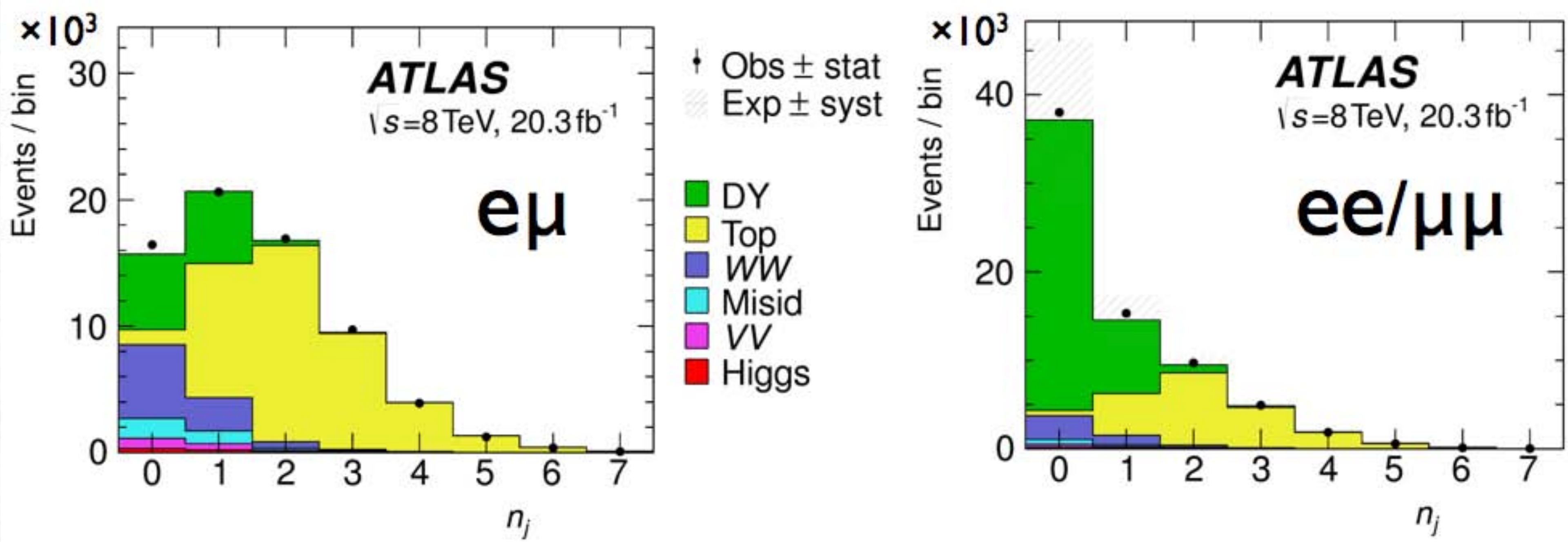
H → WW → ℓν ℓν

- BR(H → WW → lνlν) ~1% for m_H ~ 125 GeV/c^2
- Neutrinos → no mass peak, → use transverse mass
- Large backgrounds: WW, Wt, tt
- Require opposite-charge lepton-pair (ee, μμ, eμ)
- Different background composition depending on nJets and di-lepton flavours
- Split analysis into distinct regions for best overall sensitivity



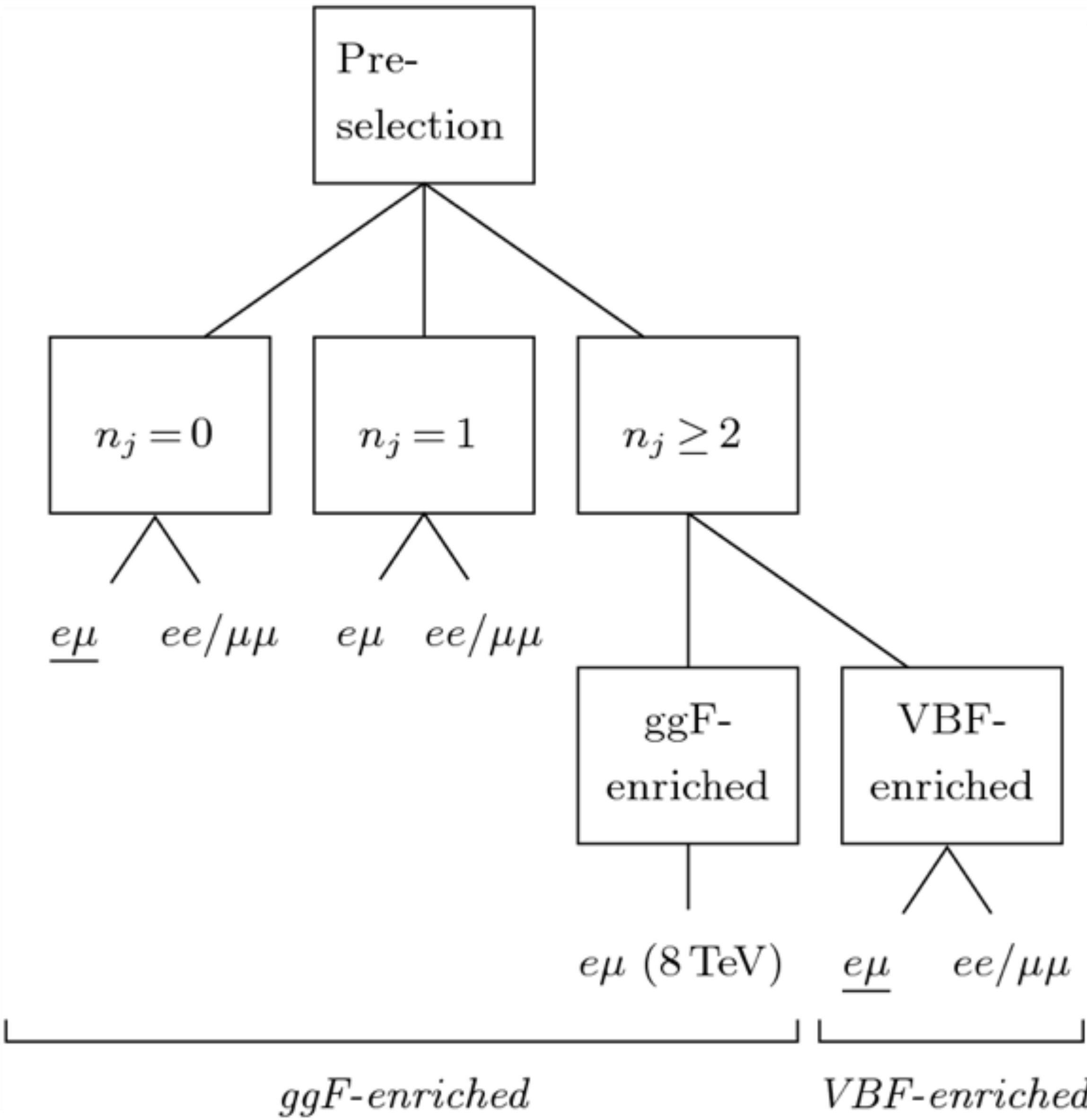
Difficulties:

(i) need precise knowledge of the backgrounds

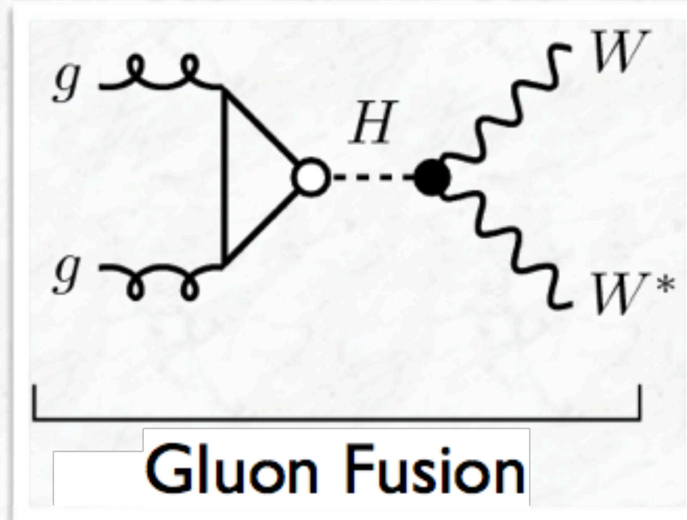
Strategy: use control region(s) in data, extrapolation in signal region

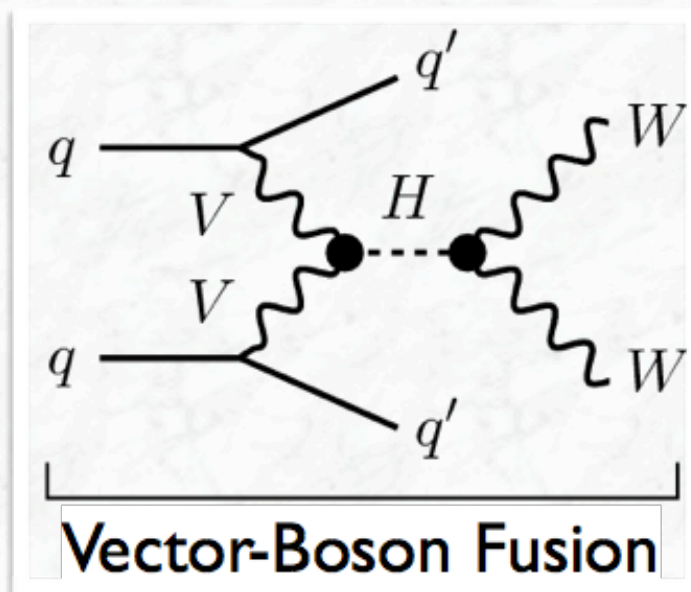
(ii) jet veto efficiencies need to be understood for signal and background events

