

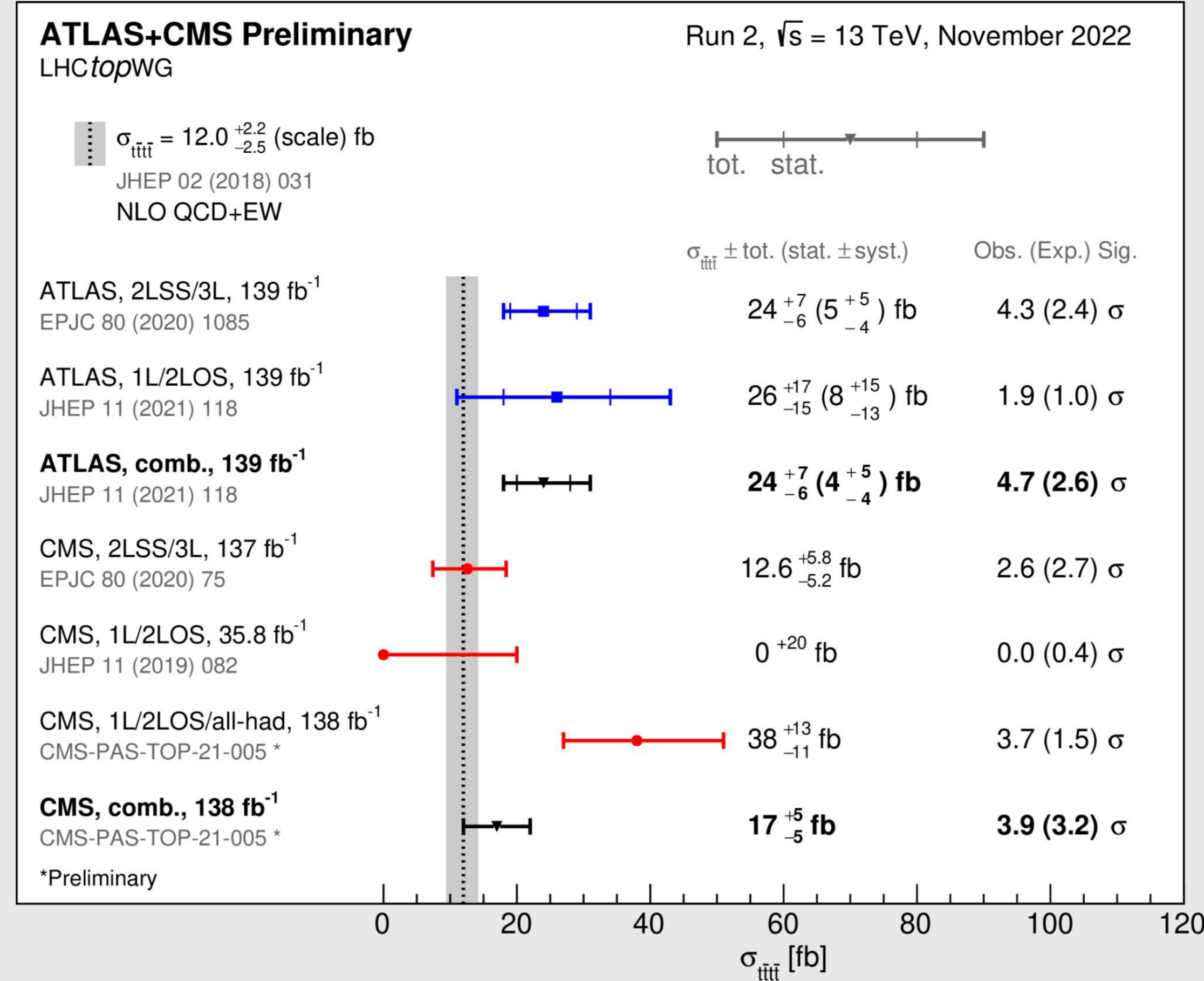
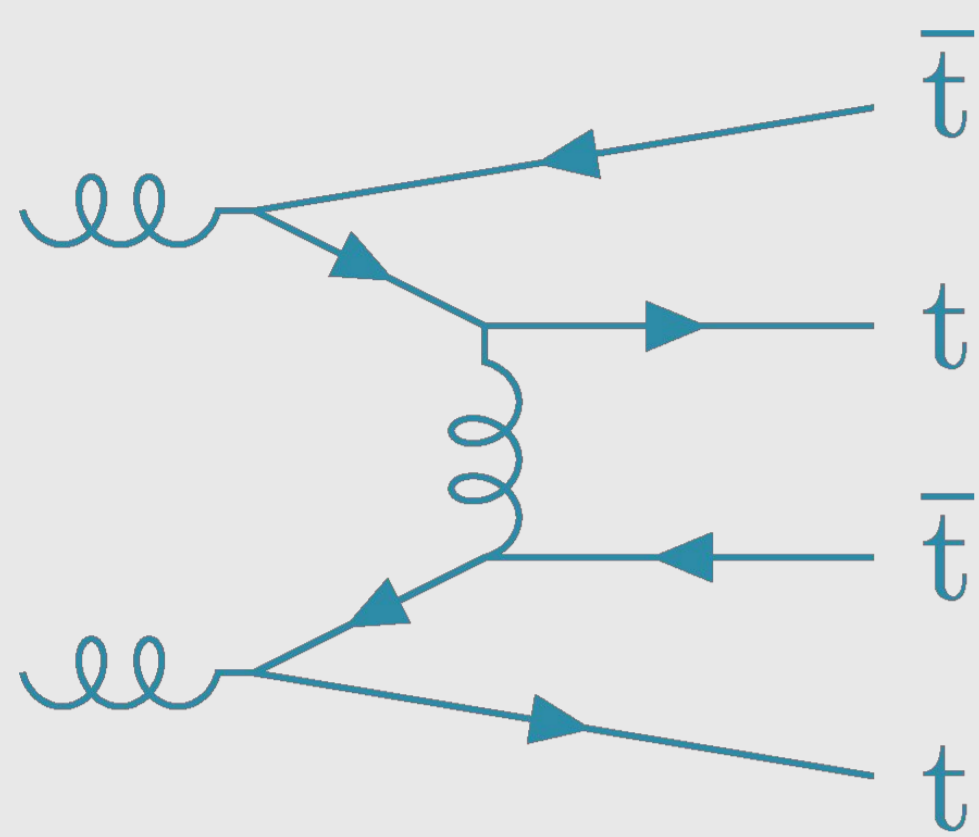
Observation of four top quark production at CMS

