Prospects for a charge-asymmetry measurement in top-quark pair-production at CMS

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on behalf of CMS

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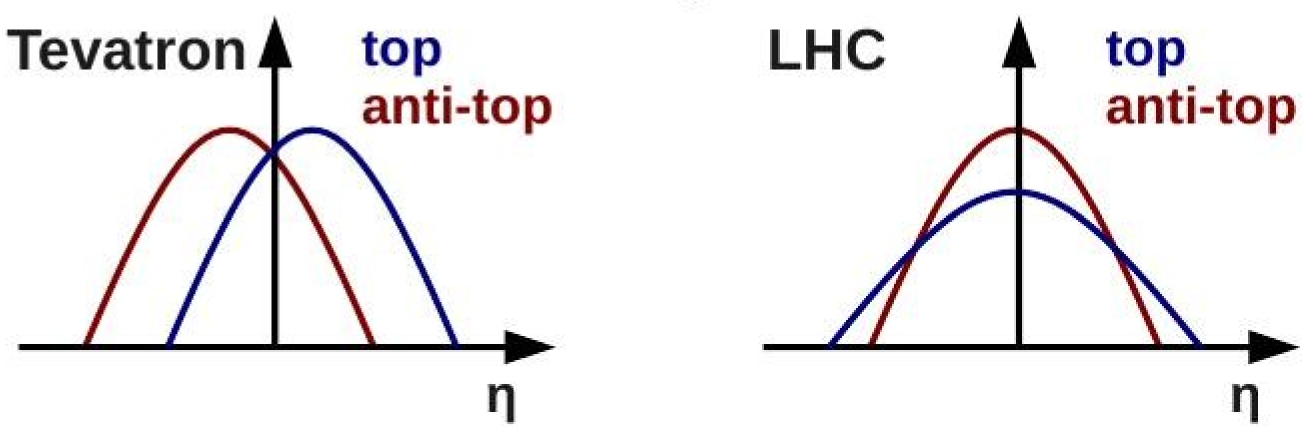
Charge Asymmetry

LHC: symmetric proton-proton collisions
→ cannot observe any forward-backward asymmetry

Effects at LHC:

- **Proton-PDF:** Quarks in initial state have on average larger momentum than anti-quarks
- This transfers a boost difference to top-antitop final states, inducing a tiny difference in t/tbar rapidity distributions.
- A new particle (e.g. an heavy boson with an axial vector coupling to quarks) in qqbar→X→ttbar can enhance this charge asymmetry



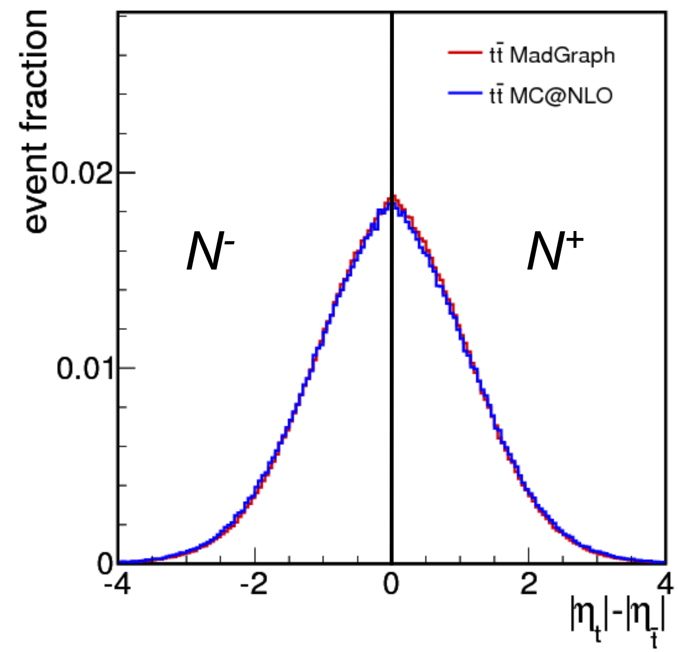
→ rapidity distributions with different widths for top and anti-tops

Sensitive Variable

- Sensitive variable in this analysis: $|\eta_{top}|-|\eta_{anti\text{-}top}|$

- Define the charge asymmetry as central/de-central asymmetry in $|\eta_{top}|-|\eta_{anti\text{-}top}|$:

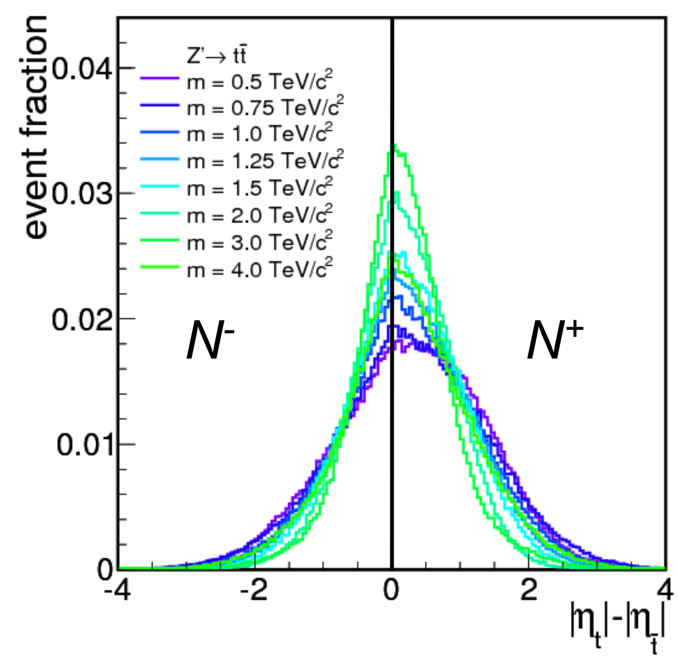
$$A_C := \frac{N^+ - N^-}{N^+ + N^-}$$



- Theory prediction for Standard Model (G. Rodrigo):
  A_C=0.0130(11)
  → only small asymmetry from NLO effects
  → only due to qqbar induced initial states

- Tevatron asymmetry would correspond to:
  A_C=0.04 to 0.05
  → effect at LHC smaller due to larger gg→tt fraction

- An axigluon with mass >1TeV would yield
  A_C-A_C^{SM}~-0.02, -0.03



Event Selection

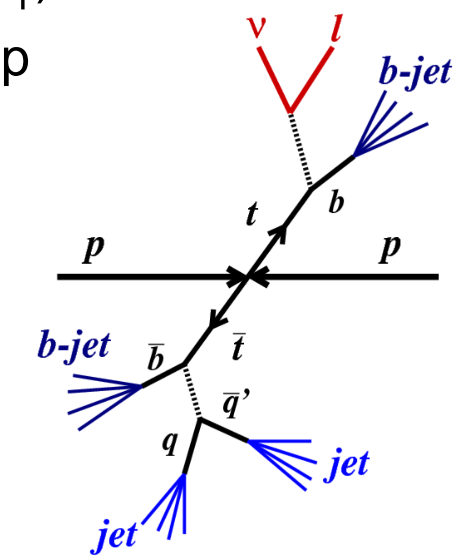
- Select events in electron+jets and muon+jets channel
- Selection is identical to event selection in cross section measurement (CMS-PAS TOP-10-002)
  - exactly one isolated muon (p_T>20 GeV/c) or electron (E_T>30 GeV)
  - at least 4 jets (p_T>30 GeV/c)
- Used CMS dataset: 36 pb^{-1} at $\sqrt{s}$=7 TeV
- Signal and background yield from cross section measurement:

process	electron channel	muon channel
tt	184±16	231±20
single top	9±3	12±4
W+jets	130±8	159±9
Z+jets	20±6	15±5
QCD	64±6	17±5
total	407±19	434±22
data	428	423

Reconstruction

The measurement of $|\eta_{top}|-|\eta_{anti\text{-}top}|$ requires a full reconstruction of top quark 4-momenta from measured detector objects (leptons, jets, miss. E_T).

Create list of hypotheses for assignments of jets and leptons to top decay products.



