Search for new Physics in Boosted $hh \to bb\tau\tau$ Decays at ATLAS

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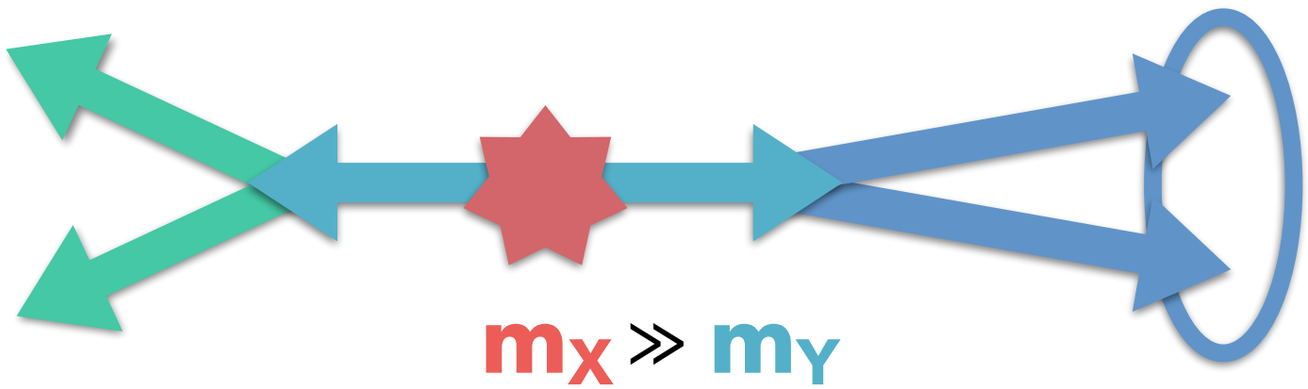
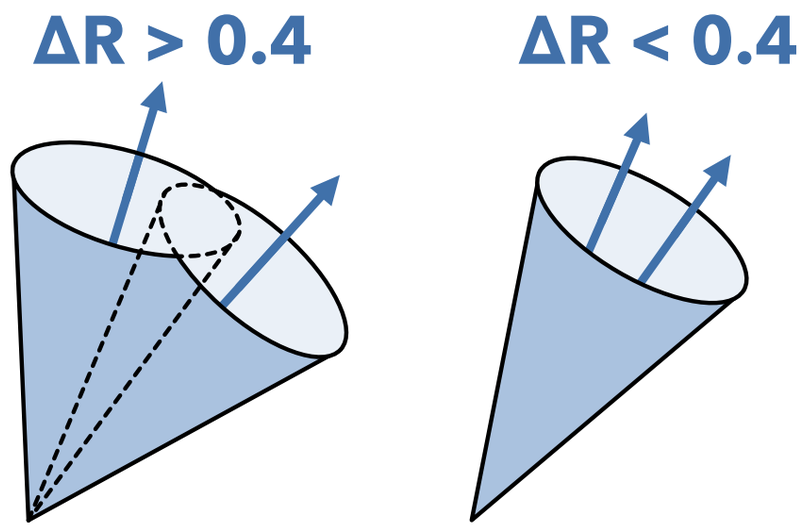
TECHNISCHE UNIVERSITÄT DRESDEN
ATLAS EXPERIMENT
FSP 103 ATLAS
GRADUIERTEN KOLLEG Masse-Spektrum-Symmetrie
iktp

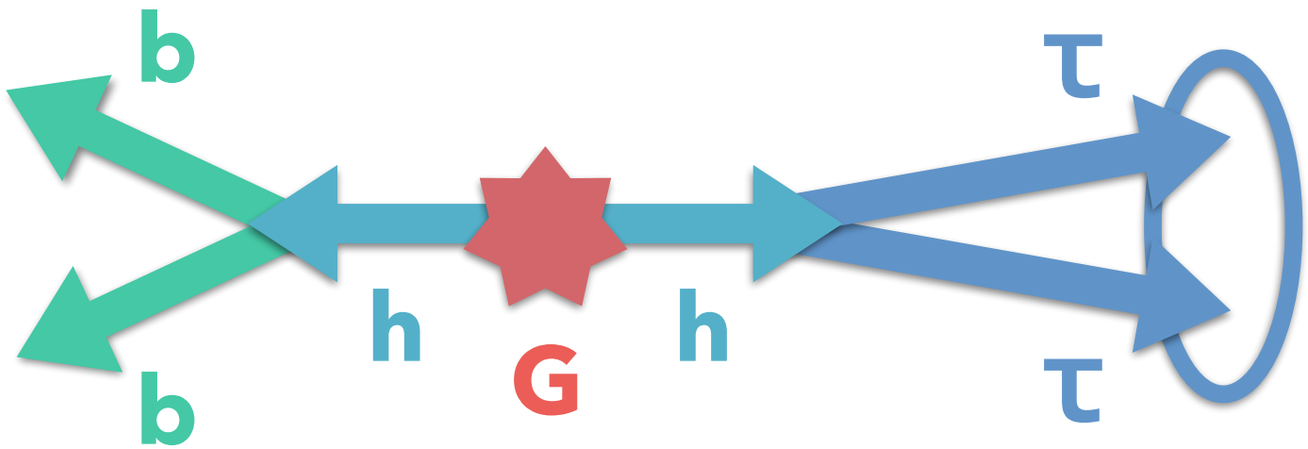
Overview

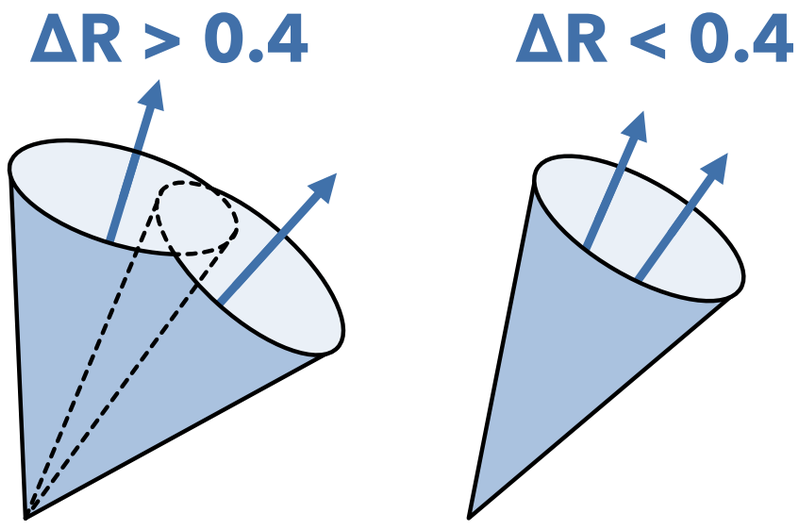




- Boosted topologies important for certain BSM searches
- Becoming more sensitive to higher masses and unexplored kinematic regions
- Requires challenging experimental techniques

Overview

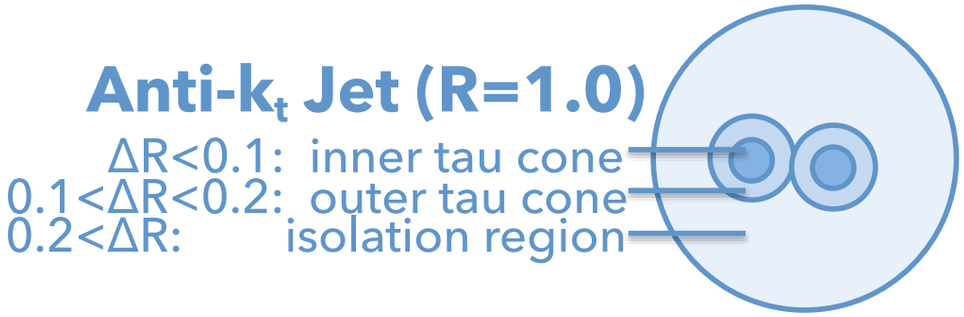


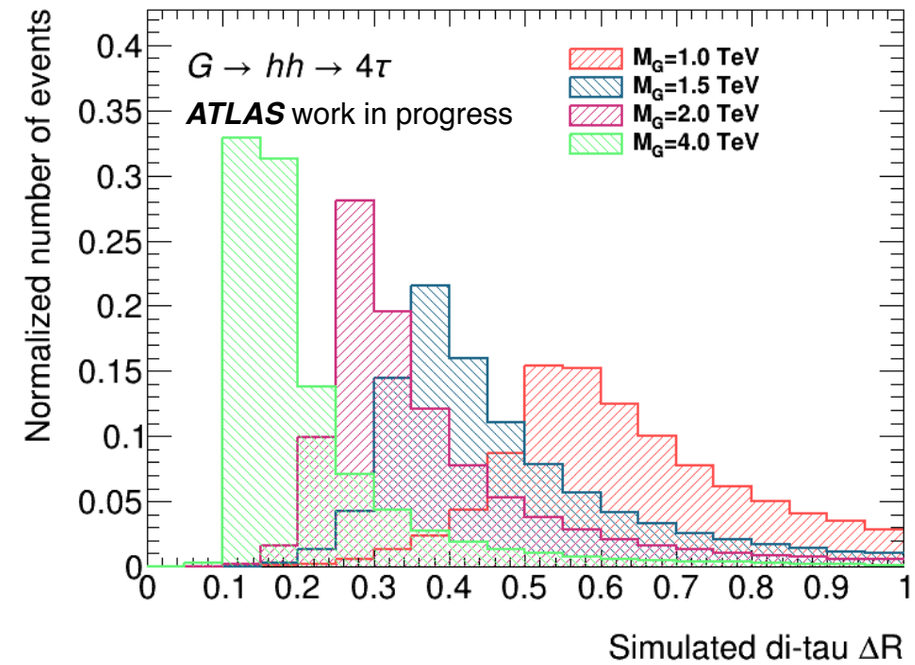


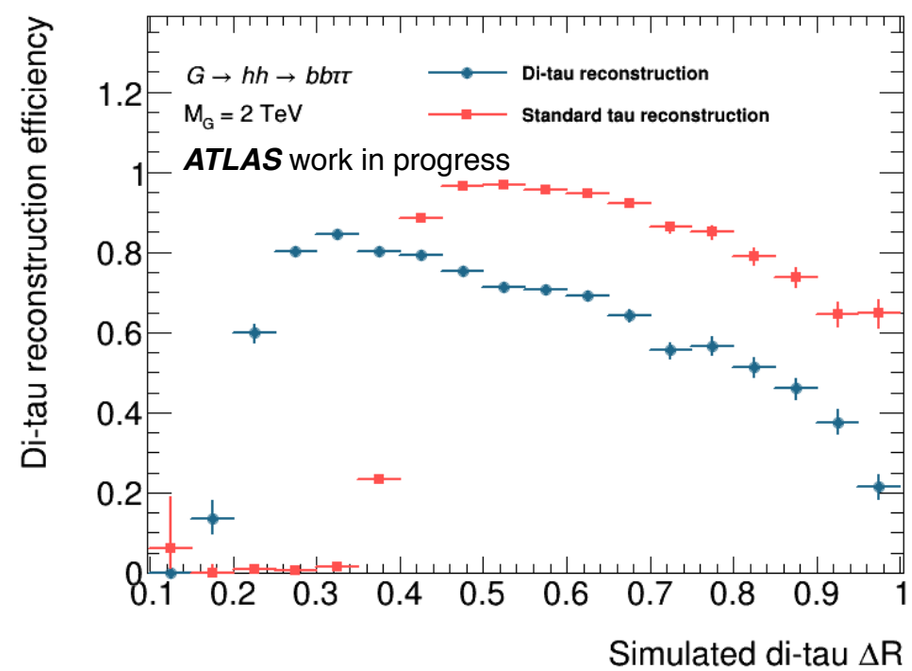
- Boosted topologies important for certain BSM searches
- Becoming more sensitive to higher masses and unexplored kinematic regions
- Requires challenging experimental techniques

Di-Tau Reconstruction

- High-p_T anti-k_T jet seeds (R = 1.0, p_T > 300 GeV)
- Anti-k_T subjets (R = 0.2)
- At least 2 subjets with at least one associated track
- Calorimeter cell based identification variable calculation

