RARE BEAUTY DECAYS AS WINDOWS ONTO EXTRA DIMENSIONS

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The purpose of this presentation is:

- To discuss some topics of modern HE physics, following to the
- CONTENT:
- I. Experimental Success of the SM.
- II. SM Theoretical Incompleteness.
- III.Role of Modern & Forthcoming Accelerators.
- IV.Beyond SM Road (SUSY…)
- V. Kaluza-Klein Phylosophy.
- VI.Theory of Everything (TOE).
- VII. Large Extra Dimension Approach.
- VIII. Large Extra Dimensions & Rare Processes.

I.Up to Date SM Experimental Success

A) Introductory Remarks.

- Great progress of HEP in recent decades first of all reflects wide belief that Observed World should obey to simple & unit basic principles, which could be understood through our efforts. The discovery of W,Z- bosons practically confirmed the hypotheses on United Nature of Weak & EM forces, while t-quark observation means that for a whole TRIUMPH of GSW SU(2) x U(1) we are in need of of last unobserved ingredient:
- The HIGGS boson!

Just the aim to create

- Unified description of at the first look different phenomena very often leads to theories, which play important role in our understanding of the NATURE

Very good examples:

FARADEY-MAXWELL ELECTRODYNAMICS

↓

UNIFIED NATURE OF MAGNETIC AND ELECTRICAL PHENOMENA

↓

And even has lead to certain technical progress

Another example is the SM

- Which is the model of electroweak unification completed by quantum chromodynamics. It is the successfully working theory which does not contradict to observed phenomena up to till investigated energies (distances) of

$\Lambda \sim O(100$ Gev) $r \sim 10^{-16}$ cm

Nevertheless, wide belief is:

THE SM IS NOT A FINAL STORY !!

B) FURTHER PROGRESS

- Our development of "standard knowledge" is connected with penetration into matter up to $r<10^{-(17:18)}$ cm.
- Major lab instrumentals for this are:acting and forthcoming accelerator facilities (Tevatron,LHC,NLC,SUPERb…).
- Speaking generally, by the circle of tasks and working conditions they should be separated in two classes:
- 1. High Luminosity Colliders of ultrahigh energies,

Where “direct “ thorough experimental search for the range of energy

$\sqrt{S} \sim (1 \div 10)$ TeV$\longrightarrow r \sim 10^{-(17:18)}$ cm is possible and

2.Accelerators with highly intensive beams, working in a fixed target mode. First of all, we mean π,K,D,μ-meson factories, where, in principle,

search for and study of rare processes with the BR up to $Br \lesssim 10^{-(10:16)}$ would be possible.This search and possible study is connected with

manifestation of “virtual (loop) effects” of NEW PHYSICS at $r \lesssim 10^{-(16 \div 21)}$ cm, or in the effective range of $E \lesssim O(PeV)$.

A brief look back:

Independently of this two conceptions , say, the study of heavy flavor hadrons starting with kaons and Hyperons has lead to many discoveries that were crucial for the evolution of today’s SM:

- The θ-τ puzzle in kaon decays provided first suggestion that parity is not conserved in the nature.

- Observation that the production rate of some “strange” hadrons exceeded their decay rate by many orders of magnitude was explained through postulating a new quantum number-”strangeness”
conserved by strong,though not the weak forces [A.Pais 1952,M.Gell-Mann 1953, T.Nakano and Nijshijima 1953].This was the beginning of the second quark family.

- The weak decays of pions,kaons and muons were related through Cabibbo universality [N.Cabibbo, 1963]

- Flavor oscillations were predicted for K(0)-K(0 bar) [M.Gell-Mann, A.Pais, 1955]
- The absence of FC neutral currents - first noticed in K(L)⇒μ+μ– and ΔM(K)- was implemented by introducing another quantum number “Charm”, which completed the second family [S.L.Glashow, J.Illiopoulos,L.Maiani, 1970]. It’ mass was predicted roughly about 2 GeV [M.K. Gaillard, B.W. Lee, 1970].

- CP violation – observed through $K(L) \Rightarrow \pi^+ \pi^-$ [J.H. Christiansen et al. 1964]-led to the postulation of yet another, third family [M.Kobayashi, T.Maskava; 1973].

!! All these feautures, which are now essential pillars of the SM, were NEW PHYSICS at that time! They came as a surprise-even a shok. Later, sometimes much later, they have been confirmed, sometimes overcoming considerable scepticism in the community:

- Charm hadrons were indeed found in the mass range around 2 GeV with the expected lifetimes of $10^{-(13:12)}$ sec and preferred coupling to strange hadrons.

- Beauty hadrons and top quarks were found , mostly with the expected properties. The lifetimes of Beauty hadrons actually turned out to be considerably longer than had been anticipated based on a naïve analogy with the Cabibbo angle. This lead to the realization that the CKM matrix is highly symmetrical and hierarchyal.

We have not digested yet the message that is encoded in this peculiar pattern.

- B(d)-B(d Bar) oscillations were found
- Most triumphantly CP violation has been firmly established

[BELLE Collaboration,2001; BABAR Coll. 2001]
B(d)⟹J/Ψ K(s) is in impressive agreement with CKM predictions [A.B.Carter,A.I.Sanda 1981; I.I Bigi, A.I.Sanda 1981]

Rich experience of HEP development has shown that achievement of results of fundamental importance depends on both successful and object oriented theoretical forecasts and profound sequence and correlations of research at various accelerators.

Again: excellent example is just the development of SM related topics: along with development of SM itself K(Kbar) mixing was discovered, weak neutral currents in neutrino interactions were observed (CERN,1973), weak gauge bosons W,Z (CERN,1983), t-quark (FERMILAB,CDF,D0;1995) were discovered etc.

In the recent past, nowadays and in a foreseen future at leading HEP facilities actually the study of phenomena, where most likely is to find important effects connected with more profound understanding of our "standard knowledge" or possible need for going Beyond SM were,are and will be performed.

To this type of research belong first of all:

C) Some of the processes, which can contribute either in our standard knowledge or BSM thoughts:
1.Experiments on precision and independent measurements of SM parameters: $\sin^2\theta w$ and ρ parameters both at pp(pp bar) colliders via measurement of $W\pm$ and $Z0$ masses along with precise measurement in e+e- annihilation processes and neutrino experiments
(Done at LEP,FNAL,Brookhaven).
2.Subsequent “attack” on quark mixing sector and CP-violation through more precision measurements of CPV parameter with $|\Delta S|=1$ in $K0$ decays $|\epsilon'/\epsilon|$ up to 10^{-4} (CERN);

Search for CP violation in $|\Delta S|=0$ transitions: precision measurement of EDM of neutron d(n); Search for D(0) oscillations in e+e- and neutrino experiments; further study of B(d,s) oscillations, precision measurements of CKM mixing matrix via heavy quark decays, search for 4-th (heavy) generation.

