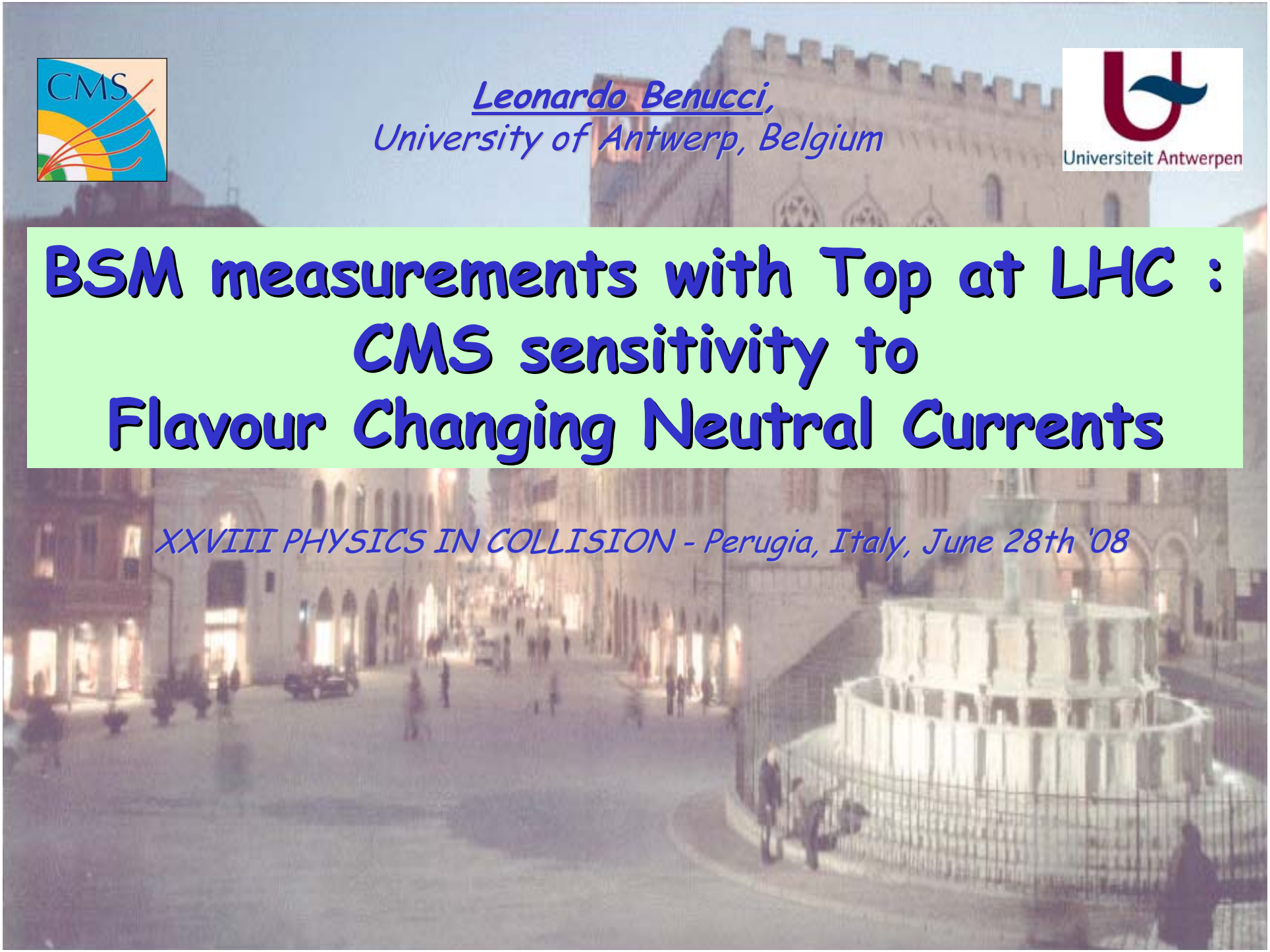
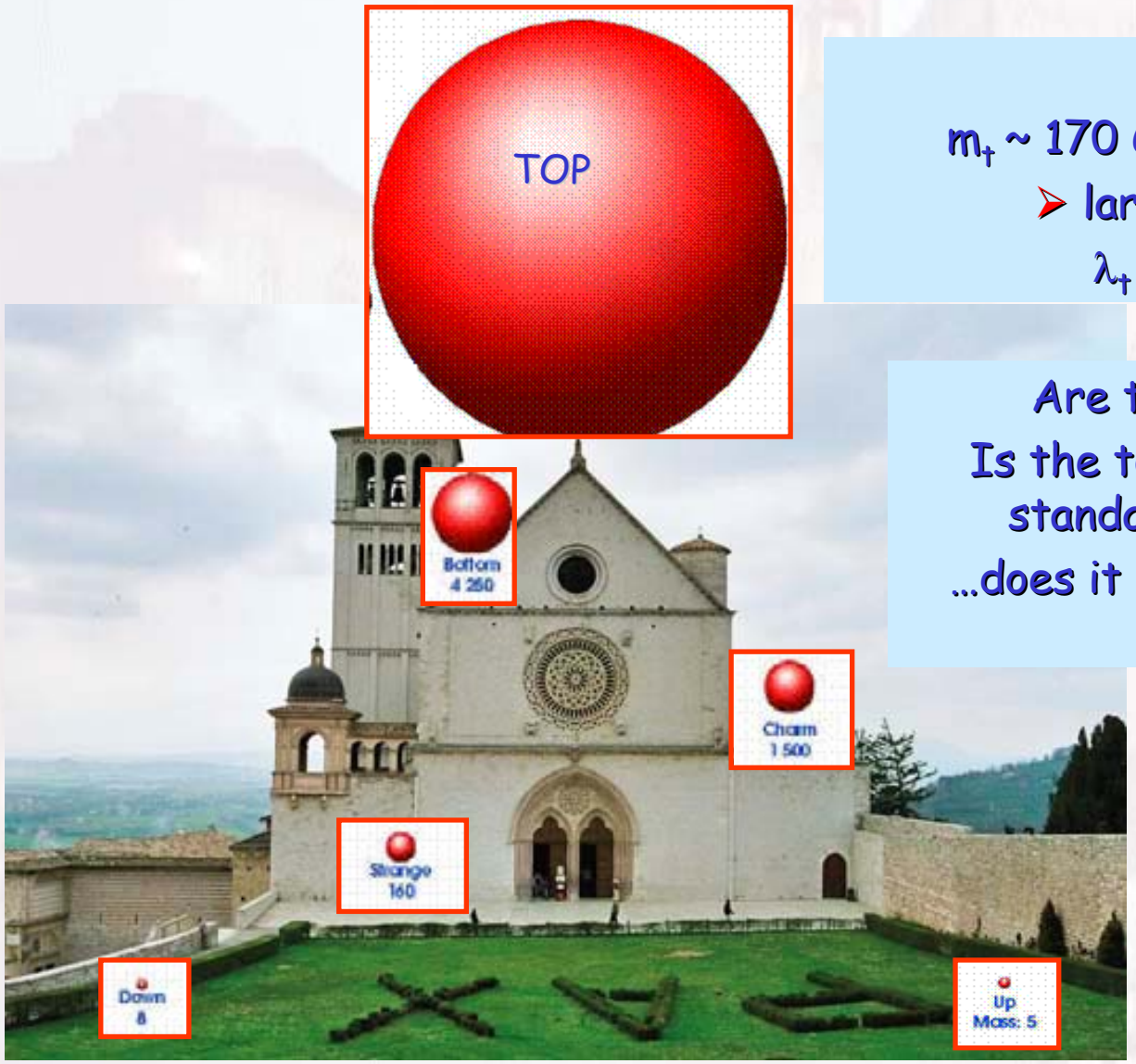


Leonardo Benucci,
University of Antwerp, Belgium

BSM measurements with Top at LHC : CMS sensitivity to Flavour Changing Neutral Currents

XXVIII PHYSICS IN COLLISION - Perugia, Italy, June 28th '08

Top quark: what is it?



- large mass:

$m_t \sim 170$ GeV $\sim 35\, m_b \sim$ EW scale

- large Yukawa coupling!

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

Are them only accidents?

Is the top mass generated by a standard Higgs mechanism?

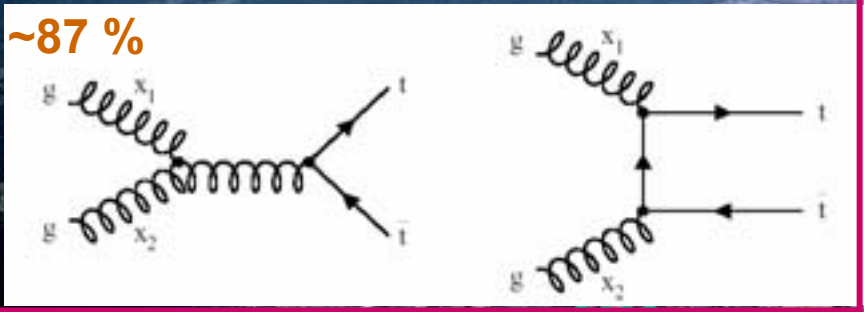
…does it play a more fundamental role in EWSB?

