$t\bar{t}$ charge asymmetry

ATLAS and CMS experimental status and combinations plans

CHARGE ASYMMETRY CMS ATLAS COMBINATION

Thorsten Chwalek (CMS), Frédéric Déliot (ATLAS), Frank Roscher (CMS) Francesco Rubbo (ATLAS)

Irfu
Institut de recherche sur les lois fondamentales de l'Univers

TOPLHCWG meeting, CERN, 12-January-2015

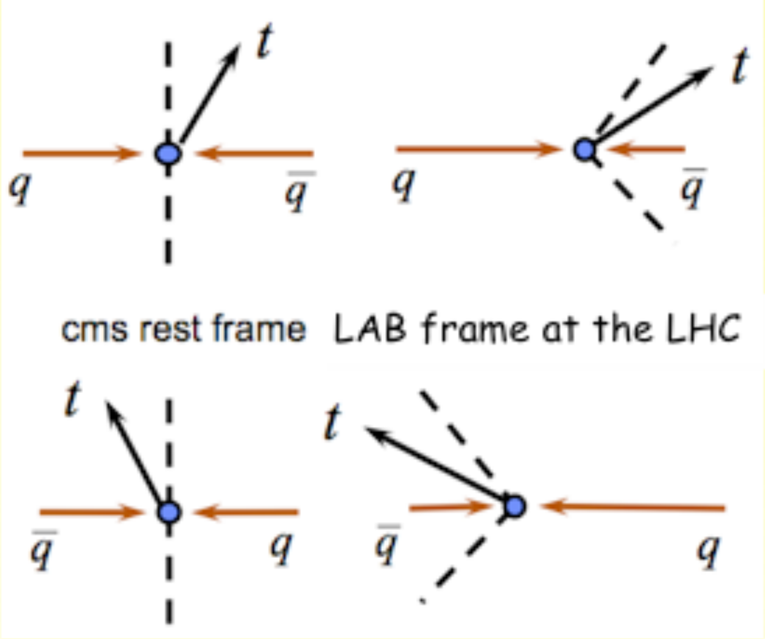
$t\bar{t}$ charge asymmetry at the LHC

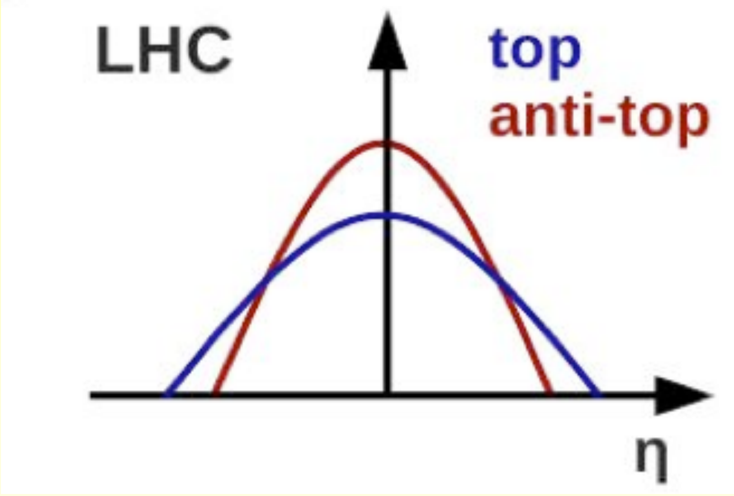
- At NLO, QCD predicts an asymmetry for $t\bar{t}$ produced via $q\bar{q}$
- At LHC, $t\bar{t}$ mainly produced via gg fusion which is symmetric
  - in the lab frame, top quarks preferentially emitted in the forward/backward directions while antitop quarks are produced more centrally
- Charge asymmetry observable:

$$A_C = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}$$

$$\Delta|y| \equiv |y_t| - |y_{\bar{t}}|$$

using the top/antitop or the leptons from the top/antitop





central-forward/backward asymmetry

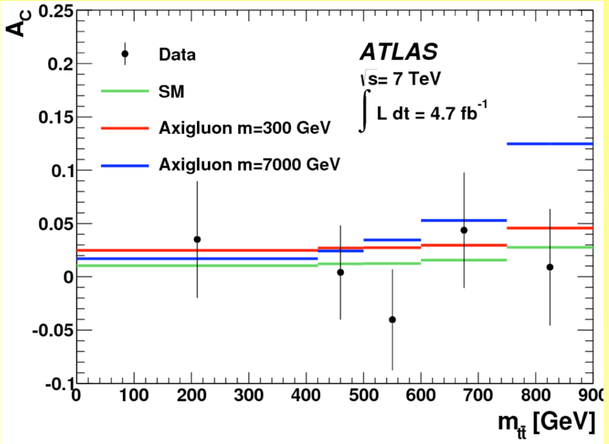
small at LHC since low $q\bar{q}$ fraction

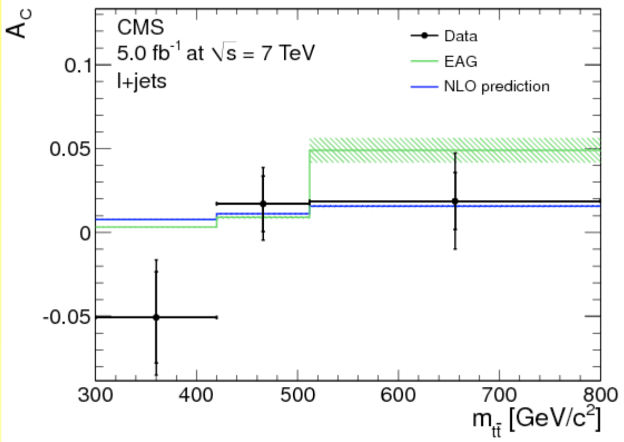
- Theory prediction:

  Ac ~ 0.010

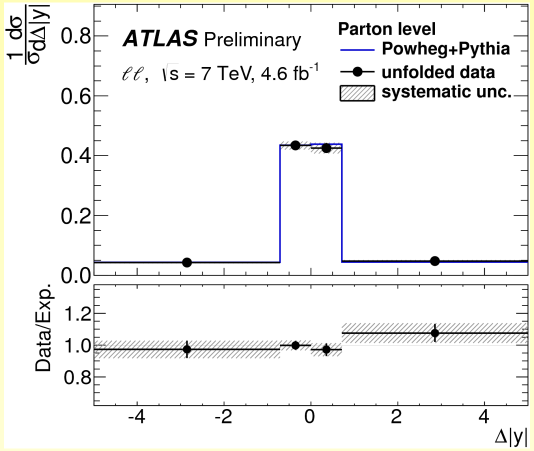
LHC measurements ($t\bar{t}$-based)

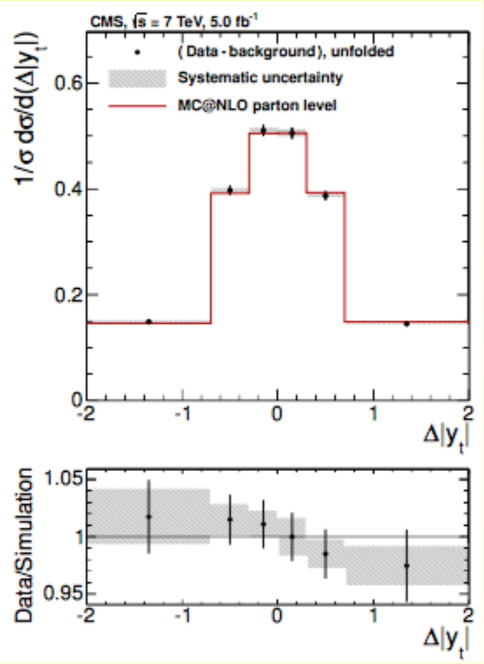
- lepton+jets 7 TeV (published)
  - ATLAS (4.7 fb^{-1}): JHEP02, 107 (2014)
    Ac = 0.006 ±0.010 (stat. + syst.)
  - CMS (5.0 fb $^{-1}$): PLB 7171, 129 (2012)
    Ac = 0.004 ±0.010 (stat.) ±0.011(syst.)



