Lepton Flavour Violation at ATLAS & CMS

Shikma Bressler on behalf of the ATLAS & CMS collaborations

- $H \rightarrow \tau\mu/\tau e/\mu e$
- $Z \rightarrow \tau\mu/\tau e/\mu e$
- Heavy $X \rightarrow \tau\mu/\tau e/\mu e$
- Others

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Higgs decays

Experiment		Process	√s [TeV]	∫L [fb^{-1}]
CMS	1502.07400	$H\to\tau\mu$	8	20
CMS	1607.03561	$H\to e\mu$ $H\to e\tau$	8	20
CMS	PAS HIG 16 005	$H\to\tau\mu$	**13**	2.3
ATLAS	1508.03372	$H\to\tau\mu$	8	20
ATLAS	1604.07730	$H\to\tau\mu$ $H\to\tau e$	8	20

LHC results — Library

Z decays

Experiment		Process	$\sqrt{s}$ [TeV]	$\int L$ [fb^{-1}]
CMS	PAS EXO 13 005	$Z\to\mu e$	8	20
ATLAS	1408.5774	$Z\to\mu e$	8	20
ATLAS	1604.07730	$Z\to\tau\mu$	8	20

Heavy resonances & others

Experiment		Process	$\sqrt{s}$ [TeV]	$\int L$ [fb^{-1}]
CMS	1604.05239	$X\to\mu e$	8	20
ATLAS	1503.04430	$X\to\tau\mu$ $X\to\tau e$ $X\to\mu e$	8	20
ATLAS	1607.08079	$X\to\tau\mu$ $X\to\tau e$ $X\to\mu e$	13	3.2
ATLAS	1601.03567	$\tau\to 3\mu$	8	20

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In general .

Theory

- Lepton Flavour is an accidental symmetry of the standard model
- Broken by neutrino oscillations ⇒ implies also breaking i.e at Higgs decays but at a very low rate (< 10^{-48})
- Many models predict LFV decays of Higgs and/or Z and/or other massive resonances

Experiment

- Complementary efforts are made by both collaborations
- Different methods are being employed
  ⇒ stringent cross checks
  ⇒ different systematic uncertainties
- Detector performance plays a leading role
  - Steep lepton reconstruction turn-on curves
  - High lepton p_T resolution
  - Misidentified lepton rate ⇒ the lower the better

Executive summary - April 2017

Process	CMS	ATLAS
$H\to\tau\mu$	BR<1.20%	BR<1.40%
$H\to\tau e$	BR<0.69%	BR<1.04%
$H\to e\mu$	BR<0.048%	-
$Z\to\tau\mu$	-	$BR<1.69\times10^{-5}$
$Z\to\tau e$	-	-
$Z\to e\mu$	$BR<7.3\times10^{-7}$	$BR<7.5\times10^{-7}$

Executive summary - April 2017

Background model strategy

The symmetry method

Process	CMS	ATLAS
$H\to\tau\mu$	BR<1.20%	BR<1.40%
$H\to\tau e$	BR<0.69%	BR<1.04%
$H\to e\mu$	BR<0.048%	-
$Z\to\tau\mu$	-	1.69×10^{-5}
$Z\to\tau e$	-	-
$Z\to e\mu$	BR<7.3×10^{-7}	BR<7.5×10^{-7}

Due to the excellent mass resolutions

Data driven

MC based

The choice of method dictates the uncertainties and hence the sensitivity

Executive summary - April 2017

Misidentified lepton estimation strategy

Process	CMS	ATLAS
$H\rightarrow\tau\mu$	BR<1.20%	BR<1.40%
$H\rightarrow\tau e$	BR<0.69%	BR<1.04%
$H\rightarrow e\mu$	BR<0.048%	-
$Z\rightarrow\tau\mu$	-	1.69×10^{-5}
$Z\rightarrow\tau e$	-	-
$Z\rightarrow e\mu$	$BR<7.3\times10^{-7}$	$BR<7.5\times10^{-7}$

Reversed isolation criteria

τ_{had} **- Estimation in same-sign region**

τ_{lep} **- Estimation using the Matrix Method**

CMS $H \rightarrow \tau\mu$

CMS 1502.07400

CMS H→τμ

Two search channels

- H→μτ$_{had}$
- H→μτ$_e$

Three jet categories

- 0-jets ⇒ targeting ggF production
- 1-jet ⇒ targeting ggF production
- 2-jets ⇒ targeting VBF production

Mass estimator

- Collinear mass

Background

CMS 1502.07400

- Z→ττ
  - Embedding (simulated τ response is embedded in $Z\to\mu\mu$ data sample)
- Misidentified leptons (W+jets, QCD)
  - Based on reverse isolation criteria
  - Validated in a same-sign region

Region I	**Region II**
$\ell_1^{\pm}$(isolated) $\ell_2^{\mp}$(isolated)	$\ell_1^{\pm}$(isolated) $\ell_2^{\pm}$(isolated)
Region III	**Region IV**
$\ell_1^{\pm}$(isolated) $\ell_2^{\mp}$(not-isolated)	$\ell_1^{\pm}$(isolated) $\ell_2^{\pm}$(not-isolated)

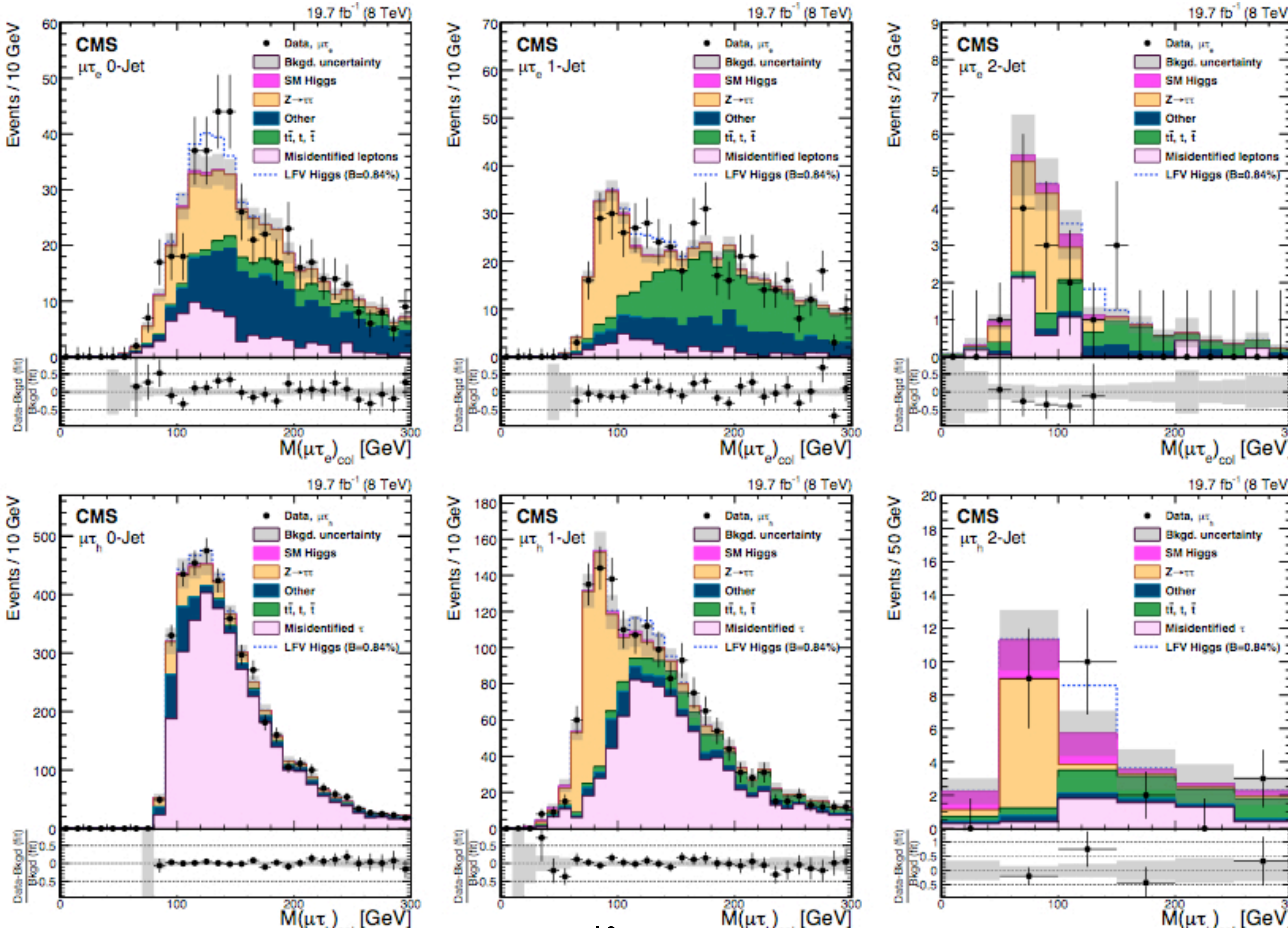
- Other (ttbar, H→ττ, WW, ZZ…)
  - From simulation

