$W_L W_L$ scattering at LHC:
(i) An approach to the Theoretical Background.
(ii)My Performance Studies.

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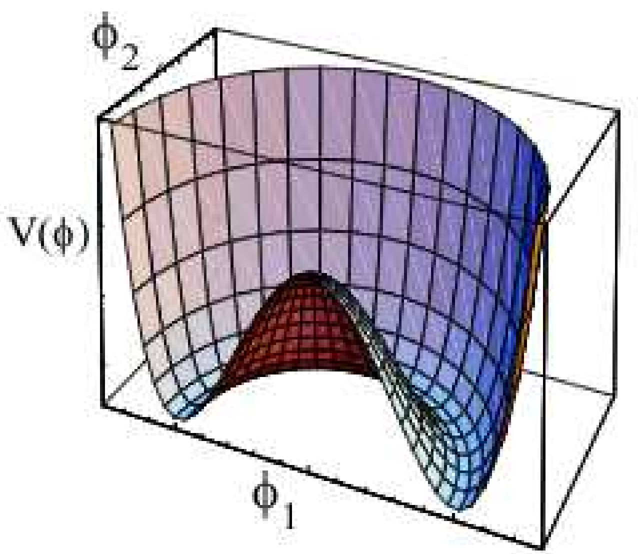
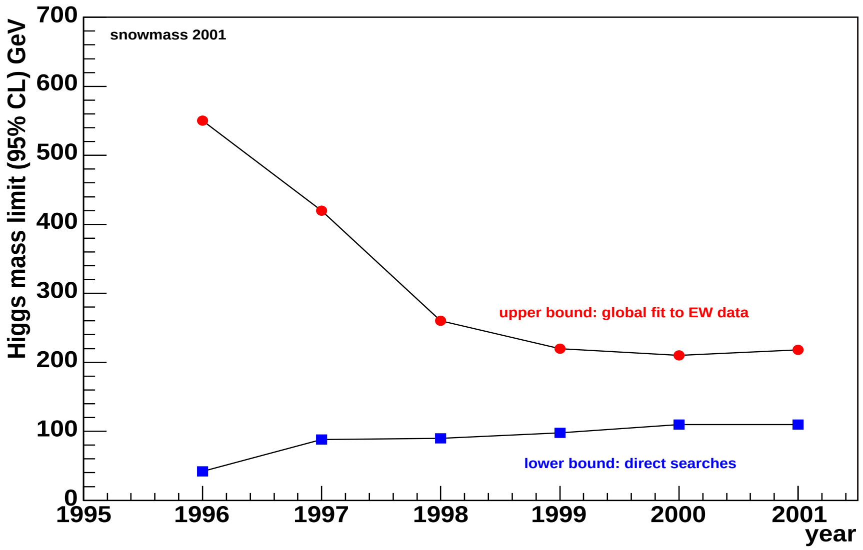
- Standard Model: A very good model satisfying theorists and experimentalists.
- It explains the **Electroweak Symmetry Breaking-EWSB** by introducing the **Higgs** boson.





- However, any assumptions and any mass limits are **model dependent.**
- Alternative models to explain EWSB: SM with heavy higgs, technicolor, composite models etc etc
- Enchanced production of **longitudinal** vector boson pairs is one of the most characteristic signals of the new physics

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- Describes the low energy effects of different strongly interacting models of the Symmetry Breaking Sector.
- The differences among underlying theories appear through the values of the effective chiral couplings.
- It includes operators up to order of s^2 (E^4).
- At thel lowest order:

$$\mathcal{L}^{(2)} = \frac{u^2}{4} Tr\{D_\mu U D^\mu U^\dagger\} \tag{1}$$

where

$$D_\mu U = d_\mu U - W_\mu U + U B_\mu$$

$$W_\mu = -ig\frac{\sigma^\alpha W_\mu^\alpha}{2} \qquad B_\mu = ig\frac{\sigma^3 B_\mu}{2} \qquad U = \exp\left(\frac{i\omega^\alpha \sigma^\alpha}{u}\right)$$

where σ are the Pauli matrice, ω are the three Goldstone bosons and $u = 246$ GeV

- The next term includes the model-dependent effective couplings:

$$\mathcal{L}^{(4)} = \alpha_4 \left(Tr\{D_\mu U D^\mu U^\dagger\}\right)^2 + \alpha_5 \left(Tr\{D_\mu U D^\nu U^\dagger\}\right)^2 \tag{2}$$

- The α_4 and α_5 depend on the model but also on the renormalization scale μ. With $\mu = 1\,TeV$ we expect them to be in the range of [-0.01, 0.01]
- Additional terms of the order of s^2 contribute to anomalous trilinear couplings between vector bosons.

