Single top photoproduction at the LHC

on behalf of the Louvain photon group
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Motivation

SM single top production :

top photoproduction : ~ 2.4 pb

50% single top ! (pp : 5%)

→ Sensitivity to $|V_{tb}|$

→ Also sensitive to top charge

Anomalous single top photoproduction :

HERA σ ($k_{tu\gamma}$ = 0.1) : 0.04 pb

LHC σ ($k_{tu\gamma}$ = 0.1) : 3.7 pb

→ Opportunity to improve limits

Outline

Standard Model	Anomalous

Production and topology(ies)

Backgrounds

Selection

systematic errors

$\|V_{tb}\|$ measurement	limit on couplings

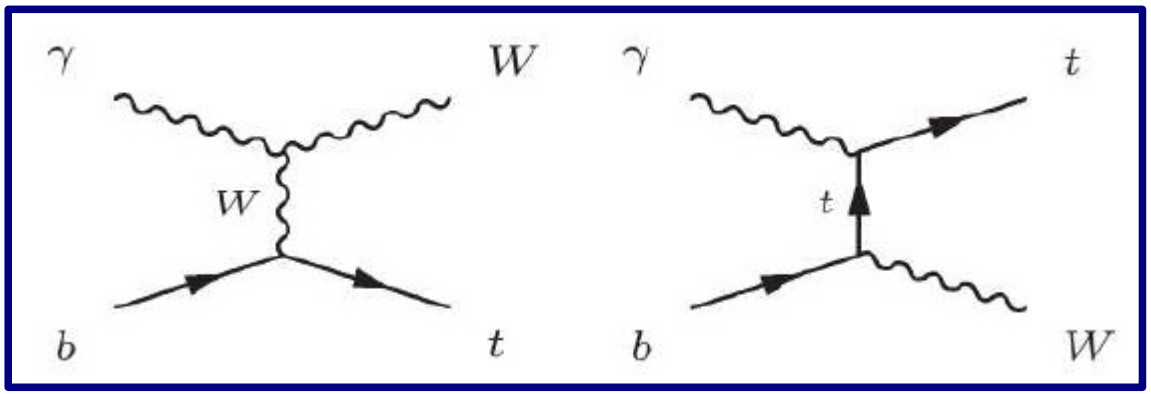
Simulation

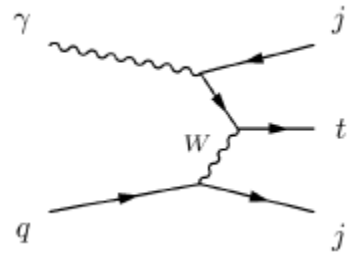
Interaction	MadGraph/MadEvent CompHep Pomwig
Hadronisation	Pythia
Forward proton	Hector
Detector	Fastsim

- MG/ME and Comphep modified to include EPA
- Fastsim :
  - perfect granularity
  - particles 4-vectors smearing
  - jet cone algorithm

Standard Model single top photoproduction

SM single top photoproduction

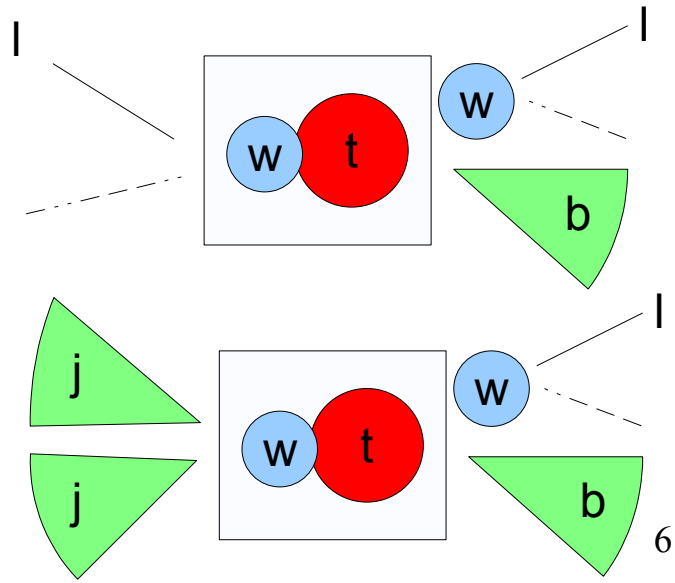




Topologies :

