CKMFITTER

Morceaux choisis en physique des saveurs :

- L'ajustement CKM standard en tant que test du Modèle Standard
- La recherche de Nouvelle Physique

Rôle du LPNHE dans CKMfitter :

- (très bref) survol historique
- activités aujourd'hui, perspectives

http://ckmfitter.in2p3.fr

CKM fitter

EPS 11

José Ocariz

LPNHE – IN2P3 et Université Paris Diderot

ocariz@in2p3.fr

Biennale du LPNHE, 19 septembre 2011

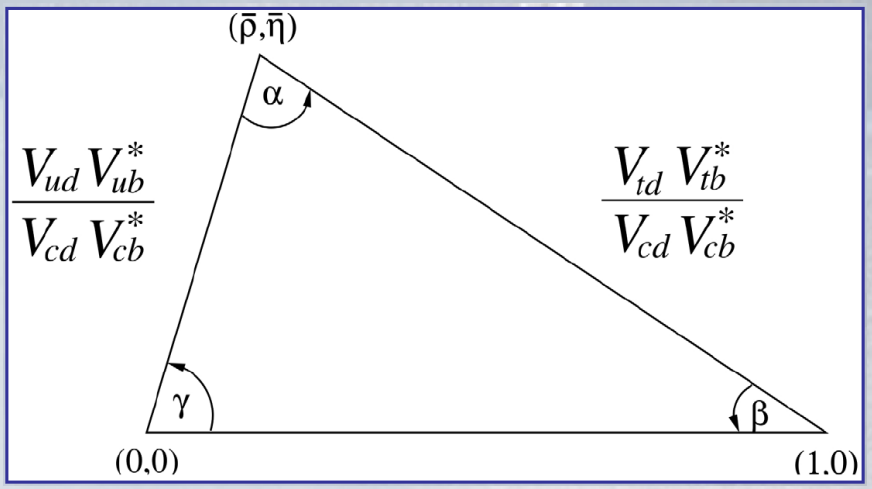
The CKM global fit

- Highly predictive structure of the CKM mechanism
  - specific correlation patterns among observables
  - overconstraining the Unitarity Triange (UT) sides and angles
    - provides a stringent test of the SM
  - if deviations from CKM are established …
    - unambiguous sign of non-SM physics !
    - patterns may provide hints about New Physics at play

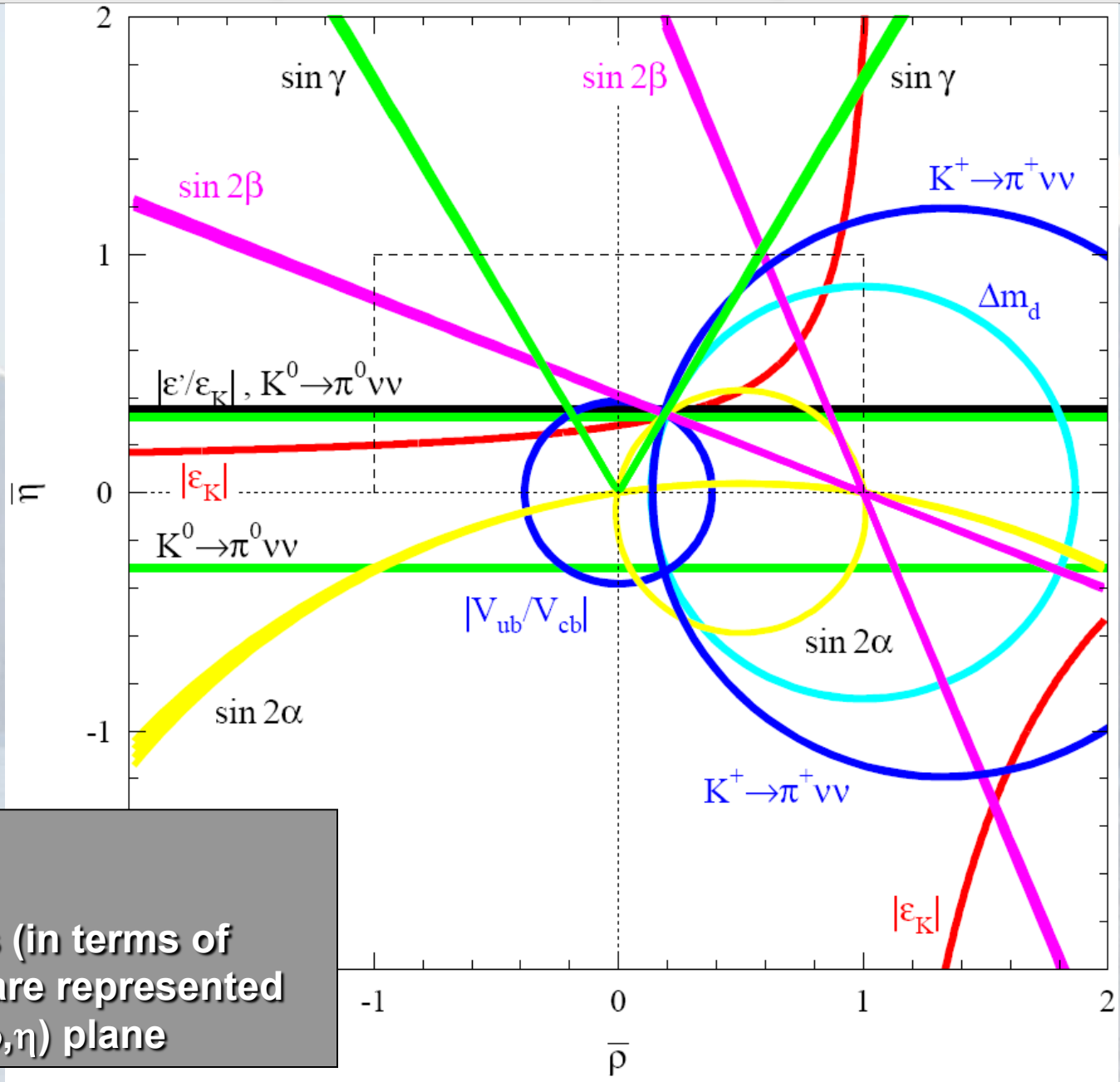
V_{CKM} Unitarity:

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$

Standard Model :
CP violation ↔ non-flat UT



(over-)constraining the Unitarity Triangle



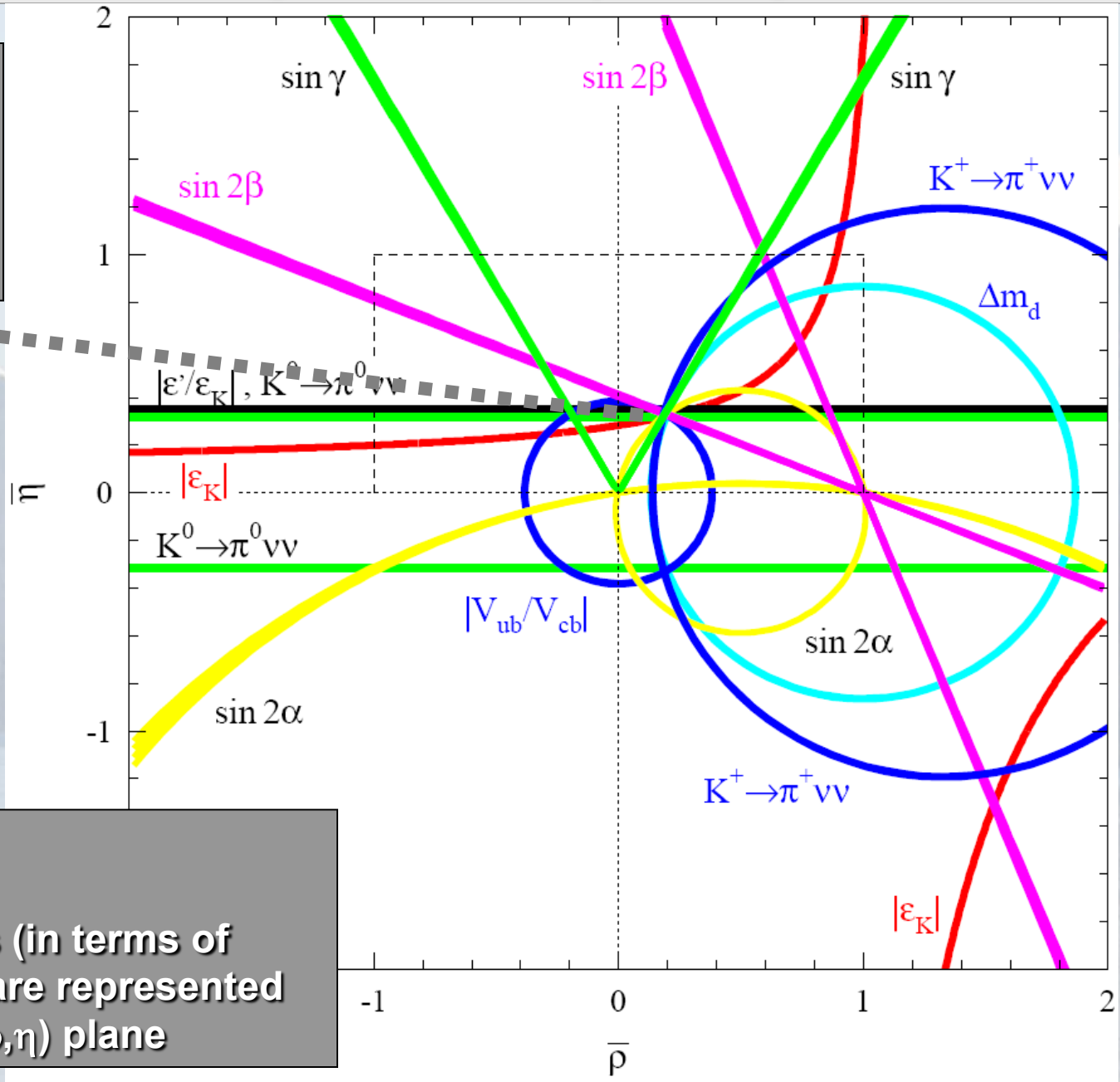
For all observables :

theoretical expressions (in terms of CKM matrix elements) are represented as constraints on the (ρ,η) plane

(over-)constraining the Unitarity Triangle

CKM predicts:

all constraints should overlap in a single point !



For all observables :

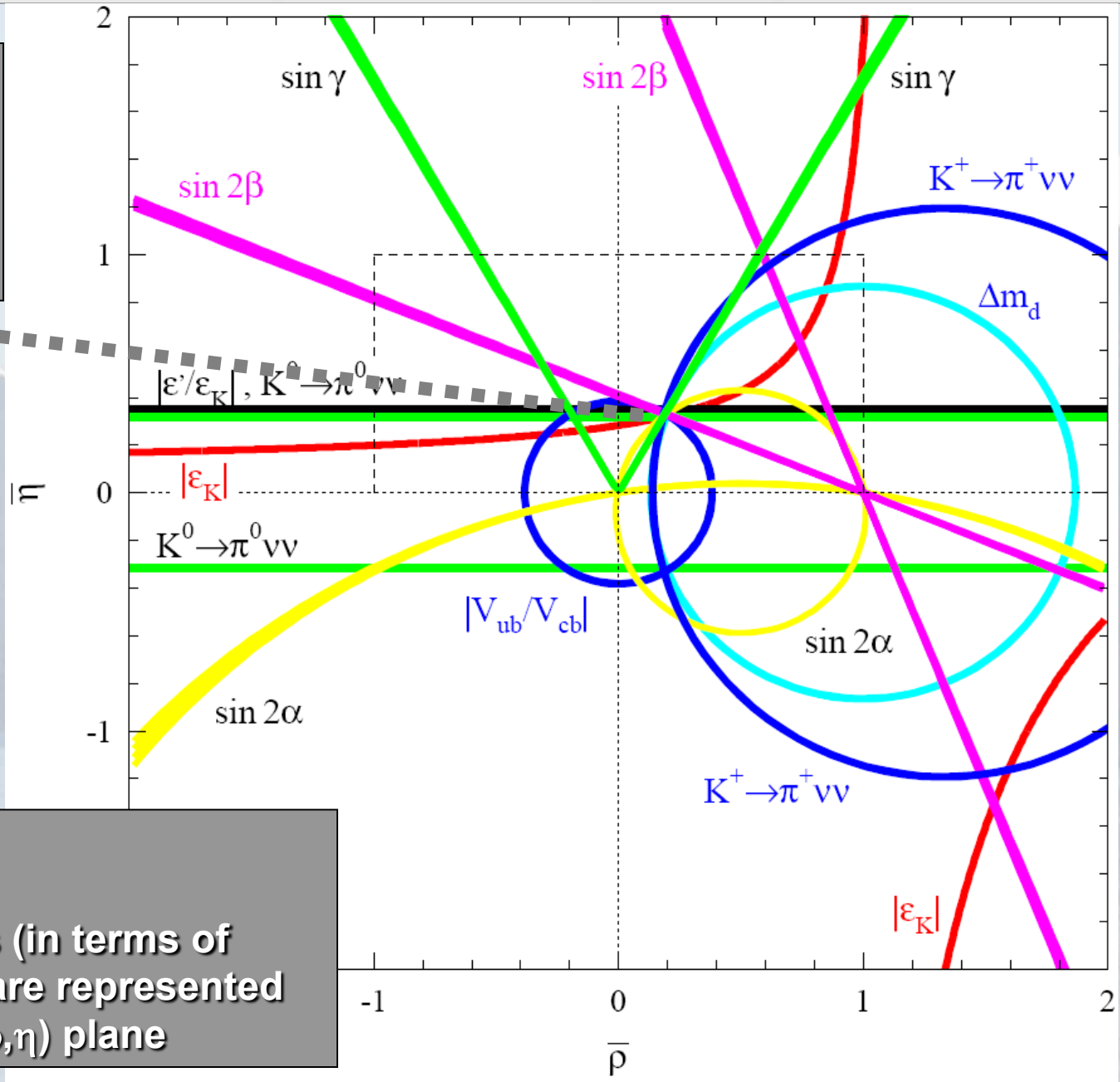
theoretical expressions (in terms of CKM matrix elements) are represented as constraints on the (ρ,η) plane

(over-)constraining the Unitarity Triangle

CKM predicts:

all constraints should overlap in a single point !

(otherwise, something's going wrong with CKM…)

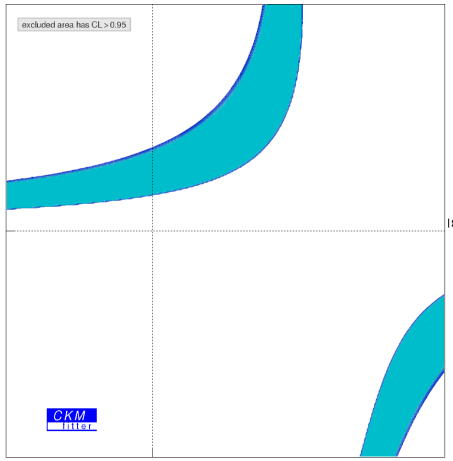


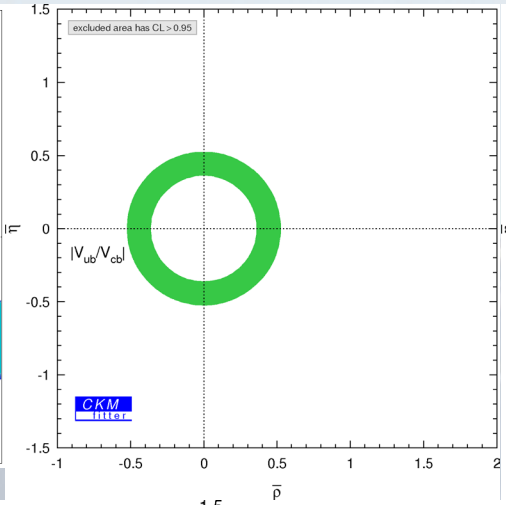
For all observables :

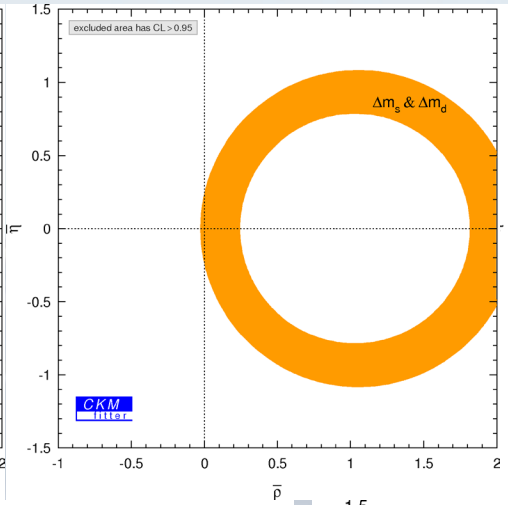
theoretical expressions (in terms of CKM matrix elements) are represented as constraints on the (ρ,η) plane

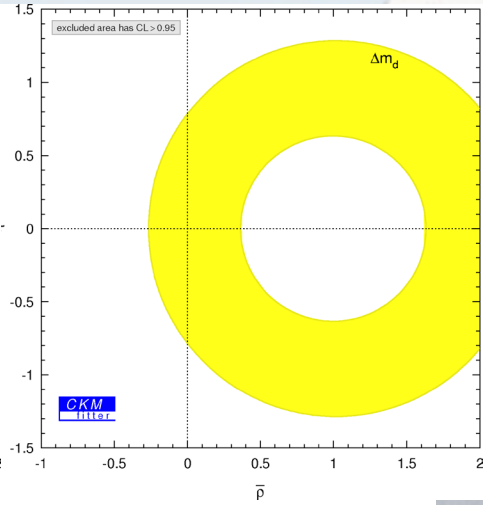
(over-)constraining the Unitarity Triangle

