# CKMfitter and CKMlive

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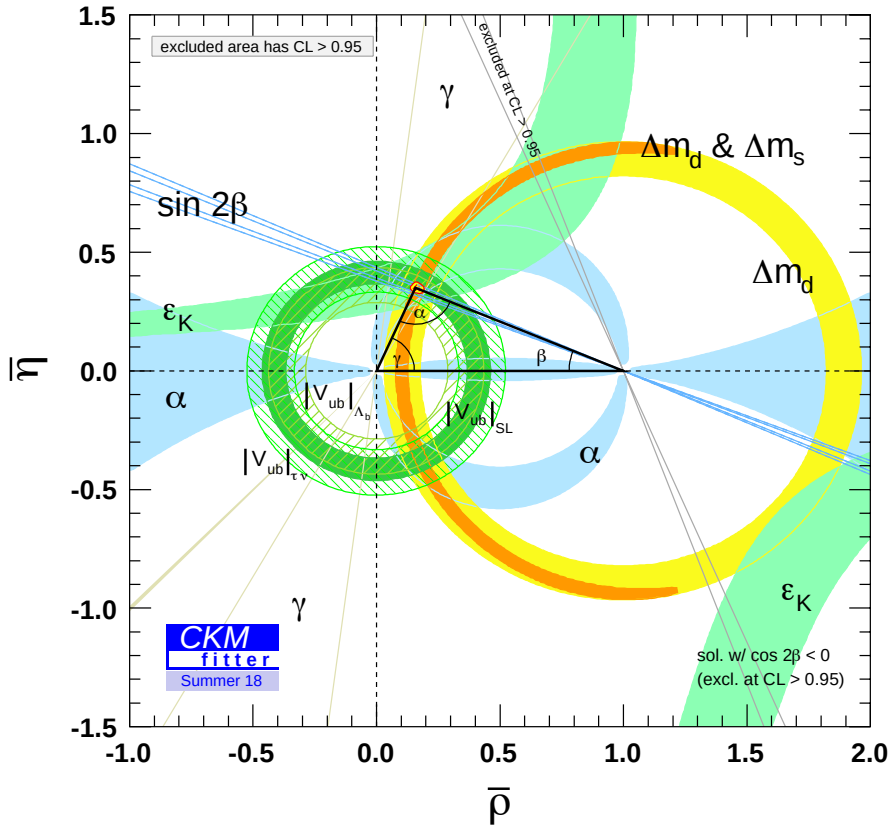
# Outline




- Determining the CKM matrix parameters (physics and statistics)
- Implementing in a software (CKMfitter and 1st tutorial)
- Using the web-based interface (CKMlive 2nd tutorial)

# CKMfitter and fastfitter

# A frequentist framework to implement

$p = (A, \lambda, \bar{\rho}, \bar{\eta} \ldots) = (q, r)$

- $q$ parameters of interest (CKM), $r$ nuisance parameters (hadronic)
- $\mathcal{O}_{\rm meas} \pm \sigma_{\mathcal{O}}$ experimental values of observables
- $\mathcal{O}_{\rm th}(p)$ theoretical description in a given model

$$\mathcal{L}(p) = \prod_{\mathcal{O}} \mathcal{L}_{\mathcal{O}}(p) \qquad T(p) = -2 \ln \mathcal{L}(p) = \sum_{\mathcal{O}} \left( \frac{\mathcal{O}_{\rm th}(p) - \mathcal{O}_{\rm meas}}{\sigma_{\mathcal{O}}} \right)^2$$

$$\chi^2(q) = \min_r T(q, r)$$

- Central value: estimator $\hat{q}$ max likelihood $\quad \chi^2(\hat{q}) = \min_q \chi^2(q)$
- Range: confidence level ($p$-value) for $q_0$ computed from $\Delta\chi^2(q_0) = \chi^2(q_0) - \min_q \chi^2(q)$, assuming $\chi^2$ law with $N = dim(q)$
- Specific (Rfit) treatment of theoretical uncertainties modifying $\mathcal{L}$, and impacting the procedure to average measurements

# CKMfitter software

General objectives for CKM fitter

- Experimentalists and theorists working together
- Frequentist determination of CKM parameters from observables
- Large number of inputs, significant theoretical uncertainties
- Numerically demanding, with many scans and minimisations (in particular w.r.t nuisance parameters)

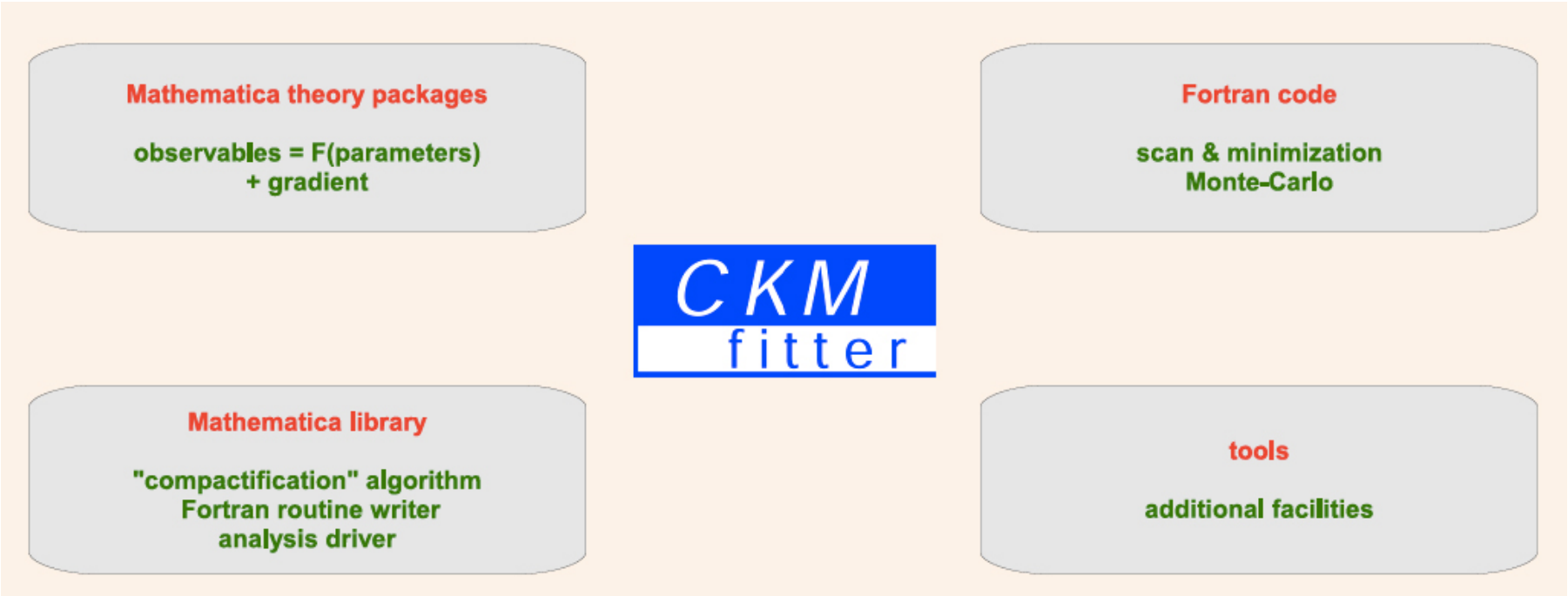
First version of the software (up to 2005)

- Fortran code + Minuit minimisation
- Fortran: legibility/modularity difficult to maintain
- Minuit: numerical determination of first derivatives (gradient)

Second version of the software (from 2005)

- Fastfitter=Mathematica code + Fortran routines
- Mathematica: building of $\chi^2$ and computation of first derivatives
- Fortran: minimisation using publicly available, MINUIT-like routines

# CKMfitter current implementation




- Theory packages: express observables (branching ratios...) in terms of parameters ($A, \lambda \ldots$)
- Libraries: compactification algo to identify subexpressions repeated in obs and derivatives for quick numerical computation
- Fortran code: numerical minimisation
- Tools: ROOT routines to draw the plots

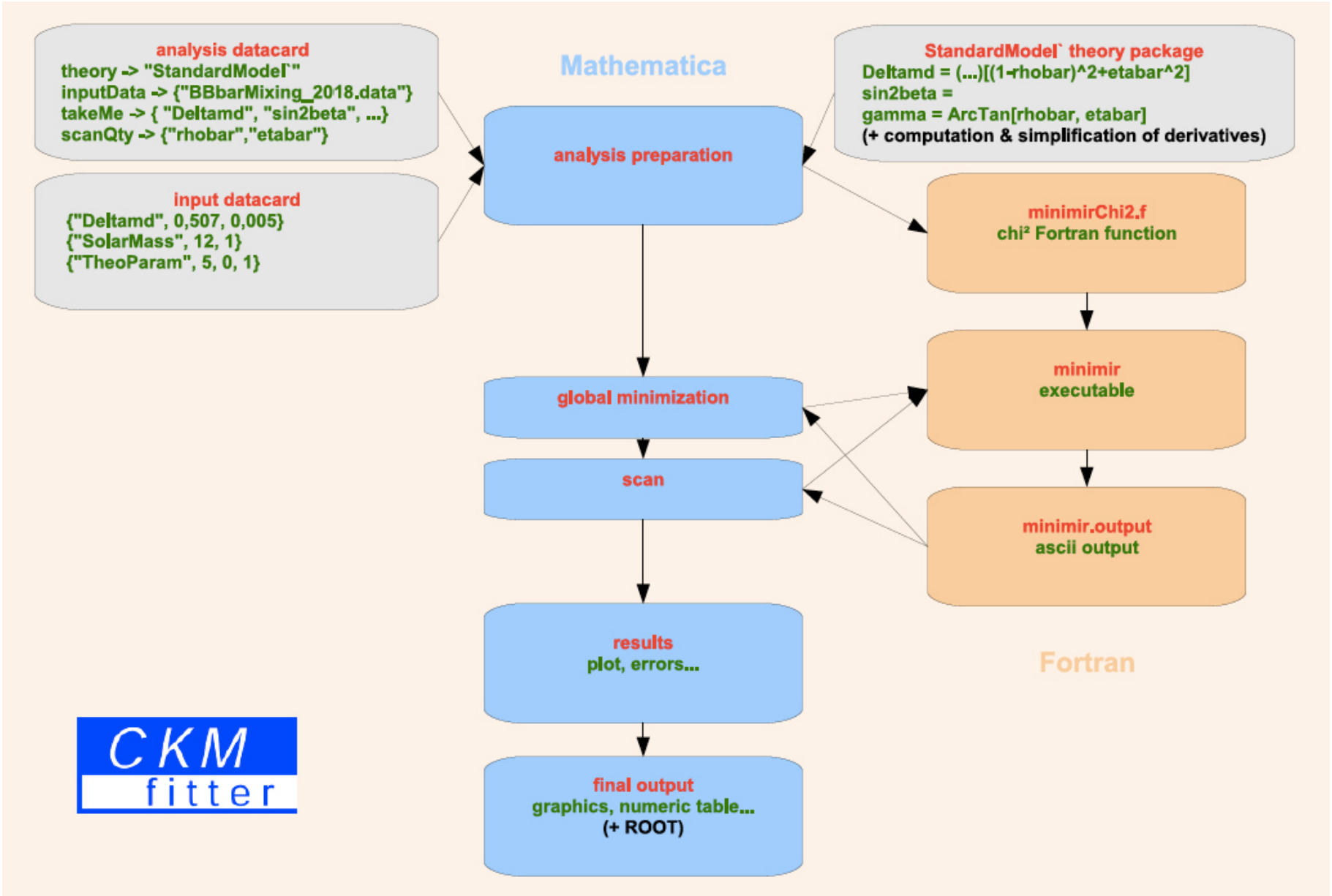
# Elements for an analysis

- Mathematica theory packages
  - observables (branching ratios...) in terms of parameters ($A, \lambda \ldots$)
  - compute derivatives and simplify expressions once and for all
  - possibility to define several models (SM, NP)
- Input datacards
  - list of inputs at a given date (PDG, HFLAV, FLAG...)
  - observables (measurements) but also parameters (lattice QCD inputs for hadronic params)
- Analysis datacard
  - Theories to be considered
  - Inputs to be considered
  - Parameter(s) to be scanned and constrained
  - Plots to be drawn

