Karlsruher Institut für Technologie

Bundesministerium für Bildung und Forschung

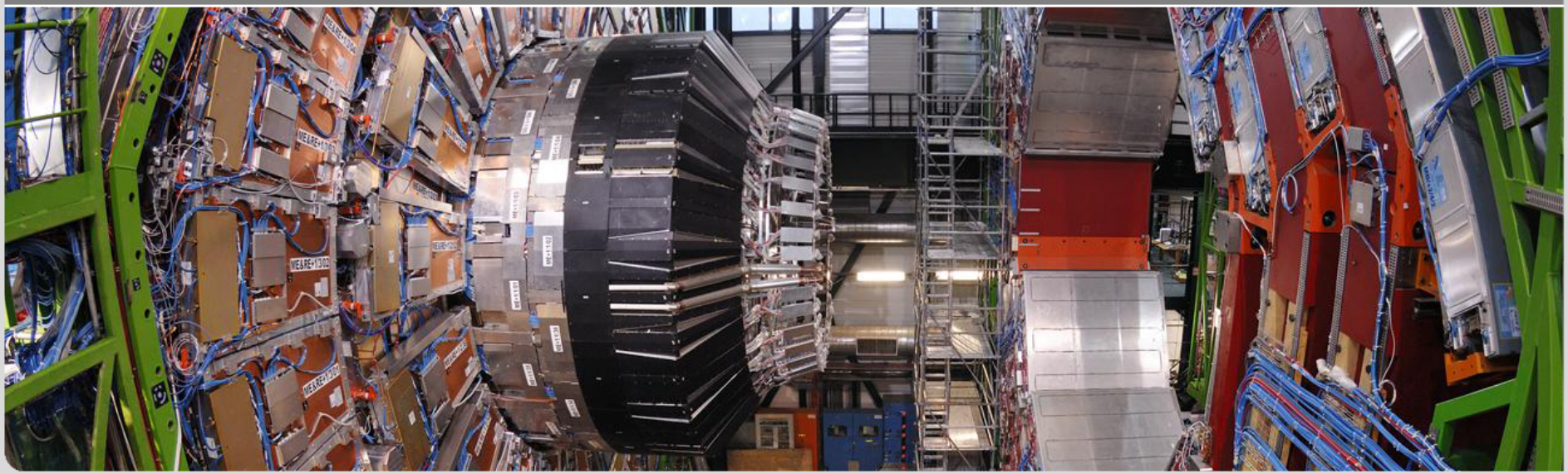
CMS

2016 SM H→ττ Analysis

26th September 2016

Raphael Friese

INSTITUT FÜR EXPERIMENTELLE KERNPHYSIK (EKP) · FAKULTÄT FÜR PHYSIK



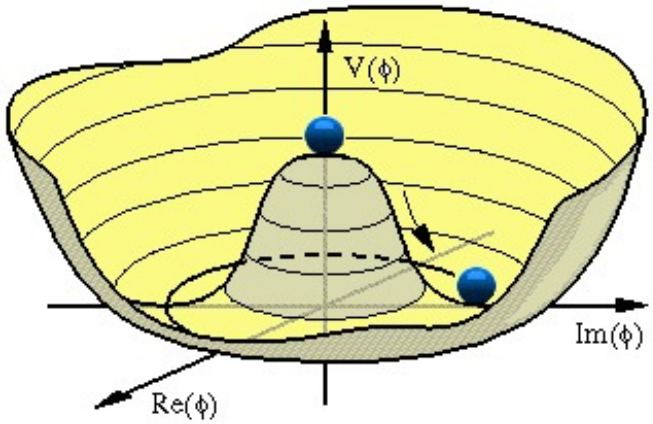
Higgs?

- The Higgs mechanism is a way to explain the masses of the W and Z bosons by introducing a field with an energy ground state that is not symmetric under $SU(2)_L$ transformations

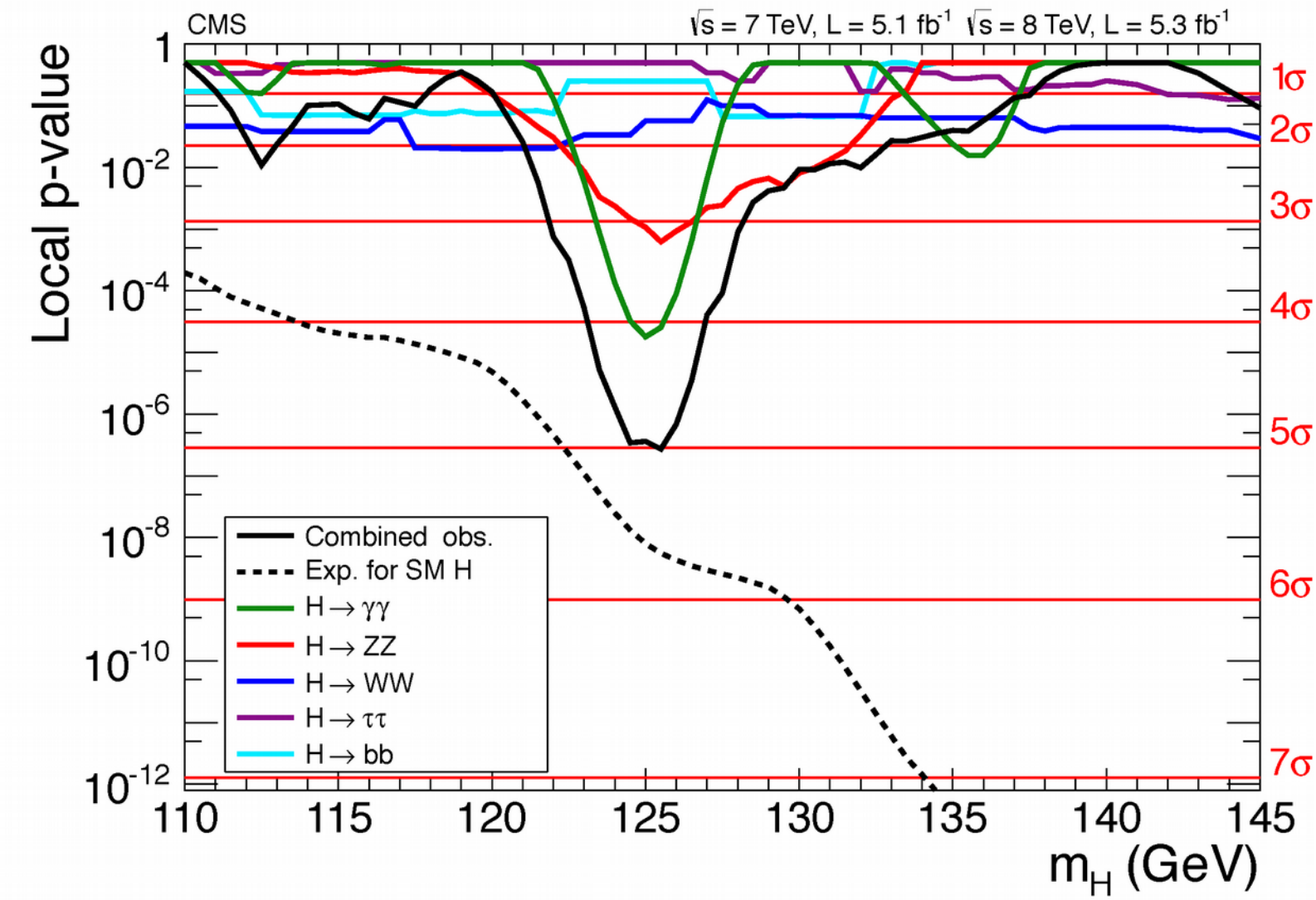
The Higgs coupling is

$\propto m_v^2$ (for force mediating W & Z boson)

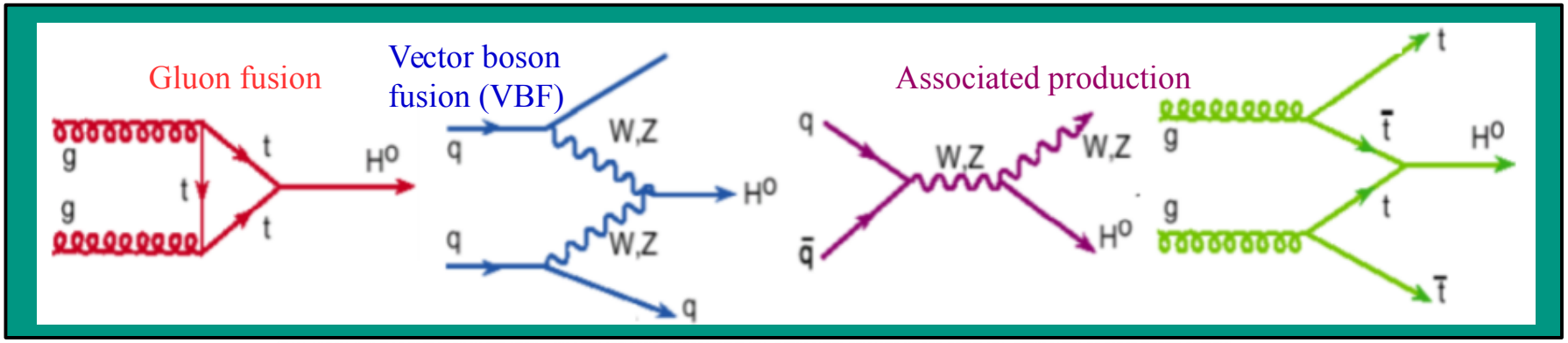
$\propto m_f$ (for weakly interacting fermions)