H → WW → ℓν ℓν Analysis Overview

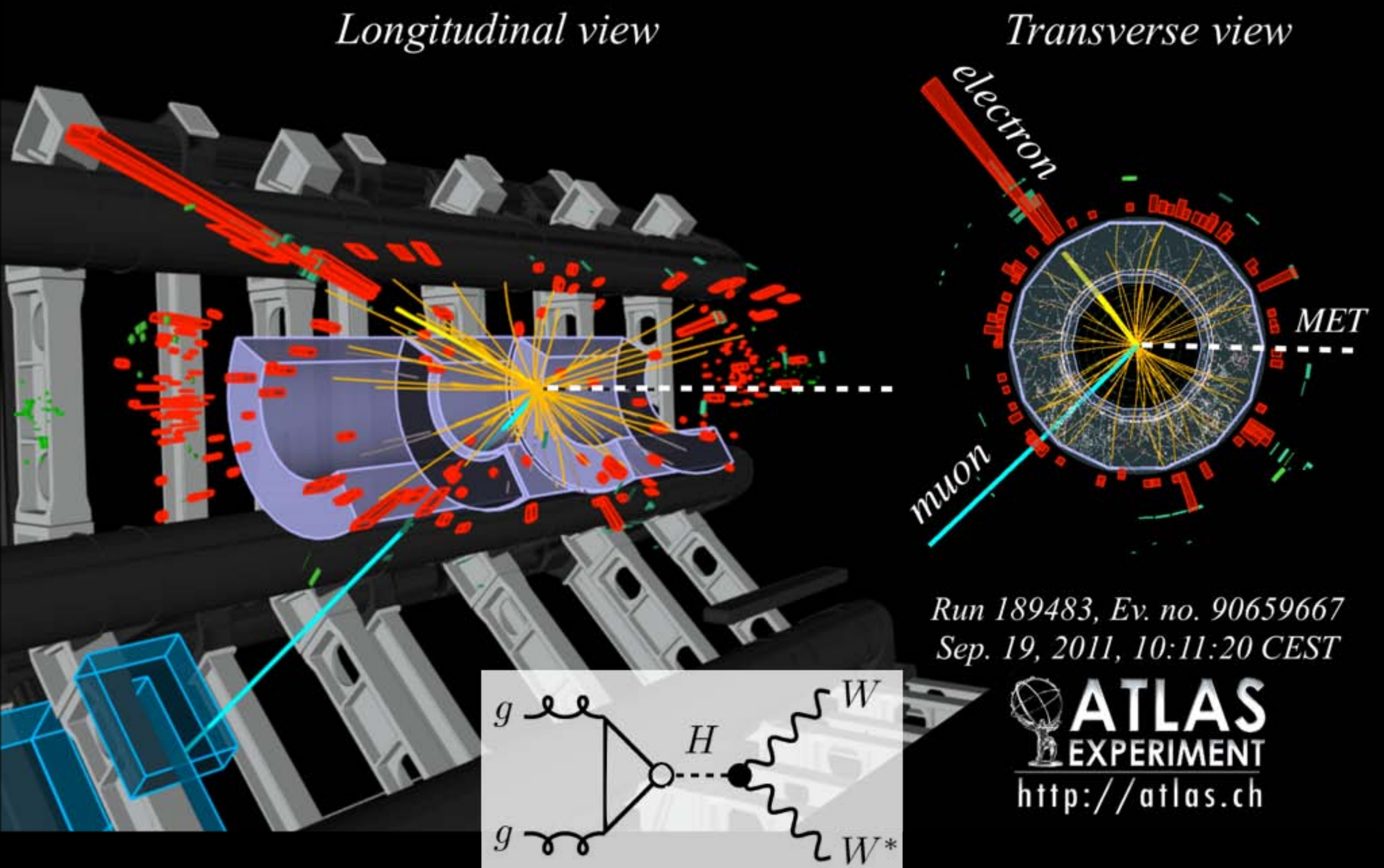


Categorization

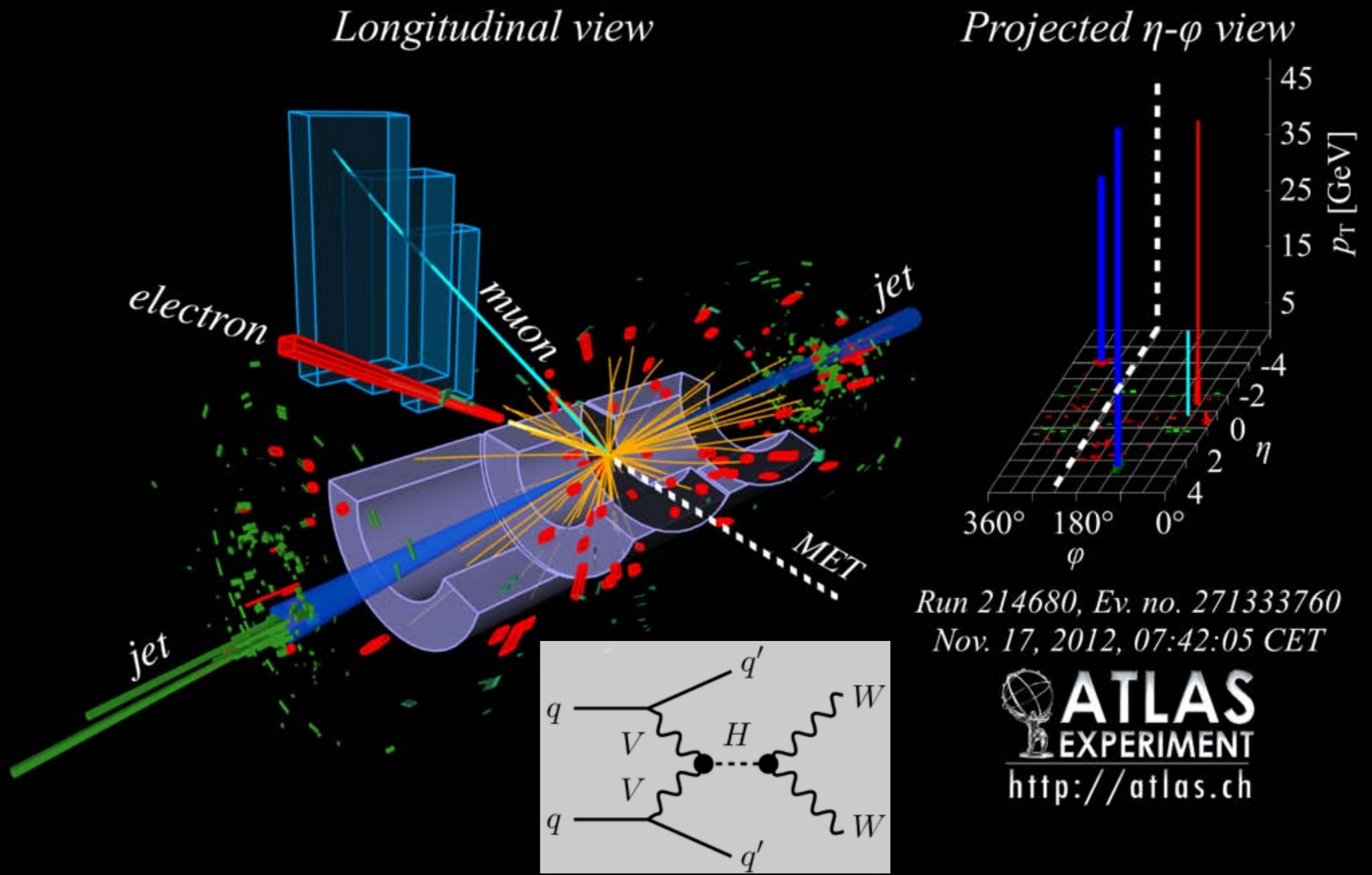




$H \rightarrow WW^* \rightarrow e\nu\mu\nu$ candidate and no jets



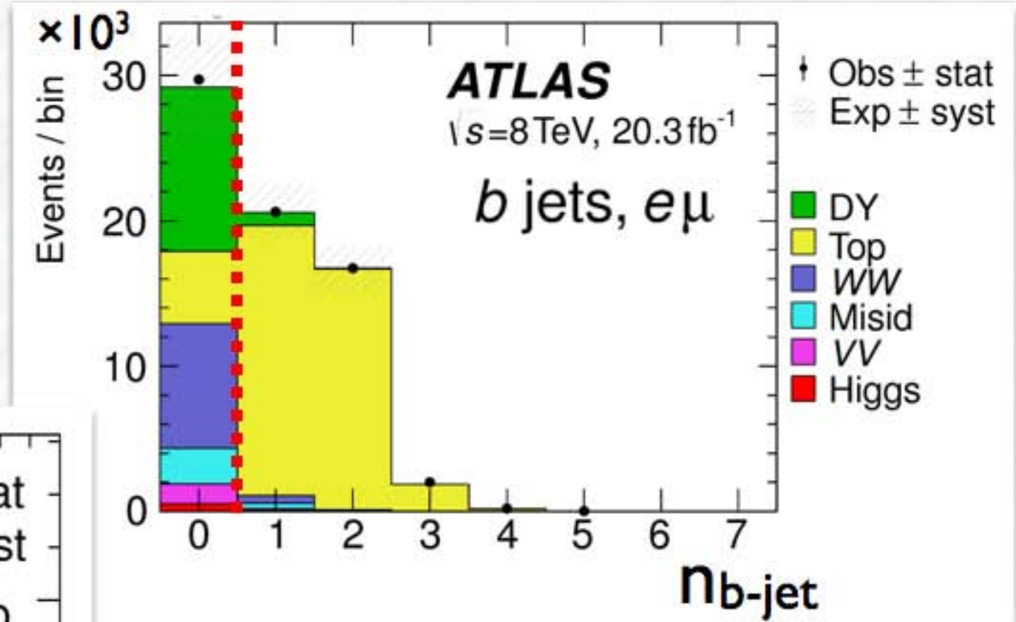
$H \to WW^* \to e\nu\mu\nu$ candidate and two jets with VBF topology

