$t\bar{t}Z$ cross section

Towards a differential measurement with the CMS experiment

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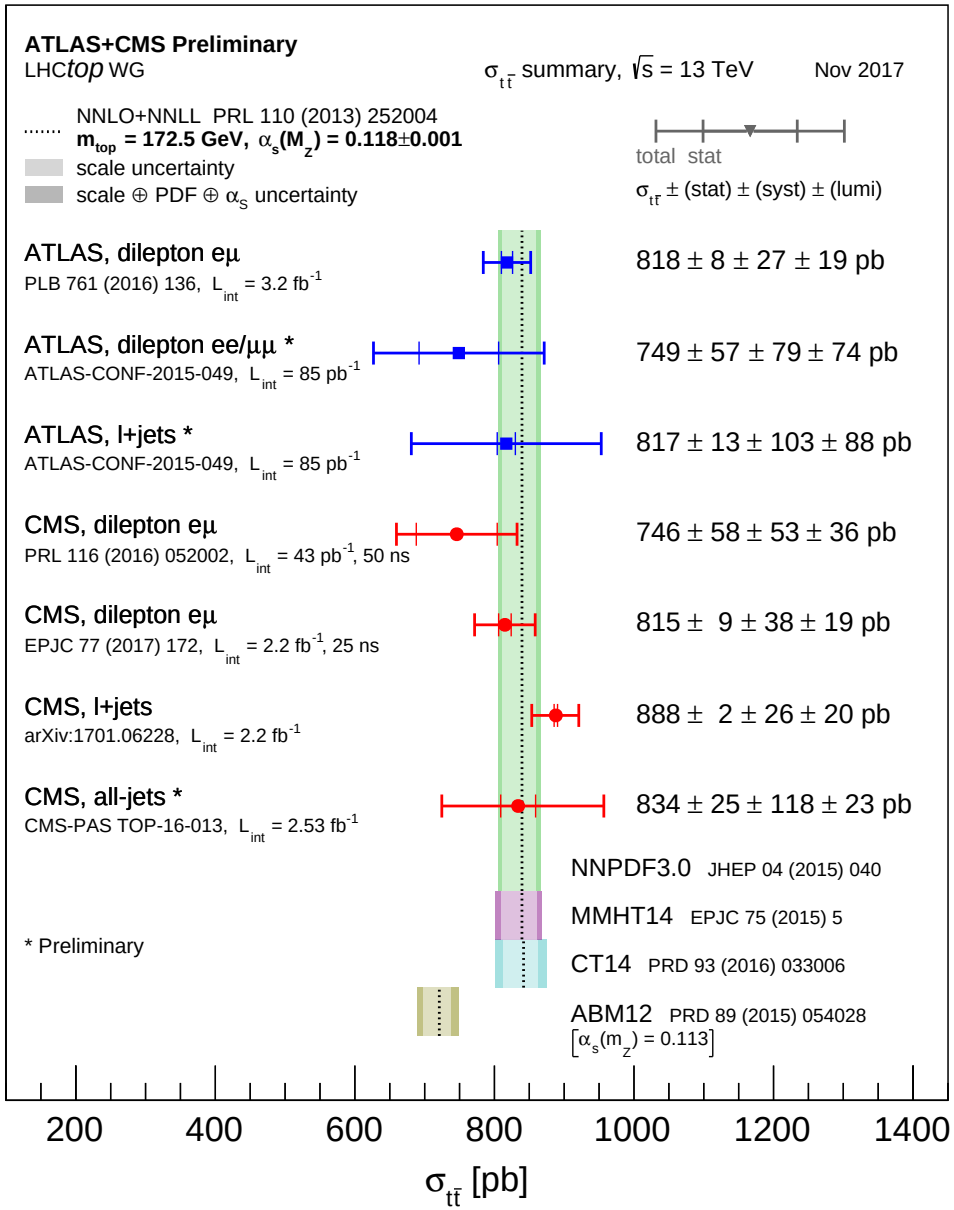
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