Modularity of the approach, allowing to add new elements easily

$\chi^2$ function to be minimised build for the analysis chosen

# Analysis flow chart



# Theory packages

- Express observables in terms of parameters, in a given model
- Compute observables and first derivatives after simplification
- Store the results in anciliary files used later to build $\chi^2$

  - CKMmatrix : Definition of the various CKM-related quantities
  - BBbarKKbarMixing: BBbar and KKbar mixing - related quantities
  - LeptonicDecay: Branching ratios for $B^+ \to l^+ \nu$ and similar leptonic decay
  - SemileptonicDecay: Branching ratios for K and D semileptonic decays
  - DiLeptonicDecay: Branching ratio of $B \to l^+ l^-$ and similar dileptonic decays
  - BtoDK: B -> D(*)K(*) modes, for use in gamma analyses (GGSZ, GLW, ADS)
  - BtoDTauNu: B->D tau nu / B -> D l nu branching ratio
  - BtoDpiDstarPiDrho: Neutral decay B -> D(*)π or Dρ for time dependent analysis of sin(2β+γ)
  - BtoKstPiSU2: Charmless B->Kππ Package
  - BtoPiKPiKSU3: B,Bs->ππ, Kπ, KK decays assuming SU(3) symmetry
  - BtoPiPiSU2: B→ππ analysis
  - BtoRhoPiSU2: B→ρπ analysis
  - BtoRhoRhoSU2: B→ρρ analysis
  - BtoVgam: Radiative decay observables for B -> V γ
  - BtoXsGamma: Br(B->$X_s\gamma$)
  - Charm: Charm observables
  - KtoPiLNu: Branching ratio of Kl3 decay
  - KtoPiNuNu: Branching ratio for K -> π ν νbar
  - QCD: Strong coupling constant
  - QED: $\alpha_{em}$
  - VcdVcs: Constraints on Vcd and Vcs

# Structure of theory package

```
BeginPackage["LeptonicDecay`",{"CKMmatrix`", "DecayBagParameters`","QCD`", "TheoryTools`"} ]
```

```
LeptonicDecay`theory::usage="B(\!\(\*SuperscriptBox[\(B\), \(+\)]\)->\!\(\*SuperscriptBox[\(e\), \(+\)]\)\!\(\*Su
  B(\!\(\*SuperscriptBox[\(Ds\), \(+\)]\)->\!\(\*SuperscriptBox[\(τ\), \(+\)]\)\!\(\*SubscriptBox[\(ν\), \(τ\)]\))
```

```
theory["SM"]={
{
{"A",A},{"λ",λ},{"\!\(\*OverscriptBox[\(ρ\), \(_\)]\)",ρbar},{"\!\(\*OverscriptBox[\(η\), \(_\)]\)",ηbar},
{"fBs",fBs},{"fBs/fBd",fBsOfBd},
{"fDs",fDs},{"fDs/fDd",fDsOfDd},
{"fK",fKLQCD}, {"fK/fπ",fKOfpi},
{"δKl2Rad",δKl2Rad}, {"δτK2Rad", δτK2Rad }
},
{"B(B->eν)","B(B->μν)",
"B(B->τν)","B(D->eν)",
"B(D->μν)",
"B(Ds->eν)","B(Ds->μν)",
"B(Ds->τν)","B(K->eν)",
"B(K->μν)","B(τ->Kν)",
"Ke2/πe2","Kμ2/πμ2",
"τK2/τπ2","fBd",
"fDd","fπ"}
}
```

```
theory["NP(H+)"]={
{
{"A",A},{"λ",λ},{"\!\(\*OverscriptBox[\(ρ\), \(_\)]\)",ρbar},{"\!\(\*OverscriptBox[\(η\), \(_\)]\)",ηbar},
{"fBs",fBs},{"fBs/fBd",fBsOfBd},
{"fDs",fDs},{"fDs/fDd",fDsOfDd},
{"fK",fKLQCD}, {"fK/fπ",fKOfpi},
{"δKl2Rad",δKl2Rad}, {"δτK2Rad", δτK2Rad },
{"tanβ",tanbeta},{"mH+",mHch},{"eps0",eps0},
{"mUbar",mUbar},{"mdbar",mdbar},{"msbar",msbar},{"\!\(\*OverscriptBox[\(mc\), \(_\)]\)",mcbar}, {"mbbar",mbbar}
},
{"B(B->eν)","B(B->μν)",
```

# Input datacard

```
{
    (*   Input datacard for SM global CKM fit  *)
    (*             used for Summer 18          *)

(*****************************************************************)
(* CKM moduli *)
(*****************************************************************)

{"|Vud|", 0.97420, 0, 0.00021}, (* Towner/Hardy: Proceeding in CKM2016, https://
pos.sissa.it/291/028/pdf *)

{"|Vus|xF+Kpi(0)", 0.2165, 0.0004},  (* PDG 16 *)

{"F+Kpi(0)", 0.9681, 0.0014, 0.0022},
(* see document AVERAGE OF LATTICE QCD INPUTS FOR CKM FITS *)

{"|Vub|",  3.98 10^-3, 0.08 10^-3, 0.22 10^-3 },
(* Summer 2018 update *)
{"|Vcb|", 41.8 10^-3, 0.4 10^-3, 0.6 10^-3},
(* Summer 2018 update *)

(* Inclusive and exclusive values averaged in the above *)
{"|Vub|slincl",  4.44*10^(-3),0.17*10^(-3),0.31*10^(-3)},(* Summer 2018 update *)
{"|Vub|slexcl",  3.72*10^(-3),0.09*10^(-3),0.22*10^(-3)},
{"|Vcb|slincl", 42.2*10^(-3),0.4*10^(-3),0.6*10^(-3)},(* Summer 2018 update *)
{"|Vcb|slexcl", 41.2*10^(-3),0.6*10^(-3),1.1*10^(-3)},(* Summer 2018 update *)

(* |Vub|/|Vcb| from Lambda b decays *)
{"gamma(lambdab->p)/gamma(lambdab->lambdac)",0.947*10^(-2),Sqrt[0.043^2+0.069^2]*10^(-2)},
  (* http://arxiv.org/pdf/1504.01568.pdf,updated according to new Lambda_c->pkpi Br,
http://www-f9.ijs.si/~zupanc/hfag-Lambda_c.pdf *)

{"zetap[15-q2max]/zetalambdac[7-q2max]",1.471,0.096, 0.290},
  (* see document AVERAGE OF LATTICE QCD INPUTS FOR CKM FITS *)

{"All(Vub/Vcb)", "gamma(lambdab->p)/gamma(lambdab->lambdac)","zetap[15-q2max]/zetalambdac[7-
```

# Input datacard format

| input type | meaning | syntax |
|---|---|---|
| "Fixed" | x = 12 | {"x",12} |
| "Gauss" | x = 12 +-4(stat) | {"x",12,4} |
| "GaussAsym" | x = 12 +5(stat)-4(stat) | {"x",12,5,-4} |
| "Range" | x = 12 +-3(theo) | {"x",12,0,3} |
| "GaussRange" | x = 12 +-4(stat) +-3(theo) | {"x",12,4,3} |
| "GaussAsymRange" | x = 12 +5(stat)-4(stat) +-3(theo) | {"x",12,5,-4,3} |
| "Correlation" | correlation matrix (upper triangle) | { {"x","y","z"}, 1,-0.2,0.1, 1,0.3, 1 } |
| "UpperLimit" | 0 < x < 3.4 10^-5 @ 90% CL | {"x",{3.4 10^-5},90} |
| "LUT" | LookUp Table for chi^2 | {"x","LUTfile.dat"} (1D) or {{"x","y"},"LUTfile.dat"} (2D) |

- Range corresponds to Rfit treatment of theoretical uncertainties
- LUT corresponds to table for inputs with specific treatments $(\alpha, \gamma)$

# Analysis datacard

```
{
    analysisName -> "Vcb_",
    job -> { 1, 2, 3, 4 },
    inputData -> "Summer18/globalCKMfit_Summer18.data",
    theoryPackage->   {"BBbarKKbarMixing`","LeptonicDecay`", "DiLeptonicDecay`","SemileptonicDecay`"},
        jobName[1] -> "indirect",
        takeMe[1] -> {
            "All(Vud-Vus)","All(Vcd-Vcs)", "|Vub|",
            "All(B->taunu)","All(Vub/Vcb)",
            "All(Deltamd)",
            "All(Deltams)",
            "All(|epsilonK|)",
            "sin2beta","cos2beta",
            "alpha",
            "gamma",
            "All(B->ll)","2beta_sb"
           },
        jobName[2] -> "incl",
        replaceInput[2]->{"|Vcb|"->"|Vcb|slaver","|Vcb|slincl"->"|Vcb|"},
        takeMe[2]->{
            "|Vcb|"
        },
        jobName[3] -> "excl",
        replaceInput[3]->{"|Vcb|"->"|Vcb|slaver","|Vcb|slexcl"->"|Vcb|"},
        takeMe[3]->{
            "|Vcb|"
        },
        jobName[4] -> "aver",
        takeMe[4]->{
            "|Vcb|"
        },
        scanQty -> "|Vcb|",
        scanMin -> 0.036,
        scanMax -> 0.046,
        (**********     common settings     **********)
        startRange -> {"A"->{0.78, 0.85}, "lambda"->{0.2245, 0.2255}, "rhobar"->{0.1, 0
            .2}, "etabar"->{0.3, 0.4},"LambdaQCD"->{0.2,0.24} },
        globalMinSearches -> 500,
```

# From CKMfitter to CKMlive

CKMfitter `ckmfitter.in2p3.fr`

- fastfitter software very powerful and modular
- but complicated to apprehend and to maintain
- still implementing new features (large expressions, alternative treatments of theo uncertainties)
- often requests: *how the global fit would change with this input ?*

