Forward-backward/charge asymmetry in top events

U. De Sanctis (Udine)
on behalf of the “Italian cluster for top”

L. Bellagamba, G. Bruni, R. Di Sipio, M. Romano (Bologna);
A. Andreazza, I. Besana, A. Favareto, T. Lari, C. Troncon (Milano);
B. Acharya, M. Cobal, M. Pinamonti, K. Shaw, R. Souhalah (Udine);

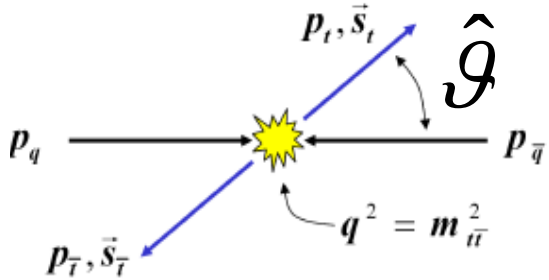
Outline

- Which asymmetry?;
- Studies ongoing @ TEVATRON;
- Asymmetries @ LHC;
- Italian contribution in ATLAS & schedule;
- Preliminary analysis on 2010/2011 data and MC;
- Conclusions and outlooks

Which asymmetry?

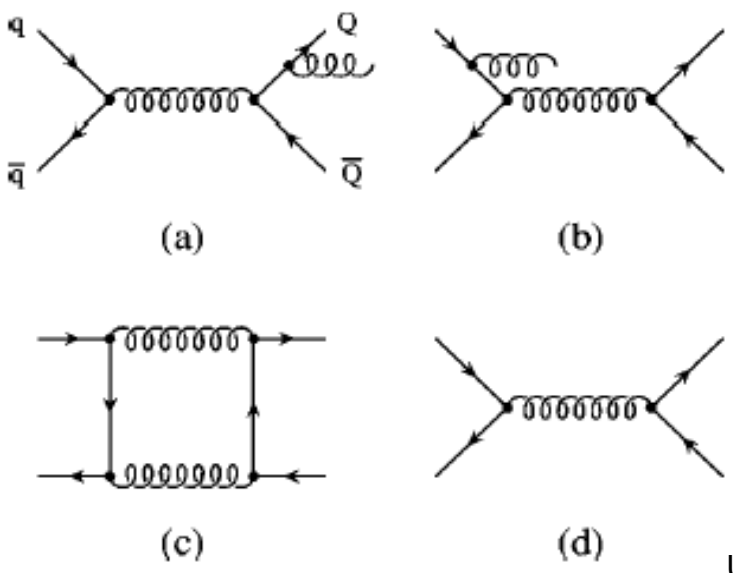
Charge asymmetry:

- No discrimination between t and tbar in LO ttbar production
- Radiative corrections and interference in NLO lead to asymmetry in differential t and tbar distributions:



- qqbar asymmetric
- gg symmetric
- qg asymmetric (but negligible)

$$\hat{A}(\cos\hat{\theta}) = \frac{N_t(\cos\hat{\theta}) - N_{\bar{t}}(\cos\hat{\theta})}{N_t(\cos\hat{\theta}) + N_{\bar{t}}(\cos\hat{\theta})}$$



Hadron colliders:
difficult to reconstruct the partons 4-vectors.
Then, look at variables in the lab. frame.
In particular:

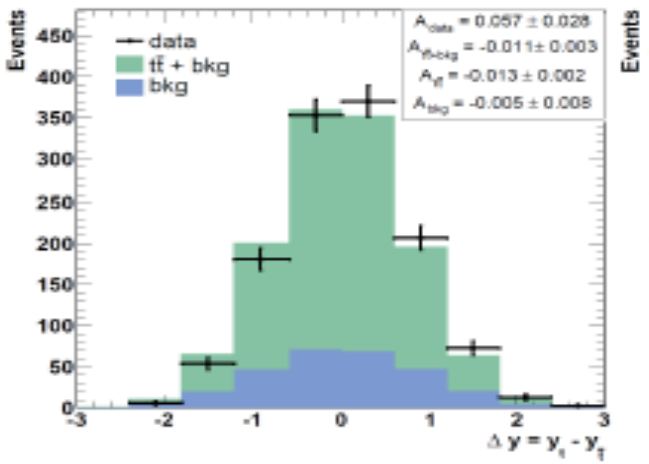
$$\hat{\vartheta} \rightarrow \Delta Y = Y_t - Y_{\bar{t}}$$

TEVATRON RESULTS (1)

Semileptonic channel (e,μ), ≥ 1 b-tag, χ^2 top reconstruction with W, top mass constraints

inclusive $\Delta y = q \cdot (y_l - y_h)$

data level

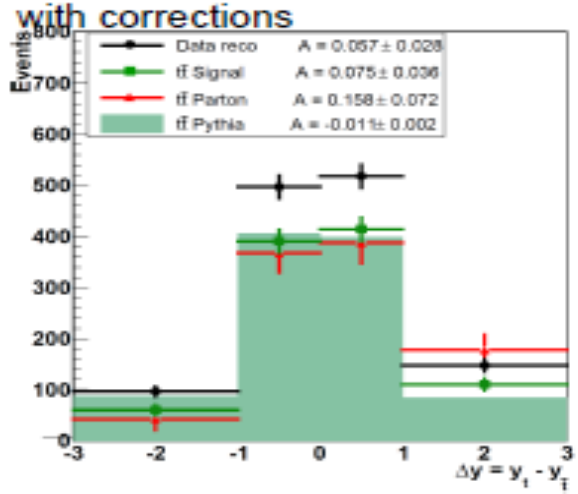


sample	level	$A^{t\bar{t}}$
data	data	0.057 ± 0.028
MC@NLO	$t\bar{t}$+bkg	0.017 ± 0.004

then

- bkg subtract
  - yields tt "signal" at reco level
- unfold acceptance & resolution
  - yields tt at "parton level"

with corrections



sample	level	$A^{t\bar{t}}$
data	data	0.057 ± 0.028
MC@NLO	$t\bar{t}$+bkg	0.017 ± 0.004
data	signal	0.075 ± 0.037
MC@NLO	$t\bar{t}$	0.024 ± 0.005
data	parton	0.158 ± 0.074
MCFM	parton	0.058 ± 0.009

Unfolded result: 0.158 ± 0.074 (QCD 0.058 ± 0.009)

TEVATRON RESULTS (2)

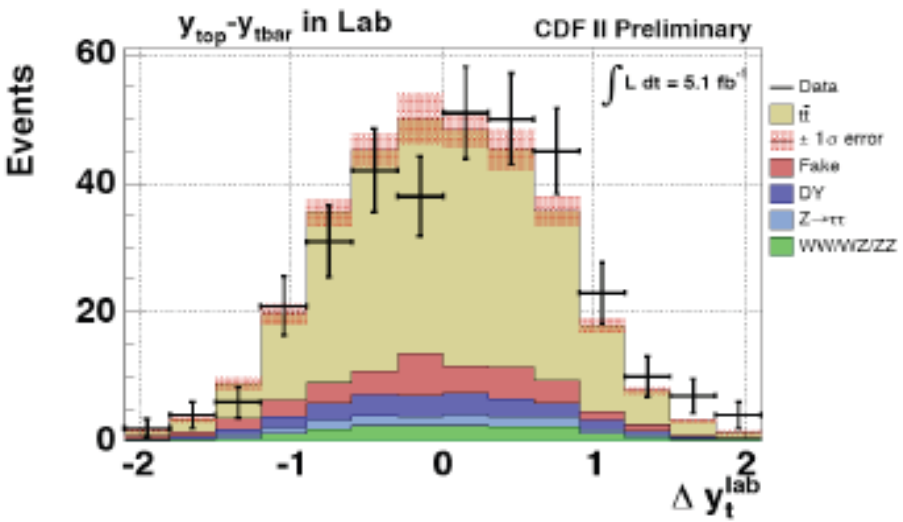
Dileptonic channel (e,μ), ≥ 2 jets, HT > 200 GeV, MET > 25 GeV.

