Reduction in the Number of Coupling Parameters and Yukawa Mission

Jisuke Kubo

Kanazawa University

PLAN

1ster Teil

2nd Part

Intermission

3rd Part

Letzter Teil

Erster Teil

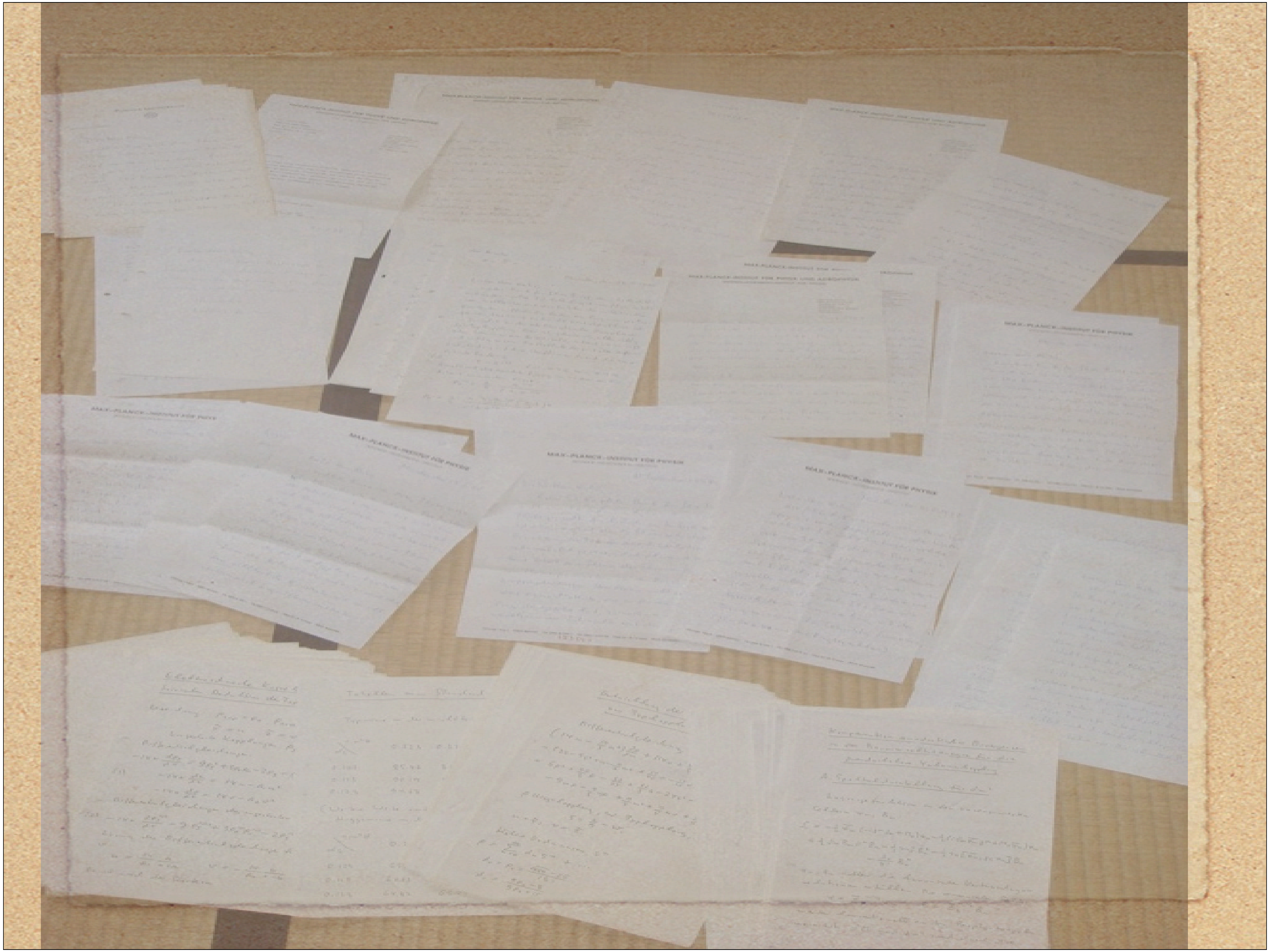
Purdue University

Department of Physics

4. 12. 1986

Lieber Herr Kulb,

endlich komme ich dazu, Ihnen zu schreiben. Falls Sie inzwischen keinen Be-
scheid von Herrn Dorr [illegible] haben, kann ich
dies gleich nachholen [illegible]
haben. Die Bestellung hatten wir [illegible]
vor meiner Abreise nach den USA [illegible]
geplant. Es handelt sich um [illegible]
[illegible] Ihnen einen [illegible] alle [illegible]
schicken und um die Verteilung [illegible]



[illegible] bedingungen. Für die [illegible]
[illegible] [illegible] [illegible] nur, dass es eine
ohne Grenze geben muss für die W[illegible]
der 3. Familie, die [illegible] der [illegible]

2nd Part

Reduction of Couplings
and
Non-renormalizable Theories

MPI-PAE/PTh 49/84
July 1984

REDUCTION IN THE NUMBER OF COUPLING PARAMETERS*)

W. Zimmermann

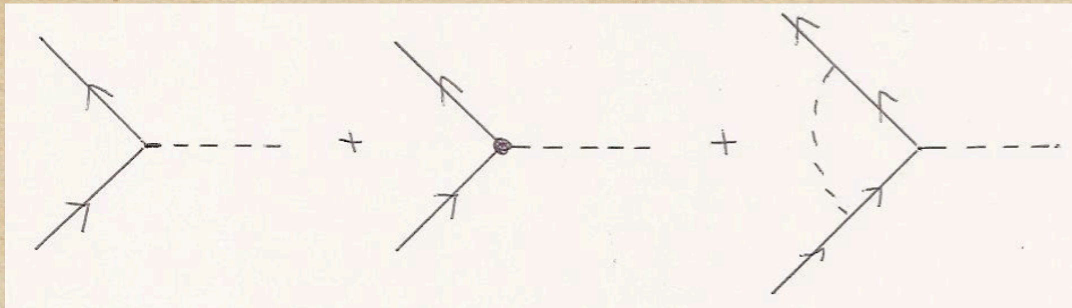
Max Planck-Institut für Physik und Astrophysik,
- Werner Heisenberg-Institut für Physik -
D-8000 Munich 40, West Germany

In this paper a more general approach for reducing the number of coupling parameters is taken which is based on the principles of renormalizability and invariance under the renormalization group. It

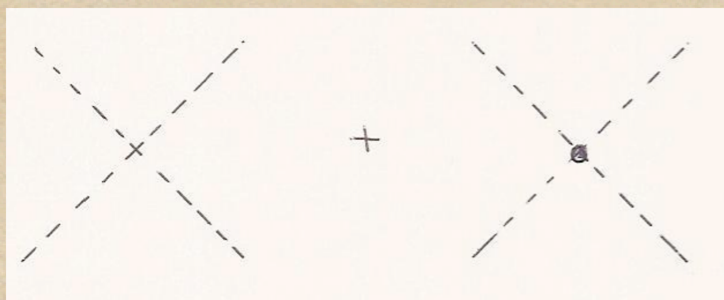
4. MODEL OF A SPINOR AND PSEUDOSCALAR FIELD

$$i g \bar{\Psi} \gamma_5 A \psi - \frac{\lambda}{4!} A^4$$

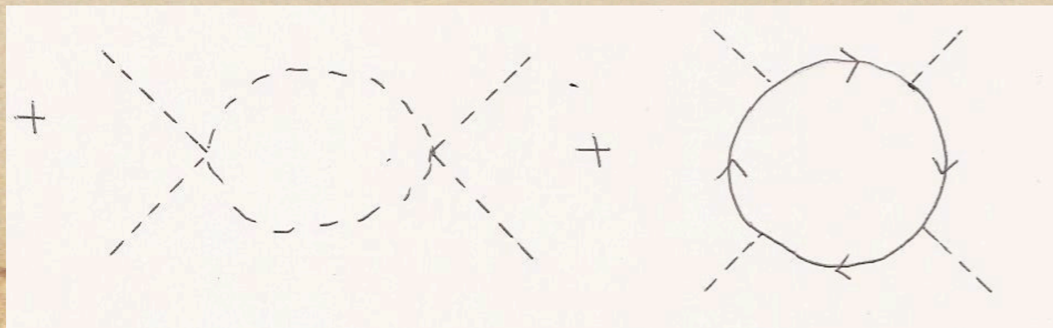
The basic idea:



$$ig\left[\ 1+\frac{1}{16\pi^2}\frac{5}{4}g^2\frac{1}{\epsilon}+\cdots\ \right]\ Z_\psi^2 Z_A\overline{\Psi}\gamma_5 A\Psi$$



$$-\frac{\lambda}{4!}\left[\ 1+\frac{1}{16\pi^2}(\frac{3}{4}\lambda+2g^2-12\frac{g^4}{\lambda})\frac{1}{\epsilon}+\cdots\ \right]\ Z_\psi^2 Z_A\overline{\Psi}\gamma_5 A\Psi$$



The basic idea:

$$ig\left[1+\frac{1}{16\pi^2}\frac{5}{4}g^2\frac{1}{\epsilon}+\cdots\right]Z_\psi^2 Z_A\overline{\Psi}\gamma_5 A\Psi$$

$$g^2\left[1+\frac{1}{16\pi^2}\frac{5}{2}g^2\frac{1}{\epsilon}+\cdots\right]$$

Renormalization of g^2 → λ

$$-\frac{\lambda}{4!}\left[1+\frac{1}{16\pi^2}(\frac{3}{4}\lambda+2g^2-12\frac{g^4}{\lambda})\frac{1}{\epsilon}+\cdots\right]Z_\psi^2 Z_A\overline{\Psi}\gamma_5 A\Psi$$

$$\left[1+\frac{1}{16\pi^2}\frac{5}{2}g^2\frac{1}{\epsilon}+\cdots\right]$$

for

$$\lambda=\frac{1\pm\sqrt{145}}{3}g^2+\cdots$$

How ...... look like?

Use of the RG technique

The power series ansatz:

$$\lambda = \rho_0 g^2 + \sum_{j=1}^{\infty} \rho_j g^{2j+2}$$

⇨ Reduction equation

$$\beta_0 \frac{d\lambda}{dg^2} = \beta_1$$

$$\beta_0 = b_0 g^4 + \dots$$

$$\beta_1 = c_1 \lambda^2 + c_2 \lambda g^2 + c_3 g^4 + \sum_{n=3}^{\infty} \sum_{m=0}^{n} c_{n-m,m} \, g^{2(n-m)} \lambda^m$$

Reduction equation

$$\beta_0 \frac{d\lambda}{dg^2} = \beta_1$$

$$\lambda = \rho_0 g^2 + \sum_{j=1}^{\infty} \rho_j g^{2j+2}$$

At the lowest order:

$$c_1 \rho_0^2 + (c_2 - b_0)\rho_0 + c_3 = 0$$

$$\rho_+ = \frac{1}{3} + \frac{1}{3}\sqrt{145} > 0$$

$$\rho_- = \frac{1}{3} - \frac{1}{3}\sqrt{145} < 0$$

At the j th order:

$$b_0[\, j \pm \xi \,]\rho_j = \text{known for } \pm \text{solution}$$

$$\xi = -\frac{c_1}{b_0}(\rho_+ - \rho_-), \qquad (b_0 \neq 0)$$

$$\xi = -\frac{1}{5}\sqrt{145} < 0$$

Classification of the solutions

$$b_0[\ j \pm \xi\ ]\rho_j = b_0[\ j \mp \sqrt{145}/5\ ]\rho_j = \text{known for } \pm \text{solution}$$

The power series is unique.

However, for ρ_+ a stable deformation from the power series is allowed:

$$d_{11} g^{2-2\xi} = d_{11} g^{2+2\sqrt{145}/5}$$

$$\lim_{\lambda_0 \to 0} \lambda_j = 0$$

$$\lambda = \frac{1}{3}(1+\sqrt{145})g^2 + \rho_{+1}g^4 + \rho_{+2}g^6$$
$$+ d_{11}g^{\frac{2}{5}\sqrt{145}+2} + \rho_{+3}g^8 + d_{12}g^{\frac{3}{5}\sqrt{145}+4}$$
$$+ \rho_{+4}g^{10} + d_{21}g^{\frac{4}{5}\sqrt{145}+2} + \cdots$$

$$b_0[\ j \pm \xi\ ]\rho_j = b_0[\ j \mp \sqrt{145}/5\ ]\rho_j = \text{known for } \pm \text{solution}$$

What would happen if ξ is an negative (positive) integer.

1. Logarithmic terms have to be added.

$$\lambda_+ = p_+ g^2 + \sum_{j=1}^{|\xi|-1} p_{+j} g^{2j+2} + p_{+|\xi|} g^{2\xi+2}$$
$$+ d\, g^{2|\xi|+2} \ell_g\, g^2 + \cdots$$

2. No logarithmic term is needed if d=0: indication of a symmetry.

Many important filed theory applications

Determination Of Correct Beta Functions For Sym Theories Using A Supersymmetry Violating Renormalization Scheme.
D. Maison (Munich, Max Planck Inst.)
Phys.Lett.B150:139,1985.

Necessary And Sufficient Conditions For All Order Vanishing Beta Functions In Supersymmetric Yang-Mills Theories.
C. Lucchesi, O. Piguet (Geneva U.) , K. Sibold (Munich, Max Planck Inst.) .
Phys.Lett.B201:241,1988.

....

Application
to
Non-renormalizable Theories

Infinite Reduction of Couplings

by D. Anselmi

Renormalization of a class of non-renormalizable theories.
Damiano Anselmi (**Pisa U.** & **INFN, Pisa**) ,

Infinite reduction of couplings in non-renormalizable quantum field theory.
Damiano Anselmi (**Pisa U.** & **INFN, Pisa**) ,

JHEP 0508:029,2005.

Dimensionally continued infinite reduction of couplings.
Damiano Anselmi, **Milenko Halat** (**Pisa U.** & **INFN, Pisa**),
in JHEP 0601:077,2006.

The basic idea:

$$\mathcal{L}_{\rm cl}[\varphi] = \mathcal{L}_{\mathcal{R}}[\varphi, \alpha] + \sum_n \lambda_n \mathcal{O}_n(\varphi)$$

(massless)

Renormalizable sector

Irrelevant deformations (non-renormalizable terms)

$$\text{dim.}[\alpha] = 0$$

$$\text{dim.}[\lambda_n] = -n \quad (n > 0)$$

Compute beta functions in D-4.

Dimensional analyses (masses=0)

$$\beta_\alpha = \alpha^2 \beta_\alpha^{(1)} + \mathcal{O}(\alpha^3).$$

$$\beta_{\lambda_n}(\alpha, \lambda) = \gamma_n(\alpha)\,\lambda_n + \delta_n(\lambda_{m<n}, \alpha)$$

$$\text{dim.}[\beta_\alpha] = 0\ ,\ \ \text{dim.}[\beta_{\lambda_n}] = -n \quad (n > 0)$$

$$\delta_n \sim \lambda_{n_1}\lambda_{n_2}\cdots\lambda_{n_2} \quad \text{with} \quad n_1 + n_2 + \cdots = n$$

at least quadratic.

