJCLab (Orsay)





Outline and Disclaimer

The HEP 2021 talk covered

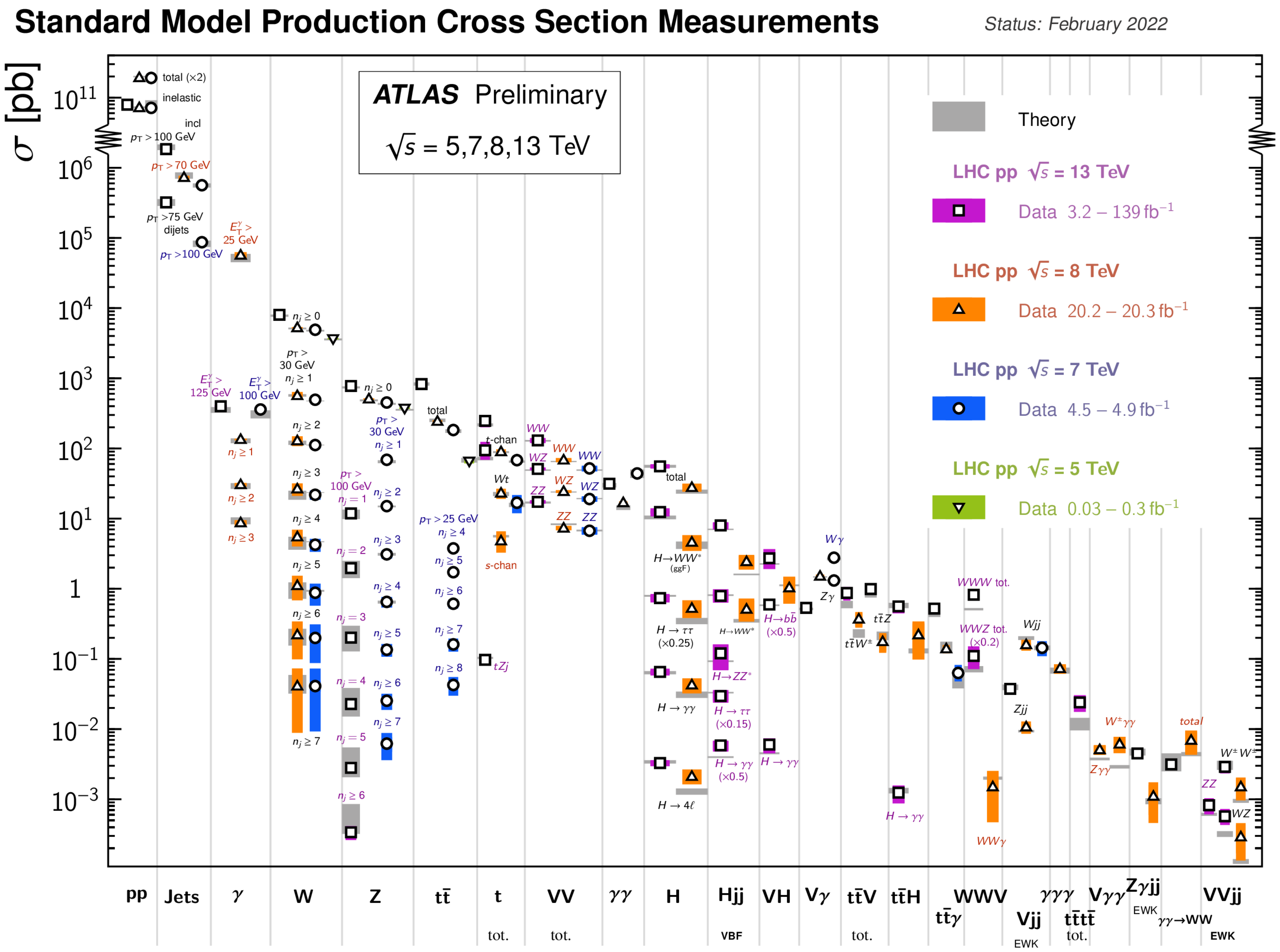
- HL-LHC perspectives

  Snowmass 2021

- Review of results from the LHC Run 2

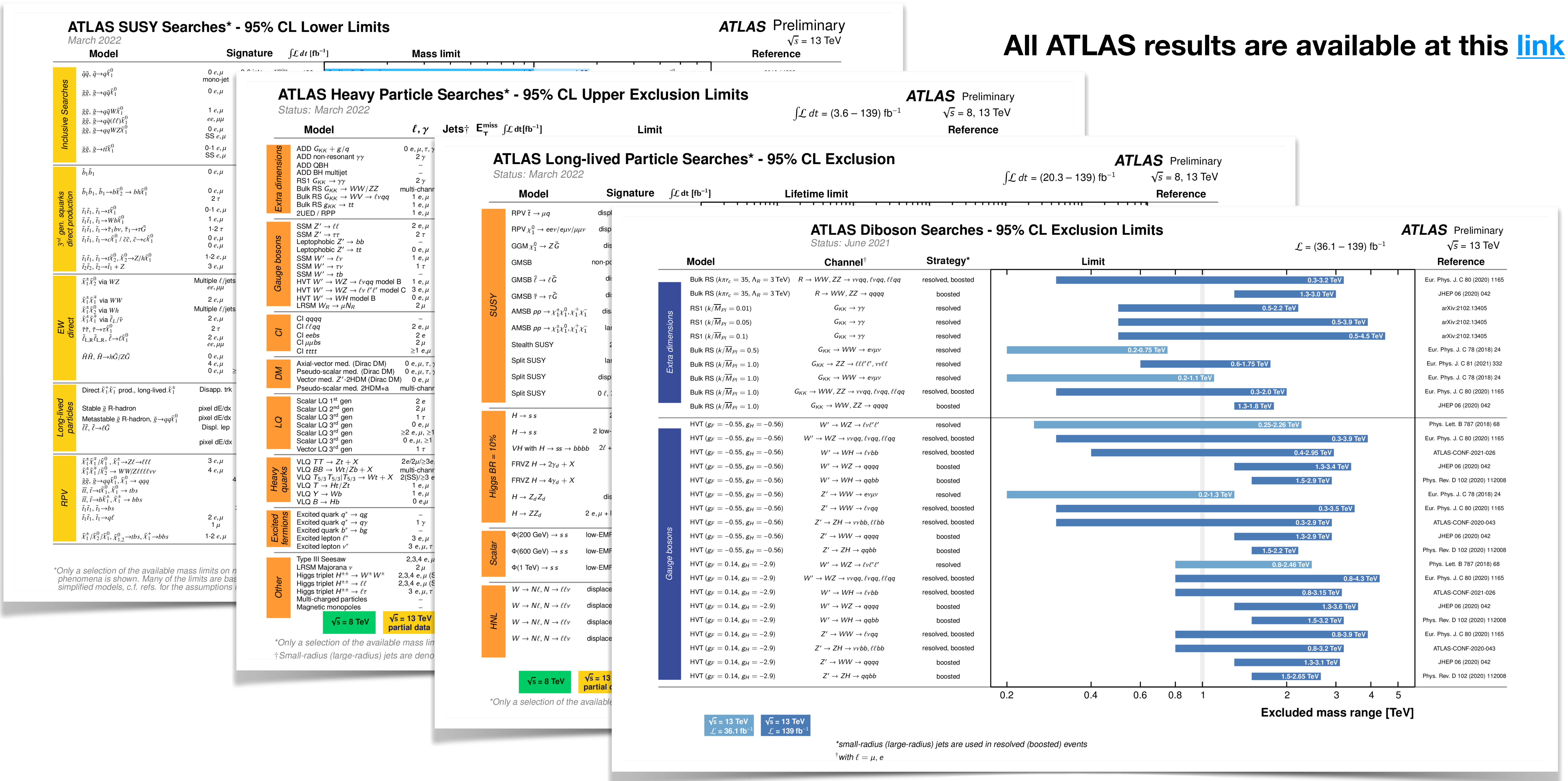
HEP 2022 talk

- Selected recent highlights
- Non exhaustive list! O(60) papers and O(50) conference notes since HEP 2021



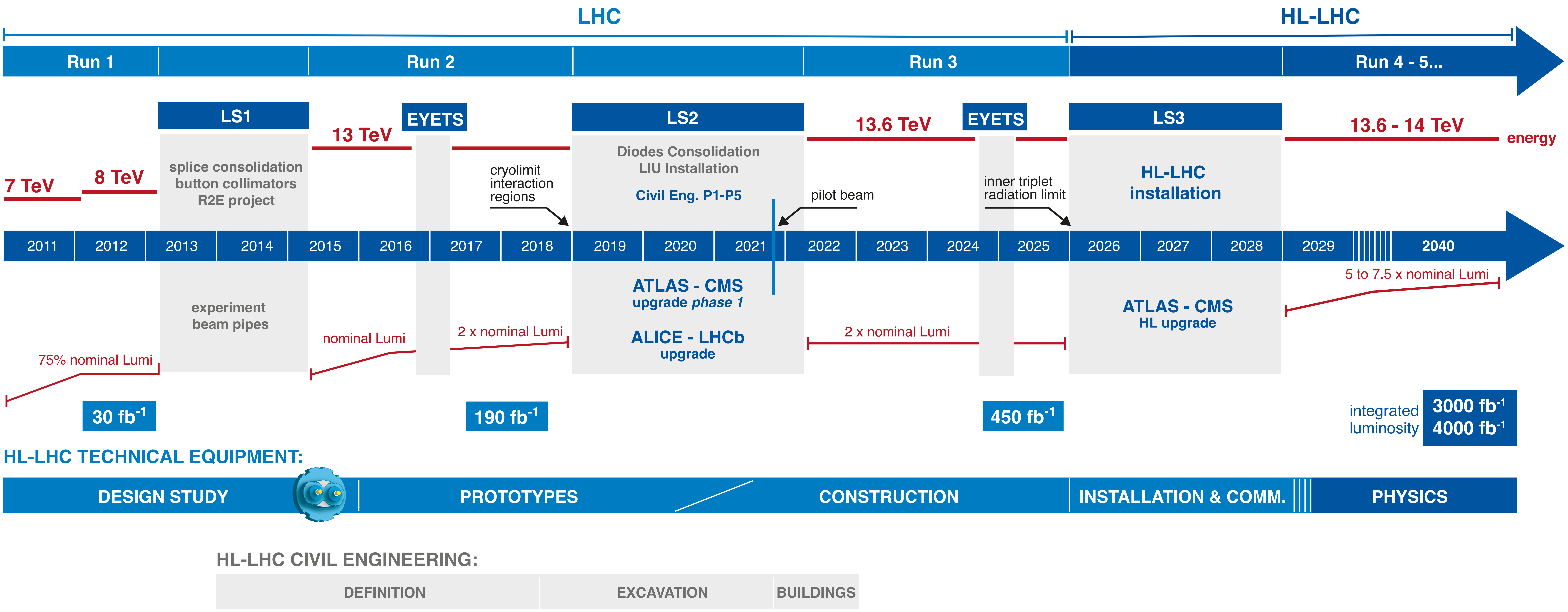
Still leaving no stones unturned!

All ATLAS results are available at this link

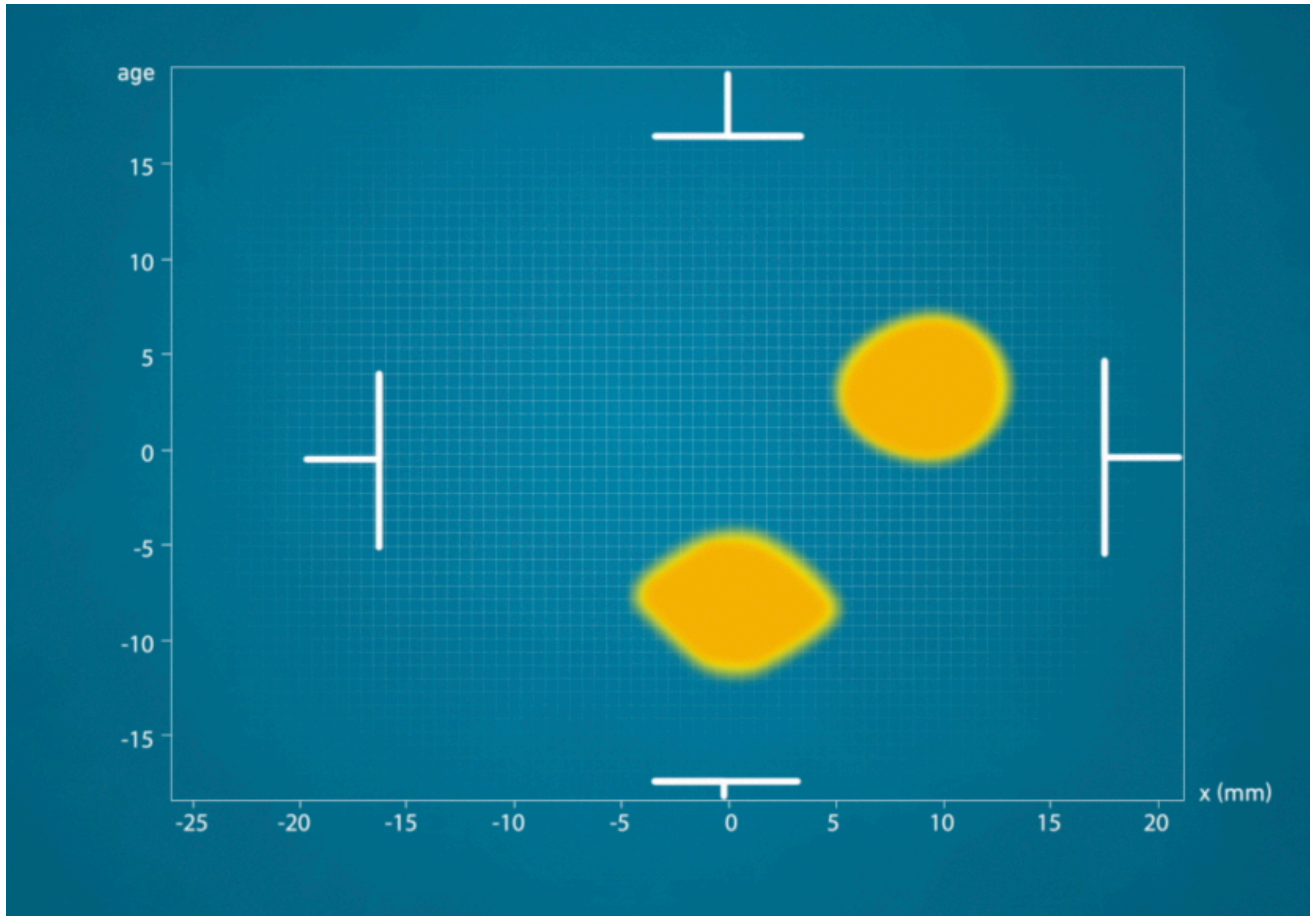


LHC and HL-LHC Schedule Update

LHC / HL-LHC Plan



Staying Tuned to ATLAS News and Results



Exciting times: start of Run 3!

CERN News (22 April 2022) on LHC restart.

ATLAS summaries from major conferences available here:

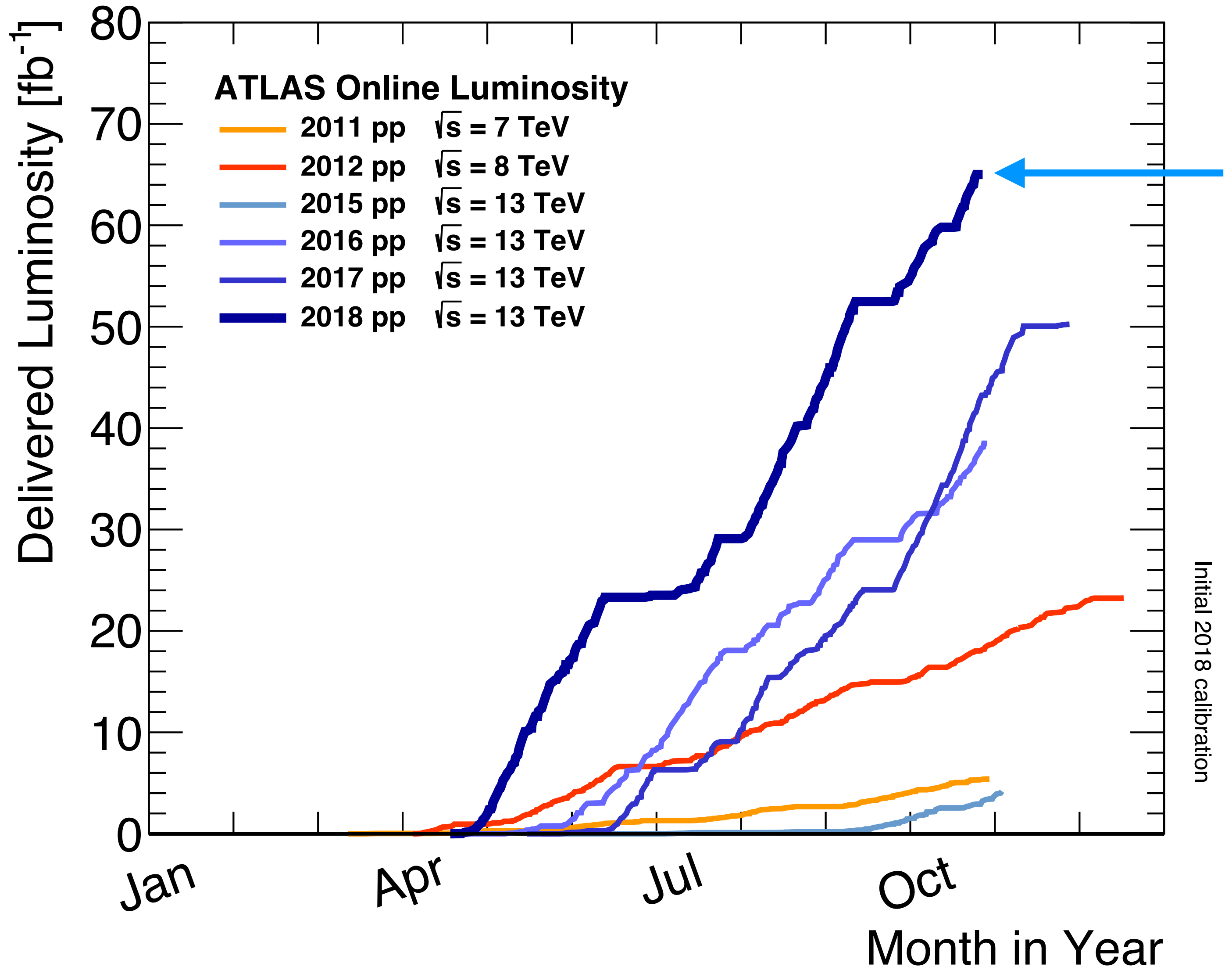
- LHCP 2022 summary
- Moriond 2022 summary and highlights
- Lepton-Photon 2021 summary
- EPS-HEP 2021 summary and highlights

Higgs 10 symposium at CERN

- Check and bookmark our news page
- Follow us on social media (click on the logos)

The ATLAS LHC Run 2 datasets

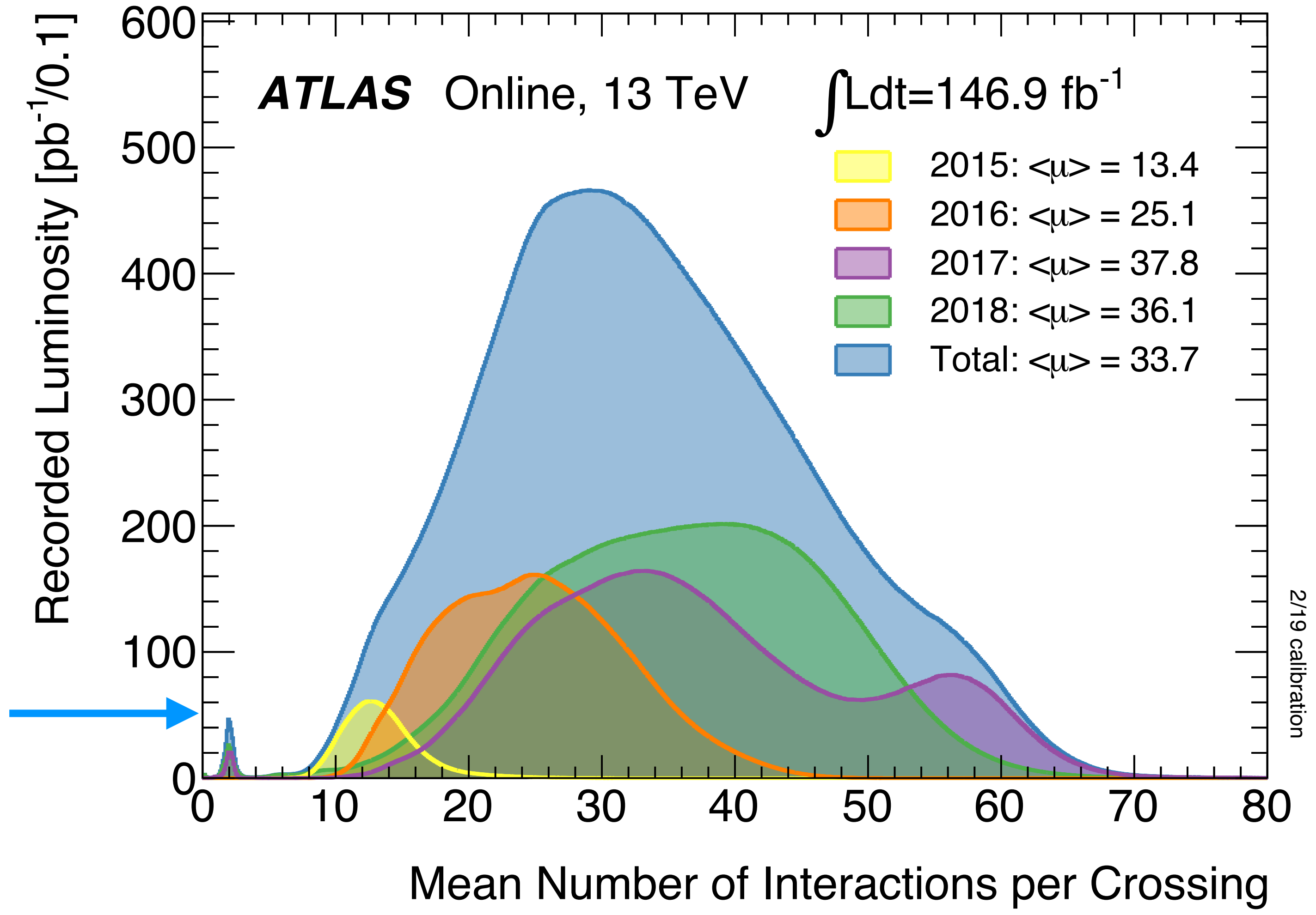
The LHC pp operations



Record year in 2018! More than 60 fb^{-1} collected

PU profile for the LHC Run 2

Special low mu runs for precision EW measurements



Run 2 dataset

pp 13 TeV 2015-2018 - **139 fb^{-1}** with 94% data taking efficiency and 95% data quality efficiency

(8M Higgs, 300M top quarks, 8B Z's, 30B W's)

Rich Heavy Ions datasets

- 2018 and 2015 **PbPb** at 5.02 TeV - 1.82 nb^{-1}
- 2017 **XeXe** at 5.44 TeV - 3 μb^{-1}
- 2016 **pPb** at 8.16 TeV - 165 nb^{-1}

Low PU pp references (but much more) collected in 2017

- 5.02 TeV - 0.26 fb^{-1}
- 13 TeV - 0.15 fb^{-1}

Well calibrated datasets for a vast, diverse and thrilling physics program!

ATLAS Performance at Run 2

- **Trigger**: Main trigger thresholds have been stable throughout Run 1 and Run 2 despite the higher PU conditions and CM energy

Signature	Run 1	Run 2
Single e (isolated)	25 GeV	27 GeV
Single photon	120 GeV	140 GeV
HT	700 GeV	700 GeV
MET	150 GeV	200 GeV

- **Reconstruction and particle identification:** Excellent and Pile Up (PU) resilient reconstruction performance

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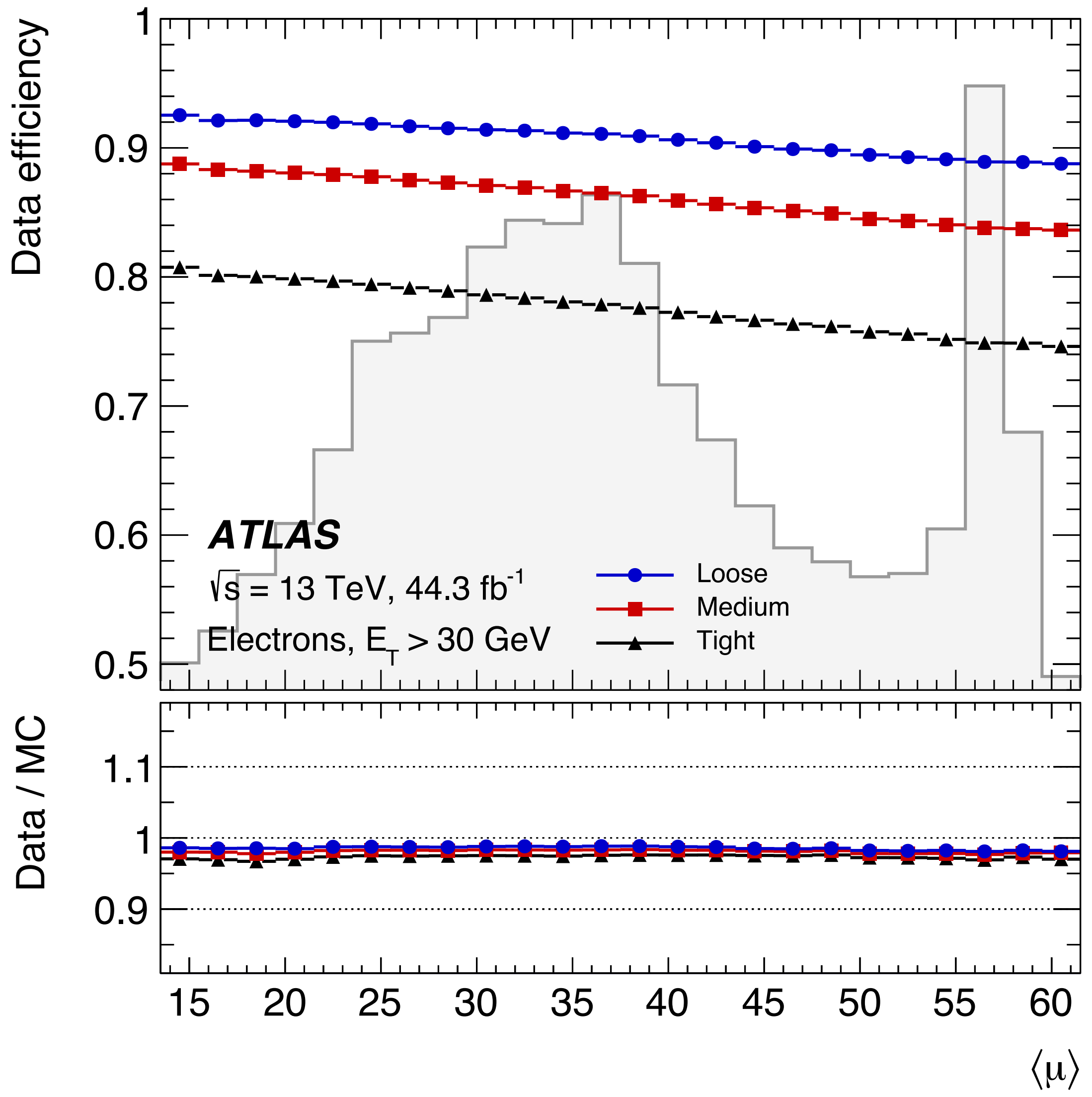
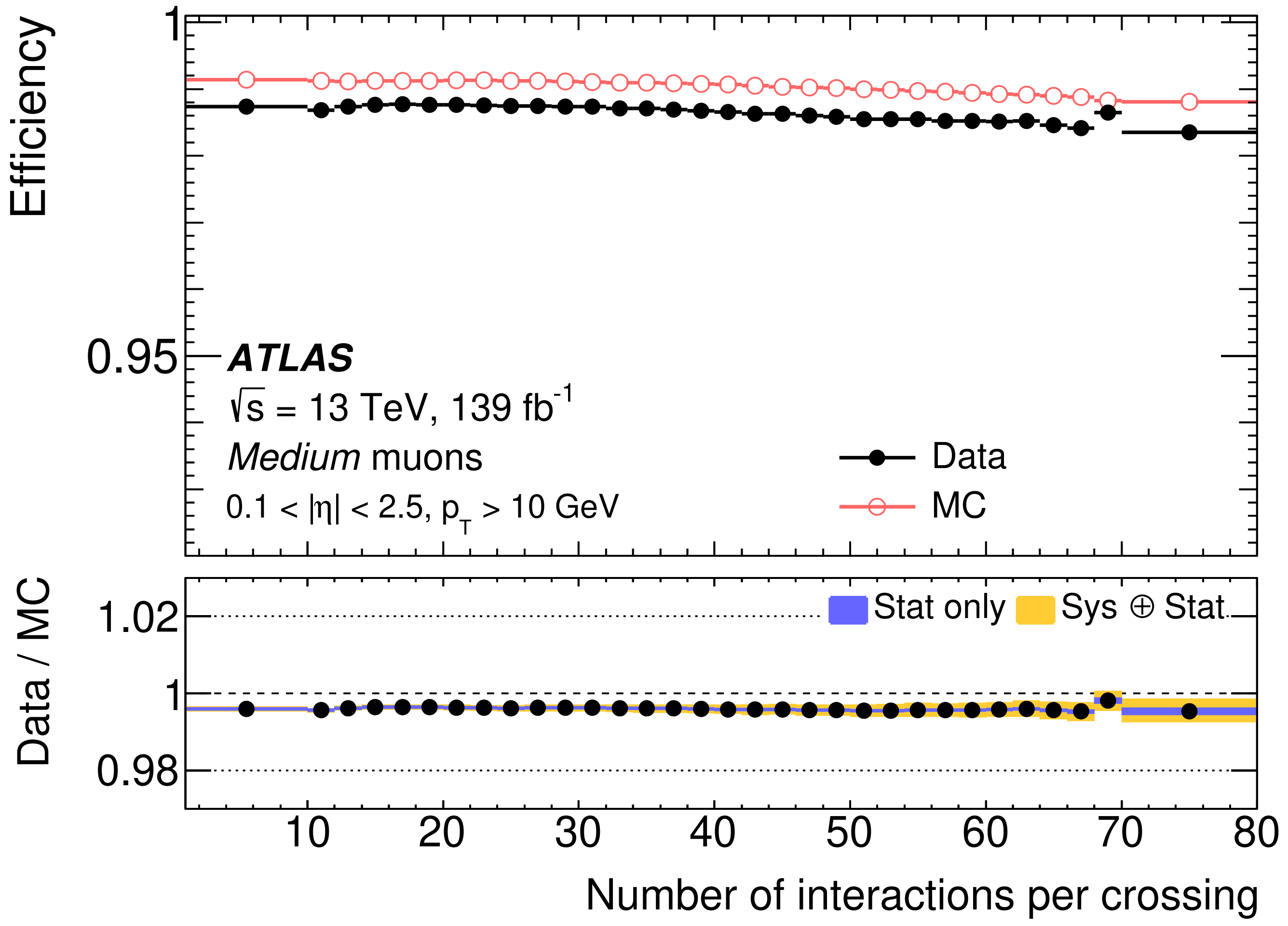


Electron identification efficiency

Eur. Phys. J. C 81 (2021) 578



Muon identification efficiency

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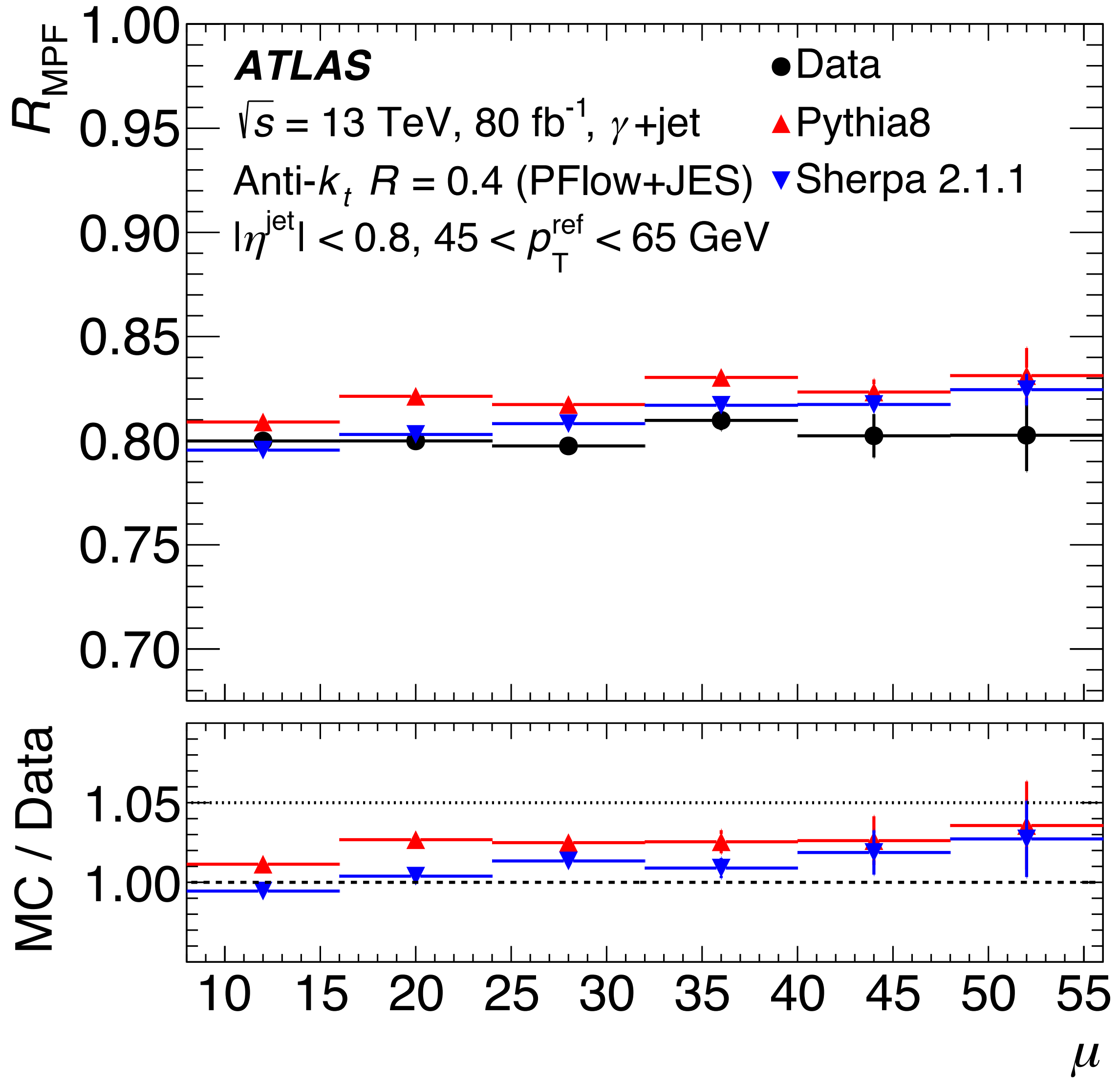

JES MET Projection fraction resolution for γ-jet events

ATLAS Performance at Run 2

- **ML based reconstruction techniques:** Improved identification algorithms based on Deep Learning techniques (e.g. b-tagging with DNN or Tau RNN ID)

- **Reconstruction calibration**: Calibrated and validated in control samples in data!

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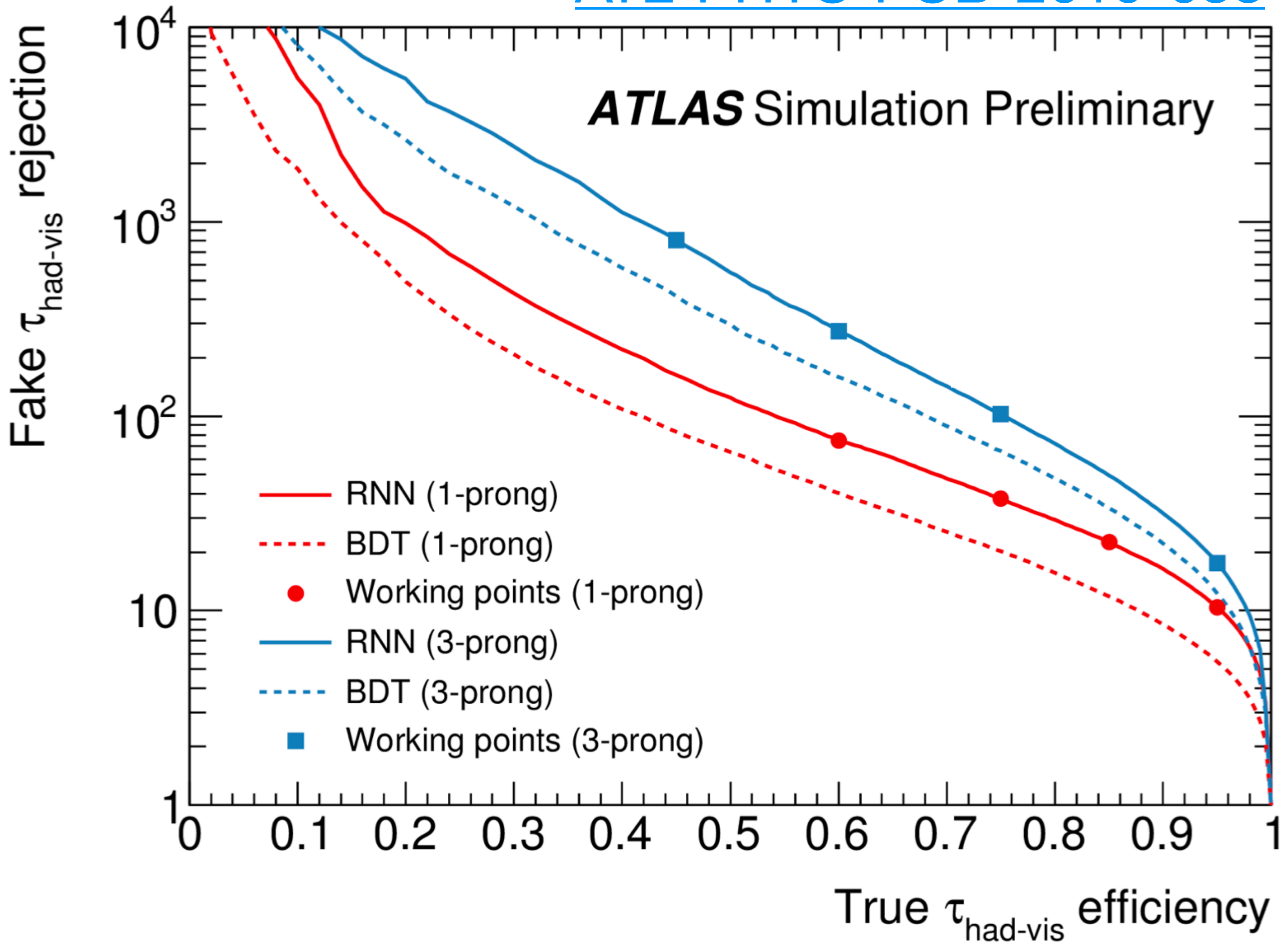

Tau RNN ID

RNN dedicated to hadronic tau classification in 1-prong and 3-prong separately

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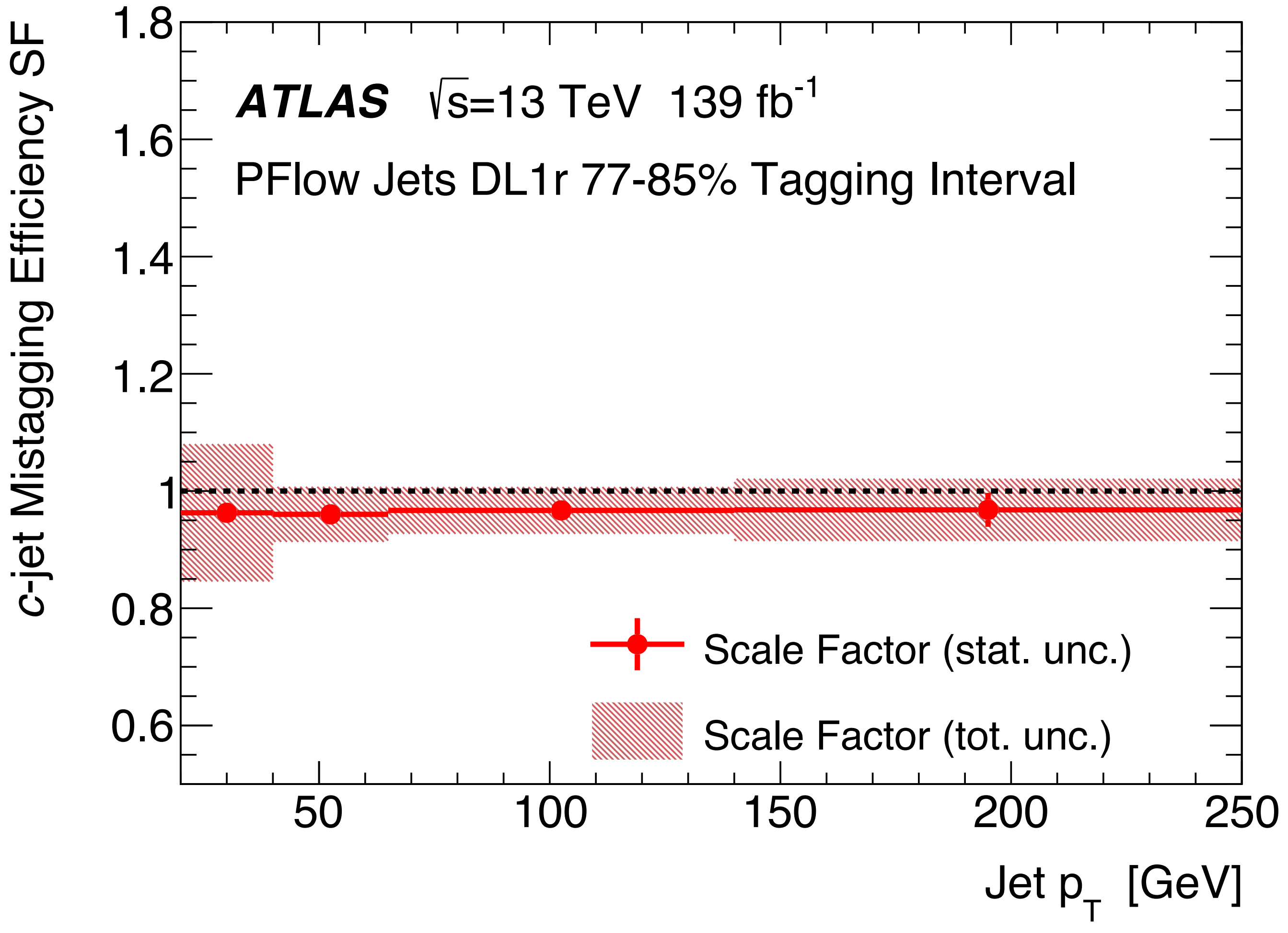

