Plans for Top properties analyses @ Run II

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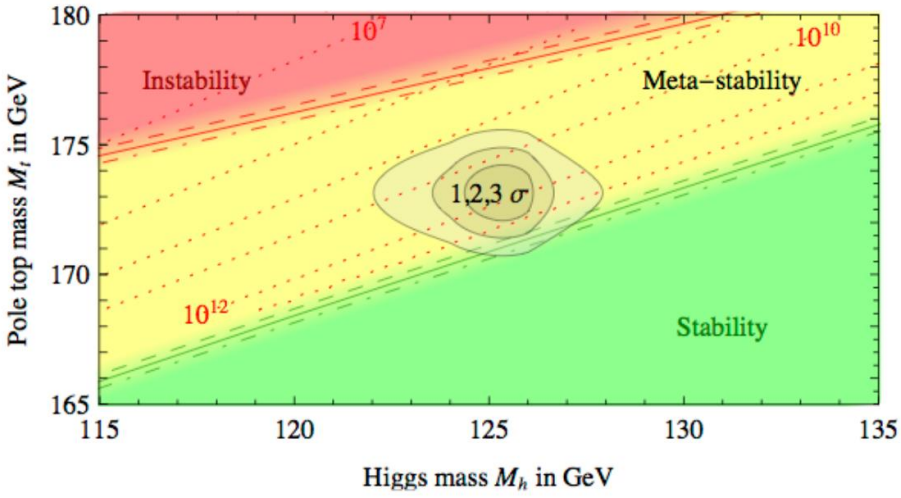
Introduction

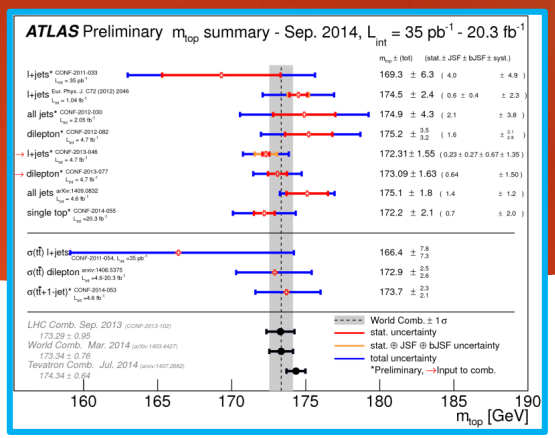
Why top properties?

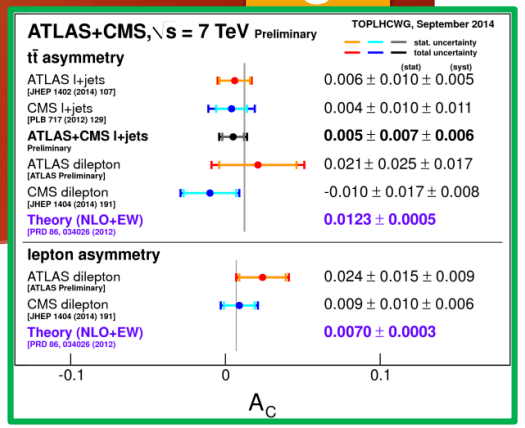
- Fundamental ingredient of the SM
  - Top quark mass
- Precision tests of SM predictions
  - Charge asymmetry
  - Spin correlations
- Can probe new physics
  - Anomalous couplings (→ $t\bar{t}V$)
  - New intermediate particles (anomalies in color flow)
  - FCNC
  - Baryon number violation

