# Boson Boson scattering analysis

**A. Ballestrero**
INFN Torino

# Outline

**Probe of EWSB**

**Properties of VBS**

**NoHiggs and Silh benchmark**

**Unitarized Models implementation**

**Comparison wit EVBA**

**Counting experiments with UM**

**Outlook at 7 TeV**

**Conclusions**

**In collaboration with: E.Maina, G. Bevilacqua, D.B. Franzosi, L.Oggero**

# Probe of EWSB

Despite the huge effort in the search for the Higgs, EWSB mechanism remains unclear

High energy vector boson scattering continues to play a central role,
either as a test of the nature of the Higgs boson
or as one of the main experimental grounds
to the understanding of which alternative theory is at work

The relevance of high energy vector boson scattering :

boson boson elastic scattering violates perturbative unitarity without higgs contributions
for L polarized vector bosons at about 1 TeV

If the higgs is not there, some other mechanism must show up to tame this violation

$V_L\, V_L$ elastic scattering depens on it

Many theories have been studied which provide alternative EWSB

Different interactions among vector bosons depend also on the scale $\Lambda$ of EWSB

$\Lambda_{SB} \lesssim 1$ TeV below unitarity limit

**SB sector is weakly coupled** (small amplitudes)

Perturbative method work

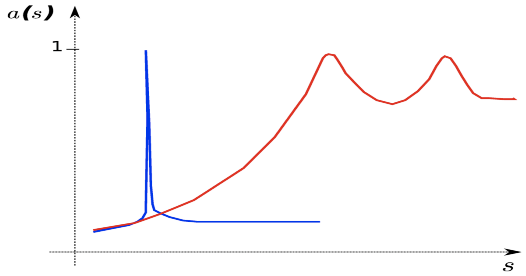
SM Higgs Boson, Susy

$\Lambda_{SB} \gtrsim 1$ TeV

**SB sector is strongly coupled** (large amplitudes)

QCD like resonance specturm

Dynamical Symmetri Breaking, Technicolor, Eztra Dimensions...




**Strong Vector Boson Scattering**

## SILH Strongly interacting light Higgs

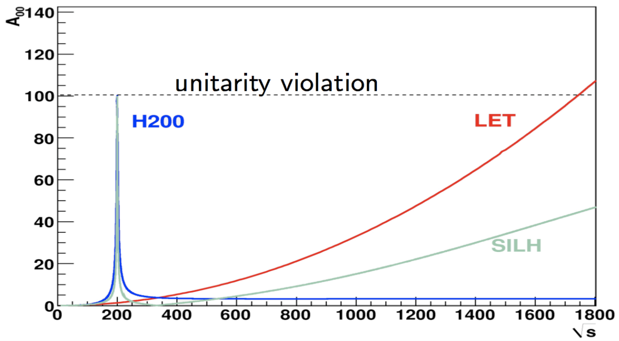
(Giudice Grojean Rattazzi...)

**Higgs a pseudo Goldstone Boson of a new strong sector**
**Both a light higgs and Bosons strongly coupled**

Modified higgs coupling

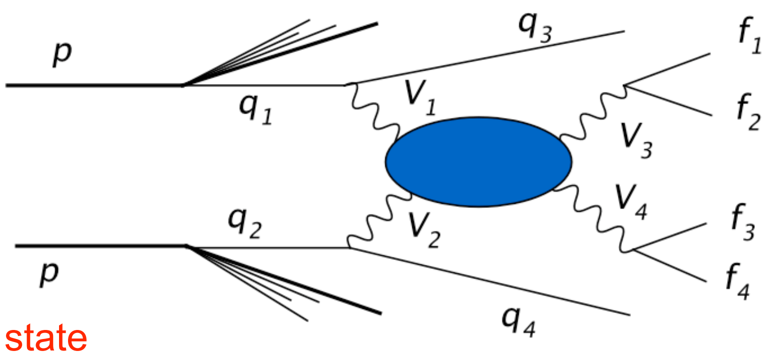
$h \rightarrow h/\sqrt{1+\xi c_H},\ \xi = v^2/f^2$

Little Higgs Holographic Higgs



# Properties of VBF

What we observe at LHC:

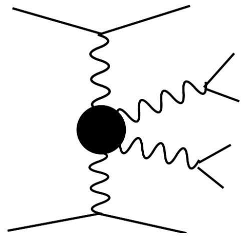



Off Shell incoming and six fermion final state

Equivalent Vector Boson Approximation connects it to elastic scattering

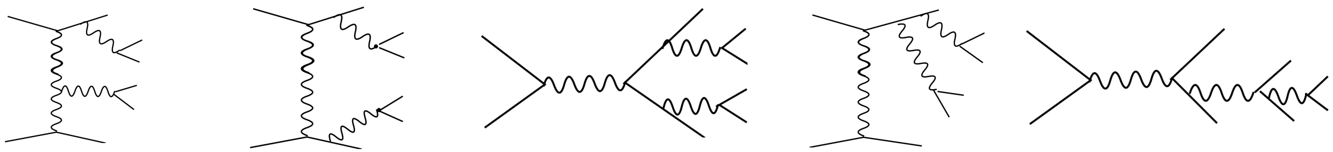
But in reality

Final state is produced by boson boson fusion diagrams



AND

all other topologies

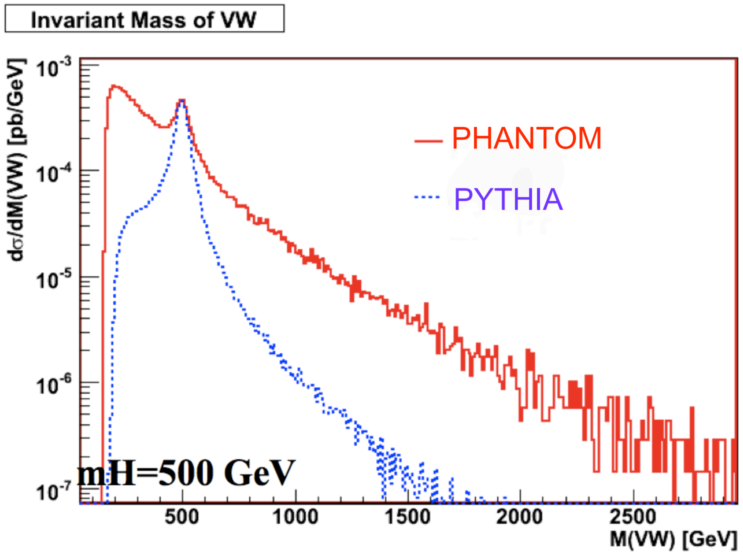


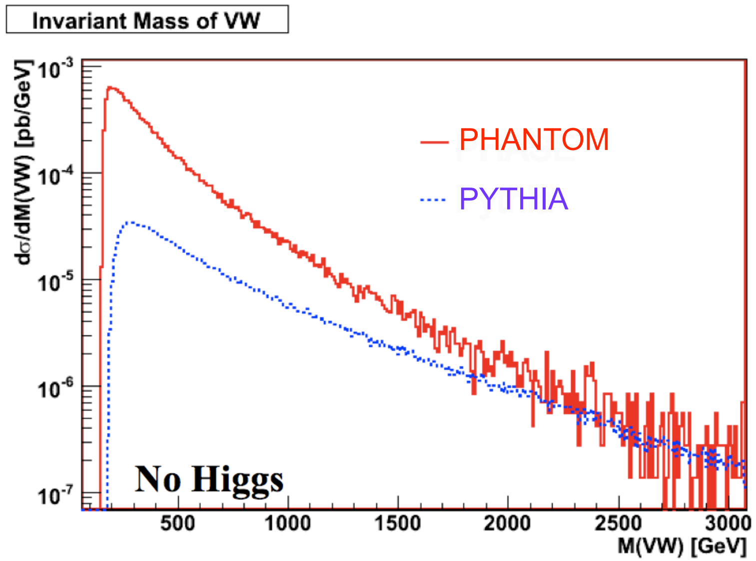
The two sets are not separately gauge invariant
and there are huge interference cancellations

# Properties of VBF

Lot of phenomenological studies have been made in EVBA

which nowadays seems inadequate




PYTHIA has only LL in EVBA approximation

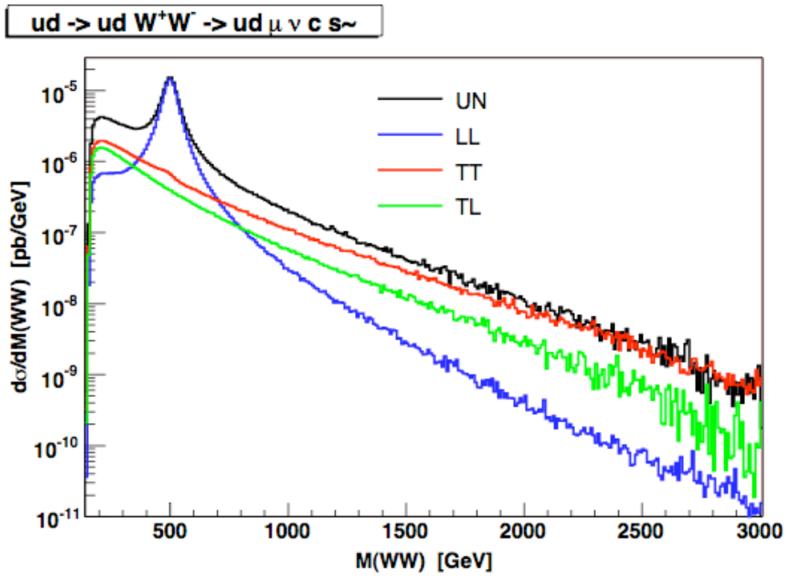
After: Top veto, W mass cut $p_T^W > 50$ GeV in WW CM