3. Experiments connected with the study of SM lepton sector with the objectives to study: a)neutrino mass problem b) its Majorana-Dirac nature c)lepton mixing angles d)search for new heavy leptons,
e) neutrino oscillations.

4.Experiments on a search of: a) proton decay and n-n bar oscillation b)SUSY particles, c)lepton number violation ($\mu \Rightarrow 3e$, $\mu \Rightarrow e\gamma \Rightarrow$ at the level of $Br = 10^{-14}$ (PSI)) d) violation of quark-lepton symmetry $\Rightarrow K(L) \Rightarrow \mu^+ e^-$ ($\mu^- e^+$) etc.

° Foreseen future maybe shows how serious could be "experimental arguments" on the BSM road. Investigations performed till now do not indicate any serious derivations from SM predictions. Maybe neutrino oscillation experiment is first exception (large enough 2-3 generation mixing in the lepton sector)

° Perhaps the reason for this "Standard Harmony" is just insufficient precision in proper theoretical calculations, maybe it's due the fact that we didn't reach yet scales of energy (distances) at which those discrepancies might manifest themselves.

° However, modern theoretical physics, based on past achievements, is in a state of great progress due to literally fantastic ideas. For example, theoretical discovery of SUSY, along with renewed Kaluza-Klein philosophy and development of the string theory have led to great breakthrough on the road of "Theory of everything" (TOE), which could pretend on the role for unification of all fundamental forces, including gravity. Doing so, people are operating with such a "nontraditional" things, as d>4 (d=10, d being space-time dimension) and considering elementary particles not as point-like but string-like objects.

- Typical scale for such "super unification" is the Planck scale⇒

⇒ 10^{19} GeV, which is technically unachievable in a distant future, if ever.

In spite of this such a theories have some "low energy echo". For instance, ν® and heavy D-quark in frames of E(6)-based GUT scheme in d=4 space time after compactification of extra dimensions.

II. THEORETICAL INCOMPLETENESS OF SM

Arguments motivating to go beyond SM , still have only theoretical origin. They are mainly connected with the desire to explain mechanisms, "ad hoc" putted into model. These are:

- 1.EW symmetry breaking problem
- 2. Chirality problem (all known leptons and quarks are in ad hoc

way placed in the EW group complex representations).

It is likely that with this last problem understanding of low energy paritv violation is connected, as well as $m(\nu) \ll m(l)$ neutrino mass problem (See-Saw mechanism of GRS)

- 3. Generation problem:
- A) how many of them and why?
- B) what's the reason for quark mixing and mass origin
- C) mechanism for violation of global symmetry of quark-lepton generations
- D) is it possible to localize so called Horizontal symmetry?

E) How high is the scale of this violation and is there connection of this problem with CP-violation one?

4. Q-l symmetry problem:
  a) what is it's nature?
  b) how to restore local Q-l symmetry at low distances:
for example: in the approach with 10 dimensional superstring theory with E(6) GU group $G \subset E(6)$ this symmetry is explicitly unbroken only in the 16-plet of SO(10):

$$\begin{array}{ccc} E(6) & & SO(10) \\ 27 & = & 16 \oplus 10 \oplus 1 \end{array}$$

5. What is the underlying principle for construction of Yukawa and Higgs sectors in the SM, which are sources for fermion and gauge boson masses?

6. What are the ways of nontrivial unification of internal and space-time symmetries (Coleman-Mandula theorem) $\Rightarrow$ SUSY

7. What is like "true" unified theory, whose "low energy image" is

$$SU(3)_c \otimes SU(2)_L \otimes U(1)_y \text{ model? …}$$

In addition to above listed: large amount of arbitrary parameters (from the point of SM itself) such as masses,charges,mixing angles etc, so many How? Which? Why? Clearly indicate:

SM COULD NOT BE THE FINAL STORY in its present form !!!

Instead of we can imagine the following scenario :

$SU(3)_c \otimes SU(2)_L \otimes U(1)_y \subset$ kind of GUT $\subset$ TOE

at 10^2 GeV $10^{15:16}$ GeV Planck scale

With or without deserts in between

iii. ROLE OF MODERN (FORTHCOMING) ACCELERATOR FACILITIES TO CONTRIBUTE INTO UNDERSTANDING OF POBLEMS, LISTED IN SECTION II.

- Already 1.5 decades ago or so there was a strong belief that much of the problems above will suffer considerable progress both at colliders and fixed target accelerators (FTA) planned that time. Thus high luminosity ($10^{33} \div 10^{34} cm^{-2}/sec$)) colliders are able to search new objects with the statistics of $10^{5:6}$ events/year, FTA could reach intensity of secondary particles at the level of $10^{(15:16)}$ particles/year.Some progress already have been done: TEVATRON discovered t-quark ($M(t) \approx 175$ GeV),LEP-II at CERN placed a limit on $M(H) > 125$ GeV… etc.

Regarding to the problem of EW breaking modern theoretical thought develop in two main directions, which forecast new phenomena in the range of scale $\Lambda \sim \sqrt{S} \sim O(TeV)$. Those directions are:

1. "Traditional view": compositeness-preons
2. Fermi-Bose equality (Supersimmetry)

SUSY approach predicts rich spectra of superpartners with masses in the range O(TeV). Exception would be so called LSP (photino, higgsino or scalar neutrino). The same is the scale for compositeness also.

Main tasks to be performed or are starting to perform on acting and planned accelerator facilities, are:

a) Further thorough investigation of established "standard " approach " to the particle interactions (quark confinement, Higgs hunting, W and Z decays, t, b decays including rare modes etc.…
b) Search for birth direct and indirect SUSY effects
c) Study of possible compositeness of quarks, leptons,gauge bosons, predicted by extended gauge theories (say, W®, Z' etc).

d) Especially popular became the Large Extra Dimension approach after appearing papers of Arcani-Hamed, Dimopoulos, Dvali (ADD,1998) and Randal and Sundrum (1998), as well as M.Gogberashvili's (1998) work.

These are very interesting from the point of view that we can probe the influence of extra d>4 dimensions on gravity rules as well as on purely particle physics experiments.