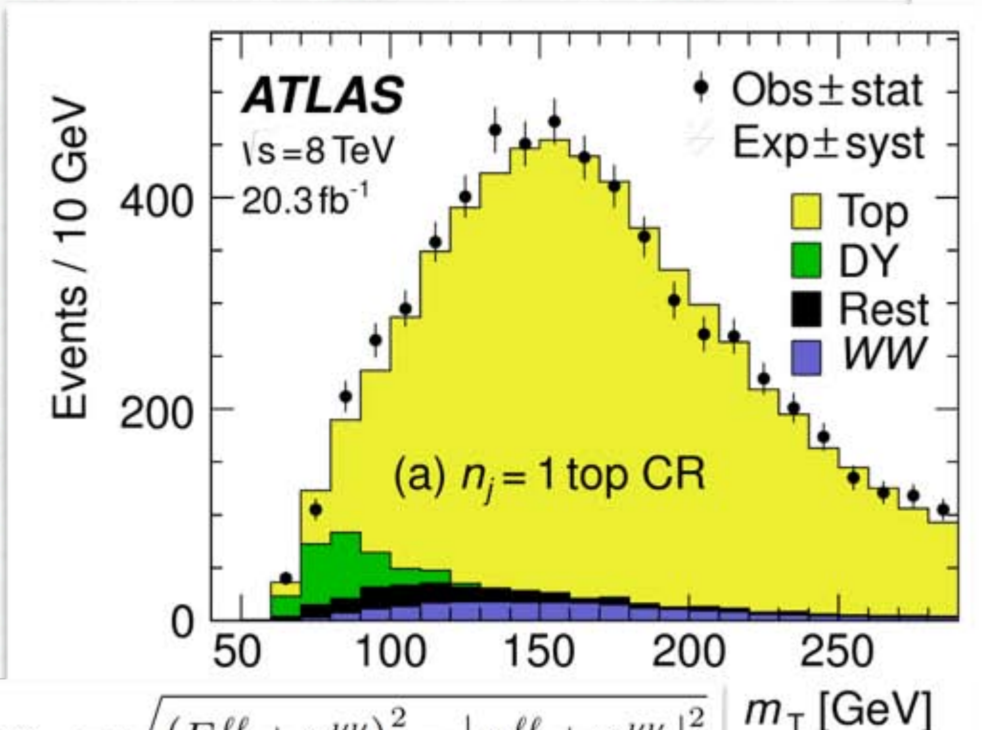


H → WW → ℓν ℓν: Top background

Top ($t\bar{t}$+t+Wt) suppression:

- Large background with (two) $W \rightarrow l\nu$
- b-jet veto





$$m_{\mathrm{T}} = \sqrt{\left(E_{\mathrm{T}}^{\ell\ell} + p_{\mathrm{T}}^{\nu\nu}\right)^2 - \left|\,\boldsymbol{p}_{\mathrm{T}}^{\ell\ell} + \boldsymbol{p}_{\mathrm{T}}^{\nu\nu}\,\right|^2}$$

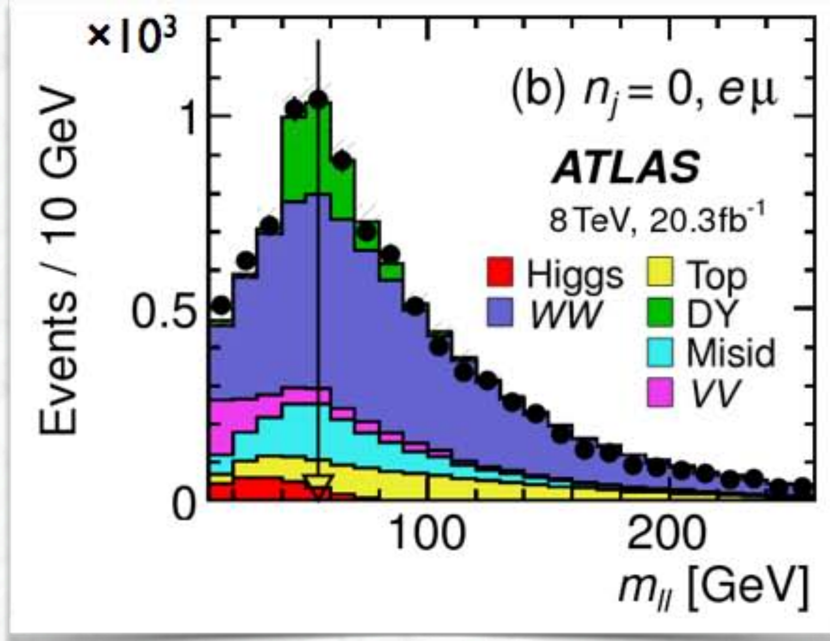
Top estimation:

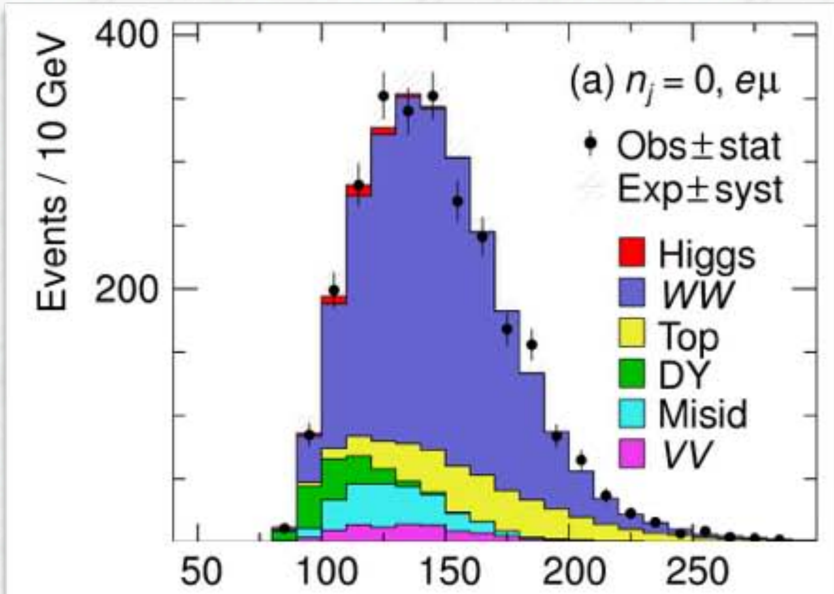
- Normalization in signal regions determined from data b-tag control regions
- Systematic uncertainty in n_{Jet}=0 category: 8%

H → WW → ℓν ℓν: WW background

WW suppression:

- Use different spin correlation and $m_H < 2 \times m_W$:
  - Reject large di-lepton invariant masses





WW control region

WW estimation:

≤1 Jet: Use high-m_{ll} data control region for normalization

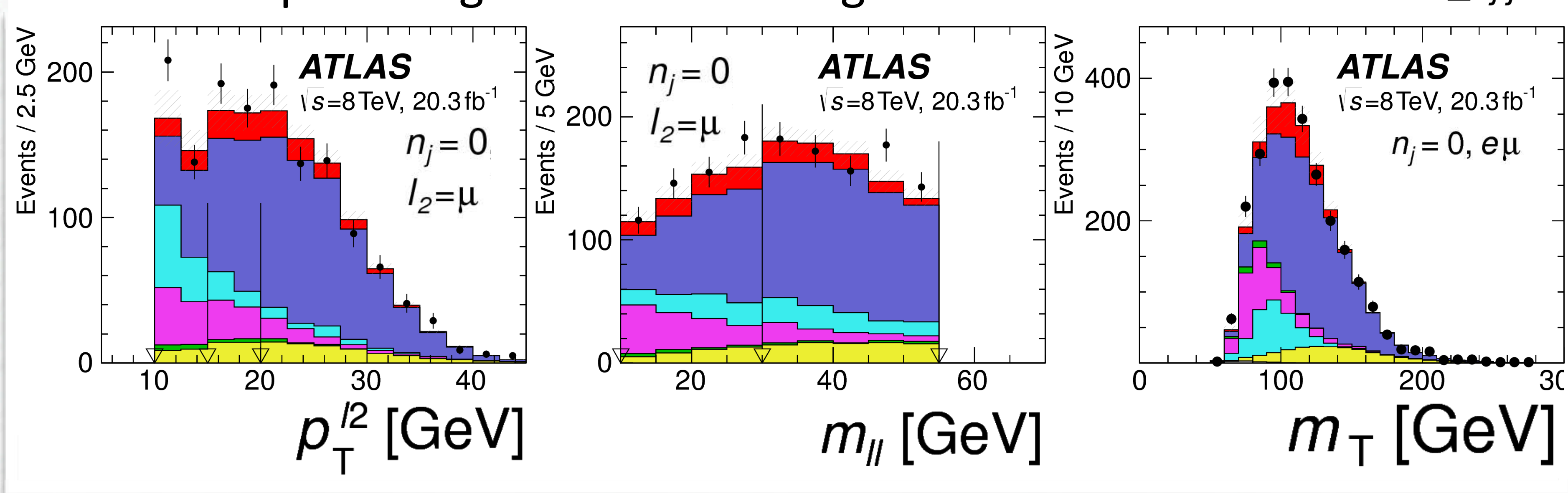
≥2 Jets: Sub-dominant background; taken from MC

$$m_{\mathrm{T}} = \sqrt{\left(E_{\mathrm{T}}^{\ell\ell} + p_{\mathrm{T}}^{\nu\nu}\right)^2 - \left|\,\boldsymbol{p}_{\mathrm{T}}^{\ell\ell} + \boldsymbol{p}_{\mathrm{T}}^{\nu\nu}\,\right|^2}$$

H → WW → ℓν ℓν: gluon-fusion analysis

Signal extraction:

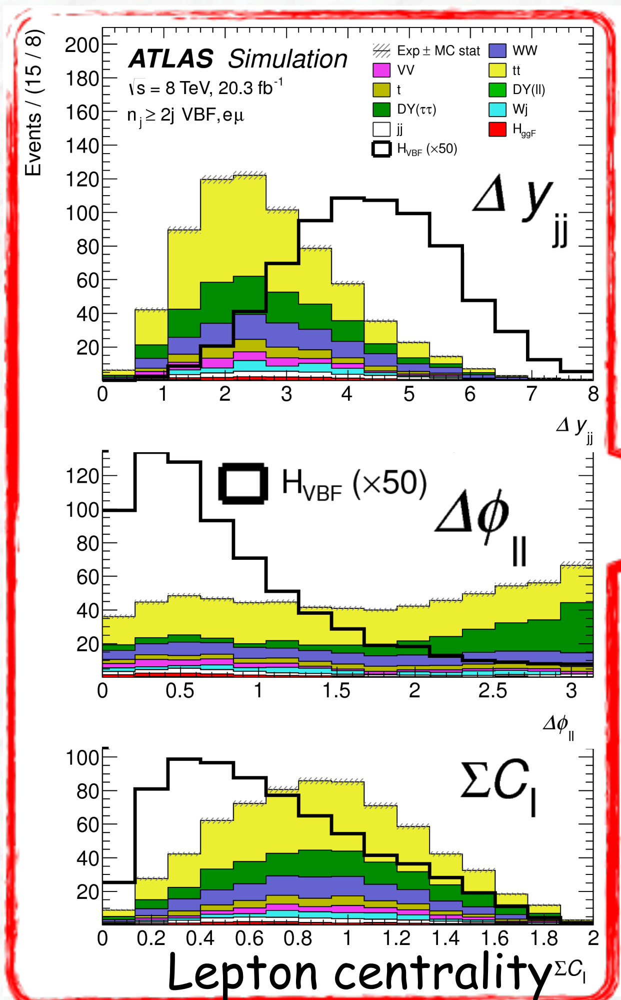
- Maximum-Likelihood Fit in $m_T = \sqrt{\left(E_{\mathrm{T}}^{\ell\ell} + p_{\mathrm{T}}^{\nu\nu}\right)^2 - \left|\boldsymbol{p}_{\mathrm{T}}^{\ell\ell} + \boldsymbol{p}_{\mathrm{T}}^{\nu\nu}\right|^2}$
  - For 0/1-jet eμ: categorized in total of 12 signal regions, binned in m_{ll}, and flavour and p_T of sub-leading lepton
  - Other channels: global
  - Multiple background control regions in fit

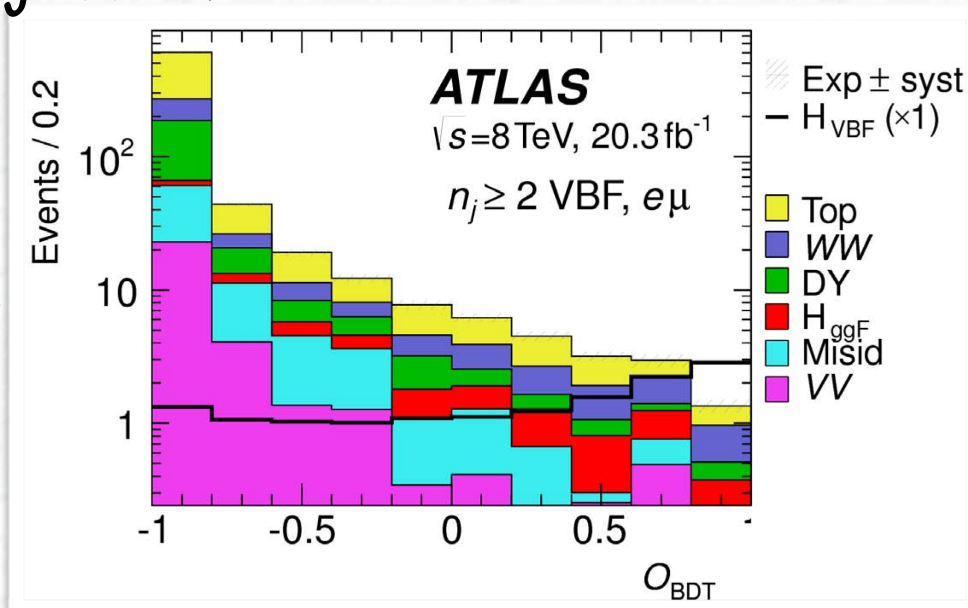


H → WW → ℓν ℓν: Vektor-boson-fusion analysis

Combine background-discriminating variables into BDT

- Input variables for *VBF production topology, Higgs boson decay topology*, as well as *background rejection*





Fit re-binned BDT distribution

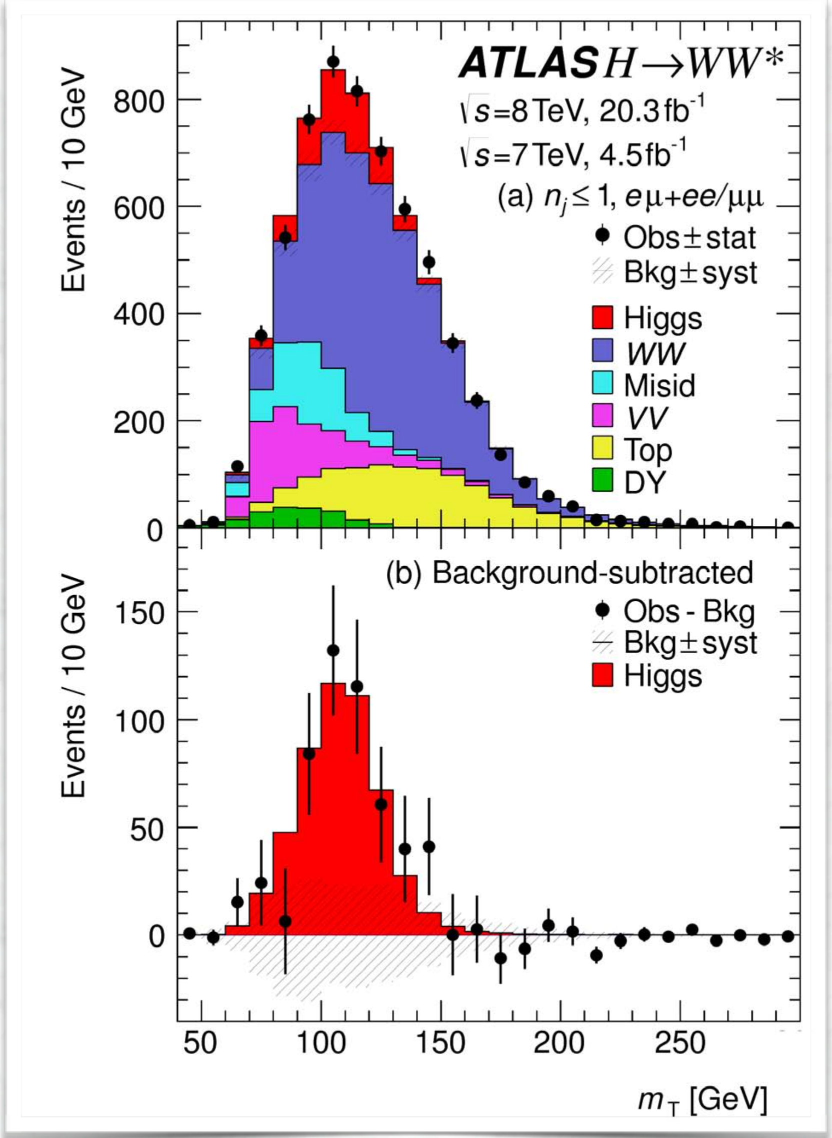
- BDT modelling validated in background regions

$H \to WW \to \ell\nu\, \ell\nu$: gluon-fusion results

Results:

- Clear signal visible in 0/1-jet category

- ***ggF signal significance:*** **4.3 σ** (4.3 σ) observed (expected) @m_H = 125.36 GeV

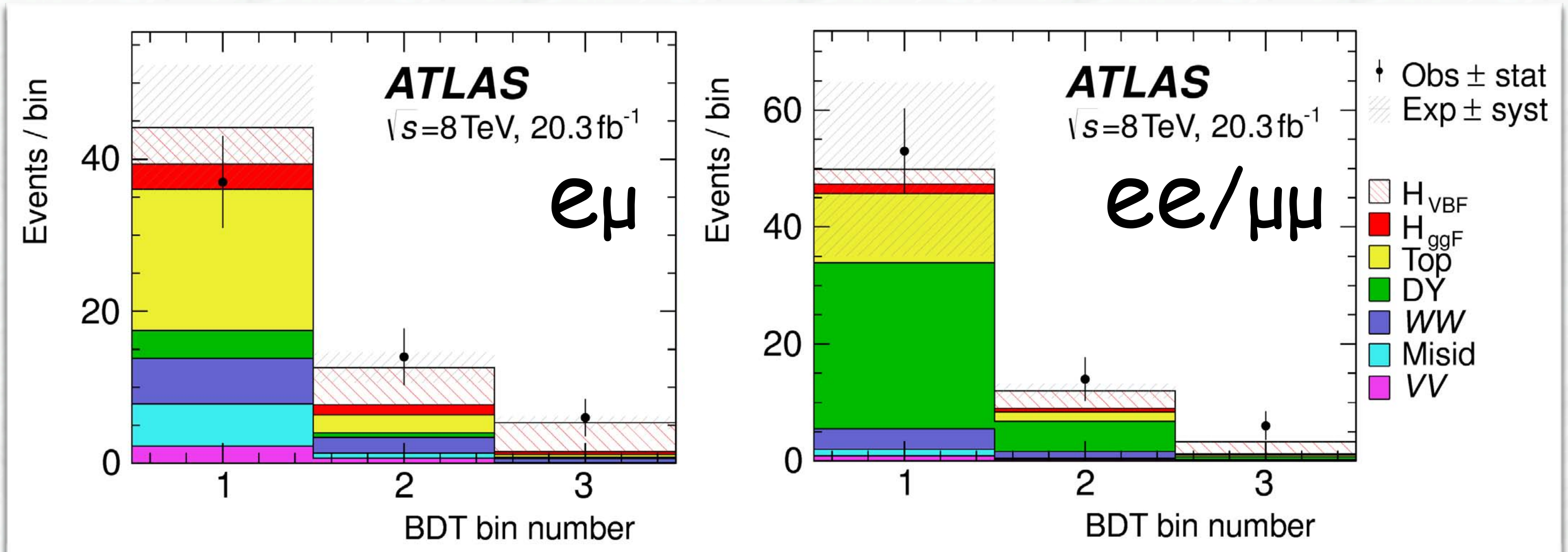


H → WW → ℓν ℓν: Vektor-boson-fusion results

Results:

- BDT outputs in good agreement with data
- ***VBF signal significance:*** **3.2 σ** (2.7 σ) observed (expected)

  ⇒ evidence of Vector-Boson-Fusion production of Higgs bosons in the H → WW* → lνlν decay channel

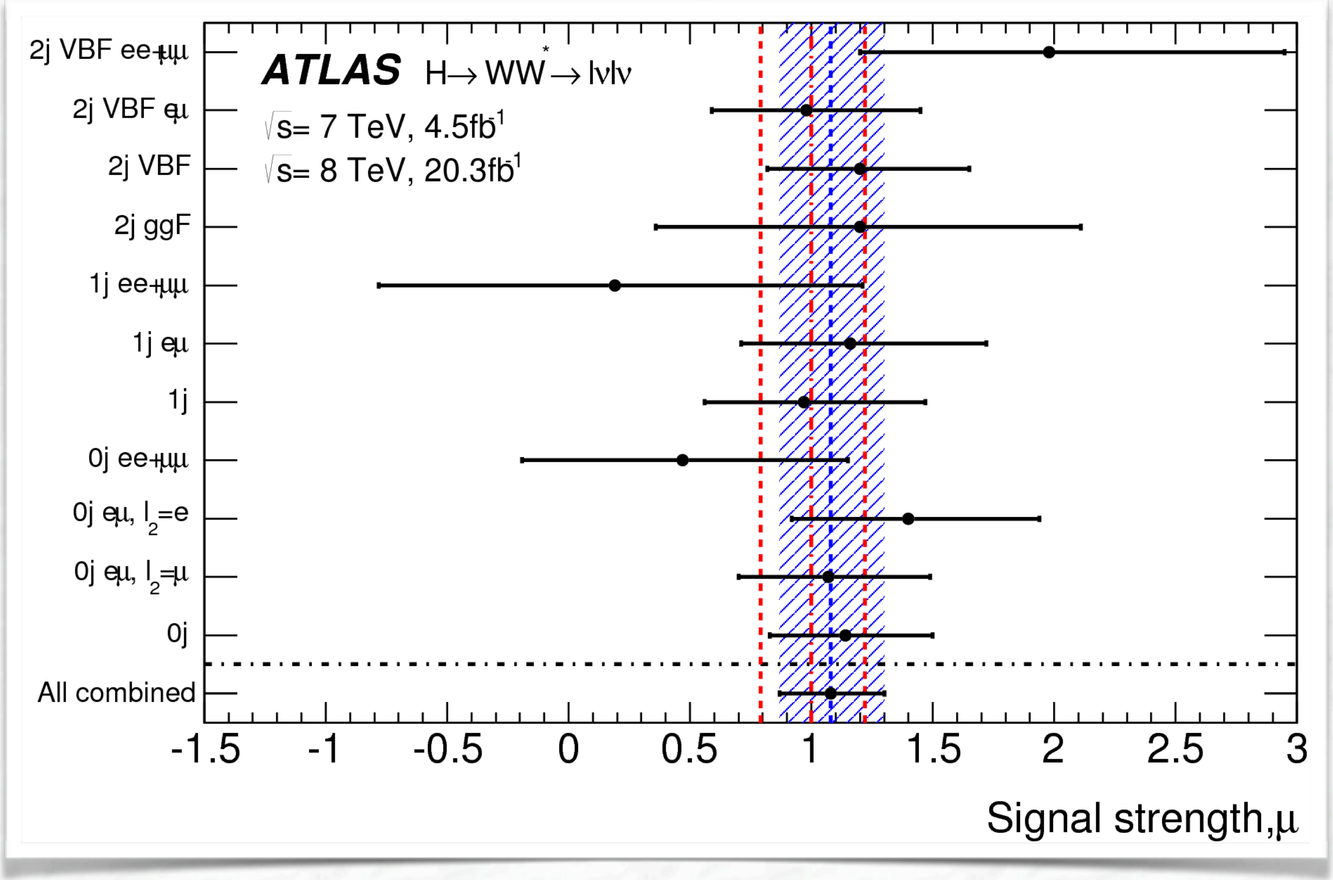


H → WW → ℓν ℓν: combined results

Signal significance: 6.1 σ observed (5.8 σ expected) @m_H = 125.36 GeV

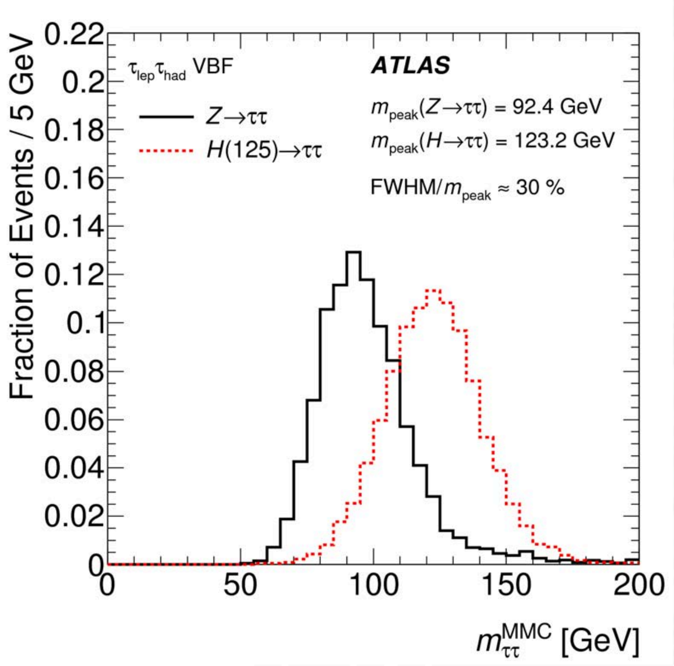
⇒ Clear observation of the H → WW* decay mode in the lνlν channel alone!

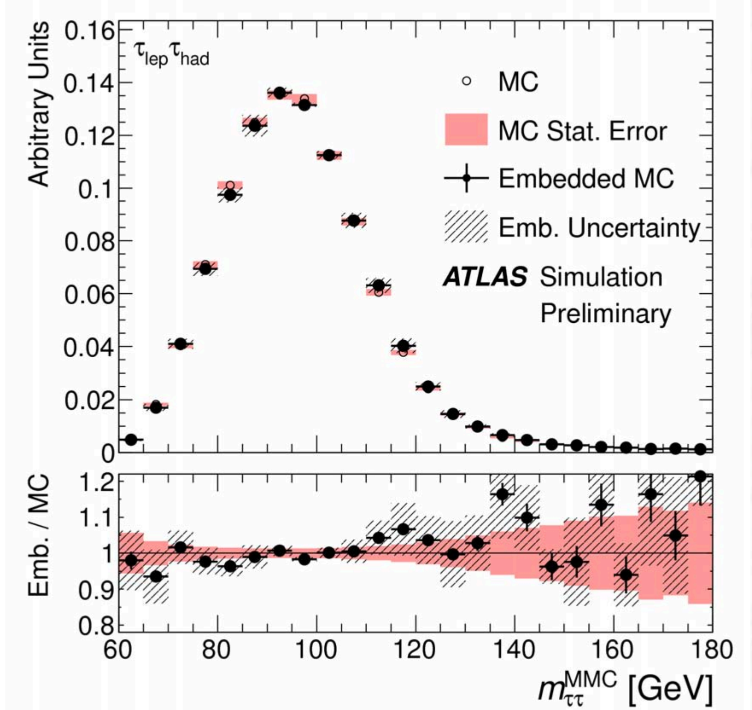
- ***Observed value*** *(@m_H = 125.36 GeV):* $\mu = 1.09^{+0.23}_{-0.21}$



H → ττ: Overview

- BR(H → ττ) ~6.32% for m_H ~ 125 GeV/c^2
- Measure Yukawa coupling to fermions directly
- Currently only accessible leptonic coupling
- Study leptonic and hadronic decay modes of taus





<u>Experimental challenge</u>:

- Identification of hadronic taus
- Good E_T^{miss} resolution
  $m_{\tau\tau}$ reconstructed with "missing-mass calculator.
  (In the past: ττ mass reconstruction in collinear approximation,
  i.e. assume that the neutrinos go in the direction of the visible decay products,
  good approximation for highly boosted taus)

  → Higgs mass can be reconstructed

- Dominant background: Z → ττ
  the shape of this background must be controlled in the high mass region
  → use data (Z → μμ) to constrain it (embedding)

