Vector Boson(VV) Scattering and EWSB

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Fundamental Questions

- What breaks Electroweak symmetry ?
- Is Electroweak symmetry breaking(EWSB) realized through weakly or strongly coupled quanta ?

Experimentalist Answer:

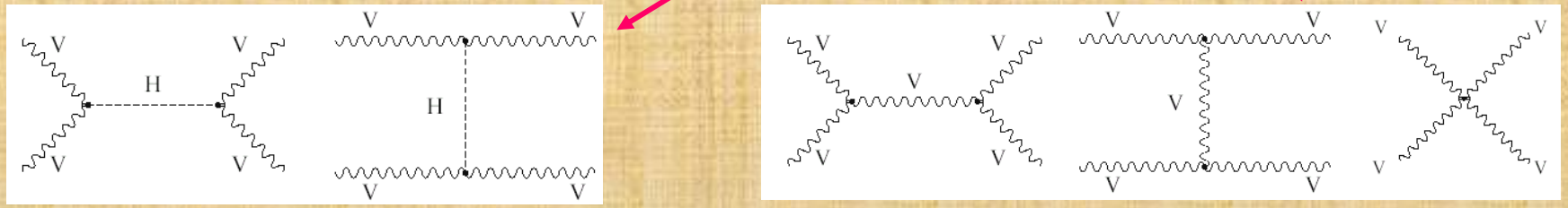
Go and measure $V_L V_L$ scattering at LHC !

This measurement essentialy probes the Higgs sector of the EW interactions

Probing EWSB

- VV scattering is model independent way to probe EWSB mechanism of SM
- SM predicts that if Higgs has a very high mass or doesn't exist then $V_L V_L$ scattering amplitude violates unitarity above 1 TeV => SM becomes strongly interacting

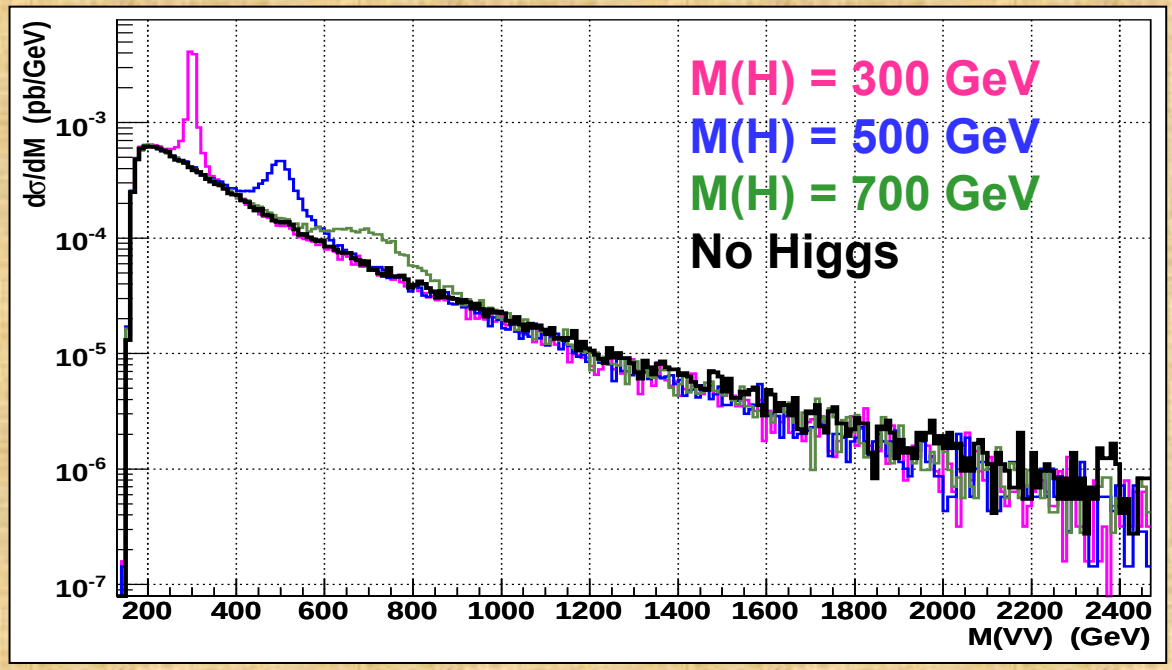
$$A(W_L W_L \to W_L W_L) \sim \frac{1}{v^2}\left(\frac{s^2}{s-m_H^2}+\frac{t^2}{t-m_H^2}-s-t\right)$$



EWSB Scenarios

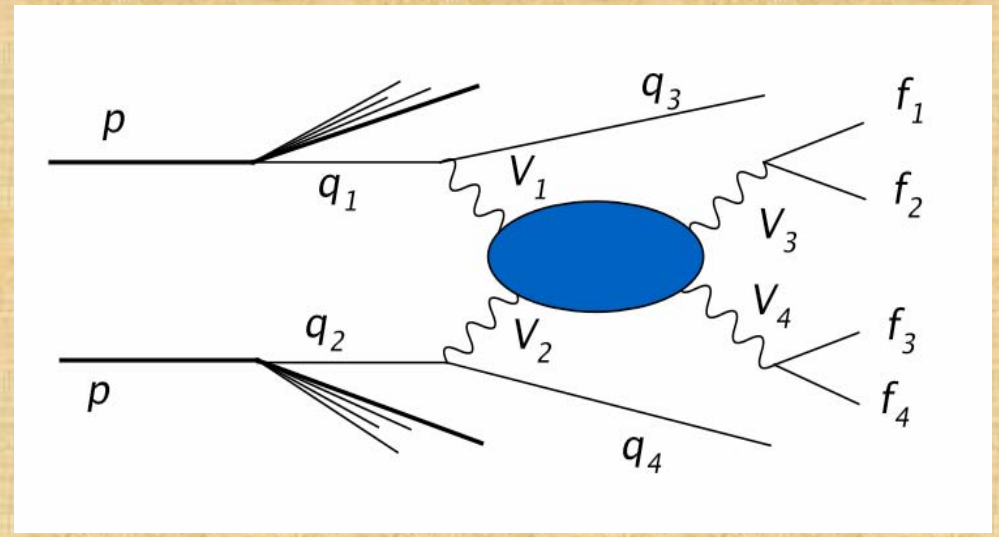
- For high mass Higgs it's important to measure σ_{VV} to disentangle it from new physics
- If there's no Higgs, SM violates unitarity and σ_{VV} should evidence new physics (new ressonances …)

=>In any scenario measurement of σ_{VV} will tell if EWSB mechanism of SM is correct. SM will be used as a benchmark for new physics !