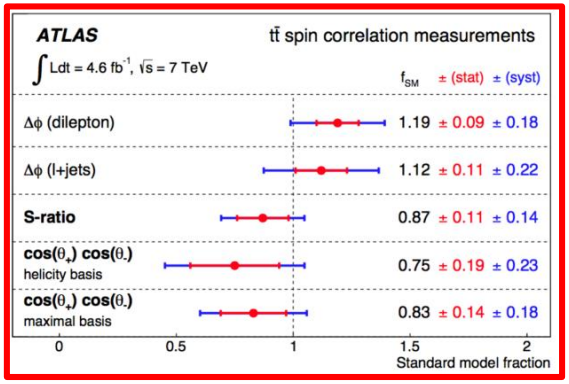


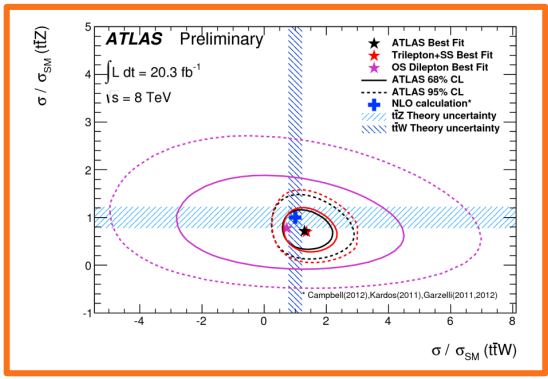
Run I analyses

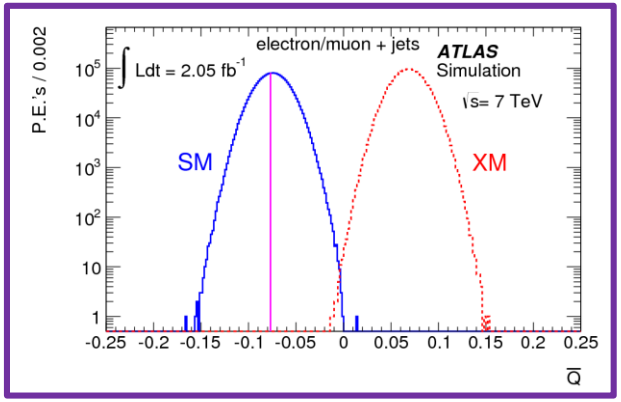
- Published world class results:
  - Top mass
  - Charge asymmetry
  - $t\bar{t}$ spin correlations and top polarizations
  - Top quark charge
  - $t\bar{t}\gamma$ e $t\bar{t}V$ (conf notes)

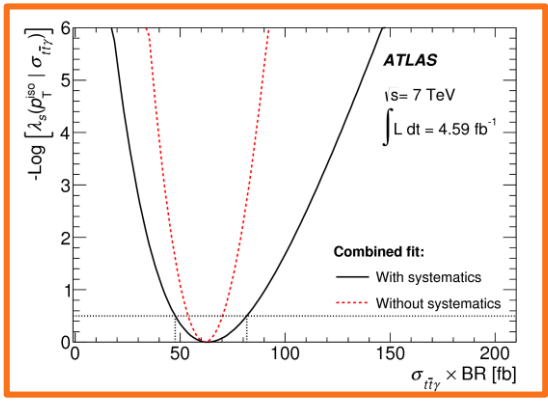












Run I analyses

What can be improved?

