$W_L W_L$ scattering at LHC.

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Outline

- **The Electroweak Chiral Langrangian (EWChL): Why and How.**
- **Application of the EWChL in the $W_L W_L$ scattering to probe new physics.**
- **Few scenarios for the new physics.**
- **Performance studies of the ATLAS Detector at the LHC : the case of the continuum spectrum.**
- **Summary.**

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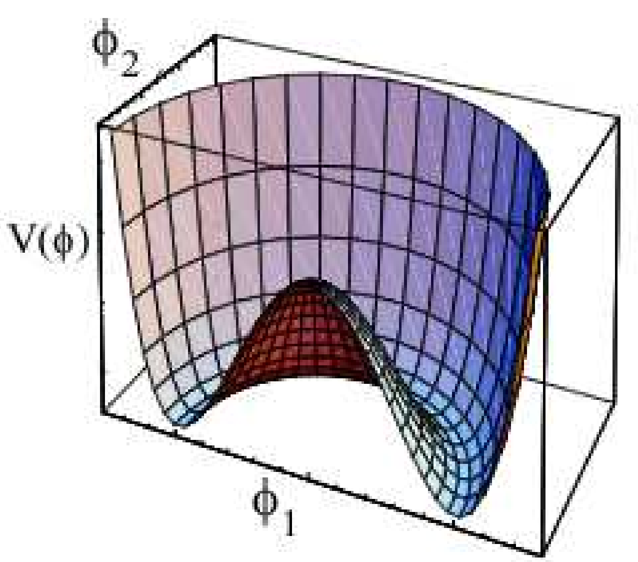
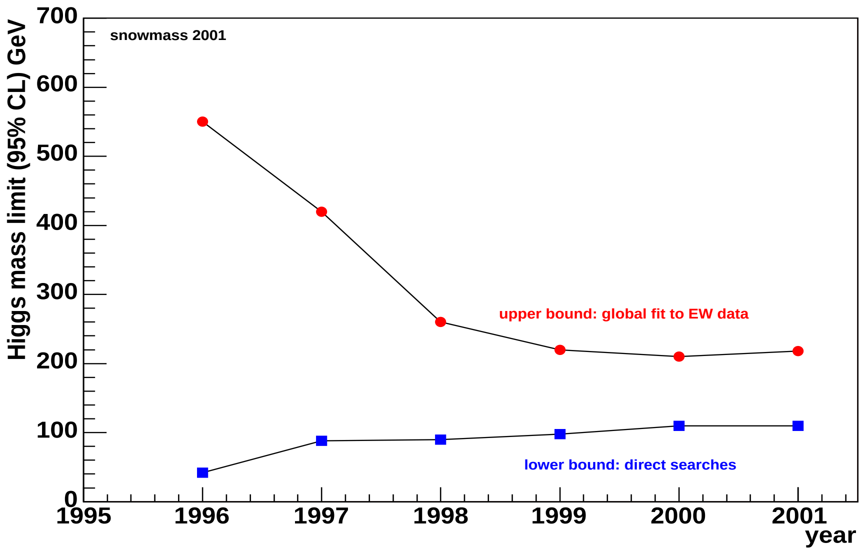
- Standard Model: A very good model satisfying theorists and experimentalists.
- It explains the **Electroweak Symmetry Breaking-EWSB** by introducing the **Higgs** boson.





- However, any assumptions and any mass limits are **model dependent.**
- Enchanced production of **longitudinal** vector boson pairs $(V_L V_L)$ 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 EWSB 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).
- The analytical form is:

$$\mathcal{L}_{EWCh} = \mathcal{L}^{(2)} + \mathcal{L}^{(4)} + ... = \frac{u^2}{4} Tr\{D_\mu U D^\mu U^\dagger\} + \alpha_4 \left(Tr\{D_\mu U D^\mu U^\dagger\}\right)^2 + \alpha_5 \left(Tr\{D_\mu U D^\nu U^\dagger\}\right)^2 \quad (1)$$

