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

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- LHC - machine designed to address the question

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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not everybody happy

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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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- mixing of ρ to elweak bosons
- prototype: BESS model - ρ couples universally to all fermions

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$$SU(2)_L : \rho \text{ to } (t_L, b_L) \ldots b_1$$

$$\text{disentangle coupling to } t_R \text{ from } b_R \rightarrow \left\{ \begin{array}{l} \rho b_R b_R \rightarrow 0 \\ \rho t_R t_R \ldots b_2 \end{array} \right.$$

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

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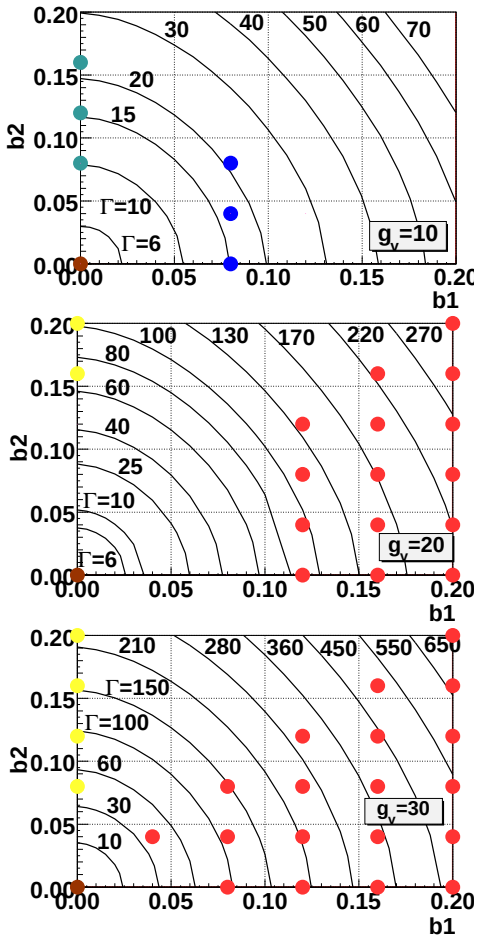
- $t\bar{t} \sim b\bar{b} \sim W^+W^-$
- $W^+W^- \gg t\bar{t}, b\bar{b}$
- $t\bar{t} \gg b\bar{b}, W^+W^-$
- $t\bar{t}, b\bar{b} \gg W^+W^-$
- $t\bar{t}, W^+W^- \gg b\bar{b}$

