Search for direct production of stau pairs in $\sqrt{s} = 13$ TeV pp collisions with the ATLAS detector

郭蕾(Lei Guo), IHEP & HENU

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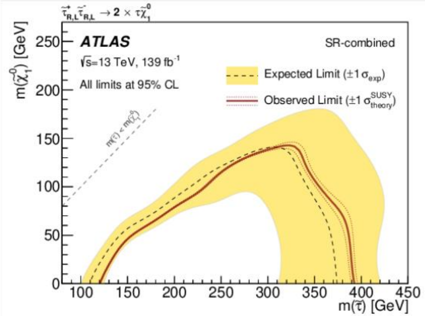
Introduction

- Motivation
  - 2nd round Full Run 2 Analysis targeting Electroweak SUSY production
  - Light Staus could play a role in Dark Matter co-annihilation in the early universe

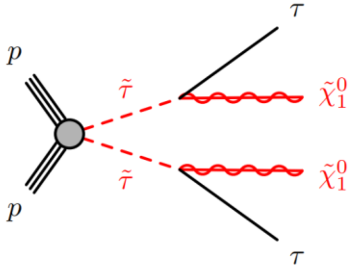


First round for L+R [Paper link]

- Strategy
  - Goal is to improve sensitivity using Machine Learning
  - Boosted Decision Trees (BDTs) used to define SR
  - Bkg: Multi-jet (fake taus), W+jets (1 real tau, 1 fake tau), Top, Z+ jets, Multi-Boson and Higgs

- Signal model in this talk: Direct Stau production

Require Taus to decay hadronically, final State is two Taus plus E_T^{miss}



Event Selection & SR optimization

- Asymmetric Di-tau Trigger used (with Tau pt efficiency plateau cuts)
- 4 binary BDT classifiers trained on different target $\tilde{\tau}$ and $\tilde{\chi}_1^0$ masses, using LightGBM link
- High level kinematics used as input features (tau p_Ts, E_T^{miss}, angular variables, transverse masses)
- Input features pre-binned to improve reliability

	BDT Training Preselection			
	≥ 2 "medium" τ (OS) asymmetric di-tau Trigger e, μ, b-jet veto $E_{\mathrm{T}}^{\mathrm{miss}} > 20\,\mathrm{GeV}$ $m_{\mathrm{T2}} > 30\,\mathrm{GeV}$ $m(\tau_1, \tau_2) > 120\,\mathrm{GeV}$ $\Delta R(\tau_1, \tau_2) < 4$			
	SR-BDT1	SR-BDT2	SR-BDT3	SR-BDT4
Target scenario	Low $m_{\tilde{\tau}}$ Small $\Delta m(\tilde{\tau}, \tilde{\chi}_1^0)$	Mid $m_{\tilde{\tau}}$ Large $\Delta m(\tilde{\tau}, \tilde{\chi}_1^0)$	Mid $m_{\tilde{\tau}}$ Small $\Delta m(\tilde{\tau}, \tilde{\chi}_1^0)$	High $m_{\tilde{\tau}}$
	$= 2$ "medium" τ			
Bin 1	BDT1 score $\in (0.73, 0.78)$	BDT2 score $\in (0.78, 0.82)$	BDT3 score $\in (0.79, 0.86)$	BDT4 score > 0.64
Bin 2	BDT1 score > 0.78	BDT2 score > 0.82	BDT3 score > 0.86	–

Background Estimation Overview

Data-driven ABCD method, dedicated VR

Multi-jet:

- Largest background at BDT preselection level
- Data-driven ABCD method (seen next slide)

Z+jets:

- $Z \rightarrow \tau\tau$ poses an irreducible background
- Largest background in low mass SR_BDT_3
- Kinematics from MC,

Kinematics from MC, normalised in **CR**, dedicated **VR**

Kinematics from MC, normalised in dedicated **CRs**, dedicated **VRs**

W+jets:

- Main contribution from one fake τ, one real τ
- Largest background (~50%) in low mass SR_BDT_1

Multi-boson:

- Irreducible WW and ZZ backgrounds
- Dominant background in SR_BDT_2 and SR_BDT_4

Kinematics and normalisation from MC, modelling validated in dedicated **VR**

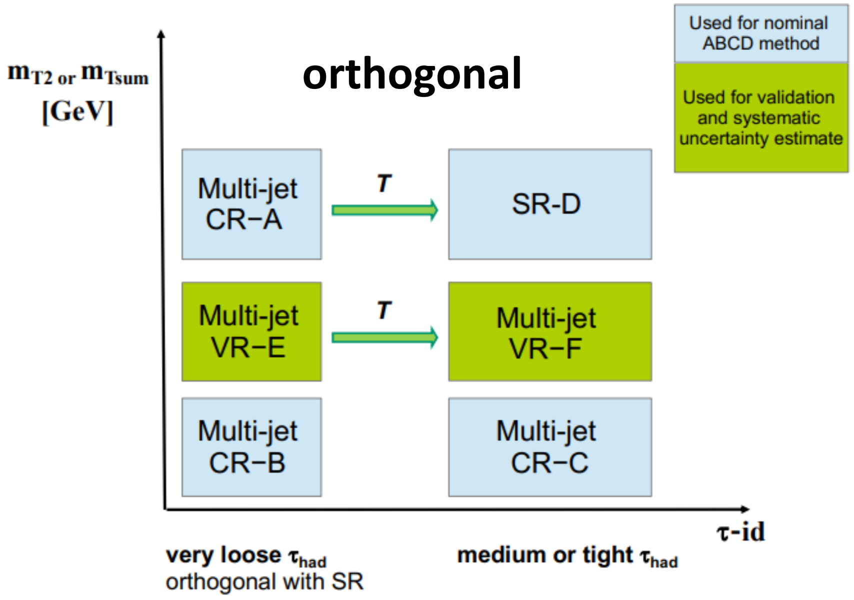
Top:

- Contributes between 7-30% in the different SRs

Also small contribution from **Higgs** backgrounds, taken from MC

Multi-jet estimate

- ABCD method using low m_{T2} and Loose/Same-Sign (SS) Tau regions
- Multi-jet prediction in pre 'SR-D' is from Data-MC in CR A multiplied by Transfer Factor (T) which is determined from CR B and CR C $\boxed{\text{transfer factor T} = N_C/N_B}$
- Fit of T is done simultaneously with normalisation factors on Z+jets, W+jets and Top backgrounds
- Disagreement in VR E and VR F is taken as a systematic uncertainty on MJ estimate as is statistical uncertainty from finite data/MC statistics in regions CR-B and CR-C

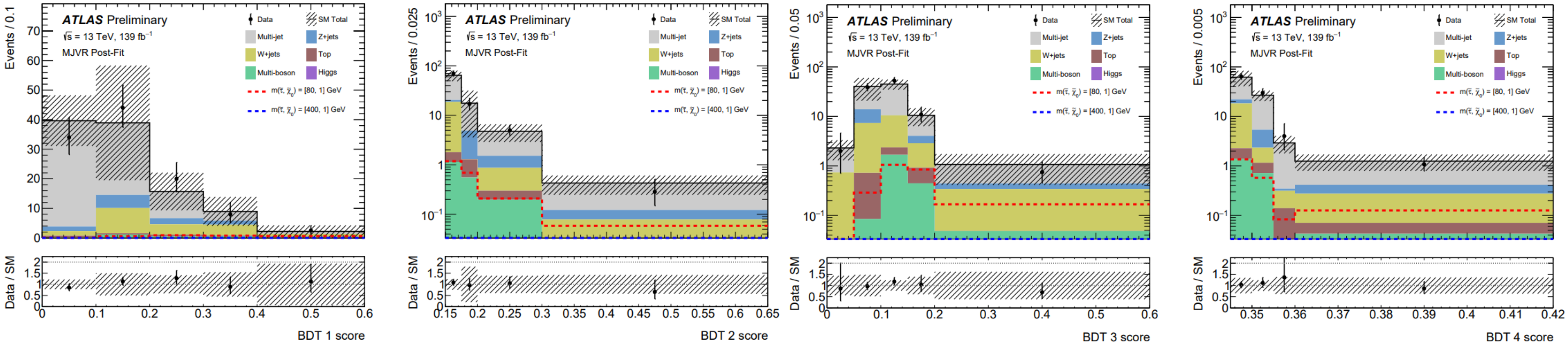


CR-A	VR-E	CR-B	pre-SR-D	VR-F	CR-C
asymmetric ditau trigger without plateau					
2 at least loose taus					
light lepton veto					
2 loose (not medium) taus OR 2 SS taus			2 at least medium taus		
$m_{T2} > 30$ GeV	$20 < m_{T2} < 30$ GeV	$10 < m_{T2} < 20$ GeV	$m_{T2} > 30$ GeV	$20 < m_{T2} < 30$ GeV	$10 < m_{T2} < 20$ GeV

Multi-jet validation region(VR)

OS, ==2 medium τ, veto b-jet; asymm. Ditau trigger, MET<50GeV, MT2>30GeV; m(τ1,τ2)>120GeV; ΔR(τ1,τ2)>3

$\text{BDT1, BDT4} \leq 0.60$
$\text{BDT2, BDT3} \leq 0.70$

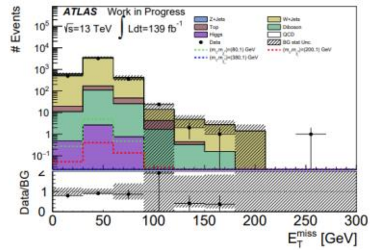


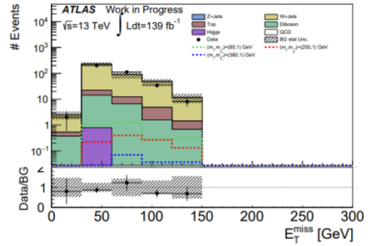
- Good agreement between data and the total SM background
- Combined statistical and systematic uncertainties of the total SM background

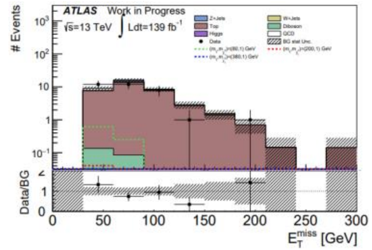
W+jets and Top control and validation regions

- **W+jets:**
  - CR and VR have 1 tau and 1 Muon, no b-jets
  - CR at low BDT score, VR at high BDT score
- **Top:**
  - CR also has 1 Tau and 1 Muon, plus at least 1 b-jet
  - VR same as SR but requiring a B-jet (and no BDT score cuts)

Process	W+jets		Top	
Region	WCR	WVR	TCR	TVR
OS/SS	OS			
N "medium" τ	$= 1$		$= 1$	$= 2$
N e/μ	$= 1\ \mu$		$= 1\ \mu$	$= 0$
N b-jets	$= 0$		≥ 1	≥ 1
Trigger	single μ		single μ	asymm. di-tau
$p_{\mathrm{T}}(\tau_1)$ [GeV]	-		-	> 95
$p_{\mathrm{T}}(\tau_2)$ [GeV]	-		-	> 65
$\max[p_{\mathrm{T}}(\tau), p_{\mathrm{T}}(\mu)]$ [GeV]	> 95		> 95	-
$\min[p_{\mathrm{T}}(\tau), p_{\mathrm{T}}(\mu)]$ [GeV]	> 60		> 60	-
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 20		> 20	-
$m_{\mathrm{T},\mu}$ [GeV]	$\in [50, 150]$		$\in [50, 150]$	-
m_{T2} [GeV]	> 30		> 30	
$m(\tau_1, \tau_2)$ [GeV]	> 120		> 120	
BDT score	All < 0.5	Any > 0.5	-	



