

WG2 - report

Diego Guadagnoli & Yasmine Amhis

WG2 : Rare, radiative and semi-leptonic B decays; Charm and Kaon Physics

Rare, radiative and semi-leptonic B decays

Charm and Kaon Physics

Rare, radiative and semi-leptonic B decays

Charm and Kaon Physics

**Joint Workshop on
future **tau-charm** factory**

December 4-7, 2018
Laboratoire de l'Accélérateur Linéaire
Orsay, France

Expected physics reach
Accelerator development
 $\tau\tau$ factory detector solutions

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<http://workshop-tau-charm-factory.lal.in2p3.fr/>

Logos: CERN, LAL Orsay, INFN, IHEP, KEK, IFJ PAN, USTC, BINP, LLR, LPNHE, LPT, IPNO, P2I.

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LAPTH-030/18

The strange side of LHCb

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We provide a general effective-theory argument relating present-day discrepancies in semi-leptonic B -meson decays to signals in kaon physics, in particular lepton-flavour violating ones of the kind $K \rightarrow (\pi)e^\pm\mu^\mp$. We show that K -decay rates of around $10^{-12} - 10^{-13}$ are possible, for effective-theory cutoffs around 5 – 15 TeV compatible with discrepancies in $B \rightarrow K^{(*)}\mu\mu$ decays. We perform a proof-of-principle study of the reach for such decays at LHCb, taking $K^+ \rightarrow \pi^+\mu^+e^-$ as a benchmark. In spite of the long lifetime of the K^+ compared to the detector size, the huge statistics anticipated as well as the overall detector performance translate into encouraging results. These include the possibility to reach the 10^{-12} rate ballpark, and thereby significantly improve current limits. We substantiate these conclusions with a range of realistic assumptions on the particle identification performance as well as on the kinematic reconstruction thresholds for the signal candidates.

Introduction – Data on $b \rightarrow s\ell\ell$ and $b \rightarrow c\ell\nu$ transitions display persistent deviations with respect to Standard-Model (SM) expectations [1–7]. Deviations are seen in both individual decay modes and in the relative rates of B -meson decays to different lepton species. These latter deviations in particular hint at a sizeable violation of Lepton Universality (LUV). The pattern of observed departures from the SM finds a straightforward interpretation within an effective-field-theory (EFT) framework [2–7]. Interestingly, among the preferred operators to explain the anomalies is the product of two left-handed currents [8,9]. This can naturally be expressed in terms of the $SU(2)_L$ -invariant fields Q_L and L_L [10,11], which is what one would expect of new effects generated above the electroweak (EW) symmetry-breaking (EWSB) scale. Furthermore, the fact that effects seem larger for heavier leptons is suggestive of new physics coupled dominantly to third-generation fermions [12] – in the ‘gauge’ basis, that in general is misaligned with the mass-eigenstate basis.¹ Therefore, without further assumptions, observable LUV is accompanied by Lepton-Flavor Violation (LFV), whose expected size is related to the measured amount of LUV.

LFV may be expected in any $d \rightarrow d'$ transition, not only $b \rightarrow s$. In this work we present general arguments to relate LFV in K decays to the existing LUV hints in B decays, and

¹ Starting from this zeroth-order hypothesis, a neat framework to explain all anomalies at one stroke is then to postulate a broken flavour symmetry distinguishing the third from the light generations, so that effects in $b \rightarrow c\nu$ and respectively $b \rightarrow s\mu\mu$ are automatically of first and respectively third order in the breaking parameter [13] (see also [14–16], and, for the original formulation of the symmetry in a context other than

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**WG2: Rare, radiative & semilep. B decays.
Charm & kaon physics.**

- *Observation #0: very wide scope*

However:

- *The challenges we are facing have also a wide scope.*

Example:

If hints of discrepancies are real then

- ➡ *To understand new dynamics in full, will need measurements encompassing all of WG2 (et encore...)*

If hints of discrepancies are not real then

- ➡ *Flavour physics will remain a crucial probe of new effects.
Wide WG2 scope equally advantageous*

Broad challenges matched by a broad expertise within the people involved in the GDR

- EFT understanding
- Model building
- interface with high P_T
- interface with astro/cosmo.

