Standart Model Ötesi 1: Standart Genişletilmeler

Saleh Sultansoy

TOBB Ekonomi ve Teknoloji Üniversitesi, Ankara
Azərbaycan Milli Elmlər Akademiyası Fizika İnstitutu, Bakı
ATLAS, LHeC and FCC Collaborations, CERN
Member of Plenary ECFA (Jan 2018 – Jul 2020)

1870's: Mendeleyev Table

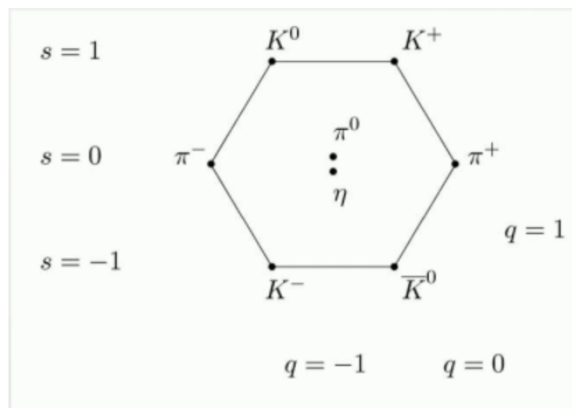
1960's: Eight-fold Way

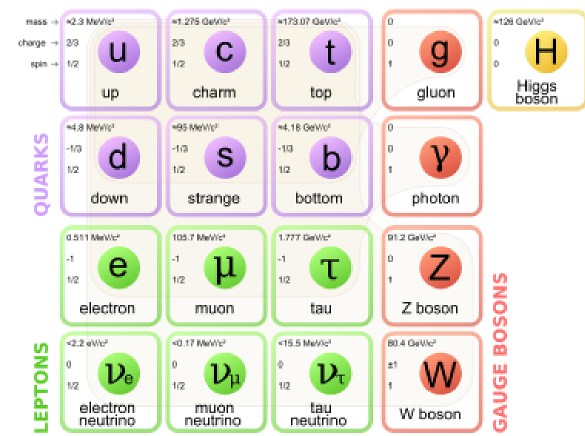
Today: Family Replication

TABELLE II

REIHEN	GRUPPE I. — R^2O	GRUPPE II. — RO	GRUPPE III. — R^2O^3	GRUPPE IV. RH^4 RO^2	GRUPPE V. RH^3 R^2O^5	GRUPPE VI. RH^2 RO^3	GRUPPE VII. RH R^2O^7	GRUPPE VIII. — RO^4
1	H = 1							
2	Li = 7	Be = 9,4	B = 11	C = 12	N = 14	O = 16	F = 19	
3	Na = 23	Mg = 24	Al = 27,3	Si = 28	P = 31	S = 32	Cl = 35,5	
4	K = 39	Ca = 40	— = 44	Ti = 48	V = 51	Cr = 52	Mn = 55	Fe = 56, Co = 59, Ni = 59, Cu = 63.
5	(Cu = 63)	Zn = 65	— = 68	— = 72	As = 75	Se = 78	Br = 80	
6	Rb = 85	Sr = 87	?Yt = 88	Zr = 90	Nb = 94	Mo = 96	— = 100	Ru = 104, Rh = 104, Pd = 106, Ag = 108.
7	(Ag = 108)	Cd = 112	In = 113	Sn = 118	Sb = 122	Te = 125	J = 127	
8	Cs = 133	Ba = 137	?Di = 138	?Ce = 140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er = 178	?La = 180	Ta = 182	W = 184	—	Os = 195, Ir = 197, Pt = 198, Au = 199
11	(Au = 199)	Hg = 200	Tl = 204	Pb = 207	Bi = 208	—	—	
12	—	—	—	Th = 231	—	U = 240	—	— — — —

Figure 2.5 Dmitri Mendeleev's 1872 periodic table. The spaces marked with blank lines represent elements that Mendeleev deduced existed but were unknown at the time, so he left places for them in the table. The symbols at the top of the columns (e.g., R^2O and RH^4) are molecular formulas written in the style of the 19th century.





Asım'ın nesline çağrı

"Sen geçenlerde demiştin ki: Yazık hala biz,
Dünkü ilmin bile biganesiyiz, cahiliyiz,
İşte fıktanı bu ihmal edilen ma'rifetin
Nesli bir acze düşürmüş ki, bugün, memleketin,
Bir yığın kuvveti var, hem ne tabii de, henüz
Biz o kuvvetlere eller gibi hakim değiliz!

Yarının ilmi nedir, halbuki? Gayet müthiş!
"Maddenin kudret-i zerriyesi" uğraştığı iş,
O yaman kudrete hakim olabilsem diyerek,
Sarf edip durmada bir çok kafa binlerce emek,
Onu bir buldu mu, artık bu zemin: Başka zemin,
Çünkü bir damla kömürden edecekler te'min,
Öyle milyonla değil, na-mütenahi kudret!
İbret al kendi sözünden aman oğlum gayret… "