leptonic σ = 104 fb

semileptonic σ = 440 fb

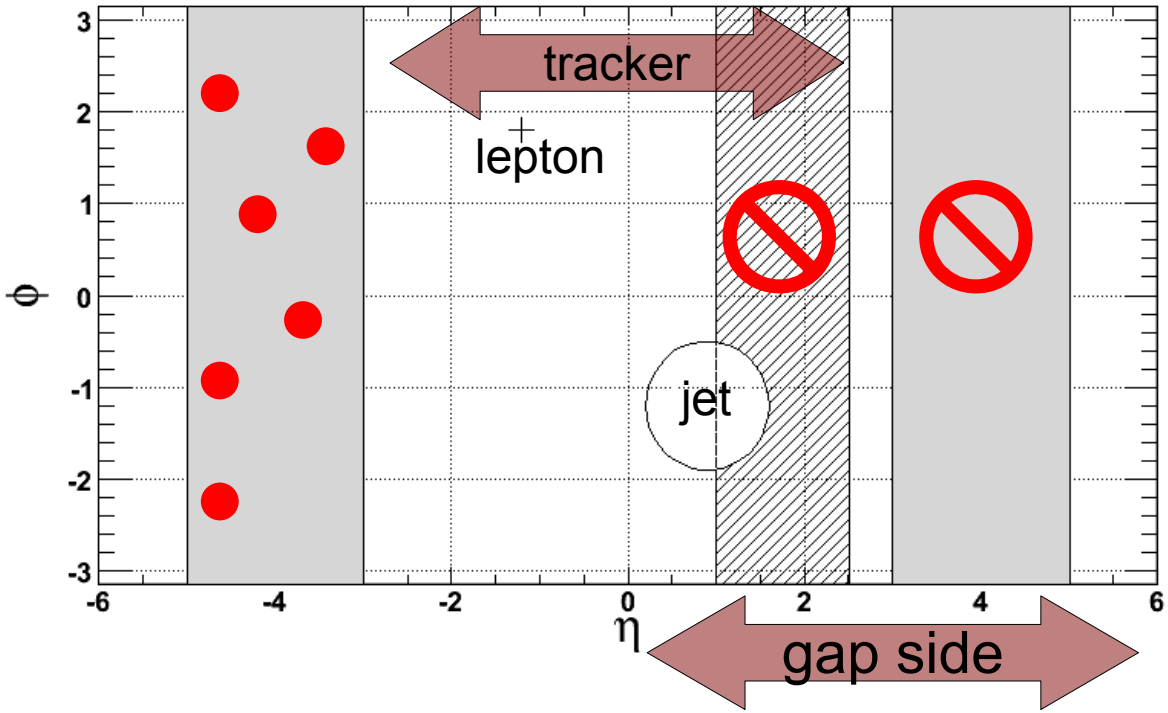


Backgrounds

Leptonic :	process	σ [fb]	Sample
photoproduction :	tt	159	100 k
	WW + q'	63	90 k
partonic (pp) :	tt	78×10^3	510 k
	WW + j	5.2×10^3	50 k
Semileptonic :			
photoproduction :	tt(1l + 2l)	831	270 k
	W + 3j	2.8×10^3	50 k
	W + bb + j	55	50 k
partonic (pp) :	tt(1l + 2l)	407×10^3	520 k
	W + jets	73×10^6	770 k
	W + bb + j	267×10^3	120 k
	t + j	67×10^3	100 k

Rejection of pp backgrounds

Rapidity gap : energy in one forward region (3<|η|<5, grey) lower than treshold (20–30 GeV).



Exclusivity : No reconstructed (primary vertex) track in central region (hatched) on « gap side », outside jet cones.

Selection

	Leptonic	semileptonic
Topology :	1 jet + 2 leptons + E_T miss	3 jets + 1 lepton
Rapgap :	E^{FCAL} < 30 GeV	E^{FCAL} < 30 GeV
Exclu :	0 tracks	0 tracks
Final :	b-tagging	ΣP_T , b-tagging, M_W

σ [fb]	signal	γp	pp
production	104.0	222	83×10^3
topology cuts	14.2	13.7	3.4×10^3
gap + exclu.	12.7	8.0	3.2
final cuts	4.9	1.6	0.6
		2.2	

σ [fb]	signal	γp	pp
production	440.0	3.6×10^3	74×10^6
topology cuts	36.0	144.4	116×10^3
gap + exclu.	24.2	77.9	187.5
final cuts	4.8	1.9	3.6
		5.5	

