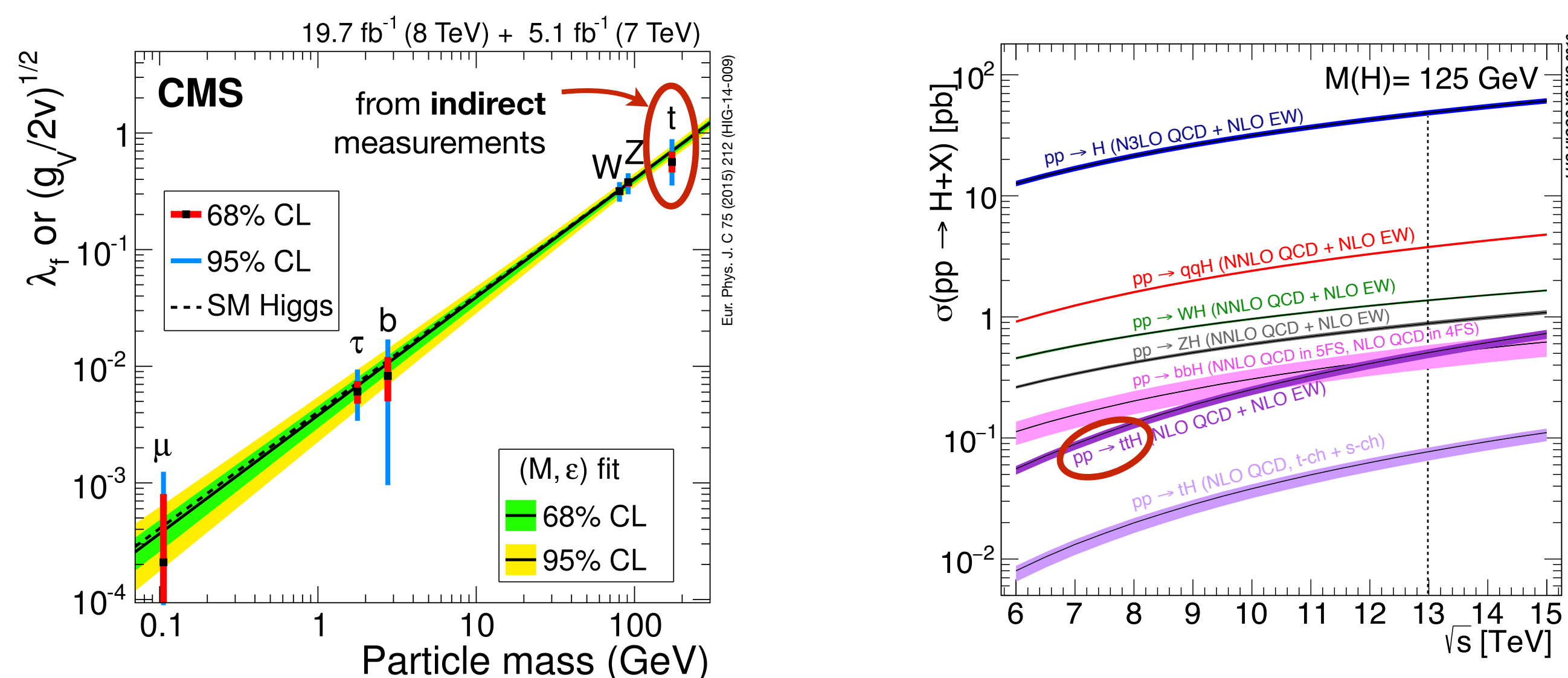


$t\bar{t}H$ in the Standard Model

Direct measurement of $t\bar{t}H$ cross section offers unique access to Yukawa coupling to decisively probe the Standard Model