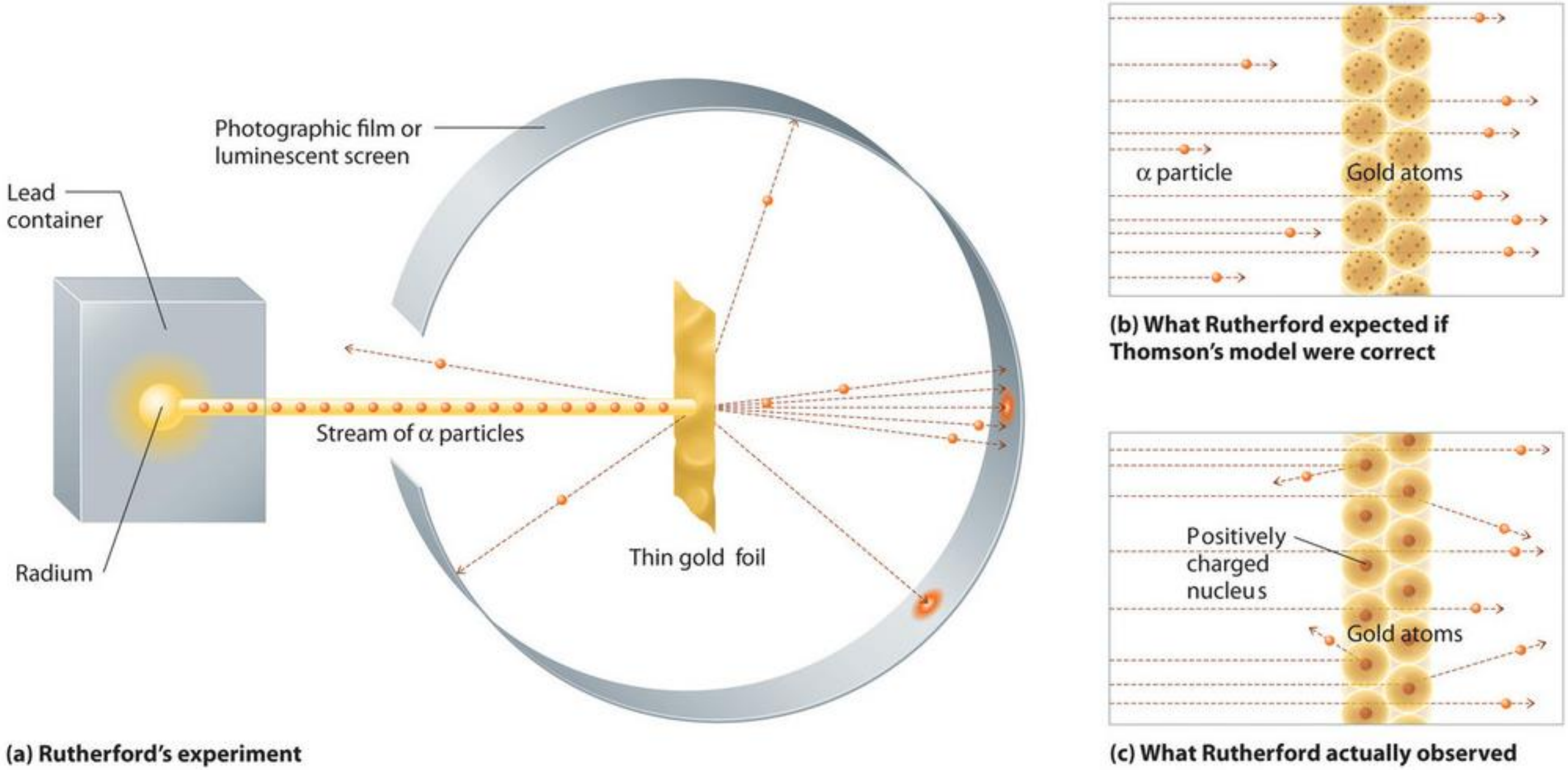
Safahat, 6.bölüm (1919)

Sebe, 3; Yunus, 61.

Nükleer

CERN, TAC ve ötesi

Aldık mı?



Deneyler 1908 ile 1913 yılları arasında Manchester Üniversitesi Fizik Laboratuarlarında Ernest Rutherford'un yönetimi altında Hans Geiger ve Ernest Marsden tarafından gerçekleştirildi.
Aslında bu deneyin amacı olası elektrik yükü dalgalanmalarını araştırmaktı.

Rutherford deneyinden elde edilen (beklenmedik!) temel bilgiler, modern bilimin ve yüksek teknolojinin temelini oluşturmaktadır.

Biyolojik enerji: birim süreç başına 0.01 eV

Kimyasal enerji: birim süreç başına 10 eV
Biyolojik enerjinin bin katı

Nükleer enerji: birim süreç başına 10 MeV
Kimyasal enerjinin milyon katı

CERN'de ulaştığımız enerji ($\sqrt{s}$ =13 TeV): birim süreç başına ≈ 2-3 TeV
Nükleerin yaklaşık milyon katı

Beklenen yeni fizik skalası: 10 TeV mertebesinde
FCC-hh (CERN) veya SppC Çin): $\sqrt{s}$ =100 TeV
Rutherford deneyine benzer şekilde bilimin temelleri değişecek, teknolojiye istisnai katkısı kuvvetle muhtemeldir!

Bu nedenle gelişmiş ülkeler Yüksek Enerji Fiziğine her yıl milyarlarca dolar harcıyorlar …

ANKARA UNIVERSITY FACULTY OF SCIENCES PHYSICS DEPARTMENT

AU-HEP-97/05
11 June 1997

Four Remarks on Physics at LHC
(Talk presented at ATLAS week, 26-31 May 1997, CERN)

S.Sultansoy
Physics Department, Faculty of Sciences, Ankara University, 06100 Tandogan, Ankara, TURKEY
and
Institute of Physics, Academy of Sciences, H.Cavid avenue 143, Baku, AZERBAIJAN

First of all, possible manifestations of the fourth SM family (which is predicted according to the democratic mass matrix approach) quarks at LHC have been considered. Then, the number of free parameters in three family MSSM is estimated to be more than two hundreds, therefore SUSY should be realized at more fundamental (preonic?) level. In this case, each SM particle has more than two (super) partners. If the nature prefers SUGRA scenario, then the existence of (at least) one new neutral vector boson with TeV scale mass seems to be highly probable. Moreover, application of DMM approach leads to the prediction that (at least) one isosinglet quark and one vector isodoublet charged lepton have relatively small (TeV?) masses. Finally, the possible existence of additional space-like dimensions at TeV scale will manifest itself in multiplication of each SM particle.

Bu sunum sayesinde AÜ 1998 yılında ATLAS deneyine katıldı, ardından GU (2002) ve TOBB ETÜ (2008) de bu deneye katılmıştır.

https://inspirehep.net/literature/448831

https://lss.fnal.gov/archive/other/au-hep-97-05.pdf

Tr. J. of Physics
22 (1998) , 575 – 594.
© TÜBİTAK

International Workshop on Linac-Ring
Type ep and γp Colliders

Four Ways to TeV Scale

S. SULTANSOY
Physics Department, Faculty of Sciences,
Ankara University, 06100 Tandogan, Ankara - TURKEY
and
Azerbaijan Academy of Sciences, Institute of Physics,
H.Cavid avenue 33, Baku - AZERBAIJAN

