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γp processes

Experimental

γp -> WHq'

Single Top

Summary

High energy photoproduction at the LHC

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Overview :

- Introduction to photon-proton procedure
- Detection and tagging
- Associated WH
- Single top
- Summary

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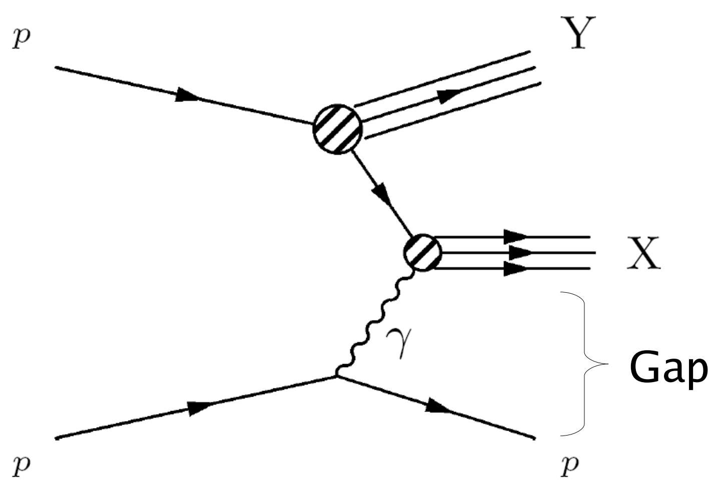
LHC : a new HERA collider !

Photoproduction is traditionally studied at e-p colliders

pp (γq/g → XY) p



- γp events can also be tagged at the LHC

  → e.g. Using Large Rapidity Gaps (LRG)

- Higher luminosity than γγ events

- Probe electroweak sector up to/beyond 2 TeV !

Using EPA

$$\sigma_{pp} = \int \sigma_{\gamma q/g}(\hat{W}_{\gamma q/g}) f_{\gamma}(x_1) f_{q/g}(x_2, Q^2) dx_1 dx_2$$

where $\hat{W}^2_{\gamma q/g} = 4 E_p x_1 x_2$

BUT pp events are more dangerous backgrounds than in γγ interactions!

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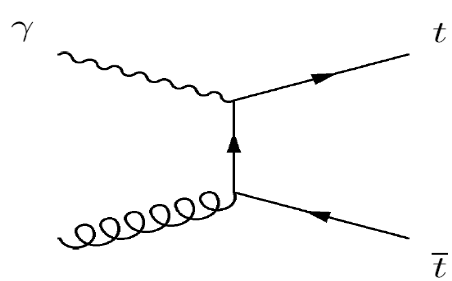
γp cross sections