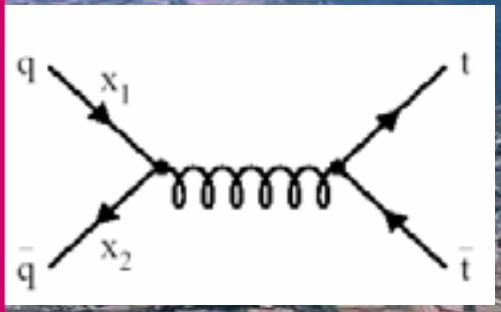
With the LHC, we hope to approach the answers…

LHC: a top factory

NLO cross-section σ^{NLO} = 833 pb □ ~8M events/10fb^{-1}

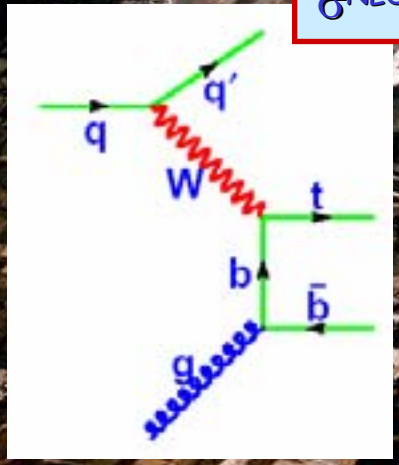
~87 %





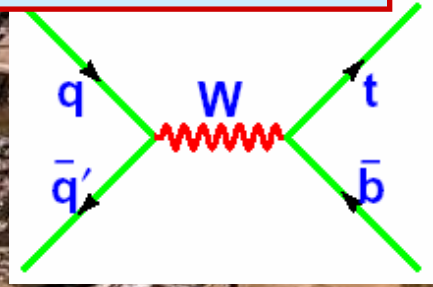
10 t $\bar{t}$ pairs /day @ Tevatron □ 2 t $\bar{t}$ pair / s @ LHC (2 10^{33}/cm^2/s)

σ^{NLO} = 153+90 pb

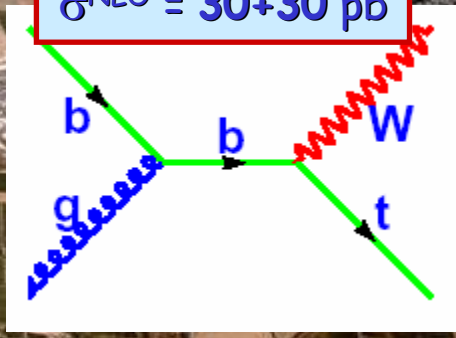


□ ~3.7M events/10fb^{-1}

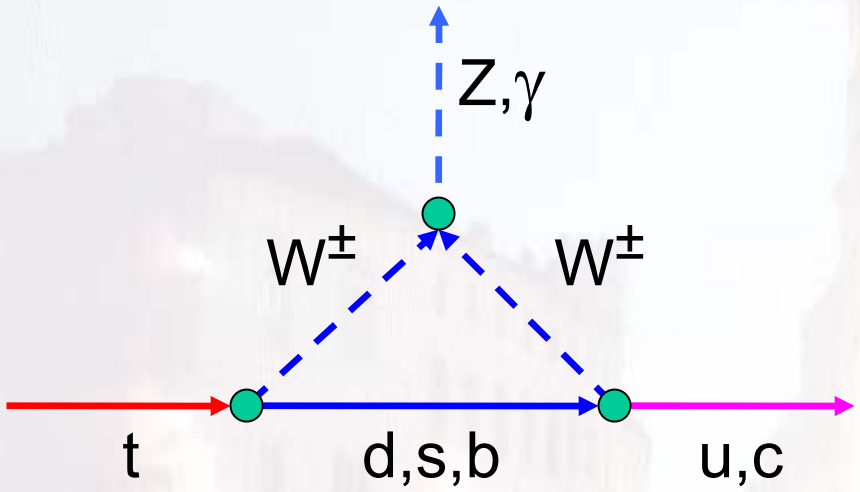
σ^{NLO} = 6.6+4.1 pb

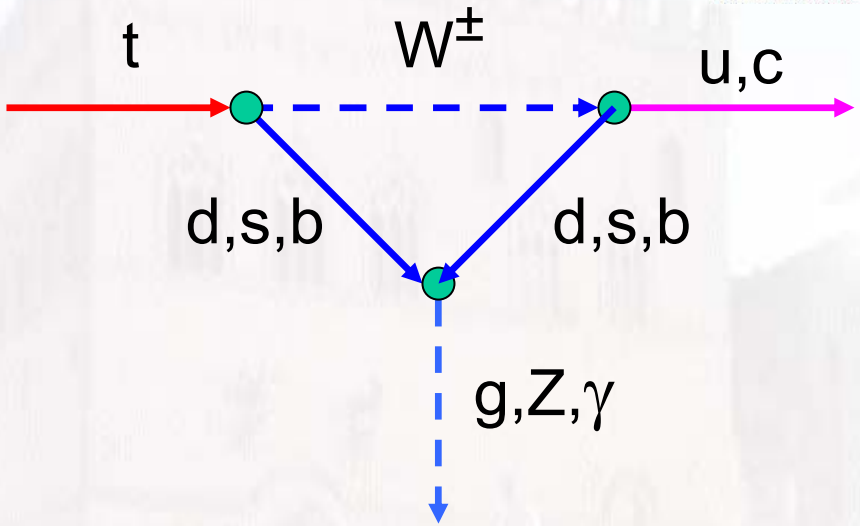


σ^{NLO} = 30+30 pb



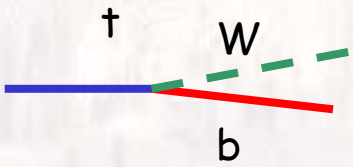
FCNC: in the Standard Model



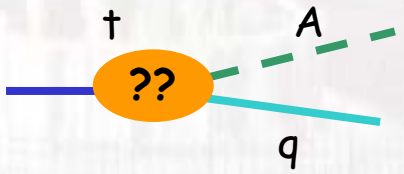


Standard Model

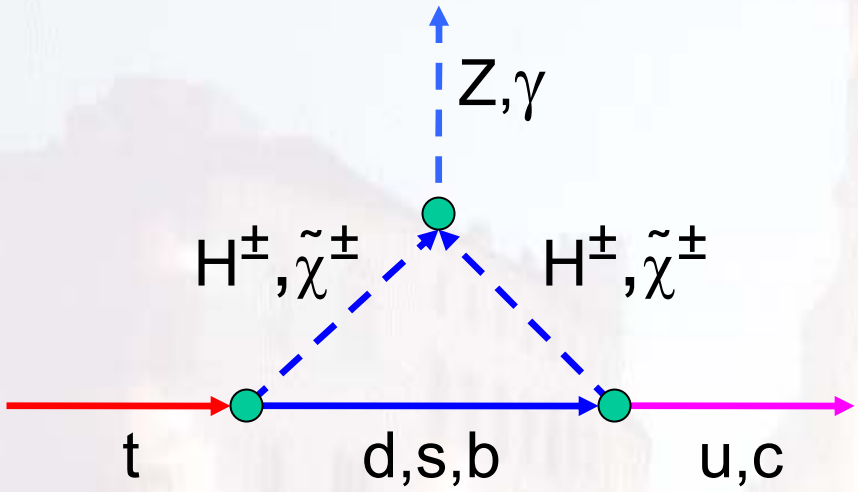
Today we only see:
$t \rightarrow W b$ (Br = 99.8%)

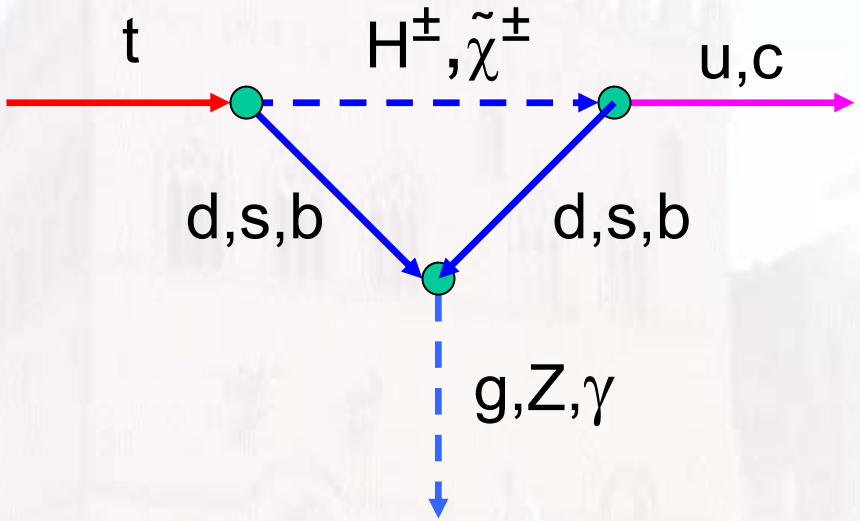


Tomorrow we could see:
$t \rightarrow Aq$ (Br =??)
where $q = u, c$, $A = Z , g, \gamma$

