Prospects for Future Collider Physics

What is the Higgs boson trying to tell us?
Is supersymmetry waiting?
Can LHC Run 2 find it?
What if X(750) exists?
Sphalerons?
Higgs Mass Measurements

- ATLAS + CMS ZZ* and γγ final states

One thing we have!

125.09 ± 0.21 (stat) ± 0.11 (syst)

- Statistical uncertainties dominate
- Allows precision tests
- Crucial for stability of electroweak vacuum
Elementary Higgs or Composite?

- Higgs field: \( \langle 0 | H | 0 \rangle \neq 0 \)

- Quantum loop problems

- Fermion-antifermion condensate

- Just like QCD, BCS superconductivity

- Top-antitop condensate? needed \( m_t > 200 \text{ GeV} \)

- New technicolour force?
  - Heavy scalar resonance?
  - Little Higgs, ...
  - Re-awakened by \( X(750) \)?

Cut-off \( \Lambda \sim 1 \text{ TeV} \) with Supersymmetry?

\( m_h^2 \sim (200 \text{ GeV})^2 \)

Cutoff \( \Lambda = 10 \text{ TeV} \)
Why is there Nothing rather than Something?

- Higher-dimensional operators as relics of higher-energy physics, e.g., dimension 6:

\[ \mathcal{L}_{\text{eff}} = \sum_n \frac{f_n}{\Lambda^2} \mathcal{O}_n \]

- Operators constrained by SU(2) × U(1) symmetry:

\[
\mathcal{L} \supset \frac{\bar{c}_H}{2v^2} \partial^\mu [\Phi^\dagger \Phi] \partial_\mu [\Phi^\dagger \Phi] + \frac{g^2}{m_w^2} \frac{\bar{c}_\gamma}{2} \Phi^\dagger \Phi B_{\mu \nu} B^{\mu \nu} + \frac{g_s^2}{m_w^2} \frac{\bar{c}_g}{2} \Phi^\dagger \Phi G_{\mu \nu}^a G_a^{\mu \nu}
\]

\[
+ \frac{2ig}{m_w^2} \bar{c}_{HW} [D^\mu \Phi^\dagger T_{2k} D^\nu \Phi] W_{\mu \nu}^k + \frac{ig'}{m_w^2} \bar{c}_{HB} [D^\mu \Phi^\dagger D^\nu \Phi] B_{\mu \nu}
\]

\[
+ \frac{ig}{m_w^2} \bar{c}_W [\Phi^\dagger T_{2k} \nabla^\mu \Phi] D^\nu W_{\mu \nu}^k + \frac{ig'}{2m_w^2} \bar{c}_B [\Phi^\dagger \nabla^\mu \Phi] \partial^\nu B_{\mu \nu}
\]

\[
+ \frac{\bar{c}_t}{v^2} y_t \Phi^\dagger \Phi^\dagger \cdot \bar{Q}_L t_R + \frac{\bar{c}_b}{v^2} y_b \Phi^\dagger \Phi^\dagger \Phi \cdot \bar{Q}_L b_R + \frac{\bar{c}_\tau}{v^2} y_\tau \Phi^\dagger \Phi^\dagger \Phi \cdot \bar{L}_L \tau_R
\]

- Constrain with precision EW, Higgs data, TGCs ...
Global Fits including LHC TGCs

- Higgs production
- LHC Triple-gauge couplings
- Global combination
- Individual operators
Projected $e^+e^-$ Colliders: Luminosity vs Energy

- Z peak
- WW
- Zh
- $t \bar{t}$ bar

All important!

Updated from TLEP physics study group: arXiv:1308.6176
FCC-ee Higgs & TGC Measurements

- LHC constraints
- **FCC-ee** constraints: see $\Lambda \sim 10$ TeV?

JE & Tevong You, arXiv:1510.04561
FCC-ee Higgs & TGC Measurements

EWPTs and Higgs

- Shadings:
  - With/without theoretical uncertainties in EWPTs

Higgs and TGCs

- Shadings of green:
  - Effect of including TGCs at ILC

JE & Tevong You, arXiv:1510.04561
• «Empty» space is unstable
• Dark matter
• Origin of matter
• Masses of neutrinos
• Hierarchy problem
• Inflation
• Quantum gravity
• ...