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- For the $W_L^a W_L^b \to W_L^c W_L^d$ in the weak isospin space:

$$\mathcal{M}(W_L^a W_L^b \to W_L^c W_L^d) \equiv A(s,t,u)\delta^{ab}\delta^{cd} + A(t,s,u)\delta^{ac}\delta^{bd} + A(u,t,s)\delta^{ad}\delta^{bc} \tag{3}$$

where the key amplitude $A(s,t,u)$ is:

$$\begin{aligned} A(s,t,u) &= \frac{s}{u^2} + \frac{1}{4\pi u^4}\left(2\alpha_5 s^2 + \alpha_4(t^2+u^2)\right) + \\ &+ \frac{1}{16\pi^2 u^4}\left(-\frac{t}{6}(s+2t)\log\left(-\frac{t}{\mu^2}\right) - \frac{u}{6}(s+2u)\log\left(-\frac{u}{\mu^2}\right) - \frac{s^2}{2}\log\left(-\frac{s}{\mu^2}\right)\right) \end{aligned} \tag{4}$$

(In the above: W_L denotes either $W_L^\pm$ or Z_L , $W_L^\pm = \frac{W_L^1 \mp i W_L^2}{\sqrt{2}}$, $Z_L = W_L^3$, $a,b,c,d = 1,2,3,4$ and s,t,u are the Mandelstam kinematical variables.)

- Precise measurement of the $W_L W_L \to W_L W_L$ scattering cross-section would allow the extraction of the α_4 and α_5 parameters.

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- The usuall EWChL approach doesn't respect **unitarityy**.
- Unitarity is restored by applying different **unitarization protocols**, for example:**Inverse Amplitude Method (Pade)**, N/D protocol etc.
- The **position** and the **nature** of the resonances **depend strongly** upon the unitarisation procedure.

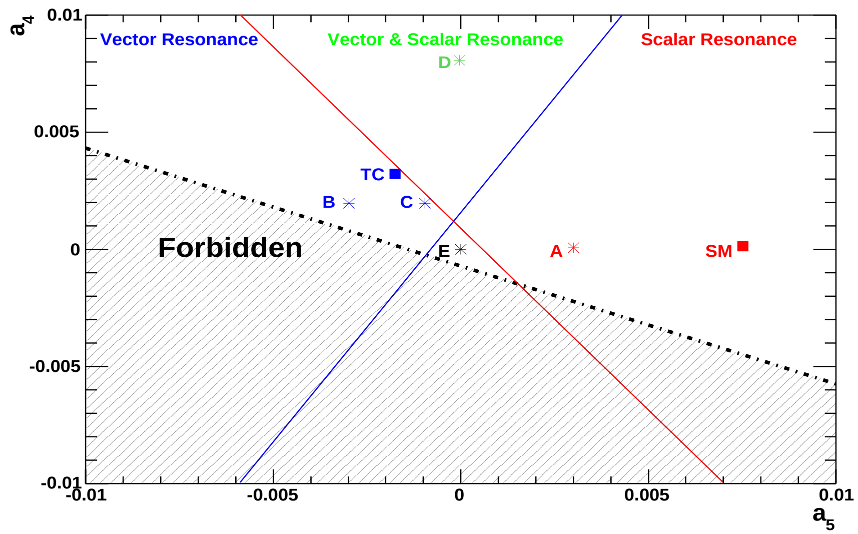
  (see for example Phys.Rev.D **65** 096014 for comparison between the Pade and the N/D protocols)
- Using the Pade protocol, we obtain the following mass and the width of the resonances:

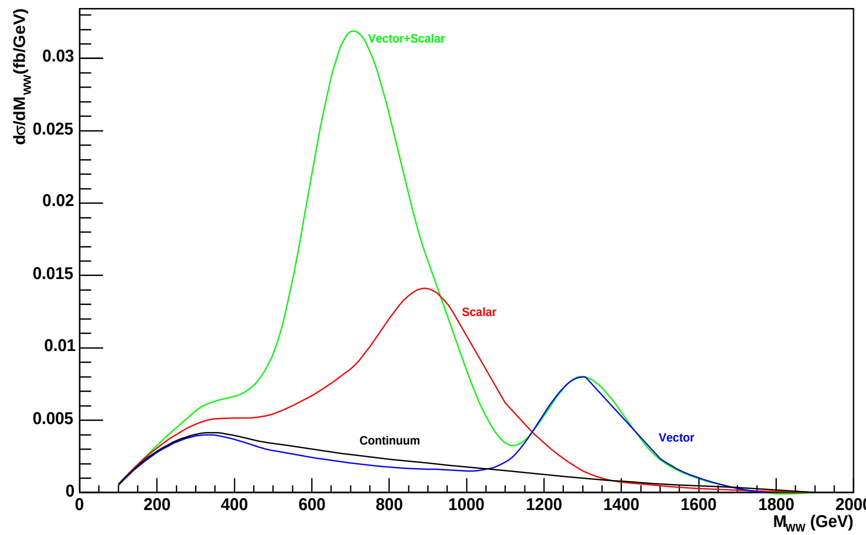
$$M_V^2 = \frac{u^2}{4(\alpha_4 - 2\alpha_5) + \frac{1}{144\pi^2}}, \qquad \Gamma_V = \frac{M_V^3}{96\pi u^2} \tag{5}$$

$$M_S^2 = \frac{12u^2}{16(11\alpha_5 + 7\alpha_4) + \frac{101}{48\pi^2}}, \qquad \Gamma_S = \frac{M_S^3}{16\pi u^2} \tag{6}$$

- For equal masses, scalar resonances would be **6 times wider** than vector resonances.

Parameter Space as determined by the Pade protocol





Scenario	α_4	α_5	Resonance Mass (GeV)
Scalar(A)	0.0	0.003	989.8
Vector(B)	0.002	-0.003	1360.3
Scalar + Vector (D)	0.008	0.0	809.6 + 1360.3
Continuum (E)	0.0	0.0	NA

- PYTHIA has been modified to include the EWChL and to produce the resonances for different parameters according to the Pade protocol.
- Forbidden region: Where causality is violated, i.e $\frac{32}{3}(\alpha_5 + 2\alpha_4) + \frac{273}{864\pi^2} < 0$

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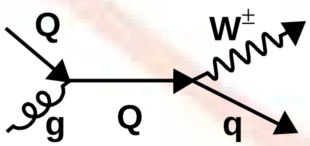
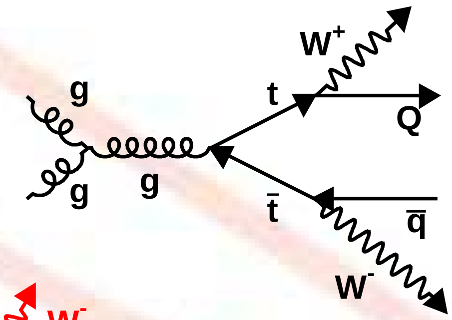
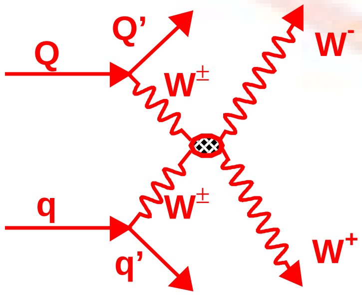
Signal and Background Processes at LHC - Data Samples







- Signal:
  - Private production of 600k Continuum Signal events.
  - Semi-leptonic decays of the W.
  - σ x $BR = 3.32fb$.
- $t\bar{t}$ Background:
  - 500k events used for Rome (T2 Sample).
  - MC@NLO - Fully hadronic events were rejected and at least 1 top has $P_T > 500\ GeV$.
  - σ x $BR = 4.12fb$.
- w+4jets Background:
  - 200k events used for DC2 (A7 Sample).
  - AlpGen (Hard Process + Matrix Element: require 4 jets) - Pythia (Parton Shower + Hadronisation).
  - Light Jets: $P_T > 20GeV$ $\eta_{max} = 5$ $\Delta R_{jj} = 0.4$.
  - Lepton: $P_T > 20GeV$ $\eta_{max} = 3$ $\Delta R_{lept-j} = 0.4$ $E_T^{miss} > 15GeV$.
  - σ x $BR = 1.20fb$.

