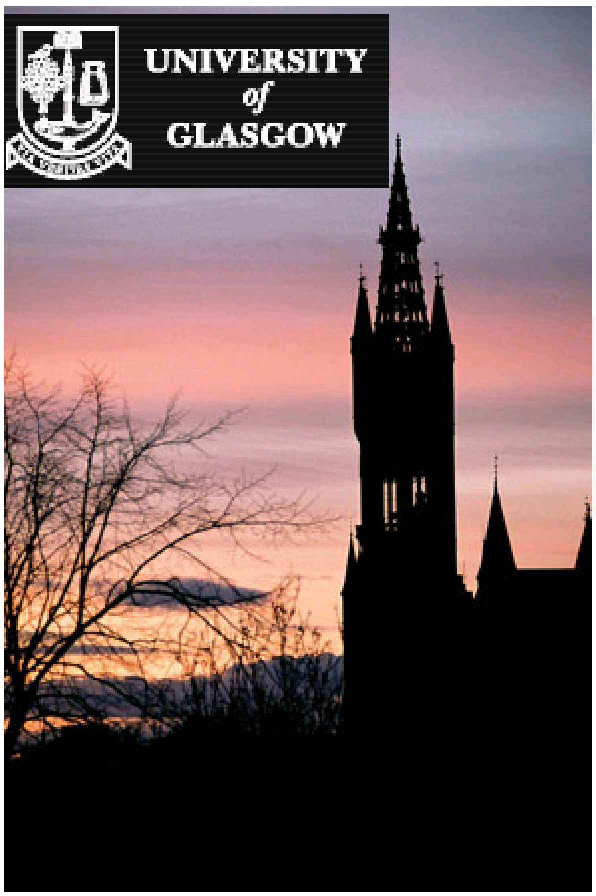
Electroweak Symmetry Breaking without a Higgs at the LHC



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Rencontres de Moriond 2007, QCD and Hadronic Interactions

Introduction

- Standard Model: Higgs mechanism generates mass for the vector bosons and fermions.
- But radiative corrections to higgs mass^2 α a quadratic term in the cutoff parameter. $\rightarrow$ HIERARCHY PROBLEM
- Solutions?

