



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 $\sigma (k_{t\gamma} = 0.1) : 0.04$ pb

LHC $\sigma (k_{t\gamma} = 0.1) : 3.7$ pb

→ Opportunity to improve limits



Outline

Standard Model

Anomalous

Production and topology(ies)

Backgrounds

Selection

systematic errors

$|V_{tb}|$ measurement

limit on couplings

Outline

SM :

- * production
- * backgrounds
- * selection
- * systematics
- * results

Anomalous :

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Conclusions



Simulation

Interaction	MadGraph/MadEvent CompHep
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

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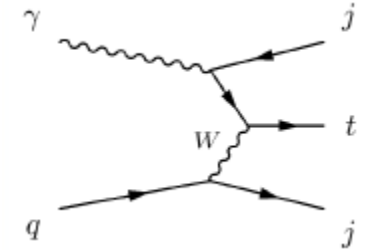
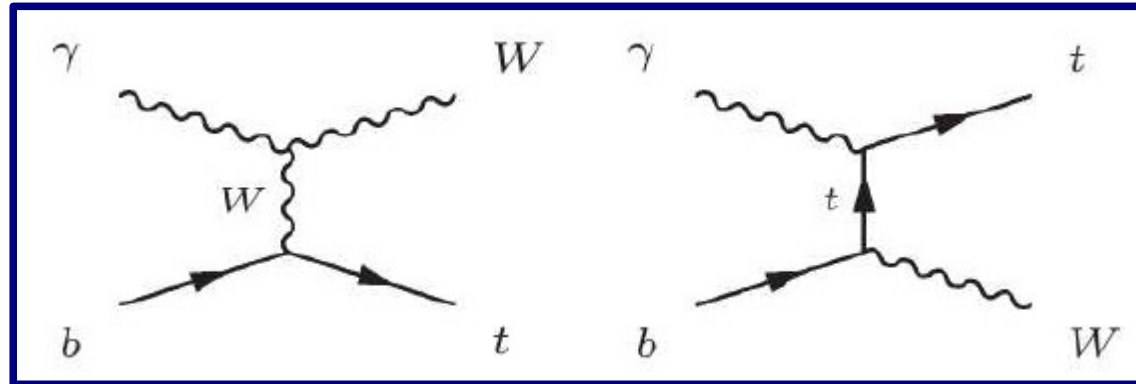
Anomalous :

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Standard Model single top photoproduction

SM single top photoproduction



Topologies :

leptonic $\sigma = 104 \text{ fb}$

semileptonic $\sigma = 440 \text{ fb}$

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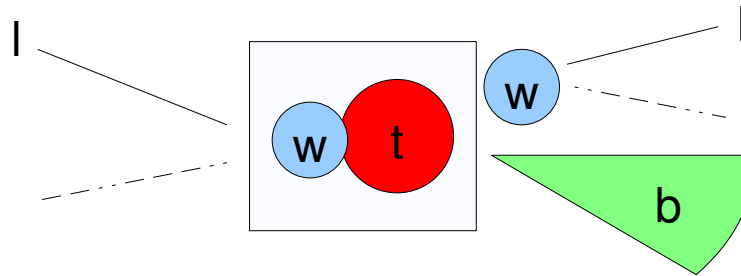
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Backgrounds : leptonic



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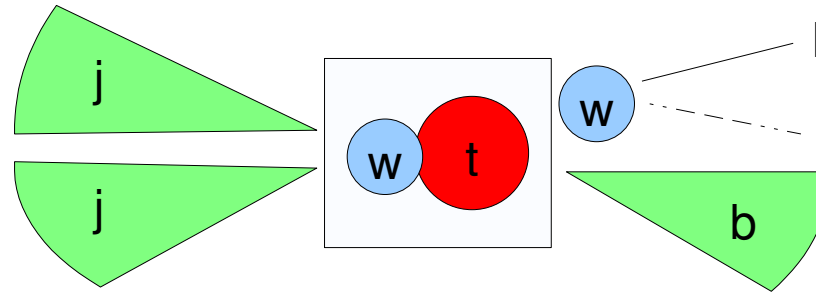
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Conclusions

	process	σ [fb]	Sample
photoproduction :	tt	159	100 k
irreducible	WW + q'	63	90 k
partonic (pp) :	tt	78×10^3	510 k
reducible	WW + j	5.2×10^3	50 k