Results

For 10 fb^{-1} :

$$\Delta|V_{tb}|/|V_{tb}| = 0.5\ [\Delta\sigma_{obs}/\sigma \ + \ \Delta\sigma_{th}/\sigma]$$

$$\Delta|V_{tb}|/|V_{tb}| = 10.1 \,/\, 16.9\ \%\ \text{(leptonic / semi)}$$

- pp foreseen $\Delta|V_{tb}|$: ~14 % (same luminosity)

- No diffractive backgrounds included
- Inelastic photoproduction not taken into account

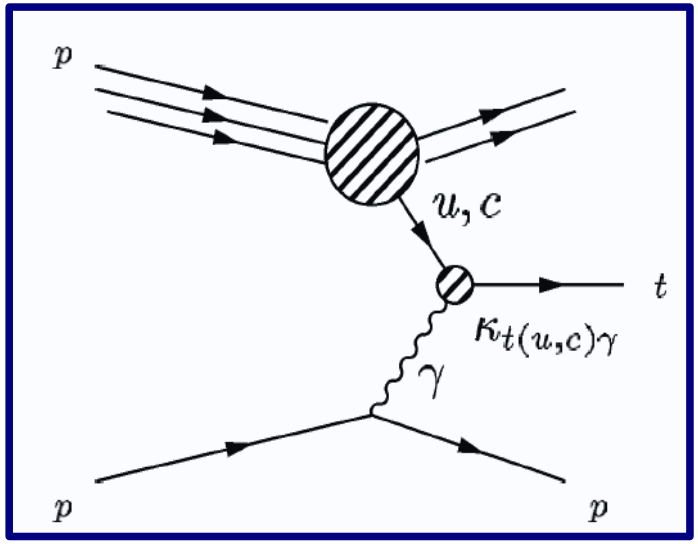
→ Signal and Background (uncertainties) are underestimated

Errors can be lowered by cutting stronger to kill pp :

stronger rapidity gap cut, exclusivity

Anomalous top photoproduction

FCNC top production



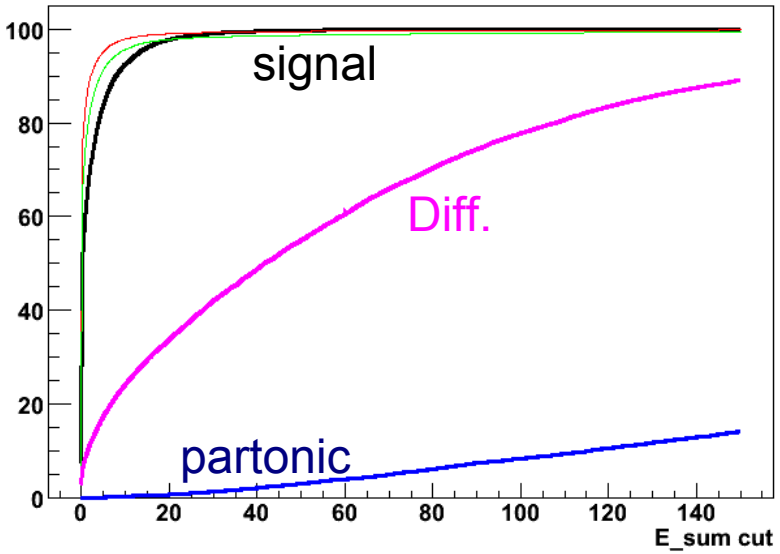
Effective : $$L = ie_t t \frac{-\sigma_{\mu\nu} q^\nu}{\Lambda} k_{tu\gamma} u A^\mu + ie_t t \frac{-\sigma_{\mu\nu} q^\nu}{\Lambda} k_{tc\gamma} c A^\mu + h.c.$$

- $k_{tu\gamma}$ has been probed at HERA : $k_{tu\gamma}$ < ~0.14 @ 95% C.L.
- $k_{tc\gamma}$ becomes important as x is much lower than at HERA

$$\sigma = 368 \text{ pb} \times k^2_{tu\gamma} + 122 \text{ pb} \times k^2_{tc\gamma} \text{ (Calchep)}$$

