Particle-level based measurements definitions in Top physics

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Introduction

- Measurements at LHC become increasingly precise

- Fast progress on theory side in many areas:

  NNLO, ME(2->n)+PS merging, N(N)LO+PS matching, e.w. corrections etc.

  Full final state instead of narrow width approximation e.g. pp -> WWbb vs pp-> tt

- Need accurate definitions of measurements to facilitate

  the comparison of data to theory predictions

- Suitable definition is based on the particle entering the detector

- Use of particle-based definition already standard methodology in HEP

- Standardized tools to compare data and predictions (Hztool, Rivet etc.)

Guiding principles

- Define observable in theoretical safe and unambiguous way

- Measure observables correcting for detector effects minimizing the dependence on the MC model

- Measure within detector acceptance (fiducial region) to avoid model dependent large extrapolations

- Define “truth” objects, e.g. stable particles entering the detector,
  as close as possible to physics objects reconstructed in the detector

- Stay practical: use simple cuts to model the main experimental acceptance effects

- Use operational definitions based on “truth”-objects to define complex observables

- Provide separately corrections to “parton-level” or “total cross-sections” to ease theory comparisons and provide a benchmark for future corrections derivation

Past work in the TopLHC WG

Top physics results have been traditionally presented in the full phase space

and with respect to the top quark

MC generators include phenomenological models that evolve over time

This model dependence can be minimized by presenting measurements

- close to detector acceptance
- based on stable particles entering the detector

TopLHC WG (ATLAS, CMS and theorists) has been very active to develop

- suitable definitions
- new concepts (pseudo-top)

Active discussions ongoing in ATLAS and CMS for Run-II preparations (next talk by Orso/Kevin)

Recent discussions in SM@LHC conference (last talk)

Contacts of TopLHC WG:

ATLAS: K. Finelli, D. Hirschbuehl

CMS: J. Goh, O. Iorio

References of previous discussions in the TopLHC WG

Several informal meetings between ATLAS, CMS and theorists have been summarized in:

- July 2012 W. Bell: Common top (pair) acceptance: definitions

- July 2012 M. Mangano:
  Suggestions for further measurements and combinations of theoretical interest

- April 2013 W. Bell/T Dorland: Pseudo top definition and common acceptance

Results of TopLHC WG discussions are documented on this twiki page
(Details on particle-definitions, fiducial phase space and pseudo-top)

Fiducial top measurements at LHC

- First fiducial measurement in 2012 (meanwhile 123 references !):
  Additional jet activity in dilepton events ATLAS EPJ C72 (2012) 2043*)

- Top pair production cross sections:
  ATLAS PRD 91 (2015) 5, 052005 , EPJ C74 (2014) 10, 3109 (7+8 TeV), arXiv:1504.04251 (8 TeV)

- Jet multiplicities, jet and lepton spectra:
  ATLAS JHEP 1501 (2015) 020*) CMS: EPJ C74 (2014) 3014, TOP-12-041 PAS (8 TeV)
  CMS Eur.Phys.J. C73 (2013) 2339 arXiv:1505.04480 (8 TeV)

- Top quark kinematic quantities (pseudo-top):
  ATLAS arXiv:1502.05923, ATLAS-CONF-2014-057 (8 TeV boosted), CMS TOP-12-028 (additional material) (8 TeV)

- Associated production to top pairs:
  tt+photon ATLAS PRD 91 (2015) 072007
  tt+b ATLAS PR D89 (2014) 072012 tt+bb/tt+jj CMS TOP-12-024, PL B 746 (2015) 132 (8 TeV)

- Jet shapes EPJ C 73 (2013) 12, 2676*)
- Single top t-channel cross-section ATLAS-CONF-2014-055 (8 TeV)

*)Rivet routine available

Pseudo-top concept

From M Mangano talk July 2012:

- General “framework” to reconstruct top quark at the particle-level applicable to large class of measurements
  Different and optimized prescriptions for special analysis possible

- Event Objects e.g. 4 jets with $P_{T,j}$>20 GeV within $|y_j|$<2.5, at least 2 jets with b-tags, leptons and E_{Tmiss}

- Function F(j,l,b,nu) to map event objects into top anti-top pair $t_1=W_{jj}+b_1$ $t_2=W_{lnu}+b_2$

