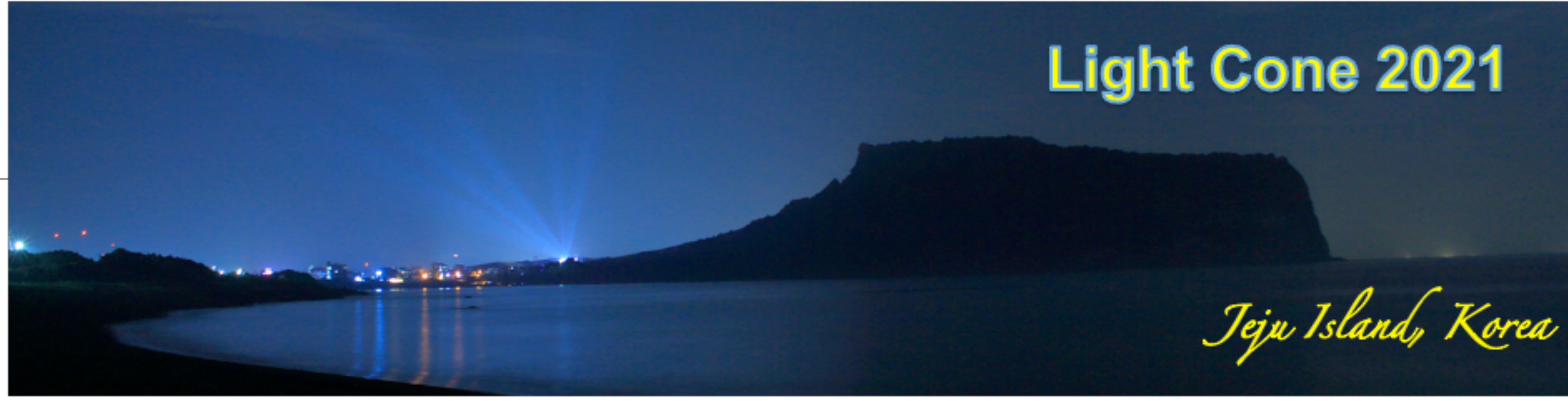


Highlights from ATLAS and Future Plans

Massimo Corradi (INFN Roma)
On behalf of the ATLAS Collaboration

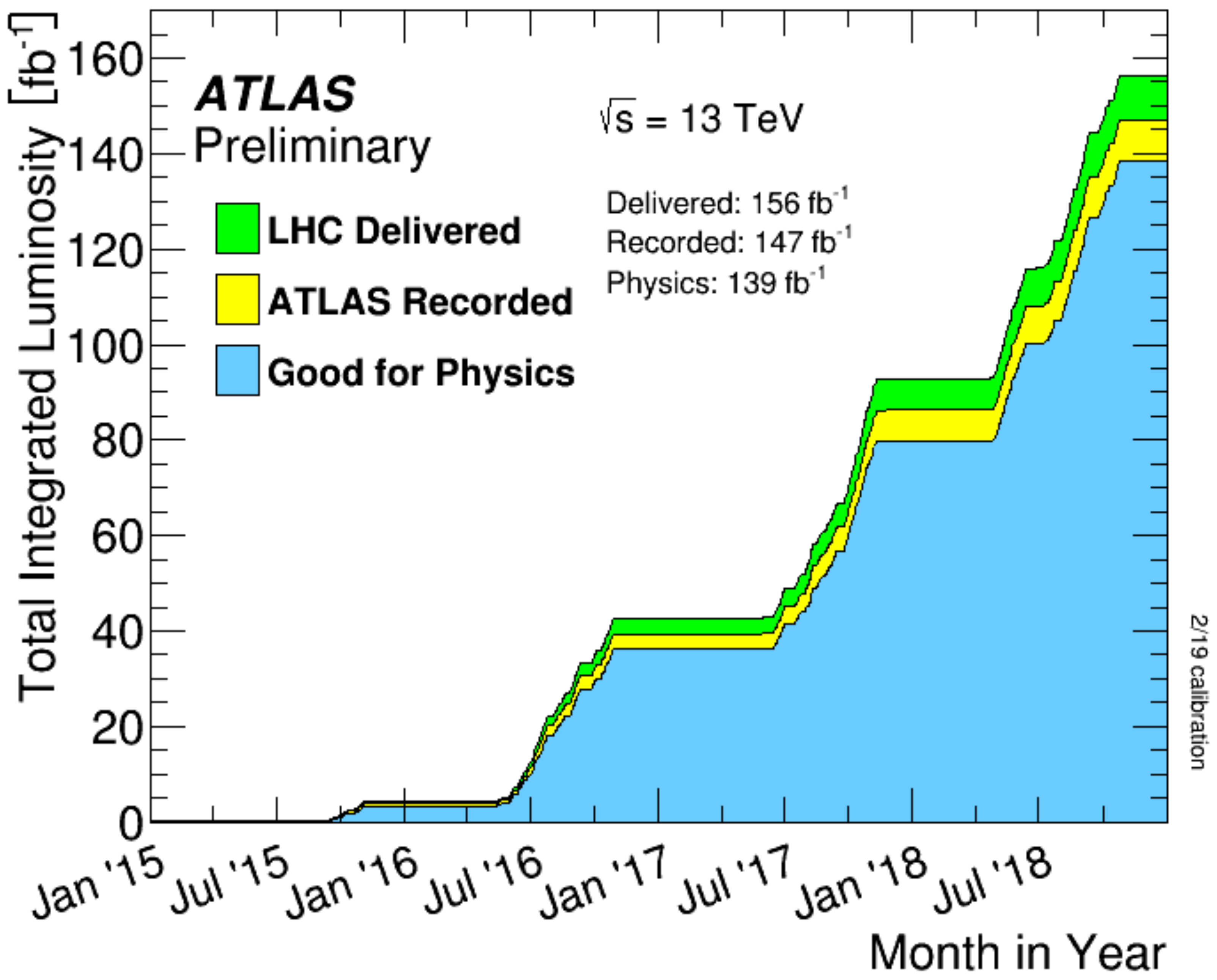
INFN
Istituto Nazionale di Fisica Nucleare

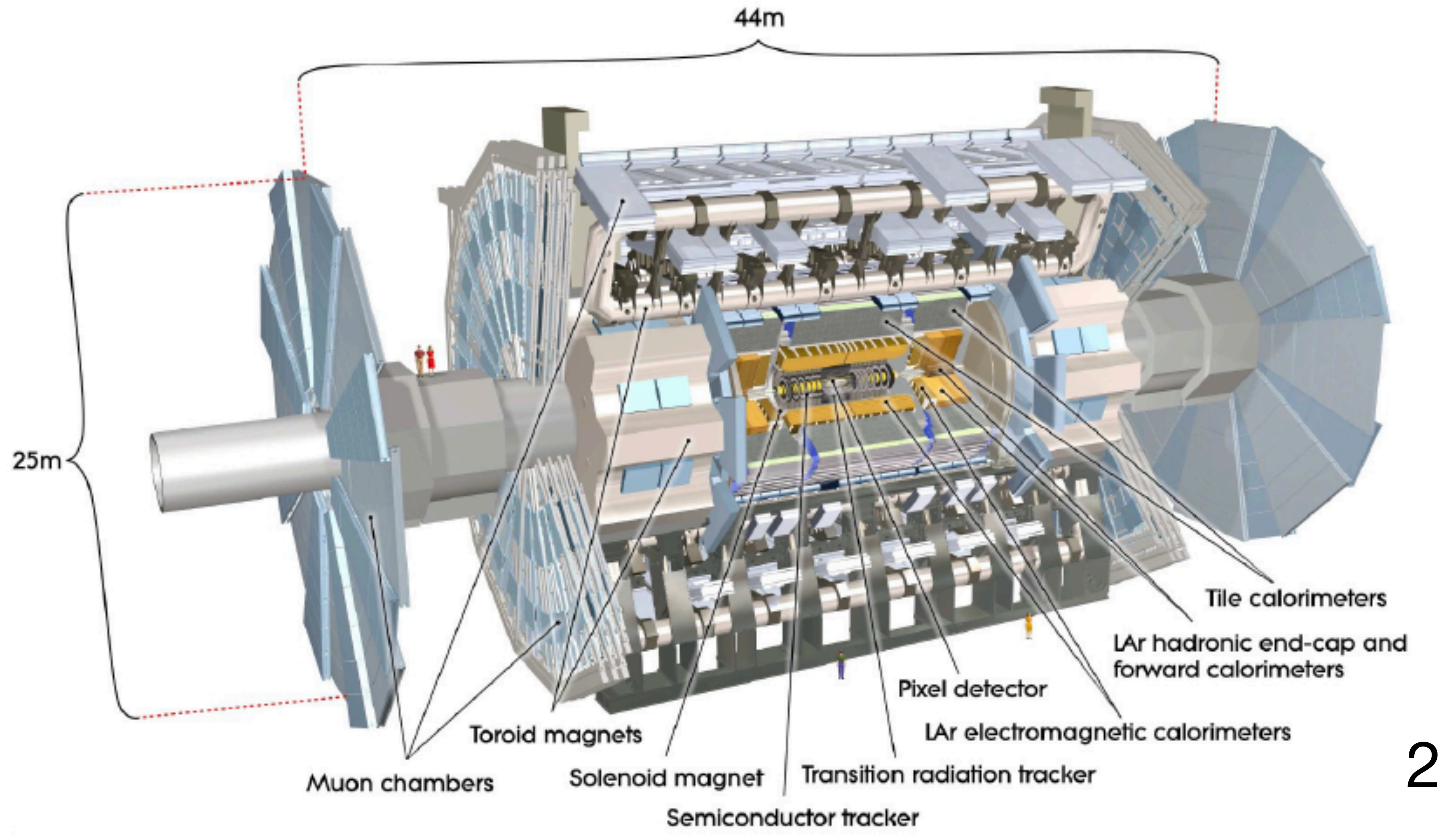
ATLAS EXPERIMENT

ATLAS Run-2 data

- LHC Run2: 2015-2018
- pp center of mass energy : 13 TeV
- Luminosity (Good for Physics): 139 fb^{-1}
- Also heavy-ion collisions (not covered here):
    - Pb+Pb, p+Pb, Xe+Xe
- Special runs at low energy (5.02 TeV) and low-pileup
- ATLAS is a multi-purpose experiment operated by a large experimental collaboration: a vast physics programme
- Many Run-2 results have been published and many analyses are ongoing
- We present here a selection of recent results, released in the last year, and an outlook for future
- New Results on Charmonium and B_c -> see talk by *Semen Turchikhin*

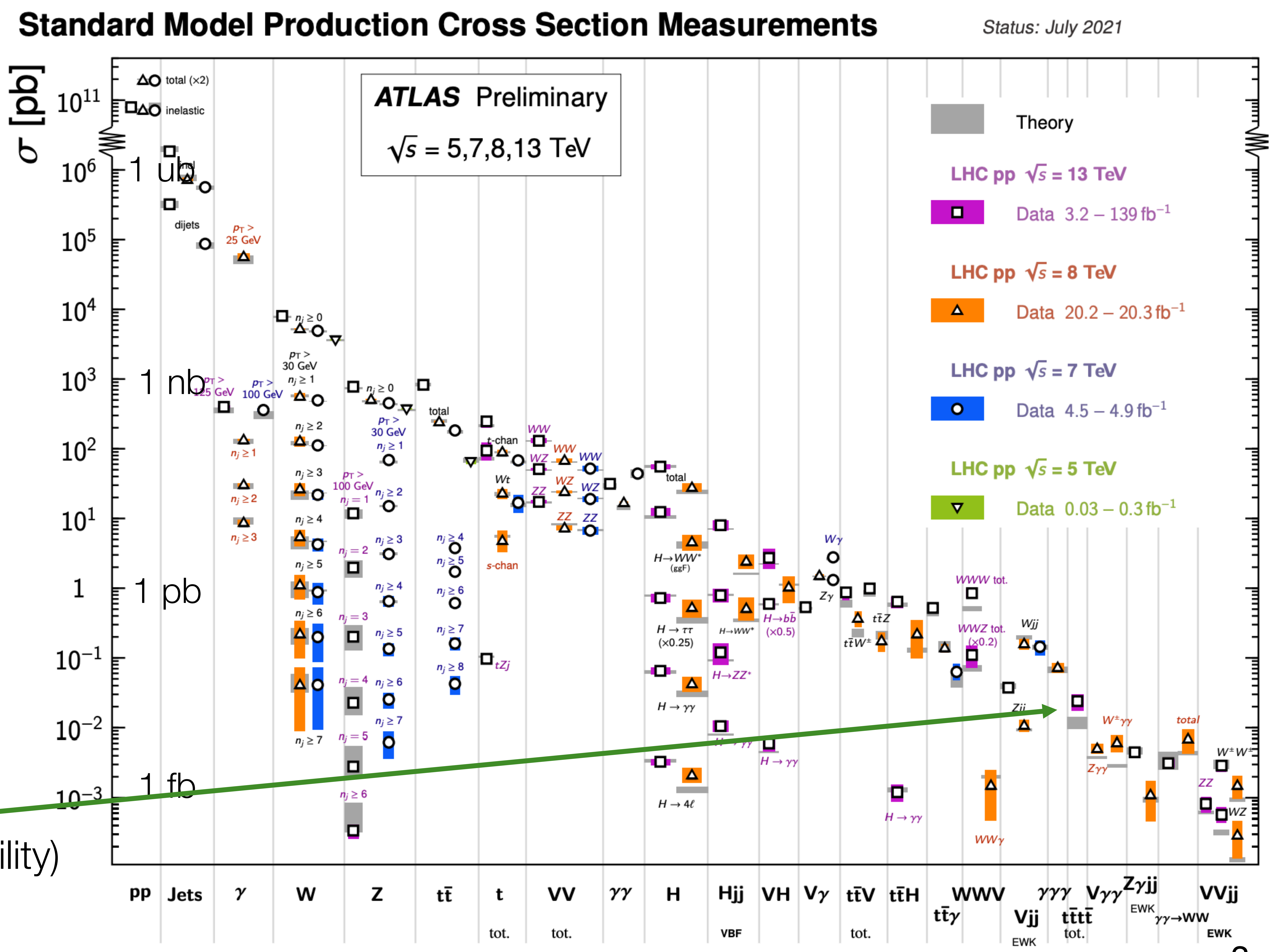
Run 2



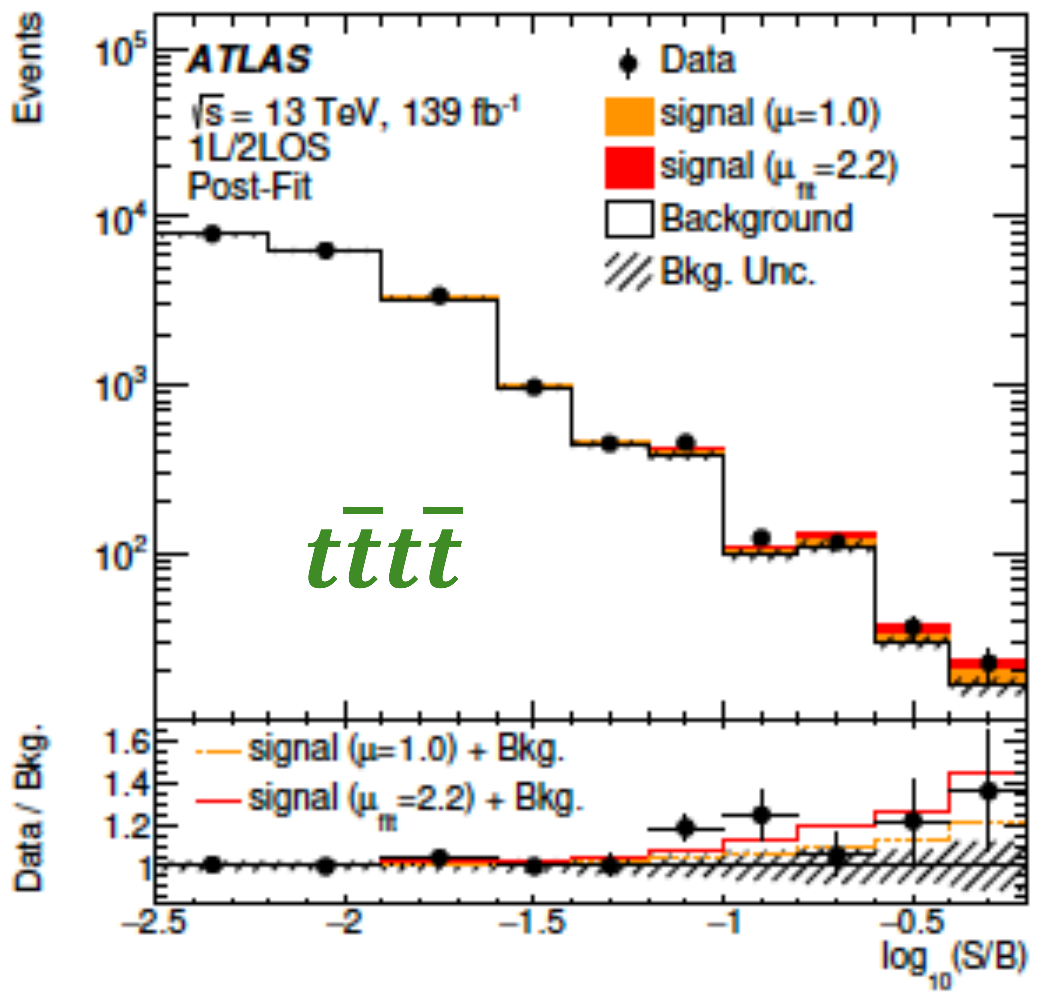


Standard Model Processes

- Cross sections of different processes in pp collisions span many orders of magnitude
- Millions of Z, W, $t\bar{t}$ => precision
- Thousands of H
- Observation of rare channels with tiny SM cross sections e.g. $t\bar{t}t\bar{t}$



arXiv:2106.11683 acc. by JHEP



$t\bar{t}t\bar{t}$

1L/2LOS/2LSS/3L

$\sigma_{t\bar{t}t\bar{t}} = 24^{+7}_{-6}$ fb

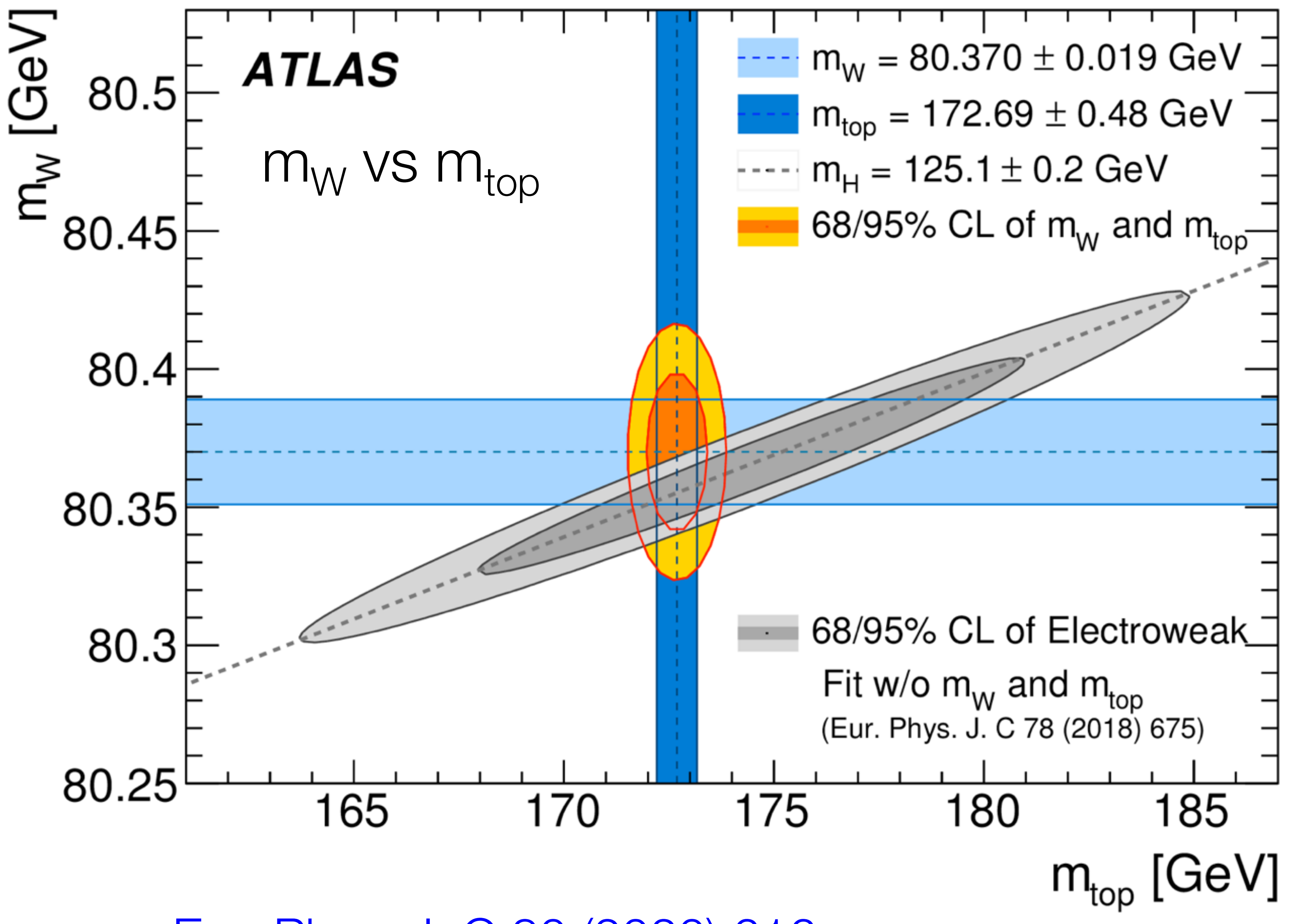
SM: 12.0±2.4 fb

(2-sigma compatibility)

Standard Model Precision measurements from W, Z:

- Precision measurents of SM parameters m_W, $\sin^2(\theta_W)$, exploiting the huge sample of Z and W
- Run-1 measurements limited by theoretical uncertainties:
  - PDF
  - W and Z p_T spectrum
  - Fragmentation
- Program to reduce these uncertainties using direct measurements, e.g. p_T^Z

Eur. Phys. J. C 78 (2018) 110



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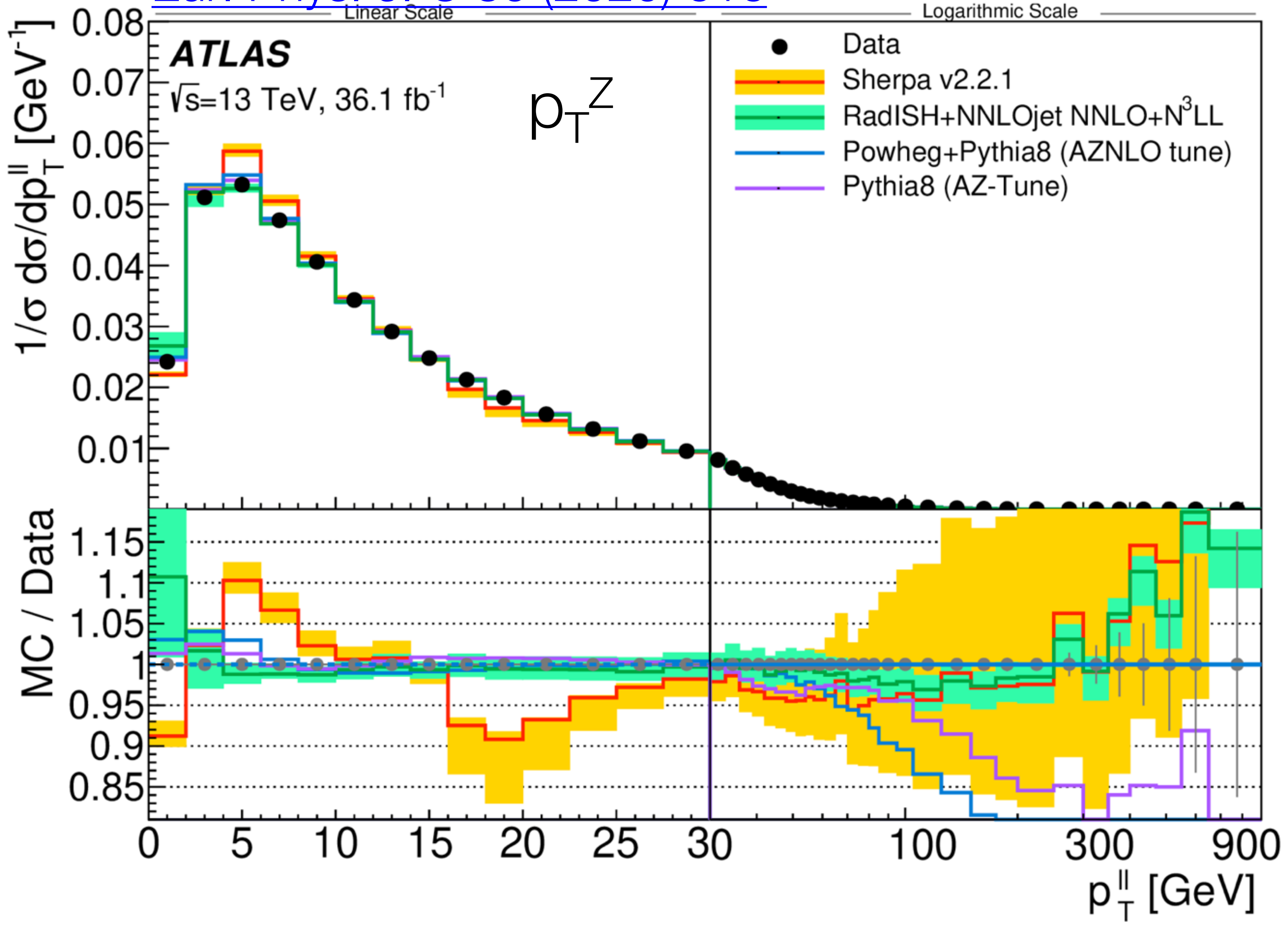

Z-boson + jets production

- Run 2: ~8 x 10^9 Z bosons produced
- Test SM in events w/ $Z(\rightarrow ee, \mu\mu)$ and $\geq$ 1 jet with $p_{\mathrm{T}} > 100\mathrm{GeV}$
  - SM predictions w/ event generators up to NLO QCD + NLO EW
  - Measure cross section in more extreme phase space: collinear vs. back-to-back jet emission, high jet p_T or high sum p_T

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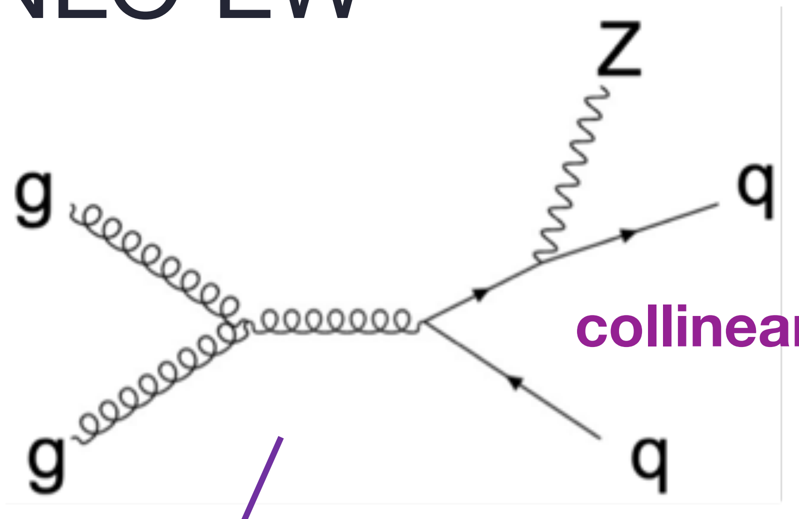

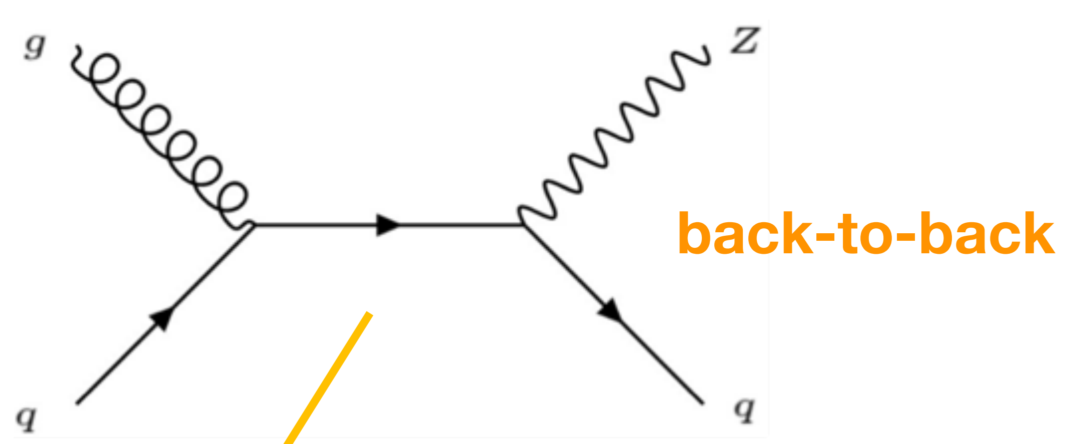

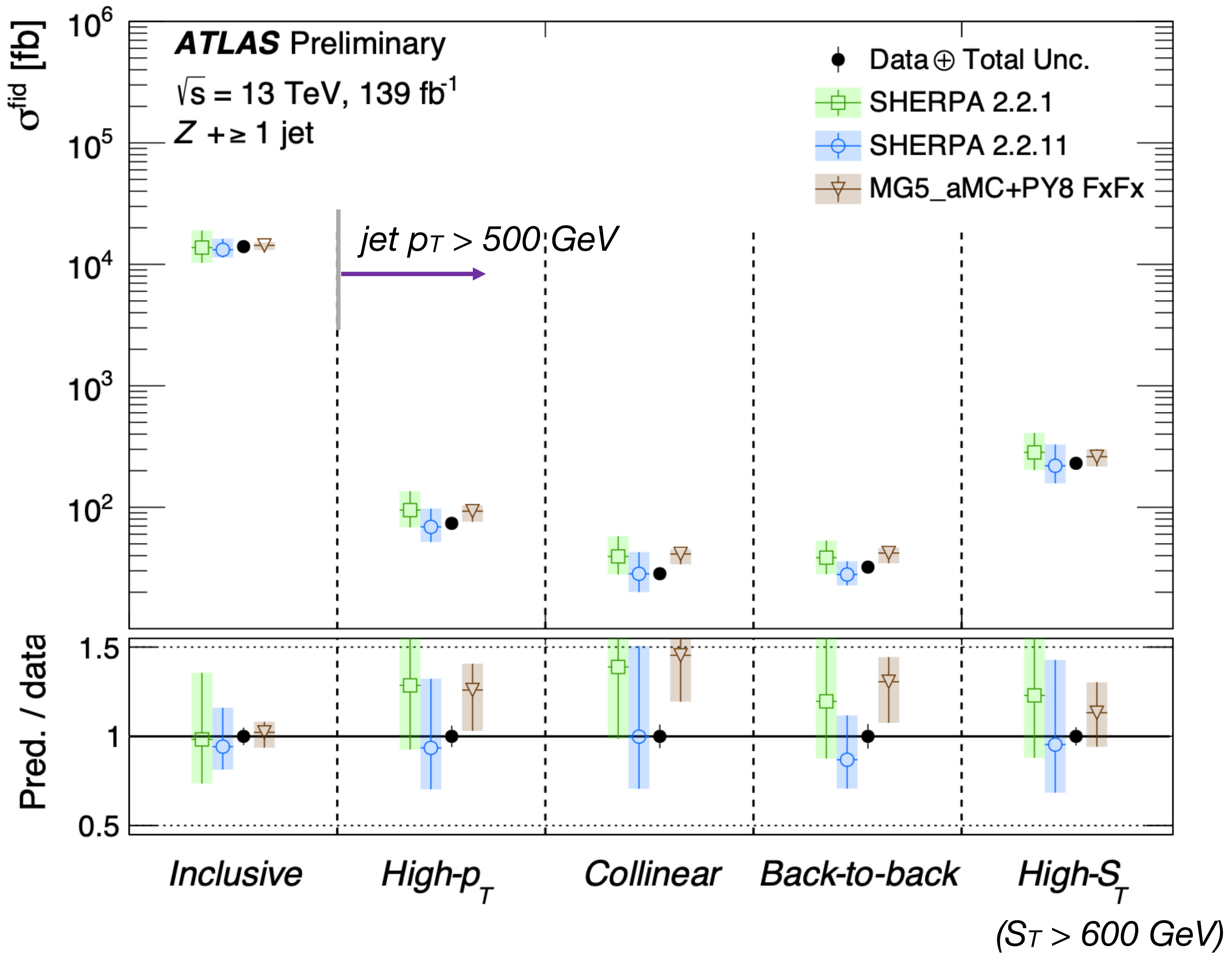

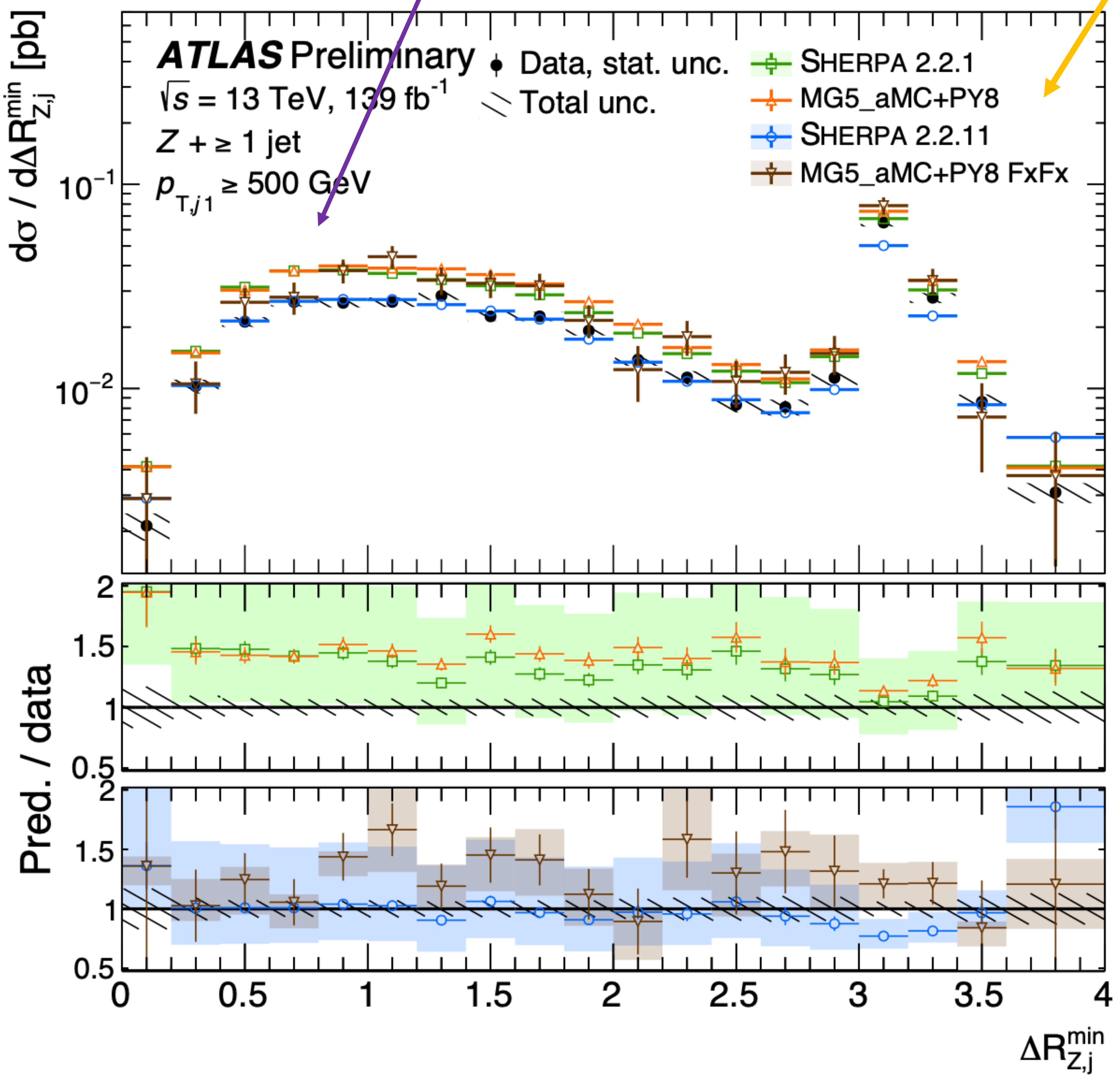

improved description with recent event generators :

Sherpa 2.2.11 (0-2 partons at NLO, 3-5 partons at LO)

MG5_aMD+PY8 (0-3 partons NLO) Frederix-Frixione merging scheme)

Standard Model: PDFs

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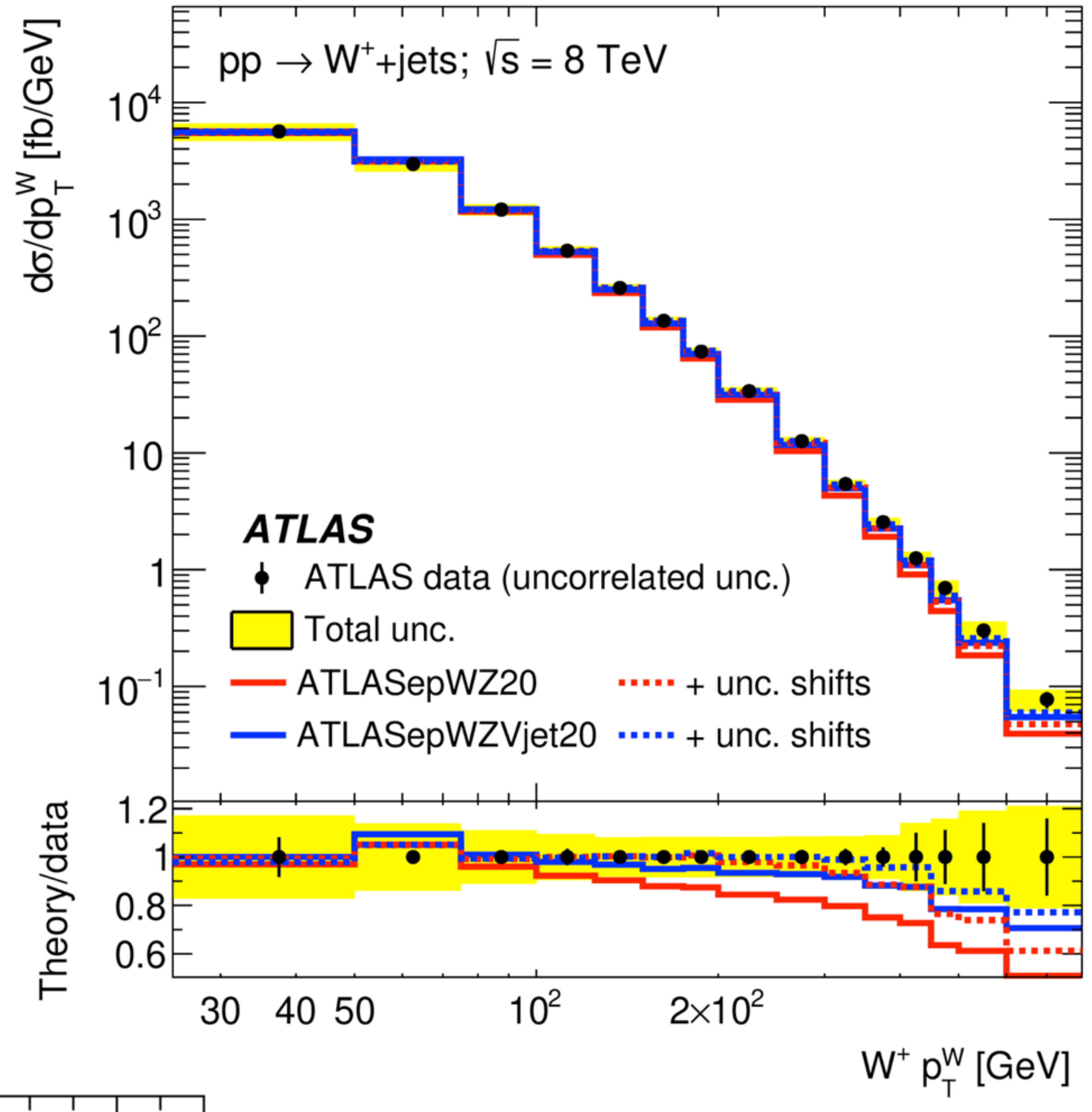
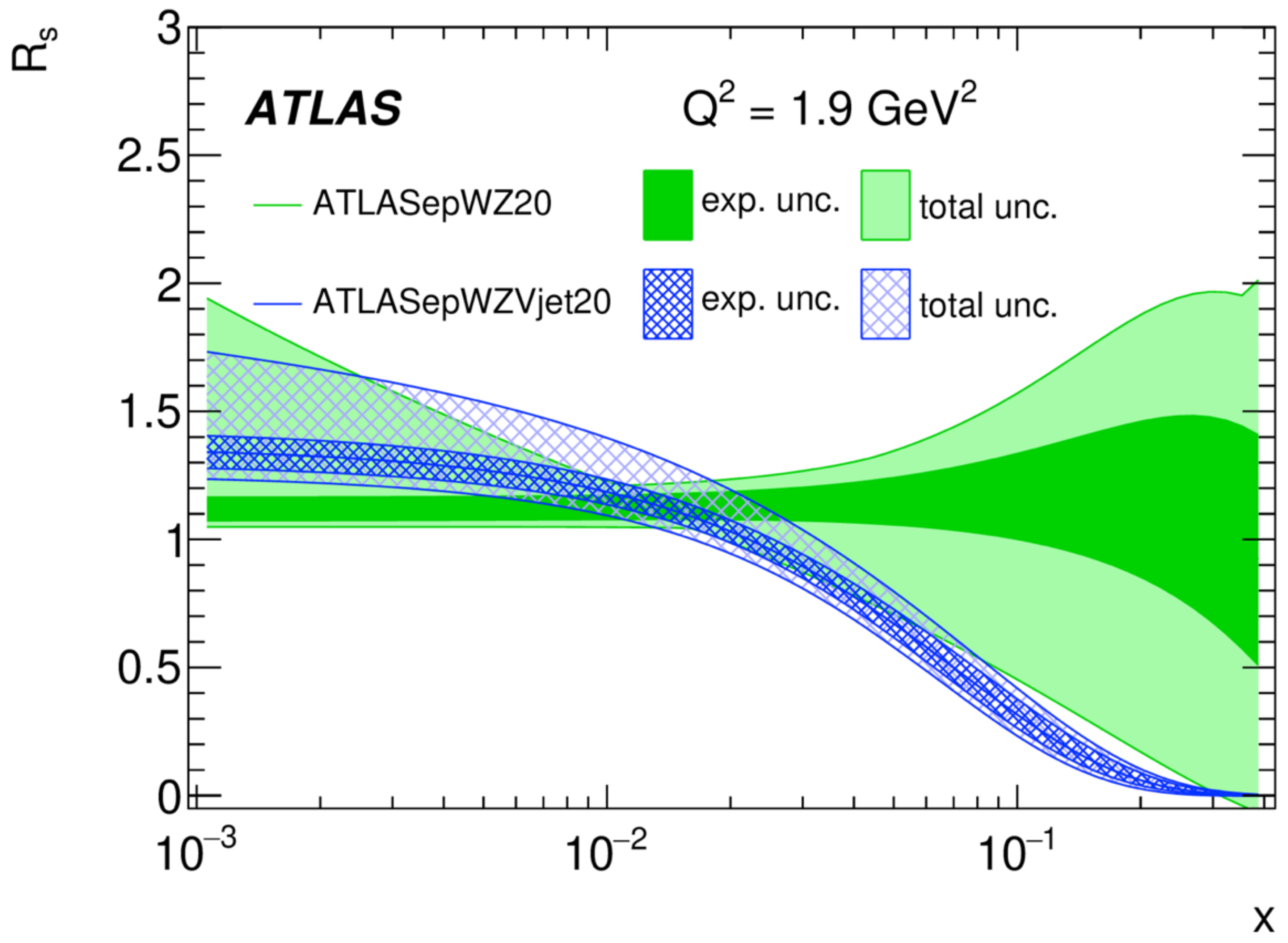
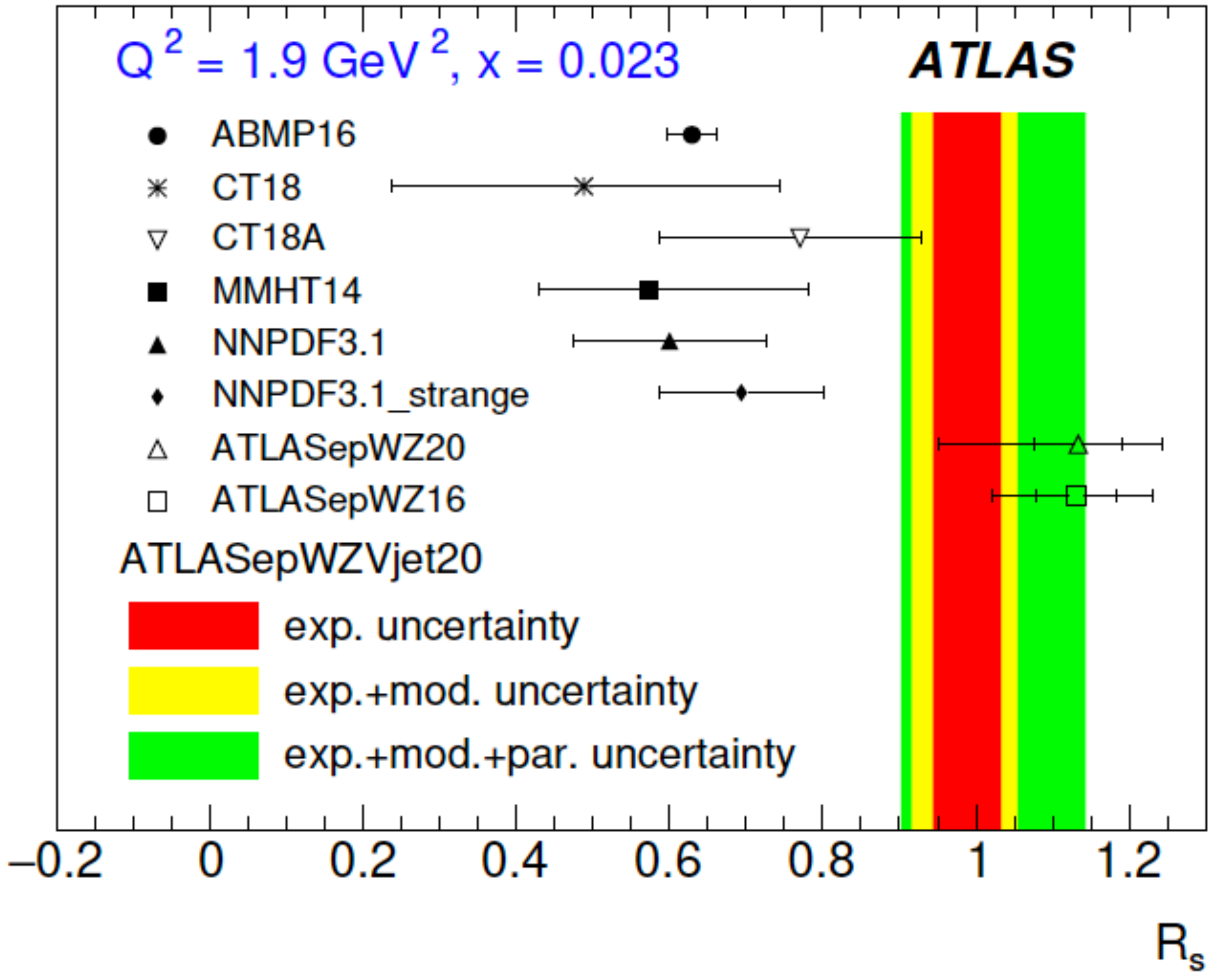
- W, Z/γ^* data at LHC data can be used to constraint PDFs
- New PDF set ATLASepWZjet20 (HERA + ATLAS W,Z inclusive + W+jet, Z+jet)
- V+Jet measurements help to separate u and d, s
- Unsuppressed strange fraction is confirmed



Rs=(s+sbar)/(ubar+dbar)





b-quark fragmentation

- Fragmentation of b-quarks important in key measurements and searches (e.g. top-quark mass or $H \rightarrow b\bar{b}$)

- Test and improve fragmentation models derived from measurements at e^+e^- colliders

- Use jet-based quantities:
  —> $z_{L,b}^{ch}$ = fraction of jet charged-track momentum carried by $B \rightarrow l^+ \nu X$
  —> z = fraction of jet momentm carried by reconstructed $B^\pm \rightarrow J/\psi K^\pm \rightarrow \mu^+\mu^- K^\pm$

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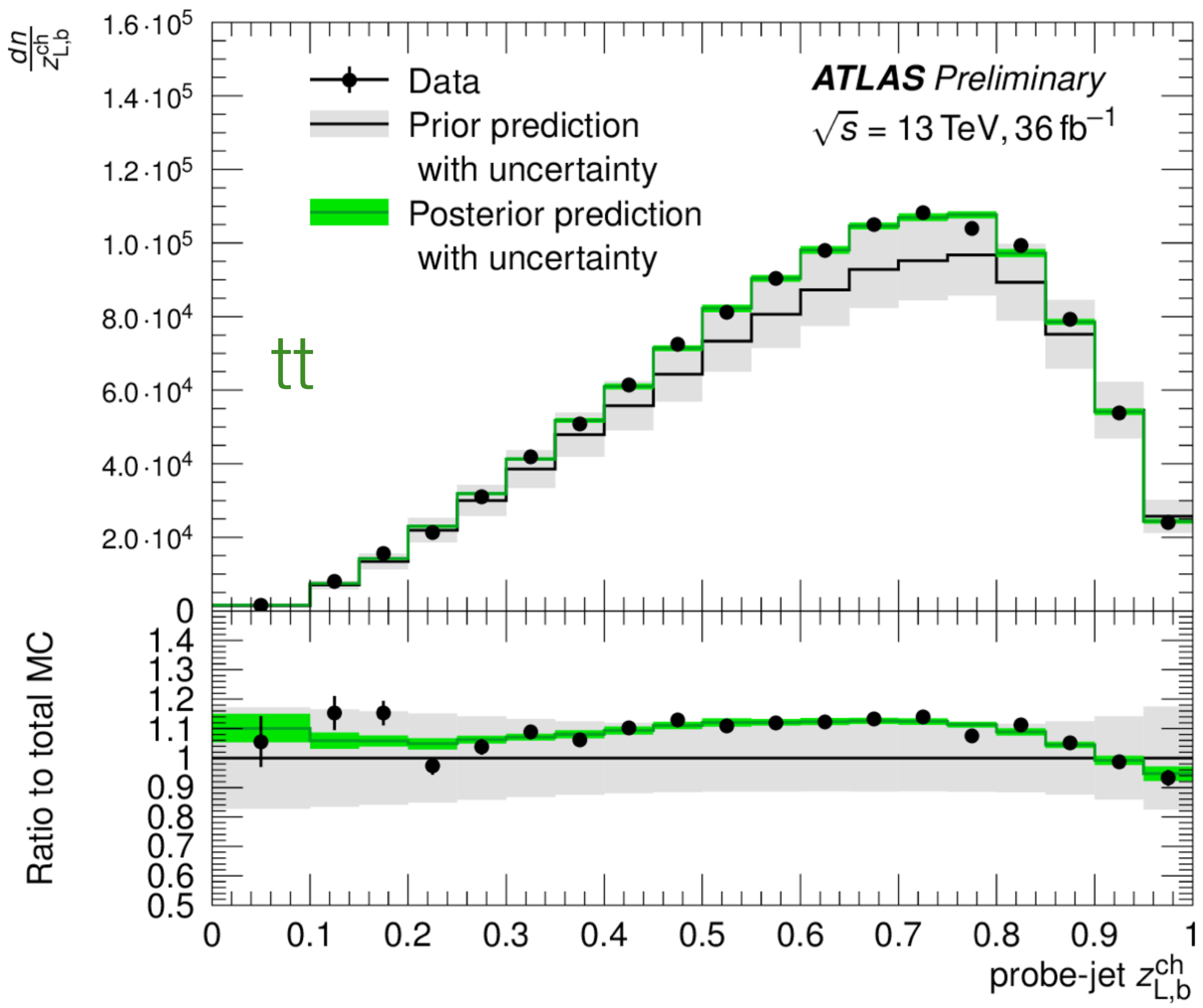
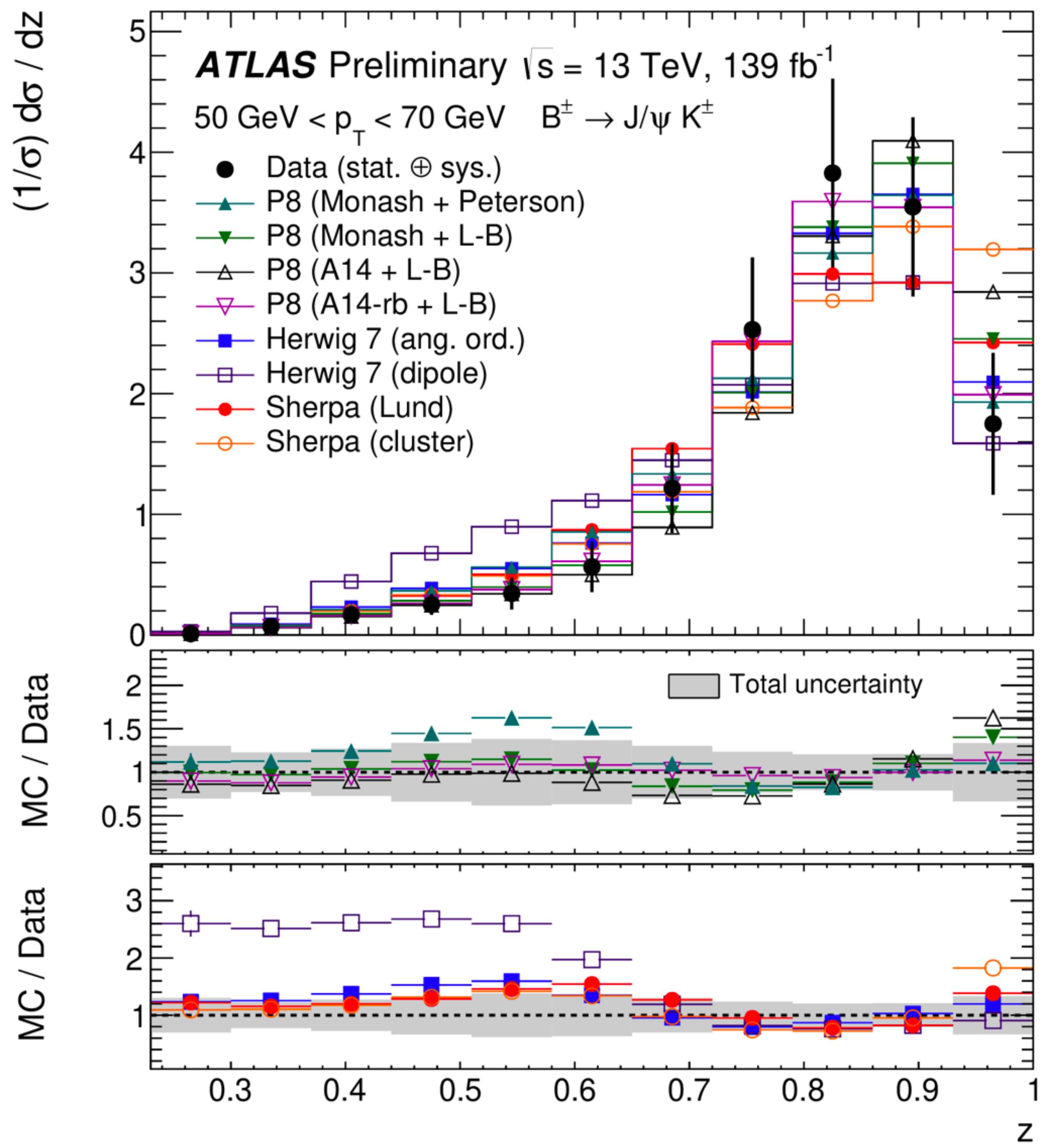
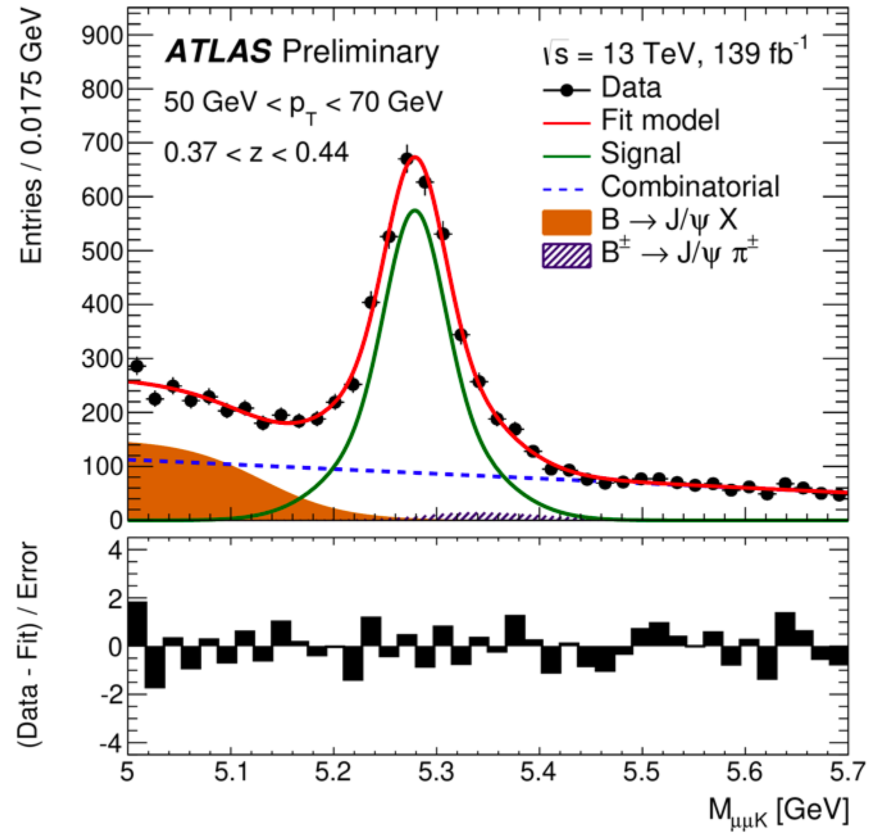