Ansatz for the infinite reduction:

$$\lambda_{n\ell} = \lambda_{n\ell}(\lambda_\ell, \alpha) = f_n(\alpha)\lambda_\ell^n, \qquad n > 1,$$

l =the smallest n

The independent couplings:

λ_l and α

$$\mathcal{L}_{\rm cl}[\varphi] = \mathcal{L}_{\mathcal{R}}[\varphi, \alpha] + \lambda_\ell \mathcal{O}_\ell(\varphi) + \sum_{n=2}^{\infty} f_n(\alpha)\lambda_\ell^n \mathcal{O}_{n\ell}(\varphi)$$

Ansatz for the infinite reduction:

$$\lambda_{n\ell} = \lambda_{n\ell}(\lambda_\ell, \alpha) = f_n(\alpha)\lambda_\ell^n, \qquad n > 1,$$

Reduction equation:

$$\beta_{\lambda_n}(\alpha, \lambda_l) = \frac{\partial \lambda_n}{\partial \lambda_l}\beta_{\lambda_l} + \frac{\partial \lambda_n}{\partial \alpha}\beta_\alpha$$

$$\left[\beta_\alpha \frac{\mathrm{d}}{\mathrm{d}\alpha} - \gamma_{n\ell}(\alpha) + n\gamma_\ell(\alpha)\right] f_n(\alpha) = \delta_n(f, \alpha)$$

$$\beta_{n\ell} = \lambda_\ell^n \left[f_n(\alpha)\gamma_{n\ell}(\alpha) + \delta_n(f, \alpha)\right]$$

↑

$$\beta_{\lambda_n}(\alpha, \lambda) = \gamma_n(\alpha)\,\lambda_n + \delta_n(\lambda_{m<n}, \alpha)$$

$$\lambda_{n\ell} = f_n(\alpha)\lambda_\ell^n = \frac{\lambda_\ell^n}{\alpha^{n-1}} \sum_{k=0}^{\infty} d_{n,k}\alpha^k$$

Meromorphic expansion!!

Unique if

$$r_{n,\ell} \equiv \frac{1}{\beta_\alpha^{(1)}} \left(\gamma_{n\ell}^{(1)} - n\gamma_\ell^{(1)}\right) + n - 1 \notin \mathbb{N}, \qquad n > 1$$

(ξ condition)

$$\xi = -\frac{c_1}{b_0}(\rho_+ - \rho_-), \qquad (b_0 \neq 0)$$

General solution:

$$\frac{1}{\alpha^{n-1}} \sum_{k=0}^{\infty} d_{n,k} \alpha^k + \xi_n \overline{s}_n(\alpha) \qquad \overline{s}_n(\alpha) \sim \alpha^{Q_n}, \qquad Q_n = \frac{\gamma_{n\ell}^{(1)} - n\gamma_\ell^{(1)}}{\beta_\alpha^{(1)}}$$

i) if Q_n not an integer, the solution is not meromorphic. $\xi_n = 0$ ▶ unique meromorphic sol.

ii) if Q_n an integer $\geq -n+1$, the logarithmic terms have to be added at that order, and ξ_n is arbitrary.

iii) if Q_n is an integer $< -n+1$, the solution is meromorphic, but ξ_n-ambiguity.

Examples:

i) $$\mathcal{L} = \frac{1}{4}(F^a_{\mu\nu})^2 + \overline{\Psi}\not{D}\Psi + \lambda_1 F^a_{\mu\nu}\overline{\Psi}T^a\sigma_{\mu\nu}\Psi + \frac{\lambda_2}{3!}f^{abc}F^a_{\mu\nu}F^b_{\nu\rho}F^c_{\rho\mu} + \cdots$$

$$Q_2 = \frac{\gamma_2^{(1)} - 2\gamma_1^{(1)}}{\beta_\alpha^{(1)}} = -\frac{15}{\Delta} \notin \mathbb{N}$$

ii) $$\mathcal{L} = \frac{1}{2}\partial_\mu\phi\partial_\mu\phi + \alpha\phi^4 + \lambda_2\phi^6 + \sum_{n=2,3,4..}\lambda_{2n}\phi^{2n+4}$$

$$Q_{2n} = \frac{2}{3}(3 - 4n + n^2)$$

=0, 2, 10,... at n=3, 4, 6,...

What about gravity in D=4?

$$\mathcal{L} = \sqrt{-g}\left(\frac{1}{2}g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi + \frac{\lambda_0}{4!}\phi^2 + \cdots + \kappa_2 R\phi^2 + \cdots \right.$$
$$\left. + \frac{1}{\lambda_1^2}\left[\, R + \lambda_{2,1}R^2 + \lambda_{2,2}R^{\mu\nu}R_{\mu\nu} + \lambda_{2,3}\epsilon^{\alpha\beta\gamma\delta}\epsilon_{\mu\nu\rho\sigma}R^{\mu\nu}{}_{\alpha\beta}R^{\rho\sigma}{}_{\gamma\delta} + \cdots \,\right]\right)$$

$$\beta_{\lambda_n}(\alpha,\lambda) = \gamma_n(\alpha)\,\lambda_n + \delta_n(\lambda_{m<n},\alpha)$$

$$\mu \frac{d\lambda_1}{d\mu} = 0 \ , \ \ \mu \frac{d\lambda_{2,i}}{d\mu} = 0 + \delta_{11,i}(\lambda_1)^2$$

$$\mu \frac{d\lambda_{4,i}}{d\mu} = 0 + \delta_{1111,i}(\lambda_1)^4 + \delta_{112,i}(\lambda_1)^2 \lambda_2 + \delta_{2,i}(\lambda_2)^2$$

It is possible to add an arbitrary constant to each λ .

(see also Atance and Cortes, 96)

No principle to fix them!!

So far no progress has been made.

Intermission

Natto

3rd Part

Yukawa mission

http://www.jahep.org/hec/doc/jahep_tenbou_eng_final.pdf

Prospects for Elementary Particle Physics

Th EP)

