Search for top compositeness with the ATLAS detector

Romain Kukla
CEA Saclay, DSM/Irfu/SPP

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Journées de rencontre jeunes chercheurs

Outline

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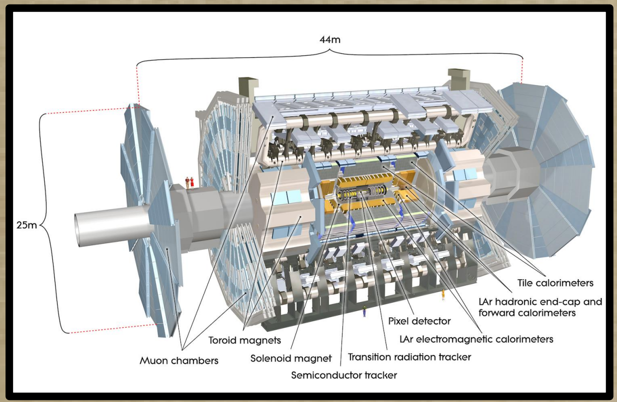
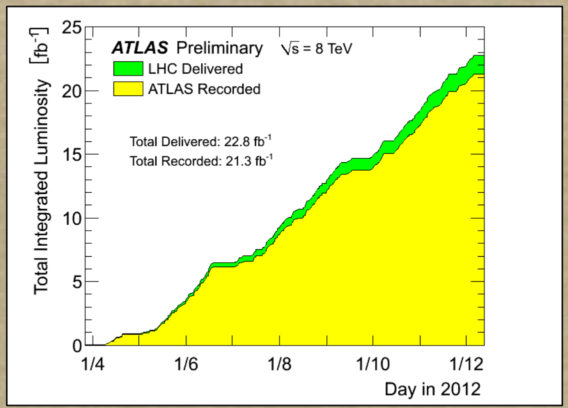
8 TeV

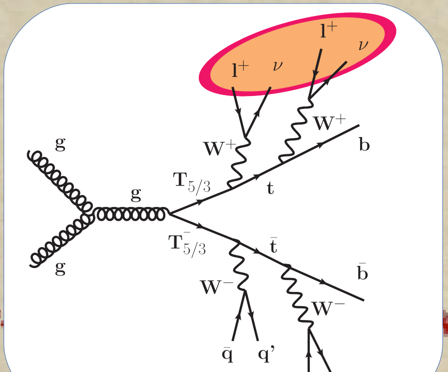
1 *already seen 5 times this week*

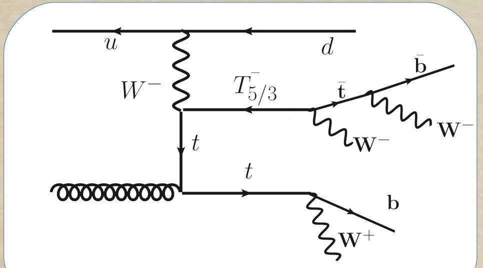
20.3 fb^{-1}





Outline


Pair production


Single production (+ sym)

VLQ

2 **$T_{5/3}$**

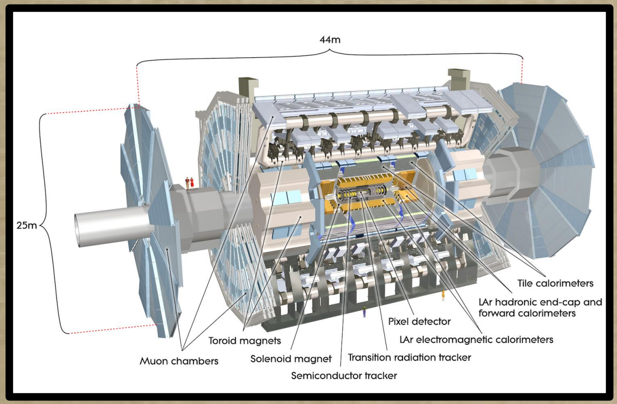
let's take our time

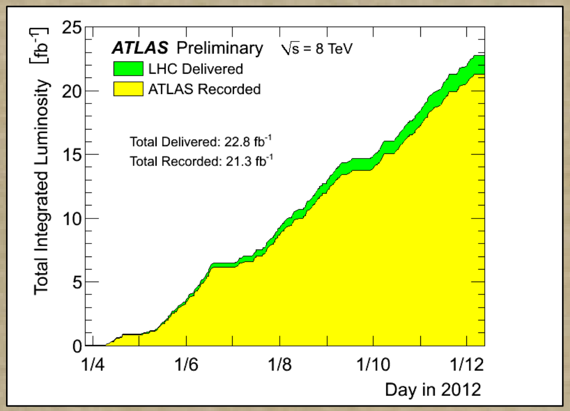
Search for top compositeness with the ATLAS detector

8 TeV

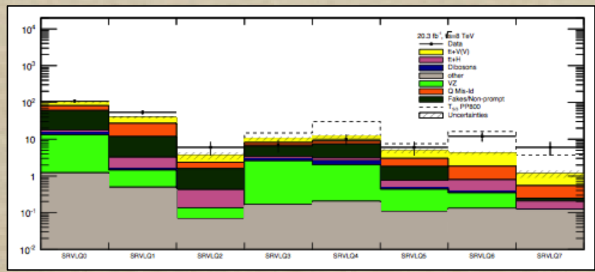
1

20.3 fb^{-1}

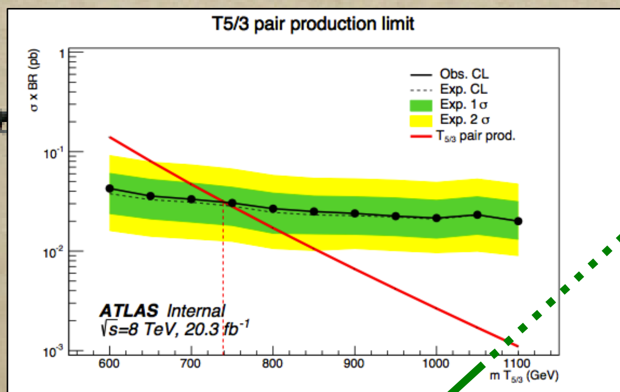




Outline



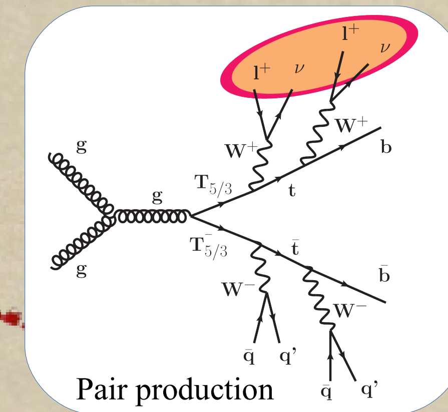
results ?

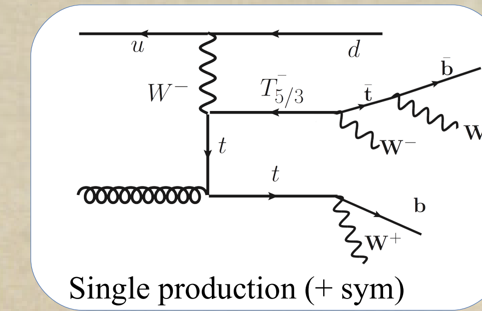


3

2LSS+3L

put everything together





VLQ

2 **$T_{5/3}$**

Search for top compositeness with the ATLAS detector

8 TeV

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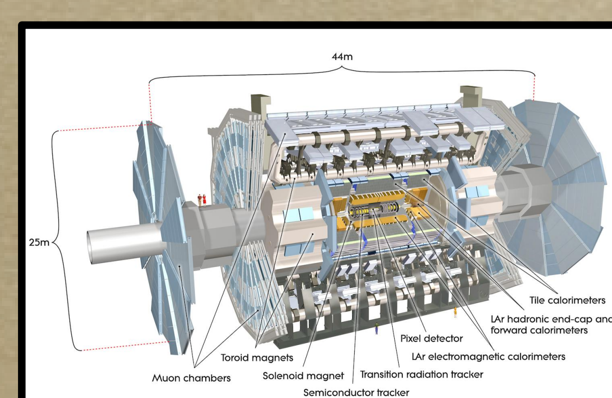
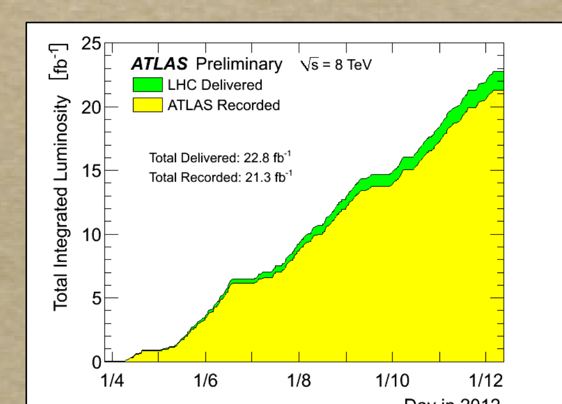
20.3 fb^{-1}

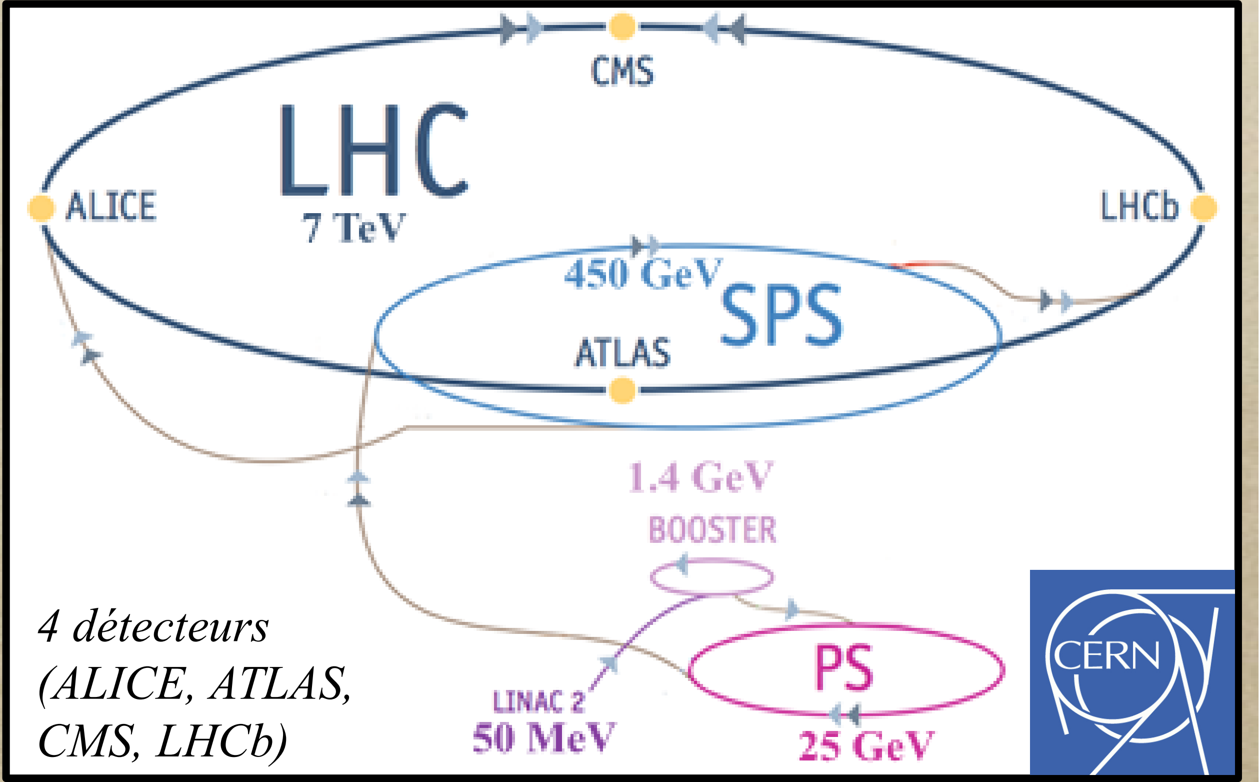




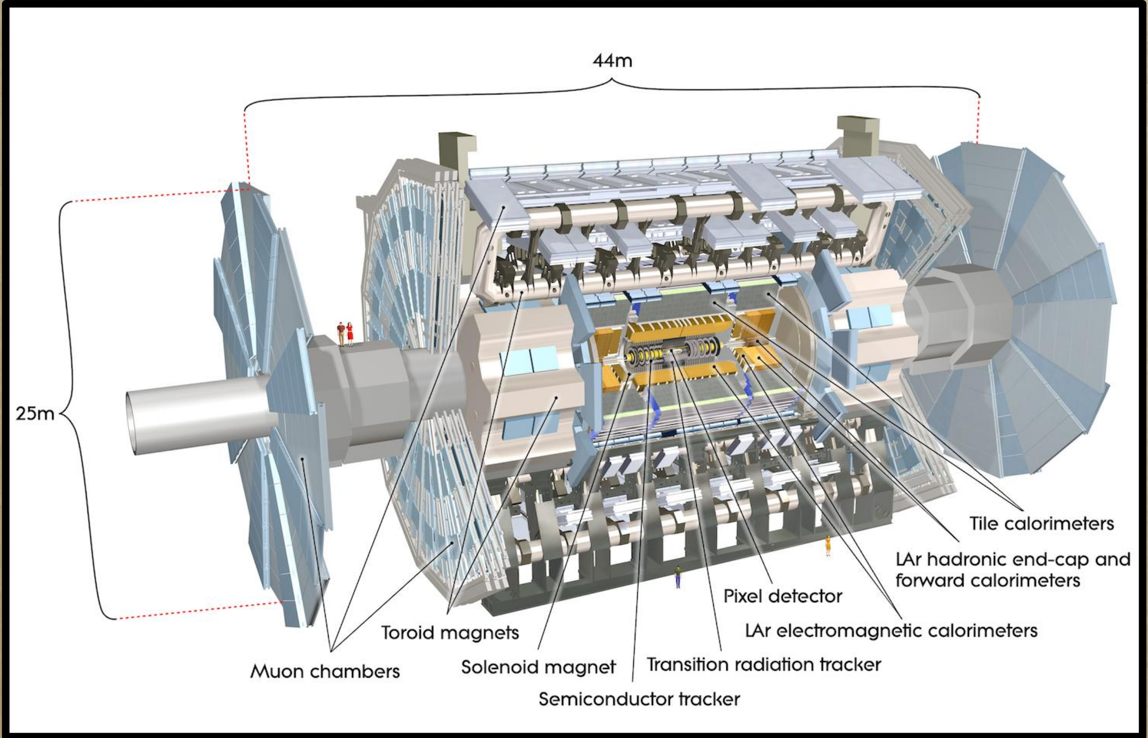
The Large Hadron Collider and ATLAS

1

- 27 km circular p-p collider
- -271.25 °C, 11 245 turns/s (each p)
- Beam energy :
  3.5 TeV (2009) – 4 TeV (2012)
  6.5 TeV (2015)



4 détecteurs (ALICE, ATLAS, CMS, LHCb)