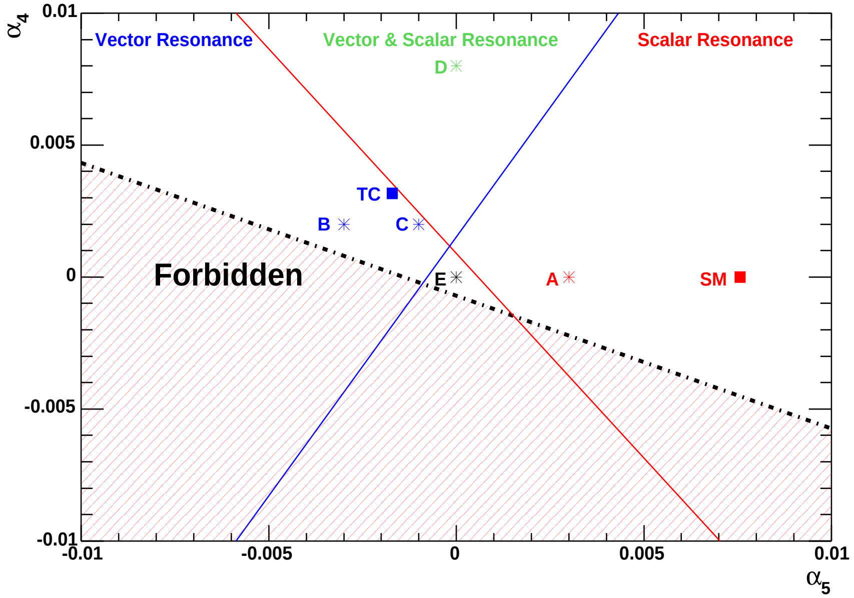
where

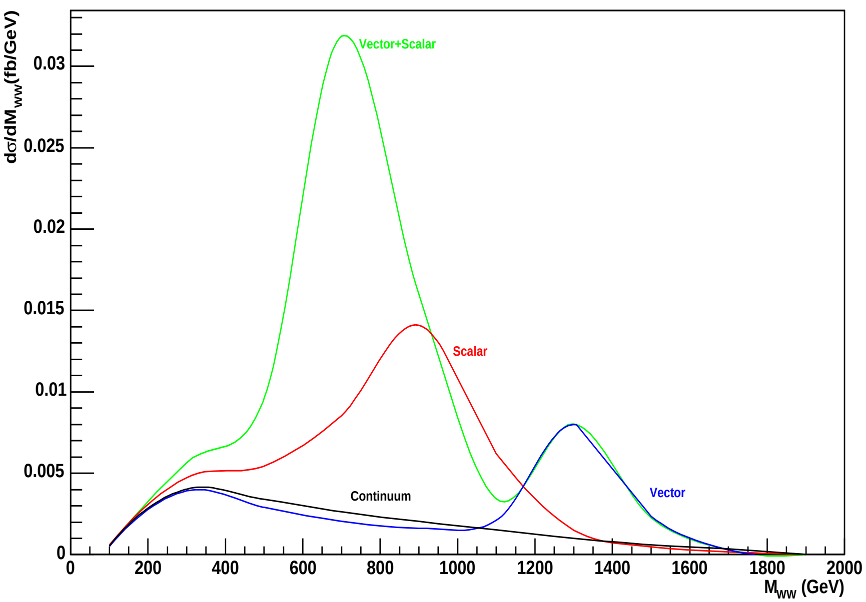
$$D_\mu U = d_\mu U - W_\mu U + U B_\mu$$

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

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

- **Precise measurement of the $W_L W_L \rightarrow W_L W_L$ scattering cross-section** would allow the extraction of the α_4 and α_5 parameters.
- The usuall EWChL approach doesn't respect **unitarity** at high energies.
- Unitarity is restored by applying different **unitarization protocols**, for example:Inverse Amplitude Method (Pade), N/D protocol etc. (see Phys. Rev, D65 096014)
- Unitarization procedure $\rightsquigarrow$ **Resonances.**

