Probing the strong electroweak symmetry breaking in a model with a vector resonance

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Outline

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Electroweak symmetry breaking

- mechanism ESB - the most pressing problem of the SM

Electroweak symmetry breaking

- mechanism ESB - the most pressing problem of the SM
- LHC - machine designed to address the question

Sept 10, 8:30AM

CERN/DG-2008-247-O 4 September 2008

MEMORANDUM

To : CERN Personnel and Users

From : R. Aymar

Subject : Start of the LHC operation on 10 September 2008

Following the design, production and installation of the LHC machine and experiments, I would like to inform you that the hardware commissioning has been carried out with success. Thus, the accelerators, the LHC experimental detectors and related computing are now ready to be put into operation.

The recommendations issued from the LHC safety audits were implemented and whenever necessary, compensatory measures were set up.

I am pleased to inform you that based on these elements I have authorized the start of the LHC operation on the planned date of 10 September 2008.

I count on the commitment of all of you to ensure a successful and safe start of the accelerator.

The start of the LHC operation is the first step of the coronation of a huge amount of work that CERN personnel, users and contractors have produced during many years, and we all have to feel proud of this achievement whilst waiting for the physics discoveries to come.

R. Aymar

Higgs boson

benchmark hypothesis:

$$\Phi(x) = \begin{pmatrix} \pi_2(x) + i\pi_1(x) \\ v + h(x) - i\pi_3(x) \end{pmatrix}, \qquad \langle \Phi \rangle_0 = v$$

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$$\Rightarrow \text{Higgs boson}$$

not everybody happy

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- Gauge-Higgs unification
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unified description of the non-SUSY models:

AdS/CFT correspondence + deconstruction

Hidden local symmetry

Effective description

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  - non-linear sigma-model
  - 3 scalar fields
  - $SU(2)_L \times SU(2)_R$ global symmetry
  - $SU(2)_L \times U(1)_Y$-gauged

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- new particle(s) to unitarize amplitudes ≈ 1 TeV

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New vector fields

HLS approach:

- $SU(2)_V$ triplet $\rho_\mu^1, \rho_\mu^2, \rho_\mu^3$

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HLS approach:

- $SU(2)_V$ triplet $\rho_\mu^1, \rho_\mu^2, \rho_\mu^3$
- mixing of ρ to elweak bosons
- prototype: BESS model - ρ couples universally to all fermions

Our modifications

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or
(t, b)-doublet
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$$SU(2)_L : \rho \text{ to } (t_L, b_L) \ldots b_1$$

$$\text{disentangle coupling to } t_R \text{ from } b_R \rightarrow \begin{cases} \rho b_R b_R \rightarrow 0 \\ \rho t_R t_R \ldots b_2 \end{cases}$$

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- **solution 2:**
  λ-terms

Model properties

$$M_\rho \approx \frac{\sqrt{a} v g_V}{2}, \qquad g_V \gg g, g'$$

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dominant ρ decays:

$\rho^0 \to \boxed{t\bar{t}}, \boxed{b\bar{b}}, \boxed{W^+W^-}$

$\rho^\pm \to \boxed{t\bar{b}/b\bar{t}}, \boxed{W^\pm Z}$

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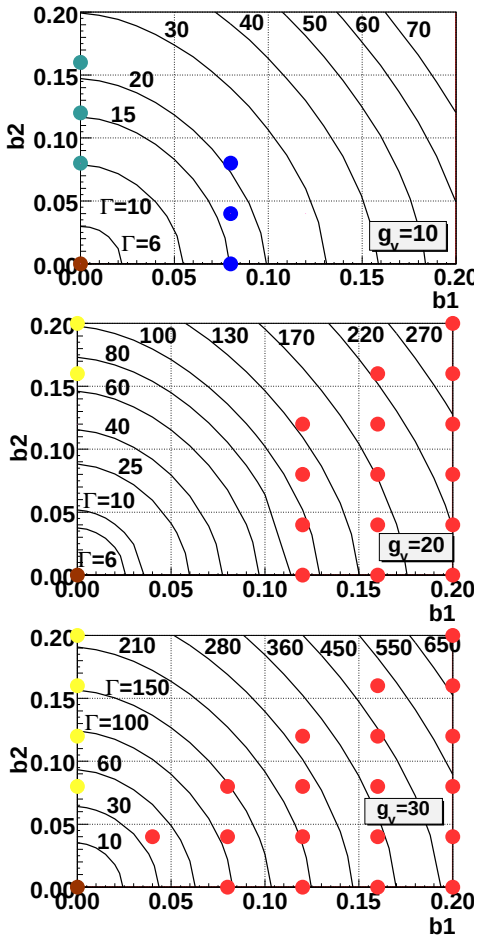
- $t\bar{t} \sim b\bar{b} \sim W^+W^-$
- $W^+W^- \gg t\bar{t}, b\bar{b}$
- $t\bar{t} \gg b\bar{b}, W^+W^-$
- $t\bar{t}, b\bar{b} \gg W^+W^-$
- $t\bar{t}, W^+W^- \gg b\bar{b}$

$M_{\rho^0} = 1$ TeV



Outline

Considered LHC processes

1. $pp \to t\bar{t}X$
2. $pp \to b\bar{b}X$
3. $pp \to t\bar{b}X$
4. $pp \to W^+ZX$
5. $pp \to W^+W^-X$

3,4 ... mixing enabled processes

Considered LHC processes

1. $pp \to t\bar{t}X$ ... g_V, b_1, b_2
2. $pp \to b\bar{b}X$ ... g_V, b_1
3. $pp \to t\bar{b}X$ ... g_V, b_1
4. $pp \to W^+ZX$ ... g_V, b_1
5. $pp \to W^+W^-X$ ... g_V

3,4 ... mixing enabled processes

Considered parametric space points

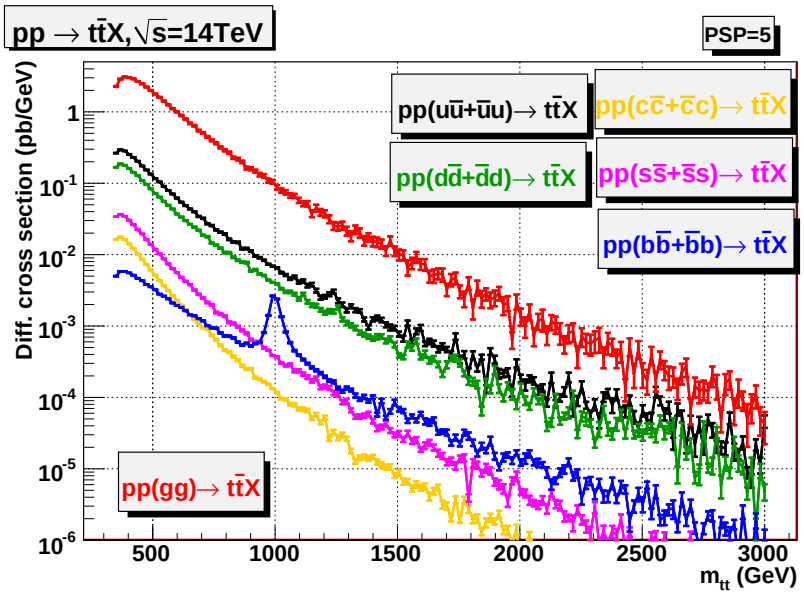
$M_{\rho^0} = 1$ TeV

P	g_V	b_1	b_2	Γ_{ρ^0} (GeV)	BR(ρ^0)			$M_{\rho^\pm}$ (GeV)	$\Gamma_{\rho^\pm}$ (GeV)	BR($\rho^\pm$)	
					W^+W^-	$t\bar{t}$	bb			$tb/\bar{t}b$	$W^\pm Z$
1	10	0.08	0.04	16.899	31%	38%	31%	999.84	15.281	64%	36%
2	10	0.12	0.04	28.256	19%	42%	39%	999.84	26.433	79%	21%
3	10	0	0	5.334	99%	0.12%	0.08%	999.84	5.443	0.2%	98%
4	20	0	0.12	42.788	3%	97%	0.0025%	999.96	1.358	0.2%	98%
5	20	0.08	0	42.471	3%	46%	51%	999.96	42.509	97%	3%
6	35	0.04	0	34.580	1%	47%	52%	999.99	34.594	99%	1%
7	10	0	0.08	10.169	52%	48%	0.042%	999.84	5.443	0.18%	98%

