B-physics and EW constraints on SM4

Alexander Lenz (CERN)

for the CKM4fitter collaboration

Third Workshop on Beyond 3 Generation Standard Model
Under the light of the initial LHC results

Istanbul, October 23, 2011

Previous Work from our Group

- 0902.3884: *How much space is left for a new family?*
  Markus Bobrowski, A.L., Johann Riedl, Jürgen Rohrwild
  University of Regensburg
- 1003.4532: *Simultaneous Extraction of the Fermi constant and PMNS matrix elements in the presence of a fourth generation*
  Heiko Lacker, Andreas Menzel HU Berlin
- 1005.3505: *Less space for a new family*
  Otto Eberhardt, A.L., Jürgen Rohrwild
  University of Regensburg, TU Dortmund
- 1104.2465 : *Fourth Generation Majorana Neutrinos*
  A. L., Heinrich Päs, Dario Schalla
  TU Dortmund, TU Munich
- 1105.3434: *Electroweak Precision Observables within a Fourth Generation Model with General Flavour Structure*
  Patrick Gonzalez, Jürgen Rohrwild, Martin Wiebusch
  RWTH Aachen, Karlsruhe Institute of Technology

The "old" approach to find constraints on V_{CKM4}:

Scans over the CKM4 parameter regions, e.g.

- 0902.4883: Bobrowski, A.L., Riedl, Rohrwild - very large effects
- 0904.3570: Chanowitz - S,T,U shrinks the allowed region
- 0909.3227: Eilam, Melic, Trampetic - CP violation
- 1002.0595: Soni,... - more Observables also 1011.6091
- 1002.2126: Buras et al. also 1004.4565 Charm; 1006.5356 Leptons
- 1004.2186, 1003.4361: Hou,...
- 1005.3505: Eberhardt, A.L., Rohrwild - full CKM-dependence of S,T,U
- 1007.0034: Chanowitz excludes $s_{34} = 0$ - this is wrong!
- ...

Bounding the SM4 parameters

The "old" parameters

Quarks:	$m_u, m_d, m_s, m_c, m_b, m_t,$	$\theta_{12}, \theta_{13}, \theta_{23},$	δ_{13}
Leptons:	$m_{\nu_e}, m_{\nu_\mu}, m_{\nu_\tau}, m_e, m_\mu, m_\tau,$	$\theta^\ell_{12}, \theta^\ell_{13}, \theta^\ell_{23},$	δ^ℓ_{13}

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The new parameters

Quarks:	$m_{b'}, m_{t'},$	$\theta_{14}, \theta_{24}, \theta_{34},$	δ_{14}, δ_{24}
Leptons:	$m_{\nu_4}, m_{\ell_4},$	$\theta^\ell_{14}, \theta^\ell_{24}, \theta^\ell_{34},$	$\delta^\ell_{14}, \delta^\ell_{24}$

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13 free parameters

Scan over the SM4 parameter space

- Create 10^{10} random parameter points for the SM4
- Calculate the values of all 16 CKM elements
- Direct bounds on the SM4 parameter points
  - Mass constraints (quarks, leptons, Higgs)
  - Direct measurements of CKM elements
  - Phase constraints on the CKM matrix

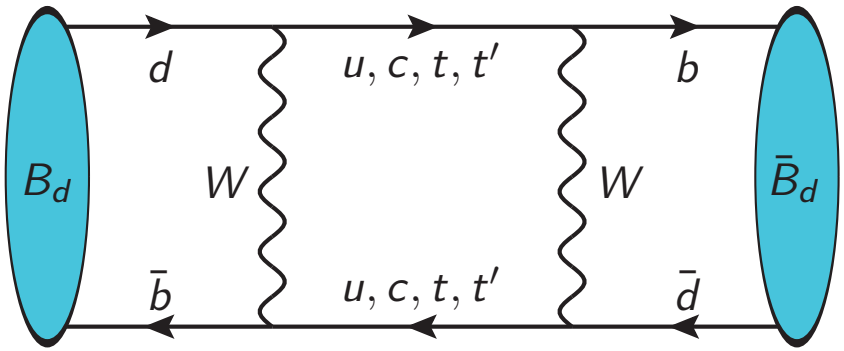
  If the parameter point is within the allowed range, we proceed, else the point is discarded
- Indirect bounds on the SM4 parameter bounds
  - FCNC
  - electro-weak precision observables
- No statistical meaning of the surviving parameter points!