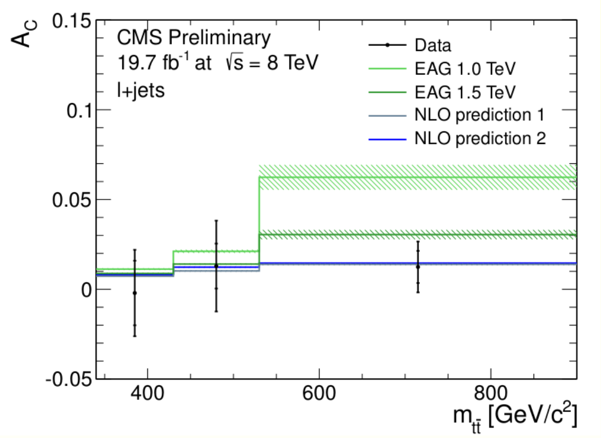


- dilepton 7 TeV
  - ATLAS (4.7 fb^{-1}): Top2014, in review
    Ac = 0.021 ±0.025 (stat.) ±0.017 (syst.)
  - CMS (5.0 fb $^{-1}$): JHEP 04 (2014) 191
    Ac = -0.010 ±0.017 (stat.) ±0.008 (syst.)





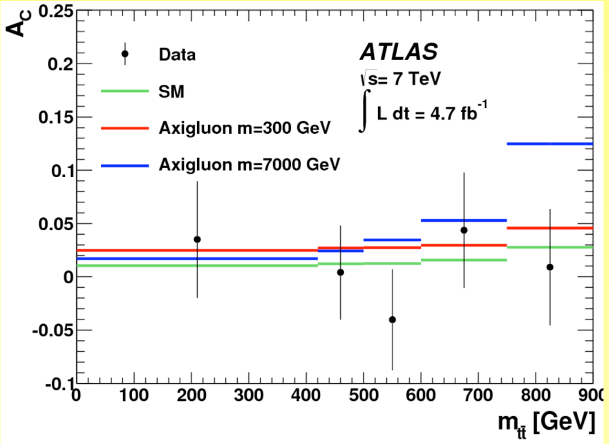
- lepton+jets 8 TeV (preliminary)
  - CMS (19.7 fb $^{-1}$): CMS PAS TOP-12-033
    Ac = 0.005 ±0.007 (stat.) ±0.006 (syst.)

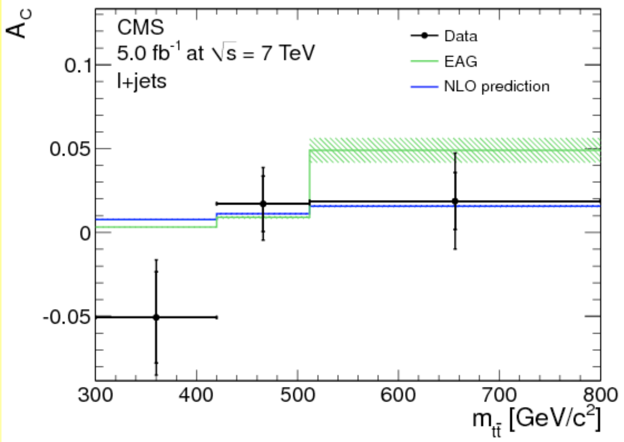


LHC measurements ($t\bar{t}$-based)