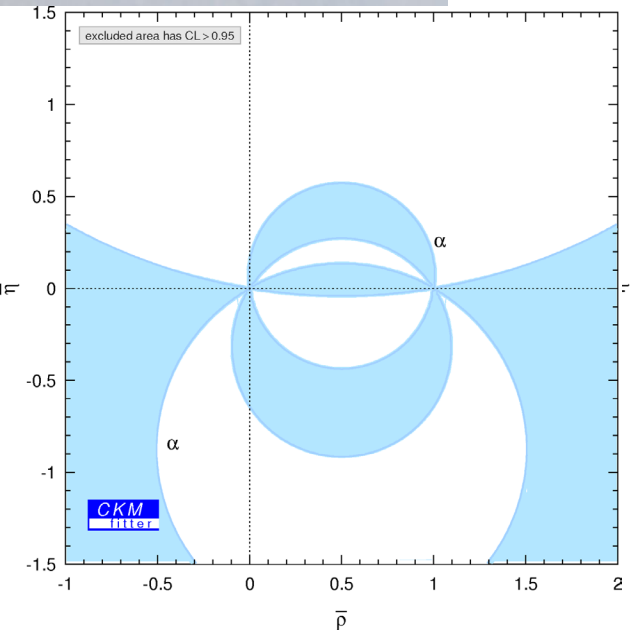
Use all available information …

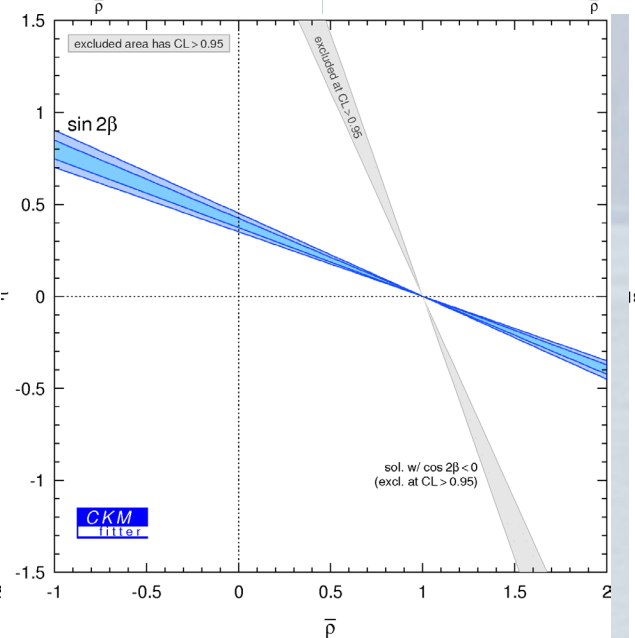


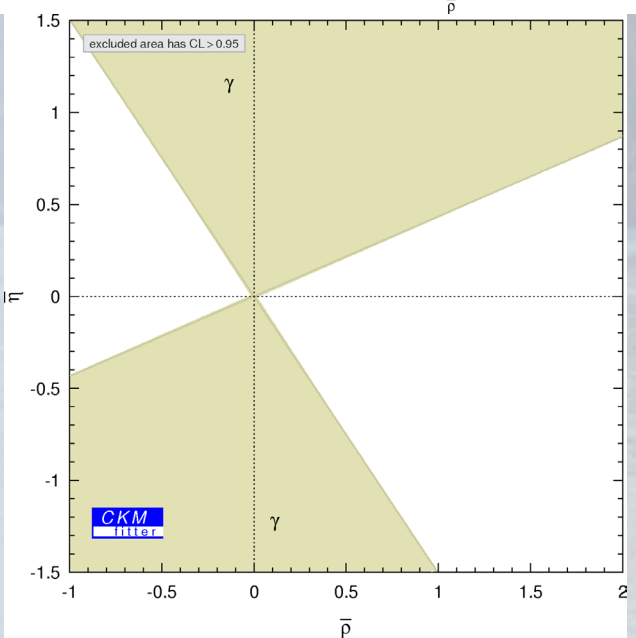






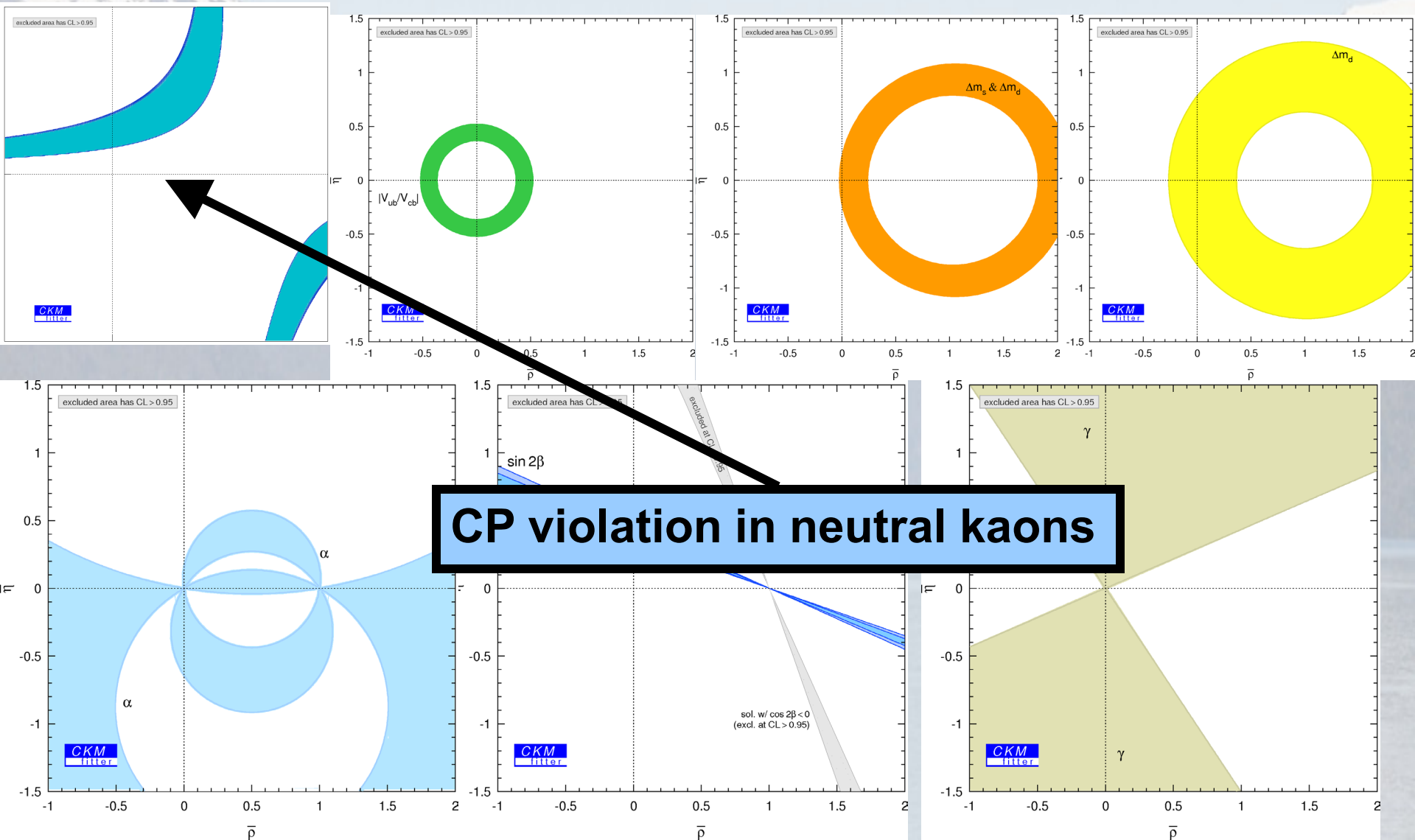






(over-)constraining the Unitarity Triangle

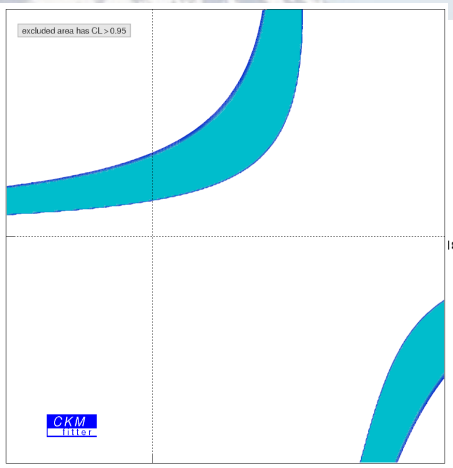
Use all available information …

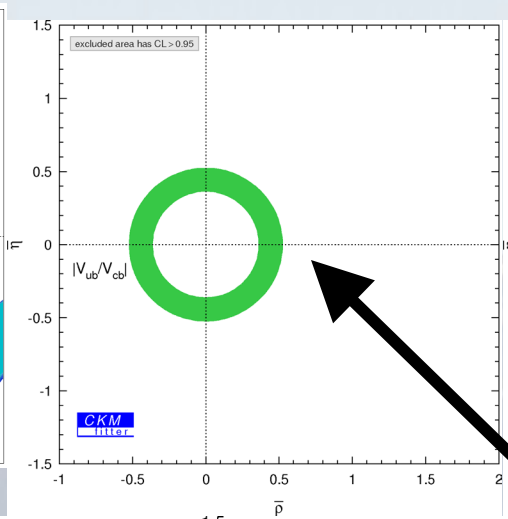


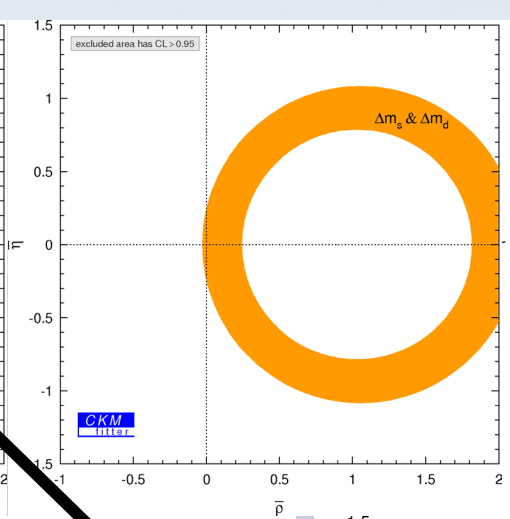
CP violation in neutral kaons

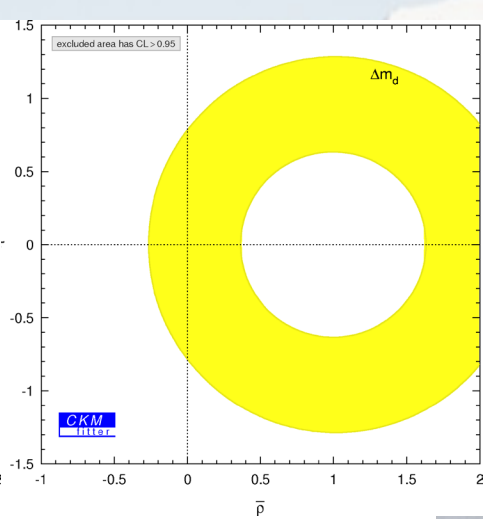
(over-)constraining the Unitarity Triangle

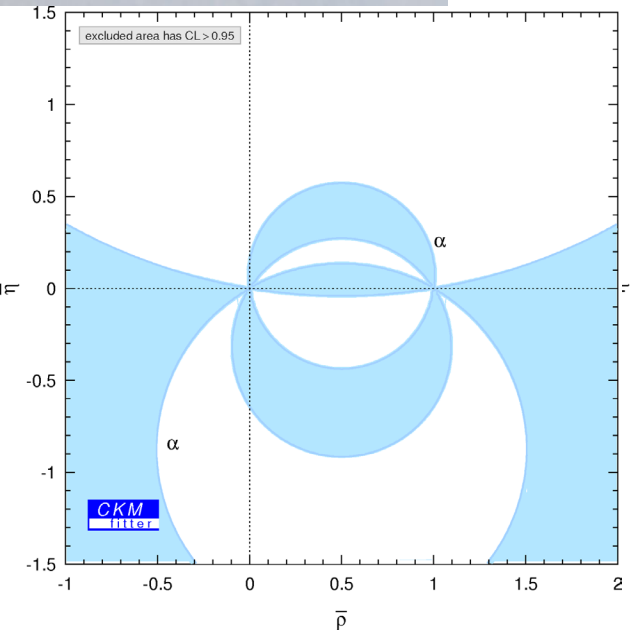
Use all available information …

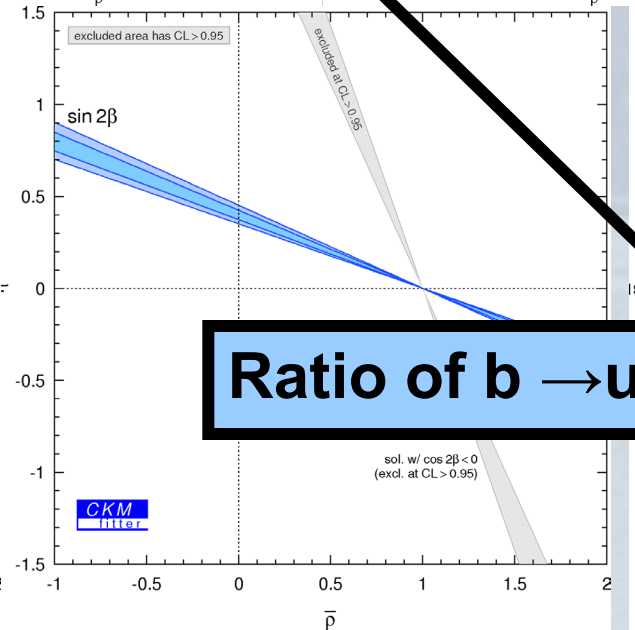


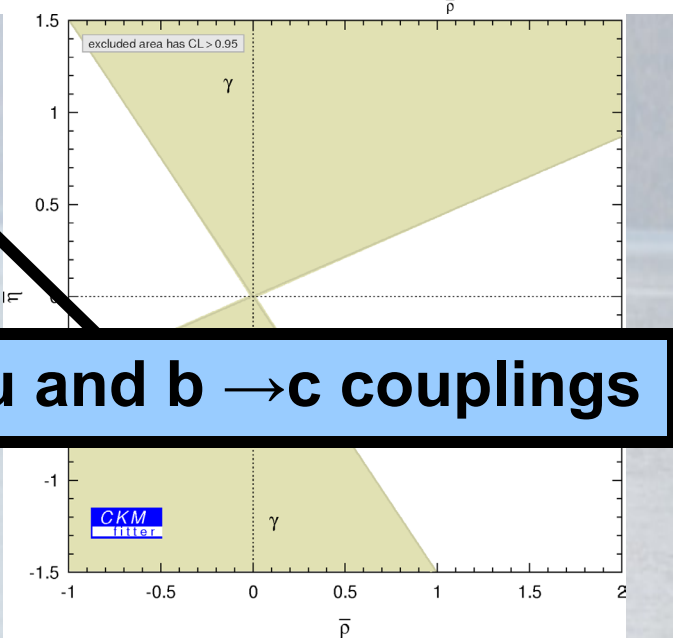








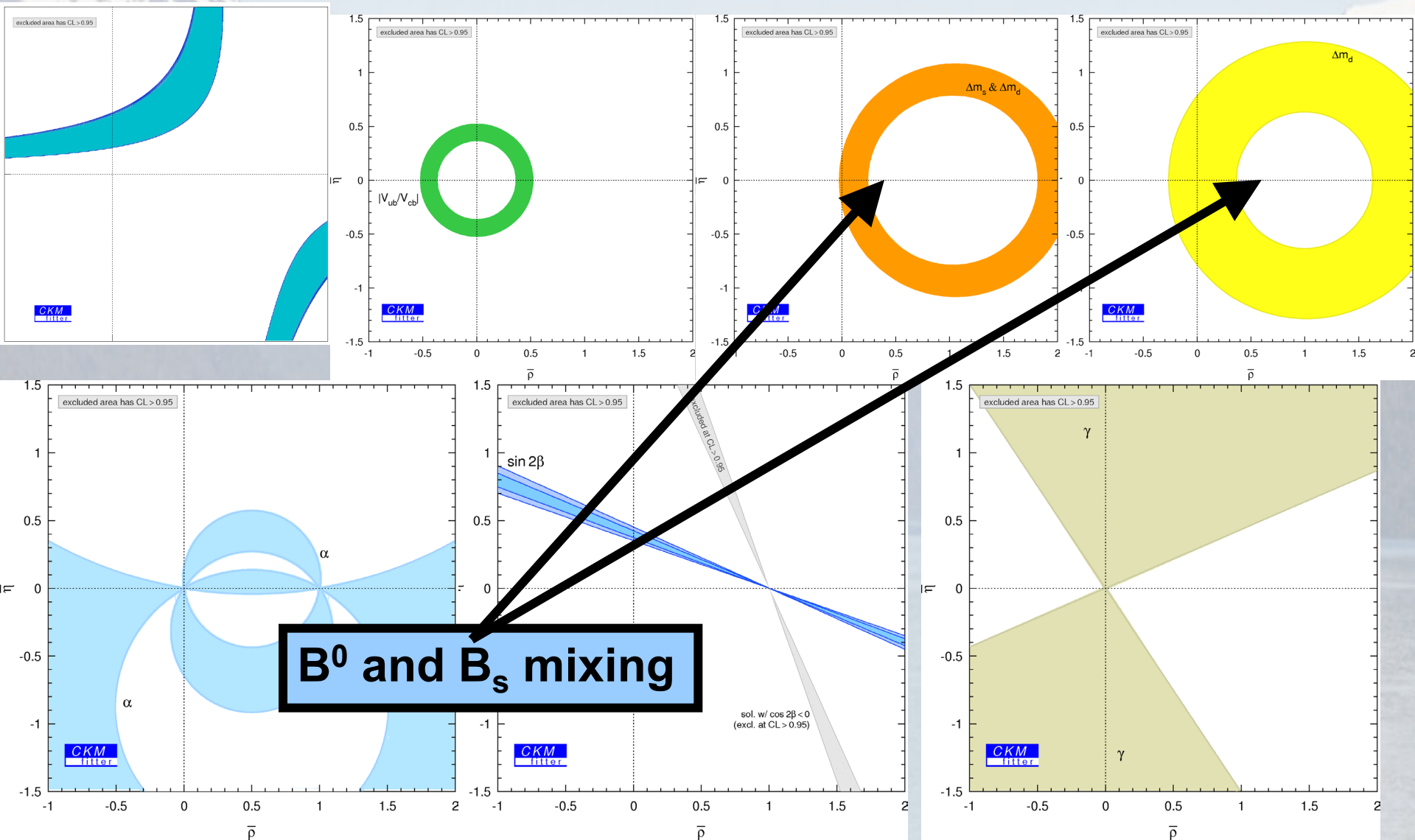




Ratio of b →u and b →c couplings

(over-)constraining the Unitarity Triangle

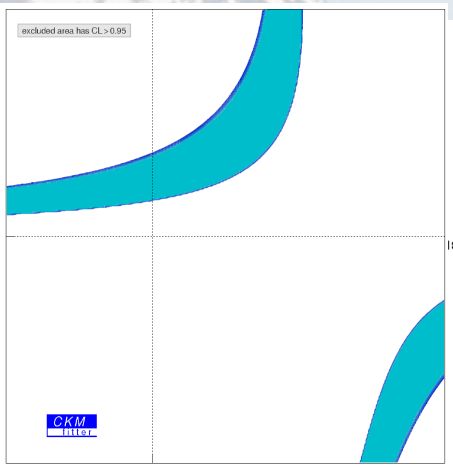
Use all available information …

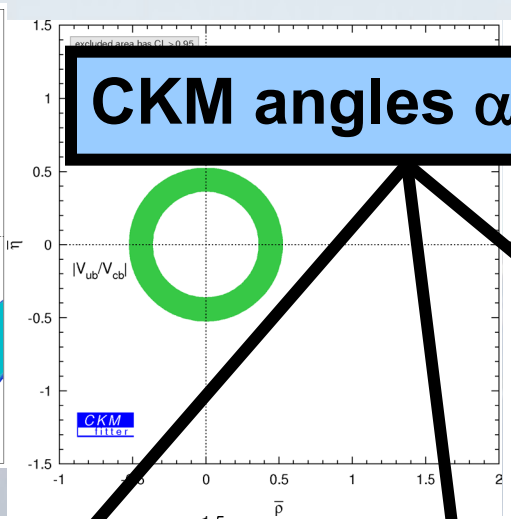


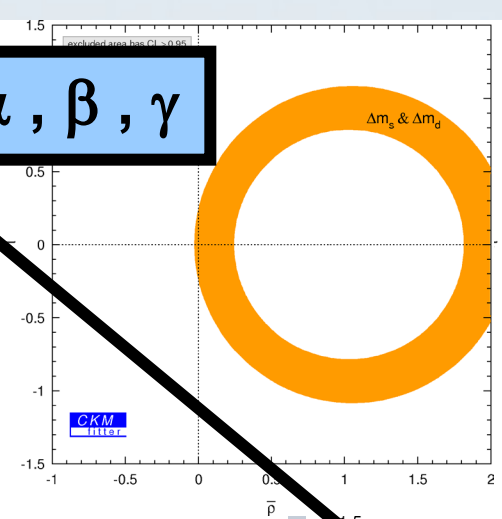
B^0 and B_s mixing

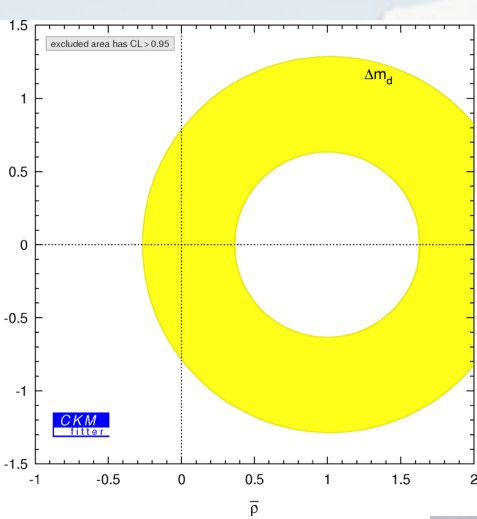
(over-)constraining the Unitarity Triangle