B-tagging DNN

c-jet mis-tagging calibration in $t\bar{t}$ evts

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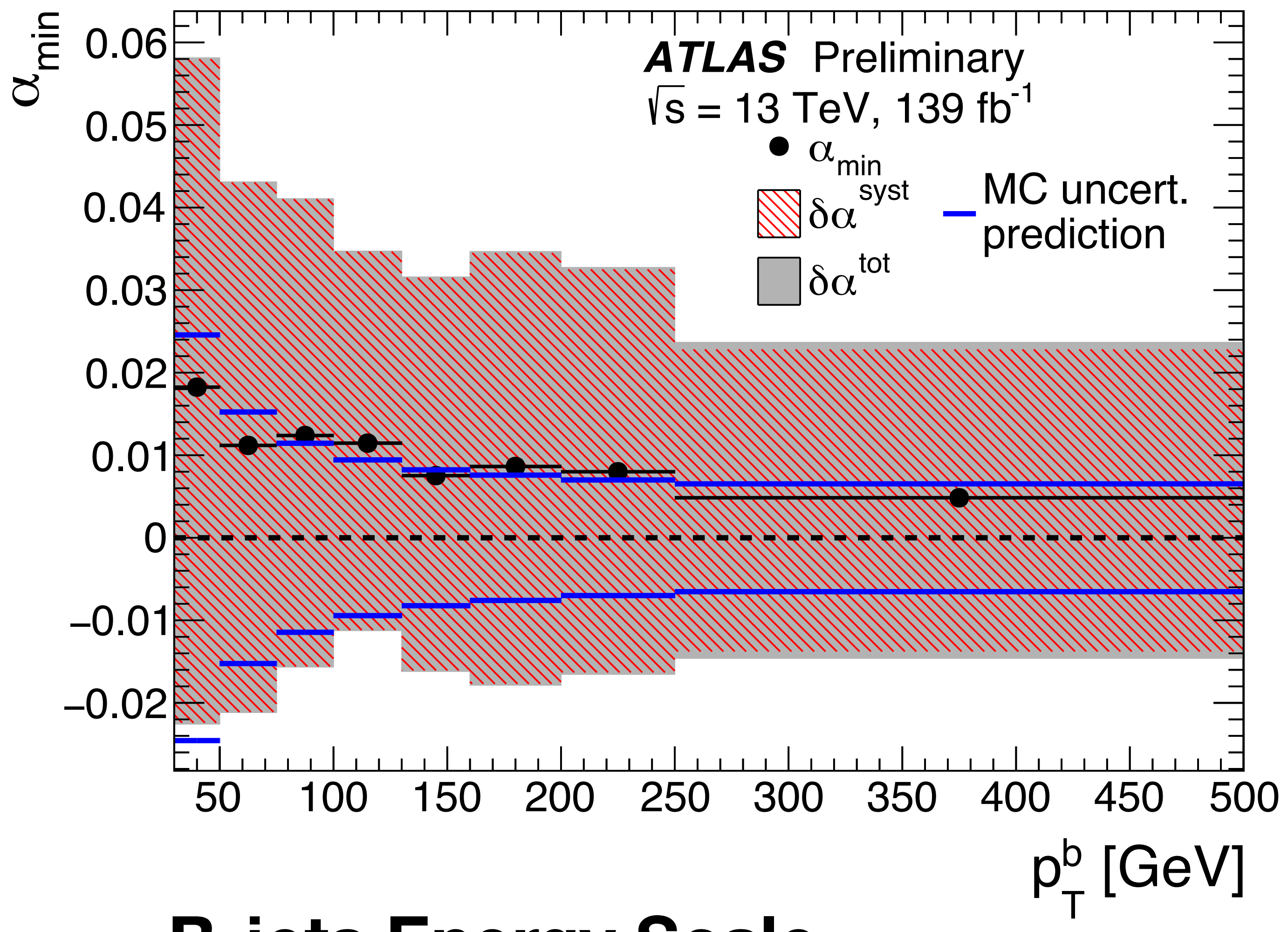

B-jets Energy Scale

In $t\bar{t}$ evts assuming $m_t = 172.5 \pm 0.5$ GeV

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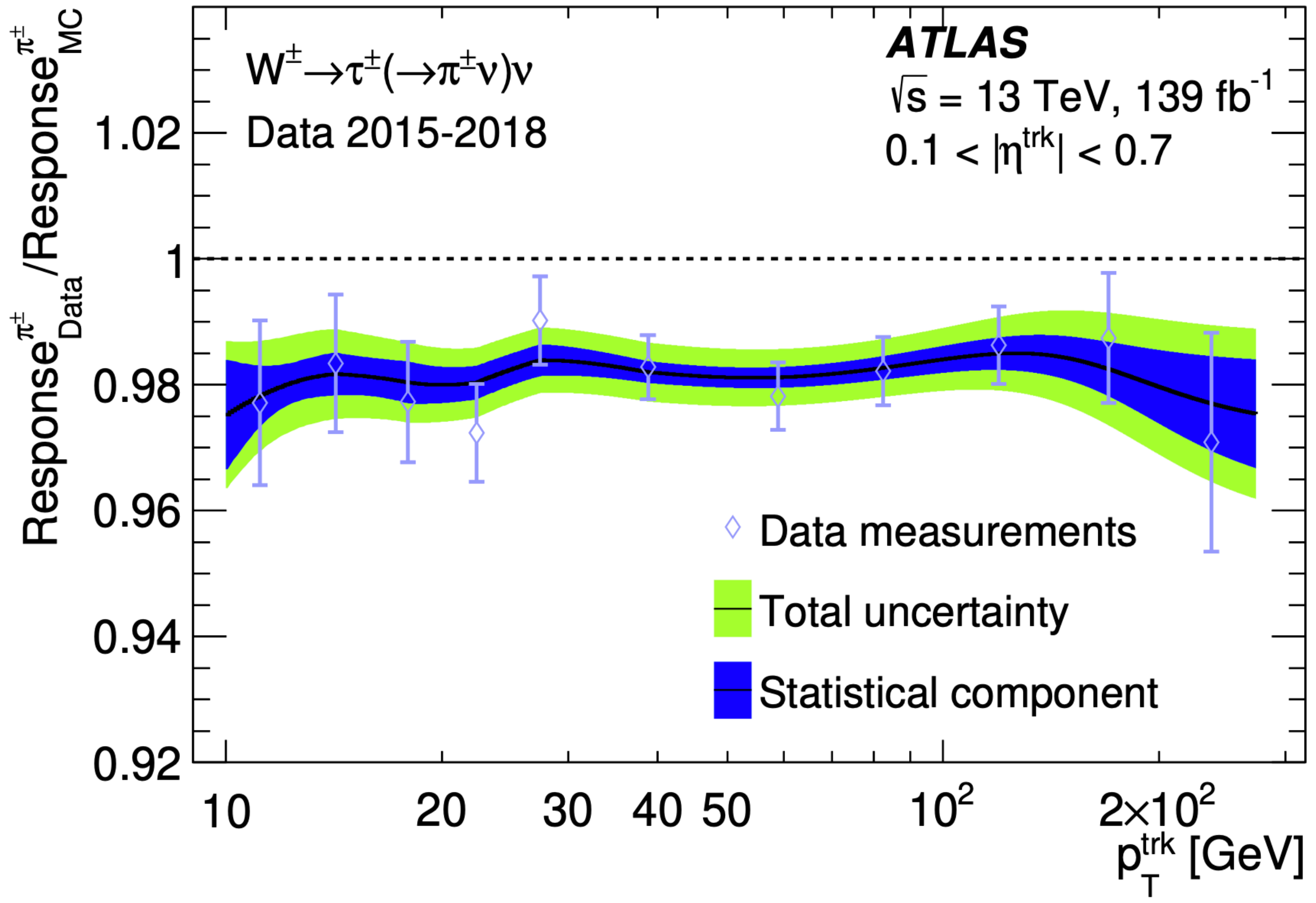
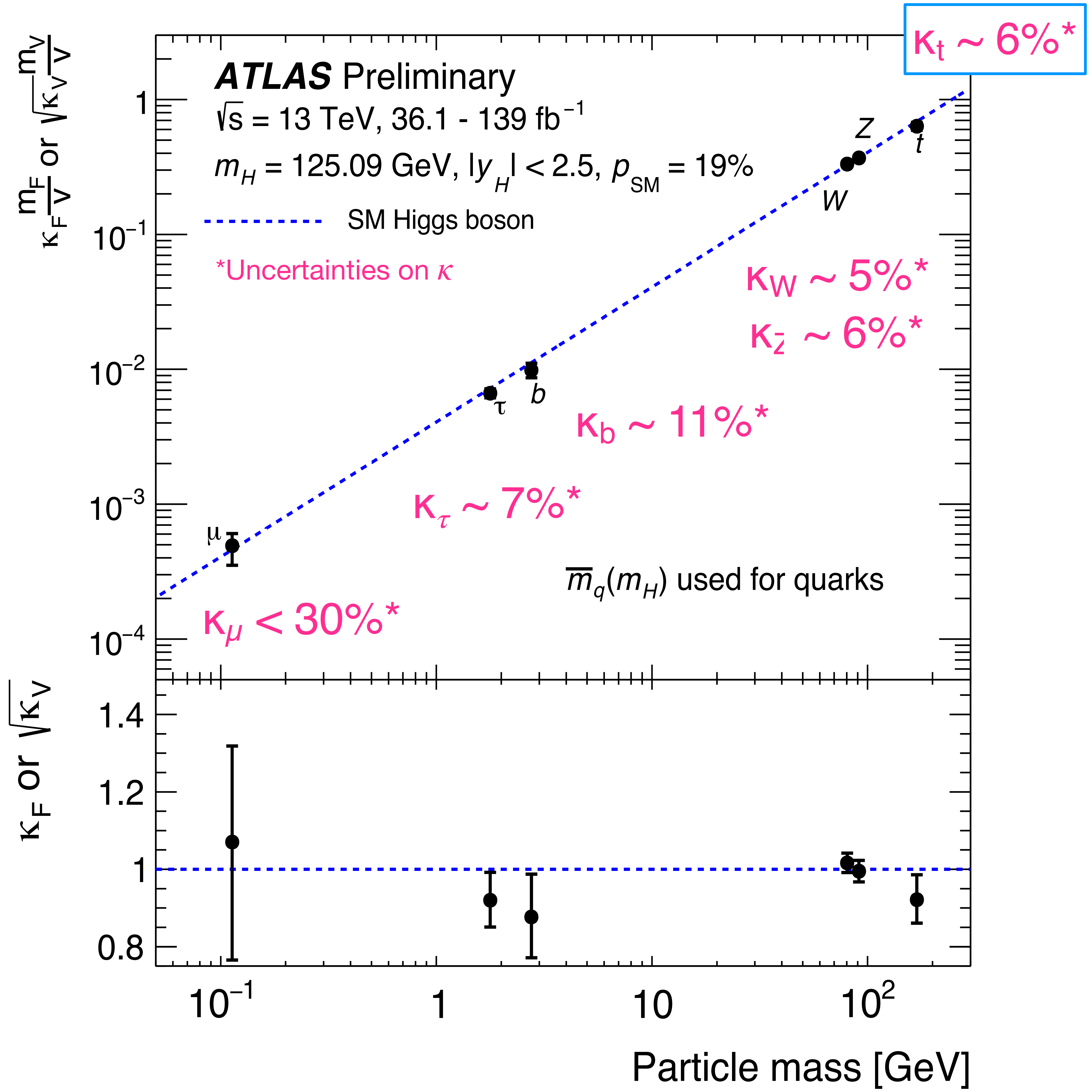


Single pion response

$W^\pm \to \tau^\pm(\to \pi^\pm \nu_\tau)\nu_\tau$

Essential for the reconstruction of jets and the jet energy scale calibration

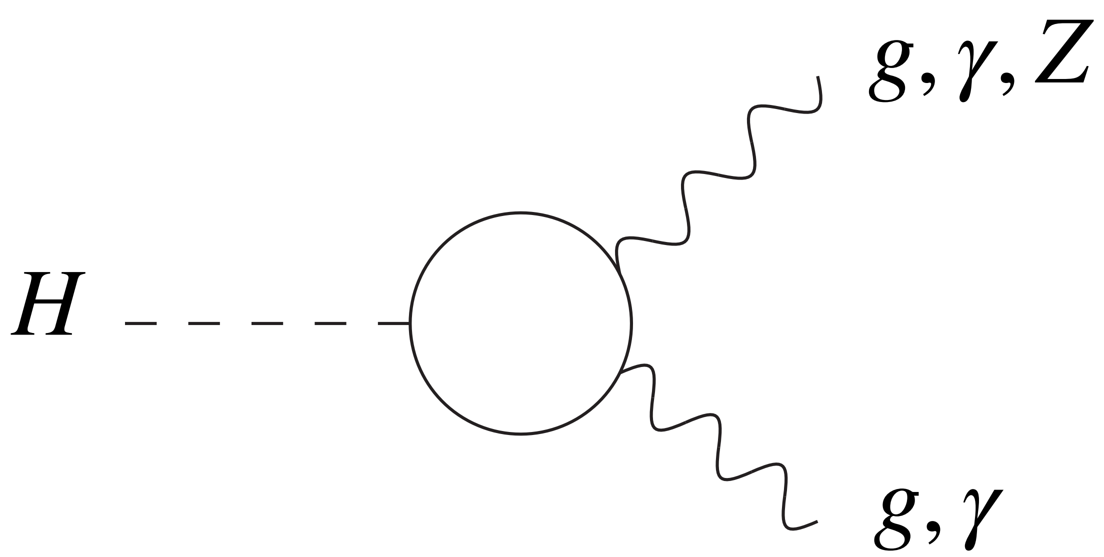
Higgs Physics



Effective tree level couplings

(assuming new particles neither in the decay nor in the loops)

Effective loop couplings (assuming $B_i = B_u = 0$)



$\kappa_\gamma \sim 1.06 \pm 0.05$

$\kappa_g = 1.00 \pm 0.05$

$\kappa_{Z\gamma} = 1.43^{+0.31}_{-0.38}$

Effective self coupling

$-1.0 < \kappa_\lambda < 6.6$ @95% CL

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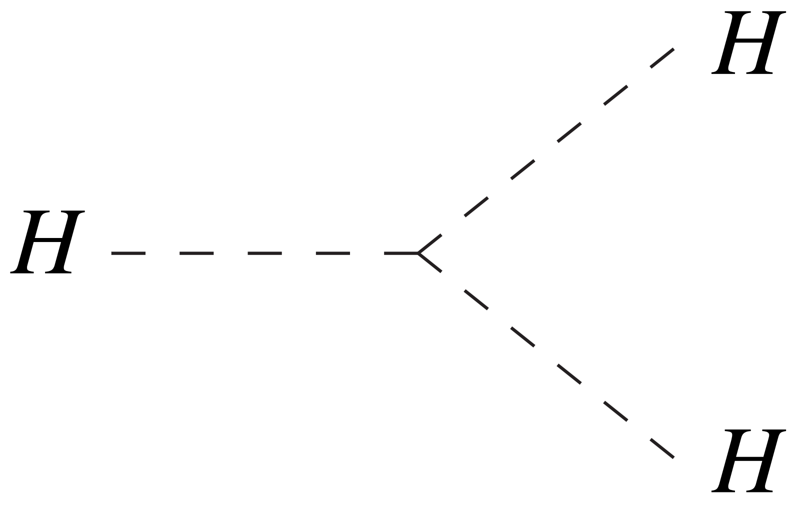
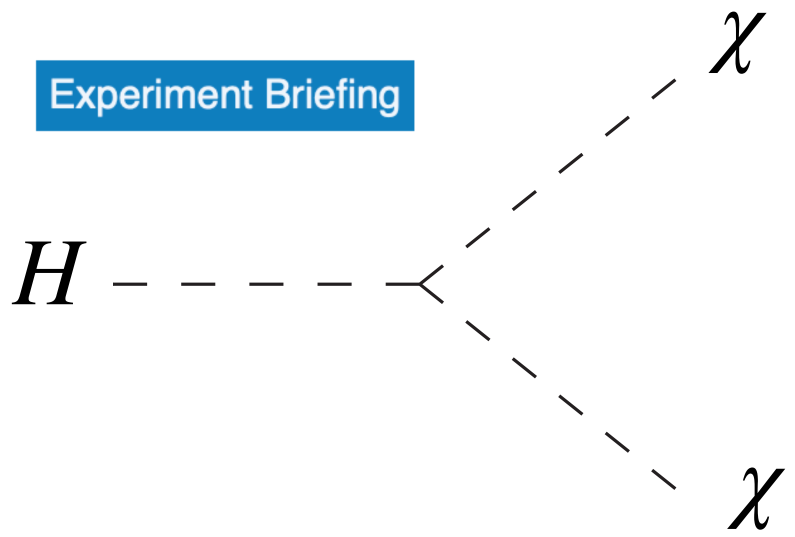


Invisible branching fraction Experiment Briefing

$Br_{inv} < 11\%$ @95% CL

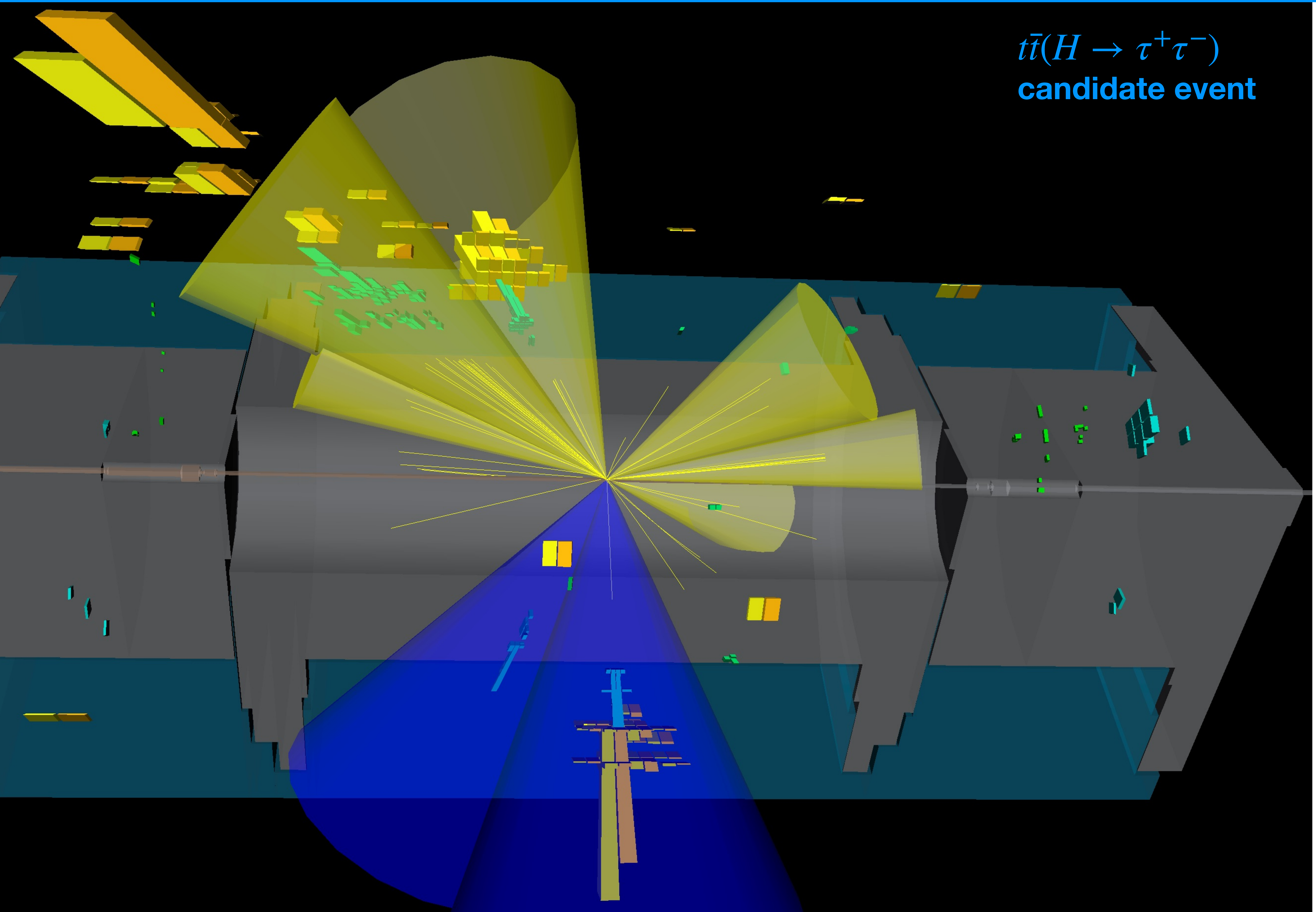
Briefing



Higgs width $\Gamma_H < 15$ MeV @95% CL 1808.01191

Large and excellent Run 2 data sample ⇒ opportunities…

Production Measurements in $H \rightarrow \tau^+\tau^-$



Higgs production cross section measurements with Higgs boson decays to taus…

…Of course a probe of the tau Yukawa coupling!

Measurement made in several channels:

- tt (0Lepton) H
- V(had) H
- VBF
- Boosted inclusive (ggH) in bins from 60 to 350 GeV

In priority order of the event selection

Higgs Yukawa to taus CP Properties

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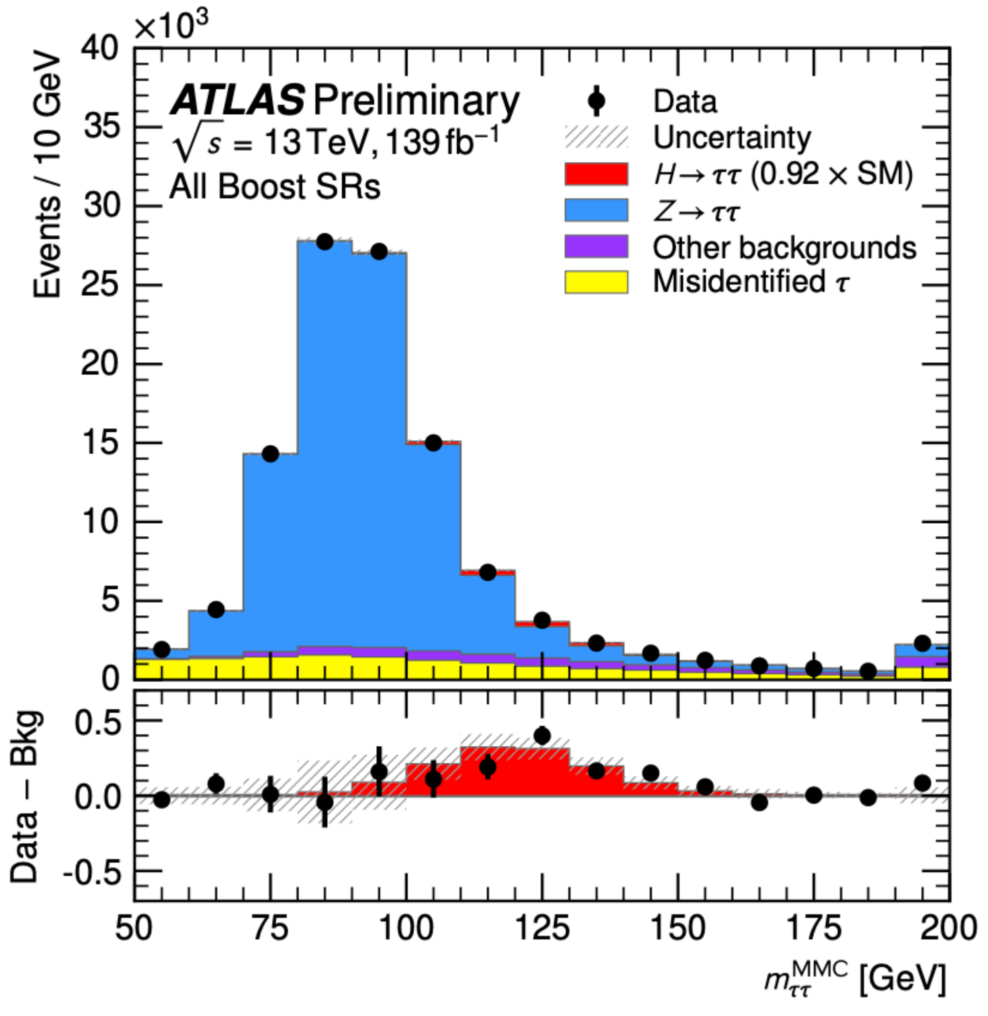
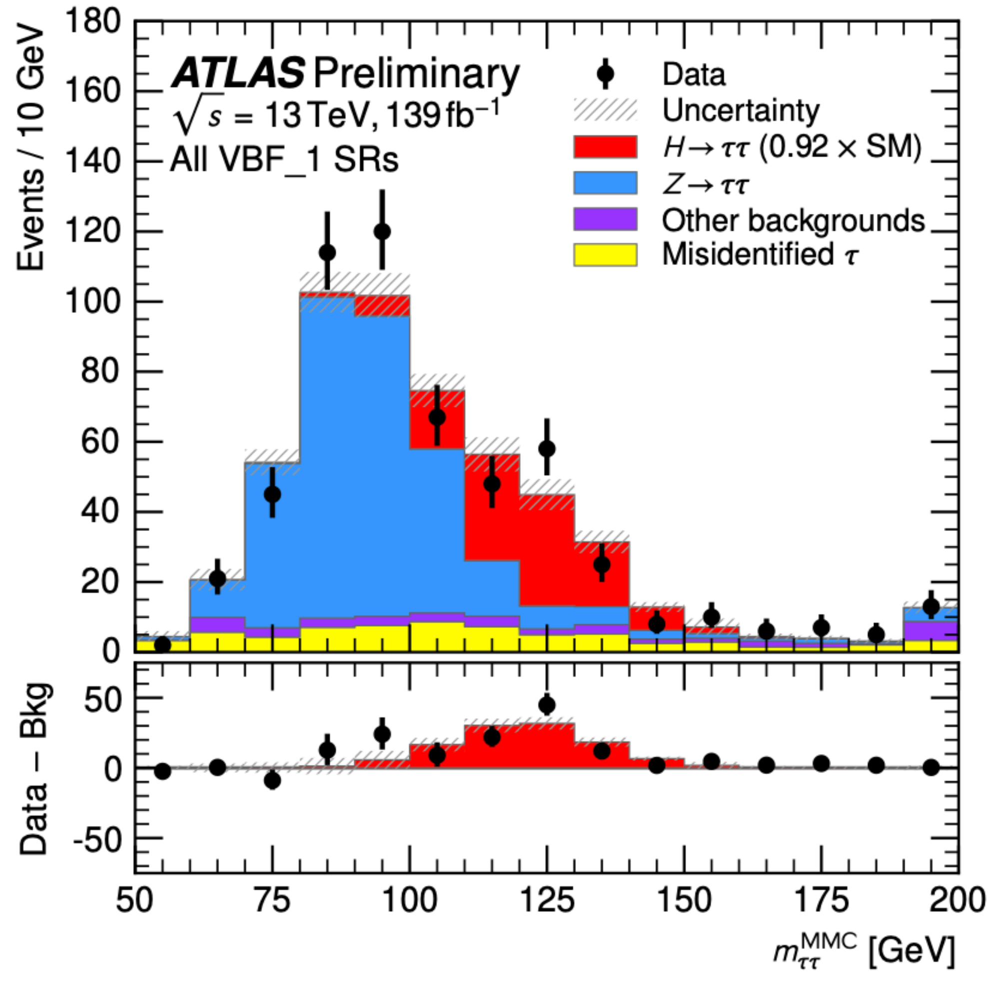
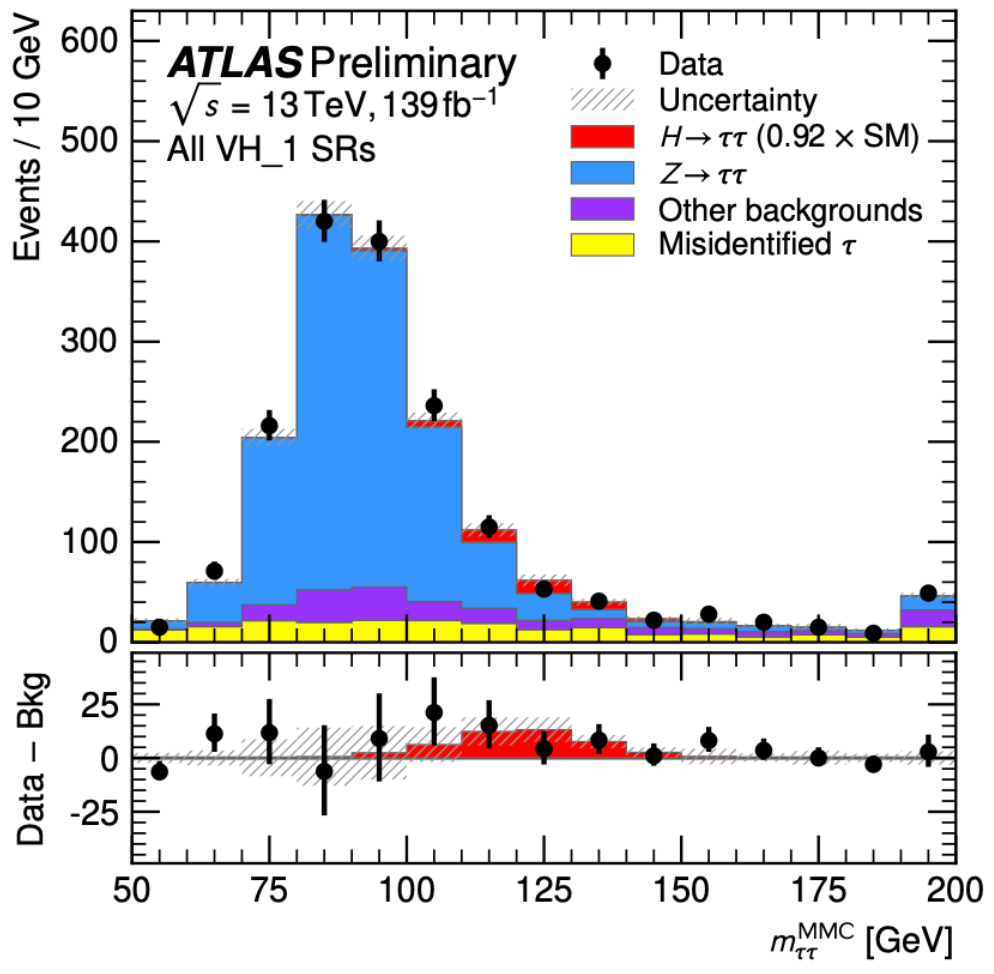


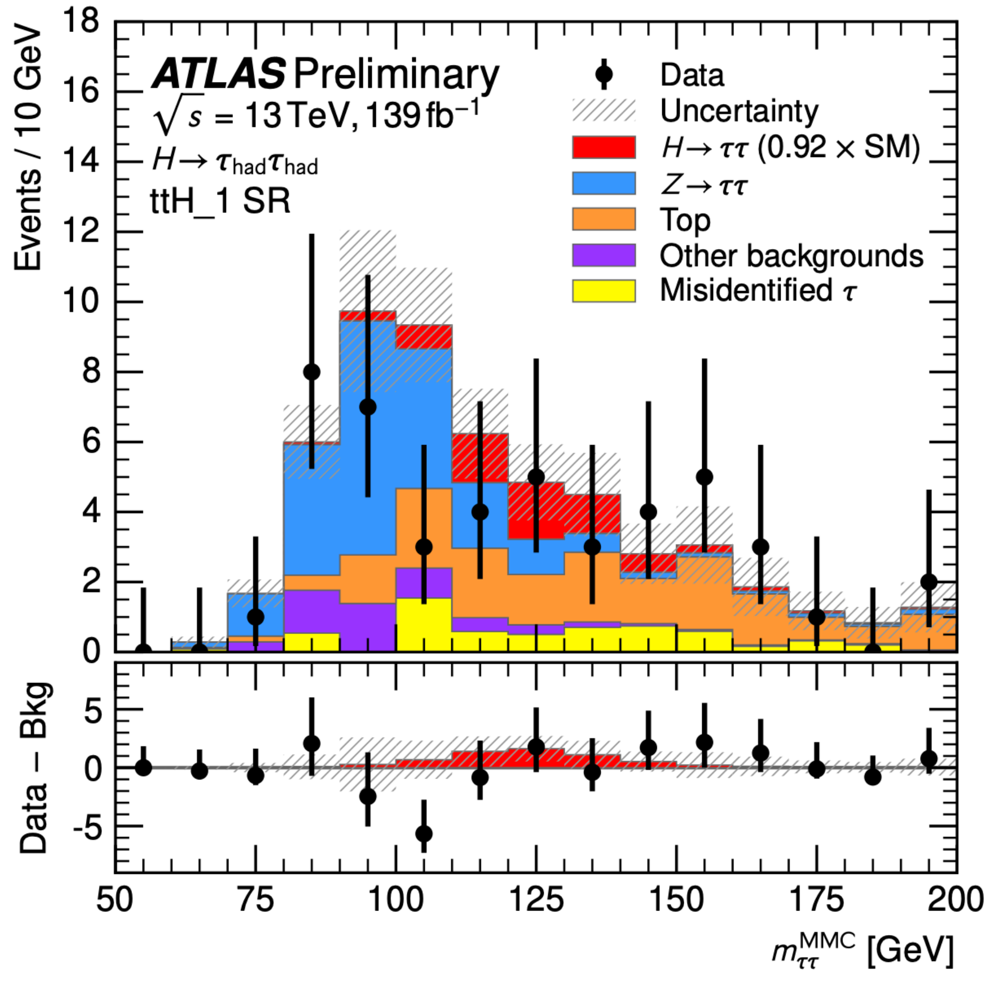
Boosted



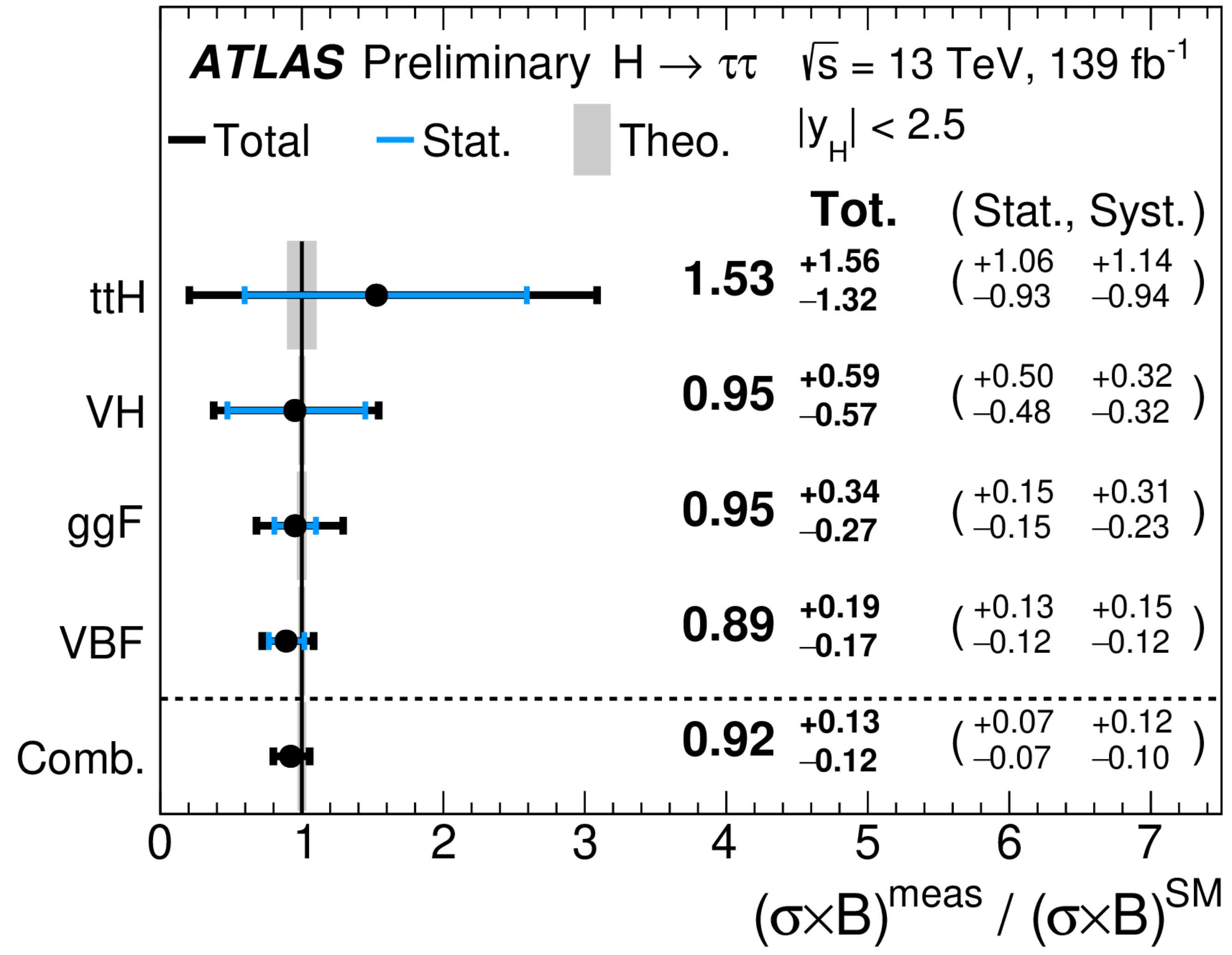
VBF



VH



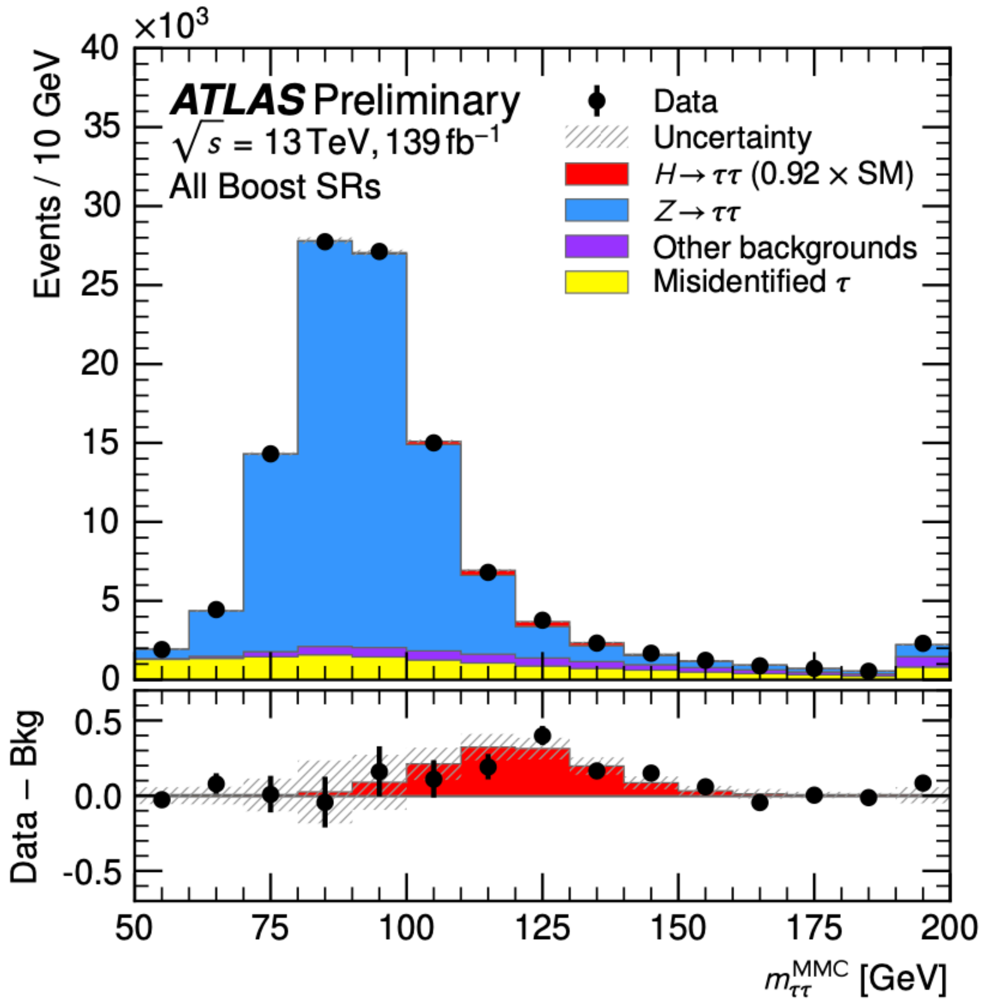
ttH



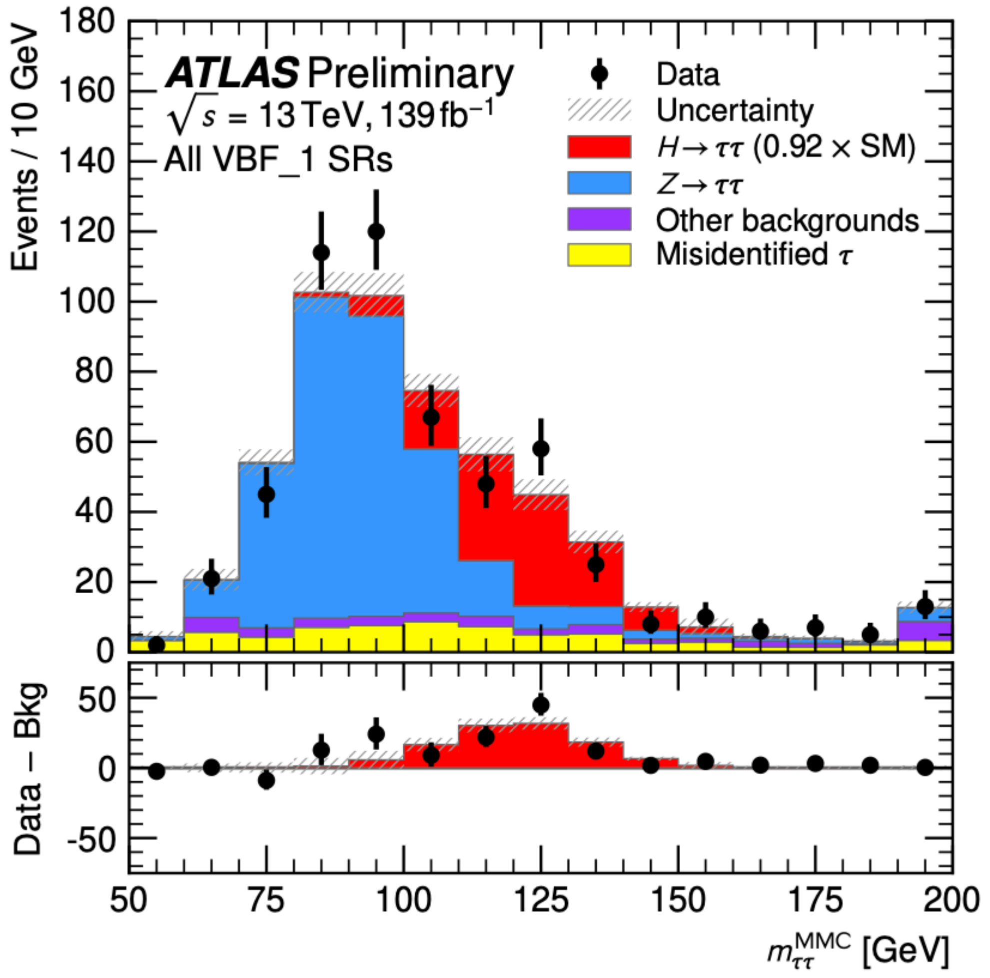
Production Mode		SM prediction [pb]	Result [pb]	Stat. unc. [pb]	Syst. unc. [pb] Th. sig.	Th. bkg.	Exp.
$t\bar{t}H$		0.031 ± 0.003	0.048 ± 0.045	±0.027	±0.011	±0.027	±0.018
VH		0.118 ± 0.003	0.11 ± 0.04	±0.02	±0.02	±0.01	±0.02
ggF	30%	2.8 ± 0.1	2.7 ± 0.9	±0.4	±0.6	±0.1	±0.5
VBF	20%	0.22 ± 0.01	0.196 ± 0.040	±0.026	±0.024	±0.005	±0.016
$pp\to H$		3.15 ± 0.09	2.90 ± 0.40	±0.22	±0.26	±0.06	±0.22