"Loser" processes

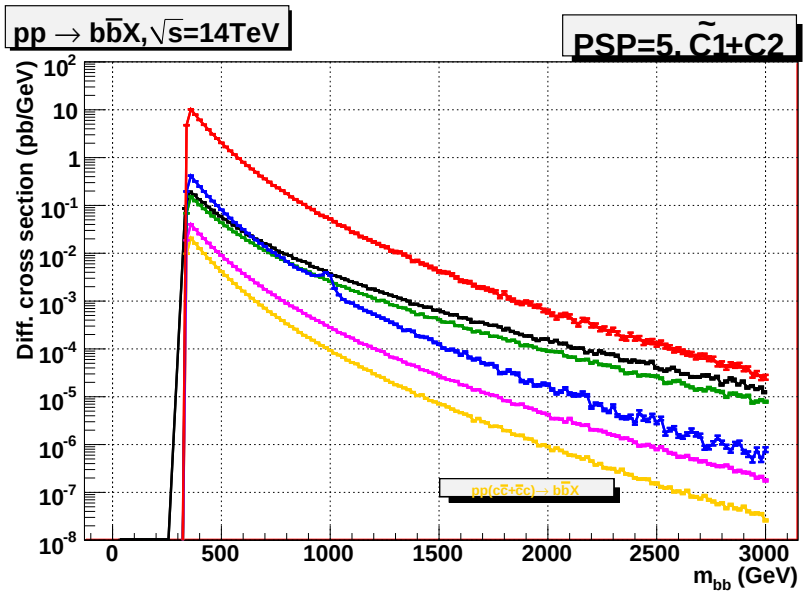
$$M_{\rho^0} = 1 \text{ TeV}$$

$t\bar{t}, b\bar{b} \gg W^+W^-$



$\sigma(gg) = 726$ pb

$t\bar{t}, b\bar{b} \gg W^+W^-$

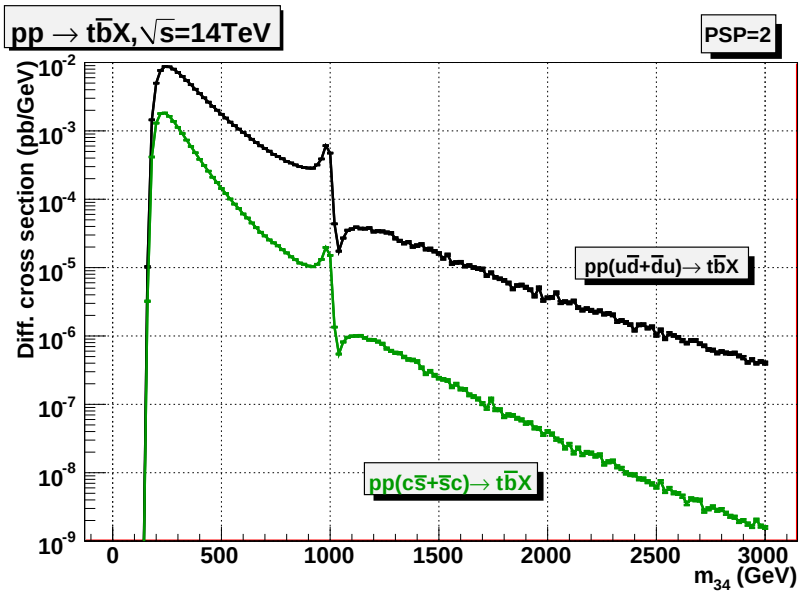


$\sigma(gg) = 1120$ pb

"Winner" processes