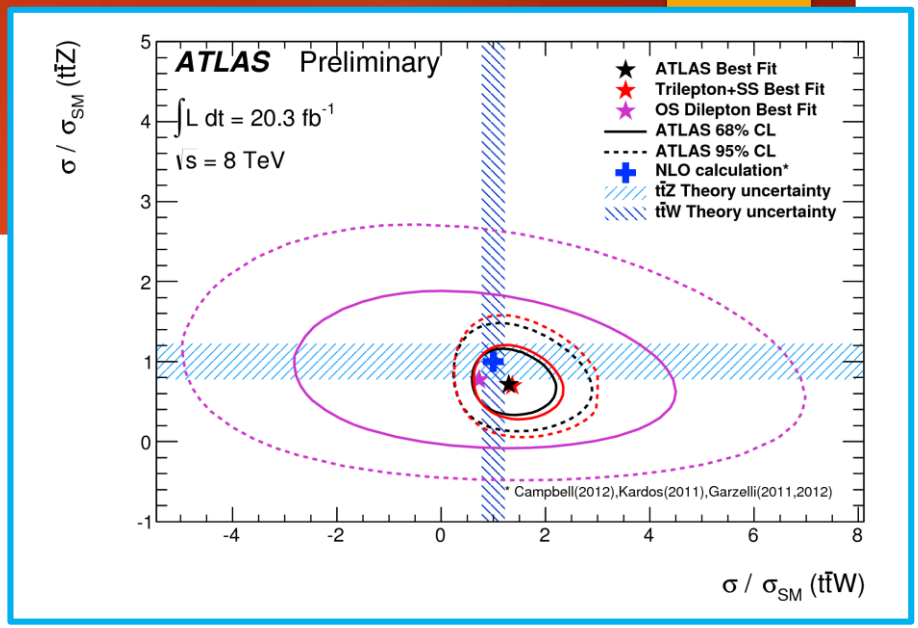
- Most of the published results are *extrapolations* of the measured quantity in the *fiducial* region to a *parton-level* quantity in the *full* phase space
  - "Parton" top not well defined theoretically
  - Strong dependence on the underlying Monte Carlo simulation
  - Go fiducial!
- Put the results in HepData with a Rivet analysis
  - Makes the paper more citable and easier to reinterpret

Run II analysis plans

- $t\bar{t}$ + heavy vector boson production
  - Argonne/BNL/Duke, Bonn, Göttingen, Stockholm, Sussex
- Spin correlation
  - Birmingham
- Charge asymmetry (with boosted objects)
  - Mainz, Michigan
- Top mass
  - No definitive plan yet
  - Use established template method & investigate alternative ways (sigma(tt) dependence…)
- Color flow in $t\bar{t}$ pairs
  - Manchester

No expression of interests from Italian groups

$t\bar{t}V$ in Run I



- Precision test of SM predictions
- Final states
  - $t\bar{t} \rightarrow ll,\ l$+jets, all hadronic
  - $Z \rightarrow ll,\ \nu\nu,\ q\bar{q}$
  - W $\rightarrow l\nu, q\bar{q}$
- Dilepton and trilepton analysis (ATLAS-CONF-2014-38)
  - Same sign di-muon: $t\bar{t}(\rightarrow \mu$+jets$)W(\rightarrow \mu\nu)$
  - Opposite sign dilepton: $t\bar{t}(\rightarrow l^{\pm}$+jets$)W(\rightarrow l^{\mp}\nu)$ and $t\bar{t}(\rightarrow all\ hadr)Z(\rightarrow ll)$
  - Trilepton: $t\bar{t}(\rightarrow ll)W(\rightarrow l\nu)$ and $t\bar{t}(\rightarrow l$+jets$)Z(\rightarrow ll)$
- 4-lepton analysis (ATLAS-COM-PHYS-2014-843): $t\bar{t}(\rightarrow ll)Z(\rightarrow ll)$

