



# CMS measurement of the differential tt cross section in the lepton+jets final state at 13 TeV

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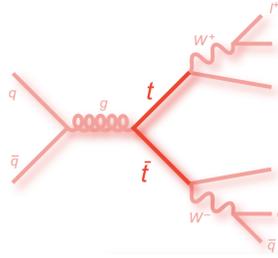
## 1. Motivation & Introduction

- The top quark physics plays an important role as:
  - test of Standard Model (SM) perturbative QCD
  - probe of PDF
  - backgrounds in other analyses
  - observation channel for physics beyond SM;
    - SUSY via Stop pair production decaying into top quarks
    - any new gauge bosons coupling to top quark will manifest itself as a resonance state
  - probing top Yukawa coupling
- We present the analysis method for the normalized differential cross section measurement in top quark pair decays into lepton+jets:

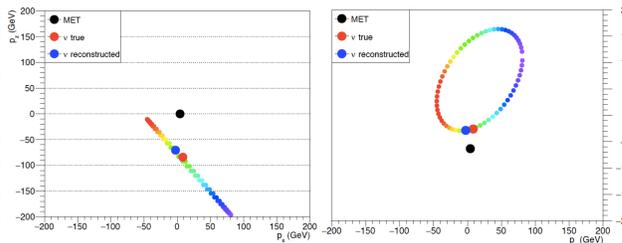
$$\frac{1}{\sigma} \frac{d\sigma}{dX} \quad \text{where } X = p_T(t), p_T(t\bar{t}), y(t), y(t\bar{t}), m(t\bar{t}), \text{ etc}$$

## 2. Top Quarks at LHC

- With a production cross section of 832 pb, about 35 thousand top quark pairs have been produced in the analysed 42 /pb dataset
- At leading-order, top pairs are produced by gluon-gluon fusions (~90%) and qq annihilation. Next-to-leading-order introduces the quark-gluon initial state
- 29.2% of top quark pairs decay semi-leptonically (e and μ only)



## 3. Neutrino Solver



$$\begin{aligned} p(l) + p(\nu)^2 &= M_W^2 \\ (p(l) + p(\nu) + p(b_l))^2 &= M_t^2 \end{aligned}$$

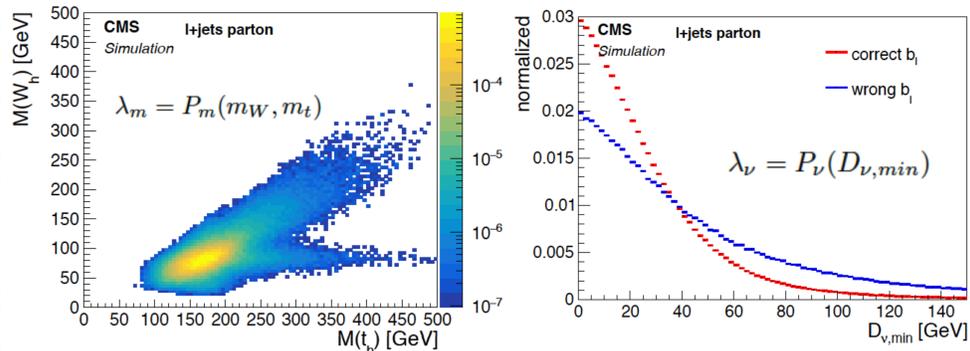
• Neutrino momentum is solved analytically using constraints on top and W masses

- The solution of these mass constraints are two ellipsoids intersecting in an ellipse in 3D neutrino momentum space
- The solution is the point on the ellipse closest to the measured missing transverse energy (MET) in the p\_x-p\_y plane

[B. A. Betchart et al., Nucl. Instrum. Meth. A 736 (2014) 169]