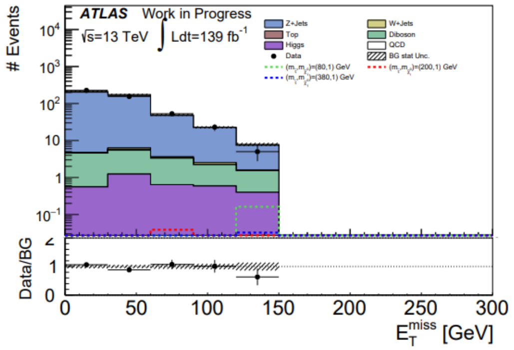


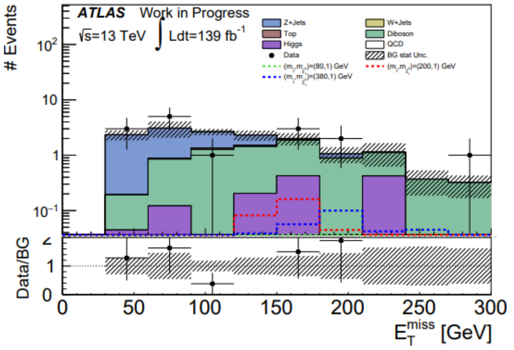


Z+jets and Multi-boson Control and Validation Regions

- **Z+jets:**
  - CR/VR has same selection as SRs, but with $m(\tau_1, \tau_2)$ cut reversed
  - CR/VR split by BDT1score (VR at higher score)
- **Multi-boson:**
  - VR like high mass SRs (high BDT4 score) but with $m(\tau_1, \tau_2)$ cut reversed

Process	Z+jets		Multi-boson
Region	ZCR	ZVR	MBVR
OS/SS			OS
N "medium" τ	$= 2$		$= 2$
N e/μ	$= 0$		$= 0$
N b-jets	$= 0$		$= 0$
Trigger	asymm. di-tau		asymm. di-tau
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	-		> 20
m_{T2} [GeV]	> 30		> 30
$m(\tau_1, \tau_2)$ [GeV]	< 120		< 120
$\Delta R(\tau_1, \tau_2)$	< 4		< 4
BDT score	BDT4 < 0.6		BDT4 > 0.61
	BDT1 < 0.1	BDT1 > 0.1	



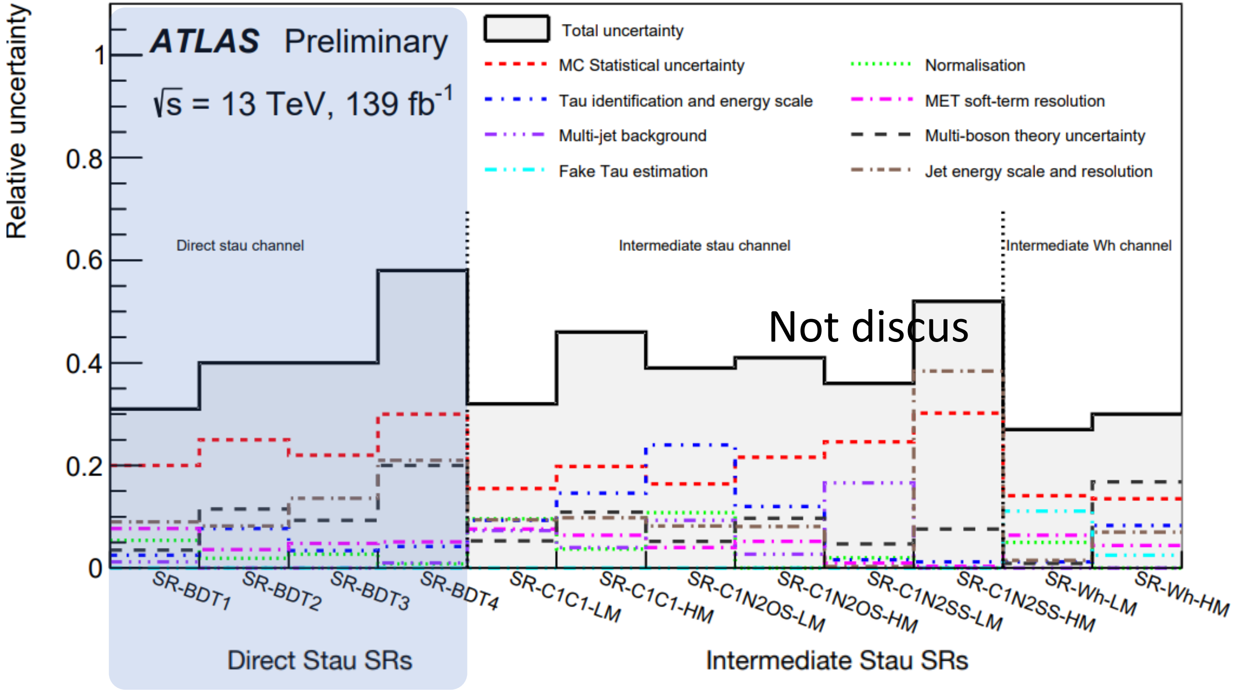


Systematic Uncertainties

- **Experimental:** following CP recommendations
  - Jet Energy calibration & resolution, Tau identification, E_T^{miss} modelling, pile up, luminosity etc.
- **Theoretical:** following PMG guildlines:
  - Renormalisation scale, factorisation, Merging/Matching scale PDF+α_s uncertainties
  - Xsection uncertainties for backgrounds without dedicated CRs (Multi-boson & Higgs)
  - For Signal, xsection, scale and radiation uncertainties evaluated
- **Multi-jet Estimate:**
  - As discussed previously, take difference in transfer factor using VR-E and VR-F as systematic uncertainty, also propagate statistical errors from finite data & MC yields in CRs used to compute transfer factor