CMS H→τμ

CMS 1502.07400

H→μτ_e

H→μτ_had

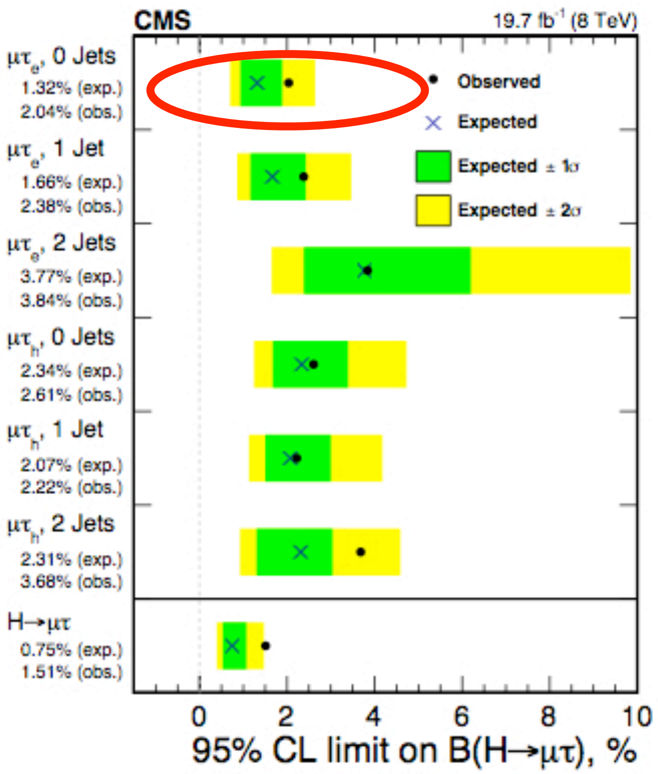


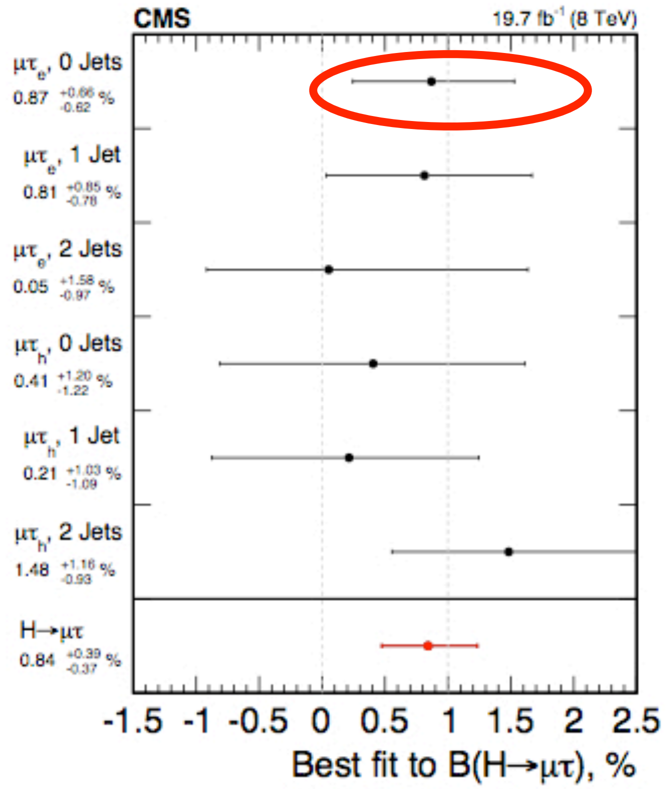
8 TeV | Higgs decays | CMS H→τμ

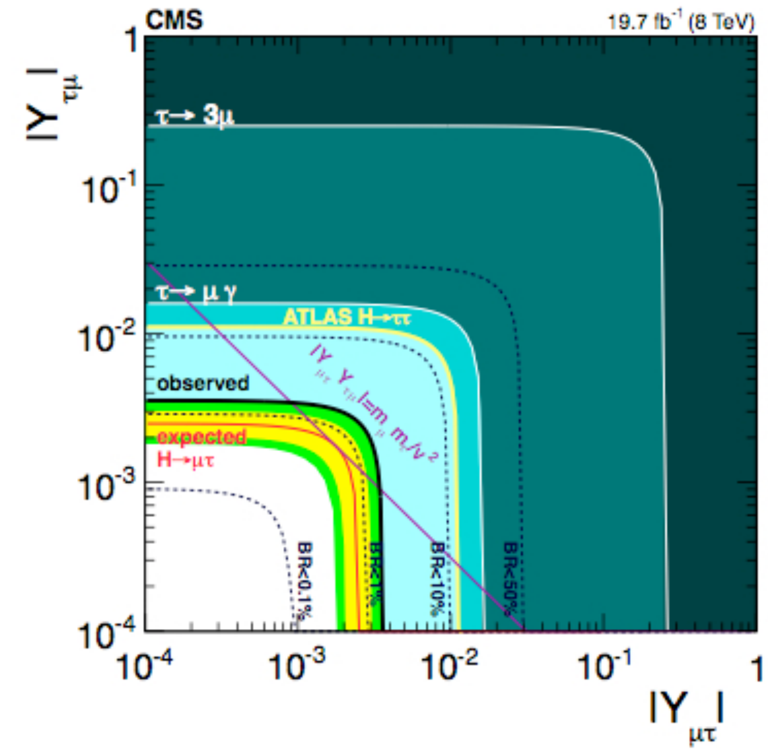
CMS 1502.07400

H→μτe

H→μτhad







	0-Jet (%)	1-Jet (%)	2-Jets (%)
Expected Limits			
$\mu\tau_e$	<1.32 (±0.67)	<1.66 (±0.85)	<3.77 (±1.92)
$\mu\tau_h$	<2.34 (±1.19)	<2.07 (±1.06)	<2.31 (±1.18)
$\mu\tau$	<0.75 (±0.38)		
Observed Limits			
$\mu\tau_e$	<2.04	<2.38	<3.84
$\mu\tau_h$	<2.61	<2.22	<3.68
$\mu\tau$	<1.51		
Best Fit Branching Fractions			
$\mu\tau_e$	$0.87^{+0.66}_{-0.62}$	$0.81^{+0.85}_{-0.78}$	$0.05^{+1.58}_{-0.97}$
$\mu\tau_h$	$0.41^{+1.20}_{-1.22}$	$0.21^{+1.03}_{-1.09}$	$1.48^{+1.16}_{-0.93}$
$\mu\tau$	$0.84^{+0.39}_{-0.37}$		

$$\sqrt{|Y_{\mu\tau}|^2 + |Y_{\tau\mu}|^2} < 3.6 \times 10^{-3}$$

$Y_{\tau\mu}$ - Off diagonal Yukawa coupling

ATLAS $H \rightarrow \tau_{had}\mu$

ATLAS 1508.03372

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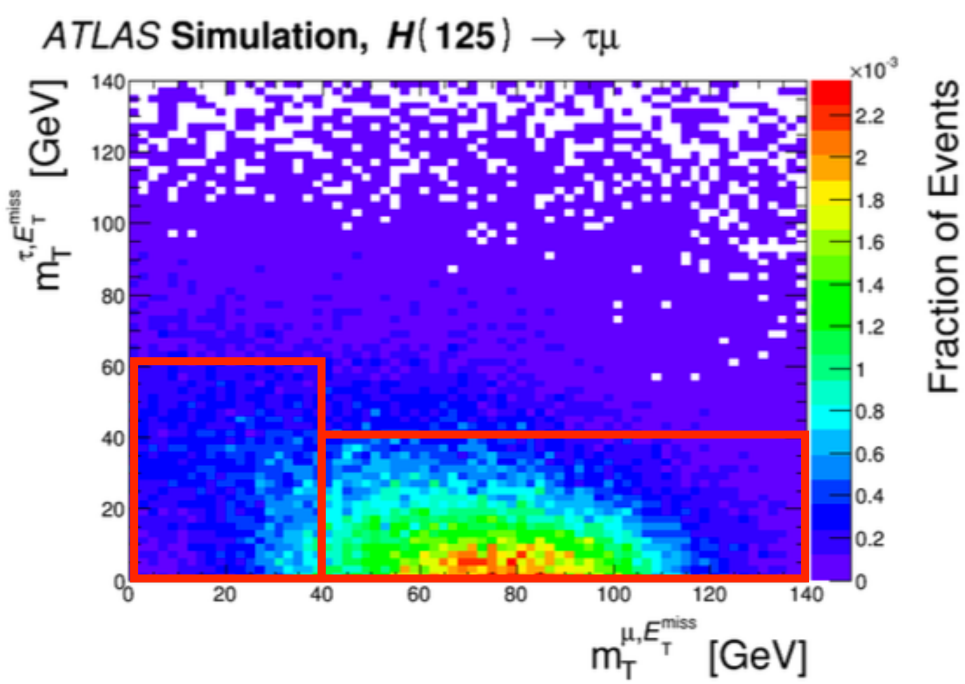
ATLAS $H\to\tau_{had}\mu$

One search channel

- $H\to\mu\tau_{had}$

Two signal regions



Mass estimator - MMC

- Missing Mass Calculator
  Exploiting the τ decay topology
  Use the τ mass a a constraint
  https://arxiv.org/abs/1012.4686

Background

ATLAS 1508.03372

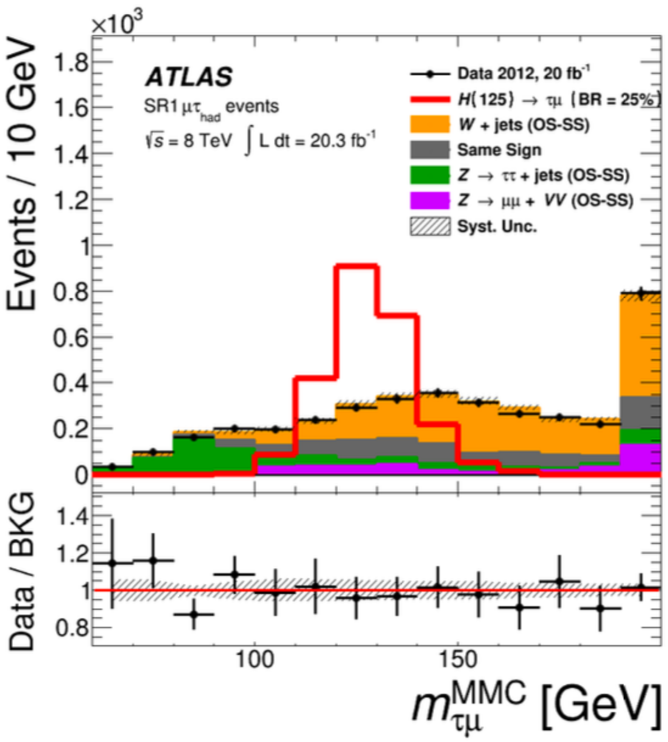
$$N_{\mathrm{OS}}^{\mathrm{bkg}} = r_{\mathrm{QCD}} \cdot N_{\mathrm{SS}}^{\mathrm{data}} + N_{\mathrm{OS-SS}}^{Z\to\tau\tau} + N_{\mathrm{OS-SS}}^{Z\to\mu\mu} + N_{\mathrm{OS-SS}}^{W+\mathrm{jets}} + N_{\mathrm{OS-SS}}^{\mathrm{top}} + N_{\mathrm{OS-SS}}^{VV} + N_{\mathrm{OS-SS}}^{H\to\tau\tau},$$

- $r_{\mathrm{QCD}} = N_{\mathrm{OS}}^{\mathrm{multi-jet}} / N_{\mathrm{SS}}^{\mathrm{multi-jet}}$

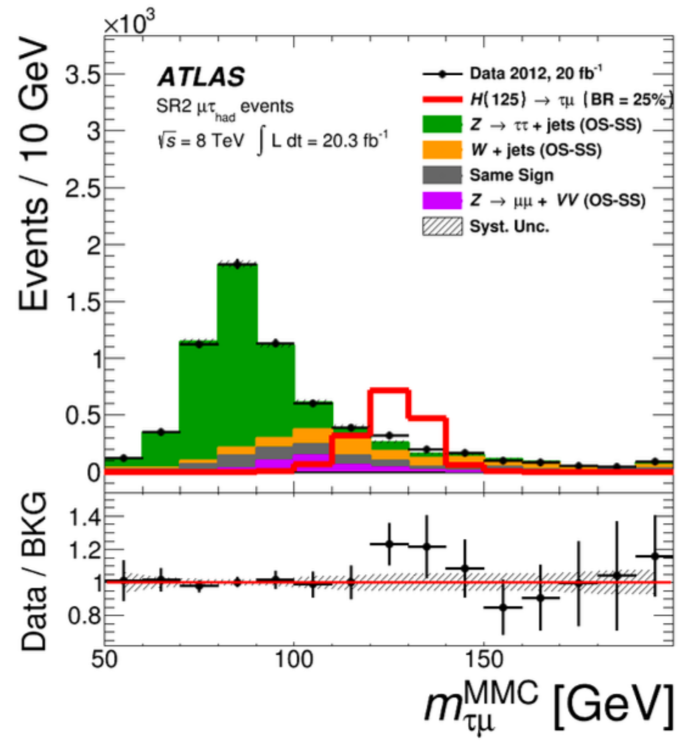
- $Z\to\tau\tau$
  - Embedding (simulated τ response is embedded in $Z\to\mu\mu$ data sample)
- Misidentified leptons (W+jets, QCD)
  - By r_{QCD}
- Other (ttbar, $H\to\tau\tau$, WW, ZZ…)
  - From simulation

