Introduction a la Physique des Saveur Lourdes

JRJC 2013
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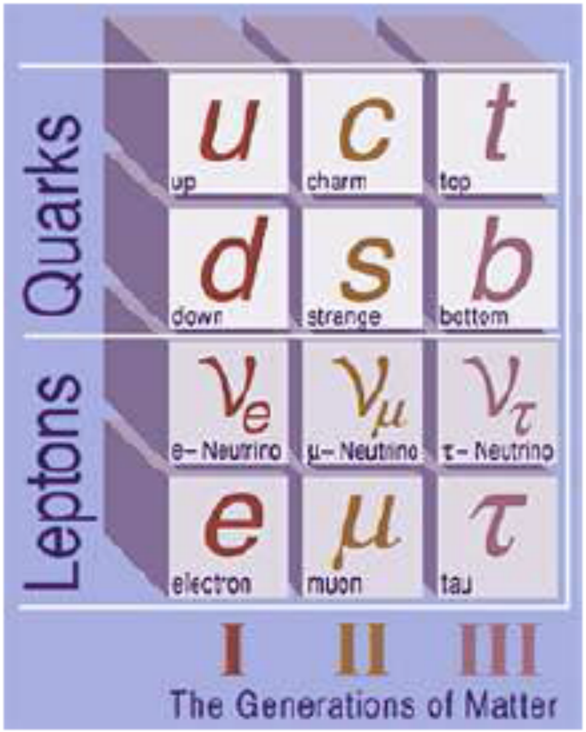
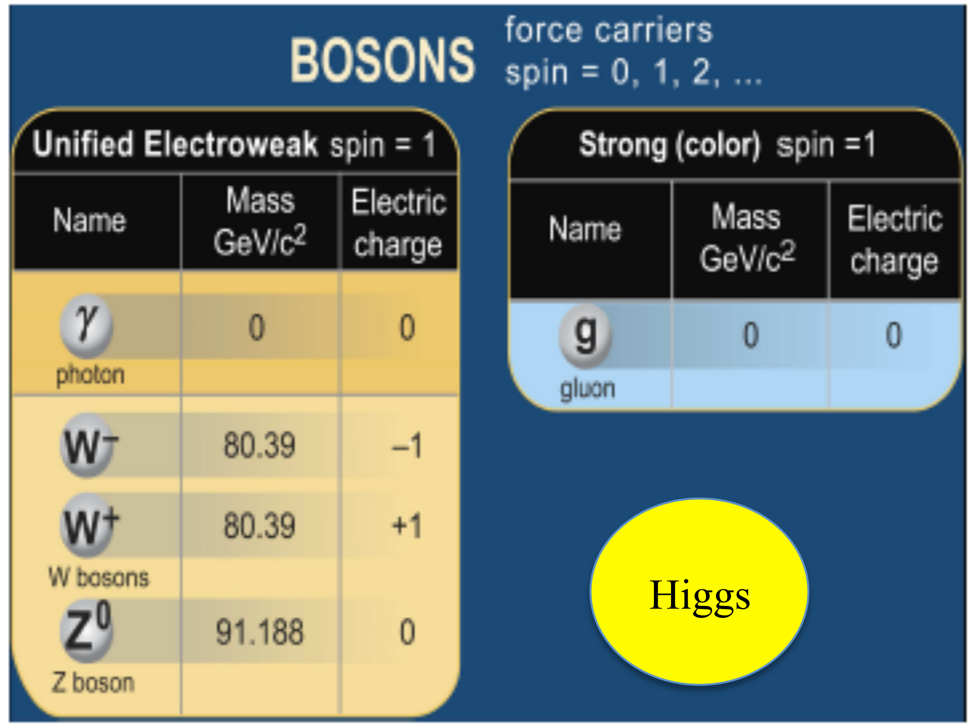
LAL - Orsay

Let’s start with some questions

- 1. What are the elementary constituents of matter?
- 2. What holds them together?
- 3. What is the correct mathematical framework to describe how the constituents are put together to form matter, how do they interact with each other and how can one predict its behavior under different conditions?