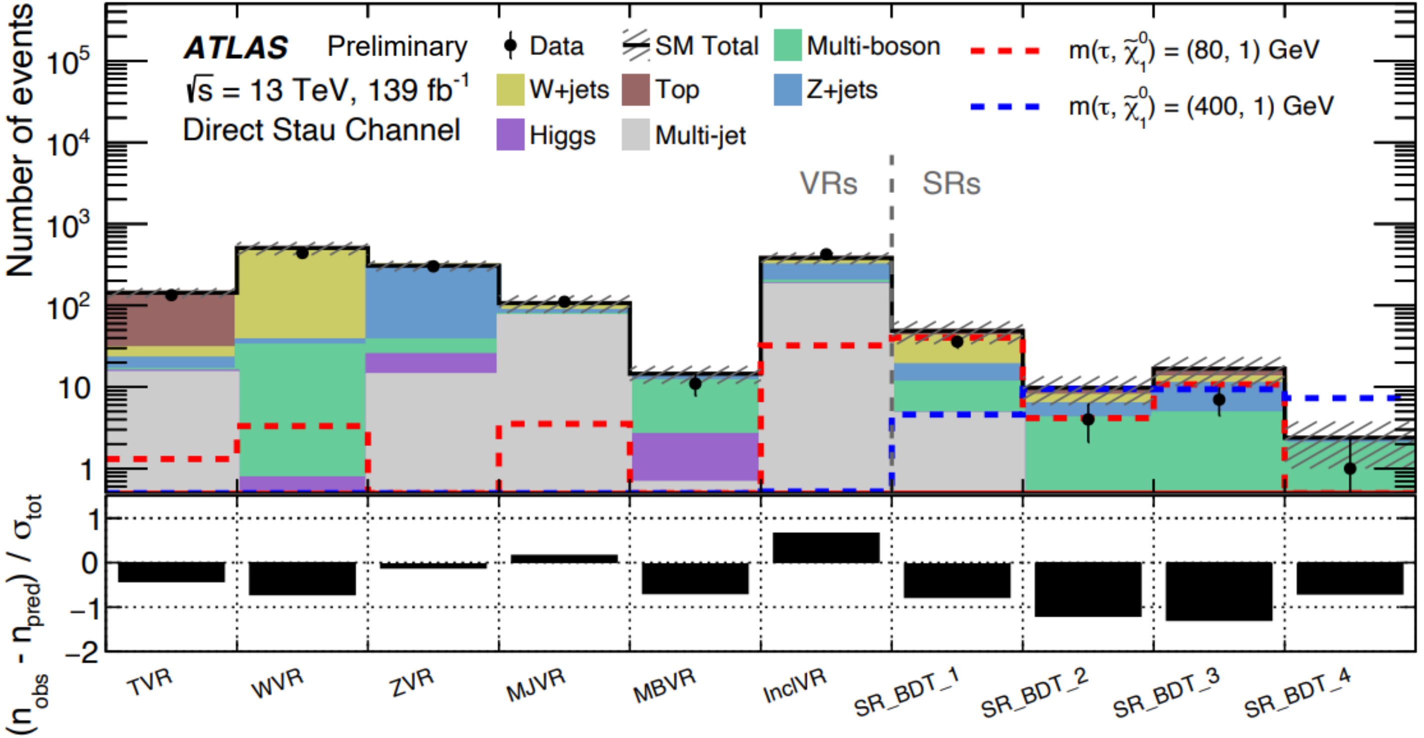
Systematic Uncertainties breakdown

- Uncertainties in SRs dominated by MC statistical uncertainties
- Jet energy scale and Multi-boson theoretical uncertainties also important