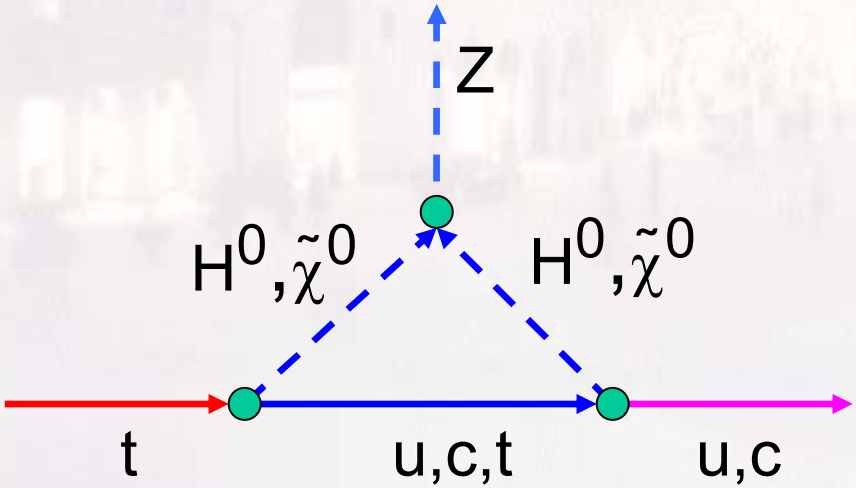


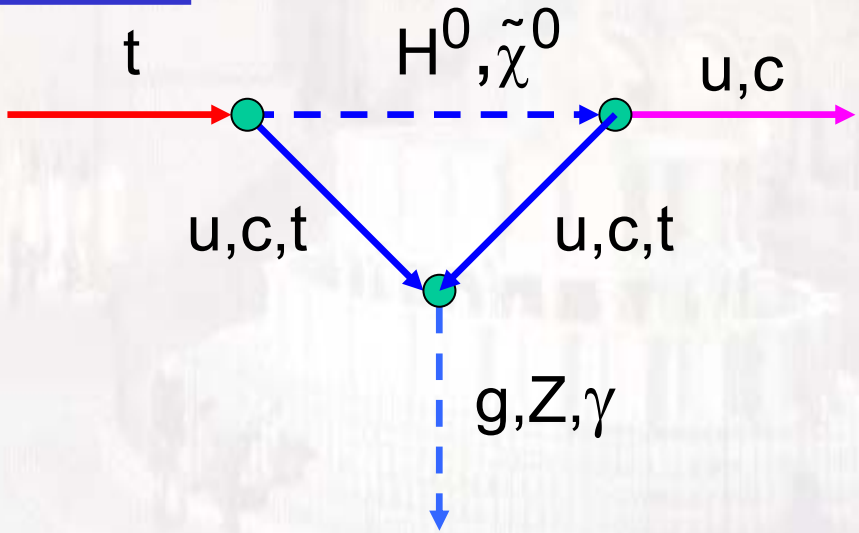
FCNC: beyond the Standard Model





Beyond Standard Model





FCNC: a signature of new physics

FCNC decay	BR in SM	BR in 2HDM-II	BR in 2HDM-III	BR in MSSM	BR in MSSM + R violation
$t \to \gamma q$	$4.6\ 10^{-14}$	$\sim 10^{-7}$	$9\ 10^{-4}$	$\sim 10^{-6}$	$\sim 10^{-5}$
$t \to Zq$	10^{-14}	$\sim 10^{-8}$	$\sim 10^{-6}$	$\sim 10^{-5}$	$\sim 10^{-4}$
$t \to g q$	$4.6\ 10^{-12}$	$\sim 10^{-5}$	$\sim 10^{-4}$	$\sim 10^{-4}$	$\sim 10^{-3}$

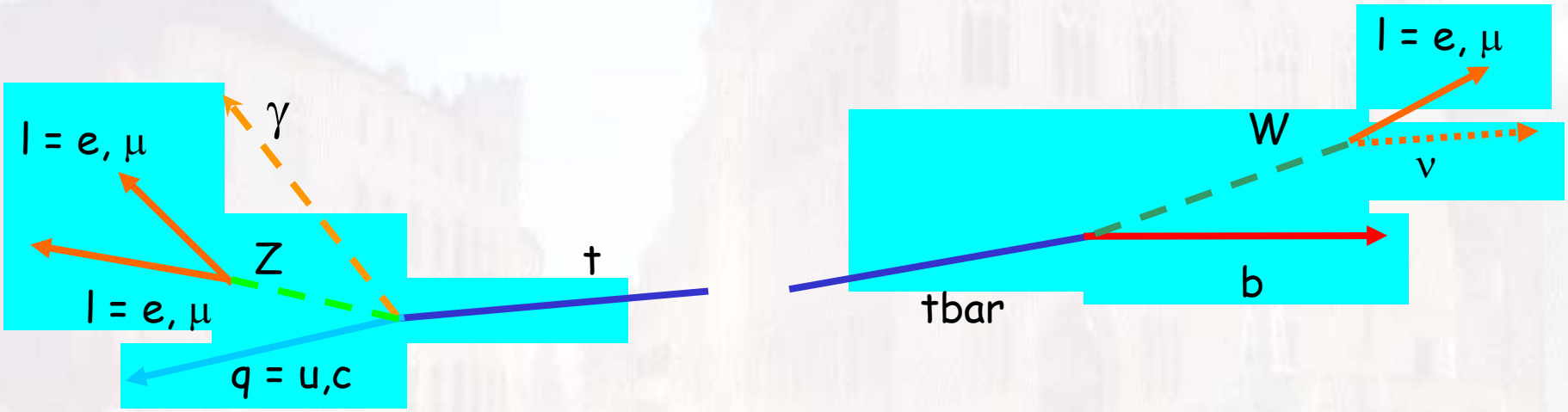
BR in TC2	BR in LR	BR in QS	Exp. Limits (95% CL)	FCNC decay
$5\ 10^{-7}$	$9\ 10^{-6}$	$\sim 10^{-8}$	$< 5.9\ 10^{-3}$ (tγu) (ZEUS)	$t \to \gamma q$
10^{-4}	$\sim 10^{-4}$	$\sim 10^{-4}$	$< 3.7\ 10^{-2}$ (CDF)	$t \to Zq$
$5\ 10^{-3}$	$\sim 10^{-5}$	$\sim 10^{-7}$	$< 3.7\ 10^{-2}$ (tgu), $< 15\ 10^{-2}$ (tgc) (D0)	$t \to g q$

→ At LHC, FCNC Branching Ratio might be at a detectable level

ANY OBSERVATION AT LHC WILL BE A SIGNAL OF NEW PHYSICS

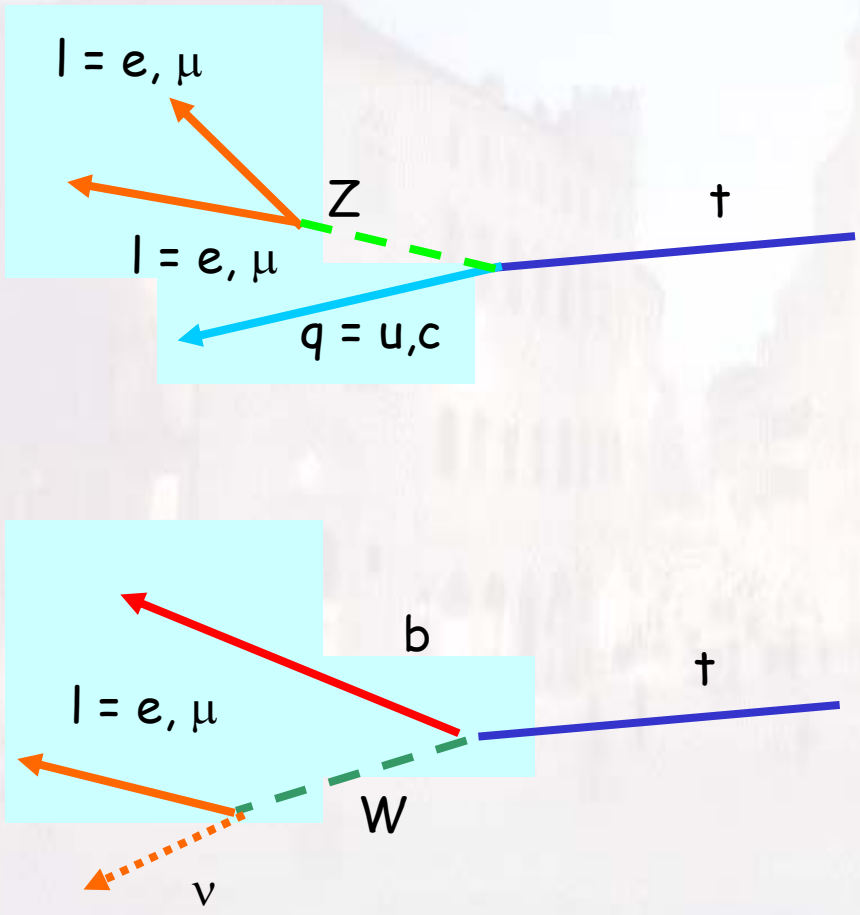
The signal Topology

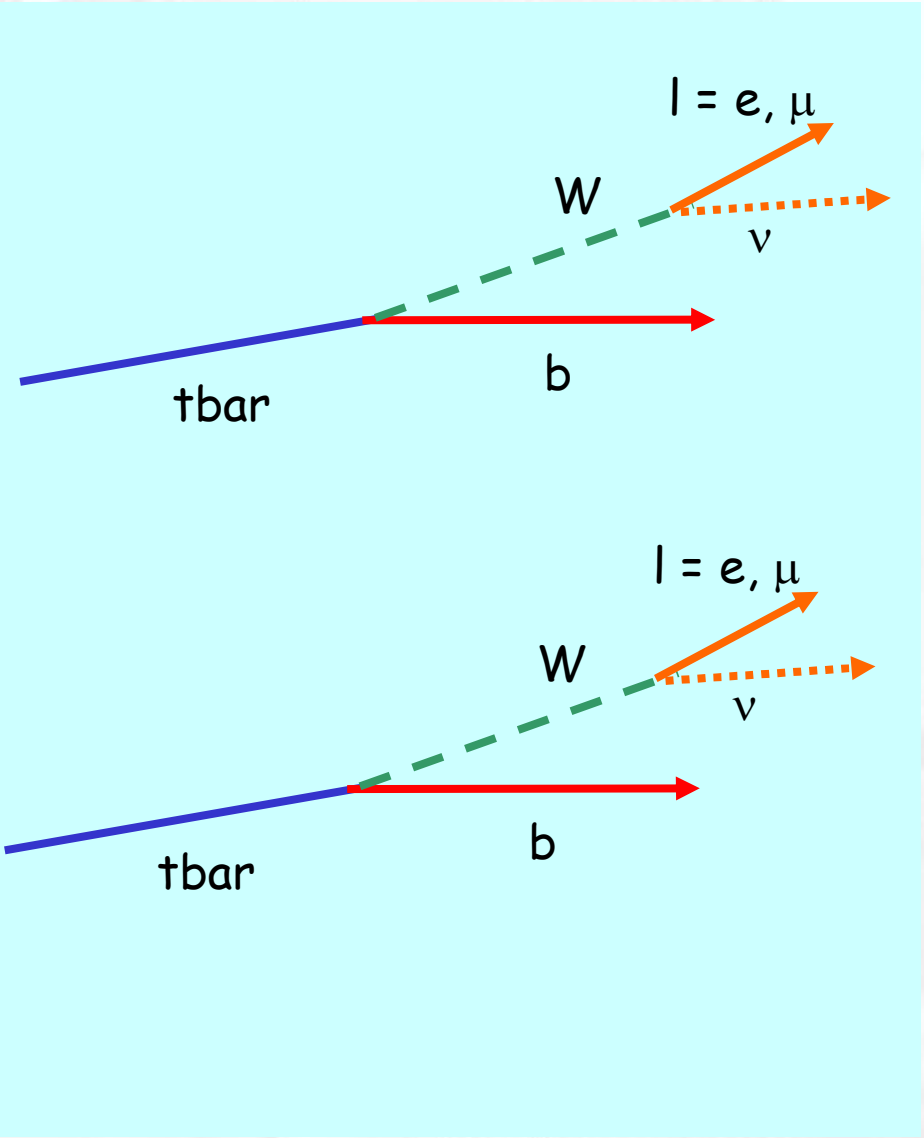
$$t - \bar{t} \rightarrow (Z/\gamma/g\ q)\ (Wb) \rightarrow (ll/\gamma/g\ q)\ (l\nu\ b)$$



