Beyond Standard Model with the top quark

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The P2IO Scientific Council

Introduction

Of Myself:

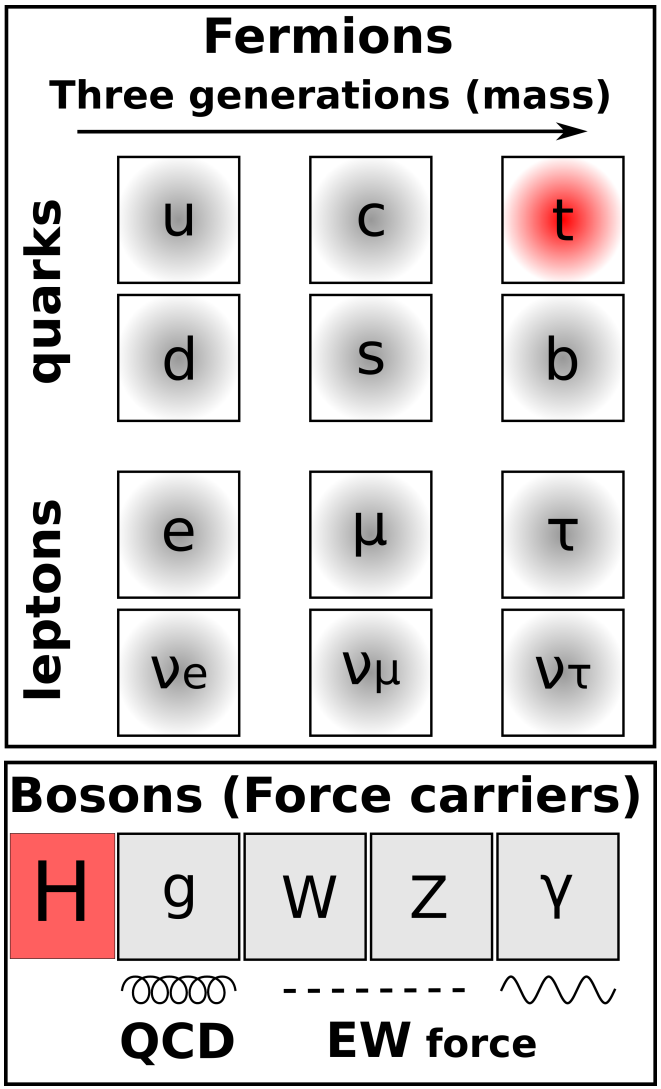
- **Liza Mijović, come from Slovenia**
- **working at CEA-Saclay, Irfu/SPP as P2IO postdoc: March 2012-2014**
- **main supervisor: Frédéric Déliot** (unfortunately @ CERN today)
- **main areas of work: high energy physics measurements** and phenomenology

Of The project:

- **joint experimental and theory project**
- **main goals: measurement and interpretation of the top charge asymmetry and top polarization at the LHC**
- **top charge asymmetry and top polarization = probes of Beyond Standard Model (BSM) physics**

In this talk I will discuss how the work done (and ongoing) within my P2IO project contributed (contributes) to the goals above.

The Standard Model and the Top (t) Quark



Facts about the t quark:

- Discovered: 1995:
  Tevatron, Fermilab, Chicago [a], [b].
- $m_t = 173.5\ \mathrm{GeV} \pm 0.6\ \mathrm{GeV}\ (\mathrm{stat}).$
  $\pm 0.8\ \mathrm{GeV}\ (\mathrm{syst.})$ [c]
  (units: c=1 $\Rightarrow$ [mass]=[Energy]).
- top mass $\sim$ mass of the atom of gold, heaviest known elementary particle
- spin (intrinsic angular momentum) -1/2
- short life-time ($\sim 0.5 \cdot 10^{-24}$s [c])
- largest production cross-section at hadron colliders : top and antitop pairs