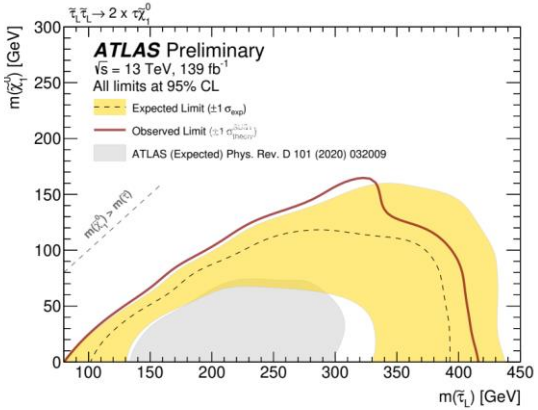


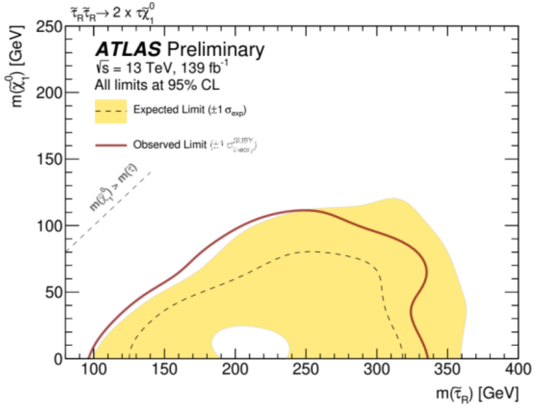
Results

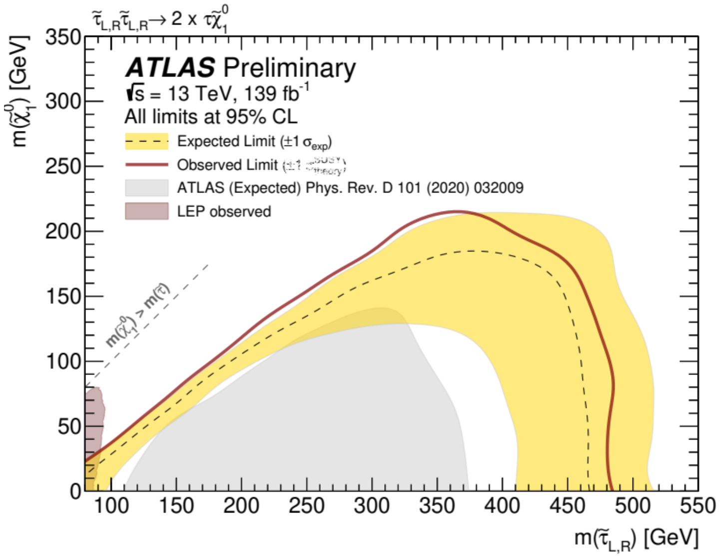
- Post-fit results:
- Good agreement seen in all VRs
- Small deficit seen in each of the SRs (max 1.3σ)
- Note that there is significant overlap between the SRs (particularly SR_BDT_2 and SR_BDT_3)



Exclusion Limits





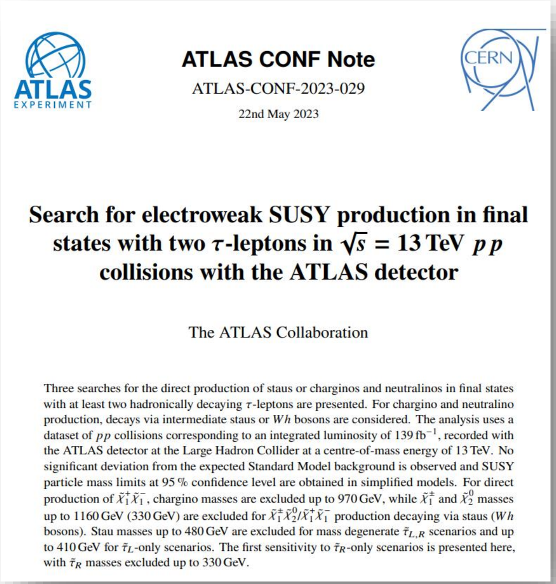


- Observe no excesses above SM prediction
- τ_R the first LHC sensitivity masses to 330 GeV
- stau masses up to 480 GeV are excluded

Summary

- Conclusion
  - 2nd round target Direct Stau scenario using ML
  - First look into right-handed Staus and get contour
  - Larger improvement compare with previous result
- Outlook
  - Compressed DiTau Analysis for Run3 & HL-LHC

Conf Note



ATLAS CONF Note

ATLAS-CONF-2023-029

22nd May 2023

Search for electroweak SUSY production in final states with two τ-leptons in $\sqrt{s}$ = 13 TeV pp collisions with the ATLAS detector

The ATLAS Collaboration

Three searches for the direct production of staus or charginos and neutralinos in final states with at least two hadronically decaying τ-leptons are presented. For chargino and neutralino production, decays via intermediate staus or Wh bosons are considered. The analysis uses a dataset of pp collisions corresponding to an integrated luminosity of 139 fb^{-1}, recorded with the ATLAS detector at the Large Hadron Collider at a centre-of-mass energy of 13 TeV. No significant deviation from the expected Standard Model background is observed and SUSY particle mass limits at 95 % confidence level are obtained in simplified models. For direct production of $\tilde{\chi}_1^+\tilde{\chi}_1^-$, chargino masses are excluded up to 970 GeV, while $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ masses up to 1160 GeV (330 GeV) are excluded for $\tilde{\chi}_1^\pm\tilde{\chi}_2^0/\tilde{\chi}_1^+\tilde{\chi}_1^-$ production decaying via staus (Wh bosons). Stau masses up to 480 GeV are excluded for mass degenerate $\tilde{\tau}_{L,R}$ scenarios and up to 410 GeV for $\tilde{\tau}_L$-only scenarios. The first sensitivity to $\tilde{\tau}_R$-only scenarios is presented here, with $\tilde{\tau}_R$ masses excluded up to 330 GeV.


Thank you !

backup

- https://indico.cern.ch/event/1199102/contributions/5423601/attachments/2687303/4662928/ICNFP_EWK.pdf
- https://cds.cern.ch/record/2688062/files/ATL-PHYS-PUB-2019-033.pdf
- https://cds.cern.ch/record/2702267/files/PoS(ICHEP2018)914.pdf CMS
- https://cds.cern.ch/record/2647985/files/FTR-18-010-pas.pdf CMS
- https://cms-results.web.cern.ch/cms-results/public-results/publications/SUS-21-001/index.html CMS
- $\tilde{\chi}_1^{\pm}$, $tilde{τ}, $\tilde{\tau}$

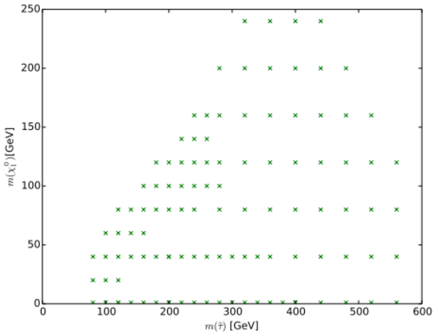
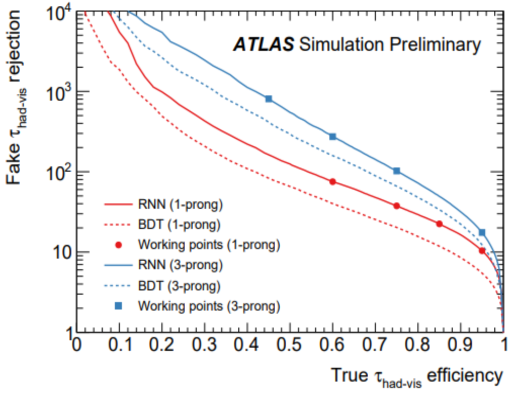