Abstract

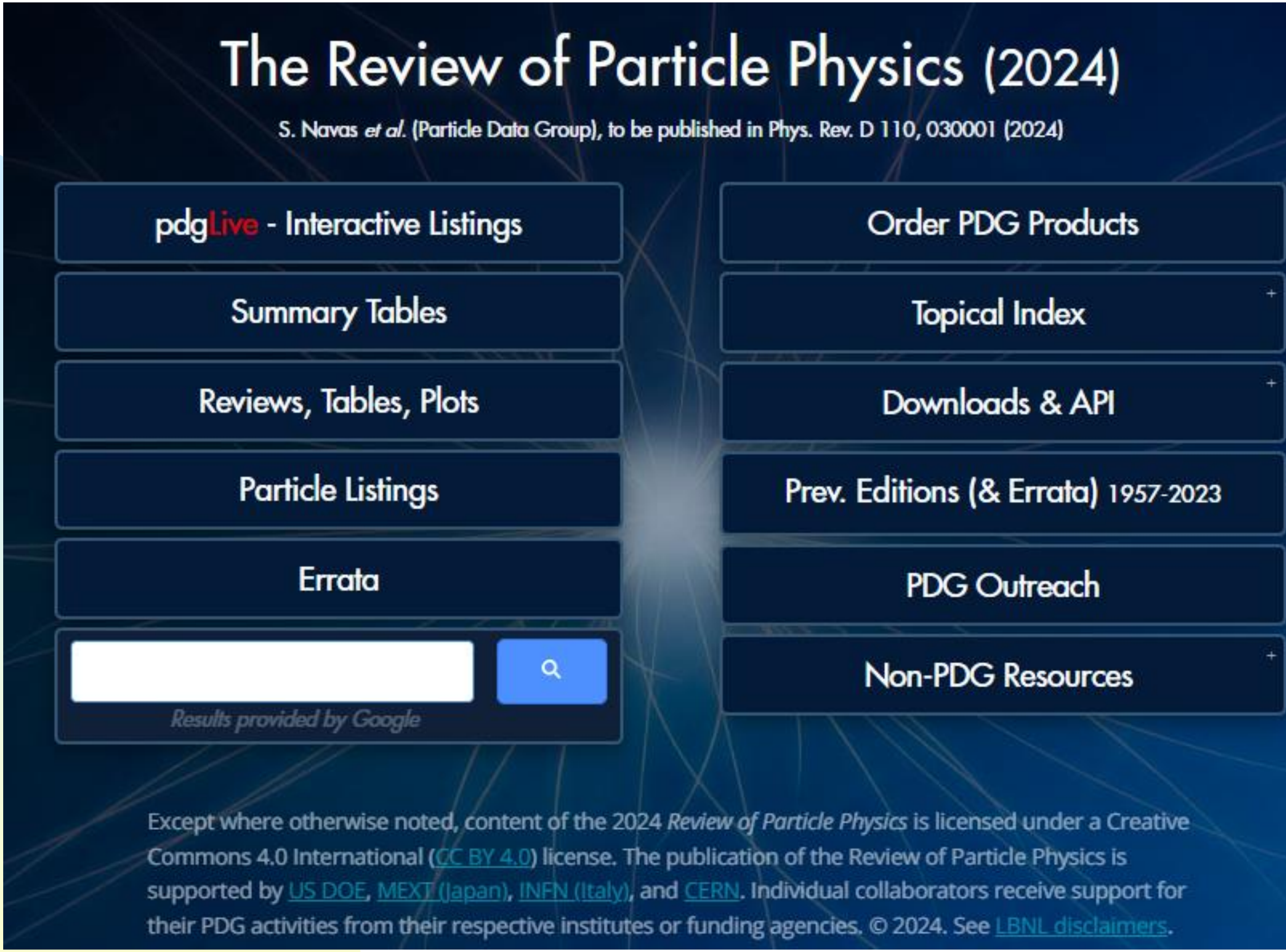
Four known types of colliders, which may give an opportunity to achieve TeV center of mass energies in the near future (10-15 years), are discussed. Parameters of the linac-ring type ep and γp machines are roughly estimated. Some speculations on TeV scale physics are given. The physics goals of the TeV energy ep and γp colliders are considered.

1. Introduction

It is known that the Standard Model with three fermion families well describes almost all of the large amount of particle physics phenomena [1]. Today, SM is proved at the level of first-order radiative corrections for energies up to 100 GeV. However, there are a number of fundamental problems which do not have solutions in the framework of the SM: quark-lepton symmetry and fermion's mass and mixings pattern, family replication and number of families, L-R symmetry breaking, electroweak scale etc. Then, SM contains unacceptably large number of arbitrary parameters even in three family case: 19 in the absence of right neutrinos (and Majorana mass terms for left neutrinos), 26 if neutrinos are Dirac particles, ≥ 30 if neutrinos are Majorana particles. Moreover, the number of "elementary particles", which is equal to 37 in three family case (18 quarks, 6 leptons, 12 gauge bosons and 1 Higgs boson), reminds the Mendeleev Table. Three decades ago similar situation led to the quark model!

For these reasons, physicists propose a lot of different extensions of the SM, most part of which predict a rich spectrum of new particles and/or interactions at TeV scale. These extensions can be grouped in two classes, namely standard and radical ones. Stan-

https://journals.tubitak.gov.tr/cgi/viewcontent.cgi?article=2191&context=physics



https://pdg.lbl.gov/index.html

pdgLive - Interactive Listings

The Review of Particle Physics (2024)

S. Navas *et al.* (Particle Data Group), to be published in Phys. Rev. D **110**, 030001 (2024)

Gauge & Higgs Bosons
reviews

- γ
- gluon
- graviton
- W
- Z
- H
- Neutral Higgs Bosons, Searches for
- Charged Higgs Bosons ($H^{\pm}$, $H^{\pm\pm}$)
- Heavy Bosons
- Axions

Leptons
reviews

- e
- μ
- τ
- Heavy Charged Lepton
- Neutrino Properties
- Number of Neutrino Types
- Double β-Decay
- Neutrino Mixing
- Heavy Neutral Leptons

Quarks
reviews

- Light quarks (u, d, s)
- c
- b
- t
- b'
- t'
- Free quark

Mesons
reviews

- Light Unflavored
- Strange
- Charmed
- Charmed, Strange (incl. possibly non-$q\bar{q}$ states)
- Bottom
- Bottom, Strange
- Bottom, Charmed
- $c\bar{c}$ (incl. possibly non-$q\bar{q}$ states)
- $b\bar{b}$ (incl. possibly non-$q\bar{q}$ states)
- Other Mesons

Baryons
reviews

- N Baryons
- Δ Baryons
- Λ Baryons
- Σ Baryons
- Ξ Baryons
- Ω Baryons
- Charmed Baryons
- Doubly-Charmed
- Bottom Baryons
- Exotic Baryons

Other Searches
reviews

- Magnetic Monopole
- Supersymmetric Particles
- Technicolor
- Quark and Lepton Compositeness
- Extra Dimensions
- WIMPs
- Other Particle Searches

Conservation Laws
reviews

- Discrete Space-Time Symm.
- Number Conservation Laws

γ (photon)

γ MASS	$< 1 \times 10^{-18}$ eV
γ CHARGE	$< 1 \times 10^{-46}$ e

g (gluon) $I(J^P) = 0(1^-)$

SU(3) color octet

Mass m = 0. Theoretical value. A mass as large as a few MeV may not be precluded, see YNDURAIN 1995.

Heavy Charged Lepton Searches

Charged Heavy Lepton MASS LIMITS	
Sequential Charged Heavy Lepton ($L^{\pm}$) MASS LIMITS	> 100.8 GeV CL=95.0%
Stable Charged Heavy Lepton ($L^{\pm}$) MASS LIMITS	> 102.6 GeV CL=95.0%

b' (4^{th} Generation) Quark, Searches for

$b'(-1/3)$-quark/hadron mass limits in $p\overline{p}$ and pp collisions	$> 1.560 \times 10^3$ GeV CL=95.0%
$b'(-1/3)$ mass limits from single production in $p\overline{p}$ and pp collisions	$> 3.000 \times 10^3$ GeV CL=95.0%
MASS LIMITS for b' (4^{th} Generation) Quark or Hadron in e^+e^- Collisions	> 46.0 GeV CL=95.0%

Reviews, Tables & Plots

S. Navas *et al.* (Particle Data Group), to be published in Phys. Rev. D **110**, 030001 (2024)

Files can be downloaded directly by clicking on the icon: PDF.

