Flavour Physics. The CKM matrix and the CP Violation

A quick Appetizer !
in 180 sec…

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introduction to the **CKM matrix and CP violation** and formally introduce the **Standard Model in the fermionic sector by showing how CP violation phenomena find their place in it**.
I thus **introduce the physics of flavor**. I then proceed to a presentation of **the experiments** where we can study flavor physics, i.e. the experiments where we can produce and study beautiful, charming and strange hadrons. I discuss in detail different measurements that allow us to determine free parameters of the Standard Model (parameters of the CKM matrix): B oscillations, CP violation in the sector of beautiful and strange mesons, rare decays… **At the end of the course "it will be clear" why the physics of the flavor is a privileged way to test the validity of the Standard Model and for the search of the new physics beyond the Standard Model.** I conclude by putting together what we have learned so far and by presenting the current experimental programs and future experiments.

1) Historical introduction to flavor physics

2) The Standard Model in the fermion sector. CKM matrix and CP violation. The unitarity triangle

3) Experimental techniques for B and charm physics. The current experiments

4) Recent results

5) Putting it all together: what we have learned so far.

Flavour Physics in the *Standard Model* (SM) in the quark sector:

10 free parameters

~ half of the *Standard Model*

6 quarks masses

4 CKM parameters

In the Standard Model, charged weak interactions among quarks are codified in a 3 X 3 unitarity matrix : the **CKM Matrix**.

« non diagonal » Mass Couplings »

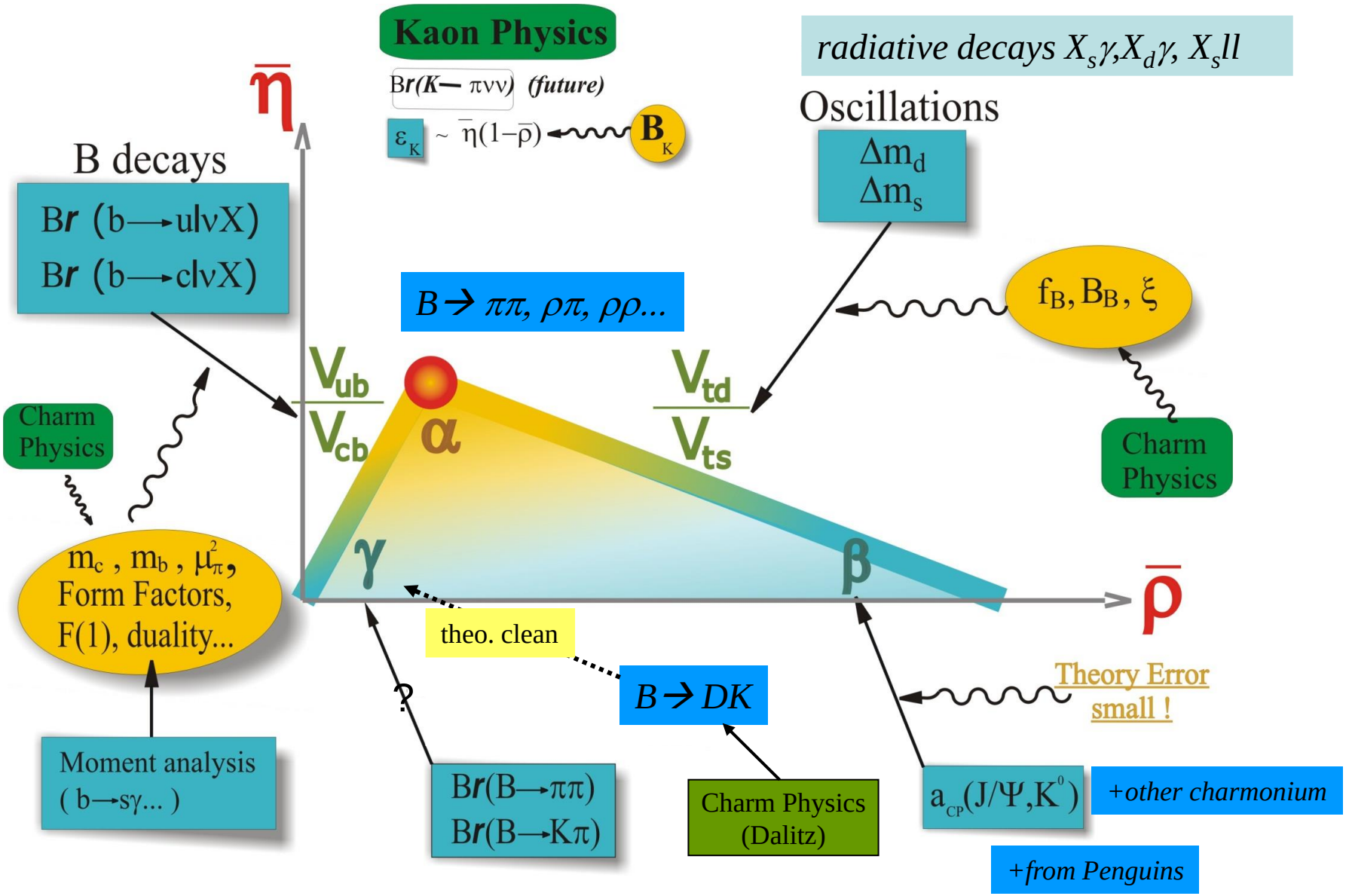
The existence of this matrix conveys the fact that the quarks which participate to weak processes are a linear combination of mass eigenstates