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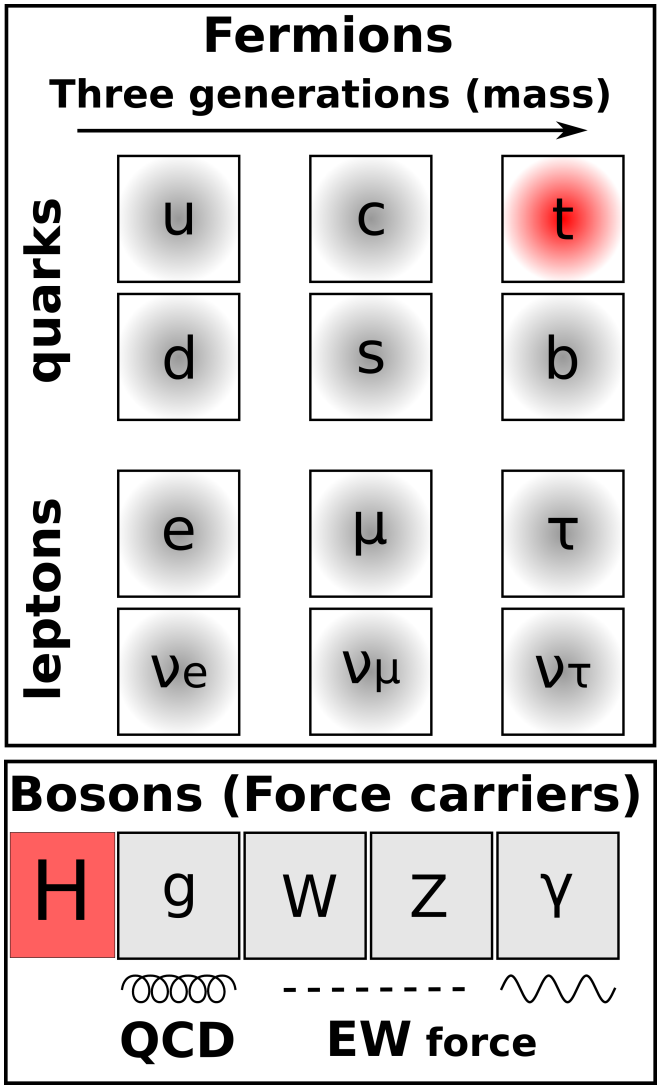
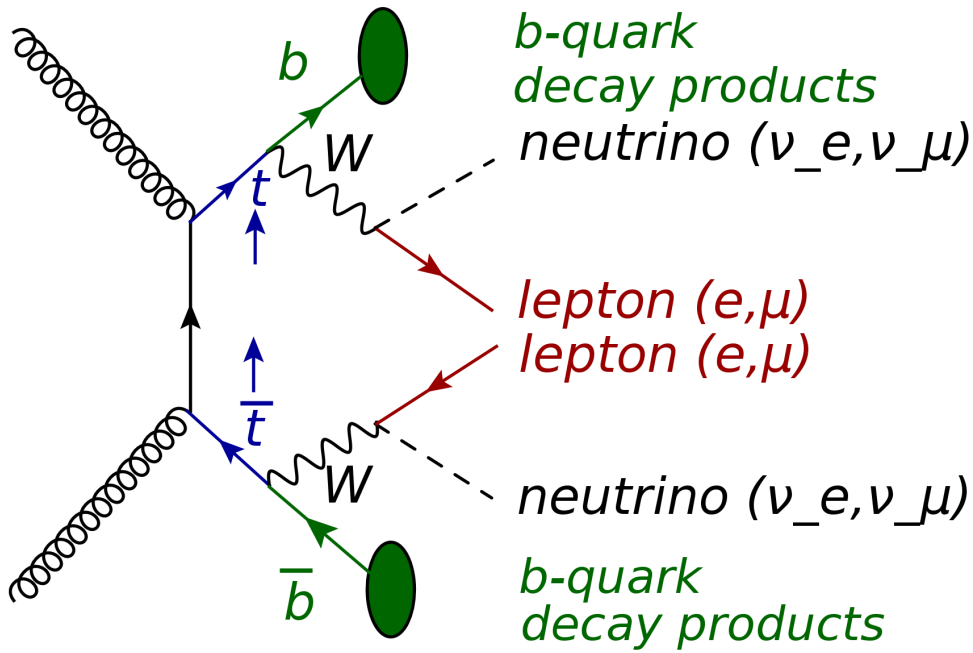
[a] F. Abe et al. [CDF], Phys. Rev. D **74**, 1995.
[b] S. Abachi et al. [D0], Phys. Rev. Lett. **74**, 1995.
[c] J. Beringer et al. [PDG], Phys.**D86**, 2012
and 2013 partial update for the 2014 edition.