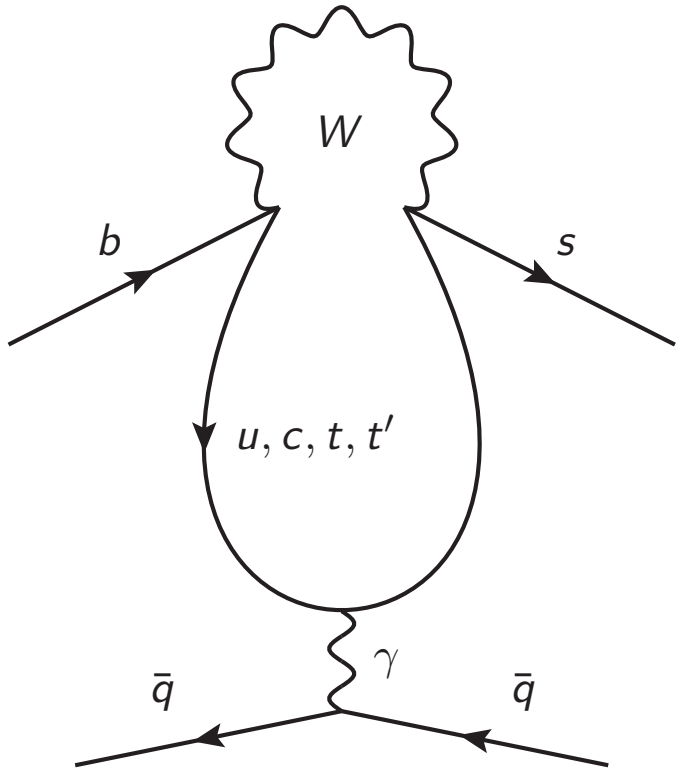
What did we learn from the scans

- Huge cancellations are possible in FCNCs
  Counter example for Minimal-Flavour Violation
- Do not forget:
  we have no direct bound on V_{td} and V_{ts}
- Even the PDG can be wrong
  $m_{t'} \leq m_{b'}$ is not excluded
- ...

Cancellations in FCNC

Flavour observables:





FCNC in the SM4

Analysis: still huge corrections possible!

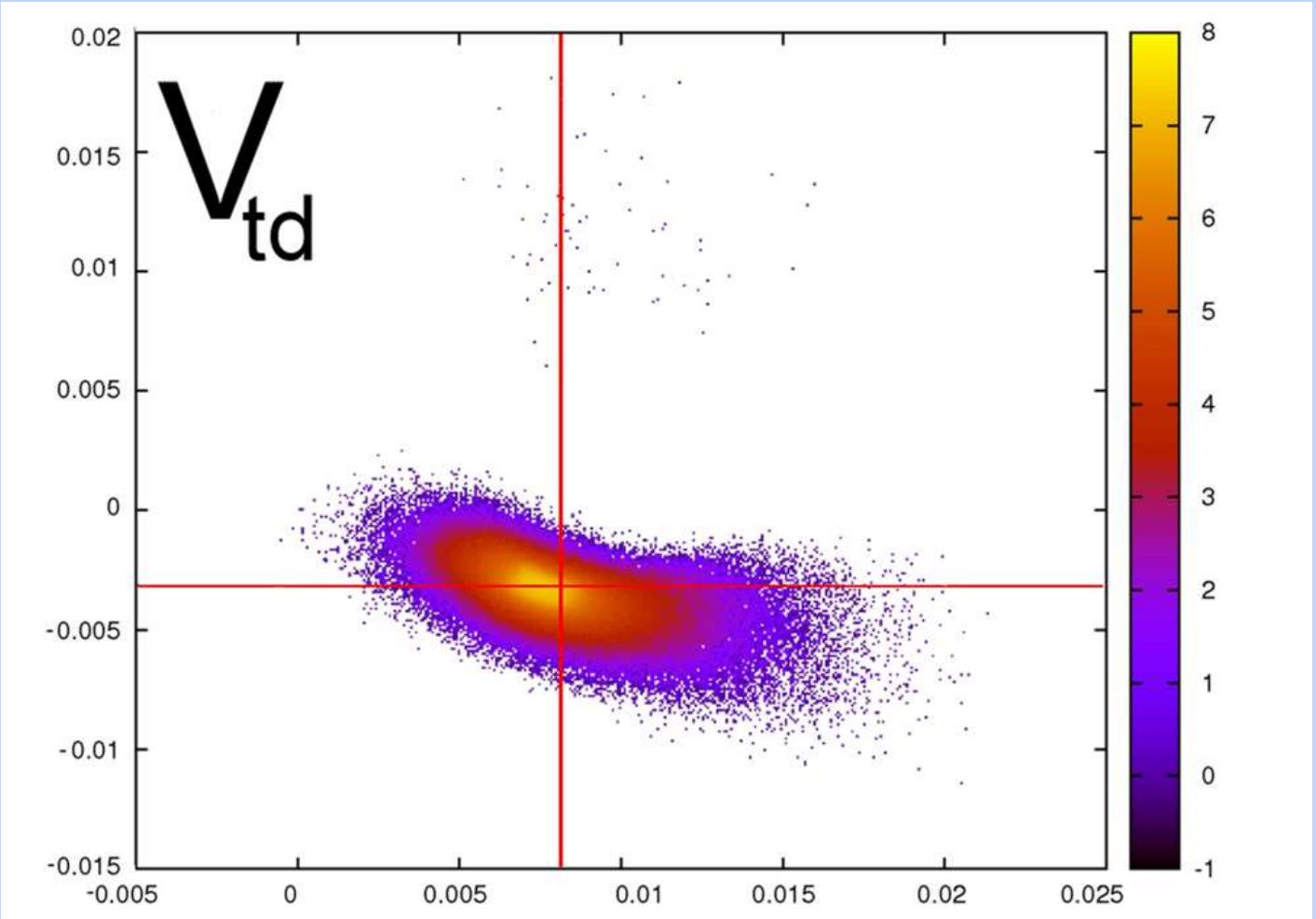
There are two effects that change the value of M_{12} in the SM4

- t' running in the loop
- The t loop is also changed, because now the CKM elements from the 3x3 fit can not be use anymore!
  This was overlooked many times!

