Strong vector boson scattering at the LHC

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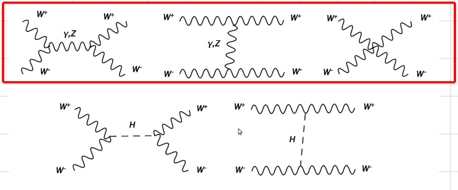
Electroweak Symmetry Breaking And Vector Boson Scattering

- The longitudinal Vector Boson Scattering (VBS) amplitudes grow with energy, eventually violating unitarity. $\rightarrow$ Symmetry Breaking Sector must intervene in order to restore unitarity.



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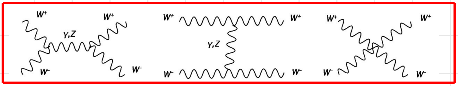
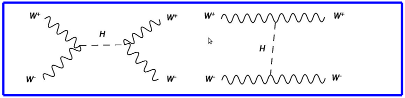


$$\rightarrow a_0(s) \sim \frac{s}{16\pi v^2} - \frac{s}{16\pi v^2}\frac{s}{s-m_H^2}$$



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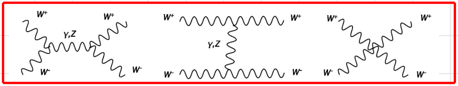
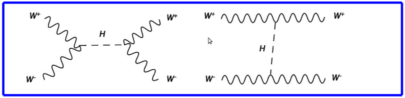




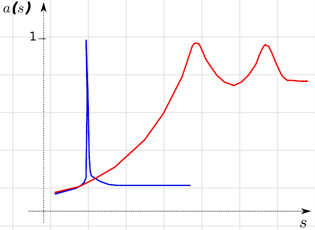
$$\to a_0(s) \sim \boxed{\frac{s}{16\pi v^2}} - \boxed{\frac{s}{16\pi v^2}\frac{s}{s-m_H^2}}$$

LET: Universal.

Higgs?: simplest possibility among many.

The scale in which the SB intervene gives the strenght of the SB sector...

1. For $\Lambda_{SB} \lesssim 1$ TeV $\rightarrow$ below unitarity limit (weakly coupled)
2. $\Lambda_{SB} \gtrsim 1$ TeV (strongly coupled)



Benchmark scenarios for strongly-interacting SB sector...

- with NO heavy resonances at reach:
  - NO HIGGS
  - SILH Strongly-Interacting Light Higgs Giudice, Grojean, Pomarol, Rattazzi
- with heavy resonances:
  - Explicit resonances (Technicolor)
  - Unitarization Protocols

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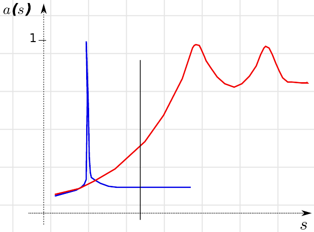

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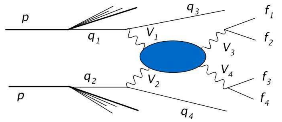
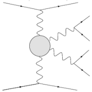
Our goal is to estimate the power of the LHC in discriminating between the SM and alternative strong-EWSB scenarios through VBS. (No Higgs and SILH)

Our approach to this goal is: 1- calculation, 2- kinematical study of signal and background and 3- statistical treatment.

1- The six-partons in the final state perspective;

- We can observe VB only through its decay to fermions;





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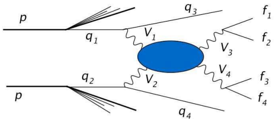
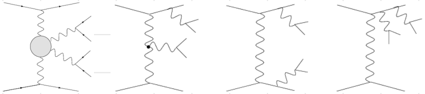




- We can observe VB only through its decay to fermions;
- Non trivial signal definition: We have to use complete calculations in order to
  - account for all irreducible backgrounds
  - avoid approximations like EVBA and NWA
  - deal with large gauge cancellations

Generated samples:

totally leptonic	**semi-leptonic**
$PP \to jj\ell^+\ell^-\ell'\nu$	$PP \to jjjj\ell\nu$
$PP \to jj\ell^\pm\ell^\pm\nu\nu$	$PP \to jjjj\ell^+\ell^-$
$PP \to jj\ell^+\ell^-\ell^+\ell^-$	
$PP \to jj\ell^+\ell^-\nu\nu$	$\ell = e, \mu$

- **PHANTOM 1.0** hep-ph/0801.3359
  - $\mathcal{O}(\alpha_{EM}^6)$: (VBS signal, irreducible background) $\to$ scenarios: $m_H = 200$ GeV, SILH and No Higgs. (Recently implemented off-shell version of unitarization models and explicit resonances)
  - $\mathcal{O}(\alpha_{EM}^4\alpha_S^2)$ (VV+2 jets, top production)
- $\mathcal{O}(\alpha_{EM}^2\alpha_S^4)$ (V+4 jets) important for semi-leptonic channels - generated with MADEVENT.