Expand/Collapse All

Introduction, History plots, Online information +

Constants, Units, Atomic and Nuclear Properties −

1 Physical constants (rev.) PDF
2 Astrophysical constants (rev.) PDF
3 International system of units (SI) PDF
4 Periodic table of the elements (rev.) PDF
5 Electronic structure of the elements (rev.) PDF
6 Atomic and nuclear properties of materials (rev.) Interactive version PDF
7 Electromagnetic relations PDF
8 Naming scheme for hadrons (rev.) PDF

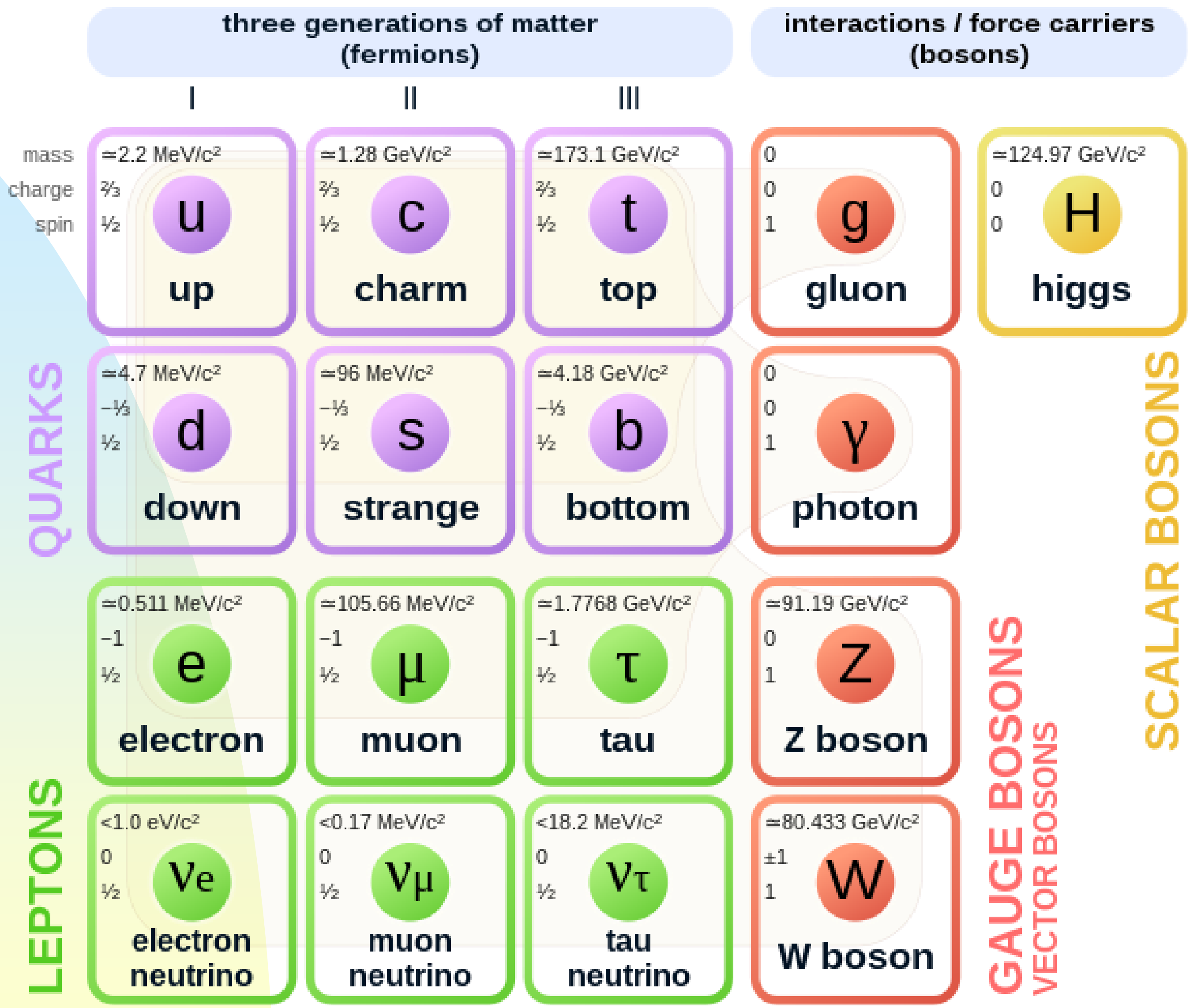
Standard Model and Related Topics −

9 Quantum chromodynamics (rev.) PDF
10 Electroweak model and constraints on new physics (rev.) PDF
11 Higgs boson physics, status of (rev.) PDF

İÇERİK

1. Standart Modelin Özeti

Standard Model of Elementary Particles



En iyi bildiğimiz **elektromanyetik etkileşmeler: $U_Q(1)$ ayar teorisi**
Abelyen olduğuna göre fotonlar bir-biriyle doğrudan etkileşmiyor

Elektromanyetik, güçlü ve zayıf etkileştirmelerin **Standart Modeli**:
$SU_C(3)\times SU_W(2)\times U_Y(1)$ ayar teorisi
$SU_C(3)$ abelyen olmadığına göre gluonlar bir-biriyle doğrudan etkileşiyor, bu nedenle QCD ile QED çok farklıdır
$SU_W(2)$ abelyen olmadığına göre W, Z ve γ bir-biriyle etkileşiyor

Higgs ile etkileşmeden sonra **$SU_C(3)\times SU_W(2)\times U_Y(1) \rightarrow SU_C(3)\times U_Q(1)$**
Zayıf izospin ve hiperyükten farklı olarak renk ve elektrik yükler korunuyor

Önemli not 1: 19.yüzyılda elektrik ve manyetik etkileşmelerin (Maxwell) birleşmesinden farklı olarak, SM temel etkileşmeleri tam olarak birleştirmiyor.
Her üç etkileşmenin kendi ayar grupları var.

Önemli not 2: $SU_W(2)$ yerine $SU_L(2)$ yazmak yanlıştır. Ayar grupları etkileşmelerin taşıyıcısı olan ara bozonlarla ilişkilidir. L ve R ise fermiyonların sal-elli ve sağ-elli bileşenlerini gösteriyor.