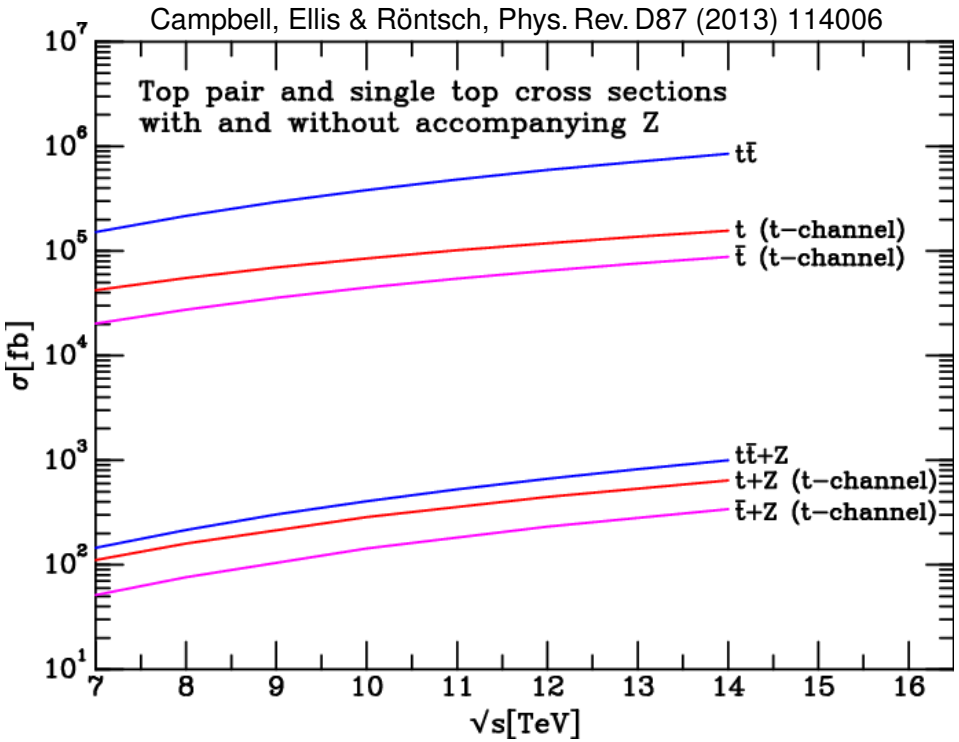
$t\bar{t}$ cross section at the LHC

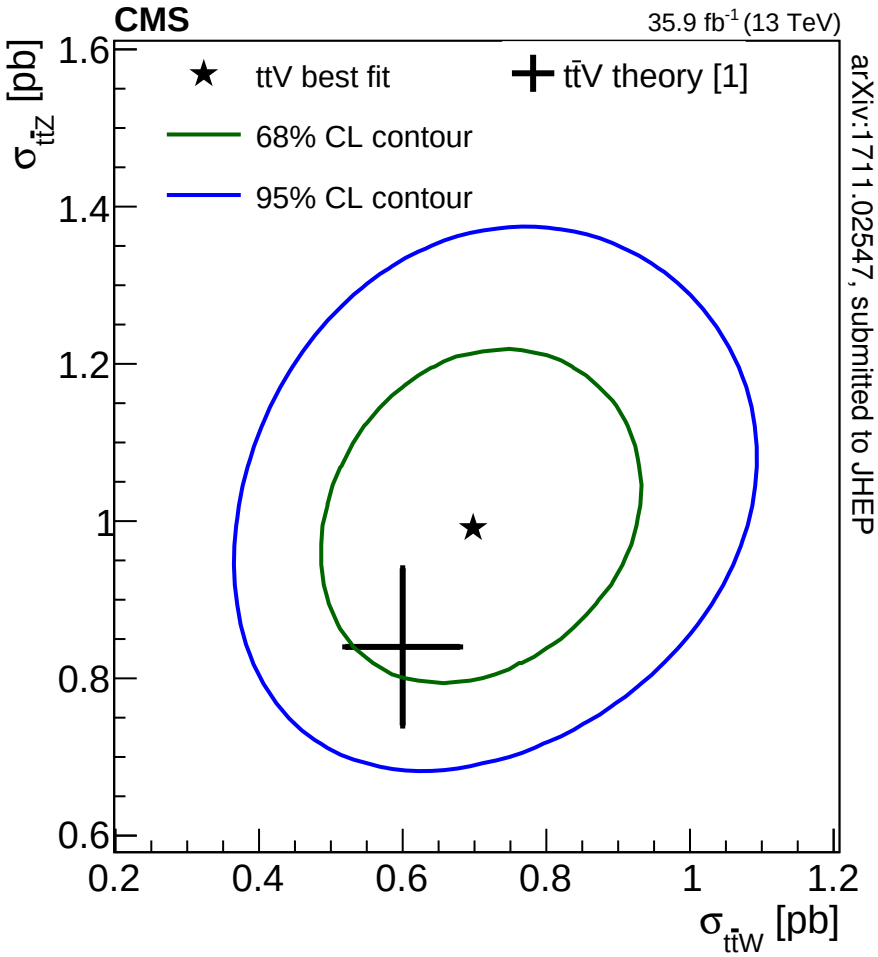


top quarks

- are the heaviest elementary particle ever observed
- allow for precision measurements of electroweak observables
- are important for the Higgs mechanism
- are today produced at a rate of one pair per second
- have been measured with a high precision at the LHC

$t\bar{t}Z$ cross section

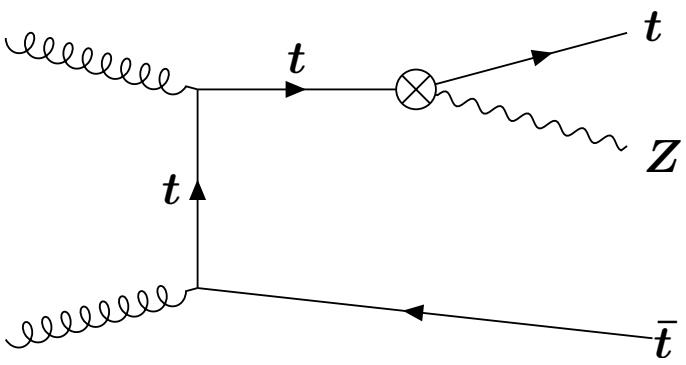




- $t\bar{t}Z$ production 1000 times weaker than $t\bar{t}$ production
- expected $t\bar{t}Z$ events at LHC:
  - $\approx 10^5$ with 100 fb^{-1} (run-2)
  - $> 10^6$ with 3 ab^{-1} (HL-LHC)

- previous CMS measurements:
  - 7 TeV: precision of $\sim$ 50 %
  - 8 TeV: precision of $\sim$ 25 %, significance of 6.4 σ
  - 13 TeV: precision of $\sim$ 15 %, significance of 9.9 σ

Probe of top quark couplings



ttZ allows to test top quark–Z boson coupling

- Standard Model:

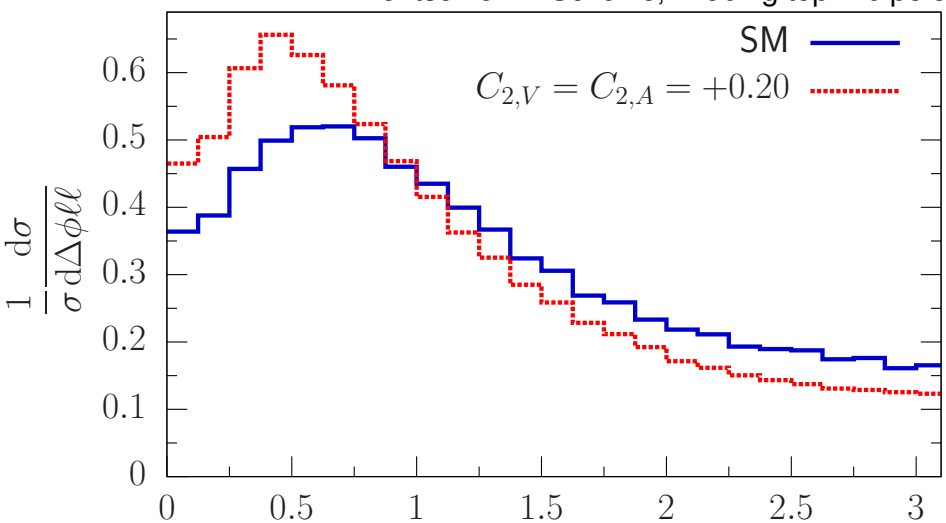
$$e\,\bar{t}\left[\gamma^{\mu}\left(C_V+\gamma_5 C_A\right)\right]tZ_{\mu}$$