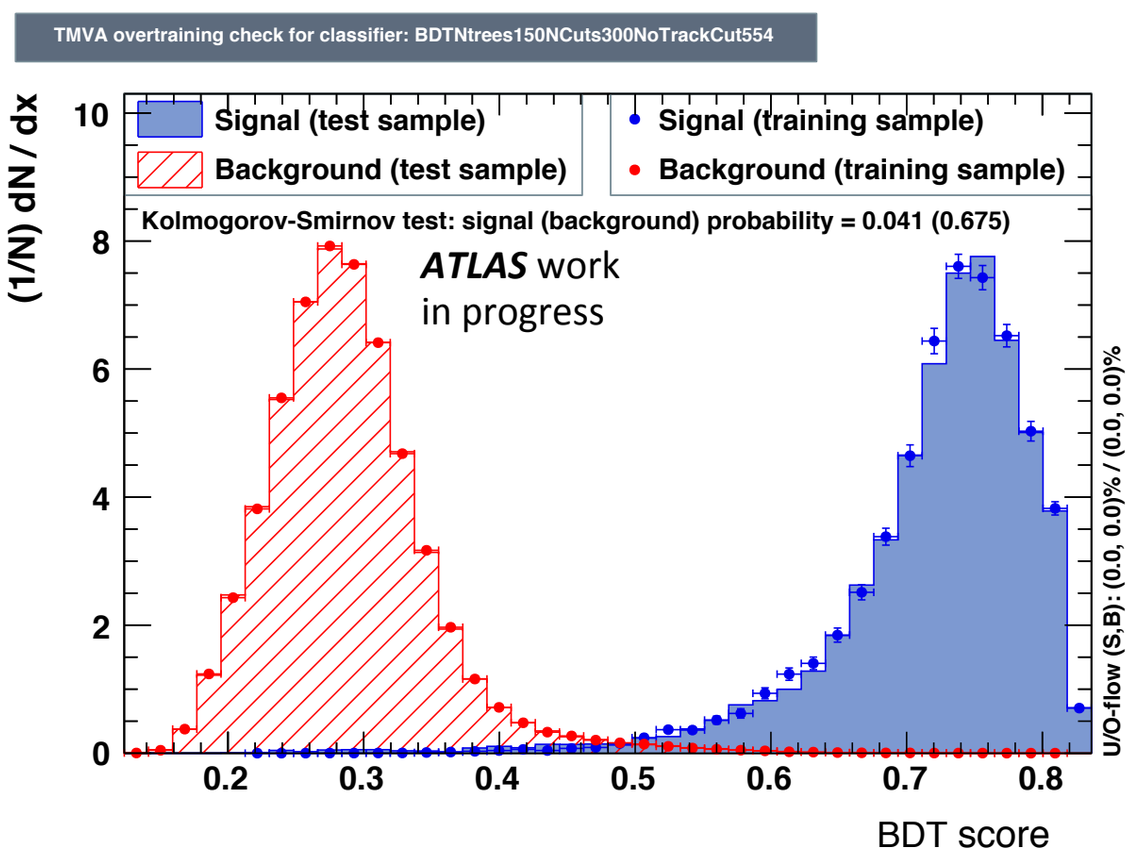


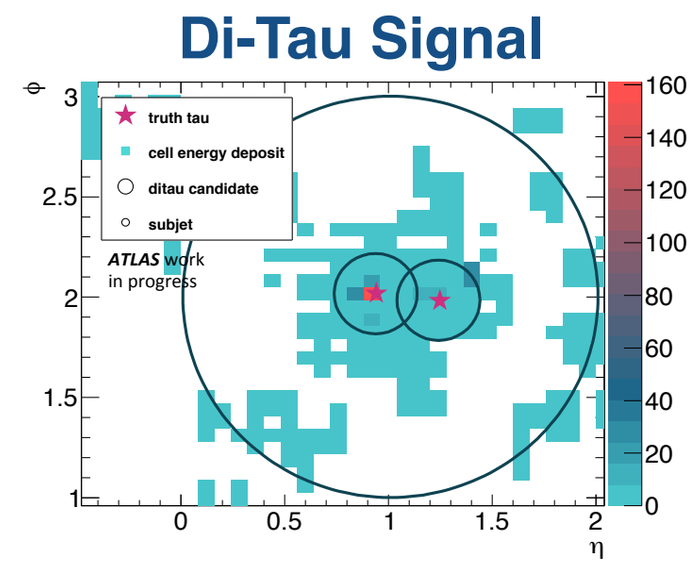


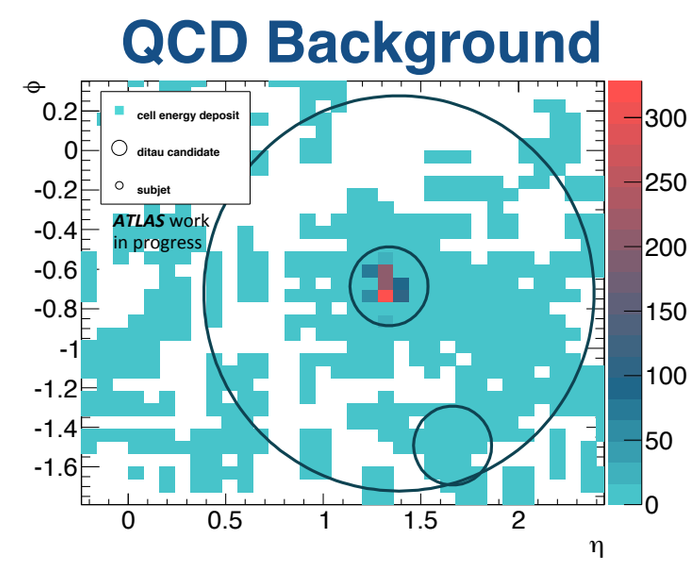


Di-Tau Identification

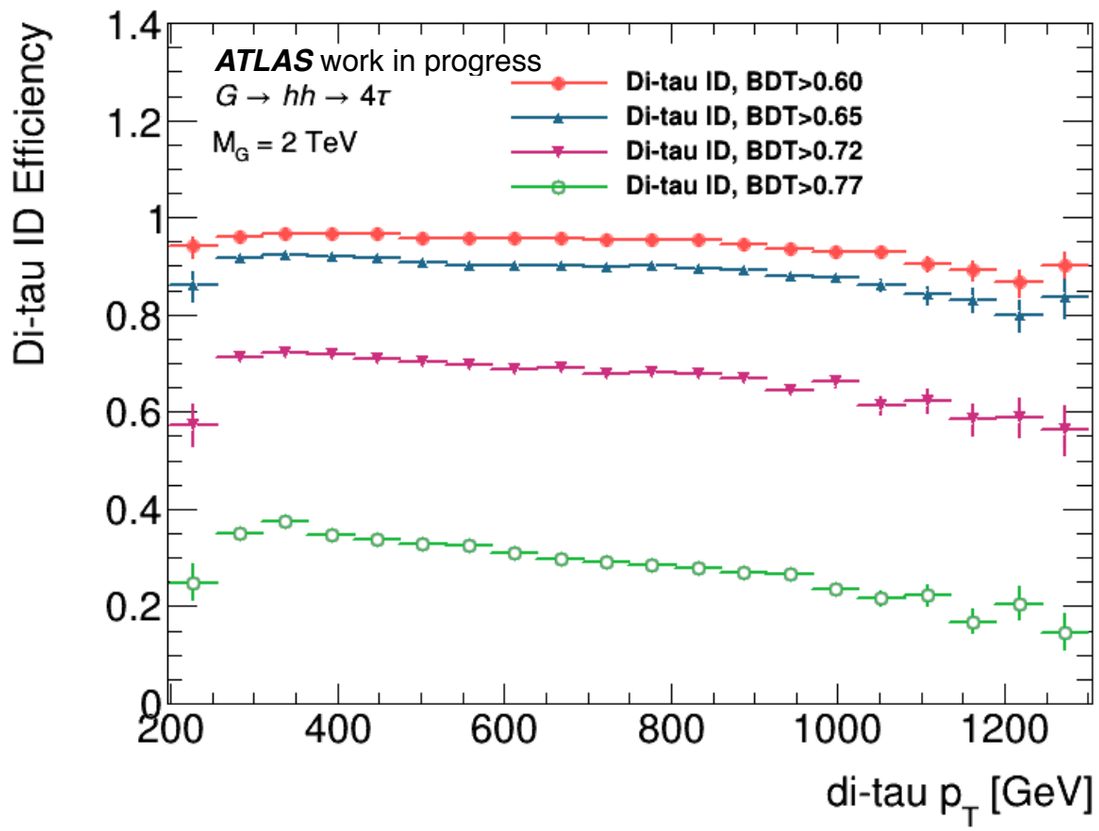
- Signal: G → hh → 4τ, M_G = 1.5 TeV… 2.5 TeV
- Background: QCD from 2015 data
- BDT based ID with variables from calorimeter cells/clusters, tracks and vertices

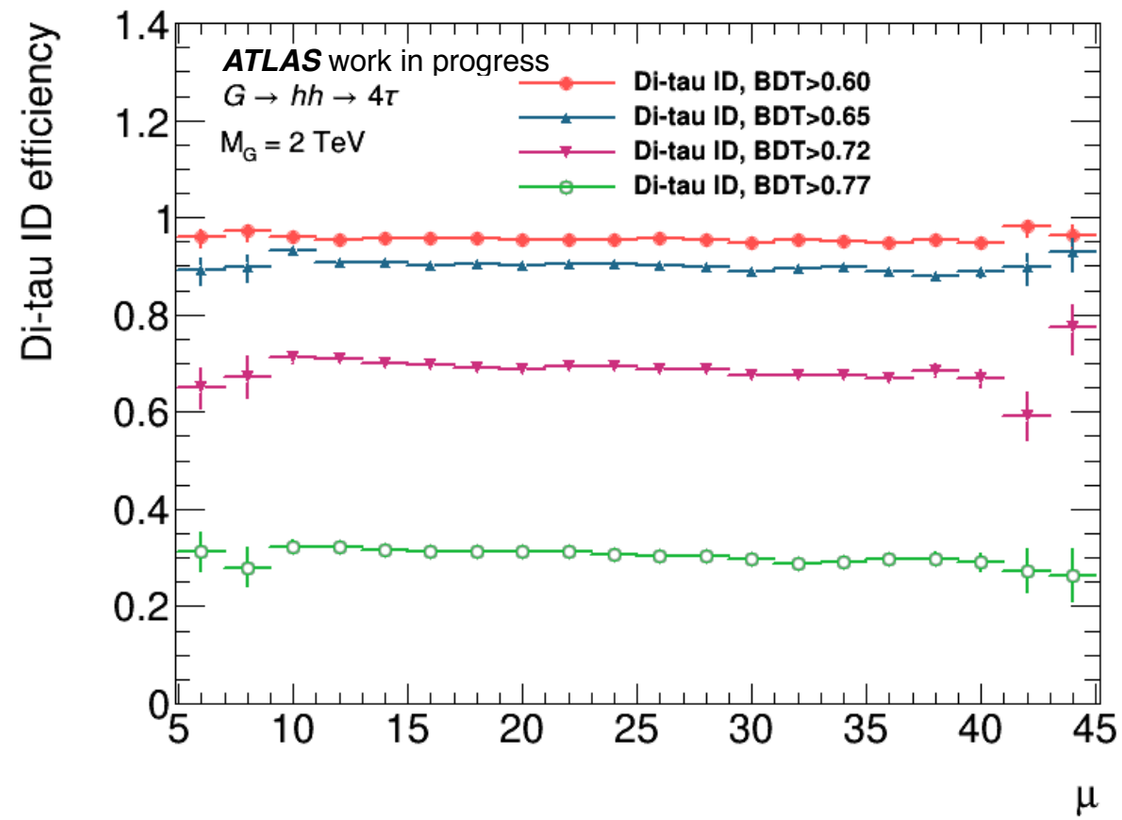






Di-Tau Identification

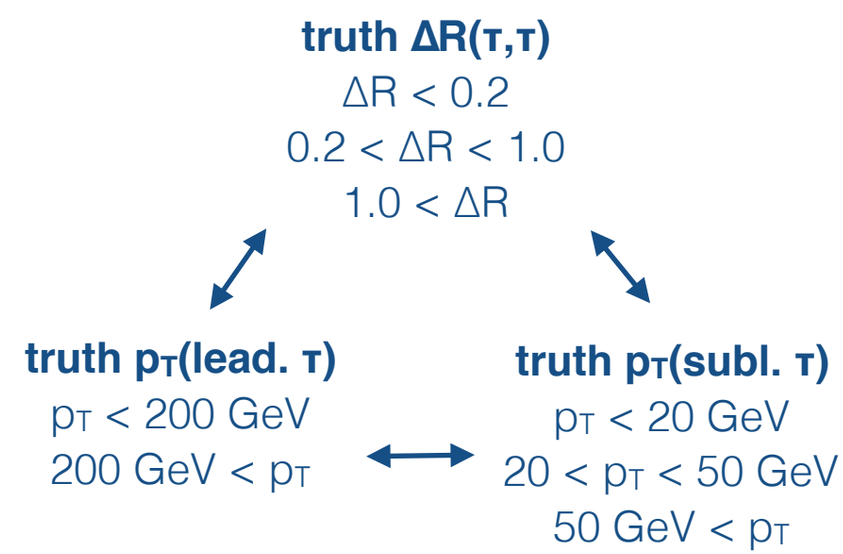


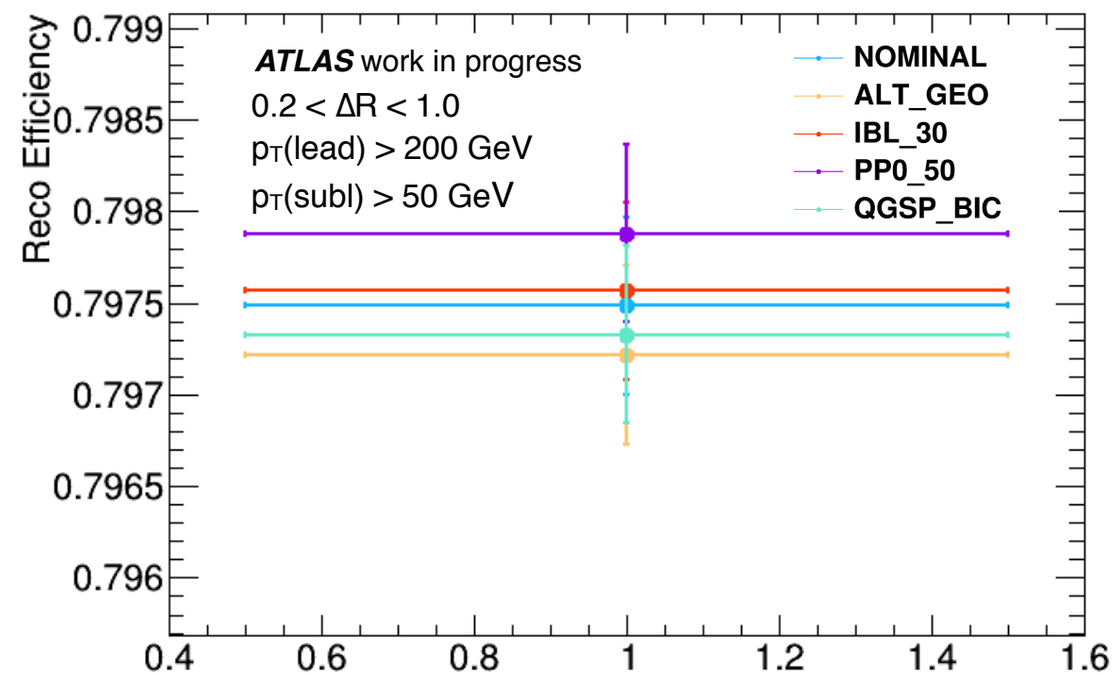


Working Point	BDT Score	ID Efficiency
very loose	0.60	≈ 95 %
loose	0.65	≈ 90 %
medium	0.72	≈ 70 %
tight	0.77	≈ 30 %

