# Nuova fisica nel settore del top ad LHC


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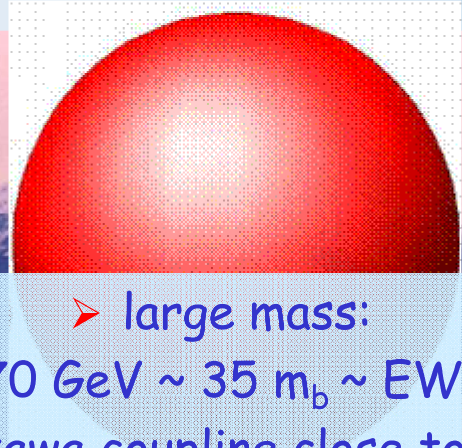
(the first and the last slide in Italian!)

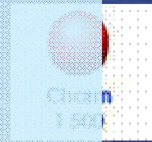
# Top quark: what is it?




- large mass:

  $m_t \sim 170$ GeV $\sim 35\, m_b \sim$ EW scale
- Yukawa coupling close to one:

  $\lambda_t = \sqrt{2}\, m_t / v \sim 0.98$




Are them only accidents?

Is the top mass generated by a standard Higgs mechanism?
…maybe it plays a more fundamental role in EWSB?

Playing with LHC, we hope to approach the answers…

Foto: Gennaro Lerre

# Top quark: why we like it?

- t quark production and decays are evaluated within the Standard Model with high accuracy without any phenomenological parameters
- t quark decays through the ONLY channel $t \rightarrow bW$. Other decay channels have $BR<10^{-3}$
- $\tau(t) \sim 5\ 10^{-25}$ s, $\tau_{QCD} \sim 10^{-24}$ s: no formation of top-hadrons

**→ Any experimental observation of unusual process with top is an indication of a New Physics**

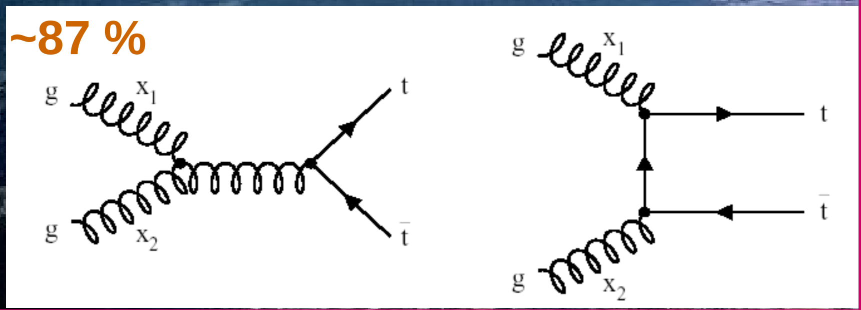
Top quark is a laboratory where unique and powerful instrument can be found:

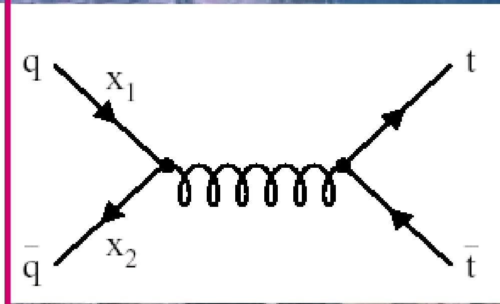
- to test precisely the Standard Model
- to look beyond it

# LHC: a top factory

NLO cross-section $\sigma^{NLO}$ = **833** pb ⇨ ~8M events/10fb$^{-1}$

~87 %

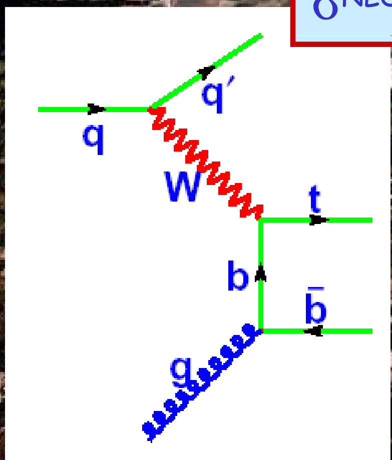


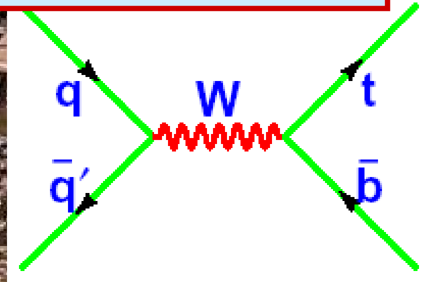

10 t $\bar{t}$ pairs per day @ Tevatron ⇨ 1 t $\bar{t}$ pair per second @ LHC

*$qq \rightarrow t\,\bar{t}$ : 85%* *$gg \rightarrow t\,\bar{t}$ : 87%*

$\sigma^{NLO}$ = **153+90** pb

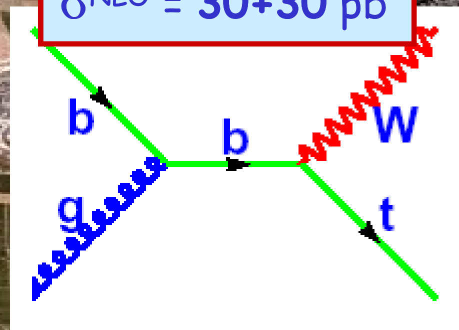



$\sigma^{NLO}$ = **6.6+4.1** pb




⇨ ~3.7M events/10fb$^{-1}$

$\sigma^{NLO}$ = **30+30** pb



# The birth of a top

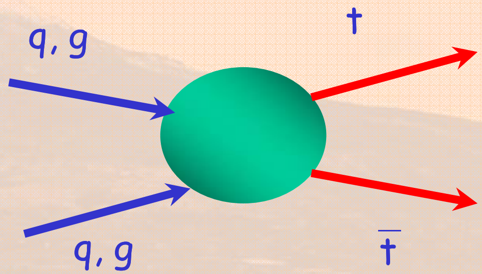
**Production cross section:**

exotic production mechanisms predicted by several models

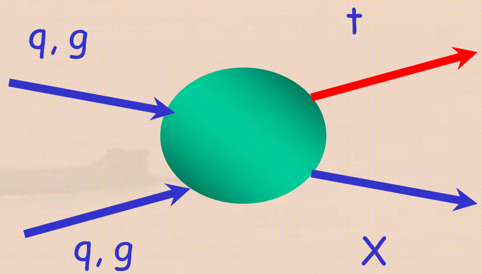
- *Flavour changing neutral couplings*
- *SUSY charged Higgs:* $H^{\pm} \rightarrow t\, b$
- *SUSY top* : t˜t → t $\bar{t}$ +X, t $\bar{t}$ → t˜t +X…
- *Topcolor-assisted technicolor, Extra EW gauge bosons…:*

  - there are heavy Z' and W' coupling preferentially to the third generation

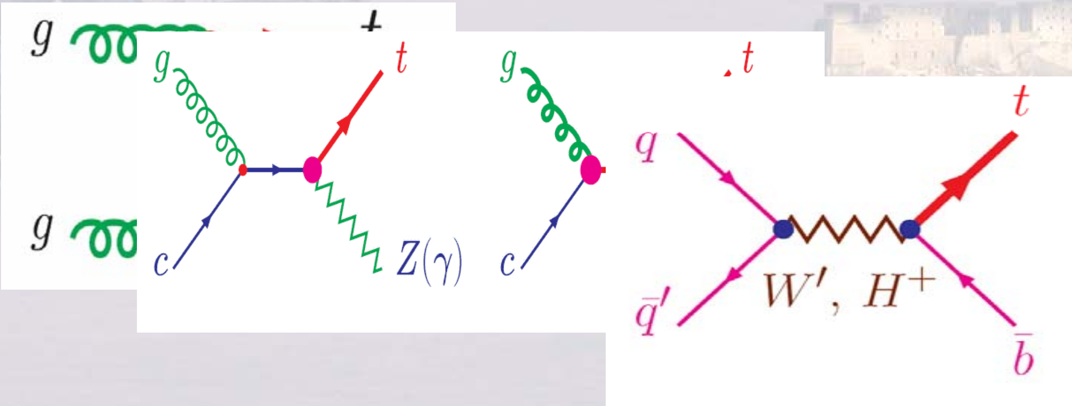
  - there are t' fermions decaying t'→ Wb
- top-pions (t $\bar{t}$, t $\bar{b}$,…) bound by the strong topcolor dynamics (visible in single top production) (*hep-ph/9911288*)




t $\bar{t}$ pair production




single-top production



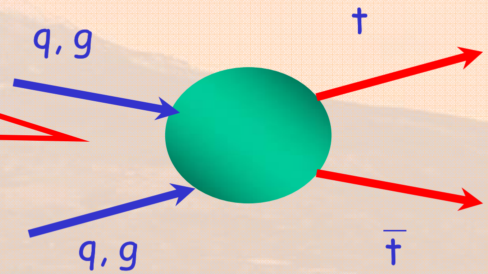
# The birth of a top

**Resonant production:**

Heavy new particles decays $X \rightarrow t\bar{t}$ and enters here

- *Topcolor* : there is a new strong gauge force coupling preferentially to the third generation