While possibilities of existing and planned colliders towards "direct search" of new objects (SUSY particles, Higgs boson(s), compositeness phenomena, new gauge bosons) are restricted by few TeV ($\leq O(10)$ TeV), new information from bigger scales of energy (less distances $r \leq 1/\sqrt{S_{effective}}$

$\sqrt{S_{effective}} \geq (10 \div 10^3)$TeV)could be accessible as indirect effects – through investigation of virtual particle exchanges in the loops. This is possible due to meson factories on the basis of high current (100-1000μkA) accelerators.Indeed, unobservation of, say $\mu+ \Rightarrow e+e+e-$ at the level of

$Br(\mu \Rightarrow 3e) \leq 2 \cdot 10^{-12}$ could mean that the scale of hypothetic "horizontal" bosons $M_{horizontal} > (50\text{-}70)$TeV. The same fact could give an information on the scale of compositeness $\Lambda \geq 50$ TeV etc.
It would be highly desirable for meson factories to reach effective scales corresponding to Energies of $(10^3 \div 10^4)$ TeV=$(1 \div 10)$PeV. For some rare processes this scale corresponds to $Br \geq 10^{-16} \div 10^{-17}$.

From the point of view of BSM breakthroughs meson factories could help to investigate chirality problem,q-l problem (among stated in section II), giving important quite precise hints on the scales of new physics.As we mentioned earlier, we have excellent examples in the particle physics history: K°⇔ K°(bar) and K(L)→$\mu+\mu-$ led us to the restriction of charmed quark mass due to existence of famous GIM mechanism. On the other hand, neutral current discovery at CERN ν(antineutrino) experiments allowed to indicate roughly the range of search for W and Z bosons. Exactly same way we could estimate via the study of CP-violation in K(0) decays on another separated physical scale in the "desert" between SM and GUT scales:the scale of (1÷3) PeV, connected, for instance with the horizontal gauge forces and their carriers. It's possible to give much more examples.

What about SUSY extension of SM, they could have important implications in rare processes too, especially when dealing with low mass LSP ($M_{LSP}<M_K$). In this case we assume that R-parity is broken in the SUSY theories. Processes like $\mu\to e\nu$ photino, $\mu\to$e scalar neutrino, K$\to\pi\mu$ photino etc are
allowed in this case (A. Liparteliani,S.Kereselidze,G.Volkov ; 1987)

Top point of SUSY approach leads to the context of 10 dimensional superstring theory ⇒TOE.

The way down to SM in this approach is as follows : at the Plank scale we have TOE itself, after compactification of extra 6 dimensions at~ 10^{18} GeV we are dealing with $E_8 \otimes E_8'$ based model, whose E_8' (hidden sector) fields interact gavitationally only while E_8 contains visible sector of the model.

As a result, visible $E_8 \Rightarrow E_6 \otimes$ N=1 SUSY in d=4 and at ($10^{15\div16}$ GeV) we have E_6 supersymmetric GUT, whose further decomposition leads us at weak

scale to SM Group $\otimes$ T with $T \equiv U(1)_E$, $U(1)_R \otimes U(1)$ or $SU(2)_R$.

In the attempts to receive low energy phenomenology at $\Lambda \sim M_W$ important role plays chirality requirement of observed quarks and leptons. These chirality feautures are connected with the problem of gauge anomaly cancellations, violation of P- and T- invariance at low energies, to the up-down asymmetry of quarks and leptons ($m_\nu \ll m_l$). In some models the question of P-parity restoration (A.Liparteliani, V. Monich, G.Volkov, 1985)at low distances is connected with adding of new gauge bosons and (or) with the expansion of fermion spectra of SM by mirror (doubling) heavy fermions θ^m (L^m) . So, observation of the effects of P-symmetry restoration in the effective range $\sqrt{S} \geq O(TeV)$ could influence on the further development of 10 dimensional superstring theory. Thus, exp. Prove of the existence of MF-s in O(TeV) range(which were used for anomaly cancellation by fixing $E_8 \otimes E_8'$ as gauge group) would work automatically.

Accounting for new massive objects could led to unique processes near to existing experimental limits. So, if there are MF-s (namely, leptons), $\mu \to e\gamma$ and $K_L^0 \to \mu^- e^+$ ($e^- \mu^+$) will enhance considerably.

- If supersymmetry really has a connection with naturalness problem than the task of "direct discovery" of SUSY is just a problem of colliders with $\sqrt{S} \geq (1 \div 40)$ TeV (operating,planned,as well as conserved). However, "indirect" highlights in this respect have also relatively low energy facilities too.Because
- $E_6 \to SU(3)c \otimes SU(2)_L \otimes U(1)_Y \otimes T$ with $T \equiv U(1)_E$, $U(1)_R \otimes U(1)$ or $SU(2)_R$, precision measurements, say : of neutral currents in neutrino experiments would give useful information on additional gauge bosons Z_R, Z_E - and measurements of charged currents →information on $W_R^{\pm}$. In addition, E_6-version of "low energy remnant" of the TOE contains new heavy quarks D(D bar) (Q_D=1/3), leptons E^0, E^-, E^0(bar), E^+(bar); N, ν^C(heavy) .
- We are not able to indicate precisely the range for new quark and lepton masses, but can apply to some experimental and (or) theoretical restrictions: $W_R^{\pm}$ of $SU(2)_L \otimes SU(2)_R \otimes U(1)$ gauge theory,

  $M(W_R^{\pm}) \geq (380 \div 450)$GeV; $M(W_R^{\pm}) \geq 1.5$ TeV; $M(W_R^{\pm}) \leq 30$ TeV

Restrictions from νN scattering tell us that: $M(Z_R) \geq (200 \div 300)$GeV and $M(Z_E) \geq 156$ GeV. So, further improvement of precision in neutrino exp-s could allow to study effects on the distances close to $r \sim 10^{-(17:18)}$ cm

- Direct search for Z_R in $pp(bar) \rightarrow Z_R^0 \rightarrow e^+e^-$ at:

TEVATRON($\sqrt{s}$=1.8TeV) is restricted by $M(Z_R)<400$GeV

UNK ($\sqrt{s}$=6 TeV, conserved) $M(Z_R)<1.5$ TeV

SSC ($\sqrt{s}$=40 TeV, conserved) $M(Z_R)<6$ TeV

These facts tell us in favor of long-term interest in the precision measurements of NC phenomena in neutrino experiments in the effective range $\Lambda \sim (1 \div 10)$TeV.

°Effects of new type of interactions in the experiments with relatively low $\sqrt{s}(\sim M_W)$ but high intensities could led to the observation of systematic shifts into $\sin^2\theta_W$, ρ,$\epsilon_{L,R}^{u,d}$ (g_A, g_V)-parameters, measured in all kinds of neutrino(antineutrino)-lepton and neutrino-nucleon experiments.Very important in this case is also the appearance in above parameters of the dependence on the generation and types of interacting particles ⇒from the point of view of $e/\mu/\tau$ universality breaking.