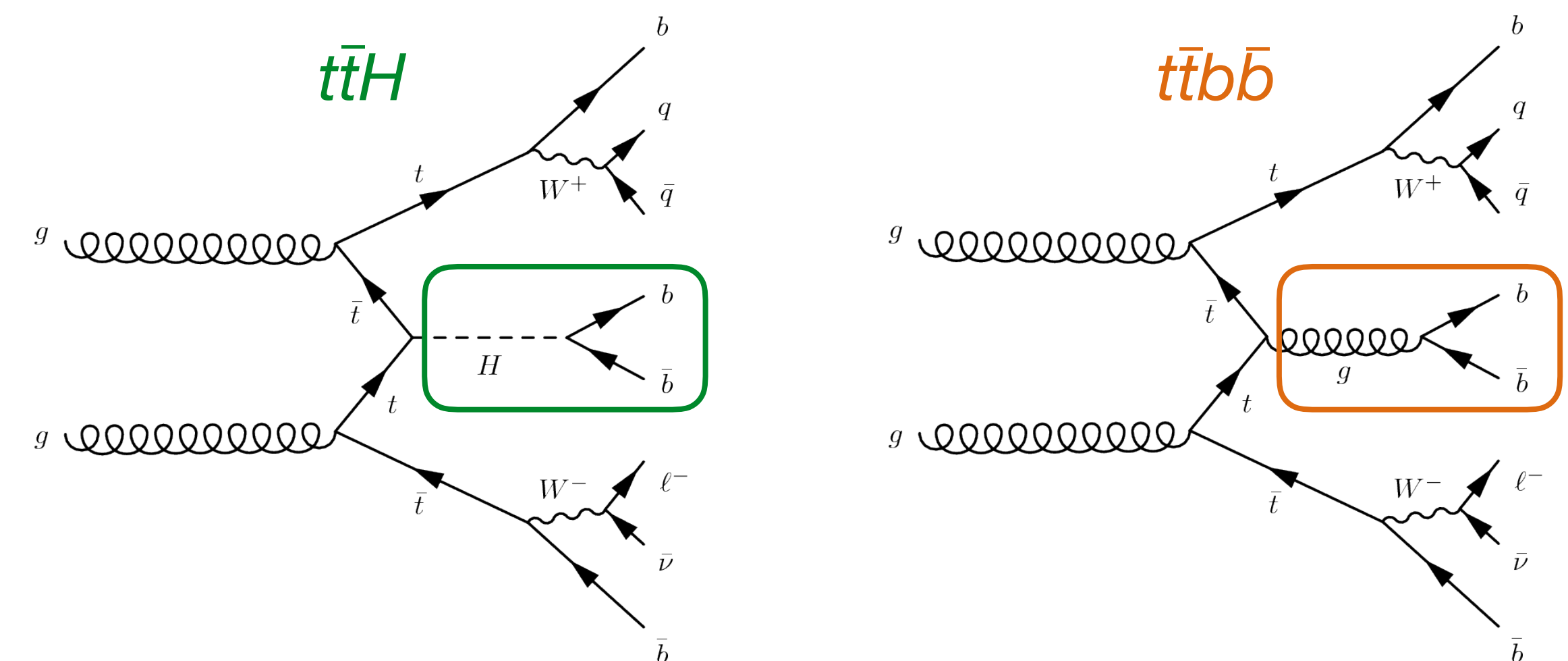
$$\mathcal{L}_{\text{Yukawa}} = - \sum_f \lambda_f \frac{\nu}{\sqrt{2}} \bar{\psi}_f \psi_f + \lambda_f \frac{1}{\sqrt{2}} \bar{\psi}_f \psi_f H$$