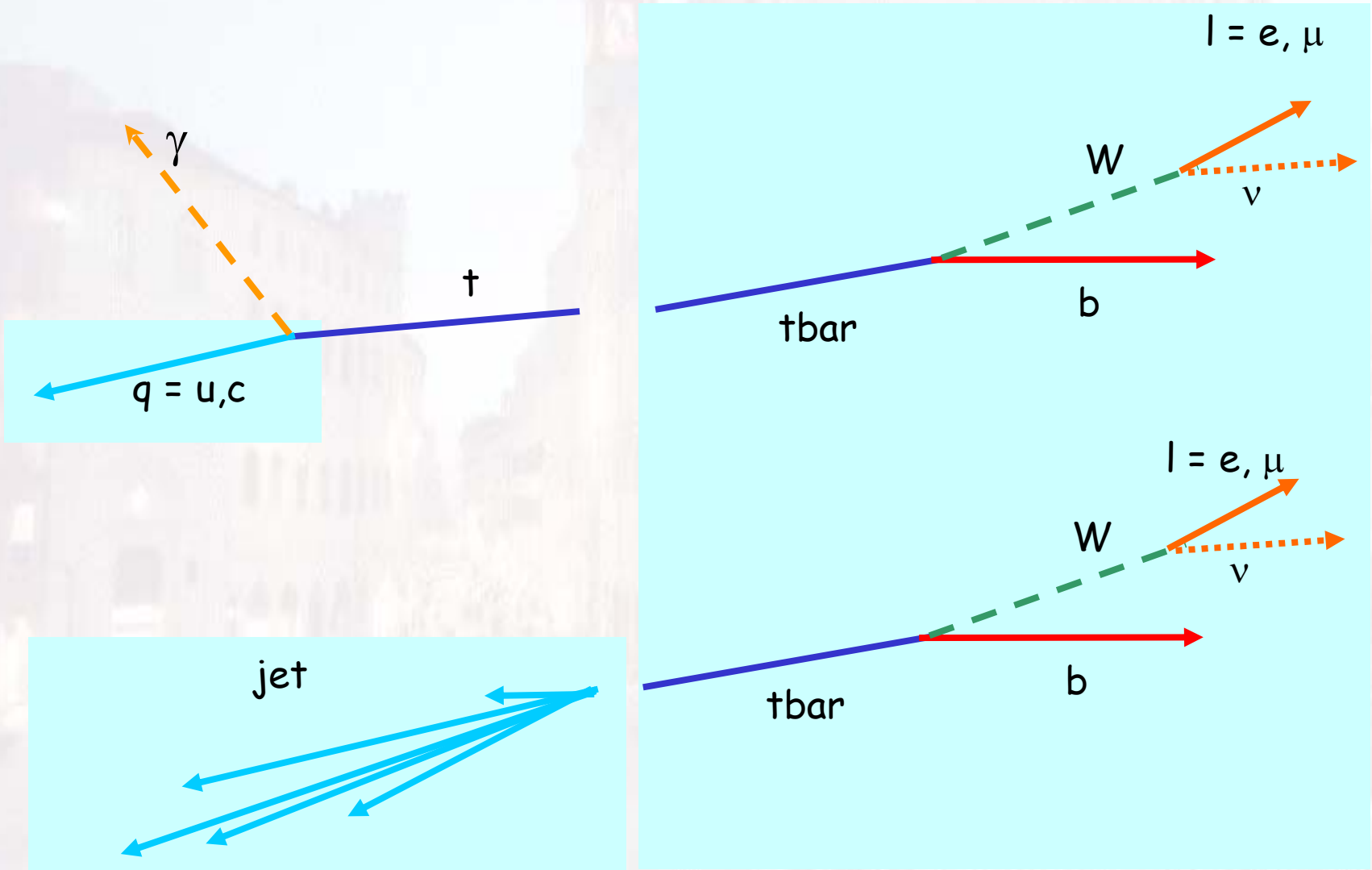
- isolated, high p_T leptons
- eventual photon with E_T > 50 GeV
- large missing transverse energy
- 2 or more jets with high p_T , 1 b-tagged