°**As stated above, SM is not able to explain problem of q-l symmetry of existed generations. Maybe progress with this status could be connected with quark and lepton compositeness ($\Lambda_{Comp} \geq 50 \div 100$ TeV) and (or) with the idea of localization of horizontal symmetry of generations. As it's known, the degree of need to extent SM-symmetry group by horizontal gauge one G_H, as well as investigation of its' breaking on the scale $\Lambda_H \sim 10^4 \div 10^7$ GeV could be performed among others, via more precise measurements of (ϵ, ϵ') CP-violating parameters in K^0-decays.**

- So, horizontal symmetry problem seems to be the problem, dealing just with meson factories.The possibility of its' confirmation and especially as localized model, should be accounted both by any GUT- and TOE-phenomenology at "lower" energies.However, it should be noticed, that the field theoretical limit of 10-d superstring theory at least with E_6 as a GU group avoids this question of local horizontal symmetries.

°**SUSY extensions of early unified theories ($\Lambda \sim 10^2 \div 10^4$TeV) of EW, 4-color q-l and horizontal symmetries in frames of $G_{EW} \otimes G_C \otimes G_H$ could be**

studied mainly on meson factories too. Localization of 4-color q-l symmetry in a number of models happens on $10^5 \div 10^7$ TeV scales. Suitable place for investigation of this phenomena is just K-factory. First of all we mean search for and study of $K_L^0 \to \mu^- e^+ (\mu^+ e^-)$

$K^\pm \Rightarrow \pi^\pm \mu^- e^+$, $K^\pm \Rightarrow \pi^\pm \mu^+ e^-$; $K^\pm \Rightarrow \pi^\pm \mu^+ \mu^-$, $K^\pm \Rightarrow \pi^\pm e^+ e^-$ … processes.

- Thus our mini-conclusion of this chapter is that both colliders and FT accelerators are able to contribute into BSM breakthroughs.
- FT facilities mostly “hint” on the scale of new phenomena,

  while colliders are “redy” to “catch them directly”.

IV. BEYOND SM ROAD (SUSY APPROACH)

1. Supersymmetry and naturalness of $SU(2)_L \otimes U(1)_Y$ interactions.Hierarchy problem.

As stated before, in spite of great phenomenological success in the explored ranges up to $\sqrt{S} \cong$ 100 GeV or even more, SM could not be a "final story".First of all, this statement is connected with the problem of EW-symmetry breaking. To be more concrete, SM is not able to keep stable with respect to quantum corrections the scale of EW breaking, which is specified by VEV of Higgs field: $<\Phi>=(G_F\sqrt{8})^{-1/2} \approx 175$ GeV. So, accounting quantum corrections to the Higgs mass parameter already at one loop level leads to the need of cutoff of the integration momenta at scale of $\Lambda \leq O$(TeV). Otherwise quantum corrections (QC) considerably destroy stability of this scale. Just $\Lambda \sim O$(TeV) is a scale of "naturalness" of EW interactions. For comparision: QED is a "natural" theory up to $\Lambda \sim M_{planck}$ (t' Hooft). That is why we are waiting for "new physics" which selfregulates contributions from QC, connected with high momenta $P^2 > \Lambda^2$ just near to the border of EW interaction naturalness.

Note: In early 70-th we had somehow like situation concerning rare processes description by effectively nondiagonal FC transitions. Need of compensation mechanism for the loop contribution into $K^0 \Leftrightarrow K^0$(bar) oscillation at Λ~few GeV scale have led to hint of the c-quark existence just with o(GeV) mass and famous GIM mechanism.

- As already have been mentioned, traditionally two major approaches were discussed as a candidates for NEW PHYSICS at TEV scale:Composite models, assuming composed Higgs, matter and gauge fields; In this case Λ is a compositeness scale and SM below it is just an effective manifestation of fundamental preonic matter. Second approach is based on the extension of SM in frames of new FERMI-BOSE symmetry (D.Volkov, Akulov; Golfand,Lichtman)

In this last case new symmetry performs cutoff of large momenta:

$$\Lambda_{effective}^2 \approx g_{BF}|m_F^2 - m_B^2| \leq O(M_W^2) \quad (♣)$$

Providing this way stability of EW breaking scale in the presence of quantum corrections to VEV of the Higgs field.

Analogy : In case of quantum corrections to the scalar mass in the EW theory F-B symmetry plays the same role as Chiral Symmetry does in case of quantum corrections to fermion mass in QED:

SUSY IN THE FORMER CASE AND CHIRAL SYMMETRY IN THE LATTER PROVIDE ABOVE CORRECTIONS TO BE :NATURAL": $\delta m \leq m$

- If it manifests itself, SUSY must be broken symmetry and estimate (♣) means: superpartners should be in the range: $M \leq O(M_W)$. This fact results in: SUSY $SU(3)^C \otimes SU(2)_L \otimes U(1)_Y$ –model could be considered as a NATURAL theory of fundamental fields at scales up to $\Lambda = M_{PL}$
- Gauge Hierarchy Problem:

In connection with question, which is a "true" theory, whose low energy image the SM is, we could mention, that established till nowadays interactions: S,EW,Gravity have a specific scales: Λ_{QCD}~200-300 MeV, Λ_{EW}~10^2 GeV, Λ_{Planck} ~10^{19}GeV.

In addition, maybe nature has separated other scales of interactions: M_{GUT}~ $10^{15\div16}$GeV, $M_{Horizontal}$~ $10^{6\pm1}$GeV etc,etc…

All of them are in a certain hierarchy with each other: $M_1 < M_2 \ldots < M_{planck}$ and are quite removed. In this regard important problem of Gauge Hierarchies (Gildener) arises. Main points of it are:
a) how to describe fundamental interactions at low scales (say, M_W), starting from the theory with the specific (say, M_{planck})scale
b) how to explain co-existence of these distant scales, e.g. which is the way to produce and then keep stable under radiative corrections as low ratios as, $M_W / M_{Planck} \approx 10^{-17}$ or M_W / M_{GUT} are ?

"Traditional" solution to the problem b) is just SUSY approach. For example: in frames of "No-Scale" version of N=1 supergravity (D. Nanopoulos et al) and via mechanism of dimensional transmutation there is a way to connect EW and Planck scales:

$M_W \sim M_{planc} \exp(-1/\alpha_t)$ α_t being t-quark Yukava coupling.