Measuring VV Scattering

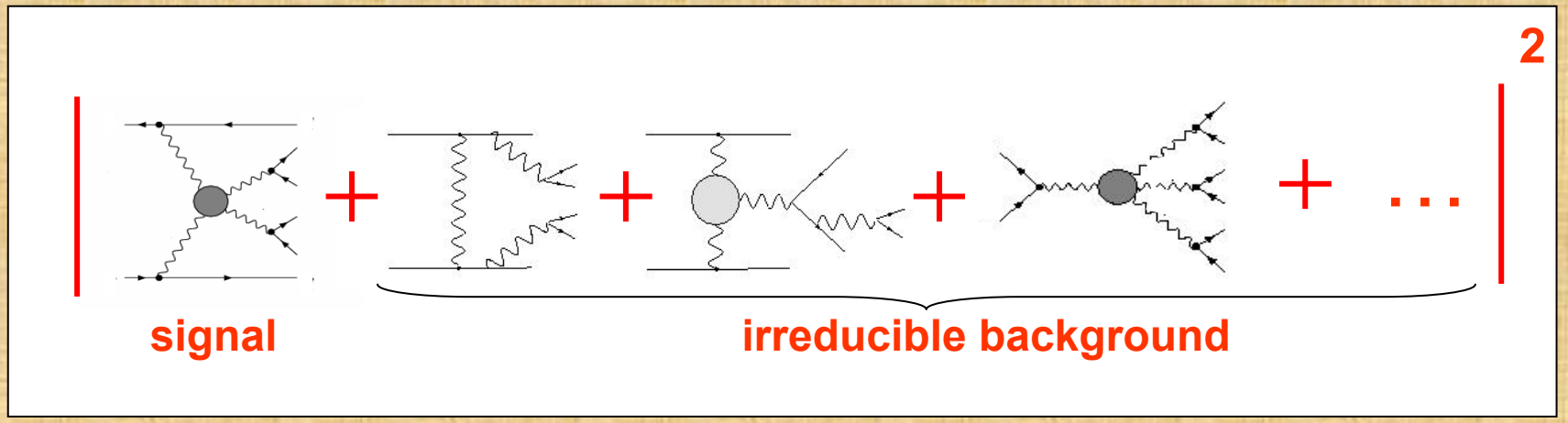
- Experimentally impossible to perform a direct measurement of VV scatering. Signal is always acompanied by irreducible background !
- Signature will be 6 fermions in the final state (2 forward jets + decay products of vector boson pair)
- To define our "signal" we have to look into regions of phase space where VV scattering gives large contributions



PHANTOM: Simulating VV Scattering

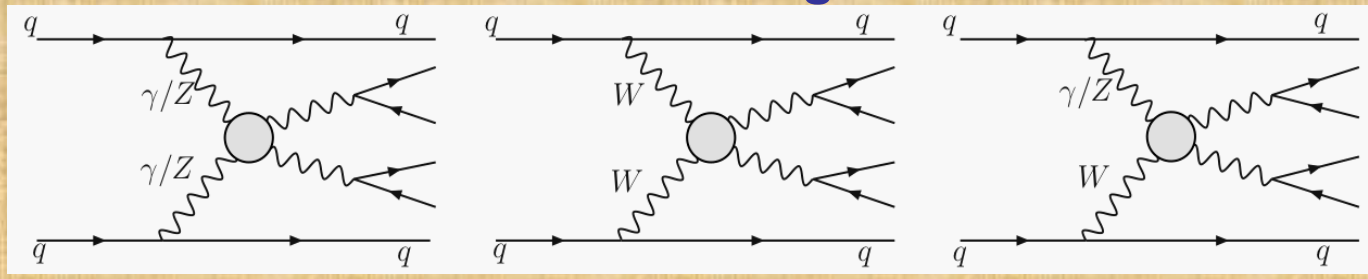
(A.Ballestrero,E.Maina,A.Belhouari,G.Bevilacqua http://www.to.infn.it/~ballestr/phase/)

- PHANTOM is a dedicated ME generator for processes with 6 fermions in final state (α_{EW}^6 , $\alpha_S^2 \alpha_{EW}^4$)
- Takes into account interference between signal and irreducible background diagrams
- Implements VV boson off shellness (important to describe the amplitude away from the Higgs ressonance)
- It uses of exact tree level matrix elements ! No EVBA or production times decay aproximation …