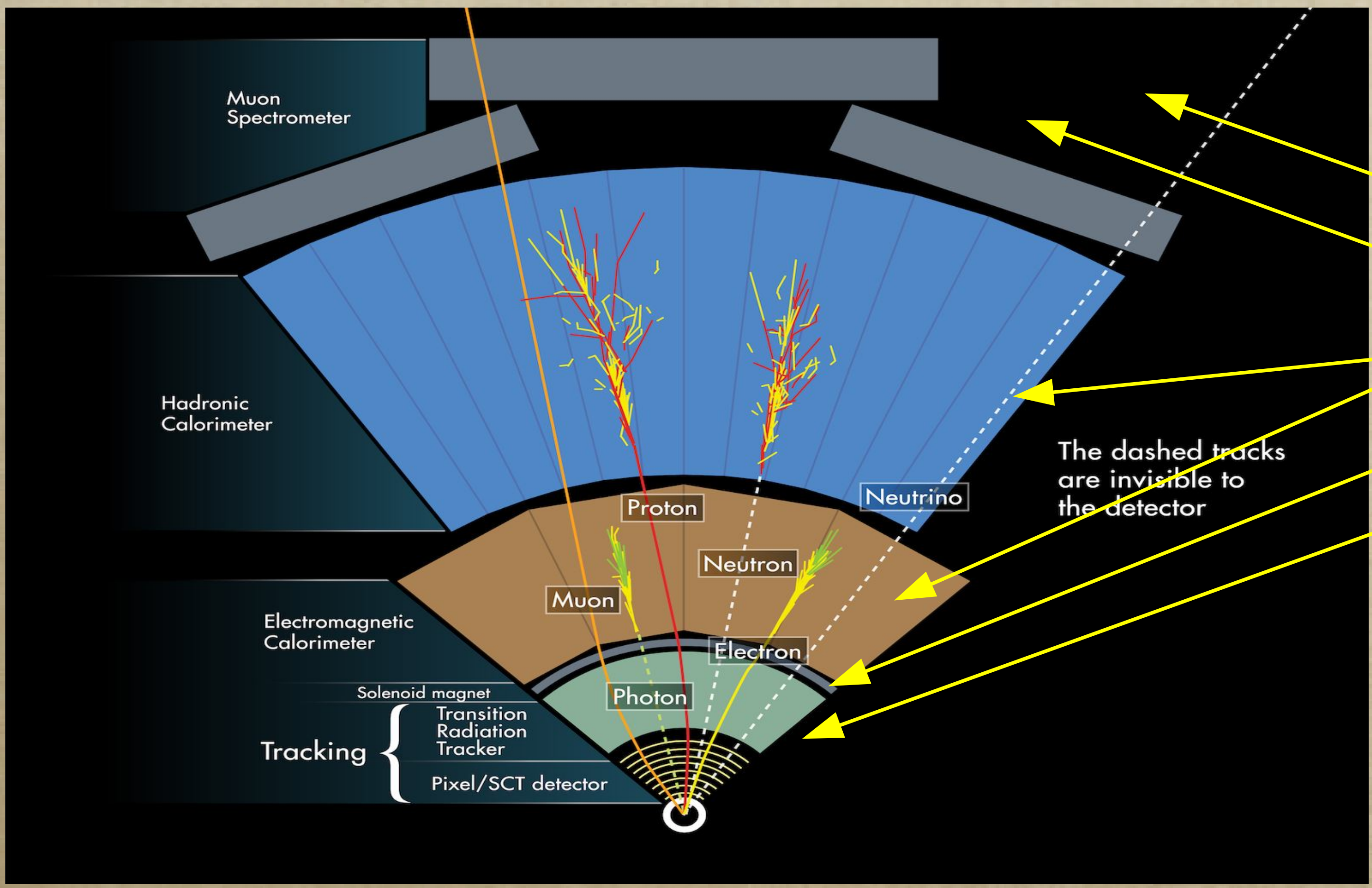


ATLAS sub-detectors designed to give different signatures for each type of particles

Goal : mesure the energy, momentum and direction of decay products to identify them

The Large Hadron Collider and ATLAS

1



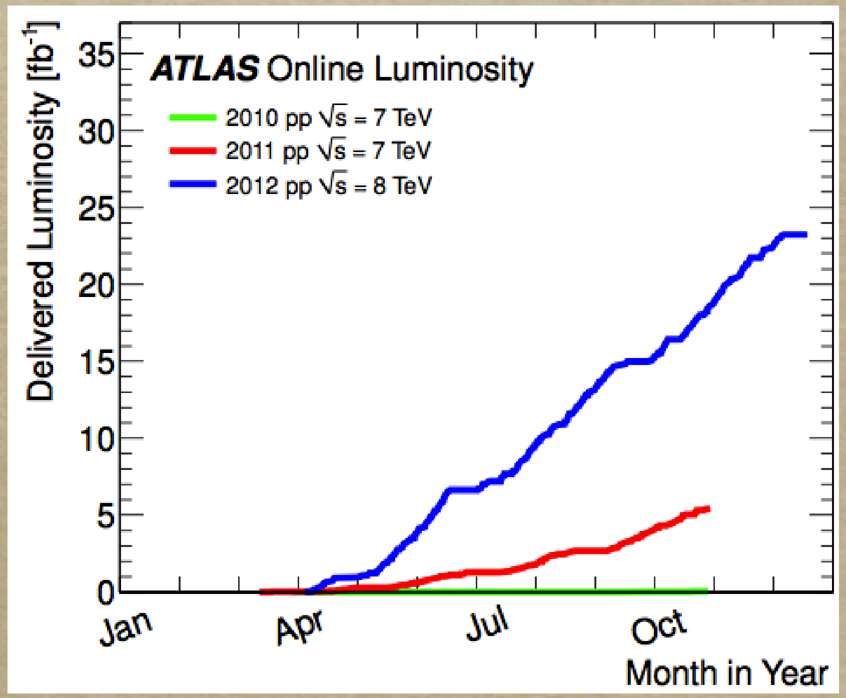
Subsystems :

- Toroïdal magnet
- Muons spectrometer
- Calorimeters (EM, hadronic)
- Solenoïde magnet
- Internal detector + tracker

Luminosity = amount of data collected

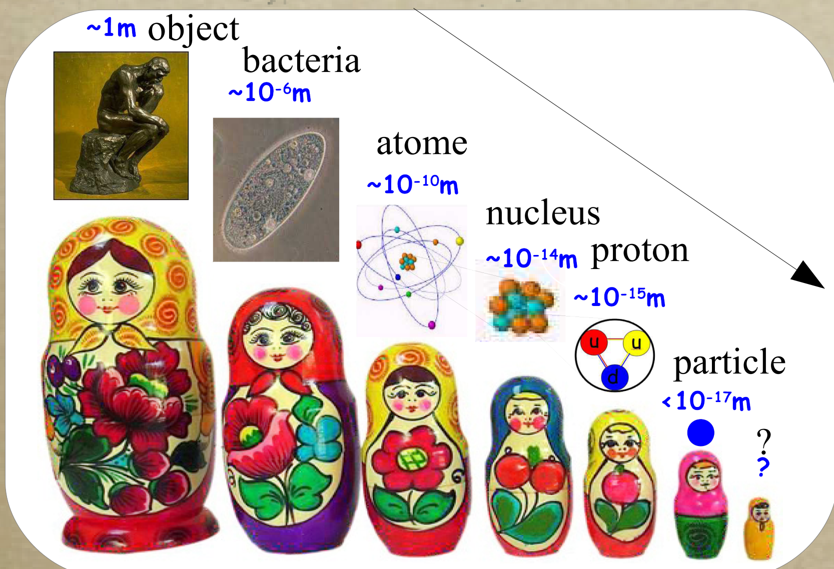
4.7 ifb at 7 TeV –VS– **20.3 ifb at 8 TeV**

(increasing energy/luminosity = research strategy to observe very rare processes)

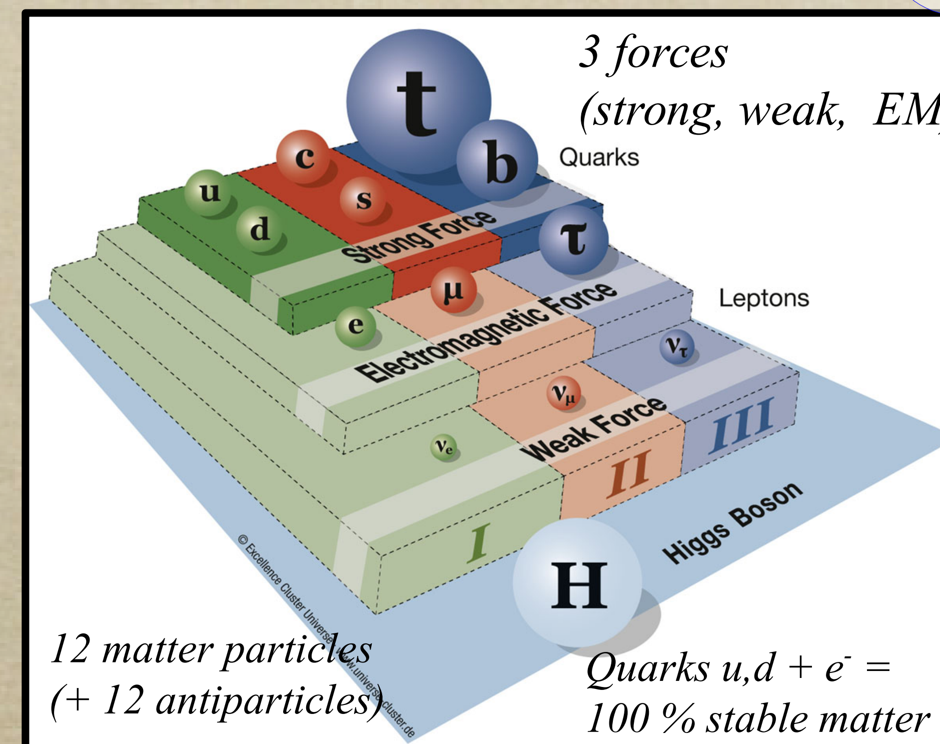


Standard Model and BSM : last status

1

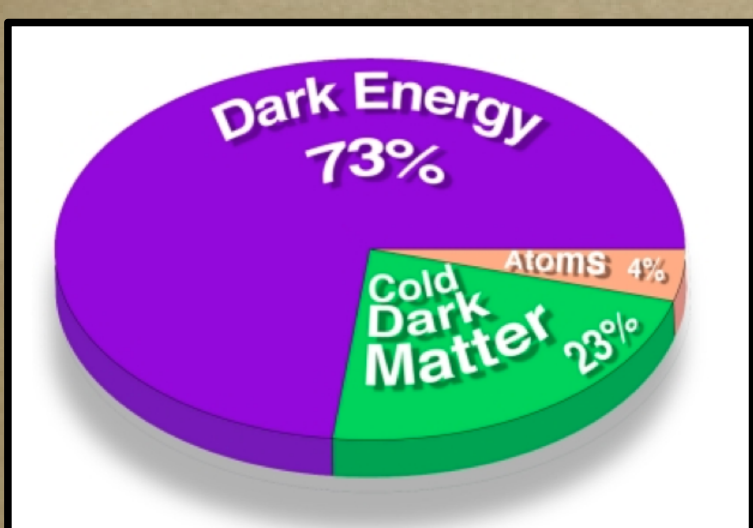


« periodic table » of elementary constituents (matter and interactions)



Latest discoveries : 1995 top quarks (Fermilab), 2012 Higgs boson (CERN)

Different BSM approaches proposed to adress some open questions : weakly coupled (SUSY) or strongly (composite)



Dark matter massive candidates

Include gravitation

What about matter/antimatter asymmetry ?

The top quark as a probe to BSM

2

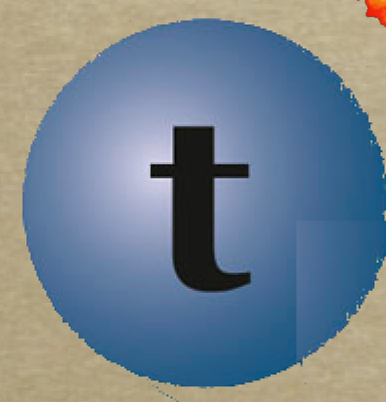
Why probing the top quark ?