- new physics parametrization:

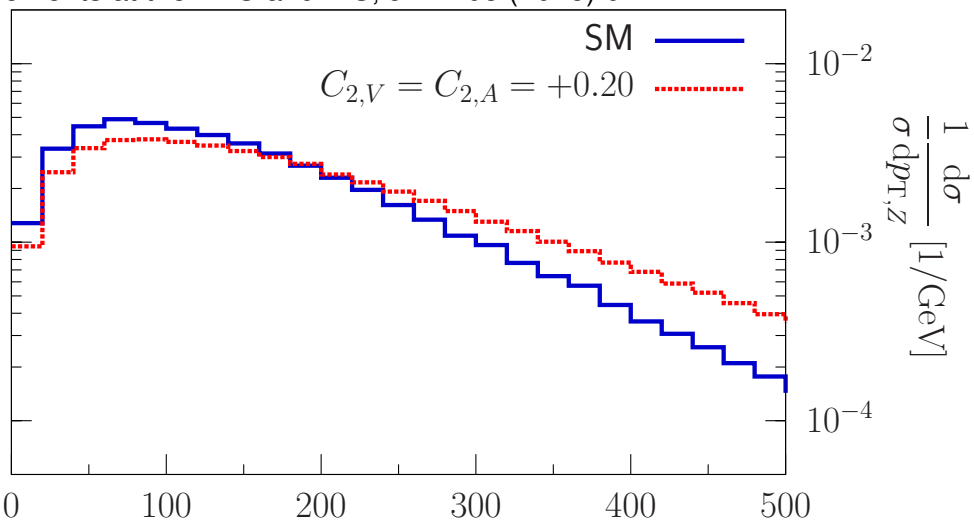
$$e\,\bar{t}\left[\gamma^{\mu}\left(C_{1,V}+\gamma_5 C_{1,A}\right)+\frac{i\sigma^{\mu\nu}q_{\nu}}{M_Z}\left(C_{2,V}+\gamma_5 C_{2,A}\right)\right]tZ_{\mu}$$

prediction with anomalous couplings for three-lepton channel:

R. Röntsch & M. Schulze, Probing top-Z dipole moments at the LHC and ILC, JHEP08 (2015) 044



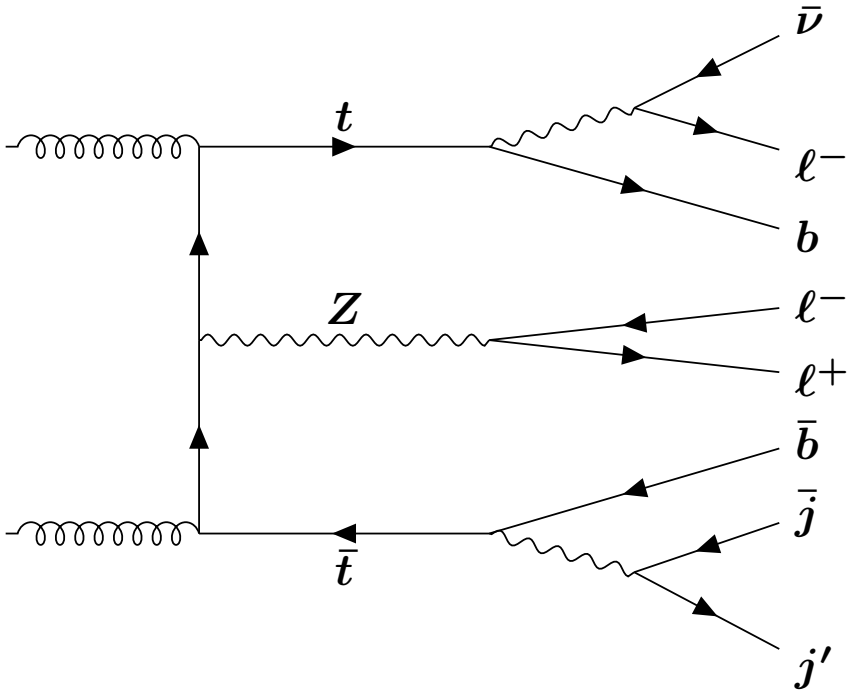
azimuthal angle between Z-leptons $\Delta\varphi(\ell\ell)$



