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

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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.

NAME

I. INTRODUCTION OR FOUR WAYS TO TEV SCALE

It is known that Standard Model with three fermion families well describes almost all of the large amount of particle physics phenomena (For present situation see Appendix 1). However, there are a number of problems (part of them, such as $\mu - e$ puzzle becoming family replication problem, proceeds since "pre-SM" era) which do not have solutions in the framework of the SM (Partial list of unanswered questions is given in Appendix 2). For this reason, physicists propose a lot of different possible extensions of the SM, which can be grouped in two classes, namely standard and radical extensions.

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.

C. Four Ways to TeV Scale

Today, there are four - more or less known - types of colliders, which may give opportunity to achieve TeV center of mass energies at constituent level in near future (10-15 years):

i) Hadron colliders, namely LHC (and may be Upgraded FNAL)
ii) Linear e^+e^- colliders (including γe and $\gamma\gamma$ options)
iii) Linac-ring type ep (γp) colliders
iv) $\mu^+\mu^-$ colliders

First two are well-known. A third type is less known: first international workshop was held in Ankara, 9-11 April 1997 (For details see Appendix 3) . The fourth type is sufficiently well-known, because a number of workshops and conferences on this subject were held during the past years.

Physics search programs of these machines are complimentary to each other and construction of all of them will give opportunity to investigate TeV scale in the best manner.

After this "long" introduction, let me turn to the main topic. Since the publication of Yellow Report 87-07, "Physics at LHC" has advanced magnificently. For this reason I restrict myself to the items, which have not received wide recognition, but they are important (in my opinion) for LHC experiments.

II. THE FOURTH SM FAMILY

According to the Standard Model quarks are grouped into following SU(2)×U(1) multiplets:

$$\begin{pmatrix} u_L^0 \\ d_L^0 \end{pmatrix} \quad u_R^0 \quad d_R^0 \qquad \begin{pmatrix} c_L^0 \\ s_L^0 \end{pmatrix} \quad c_R^0 \quad s_R^0 \qquad \begin{pmatrix} t_L^0 \\ b_L^0 \end{pmatrix} \quad t_R^0 \quad b_R^0$$

It is useful to consider three different bases:

- Standard Model basis $\{f^0\}$
- Mass basis $\{f^m\}$
- Weak basis $\{f^w\}$

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

$$\mathcal{L}_Y^{(d)} = a_d \left(\overline{u}_L \ \overline{d}_L\right) \begin{pmatrix} \varphi^+ \\ \varphi^0 \end{pmatrix} d_R + h.c. \Longrightarrow \mathcal{L}_m^{(d)} = m_d \overline{d} d$$

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

$$\mathcal{L}_Y^{(d)} = \sum_{i,j=1}^{n} a_{ij}^d \left(\bar{u}_{L_i}^0 \; \bar{d}_{L_i}^0\right) \begin{pmatrix} \varphi^+ \\ \varphi^0 \end{pmatrix} d_{R_j}^0 + h.c. \Longrightarrow \mathcal{L}_m^{(d)} = \sum_{i,j} m_{ij}^d \bar{d}_i^0 d_j^0, \quad m_{ij}^d = a_{ij}^d \eta.$$

Before the spontaneous symmetry breaking all quarks are massless and there 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:*

equal Yukawa constants for each fermion type $a_{ij}^d \equiv a^d, a_{ij}^u \equiv a^u, a_{ij}^l \equiv a^l, a_{ij}^\nu \equiv a^\nu$ (*flavor democracy:* Harari, Fritzsch,...).

Because there is only one Higgs doublet which gives Dirac masses to all four types of fermions (up quarks, down quarks, charged leptons and neutrinos), it seems natural to make *second assumption:*

(nearly) equal Yukawa constants for different types of fermions $a^d \simeq a^u \simeq a^l \simeq a^\nu \simeq a$ take place.

As the result (n-1) families are massless and n^{th} family fermions have masses $na\eta$. In three family case we obtain: $a^\nu < 4 \times 10^{-5}, a^l \approx 2.4 \times 10^{-3}, a^u \approx 0.23, a^d \approx 6 \times 10^{-3}$. Therefore, *according to flavor democracy the fourth SM family should exist* (Datta; Çelikel, Çiftçi and Sultansoy). As we will see later the existence of fifth family seems to be unnatural.