■ Omiting some technical details of SUSY, let us note that in the development of supersymmetry conception stages of rigid ($x \neq x(\theta)$) SUSY and SUGRA ($x = x(\theta)$) could be mentioned. Global (rigid) SUSY with N=1 (N-number of supersimmetries) were considered in the context of N=1 (SIMPLE) SUSY SM , as well as in SUSY GUT context s {SU(5), SO(10)} with the unification scale of $M_X \sim 10^{16}$ GeV. SUSY SM, completed with so called soft breaking terms, solves naturaleness problem. The strong CP-violation problem is automatically solved as well: this means that $\theta_{QCD} = 0$ in case of exact symmetry and $|\theta_{QCD}| < 10^{-9}$ in the softly broken SUSY case.

In General: improved ultraviolet convergence is a common feature for all SUSY models : in case of "naturalization" of m_H it is very transparence thing: one loop correction to m_H contain opposite sign rad. Corrections due to fermion and boson loops :

m_H —— ( ) —— m_H + m_H —— ( ) —— m_H =↑↓ 0 (exact SUSY) / finite (broken case)

- To be short, finally, we have scheme:

L(N=1 SUGRA) → L_{global} [$(SU(3)^C \otimes SU(2)_L \otimes U(1)_Y)$ $\otimes$ N=1 global SUSY] + $L_{soft\ breaking}$ at the scales below the Pl. Scale: $\Lambda < M_{Planck}$

Reduction to the low energies is governed by so called Koeller potential G and kinetic term $f_{\alpha\beta}$. They specify soft breaking mass parameters m_{scalar} and $m_{fermion}$. Thus, the choice of K. potential and kinetic terms of SUGRA determines the pattern of L_{soft} . This choice is dictated by number of conditions (cosmological problem, $\Lambda_C \sim 0$, possibility to solve hierarchy problem etc…)

- Though one of the main goals of SUGRA originally was to achieve "superunification" at Planck scale, as further development demonstrated, this task is possibly reached outside of point-like view on elementary particle structure (superstring, d>4; d=10). NEVERTHELESS, SUGRA gave the possiblity:

A)To organize interaction of YM fields with that of GE

B) To work with SUSY SM (SUSY GUT-s) with SUSY breaking parameters ($m_{scalar,}$ $m_{fermion}$) SUPERGRAVITY IS A LOCAL THEORY OF SUPERSYMMETRY : $[\xi_1 Q, \xi_2$ (bar)Q(bar)]= 2 $\xi_1 \sigma_\mu \xi_2$ (bar) P^μ : in case of local $\xi = \xi(x)$ leads to: product of two supertransformations (ξ,ζ) is equivalent to shift in the space-time, which depends on point, e.g. leads to

GENERAL COORDINATE TRANSFORMATION GROUP!

VII. Large Extra Dimension Approach.

- While people were thinking how to create TOE following to the scheme:

0	10^2	$10^{15\div16}$	$10^{17\div18}$	10^{19}
⇕ – – –	⇕ – – – – – – –	⇕ – – – – – – –	⇕ – – – – – – –	⇕ GeV
	d=4 EW	d=4 GUT (point –like)	compactification	d=10 TOE (string-like)

- Experimental searches for a deviation from Newton's law of universal gravitation has received great deal of attention over past three decades and earlier too in parallel. Motivation come from reports of experimental anomalies and from new theoretical predictions. Searches have involved a great variety of planetary, lunar, geological and laboratory scales. Fishbach and Talmadge's ("Ten years of fifth Force" xxxi Recontres de Moriond,1996) review showed that new forces with a strength weaker than or comparable to gravity have been excluded over distances ranging between $1\div10^{17}$ cm .
- Experiments have only marginally explored the distance range under 1 cm and there is little knowledge of gravity itself in this range (J.C.Price in: Proc. Of the Int. Symposium on exp. Gravit. Physics D.Reidel, Dordrecht, 1987).

Furthermore, sub-cm region is of increasing experimental interest, given a number of recent predictions of new forces from modern theories which attempt to unify gravity with other fundamental forces.
Exp. Results from searches for new long-range forces of gravitational strength has been parametrized several ways and one of these is due gravity +Yukawa between two macroscopic objects:

$$V(r) = -\int dr_1 \int dr_2 G_N [\rho_1(r_1)\,\rho_2(r_2)/r_{12}]\,[1+\alpha \exp(-r_{12}/\lambda)]$$

$\lambda \sim 1$ cm is just the edge of the sensitivity for existing experiments for macroscopic study of gravity [J.C.Long, H.W.Chang and J.C. Price hep-ph/980527].

- Theoretical motivations.

Recently ADD (N.Arcani-Hammed, S.Dimopoulos and G.Dvali: Ph.L. B429 (1998); Ph.R. D59(1998)) proposed a theory in which gravity and gauge interactions are united at the weak scale, which is taken ONLY FUNDAMENTAL SHORT DISTANCE SCALE of the nature. This model does not rely on supersymmetry as a cure for the solution of Hierarchy problem, which, as we diuscussed above, is one of the weak points of SM theoretical status . On the other hand, relative weakness of gravitational interaction in this approach is a consequence of $n \geq 2$ NEW COMPACT DIMENSIONS which are large compared to weak scale. This can be inferred from the relation between Planck scales of (4+n)-dimensional theory $M_{Pl\,(4+n)}{}^2$ and long-distance 4-dimensional theory M_{Pl} (4):

$$M_{Pl}{}^2(4) \sim r_n{}^n M_{Pl\,(4+n)}{}^{n+2} \quad (**)$$

where r_n is size of extra dimension. Putting $M_{Pl\,(4+n)} \sim 1$ TeV, we have:

$$\underline{r_n \approx 10^{(30/n)-17}\ \text{cm}\ (***)}$$

The case n=1 → $r_1 \sim 10^{13}$ cm is too large; n=2 → $r_2 \sim o(1mm)$, which is precisely the distance, where our knowledge of gravity strength stops.

$$F_{(4+n)}(r) = G_{N(4+n)}\, m_1\, m_2 / r^{n+2} \qquad (***)$$

So, for the smallest number of new dimensions yet to be ruled out by experiment (n=2) the size of new dimension is the submm region. Probably the most exciting is that the size of ED can be amazingly large without contradiction to present exp. data.