$M_{\rho^0} = 1$ 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

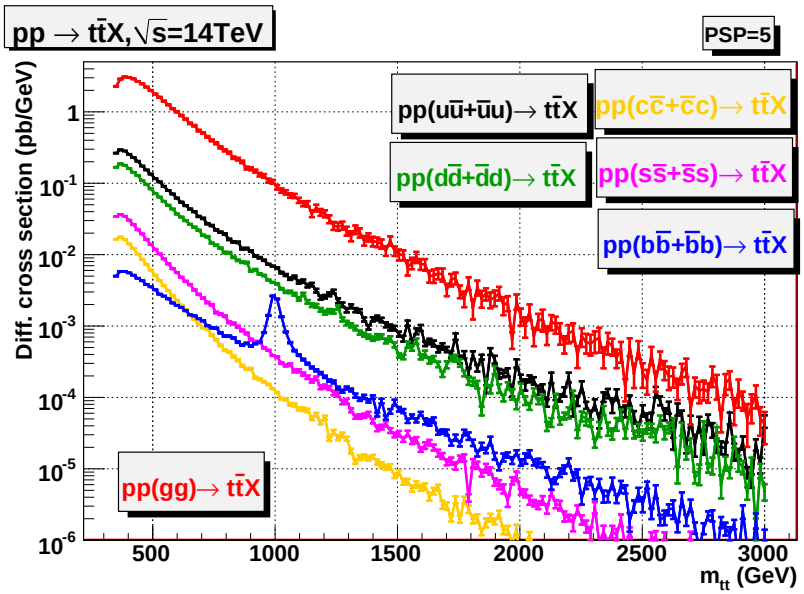
$M_{\rho^0} = 1$ TeV

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

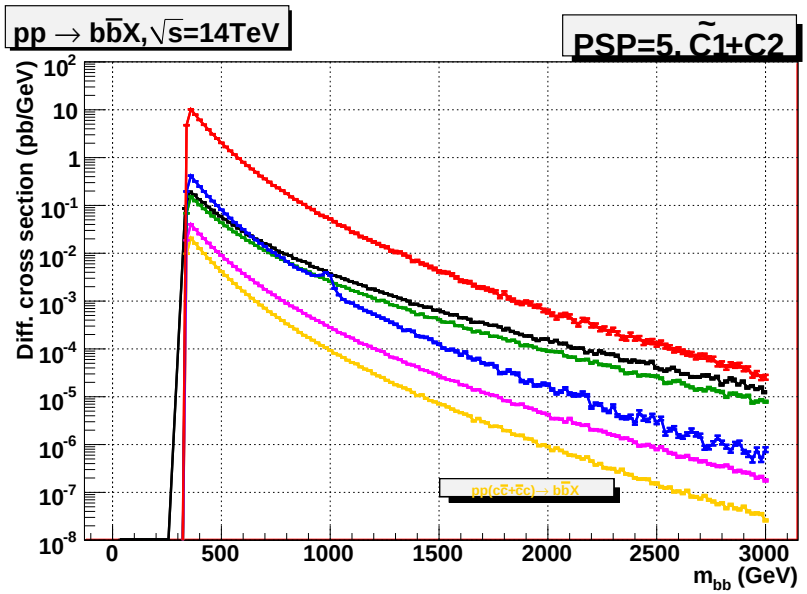
$$M_{\rho^0} = 1 \text{ TeV}$$

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



$\sigma(gg) = 726$ pb

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

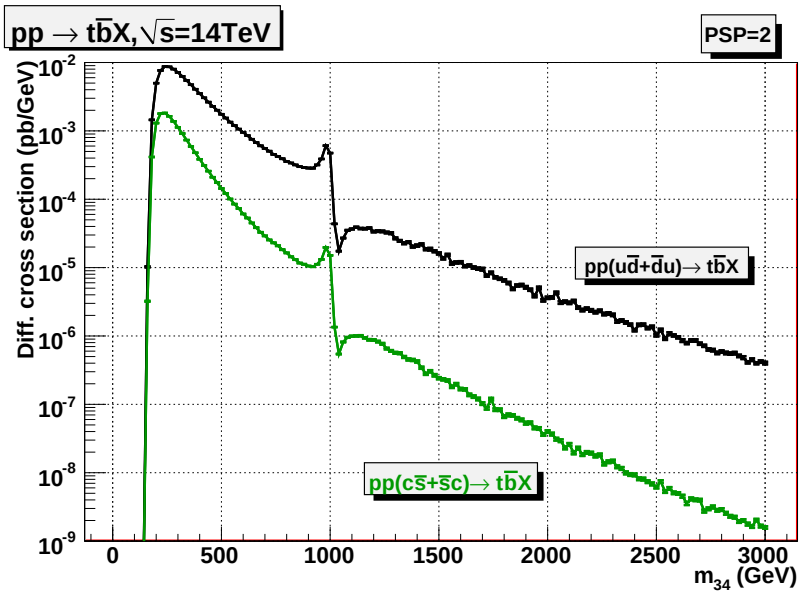