Backgrounds : semileptonic



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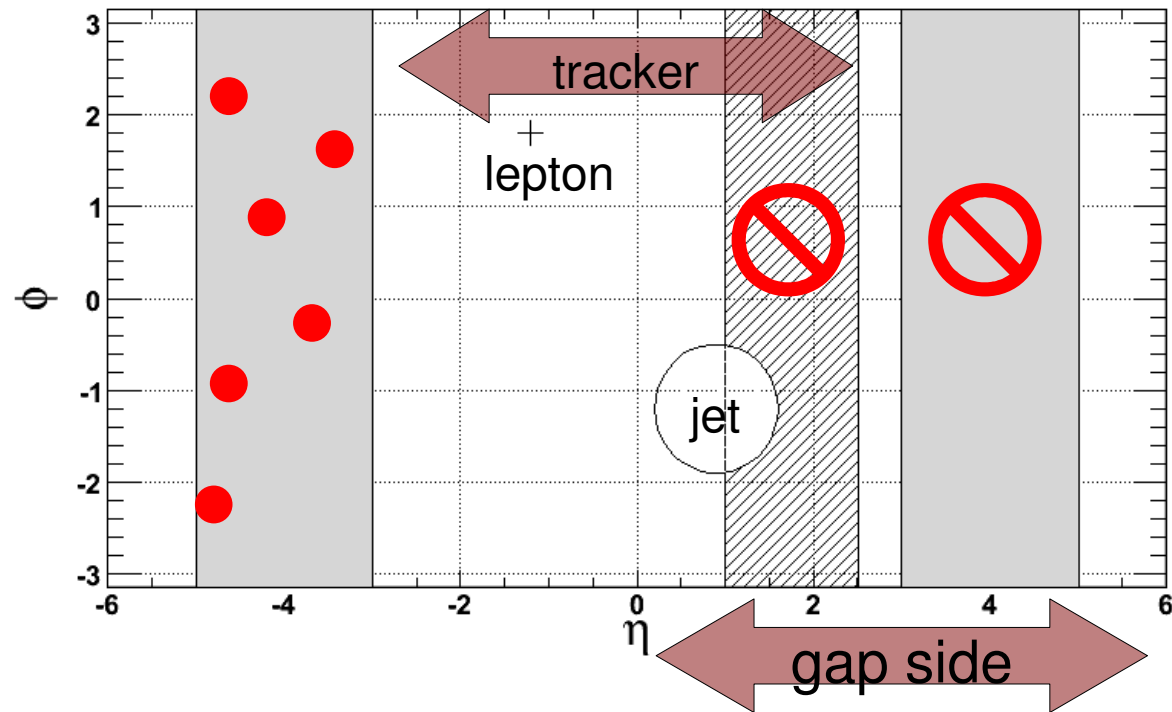
- * production
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Conclusions

	process	σ [fb]	Sample
photoproduction : irreducible	$tt(1l + 2l)$	831	270 k
	$W + 3j$	2.8×10^3	50 k
	$W + bb + j$	55	50 k
partonic (pp) : reducible	$tt(1l + 2l)$	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

Selection : pp backgrounds

Rapidity gap : energy in one forward region ($3 < |\eta| < 5$, grey) lower than threshold (20–30 GeV).



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

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Selection : leptonic channel

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
			3.2

Topology : 1 jet + 2 leptons + missing E_T

Rapidity gap : $E^{\text{FCAL}} < 30 \text{ GeV}$

Exclusivity : 0 tracks

Final cuts : b-tagging

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Selection : semileptonic channel