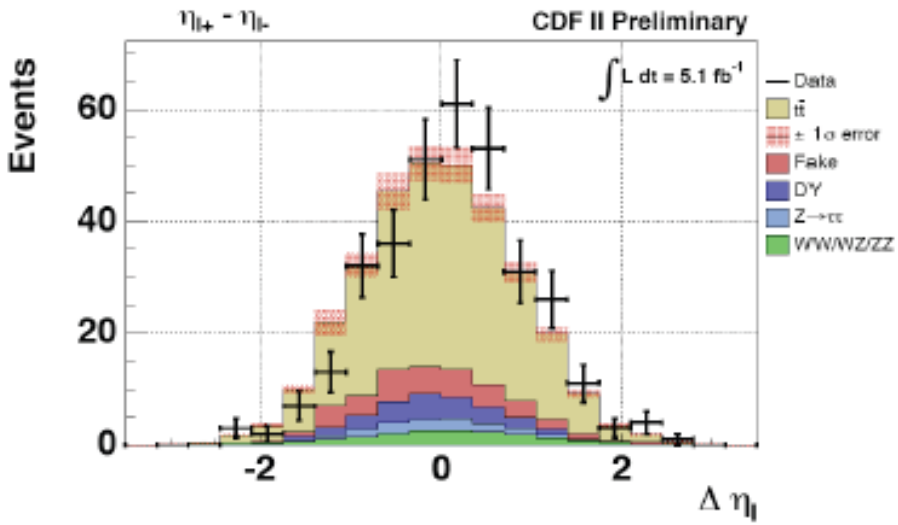
tt system reconstruction

Kinematic likelihood fit +
W and top mass constraints

Leptons informations

Look at $\Delta\eta$ between leptons, quite well correlated with ΔY





$A_{obs}^{\Delta y_t} = 0.138 \pm 0.054$

$A_{pred}^{\Delta \eta_l} = -0.015 \pm 0.023$

0.417 ± 0.157
Unfolded

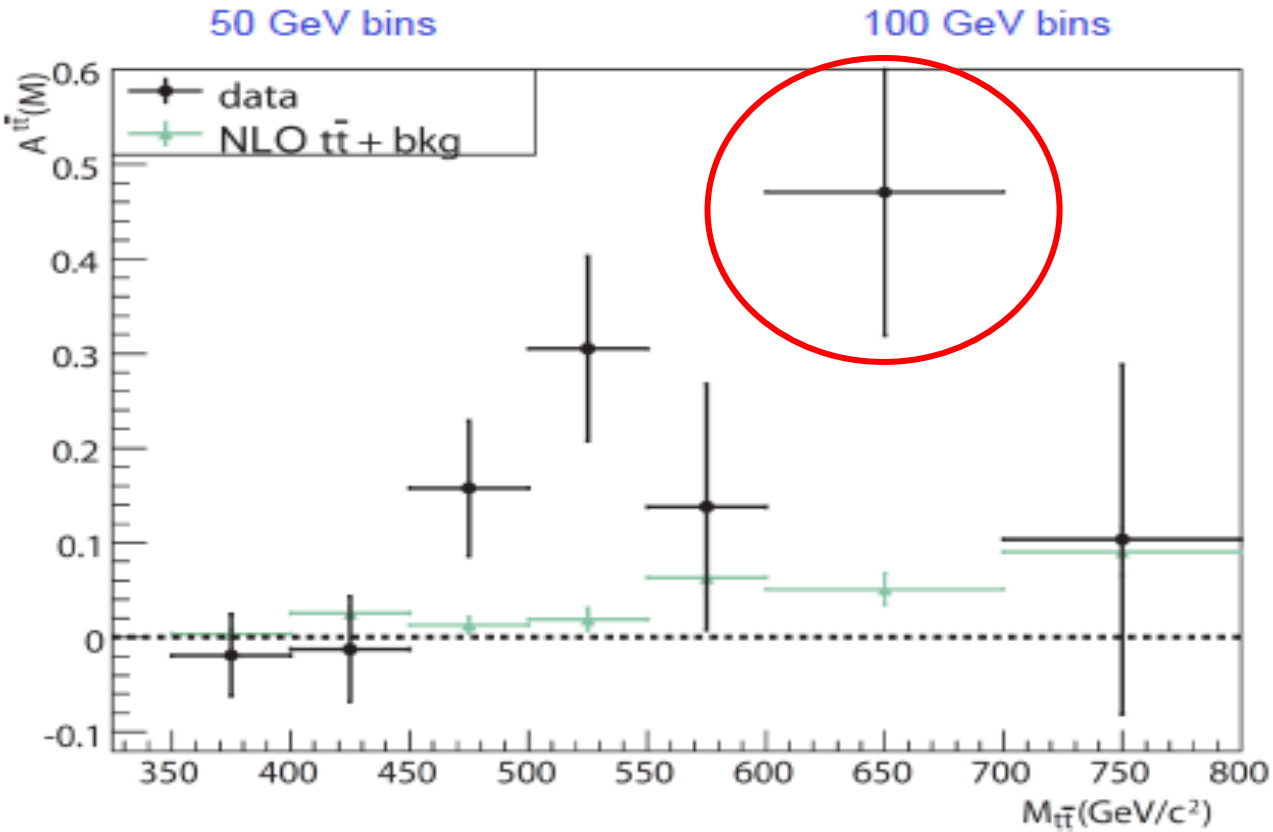
$A_{obs}^{\Delta \eta_l} = 0.138 \pm 0.054$

$A_{pred}^{\Delta \eta_l} = -0.022 \pm 0.022$

TEVATRON RESULTS (3)