- Large variety of processes
- Significant cross sections up to 2 TeV

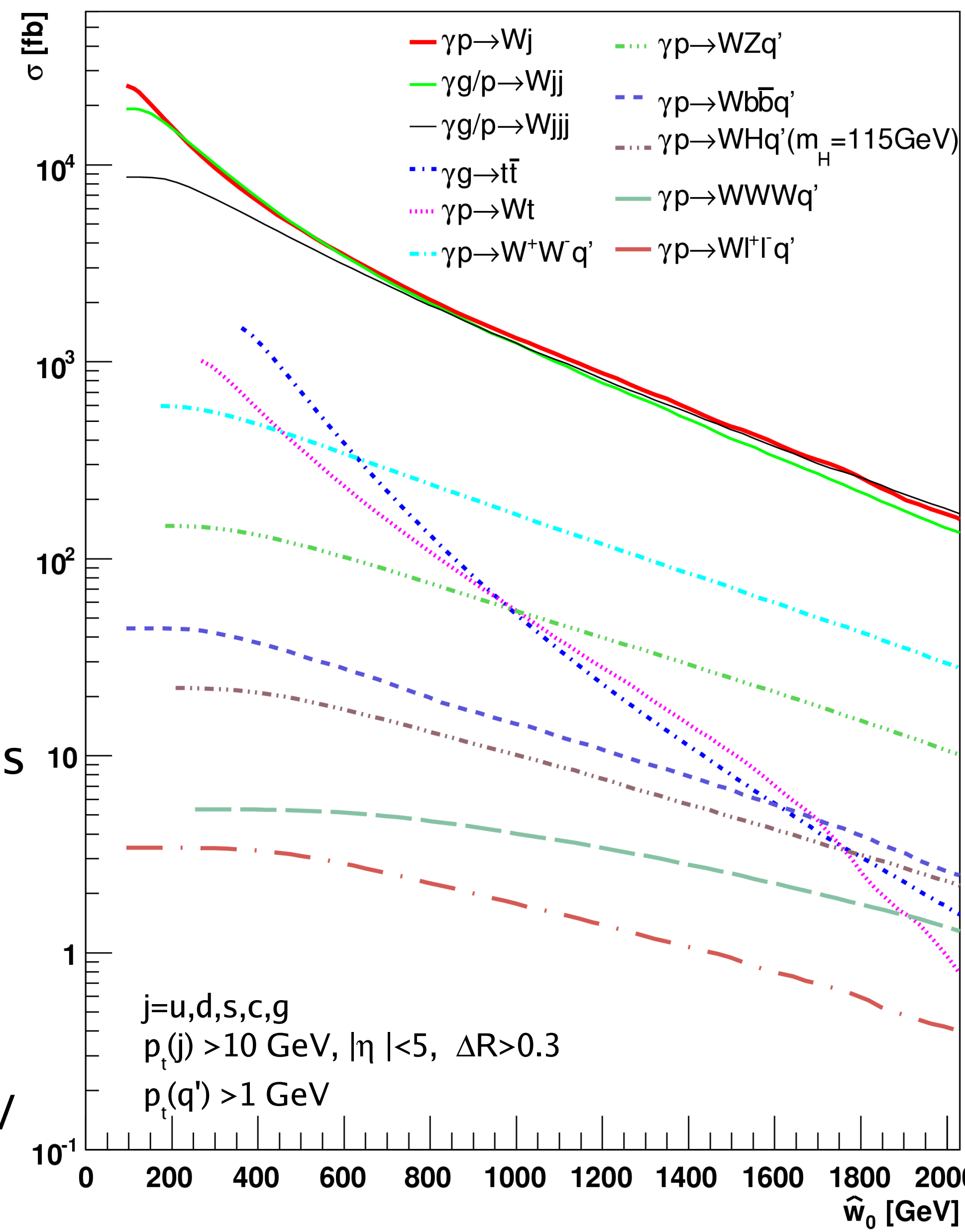
e.g.



1.5 pb

- Alternative way to pp interactions to study
  1. Higgs search
  2. Top physics (e.g. $|V_{tb}|$)
  3. New phenomena up to 2 TeV
- Very good S/B expected

Obtained using MadGraph/MadEvent



Simulation procedure

Jets in the final state require careful simulation of acceptance cuts!

MG/ME
Calchep

Generation

PYTHIA

Showering
Hadronization
Fragmentation,...

FastSim

Detector simulation of a LHC-like detector :