in the same-sign dilepton and multilepton channels in pp collisions at 13 TeV

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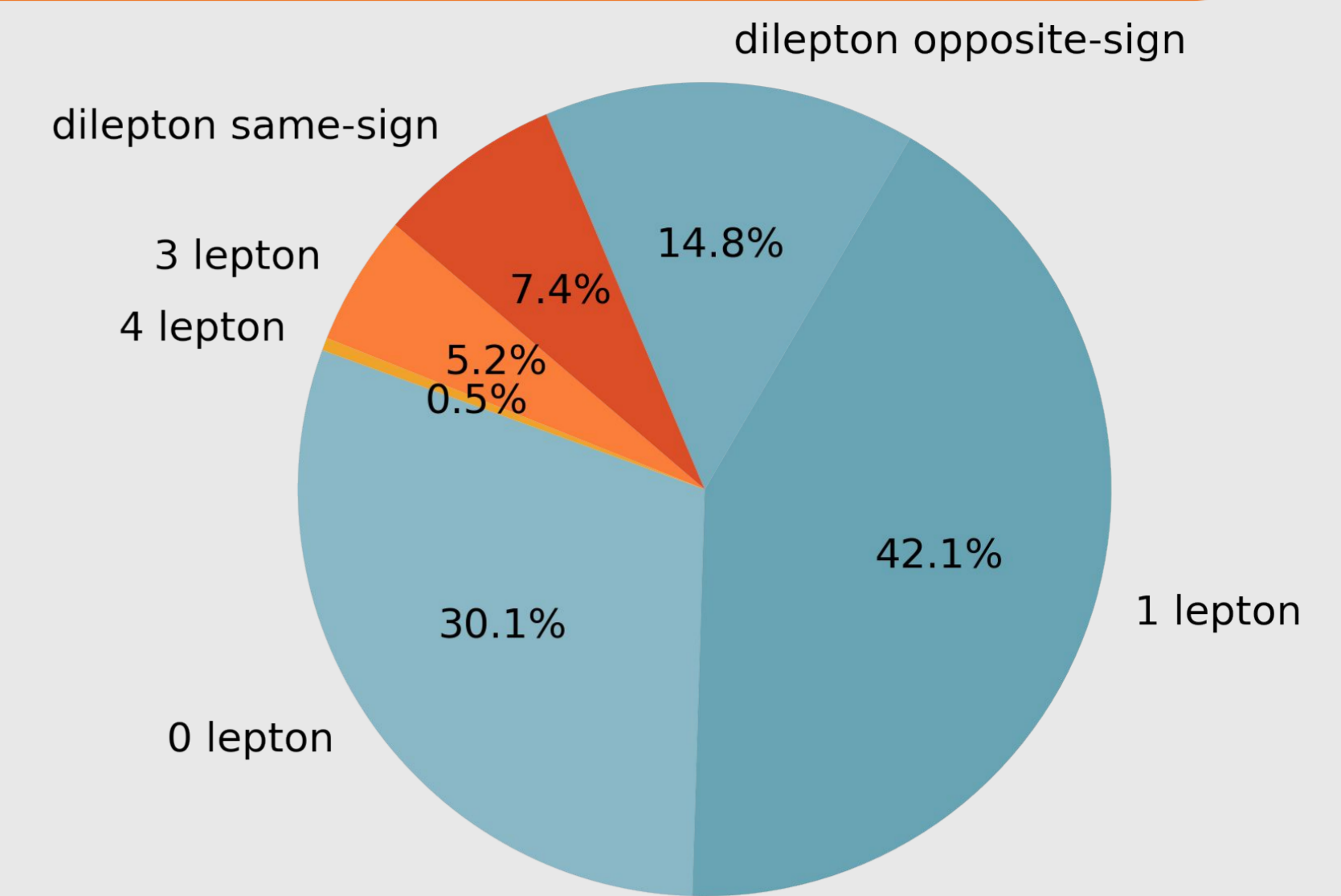
Motivation and state-of-the-art