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	

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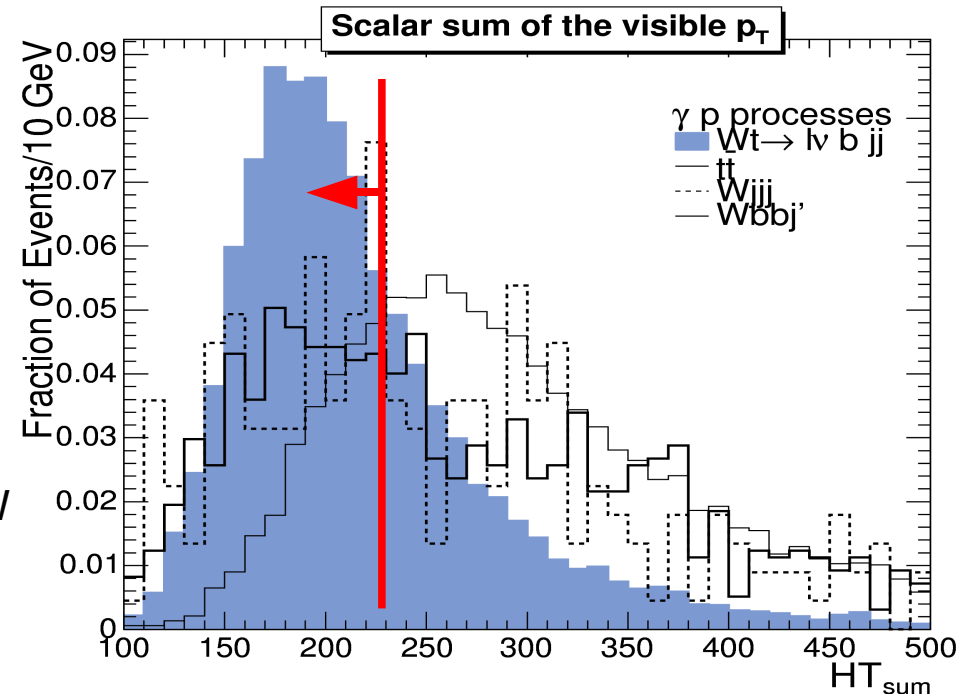
Conclusions

Topology : 3 jets + 1 lepton

Rapidity gap : $E^{FCAL} < 30$ GeV

Exclusivity : 0 tracks

Final cuts : ΣP_T , b-tagging, M_W





Systematic errors

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

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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

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Results : σ error

efficiency syst. lumi. bkg systematics statistical

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

semileptonic : 6.8% \oplus 5.0% \oplus 0.85 \times 20.4% \oplus 1.85 \times 9.8% = 33.3%

leptonic : 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

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Results

For 10 fb^{-1} :

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

$$\Delta|V_{tb}|/|V_{tb}| = 16.9 \% \text{ (semileptonic)}$$

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

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

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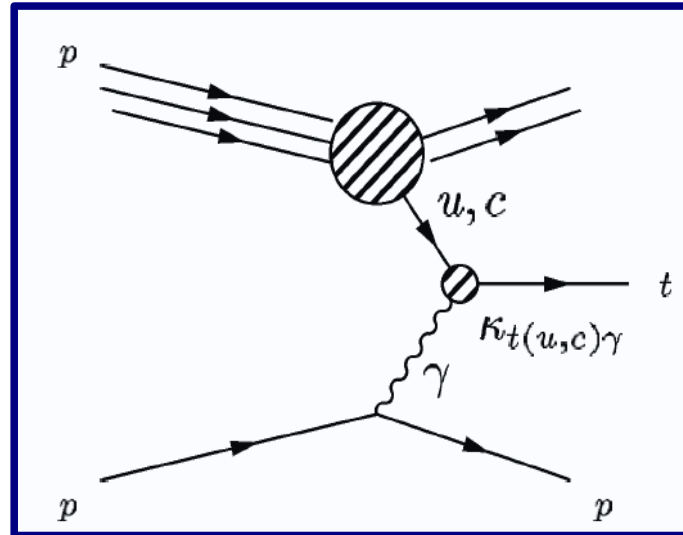
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Anomalous top photoproduction

FCNC top production

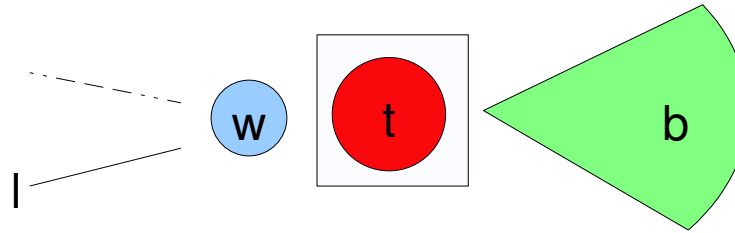


Effective :
$$L = ie_t t \frac{-\sigma_{\mu\nu} q^\nu}{\Lambda} k_{tu\gamma} u A^\mu + ie_t t \frac{-\sigma_{\mu\nu} q^\nu}{\Lambda} k_{tc\gamma} c A^\mu + h.c.$$

- $k_{tu\gamma}$ has been probed at HERA : $k_{tu\gamma} < \sim 0.17 @ 95\% \text{ C.L.}$
- $k_{tc\gamma}$ becomes important as x is much lower than at HERA