Precision reached $\sigma(\mu) \sim 14\,\%$

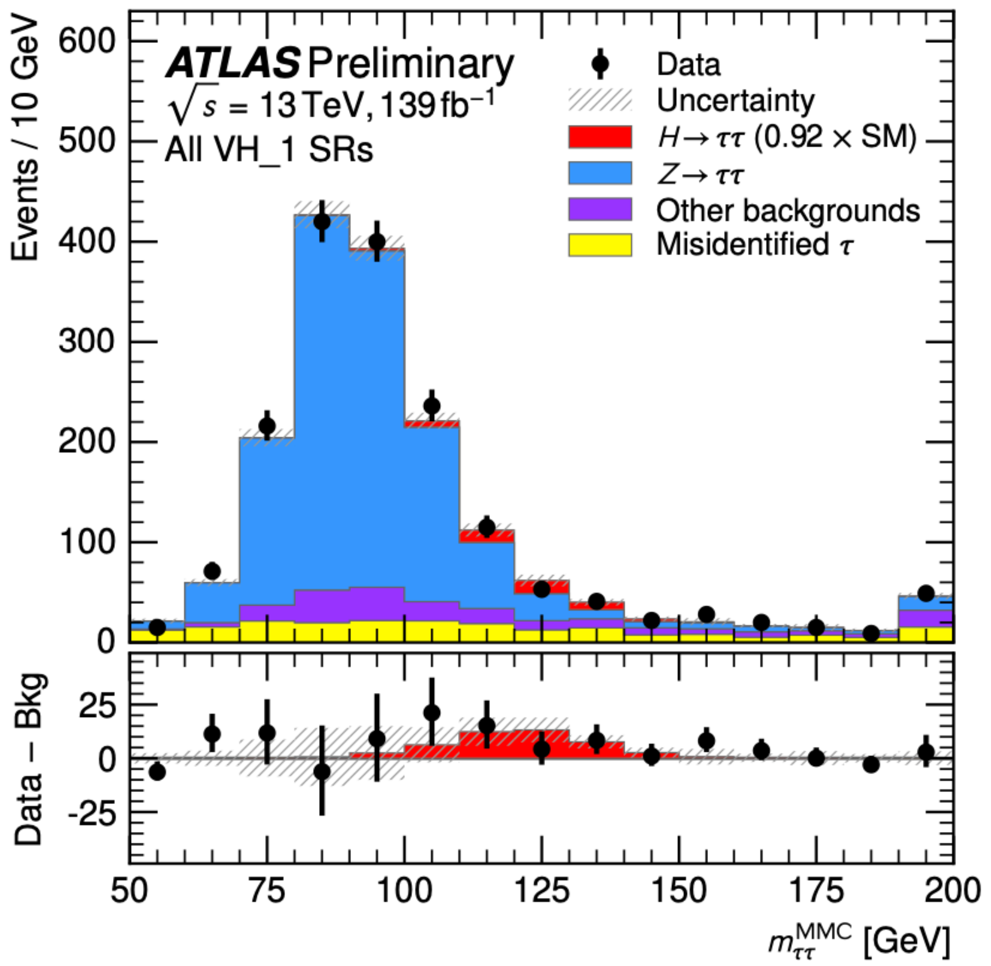
Higgs Yukawa to taus CP Properties



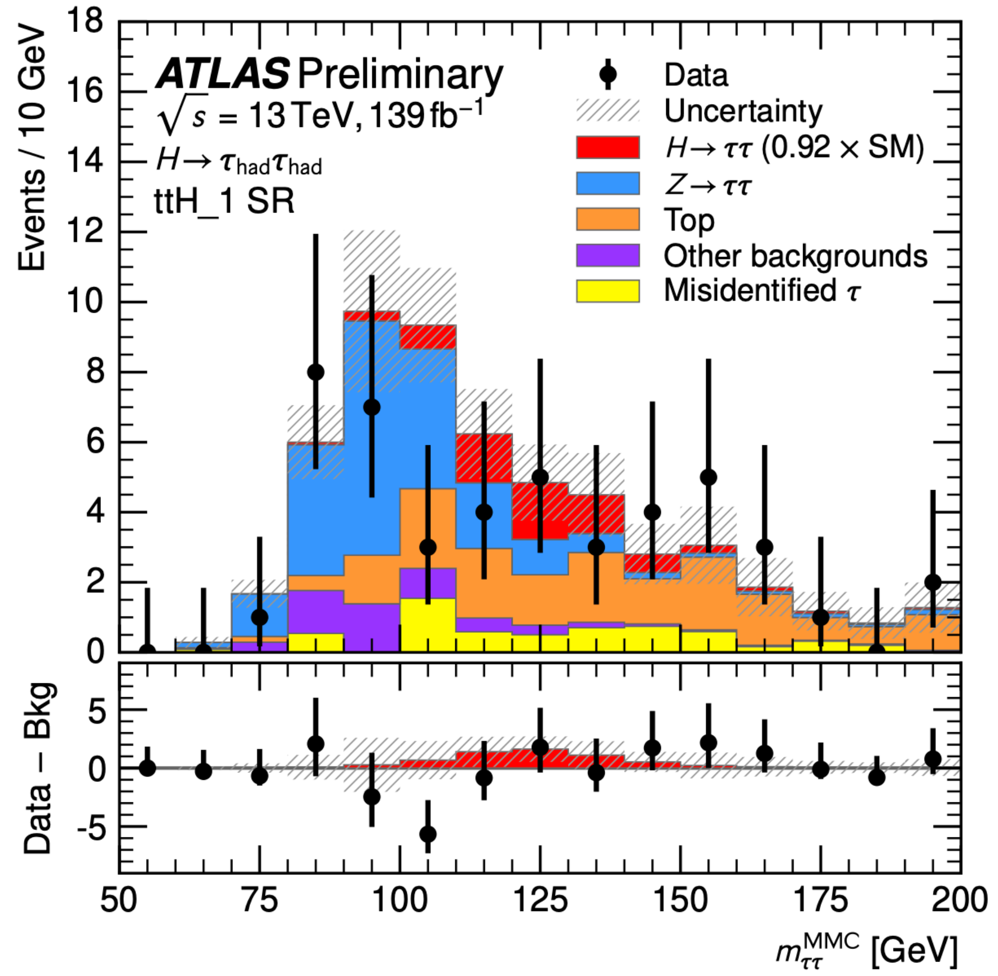
Boosted



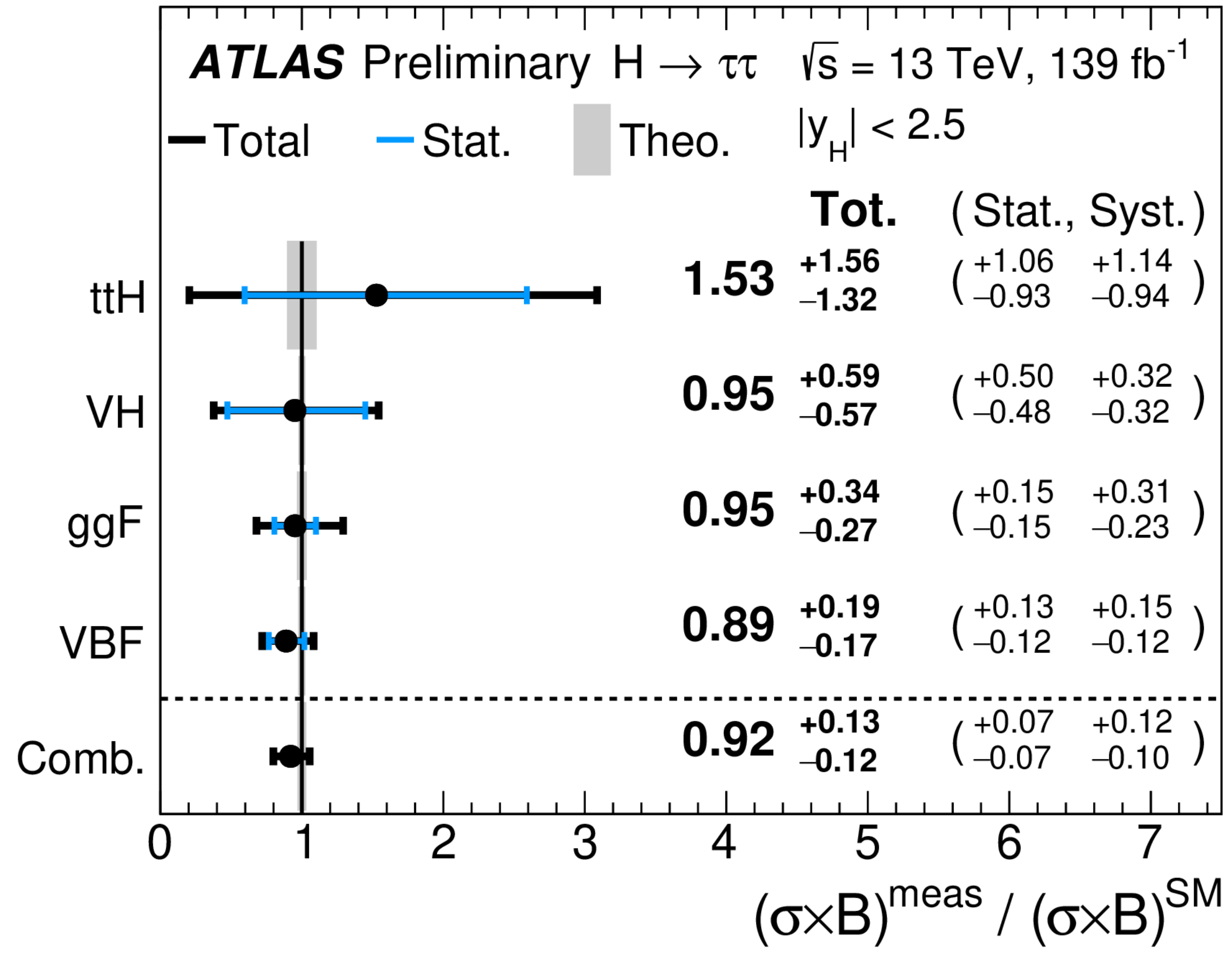
VBF



VH

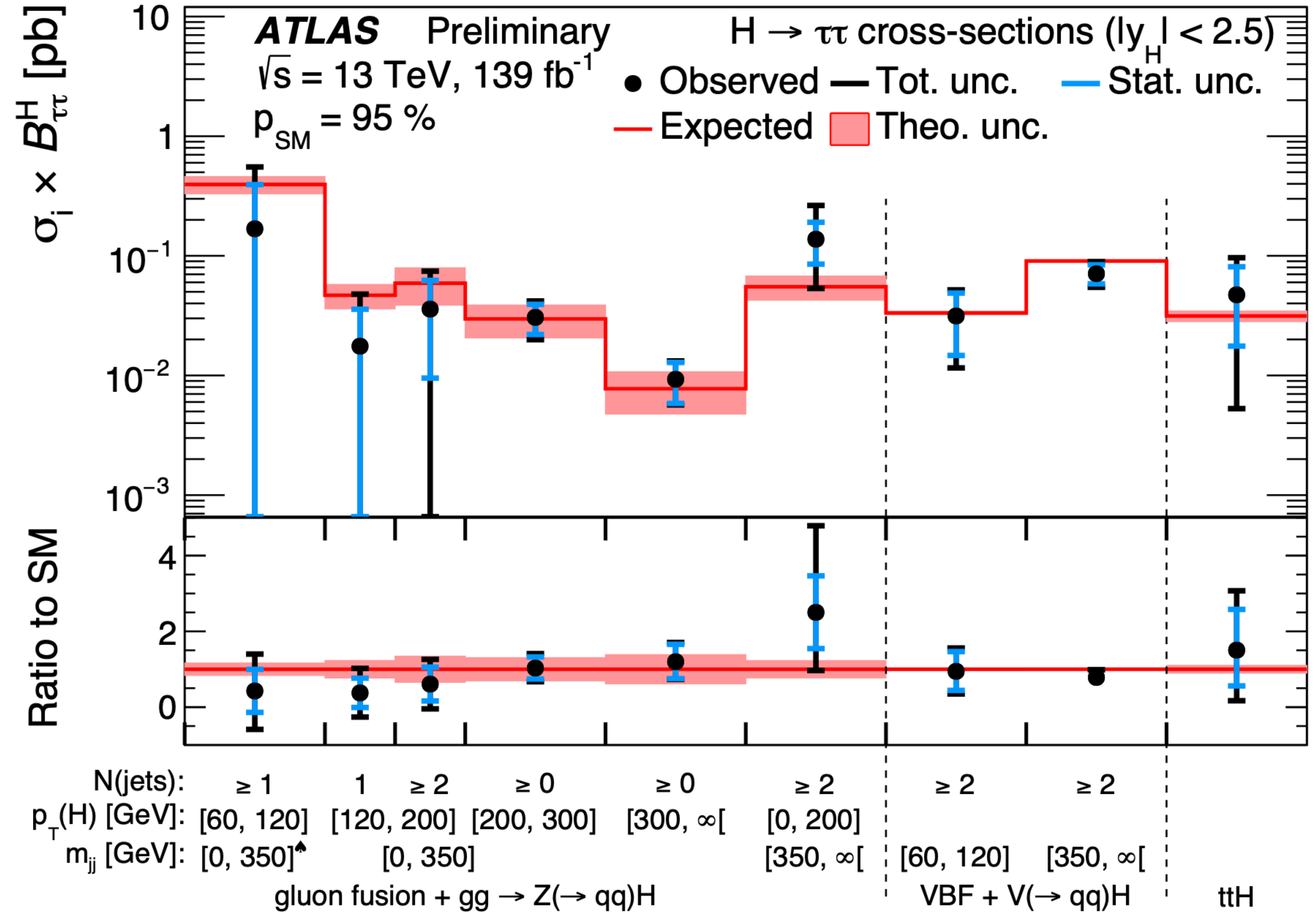


ttH

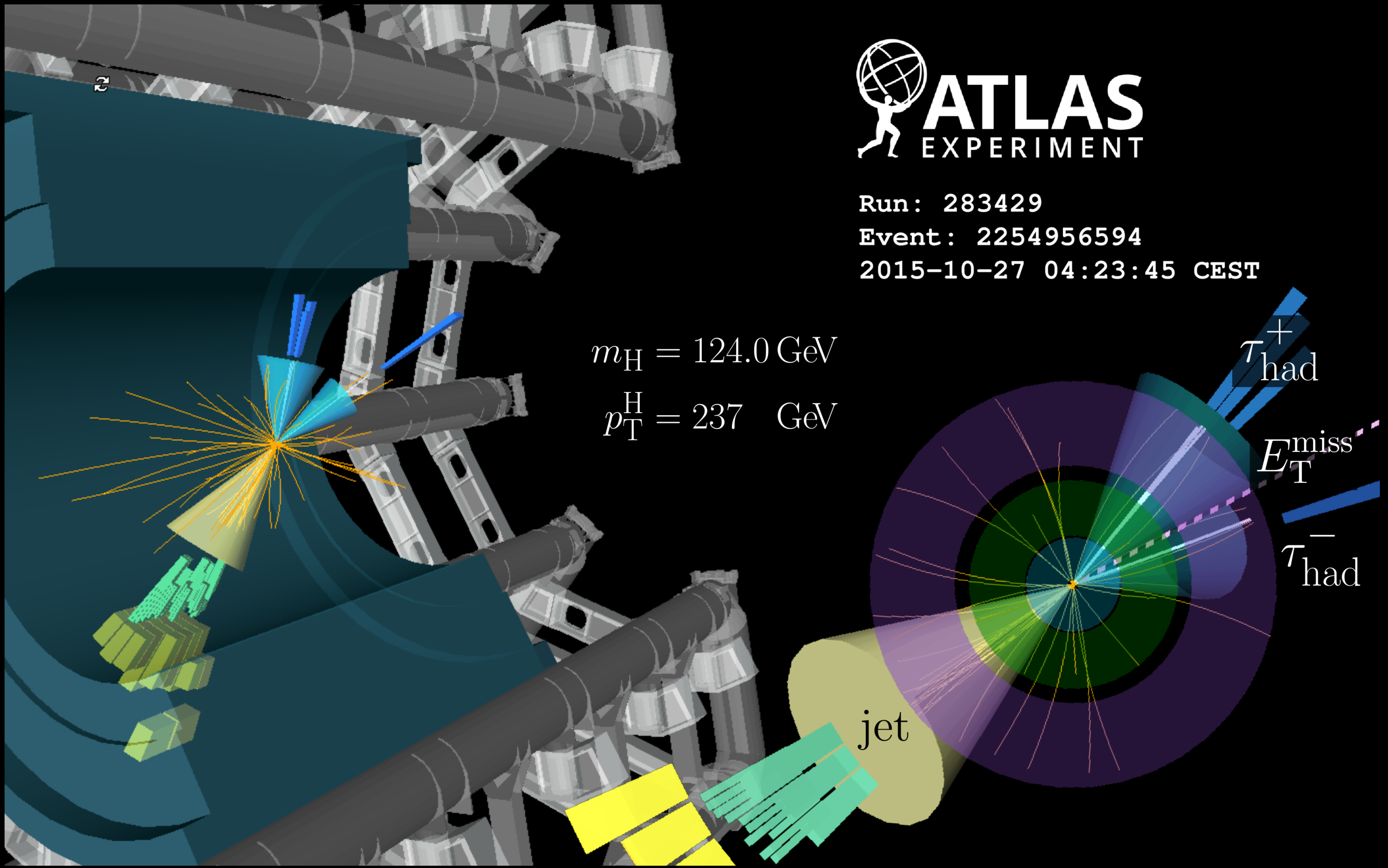


STXS Measurement

Highest ggH precision obtained in [200,300] GeV bin!



Higgs Yukawa to taus CP Properties



CP properties of the tau Yukawa through polarisation correlations in $H \to \tau^+\tau^-$ decay

Boosted $H \to \tau^+\tau^-$ candidate event

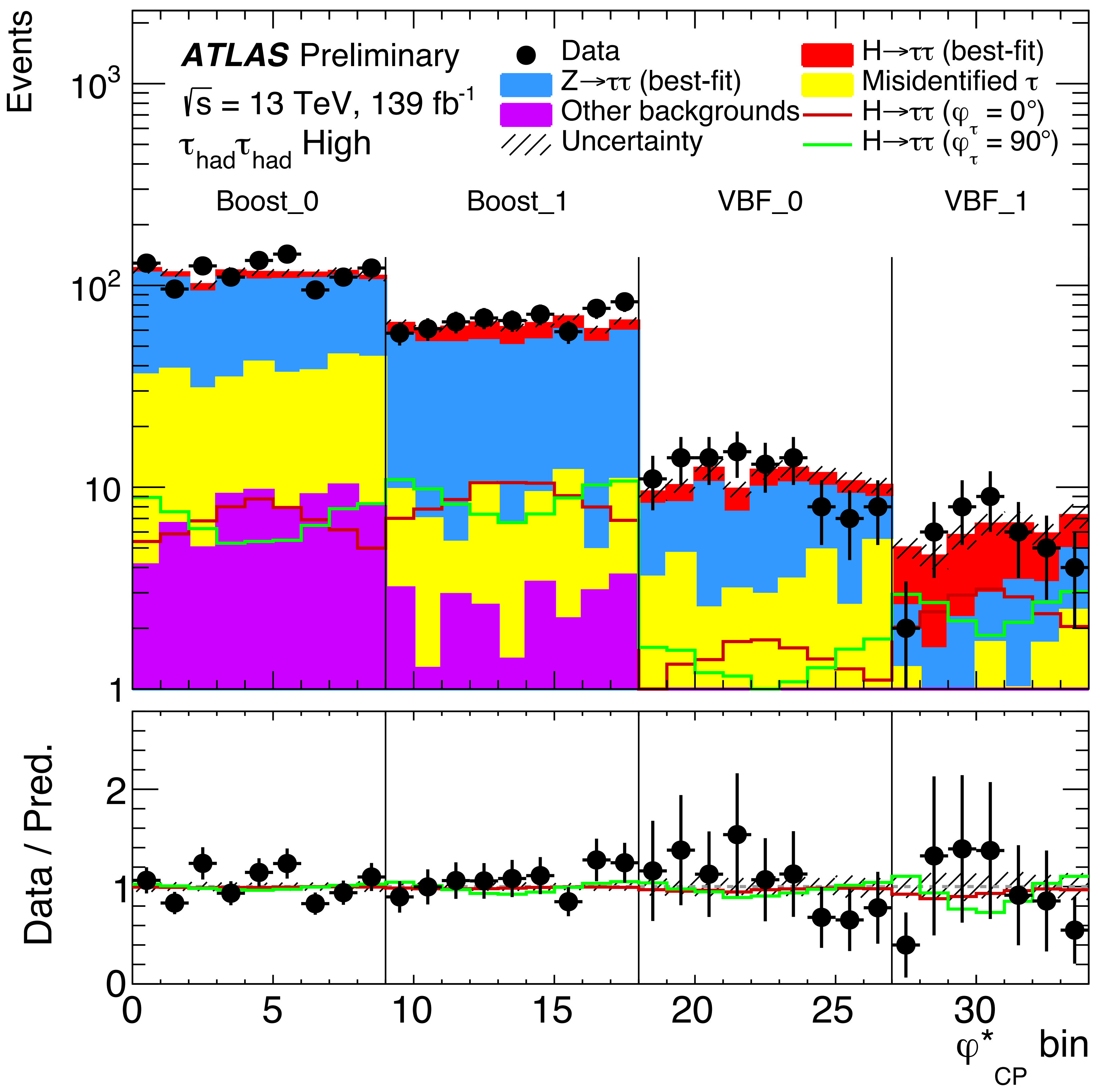
Higgs Yukawa to taus CP Properties

CP-odd contributions in Higgs-Gauge interactions occur via higher-order operators.

CP-odd contribution in the Yukawa interaction can be present at the tree level

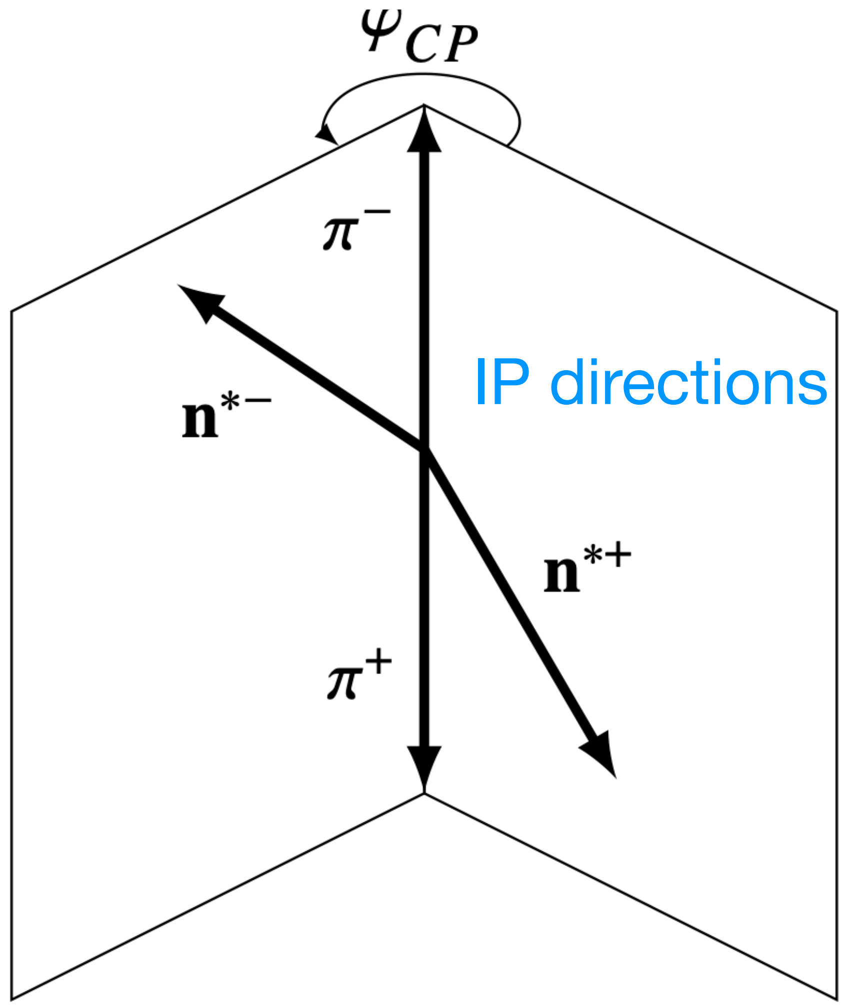
Using several decay modes of the taus

Boosted and VBF (using a BDT) categories



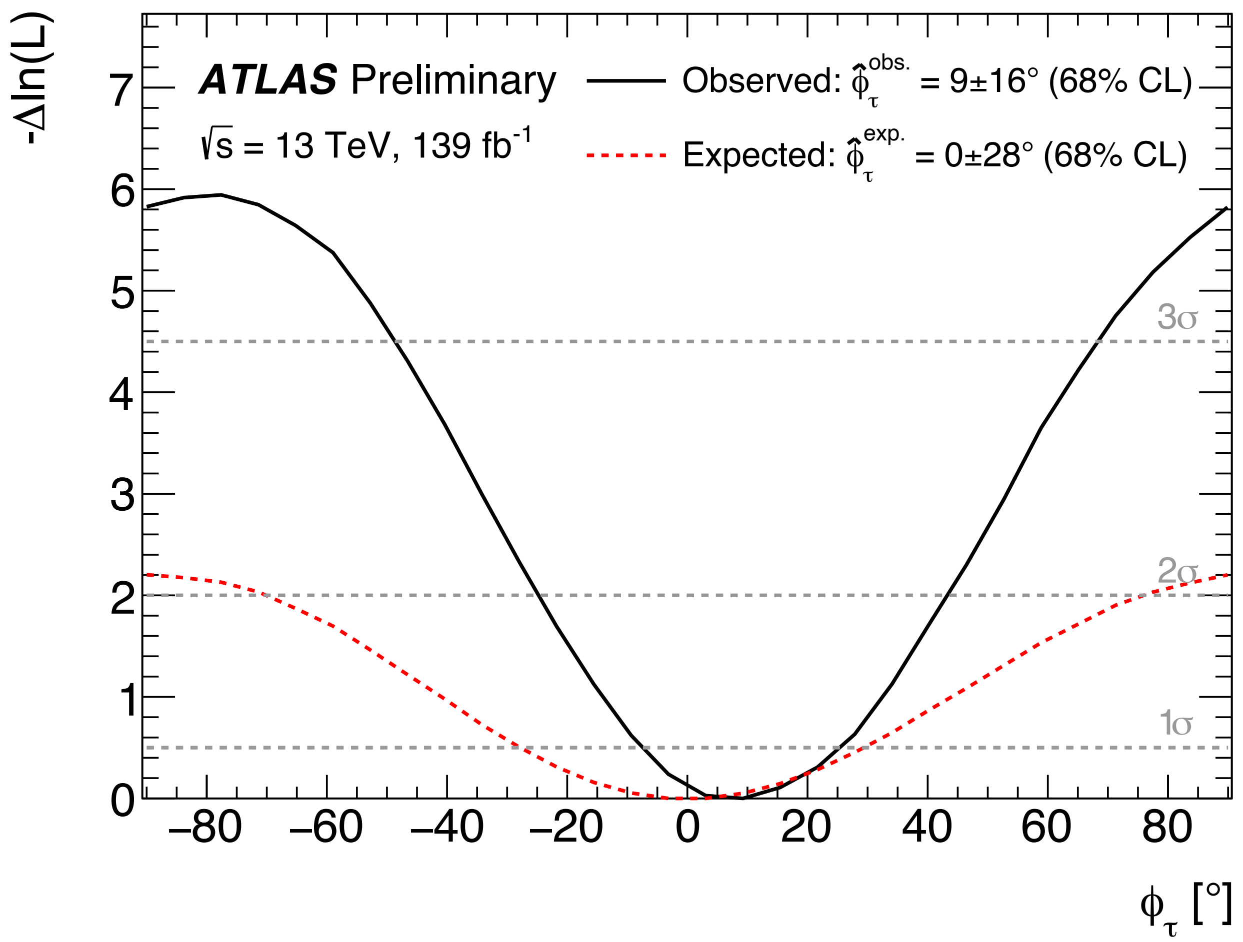
$$H \to \tau^+\tau^- \to \pi^+\pi^- + 2\nu$$

Zero Momentum Frame



Tau transverse spin correlation sensitive variable

$$\mathcal{L}_{H\tau\tau} = -\frac{m_\tau}{v}\kappa_\tau(\cos\phi_\tau\bar{\tau}\tau + \sin\phi_\tau\bar{\tau}i\gamma_5\tau)H$$



Fit the ϕ_τ parameter to the ϕ^*_{CP}

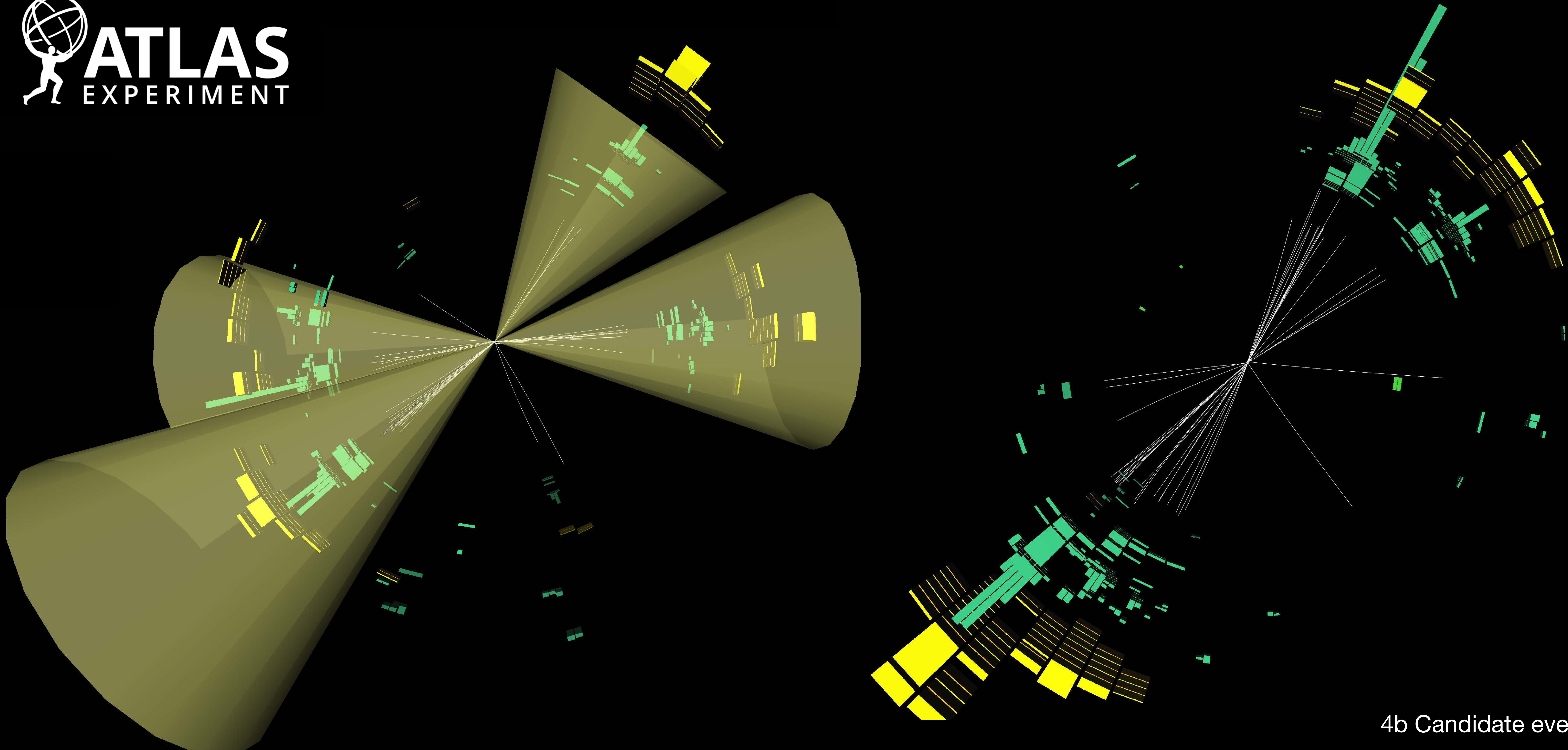
Pure CP-Odd hypothesis excluded at 3.4σ

$$\boxed{\phi_\tau = 9^o \pm 5^o\,(\text{sys}) \pm 16^o\,(\text{stat})}$$

Hot off the press! Non resonant $HH \to b\bar{b}b\bar{b}$

ATLAS-CONF-2022-035

ATLAS EXPERIMENT



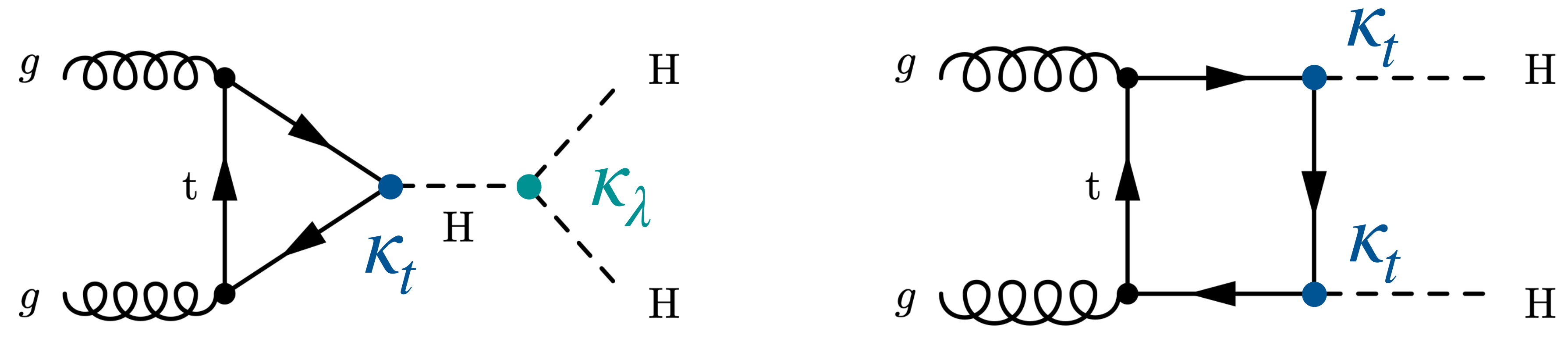
4b Candidate event

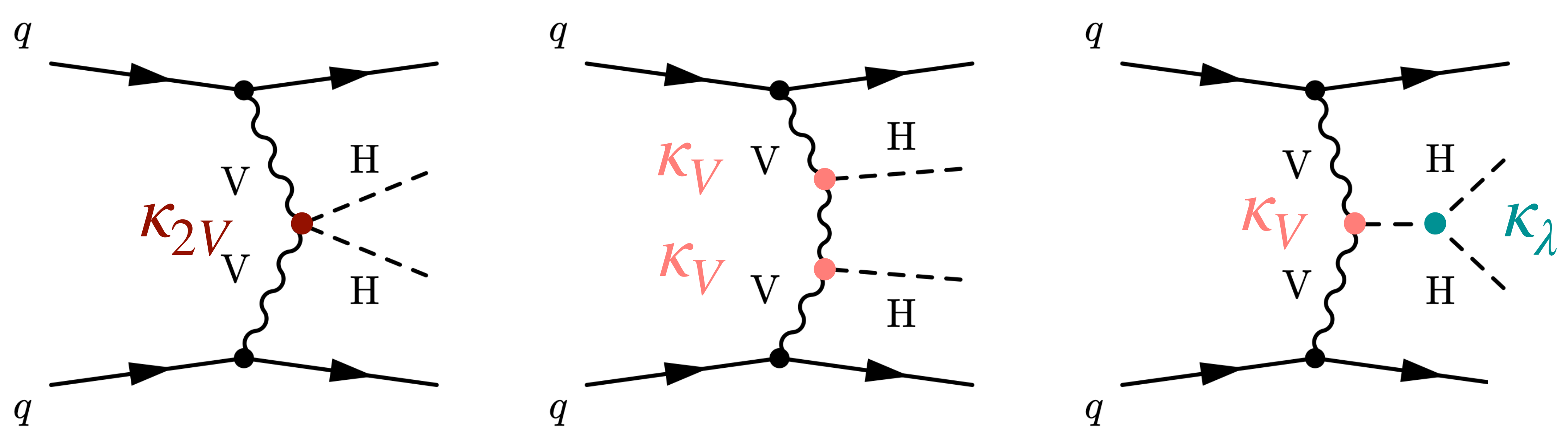
Hot off the press! Non resonant $HH \rightarrow b\bar{b}b\bar{b}$

ATLAS-CONF-2022-035

Higgs pair production through gluon fusion and VBF

Search through non trivial interference



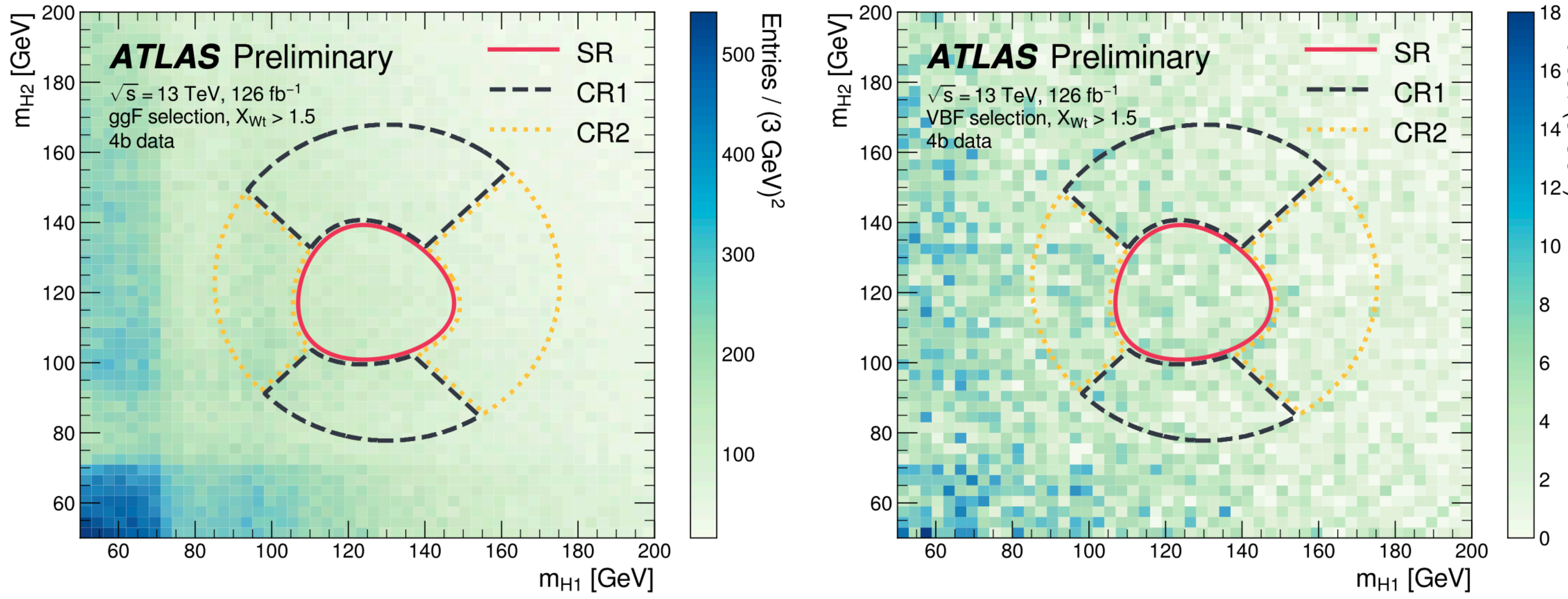


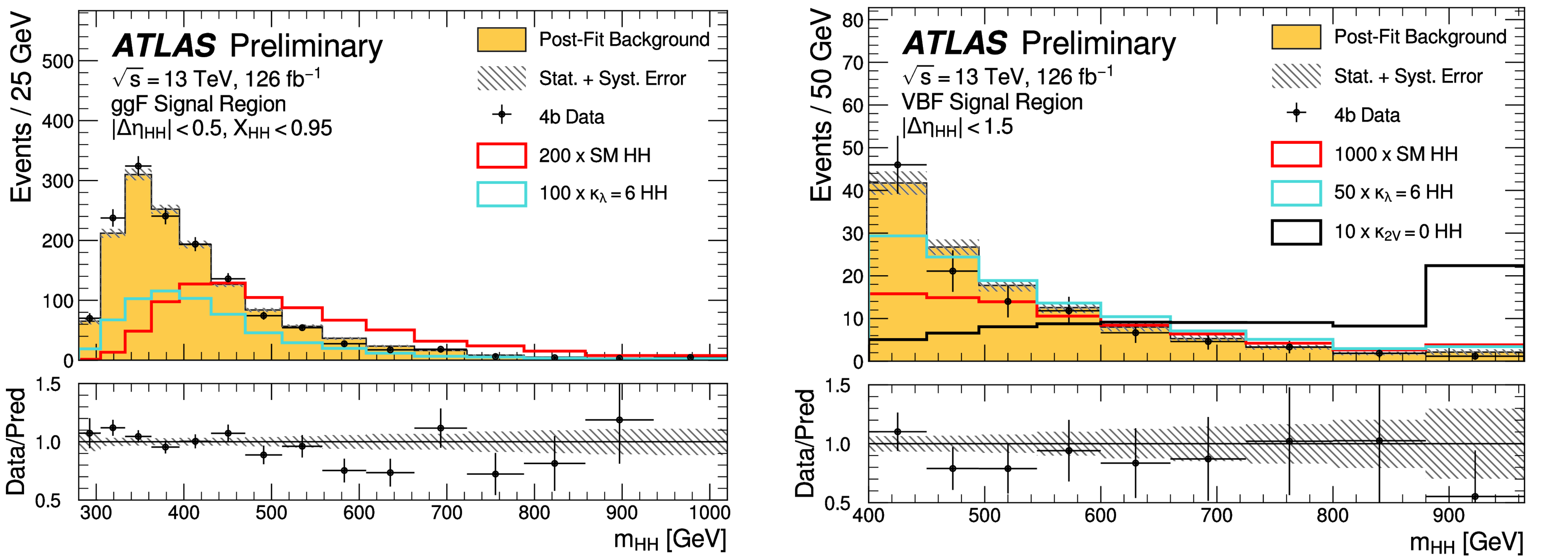
With the VBF production mode not only limits on κ_λ also on κ_{2V}

Bishara, Contino, Rojo

Critical aspect in this channel is the estimate of the QCD background!

NN used to correct for biases in the data driven method (trained in data control regions - density estimation through NN)!



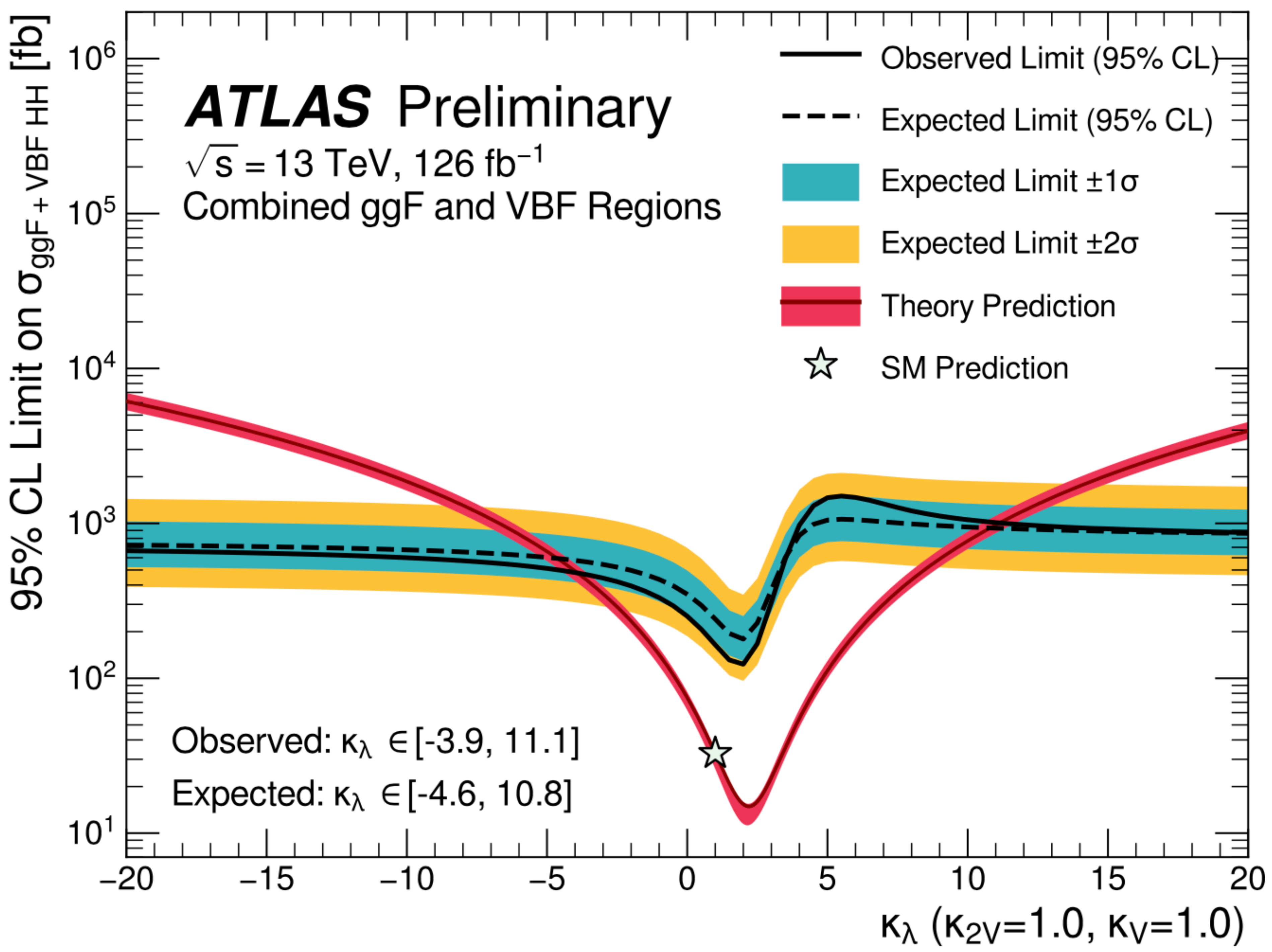


Hot off the press! Non resonant $HH \rightarrow b\bar{b}b\bar{b}$

ATLAS-CONF-2022-035

Limit on rate w.r.t. SM 5.4 (8.1) at 95% CL

Strong variation of cross section (and acceptance) yield quite strong constraints at 95% CL:

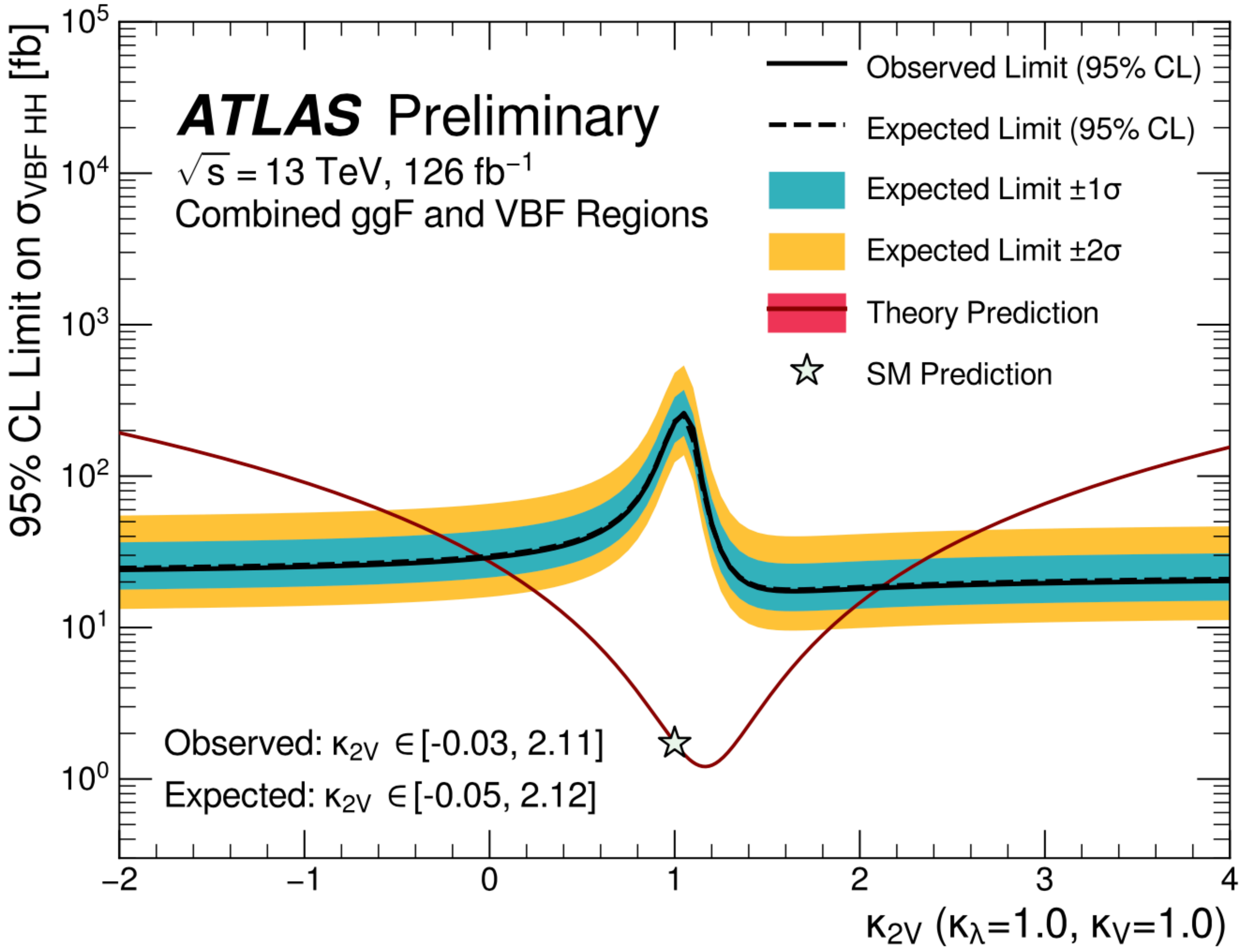


Observed constraint on trilinear coupling at 95% CL:

$$-3.9 < \kappa_\lambda < 11.1$$

Uses the latest N3LO-QCD estimate of the VBF-HH cross section!