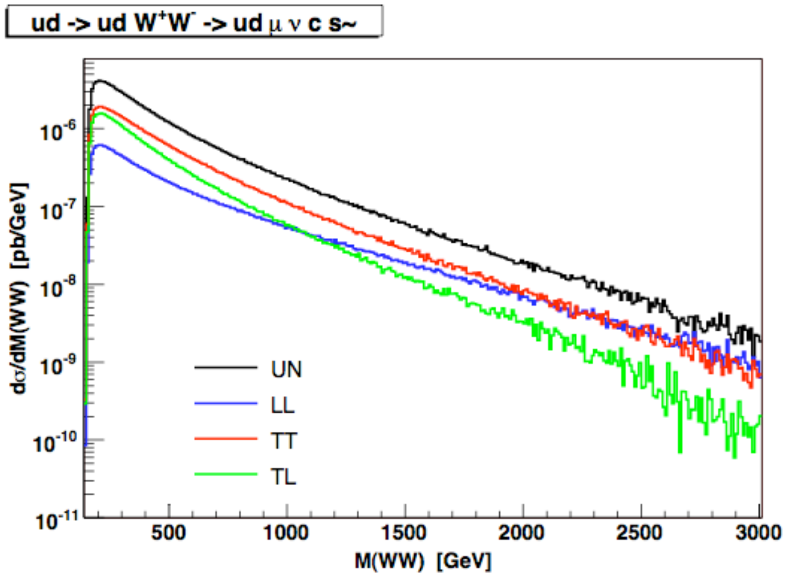
PHANTOM is a LO Monte Carlo and generator which can compute full contributions to any process with 6 parton in the final state for LHC, Tevatron, ILC at $\mathcal{O}(\alpha_{em}^6) + \mathcal{O}(\alpha_{em}^4 \alpha_s^2)$

VBFNLO (Zeppenfeld Oleari ...) computes vector boson scattering at NLO in six fermion final states for fully leptonic boson decays.

General purpose ME MC may be used

Contrary to what one expects LL do not dominate at high VV invariant mass




The decrease in the cross section at high invariant masses due to PDF suggests that careful analysis must be performed to evidentiate boson boson scattering effect

The invariant VV mass is the equivalent of the cm energy of the elastic VV scattering

Regions of the order of the TeV or higher in invariant mass must be examined for effects of alternative EWSB theories.

## The 7 channels:

**totally leptonic**

$PP \to jj\ell^+\ell^-\ell'\nu$

$PP \to jj\ell^+\ell^-\ell^+\ell^-$

$PP \to jj\ell^\pm\ell^\pm\nu\nu$

$PP \to jjW^+W^- \to jj\ell^+\ell^-\nu\nu$

$PP \to jjZZ \to jj\ell^+\ell^-\nu\nu$

**semi-leptonic**

$PP \to jjjj\ell\nu$

$PP \to jjjj\ell^+\ell^-$

$\ell = \mu,\, e$

**For the last 3 (2$\nu$) VV mass cannot be reconstructed**

Few analysis with complete calculations (not EVBA):

- CMS studies at hadron level with fast detector simulation
  CMS AN 2007/005 arXiv:1010.5848

- Studies on specific models
  eg. Zeppenfeld et al arXiv:0812.2564
  on warped higgless models

- Our results on benchmark and Unitarized Models

To study **VBS one would like to separate it from irreducible background** due to all other diagrams contributions

**Huge interferences and non gauge invariance forbid to do so**

**One has to rely on appropriate cuts to evidentiate boson boson contributions**

**Some cuts are obvious and well known :**

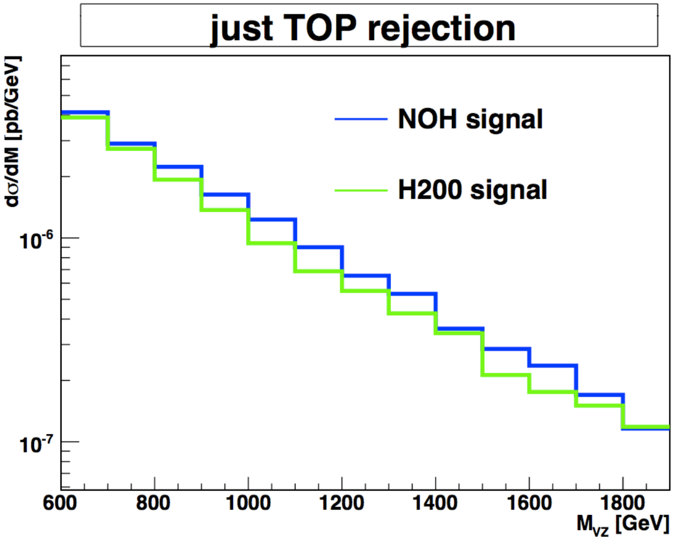
eg. large Δη separation between forward and backward jet

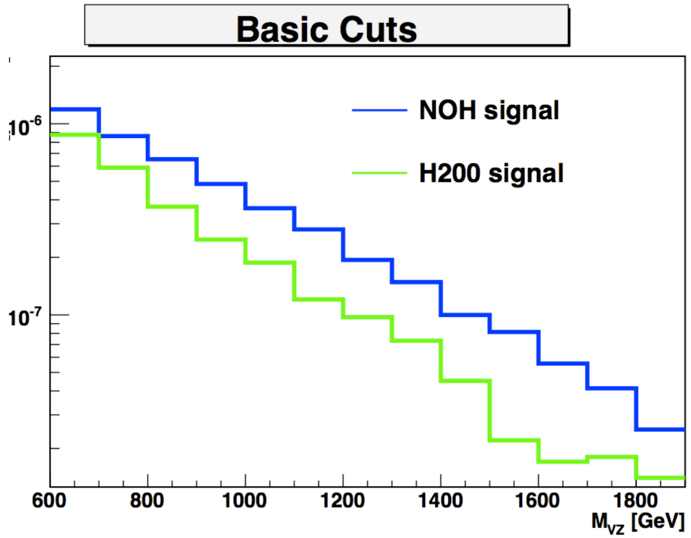
**A good strategy is that of looking for the cuts which increase the difference between light higgs (weak coupling) and no-higgs (strong coupling) distributions at high invariant VV masses**

PP -> 4jμμ

| Generation Cuts | |
|---|---|
| $\|\eta(\ell^\pm)\| < 3.0$ | $E(\ell^\pm) > 20$ GeV |
| $p_T(\ell^\pm) > 20$ GeV | $M(\ell^\pm\ell^\pm) > 20$ GeV |
| $\|\eta(j)\| < 6.5$ | $E(j) > 20$ GeV |
| $p_T(j) > 30$ GeV | $M(jj) > 60$ GeV |

| 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 |
| $\|M(jjj) - M_{TOP}\| > 15$ GeV |



Benchmark studies performed on two scenarios: no-higgs and Silh

✓ **no-higgs** :

model independent representative at LHC of Strong InteractingTheories

- One expects predictions similat to those of SIT at LHC:
  - sligtly higher than theories with no resonances below 2TeV
  - lower than those with lower mass resonant states
- Pdf strongly depress high VV invariant mass where its predictions are higher than unitary theories
- No higgs prescription is gauge invariant: corresponds to $m_H \to \infty$
  It is however not a consistent theory .