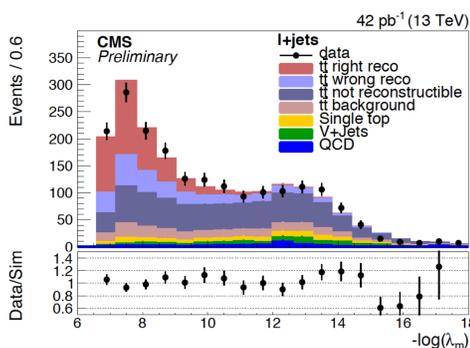
## 4. Event Selections & Reconstruction

- Event selections:
  - >= 4 jets
  - p\_T > 25 (30) GeV for jets (leptons), |η| < 2.4 (2.1) for jets (leptons)
  - at least one b-tagged jet
  - leading (b-tagged) jet p\_T > 35 GeV
- The Probability Density Function (PDF) of tt events is built out of variables with discriminating power between signal and backgrounds
  - 2D PDF for W boson and Top mass considering the correlation
  - PDF of Neutrino solver (distance between MET and ellipse)



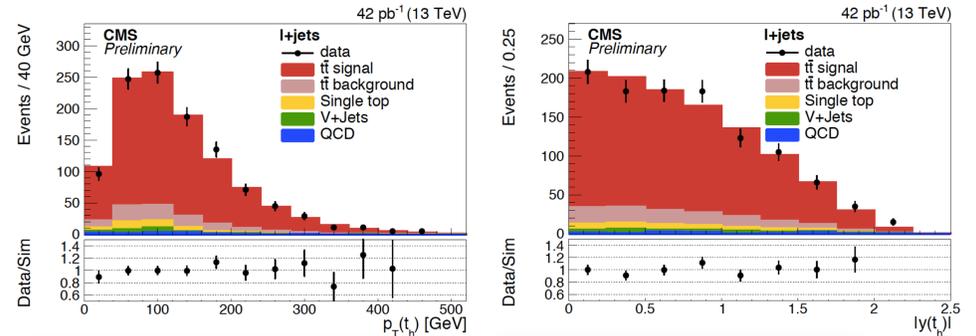
- Build all possible permutations. Calculate the corresponding likelihood value and choose the permutation with maximum likelihood value as tt pair candidate
- Not all the jets come from tt decays; wrong assignment might happen

$$-\ln(\lambda) = -\ln(\lambda_m) - \ln(\lambda_\nu)$$



## 5. Reconstruction Level Measurements

- Good agreement is found between data and simulation after reconstruction

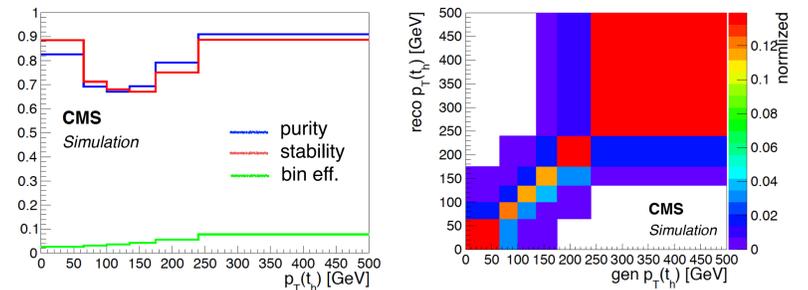


- The backgrounds are subtracted based on the simulation estimations:
  - W+jets, Z+jets, single top, QCD - small contributions (~7%)
  - tt background - subtract predicted fraction of non lepton+jets event

## 6. Unfolding & Differential Cross Section

- Unfold the reconstructed distribution to correct for acceptance and detector effects:

- iterative D'Agostini method has been used [G. D'Agostini, Nucl. Instrum. Meth. A 362 (1995) 487]
- a migration matrix shows the relation between the reconstructed and the truth events bin-by-bin
- accounts for trigger and selection efficiencies, and the detector resolution



migration matrix

tt signal events

$$\frac{d\sigma^i}{dX} = \frac{\sum_{i,j} \mathbf{A}_{ij}^{-1} (N_{data}^j - N_{bkg}^j)}{\Delta x^i \cdot \epsilon^i \cdot \mathcal{L} \cdot \mathcal{B}}$$

reconstruction eff.      data luminosity      branching fraction

- Normalized differential cross-section measured in full phase space

## 7. Results

- First CMS tt differential cross section measurement in lepton+jets at 13 TeV
- With this luminosity, we had large statistical uncertainties
- The results agree within uncertainties with the SM predictions provided by different generators

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