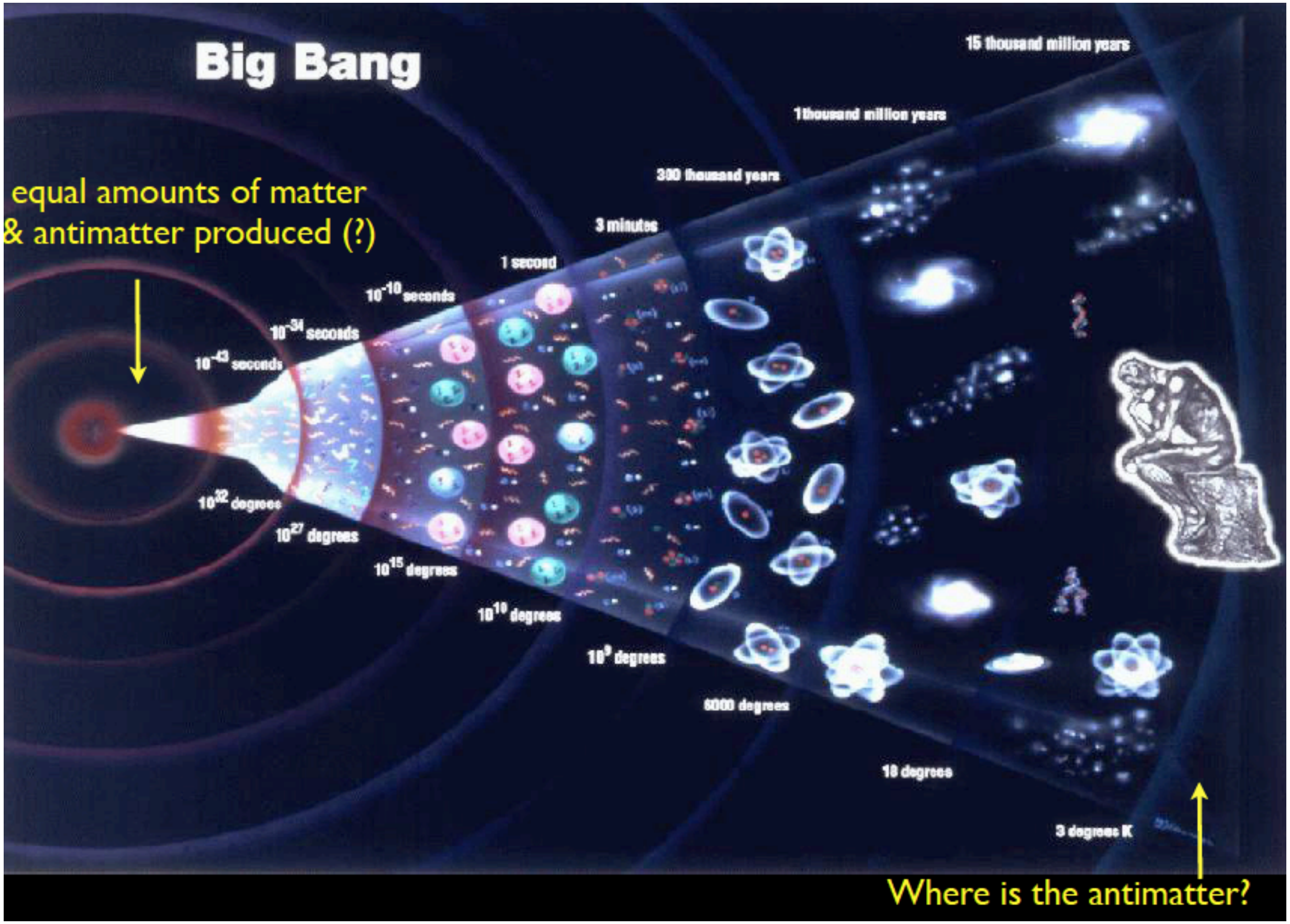
The Standard Model as we know it





Almost a complete picture

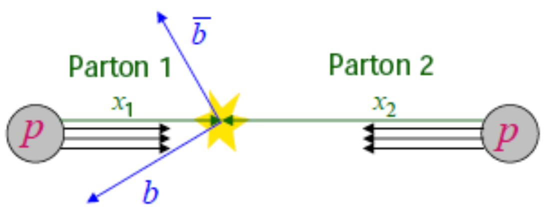
Question

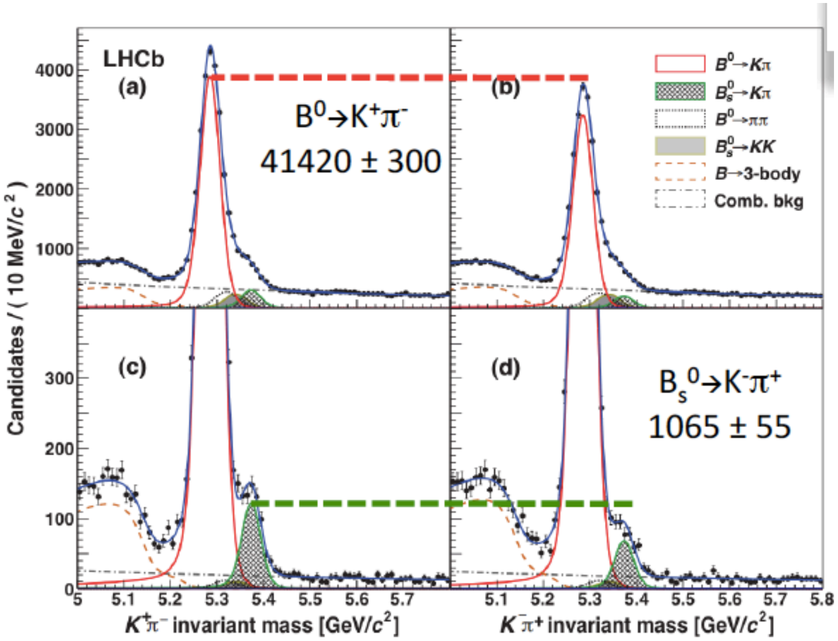


Some asymmetry between matter and anti-matter…
How does CP Violation work?

A concrete example of CP Violation

Take decays produced at the LHC and detected by LHCb.





$$B^0 \longrightarrow K^+\pi^- \neq \bar{B}^0 \longrightarrow K^-\pi^+$$

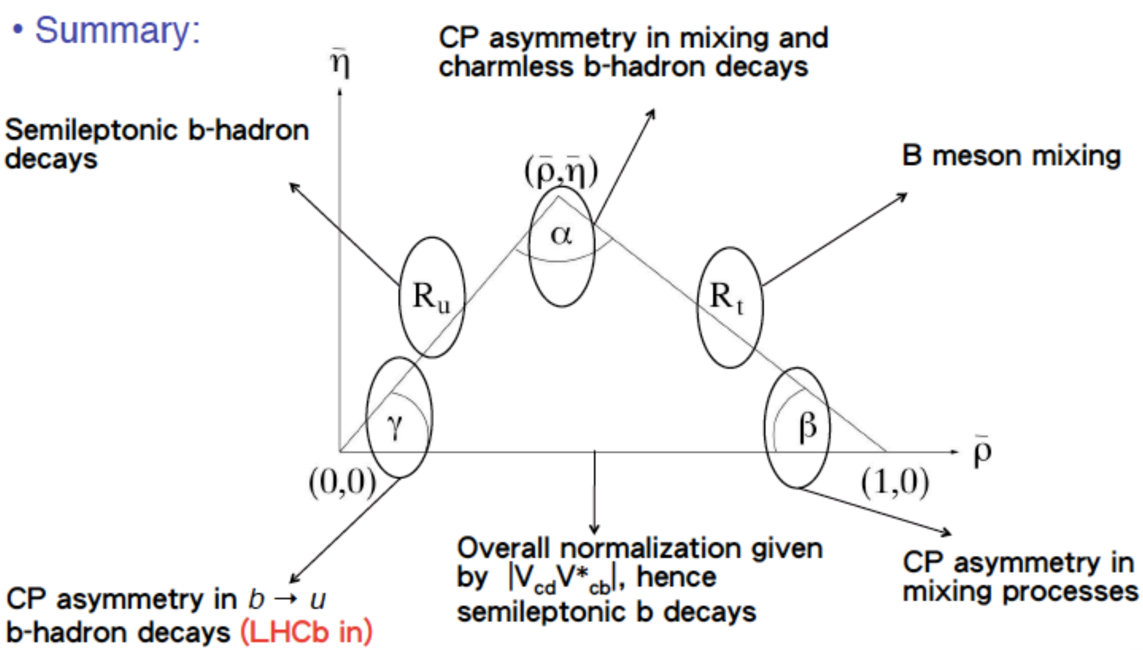
From a formal point of view

After spontaneous symmetry breaking, and once the mass matrices are diagonalized, it determines also how the mass and weak eigenstates are related. This is the CKM matrix. As for the (fermion) masses, nothing is predicted except the mass matrix must be unitary and complex.

$$\begin{pmatrix} u \\ s \\ b \end{pmatrix}_{EW} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} u \\ s \\ b \end{pmatrix}_{MASS}$$

CKM la suite

This matrix is a 3X3, unitary, complex, and hence described by means of four parameters: 3 rotation angles and a phase. The latter makes possible the CP symmetry violation in the Standard Model.