→ **a $t\bar{t}$ condensate is formed**

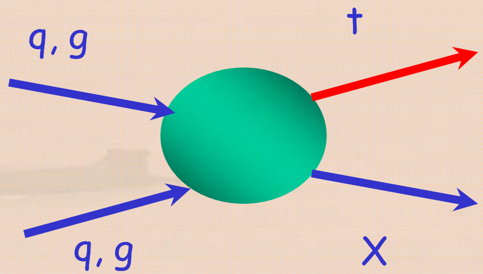



$t\bar{t}$ pair production

**Top Spin Polarization:**

The SM predicts how $t$ and $\bar{t}$ spin are correlated

- right-handed weak interactions or production via intermediate scalar may cause a deviation from SM




single-top production

These processe affect both QCD and EW production

# Resonant production

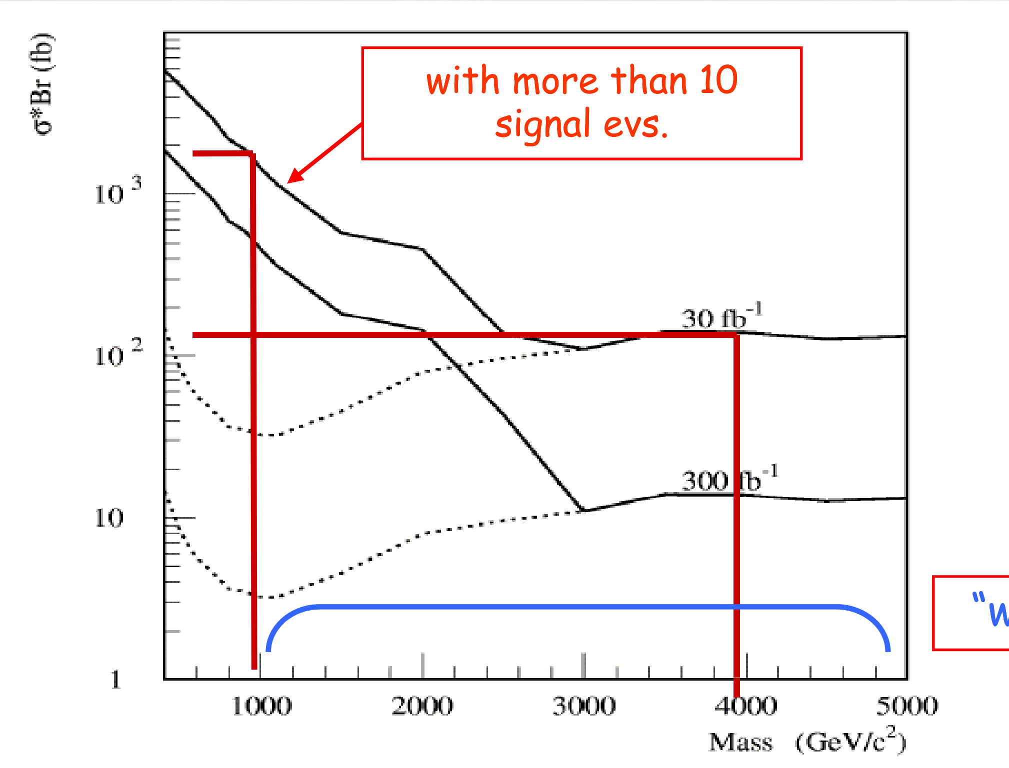
Search for resonances in the $t\bar{t}$ mass spectrum $d\sigma(t\bar{t})/dm(t\bar{t})$

No narrow $X(t\bar{t})$ resonance was found at Tevatron:

**CDF**: $M_X < 725$ GeV, **DØ**: $M_X < 680$ GeV

CDF conference note 8087 (2006)

DØ conference note 4880 (2005)




**ATLAS** (ATL-PHYS-PUB-2006-033):

Which is the minimum $\sigma$ (x BR) prod. cross-section to discover X at $5\sigma$?

→ It depends from $M_X$ and from $\int \mathcal{L}$

other distr. addressable with high statistic:

$d\sigma/d\eta$, $d\sigma/dp_T$ in pair or single prod.

→ sensitive to New Phys.

"where no man has never gone before"...

# Production cross section: top pair

Measure of $\sigma (t\bar{t})$ are becoming better and better...

**The present:** no claims for deviations @Tevatron:

**DØ** combined $7.1^{+1.9}_{-1.7}$ pb

**CDF** combined 7.3±0.9 pb

Theo expect.($\sqrt{s}$ = 1.96 TeV, $m_t$=175 GeV): 5.8 - 7.4 pb

*Tevatron with 10 fb $^{-1}$: $\Delta\sigma (t\bar{t})/\sigma (t\bar{t}) < 6\%$*

**The future:**

CMS 10 $fb^{-1}$ (similar results for ATLAS ):

- *semilept:*

$\Delta\sigma (t\bar{t})/\sigma (t\bar{t})$ = 0.4%(stat) ±9.7%(syst) ± 3%(lum)

systematic uncertainties in the btag eff( 5%)→7%, PDF→3.4%, pileup→3.2%

- *di-lept:*

$\Delta\sigma (t\bar{t})/\sigma (t\bar{t})$ = 0.9%(stat) ±11%(syst) ± 3%(lum)

- *fully had:*

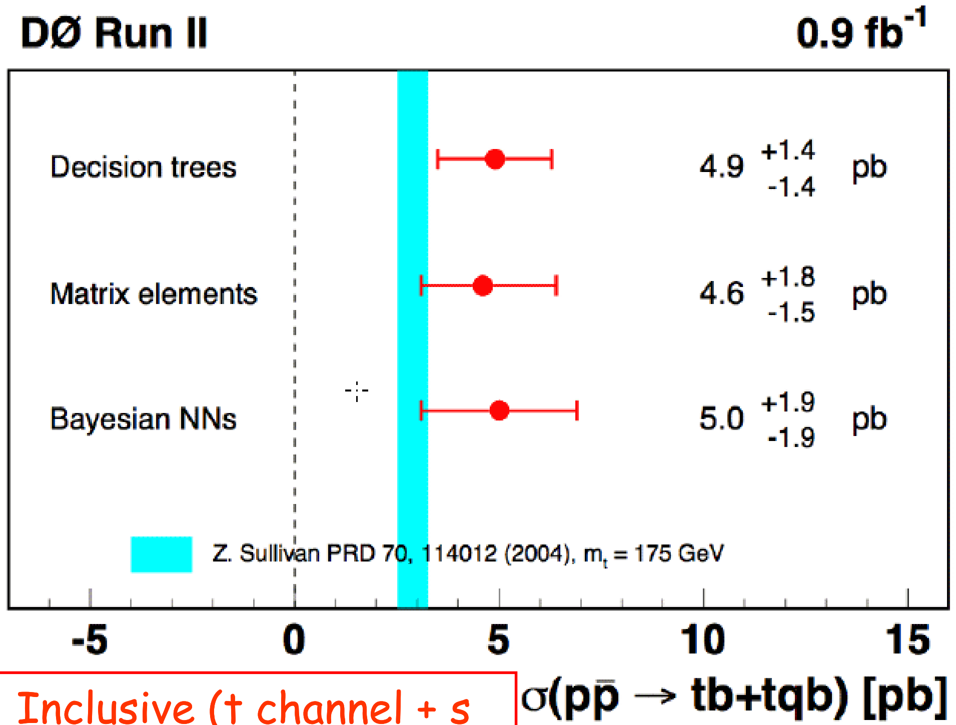
$\Delta\sigma (t\bar{t})/\sigma (t\bar{t})$ = 3%(stat) ±20%(syst) ± 3%(lum)

# Production cross section: single top

**The present:**

**DØ:** single top events with 3.4s have been observed with cross-section exceeding SM (hep-ex/0612052)

**CDF, different results:** $\sigma_{s+t} < 2.6$ pb 95% (CDF Note 8677), $\sigma_{s+t} < 3.4$ pb 95% (CDF Note 8185)




3 different (correlated) extraction techniques

Inclusive (t channel + s channel) analysis

- Much more statistic is needed to draw significant conclusion
- LHC is expected to provide an indipendent estimate

# Production cross section: single top

**The future:** much larger statistic, much better S/B ☺

| | | | |
|---|---|---|---|
| Single top (s-channel) | 0.88±0.12 pb | 10±1 pb | (x10) |
| Single top (t-channel) | 1.98±0.22 pb | 245±17 pb | (x120) |
| Single top (Wt channel) | 0.15±0.04 pb | 60±10 pb | (x400) |
| Wjj (*) | ~1200 pb | ~7500 pb | (x6) |
| bb+other jets (*) | ~2.4x10$^5$ pb | ~5x10$^5$ pb | (x2) |

(*) with kinematic cuts in order to better mimic signal
Belyaev, Boos, and Dudko [hep-ph/9806332]

- t-ch: $\Delta\sigma/\sigma$= 3%(stat) ± 7%(syst) ± 5%(lumi) (10 fb$^{-1}$) (hep-ph/0408049)
- s-ch: $\Delta\sigma/\sigma$= 18%(stat) ± 31%(syst) ± 5%(lumi) (10 fb$^{-1}$) (CMS note 2006/084)
- Wt-ch: $\Delta\sigma/\sigma$= 6%(stat) ± 16%(syst) ±5%(lumi) (10 fb$^{-1}$) (CMS note 2006/086)