➢ Cut-off parameter is fairly low, i.e. other new physics enters at ~TeV

OR

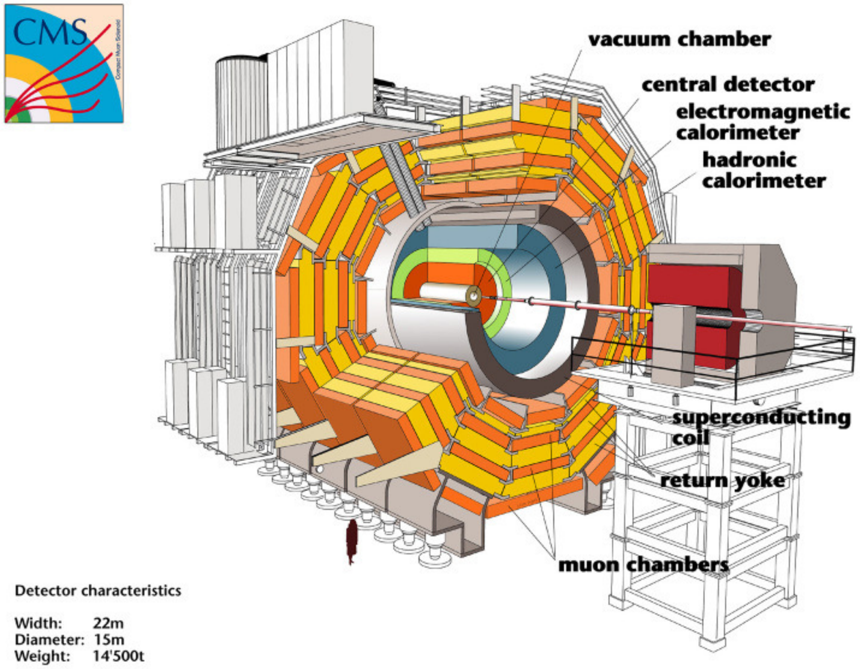
➢ No higgs…

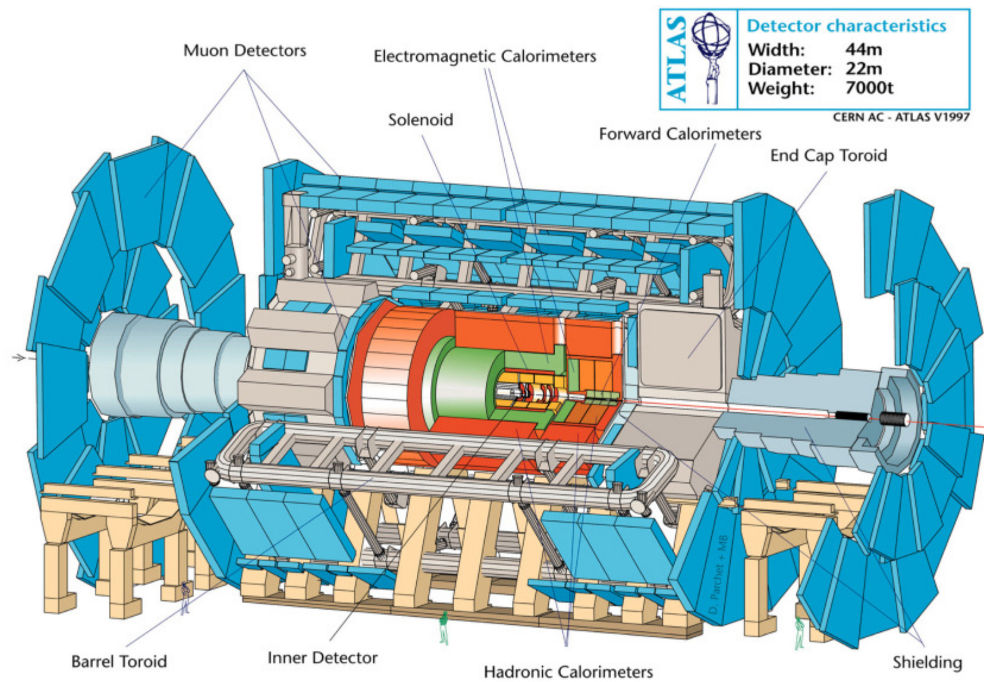
In this talk, consider strong symmetry breaking scenarios:

- the Electroweak Chiral Lagrangian: studies at ATLAS
- technicolour: search for ρ_{TC} at CMS

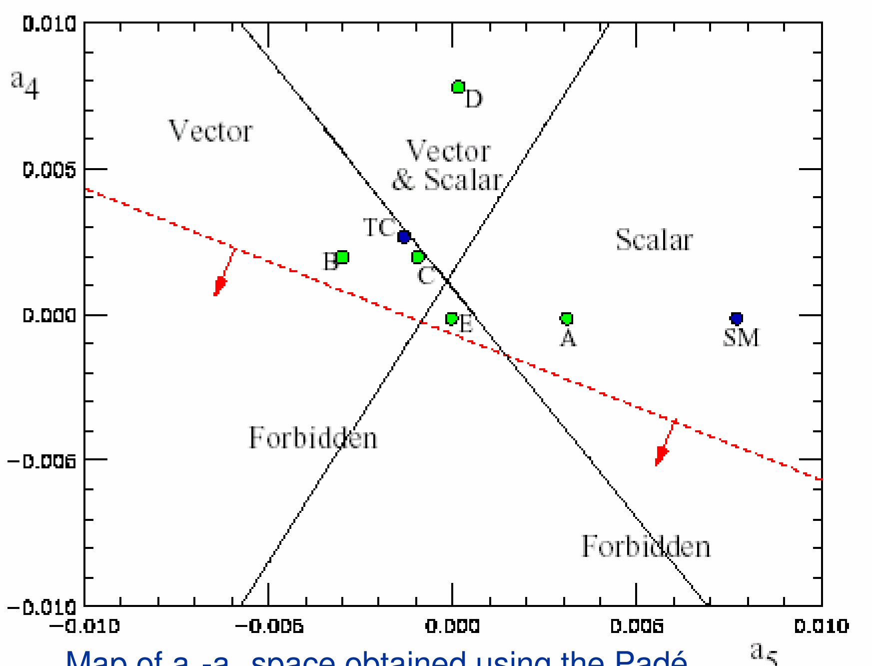
Detectors

- At the LHC: p-p collisions, $\sqrt{s}$ =14TeV (2008 onwards)
- low luminosity: $2*10^{33}cm^{2}s^{-1}$, $10fb^{-1}$/year /detector
- high luminosity: $10^{34}cm^{2}s^{-1}$, $100fb^{-1}$/year /detector





