

Exercises, part 10

Thursday 2004-01-08 - Thursday 2004-01-15 16:00

**1. CKM matrix**

2 + 1 + 1 + 2\* + 3 + 2 + 1 points

a) Review the meaning of the 3x3 CKM matrix  $V$ , in particular write down

i) the 'standard parametrization' as used by the particle data group.

ii) the Wolfenstein parametrization

iii) the magnitude of the 9 matrix elements (from measurements).

b) How large is the phase  $\delta$  (approximately)? See appendix, where  $\bar{\eta} \approx \eta$  und  $\bar{\rho} \approx \rho$  are two of the Wolfenstein parameters.

c) Are the two parametrizations i) and ii) in a) equivalent? If yes, prove it. If not, explain the differences.

d\*) Show that for  $\delta = 0$  matrix i) can be constructed from three rotations.e) The phase  $\delta \neq 0$  is a prerequisite for CP violation. Why is  $\delta$  distributed so 'asymmetrically' in i)? Can one construct a CKM parametrization  $V^H$  ('Hebbeker parametrization') equivalent to i) such that  $V^H$  has NO imaginary components in the third row and third column (i.e.  $V_{td}^H, V_{ts}^H, V_{tb}^H, V_{ub}^H, V_{cb}^H, V_{tb}^H$  are real)?Hint: Any phase transformation  $e^{i\phi_i}$  applied to the wave function of quark type  $i$  ( $=1 \dots 6$ ) is unobservable.f) In the 3 family Standard Model  $V$  is a **complex unitary** matrix.1) what does this imply for the values  $|V_{xy}|$ ? Do the numbers iii) fulfill these conditions? Does this come as a surprise?

2) In the complex plane some of the unitarity equations can be interpreted as triangles. Explain this for one triangle. How many triangles can be constructed in total? In the literature only one very specific unitarity triangle is discussed frequently; what about the other ones?

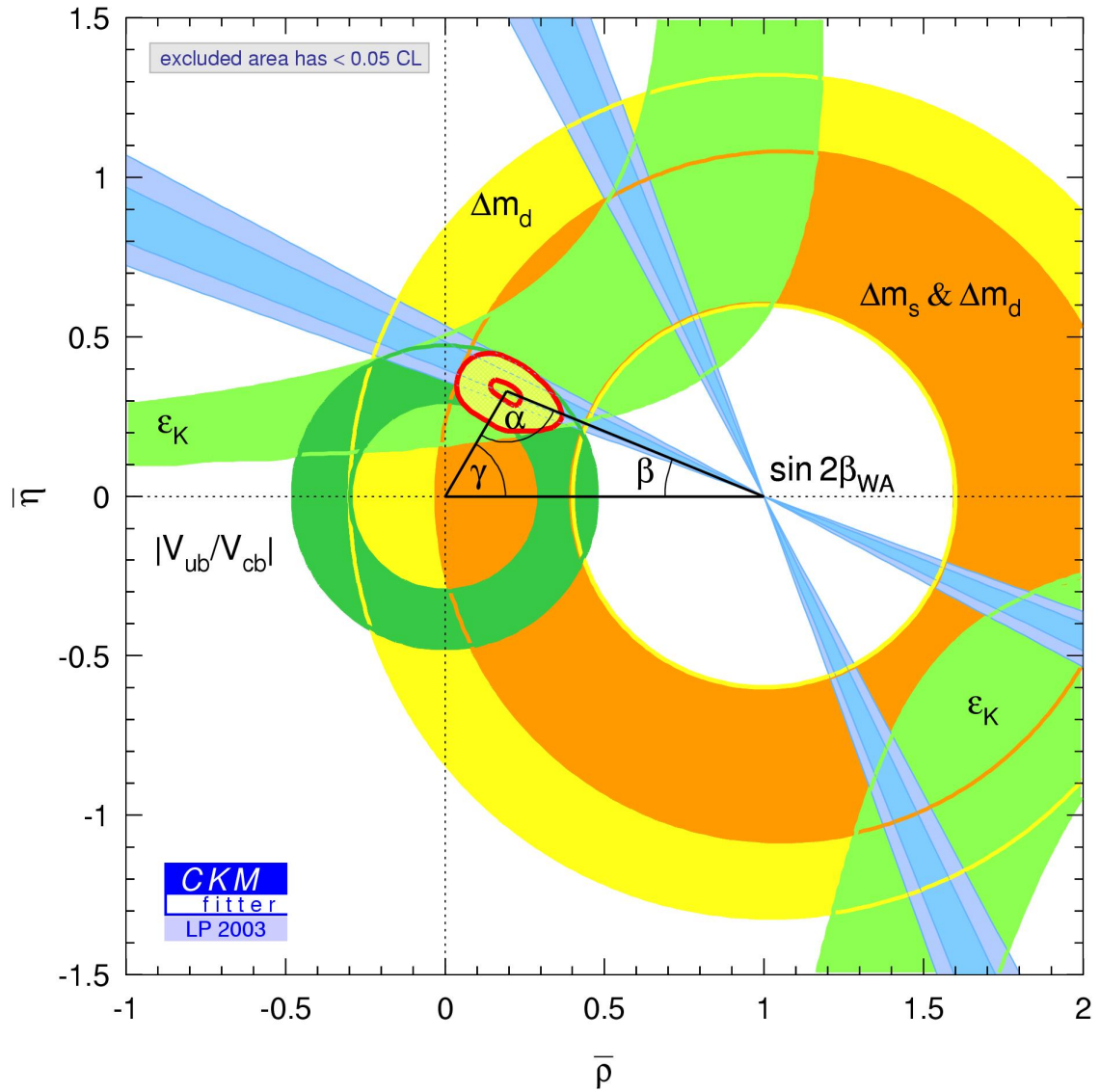
g) Discuss (in general), for what classes of processes

1) only  $|V_{xy}|$  can be measured,

2) also the phase plays a role

## APPENDIX

Global CKM-fit (summer 2003):



The upper corner of the triangle defines  $\rho$  and  $\eta$ .