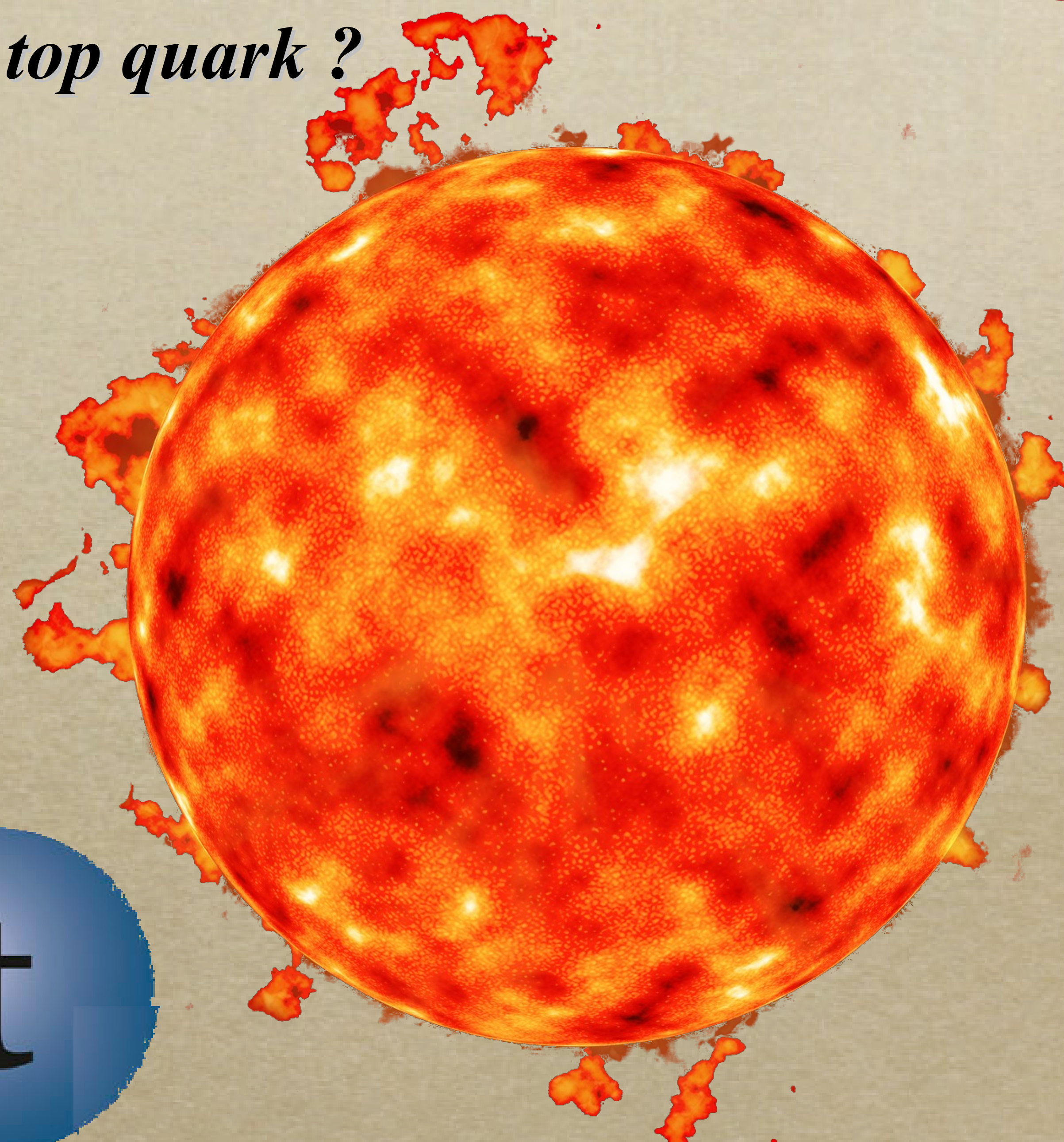
Earth mass = **6.10^{24} kg**

Electron = **$5{,}11.10^{2}$ keV**

Jupiter mass = **2.10^{27} kg**

Strange quark = **$9{,}5.10^{4}$ keV**





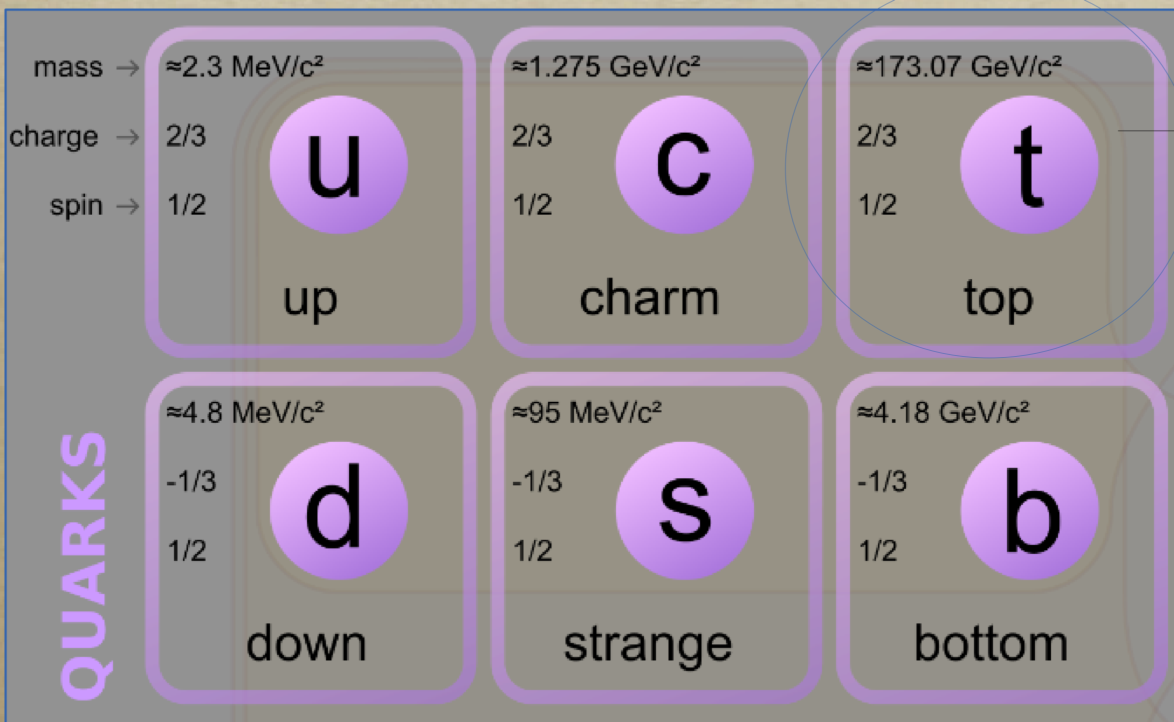
Sun mass = **2.10^{30} kg**

Top quark = **$1{,}73.10^{8}$ keV**

Very hard not to be intrigued

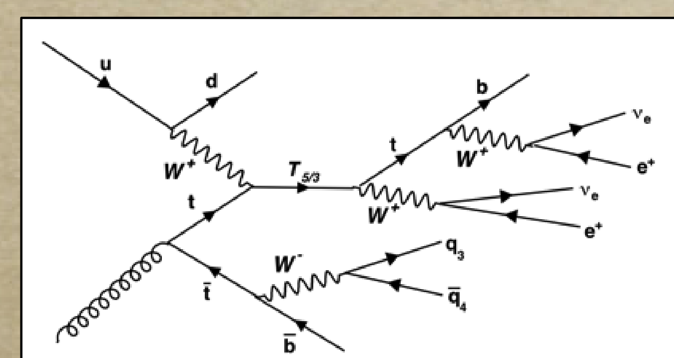
The top quark as a probe to BSM

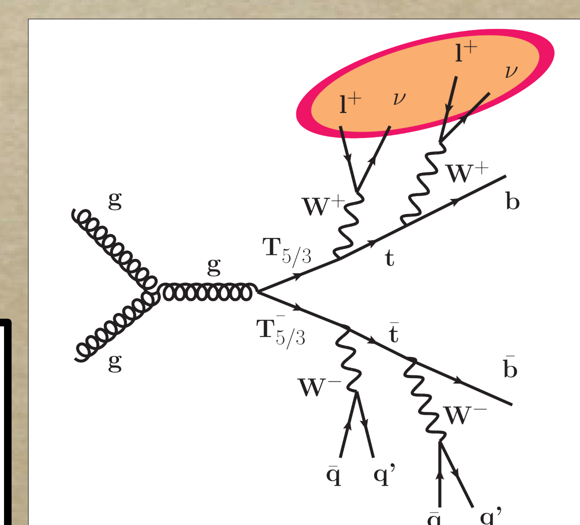
2



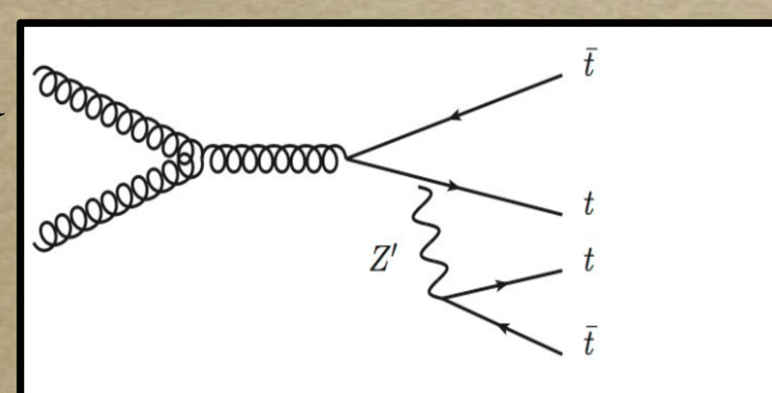
► ***Why the top is very peculiar ?***

- heaviest particle observed
- priviledged coupling to the Higgs and to any BSM involving it
- LHC = a « top factory »
- involved in the Higgs mass fine-tuning





The exotic models I deal with have **final states involving tops** (ttWW-ttW-tttt).
→ top pairs (ttbar) is the main background
250pb (ttbar) vs 21fb (VLQ) à 8 TeV

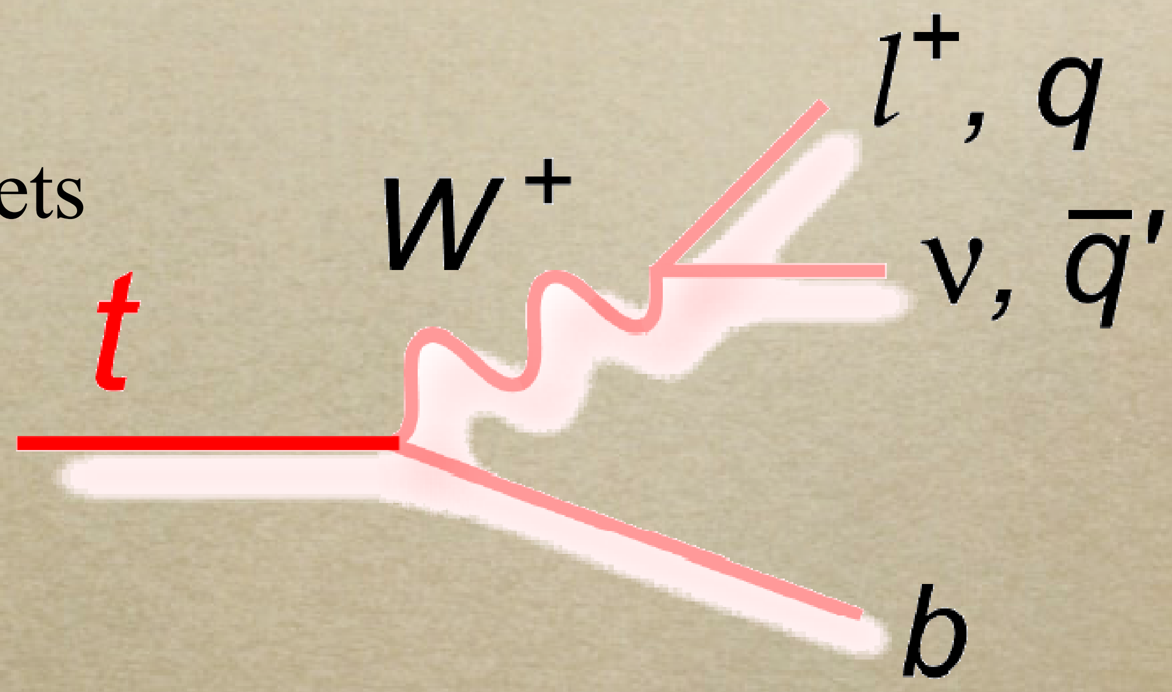


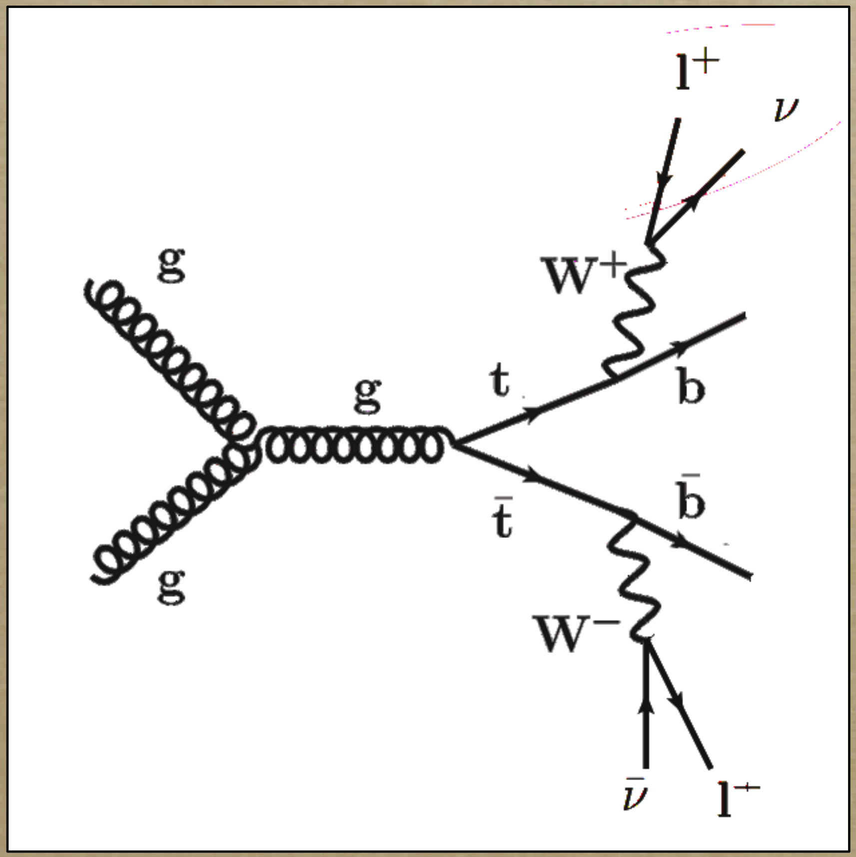
Same-sign dilepton channel

2

Reminder : tops decay in :

- **b quark** → will give b-jets
- **W boson** → can give lepton+MET or jets



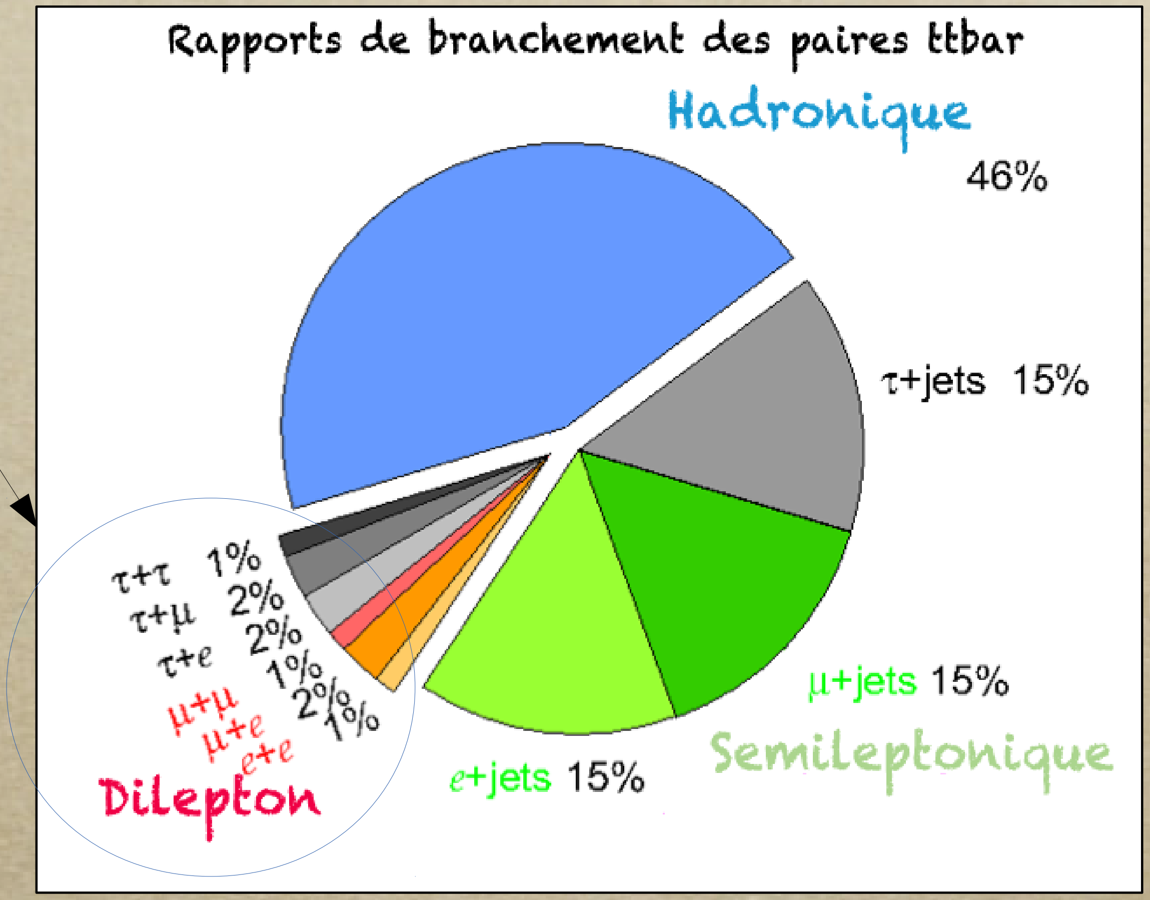


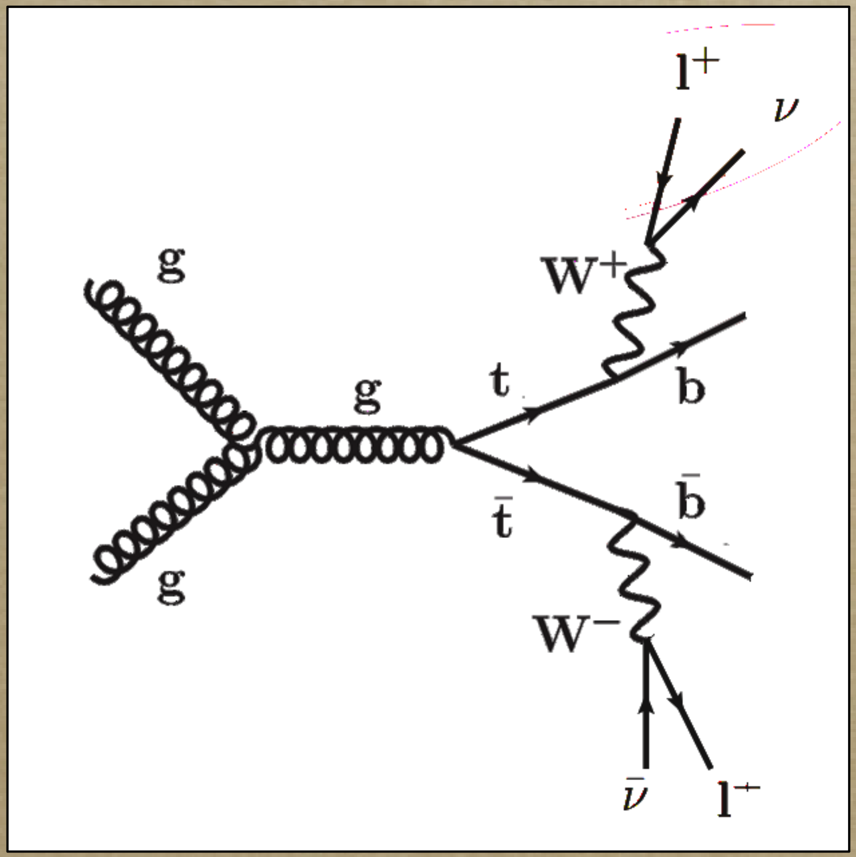
(5 millions de paires de top produites en 2012)

Same-sign dilepton channel

Will consider **dileptonic** (+ trileptonic) channels

GOAL : suppress most of the top pairs produced at LHC



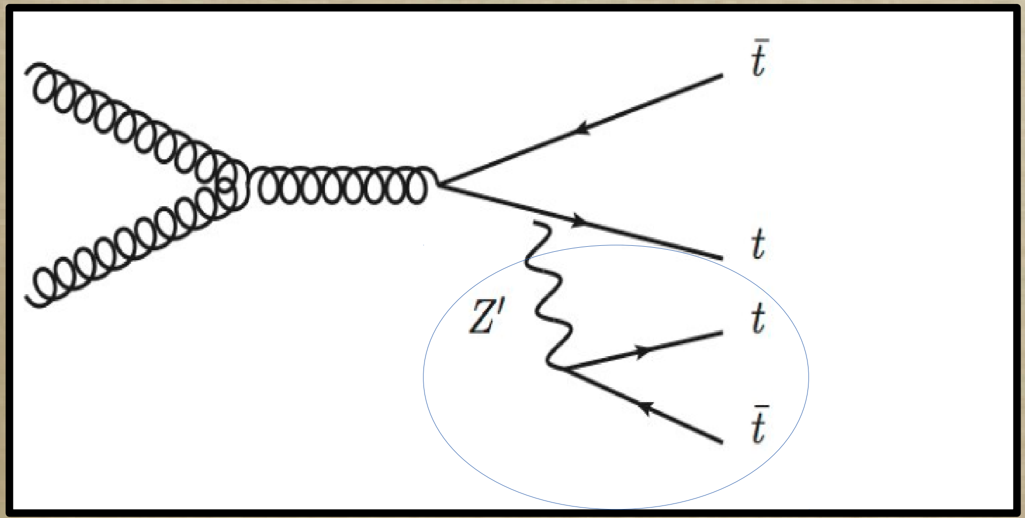


VLQ models and 4 tops can give same-sign lepton pairs : huge opportunity to kill ttbar
→ **2 same-sign leptons is the golden channel (3 leptons also)**

Beyond the SM 4tops @ 14 TeV

2

4tops = ~14 events in 2012 data : very (very very ..) rare process at 8 TeV



Generic model : let's add a new physics top-philic resonance (Z')

Z' mass ↔ new particles energy scale

Higher cross-section compared to SM 4tops. Will estimate the sensitivity we can have at 13/14 TeV.