*Fight with system. from:*

- detector: JES at high eta,ISR+FSR for jet veto, b eff
- theory: PDF, QCD scale, $m_t$

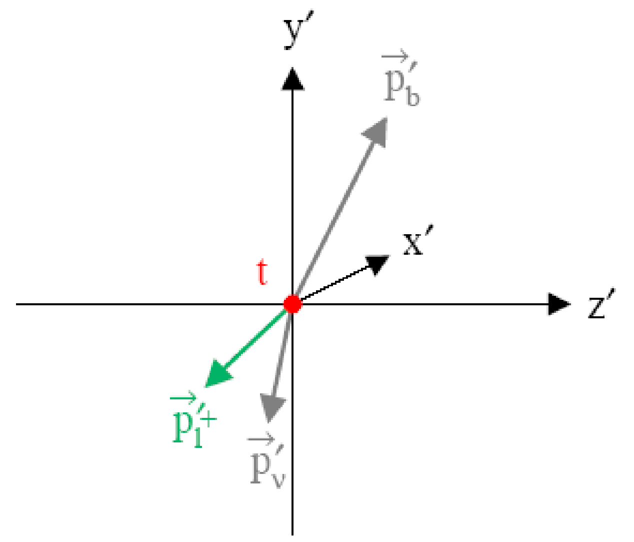
# Spin of top and spin of antitop

**How LHC can look at top spin?**

no t hadronization → spin is transferred to decay products

- choose the helicity base: t and $\bar{t}$ flight direction
- count production rates of like-spin and unlike-spin pairs
- evaluate A:

$$\mathcal{A} = \frac{N(t_L\bar{t}_L + t_R\bar{t}_R) - N(t_L\bar{t}_R + t_R\bar{t}_L)}{N(t_L\bar{t}_L + t_R\bar{t}_R) + N(t_L\bar{t}_R + t_R\bar{t}_L)}$$




The SM says:

- when produced by gg: $3S^1$ state (⇑ ⇑)
- when produced by qq: $3S^0$ state (⇑⇓)

(close to production threshold)

→ An excess of spin point in the same direction is expected:

$$A = 0.311^{+0.034}_{-0.035}(stat) \pm 0.028(syst)$$

The problem is: what can we choose as 'spin analyzer'? t is correlated with its decay products:

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\chi} = \frac{1}{2}(1 + \alpha\cos\chi)$$

$\chi$: angle between the decay products of t and $\bar{t}$ in the respective rest frame

$\alpha(l,d)=+1$, $\alpha(\nu)=-0.31$ , $\alpha(W)=0.41$, $\alpha(u,b)=-0.41$

**So looking at the l from W is the best choice: LHC will deliver ~400 kevs dilept after 10 fb$^{-1}$**

# Spin of top and spin of antitop

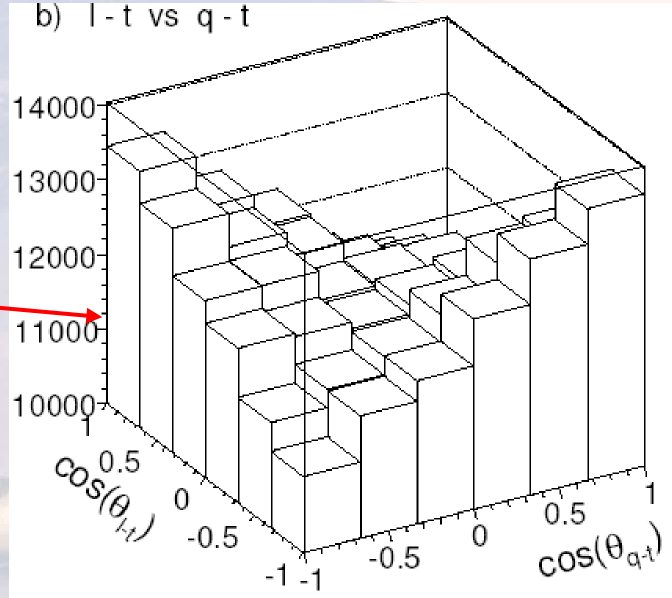
- **Di-lepton channel:** spin analyzers are both l←W←t
- **Lepton+jets channel:** spin analyzers are l←W←t and d←W←t (~100% polarized wrt the t spin)

***pratically***: the least energetic jet in the t ( $\bar{t}$) rest frame (only 51% polarization)

$$\frac{1}{N}\frac{d^2N}{d\cos\theta_l\, d\cos\theta_q} = \frac{1}{4}(1 - \mathcal{A}\kappa_l\kappa_q \cos\theta_l \cos\theta_q)$$

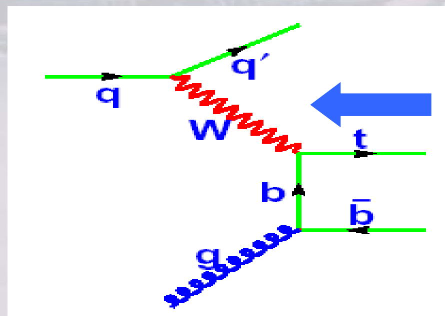
$\theta_1$ ($\theta_1$): angle between the spin analyzers of t ($\bar{t}$) in the t ( $\bar{t}$) rest frame and the t( $\bar{t}$) direction in the t $\bar{t}$ frame

FIT THIS DISTRIBUTION AND FIND $\mathcal{A}$




**Tevatron,**
poor limits:
A > -0.25 (at 68%CL)
($A_{exp}$~ 0.9)

**CMS(30 fb$^{-1}$)** :
$\mathcal{A}$ = 0.346 ± 0021(stat) $^{+0.026}_{-0.055}$ (syst)
(quite similar for ATLAS)




Single top can be addressed to search spin correlation:
- top is highly polarized in some bases ('spectator' jet can be chosen)
- very large statistic

# The top during its life

**Top Mass:**

- is an important input in the SM
- is an important input into theories for BSM (key role in the MSSM, and inspires theories such as top color)

Constraint on h mass:

$m_h$ < 130 GeV with current $m_t$ values

$$M_h^2 < M_Z^2 \cos^2(2\beta) + \frac{3G_f}{\sqrt{2}\pi^2}\, m_t^4\, ln\left(\frac{\tilde{m}^2}{m_t^2}\right)$$

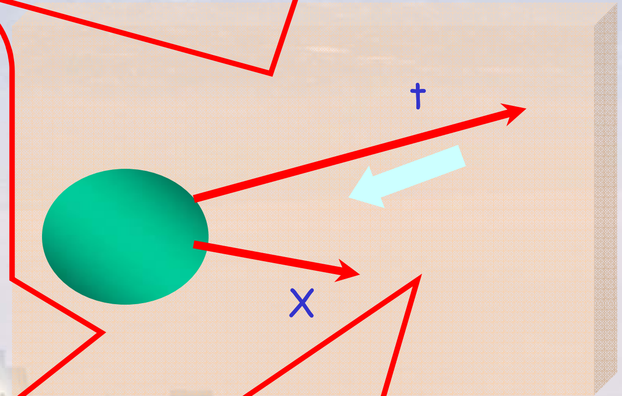
**Top Width:**

- $\Gamma(t)/|V_{tb}|^2$ =1.42 GeV : the total $\Gamma$ not measured yet!
- $\tau = 1/\Gamma \sim 5\ 10^{-24}$ s → $c\tau \sim 3\ 10^{-10}$ $\mu$m

Additional quark generations, non-standard top quark decays or other SM extensions could yield long-lived top quarks in the data

**CDF**: measurement of distance between primary vertex and leptonic $W^\pm$ decay vertex in lept+jets events

$c\tau$ < 52.5 $\mu$m is found at 95% CL (CDF conference note 8104,2006)




**Top charge:**

Are we looking to an exotic Q=4/3 particle? ($t \to W^+ \bar{b}$)

Tevatron Run-II has enough statistic to rule it out:

Q=2/3 at 94% C.L. (DØ conference note 4876, 2005)

# Top is becoming thin…

Better and better at Tevatron:

**End of Run-I:** 178.0 ± 4.3 GeV

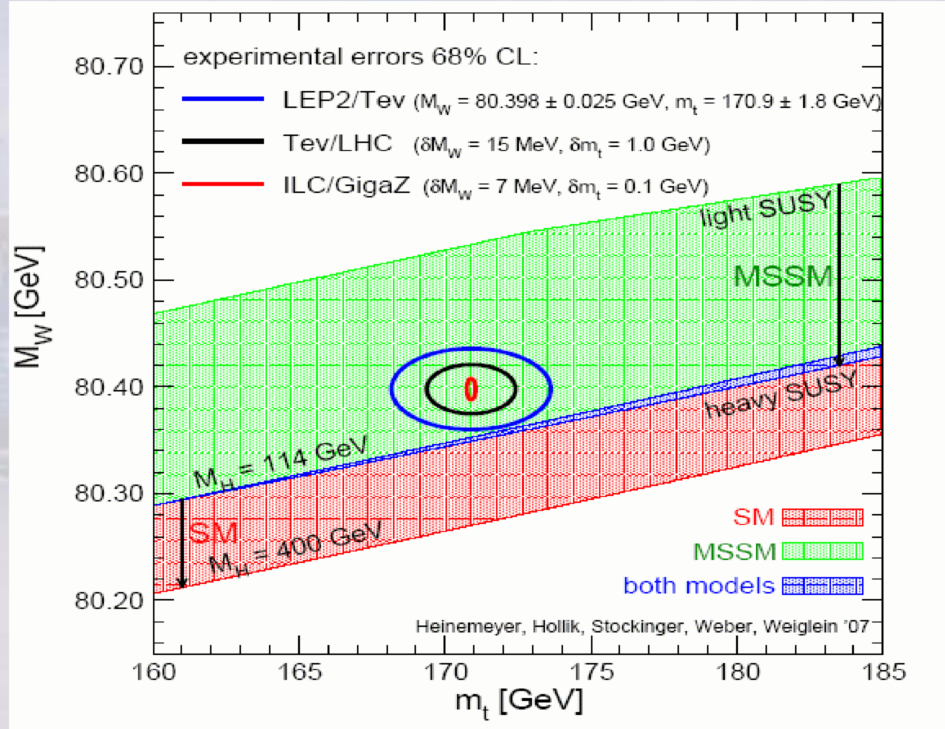
**Preliminary data from Run-II:** 172.5 ± 1.3(stat) ± 1.9(syst) GeV