F. Dreyer and A. Karlberg



Observed constraint on HHVV coupling at 95% CL:

$$-0.03 < \kappa_{2v} < 2.11$$

Almost excludes $\kappa_{2V} = 0$ at 95% CL!

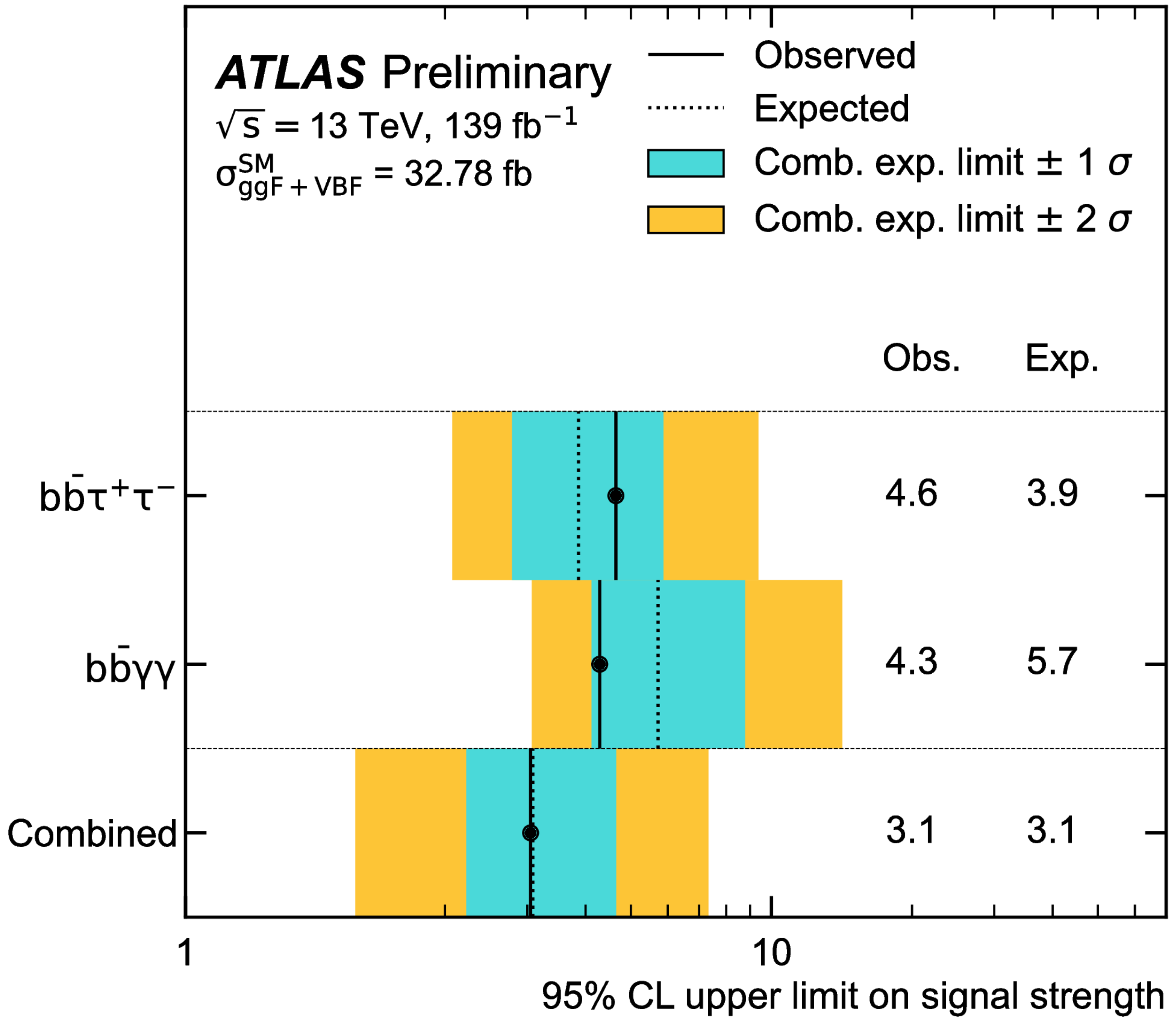
Towards a Measurement of the Higgs Self Coupling

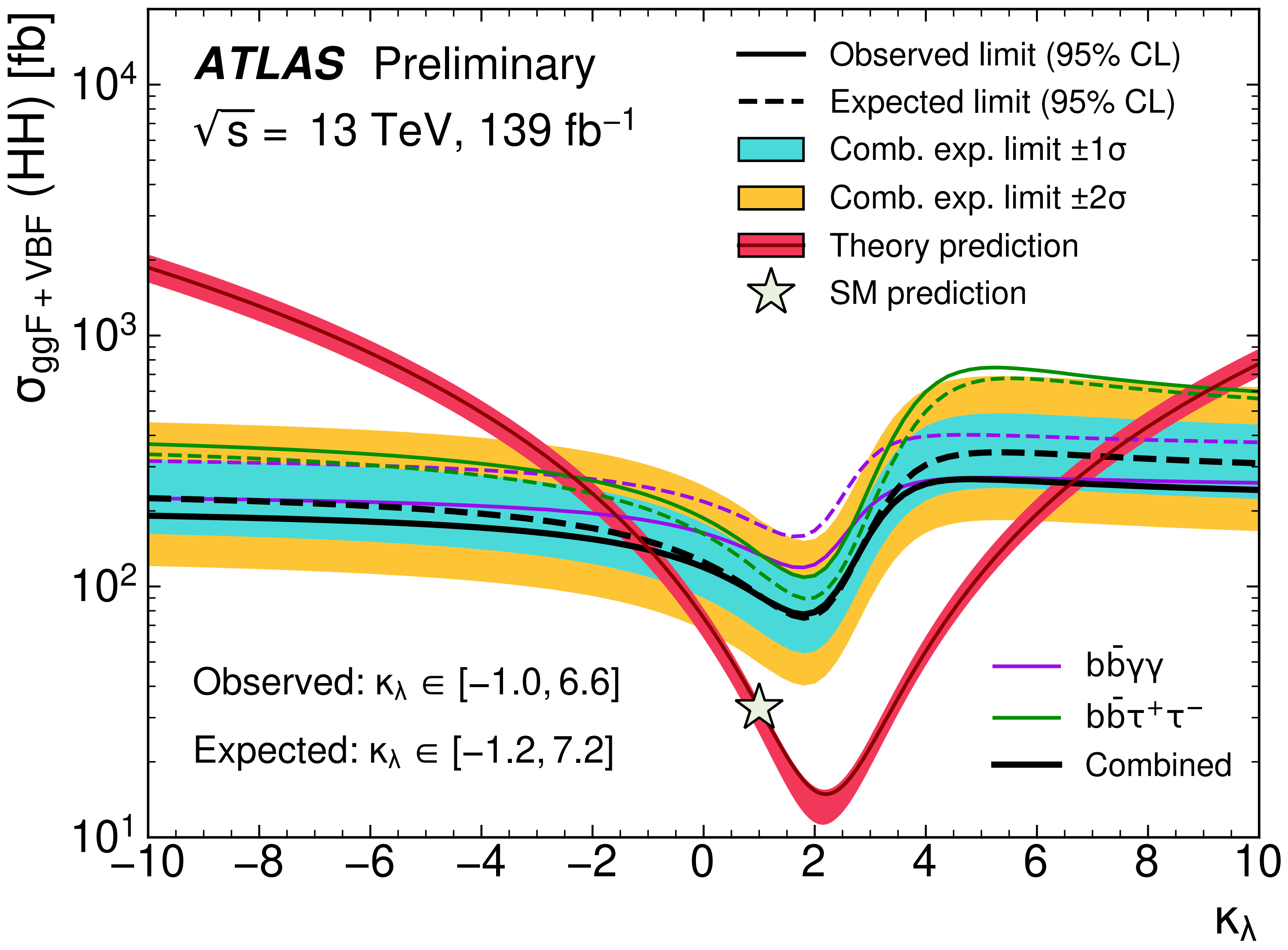
Summary in terms of limits on HH production

exp.	WW $\gamma\gamma$	bb $\gamma\gamma$	bb $\tau\tau$	bbWW	bbbb	bb4l
$\sigma \times \mathrm{Br}$	0.1 %	0.26 %	7%	25%	34%	1.5%*
ATLAS	<747 (386)	<4.1 (5.5)	<4.7 (3.9)	-	<5.4 (8.1)	-

*without the Z leptonic branching of 3.3% ~4 events expected at HL-LHC high s/b ~ 5

Full data results in all channels are being finalised and combinations starting!





ATLAS Combination of $b\bar{b}\tau\tau$ and $b\bar{b}\gamma\gamma$
current best constraint

Observed constraint on trilinear coupling at 95% CL:

$$-1.0 < \kappa_\lambda < 6.6$$

Expected range:

$$-1.2 < \kappa_\lambda < 7.2$$

Many interesting combinations to appear soon, stay tuned!

As well as major and exciting challenge for Run 3 - and of course at HL-LHC!

Tri-boson WWW Observation!

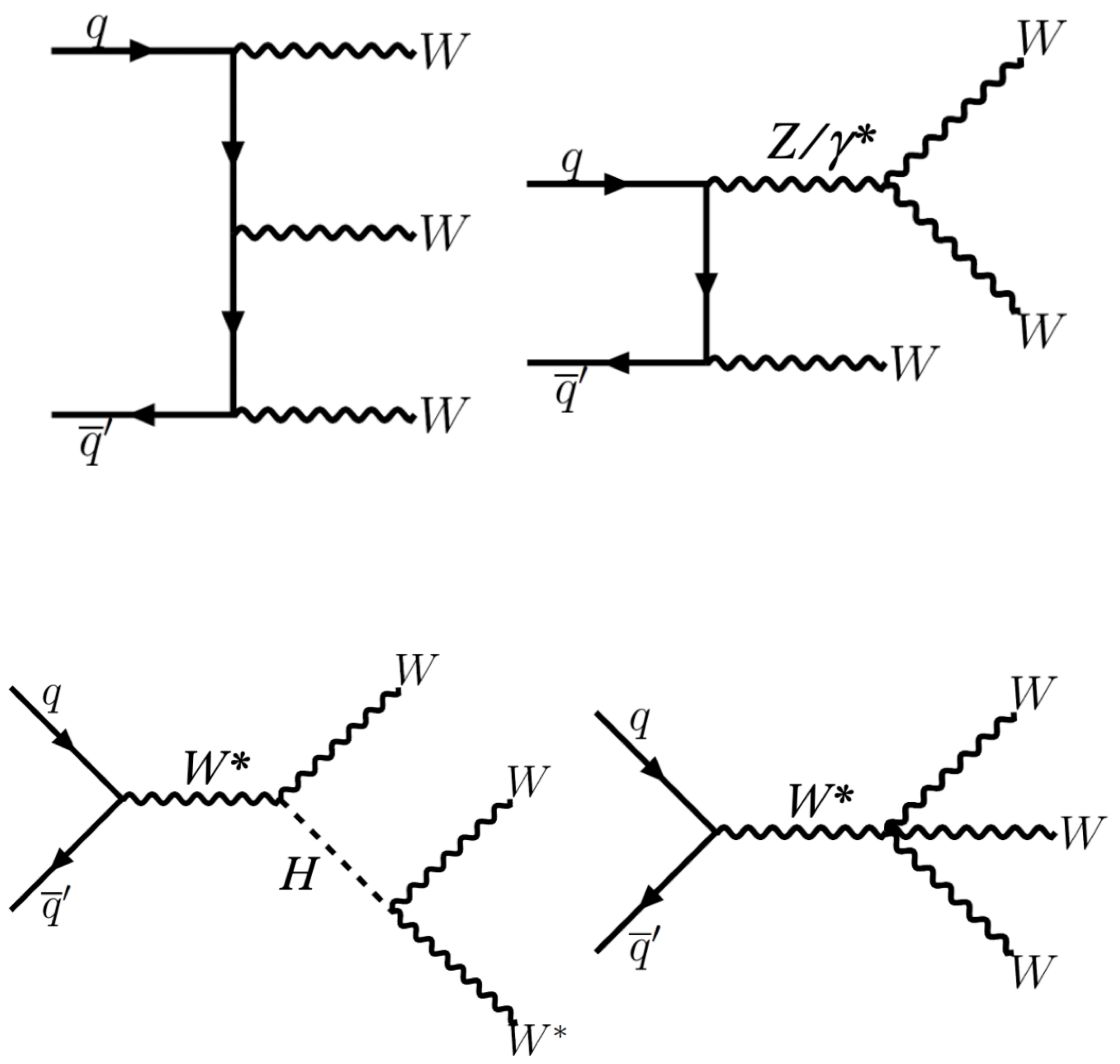
ATLAS-CONF-2021-053

Boosted $ee\mu$ candidate event

Triboson $W^{\pm}W^{\mp}W^{\mp}$ observation

Search for three W bosons production

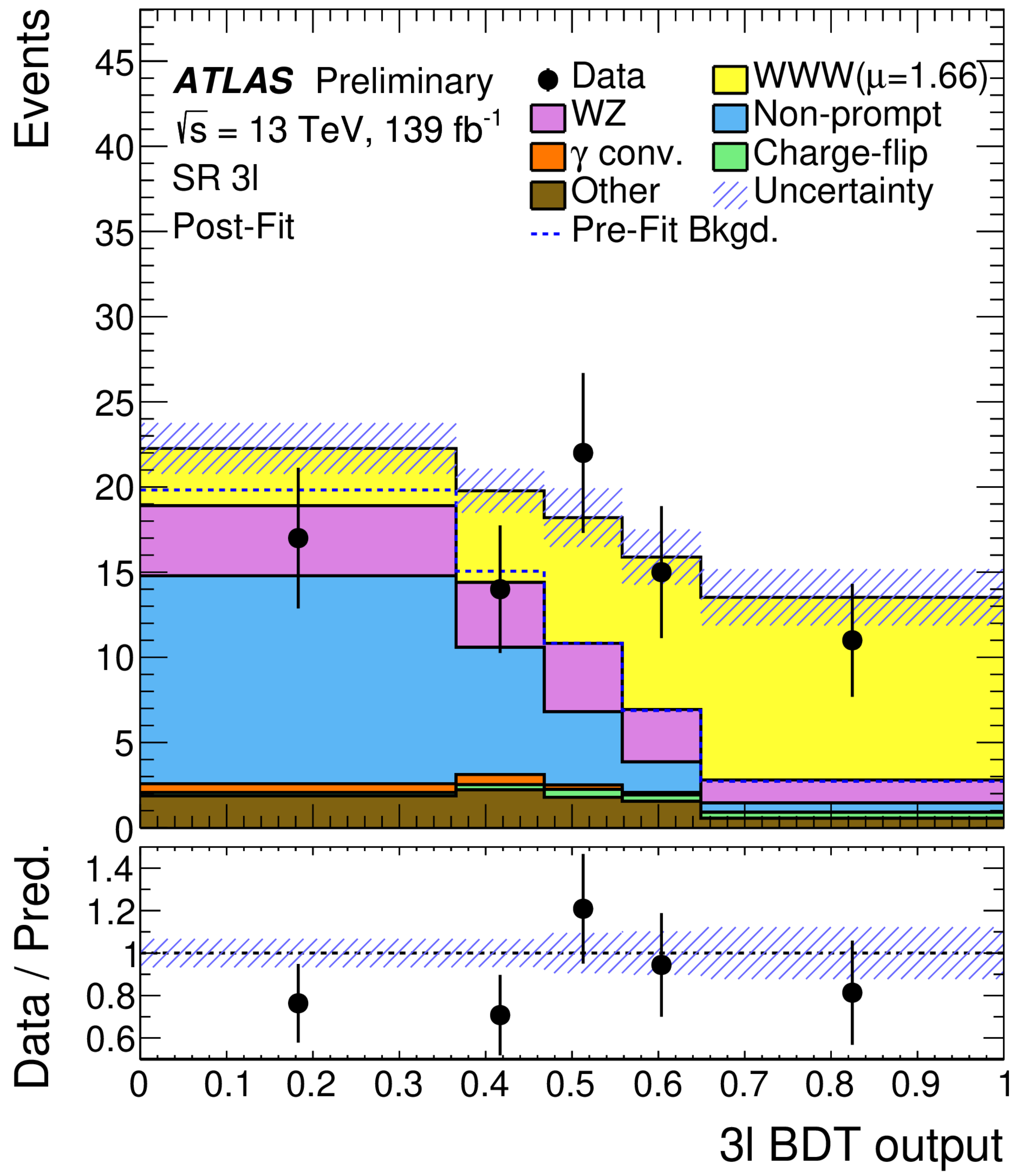
Last year shown observation of four top-quark production (see talk)!



First observation of $W^{\pm}W^{\mp}W^{\mp}$ at **8.2σ** (5.4σ expected)!

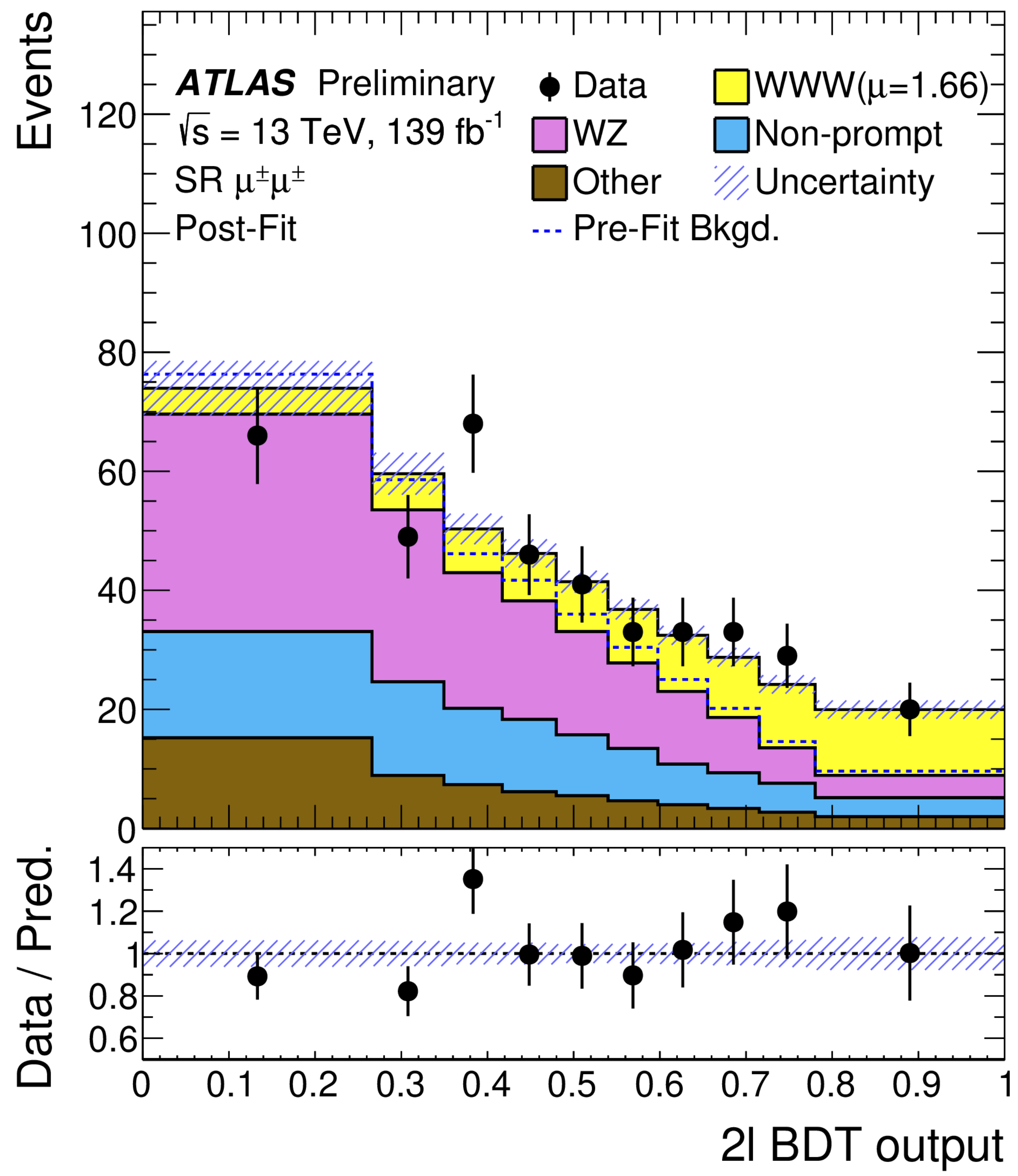
Measured cross section:

$$\sigma(pp \to WWW) = 820 \pm 100\ (\text{stat.}) \pm 80\ (\text{syst.})\ \text{fb}$$



Same sign 2-lepton channel

$\ell^{\pm}\nu\ell^{\pm}\nu jj$



3-lepton channel

$\ell^{\pm}\ell^{\pm}jj$

Predictions:

511 ± 18 fb

$pp \to W^+W^-W^-$ $\quad 76\ ^{+4}_{-3}$ (scale) ± 2 (PDF) fb

$pp \to W^-W^+W^+$ $\quad 136\ ^{+6}_{-5}$ (scale) ± 4 (PDF) fb

$pp \to WH \to WWW^*$ $\quad 293\ ^{+1}_{-2}$ (scale) $^{+6}_{-5}$ (PDF) ± 3 (α_s) fb

Compatibility 2.6σ

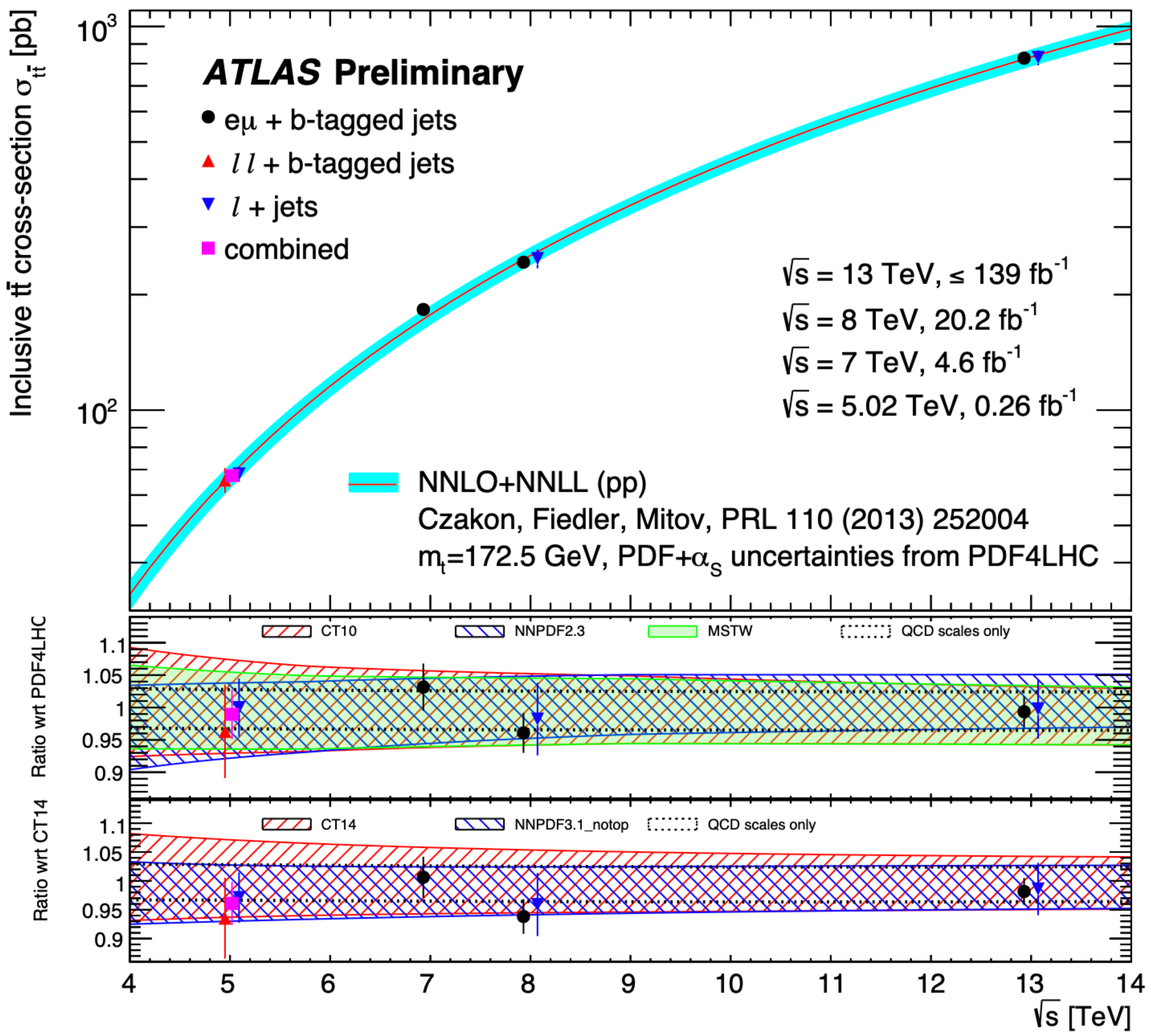
Top Pair Production at 5.02 TeV

ATLAS-CONF-2022-030

Top pair production cross section measurement at 5.02 TeV

New lepton-jets measurement and combination with earlier di-lepton channel in low PU runs at 5.02 TeV

Excellent precision reached with small dataset of 0.26 fb^{-1}

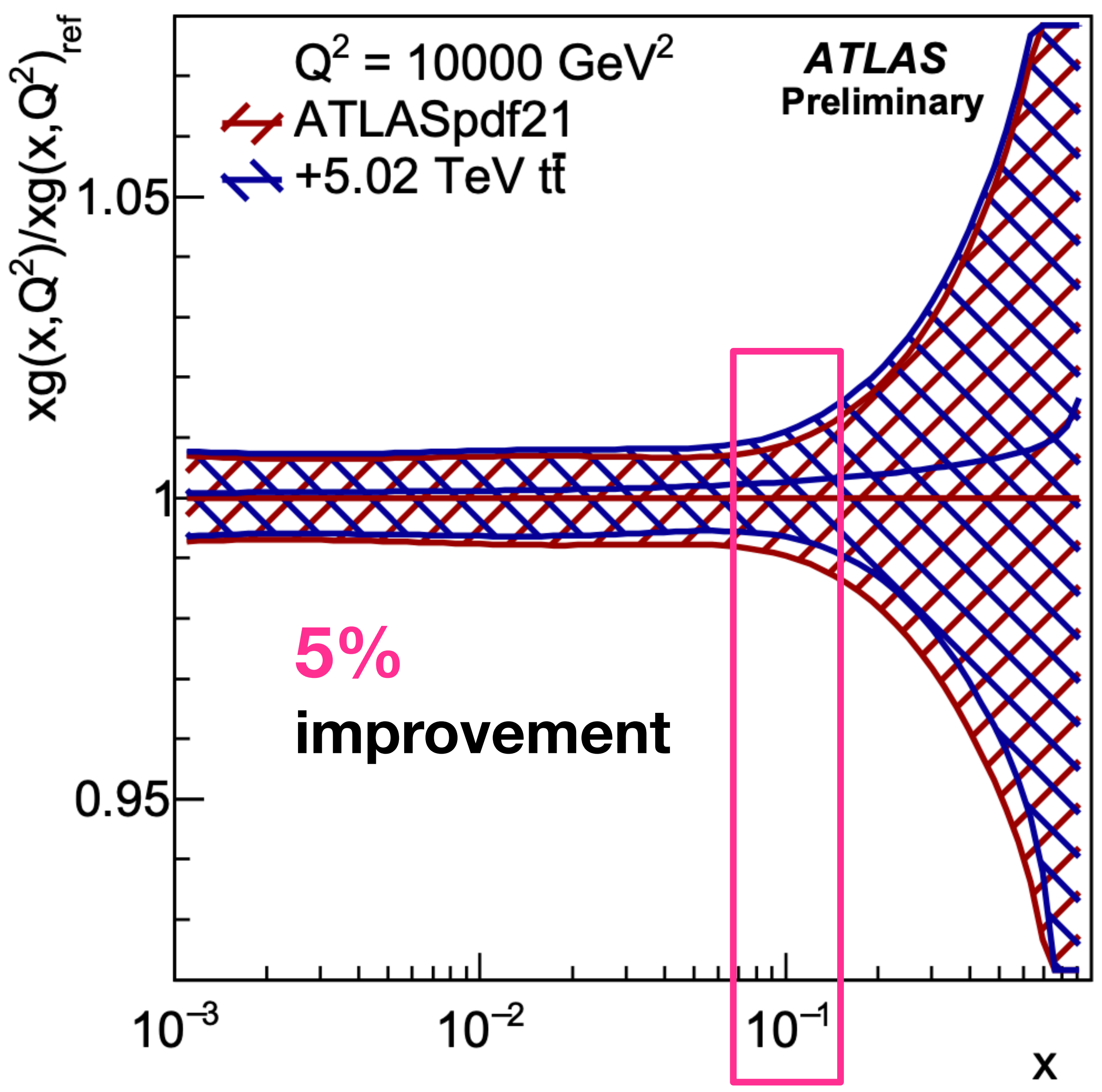


$$\sigma_{t\bar{t}} = 67.5 \pm 0.9\,(\text{stat.}) \pm 2.3\,(\text{syst.}) \pm 1.1\,(\text{lumi.}) \pm 0.2\,(\text{beam})\ \text{pb}$$

In excellent agreement with the NNLO-NNLL Top++ prediction

$$68.2 \pm 4.8^{+1.9}_{-2.3}\ \text{pb}$$

Gluon PDF



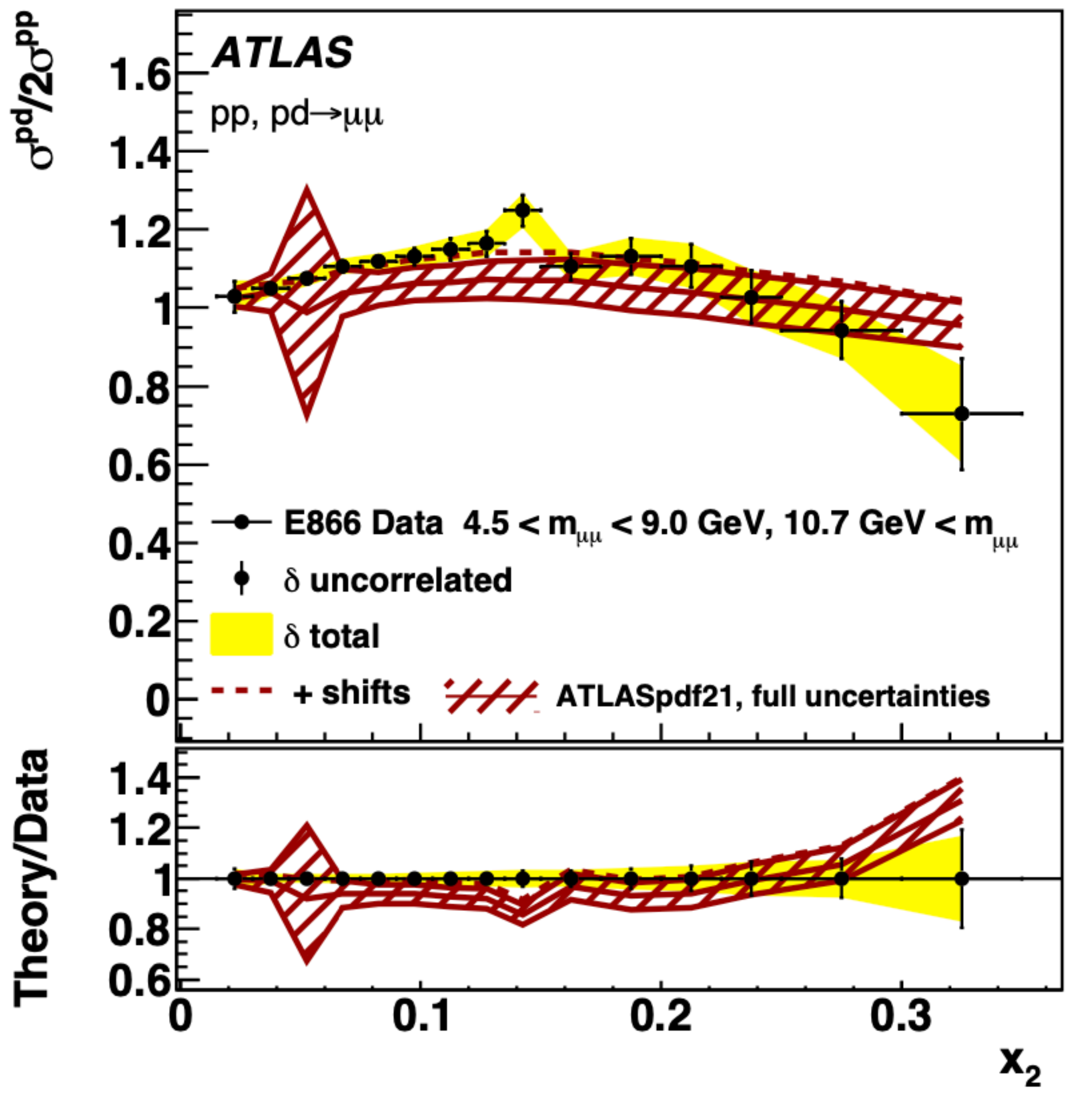
Important feedback to improve Higgs precision measurements

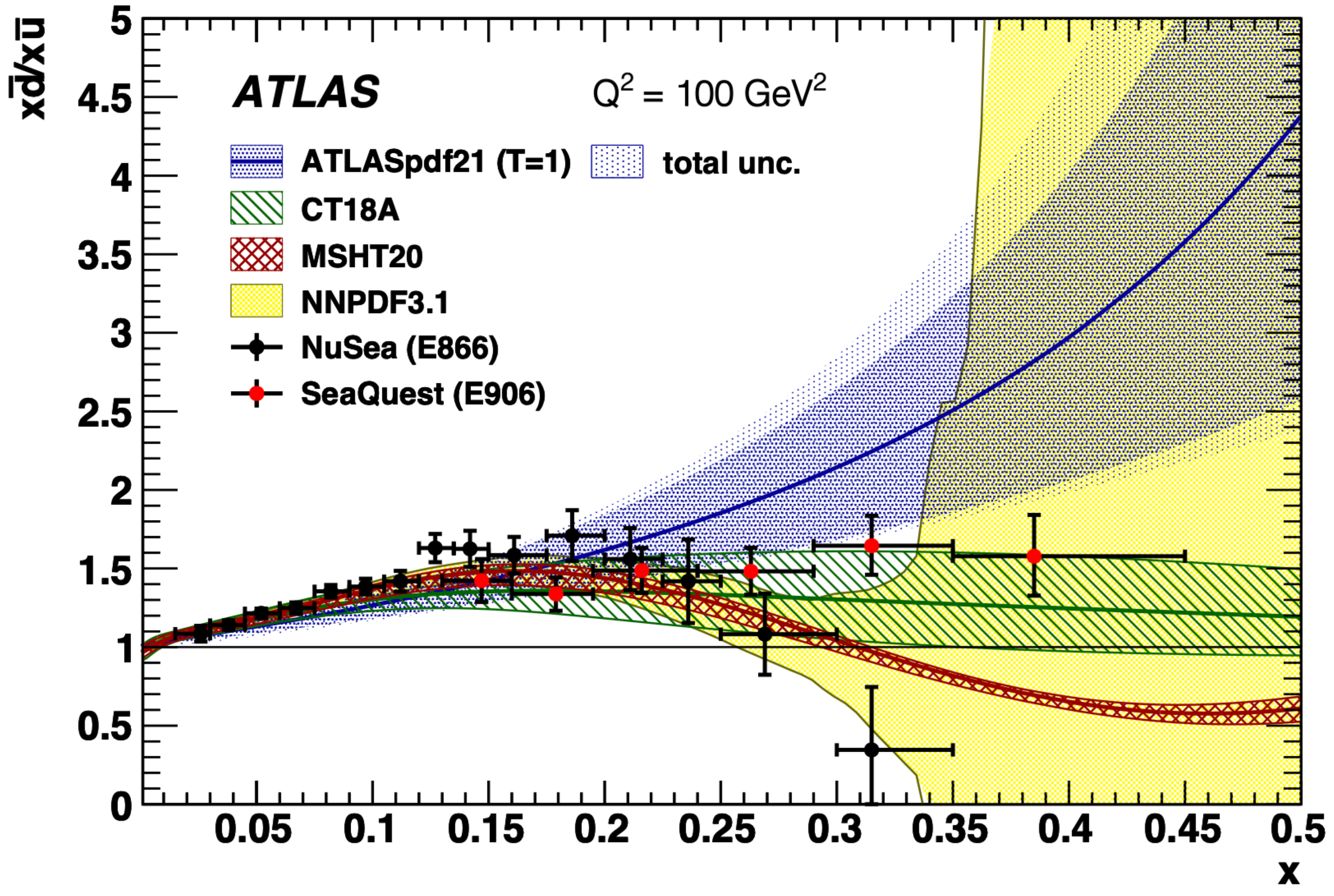
Global PDF Fits

ATLAS PDF fit

Using exclusively HERA ep data and ATLAS with the addition of W, Z (+jets), tt, jets, photon differential cross section measurements (fit done at NNLO in QCD, NLO in EW)

Light sea-quark contributions

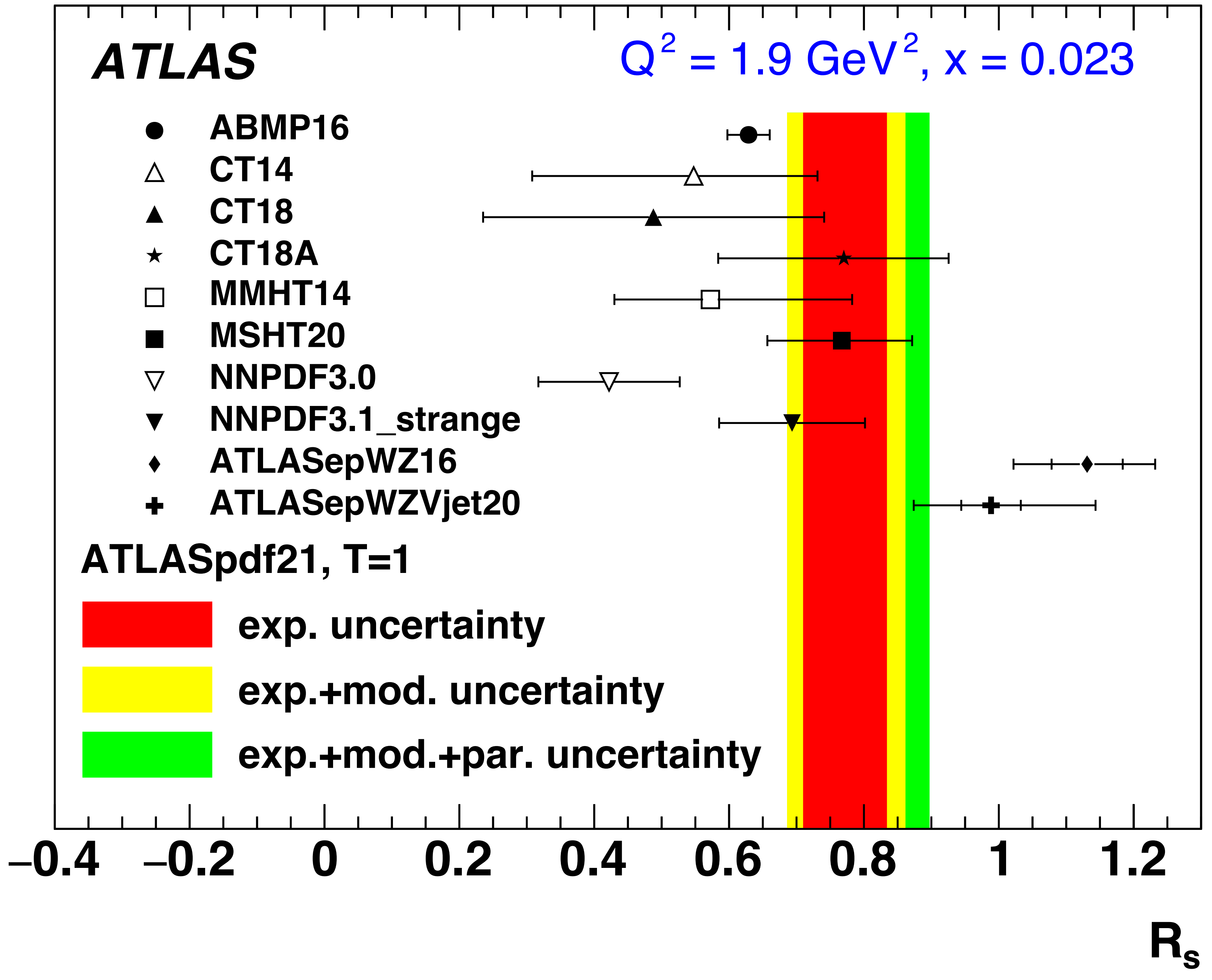




ATLAS data can be used to predict pD fixed target DY cross sections

Check relative densities of $\bar{u}$ and $\bar{d}$ sea contributions compatible with recent SeaQuest data E906 (at high x) than with NuSea (E866)

Strange quark composition

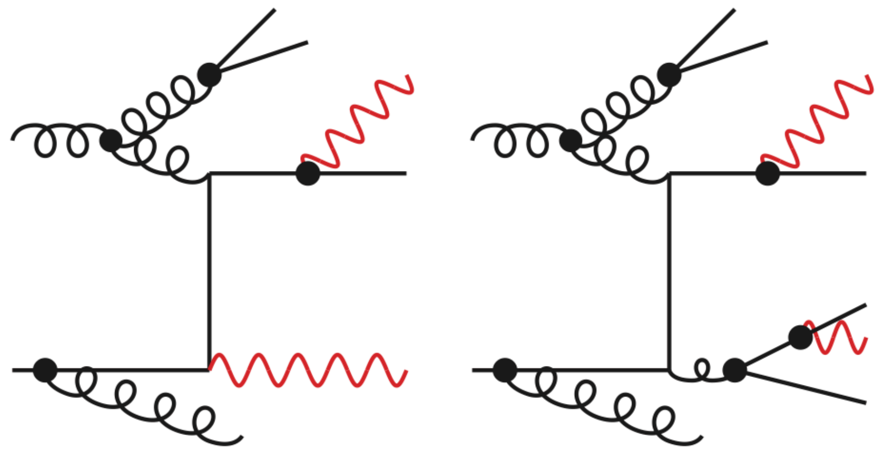


Improvement w.r.t. previous ATLAS PDFs

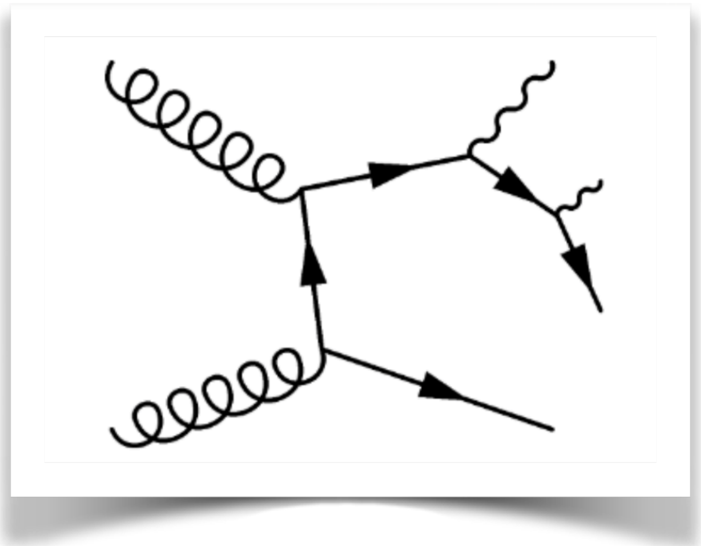
V+jets data suppresses R_s at high x (with effect on low x), as well as improved low-x parametrisation

Diphoton Production Cross Section

Measuring diphoton production is not only an electromagnetic process also non trivial strong dynamics!