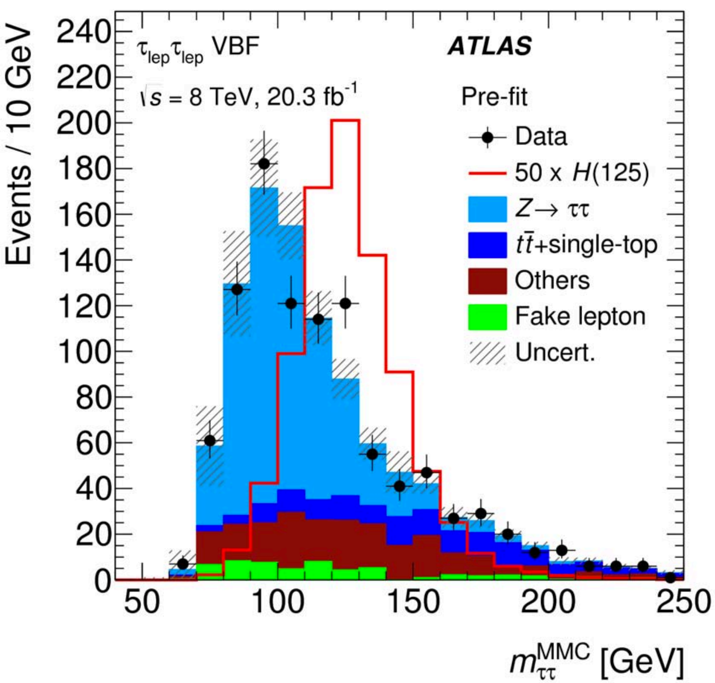
H → ττ: Analysis

<u>Event categorization:</u>

- VBF (loose/tight): two tag jets
- Boosted: large Higgs-boson p_T sd

<u>Signal extraction:</u>

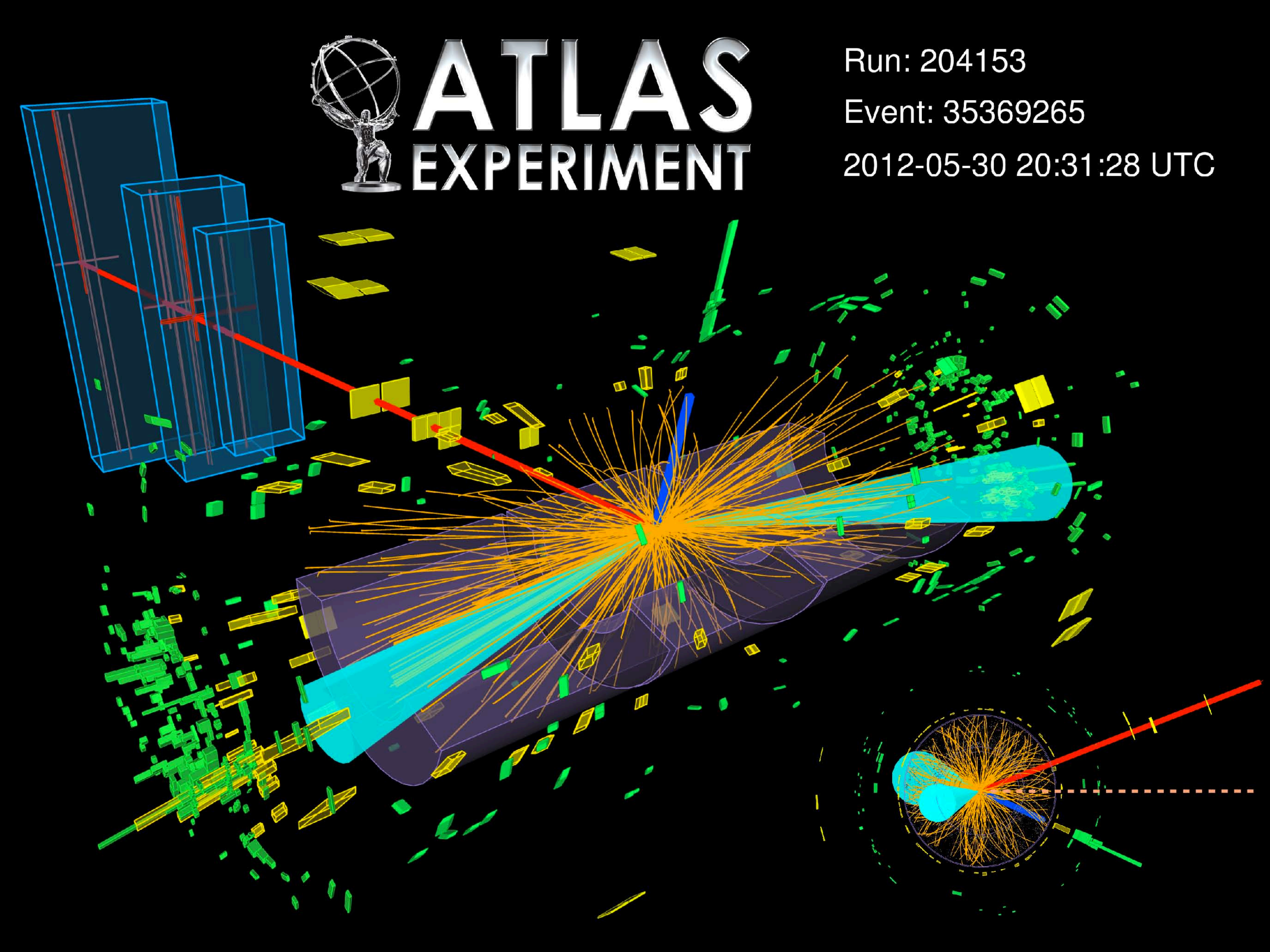
- Maximum likelihood fits
- Fit variable: BDT output
- Various data control regions



<u>Background suppression:</u>

- Boosted Decision Trees (BDT)