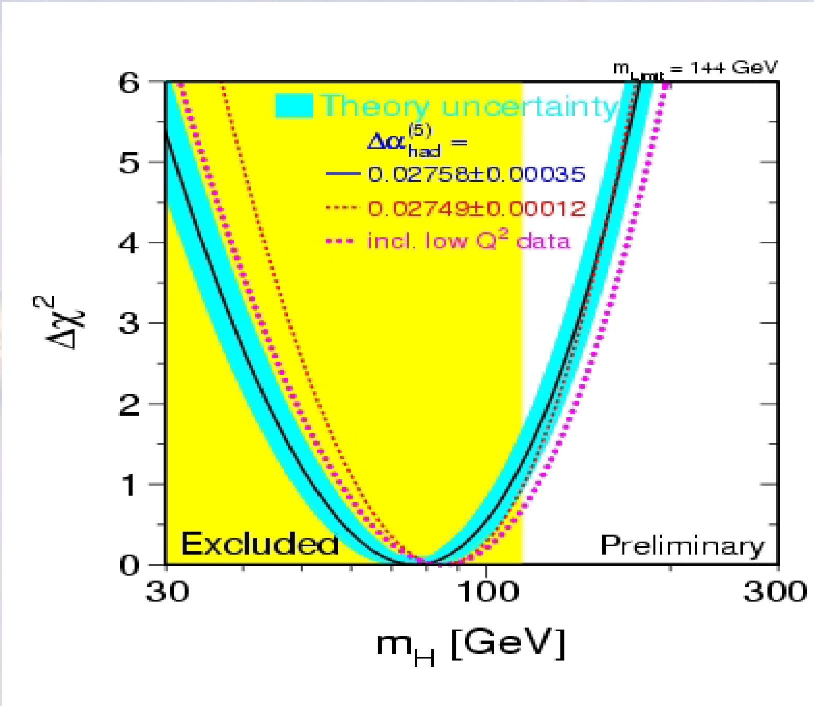
**March 2007:** 170.9 ± 1.1(stat) ± 1.5(syst) GeV

From a EW fit (~indipendent from $m_t$ meas.): $m_t = 172.3^{+10.2}_{-7.6}$ GeV (PDG'06)

Radiative corrections to many precision EW observables are ~$m_t^2$

Meas. $M_W$ and $m_t$ + SM predictions → test the consistency of the SM or point to SUSY



# The future of top mass

**LHC:** Tevatron performances should be reached and improved

- Di-lepton channel: $\Delta m_t / m_t$ = 0.5 (stat)± 1.1 (syst) GeV @10 $fb^{-1}$
- Lepton+jet channel: $\Delta m_t / m_t$ = 0.3 (stat)± 1.1 (syst) GeV @10 $fb^{-1}$

(ATLAS hep-ex/0403021, CMS TDR 8.2, CERN/LHCC 2006-021)

| | Standard Selection | | | Alternative Selection |
|---|---|---|---|---|
| | Gaussian Fit $\Delta m_t$ (GeV/$c^2$) | Gaussian Ideogram $\Delta m_t$ (GeV/$c^2$) | Full Scan Ideogram $\Delta m_t$ (GeV/$c^2$) | Full Scan Ideogram $\Delta m_t$ (GeV/$c^2$) |
| Pile-Up | 0.32 | 0.23 | 0.21 | 0.21 |
| Underlying Event ***(5% On-Off)*** | 0.50 | 0.35 | 0.25 | 0.25 |
| Jet Energy Scale ***(1.5%)*** | 2.90 | 1.05 | 0.96 | 0.90 |
| Radiation (pQCD) | 0.80 | 0.27 | 0.22 | 0.20 |
| Fragmentation | 0.40 | 0.40 | 0.30 | 0.30 |
| b-tagging ***(2%)*** | 0.80 | 0.20 | 0.18 | 0.18 |
| Background | 0.30 | 0.25 | 0.25 | 0.25 |
| Parton Density Functions | 0.12 | 0.10 | 0.08 | 0.10 |
| Total Systematical uncertainty | 3.21 | 1.27 | 1.13 | 1.07 |
| Statistical Uncertainty (10$fb^{-1}$) | 0.32 | 0.36 | 0.21 | 0.31 |
| Total Uncertainty | 3.23 | 1.32 | 1.15 | 1.11 |

With a good systematics control (ΔbJES<1%, Δbtag eff.<2%, accounting for FSR…)

**( $\Delta m_t / m_t)_{TOT}$ ~1 GeV is at hand**

# The death of a top

The focus is on the **tWb vertex**:

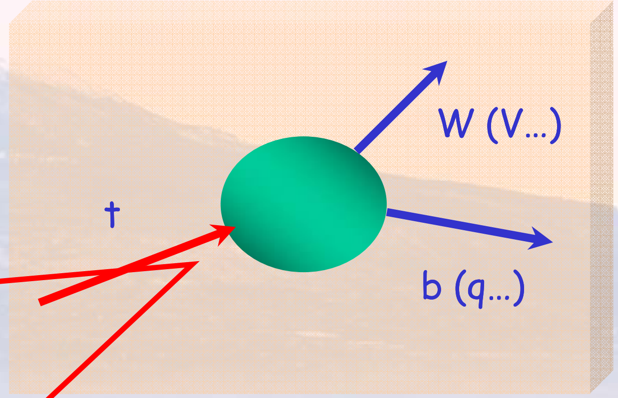
The SM says:

- tWb coupling is purely left-handed at tree level (V-A)
- its size is given by the CKM matrix element $|V_{tb}|$
- flavour changing neutral (FCN) couplings are forbidden at tree level

→ New anomalous couplings (e.g. new radiative contributions) can appear already at tree level and modify the structure of the tWb vertex

→ A window to a new world is open: SM Higgs, MSSM, s-fermion, SUSY with R violation…

CP Violation: very small effects in SM and in BSM (maybe some chances at $\int \mathcal{L} > 150\ fb^{-1}$)



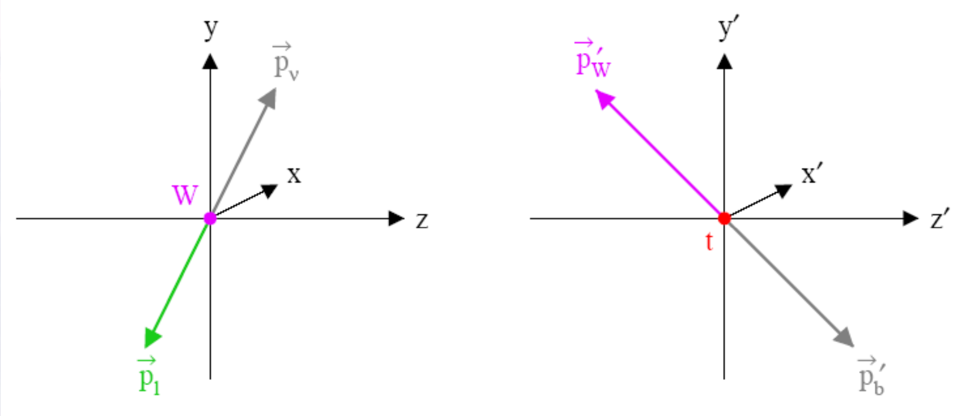
# W boson: how does it spin around?