dilepton transverse momentum $p_T(\ell\ell)$

Analysis strategy

Three-lepton final state



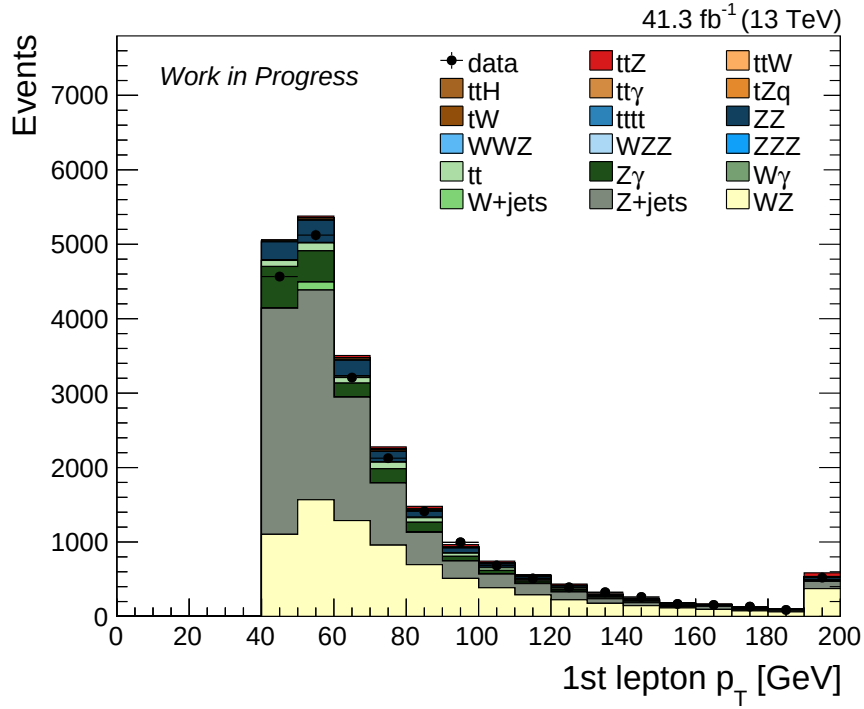
- small branching ratio ($\approx 2\,\%$)
- but: leptons precisely reconstructable from measured data

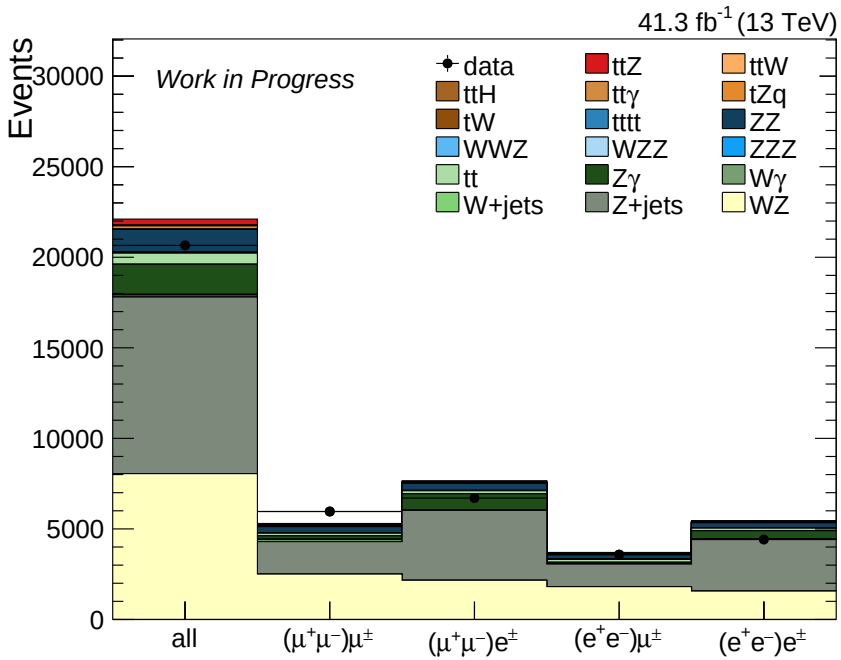
Datasets, object selection

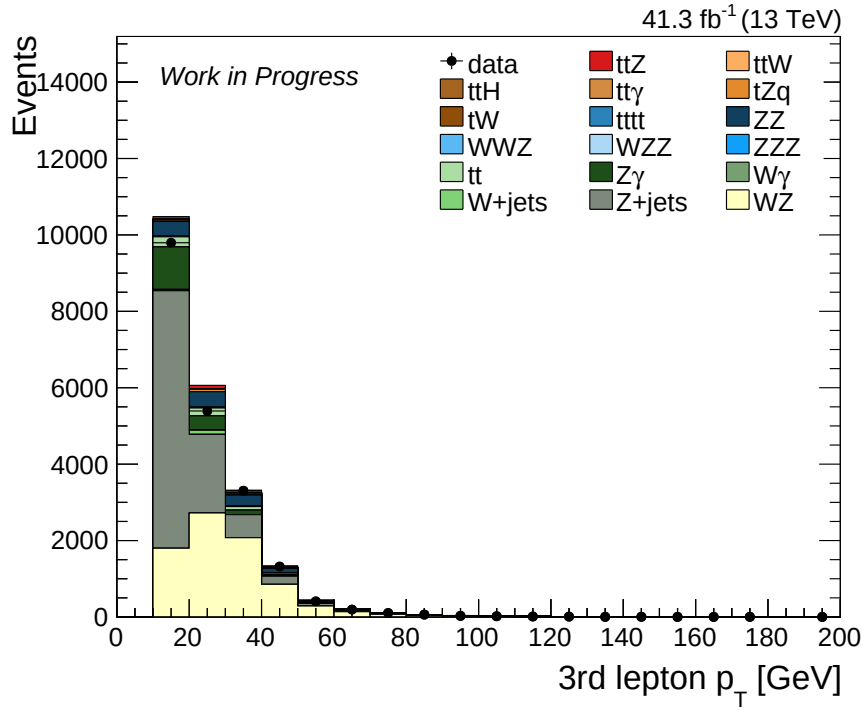
- full 2017 dataset with 41.3 fb^{-1}
- single lepton and double lepton triggers
- electrons/muons: medium ID, relative isolation, additional vertex cuts to reduce fake contamination
- jets: tight ID, loose pileup removal, separated from leptons
- b-tagging: DeepCSV tagger with medium working point
- Monte Carlo for signal and all background processes

Event selection

- **exactly three leptons with $p_T(\ell) > 40,\ 20,\ 10$ GeV**
- ***Z* candidate with $M(\ell^+\ell^-) = (91 \pm 10)$ GeV**