ArXiv:2108.1165

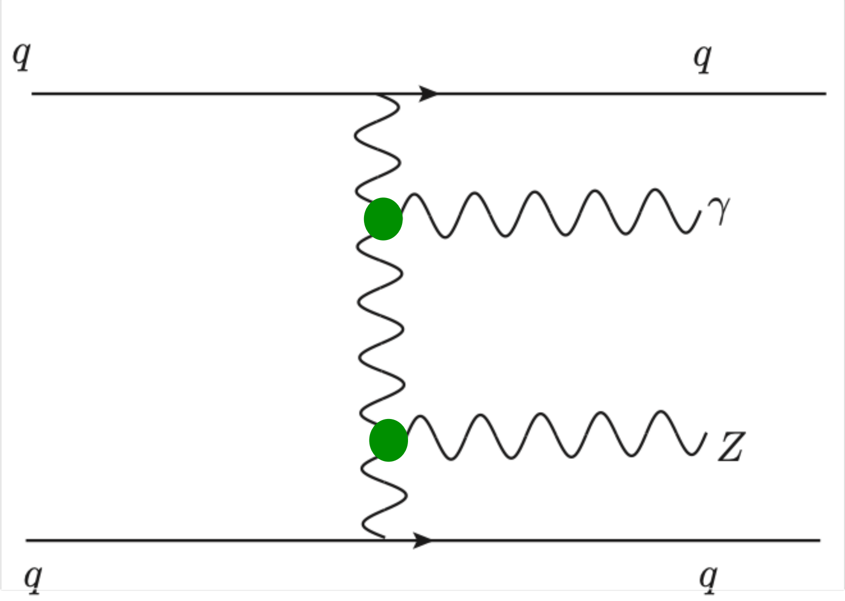


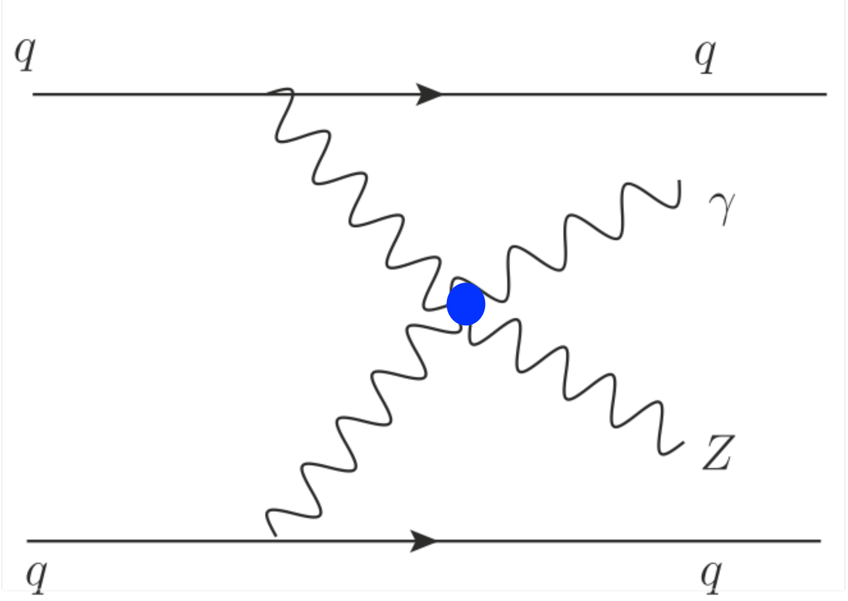


- z distribution also sensitive to rate of gluon splitting to $b\bar{b}$
- Pythia8 and SHERPA generally model data well

Multi-boson production: vector boson scattering

- Key test of EW symmetry
  —> **vector boson self-interactions**
  —> cubic and quartic couplings; previously observed all $VVjj$, except $Z\gamma jj$
- Events characterized by jets with large mass and rapidity gap
- Signal strength for $Z\gamma jj$ EW production (rel. to LO prediction)
  - $Z \to \nu\nu$: $\mu_{\mathrm{EW}} = 1.03 \pm 0.16(\mathrm{stat}) \pm 0.19(\mathrm{syst})$
  - $Z \to \ell\ell$: $\mu_{\mathrm{EW}} = 0.95 \pm 0.08(\mathrm{stat}) \pm 0.11(\mathrm{syst})$





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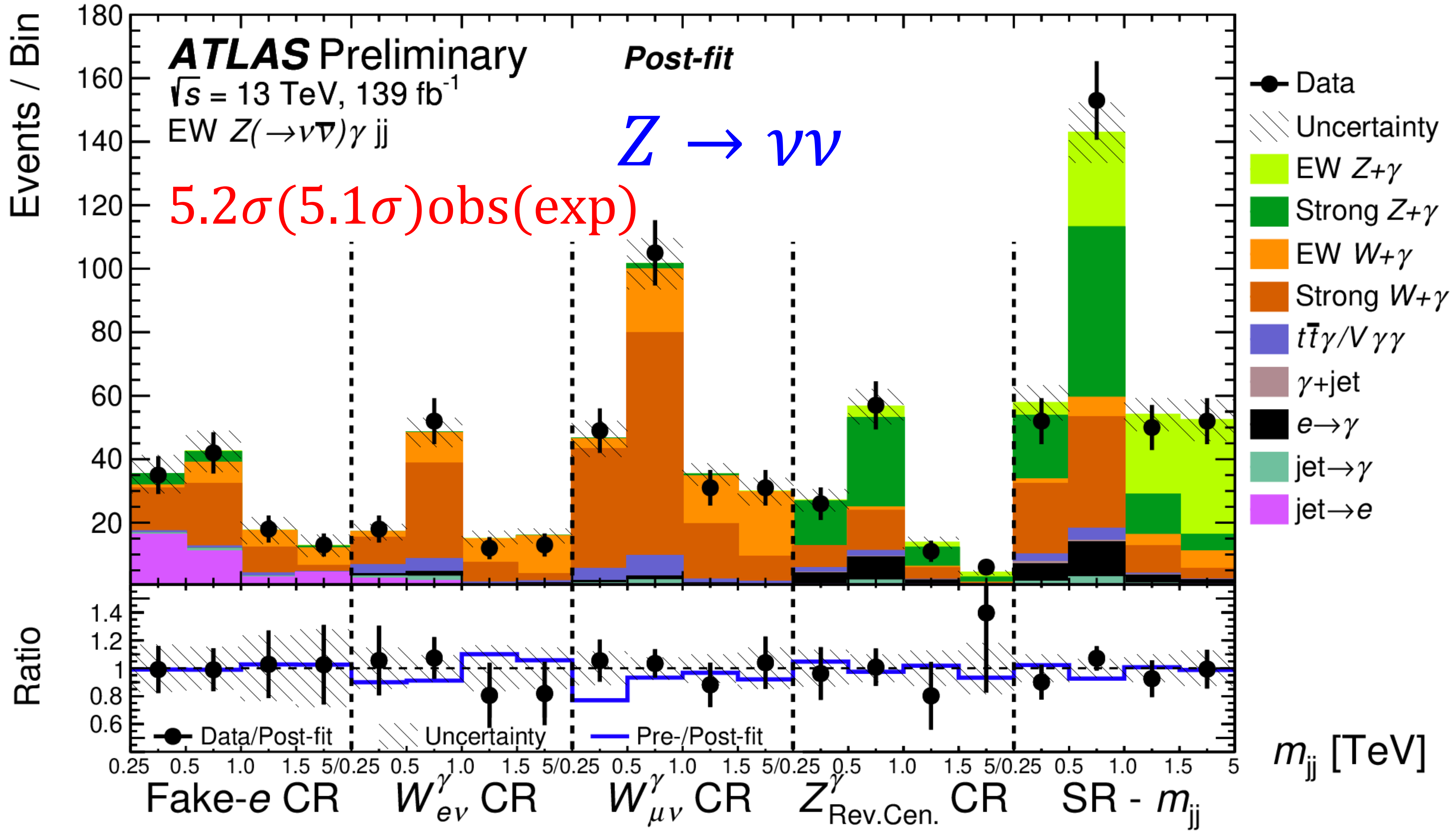
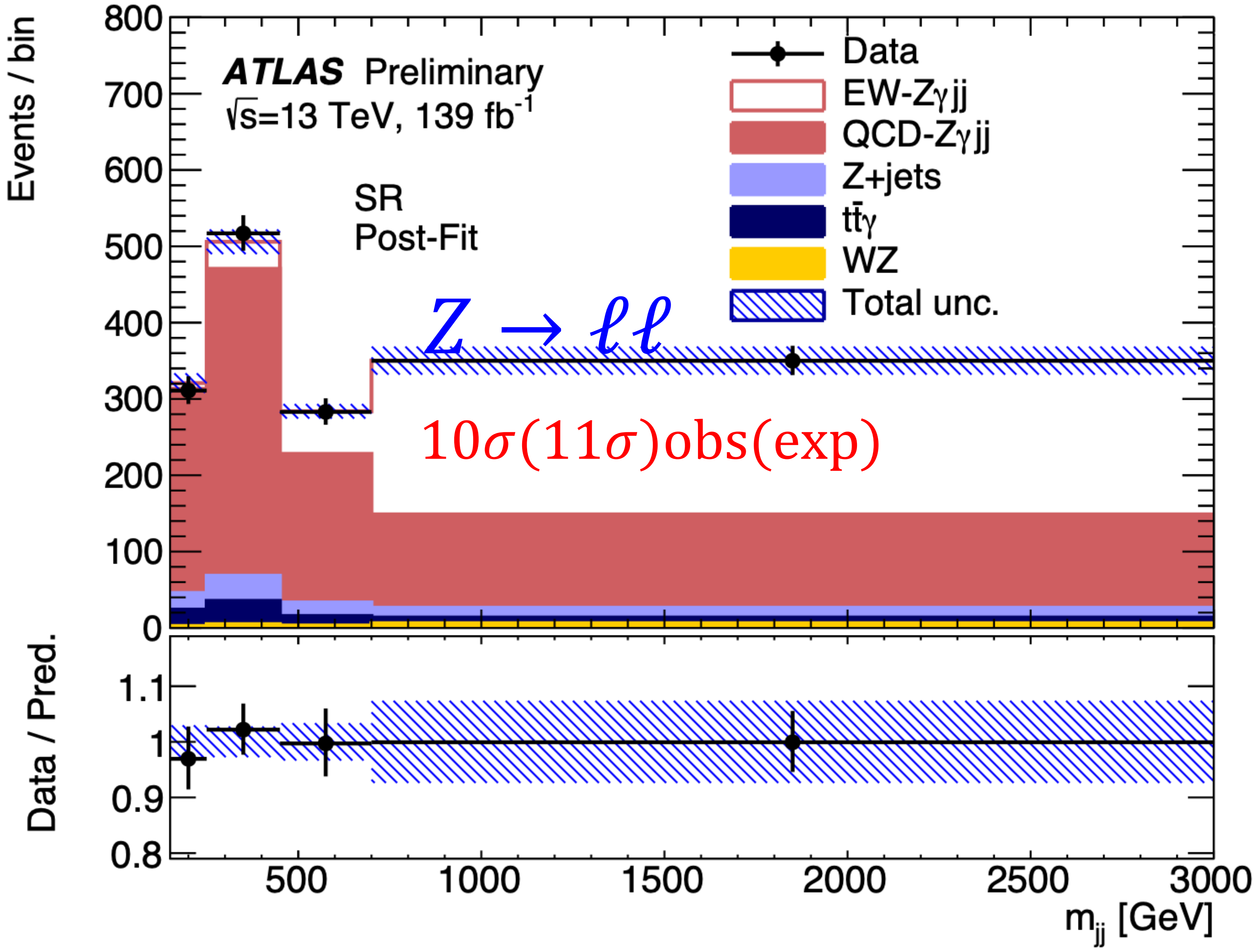
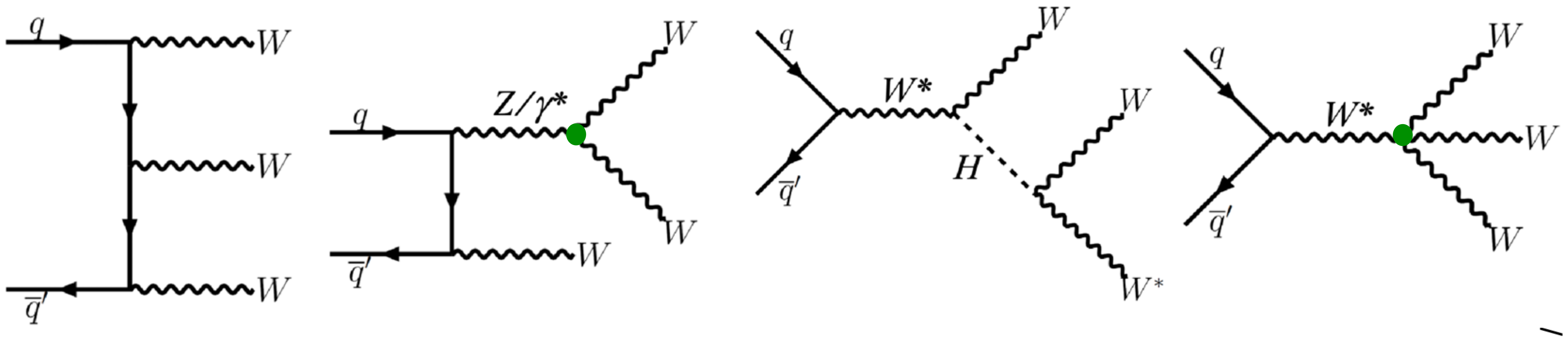


most precise with 13% cross-section uncert.



WWW production

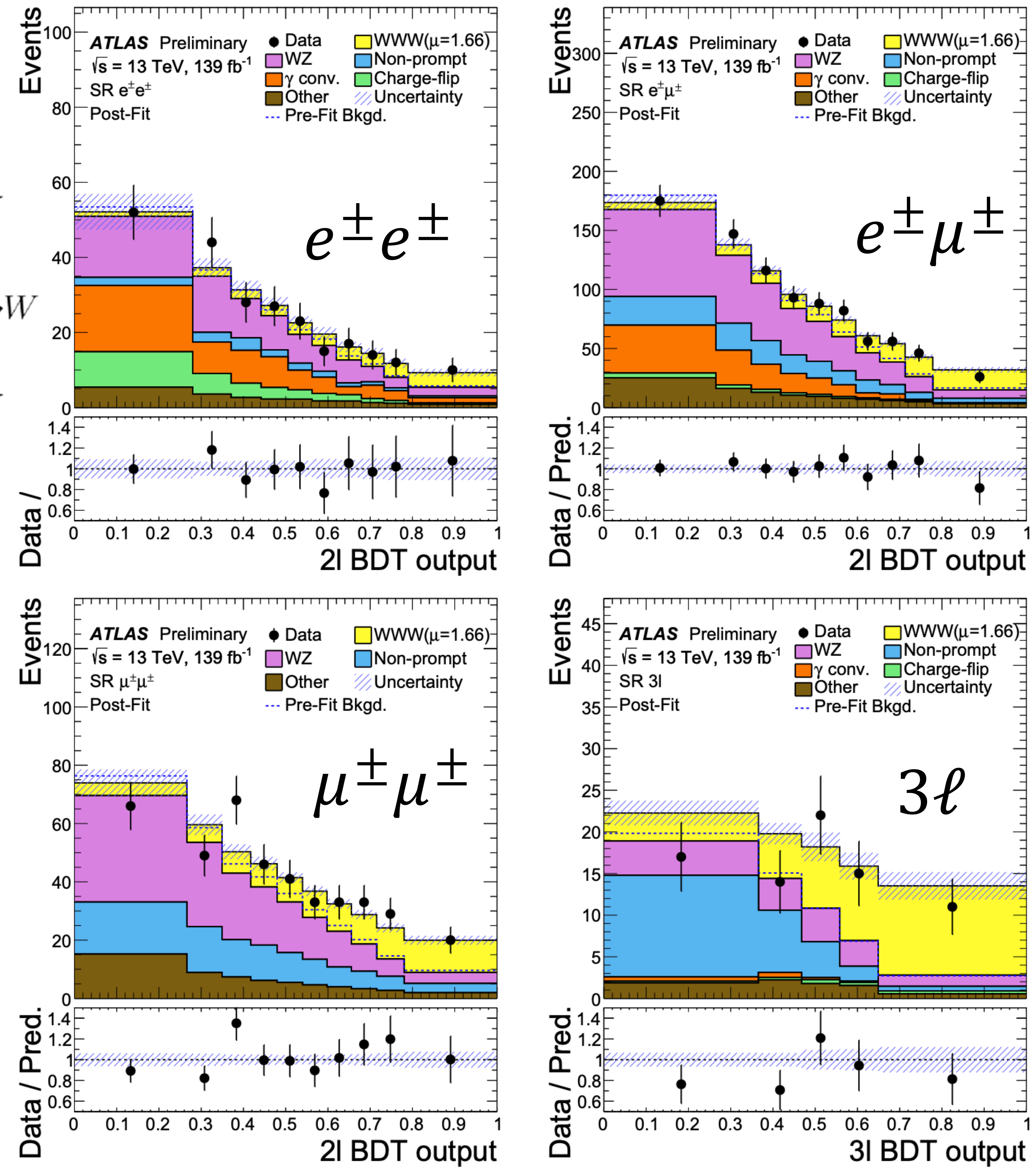
- Rare process providing access to **W/Z self-interactions** —> cubic and quartic couplings



- Channels: $W^{\pm}W^{\pm}W^{\mp} \rightarrow \ell^{\pm}\nu\ell^{\pm}\nu q q'$ with $\ell = e, \mu$
- **First WWW observation**

$$\sigma(pp \rightarrow W^{\pm}W^{\pm}W^{\mp}) = 850 \pm 100(\text{stat}) \pm 80(\text{syst})\text{fb}$$

Signal strength: 1.66 ± 0.28

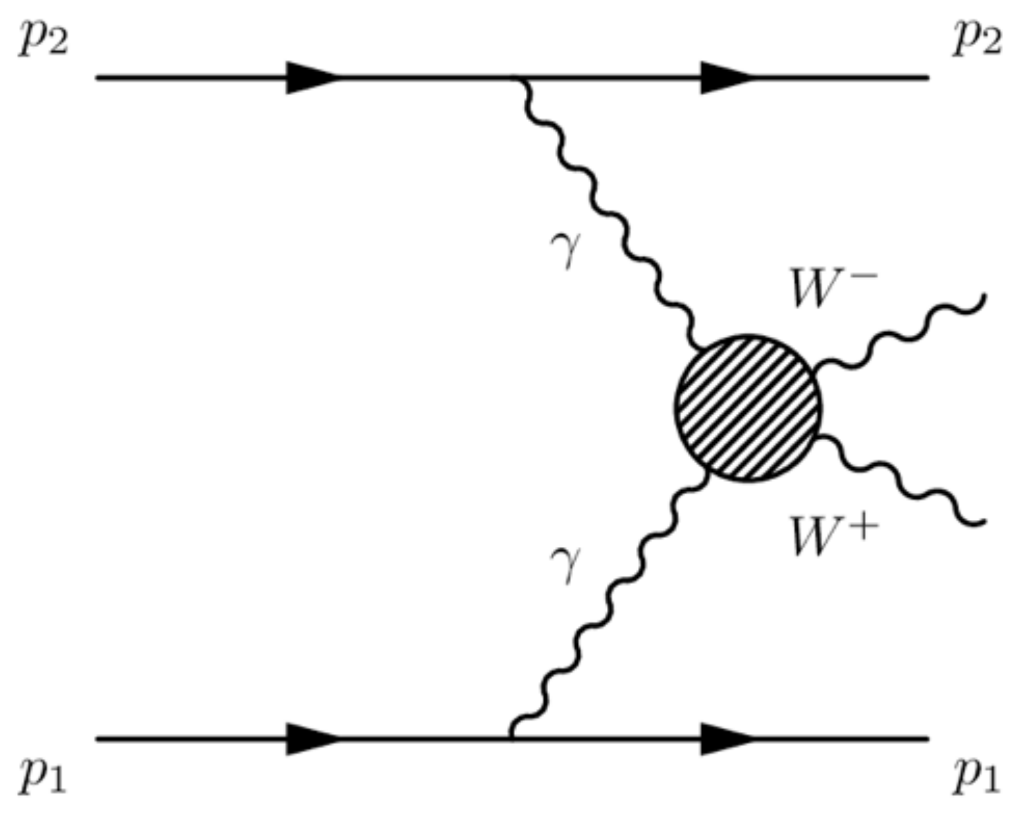


Exclusive WW production

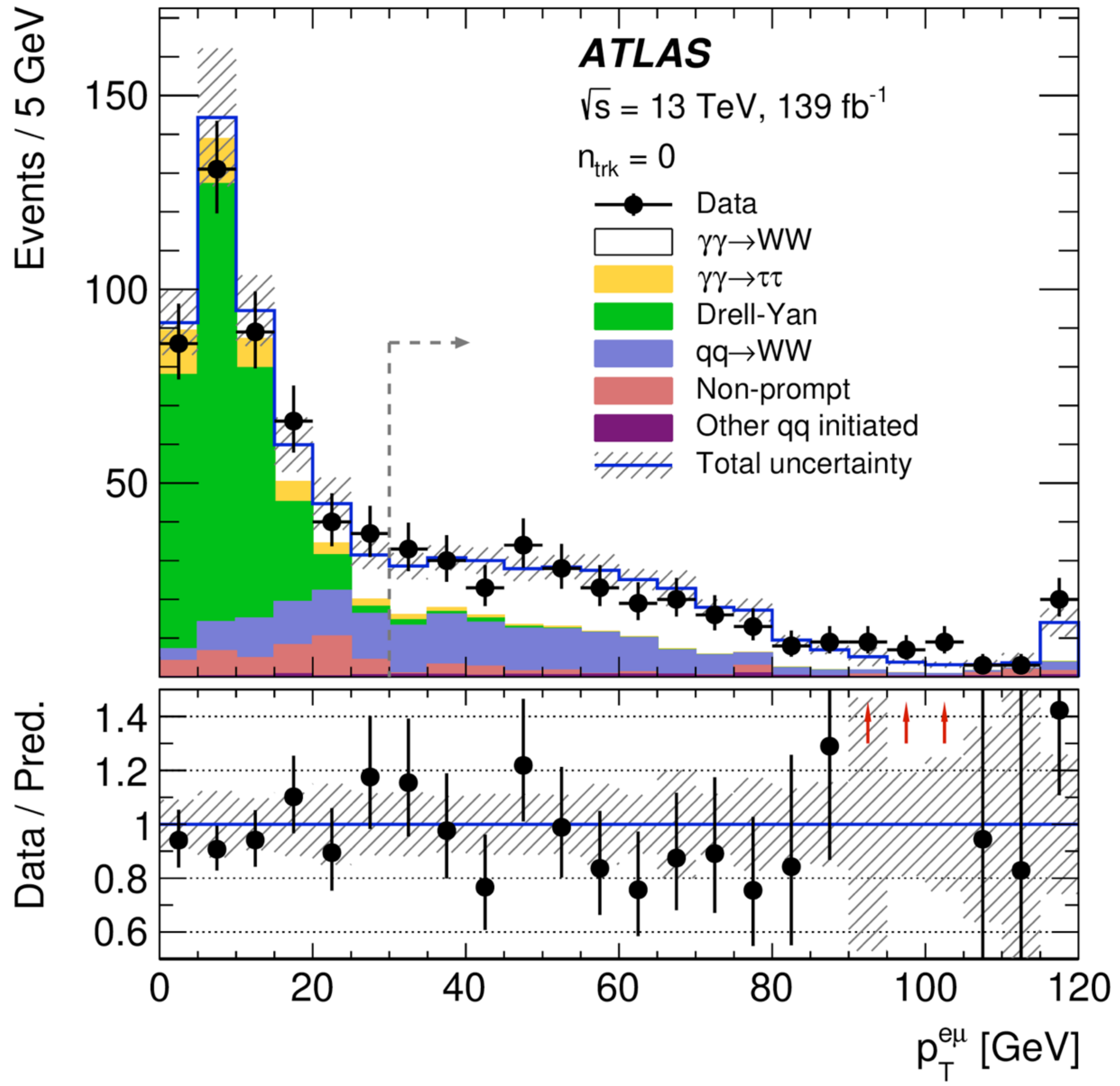
- Exclusive Gamma-gamma-> WW, sensitivity to quartic coupling
- Striking signature: WW and no other tracks emerging from interaction vertex.
- Elastic, single/double-diffractive components
- Channel: opposite charge W->ev, W->μ v

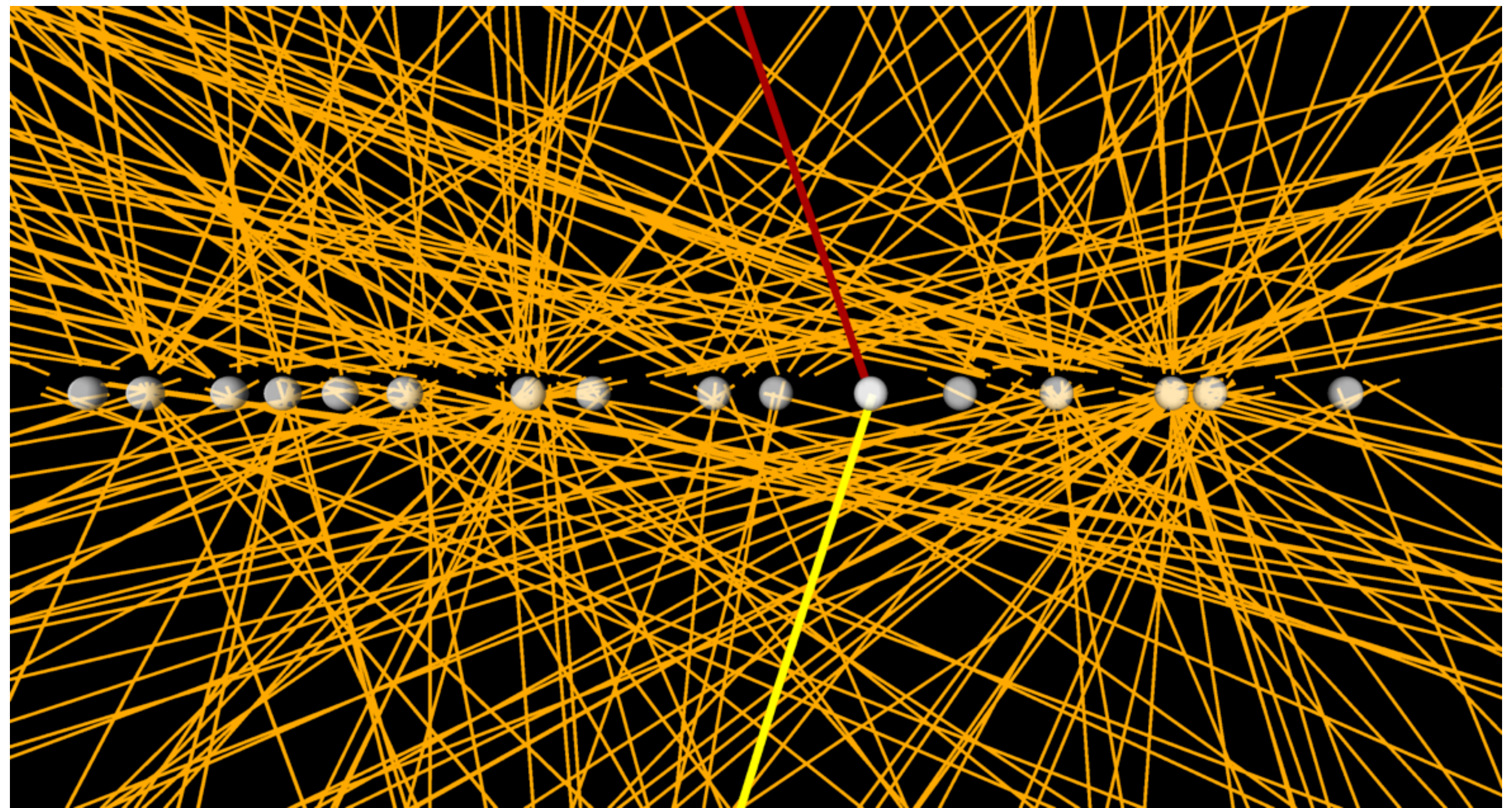
$$\sigma_{\text{meas}} = 3.13 \pm 0.31\,(\text{stat.}) \pm 0.28\,(\text{syst.})\,\text{fb}$$

- In agreement with predictions (MG_aMC@NLO+Py8) once survival factors (0.65-0.82) for proton rescattering are included, consistent with survival factors measured in exclusive di-lepton production



Phys. Lett. B 816 (2021) 136190





Effective field theory

- **EFT**: allows to systematically study impact on BSM physics at higher E

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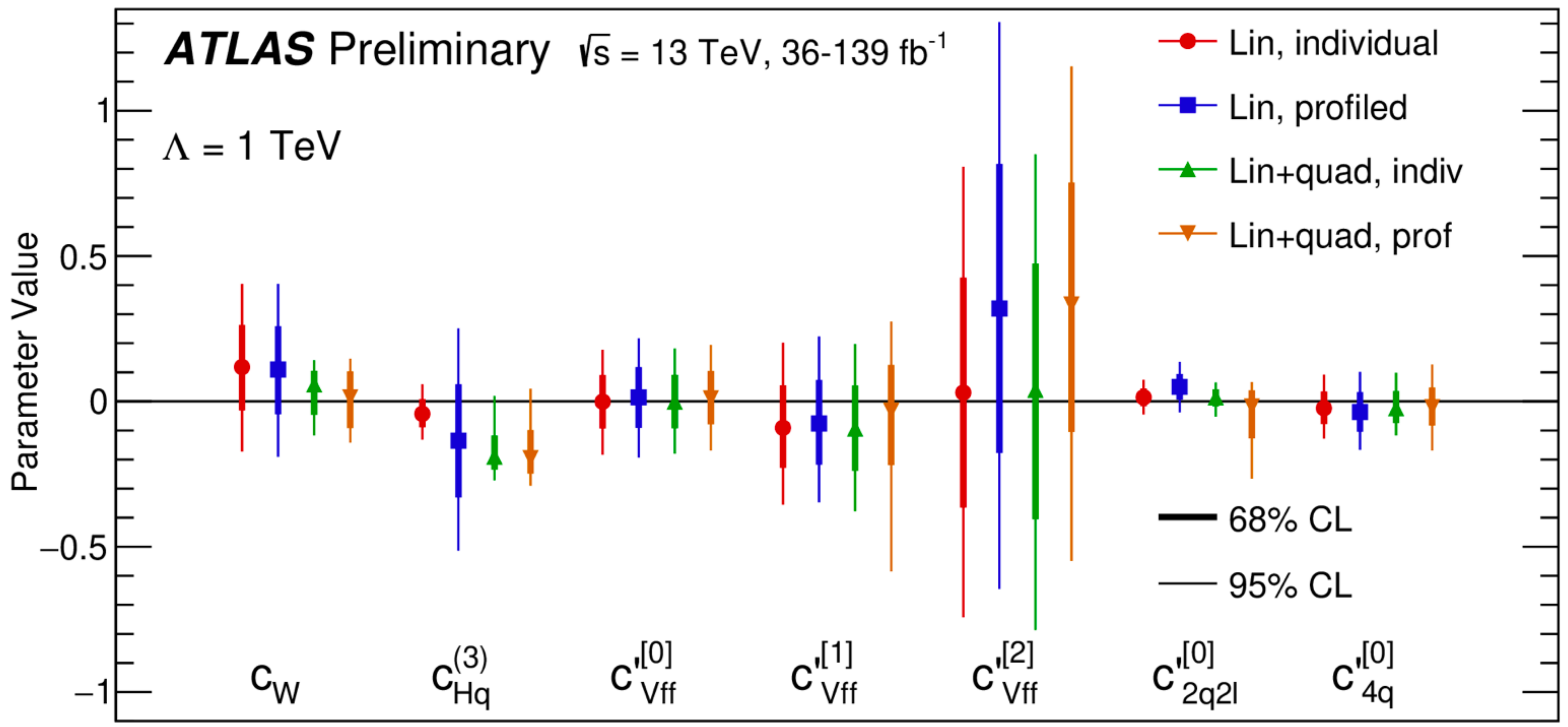
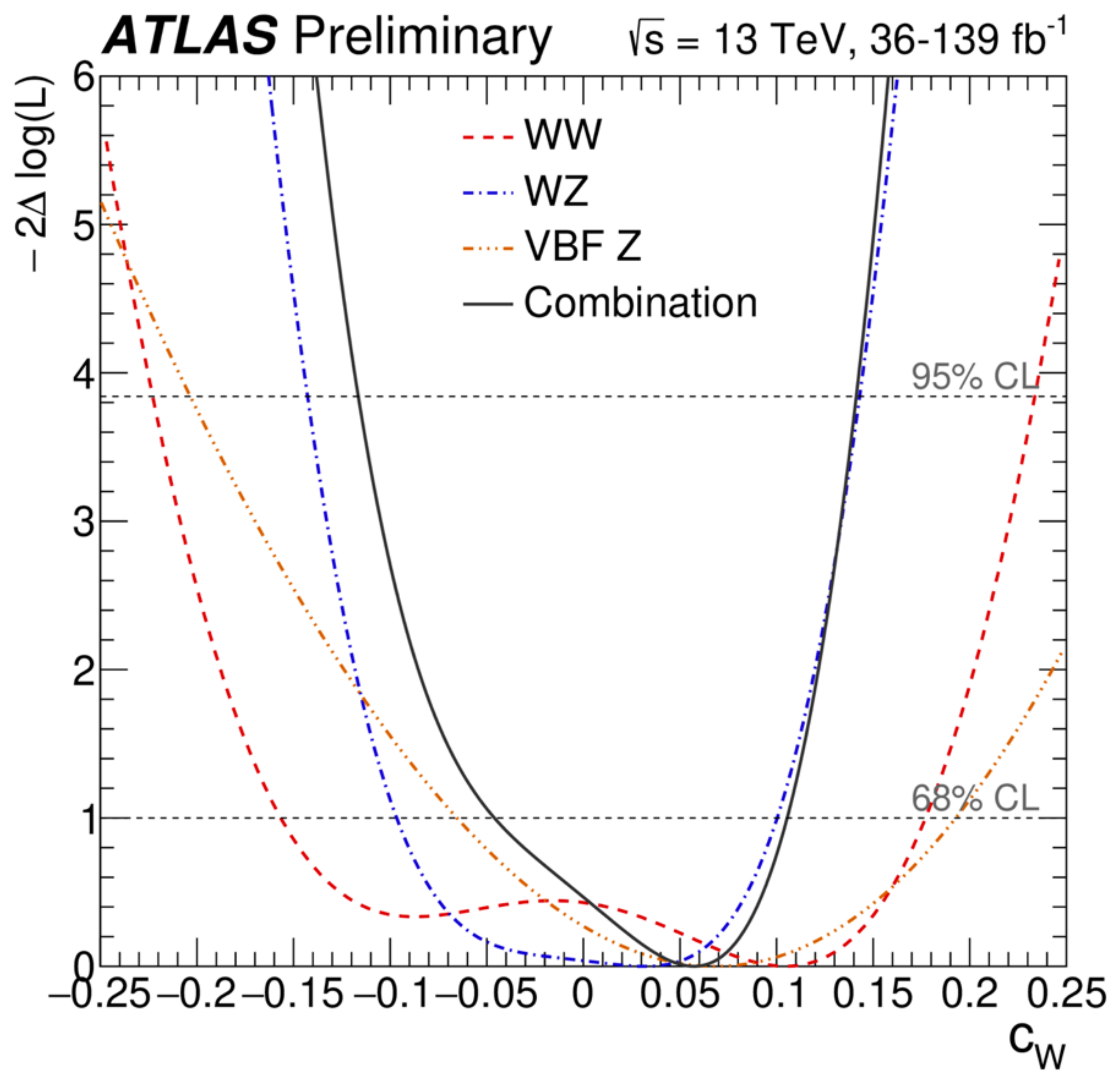
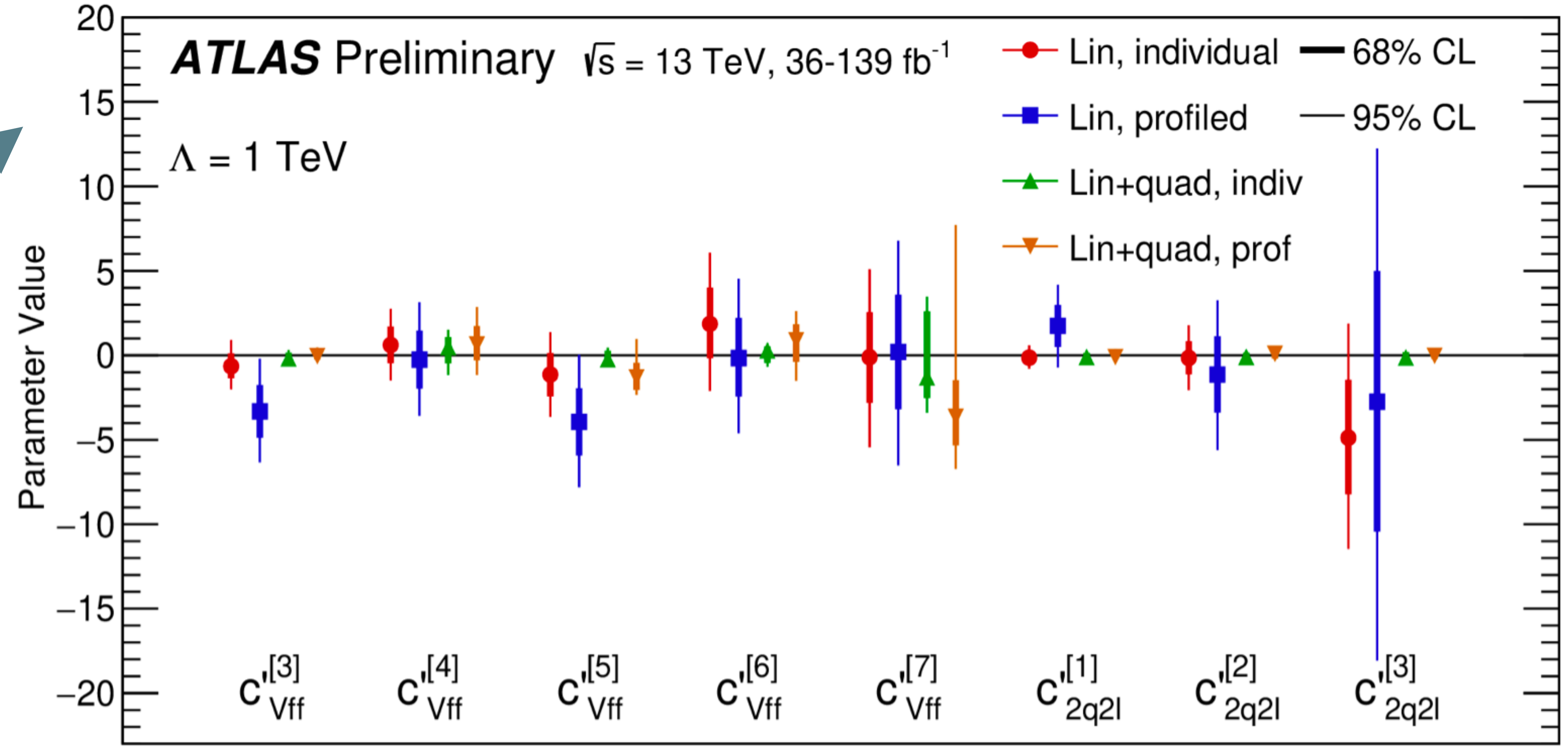
$$\mathcal{L}_{\mathrm{EFT}} = \mathcal{L}_{\mathrm{SM}} + \sum_i \frac{c_i^{(6)}}{\Lambda^2}\mathcal{O}_i^{(6)} + \sum_i \frac{c_i^{(8)}}{\Lambda^4}\mathcal{O}_i^{(8)} + \ldots$$

- Study here is a step toward global EFT fits
- **Input**: 1 differential cross-section for each of WW, WZ, 4-lepton (Z/ZZ*/ZZ), and VBF Z analyses
- **Output**: constrain operators affecting W/Z self-couplings, W/Z couplings to fermions, 4-fermion couplings





Coefficients of all 15 eigenvectors consistent with SM within 2σ



Top quark: mass

- Run 2: ~1.2 x 10^8 $t\bar{t}$ produced
- Top mass: key SM parameter
- m_{Top} from reconstructed final state, very precise but suffers from hadronization uncertainties $O(\Lambda_{QCD})$
- Rigorous study of relation between mass from Powheg-Pythia MC-template and MSR mass, fitting fragmentation parameters from data:

$$m_t^{MC} = m_t^{MSR}(1\text{ GeV}) + 80^{+350}_{-410}\text{ MeV},$$

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- Measurement of m_{Top} from cross-sections: closer to theoretical definition but larger uncertainty

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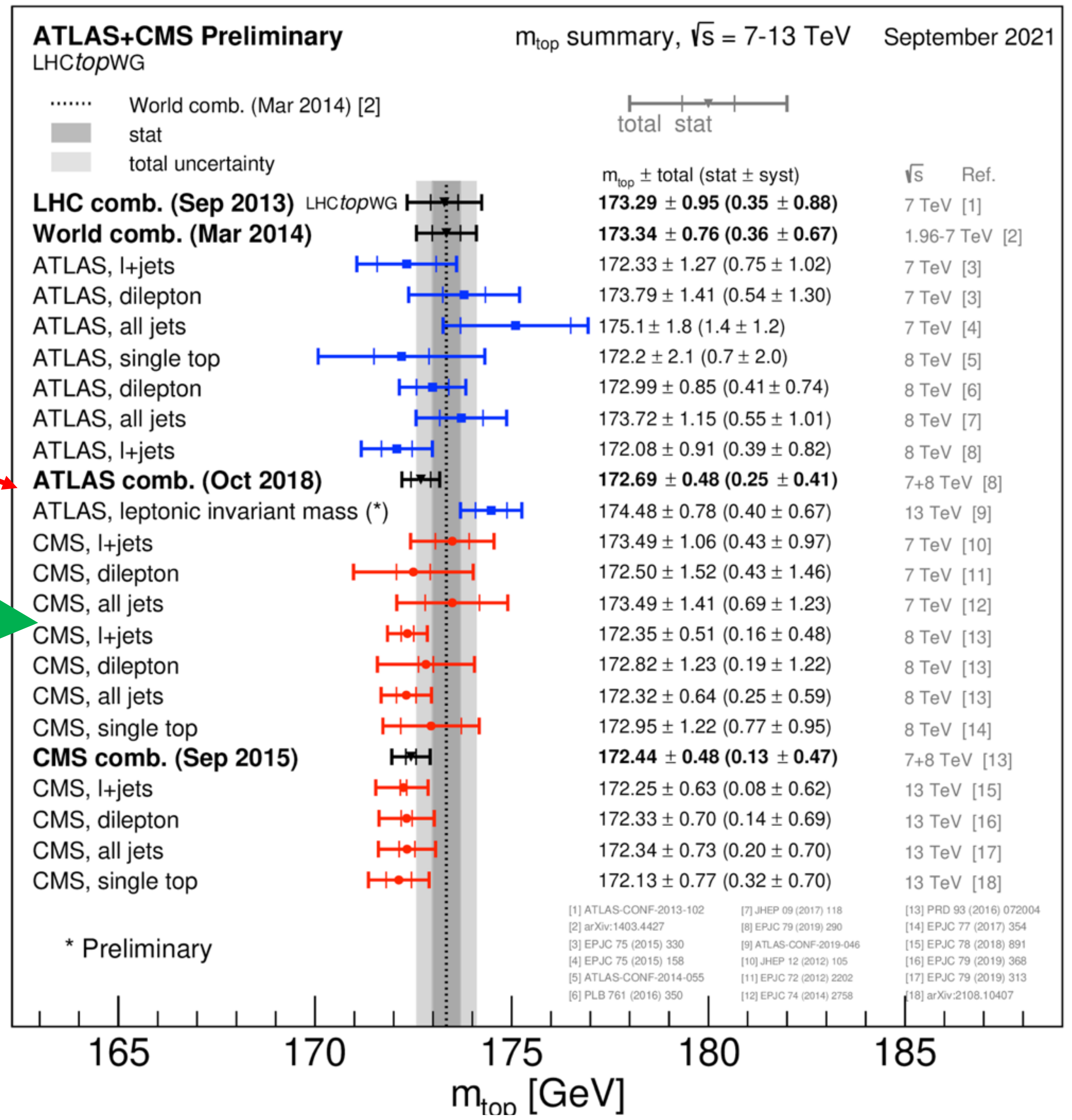
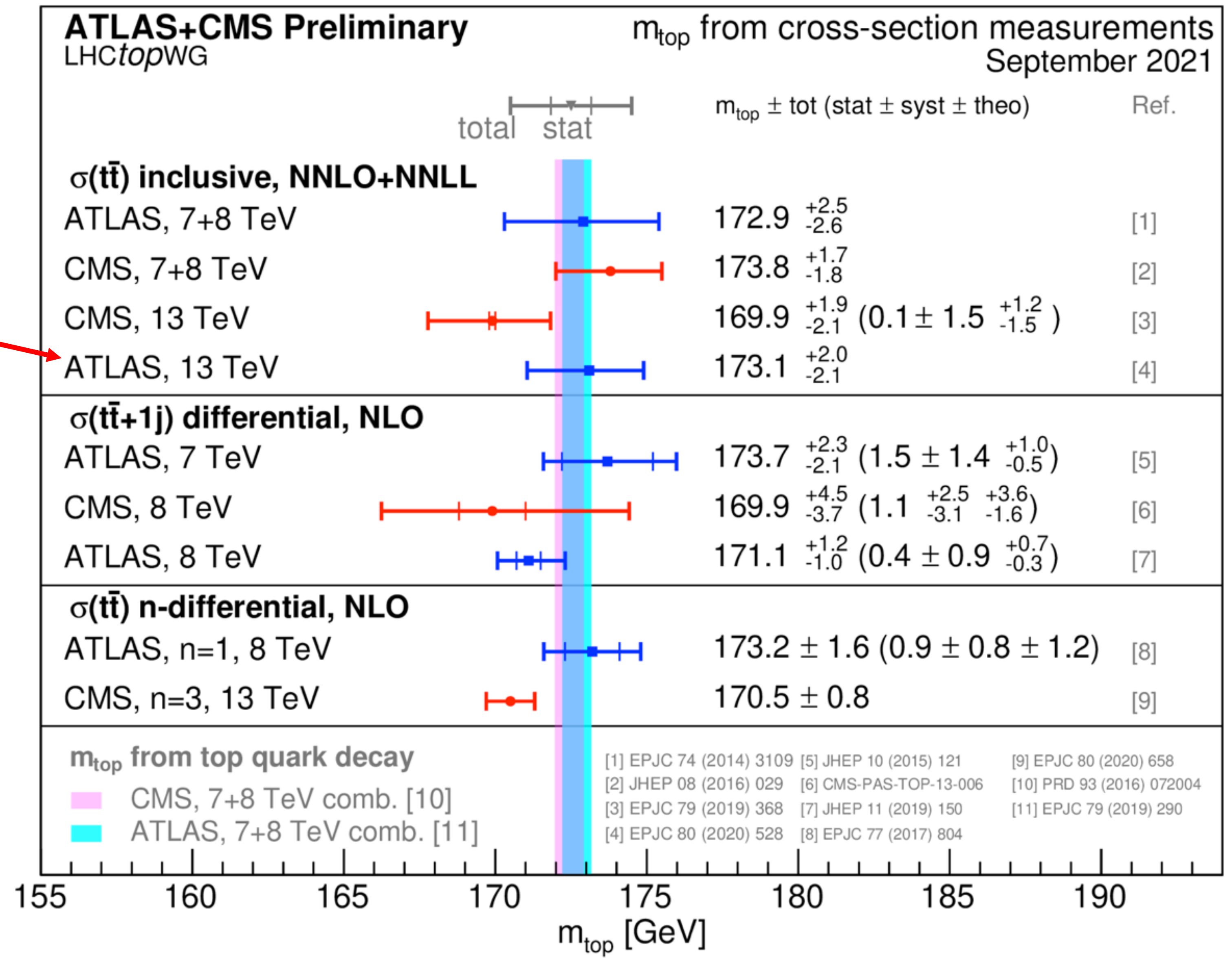
Run2