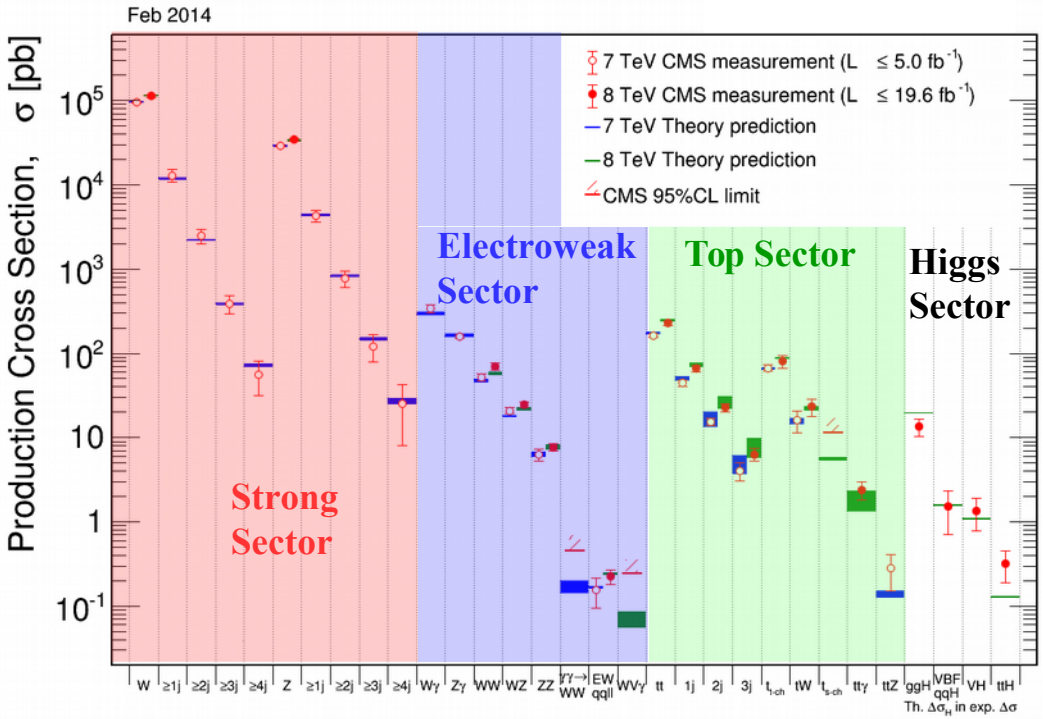


Discovery of a new particle 4th of July 2012



Higgs Boson production





Higgs Boson decay modes

Higgs boson mean lifetime : $1.56 \times 10^{-22} s$

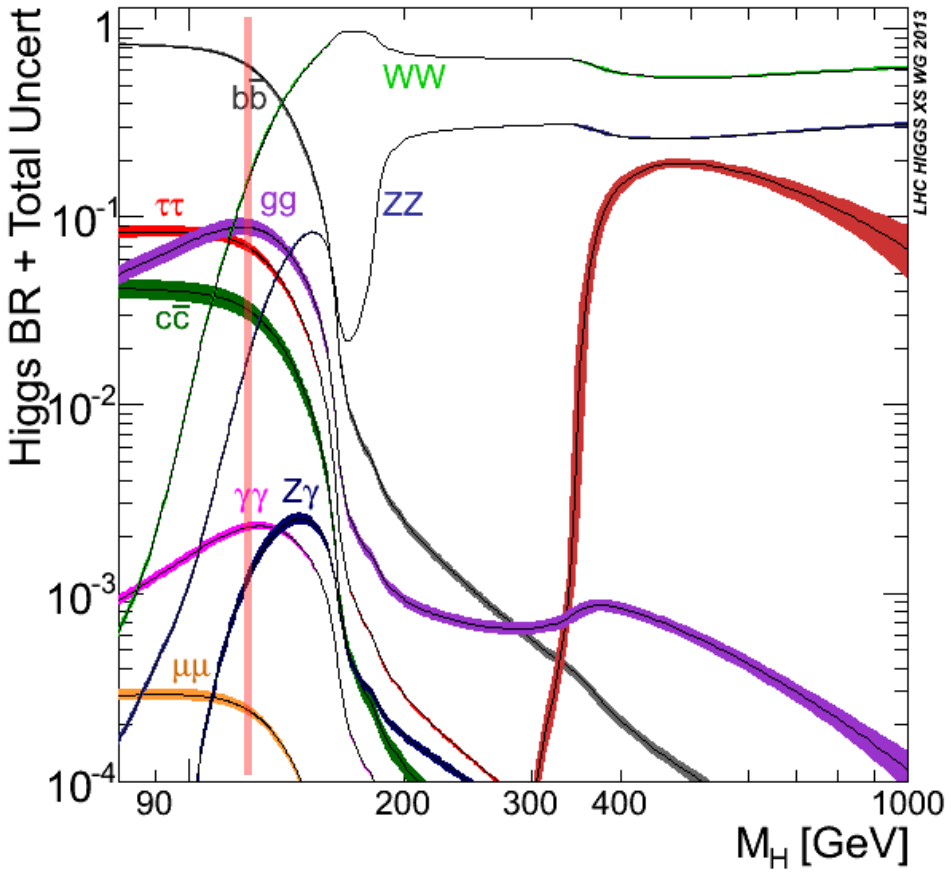
	Fermions		
Quarks	u up	c charm	t top
	d down	s strange	b bottom
Leptons	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino
	e electron	μ muon	τ tau

too heavy

large backgrounds

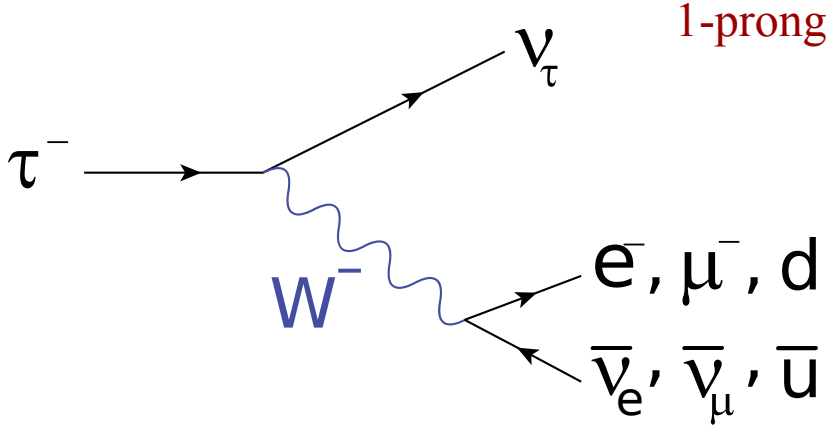
low mass

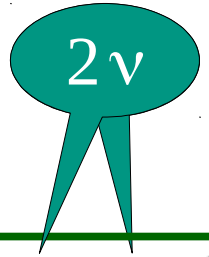
perfect!



Tau decays

mean τ liftetime:
$2.9 \times 10^{-13}\, s$





Branching ratio

Leptonic

$\tau^- \to e^- + \bar{\nu}_e + \nu_\tau \quad (17{,}83 \pm 0{,}04)\,\%$

$\tau^- \to \mu^- + \bar{\nu}_\mu + \nu_\tau \quad (17{,}41 \pm 0{,}04)\,\%$

1-prong

$\tau^- \to \pi^- + \pi^0 + \nu_\tau \quad (25{,}52 \pm 0{,}09)\,\%$

$\tau^- \to \pi^- + \nu_\tau \quad (10{,}83 \pm 0{,}06)\,\%$

$\tau^- \to \pi^- + 2\pi^0 + \nu_\tau \quad (9{,}30 \pm 0{,}11)\,\%$

$\tau^- \to K^*(892)^- + \nu_\tau \quad (1{,}20 \pm 0{,}07)\,\%$

$\tau^- \to \pi^- + 3\pi^0 + \nu_\tau \quad (1{,}05 \pm 0{,}07)\,\%$

$\tau^- \to \pi^- + \bar{K}^0 + \nu_\tau \quad (0{,}84 \pm 0{,}04)\,\%$

$\tau^- \to K^- + \nu_\tau \quad (0{,}70 \pm 0{,}01)\,\%$

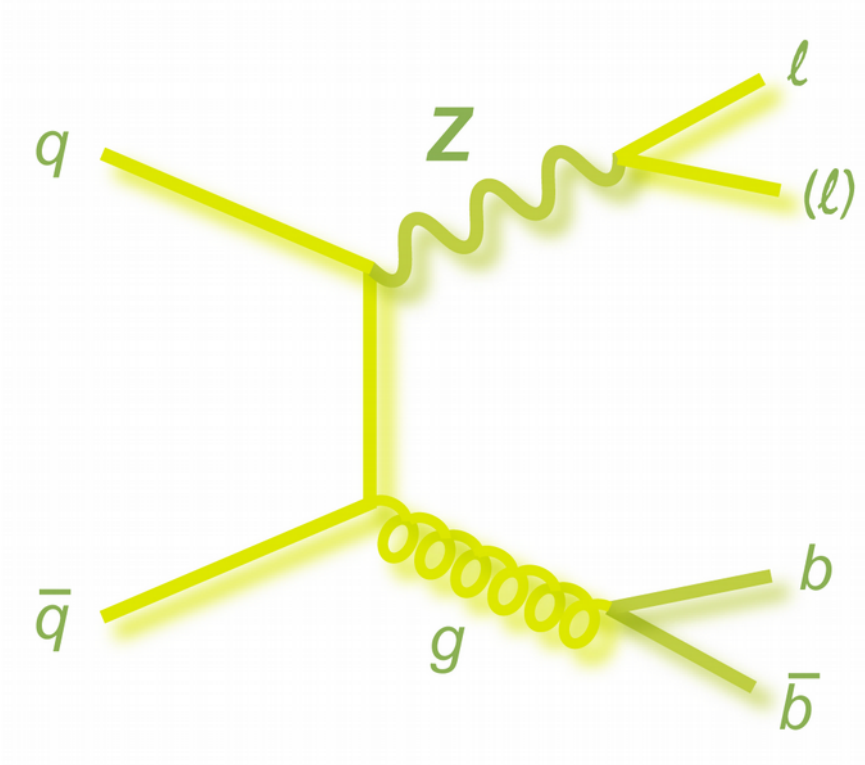
3-prong

$\tau^- \to 2\pi^- + \pi^+ + \pi^0 + \nu_\tau \quad (4{,}62 \pm 0{,}06)\,\%$

$\tau^- \to 2\pi^- + \pi^+ + \nu_\tau \quad (9{,}31 \pm 0{,}06)\,\%$

$Z \rightarrow \tau\tau$

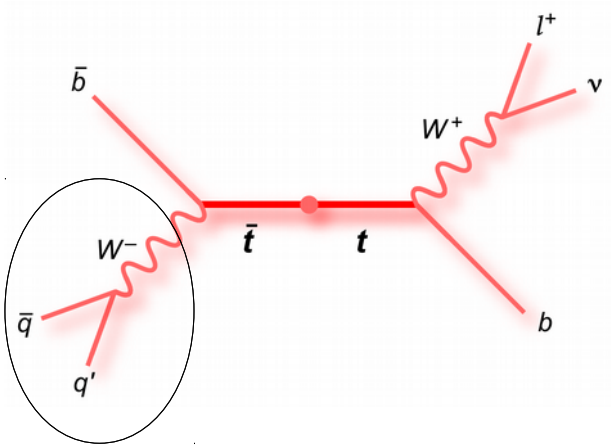
- Highest irreducible background contribution
- Often in boosted Z+Jets topologies

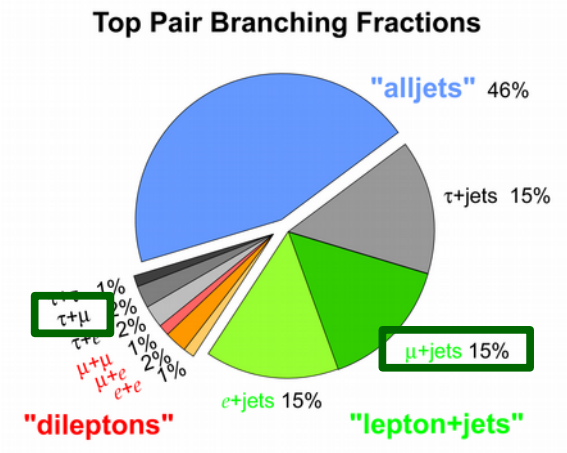


real or fake?

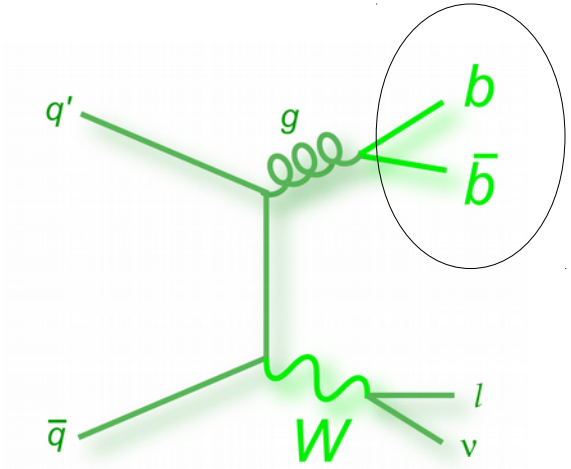
Jets “faking” hadronic τ decays - and some real ones

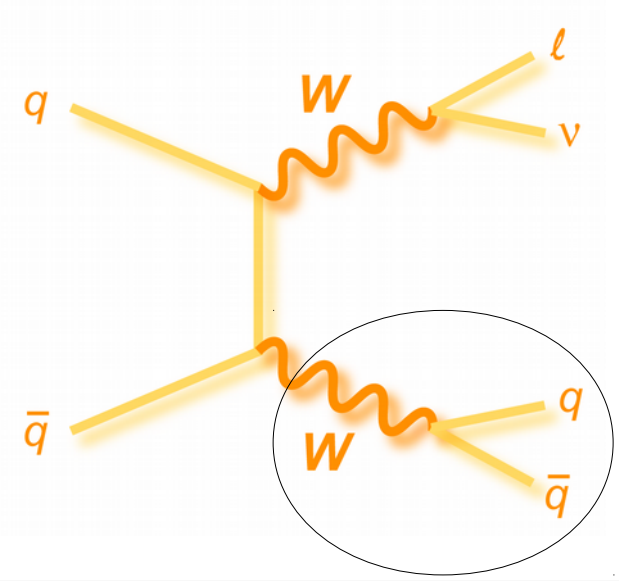
$t\,\bar{t}$





W+Jets,
Di-Boson





Tau reconstruction and identification

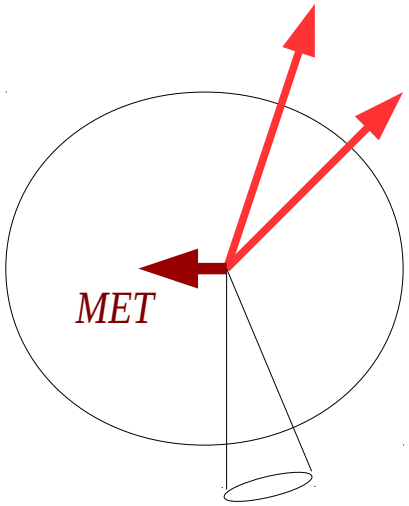
- start with jets with pT > 14 GeV
- "**H**adron **P**lus **S**trips" algorithm
- Rejection against jets to reach high purity, e.g.
  - Cut-based isolation:

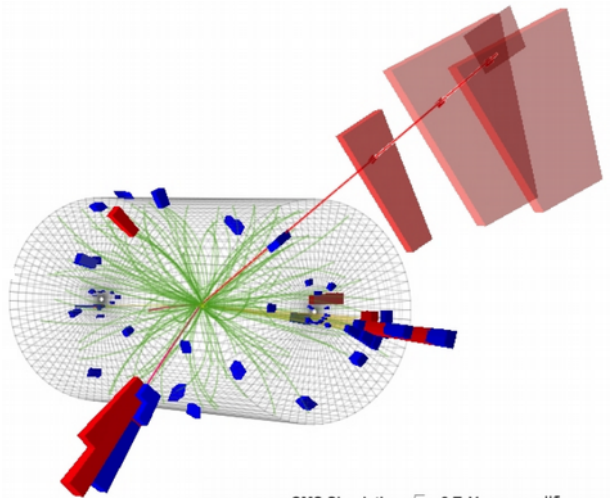
$$I_\tau = \sum_{\text{charged},\Delta z<0.2\,\text{cm}} p_\text{T} + \max\left\{0, \sum_\gamma p_\text{T} - \Delta\beta\right\}, \qquad \Delta\beta = 0.46 \sum_{\text{charged},\Delta z>0.2\,\text{cm}} p_\text{T}.$$

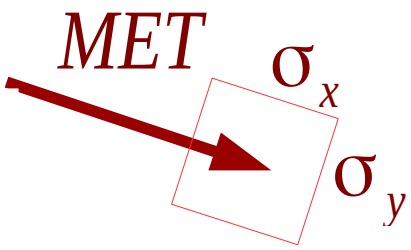
  - MVA based tau-ID
  - MVA & cut based anti-electron ID
  - MVA & cut based anti-muon ID

Reconstruction of the missing energy

- Missing transverse energy (MET):
  - momentum in plane perpendicular to beam axis, in theory equivalent to neutrino momentum
- A multivariate regression technique removes biasing effects and gives an estimation of phase space of the neutrinos

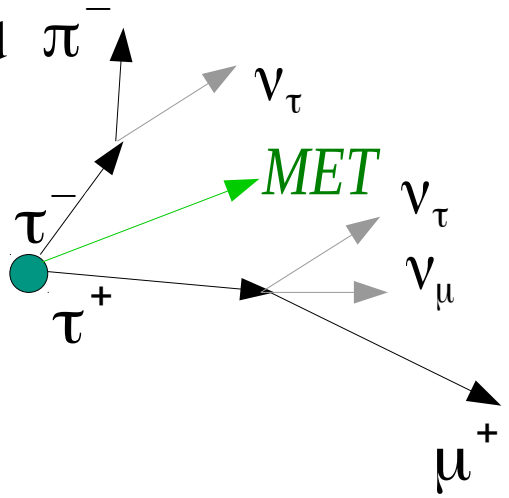






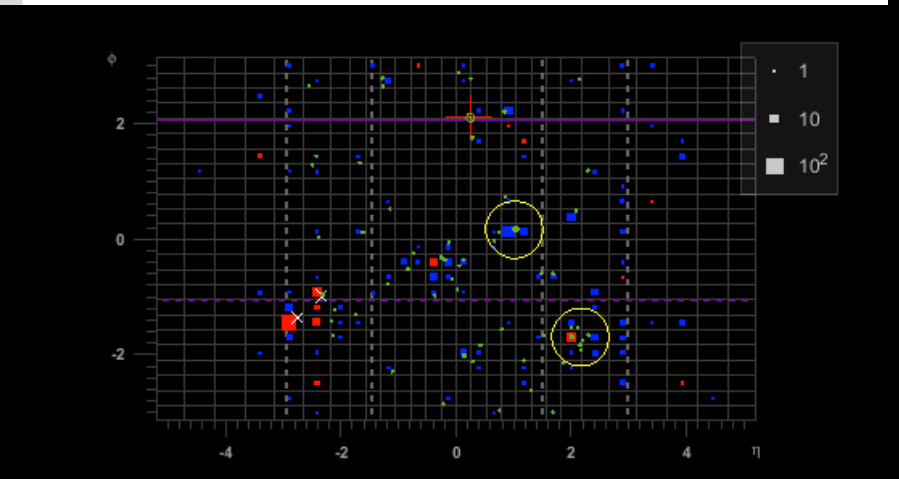
Bringing it all together:
full reconstruction of the di-tau system

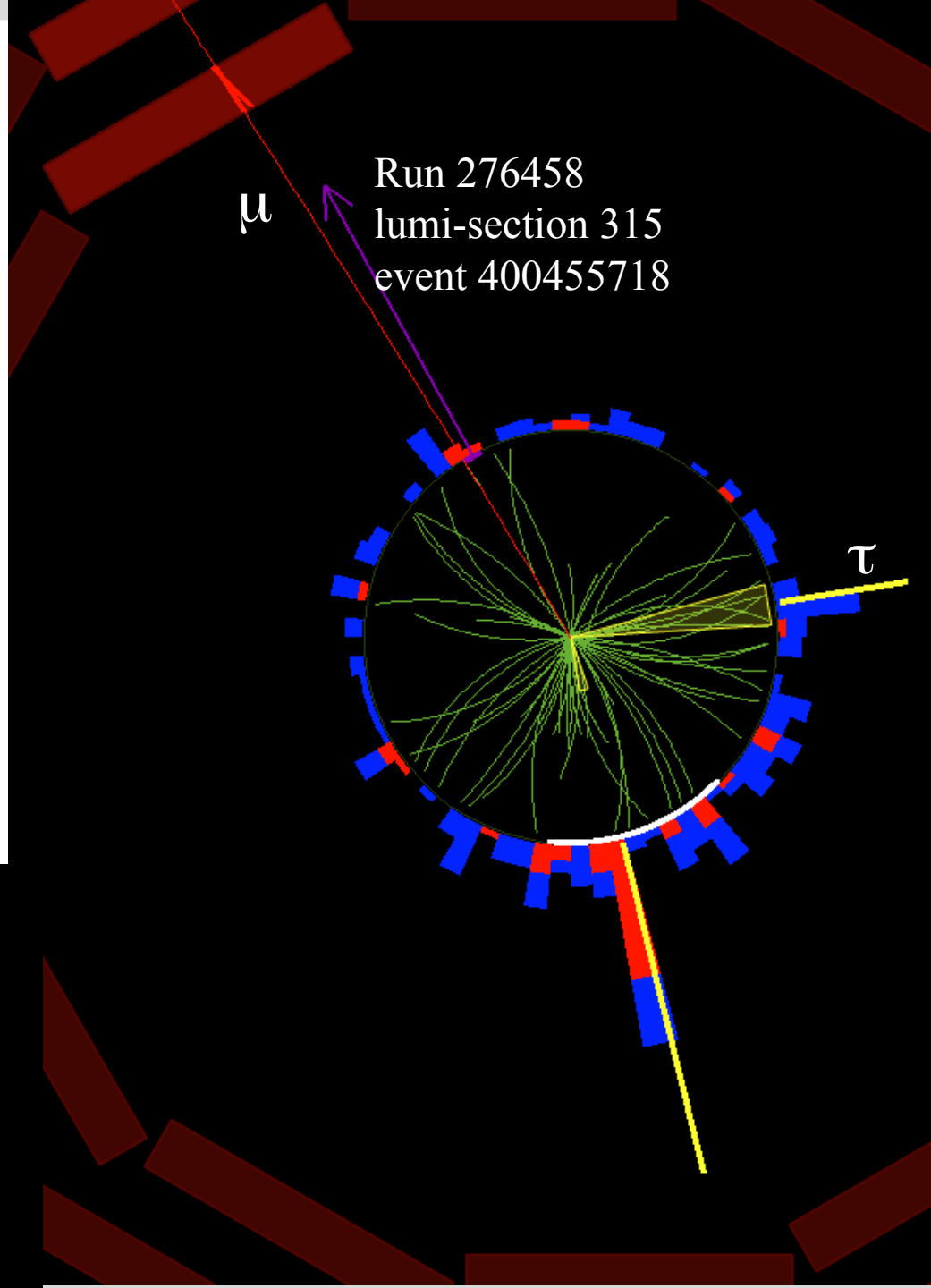
- di-tau decays result in 2 to 4 neutrinos in the final state
  - -> under-constrained problem
- 3 free parameters per tau decay
  - fraction of visible energy
  - azimuthal angle
  - invariant neutrino mass
- Additionally known: MET (2 parameters)
- Calculate probability of di-tau hypothesis to be true and take the **mass with the highest probability**



Analysis strategy

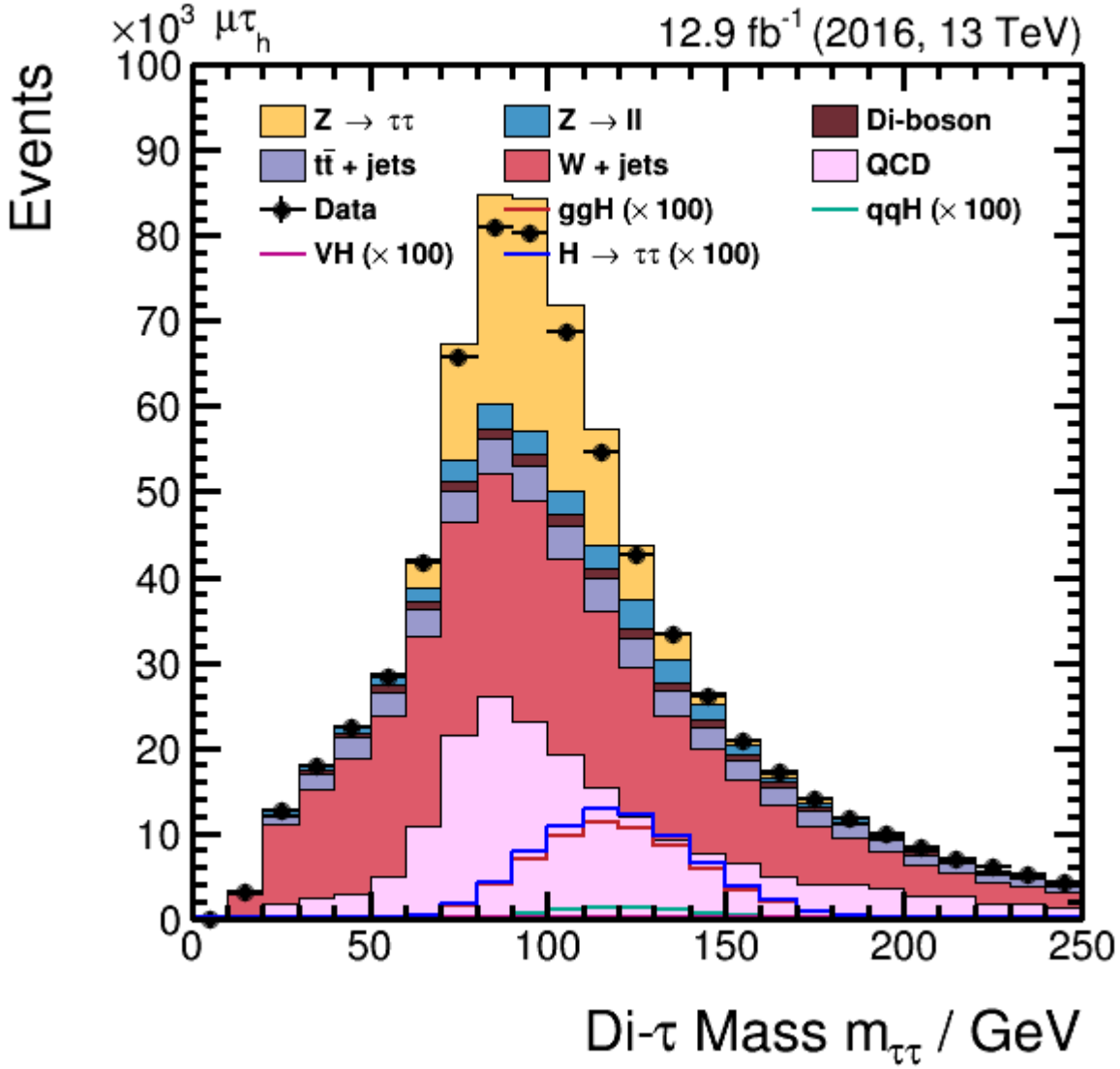
- Selection depending on final state
- Starting the background estimation with simulated Events
- Applying a reasonable set of selection steps
- Data-Based background estimation techniques
- Cross check simulation in control regions