Figure 2: Direct stau signal grid



Outline

- Introduction
- Event Selection & SR optimization
- Background Estimation & Validation
- Fit and limit Results
- Summary

Conf Note

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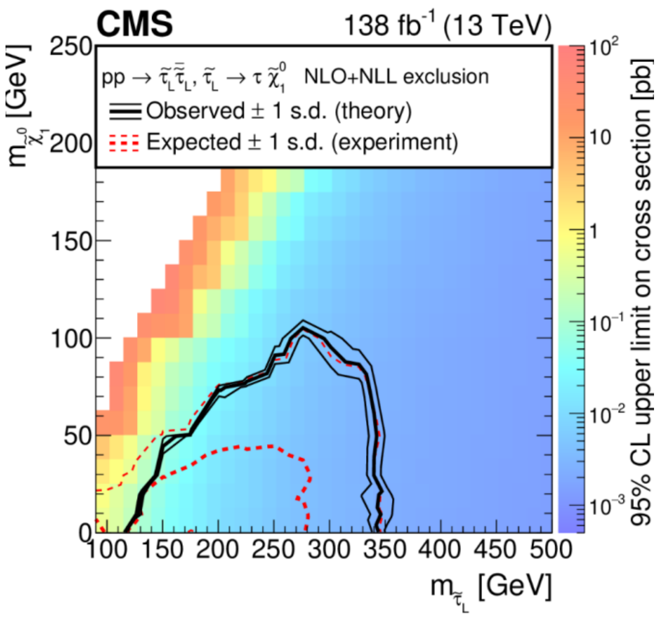
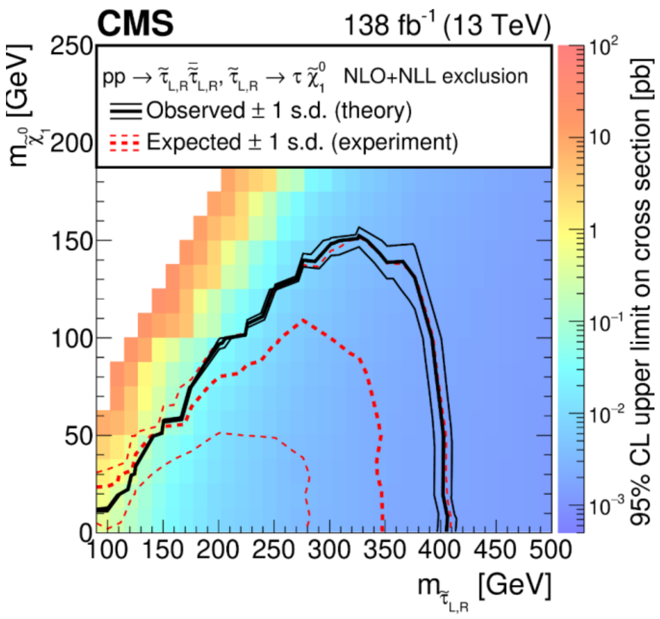
CMS results


CMS
138 fb^{-1} (13 TeV)
pp → $\tilde{\tau}_L\bar{\tilde{\tau}}_L$, $\tilde{\tau}_L \to \tau\tilde{\chi}^0_1$ NLO+NLL exclusion
Observed ± 1 s.d. (theory)
Expected ± 1 s.d. (experiment)
$m_{\tilde{\chi}^0_1}$ [GeV]
$m_{\tilde{\tau}_L}$ [GeV]
95% CL upper limit on cross section [pb]


CMS
138 fb^{-1} (13 TeV)
pp → $\tilde{\tau}_{L,R}\bar{\tilde{\tau}}_{L,R}$, $\tilde{\tau}_{L,R} \to \tau\tilde{\chi}^0_1$ NLO+NLL exclusion
Observed ± 1 s.d. (theory)
Expected ± 1 s.d. (experiment)
$m_{\tilde{\chi}^0_1}$ [GeV]
$m_{\tilde{\tau}_{L,R}}$ [GeV]
95% CL upper limit on cross section [pb]

SR Yields table breakdown

	SR-BDT1	SR-BDT2	SR-BDT3	SR-BDT4
Target scenario	Low $m_{\tilde{\tau}}$ Small $\Delta m(\tilde{\tau}, \tilde{\chi}_1^0)$	Mid $m_{\tilde{\tau}}$ Large $\Delta m(\tilde{\tau}, \tilde{\chi}_1^0)$	Mid $m_{\tilde{\tau}}$ Small $\Delta m(\tilde{\tau}, \tilde{\chi}_1^0)$	High $m_{\tilde{\tau}}$
	= 2 "medium" τ			
Bin 1	BDT1 score $\in (0.73, 0.78)$	BDT2 score $\in (0.78, 0.82)$	BDT3 score $\in (0.79, 0.86)$	BDT4 score > 0.64
Bin 2	BDT1 score > 0.78	BDT2 score > 0.82	BDT3 score > 0.86	–