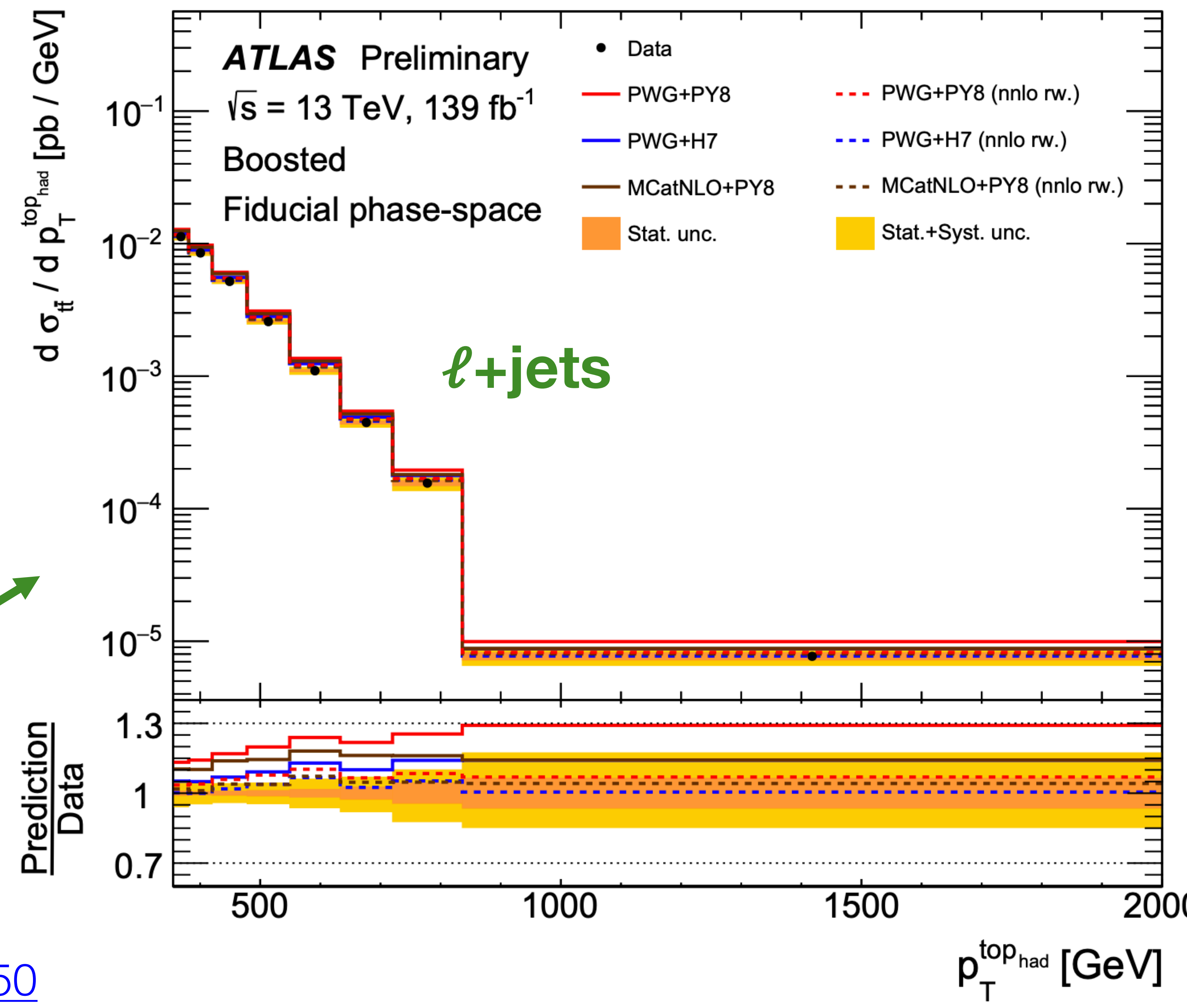
Run2

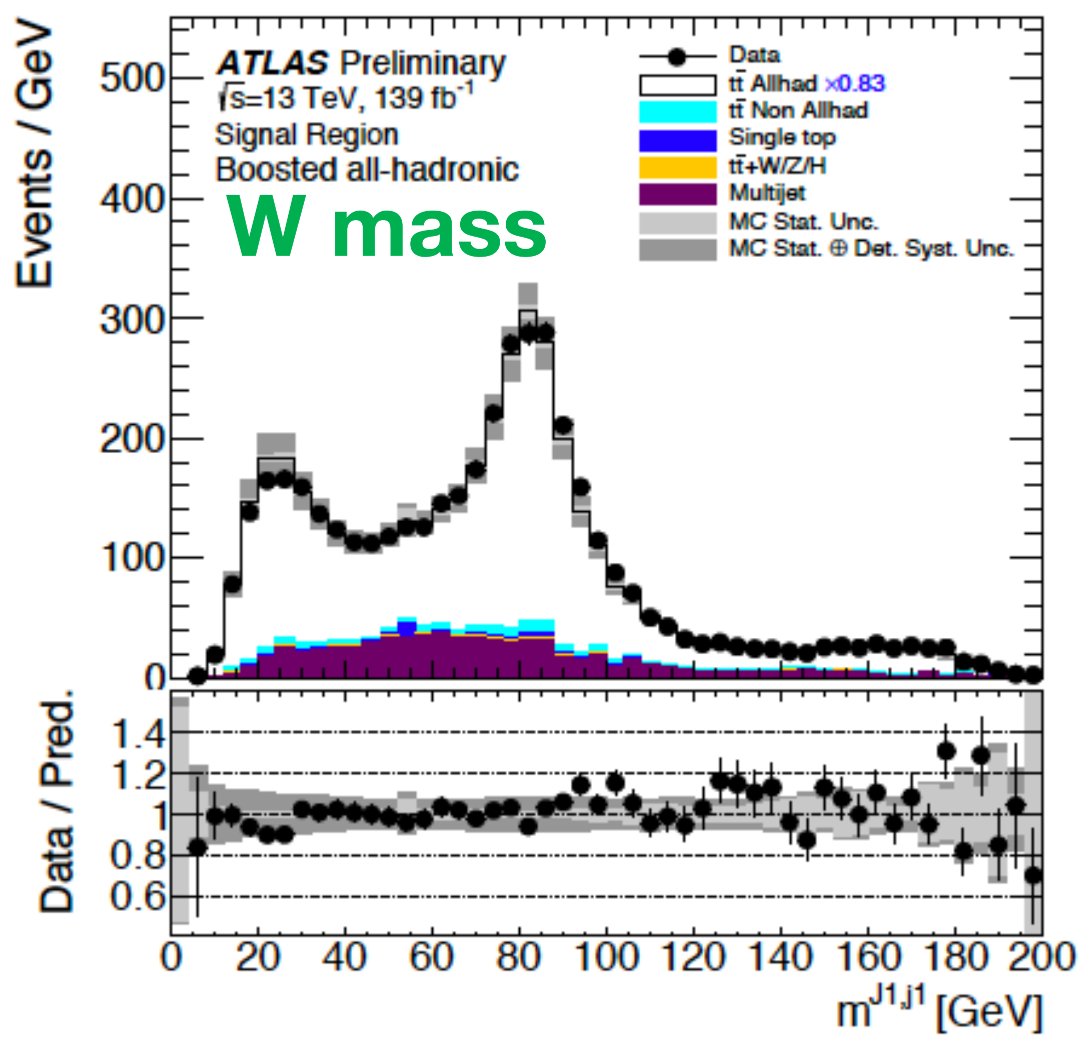


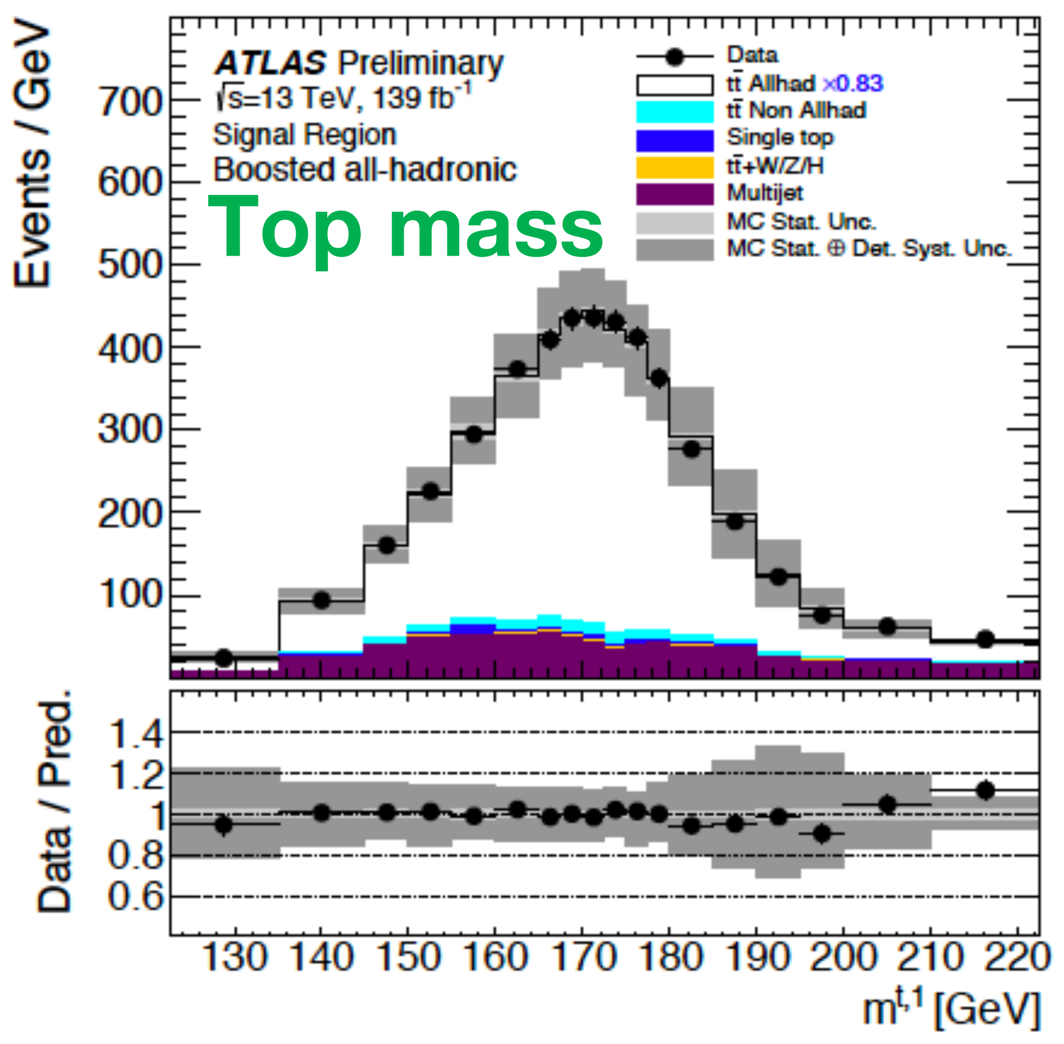
Boosted top-quark production

- Test SM at high p_T^{top}, where deviations expected from BSM
- SM predictions at NNLO QCD + NLO EW
  - ℓ+jets channel: $t\bar{t} \rightarrow WbWb \rightarrow \ell\nu b\ qq'b$
  - All hadronic channel: $t\bar{t} \rightarrow WbWb \rightarrow qq'b\ qq'b$
- Reconstruct hadronic top as reclustered R=1.0 anti-kt jet
- Energy scale constraint from top (and W) mass
- p_T^{top} spectrum too hard for NLO generators but improves with NNLO calculation

ATLAS-CONF-2021-031







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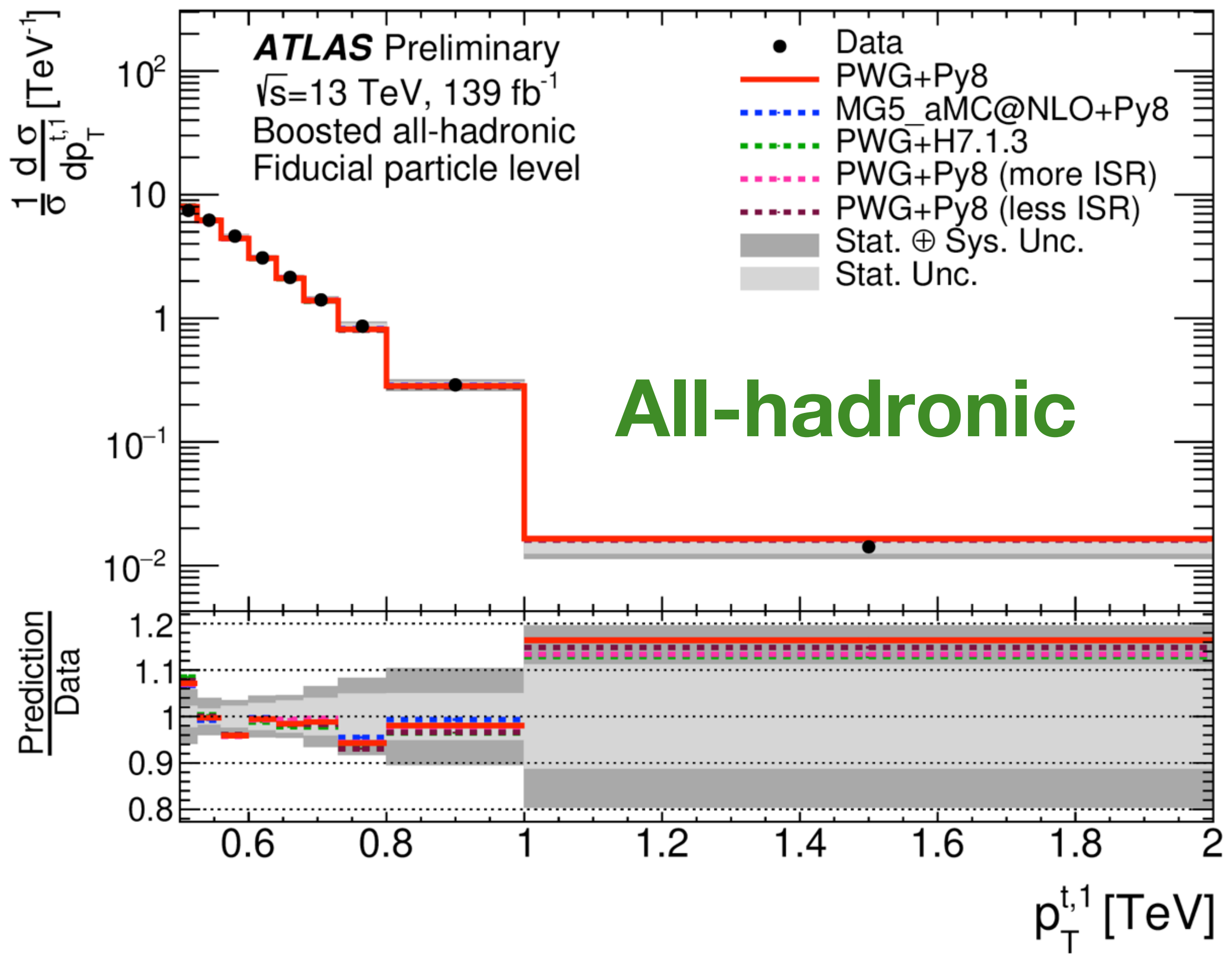

Single-top quark polarization

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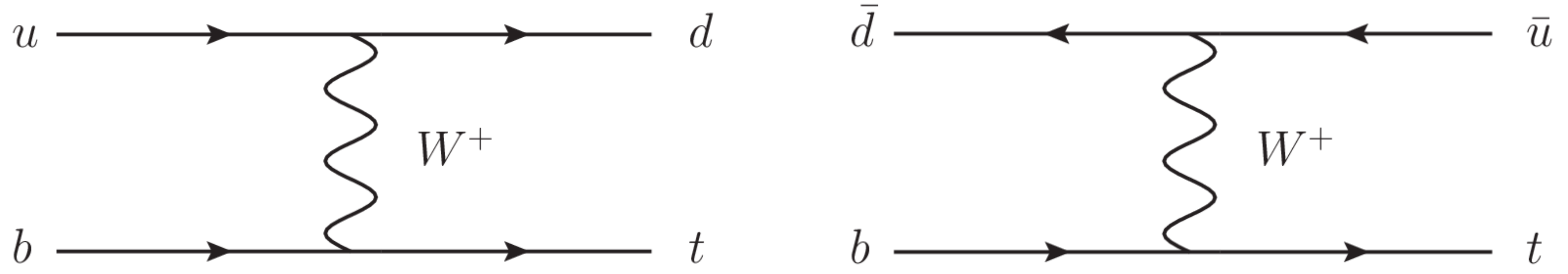
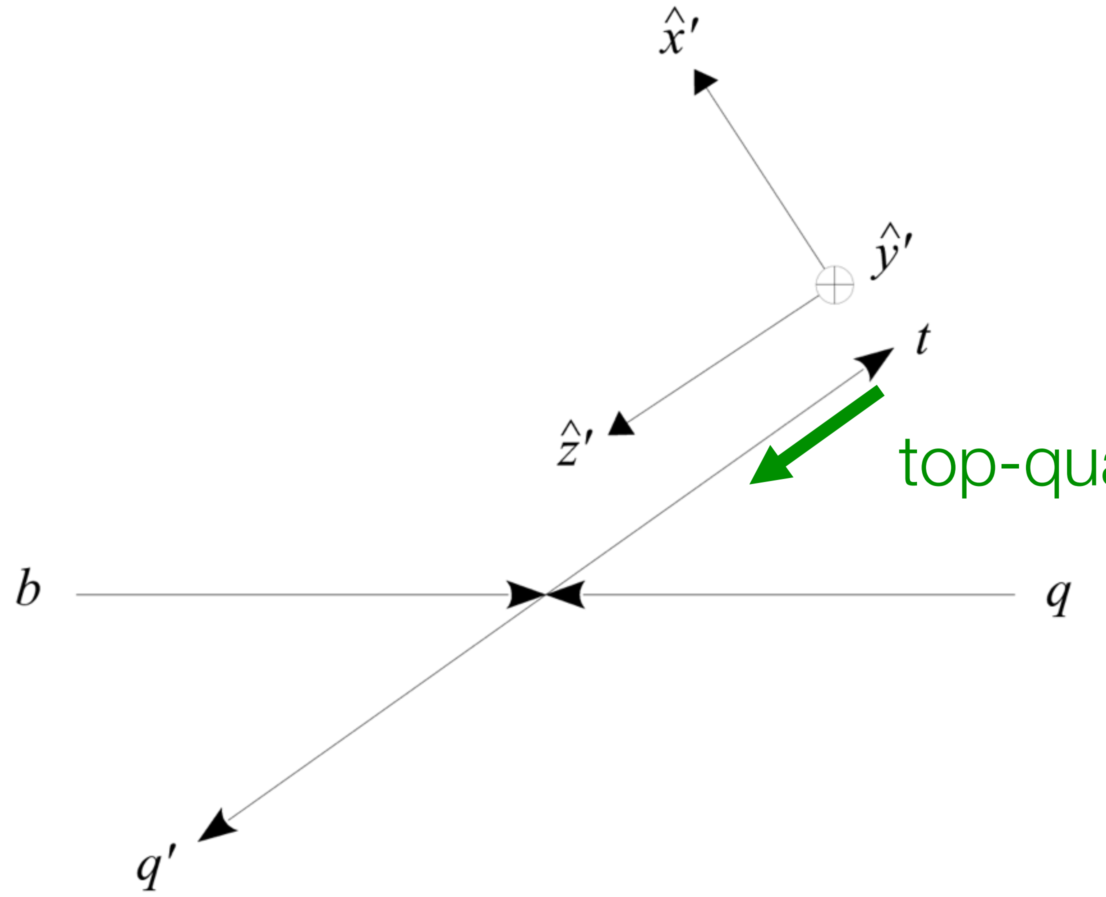
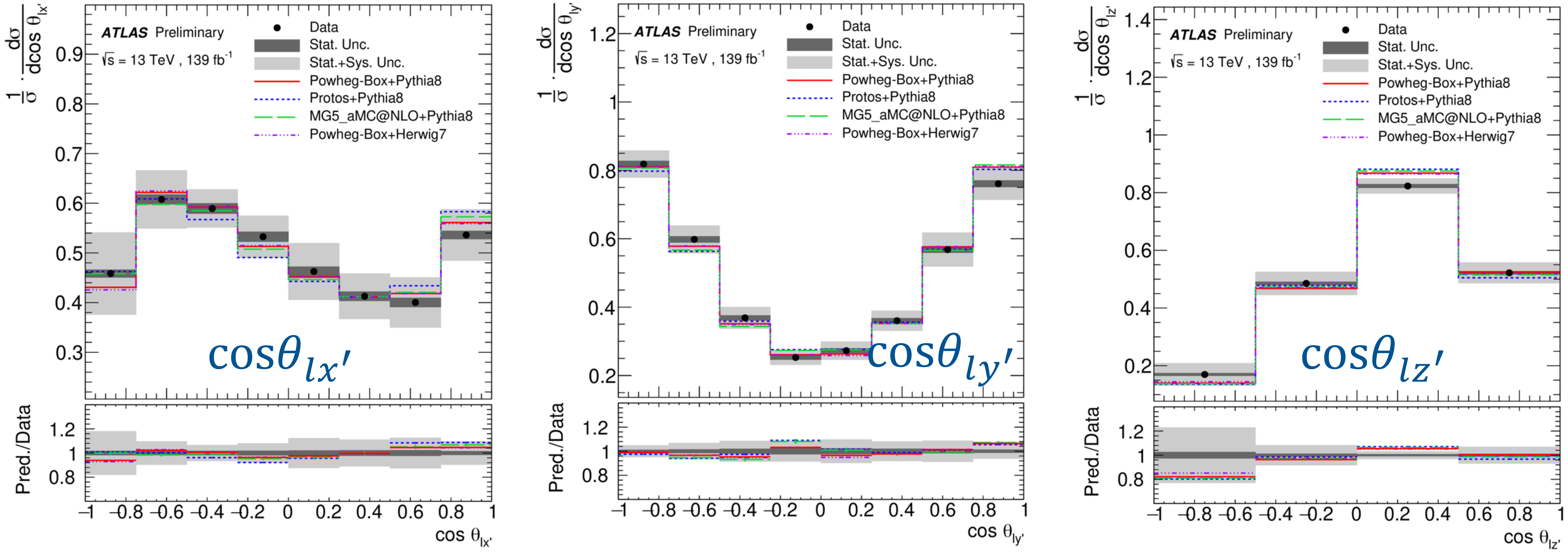
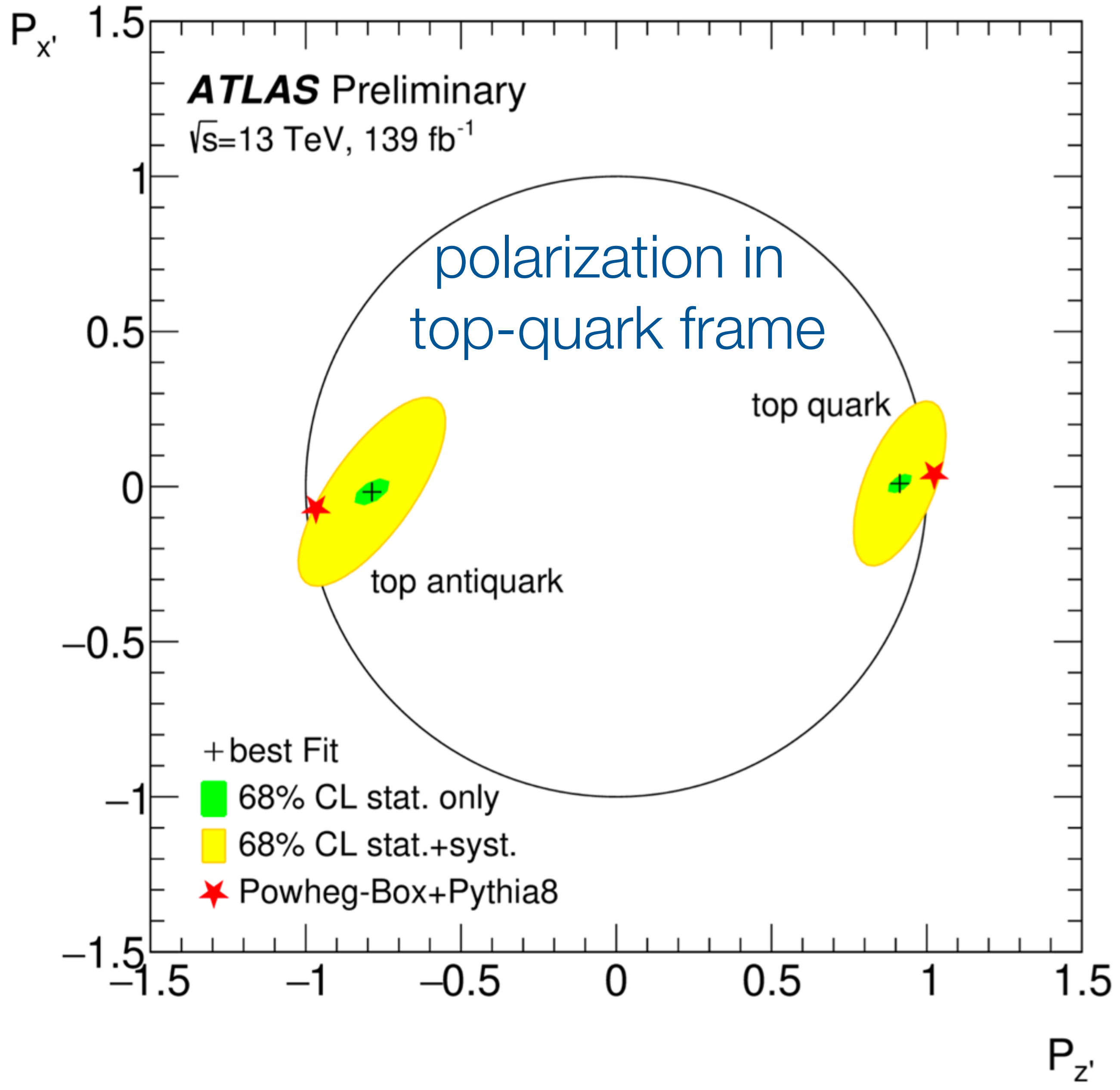
- t-channel dominates single top-quark production





- High polarization expected from V-A structure of CC weak interaction + test BSM impact on tWb vertex
- First measurement of polarization vector in 3-D via angular distributions of lepton (e or μ) from $t \to b\ell\nu$ decay





- Constraints placed on Re and Im parts of EFT operator $\mathcal{O}_{tW}$

Higgs Physics:

- Run 2: ~8 x 10^6 Higgs bosons produced
- Program: Categorize by decay channel and prod. mechanism, measure data/theory
- Most precise channels ggF: H ->$\gamma\gamma$, WW*, ZZ* with ~11-13% precision, many Run-2 analyses are ongoing

4-lepton mass spectrum

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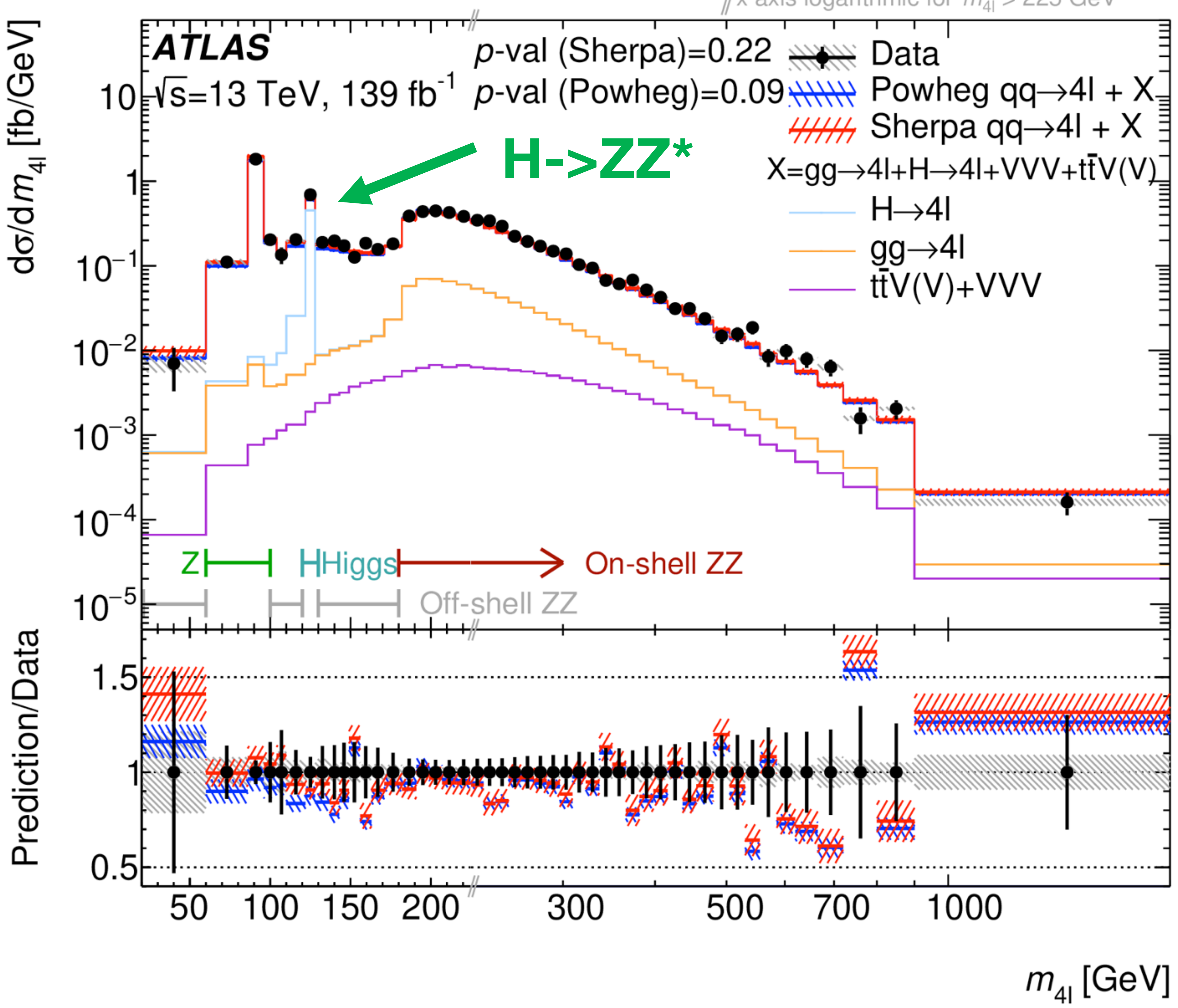

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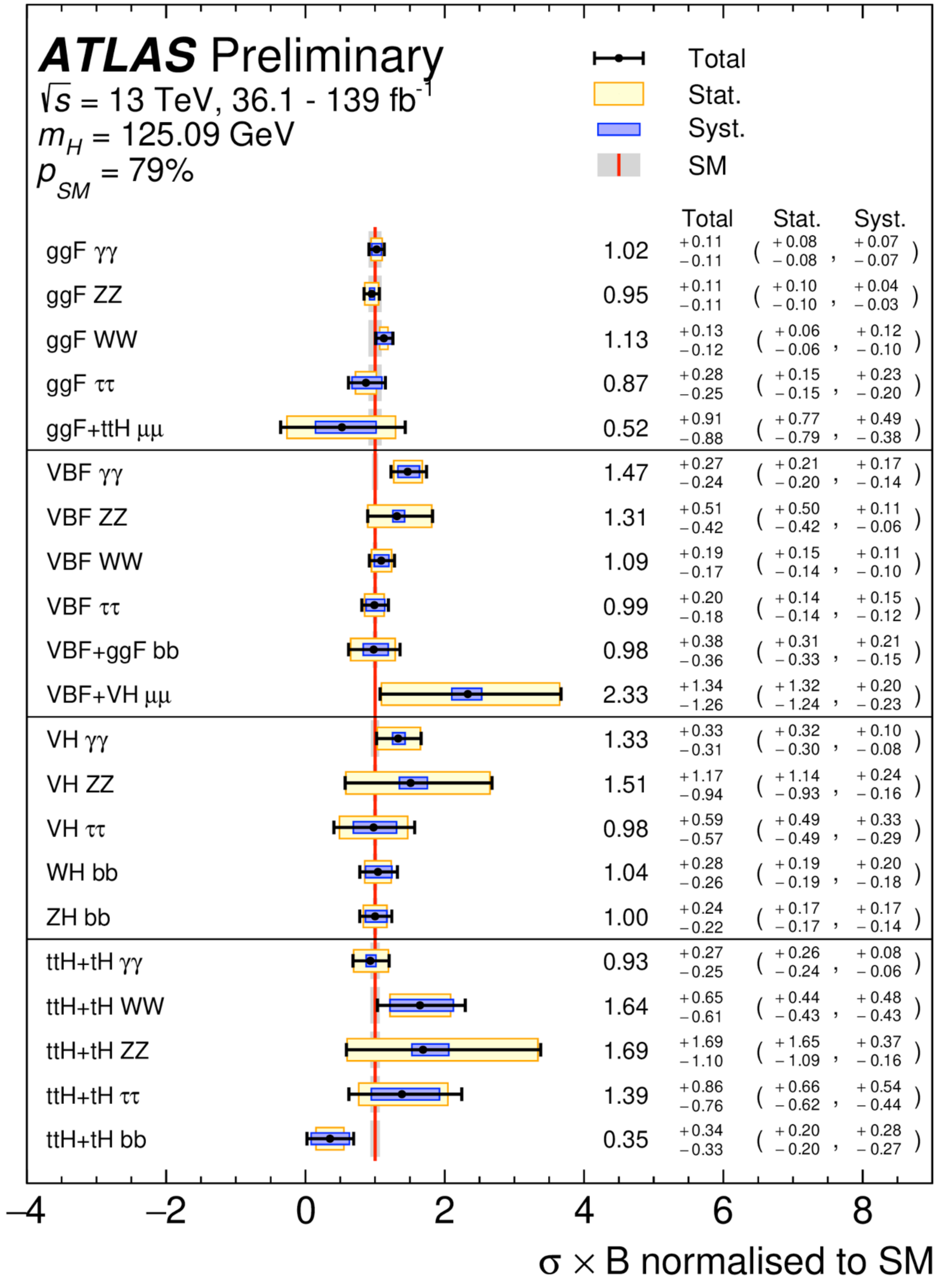
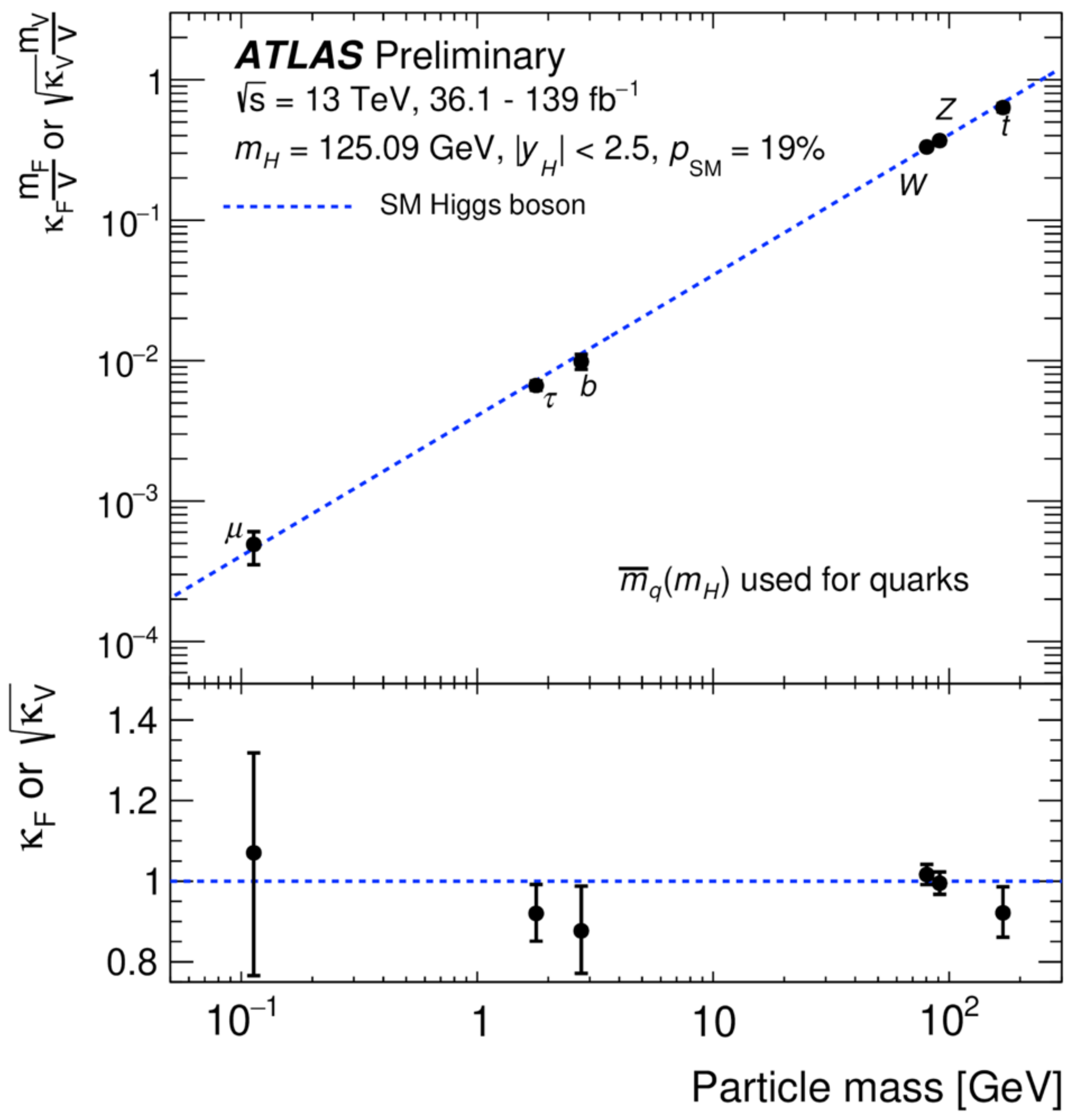


Higgs Physics:

- Run 2: ~8 x 10^6 Higgs bosons produced
- Program: Categorize by decay channel and prod mechanism, measure data/theory
- Most precise channels ggF: H ->$\gamma\gamma$, WW*, ZZ* with ~11-13% precision, many Run-2 analyses are ongoing
- Interpretation with fermion / bosons coupling modifiers



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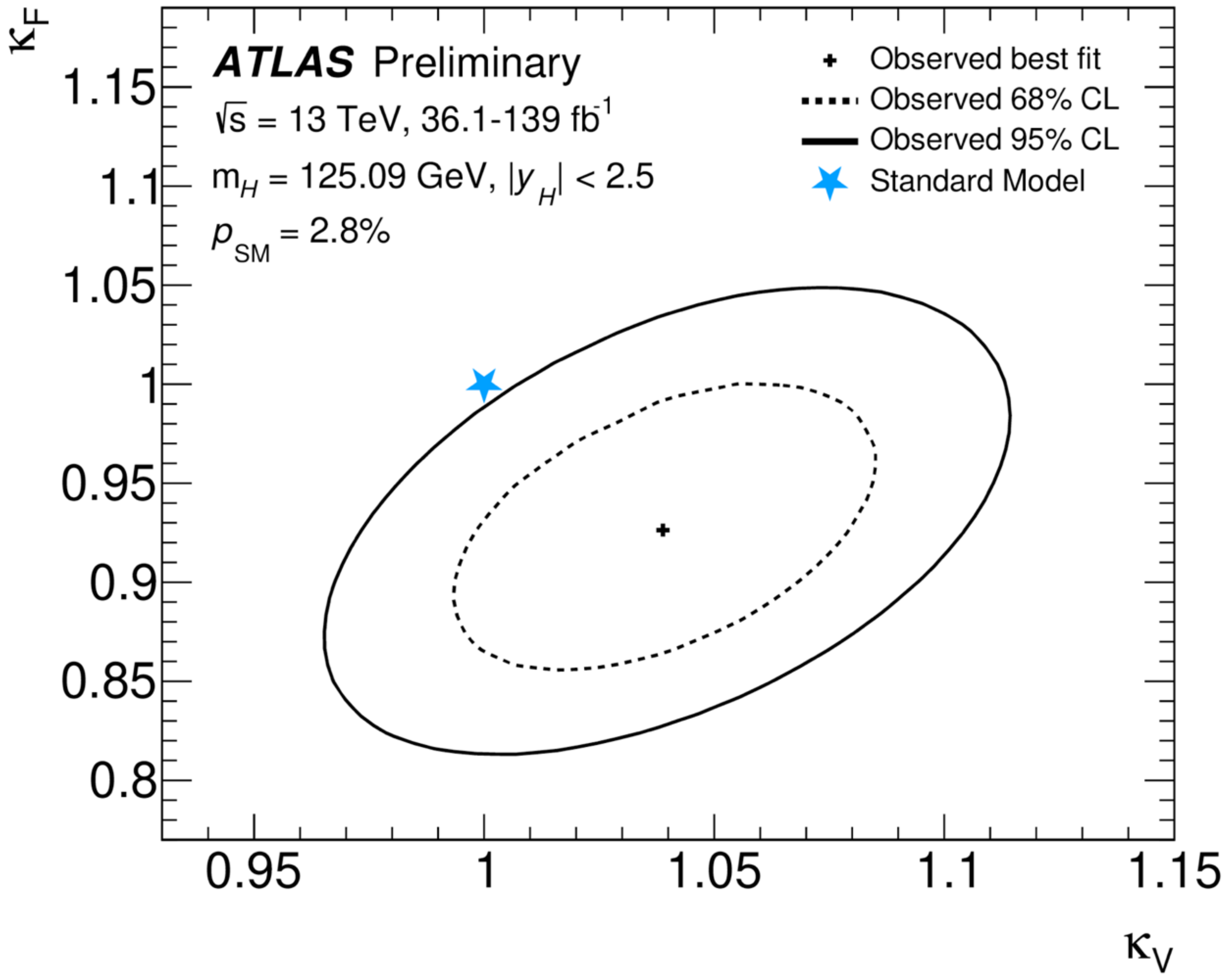

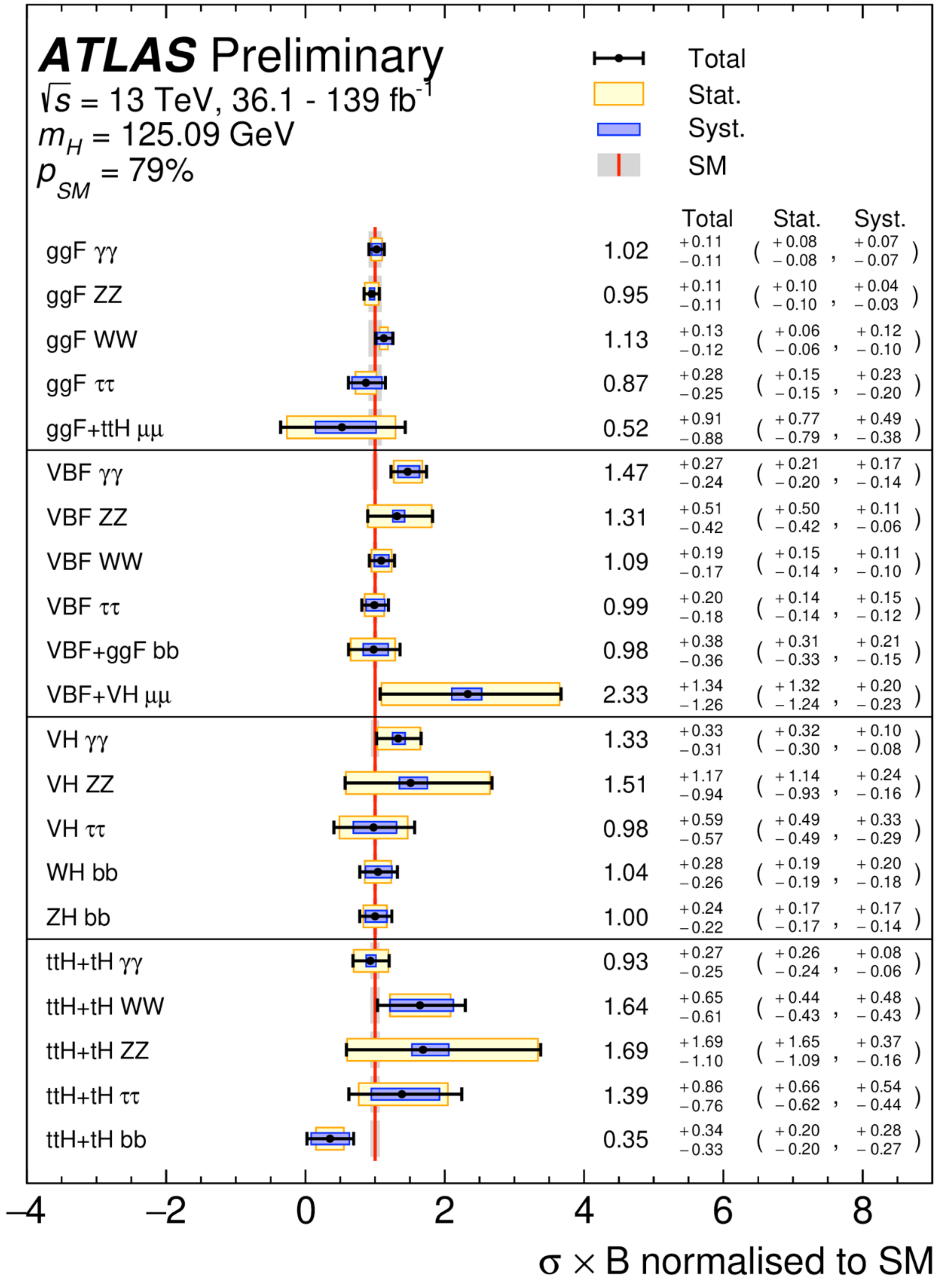

Higgs couplings: τ leptons

- $\mathcal{B}(H \to \tau\tau) = 6.3\%$ —> test **Yukawa interactions with leptons**
- Expt. challenge: 2-4 neutrinos in final state, poor mass resolution
- Multiple BDTs used to suppress $Z \to \tau\tau$ and $t\bar{t}$ background, and categorize event purity for VBF, VH and ttH mechanism
- Dominant $Z \to \tau\tau$ background from MC, controlled with $Z \to \ell\ell$ data via kinematic embedding procedure

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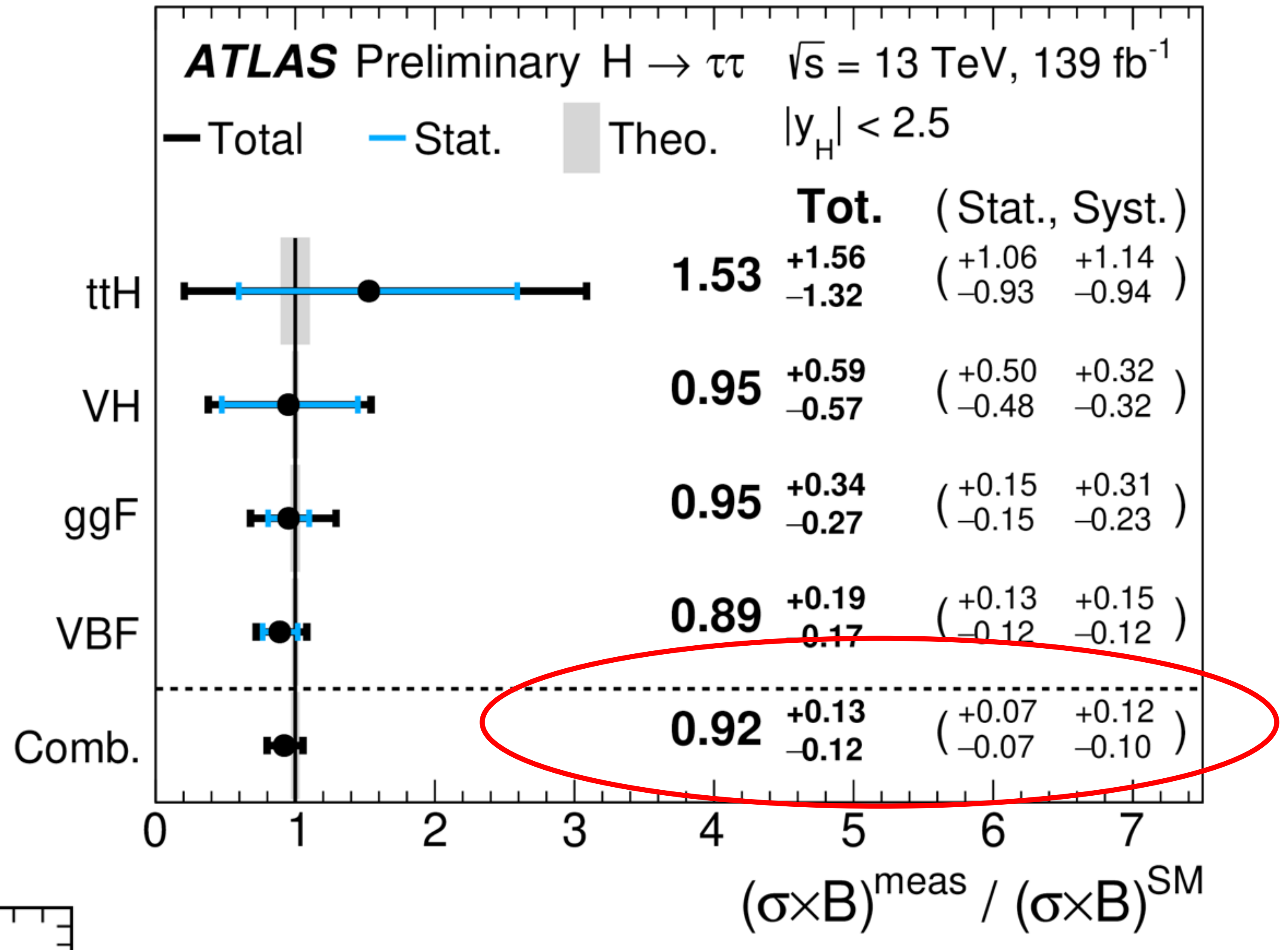
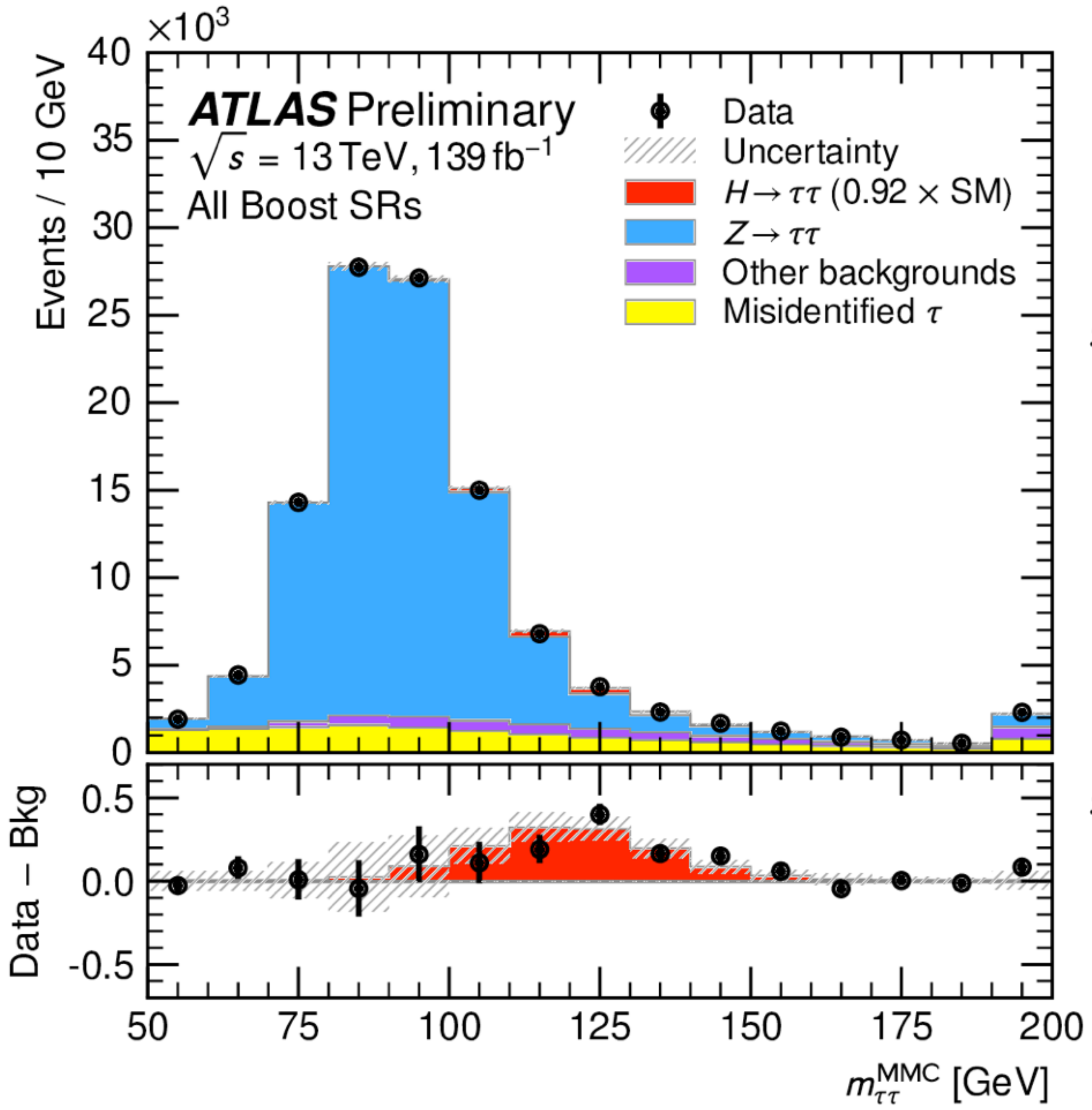
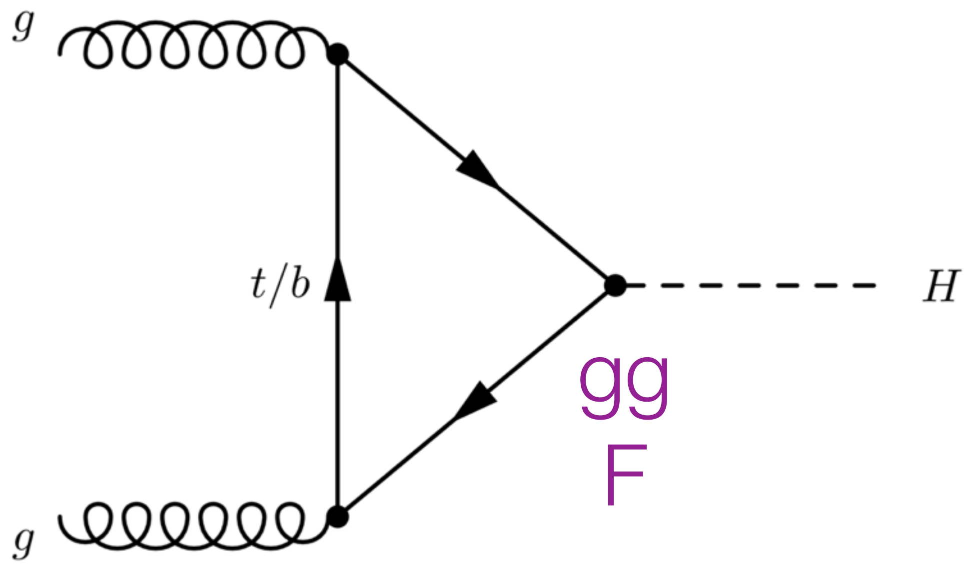
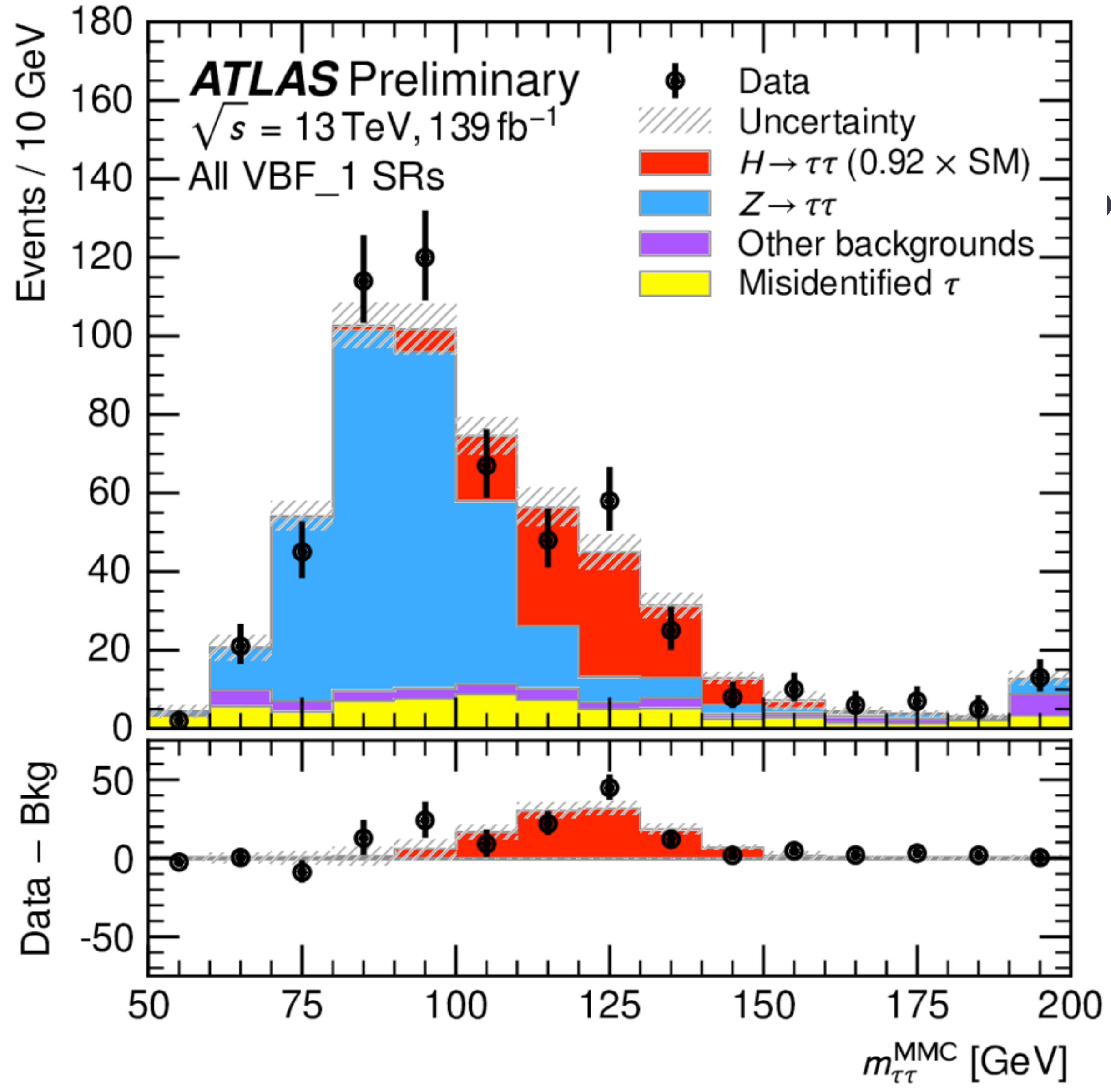