The Generated Events were then Simulated using ATLFAST.

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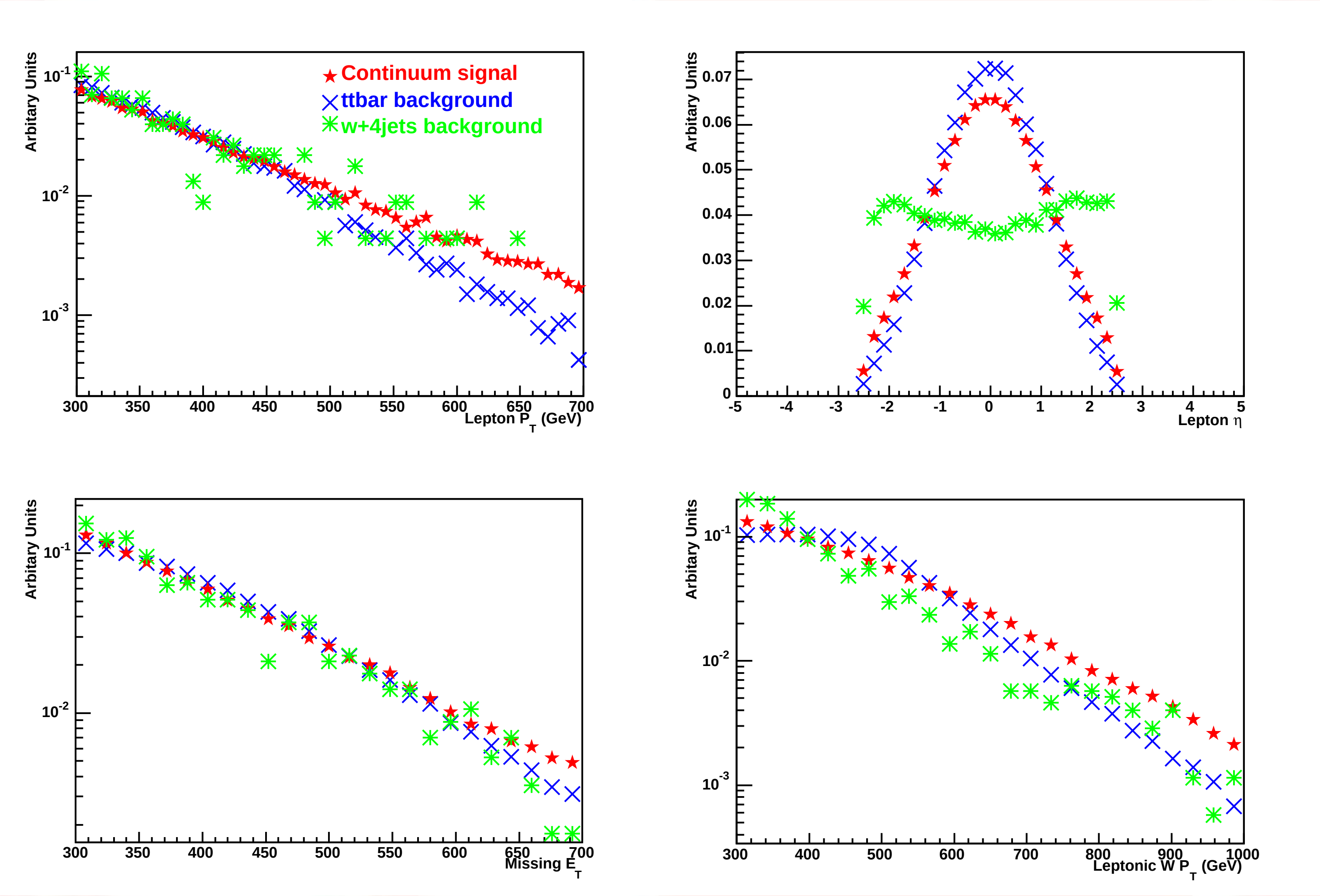
Initial Distributions: The Leptonic sector.