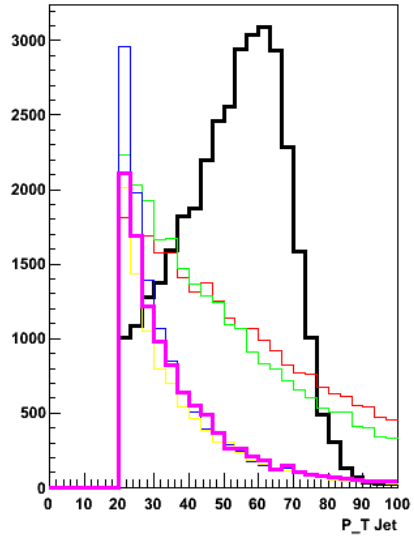
Diffractive background

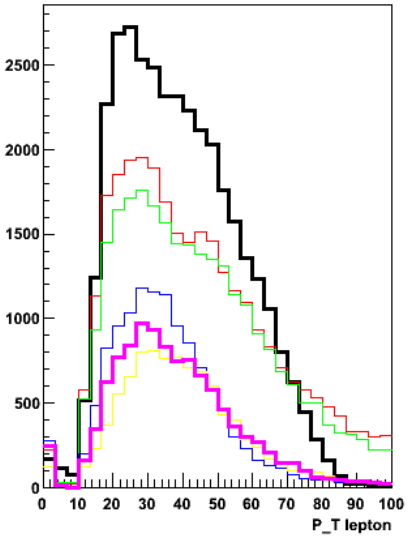
Diffractive W + jet may contribute to the background beside photoproduction, with high cross-section.



Effect of Rap gap cut :
Diffraction is intermediate between Photoproduction and partonic

Jet and lepton P_T :
Very similar to partonic





Backgrounds

	process	σ [pb]	Sample
photoproduction :	W + j	41.6	100 k
	W + c	11.5	100 k
partonic (pp) :	W + j	77.3×10^3	100 k
	W + c	8.8×10^3	100 k
Diffraction :	W + j (c incl.)	1.4×10^3	100 k

- c-jets contribute because of the high probability to be mistagged as b-jets (10%)
- Diffractive W is elastic only, with gap survival $S^2 = 0.05$ (included)
- An error of 50 % has been taken on S^2

Selection : very low lumi

($\sim 10^{32}$ cm^{-2} s^{-1})

- 1 isolated lepton with $p_t > 20$ GeV
- 1 tagged b-jet with $p_t > 45$ GeV
- Reconstructed top mass between 140 and 210 GeV
- Rapidity gap (E < 20 GeV)
- Exclusivity
- Missing $E_T < 20$ GeV

σ_{sel} (Signal) = 61.1 fb ($k_{tu\gamma} = 0.15$, $k_{tc\gamma} = 0$)

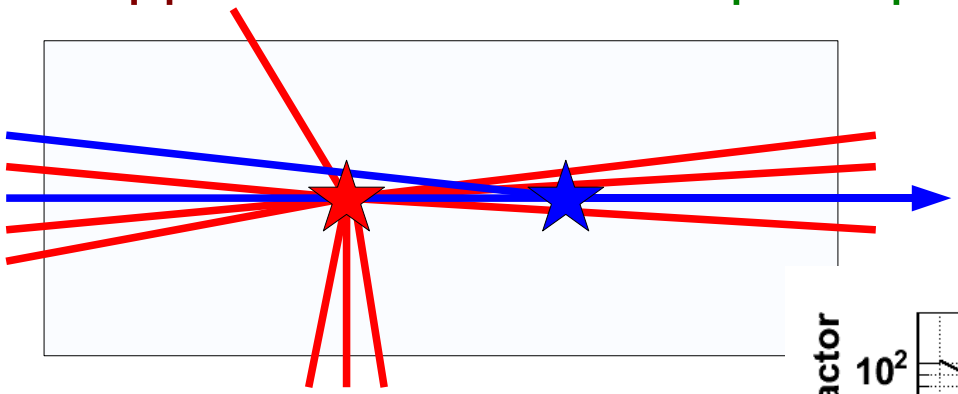
σ_{sel} (Background) = 7.3 fb (30/55/15% pp/γp/diff.)

higher lumi pp rejection

Low lumi (~10^{33} $cm^{-2}s^{-1}$) pile-up fills rapgaps !

→ one needs forward detectors

BUT : accidental coincidences between diffractive pileup and pp events can mimic photoproduction.

