Awaiting the final details or a revolution.
In principle - SM with a 140 GeV Higgs could be complete (think Mendeleev’s table for chemistry)

However it seems incomplete

- Why are the Higgs coupling to fermions what they are?
- What about Gravity?
- Why Three Generations?
- What about Dark Matter?
Higgs also acquires mass from gauge bosons and fermions via loops

But are quadratically divergent

requires fine tuning!
ALTERNATIVES

- SUSY
- Technicolor
- Extra-Dimensions
- Little Higgs
- GUT
- new generations
Players

1.96 TeV
~10 fb$^{-1}$

7.0 TeV
~2 fb$^{-1}$
and growing
Heavy Gauge Bosons

- Often arise in GUT theories as a leftover symmetry (e.g., an extra U(1) gives rise to a Z’)

- SSM

- LR Symmetric: SU(2)_L x SU(2)_R x U(1)_{B-L}

- E_6 \rightarrow SO(10) \times U(1)_\psi \rightarrow SU(5) \times U(1)_\chi \times U(1)_\psi

- G = U(1)_\theta = \cos(\theta) U(1)_\chi - \cos(\theta) U(1)_\psi

<table>
<thead>
<tr>
<th>Model</th>
<th>\psi</th>
<th>\chi</th>
<th>\eta</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>\theta</td>
<td>0</td>
<td>90</td>
<td>37.75</td>
<td>-52.24</td>
</tr>
</tbody>
</table>
Kalutza-Klien theories with extra dimensions give excited states of Standard Model gauge bosons

Little Higgs theories have partners of W and Z

SUSY without R parity

...
If $Z'$ mixes with $Z$ for a sufficiently light $Z'$ should see mixing effects.

arXiv:0904.2534
Direct Limits (SSM)

LHC:
- ATLAS ~1.83 TeV
- CMS ~1.94 TeV

Tuesday, August 9, 2011
Similar (or the same!) models also predict a heavy $W'$

- 'natural' in the same way a $Z'$ is introduced by the breaking of some higher symmetry group to the SM

Attractive Features:

- IF coupling is similar to SM $W/Z$ the $W'$ would have a larger cross-section at a hadron collider

- Generally avoid the strict indirect limits from LEP as they would have had to been produced in pairs there
W’ production in most considered models is not very sensitive to exact coupling.

Interference with SM $W$ is important $W’$ - in particular in identifying the $W’$. 

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*Figure: T. Rizzo, hep-ph/0704.0235*
W' Decay

W' Signatures:
- Leptonic: e ν, μν, τν
- Bosonic: WZ, Wγ
- Hadronic: qq', tb, lN

Large W' mass opens new channels

Favored Decay modes depend highly on exact model (eg SSM compared to models where large coupling to 3rd generation)
CURRENT LIMITS

Limits (SSM)
ATLAS: 2.15 TeV
CMS: 2.27 TeV

note expected limit
~2.2 TeV
in both cases
SUPERSYMMETRY

Postulate a symmetry between fermions and bosons

Minimal version doubles the amount of particles

Cancelation of quadratic divergences present in SM

Models with R parity would have a stable neutral particle as a dark matter candidate
GUTs and SUSY were proposed independently though closely connected.

Introduction of new SUSY particles MAY modify the evolution of the coupling so that they unify at high energy.
SUSY is not one model but rather a collection

- R-parity, SUSY breaking scenarios, ...
THE GOOD, THE BAD, ... 

- SUSY has a number of attractive features
  - Could explain a light Higgs naturally
  - Gauge Coupling Unification
  - Dark Matter Candidate
  - No New Forces
- Come at some cost
  - Many new particles: masses and mixing angles (set it and forget it)
  - What sets the SUSY mass scale?
  - What causes SUSY breaking?
huge gains in short period of time - limits approaching 1 TeV
Technicolor

- ‘Dynamic’ explanation of electroweak symmetry breaking
- Instead of Higgs particle - new strong interactions
- Technicolor:
  - New Strong Dynamics: SU($N_T$) gauge theory similar to QCD
  - $N_T^2-1$ new gauge bosons: technigluons
  - In analogy with QCD breaking of the chiral symmetry produces
    - Goldstone bosons (technipions):
    - 3 technipions are eaten to become longitudinal $W$ and $Z$
As a new strongly interacting theory - would produce a whole new set of QCD like particles

Search for the lightest ones: $\pi_T, \rho_T, \omega_T$

Some model dependence but popular searches for

- $\rho_T \rightarrow W \pi_T \rightarrow l\nu bb$ (best reach at Tevatron, harder at LHC)
- $\rho_T \rightarrow WZ$
- $\rho_T \rightarrow ll$
Limits from Tevatron
~ several hundred GeV

Limits from LHC: Forthcoming!
Recently much excitement over bump seen in Wjj spectrum at CDF

4.1 $\sigma$ in significance

$q_T \rightarrow W \pi_T \rightarrow l\nu jj$ ???

measured cross-section $\sim 3\pm 0.7$ pb roughly consistent with technicolor prediction
• Unfortunately excess is not confirmed by D0

• Ongoing investigations to compare analysis and results
ATLAS also does not see an excess in the same region.

Note however that conclusions are VERY model dependent.

- Eichten, Lane, Martin point out that if it was technicolor do not expect to see anything yet at LHC.
CONCLUSIONS

- Too many BSM scenarios to fit into one talk!
- Many exciting times ahead - LHC has already doubled the limits on many models
- Hopefully we will produce more than limits!