The signal background

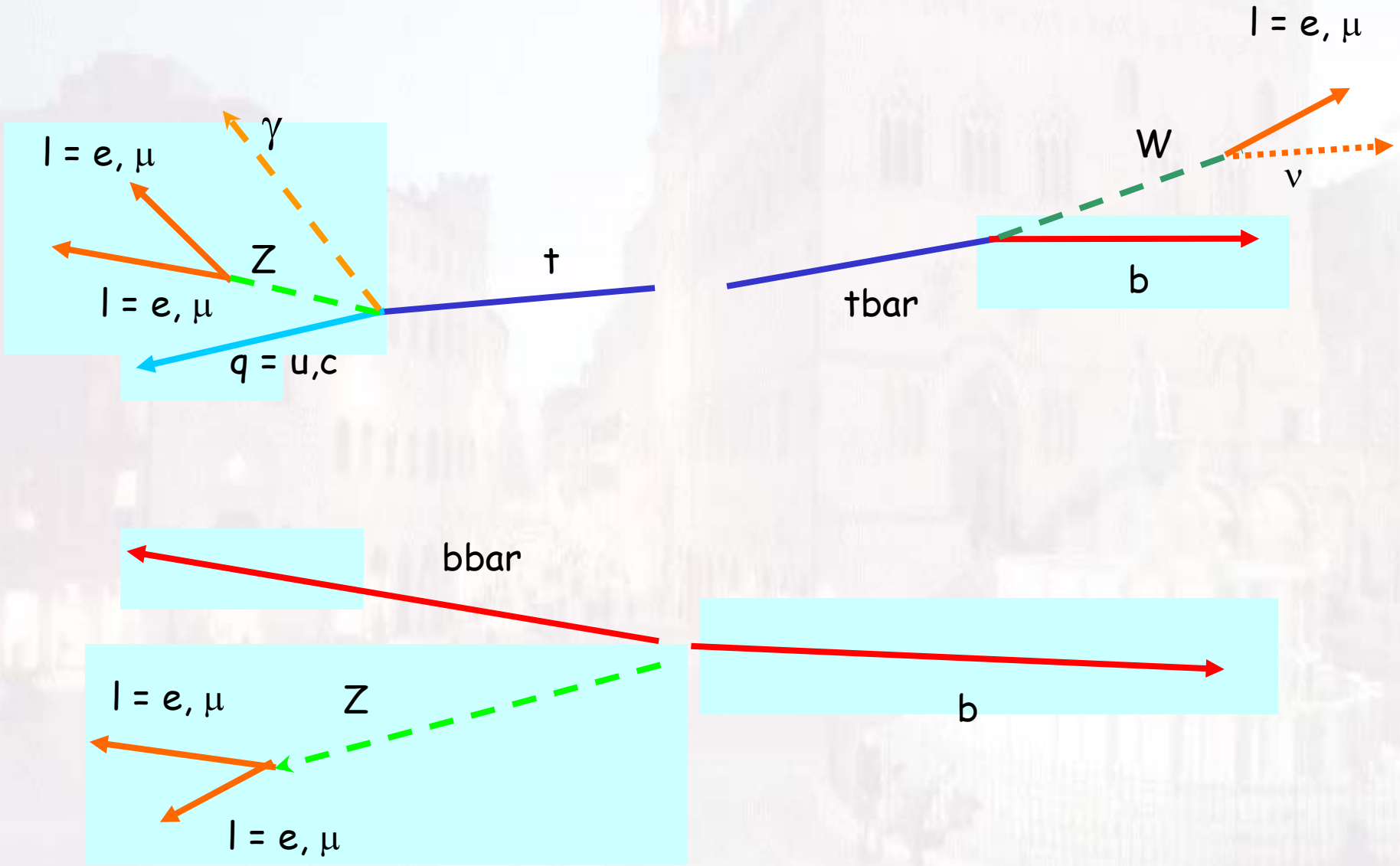




The signal background



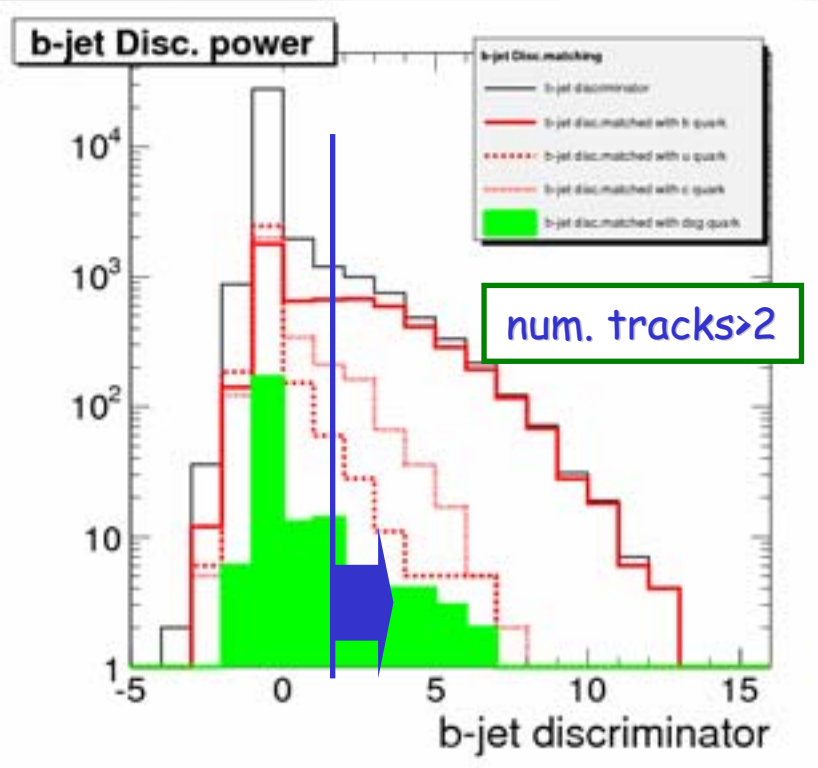
The signal background



Physics objects selection

b-jet selection

- Applies to IC calibrated jet ($\Delta R<0.5$) → ***Discriminator***
- constraints on track number and Discriminator



Disc > 2 ÷ 3 , p_T(b) > 40-50 GeV: **80-85% purity**

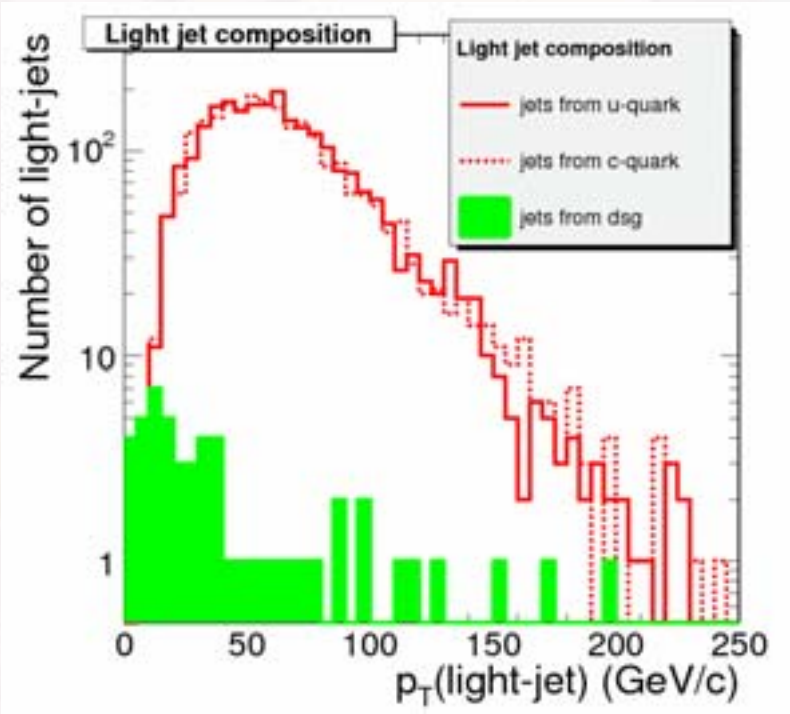
Disc	> 1.0	> 1.5	> 2.0	> 2.5	> 3.0	> 3.5
b-Mistag with c	0.118	0.106	0.096	0.080	0.062	0.055
b-Mistag with u	0.023	0.019	0.015	0.014	0.011	0.009

light-jet selection:

All reconstructed jets, cleaned from:

- reconstructed b-jet
- lepton from W/Z and photons

→ spurious jet (from QCD processes) are rejected with **p_T(light) > 40-50 GeV** , **$|\eta|<2.3$**



complementarity between u and c

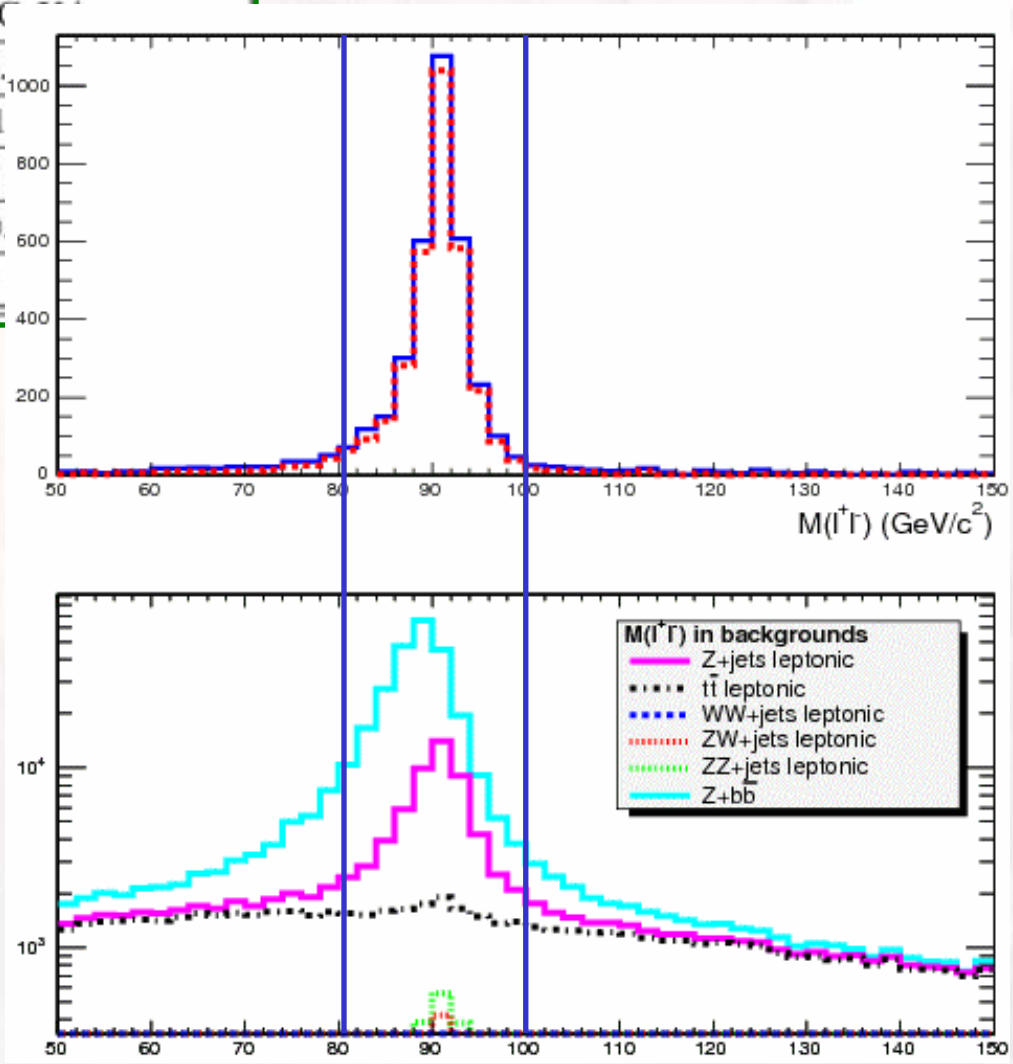
Selection for t→qZ

electron selection:

L1	Di-electron ("Relaxed") Trigger, 12(19) GeV/c
HLT	Di-electron Trigger, 17 G
Isolation	$\Delta R < 0.1$, $Isol < 0.$
Track/Cluster energy	$E/p > 0.8$, $E/p < 1$
Track/Cluster	$\lvert\Delta\eta_{in}\rvert < 0.0032$
HCAL/ECAL	$E_{HCAL}/E_{ECAL} < 0$
Transv. momentum	$p_T > 20\,\mathrm{GeV}/c$

Z^0 selection:

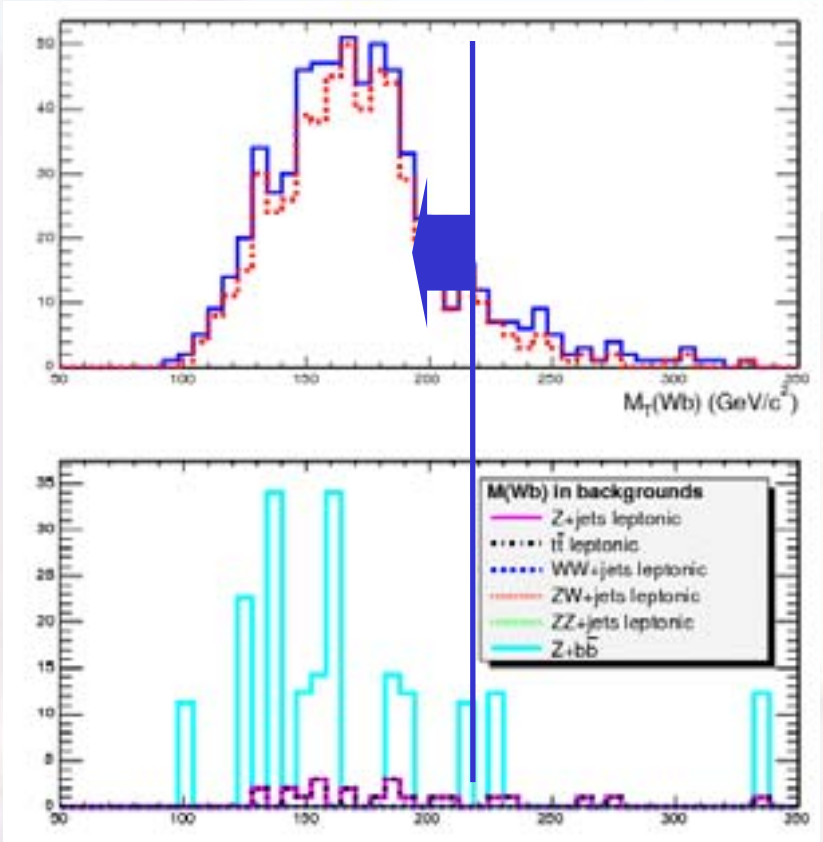
Same flavour opposite sign e/μ with M(ll) closest to $M(Z^0)$ → only ONE Z