Huge cancellations between these two effects are possible
0902.4883,1005.3505: Parameter sets with $\mathcal{O}(300\%)$ effects found

Bounds on the CKM element V_{td}

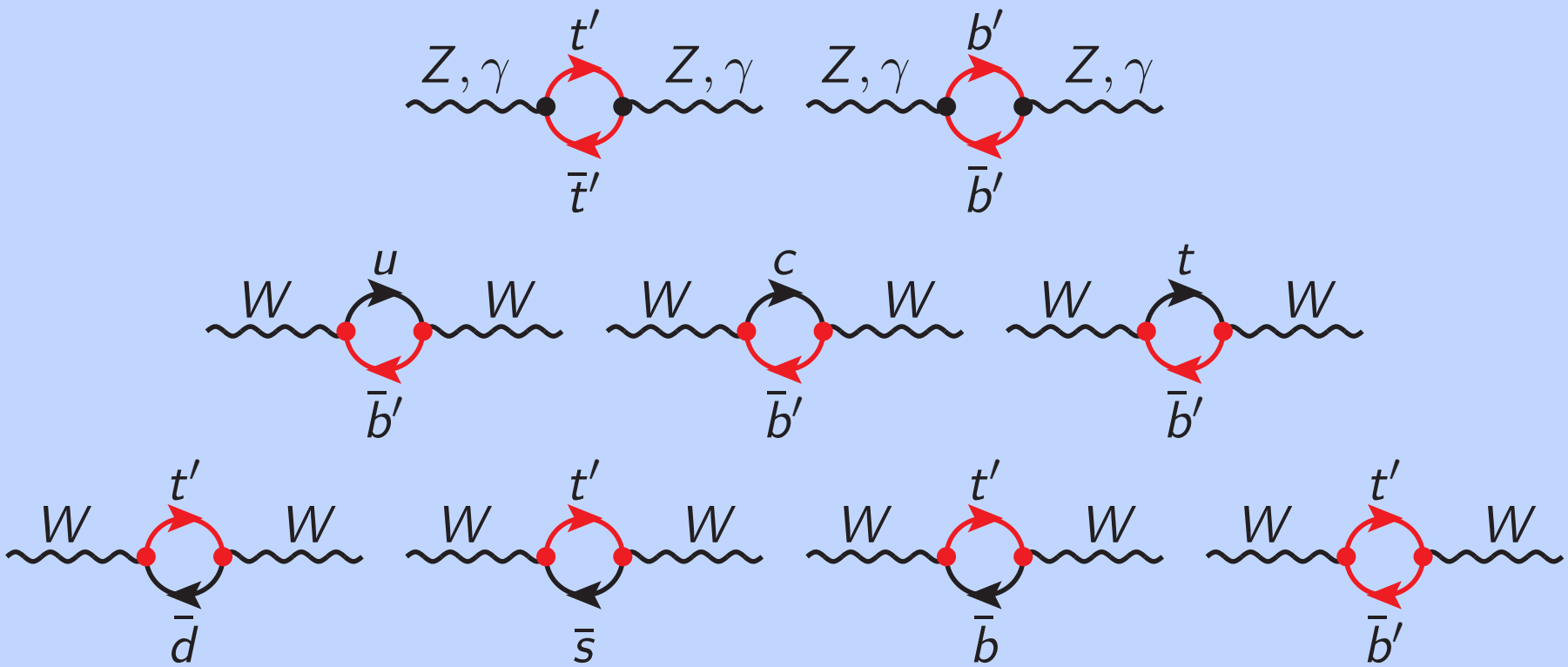
Im V_{td} vs. Re V_{td}



Eberhardt, A.L., Rohrwild: 1005.3505

What are S, T and U?