- infinitely good granular resolution
- finite E resolution depending on η

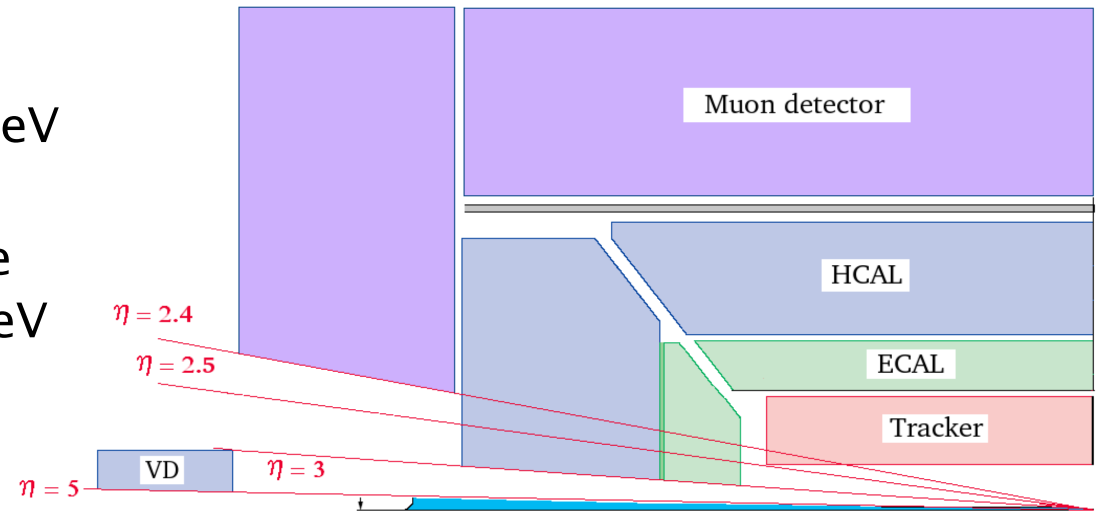
Objects reconstruction

Leptons : $|\eta| < 2.5$, $p_T > 10$ GeV

Jets : reconstructed in a cone $R = 0.7$ for $|\eta| < 3$, $p_T > 20$ GeV

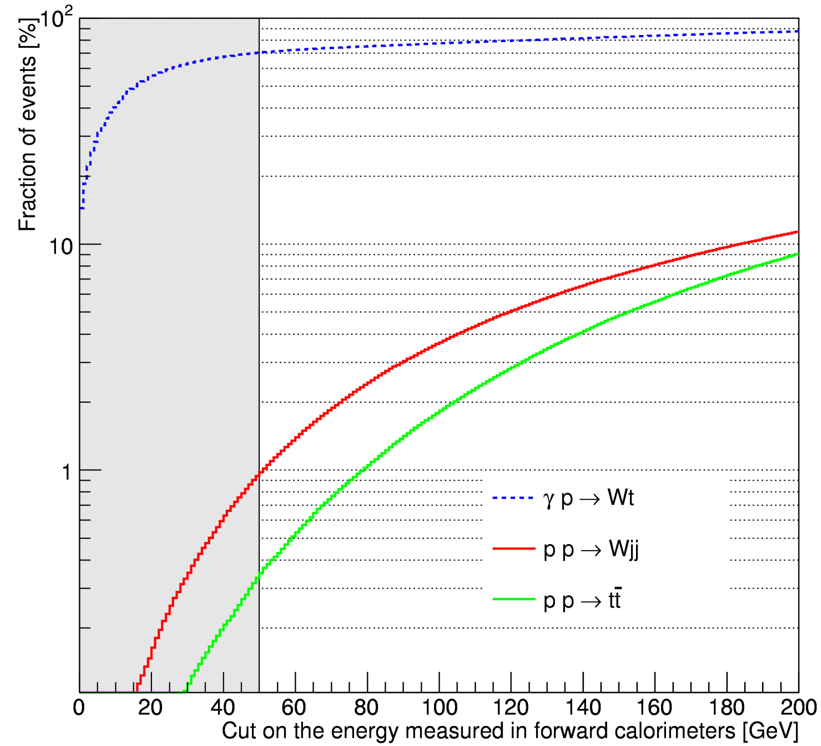
b-tagging : for $|\eta| < 2.5$

- tagging efficiency : 40%,
- mistagging of 1% for j=u,d,s,g
- mistagging of 10% for j=c.



Observability of photo-induced processes is determined using acceptance cuts with these thresholds

Detection and tagging



Very low luminosity phase (<10^{33} cm^{-2} s^{-1})

- Small event pile-up

→ Large rapidity gap (LRG) signature can be used

- For example, forward energy flows (into 3<|η|<5) in one of the two hemispheres less than 50 GeV

Advantage : independent on very forward detectors features (Roman Pots)

Drawback : - low integrated luminosity expected

- kinematics is less constrain

- Expected integrated luminosity of 1 fb^{-1}

Low luminosity phase (~ 10^{33} cm^{-2} s^{-1})

- Use of very forward detector is mandatory !
- Exclusivity cuts can be applied (e.g. vetoing soft tracks from event vertex)
- Expected integrated luminosity of 10-30 fb^{-1}

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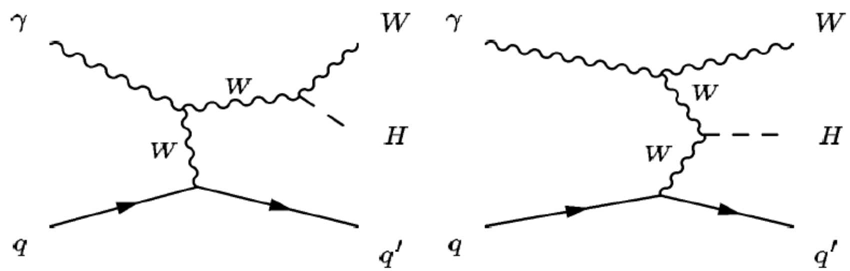
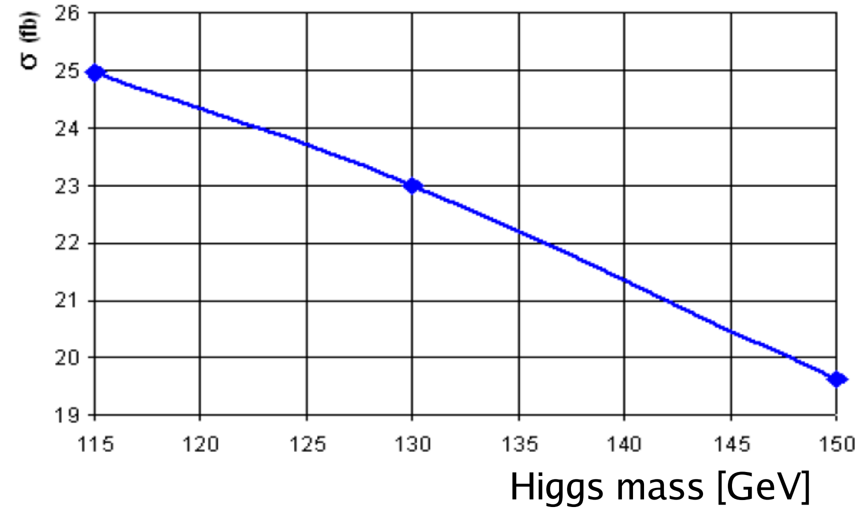
Associated WH production



