Irfu
Institut de recherche sur les lois fondamentales de l'univers
saclay

Top Quark Physics at D0

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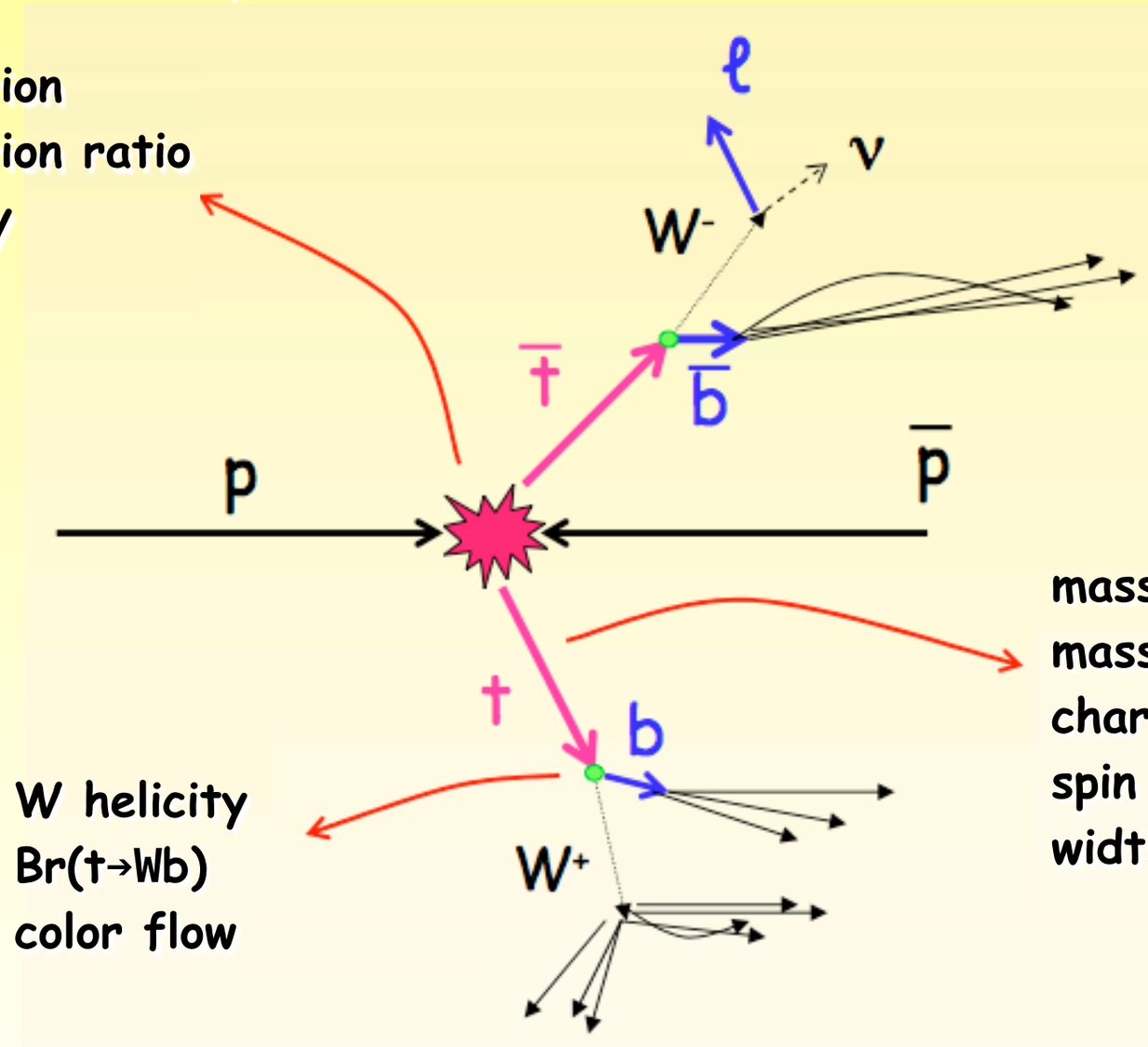
D0 France, 30-MAY-11

Why Do We Study the Top Quark ?

- due to its mass, the top quark is a special quark
- measure properties : find out if it is the particle as predicted in the SM
- what kind of role does it play in EW symmetry breaking ? new physics ?

quantities that D0 has measured

cross section
cross section ratio
asymmetry



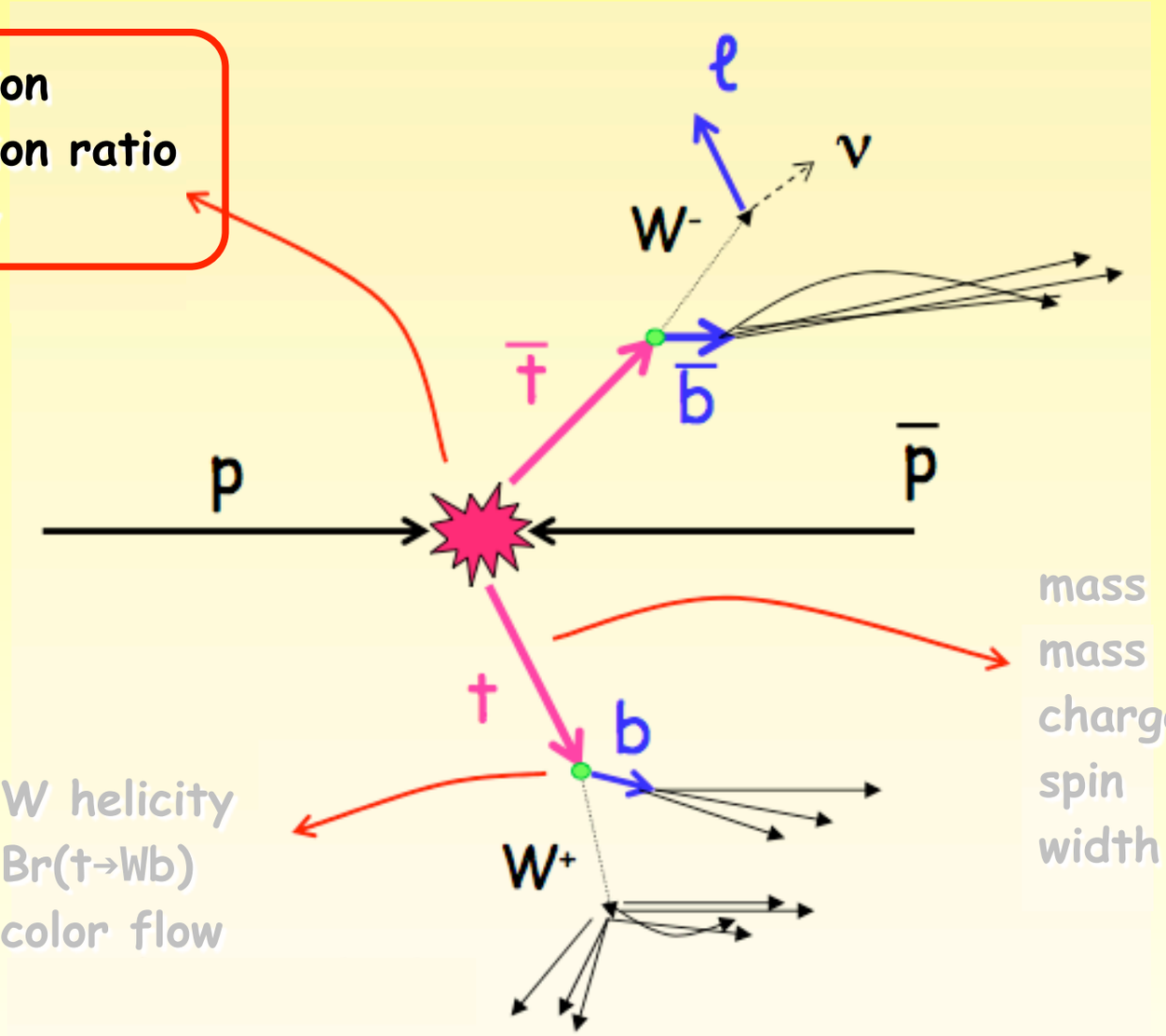
mass
mass difference
charge
spin
width

W helicity
Br(t→Wb)
color flow

+ observation of single top production

Top Quark Production

cross section
cross section ratio
asymmetry



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ttbar Cross Sections

- with 5.4 fb^{-1} (mtop = 172.5 GeV):
  - ➔ ljets w/ or w/o b-tag (arXiv:1101.0124, submitted to PRD)

$$\sigma_{t\bar{t}} = 7.78^{+0.77}_{-0.64}\ (\text{stat} + \text{syst} + \text{lumi})\ \text{pb}$$

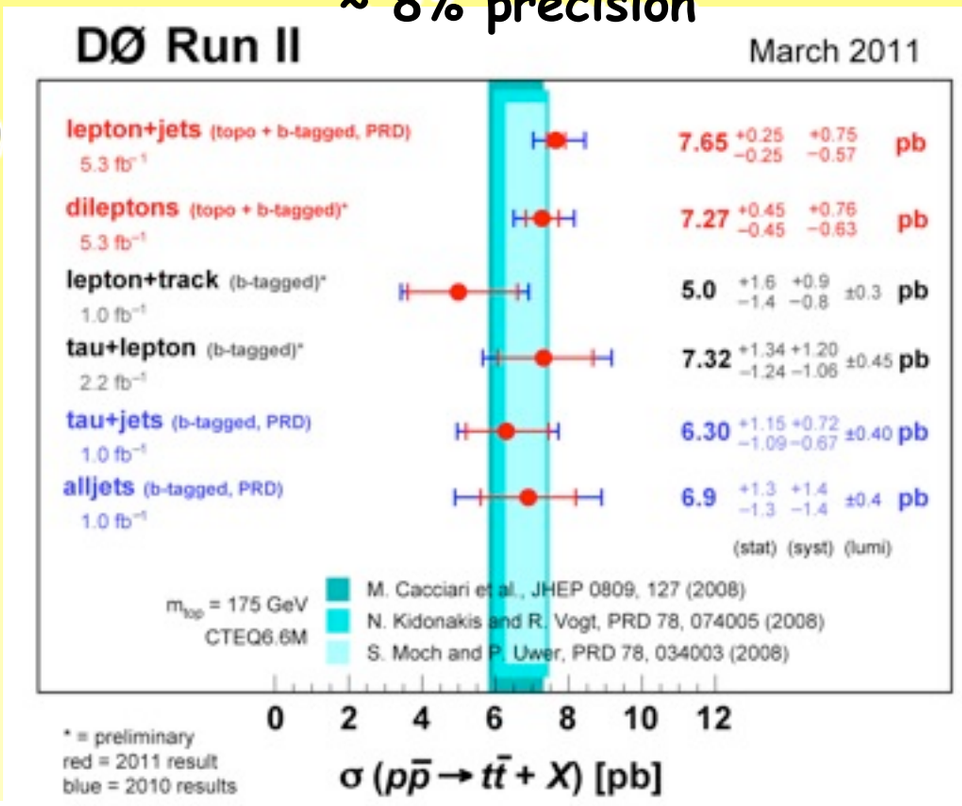
  - ➔ dilepton w/ b-tag (arXiv:1105.5384, submitted to PLB)