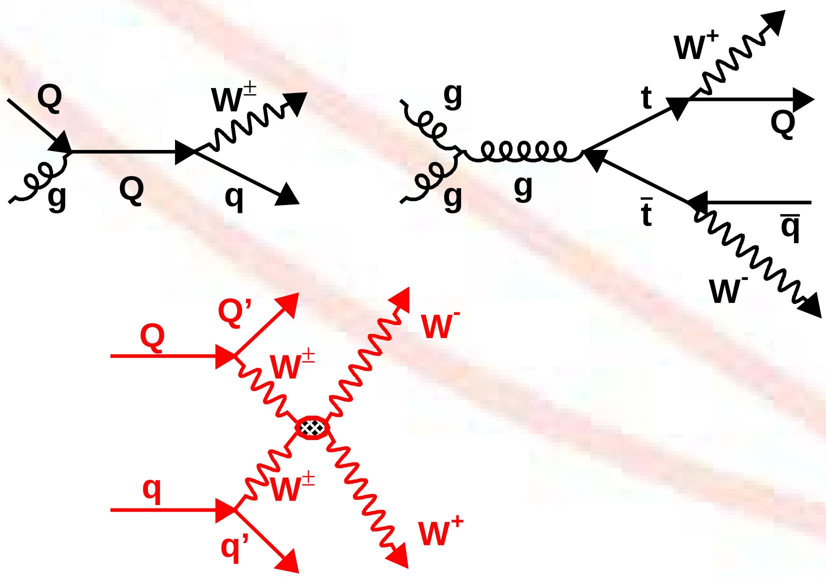




Scenario	α_4	α_5	Resonance Mass (GeV)
Scalar(A)	0.0	0.003	989.8
Vector(B)	0.002	-0.003	1360.3
Scalar + Vector (D)	0.008	0.0	809.6 + 1360.3
Continuum (E)	**0.0**	**0.0**	**NA**

- The masses (...and the widths) of each resonance depend on the values of α_4, α_5.
- PYTHIA has been modified to include the EWChL and to produce the resonances for different parameters.

Signal and Background Processes at LHC - Data Samples



- Signal:
  - PYTHIA ; Continuum ; $W_L^+ W_L^- \rightarrow W_L^+ W_L^-$.
  - Semi-leptonic decays of the W.
  - σ x $BR = 3.32\ fb$.
- $t\bar{t}$ Background:
  - PYTHIA (MSEL 6, MSUB 81-82).
  - Semi-leptonic decays of the top.
  - Hard Scatter $P_T > 250\ GeV$.
  - σ x $BR = 4.58\ pb$.
- w+jets Background:
  - PYTHIA (MSUB 16, 31).
  - W decays only leptonically
  - Hard Scatter $P_T > 250\ GeV$.
  - σ x $BR = 13.5\ pb$.

The generated events were then simulated using the **Fast Simulation** package for the ATLAS Detector.

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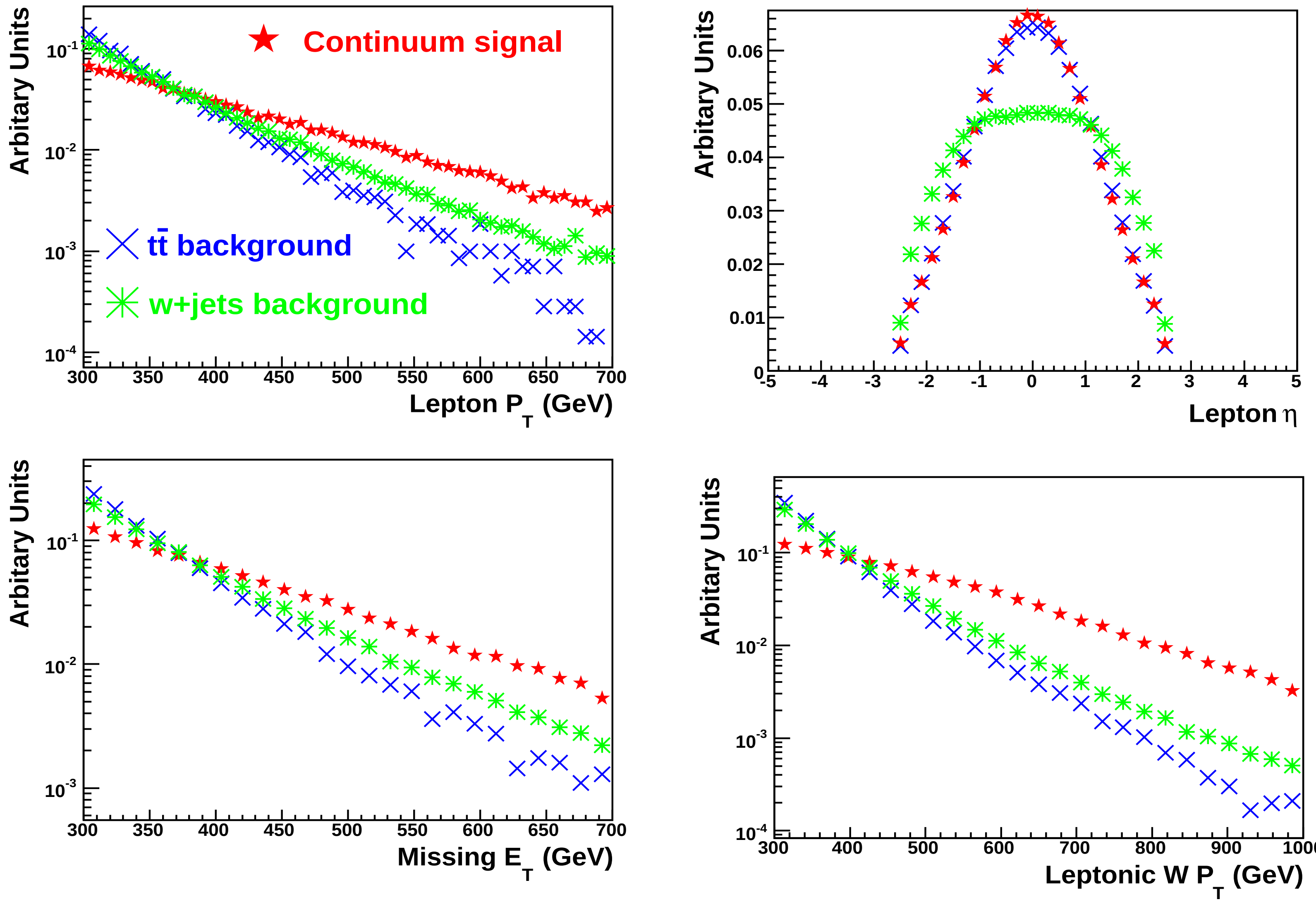