EW Chiral Lagrangian



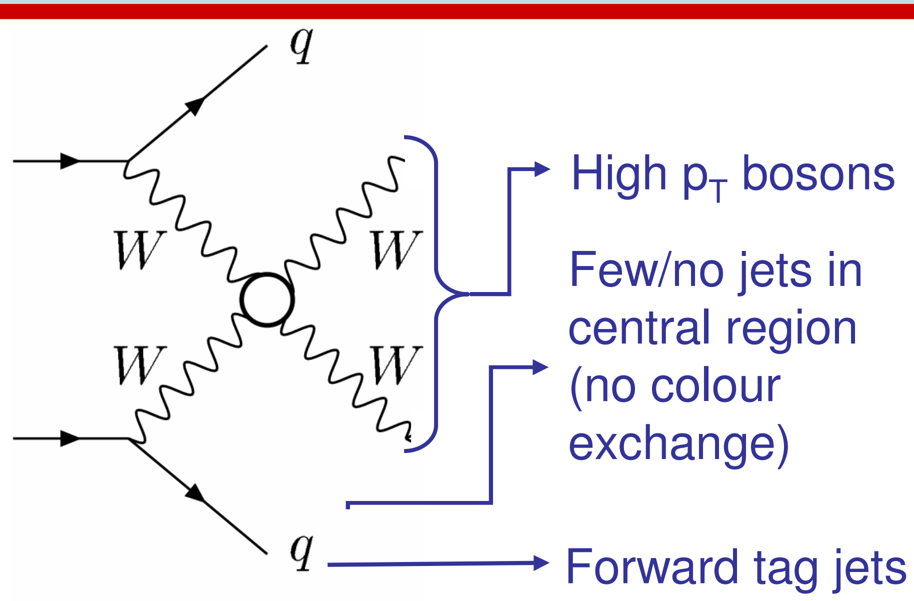
Map of a_4-a_5 space obtained using the Padé unitarisation protocol. Points A-E were investigated in WW study. "TC" is a naïve technicolour model with N_{TC} =3, "SM" is higgs with tree level mass=1TeV. (hep-ph/0201098 J.M. Butterworth, B.E. Cox, J.R. Forshaw.)

- Effective Lagrangian (EWChL) describes effects of different strong EWSB models at low energy.
- Two terms with coefficients a_4 and a_5 parameterise the "new physics" in $W_L W_L \rightarrow W_L W_L$
- EWChL made valid up to higher energies by unitarity constraints

$\rightarrow$ resonances (dependent on unitarisation procedure – Padé (IAM) used here).

σ's for WW→WW ~ 10's of fb.

High Mass Vector Boson Fusion



Backgrounds :

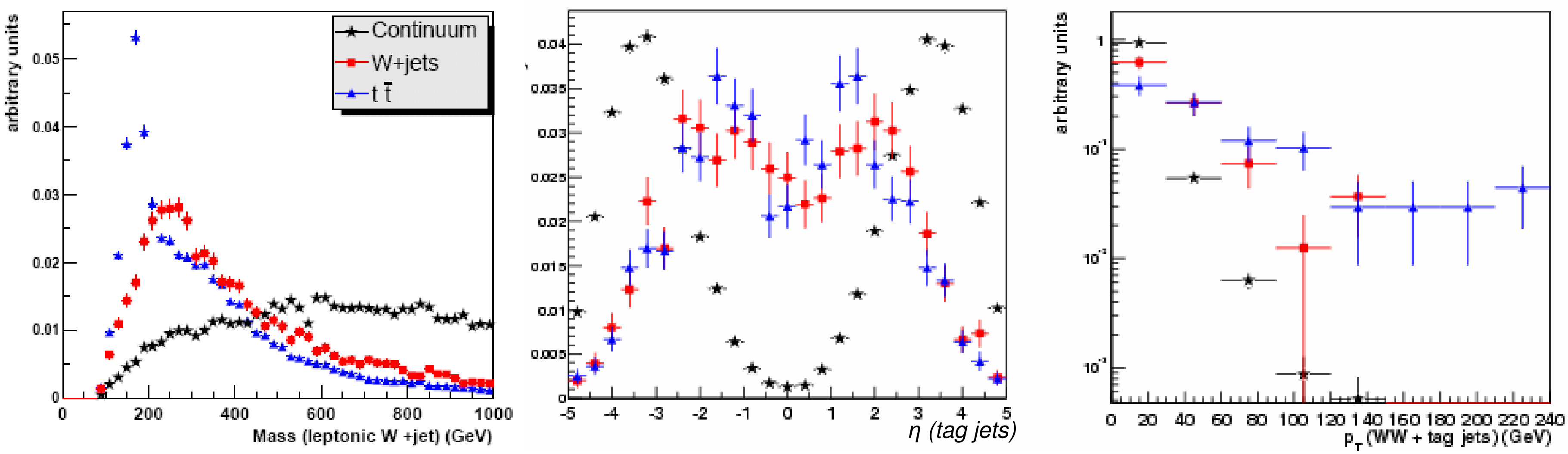
- W+jets, Z+jets
- $t\bar{t}$
- qq→WZqq , WWqq