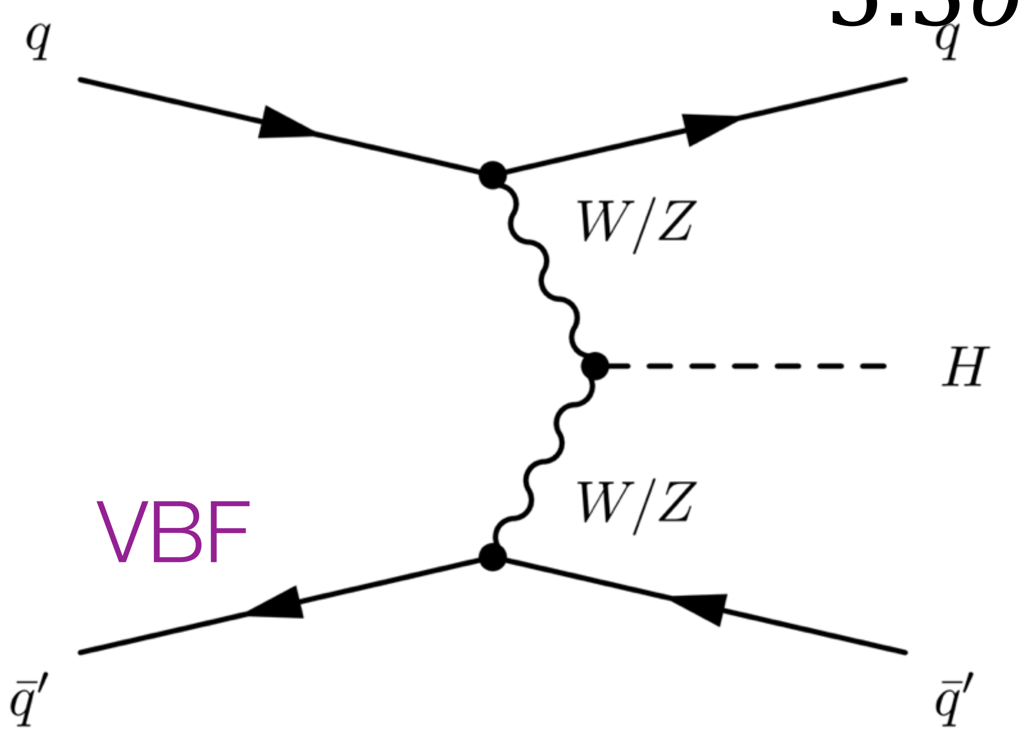


ggF significance 3.9σ



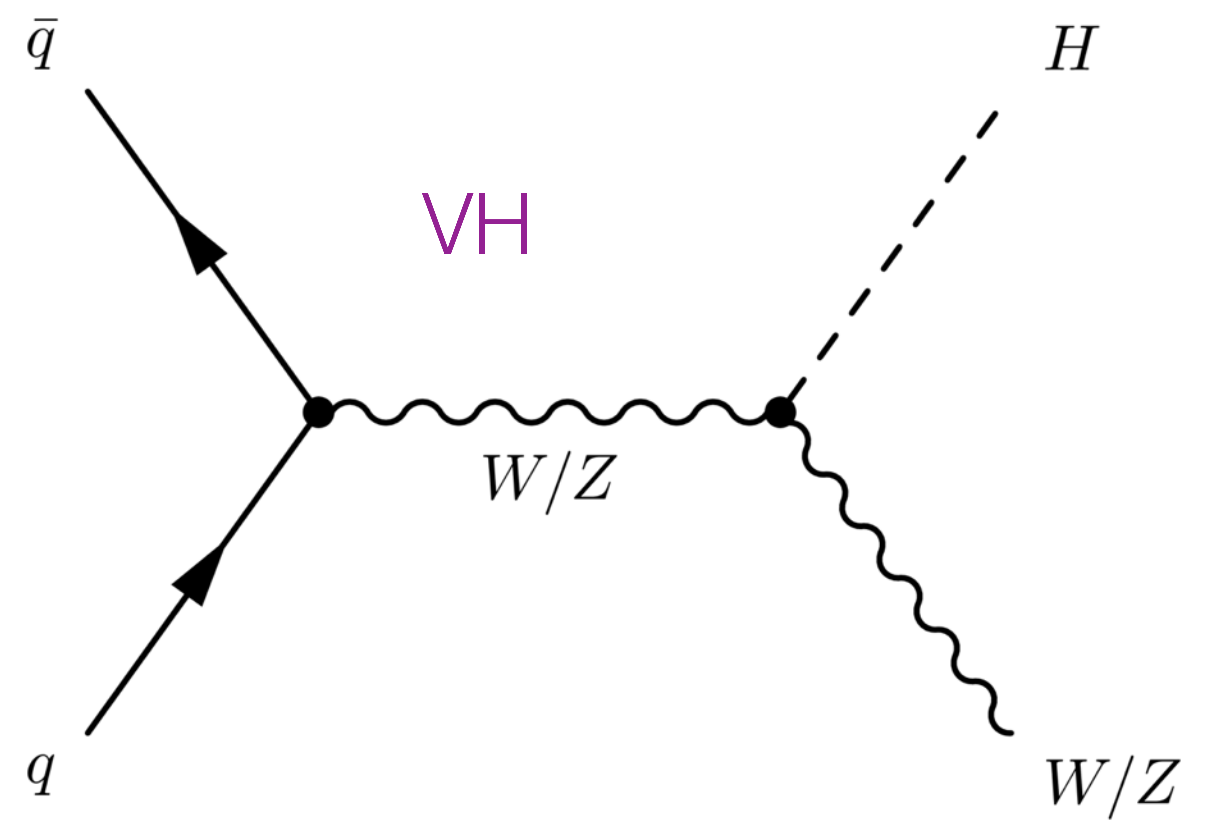


VBF significance 5.3σ



Higgs couplings to 2nd gen quarks

- Test of **Yukawa interactions w/ 2nd generation fermions**: evidence for leptons only
- **Search for H—> cc** in associated $V(\ell\ell, \ell\nu, \nu\nu)H$ production
- Dedicated charm tagging
- Results:



$$VH(\to cc) < 26\ \ (31)\ \sigma_{\text{SM}}\ \ \text{obs(exp)}$$

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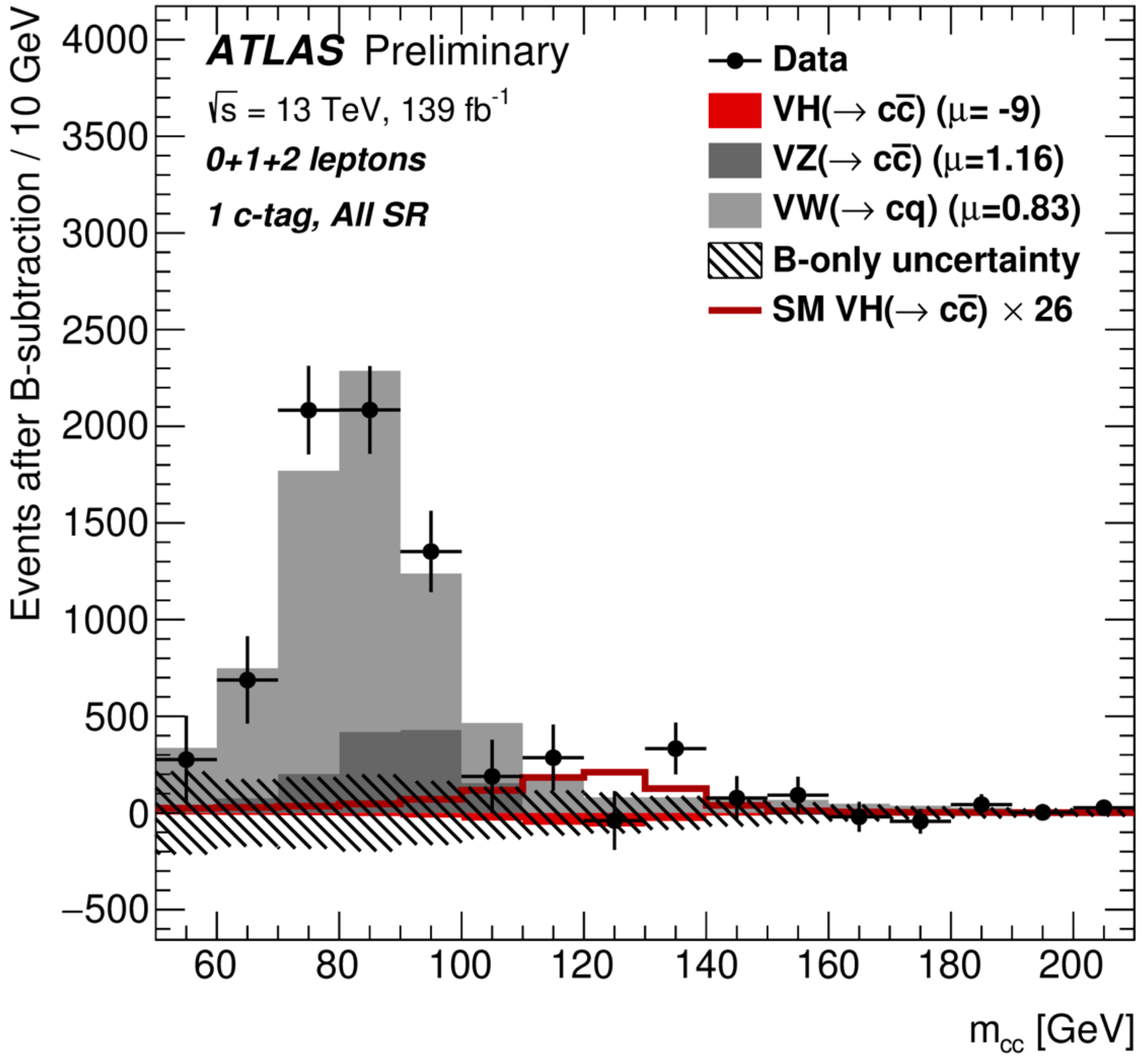
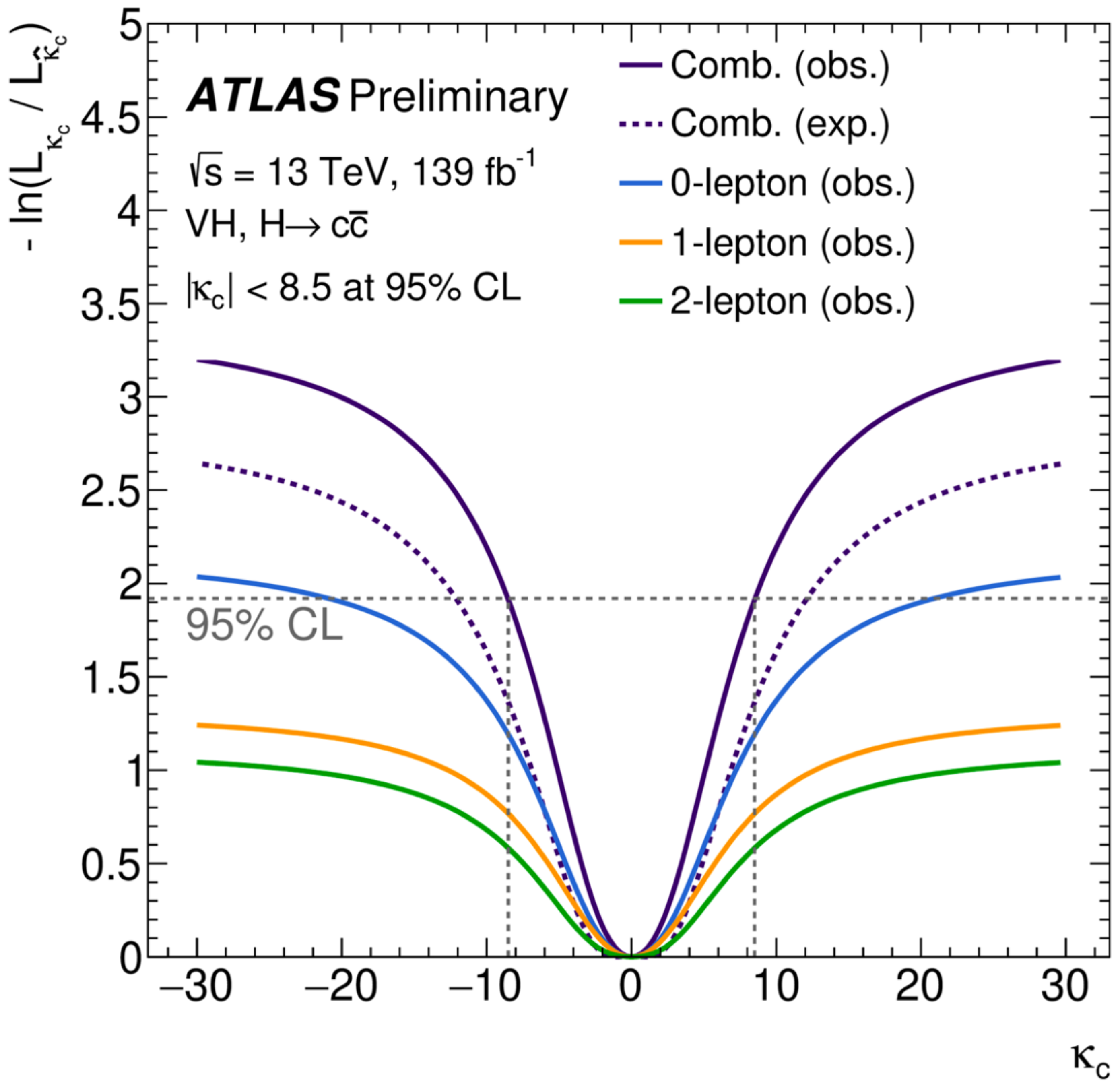




- Charm Yukawa modifier

$$|\kappa_c| < 8.5(12.4)\text{obs(exp)}$$

first direct constraint

Di-Higgs production

$$\mathcal{L}_{SM} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + i\bar{\psi}\not{D}\psi + \psi_i y_{ij}\psi_j\phi + \text{hc} + |D_\mu\phi|^2 - V(\phi)$$

- **Direct access to Higgs potential**
  - Last part of SM needing direct test
  - Small HH XS (ggF 31 fb @NNLO, VBF 1.7 fb @N3LO)
- HH —> bbbb (33%), bbττ (7.3%), bbγγ (0.3%)
- **HH —> bbττ channel**
  - Leptonic and hadronic taus

$$\sigma_{HH}/\sigma_{HH}^{SM} < 4.7(3.9)\text{obs(exp)}$$

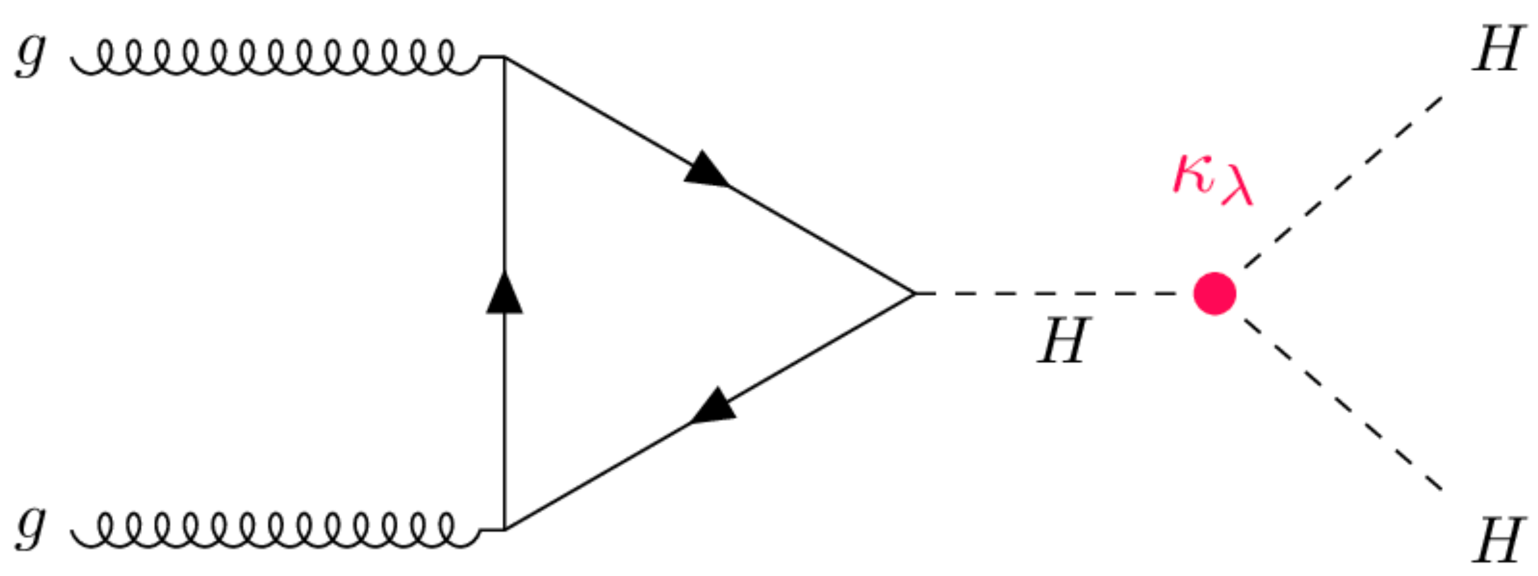
ATLAS-CONF-2021-030

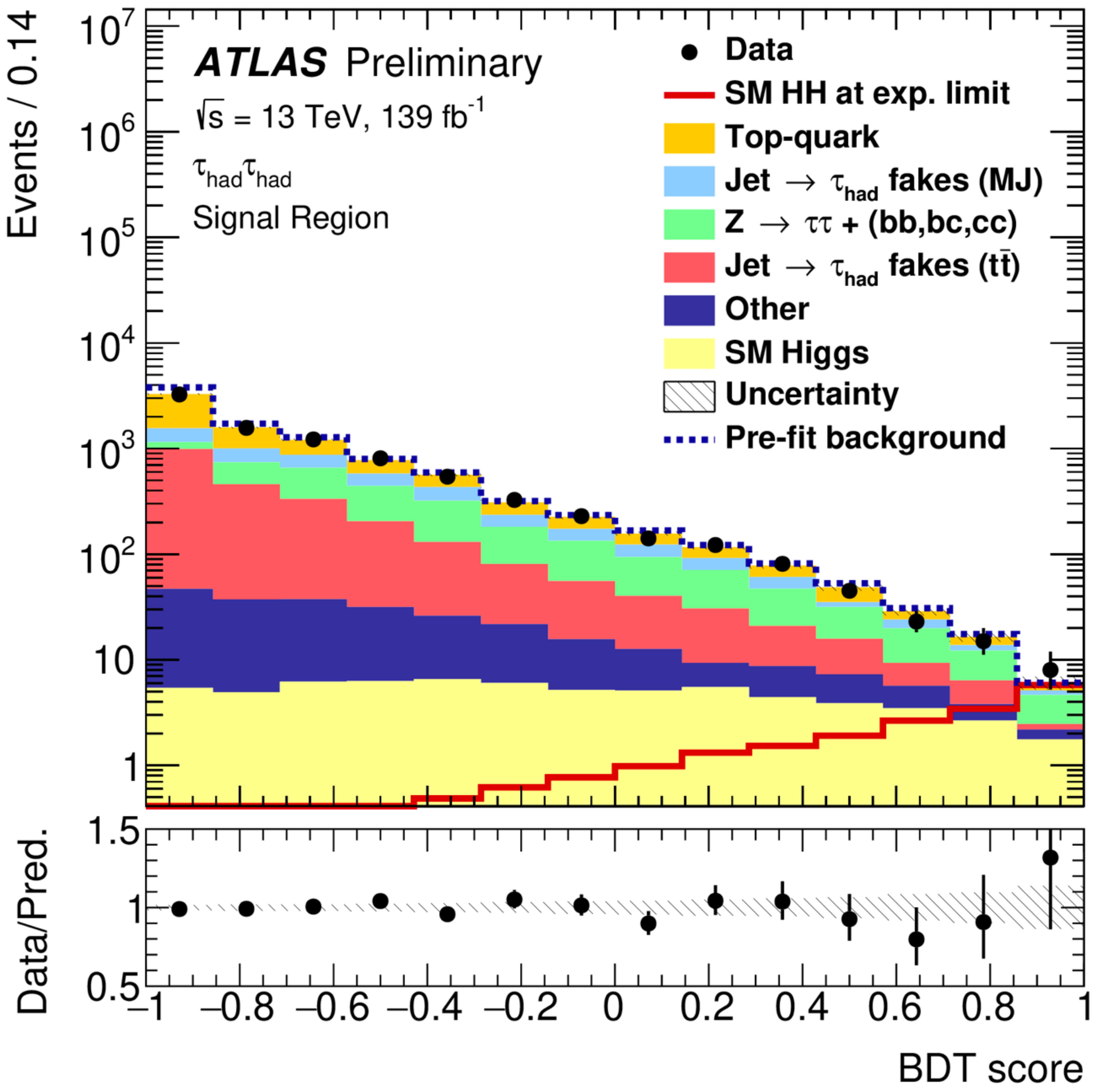
- **HH —> bbγγ**

$$\sigma_{HH}/\sigma_{HH}^{SM} < 4.1(5.5)\text{obs(exp)}$$

ATLAS-CONF-2021-016

factor of 4 -5 improvement over 36 fb^{-1} analysis

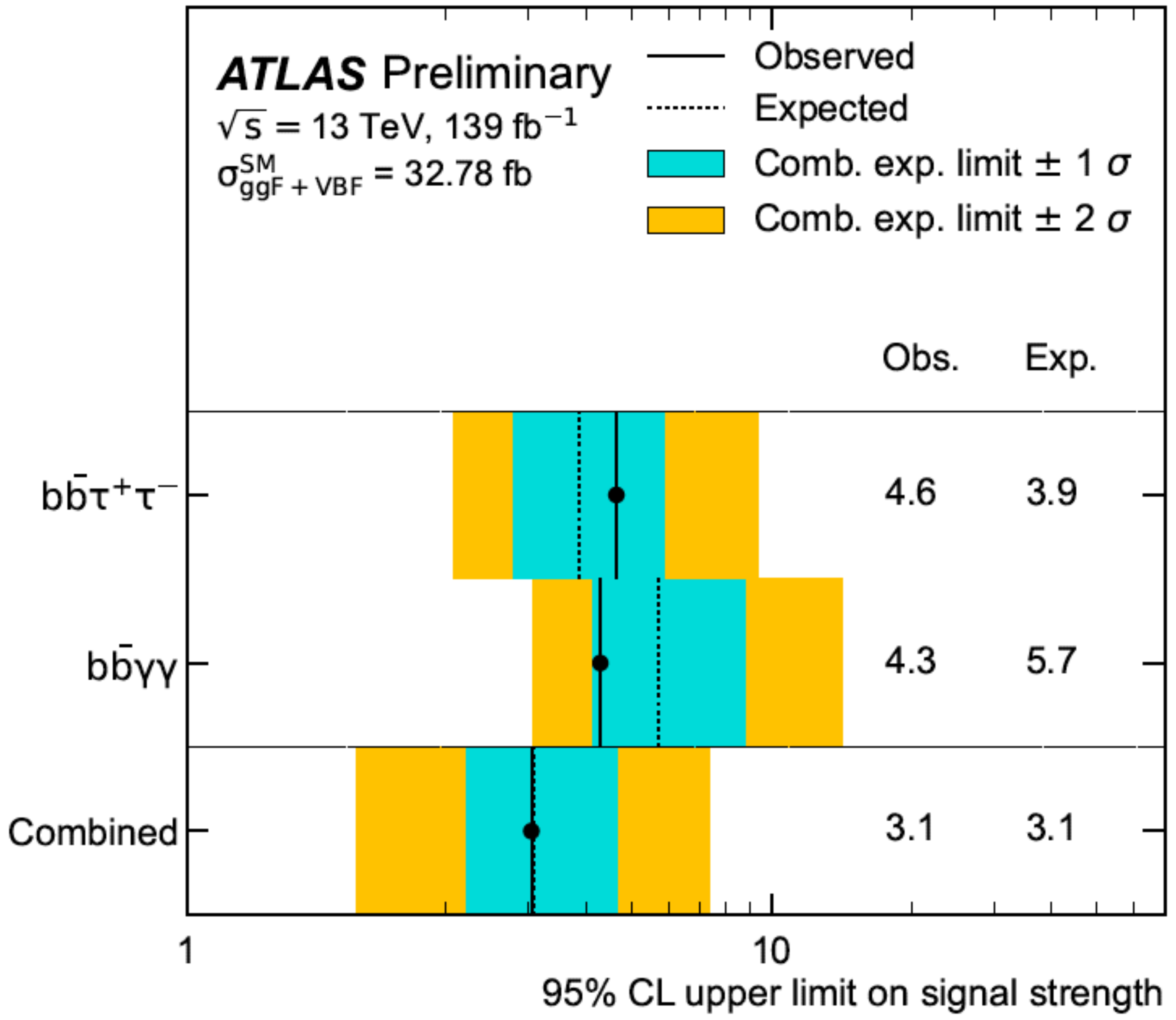


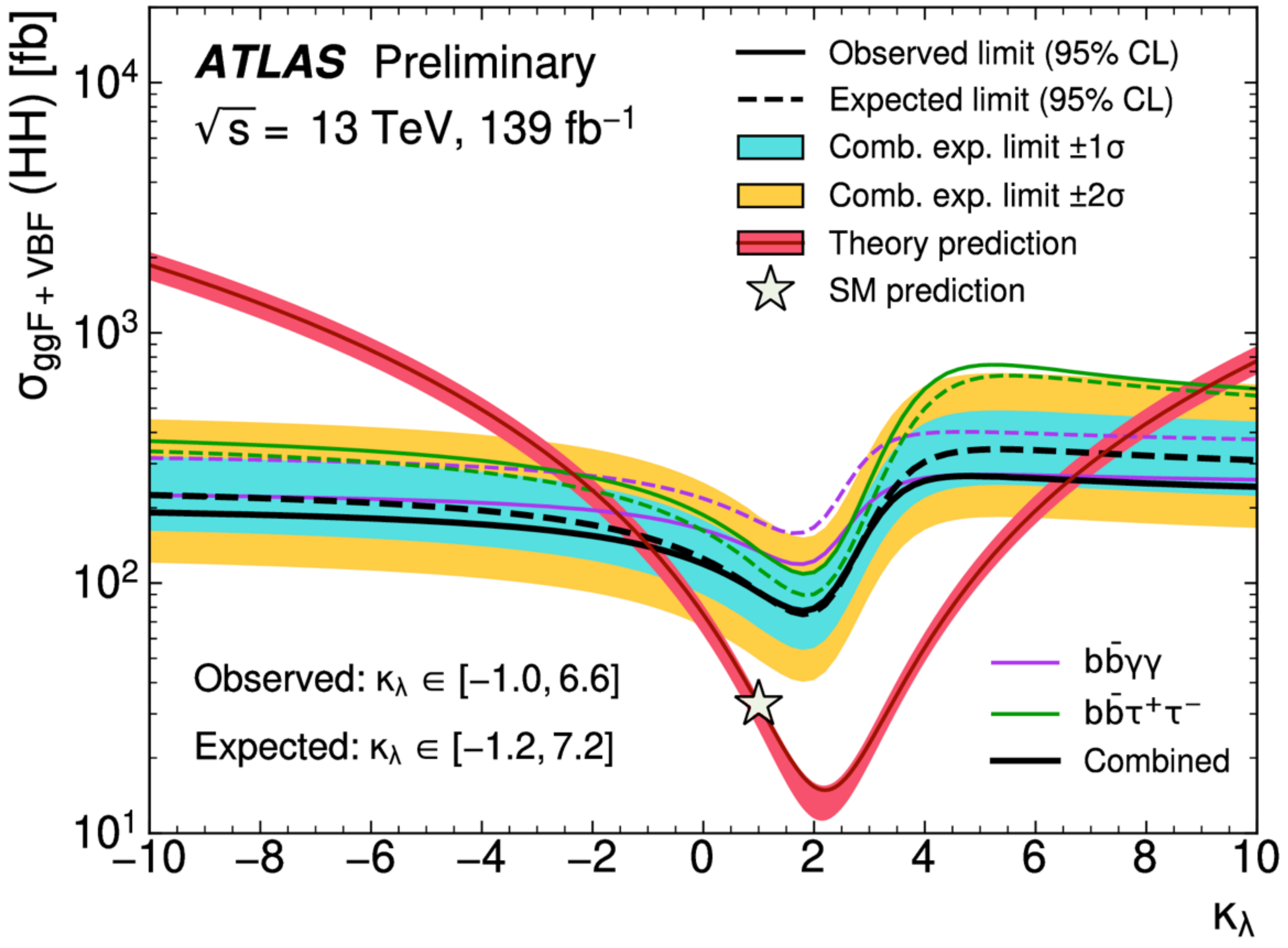


Di-Higgs production: combination

- **Combination of**
  - HH —> bbττ, bbγγ
  - Limit on signal strength <3.1
- **Limit on modifier k_λ**

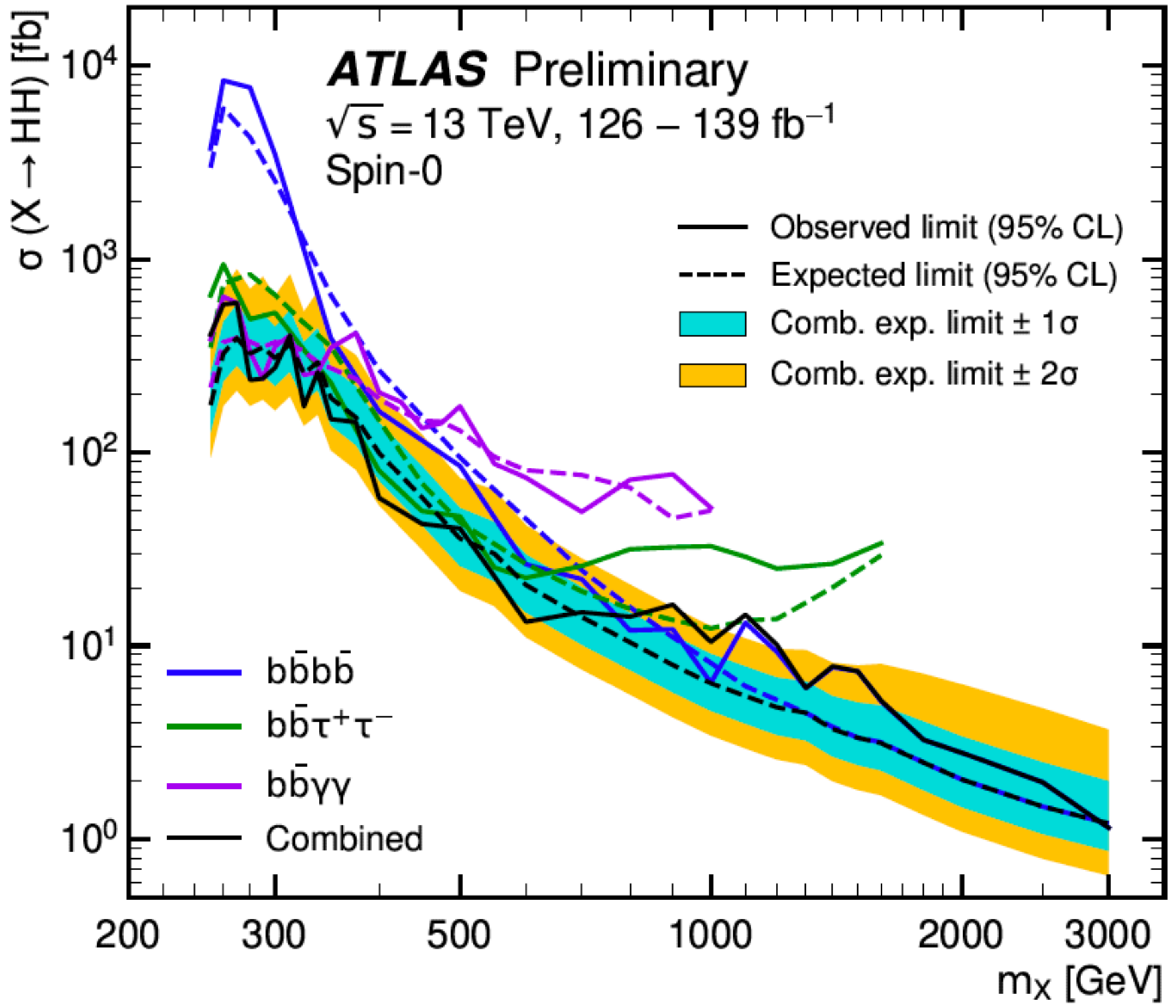
[ATLAS-CONF-2021-052](#)





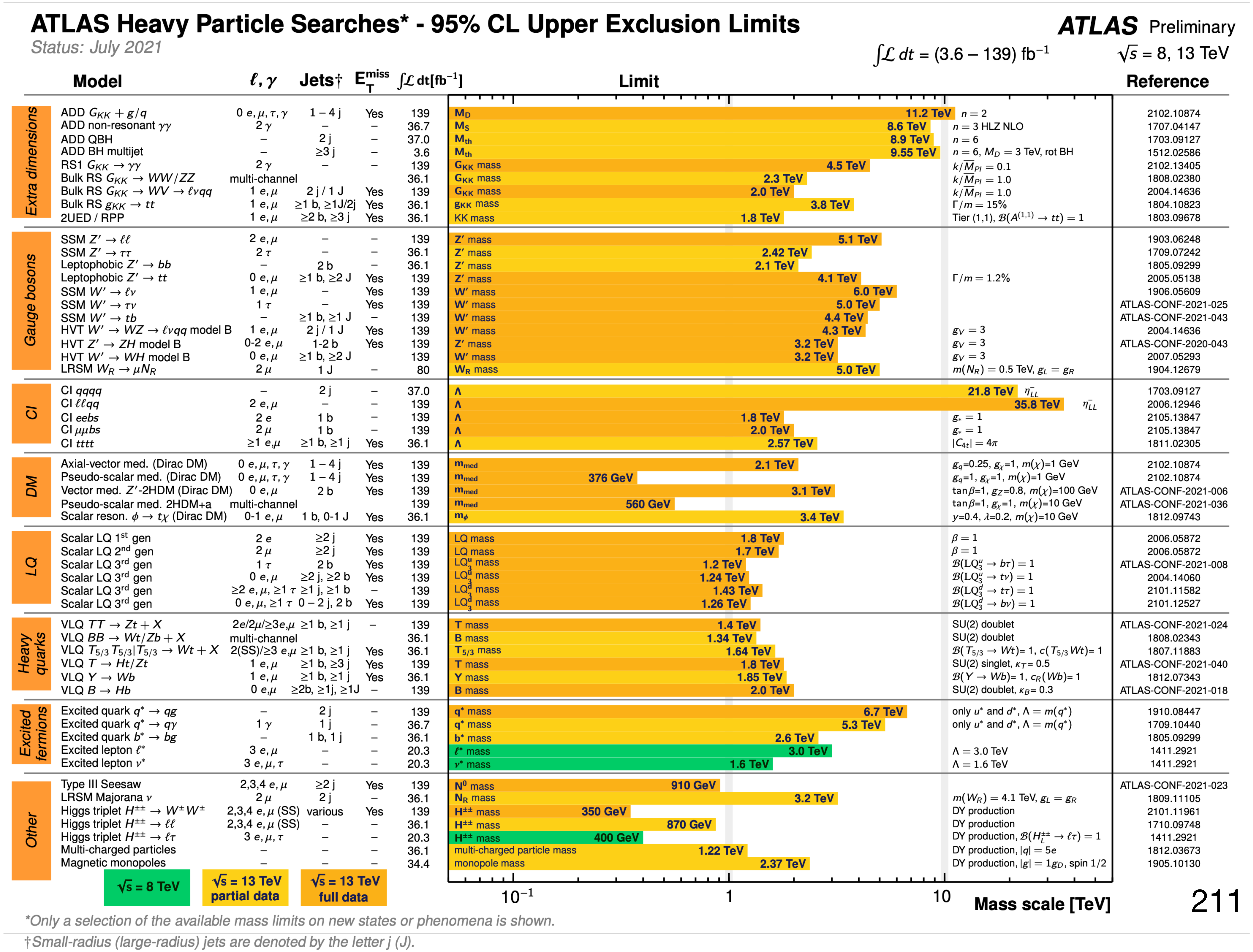
- **Search for HH resonances**
  - HH —> bbbb with both resolved and merged topologies
    - Dominates for m(X) > 700 GeV [ATLAS-CONF-2021-035](#)

HH —> bbbb, bbττ, bbγγ



Direct searches for new Physics

- **New limits on SUSY, 2HDM, Dark Matter, Extra Dimensions, Contact Interactions, Lepto-Quarks, Heavy Quarks, Excited fermions etc.**
- **No deviation from SM found so far**
- **Not covered here except a pair of examples**

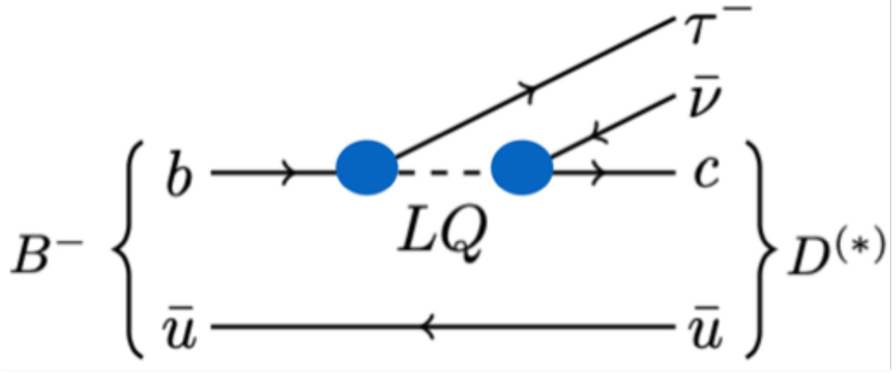


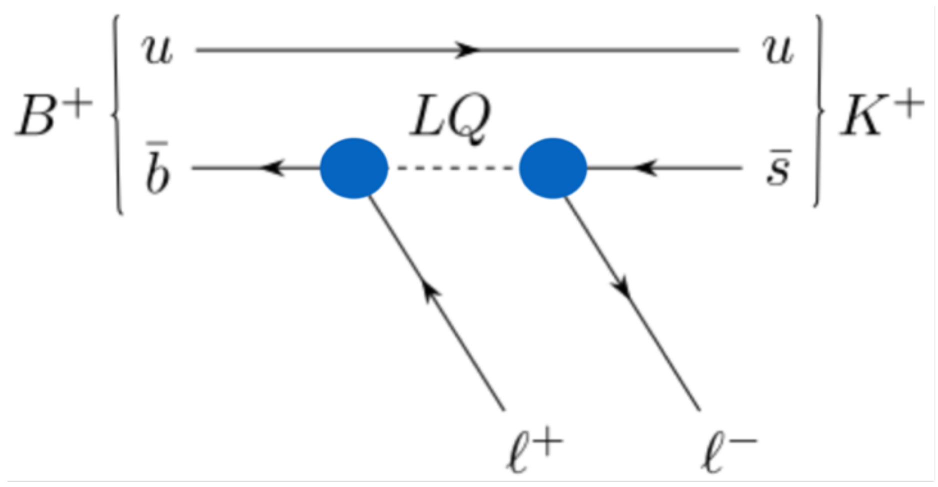
Flavor anomalies

(diagrams by LHCb and D.Zanzi)

- Recent results from B decays indicate deviations from lepton-flavor universality

both $R(K^{(*)}) = \dfrac{\mathcal{B}(B \to K^{(*)}\mu^+\mu^-)}{\mathcal{B}(B \to K^{(*)}e^+e^-)}$ and $R(D^{(*)}) = \dfrac{\mathcal{B}(B \to D^{(*)}\tau\nu)}{\mathcal{B}(B \to D^{(*)}\ell\nu)}$ disagree w/ SM at ~3 $(\ell = e, \mu)$

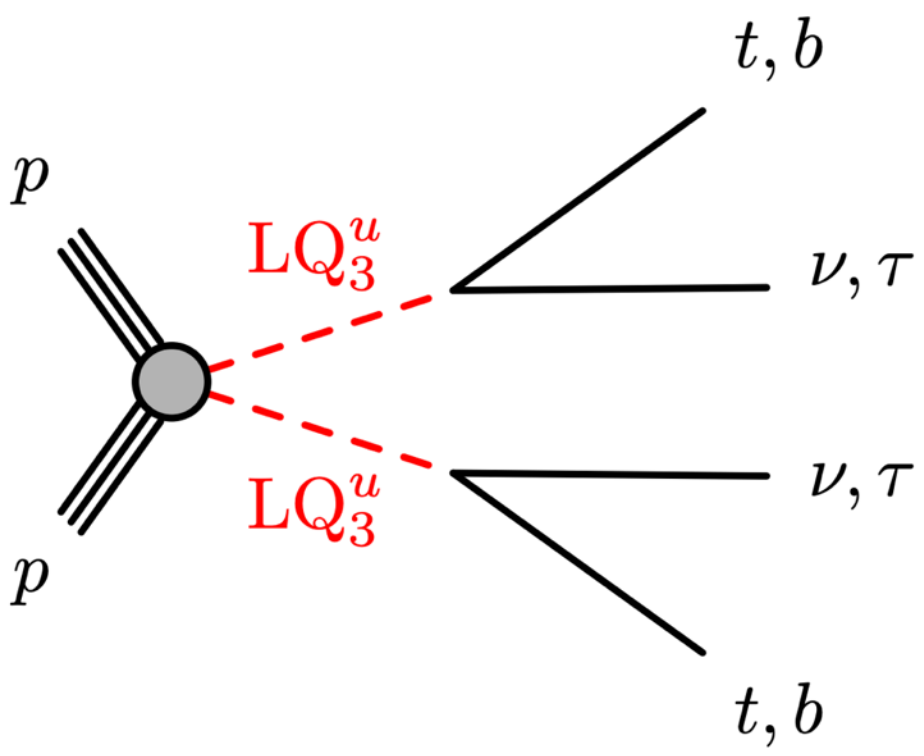




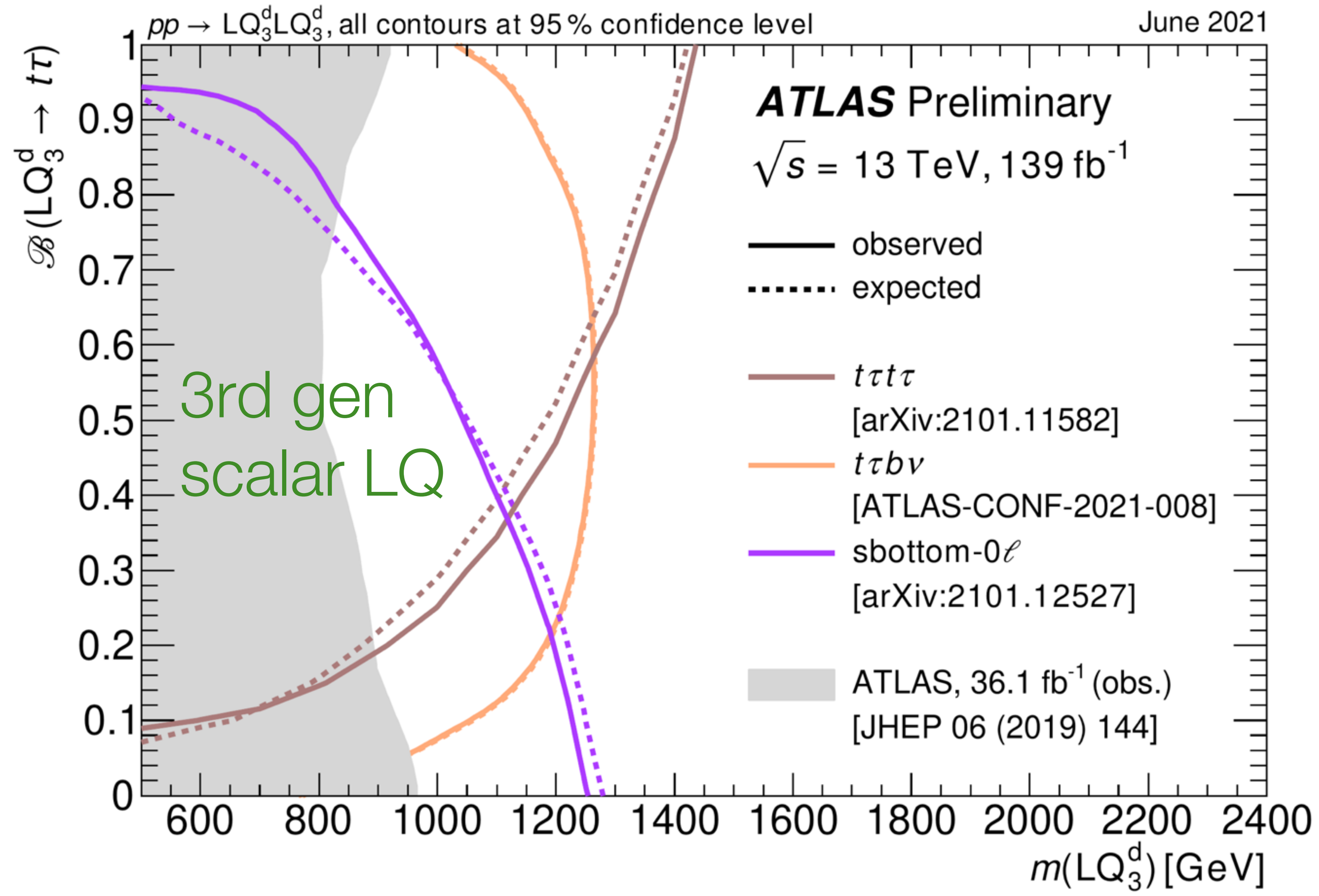
- Leptoquarks are a potential explanation

- Search for 3rd gen. LQ pair production in various channels

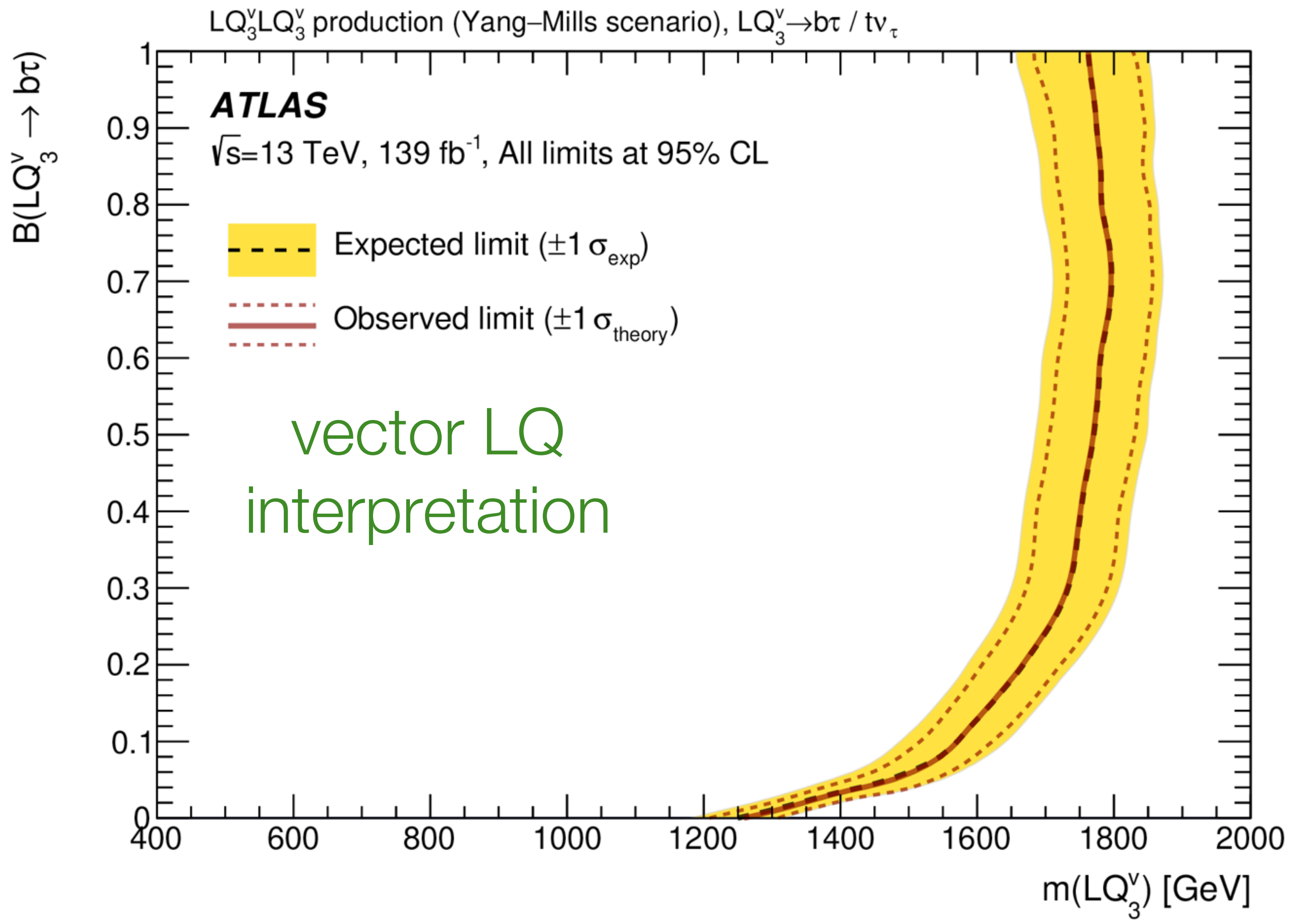
- **Addresses $R(D^{(*)})$ anomaly at ~expected scale**



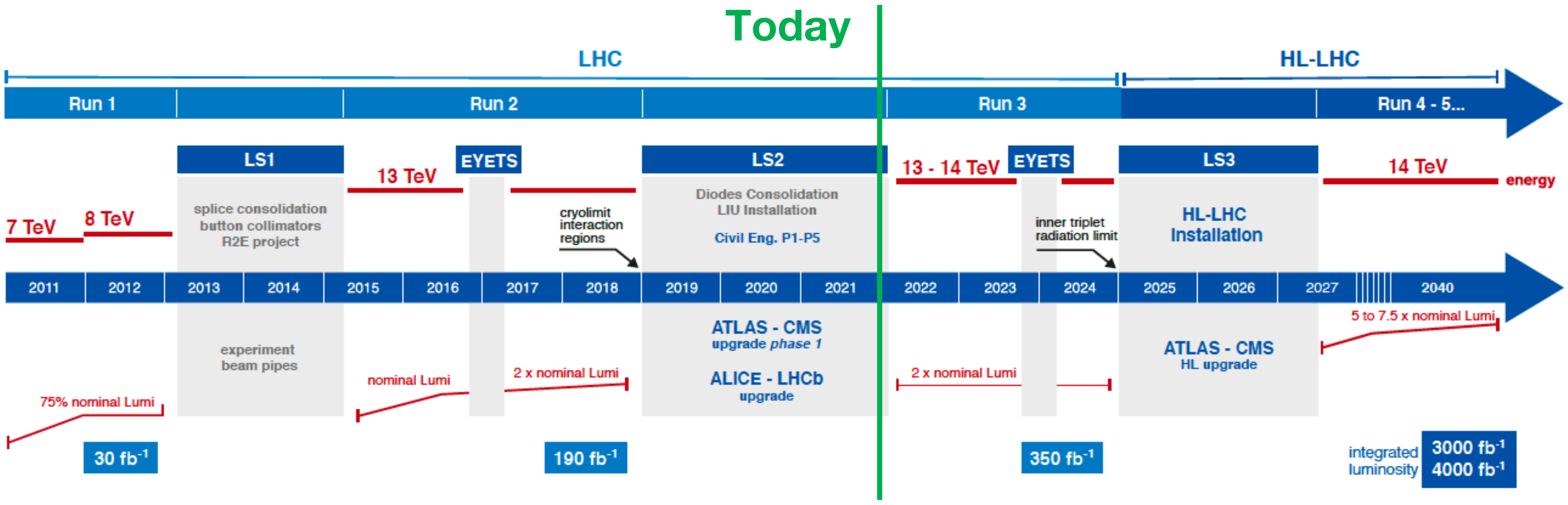
ATL-PHYS-PUB-2021-017



ArXiv:2108.07665



LHC Past, present, future



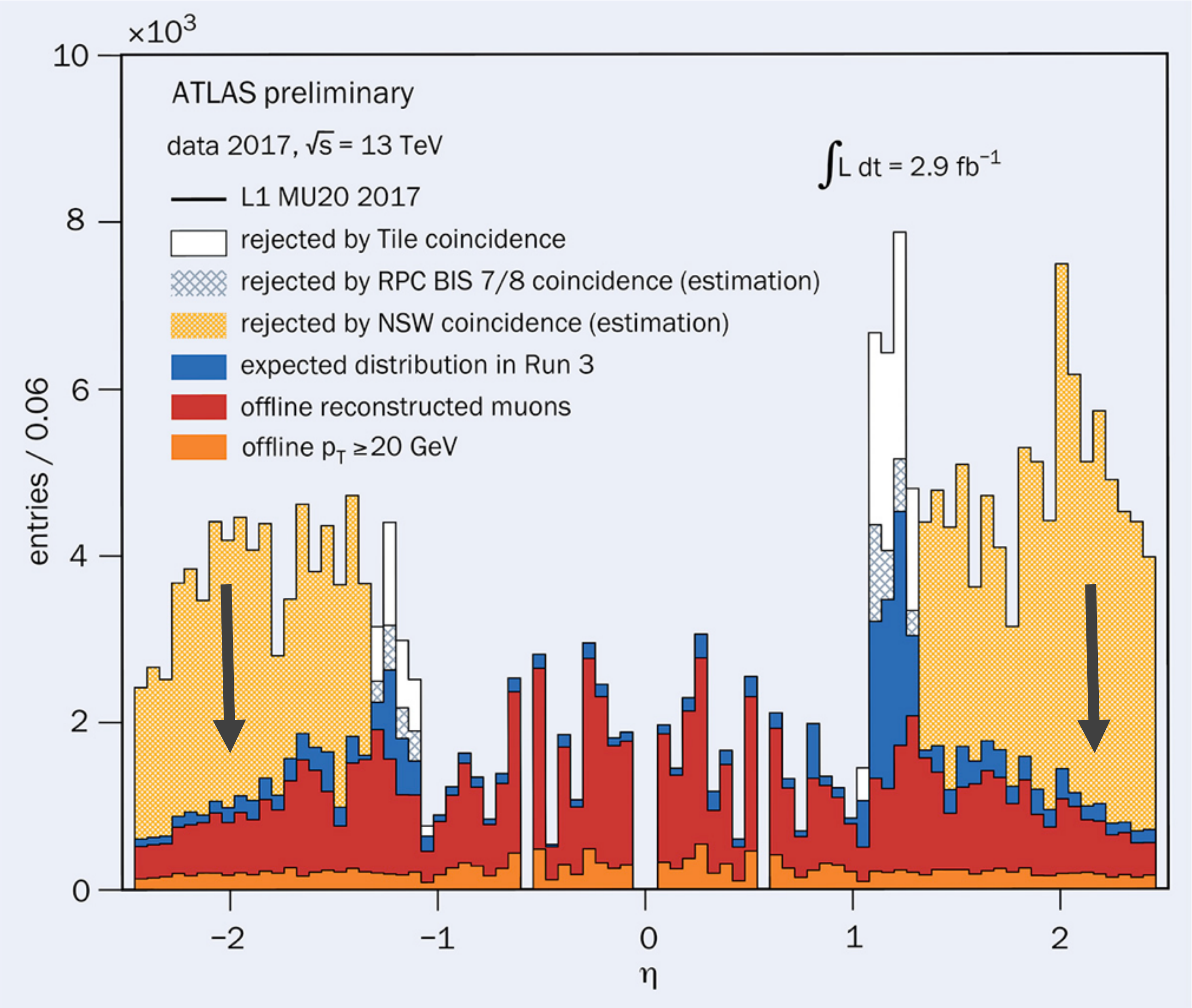
Long Shutdown 2 (LS2) is near completion: Run-3 will start next year, goal is to collect 2 times the Run-2 luminosity (additional year under discussion => x4 data set ?)