Obtained using MadGraph/MadEvent



- Associated production of WH has significant cross section at LHC !
- tt less overwhelming than in pp case!

Five topologies where studied

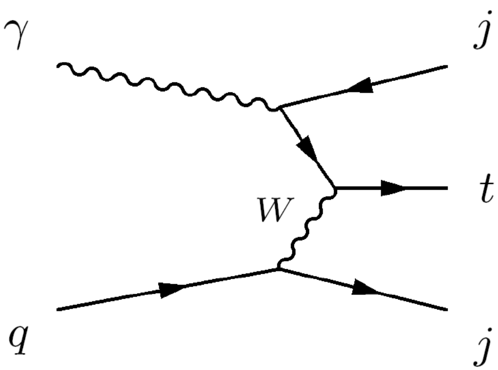
- WH → lνbb, l=e,μ,τ,
- WH → $W\tau^+\tau^-$ → jjl^+l^-, l=e,μ,
- WH → $W\tau^+\tau^-$ → $jjl^+\tau_h$, l=e,μ,
- WH → WW^+W^- → lll, l=e,μ,τ,
- WH → WW^+W^- → $jjl^\pm l^\pm$, l=e,μ,τ.

	M_H=115 GeV			M_H=170 GeV	
Topology	lνbb	jjl^+l^-	$jjl^+\tau_h$	lll	$jjl^\pm l^\pm$
σ WHq' [fb]	5.42	0.14	0.52	0.55	1.17
σ_{acc}	0.11	0.01	0.04	0.07	0.23
Irreducible backgrounds (tt, Wt, Wzq', WWW, Wllq' Wbbq')					
σ_{acc} bkg	3.21	28.6	8.26	1.44	0.30

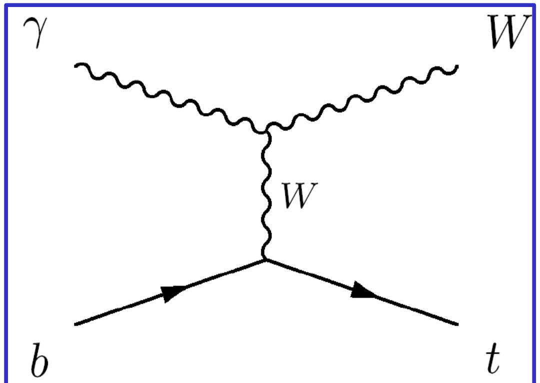
Results after application of acceptance cuts

- Very small statistics ➡ not a discovery channel
- Interesting sensitivity for 2 topologies : lνbb and $jjl^\pm l^\pm$
- For analysis, more specified cuts can be applied.

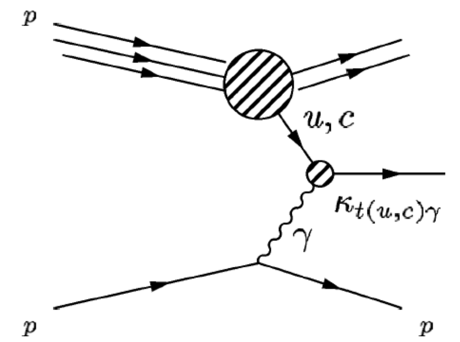
The LHC is a Top factory!



t-channel



Wt-channel



Anomalous top

Physics highlights

- Wt and t-channel related to V_{tb}
- Sensitivity to new physics : FCNC
- Possibility to study top properties (mass, charge,...)

pp vs γp cross sections

	pp	γp
Wt-channel	~ 60 pb	~ 1pb
t-channel	~ 245 pb	~ 6.2 fb
Wjjj	~ 35 nb	8.7 pb
tt	~ 720 pb	1.5 pb

- Wt-channel : more favorable background condition than pp case $\frac{\sigma_{Wt}}{\sigma_{tt}} \simeq 0.7$
- What kind of uncertainty is reachable on $|V_{tb}|$?