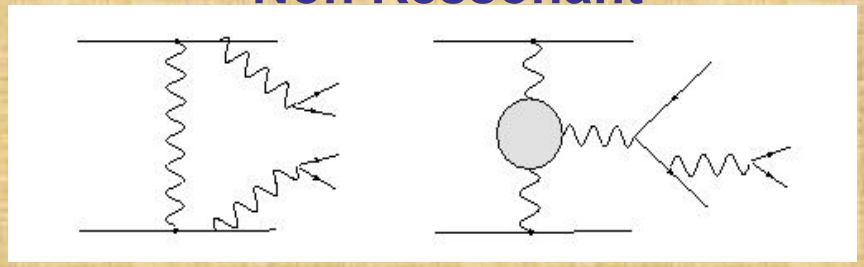


Examples of PHANTOM Processes

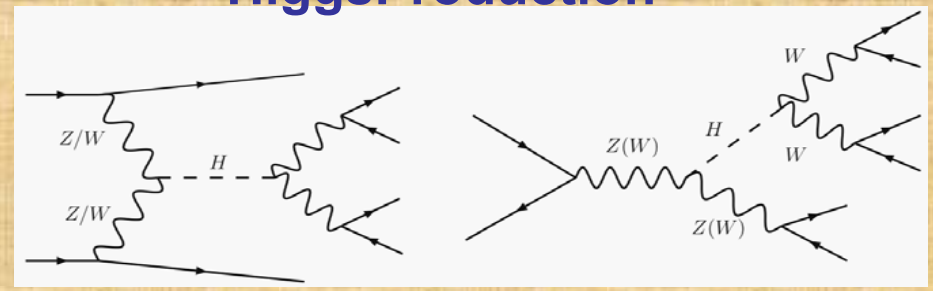
VV scattering



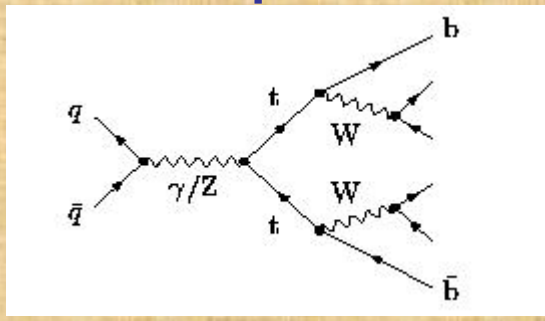
Non Ressonant



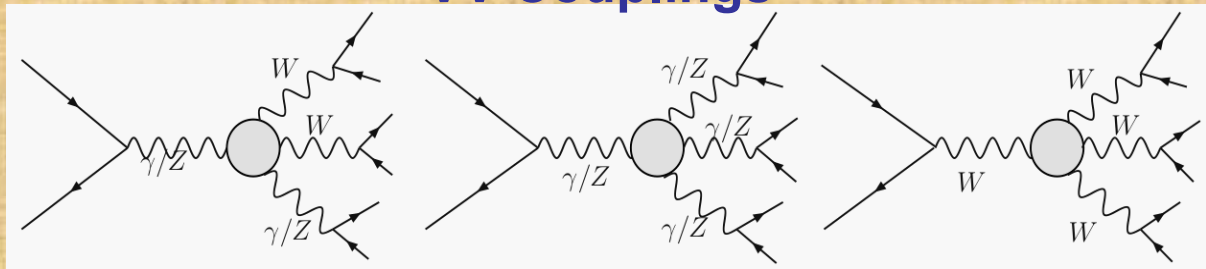
HiggsProduction



Top

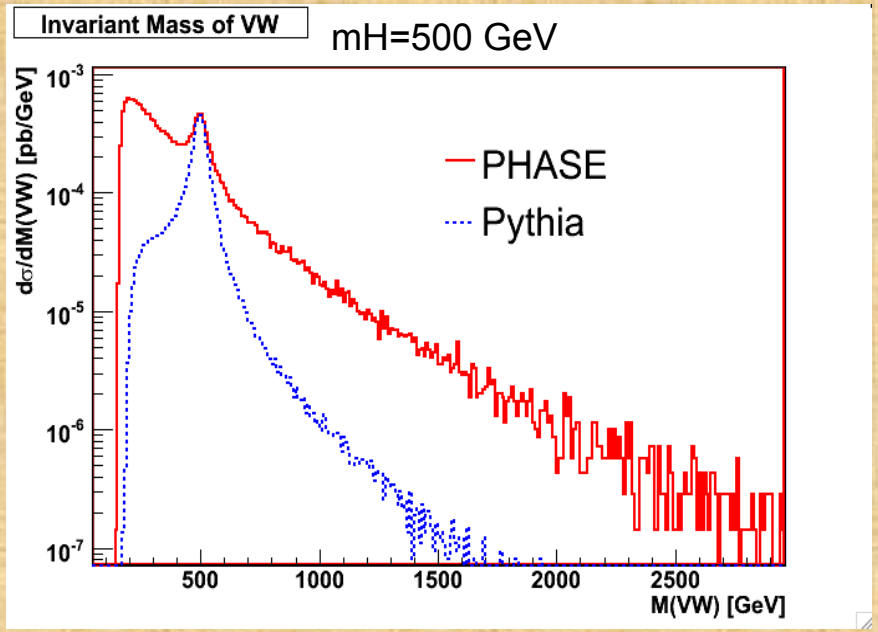


VV Couplings



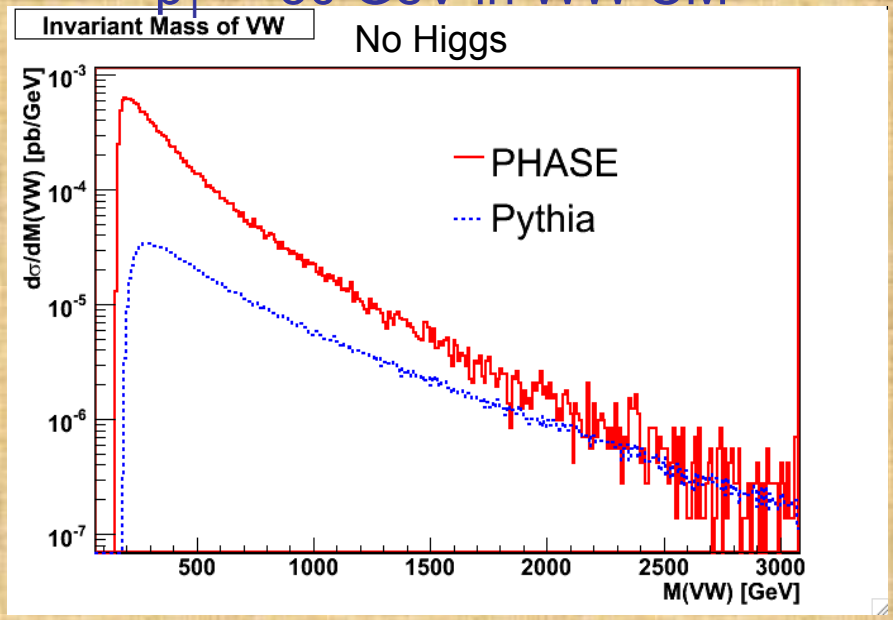
PHANTOM vs PYTHIA (qq→4qlv)

