A Brief Introduction to Particle Physics

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Special Relativity + Quantum Mechanics

↓

Quantum Field Theory （QED）

Fields describe "elementary" particles

Maxwell equation for photon field

Dirac equation for electron fields

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Quantization of fields -- single particle

Anti-particles predicted

Divergences → renormalization

Feynmann, Schwinger, 朝永振一郎

Interactions

0. Gravitation

1. EM

2. Strong interaction

   nuclei

3. Weak interaction

   β decays:

   neutron --> proton + e + neutrino

Elementary particles:

photon, e, μ , τ , neutrinos, proton, neutron, pion, kaon, ...

Weak Interaction

4 fermions -- Fermi

(θ - τ puzzle) Parity violation -- 李政道、杨振宁

Strong Interaction

pion exchange

proton, neutron, pion, kaon

SU(3) flavor symmetry -- Gell-mann ...

Quarks -- Gell-mann & Zweig （64）

u, d, s, ...

层子模型 （65）

Principle of interactions

杨振宁-Mills (54) -- Gauge symmetry

non-Abelian gauge theory

(EM: U(1) Abelian)

Schwinger & Glashow (late 50's, 61):

EM + weak interaction unification

-- not fully realistic

Spontaneous symmetry breaking

Superconductivity (Anderson), Nambu,

Higgs, Englert, Brout (Nobel 2013)

Weak Interaction (cont'd)

Weinberg + Salam = Glashow + Higgs

unify weak interaction and EM into a gauge theory

at 100 GeV

Strong Interaction (cont'd)

Dynamics of quarks?

no free quarks observed: e = 1/3, 2/3

Non-Abelian gauge theory!

quark/gluon confinement

Standard Model

QCD + electro-weak unification

$SU(3) \times SU(2) \times U(1)$

leptons, quarks, photon, gluon, W, Z

--perfect experimentally up to now

What is next?

Grand Unification

$$SU(3) \times SU(2) \times U(1) \rightarrow SU(5)$$

both theoretically and experimentally

problem: Why 100 GeV scale?

answer: Supersymmetry

breaks at 1000 GeV

Other ideas

Higgs composite

Extra dimensions

……

LHC experiment will test SUSY and them

Dark Matter

Astro-physics

Gravity

Weakly Interacting Massive Particles

1000 GeV with weak interaction

Gravity

Special relativity and Law of universal gravitation ?

↓ (new concept)

General Relativity

Cosmology:

Hubble observation: Expansion of the Universe

BBN successful (2 sec.- 3 min.)

problem: flatness

Inflation:

A short (10^{-35} sec) exponential expansion

What is the inflaton?

Experiments: COBE, WMAP

Quantum gravity

General Relativity + Quantum Mechanics

↓ (new)

String Theory

Loop gravity

N=8 supergravity

? ? ?

Cosmological Constant (dark energy)

$$\lambda \approx (10^{-4}\ \text{eV})^4 \neq 10^{108}\ \text{eV}^4$$

Future Experiments

LHC
大亚湾中微子
FERMI/GLAST
PLANCK
羊八井宇宙线
北京谱仪
兰州HIRFL-CSR
……

ILC, ???

Problems and Comments

Higgs, SUSY, or anything new at 1000 GeV ?

LHC will find a 145 GeV Higgs, nothing else.

Dark matter ?

maybe axion

Quark/gluon confinement ?

basically understood, difficult

Inflation model ?

$m^2 \phi \phi$

Baryon asymmetry ?

CP violation at high energy & lepton number violation

Cosmological constant ?

just so! (Don't make more problems, please.)

Fermion masses ?

who really cares?