- neutrino p_x and p_y from miss. E_T, p_z from W mass constraint
  (p_z: in general two solutions from a quadratic equation, take real part for non-real solutions)
- assign one jet to each of the four quarks in final state
- take hypothesis with smallest

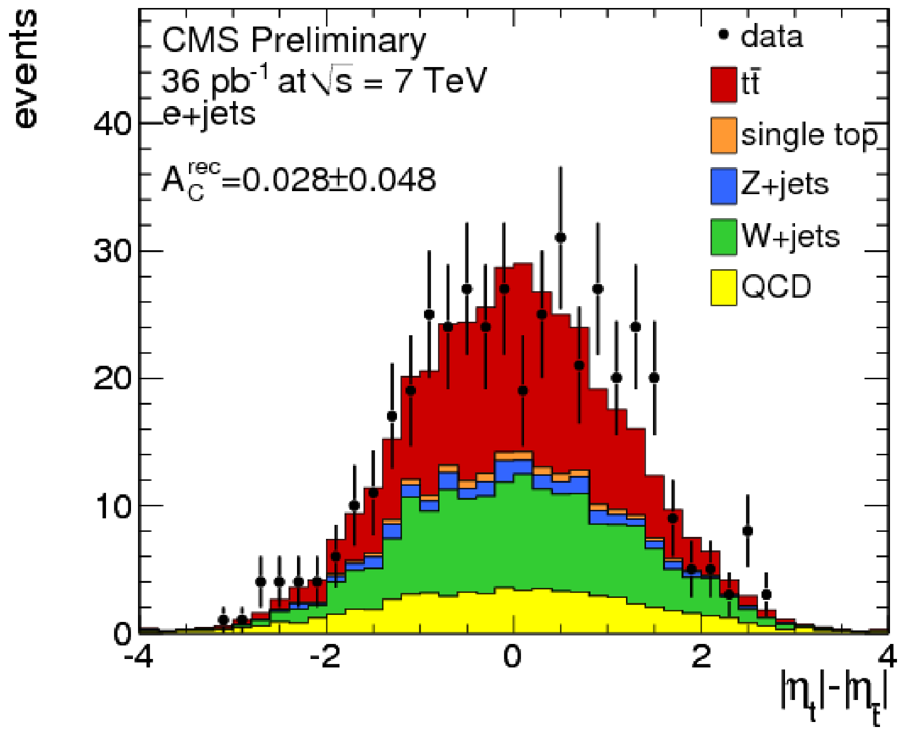
$$\psi = \left(\frac{(M_{Whadrec} - x_1)^2}{\sigma_1^2} + \frac{(M_{thadrec} - x_2)^2}{\sigma_2^2} + \frac{(M_{tleprec} - x_3)^2}{\sigma_3^2} \right) * P_b(q_1) * P_b(q_2) * (1 - P_b(b_1)) * (1 - P_b(b_2))$$

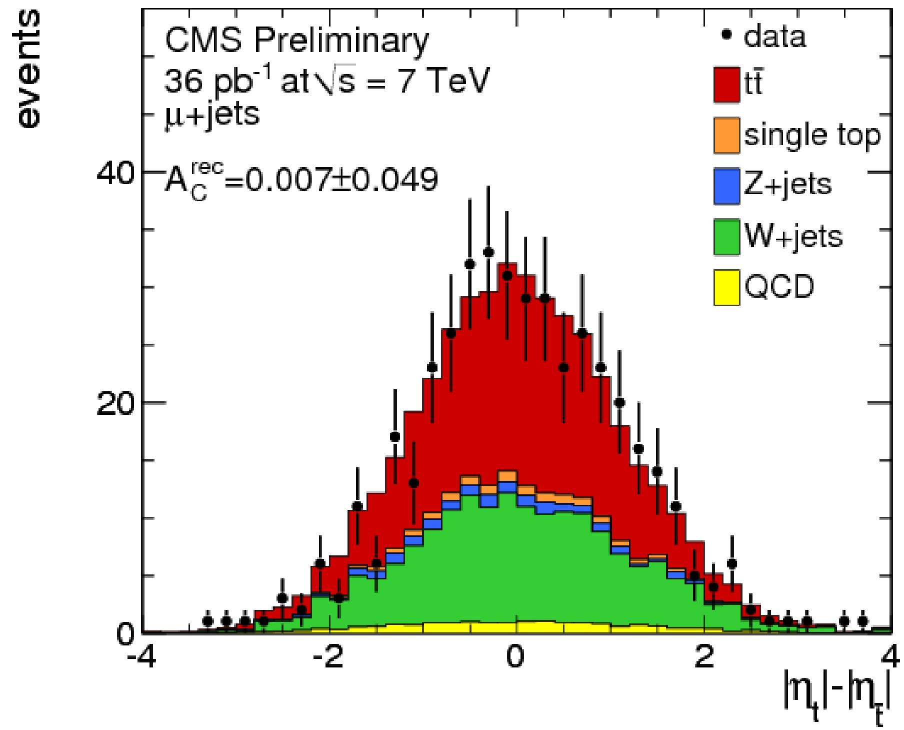
where x_i and σ_i are determined from best possible hypothesis on MC,
P_b is a parametrization of a b-tagger output in the best possible hypothesis