8 TeV | Higgs decays | ATLAS H→$\tau_{had}\mu$

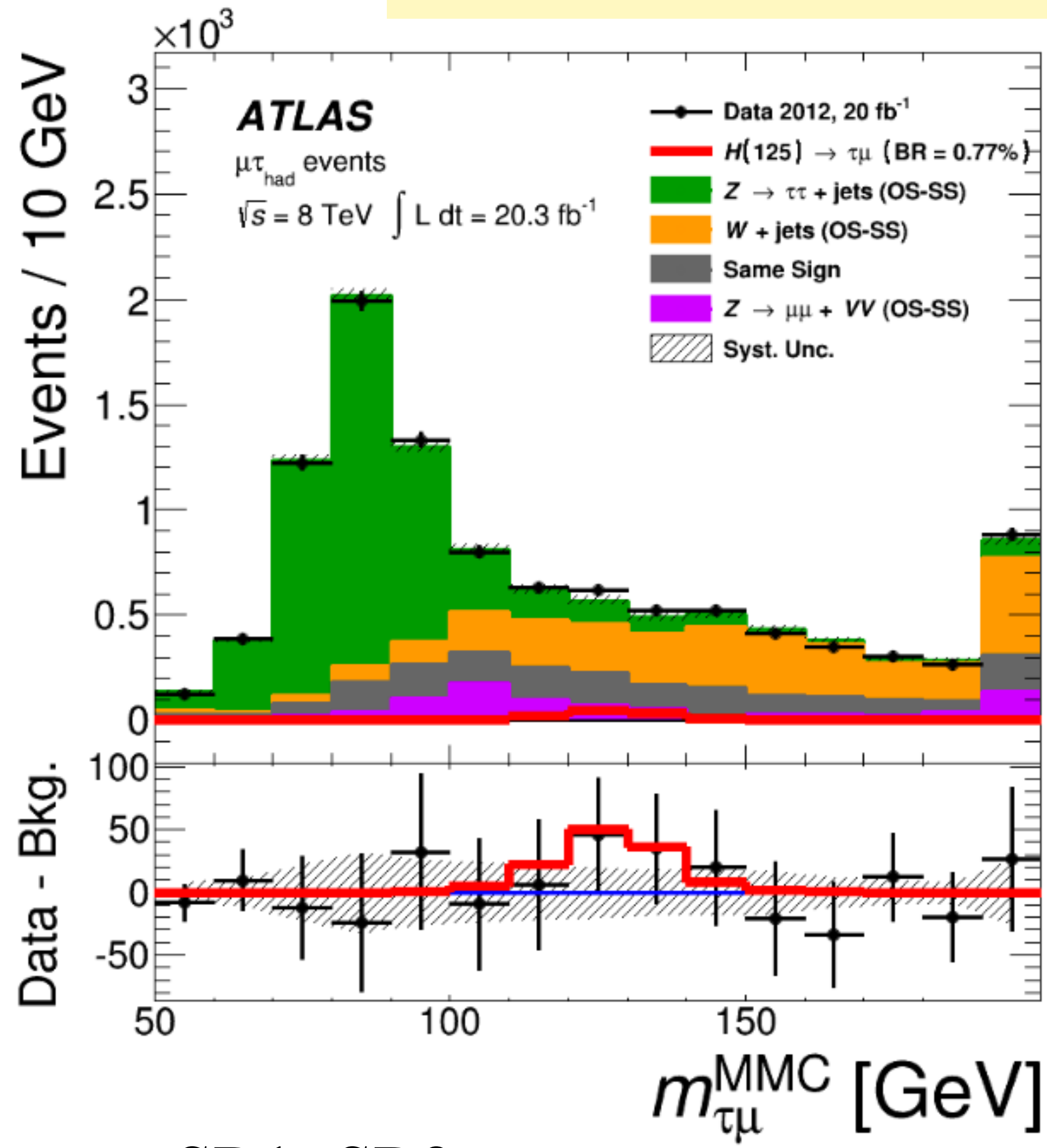
ATLAS 1508.03372



SR1



SR2



SR1+SR2

	SR1	SR2	Combined
Expected limit on Br($H \to \mu\tau$) [%]	$1.60^{+0.64}_{-0.45}$	$1.75^{+0.71}_{-0.49}$	$1.24^{+0.50}_{-0.35}$
Observed limit on Br($H \to \mu\tau$) [%]	1.55	3.51	1.85
Best fit Br($H \to \mu\tau$) [%]	$-0.07^{+0.81}_{-0.86}$	$1.94^{+0.92}_{-0.89}$	0.77±0.62

ATLAS H→τμ/τe

ATLAS 1604.07737

8 TeV | Higgs decays | ATLAS H→τμ/τe

ATLAS 1604.07730

Two searches & search channels

- H→$e\tau_{had}$
- H→$\mu\tau_e$ & H→$e\tau_\mu$

H→$e\tau_{had}$

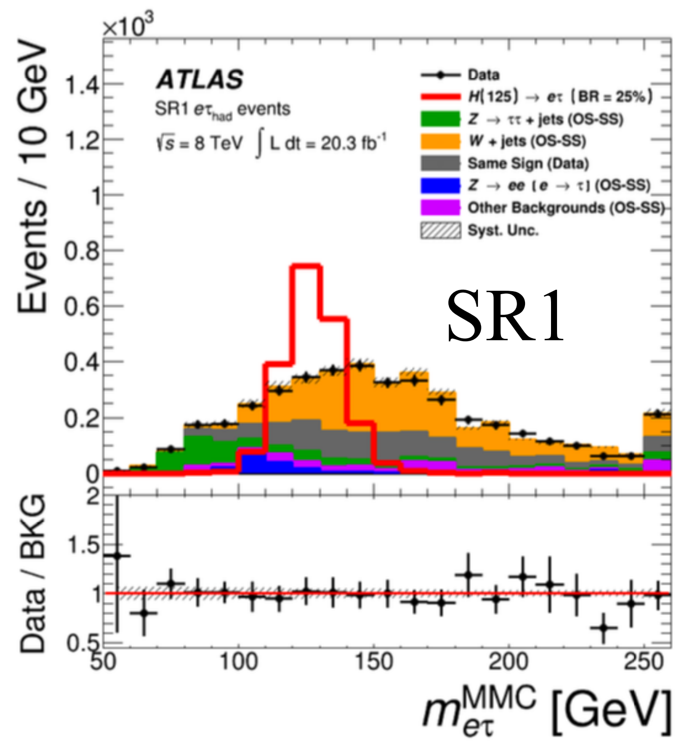
- Similar to H→$\mu\tau_{had}$
- Similar SRs and methodologies

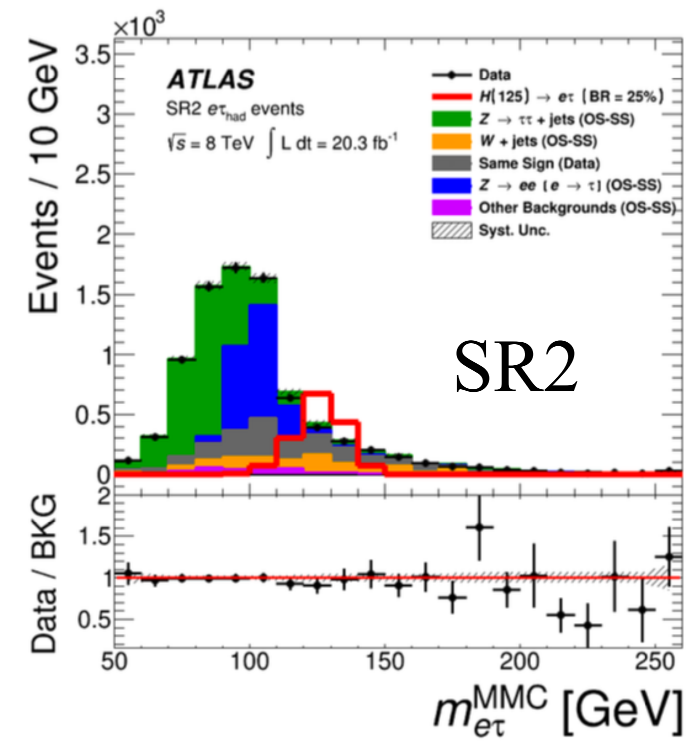
Mass estimator

- MMC

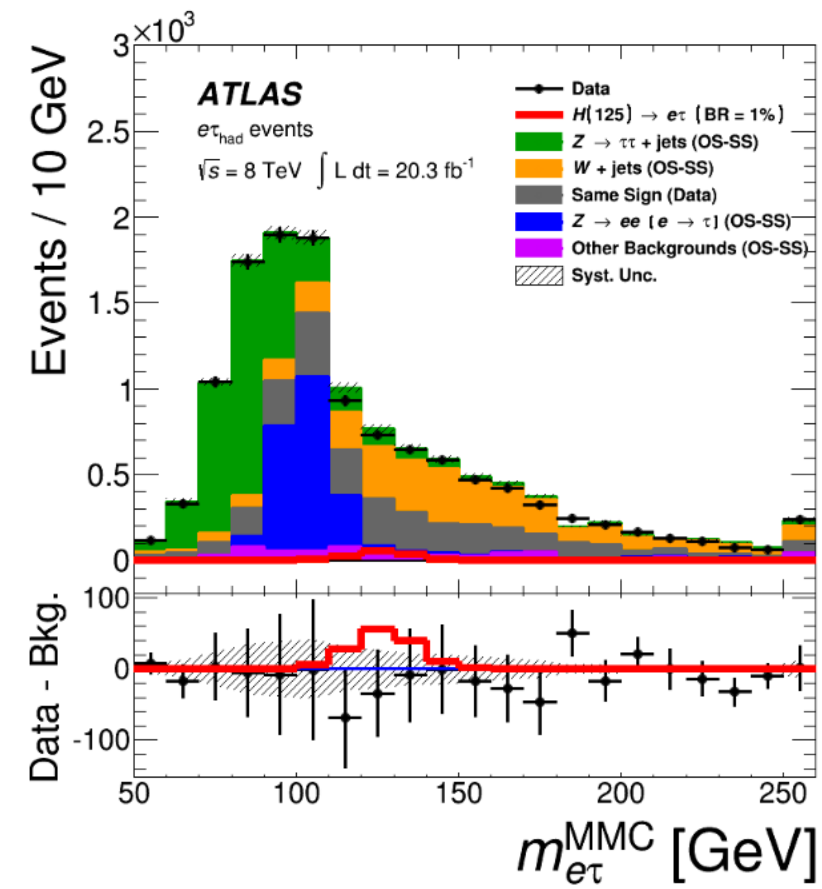
Background estimation

$$N_{OS}^{bkg} = r_{QCD} \cdot N_{SS}^{data} + N_{OS-SS}^{Z\to\tau\tau} + N_{OS-SS}^{Z\to\mu\mu} + N_{OS-SS}^{W+jets} + N_{OS-SS}^{top} + N_{OS-SS}^{VV} + N_{OS-SS}^{H\to\tau\tau},$$