$A^{tt}(M_{tt,\,i})$

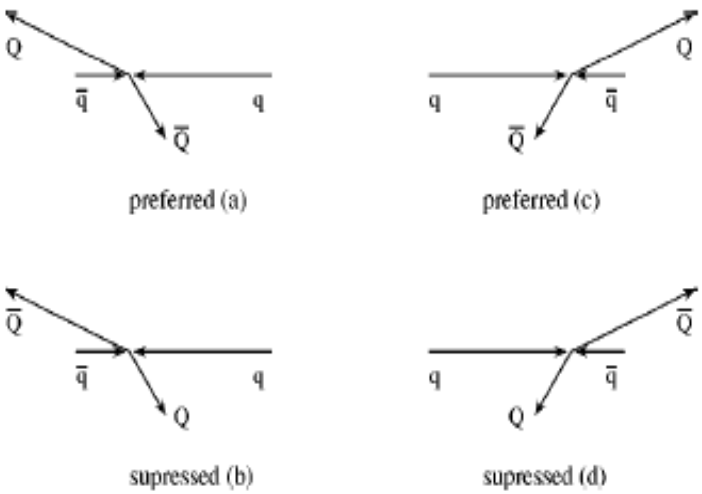
Asymmetry as a function of ttbar invariant mass…



selection	all M	$M < 450$ GeV/c^2	$M \geq 450$ GeV/c^2
reco data	0.057±0.028	-0.016±0.034	0.212±0.049
MC@NLO	0.017±0.004	0.012±0.006	0.030±0.007

Which asymmetry @ LHC ?

- pp collider → gg dominates the tt production (~80%) + asymmetry is a tiny NLO effect present only in qq events;
- In qq events one cannot distinguish the direction of the quark → ΔY and $\Delta\eta$ symmetric, need other variables.
- Use the pdf: valence q are more boosted than sea anti-q;



- use ΔY and $\Delta\eta$ + request Y(tt) >0 (or < 0);
- use $\Delta|Y|$ and $\Delta|\eta|$ (as CMS) ;

TRUTH STUDIES (Udine):

MC@NLO tt (8.6 fb-1):

qq sample → $A(\Delta|Y|) = 0.027 \pm 0.004$

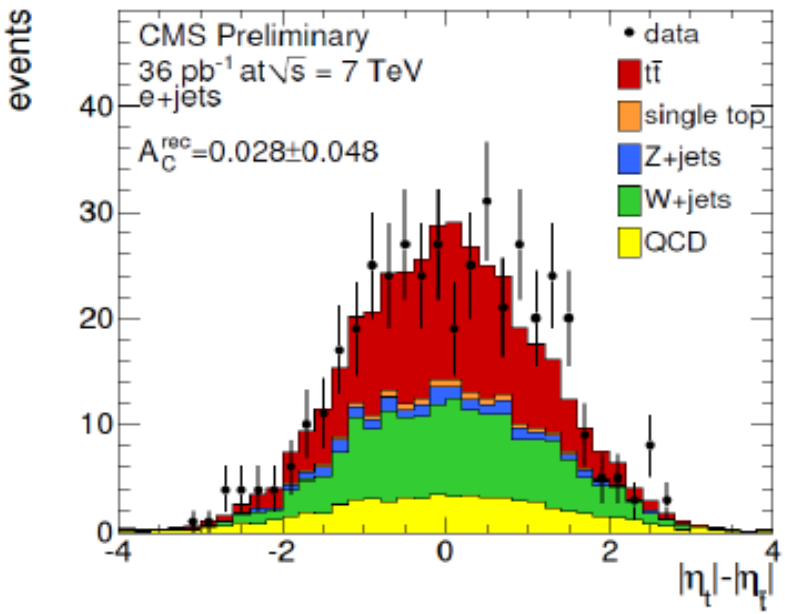
gg+qq sample → $A(\Delta|Y|) = 0.009 \pm 0.002$

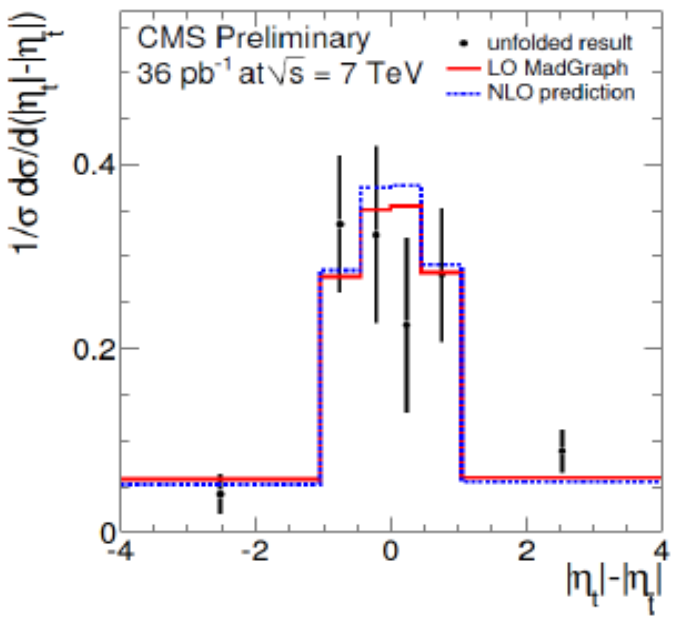
Very challenging measurement with 1 fb^{-1}!!!

CMS RESULTS

CMS measurement:

- Asymmetry variable: $|\eta_t| - |\eta_{\bar{t}}|$ $\qquad A_C = \dfrac{N^+ - N^-}{N^+ + N^-}$
- SM prediction: $A_C^{SM} = 0.0130(11)$





- Observation: $A_C = 0.060 \pm 0.134(\text{stat.})$

ATLAS situation

Common effort: no different analyses to measure the asymmetry.
The collaboration among different institutes just started based on a Twiki where all the groups involved put their interests.
We have studied both single and dilepton channels: even if dilepton signal is cleaner, the lower cross-section and difficulty to reconstruct the tt system make this measurement more difficult with the target int. luminosity of 1 fb-1.

Italian interests: single lepton channel

- tt selection: **BO, MI, UD** + Barcelona , Annecy;
- tt reco: **BO, MI, UD** (χ2 method) + Gottingen, Barcelona (KL fitter);
- Background est. : QCD (**UD**), W+jets (**UD, MI**) + Barcelona;
- Observables: **BO, MI, UD**;
- Unfolding: **BO** + Hamburg

- Following the tt cross-section experience, we are already clustered and coordinated in our activities.
- Weekly-based meeting to update our studies and common talks at the WG (bi-weekly).
- No other groups (apart those above) seem interested in single-lepton channel, but never say never...

Goals & timescale

- goal:
  - draft of journal publication ready for approval on the time scale of the EPS conference
  - preliminary result if time is too short

- timescale for EPS:

https://indico.cern.ch:443/getFile.py/access?contribId=2&resId=1&materialId=slides&confId=133328

- INT note posted on June 10th with dataset for pre-approval
- INT note posted on June 27th on the full dataset

Proposed EPS schedule – working backwards

- Thu July 21- Conference starts
- Mon July 18 – Final reader approval
- Tue July 12 – ATLAS approval meeting
- Mon July 4 – CONF note circulation
- Tue June 28 – top-wg approval on full data
- Mon June 27 – INT/CONF on full data posted
- Wed June 22 – full dataset available for analysis
- Wed June 15– End of LHC run
- Tue June 14 – top-wg analysis pre-approval
- Fri June 10 - INT note posted
- Fri June 3 – Cut dataset for preapproval
- Thu May 19– Signoff on TopPhys production cache
- Sat May 14– Start of LHC run
- Thu May 12 – Finalization of object definitions

5.5 weeks approval time starting from pre-approval

VERY TIGHT SCHEDULE!!