- **Applied Cuts:** $P_T^{lept} > 100\ GeV;\ P_T^{W_{lept}} > 320\ GeV;\ E_T^{miss} > 100\ GeV$

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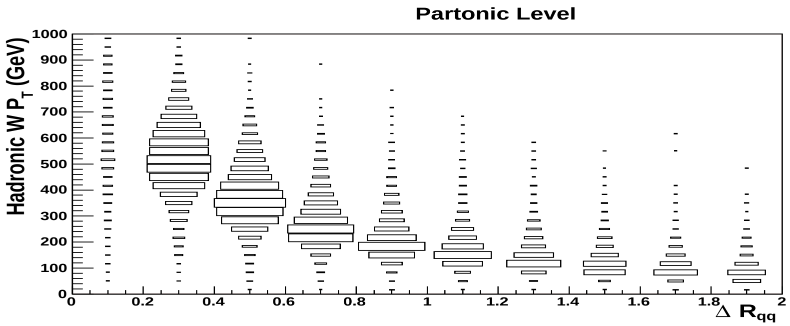
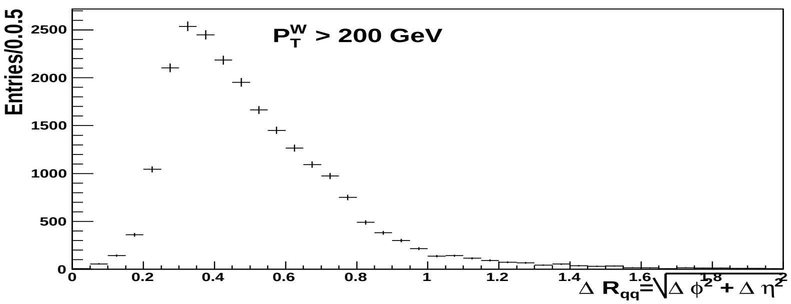
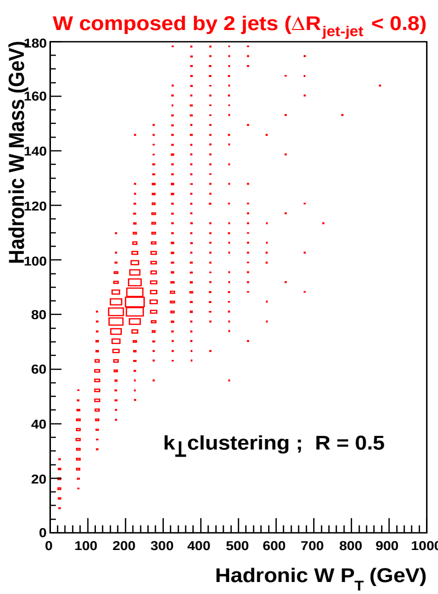
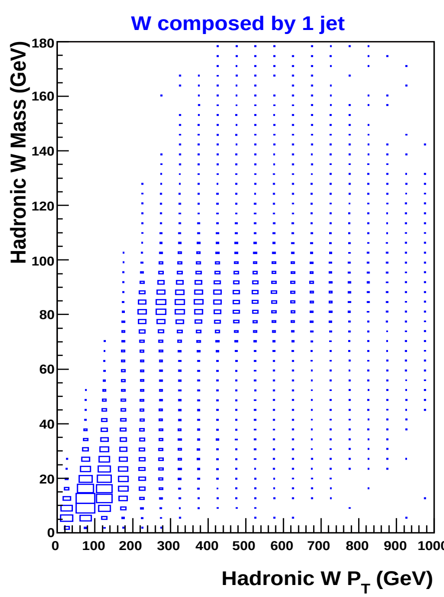
Initial Distributions: The case of the Hadronic W reconstruction.