Use all available information …

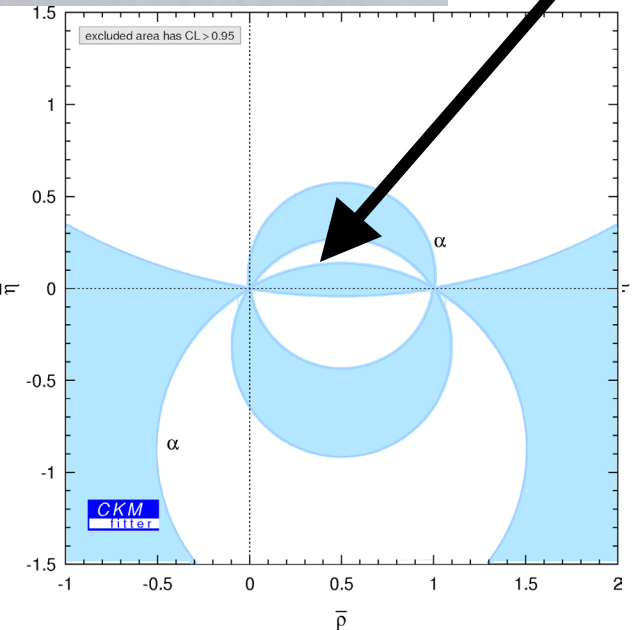


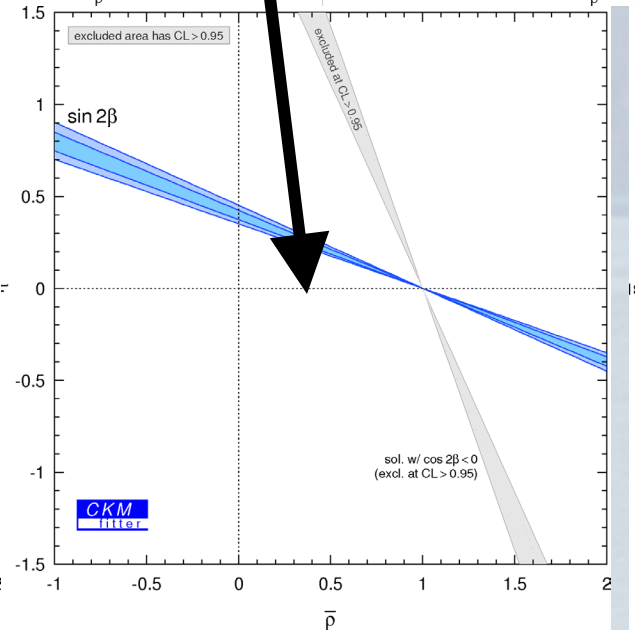


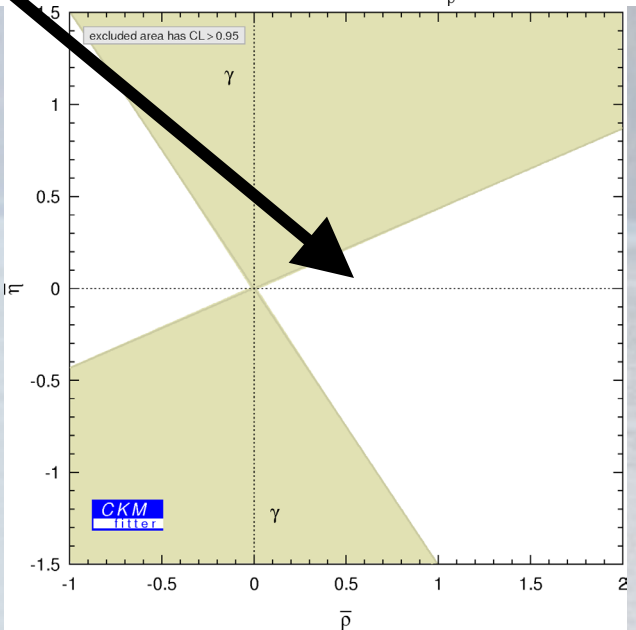




CKM angles α , β , γ

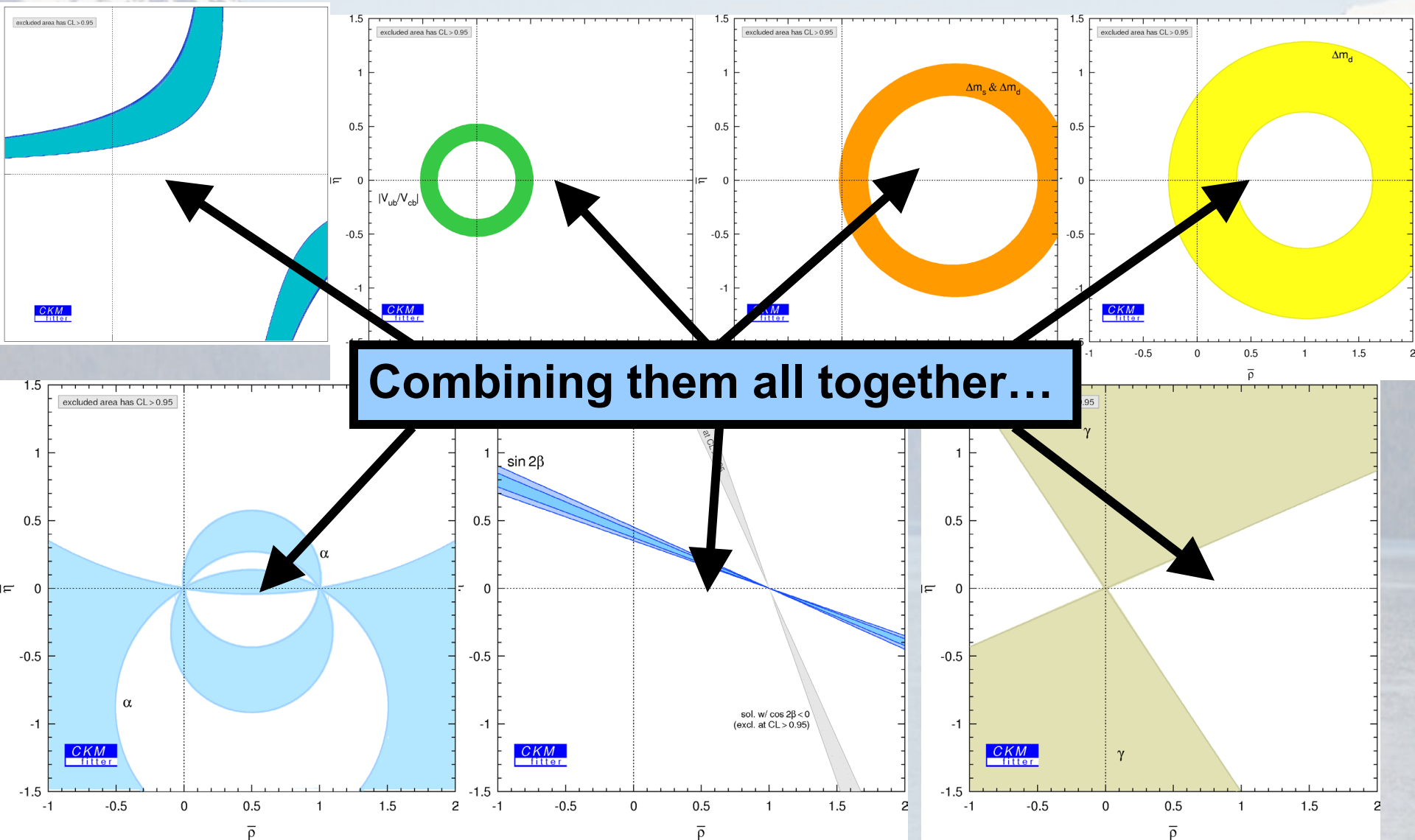






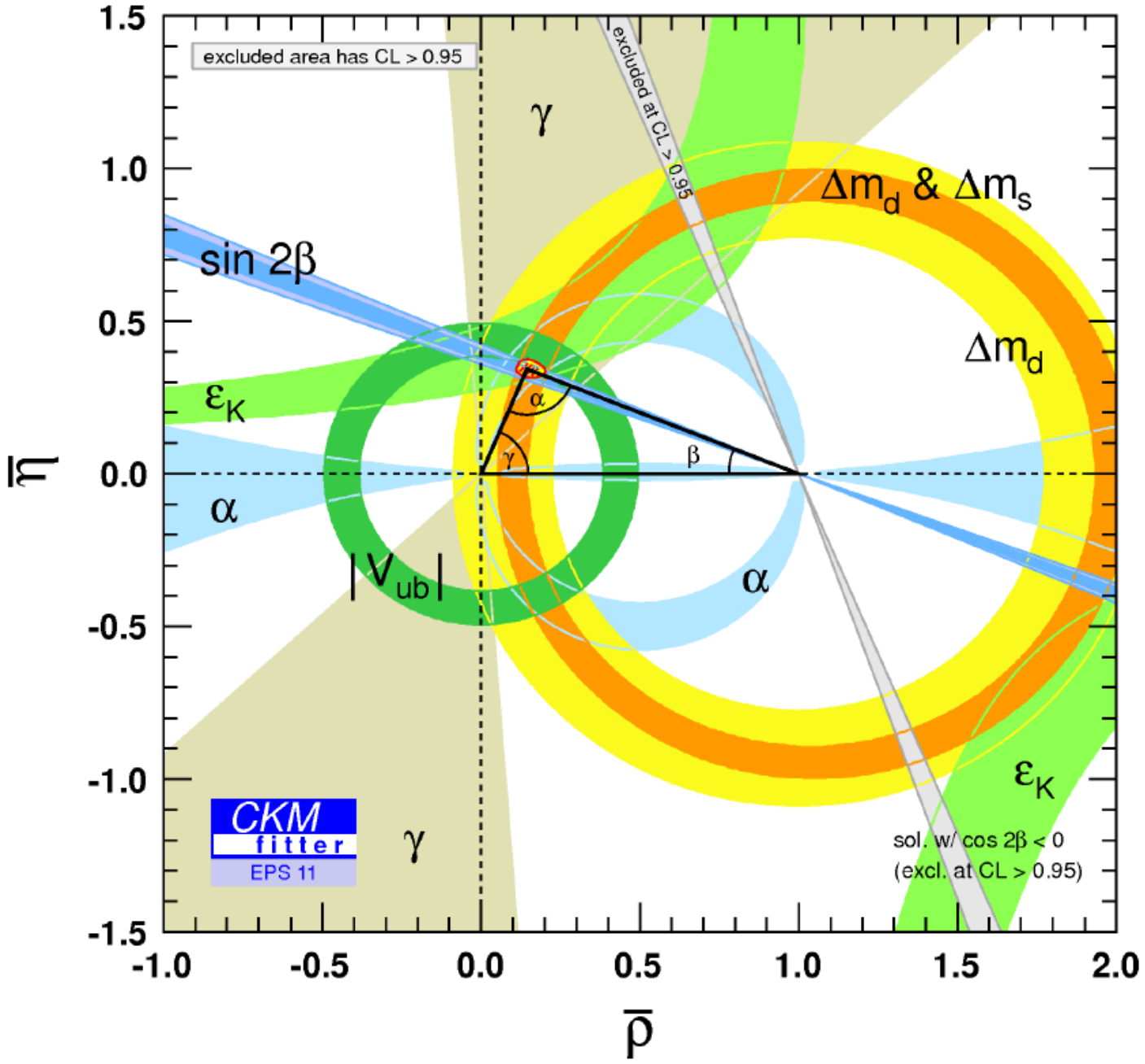
(over-)constraining the Unitarity Triangle

Use all available information …



Combining them all together…

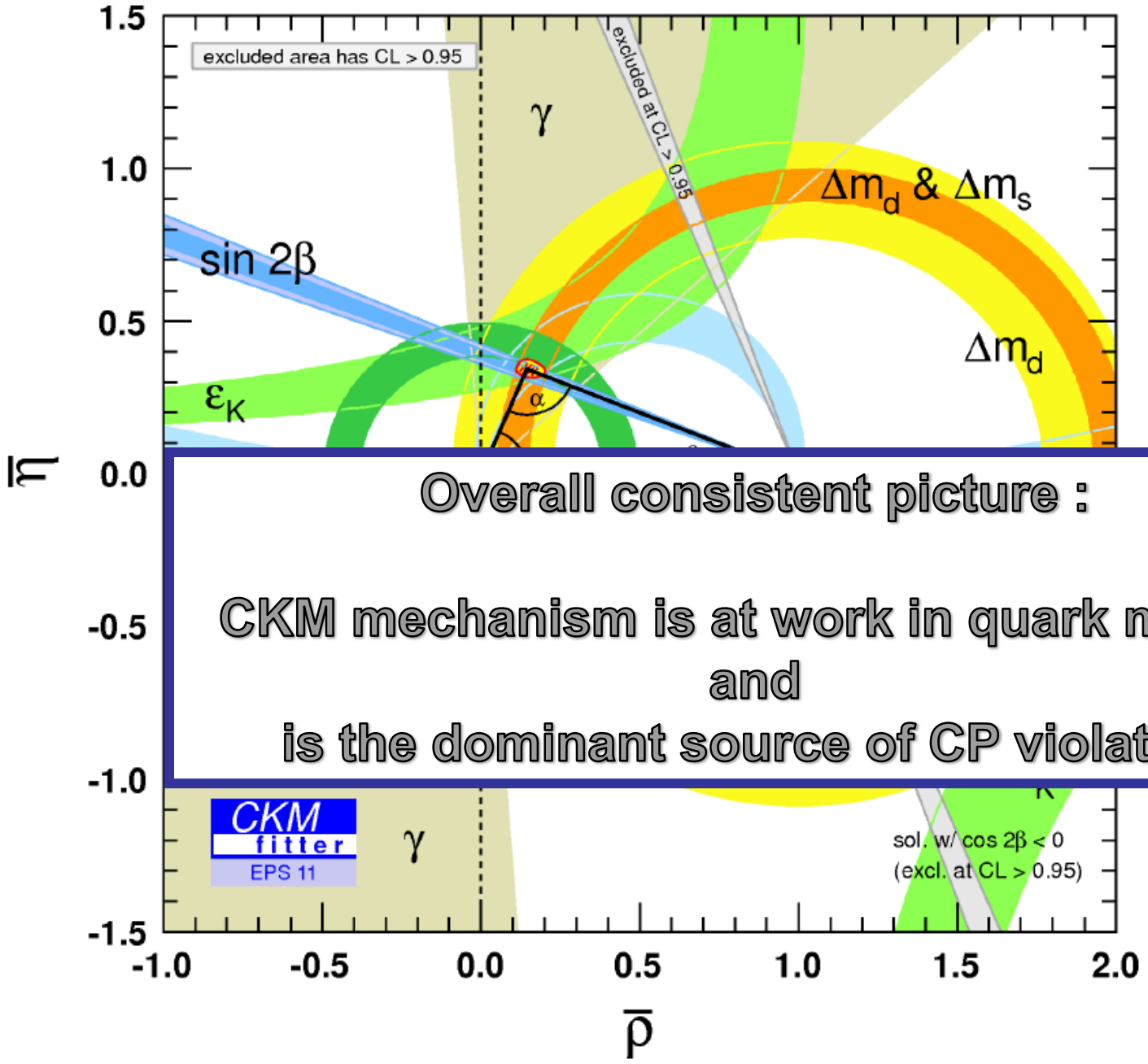
The global CKM fit as of Summer 2011



$|V_{ud}|$, $|V_{us}|$
$|V_{cb}|$, $|V_{ub}|$
$B \to \tau\nu$
Δm_d, Δm_s
ϵ_K
$\sin 2\beta$
α
γ

Fit of UT apex is dominated by **sin(2β)**, **$\Delta m_d/\Delta m_s$** and **α**. Excellent agreement between these 3 inputs.

The global CKM fit as of Summer 2011



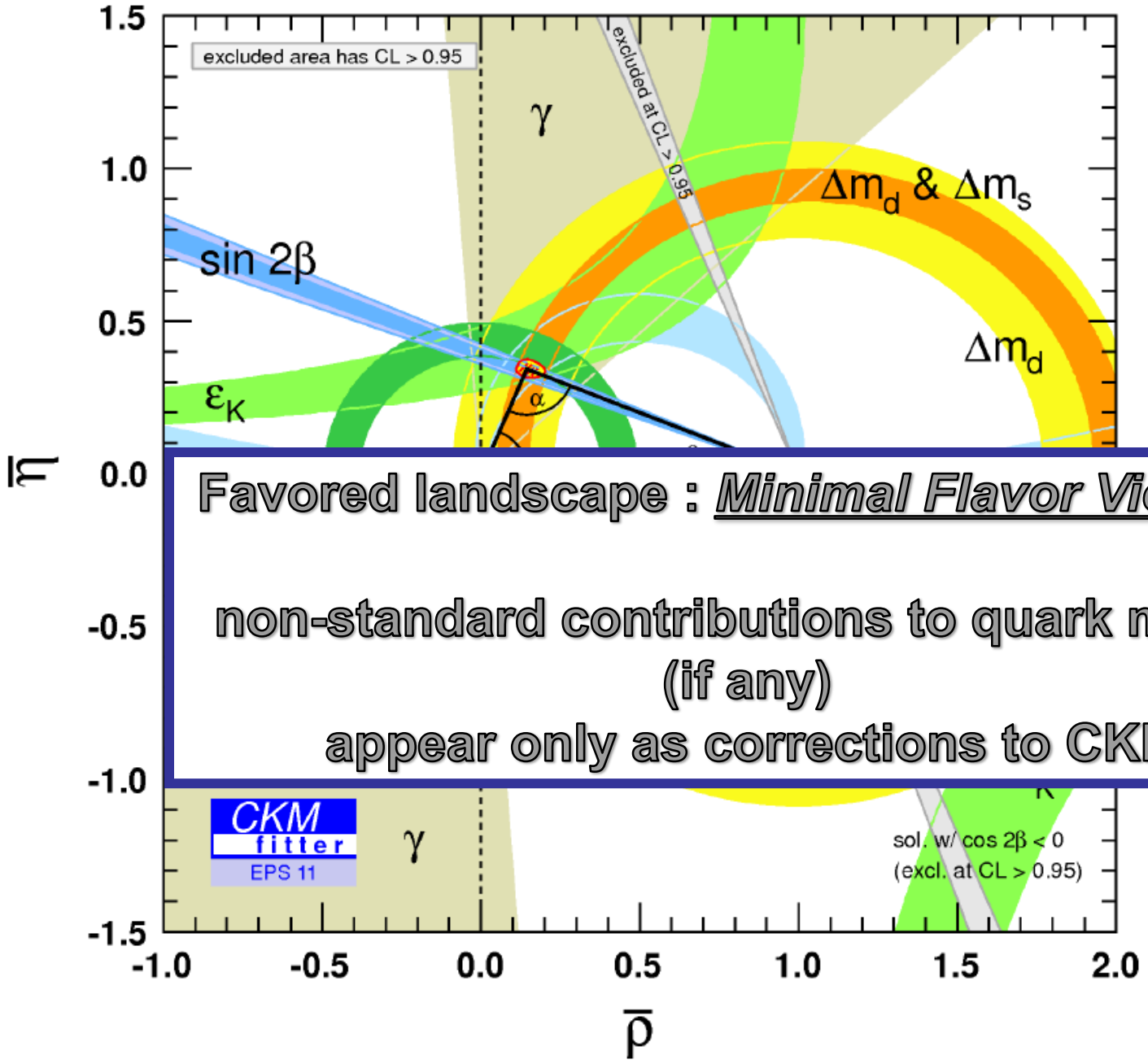
$|V_{ud}|$, $|V_{us}|$
$|V_{cb}|$, $|V_{ub}|$
$B \to \tau\nu$
Δm_d, Δm_s
ϵ_K
$\sin 2\beta$
α
γ

Overall consistent picture :

CKM mechanism is at work in quark mixing and is the dominant source of CP violation

T apex is dominated by **sin(2β)**, **$\Delta m_d/\Delta m_s$** and **α**. Excellent agreement between these 3 inputs.

The global CKM fit as of Summer 2011



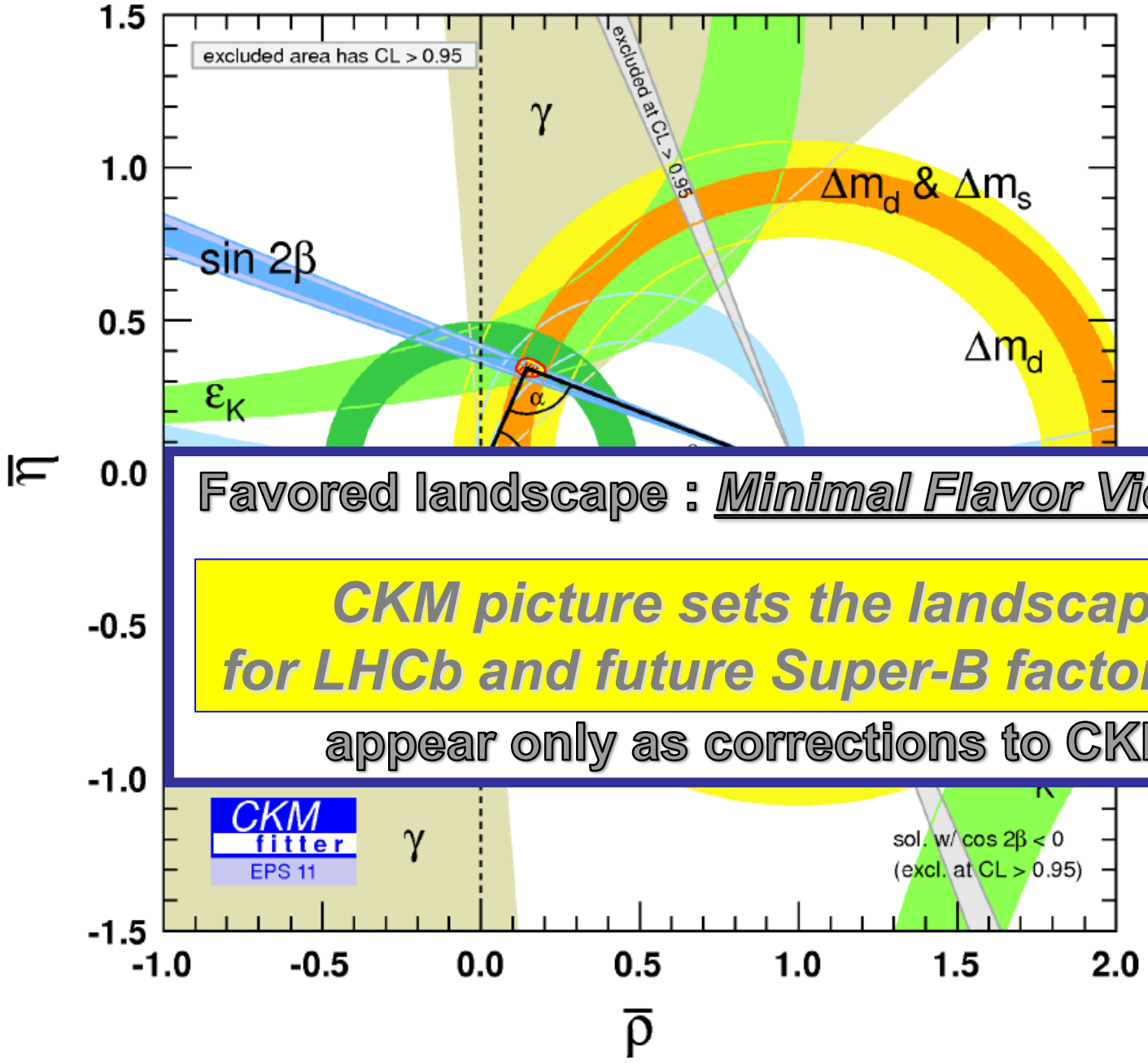
$|V_{ud}|$, $|V_{us}|$
$|V_{cb}|$, $|V_{ub}|$
$B \to \tau\nu$
Δm_d, Δm_s
ϵ_K
$\sin 2\beta$
α
γ

Favored landscape : *Minimal Flavor Violation*

non-standard contributions to quark mixing (if any) appear only as corrections to CKM

T apex is dominated by **sin(2β)**, **$\Delta m_d/\Delta m_s$** and **α**. Excellent agreement between these 3 inputs.