PYTHIA has only LL in EVBA approximation



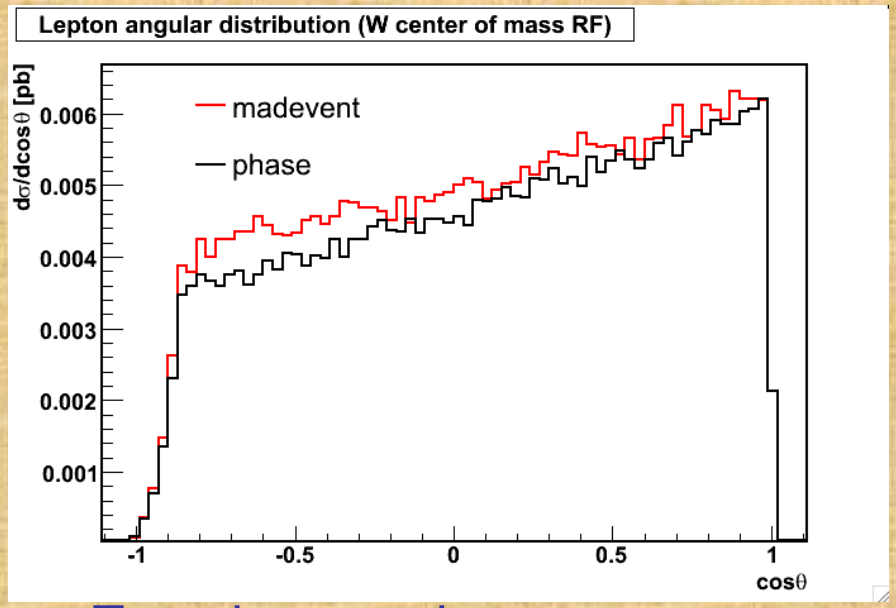
After: Top veto, W mass cut

p_T^W >50 GeV in WW CM



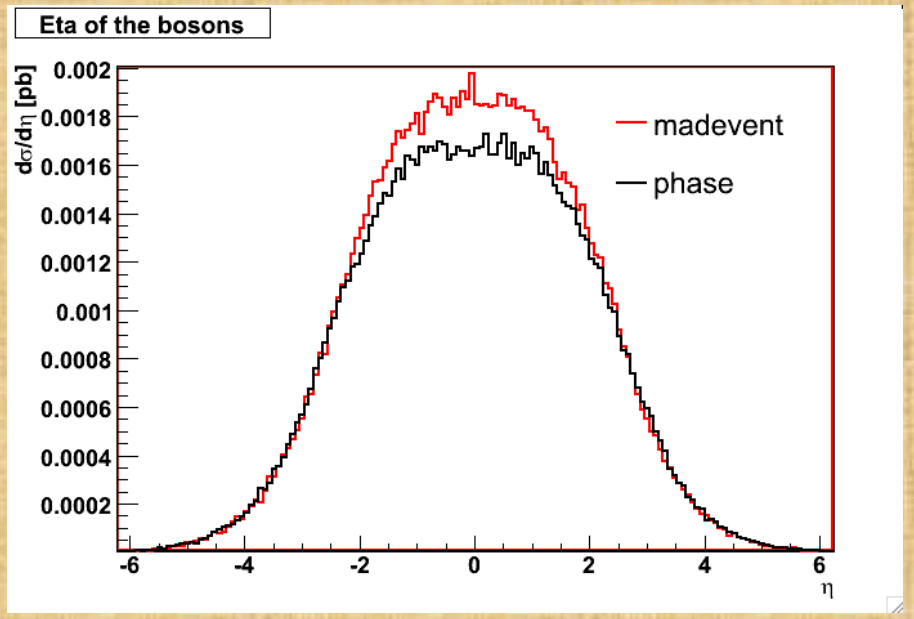
PHANTOM vs MADEVENT

MADEVENT qqWV Production⊗Decay aproximation.
(Can produce exact results but takes a lot of CPU time)



Tuned comparison
VVV production vetoed

uu->uuqq Single process
qq=u-dbar,c-sbar



VV Scattering and Cross Sections for No Higgs Scenario

Semileptonic Decay Modes:

- VW -> qqμν/eν (158 fb)
- VZ -> qqμμ/ee (16.4 fb)

Leptonic Decay Modes:

- WW -> μνμν same sign (9.52 fb oposite signs)
- WW -> μνμν same sign (4.30 fb same signs)
- ZW -> μμμν (1.20 fb)
- ZZ -> μμμμ (0.180 fb)

VV Scattering Reducible Backgrounds

Main backgrounds comes from $t\bar{t}$, VV+jets and V+jets.
Samples generated with ALPGEN 2.05 (bug fixed !)

WW	
SIGNAL	
$M_h = 500$ GEV	$\sigma = 60$ FB
$No - Higgs$	$\sigma = 20$ FB
BACKGROUND	
TOP–TOP	$\sigma = 6.2 \times 10^5$ FB
W+JETS	$\sigma = 7.7 \times 10^4$ FB
WW	$\sigma = 1.1 \times 10^3$ FB

ZZ+ZW	
SIGNAL	
$M_h = 500$ GEV	$\sigma = 9.1$ FB/ 0.7 FB
$No - Higgs$	$\sigma = 1.7$ FB/ 1.4 FB
BACKGROUND	
TOP–TOP	$\sigma = 6.2 \times 10^5$ FB
Z+JETS	$\sigma = 1.4 \times 10^7$ FB
ZZ	$\sigma = 6.6 \times 10^5$ FB
WZ	$\sigma = 6.6 \times 10^5$ FB