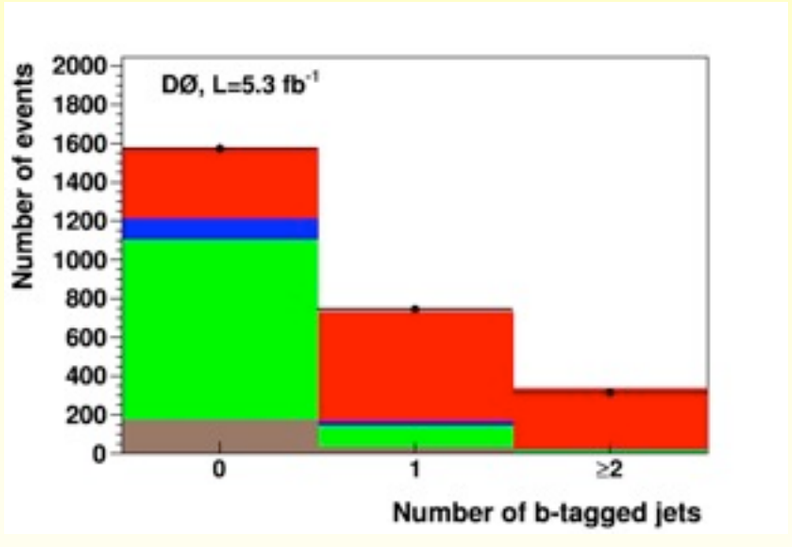
$$\sigma_{t\bar{t}} = 7.36^{+0.90}_{-0.79}\ (\text{stat} + \text{syst})\ \text{pb}$$

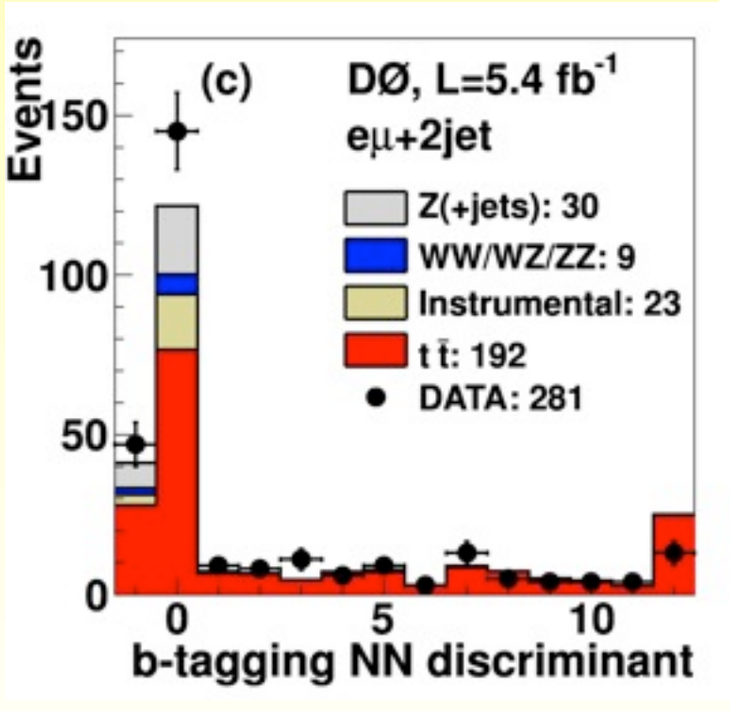
  - ➔ ljets/dilepton: R=B(t→Wb)/B(t→Wq) (collab. review)

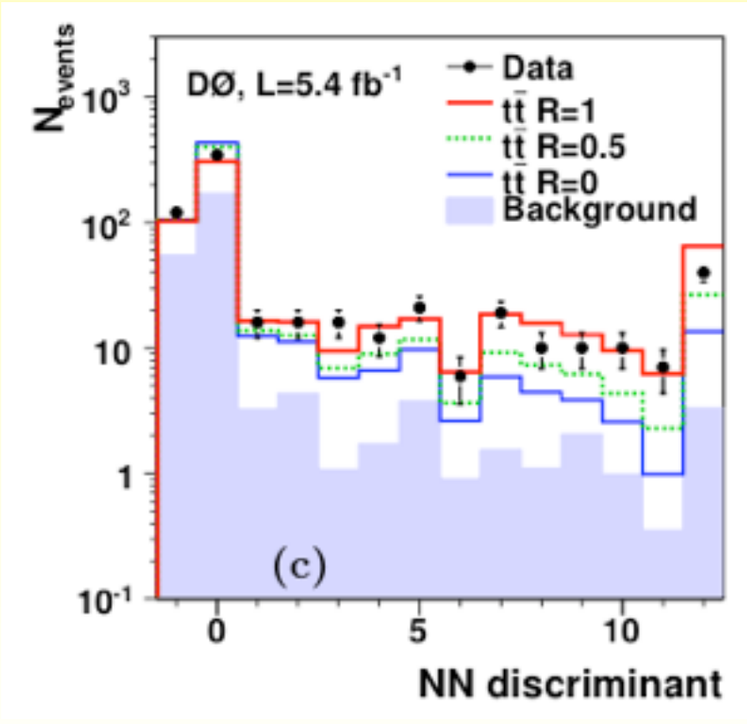
$$R = 0.90 \pm 0.04\ (\text{stat+syst})$$

ljets/dilepton:
~ 8% precision









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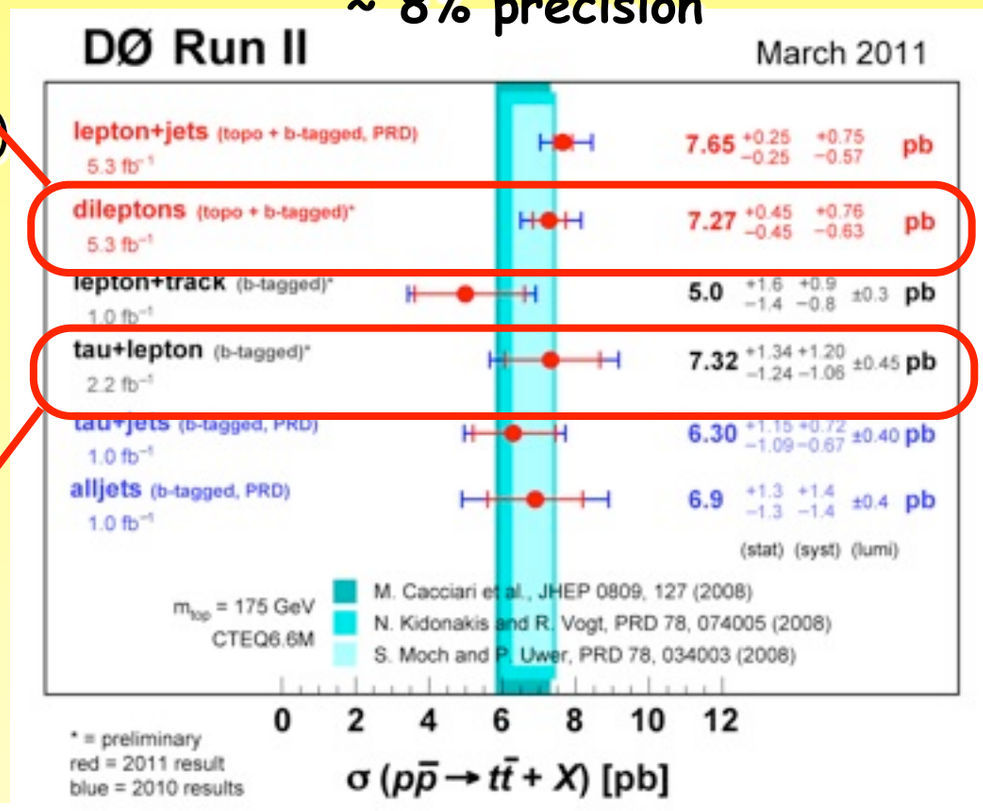
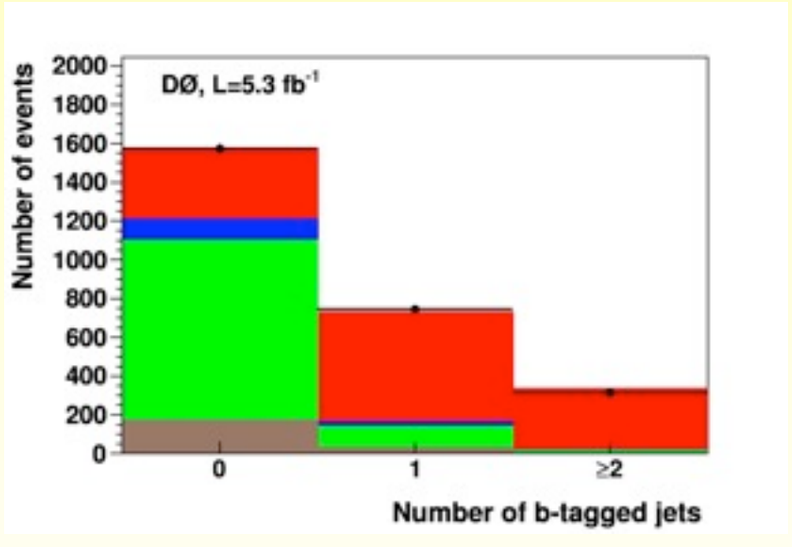
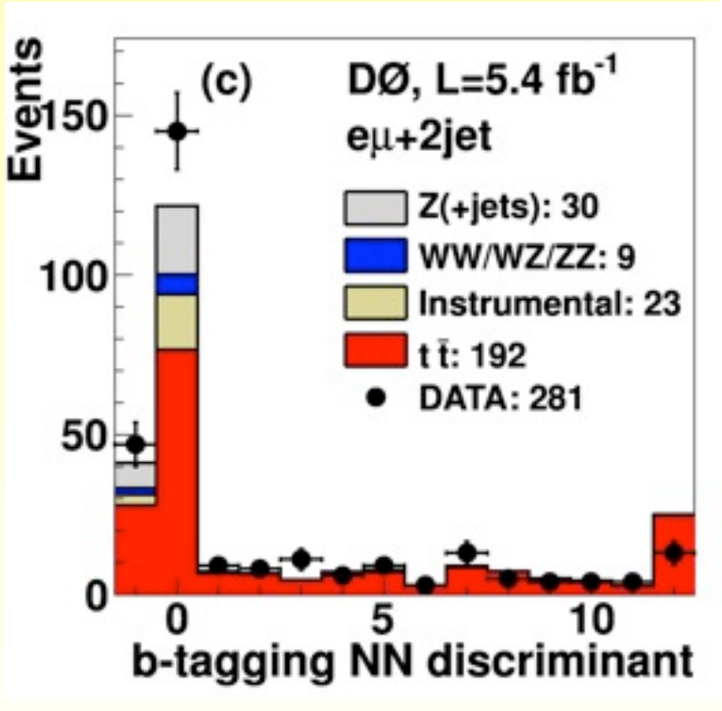
Cecile's talk