(An excerp

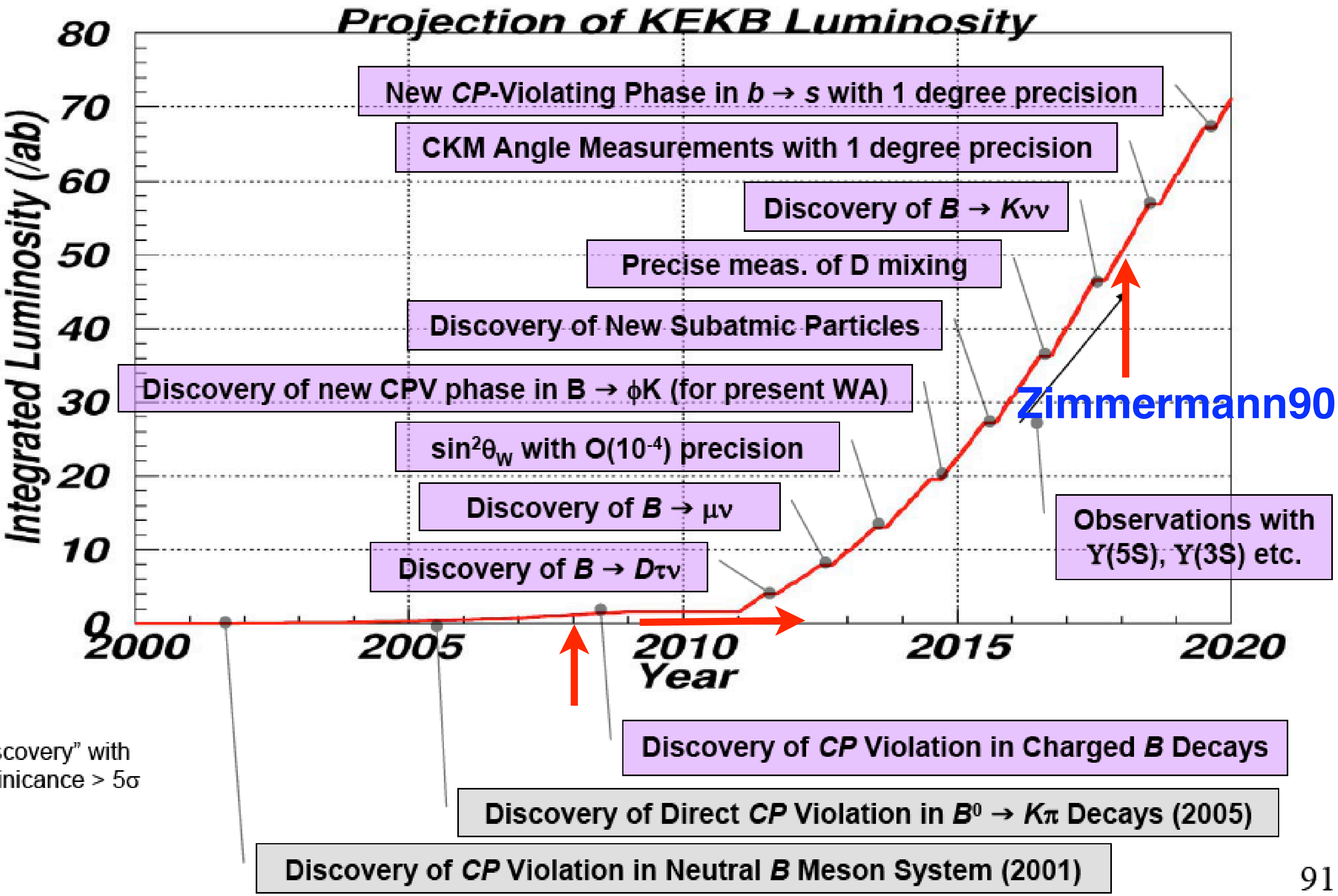
We, the Jap frontier is of pri-
mary impor to the realization
of the ILC. I lavor physics that
is compleme e above two goals
as a single r

....

Based on these achievements, we will endeavor to make neutrino and kaon experiments at J-PARC successful, and promote an upgrade of the B factory to achieve a significant breakthrough in luminosity in order to explore new physics that emerges in the phenomena of b, c and τ decays.

from Hazumi, Belle at KEK

Major Achievements Expected at SuperKEKB: An Image



"Discovery" with sigfinicance > 5σ

Yukawa mission

To explore the Yukawa sector of
the Standard Model
experimentally as well as theoretically.

MPI-PAE/PTh 19/85

Higgs and Top Mass from Reduction of Couplings

J. Kubo*

K. Sibold**

W. Zimmermann

Max-Planck-Institut für Physik und Astrophysik

- Werner-Heisenberg-Institut für Physik -

Föhringer Ring 6, 8000 München 40

Federal Republic of Germany

PURD-TH-86-22

Quark Family Mixing and Reduction of Couplings

Klaus Sibold

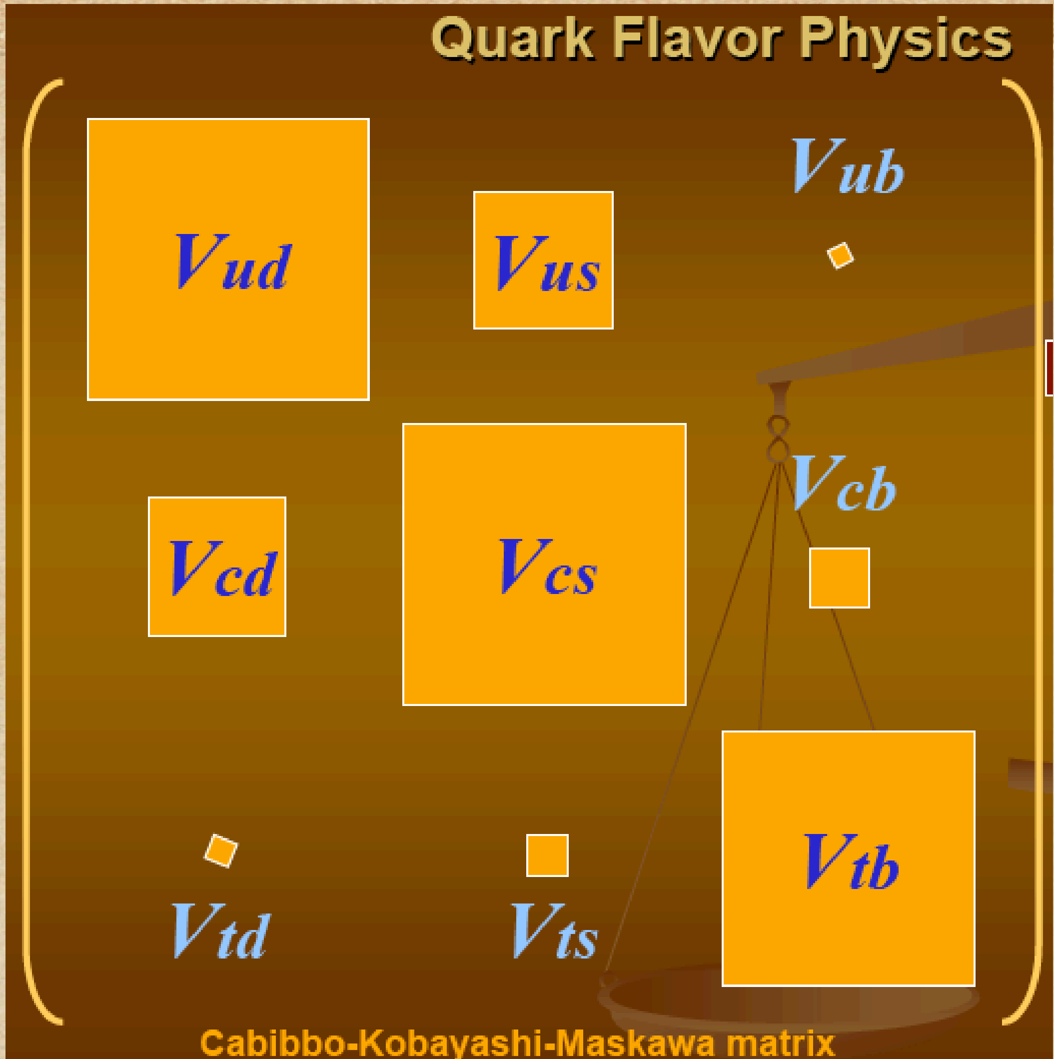
Max-Planck-Institut für Physik und Astrophysik
Werner-Heisenberg-Institut für Physik
Munich, West Germany

Wolfhart Zimmermann*

Physics Department
Purdue University
West Lafayette, IN 47907 U.S.A.