The V-A interaction controls the helicity fractions of the W

W is produced with different helicity fractions:

- longitudinal $F_0$ = **0.703**
- left-handed $F_L$ = **0.297**
- right-handed $F_R$ = **3.6 $10^{-4}$**

(SM at tree level, $m_t$ = 175 GeV, $M_W$ = 80.39 GeV $m_b$ = 4.8 GeV)




**How to measure them?**

- look at the W→ l ν decays
- measure the angle θ* between the l in the W rest frame and the W in the t rest frame
- extract F fractions from

$$\frac{1}{N}\frac{dN}{d\cos\theta^*} = \underbrace{\frac{3}{8}\frac{1}{1+f}}_{F_L}(1-\cos\theta^*)^2 + \underbrace{\frac{3}{4}\frac{f}{1+f}}_{F_0}\sin^2\theta^* + \underbrace{const}_{F_R}\cdot(1+\cos\theta^*)^2$$

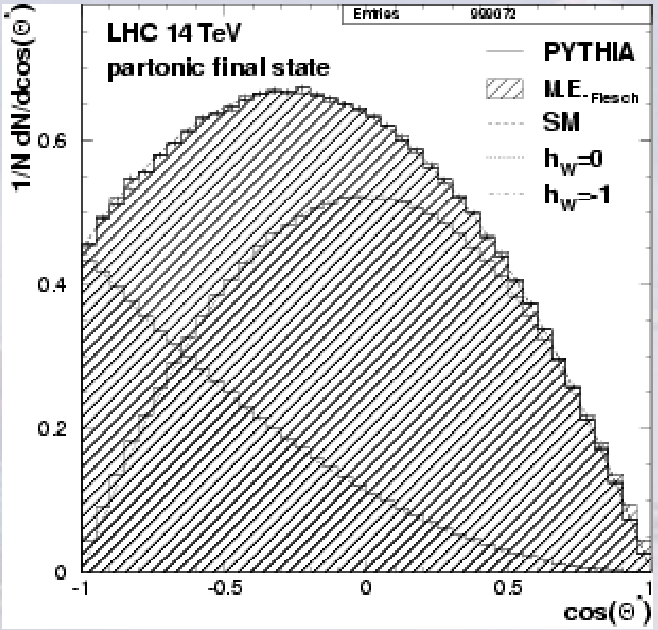
$$f = \frac{m_t^2}{2m_W^2}$$

# W boson: how does it spin around?

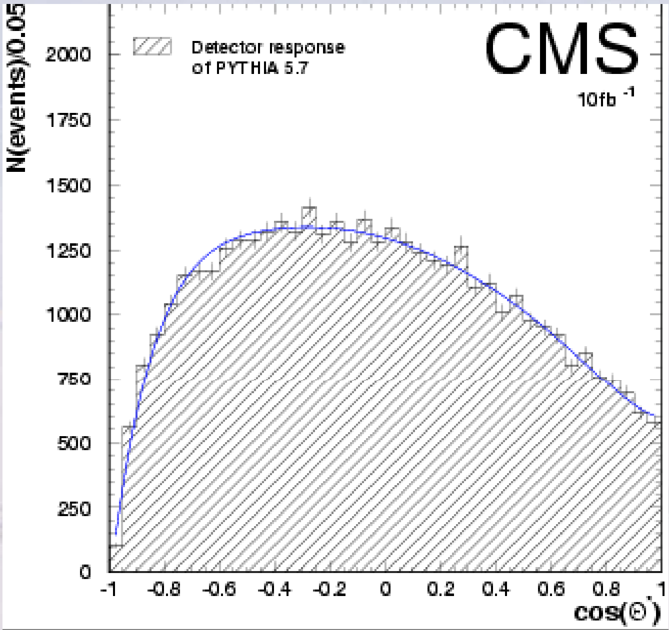
**Tevatron:**

Because of lack of statistic, M(lb) (related to cos $\theta^*$ ) and $p_T$ (l) (related to polarization) better suited

**CDF:** $F_0 = 0.74^{+0.22}_{-0.34}$ , $F_R < 0.18$ 95% C.L




MC generator level




CMS reconstruction level (full sim):
- there is the background
- there are detector effects

**CMS 10 $fb^{-1}$:**

$\Delta F_0/F_0$ = 0.023 (stat) ±0.022 (syst)

significant impact of systematics:

- b-jet energy scale
- b-tag efficiency
- input $m_t$
- ISR/FSR

# tWb: not only W helicity…

Other variables (less prone to systematics) can be looked at:

- $F_{L,R}/F_0$ ratios
- top angular asymmetries, e.g.:

$$A_{FB} \equiv \frac{N(x>0)-N(x<0)}{N(x>0)+N(x<0)}$$

Nice systematic effects reduction is obtained (ATL-PHYS-PUB-2006-031)

| Observable | Result ($L=10\ fb^{-1}$) | | |
|---|---|---|---|
| $F_0$ | 0.699 | $\pm0.004$ (stat) | $\pm0.020$ (sys) |
| $F_L$ | 0.299 | $\pm0.004$ (stat) | $\pm0.019$ (sys) |
| $F_R$ | 0.0021 | $\pm0.003$ (stat) | $\pm0.003$ (sys) |
| $\rho_L$ | 0.4274 | $\pm0.008$ (stat) | $\pm0.036$ (sys) |
| $\rho_R$ | 0.0004 | $\pm0.002$ (stat) | $\pm0.002$ (sys) |
| $A_{FB}$ | $-0.2231$ | $\pm0.004$ (stat) | $\pm0.013$ (sys) |
| $A_+$ | 0.5472 | $\pm0.003$ (stat) | $\pm0.010$ (sys) |
| | $-0.8387$ | $\pm0.002$ (stat) | $\pm0.003$ (sys) |

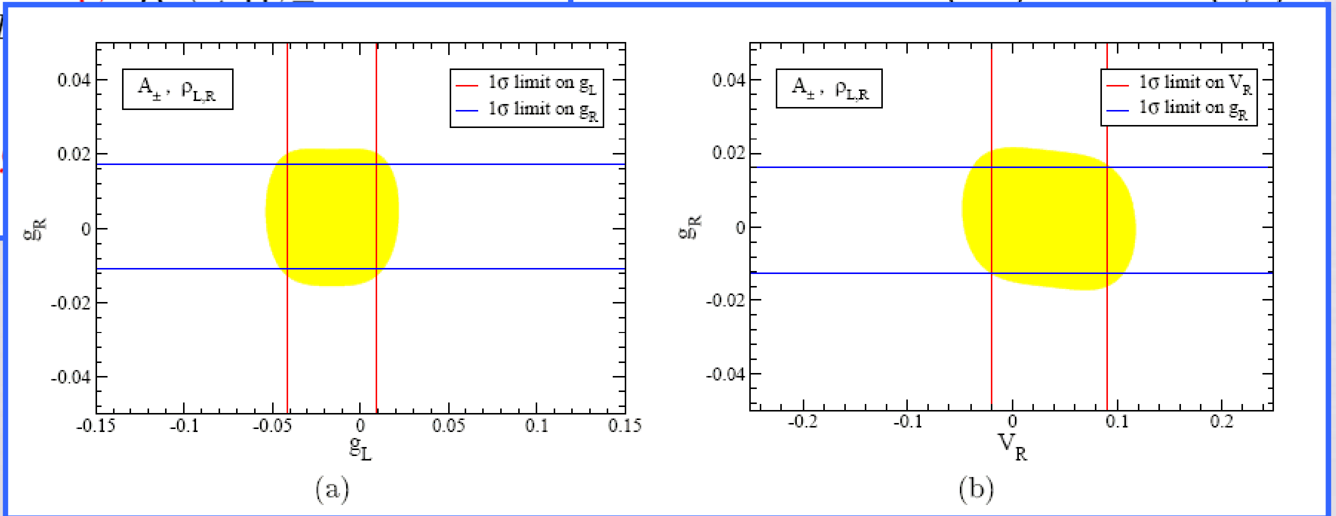
Then the observables can be used to constrain the couplings in the general Lagrangian:

$$\mathcal{L} = -\frac{g}{\sqrt{2}}\bar{b}\,\gamma^{\mu}\,(V_L P_L \ldots$$
$$-\frac{g}{\sqrt{2}}\bar{b}\,\frac{i\sigma^{\mu\nu}q_{\nu}}{M_W}\,(\ldots$$

$-0.0566 < V_R < 0.128$

$-0.0579 < g_R < 0.0258$

$-0.0260 < g_L < 0.312$



# $|V_{tb}|$: a window to New Physics

If $|V_{tb}| < |V_{tb}|_{CKM} \sim 0.9991$ : $t \rightarrow XW$ would be possible
(4th generation of quarks or other...)