- sensitivity to:
 - BSM physics (2HDM, SUSY, ...)
 - top quark Yukawa coupling [2]
 - various EFT operators [3]
- cross section at NLO(QCD+EW)+NLL' (13 TeV): 13.4 [+1.0, -1.8] fb [4]
- 1800 events expected in Run 2 CMS dataset
- Run 3: 18% higher cross section at 13.6 TeV



Analysis channels:

- low branching fraction but higher purity
- main background: ttX and nonprompt leptons



Other channels:

- high branching fraction but larger background
- challenging background: tt (ttbb)
- dedicated CMS analysis (ArXiv:2303.03864)

Backgrounds

tt with nonprompt or charge misidentified leptons:

- largely reduced by MVA for prompt lepton identification
- estimated using datadriven methods:
 - nonprompt: fakerate method
 - Charge misID: rate from MC, corrected in data

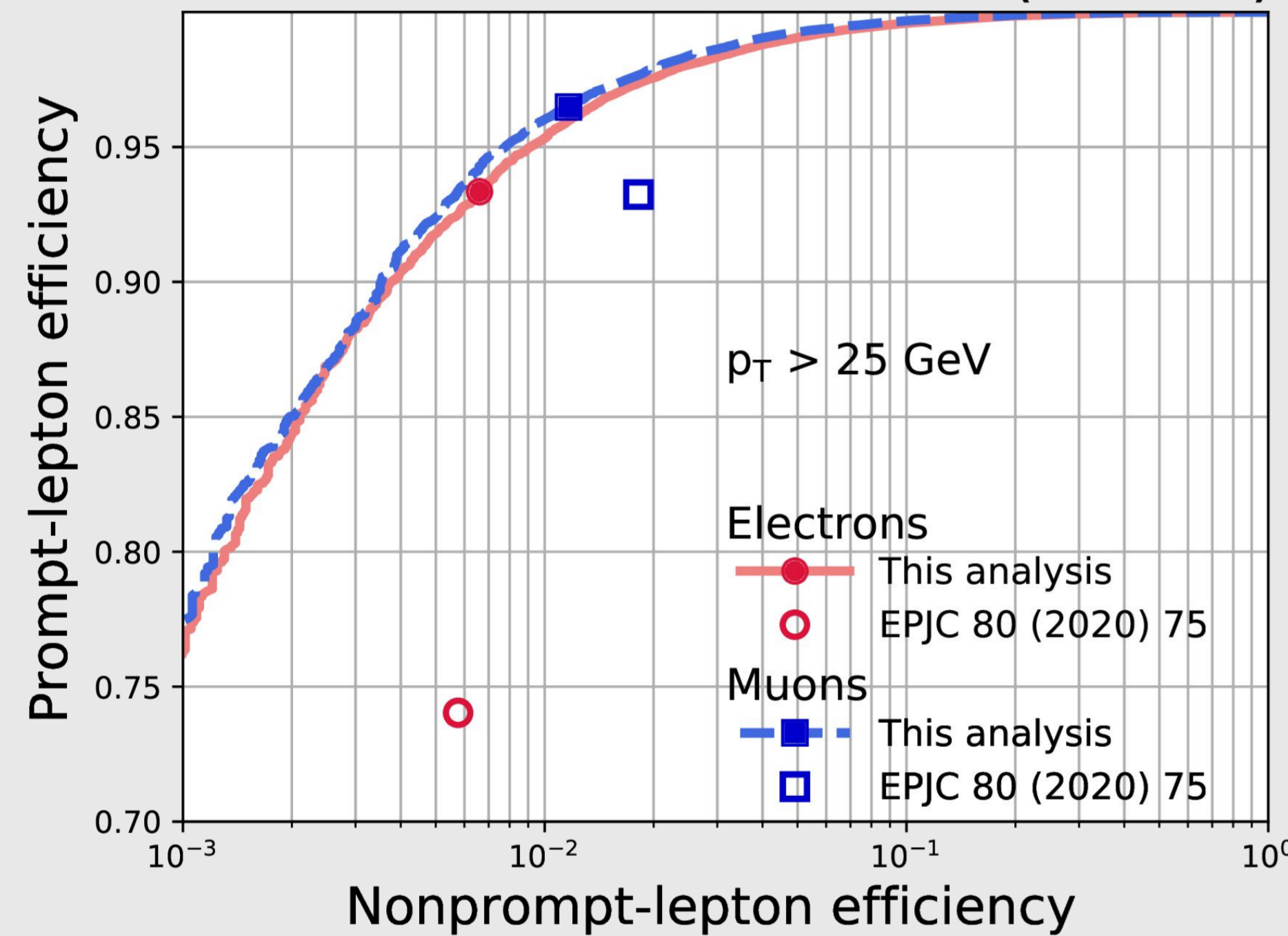
ttW/ttZ/ttH:

- predicted from MC
- modelling uncertainties on additional jets (ttW) and b-jets (all)

ttt(q/W):

- highly correlated with signal
- total cross section ~2 fb

CMS Simulation (13 TeV)

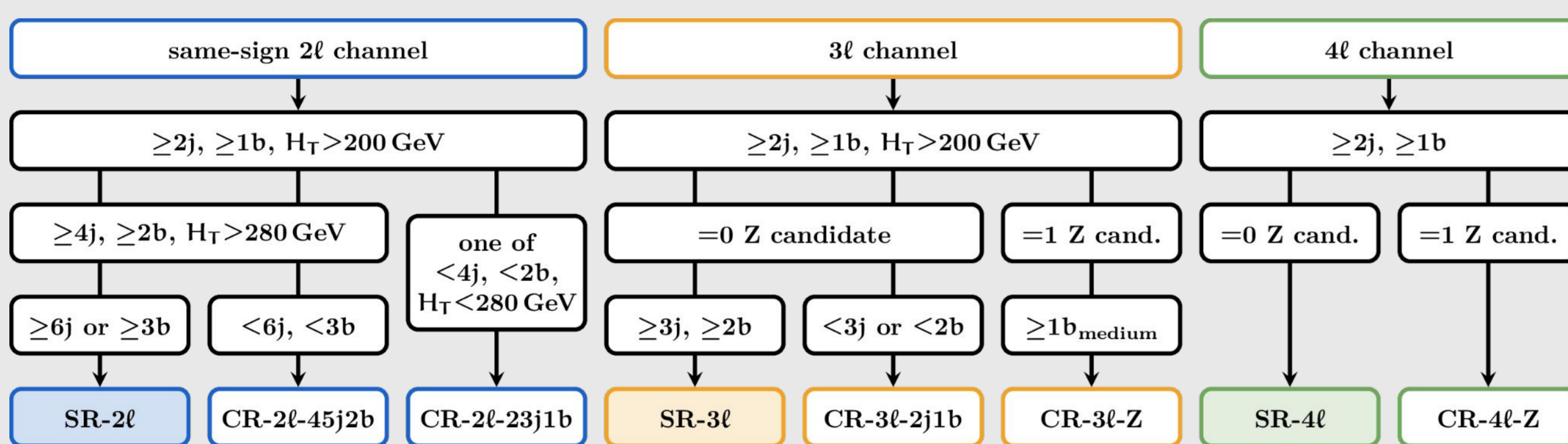


Object and event selection

- leptons: p_T > 10 GeV
- jets: p_T > 25 GeV

Signal and control regions:

- one signal region per channel
- on-Z control regions: handle on ttZ/W/Z
- control regions with lower (b) jet activity: handle on nonprompt and ttW



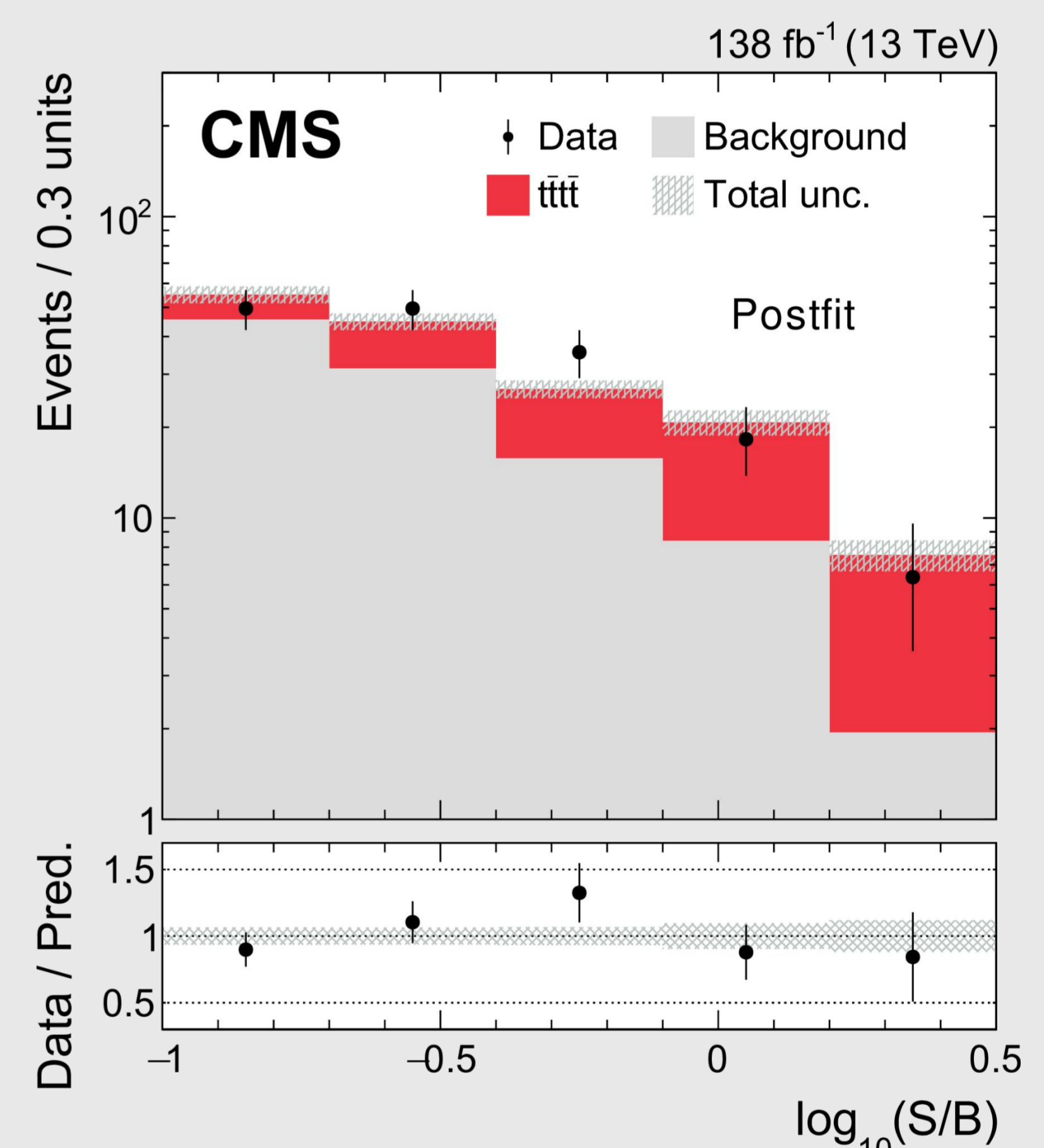
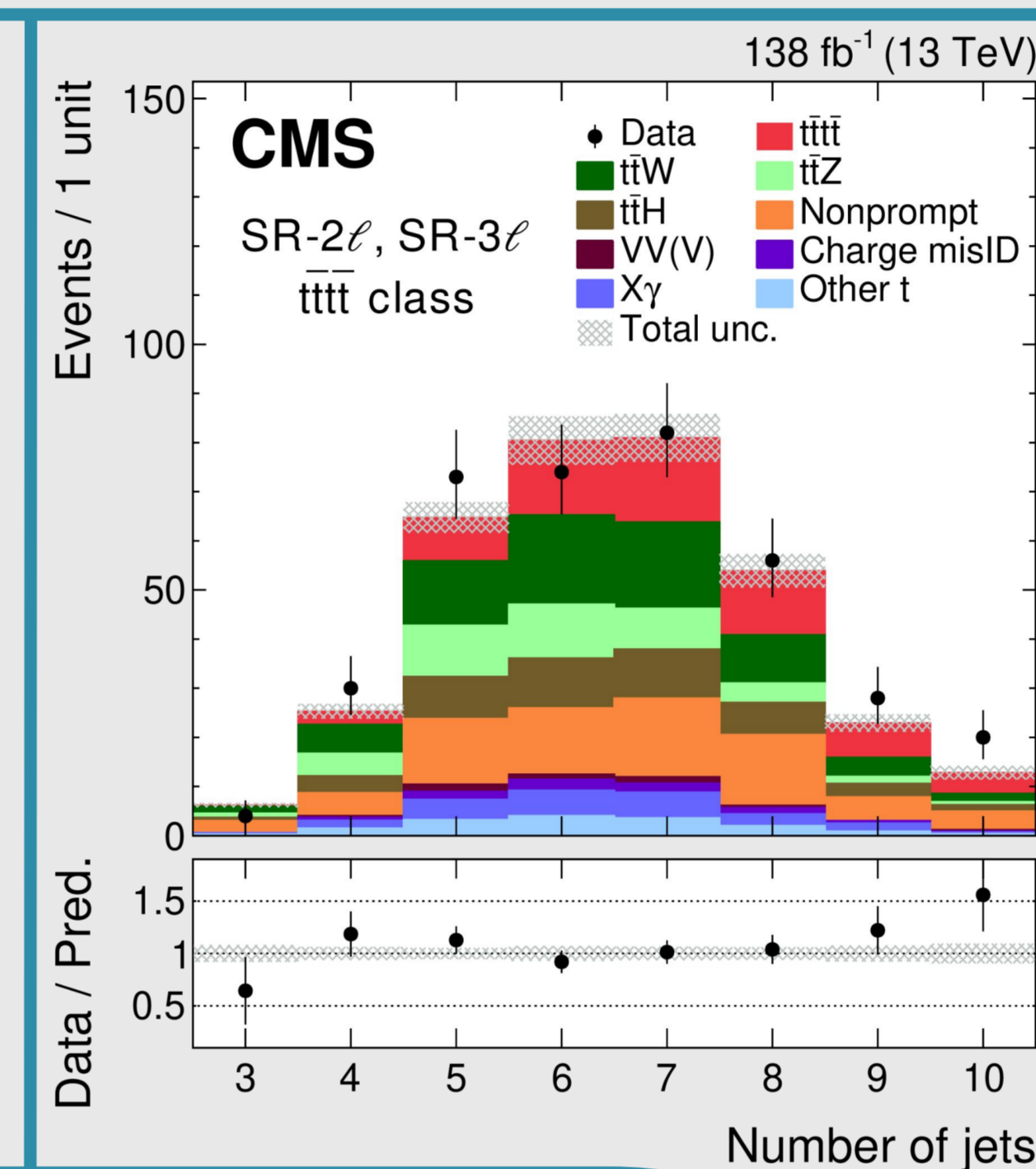
Signal regions

Events classified with a BDT:

- three classes: tt, ttX (ttW, ttZ, ttH), tttt
- multiclassification to better handle systematics and major backgrounds
- Separate BDTs for SR-2L and SR-3/4L

Dominant experimental systematics:

- b-tagging uncertainties
- jet energy variations

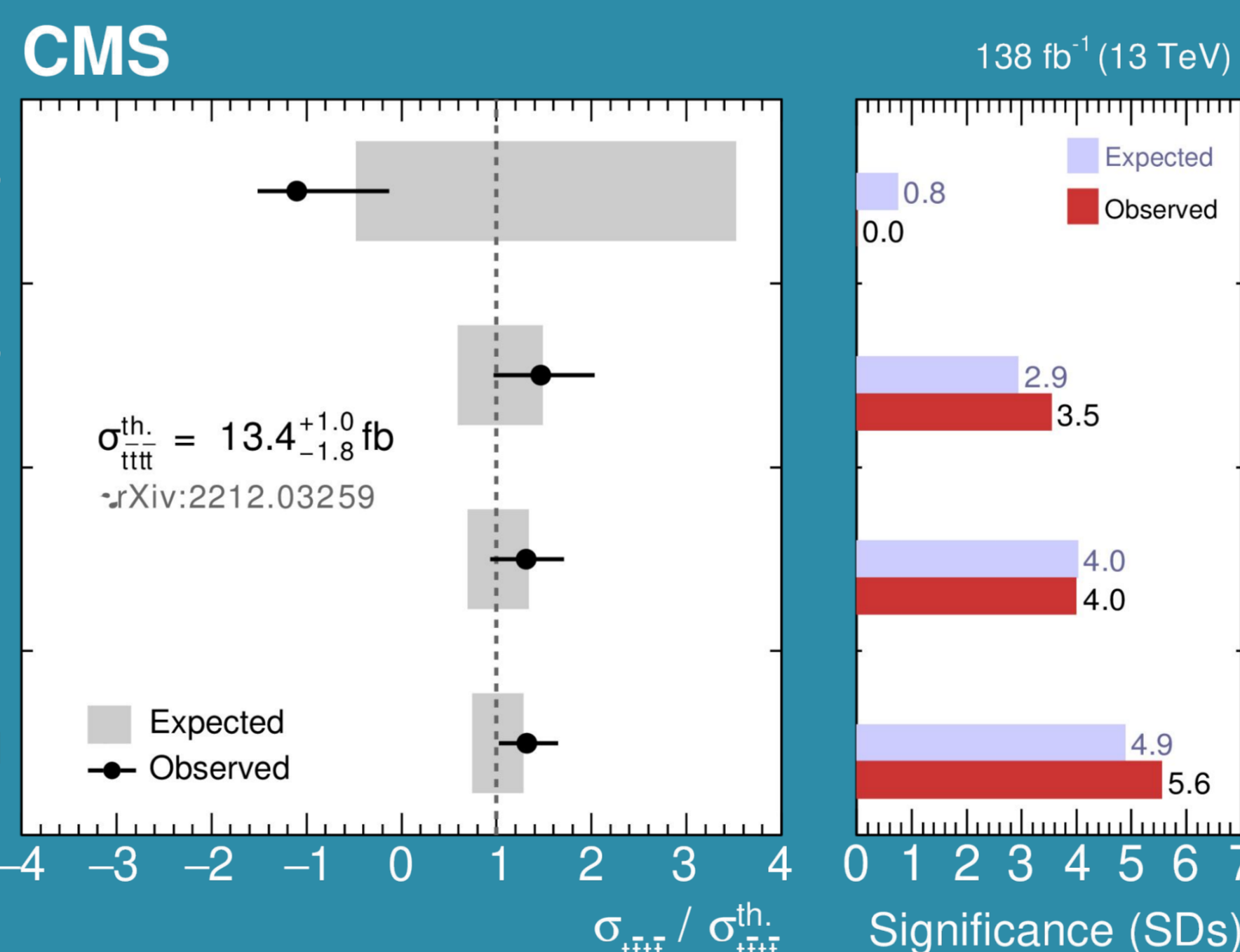


Observation!

- Significance: 5.6σ (4.9σ) observed (expected)
- σ_{tttt} = 17.7 [+3.7, -3.5] (Stat) [+2.3, -1.9] (Syst) fb

ttW and ttZ normalization free floating in fit:

- σ_{ttW} = 990 ± 58 (Stat) ± 79 (Syst) fb
- σ_{ttZ} = 945 ± 43 (Stat) ± 69 (Syst) fb



Control regions

- constrain major backgrounds
- handle on some systematics
- check for mismodeling of ttX backgrounds
- apply signal region BDTs to increase purity in ttW and nonprompt