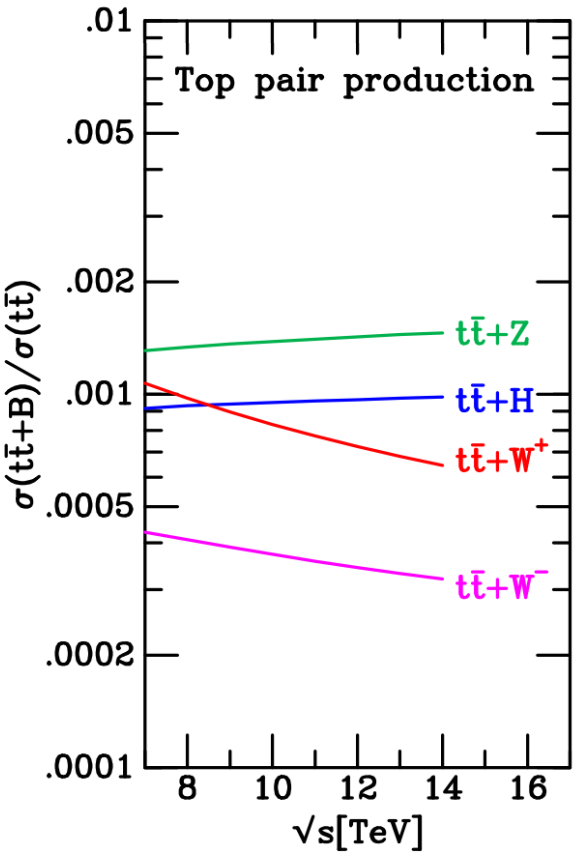
$t\bar{t}V$ in Run II

Effort has not yet started

- Mostly busy with finalization of 8 TeV measurements

Channels of interest

- Dilepton opposite sign (Gottingen)
  - Use neural network
  - Parton level reconstruction → upgrade KLFitter for Run 2
- Dilepton same sign (Argonne/Sydney/Duke)
  - Simultaneously fit of multi-dimensional distributions (e.g. $\mathrm{E_T^{miss}} - N_{jets} - N_{bjets}$) with signal and background components (AIDA method)
  - Interest in measuring WZ/ZZ +HF cross sections with the AIDA method

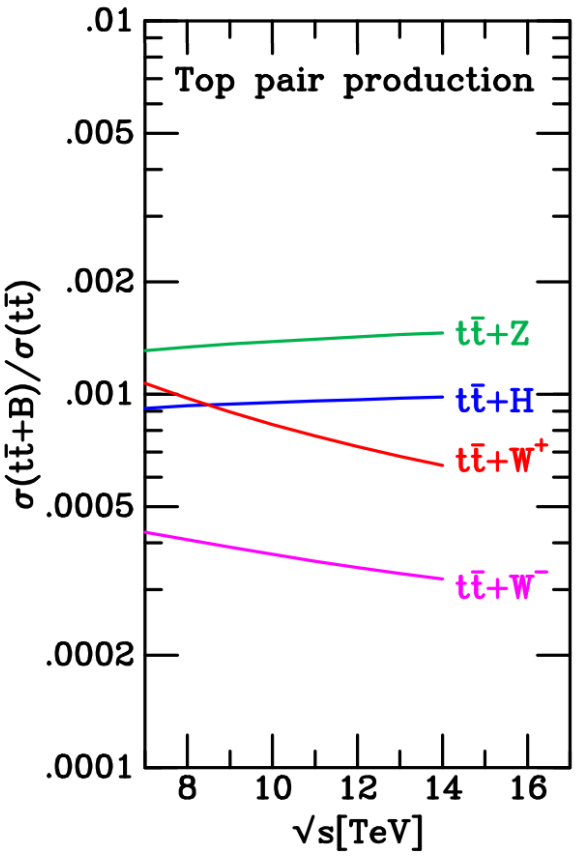


ttV in Run II

- Multi (3/4) leptons(Sussex, Bonnl, Stoccolma)
  - Finalizing $4l$ 8 TeV analysis (expected sensitivity: 2.1σ)
  - Data Driven background extimation feasible thanks to the higher statistics
    - Reduction of the WZ+jets systematic uncertainties

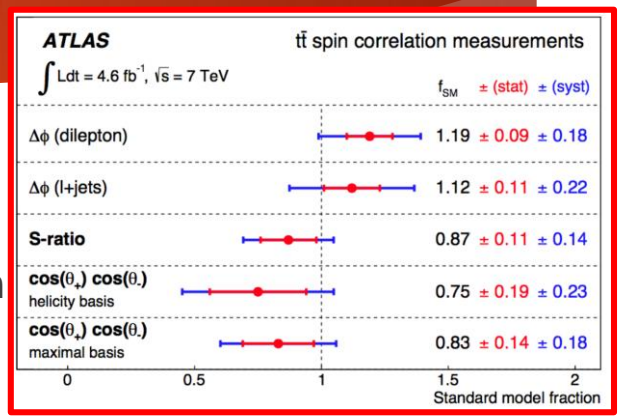
→Expect ~5σ for $t\bar{t}Z$ with 5 fb^{-1}