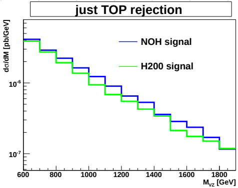
2- Systematic study of the kinematics of signal and background, apply selection cuts to supress the background and enhance the differences between alternative scenario and SM.

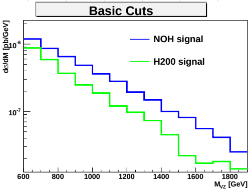
Guideline parameter: Probability of excluding the SM with 95% of CL assuming the strong scenario (PBSM@95%CL) ($L \approx 200 fb^{-1}$) .

Basic signature:

- tag-jets: two high energetic jets in forward-backward direction;
- two pairs of fermions associated with the bosons in the central region with high P_T.

Basic Selection Cuts
$\Delta\eta(j_f j_b) > 4$
$M(j_f j_b) > 100$ GeV
$\eta(\mu\mu) < 2$
70GeV$< M(j_c j_c) <$ 100GeV
$\lvert M(jjj) - M_{TOP}\rvert > 15$ GeV

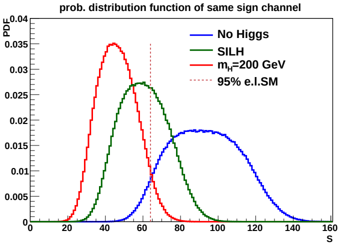




Further supression of $\mathcal{O}(\alpha_{EM}^4\alpha_S^2)$ and $\mathcal{O}(\alpha_{EM}^2\alpha_S^4)$ backgrounds and enhancement of discrepancies between scenarios in order to optimize significance.

3- Statistical treatement for estimating the discriminatory power of each model at the LHC: computing the PBSM@95%CL.

- theoretical error due to parton distribution and higher order corrections: $\lambda \pm 30\%$ (not on V+4 jets);
- statistical fluctuation considered as poissonian.



$PP \to jjjj\ell\nu$

Selection Cuts
70 GeV $< M(j_c j_c) <$ 100 GeV
$M(j_f j_b) >$ 1000 GeV
$\Delta\eta(j_f j_b) >$ 4.8
$\lvert\eta(\ell)\rvert < 2$
$\Delta R(jj) > 0.3$
$jjjj\ell\nu$
$\lvert M(jjj; j\ell\nu) - M_{top}\rvert >$ 15 GeV
$p_T(\ell\nu_{rec}) >$ 200 GeV
$\Delta\eta(Vj) > 0.6$
$p_T(j_c) >$ 70 GeV
missing p_T >100GeV
$M(j_c j_c \ell\nu) >$ 600 GeV

events expected for $L = 200 fb^{-1}$:

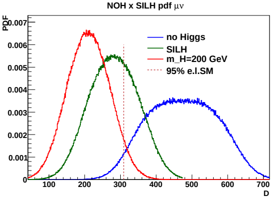
$PP \to jjjj\ell\nu$

S(noHiggs)=473.6

S(SILH)=281.6

S(m_H = 200GeV)=210.4

B(V+4jets)=1956



PNOH@95%CL = 97%

PSILH@95%CL = 35%

Combining results

non-reconstructable ($2j\ell^{\pm}\ell^{\pm}\nu\nu$, $2j\ell^{+}\ell^{-}\nu\nu$)		
	NOH	SILH
95%CL	99.9383 %	54.0718 %
99.7%CL	98.9175 %	33.9020 %

reconstructable ($4j\ell\nu$, $4j\ell\ell$, $2j3\ell\nu$)		
	NOH	SILH
95%CL	99.9376 %	51.5 %
99.7%CL	98.9751 %	30.5035 %

hep-ph/0909.3838

Last comments

- Unitarization models implemented in PHANTOM, under study;
- Hadronic issue: merged jets;
- In collaboration with CMS, analysis notes: AN2007/005 and AN2010/061;