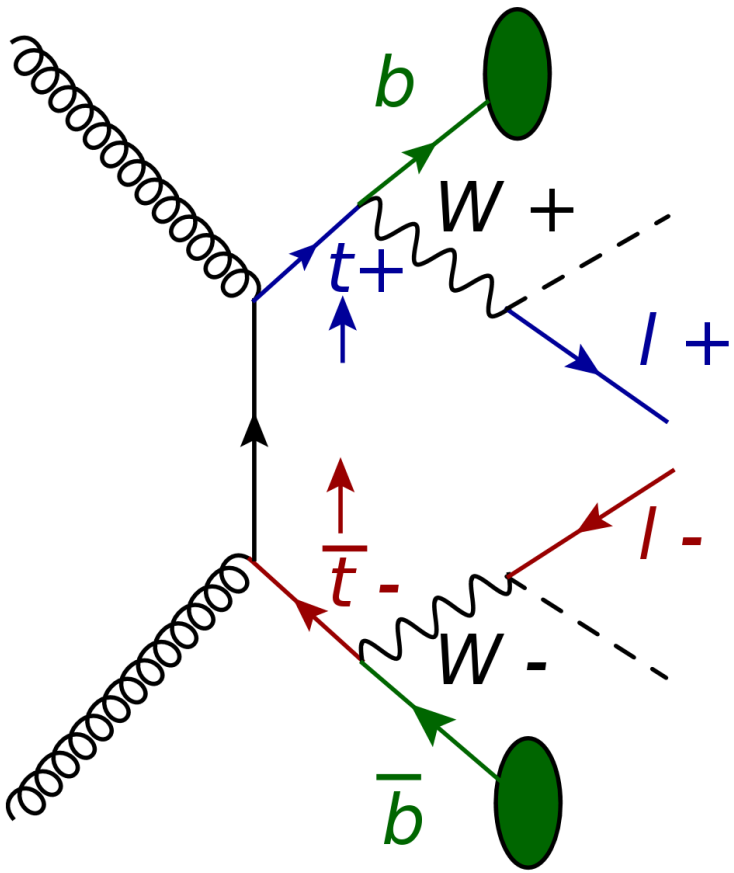
The Standard Model and the Top (t) Quark



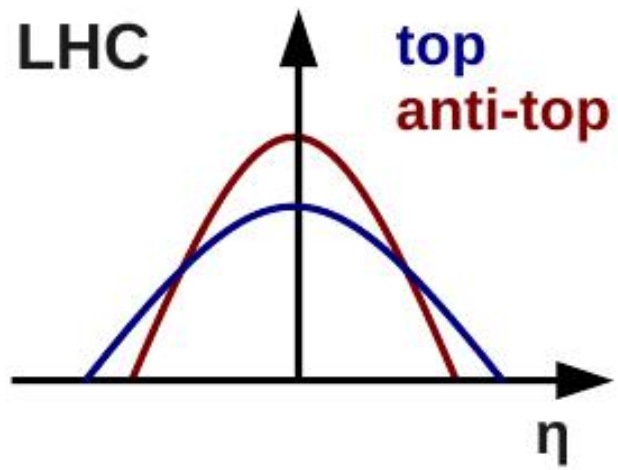
Experimental signature:



Charge Asymmetry



- top (t) and antitop ($\bar{t}$) have different electric charges
- **charge asymmetry** : we can measure if top is produced more forward than antitop in our detector
- **charge asymmetry is predicted to be small in SM**