Alexis et Robert Maria

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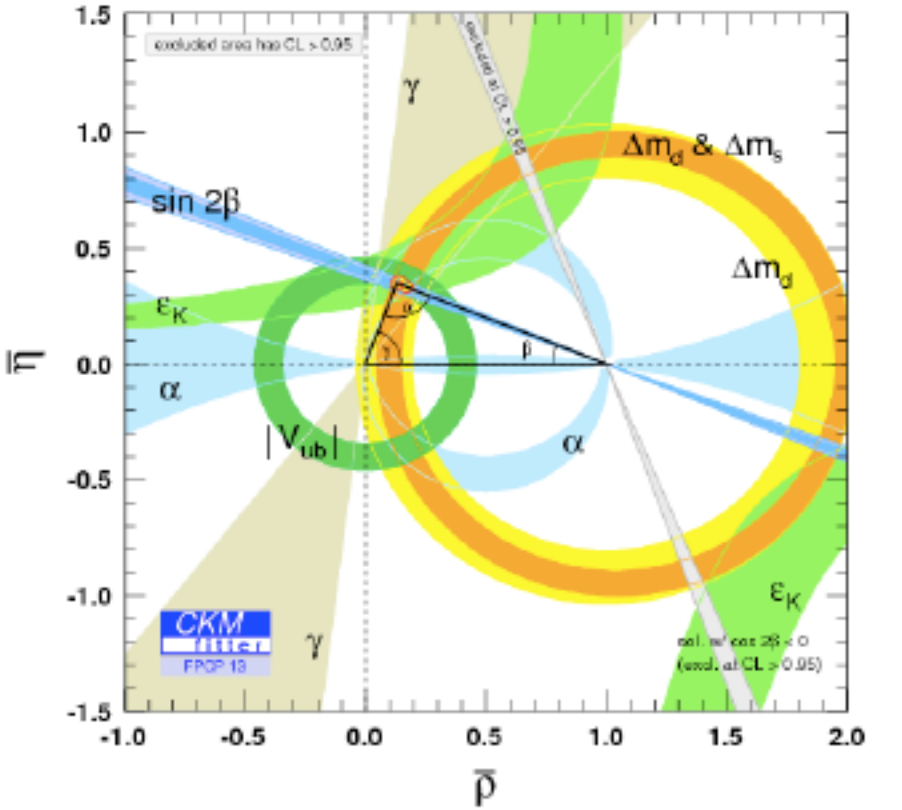
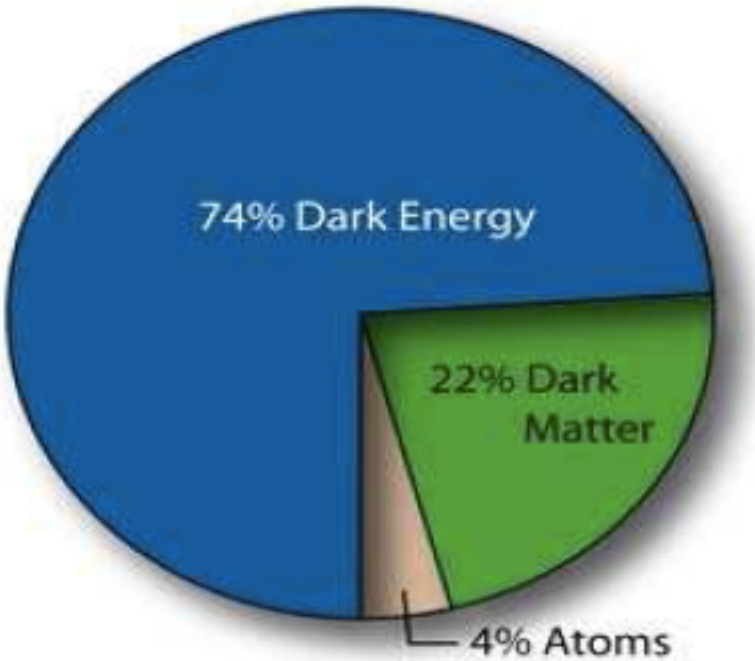
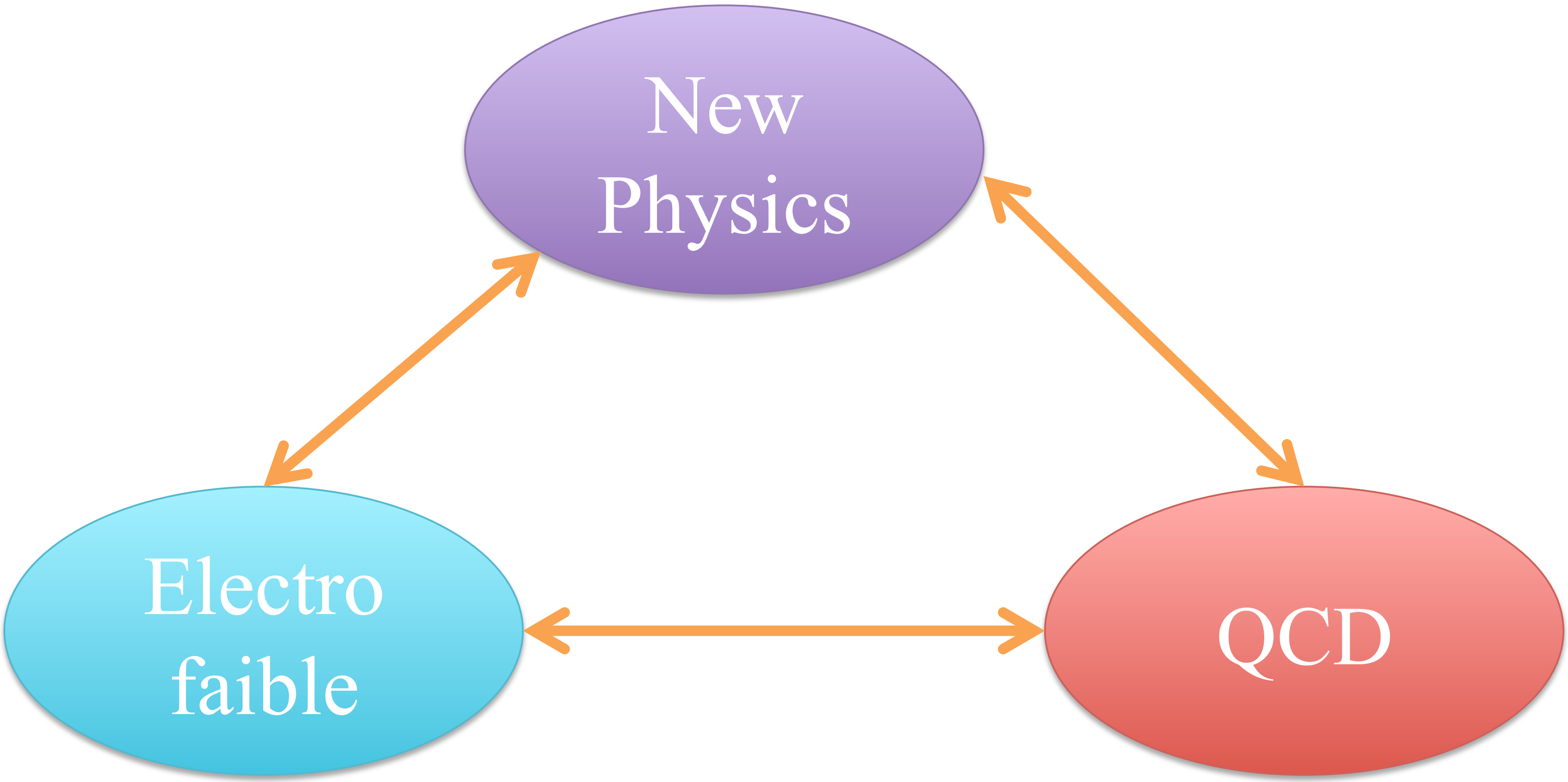