Variable	VBF			Boosted		
	$\tau_{lep}\tau_{lep}$	$\tau_{lep}\tau_{had}$	$\tau_{had}\tau_{had}$	$\tau_{lep}\tau_{lep}$	$\tau_{lep}\tau_{had}$	$\tau_{had}\tau_{had}$
$m_{\tau\tau}^{MMC}$	•	•	•	•	•	•
$\Delta R(\tau_1, \tau_2)$	•	•	•		•	•
$\Delta\eta(j_1, j_2)$	•	•	•			
m_{j_1,j_2}	•	•	•			
$\eta_{j_1} \times \eta_{j_2}$		•	•			
p_T^{Total}		•	•			
Sum p_T					•	•
$p_T^{\tau_1}/p_T^{\tau_2}$					•	•
$E_T^{miss}\phi$ centrality		•	•	•	•	•
m_{ℓ,ℓ,j_1}				•		
m_{ℓ_1,ℓ_2}				•		
$\Delta\phi(\ell_1, \ell_2)$				•		
Sphericity				•		
$p_T^{\ell_1}$				•		
$p_T^{j_1}$				•		
$E_T^{miss}/p_T^{\ell_2}$				•		
m_T		•			•	
$\min(\Delta\eta_{\ell_1\ell_2,\text{jets}})$	•					
$C_{\eta_1,\eta_2}(\eta_{\ell_1}) \cdot C_{\eta_1,\eta_2}(\eta_{\ell_2})$	•					
$C_{\eta_1,\eta_2}(\eta_\ell)$		•				
$C_{\eta_1,\eta_2}(\eta_{j_3})$	•					
$C_{\eta_1,\eta_2}(\eta_{\tau_1})$			•			
$C_{\eta_1,\eta_2}(\eta_{\tau_2})$			•			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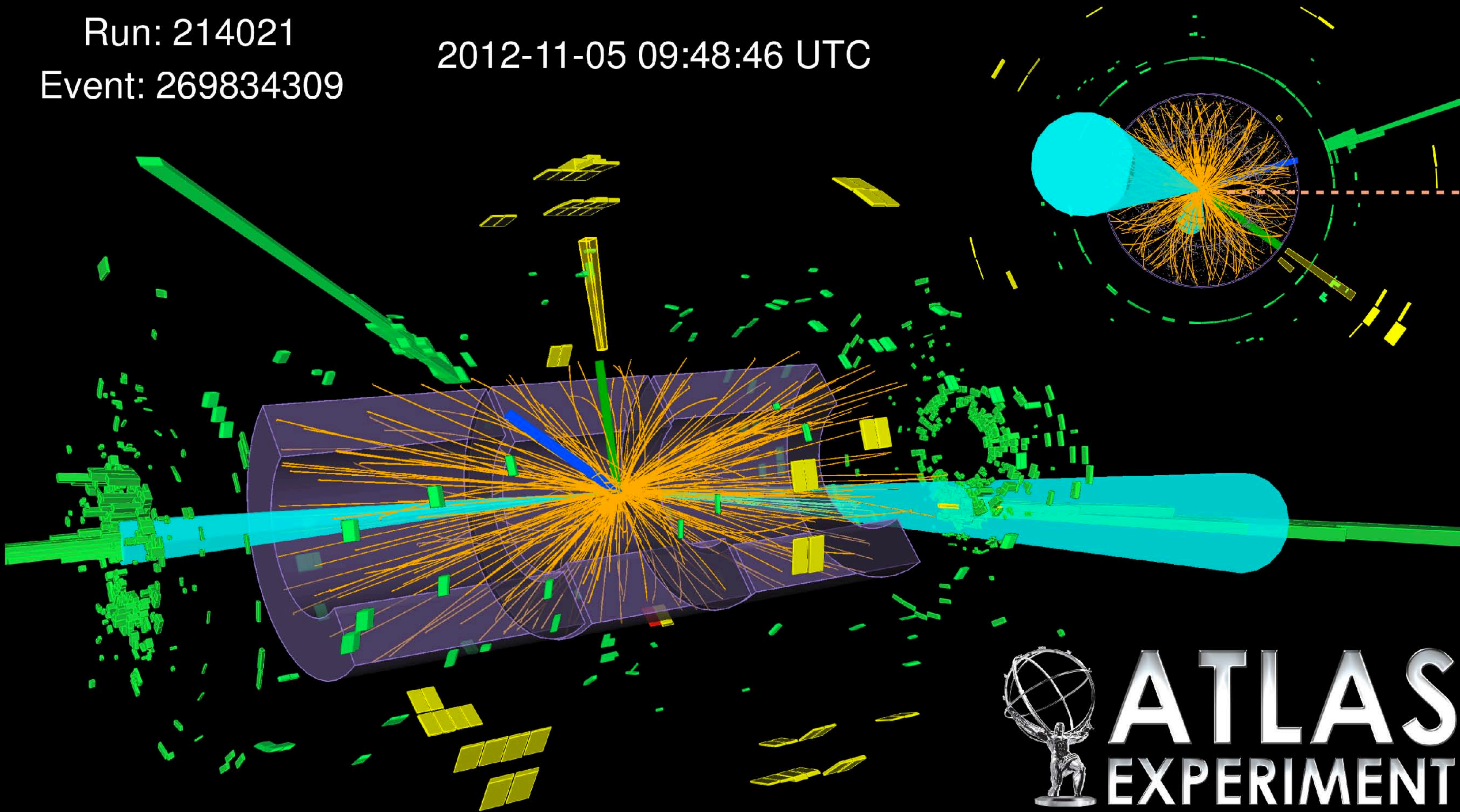
EXPERIMENT
Run: 204153
Event: 35369265
2012-05-30 20:31:28 UTC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2012-11-05 09:48:46 UTC
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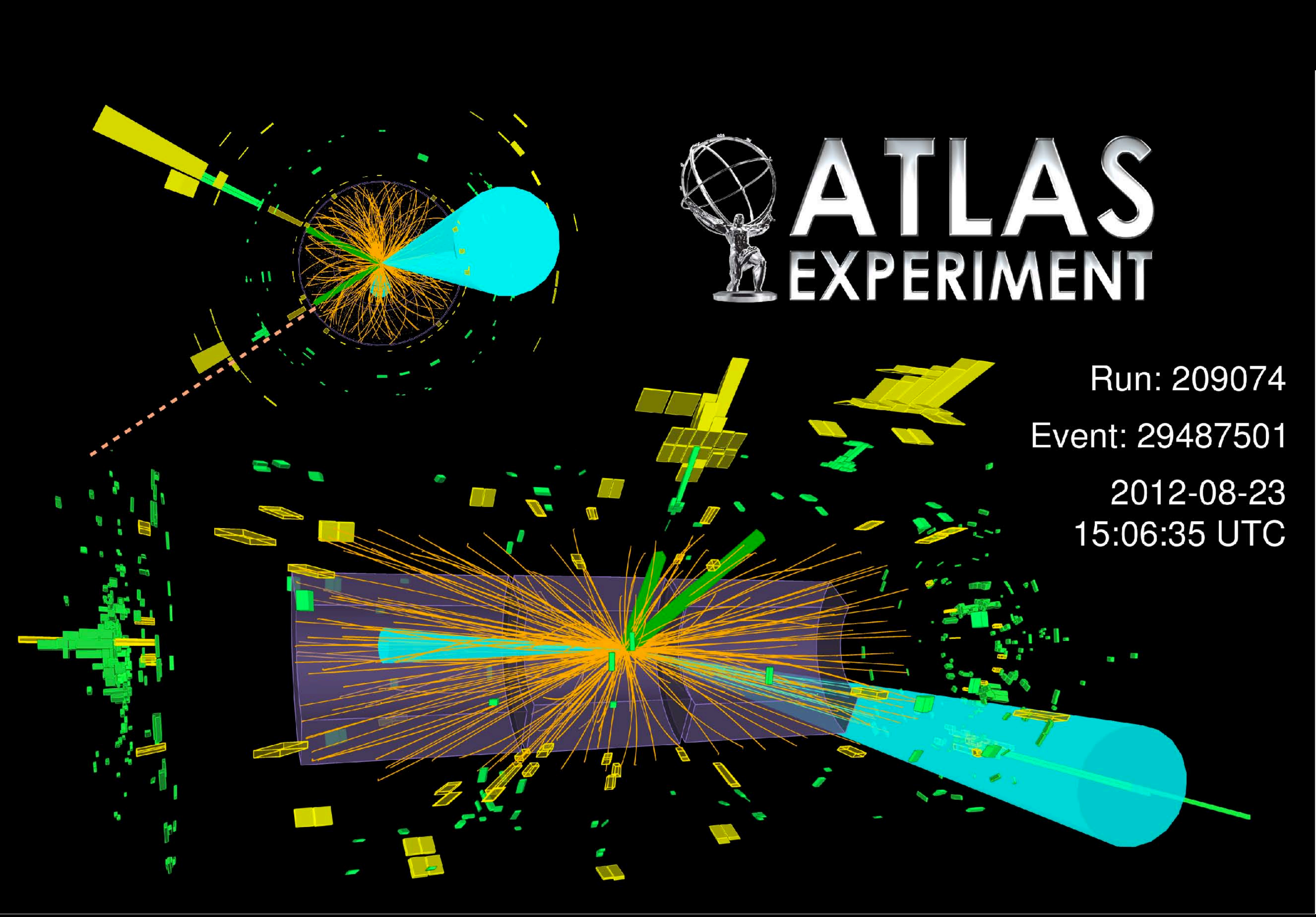
EXPERIMENT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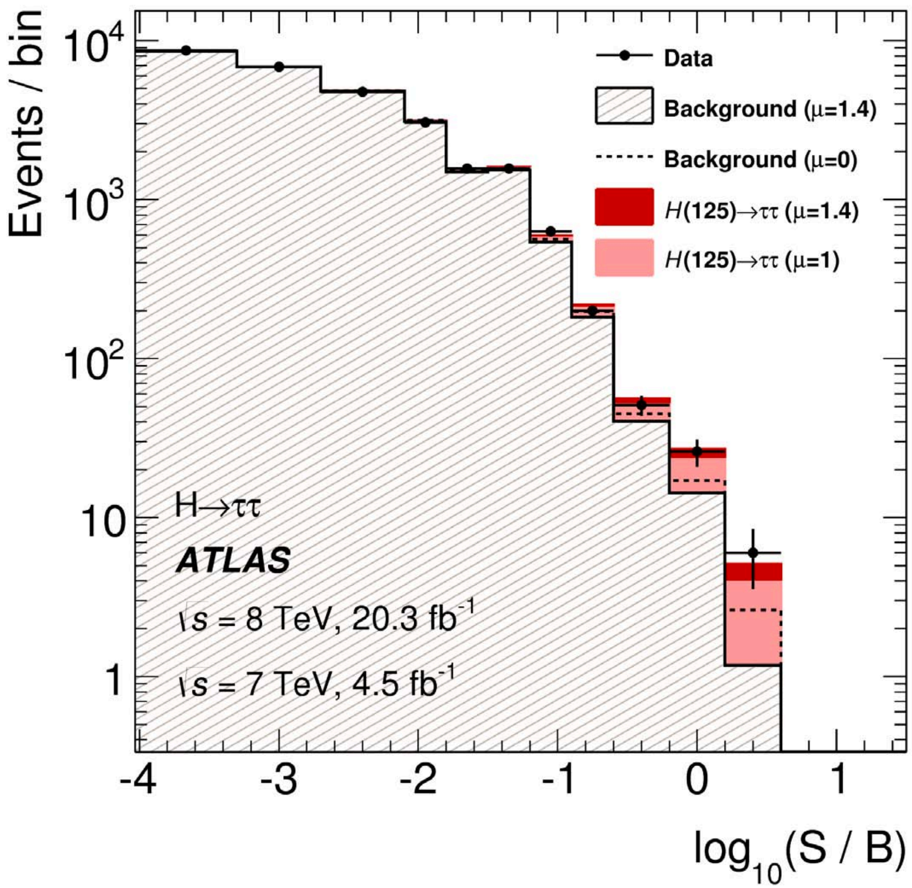
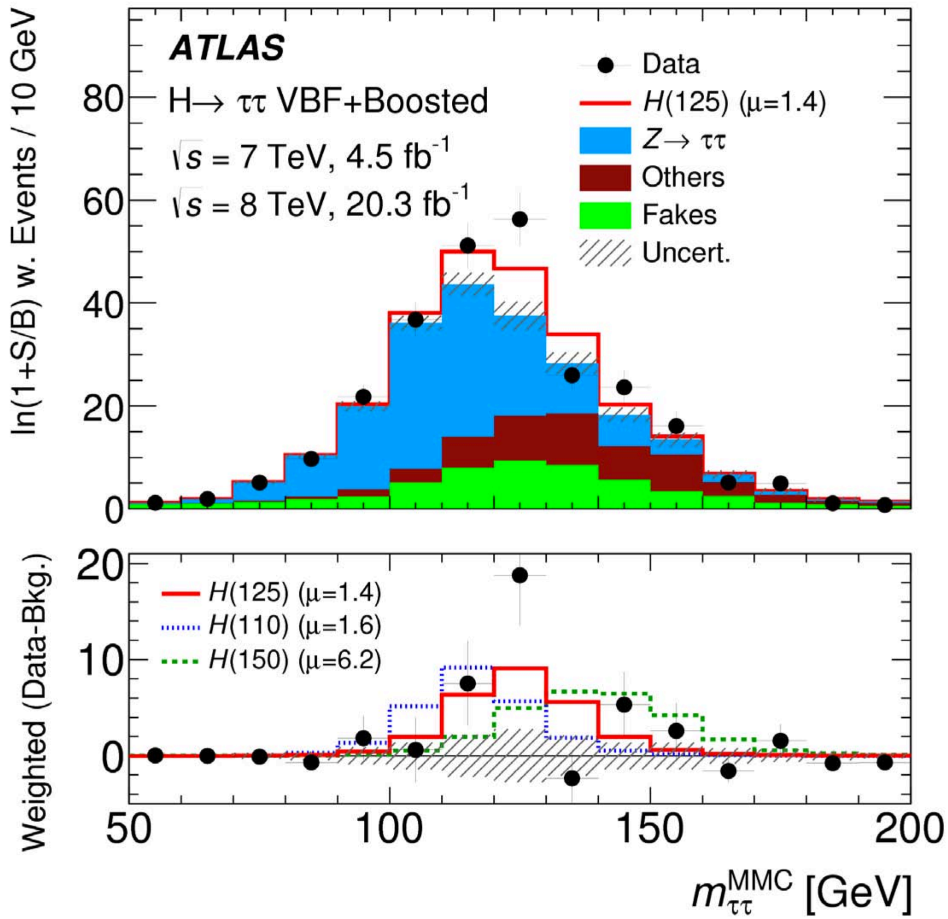
H → ττ: combined results