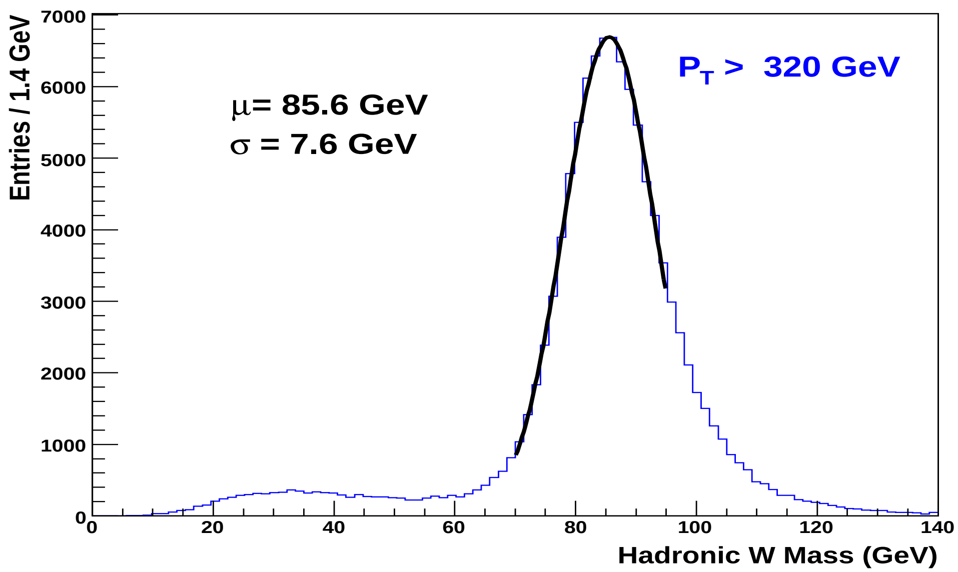




- Due to the high boost of the W, the 2 jets can be very close (MPV∼0.3) and will overlap.
- Detailed comparison between the Cone and $k_\perp$ algorithms for the jet finding has been carried out.
- For reconstructing the hadronic W from 1 jet we use the $k_\perp$ algorithm with R-parameter = 0.5:







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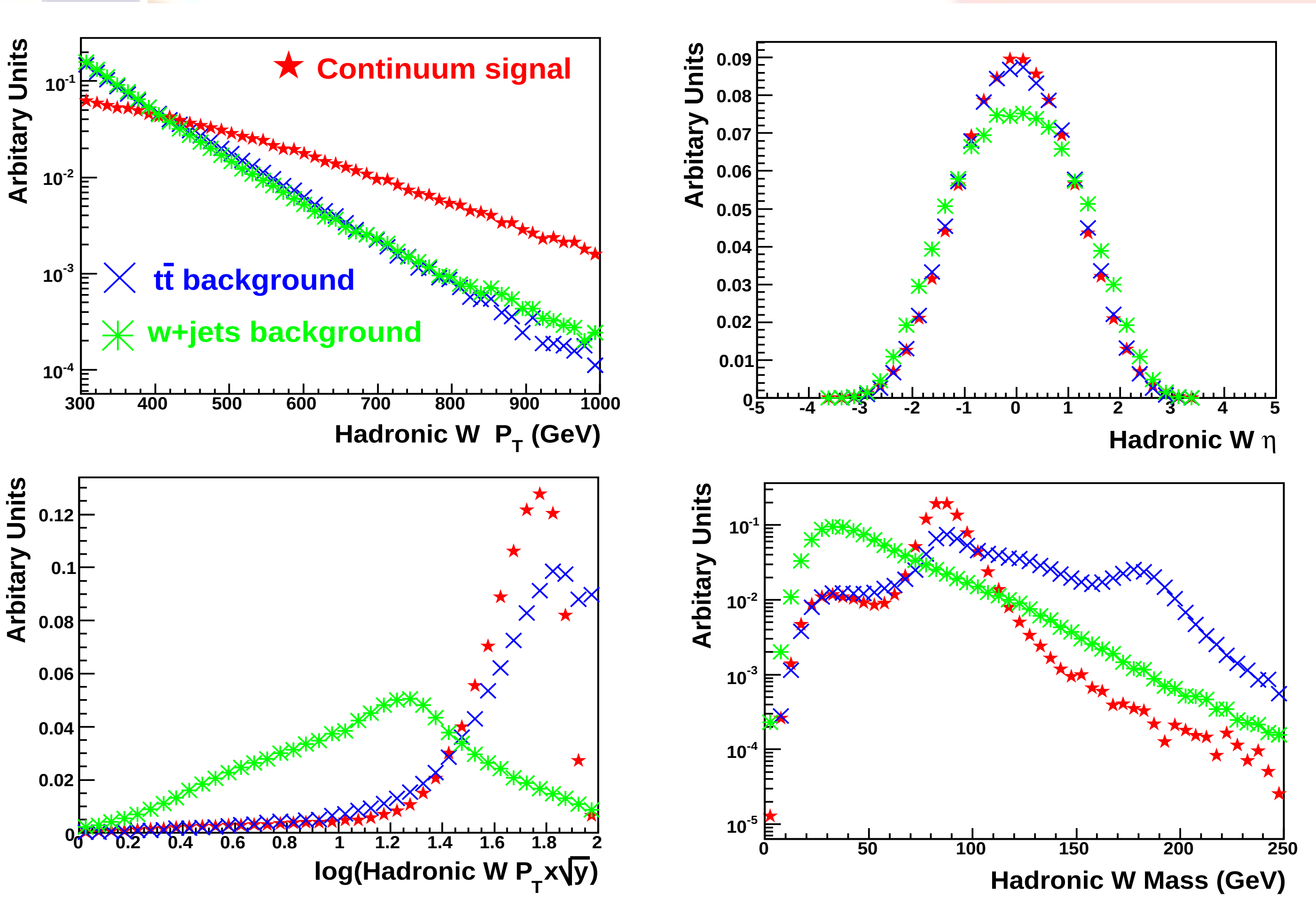