And an other question



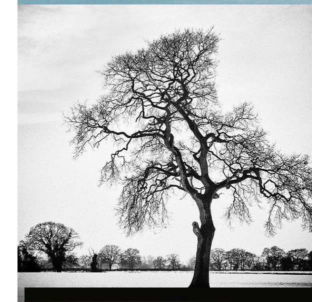
Are they new particles beyond those of the Standard Model that could explain this?

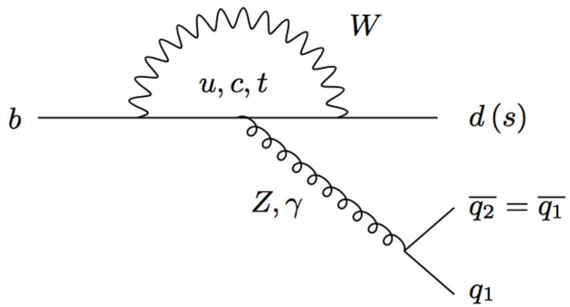
How does Flavour Physics seek for New Physics?

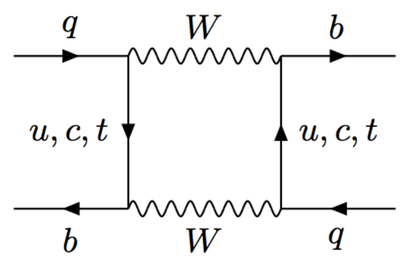


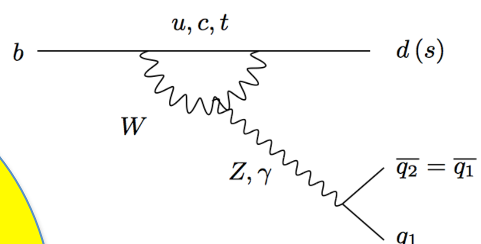
Trinite de l'analyse de la saveur