$\sigma(gg) = 1120$ pb

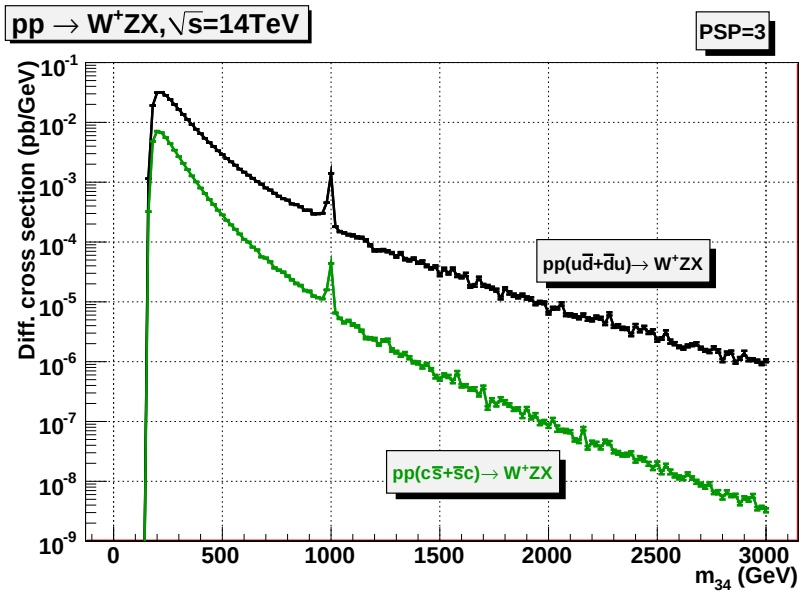
"Winner" processes

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

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



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



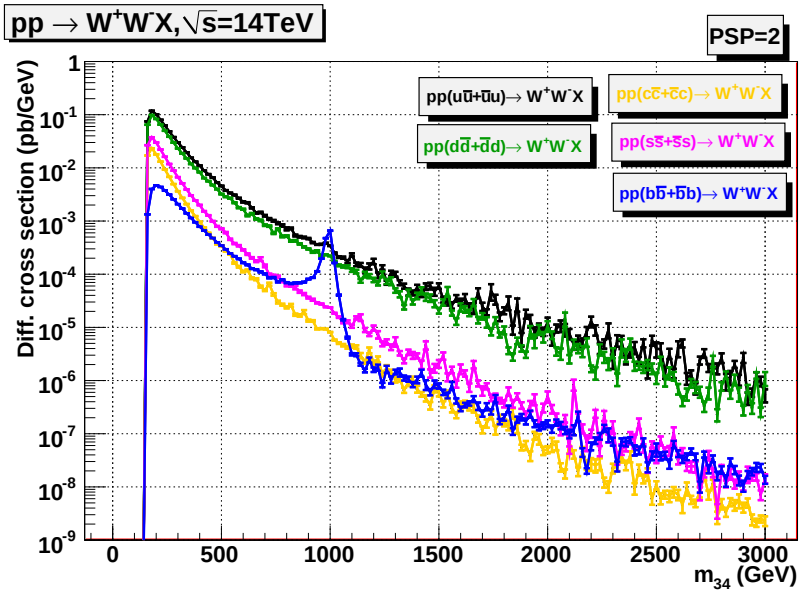
$$\sigma(u\bar{d} + \bar{d}u) = 3.92 \text{ pb}$$

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

"Winner" processes (cont'd)