HL-LHC majot LHC upgrade, ultimate lumi: 4000 fb-1 (Run3 x10)
Obtained with flat luminosity profile at 7.5 $x10^{34}$ cm^2s^{-1} (7.5 x original LHC Luminosity)
Pileup : 200 inelastic pp collisions / bunch crossing

Run 3 : ATLAS phase-I upgrades

- Preparations ongoing w/ maintenance and multiple improvements to trigger, detector, and computing systems, as well as software
- **New for Run 3:**
  - L1-Calorimeter trigger with improved granularity
  - New topological L1 trigger
  - Muons: New Small Wheel (NSW) and new "EndCap" trigger
  - AFP (forward proton tagger) with new time-of-flight capability
  - Increased performance of software algorithms (Multi-Threading)

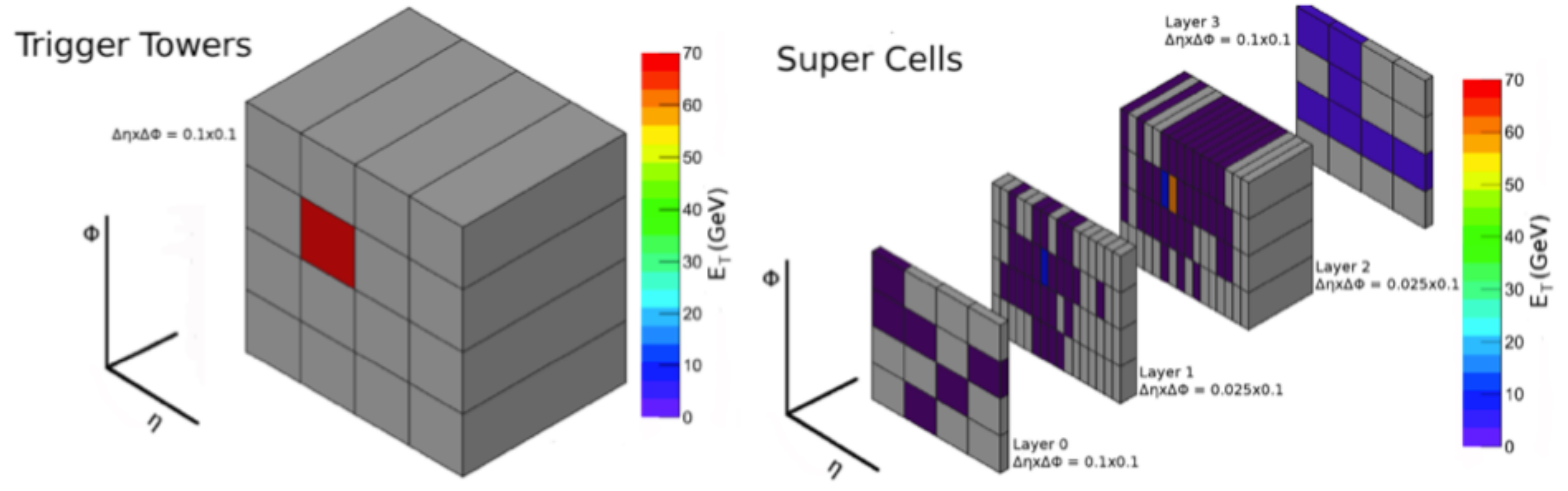
NSW: Reduction of fake μ triggers



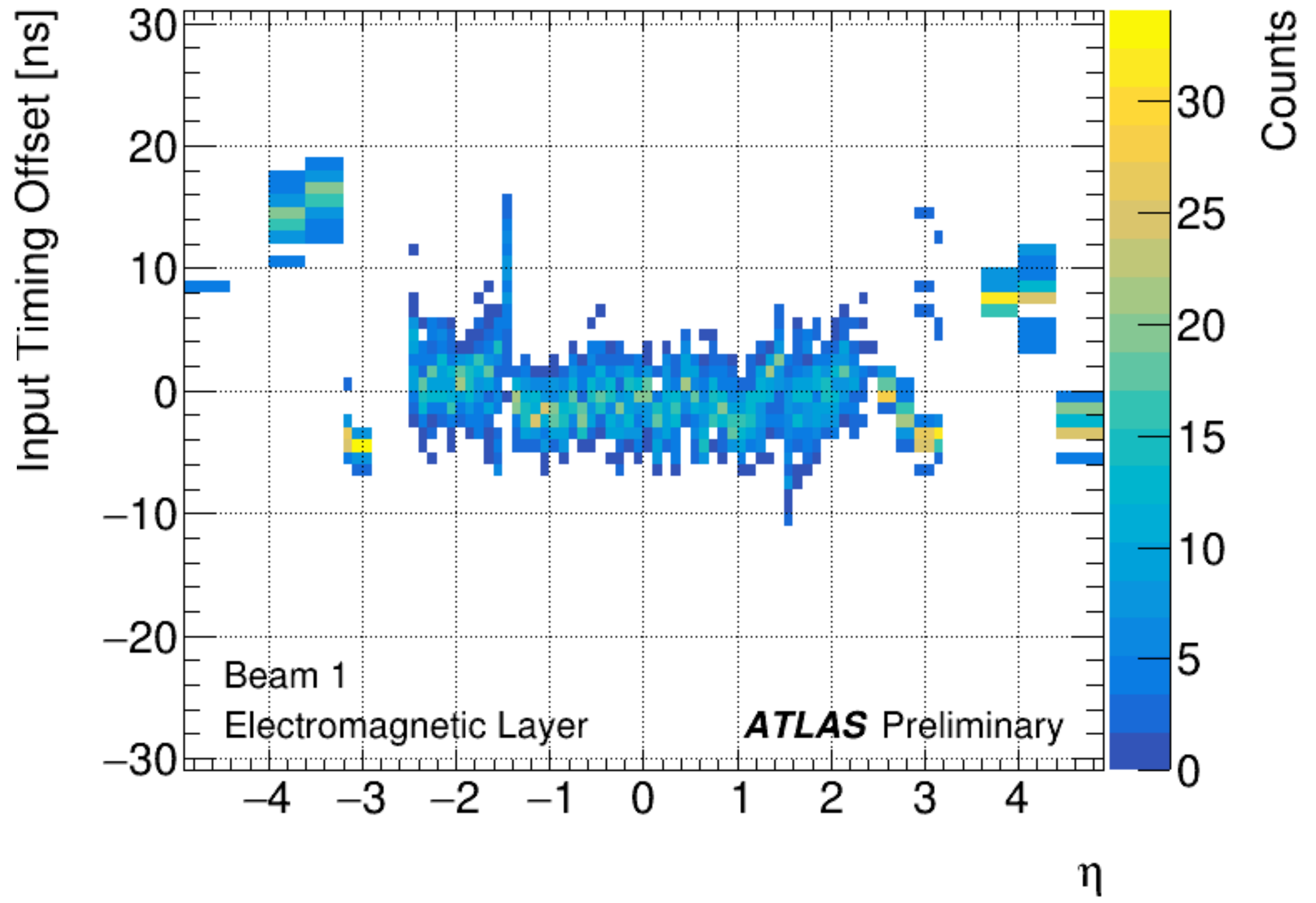
L1Calo

Run2

Run3



(a) (b)

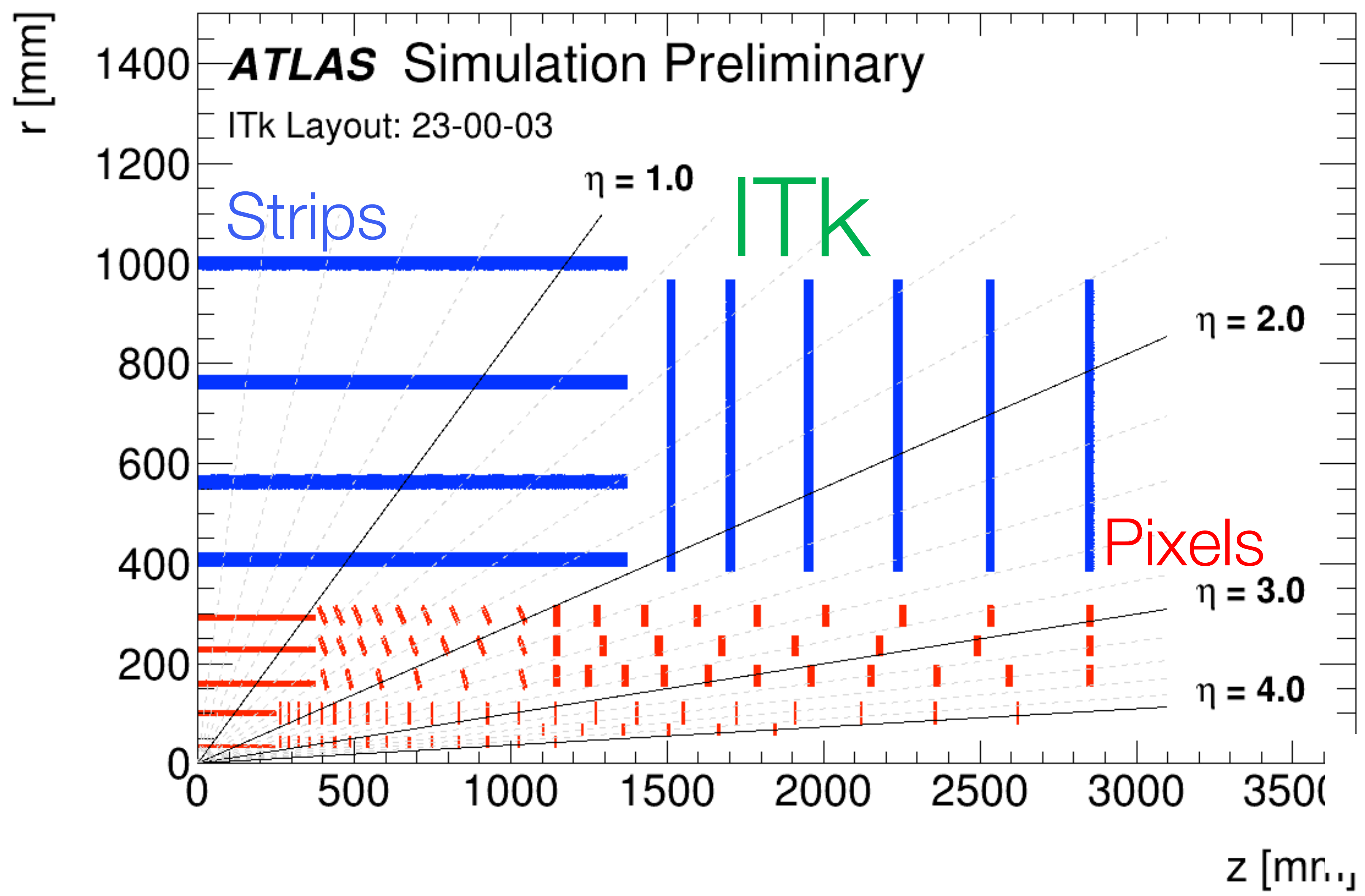


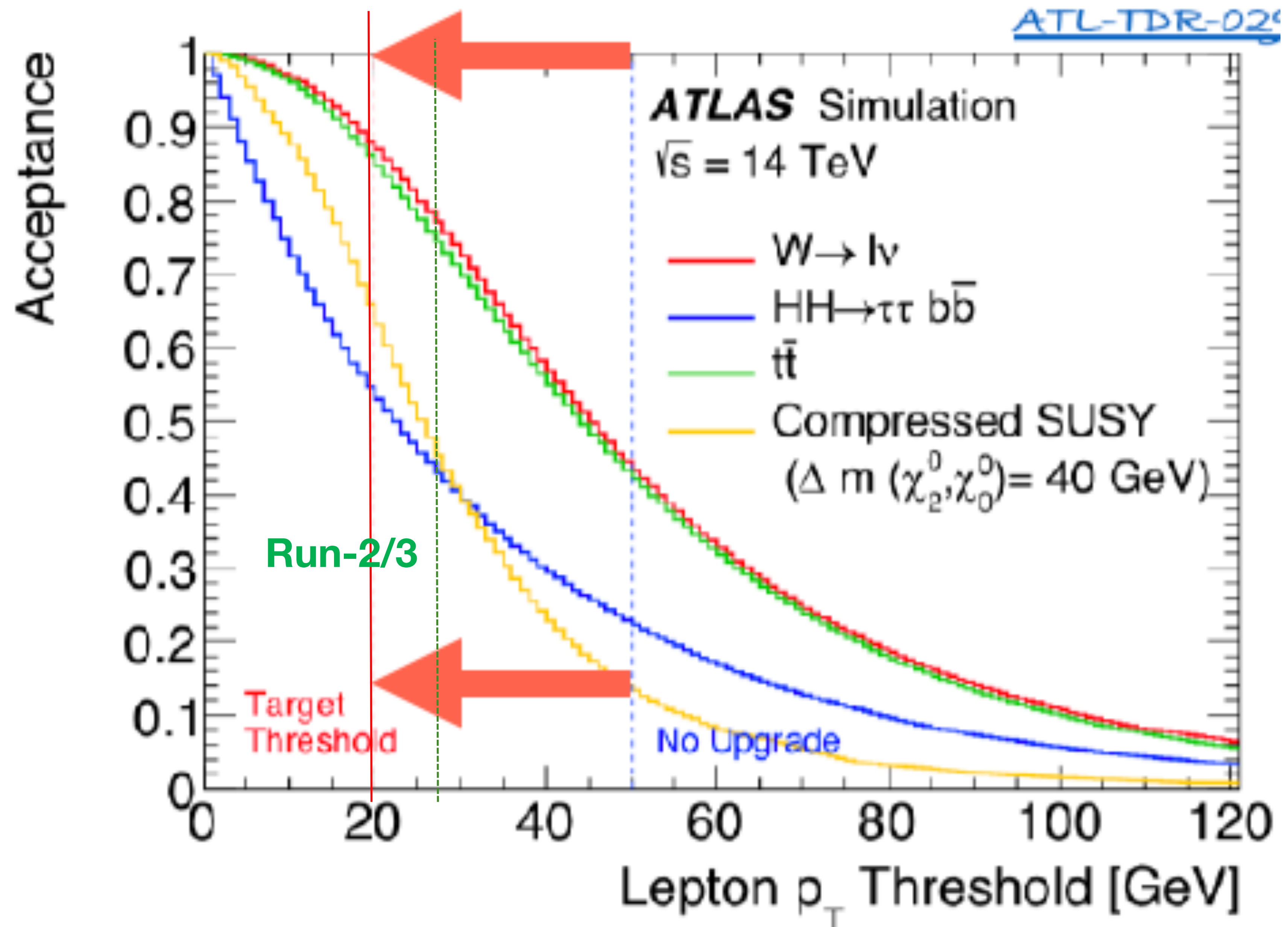
Calibration with beam splashes in October

HL-LHC: ATLAS Phase-2 Upgrade (1)

Major ATLAS upgrade to cope with higher luminosity (higher pileup, higher radiation rates, ageing)

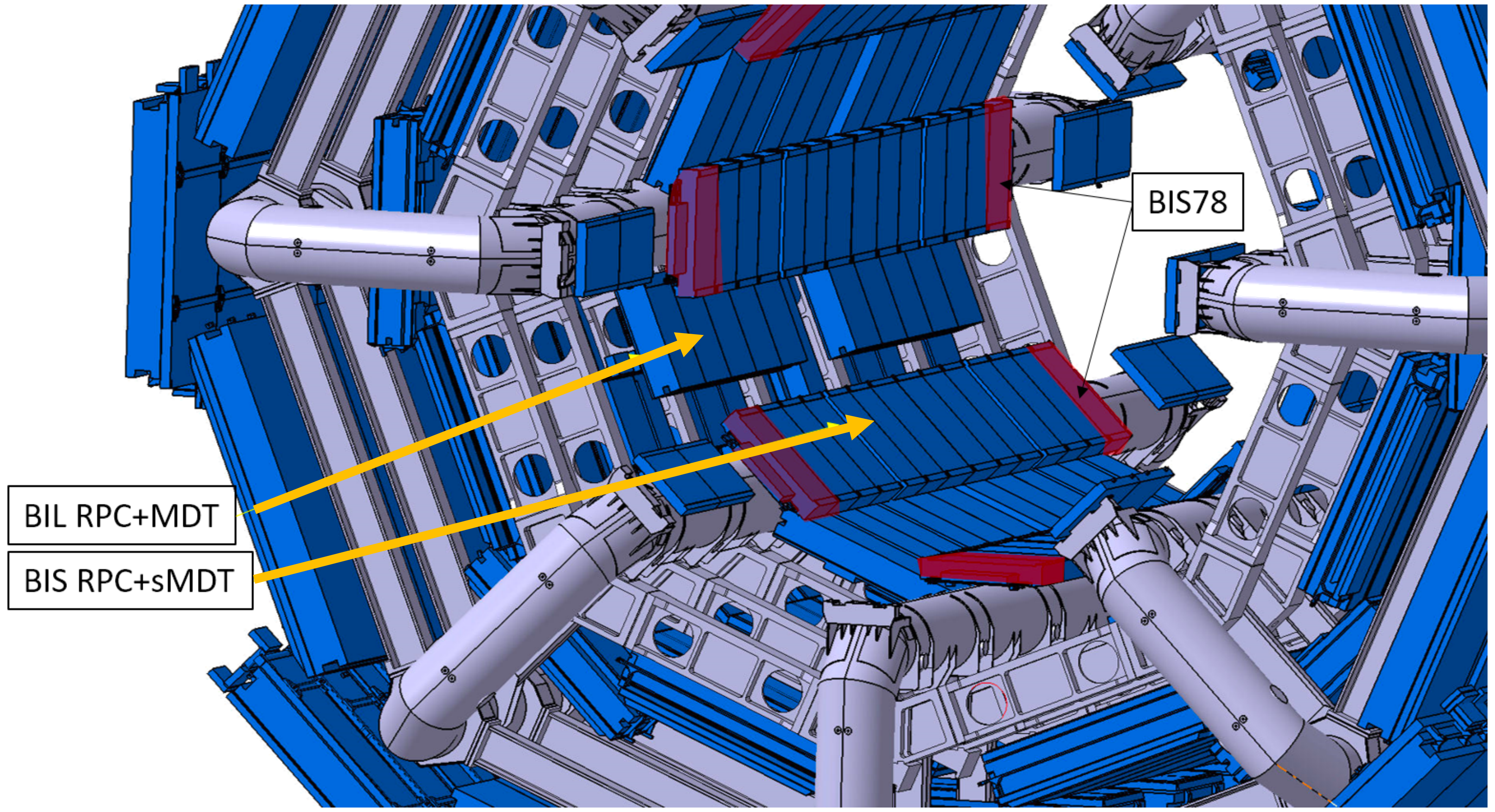
- ITk: new Silicon pixel/strip tracker
  - Excellent tracking performance (vertexing, p_T resolution, b-tagging) even at highest pileup = 200
  - Extend coverage from |η|<2.5 to |η|<4
- Single Hardware Level-0 trigger rate from current 100 kHz to 1 MHz (extendable to 4 MHz)
  - Lower lepton (and jet) p_T threshold desipite higher luminosity
  - Exploit technological advances (high throughput optical transmissions, FPGAs) to perform more sophisticate trigger algorithms, closer to offline rec



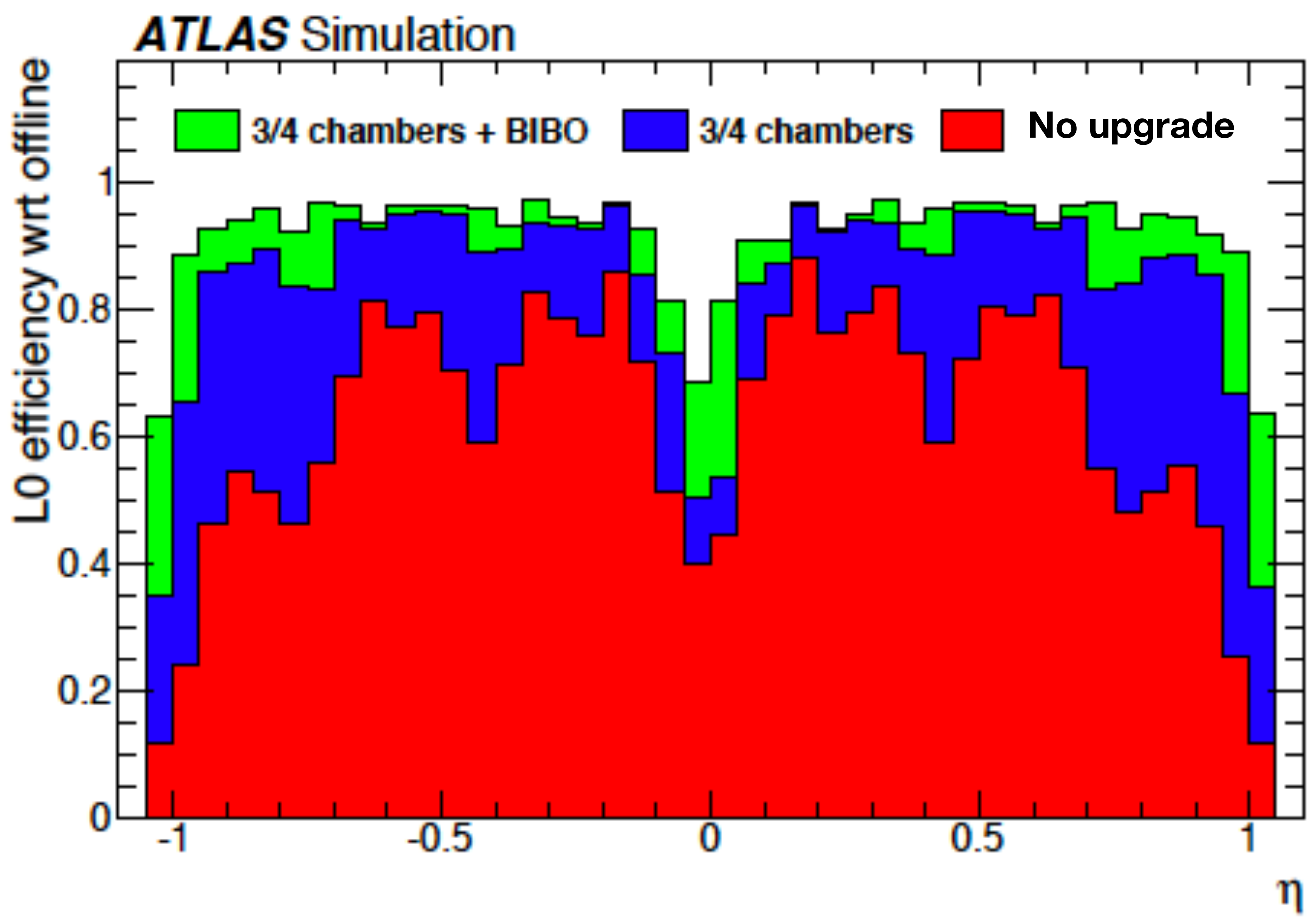


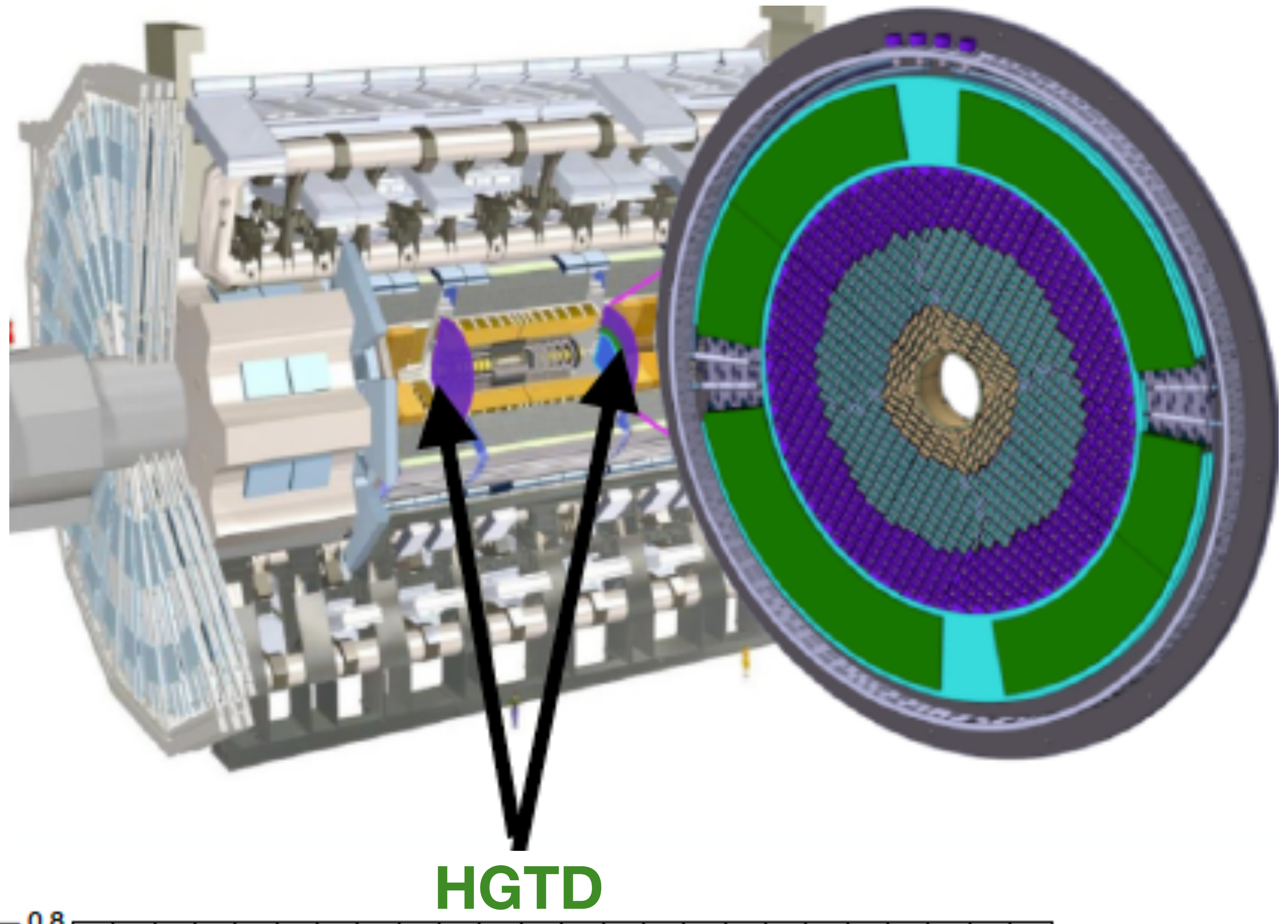
ATLAS Phase-2 Upgrade (2)

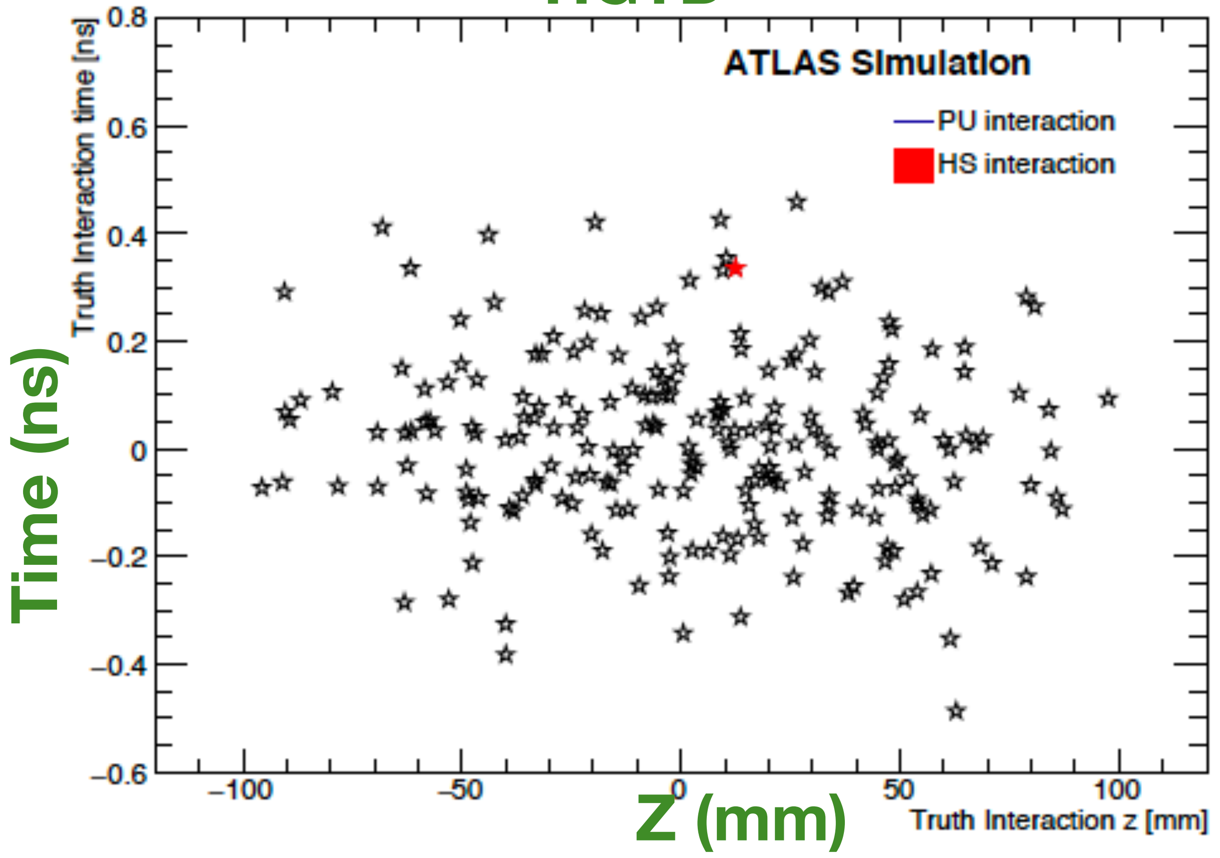
- **New layer of inner chambers in the barrel-inner layer of the muon system**
  - Improve trigger acceptance keeping similar rate (thin gap RPCs + small drift tube (sMDT) chambers)
- **High granularity Timing Detector (2.4 < |η|< 4)**
  - Separate tracks from different collision vertices using timing: effectively remove tracks/jets from pileup
  - LGAD (Low-Gain avalanche detectors) timing resolution 30-50ps



μ Trigger Acc x Efficiency (worst Case Scenario)







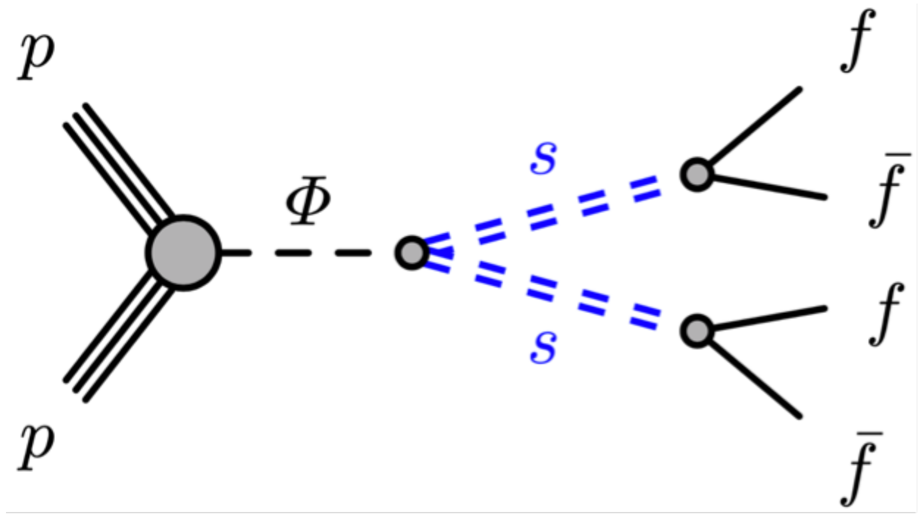
Conclusions

- **Vibrant ATLAS physics program** continues to exploit the Run 2 data gold mine
  - Precision measurements
    - Improving understanding of SM in extreme phase space, measurements of PDF, Fragmentation
    - Progress toward more global approaches, esp. global EFT fits
  - Observation/study of rare processes
    - Large dataset to explore rare processes: tttt (4.7σ), WWW (8.2σ), or HH prod. ($\sigma_{HH}/\sigma_{HH}^{SM} < 4.1$)
- **Preparations for Run 3 underway**
  - Looking forward to extend physics reach beyond Run 2
- **Very significant effort on Phase-II upgrade for high-luminosity LHC**

Extra material

Long-lived particles

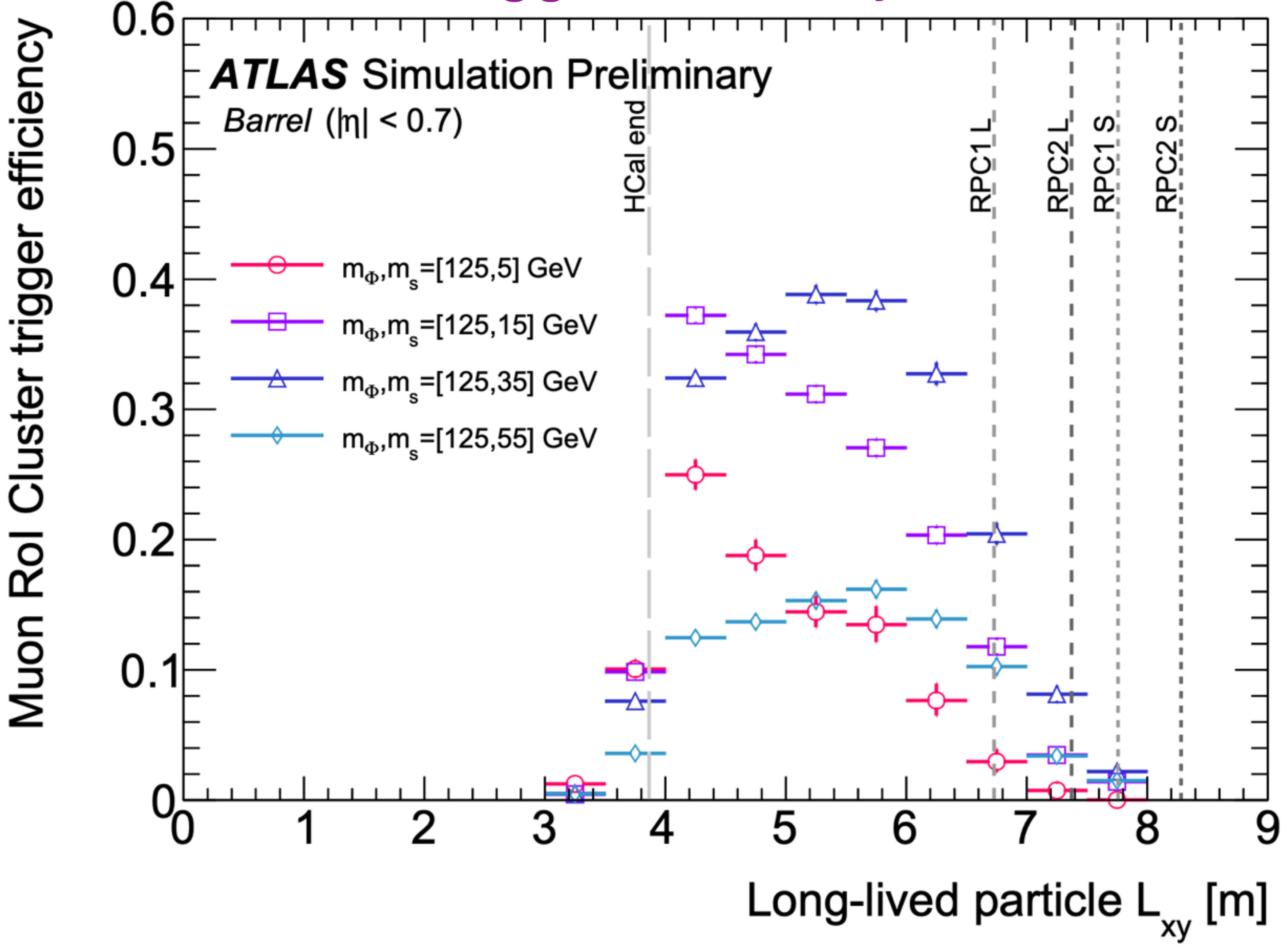
- **Higgs portal** / Hidden sector models predict exotic Higgs decays to LLP (*s*)
- Large expt. program for searching different types of LLPs
- Dedicated muon spectrometer (MS) multi-RoI trigger
  + track segment and vtx reconstruction in barrel & endcap MS
- Require 2 DVs: 0 events observed w/ 0.32 +/- 0.05 expected bkg



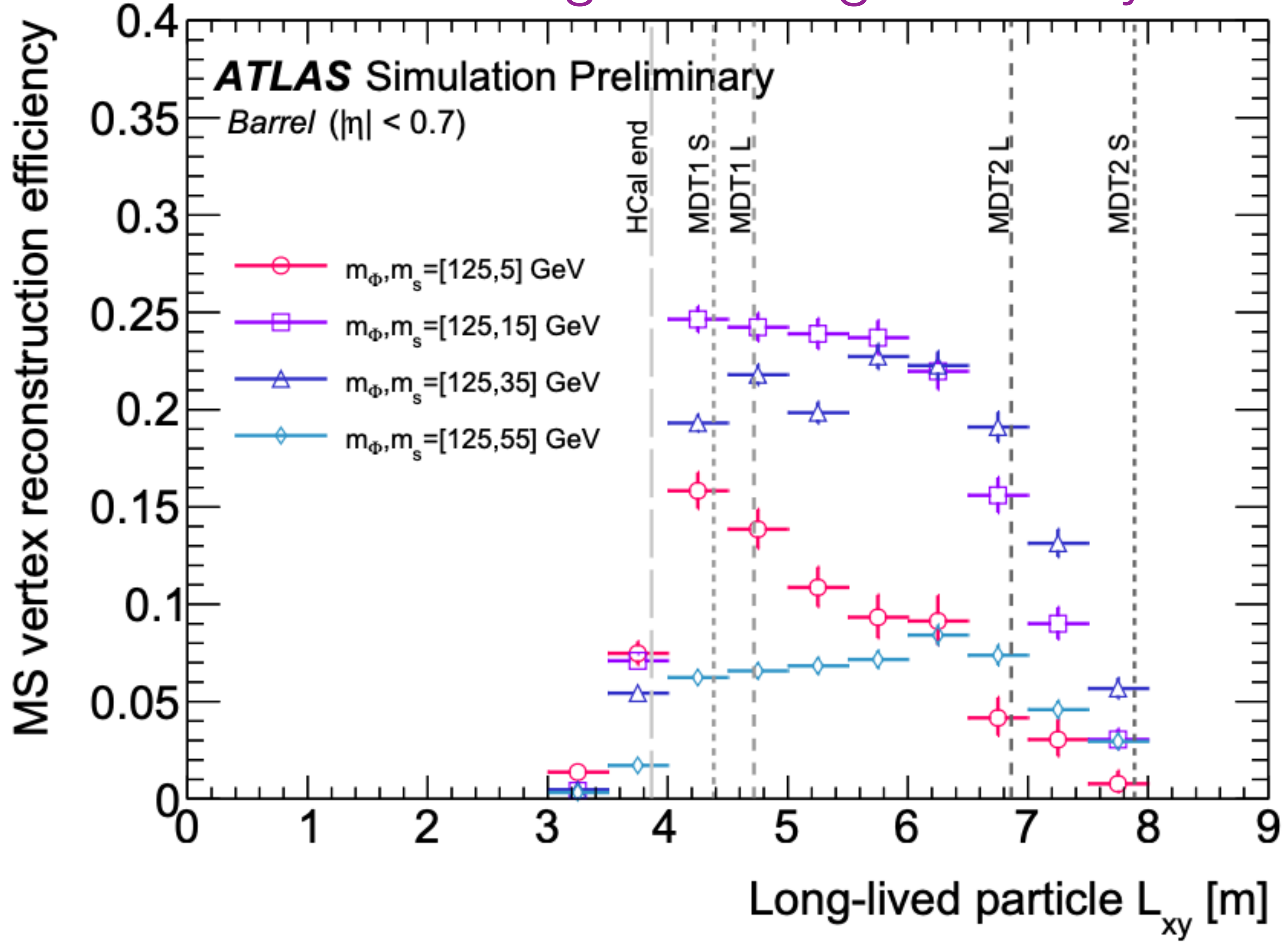
BF(Φ(125)—>*ss*) =10%
excluded for cτ(*s*) in range
4 cm — 7.8 m
for m(s) = 5 GeV

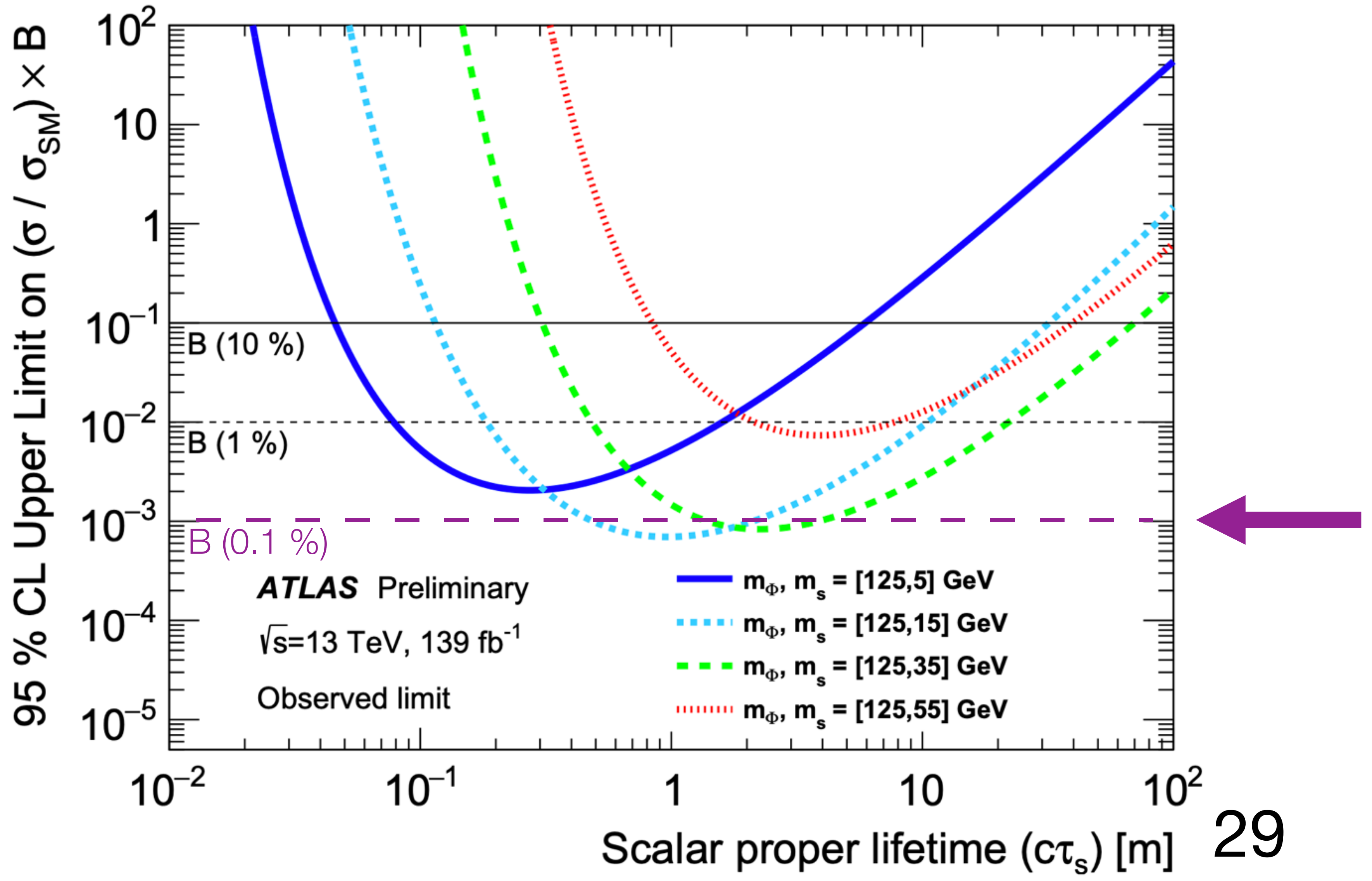
ATLAS-CONF-2021-032

trigger efficiency



tracking/vertexing efficiency





Pentaquarks

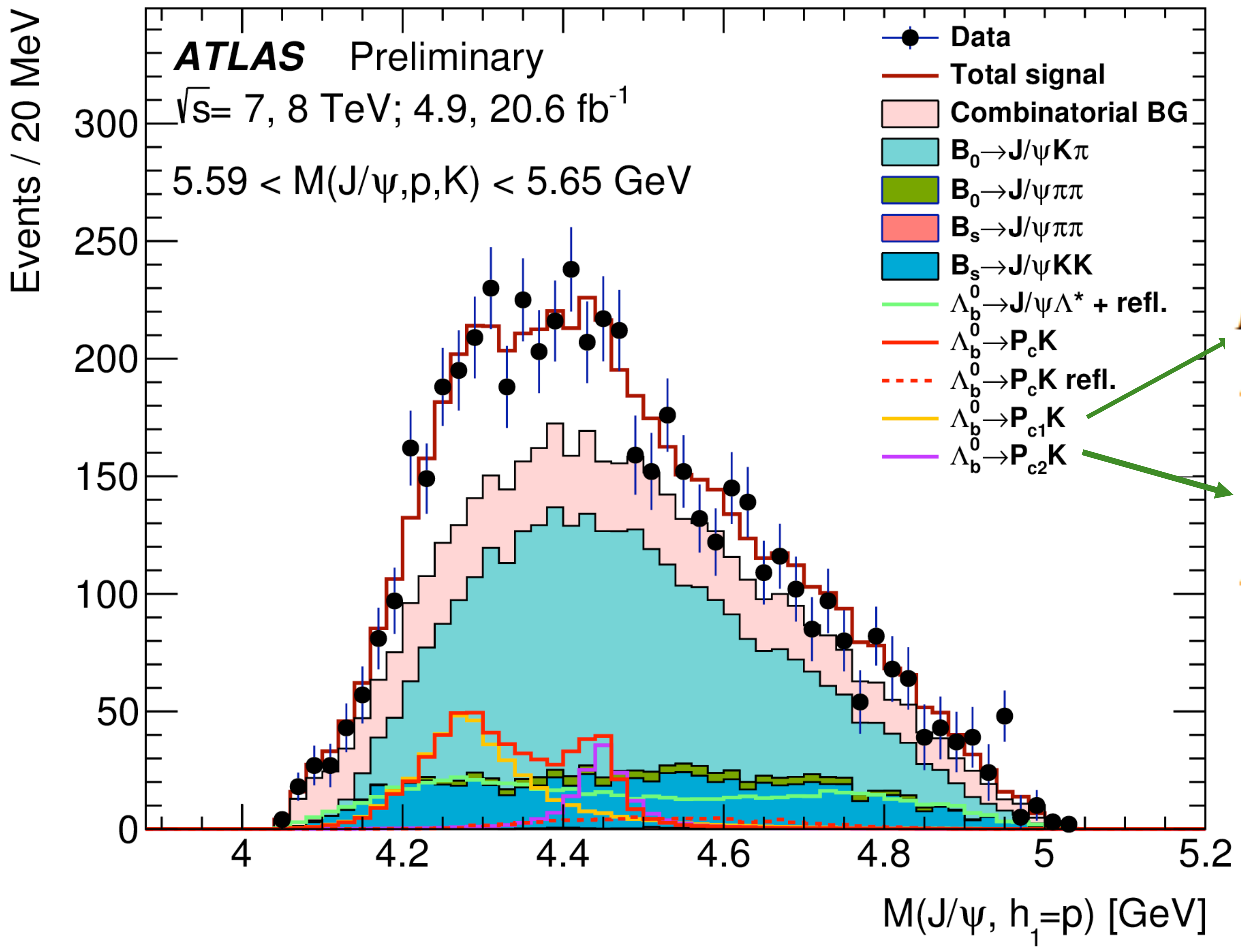
Search for $c\bar{c}uud$ pentaquarks in Λ_b decays