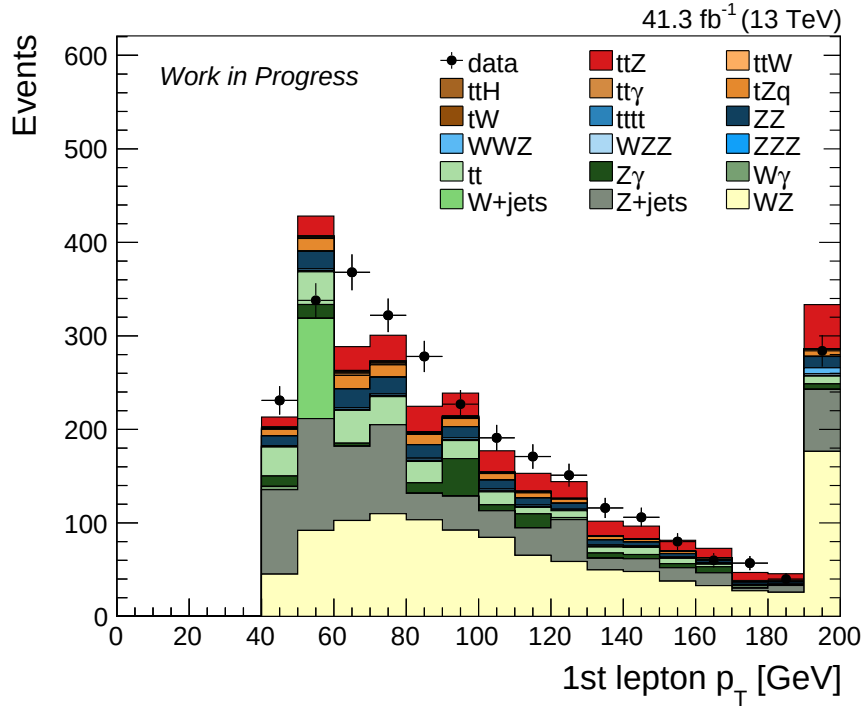


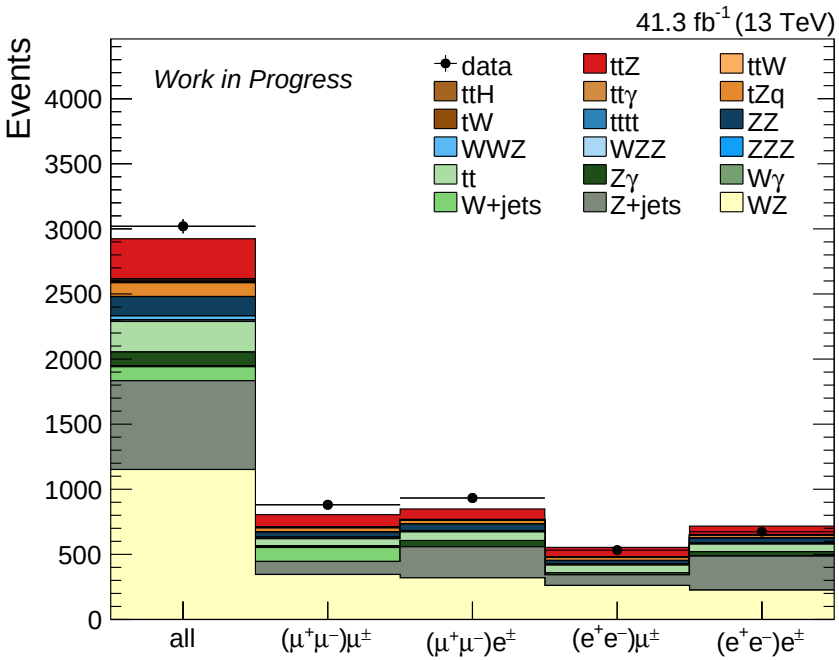


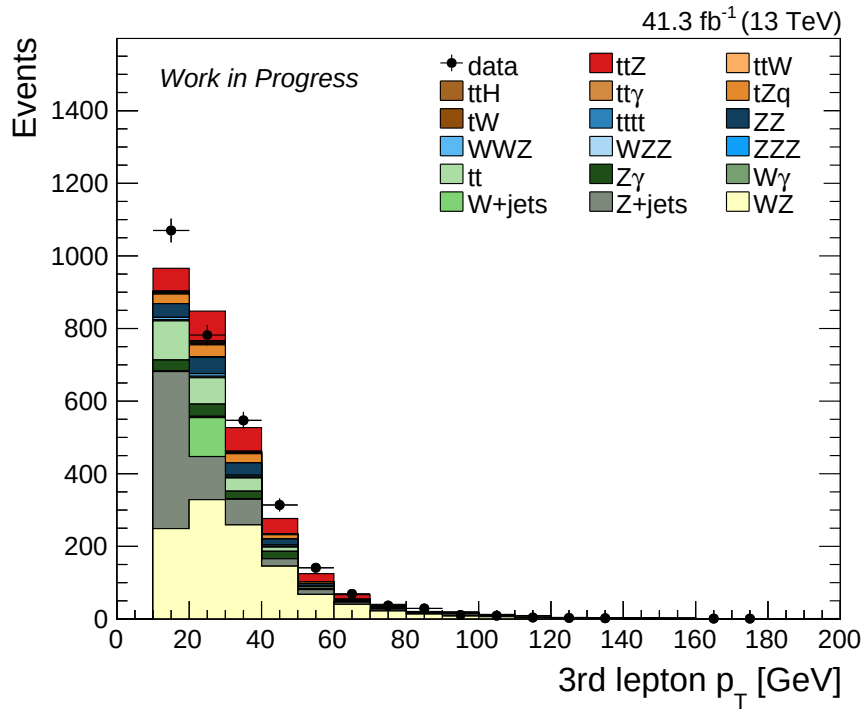


Event selection

- exactly three leptons with $p_T(\ell) > 40, 20, 10\,\text{GeV}$
- Z candidate with $M(\ell^+\ell^-) = (91 \pm 10)\,\text{GeV}$
- **$\geq$ 2 jets with $p_T(j) > 30\,\text{GeV}$**