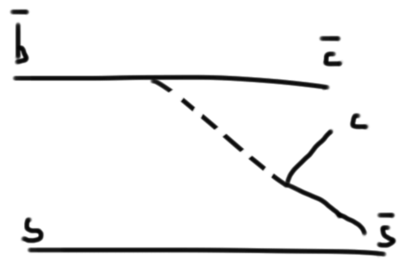
We study many processes



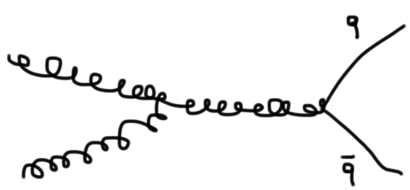


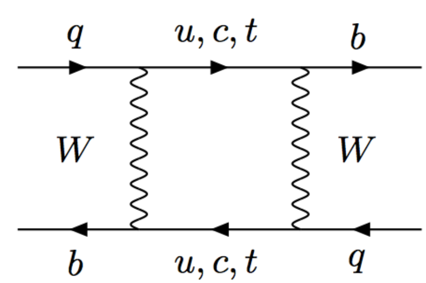






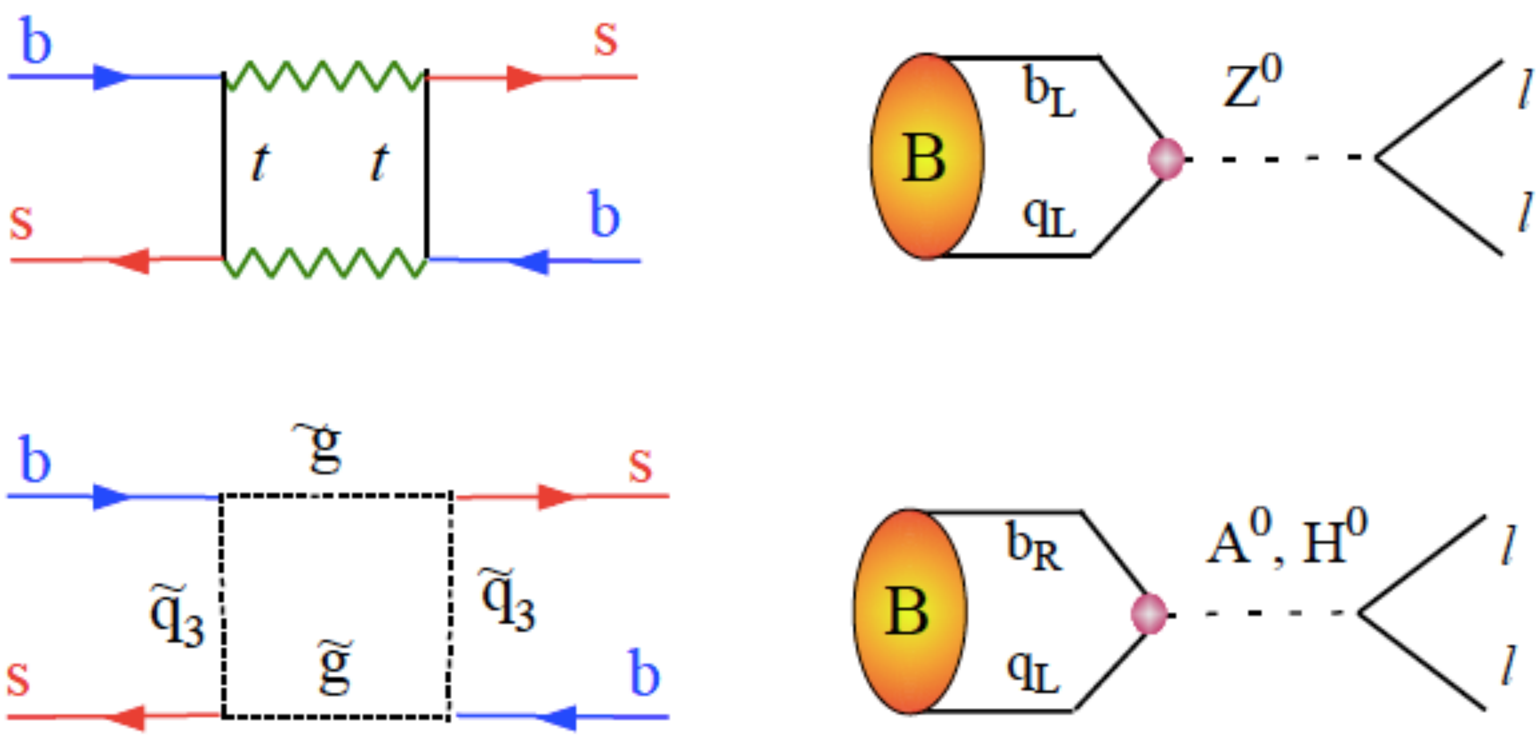
Maksym
Olga
Mostafa
Walaa
Samuel





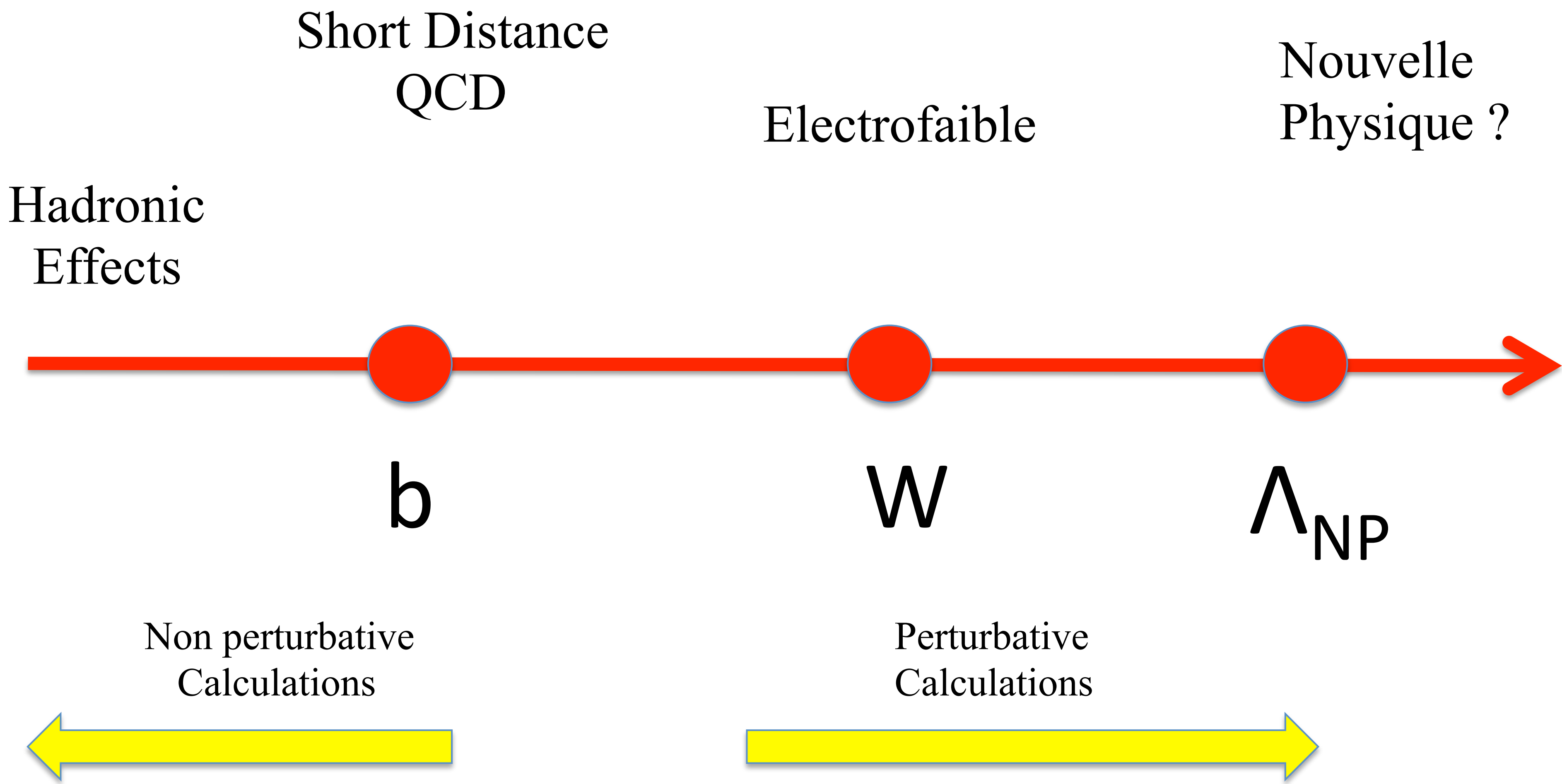
Access different observables such as Branching ratio, cross-sections, phases, angular observables…