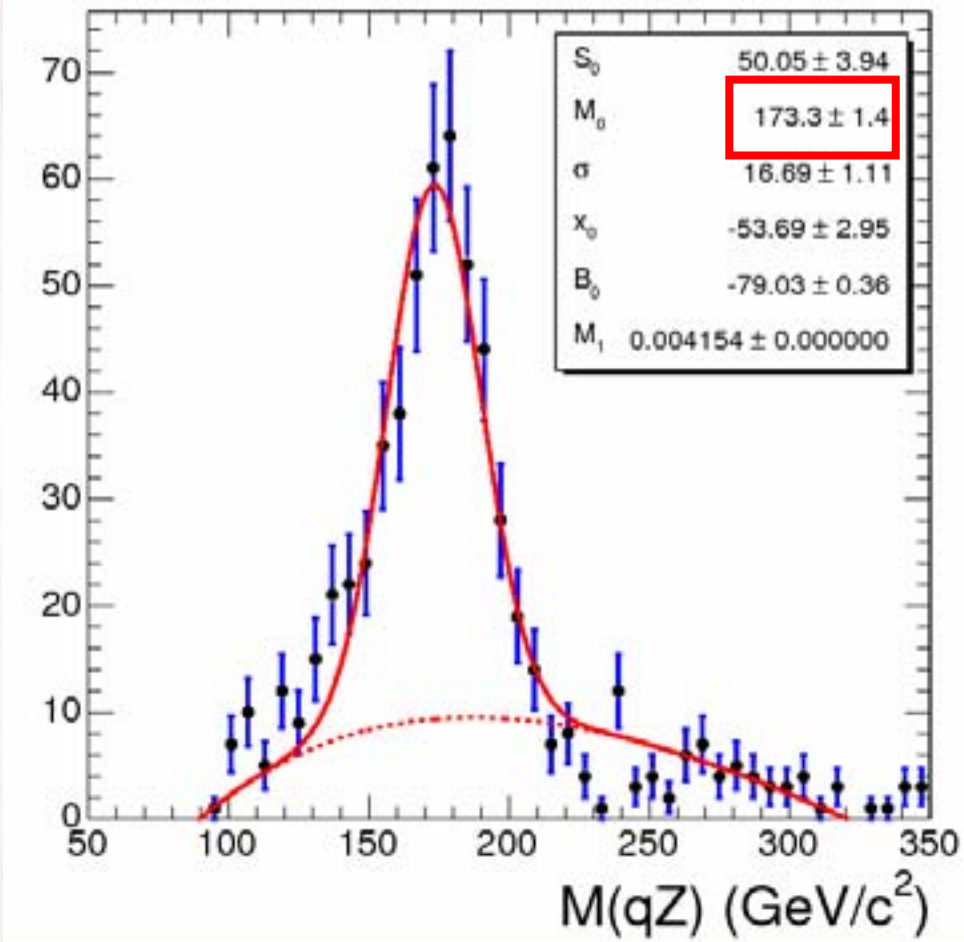


Selection for t→qZ

top SM selection:

- $M_T(Wb) < 220$ GeV
- only ONE SM top





top FCNC selection:

- $p_T(light) > 60$ GeV
- no further cuts on M(qZ) are needed
- signal+combinat. fit → combinat, subtraction

Selection for t→qZ

Selection	Signal $t \to qZ$	$t\bar{t} \to 2l$	$Z(\to ll)b\bar{b}$	$ZZ \to 4l$
HL Trigger	89.0 ± 1.3	42.95 ± 0.07	92.3 ± 0.3	59.1 ± 0.2
one good $Z^0 \to ll$, after $\Delta M(ll)$	42.8 ± 0.7	1.500 ± 0.013	34.51 ± 0.19	27.08 ± 0.17
one good $W \to l\nu$ (with $M_T(l\text{-}E_T^{miss})$ cut)	20.7 ± 0.5	0.0130 ± 0.0012	0.120 ± 0.011	4.19 ± 0.07
one good Z + one good W + one b-jet	6.09 ± 0.31	0.0044 ± 0.0003	0.079 ± 0.002	$\sim 3 \cdot 10^{-5}$
one good Z + one $t \to Wb$	5.50 ± 0.26	$(9.91 \pm 1.4) \cdot 10^{-4}$	$(1.02 \pm 0.32) \cdot 10^{-3}$	0
$100 < M(qZ) < 250$	5.32 ± 0.24	$(9.91 \pm 1.4) \cdot 10^{-4}$	$(0.76 \pm 0.24) \cdot 10^{-3}$	0

W + Z: reduces $t\bar{t}$ and $Zb\bar{b}$

W +Z + b-jet: reduces di-boson and W/Z+jet

M(qZ) constrain: supresses $Zb\bar{b}$ and reduce $t\bar{t}$

→*FCNC decay reconstructed with suppression of all back. but $t\bar{t}$→ 2l and $Zb\bar{b}$*

Selection for t→qγ

W selection:

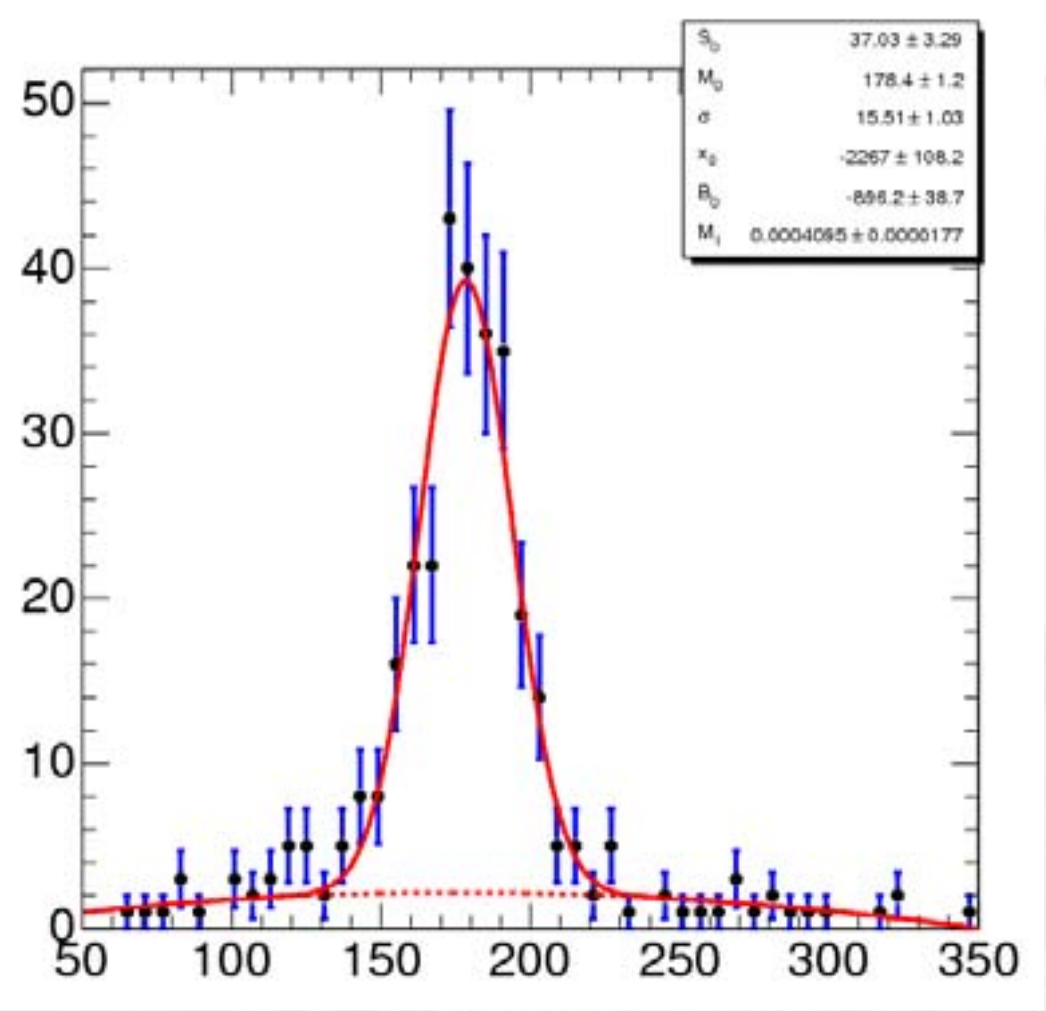
- MET > 25 GeV
- only ONE W
- cut on p_T(l-MET)
- M_T(l-MET) < 130 GeV

→ Background dominated by **W+jet**

t→ qγ selection:

- p_T(light) > 60 GeV
- Hard (p_T > 60 GeV) isolated (Isol<0.01) photons
- signal+combinat. fit on M(qγ)

→ combinatorial subtraction



Selection for t→qγ

Selection	Signal $t \to q\gamma$	$t\bar{t} \to l + X$	single-t	$Zb\bar{b}$	$W + j_{85-150}$
HLT Trigger	95.74 ± 1.2	39.1 ± 0.4	69.8 ± 0.2	80.1 ± 0.3	37.03 ± 0.14
one good $W \to l\nu$ (with $M_T(l\text{-}E_T^{miss})$ cut)	24.2 ± 0.5	8.59 ± 0.14	0.60 ± 0.06	8.64 ± 0.07	5.99 ± 0.04
one good $W \to l\nu$ and one b-jet	6.8 ± 0.3	3.17 ± 0.09	0.222 ± 0.002	1.22 ± 0.02	0.089 ± 0.005
one $t \to Wb$	6.37 ± 0.29	1.89 ± 0.07	0.1070 ± 0.0010	0.509 ± 0.012	0.0354 ± 0.0030
$100 < M(q\gamma) < 250$	5.15 ± 0.16	$(1.71 \pm 0.14) \cdot 10^{-3}$	$(6.7 \pm 3.4) \cdot 10^{-5}$	0	0

single-γ Trigger: reduces single-t

W + b-jet: reduces di-boson and W/Z+jet

M(qγ) constraint: suppresses Z b $\bar{b}$ and single-t

→ *FCNC decay reconstructed with suppression of all back. but* $t\ \bar{t} \to l+X$

Systematic effects

- Usage of official parameters and strategies frozen by CMS collaboration
- Assume **all relevant background sources estimated from data**

→ ***Impact of systematics evaluated only for variables discriminating control/signal region***

(lepton eff. - MET eff – b/light jet eff. – b/light jet number)

From detector:

Jet Energy Scale uncertainty	3-5% (low Lumi), 1.5-2.5%(high Lumi) depending from p_T(jet)	~ **15%** in b and light jet efficiency **7%(2%)** effect on b(light) jet mult. **3%(1%)** in MET
b-tag uncertainty	5% at low Lumi, 2% at high Lumi:	**+18%/-21%** at low Lumi **+13%/-14%** at high Lumi

From theory:

jet fragmentation	uncertainties in Lund model parameters	**~9%** in b-jets, **11%** in light jets
Pile-up	may affect jet multiplicity and b-tagging	< **5-10%** after doubling minimum bias

Background from (future!) data

The problem :

When B is evaluated by counting in the last selection, it is affected by:

- syst. uncertainty from Luminosity (about 5%)
- high statistical error due to little B
- theoretical error in the cross sections
- many systematics effects due to several cuts

The solution :

1. identify a region rich in only one source of B (few cuts with little systematics), suitable to be searched for in future data samples
2. count B in this region
3. rescale for efficiency factors from this region to the final one

Uncertainty will be:

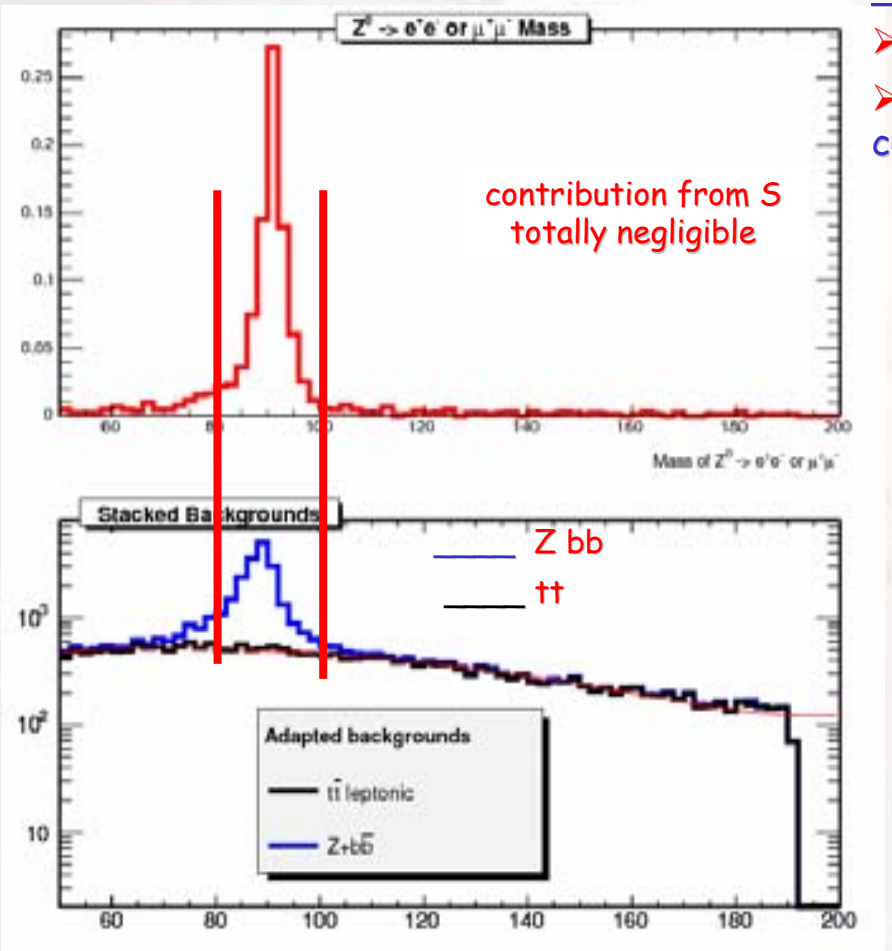
- statistic (with a high B could be < 1%)
- Background parametrization (usually not greater than few %)
- contamination from other sources (the most difficult to reduce in the present case)
- syst. uncert. on scaling factors (few cuts, strongly reduced)

Background for t→ Zq

At the end of selection, the only B we have to face are:

- **t $\bar{t}$ all leptonic:** it has 2 b-jets, no Z peak, large MET
- **Z b $\bar{b}$** : it has 2 b-jets, Z peak, no large MET

Signal has 1 b-jet and Z peak

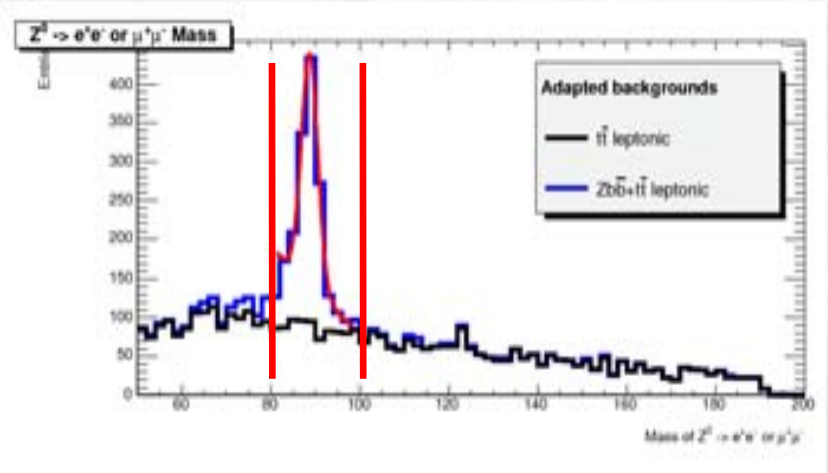


To isolate the tt background:

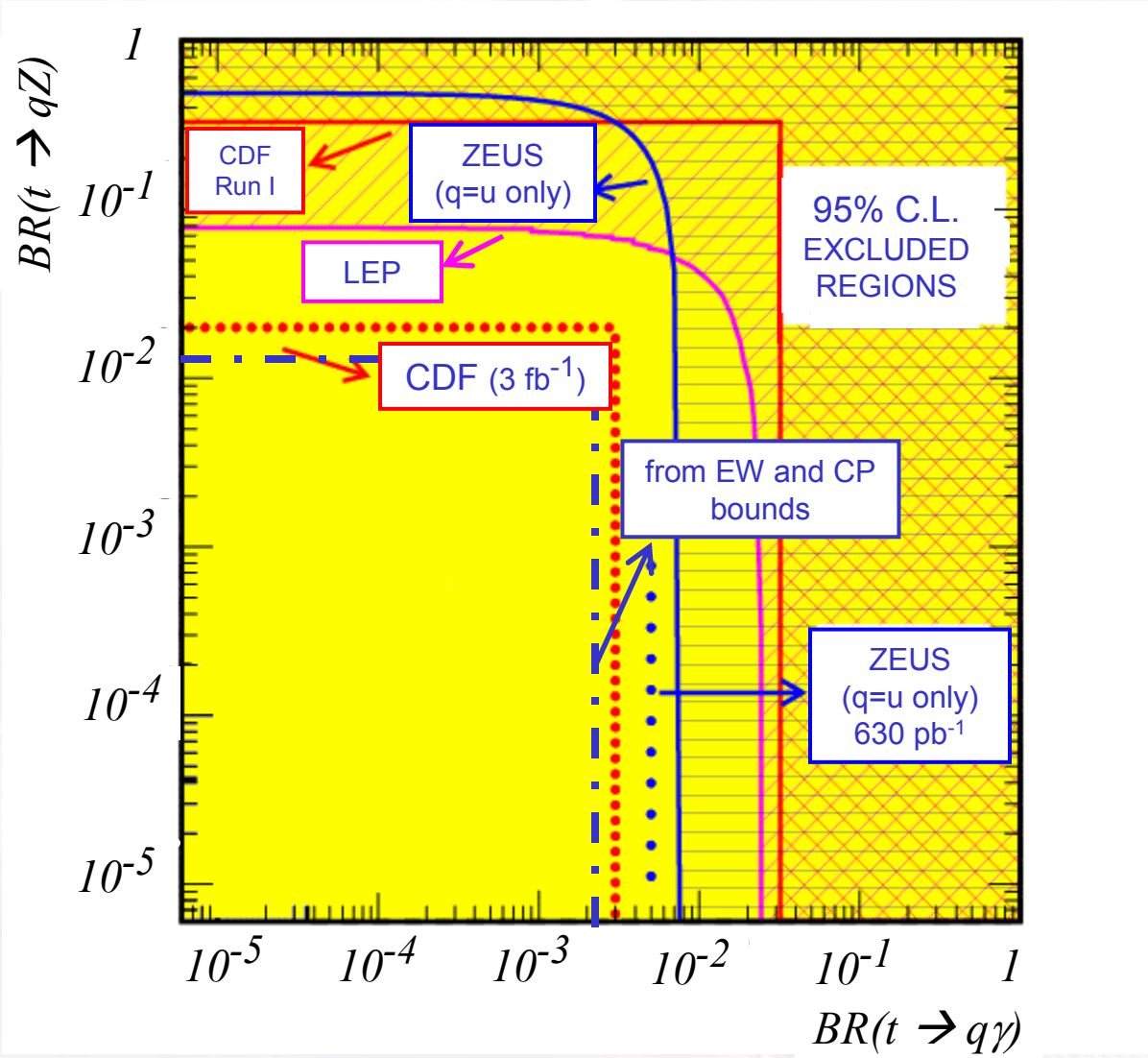
- **Control region**: l^+l^- + ONLY ONE b-jet + MET > 85 GeV
- **Look at the M(ll) plot**: Fit on the left side-band, then count in a window $M_Z \pm$ 10 GeV