H→τ_{had}e



ATLAS $H\to\tau\mu/\tau e$

ATLAS 1604.07730

$H\to\tau_e\mu$ & $H\to\tau_\mu e$

Mass estimator

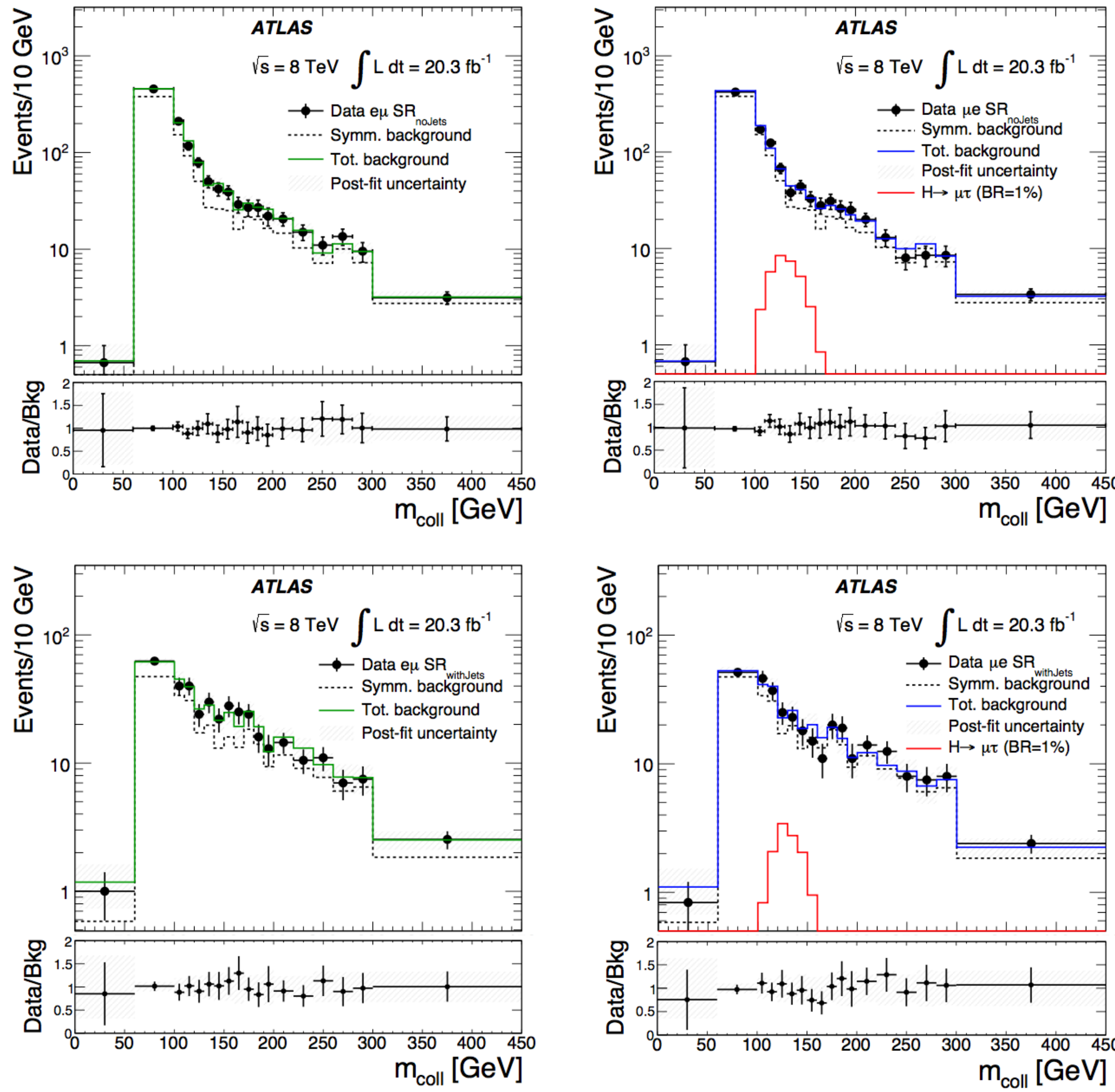
- Collinear mass

Two signal regions

- SR_{noJets}
- SR_{jets}

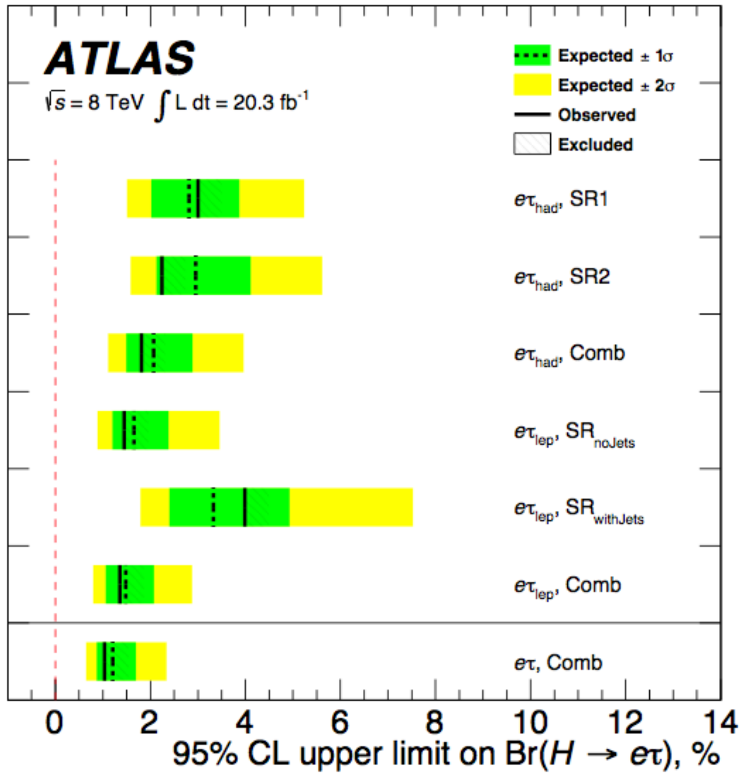
Background - the symmetry assumption

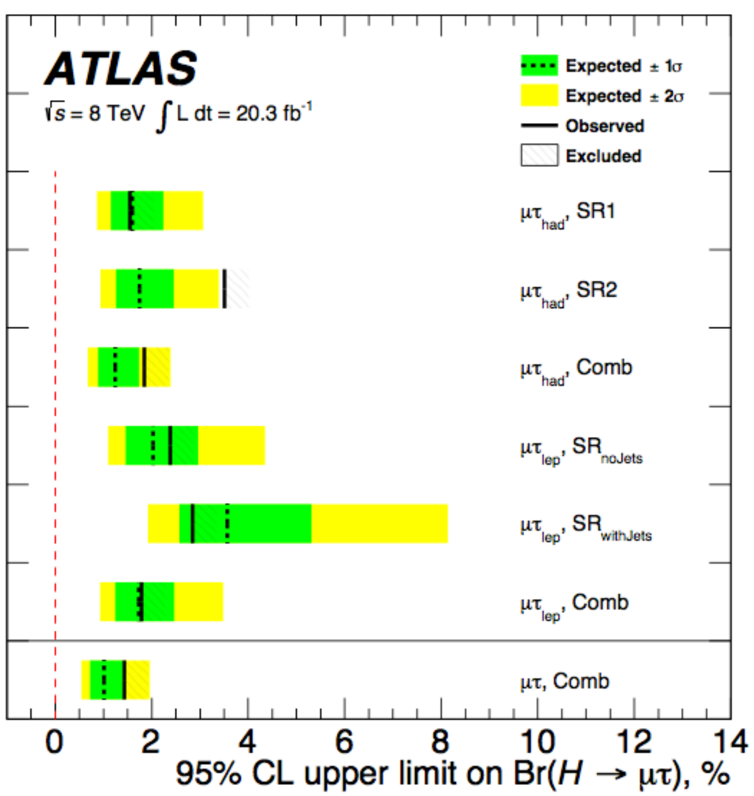
- Comparing eμ and μe events
- SM events are symmetric to the replacement of prompt electron with prompt muons
- Signal events break this symmetry
- Correction for asymmetric componenets
  - Fake and non prompt leptons
  - p_T dependent effects
- Uncertainties governed by statistics ⇒ Room for significant improvement when more data is available



8 TeV Higgs decays ATLAS H→τμ/τe

ATLAS 1604.07730





Channel	Category	Expected limit [%]	Observed limit [%]	Best fit Br [%]
	SR1	$2.81^{+1.06}_{-0.79}$	3.0	$0.33^{+1.48}_{-1.59}$
$H \to e\tau_{had}$	SR2	$2.95^{+1.16}_{-0.82}$	2.24	$-1.33^{+1.56}_{-1.80}$
	Combined	$2.07^{+0.82}_{-0.58}$	1.81	$-0.47^{+1.08}_{-1.18}$
	SR_{noJets}	$1.66^{+0.72}_{-0.46}$	1.45	$-0.45^{+0.89}_{-0.97}$
$H \to e\tau_{lep}$	$SR_{withJets}$	$3.33^{+1.60}_{-0.93}$	3.99	$0.74^{+1.59}_{-1.62}$
	Combined	$1.48^{+0.60}_{-0.42}$	1.36	$-0.26^{+0.79}_{-0.82}$
$H \to e\tau$	Combined	$1.21^{+0.49}_{-0.34}$	1.04	$-0.34^{+0.64}_{-0.66}$
	SR1	$1.60^{+0.64}_{-0.45}$	1.55	$-0.07^{+0.81}_{-0.86}$
$H \to \mu\tau_{had}$	SR2	$1.75^{+0.71}_{-0.49}$	3.51	$1.94^{+0.92}_{-0.89}$
	Combined	$1.24^{+0.50}_{-0.35}$	1.85	$0.77^{+0.62}_{-0.62}$
	SR_{noJets}	$2.03^{+0.93}_{-0.57}$	2.38	$0.31^{+1.06}_{-0.99}$
$H \to \mu\tau_{lep}$	$SR_{withJets}$	$3.57^{+1.74}_{-1.00}$	2.85	$-1.03^{+1.66}_{-1.82}$
	Combined	$1.73^{+0.74}_{-0.49}$	1.79	$0.03^{+0.88}_{-0.86}$
$H \to \mu\tau$	Combined	$1.01^{+0.40}_{-0.29}$	1.43	$0.53^{+0.51}_{-0.51}$