The global CKM fit as of Summer 2011



$|V_{ud}|$, $|V_{us}|$
$|V_{cb}|$, $|V_{ub}|$
$B \to \tau\nu$
Δm_d, Δm_s
ϵ_K
$\sin 2\beta$
α
γ

Favored landscape : *Minimal Flavor Violation*

CKM picture sets the landscape for LHCb and future Super-B factor(ies)

appear only as corrections to CKM

T apex is dominated by **sin(2β)**, **$\Delta m_d/\Delta m_s$** and **α**. Excellent agreement between these 3 inputs.

LPNHE and CKMfitter

The CKMfitter Group

Jérôme Charles	Theory	CPT Marseille (France)
Olivier Deschamps	LHCb	LPC Clermont-Ferrand (France)
Sébastien Descotes-Genon	Theory	LPT Orsay (France)
Ryosuke Itoh	Belle/BelleII	KEK Tsukuba (Japan)
Heiko Lacker	ATLAS/BABAR	Humboldt-Universität Berlin (Germany)
Andreas Menzel	ATLAS	Humboldt-Universität Berlin (Germany)
Stéphane Monteil	LHCb	LPC Clermont-Ferrand (France)
Valentin Niess	LHCb	LPC Clermont-Ferrand (France)
José Ocariz	ATLAS/BABAR	LPNHE Paris (France)
Jean Orloff	Theory	LPC Clermont-Ferrand (France)
Fabian Spettel	ATLAS	Humboldt-Universität Berlin (Germany)
Stéphane T'Jampens	LHCb	LAPP Annecy-Le-Vieux (France)
Vincent Tisserand	LHCb/BABAR	LAPP Annecy-Le-Vieux (France)
Karim Trabelsi	Belle/BelleII	KEK Tsukuba (Japan)

<u>Group composition :</u>

Experimentalists
(B-factories, LHC expt's)

Theorists
(in increasing number)

Mostly french people
(but not only)

One person from LPNHE
(yours truly)

LPNHE and CKMfitter

Former Members:

Francois R. Le Diberder	BABAR	LAL Orsay (France)
Andreas Höcker	ATLAS	CERN Geneva (Switzerland)
Sandrine Laplace	ATLAS	LAPP Annecy-Le-Vieux (France)
Guillaume Therin	BABAR	LPNHE Paris (France)
Lydia Roos	BABAR	LPNHE Paris (France)
Christian Kaufhold	Theory	LAPP Annecy-Le-Vieux (France)
Muriel Pivk	LHCb	CERN Geneva (Switzerland)
Julie Malcles	BABAR	LPNHE Paris (France)
Stéphane Pruvot	BABAR	LAL Orsay (France)
Arnaud Robert	LHCb	LPC Clermont-Ferrand (France)
Andreas Jantsch	ATLAS	MPI Munich (Germany)

In the past :

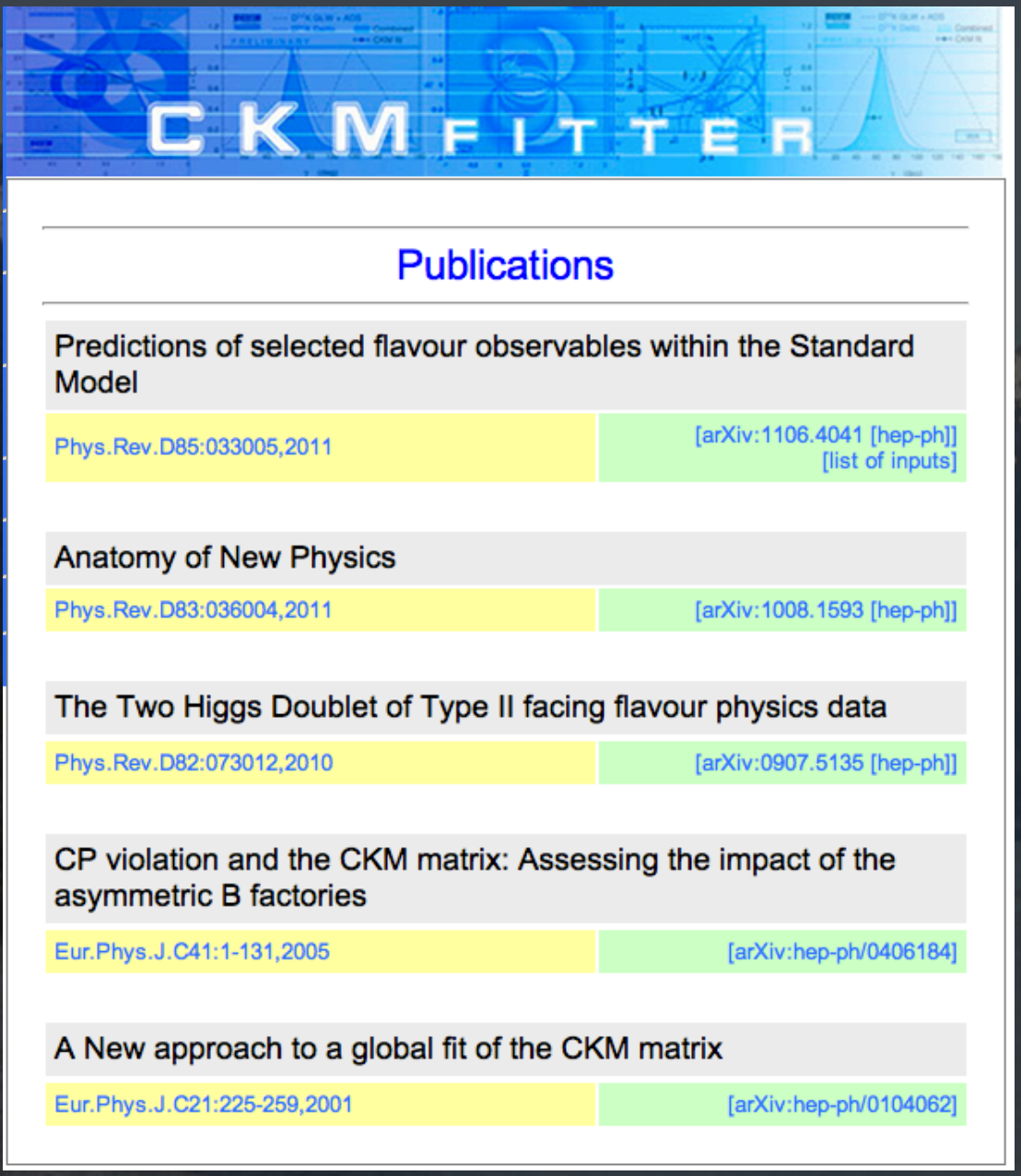
Several contributors from LPNHE

… some are now at LPNHE !

A few *BaBar* PhD students performed phenomenology studies during their thesis (including a few well-valued publications out of the large experimental collaborations)

… plus several stagiaires, or “outsider” CKMfitter users…

Scientific production



5 publications in refereed journals

Including one TOPCITE=500+

Many talks in conferences

We often struggle to fit requests…

(6 conference talks for me)

Scientific production

CP violation and the CKM matrix: Assessing the impact of the asymmetric B factories - HEP

http://inspirebeta.net/record/652597?ln=en#

Welcome to INSPIRE β: the upgrade of SPIRES
We now recommend that you use this site instead of SPIRES
Please send feedback on INSPIRE to feedback@inspirebeta.net

HEP :: INST :: HELP ..::.. SPIRES HEPNAMES :: CONF :: EXP :: JOBS

Information | References (301) | Citations (799) | Files | Plots

CP violation and the CKM matrix: Assessing the impact of the asymmetric $\mathcal{B}$ factories.

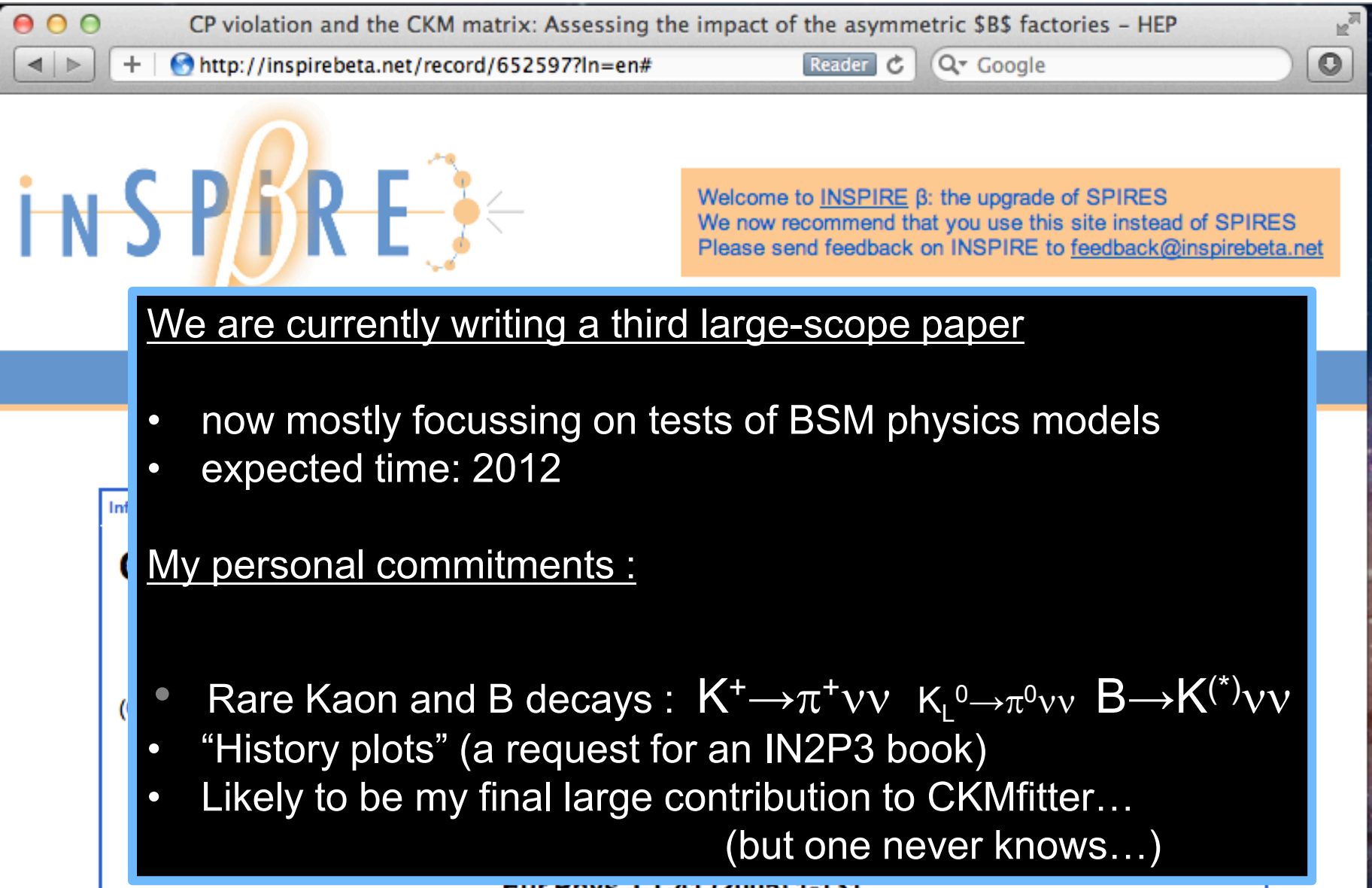
CKMfitter Group Collaboration (J. Charles (Marseille, CPT & Sud Toulon Var U.) , Andreas Hocker (Orsay, LAL), H. Lacker (Dresden, Tech. U.), S. Laplace (Annecy, LAPP), F.R. Le Diberder (Orsay, LAL), J. Malcles, J. Ocariz (Paris U., VI-VII), M. Pivk (CERN), L. Roos (Paris U., VI-VII)) Hide.

CPT-2004-P-030, LAL-04-21, LAPP-EXP-2004-01, LPNHE-2004-01.
Jun 2004
176 pp.

Eur.Phys.J. C41 (2005) 1-131
e-Print: **hep-ph/0406184**

Abstract: We update the profile of the CKM matrix. The apex (rhobar,etabar) of

Scientific production



We are currently writing a third large-scope paper

- now mostly focussing on tests of BSM physics models
- expected time: 2012

My personal commitments :

- Rare Kaon and B decays : $K^+ \to \pi^+ \nu\nu$ $K_L^0 \to \pi^0 \nu\nu$ $B \to K^{(*)} \nu\nu$
- "History plots" (a request for an IN2P3 book)
- Likely to be my final large contribution to CKMfitter…
  (but one never knows…)

A word on the rare kaon decay $K^+ \to \pi^+ \nu\bar{\nu}$

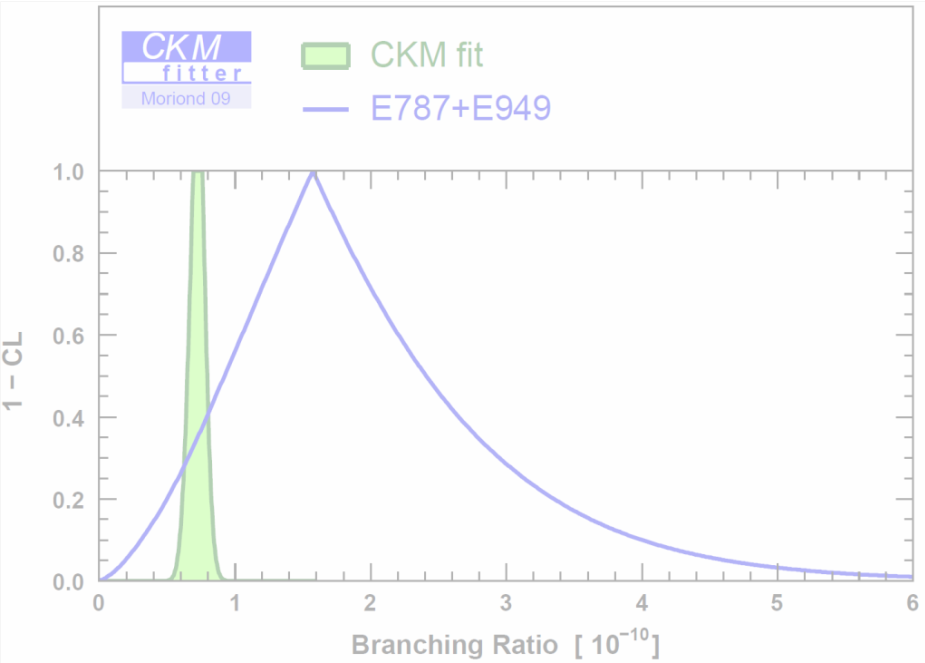
With contributions from R. Camacho

- Recent E949 update (arXiv:0903.0030 with 5 events (& incl. E787)):

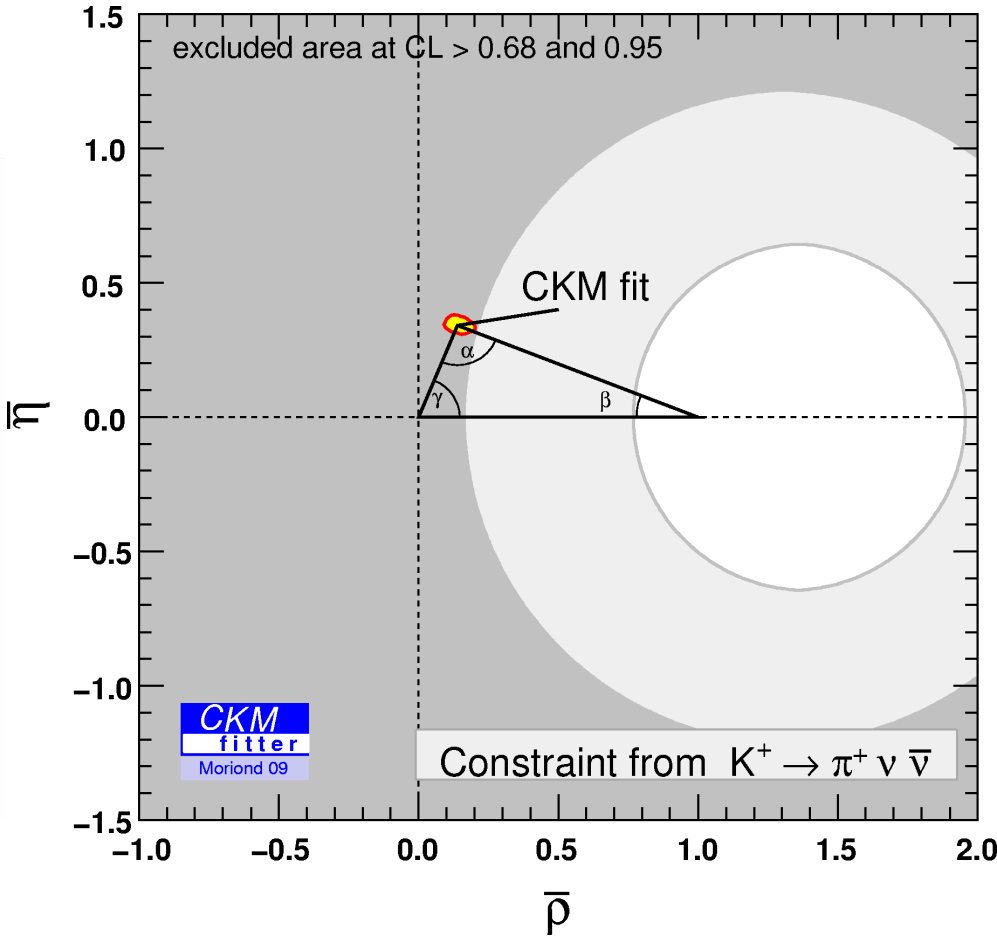
$$(1.73^{+1.15}_{-1.05}) \cdot 10^{-10}$$

- BR parameterization as Brod & Gorbahn '08 (PRD 78, 034006)
  NLO QED-QCD & EW corr. to the charm quark contribution
  $\alpha_s(m_Z)=0.1176(20)$ & $m_c(m_c)=1.286(13)(40)$

Charm term Pc(X) controlled at ~few %



$$(0.811^{+0.027}_{-0.021} \pm 0.096) \cdot 10^{-10}$$



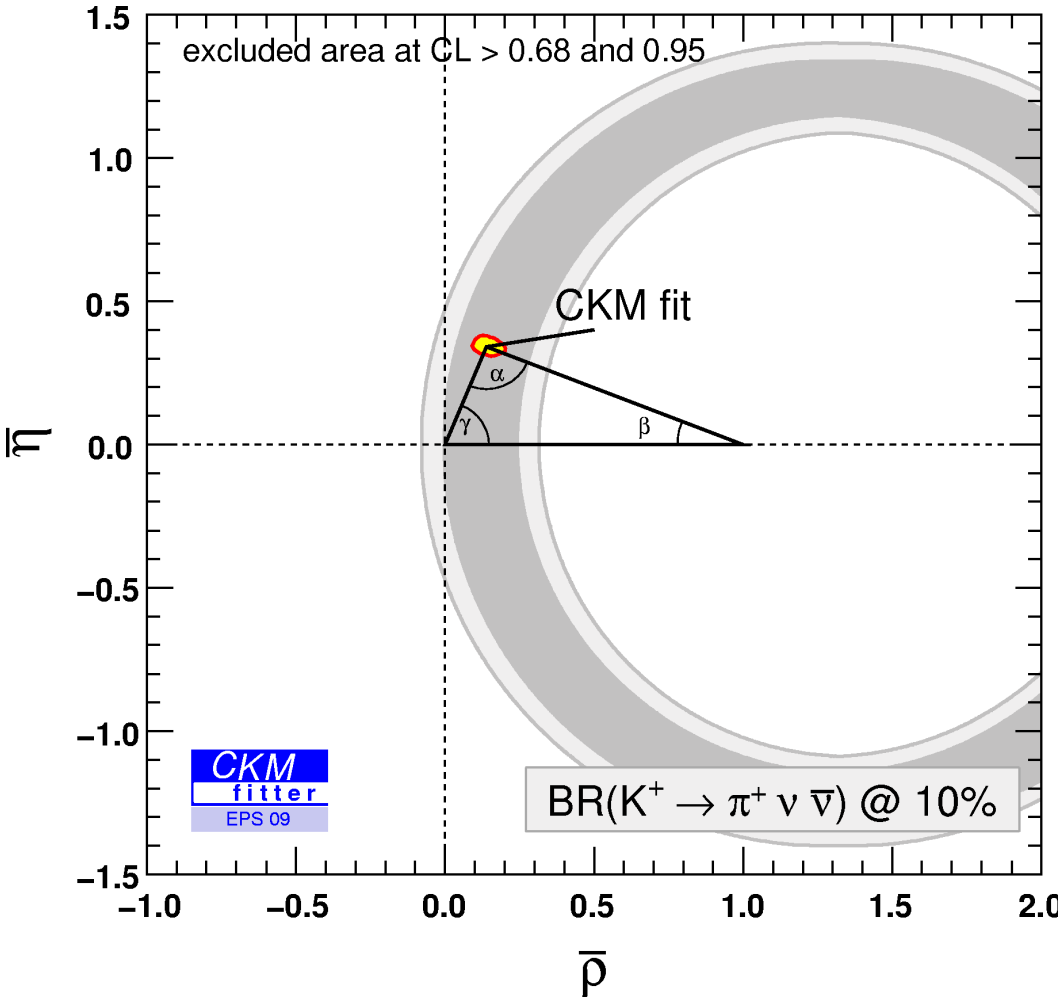
A word on the rare kaon decays $K^+ \to \pi^+ \nu\bar{\nu}$ and $K_L \to \pi^0 \nu\bar{\nu}$