- Collider probes of new large space dimensions

If indeed gravity becomes strong at ~ TeV energies (ADD predicts just TeV scale unification), gravitons (G) appear as a massive spin 2 neutral particle, which are not observed by detectors.As ADD pointed out, G-radiation leads to missing energy signatures with photon or jet is produced with no observable particles balancing its transverse momentum. So, basic processes are:

$e^+e^- \to \gamma G$(missing energy) and pp(bar) → jet + G(missing energy)

For $e_L^- e_R^+ \to \gamma G$ and with $m=m_G$, s= e^+e^- cm energy:

$d\sigma/d\cos\theta == \pi\alpha G_N/(1-m^2/s)\, [(1+\cos^2\theta)(1+\{m^2/s\}^4) + (\{1-3\cos^2\theta+4\cos^4\theta\}/\{1-\cos^2\theta\})\,(m^2/s)\,(1+\{m^2/s\}^2) + 6\cos^2\theta\,(m^2/s)^2]$ (1)

The same formula holds for e_R-e_L+ $\rightarrow\gamma$G. Helicity violation cross sections are thero. These expressions must be integrated over the phase space, cross section behaves as

$\sigma \sim s^{n/2}/M^{n+2}$ (2) where $M^{n+2} R^n = (4\pi G_N)^{-1}$,
thus, the production of anomalous single photons increase dramatically as the cm energy is raised. In SM single photon events are produced in the reaction $e^+e^- \rightarrow \gamma\, \nu\nu$ (bar) through

s-channel Z^0-exchange or (in case of electron neutrino) through t-channel W-exchange. The effect of G emission would be observable as an enhancement of the cross section for single γ production above that of this SM source. At the LEP 2 single γ-production has been measured at $\sqrt{S}$=183 GeV. If we integrate prediction for G-signal over the kinematic region studied in these experiments, for the case of n=2 one can find: R<0.48 mm, M>1200 GeV at 95%confidence level (Mirabelli, Perelstein, Peshkin,1998)

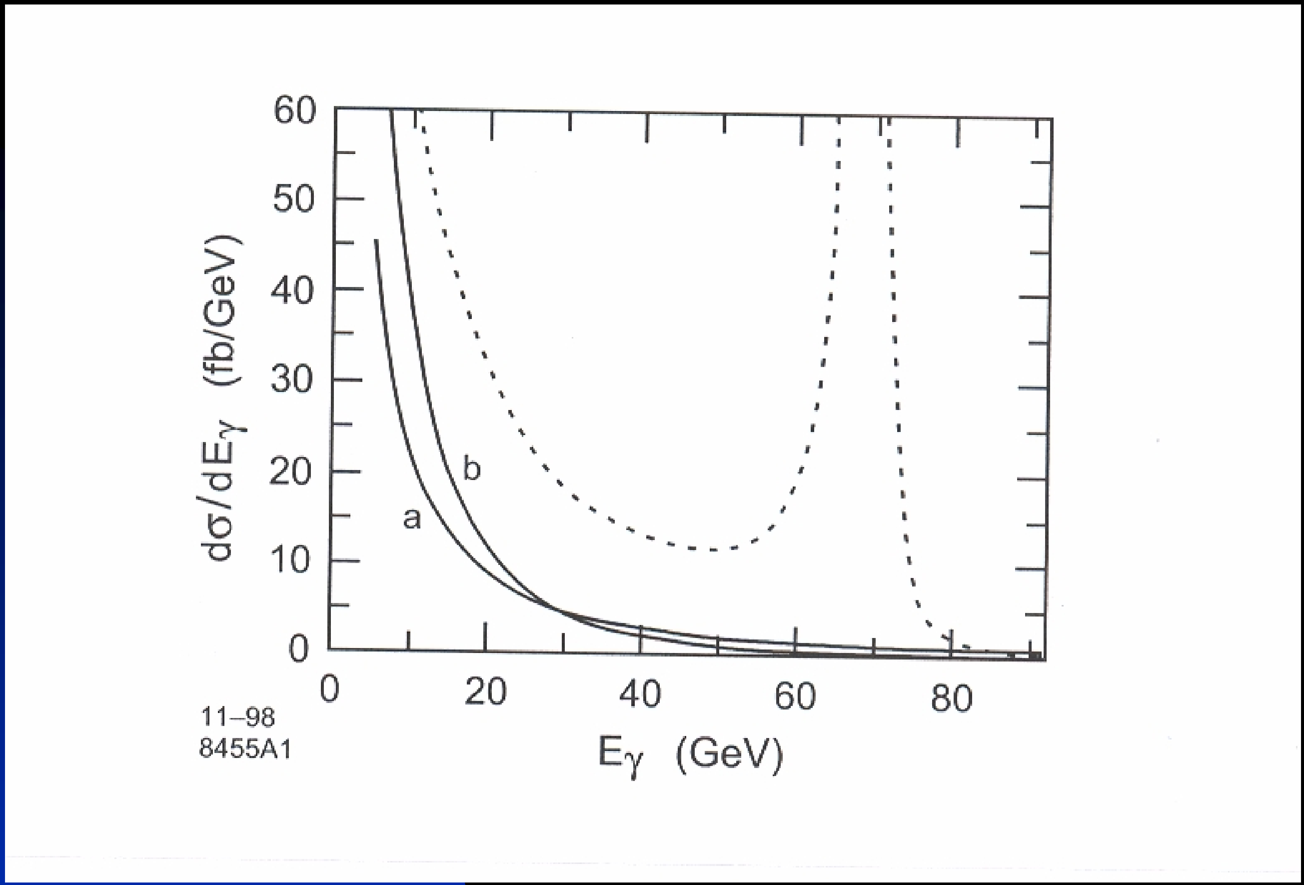

Figure 1:Energy spectrum of single photons recoiling against higher dimensional gravitons G, computed for e+e – collisions at √S=183 GeV with angular cut |cosθ |<0.95. The dotted curve is SM expectation. The solid curves show additional cross section expected in ADD with (a) n=2, M=1200 GeV, (b) n=6, M=520 GeV.

In Fig.1 the peak of SM cross section results from the process in which γ recoils against on shell Z^0 which decays invisibly. Some additional advantages can be gained, in applying a cut which excludes this peak. For the kinematic region $20<E_\gamma<50$ GeV, $|\cos\theta_\gamma|<0.95$ and $\sqrt{S}=183$ GeV, we find the cross section for G production

$$\sigma = 267/M^4,\ 19/M^6,\ 0.65/M^8\ (\text{fb}). \qquad (3)$$

for n=2 n=4 n=6 and M in TeV

Higher energy study of e+e –annihilation will be done at LC. Higher energy alone should lead to much higher sensitivity to G production. But the LC also offers another advantage, the possibility of electron beam polarization, which can be used to suppress dominant t-channel W-exchange peace of the SM background process. At $\sqrt{S}=1$ TeV with electron polarization P=+0.9 (right handed), integrating over the kinematic region $20<E_\gamma<50$ GeV, $|\cos\theta_\gamma|<0.95$ we find a SM background cross section of 82 fb and G signal cross section

of $$\sigma = 20/M^4,\ 46/M^6,\ 55/M^8\ (\text{pb}),$$
for n=2 n=4 n=6 and M in TeV (4)

To quantify the effect of this measurement , it is assumed that this cross section can be measured with 5% accuracy , and that the value to be found agrees with the SM.