The Standard Model
What lies beyond the Standard Model?

Supersymmetry

- Stabilize electroweak vacuum
- Successful prediction for Higgs mass
  - Should be < 130 GeV in simple models
- Successful predictions for couplings
  - Should be within few % of SM values
- Naturalness, GUTs, string, …, dark matter

New motivations
From LHC Run 1
Theoretical Constraints on Higgs Mass

- Large $M_h \rightarrow$ large self-coupling $\rightarrow$ blow up at low energy scale $\Lambda$ due to renormalization.

- Small: renormalization due to $t$ quark drives quartic coupling $< 0$ at some scale $\Lambda$ $\rightarrow$ vacuum unstable.

- Vacuum could be stabilized by Supersymmetry.

\[
\lambda(Q) = \lambda(v) - \frac{3m_t^4}{2\pi^2v^4} \log \frac{Q}{v}
\]

Instability @ $10^{11.1 \pm 1.3}$ GeV

Vacuum Instability in the Standard Model

- Very sensitive to $m_t$ as well as $M_H$

Instability scale:

$$m_t = 173.3 \pm 1.0 \text{ GeV} \Rightarrow \log_{10}(\Lambda/\text{GeV}) = 11.1 \pm 1.3$$

Bednyakov, Kniehl, Pikelner and Veretin: arXiv:1507.08833

Buttazzo, Degrassi, Giardino, Giudice, Sala, Salvio & Strumia, arXiv:1307.3536
How to Stabilize a Light Higgs Boson?

- Top quark destabilizes potential: introduce stop-like scalar:
  \[ \mathcal{L} \supset M^2 |\phi|^2 + \frac{M_0}{v^2} |H|^2 |\phi|^2 \]
- Can delay collapse of potential:
- But new coupling must be fine-tuned to avoid blow-up:
- Stabilize with new fermions:
  - just like Higgsinos
- Very like Supersymmetry!

JE + D. Ross
PLETHORA OF MODELS CONSISTENT WITH DATA, MANY OF THEM NATURAL. WHERE DOES THE DATA POINT US?
MasterCode

- Combines diverse set of tools
  - different codes: all state-of-the-art
    - Electroweak Precision (FeynWZ)
    - Flavour (SuFla, micrOMEGAs)
    - Cold Dark Matter (DarkSUSY, micrOMEGAs)
    - Other low energy (FeynHiggs)
    - Higgs (FeynHiggs)
  - different precisions (one-loop, two-loop, etc)
  - different languages (Fortran, C++, English, German, Italian, etc)
  - different people (theorists, experimentalists)
- Compatibility is crucial! Ensured by
  - close collaboration of tools authors
  - standard interfaces

---

Sample Supersymmetric Models

• Universal soft supersymmetry breaking at input GUT scale?
  – For gauginos and all scalars: CMSSM
  – Non-universal Higgs masses: NUHM1,2

• **Strong pressure from LHC (p ~ 0.1)**

• Treat soft supersymmetry-breaking masses as phenomenological inputs at EW scale
  – pMSSMn (n parameters)
  – With universality motivated by upper limits on flavour-changing neutral interactions: pMSSM10

• **Less strongly constrained by LHC (p ~ 0.3)**
Fit to Constrained MSSM (CMSSM)

2012 ATLAS + CMS with 20/fb of LHC Data

Allowed region extends to large $m_0$


p-value of simple models $\sim 10\%$ (also SM)
Constrained MSSM (CMSSM)

LHC MET searches

$g_\mu - 2$

Contributions to global $\chi^2$ from different observables

Dark Matter Density Mechanisms

2012 \textbf{ATLAS + CMS with 20/fb of LHC Data}

- \tilde{\tau}_1 coannihilation (pink): \( \frac{m_{\tilde{\tau}_1}}{m_{\chi_1^0}} - 1 < 0.15 \),
- A/H funnel (blue): \( \left| \frac{M_A}{2m_{\chi_1^0}} - 1 \right| < 0.2 \),
- \tilde{\chi}_1^\pm coannihilation (green): \( \frac{m_{\tilde{\chi}_1^\pm}}{m_{\chi_1^0}} - 1 < 0.1 \),
- \tilde{\ell}_1 coannihilation (grey): \( \frac{m_{\tilde{\ell}_1}}{m_{\chi_1^0}} - 1 < 0.2 \).