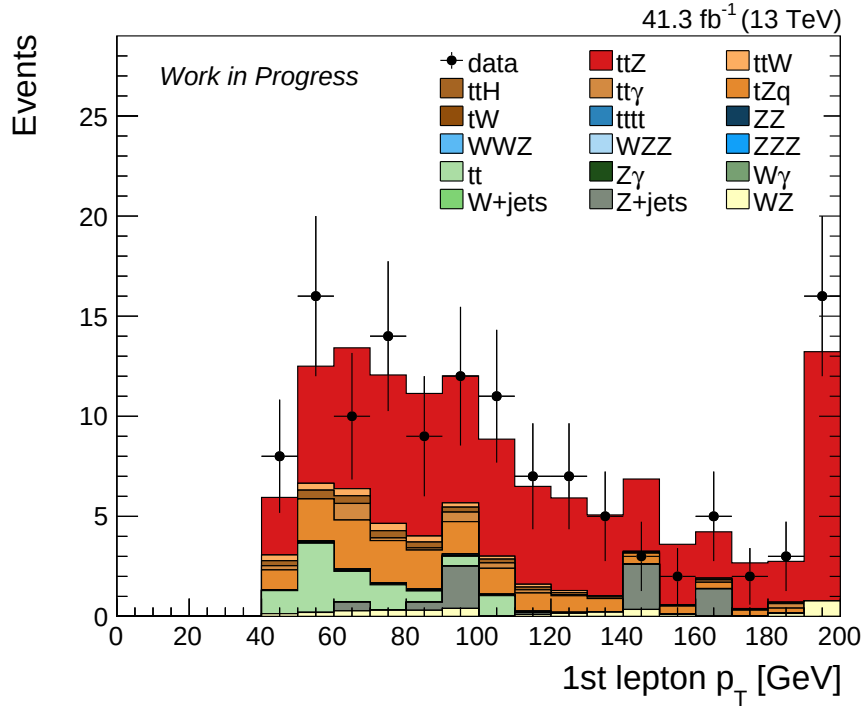


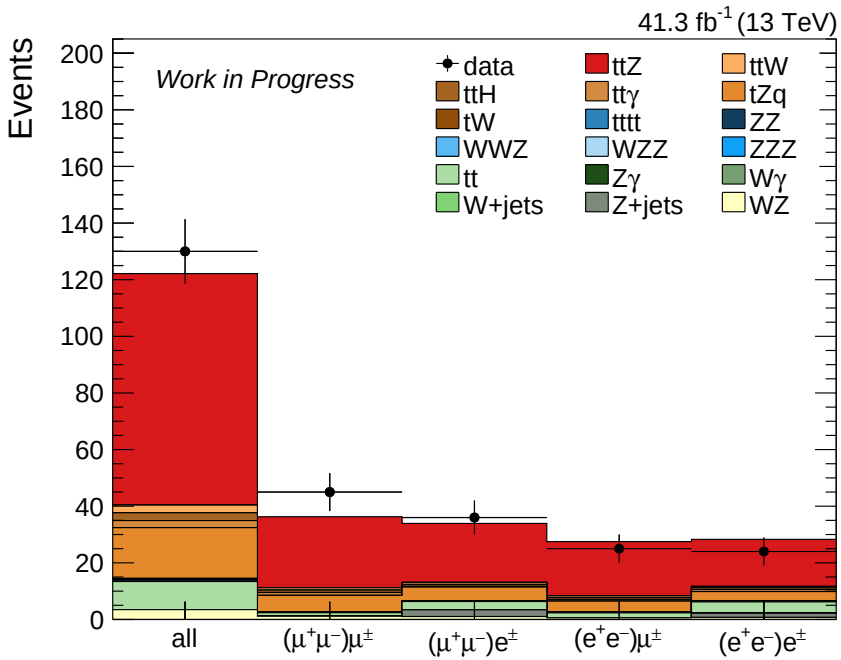


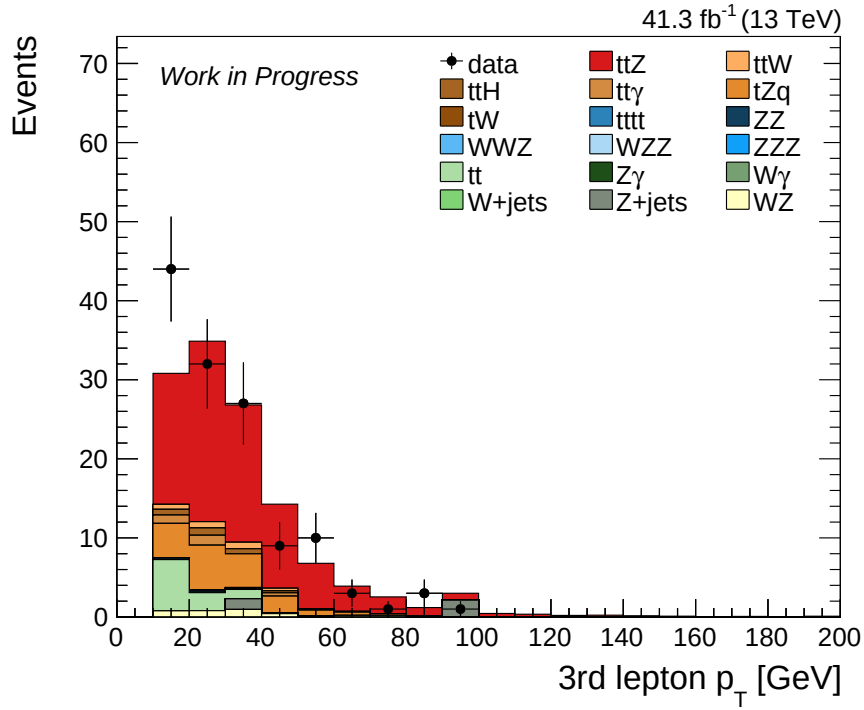


Event selection

- exactly three leptons with $p_T(\ell) > 40, 20, 10\,\text{GeV}$
- Z candidate with $M(\ell^+\ell^-) = (91 \pm 10)\,\text{GeV}$
- ≥ 2 jets with $p_T(j) > 30\,\text{GeV}$
- **≥ 2 *b*-tagged jets**