In terms of the mass matrix above arguments means

$$M^0 = a\eta \begin{pmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{pmatrix} \rightarrow M = 4a\eta \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Because at least charged leptons and quarks from the first three families have nonzero masses, M^0 needs appropriate modification. Assuming minimal deviations from full democracy we propose (Atag, ..., Yilmaz)

$$M^0 = a\eta \begin{pmatrix} 1 & 1+\gamma & 1+\beta & 1 \\ 1+\gamma & 1+2\gamma & 1+\beta & 1 \\ 1+\beta & 1+\beta & 1+\alpha & 1-\alpha \\ 1 & 1 & 1-\alpha & 1+\alpha \end{pmatrix}$$

Here, γ generates masses for the first family fermions and regulates Cabibbo mixing, β gives masses for the second family fermions and arranges b-c transition, α generates the third family fermion masses.

Now, let us turn to the *third assumption:* a lies between $\sqrt{4\pi\alpha_{em}}$ and g_w (with preferable value $a = g_w$). At $a = g_w$: $\gamma_u = -0.00076, \beta_u = -0.0078, \alpha_u = 0.55, m_{u_4} = 639$ GeV; $\gamma_d = -0.00043, \beta_d = -0.0014, \alpha_d = 0.013, m_{d_4} = 640$ GeV. At $a = \sqrt{4\pi\alpha_{em}}$: $m_{u_4} = 319$ GeV and $m_{d_4} = 320$ GeV. Therefore: the predicted masses of fourth family SM fermions are close to each other within accuracy of the order of few GeV and lie between 300 and 700 GeV (The Majorana neutrinos are another story).

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. In four family case CKM matrix $U_{CKM} = (U_L^u)^+ \, U_L^d$ contains 6 observable mixing angles and 3 observable CP-violating phases. Neglecting the phase parameters, at $a = g_w$ we obtain

$$O_{CKM} = \begin{pmatrix} 0.9755 & -0.2198 & 0.0021 & 0.0001 \\ 0.2196 & 0.9749 & 0.0034 & 0.0001 \\ -0.0094 & -0.0321 & 0.9994 & -0.0017 \\ -0.0001 & -0.0001 & 0.0017 & \simeq 1.0000 \end{pmatrix}$$

We see that the fourth family is practically decoupled from first two families and predictions for first three families are in excellent agreement with experimental data. It is clear that the dominant decay modes of new quarks are: $u_4 \rightarrow b + W$ and $d_4 \rightarrow t + W$. The pair production of fourth family up quarks at LHC is the subject of report of A.Mailov. Let us conclude this section by two arguments against the fifth SM family:

1) large value of m_t ($\simeq$175 GeV). Indeed, partial-wave unitarity at high energies leads to $m_Q \leq 700$ GeV ($\approx 4\, m_t$) and in general we expect that $m_{i-1} \ll m_i$.

2) neutrino counting at LEP results in fact that there are only 3 "light" ($m_\nu < m_Z/2$) nonsterile neutrinos. If neutrinos are Dirac particles, in five family case we have 4 "light" neutrinos.

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)?

A. CKM mixings in MSSM

The numbers of observable mixing angles and phases in n family SM are given by well-known formulae:

$$N_\Theta = \frac{n(n-1)}{2}, N_\varphi = \frac{(n-1)(n-2)}{2}.$$

Let us estimate corresponding numbers in MSSM (Aydin, Sultansoy and Yilmazer). In the framework of $SU_C(3) \times SU_W(2) \times U_Y(1)$ model with l up quarks and m down quarks, whose left-handed components form n weak isodoublets, we obtain (following Kobayashi-Maskawa arguments):

$$N_\Theta = \frac{n(n-1)}{2} + n(l+m-2n), N_\varphi = \frac{(n-1)(n-2)}{2} + (n-1)(l+m-2n).$$

For illustration let us consider N_Θ in details. The number of observable mixing angles is given by:

$$N_\Theta = N^0 - N^R - N^s - N^d + N^W$$

where

$$N^0 = l(l-1) + m(m-1)$$

is total number of mixing angles from diagonalization of mass matrices,

$$N^R = \frac{l(l-1)}{2} + \frac{n(n-1)}{2}$$

it is obvious that rotations in right-handed sector did not lead to observable results,

$$N^s = \frac{(l-n)(l-n-1)}{2} + \frac{(m-n)(m-n-1)}{2}$$

unobservable rotations within left-handed singlets,

$$N^d = 2 \times \frac{(n-1)}{2}$$

rotations within left-handed components combined in doublets are unobservable in the interactions with γ, Z-boson and gluons,

$$N^W = \frac{n(n-1)}{2}$$

reappear in the interactions with W-boson.

For n-generation E_6-induced model ($m = 2l = 2n$) we obtain $N_\Theta = n(3n-1)/2$ and $N_\varphi = (n-1)(3n-2)/2$. In the three family case this gives 12 mixing angles and 7 phases in quark sector.