Best possible hypothesis: hypothesis on MC with smallest ΔR between true and reconstructed top and W 4-momenta

Reconstruction

Reconstructed $|\eta_{top}|-|\eta_{anti\text{-}top}|$ distribution in electron and muon channels:





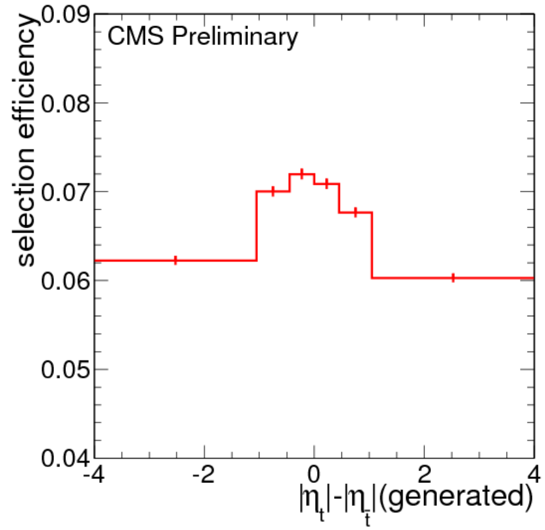
combined uncorrected asymmetry: **A_C^{rec}=0.018±0.034(stat)**

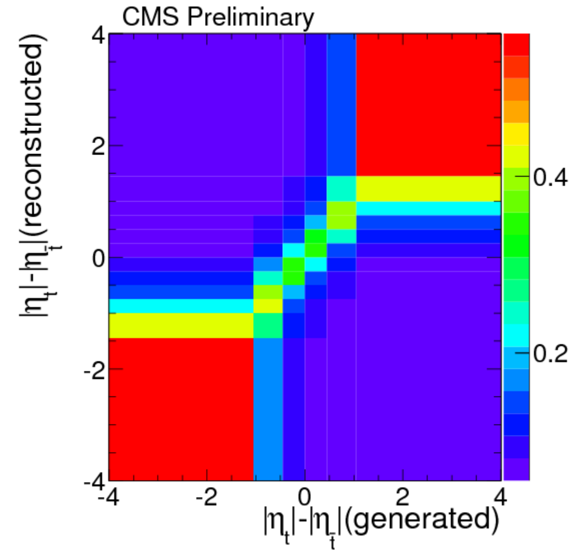
Unfolding

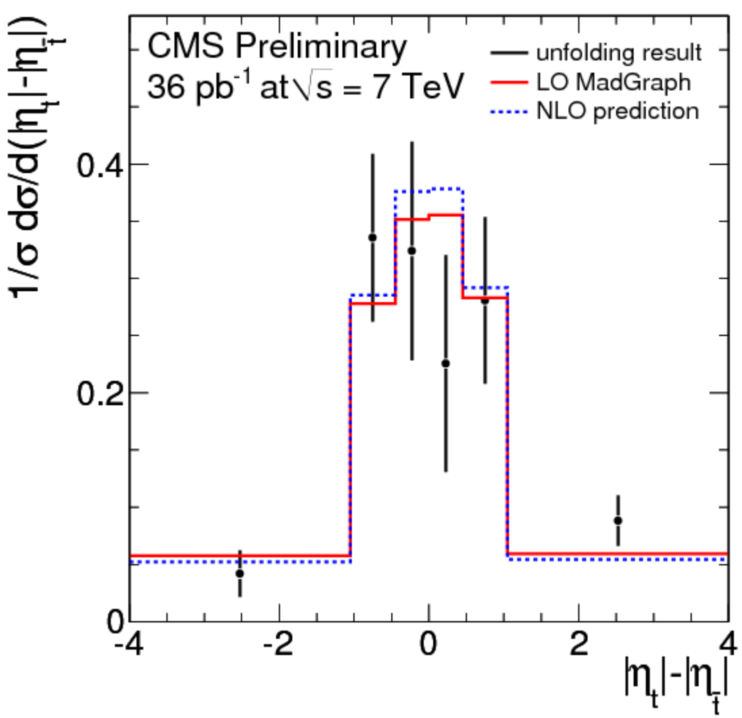
Reconstructed $|\eta_{top}|-|\eta_{anti\text{-}top}|$ distribution does not correspond directly to true distribution:

- background contributions, detector smearing, non flat efficiency in $|\eta_{top}|-|\eta_{anti\text{-}top}|$

→ correct for these effects with a regularized unfolding method based on a generalized matrix inversion (using TUnfold package).







Result of the unfolding: differential cross section in $|\eta_{top}|-|\eta_{anti\text{-}top}|$ including the full covariance matrix between all bins of the distribution.

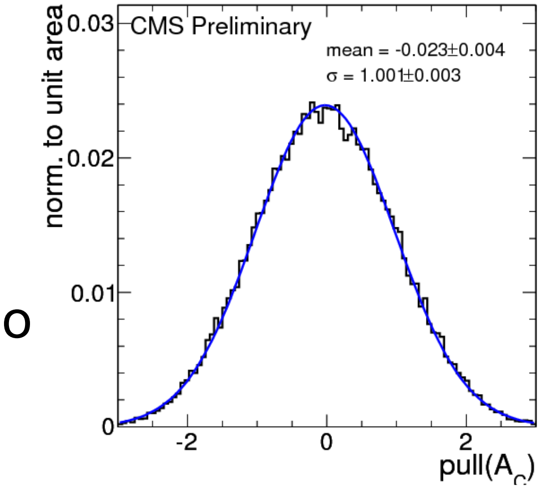
Corrected asymmetry from Gaussian error propagation:

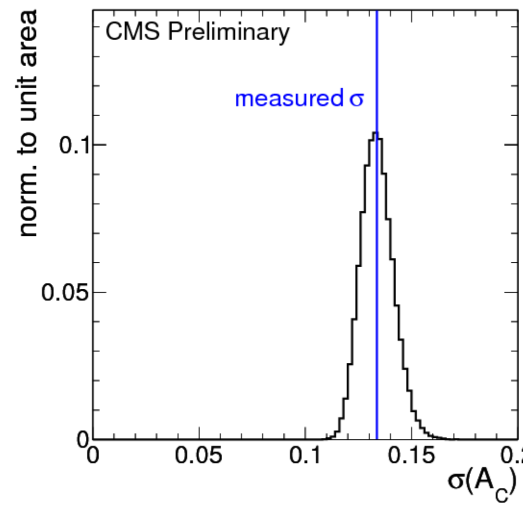
A_C=0.060±0.134(stat)

Checks on the method

Unfolding is tested in ensemble test with pseudo experiments.

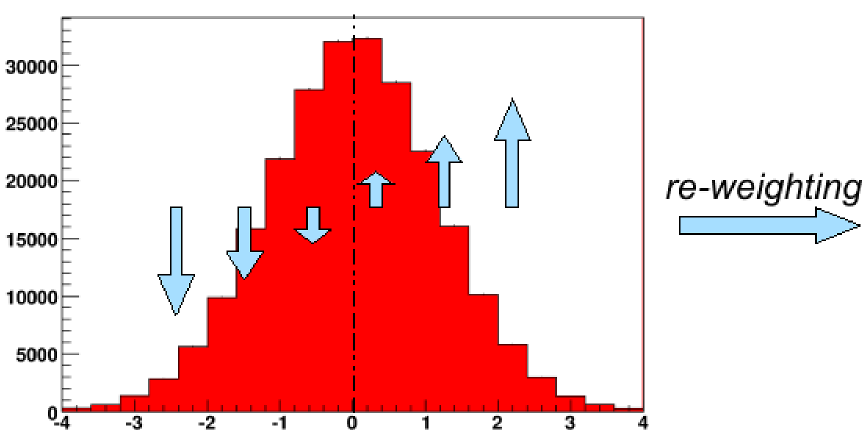
- Asymmetry of ~0 in MC sample is found correctly on average.
- Pull distribution indicates a correct uncertainty treatment.
- Measured uncertainty is consistent with expectation from pseudo experiments.