2 weeks available for analysis of full data to pre-approval

5 weeks available for analysis (from ~100 pb-1 to pre-approval)

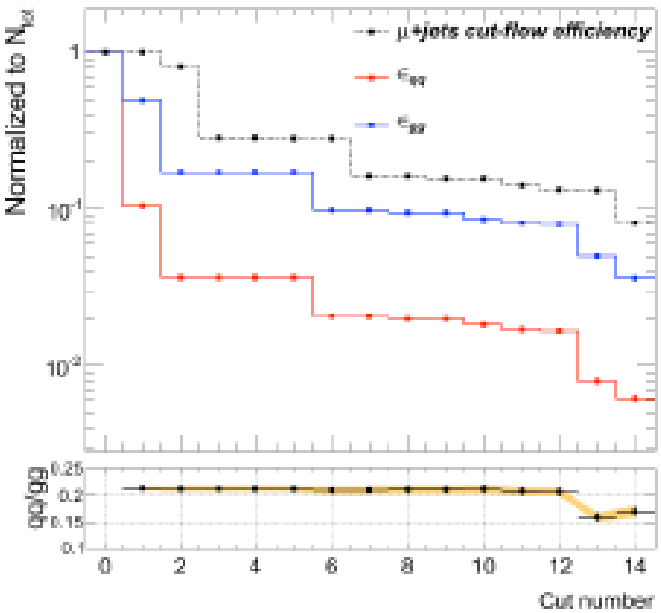
+2 weeks to final approval for both

from W. Werkerke

Selection/reconstruction issues (1)

Evaluate the number of tt events (MC@NLO) passing cuts and evaluate the efficiencies and the ratio **qq/gg**

Effect of selection cuts on qq fraction II



SELECTION CUTS	
1.	All events
2.	Trigger
3.	Good vertex
4.	Jet/MET cleaning
5.	# mu > 0
6.	# mu = 1
7.	# el = 0
8.	Trigger match
9.	el/mu overlap removal
10.	MET>20 GeV
11.	MET + W_mT > 65 GeV
12.	2j25
13.	4j25
14.	1 b-tag

- Our selection is enhancing gg contribution:
  - more jets in event coming from gg production mechanism
- Optimization? BUT it's dangerous to optimize something that is not completely under control (PDF uncert, qg channel?, etc..)
- Since this enhancement is not dramatic, we can live with this selection for the moment and then provide an optimized selection or a likelihood later on.

μ channel from Bologna

-Moriond cuts seems to slighlty enhance the gg (blue) fraction w.r.t the qq (red);
- Same for e channel

Selection/reconstruction issues (2)

Comparison between χ^2 fitter and CSC reconstruction method I

- Comparison between χ^2 fitter and CSC top reconstruction method,
- The fraction of events in which the reconstructed top is within $\Delta R=0.4$ from true top is calculated

CSC Method

t_{had} = m_{jj} maximizing p_T

W_{had} = min $|m_{jj}-m_W^{PDG}|$ in t_{had}

b_{had} = j in t_{had} not in W_{had}

W_{lept} = $l^{\pm}$ + ν(m_W constraint)

b_{lept} = $\Delta R_{min}(W_{lept}, j)$, j not in t_{had}

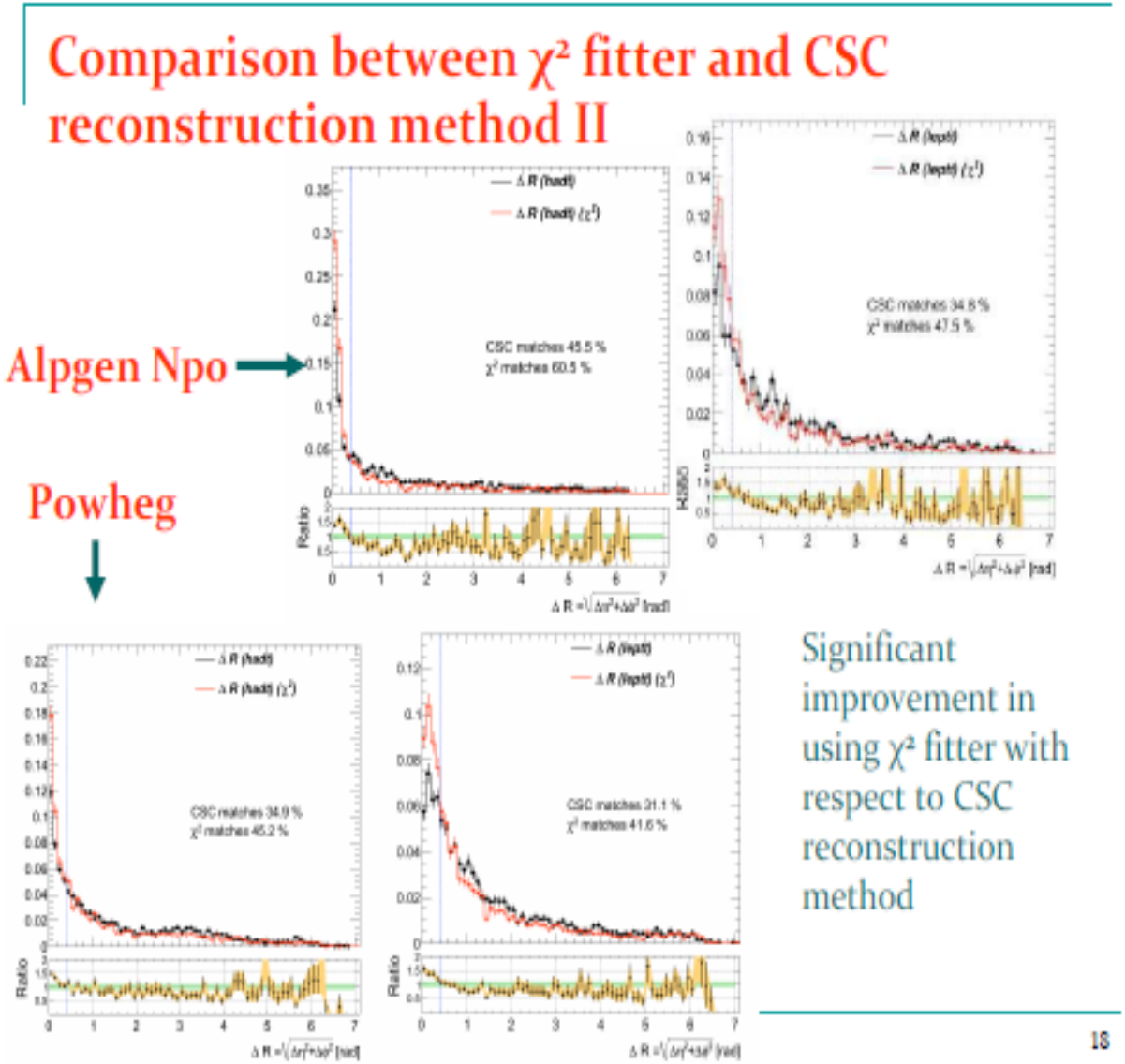
χ^2 fitter

$$\chi^2 = \left(\frac{m_{jjj} - m_t}{\sigma_{had-t}}\right)^2 + \left(\frac{m_{jj} - m_W}{\sigma_{had-W}}\right)^2 + \left(\frac{m_{lvj} - m_t}{\sigma_{lep-t}}\right)^2$$