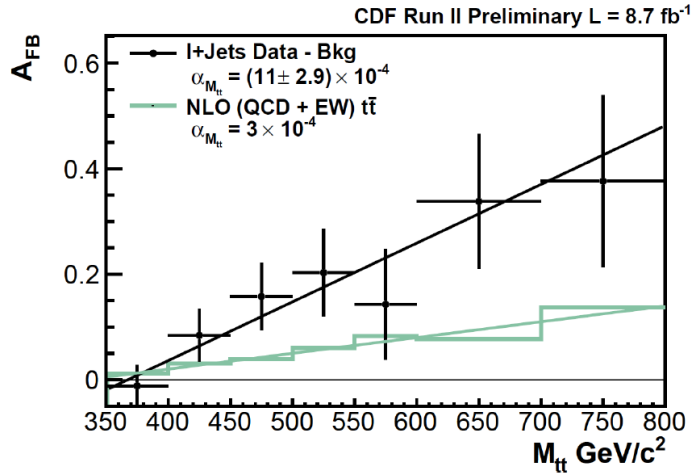


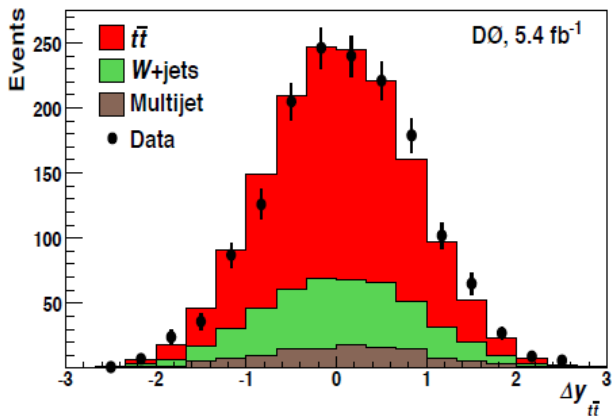
- we can also measure **charge asymmetry** using the leptons

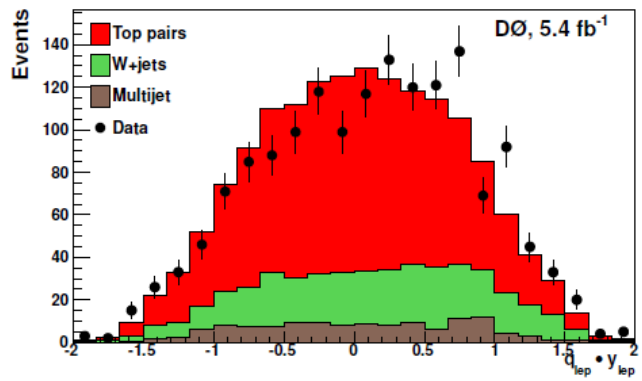
Asymmetries in top-antitop events

Asymmetries in top-antitop events measured to differ significantly from SM by Tevatron experiments;

- observed in independent measurements by 2 Tevatron experimental collaborations
- **top**: **CDF result** [1],**bottom**: **D0 result** [2]
- **BSM physics? Which theories are compatible with exp. data?**
- **A : need more info from LHC.**







Fully reconstracted $t\bar{t}$ asymmetry

$$A_{gen} = (19.6 \pm 6.0^{+1.8}_{-2.6})\%$$

$$A(MC@NLO) = 4.4\%$$

Asymmetry of leptons from top decay

$$A_l = 15.2 \pm 3.8^{+1.0}_{-1.3}\%$$

$$A_l(MC@NLO) = 2.1 \pm 0.1\%$$

[1] talk by Dan Amidei, `http://indico.cern.ch/conferenceOtherViews.py?view=standard&confId=175916`

[2] talk by R. Demina, `http://eps-hep2013.eu/`

Top Polarization

- Polarization = degree to which the spin is aligned with a given direction
- Standard Model prediction : top polarization is negligible (spin is not aligned with any particular direction)
- **prediction of a number of BSM models: top polarization is not negligible**
- **in particular true for BSM models that can explain Tevatron asymmetries data-SM difference** [1].
- **Ergo :**
  Useful to measure both charge asymmetry and polarization at the LHC.

How to measure polarization:

- top decays faster than the characteristic time on which its spin would get distorted; hence we can infer top spin from the spin of its decay products
- e.g.: choose direction of top quark in the rest frame of the top-antitop as the given direction
- check if the angles of the top decay products 1 and 2 follow the distribution of the non-polarized top decays:

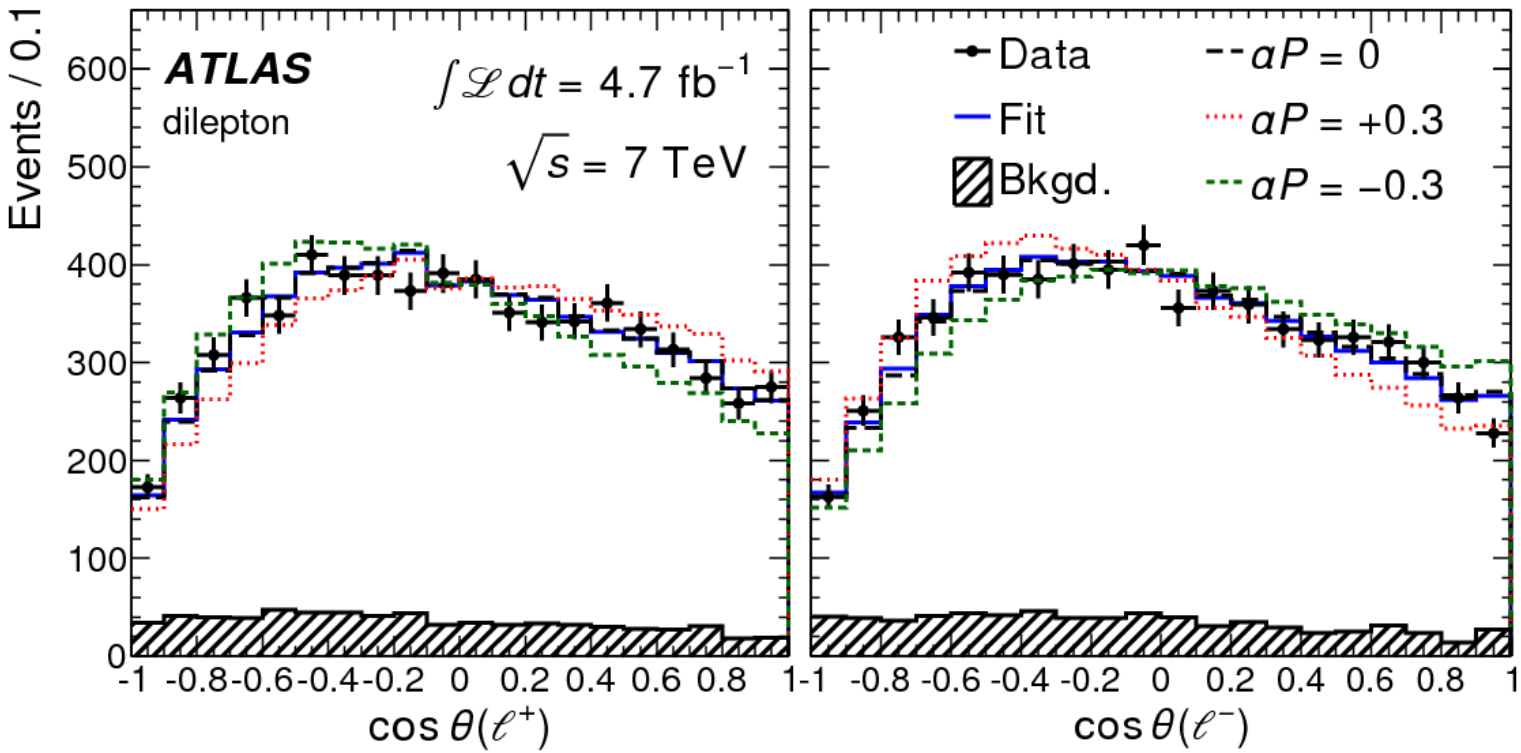
$$\frac{1}{\sigma}\frac{d\sigma}{d\ cos\theta_1\ d\ cos\theta_2} = \frac{1}{4}(1 + \alpha_1 P_1 cos\theta_1 + \alpha_2 P_2 cos\theta_2 - C cos\theta_1 cos\theta_2),$$

θ_1, θ_2 = angles of the top decay products and the top in the selected frame
αP = coefficients sensitive to polarization that we would like to measure

[1] D. Krohn et al, *A Polarized View of the Top Asymmetry*, Phys. Rev. **D84** 074034 (2011).