Self-energy contributions by the fourth family



Explicit expressions

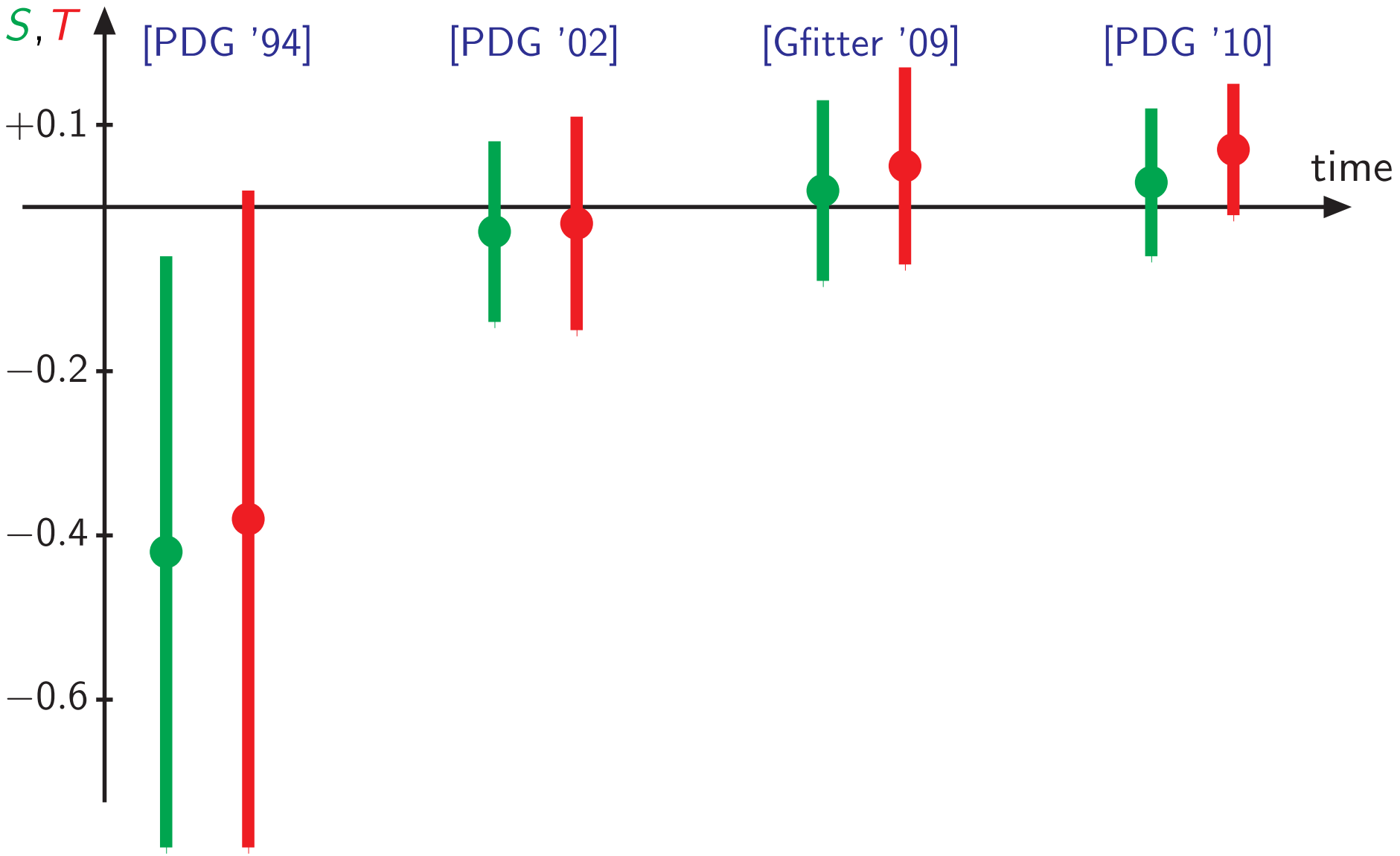
The exact formulae for S and T

$$S_{\text{ferm}} = \frac{N_c}{6\pi}\sum_{(U,D)}\left[1-\frac{2}{3}\ln\left(\frac{m_U}{m_D}\right)\right]+\frac{1}{6\pi}\sum_{(\nu,l)}\left[1+2\ln\left(\frac{m_\nu}{m_l}\right)\right]$$

$$T_{\text{ferm}} = \frac{N_c}{16\pi s^2 c^2 M_Z^2}\left[\sum_{i=U,D} m_i^2 - 4\sum_{U,D}\left|V_{UD}^{(\text{CKM})}\right|^2 \frac{m_U^2 m_D^2}{m_U^2-m_D^2}\ln\left(\frac{m_U}{m_D}\right)\right]$$

$$+\frac{1}{16\pi s^2 c^2 M_Z^2}\left[\sum_{i=\nu,l} m_i^2 - 4\sum_{\nu,l}\left|V_{\nu l}^{(\text{PMNS})}\right|^2 \frac{m_\nu^2 m_l^2}{m_\nu^2-m_l^2}\ln\left(\frac{m_\nu}{m_l}\right)\right] \geq 0$$