CKMlive (2015) `ckmlive.in2p3.fr`

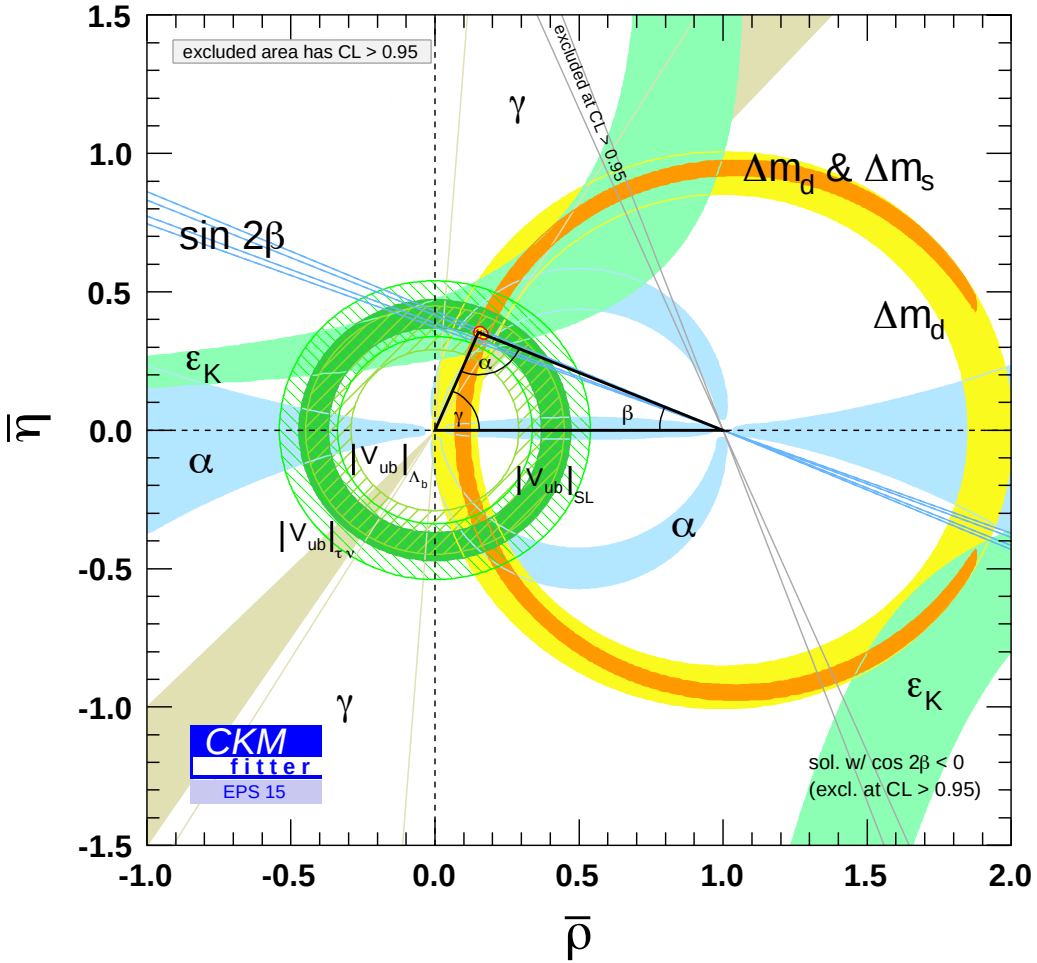
- Web interface for standard analyses (SM global fit)
- Based on same elements as CKMfitter, more user friendly (hopefully)
- Less powerful, only limited subsets of analyses available
- Main focus of the rest of the tutorial

# Apologies


- Bugs in Summer 16 and Summer 18 datacards, which will be solved next week
  $\Longrightarrow$we will work today with EPS15 data (old, but still valid)
- Computer server in France, so time of connection from Japan might take some time
  $\Longrightarrow$we may have to wait at some point...
- Unusual to have so many requests at the same time
  $\Longrightarrow$could you form teams of two/three people to run analyses on a single computer ?

# A first fit with CKMlive

# First exercise




- Use the same data as the global fit for EPS15
- Perform the fit for $\bar{\eta}$
- Obtain the data file, the plot and confidence interval

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2.Your analyses/Start an analysis

1.Sign in

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# Home - The CKMlive project and the CKMfitter group

## CKMlive Web Project

CKMlive is meant to allow the High Energy Physics community to run dedicated analyses conducted with the CKMfitter software.

You must register here first. Once registered, you will be able to start analyses using the CKMfitter environment.

The CKMlive project is brought to you by **Jérôme CHARLES, Alexandre CLAUDE, Sébastien DESCOTES-GENON, Stéphane MONTEIL.** The mailing list ckmlive@clermont.in2p3.fr is available to ask any questions on the project.

Some slides introducing the project.

## CKMfitter Group

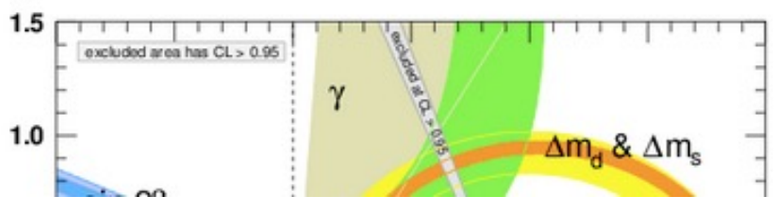
**CKMfitter** is a group of theoreticians and experimentalists who propose global interpretations of the Flavour Physics data in the framework of the Standard Model (SM) of Particle Physics and beyond (BSM). The involved laboratories are by alphabetical order: **CPT (Marseille), KEK (Japan), LAPP (Annecy-Le-Vieux), LPC (Clermont), LPNHE (Paris), LPT (Orsay), and the Universities of Berlin (Germany) and Melbourne (Australia).**

A rather complete description of the group and its activities (including the main results and publications) can be found here. In particular, we provide the High Energy Physics community with the metrology of the four SM parameters describing the quark flavour charged current transitions in the **Cabibbo-Kobayashi-Maskawa (CKM) paradigm**, established with frequentist statistical techniques.

**CKMlive is a web interface** that will allow you to perform similar analysis for given scenarios (in particular the Standard Model global fit), either taking inputs from analyses already performed by the CKMfitter group or choosing your preferred inputs.

## SM global fit

In the framework of the Standard Model, charged-current quark transitions are described by the CKM matrix, which can be parameterised with four independent parameters. CKMlive allows you to perform the metrology of these parameters using experimental constraints on observables with a good control of theoretical uncertainties.




## New Physics in ΔF = 2

CKMlive will be extended to flavour analyses beyond the Standard Model in the future. For instance, it is possible to introduce New Physics contributions in neutral mesons mixing processes in a model-independent way by multiplying the SM mixing matrix

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# Analysis - Scenario & Scan constraint

## Choose your scenario

Select the model and the scenario that will be the basis of your analysis

Each step will help you to define the elements of your analysis. If you have already completed one step but change your mind, please do not use the "Back" feature of your browser. Instead, keep on following the steps up to the summary of your analysis, where you will be able to modify the information already provided, if necessary.

**Name**

etabar-SDG

**Scan constraint**

1D

**Model**

Standard Model

**Scenario**

EPS15

✖ Cancel Analysis ✔ Continue

1.Fill the fields one after the other

2. Continue

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# Analysis - Target Input

## Choose your target

Select the target(s), i.e., the quantity(ies) that you want to constrain through your analysis

Each step will help you to define the elements of your analysis. If you have already completed one step but change your mind, please do not use the "Back" feature of your browser. Instead, keep on following the steps up to the summary of your analysis, where you will be able to modify the information already provided, if necessary.

You can cancel the current selection by typing CTRL and selecting another element (on Unix/Windows) or by typing Command reselecting the selection (on Mac OS).

You can select several elements by pressing Command/Alt (on Mac OS) or shift (on Unix/Windows) at the time of selection

Information on this scenario (including the default input values) can be found on the **EPS15 documentation page**

Info on params

**Target observable**

$|V_{ub}|$
$|V_{cb}|$
$\alpha$
$\sin 2\beta$
$\cos 2\beta$
$\gamma$
$\Delta m_d$
$\Delta m_s$

A meaningful range for etabar can be between -5 and 5

**Scan min of the first target** (etabar)

0.3

**Scan max of the first target** (etabar)

0.4

**Target parameter**

$A$
$\lambda$
$\bar{\rho}$
$\bar{\eta}$
$R_b$
$\frac{B_{B_s}}{B_{B_d}}$
$f_{B_s}$

1.Select the observable or the parameter to scan

✖ Cancel Analysis  ✔ Continue

# Documentation - EPS15

## Standard Model > EPS15

Model | Scenario | Input

### > $|V_{ud}|$

$|V_{ud}|$ is the $d \to u$ left-handed current coupling. It has been extracted using super-allowed nuclear $\beta$-decays, The PDG average is $0.97425 \pm 0 \pm 0.00022$.

### > $|V_{us}| \times F_+^{K\pi}(0)$

$|V_{us}| \times F_+^{K\pi}(0)$ corresponds to the $s \to u$ left-handed current coupling. It has been extracted from semileptonic kaon decays ($K_{\ell 3}$). The PDG 2015 experimental data is $0.2163 \pm 0.0005$.

### > $|V_{ub}|$

$|V_{ub}|$ is the $b \to u$ left-handed current coupling. It has been extracted from inclusive and exclusive semileptonic $b \to u$ transitions. The combination of experimental data with theoretical inputs on the relevant hadronic quantities leads to the CKMfitter average $(4.01 \pm 0.08 \pm 0.22) \times 10^{-3}$.

### > $|V_{cb}|$

$|V_{cb}|$ is the $b \to c$ left-handed current coupling. It has been extracted from inclusive and exclusive semileptonic $b \to c$ transitions. The combination of experimental data with theoretical inputs on the relevant hadronic quantities leads to the CKMfitter average $(41.00 \pm 0.33 \pm 0.74) \times 10^{-3}$.

### > $\Gamma(\Lambda_b \to p)/\Gamma(\Lambda_b \to \Lambda_c)$

$\Gamma(\Lambda_p \to p)/\Gamma(\Lambda_b \to \Lambda_c)$ is the ratio of semileptonic $\Lambda_b$ decay rates measured by LHCb $(1.00 \pm 0.09) \times 10^{-2}$,

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# Analysis - Target Input

## Choose your target

Select the target(s), i.e., the quantity(ies) that you want to constrain through your analysis

Each step will help you to define the elements of your analysis. If you have already completed one step but change your mind, please do not use the "Back" feature of your browser. Instead, keep on following the steps up to the summary of your analysis, where you will be able to modify the information already provided, if necessary.

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You can select several elements by pressing Command/Alt (on Mac OS) or shift (on Unix/Windows) at the time of selection

Information on this scenario (including the default input values) can be found on the **EPS15 documentation page**

**Target observable**

$|V_{ub}|$
$|V_{cb}|$
$\alpha$
$\sin 2\beta$
$\cos 2\beta$
$\gamma$
$\Delta m_d$
$\Delta m_s$

**Target parameter**

$A$
$\lambda$
$\bar{\rho}$
$\bar{\eta}$
$R_t$
$\frac{B_{B_s}}{B_{B_d}}$
$f_{B_s}$

A meaningful range for etabar can be between -5 and 5

**Scan min of the first target** (etabar)

0.3

**Scan max of the first target** (etabar)

0.4

2.Select the scan range

1.Select the observable or the parameter to scan

✖ Cancel Analysis ✔ Continue

3. Continue

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# Analysis - Input Element

## Choose your inputs

Select the inputs, i.e., the quantities that will be used to constrain your target

Each step will help you to define the elements of your analysis. If you have already completed one step but change your mind, please do not use the "Back" feature of your browser. Instead, keep on following the steps up to the summary of your analysis, where you will be able to modify the information already provided, if necessary.

You can cancel the current selection by typing CTRL and selecting another element (on Unix/Windows) or by typing Command reselecting the selection (on Mac OS).