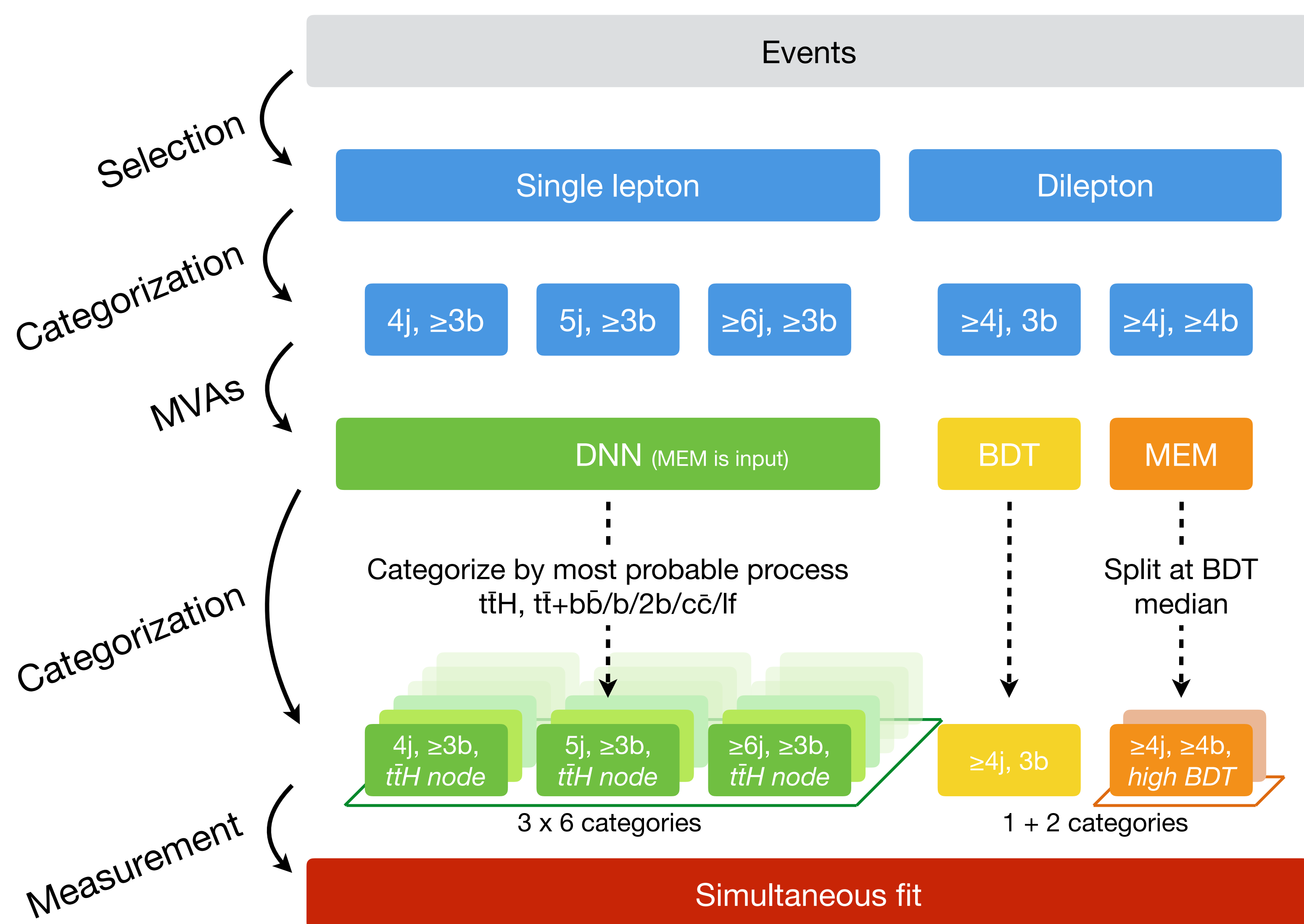
→ Challenging analyses require sophisticated methods

Analysis Challenges

- $t\bar{t}H$ is **very rare** compared to $t\bar{t}$ (main background):
 $\sigma_{t\bar{t}H} = 0.5071 \text{ pb}$ vs. $\sigma_{t\bar{t}} = 831.76 \text{ pb}$ ($\sqrt{s} = 13 \text{ TeV}$, $m_H = 125 \text{ GeV}$)
- Irreducible** backgrounds:
(e.g.) $t\bar{t}b\bar{b}$ has same final state and event topology
- Uncertain **background modeling**:
 $\Delta \sigma_{t\bar{t}b\bar{b}} \sim 50\% \rightarrow \Delta \sigma_{t\bar{t}b\bar{b}} \cong 7 \times \sigma_{t\bar{t}H}$