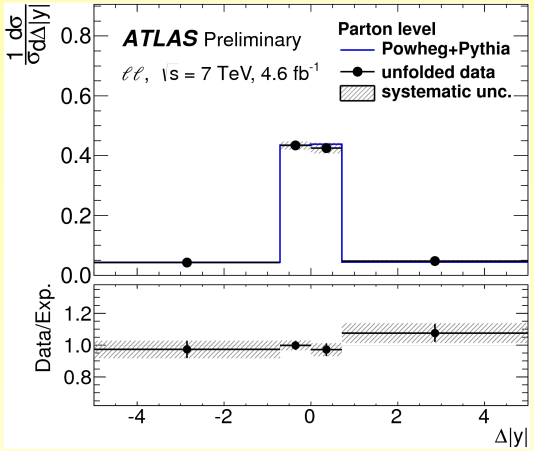
- lepton+jets 7 TeV (published)
  - ATLAS (4.7 fb^{-1}): JHEP02, 107 (2014)
    Ac = 0.006 ±0.010 (stat. + syst.)
  - CMS (5.0 fb^{-1}): PLB 7171, 129 (2012)
    Ac = 0.004 ±0.010 (stat.) ±0.011(syst.)

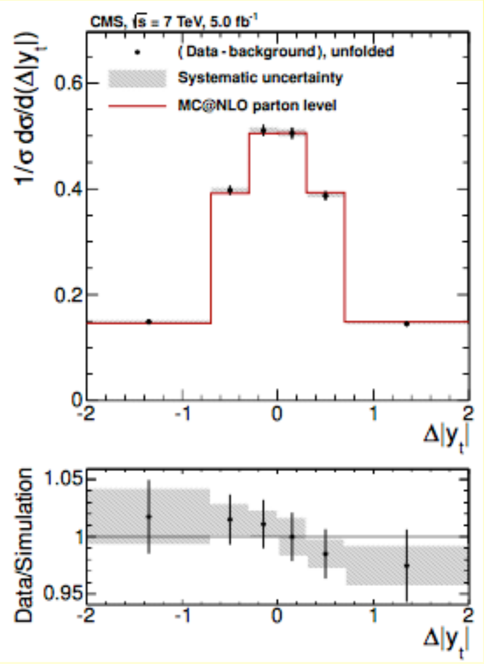
first (simple) combination performed in 2014



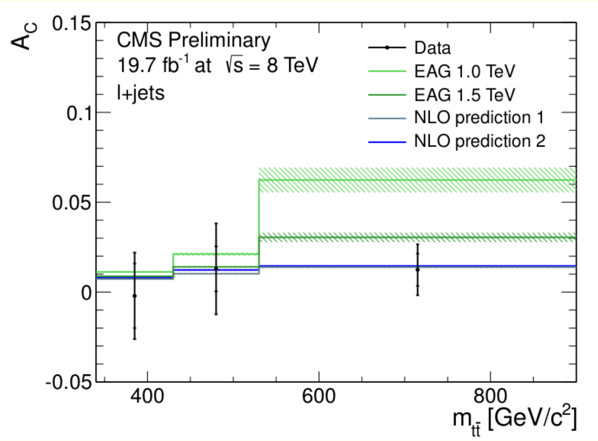


- dilepton 7 TeV
  - ATLAS (4.7 fb^{-1}): Top2014, in review
    Ac = 0.021 ±0.025 (stat.) ±0.017 (syst.)
  - CMS (5.0 fb^{-1}): JHEP 04 (2014) 191
    Ac = -0.010 ±0.017 (stat.) ±0.008 (syst.)





- lepton+jets 8 TeV (preliminary)
  - CMS (19.7 fb^{-1}): CMS PAS TOP-12-033
    Ac = 0.005 ±0.007 (stat.) ±0.006 (syst.)



7 TeV inclusive lepton+jets results

Ac = 0.006 ±0.010 (stat. + syst.)

Ac = 0.004 ±0.010 (stat.) ±0.011(syst.)