- Recent E949 update (arXiv:0903.0030 with 5 events (& incl. E787)):

BR $[10^{-10}] = 1.73^{+1.15}_{-1.05}$

- BR parameterization as Brod & Gorbahn '08 (PRD 78, 034006)
  NLO QED-QCD & EW corr. to the charm quark contribution
  $\alpha_s(m_Z)=0.1176(20)$ & $m_c(m_c)=1.286(13)(40)$

Prospective study : assume
- **$K^+ \to \pi^+ \nu\nu$ measured by NA62 (~10%)**



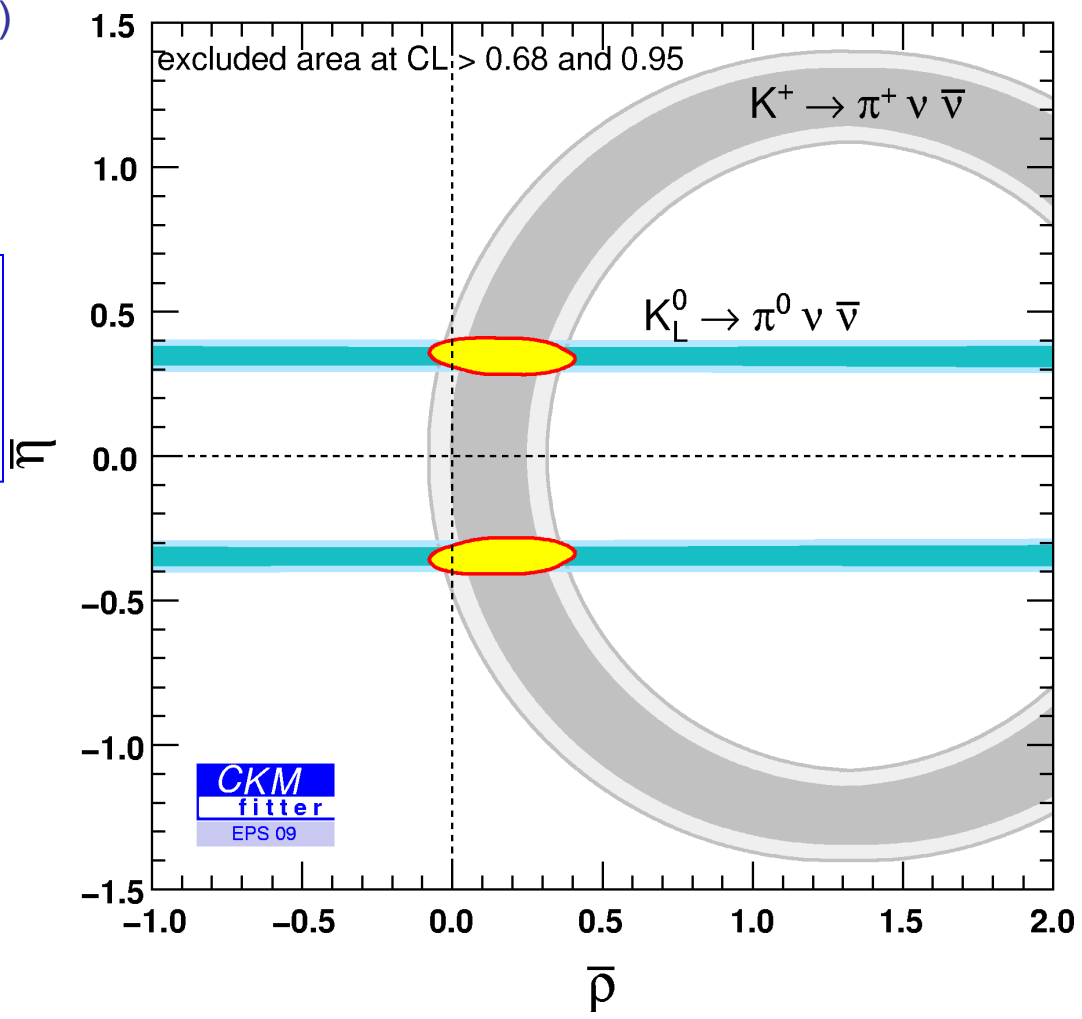
A word on the rare kaon decays $K^+ \to \pi^+ \nu\nu$ and $K_L \to \pi^0 \nu\nu$

- Recent E949 update (arXiv:0903.0030 with 5 events (& incl. E787)):

BR $[10^{-10}] = 1.73^{+1.15}_{-1.05}$

- BR parameterization as Brod & Gorbahn '08 (PRD 78, 034006)
  NLO QED-QCD & EW corr. to the charm quark contribution
  $\alpha_s(m_Z)=0.1176(20)$ & $m_c(m_c)=1.286(13)(40)$

Prospective study : assume
- **$K^+ \to \pi^+ \nu\nu$ measured by NA62 (~10%)**
- **$K_L \to \pi^0 \nu\nu$ measured by J-PARC (~15%)**



A word on the rare kaon decays $K^+ \to \pi^+ \nu\nu$ and $K_L \to \pi^0 \nu\nu$

- Recent E949 update (arXiv:0903.0030 with 5 events (& incl. E787)):

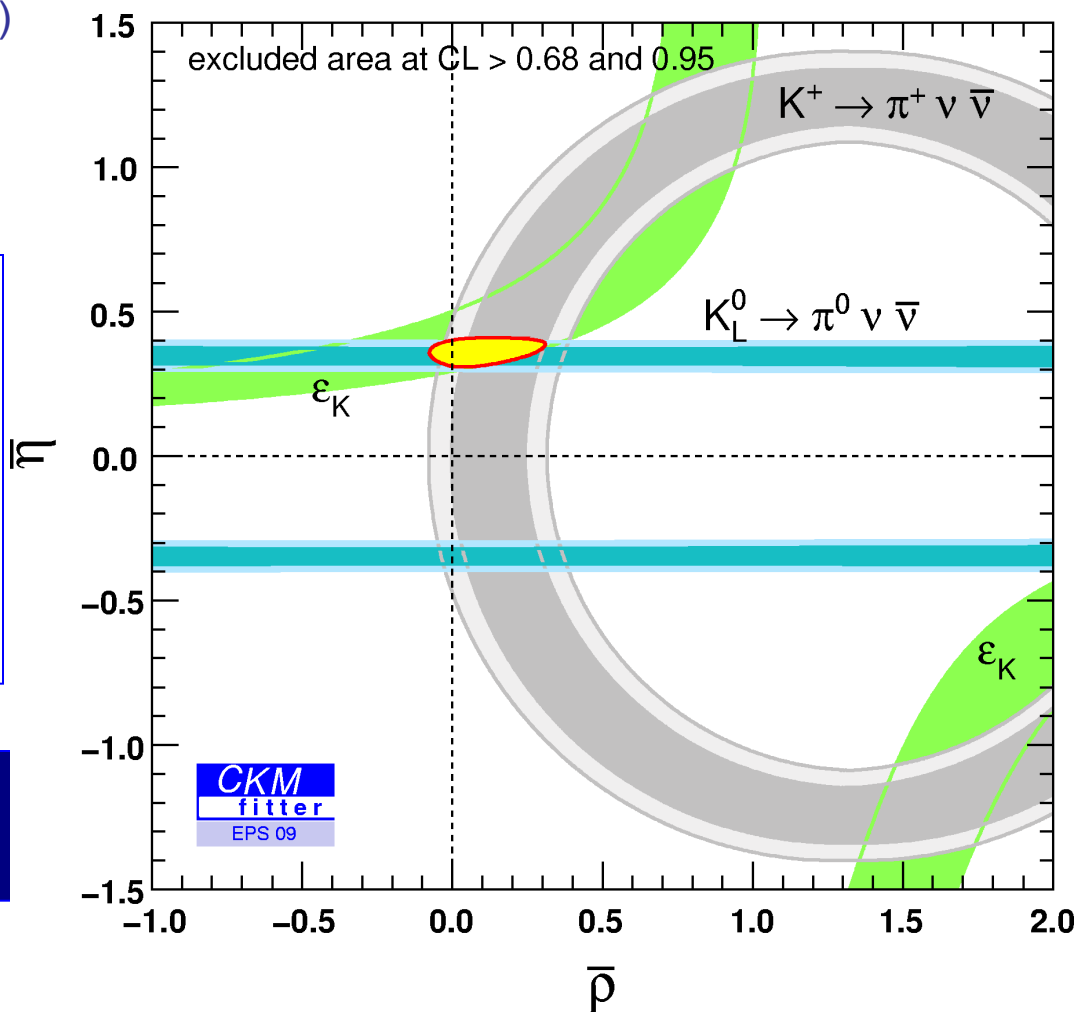
$$\mathbf{BR\ [10^{-10}] = 1.73^{+1.15}_{-1.05}}$$

- BR parameterization as Brod & Gorbahn '08 (PRD 78, 034006)
  NLO QED-QCD & EW corr. to the charm quark contribution
  $\alpha_s(m_Z)=0.1176(20)$ & $m_c(m_c)=1.286(13)(40)$

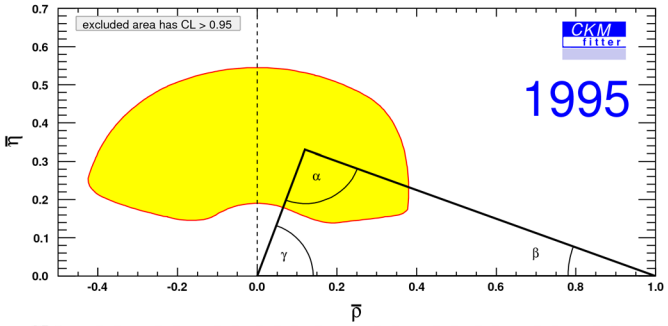
Prospective study : assume
- **$K^+ \to \pi^+ \nu\nu$ measured by NA62 (~10%)**
- **$K_L \to \pi^0 \nu\nu$ measured by J-PARC (~15%)**
- **Use ε_K (and ε'/ε ?) to lift ambiguities**

(pessimistic scenario: no improvement of theoretical errors)

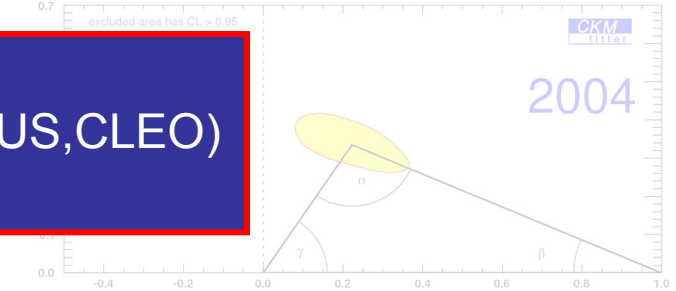
A strong constrain on the CKM matrix only using Kaon inputs



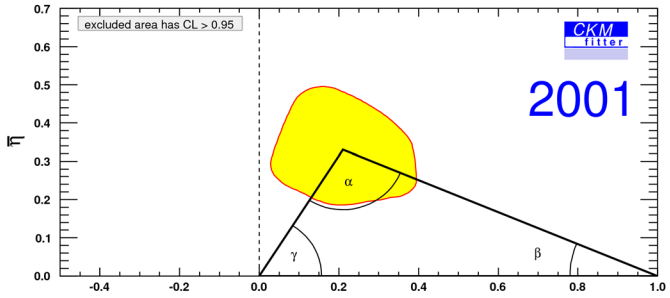
Final plots : a brief history of the CKM matrix

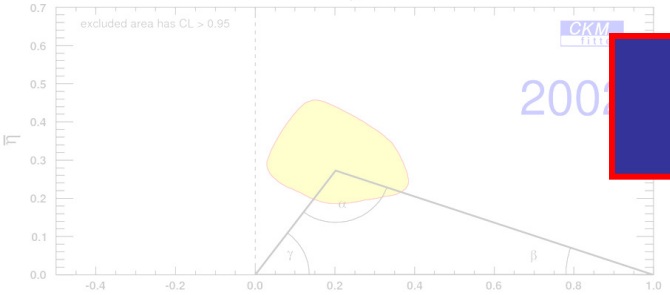


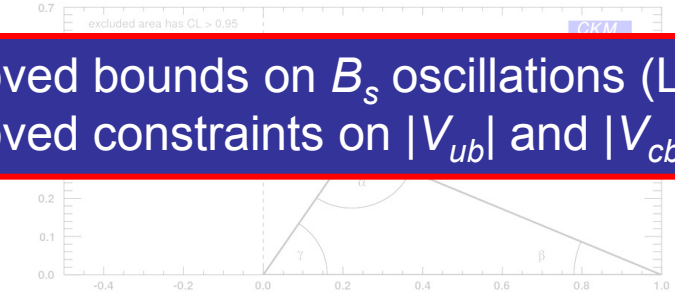
- Observation of top quark (CDF+D0)
- Evidences for exclusive $b \to u$ decays (ARGUS,CLEO)
- First limits on B_s mixing (ALEPH)



Final plots : a brief history of the CKM matrix

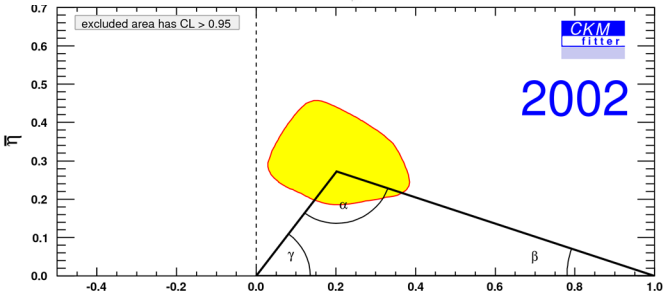


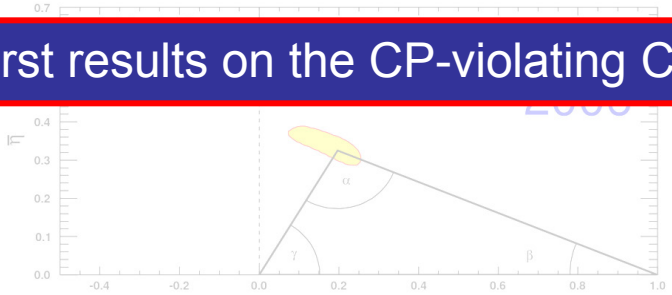


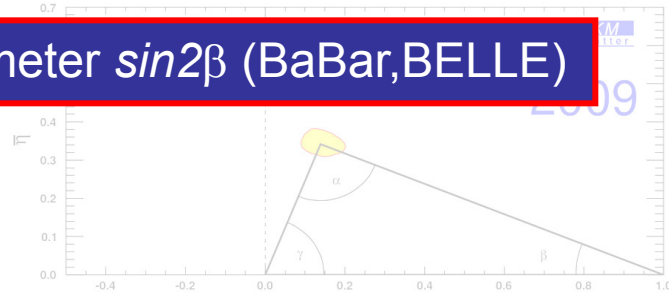


- Improved bounds on B_s oscillations (LEP)
- Improved constraints on $|V_{ub}|$ and $|V_{cb}|$ (LEP)

Final plots : a brief history of the CKM matrix

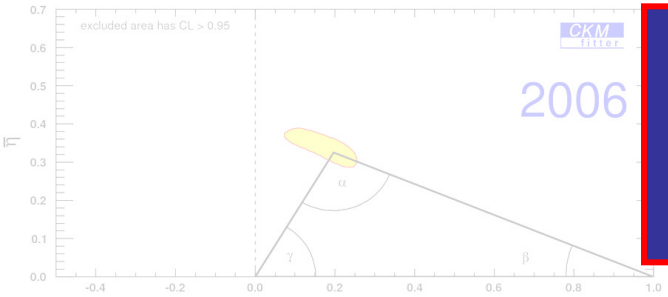


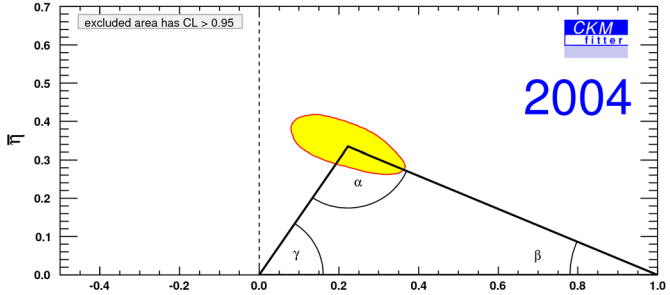




- First results on the CP-violating CKM parameter *sin2*β (BaBar,BELLE)

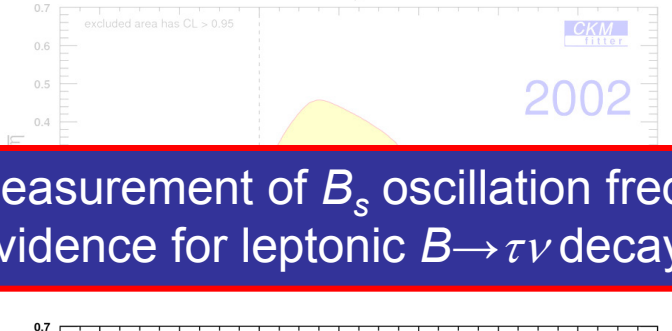
Final plots : a brief history of the CKM matrix

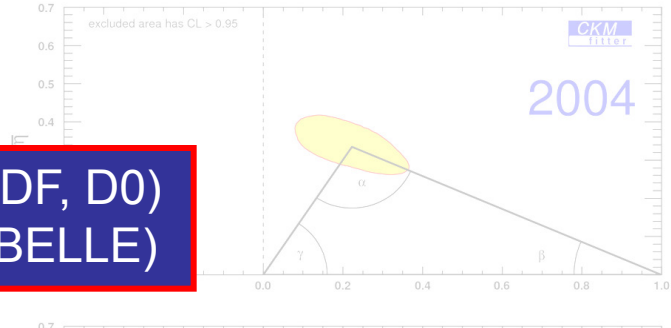




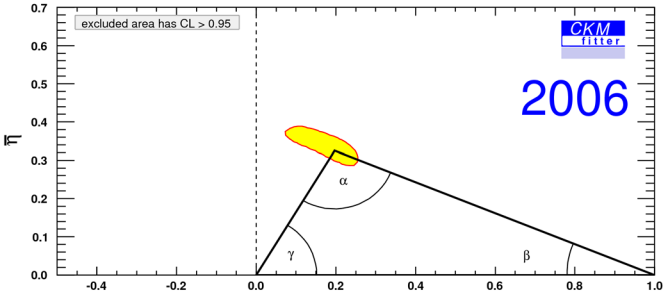
- First results on the CKM angle α
- Improved measurements on *sin2*β
- Improved measurements on $|V_{ub}|$ and $|V_{cb}|$
- First unquenched results from LQCD

Final plots : a brief history of the CKM matrix

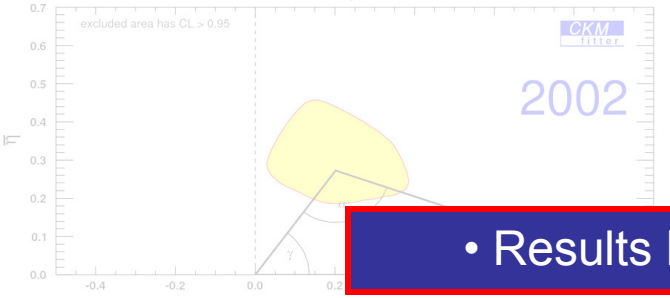


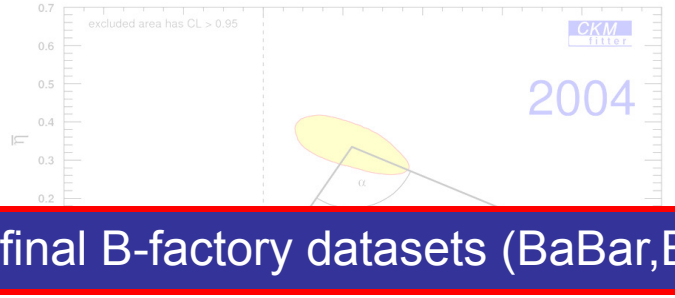


- Measurement of B_s oscillation frequency (CDF, D0)
- Evidence for leptonic $B \rightarrow \tau\nu$ decay (BaBar, BELLE)