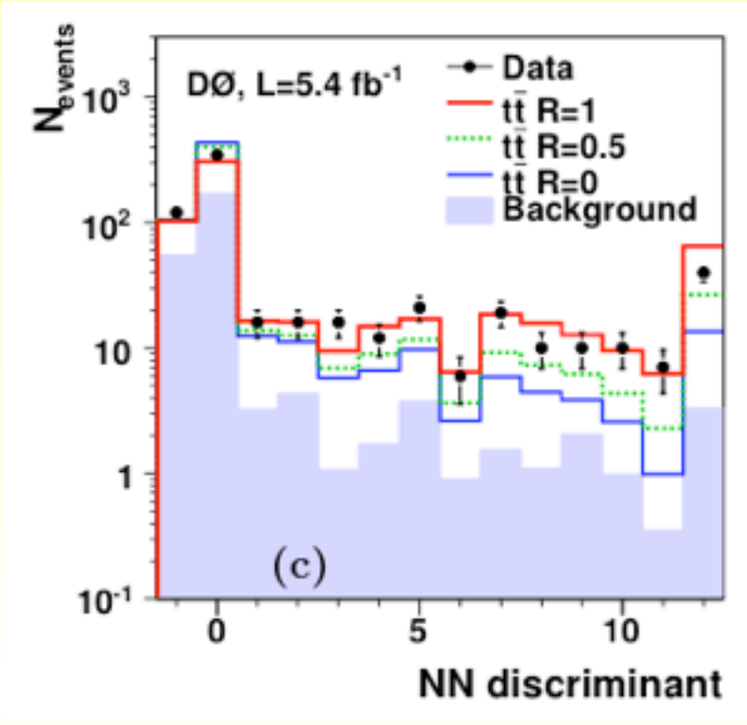
Frederique's talk

ljets/dilepton:
~ 8% precision







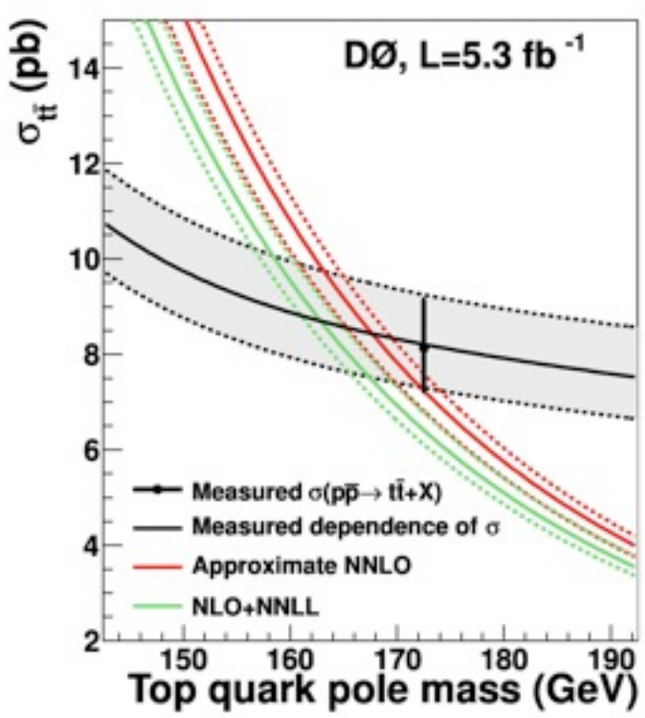


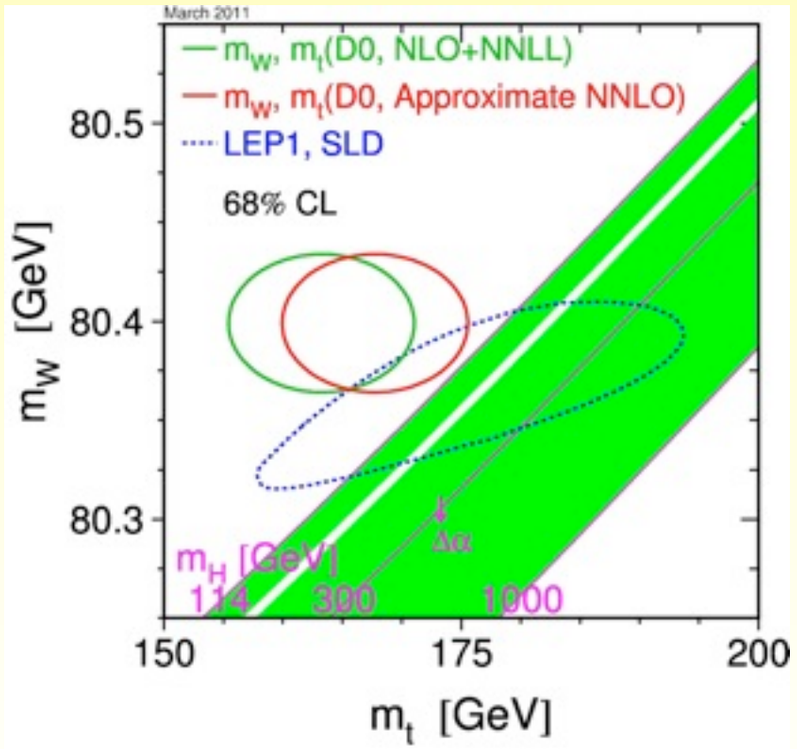
Mass From ttbar Cross Sections

- with 5.4 fb^{-1} :

➔ extract both the pole and MSbar masses using the theoretical and experimental ttbar cross sections (arXiv:1104.2887, submitted to PLB)

Theoretical prediction	$m_t^{\rm pole}$ (GeV)	$\Delta m_t^{\rm pole}$ (GeV)
MC mass assumption	$m_t^{\rm MC} = m_t^{\rm pole}$	$m_t^{\rm MC} = m_t^{\overline{\rm MS}}$
NLO [12]	$164.8^{+5.7}_{-5.4}$	-3.0
NLO+NLL [13]	$166.5^{+5.5}_{-4.8}$	-2.7
NLO+NNLL [14]	$163.0^{+5.1}_{-4.6}$	-3.3
Approximate NNLO [15]	$167.5^{+5.2}_{-4.7}$	-2.7
Approximate NNLO [16]	$166.7^{+5.2}_{-4.5}$	-2.8

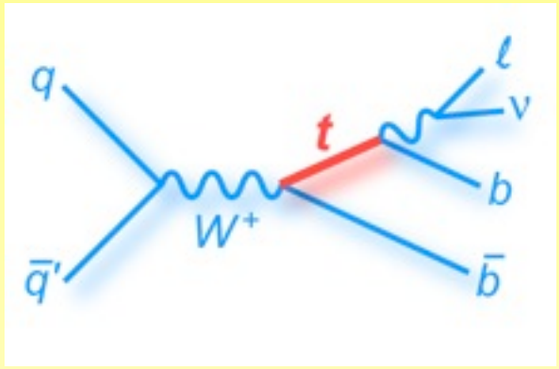


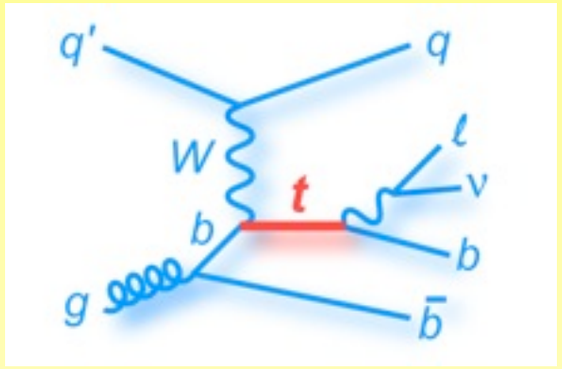


Single Top Cross Sections

- with 5.4 fb^{-1} :

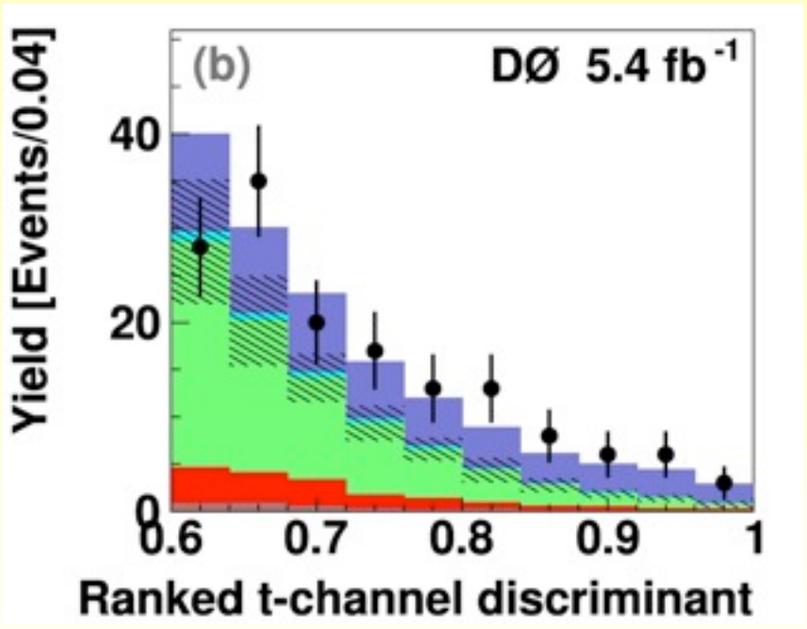
➔ s-channel (~ 1 pb) and t-channel (~2.3 pb) for mt=172.5 GeV

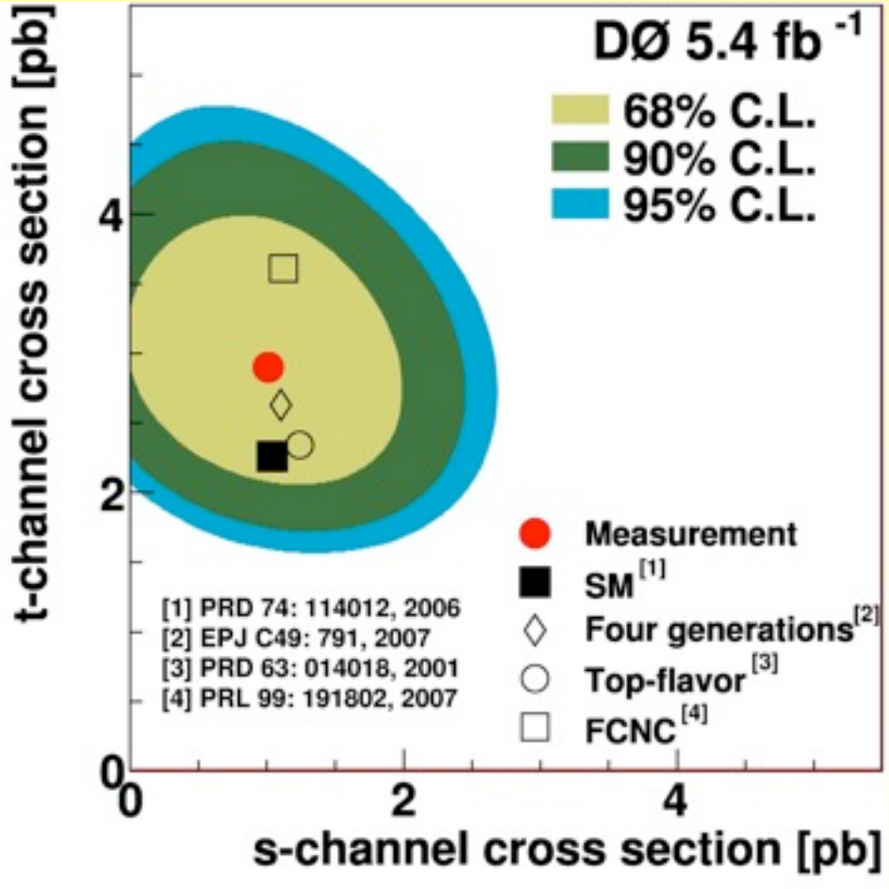




➔ observation of t-channel (arXiv:1105.2788, submitted to PLB)