Theory errors

- Non perturbative QCD.
- FF QCD inspired approaches.
- interplay between perturbative and non-perturbative errors

$R(D^*)$ with hadronic τ decays.

$R(D^*)$ with electrons.

$B \rightarrow D^{**} D_s^*$

$R(\Lambda_c)$ with hadronic τ decay.

$R(K^+), R(K^*), (RpK)$

$\Lambda_b \rightarrow pK ee / pK \gamma$ angular analysis

$B \rightarrow K^* ee$ angular analysis

$\Lambda_b \rightarrow \Lambda \gamma$ BR

$B^0 \rightarrow \rho^0 \gamma$ BR

$B^0 \rightarrow K^{*2}/K_1(1410)\gamma$ and $B_s \rightarrow f'_2 \gamma$

$B^0 \rightarrow K_S \pi^+ \pi^- \gamma$

$B \rightarrow K^* \tau \tau$ BR

$B_s \rightarrow \tau \tau / \mu \mu / \mu \mu \gamma$

$B \rightarrow K \tau \mu$

$B^+ \rightarrow K e \mu$

$B^0 \rightarrow K^* \tau \mu$

$B^+ \rightarrow K^+ \tau \mu$

$B_s \rightarrow \tau \mu$



$b \rightarrow s ll$ (LFNU et LFV)

$B^0 \rightarrow K \pi \pi \gamma / B^0 \rightarrow K_S \pi^+ \pi^- \gamma$

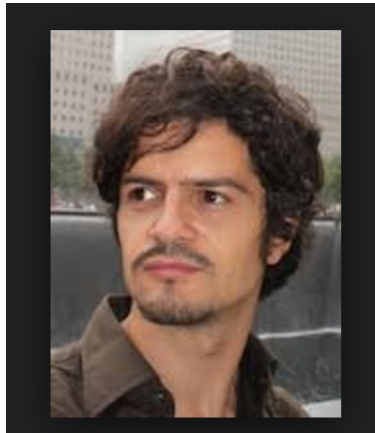


GDR lectures - The Concept

This series of lectures, organized in the framework of the GDR-InF, is devoted to topics currently of considerable interest in the high-intensity frontier.

Two experts, one theorist and one experimentalist, will dissect a given subject entirely on the blackboard, starting from the basics. Lectures aimed at people in the early stages of their research career, but more senior researchers more than welcome to attend.

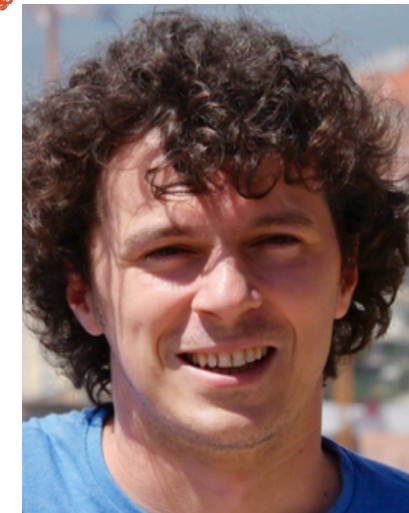
LFUV in rare meson decays



Diego (TH)



Lucia (EXP)



Martino (EXP)

TH: SM systematics, incl. status of EFT expansion, form-factor cancellation, bremsstrahlung; model-building, incl. leptoquarks & extended gauge sectors; relevant constraints.

EXP: intro to corresponding measurements and their subtleties, incl. normalization channels, again bremsstrahlung, efficiencies, backgrounds; detailed look at systematic uncertainties.