You can select several elements by pressing Command/Alt (on Mac OS) or shift (on Unix/Windows) at the time of selection

Information on this scenario (including the default input values) can be found on the **EPS15 documentation page**

**Inputs**

**Recommended Global Fit**

- $|V_{ud}|$
- $|V_{us}| \times F_+^{K\pi}(0)$
- $|V_{ub}|$
- $|V_{cb}|$
- $\alpha$
- $\sin 2\beta$
- $\cos 2\beta$
- $\gamma$
- $\Delta m_d$
- $\Delta m_s$
- $|\epsilon_K|$
- $\alpha_S(m_Z)$
- $B(B \to \tau\nu)$
- $B(K \to e\nu)$
- $B(K \to \mu\nu)$
- $B(\tau \to K\nu)$
- $B_{K\mu 2}/B_{\pi\mu 2}$
- $B_{\tau K2}/B_{\tau\pi 2}$

**Additional observables**

- $2\beta_{sb}$

**Your target choice**

✔ $\bar{\eta}$ $[0.3, 0.4]$

1.Select the inputs of the fit (recommended global fit)

✖ Cancel Analysis ✔ Continue

2. Continue

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# Analysis - Plotting

## Parametrise the plotting

**This step is not mandatory and it can be skipped clicking the green button "Skip plotting"**

Skip plotting step

Plot : optional

Each step will help you to define the elements of your analysis. If you have already completed one step but change your mind, please do not use the "Back" feature of your browser. Instead, keep on following the steps up to the summary of your analysis, where you will be able to modify the information already provided, if necessary.

CKM live By nickname

**Please enter a nickname. This will appear on the plot as CKMlive by nickname**

SDG

**Please enter a title for the plot of the result**

Global fit

1.Give a nickname and a title

Cancel Analysis

Continue

2. Continue

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# Analysis - List

success Your analysis [700] - "etabar-SDG" has been submitted. You will soon receive an email notification informing you of the end of its execution.

## Your Analysis

| Analysis | Name | Date | Element target | scan constraint | status | Scenario | Edit | Remove |
|---|---|---|---|---|---|---|---|---|
| 700 | etabar-SDG | 02/18/2019 - 06:22 | $\bar{\eta}$ | 1 | Prepared to be launched | EPS15 | | |

1 The process is launched

From CKM Live Web <ckmliveweb@in2p3.fr>
Subject **incoming result analysis etabar-SDG.dat**
To Me <sebastien.descotes-genon@th.u-psud.fr>

Reply | Forward | Archive | Junk | Delete | More

06:51

```
Hello ,
The result for analysis etabar-SDG.dat (id#700) is now available. You can find it by selecting the
analysis in Your analyses/Ongoing analyses, clicking the green button to access the page "Personalise
your analysis" and selecting "Obtain the results".
The requested plot is coming soon, and you will receive an additional mail when it is available.

With our best regards,
CKMlive Web Server

_____

This is an automatic notification from http://ckmlive.in2p3.fr
Please DO NOT reply to this message.
Thanks
```

After a while, 2 mails, one for the data file, the other for the plot

From CKM Live Web <ckmliveweb@in2p3.fr>
Subject **incoming plot analysis 2019-02-18-plot-analysis-700.end.eps**
To Me <sebastien.descotes-genon@th.u-psud.fr>

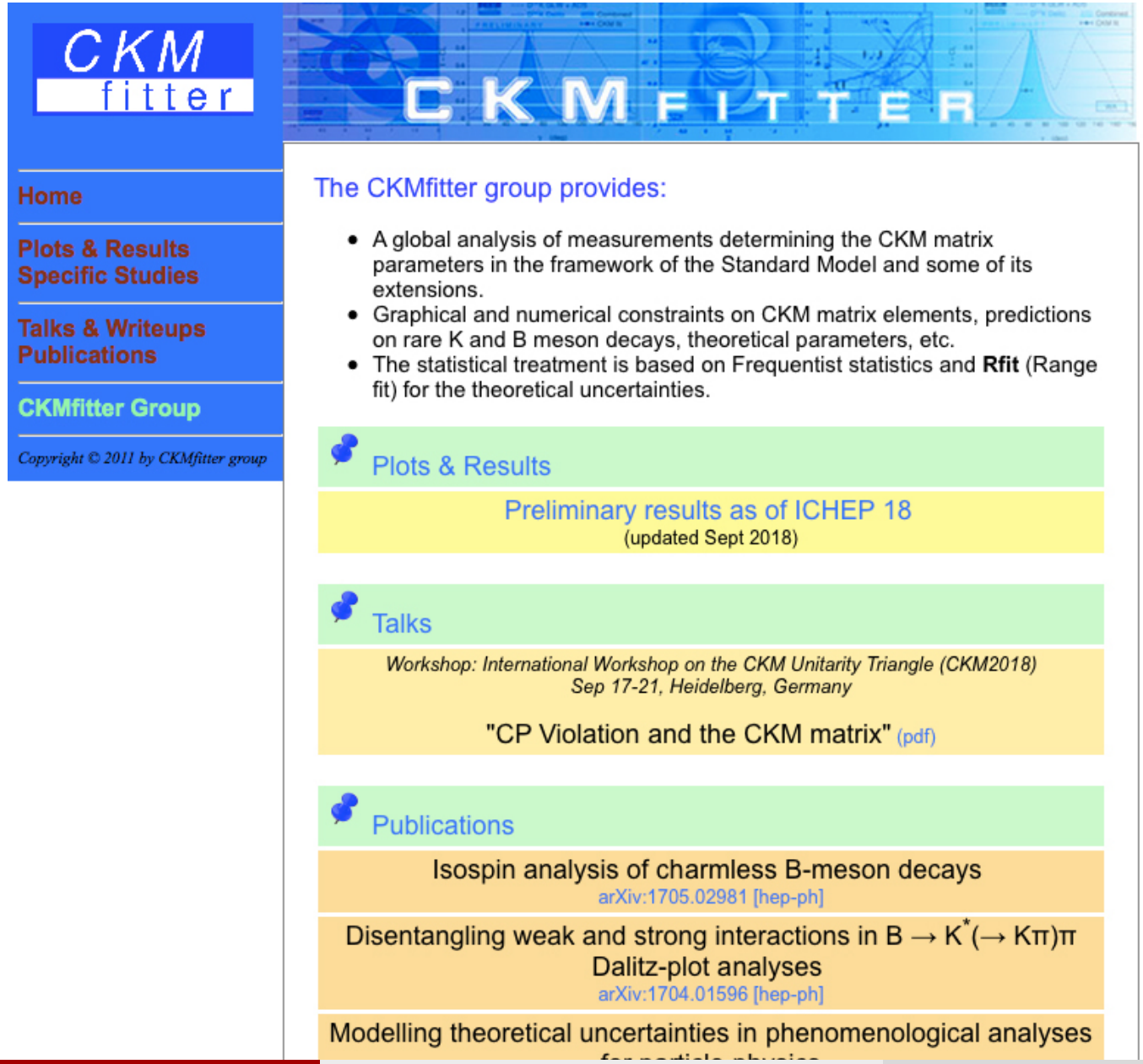
Reply | Forward | Archive | Junk | Delete | More

06:58

```
Hello ,
The plot 2019-02-18-plot-analysis-700.end.eps for analysis id#700 is now available. You can find it by
selecting the analysis in Your analyses/Ongoing analyses, clicking the green button to access the page
"Personalise your analysis", and selecting the tab "Plot" to "See the eps plot"

Greetings,
CKMlive Web Server

_____

This is an automatic notification from http://ckmlive.in2p3.fr
Please DO NOT reply to this message.
Thanks
```

# Advertisement

# The ckmfitter.in2p3.fr web page



# Regular updates of CKM in the SM

CKM fitter

CKMFITTER

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## Preliminary results as of Summer 2018 (ICHEP 2018 conference)

Menu:

The global CKM fit: Inputs and Numerical results
The global CKM fit: Pulls
The global CKM fit in the large (ρ-bar,η-bar) plane
The global CKM fit in the small (ρ-bar,η-bar) plane (zoom)
The global CKM fit in the large ($\bar{\rho}_M$, $\bar{\eta}_M$) plane with M = sb, ds, ct, ut, uc
The global CKM fit in the ($|V_{ud}|$,$|V_{us}|$) plane
The global CKM fit in the ($|V_{cd}|$,$|V_{cs}|$) plane
The global CKM fit in the ($|V_{ub}|$,$|V_{cb}|$) plane
The global CKM fit for $|V_{td}|$ and $|V_{ts}|$
Branching ratio of $B_s \to \mu^+ \mu^-$
Constraints on the angle $\alpha/\phi_2$ from charmless B decays

Numerical results:

The results of the global CKM analysis include:

- Wolfenstein parameters,
- UT angles and sides,
- $UT_s$ angle and apex,
- CKM elements,
- theory parameters,
- rare branching fractions (B->lν, B->ll).

Numerical Results

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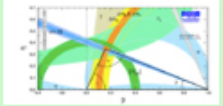
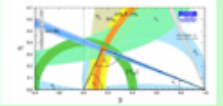
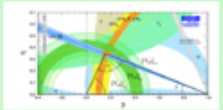
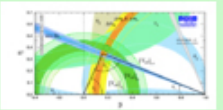
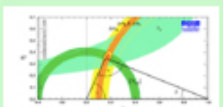
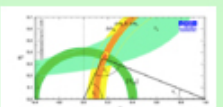
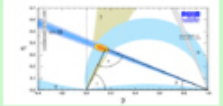
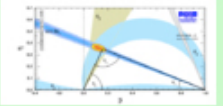
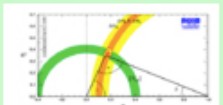
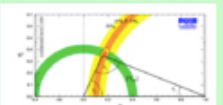
## The global CKM fit in the small (ρ-bar,η-bar) plane (zoom):

| | α, β, γ convention | $\phi_1, \phi_2, \phi_3$ convention |
|---|---|---|
| Zoomed constraints in the (ρ-bar,η-bar) plane.The red hashed region of the global combination corresponds to 68% CL. |  eps png |  eps png |
| Zoomed constraints in the (ρ-bar,η-bar) plane. The $\|V_{ub}\|$ constraint has been split in three contributions: $\|V_{ub}\|$ from inclusive and exclusive semileptonic B decays (plain dark green), $\|V_{ub}\|$ from $B^+ \to \tau^+ \nu$ (hashed darker green), and $\|V_{ub}\|/\|V_{cb}\|$ from $\Lambda_b$ decays (hashed ligher green). The red hashed region of the global combination corresponds to 68% CL. |  eps png |  eps png |
| Zoomed constraints in the (ρ-bar,η-bar) plane not including the angle measurements in the global fit. |  eps png |  eps png |
| Constraints in the (ρ-bar,η-bar) plane including only the angle measurements. |  eps png |  eps png |
| Constraints from CP conserving quantities ($\|V_{ub}/V_{cb}\|$, $\Delta m_d$, ($\Delta m_d$ and $\Delta m_s$) and $B^+ \to \tau^+ \nu$) in the (ρ-bar,η-bar) plane. |  eps png |  eps png |

# Regular updates of CKM in the SM

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## CKMfitter global fit results as of Summer 18:

- Wolfenstein parameters
- UT angles and sides
- $UT_s$ angle and apex
- CKM elements
- Input parameters
- Decay branching fractions

These results correspond to the usual global fit. For a more extensive discussion, please read the summary of inputs and results.