New Physics Process can compete with Standard Model Process

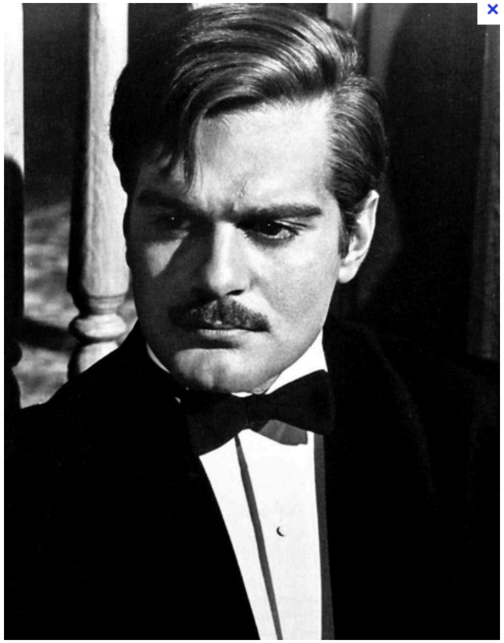


Alessandro

To each diamgram corresponds an energy scale



Effectif Hamiltonian



Wilson Coefficients

Matrix Elements

$$\langle f|\mathcal{H}_{\text{eff}}|i\rangle = \frac{G_{\text{F}}}{\sqrt{2}}\lambda_{\text{CKM}}\sum_k C_k(\mu)\langle f|Q_k(\mu)|i\rangle$$

CKM Couplings

Expression d’une transition d’un etat *i* vers un etat *f*.

Effectif Hamiltonian

Wilson
Coefficients

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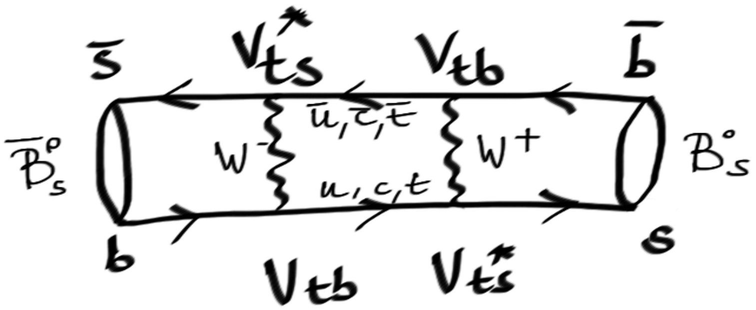
From flavour physics to heavy particles – Indirect searches



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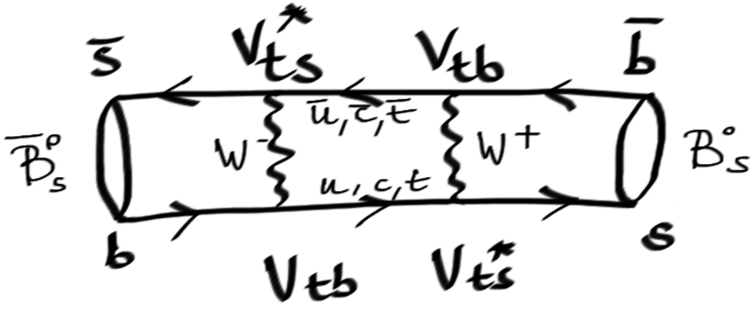
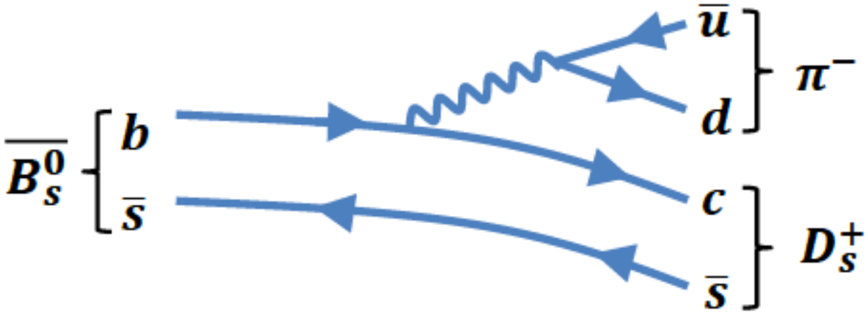


A Flavour specific decay



New J. Phys. 15 (2013) 053021

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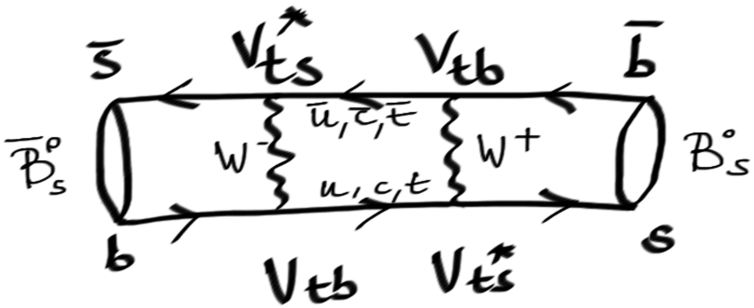
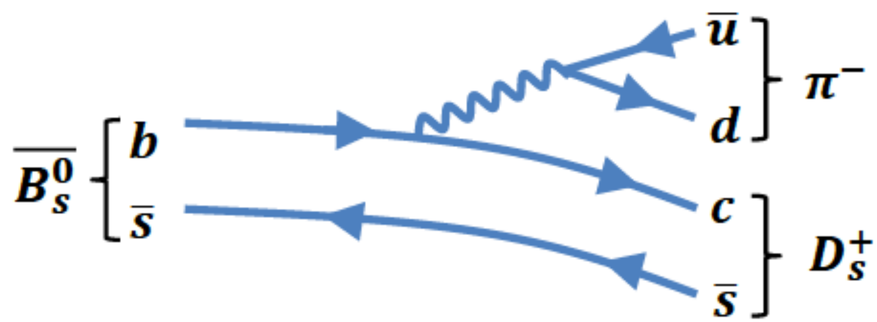