- σ_{top} ~ 16 GeV, measured from a gaussian fit on m_{jjj} distribution (selected with CSC method) only for events in which all the 4 jets are matched with truth
- σ_W ~ 8.6 GeV, measured from a gaussian fit on m_{jj} distribution only for events in which both the 2 jets are matched with truth
- the fit method works for any number of tagged jets:
  - 0 tagged jets: all combination taken into account,
  - 1 tagged jet: this jet is required to come from top and not from W,
  - 2 tagged jets: both included in top reconstruction mass,
  - >2 tagged jets: 2 of them included in top reconstruction

Under study the addition of the jet resolution term into the formula.

Selection/reconstruction issues (3)



From BO:
-Evaluation of the matching between reco and truth tops;

- CSC vs $\chi 2$ method;
- $\chi 2$ better than CSC (60% vs 45% in $\Delta R<0.4$);

From UD:
- Effect of the reco algorithms on ΔY:
- 76% efficiency in correctly reconstructing ΔY sign (70% with CSC)

Do selection cuts affect the asymmetry?

Asymmetry changes after selection cuts: acceptance or detector effect?
To disentangle: look at the truth info for events passing the reco cuts.
In particular evaluate charge asymmetry using **truth tops 4-vectors** after:
- No selection cuts;
- Acceptance cuts on the truth objects (PT, η, MET);
- Reconstruction cuts;

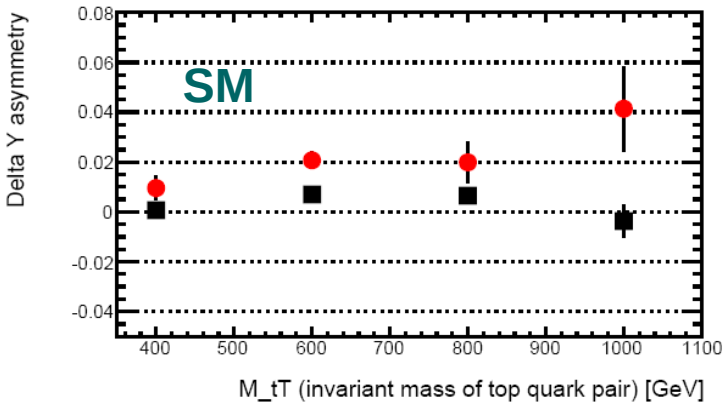
In addition, following B. Webber suggestions, we prepared a reweighting tool that change the weight of qq events in order to simulate the excess measured by CDF at high inv.mass of the ttbar system:

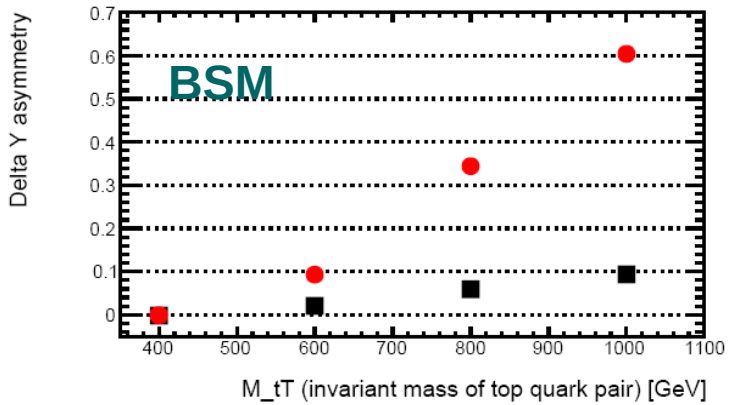
$$1+ f(m_{t\bar{t}})\tanh(\Delta y/2) \text{ where } f(m_{t\bar{t}}) = m_{t\bar{t}}/(200GeV) - 2$$

In practice, instead of simulating dozen of BSM samples, one introduces a fictitious contribution following what CDF measured...cheapest and easiest!!
STUDY: evaluate the evolution of the asymmetry w.r.t ttbar inv.mass and production mechanisms.

Do selection cuts affect the asymmetry?