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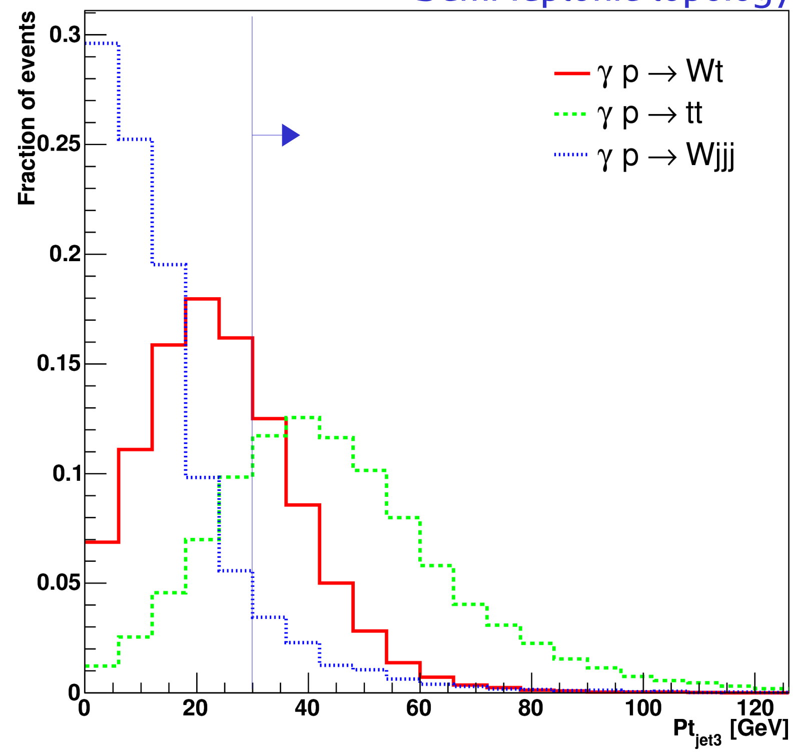
Typical analysis cuts

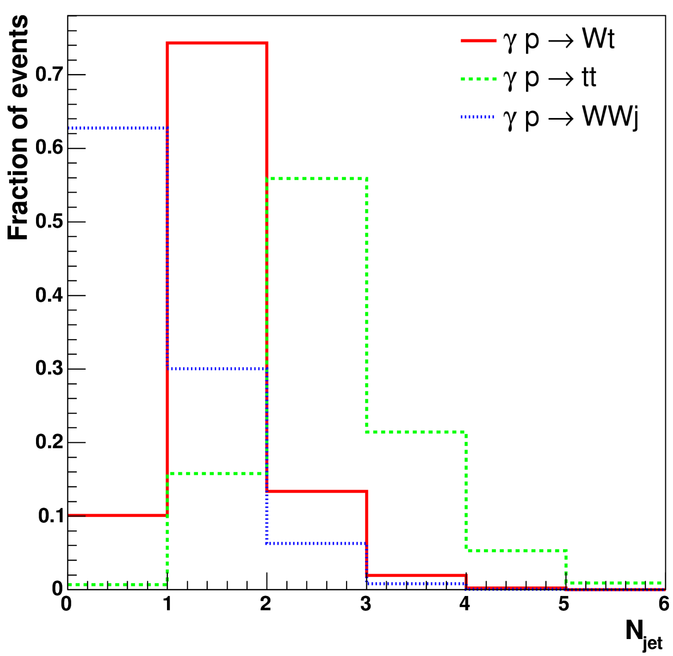
Semi-leptonic topology

- 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_t

Semi-leptonic topology



Di-leptonic topology



Di-leptonic topology

- 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

σ uncertainty : semi-leptonic topology

- Cross sections after analysis cuts

	γp backgrounds					pp backgrounds				
	Wt	tt(1l)	tt(2l)	W3j	Wbbj	tt(1l)	tt(2l)	W+jets	Wbbj	tj
σ [fb]	440.6	671.75	159.08	2792.97	55.22	328025	77680	3261000	266587	67005
σ_{acc}	7.35	3.39	0.63	0.79	0.04	8.3	1.76	9.65	2.73	0.56

- Uncertainties after 10 fb^{-1}

Source	Uncertainty	Δσ/σ (semi-lept)
Statistical uncertainty	-	25.5%
Integrated luminosity	5%	10.5%
Theoretical uncertainty	-	9.7%
Jet energy Scale	5% (20 GeV) 3% (50 GeV)	23.4%
b-tagging efficiency	5%	24.0%
Total systematic uncertainty		34.9%

- This result can be improved (e.g. : tagging, exclusivity,...)
- More efficient suppression of pp backgrounds is mandatory!