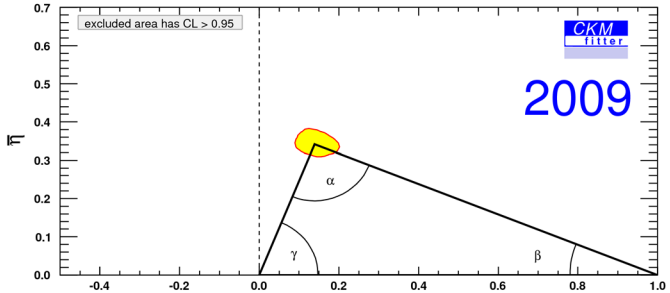


Final plots : a brief history of the CKM matrix

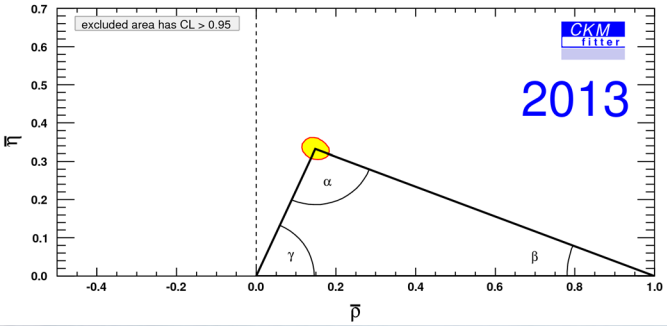




- Results based on final B-factory datasets (BaBar,BELLE)

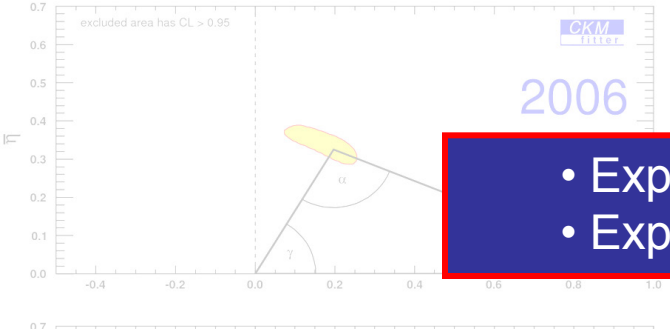


Final plots : a brief history of the CKM matrix

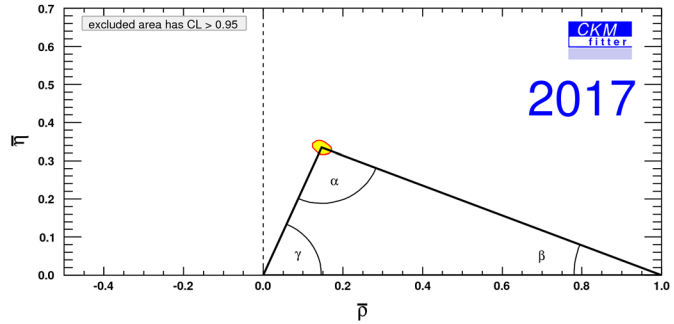


- Expected LHCb performances with *2 fb^{-1}*
- Expected improvements on LQCD

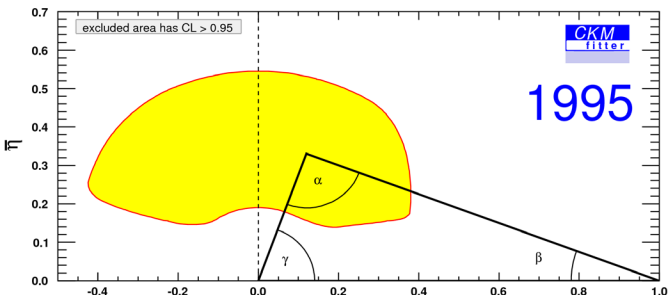
Final plots : a brief history of the CKM matrix

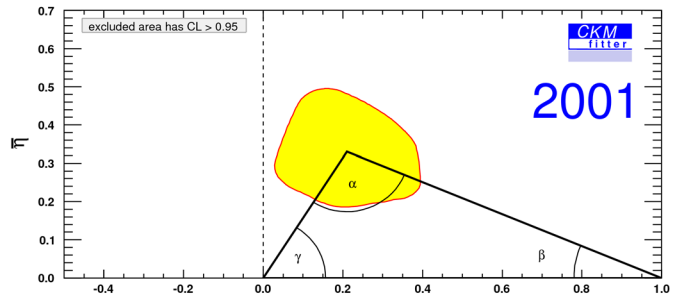


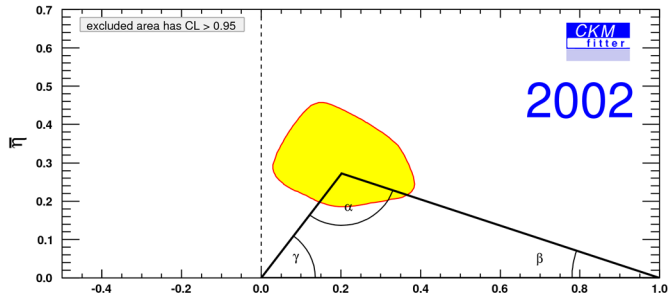
- Expected LHCb performances with *10 fb^{-1}*
- Expected Super-B-factory performances with *10 ab^{-1}*

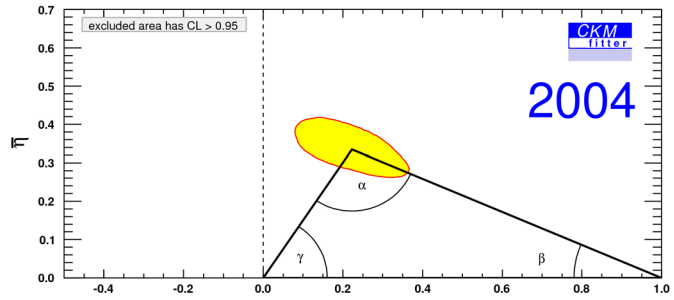


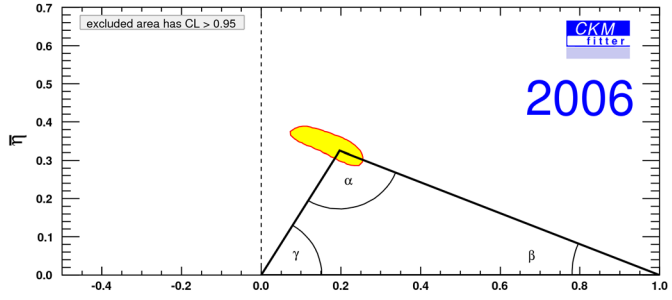
Final plots : a brief history of the CKM matrix

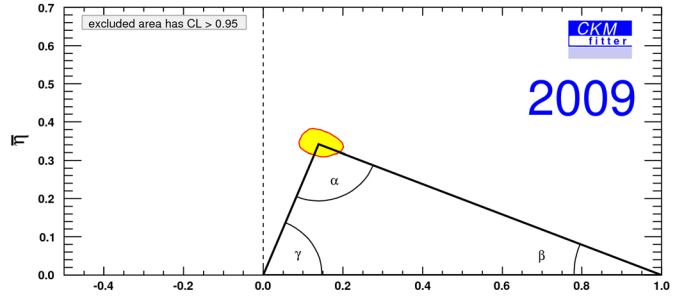


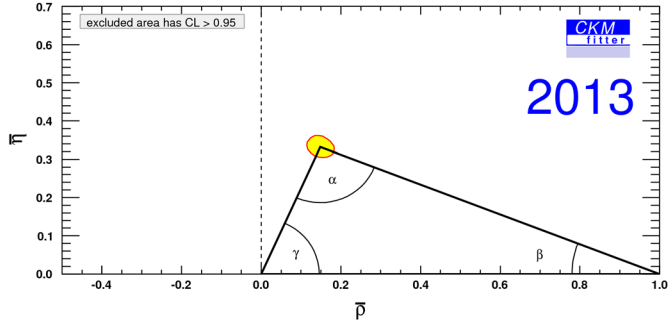


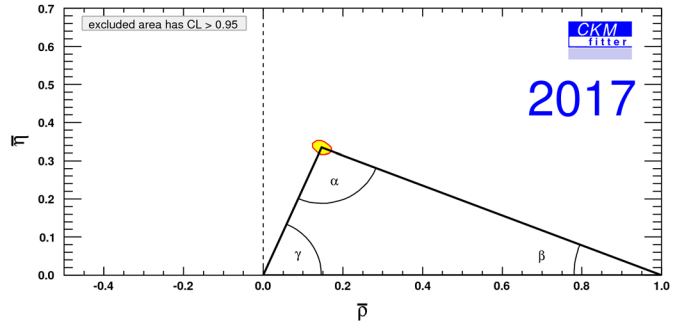




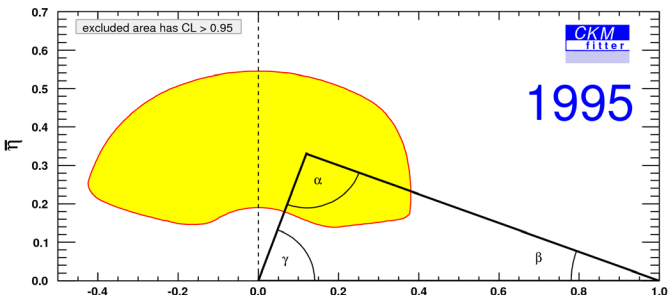


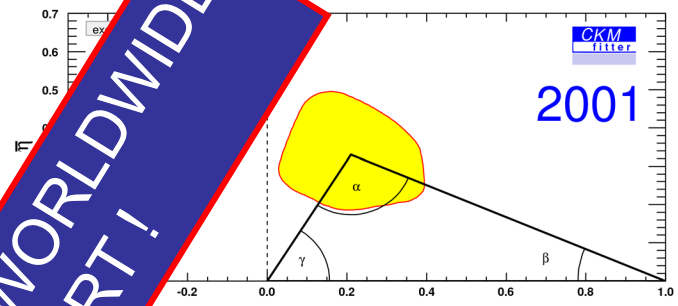


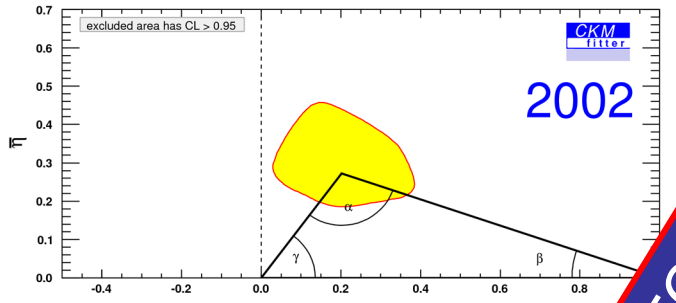


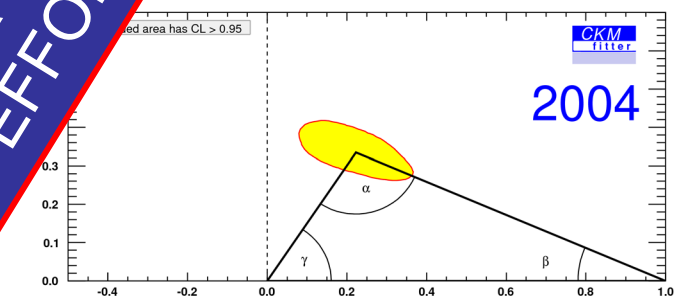


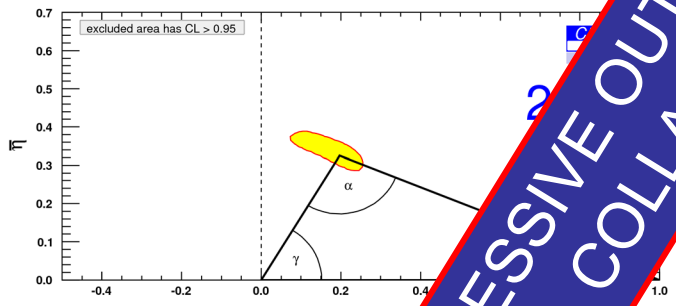
Final plots : a brief history of the CKM matrix

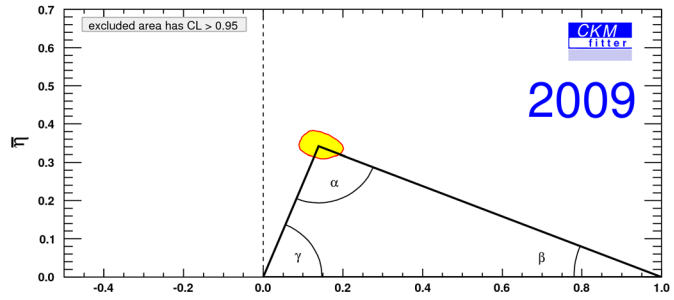


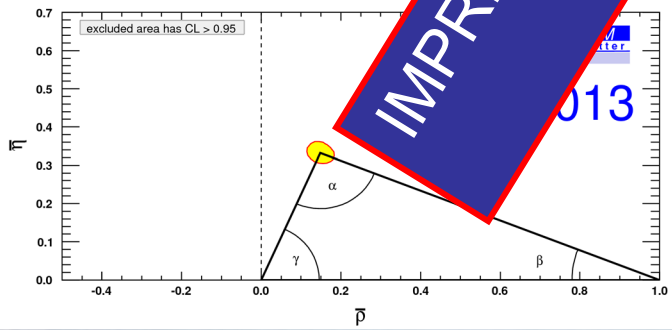


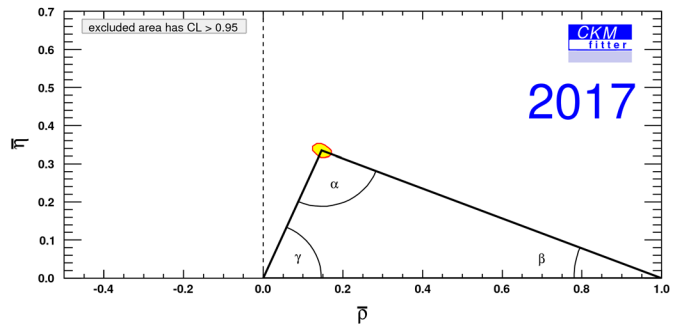






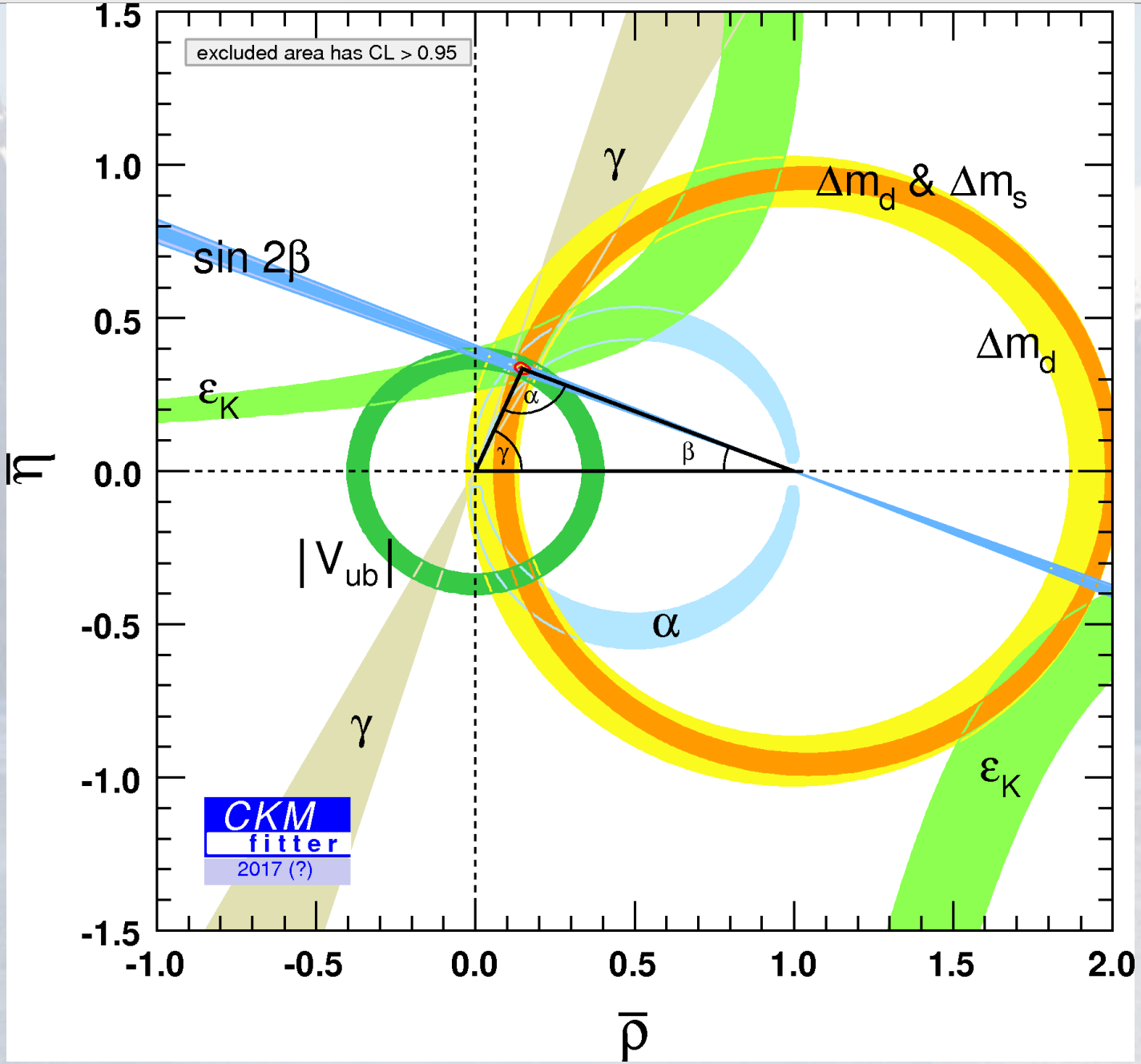






IMPRESSIVE OUTCOME OF A WORLDWIDE COLLABORATIVE EFFORT !

Perspectives : the future ?



Conclusions

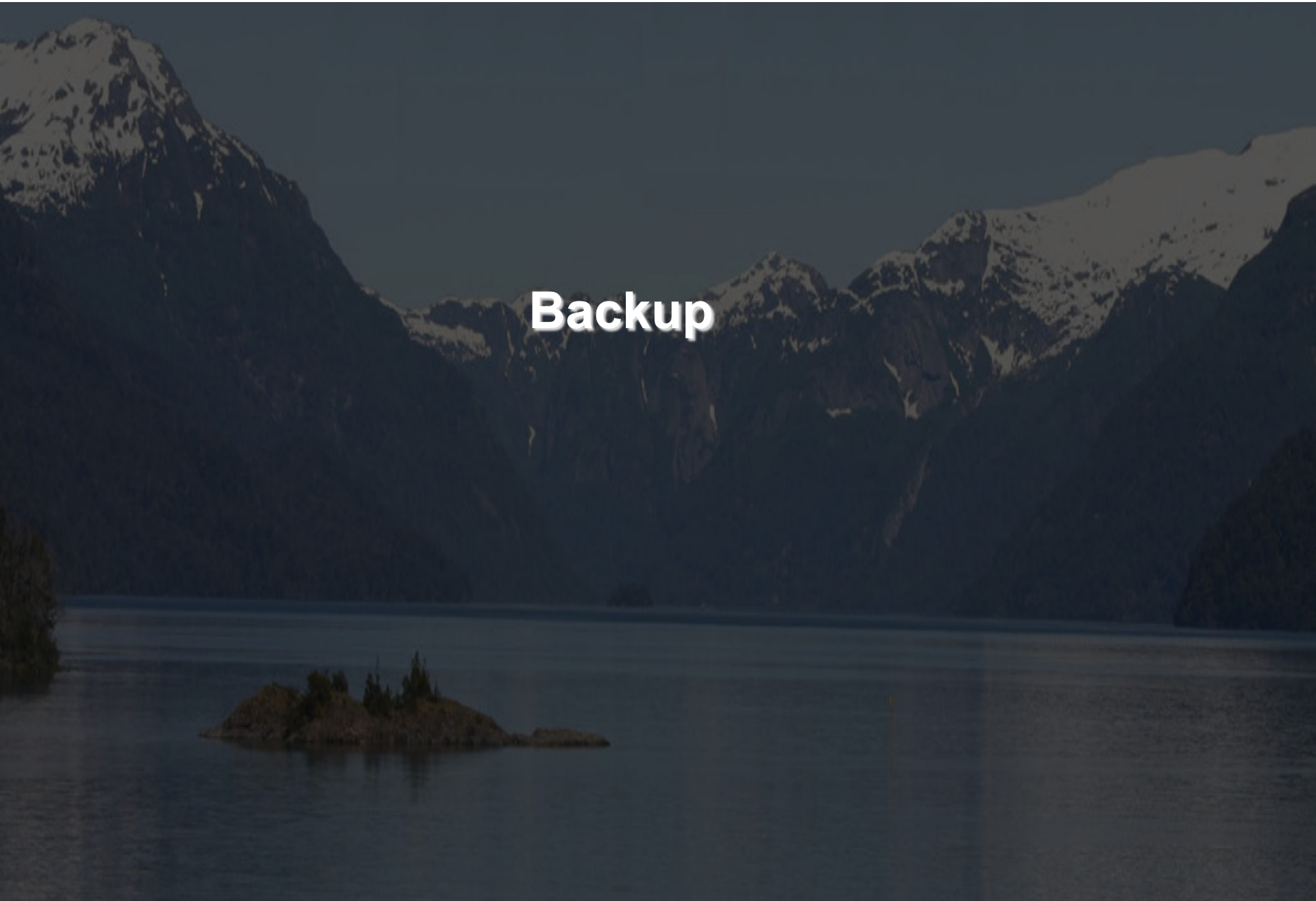
- CKM mechanism is at play in quark mixing
  - dominant source of observed CP violation

- CKMfitter showed the excellent overall agreelent in CKM picture
  - be it at CP-conserving vs. CP-violating level
  - on tree vs. loop processes

- You may have heard of “amusing” 2-3σ effects here and there
  - beware of overinterpretation …
  - no true uncontroversial smoking gun !