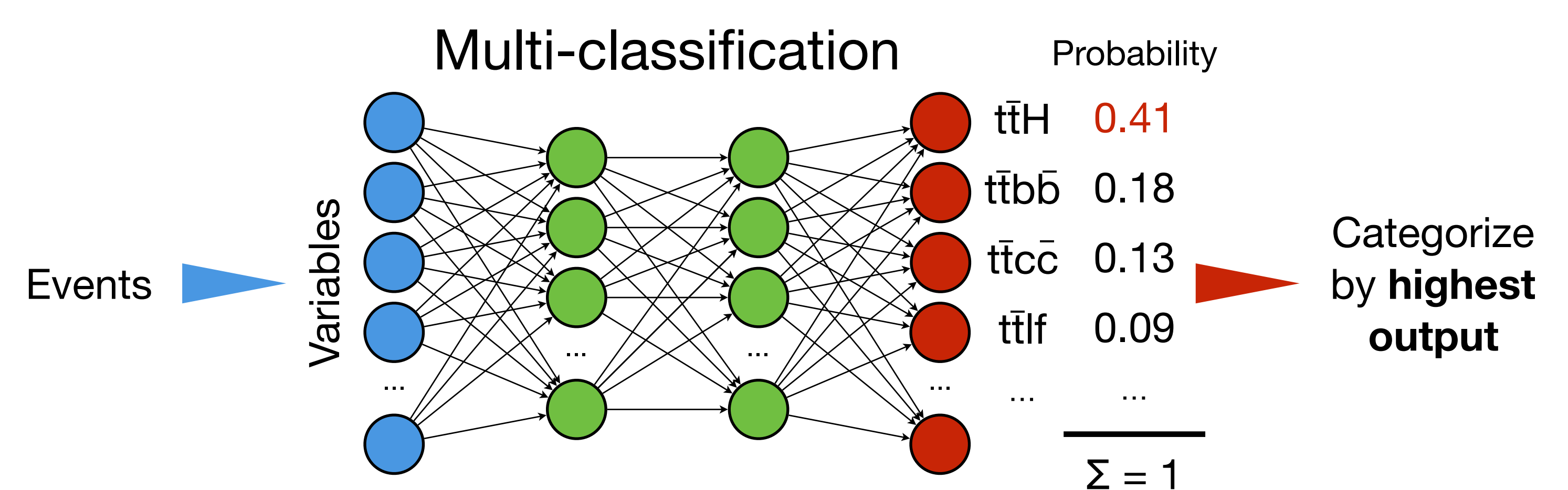
Analysis Flow



Event Categorization with Deep Neural Networks

Precision of categorization scheme using **jets & b-tags** degrades with **high b-tag multiplicity**