Following the similar arguments for n family MSSM one can obtain

$$N_\Theta^{q,\tilde{q}} = N_\varphi^{q,\tilde{q}} = n(5n-3)$$

Indeed, quark-squark-gaugino interactions restore all the mixing angles and phases that have been absorbed in the interactions with usual gauge bosons. Therefore, we have:

$$\widetilde{N}^0_\Theta = \frac{2n(2n-1)}{2} + \frac{2n(2n-1)}{2} = 2n(2n-1)$$

angles from up and down squark sectors and

$$N^0_\Theta = \frac{n(n-1)}{2} + \frac{n(n-1)}{2} = n(n-1)$$

angles from quark sector. If neutrinos are Dirac particles the same number of free parameters

$$N^{l,\widetilde{l}}_\Theta = N^{l,\widetilde{l}}_\varphi = n(5n-3)$$

is added from lepton-slepton sector. Moreover, we have also $12n$ mass values for leptons, sleptons, quarks and squarks. In addition, one has:

- 2 angles and 4 phases from chargino diagonalization
- 6 angles and 10 phases from neutralino diagonalization
- .....

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?

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 $\delta m^2_{\widetilde{q}} \approx \delta m^2_q$ ($m^2_{\widetilde{u}} - m^2_{\widetilde{c}} \approx m^2_c$ etc.) and $U^{\widetilde{q}}_{CKM} \approx U_{CKM}$. 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 $(\widetilde{F}S)$ with $m \sim \mu$, scalar $(F\widetilde{S})$ with $m \sim \mu$ and fermion $(\widetilde{F}\widetilde{S})$ 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 $(\widetilde{F}_1F_2F_3)$, $(F_1\widetilde{F}_2F_3)$ and $(F_1F_2\widetilde{F}_3)$ with $m \sim 2\mu$, three fermions $(\widetilde{F}_1\widetilde{F}_2F_3)$, $(\widetilde{F}_1F_2\widetilde{F}_3)$ and $(F_1\widetilde{F}_2\widetilde{F}_3)$ with $m \sim 3\mu$ and scalar $(\widetilde{F}_1\widetilde{F}_2\widetilde{F}_3)$ 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.

IV. SUGRA MANIFESTATIONS

As we mentioned in previous section, second favorite candidate to solve problems left unsolved by the Standard Model is SUGRA, which simultaneously unifies all known fundamental interactions including gravitation. Unfortunately, SUGRA does not solve the masses and mixings problem (at least for today).

The most realistic scenario from SUGRA scale to SM scale in short looks as:

- $E_8 \times E_8'$, 10 space-time dimensions at $M_{Pl} \sim 10^{19}$ GeV
- $E_8 \to E_6 \times SU(3)$, 4 dimensions at $M \sim 10^{18}$ GeV
- $E_6 \to ?$ at $M \sim 10^{16}$ GeV
- •
- •
- $SU_c(3) \times SU_W(2) \times U(1) \times U(1)$ at $M \sim 10^3$ GeV ?

} SUSY breaking ?

- $SU_c(3) \times SU_W(2) \times SU_Y(1)$ at $M \sim 10^2$ GeV (SM + nonstandard fermions).

According to this scenario additional neutral intermediate vector boson with mass in the region 1 to 10 TeV is predicted. The discovery limit for new Z' boson at LHC is about 5 TeV.

A. Isosinglet Quarks

First family fermion sector of the model at last stage looks as

$$\begin{pmatrix} u_L \\ d_L \end{pmatrix} \quad u_R \quad d_R \quad D_L \quad D_R \quad \begin{pmatrix} \nu_{e_L} \\ e_L \end{pmatrix} \quad \nu_{e_R} \quad e_R \quad \begin{pmatrix} N_{e_L} \\ E_L \end{pmatrix} \quad \begin{pmatrix} N_{e_R} \\ E_R \end{pmatrix} \quad \mathcal{N}_e$$

Only quark (and squark) sector is matter of interest for LHC. New isosinglet quarks decays only due to mixings with usual down-type quarks d, s and b. Remind that in the three family case quark sector contains 12 observable mixing angles and 7 observable phases. Let us suppose that:

i) interfamily mixing is dominant

ii) usual CKM mixings lie in up-quark sector.