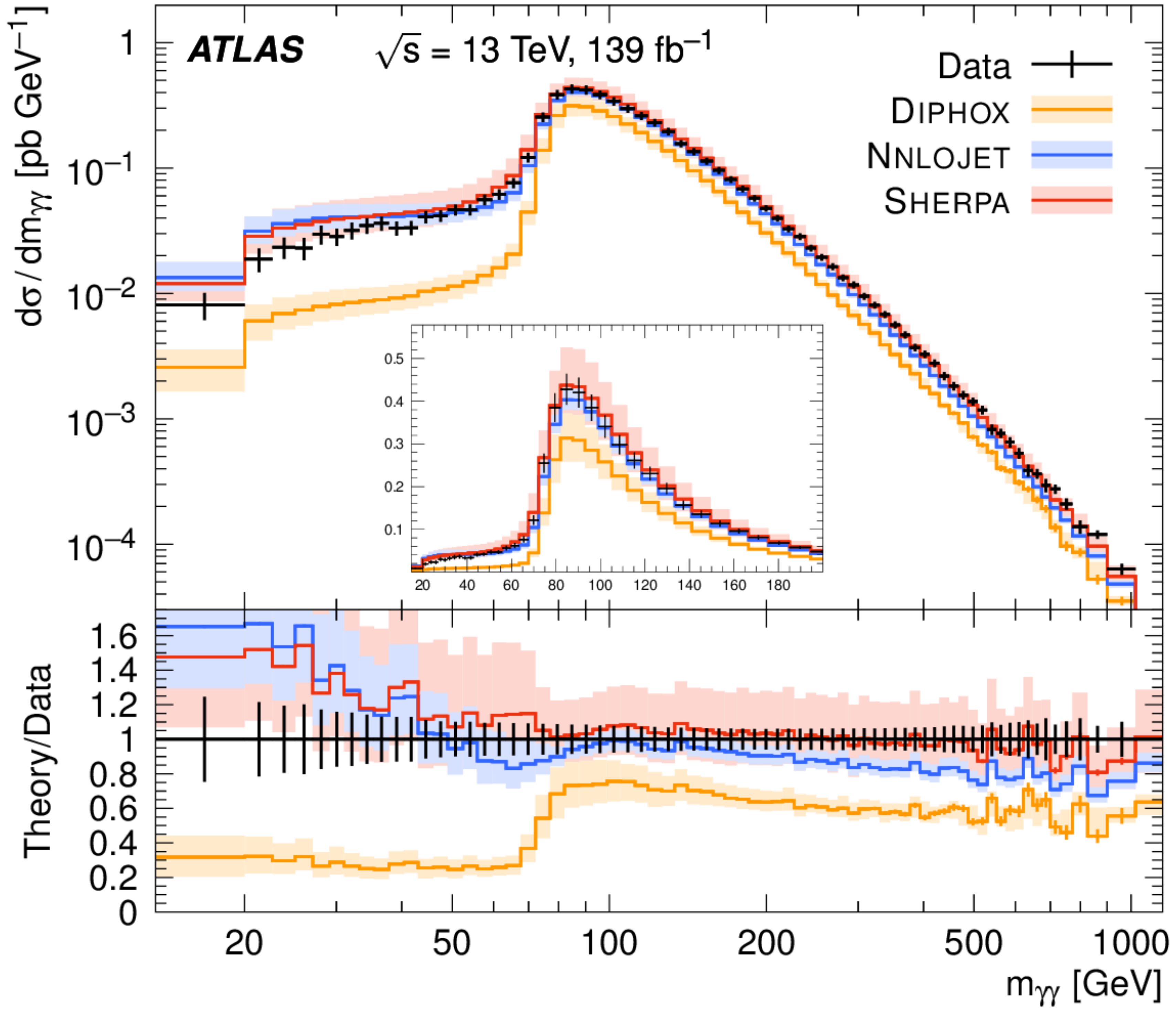


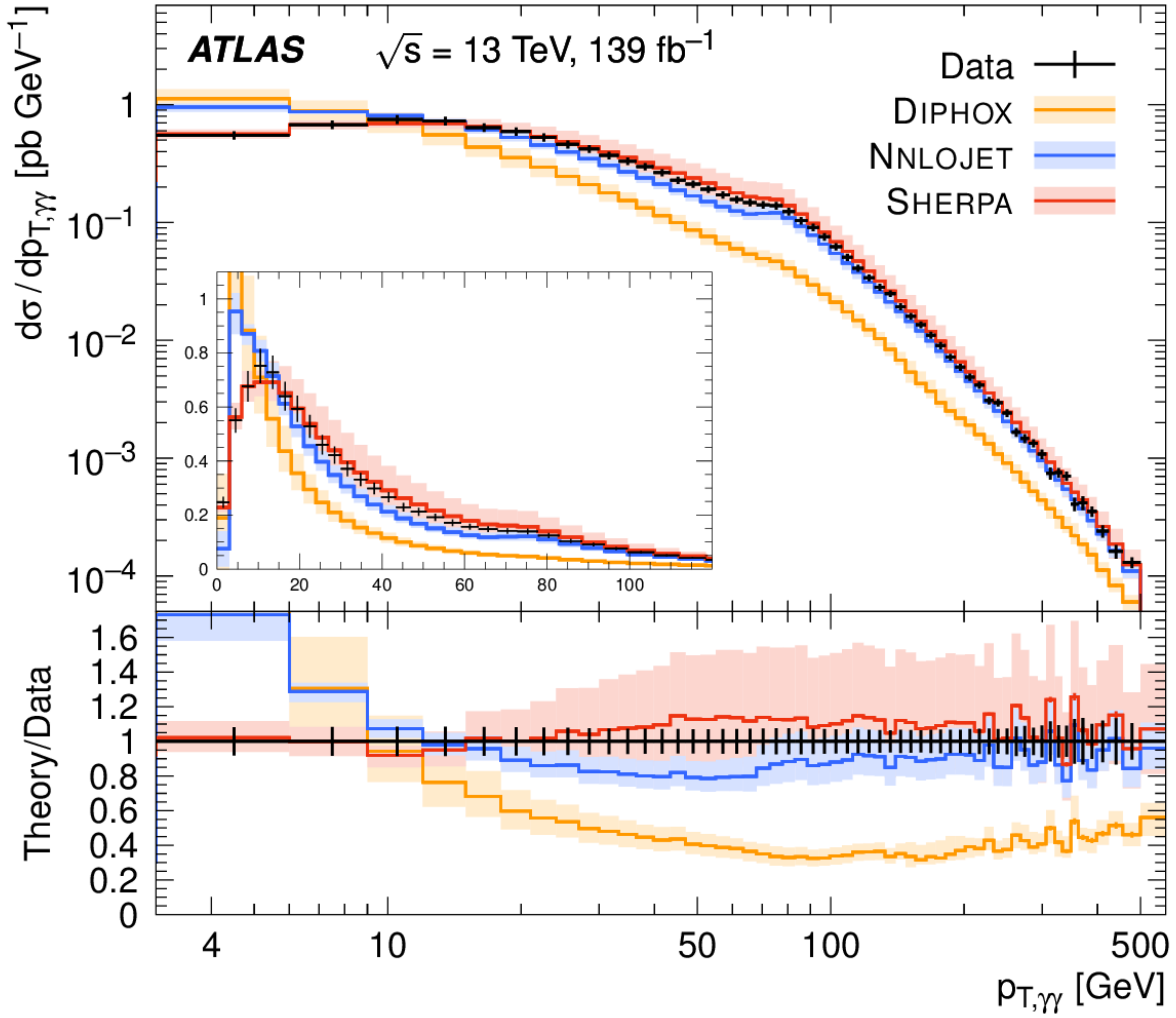
Estimate of PU events with two $\gamma - jet$ events in same bunch crossing (estimated using photon conversions)



Intricate effects as peak in $p_{T,\gamma\gamma}$ from double emission and kinematic cuts

$p_{T,\gamma_1(\gamma_2)} > 40\,(30)$





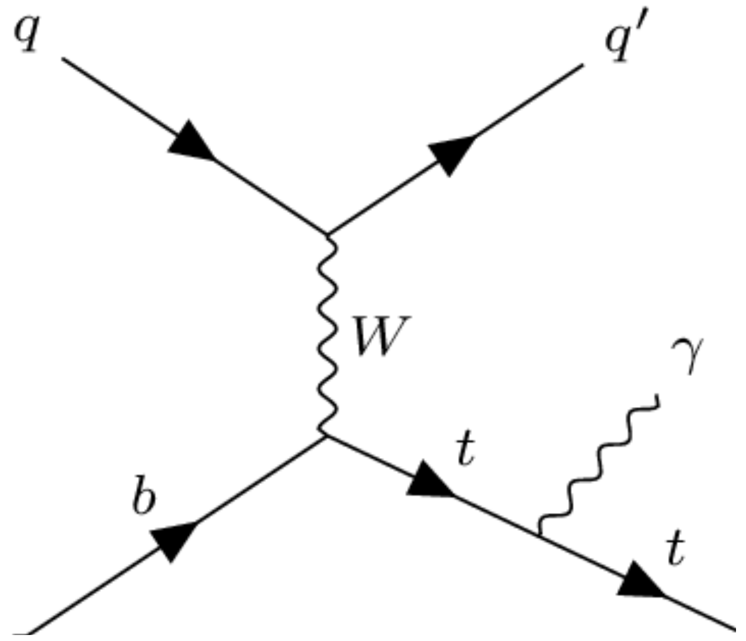
	Fixed-order accuracy						Fragmentation		QCD	NP
	$\gamma\gamma$	$+1j$	$+2j$	$+3j$	$+\geq 4j$	$gg \to \gamma\gamma$	single	double	res.	effects
DIPHOX	NLO	LO	-	-	-	LO	NLO		–	–
NNLOJET	NNLO	NLO	LO	-	-	LO	–	–	–	–
SHERPA	NLO		LO		PS	LO	ME+PS		PS	✓

Rare single top production

Rare single top process observation

$tq\gamma$ Single-top quark and a photon

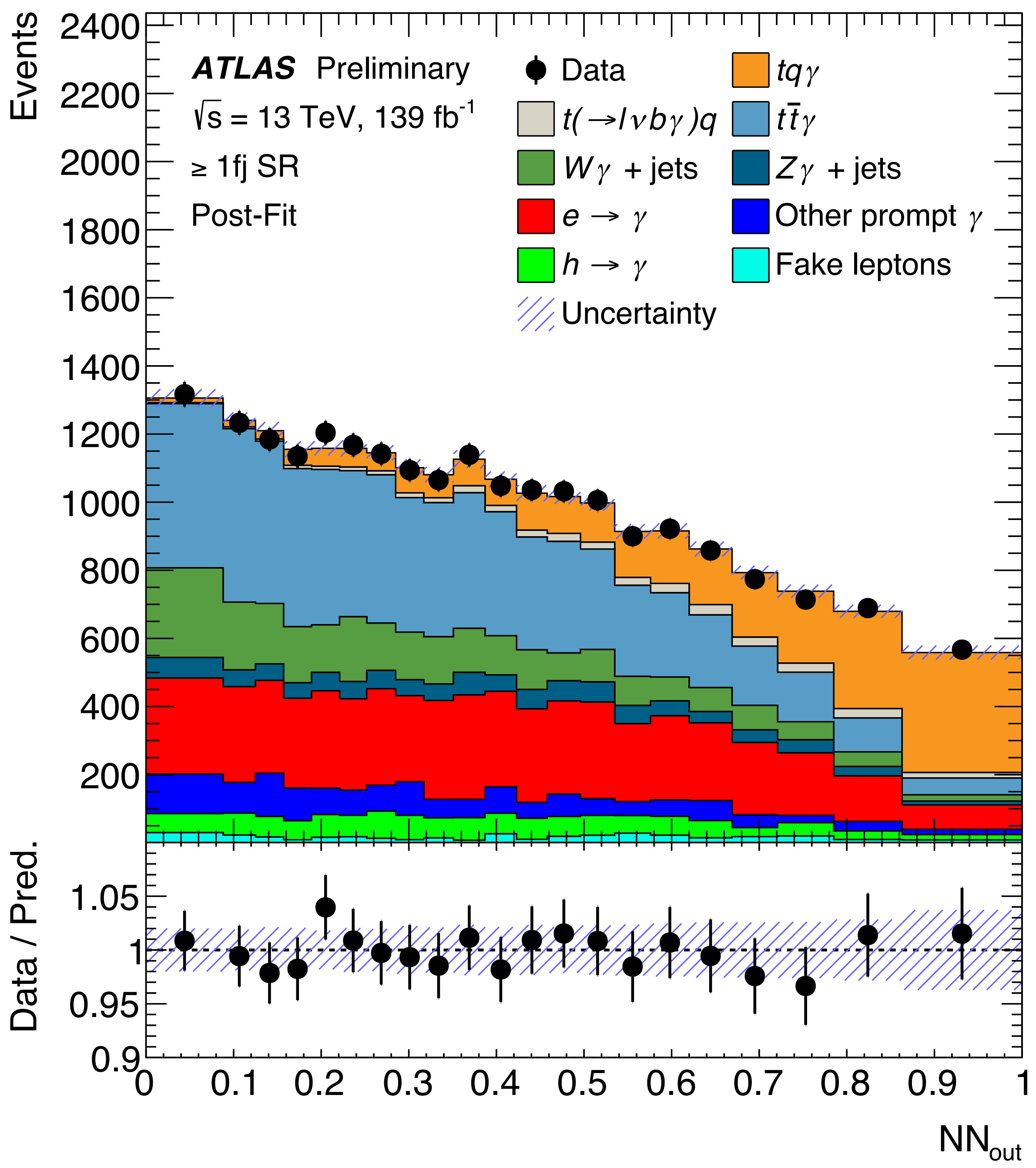
Powerful probe of top-EW coupling (and constraints on new physics)



Search in the semi-leptonic top decay mode

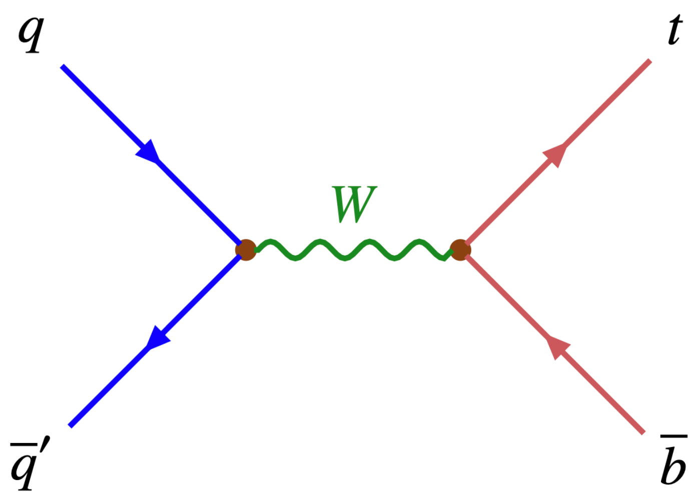
Requires 1-forward jet

$$2.5 < |\eta_{jet}| < 4.5$$



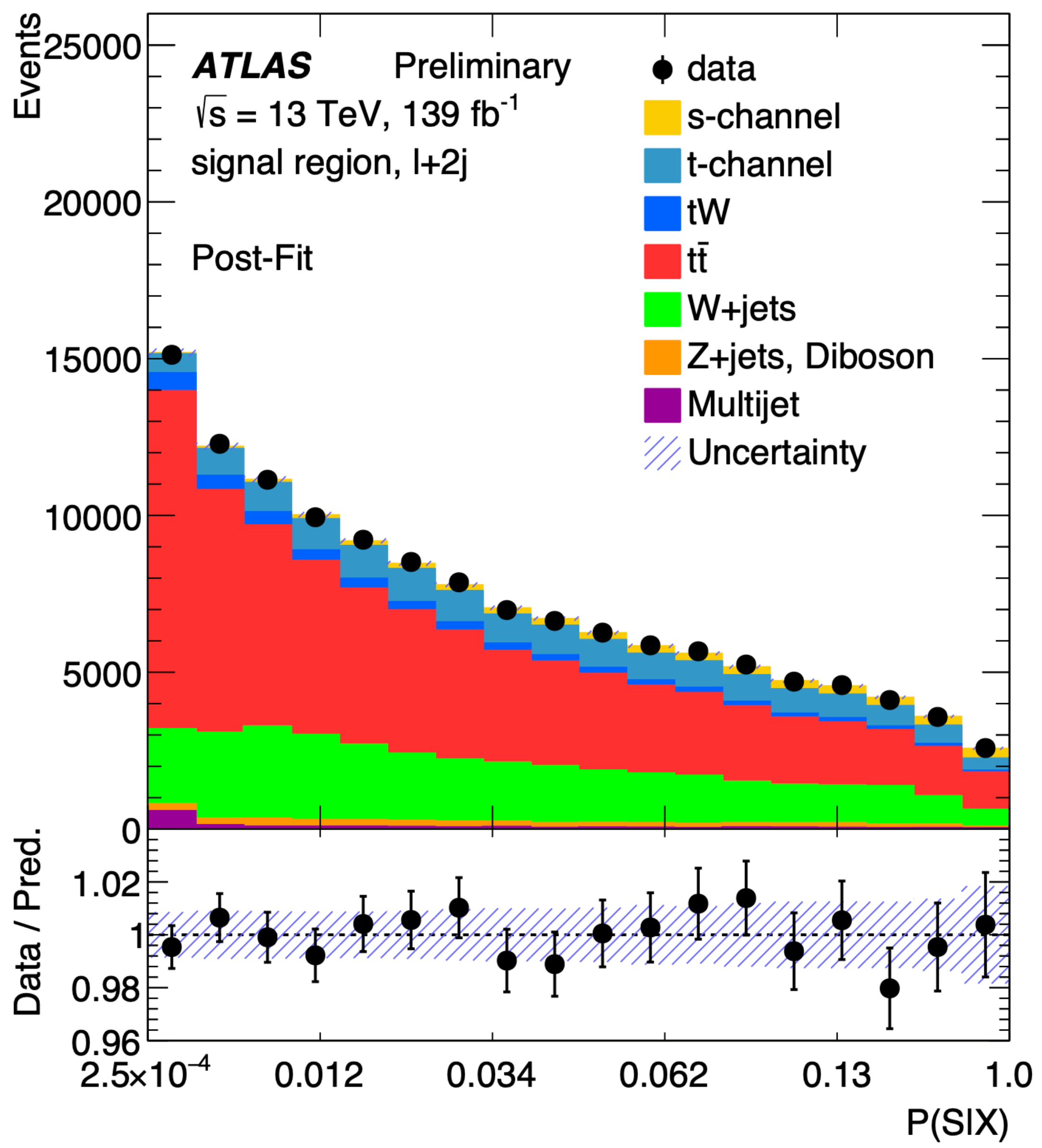
S-channel single top production

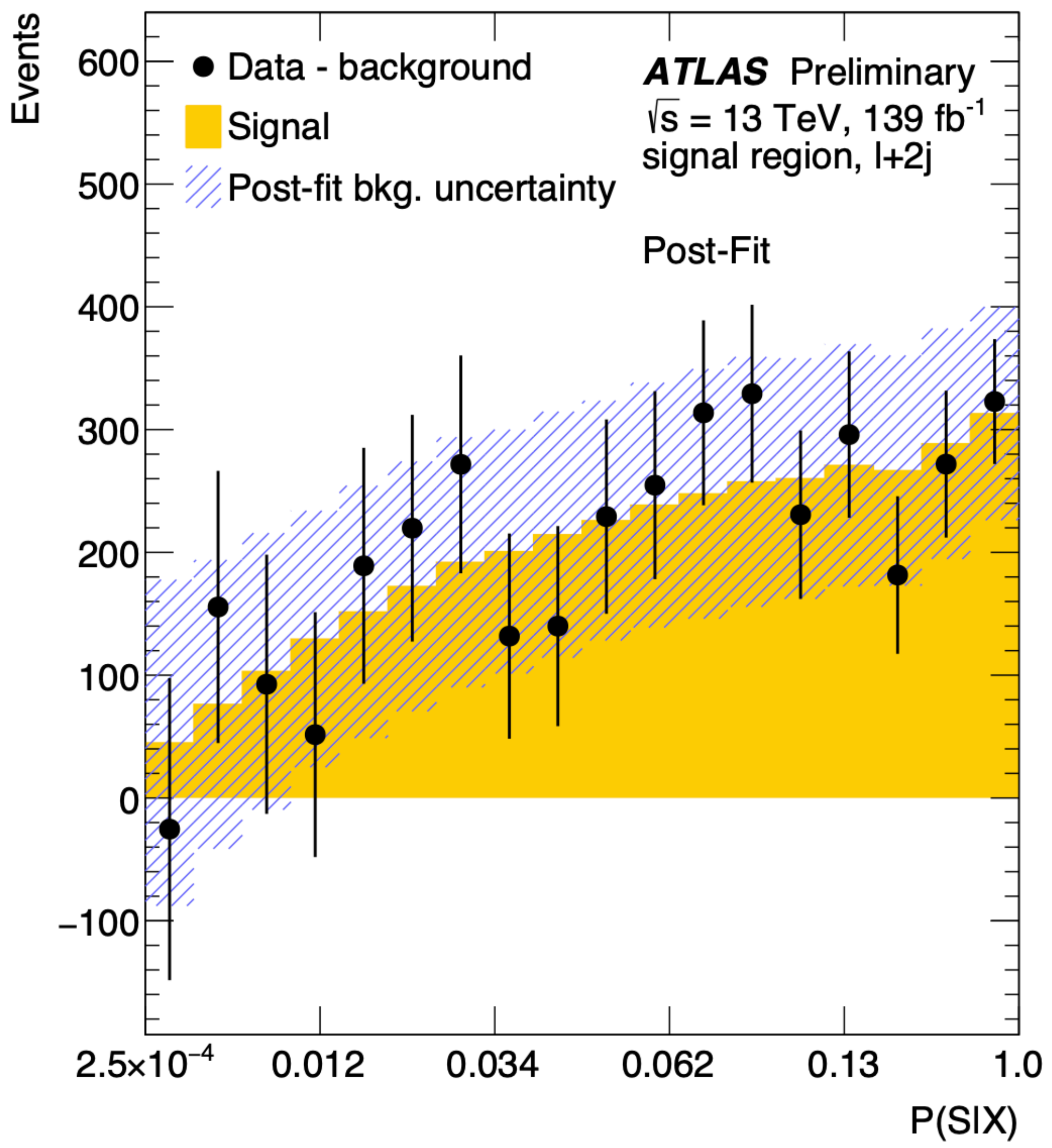
More challenging at higher energies to the smaller relative increase w.r.t. top pairs



Lowest cross-section measurement of all single-top processes!

Same sensitivity as Run 1 with **7 times more data!**





Matrix Element Probability for a given event X to be a signal event S P(S|X)

3.3σ Observed (3.9 σ expected)

Main systematic:

W-jets and top modelling

Jet energy scale and resolution

Measurement dominated by systematic uncertainties:

$$\sigma_s = 8.2^{+3.5}_{-2.9}\,\text{pb}$$

Prediction at NLO QCD

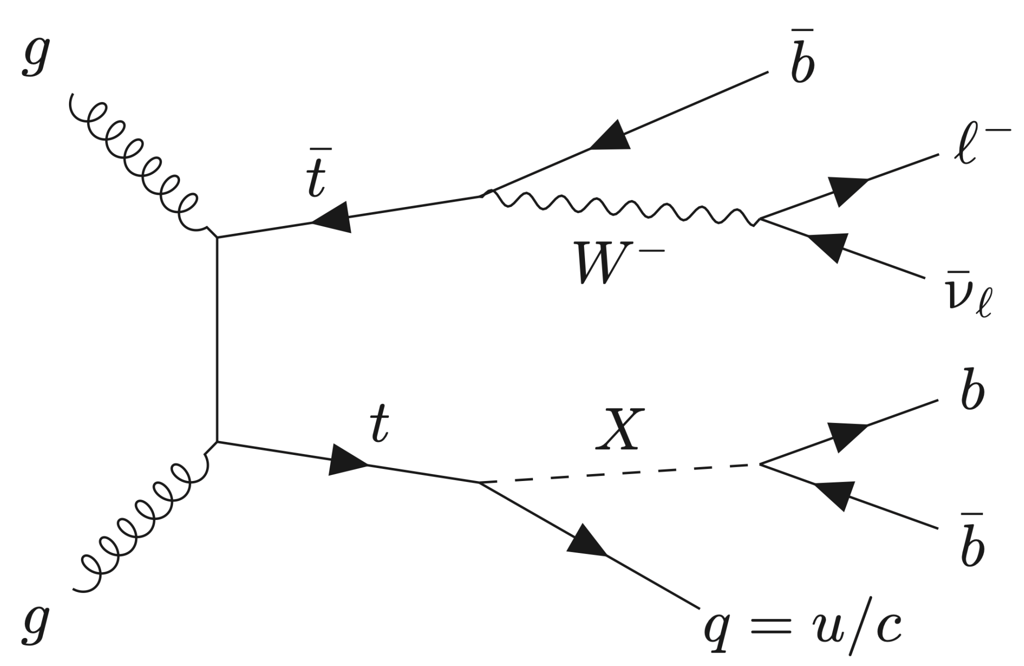
$$\sigma_s^{SM} = 10.3 \pm 0.4\,\text{pb}$$

Search for exotic FCNC top decays

Search to shed light on the Flavour Hierarchy problem

Search for intermediate mass “flavon” scalar field X in **Frogatt-Nielsen** models in top decays

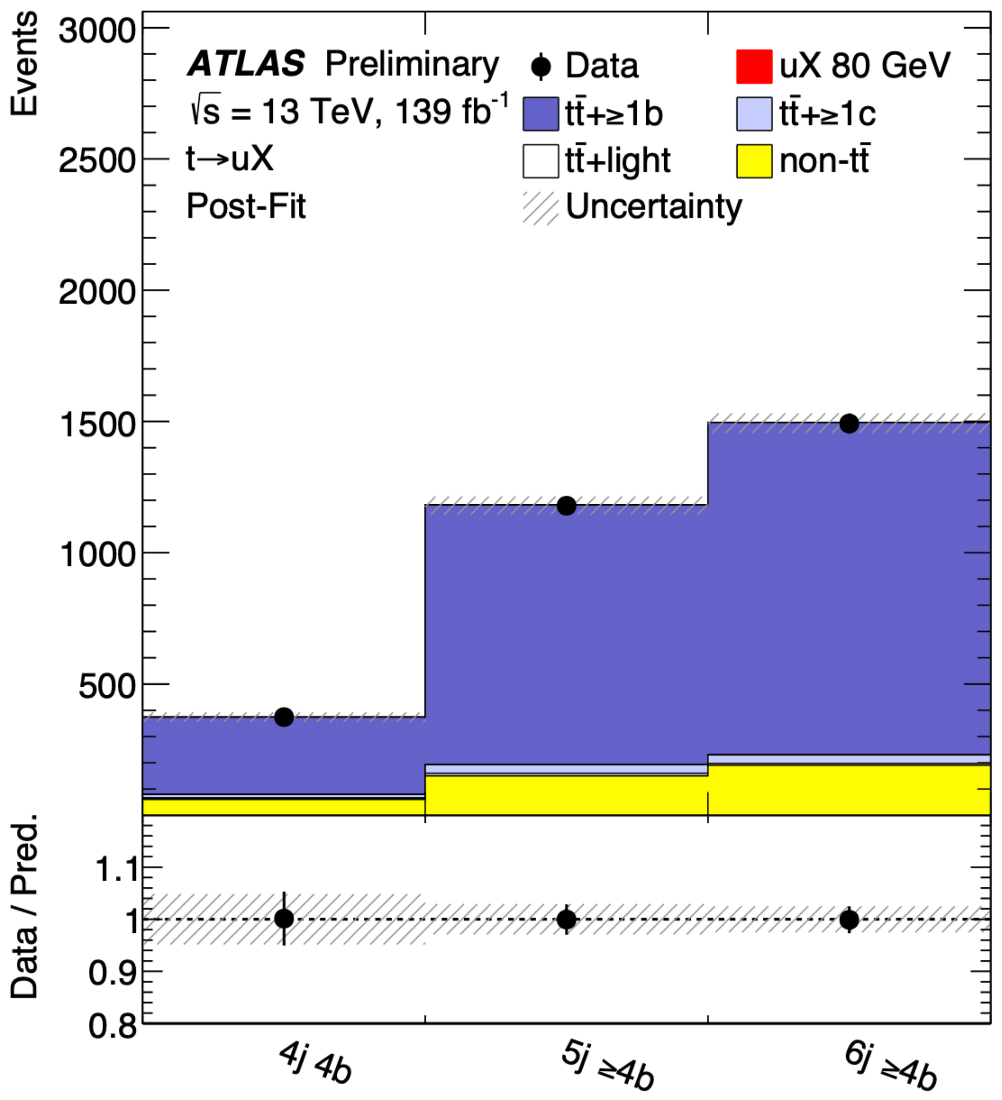
Large top production sample can be used to search for exotic top decays!

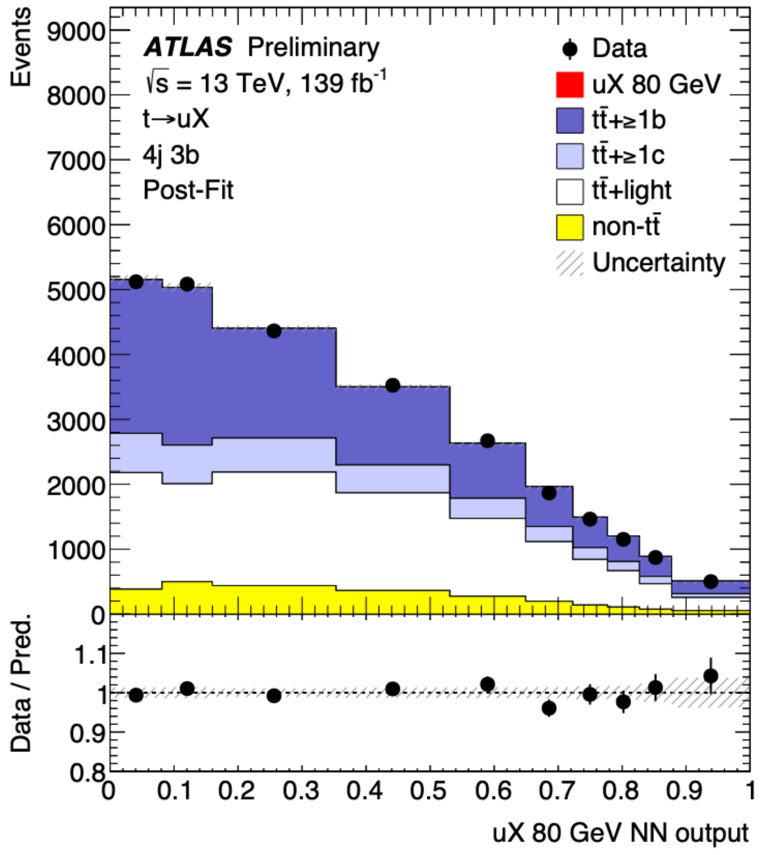


Complex signatures searched in 4j, 5j and 6j with 3 b-tagged jets

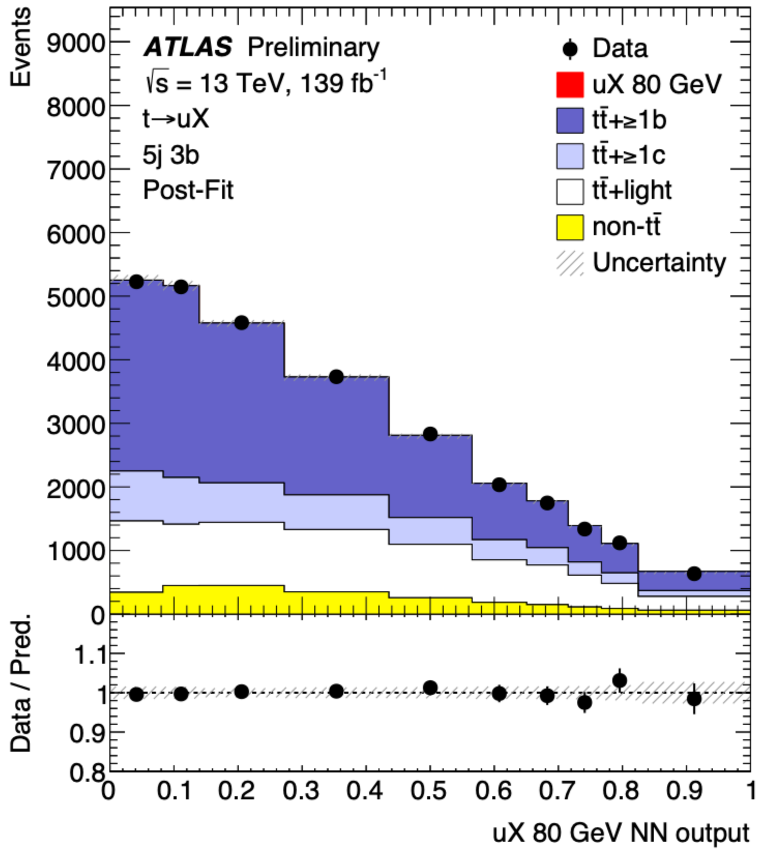
- Intricate tt-HF production control region in 4-b-tagged jets events

- A BDT trained in each SR for uX and cX signatures separately

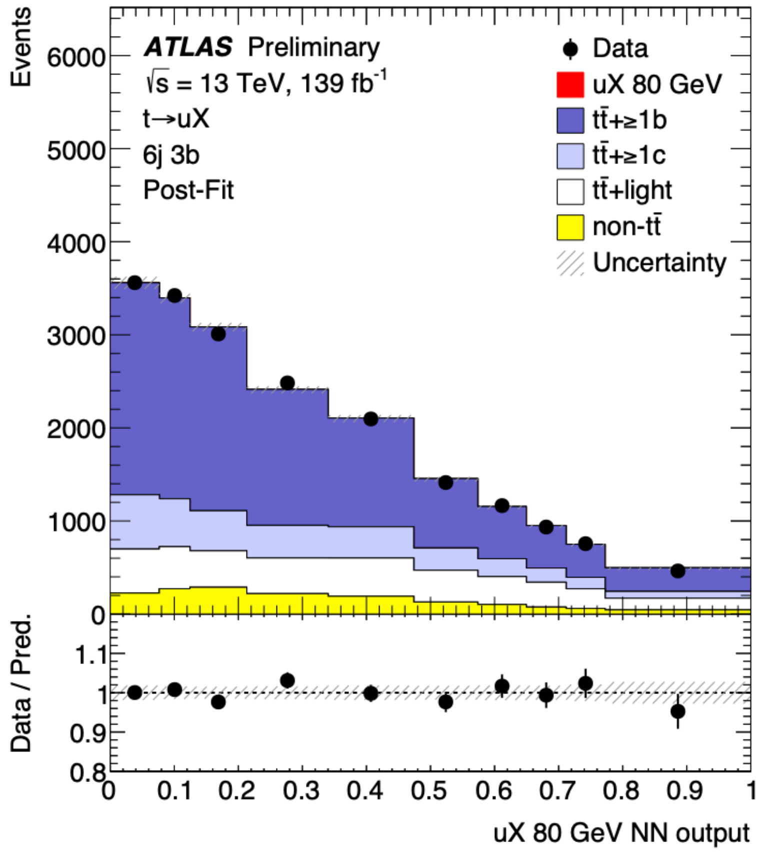




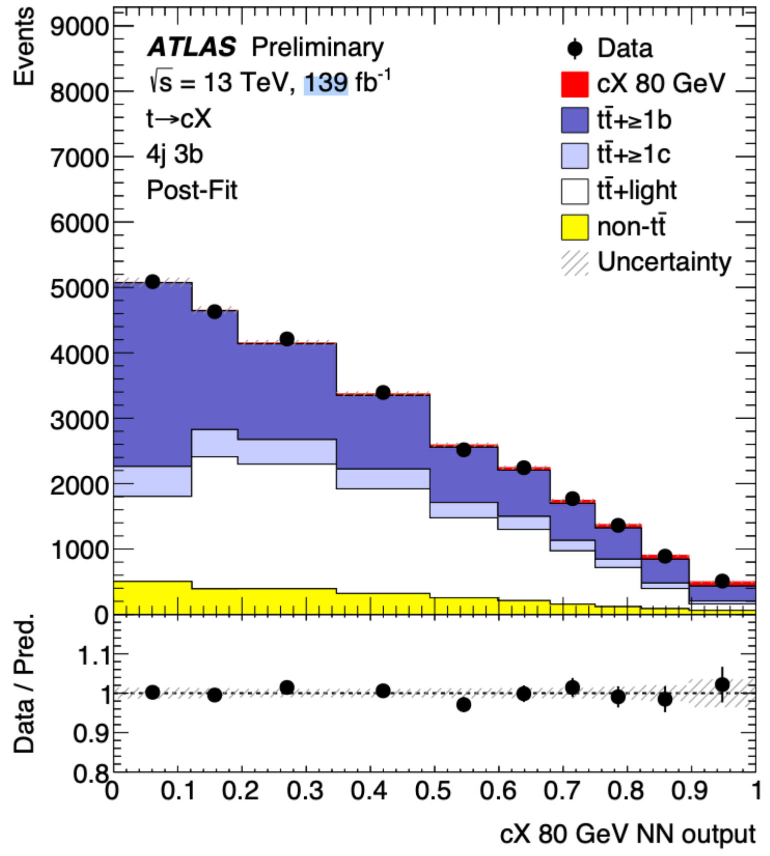
$t \to uX$, 4j 3b



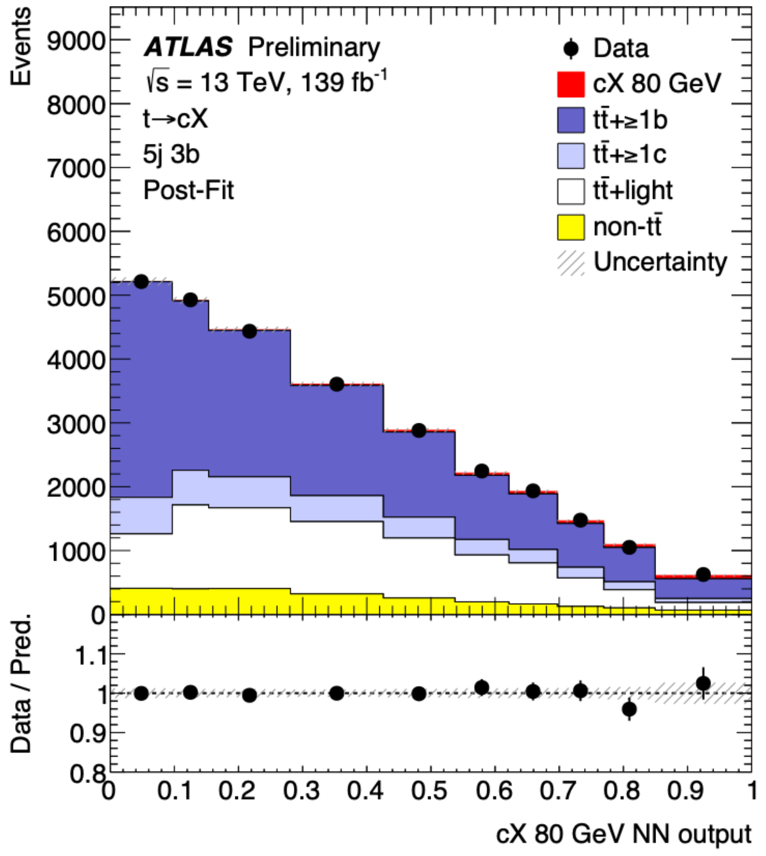
$t \to uX$, 5j 3b



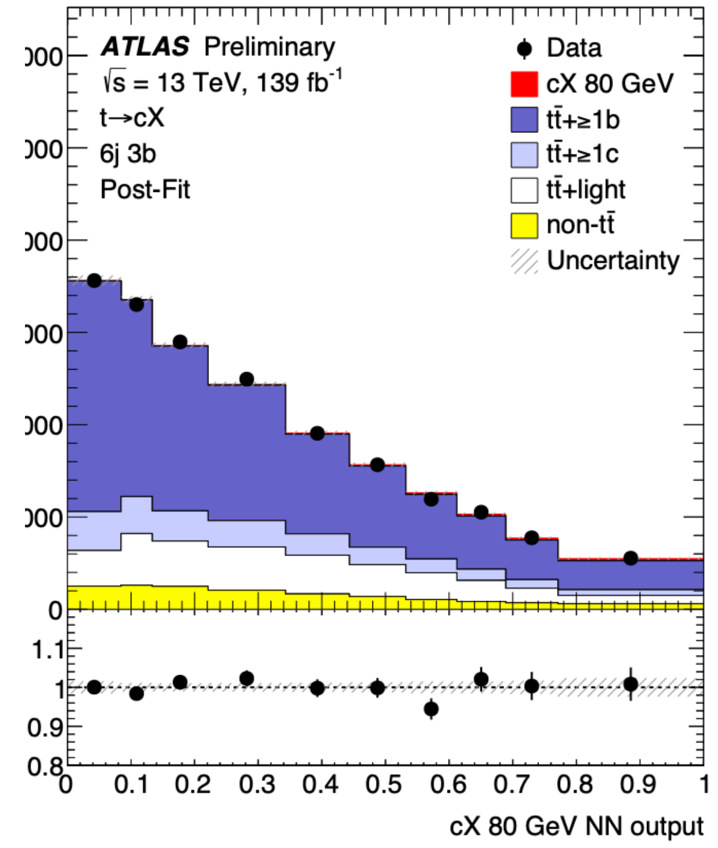
$t \to uX$, 6j 3b



$t \to cX$, 4j 3b



$t \to cX$, 5j 3b



$t \to cX$, 6j 3b

Limits on product of branching fractions of:

$$\mathscr{B}(t \to Xq) \times \mathscr{B}(X \to b\bar{b}) \lesssim 0.02\,\%$$

Independently of the accompanying quark flavour

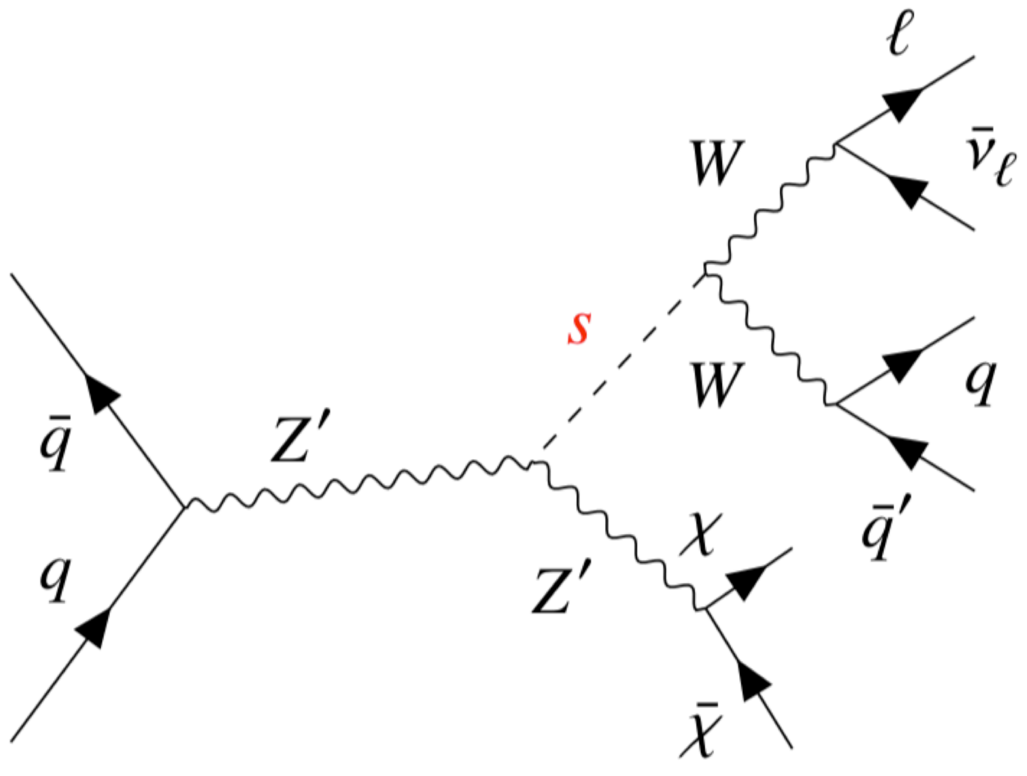
Search for DM and a Dark Higgs

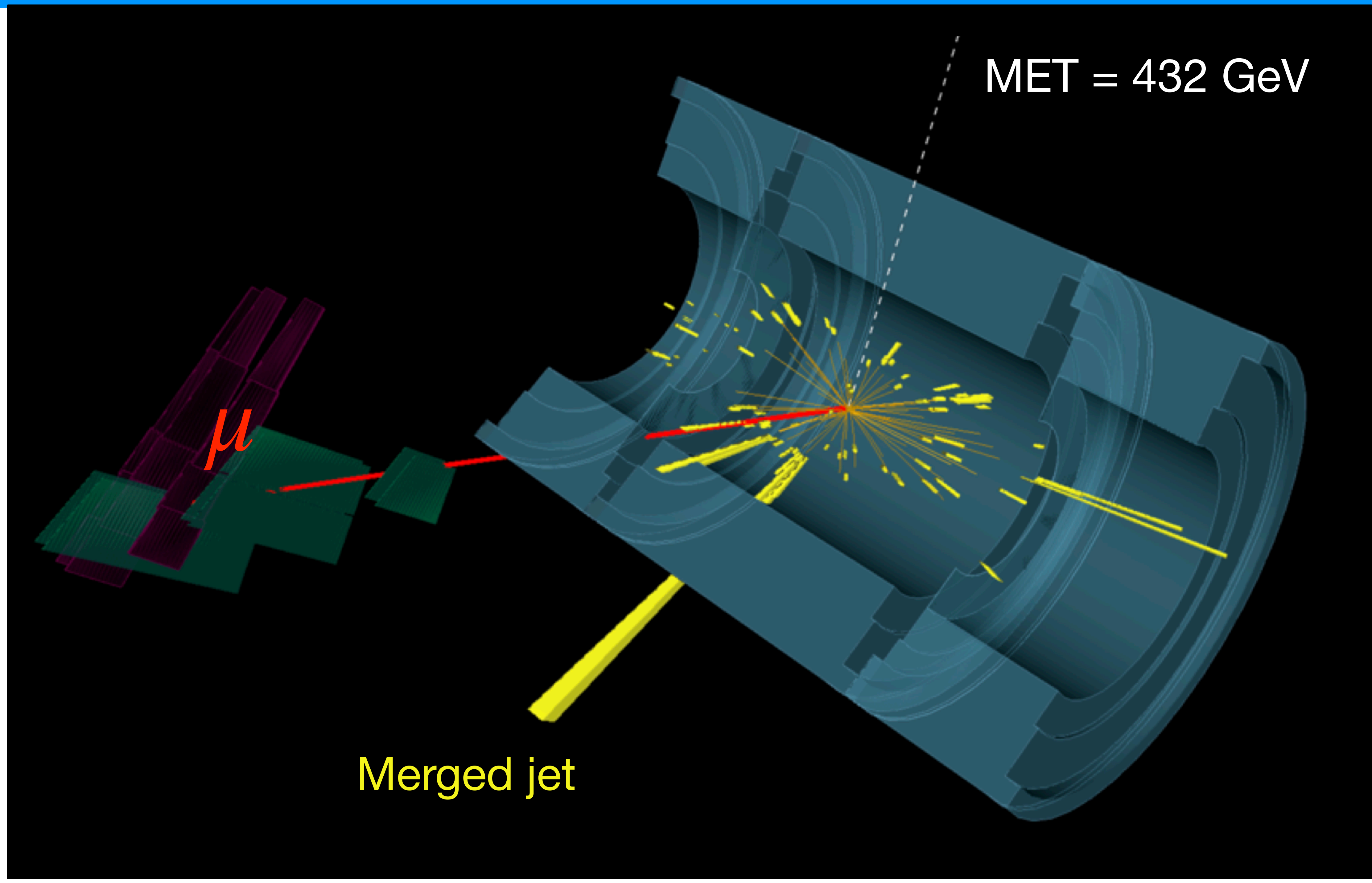
ATLAS-CONF-2022-029

Search for Dark Matter and a Dark Sector compatible with the Relic Density

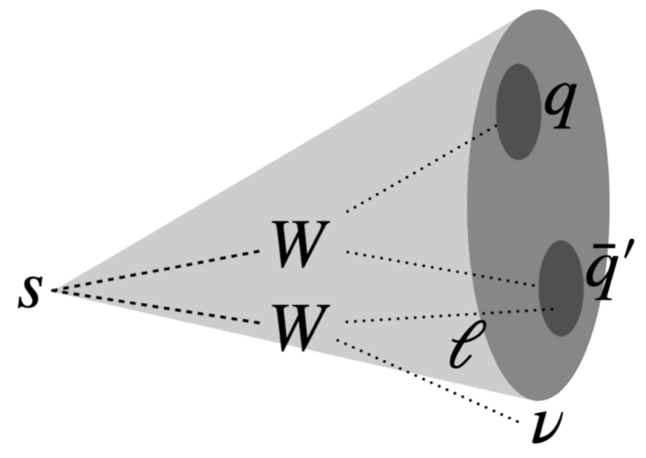
Dark sector with a dark Higgs boson **s** lighter than DM and an additional vector boson **Z’**

JHEP 1704 (2017) 143

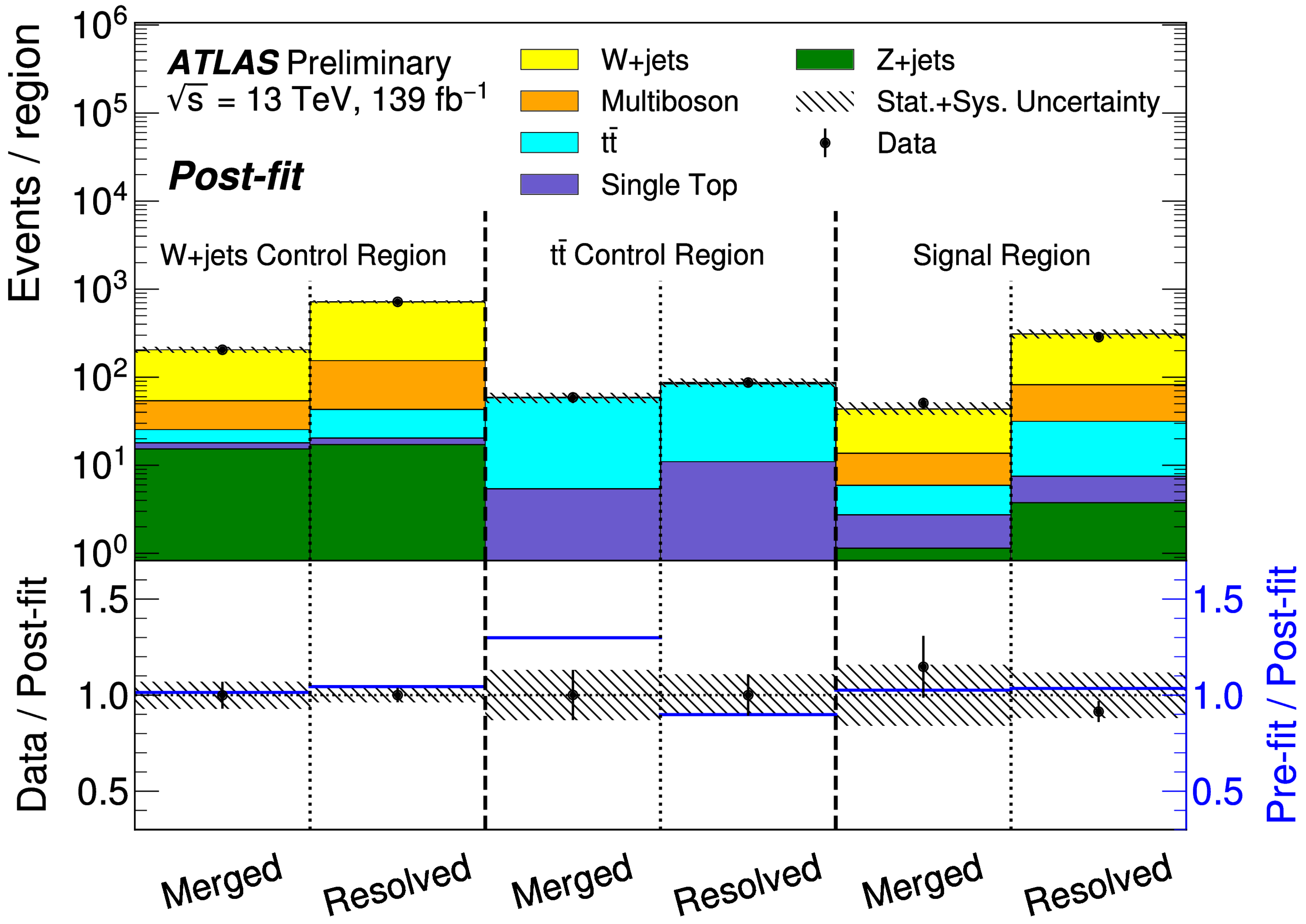




Using Track Assisted Reclustering TAR substructure technique

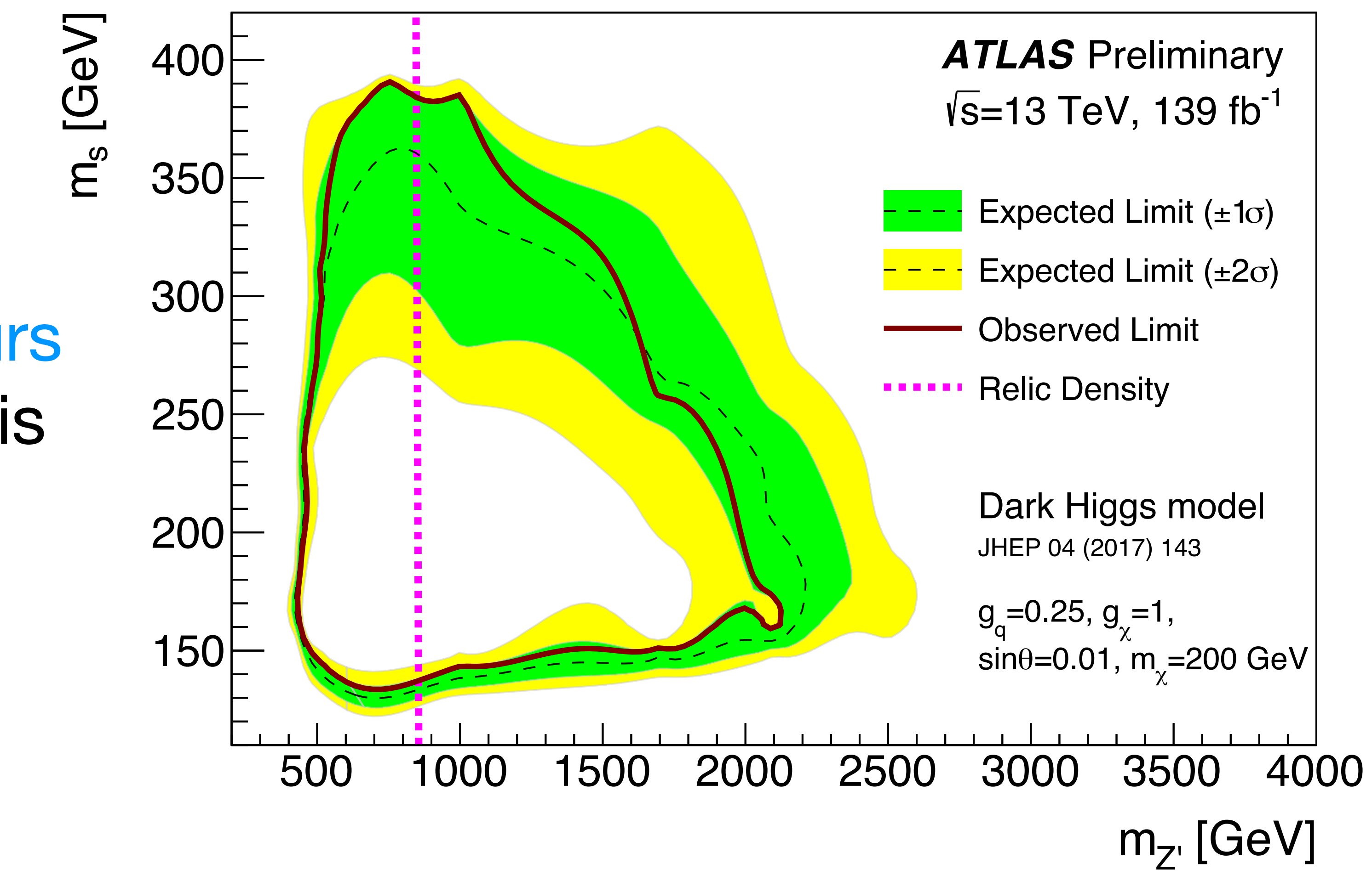


based on R=0.2 calorimeter jets then use tracks to estimate the mass



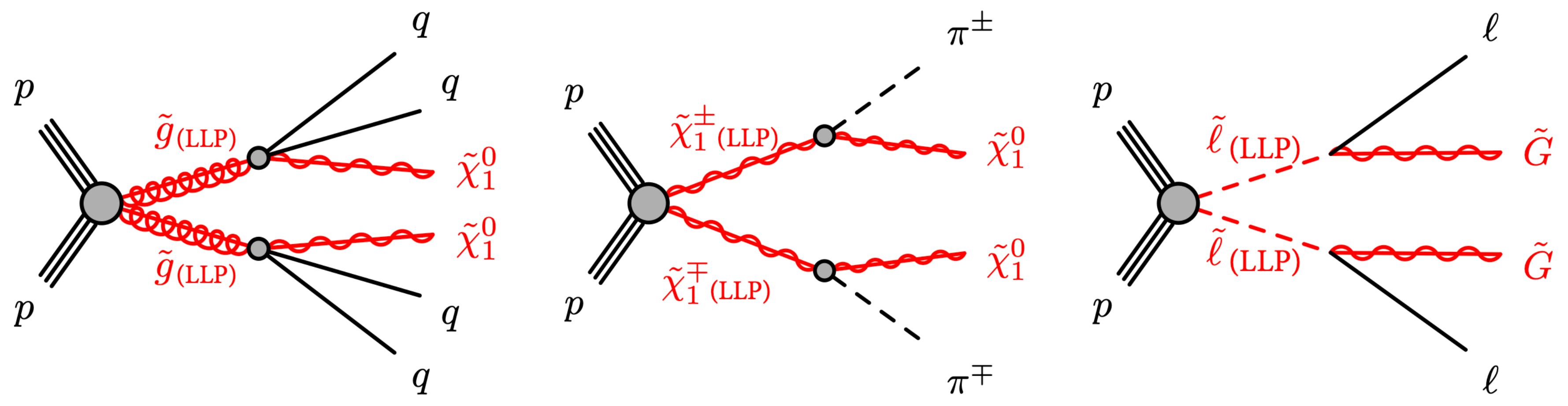
Exclusion contours

The relic density is obtained for **$m_{Z'}$=850 GeV**



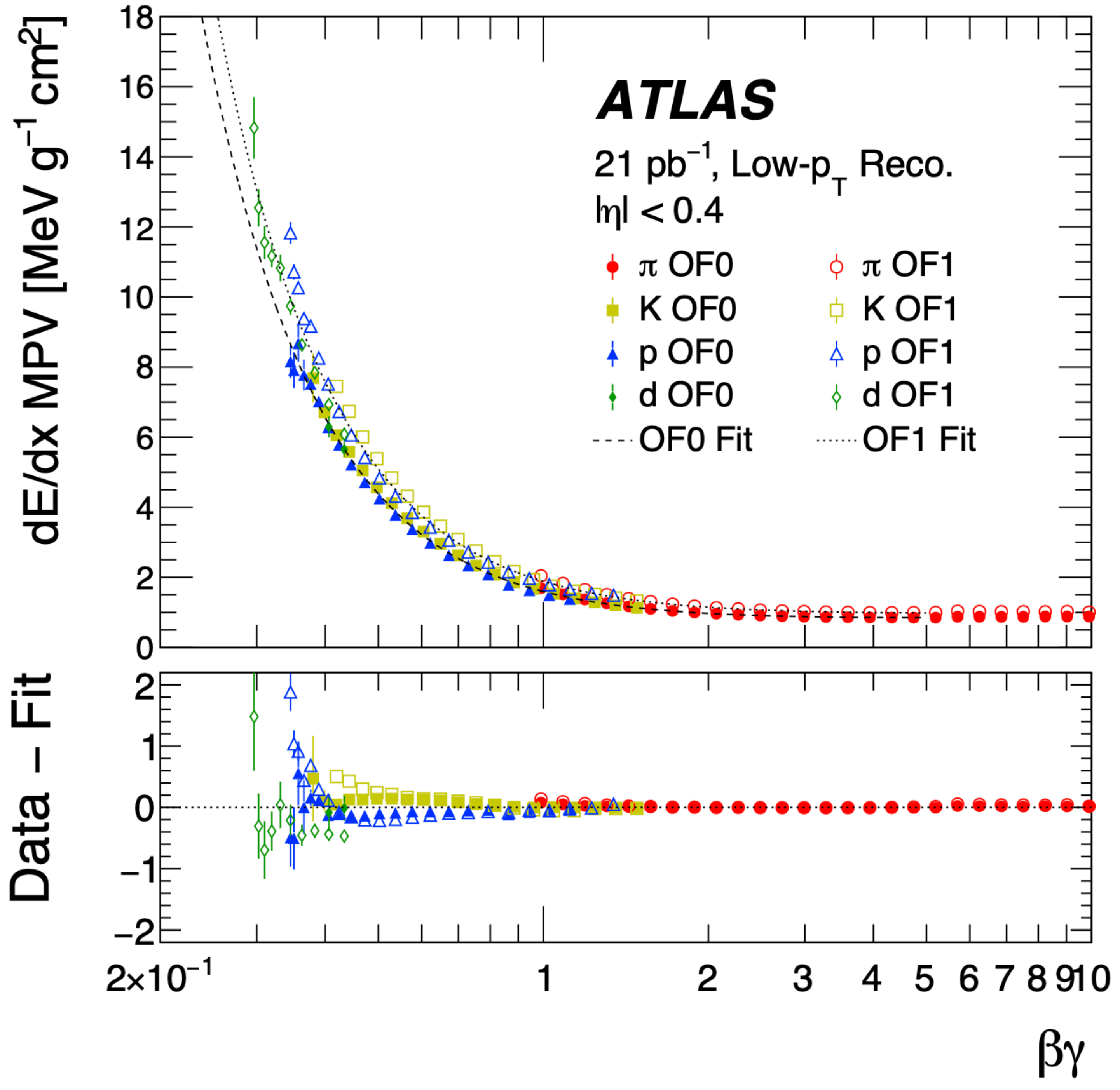
Search for Heavy Long Lived Charged Particles

ATLAS-CONF-2022-034



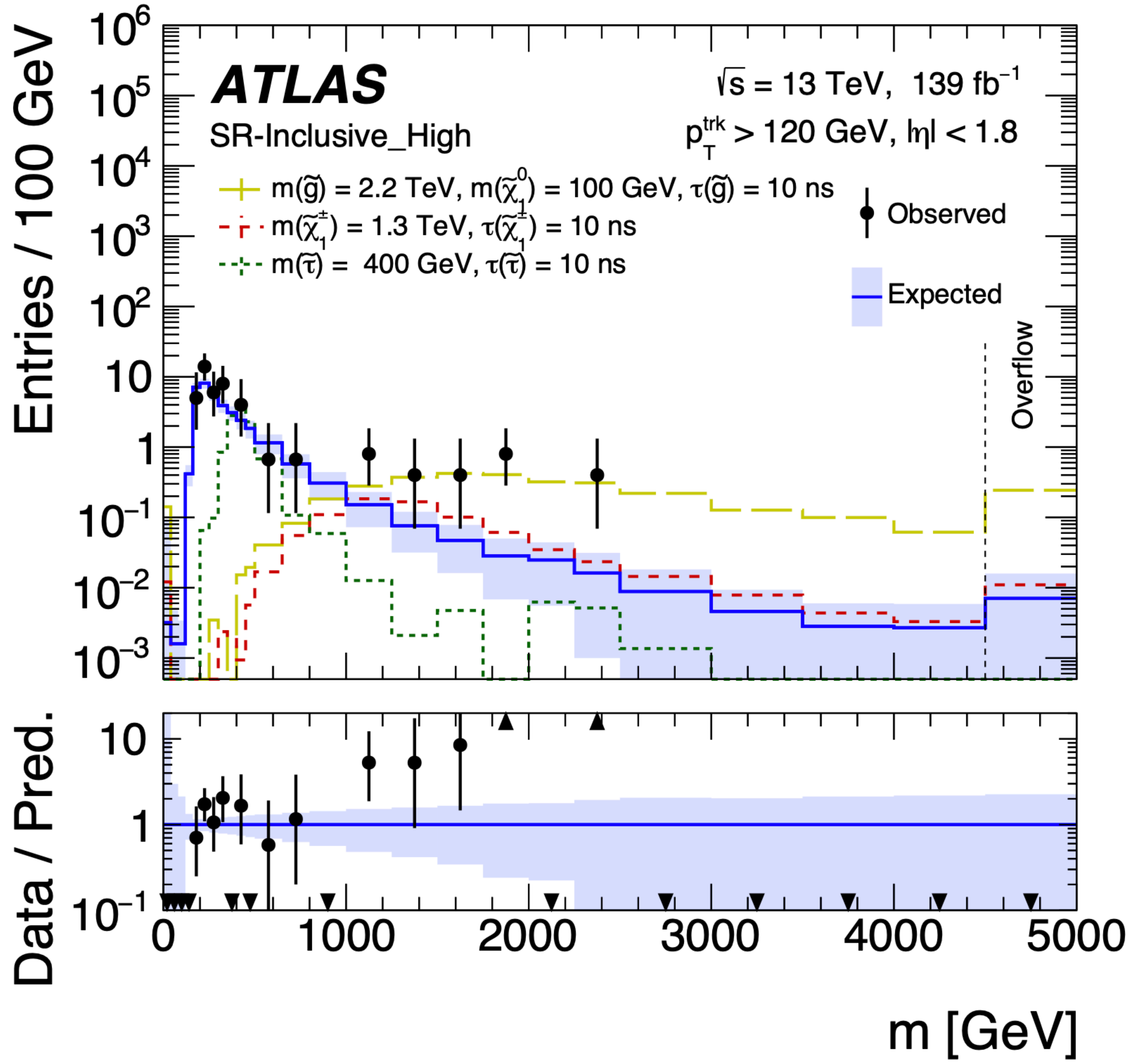
Searches for R-hadrons, chagrinos or sleptons

Search for high ionisation in the pixel detector using TOT information, and IBL overflow fraction!



Most Probable Value (MPV) of Pixel dE/dx as function of particle $\beta\gamma$

Events triggered using MET either due to neutrinos or gravitons or non reconstructed energy from stable LLP

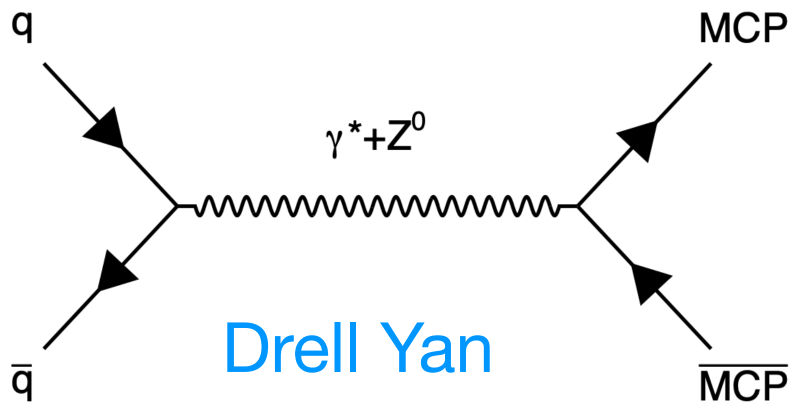


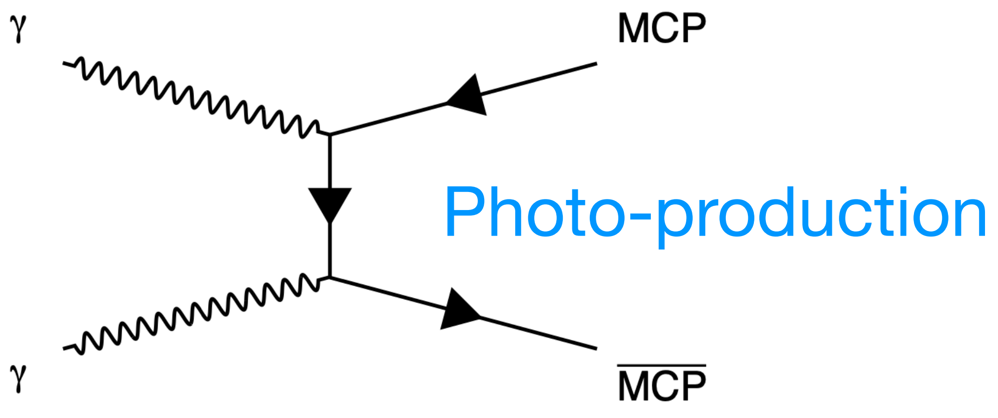
Excess of 3.6σ local and (3.3σ global) is observed - 7 candidates not at high mass not confirmed by TOF measurements (Muons and Tile calorimeter)

Search for Multicharged Particles

Search for Multi Charged Particles

MCPs are predicted by several BSM models (e.g. 1-2-3-4-5)





Single muon, “late” muon triggers* for slow particles (below β~0.7) and MET triggers (from ISR jet - muons not in MET)

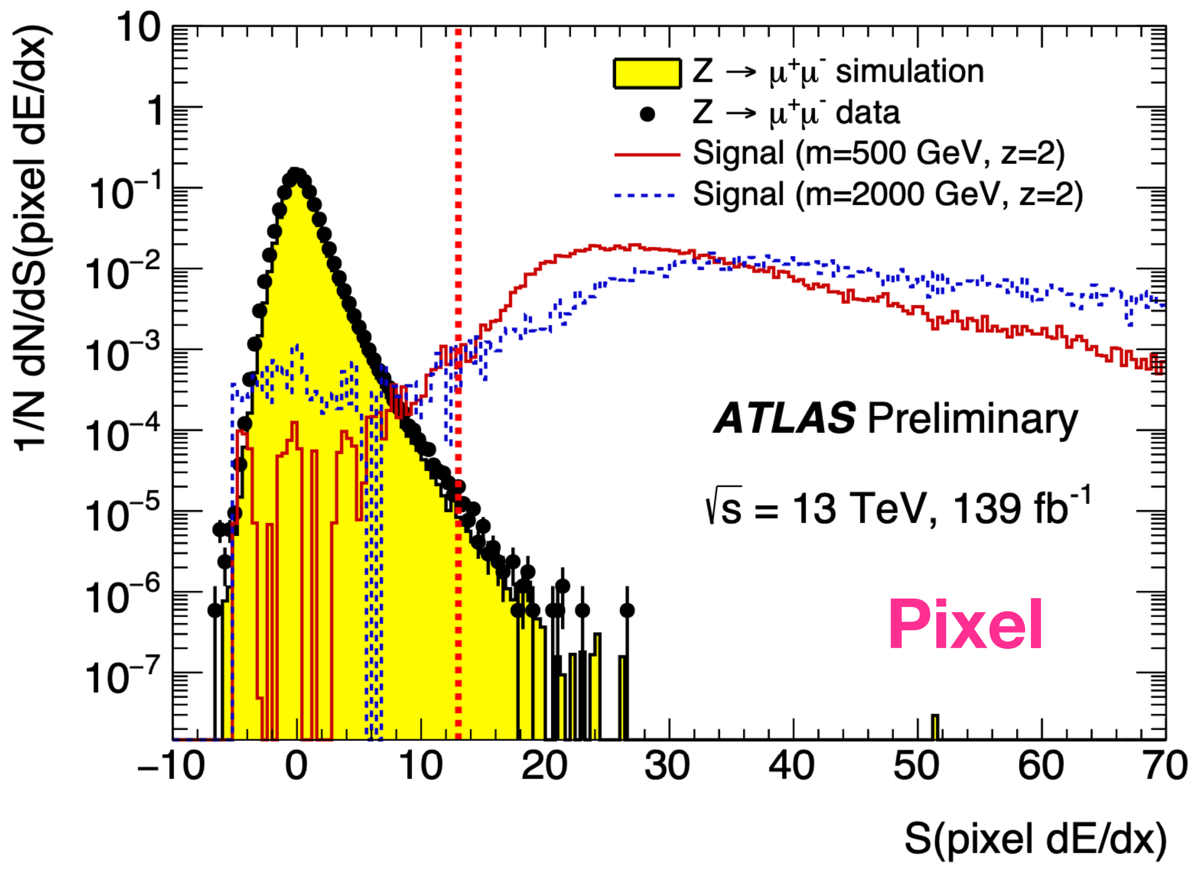
*Trigger firing on the bunch crossing following on events with one muon >50 GeV in one event and a muon >10 GeV in the next BC.

Main background from muons ionisation fluctuations estimated with data-driven ABCD method

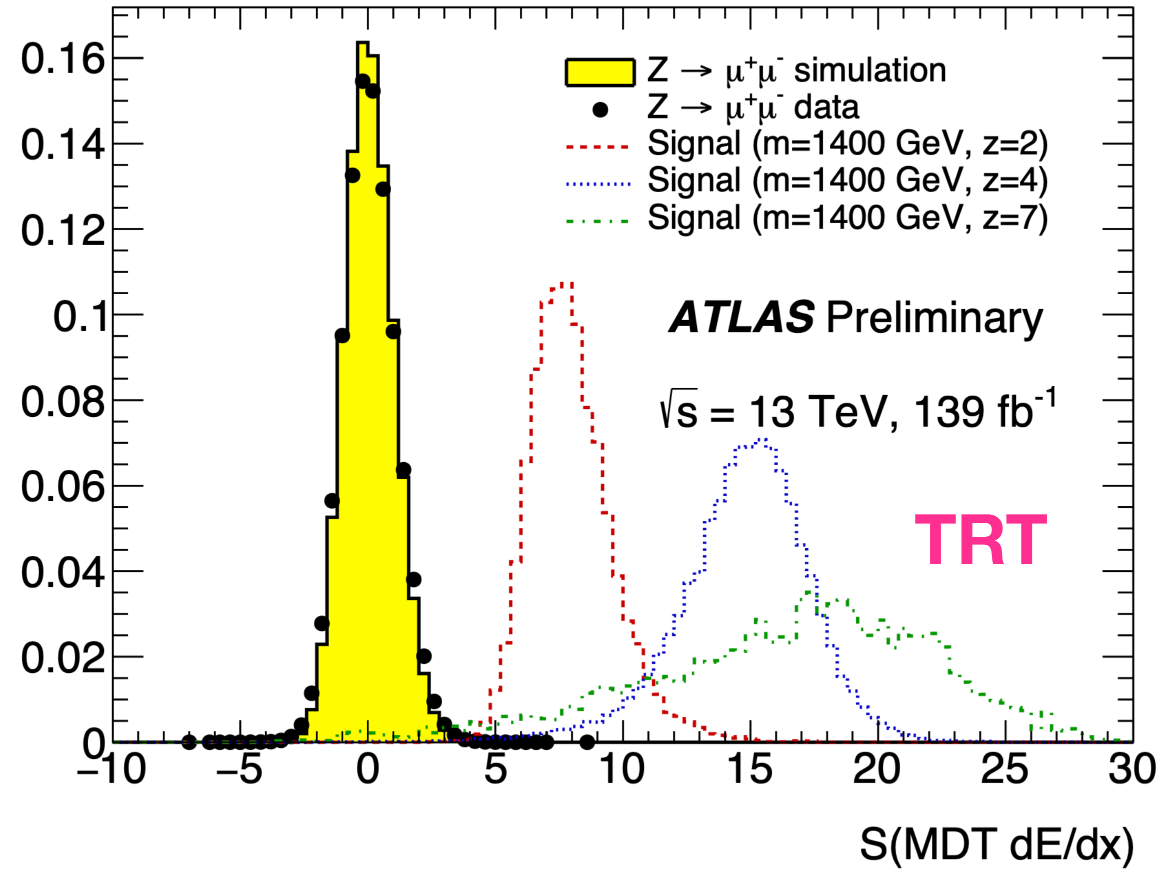
High ionisation signals to be measured in the **Pixel**, the **Transition Radiation Tracker** (TRT - from time above threshold and High Threshold hits) and the **Monitored Drift Tubes** (MDT)

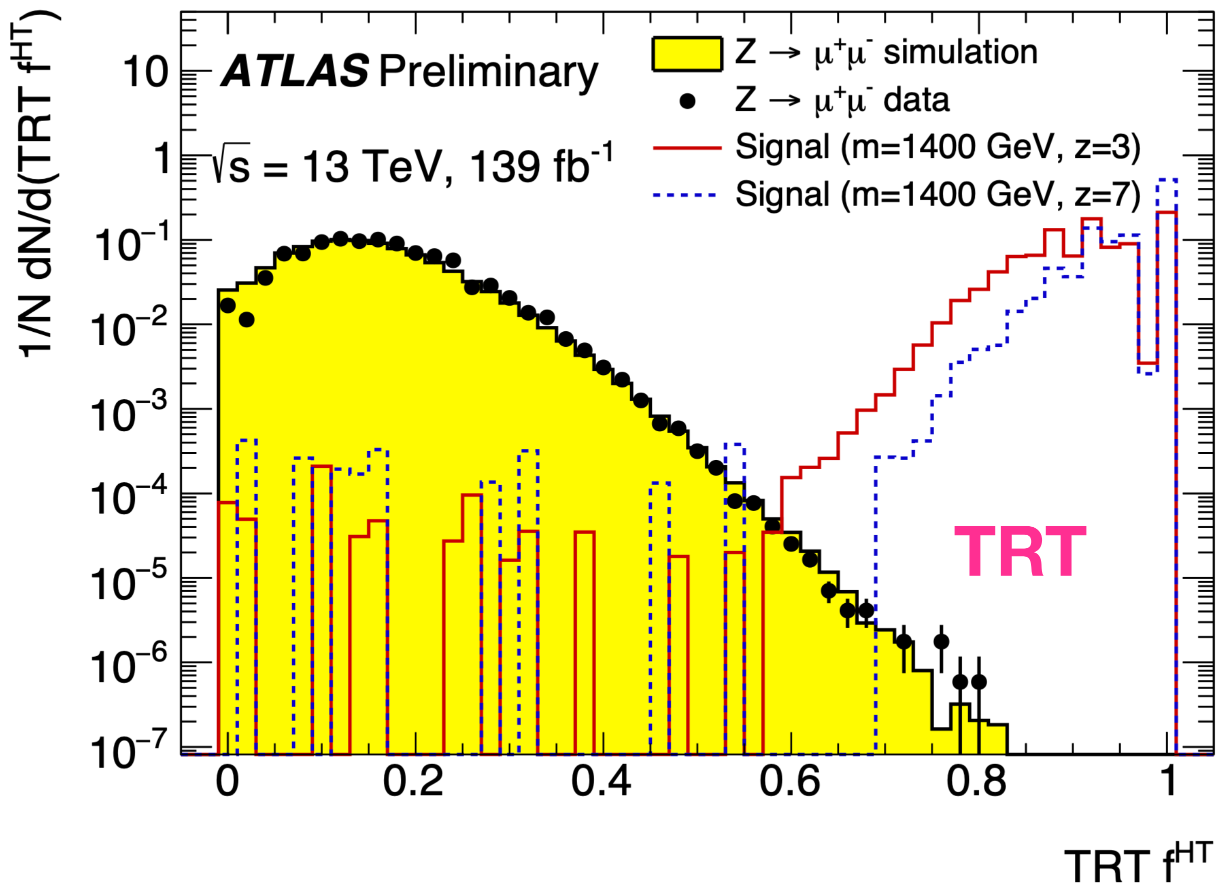
Mass limits ranging from ~ **1 TeV** ($q=|2e|$) and **1.6 TeV** ($q=|6e|$)

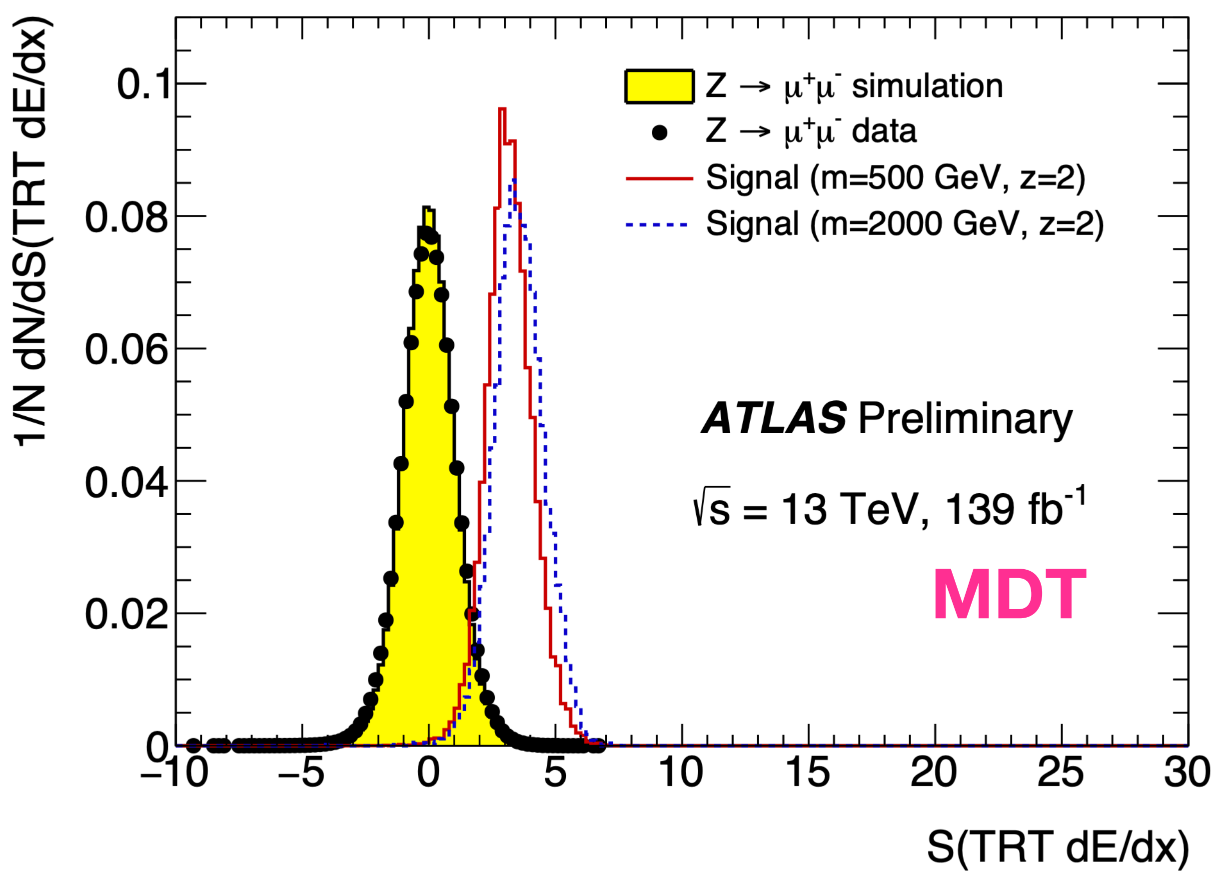
Time over threshold



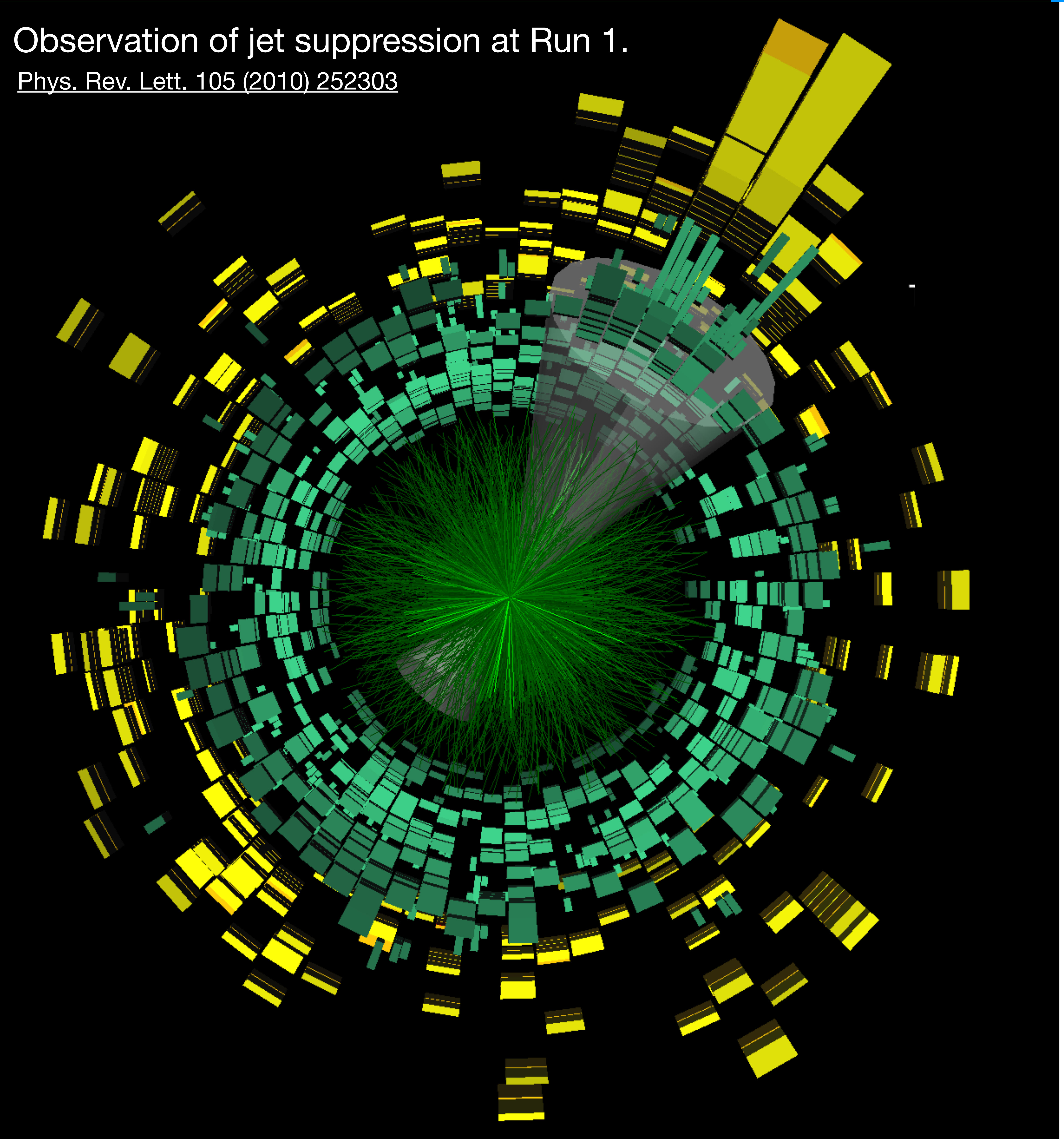
Time above threshold







Jet R_{AA} in Heavy Ion Collisions



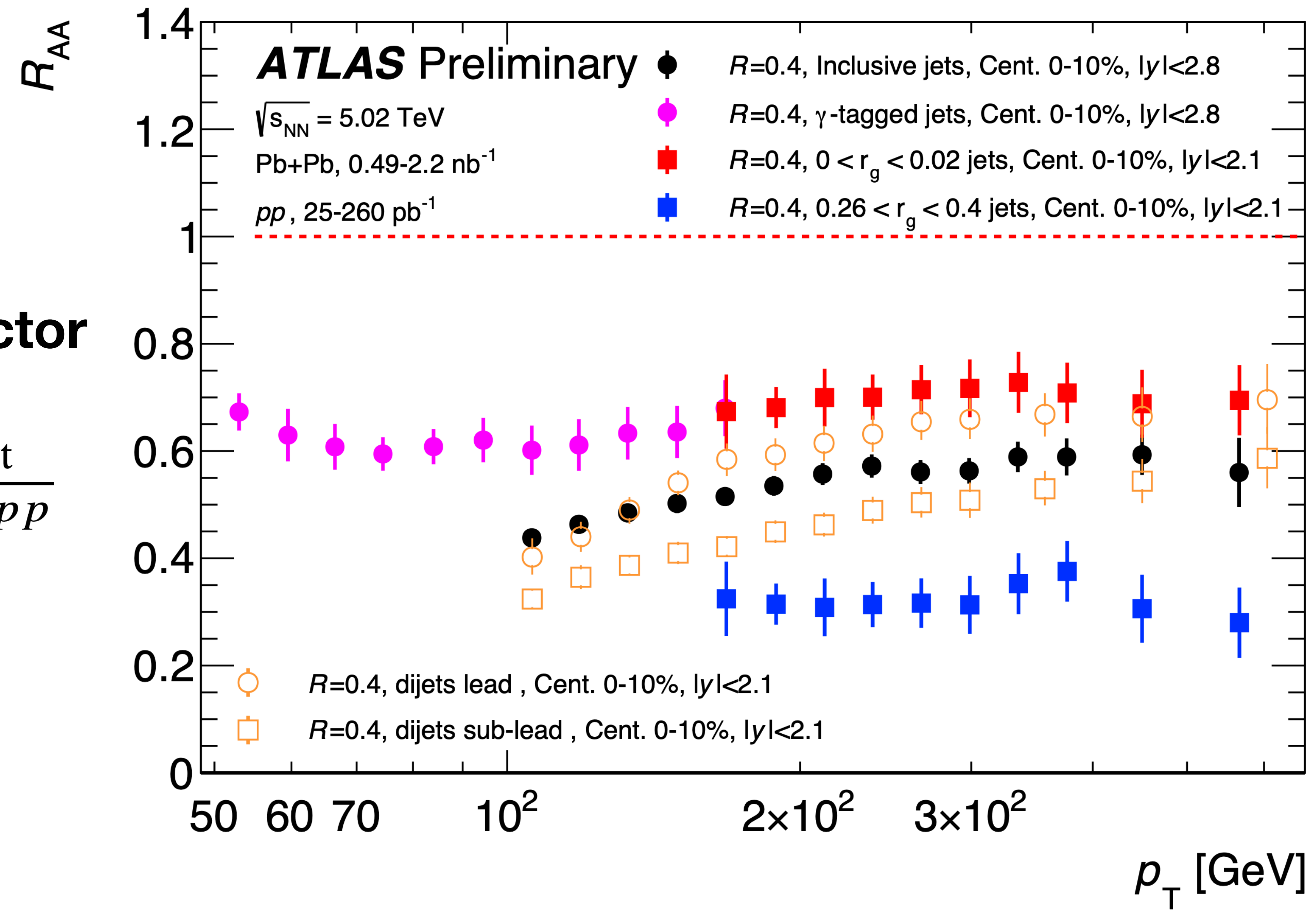
Closer look at jet suppression with different jet properties