Reconstruction and ID Uncertainties

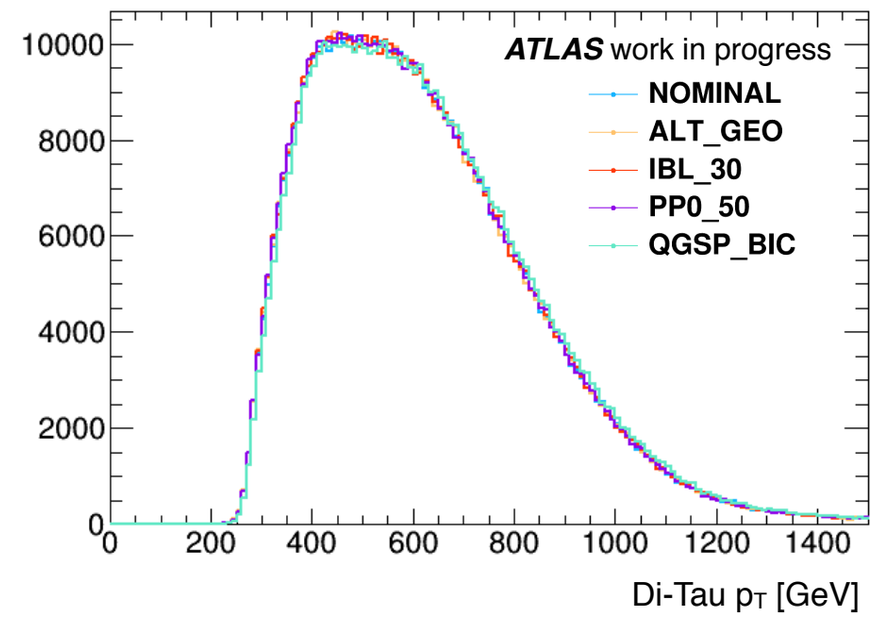
- MC based uncertainty estimation
- Comparing efficiency differences between nominal sample and 4 variation samples
  - $G \rightarrow hh \rightarrow 4\tau$ sample, $M_G = 1 \ldots 5$ TeV
  - Alternative detector geometries
  - Alternative physics model
- Kinematic regions binned in $\Delta R(\tau,\tau)$, p_T(leading τ), p_T(subl. τ)





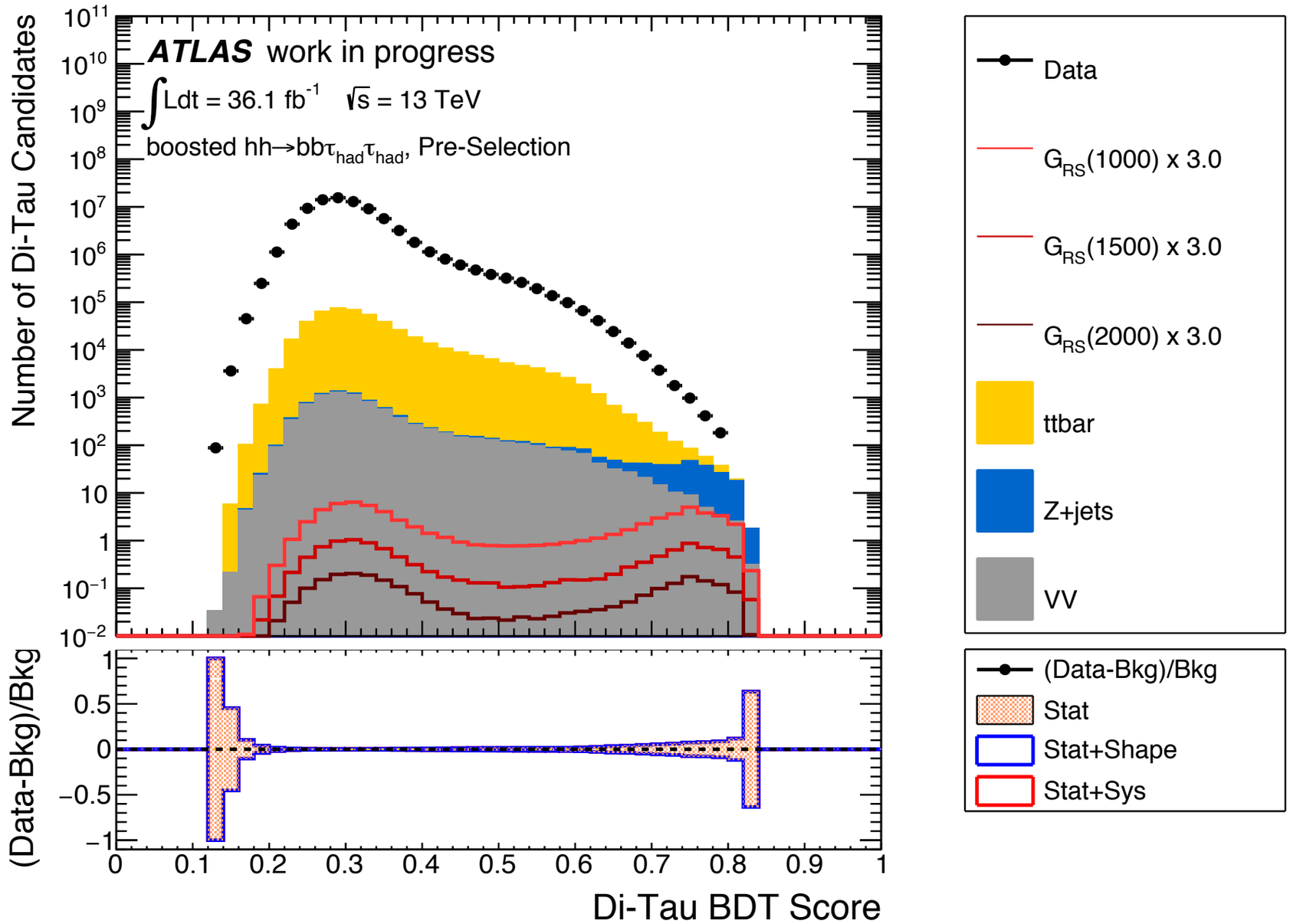
Energy Scale Uncertainties

- MC based uncertainty estimation
- Compare ditau p_T in nominal sample against 4 variations
- Compare ditau p_T shapes between nominal and variations
  - Nominal: $p_T \mapsto sf \cdot p_T$
  - Uncertainties derived from sf with best nominal-variation agreement



Region	$\Delta p_T/p_T$
$\Delta R < 0.2$	2.0 %
$0.2 < \Delta R < 1.0$	0.7 % - 1.4 %
$\Delta R > 1.0$	3.1 %

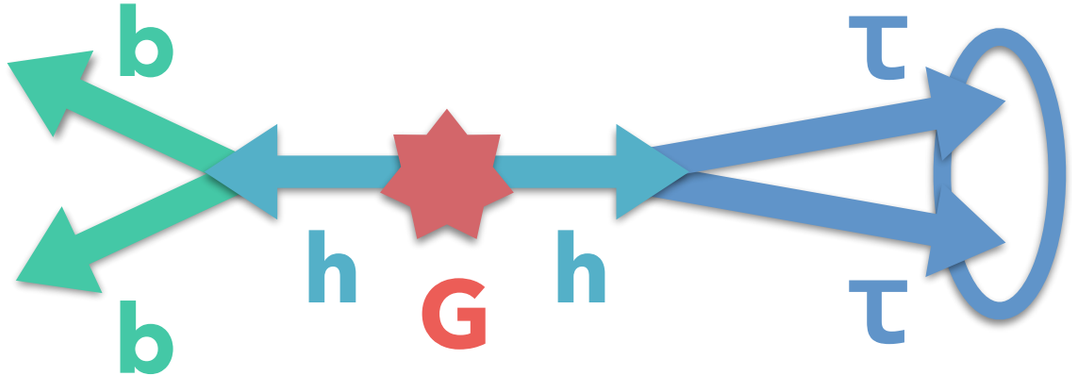
Boosted bbττ Analysis

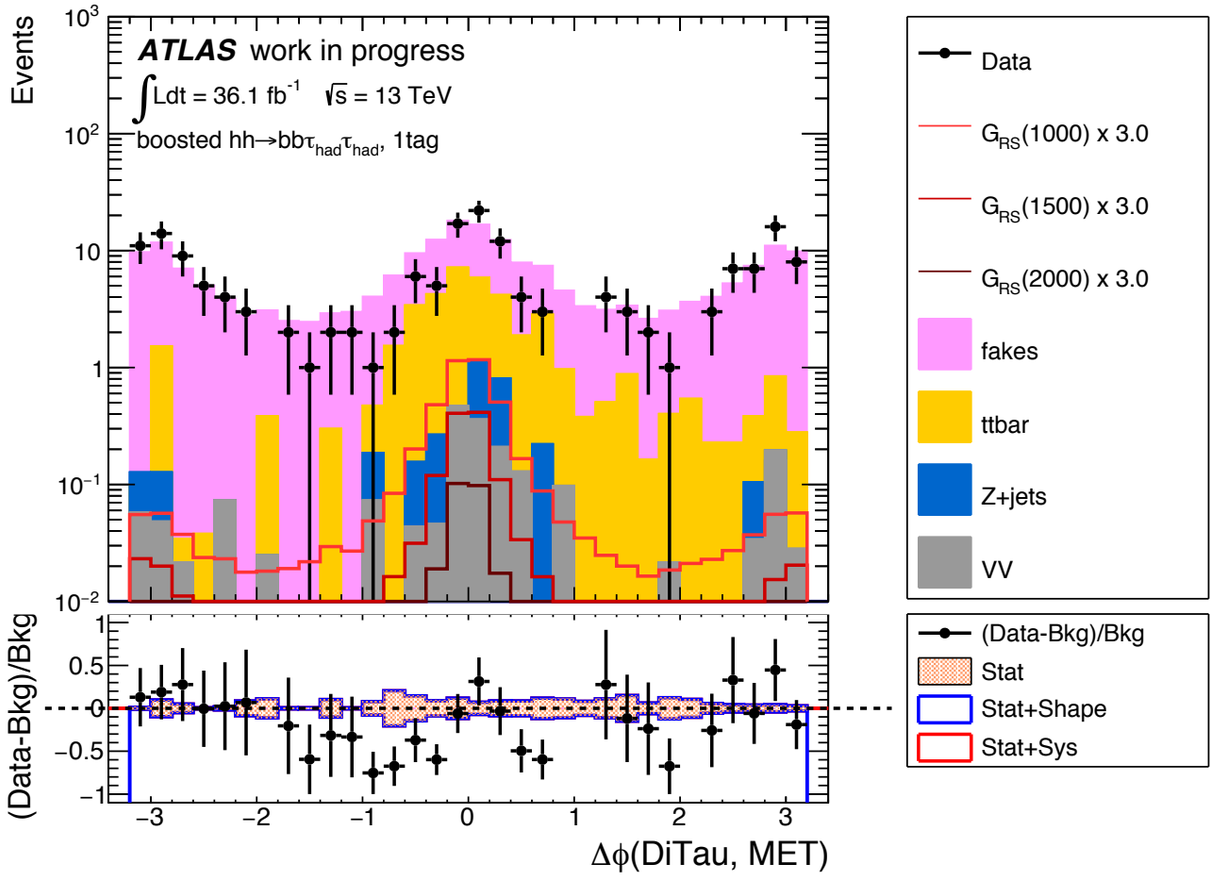


- Blinding in this and following slides: S/(S+B) < 4%

Boosted bbττ Analysis

- **Large-R jet trigger:** p_T > 360, 420 GeV
- **Di-tau:** p_T > 300 GeV, medium ID, $2 \leq n_{subjets} \leq 3$
- **Large-R jet:** p_T > 300 GeV, 1- or 2-b-tagged
- Leading p_T > 450 GeV
- MET > 20 GeV
- $\Delta\varphi$(di-tau, MET) < 1





Boosted bbττ Analysis

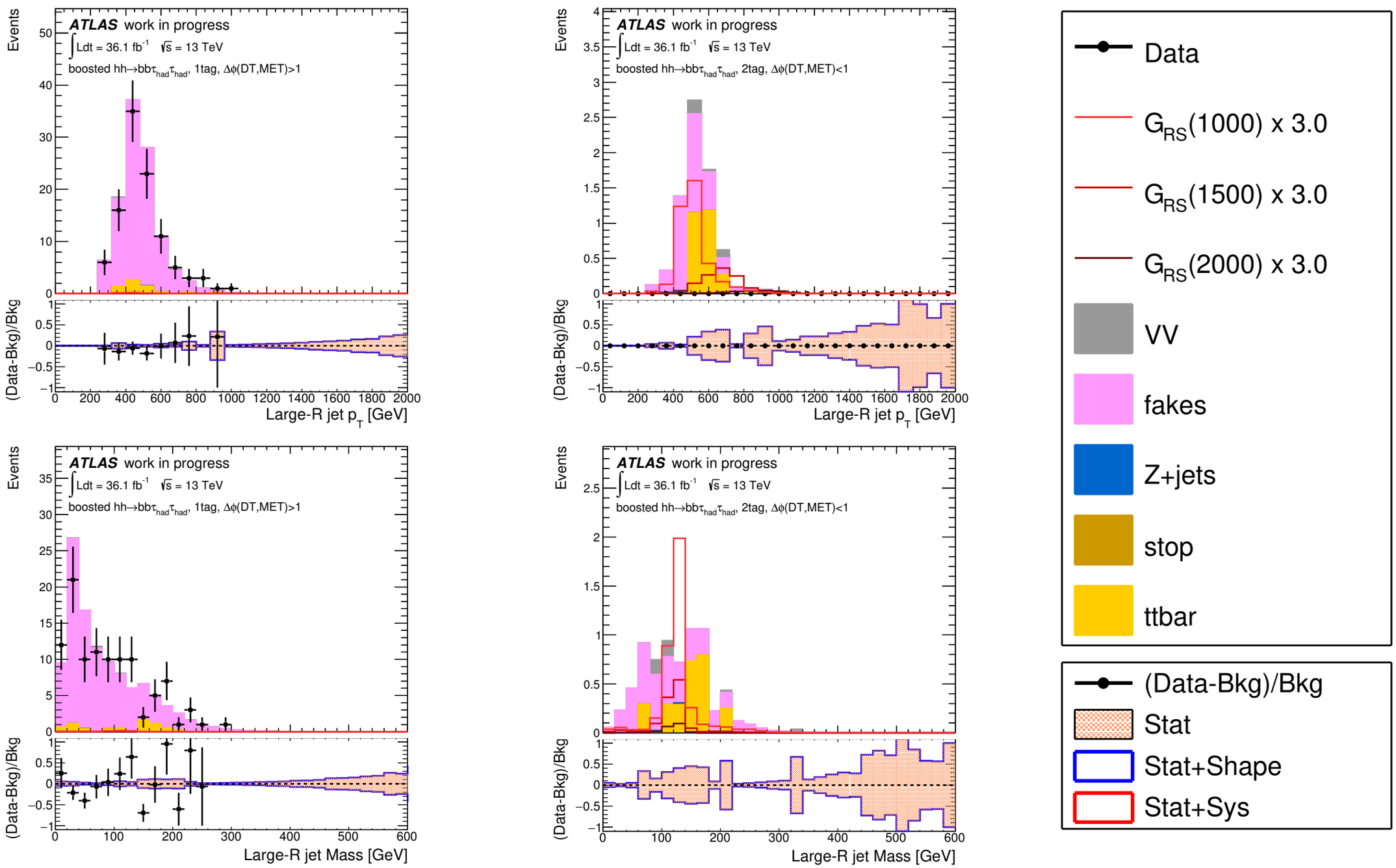
- Data driven multi-jet background estimation
- $N_B = N_D * N_A/N_C$
- $N_{A,B,C,D} = N_{data} - N_{MC}$
- Evaluation binned in di-tau p_T and η