Periodic Table of the Elementary Particles

	ν (direct)	*l*	*u*	*d*
1.aile	< 2 eV	510.998928(11) keV	1.8 to 3.0 MeV	4,5 to 5.3 MeV
2.aile	< 190 keV	105.6583715(35) MeV	1.275(25) GeV	95(5) MeV
3.aile	< 18.2 MeV	1.77686(12) GeV	173.21(1.22) GeV	4.18(3) GeV

Standart Model Kuark sektörü karışımları (CKM matrisi)

$$V_{CKM} = \begin{pmatrix} 0.97401 \pm 0.00011 & 0.22650 \pm 0.00048 & 0.00361^{+0.00011}_{-0.00009} \\ 0.22636 \pm 0.00048 & 0.97320 \pm 0.00011 & 0.04053^{+0.00083}_{-0.00061} \\ 0.00854^{+0.00023}_{-0.00016} & 0.03978^{+0.00082}_{-0.00060} & 0.999172^{+0.000024}_{-0.000035} \end{pmatrix}$$

Standart Model Lepton Sektörü Karışımları (PMNS Matrisi)

$$|U|^{withSK-atm}_{3\sigma} = \begin{pmatrix} 0.801 \to 0.845 & 0.513 \to 0.579 & 0.143 \to 0.155 \\ 0.234 \to 0.500 & 0.471 \to 0.689 & 0.637 \to 0.776 \\ 0.271 \to 0.525 & 0.477 \to 0.694 & 0.613 \to 0.756 \end{pmatrix}$$

Neden **m_H = 125 GeV** olduğunu merak ediyoruz.

Ancak SM fermiyon kütlelerinin ve karışımlarının tesadüfi olan değerleri konusunda endişelenmiyoruz…; **mesela $m(e)/m(t) \sim 10^{-5}$**

Önemli notlar (detayları tahtada anlatmak)

Sağ-elli nötrinolar SMÖ değildir, kuark-lepton simetrisine göre üst kuarkların sağ-elli bileşenlerinin partnerleridir (Okun 1975, Salam 1989)

$$\begin{pmatrix} u_L \\ d_L \end{pmatrix} \; \boldsymbol{u_R} \; d_R \;\leftrightarrow\; \begin{pmatrix} \nu_{eL} \\ e_L \end{pmatrix} \; \boldsymbol{\nu_{eR}} \; e_R$$

Tam birleşme gerçekleşmiyor: her etkileşme için kendi ayar grubu (→ GUT?)

Higgs bozonunun keşfi ile SM'in elektro-zayıf kısmı tamamlandı!

Kuvvetli etkileşmeler SM'in en az bildiğimiz kısmıdır; confinement, hadronlaşma, çekirdekleşme aydınlatılmayı bekliyorlar

Önemli not: Higgs mekanizması görünür evrenin kütlesinin %2'sinden azını temin ediyor, **%98'den güçlü etkileşmeler sorumludur!**

2. SM’in Çözemediği Problemler

SM tarafından çözülemeyen sorunların kısmi listesi:

- Kuark ve lepton kütlelerinin desenlerinini ve CKM ve PMNS matrislerinin karışım açılarını ve fazlarını ne belirler?
- Kuark-lepton nesilleri neden tekrarlanıyor? Doğada kaç nesil var?
- Kuark-lepton simetrisinin kökeni nedir?
- nötrinolar Dirac mı yoksa Majorana mı parçacıklarıdır?
- Sol-sağ simetri kırılmasının kökeni nedir? SM'de bu elle konur.
- Bilinen tüm etkileşimler neden ayar simetrisi üzerine inşa edilmiştir?
- CP ihlalinin (gerçek) kaynağı nedir?
- Kütle çekimi birleşik bir şekilde nasıl dahil edilebilir?

- **Neden bu kadar çok keyfi parametre var? Üç aileli SM şunları içerir:**

3 bağlantı sabiti as, aem ve sin 9w,

6 kuark kütlesi,

3 kuardk karışım açısı ve 1 faz,

Higgs potansiyelinin 2 parametresi,

3 yüklü lepton kütlesi,

1 QCD vakum faz açısı,

3 nötrino kütlesi (Majorana durumunda 6),

3 lepton karışım açısı (Majorana durumunda 15),

1 faz (Majorana durumunda ?? faz).

Toplam 19 (kütlesiz nötrinolar), daha doğrusu **26 (Dirac nötrinoları) veya 30+? (Majorana nötrinoları) keyfi parametre!**

- **SM kuarkları ve leptonları** (ayrıca Higgs bozonu ve ayar bozonlarının bir kısmı veya tamamı) **temel mi yoksa bileşik mi?** Üç SM ailesi şunları içerir: 18 kuark, 18 anti-kuark, 6 lepton, 6 anti-lepton, 1 foton, 8 gluon, 3 kütleli ara bozon ve 1 Higgs bozonu; **toplamda 60 "temel parçacık"! Üçüncü Mendeleev Tablosu?**

  İkinci Mencleleev Tablosu (hadronlar) kuark modeliyle sonuçlandı!

- renkli nesnelerin "hapsedilmesinin" kökeni nedir? "Gerçekten apisteler" mi?

- Karanlık madde?

- Karanlık enerji?

Dolayısıyla "fiziğin sonu"ndan çok uzaktayız!

3. SM Ötesi Modeller

ATLAS Week 1997

https://lss.fnal.gov/archive/other/au-hep-97-05.pdf

A. Standard extensions of the Standard Model

In this class we restrict ourselves within the framework of gauge theories with spontaneously broken gauge symmetry.

1. Higgs sector:

- two or more Higgs doublets (CP violation in scalar instead of fermion sector)
- isodoublet φ (Dirac mass terms), vector isotriplet ξ (Majorana mass term for left-handed neutrino), isotriplet Φ (in order to satisfy relation ρ=1).

A number of new neutral and charged Higgs bosons (including double charged ones for last case) are predicted.

2. Fermion sector:

- fourth SM family
- new isosinglet left-handed ν_L (for ν-oscillation experiments)
- new isosinglet quarks and vector-like lepton isodoublets (E_6 -induced)
- fermion isotriplets etc.

A number of new (non-standard) leptons and quarks are predicted.

3. Gauge sector:

- additional U(1) factor (i.e. leptonic photon or E_6 -induced)
- additional SU(2) factor (L-R "symmetric" electroweak sector)
- etc.

New (massive) neutral and charged intermediate vector bosons are predicted.
The next stage in this direction is represented by GUTs.

B. Radical extensions of the Standard Model

This class includes two well-known directions: Compositness and SUSY.

1. Compositness:

- composite Higgs
- composite quarks and leptons
- composite W and Z
- composite γ and g's ?

A number of new exotic particles (leptoquarks, leptogluons, exited fermions and bosons etc.) and interactions (including residual ones) are predicted.

2. SUSY:

- three family MSSM
- four family MSSM
- SUSY GUTs
- SUGRA

Spectrum of fundamental particles is enriched with inclusion of superpartners.