Jobs on the grid, TMVA etc



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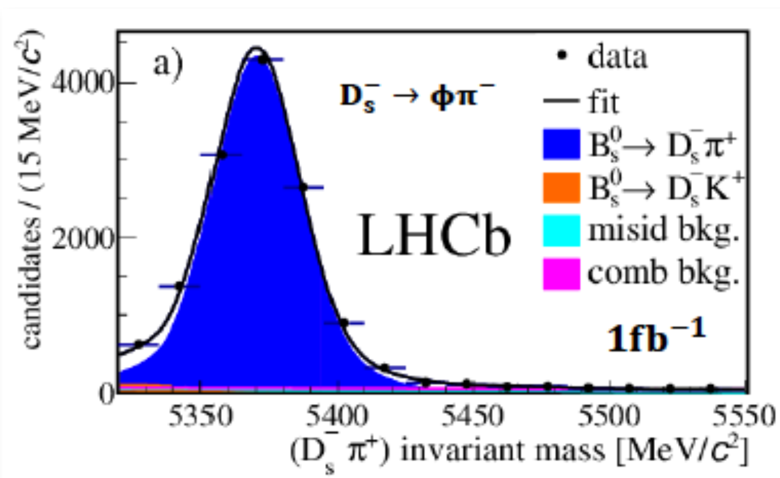
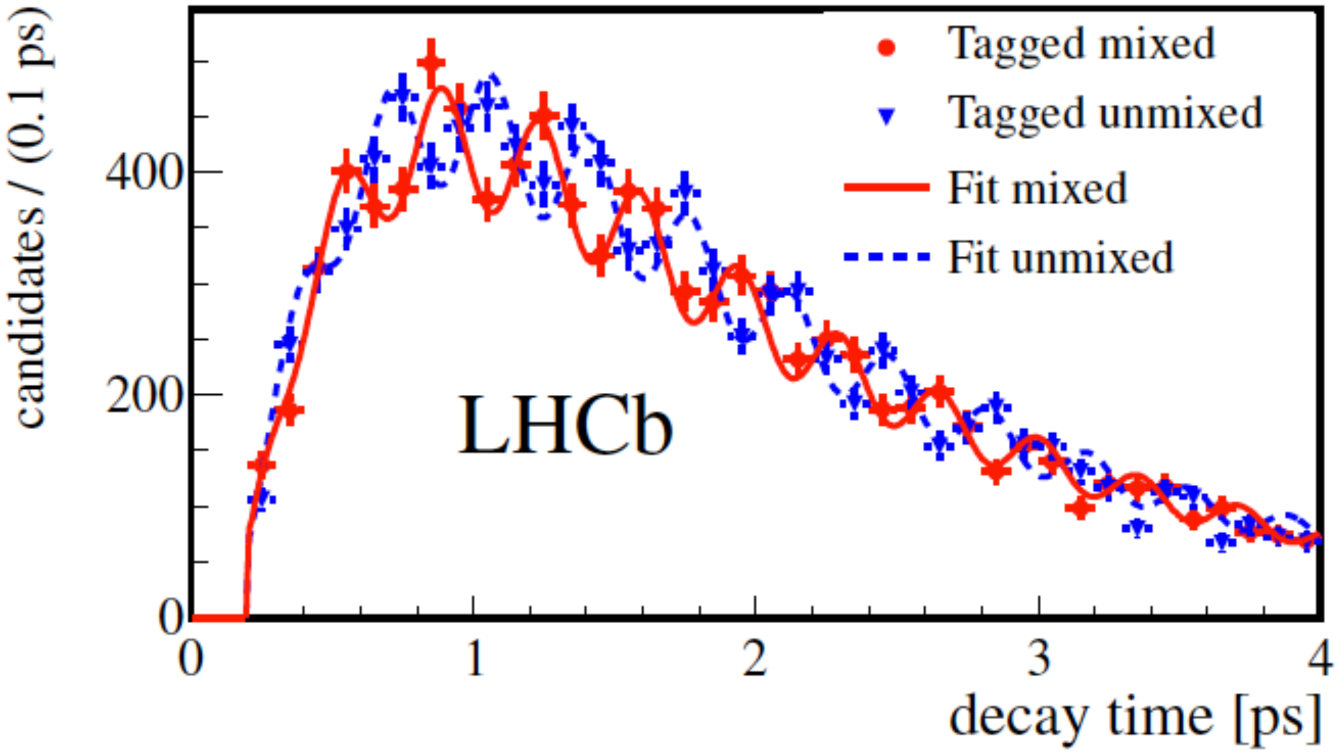


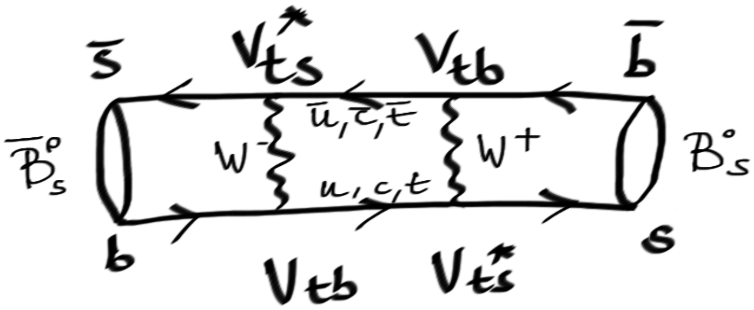
From flavour physics to heavy particles – Indirect searches

You have a fight with RooFit.
Compute all the systematics…
Collaboration Review etc, etc…



$$\Delta m_s = 17.768 \pm 0.023(stat) \pm 0.006(syst)\, ps^{-1}$$

Putting it all together



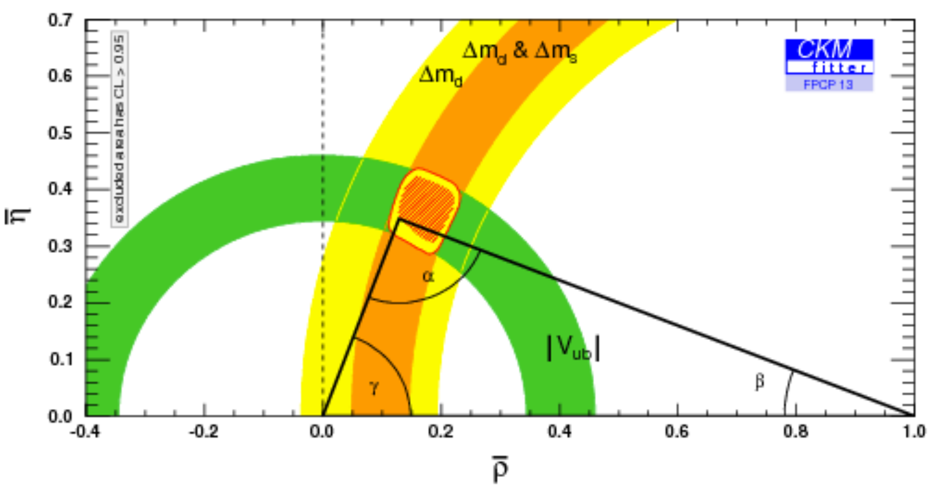
CKM Elements

QCD corrections

$$A(B^0 \to \bar{B}^0) = \frac{G_F^2}{6\pi^2} m_W^2 m_B \left(V_{tb}^* V_{td}\right)^2 S_0(x_t)\, \hat{\eta}_B\, f_B^2 \hat{B}$$

Short Distance Contributions

Input from Lattic



The study of the B mixing lead to the prediction of the Top quark mass !

Le Questionnaire de Proust
How to survive a Flavour Physics talks?