SM process	SR-BDT1	SR-BDT1_bin0	SR-BDT1_bin1	SR-BDT2	SR-BDT2_bin0	SR-BDT2_bin1	SR-BDT3	SR-BDT3_bin0	SR-BDT3_bin1	SR-BDT4
Multi-boson	6.6 ± 2.9	3.3 ± 1.7	3.3 ± 1.7	4.1 ± 1.9	1.7 ± 1.0	2.3 ± 1.1	4.5 ± 2.1	2.0 ± 1.1	2.5 ± 1.3	1.8 ± 0.9
W+jets	23 ± 9	12 ± 6	11 ± 4	$1.6^{+1.7}_{-1.6}$	$1.5^{+1.6}_{-1.5}$	$0.1^{+0.1}_{-0.1}$	$2.3^{+3.2}_{-2.3}$	$1.8^{+3.2}_{-1.8}$	0.5 ± 0.5	$0.01^{+0.68}_{-0.01}$
Top quark	7.8 ± 2.5	3.3 ± 1.6	4.5 ± 1.9	2.06 ± 1.23	1.0 ± 1.0	1.0 ± 0.7	3.7 ± 1.5	2.7 ± 1.3	1.0 ± 0.9	$0.16^{+0.19}_{-0.16}$
Z+jets	7 ± 6	4 ± 4	2.8 ± 2.3	1.96 ± 1.07	1.6 ± 0.9	0.4 ± 0.2	6.1 ± 3.5	$1.9^{+2.7}_{-1.9}$	4.1 ± 2.2	$0.25^{+0.92}_{-0.25}$
Higgs	0.01 ± 0.01	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$0.02^{+0.12}_{-0.02}$	$0.0^{+0.1}_{-0.0}$	0.0 ± 0.0	0.12 ± 0.09	0.1 ± 0.1	$0.0^{+0.0}_{-0.0}$	0.01 ± 0.00
Multi-jet	4.6 ± 1.2	2.2 ± 0.8	2.4 ± 0.7	0.02 ± 0.00	0.0 ± 0.0	0.0 ± 0.0	0.02 ± 0.01	0.0 ± 0.0	0.0 ± 0.0	0.20 ± 0.07
SM total	49 ± 15	25 ± 10	24 ± 8	10 ± 4	5.9 ± 3.1	3.9 ± 1.5	17 ± 6	9 ± 5	8.2 ± 3.3	2.4 ± 1.4
Observed	36	22	14	4	3	1	7	6	1	1
$m(\tilde{\tau}, \tilde{\chi}_1^0) = (80, 1)$ GeV	40.3 ± 1.4	13.6 ± 0.8	26.7 ± 1.1	4.2 ± 0.4	3.4 ± 0.4	0.75 ± 0.19	10.8 ± 0.7	8.6 ± 0.7	2.19 ± 0.30	0.13 ± 0.07
$m(\tilde{\tau}, \tilde{\chi}_1^0) = (400, 1)$ GeV	4.59 ± 0.08	1.21 ± 0.04	3.38 ± 0.07	9.46 ± 0.12	2.08 ± 0.05	7.38 ± 0.10	9.39 ± 0.12	3.69 ± 0.07	5.70 ± 0.09	7.31 ± 0.10

• LightGBM相对于传统的梯度提升决策树算法

1. 高效性：LightGBM采用了基于直方图的决策树算法，能够更高效地处理大规模数据集和高维特征，训练速度快，内存占用低。
2. 高准确性：LightGBM在处理大规模数据时，能够更好地捕捉数据的特征，提高了模型的准确性和泛化能力。
3. 分布式支持：LightGBM支持并行化训练，可以在分布式计算环境下进行模型训练，加快了训练速度。
4. 支持大规模数据：LightGBM能够处理大规模数据集，适用于大数据场景，且在内存占用和计算效率上有明显优势。
5. 内置特征处理：LightGBM内置了对缺失值和类别特征的处理机制，能够更好地处理真实世界中的数据。
6. 可扩展性：LightGBM支持自定义损失函数和评估指标，可以满足各种复杂的模型训练需求。

Rank	LowMassBDT Variable	HighMassBDT Variable
1	$m_{T2}(\tau_1,\tau_2)$ [$m_{\text{invisible}}$ = 0 GeV]	$m_T(\tau_1,\tau_2)$
2	$m_T(\tau_1,\tau_2)$	$m_{T2}(\tau_1,\tau_2)$ [$m_{\text{invisible}}$ = 0 GeV]
3	$\Delta\phi(\tau_1, E_T^{\text{miss}})$	$\Delta R(\tau_1,\tau_2)$
4	$\Delta\phi(\tau_1,\tau_2)$	$m_{T2}(\tau_1,\tau_2)$ [$m_{\text{invisible}}$ = 40 GeV]
5	E_T^{miss}	$p_T(\text{jet}_1)$
6	$m_{T2}(\tau_1,\tau_2)$ [$m_{\text{invisible}}$ = 40 GeV]	$m_{\text{inv}}(\tau_1,\tau_2)$
7	$\Delta R(\tau_1,\tau_2)$	$\Delta\phi(\tau_1,\tau_2)$
8	$\Delta\phi(\tau_2, E_T^{\text{miss}})$	$N(b\text{-tags})$
9	$p_T(\tau_2)$	$p_T(\tau_2)$
10	$\Delta\eta(\tau_1,\tau_2)$	E_T^{miss}
11	$m_{\text{inv}}(\tau_1,\tau_2)$	$\Delta\eta(\tau_1,\tau_2)$
12	$p_T(\text{jet}_1)$	$p_T(\tau_1)$
13	m_{eff}	$\Delta\phi(\tau_2, E_T^{\text{miss}})$
14	$p_T(\tau_1)$	$\Delta\phi(\tau_1, E_T^{\text{miss}})$
15	$p_T(\text{jet}_2)$	$p_T(\text{jet}_2)$
16	$N(\text{jets})$	$N(\text{jets})$
17	$N(b\text{-tags})$	m_{eff}

Parameter	LowMassBDT Setting	HighMassBDT Setting
Model	GradientBoost	GradientBoost
N (trees)	500	500
Maximum Depth	3	3
Shrinkage	0.1	0.01
Loss function	deviance	deviance
Signal	$80 \leq m_{\tilde{\tau}} \leq 160$ GeV $1 < m_{\tilde{\chi}_1^0} < 100$ GeV $\tilde{\tau}_R\tilde{\tau}_R$ and $\tilde{\tau}_L\tilde{\tau}_L$	$360 \leq m_{\tilde{\tau}} \leq 440$ GeV $1 < m_{\tilde{\chi}_1^0} < 40$ GeV $\tilde{\tau}_R\tilde{\tau}_R$ and $\tilde{\tau}_L\tilde{\tau}_L$
Background	Z+Jets, W+Jets, Diboson, QCD	Z+jets, W+jets, Multiboson, Top, QCD
Selection (pre-training)	asymmetric ditau trigger (without plateau cuts) at least two medium taus OS $\Delta R < 4$ $m_{T2} > 30$ GeV $m_{\text{vis}}(\tau_1,\tau_2) > 80$ GeV	asymmetric ditau trigger (without plateau cuts) at least two medium taus OS $m_{\text{vis}}(\tau_1,\tau_2) > 80$ GeV

First round for Direct Stau

TABLE I. Summary of selection requirements for the signal regions.