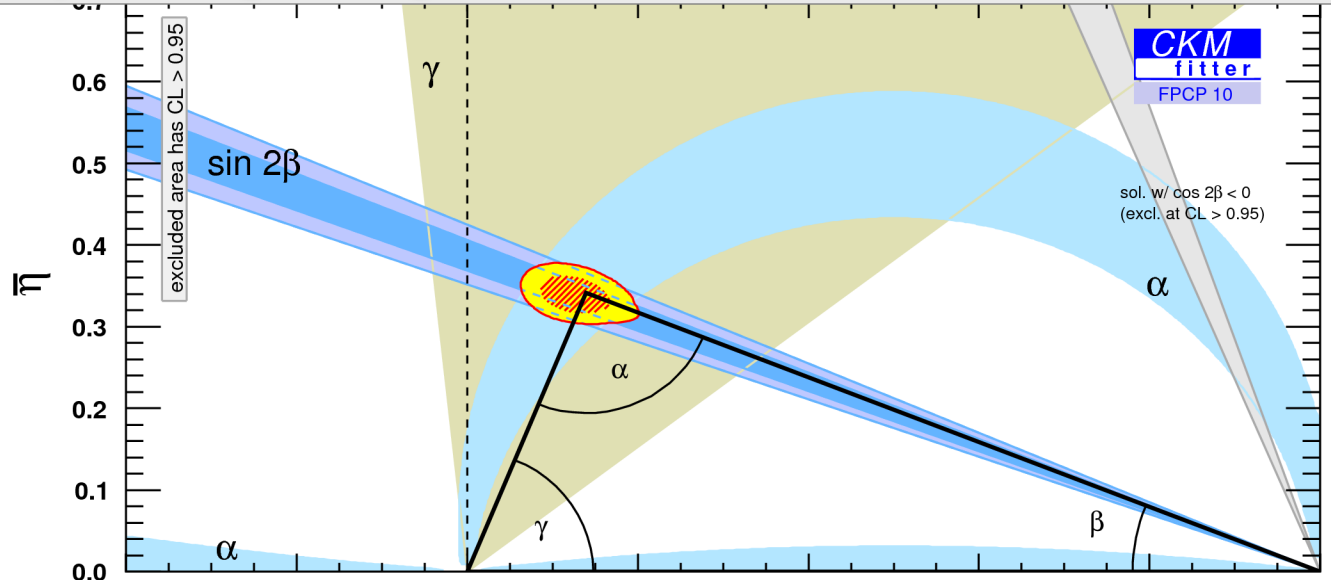
- Still room for non-SM contributions in FCNC processes
  - need to comply with tight constraints from MFV

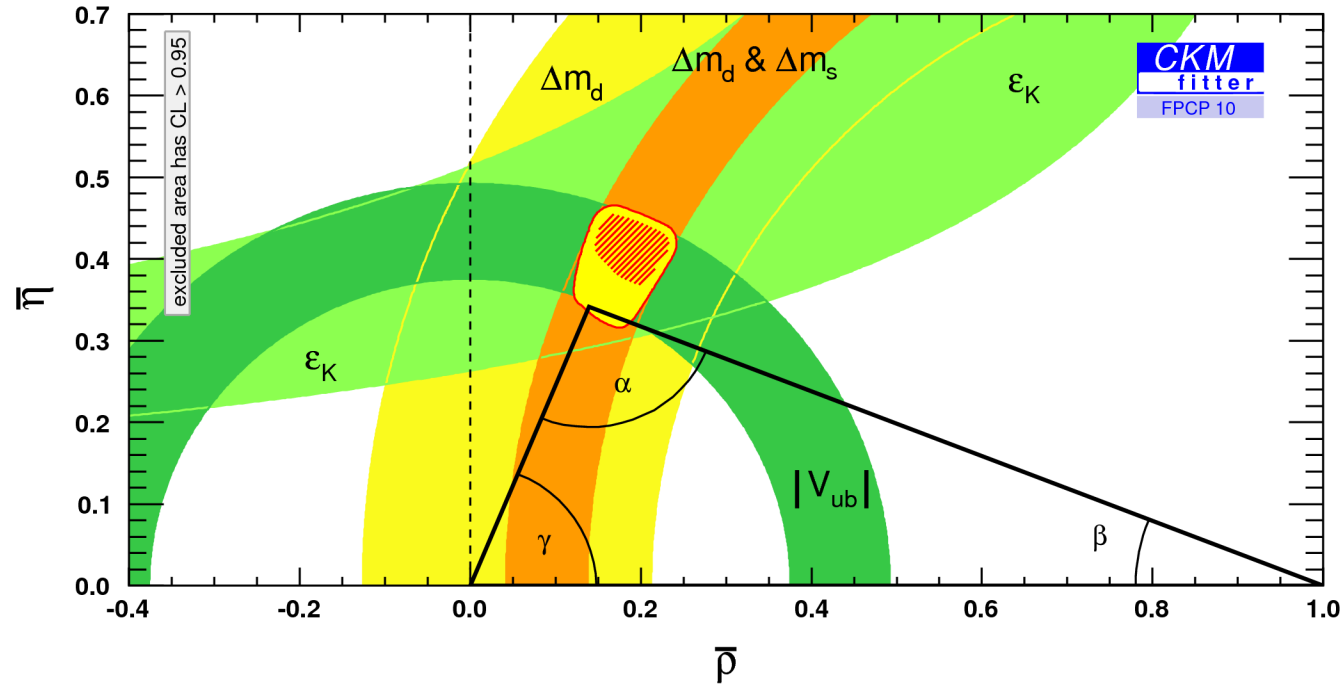
- Left uncovered many interesting topics …


Backup

Exploring the global CKM fit …

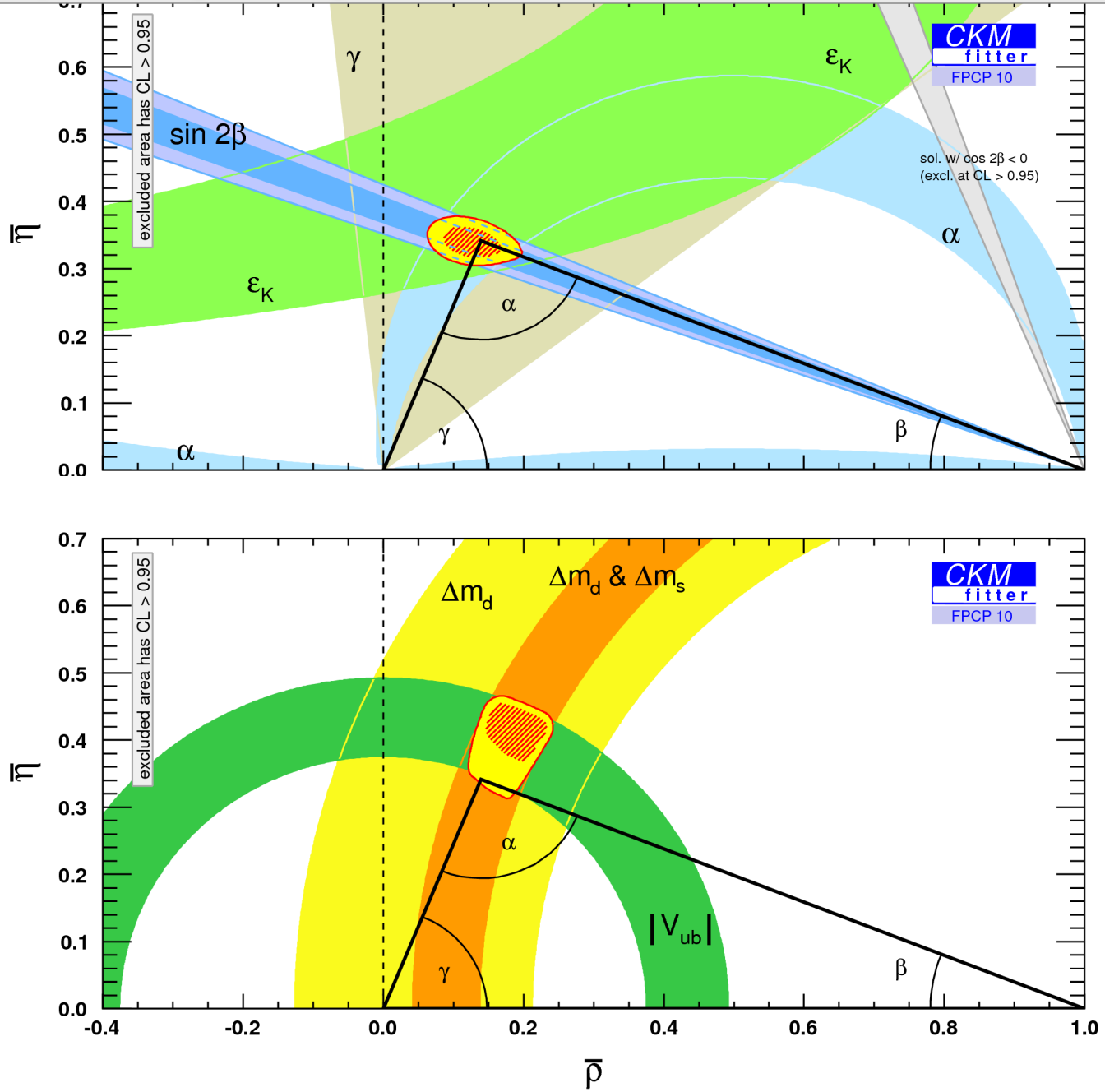
… UT angles
vs.
non-angles …





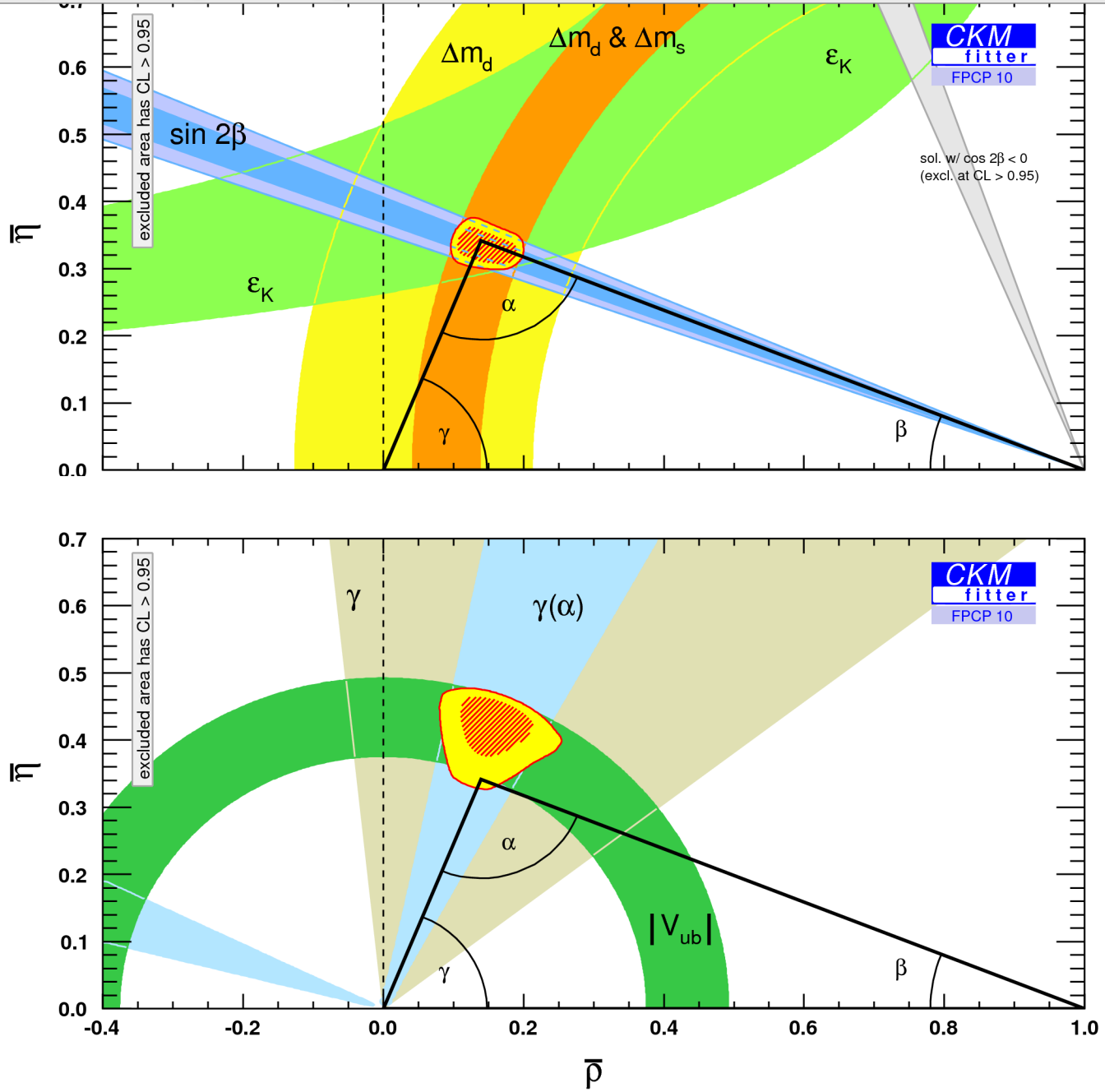
Exploring the global CKM fit …

… CP-violating
vs.
CP-conserving …

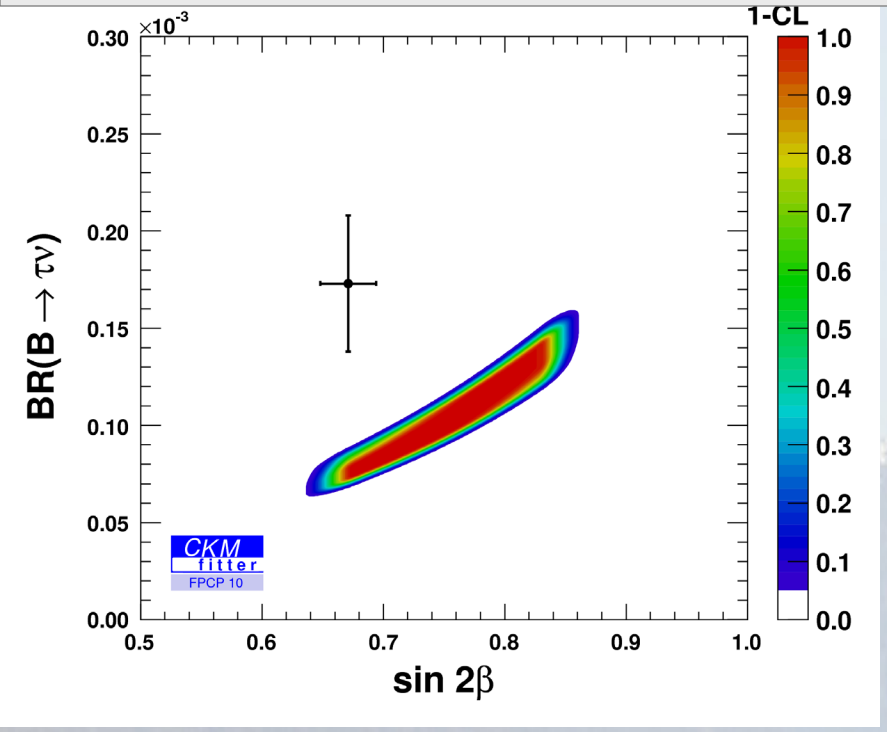


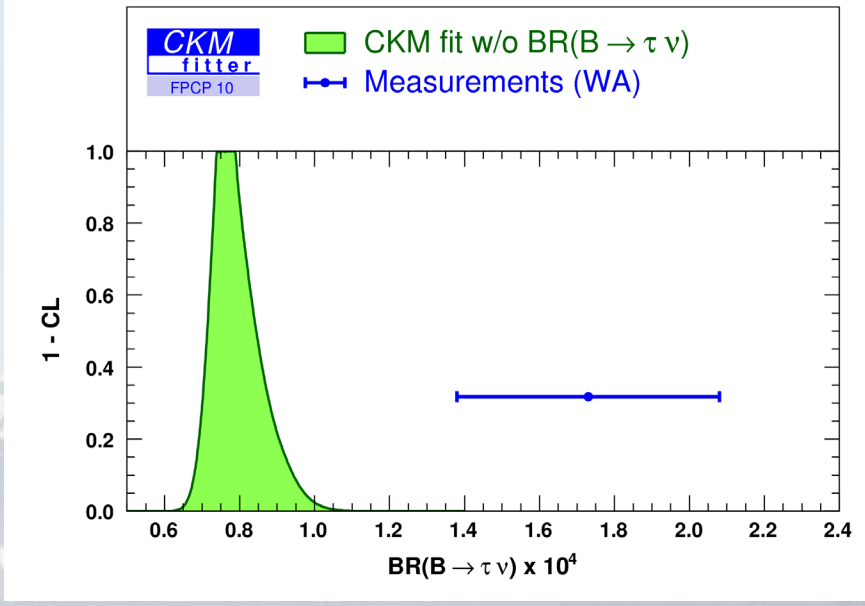
Exploring the global CKM fit …

… Loop-processes
vs.
Tree-processes …



The Global CKM fit : β and B→τν

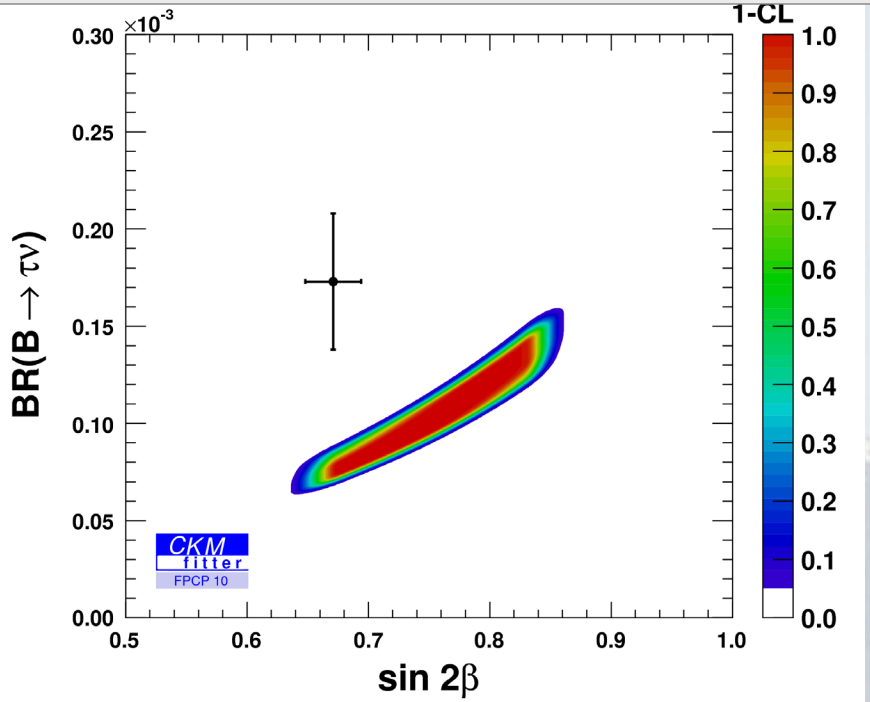


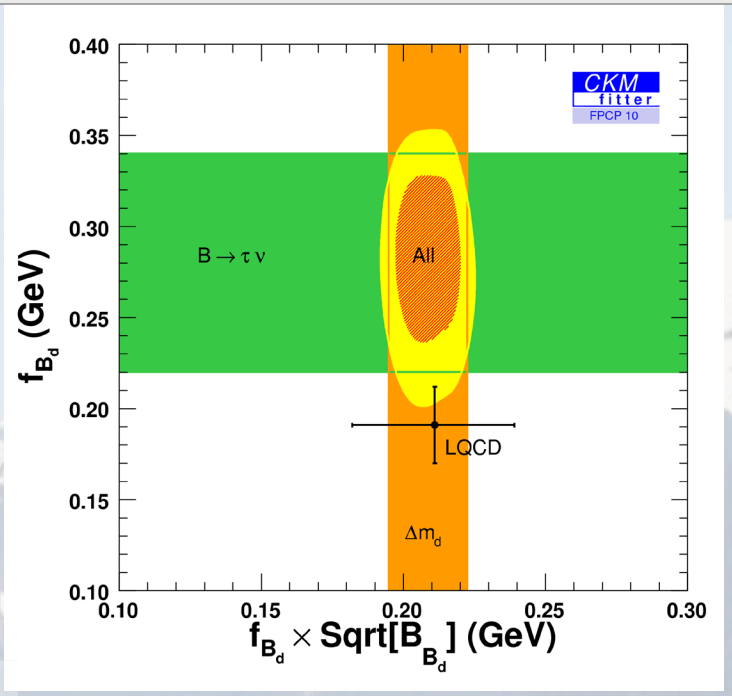


$\sin 2\beta_{c\bar{c}}$ or $B \to \tau\nu$ removed $\longrightarrow$ global fit χ^2_{min} drops by $\sim 2.6\sigma$