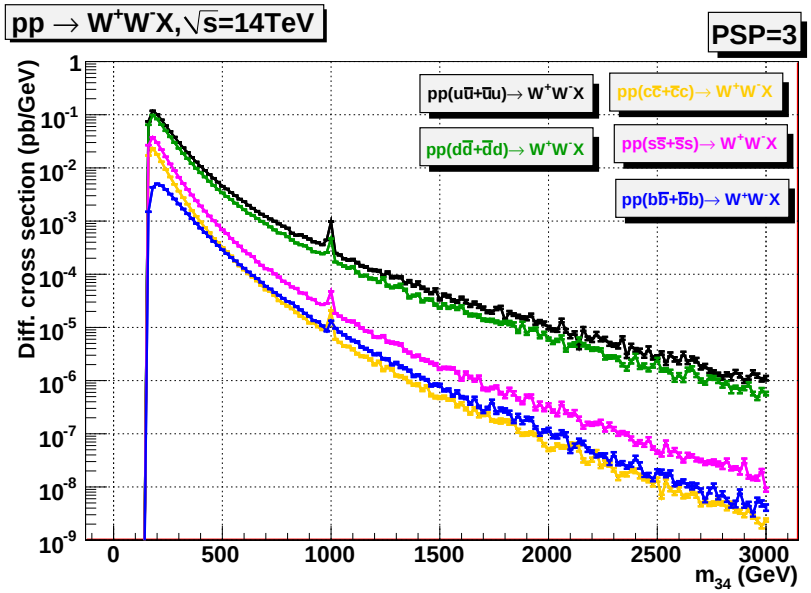
$$M_{\rho^0} = 1 \text{ TeV}$$

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



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

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



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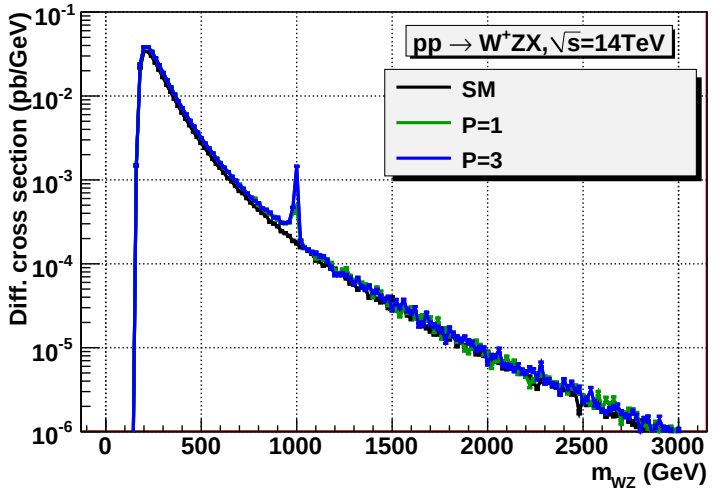
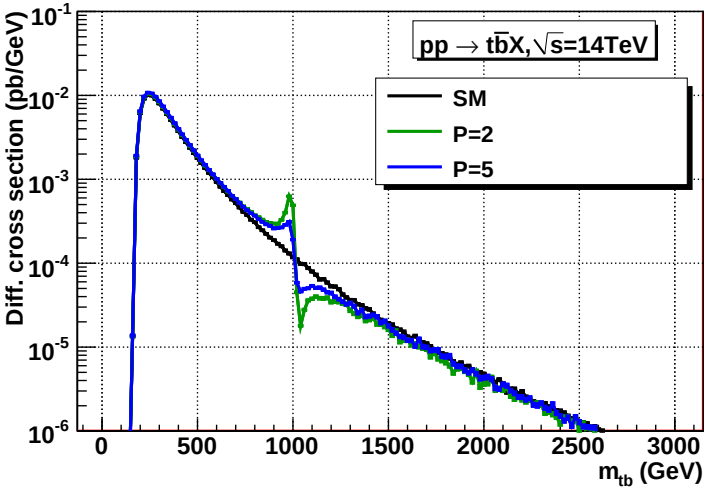
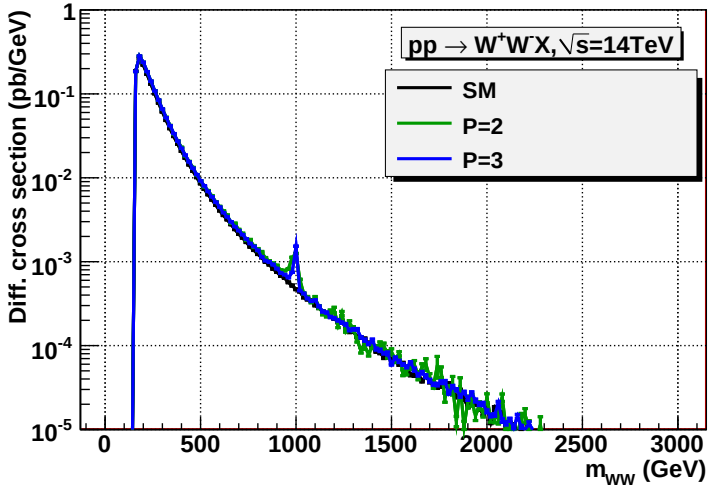
...SUMMING EVERYTHING UP:

$M_{\rho^0} = 1$ 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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