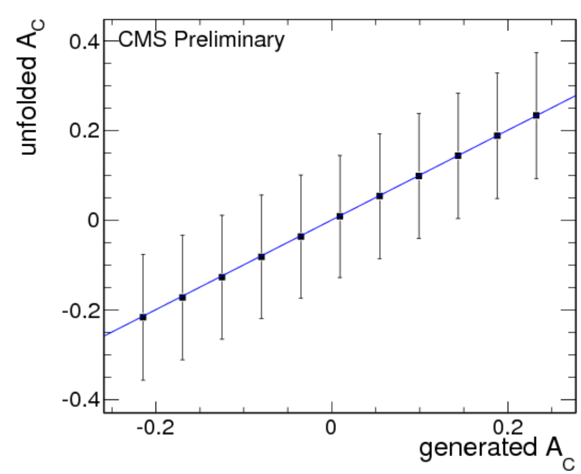




Does the unfolding give the correct answer in case of an asymmetry?

Re-weight the SM model sample with a factor $k*(|\eta_{top}|-|\eta_{anti\text{-}top}|)+1$ with different k values and unfold it with the un-weighted samples.





Generated asymmetry is found correctly with unfolding in PEs.

Systematics

- Draw PE from systematically shifted templates.
- Perform unfolding with standard samples
- Observed shifts of the central/de-central asymmetry:

source of systematic	positive shift in A_C	negative shift in A_C
jet energy scale	0.017	-
jet energy resolution	0.007	-0.006
Q^2 scale	0.003	-0.007
ISR/FSR	0.005	-0.0006
matching threshold	0.004	-0.006
PDF	0.004	-0.011
b tagging	0.007	-
lepton efficiency	0.017	-0.018
QCD model	0.005	-0.005
overall	± 0.026	

Systematic uncertainties are much smaller than statistical uncertainty.

Conclusion/outlook

- We established a method to measure the charge asymmetry in top-pair production at pp-colliders.
- We measure, at 7TeV: **A_C=0.060±0.134(stat)±0.026(syst)**
- The measurement is largely dominated by statistical uncertainty.
- So far, no deviation from SM value found → no indication for new physics

- Preliminary estimations in CMS conclude that a sensitivity similar to the Tevatron results can be reached with a collected statistics of about 1/fb.
- More data will also allow for asymmetry measurements differentially in M_{tt}, increasing the sensitivity to the presence of new physics

Documentation: CMS-PAS TOP-10-010

Sensitive Variable

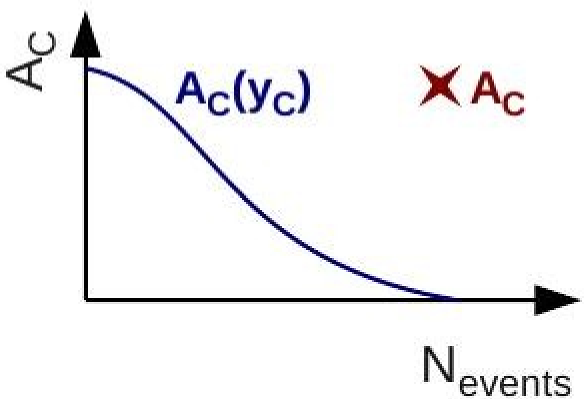
We use the variable $|\eta_{top}|-|\eta_{anti\text{-}top}|$ and determine its asymmetry.

Most theory predictions are using a different definition with a rapidity cut y_C:

$$A_C(y_C) := \frac{N_{\mathrm{t}}(|y| < y_C) - N_{\bar{\mathrm{t}}}(|y| < y_C)}{N_{\mathrm{t}}(|y| < y_C) + N_{\bar{\mathrm{t}}}(|y| < y_C)}$$

Advantages of our definition:

- In our definition all events are used; no cut on y_C is needed which reduces available statistics.
- It is defined event-by-event which allows a simpler statistical treatment and unfolding



Example: Z' →tt, m=1TeV
A_C=20% in our definition
Maximal A_C=20% in other def.
only with hard y_C cut