Therefore, in the weak base one has

$$\begin{pmatrix} u_L^{\Theta} \\ d_L^{\varphi} \end{pmatrix} \quad u_R \quad d_R \quad D_L^{\varphi} \quad D_R$$

where

$$\begin{cases} d^{\varphi} = d\cos\varphi + D\sin\varphi \\ D^{\varphi} = -d\sin\varphi + D\cos\varphi \end{cases}$$

and $\sin^2\varphi \ll 1$. For $m_D - m_w \approx m_D - m_Z \gg m_Z - m_W$ one has $BR(D \to u^{\Theta} + W) \approx 0.6$ and $BR(D \to d + Z) \approx 0.4$. Therefore, we expect $BR(D \to jet + l^+l^-) \approx 0.012$ and $BR(D \to jet + \overline{\nu}\nu) \approx 0.072$ for decay modes which differ isosinglet quarks from the fourth SM family quarks.

LHC with $\mathcal{L}^{int} \approx 10^5 pb^{-1}$ will produce $\approx 5 \times 10^5$ (3×10^4) $\overline{D}D$ pairs per year if $m_D = 0.5$ (1.0) TeV.

B. Flavor Democracy (night before talk)

In the case of three E_6 families, quark sector of the model has the form

$$\begin{pmatrix} u_L^0 \\ d_L^0 \end{pmatrix} \quad u_R^0 \quad d_R^0 \quad D_L^0 \quad D_R^0 \qquad \begin{pmatrix} c_L^0 \\ s_L^0 \end{pmatrix} \quad c_R^0 \quad s_R^0 \quad S_L^0 \quad S_R^0 \qquad \begin{pmatrix} t_L^0 \\ b_L^0 \end{pmatrix} \quad t_R^0 \quad b_R^0 \quad B_L^0 \quad B_R^0$$

According to the flavor democracy we deal with following mass matrices for up and down quarks:

$$M_u = a_u\eta \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$$

and

$$M_d = a_d\eta \begin{pmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 \\ k & k & k & k & k & k \\ k & k & k & k & k & k \\ k & k & k & k & k & k \end{pmatrix}$$

where $k = \mu/a_d\eta$, μ is the next to SM scale ($\mu \gg 100$ GeV).

As a result we obtain:

- $m_t = 3g_u\eta$ and $m_u = m_c = 0$ in up sector
- $m_B = 3g_d\eta + 3\mu$ and $m_d = m_s = m_D = m_S = 0$ in down sector.

After breaking of flavor democracy it is natural to expect that $m_D \ll m_S \ll \mu$. Therefore, with high probability at least one isosinglet quark (D-quark) will be covered by LHC.

V. AN EXAMPLE OF "UNEXPECTED" NEW PHYSICS

In this section, we consider in brief the consequences of possible low-energy compactification, that is new (space) dimensions, at TeV?? scale. The work on this subject is in progress (Arik, Sultansoy and Ünel) and presented results are (very?) preliminary. Firstly, the existence of two new dimensions seems preferable, otherwise one encounters problems in formulation of SM. "Infinite" number of "electrons", "muons" and other fundamental particles are predicted. The mass spectrum depends on compactification mechanism and there are two extreme cases:

- $m_{e_n} = n \times M$

- $m_{e_n} = n^2 \times M$

where $M \sim 1/r$ denotes the compactification scale. The usual electron corresponds to e_0. Same relations take place for other SM particles. In principle, "heavy electrons" and other new particles are expected to be stable and should be produced pairly, but.....

Wait for the next (ATLAS) week!

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Appendix 1. The Standard Model Contents (PDG 96)

According to the SM, fundamental fermions are grouped into three families:

1	$\nu_e(< 10eV)$	$e(0.51099907(15)MeV)$	$u(2 \div 8MeV)$	$d(5 \div 15MeV)$
2	$\nu_\mu(< 170KeV)$	$\mu(105.658389(34)MeV)$	$c(1.0 \div 1.6GeV)$	$s(100 \div 300MeV)$
3	$\nu_\tau(< 24MeV)$	$\tau(1777.0^{+0.30}_{-0.27}MeV)$	$t(175 \pm 6GeV)$	$b(4.1 \div 4.5GeV)$
4?	$\nu_4(> 45GeV)$	$l_4(> 45GeV)$	$u_4(> 200GeV)$	$d_4(> 100GeV)$

Fundamental interactions are mediated by gauge bosons:

$$\gamma(0MeV), \quad 8 \quad g's(0MeV), \quad W^{\pm}(80.33 \pm 0.15GeV) \quad and \quad Z(91.187 \pm 0.007GeV).$$

The scalar Higgs boson $H^0(> 60GeV)$ with mass $5GeV < m_H < 1TeV$ (theory) should also exist.