Selection steps

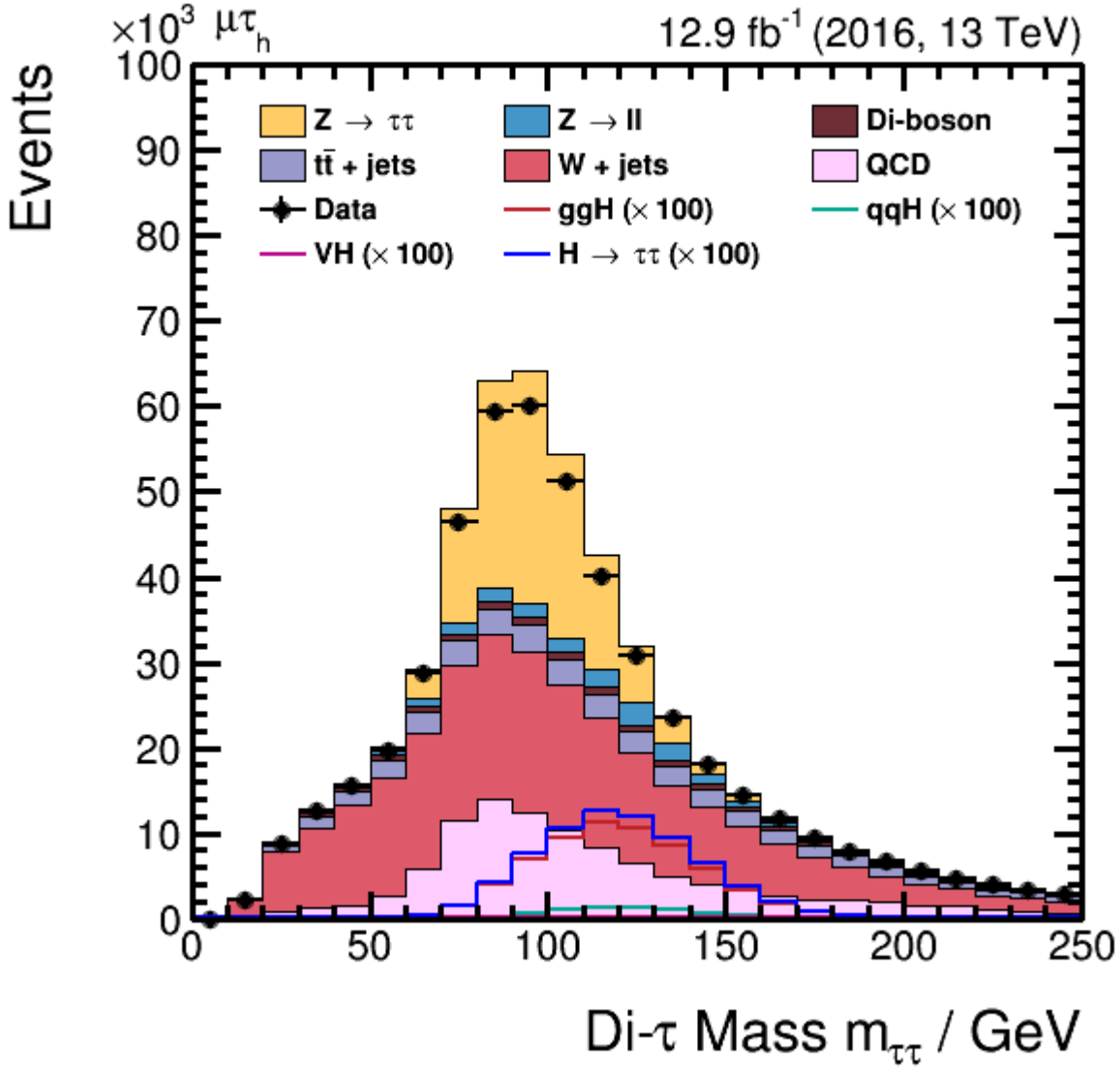
inclusive



Selection steps

inclusive

opposite charge

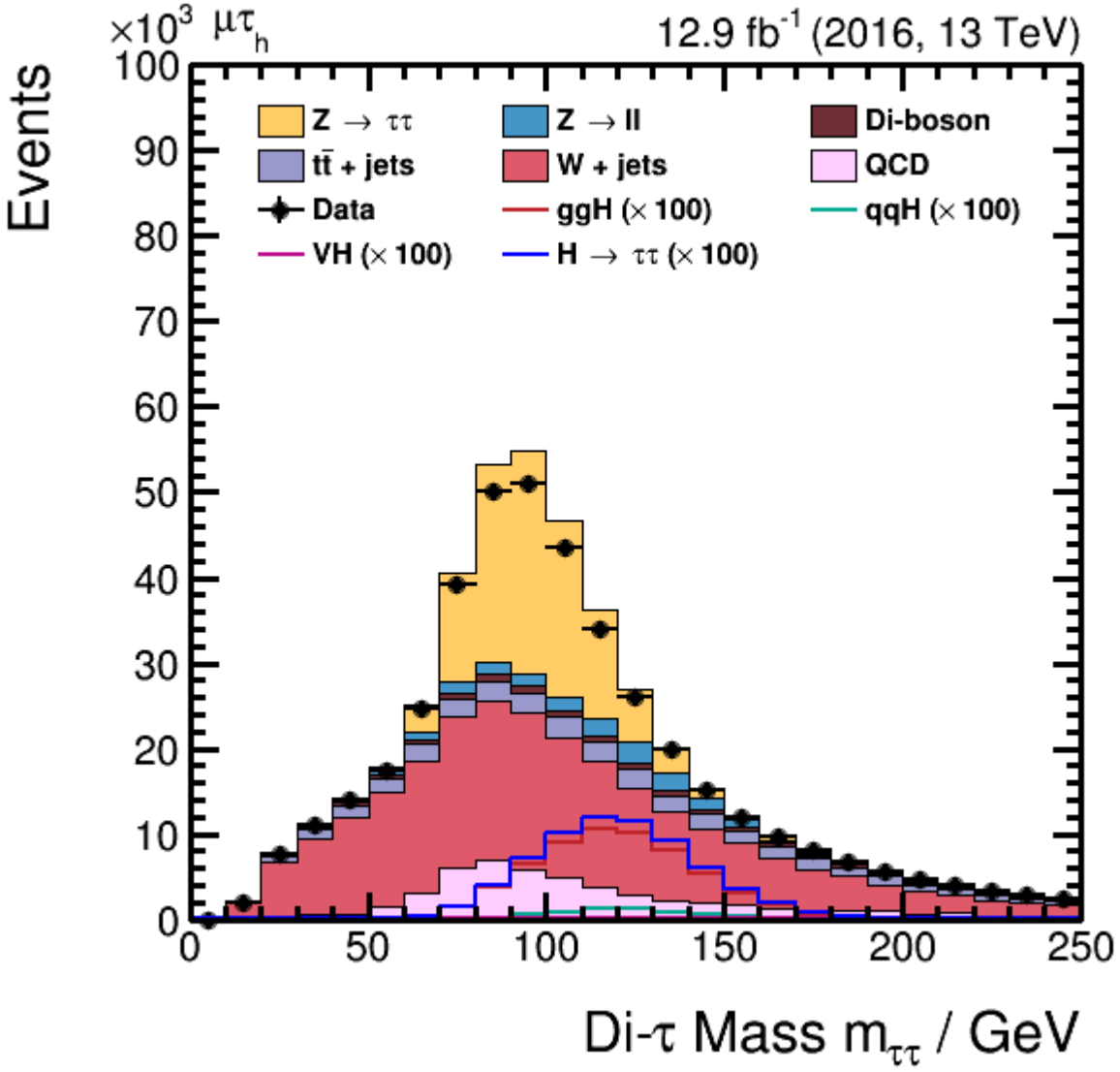


Selection steps

inclusive

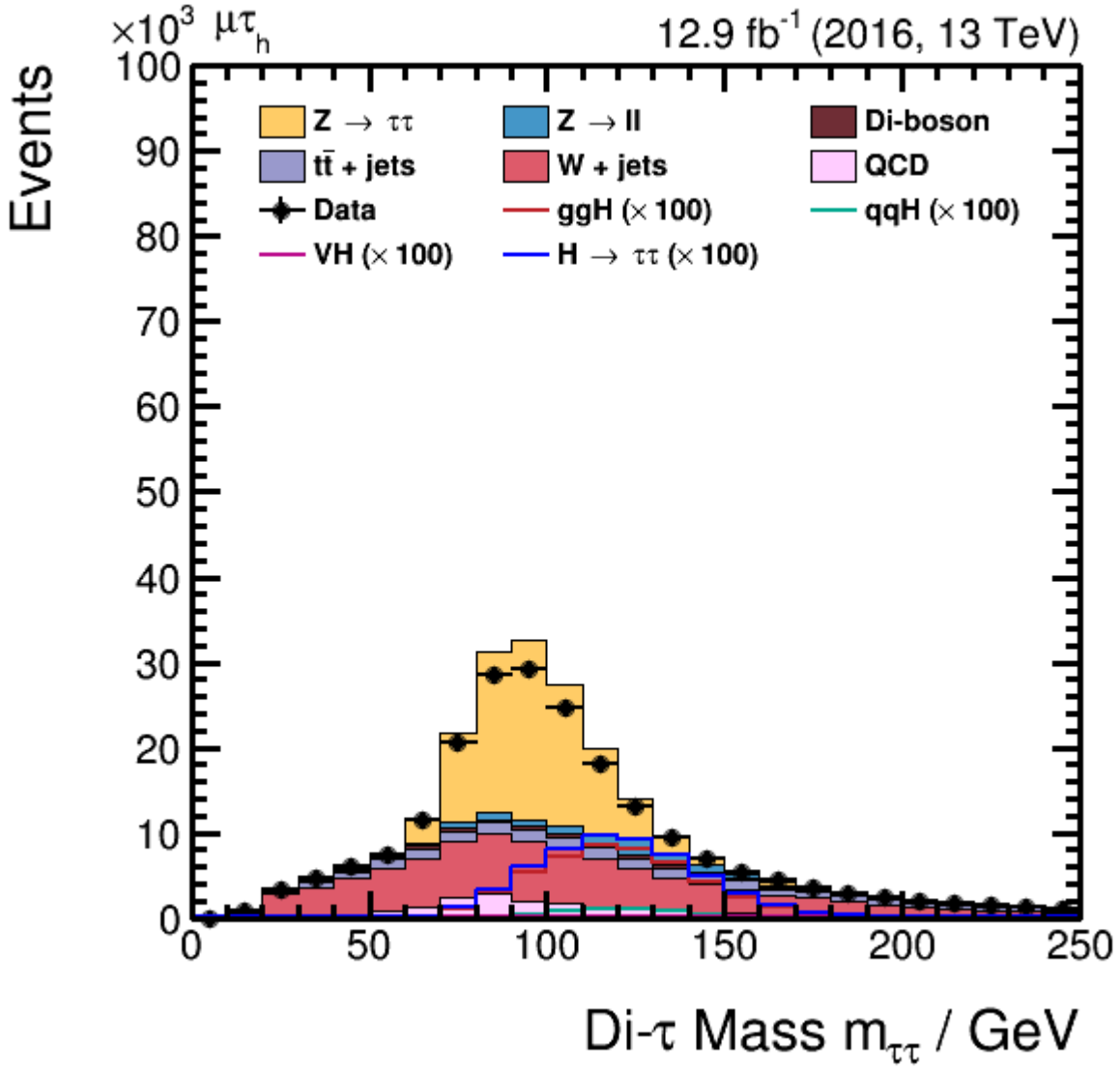
opposite charge

muon isolation



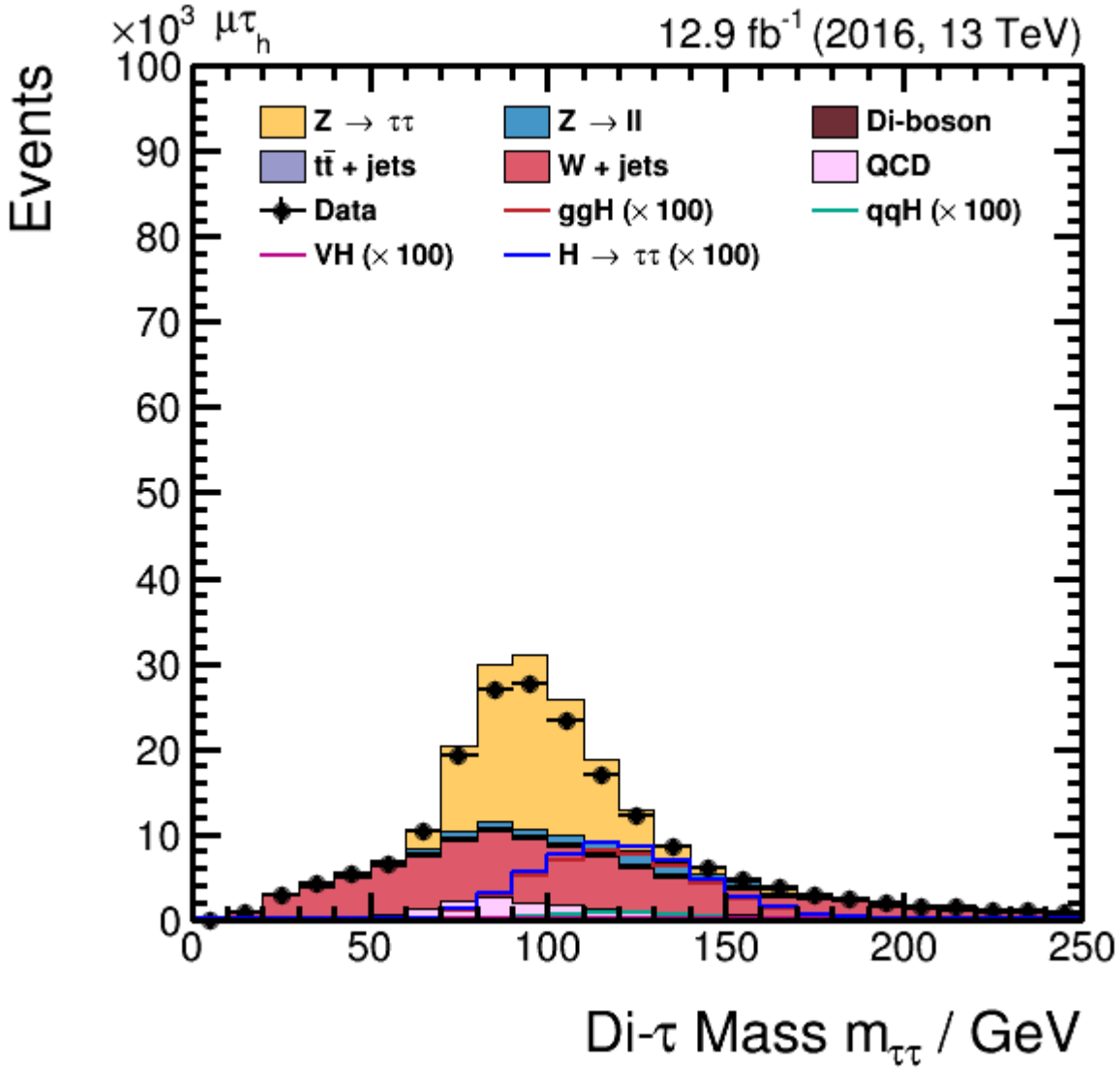
Selection steps

- inclusive
- opposite charge
- muon isolation
- tau isolation



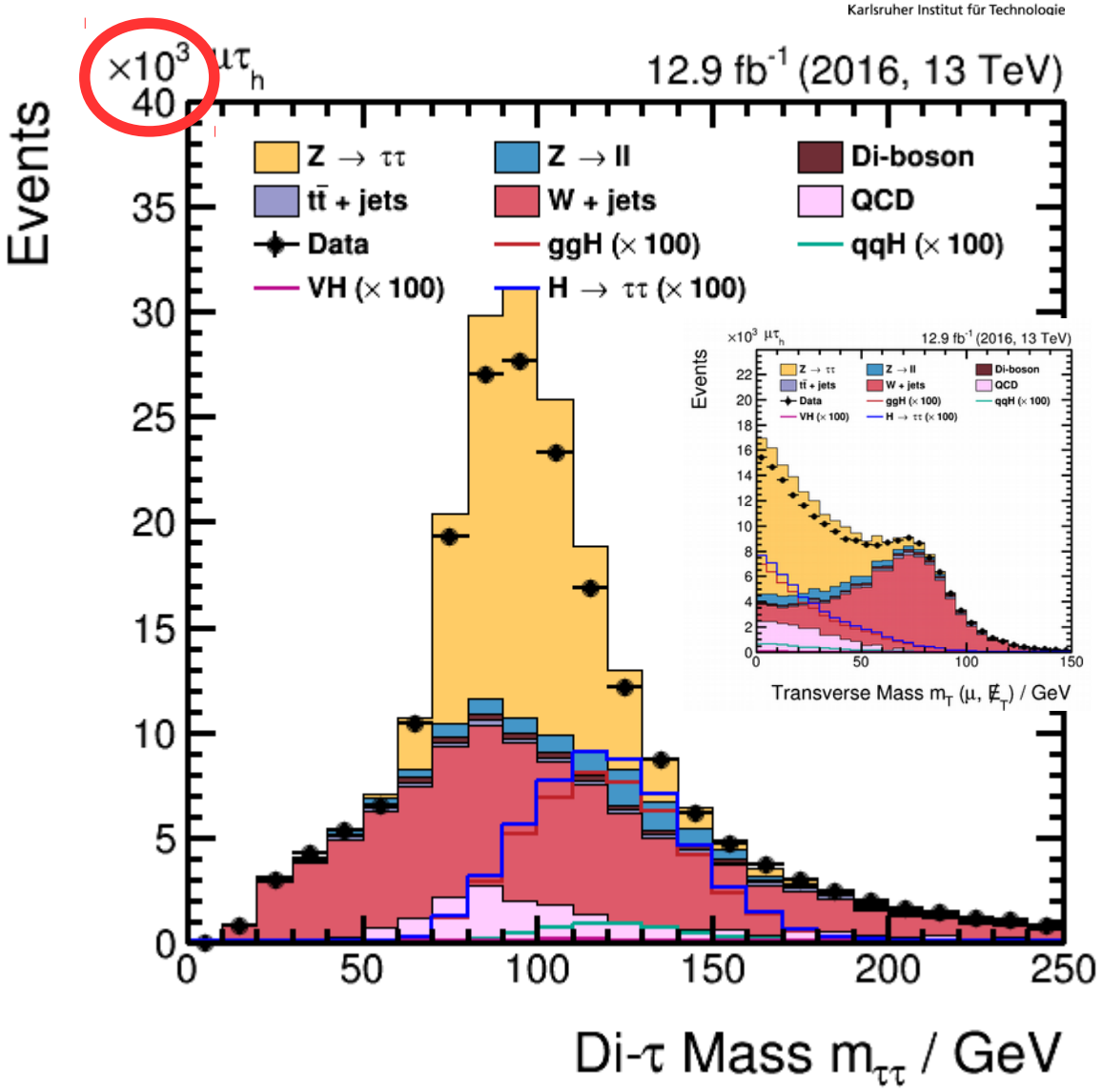