→ Use **DNNs** to categorize using jets & **most probable process**



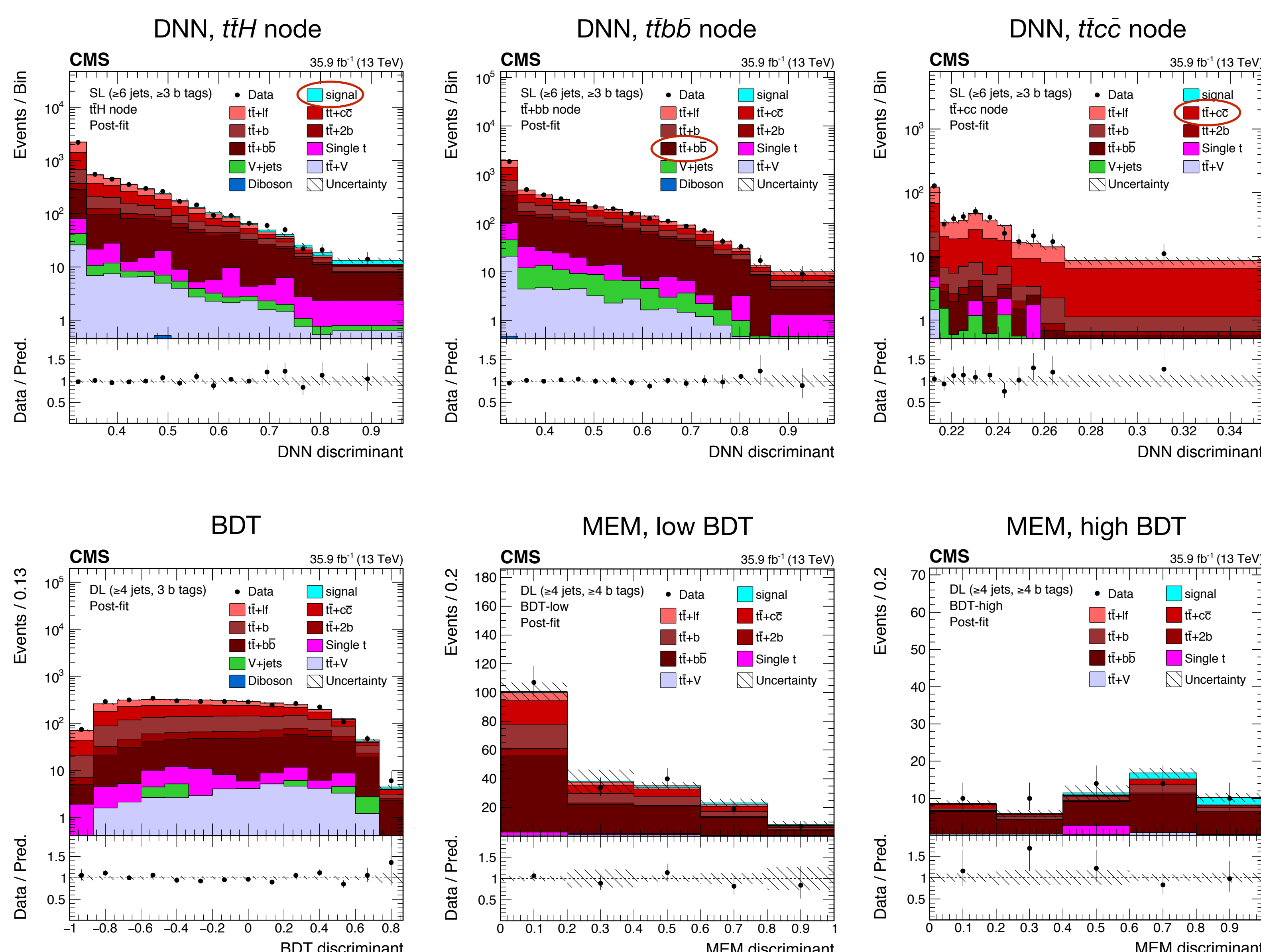
Multi-class approach generates **enriched categories** for **signal** and **each background**