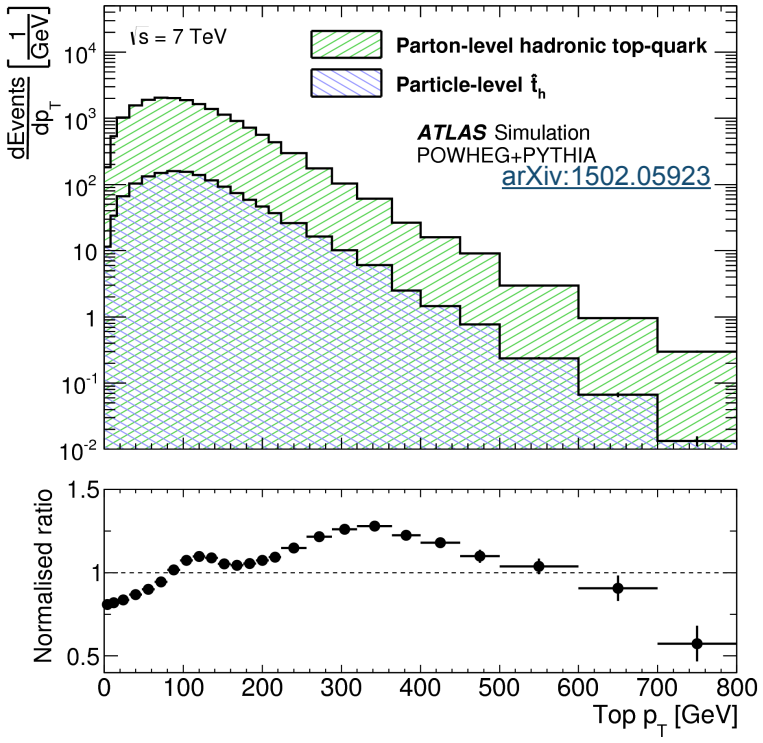
- Should be formulable as Rivet routine to act on MC generated final state

- Could include “fiducial region” like $|y_{top}| < 2.5$
  Possibly cuts on top likelihood to optimise relation between top parton and pseudo-top objects

- Measurements can be corrected to top quarks using MC to parton level to compare to fixed-order calculations

Pseudo-top concept

Pseudo-top is operational definition based on stable particles to reconstruct kinematic quantities closely related to the top quark



Example of simple prescription for l+jet events:

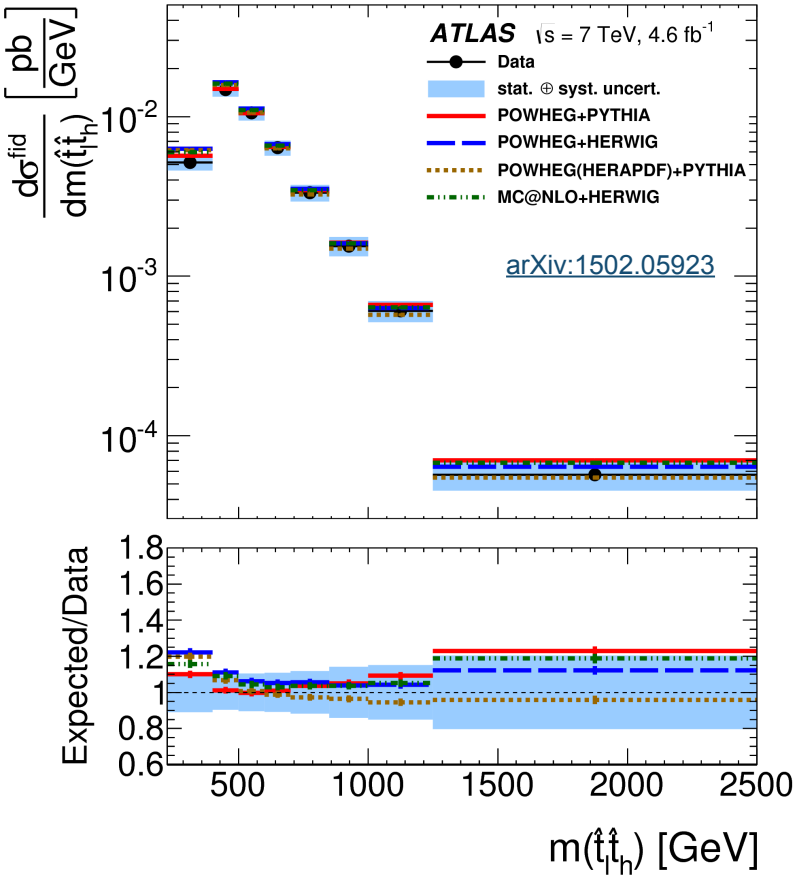
- Select prompt dressed lepton and form E_{Tmiss} from neutrinos
- Cluster jets from stable particles excluding the identified leptons
- Identify jets with b-hadron content and select the two highest p_T b-jets
- The remaining two highest p_T jets form the hadronic W-boson
- The b-jet closed to the lepton form the leptonic top-quark decay
- The hadronic top quark is defined from the hadronic W-boson the remaining jets
- The leptonic W-boson is assigned from the remaining lepton and the E_{Tmiss} using the W-mass to constrain for the neutrino p_z-momentum (two solutions from kinematics)