- Fast simulation studies: WW→lνqq for scalar, vector, no resonance signals. (*Cuts similar to hep-ph/0201098, J. Butterworth, B. Cox, J. Forshaw)*
  - *W+jets and $t\bar{t}$ backgrounds, generated in Pythia*
- Full simulation studies: Vector signal 1.15 TeV WZ→lνll, WZ→llqq, WZ→lνqq.
  - *WZqq, WWqq, W+jets, $t\bar{t}$ backgrounds included*

Cuts for WW→lνqq

- Leptonic W: highest-p_T lepton + E_T^{miss}
- Hadronic W: highest-p_T jet(s)
- top cut: reject events with m(W+jet)~m_{top}
- tag jets: forward of the W's
- p_T(WW+tag jets) ~0:
- central jet veto:

- Cut at p_T^W>320GeV
- Cut at p_T^W>320GeV, m_W±2σ
- 140 < m(W+jet) <270GeV
- E>300GeV, |η|>2.5
- p_T(WW+tag jet) <50GeV
- ≤1 extra jet, p_T> 20GeV,



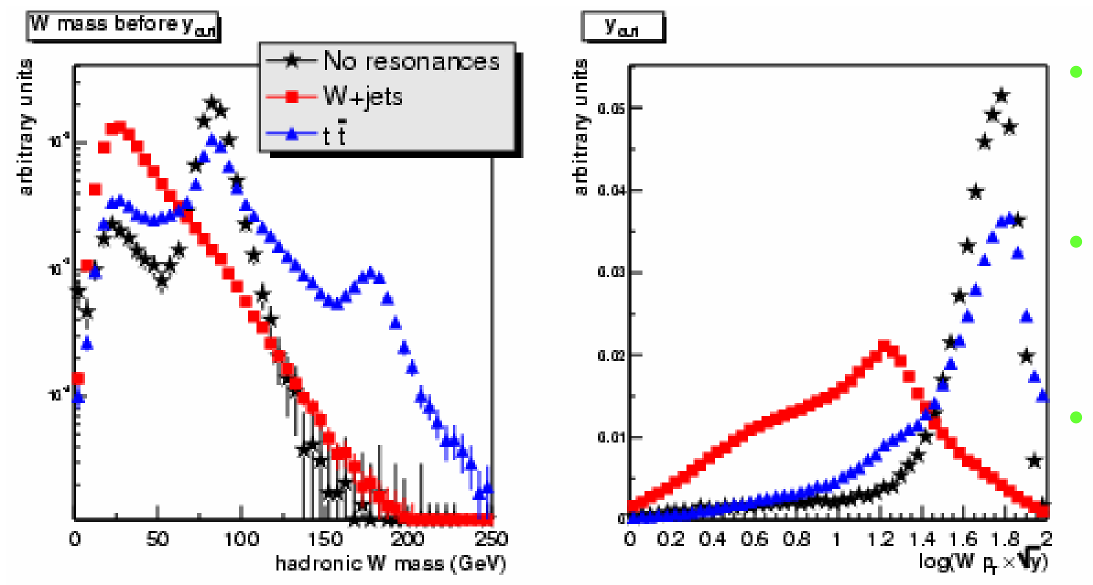
(plots area normalised to one)

$W \to jj$ reconstruction

Hadronic W:

High-p_T overlapping jets → can be reconstructed as 1 or 2 jets.