- comparison of the two results
  - similar statistical error
  - ATLAS systematics uncertainty negligible due to the marginalization procedure

likelihood from signal/bkg posterior distributions using full bayesian unfolding

marginalization: integration on nuisance parameters

before marginalization

Source of systematic uncertainty	Inclusive
Lepton reconstruction/identification	< 0.001
Lepton energy scale and resolution	0.003
Jet energy scale and resolution	0.003
Missing transverse momentum and pile–up modelling	0.002
Multi–jets background normalisation	< 0.001
b–tagging/mis–tag efficiency	< 0.001
Signal modelling	< 0.001
Parton shower/hadronisation	< 0.001
Monte Carlo statistics	0.002
PDF	0.001
W+jets normalisation and shape	0.002
Statistical uncertainty	0.010

repeat the measurement for each source of systematics

Systematic uncertainty	Shift (±)
JES	0.003
JER	0.002
Lepton ID/sel. efficiency	0.006
Generator	0.001
Hadronization	0.001
Q^2 scale	0.002
PDF	0.002
Pileup	< 0.001
W + jets	0.004
Multijet	0.001
Migration matrix	0.002
Model dependence	0.007
Total	0.011

- first ATLAS+CMS combination using BLUE:
  - using ATLAS result before marginalization:
    Ac = 0.006 ±0.010 (stat) ±0.006 (syst) = 0.006 ±0.011
    (the central value is not significantly affected by marginalization)
  - the two lists of systematics are close (even if sometimes different estimation methods)

7 TeV inclusive lepton+jets combination

- mapping of the different systematics

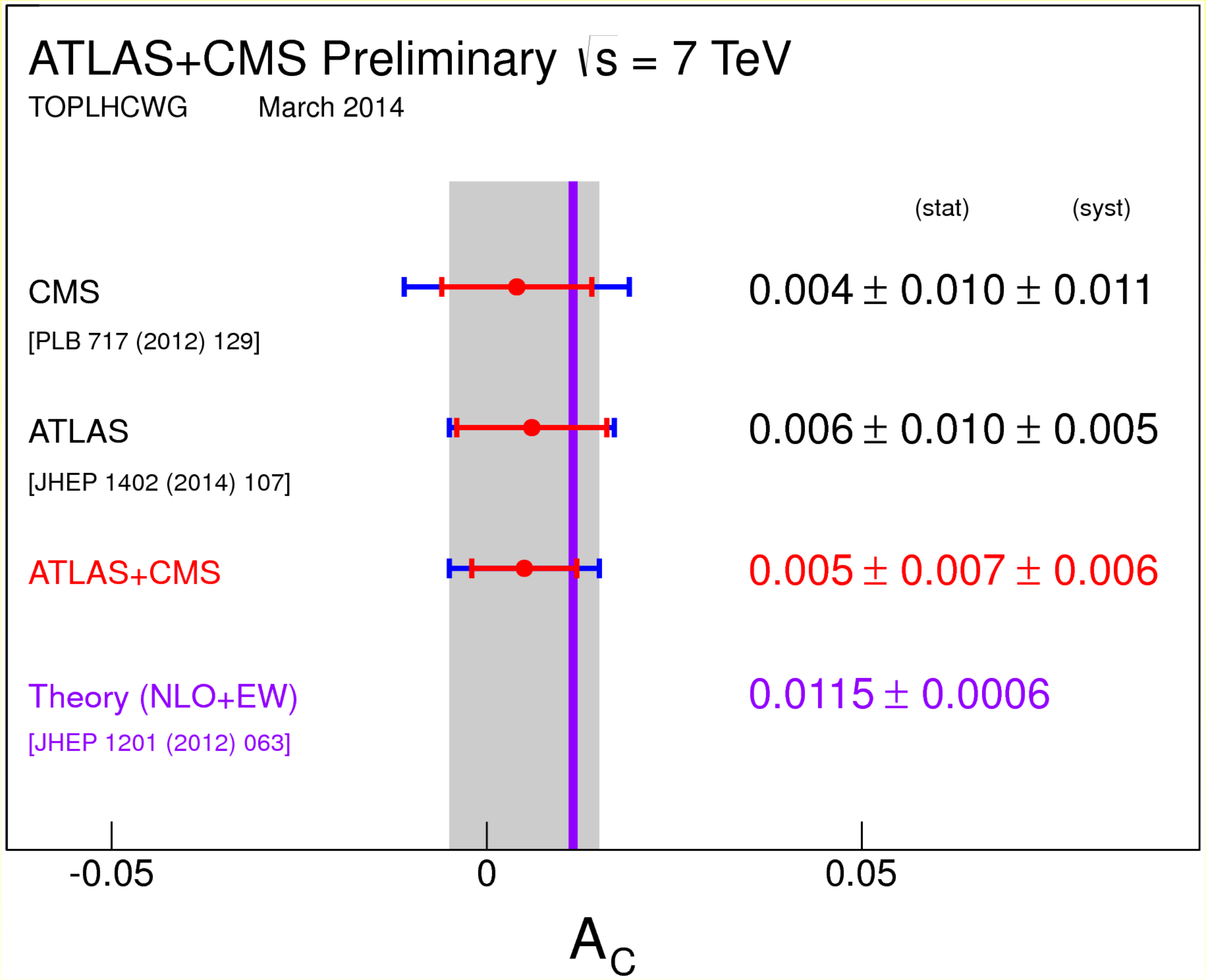
		ATLAS	CMS	Comb.	Corr.
	A_C	0.006	0.004	0.005	0.058
Uncertainties	Statistical	0.010	0.010	0.007	0
	Detector response model	0.004	0.007	0.004	0
	Signal model	< 0.001	0.002	0.001	1
	W+jets model	0.002	0.004	0.003	0.5
	QCD model	< 0.001	0.001	0.000	0
	Pileup+MET	0.002	< 0.001	0.001	0
	PDF	0.001	0.002	0.001	1
	MC statistics	0.002	0.002	0.001	0
	Model dependence				
	Specific physics models	< 0.001	*	0.000	0
	General simplified models	*	0.007	0.002	0
	Systematic uncertainty	0.005	0.011	0.006	
	Total uncertainty	0.011	0.015	0.009	