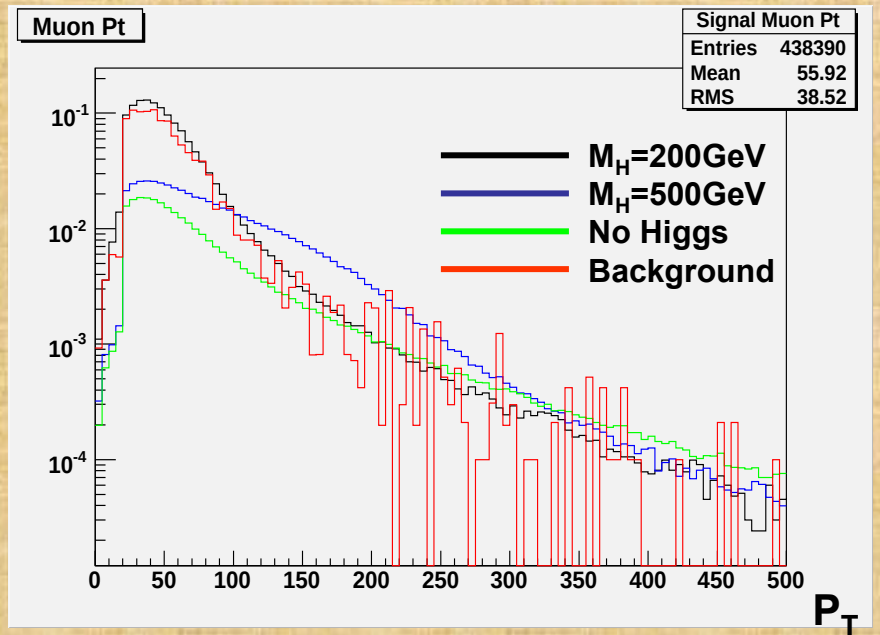
ZZ -> μμμμ (A.Sznajder)

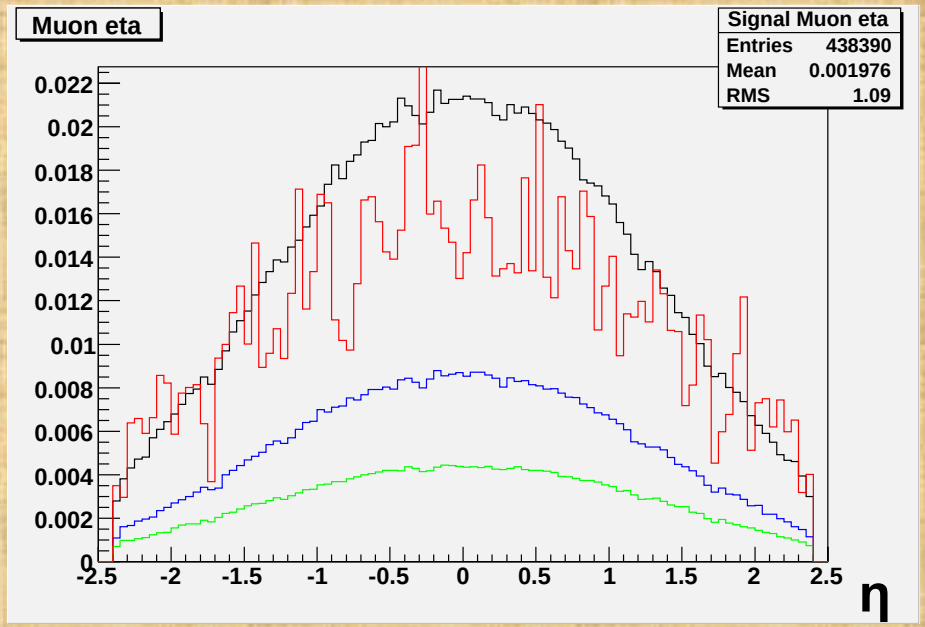
- Golden channel for Higgs search($M_{Higgs}>2M_{W/Z}$)
- Allows full reconstruction of the M_{Higgs} and precise measurement of σ_{VV}
- Unique signature: 2 isolated muon pairs from Z decay + two forward jets + no missing E_T
- Very low cross section ! (long term measurement)
- Phantom signal processed through FAMOS
  (M_H=200GeV , M_H=500GeV, No Higgs)
- Alpgen background processed through FAMOS
  (ZZ+njets, WZ+njets, tt+njets,)
- Working on adding Zbb background and getting the significance of the signal