3. "Unexpected" new physics

- new space-time dimensions
- ?

All extensions (with exceptions of minimal SU(5) and SO(10) GUTs) predict a rich spectrum of new particles and/or interactions at TeV scale. Therefore an exploration of this region will require all possible types of colliding beams.

1997 yılından sonra çok sayıda yeni model önerildi. **Tüm SM ötesi modeller çok sayıda yeni parçacık ve etkileşme öngörüyor.**

Paradigma değişikliği:

Pauli nötrino'sundan yüzlerce (hatta milyonlarca) yeni parçacık öneren modellere!!! Nötrino, β-bozunumunda enerji-momentum korunumu sağlamak için önerildi. Öneri Tübingen'de yapılan toplantıya mektup şeklinde gönderildi. O zaman eneri-momentum korunumunda imtina etmek, yeni parçacık önermekten daha uygun sayılıyordu …
https://ddd.uab.cat/pub/ppascual/ppascualapu/ppascualapu_41-001@benasque.pdf

Ek modeller ?

- SUGRA ⇒ Superstrings (aslında «theory of nothing»!!)
- …

Son 25 yılda Ek Uzay(-Zaman) Boyutlar «unexpected» sınıfından «radical» sınıfına geçti

«Unexpected»:

- CPT violation
- Fundamental length
- Parastatistics
- …

4. Higgs Sektörünün Genişletilmesi

İki örnek (Tahtada anlatmak)

1) Ek vector isotriplet

Güneş nötrinolarının aranmasında gözlenen olayların eksikliği, nötrino salınımlarının sonucu olarak yorumlandı. SM'de sağ-elli nötrinolar yoksa, bunlara kütle kazandırmanın tek yolu izo-dublet Higgs alanına ilaveten yeni bir izo-triplet Higgs alanı eklemektir:

$$\begin{pmatrix} \xi^{++} \\ \xi^{+} \\ \xi^{0} \end{pmatrix} \quad <\xi^0> = v_\xi \text{ ; } \rho = m_Z \times \cos\theta_W / m_W \approx 1 \text{ koşulunu sağlamak için}$$

bir izo-triplet daha klemeliyiz:

$$\begin{pmatrix} \Phi^{+} \\ \Phi^{0} \\ \Phi^{-} \end{pmatrix} \quad <\xi\,\Phi^0> = v_\Phi$$

Sonuç olarak SM'in Higgs bozonuna 8 adet yeni Higgs bozonu ekleniyor (2 çift-yüklü, 2 tek-yüklü ve 4 nötr).
Güneş nötrinolarının salınımı sağlamak için çok fazla yeni parçacık !

Sağ-elli nötrinoların eklenmesi çok daha doğaldır !

2) Ek isodublet

CKM fazı BAU için yetmiyor! (BAU – Evrenin Baryon Asimetrisi)

Higgs sektörü sayesinde CP bozulmasını sağlamak için en basit çözüm yeni izodublet Higgs alanlarının eklenmesidir.

İlginç bir şekilde MSSM iki tane izodublet Higgs alanlarının. Bunun nedeni tek Higgs alanı hem üst hemde alt fermiyonlar için kütle sağlayamıyor.

Bu durumda 4 adet yeni Higgs bozonu ekleniyor (2 tane tek-yüklü ve 2 tane nötr).

5. Fermiyon Sektörünün Genişletilmesi

Weinberg’s statement

Çeşni Demokrasisi

Vektor-benzer leptonlar (VBL) ve kuarklar (VBK) https://arxiv.org/pdf/2103.08222

2 Flavor democracy calls for iso-singlet quarks and vector-like leptons

2.1 Weinberg's statement

Mass and mixing patterns of the SM fermions are among the most important issues, which should be clarified in particle physics. In recent interview published in CERN Courier [5] Steven Weinberg emphasized this point: "Asked what single mystery, if he could choose, he would like to see solved in his lifetime, Weinberg doesn't have to think for long: he wants to be able to explain the observed pattern of quark and lepton masses". What Weinberg meant can be understood from Table 1, where current values of the SM charged leptons and quarks are presented. One can see that the top quark mass is of order of electroweak scale, whereas masses of remaining SM fermions are much smaller. In our opinion, Flavor Democracy (see reviews [3, 4, 7, 16–18] and references therein) could provide an important key to solve this mystery.

Table 1: Mass pattern of charged leptons and quarks

	charged leptons	Up type quarks	Down type quarks
1^{st} Family	$0.5109989461 \pm 0.0000000031$ MeV	$2.16^{+0.49}_{-0.26}$ MeV	$4.67^{+0.48}_{-0.17}$ MeV
2^{nd} Family	$105.6583745 \pm 0.0000024$ MeV	1.27 ± 0.02 GeV	93^{+11}_{-5} MeV
3^{rd} Family	1776.86 ± 0.12 MeV	172.76 ± 0.30 GeV	$4.18^{+0.03}_{-0.02}$ GeV

[5] M. Chalmers. Model physicist, CERN courier. url: http://cerncourier.com/cws/article/cern/70138 , 2017.

Çeşni Demokrasisi

It is useful to consider three different bases:

- Standard model basis $\{f^0\}$,
- Mass basis $\{f^m\}$ and
- Weak basis $\{f^w\}$.

According to the three-family SM, before the spontaneous symmetry breaking quarks are grouped into the following SU(2)×U(1) multiplets:

$$\begin{pmatrix} u_L^0 \\ d_L^0 \end{pmatrix},\ u_R^0,\ d_R^0;\ \begin{pmatrix} c_L^0 \\ s_L^0 \end{pmatrix},\ c_R^0,\ s_R^0;\ \begin{pmatrix} t_L^0 \\ b_L^0 \end{pmatrix},\ b_R^0,\ t_R^0. \qquad (1)$$

In one-family case all bases are equal and for example, d-quark mass is obtained due to Yukawa interaction

$$L_Y^{(d)} = a_d \left(\bar{u}_L\ \bar{d}_L\right)\begin{pmatrix} \varphi^+ \\ \varphi^- \end{pmatrix} d_R + \text{h.c.} \Rightarrow L_m^{(d)} = m_d \bar{d}d \qquad (2)$$

where $m_d = a_d\eta$, $\eta = \langle \varphi^0 \rangle \cong 249$ GeV. In the same manner $m_u = a_u\eta$, $m_e = a_e\eta$ and $m_{\nu_e} = a_{\nu_e}\eta$ (if neutrino is Dirac particle). In n-family case

$$L_Y^{(d)} = \sum_{i,j=1}^{n} a_{ij}^d \left(\bar{u}_{Li}^0\ \bar{d}_{Li}^0\right)\begin{pmatrix} \varphi^+ \\ \varphi^- \end{pmatrix} d_{Rj}^0 + \text{h.c.} \Rightarrow L_m^{(d)} = \sum_{i,j=1}^{n} m_{i,j}^d \bar{d}_i^0 d_j^0,\ m_{i,j}^d = a_{ij}^d\eta \qquad (3)$$