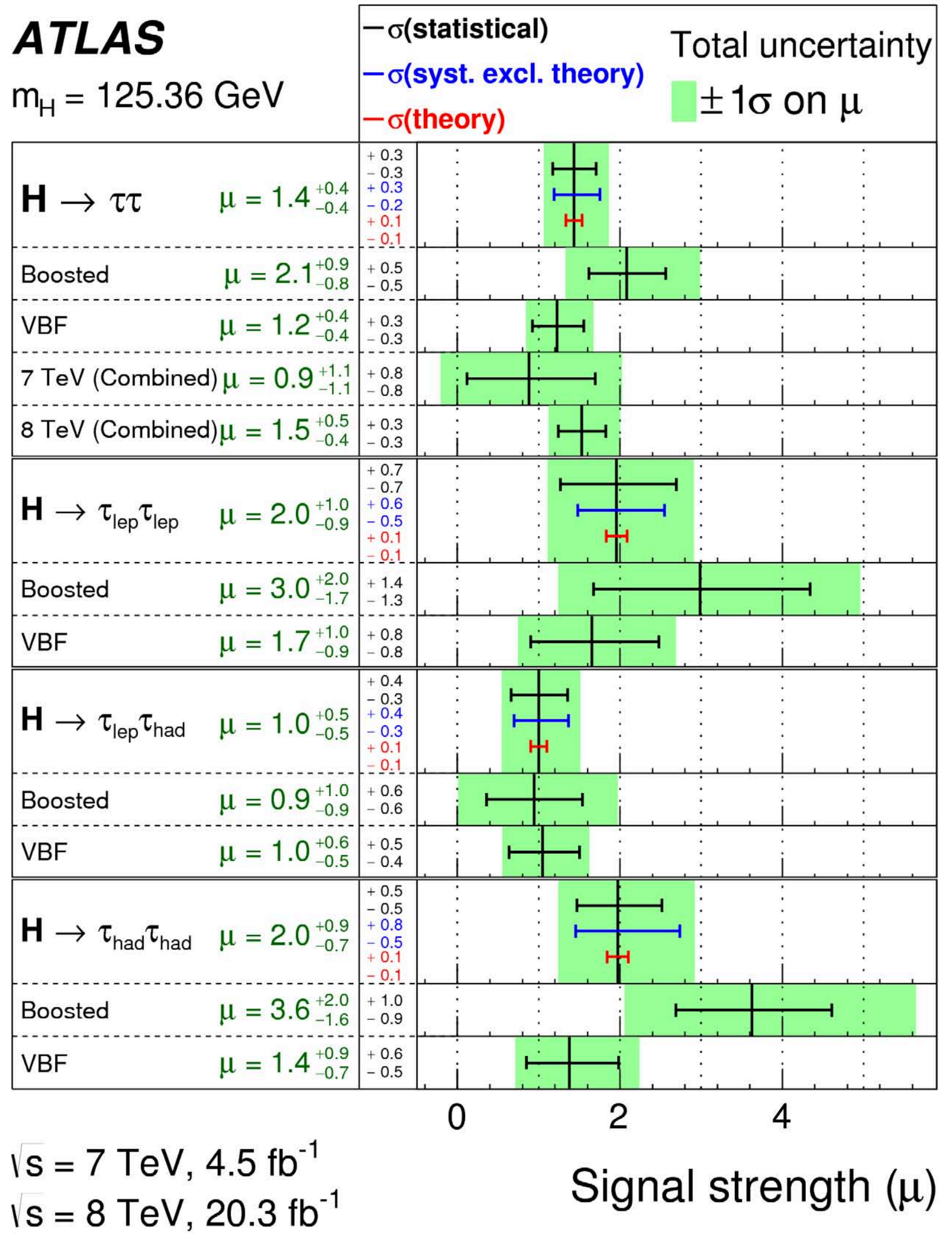


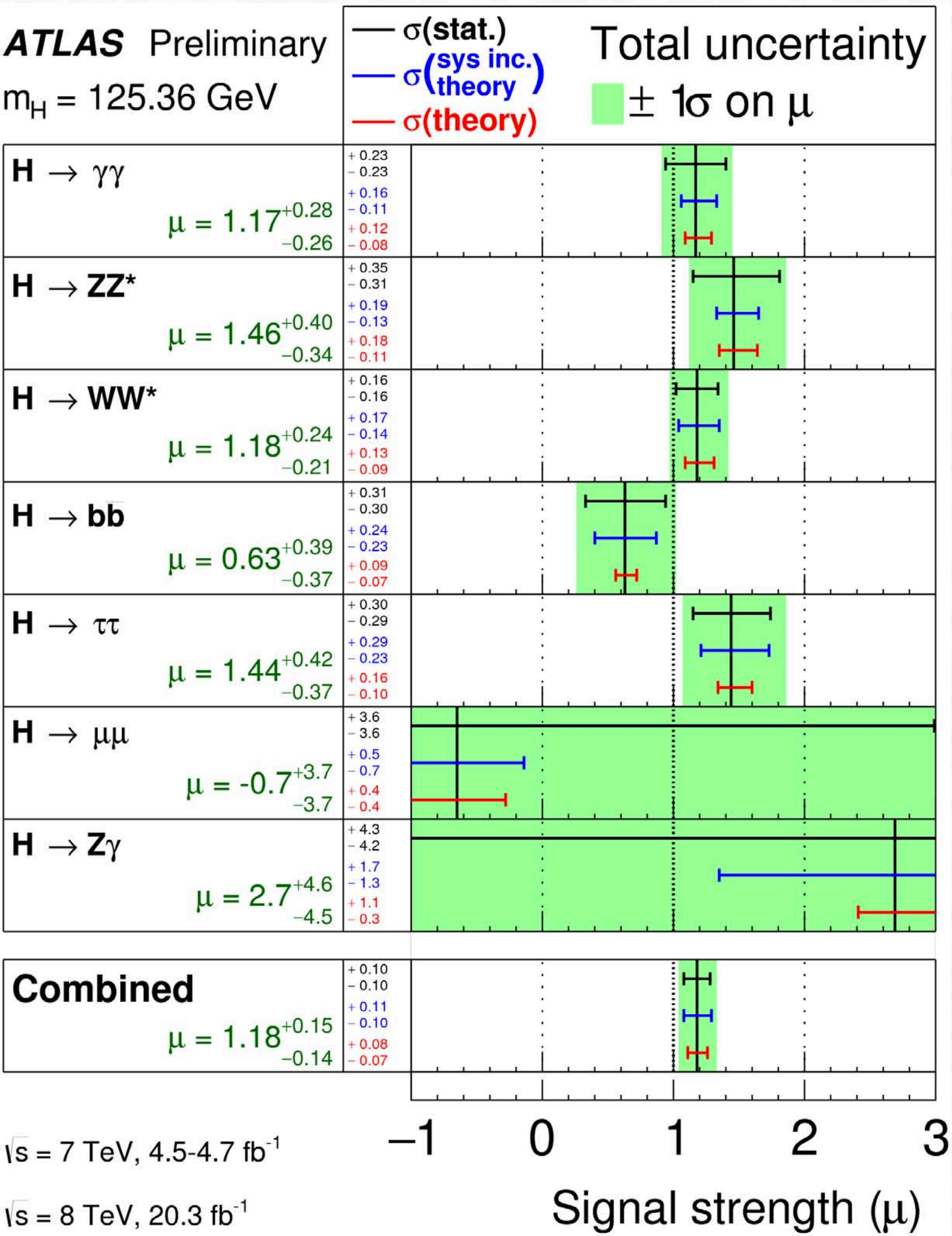


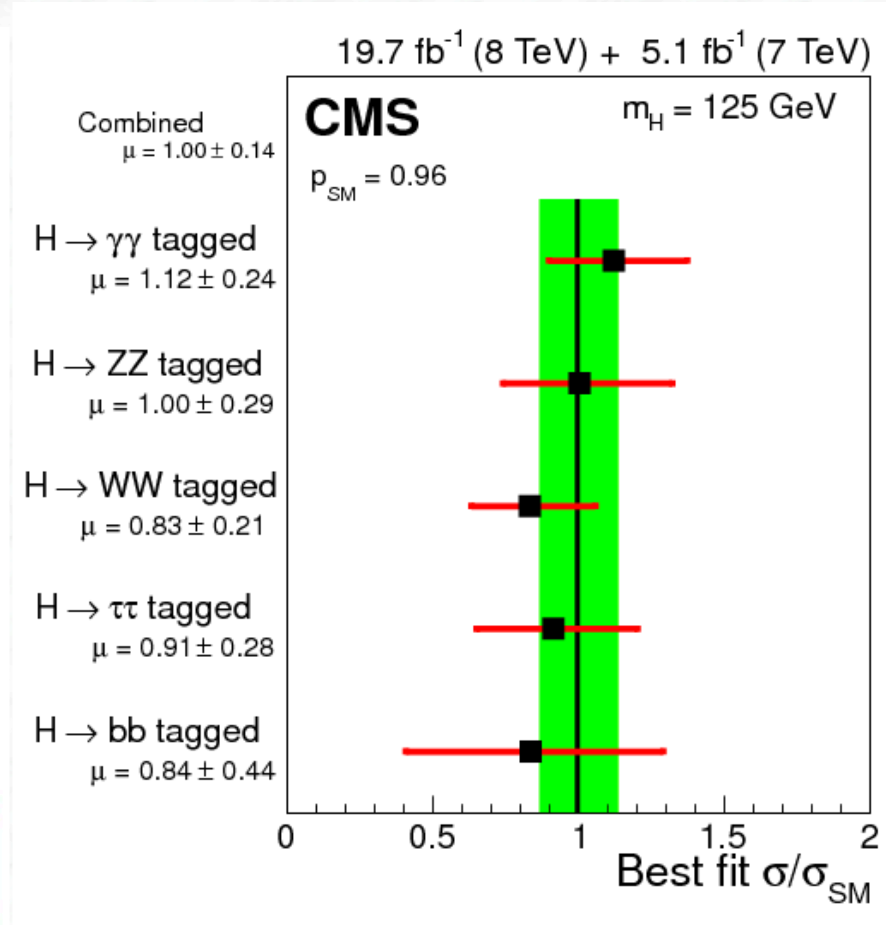
H → ττ: combined results

Significance of result:

- 4.5σ observed
- 3.4σ expected







Overview over all channels

Standard Model Total Production Cross Section Measurements