✓ **Silh:**

We have chosen Silh with $\xi c_H$=1 as representative of upper limit of model independent lagrangian description of these theories

- The main effect for these processes is the variation of the higgs coupling that correspond to a redefinition of higgs propagator.

$$\frac{1}{p^2-m_H^2} \longrightarrow \frac{1}{1+\xi c_H}\,\frac{1}{p^2-m_H^2}$$

- Cancellations do not occur exactly and the model violates unitarity
- The onset of the violation is postponed to higher a higher scale than SM

**All 7 channels analyzed at parton level at 14 TeV**

**Generated with Phantom all signals and irreducible backgrounds**

**Madevent used for Z /W +4jets at $\mathcal{O}(\alpha_{EM}^2 \alpha_S^4)$ and tt+jets**

**Performed careful analysis of the best cuts for the regions of interest**

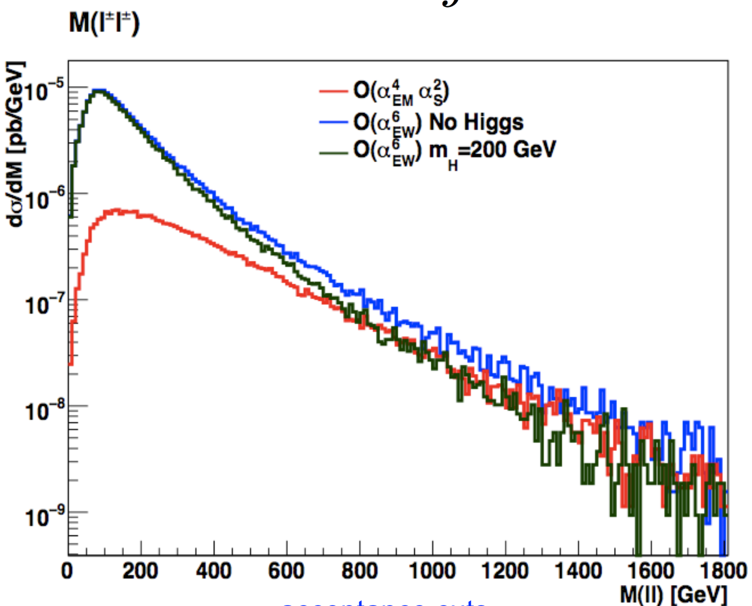
Typical basic and selection cuts used for the analysis

| **Basic Cuts** |
|---|
| $p_T(\ell^\pm) > 20$ GeV |
| $\|\eta(\ell^\pm)\| < 3.0$ |
| $M(\ell^+\ell^-) > 20$ GeV<br>$M(\ell^+\ell^-) > 250$ GeV $(2jW^+W^-)$<br>76 GeV $< M(\ell^+\ell^-) <$ 106 GeV $(2jZZ)$ |
| $p_T(j) > 30$ GeV |
| $\|\eta(j)\| < 6.5$ |
| $M(jj) > 60$ GeV<br>$M(j_f j_b) < 70$ GeV; $M(j_f j_b) > 100$ GeV |
| $\|\Delta\eta(jj)\| > 3.0$ $(2j2\ell 2\nu)$<br>$\|\Delta\eta(j_f j_b)\| > 4.0$ $(2j4\ell,\ 4j\ell\nu,\ 4j\ell\ell)$ |
| $\|M(jjj) - M_{top}\| > 15$ GeV $(4j\ell\nu,\ 4j\ell\ell)$<br>$\|M(j\ell\nu_{rec}) - M_{top}\| > 15$ GeV $(3\ell\nu + 2j,\ 4j\ell\nu)$ |
| 70 GeV $< M(j_c j_c) <$ 100 GeV $(4j\ell\nu,\ 4j\ell\ell)$ |
| $\Delta R(jj) > 0.3$ $(4j\ell\nu,\ 4j\ell\ell)$ |

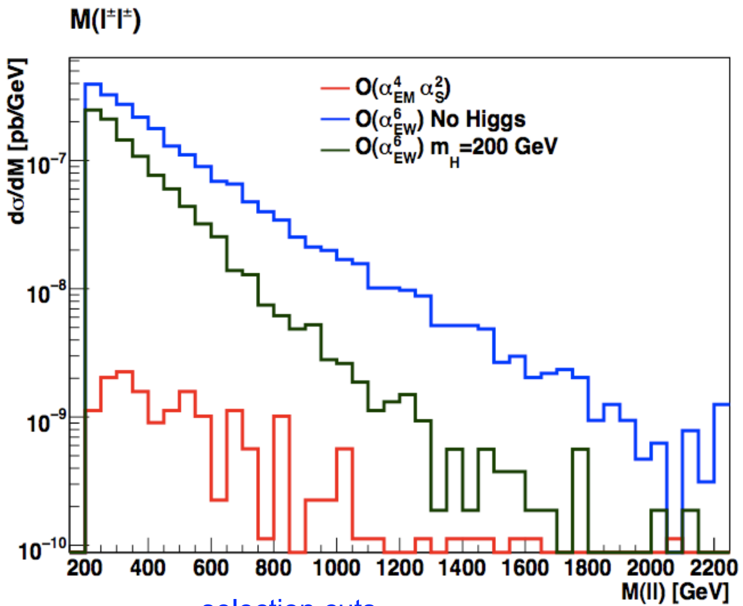
| Cuts / Processes | $2j\ell^+\ell'^-\nu\bar\nu$ $(W^+W^-)$ | $2j\ell^+\ell^-\nu\bar\nu$ $(ZZ)$ | $2j\ell^\pm\nu\ell^\pm\nu$ | $4j\ell\nu$ | $4j\ell\ell$ | $2j3\ell\nu$ | $2j4\ell\nu$ |
|---|---|---|---|---|---|---|---|
| $\|\eta(\ell^\pm)\| <$ | 2.0 | | | 2.0 | | 2.0 | |
| $M(j_f j_b) >$ | 1000 | 800 | | 1000 | 1000 | 1000 | 800 |
| $\|\Delta\eta(j_f j_b)\| >$ | 4.8 | 4.5 | 4.5 | 4.8 | 4.8 | 4.8 | |
| $p_T(j_c) >$ | | | | 70 | 60 | | |
| $p_T(j_c j_c) >$ | | | | | 200 | | |
| $p_T(\ell\nu) >$ | | | | 200 | | 200 | |
| $p_{T miss} >$ | | 120 | | 100 | | | |
| $p_T(\ell^+\ell^-) >$ | | 120 | | | 200 | 200 | 100 |
| $p_T(\ell) >$ | | | 50 | | | | |
| $min p_T(j) <$ | | | 120 | | | | |
| $E(j) >$ | 180 | | | | | | |
| $max\|\eta(j)\| >$ | 2.5 | | 2.5 | | 2.8 | | |
| $\|\eta(j)\| >$ | 1.3 | 1.9 | | | | 1.2 | |
| $\|\Delta\eta(Vj)\| >$ | | | | 0.6 | 1.1 | 1.5 | |
| $\Delta\eta(\ell j) >$ | 0.8 | 1.3 | | | | | |
| $\Delta R(\ell j) >$ | 1 | | 1.5 | | | | |
| $\Delta R(Zj) >$ | | | | | | | 1 |
| $M(\ell j) >$ | 180 | | | | | | |
| $M(Vj) >$ | | | | | 300 | | |
| $\|\vec{p}_T(\ell_1) - \vec{p}_T(\ell_2)\| >$ | 220 | | 150 | | | | |
| $\|\vec{p}_T(\ell^+\ell^-) - \vec{p}_T^{miss}\| >$ | | 290 | | | | | |
| $\cos(\delta\phi_{\ell\ell}) <$ | -0.6 | | -0.6 | | | | |
| $\cos(\delta\phi_{ZZ}) <$ | | | | | | | -0.4 |
| $\Delta R(\ell^+\ell^-) <$ | | | | | 1.0 | | |

# NoHiggs and Silh benchmark

## Result for one channel: $2j\ell^{\pm}\ell'^{\pm}\nu\nu$

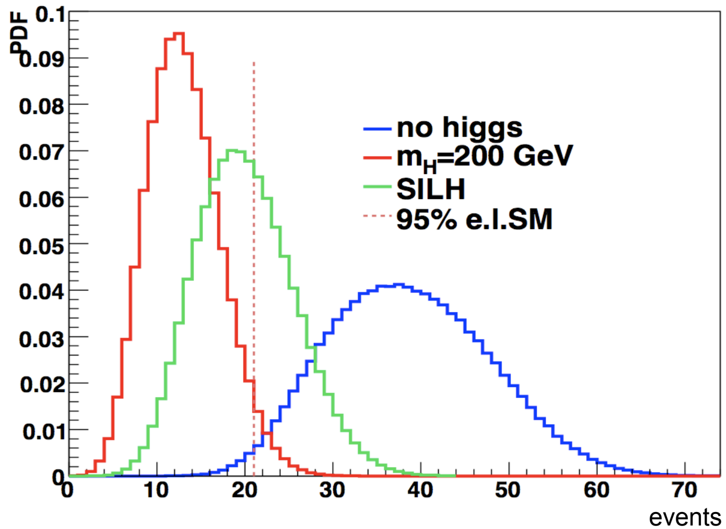



acceptance cuts




selection cuts

PDF. Statistical and th errors.