Estimated reach with Run 2 of the LHC

Current LHC reach

---

\textbf{CMSSM: best fit, 1\sigma, 2\sigma}
Measuring the CMSSM with the LHC

Dark Matter in CMSSM, NUHM1/2, pMSSM10

Estimated future LHC reach

Current LHC reach

Long-Lived Stau in CMSSM, NUHM?

Possible if $m_{\text{stau}} - m_{\text{LSP}} < m_{\tau}$

Generic possibility in CMSSM, NUHM

(stau coannihilation region)

$\tau_{\text{stau}} > 10^3$ s gives problems with nucleosynthesis

$\tau_{\text{stau}} > 10^{-7}$ s gives separated vertex signature for $\tau$-like decays

Phenomenological MSSM (pMSSM10)

3 gaugino masses: $M_{1,2,3}$
2 squark masses: $m_{	ilde{q}_1} = m_{	ilde{q}_2} \neq m_{	ilde{q}_3}$
1 slepton mass: $m_{\tilde{e}}$
1 trilinear coupling: $A$
Higgs mixing parameter: $\mu$
Pseudoscalar Higgs mass: $M_A$
Ratio of vevs: $\tan \beta$.


Contributions to global $\chi^2$ from different observables

$LHC$ MET searches

$g_\mu - 2$
Anomalous Magnetic Moment of Muon

2012 ATLAS + CMS with 20/fb of LHC Data

$g_\mu - 2$ anomaly

Cannot be explained by models with GUT-scale unification

Can be explained in pMSSM10

$pMSSM10$ can explain experimental measurements of $g_\mu - 2$

Fits to Supersymmetric Models

ATLAS + CMS with 20/fb of LHC Data

Gluino mass

Reach of LHC at High luminosity


Favoured values of gluino mass also significantly above pre-LHC, > 1.2 TeV
Fits to Supersymmetric Models

2012 ATLAS + CMS with 20/fb of LHC Data

Remaining possibility of a light “natural” stop weighing ~ 400 GeV

Stop mass

Compressed stop region


Exploring Light Stops @ Run 2

Part of region of light “natural” stop weighing ~ 400 GeV can be covered

Why we are so excited by Run 2

- 2015 luminosity already explores new physics
Prospects for SUSY Searches

- Different models, various dark matter mechanisms

<table>
<thead>
<tr>
<th>DM mechanism</th>
<th>Exp’t</th>
<th>CMSSM</th>
<th>Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \tilde{\tau}_1 ) coann.</td>
<td>LHC</td>
<td>✓ ( E_T ), ✓ LL</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DM</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>( \tilde{\chi}_1^\pm ) coann.</td>
<td>LHC</td>
<td>–</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>DM</td>
<td>–</td>
<td>✓</td>
</tr>
<tr>
<td>( t_1 ) coann.</td>
<td>LHC</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DM</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>( A/H ) funnel</td>
<td>LHC</td>
<td>✓ ( A/H )</td>
<td>✓ ( A/H )</td>
</tr>
<tr>
<td></td>
<td>DM</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Focus point</td>
<td>LHC</td>
<td>(✓ ( E_T ))</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>DM</td>
<td>✓</td>
<td>–</td>
</tr>
<tr>
<td>( h, Z ) funnels</td>
<td>LHC</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>DM</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

- No guarantees, but good prospects

Squark-Gluino Plane

Discover 12 TeV squark, 16 TeV gluino @ 5σ
“Who ordered that”

He was talking about the muon …
Reported on Tuesday, Dec. 15

- Peaks in $\gamma\gamma$ invariant mass distributions

- Possible new particle X with mass ~ 750 GeV decaying into 2 photons
Global Analysis of X Signal

- Assume scalar/pseudoscalar (angular distribution?)
- Combined analysis of CMS and ATLAS data

Some tension between data from Run 1 and Run 2?