5.5 sigma: $\sigma(p\bar{p} \to tqb + X) = 2.90 \pm 0.59\ (\text{stat} + \text{syst})\ \text{pb}$





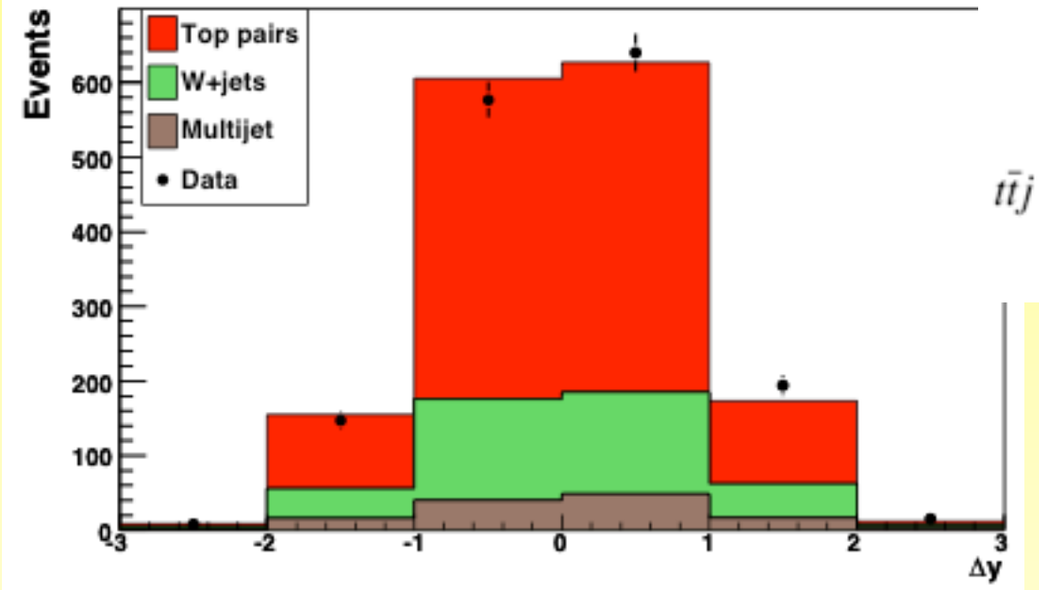
ttbar Forward-Backward Asymmetry

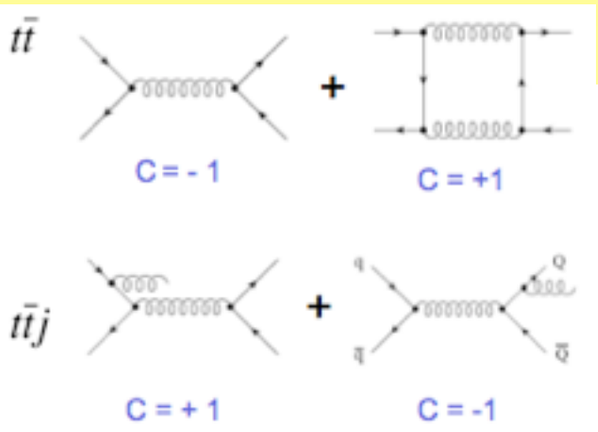
work in progress
EB review

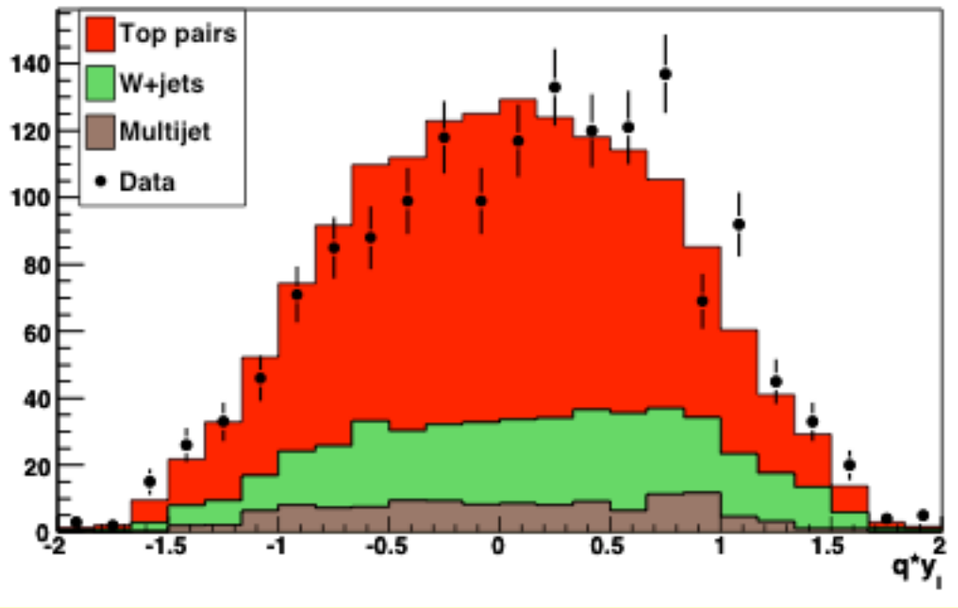
- large in qqbar initial state :

➔ CDF sees a 3 sigma excess at high Mttbar

$$\Delta y = y_t - y_{\bar{t}} = q_{\rm lep} \cdot (y_{t,\rm lep} - y_{t,\rm had})$$







$$A_{fb} = \frac{N_f - N_b}{N_f + N_b}$$

$$A_{fb}^{\rm lep} = \frac{N_f^{\rm lep} - N_b^{\rm lep}}{N_f^{\rm lep} + N_b^{\rm lep}}$$

➔ check the influence of ttbar pt

	Asymmetries (%)	
	Data	MC@NLO
Reconstructed A_{fb}	9.5 ± 3.8	7.3 ± 0.4
Gen. level A_{fb}	18.0 ± 4.4	11.5 ± 0.1
Reconstructed $A_{fb}^{\rm lep}$	14.1 ± 3.8	4.5 ± 0.4
Gen. level $A_{fb}^{\rm lep}$	13.5 ± 3.2	4.3 ± 0.1

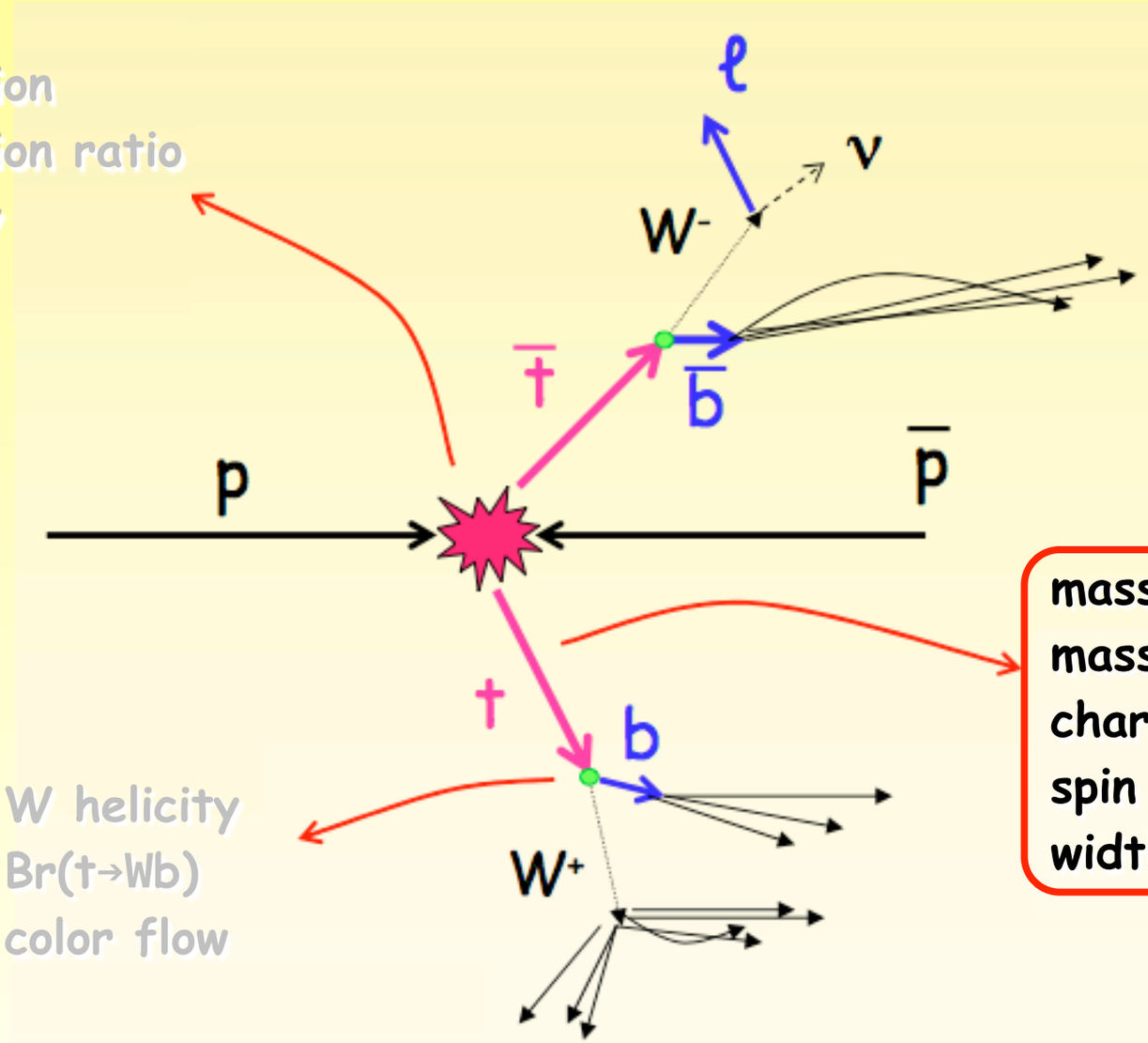
- dilepton asymmetry :

➔ expected for summer

$$A^{\ell\pm} = \frac{\int_{y>0} N_{\ell\pm}(y) - \int_{y<0} N_{\ell\pm}(y)}{\int_{y>0} N_{\ell\pm}(y) + \int_{y<0} N_{\ell\pm}(y)}$$

Intrinsec Top Quark Properties

cross section
cross section ratio
asymmetry



mass
mass difference
charge
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W helicity
Br(t→Wb)
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Top Quark Mass

- most precise measurements used the matrix method :