combination weights:

Estimate	CVW [%]	IIW [%]	MIW [%]	Pull
ATLAS	64.6	67.3	61.7	0.109
CMS	35.4	38.3	32.7	-0.109

ATLAS-CONF-2014-012

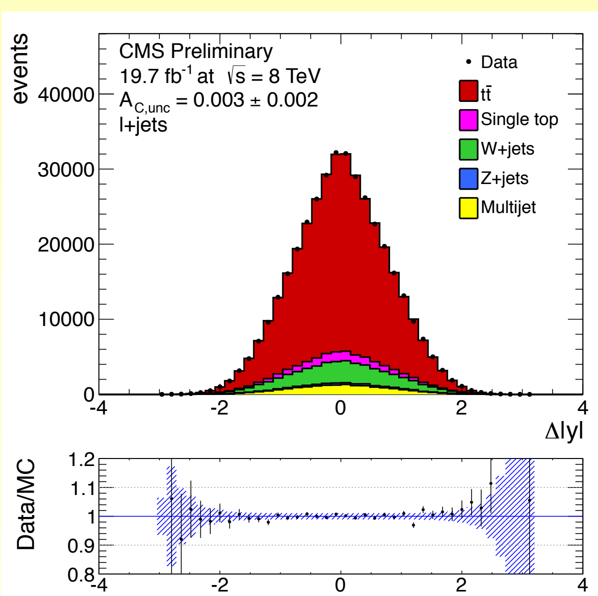
CMS PAS TOP-14-006

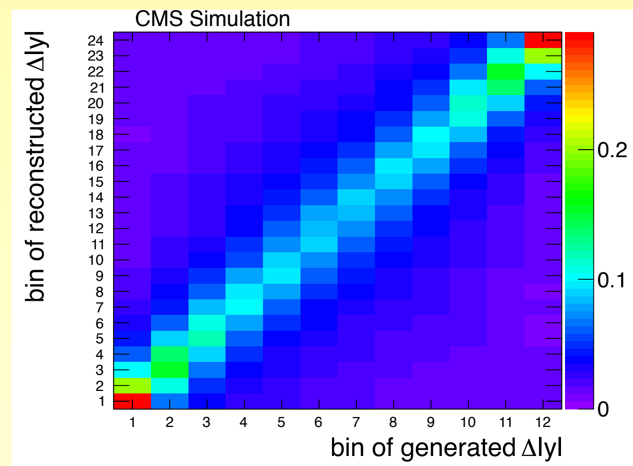


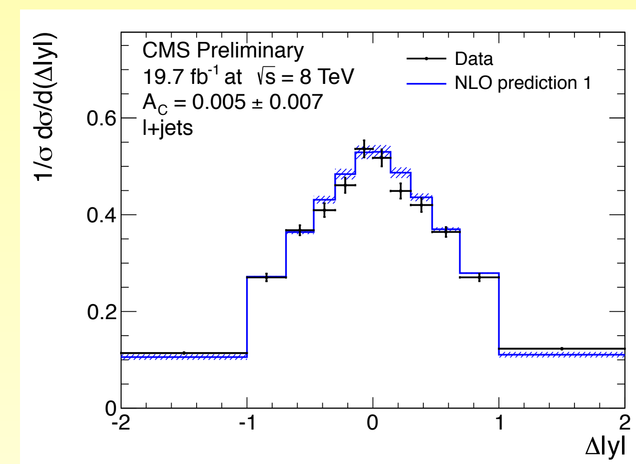
8 TeV lepton+jets CMS result

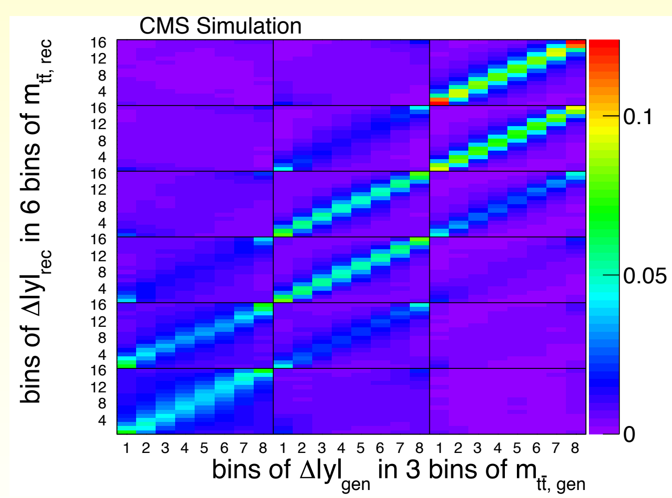
CMS PAS TOP-12-033

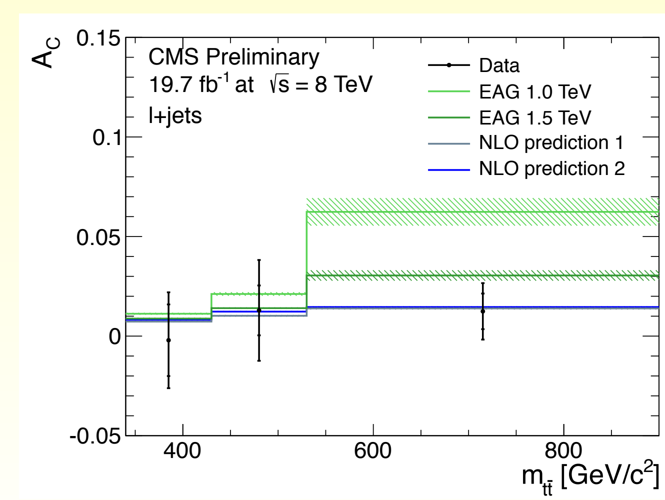
- measurement steps
  - background subtraction
  - unfolding to parton level before selection using generalized matrix inversion: w = S x (x: true spectrum)
  - smearing matrix S: product of migration matrix and diagonal efficiency correction matrix
  - separate migration matrices for inclusive and differential measurements
  - systematics are assessed by performing the measurements with shifted samples according to uncertainties