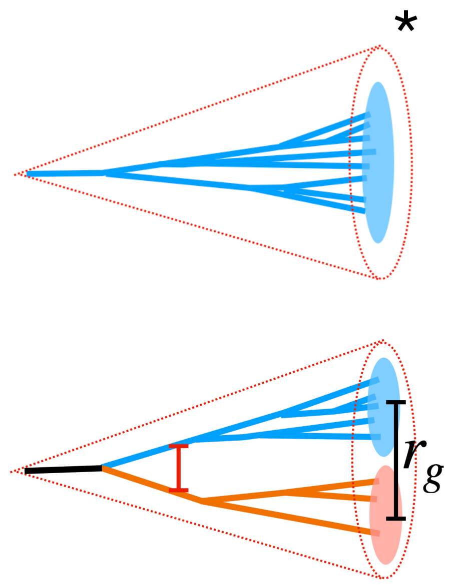
- Different production modes dijets, γ-jets
- b-jets (using semi-leptonic decays of b-jets)
- Grooming to isolate prongs within jets: r_g

Phys. Lett. B 790 (2019) 108
ATLAS-CONF-2022-019
CERN-EP-2022-043
ATLAS-CONF-2022-026
CERN-EP-2022-046

Nuclear mod. factor

$$R_{\mathrm{AA}} = \frac{N_{\mathrm{AA}}/N_{\mathrm{evt}}}{\langle T_{\mathrm{AA}}\rangle \times \sigma^{pp}}$$





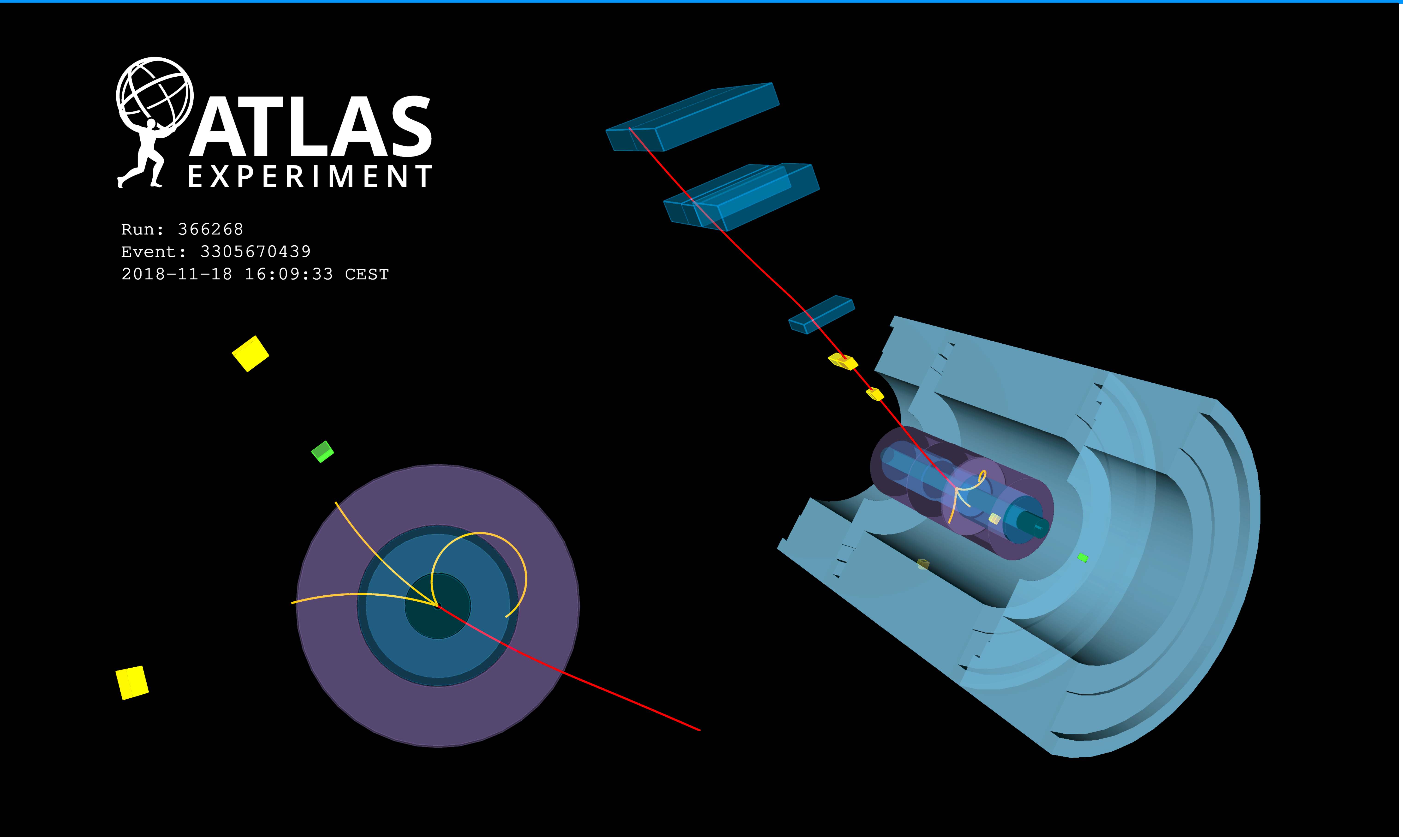
The p_T and and r_g dependences corroborate the color coherence model

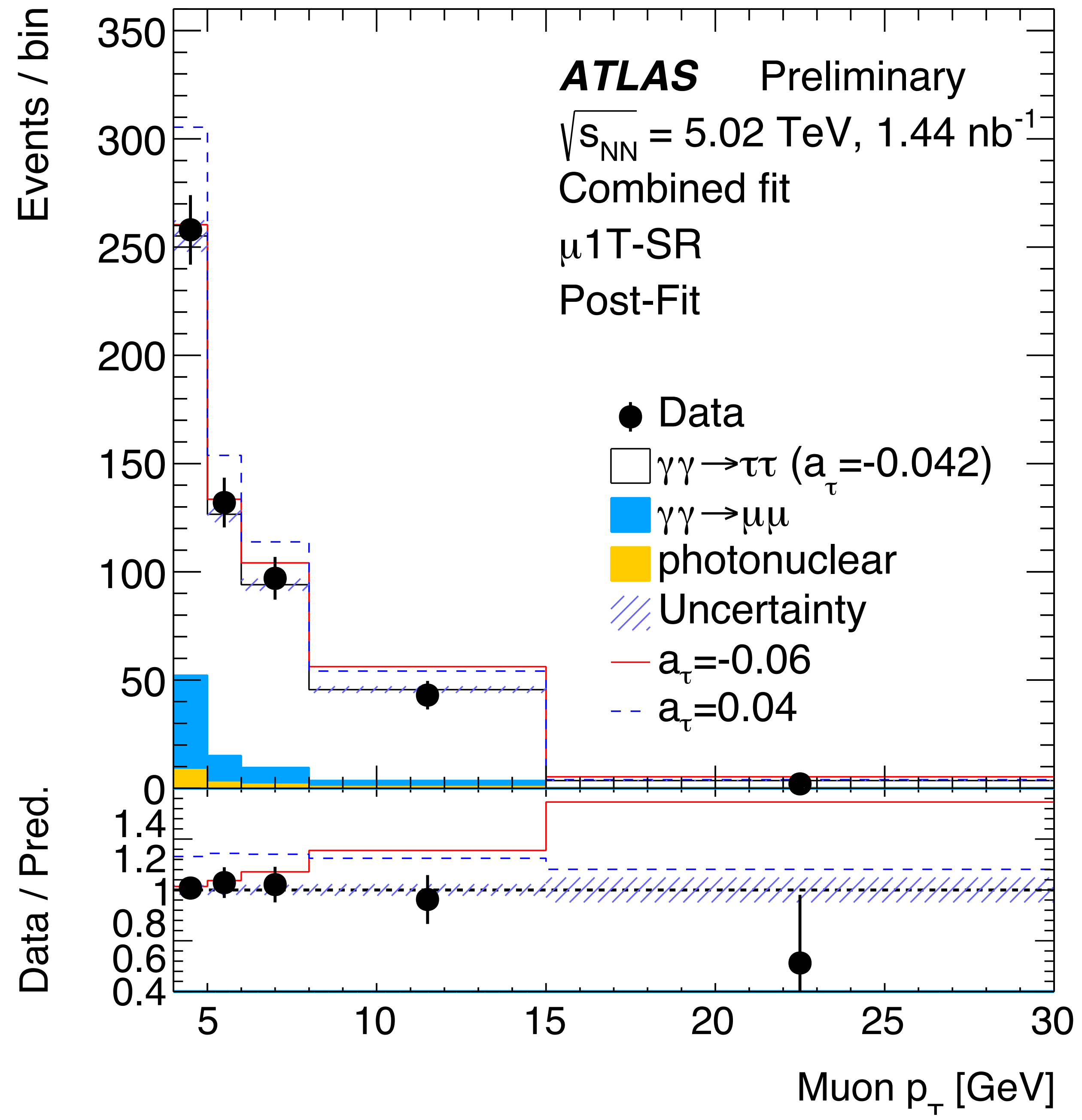
Provide powerful probes of models of Parton interaction in the QGP medium

*Diagrams from Q. Hu CERN seminar

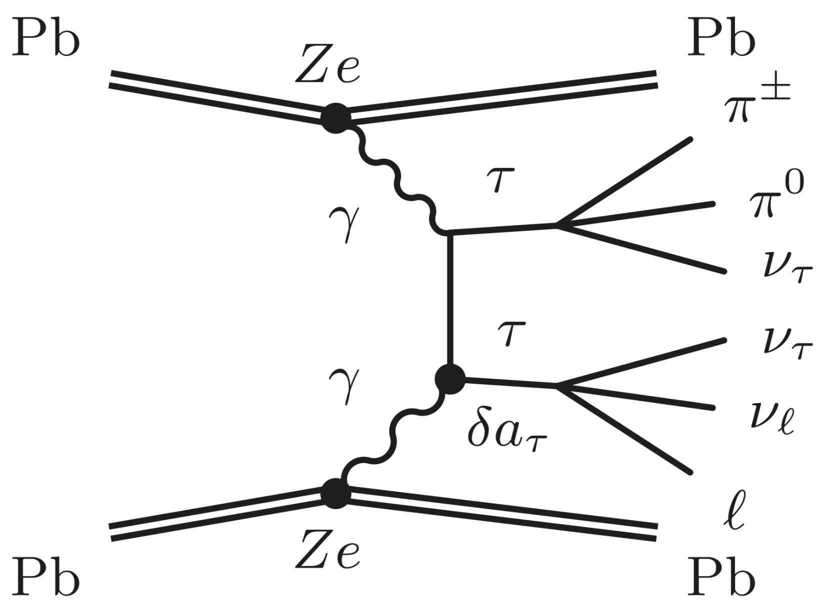
Tau magnetic moment and γγ → ττ Observation in PbPb

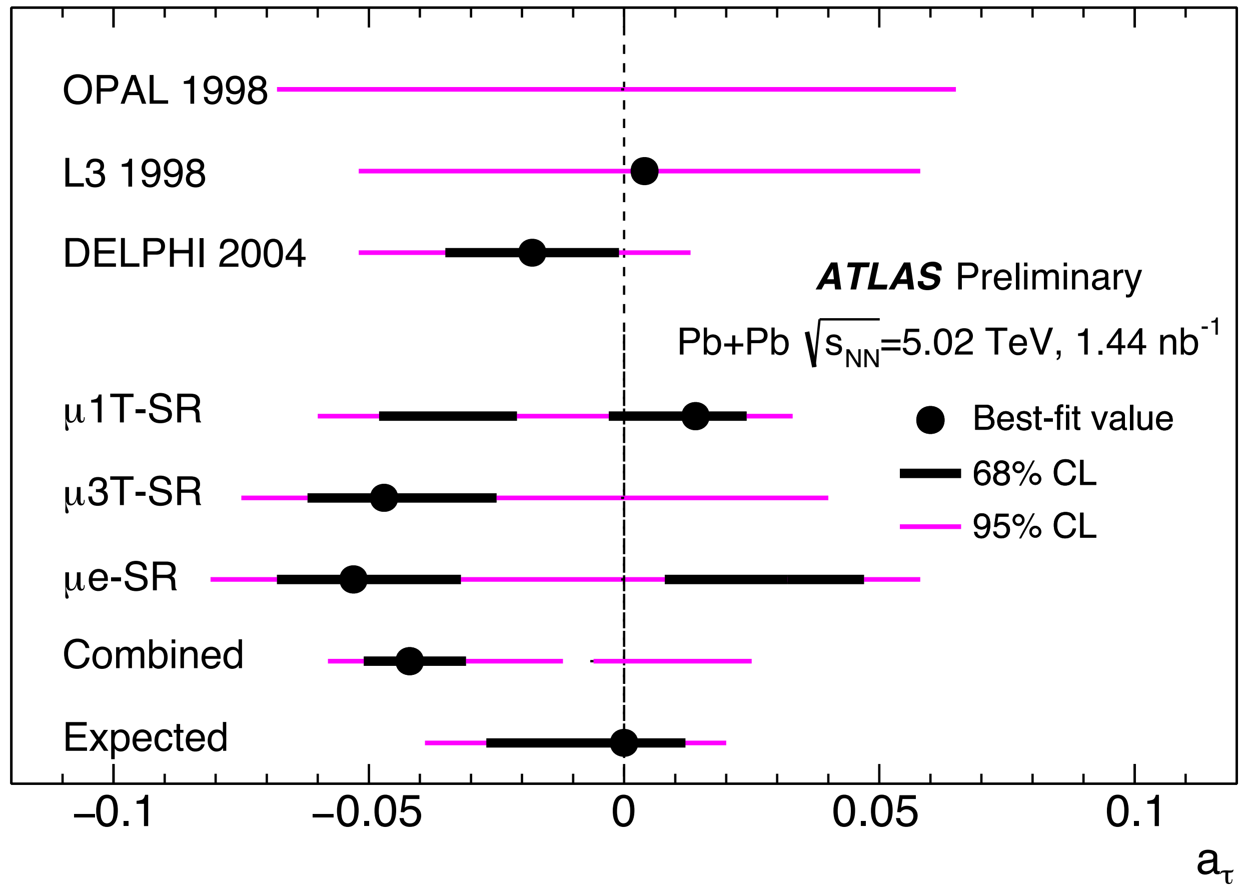
CERN-EP-2022-079





Observation of γγ → ττ in Pb-Pb collisions and constraint on tau anomalous magnetic moment

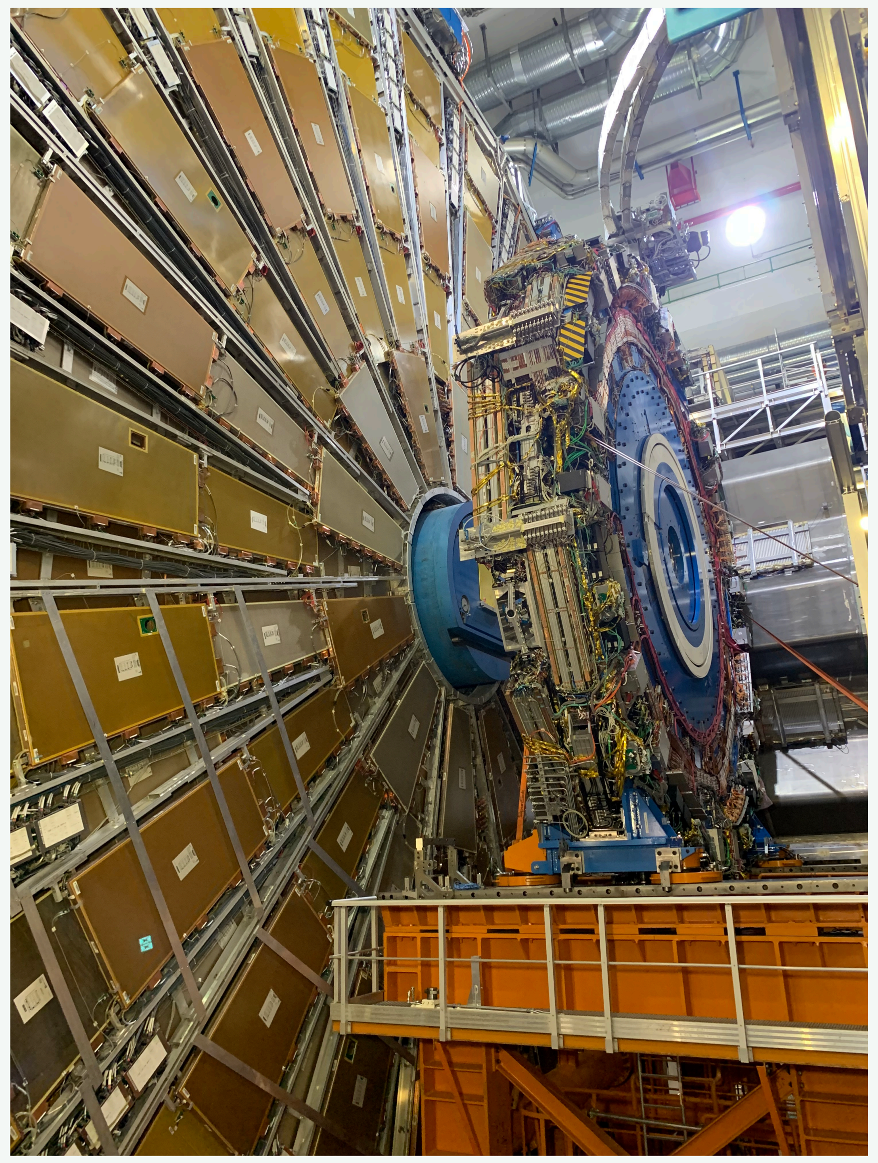




Physics Briefing, Interview

ATLAS Detector LS2 Upgrades

Upgrade in ATLAS News

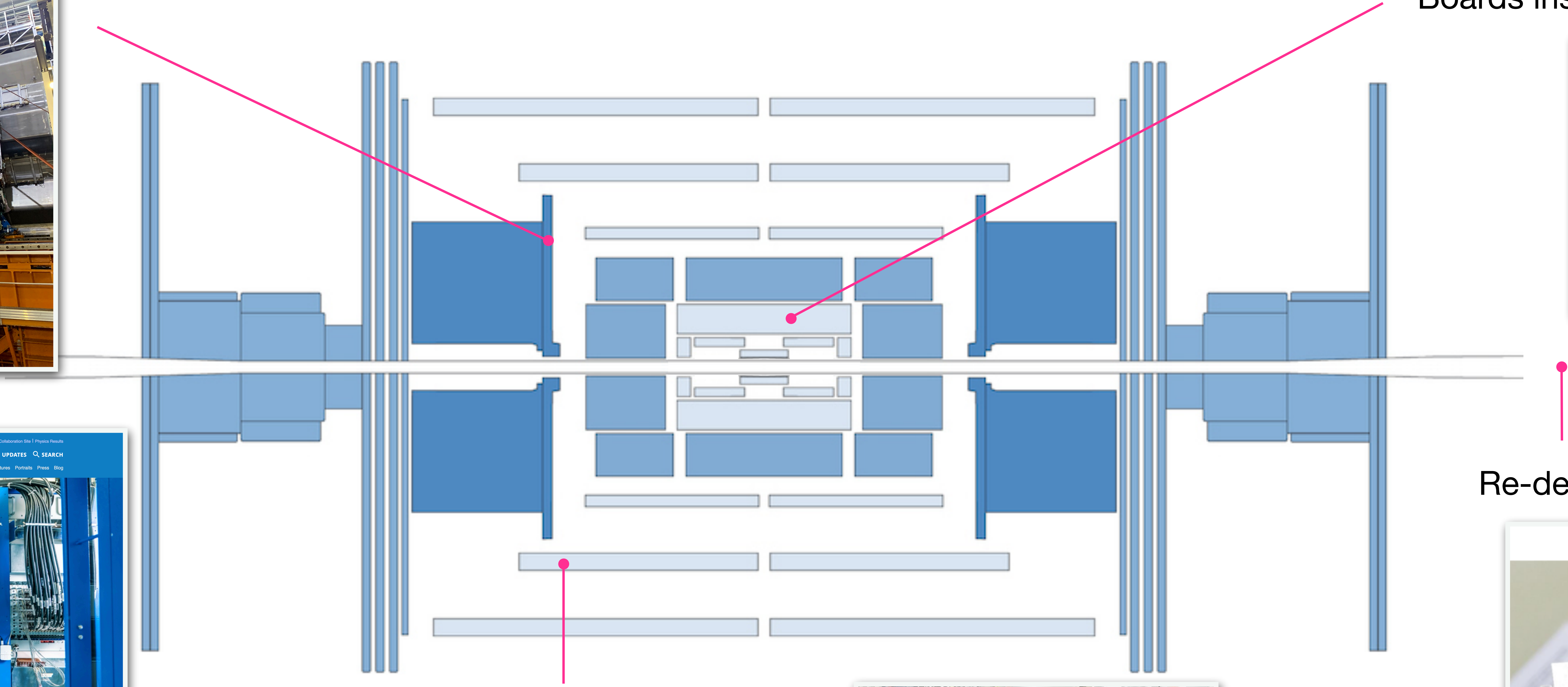


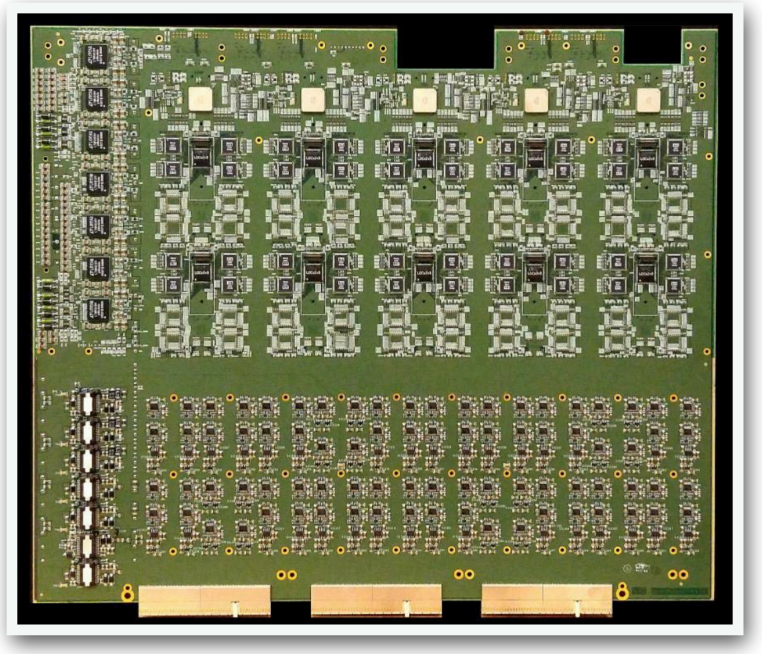
Muon New Small Wheels

Precision tracking, identification and triggering

New LAr Calorimeter digital trigger electronic boards

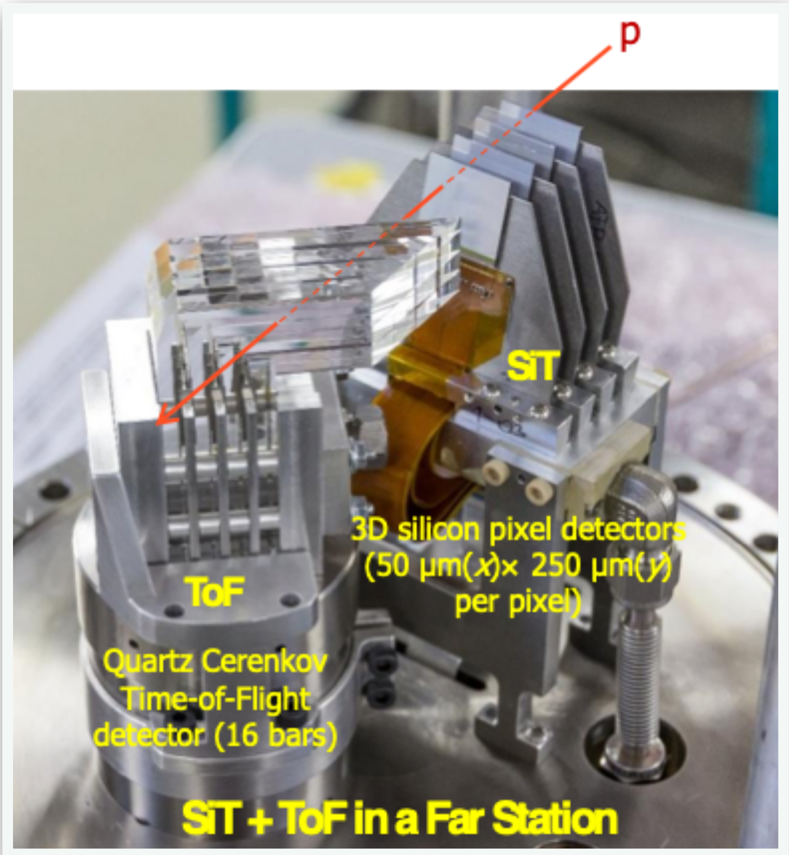
Improved trigger granularity
Boards installed in all FE crates!

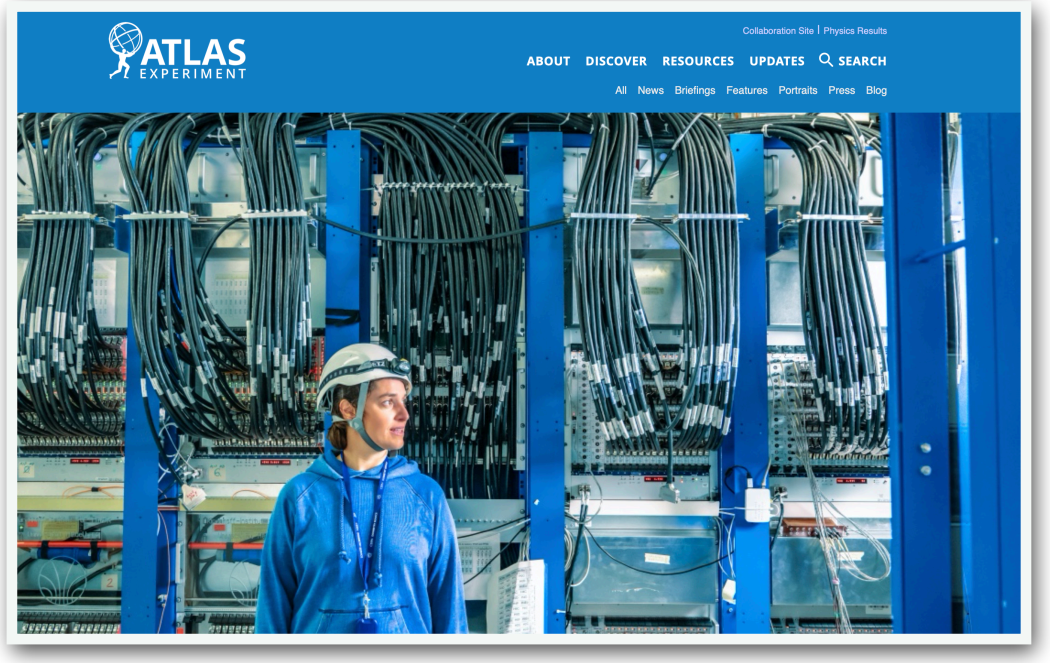




AFP

Re-designed TOF detector





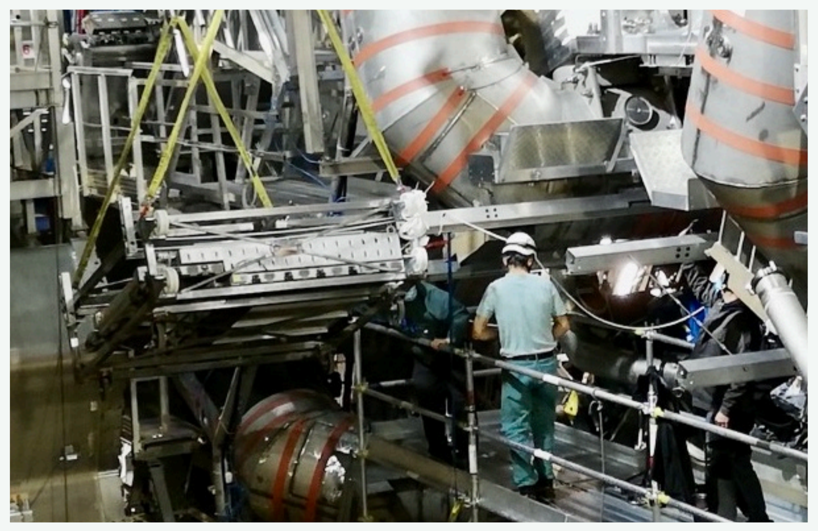
Trigger and Data Acquisition

Upgraded hardware, firmware and software for improved trigger and DAQ

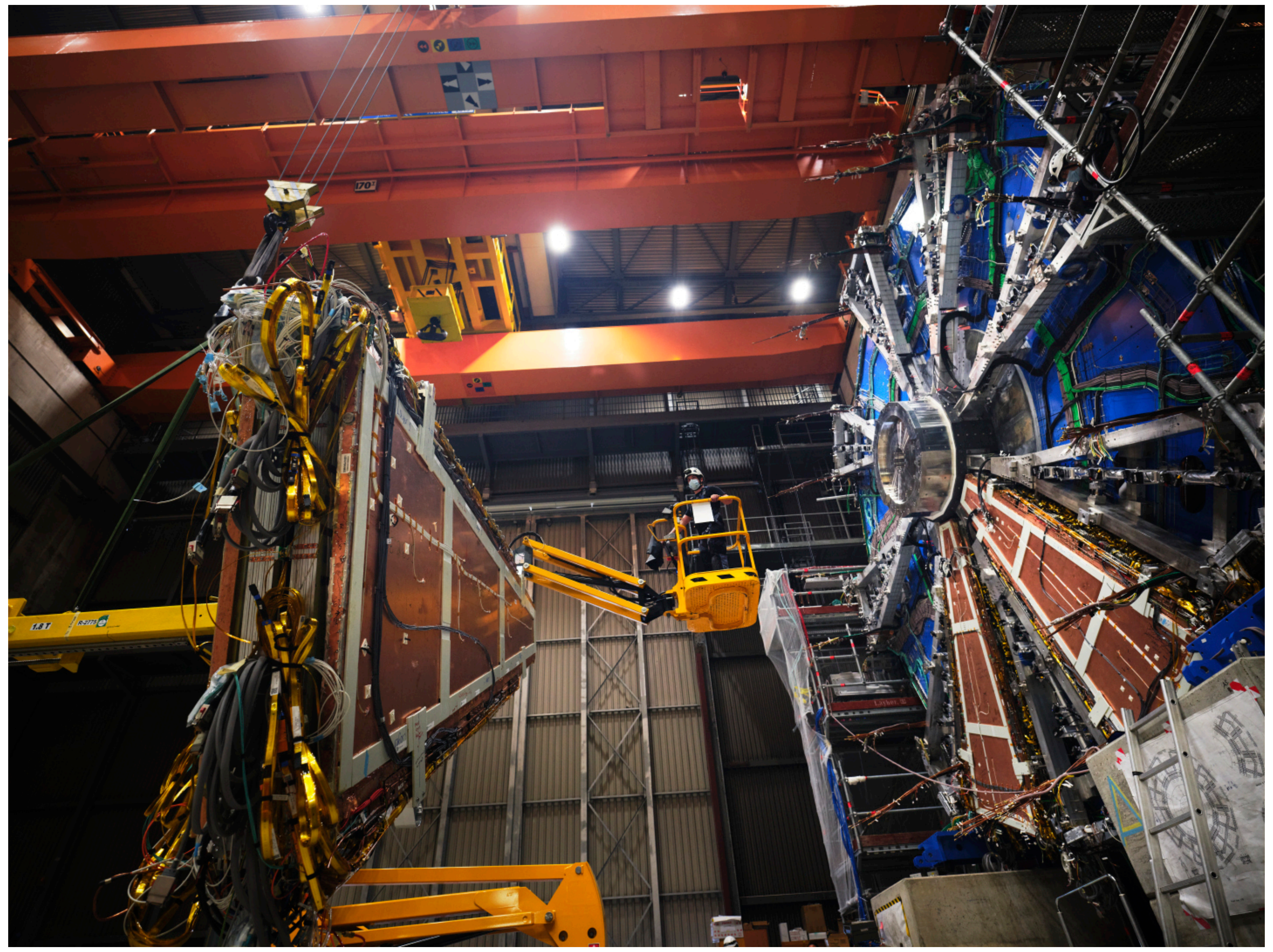
TDAQ Upgrade briefing

BIS78

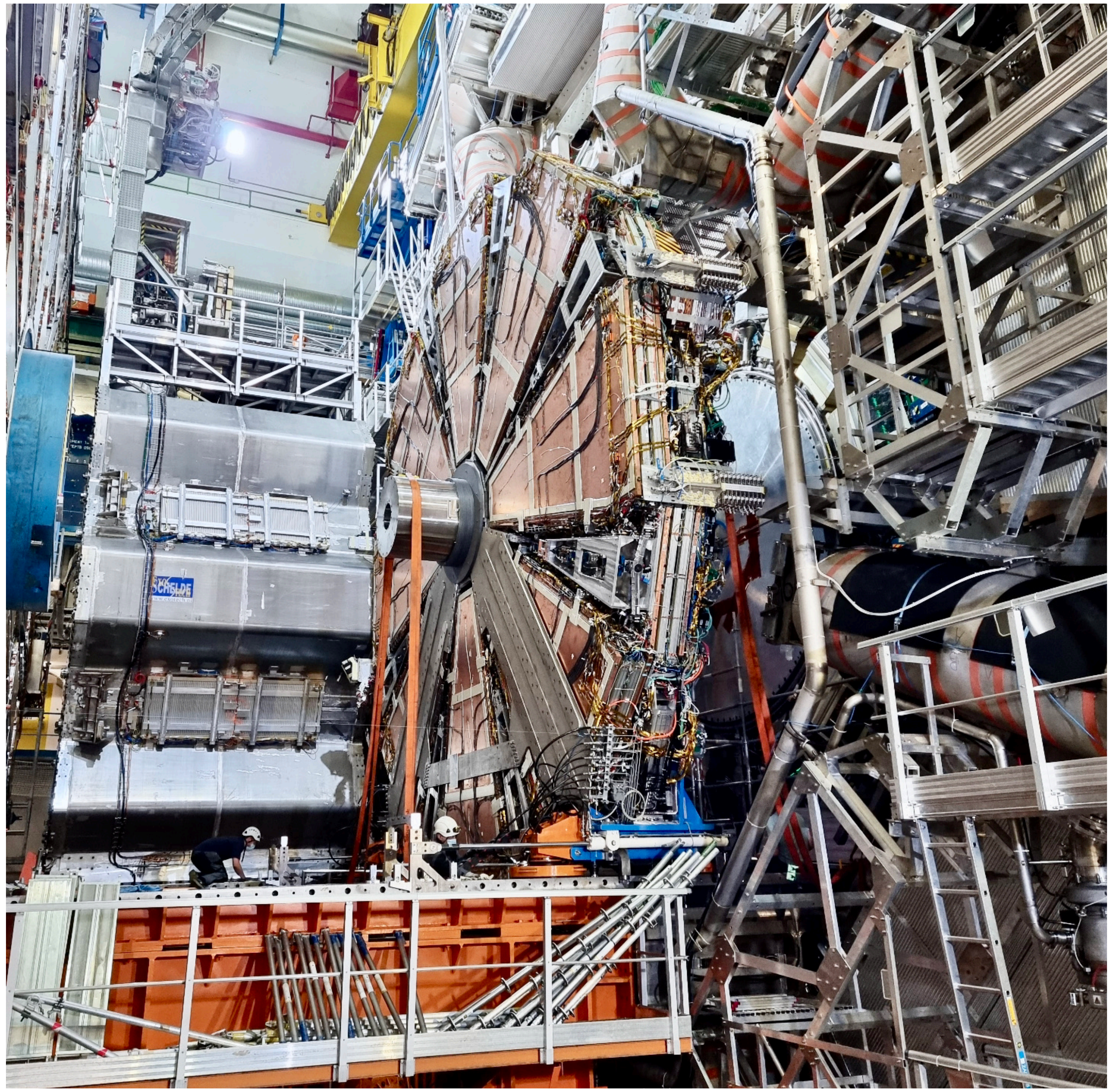
New Muon chambers sMDT and new generation RPC (8 chambers installed)