σ uncertainty di-leptonic topology

- Cross sections after analysis cuts

		γp bkg		pp bkg	
	Wt	tt	WWq'	tt	WWj
σ [fb]	104.33	159.1	62.5	77680	5234
σ_{acc}	5.8	1.97	0.12	2.55	0.23

- Uncertainties after 10 fb^{-1}

Source	Uncertainty	Δσ/σ(di-lept)
Statistical uncertainty	-	17.6%
Integrated luminosity	5%	5.7%
Theoretical uncertainty	-	2.75%
Jet Energy Scale	5% (20 GeV) 3% (50 GeV)	10.7%
Btagging efficiency	5%	9.1%
Total systematic uncertainty		14.3%

Uncertainty on $|V_{tb}|$: 12.1%

→ di-leptonic topology is competitive !

Single top photoproduction

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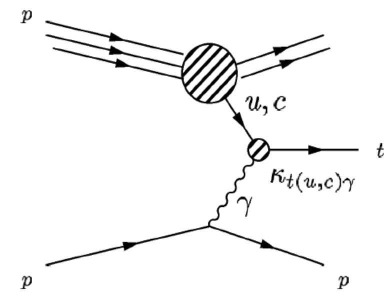
Anomalous top production

J. de Favereau

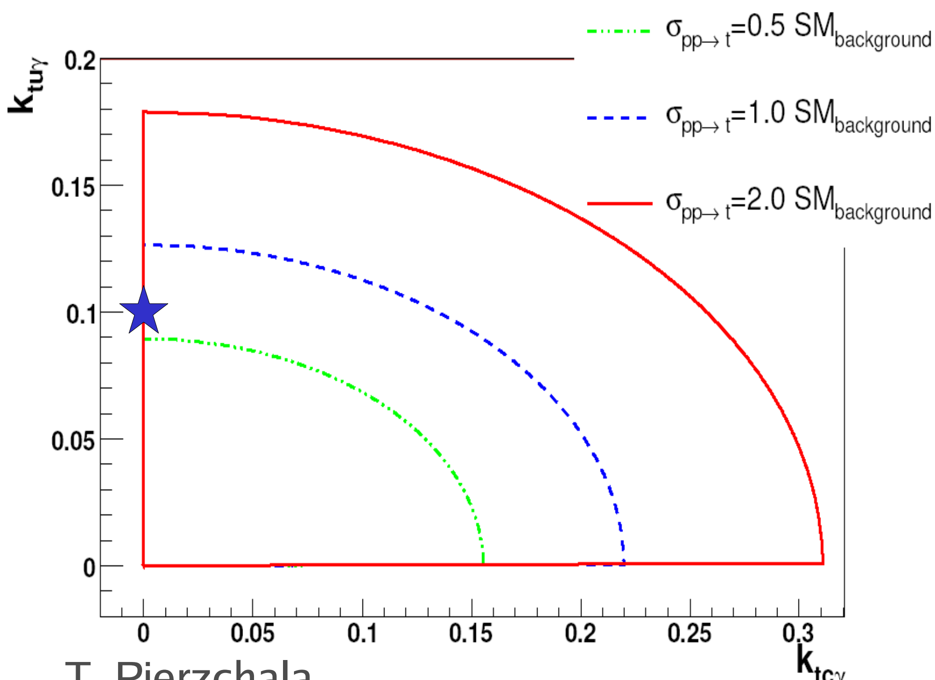


Effective Lagrangian for anomalous coupling :

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

- Current limit obtained by Zeus : $k_{tu\gamma} \approx 0.18$
- At HERA only u-quark relevant, at LHC also c-quark contribute

$$\Rightarrow \sigma_{pp\to t} = \alpha_u k_{tu\gamma}^2 + \alpha_c k_{tc\gamma}^2$$



T. Pierzchala

Results after acceptance cuts
($k_{tu\gamma}$ = 0.1, $k_{tc\gamma}$ = 0)

Topology	$lE^T_{mis}b$
σ t [fb]	3680
σ_{acc}	123.8
Irreducible backgrounds (Wj, Wc)	
σ_{acc} bkg	198.1

Limit on $k_{tu\gamma}$ could be significantly improved even at very low luminosity !