- Applied Cuts: $P_T^{lept} > 100GeV$; $P_T^{W_{lept}} > 320GeV$; $E_T^{miss} > 100GeV$

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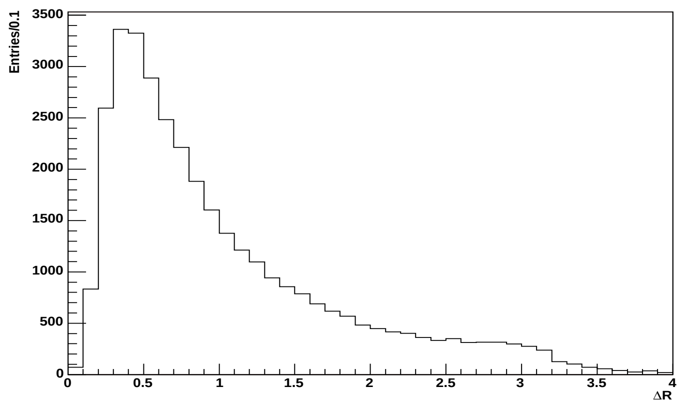
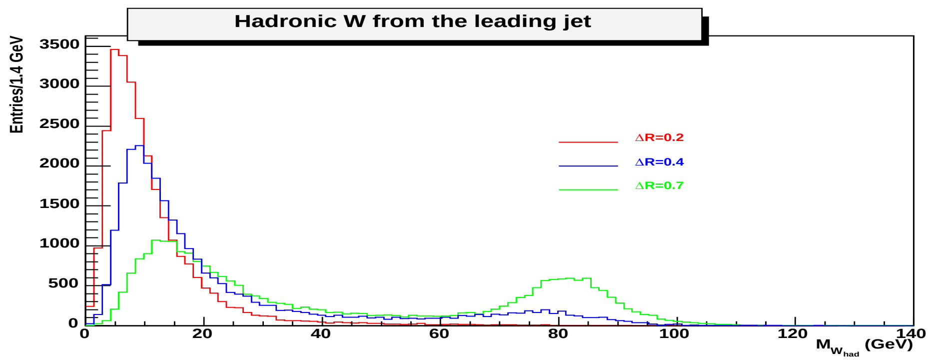
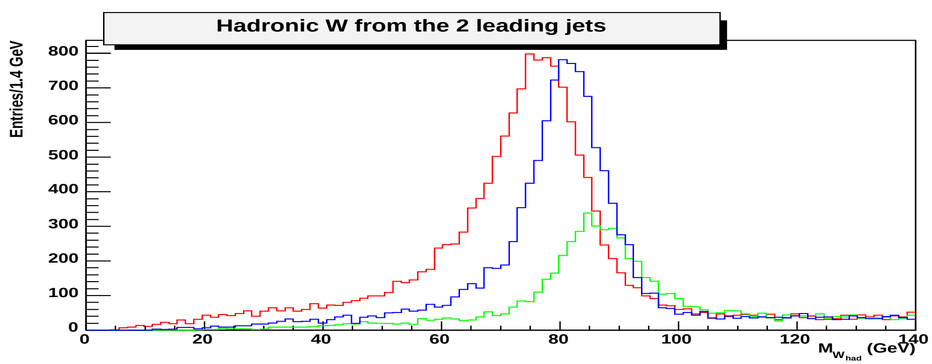
Initial Distributions: The Case of the Hadronic W reconstruction.



- Due to the high boost of the W, the 2 jets can be very close (MPV$\sim$0.5) and will overlap.
- The Cone Algorithm has been used for the jet finding.
- $\Delta R = 0.4$ is the optimum size for reconstructing the hadronic W from 2 jets.