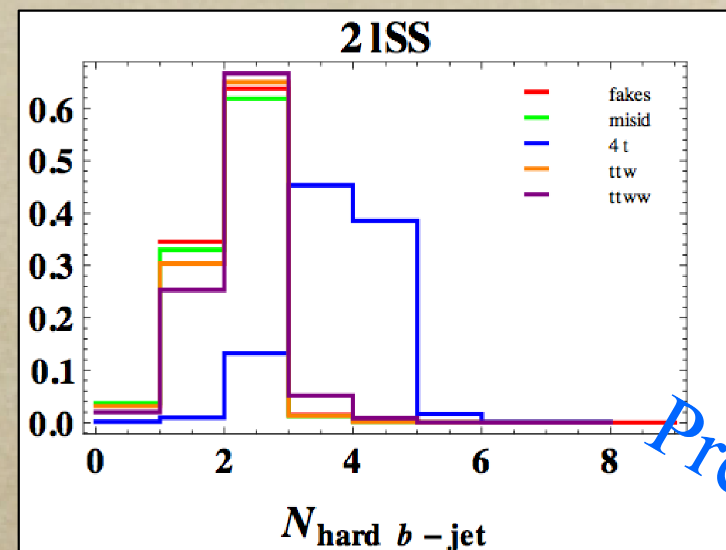
→ **generator level study = only Monte-Carlo, NO ATLAS data**

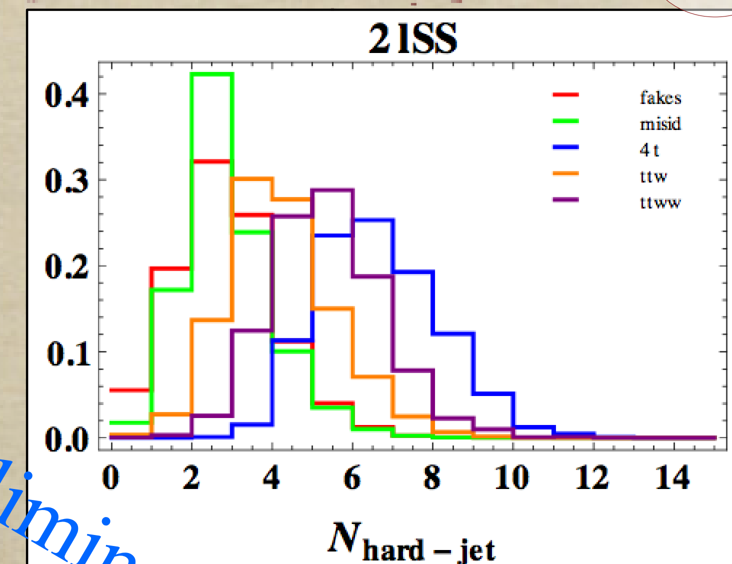
SM backgrounds : MadGraph + Pythia ; instrumental : estimated from ATLAS public notes

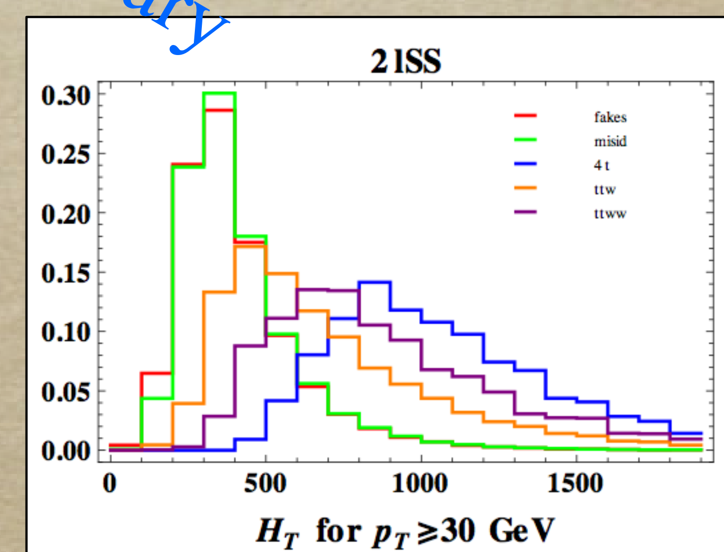
Beyond the SM 4tops @ 14 TeV

2

« Cut & count » basic analysis using optimized HT, n(jets), n(bjets), MET cuts for 4 channels : 1L, 2L OS, 2L SS and 3L







	init	SR1	SR2	SR3	SR4	SR5	SR6	SR7	SR8	SR9
Signal	71.2	44.8	44.2	42.5	36.7	27.2	23.4	44.2	32.5	27.8
$t\bar{t}$ **mis-Id**	8.5	0.4	0.3	0.2	0.2	0.1	0.1	0.3	0.2	0.1
SM Irr	280.5	2.	1.8	1.6	1.1	0.7	0.5	1.5	1.	0.7
Fakes	769.3	295.1	206.2	153.2	83.2	49.2	34.	128.6	71.9	51.1
Tot. back.	1058.3	297.5	208.2	155.	84.4	50.	34.6	130.4	73.	52.
Significance	-	2.6	3.1	3.4	4.	3.9	4.	3.9	3.8	3.9

	σ	N_S	N_B	L_{deco}
-	4.	36.7	84.4	15.7

ex : Yields + significance

Z' (1 TeV) resonance should be observable using Run 2 2015 ATLAS data (~4 fb^{-1}) at 13 TeV mainly in 2LSS channel
SM 4tops would need a bit more than 100 fb^{-1} of 14 TeV data

Paper in preparation, stay tuned

BSM top partial compositeness and (VLQ) top exotic partners

2

'Partial compositeness' : 2 sites study model

Exotic sector

$$\begin{bmatrix} T & T_{5/3} \\ B & T_{2/3} \end{bmatrix} \quad \begin{bmatrix} \phi_0^\dagger & \phi^+ \\ -\phi^- & \phi_0 \end{bmatrix} \quad \tilde{T}$$

Mass mixing terms between the 2 sectors

$$\mathcal{L}_{yuk} = Y_* sin\varphi_L sin\varphi_R(\bar{t_L}\phi_0^\dagger t_R - \bar{b_L}\phi^- t_R) + Y_* cos\varphi_L sin\varphi_R(\tilde{T}\phi_0^\dagger t_R - \bar{B}\phi^- t_R)$$
$$+ Y_* sin\varphi_L cos\varphi_R(\bar{t_L}\phi_0^\dagger \tilde{T} - \bar{b_L}\phi^- \tilde{T}) + Y_* sin\varphi_R(\bar{T_{5/3}}\phi^+ t_R + \bar{T_{2/3}}\phi_0 t_R) + F.L.$$

Higgs doublet ∈ composite sector

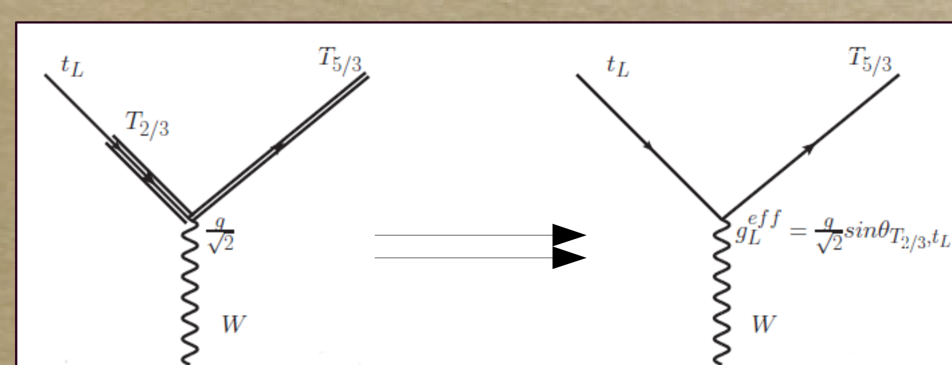
→ *Yukawa interaction via composite states*

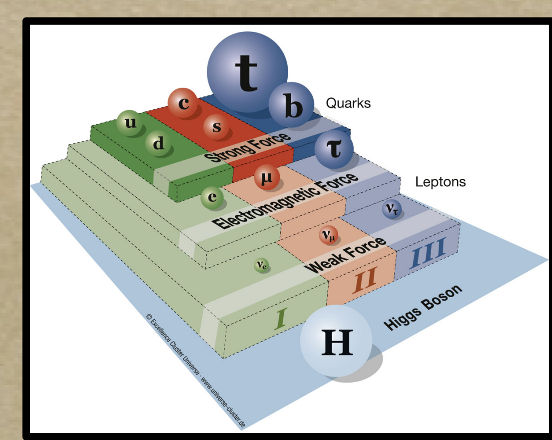
$$\hat{t_L} = cos\phi_L.t_L + sin\phi_L.T_L$$
$$\hat{T_L} = -sin\phi_L.t_L + cos\phi_L.T_L$$

Massive *SM* *Composite*

elementary SM sector

Massive states = mixing between elementary SM and composite states





Search of such heavy quarks @ 8 TeV

3

Search for anomalous production of trilepton and same-sign dilepton events associated with *b*-jets in 20.3 fb^{-1} of *pp* collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector

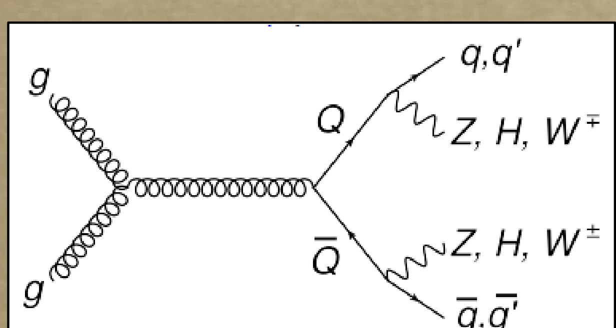
D. Boumediene[3], E. Busato[3], D. Calvet[3], S. Calvet[3], E. Dubreuil[3], S. Grancagnolo[2], R. Kukla[4], H. Lacker[2], X. Lei[1], R. Nayyar[1], F. O'Grady[1], D. Paredes[3], D. Simon[3], D. Sperlich[2], L. Valéry[3], E. Varnes[1]

[1]*Department of Physics, University of Arizona, USA*
[2]*Institute of Physics, Humboldt University of Berlin, Germany*
[3]*LPC Clermont-Ferrand, CNRS/IN2P3, Université Blaise Pascal, France*
[4]*IRFU, CEA, Saclay, France*

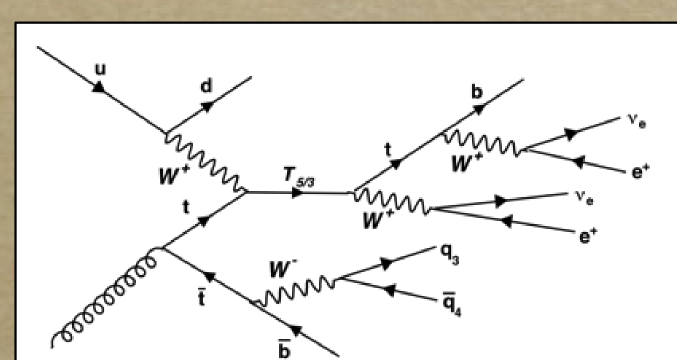
cf : CERN-PH-EP-2015-060, arxiv:1504.04605 (paper)

4 labs involved
using 20.3 fb^{-1} at 8 TeV
→ internal note + JHEP paper

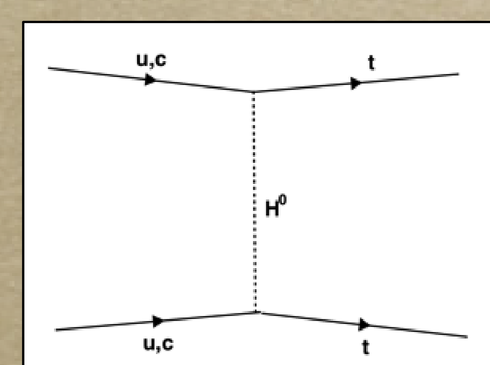
Search for exotic models sharing a similar signature



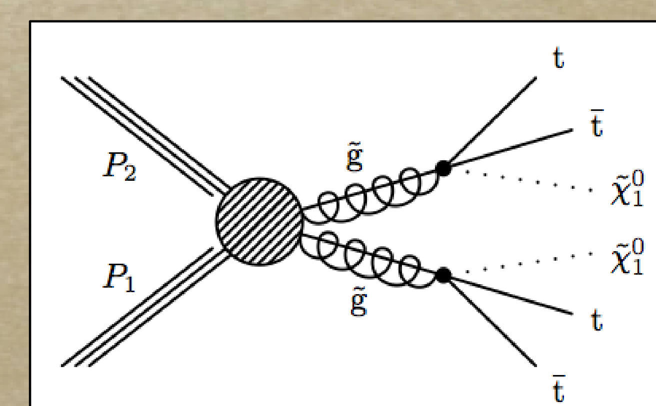
VLQ (pair production)



VLQ single production (here T5/3)



FCNC (tt)



SUSY

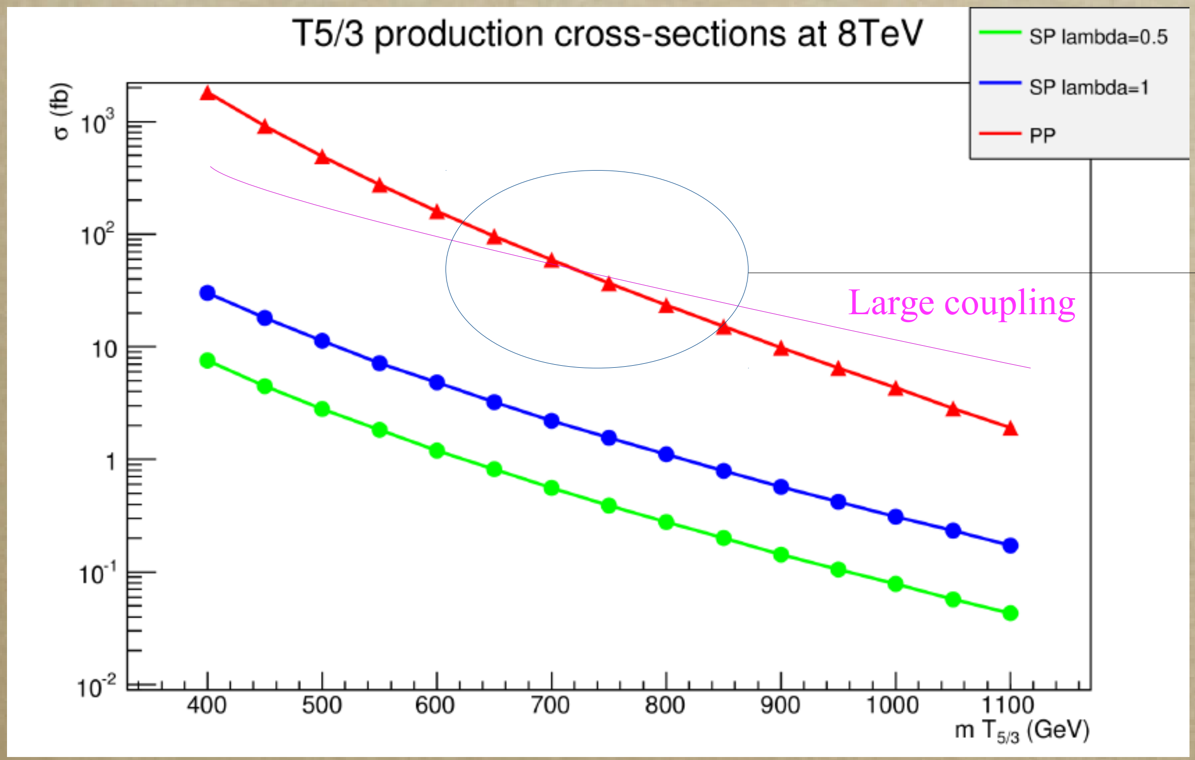
etc ...