The fermion sector is poorly constrained by SM + Higgs Mechanism

mass hierarchy and CKM parameters

CKM/The Unitarity Triangle:

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

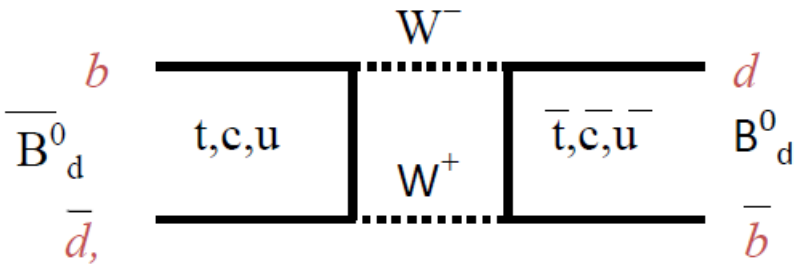


Example for B oscillations (FCNC-ΔB=2)

FCNC porcesses are ideal place to look for NP effects because they are suppressed in SM

Precise measurements are needed.
Effects goes $1/\Lambda^2$

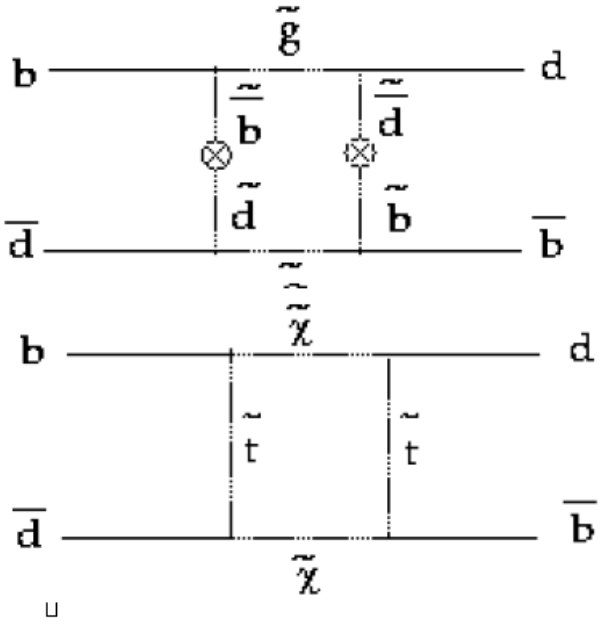
SM



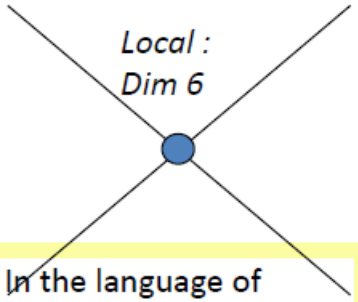
$$\frac{\left|V_{tb}^{*}V_{tq}\right|^{2}}{M_{W}^{2}}$$

In this particular case also ~m^2(t)