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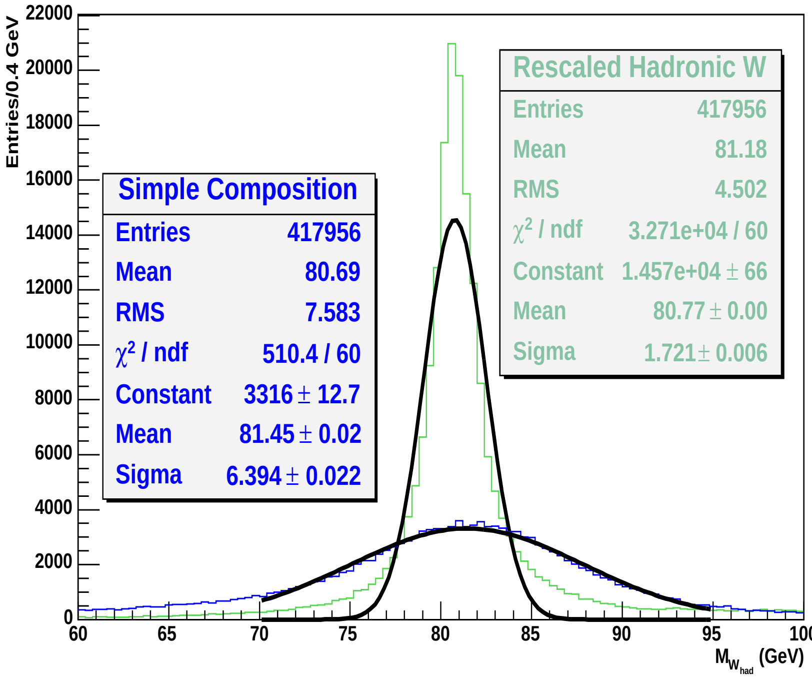
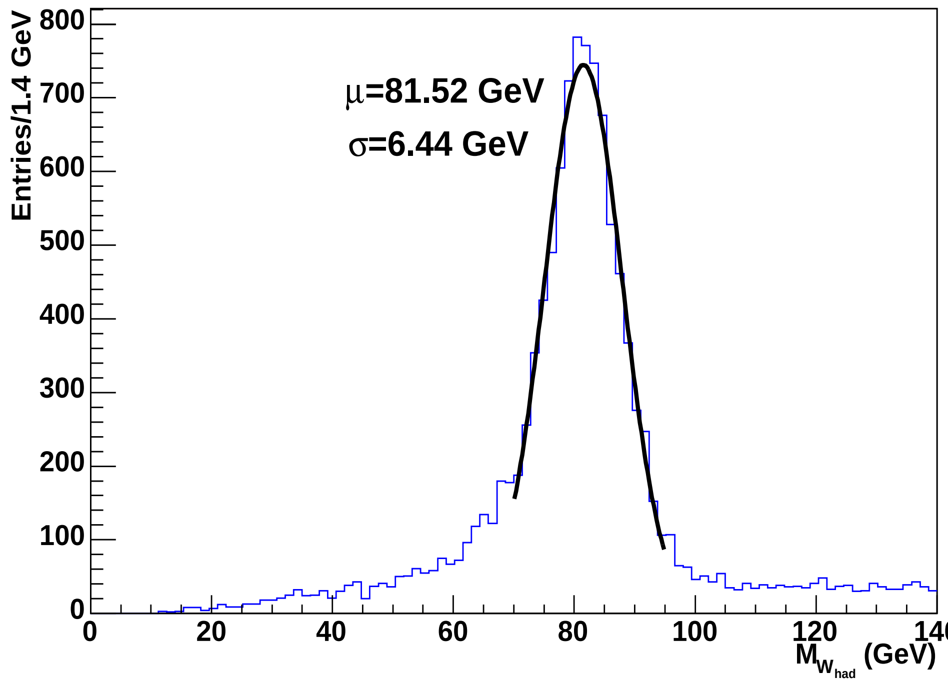
Checking Simon's tool for rescalling the hadronic W (see talk on 4th November 2005).





- The rescaling method gives $\Gamma_W << \Gamma_W^{natural} = 2.06$ GeV!!
- Use the simple composition of the 2 jets