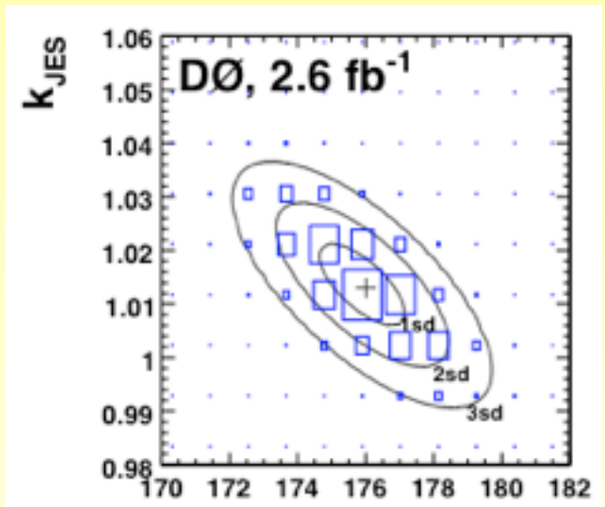
$$P_{t\bar{t}}(x; M_{top}, JES) = \frac{1}{Acc \times \sigma} \int d^6\sigma(y; M_{top})\, f(q_1) f(q_2)\, W(x, y, JES)\, dq_1 dq_2$$

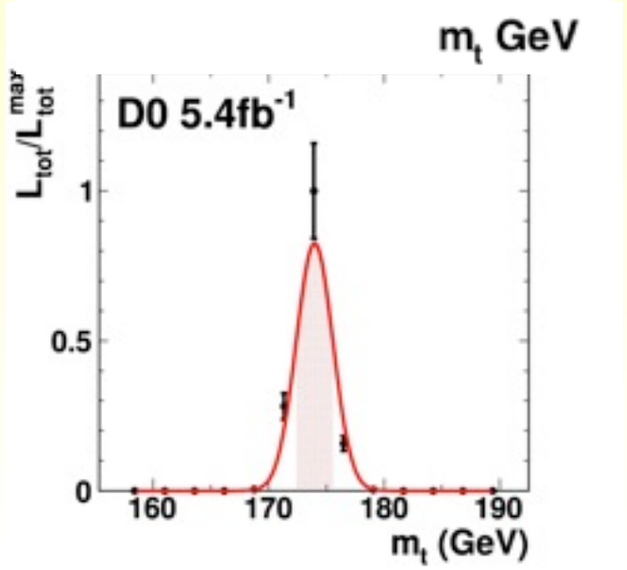
➔ ljets 3.6 fb^{-1} (sign-off) :

$$m_t = 174.94 \pm 0.83(\text{stat}) \pm 0.78(\text{JES}) \pm 0.96(\text{syst})\ \text{GeV}$$

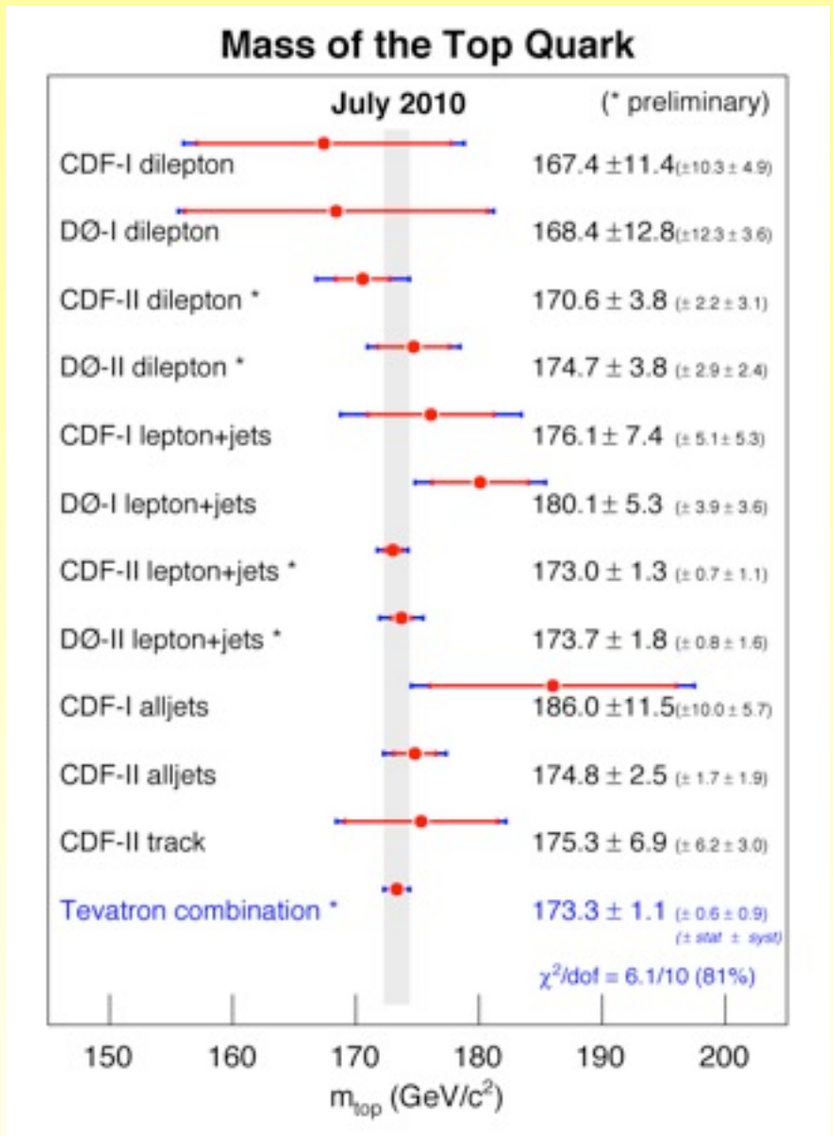
➔ dilepton 5.4 fb^{-1} (arXiv:1105.0320, submitted to PRL)

$$m_t = 174.0 \pm 1.8(\text{stat}) \pm 2.4(\text{syst})\ \text{GeV}$$





Source	Uncertainty (GeV)
Modeling of production:	
Modeling of signal:	
Higher-order effects	±0.25
ISR/FSR	±0.26
Hadronization and UE	±0.58
Color reconnection	±0.28
Multiple $p\bar{p}$ interactions	±0.07
Modeling of background	±0.16
W+jets heavy-flavor scale factor	±0.07
Modeling of b quark	±0.09
Choice of PDF	±0.24
Modeling of detector:	
Residual jet energy scale	±0.21
Data-MC jet response difference	±0.28
b-tagging efficiency	±0.08
Trigger efficiency	±0.01
Lepton momentum scale	±0.17
Jet ID efficiency	±0.26
Jet energy resolution	±0.32
Method:	
Multijet contamination	±0.14
Signal fraction	±0.10
MC calibration	±0.20
Total	±1.02



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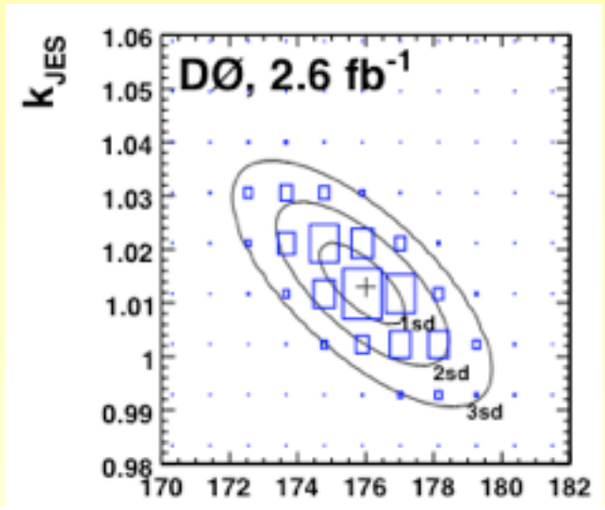

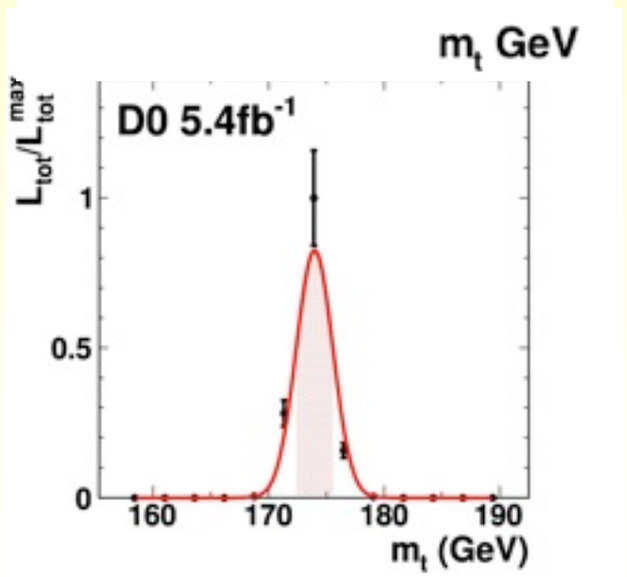

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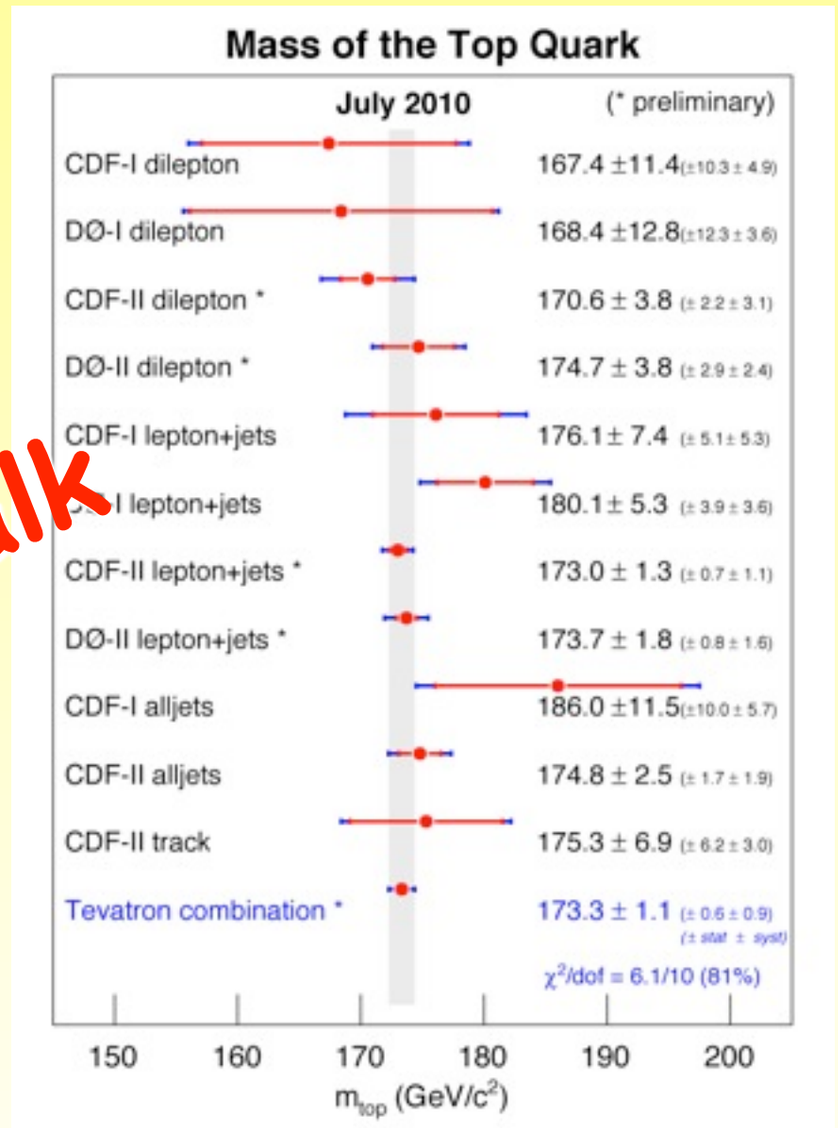
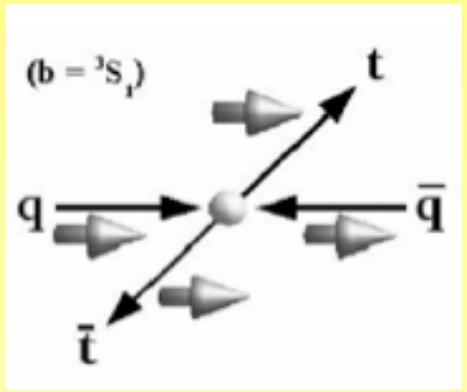
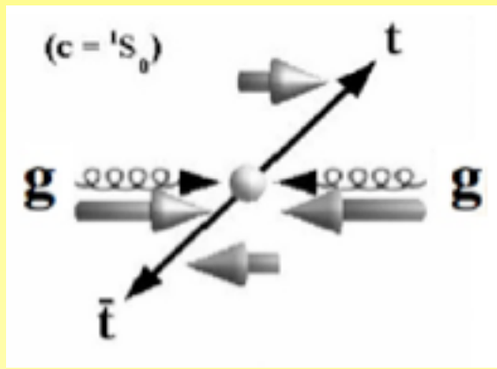