Best fit with two (or more) PQ compatible with LHCb observation

Anyway a fit without PQ but with an extended $\Lambda_b^0 \rightarrow J/\psi \Lambda^{*0}$ decay model is not excluded

$$\Lambda_b^0 \rightarrow J/\psi\, p K^-$$

ATLAS-CONF-2019-048



$P_c(4380)^+$ $3/2^-$

$4282^{+33}_{-26}(\text{stat})^{+28}_{-7}(\text{syst})$ MeV

$P_c(4450)^+$ $5/2^+$

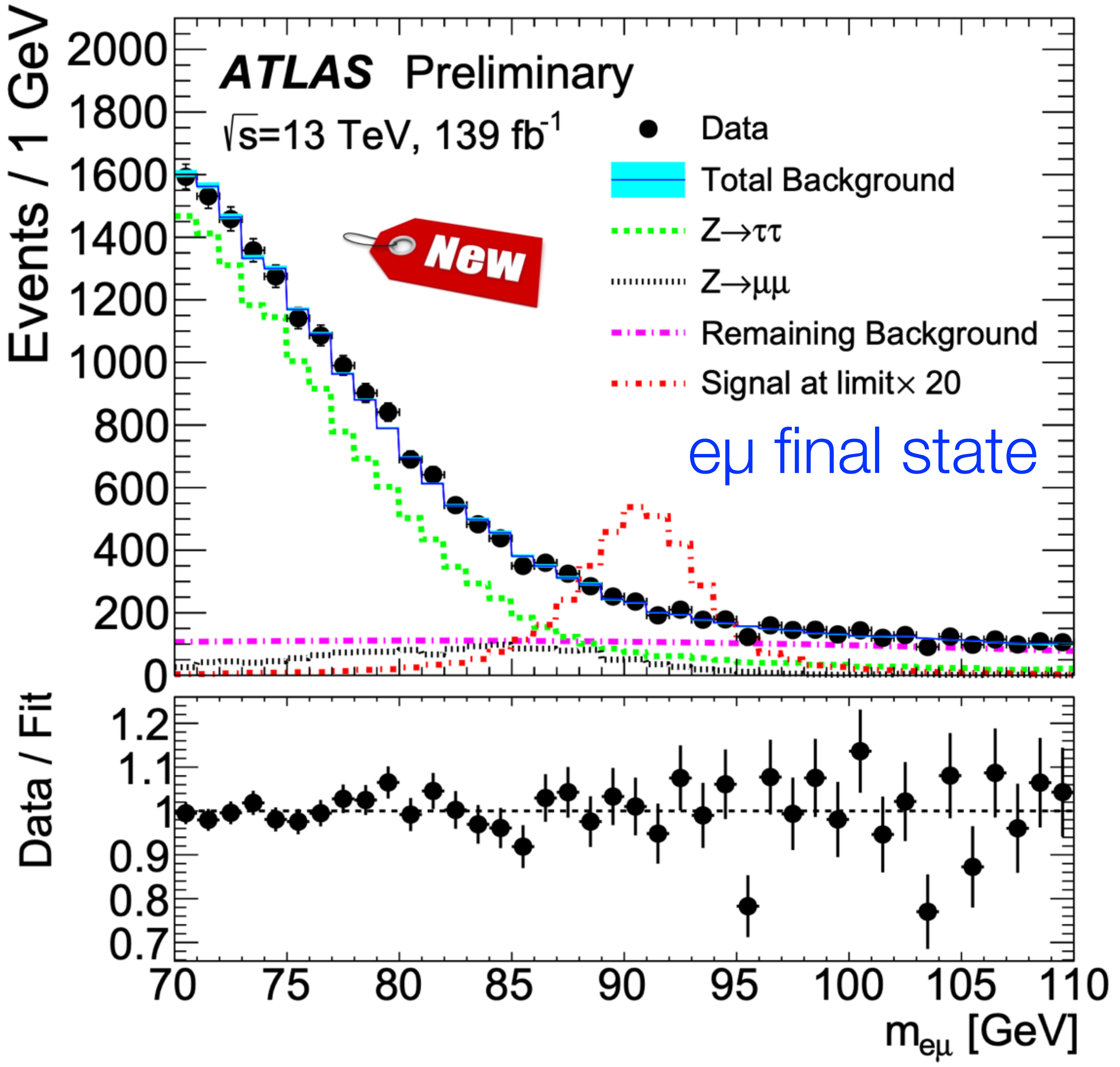
$4449^{+20}_{-29}(\text{stat})^{+18}_{-10}(\text{syst})$ MeV

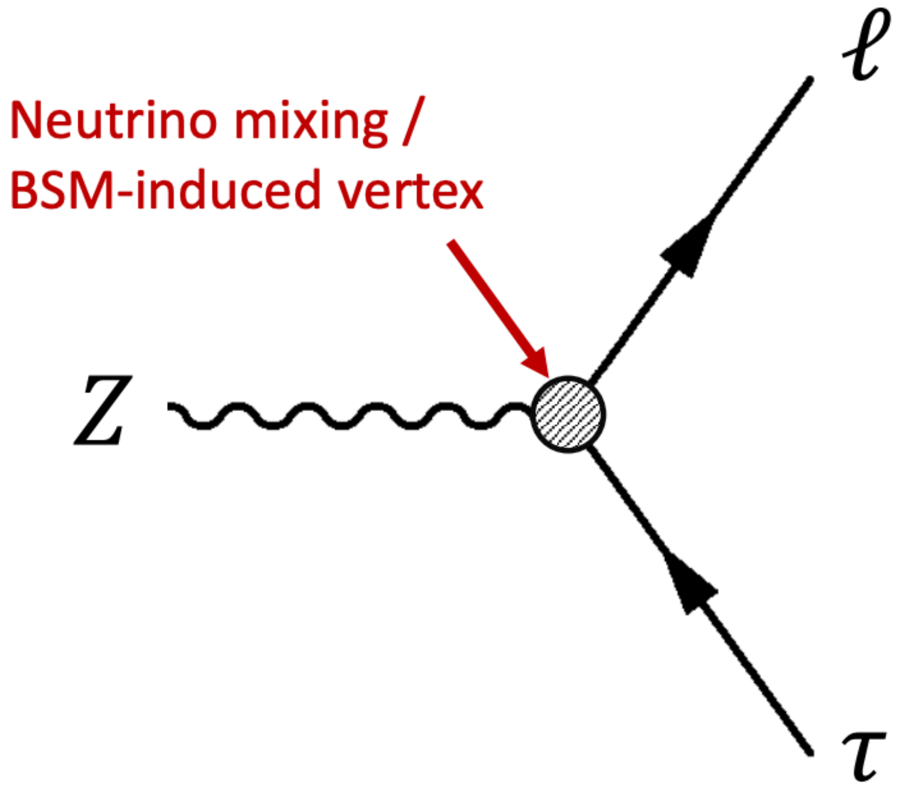
Lepton flavor violation

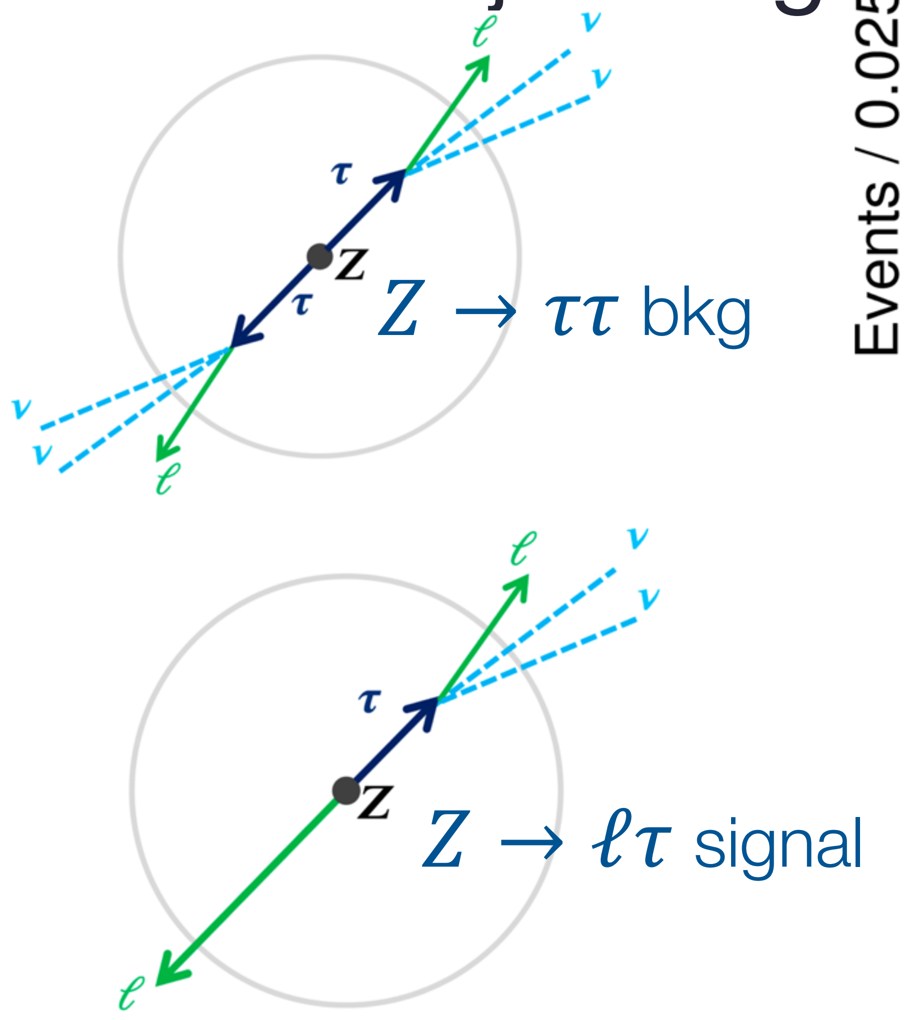
ATLAS-CONF-2021-042 arXiv:2105.12491

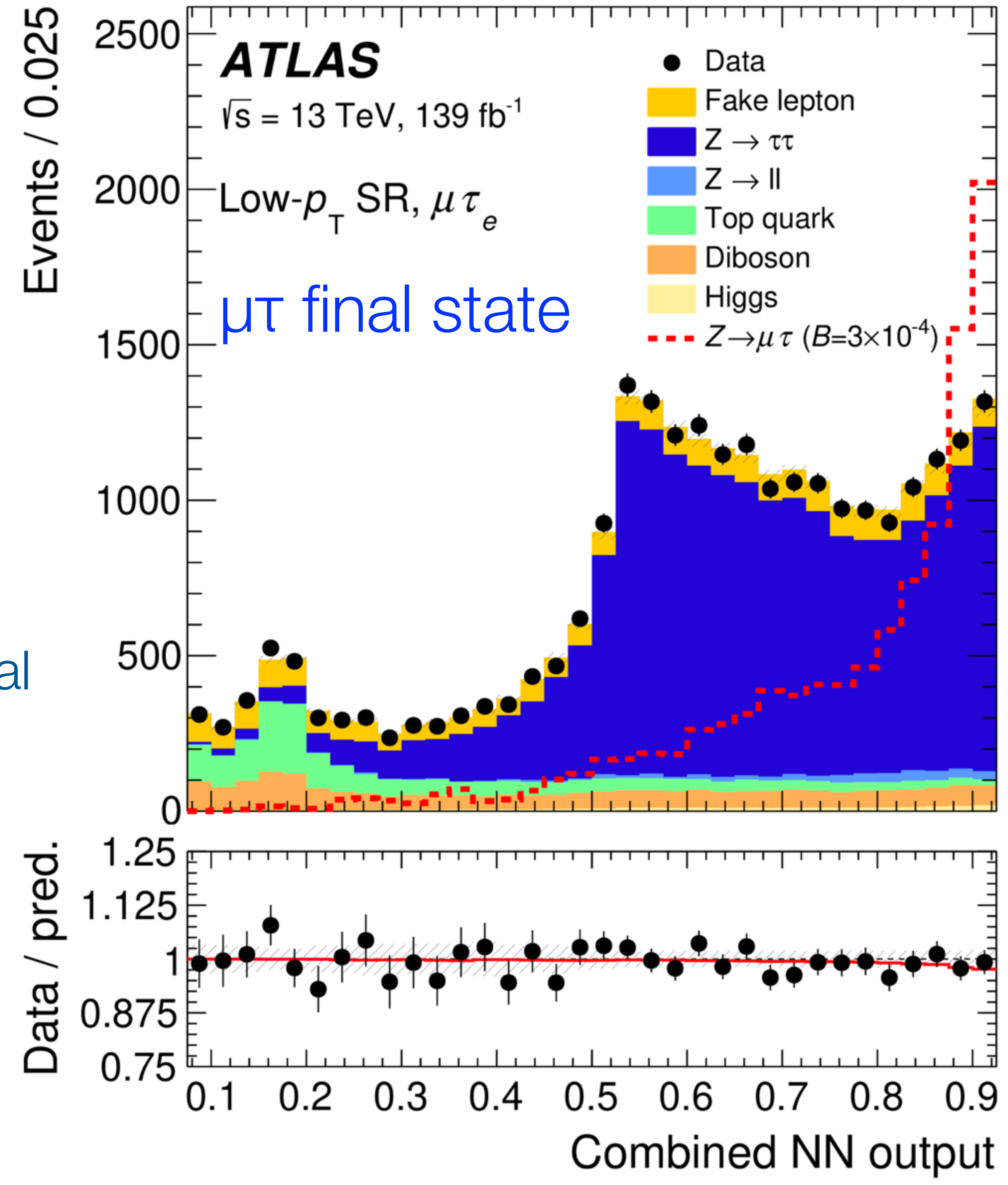
$\mathcal{L} = \mathcal{L}_{SM} + \mathcal{L}_{BSM}$

- Run 2: ~8 x 10^9 Z bosons produced
- Lepton flavor violation only observed in neutrino oscillations, ~negligible for $\ell^{\pm}$ in SM
- Z —> e μ search based on $m_{\ell\ell}$, w/ reduced uncert. normalizing to Z—>ee, μμ
- Z —> e τ, μ τ search w/ NNs to suppress $Z \to \tau\tau, t\bar{t}, VV$ & $W \to \ell\nu$ + jets bkg





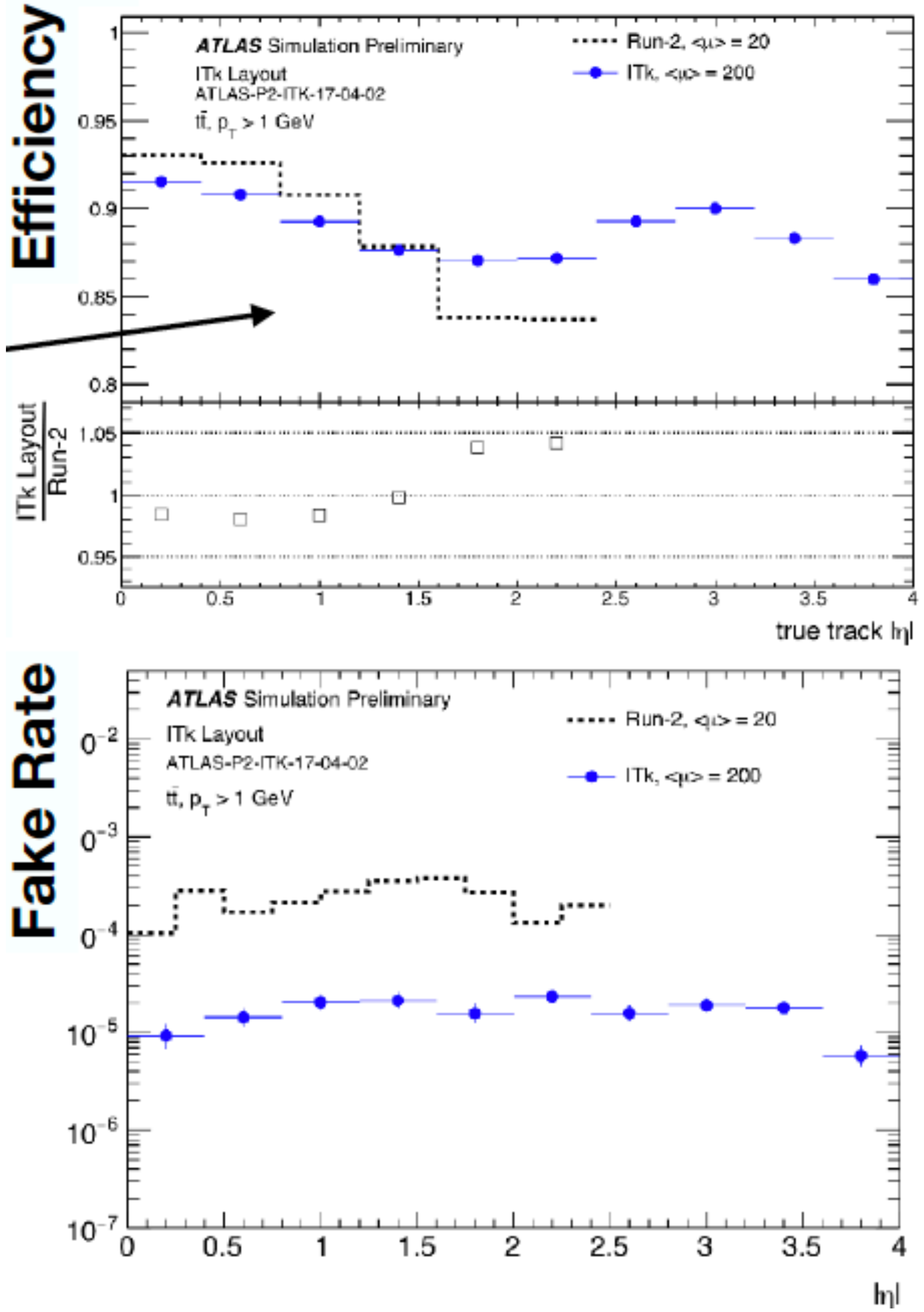




Upper limits at 95% CL	ATLAS	LEP
B(Z —> e μ)	0.34 × 10^{-6}	1.7 × 10^{-6} (OPAL)
B(Z —> e τ)	5.0 × 10^{-6}	9.8 × 10^{-6} (OPAL)
B(Z —> μ τ)	6.5 × 10^{-6}	12 × 10^{-6} (DELPHI)

- LEP limits surpassed by factors of 5 ($Z \to e\mu$) and 2 ($Z \to e\tau, \mu\tau$)

ITK performance

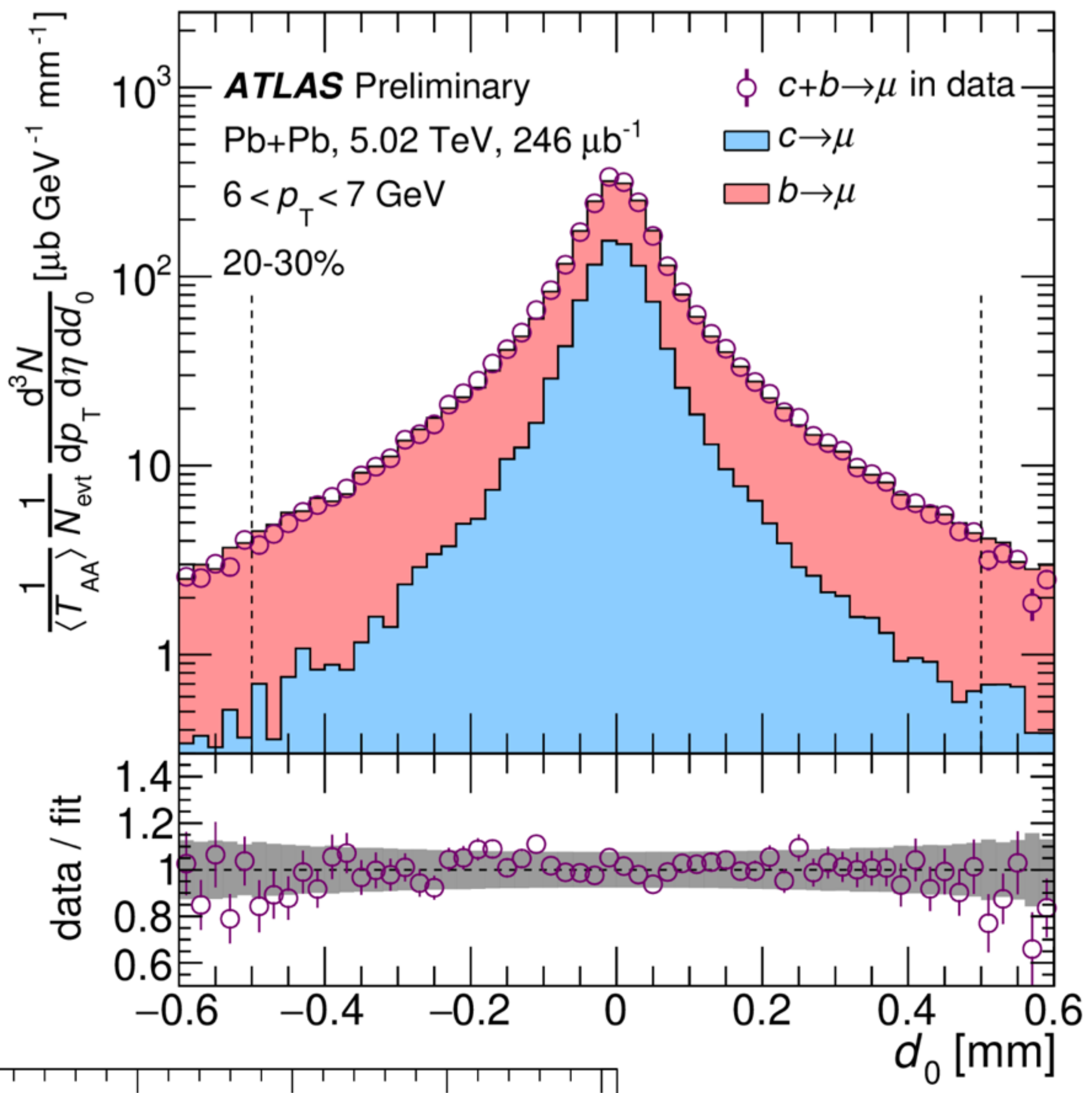


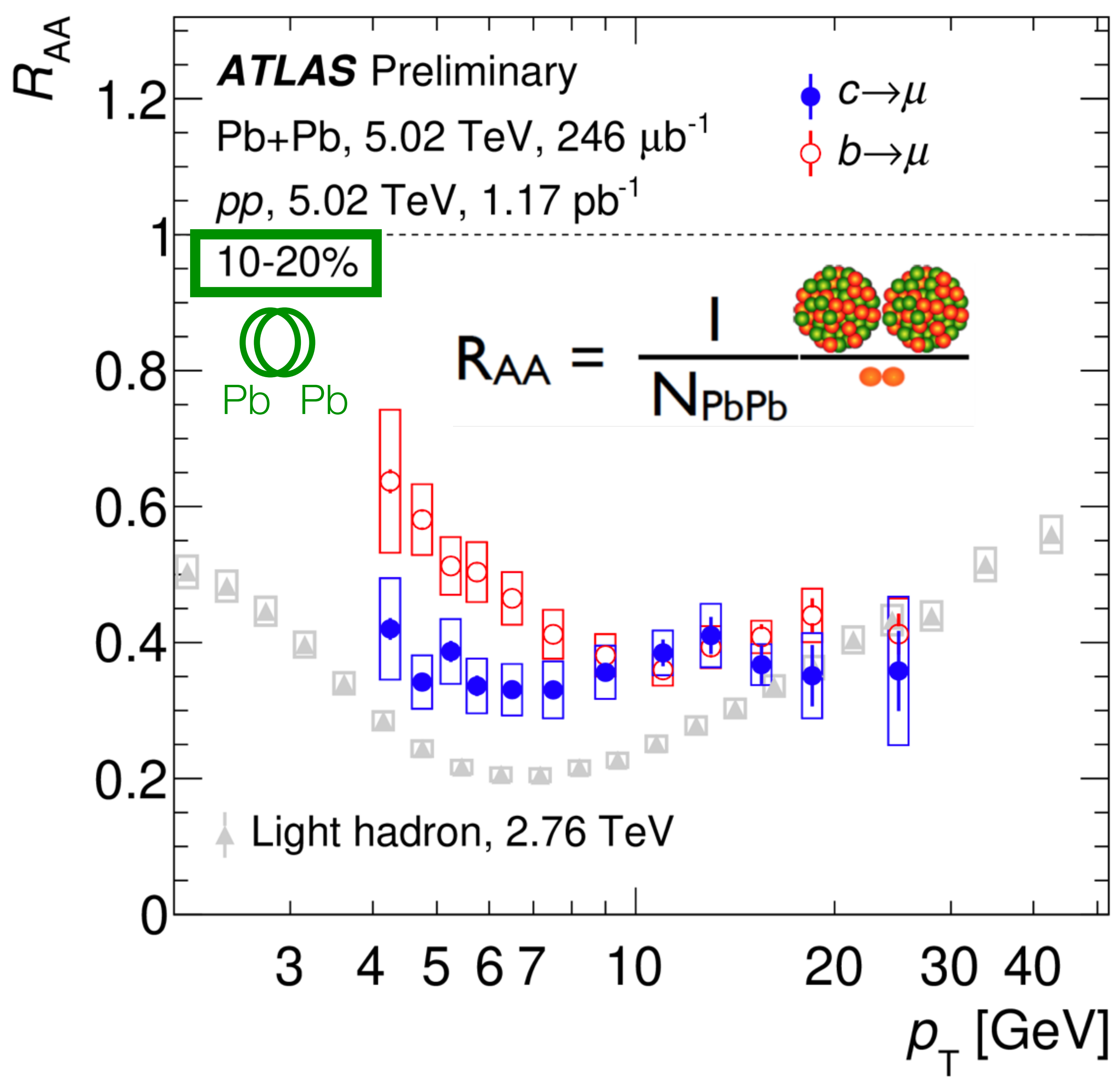
Bottom & charm energy loss in dense nuclear medium

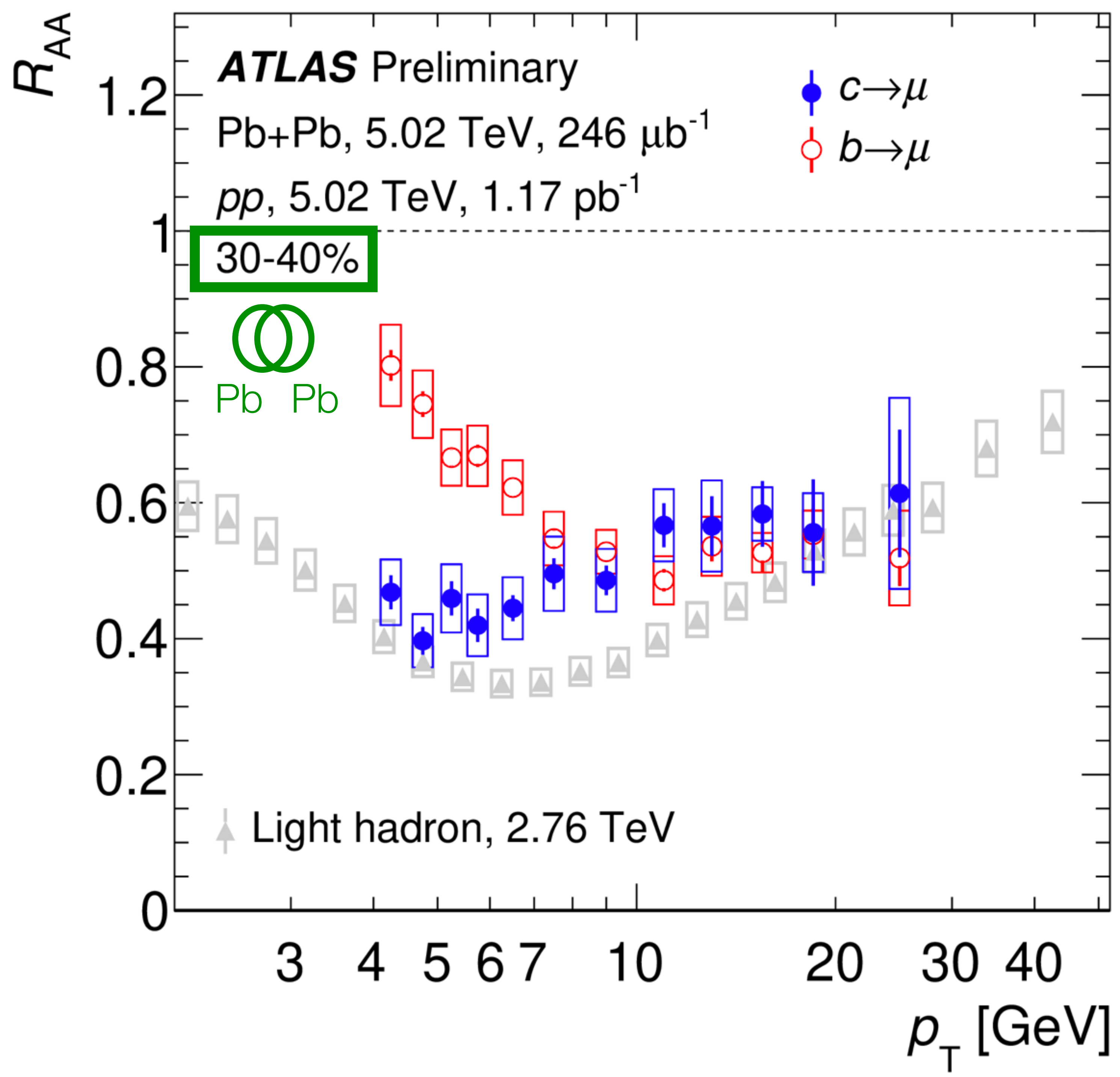
ATLAS EXPERIMENT

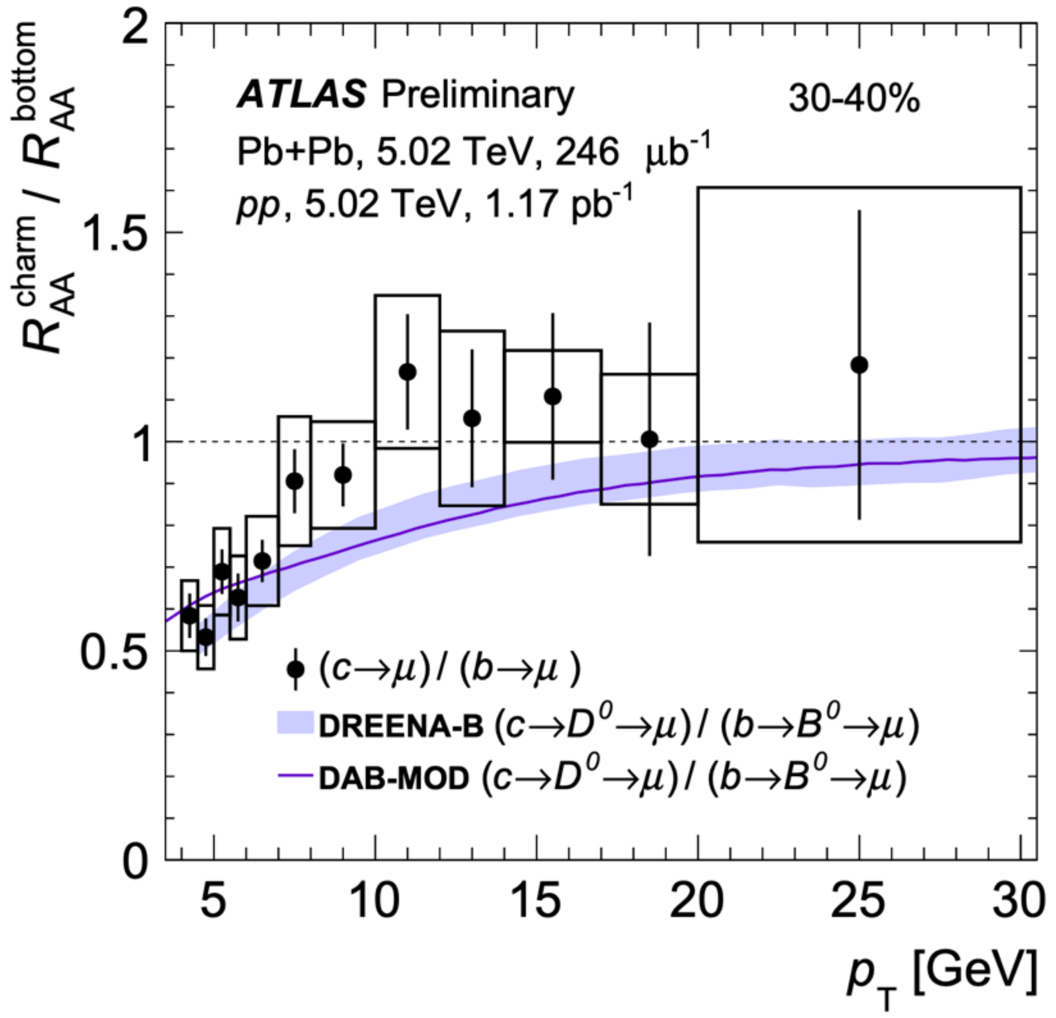
ATLAS-CONF-2021-020

- Study muons from decay of bottom and charm hadrons in pp and PbPb collisions —> learn about energy loss mechanisms for heavy flavors in quark-gluon plasma
- Light/heavy-flavor hadron separation w/ muon p_T imbalance inner tracker vs. muon spectrometer
- b/c-hadron separation using muon impact parameter
- Stronger nuclear suppression for charm vs. bottom as predicted
  - Suppression also depends on p_T and centrality of PbPb collision









Heavy-ion collisions

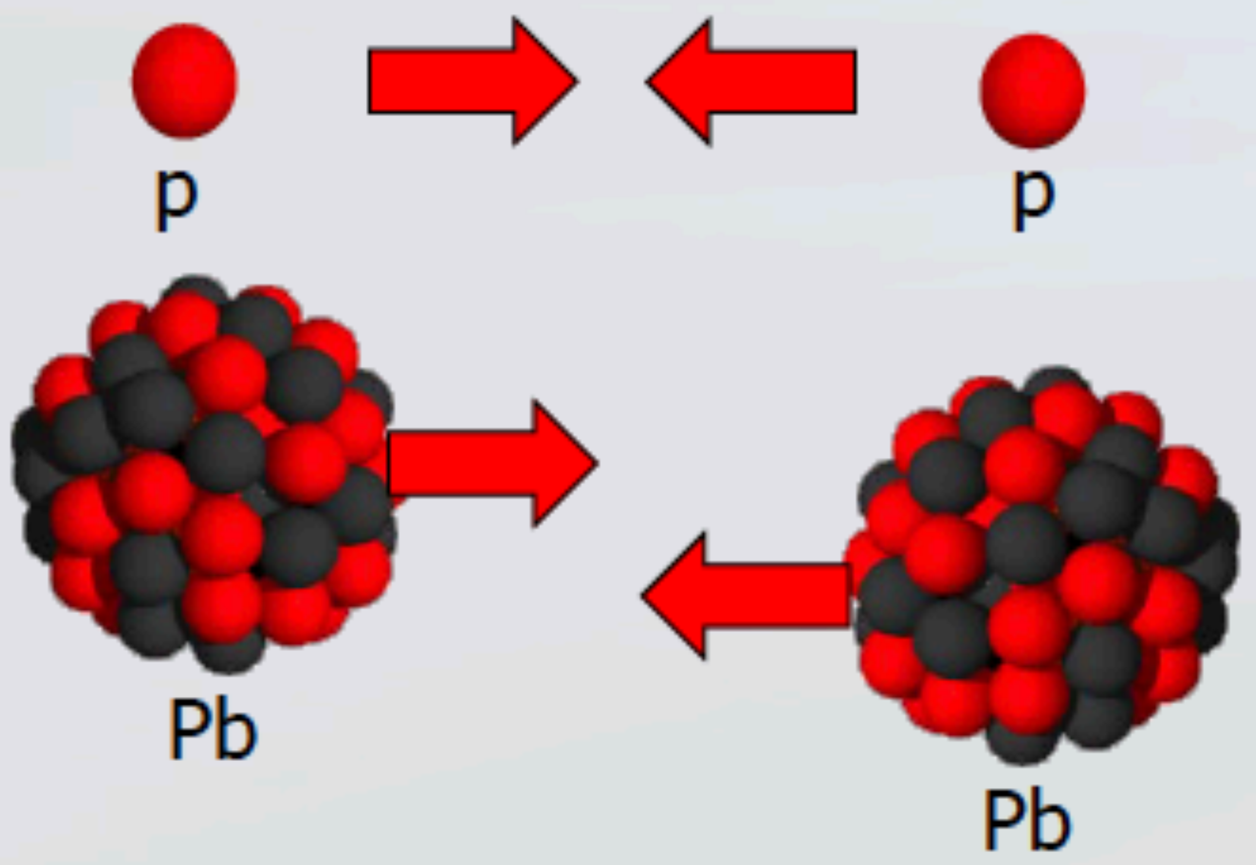
To probe the quark-gluon plasma…

5.02 TeV, PbPb: 246 μb^{-1}, pp: 1.17 pb^{-1}
b→μ, c→μ

- Partons lose energy when traverse nuclear medium
- Suppression of small-angle gluon radiation for massive quarks at low p_T

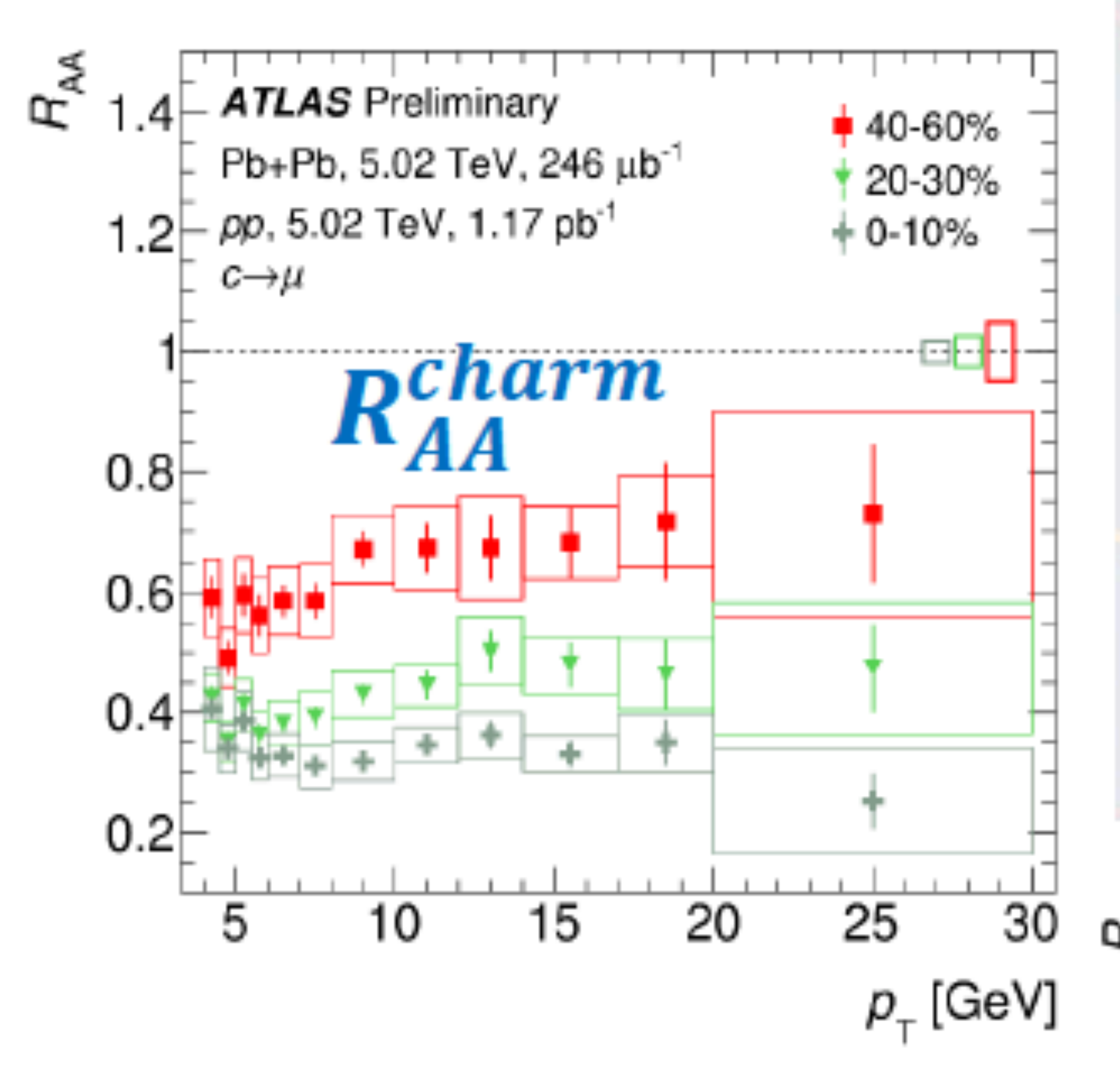
$$R_{AA} = \frac{N_{AA}/N_{evt}}{\langle T_{AA}\rangle \times \sigma^{pp}}$$

Modification to particle yields compared to pp scattering



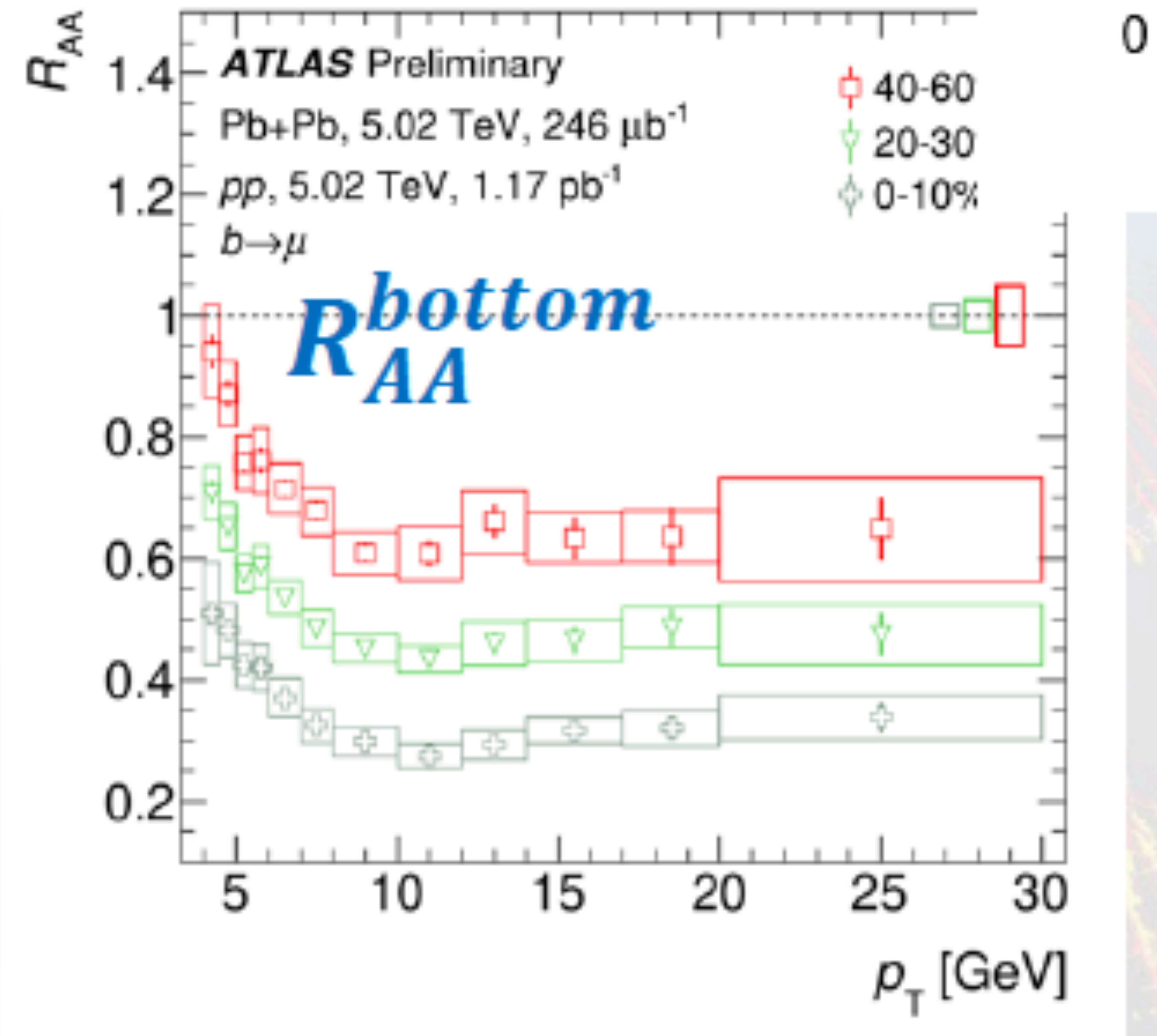
0-10% **40-60%**

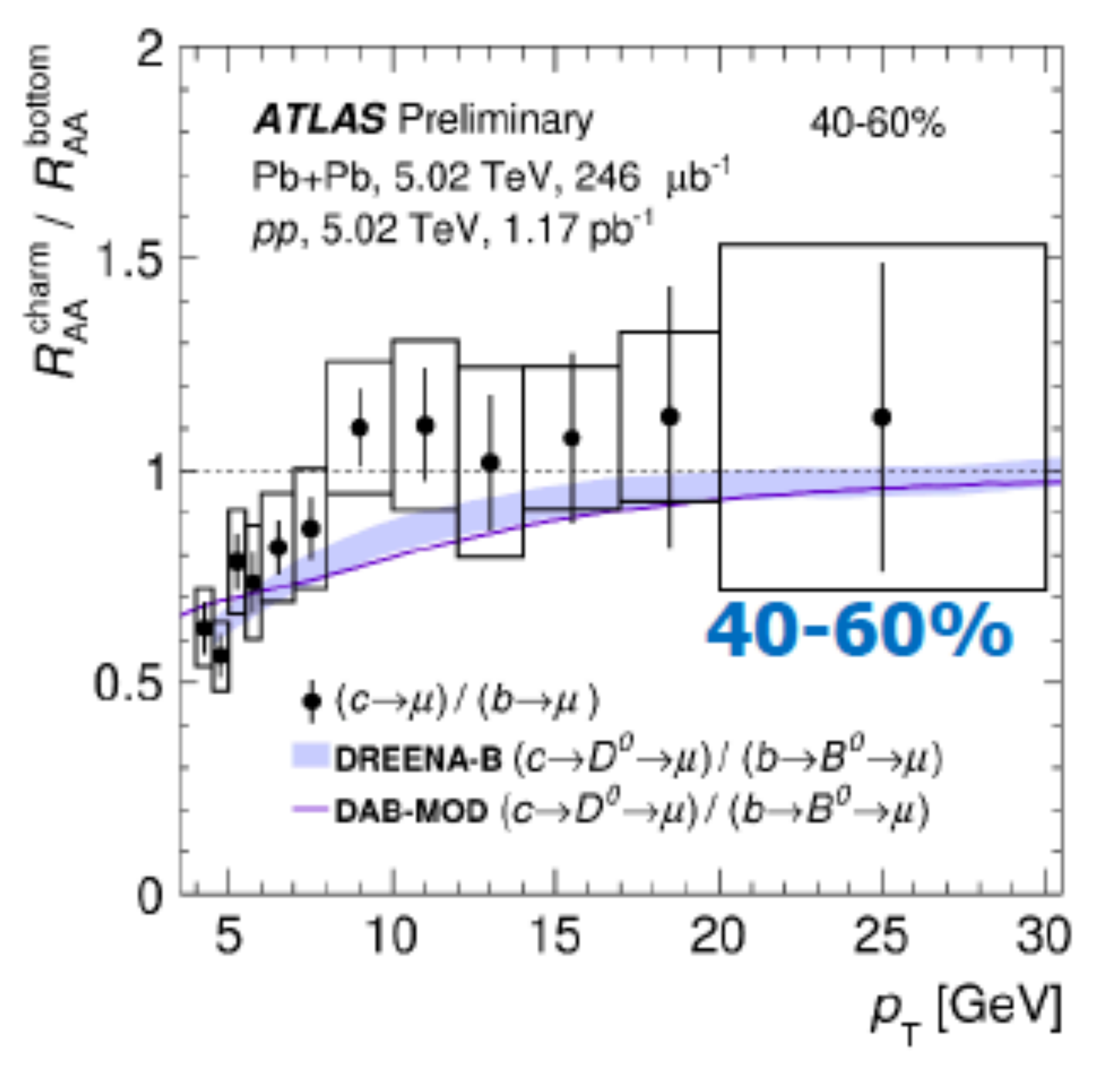
Centrality: overlap of colliding nuclei



Suppression increases monotonically from peripheral to central collisions

Stronger c→μ modification at low p_T

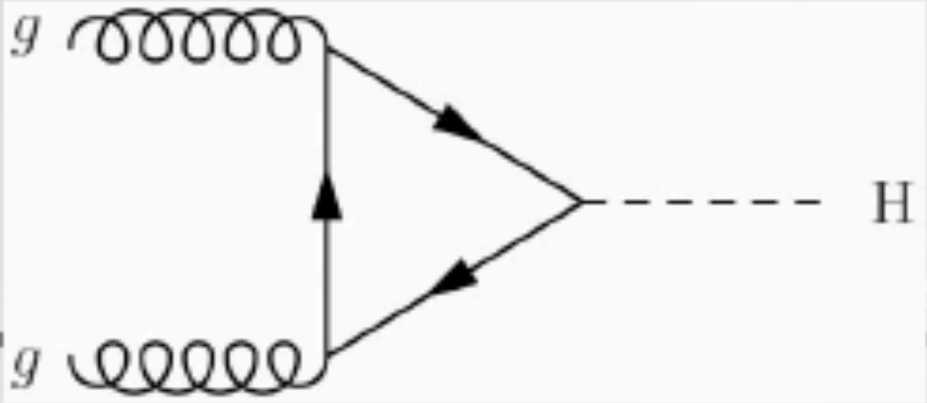




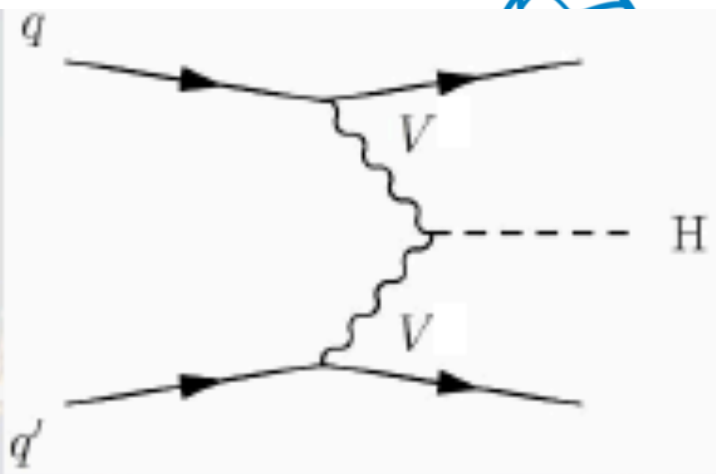
$$\frac{R_{AA}^{charm}}{R_{AA}^{bottom}}$$

$H \to WW^*$ production

13 TeV, 139 fb^{-1}
$H \to W^{\pm}W^{\mp *} \to e^{\pm}\nu\mu^{\mp}\nu$

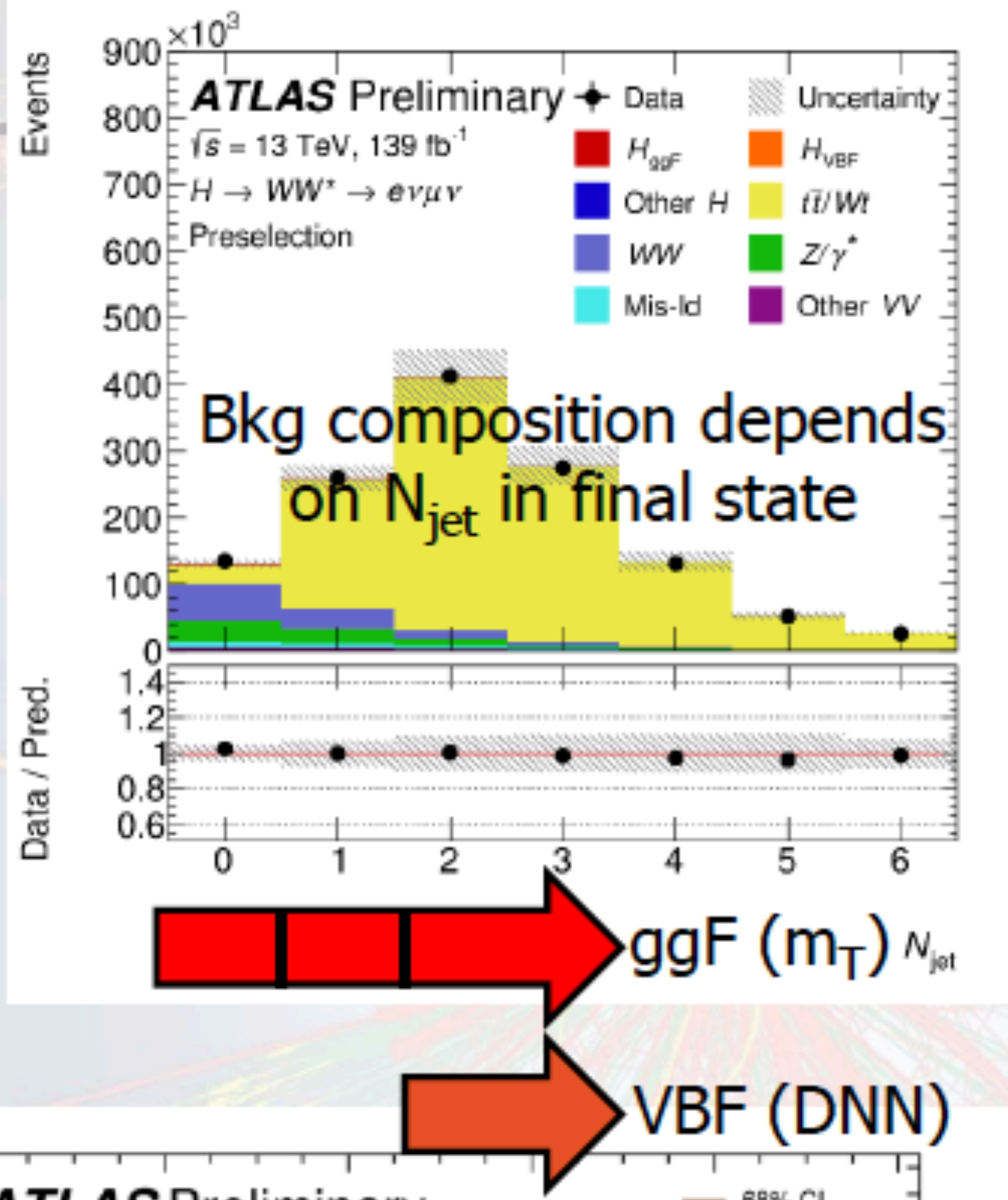


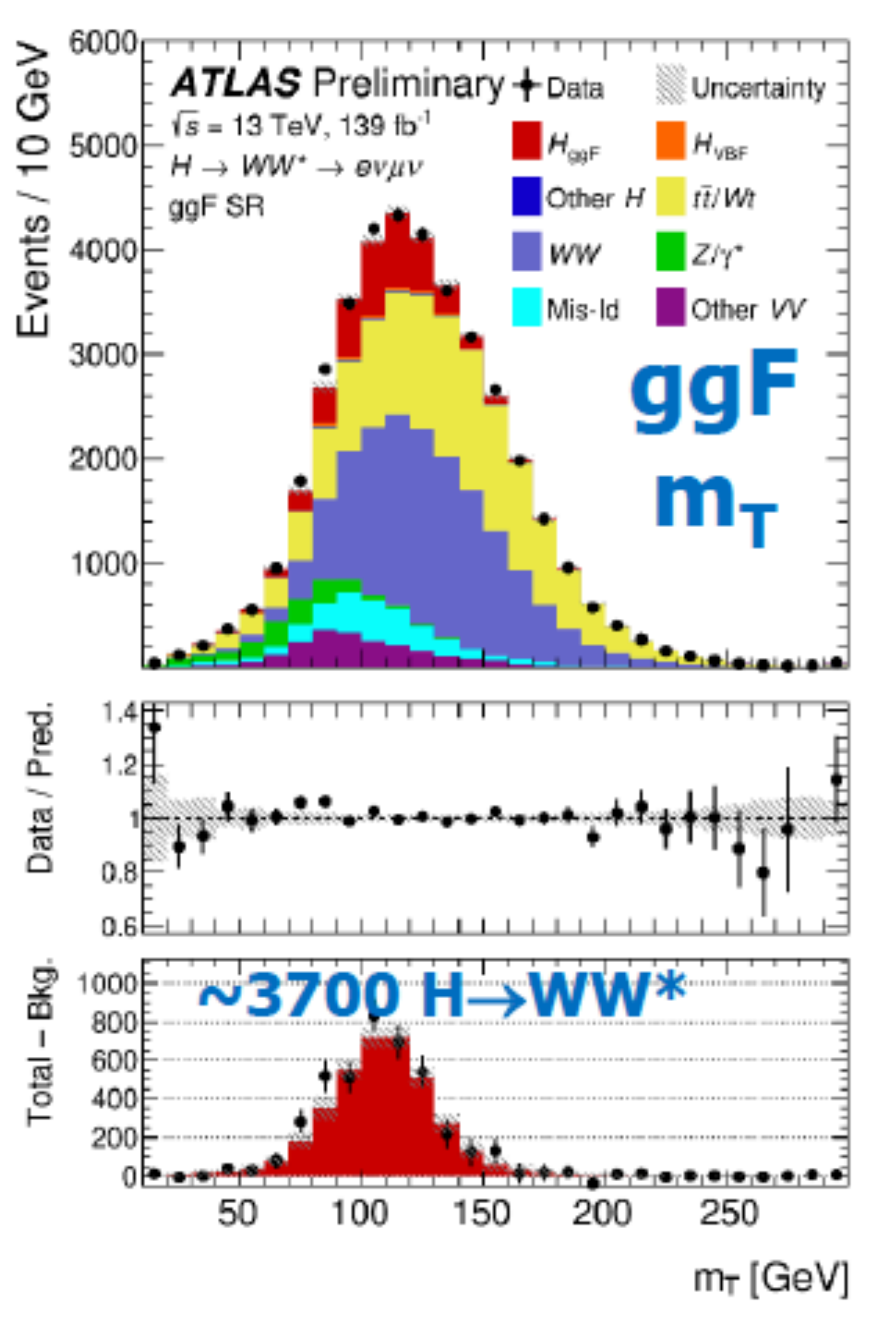
Gluon fusion ggF
$\sigma \cdot B(H \to WW^*) \sim 10$ pb