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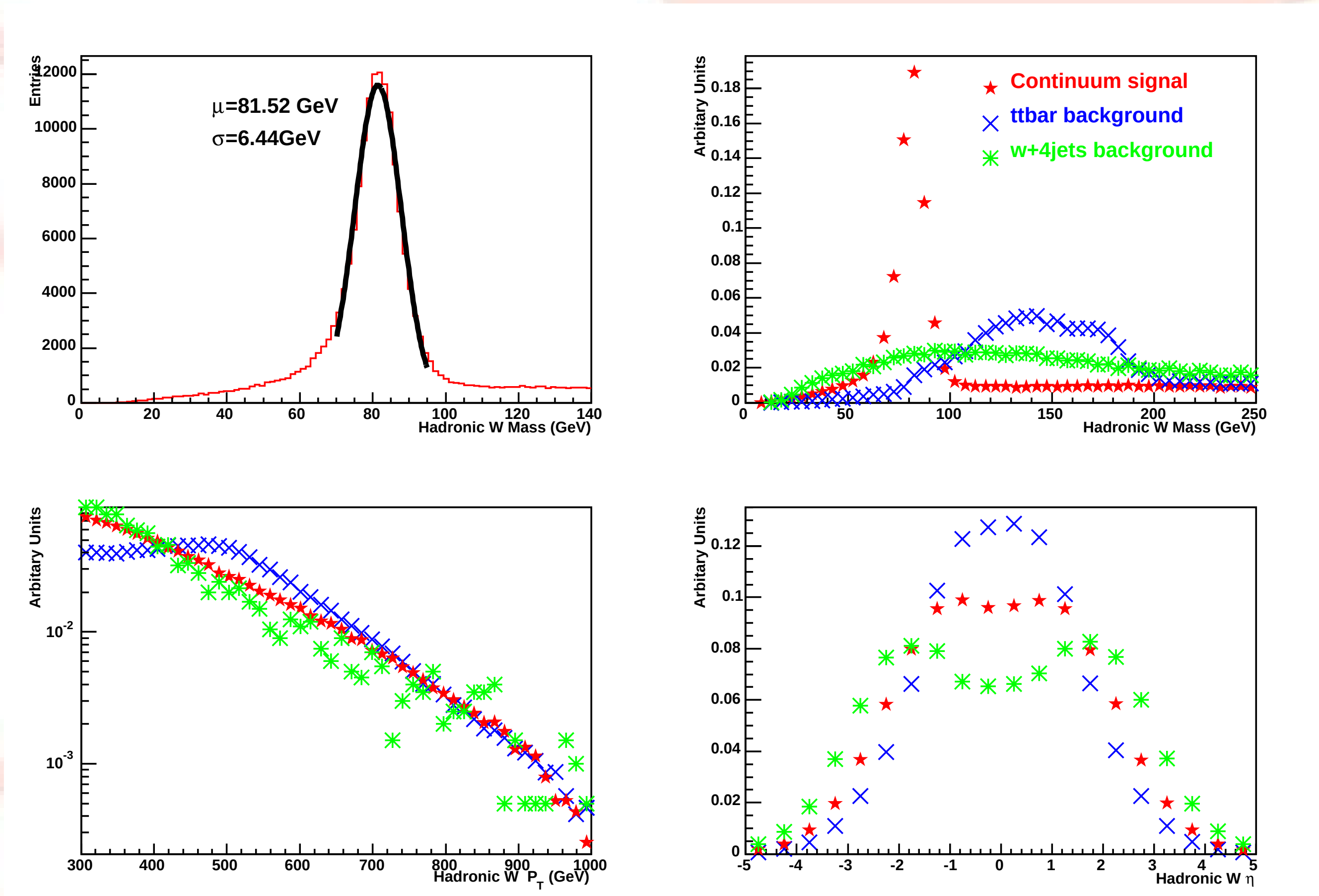
Initial Distributions: The Hadronic Sector.



- Applied Cuts:$P_T^{W_{had}} > 320GeV$; $67GeV < M_{W_{had}} < 97GeV$; $\eta_{W_{had}} > 4$
- The cut on the mass of the hadronic W kills the majority of the background events.
- Some distributions appear different from those in the note!!!