The S-T ellipse: Experimental values



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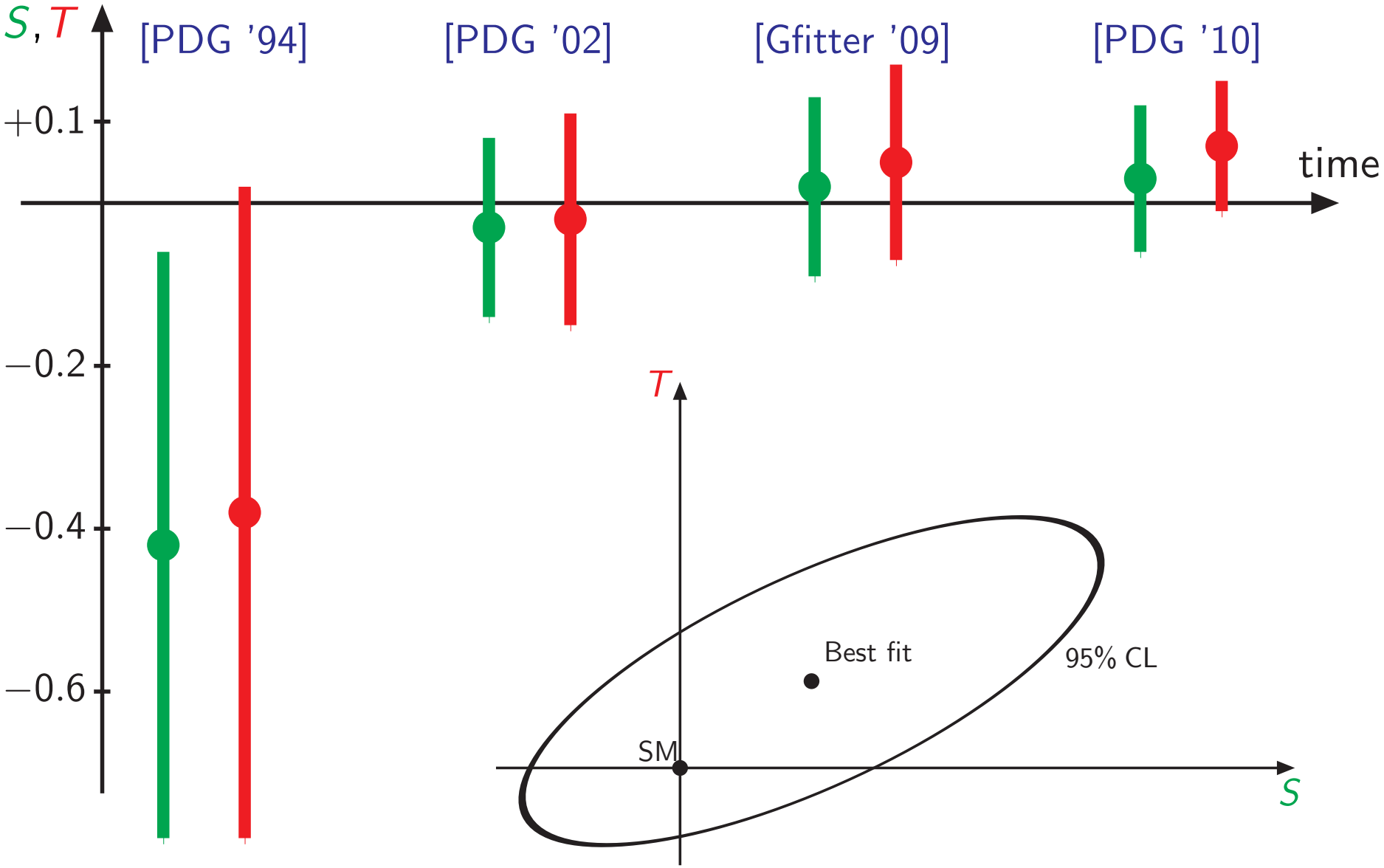
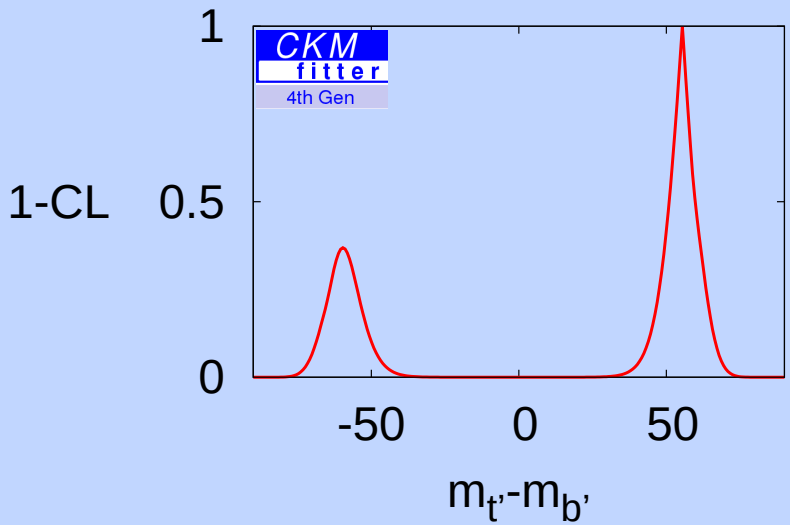


