Advanced Particle Physics II

Journal Club: Experimental Signatures of Physics beyond the Standard Model

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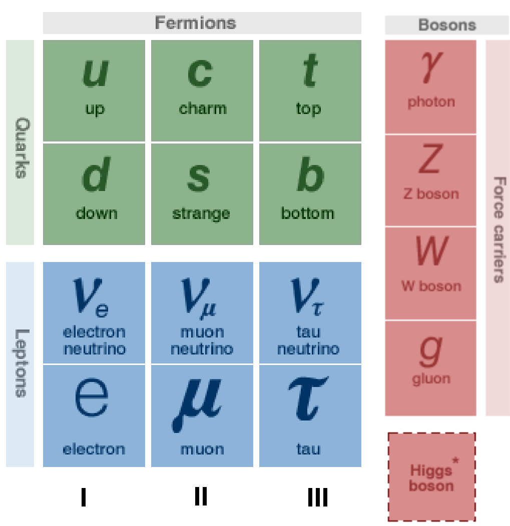
Thursday 9:15 - 11:00 Phil 12 kHS

http://www.physi.uni-heidelberg.de/~uwer/lectures/JournalClub/BeyondSM/

Standard Model

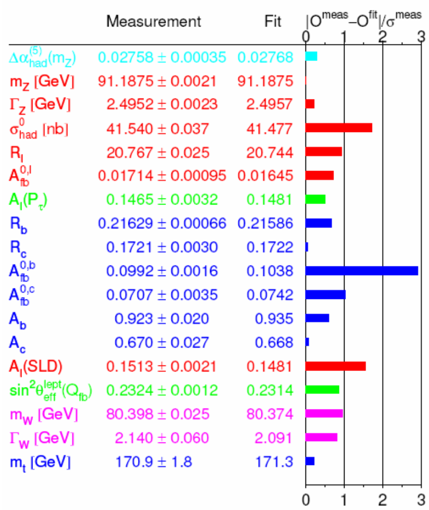


Based on the principle of local gauge invariance
$SU_C(3) \times SU_L(2) \times U_Y(1)$

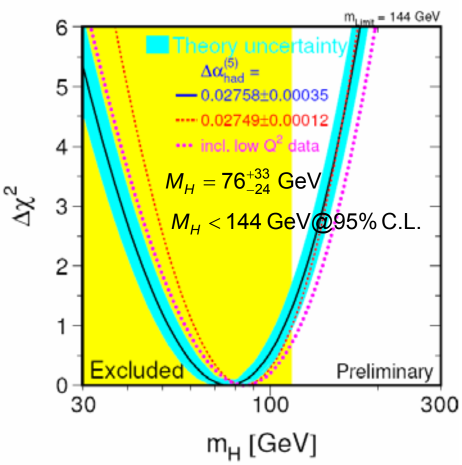
⇦ 12 gauge fields

⇦ Not yet directly observed

Experimental Test



Extremely well supported by data.



Tested at quantum level.
Allows predicition of Higgs mass.

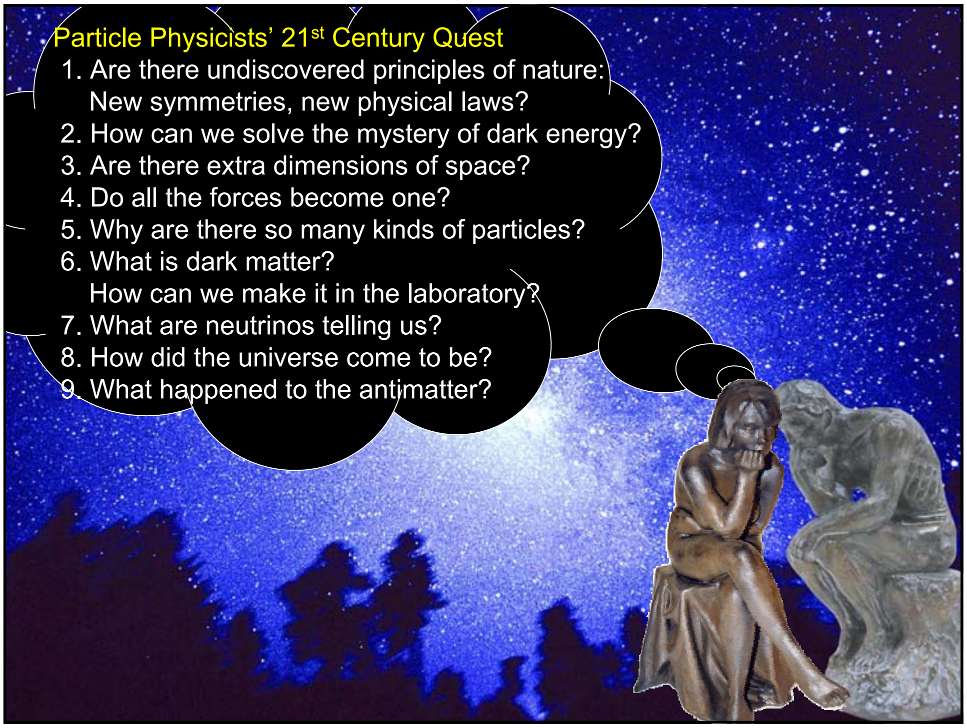
Shortcomings of the Standard Model

Observations

- Neutrino masses and mixing
- Baryogenesis (matter anti-matter symmetry)
- Dark matter, dark energy