SR-lowMass	SR-highMass
2 tight τ (OS)	2 medium τ (OS), ≥ 1 tight τ
asymmetric di-τ trigger	di-$\tau + E_{\mathrm{T}}^{\mathrm{miss}}$ trigger
$75 < E_{\mathrm{T}}^{\mathrm{miss}} < 150$ GeV	$E_{\mathrm{T}}^{\mathrm{miss}} > 150$ GeV
τp_{T} cut described in Sec. V	
light lepton veto and 3rd medium τ veto	
b-jet veto	
Z/H veto ($m(\tau_1, \tau_2) > 120$ GeV)	
$\lvert\Delta\phi(\tau_1, \tau_2)\rvert > 0.8$	
$\Delta R(\tau_1, \tau_2) < 3.2$	
$m_{\mathrm{T2}} > 70$ GeV	

The model-dependent fits

SM process	SR-BDT1	SR-BDT1_bin0	SR-BDT1_bin1	SR-BDT2	SR-BDT2_bin0	SR-BDT2_bin1
Multi-boson	6.6 ± 2.9	3.3 ± 1.7	3.3 ± 1.7	4.1 ± 1.9	1.7 ± 1.0	2.3 ± 1.1
W+jets	23 ± 9	12 ± 6	11 ± 4	$1.6^{+1.7}_{-1.6}$	$1.5^{+1.6}_{-1.5}$	$0.1^{+0.1}_{-0.1}$
Top quark	7.8 ± 2.5	3.3 ± 1.6	4.5 ± 1.9	2.1 ± 1.2	1.0 ± 1.0	1.0 ± 0.7
Z+jets	7 ± 6	4 ± 4	2.8 ± 2.3	2.0 ± 1.1	1.6 ± 0.9	0.4 ± 0.2
Higgs	0.01 ± 0.01	$0.0^{+0.0}_{-0.0}$	$0.0^{+0.0}_{-0.0}$	$0.02^{+0.12}_{-0.02}$	$0.0^{+0.1}_{-0.0}$	0.0 ± 0.0
Multi-jet	4.6 ± 1.2	2.2 ± 0.8	2.4 ± 0.7	0.02 ± 0.00	0.0 ± 0.0	0.0 ± 0.0
SM total	49 ± 15	25 ± 10	24 ± 8	10 ± 4	5.9 ± 3.1	3.9 ± 1.5
Observed	36	22	14	4	3	1
$m(\tilde{\tau}, \tilde{\chi}_1^0) = (80, 1)$ GeV	40.3 ± 1.4	13.6 ± 0.8	26.7 ± 1.1	4.2 ± 0.4	3.4 ± 0.4	0.75 ± 0.19
$m(\tilde{\tau}, \tilde{\chi}_1^0) = (400, 1)$ GeV	4.59 ± 0.08	1.21 ± 0.04	3.38 ± 0.07	9.46 ± 0.12	2.08 ± 0.05	7.38 ± 0.10
p_0	0.5	-	-	0.5	-	-
Expected σ_{vis}^{95} [fb]	0.21	-	-	0.06	-	-
Observed σ_{vis}^{95} [fb]	0.17	-	-	0.04	-	-

SM process	SR-BDT3	SR-BDT3_bin0	SR-BDT3_bin1	SR-BDT4
Multi-boson	4.5 ± 2.1	2.0 ± 1.1	2.5 ± 1.3	1.8 ± 0.9
W+jets	$2.3^{+3.2}_{-2.3}$	$1.8^{+3.2}_{-1.8}$	0.5 ± 0.5	$0.01^{+0.68}_{-0.01}$
Top quark	3.7 ± 1.5	2.7 ± 1.3	1.0 ± 0.9	$0.16^{+0.19}_{-0.16}$
Z+jets	6.1 ± 3.5	$1.9^{+2.7}_{-1.9}$	4.1 ± 2.2	$0.25^{+0.92}_{-0.25}$
Higgs	0.12 ± 0.09	0.1 ± 0.1	$0.0^{+0.0}_{-0.0}$	0.01 ± 0.00
Multi-jet	0.02 ± 0.01	0.0 ± 0.0	0.0 ± 0.0	0.20 ± 0.07
SM total	17 ± 6	9 ± 5	8.2 ± 3.3	2.4 ± 1.4
Observed	7	6	1	1
$m(\tilde{\tau}, \tilde{\chi}_1^0) = (80, 1)$ GeV	10.8 ± 0.7	8.6 ± 0.7	2.19 ± 0.30	0.13 ± 0.07
$m(\tilde{\tau}, \tilde{\chi}_1^0) = (400, 1)$ GeV	9.39 ± 0.12	3.69 ± 0.07	5.70 ± 0.09	7.31 ± 0.10
p_0	0.5	-	-	0.5
Expected σ_{vis}^{95} [fb]	0.08	-	-	0.03
Observed σ_{vis}^{95} [fb]	0.05	-	-	0.03

Channel	Direct stau
Normalisation factor	$\tilde{\tau}\tilde{\tau}$
$\mu_{W\text{+jets}}$	0.93 ± 0.11
$\mu_{Z\text{+jets}}$	0.91 ± 0.07
μ_{Top}	0.85 ± 0.05
$\mu_{\text{Multi-jet}}$	-