CMS H→τe/eμ

CMS 1607.03561

CMS H→τe/eμ

CMS 1607.03561

Two searches

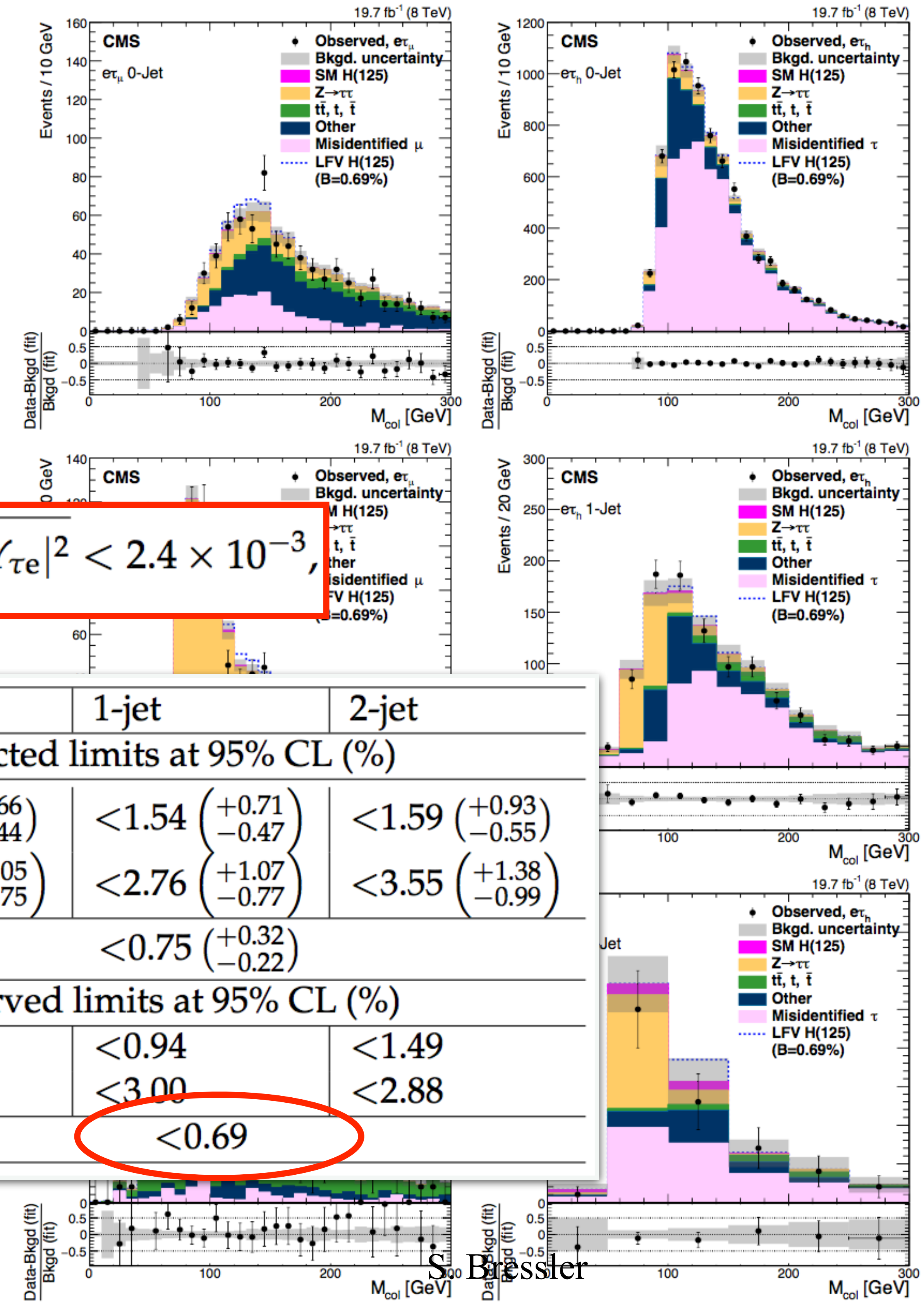
- H→eτ
- H→eμ

H→eτ

- Similar to H→μτ
- Collinear mass
- N_{Jet}-based categories
- Background
  - Z→ττ - embedded sample
  - Misidentified leptons scaling from sample with reversed isolation
  - Other - MC

$$\sqrt{|Y_{e\tau}|^2 + |Y_{\tau e}|^2} < 2.4 \times 10^{-3},$$

	0-jet	1-jet	2-jet
	Expected limits at 95% CL (%)		
$e\tau_\mu$	$<1.63\ (^{+0.66}_{-0.44})$	$<1.54\ (^{+0.71}_{-0.47})$	$<1.59\ (^{+0.93}_{-0.55})$
$e\tau_h$	$<2.71\ (^{+1.05}_{-0.75})$	$<2.76\ (^{+1.07}_{-0.77})$	$<3.55\ (^{+1.38}_{-0.99})$
$e\tau$		$<0.75\ (^{+0.32}_{-0.22})$	
	Observed limits at 95% CL (%)		
$e\tau_\mu$	<1.83	<0.94	<1.49
$e\tau_h$	<3.92	<3.00	<2.88
$e\tau$		<0.69	



CMS H→τe/eμ

CMS 1607.03561

H→eμ

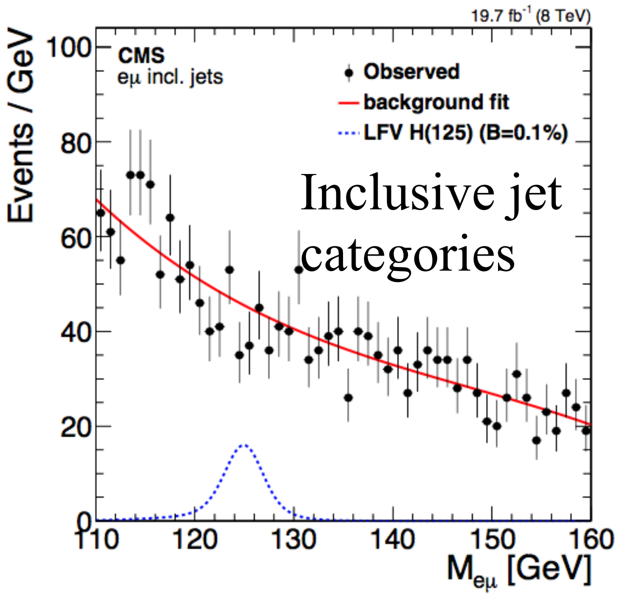
11 categories

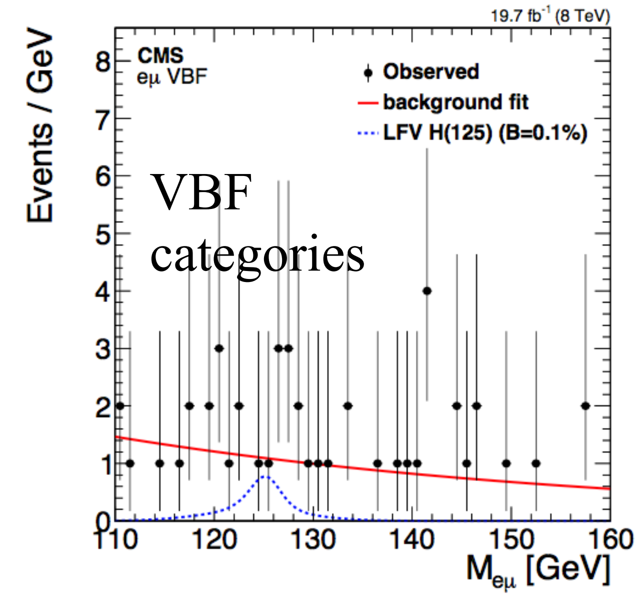
- Motivated by detector performance
  - Signal mass resolution varied with lepton region
  - Background composition dictated by the number of jets

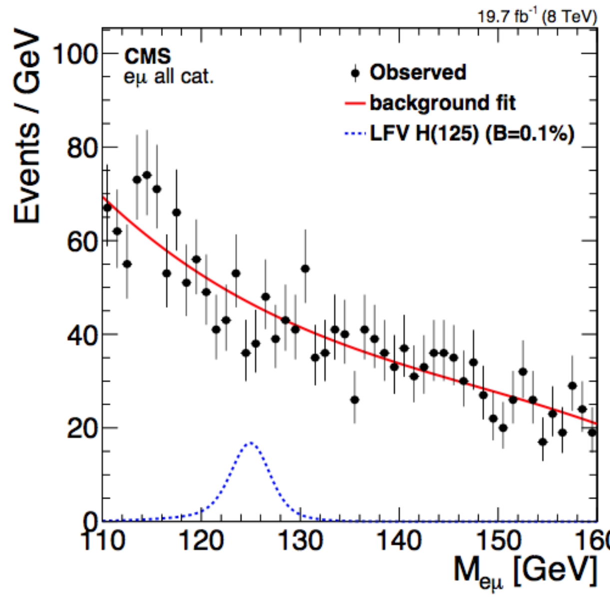
Background

- Functional fit

Category	Description	N-jets	p_T^ℓ [GeV]	E_T^{miss} [GeV]	Background model: Function	Background model: Order
0	$e_B\mu_B$	0	>25	<30	polynomial	4
1	$e_B\mu_B$	1	>22	<30	polynomial	4
2	$e_B\mu_B$	2	>25	<25	power law	1
3	$e_B\mu_{EC}$	0	>20	<30	polynomial	4
4	$e_B\mu_{EC}$	1	>22	<20	exponential	1
5	$e_B\mu_{EC}$	2	>20	<30	exponential	1
6	$e_{EC}\mu_{B\text{ or }EC}$	0	>20	<30	polynomial	4
7	$e_{EC}\mu_{B\text{ or }EC}$	1	>22	<20	power law	1
8	$e_{EC}\mu_{B\text{ or }EC}$	2	>20	<30	polynomial	4
9	VBF Tight	2	>22	<30	exponential	1
10	VBF Loose	2	>22	<25	exponential	1







All categories combined

$$\mathcal{B}(H \to e\mu) < 0.048\% \text{ at } 95\%$$

$$\sqrt{|Y_{e\mu}|^2 + |Y_{\mu e}|^2} < 5.4 \times 10^{-4}$$

CMS H→τμ

PAS HIG 16 005

PAS HIG 16 005

Analysis similar to run-1

- One exception - Z→ττ model also from MC
- Deficit in the H mass window

CMS 1502.07400 ➠ $Y_{\tau\mu}$

	Expected Limits		
	0-Jet (%)	1-Jet (%)	2-Jets (%)
$\mu\tau_e$	<1.32 (±0.67)	<1.66 (±0.85)	<3.77 (±1.92)
$\mu\tau_h$	<2.34 (±1.19)	<2.07 (±1.06)	<2.31 (±1.18)
$\mu\tau$		<0.75 (±0.38)	
	Observed Limits		
$\mu\tau_e$	<2.04	<2.38	<3.84
$\mu\tau_h$	<2.61	<2.22	<3.68
$\mu\tau$		<1.51	
	Best Fit Branching Fractions		
$\mu\tau_e$	$0.87^{+0.66}_{-0.62}$	$0.81^{+0.85}_{-0.78}$	$0.05^{+1.58}_{-0.97}$
$\mu\tau_h$	$0.41^{+1.20}_{-1.22}$	$0.21^{+1.03}_{-1.09}$	$1.48^{+1.16}_{-0.93}$
$\mu\tau$		$0.84^{+0.39}_{-0.37}$	