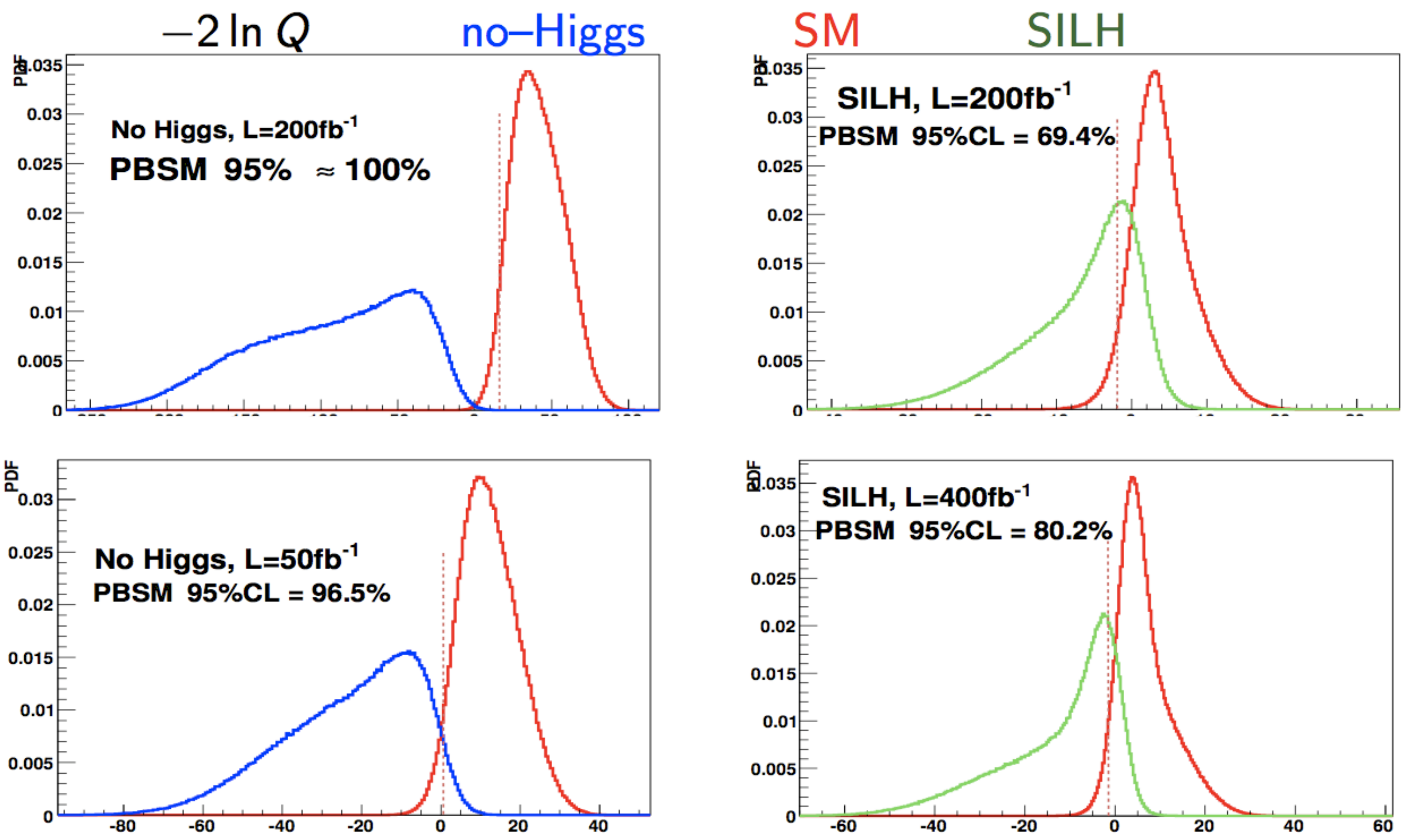

Th error assumed +- 30% Only stat for tt+2j and V+4j

Cross sections

| $M_{cut}$ (GeV) | no Higgs | | SILH | | $M_H = 200$ GeV |
|---|---|---|---|---|---|
| | $\sigma$(fb) | PBSM | $\sigma$(fb) | PBSM | $\sigma$(fb) |
| 200 | .435(.431) | 94.9% | .276 (.273) | 39.1% | .206(.203) |
| 300 | .290(.288) | 98.2% | .166 (.164) | 42.3% | .114(.111) |
| 400 | .191(.189) | 98.7% | .0977(.0958) | 41.2% | .0629(.0609) |
| 500 | .129(.128) | 98.7% | .0604(.0588) | 34.4% | .0351(.0336) |
| 600 | .0886(.0876) | 97.5% | .0385(.0375) | 37.1% | .0194(.0183) |
| 700 | .0614(.0607) | 96.6% | .0262(.0254) | 42.3% | .0112(.0105) |
| 800 | .0438(.0432) | 91.1% | .0184(.0178) | 31.2% | .00701(.00640) |

Full set of cuts . () = EW only PBSM at 95% L=200 $fb^{-1}$

## Combining all 7 channels (likelihood ratio)




$$Q(\vec{k};\vec{\lambda}_{BSM},\vec{\lambda}_{SM}) = \frac{\mathcal{P}(\vec{k};\vec{\lambda}_{BSM})}{\mathcal{P}(\vec{k};\vec{\lambda}_{SM})}, \qquad \sum_{\vec{k}} \mathcal{P}(\vec{k};\vec{\lambda}_{SM})\,\theta(\alpha - Q(\vec{k};\vec{\lambda}_{BSM},\vec{\lambda}_{SM})) = 95\%.$$

$$\text{PBSM@95\%CL} = \sum \mathcal{P}(\vec{k};\vec{\lambda}_{BSM})\,\theta(Q(\vec{k};\vec{\lambda}_{BSM},\vec{\lambda}_{SM}) - \alpha).$$

# Unitarization Models

Low energy VBS amplitudes violate unitarity at $\sqrt{s} \approx 1 - 2\ \mathrm{TeV}$. Unitarization models give a phenomenological description of these amplitudes much beyond these scales by forcing the divergent amplitudes to satisfy the unitarity condition.

- EWChL, describes the EW interaction at low energies through an expansion in $E/\Lambda$,

  $\mathcal{L} = \frac{v^2}{4} Tr\left[(D_\mu \Sigma)^\dagger D^\mu \Sigma\right]$ (W,Z masses, LET) $\Sigma = exp(i \frac{\sigma \cdot \omega(x)}{v^2})$

  $+\alpha_4 [TrV_\mu V_\nu]^2 + \alpha_5 [TrV_\mu V^\mu]^2$ (higher order operators) $V_\mu = (D_\mu \Sigma)\Sigma^\dagger$

  $+$ standard YM terms

  We compute the leading part of longitudinal VBS at high energies, e.g:

  $$A(W_L^+ W_L^- \to Z_L Z_L) = \frac{s}{v^2} + 4\alpha_4 \frac{t^2+u^2}{v^4} + 8\alpha_5 \frac{s^2}{v^4} + \cdots,$$

- To study unitarity issues, it is always convenient to expand $V_L$ elastic scattering in terms of partial wave amplitudes of definite angular momenta, $J$, and isospin, $I$ (associated with the custodial symmetry $SU(2)_{L+R}$ group).

  $$A_I(s,t) = 16\pi \sum_J (2J+1) a_{IJ}(s) P_J(cos\theta), \quad a_{IJ}(s) = a_{IJ}^{(1)}(s) + a_{IJ}^{(2)}(s) + \cdots.$$

- Elastic unitarity condition, Im $\hat{a}_{IJ}(s) = |\hat{a}_{IJ}(s)|^2$.

# Unitarized Model Implementation

Unitarized models modify the amplitudes in such a way that unitarity is satisfied keping the same low energy behaviour

Models implemented in PHANTOM

- K-matrix scheme:

$$a_{IJ}(s) \rightarrow \frac{1}{Re(1/a_{IJ}(s)) - i}$$

- Inverse Amplitude Method:

$$a_{IJ}(s) \rightarrow \frac{a^{(1)}_{IJ}(s)}{1 - a^{(2)}_{IJ}(s)/a^{(1)}_{IJ}(s)}$$

- N/D protocol:

$$a_{IJ}(s) \rightarrow \frac{N_{IJ}(s)}{1 + G(s)N_{IJ}(s)}$$

$$G(s) = \frac{1}{32\pi^2} \ln\left(-\frac{s}{M^2}\right)$$

$$N_{IJ}(s) = a^{(1)}_{IJ}(s) + a^{(2)}_{IJ}(s) + G(s)(a^{(1)}_{IJ}(s))^2 ;$$

In K-matrix scheme specific resonances (scalar vector or tensor) can be added to $a_{IJ}(s)$, while IAM and N/D prescriptions produce different resonances dependent on the specific value of $\alpha_4$ and $\alpha_5$ .

$\alpha_4$ and $\alpha_5$ constrained in the range (Eboli et al hep-ph/0606118)

$$-7.7 \times 10^{-3} < \alpha_4 < 15 \times 10^{-3}$$

$$-12 \times 10^{-3} < \alpha_5 < 10 \times 10^{-3}$$

# Off-Shell Implementation

It has been proposed (Chanowitz, hep-ph/9512358) and implemented in the WHIZARD MC (Kilian et al, hep-ph/0806.4145) an off-shell realization of UM; however, only on-shell phenomenological studies have been performed so far, relying on EVBA and NWA. We have independently implemented complete 6 fermions final state UM in PHANTOM and studied their phenomenological implications.