In boosted regime the top quark can be easily identified with a large-R jets (ATLAS-CONF-2014-057)

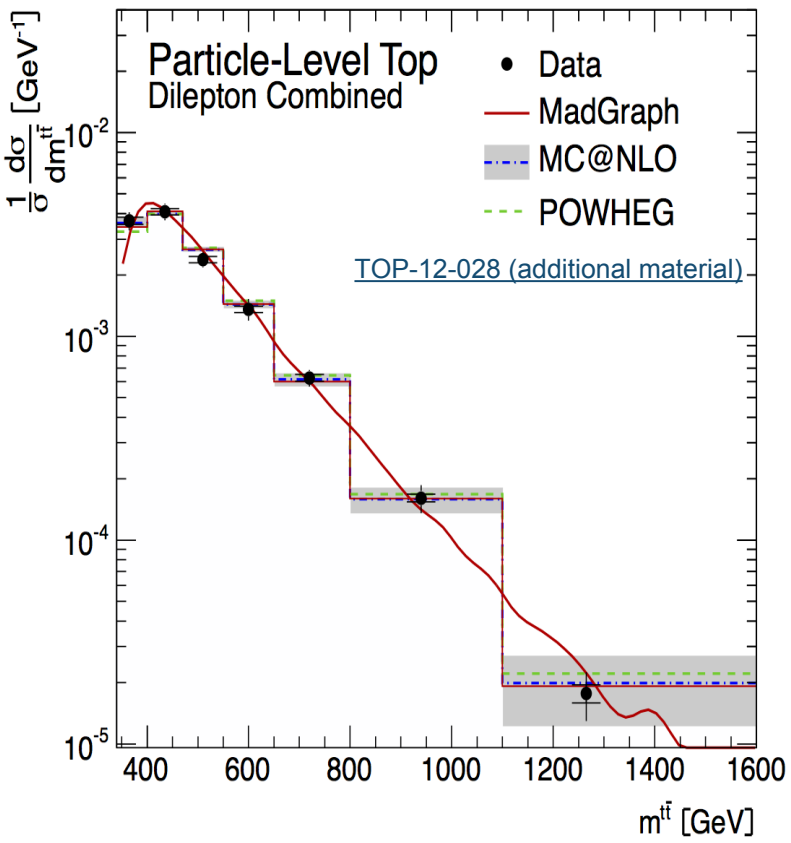
- Large extrapolation from full phase space to measured phase space
- Shape difference of top quark distribution and pseudo-top distribution from stable particles 20-30%
- When quoting the top quark p_T the particle->parton correction is done with one MC and one relies that MC variations model the systematics

Pseudo-top first differential cross-section results

ATLAS l+jets



CMS Preliminary, 12.2 fb-1 at √s = 8 TeV



- First differential particle-based ttbar cross section available
- Comparison of MC generators via Rivet at any time → assessment of new MC developments (MC@NLO etc.)
- Comparison to fixed order calculations via corrections derivable with Rivet at any time

Summary

- Push in top quark physics to provide fiducial measurements
- New concept to reconstruction “top quark” by operational definition from stable particle

- Need to provide corrections for easy comparison to fixed order calculations
- Need to provide data tables and Rivet routine to compare to MC generators
  and to re-do the corrections to parton-level

Concrete definition of particle object will be discussed in next talk