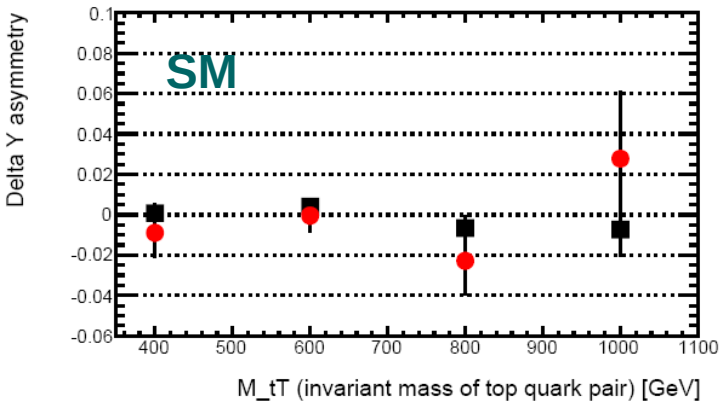
From Milano

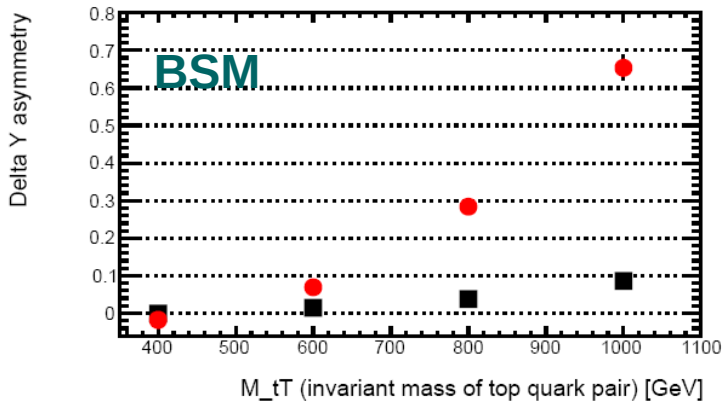




NO selection cuts applied

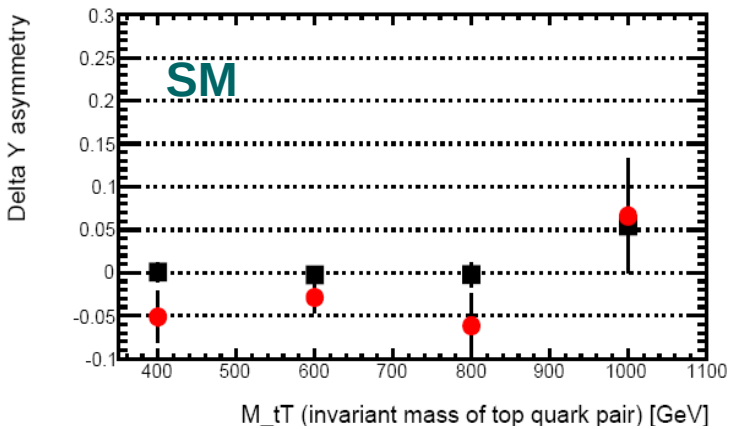
- ALL
- qq

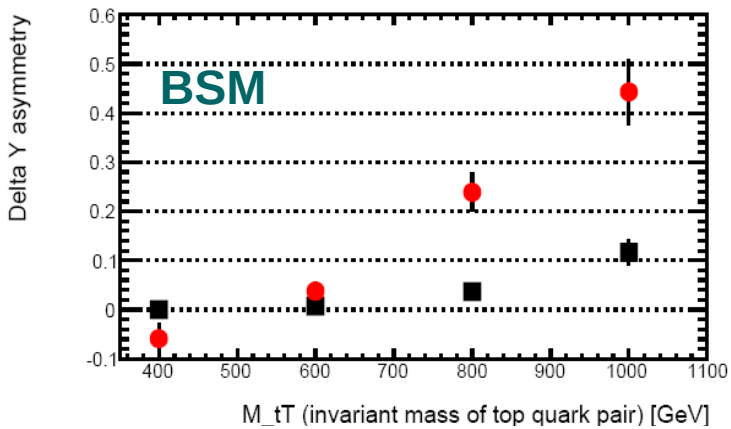




selection at MC level

- ALL
- qq





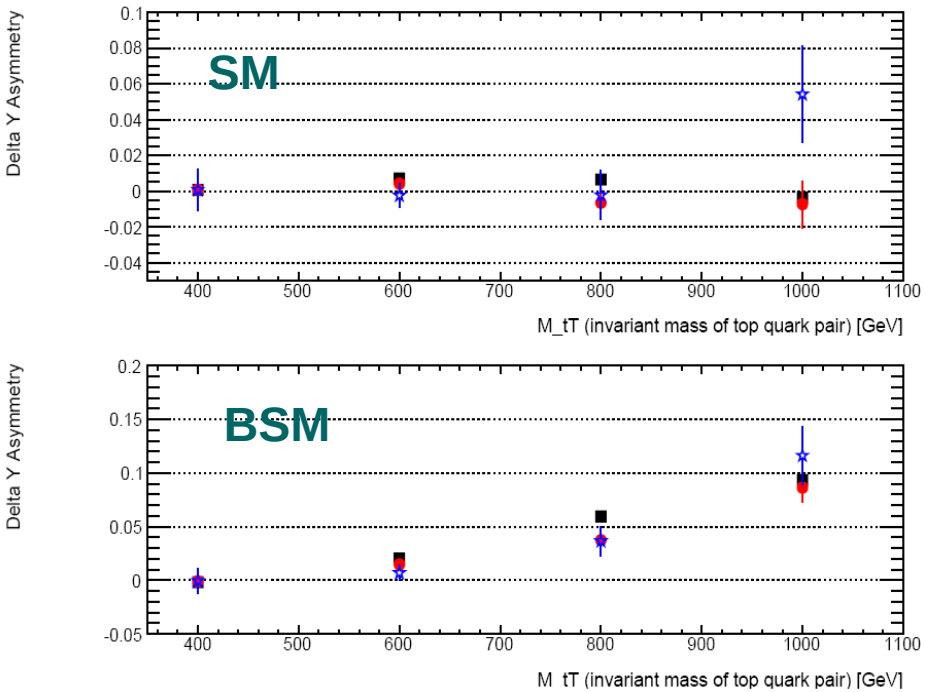
selection at RECO level

- ALL
- qq

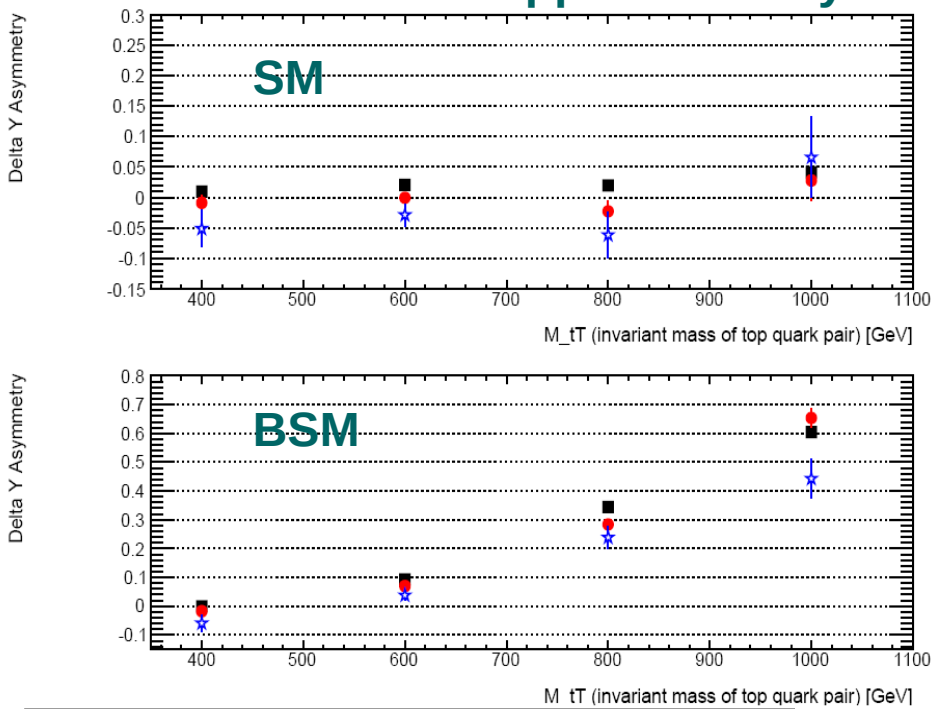
Do selection cuts affect the asymmetry?