  - MC studies for WZ+jets and $t\bar{t}V$
    - $t\bar{t}V$: aMC@NLO and Sherpa2
    - WZ+jets: Sherpa with MEPS@NLO

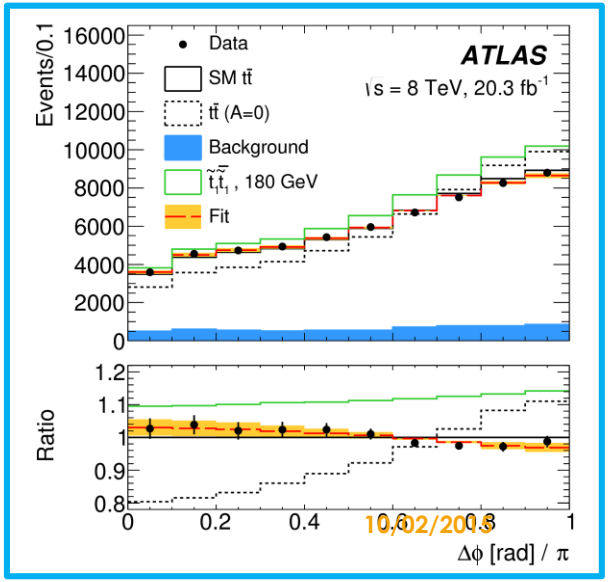


Spin correlation in Run I

$$A = \frac{N(\uparrow\uparrow) + N(\downarrow\downarrow) - N(\uparrow\downarrow) - N(\downarrow\uparrow)}{N(\uparrow\uparrow) + N(\downarrow\downarrow) + N(\uparrow\downarrow) + N(\downarrow\uparrow)}$$



- 7 TeV analysis (Phys. Rev. D. 90, 112016 (2014)
  - Four observable used to extract the spin correlation from a binned likelihood fit of f_{SM} where
    $$A_{measured} = f_{SM} A_{SM}$$
  - $\Delta\phi(ll)$ shows highest sensitivity



- 8 TeV analysis (Submitted to PRL)
  - Spin correlation extracted via a template fit on $\Delta\phi(ll)$ distribution
    $$f_{SM} = 1.20 \pm 0.05(stat) \pm 0.13(syst)$$
  - Most precise measurement to date

Spin correlation in Run II

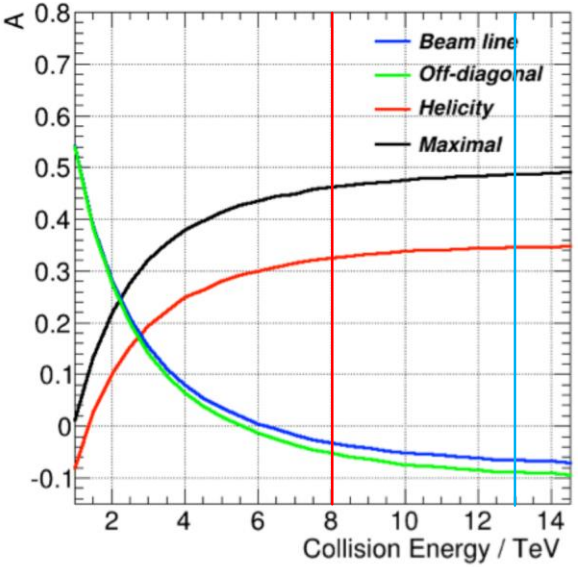
$$A = \frac{N(\uparrow\uparrow) + N(\downarrow\downarrow) - N(\uparrow\downarrow) - N(\downarrow\uparrow)}{N(\uparrow\uparrow) + N(\downarrow\downarrow) + N(\uparrow\downarrow) + N(\downarrow\uparrow)}$$

No big change in A from 8 to 13 TeV

Keep the analysis simple

- Dilepton channel
- Statistical uncertainty levels with 1/fb @13 TeV similar to full 7 TeV dataset