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Summary - outlook

- High energy γp interactions have significant cross section at the LHC

- γ p -> WHq' (100 fb^{-1}) events only sensitive for 2 topologies : lνbb and $jjl^{\pm}l^{\pm}$
  - Analysis are ongoing for those 2 cases, using analysis cuts.

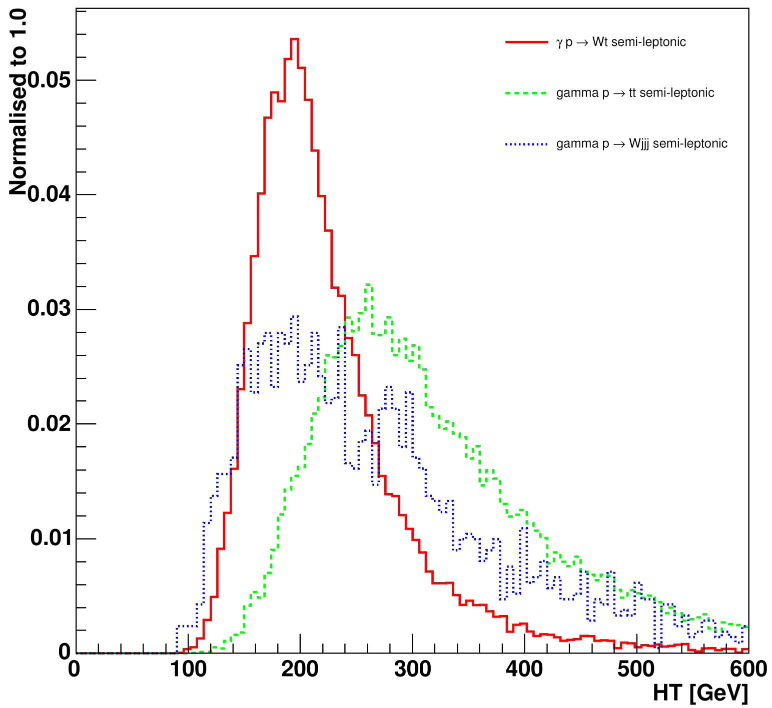
- Wt-channel (10 fb^{-1}) seems very promising
  - For the di-leptonic topology, $|V_{tb}|$ uncertainty is similar to the one obtained using pp->Wt
  - The sensitivity at reconstructed level has to be evaluated
  - For the semi-leptonic topology, one needs to tackle pp backgrounds

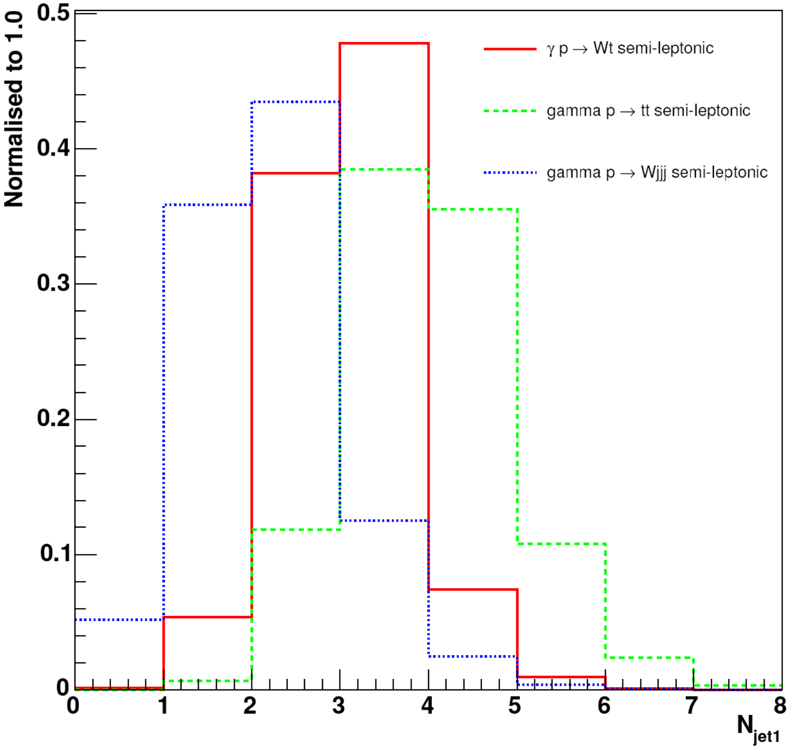
- Anomalous top (1 fb^{-1}) can also be probed using very low integrated luminosity