From Milano

ALL events



qq events only



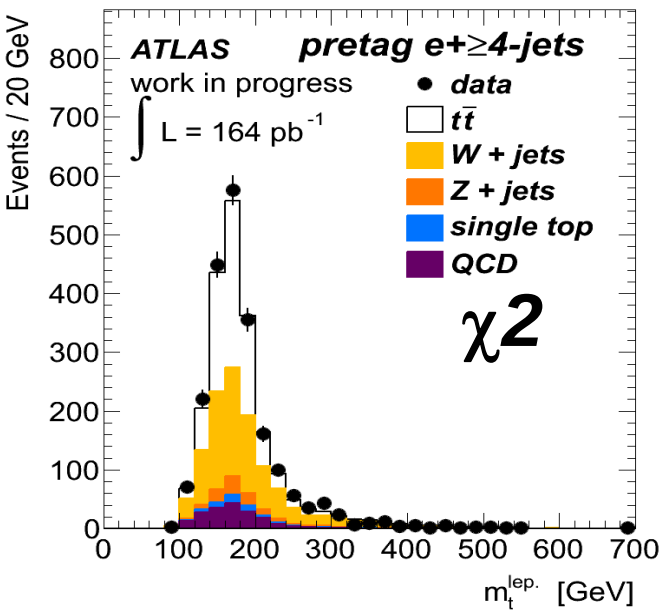
- NO selection cuts
- selection cuts at MC level
- * selection cuts at RECO level

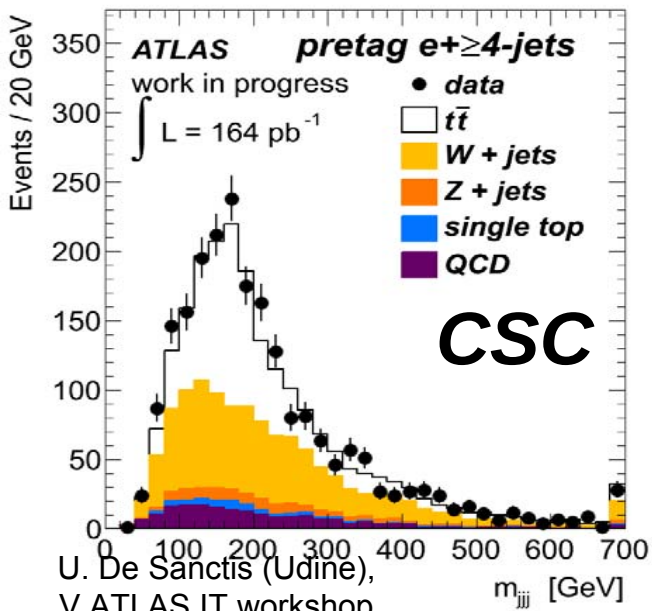
Conclusions:

- Asymmetry diluted at the reco level (visible in BSM sample rich in qq);
- Not so trivial to disentangle…need unfolding and more careful investigation on MC acceptance;
- Estimated significance: 2σ (only stat) with 1 fb^{-1} for M(tt) > 800 GeV.

2010/2011 DATA (1)

- DATA 2010 + 2011 (B2-D6 period); MC10a (with pile-up);
- Selection cuts as Moriond: (PT(lep) > 20 GeV, MET>20 GeV, at least 4 jets with PT> 25 GeV) BUT PT threshold for electron raised to 25 GeV (e20 is used in 2011 data);
- MC rescaling using the pileup reweighting tool;
- Top reco algorithms: $\chi 2$ and CSC methods;
- No lepton or b-jet scale factors used;
- QCD estimation: matrix method





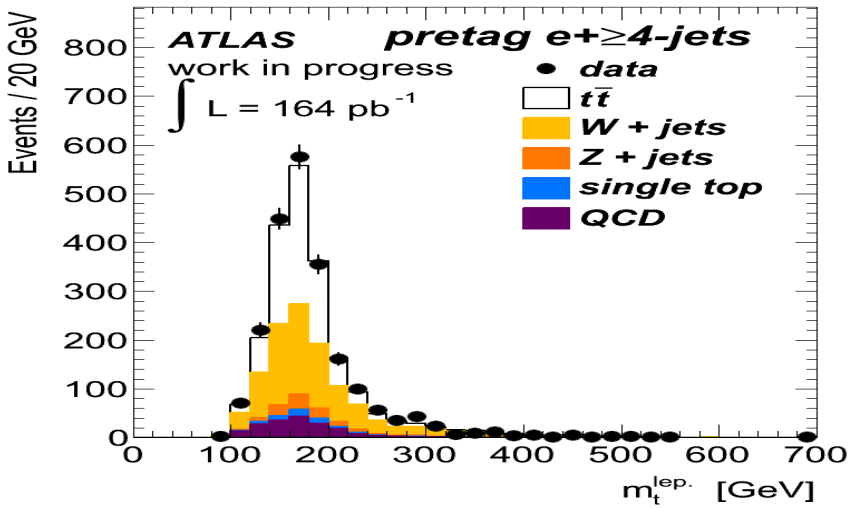
Improvement in hadronic top mass using $\chi 2$

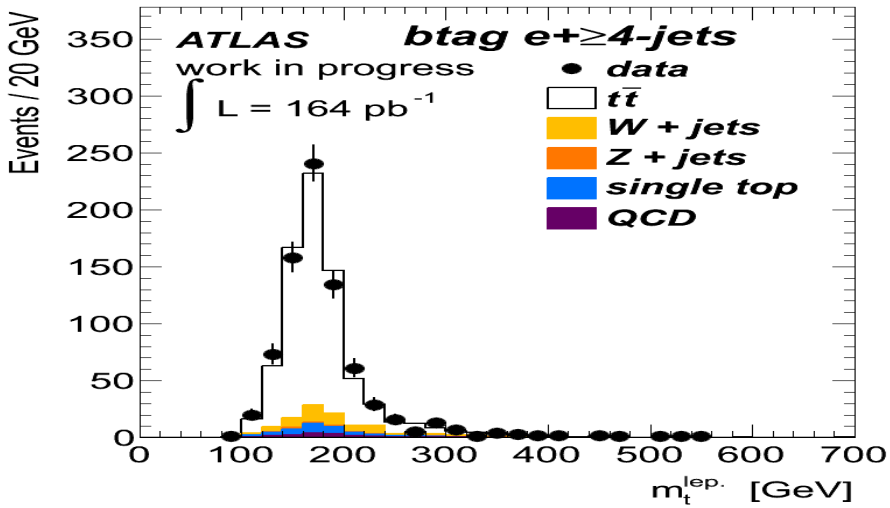
From Udine

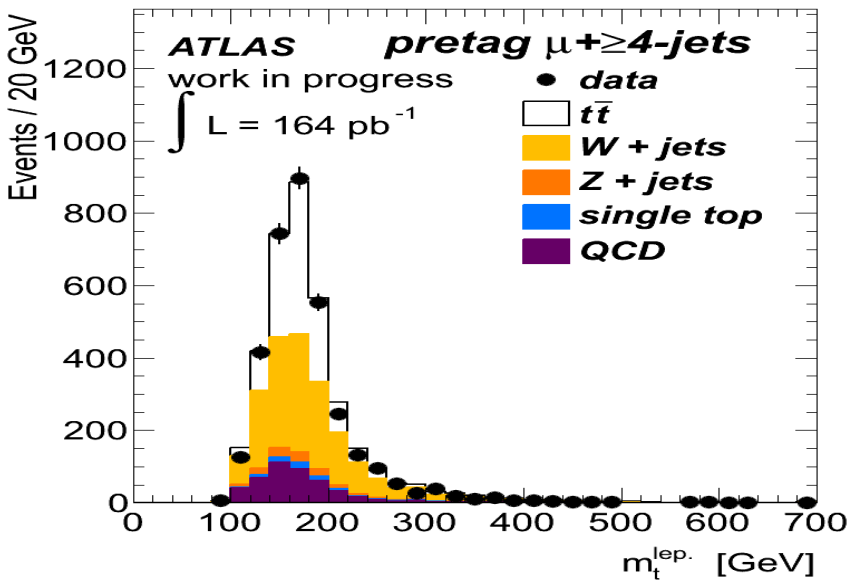
2010/2011 DATA (2)