Search for VLQ in 2LSS+3L @ 8 TeV

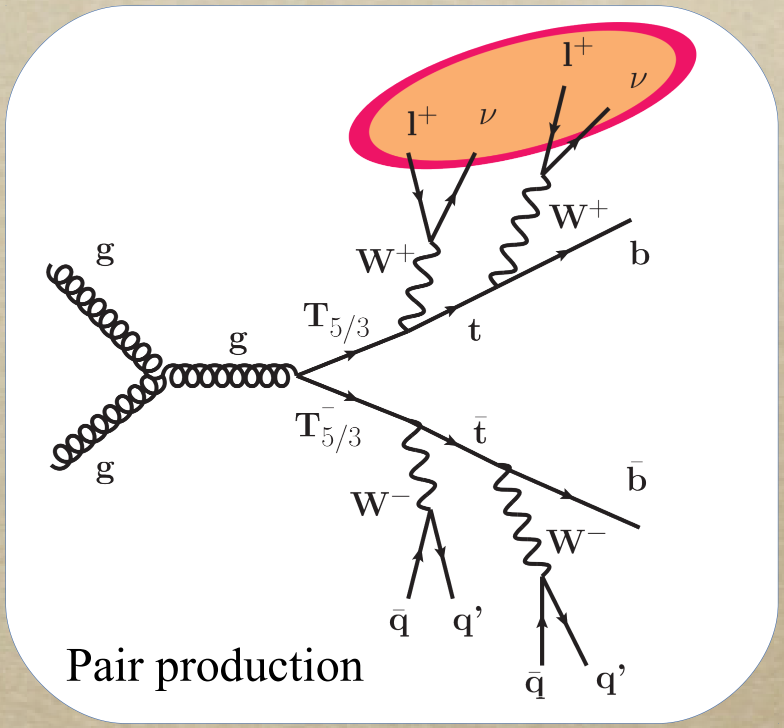
top compositeness partner $T_{5/3}$

3

Process occurs more often than (SM/BSM) 4tops because it requires ONLY 2 tops : $T_{5/3}$ exotic top partner with charge +5/3

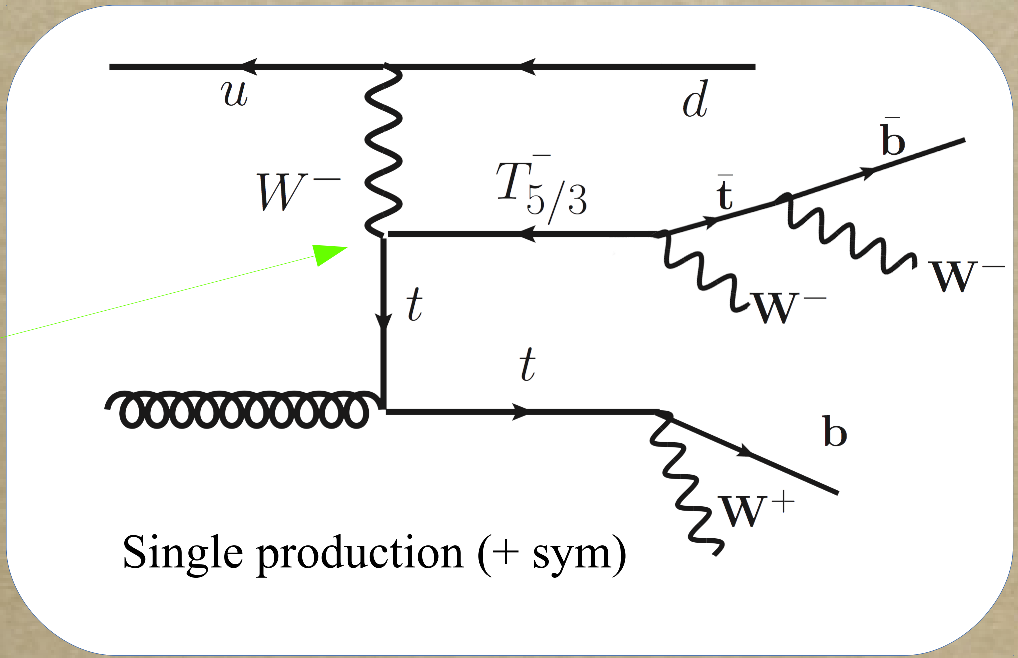


single prod. can be as important as pair prod !



2 production modes :

- pair : dominant, depends only on mass
- single: model dependant (coupling)

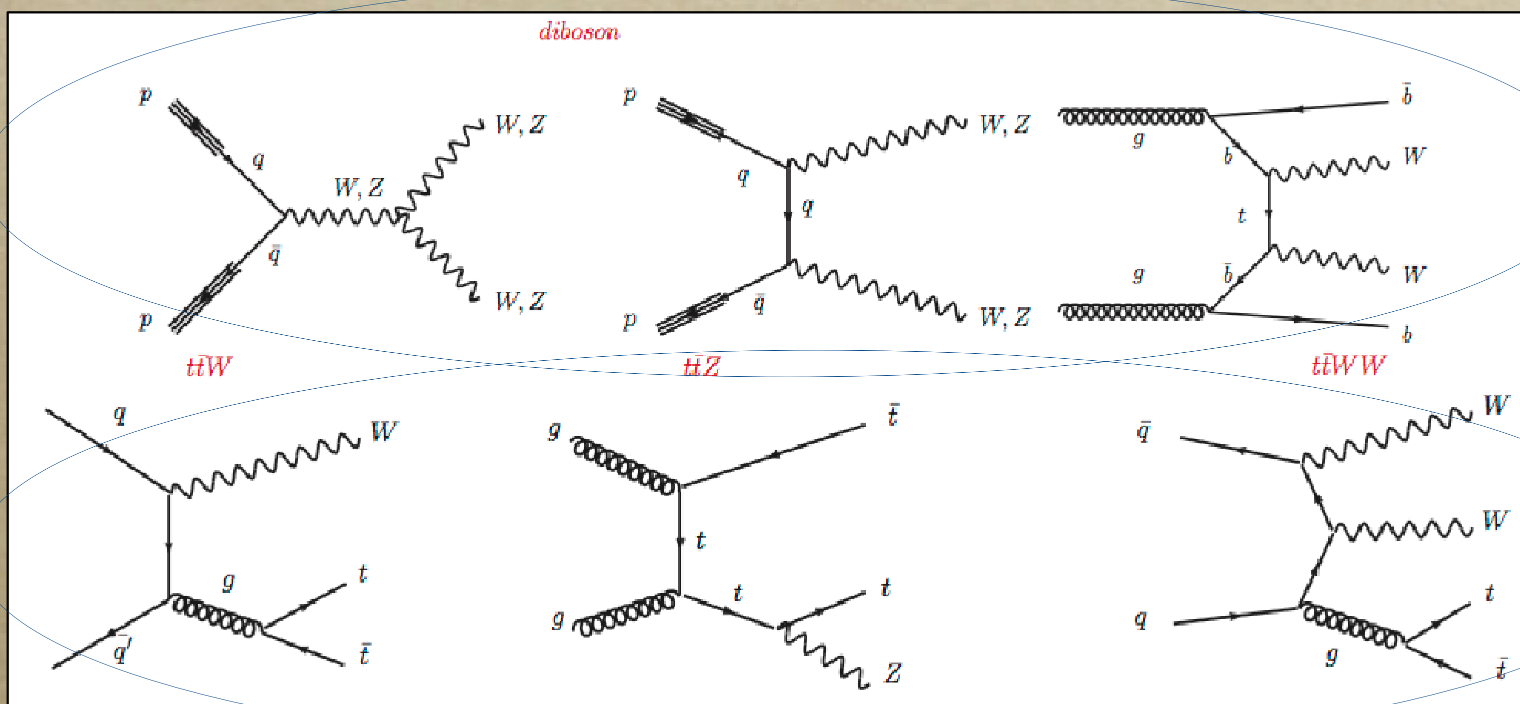


Search for VLQ in 2LSS+3L @ 8 TeV

Analysis backgrounds

3

SM processes with true 2SS leptons in the (partonic) final state



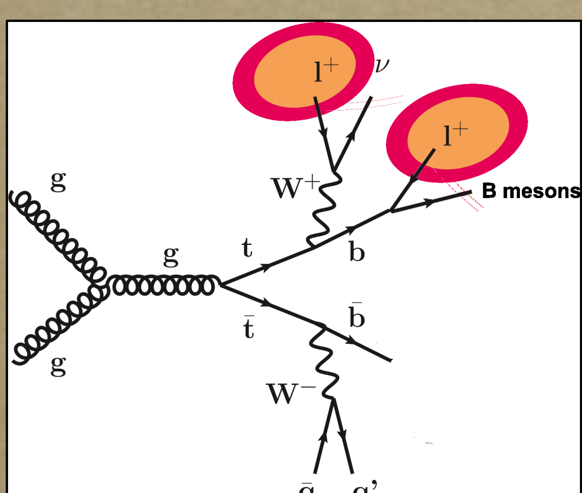
Dibosons ~ 10 pb

ttV(V) ~ 400 fb

+ others :
VVV ~ 10 fb
VH ~ 100 fb
ttH ~ 30 fb
tV ~ 10 fb

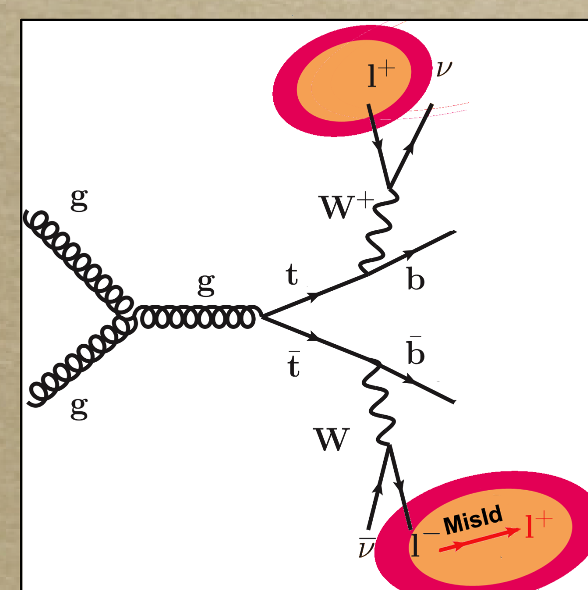
MC simulations

Instrumental backgrounds



Fakes/non-prompt (from a B decay or jet identified as lepton)

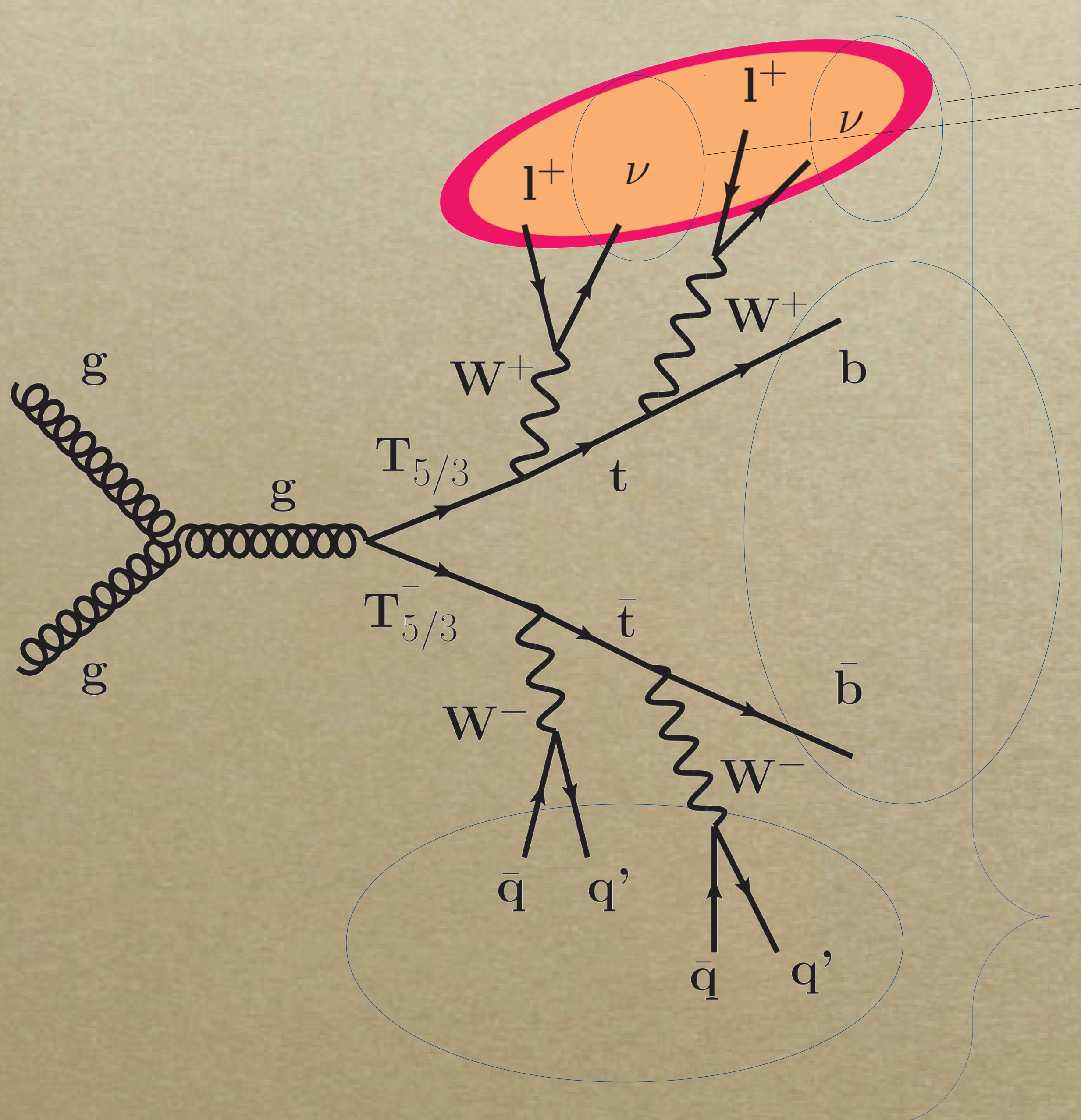
Charge misidentification for electrons (or trident)



Data extracted

Search for VLQ in 2LSS+3L @ 8 TeV
Relevant observables

3



MET

Nb b-jets

HT sum of |pT| of leptons and jets

Nb jets

+ isolation / overlap criteria :

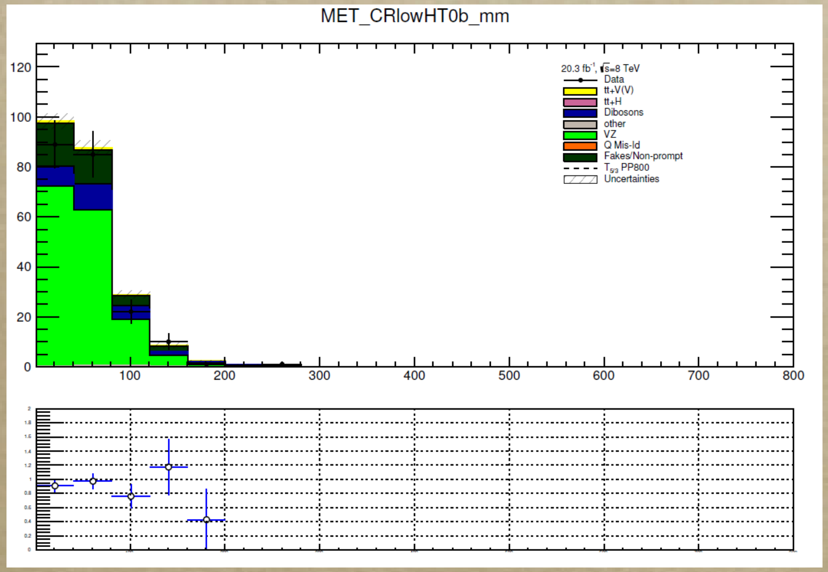
ΔR(lep,jet)
ΔR(e,mu)