Z-> μμμμ

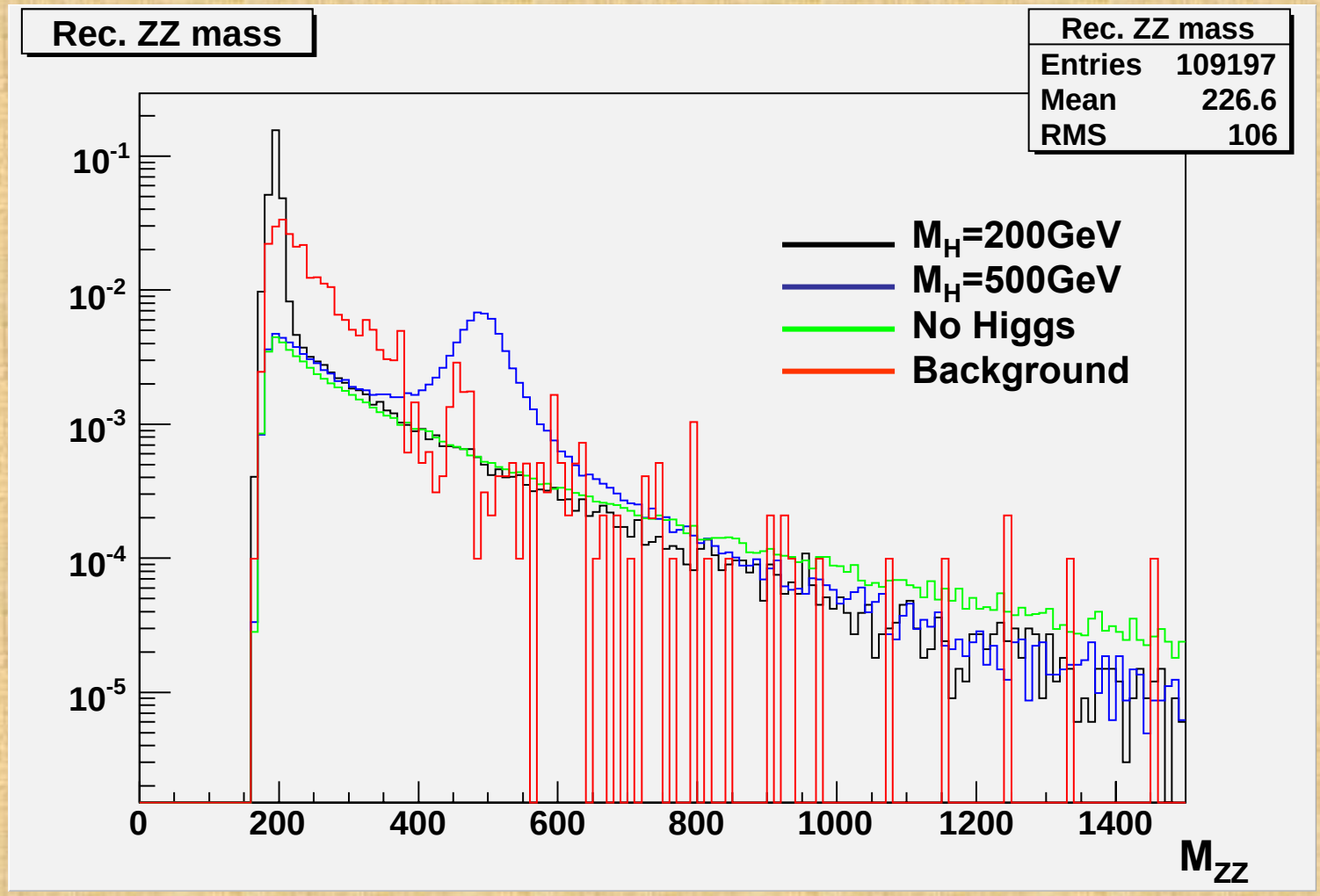
Signal definition:

- 4 muons with P_T>20GeV and |η|<2.4
- 2 reconstructed Z's within the mass window of 10GeV
- Muon isolation requirement (not applied)
- 2 forward jets requirement (not applied)





M_{zz} Distribution



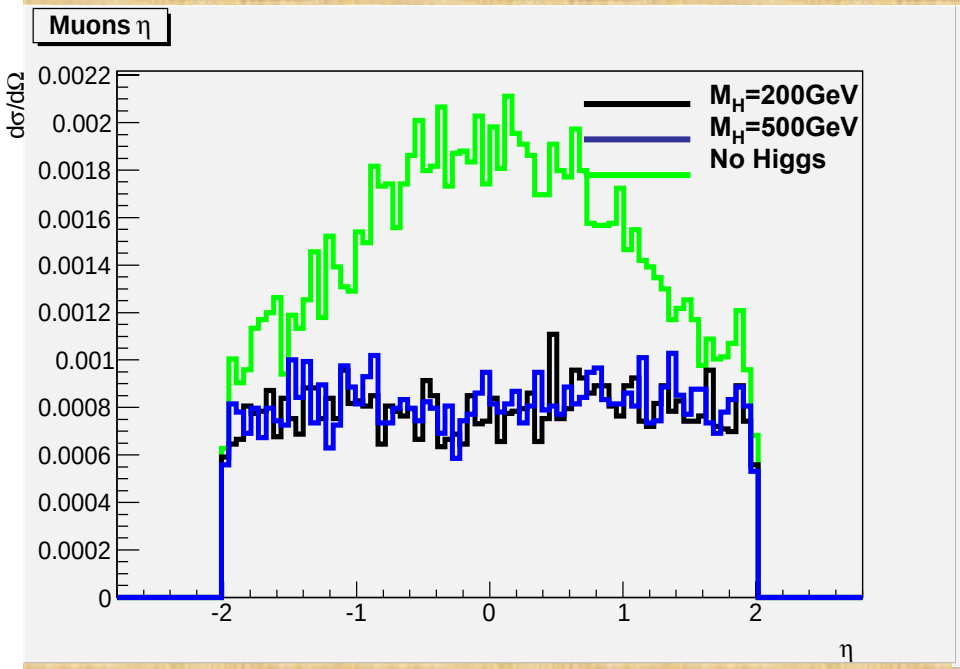
$W^{\pm}W^{\pm}$-> μνμν (D.Franzosi)

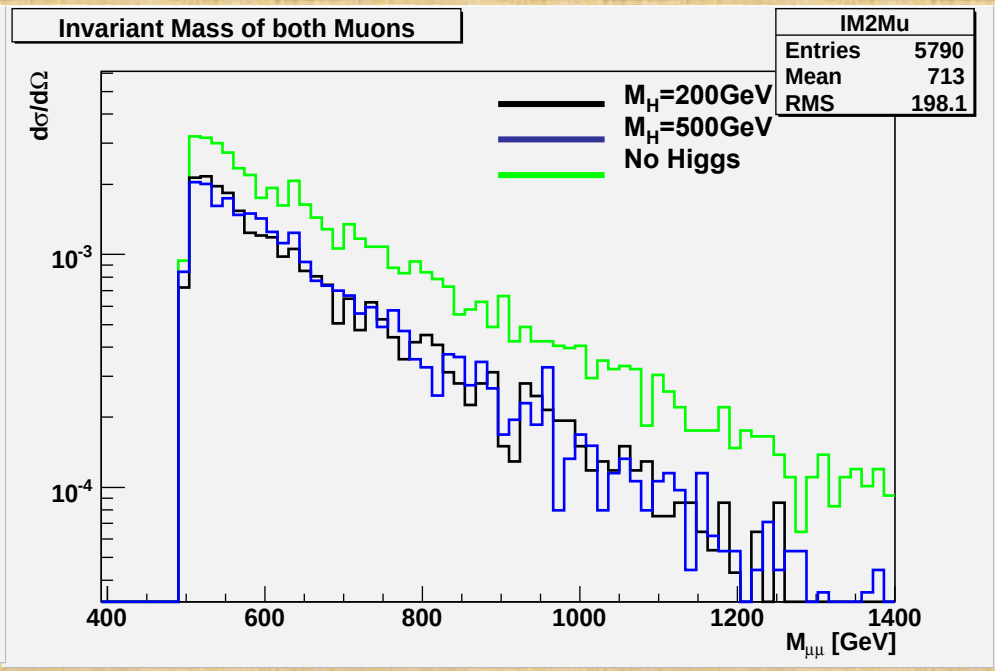
- Same sign requirement reduces background
- No H->WW contribution
- Very difficult to reconstruct WW invariant mass.
- Signature: same sign pair of isolated muons + large missing ET + two forward jets
- Low cross section (long term measurement)
- Working on adding more backgroubd statistics and getting the significance