Using k_T algorithm, R=0.5 :

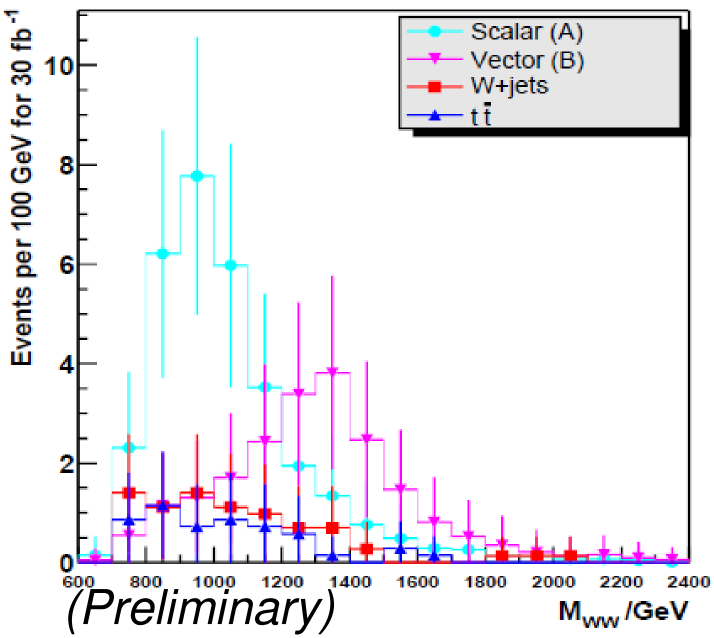


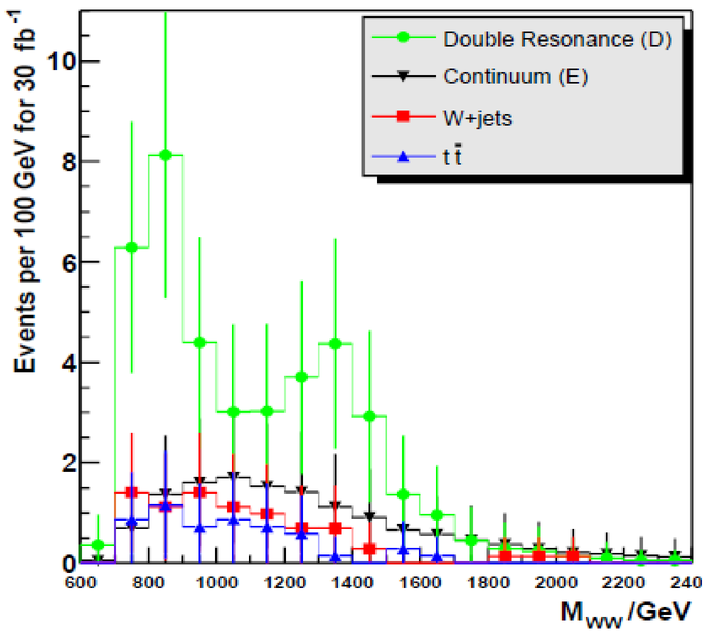
(plots area normalised to one)

- Run k_T algorithm in subjet mode on the cells in the highest p_T jet.
- Clustering is stopped at a scale $y_{21} p_T^2$ → clusters remaining are subjets.
- Scale at which jet is resolved into two subjets is $\sim m_W^2$ for a true W.

Cut at $1.6 < \log(p_T(W)\sqrt{y}) < 2$

Reconstructed Resonances



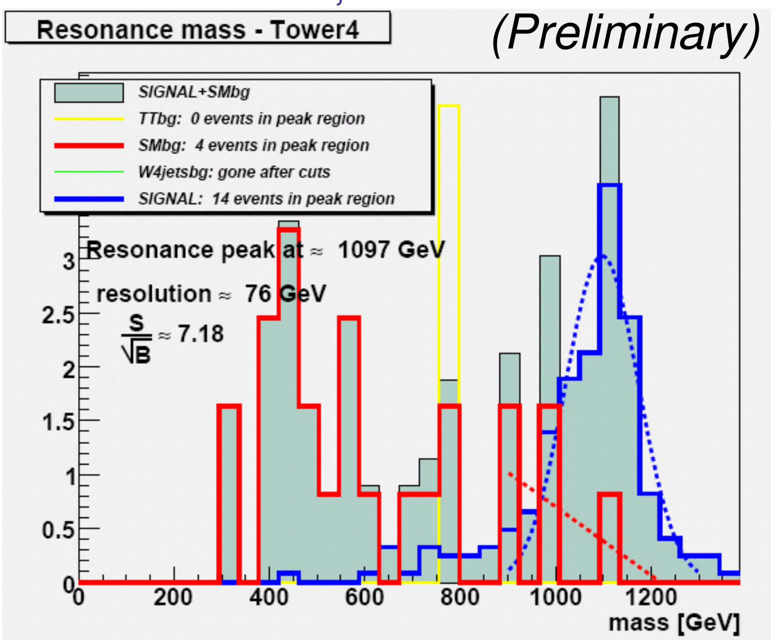


(Preliminary)