	Expected limits			
	0-jet (%)	1-jet (%)	2-jets (%)	Combined (%)
$\mu\tau_h$	<4.17	<4.89	<6.41	<2.98
$\mu\tau_e$	<2.24	<4.36	<7.31	<1.96
$\mu\tau$		<1.62 %		
	Observed limits			
	0-jet (%)	1-jet (%)	2-jets (%)	Combined (%)
$\mu\tau_h$	<4.24	<6.35	<7.71	<3.81
$\mu\tau_e$	<1.33	<3.04	<8.99	<1.15
$\mu\tau$		<1.20 %		
	Best-fit branching fractions			
	0-jet (%)	1-jet (%)	2-jets (%)	Combined (%)
$\mu\tau_h$	$0.12^{+2.02}_{-1.91}$	$1.70^{+2.41}_{-2.52}$	$1.54^{+3.12}_{-2.71}$	$1.12^{+1.45}_{-1.40}$
$\mu\tau_e$	$-2.11^{+1.30}_{-1.89}$	$-2.18^{+1.99}_{-2.05}$	$2.04^{+2.96}_{-3.31}$	$-1.81^{+1.07}_{-1.32}$
$\mu\tau$		$-0.76^{+0.81}_{-0.84}$%		

CMS Z→μe

CMS-PAS-EXO-13-005

CMS Z→μe

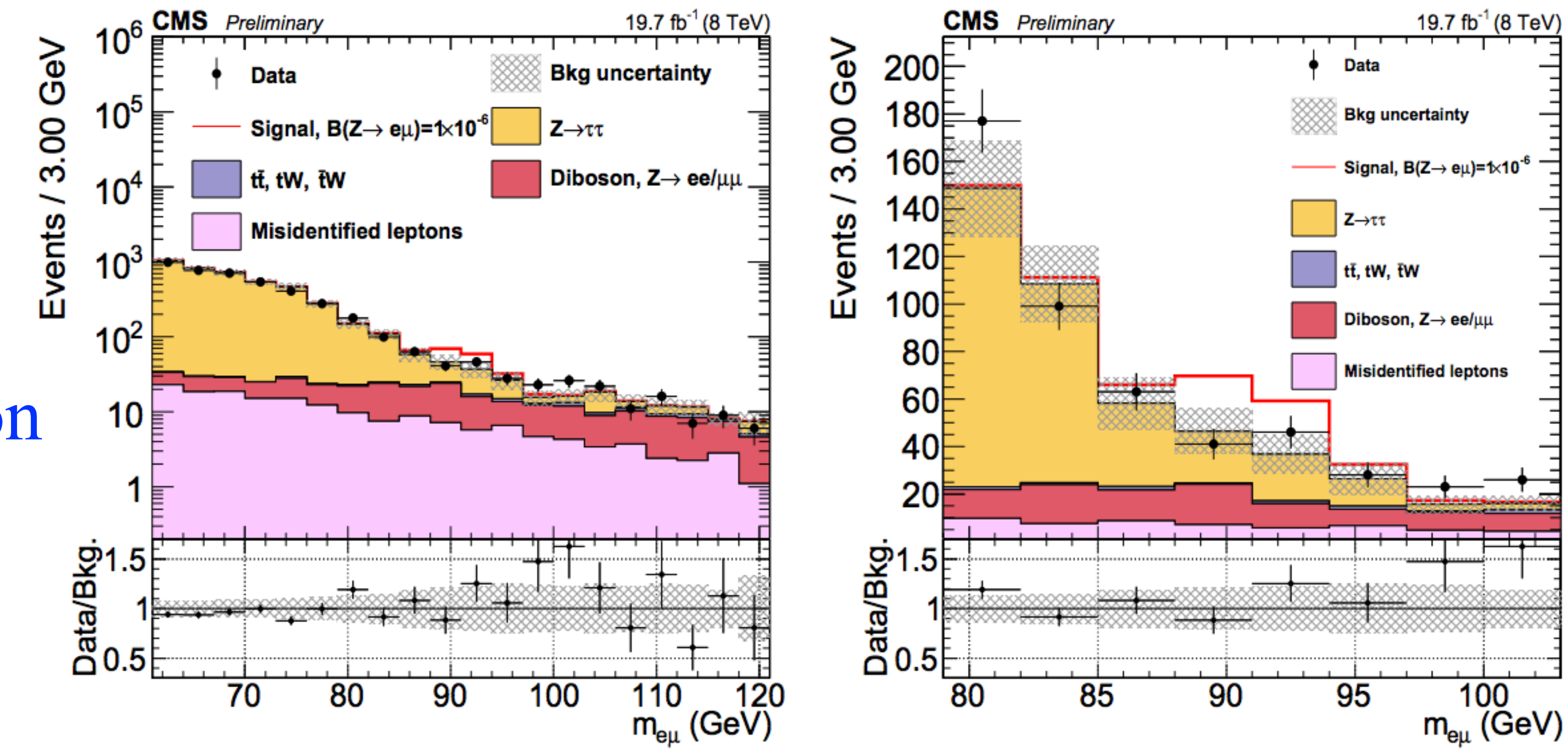
CMS-PAS-EXO-13-005

Background estimation

$Z \to \ell\ell \, (\ell = e, \mu, \tau)$
WW, WZ, ZZ
$t\bar{t}$
$tW/\bar{t}W$

MC-based

Misidentified leptons — multi-jet region



Mass estimator

- Invariant mass (no MET)

$$\mathcal{B}(Z \to e\mu) < 7.3 \cdot 10^{-7}$$

Source	Uncertainty: Background	Uncertainty: Signal
Luminosity	2.6%	2.6%
Pileup	3.3%	0.8%
Trigger	0.3%	0.5%
Muon Id	0.5%	0.8%
Muon p_T scale	2.9%	0.2%
Muon p_T resolution	0.4%	0.1%
Electron Id	0.5%	0.8%
Electron energy scale	3.1%	1.1%
Electron energy resolution	0.3%	0.4%
Jet energy scale	0.2%	$<$ 0.1%
Jet energy resolution	$<$ 0.1%	$<$ 0.1%
E_T^{miss}	0.6%	2.2%
Dilepton p_T	0.4%	1.1%
PDF	1.0%	1.0%
Limited number of simulated events	10.6%	1.2%
Normalization (Tab. 1)	6.8%	3.3%

ATLAS Z→μe

ATLAS 1408.5774

ATLAS Z→μe

ATLAS 1408.5774

Event selection

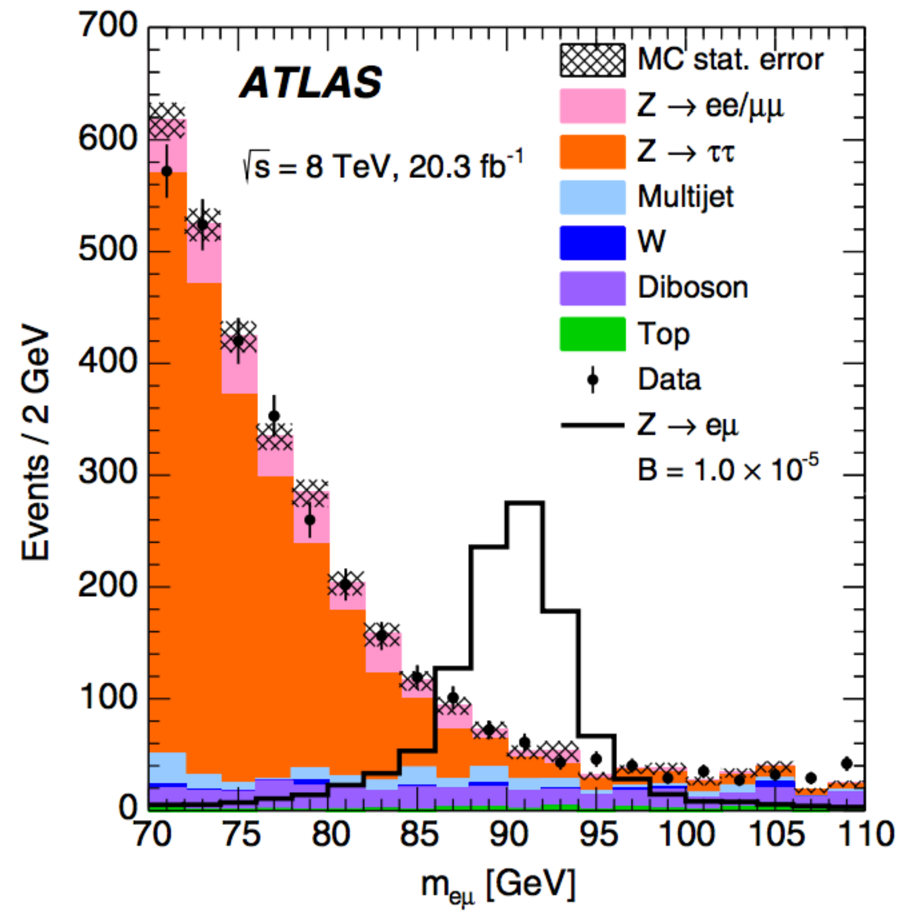
- High p_T e and μ
- Little jet activity
- Little MET

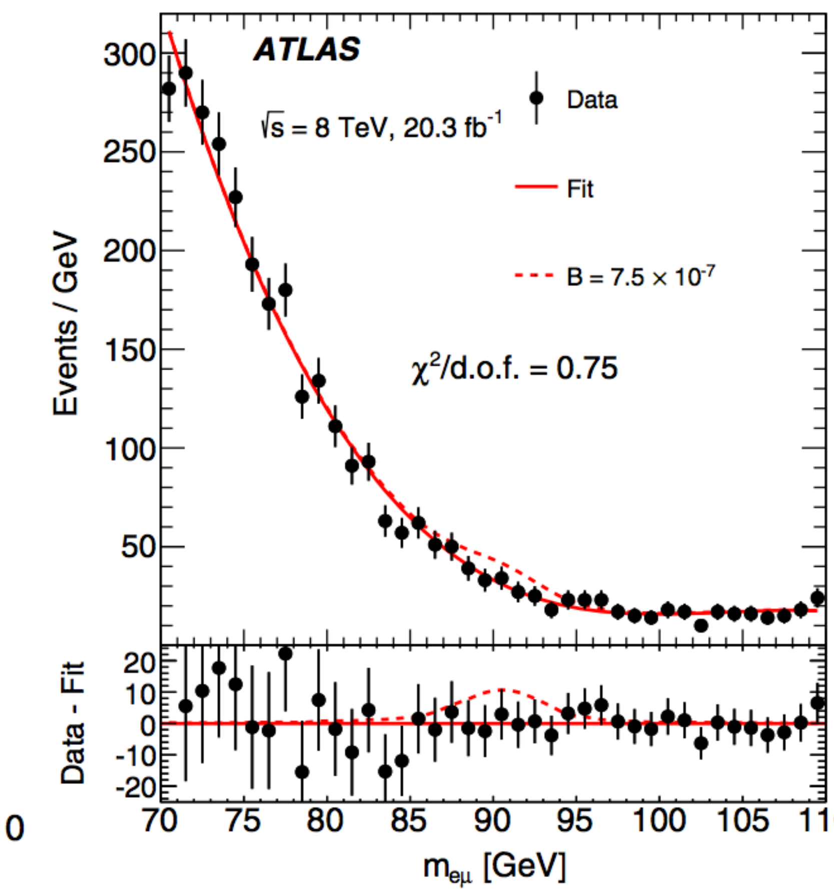
Background estimation

- Side-band fit
  - Possible due to the good mass resolution and the narrow mass range
- Third order polynomial
  Shape studied in MC