The results for the tree-only fit are available here.

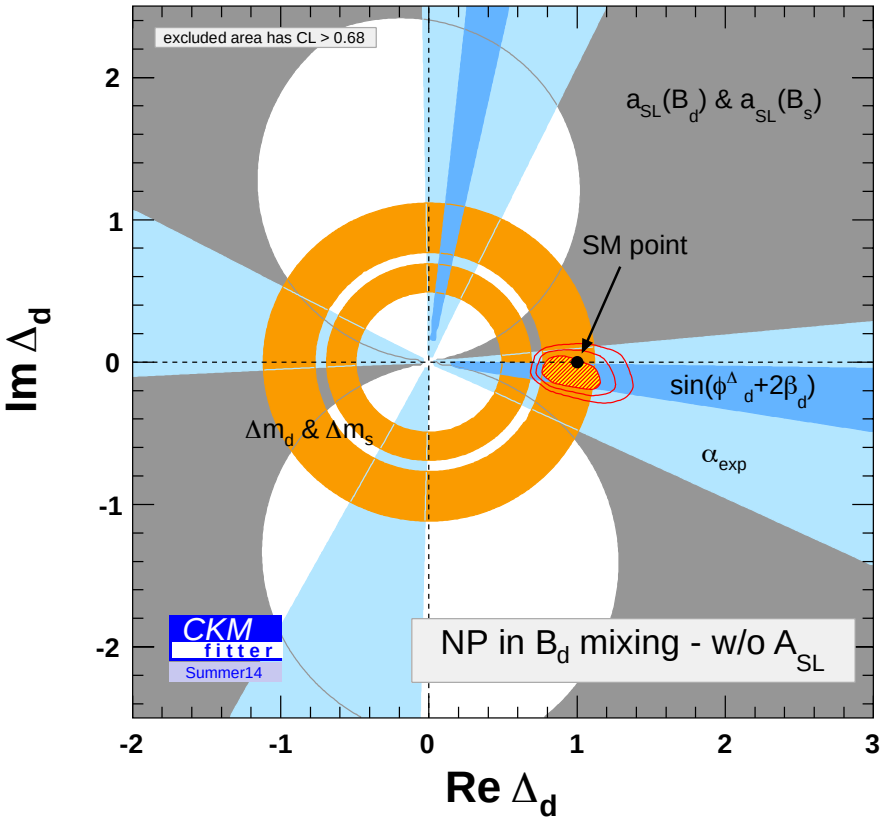
Wolfenstein parameters and Jarlskog invariant:

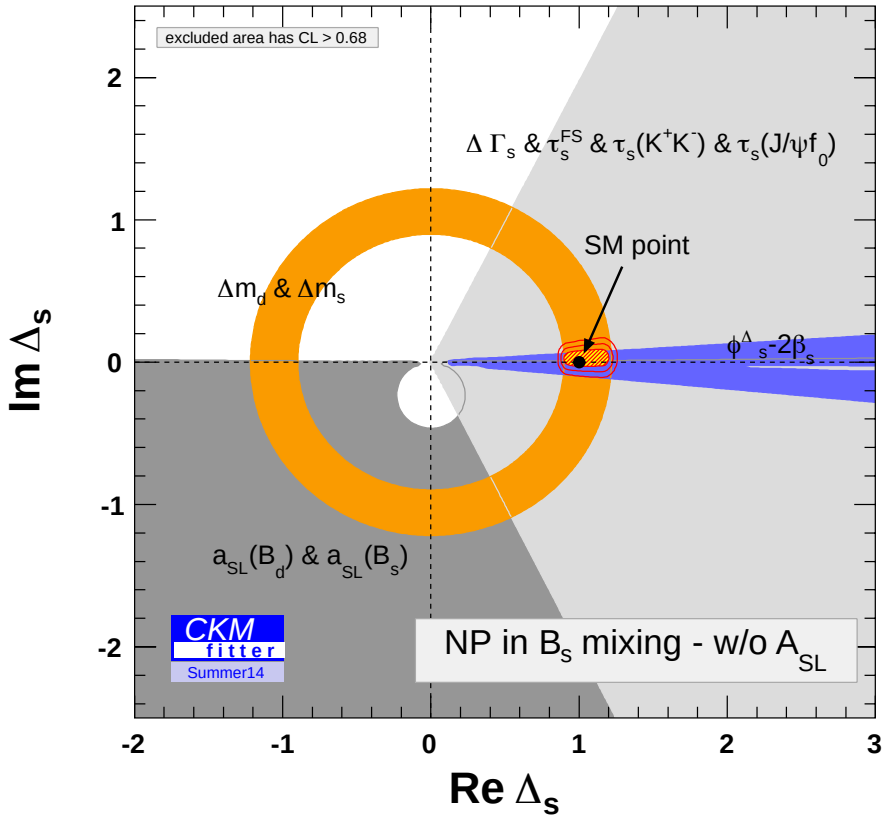
| Observable | Central ± 1 σ | ± 2 σ | ± 3 σ |
|---|---|---|---|
| A | 0.8403 [+0.0056 -0.0201] | 0.840 [+0.011 -0.035] | 0.840 [+0.016 -0.043] |
| λ | 0.224747 [+0.000254 -0.000059] | 0.22475 [+0.00062 -0.00012] | 0.22475 [+0.00106 -0.00018] |
| ρbar | 0.1577 [+0.0096 -0.0074] | 0.158 [+0.027 -0.014] | 0.158 [+0.036 -0.020] |
| ηbar | 0.3493 [+0.0095 -0.0071] | 0.349 [+0.019 -0.017] | 0.349 [+0.029 -0.025] |
| J [$10^{-5}$] | 3.172 [+0.094 -0.098] | 3.17 [+0.19 -0.25] | 3.17 [+0.29 -0.34] |

UT angles and sides:

| Observable | Central ± 1 σ | ± 2 σ | ± 3 σ |
|---|---|---|---|
| sin 2α | -0.057 [+0.038 -0.061] | -0.057 [+0.079 -0.155] | -0.06 [+0.12 -0.21] |
| sin 2α (meas. not in the fit) | -0.077 [+0.048 -0.085] | -0.077 [+0.091 -0.161] | -0.08 [+0.13 -0.20] |
| sin 2β | 0.708 [+0.013 -0.010] | 0.708 [+0.029 -0.021] | 0.708 [+0.044 -0.032] |

# Determination of constraints on NP



# Who we are


## The CKMfitter Group

If you have a specific request, a question or a comment, don't hesitate to send an email to the CKMfitter group:

ckmfitter-l@in2p3.fr

| | | |
|---|---|---|
| Jérôme Charles | Theory | CPT Marseille (France) |
| Olivier Deschamps | LHCb | LPC Clermont-Ferrand (France) |
| Sébastien Descotes-Genon | Theory | LPT Orsay (France) |
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| Karim Trabelsi | Belle/Belle II | KEK Tsukuba (Japan) |
| Philip Urquijo | Belle/Belle II | Melbourne Universiy (Australia) |
| Luiz Vale Silva | Theory | Univ. Sussex (UK) |

# Back to our first fit

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# Analysis - List

In « Your analyses/Ongoing analyses »

## Your Analysis

| Analysis | Name | Date | Element target | scan constraint | status | Scenario | Edit | Remove |
|---|---|---|---|---|---|---|---|---|
| 700 | etabar-SDG | 02/18/2019 - 06:22 | $\bar{\eta}$ | 1 | Achieved | EPS15 | | |
| 701 | rhobaretabar-SDG | 02/18/2019 - 06:39 | $\bar{\rho}$ $\bar{\eta}$ | 2 | Achieved | EPS15 | | |
| 702 | Vub-SDG | 02/18/2019 - 06:49 | $\|V_{ub}\|$ | 1 | Transfered on the computing server | EPS15 | | |
| 704 | Vub-SDG-Indirect | 02/18/2019 - 07:04 | $\|V_{ub}\|$ | 1 | Prepared to be launched | EPS15 | | |

1

The process is achieved and the results can be retrieved

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# Personalise your analysis

You can change the value of any input by clicking on the associated green button (both in the "Target" and "Inputs" thumbnails). You can see the parameters on which a given input depends by clicking on the corresponding grey button

## ✱ ETABAR-SDG

Targets | Inputs | Plot

### Your Target(s)

✔ $\bar{\eta}$ $[0.3, 0.4]$

**State**

This analysis is achieved

Obtain the results

### Choose the next step

✔ See datacard

✔ **Duplicate the analysis**

For the data file

### Your analysis properties

✔ Modify granularity 250

```
//    analysisName -> "etabar-SDG"
//    theoryPackage -> {{"BBbarKKbarMixing`", version -> "SM"}, {"LeptonicDecay`",
version -> "SM"}, {"SemileptonicDecay`", version -> "SM"}, {"DiLeptonicDecay`",
version -> "SMNNLO"}, {"KtoPiNuNu`", version -> "SM"}}
//    inputData -> {}
//
//    analysisName -> "etabar-SDG"
//    takeMe -> {{"|Vud|", 0.97425, 0, 0.00022}, {"|Vus|xF+Kpi(0)", 0.2163, 0.0005},
{"|Vub|", 0.00398, 0.00008, 0.00022}, {"|Vcb|", 0.041, 0.00033, 0.00074}, {"alpha",
"Winter15/alpha_Winter15.dat"}, {"sin2beta", 0.691, 0.017}, {"cos2beta", 0.5, 0,
0.5}, {"gamma", "Summer14/gamma_CKM14.dat"}, {"Deltamd", 0.51, 0.003}, {"Deltams",
17.757, 0.021}, {"|epsilonK|", 0.0022280000000000004, 0.000011}, {"alphaS(mZ)",
0.1185, 0, 0.0006}, {"B(B->taunu)", 0.00010800000000000001, 0.000021}, {"B(K->enu)",
0.00001581, 8.*^-8}, {"B(K->munu)", 0.6355, 0.0011}, {"B(tau->Knu)", 0.006955,
0.000096}, {"Kmu2/pimu2", 1.3365, 0.0032}, {"tauK2/taupi2", 0.06431, 0.00094}, {"F
+Kpi(0)", 0.9645, 0.0015, 0.0045}, {"Bs", 1.32, 0.016, 0.03}, {"Bs/Bd", 1.023,
0.013, 0.014}, {"fBs", 0.224, 0.001, 0.002}, {"fBs/fBd", 1.205, 0.003, 0.006},
{"mtbar", 165.95, 0.35, 0.64}, {"etaB", 0.551, 0, 0.0022}, {"BK", 0.7615, 0.0027,
0.0137}, {"fK", 0.1552, 0.0002, 0.0006}, {"kappa_epsilonK", 0.94, 0.013, 0.023},
{"mcbar", 1.286, 0.013, 0.04}, {"etact", 0.497, 0, 0.047}, {"etatt", 0.5765, 0,
0.0065}, {"fK/fpi", 1.1952, 0.0007, 0.0029}, {"deltaKl2Rad", -0.007, 0, 0.0035},
{"deltatauK2Rad", 0.0073, 0, 0.0027}}
//    scenario -> "EPS15"
//    nickname -> "SDG"
//    title -> "Global fit"
//    plotQty -> {"#bar#eta"}
//    scanQty -> {"etabar"}
//    scanMin -> {0.3}
//    scanMax -> {0.4}
//    granularity -> 250
//    startRange -> {"A" -> {0.7, 0.9}, "lambda" -> {0.22, 0.23}, "rhobar" -> {-1.,
1.}, "etabar" -> {-1., 1.}, "LambdaQCD" -> {0.2, 0.24}}
//    verbose -> True
//    equivalence -> {}
//    plotMin -> {0.3}
//    plotMax -> {0.4}
//
//    alpha          Winter15/alpha_Winter15.dat LUT
//    gamma          Summer14/gamma_CKM14.dat    LUT
//    B(B->taunu)    0.00010800000000000001      0.000021 Gauss
//    B(K->enu)      0.00001581                  8.*^-8   Gauss
//    B(K->munu)     0.6355                      0.0011   Gauss
//    B(tau->Knu)    0.006955                    0.000096 Gauss
//    Kmu2/pimu2     1.3365                      0.0032   Gauss
//    sin2beta       0.691                       0.017    Gauss
//    |Vus|xF+Kpi(0) 0.2163                      0.0005   Gauss
//    Deltamd        0.51                        0.003    Gauss
//    Deltams        17.757                      0.021    Gauss
//    |epsilonK|     0.0022280000000000004       0.000011 Gauss
//    tauK2/taupi2   0.06431                     0.00094  Gauss
//    BK             0.7615                      0.0027   0.0137  GaussRange
//    Bs             1.32                        0.016    0.03    GaussRange
```