	0-tag	1-tag
pass ID	A	B
fail ID	C	D

Large-R-Jet Kinematics

1-tag, $\Delta\varphi > 1$

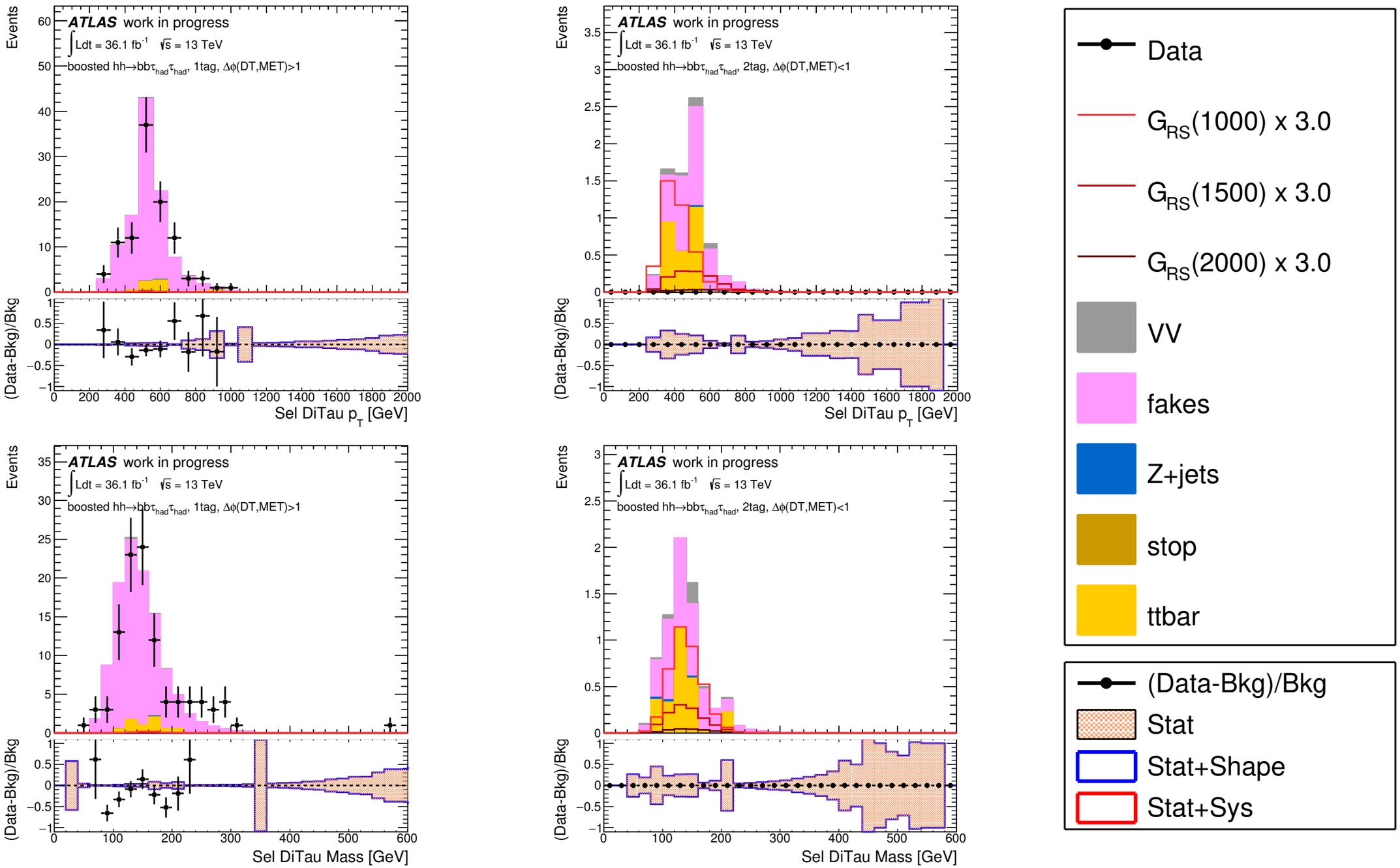
2-tag, $\Delta\varphi < 1$



Di-Taus Kinematics

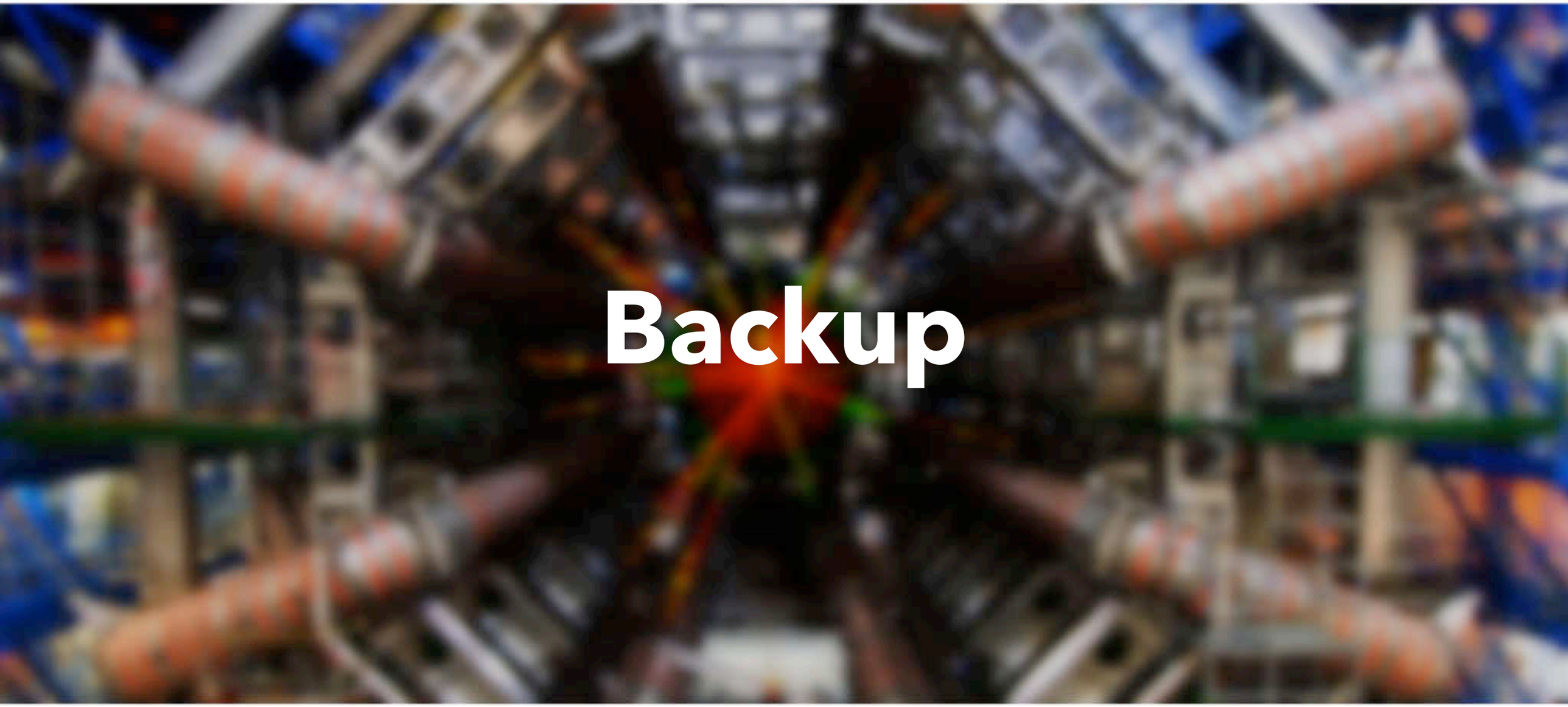
1-tag, $\Delta\varphi > 1$

2-tag, $\Delta\varphi < 1$



Summary and Outlook

- Efficient di-tau reconstruction and identification with high background rejection
- First implementation in boosted bbττ analysis
- Preparations for 2017/18 data takings
- Further optimisation in selection and background estimation
- Statistical analysis



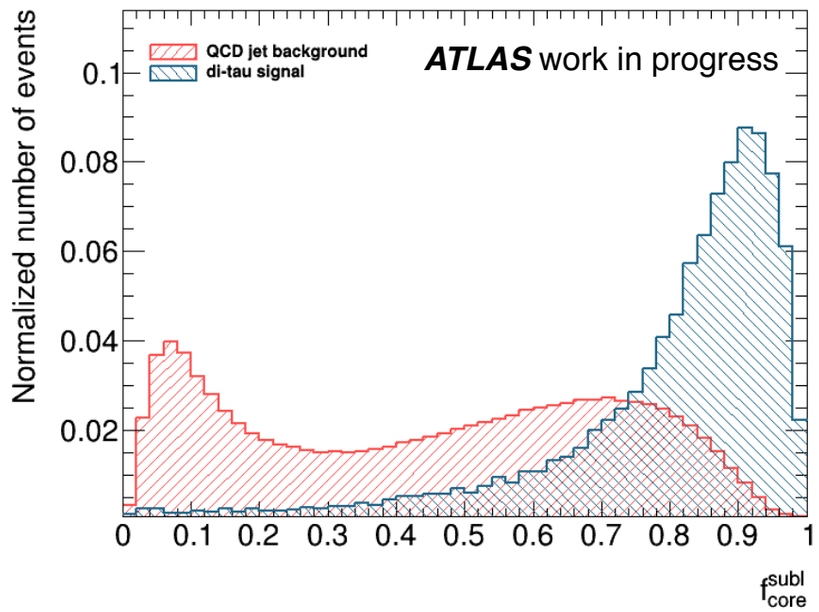
Backup

Di-Tau Identification

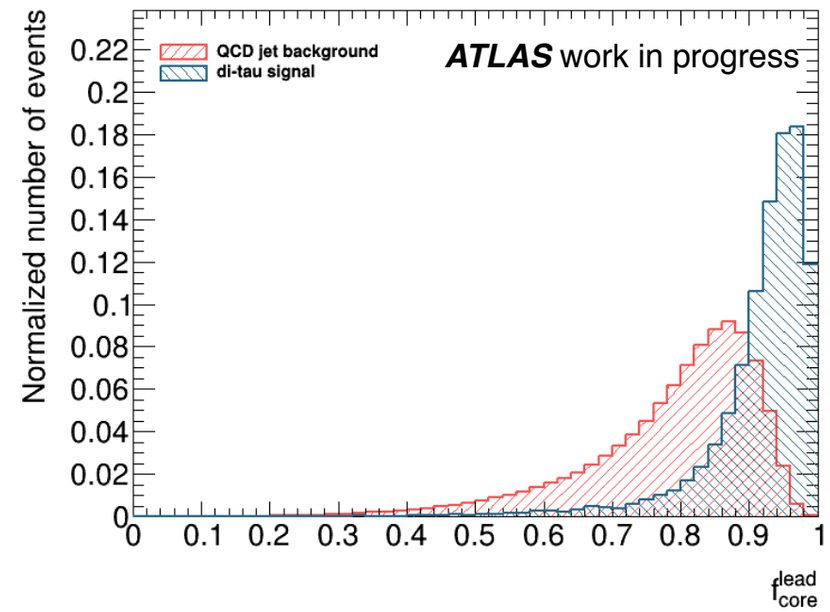
Core p_T fraction

$$f_{\text{core}} = \frac{\sum_{\text{cells}}^{\Delta R<0.1} p_{\text{T}}^{\text{cell}}}{\sum_{\text{cells}}^{\Delta R<0.2} p_{\text{T}}^{\text{cell}}}$$