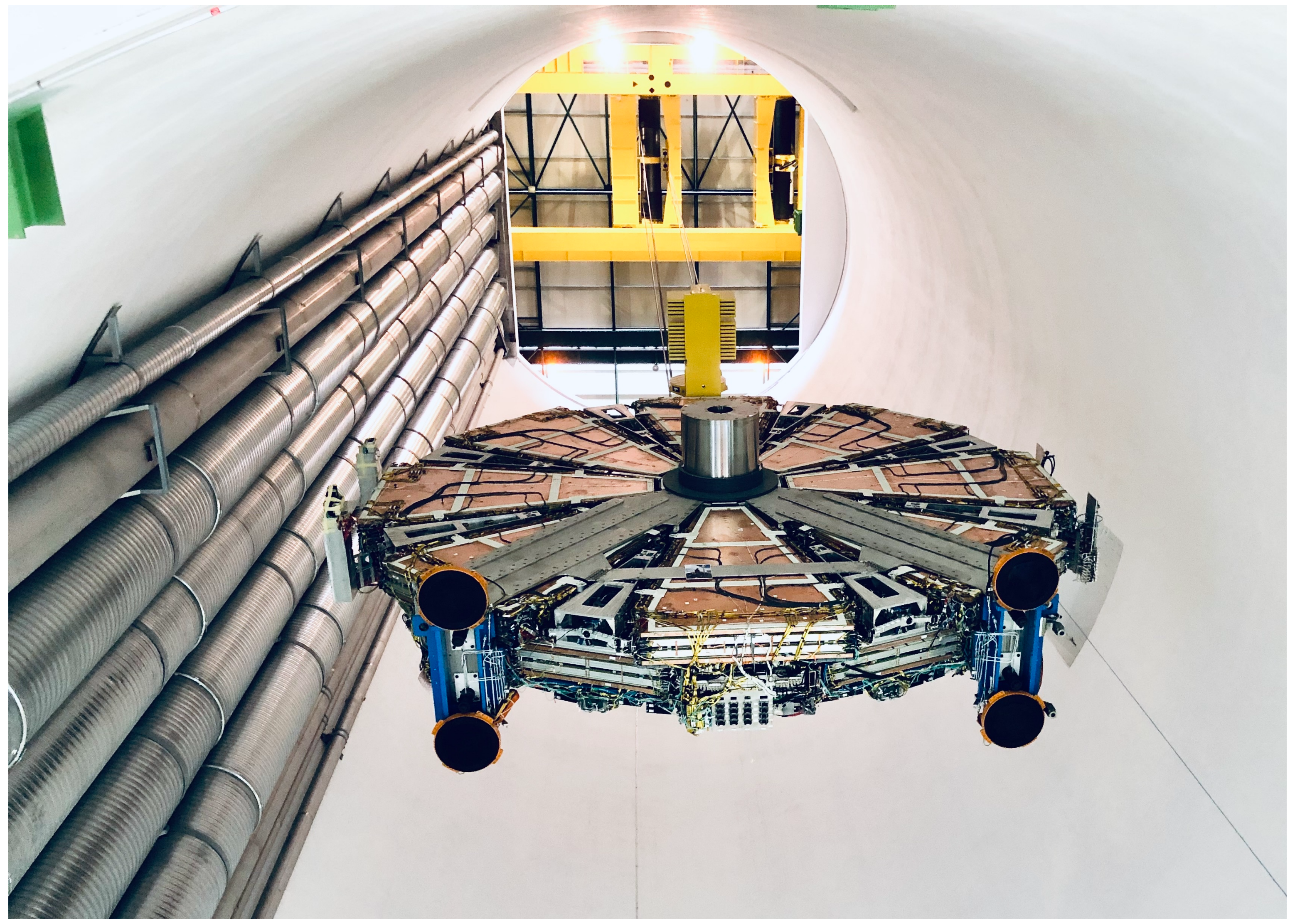
Muon New Small Wheel


Assembly of NSW-A


Completion of NSW-A on 28 May 2021

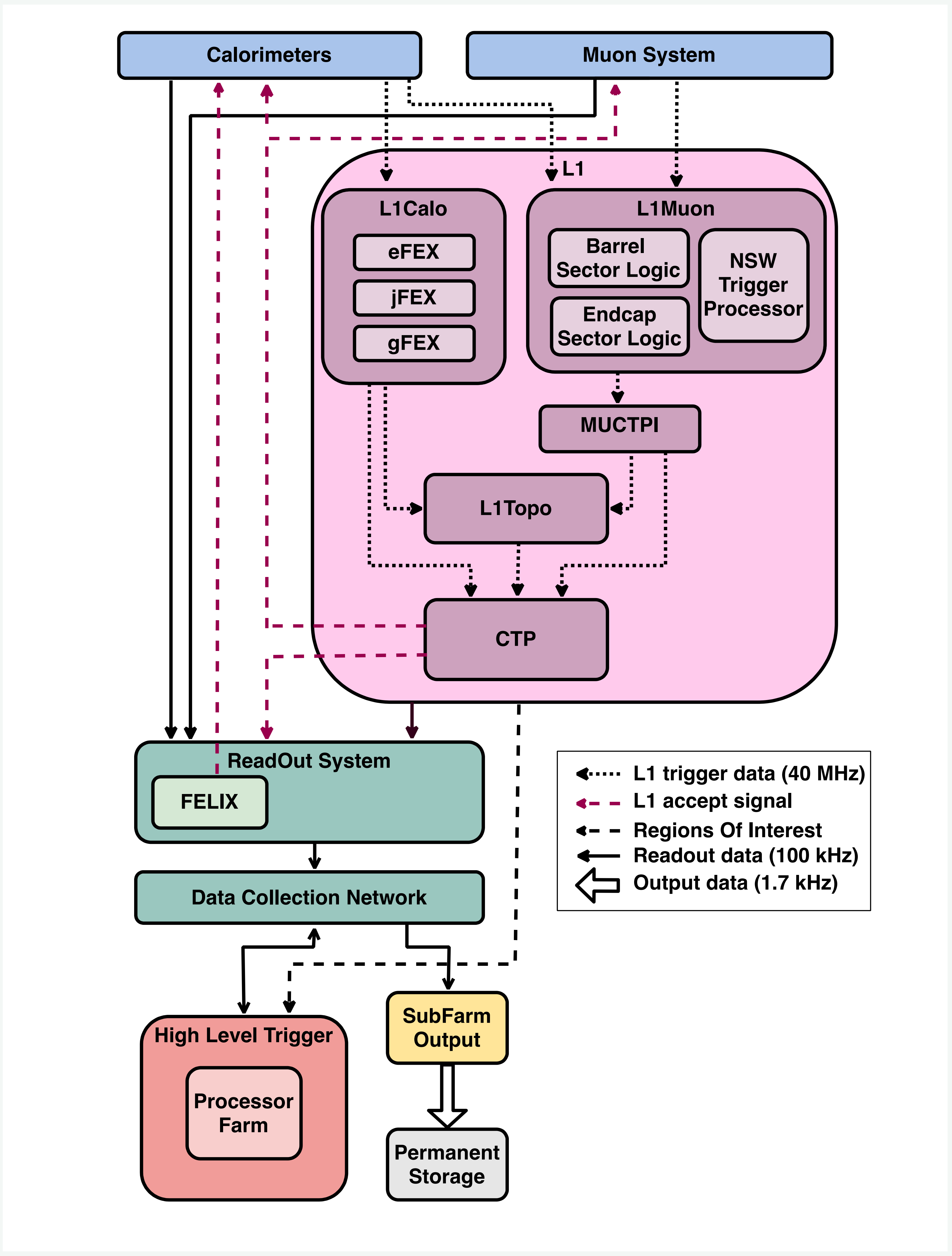

NSW being positioned


Completion of NSW-C on 13 September 2021

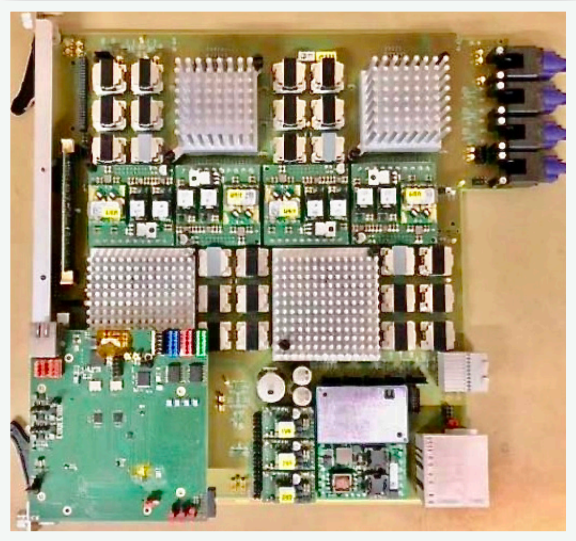

July 12, 2021, lowering of NSW-A

Intense preparation, assembly, installation, and now fully focussed on commissioning

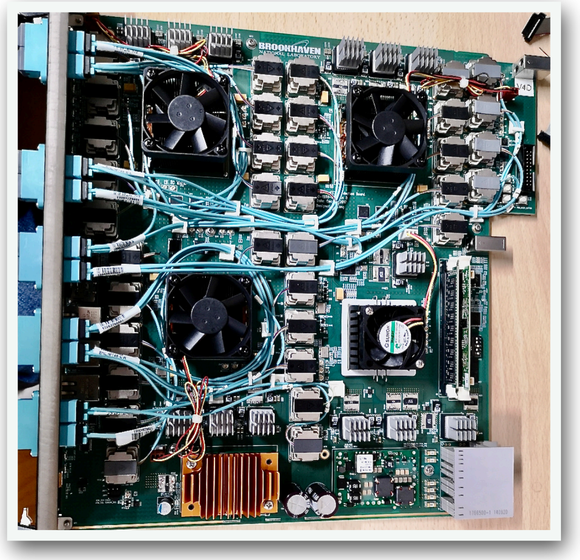
Trigger and Data Acquisition Upgrades



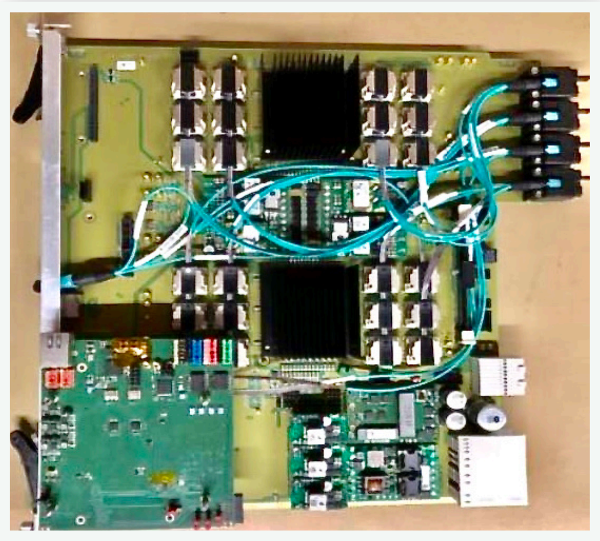
eFEX



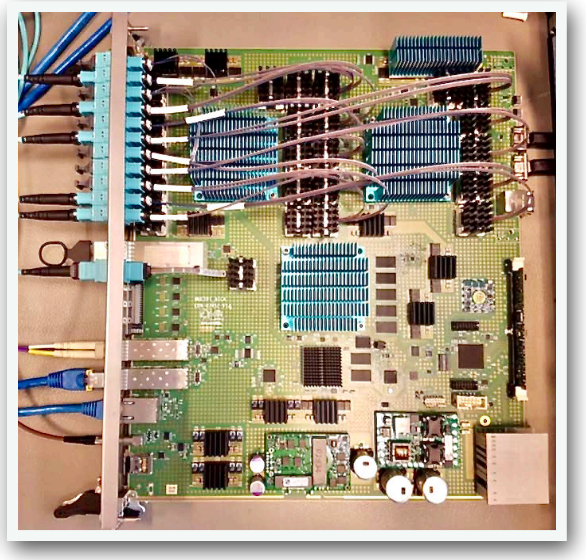
jFEX



gFEX



L1Topo



MUCTPI

Trigger phase-I upgrades and preparation

- New L1Calo: Feature extractors (electrons, jets, global)
- New L1Topo and Central Trigger processor
- New Muon Central Trigger Processor Interface

Installation nearly completed, hardware and firmware commissioning in full swing!

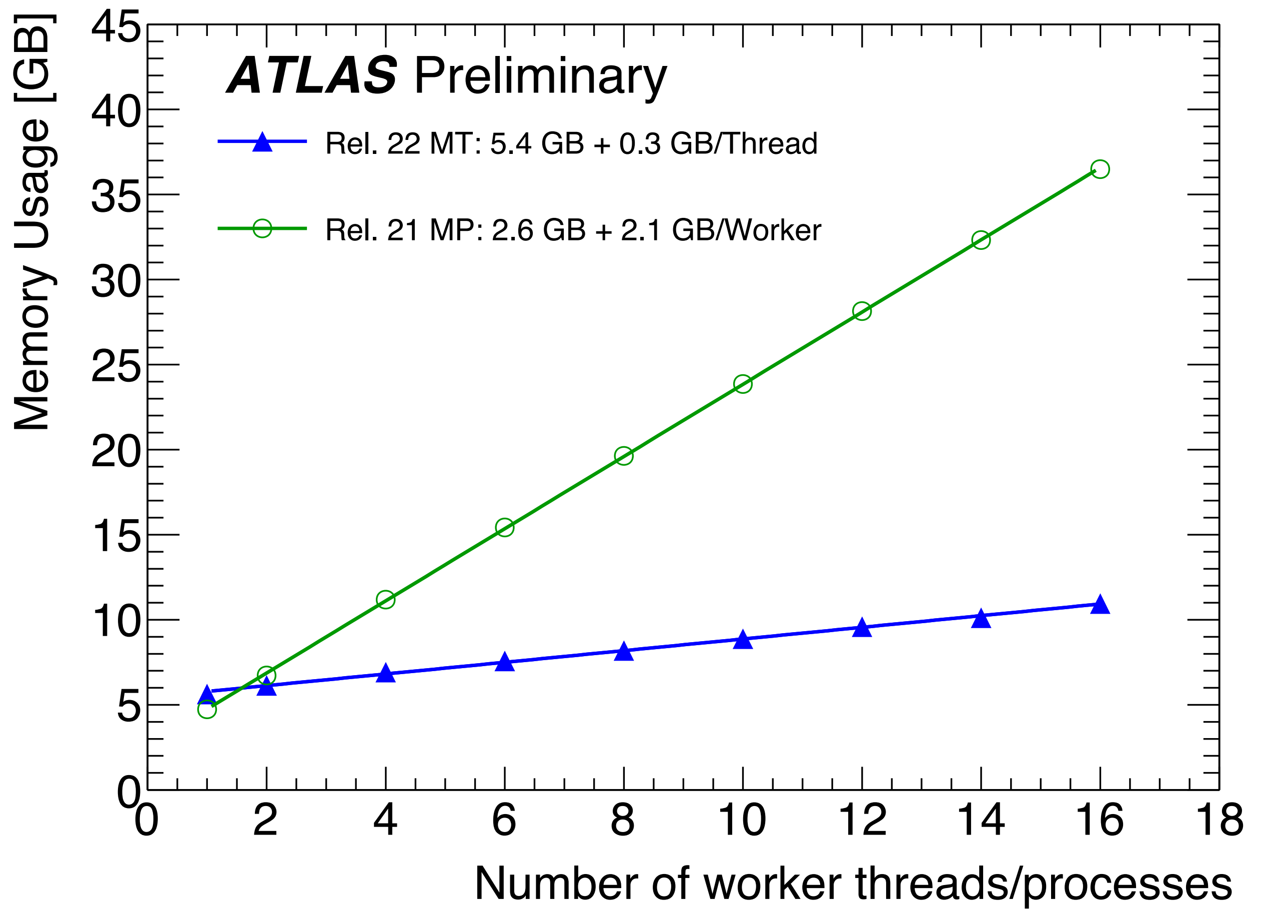
Trigger menu preparation

Run 3 Menu is in preparation with increased rates for delayed stream and trigger level analysis!

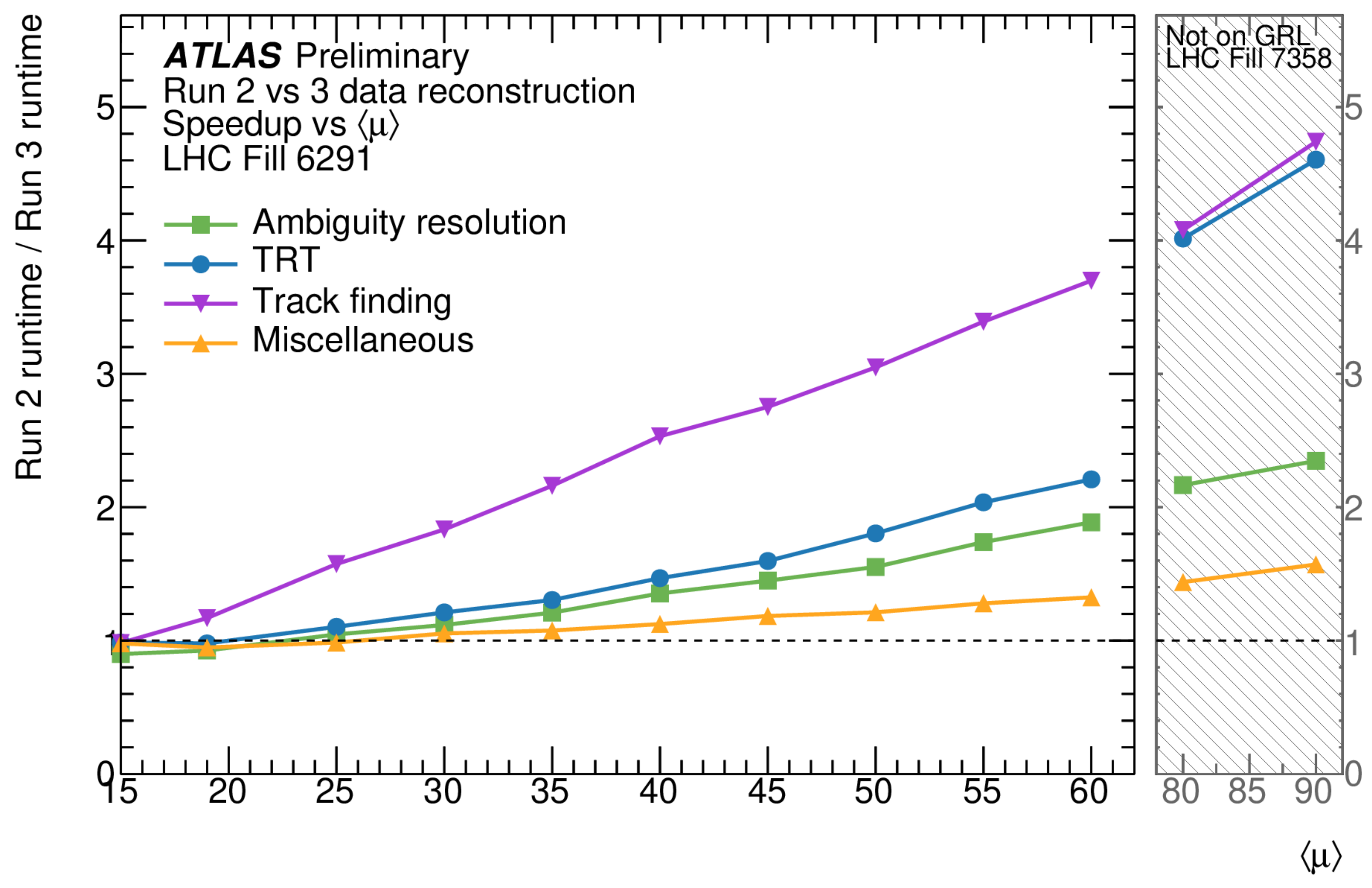
Will determine the dataset for **physics 10 years to come**!

ATLAS Software

ATL-PUB-SOFT-2021-02



ATL-PHYS-PUB-2021-012



News

Bringing new life to ATLAS data

Tags: computing

15 October 2021 | By ATLAS Collaboration

https://atlas.cern/updates/news/reprocessing-Run2-data

Experiment Briefing

Teaching established software new tricks

ATLAS Athena framework undergoes important renovation

Tags: computing, software

15 October 2021 | By ATLAS Collaboration

https://atlas.cern/updates/briefing/renovating-athena

New multithreaded and optimised software!

- Large gains in memory usage and improved timing performance
- Run-2 data and MC fully reprocessed (27B data and 32B MC events)
- New pre-digitised pileup overlay procedure for MC
- Unified and streamlined analysis model
- Improved G4 timing performance full simulation and New fast calorimeter simulation (AF3) with improved accuracy
- Run 3 MC campaign is starting and trigger and reconstruction software is almost ready to be frozen at T0 (offline) and at Point 1 (online)

Summary and Conclusions

ATLAS is continuing to produce thrilling physics results with excellent and diverse LHC Run 2 data

- **The LHC Run 2 continues to offer vast opportunities for measurements and searches, well beyond initial planning!**
  - Performing more and more precise measurements probing the Standard Model in broad range of phase space
  - Pursuing the observation of new rare processes
  - Continuing to broaden the range of direct searches
- **Made possible by the immense efforts in improving predictions as well as modelling and simulation of LHC processes!**
- **Improvement of reconstruction algorithms to optimally exploit the LHC data!**

Control room at the start of beam commissioning 22 April, 2022

Run 3 is about to start!

- ATLAS is getting ready for Run 3 at 13.6 TeV and restarting operations.
- Phase-I upgrades, LS2 refurbishments, firmware being commissioned.
- Focus on optimal trigger strategy for the LHC physics of the 10 years to come!

With double the luminosity of Run 2, exciting new results expected at Run 3!

ATLAS Phase-II Upgrades

Phase-II upgrades and preparations of the HL-LHC

Altogether 7 TDRs (See links)

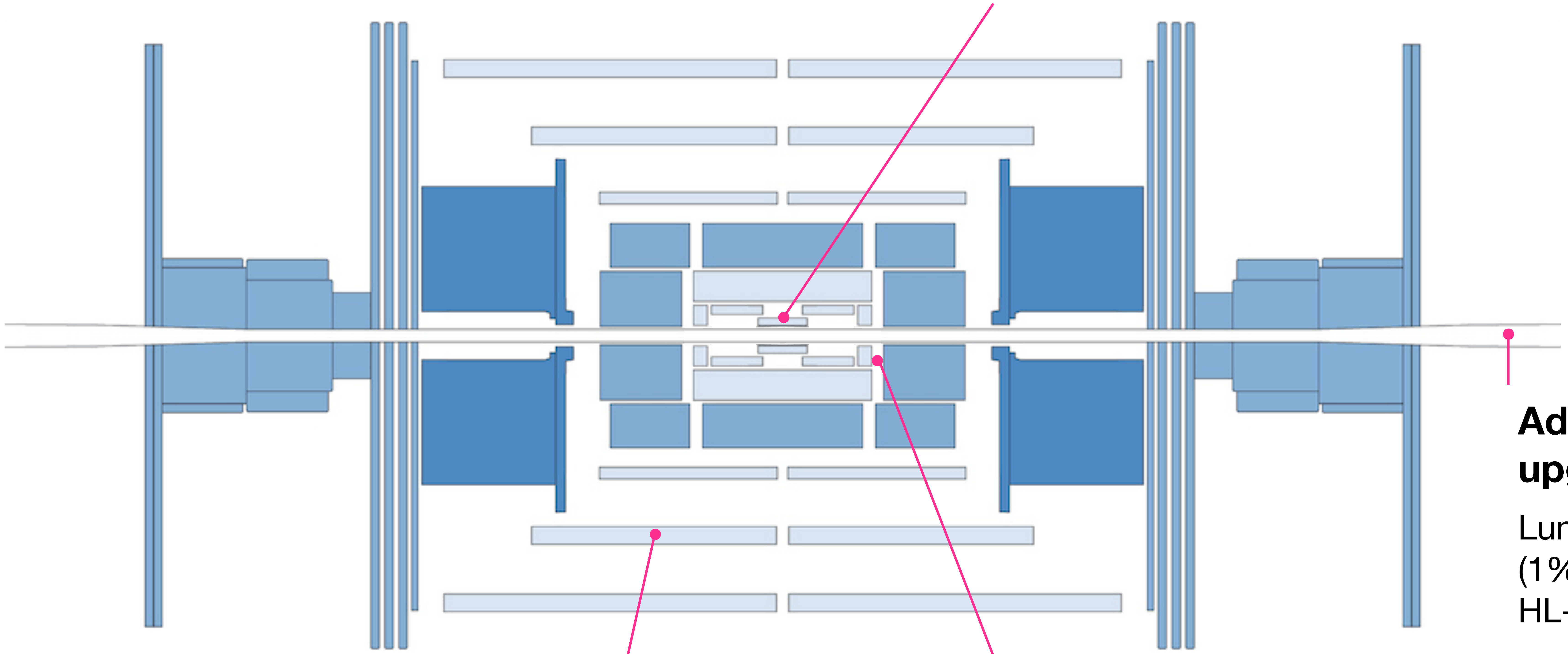
New Inner Tracking Detector (ITk)

All silicon, up to $|\eta| = 4$ Pixel **TDR**, Strips **TDR**

Upgraded Trigger and Data Acquisition

Level-0 Trigger at 1 MHz,
Improved High-Level Trigger
(150 kHz full-scan tracking)

TDAQ **TDR**, **TDR Amendment**



Additional small upgrades

Luminosity detectors
(1% precision goal)
HL-ZDC

Electronics Upgrades

LAr Calorimeter	LAr **TDR**
Tile Calorimeter	Tile **TDR**
Muons	Muons **TDR**

New Muon Chambers

Inner barrel region with new
RPC and sMDT detectors

Muons **TDR**

High Granularity Timing Detector (HGTD)

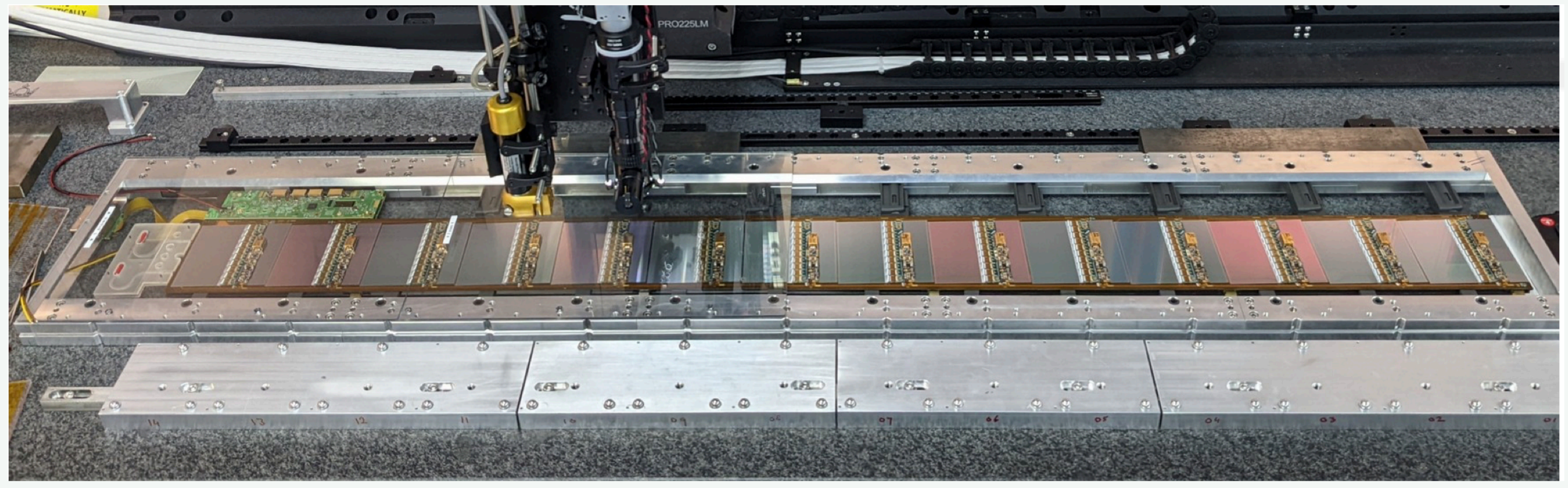
Forward region ($2.4 < |\eta| < 4.0$)

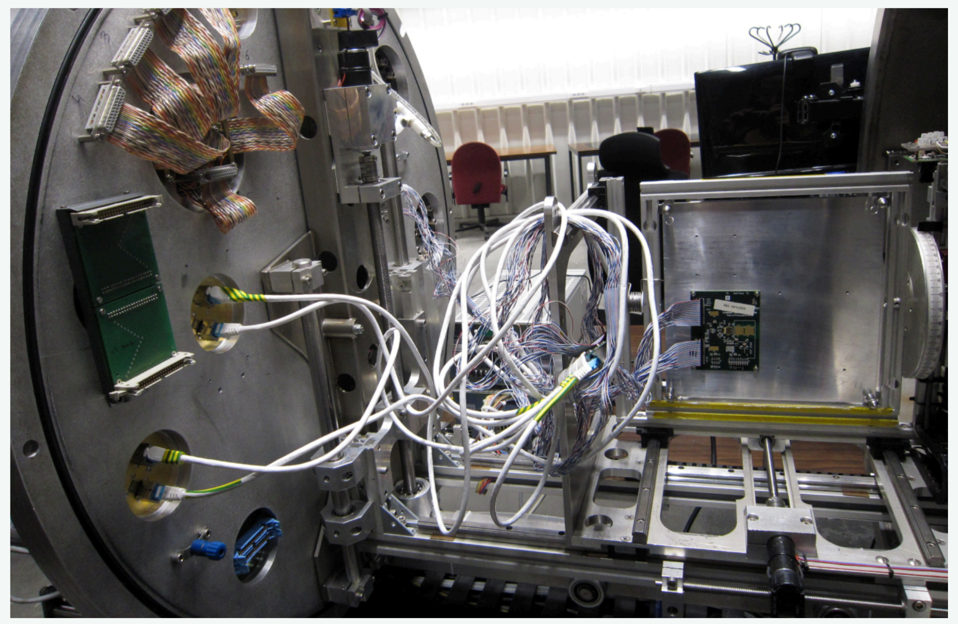
Low-Gain Avalanche Detectors (LGAD) with 30 ps
time resolution on tracks

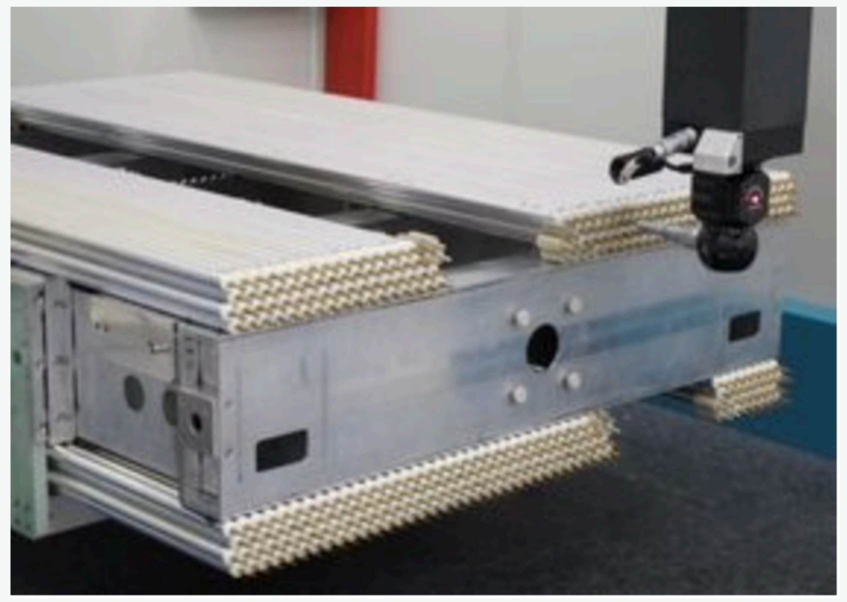
HGTD **TDR**

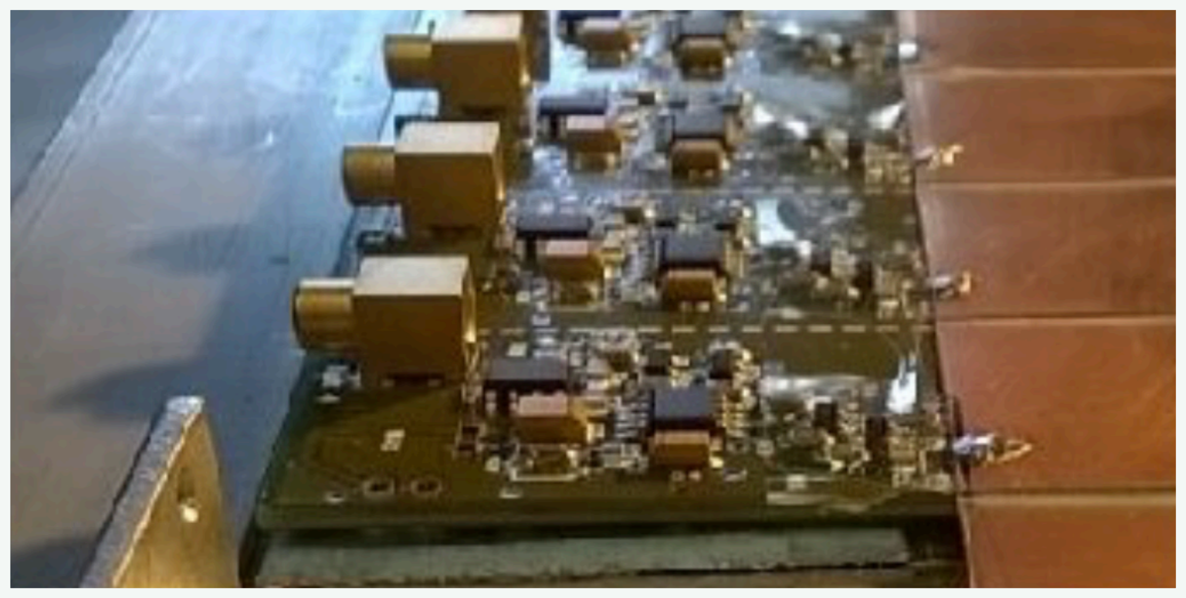
ATLAS Phase-II Upgrades

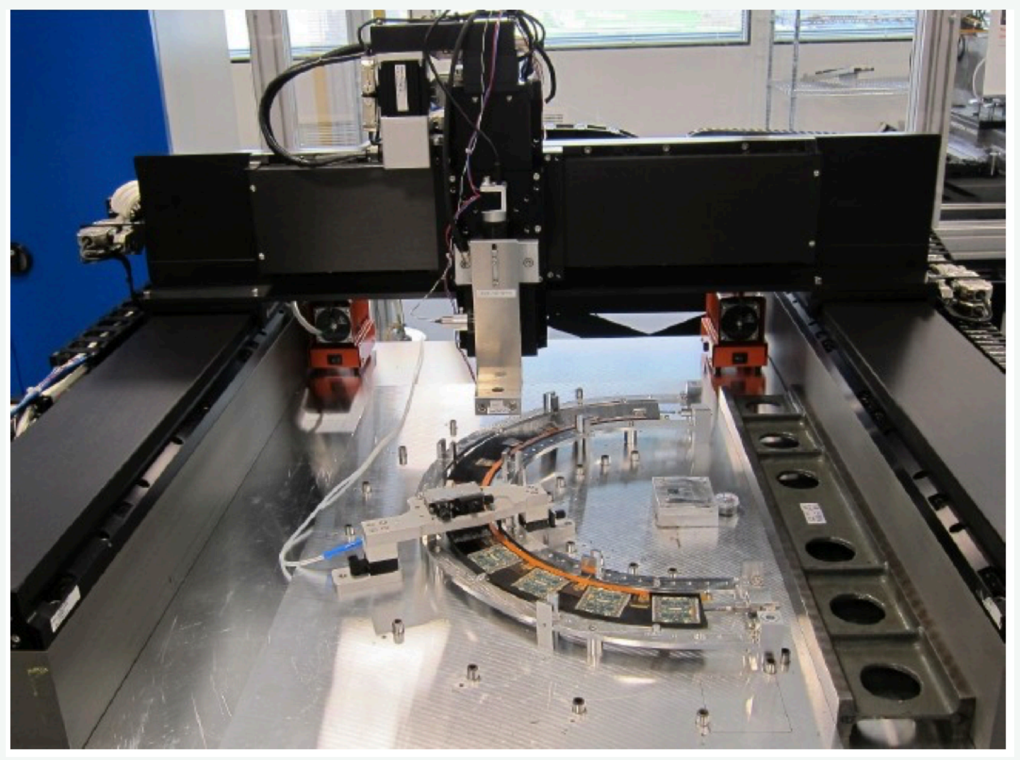
Good progress (pre)production starting!

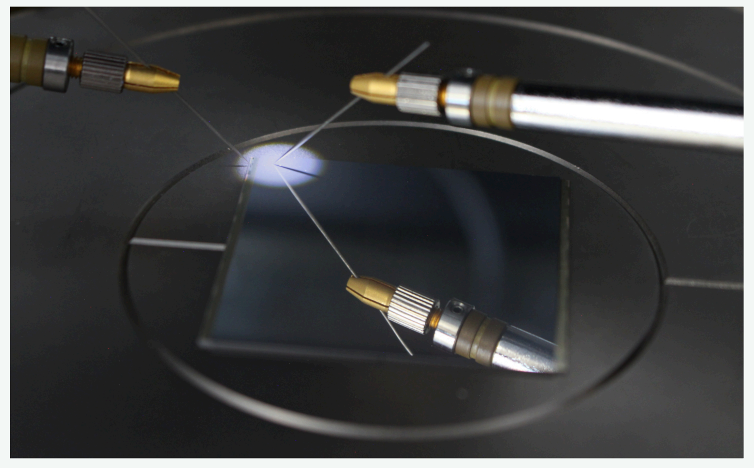

SCT global support mounting

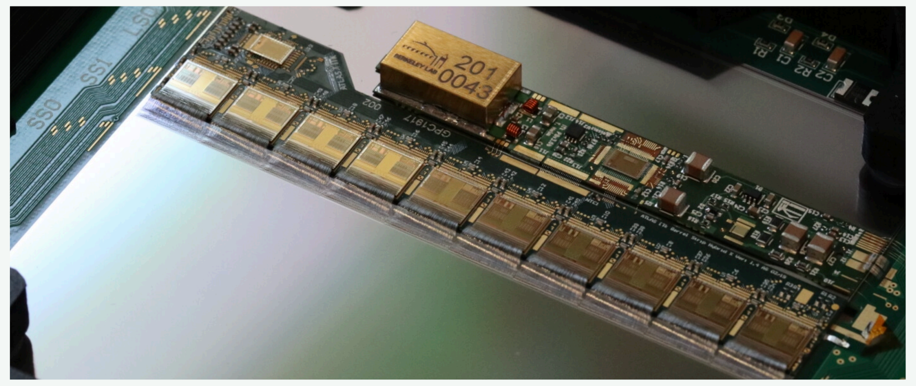

ABCstar SEU test-beam

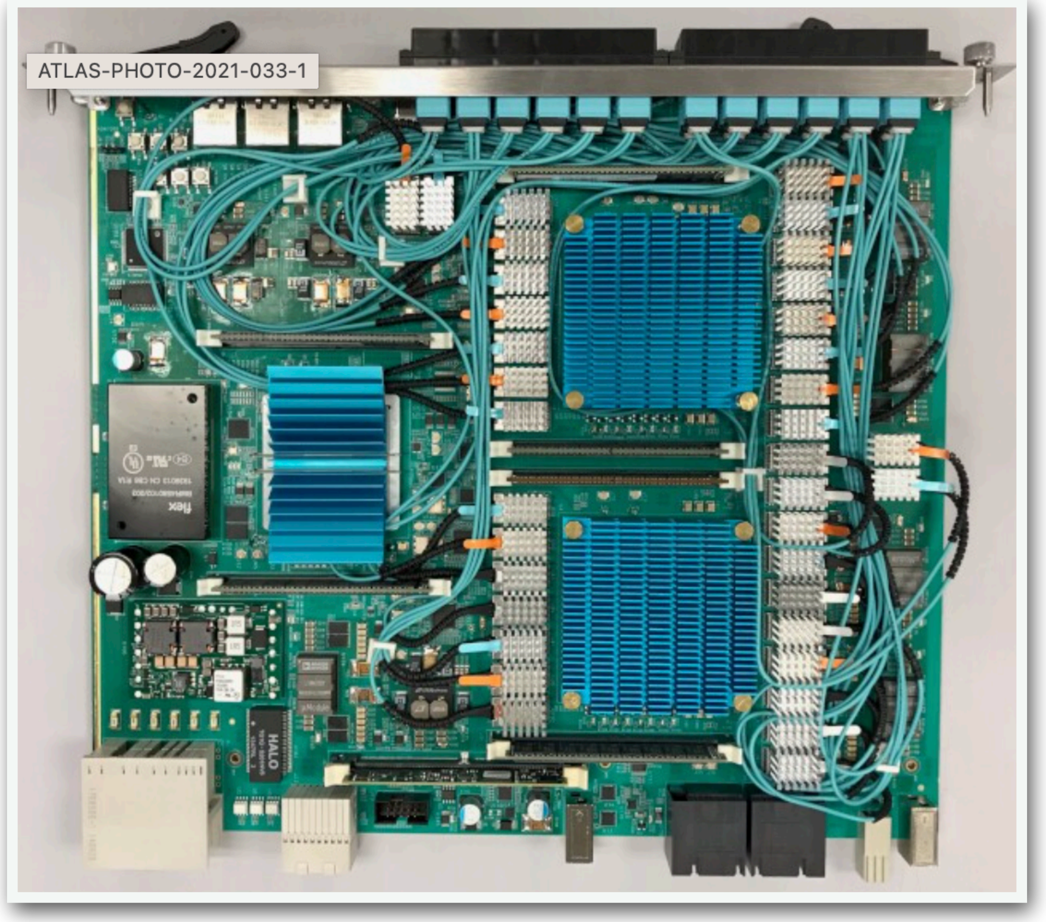

sMDT prototype


Thin gap RPC readout strips


Pixel Outer Endcap loading

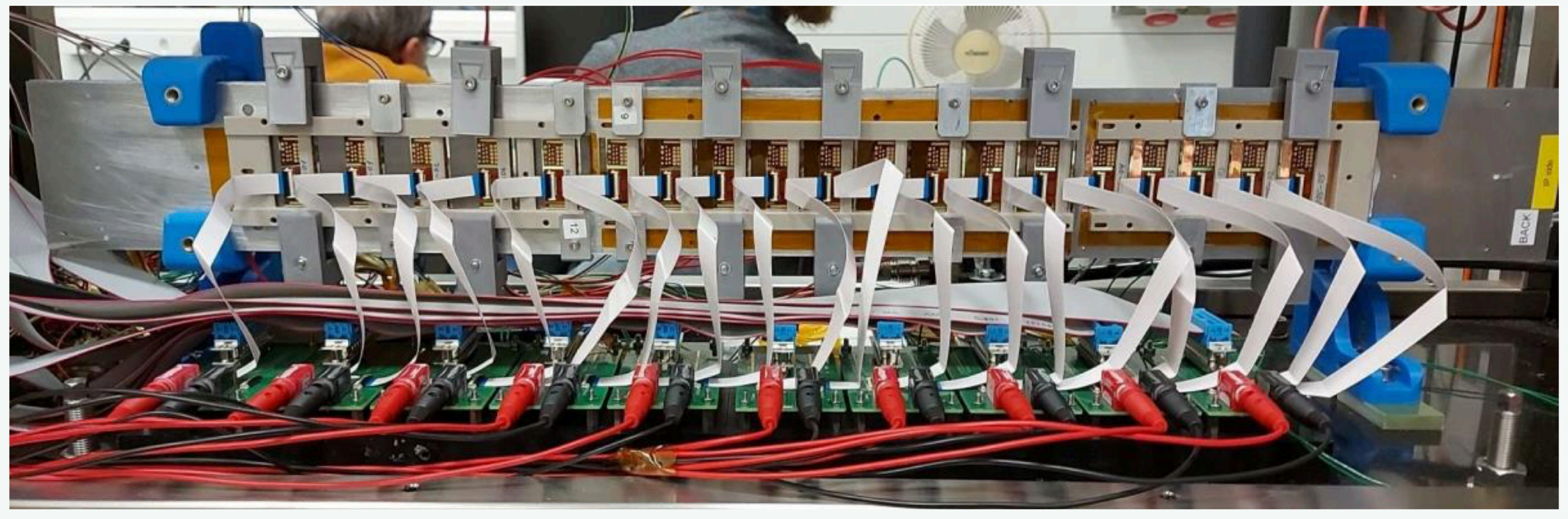

ITk bare module prototype


ITk Strip module

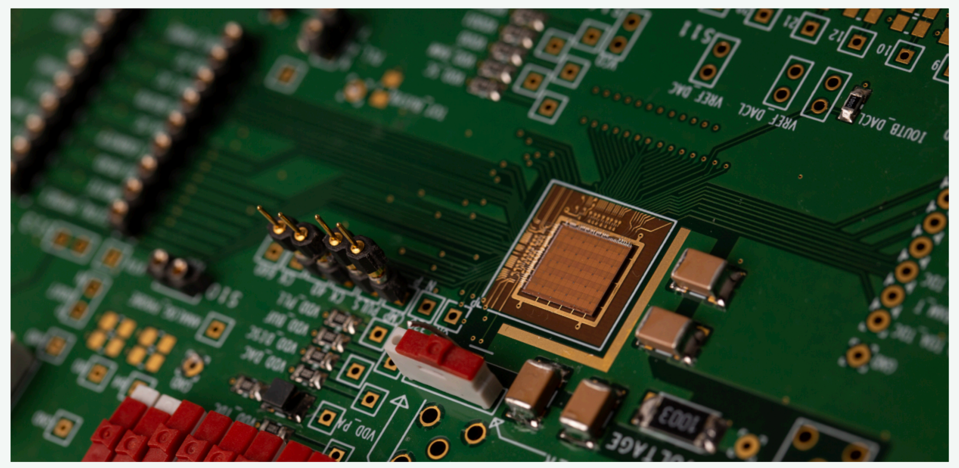


TDAQ L0 Global common module

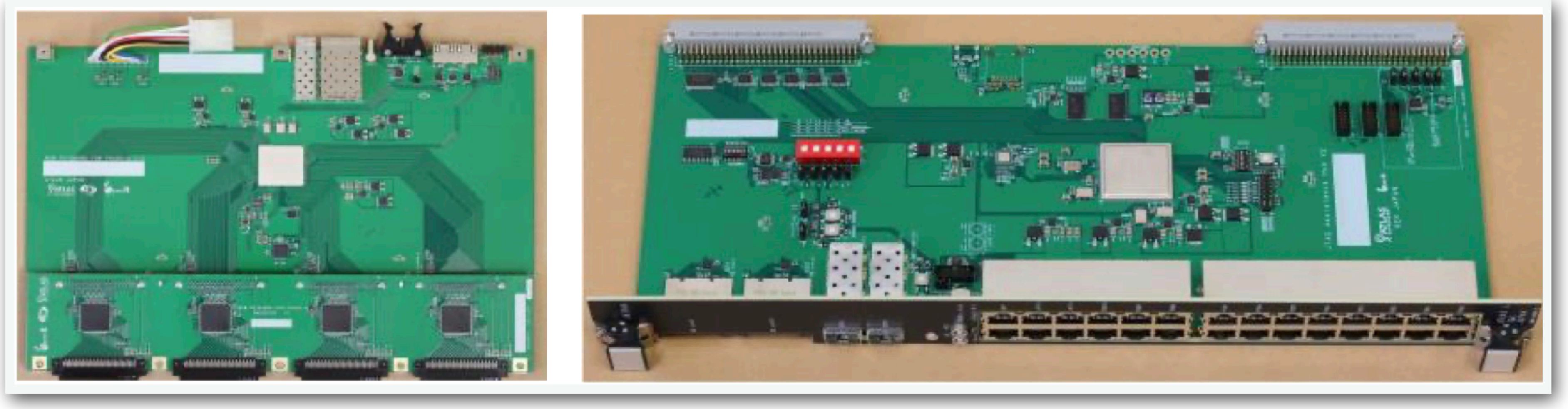

LUCID-3 prototypes


HGTD demonstrator


SR1 at CERN for ITk Integration


Altiroc HGTD readout chip prototype


TGC-EIL4 Chamber prototype


TGC-Electronics