The number of events with 0, 1 and 2 tagged b-jets is compared (in di-lepton and lept+jets) to extract the ratio:

$$R(2b/\geq 1b) = BR(t \rightarrow Wb) / \left( BR(t \rightarrow Wd) + BR(t \rightarrow Ws) + BR(t \rightarrow Wb) \right) =$$

$$|V_{tb}|^2 / \left( |V_{td}|^2 + |V_{ts}|^2 + |V_{tb}|^2 \right) = |V_{tb}|^2$$

assuming only 3 generations and CKM unitarity

**At Tevatron:**

**DØ:** $R = 1.03^{+0.19}_{-0.17}$ , $R > 0.64$

**CDF:** $R$ (stat) $= 0.94^{+0.21}_{-0.19}$ (stat) $^{+0.17}_{-0.13}$ (stat) , $R > 0.61$

$|V_{tb}| > 0.78$ (0.75) at 90% (95%) CL

$\Delta|V_{tb}|/|V_{tb}| \sim 5\%$ at Run IIb

**LHC with the same technique:**

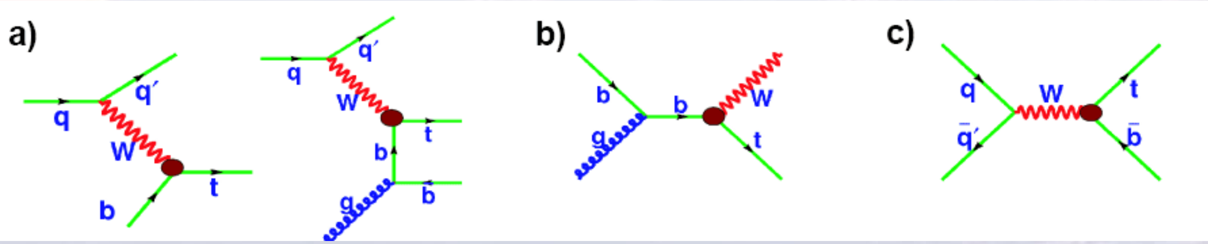
$\Delta R/R \sim 0.2\%$(stat) @ 10 fb$^{-1}$ $\rightarrow \Delta|V_{tb}|/|V_{tb}| \sim 0.1\%$
(Systematic: b-tagging uncert. )

# $|V_{tb}|$: the promises of single-top

**At Tevatron:**

**DØ**: $|V_{tb}|$ estimated in the first single-top observation:

$|V_{tb}| = 1.00^{+0.00}_{-0.12}$

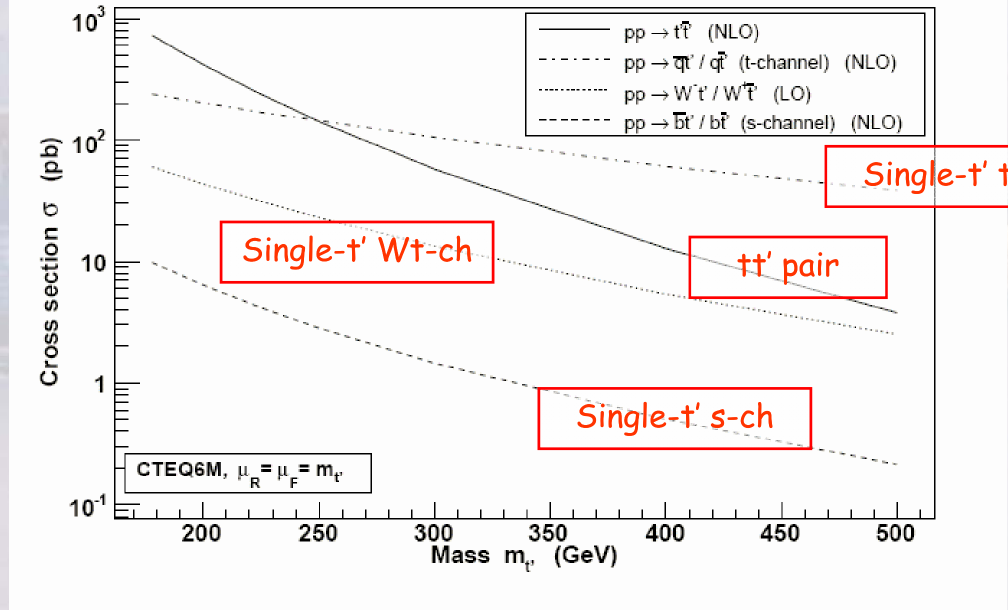



$\sigma_{EW}(t) \propto |V_{tb}|^2$

**$|V_{tb}|$ can be extracted directly:**

no assumption is needed on the number of families or CKM unitarity

If not observed: maybe t-t′ mixing? (hep-ph/0607115)



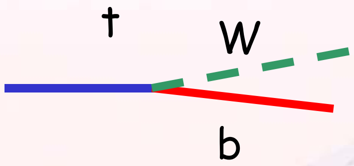

**LHC (t-channel):**

$\Delta\sigma_{EW}(t) / \sigma_{EW}(t) \sim 10\%$

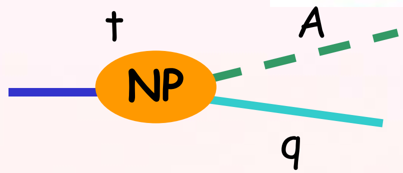
$\rightarrow \Delta|V_{tb}|/|V_{tb}| \sim 5\%$ @30 $fb^{-1}$

# FCNC: a signature of new physics

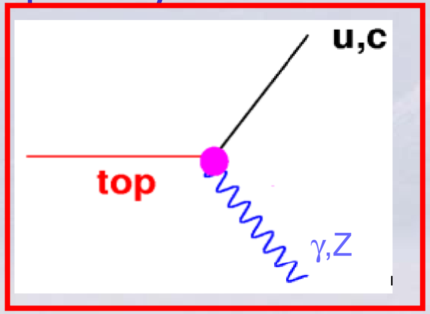
Today we only see:
$t \to W b$ (Br > 99.9%)



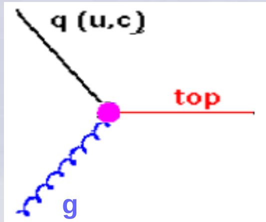

Tomorrow we could see:
$t \to Aq$ (Br =??)
where $q = u, c$ , $A = Z, g, \gamma$



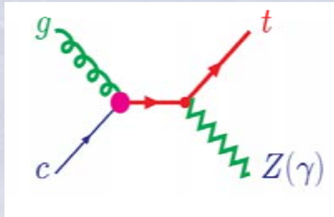

top decay in $t\,\bar{t}$ events



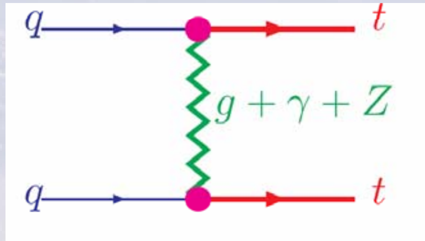

single top production




tZ/γ production




tt like-sign production

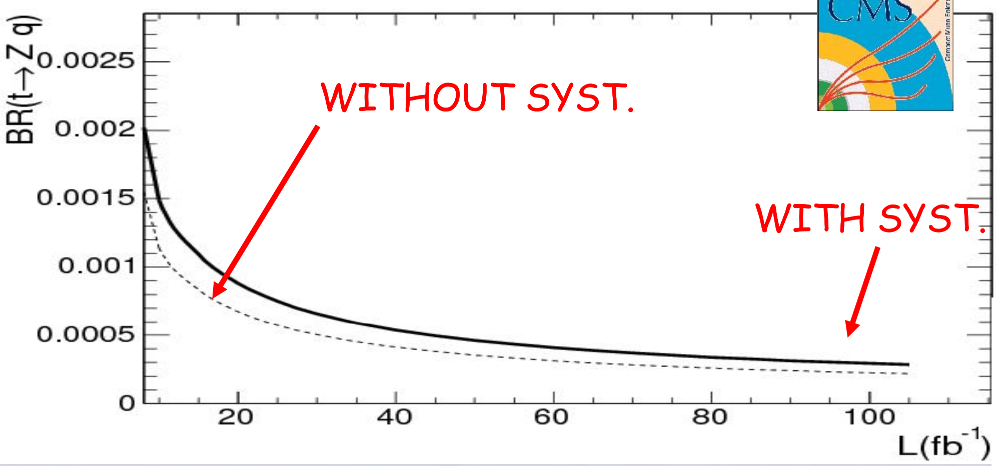



| FCNC decay | Br in SM | Br in 2HDM | Br in SUSY + R violation | LR - SUSY | Exp. Limits (95% CL) |
|---|---|---|---|---|---|
| $t \to \gamma q$ | $5\ 10^{-13}$ | $\sim 10^{-7}$ | $\sim 10^{-5}$ | $\sim 10^{-6}$ | < 0.006(HERA) |
| $t \to Zq$ | $1.3\ 10^{-13}$ | $\sim 10^{-6}$ | $\sim 10^{-4}$ | $\sim 10^{-4}$ | < 0.14(LEP2) |
| $t \to g\, q$ | $5\ 10^{-11}$ | $\sim 10^{-4}$ | $\sim 10^{-3}$ | $\sim 10^{-3}$ | < 0.17(CDF) |

*→ At LHC, FCNC Br might reach a detectable level*

***ANY OBSERVATION AT LHC WILL BE A SIGNAL OF NEW PHYSICS***

# FCNC: a signature of new physics

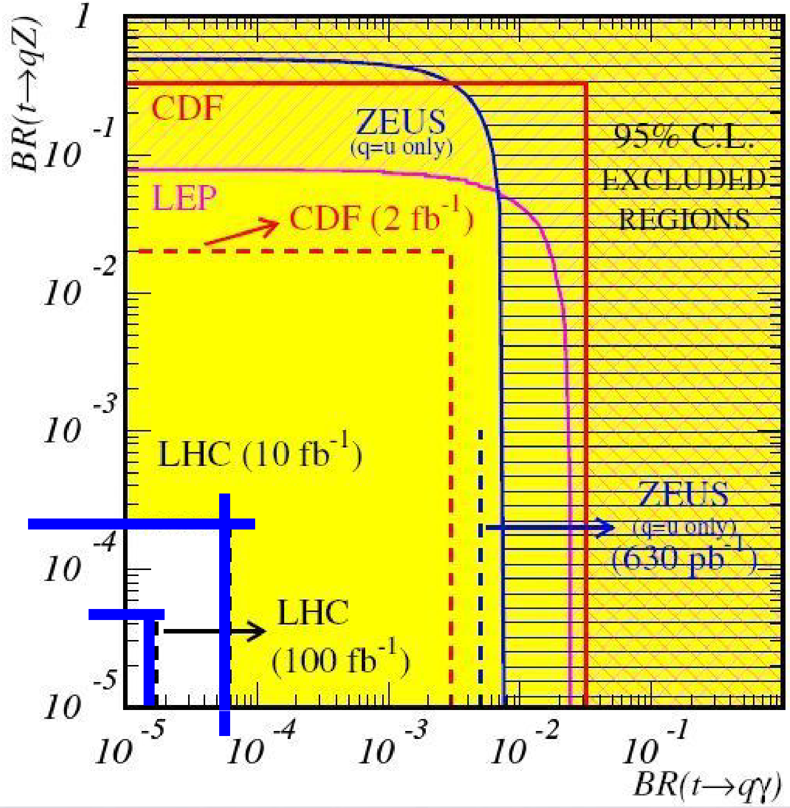



further constraints may come from $qq' \rightarrow tZ/\gamma$ and single-top t-ch

| ATLAS + CMS @ 10 $fb^{-1}$ /exp |
|---|
| $t \rightarrow qZ$: 2.1 $10^{-4}$ |
| $t \rightarrow q\gamma$: 6.2 $10^{-5}$ |