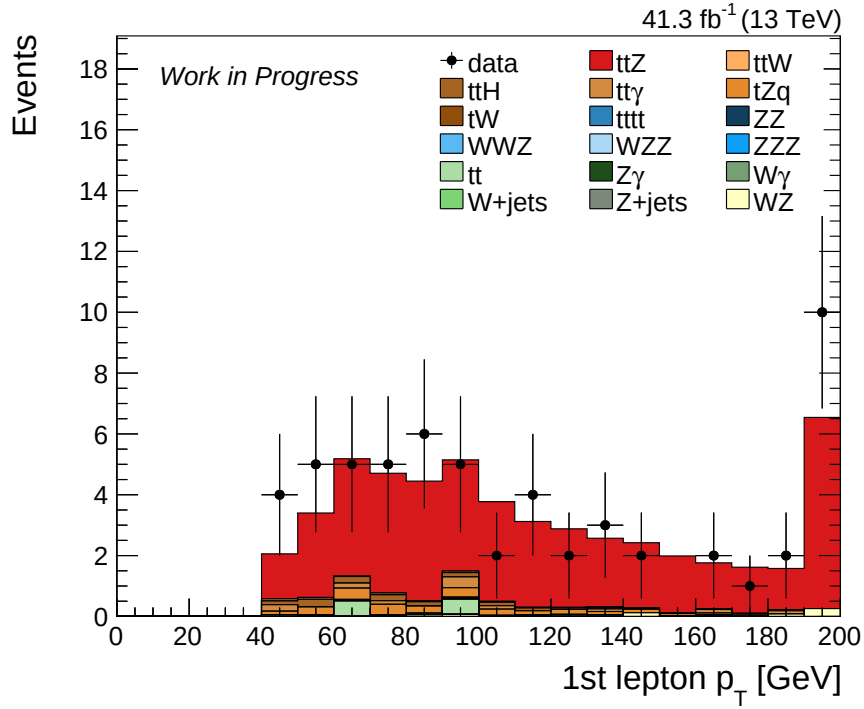


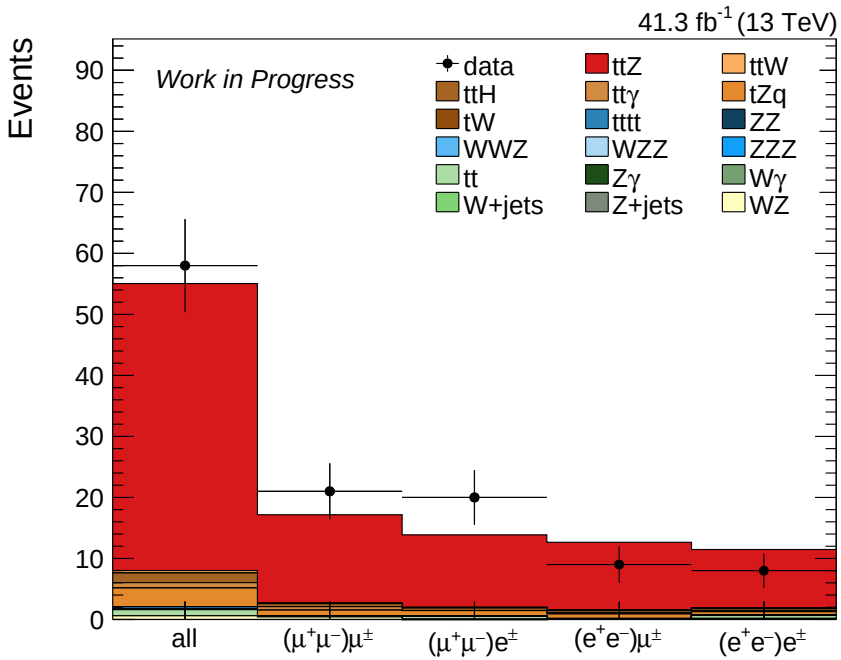


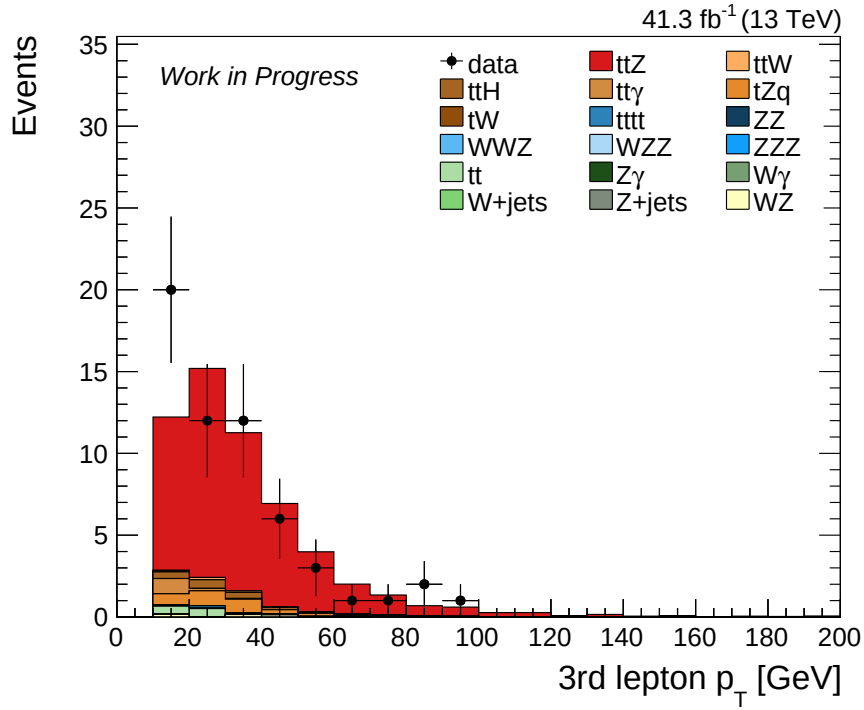


Event selection

- exactly three leptons with $p_T(\ell) > 40, 20, 10\,\text{GeV}$
- Z candidate with $M(\ell^+\ell^-) = (91 \pm 10)\,\text{GeV}$
- $\geq$ **4 jets** with $p_T(j) > 30\,\text{GeV}$
- ≥ 2 b-tagged jets