$W^{\pm}W^{\pm}$-> μνμν

Signal definition:

- 2 isolated muons of same sign with P_T>20GeV and |η|<2.0
- High muon pair invariant mass
- Missing E_T >70GeV
- 2 forward jets requirement (not applied)



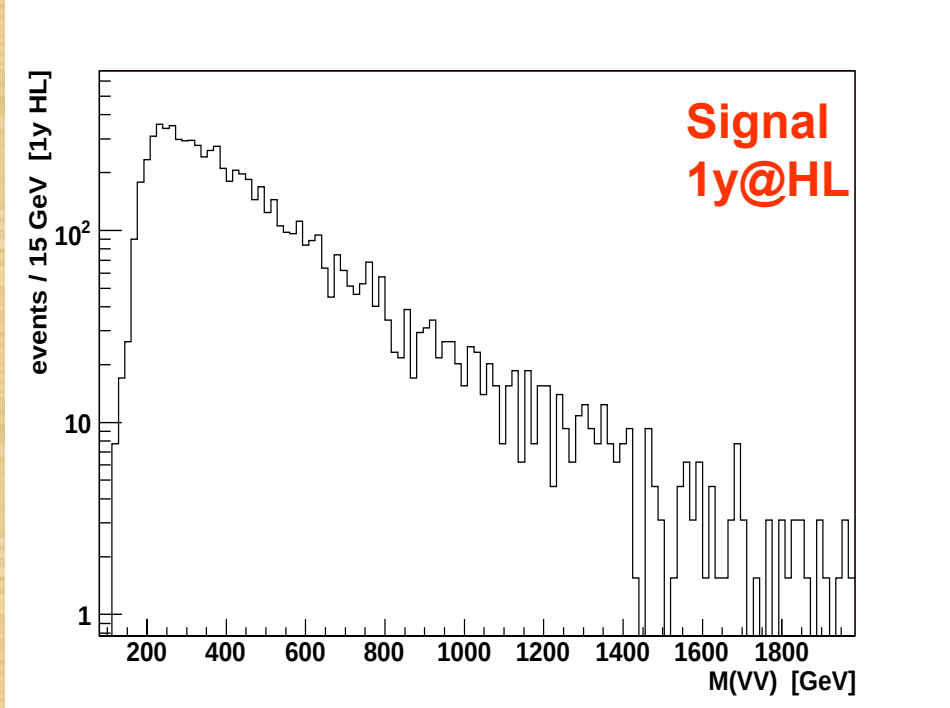


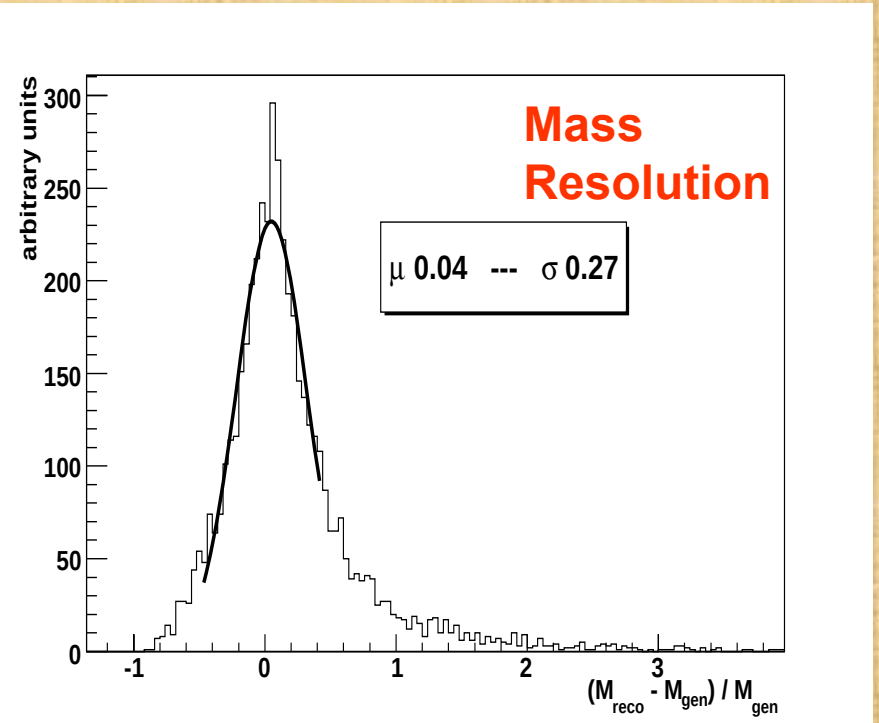
VW->jjμν (S.Bolognesi)

Signal definition:

- 4jets with pt>30,
- at least one muon with pt>20
- muon choosen as the most central (if more then one muon)
- MET>20
- Tag(forward) jets choosen as the pair of quarks with the largest invariant mass
- Jets from V choosen as the two with smallest deltaEta