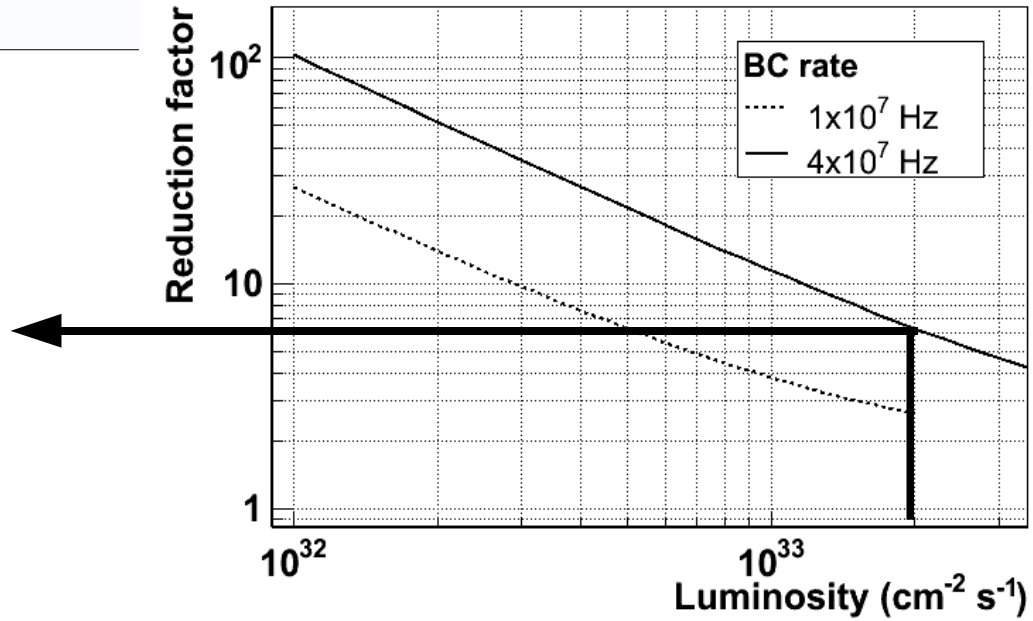


Surviving proton from pile-up

pp reduction factor :