where d_1^0 denotes d^0, d_2^0 denotes s^0 etc. The diagonalization of mass matrix of each type of fermions, or in other words transition from SM basis to mass basis, is performed by well-known bi-unitary transformation. Then, the transition from mass basis to weak basis result in CKM matrix

$$U_{CKM} = \left(U_L^u\right)^+ U_L^d \qquad (4)$$

which contains 3 (6) observable mixing angles and 1 (3) observable CP-violating phases in the case of three (four) SM families. Before the spontaneous symmetry breaking, all quarks are massless and three are no differences between d^0, s^0 and b^0. In other words, fermions with the same quantum numbers are indistinguishable. This leads us to the **first assumption** [1-3, 22], namely, Yukawa couplings are equal within each type of fermions:

$$a_{ij}^d \cong a^d,\ a_{ij}^u \cong a^u,\ a_{ij}^l \cong a^l,\ a_{ij}^\nu \cong a^\nu \qquad (5)$$

The first assumption result in n-1 massless particles and one massive particle with $m = na^F\eta$ (F = u, d, l, ν) for each type of the SM fermions.

Because there is only one Higgs doublet which gives Dirac masses to all four types of fermions, it seems natural to make the **second assumption** [5,6], namely, Yukawa constant for different types of fermions should naturally be equal:

$$a^d \approx a^u \approx a^l \approx a^\nu . \qquad (6)$$

Taking into account the mass values for the third generation, the second assumption leads to the statement that according to the flavor democracy, the fourth SM family should exist.

In terms of the mass matrix, the above arguments mean

$$M^0 = a\eta \begin{pmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{pmatrix} \Rightarrow M^m = 4a\eta \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \qquad (7)$$

Higgs bozonunun özellikleri (üretim ve bozunum kanalları: **Minimal SM4 deneysel olarak dışlanmıştır**.

⟹ VBL ve VBK ! E_6 ile benzerlik!!!

(Tahtada anlatmak : U.Kaya ve S. Sultansoy, e-Print: 1801.03927 [hep-ph]**)**

Çeşni Demokrasisi Hipotezi ve VBK/VBL için referansalar

...

…

6. Ayar Grubunun Genişletilmesi

İki örnek (Tahtada anlatmak)

1) Leptonik foton https://inspirehep.net/literature/406279

ELSEVIER

3 August 1995

PHYSICS LETTERS B

Physics Letters B 355 (1995) 494–498

Compensation of lepton charge of matter with relic anti-sneutrinos

A.K. Çiftçi, S. Sultansoy [1], Ş. Türköz

Department of Physics, Faculty of Sciences, Ankara University, 06100 Tandoğan, Ankara, Turkey [2]

Received 24 April 1995; revised manuscript received 6 June 1995
Editor: R. Gatto

Abstract

We reconsider the idea of the leptonic photon by taking into account the possible compensation of the lepton charge of matter with relic anti-sneutrinos. As a consequence of this compensation we have shown that the available experimental data admit the range of the leptonic interaction constant to be $10^{-38} < \alpha_\ell < 10^{-14}$.

$$F = -G\frac{m_1 m_2}{r^2} + \alpha_{em}\frac{q_1 q_2}{r^2} + \alpha_{lep}\frac{a_1 a_2}{r^2}$$

$$F = -G\frac{m_1 m_2}{r^2} + \beta_1\beta_2\alpha_{lep}\frac{N_{e_1} N_{e_2}}{r^2}$$

$$G = G_{SM} \times U(1) \qquad \partial_\mu \to D_\mu = \partial_\mu - ig_2 \boldsymbol{T}\cdot\boldsymbol{A}_\mu - ig_1\frac{Y}{2}B_\mu - ihaA^\ell_\mu$$

2) Sağ-sol simetrik model

Ayar grubu: $SU_C(3)\times SU_W(2)\times U_Y(1) \rightarrow SU_C(3)\times SU_L(2)\times SU_R(2)\times U_Y(1)$

Birinci aile fermiyonları: $\begin{pmatrix} u_L \\ d_L \end{pmatrix} \begin{pmatrix} u_R \\ d_R \end{pmatrix} \quad \begin{pmatrix} \nu_{eL} \\ e_L \end{pmatrix} \begin{pmatrix} \nu_{eR} \\ e_R \end{pmatrix}$

Higgs sektörü: ….

Sonuç olarak: 3 yeni ara bozon (W'^+, W'^- ve Z') ve ?? Yeni Higgs bozonu öngörülüyor (….).

Sağ-sol simetrinin kırılması Higgs alanlarının vakum beklenme değerleri sayesinde sağlanıyor.

7. Radikal Genişletilmeler (bazı notlar)

⇒ YARIN

More than 50 fundamental particles and **26 free parameters** in the minimal SM3 indicates that the Standard Model is manifestation of **more fundamental theory.**

Physics met similar situation two times in the past:

Stages	1870s-1930s	1950s-1970s	1970s-2020s
Fundamental Constituent İnflation	Chemical Elements	Hadrons	Quarks, leptons
Systematic	Periodic Table	Eight-fold Way	Family replication
Confirmed Predictions	New elements	New Hadrons	BSM particles
Clarifying Experiments	Rutherford	SLAC DIS	LHC or rather FCC
Building Blocks	Proton, neutron, electron	Quarks	Preons?
Energy Scale	MeV	GeV	TeV?
İmpact on Technology	Exceptional	Indirect	Exceptional?

- Periodic Table of the Elements was clarified by Rutherford's experiment
- Hadron inflation has resulted in quark model
- This analogy implies the preonic structure of the SM fermions

arXiv:1803.01865 [pdf, other]

Supersymmetry versus Compositeness: 2HDMs tell the story

Stefania De Curtis, Luigi Delle Rose, Stefano Moretti, Kei Yagyu

Comments: 5 pages, 6 figures

Subjects: **High Energy Physics - Phenomenology (hep-ph)**; High Energy Physics - Theory (hep-th)

Supersymmetry versus Compositeness: 2HDMs tell the story

Stefania De Curtis[a], Luigi Delle Rose[a], Stefano Moretti[b,c], and Kei Yagyu[a]

[a] *INFN, Sezione di Firenze, and Department of Physics and Astronomy, University of Florence, Via G. Sansone 1, 50019 Sesto Fiorentino, Italy*

[b] *School of Physics and Astronomy, University of Southampton, Highfield, Southampton SO17 1BJ, United Kingdom*

[c] *Particle Physics Department, Rutherford Appleton Laboratory, Chilton, Didcot, Oxon OX11 0QX, United Kingdom*

Supersymmetry and Compositeness are two prevalent paradigms providing both a solution to the hierarchy problem and a motivation for a light Higgs scalar state. As the latter has now been found, its dynamics can hold the key to disentangle the two theories. An open door towards the solution is found in the context of 2-Higgs Doublet Models, which are necessary to Supersymmetry and natural within Compositeness in order to enable Electro-Weak Symmetry Breaking. We show how 2-Higgs Doublet Model spectra of masses and couplings accessible at the Large Hadron Collider can allow one to reveal the true mechanism behind mass generation in Nature.