Information on analysis, parameters, observables, scan and plot

Value of the inputs

```
//    etaB            0.551                          0         0.0022  Range
//    etact           0.497                          0         0.047   Range
//    etatt           0.5765                         0         0.0065  Range
//    kappa_epsilonK 0.94                            0.013     0.023   GaussRange
//
//    global minimum Chi2 = 12.779 has been found at point
//    A -> 0.822673
//    lambda -> 0.225485
//    rhobar -> 0.150552
//    etaB -> 0.5525331276847826
//    fBs -> 0.226047
//    Bs -> 1.29235
//    fBs/fBd -> 1.21131
//    Bs/Bd -> 1.04116
//    fK -> 0.155818
//    BK -> 0.753141
//    delta1 -> 2.0801
//    etact -> 0.5398129335682634
//    etatt -> 0.5781333841352221
//    kappa_epsilonK -> 0.919654
//    mtbar -> 166.445
//    mcbar -> 1.30324
//    LambdaQCD -> 0.225059
//    fK/fpi -> 1.193
//    deltaKl2Rad -> -0.008414151344995836
//    deltatauK2Rad -> 0.00460001151867186
//    F+Kpi(0) -> 0.959764
//    etabar -> 0.3538
//
//    approximate pValue (from Prob) is 46.5 %
//
//    etabar = 0.3538 [+0.0069 -0.0067](1sigma)
//    etabar = 0.354 [+0.016 -0.018](2sigma)
//    etabar = 0.354 [+0.026 -0.027](3sigma)
//
//    TeX etabar & $0.3538^{+0.0069}_{-0.0067}$ & $0.354^{+0.016}_{-0.018}$ &
$0.354^{+0.026}_{-0.027}$ \\
//
//    Chi2Min = 12.779 is substracted
//
//    column format: xbin (ybin)  x  (y)  Chi2|1-p  p-value
//
//    end of header
134.983 0.353793 0.0007 0.978892
1 0.3002 45.814 1.30031E-11
2 0.3006 45.0176 1.95272E-11
3 0.301 44.2322 2.91644E-11
4 0.3014 43.4489 4.35176E-11
5 0.3018 42.6796 6.44813E-11
6 0.3022 41.9106 9.55433E-11
7 0.3026 41.1482 1.41113E-10
```

Global minimum and confidence intervals

p-value curve

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# Personalise your analysis

You can change the value of any input by clicking on the associated green button (both in the "Target" and "Inputs" thumbnails). You can see the parameters on which a given input depends by clicking on the corresponding grey button

## ✱ ETABAR-SDG

Targets | Inputs | Plot

### Your Target(s)

✔ $\bar{\eta}$ $[0.3, 0.4]$

For the plot

### State

This analysis is achieved

Obtain the results

### Choose the next step

✔ See datacard

✔ **Duplicate the analysis**

### Your analysis properties

✔ Modify granularity 250

CKM live

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# Personalise your analysis

You can change the value of any input by clicking on the associated green button (both in the "Target" and "Inputs" thumbnails). You can see the parameters on which a given input depends by clicking on the corresponding grey button