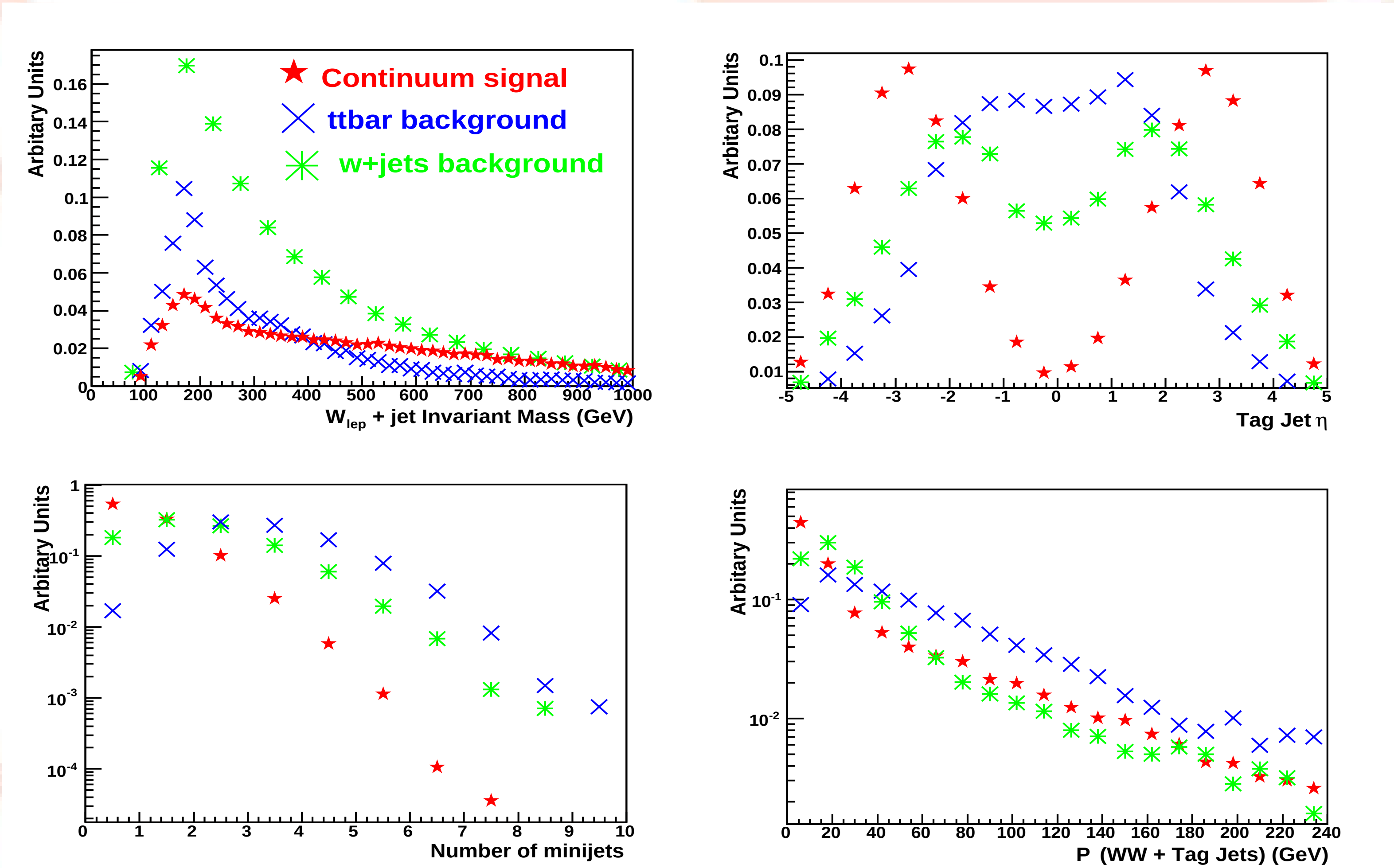
Applied Cuts:

- $P_T^{W_{had}} > 320\ GeV$
- $|\eta_{W_{had}}| < 2$
- $1.55 < \log(P_T \times \sqrt{y}) < 2$
- $67\ GeV < M_{W_{had}} < 97\ GeV$

Subjet Analysis with the $k_\perp$ (see hep-ph/0210022)

- For the leading jet, re-run the $k_\perp$ algorithm to find its structure.
- $P_T \times \sqrt{y}$: scale at which the jet is resolved into 2 subjets $\sim \mathcal{O}(M_W)$

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



Applied Cuts:

- **Top Veto:** $130\ GeV < M_{W+jet} < 240\ GeV$
- **Tag Jets:** $P_T > 20\ GeV;\ E > 300\ GeV;\ |\eta| > 1.5$
- **MiniJets:** Number of miniJets $<\ 1$
- **Hard Scatter P_T:** $P_T^{WW+tagJets} < 50\ GeV$