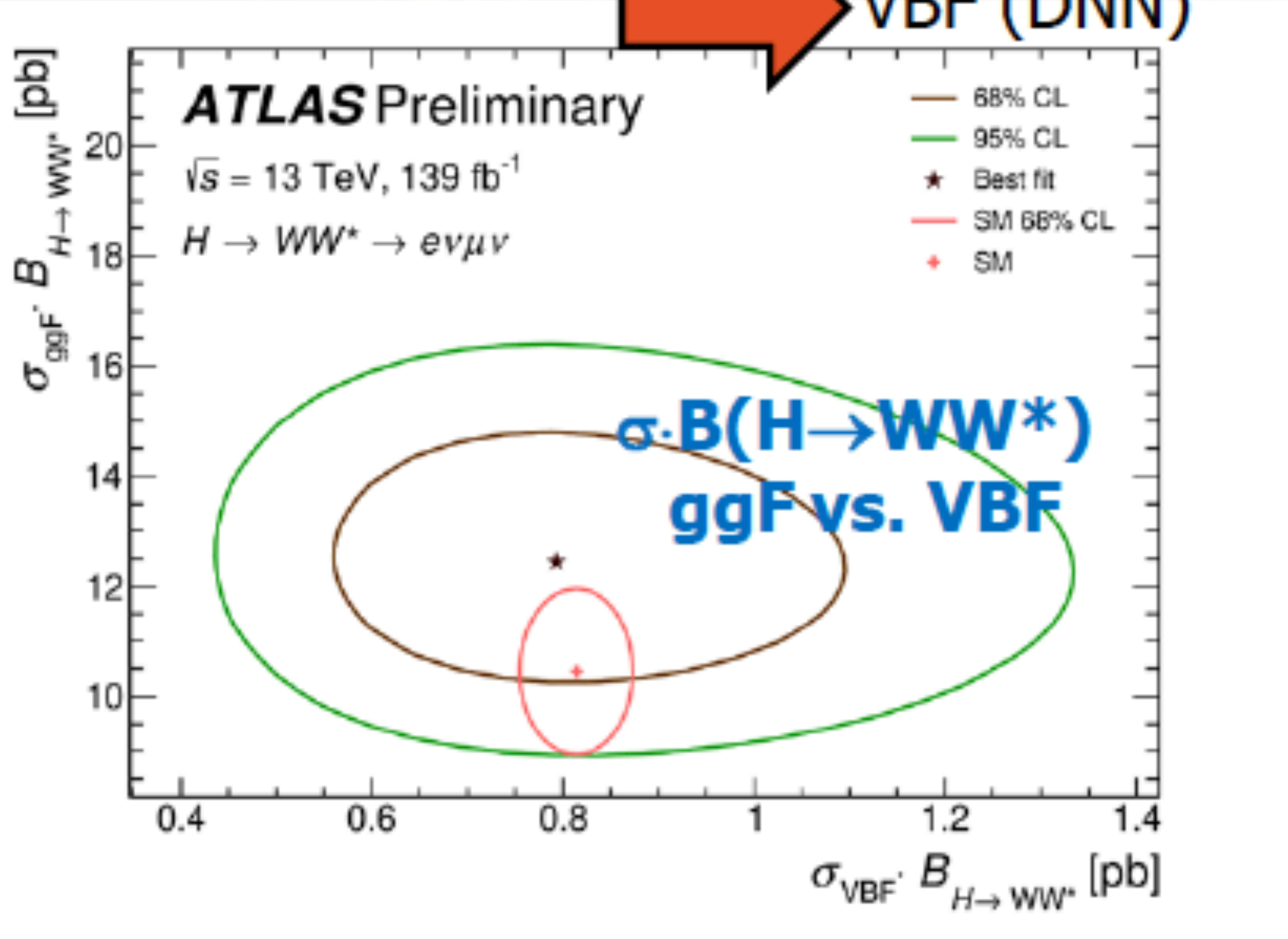


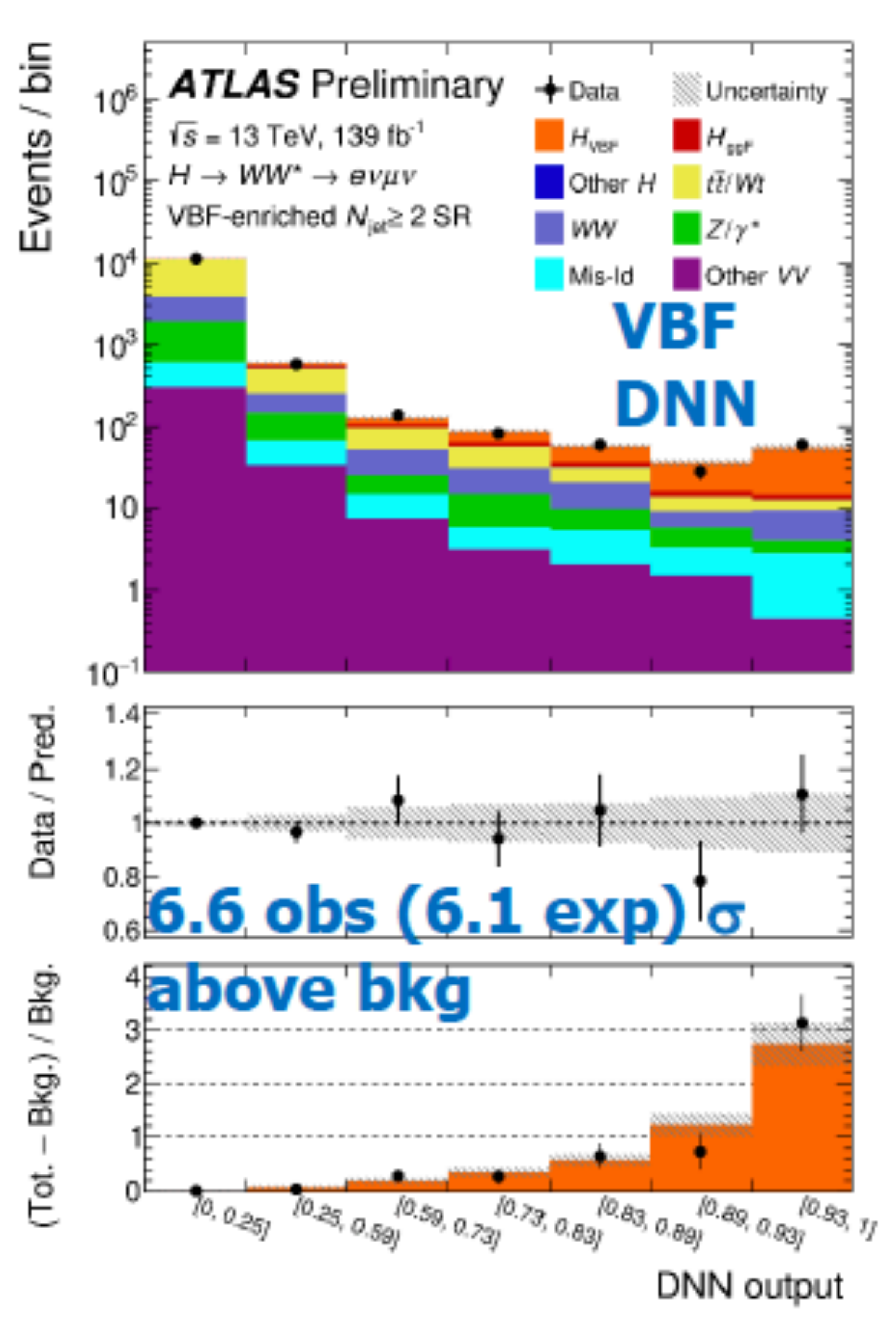
Vector-boson fusion VBF
$\sigma \cdot B(H \to WW^*) \sim 1$ pb

To probe Higgs-boson production and decay mechanisms…





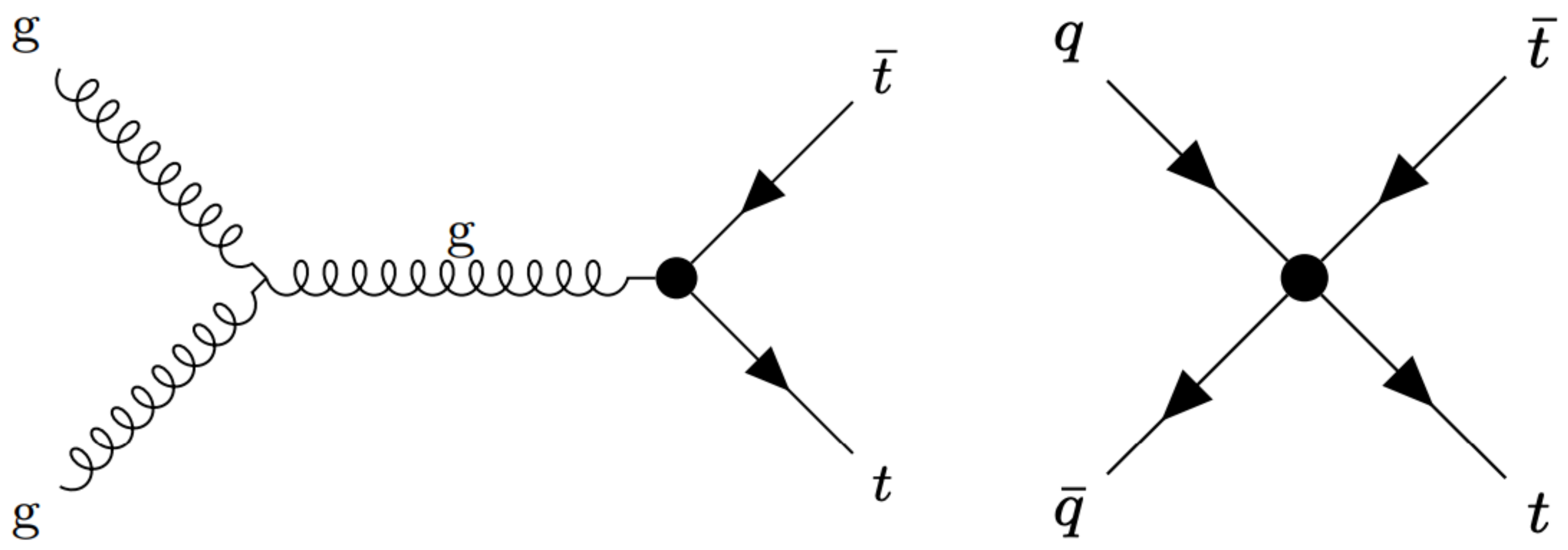


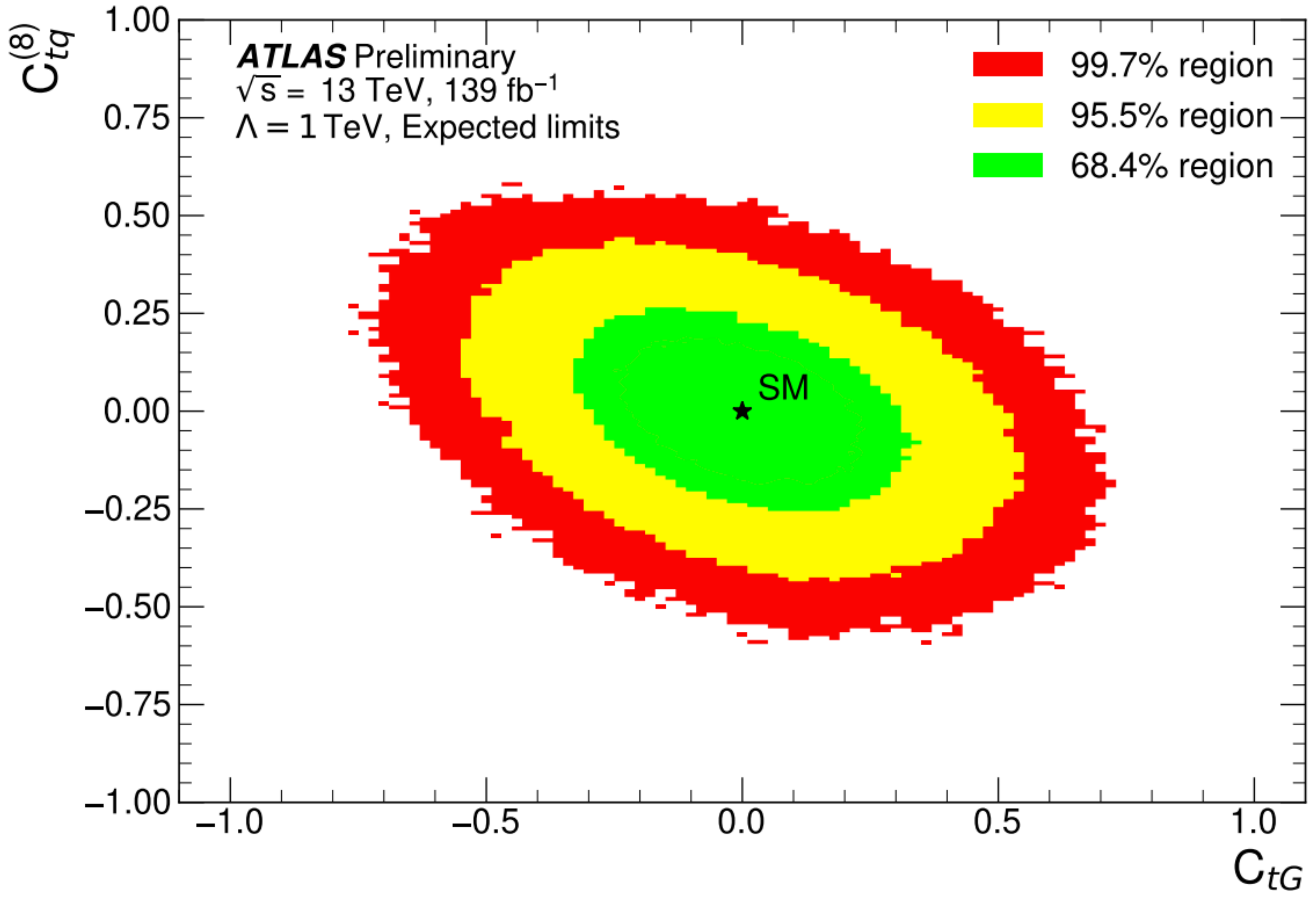


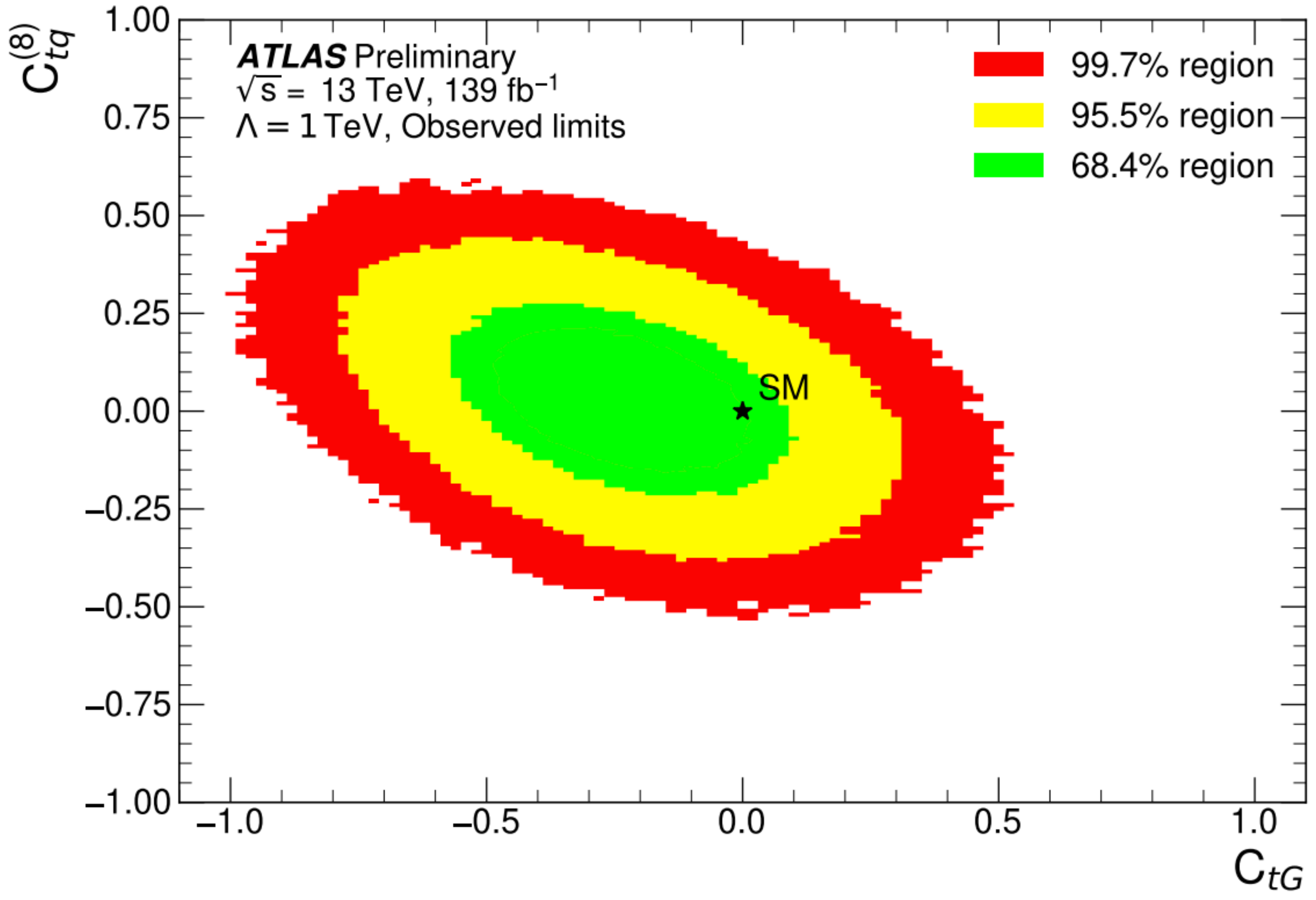
11 fiducial [Stage 1.2 STXS] cross sections
(6 ggH, 5 EW qqH)
[see backup]

Top-quark EFT constraints

- EFT constraints from $t\bar{t}$ production

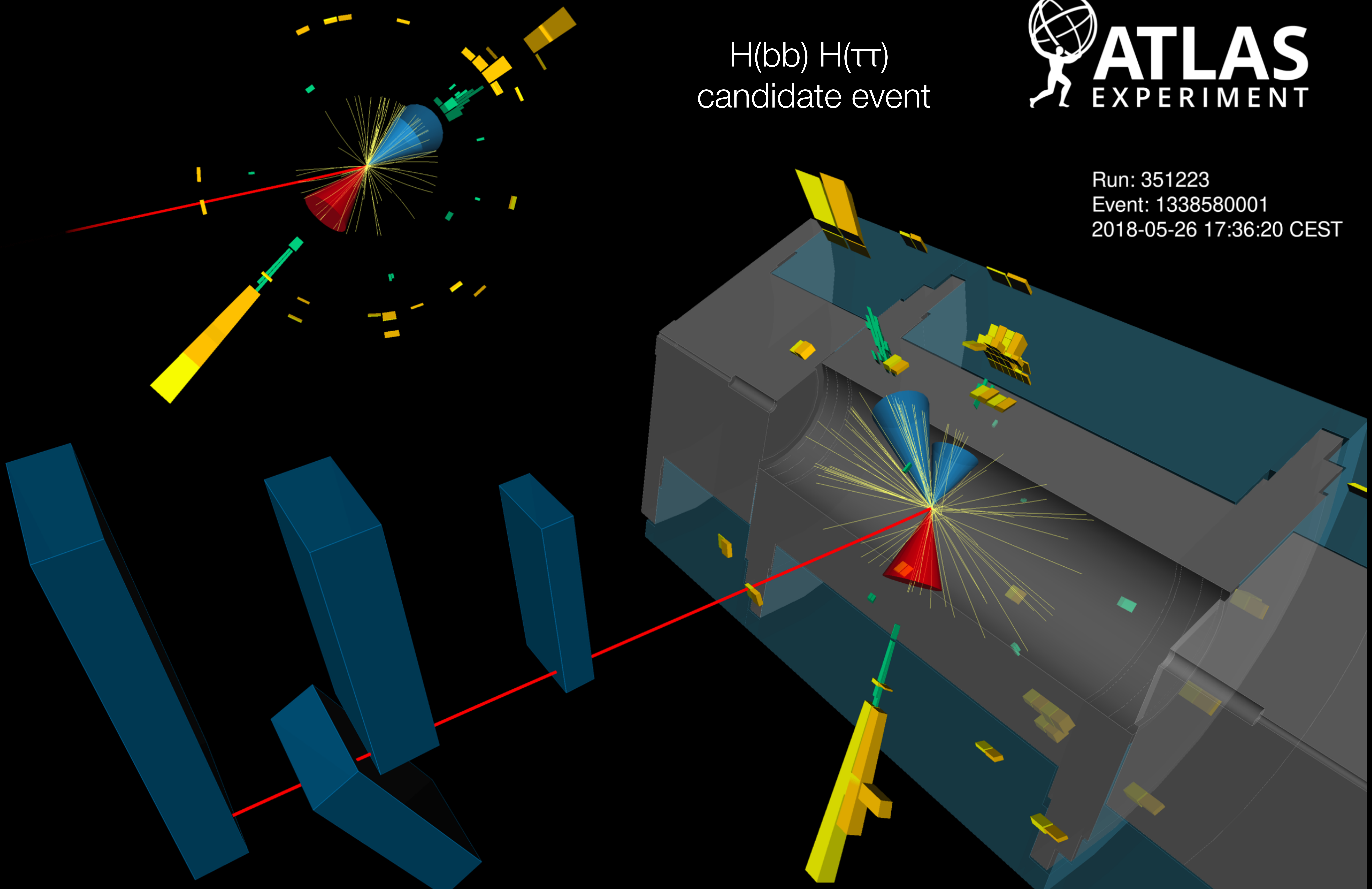






H(bb) H(ττ)
candidate event

ATLAS EXPERIMENT



Run: 351223
Event: 1338580001
2018-05-26 17:36:20 CEST

Heavy particle searches

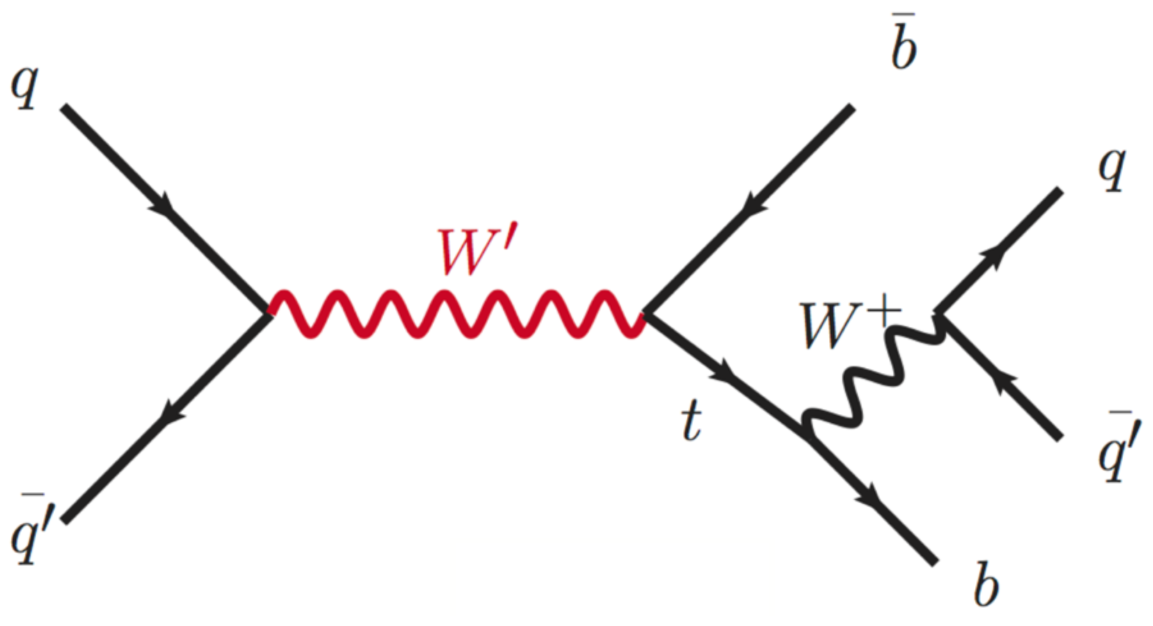
New

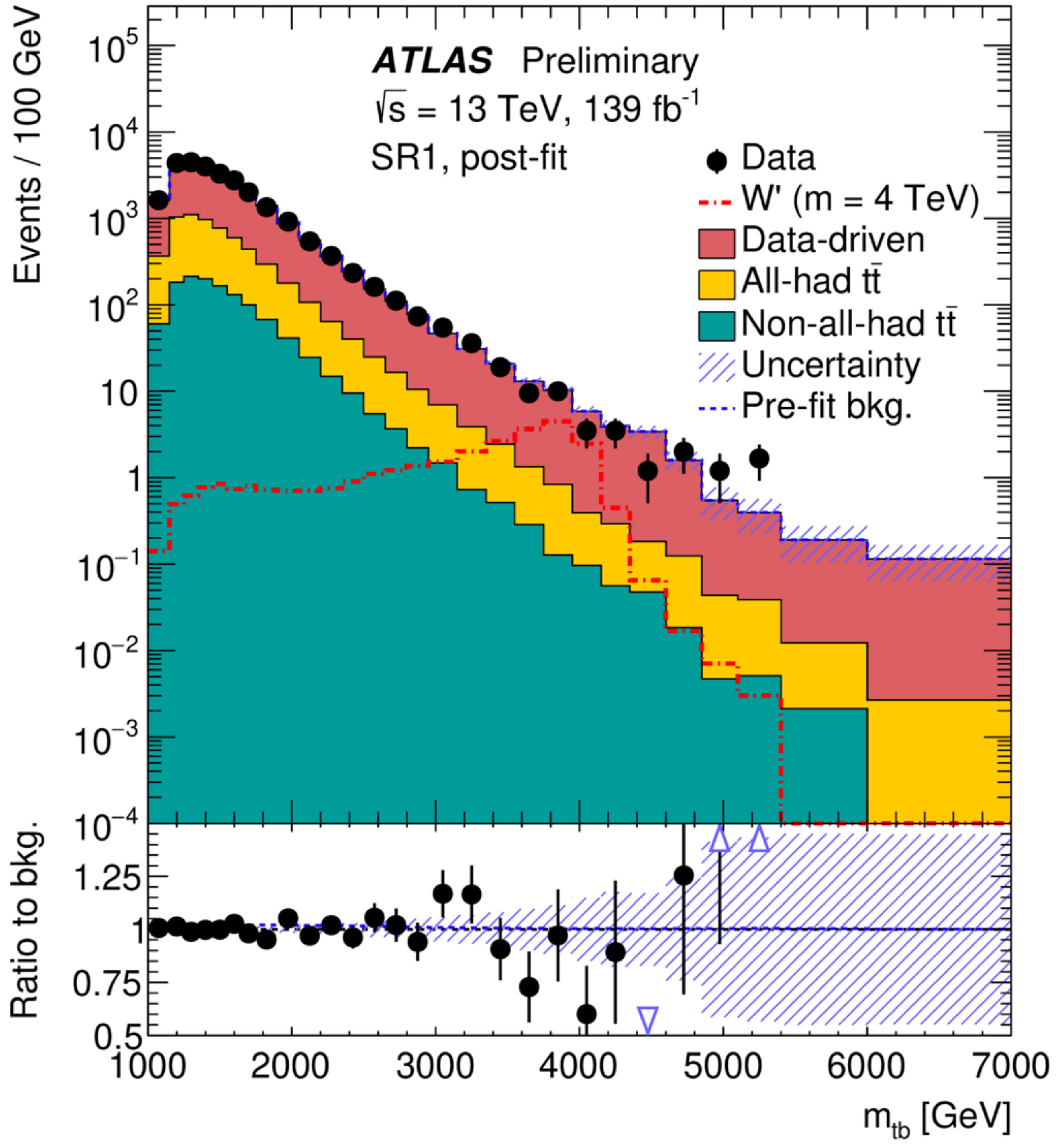
ATLAS-CONF-2021-043 ATLAS-CONF-2021-040

ATLAS EXPERIMENT

$\mathcal{L} = \mathcal{L}_{SM} + \mathcal{L}_{BSM}$

- Motivated by hierarchy problem —> new physics at TeV scale
- **Heavy gauge boson** with right-handed couplings
  - Top-tagged large-R jet + b-tagged small-R jet
  - Deep NN top tagger using jet substructure
  - Discriminant: m_{tb}



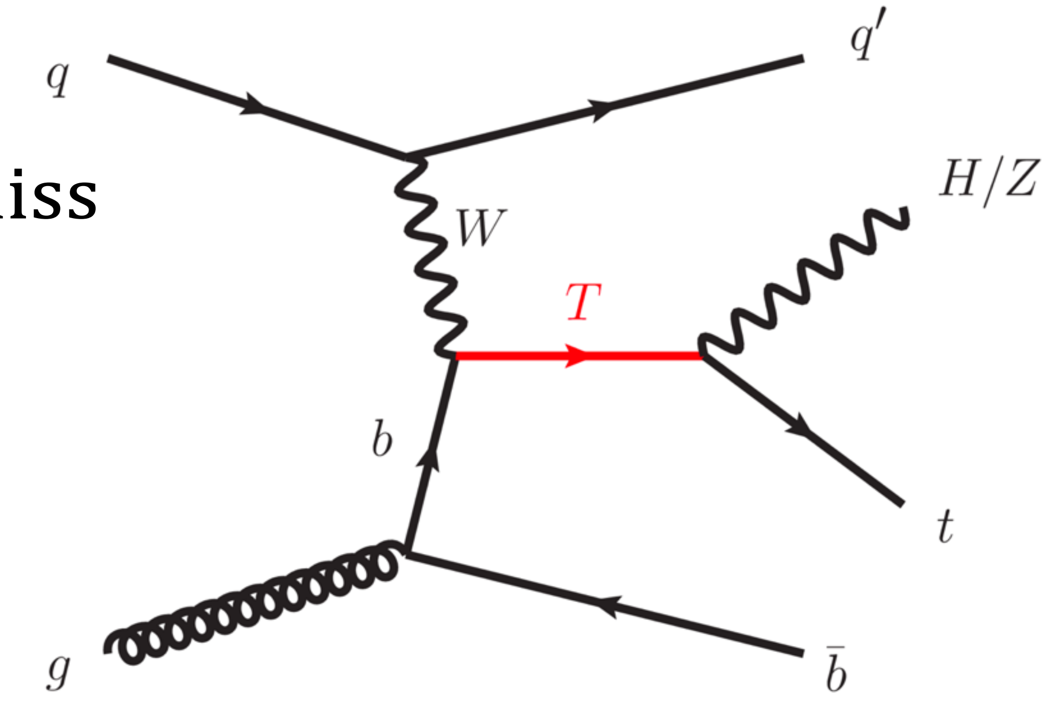


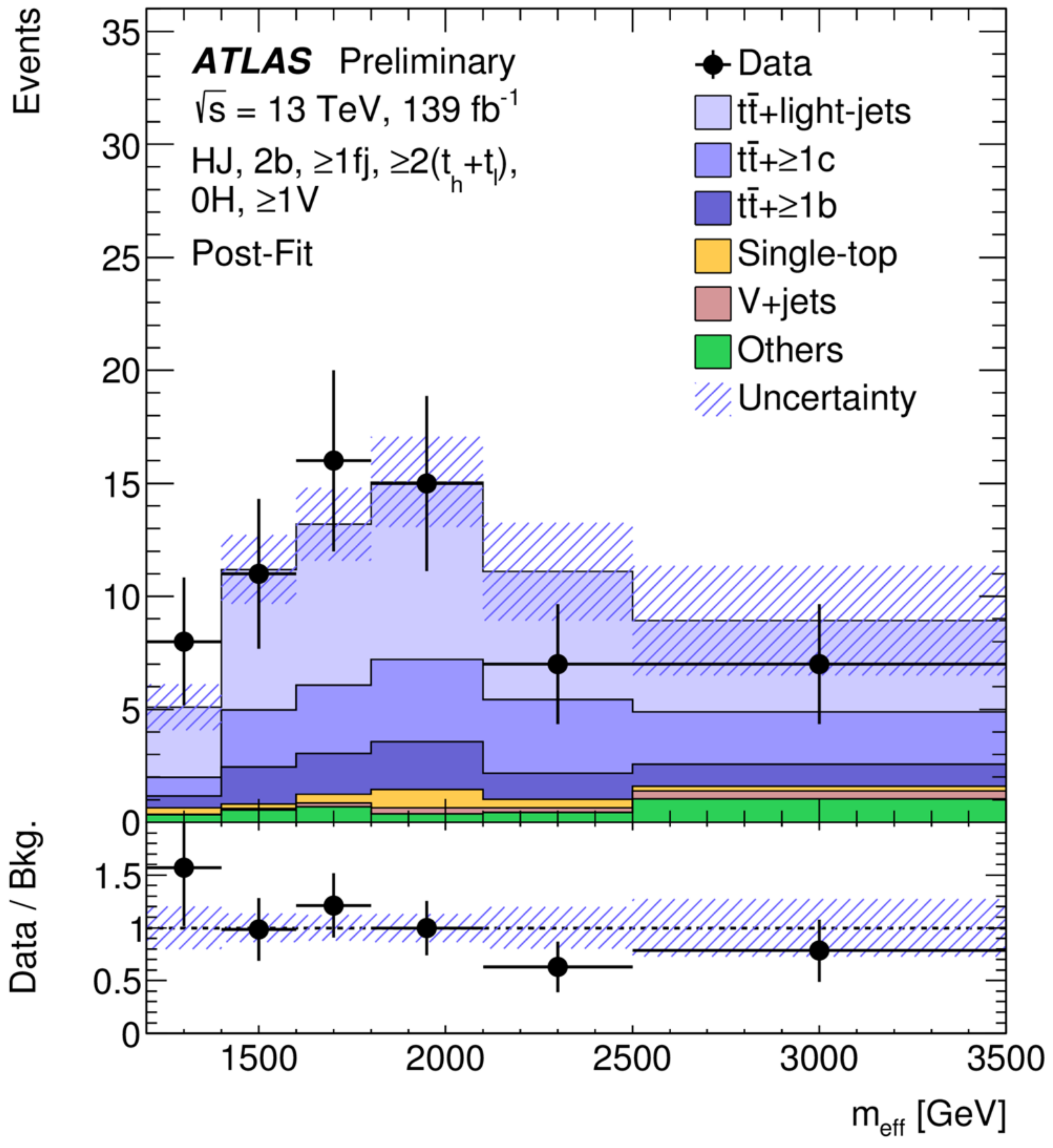
$m(W_R') > 4.4\text{TeV}(4.1\text{TeV})$

obs(exp)

lower limit improves upon best previous limit by 1 TeV

- **Vector-like top quark** (single production)
  - e/μ + Z/H-tagged large-R jet + small-R jets (some b-tagged)
  - Discr.: $m_{\text{eff}} = \sum_i p_{T\,i} + E_T^{\text{miss}}$





$m(T) > 1.8\text{TeV}(1.5\text{TeV})$

obs(exp)

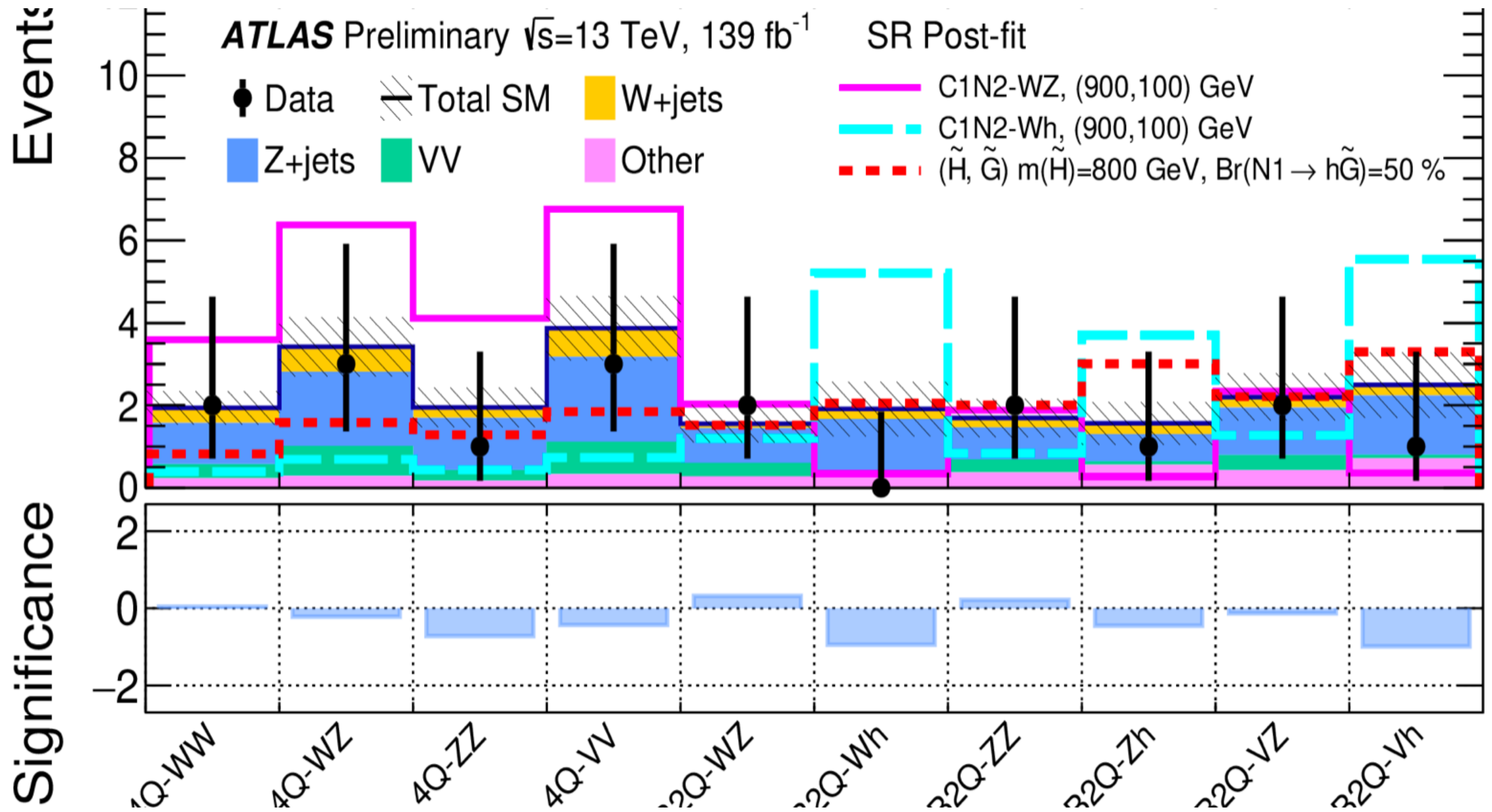
$\text{for coupling}\, \kappa \geq 0.5$

SUSY: Electroweak production

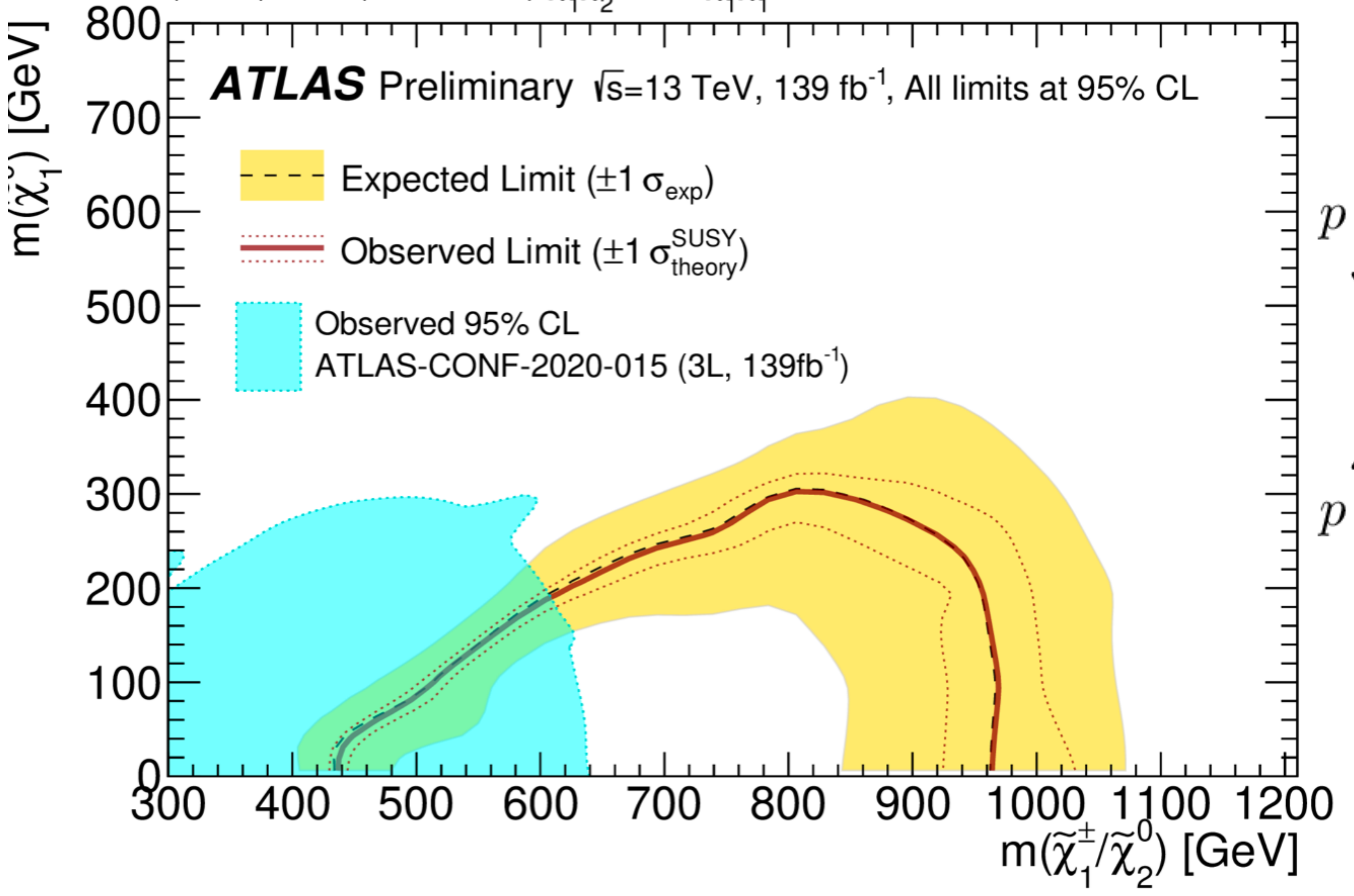
ATLAS-CONF-2021-022

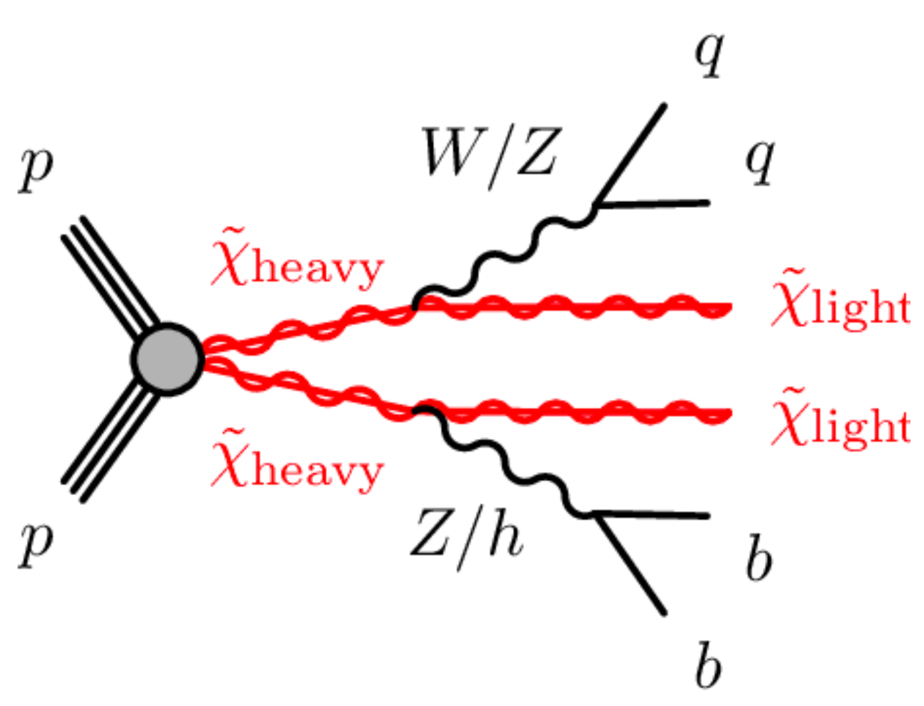
$$\mathcal{L} = \mathcal{L}_{SM} + \mathcal{L}_{SUSY}$$

- **Electroweakinos** with mass ~0.1—1 TeV well motivated:
  - Neutralino LSP as dark matter, naturalness problem, muon g-2 anomaly
- Target mass splitting between NLSP and LSP > 400 GeV
- *First SUSY EW search* with fully hadronic final state using large-R jets tagged as W/Z or H jets
- Strongest limits at high electroweakino mass