JE, S.Ellis, Quevillon, Sanz & You, arXiv:1512.05327
X Decays?

- Decay to $\gamma\gamma$ via anomalous triangle diagrams
- Probably also production via gluon fusion
- Loops need heavy particles, $m > 350$ GeV
- Can’t be 4th generation/minimal supersymmetry
- Single vector-like quark enough, could be more
  - 1: Single VL quark, cf, $t_R$
  - 2: Doublet of VL quarks, cf, $q_L$
  - 3: Doublet + 2 singlets, cf, $q_L$, $t_R$, $b_R$
  - 4: Complete VL generation, including leptons
- Assume $gg$ decays dominant

JE, S.Ellis, Quevillon, Sanz & You, arXiv:1512.05327
Scalar/Pseudoscalar Models for X

- Required X couplings $\lambda$ to heavy fermions in different models
- Black line = best fit
- Band = 1 $\sigma$
- Perturbative limit
- Neutral fermion could be dark matter

JE, S. Ellis, Quevillon, Sanz & You, arXiv:1512.05327
How to Probe Possible Models?

- Other possible decay modes

<table>
<thead>
<tr>
<th>Model</th>
<th>$Tr[Y^2]$</th>
<th>$Tr[D(r)^2]$</th>
<th>$\frac{BR(X \rightarrow gg)}{BR(X \rightarrow \gamma \gamma)}$</th>
<th>$\frac{BR(X \rightarrow Z\gamma)}{BR(X \rightarrow \gamma \gamma)}$</th>
<th>$\frac{BR(X \rightarrow ZZ)}{BR(X \rightarrow \gamma \gamma)}$</th>
<th>$\frac{BR(X \rightarrow W^\pm W^\mp)}{BR(X \rightarrow \gamma \gamma)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$\frac{8}{3}$</td>
<td>0</td>
<td>180</td>
<td>1.2</td>
<td>0.090</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>$\frac{1}{3}$</td>
<td>3</td>
<td>460</td>
<td>10</td>
<td>9.1</td>
<td>61</td>
</tr>
<tr>
<td>3</td>
<td>$\frac{11}{3}$</td>
<td>3</td>
<td>460</td>
<td>1.1</td>
<td>2.8</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>$\frac{20}{3}$</td>
<td>4</td>
<td>180</td>
<td>0.46</td>
<td>2.1</td>
<td>11</td>
</tr>
<tr>
<td>Current limit</td>
<td>$\sim 2 \times 10^4$</td>
<td>7</td>
<td>13</td>
<td>46</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Predictions ≤ experimental limits
- Potentially accessible to experiment
- Also look for heavy fermions!
- Work for a generation – if X particle exists!
- Will know in 2016

JE, S.Ellis, Quevillon, Sanz & You, arXiv:1512.05327
Scalar/Pseudoscalar Models for X

- What if $\Gamma_X = 45$ GeV?
- Required $X$ couplings $\lambda$ to heavy fermions in different models
- Black line = best fit
- Green band = 1 $\sigma$
- Perturbative limit
- More fermions in loops?

JE, S.Ellis, Quevillon, Sanz & You, arXiv:1512.05327
Possible Future X Signal

- Assuming production by gluon-gluon fusion
- Normalized to $\sigma_B(\gamma\gamma) = 6 \text{ fb}$

PDF, ren’èn scale uncertainties @ 100 TeV ~ 30%

Djouadi, JE, Godbole, Quevillon, arXiv:1601.03696
\( \gamma\gamma \rightarrow X \) Signal at \( e^+e^- \) Collider

- For \( \sigma_B(\gamma\gamma) = 6 \text{ fb} \), assuming \( X \rightarrow gg \) dominant

- Centre-of-mass energy \( \sim 1 \text{ TeV} \) preferred!