Alexander's talk

ttbar Spin Correlations

- initial state specific:





$$\frac{1}{\sigma}\frac{d^2\sigma}{d\cos\theta_1 d\cos\theta_2} = \frac{1}{4}(1 - C\cos\theta_1\cos\theta_2)$$

$C = 0.777^{+0.027}_{-0.042}$ is predicted at NLO

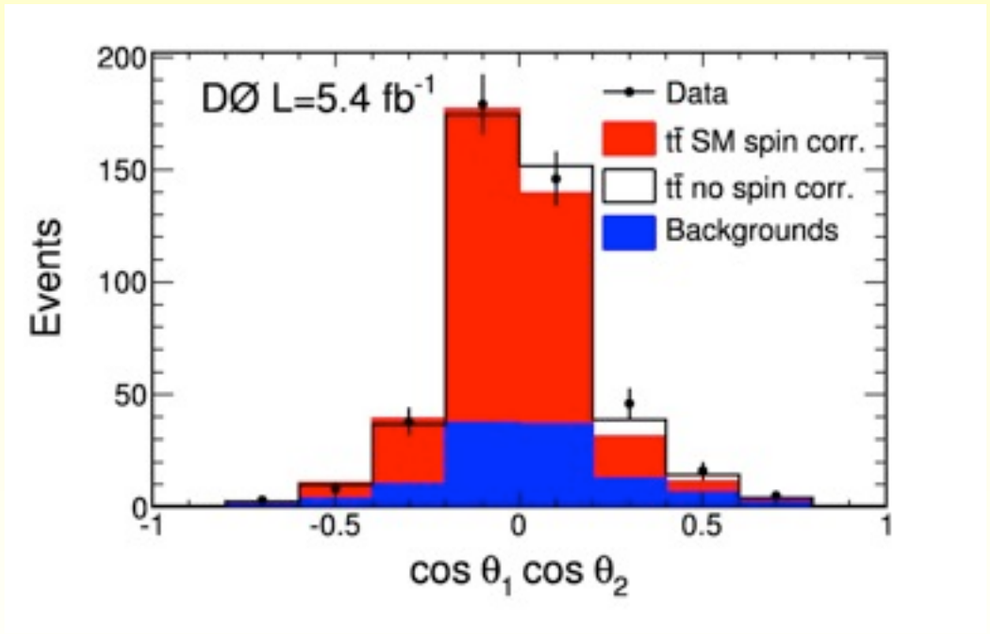
➔ template, dilepton 5.4 fb-1 (arXiv:1103.1871, submitted to PLB)

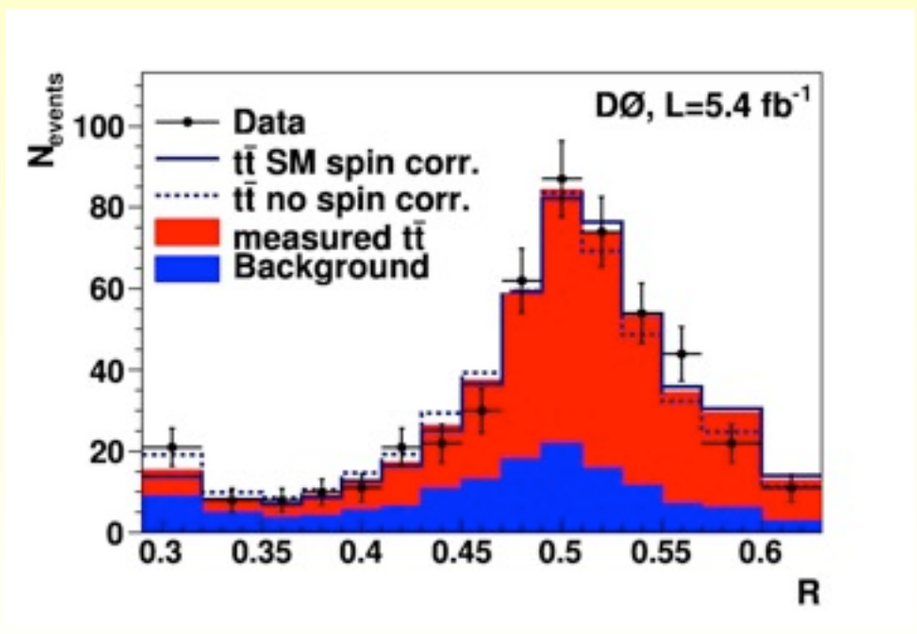
$$C = 0.10^{+0.45}_{-0.45}$$

➔ using the matrix element method, dilepton 5.4 fb-1 (submitted to PRL):

$$R = \frac{P_{\rm sgn}(H=c)}{P_{\rm sgn}(H=u) + P_{\rm sgn}(H=c)}$$

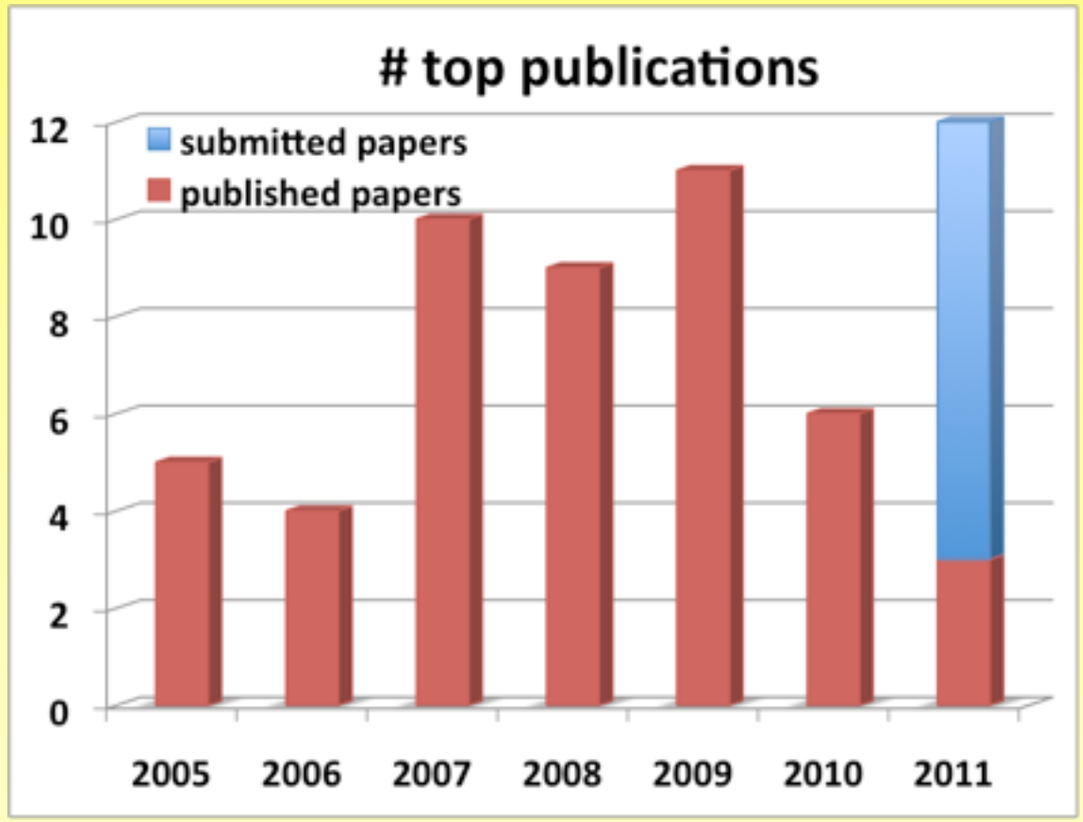
$$C_{\rm meas} = 0.57 \pm 0.31\,({\rm stat+syst})$$



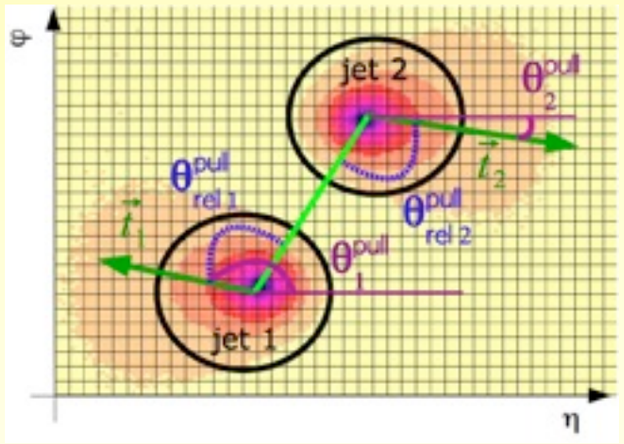


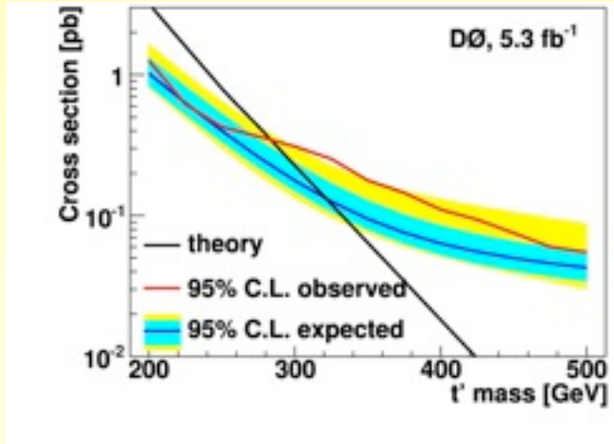
And Many More Results

- 2011 publications so far:
  - ➔ search for W'
  - ➔ W helicity
  - ➔ Color flow
  - ➔ ljets and dilepton ttbar cross sections
  - ➔ ttbar spin correlation (template, ME)
  - ➔ search for FCNC
  - ➔ search for t'
  - ➔ t-channel single top
  - ➔ mass from xsection
  - ➔ dilepton ME mass