The model is based on spontaneously broken gauge symmetry

$$[SU(3)]_{color} \times [SU(2)]_{\substack{weak \\ isospin}} \times [U(1)]_{\substack{weak \\ hiperch\,arg\,e}} \rightarrow [SU(3)]_{color} \times [U(1)]_{em}$$

and proved up to the first-order radiative corrections. Gauge part contains three coupling constants (or their combinations) and one mass parameter $\eta \sim 249GeV$ characterizing weak scale ($\Lambda_{QCD} \sim 250MeV$ - second mass parameter?):

$$\alpha_s(M_Z) = 0.112 \pm 0.002 \pm 0.004, \quad \alpha_{em} = 1/137.036, \quad \sin^2\Theta_W = 0.2237 \pm 0.0002 \pm 0.0008.$$

Additionally, there are fermion masses (more exactly fermion-Higgs Yukawa constants) and CKM mixings in quark and lepton sectors. In the three family case experimental values of quark CKM elements are (90% CL):

$$\begin{pmatrix} 0.9745 \div 0.9757 & 0.219 \div 0.224 & 0.002 \div 0.005 \\ 0.218 \div 0.224 & 0.9736 \div 0.9750 & 0.036 \div 0.046 \\ 0.004 \div 0.014 & 0.034 \div 0.046 & 0.9989 \div 0.9993 \end{pmatrix}.$$

Appendix 2. Unanswered Questions

Below, we present partial list of problems which have not been solved by the SM

o What determines the pattern of quark and lepton masses and the mixing angles and phases of the CKM matrices?

o Why do the quark-lepton generations repeat? How many generations exist in the nature?

o What is the origin of quark-lepton symmetry? Do the right-handed neutrino components exist in Nature? Are the neutrinos Dirac or Majorana particles?

o What is the origin of L-R symmetry breaking? In the SM this is put by hand.

o Why are there so many arbitrary parameters? Three family SM contains:

3 coupling constants α_s, α_{em} and $\sin\Theta_W$,
6 quark masses, 3 mixing angles and 1 phase,
2 parameters of the Higgs potential,
3 charged lepton masses,
1 QCD vacuum phase angle,
3 neutrino masses (6 in Majorana case),
3 lepton mixing angles (15 in Majorana case),
1 phase (? in Majorana case).
A total of 19 (26 for Dirac neutrinos or 30+? for Majorana neutrinos) arbitrary parameters!

o Why are the all known interactions built on the gauge symmetry?
o What is the (real) origin of CP-violation?
o How is the gravity included in a unified way?
o Are the quarks and leptons (as well as part of or all gauge and Higgs bosons) of the SM elementary or composite? Three family SM contains: 18 quarks, 6 leptons, 1 photon, 8 gluons, 3 massive IVB's, 1 H^0 and 1 graviton; a total of 38 "elementary particles"! Third Mendeleev Table? Second Mendeleev Table (hadrons) result in quark model!
o What is the origin of "confinement" of colored objects? Are they "truly confined"?
o o o
Therefore, we are far from the "end of physics"!

Appendix 3. Linac-Ring type *ep* and γp Colliders

If future linear e^+e^- colliders (or special e-linacs) are constructed near the existing (HERA, FNAL) or constructing (LHC) proton rings, a number of additional opportunities will appear. For example,

LHC⊗TESLA = LHC⦶TESLA
⦶ TeV scale *ep* Collider
⦶ TeV scale γp Collider
⦶ Multi-TeV scale $e - nucleus$ Collider
⦶ Multi-TeV scale $\gamma - nucleus$ Collider
⦶ FEL $\gamma - nucleus$ (≡MeV energy laser in the nucleus rest frame)

Ankara Workshop Summary and Recommendations:

1. Physics (AU-DESY-BINP-IHEP-FNAL-METU-BOUN)
o Linac-Ring type *ep* and γp colliders will be complementary to TeV scale hadron and lepton machines
o there are a number of important physical problems which can be solved in a best manner at these new type colliders
o if the new results from HERA are going to be verified, this will give a new strong argument in favor of TeV energy lepton-hadron machines

2. Machine parameters (DESY-AU Collaboration)
o there are strong arguments favoring the using superconducting linear collider as a source of e-beam for linac-ring type colliders
o L=10^{31}cm^{-2}s^{-1} for HERA+TESLA ($\sqrt{s} \approx 1$ TeV) and L=10^{32}cm^{-2}s^{-1} for LHC+TESLA ($\sqrt{s} \approx 5$ TeV) can be achieved within moderate improvement of proton beam parameters etc.
o more radical improvements (such as cooling in main ring, revision of interaction region beam optics etc.) will give opportunity to increase luminosity up to L=10^{32}cm^{-2}s^{-1} for HERA+TESLA and L=10^{33}cm^{-2}s^{-1} for LHC+TESLA

3. Recommendations
o Two Workshops during next (1998) year: one on physics and other on machine parameters.