What is the Process ?
A tree, a penguin ?

What is the observable ?

What does it probe ?
SM, NP, QCD ?

What is the statistics?
Is it a rare decay ?

What is the topology ?
Are you ever going to see it?

What about the systematics?

Do we really care about it ?

Conclusion

Flavour Physics is a very rich field !
Many observables to study and different approaches.
A lot of progress and discovries in the past decades,
yet there is a lot still to understand…

Merci a G.Raven, S.Monteil

Mettons les mains a la pate !

Maksym : Charmonium production studies at the LHCb experiment

Alexis : Mesure de l'angle gamma du triangle d'unitarité, avec la désintégration $B^0 \rightarrow D(K_s\pi\pi) K^{*0}$ dans l'expérience LHCb.

Robert : Study of the sensitivity in measuring βc, one of the angles of the charm unitarity triangle

Cafeeeee ! 

Olga : Recherche de physique au-delà du Modèle standard dans les désintégrations très rares de mésons charmés à LHCb.

Mostafa : Radiative decays at LHCb.

Walaa : Controle de diagrammes pingouins dans $B_s \rightarrow J/\psi\phi$.

Alessandro : Rare dipleptonic $B_{s,d}$ decays at LHCb.

Samuel : The $B^0 \rightarrow K^* \mu\mu$ decay at LHCb.

The perfect flavour physics detector

Vertex Reconstruction

Momentum Resolution

Particle Identification

Neutral Reconstruction

High Amount of Signal

Low Background

Flavour Tagging

Sakharov's conditions on the Big Bang

VIOLATION OF CP INVARIANCE, C ASYMMETRY, AND BARYON ASYMMETRY OF THE UNIVERSE

A. D. Sakharov
Submitted 23 September 1966
ZhETF Pis'ma 5, No. 1, 32-35, 1 January 1967

The theory of the expanding Universe, which presupposes a superdense initial state of matter, apparently excludes the possibility of macroscopic separation of matter from anti-matter; it must therefore be assumed that there are no antimatter bodies in nature, i.e., the Universe is asymmetrical with respect to the number of particles and antiparticles (C asymmetry). In particular, the absence of antibaryons and the proposed absence of baryonic neutrinos implies a non-zero baryon charge (baryonic asymmetry). We wish to point out a possible explanation of C asymmetry in the hot model of the expanding Universe (see [1]) by making use of effects of CP invariance violation (see [2]). To explain baryon asymmetry, we propose in addition an approximate character for the baryon conservation law.

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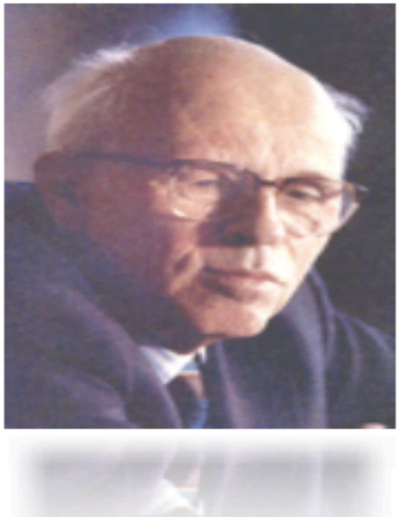

Three requirements for a universe with a baryon asymmetry: Sakharov’s conditions on the Big Bang

1. A process that violates baryon number.
2. C and CP violation, i.e. breaking of the C and CP symmetries.
3. 1 & 2 should occur during a phase which is NOT in thermal equilibrium

The Standard Model wasn't built in a day…

- 1. 1936: Victor Franz Hess for his discovery of cosmic radiation and Carl David Anderson for his discovery of the positron.
- 2. 1950: Cecil Powell for his development of the photographic method of studying nuclear processes and his discoveries regarding mesons made with this method. (π meson and μ)
- 3. 1957: Chen Ning Yang, Tsung-Dao Lee For their penetrating investigation of the so-called parity laws which has led to important discoveries regarding the elementary particles.
- 4. 1965: Sin-Itiro Tomonaga, Julian S. Schwinger, Richard P. Feynman for their fundamental work in quantum electrodynamics, with profound consequences for the physics of elementary particles
- 5. 1969: Murray Gell-Mann For his contributions and discoveries concerning the classification of elementary particles and their interactions. (Quark Model).
- 6. 1976: Burton Richter, Samuel Ting. For their pioneering work in the discovery of a heavy elementary particle of a new kind. (Charmonium: bound state of charm c and anti-charm c) (November revolution).
- 7. 1979: Sheldon L. Glashow, Abdus Salam, Steven Weinberg. For their contributions to the theory of the unified weak and electromagnetic interaction between elementary particles, including the prediction of the weak neutral current.
- 8. 1980: James W. Cronin, Val Logsdon Fitch. For the discovery of violations of fundamental symmetry principles in the decay of neutral K-mesons. (CP symmetry)

The Standard Model wasn't built in a day…

- 9. 1984: Carlo Rubbia, Simon Van Der Meer. For their decisive contributions to the large project, which led to the discovery of the field particles W and Z, communicators of weak interaction.
- 10. 1988: Leon M. Lederman, Melvin Schwartz, Jack Steinberger. For the neutrino beam method and the demonstration of the doublet structure of the leptons through the discovery of the muonneutrino.
- 11. 1995: Martin L. Perl, Frederick Reines. 1)For pioneering experimental contributions to lepton physics, specifically for the discovery of the tau lepton. 2) For pioneering experimental contributions to lepton physics, specifically for the detection of the neutrino.
- 12. 1999: Gerardus 't Hooft, Martinus J.G. Veltman. For elucidating the quantum structure of Electroweak interactions in physics. (QFT description of EW interactions)
- 13. 2002: Raymond Davis, Jr., Masatoshi Koshiba, Riccardo Giacconi. 1)For pioneering contributions to astrophysics, in particular for the detection of cosmic (extra terrestrial) neutrinos. 2)For pioneering contributions to astrophysics, which have led to the discovery of cosmic X-ray sources.
- 14. 2004: David J. Gross, H. David Politzer, Frank Wilczek For the discovery of asymptotic freedom in the theory of the strong interaction. (QCD).
- 15. 2008 Yoichiro Nambu; Makato Kobayashi and Toshihide Masakawa 1)For the discovery of the mechanism of spontaneous broken symmetry in subatomic physics (Electroweak Symmetry breaking) 2) For the discovery of the origin of the broken symmetry whichpredicts the existence of at least three families of quarks in nature (CP violation).
- 16. 2013 Higgs et Engelert.