- final stage of review process:
  - ➔ ljets/dilepton Rb
  - ➔ mass difference
  - ➔ ljets ME mass
  - ➔ single top cross sections
  - ➔ forward-backward asymmetry
  - ➔ CDF/D0 W helicity combination

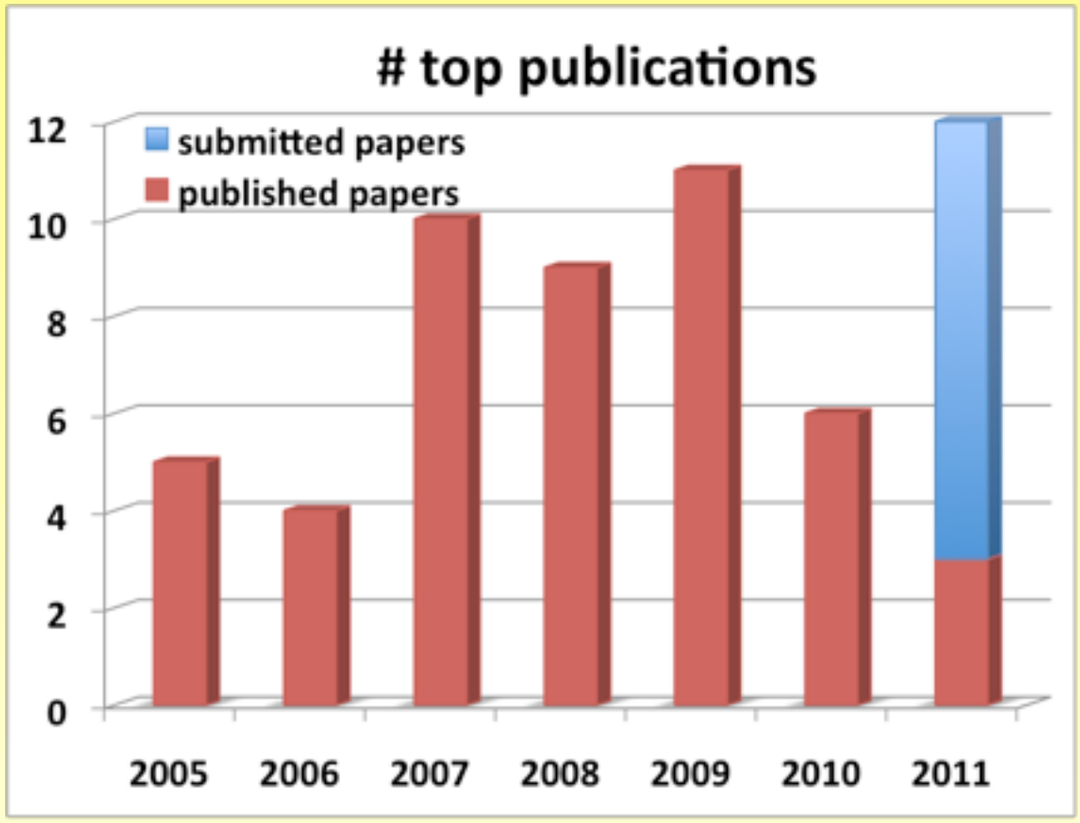




- in (group review):
  - ➔ dilepton neutrino weighting mass
  - ➔ search for Z'

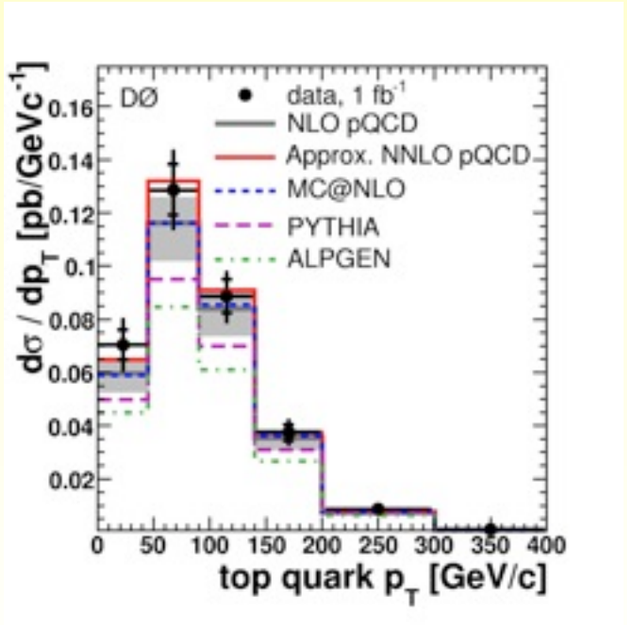
Expected for the Summer

- using 5.4 fb^{-1}:
  - ➔ search for Lorentz invariance
  - ➔ top charge
  - ➔ dilepton asymmetry
  - ➔ search for anomalous couplings in single top
  - ➔ search for CP violation in single top
  - ➔ determination of the top width



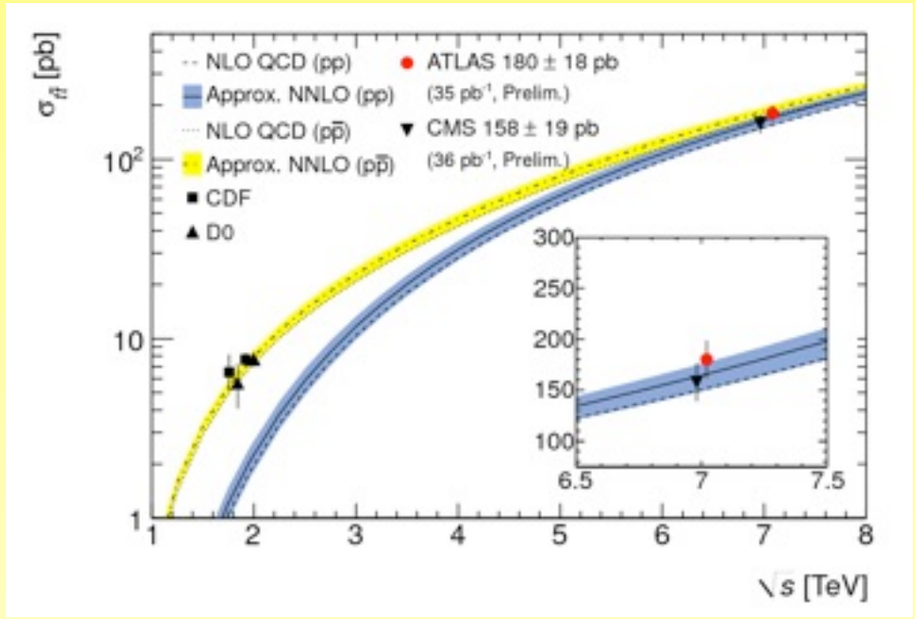
- ➔ ljets spin correlation
- ➔ ljets ideogram mass
- ➔ search for ttH
- ➔ search for ttbar resonance

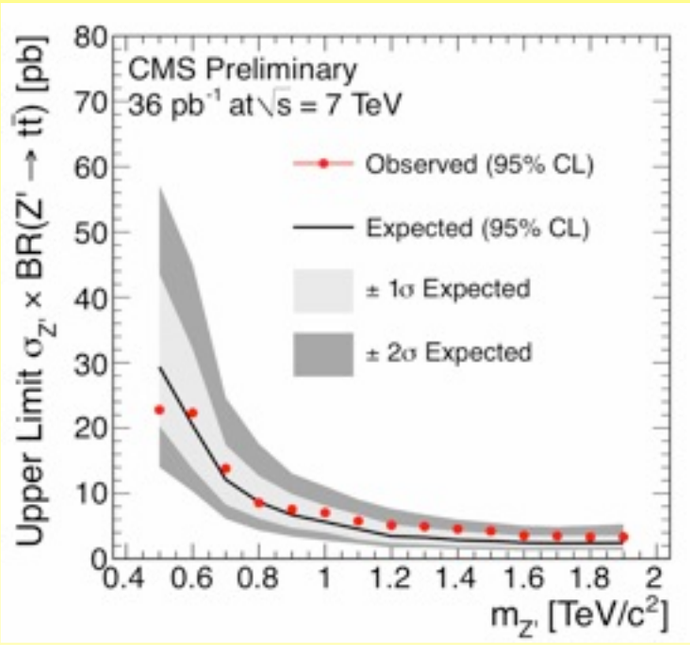
- using 7 fb^{-1}:
  - ➔ template dilepton spin correlation
  - ➔ dilepton ME mass update
  - ➔ ttbar ljets differential xsection