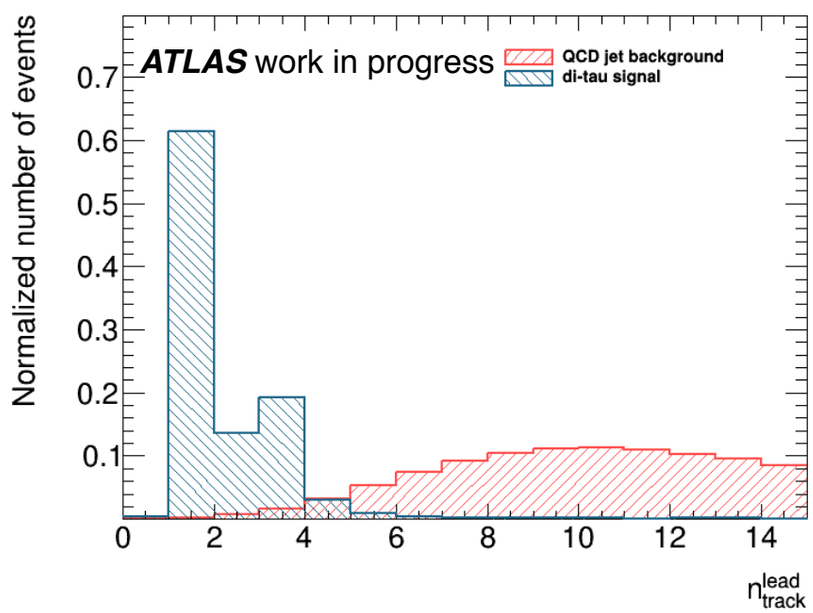
Leading sub-jet

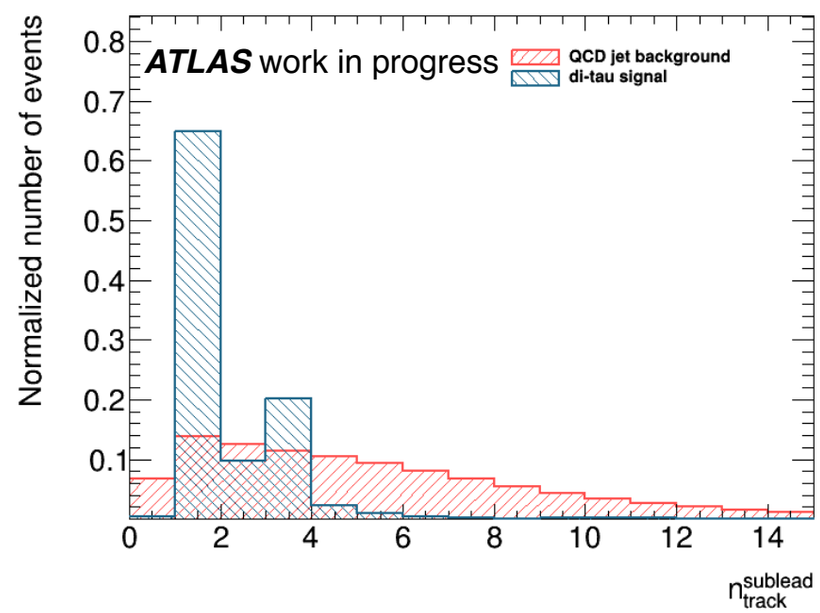


Sub-leading sub-jet



Number of tracks in inner sub-jet cone





Reco + JetID Uncertainties

Relative Uncertainties

ATLAS work in progress

	reco	veryloose	loose	medium	tight
deltaR-00-02	0.0447718	0.0495049	0.0971153	0.0980454	0.142072
deltaR-02-10_sublPt-00-20_leadPt-00-200	0.0440461	0.0598464	0.0799499	0.148531	0.307018
deltaR-02-10_sublPt-00-20_leadPt-200-xx	0.0366539	0.0308862	0.0330026	0.0429868	0.0585735
deltaR-02-10_sublPt-20-50_leadPt-00-200	0.0578752	0.0562219	0.0670779	0.080029	0.143703
deltaR-02-10_sublPt-20-50_leadPt-200-xx	0.00757488	0.0086739	0.0099398	0.0135999	0.0185988
deltaR-02-10_sublPt-50-xx_leadPt-00-200	0.056393	0.0557237	0.0556697	0.0603137	0.0579805
deltaR-02-10_sublPt-50-xx_leadPt-200-xx	0.000638537	0.00089241	0.00106505	0.00385522	0.0105192
deltaR-10-xx	0.0740146	0.0789185	0.0646248	0.209797	0.27965

Nominal Reco / ID Efficiencies

ATLAS work in progress

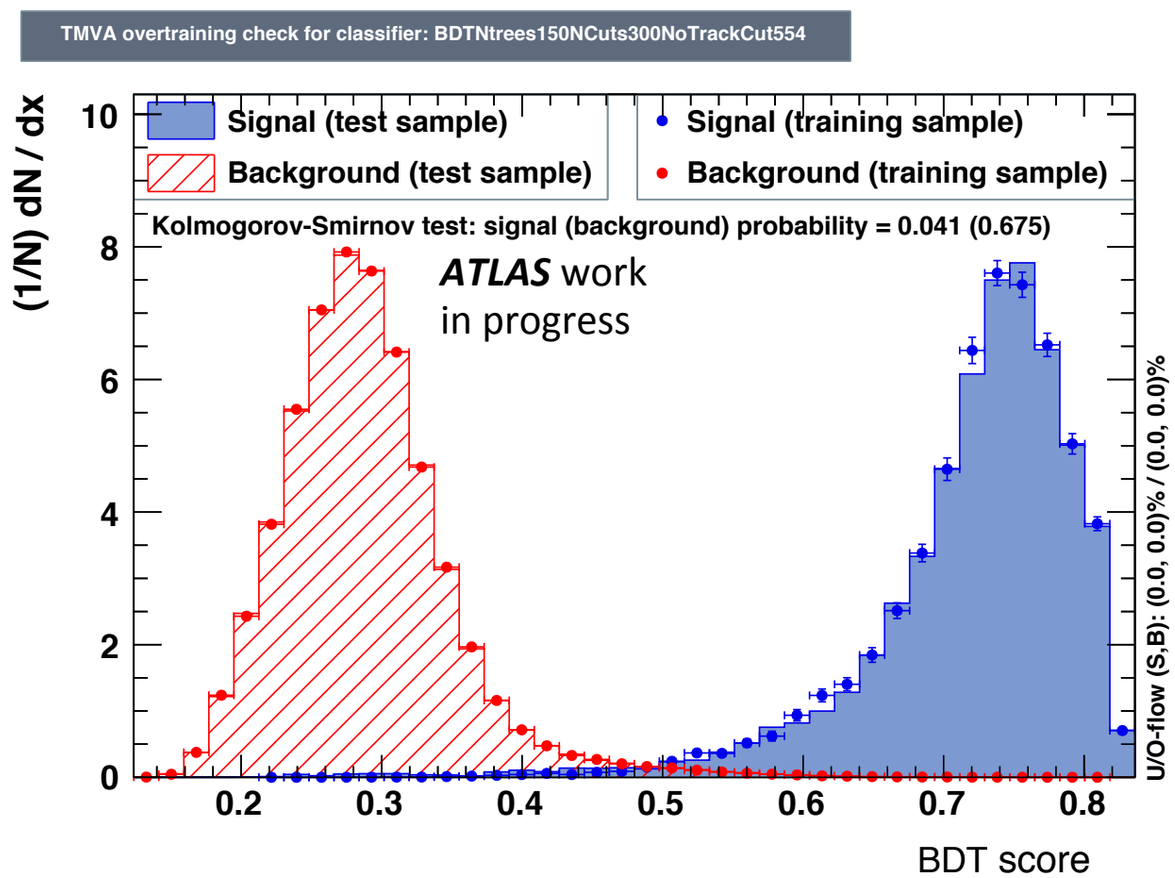
	reco	veryloose	loose	medium	tight
deltaR-00-02	0.0603625	0.0362939	0.0252858	0.00590982	0.000635085
deltaR-02-10_sublPt-00-20_leadPt-00-200	0.0392879	0.0326376	0.0274197	0.0140168	0.00358093
deltaR-02-10_sublPt-00-20_leadPt-200-xx	0.359587	0.322315	0.275141	0.132269	0.0353253
deltaR-02-10_sublPt-20-50_leadPt-00-200	0.0737516	0.0635595	0.0560569	0.0341508	0.0119262
deltaR-02-10_sublPt-20-50_leadPt-200-xx	0.684946	0.641733	0.591251	0.396476	0.146915
deltaR-02-10_sublPt-50-xx_leadPt-00-200	0.410837	0.392018	0.370636	0.286023	0.141082
deltaR-02-10_sublPt-50-xx_leadPt-200-xx	0.797484	0.76407	0.724561	0.55704	0.243369
deltaR-10-xx	0.00949883	0.0080283	0.00684922	0.0036962	0.000940609