Non-trivial correlation of indirect constraints on β and B→τν …

The Global CKM fit : β and B→τν





$$\frac{BR(B^+ \to \tau^+ \upsilon)}{\Delta m_d} = \frac{3\pi}{4} \frac{m_\tau^2 \tau_{B^+}}{m_W^2 S(x_t)} \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 \frac{\sin^2(\beta)}{\sin^2(\gamma)} \frac{1}{|V_{ud}|^2} B_{B_d}$$

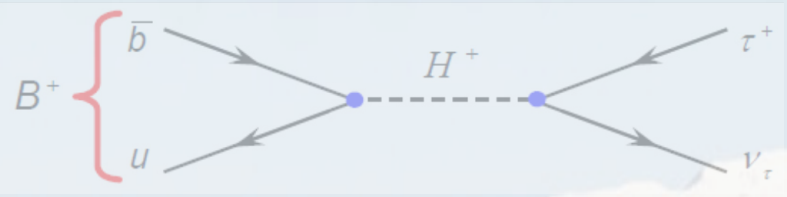
Theory-free extraction of B_d bag parameter

A few ways out

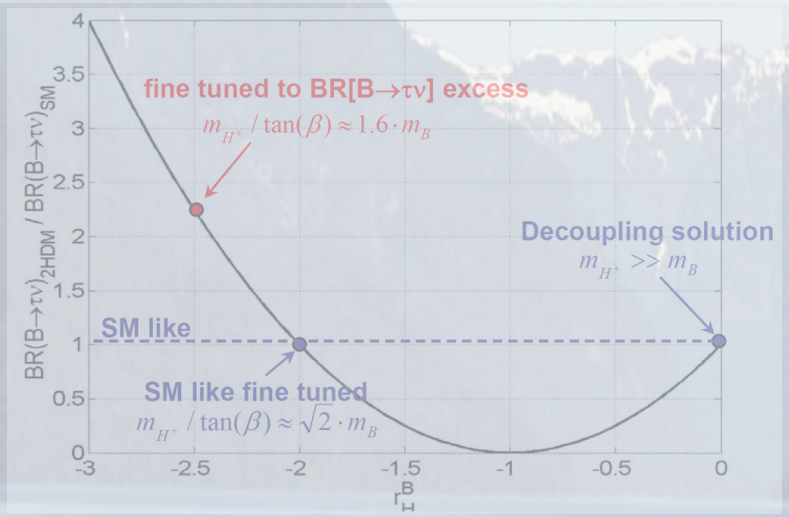
- Change in measured $Br(B \to \tau\nu)$ (2.6 σ)
- Correlated change in lattice values for f_{B_d} (2.6 σ) and B_{B_d} (2.7 σ)
- NP in mixing ($\Delta F = 2$)
- NP in tree decays ($\Delta F = 1$)
- Change in CKM mechanism

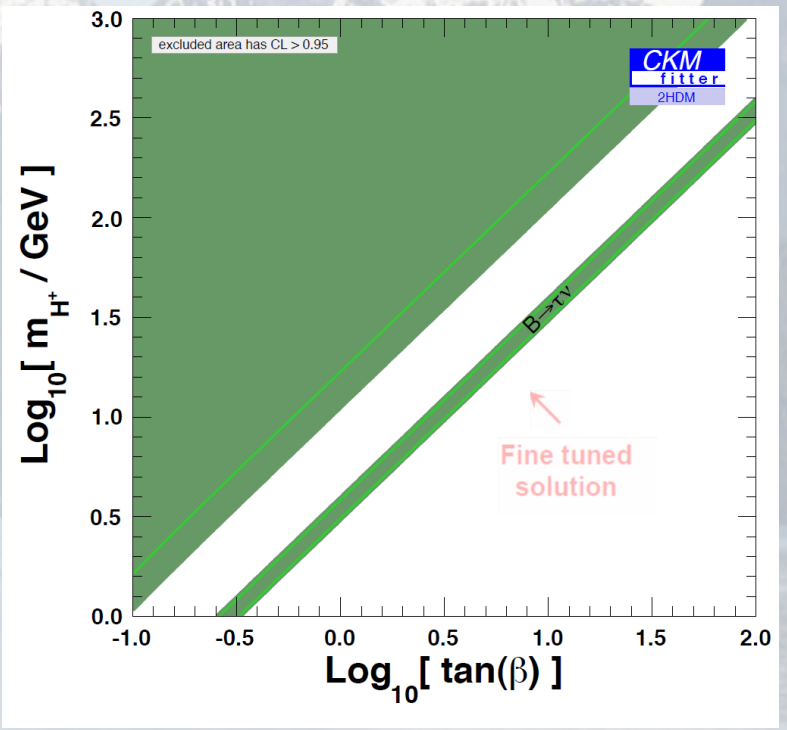
Beyond the global CKM fit : B→τν

$$\frac{BR(B^+ \to \tau^+ \upsilon)(NP)}{BR(B^+ \to \tau^+ \upsilon)(SM)} = \left(1 - \frac{m_B^2}{m_{H^+}^2} \tan^2 \beta\right)^2$$



- **Charged higgs** contribution can modify B[B→τν] as a multiplicative term: $r_H^B \approx -\tan^2(\beta) m_B^2 / m_{H^+}^2$ in **2HDM Type II** model. Note that one would need $r_H^B \approx -2.5$ to fit B[B→τν] (fine tuned solution).





Agreement with the SM can be recovered 2 ways:

- $r_H^B \to 0 \Rightarrow m_{H+}/m_B \to \infty$ irrespective tan(β). This is the **decoupling solution**

- $r_H^B = -2 \Rightarrow m_{H^+} / \tan(\beta) \approx \sqrt{2} \cdot m_B$; requires a **fine tuning of m_{H+}/tan(β) to the meson mass**.

Fine-tuned solution can be ruled out

By using other semileptonic information

NP : model-independent constraints in B_d,B_s meson mixing

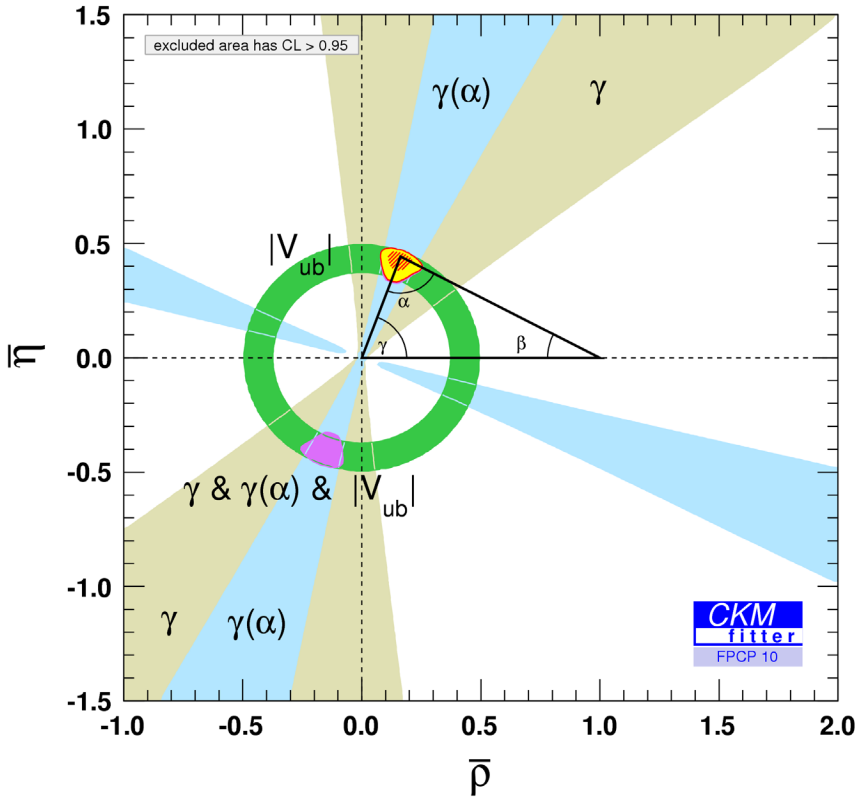
$$\langle B_q|\mathcal{H}_{eff}^{SM+NP}|\bar{B}_q\rangle = \langle B_q|\mathcal{H}_{eff}^{SM}|\bar{B}_q\rangle \times [Re(\Delta_q) + i \cdot Im(\Delta_q)]$$

A two-step approach :

- **fix the CKM part with NP-insensitive inputs**
- **use all inputs to constrain Δ_d,Δ_s**

$|V_{ud}|$, $|V_{us}|$, $|V_{ub}|$, $|V_{cb}|$,
γ and $\gamma(\alpha) \equiv \pi - \alpha - \beta$
(ϕ_{B_d} cancels)

Two solutions : "SM-like" favoured



NP : model-independent constraints in B_d,B_s meson mixing

$$\langle B_q|\mathcal{H}_{eff}^{SM+NP}|\bar{B}_q\rangle = \langle B_q|\mathcal{H}_{eff}^{SM}|\bar{B}_q\rangle \times [Re(\Delta_q) + i \cdot Im(\Delta_q)]$$

A two-step approach :

- **fix the CKM part with NP-insensitive inputs**
- **use all inputs to constrain Δ_d,Δ_s**

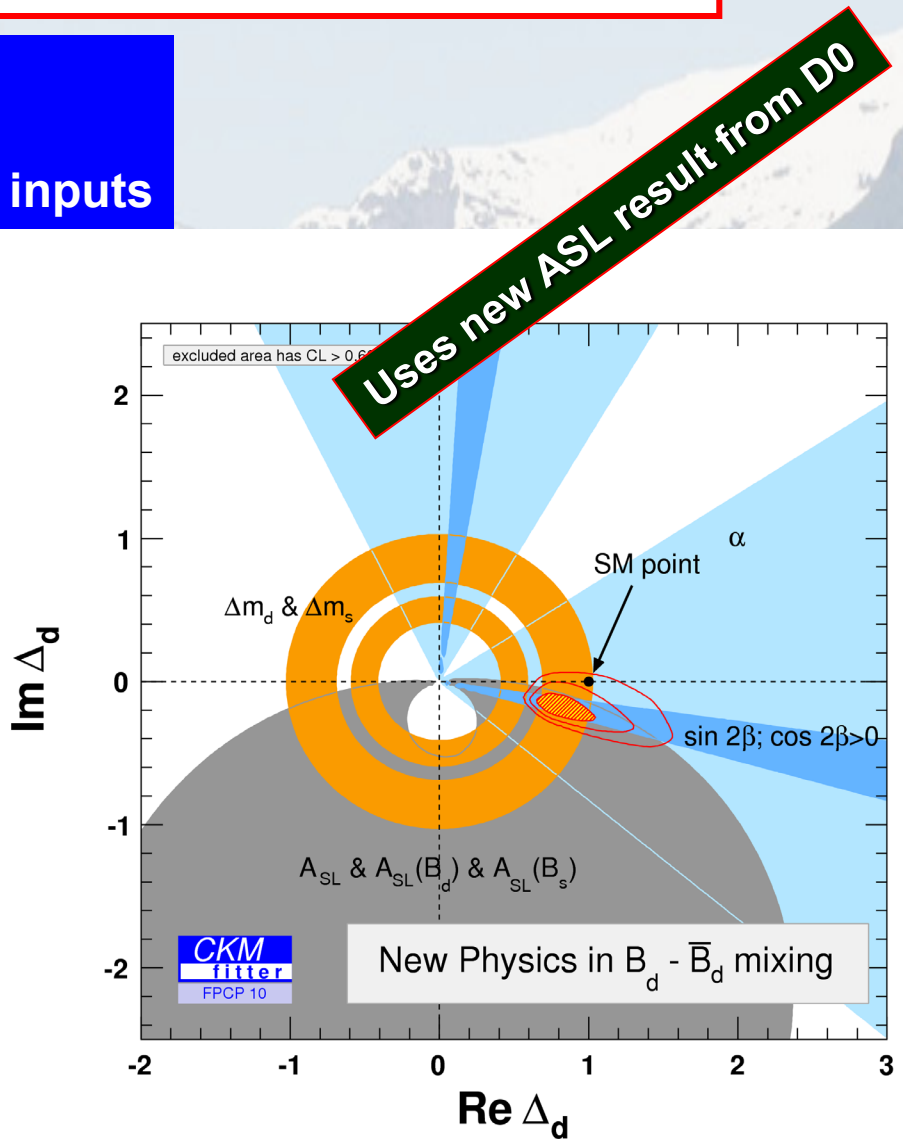
Neutral-meson oscillation Δm_d, Δm_s

Lifetime difference $\Delta\Gamma_d$

Time-dep asymmetries related to ϕ_{B_d}, ϕ_{B_s}

Semileptonic asymmetries a^d_{SL}, a^s_{SL}, A_{SL}

α (interference between decay and mixing)



NP : model-independent constraints in B_d,B_s meson mixing

$$\langle B_q|\mathcal{H}_{eff}^{SM+NP}|\bar{B}_q\rangle = \langle B_q|\mathcal{H}_{eff}^{SM}|\bar{B}_q\rangle \times [Re(\Delta_q) + i \cdot Im(\Delta_q)]$$

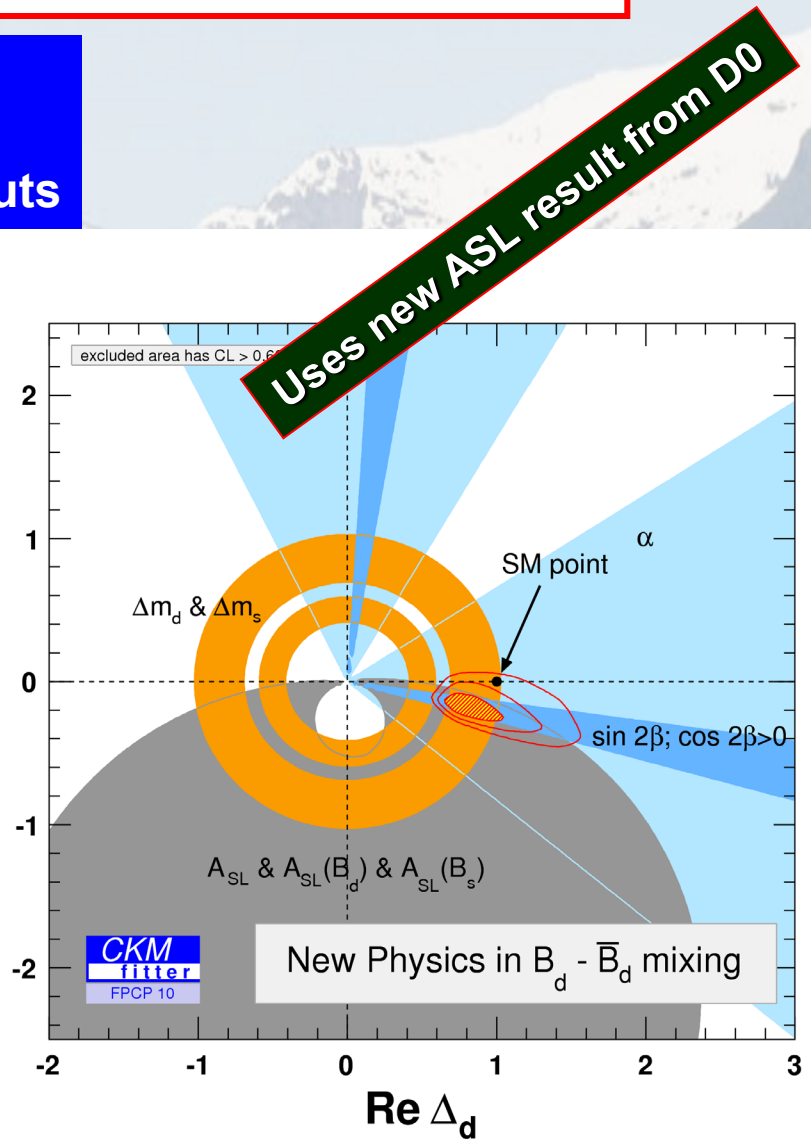
A two-step approach :

- **fix the CKM part with NP-insensitive inputs**
- **use all inputs to constrain Δ_d,Δ_s**

2.5 σ compatibilty with SM hypothesis

→ 1.1σ by removing B→τν
→ 2.2σ by removing A_{SL}

Both inputs drive the disagreement in the same direction



NP : model-independent constraints in B_d,B_s meson mixing

$$\langle B_q|\mathcal{H}_{eff}^{SM+NP}|\bar{B}_q\rangle = \langle B_q|\mathcal{H}_{eff}^{SM}|\bar{B}_q\rangle \times [Re(\Delta_q) + i \cdot Im(\Delta_q)]$$

A two-step approach :

- **fix the CKM part with NP-insensitive inputs**
- **use all inputs to constrain Δ_d,Δ_s**

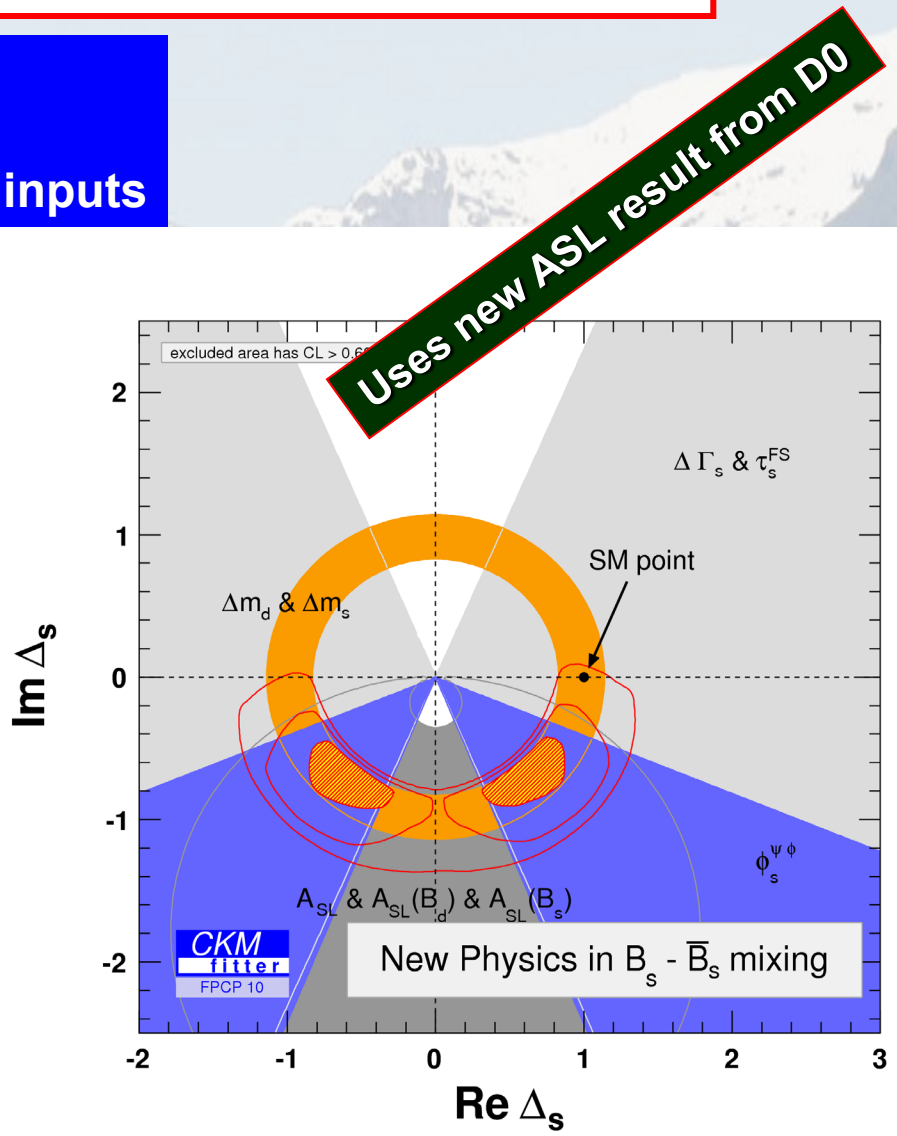
Neutral-meson oscillation Δm_d, Δm_s

Lifetime difference $\Delta\Gamma_d$

Time-dep asymmetries related to ϕ_{B_d}, ϕ_{B_s}

Semileptonic asymmetries a^d_{SL}, a^s_{SL}, A_{SL}

α (interference between decay and mixing)



NP : model-independent constraints in B_d,B_s meson mixing

$$\langle B_q|\mathcal{H}_{eff}^{SM+NP}|\bar{B}_q\rangle = \langle B_q|\mathcal{H}_{eff}^{SM}|\bar{B}_q\rangle \times [Re(\Delta_q) + i \cdot Im(\Delta_q)]$$

A two-step approach :

- **fix the CKM part with NP-insensitive inputs**
- **use all inputs to constrain Δ_d,Δ_s**

2.7σ compatibilty with SM hypothesis

→ 2.7σ by removing $B \to \tau\nu$
→ 1.9σ by removing A_{SL}
→ 1.7σ by removing $B_s \to J/\psi\phi$