Search for VLQ in 2LSS+3L @ 8 TeV

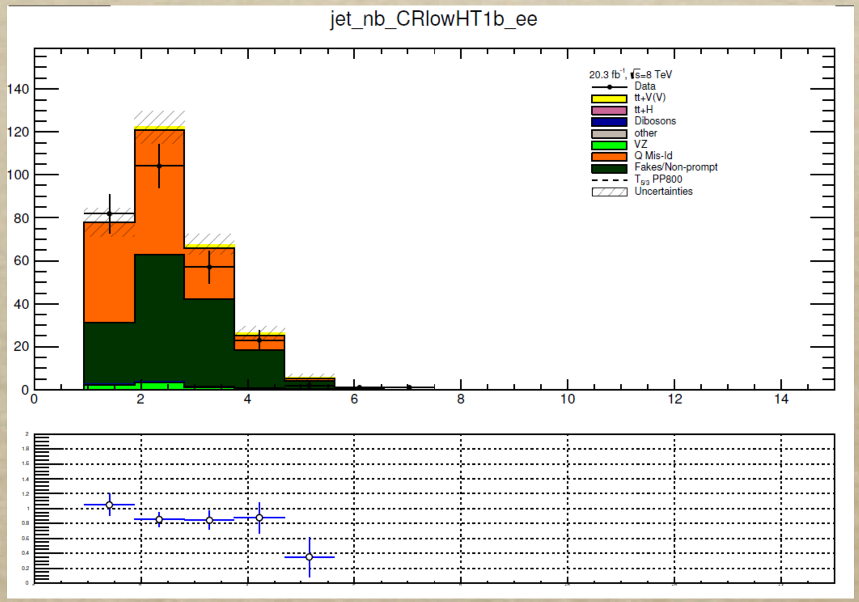
Control & signal regions

3

Multiple steps for **background validation** in lowHT control regions



1) rough BKG validation in simple Control Regions
2) BKG composition in simple Signal Regions
3) Validation of BKG in precise CR where BKGcomposition = in SR
4) Look data & BKG at precise optimized SR regions



Definition			Name	
$e^{\pm}e^{\pm} + e^{\pm}\mu^{\pm} + \mu^{\pm}\mu^{\pm} + eee + ee\mu + e\mu\mu + \mu\mu\mu$, $N_j \geq 2$				
$400 < H_{\mathrm{T}} < 700$ GeV	$N_b = 1$	$E_{\mathrm{T}}^{\mathrm{miss}} > 40$ GeV	SRVLQ0	
	$N_b = 2$		SRVLQ1	SR4t0
	$N_b \geq 3$		SRVLQ2	SR4t1
$H_{\mathrm{T}} \geq 700$ GeV	$N_b = 1$	$40 < E_{\mathrm{T}}^{\mathrm{miss}} < 100$ GeV	SRVLQ3	
		$E_{\mathrm{T}}^{\mathrm{miss}} \geq 100$ GeV	SRVLQ4	
	$N_b = 2$	$40 < E_{\mathrm{T}}^{\mathrm{miss}} < 100$ GeV	SRVLQ5	SR4t2
		$E_{\mathrm{T}}^{\mathrm{miss}} \geq 100$ GeV	SRVLQ6	SR4t3
	$N_b \geq 3$	$E_{\mathrm{T}}^{\mathrm{miss}} > 40$ GeV	SRVLQ7	SR4t4

8 orthogonal signal regions defined for multiple signals

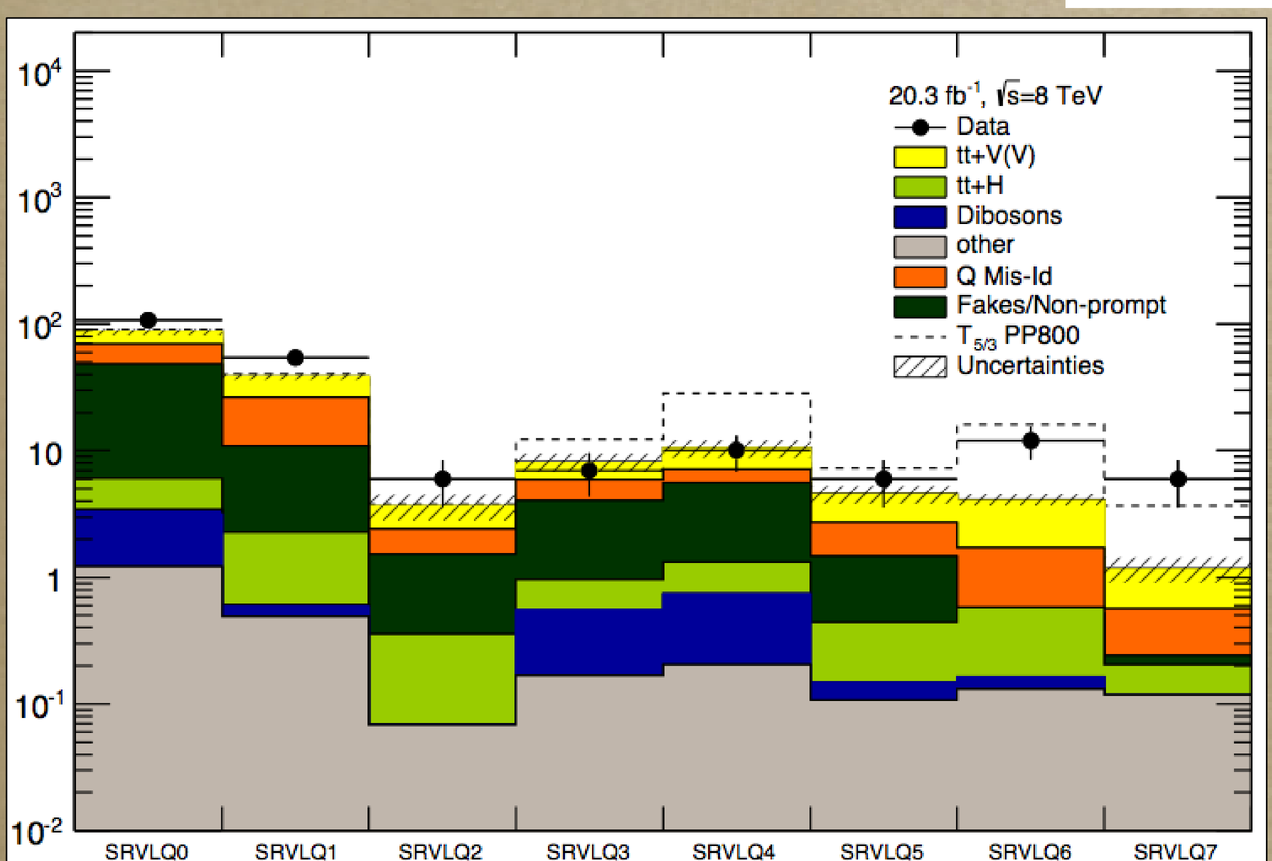
Search for VLQ in 2LSS+3L @ 8 TeV

Results

3

For each SR, here are the expected yields for each type of background

	SRVLQ0	SRVLQ1	SRVLQ2	SRVLQ3	SRVLQ4	SRVLQ5	SRVLQ6	SRVLQ7
$t\bar{t}t\bar{t}$	0.02±0	0.04±0	0.03±0	0.01±0	0.03±0	0.02±0	0.05±0	0.09±0
VZ	11.93±0.64	0.96±0.19	0.06±0.04	2.39±0.31	1.81±0.23	0.32±0.14	0.21±0.08	0±0
WW	1.89±0.09	0.09±0.02	0±0	0.38±0.04	0.53±0.05	0.04±0.01	0.03±0.01	0±0
ttV	17.18±0.33	11.83±0.25	1.24±0.08	2.15±0.1	3.26±0.13	1.79±0.08	2.3±0.1	0.58±0.05
$t\bar{t}WW$	0.26±0	0.17±0	0.01±0	0.06±0	0.1±0	0.03±0	0.08±0	0.02±0
$t\bar{t}H$	2.61±0.1	1.66±0.07	0.28±0.03	0.41±0.04	0.57±0.05	0.29±0.03	0.41±0.03	0.08±0.01
VVV	0.03±0	0±0	0±0	0±0	0±0	0±0	0±0	0±0
VH	0.3±0.14	0.01±0.01	0±0	0±0	0±0	0±0	0±0	0±0
tX	1.03±0.03	0.39±0.01	0.03±0	0.13±0.01	0.14±0.01	0.07±0	0.06±0	0.01±0
$Fake$	42.12±5.35	8.6±2.34	1.16±0.82	3.08±1.29	4.23±1.59	1.02±0.97	-0.05±1.02	0.03±0.83
$Qmisid$	20.83±0.71	15.09±0.55	0.73±0.11	1.72±0.21	1.45±0.16	1.17±0.16	1.08±0.13	0.29±0.09
Total	98.26±5.45	38.89±2.42	3.58±0.83	10.37±1.35	12.17±1.62	4.79±0.99	4.2±1.03	1.14±0.83
Données	107	54	6	7	10	6	12	6

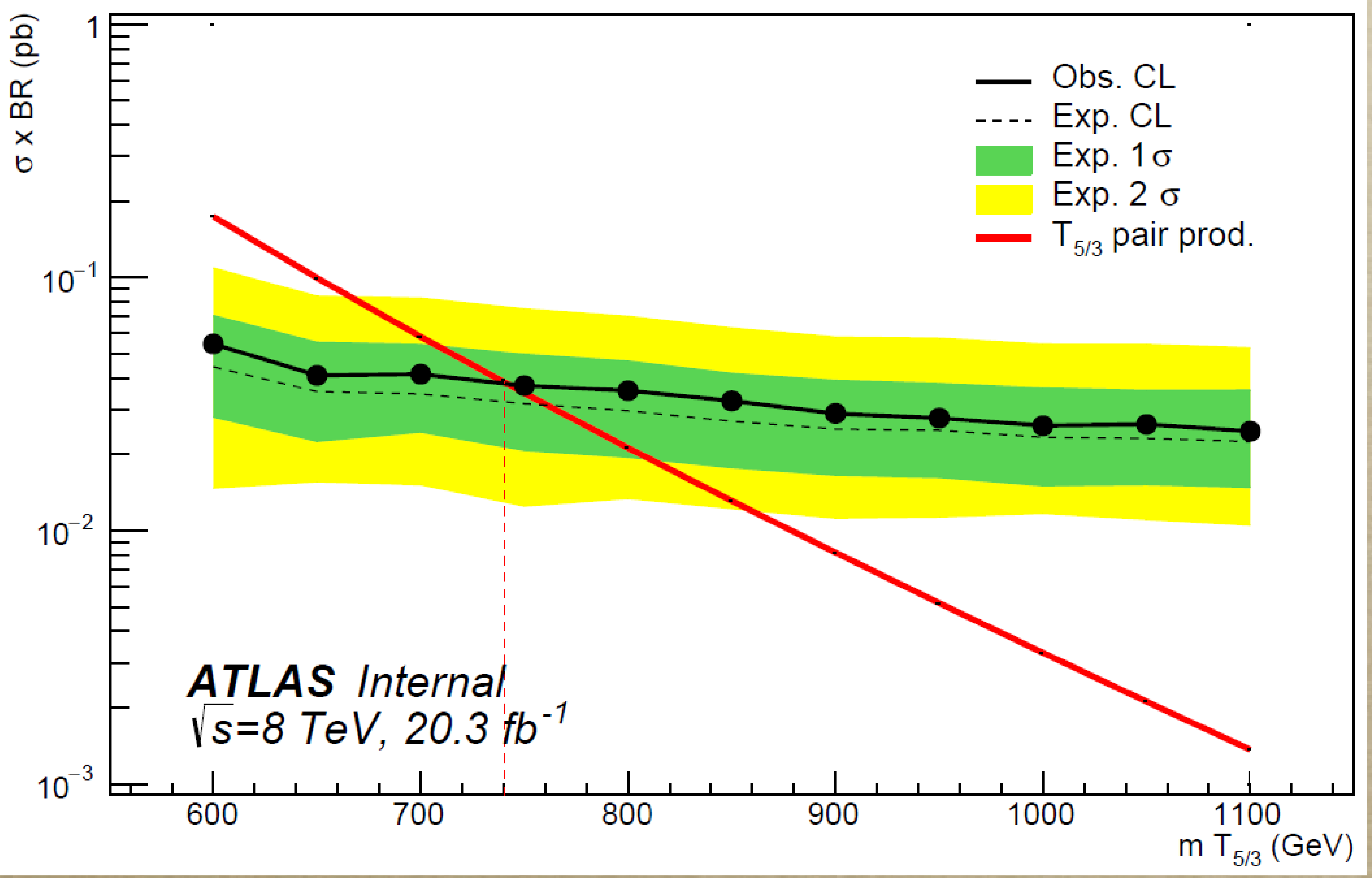


We observe some excess in high HT and high b-jet multiplicity (around 2.5 σ in SRVLQ6/7)

Search for VLQ in 2LSS+3L @ 8 TeV
Statistical interpretation

3

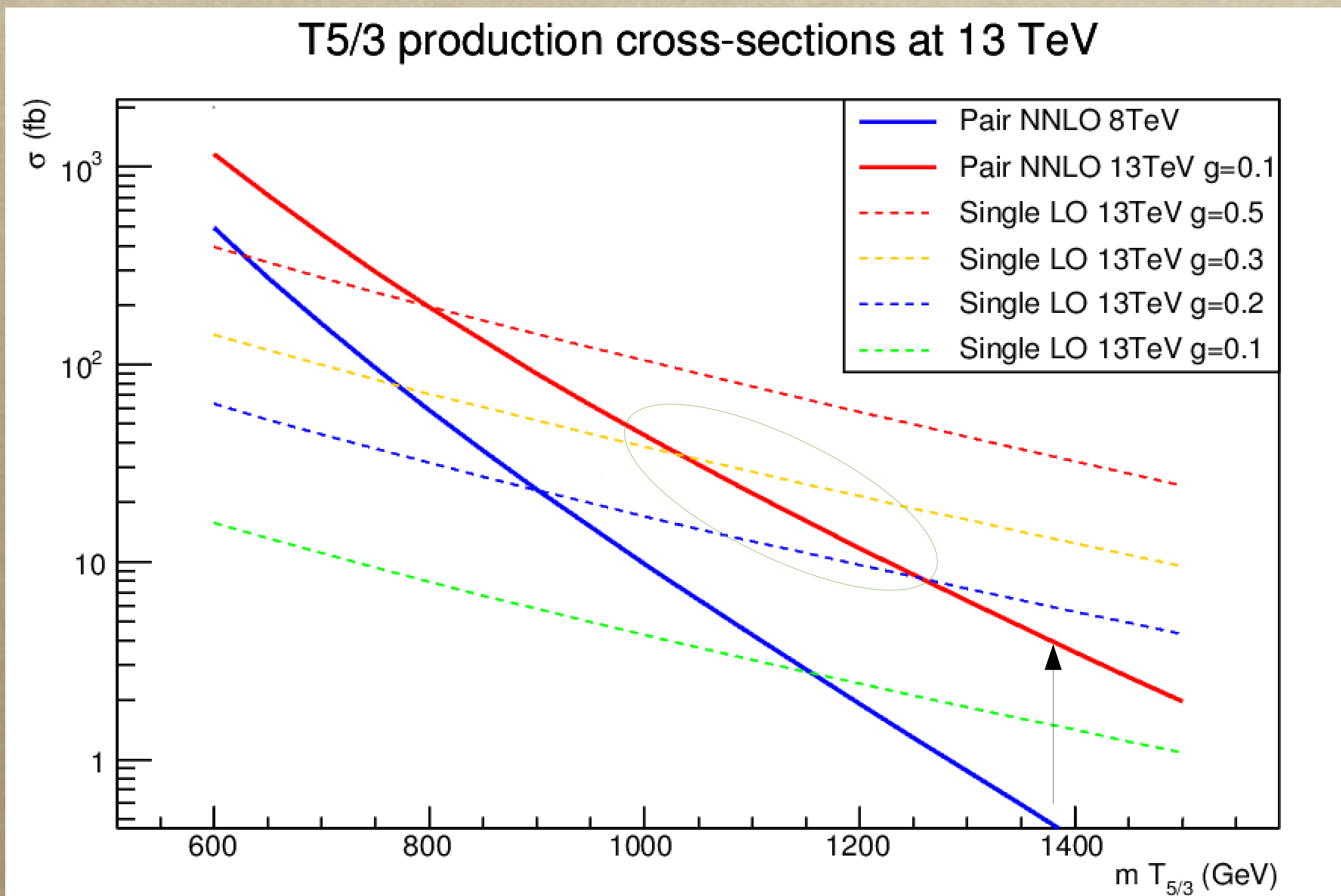
If we consider that the data contained only SM backgrounds, we can extract exclusions limits using Confidence Limits for each mass points which will give a inferior mass constraint on the model (cross-section)



Pair production T5/3 : **m(T5/3) < 0,74 TeV**
Pair + single productions , **m(T5/3) < 0,75 TeV**

Towards run 2

3



New benchmark for single production :
1 TeV mass point reachable + SP contributes as much as PP

Signal cross-sections increase (x6-x10) between 8TeV and 13 TeV
(bkg exp to be x3-x4)

Stay tuned for Run 2 results + BSM 4tops publication !

Thanks !