Mass estimator

- Invariant mass (no MET)





$$\mathcal{B}(Z \to e\mu) < 7.5 \times 10^{-7}$$

ATLAS $Z \to \tau\mu$

ATLAS 1604.07737

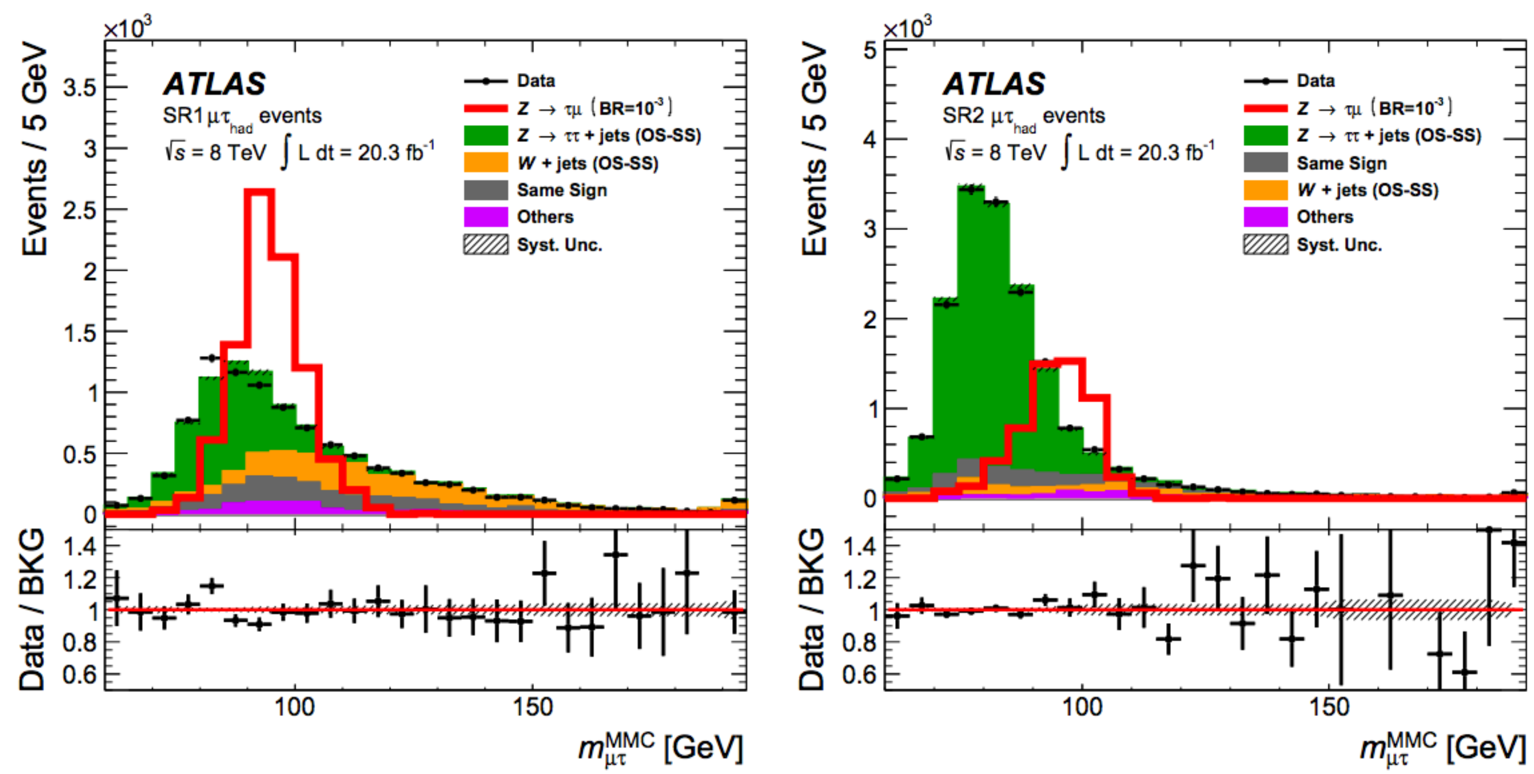
ATLAS 1604.07737

One search channels

- $Z \rightarrow \mu\tau_{had}$

Methodology

- Similar to the one employed in the corresponding Higgs search
- Cut values are lowered to match the kinematics of Z decays
  ⇒ Larger background contribution from W+jets
  ⇒ Estimated in more bins



$Br(Z \rightarrow \mu\tau)\ (10^{-5})$	SR1	SR2	Combined
Expected limit	$2.6^{+1.1}_{-0.7}$	$6.4^{-1.8}_{+2.8}$	$2.6^{+1.1}_{-0.7}$
Observed limit	1.5	7.9	1.7
Best fit	$-2.1^{+1.2}_{-1.3}$	$2.6^{+2.9}_{-2.6}$	$-1.6^{+1.3}_{-1.4}$

CMS X→μe

CMS 1604.05239

CMS X→μe

CMS 1604.05239

Motivations

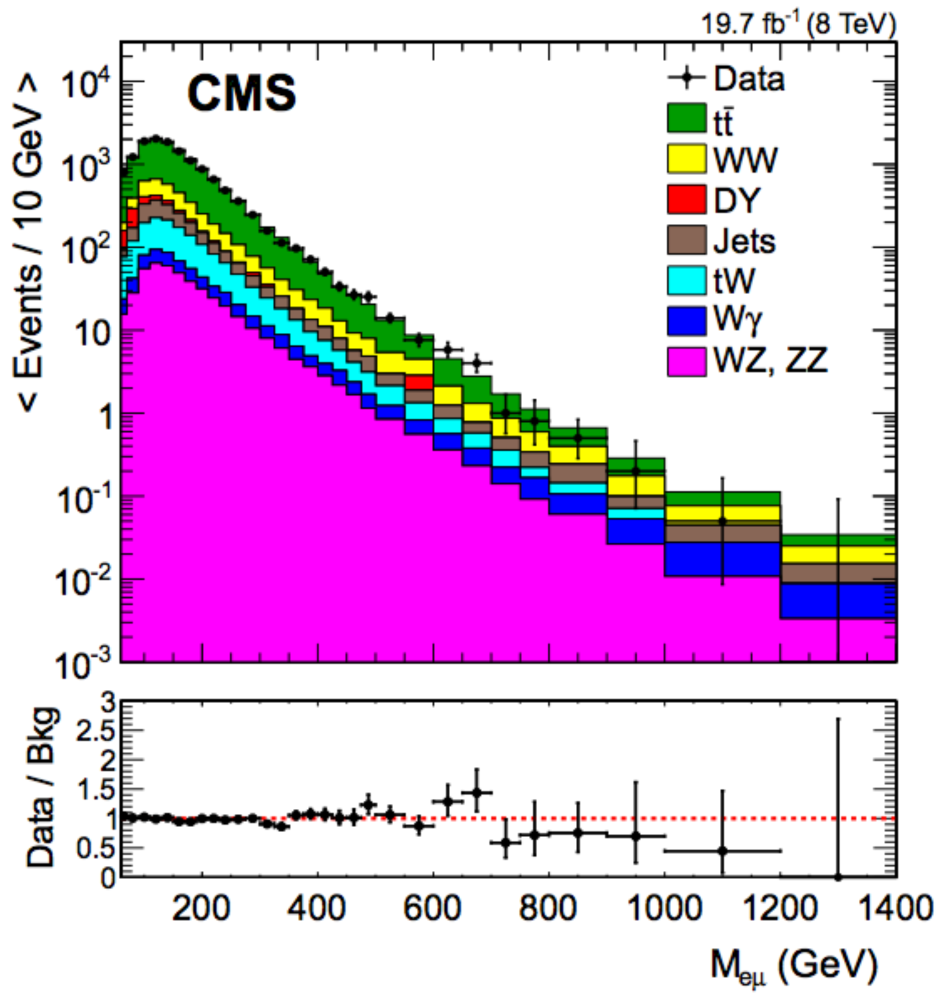
- τ sneutrino in RPV SUSY

$$W_{\mathrm{RPV}} = \frac{1}{2}\lambda_{ijk}L_iL_j\bar{E}_k + \lambda'_{ijk}L_iQ_j\bar{D}_k \; (i,j,k \in 1,2,3)$$

- Z' and γ'
- Quantum black holes (non resonant)
  - Within a specific model

Background estimation

- Irreducible - MC based
- Reducible - combination



Signal model	Lower limit signal mass (TeV)	
	Observed	Expected
RPV $\tilde{\nu}_\tau$ ($\lambda_{132} = \lambda_{231} = \lambda'_{311} = 0.01$)	1.28	1.24
RPV $\tilde{\nu}_\tau$ ($\lambda_{132} = \lambda_{231} = 0.05,\ \lambda'_{311} = 0.10$)	2.16	2.16
RPV $\tilde{\nu}_\tau$ ($\lambda_{132} = \lambda_{231} = 0.07,\ \lambda'_{311} = 0.11$)	2.30	2.30
LFV Z′ ($\kappa = 0.05$)	1.29	1.25
QBH $n = 0$	1.99	1.99
QBH $n = 1$ (RS)	2.36	2.36
QBH $n = 1$ (PDG)	2.81	2.81
QBH $n = 2$	3.15	3.15
QBH $n = 3$	3.34	3.34
QBH $n = 4$	3.46	3.46
QBH $n = 5$	3.55	3.55
QBH $n = 6$	3.63	3.63