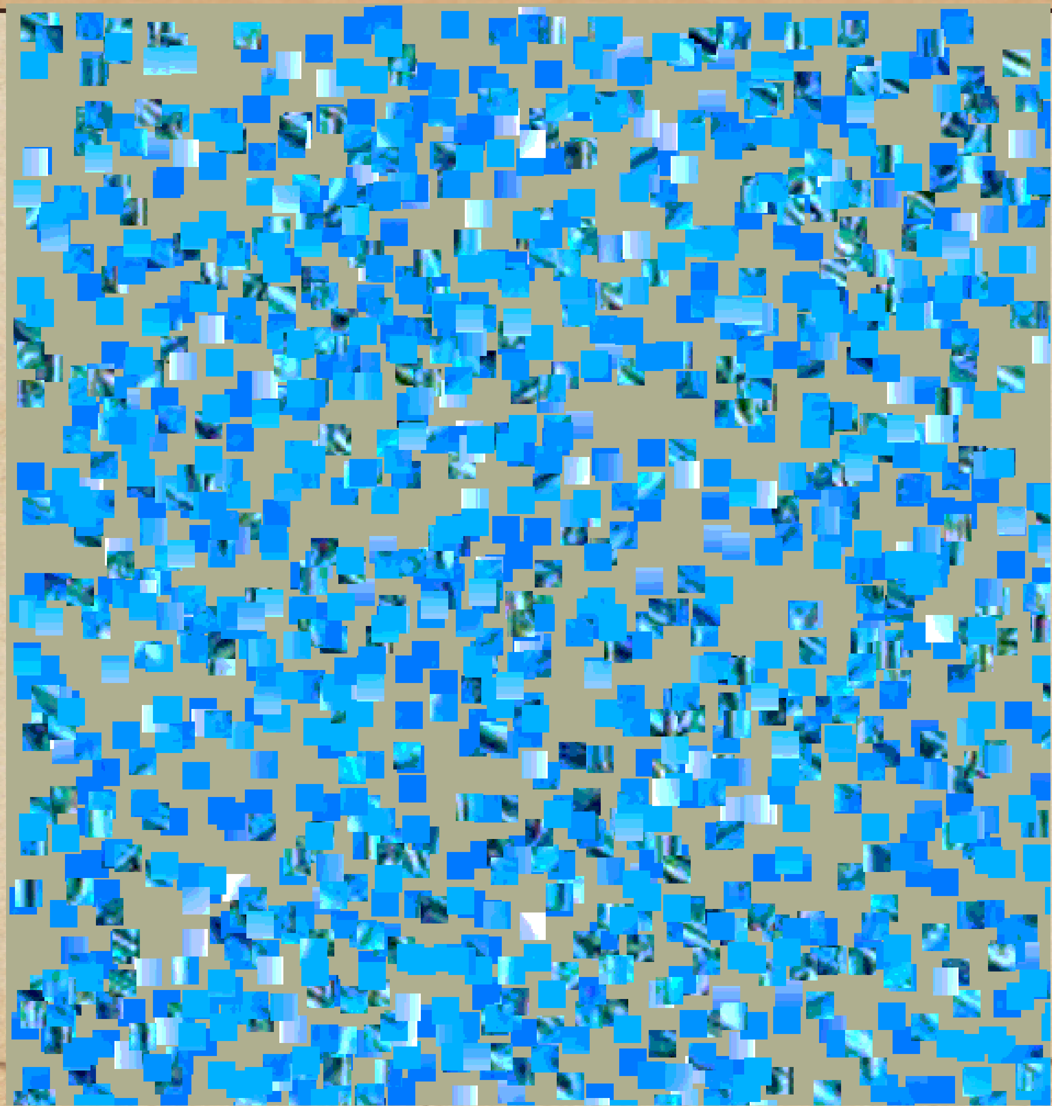
Am Anfang war die Symmetrie.

Heisenberg may be right even at the electroweak scale.



Is there any symmetry behind?

At first sight it looks chaotic, but ...



Flake Symmetry

(Flavor Symmetry)

兼六園 Kanazawa

金沢城

In the case of CKM

this could happen

if you increase the energy scale,

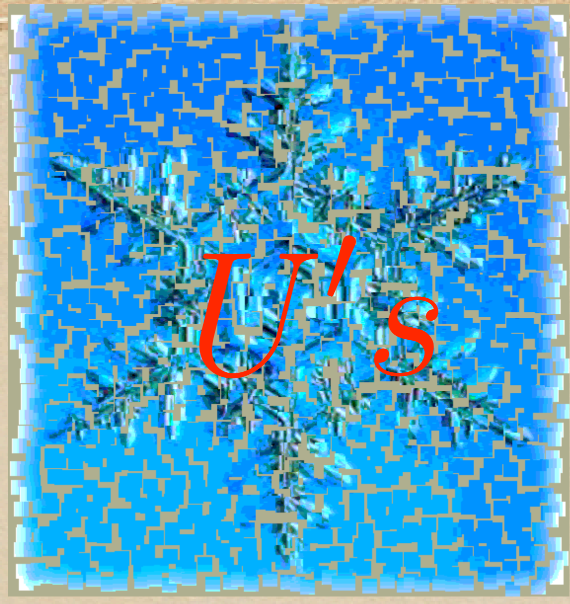
(symmetry restortion)

OR

if you rearrange the quarks,

OR

$U_L^\dagger \mathbf{m} U_R$



$$V_{\rm CKM} = U_{uL}^\dagger U_{dL}$$

However, there is no viable symmetry

in **m**

Y. Koide:

Phys. Rev. D71, (2005) 016010
[arXiv:hep-ph/0406286].

This NO-GO theorem does not apply to multiple Higgs models.

↓

<u>Extension of the Higgs sector</u>

to restore a Flavor symmetry

↓

Higgs Family

In particular flavor symmetries based on a finite (discrete) group:

The symmetry group of

is D6 , one of the finite groups.

Finite groups

The classification of the finite groups has been completed 1981 (Gorenstein);
about <u>100 years</u> later than the case of the continues group.

Recent models

(Table from Frampton and Kephart, '01)

g	
6	$D_3 \equiv S_3$
8	$D_4, Q = Q_4$
10	D_5
12	D_6, Q_6, A_4
14	D_7
16	$D_8, Q_8, Z_2 \times D_4, Z_2 \times Q$
18	$D_9, Z_3 \times D_3$
20	D_{10}, Q_{10}
22	D_{11}
24	$D_{12}, Q_{12}, Z_2 \times D_6, Z_2 \times Q_6, Z_2 \times T,$
	$Z_3 \times D_4, Z_3 \times Q, Z_4 \times D_3, S_4$
26	D_{13}
28	D_{14}, Q_{14}
30	$D_{15}, D_5 \times Z_3, D_3 \times Z_5$

g	
16	$Z_2 \tilde{\times} Z_8$ (two, excluding D_8), $Z_4 \tilde{\times} Z_4, Z_2 \tilde{\times} (Z_2 \times Z_4)$ (two)
18	$Z_2 \tilde{\times} (Z_3 \times Z_3)$
20	$Z_4 \tilde{\times} Z_5$
21	$Z_3 \tilde{\times} Z_7$
24	$Z_3 \tilde{\times} Q, Z_3 \tilde{\times} Z_8, Z_3 \tilde{\times} D_4$
27	$Z_9 \tilde{\times} Z_3, Z_3 \tilde{\times} (Z_3 \times Z_3)$

T', $\Delta 27$, $\Delta 54$, $\Sigma 81$

Predictive Models

Selection rules

The flavor symmetry:

1. is a low energy symmetry,
2. is not hardly broken, and
3. makes testable predictions

in the CKM and MNS.

within the framework of renormalizability.

b(u)y-16 get-22 model

Babu and Kubo; Itou, Kajiyama and Kubo

Q_6 with sponatneou $\not{C}\not{P}$

$$(U, D) \sim \mathbf{2}_1 + \mathbf{1}_{+,2} \; ; \; U^c \; , \; D^c \sim \mathbf{2}_2 + \mathbf{1}_{-,1}$$