Djouadi, JE, Godbole, Quevillon. arXiv:1601.03696
Cross Sections for Vector-Like Q

- Pair-production at LHC, future circular colliders

- Present lower mass limit $\sim 800$ GeV

Djouadi, JE, Godbole, Quevillon. arXiv:1601.03696
Cross Sections for Vector-Like L

- Pair-production at LHC, future circular colliders
- Present mass limit < 400 GeV

Djouadi, JE, Godbole, Quevillon, arXiv:1601.03696
Single Vector-Like Q, L Production

- Single production at LHC, future circular colliders

- Assuming mixing angle with light fermions $\xi = 0.1$

Djouadi, JE, Godbole, Quevillon. arXiv:1601.03696
Sensitivity to Vector-Like Q, L

<table>
<thead>
<tr>
<th>model</th>
<th>Vector-like quark mass sensitivity</th>
<th>Vector-like lepton mass sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100 fb^{-1} 300 fb^{-1} 300 fb^{-1} 20 ab^{-1}</td>
<td>100 fb^{-1} 300 fb^{-1} 300 fb^{-1} 20 ab^{-1}</td>
</tr>
<tr>
<td></td>
<td>13 TeV 14 TeV 33 TeV 100 TeV</td>
<td>13 TeV 14 TeV 33 TeV 100 TeV</td>
</tr>
<tr>
<td>1</td>
<td>1.4 1.7 3.1 11.7</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>1.5 1.8 3.4 12.7</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>1.6 2.0 3.7 13.7</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>1.6 2.0 3.7 13.7</td>
<td>0.56 0.73 1.7 5.3</td>
</tr>
</tbody>
</table>

- Model 1: Single VL quark, cf, t_R
  - Non-perturbative coupling required
- Model 2: Doublet of VL quarks, cf, q_L
  - Non-perturbative coupling favoured
- Model 3: Doublet + 2 singlets, cf, q_L, t_R, b_R
  - Perturbative range covered by LHC
- Model 4: Complete VL generation, including leptons
  - Covering perturbative range needs higher energy

Djouadi, JE, Godbole, Quevillon, arXiv:1601.03696
Alternative Higgs Doublet Scenario

- After singlet, doublet?
- Heavy Higgses in 2 Higgs doublet model: $\Phi = H, A$
- Nearly degenerate in many versions, e.g., SUSY
- Expect $t \bar{t}$ bar decays to dominate
- Can accommodate $\Gamma_\Phi \sim 45$ GeV (ATLAS)
- Need larger enhancement of loops compared to singlet model
- **Rich bosonic phenomenology**

Djouadi, JE, Godbole, Quevillon, arXiv:1601.03696
\[ \Phi = H, A \text{ Decays in Doublet Model} \]

- Dependences on \( \tan \beta \) of branching ratios, \( \Gamma_{\Phi} \)

- Prefer \( \tan \beta \sim 1 \)

- Dominant \( \Phi \) decays to \( t \bar{t} \)

Djouadi, JE, Godbole, Quevillon. arXiv:1601.03696
Lineshape in $pp$ Collisions

- $+$MSSM: $\tan \beta = 1$
- $M_H - M_A \sim 15$ GeV
- $\Gamma_H, \Gamma_A \sim 32, 35$ GeV
- $\sigma_B(A \rightarrow \gamma\gamma) = 2 \times \sigma_B(H \rightarrow \gamma\gamma)$
- Asymmetric
  - ‘Breit-Wigner’
- Resolvable?

Djouadi, JE, Godbole, Quevillon, arXiv:1601.03696
Fermion Loop Form Factors

- Triangle diagrams suppressed for small $M_F$

- Enhanced if $m_F \sim M_\Phi/2$

Djouadi, JE, Godbole, Quevillon, arXiv:1601.03696
Obtaining Loop Enhancement

- Need loop enhancement ~ 500 if $\Gamma \sim 45$ GeV
- Vector-like generation of quarks and leptons
- 3 doubly-charged leptons
- 3 pairs of vector-like leptons

