

The neutron EDM vs flavour-violating D meson decays

Filippo Sala

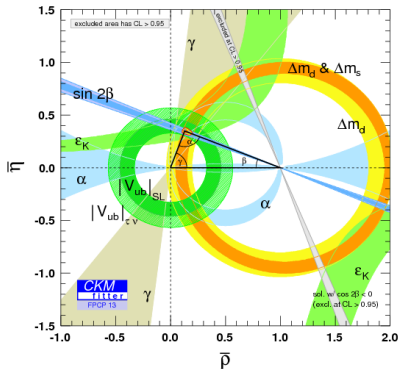
IPhT, CEA-Saclay and CNRS



Planck 2014, Paris, 29 May 2014

based on: F.S. [arXiv:1312.2589](https://arxiv.org/abs/1312.2589)

Why is CKM description of flavour and CP so good?



"NP flavour problem"

$$\mathcal{L}_{\text{NP}} = \sum_i \frac{1}{\Lambda_i^2} \mathcal{O}_i$$

↓

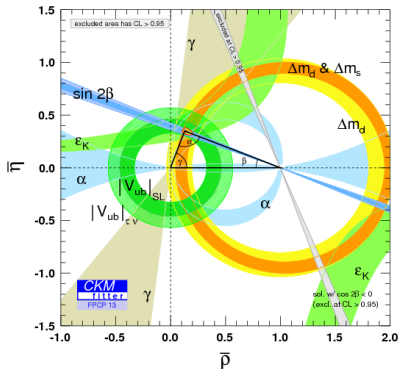
$$\Lambda_i \gtrsim 10^4 \div 10^5 \text{ TeV}$$

Hierarchy problem:

$$m_h \approx \Lambda$$

[Λ = highest scale h couples to]

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Hierarchy problem: $m_h \approx \Lambda$ [$\Lambda =$ highest scale h couples to]

Solution [insisting on naturalness] $\mathcal{L}_{\text{NP}} = \sum_i \xi_i \frac{c_i}{\Lambda^2} \mathcal{O}_i$ $c_i \sim O(1)$ $\Lambda \sim \text{TeV}$

ξ_i small due to some "feature", e.g. a flavour symmetry, partial compositeness

A class of solutions of NP flavour problem

Current constraints

Stronger ones: down sector [ϵ_K , $B - \bar{B}$ mixing, $B \rightarrow X_s \gamma$, ...]

Up sector: larger effects allowed! [$D \rightarrow KK, \pi\pi$, ...]

Many examples realising this picture, like:

- Flavour alignment [Nir Seiberg hep-ph/9304307, ...]
- Partial compositeness [D.B. Kaplan, NPB (1991), ...]
- Generic $U(2)^3$ [Barbieri Buttazzo S. Straub 1206.1327]

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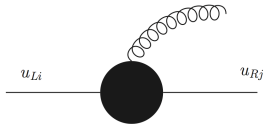
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Separation of new physics scales

favoured by natural solution to hierarchy problem

Hot flavour observables



$$\mathcal{L}_{\text{NP}} \supset c_{ij} \frac{m_t}{\Lambda^2} (\bar{u}_{Li} \sigma_{\mu\nu} T^a u_{Rj}) g_s G_{\mu\nu}^a$$

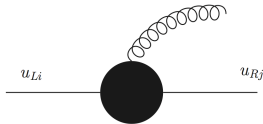
Typical situation: up-quarks dipoles can be largish

Most sensitive observables

$$\Delta A_{\text{CP}} = A_{\text{CP}}(D \rightarrow K^+ K^-) - A_{\text{CP}}(D \rightarrow \pi^+ \pi^-) \propto c_{uc}, c_{cu}$$

$$d_n = (1 \pm 0.5) [1.4(d_d - 0.25d_u) + 1.1e(\tilde{d}_d + 0.5\tilde{d}_u)] \propto c_{uu}$$

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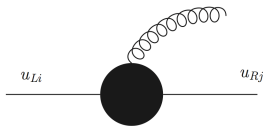
Very general class of models

They realise $c_{uc}c_{cu} = c_{uu}c_{cc}$

\Rightarrow one can have largish ΔA_{CP} , and respect d_n bound!

[big amount of literature exploiting this]

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This talk: point out d_n sensitive to $c_{cc} \Rightarrow$ now d_n constrains ΔA_{CP} !