	Data(fb^{-1})	x-sec(pb)	Events
7 TeV	4.7	177.3	833,310
13 TeV	1.0	831.8	831,760

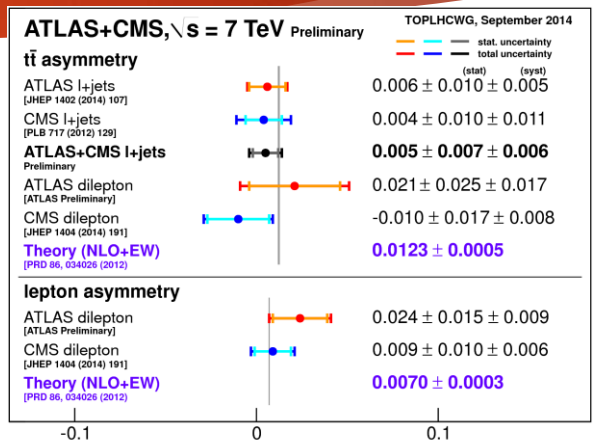


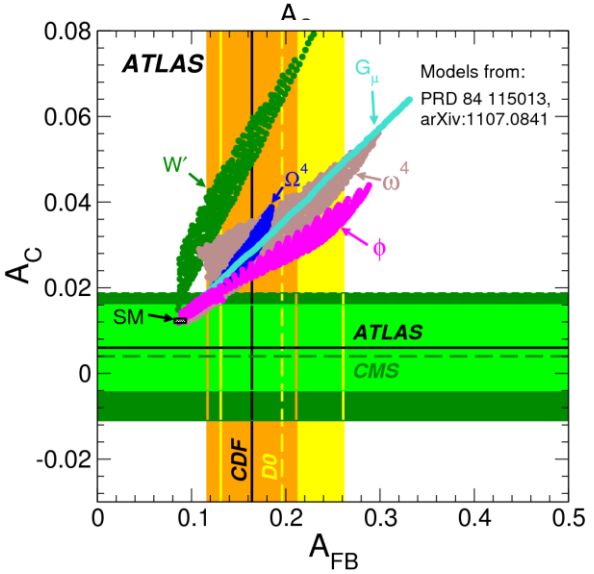
- Use $\Delta\phi(l, l)$
  - Sensitive to $t\bar{t}$ spin correlation, without requiring full reconstruction
- Spin correlation varies with m_{tt}
  - Use m_{ll} as proxy for m_{tt}

Tt charge asymmetry in Run I

$$A_C = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)} \qquad \Delta|y| = |y_t| - |y_{\bar{t}}|$$

- Extensively measured @ 7 TeV
- All results obtained after unfolding to parton level
  - Dilepton channel (submitted to JHEP)
    - Simultaneous measurement of $A_C(tt)$ and $A_C(ll)$
  - Single lepton channel (JHEP02(2014)107)
    - Strong contributions by Udine/ICTP
    - W+jets and QCD multijet background with data-drive methods. → Standard in top WG
  - Combination with CMS (ATLAS-CONF-2014-012)
- Results in agreement with SM predictions
  - To understand the discrepancies in A_{FB} @ Tevatron





Tt charge asymmetry in Run II

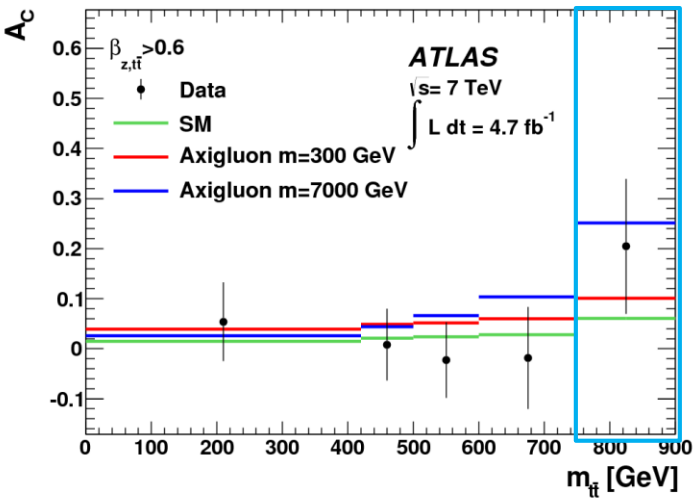
$$A_C = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)} \qquad \Delta|y| = |y_t| - |y_{\bar{t}}|$$