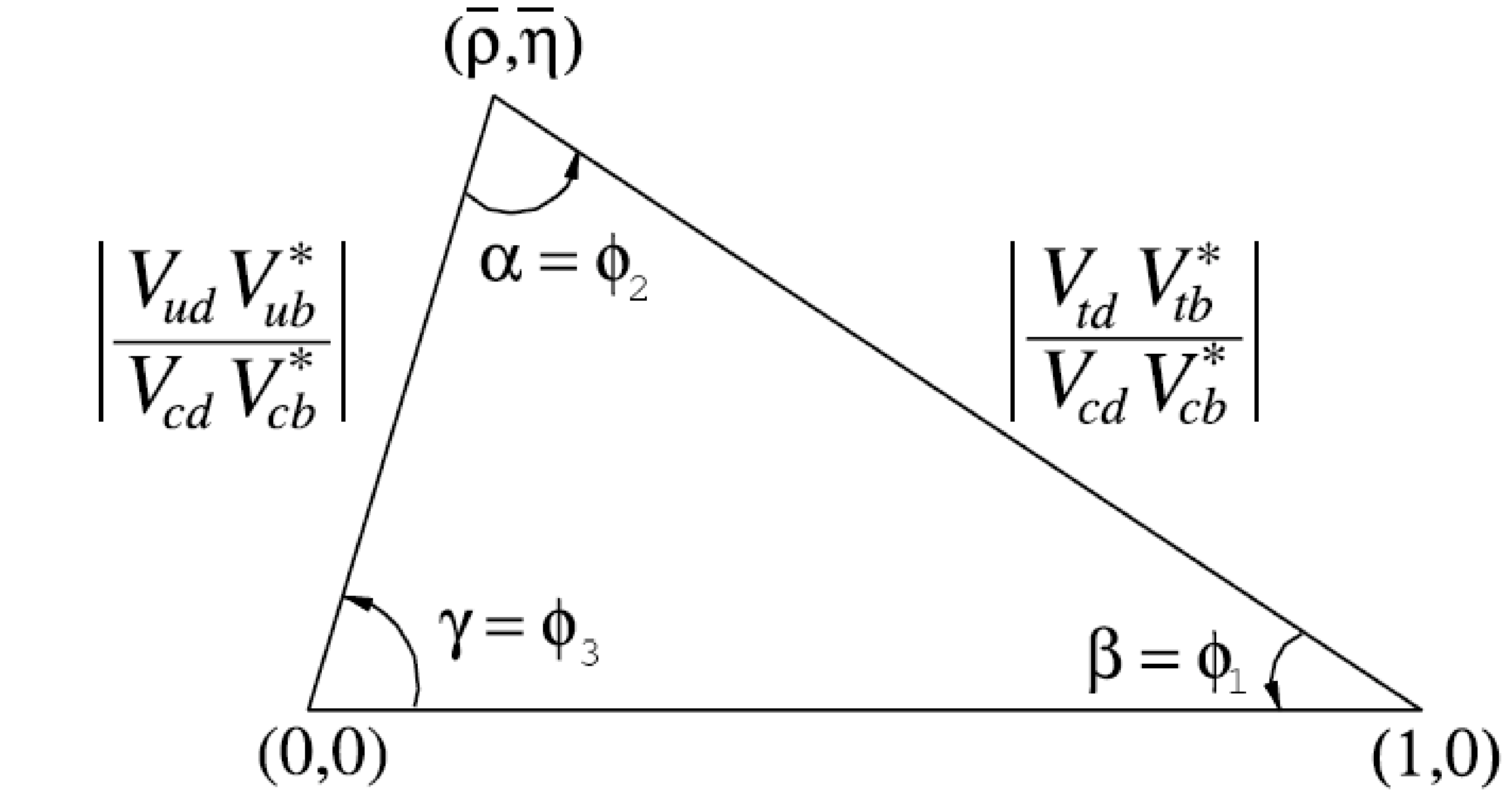
$$(N, E) \; , \; E^c \sim \mathbf{2}_2 + \mathbf{1}_{+,0} \; ; \; N^c \sim \mathbf{2}_2 + \mathbf{1}_{-,3}$$

$$H^u \; , \; H^d \sim \mathbf{2}_2 + \mathbf{1}_{-,1}$$

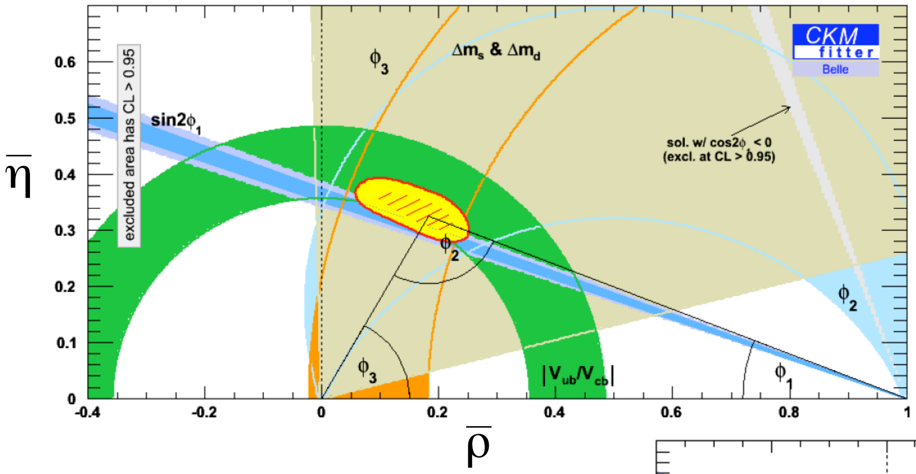
$$\mathbf{m}^u \sim \begin{pmatrix} 0 & \times & 0 \\ \times & 0 & \times \\ 0 & \times & \times \end{pmatrix} \; , \; \mathbf{m}^d \sim \begin{pmatrix} 0 & \times & 0 \\ \times & 0 & \times \\ 0 & \times & \times \end{pmatrix}$$

9 parameters to produce 10 observables in the quark sector.

Unitarity Triangle

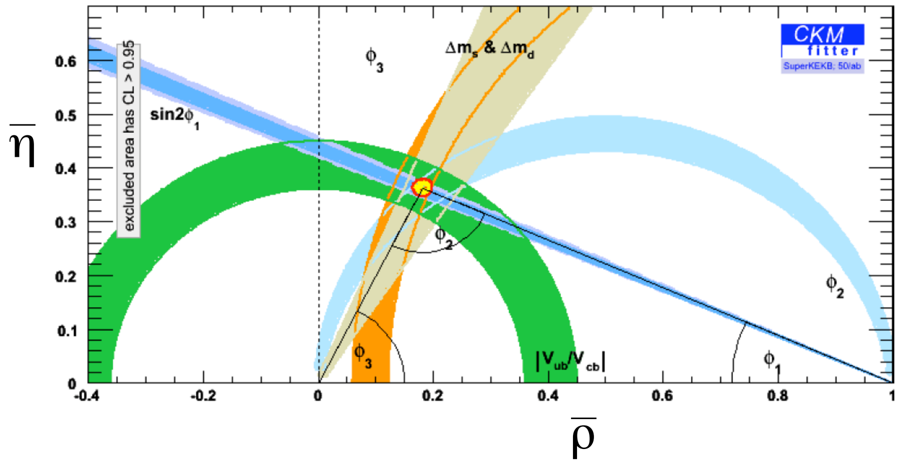


Unitarity Triangle



0.5 ab^{-1} (Belle)