Measurement of the top polarization @ LHC

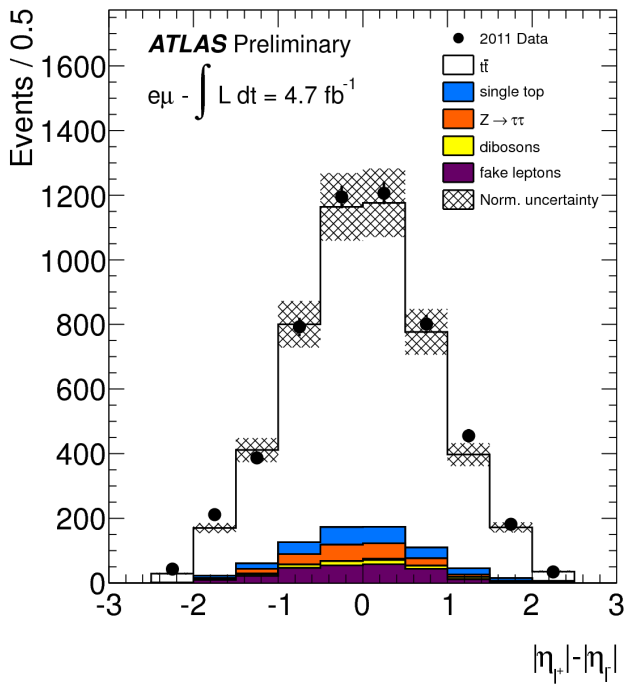
- project with DESY (Germany), Tufts (US) colleagues
- F. Déliot, L. Mijović, the ATLAS collaboration, *Measurement of top quark polarization in top-antitop events from proton-proton collisions at* $\sqrt{s} = 7$ *TeV using the ATLAS detector*, `arXiv:1307.6511`, submitted to PRL.

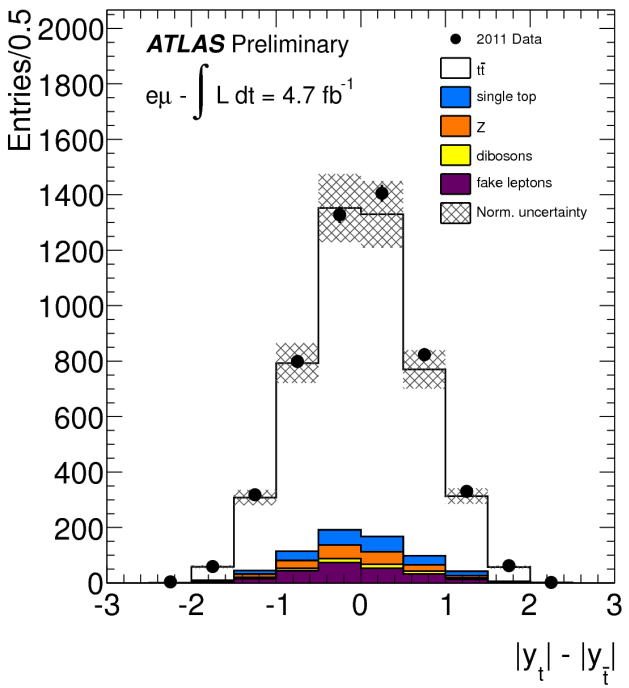


Top polarization measured to be consistent with the SM prediction.

Measurement of the charge asymmetry @ LHC

- project with DESY (Germany) colleagues
- preliminary measurement of lepton and top-antitop asymmetries at 7 TeV exists [1]
- **working on detector corrections that will enable systematic comparisons of the measurements with the BSM models (unfolding)**
- **+ working on BSM model comparisons with the (updated) measurement**