	σ after cuts (fb)			
Signal scenario	Signal	ttbar	W+jets	S/√B for 30 fb $^{-1}$
Scalar 1TeV	1.05	0.04	0.28	10.17
Vector 1.4TeV	0.70	0.04	0.28	6.78
Double Resonance	1.33	0.04	0.28	12.88
No resonance (continuum)	0.47	0.04	0.28	4.26

WZ→jjll study

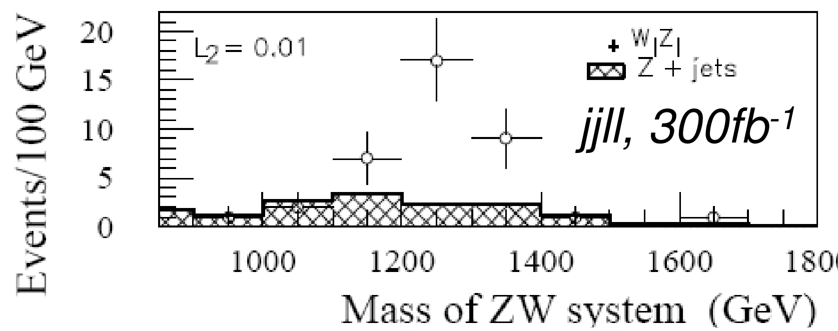
Vector 1.15TeV, $100 fb^{-1}$:



- Z: 2 high-p_T isolated leptons, $m_Z \pm 15$GeV
- Tag jets: E>200GeV, p_T>15GeV, $\Delta\eta_{jj}>4$
- W: 1 or 2 jets, p_{Tj}>40GeV, $m_W \pm 15$GeV
- Central Jet veto: 0 extra jets, p_{Tj}>40GeV
- $\Delta\eta_{WZ}>1.0$
- Reject events with b-jets

Significant signals for $100 fb^{-1}$ in WZ → jjll, lvjj channels and for $300 fb^{-1}$ in WZ → lllv channel.
Study is ongoing.

Fast sim analysis for this channel (ATL-PHYS-99-006 A. Miagkov, for m_{res}=1.2TeV):



Technicolour

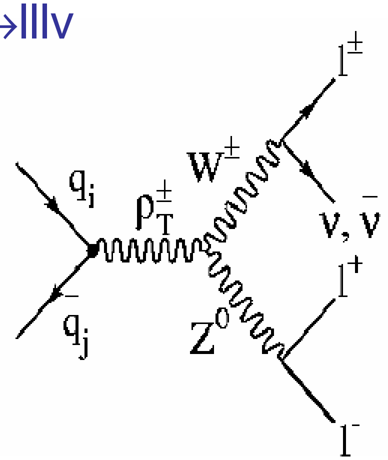
- Simplest model is QCD scaled up:
  - $SU(3)_C \to SU(N)_{TC}$
  - quarks $\to$ techniquarks
  - pions $\to$ technipions
  - Λ_{QCD}~200MeV $\to$ Λ_{TC}~500GeV
  - Chiral symmetry breaking produces Goldstone bosons, π_{TC}. 3 of these become W_L
- ruled out by EW precision data (S, T out by 3σ).

$\to$ Extensions:

- Extended technicolour: gives mass to the fermions by coupling technifermions to ordinary fermions,
- But then FCNCs are predicted: require "walking" rather than running coupling α_{TC} to solve this $\to$ many technifermions.
- To obtain top mass: top assisted technicolour.