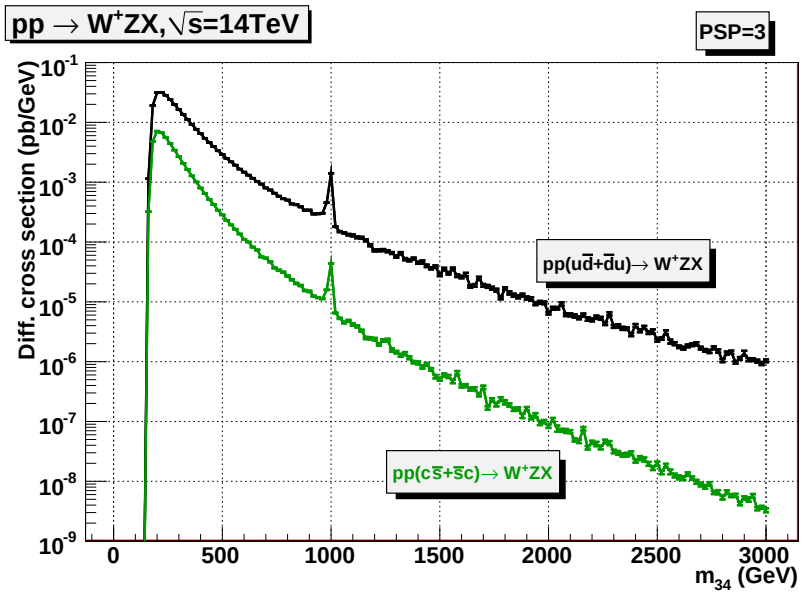
$$M_{\rho^0} = 1 \text{ TeV}$$

$t\bar{t} \sim b\bar{b} \sim W^+W^-$



$\sigma(u\bar{d} + \bar{d}u) = 3.92$ pb

$W^+W^- \gg t\bar{t}, b\bar{b}$

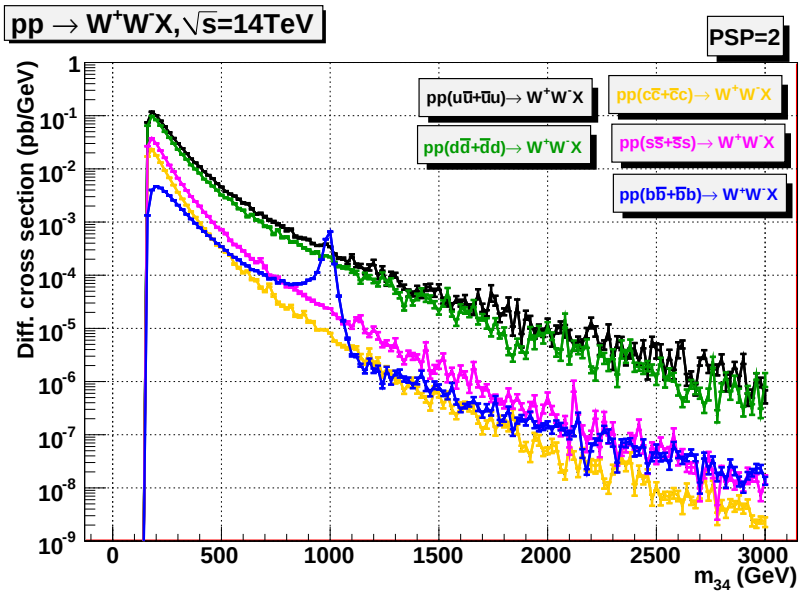


$\sigma(u\bar{d} + \bar{d}u) = 10.56$ pb

"Winner" processes (cont'd)