## ✱ ETABAR-SDG

Targets | Inputs | Plot

### Your plot(s)

**Nickname:** SDG

**Plot title:** Gobal fit

**Result:**

- 2019-02-18-plot_analysis-700.end.eps

See the eps plot

For the plot

### State

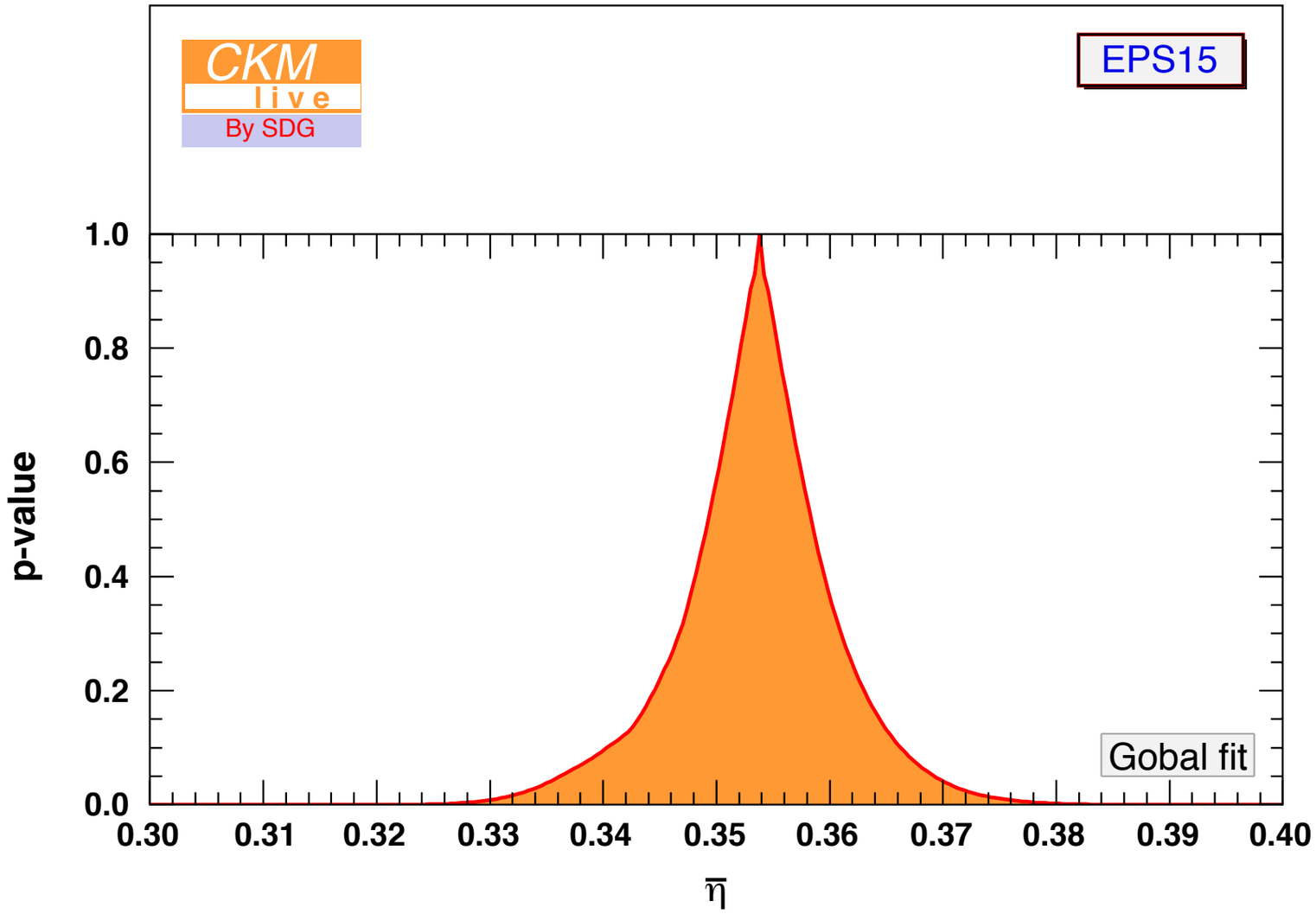
This analysis is achieved

Obtain the results

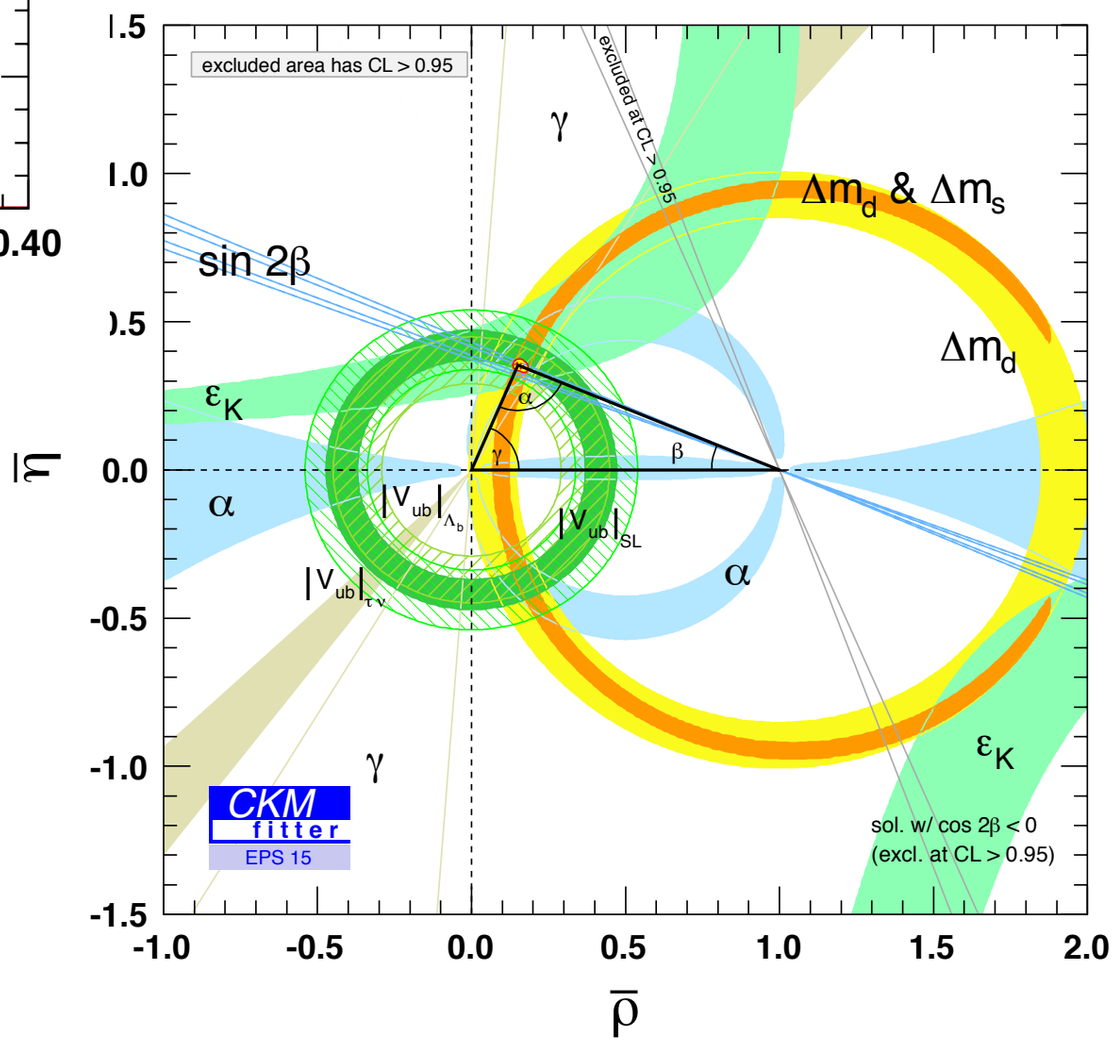
### Choose the next step

✔ See datacard

✔ Duplicate the analysis



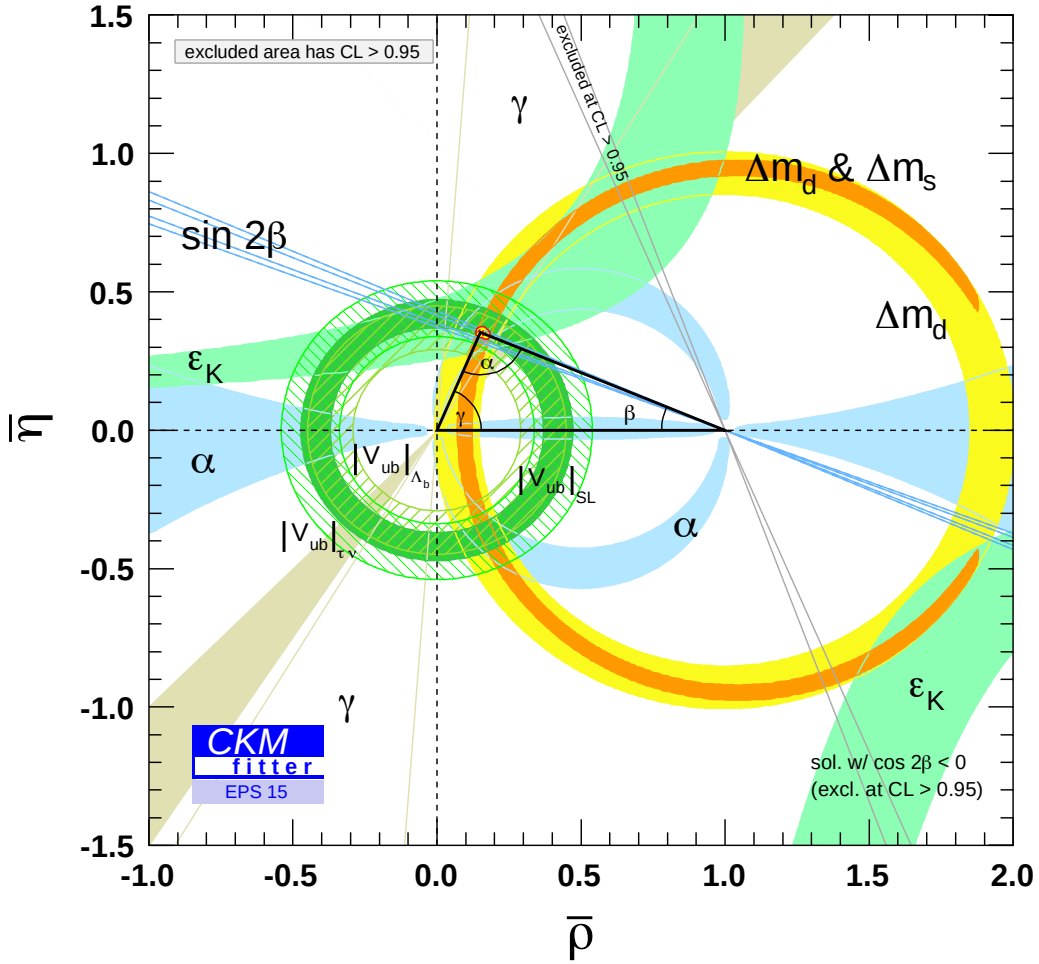

The value of the CKM parameter determined from the global fit



# Any questions ?

# A first fit with CKMlive (bonus track)

# First exercise (bonus track)




- Use the same data as the global fit for EPS15
- Perform the fit for $\bar{\eta}$ using only tree-level inputs
- Obtain the data file, the plot and confidence interval

CKM live

sedescot

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# Analysis - Scenario & Scan constraint

## Choose your scenario

Select the model and the scenario that will be the basis of your analysis

Each step will help you to define the elements of your analysis. If you have already completed one step but change your mind, please do not use the "Back" feature of your browser. Instead, keep on following the steps up to the summary of your analysis, where you will be able to modify the information already provided, if necessary.

**Name**

etabar-SDG-tree

**Scan constraint**

1D

**Model**

Standard Model

**Scenario**

EPS15

✖ Cancel Analysis ✔ Continue

1.Fill the fields one after the other

2. Continue

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# Analysis - Target Input

## Choose your target

Select the target(s), i.e., the quantity(ies) that you want to constrain through your analysis

Each step will help you to define the elements of your analysis. If you have already completed one step but change your mind, please do not use the "Back" feature of your browser. Instead, keep on following the steps up to the summary of your analysis, where you will be able to modify the information already provided, if necessary.

You can cancel the current selection by typing CTRL and selecting another element (on Unix/Windows) or by typing Command reselecting the selection (on Mac OS).

You can select several elements by pressing Command/Alt (on Mac OS) or shift (on Unix/Windows) at the time of selection

Information on this scenario (including the default input values) can be found on the **EPS15 documentation page**

Info on params

**Target observable**

$|V_{ub}|$
$|V_{cb}|$
$\alpha$
$\sin 2\beta$
$\cos 2\beta$
$\gamma$
$\Delta m_d$
$\Delta m_s$

A meaningful range for etabar can be between -5 and 5

**Scan min of the first target** (etabar)

0.2

**Scan max of the first target** (etabar)

0.5

**Target parameter**

$A$
$\lambda$
$\rho$
$\bar{\eta}$
$B_{B_s}$
$\frac{B_{B_s}}{B_{B_d}}$
$f_{B_s}$

1.Select the observable or the parameter to scan

✖ Cancel Analysis  ✔ Continue

CKM live

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# Analysis - Input Element

## Choose your inputs

Select the inputs, i.e., the quantities that will be used to constrain your target

Each step will help you to define the elements of your analysis. If you have already completed one step but change your mind, please do not use the "Back" feature of your browser. Instead, keep on following the steps up to the summary of your analysis, where you will be able to modify the information already provided, if necessary.

You can cancel the current selection by typing CTRL and selecting another element (on Unix/Windows) or by typing Command reselecting the selection (on Mac OS).

You can select several elements by pressing Command/Alt (on Mac OS) or shift (on Unix/Windows) at the time of selection

Information on this scenario (including the default input values) can be found on the **EPS15 documentation page**

**Inputs**

**Recommended Global Fit**

- $|V_{ud}|$
- $|V_{us}| \times F_+^{K\pi}(0)$
- $|V_{ub}|$
- $|V_{cb}|$
- $\alpha$
- $\sin 2\beta$
- $\cos 2\beta$
- $\gamma$
- $\Delta m_d$
- $\Delta m_s$
- $|\epsilon_K|$
- $\alpha_S(m_Z)$
- $B(B \to \tau\nu)$
- $B(K \to e\nu)$
- $B(K \to \mu\nu)$
- $B(\tau \to K\nu)$
- $B_{K\mu 2}/B_{\pi\mu 2}$
- $B_{\tau K2}/B_{\tau\pi 2}$

**Additional observables**

- $2\beta_{sb}$

**Your target choice**

✔ $\bar{\eta}$ [ 0.2 , 0.5 ]

1.Select the inputs of the fit (tree observables from recommended global fit)

✖ Cancel Analysi ✔ Continue

2. Continue

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# Analysis - Plotting

## Parametrise the plotting

**This step is not mandatory and it can be skipped clicking the green button "Skip plotting"**

Skip plotting step

Each step will help you to define the elements of your analysis. If you have already completed one step but change your mind, please do not use the "Back" feature of your browser. Instead, keep on following the steps up to the summary of your analysis, where you will be able to modify the information already provided, if necessary.

CKM live
By nickname

**Please enter a nickname. This will appear on the plot as CKMlive by nickname**

SDG

**Please enter a title for the plot of the result**

Tree only

1.Give a nickname and a title

Cancel Analysis

Continue

2. Continue

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# Personalise your analysis

You can change the value of any input by clicking on the associated green button (both in the “Target” and “Inputs” thumbnails). You can see the parameters on which a given input depends by clicking on the corresponding grey button

## ✱ ETABAR-SDG-TREE

Targets | Inputs | Plot

### Your Target(s)

✔ $\bar{\eta}$ $[0.2, 0.5]$

### Choose the next step

- ✔ Redefine target
- ✔ Redefine input
- ✔ See datacard
- ✔ **Abort**
- ✔ **Submit**

### Your analysis properties

- ✔ Modify granularity 250

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# Analysis - List

success Your analysis [809] - "etabar-SDG-tree" has been submitted. You will soon receive an email notification informing you of the end of its execution.

## Your Analysis

| Analysis | Name | Date | Element target | scan constraint | status | Scenario | Edit | Remove |
|---|---|---|---|---|---|---|---|---|
| 803 | etabar-SDG | 02/22/2019 - 05:58 | $\bar{\eta}$ | 1 | Achieved | EPS15 | | |
| 809 | etabar-SDG-tree | 02/22/2019 - 07:18 | $\bar{\eta}$ | 1 | Prepared to be launched | EPS15 | | |