Technicolour studies at CMS

- Technicolour "straw man" model: Assumes low E phenomenology determined by lowest lying bound states → $\rho_{TC}^{\pm,0}$, ω_{TC}, $\pi_{TC}^{\pm,0}$.
- CMS study: colour-singlet ρ_{TC}
- Cleanest experimental signature: $qq \rightarrow \rho_{TC} \rightarrow WZ \rightarrow lll\nu$



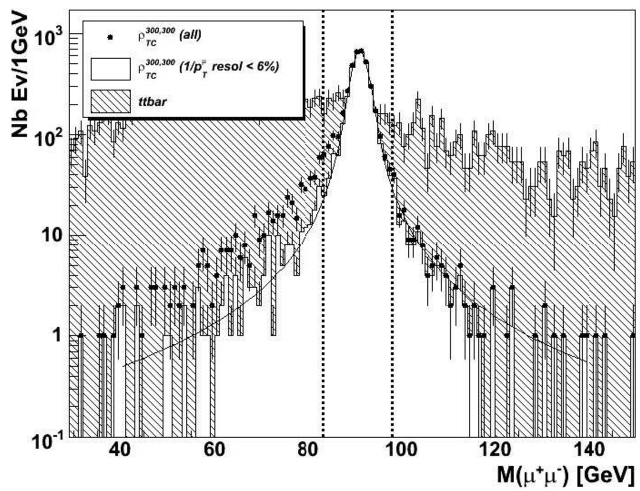
$\sigma \times BR$ ~ few to few hundred fb depending on $m(\rho_{TC})$ and $m(\pi_{TC})$

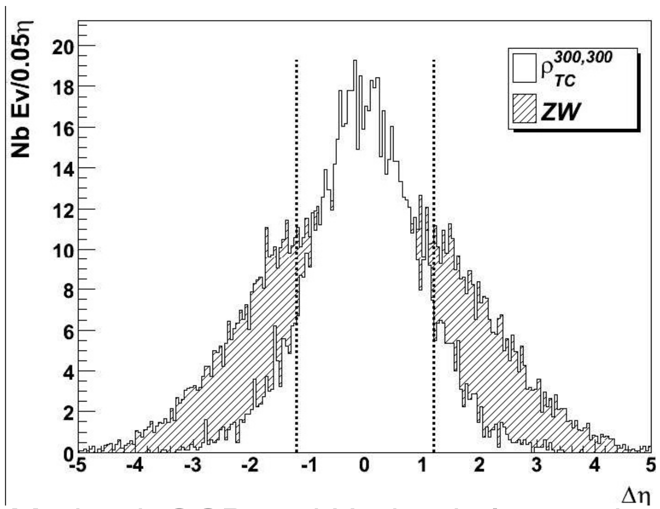
- Main backgrounds:
  - WZ – 0.38pb
  - ZZ – 0.07pb
  - $Zb\bar{b}$ – 330pb
  - $t\bar{t}$ – 490pb

- All generated using Pythia
- 200GeV< $m(\rho_{TC})$ < 600GeV studied
- Fast simulation analysis, validated against full for $m(\rho_{TC})$ = 300 GeV.

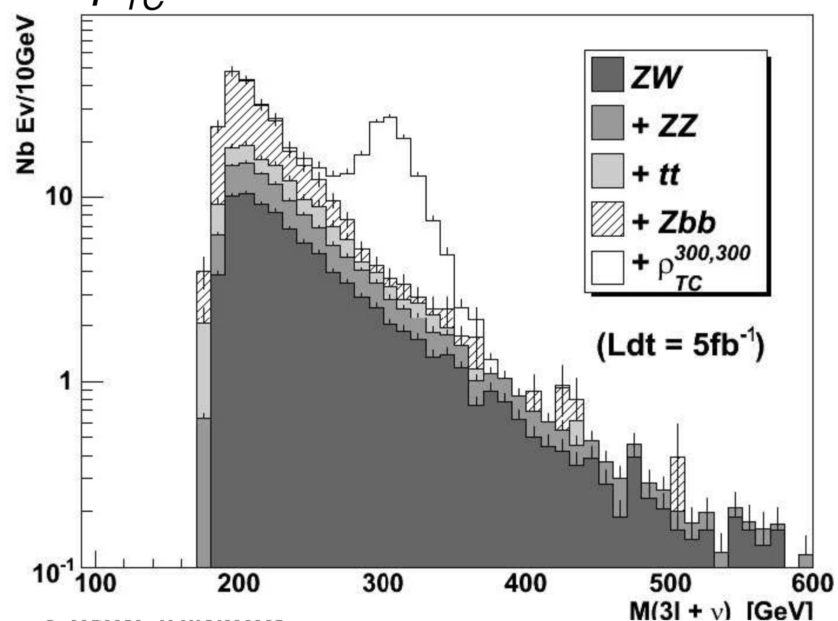
Selection cuts W / Z

- 2 same flavour opp sign leptons = m_Z
- 3^{rd} lepton +missing E_T = m_W
- W, Z p_T >30GeV
- $|M(Z)–M(Z_0)|<7.8$GeV
- $|\eta(Z)–\eta(W)| < 1.2$