Backup

Systematics

Source	VLQ signal region number							
	0	1	2	3	4	5	6	7
Cross section	±8.0	±13.6	±15.1	±11.1	±12.1	±16.8	±25.2	±23.8
Fake/non-prompt leptons	±33	±18	±25	±23	±26	±16	±1.5	±3.8
Charge misID	$^{+5.9}_{-5.7}$	$^{+9.3}_{-9.1}$	$^{+5.4}_{-5.1}$	$^{+7.4}_{-6.7}$	$^{+5.0}_{-4.6}$	$^{+8.7}_{-8.1}$	$^{+9.0}_{-8.5}$	$^{+11.0}_{-10.1}$
Jet energy scale	$^{+1.7}_{-1.6}$	$^{+1.2}_{-1.8}$	$^{+1.4}_{-1.7}$	$^{+1.8}_{-2.1}$	$^{+2.6}_{-4.2}$	$^{+3.8}_{-1.5}$	$^{+8.5}_{-4.8}$	$^{+7.3}_{-2.9}$
b-tagging efficiency	±1.0	±2.6	$^{+5.7}_{-5.5}$	$^{+1.9}_{-2.0}$	$^{+1.6}_{-1.7}$	$^{+3.8}_{-3.7}$	$^{+5.1}_{-5.0}$	$^{+8.3}_{-8.2}$
Lepton ID efficiency	±1.3	±1.6	±1.6	$^{+2.1}_{-2.0}$	$^{+2.1}_{-2.0}$	$^{+2.2}_{-2.1}$	$^{+2.8}_{-2.2}$	±2.5
Jet energy resolution	±0.5	±0.2	±3.1	±1.9	±0.3	±0.9	±0.8	±3.4
Luminosity	±0.9	±1.1	±1.3	±1.4	±1.5	±1.5	±2.1	±1.9

For background

Source	VLQ signal region number							
	0	1	2	3	4	5	6	7
Jet energy scale	$^{+11.3}_{-9.0}$	$^{+11.5}_{-6.3}$	$^{+28.0}_{-17.3}$	$^{+3.7}_{-2.1}$	$^{+5.4}_{-2.4}$	$^{+3.9}_{-2.0}$	$^{+4.5}_{-6.5}$	$^{+6.6}_{-3.0}$
b-tagging efficiency	$^{+2.5}_{-3.0}$	$^{+6.3}_{-6.1}$	$^{+16.4}_{-15.9}$	$^{+3.1}_{-3.7}$	$^{+3.4}_{-4.0}$	$^{+7.4}_{-7.2}$	$^{+7.6}_{-7.4}$	$^{+12.1}_{-11.9}$
Lepton ID efficiency	±2.9	±2.9	±2.8	±2.9	$^{+3.2}_{-3.1}$	±2.9	$^{+3.2}_{-3.1}$	$^{+3.0}_{-2.9}$
Jet energy resolution	±0.8	±2.5	±3.9	±0.3	±0.7	±0.7	±1.0	±0.1
Luminosity	±2.8	±2.8	±2.8	±2.8	±2.8	±2.8	±2.8	±2.8

For one signal (BB 600)

Yields including systematics

	SRVLQ0	SRVLQ1/SR4t0	SRVLQ2/SR4t1
$t\bar{t}W/Z$	16.2 ± 0.3 ± 7.0	12.6 ± 0.3 ± 5.4	1.24 ± 0.09 ± 0.53
$t\bar{t}H$	2.5 ± 0.1 ± 0.3	1.8 ± 0.1 ± 0.2	0.26 ± 0.03 ± 0.05
Dibosons	11.2 ± 0.6 ± 2.8	0.95 ± 0.19 ± 0.25	0.07 ± 0.12 ± 0.05
Fake/Non-prompt	42.1 ± 5.4 ± 24.6	8.61 ± 2.34 ± 5.02	1.17 ± 0.82 ± 0.68
Q mis-Id	20.8 ± 0.7 ± 5.2	15.1 ± 0.6 ± 3.5	0.74 ± 0.11 ± 0.18
Other bkg.	1.76 ± 0.13 ± 0.17	0.75 ± 0.04 ± 0.10	0.10 ± 0.08 ± 0.03
Total bkg.	94.5 ± 5.4 ± 24.9	40.0 ± 2.4 ± 7.3	3.6 ± 0.9 ± 0.8
Data	107	54	6
p-value	0.36	0.12	0.24

	SRVLQ3	SRVLQ4
$t\bar{t}W/Z$	2.07 ± 0.10 ± 0.89	3.14 ± 0.13 ± 1.35
$t\bar{t}H$	0.40 ± 0.04 ± 0.07	0.57 ± 0.05 ± 0.07
Dibosons	2.36 ± 0.29 ± 0.61	2.03 ± 0.25 ± 0.49
Fake/Non-prompt	3.09 ± 1.29 ± 1.80	4.24 ± 1.59 ± 2.47
Q mis-Id	1.72 ± 0.22 ± 0.63	1.45 ± 0.17 ± 0.52
Other bkg.	0.22 ± 0.08 ± 0.03	0.41 ± 0.10 ± 0.06
Total bkg.	9.87 ± 1.35 ± 2.10	11.9 ± 1.6 ± 2.8
Data	7	10
p-value	0.83	0.71

	SRVLQ5/SR4t2	SRVLQ6/SR4t3	SRVLQ7/SR4t4
$t\bar{t}W/Z$	1.87 ± 0.09 ± 0.80	2.46 ± 0.11 ± 1.06	0.57 ± 0.05 ± 0.25
$t\bar{t}H$	0.31 ± 0.04 ± 0.05	0.44 ± 0.04 ± 0.06	0.08 ± 0.02 ± 0.02
Dibosons	0.33 ± 0.14 ± 0.10	0.04 ± 0.12 ± 0.03	0.00 ± 0.12 ± 0.00
Fake/Non-prompt	1.03 ± 0.97 ± 0.60	0.00 ± 1.02 ± 0.28	0.04 ± 0.83 ± 0.24
Q mis-Id	1.17 ± 0.16 ± 0.38	1.09 ± 0.14 ± 0.34	0.30 ± 0.09 ± 0.10
Other bkg.	0.16 ± 0.08 ± 0.02	0.23 ± 0.08 ± 0.05	0.14 ± 0.08 ± 0.08
Total bkg.	4.9 ± 1.0 ± 1.0	4.3 ± 1.1 ± 1.1	1.1 ± 0.9 ± 0.4
Data	6	12	6
p-value	0.46	0.029	0.036

Data driven methods

Fakes/non-prompt

The fake lepton should not pass the selection criteria

How to estimate it ?

Define 2 quality definitions :
- *loose* with relaxed criteria (ID/isolation)
- *tight* standard analysis definition

Then, estimate in data the probability for **a loose lepton to pass tight criteria** in CR and apply it in SR

Charge mis-identification

The electron's charge is wrong (high pT or tridents)

How to estimate it ?

Estimate the probability of flipping the charge in a pure region ($Z \rightarrow e^+e^-$) in data

Then, apply the probability to MC simulation of the contributing processes **requiring OS events**

ATLAS generic search

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Fakes : matrix method

Observed in data →

$$\begin{pmatrix} N^{tt} \\ N^{tl} \\ N^{lt} \\ N^{ll} \end{pmatrix} = \mathbf{M} \begin{pmatrix} N^{ll}_{rr} \\ N^{ll}_{rf} \\ N^{ll}_{fr} \\ N^{ll}_{ff} \end{pmatrix}$$

← Estimation

$$\mathbf{M} = \begin{pmatrix} r_1 r_2 & r_1 f_2 & f_1 r_2 & f_1 f_2 \\ r_1 \overline{r_2} & r_1 \overline{f_2} & f_1 \overline{r_2} & f_1 \overline{f_2} \\ \overline{r_1} r_2 & \overline{r_1} f_2 & \overline{f_1} r_2 & \overline{f_1} f_2 \\ \overline{r_1}\,\overline{r_2} & \overline{r_1}\,\overline{f_2} & \overline{f_1}\,\overline{r_2} & \overline{f_1}\,\overline{f_2} \end{pmatrix}$$

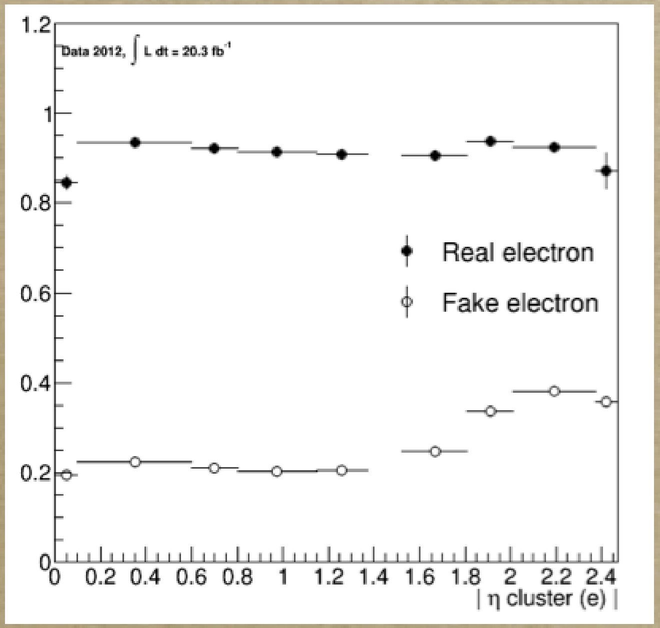
$$\begin{aligned} N^{tt}_{fake} &= N^{tt}_{rf} + N^{tt}_{fr} + N^{tt}_{ff} \\ &= r_1 f_2 N^{ll}_{rf} + f_1 r_2 N^{ll}_{fr} + f_1 f_2 N^{ll}_{ff} \end{aligned}$$

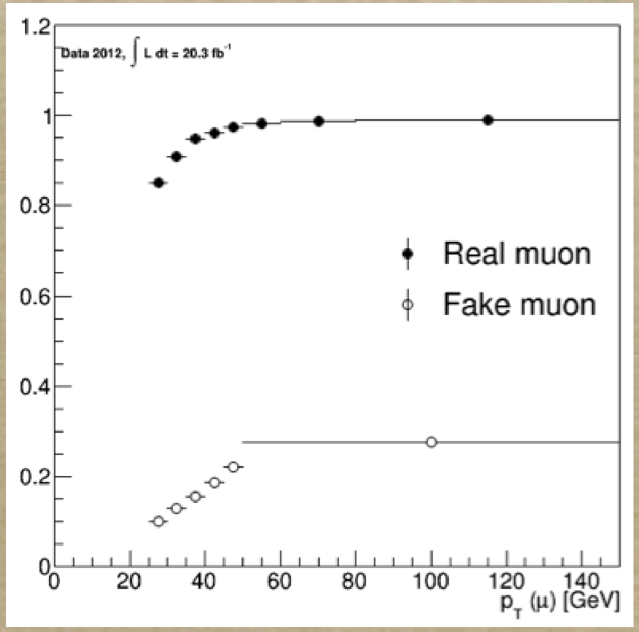
Tight = leptons passing the analysis criteria (isolation, tight ++)
Loose = medium++ electrons, tight muons, no isolation

Real efficiencies (r) extracted from high MET or mT(W) region
Fake eff. (f) from low MET, mT(W) or high |d0sign| region

Systematics : choice of the regions, statistics, MC substraction
→ 70 % uncertainty in final SR

Cross-checked with OS regions, different triggers, other isolation, to understand the excess.





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Misid likelihood method

$$N_{ij}^{ss} \simeq (\epsilon_i + \epsilon_j)N_{ij}$$

Charge flip for electron i and j

SS/OS events in Z peak → charge flip probability as f(pT, eta)
Extrapolated to high pT with ttbar MC truth matching

Systematics : likelihood stat, pT extrapolation, Z peak definition, fake removal)
→ 30 % uncertainty in final SR

Trident fake lepton overlap removed

Charge flip prob.

	p_T range				
$\|\eta\|$ range	[0, 50] GeV	[50, 80] GeV	[80, 100] GeV	[100, 200] GeV	[200, 1000] GeV
[0, 0.8]	0.000565	0.000708	0.00178	0.0024	0.00427
[0.8, 1.1]	0.000909	0.002	0.00739	0.00869	0.0168
[1.1, 1.37]	0.0025	0.00162	0.00552	0.0066	0.00686
[1.52, 1.8]	0.00844	0.0087	0.0195	0.0266	0.0303
[1.8, 2.3]	0.0128	0.0155	0.0393	0.0467	0.055
[2.3, 2.6]	0.0315	0.0349	0.053	0.0606	0.123

Sample	ee	$e\mu$	$\mu\mu$
Q mis-Id	$136 \pm 2 \pm 41$	$118 \pm 1 \pm 35$	—
Fake/Non-prompt	$153 \pm 11 \pm 107$	$225 \pm 11 \pm 158$	$29 \pm 3 \pm 20$
$t\bar{t}W/Z$	$4.57 \pm 0.19 \pm 1.88$	$14.2 \pm 0.3 \pm 5.8$	$8.43 \pm 0.27 \pm 3.56$
$t\bar{t}H$	$0.39 \pm 0.04 \pm 0.04$	$1.31 \pm 0.08 \pm 0.13$	$0.76 \pm 0.06 \pm 0.07$
Dibosons	$5.57 \pm 0.45 \pm 1.08$	$15.9 \pm 0.8 \pm 2.9$	$9.00 \pm 0.58 \pm 1.79$
Other bkg.	$0.32 \pm 0.11 \pm 0.11$	$0.75 \pm 0.20 \pm 0.20$	$0.27 \pm 0.06 \pm 0.06$
Total bkg.	$299 \pm 11 \pm 115$	$375 \pm 11 \pm 162$	$47 \pm 3 \pm 20$
Data	271	307	52

Sample	eee	$ee\mu$	$e\mu\mu$	$\mu\mu\mu$
Fake/Non-prompt	$8.0 \pm 2.3 \pm 5.6$	$13.2 \pm 2.4 \pm 9.2$	$17.9 \pm 2.8 \pm 12.5$	$1.34 \pm 0.55 \pm 0.94$
$t\bar{t}W/Z$	$1.20 \pm 0.09 \pm 0.46$	$2.55 \pm 0.13 \pm 0.87$	$3.38 \pm 0.16 \pm 1.15$	$2.70 \pm 0.14 \pm 1.00$
$t\bar{t}H$	$0.07 \pm 0.02 \pm 0.01$	$0.28 \pm 0.03 \pm 0.03$	$0.32 \pm 0.03 \pm 0.03$	$0.14 \pm 0.02 \pm 0.01$
Dibosons	$5.78 \pm 0.51 \pm 1.14$	$6.78 \pm 0.57 \pm 1.33$	$8.42 \pm 0.57 \pm 1.78$	$9.23 \pm 0.65 \pm 1.82$
Other bkg.	$0.04 \pm 0.02 \pm 0.02$	$0.11 \pm 0.02 \pm 0.02$	$0.12 \pm 0.02 \pm 0.02$	$0.15 \pm 0.03 \pm 0.03$
Total bkg.	$15.1 \pm 2.4 \pm 5.7$	$22.9 \pm 2.5 \pm 9.4$	$30.1 \pm 2.8 \pm 12.7$	$13.6 \pm 0.9 \pm 2.4$
Data	15	18	36	14