To isolate the Z+b $\bar{b}$ background:

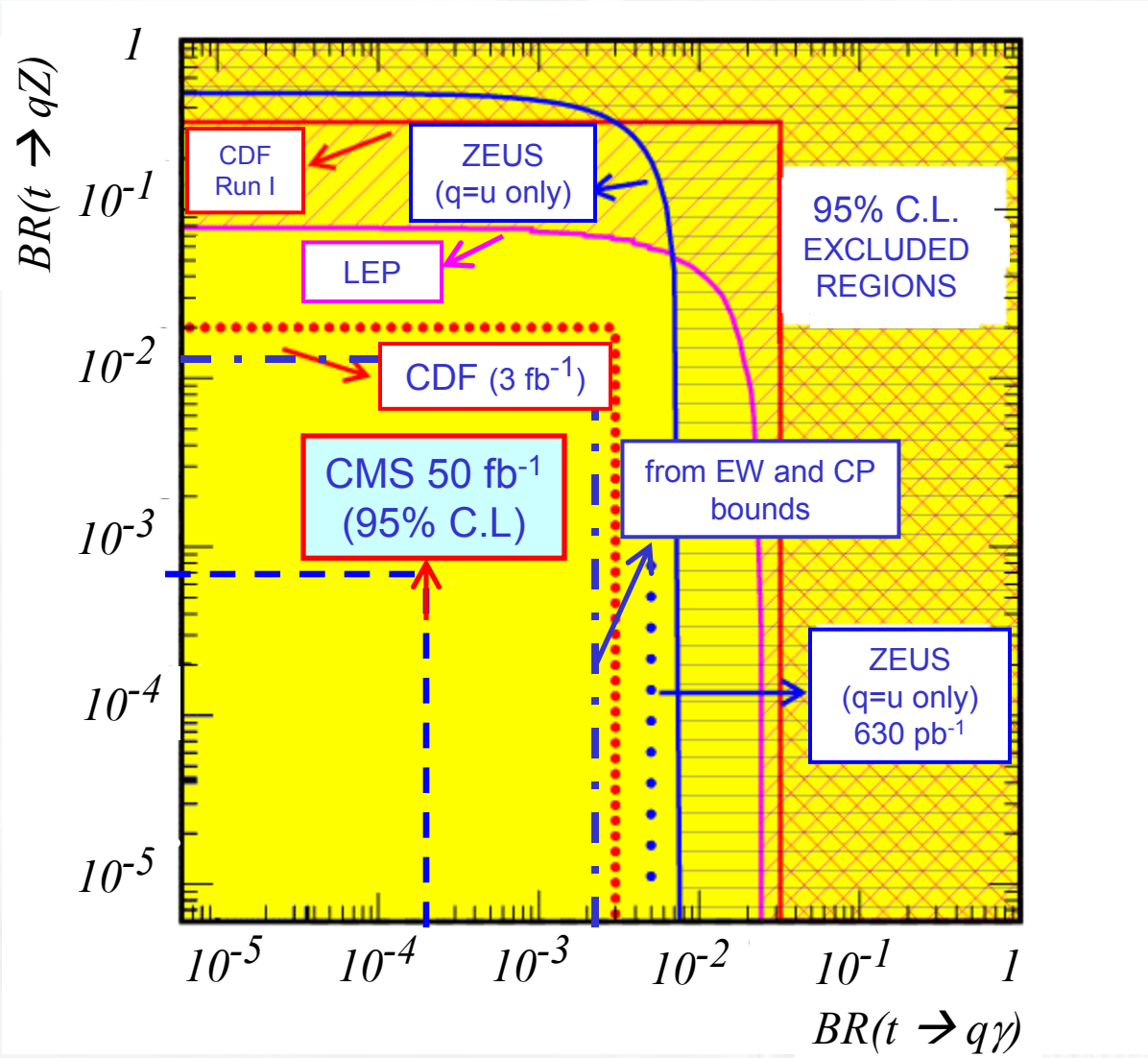
- **Control region**: ONE Z + TWO b-jet requirement
- **Look at the M(ll) plot**: count inside the signal region $M_Z \pm$ 10 GeV
- subtract the amount of t $\bar{t}$ contamination from the fit on continuum



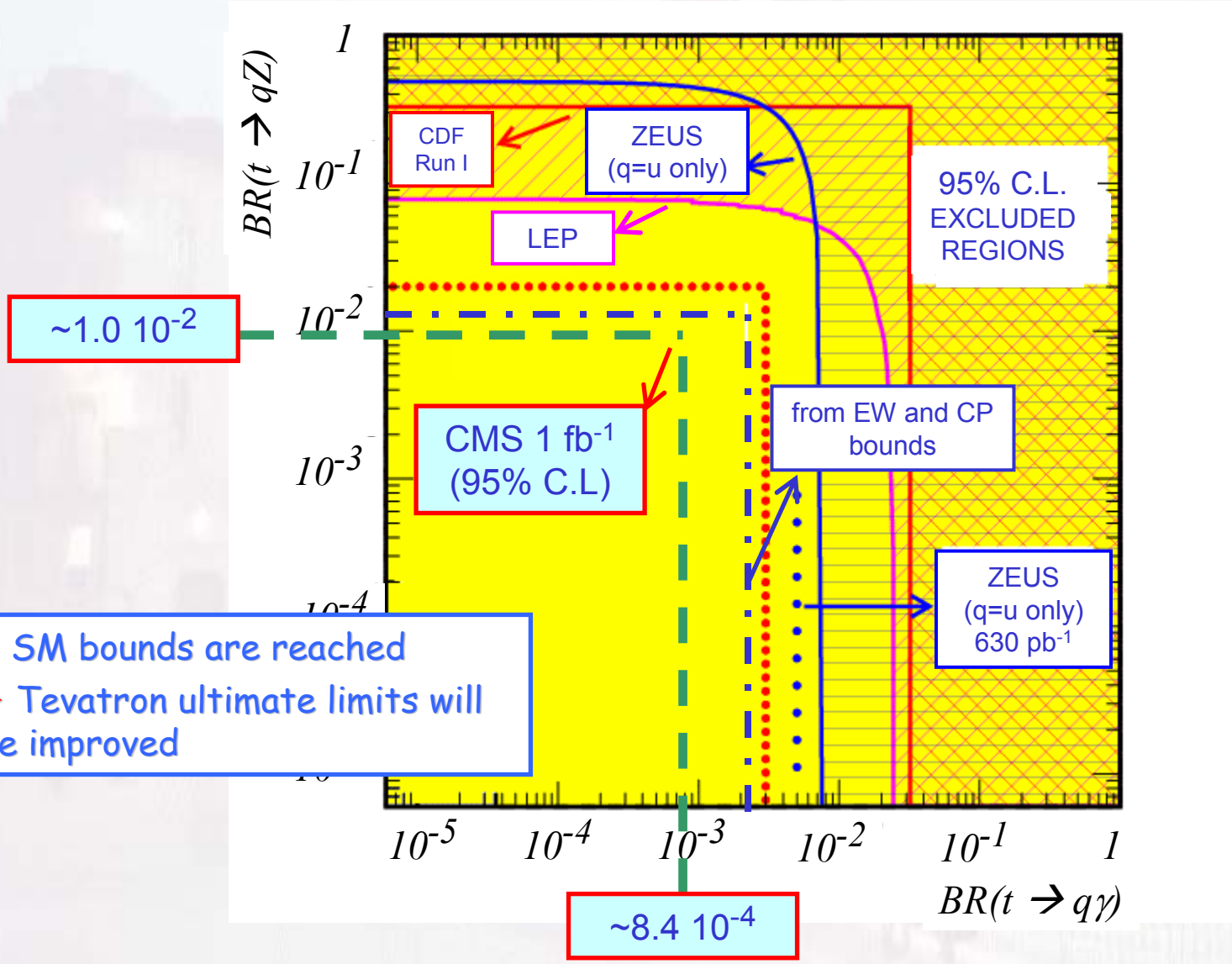
FCNC constraints: the present



FCNC constraints: the future



FCNC constraints: the future



- SM bounds are reached
- Tevatron ultimate limits will be improved

...LHC is waiting round the corner!

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