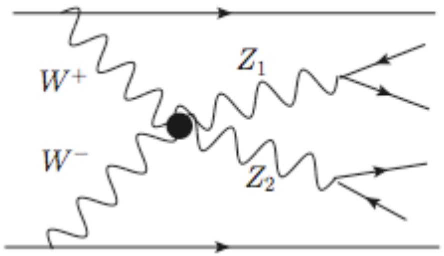
- Notice that the SM without Higgs already contains the LET part. Subtract LET part from on-shell amplitudes $\Delta A_{IJ}(s) = \hat{A}_{IJ}(s) - A_{IJ}^{LET}(s)$;
- Identify the process looking at the incoming and outcoming particles;
- Translate $A_{IJ}$ into individual scattering amplitudes, e.g.: $\Delta A(W_L^+ W_L^- \to Z_L Z_L) = 4\left[\frac{v^4}{12s^2}(\Delta A_{00}(s) - \Delta A_{20}(s)) - \frac{5v^4}{6s^2}(\Delta A_{02}(s) - \Delta A_{22}(s))\right]\frac{s^2}{v^4} + \left[\frac{5v^4}{s^2}(\Delta A_{02}(s) - \Delta A_{22}(s))\right]\frac{t^2+u^2}{v^4}$
- Embed elastic amplitude as effective quartic coupling, identifying the factors $s^2$, $t^2$ and $u^2$ with appropriate contraction of polarization vectors, e.g. in $W_L^+ W_L^- \to Z_L Z_L$

$s^2 \to 4M_W^2 M_Z^2\ \epsilon^+ \cdot \epsilon^-\ \epsilon^1 \cdot \epsilon^2$

$t^2 \to 4M_W^2 M_Z^2\ \epsilon^+ \cdot \epsilon^1\ \epsilon^- \cdot \epsilon^2$

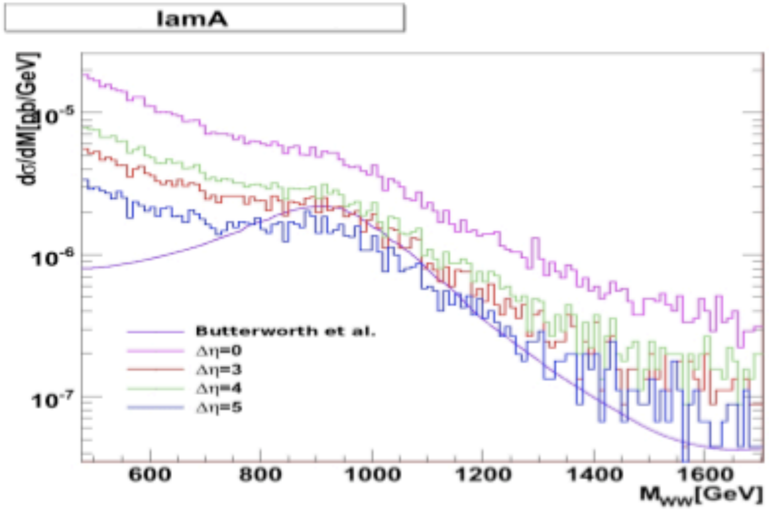
$u^2 \to 4M_W^2 M_Z^2\ \epsilon^+ \cdot \epsilon^2\ \epsilon^- \cdot \epsilon^1$

$\epsilon =$ 



# Results for Unitarization Models

Comparison with previous study (Butterworth et al, hep-ph/0201098) based on on-shell amplitudes and EVBA.



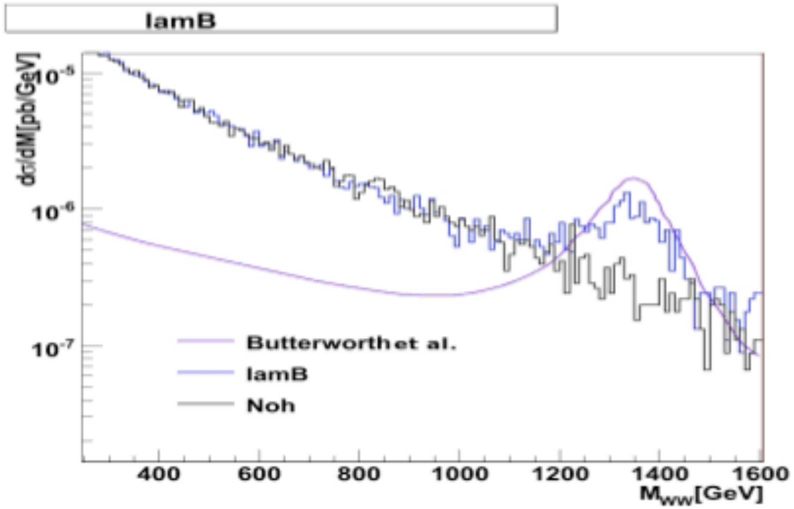

$2j\mu^{\pm}e^{\mp}\nu\bar{\nu}$

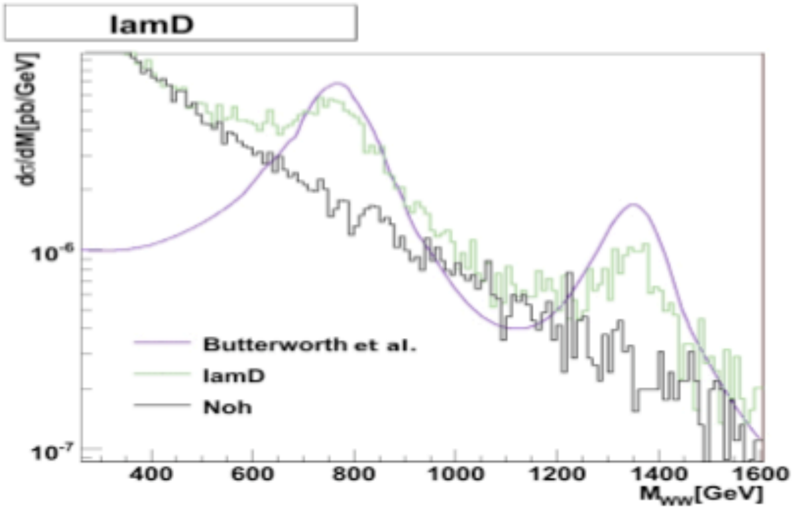
$\Delta\eta(jj) > 4$

no top processes

| scenario | $\alpha_4$ | $\alpha_5$ |
|---|---|---|
| IAM A | 0.0 | 0.003 |
| IAM B | 0.002 | -0.003 |
| IAM D | 0.008 | 0.0 |

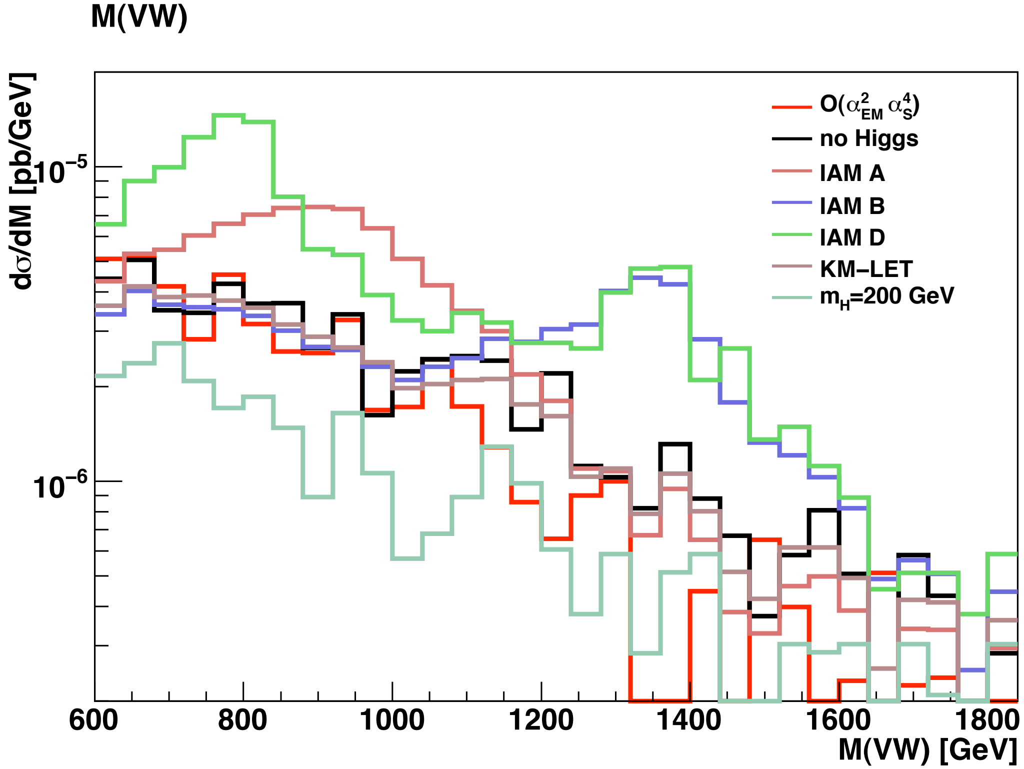
IAM determines resonances depending on chiral coeff:
IAMA 1 TeV scalar
IAMB 1.4 vector
IAMD 0.8 scal 1.4 vect