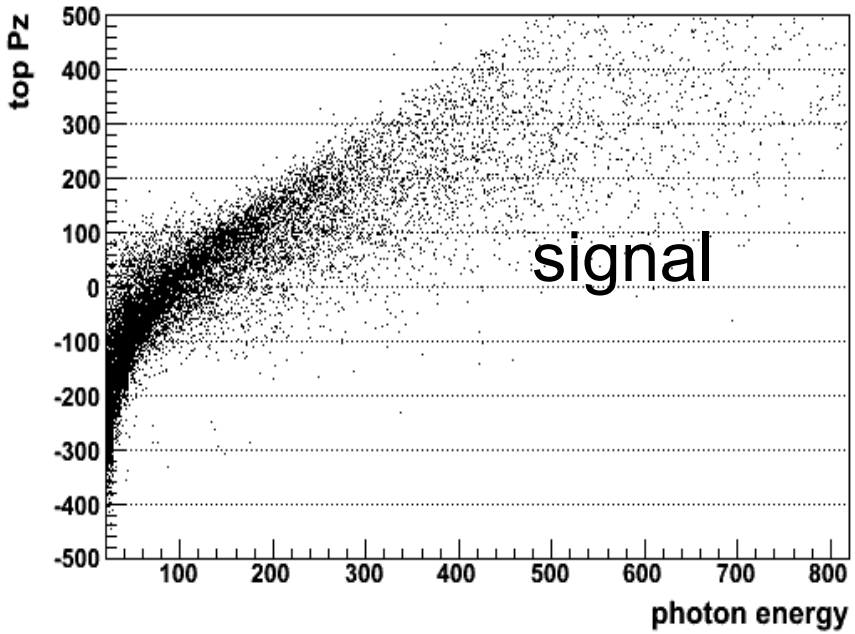
$2x10^{33}$ $cm^{-2}s^{-1}$: 5.6

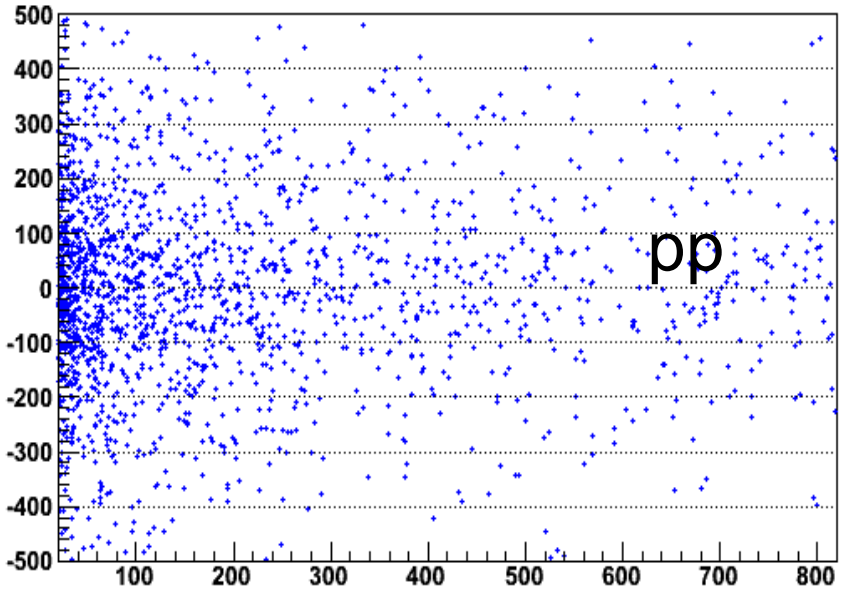
10^{33} $cm^{-2}s^{-1}$: 10.7



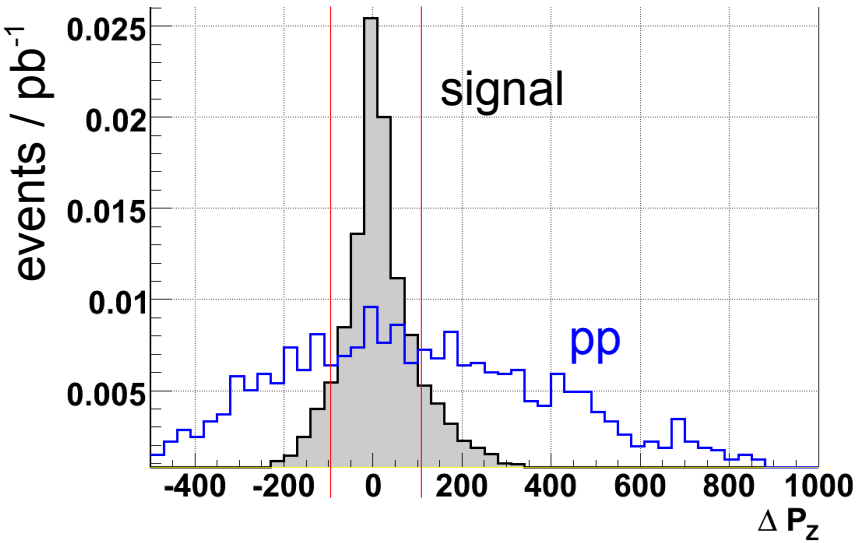
Selection : low lumi

Using proton energy loss to reject pp backgrounds :





Computing **top P_Z** from central event and from photon energy :



Selection : low lumi

(2×10^{33} cm^{-2} s^{-1})

- 1 isolated lepton with $p_t > 20$ GeV
- 1 tagged b-jet with $p_t > 45$ GeV
- reconstructed top mass between 140 and 210 GeV
- Hit in at least one forward detector ($20 < E_\gamma < 800$ GeV)
- Exclusivity (0 track on tagged proton side)
- $|\Delta P_Z|$ (previous slide) < 100 GeV

σ_{sel} (Signal) = 57.1 fb ($k_{tu\gamma} = 0.15$, $k_{tc\gamma} = 0$)

σ_{sel} (Background) = 13.6 fb (60/30/10% pp/γp/diff.)

Results

- Very low lumi : 1 fb-1

  signal : 61.1 ± 7.8 (stat.) ± 5.9 (syst.) events

  Bkg : 7.3 ± 2.7 (stat.) ± 1.4 (syst.) events

- Low lumi : 30 fb-1

  signal : 1713 ± 41 (stat.) ± 153 (syst.) events

  Bkg : 408 ± 20 (stat.) ± 40 (syst.) events

→ Very low lumi :

$k_{tu\gamma} < 0.046$, $k_{tc\gamma} < 0.080$ after 1 fb^{-1}

Low lumi :

$k_{tu\gamma} < 0.032$, $k_{tc\gamma} < 0.056$ after 30 fb^{-1}

Conclusions and prospects

Conclusions :

- $|V_{tb}|$ could be measured with similar accuracy than from pp interactions,
- Limit on $k_{tu\gamma}$ can be improved significantly after only 1 fb-1,
- First limit on $k_{tc\gamma}$ can be obtained.