ATLAS $X \to \tau\mu/\tau e/\mu e$

ATLAS 1607.08079

13 TeV | Heavy resonances | ATLAS $X \to \tau\mu/\tau e/\mu e$

ATLAS 1607.08079

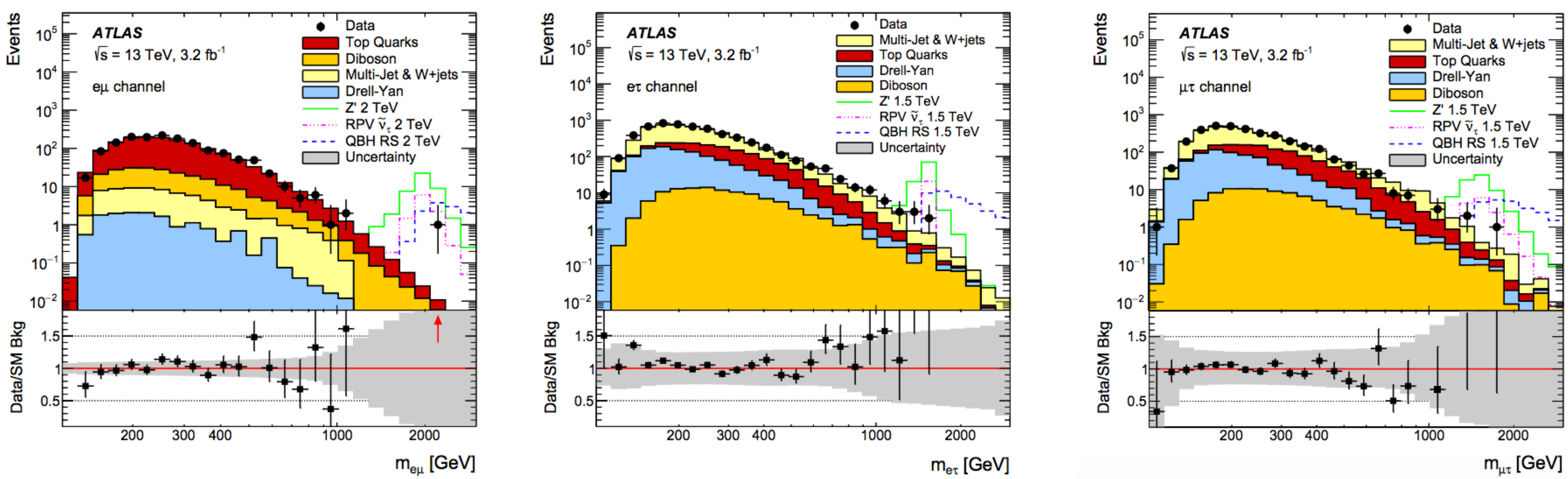
Motivations

- Z'
  - Assumes SM coupling to quarks
  - Only one LFV decay is allowed
- τ sneutrino in RPV SUSY
- Quantum black holes (non resonant)
  - Within two specific models

Background estimation

- Irreducible - MC based
  - With some extrapolation when the MC statistics is limited
- Reducible - combination

Model	Expected Limit [TeV]			Observed Limit [TeV]		
	$e\mu$	$e\tau$	$\mu\tau$	$e\mu$	$e\tau$	$\mu\tau$
Z'	3.2	2.7	2.6	3.0	2.7	2.6
RPV SUSY $\tilde{\nu}_\tau$	2.5	2.1	2.0	2.3	2.2	1.9
QBH ADD $n = 6$	4.6	4.1	3.9	4.5	4.1	3.9
QBH RS $n = 1$	2.5	2.2	2.1	2.4	2.2	2.1



(a) $e\mu$ channel | **(b)** $e\tau$ channel | **(c)** $\mu\tau$ channel

ATLAS $\tau \to 3\mu$

ATLAS 1601.03567

8 TeV | Others | ATLAS τ→3μ

ATLAS 1601.03567

Search channel

- $W \to \tau\nu$; $\tau \to 3\mu$

Main discriminators

- 3 nearby muons
- $m_T = \sqrt{2 p_T^{3\mu} E_T^{miss} (1 - \cos\Delta\phi)},$
- τ lifetime ⇒ muons originating from a secondary vertex
- $m_{3\mu} \sim m_\tau$

Strategy

- Step 1: event selection based on the discriminators
- Step 2: BDT - with loose selections
  - To ensure enough statistics
  - 16 input variables
- Step 3: tight cuts on the BDT output score
- Step 4: optimize selection based on estimation in the sideband region

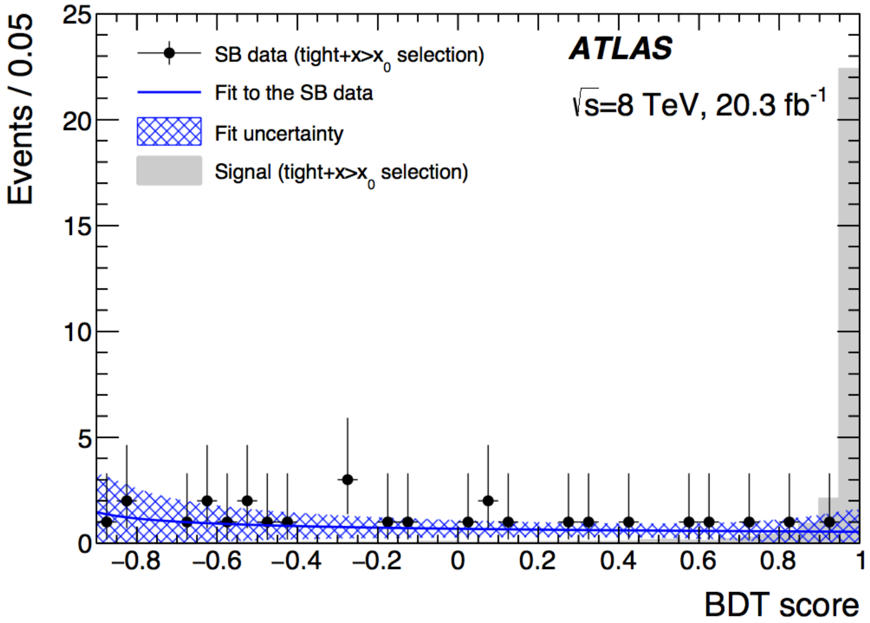
Region	Range in $m_{3\mu}$ [MeV]
Signal region	[1713, 1841]
Blinded region	[1690, 1870]
Sideband region	[1450, 1690] and [1870, 2110]
Training region	[750, 1450] and [2110, 2500]

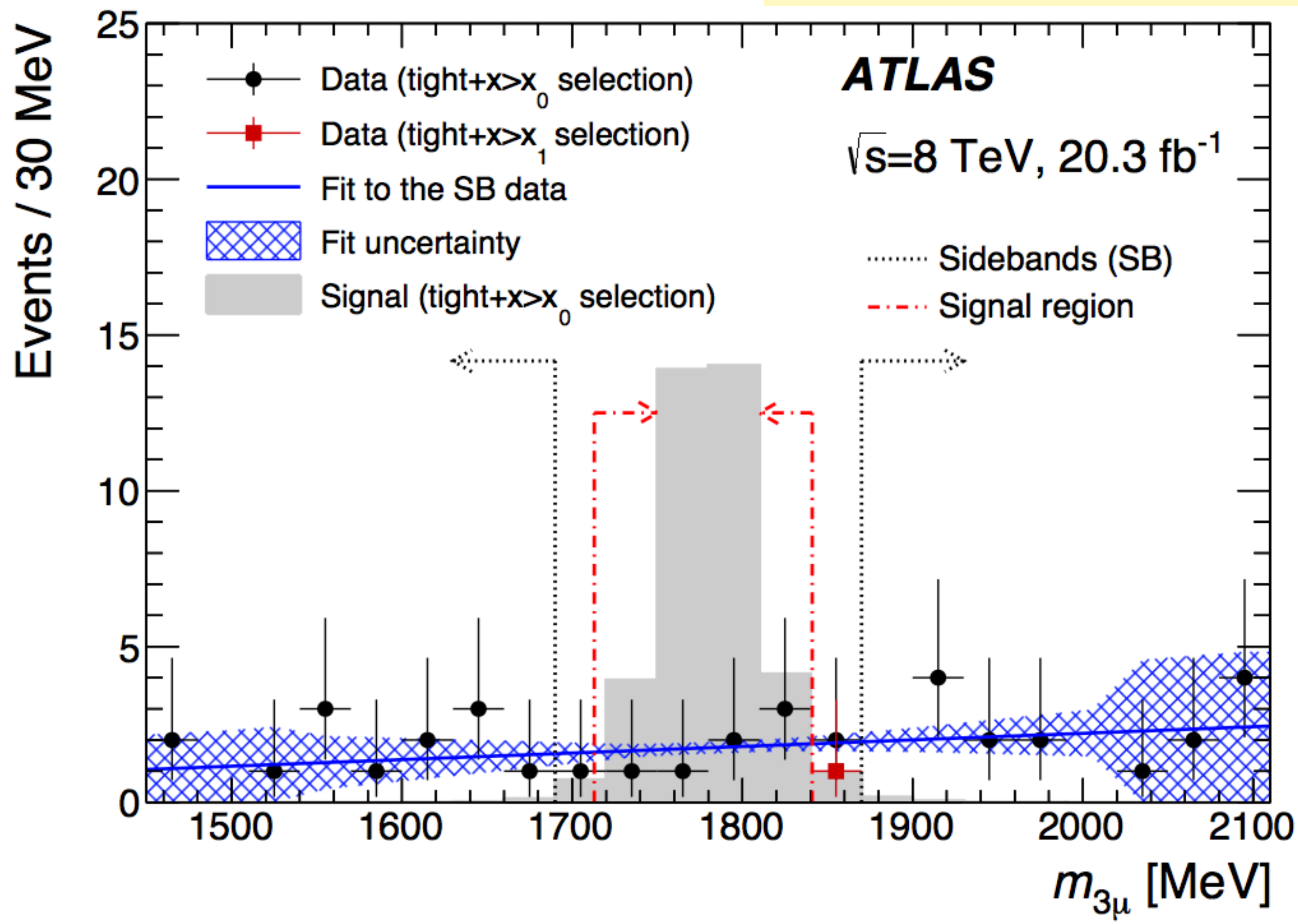
Background

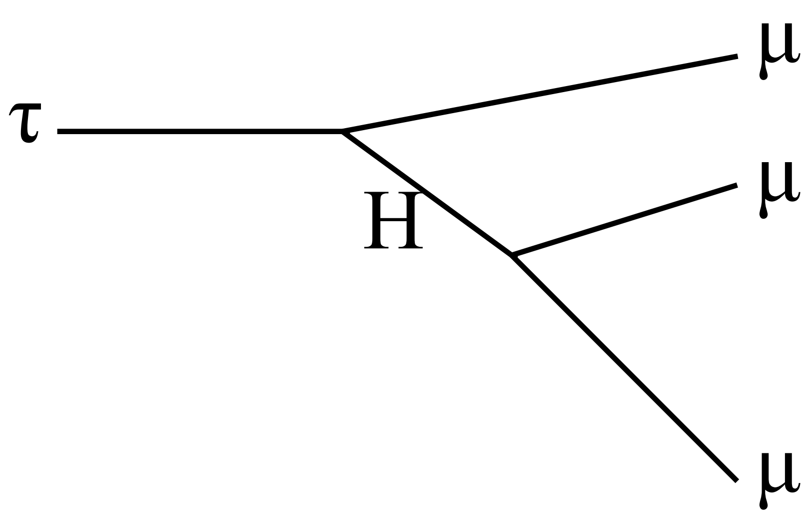
- Main source: Heavy Flavour decays
- Extrapolated from the sideband region

ATLAS $\tau \to 3\mu$

ATLAS 1601.03567







$$3.76\times10^{-7}\ (3.94\times10^{-7})\ \text{on}\ \mathrm{Br}(\tau\to3\mu)\ \text{at}\ 90\%\ \text{CL}.$$

Observed **(expected)**

Next steps

- Analyses are being repeated now with more data
- Optimization and improvements are done in parallel
- Multivariate analysis techniques are being exploited to further improve the sensitivity of the analyses

- …
- Clear view of which paths are available for searching for LFV decays
  - The track is pretty well defined
  - Not all fronts are covered
- Are we missing anything?