Around the Standard Model
Biggest Problem with the Standard Model:

"Standard Model"

Highly Unique Gauge Elucidation

Splendid Theory of Everything Perceivable
Temperature

$10^{12} \text{K}$

Chiral symmetry broken: $\langle \bar{q}_L q_R \rangle$

First order

Quark chemical potential

CFL

2SC
Agenda:

Hard probes

Phase transition?

Surprises?

\( \Rightarrow \) e.g. 1st order behaviour
disordered chiral condensate

Making sure we know what we're doing!
High Density QCD

rigorous: weak coupling
but nonperturbative

\[ \langle q_a^i : q_b^j \rangle = (K_1 \delta_a^i \delta_b^j + K_2 \delta_a^j \delta_b^i) \epsilon_{ij} \neq 0 \]

"color-flavor locking"
confinement, chiral symmetry breaking
quark-hadron continuity

recently

magnetic properties
K-condensation
'crystalline' phase
Result From 1998 Running

\[ a_\mu + (\mu_{\text{inj}}) = 116\ 591\ 91\ (59) \times 10^{-10} \ (\pm 5\text{ppm}) \]

Errors statistically dominated

<table>
<thead>
<tr>
<th>Experiment</th>
<th>( a_\mu \times 10^{10} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>CERN(^1) ( \mu^+ )</td>
<td>116 591 00 (110) (9.4 ppm)</td>
</tr>
<tr>
<td>CERN(^1) ( \mu^- )</td>
<td>116 593 65 (120) (10 ppm)</td>
</tr>
<tr>
<td>ES21(^2) ( \mu^+ \pi_{\text{inj}} )</td>
<td>116 592 51 (152) (13 ppm)</td>
</tr>
<tr>
<td>ES21 ( \mu^+ \mu_{\text{inj}} )</td>
<td>116 591 91 (59) (5 ppm)</td>
</tr>
<tr>
<td>New Average ( \chi^2/\nu = 2.7/3 )</td>
<td>116 592 05 (45) (3.9 ppm)</td>
</tr>
<tr>
<td>Theory(^3)</td>
<td>116 591 62 (8) (0.66 ppm)</td>
</tr>
</tbody>
</table>

\(^1\) J. Bailey et al., Nucl. Phys. B150, 1 (1979) and the PDG


\(^3\) V.W. Hughes and T. Kinoshita, Rev. Mod. Phys. 71, S133 (1999).

Experiment − Theory = \((43 \pm 45) \times 10^{-10}\)
Lattice Gauge Theory

defining image ...

* Standard Model regularized! *

many useful targets

$(g-2)_{\text{hadronic}}$

$B$ physics

$\langle p_l m_s J_5 s_l p_r \rangle$
\[
\begin{array}{cccccc}
\text{R} & \text{W} & \text{B} & \text{G} & \text{P} \\
+ & - & - & + & - \\
- & + & - & - & + \\
+ & - & + & - & - \\
- & + & - & + & - \\
+ & - & + & - & + \\
- & + & - & + & - \\
\end{array}
\]

\[Y = -\frac{1}{6} (R + W + B) + \frac{1}{4} (G + P)\]
MSSM

$M_{\text{susy}} = M_z$

$\alpha_1^{-1}(\mu)$

$\alpha_2^{-1}(\mu)$

$\alpha_3^{-1}(\mu)$

$log_{10} (\mu/\text{GeV})$
The Higgs mass is driven negative by the large top quark Yukawa.
Seven Pillars of Unification

Wisdom

1. Unification of representations
2. Unification of couplings (\(\leftrightarrow\) SUGRA)
3. Emergence of a protected heavy scale

- Small radiative corrections
- Small \(\Delta F \neq 0\) processes

4. Neutrino masses by "seesaw"

- \(\nu_{\odot}\) degree of freedom
- Semi-quantitative

5. Emergence of Planck scale

6. Radiative electroweak breaking (\(\xi\))

7. Emergence of dark matter candidates
Combined CDF / DØ analysis

Run II SHWG
Susy Dark Matter

- New development: focus point
  - 2 TeV squarks + sleptons
- Gaugino-Higgsino mixing - much enhanced interactions of LSP
- Cosmologically interesting densities in a huge swath of parameter space
- Very testable!
experiments
Agenda:

Low scale SUSY
  ‘Light’ Higgs
  Find it!!

needed: theory and experiment
  for breaking pattern

Proton decay
  Find it!!

ν spectroscopy
  sort it out
  why??
$\Delta F = 0$ CP Violation

Why is it small?

Axions!

Electric dipole moments
III Explorations
Extra large dimensions?

Seven snares and delusions??????

An ultralight sector?
axions
familons
dilatons
modulons

Find it!!
The Problem of Problems: The Cosmological Term

\[ \Lambda_{\text{Planck}} \sim 10^{72} \text{ GeV}^4 \]

\[ \Lambda_{\text{un.}} \sim 10^{64} \text{ GeV}^4 \]

\[ \Lambda_{\text{TeV}} \sim 10^{12} \text{ GeV}^4 \]

\[ \Lambda_{\text{XSB}} \sim 10^{-2} \text{ GeV}^4 \]

\[ \Lambda_{\text{obs.}} \sim 10^{-48} \text{ GeV}^4 \]

**Numerics:**

\[ \Lambda_{\text{obs.}} = \left( \frac{\text{TeV}^2}{M_{\text{Pl}}} \right)^4 \]

\[ \Lambda_{\text{obs.}} \approx \left( e^{-\frac{\pi}{d_{\text{un.}} M_{\text{Pl}}}} \right)^4 \]
This could bring down the whole house of cards.

(A Theory of Everything that's not even a theory of Nothing?)
Vague ideas:

holography

extra dimensional "feed back"

* 4-form field dynamics

\[ F_{\alpha \beta \gamma \delta} \neq \sqrt{g} \varepsilon_{\alpha \beta \gamma \delta} \]

\[ \uparrow \text{couples to 2-branes} \]
IV. Conclusion

No conclusion!

We've made a HUGE STEP, but there's BIG GNUS* ahead.

Brilliant Investigations Geared to Garner Nobels and Unearth Surprises