Then the measurement would give very strong limits on R and M, which are listed in Table 1.

Collider		R/M (n=2)	R/M (n=4)	R/M (n=6)
PRESENT:	LEP2	4.8×10^{-2}/1.2	4.9×10^{-9}/.73	6.9×10^{-12}/.52
	TEVATRON	11×10^{-2}/.75	2.4×10^{-9}/.61	5.8×10^{-12}/.61
FUTURE:	TEVATRON	3.9×10^{-2}/1.3	1.4×10^{-9}/.9	4.0×10^{-12}/.81
	LC	1.2×10^{-3}/7.7	1.2×10^{-10}/4.5	6.5×10^{-13}/3.1
	LHC	3.4×10^{-3}/4.5	1.9×10^{-10}/3.4	6.1×10^{-13}/3.3

Table1. Current and future sensitivities to large extra dimensions, expressed as 95% confidence limits on the size of extra dimensions R(in cm) and the effective Planck scale M (in TeV).

Proton-antiproton collisions.

In the similar way, pp(bar) collisions can lead to processes in which a single parton is produced at large transverse momentum recoiling against G. This leads to a monojet signature of G production

pp(bar)⇒jet +(missing transverse energy (E_T)

which maybe visible at Tevatron.

Contributing subprocesses are: qq(bar)→Gg, qg →qG, q(bar)g→q(bar)G, and gg →Gg. Polarization- and color averaged cross section for qq(bar)→Gg:

$d\sigma/d\cos\theta == (2/9)\pi\alpha_S G_N/(1-m^2/s)\ [\ (2-4ut/(s-m^2)^2)\ (1+\{m^2/s\}^4) +$

$+(2(t-m^2)^2/\ 4us - 5 + 4\ 4ut\ /\ (s-m^2)^2)\ (m^2/s)\ (1+\{m^2/s\}^2) + 6\ ((u-t)/(s-m^2)^2\ ]$ (5)

where s,t,u are Mandelstam variables: $t,u = -0.5s(1-m^2/s)(1 \mp \cos\theta)$

the cross section for qg →qG can be obtained by crossing s⇔t.

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All these formulae must be integrated over G mass spectrum using the measure:

$\Sigma_{K(T)} = R^n \int d^n m = (\Omega_n)\ M^{-(n+2)} \int (m^2)^{(n-2)/2}\ dm^2\ G_N^{-1}$

The processes q q(bar) $\rightarrow gZ^0$, q g $\rightarrow qZ^0$, followed by an invisible decay of Z^0, give an irreducible physics background to G production. There are other important background sources from mismeasured jets and W production with forwarded leptons, but these backgrounds decrease sharply as the lower bound on missing E_T is increased. Unlike the case of e^+e^- reactions, the detector does not measure the imbalance in longitudinal momentum, and there is not enough kinematic information from the single observed jet to exclude the kinematic region in which the Z^0 is on –shell. On the other hand, the parton cm of energies available at Tevatron are higher than those of LEP2, and we have seen that G-signal increases rapidly with energy. It is therefore reasonable to look for monojet signal as an excess above SM cross section for on shell Z^0 production. Though it is not easy to compute SM background rate accurately, this rate can be normalized to the corresponding process in which Z^0 decays to a lepton pair.

The CDF collaboration has presented a bound on monojet production based on 4.7 pb^{-1} of data in pp(bar) collisions at $\sqrt{s}$=1.8 TeV. The analysis searched for events with missing E_T greater than 30 GeV and one jet in the rapidity region |y|<1.2. Mirabelli et al converted this to limit on G production by comparing the cross sections for the G signal and SM process, computed in the same framework.Results are in Table 1.