Djouadi, JE, Godbole, Quevillon, arXiv:1601.03696
Possible $\Phi = H, A$ Signals

- Normalized to $\sigma_B(\gamma\gamma) = 6 \text{ fb @ 13 TeV}$

Djouadi, JE, Godbole, Quevillon, arXiv:1601.03696
Possible $H^{\pm}$ Signals

- $\sqrt{s} = 14, 100$ TeV for varying $M_{H^\pm} \neq M_{\Phi}$ in general

Djouadi, JE, Godbole, Quevillon, arXiv:1601.03696
$\gamma \gamma \rightarrow \Phi$ Signal at $e^+e^-$ Collider

- For $\sigma_B(\gamma \gamma) = 6 ~ \text{fb}$, assuming $\Gamma(\Phi=H,A) = 45 ~ \text{GeV}$
- $e^+e^-$ centre-of-mass energy $\sim 1 ~ \text{TeV}$

Djouadi, JE, Godbole, Quevillon, arXiv:1601.03696
“Plus un fait est extraordinaire, plus il a besoin d’être appuyé de fortes preuves”

Laplace, 1812

“The more extraordinary a claim, the stronger the proof required to support it.”
Higgs champagne in Singapore
Search for Sphalerons in $pp$ Collisions

- Used to think sphaleron transitions very suppressed
- Challenged by Tye & Wong
- Recall periodic potential, construct Bloch wave
  \[
  \left( -\frac{1}{2m} \frac{\partial^2}{\partial Q^2} + V(Q) \right) \Psi(Q) = E \Psi(Q)
  \]
  \[
  V(Q) \approx 4.75 \left( 1.31 \sin^2(Qm_W) + 0.60 \sin^4(Qm_W) \right) \text{TeV}
  \]
- Enhanced transition rate below/above $E_{\text{Sph}} \sim 9$ TeV
  \[
  \sigma(\Delta n = \pm 1) \propto \exp \left( c \frac{4\pi}{\alpha_W} S(E) \right)
  \]
  \[
  S(E) = (1 - a) \hat{E} + a \hat{E}^2 - 1 \quad \text{for} \quad 0 \leq \hat{E} \leq 1
  \]
- Estimated transition rate: unknown prefactor $p$
  \[
  \sigma(\Delta n = \pm 1) = \frac{p}{m_W^2} \sum_{ab} \int dE \frac{d\mathcal{L}_{ab}}{dE} \exp \left( c \frac{4\pi}{\alpha_W} S(E) \right)
  \]
Sphaleron Transitions

- Final-state invariant mass distribution @ LHC
- Including different parton processes

JE, Sakurai, arXiv:1601.03654
Sphaleron Transitions

- Growth of cross section with energy, if $p$ constant

- For different sphaleron masses (9 TeV expected)

- Normalization $p$ poorly known

JE, Sakurai, arXiv:1601.03654
Sphaleron Transitions

- Mass distributions in sphaleron-induced transitions
- Reduced by neutrino emission, etc.
- Broader mass distributions at higher energies

JE, Sakurai, arXiv:1601.03654
Sphaleron Transitions

- Properties of $\Delta n = \pm 1$ 10- and 14-particle final states

JE, Sakurai, arXiv:1601.03654
Sphaleron Transitions

• Energy dependence of 10-particle final states

• Events with plenty of missing $E_T$

JE, Sakurai, arXiv:1601.03654
Comparison with Black Hole Search

• Data from ATLAS search with 3/fb @ 13 TeV

• Expect plenty of events with large missing $H_T$
Constraint from Black Hole Search

- High acceptance for 10-particle final states of ATLAS search with 3/fb @ 13 TeV

- Exclude $p \sim 0.3$ for expected $E_{\text{Sph}} = 9$ TeV
- Stronger constraint for 14-particle final states

JE, Sakurai, arXiv:1601.03654
Summary

- Rumours of the death of SUSY are exaggerated
  - Still the best framework for TeV-scale physics
- Still the best candidate for cold dark matter
- Simple models (CMSSM, etc.) under pressure
  - More general models quite healthy
- Good prospects for LHC Run 2 and for direct dark matter detection – no guarantees!
  - Whole new world if X(750) is real!
  - Think again about sphalerons!