## 2 examples

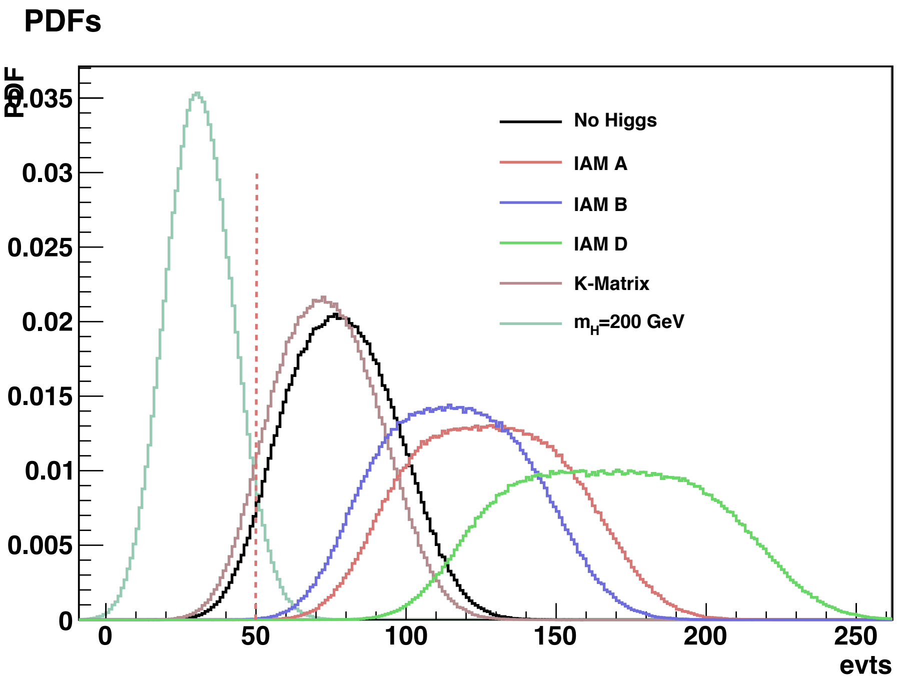
4jlν

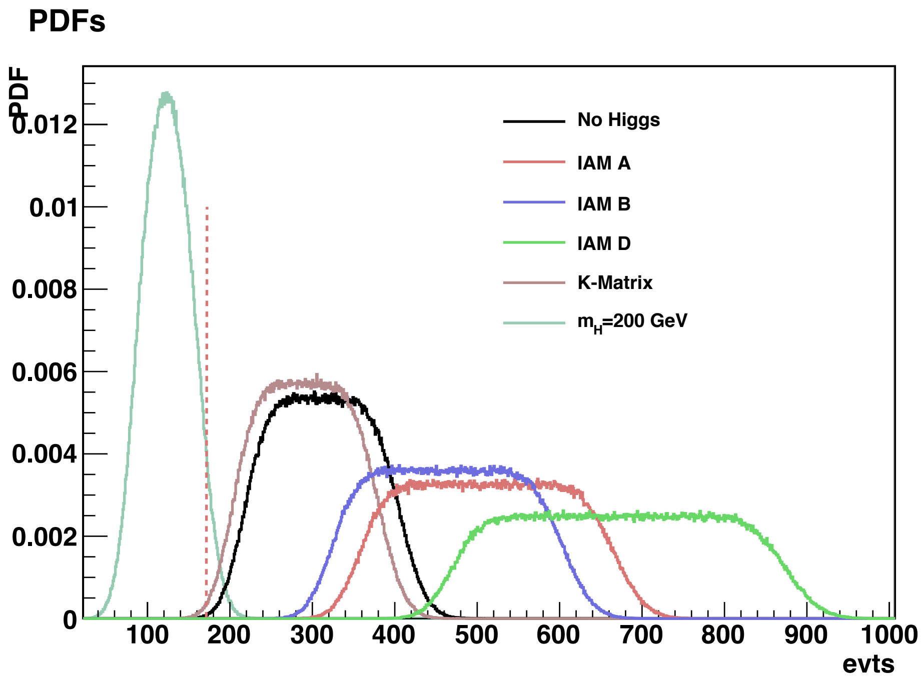



cross sections fb$^{-1}$
with all selection cuts

| $M_{cut}$ | no Higgs | KM-LET | IAM A | IAM B | IAM D | SM | $W+4j$ | $t\bar{t}+2j$ |
|---|---|---|---|---|---|---|---|---|
| 600 | 2.36 | 2.23 | 3.66 | 3.04 | 5.46 | 1.048 | 2.03 | .432 |
| 800 | 1.558 | 1.46 | 2.56 | 2.32 | 3.36 | .618 | 1.15 | .167 |
| 1000 | .966 | .877 | 1.13 | 1.76 | 1.90 | .338 | 0.62 | .0617 |
| 1200 | .526 | .478 | .414 | 1.26 | 1.27 | .188 | 0.30 | .0264 |

# Counting experiment with UM



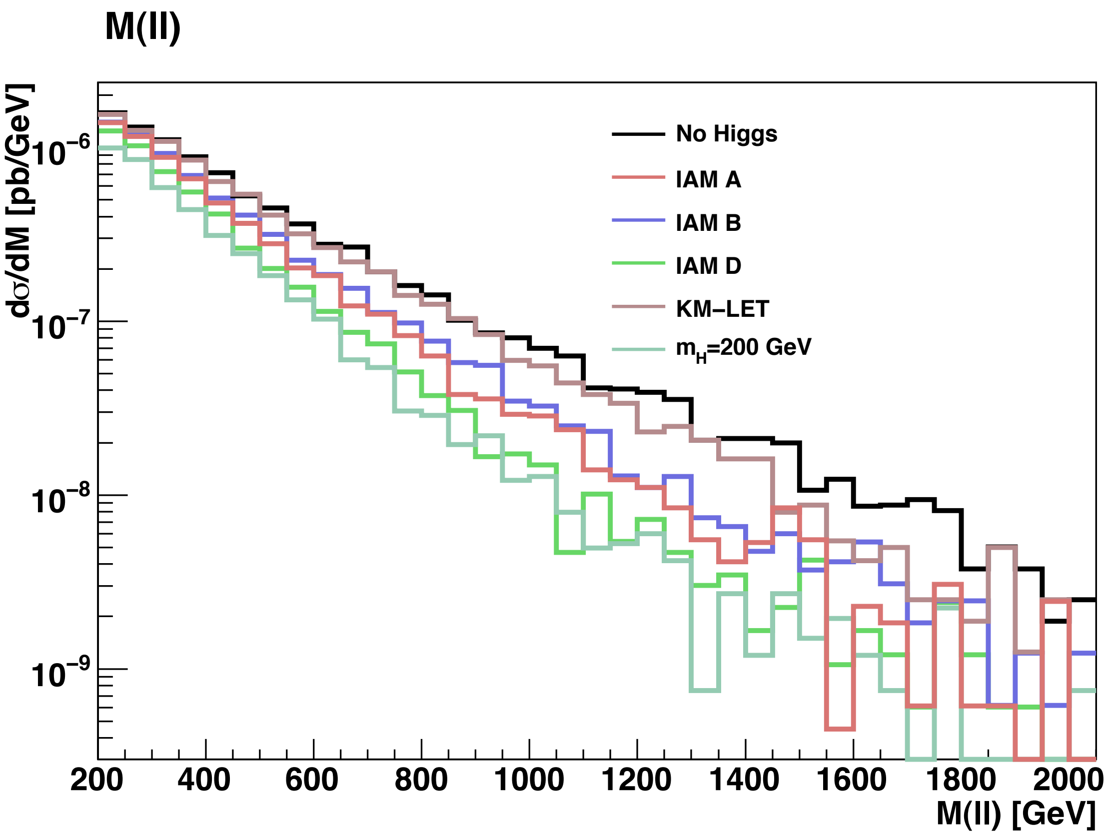




PBSM@95Cl

| $L$ fb$^{-1}$ | $M_{cut}$ | no–Higgs | KM-LET | IAM A | IAM B | IAM D |
|---|---|---|---|---|---|---|
| 50 | 800 | 94.51% | 91.03% | 99.99% | 99.97% | 100% |
| 200 | 800 | 99.93% | 99.64% | 100% | 100% | 100% |

