Phys 8911 (18.01.2005)
Introduction to Supersymmetry

Texts

"Supersymmetry and Supergravity" Wess & Bagger

"Supersymmetric gauge field theory & String Theory" Bailin & Love

Also P. West "Intro to Susy & Supergravity"
S. Weinberg "QFT Vol III"
Buchbinder & Kuzenko "Ideas and Methods of Supersymmetry & Supegr."

Review articles

S.P. Martin hep-ph/9709356
www.arXiv.org
J. Lykken hep-th/9612114
M. Sohnius Phys. Rept. 128, 39 (1985)

Outline 1. Formal Developments
2. Applied Developments

1. → Motivation, Coleman-Mandula thm
4d Susy algebra and representation
Superspace and superfields
Susy gauge theories, Nonrenormalisation thms.
SUSY standard model.

Supersymmetry breaking
Phenomenology / Supergravity.

<u>Motivation</u> Why study supersymmetry?

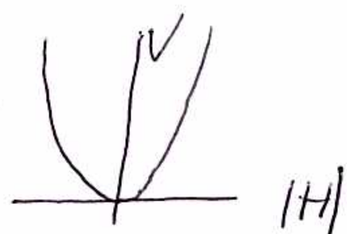
① Supersymmetry is the <u>only</u> possible extention of the known spacetime symmetries.

↳ energy-mtm p_μ
Lorentz transf. $M_{\mu\nu}$

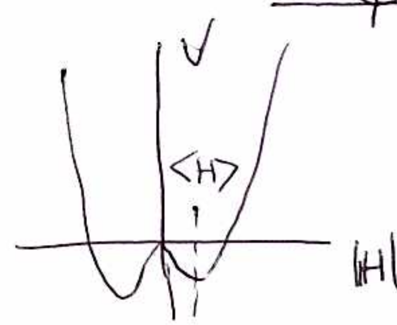
② <u>Hierarchy problem</u>

Higgs boson

Higgs scalar potential $V = m_H^2 |H|^2 + \lambda |H|^4$

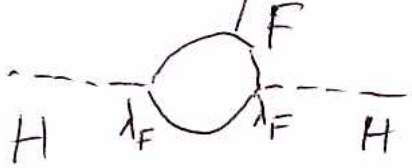


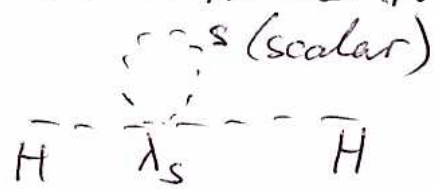
If $m_H^2 < 0$ then min. occurs at $\langle H \rangle = \sqrt{\dfrac{-m_H^2}{2\lambda}}$



experimentally $\langle H \rangle = 174$ GeV $\Rightarrow$ $-m_H^2 \sim (100\,\text{GeV})^2$

Consider quantum corrections to m_H^2:





$$\Delta m_H^2 \sim \frac{1}{16\pi^2}\left(\lambda_S - \lambda_F^2\right)\Lambda_{UV}^2 + \frac{m^2}{16\pi^2}\ln\frac{\Lambda_{UV}}{m}$$

But $\Lambda_{UV} \sim \underbrace{M_p}_{\text{Plank scale}} \sim 10^{19}\,GeV$

$\lambda_S \sim \lambda_F \sim 1 \Rightarrow \Delta m_H^2 \gg (100\,GeV)^2$

Supersymmetry $\Rightarrow \lambda_S = \lambda_F^2$

$\Rightarrow \Delta m_H^2$ not quadratically sensitive to Λ_{UV}

Solves hierarchy problem!

<u>Review spacetime symmetries</u>

Let x^m $(m = 0,1,2,3)$ denote a spacetime point

Then
$$x'^m = \Lambda^m{}_n x^n + b^m$$
leaves the metric $ds^2 = \eta_{mn} dx^m dx^n$ invariant

where $x^m = (x^0, x^1, x^2, x^3)$ $x^0 = ct$ $\eta_{mn} \overset{diag}{=} (-1\ {+1}\ {+1}\ {+1})$

$\det \Lambda = +1$ and $\Lambda^0{}_0 \geq 1$

The transformations (Λ, b) are known as <u>Poincaré</u> transformations

When $b=0$; Λ are the Lorentz transformations satisfying $\Lambda^T \eta \Lambda = \eta$

The union of all $\left\{\begin{matrix}\text{Poincaré}\\ \text{Lorentz}\end{matrix}\right\}$ transformations are known as $\left\{\begin{matrix}\text{Poincaré}\\ \text{Lorentz}\end{matrix}\right\}$ group denoted by

(proper, orthochronous

$$\left\{\begin{matrix}\Pi\\ SO(3,1)^{\uparrow}\end{matrix}\right\}$$

Рамон Теория Поля

Ref. Bailin & Love
Wess & Bagger
Buchbinder & Kuzenko

Lorentz group

$$SO(3,1)^{\uparrow} \cong SU(2) \times SU(2)$$

generators $\frac{1}{2}(J_i \pm K_i)$ $\quad i = 1, 2, 3$

J_i = rotation gen

K_i = boost gen.

Representations are labelled by integers (m,n) with spin $m+n$ where $m, n = 0, \frac{1}{2}, 1, \frac{3}{2}, \ldots$

Egs $(0,0)$ spin 0, scallar rep.

$(\frac{1}{2},0)$ spin $\frac{1}{2}$, "left handed" spinor

$(0,\frac{1}{2})$ spin $\frac{1}{2}$, "right handed" spinor

$(\frac{1}{2},0) \otimes (0,\frac{1}{2}) = (\frac{1}{2},\frac{1}{2})$ spin 1, ~~rep.~~ vector rep.

$\rightarrow$ 4-vector V^{μ}

$$\left(\frac{1}{2},\frac{1}{2}\right)\otimes\left(\frac{1}{2},\frac{1}{2}\right)\supset\overset{1}{(1,1)}_S$$ – spin 2 → symmetric thensor $h_{\mu\nu}$

S–symmetric

metric perturbation.

see Ramond "Field theory"

Lorentz algebra

Simply connected groups have a 1-1 correspondence between rep of group and algebra

$SO(3,1)^{\uparrow}$ is not simply connected.

Use "universal covering group" (that will be simply connected).

→ $SL(2,\mathbb{C})$ wich is simply connected

↳ set of 2x2 complex unimodular matrices (det = 1)

$x' = \Lambda x$.