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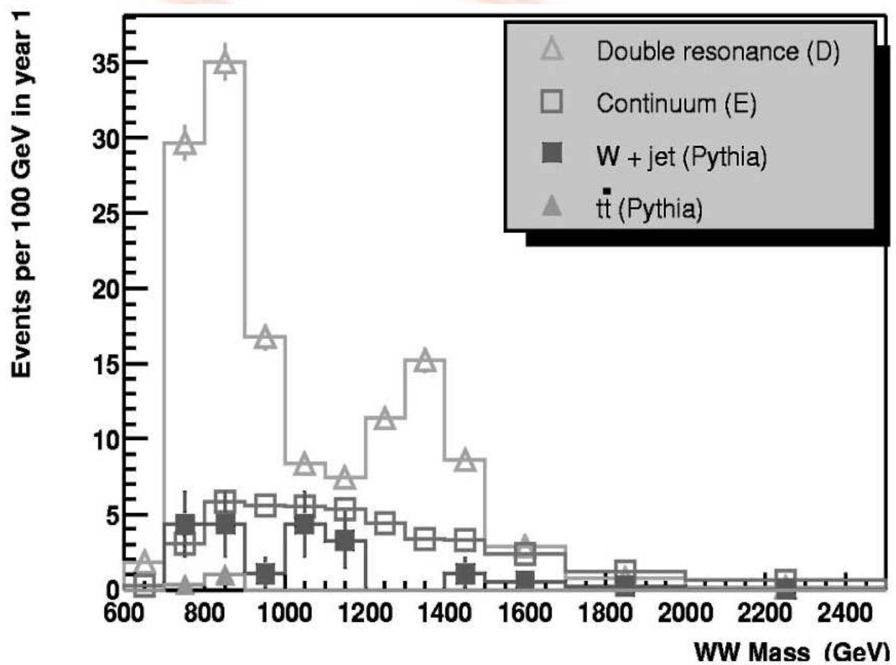
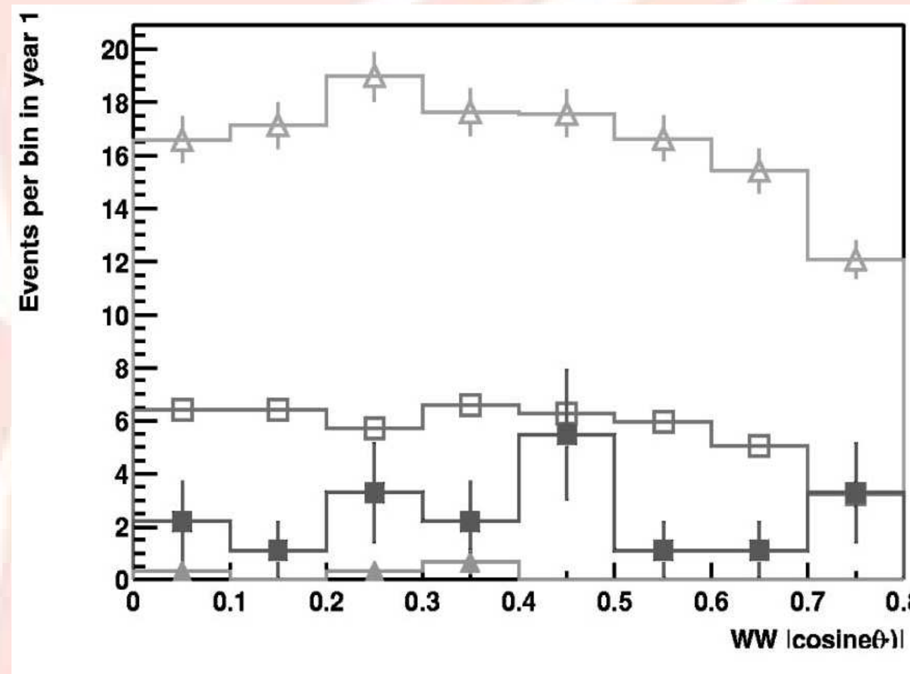
What we can observe in 1 year (error bars only due to statistics):





*Plots taken from *WW scattering at the CERN LHC,* **J.M. Butterworth, B.E. Cox, J.R. Forshaw (Phys.Rev D65, 096014)**

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Summary.

- The motivation and the functionality of the **EWChL** have been presented for the $W_L W_L \rightarrow W_L W_L$ scattering.
- Signal & Background samples have been generated for the $W_L^+ W_L^- \rightarrow W_L^+ W_L^-$ process using **PYTHIA** and reconstructed using **ATLFAST**.
- Study of the reconstructed kinematics and the features of the hadronic environment.
- The **subjet** analysis using the $k_\perp$ clustering improves the identification of highly boosted hadronically decaying Ws.
- The applied cuts result in a very clean signal compared to the background events even during the first year of the LHC operation. Possible to measure also the spin of the resonances.

Next Steps:

- **Triggering:** Not a real problem with the highly energetic final state signatures.
- **Pile-up: 2 GeV** (High Luminosity) cut at the calorimeter cells.
- Extend the study at the $W_L^\pm W_L^\pm \rightarrow W_L^\pm W_L^\pm$ with all the scenarios. The **Full Simulation** is the big challenge.
- Compare PYTHIA to the ME generators.
- .....

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