BSM



$$\frac{\left|\delta_{bq}\right|^{2}}{\Lambda_{eff}^{2}}$$



In the language of
The EFT, the operators
have dimension 6
→ $1/\Lambda^2$

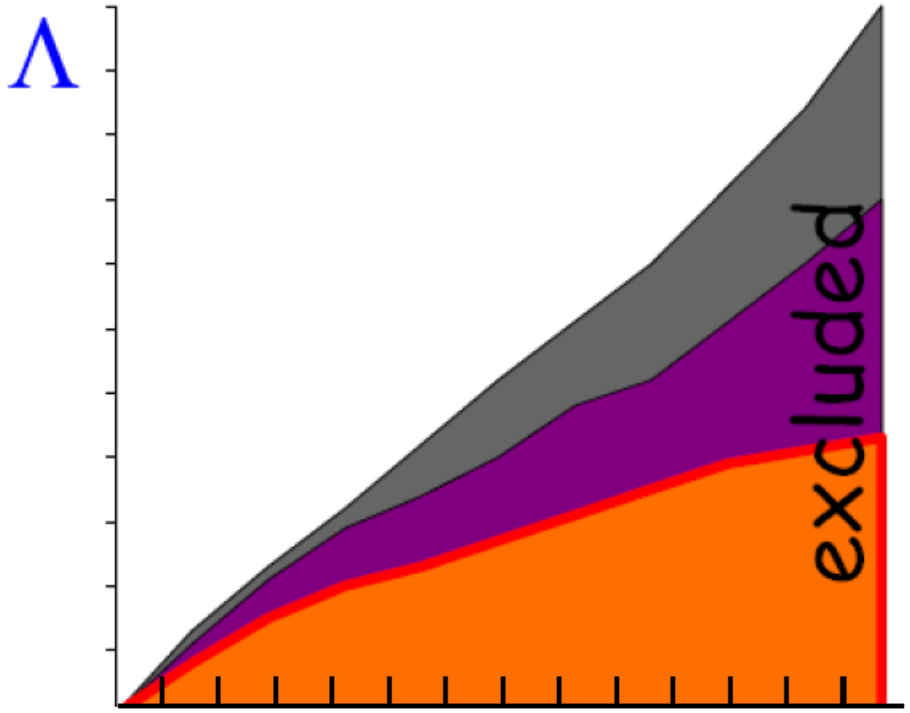
The measurements (in this case Δm_d)
are modified wrt the predictions of the SM by the presence of BSM particles.

modifications are important if couplings are larger and/or NP masses are lighter

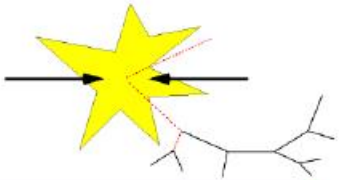
Pictorially

Flavour Physics

It is a game of couplings and scales



...Indeed historically we have always followed the two ways...



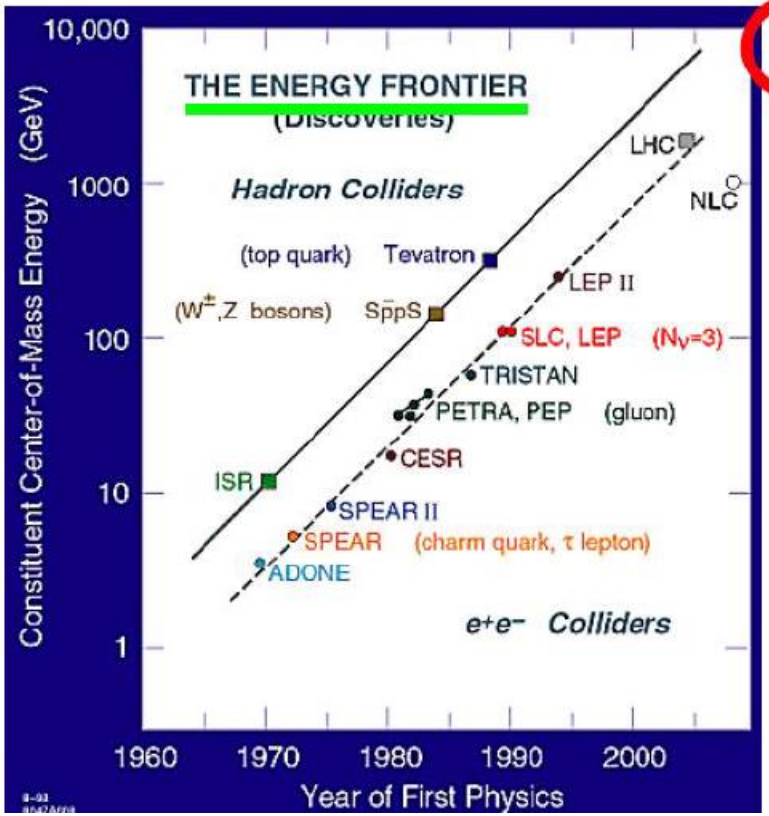
"Relativistic path"