Selection steps

- inclusive
- opposite charge
- muon isolation
- tau isolation
- b-tag veto



Selection steps

- inclusive
- opposite charge
- muon isolation
- tau isolation
- b-tag veto
- transverse mass



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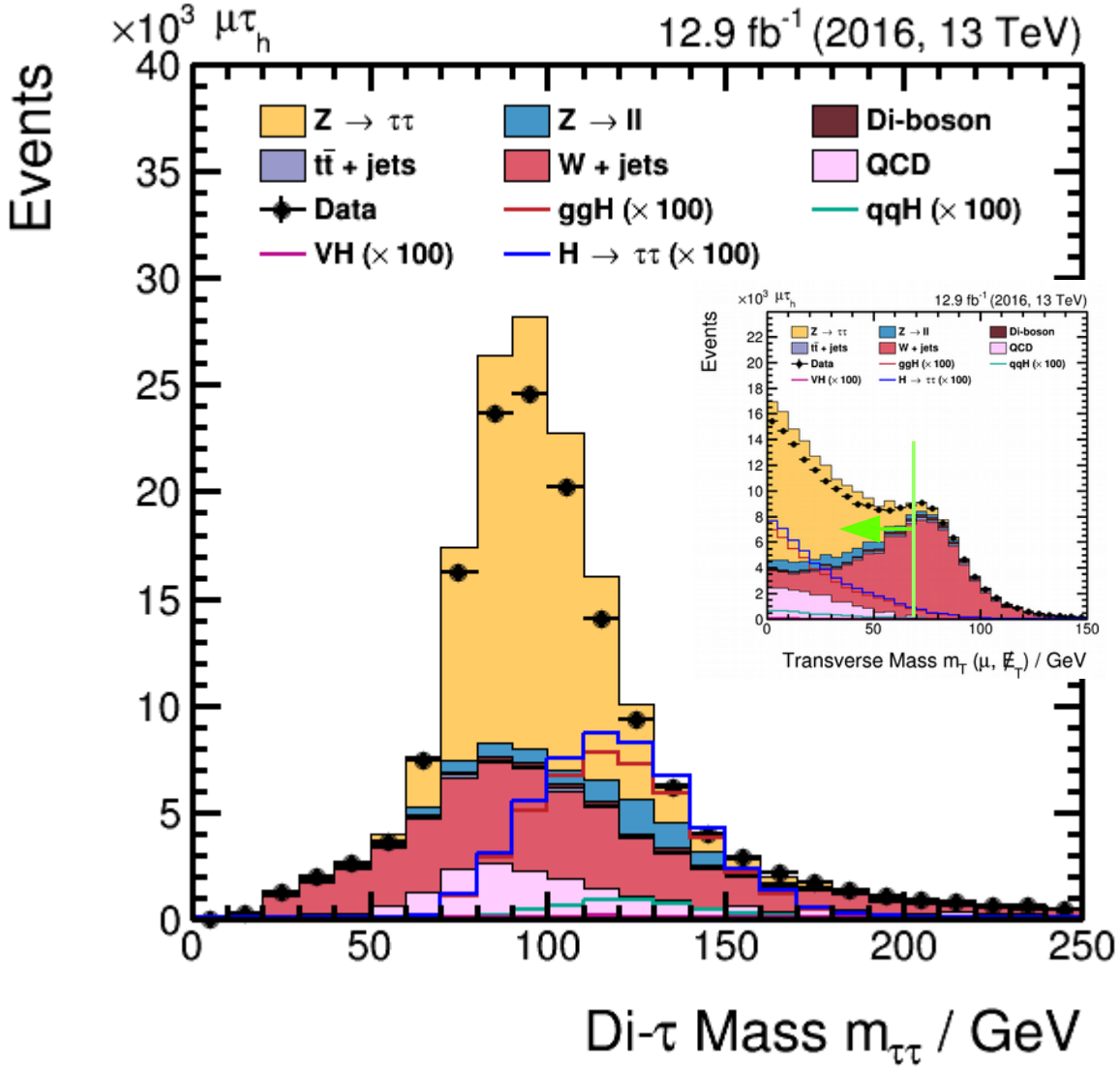

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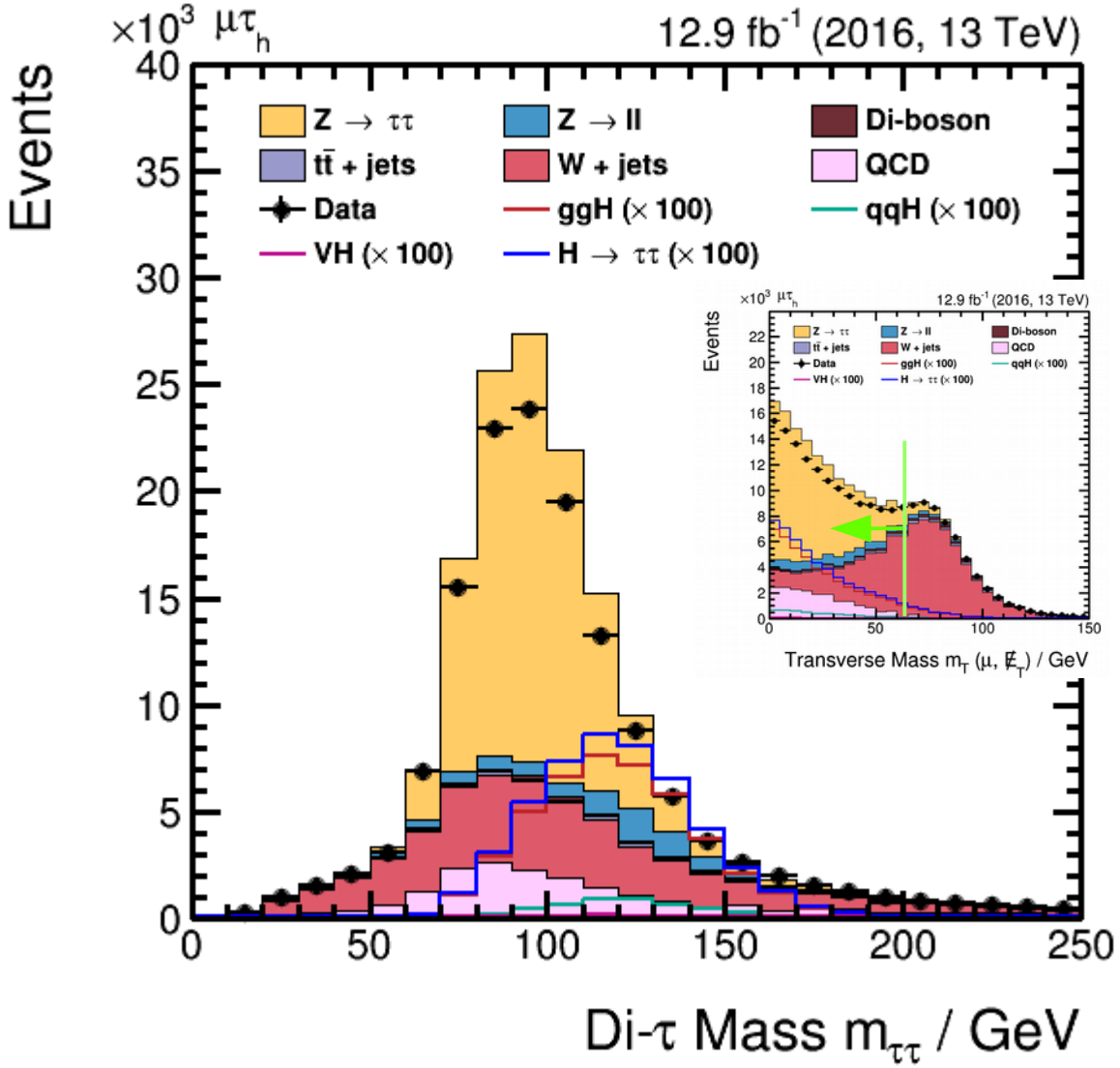