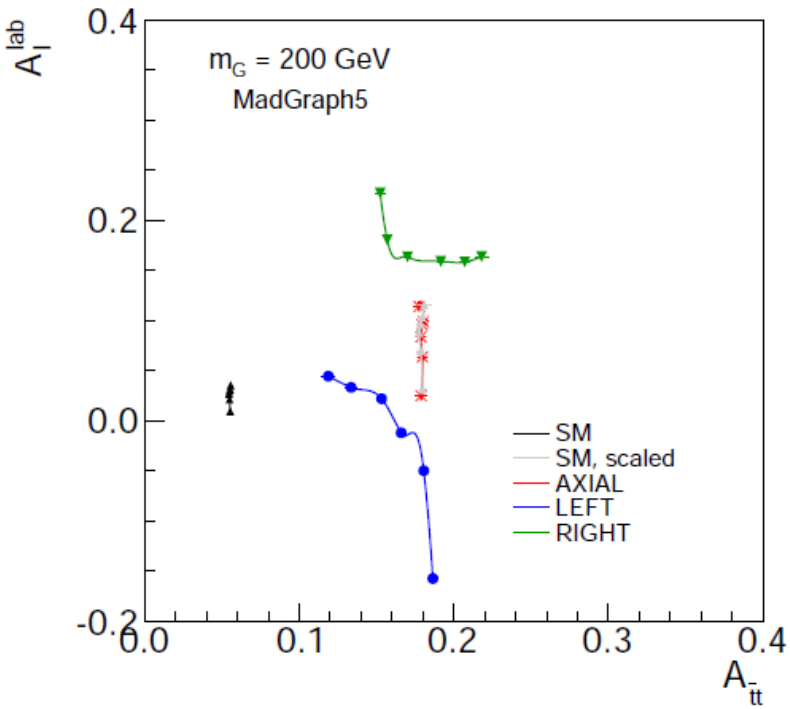


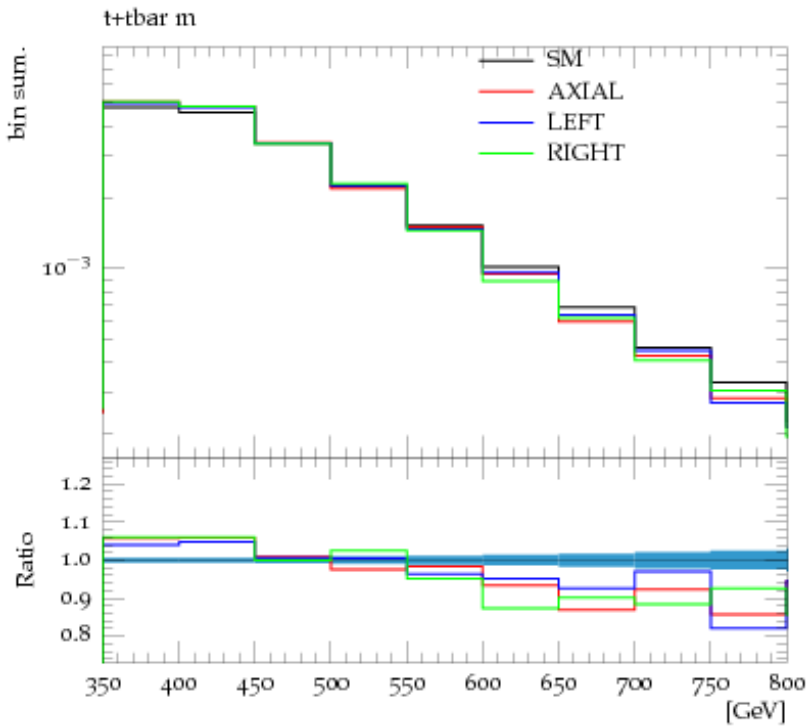


[1] F. Déliot, ATLAS collaboration, *Measurement of the charge asymmetry in dileptonic decays of top quark pairs in pp collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector*, ATLAS-CONF-2012-057.

BSM models

- A. Falkowski et al, *Data driving the top quark forwardbackward asymmetry with a lepton-based handle*, Phys. Rev. **D87**, 034039 (2013).
- **dependence of the top-antitop and lepton asymmetries on the lepton pt is notably different between SM and BSM models**
- **ditto for BSM vs BSM models**
- **axigluon** BSM models : SM + extra non-zero mass gluon with different couplings to quarks and anti-quarks
- LHS : Phys. Rev. **D87**, **RHS: Adam, Frédéric & Liza, for ATLAS measurement**.