Fermion mass difference

Neglecting the leptons



$(V^{\mathrm{CKM}} = \mathbb{1})$

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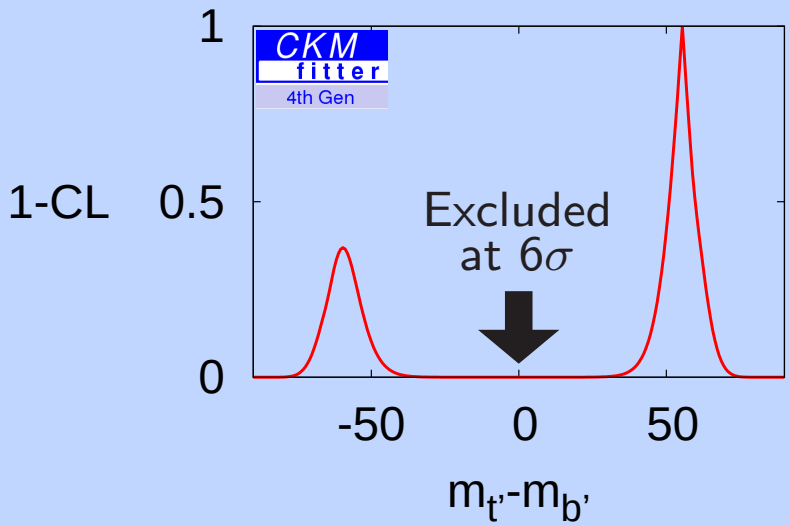

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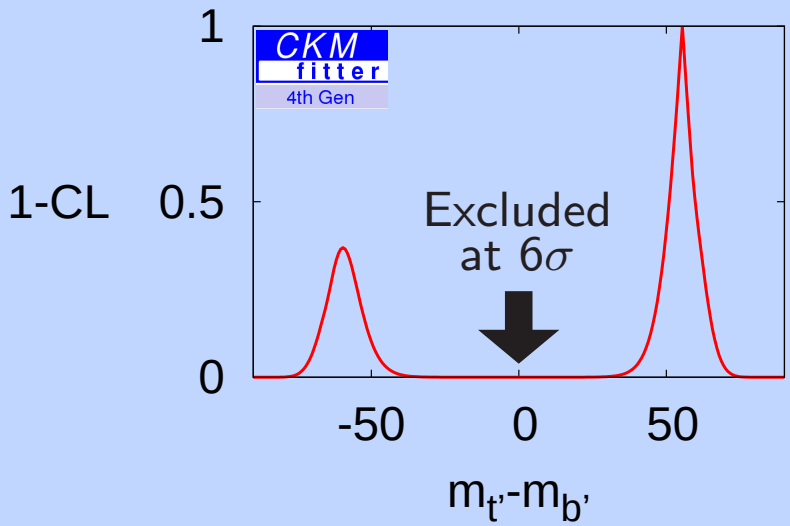

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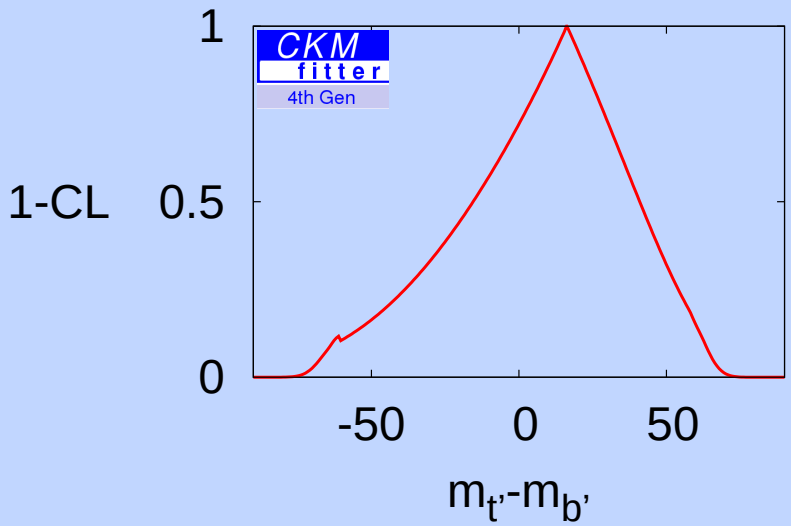
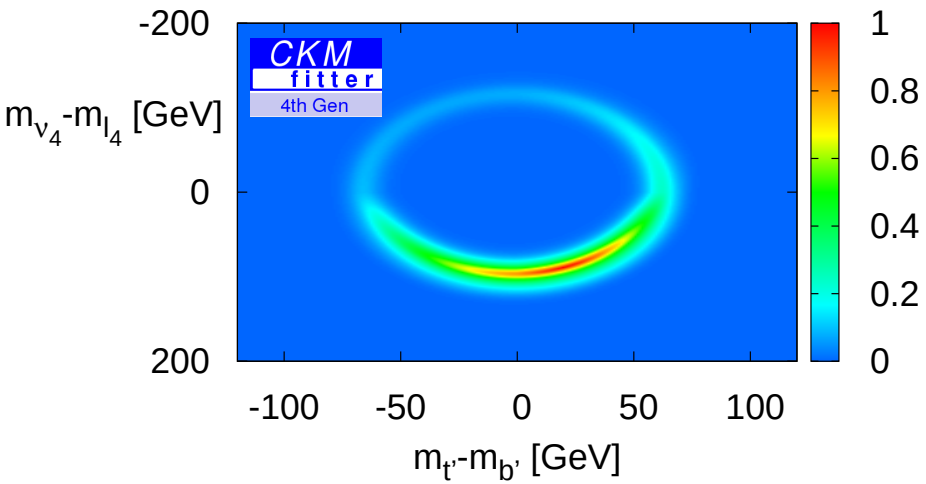