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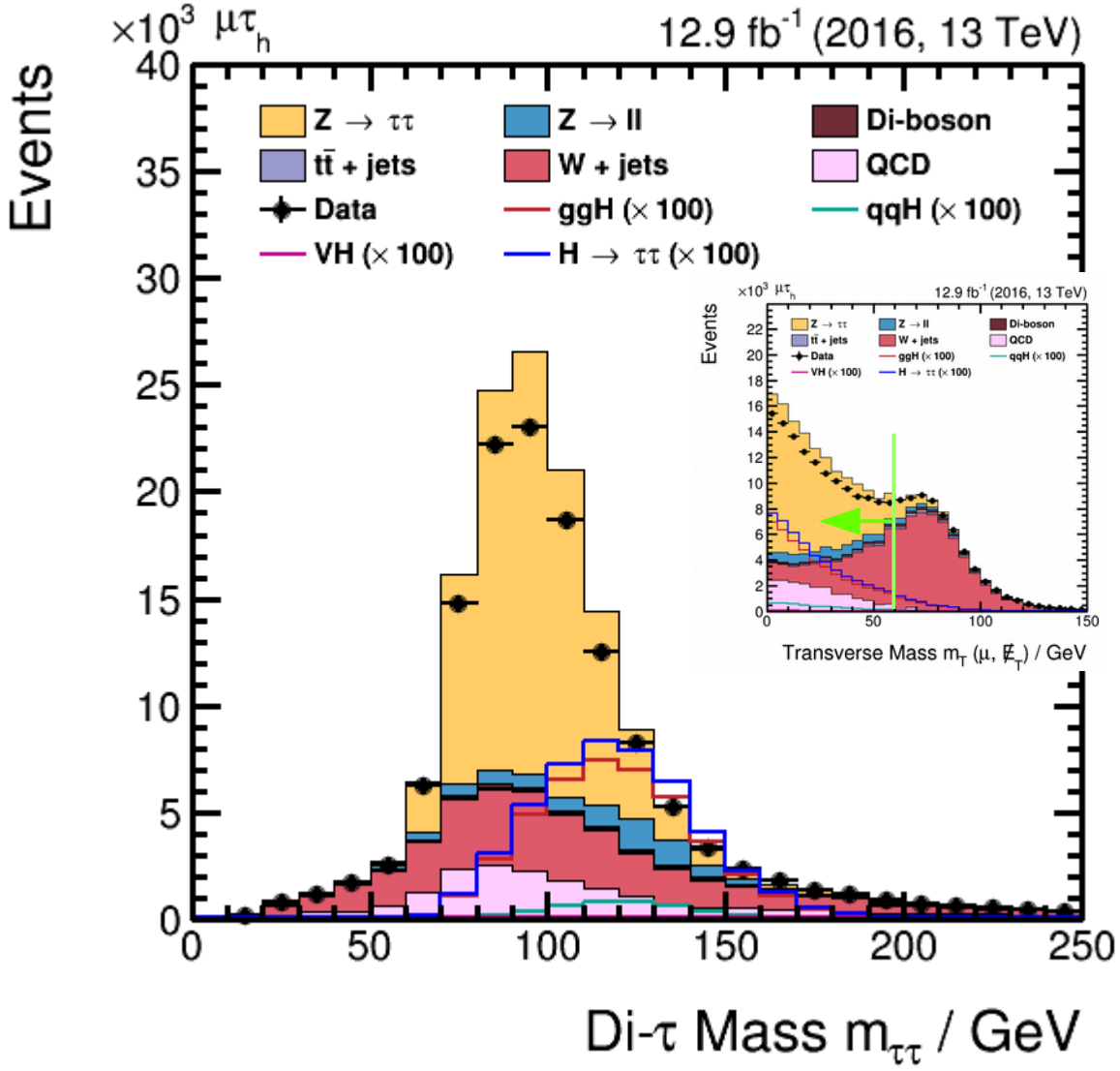

Selection steps

- inclusive
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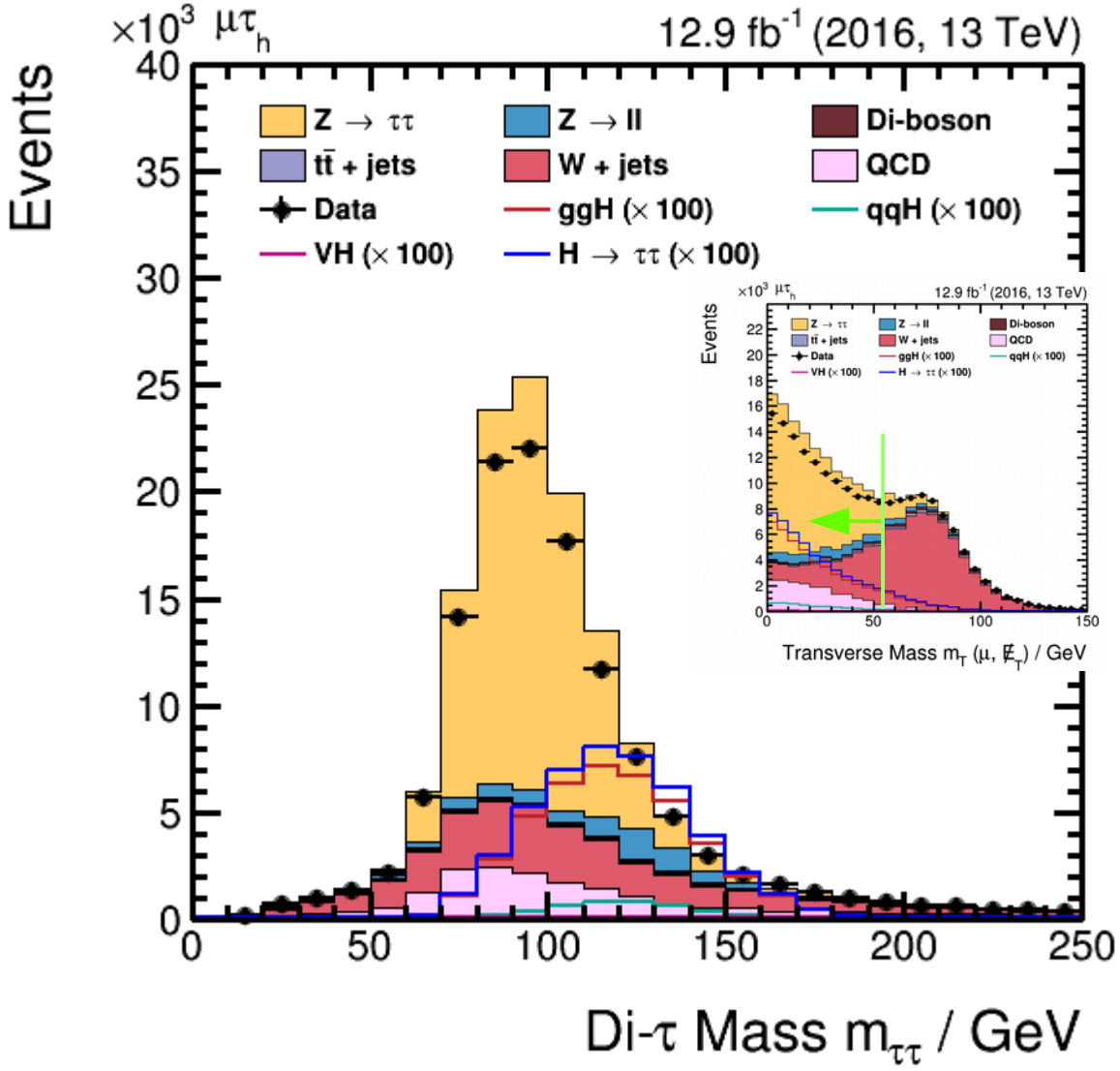
- transverse mass



Selection steps

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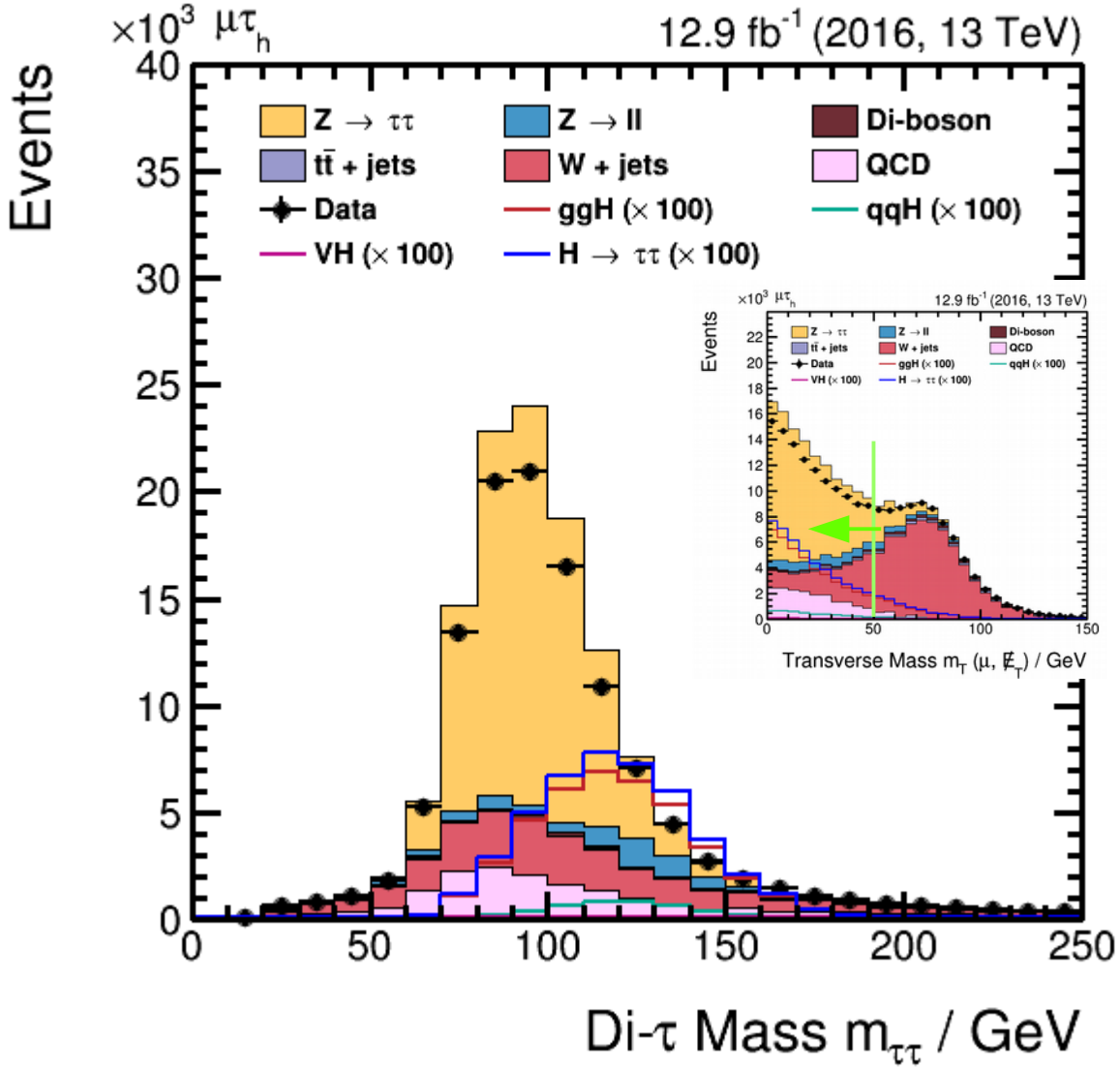