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

Backgrounds



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

c-jets contribute because of the high probability to be mistagged as b-jets (10%)



Selection : very low lumi

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

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

$$\sigma_{\text{sel}} (\text{Signal}) = 83.2 \text{ fb} (k_{t\bar{u}\gamma} = 0.15, k_{t\bar{c}\gamma} = 0)$$

$$\sigma_{\text{sel}} (\text{Background}) = 12.7 \text{ fb} (\sim 50\% \text{ pp})$$

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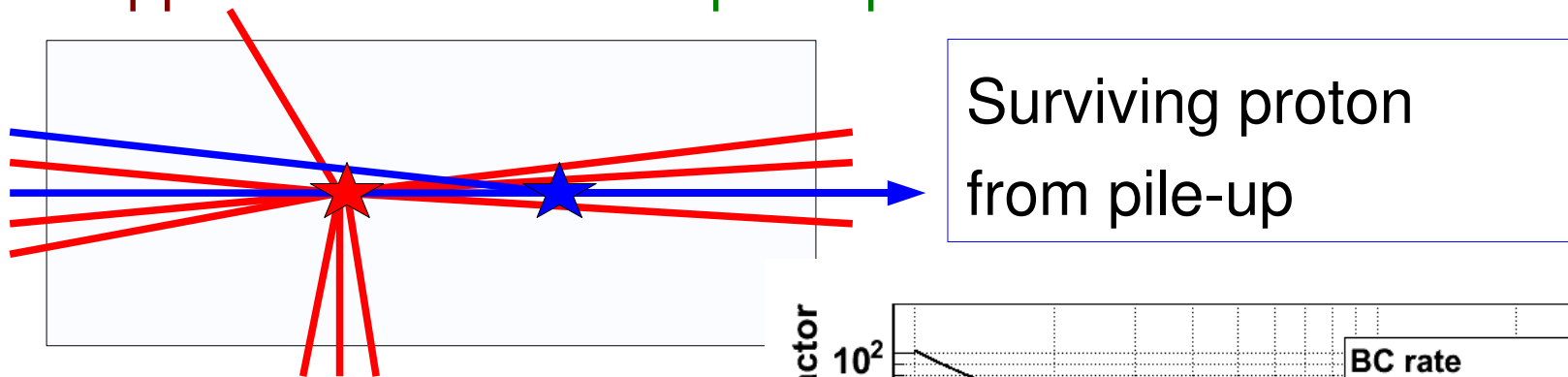
Conclusions



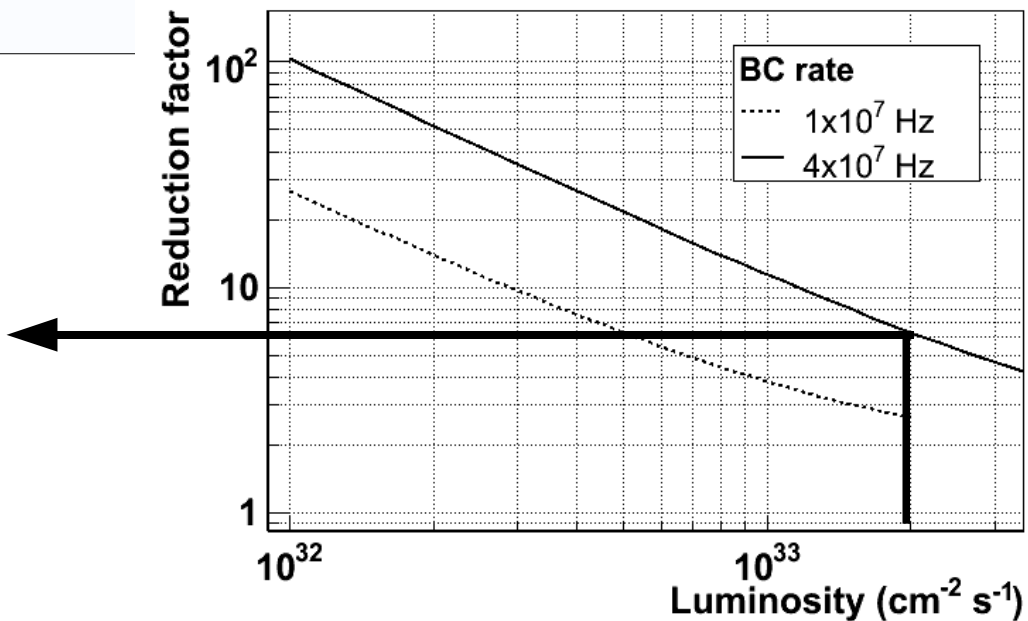
higher lumi pp rejection

- Low lumi ($\sim 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$) pile-up fills rapgaps !
→ one needs forward detectors (Xavier's talk)