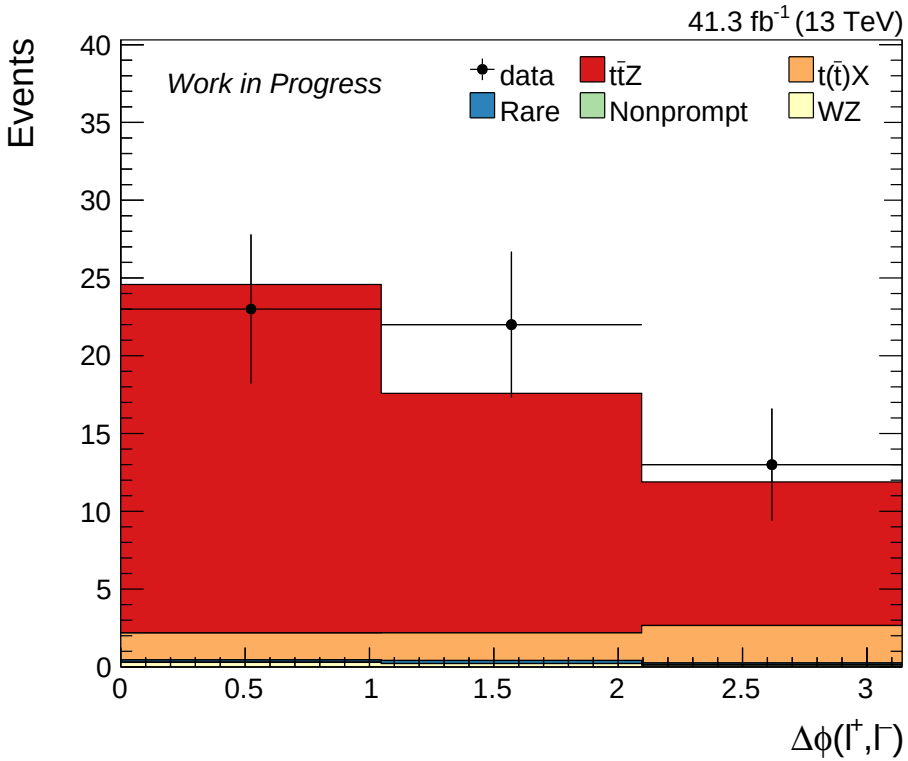




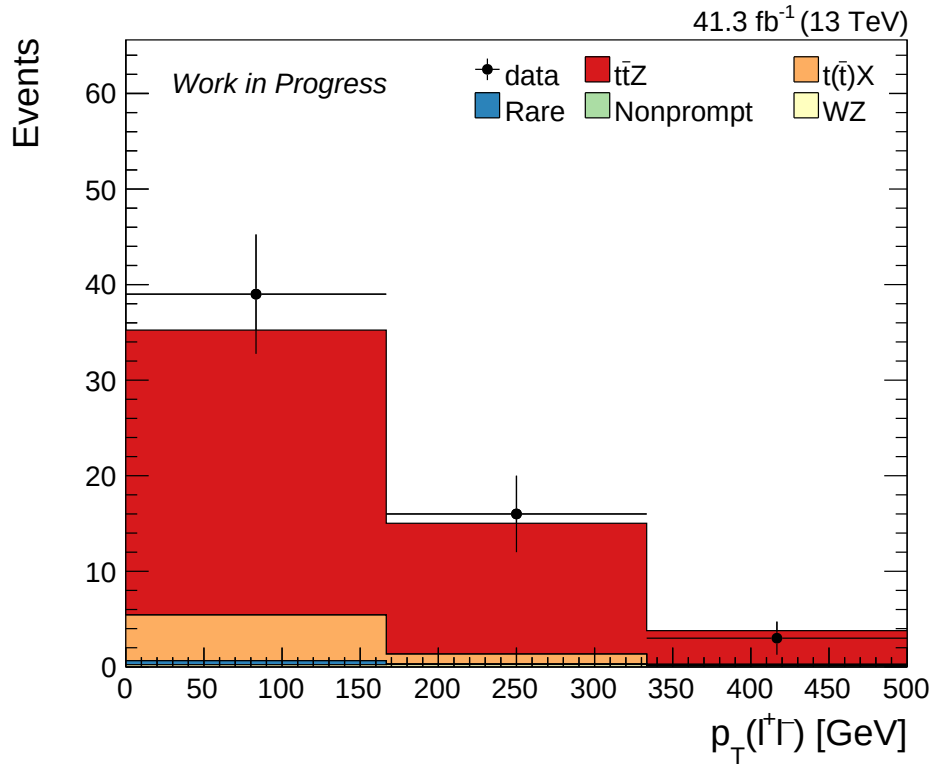
Differential distributions

- have 58 events in highest-purity selection ($N_j \geq 4$, $N_b \geq 2$), with 8 expected background events
- look into differential distributions:

azimuthal angle between Z-leptons $\Delta\varphi(\ell\ell)$



dilepton transverse momentum $p_T(\ell\ell)$



Outlook

2017 analysis

- analysis in very early stage
- determine backgrounds from data: WZ, non-prompt leptons
- larger Monte Carlo statistics for other processes
- dedicated lepton identification
- scale factors, systematic uncertainties, . . .

Long-term plans

- combination of 2016, 2017 and 2018 data
- include lower-purity categories
- investigate other observables that might be sensitive to new physics contributions (esp. observables including top-quark information)
- investigate interpretations of measurements in context of effective field theories

2016 result: 3-lepton channel

arXiv:1711.02547, submitted to JHEP

previous analysis, led by UGent