Selection steps

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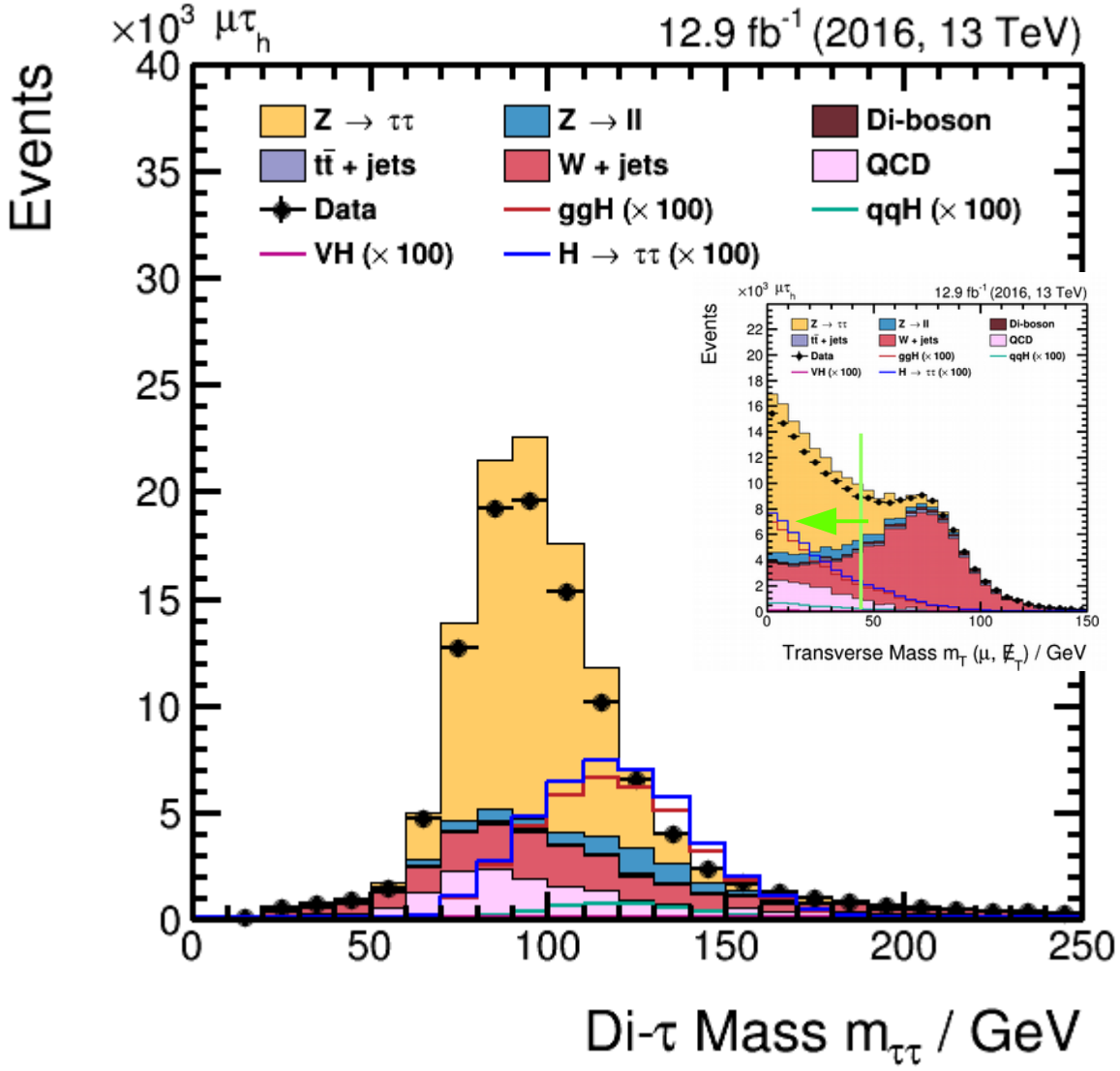

Selection steps

- inclusive
- opposite charge
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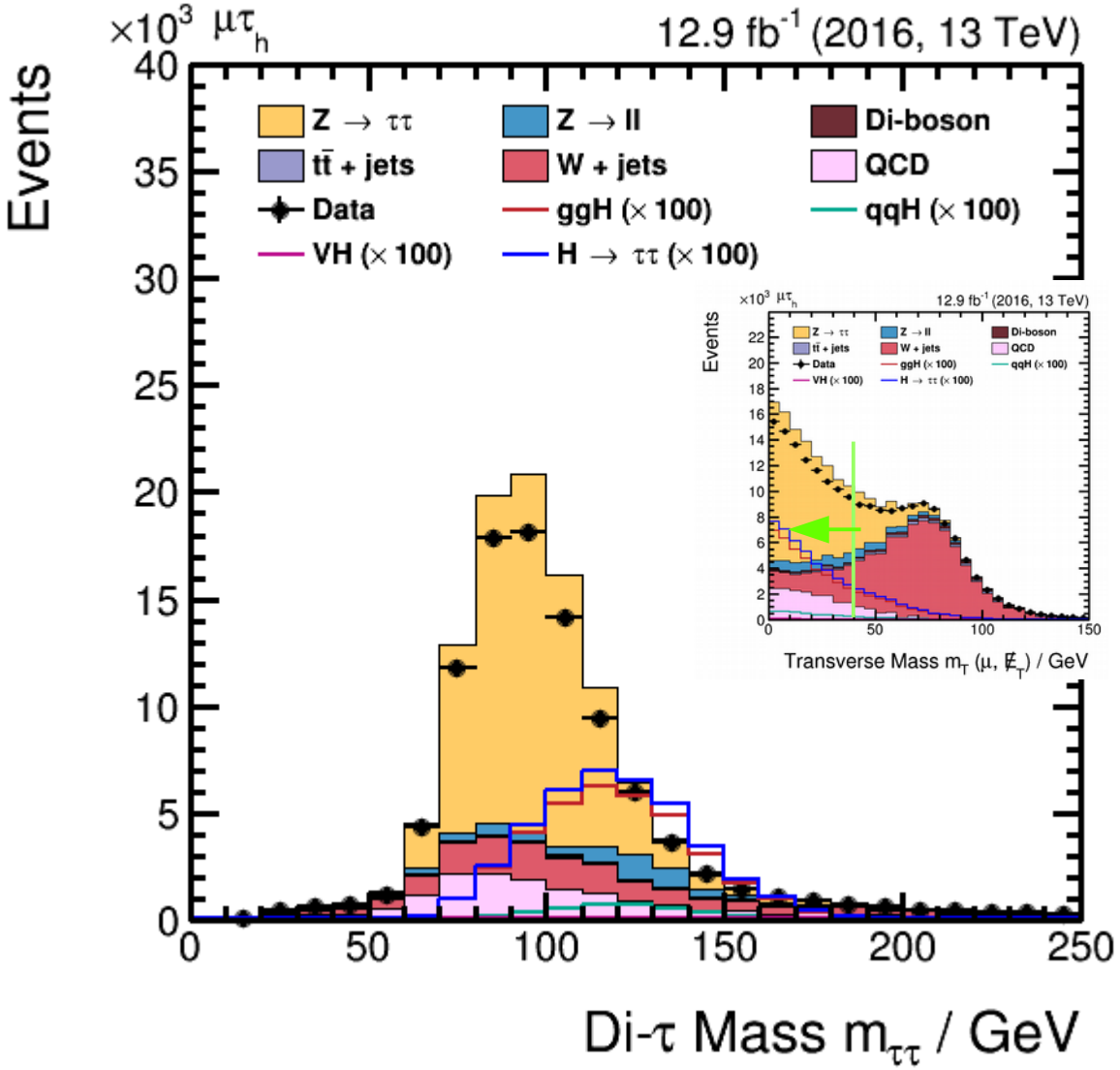
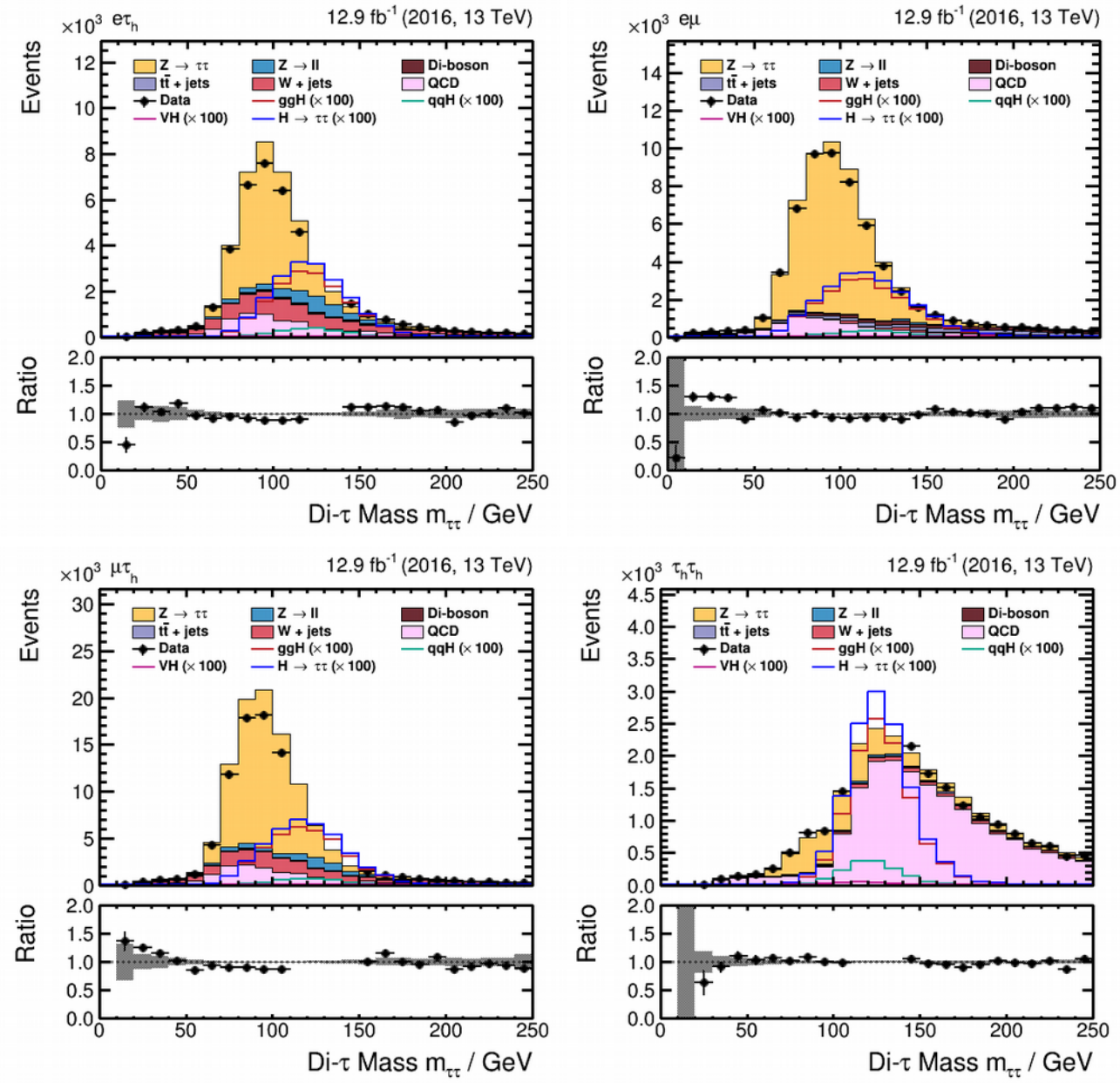
- transverse mass