Neutron EDM

Current bound: $d_n < 2.9 \cdot 10^{-26} e \text{ cm}$ (90%CL) ILL, Grenoble

Future sensitivity: $d_n \sim 10^{-28} e \text{ cm}$ ILL, PSI, TRIUMF...

Standard Model contribution: $d_n \sim 10^{-31} e \text{ cm}$ [long distance effect]

CP asymmetry in D decays

(2 weeks old) world average: $\Delta A_{CP} = (-3.29 \pm 1.21) \times 10^{-3}$

Standard Model contribution: a few $\times 10^{-3}$, big uncertainties!

LHCb will not increase sensitivity to NP (unless we understand SM)

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NEW LHCb : $\Delta A_{CP} = (+0.14 \pm 0.16 \pm 0.08) \times 10^{-3}$

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- New bound on the charm chromo-EDM
- Implications for phenomenology of new physics

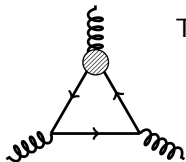
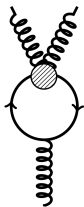
Bound on the chromo-EDM of the charm quark

$$d_n = (1 \pm 0.5) [1.4(d_d - 0.25d_u) + 1.1e(\tilde{d}_d + 0.5\tilde{d}_u)] \pm (22 \pm 10) \text{ MeV } w$$

$$\mathcal{L}_{\text{NP}} \supset w \frac{1}{6} f^{abc} \epsilon^{\mu\nu\lambda\rho} G_{\mu\sigma}^a G_{\nu}^{b\sigma} G_{\lambda\rho}^c$$

Threshold effect $w = \frac{\tilde{d}_q}{m_q} \frac{g_s^3}{32\pi^2}$ [known since 1990]

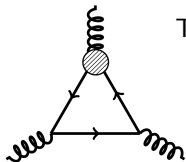
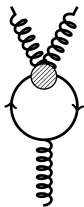
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$$\text{Im}(c_{uu}) \lesssim 1.3 \times 10^{-8} (\Lambda/\text{TeV})^2$$

$$\text{Im}(c_{cc}) \lesssim 1.8 \times 10^{-5} \quad "$$

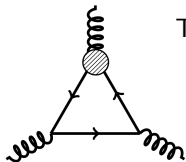
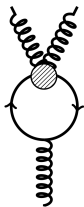
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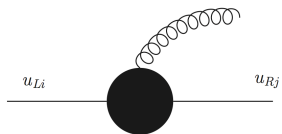
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What if one ignores w in d_n ? Still w runs in $d_{u,d}$, $\tilde{d}_{u,d} \Rightarrow \tilde{d}_c < 1.2 \times 10^{-20} e \text{ cm}$

Implications for New Physics

Reminder: i) largish flavour violation in up quark sector ii) $\Lambda_{1,2} \gg \Lambda_3$



$$C_{ij} = c W_{i3}^L W_{3j}^R$$

→ $W_{k3}^{L,R}$ = how much k^{th} generation of quarks communicates with Λ_3

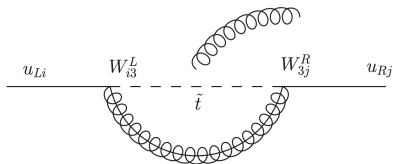
→ Typically $W_{i3}^L \simeq V_{ib}^{\text{CKM}}$

$$d_n \Rightarrow |W_{3c}^R| < 4.4 \times 10^{-4} \quad |W_{3u}^R| < 3.7 \times 10^{-6}$$

$$\Delta A_{\text{CP}} \Rightarrow |W_{3c}^R| < 1.1 \times 10^{-3} \quad |W_{3u}^R| < 9.2 \times 10^{-5}$$

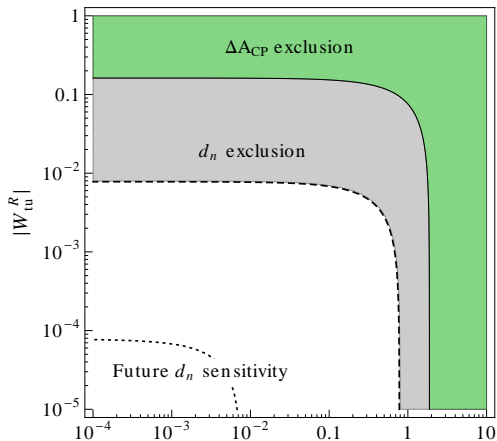
No bound on $\tilde{d}_c \Rightarrow$ largish W_{3c}^R allowed, without conflict with d_n !