$(V^{\mathrm{CKM}} \neq \mathbb{1})$

Fermion mass difference

Taking also the leptons into account:



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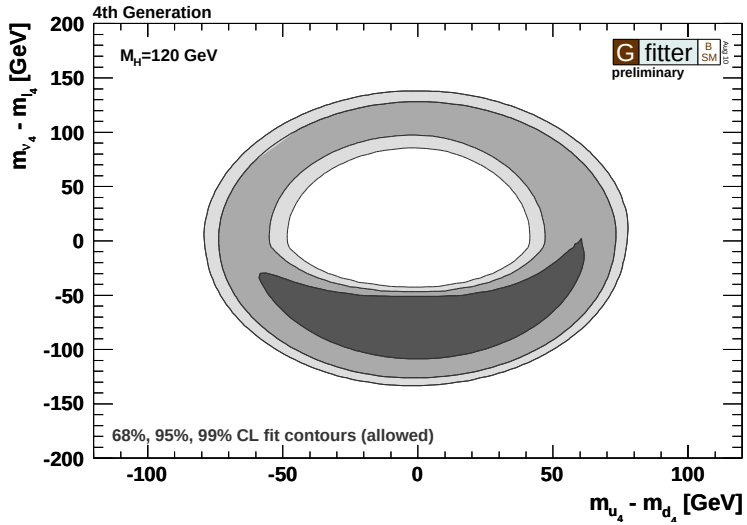

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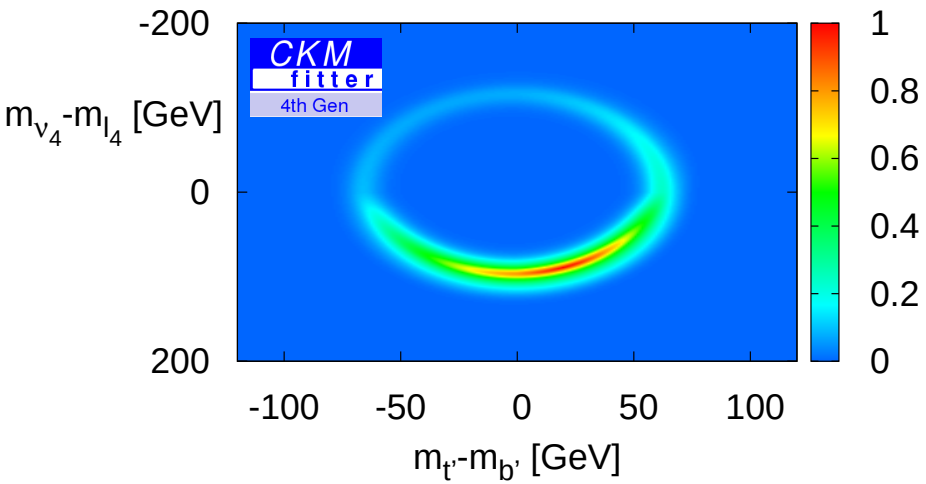

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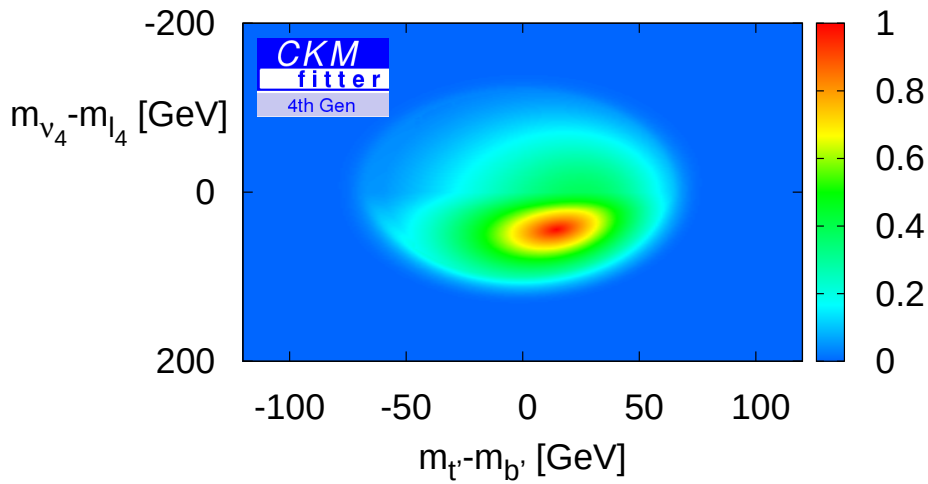


$(V^{\mathrm{CKM}} \neq \mathbb{1})$

The "new" approach to find constraints on V_{CKM4}

Implement the SM4 in the CKMfitter-package

CKM4fitter

- HU Berlin:
  Heiko Lacker, Andreas Menzel, Florian Spettel,...
- University of Karlsruhe:
  Ulrich Nierste, Martin Wiebusch, Otto Eberhardt,...
- CERN:
  Alexander Lenz