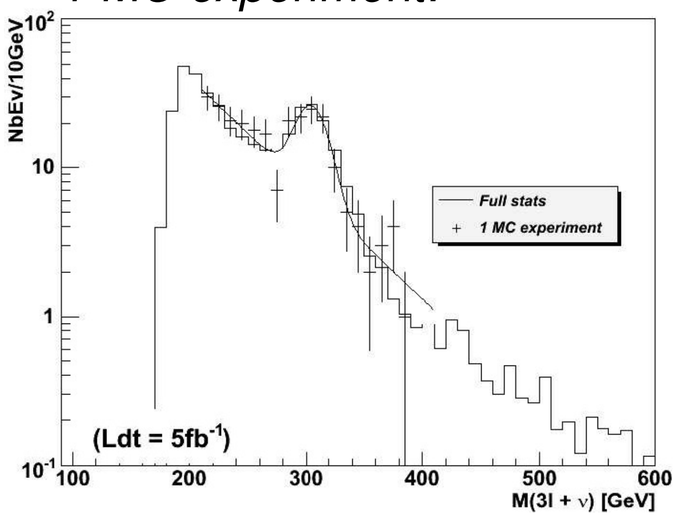
ρ_{TC} reconstructed mass:



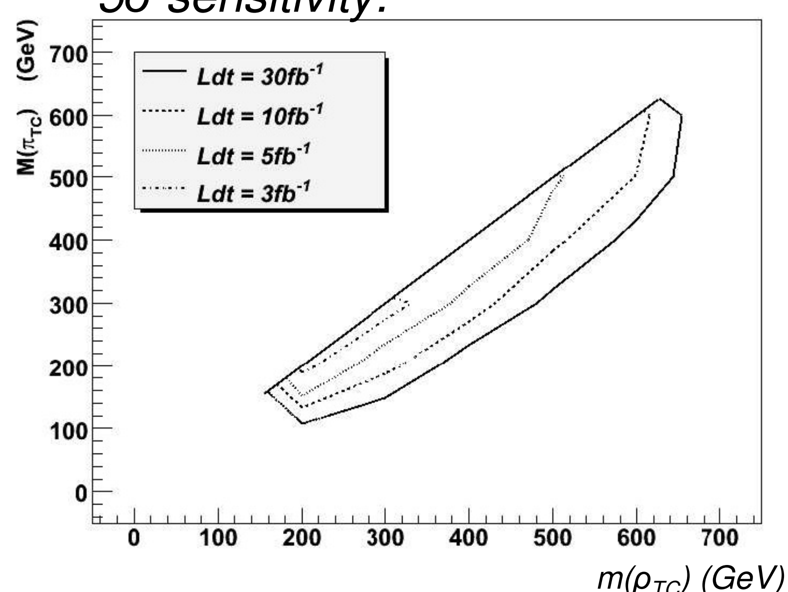
Signal Sensitivity

- Signal: single Gaussian $\mathcal{P}_S$
- Background: single exponential $\mathcal{P}_B$
- Perform many MC experiments (each at stats expected for given luminosity)
- Fit by minimising likelihood function $\mathcal{L}_{S+B} \sim \Pi[(n_S\mathcal{P}_S + n_B\mathcal{P}_B)/(n_S+n_B)]$
- Sensitivity estimator: $S_L = \sqrt{2\ln(\mathcal{L}_{S+B}/\mathcal{L}_B)}$

1 MC experiment:



5σ sensitivity:



Summary

- In the case where there is no light higgs, we expect "new physics" at ~TeV.
- Vector boson scattering is an important channel in which to search.
- We can find significant signals in Chiral Lagrangian model for 30 fb^{-1}. Studies in ATLAS fast and full simulation are continuing in "Computing System Commissioning" note for ATLAS → Summer 2007.
- $\rho_{TC}^{+-} \rightarrow W+Z$ study at CMS shows potential for technicolour discovery from 3 - 4 fb^{-1}.