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



pp reduction factor :
 $2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$: 5.6
 $10^{33} \text{ cm}^{-2} \text{ s}^{-1}$: 10.7

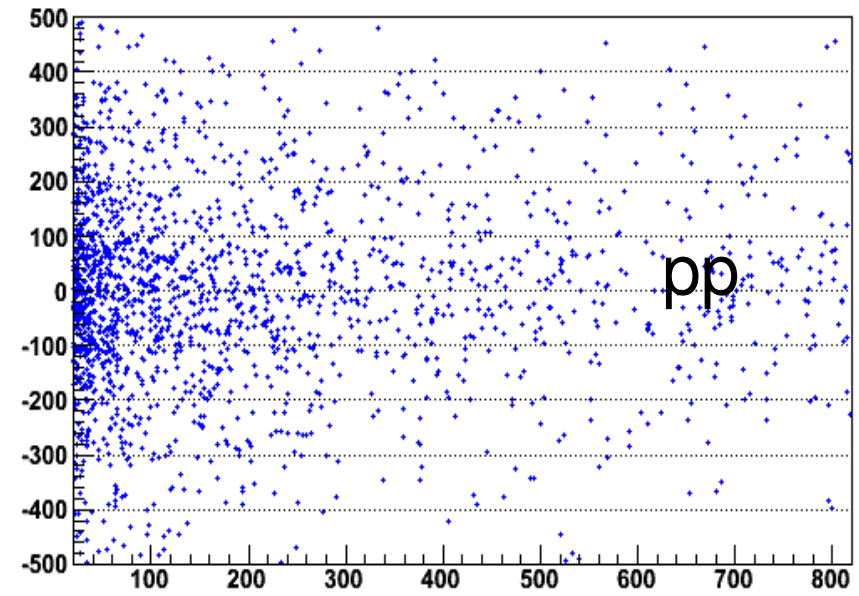
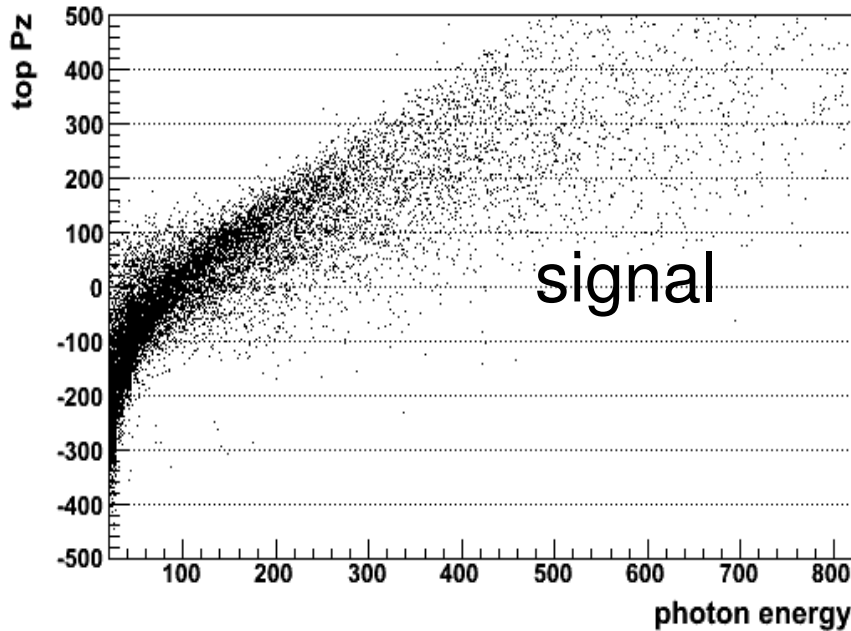