See also: 1011.2634 Alok, Dighe, London

Indirects Bounds from FCNC and electro-weak

Observables used as bounds

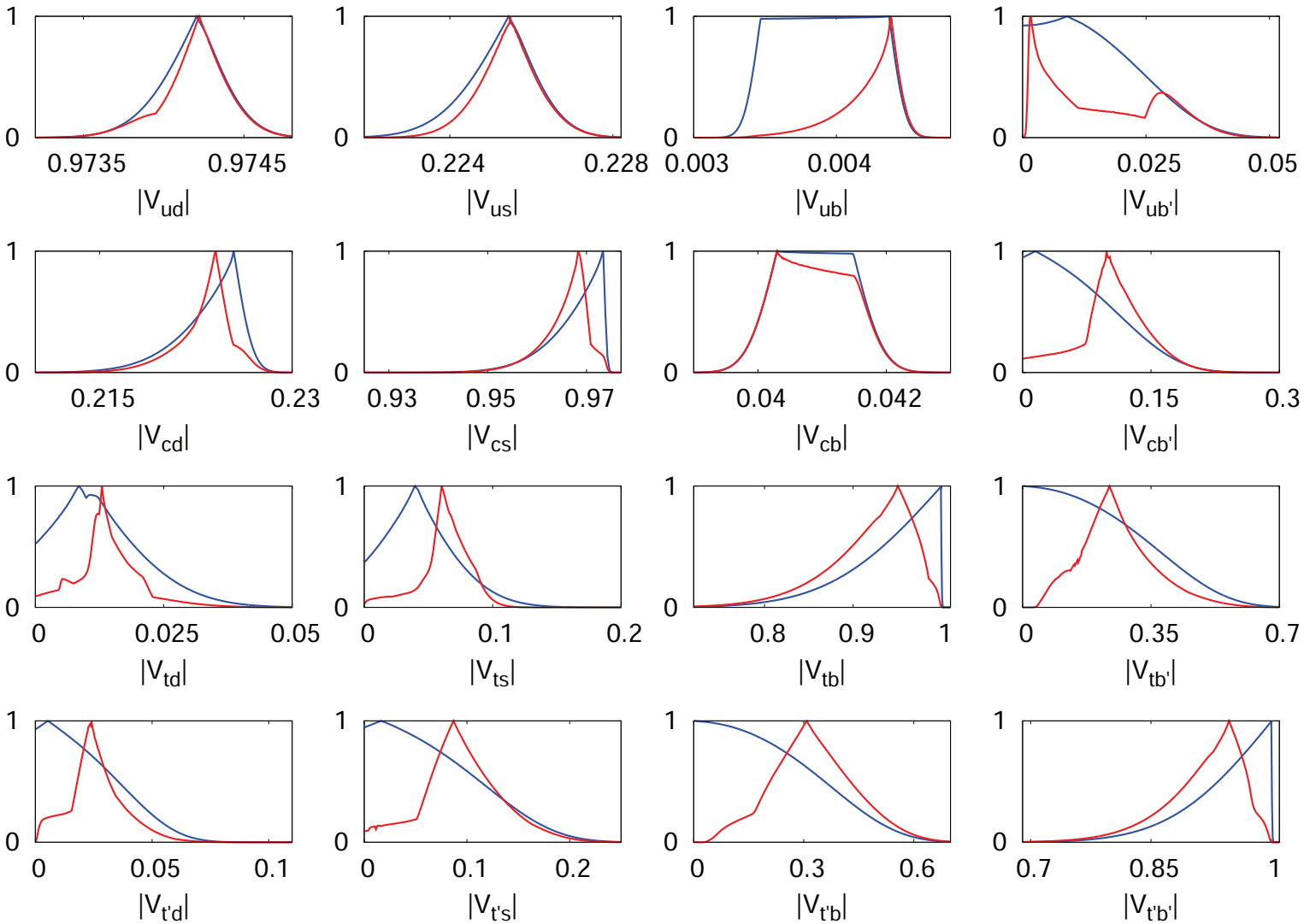
- ΔM_s, ΔM_d
- ϵ_K: CP violation in K decays
- $b \to s\gamma$, $B_s \to \mu\mu$
- S-, T-parameter
- Dimuon asymmetry $\Rightarrow$ we will see $V_{x4} \neq 0$!

Observables not yet implemented

- D mixing
- $B \to K^{(*)} ll$
- Rare K decays
- $sin2\beta$ from $B_d \to \psi K_s$, $sin2\beta_s$ from $B_s \to \psi\phi$
- Full electro-weak observables

First results of our global fit

Moduli of the CKM matrix without and with EW and flavour constraints:



What is still missing?

- Implementation of the CKM dependence of the direct mass bounds from LHC
- Implementation of the Higgs bounds from LHC
- How to treat the SM4 penguin contributions to $B_d \to J/\psi K_s$ and $B_d \to J/\psi K_s$
- Implementation of the lepton sector
- Is the pure SM4 excluded?
  - What is x in SM4+x?
  - Non-perturbative new generation
- Do the full programme (CKM+PMNS+electro-weak) for the "real" extension of the SM