→ Backgrounds constrained separately in fitting procedure

→ Improves extraction of signal strength parameter

Discriminants

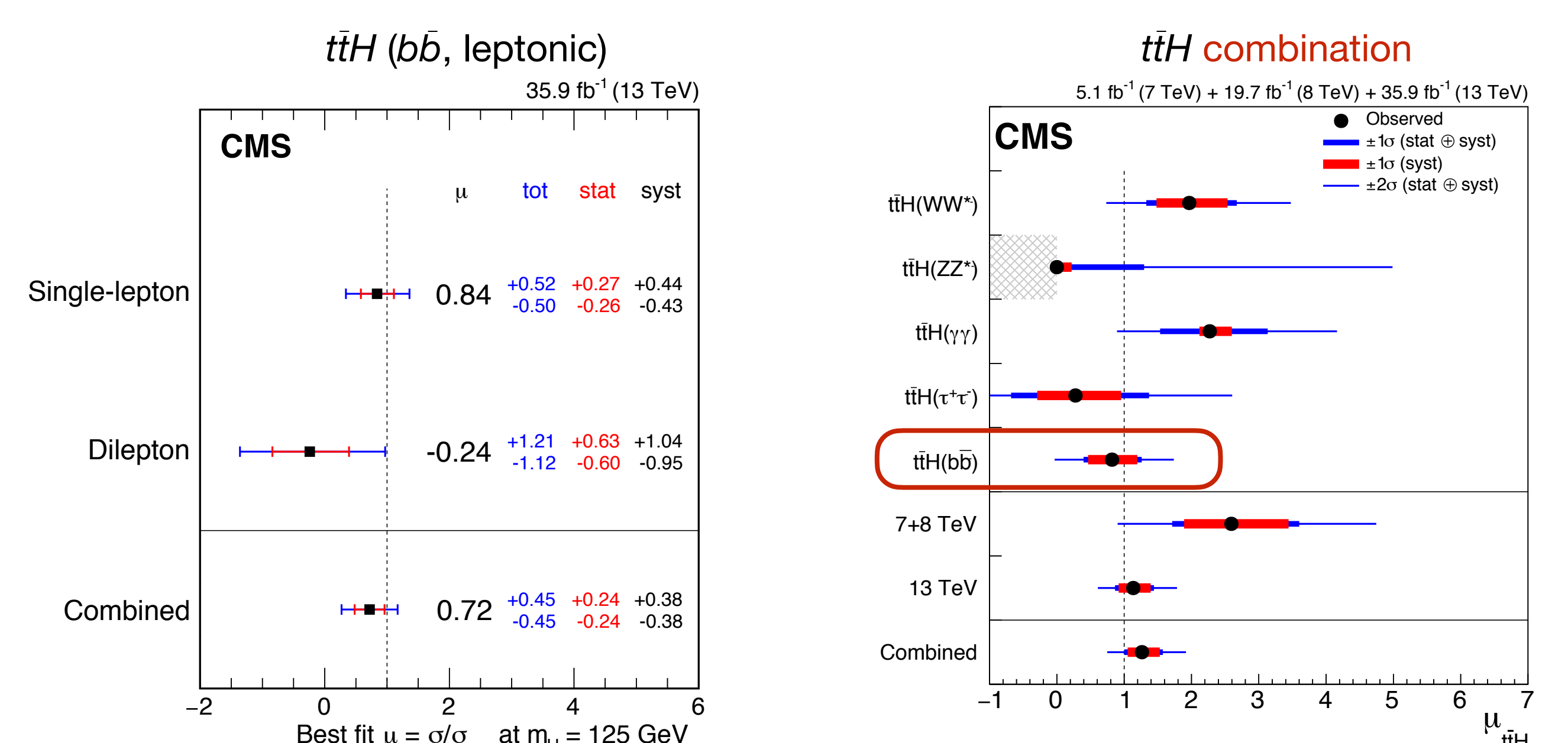
Discriminants selected by highest expected significance



Results

Channel	95% CL upper limit		Best-fit μ
	observed	expected	
Single-lepton	1.75	$1.03^{+0.44}_{-0.29}$	$0.84^{+0.52}_{-0.50} \left({}^{+0.27}_{-0.26} \right) \left({}^{+0.44}_{-0.43} \right)$
Dilepton	2.34	$2.48^{+1.17}_{-0.76}$	$-0.24^{+1.21}_{-1.12} \left({}^{+0.63}_{-0.60} \right) \left({}^{+1.04}_{-0.95} \right)$
Combined	1.51	$0.92^{+0.39}_{-0.26}$	$0.72^{+0.45}_{-0.45} \left({}^{+0.24}_{-0.24} \right) \left({}^{+0.38}_{-0.38} \right)$

$t\bar{t}H$ ($b\bar{b}$) analysis with MVA techniques has **significant impact on $t\bar{t}H$ observation**



Observed (expected) significance: **1.6 (2.2) σ**

arXiv:1804.03682, CMS-HIG-17-026

Observed (expected) significance: **5.2 (4.2) σ**

arXiv:1804.02610, CMS-HIG-17-035