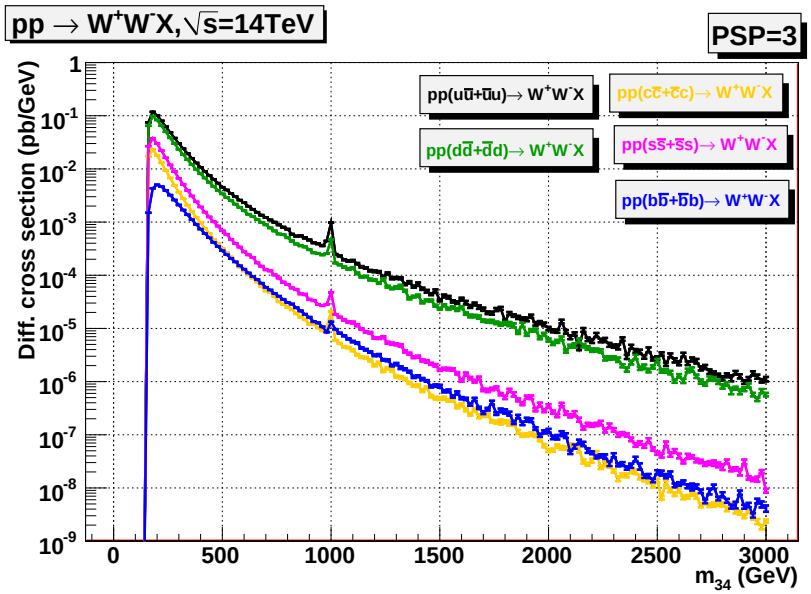
$$M_{\rho^0} = 1 \text{ TeV}$$

$t\bar{t} \sim b\bar{b} \sim W^+W^-$



$\sigma(u\bar{u} + \bar{u}u) = 28.04$ pb

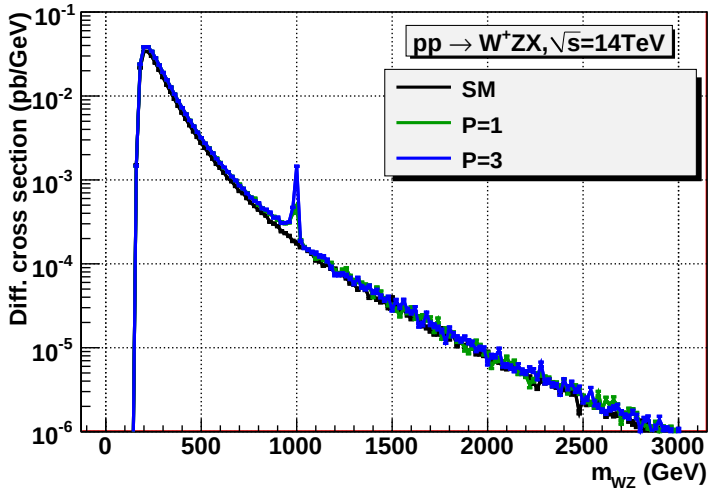
$W^+W^- \gg t\bar{t}, b\bar{b}$

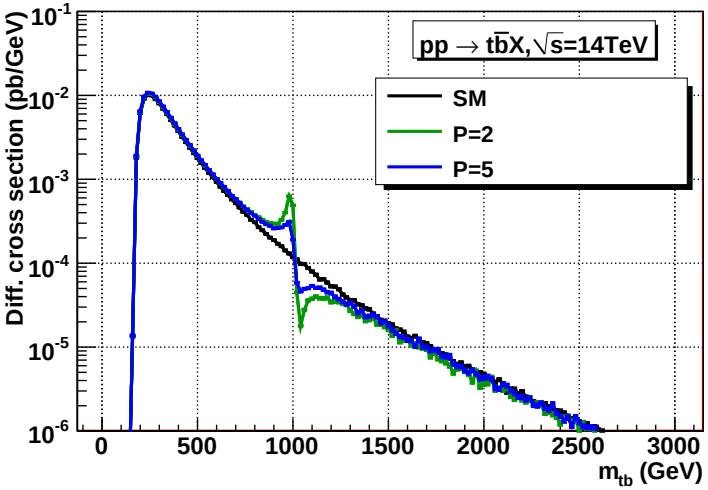


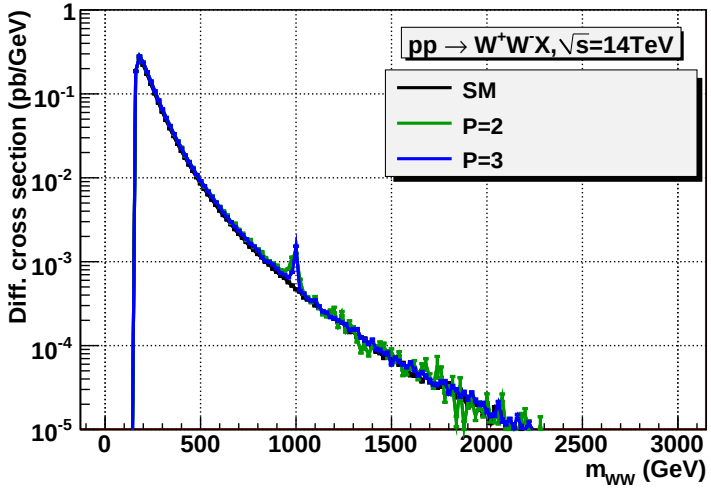
$\sigma(u\bar{u} + \bar{u}u) = 28.04$ pb

...SUMMING EVERYTHING UP:

$M_{\rho^0} = 1$ TeV







New physics *vs.* SM

$$R = \frac{N_P - N_{SM}}{\sqrt{N_{SM}}}$$

process	P	cut	σ (pb)	R_0	R (100 fb^{-1})
$pp \to t\bar{b}X + c.c$	SM	no	5.84	0	0
	2		6.17	0.136	43.04
	SM	0.7 TeV $\leq m_{tb} \leq 1.1$ TeV	0.14	0	0
	2		0.20	0.163	51.47
$pp \to W^+ZX + c.c$	SM	no	14.77	0	0
	3		16.96	0.570	180.37
	SM	0.7 TeV $\leq m_{WZ} \leq 1.1$ TeV	0.20	0	0
	3		0.29	0.188	59.30
$pp \to W^+W^-X$	SM	no	29.86	0	0
	3		31.86	0.366	115.74
	SM	0.7 TeV $\leq m_{WW} \leq 1.1$ TeV	0.37	0	0
	3		0.42	0.097	30.75

...GETTING MORE REALISTIC

final state	P	cut	events ($100\ \text{fb}^{-1}$)	R ($100\ \text{fb}^{-1}$)
$pp \to t\bar{b}X + c.c.$				
$\ell^+\nu_\ell b\bar{b} + c.c$	2	no	1.70×10^4	7.14
		yes	5.40×10^2	8.53
$jjb\bar{b} + c.c$	2	no	9.86×10^4	17.22