Prospects :

- Influence of (inelastic) diffractive and photon-induced processes still to be computed,
- Full detector simulation will provide more realistic estimate for systematics, especially on rapidity gap and exclusivity.

Systematic errors

- Jet energy scale :
  - jets energy ± 5% (Pt < 30 GeV)
  - jets energy ± 3% (Pt > 50 GeV)
  - interpolation between 30 – 50 GeV
- Exclusivity :
  - Track reconstruction efficiency (90 %) ± 5%
- Rapidity gap :
  - Energy in forward detectors ± 10%
- Luminosity uncertainty : 5%
- Theoretical cross-section : process-dependant
- b-tagging : 5%

Systematic errors (II)

leptonic			semileptonic		
error	signal	Bkg	error	signal	Bkg
JES	0.6 %	3.7 %	JES	6.7 %	10.6 %
rapgap	0.8 %	3.0 %	rapgap	0.5 %	12.5 %
exclu.	1.4 %	7.9 %	exclu.	1.2 %	2.6 %
lumi.	5.0 %	5.0 %	lumi.	5.0 %	5.0 %
theo.	6.0 %	3.4 %	theo.	6.0 %	2.0 %
b-tag	5.0 %	0.0 %	b-tag	5.0 %	0.0 %
total	9.4 %	11.0 %	total	11.5 %	17.5 %

Dominated by Rapgap + exclusivity on pp

Systematic errors

very low			low		
error	signal	Bkg	error	signal	Bkg
JES	1.6 %	2.9 %	JES	1.6 %	3.2 %
rapgap	0.0 %	9.0 %			
exclu.	1.0 %	5.1 %	exclu	1.0 %	7.0 %.
lumi.	5.0 %	5.0 %	lumi.	5.0 %	5.0 %
theo.	5.0 %	13.3 %	theo.	5.0 %	5.1 %
b-tag	5.0 %	0.0 %	b-tag	5.0 %	0.0 %
$E_T$miss	3.6 %	4.5 %			
Total	9.6 %	18.3 %	Total	8.9 %	10.5 %

Assuming no error on forward proton tagging

Results : σ error

efficiency syst. lumi. bkg systematics statistical

$$\frac{\Delta\sigma}{\sigma} = \frac{\Delta\varepsilon}{\varepsilon} \oplus \frac{\Delta L}{L} \oplus \left[\frac{B}{S}\right]\frac{\Delta B}{B} \oplus \left[\frac{B}{S}+1\right]\frac{\Delta N}{N}$$

$$\text{semileptonic :} \quad 6.8\% \oplus 5.0\% \oplus 0.85 \times 20.4\% \oplus 1.85 \times 9.8\% = 33.3\%$$

$$\text{leptonic :} \quad 5.3\% \oplus 5.0\% \oplus 0.47 \times 13.6\% \oplus 1.47 \times 11.8\% = 19.4\%$$

- No diffractive backgrounds included
- Inelastic photoproduction not taken into account

→ Signal and Background (uncertainties) are underestimated

Errors can be lowered by cutting stronger to kill pp :

stronger rapidity gap cut, exclusivity

Selection : leptonic channel

- 2 isolated leptons with $p_t > 20$ GeV
- 1 jet with $p_t > 30$ GeV
- jet tagged as b-jet
- Missing $E_t > 20$ GeV
- Rapidity gap (E < 30 GeV)
- Exclusivity (0 tracks)

σ_{sel} (signal) = 5.80 fb

σ_{sel} (Background) = 4.87 fb (~50% pp)

Selection : semileptonic channel

- 1 isolated lepton with p_t > 20 GeV
- 3 jets with p_t > 30 GeV
- 1 tagged b-jet
- H_t (scalar sum of all visible E_t's) < 230 GeV
- M(bb) in a window of 20 GeV around M_W
- Rapidity gap (E < 30 GeV)
- Exclusivity (0 tracks)

σ_{sel} (signal) = 7.35 fb

σ_{sel} (Background) = 27.89 fb (>80% pp)