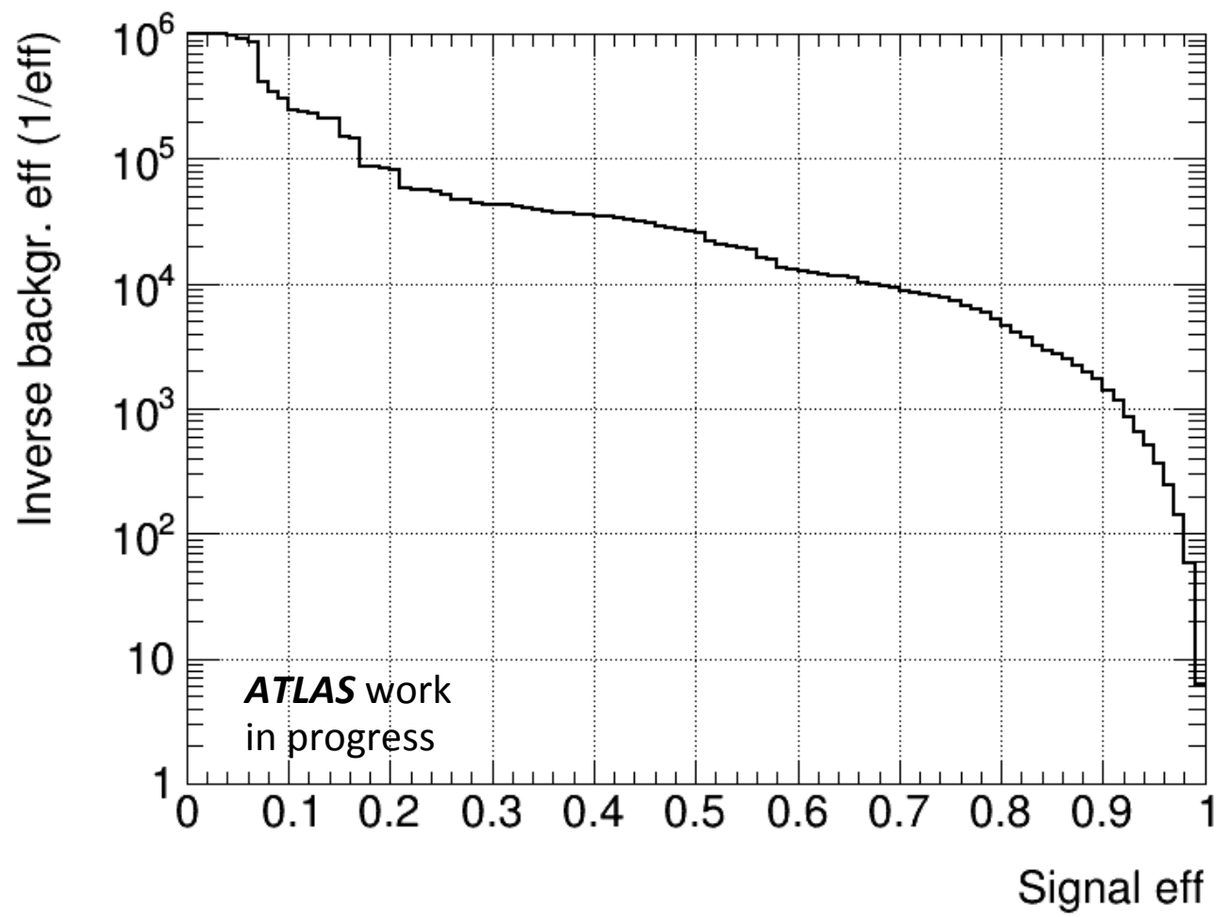
Energy Scale Uncertainties

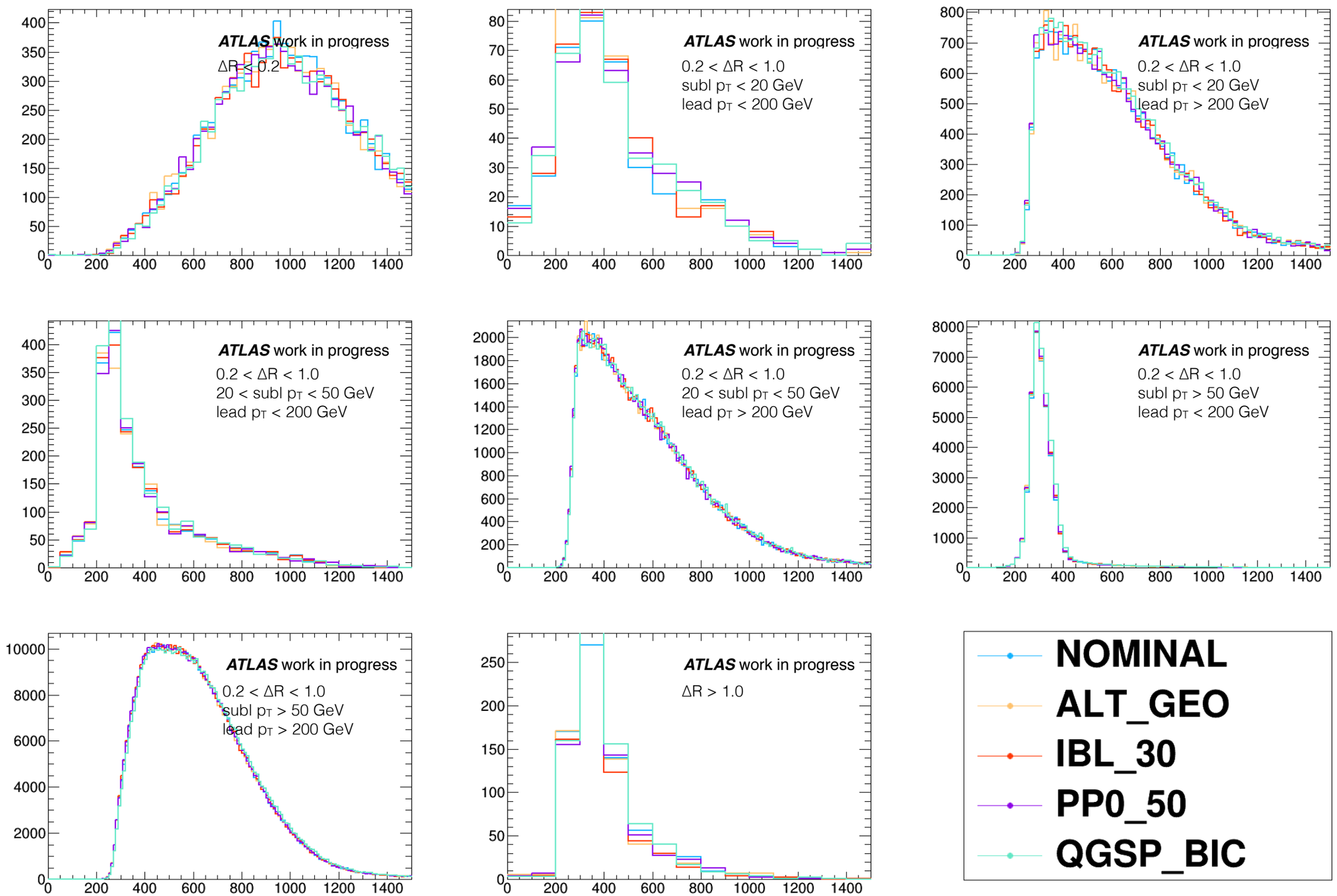
ATLAS work in progress

	TOTAL	QGSP_BIC	ALT_GEO	IBL_30	PP0_50
deltaR-00-02	0.0207	0.0010	0.0200	0.0010	0.0050
deltaR-02-10_sublPt-00-20_leadPt-00-200	0.0121	0.0100	0.0050	0.0020	0.0040
deltaR-02-10_sublPt-00-20_leadPt-200-xx	0.0060	0.0030	0.0030	0.0030	0.0030
deltaR-02-10_sublPt-20-50_leadPt-00-200	0.0142	0.0100	0.0100	0.0010	0.0005
deltaR-02-10_sublPt-20-50_leadPt-200-xx	0.0066	0.0040	0.0030	0.0030	0.0030
deltaR-02-10_sublPt-50-xx_leadPt-00-200	0.0100	0.0100	0.0002	0.0002	0.0002
deltaR-02-10_sublPt-50-xx_leadPt-200-xx	0.0101	0.0100	0.0010	0.0010	0.0002
deltaR-10-xx	0.0316	0.0200	0.0100	0.0100	0.0200

Di-Tau Identification






ATLAS work in progress
ΔR < 0.2
ATLAS work in progress
0.2 < ΔR < 1.0
subl pT < 20 GeV
lead pT < 200 GeV
ATLAS work in progress
0.2 < ΔR < 1.0
subl pT < 20 GeV
lead pT > 200 GeV
ATLAS work in progress
0.2 < ΔR < 1.0
20 < subl pT < 50 GeV
lead pT < 200 GeV
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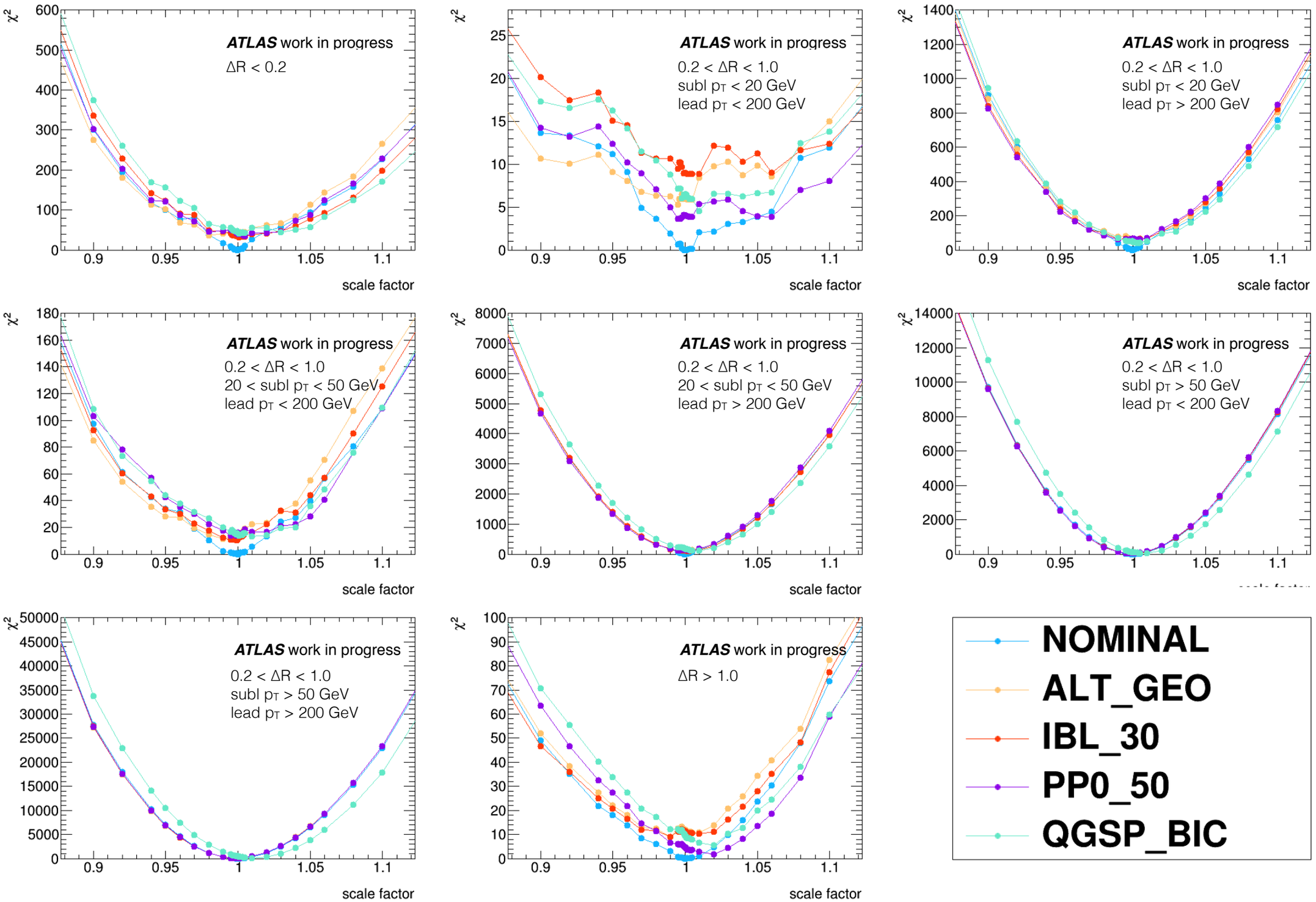
0.2 < ΔR < 1.0
subl pT > 50 GeV
lead pT > 200 GeV
ATLAS work in progress
ΔR > 1.0
NOMINAL
ALT_GEO
IBL_30
PP0_50
QGSP_BIC


ATLAS work in progress
ΔR < 0.2
0.2 < ΔR < 1.0
subl pT < 20 GeV
lead pT < 200 GeV
0.2 < ΔR < 1.0
subl pT < 20 GeV
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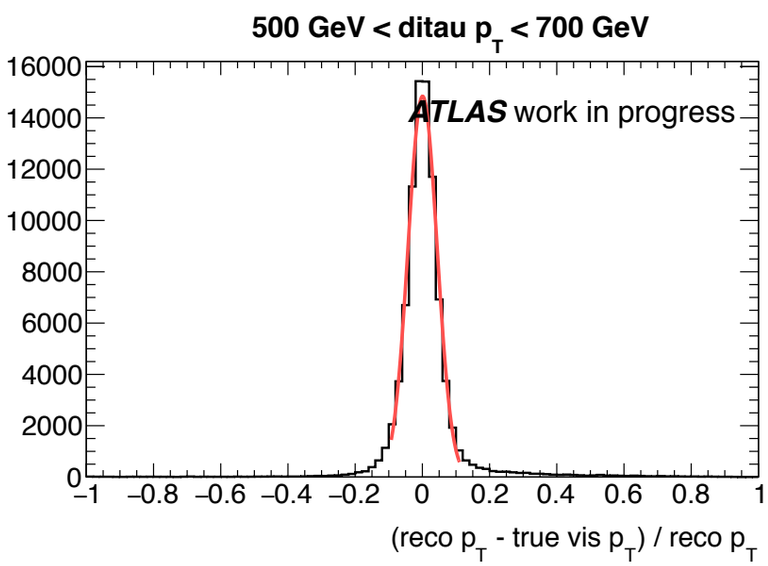
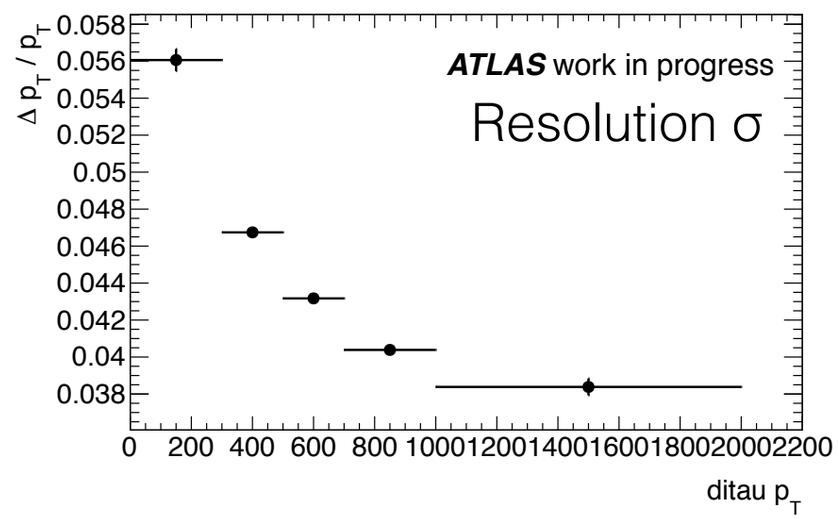
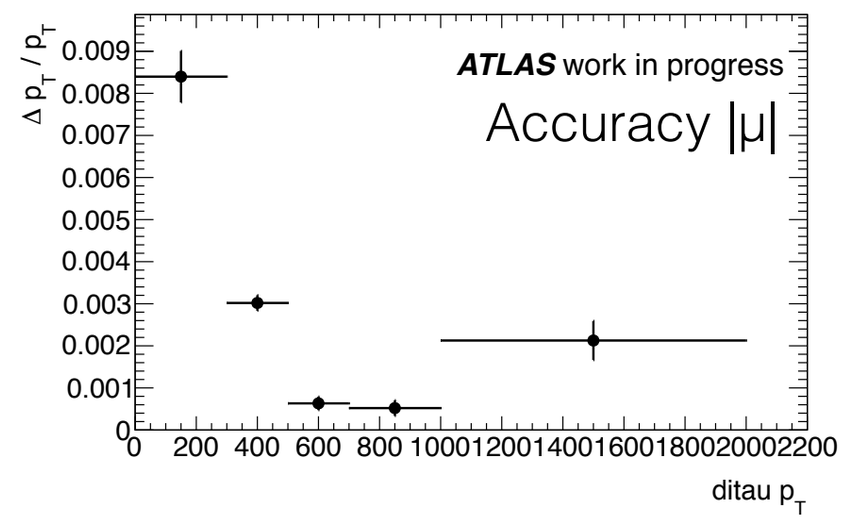
subl pT > 50 GeV
lead pT < 200 GeV
0.2 < ΔR < 1.0
subl pT > 50 GeV
lead pT > 200 GeV
ΔR > 1.0
χ²
scale factor
NOMINAL
ALT_GEO
IBL_30
PP0_50
QGSP_BIC

Di-Tau Energy Resolution

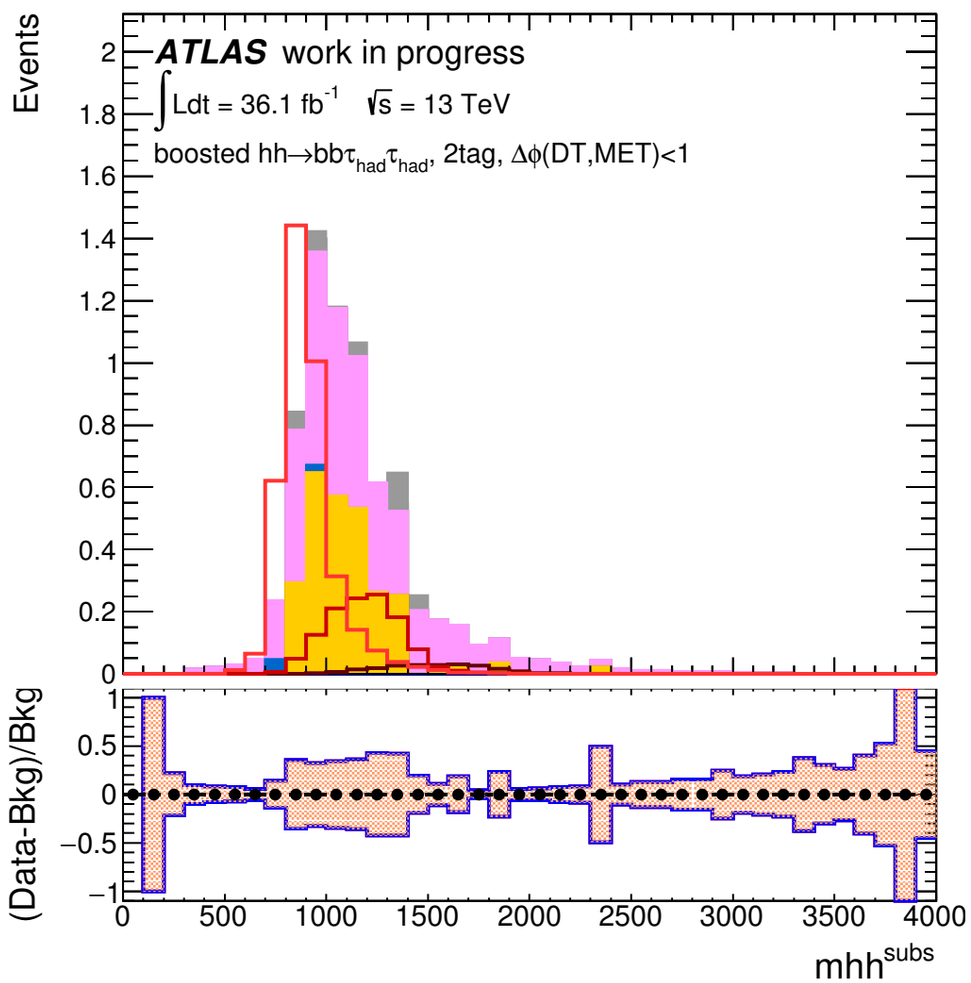
- Nominal G -> hh -> 4τ sample
- Relative difference between reconstructed and simulated p_T