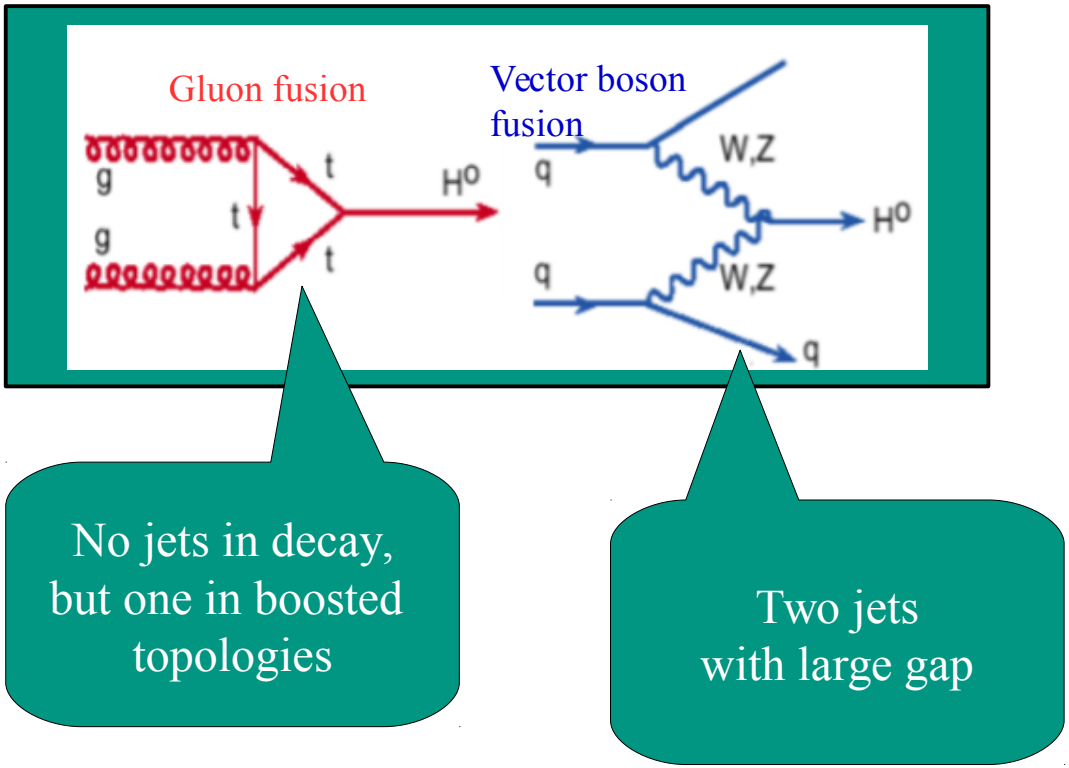


Final selection in all four decay channels

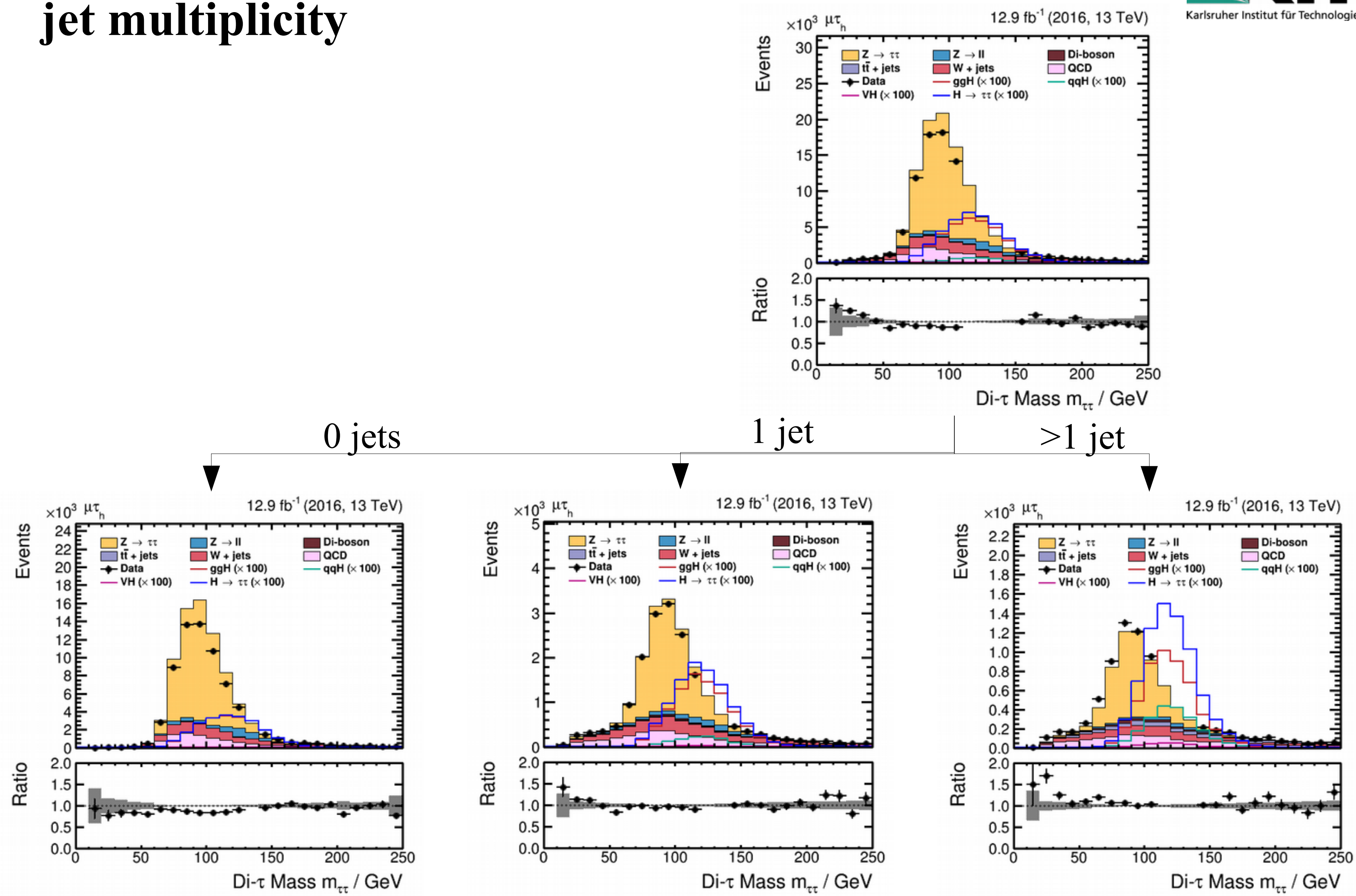


bins with significant signal expectation blinded

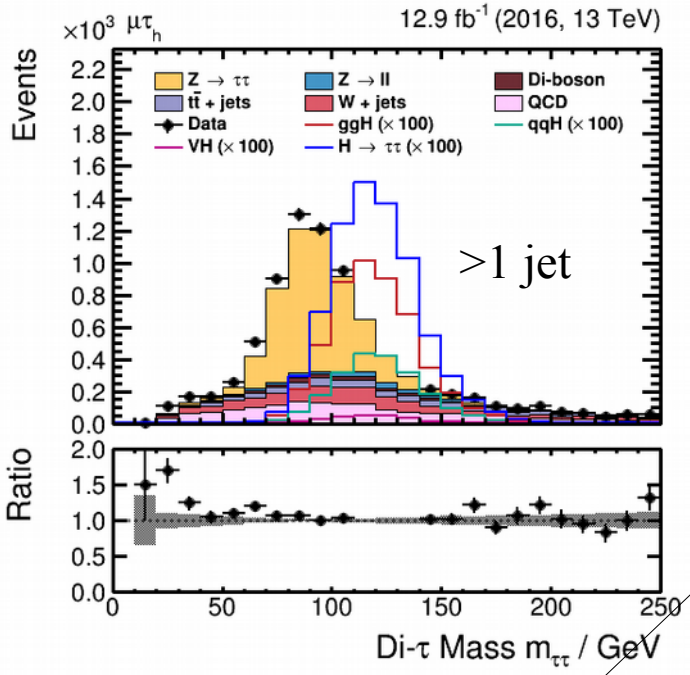
Event categorization

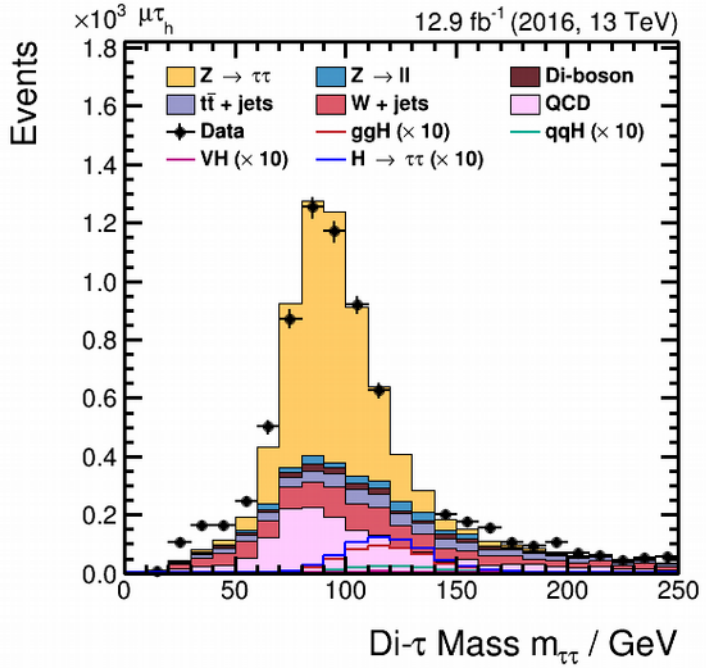


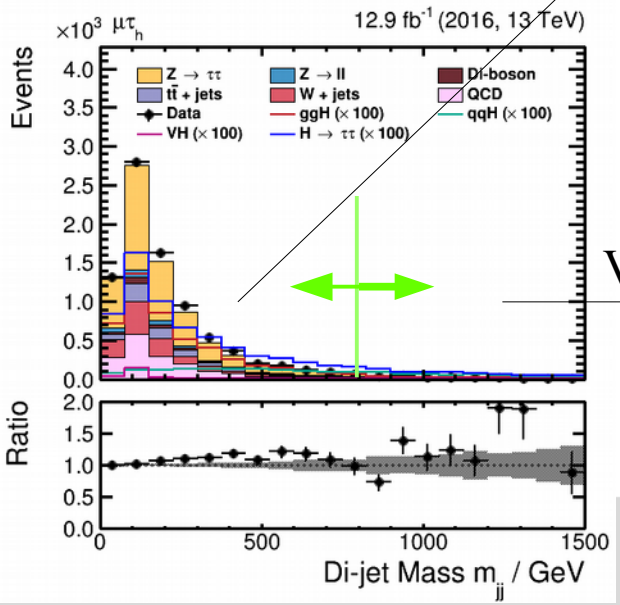
Categorization in terms of jet multiplicity



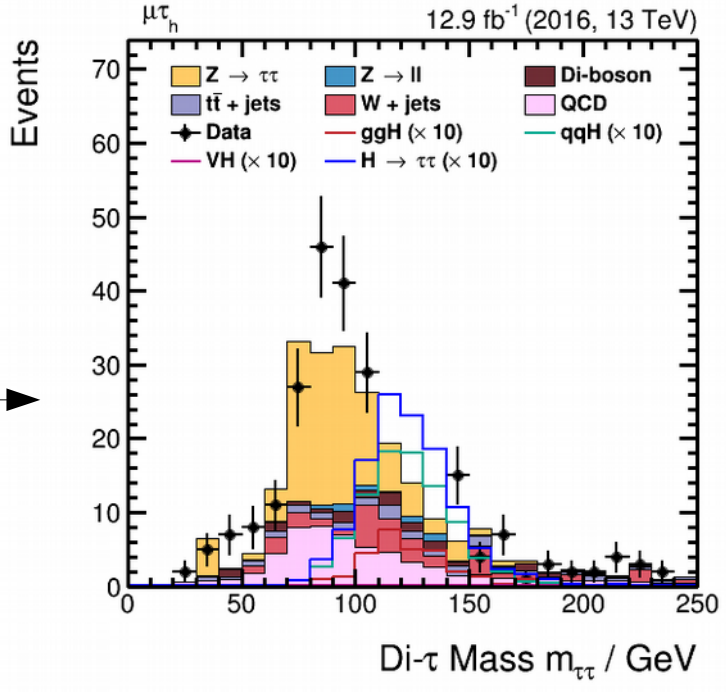
Further signal extraction







VBF-enriched region



Expected Significances with $12.9\,fb^{-1}$

Jet binned combined: 1.8	Channel	0 jets	1 jet	> 1jet
	$\mu\,\tau_{had}$	0.37	0.48	0.72
	$e\,\tau_{had}$	0.17	0.30	0.48
	$\tau_{had}\,\tau_{had}$	0.40	0.46	0.86
	$e\,\mu$	0.32	0.37	0.41

Categorized combined: 3.3	Channel	0 jets	1jet low	1 jet high	> 1jet	VBF
	$\mu\,\tau_{had}$	0.37	0.64	1.31	0.60	0.97
	$e\,\tau_{had}$	0.17	0.40	0.99	0.40	0.71
	$\tau_{had}\,\tau_{had}$	0.40	0.63	1.7	0.70	0.94
	$e\,\mu$	0.32	0.44	0.55	0.32	0.65

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Thank you for your attention!