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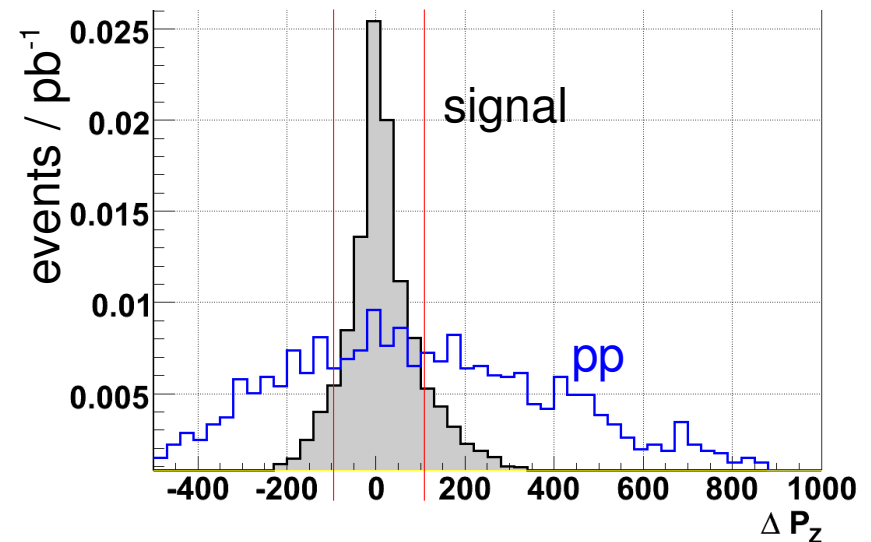


Selection : low lumi

Using proton energy loss to reject pp backgrounds :



Computing **top P_z** from central event and from photon energy : \longrightarrow



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Selection : low lumi

$(2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1})$

- 1 isolated lepton with $p_t > 20 \text{ GeV}$
- 1 tagged b-jet with $p_t > 45 \text{ GeV}$
- reconstructed top mass between 140 and 210 GeV
- **Exclusivity**
- Hit in at least one forward detector ($20 < E_\gamma < 800 \text{ GeV}$)
- ΔP_z (previous slide) $< 100 \text{ GeV}$

$$\sigma_{\text{sel}} (\text{Signal}) = 51.8 \text{ fb} (k_{t\gamma} = 0.15, k_{t\gamma} = 0)$$

$$\sigma_{\text{sel}} (\text{Background}) = 10.9 \text{ fb} (\sim 65\% \text{ pp})$$

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Systematic errors

very low			low		
error	signal	Bkg	error	signal	Bkg
JES	1.6 %	3.0 %	JES	1.6 %	3.3 %
rapgap	0.0 %	9.9 %			
exclu.	1.0 %	5.5 %	exclu	1.0 %	6.9 %.
lumi.	5.0 %	5.0 %	lumi.	5.0 %	5.0 %
theo.	5.0 %	1.9 %	theo.	5.0 %	1.3 %
b-tag	5.0 %	0.0 %	b-tag	5.0 %	0.0 %
total	8.9 %	12.9 %	total	8.9 %	9.3 %

Assuming no error on forward proton tagging

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Results

- Very low lumi : 1 fb⁻¹
 signal : 83.2 ± 9.1 (stat.) ± 7.4 (syst.) events
 Bkg : 12.7 ± 3.6 (stat.) ± 1.6 (syst.) events
- Low lumi : 30 fb⁻¹
 signal : 1554 ± 39 (stat.) ± 138 (syst.) events
 Bkg : 327 ± 18 (stat.) ± 30 (syst.) events

→ Very low lumi :

$$k_{tu\gamma} < 0.044, k_{tc\gamma} < 0.077 \text{ after } 1 \text{ fb}^{-1}$$

Low lumi :

$$k_{tu\gamma} < 0.029, k_{tc\gamma} < 0.050 \text{ after } 30 \text{ fb}^{-1}$$

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Conclusions and prospects

Conclusions :

- Vtb could be measured with similar accuracy than from pp interactions,
- Limit on $k_{t\gamma}$ can be improved significantly after only 1 fb⁻¹,
- First limit on $k_{t\gamma}$ can be obtained.

Prospects :

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

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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)

$$\sigma_{\text{sel}} (\text{signal}) = 5.80 \text{ fb}$$

$$\sigma_{\text{sel}} (\text{Background}) = 4.87 \text{ fb } (\sim 50\% \text{ pp})$$

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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)

$$\sigma_{sel} \text{ (signal)} = 7.35 \text{ fb}$$

$$\sigma_{sel} \text{ (Background)} = 27.89 \text{ fb } (>80\% \text{ pp})$$

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