+

| ATLAS + CMS @ 100 $fb^{-1}$ /exp |
|---|
| $t \rightarrow qZ$: 4.7 $10^{-5}$ |
| $t \rightarrow q\gamma$: 1.7 $10^{-5}$ |



# When a top meets a Higgs...

SM Higgs

tH Yukawa coupling is strong:

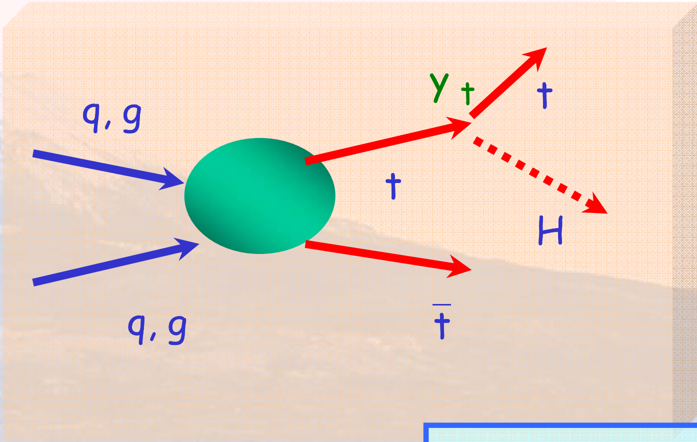
if the Higgs exists, qq' → tt H will be visible

→ t $\bar{t}$ pair could provide the Higgs discovery!

Best way to search for it:

- fully reconstruct the tt pair
- search for a large BR Higgs decay (H→b $\bar{b}$, t $\bar{t}$)

ATL-PHYS-2004-031, CMS NOTE 2003/03




SUSY Higgs

In light SUSY scenario: t → $H^+$ b (large when tan β»6 or tan β« 6)

**tan β«6**: H→τ ν , **tan β»6**: H→cs

**Tevatron:**

Selection criteria are optimized for standard decays, H decays has no energetic isolated leptons

→ t "disappearance" in lept+jets

BR(t→$H^\pm$b) < 0.4 (if only H →τν is present)

BR(t→$H^\pm$b) < 0.91 (model independent)

**LHC:**

R(2l/1l) = BR(dilept)/BR(lept+jets) = BR(W→e/μ)/2BR(W→had) ~ 1/6

LHC: ΔR/R ~ 0.5%( stat) @ 10 $fb^{-1}$

# The promises of LHC
(in a nutshell)

When at LHC (ATLAS and CMS) we will have:

- negligible statistic uncertainty (10-30 $fb^{-1}$)
- most of systematics under control

we expect:

| | Tevatron today | LHC | LHC > 100 $fb^{-1}$ |
|---|---|---|---|
| $\delta\sigma(t\bar{t})$ | 12% | <7-8% | <7-8% |
| $\delta\sigma_{EW}(t)$ | 30% | < 9-10% | < 7-8% |
| $\Delta m_t$ (GeV) | 1.5 | ~ 1.0-1.2 | ~1.0-1.2 |
| $\Delta \mathcal{A}/\mathcal{A}$ (spin correlation) | ≈50% | <7-8% | <5-6% |
| $\delta \lvert V_{tb} \rvert$ (direct meas.) | 15% | <4-5% | <3-4% |
| $BR(t\to Zq)$ (CDF 2 $fb^{-1}$) | 2 $10^{-3}$ | 5 $10^{-4}$ | 1 $10^{-4}$ |
| $BR(t\to \gamma q)$ (CDF 2 $fb^{-1}$) | 3 $10^{-3}$ | 1 $10^{-4}$ | 4 $10^{-5}$ |

…further improvements when ATLAS and CMS will be combined together!

Foto: Gennaro Lerro

# Conclusion: looking forward to produce many top…

LHC will open an entirely new era of top physics
... to do much better measures of the known
... to start elucidating the unknown

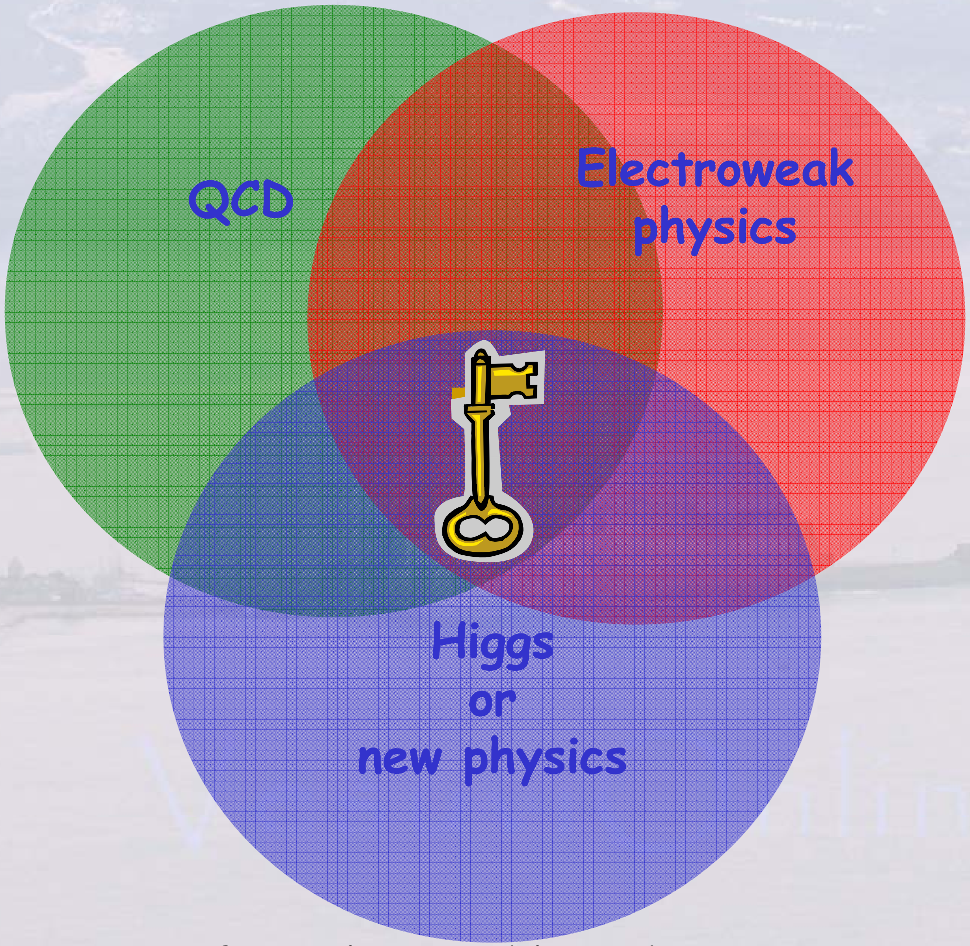
- precise $m_t$ measures will constrain the Higgs and enter the SUSY world
- cross-section and spin correlation in $t\,\bar{t}$ examine the QCD production
- the secrets of single-top: precise $|V_{tb}|$, hints of W', $H^{\pm}$, FCNC
- sensitivity to anomalous coupling is good and points directly to New Physics