Conceptual problems

- Quadratic divergences in Higgs mass correction (fine tuning)
- Origin of generations
- Explanation of masses
- Origin of gauge symmetries / quantum numbers
- Unification with gravity



Excited Leptons

Three Fermion generations and mass hierarchy ?

Possible explanation: Fermion substructure: new constituents stronly bound together

Excited states of the non leptons/quarks

Higgs Searches

Does the scalar Higgs really exists ?

Standard Model:

$$\phi = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}$$

One Higgs doublet of complex scalar fields.

After symmetry breaking:

➡ $\phi^0 = H \quad \langle H \rangle = \upsilon$

One Higss boson w/ $M_H = \upsilon\sqrt{2\lambda}$

Minimal Super Symmetric Model:

$$\mathbf{H}_u = \begin{pmatrix} H_u^+ \\ H_u^0 \end{pmatrix} \qquad \mathbf{H}_d = \begin{pmatrix} H_d^0 \\ H_d^- \end{pmatrix}$$

After symmetry breaking:

- h^0, H^0 Light / heavy neutral Higgs (scalar)
- A^0 neutral Higgs, CP-odd (pseudo scalar)
- $H^\pm$ Charged Higgs, (scalar)

$$\tan\beta = \frac{\langle H_u^0 \rangle}{\langle H_d^0 \rangle} = \frac{\upsilon_u}{\upsilon_d}$$

Supersymmetry

sParticle spectra

$[u,d,c,s,t,b]_{L,R}$	$[e,\mu,\tau]_{L,R}$	$[\nu_{e,\mu,\tau}]_L$	Spin $\frac{1}{2}$
$[\tilde{u},\tilde{d},\tilde{c},\tilde{s},\tilde{t},\tilde{b}]_{L,R}$	$[\tilde{e},\tilde{\mu},\tilde{\tau}]_{L,R}$	$[\tilde{\nu}_{e,\mu,\tau}]_L$	Spin 0

g	$\underbrace{W^\pm, H^\pm}$	$\underbrace{\gamma, Z, H_1^0, H_2^0}$	Spin 1 / Spin 0
$\tilde{g}$	$\tilde{\chi}_{1,2}^{\pm}$	$\tilde{\chi}_{1,2,3,4}^{0}$	Spin $\frac{1}{2}$
	charginos	neutralinos	

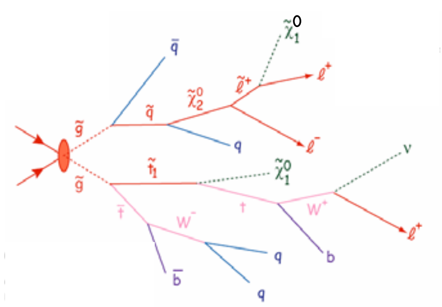
Lightest SUYS particle (LSP): Lightest Neutralino (mSUGRA)

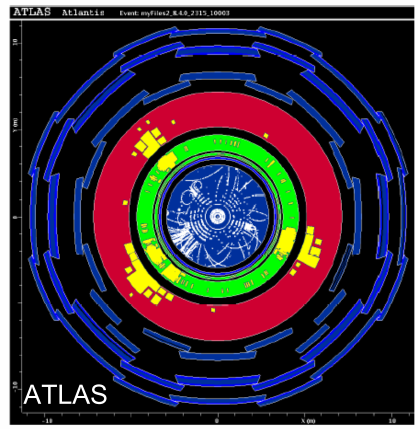
R-Parity: $R_P = (-1)^{L+3B+2S}$
- R_P=+1 for Particles
- R_P=-1 for sParticles

Search for Missing Energy

very generic New Physics signature

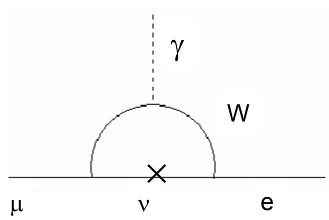
SUSY cascade decays end w/ LSP





Lepton Flavor Violation $\mu \to e\gamma$

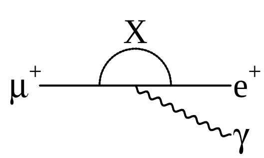
Standard model process:



Effect of neutrino mass is "GIM suppressed" by a factor of $(\Delta m_\nu^2/M_W^2)^2$:

$BR(\mu \to e\gamma) \sim 10^{-50}$

New Physics scenarios predict larger BR for LFV decays:



Current limits

$$BR_{\mu \to e\gamma} = \frac{\Gamma(\mu \to e\gamma)}{\Gamma(\mu \to e\bar{\nu}_e \nu_\mu)} < 1.2 \cdot 10^{-11}$$

translates into a mass limit

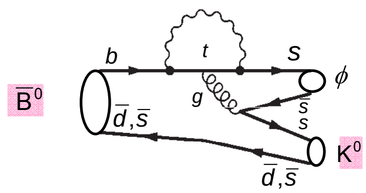
$m_X > 21\text{TeV}$

Rare B Meson Decays

CP violation as probe for New Physics

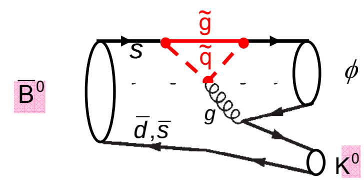
$$A_{CP}(t) = \frac{\Gamma(\overline{B}^0 \to \phi K_s)(t) - \Gamma(B^0 \to \phi K_s)(t)}{\Gamma(\overline{B}^0 \to \phi K_s)(t) + \Gamma(B^0 \to \phi K_s)(t)} = \sin 2\beta \sin(\Delta m t)$$

Standard Model



$A_{CP}(t) = \sin 2\beta \sin(\Delta m t)$

New Physics (e.g. SUSY)



$A_{CP}(t) = \sin 2\beta_{eff} \sin(\Delta m t)$

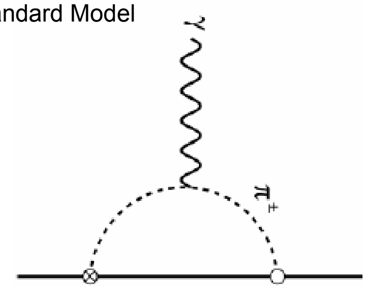
sin(2β) = sin(2βeff) ??

Electric Dipol Moment

EDM searches = „poor man‘s high energy physics“ (S. Lamoreaux)

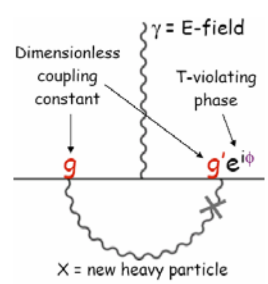
Neutron EDM:

Standard Model



$(d_n)_{SM} \sim 10^{32} e.cm$

SUSY models



$(d_n)_{SUSY} \sim 10^{26} e.cm$

Axions – Solution the Strong CP Problem

Strong CP problem: Why QCD does not violate CP ?

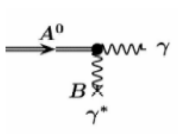
➡ Solution: Pseudo-Scalar Field = Axion

(Excellent dark matter candidate)

If axions exist they can be copiously produced in the sun and play an important role in stellar evolution:

$$n + n \rightarrow n + n + a$$

Detection on earth via Primakoff Effect

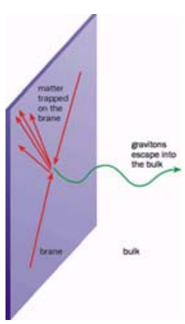


CAST, LHC Point 8 (LHCb)

Mini-Black Holes

Proton Energy to form a Mini-Black hole: $M_{Planck} \approx 10^{19}$GeV

$$M_{Planck} = \frac{1}{\sqrt{G}}$$



Extra dimensions:

Gravity may be strong, but *appear* weak, because it is leaking into extra dimensions.

➡ Larger effective coupling constant G:

$$M_{Planck} \sim \frac{1}{\sqrt{G}}$$ becomes smaller.

In addition :
Schwarzschild radius decreases:

$$R_S \approx \frac{1}{M_{Planck}} \left(\frac{M_{BH}}{M_{Planck}} \right)^{1/n+1}$$

➡ Formation of mini-black holes possible

Topics & Schedule

Oct 25th	Excited Electrons at HERA
Nov 8th	Standard Model Higgs search
Nov 15th	MSSM Higgs search
Nov 22nd	SUSY Search at the Tevatron

5.) Search for Lepton Flavor Violation (MEGA Results)
6.) Rare Heavy Meson Decays
7.) Electroweak Measurements (sin_theta_W)
8.) Electric Dipole Moments
9.) Mini Black Holes at ATLAS
10.) Axion search (CAST)