(ATLAS Week 1997)

III. COMPOSITNESS VS SUSY OR COMPOSITNESS & SUSY

It is known that the number of free observable parameters put by hand in SM is equal to 26 in three family case and 40 in four family case (DMM approach reduces this numbers to 20 and 28, respectively), if neutrinos are Dirac particles. The natural question: How many free parameters contain minimal supersymmetric extension of the Standard Model (MSSM)?

- ......

Total number of free parameters is

$$N > 20n^2 + 22,$$

i.e. N>202 for the three family and N>342 for the four family MSSM. Let me remind that 19 free parameters in the three family SM without right-handed neutrinos was one of the main arguments to go Beyond the Standard Model!

Message: *SUSY should be realized at a more fundamental level.*

Today there are two favorite candidates:

1. Preonic level!
2. SUGRA?

Aslında SM düzeyinde SUSY için 2 gerekçe vardı:

- Higgs bozonunun kütlesi
- Etkileşme sabitlerinin birleşmesi

İlki mH = 125 GeV ve SUSY parçacıklarının TeV altında görülmemesinden dolayı geçerliliğini kaybetti

İkincisi gerekçe sadece SU(5) GUT için geçerlidir

B. Supersymmetric Preonic Models of Quarks and Leptons

There are at least two arguments favoring compositness:

1. SUSY GIM cancellation (K_L-K_S transition etc.) requires $\delta m^2_{\tilde{q}} \approx \delta m^2_q$ ($m^2_{\tilde{u}} - m^2_{\tilde{c}} \approx m^2_c$ etc.) and $U^{\tilde{q}}_{CKM} \approx U_{CKM}$. This has a natural explanation in preonic models.

2. MSSM includes two observable phases even in the simplest case of one family: $N_\Theta = N_\varphi = 2$ for n=1.

Composite models of leptons and quarks can be divided into two classes: fermion-scalar models and three-fermion models. Let us briefly consider main consequences of SUSY extensions for these classes. Below we present the simplified options where only one superpartner for each preon is introduced and flavor mixings are absent (according to N=1 SUSY each charged fermion has two superpartners etc.). More realistic versions will be considered in details elsewhere (Sultansoy, in preparation).

1. *Fermion-Scalar Models*

In this class SM fermions (quarks and leptons) are composites of scalar preons, denoted by S, and fermion preons, denoted by F. In minimal variant $q, l = \{FS\}$. In principle, there are two opportunities:

- scalar preons are superpartners of fermion preons
- each of them have their own superpartners.

Second option leads to the quadrupling of SM matter fields (instead of doubling in MSSM). One has following states: SM fermion (FS) with $m \sim 0$, scalar $(\tilde{F}S)$ with $m \sim \mu$, scalar $(F\tilde{S})$ with $m \sim \mu$ and fermion $(\tilde{F}\tilde{S})$ with $m \sim 2\mu$.

2. *Three-fermion Models*

In this class quarks and leptons are composites of three fermionic preons and each of them has at least seven partners. In other words we have: SM fermion $(F_1F_2F_3)$ with $m \sim \mu$, three scalars $(\tilde{F}_1F_2F_3)$, $(F_1\tilde{F}_2F_3)$ and $(F_1F_2\tilde{F}_3)$ with $m \sim 2\mu$, three fermions $(\tilde{F}_1\tilde{F}_2F_3)$, $(\tilde{F}_1F_2\tilde{F}_3)$ and $(F_1\tilde{F}_2\tilde{F}_3)$ with $m \sim 3\mu$ and scalar $(\tilde{F}_1\tilde{F}_2\tilde{F}_3)$ with $m \sim 4\mu$.

Of course, mixings between quarks (leptons, squarks, sleptons) can (and should?!) drastically change the simple mass relations given above. Therefore, it is quite possible that the search for SUSY at LHC will give rather unexpected results.

C. General Remarks on Composite Models

In principle, one can consider four stages of compositness (each stage includes previous ones):
i) Composite Higgs
ii) Composite quarks and leptons
iii) Composite W- and Z- bosons
iv) Composite photon and gluons?

1. New Particles

The well-known representative of the first stage is Technicolor Model, which gives masses to W- and Z- bosons in a best manner but has serious problems with fundamental fermion masses (Extended Technicolor etc.). Therefore, one should deal at least with the second stage. In this case composite models predict a number of new particles with rather unusual quantum numbers: excited quarks and leptons, leptoquarks (HERA events!?), color-sextet quarks and color-octet leptons. If the third stage is realized in nature, excited W and Z, color octet W and Z, scalar W and Z are predicted also. The realization of the fourth stage seems today less natural because photon and gluons correspond to the unbroken gauge symmetries.

The masses of new particles are expected to lie in the range of compositness scale Δ, which exceeds TeV. Of course, if SUSY is realized at preonic level all these new particles have a number of (SUSY) partners.

Finally, it is quite possible that SUSY is realized at pre-preonic level!

2. New Interactions

Nobody knows real dynamics, which keeps together preons to form SM particles. Today, the most popular candidate is hypercolor (some extension of QCD). However, it is quite possible that a new dynamics is based on certain concepts, which differ drastically from known ones (like the difference between quantum and classic physics). In any case, we expect that some residual "contact" (Fermi-like) interactions should manifest themselves at scale $\leq \Lambda$ with intensity proportional to $1/\Lambda^2$.

In our opinion, it is useful to form "Preonic subgroup" within ATLAS Physics Working Group in order to analyze possible manifestations of compositness at LHC.

SMÖ için İki ana akım

1. Mega alan (Einstein vb)

Tarihi analoji: astronomide episikllar (dış tekerlemeler)

Düşünce tarzı: matematik

2. Yeni daha temel yapılar (Bohr vb)

Tarihi analoji: Güneş merkezli sistem

Düşünce tarzı: fizik (doğa bilimci)

3. Tamamen farklı ve beklenmedik

Tarihi analoji: klasik fizikten kuantum fiziğine geçiş

Bilimin mantığı değişecektir …

Yüz yıl önce klasik fizikten kuantum fiziğine geçişine benzer şekilde

Önemli not:

Bu slaytlar ders notlarının 29 Temmuz 2024 tarihine dek yenilenmiş halidir.

Son halini sonbaharda tamamlayıp yerleştirmeyi planlıyorum.

Tamamlandığında haber vereceğiz.