# …to shed light on Physics misteries

We know there is new Physics at the electroweak scale

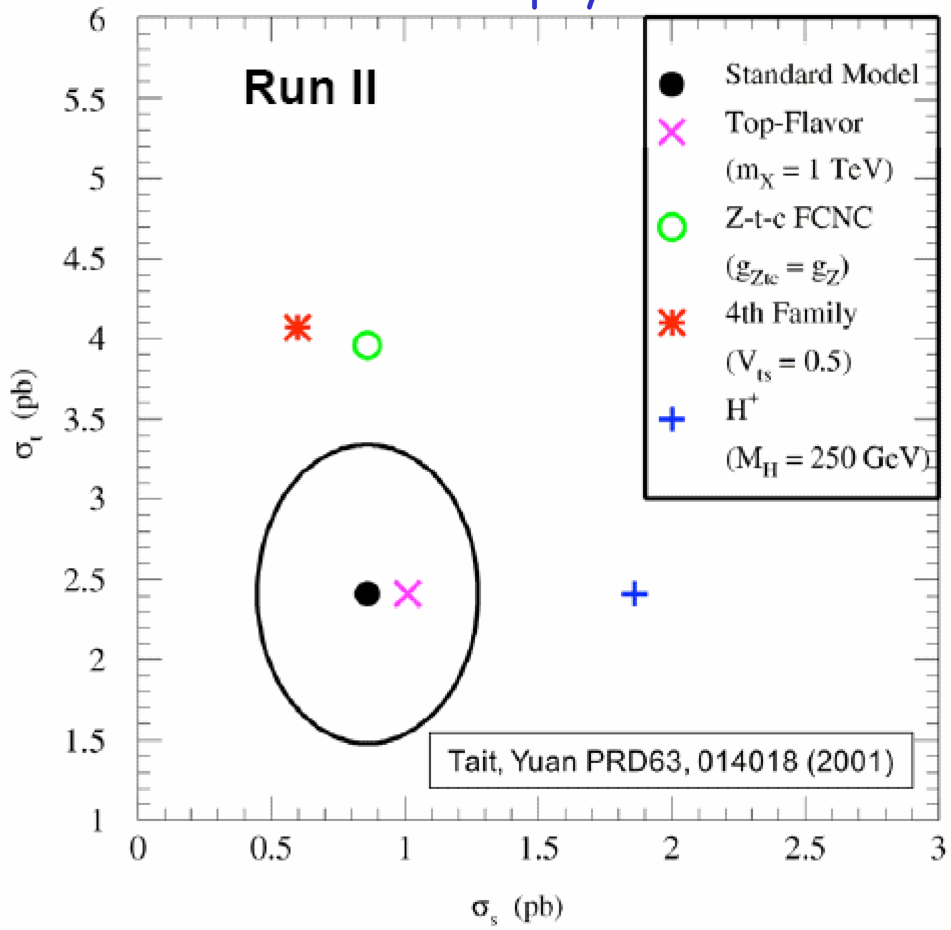
We really don't know what it is

Top quark is the THE key to enter this physics

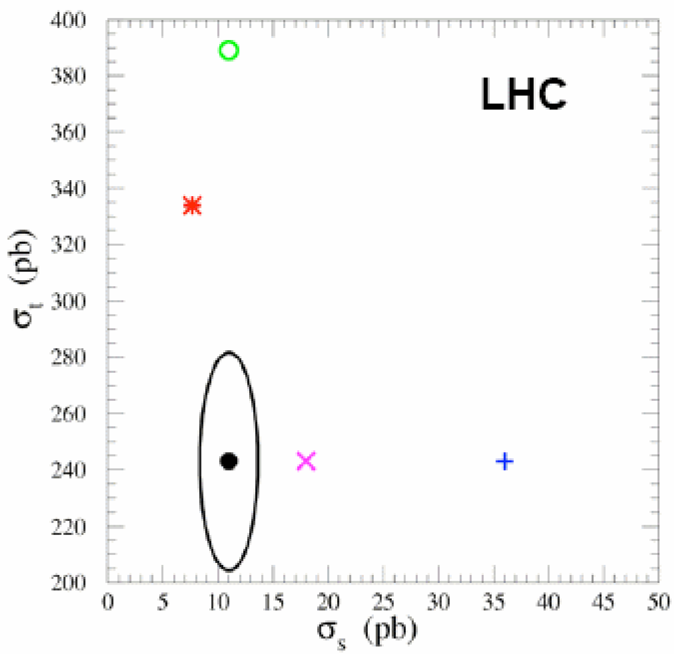


# Production cross section: single top

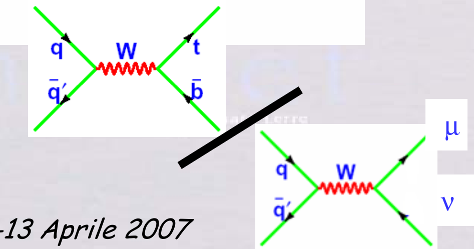
…How far is new physics?




**Theory + statistical (2/100 fb$^{-1}$)**
**3σ deviation curves**




…The ratio s (W→tb)/s (W→μ ν) could be sensitive to $W^H$ bosons up to 1.5 TeV:



- Three top quark mass estimators are investigated:
  1. *Gaussian fit on reconstructed mass spectrum* → $m_t^{Simple}$
  2. *convolution with Gaussian parametrized ideogram* → $m_t^{ParamIdeo}$
  3. *convolution with full scanned ideogram* → $m_t^{FullIdeo}$
- A likelihood variable is constructed reflecting the probability for signal → $P_{sign}$
- Jet combinations are ordered according to a likelihood variable → $P_{comb}$
- A kinematic fit is applied (CMS Note 2006/023) forcing the W boson mass

$$\chi^2(\{\overline{p}_j\}|m_t) = \left(\frac{m_t - m_t^{fit}}{\sigma_{m_t}^{fit}}\right)^2 \Rightarrow P(\{\overline{p}_j\}|m_t)\, dm_t \sim exp\left(-\frac{1}{2}\cdot\chi^2(\{\overline{p}_j\}|m_t)\right)$$

*can be fixed in kinematic fit*

- The Ideogram is convoluted with a theoretical template

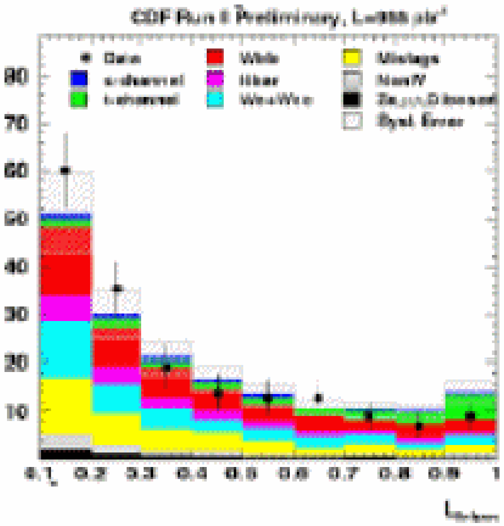
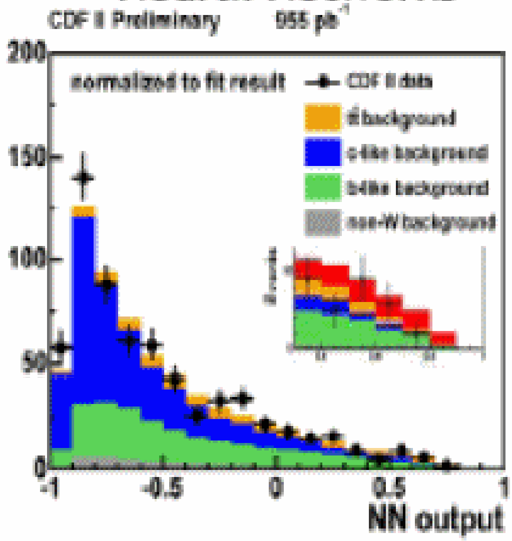
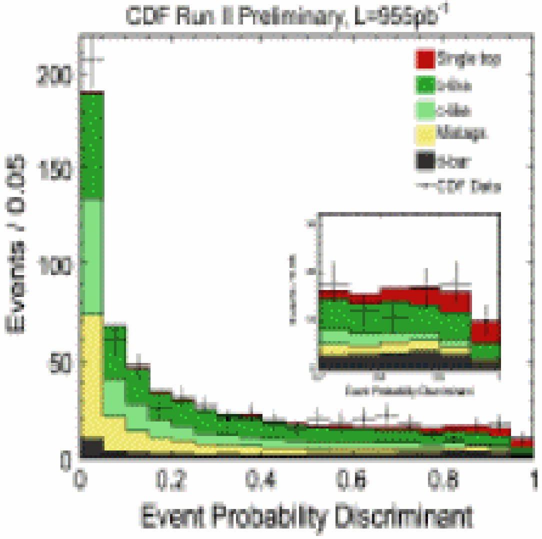
$$\mathcal{L}_i(M_t) = \int P(\{\overline{p}_j\}|m_t)\cdot P(m_t|M_t)\, dm_t$$

$$P(m_t|M_t) = P_{sign}\cdot[P_{comb}\cdot S(m_t|M_t) + (1-P_{comb})\cdot B_{comb}(m_t)] + (1-P_{sign})\cdot B_{proc}(m_t)$$

Breit-Wigner — Monte Carlo parametrized

- Maximum likelihood gives the estimated top quark mass
- 4th estimator: $m_t^{FullIdeo}$ but IterCone, MidPoint & $k_T$ should give same jet direction

# Single top: CDF

| Likelihood | Neural Networks | Matrix Element |
| --- | --- | --- |
|  |  |  |
| No evidence of signal | No evidence of signal | p-value = 1.0% (2.3$\sigma$) |
| $\sigma_{s+t}$<2.7pb at 95% C.L. | $\sigma_{s+t}$<2.6pb at 95% C.L. | $\sigma_{s+t}$=2.7(+1.5/-1.3)pb |





- SM: $\sigma$(tb+tqb)=2.9 pb
- Correlazioni tra NN, LF e ME: 60-70%
- Compatibilita' tra loro: 0.65%

"Grande confusione: situazione eccellente"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