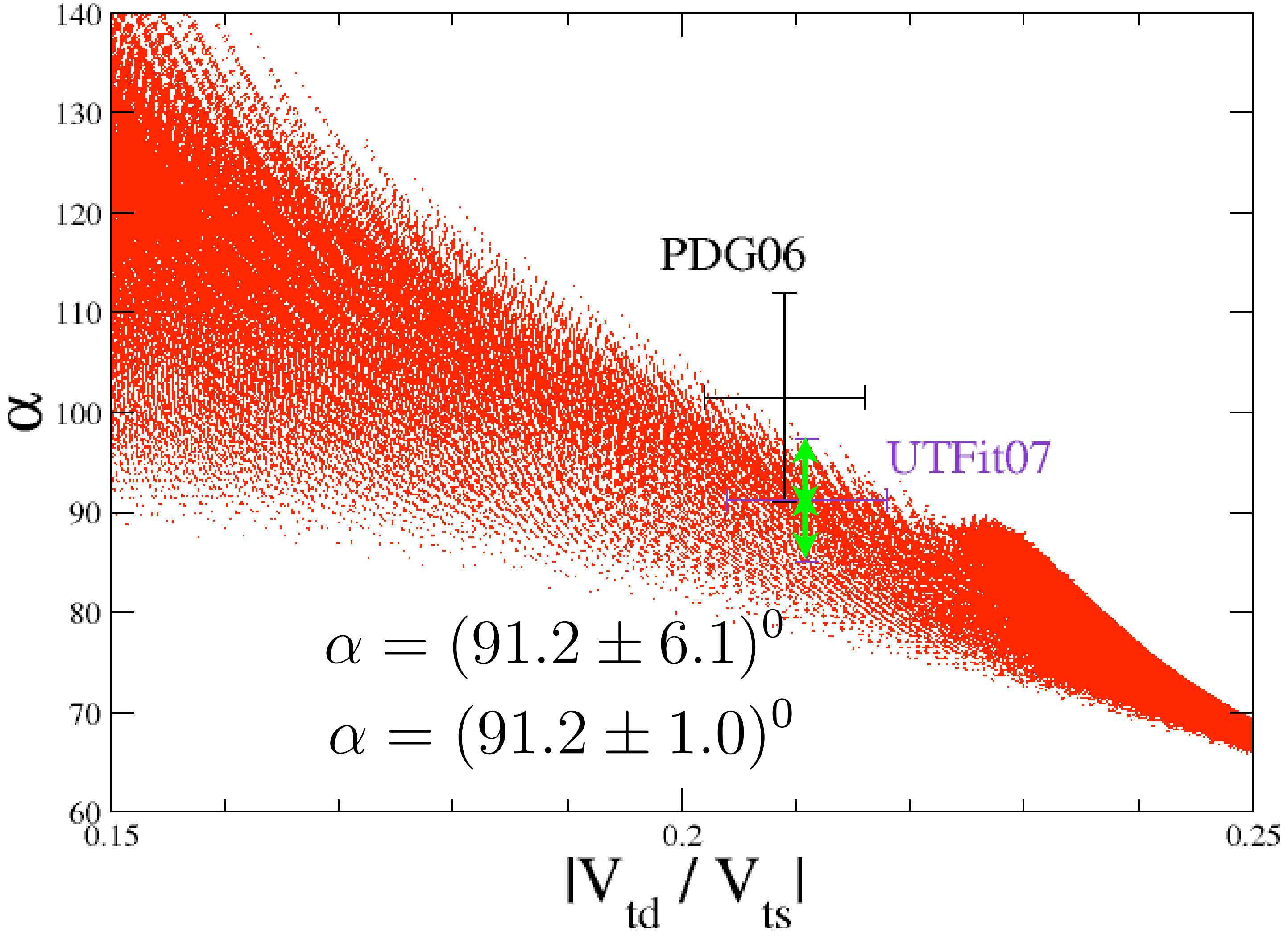
(SuperBelle) 50 ab^{-1}



	$\sigma(\bar{\rho})$	$\sigma(\bar{\eta})$
0.5 ab^{-1}	20.0%	15.7%
50 ab^{-1}	3.4%	1.7%

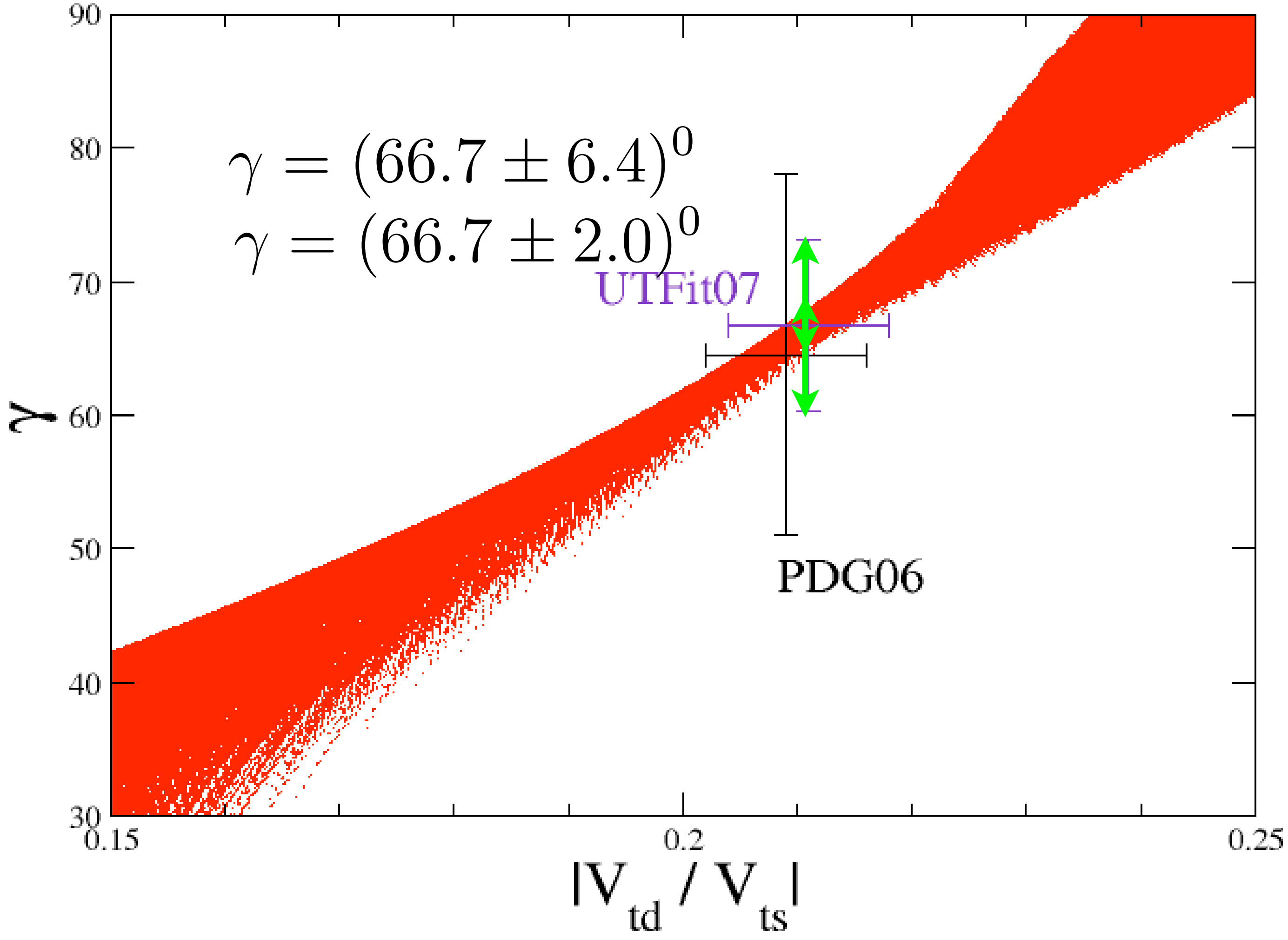
at Zimmermann 90

Prediction



PDG06
UTFit07
$\alpha = (91.2 \pm 6.1)^0$
$\alpha = (91.2 \pm 1.0)^0$
α
$|V_{td} / V_{ts}|$
140
130
120
110
100
90
80
70
60
0.15
0.2
0.25