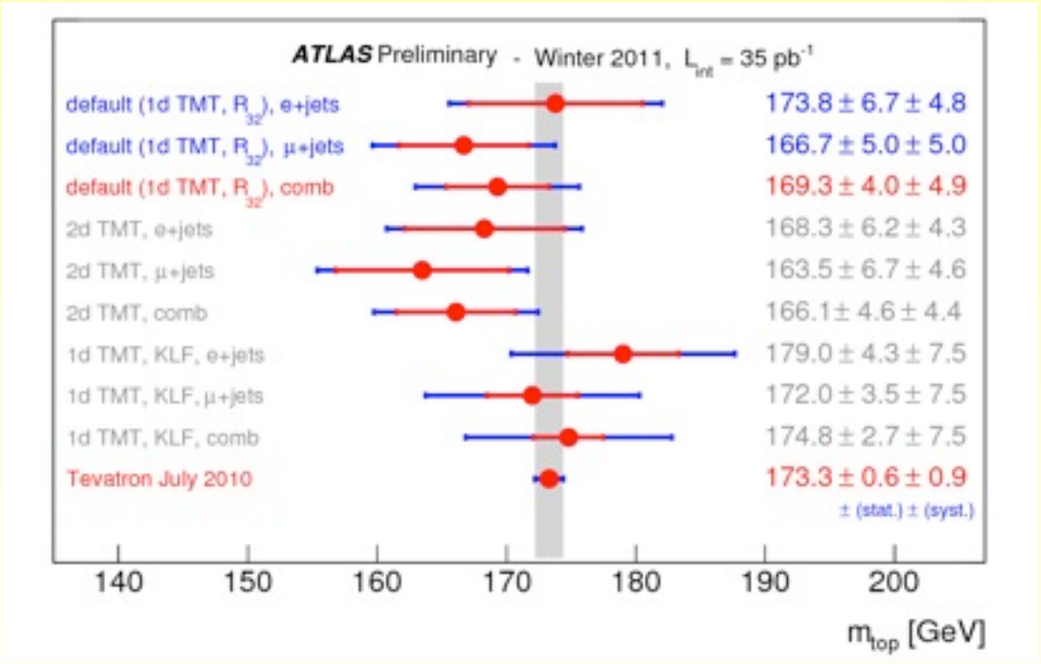


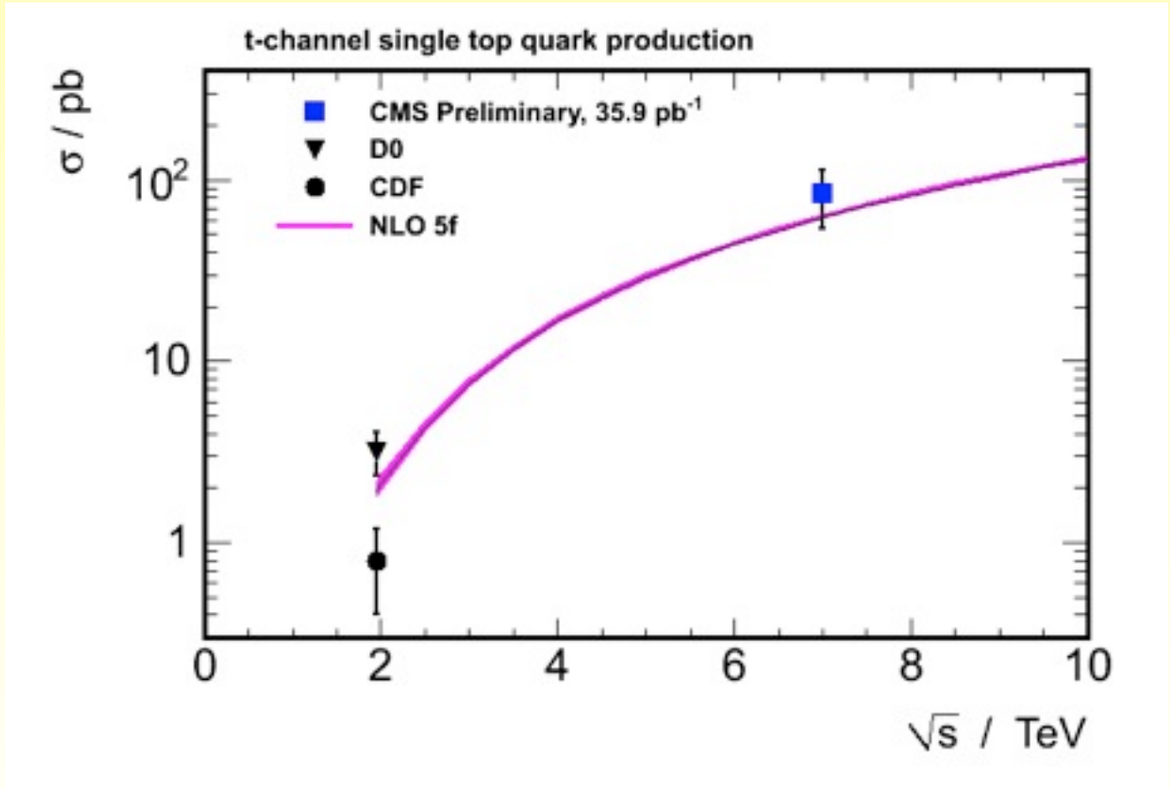
LHC Winter 2011 Results

- ttbar cross section :
  ~ 10 % precision
- single top cross section :
  > 3 σ for t-channel
- mass:
  > 6 GeV
- other properties:
  - first W helicity, asymmetry, searches



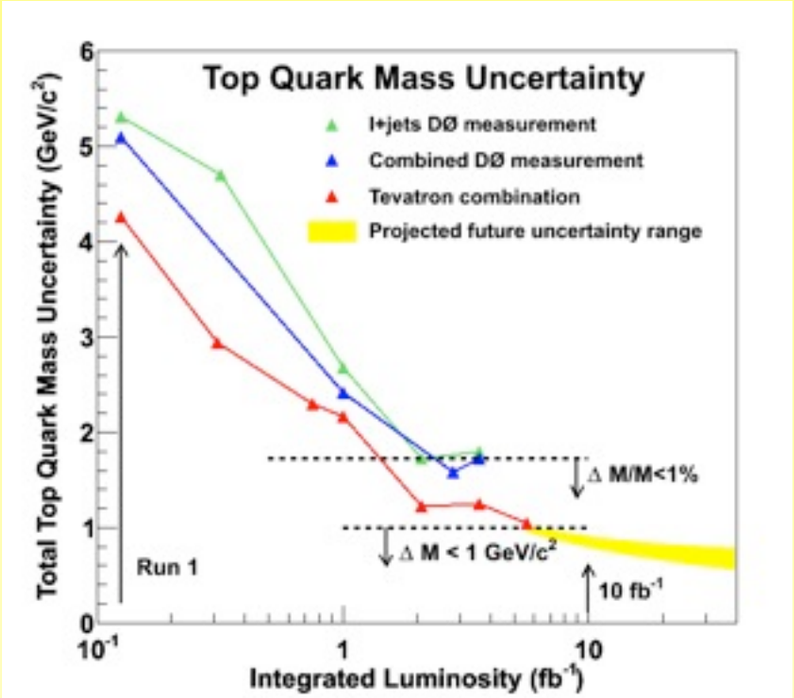






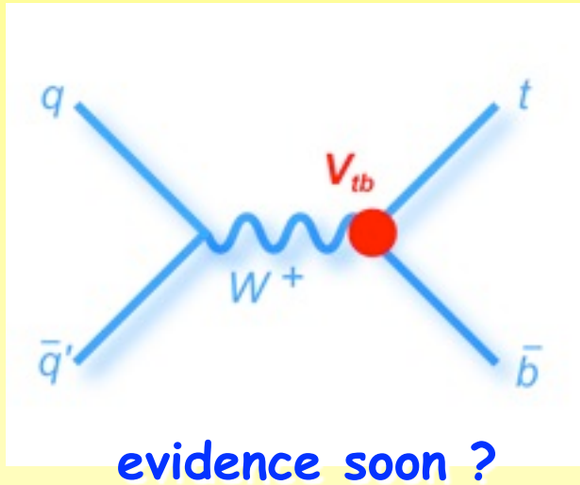
Tevatron Top Legacy Measurements

- legacy:
  - top mass



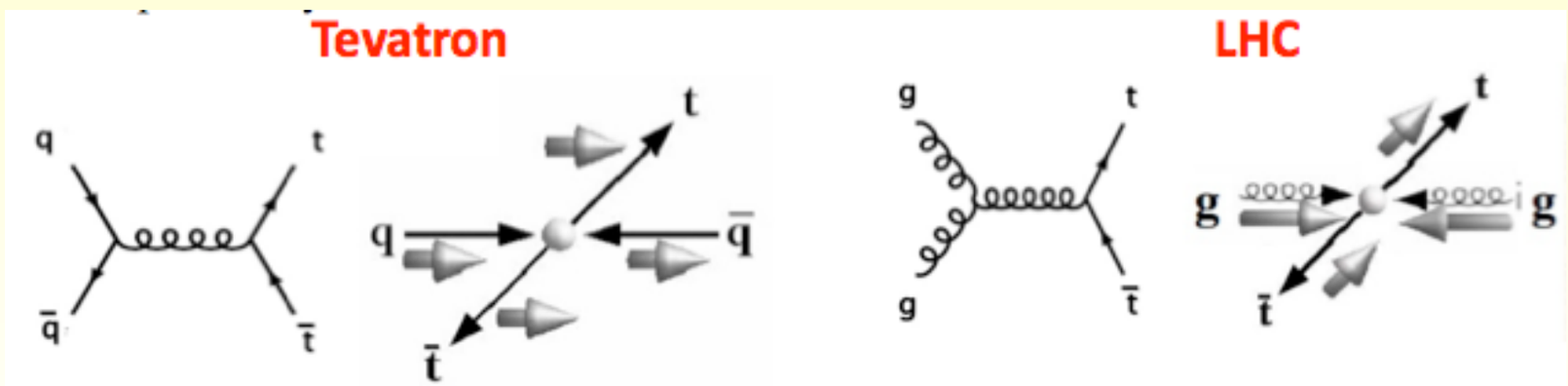
Tevatron top mass error below 1 GeV possible

- competitive with LHC:
  - s-channel single top

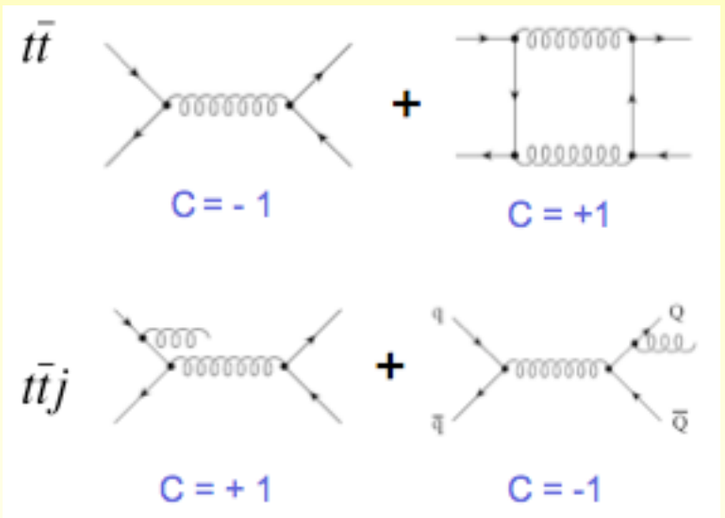


evidence soon ?

- complementary with LHC:
  - ttbar spin correlation
  - top forward-backward asymmetry



first observation spin correlation possible



confirm or not CDF excess

Improving the Mass Measurements

- it is all about systematics !
- dedicate effort to discuss these specific issues
- dilepton channel:
  - using the corrections for the MC/Data jet response
  - using the ljets in-situ JES calibration (detailed studies ongoing)

Source	Uncertainty (GeV)
Physics modeling:	
Signal modeling:	
Higher order effects	±0.25
ISR/FSR	±0.26
Hadronization and UE	±0.58
Color reconnection	±0.28
Multiple hadron interactions	±0.07
Background modeling	±0.16
W+jets heavy flavor scale factor	±0.07
b-modeling	±0.09
PDF uncertainty	±0.24
Detector Modeling:	
Residual jet energy scale	±0.21
Data-MC jet response difference	±0.28
b-tagging efficiency	±0.08
Trigger efficiency	±0.01
Lepton momentum scale	±0.17
Jet ID efficiency	±0.26
Jet energy resolution	±0.32
Method:	
Multijet contamination	±0.14
Signal fraction	±0.10
MC calibration	±0.20
Total	±1.02

- ljets channel:
  - check if no double counting
  - difference in response between Pythia and Herwig
  - update method to determine ISR/FSR systematics

- Higher Order: difference between Alpgen+Herwig and MC@NLO
- ISR/FSR: parameter variations inside Pythia (estimated by CDF)
- Hadronization: difference between Alpgen+Pythia and Alpgen+Herwig

Conclusion

- the Tevatron is performing high precision measurements in the top sector
- A lot of published top results this year with a large implication of D0-France people (Saclay, Clermont)
- prepare the top legacy measurements :
  - measurements that are statistically limited
  - measurements that can't be done at the LHC
  - measurements that will remain competitive for a long time
  - combinations with CDF
- searches: make sure we don't miss anything