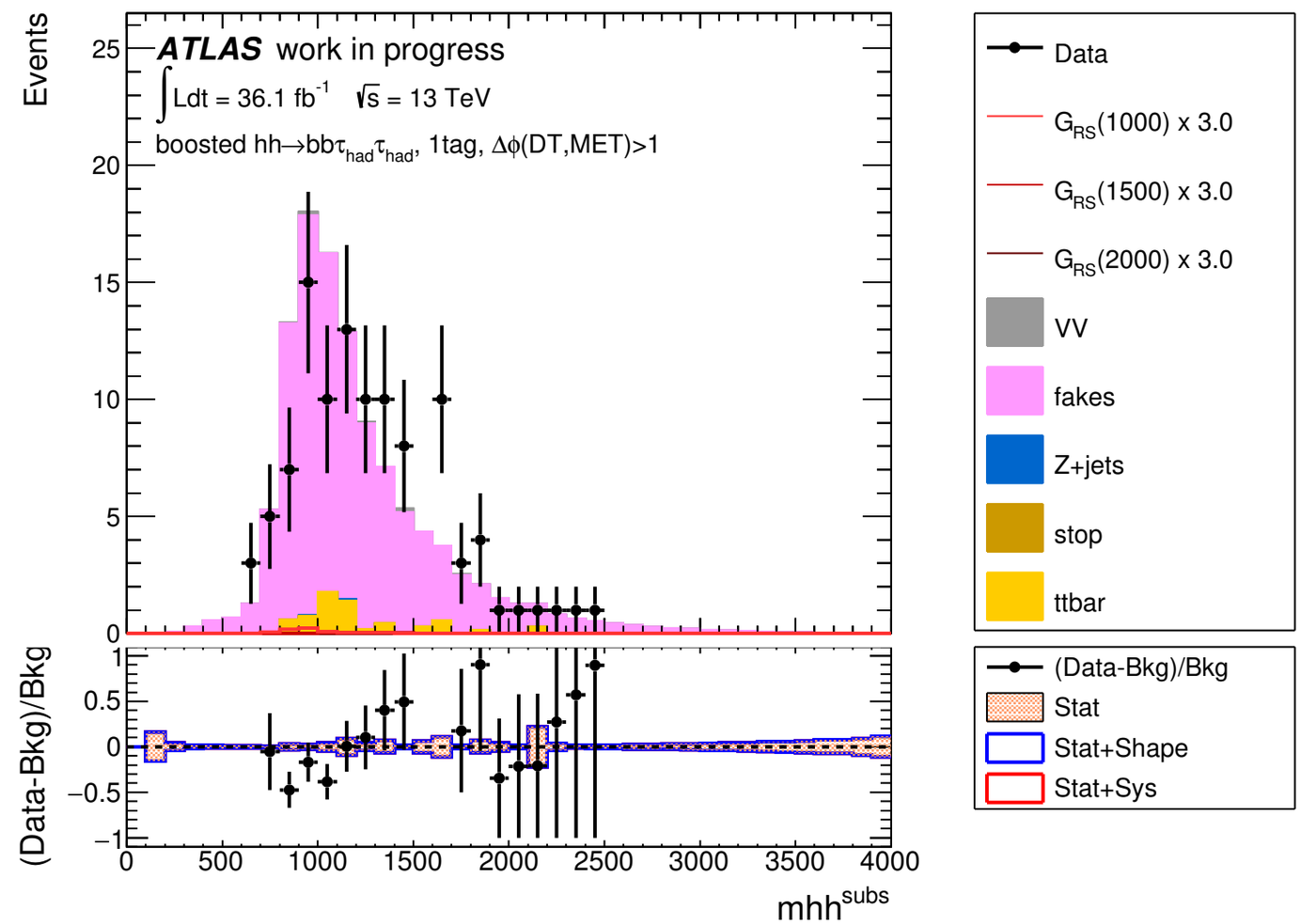




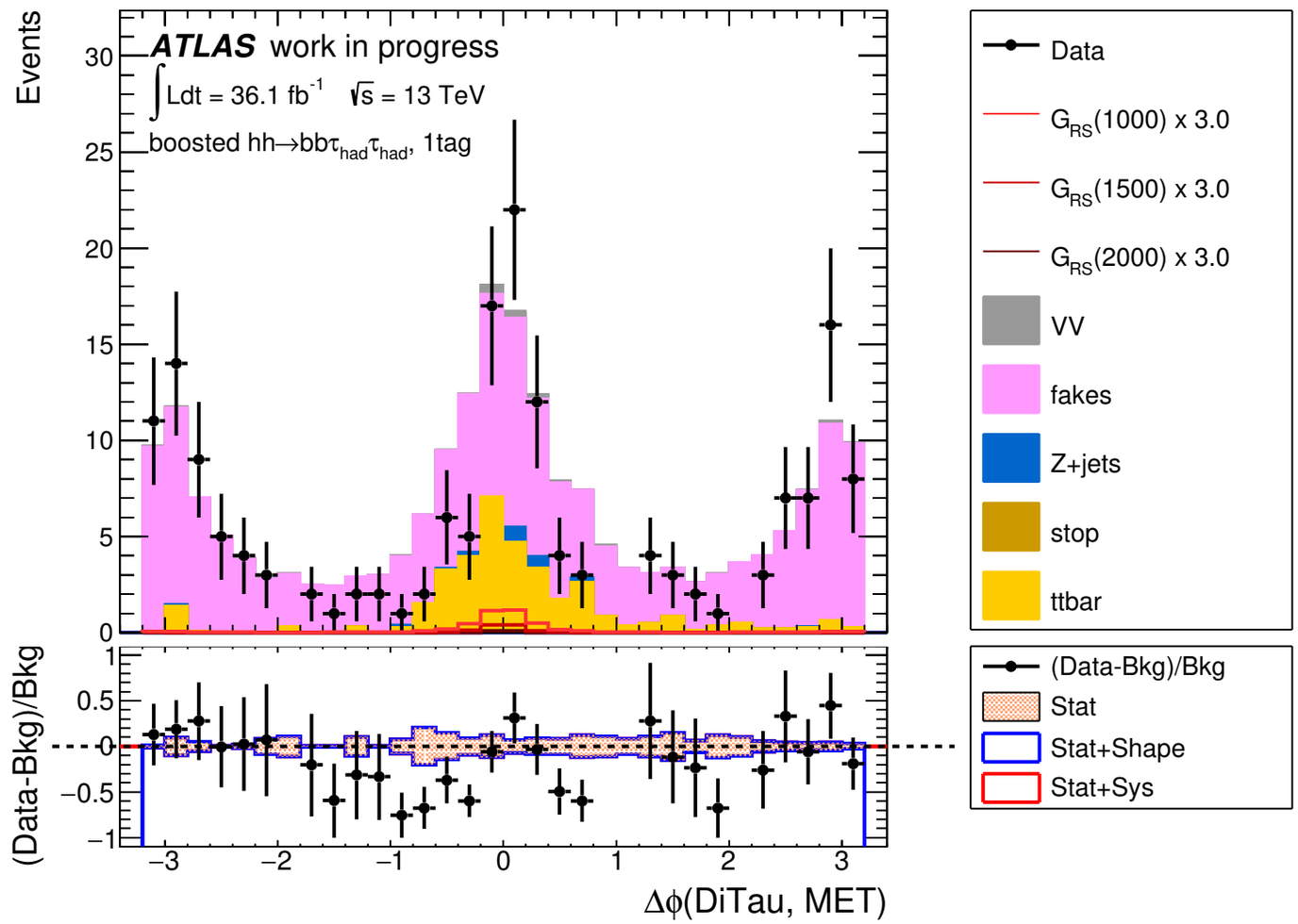
2-tag, $\Delta\varphi < 1$



1-tag, $\Delta\varphi > 1$

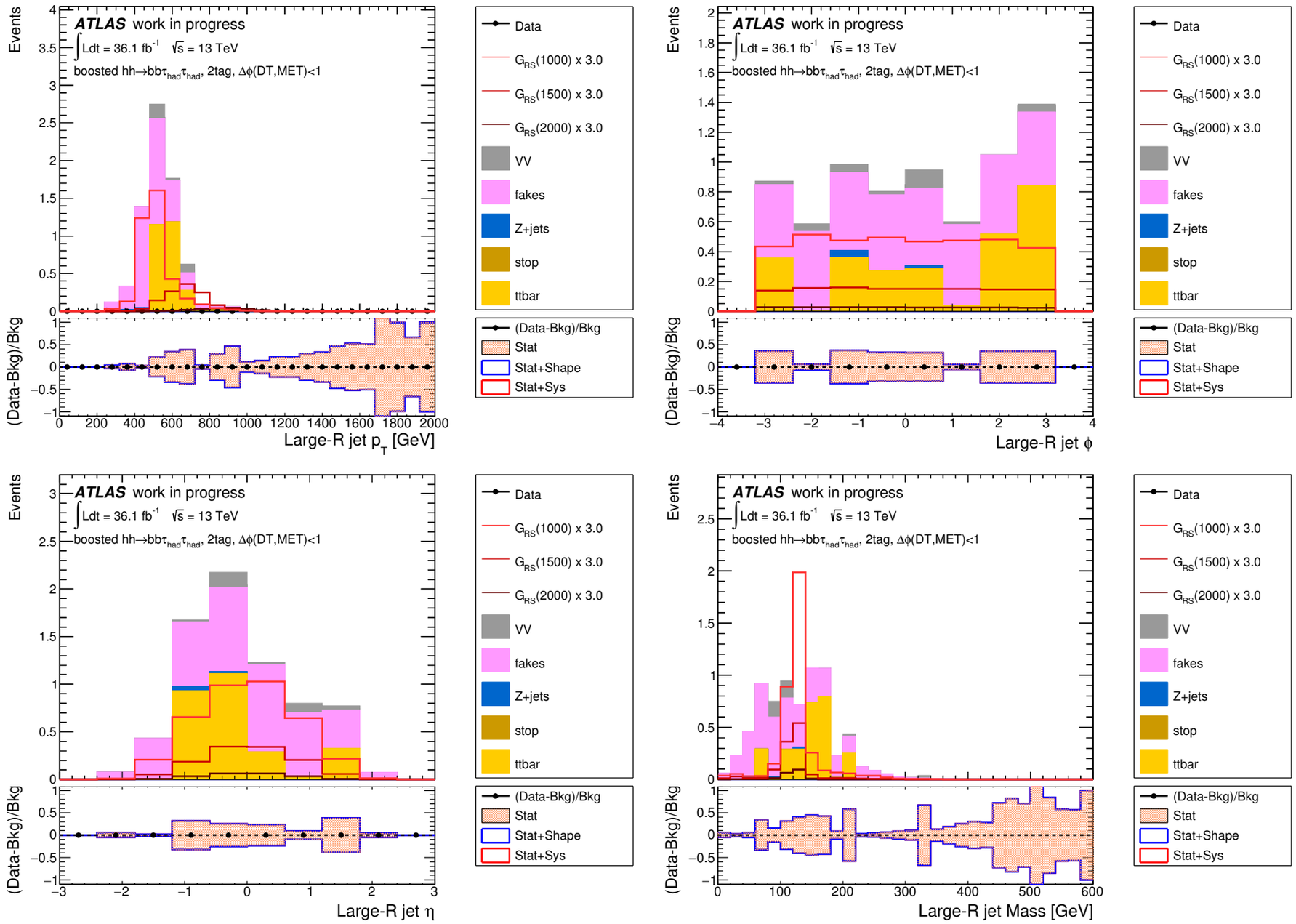


1-tag, $\Delta\varphi$ inclusive



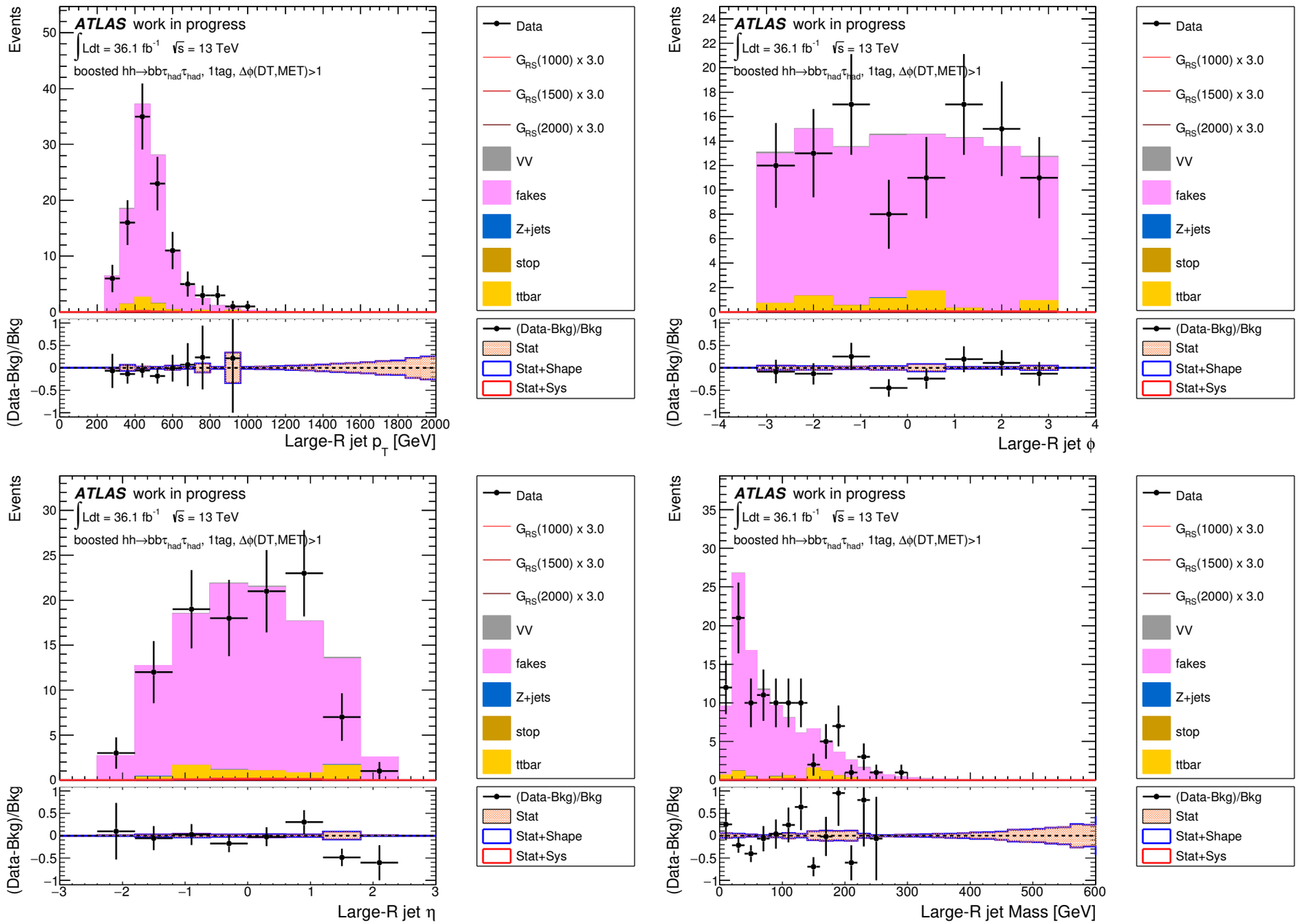
Jets in Signal Region

- 2-tag, $\Delta\varphi < 1$, jet kinematics:



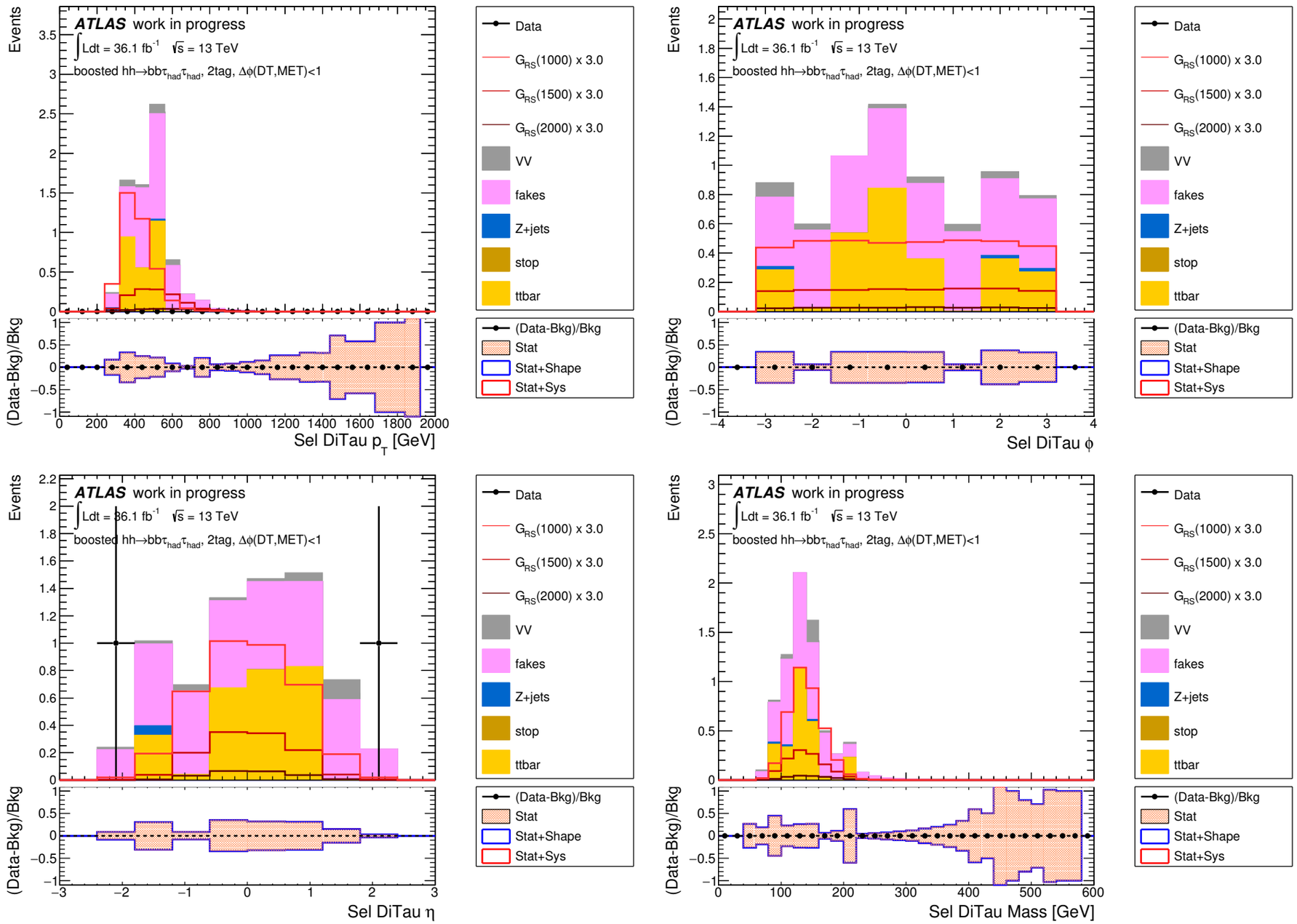
Jets in Validation Region

- 1-tag, $\Delta\varphi > 1$, jet kinematics:



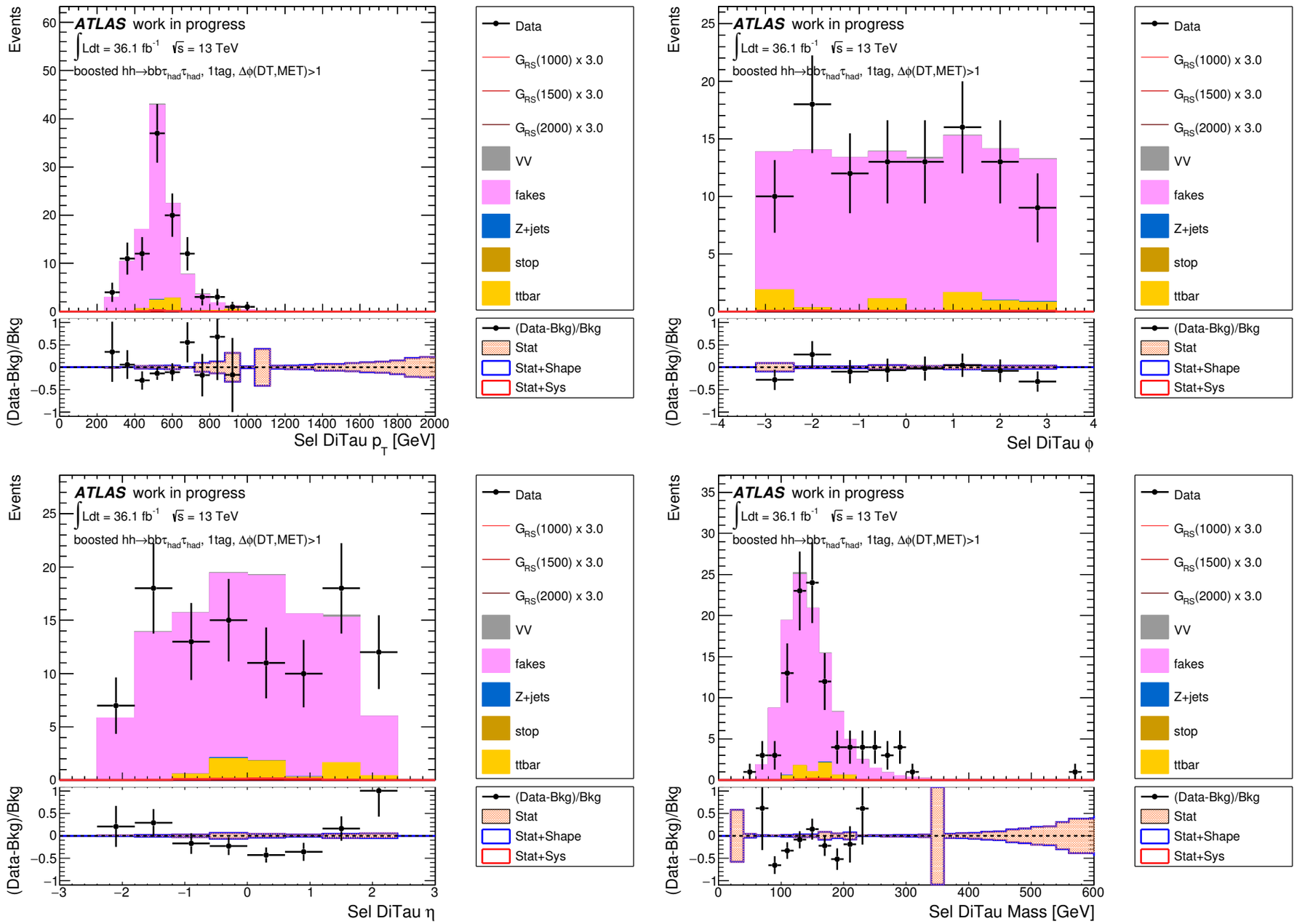
Di-Taus in Signal Region

- 2-tag, $\Delta\varphi < 1$, DiTauJet kinematics:



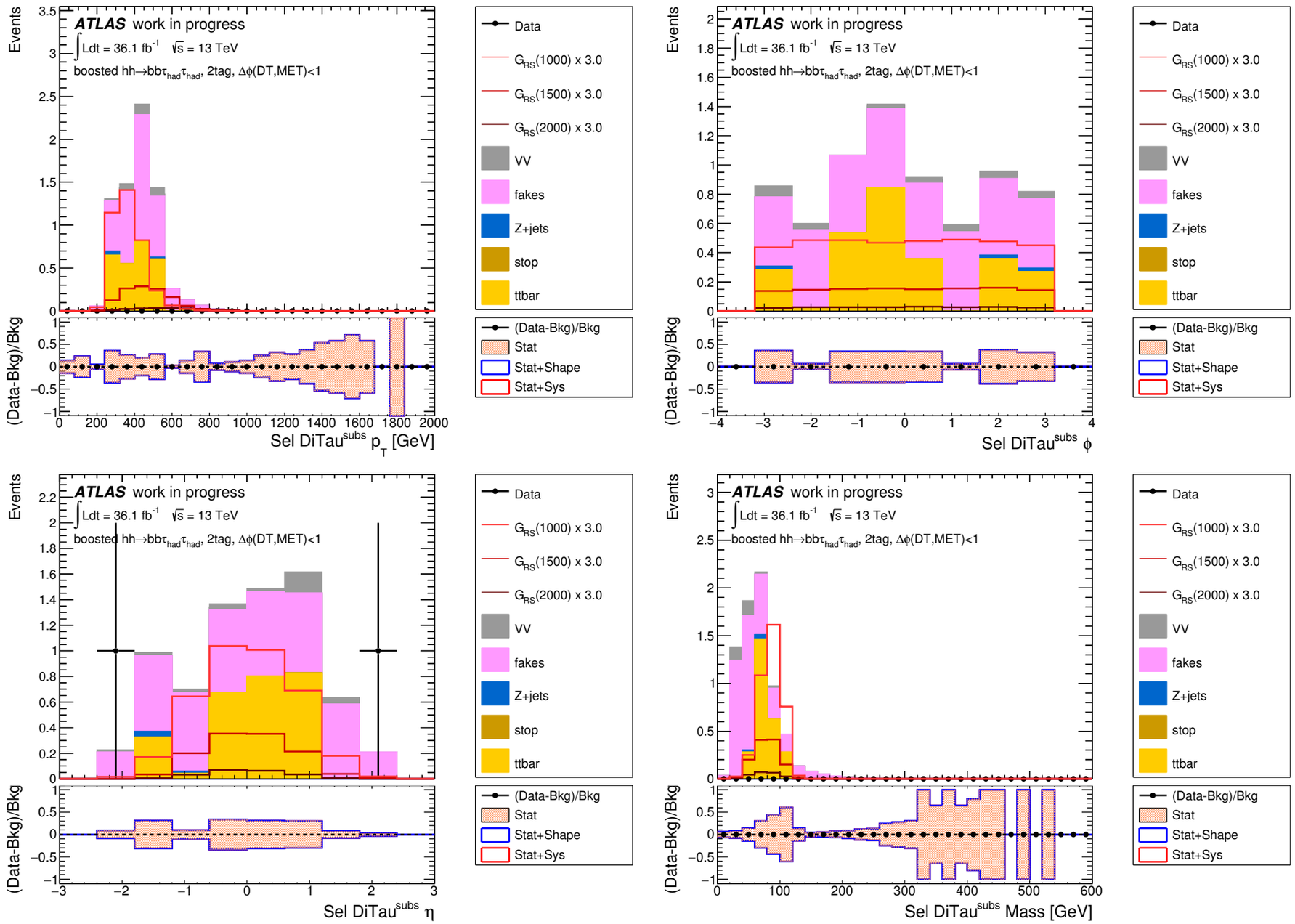
Di-Taus in Validation Region

- 1-tag, $\Delta\varphi > 1$, DiTauJet kinematics:



Di-Taus in Signal Region

- 2-tag, $\Delta\varphi < 1$, substructure kinematics:



Di-Taus in Validation Region

- 1-tag, $\Delta\varphi > 1$, substructure kinematics: strong mis-modelling in mass has to be investigated