VW->jjμν


Signal
1y@HL
events / 15 GeV [1y HL]
10²
10
1
200
400
600
800
1000
1200
1400
1600
1800
M(VV) [GeV]


Mass
Resolution
μ 0.04 --- σ 0.27
arbitrary units
300
250
200
150
100
50
0
-1
0
1
2
3
(M_reco - M_gen) / M_gen

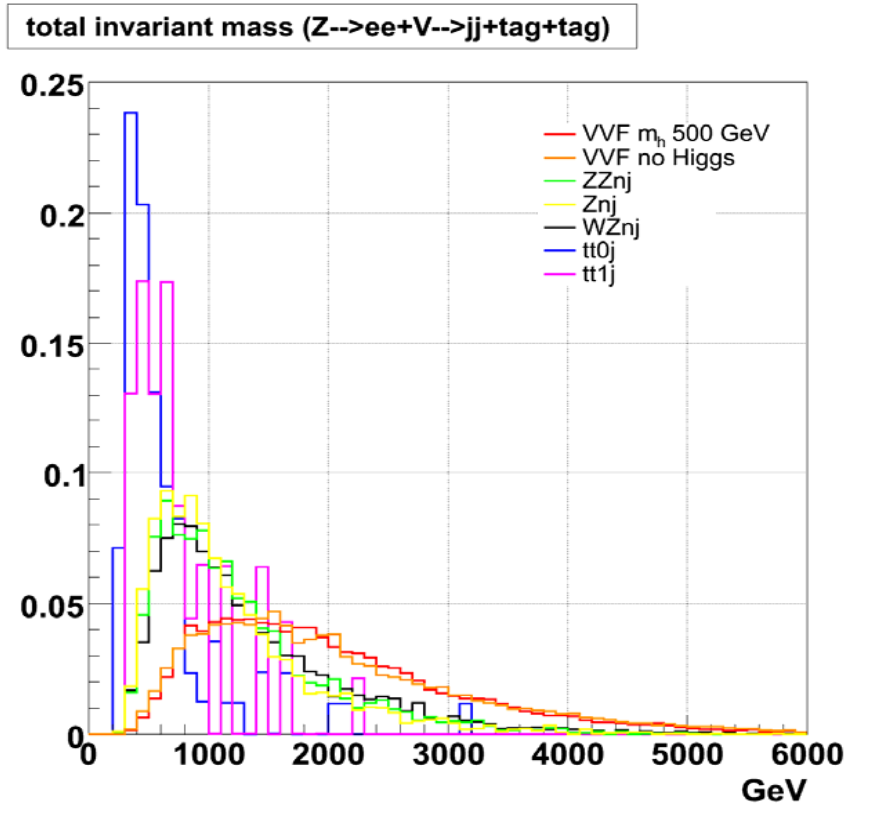
VZ->jjee (V.Tancini)

Signal definition:

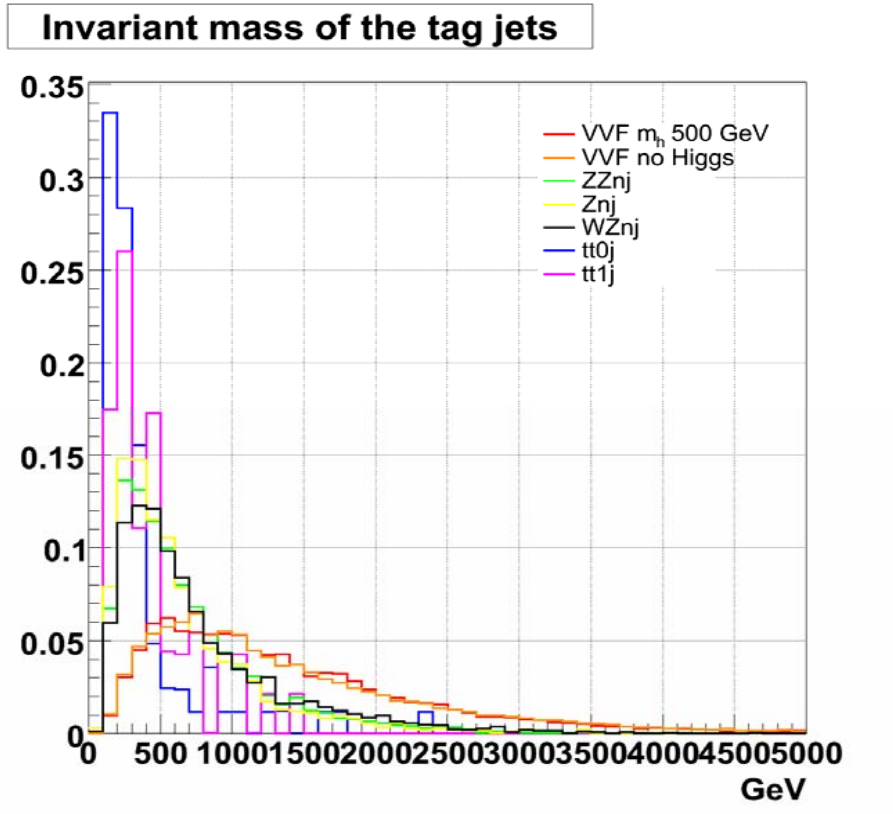
- 4jets with E_T>25GeV
- one electron+positron pair resonant at the Z
- no MET
- two collinear jets to reconstruct the V
- tag jets chosen as the pair with largest invariant mass

VZ->jjee

Invariant mass of the total system Z+V+2tagJets > 1500 GeV



Invariant mass of the two reconstructed tag jets > 900 GeV



People Working on VV Scattering

- Torino:

  - Theory: A.Ballestrero, G.Bevilacqua, A.Belhouari, E.Maina

  - Experiment: R.Bellan, S.Bolognesi, G.Cerminara, C.Mariotti, G.Mila, Petrillo

- Milano:

  P.Govoni, V.Tancini, M.Paganoni

- Brasil(UERJ):

  D. Franzosi, A. Sznajder