- Interest shown for boosted analyses (Mainz, Michigan)
  - Combinations with resolved analyses could improve the precision
- A_C at high m_{tt} particularly sensitive to new physics
- Run II ideal environment for boosted analyses
  - Expected 7x more boosted tops (m_{tt}>1TeV) with 5/fb

Interest shown also for $A_C(tl)$ with a high p_T hadronically decaying top (arXiv:1401.2443)

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

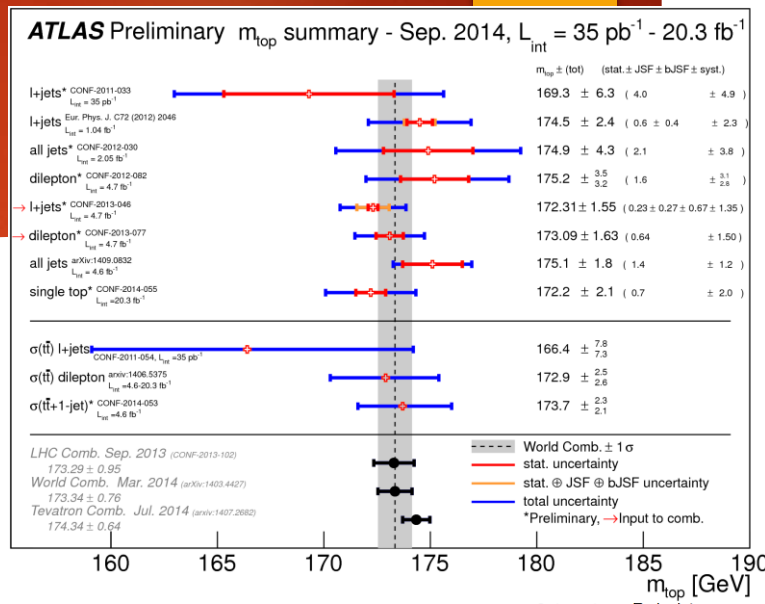
No ambiguity due to the z-component of the neutrino



Top Mass

Extensively measured in Run I

- Effort still ongoing
- ATLAS 7 TeV best measurement $\delta m_{top} = 0.88\%$
- Combination close to circulation ($\delta m_{top} = 0.53\%$)