Possible to consider all dominant contributions to both d_n and ΔA_{CP}^*



$$\frac{C_{ij}}{\Lambda^2} = \frac{\alpha_s}{4\pi} \frac{1}{m_{\tilde{g}}^2} \frac{A_t - \mu \cot \beta}{m_{\tilde{t}}} f\left(\frac{m_{\tilde{g}}^2}{m_{\tilde{t}}^2}\right) W_{i3}^L W_{3j}^R$$

[Perez on Wednesday $|W_{tc}^R| \simeq 0.3$]



$|W_{tc}^R|$

$[m_{\tilde{g}} = 1.5 \text{ TeV} = 2m_{\tilde{t}}]$

*down quark CPV strongly constrained by ϵ_k

Higgs and gaugino phases by d_e [Barbieri Buttazzo S Straub 1402.6677]

Composite Higgs models

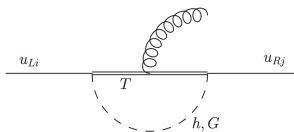
Other main paradigm for natural solution to hierarchy problem

- Higgs as pseudo-Goldstone boson
- Simplified pheno: a composite state for every SM field (e.g. top partners T)
- natural m_h + precision tests \Rightarrow i) $m_T \lesssim \text{TeV}$ ii) strong coupling $Y^* \sim 1$

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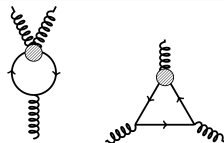
$$\begin{aligned} d_n &\Rightarrow m_T \gtrsim 2.1 Y_u^* \text{ TeV} & m_T \gtrsim 1.2 Y_c^* \text{ TeV} \\ \Delta A_{\text{CP}} &\Rightarrow m_T \gtrsim 1.3 Y_8^* \text{ TeV} & m_T \gtrsim 0.26 Y_{8'}^* \text{ TeV} \end{aligned}$$

See [Konig on Tuesday \[Konig Neubert Straub 1403.2756\]](#) for detailed analysis:

Now d_n is giving the strongest bound on masses of up composite partners

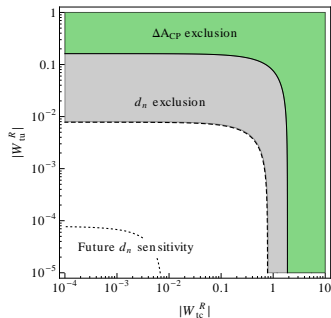
- New bound on the charm chromo-EDM (via w)

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- General class of models with
 - i) largish flavour violation in up quark sector
 - ii) $\Lambda_{1,2} \gg \Lambda_3$

$$\Rightarrow \underline{d_n \text{ constrains } \Delta A_{CP}}$$



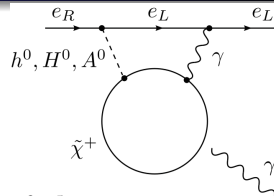
Future

- Understand ΔA_{CP} in SM
- Improve on w contribution to d_n
- Long distance charm contribution to d_n ?
- Measure deuteron EDM

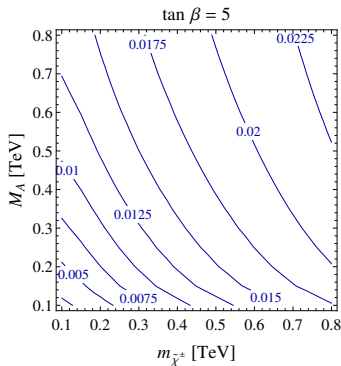
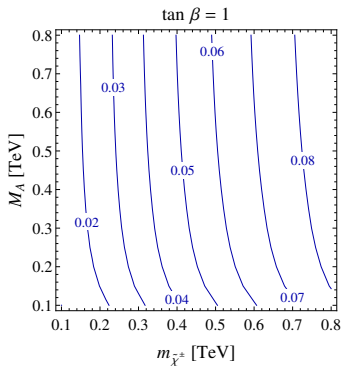
Back up

$$|d_e| < 8.7 \times 10^{-29} e \text{ cm}$$

[ACME collaboration, 1310.7534]



Bounds on phase of μ from two-loop diagrams:



$O(1)$ phase of μ is no longer allowed!