Yields in validation region for all the background in 2lSS and 3l channels

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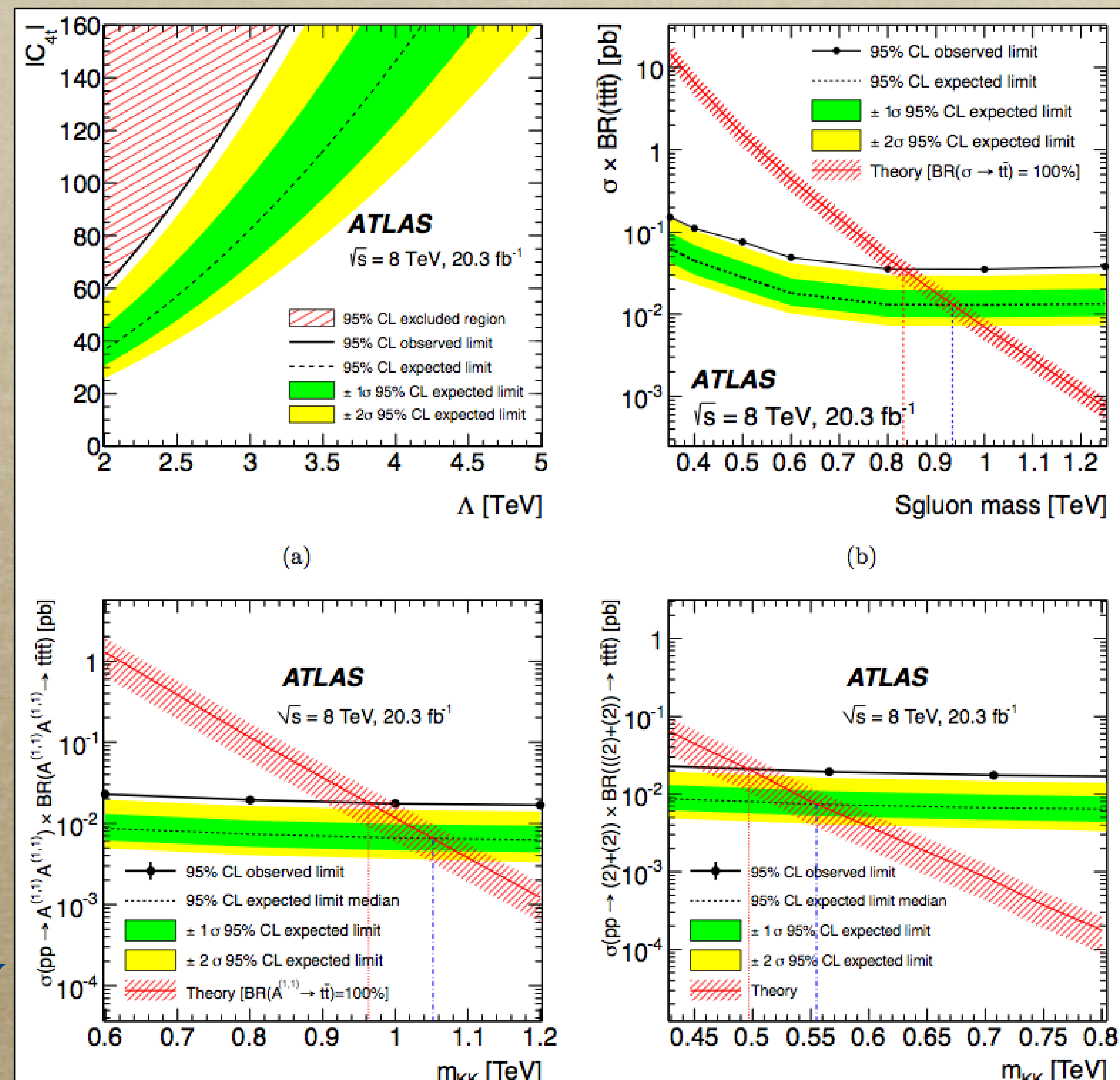
Exclusion limits : 4tops

For 3 models :
- contact interaction
- 2UED-RPP
- sgluon

Limit at 95 % CL on SM cross-section : **σ > 70 fb**

BSM contact interaction : **$|C|/\Lambda^2$ >15.1** and cross-section **σ > 61 fb**

Sgluons limit at 95 % CL **m>0.83 TeV**



ATLAS generic search

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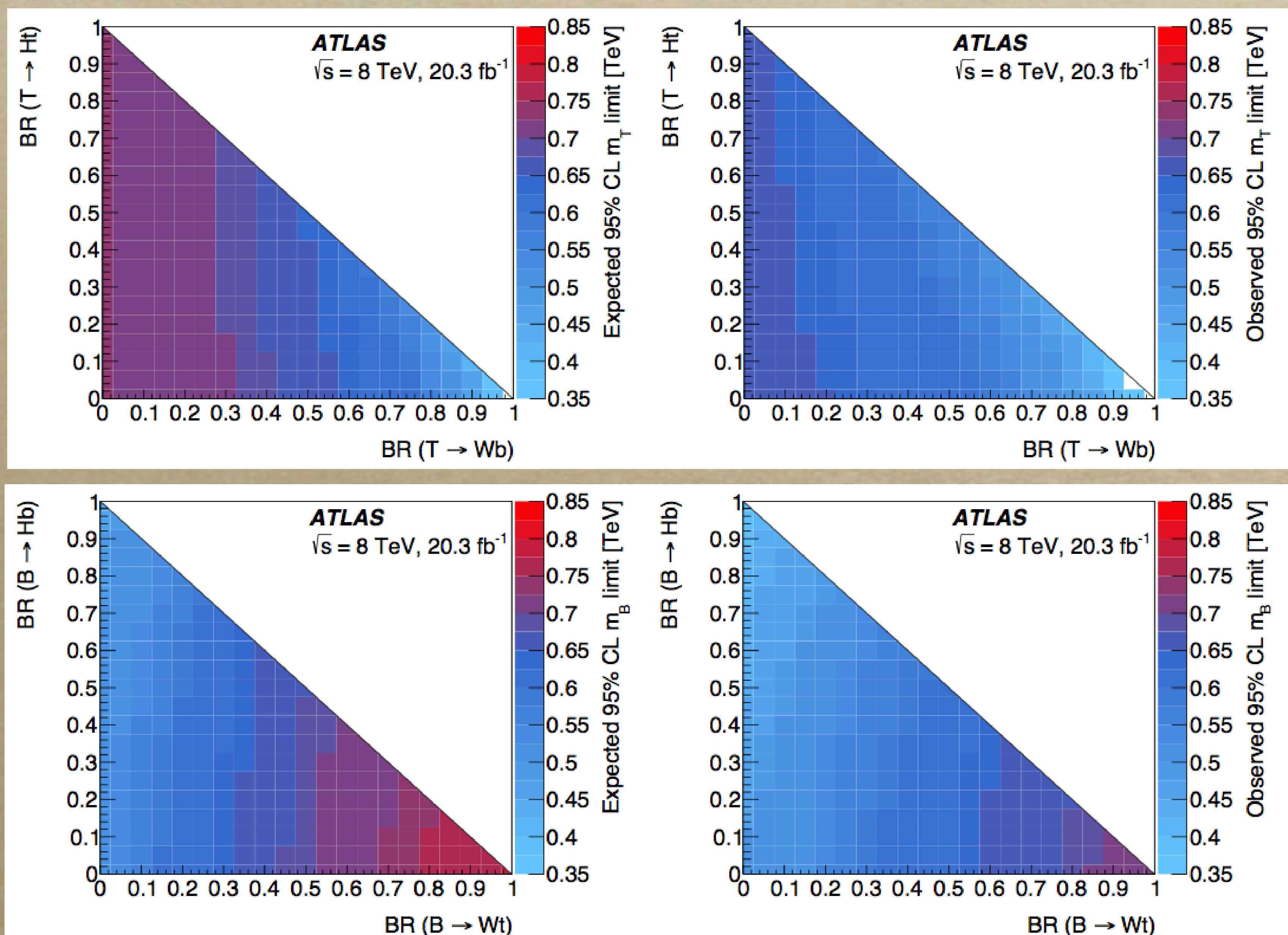
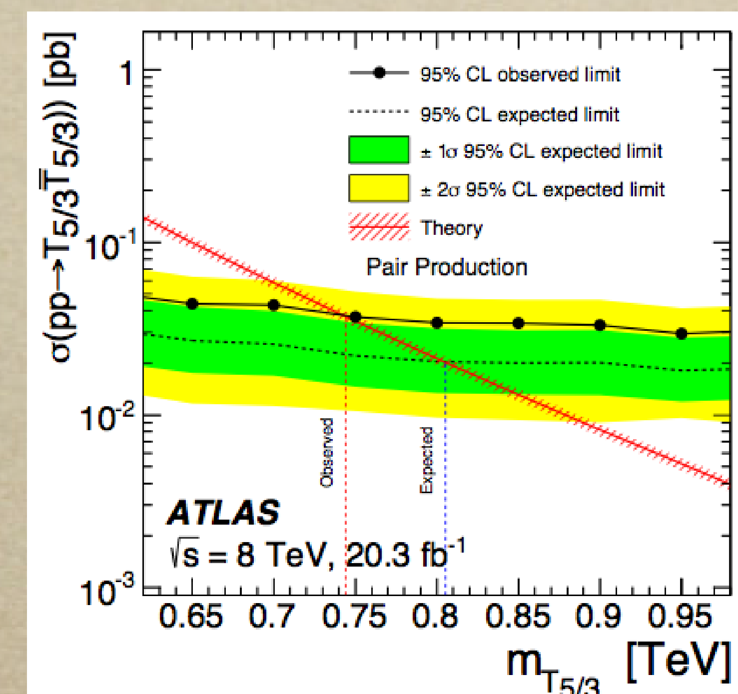
Exclusion limits : VLQ TT, BB and T5/3

For various BR (T → Wb) and (T → Ht)





T5/3 → tW 100 %

Single production too conservative

m(T5/3)>0.74 TeV (PP)

m(T5/3)>0.75 TeV (PP+SP)

Assuming singlet BR : **m(B)>0.62 TeV** and **m(T)>0.59 TeV**

ATLAS generic search

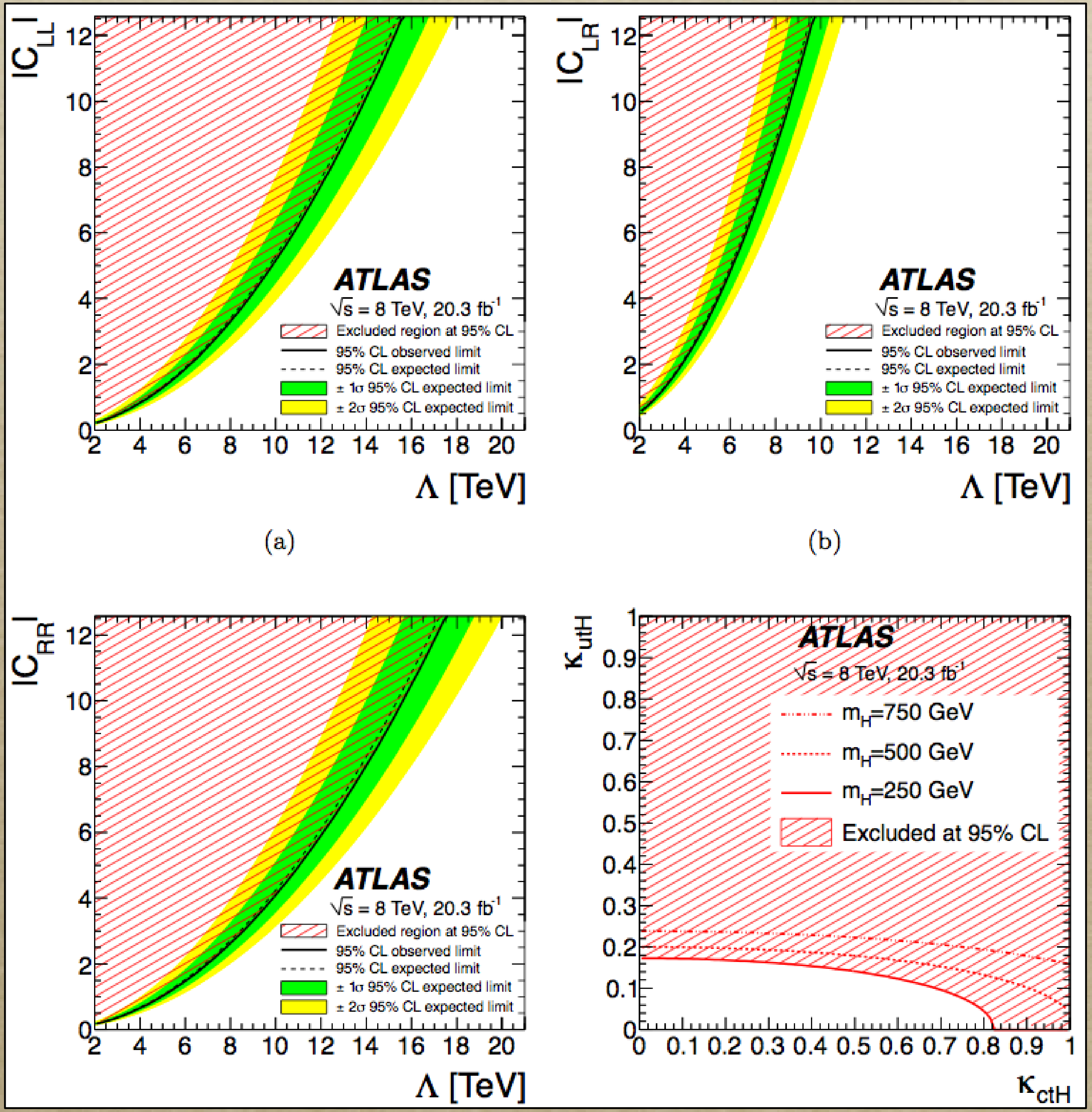
CERN-PH-EP-2015-060

Exclusion limits : tt

Tested for 3 chiralities (LL, RR, LR)
No excess found in tt specific regions

Model	$\sigma(pp \to tt)$ [fb] Exp.	Obs.	Coupling const. Observed
Contact interaction model			$\lvert C\rvert/\Lambda^2$ [TeV^{-2}]
Left-left	64	62	0.053
Left-right	53	51	0.137
Right-right	40	38	0.042
Higgs-like FCNC model			κ_{utH} or κ_{ctH}
$uu \to tt$ (m_H = 125 GeV)	37	35	0.16
$uu \to tt$ (m_H = 250 GeV)	21	20	0.17
$uu \to tt$ (m_H = 500 GeV)	12	11	0.20
$uu \to tt$ (m_H = 750 GeV)	9.3	8.4	0.24
$cc \to tt$ (m_H = 250 GeV)	71	69	0.81
$cc \to tt$ (m_H = 500 GeV)	37	35	1.02
$cc \to tt$ (m_H = 750 GeV)	28	27	1.29

$$\mathcal{L}_{tt} = \frac{1}{2}\frac{C_{LL}}{\Lambda^2}(\bar{u}_L\gamma^\mu t_L)(\bar{u}_L\gamma_\mu t_L) + \frac{1}{2}\frac{C_{RR}}{\Lambda^2}(\bar{u}_R\gamma^\mu t_R)(\bar{u}_R\gamma_\mu t_R) - \frac{1}{2}\frac{C_{LR}}{\Lambda^2}(\bar{u}_L\gamma^\mu t_L)(\bar{u}_R\gamma_\mu t_R) - \frac{1}{2}\frac{C'_{LR}}{\Lambda^2}(\bar{u}_{La}\gamma^\mu t_{Lb})(\bar{u}_{Rb}\gamma_\mu t_{Ra})$$



ATLAS generic search

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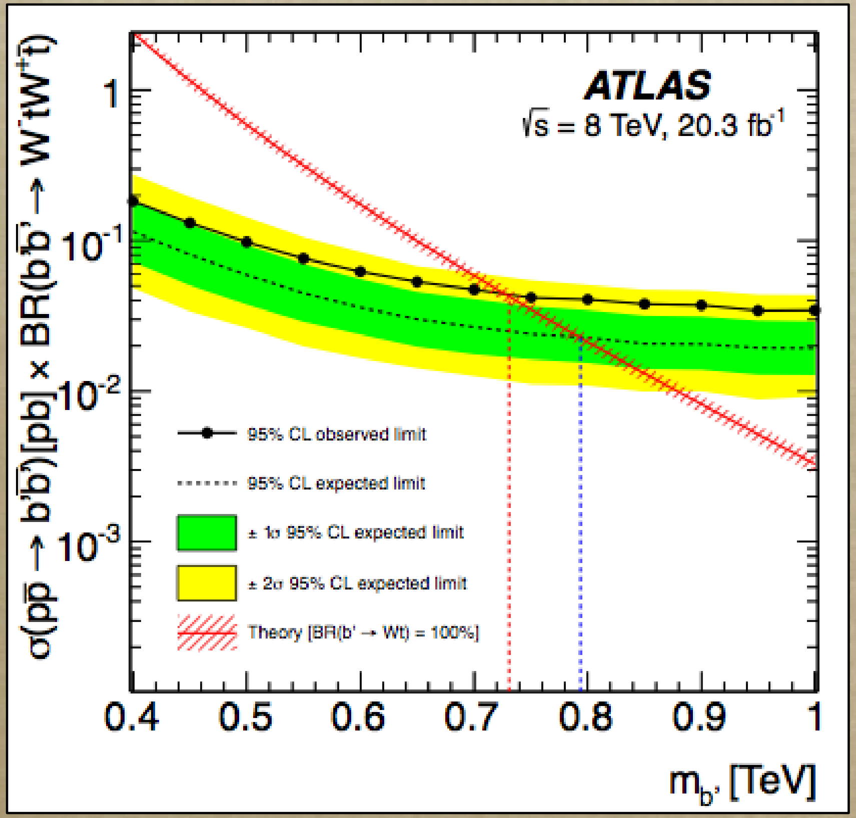
Exclusion limits : b'



For BR(b' → tW)=100 %
b' pair production excluded at 95 % CL for
m(b') < 0.73 TeV

With different BR(b' → tW) and BR(b' → cW)