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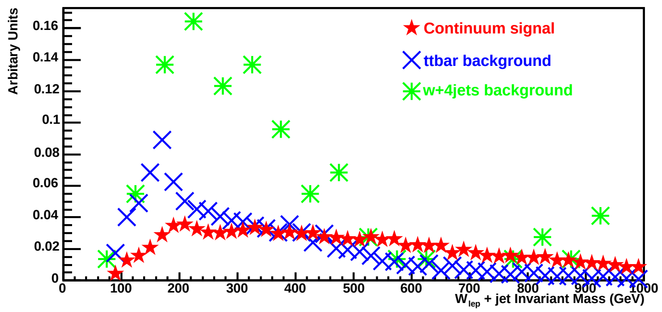
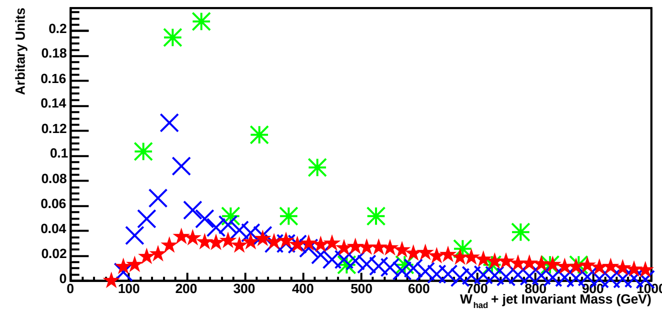
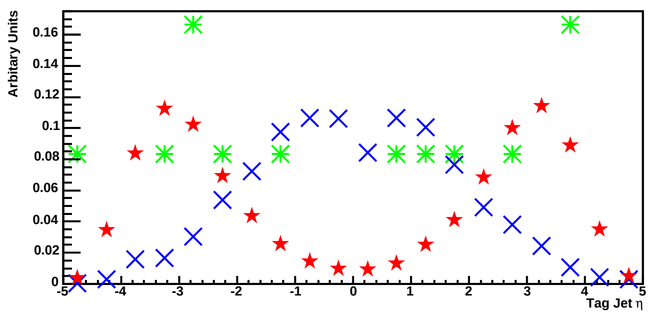
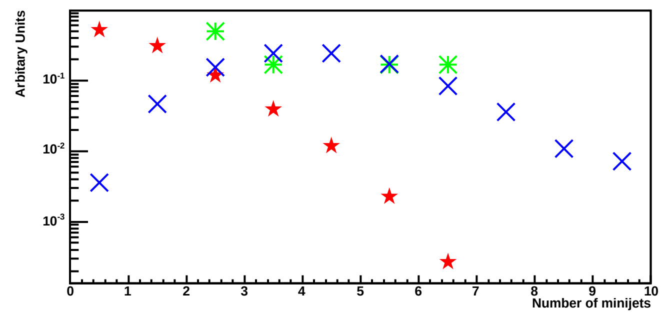
Characteristics of the Hadronic environment.

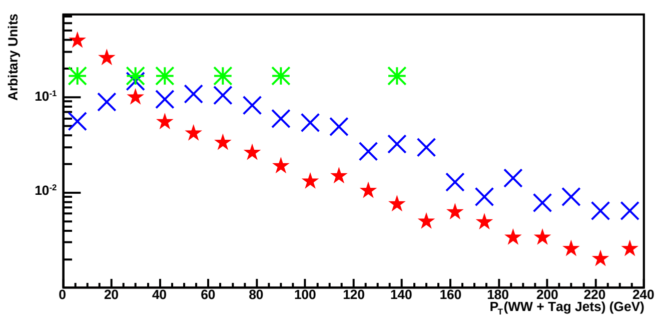
After applying the previous cuts, we investigate the features of the hadronic environment:











Cuts:

(a-b) Top quark veto: 130 GeV < M_{Wjet} < 240 GeV

(c) Tag Jets: Both in Forward/Backward regions, P_T^{jet}>20 GeV; E^{jet}>300 GeV; |η|>2

(d) Hard P_T: $P_T^{WW+tag\ jets}$ <50 GeV

(e) MiniJet veto: Number of minijets < 1

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- A theoretical introduction to the EWChL and its dynamics to descibe different strongly interaction models of the EWSB has been given.
- My (very initial) analysis on the $W_L W_L$ scattering at high masses has been presented.
- The analysis has taken into account the effects of the **multi-parton interactions (Rome tunning)** but **not pile-up** effects.
- The **Cone** Algorithm has been used (only for convenience reasons). Migrate to **KtJet** and apply the **subjet** analysis.
- The signal appears to have the expected behaviour. It not always the case for the background samples (especially w+4jets).
- Problems may be due to:
  - The **analysis code**: Some impovements still to be done together the subjet analysis.
  - The **background samples**: Different from what has been used in the note. Wait for the new data production (DC3).
- The exotics group has proposed to have samples of W+xJets (x=1,..,5) with $P_T^{jet} > 40 GeV$ and $P_T^{jet} > 100 GeV$. UCL (sstef) will be responsible for this production (at least for the high energy samples).

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