## Counting experiment with UM

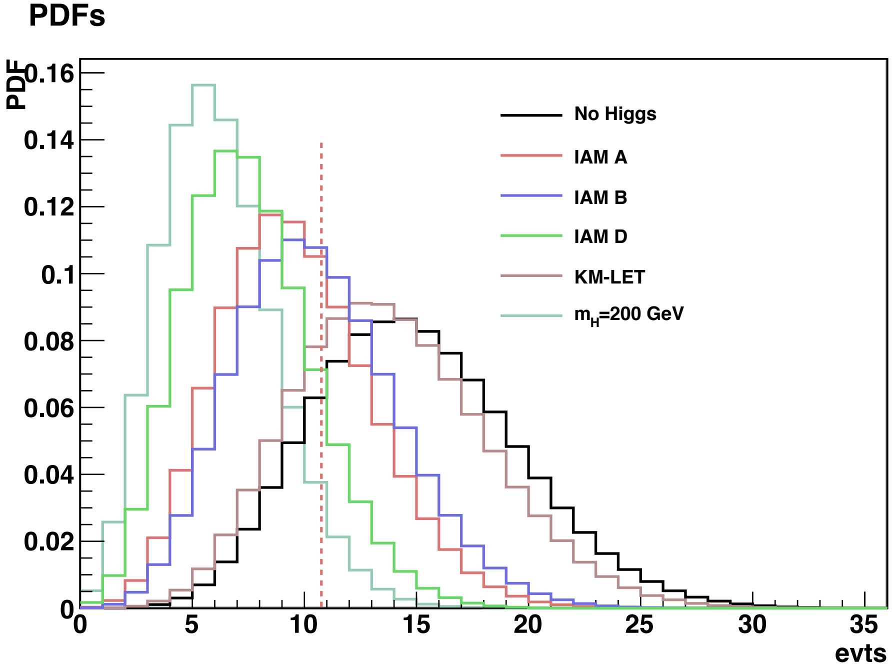
2jll$\nu\nu$ samesign

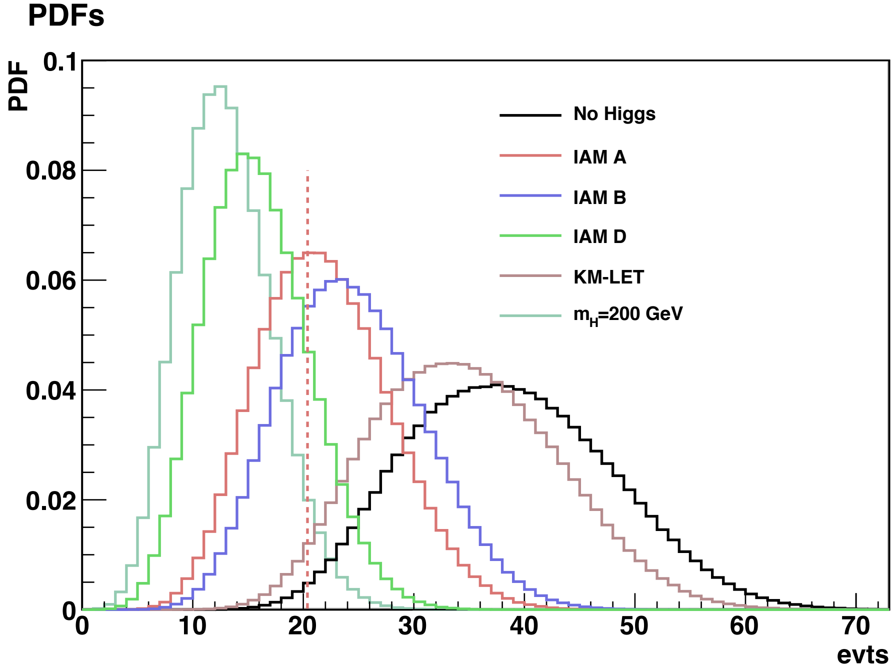



cross sections fb$^{-1}$
with all selection cuts

| $M_{cut}$ | no Higgs | KM-LET | IAM A | IAM B | IAM D | SM |
|---|---|---|---|---|---|---|
| 200 | .435 | .407 | .310 | .332 | .254 | .206 |
| 300 | .290 | .267 | .183 | .201 | .141 | .114 |
| 400 | .191 | .171 | .107 | .120 | .0768 | .0629 |
| 500 | .129 | .112 | .0643 | .0744 | .0430 | .0351 |
| 600 | .0886 | .0760 | .0403 | .0474 | .0250 | .0194 |
| 700 | .0614 | .0517 | .0250 | .0304 | .0150 | .0112 |

# Counting experiment with UM




PBSM@95CI

| $L$ fb$^{-1}$ | $M_{cut}$ | no–Higgs | KM-LET | IAM A | IAM B | IAM D |
|---|---|---|---|---|---|---|
| 50 | 300 | 81.42% | 74.36% | 34.48% | 44.36% | 13.60% |
| 200 | 400 | 98.96% | 96.92% | 57.72% | 72.03% | 17.21% |

# Outlook at 7 TeV

## Is it possible to study Boson Boson scattering at 7 TeV?
## With what L?

Preliminary work

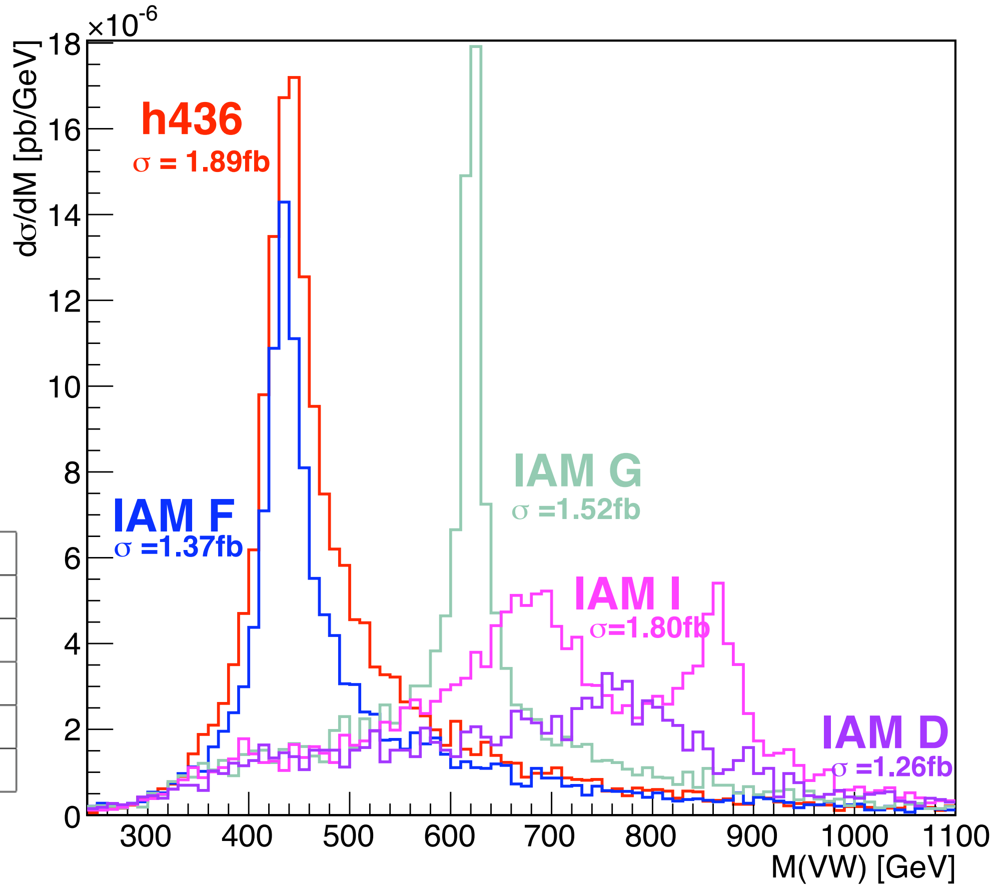
### New light resonances scenarios

| scenario | $\alpha_4 \times 10^3$ | $\alpha_5 \times 10^3$ | res | $\sim$ M$_r(TeV)$ |
|---|---|---|---|---|
| IAM A | 0 | 3 | s | 1 |
| IAM B | 2 | -3 | v | 1.4 |
| IAM D | 8 | 0 | s+v | 0.8 1.4 |
| IAM F | 15 | 10 | s | 0.44 |
| IAM G | 15 | -12 | v | 0.62 |
| IAM I | 15 | -2.5 | s+v | 0.7 0.87 |

### New reduced set of cuts

| **Cuts** $4j\ell\nu$ | |
|---|---|
| $\eta(\mu) < 2$ | $M(j_f j_b) > 100$ GeV |
| $p_T(\mu) > 20$ GeV | $\Delta\eta(j_f j_b) > 3$ |
| $\not{p}_T > 70$ GeV | $p_T(j) > 30$ GeV |
| $\Delta\eta(V j_{f,b}) > 0.3$ | $p_T(j_c) > 70$ GeV |
| $M(jV) - M_{TOP}\| > 15$ GeV | 60 GeV $< M(j_c j_c) <$ 100 GeV |