ATLAS lepton+jets method

7 TeV: JHEP02, 107 (2014)
8 TeV publication in preparation

- fully bayesian unfolding
  - posterior probability of the true spectrum **T**: $p(\boldsymbol{T}|\boldsymbol{D},\mathcal{M}) \propto \mathcal{L}(\boldsymbol{D}|\boldsymbol{T},\mathcal{M}) \cdot \pi(\boldsymbol{T})$
    L: likelihood of observing **D** given **T**, π: prior (can implement a regularization term)

$$\mathcal{L}(\boldsymbol{D}|\boldsymbol{T},\mathcal{M},\boldsymbol{B}) = \prod_{i=1}^{N_r} Poisson(d_i, r_i(\boldsymbol{T},\mathcal{M}) + b_i)$$

element of the response matrix: $m_{ij} = \epsilon_{t_j} \cdot p(r_i|t_j)$

reconstructed spectrum: $r_i(\boldsymbol{T},\mathcal{M}) = \sum_{j=0}^{N_r} m_{ij} \cdot t_j$

  - result: mean of the posterior, uncertainty: RMS

- marginalization
  - extension of the likelihood with nuisance parameter terms θ and η (bkg normalisation):

$$\mathcal{L}(\mathbf{D}|\mathbf{T}) = \int \mathcal{L}(\mathbf{D}|\mathbf{R}(\mathbf{T},\theta),\mathbf{B}(\eta,\theta)) \cdot Gaus(\eta)\, Gaus(\theta)\, \mathrm{d}\theta \mathrm{d}\eta$$

- improvement for 8 TeV analysis
  - splitting in b-tagging multiplicity (inclusion of 0-tag bin)
  - full integration on the nuisance parameters in likelihood

8 TeV lepton+jets combination plan

- likelihood combination

$$p(\mathbf{T}|\mathbf{D}_1,\mathbf{D}_2) \propto (\mathcal{L}(\mathbf{D}_1|\mathbf{T}) \times \mathcal{L}(\mathbf{D}_2|\mathbf{T})) \cdot \pi(\mathbf{T})$$

  - inputs:
    - ATLAS marginalized likelihood: $\mathcal{L}(\mathbf{D}|\mathbf{T}) = \int \mathcal{L}(\mathbf{D}|\mathbf{R}(\mathbf{T},\boldsymbol{\theta}),\mathbf{B}(\boldsymbol{\eta},\boldsymbol{\theta})) \cdot \mathit{Gaus}(\boldsymbol{\eta})\,\mathit{Gaus}(\boldsymbol{\theta})\,\mathrm{d}\boldsymbol{\theta}\mathrm{d}\boldsymbol{\eta}$
    - CMS will « construct » a likelihood using pseudo-experiments:
      * start from the data distribution
      * smear it with MC systematics samples « nominal minus shifted ratio » using gaussians
      * add poisson fluctuations
      * still discuss on how to include the modeling systematics
  - full correlation between experiments implemented by using the same nuisance parameters

- common binning choice for differential combination:
  - 6 bins for $m_{t\bar{t}}$: Atlas binning (0-420,420-500,500-600,600-750,750-900, 900-inf)
  - 3 bins in $pT_{t\bar{t}}$: CMS binning (0-41, 41-92, 92-inf)

- work on-going :
  - machinery for the combination
  - common format to exchange inputs

Conclusion

- ATLAS-CMS charge asymmetry combination
  - first combination performed using 7 TeV ljets measurement
  - using BLUE with ATLAS result before marginalization

- working towards 8 TeV combination
  - need published ATLAS and CMS ljets results
  - plan to perform a likelihood combination
  - both inclusive and differential measurements are planned to be combined
  - will discuss the dilepton channel and the lepton-based asymmetry later