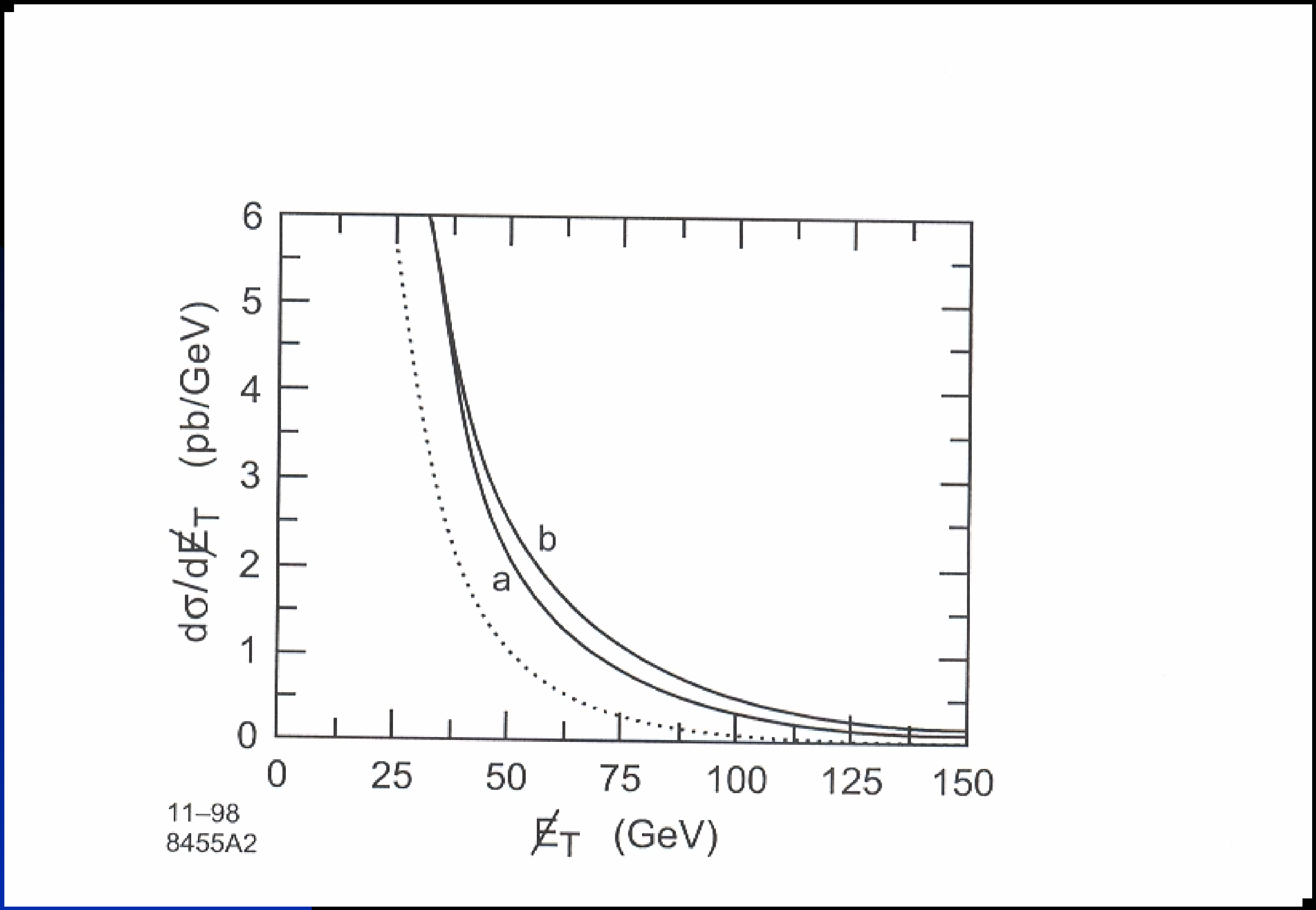

Fig.2 Spectrum of missing energy in events with one jet, computed for pp(bar) collisions at √S=1.8 TeV with a rapidity cut |y|<2.4. The dotted curve is SM expectation. The solid curves show the additional cross section expected in ADD model with (a) n=6, M=750 GeV, (b) n=6, M=610 GeV

The CDF collaboration has presented a bound on monojet production based on 4.7 pb^{-1} of data in pp(bar) collisions at $\sqrt{s}=1.8$ TeV. The analysis searched for events with missing E_T greater than 30 GeV and one jet in the rapidity region |y|<1.2. Mirabelli et al converted this to limit on G production by comparing the cross sections for the G signal and SM process, computed in the same framework. This implies the limit:

for n=2 R<1.2 mm M>750 GeV. Limits for higher values of n→Table 1. It is advantageous to make tight cut on missing E_T to remove the backgrounds from mismeasured jets which are problem for CDF analysis. Integrating the signal and background rates over the region with missing E_T >60 GeV and jet rapidity |y|<2.4, one can find SM background cross section for Z production of 10 pb, and signal cross sections in the ratios

	$S/B=0.85/M^4$,	$0.15/M^6$,	$0.15/M^8$	
for M in TeV and	n= 2	n=4	n=8	(♠♠)

Hadron-hadron collisions at higher energies will be studied at LHC. Repeating analysis leading to (♠♠) at the LHC energy of 14 TeV using kinematic cuts

E_T >60 GeV, |y|<2.4 , one can find SM background cross section of 11pb and signal cross sections in the ratios:

	$S/B=110/M^4$	$S/B= 420/M^6$	$S/B=3600/M^8$
for M in TeV and	n=2	n=4	n=6

Mini conclusion:

High Energy collider searches for events with missing energies and transverse momentum provide relevant model-independent test of theories with Large Extra Dimensions. Current e^+e^- p p(bar) already placed the strong direct constraints on these theories. Higher energy experiments may place much stronger constraints.

More optimistic view of point is: they may allow us to observe an excess of missing energy events above SM expectations, providing direct evidence for this remarkable extent of new conception of the universe.

SEARCH IN RARE PROCESSES.

With the above interest to the models with extra dimension another strategy also work. This is the strategy to search for contributions into loop processes, which are suppressed in SM itself. By occasional reasons we review some of processes in the framework of so called models with universal extra dimensions (UED) which differ from ADD by allowing to all SM fields to propagate into all available dimensions . Above the compactification scale 1/R a given UED model becomes higher dimensional field theory whose equivalent description in 4 dimensions consists of SM fields, the towers of their KK partners and additional towers of their KK-modes that do not correspond to any field in the SM. Simplest model of this type is the ACD model of T. Appelquist, H-C Cheng and B.A.Dobrescu (phys.Rev. D64 (2001) Hep-ph/00121000). It is a model with one extra dimension. Only free parameter relative to SM is a compactification scale 1/R . Thus all the masses of KK particles and their interactions among themselves are described in terms of 1/R and SM parameters.

Very important feature of ACD model is the conservation of so called KK parity, which implies to the absence of tree level KK contributions to the low energy processes taking place at $\mu \ll 1/R$. In this contest FCNC processes like particle-antiparticle mixing and rare K and B decays are of special interest because as a TRUE and HEALTHY FCNC processes, they arise first time as a LOOP processes in the SM and hence, are suppressed. SO, LOOP CONTRIBUTIONS FROM KK MODES WOULD BE , IN PRINCIPLE, IMPORTANT.

The effects of KK modes in various processes of interest have been investigated in a number of papers. So, ACD themselves showed their impact on the precision EW observable s assuming light Higgs ($M_H \leqq 250$ GeV) led to the lower bound $(1/R) \geq 300$ GeV. Analysis of $B \rightarrow X_s \gamma$ {K.Agashe,Deshpande,Wu Phys.LettB514(2001),309} and anomalous magnetic moment (Agashe et al Phys.Lett.-2001;Appelquist and Dobrescu Phys.Lett.-2001) have shown the consistency of ACDwith data for $(1/R) \geq 300$ GeV.

Very recently Appelquist and Yee (hep-ph/0211023) has their analysis of ACD by considering heavy Higgs ($M_H \geq 250$) . It turns out that in this case the lower bound on (1/R) can be decreased to 250 GeV, implying larger KK cotributions to various low energy processes in particular to FCNC processes. Further part of the report will follow to Buras, Springer and Weiler: TUM-HEP-496/02, MPI-phT/2002/-80; hep-ph/0212143

CONCLUSIONS:

- Progress in fundamental physics is dependent on the identification of underlying symmetries such as general coordinate invariance or gauge invariance. Usually people were looking for possible symmetries beyond those of Standard Model. The latter is based on on Cartan-Lie Algebras and their direct products, and is very successful. There have been valiant efforts to extend the SM within the framework of CL algebras and with the objective of, for example, reducing the number of free parameters appearing in the theory.However, attempts to formulate GUTs in which the direct product of the symmetries of SM is embedded into some larger simple Cartan-Lie group have not had the same degree of success as SM.

- Possibility of unifying the gauge interactions with gravity in some "Theory of Everything" based on string theory is enticing, in particular because this offers novel algebraic structures.

- Large extra dimension approach established only fundamental short distance scale in the region of O(TeV) explaining weakness of gravity through the "brane" approach.

It is very interesting what the answers give or new questions ask new experiments on the effective or direct ~TEV scale.