Louvain Photon group

J.de Favereau, V. Lemaître, Y. Liu, S. Ovyn, T. Pierzchala,
K. Piotrzkowski, X. Rouby, N.Schul, M. Vander Donckt

Backup slides





<u>Theoretical errors</u>

single top events : 6%

tt events : 5%

Wjjj events : 3%

Wbbj events : 17%

WWj : 6%

Semi-leptonic topology

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		γp backgrounds				pp backgrounds				
	Wt	$t\bar{t}(1\ell)$	$t\bar{t}(2\ell)$	W3j	Wbbj	tj.	$t\bar{t}(1\ell)$	$t\bar{t}(2\ell)$	Wjets	Wbbj
$E_{\gamma Hem}$	309	489	131	2301	47	536	1095	291	28508	3901
$N_{lept} = 1$	146.7	229	64.0	1111	22.9	261	474	148.8	13347	1661
$N_{jet} = 3$	37.6	95.4	13.6	66.1	1.58	14.0	188	35.9	851	55.5
HT sum	22.0	18.2	3.82	17.7	0.32	5.36	47.1	11.9	343.4	22.22
b-tagging	9.05	8	1.78	2.14	0.15	2.21	20.7	5.53	29.8	9.5
RecW	7.35	3.39	0.63	0.79	0.04	0.56	8.3	1.76	9.65	2.73
Expected for 10/fb	73	34	6	8	negl.	1	83	18	96	27

	sample	selected	$\Delta\sigma$	JES	ΔN_{b-tag}	ΔN_{Lum}	ΔN_{stat}
	S: Wt	73	4.38	3.72	3.65	3.65	8.5
γp proces	B: $t\bar{t}(1l)$	33	1.65	1.51	1.65	1.65	5.7
	B: $t\bar{t}(2l)$	6	0.3	0.37	0.3	0.3	2.4
	B: Wjjj	8	0.24	0	0.4	0.4	2.8
	B: Wbbj	0	0	0.03	0.	0	0
pp proces	B: $t\bar{t}(1l)$	83	4.15	1.98	4.15	4.15	9.1
	B: $t\bar{t}(2l)$	18	0.9	2.1	0.9	0.9	4.2
	B: W+jets	96	2.88	5.41	4.8	4.8	9.79
	B: tj	6	0.36	0.29	0.3	0.3	2.4
	B: Wbbj	27	4.59	1.65	1.35	1.35	5.2

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		γp backgrounds			pp backgrounds	
	Wt	$\mathbf{t\bar{t}(2\ell)}$	$\mathbf{WW(2\ell)}$	$\mathbf{WW(1\ell)}$	$\mathbf{t\bar{t}(2\ell)}$	$\mathbf{WW(2\ell)}$
$\mathbf{E_{\gamma Hem}}$	89.0	130.6	58.0	222.8	291	105.9
$\mathbf{N_{lept} = 2}$	21.3	31.6	14.7	0.01	57.9	22.3
$\mathbf{N_{jet} = 1}$	15.8	5.2	4.4	0.01	7.17	8.36
$\mathbf{b - tagged}$	6.37	2.1	0.13	0.00	2.71	0.27
$\mathbf{E^T_{miss}}$	5.84	1.97	0.12	0.00	2.55	0.23
Expected in 10 fb^{-1}	58	20	1	0	25	2

	sample	selected	$\Delta\sigma$	JES	ΔN_{b-tag}	ΔN_{Lum}	ΔN_{stat}
	S: Wt	58	3.48	0.5	2.9	2.9	7.6
γp	B: $t\bar{t}(2l)$	20	1	1.06	1	1	4.5
γp	B: WWj (2l)	1	0.06	0.01	0.05	0.05	1
pp	B: $t\bar{t}(2l)$	25	1.25	4.39	1.25	1.25	5
pp	B: WWj (2l)	2.26	0.14	0.27	0.11	0.11	1.5
	ΔN_b	-	1.6	5.73	2.41	1.55	-

$$\frac{\Delta|V_{tb}|}{|V_{tb}|} = \frac{1}{2}\frac{\Delta|V_{tb}|^2}{|V_{tb}|^2} = \frac{1}{2}\left[\frac{\Delta\sigma_{obs}}{\sigma} \oplus \frac{\Delta\sigma_{th}}{\sigma}\right]$$

Fast simulation of a LHC-like detector

Longitudal view of the detector