Prediction



$\gamma = (66.7 \pm 6.4)^0$
$\gamma = (66.7 \pm 2.0)^0$
UTFit07
PDG06
γ
90
80
70
60
50
40
30
0.15
0.2
0.25
|V_td / V_ts|

Neutrino sector(Q6):

1. Inverted neutrino mass spectrum, i.e., $m_{\nu_3} < m_{\nu_1}, m_{\nu_2}$

2. $m_{\nu_2}^2/\Delta m_{23}^2 = \frac{(1+2t_{12}^2+t_{12}^4-rt_{12}^4)^2}{4t_{12}^2(1+t_{12}^2)(1+t_{12}^2-rt_{12}^2)\cos^2\phi_\nu} - \tan^2\phi_\nu$

$(r = \Delta m_{21}^2/\Delta m_{23}^2,\ t_{12} = \tan\theta_{12})$

Dirac phase

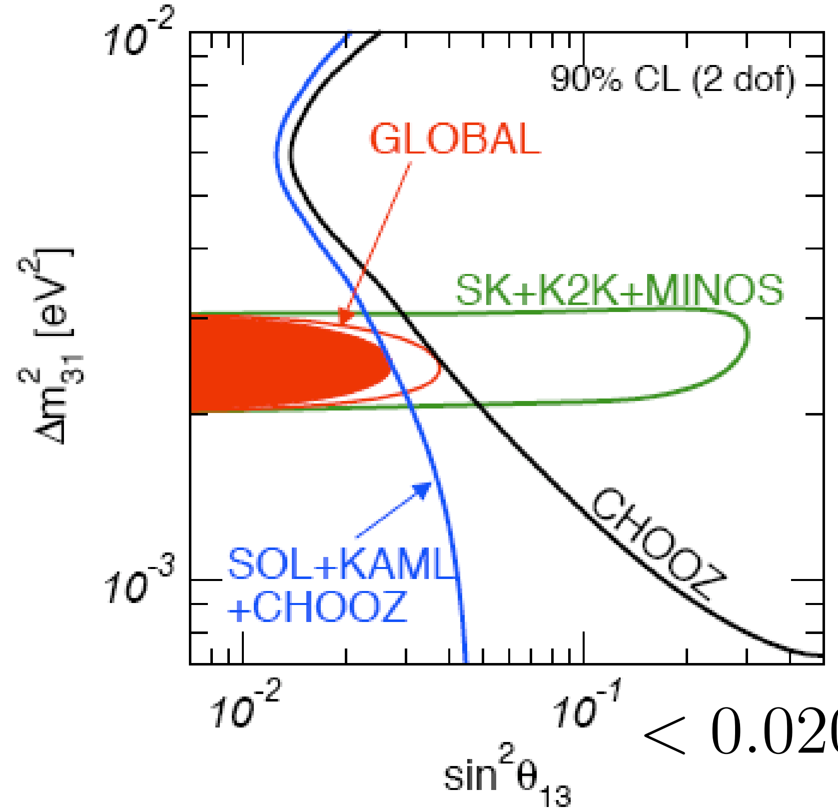
3.

$$\sin^2\theta_{13} = \frac{1}{2}(m_e/m_\mu)^2 \simeq 10^{-5}$$

$$\sin^2\theta_{23} = \frac{1}{2} + O((m_e/m_\mu)^2)$$

$$\sin^2\theta_{13} = \frac{1}{2}(m_e/m_\mu)^2 \simeq 10^{-5}$$

$$\sin^2\theta_{23} = \frac{1}{2} + O((m_e/m_\mu)^2)$$

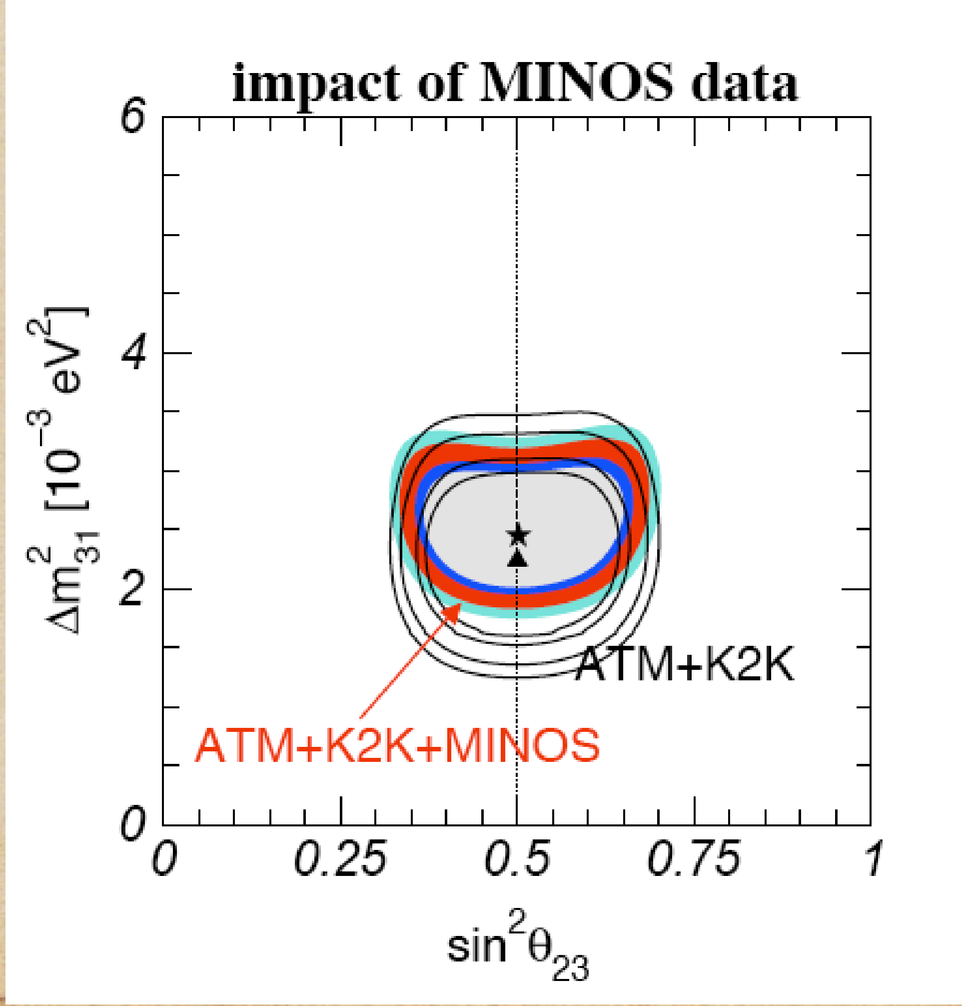


< 0.020

Maltoni et al

$$\sin^2\theta_{13} = \frac{1}{2}(m_e/m_\mu)^2 \simeq 10^{-5}$$

$$\sin^2\theta_{23} = \frac{1}{2} + O((m_e/m_\mu)^2)$$



Maltoni et al

More about discrete flavor symmetries

1. SUSY flavor problem
2. Proton decay modes
3. Where does the discrete family symmetry come from?
4. Anomalies of discrete symmetries and gauge coupling unification

5,6,.....

Letzter Teil

Noch viele glückliche Jahre mit
Ihrer Frau, Kindern und
Enkelkindern, und
Guten Appetit!!

THANK YOU VERY MUCH!