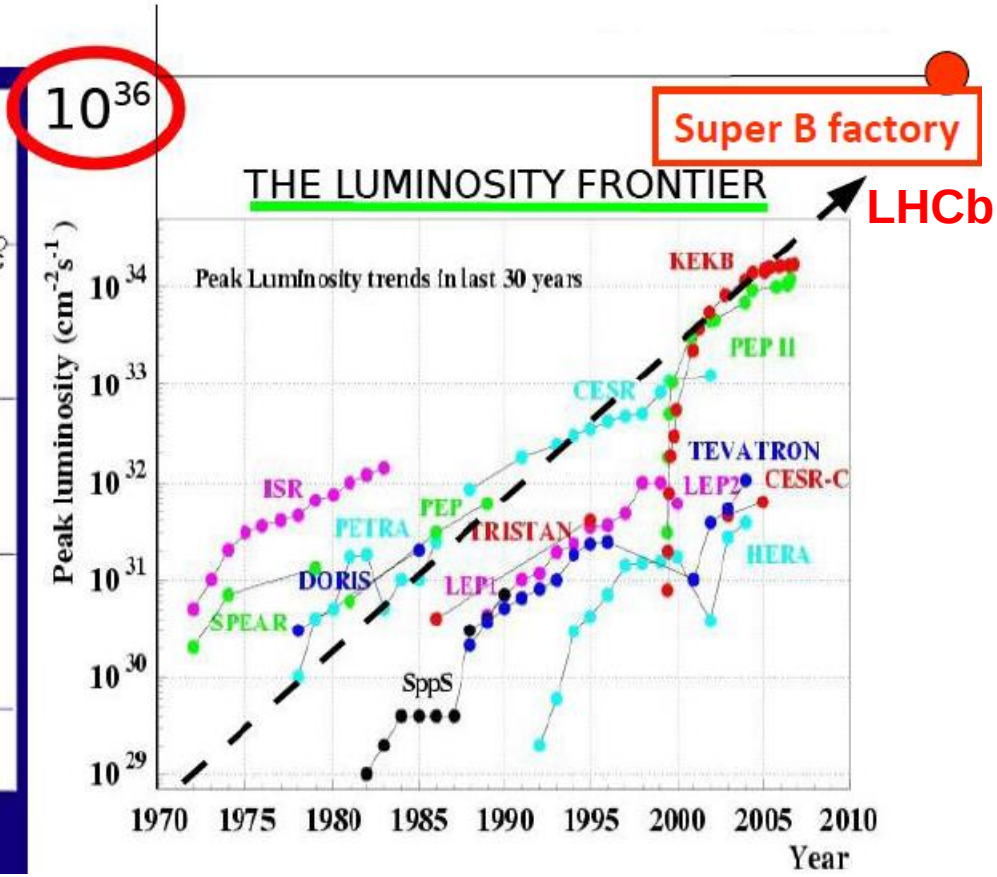
Crucial : Center-of-mass energy

"Quantum path"

Crucial : Luminosity

Look for discrepancy wrt SM on many different measurements

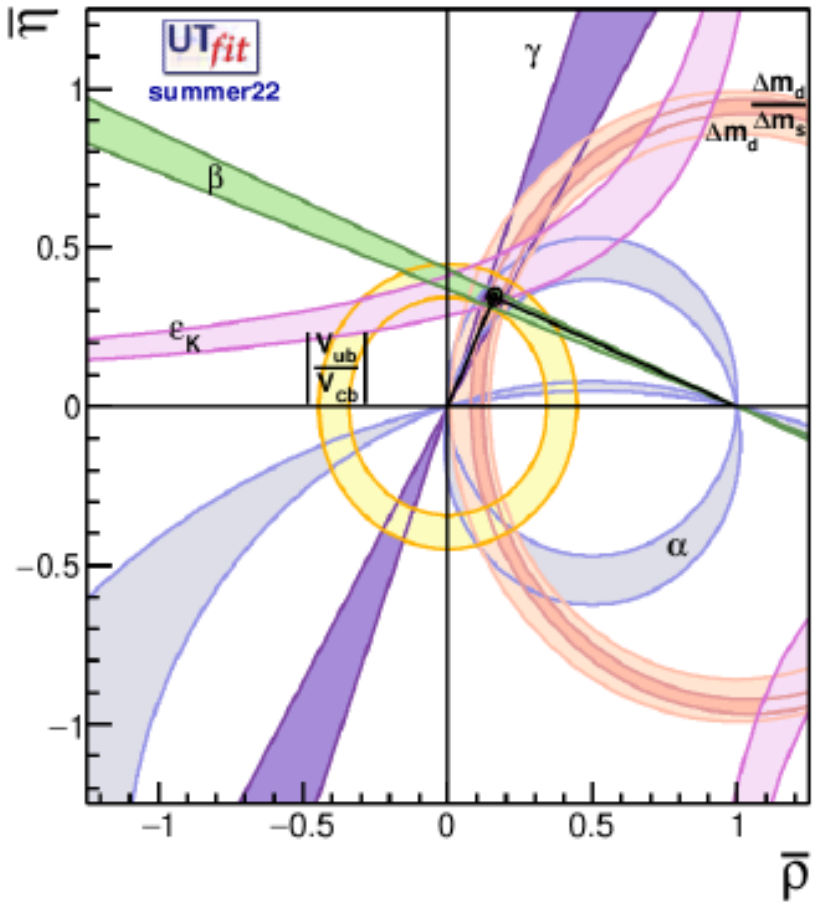




The test of the SM (in fermion sector)

..Or the « not discovery » of any new physics beyond the SM

1990-now → a huge number of precise measurements



All the constraints Look compatibles !

Discovery : absence of New Particles up to the ~2×Electroweak Scale !