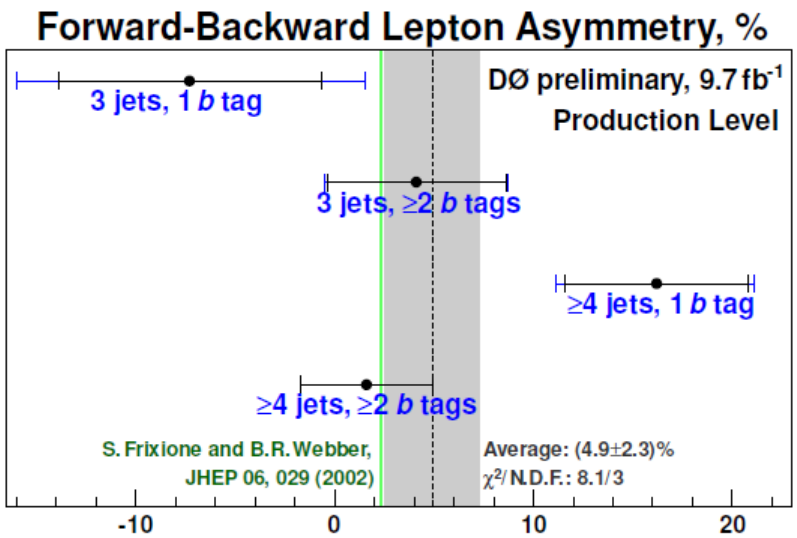


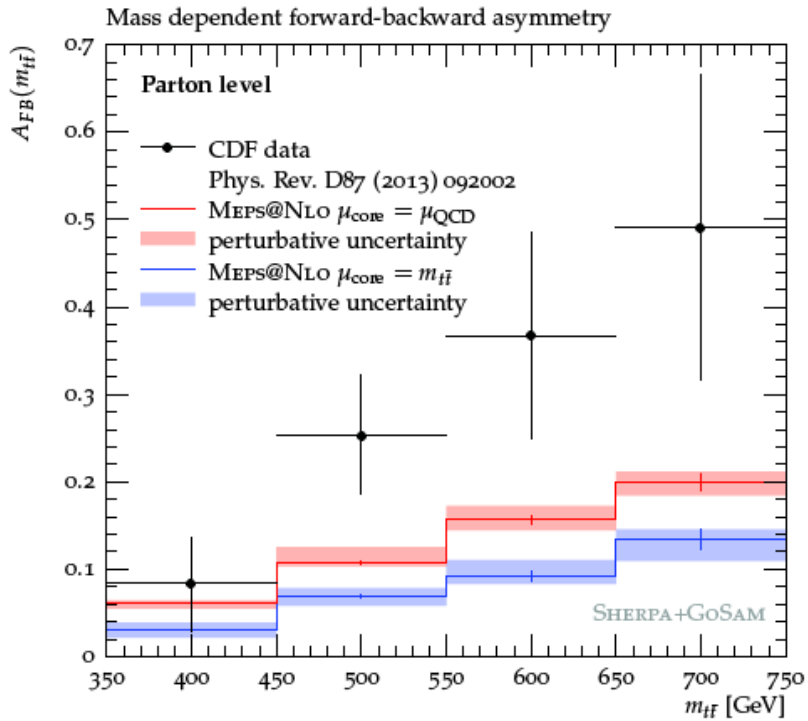


In the mean time . . .

Interesting updates on charge asymmetry from Tevatron and theory:

- CDF and D0 collaborations : **lepton asymmetry** consistent with SM (LHS, [1])
- theory : improved calculations can explain part of the Tevatron data-SM differences for **top-antitop asymmetry**, though also the latest-greatest SM predictions remain below the Tevatron data (RHS, [2])
- $\Rightarrow$ **the hunt for the answer to the BSM interpretation questions continues!**





[1] talk by R. Demina, `http://eps-hep2013.eu/`

[2] Hoche et al, *Zero and one jet combined NLO analysis of the top quark forward-backward asymmetry*, Phys. Rev. **D88**, 014040 (2013).

Summary

My P2IO project: top charge asymmetry and top polarization at the LHC:

- **measurements at the LHC done(polarization) or in progress(CA)**
- **interpretation in terms of BSM models ongoing:**
  - collaboration between LABs and between theorists and experimentalists to exchange viable BSM models for direct use by the experiments
  - the measurements benefit from theoretical ideas on observables of choice to increase SM-BSM and BSM-BSM model separation power
  - **Theorists provided us info and models in the format very useful for the experimental measurements!**
- **We also aim to provide experimental measurements of BSM sensitive quantities unfolded for the detector effects = in the format that can be used directly by theory!**

Mercie de votre attention!

Extra Slides

Where is Slovenia? ;-)