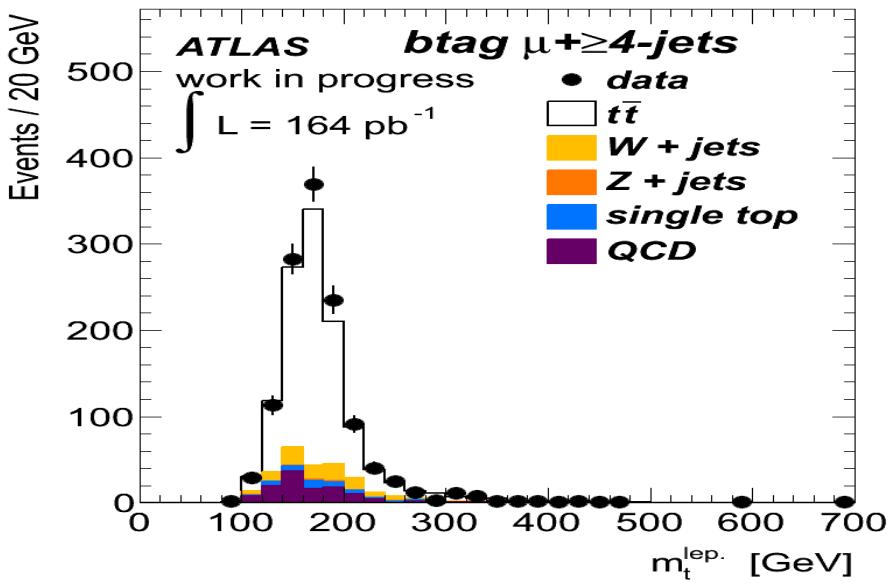
From Udine

$\chi 2$ method for all plots





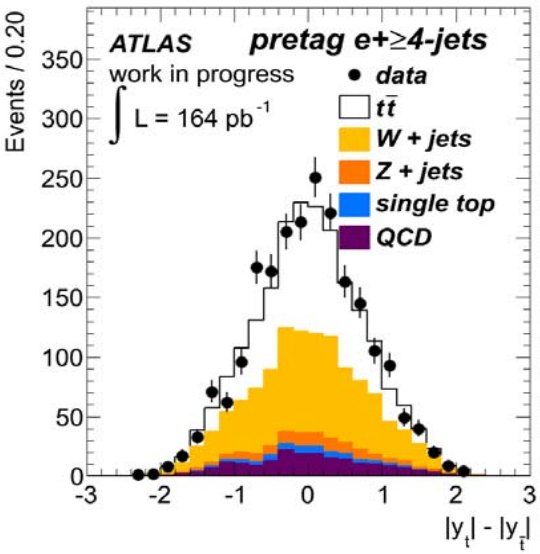


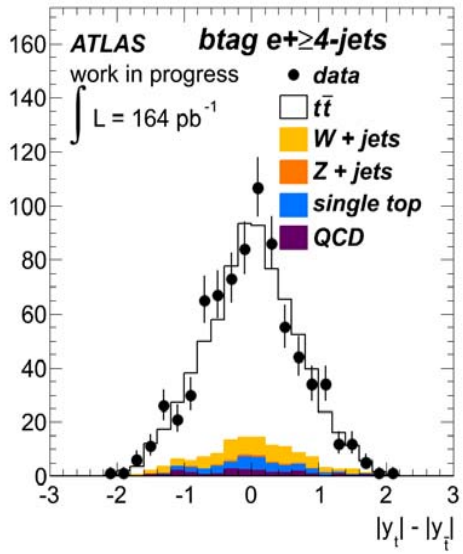


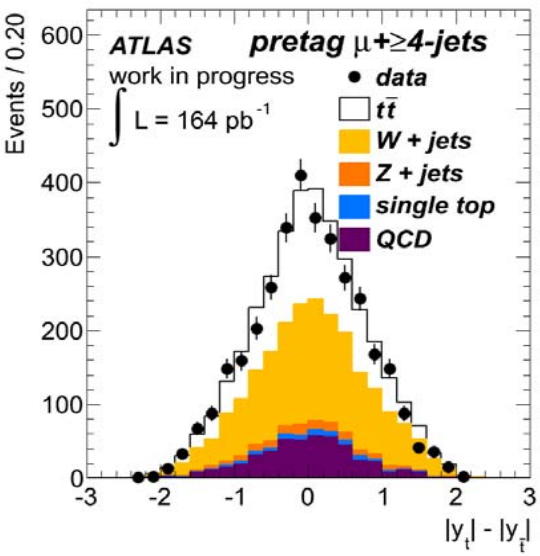
2010/2011 DATA (3)

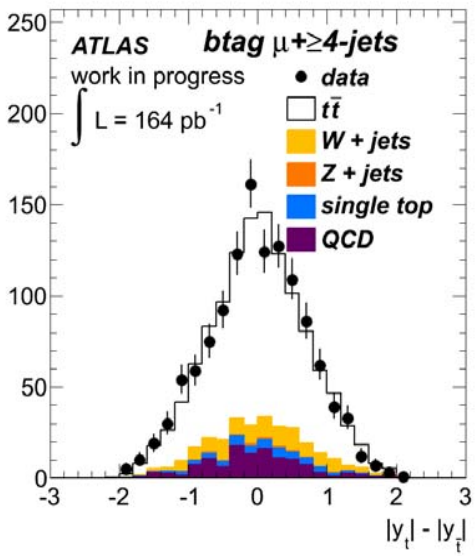
$\chi 2$ method for all plots

From Udine









$$A = \frac{N(\Delta > 0) - N(\Delta < 0)}{N(\Delta > 0) + N(\Delta < 0)}$$

where Δ=|Ytop| - |Yantitop|

- No unexpected huge asymmetry ☹ ;
- A = -0.080 ± 0.046 (μ pre-tag);
  A = -0.027 ± 0.037 (μ b-tag);
- Need data driven estimation of W+jets background (asymmetric?)
- Ask for 2 b-tags: less background but dominated by the statistical errors;

Udine),
orkshop

Conclusions & outlooks

- The effort to measure the charge asymmetry in ttbar events started;
- Difficult measurement, but feasible with some fb-1;
- Italian cluster is working well (good information flow, regular meetings, real collaboration and tasks division) and also our contribution to the WG is clearly visible;
- ATLAS effort just started. We will have a tight schedule to fit within EPS deadline;
- Still some technicalities to be put in place (pile-up, KL fitter, systematics);
- We are finishing a preliminary phase: the discussion about tools, variables and tasks in the WG will be finalized soon and the hunt will be open….