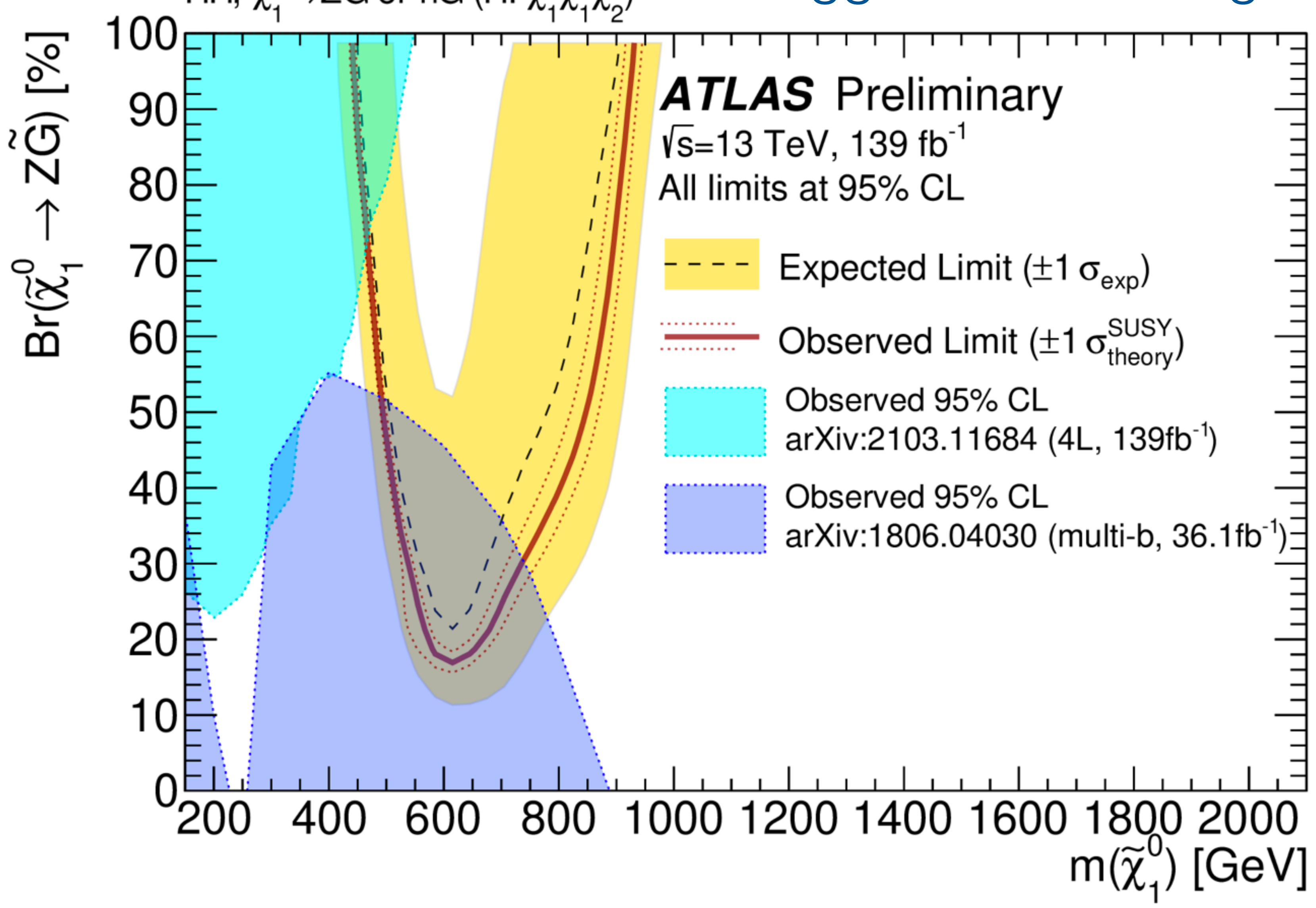


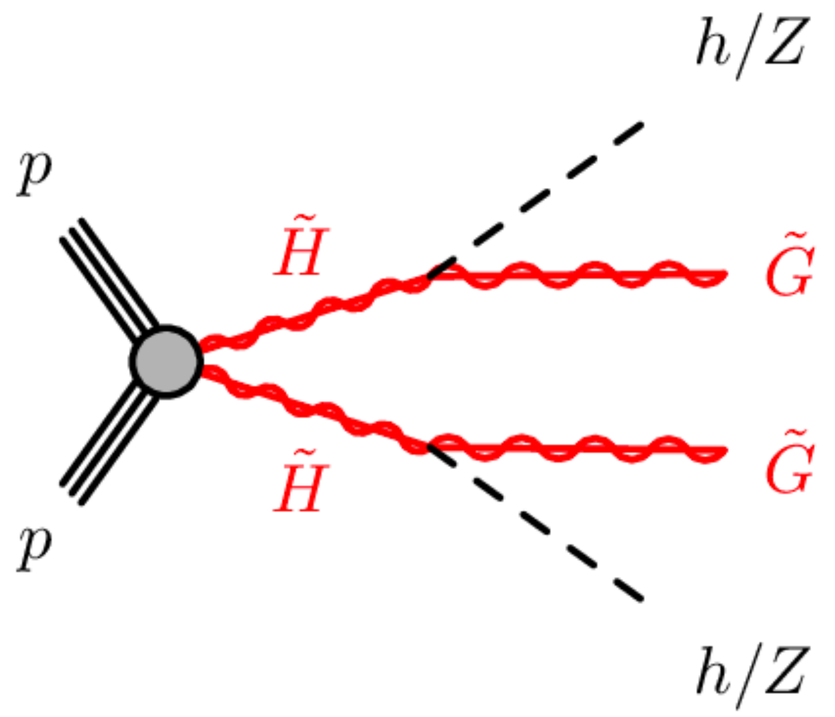
wino NLSP to bino LSP





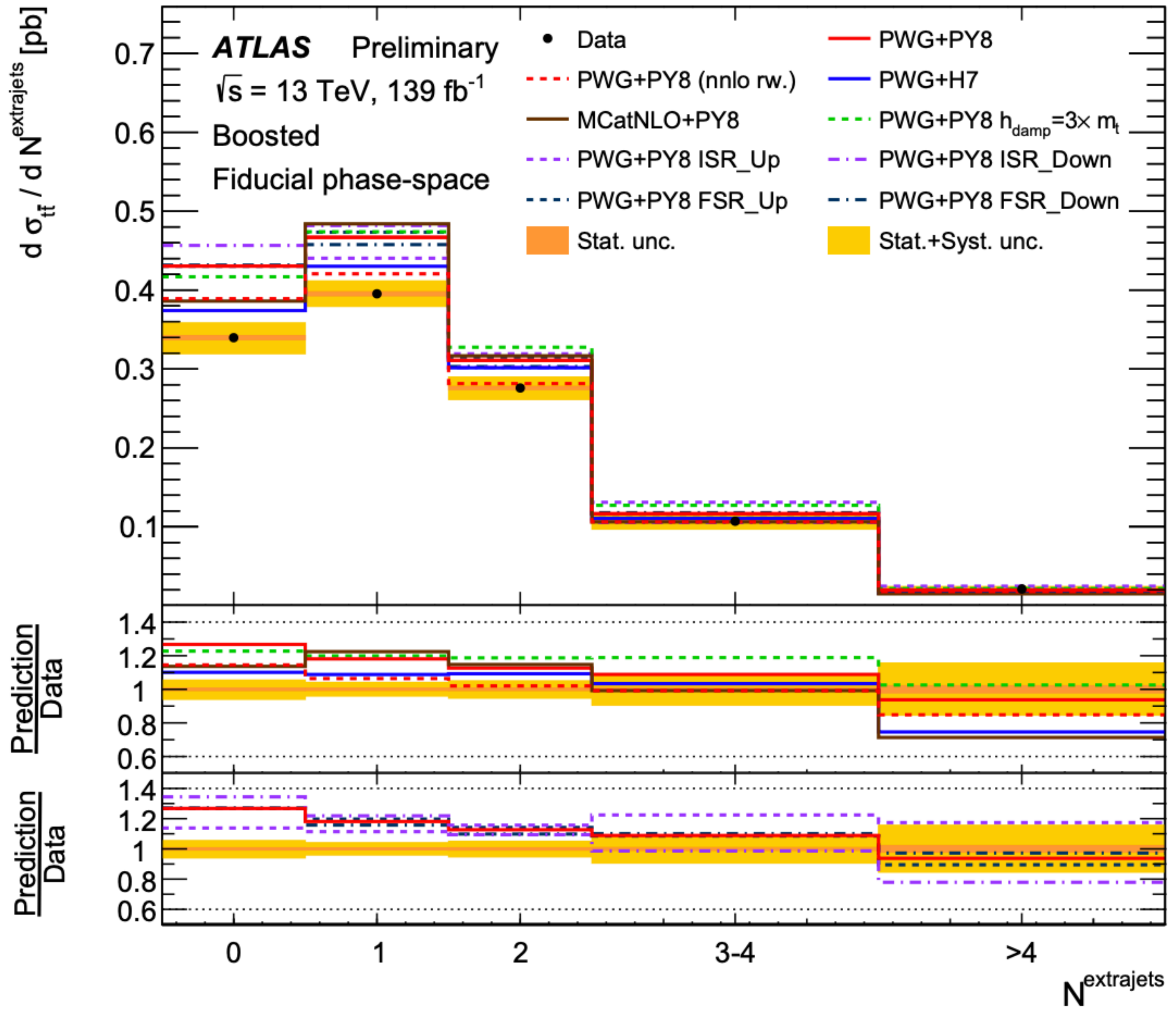
higgsino NLSP to gravitino LSP

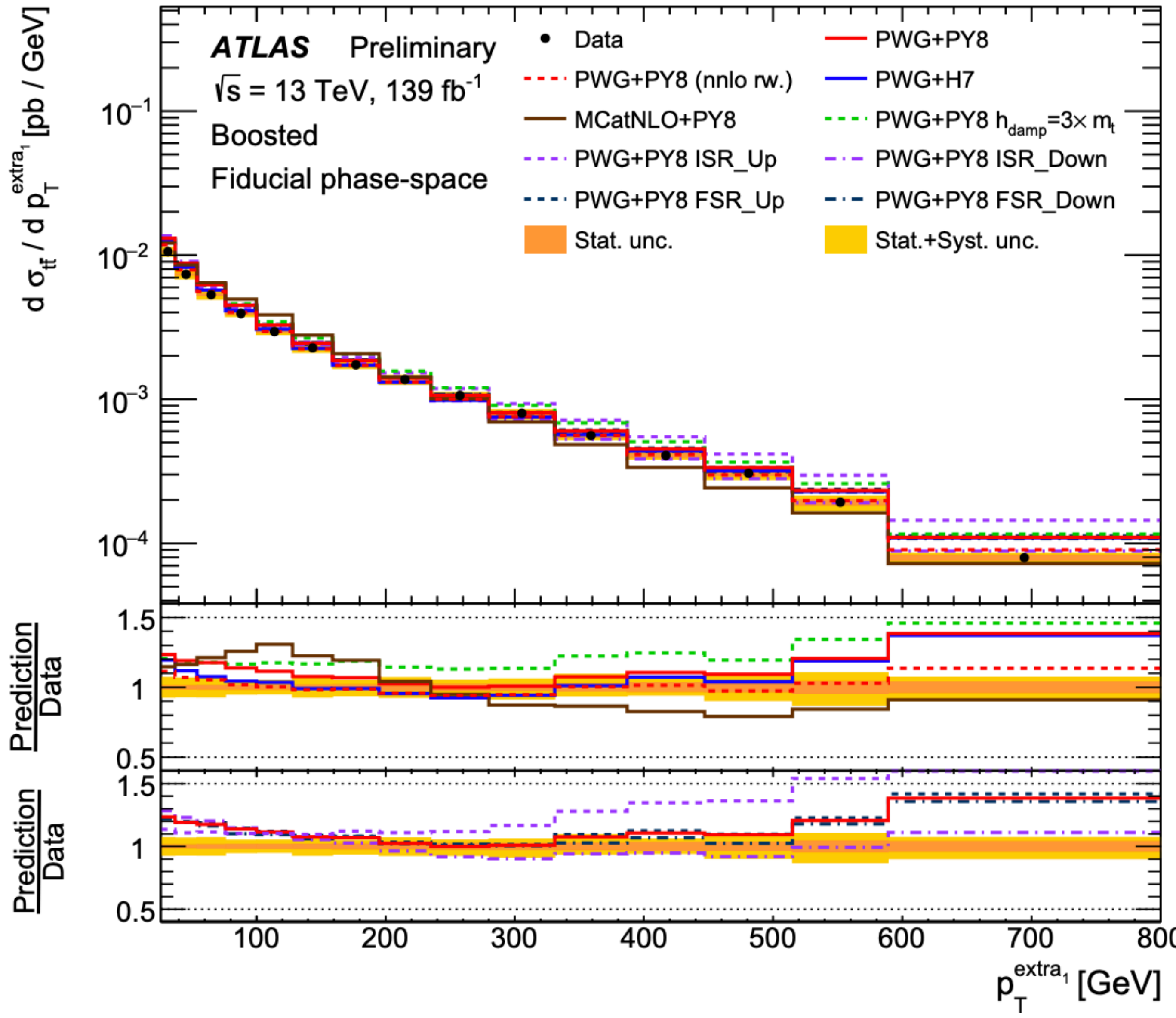


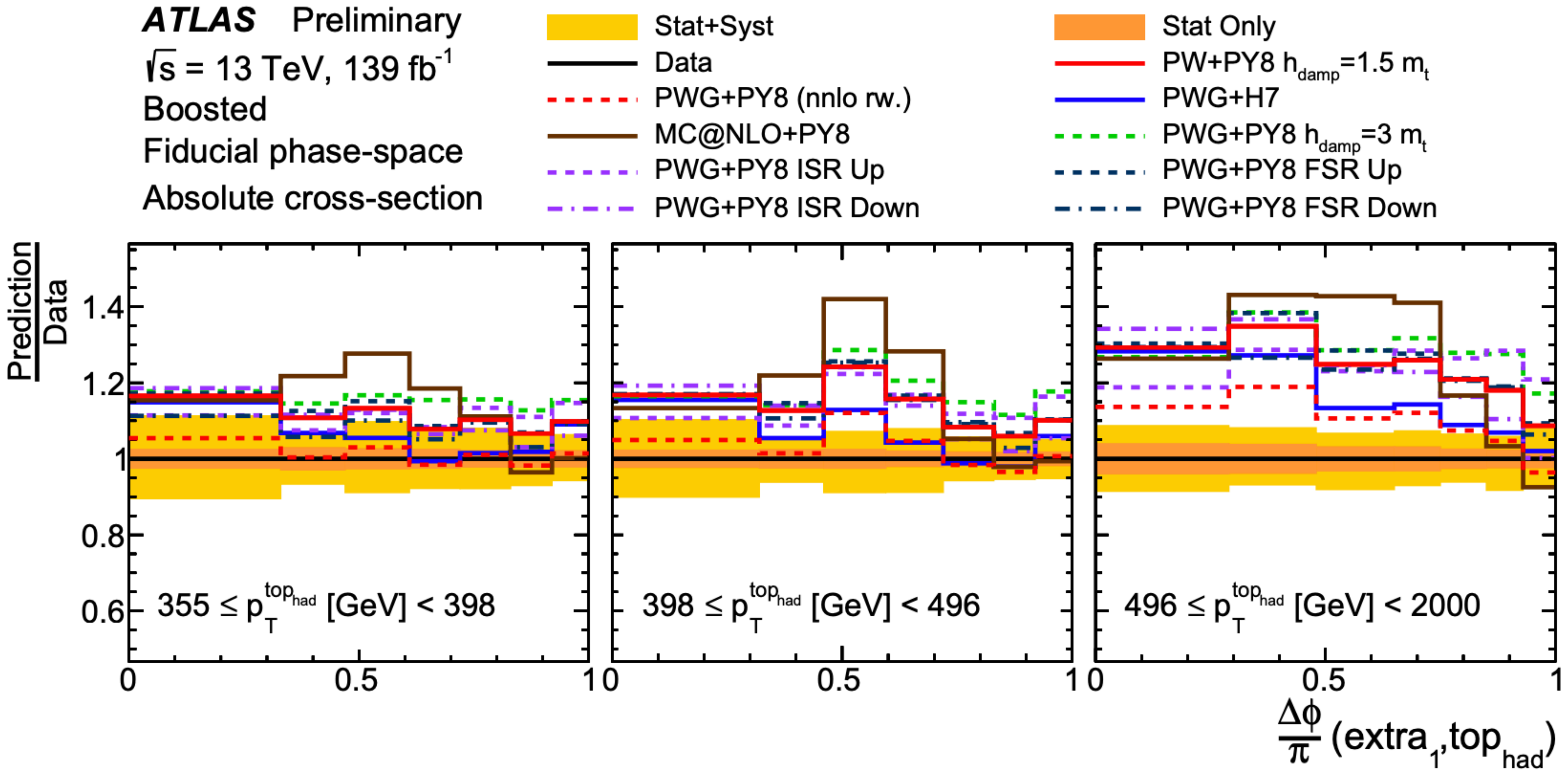


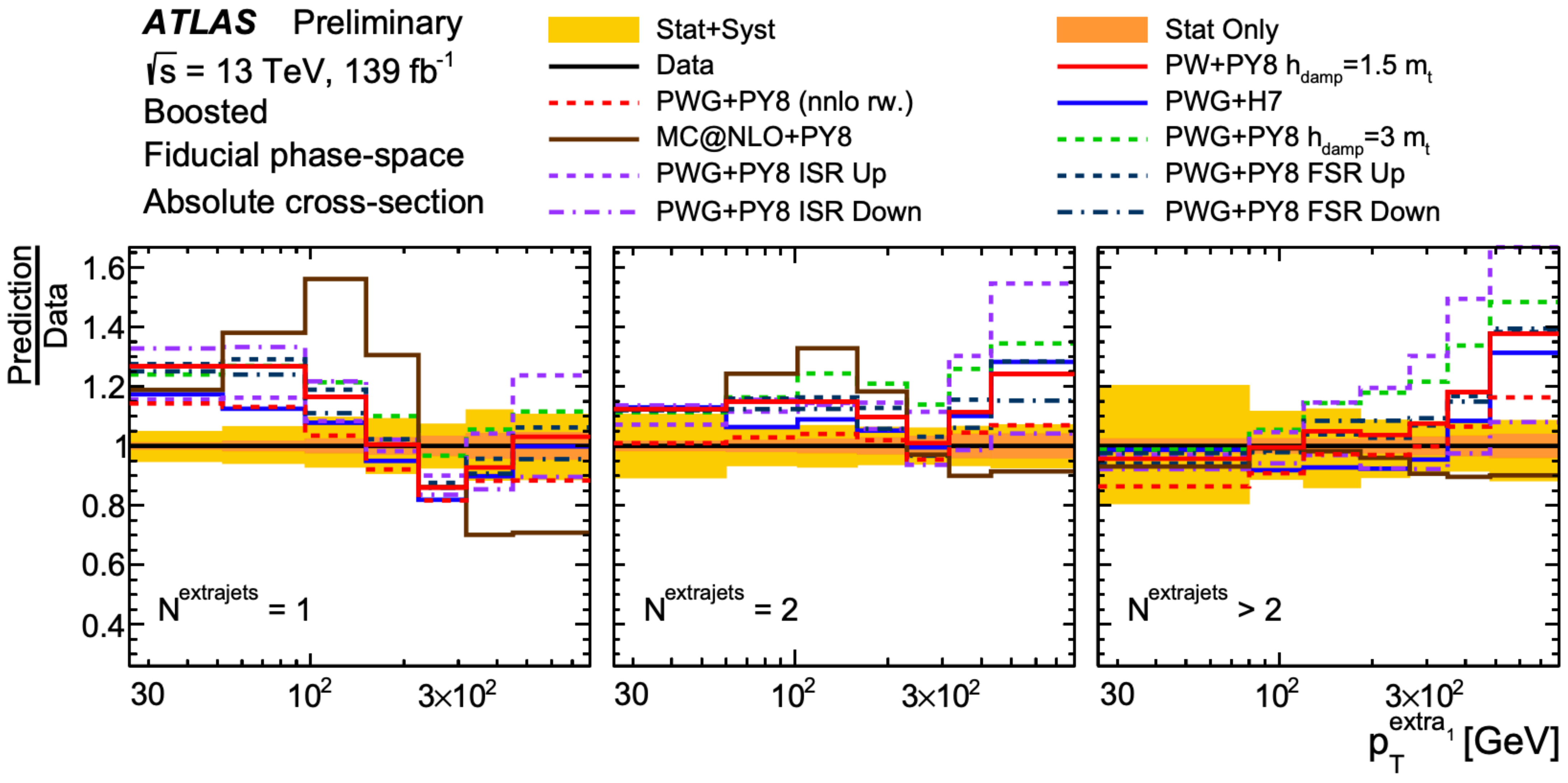
Top-quark production

- Measurements of $t\bar{t}$ system + additional jets
  - Difficulties in modeling of additional radiation in events with high-pT top quarks —> test of parton shower









$t\bar{t}t\bar{t}$ production

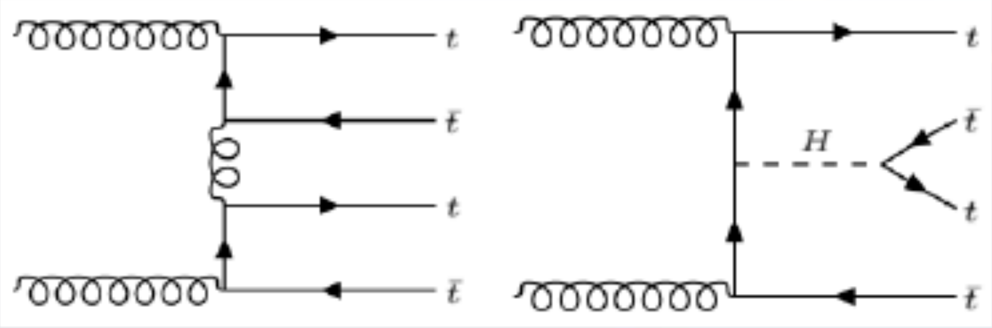
[ATLAS-CONF-2021-013](#)
[Physics Briefing](#)

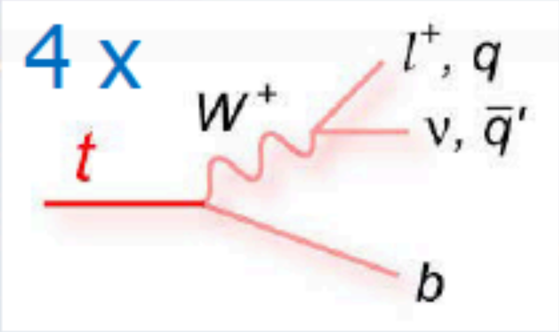
To probe t-H Yukawa coupling, sensitivity to BSM processes…

Enhancements from pair production gluino & scalar gluons, 2HDM

13 TeV, 139 fb^{-1}
$t\bar{t}t\bar{t}$ 1 ℓ / 2 ℓ OS (ℓ = e,μ)
[57% of $t\bar{t}t\bar{t}$ events]

Challenge: $t\bar{t}$ bkg

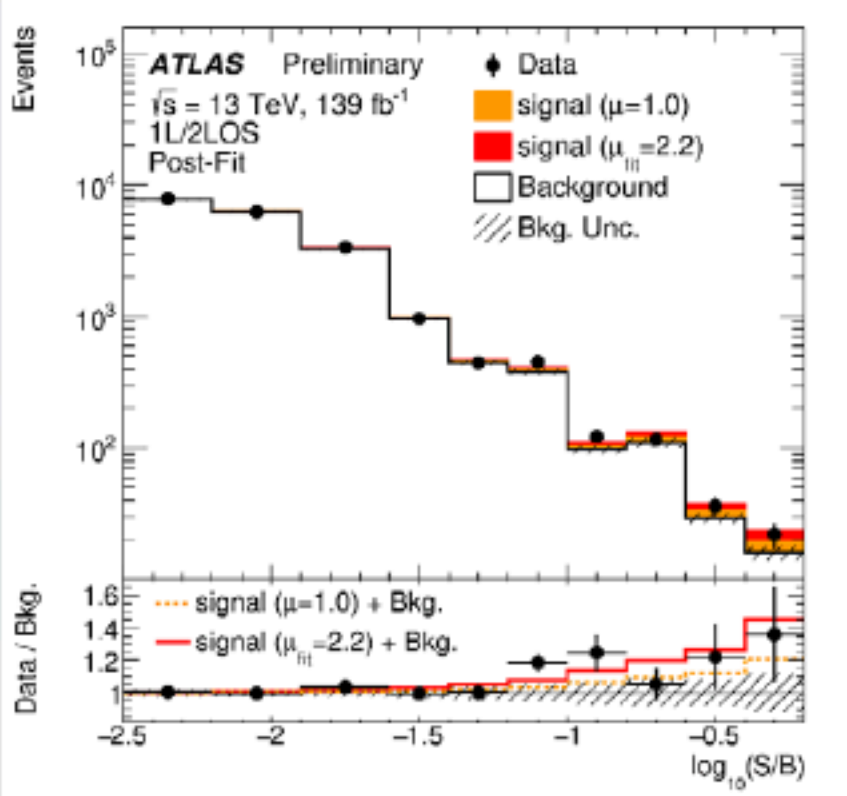


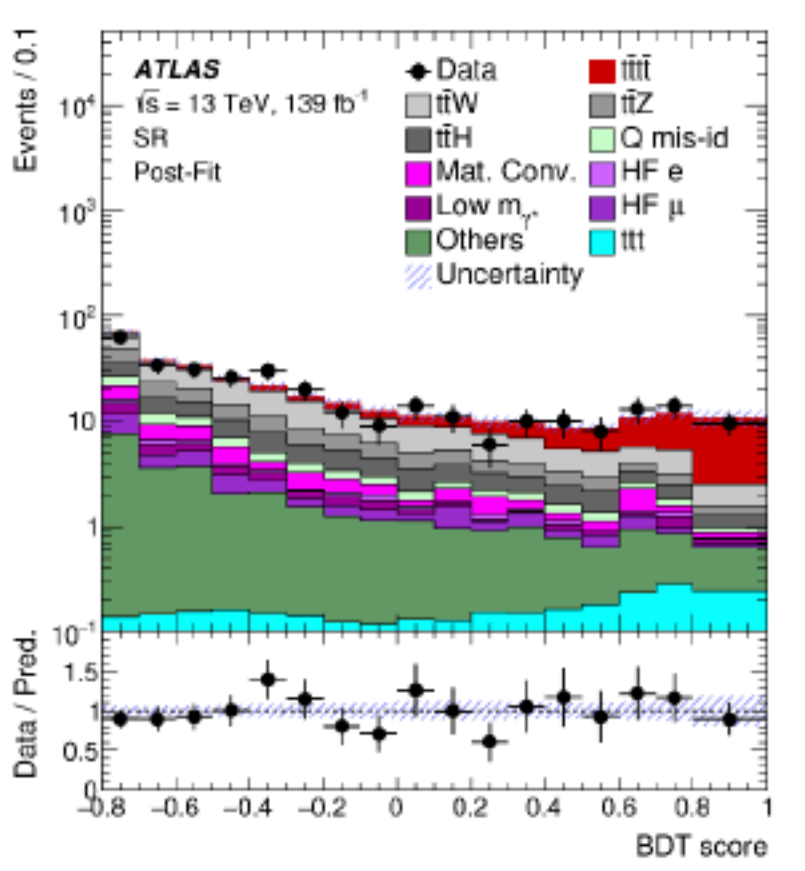


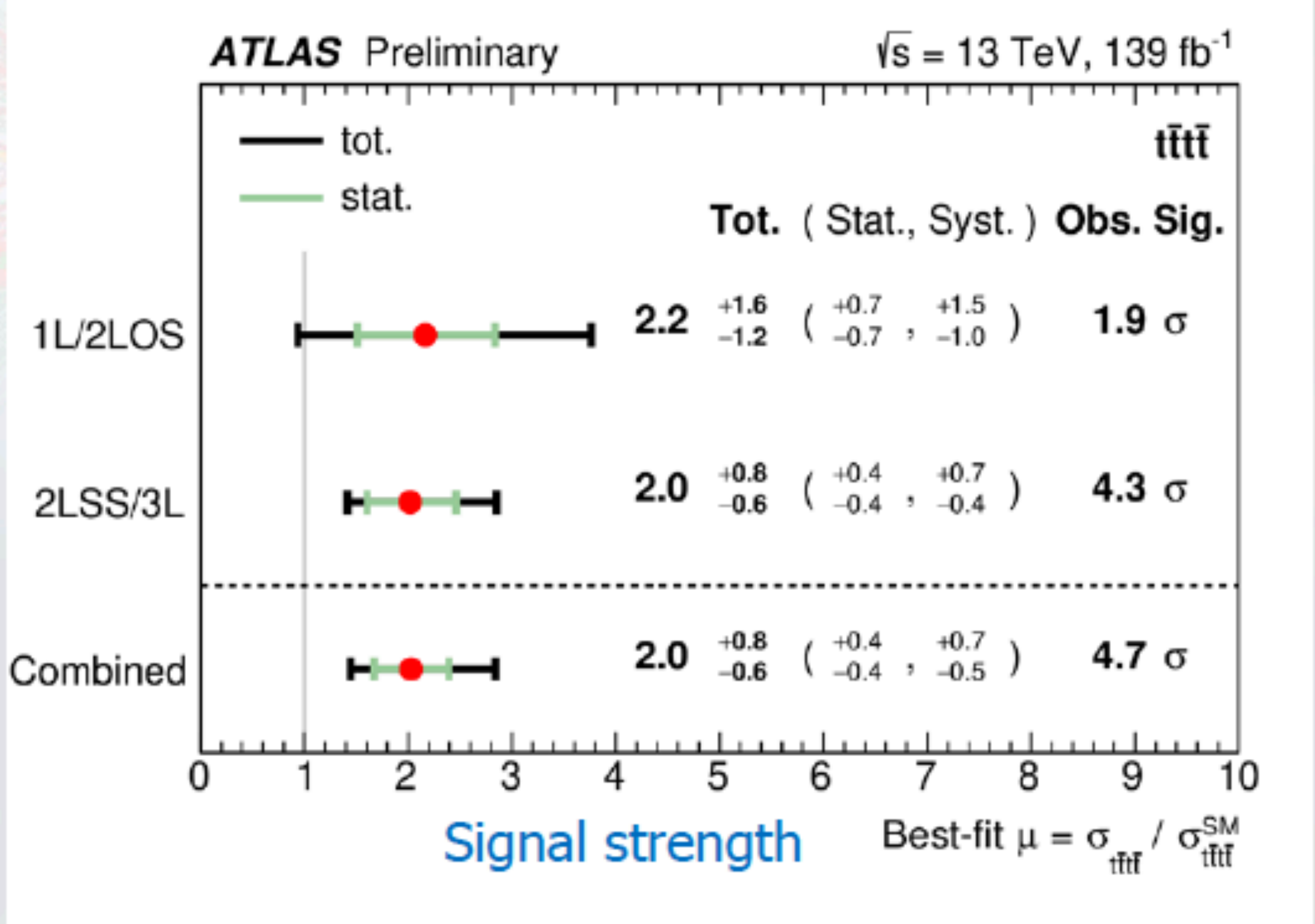
+ combined fit with Eur. Phys. J. C 80 (2020) 1085

13 TeV, 139 fb^{-1}
$t\bar{t}t\bar{t}$ 2 ℓ SS / 3 ℓ (ℓ = e,μ)
[13% of $t\bar{t}t\bar{t}$ events]

Binned profile likelihood [BDT in signal regions]





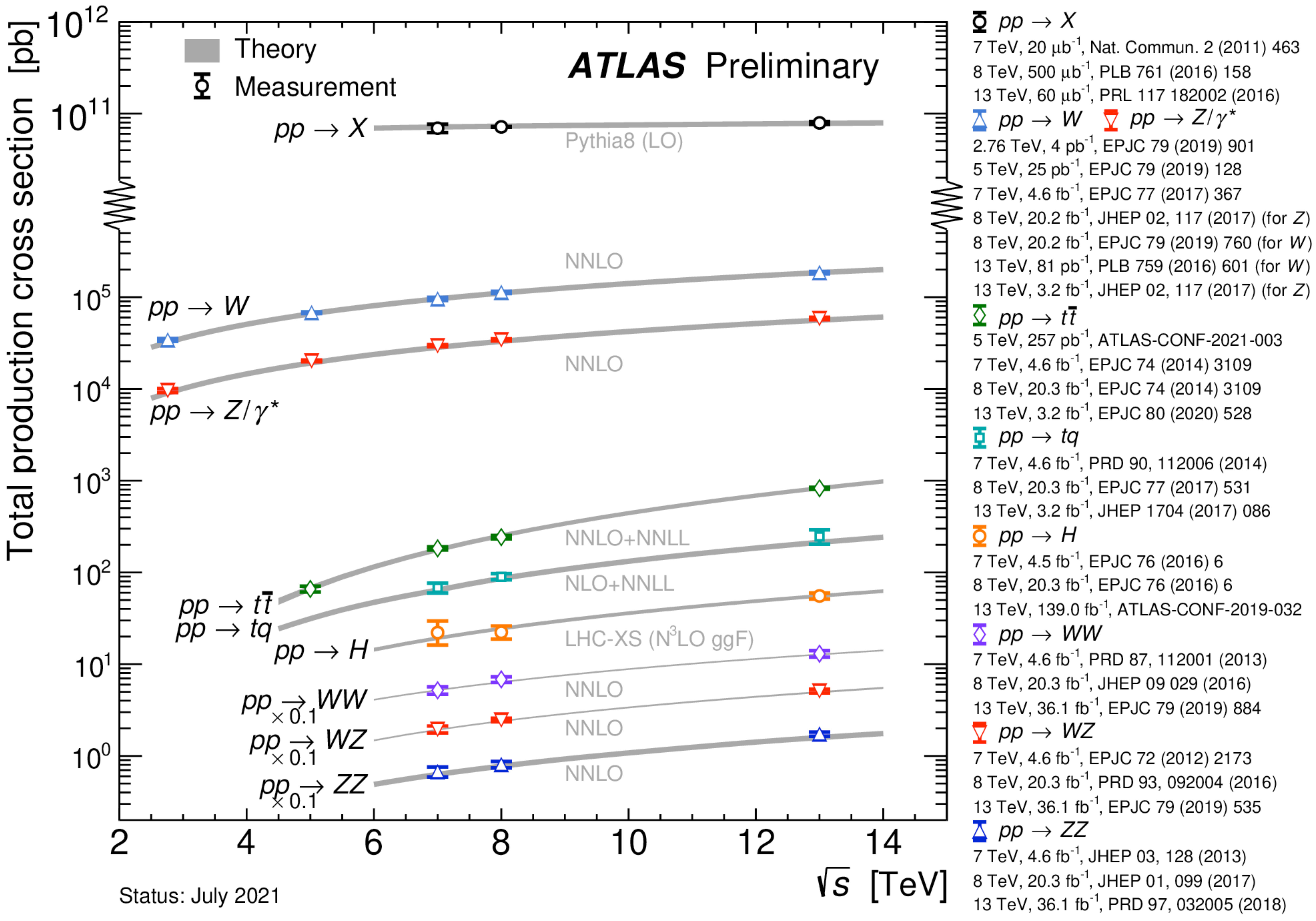


Prediction: $\sigma_{t\bar{t}t\bar{t}} = 12.0 \pm 2.4$ fb (NLO, incl EW corrs.)

Result: $\sigma_{t\bar{t}t\bar{t}} = 26 \pm 8\,(\text{stat.}) \pm^{15}_{13}\,(\text{syst.})$ fb, 1.9 obs. (1.0 exp.) σ

4.7 σ obs. (2.6 σ exp.) above bkg-only hypothesis

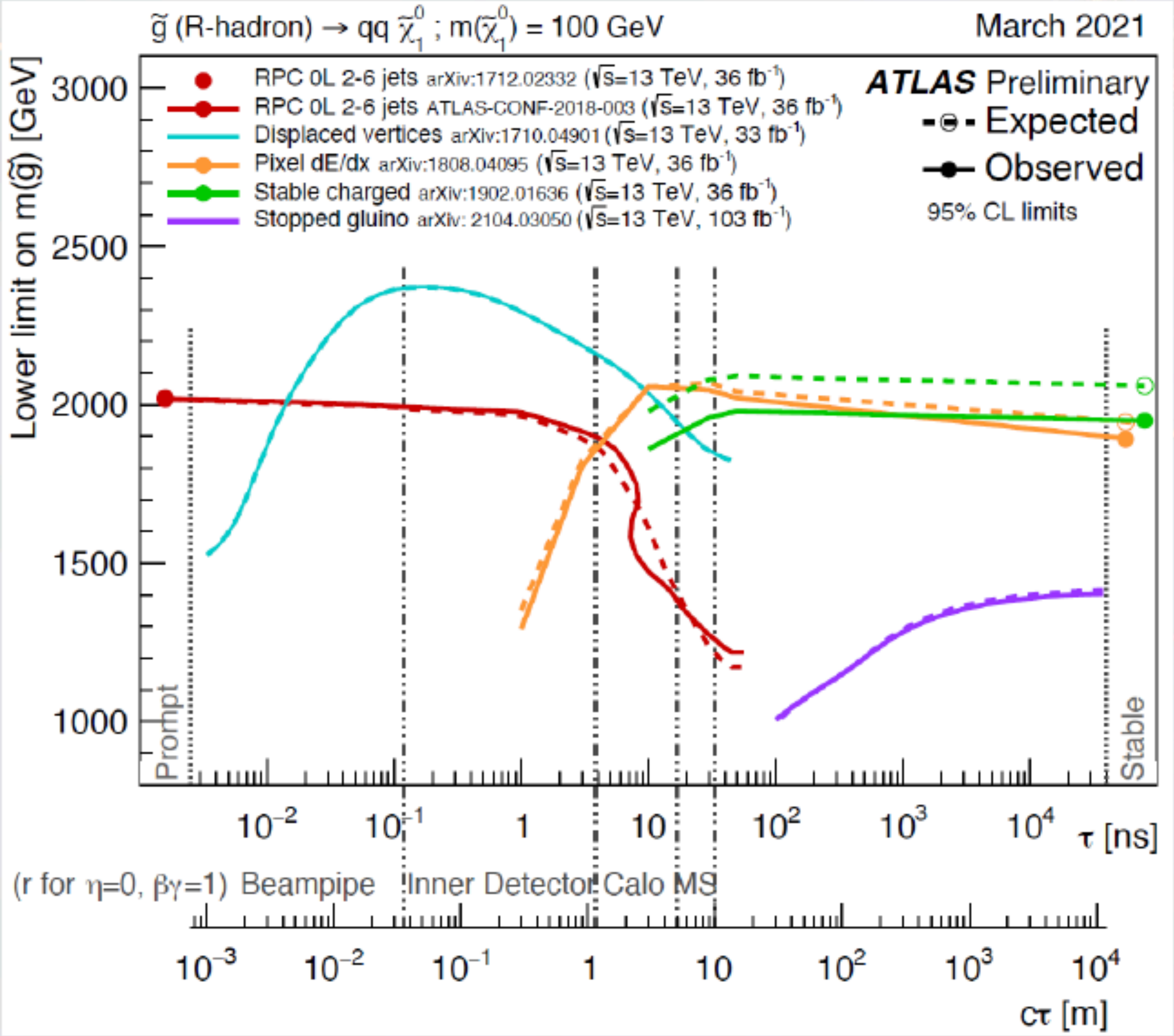
Standard Model:



Full LLP programme covers extensive range...

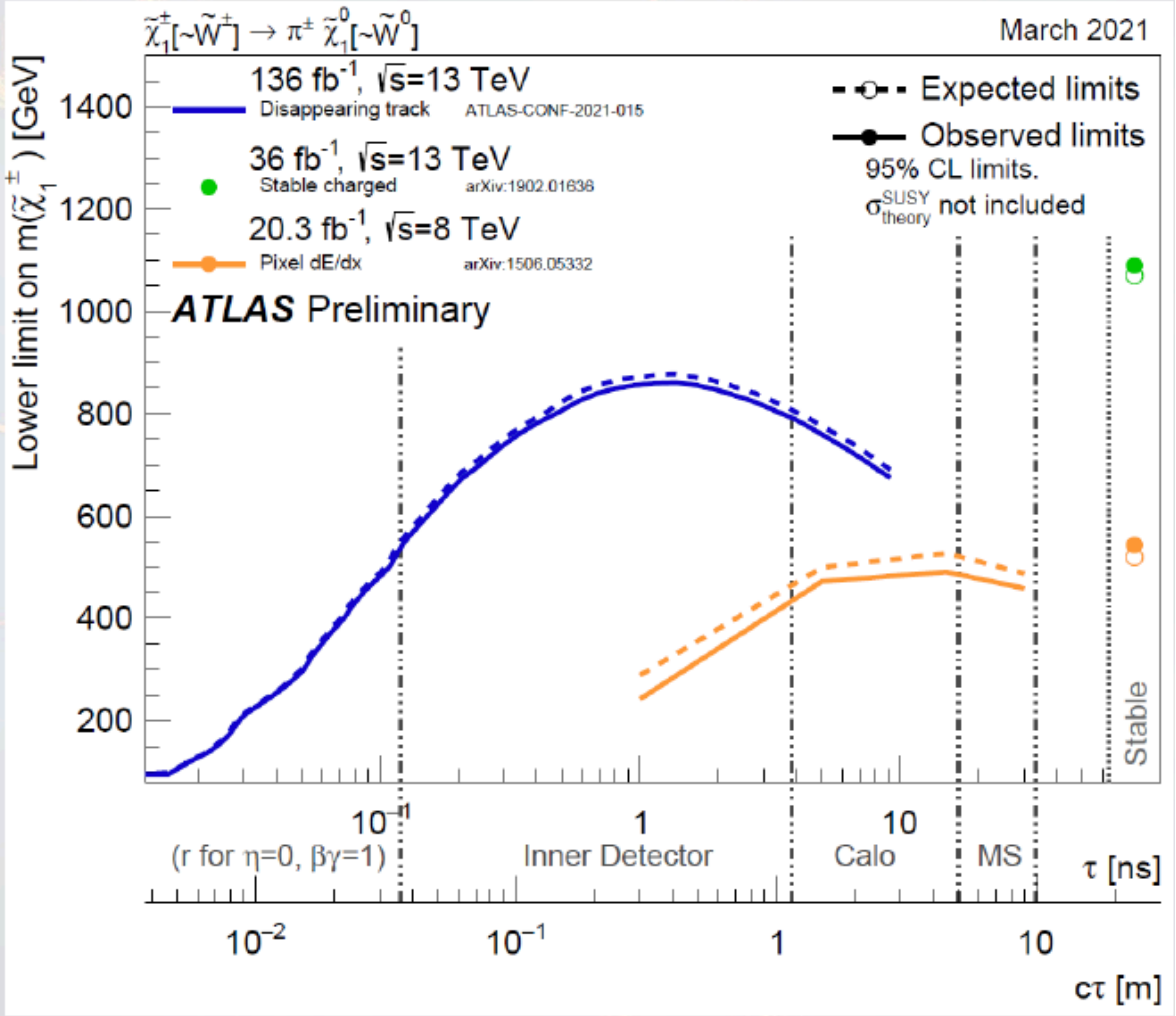
ATL-PHYS-PUB-2021-019

Constraints on gluino mass vs. lifetime



Gluino mass vs. lifetime for split-SUSY model with gluino R-hadron decaying into a gluon or light quarks and a neutralino with mass of 100 GeV.

Constraints on chargino mass vs. lifetime

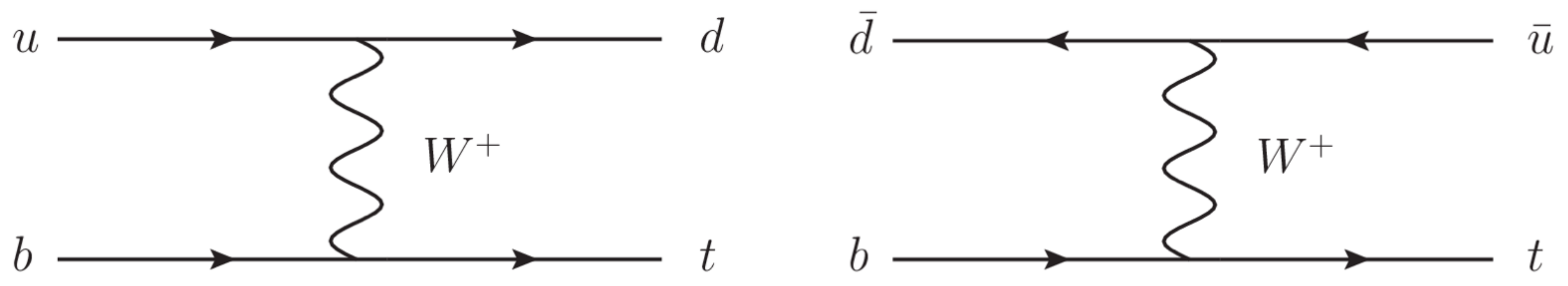


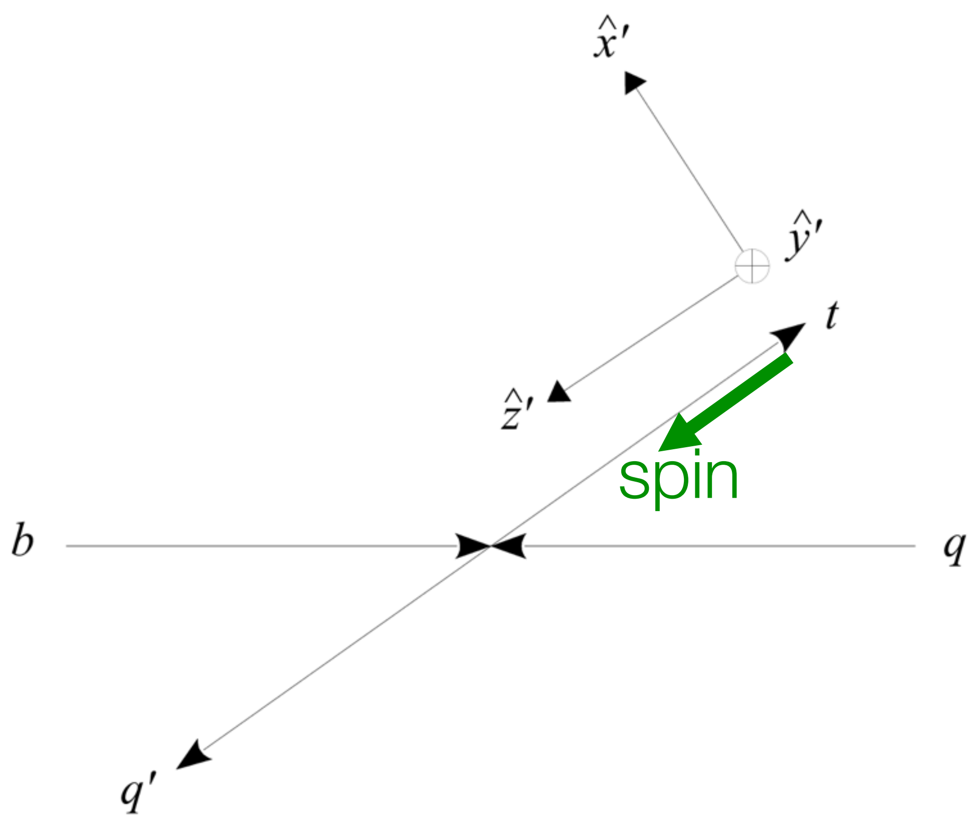
Chargino mass vs. lifetime for AMSB model with tan(β)=5, μ>0. Wino-like chargino is pair-produced and decays to wino-like neutralino and a very soft charged pion.

EFT from top measurements

- Single top polarization

  - t-channel dominates single top-quark production, large polarization from V-A





  -Measurement of polarization in 3-D via angular distributions from $t \to b\ell\nu$ decay $(\ell = e, \mu)$

- Measurement of energy asymmetry in tt+j: $A_E(\theta_j) \equiv \dfrac{\sigma^{\rm opt}(\theta_j|\Delta E > 0) - \sigma^{\rm opt}(\theta_j|\Delta E < 0)}{\sigma^{\rm opt}(\theta_j|\Delta E > 0) + \sigma^{\rm opt}(\theta_j|\Delta E < 0)}$ $\quad \Delta E = E_t - E_{\bar{t}}$

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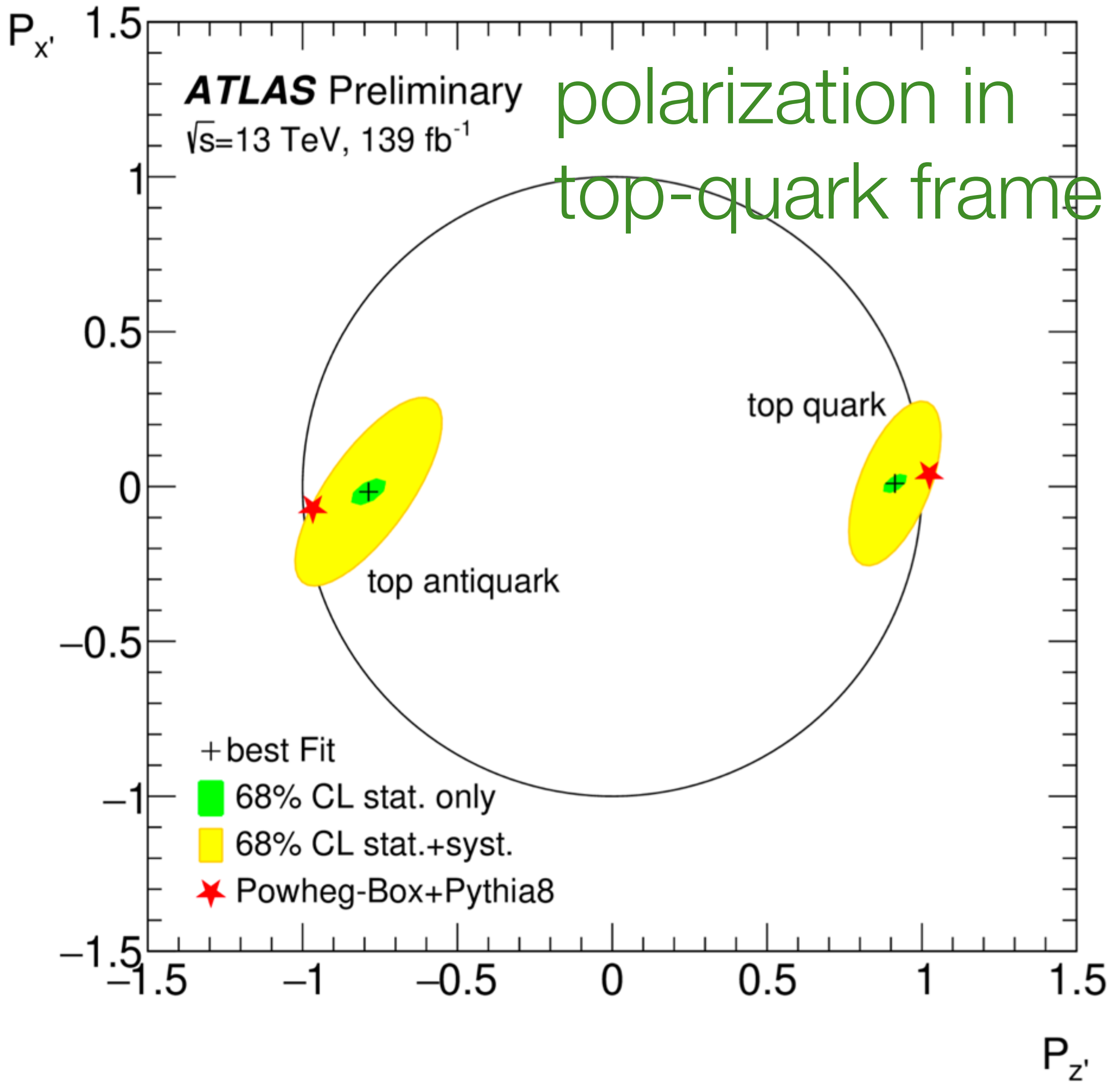
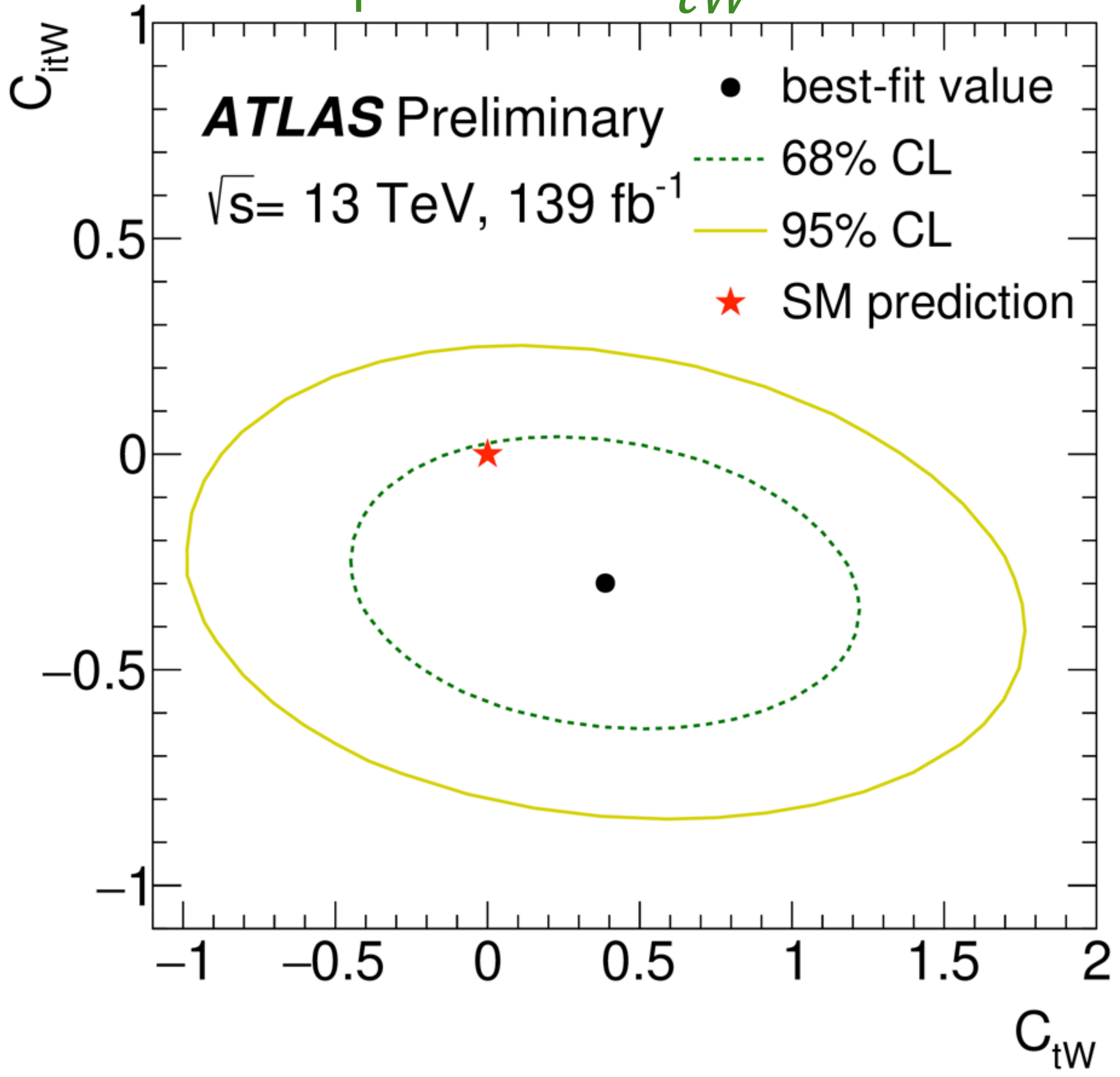
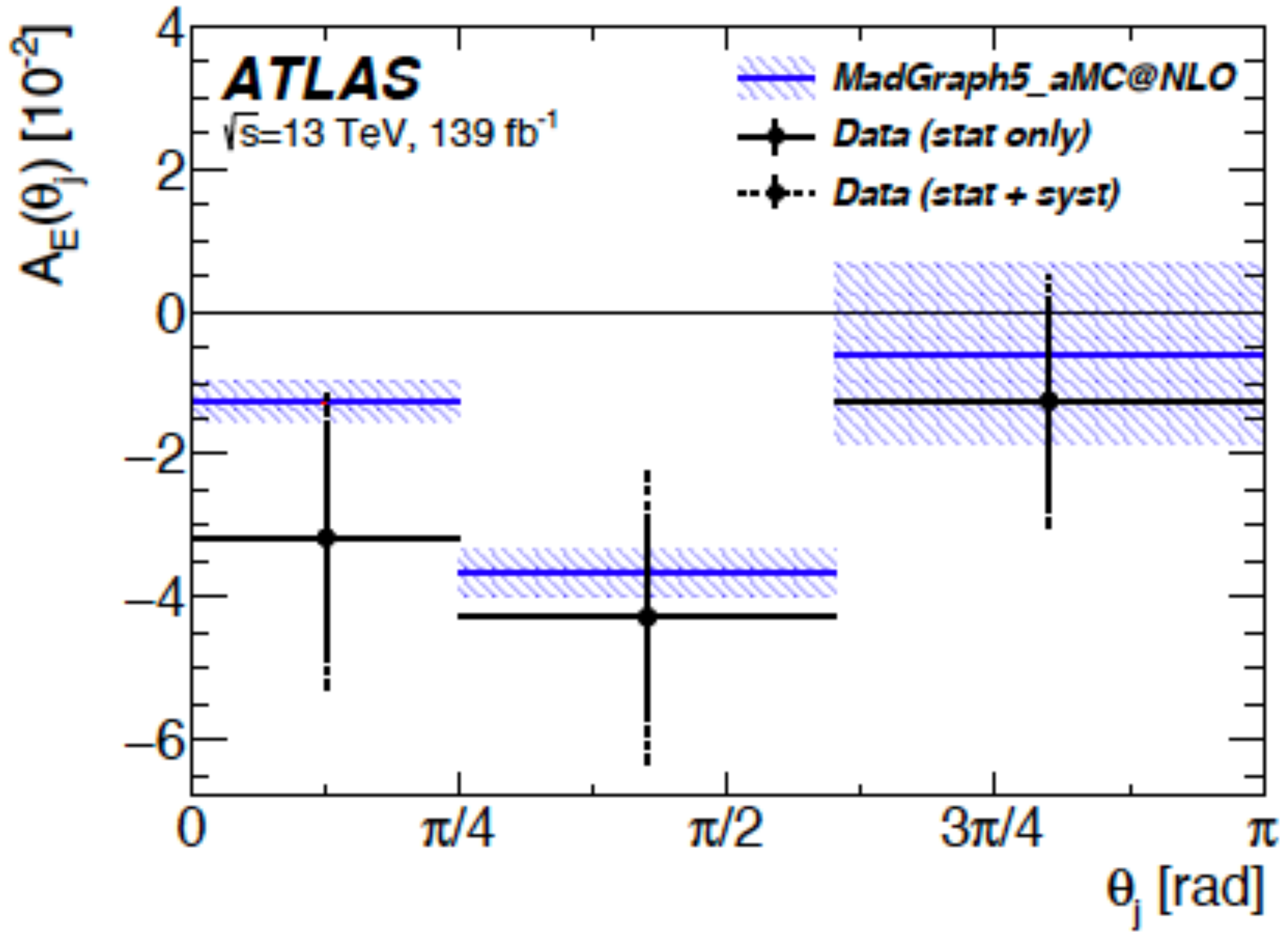


Re and Im part of EFT operator $\mathcal{O}_{tW}$



ArXiv:2110.05453

Energy asymmetry in ttj



Constraints on t-q EFT operators