		yes	3.14×10^3	20.59
$pp \to W^+W^-X$				
$\ell_1^+\nu_{\ell_1}\ell_2^-\nu_{\ell_2}$	3	no	3.86×10^4	12.73
		yes	5.14×10^2	3.38
$\ell^+\nu_\ell jj$	3	no	2.24×10^5	30.71
		yes	2.99×10^3	8.16
$jjjj$	3	no	1.30×10^6	74.07
		yes	1.74×10^4	19.68

final state	P	cut	events ($100\ \text{fb}^{-1}$)	R ($100\ \text{fb}^{-1}$)
$pp \to W^+ZX + c.c.$				
$\ell^+\nu_\ell\ell'^+\ell'^- + c.c$	3	no	6.34×10^3	11.03
		yes	1.08×10^2	3.63
$jj\ell^+\ell^- + c.c$	3	no	3.69×10^4	26.61
		yes	6.26×10^2	8.75
$\ell^+\nu_\ell jj + c.c$	3	no	1.00×10^5	43.89
		yes	1.70×10^3	14.43
$jjjj + c.c.$	3	no	5.84×10^5	105.84
		yes	9.91×10^3	34.80
$jjb\bar{b} + c.c.$	3	no	4.12×10^4	28.13
		yes	7.00×10^2	9.25
$\ell^+\nu_\ell b\bar{b} + c.c.$	3	no	7.12×10^3	11.69
		yes	1.21×10^2	3.84

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Summary and conclusions

- LHC - new era in attacking ESB
- effective description of new physics: HLS, new vector $SU(2)_V$ triplet
- $pp \to abX$, $ab = t\bar{t}, b\bar{b}, t\bar{b}, W^+Z, W^+W^-$
- promising $\to$ further analysis: cuts, reconstruction

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