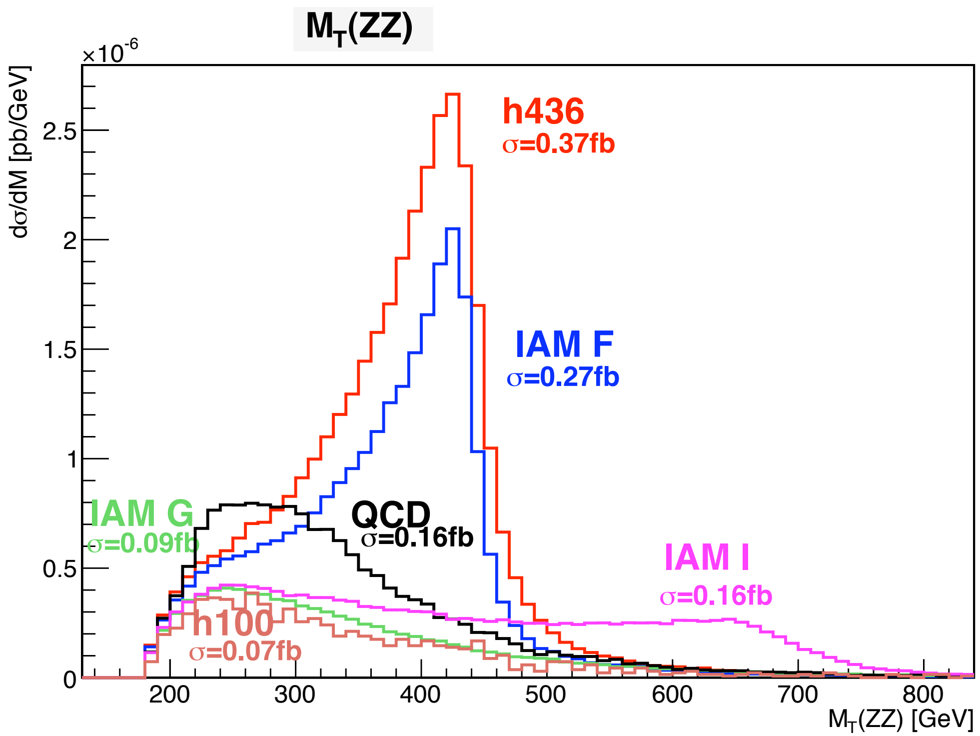
$$4j\ell\nu$$



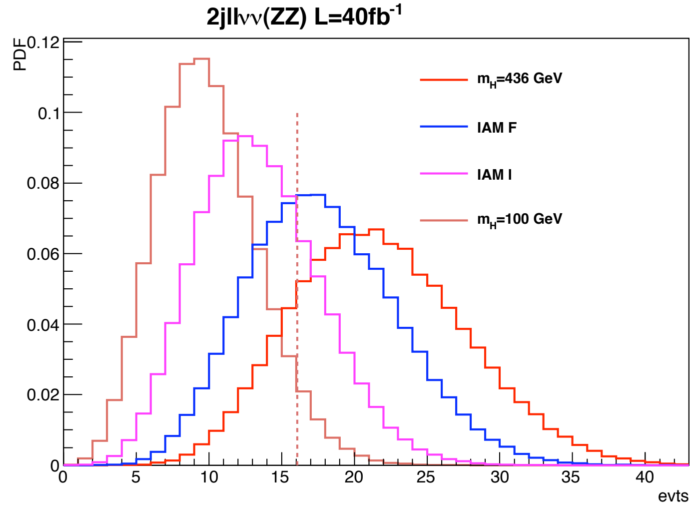
# Outlook at 7 TeV

$$2jZZ \rightarrow 2j\ell^+\ell^-\nu\nu$$

| Cuts $2jZZ \rightarrow 2j\ell^+\ell^-\nu\nu$ | |
|---|---|
| $\eta(\mu) < 3$ | $M(jj) > 100$ GeV |
| $p_T(\mu) > 20$ GeV | $\Delta\eta(jj) > 3$ |
| $\lvert M(\mu\mu) - M_Z \rvert < 15$ GeV | $p_T(j) > 30$ GeV |
| $\not{P}_{\mathbf{T}} > 120$ GeV | |



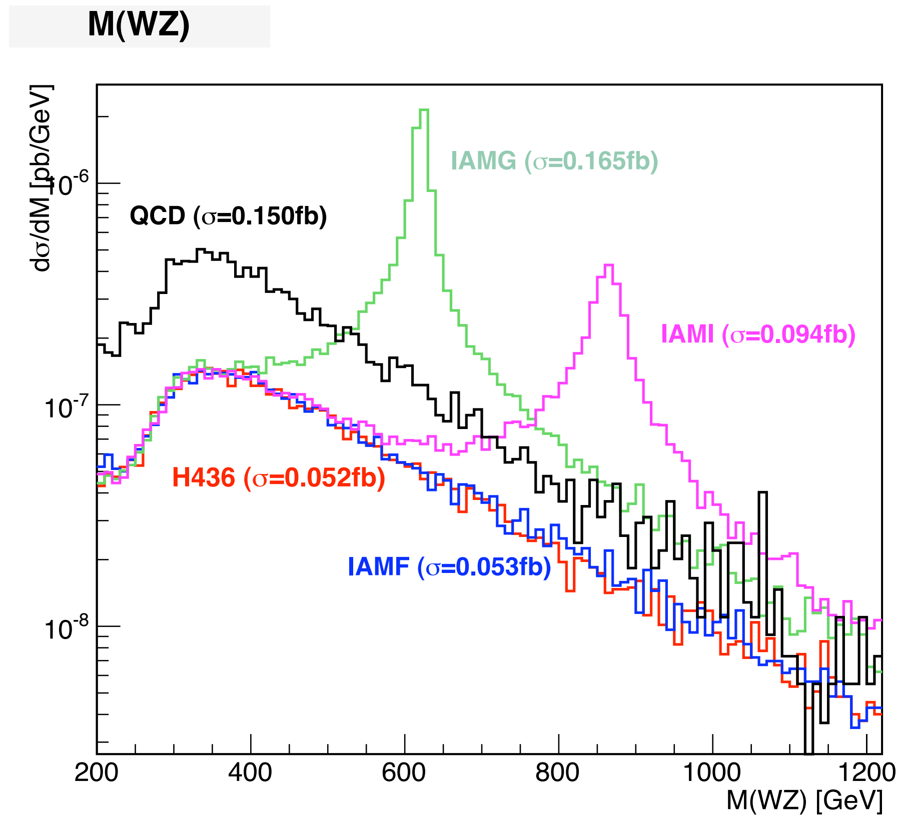

| Cross Sections (fb) and PBSM@95%CL | | | | | | |
|---|---|---|---|---|---|---|
| | IAM F | IAM G | IAM I | H436 | H100 | QCD |
| $\sigma$ | .270 | .090 | .159 | .368 | .0744 | .163 |
| PBSM $L = 20$ fb$^{-1}$ | 44.1714 | n.c. | 18.50 | 65.39 | — | — |
| PBSM $L = 40$ fb$^{-1}$ | 61.0219 | n.c. | 25.53 | 82.81 | — | — |



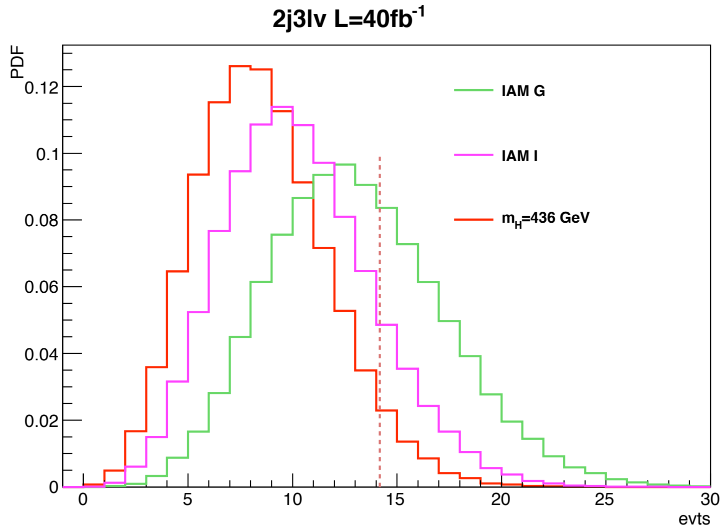
Outlook at 7 TeV

# $2j3\ell\nu$

| Cuts $2j3\ell\nu$ | |
|---|---|
| $\eta(\mu) < 3$ | $M(jj) > 100$ GeV |
| $p_T(\mu) > 20$ GeV | $\Delta\eta(jj) > 3$ |
| $p_T(Z) > 100$ GeV | $p_T(j) > 30$ GeV |
| $p_T(W) > 100$ GeV | $\Delta\eta(Vj) > 0.6$ |
| $\not{p}_T > 20$ GeV | |




| Cross Sections (fb) and PBSM@95%CL (%) | | | | | |
|---|---|---|---|---|---|
| | IAM F | IAM G | IAM I | H436 | QCD |
| $\sigma$ | .053 | .165 | .094 | .052 | .150 |
| PBSM $L = 20$ fb$^{-1}$ | n.c. | 26.50 | 11.00 | — | — |
| PBSM $L = 40$ fb$^{-1}$ | n.c. | 37.82 | 14.01 | — | — |



# Conclusions

- Boson Boson scattering is the most important channel for EWSB

- strong experimental effort needed:

  If higgs not found: to investigate it and try to discover fingerprints of new theories

  If a higgs is found: VV scattering could still be strong and different from SM predictions

- Unitarized models can serve as a guide to the exploration of this region and to predict what one could expect from a phenomenological point of view

- 7 TeV run at foreseen luminosity can only start to examine this region and possible scenarios

- 14 TeV at full lumi will surely prove or exclude most of possible alternatives to SM EWSB