The process is launched

1

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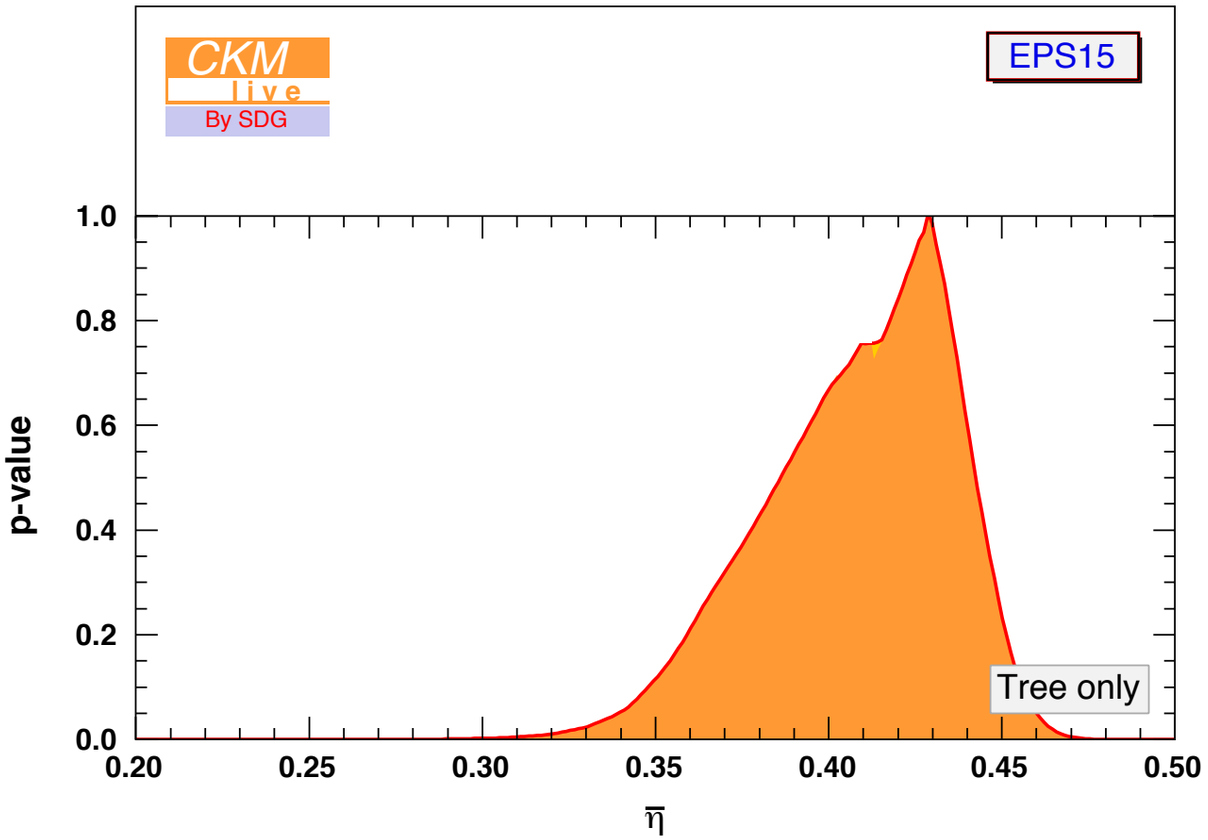
# Analysis - List

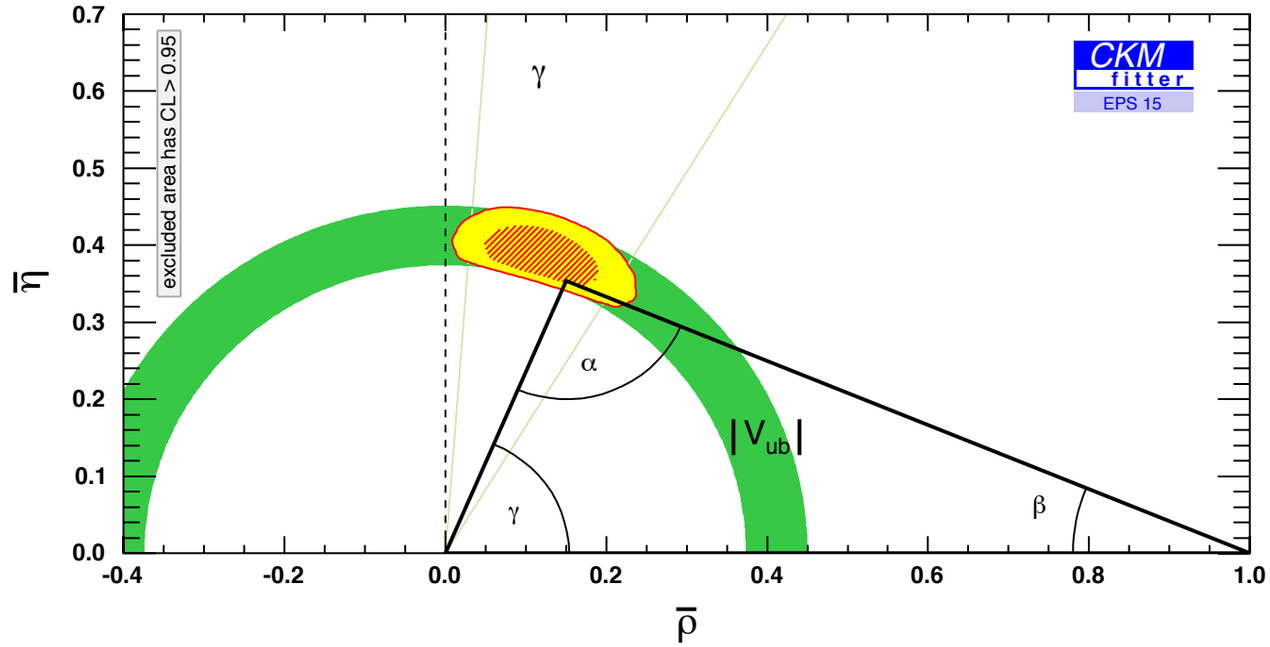
## Your Analysis

| Analysis | Name | Date | Element target | scan constraint | status | Scenario | Edit | Remove |
|---|---|---|---|---|---|---|---|---|
| 803 | etabar-SDG | 02/22/2019 - 05:58 | $\bar{\eta}$ | 1 | Achieved | EPS15 | | |
| 809 | etabar-SDG-tree | 02/22/2019 - 07:18 | $\bar{\eta}$ | 1 | Achieved | EPS15 | | |

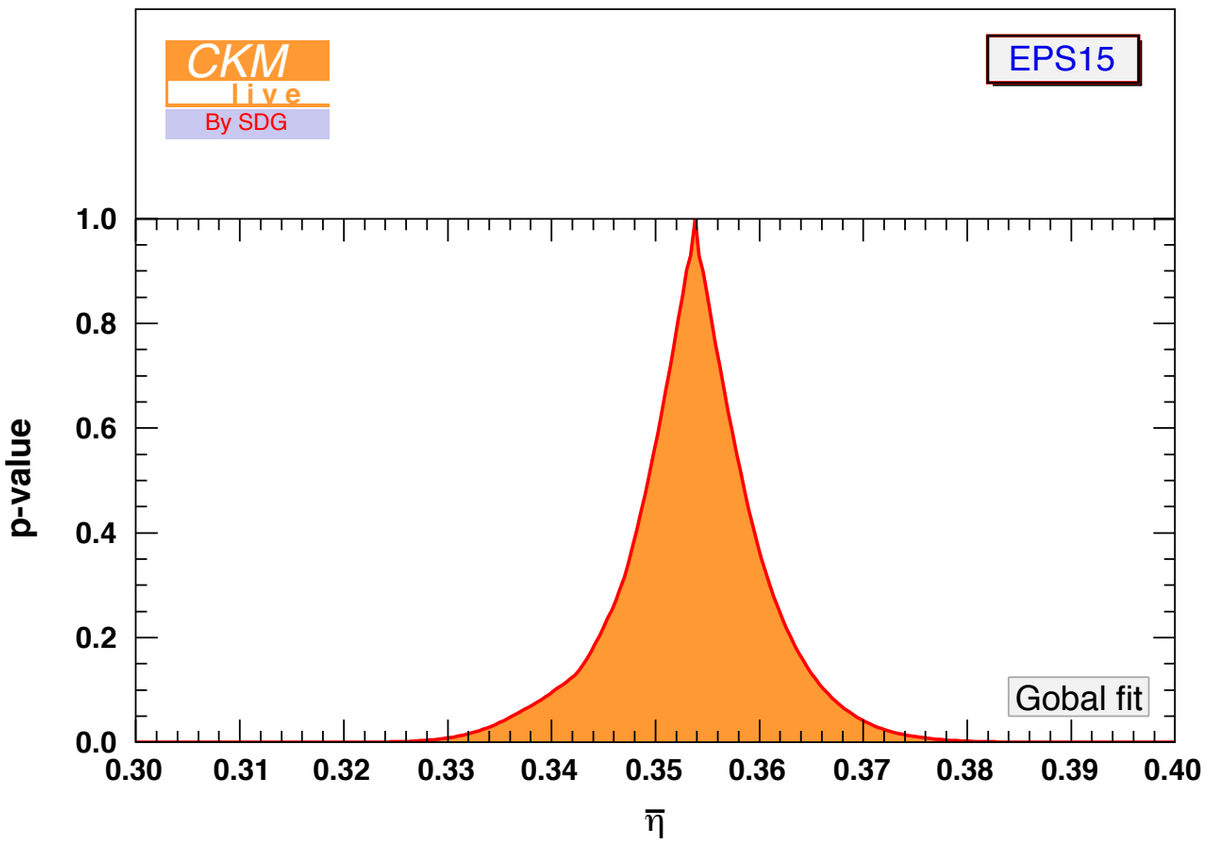
1

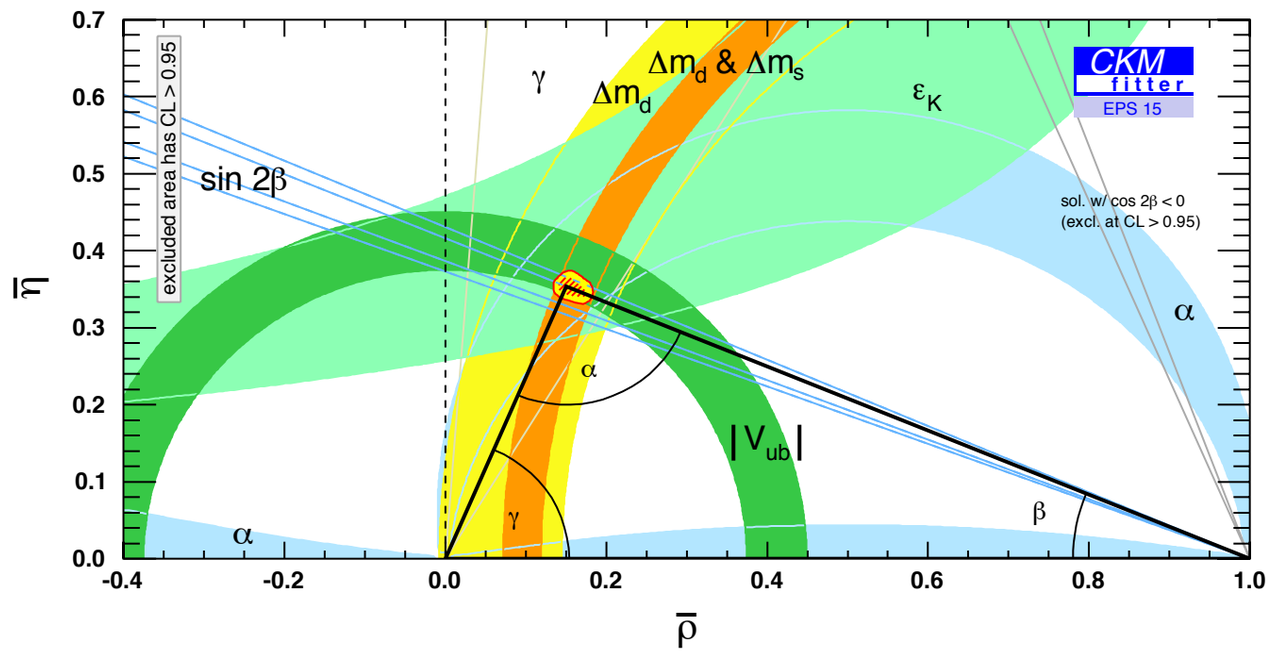
When you get the mails telling you that the process is achieved, the results can be retrieved




Tree versus Global



# Any questions ?