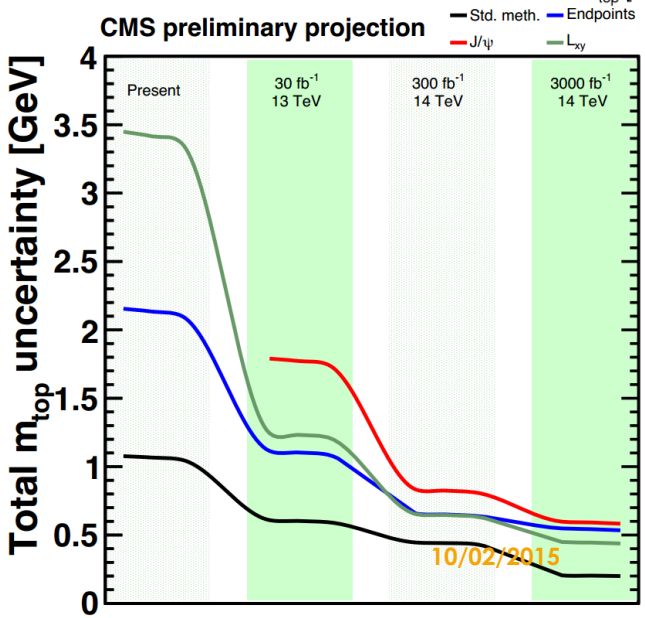


For 13 TeV plan to use established template method

- Performance will depend on the understanding of input objects

Alternative top mass extractions become viable

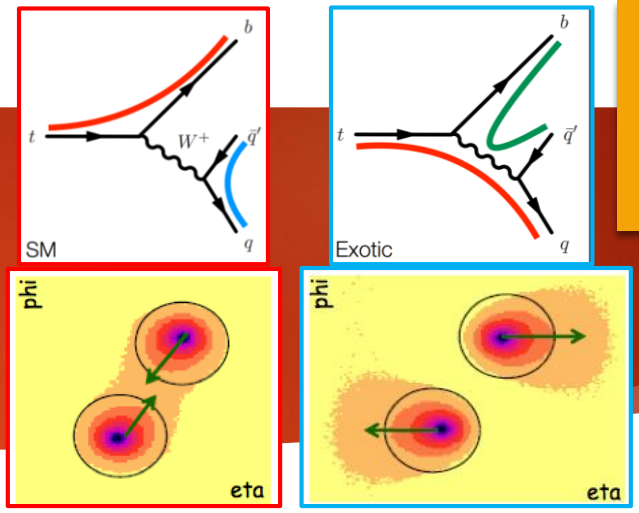
- Exploit dependence on σ(tt) (probably first result for Run II)
- Use $t\bar{t}$+1jet, (recently 7 TeV approved analysis)
- Lepton p_T, b-hadron decay lenght, …



Not for early Run II

Color flow in Run I

ATL-COM-PHYS-2014-767



Analysis ongoing on 8 TeV

Single lepton channel

- Goal: unfold pull angle between the two jets coming from a W and compare it to different color flow models
- Pull vector of a jet *J* is defined as:

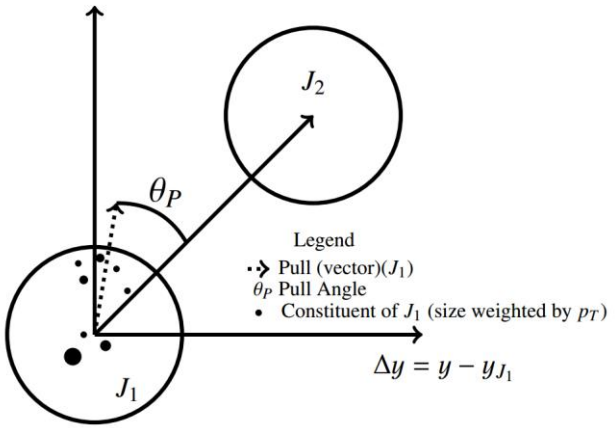
$$\vec{v}(J) = \sum_{i \in J} \frac{p_T^i |r_i|}{p_T^J} \vec{r_i}$$

Where i runs over the subcomponents of J and r_i is the i-J vector in the $y - \phi$ plane

- Pull angle $\theta_P(J_1, J_2)$:

angle between $\vec{v}(J_1)$ and $\overrightarrow{J_1 J_2}$

$\Delta\phi = \phi - \phi_{J_1}$ $\theta_P \sim 0 \rightarrow$ color-connected



Color flow in Run II

- Manchester interested in (continuing) the investigation of color flow
  - Analysis will follow a similar strategy to the current 8 TeV measurement
  - Present unfolded distributions (like jet pull), using the full 2015 dataset
  - Not an early result (Moriond 2016 optimistic)

Conclusions

- In general, current focus of top properties groups is on finishing the measurements with Run I data
- General plans and expectations for Run II analyses
  - Aim for a first $t\bar{t}V$ observation with 5/fb
  - Charge asymmetry with boosted final states: 7x more statistics respect to 7 TeV analysis with 5/fb
  - Competitive spin correlation measurement with ~1/fb
  - First top mass measurement expected to extracted from σ_{tt}
- Examples of interesting but yet uncovered topics:
  - $t\bar{t}\gamma$
  - Baryon number violation

As for today, no expression of interests from Italian groups

Plenty of topics in Top Properties where Italian groups can give important contributions during Run II