In total 26 + 18 participants

Write up / video

26/27 Oct 2017 - 13/14 Feb 2018

V_{cb}

② V_{cb} [G. Ricciardi (TH), M. Rotondo (EXP)]

2-3 Jul. 2018

TH: CKM matrix, semilep. & leptonic decays, th. tools needed to access V_{cb} from exclusive and inclusive $b \rightarrow c \ell \nu$ decays.

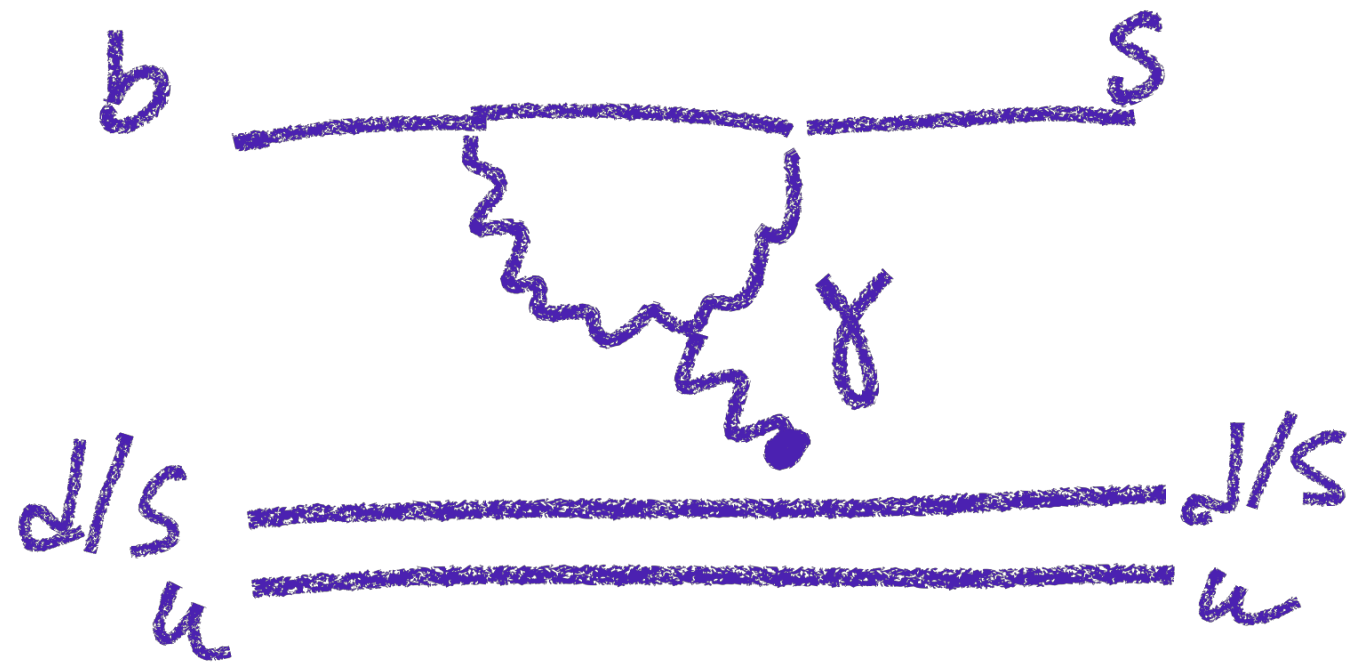
EXP: pheno of semilep. B decays, reconstruction at B-Factories and LHCb, studies of the subtleties connected with signal efficiency, physical backgrounds, signal parameterisation.

MORE!

**“Dedicated sessions” on
radiative corrections**

**This includes learning sessions: SCET
for example**

IF Yes, find a date soon.



- TD CP asym.
- Ang. Analyses
 - $3h$
 - e^+e^-
 - Λ



Radiative baryon decays

Carla MARIN BENITO

Arles

11:30 - 11:50

Radiative B decays into orbitally excited mesons at LHCb

Boris Quintana

Arles

11:50 - 12:05

Time-dependent CP asymmetries in $b \rightarrow s$ gamma transitions at Belle II

Sviatoslav Bilokin

Arles

12:05 - 12:25



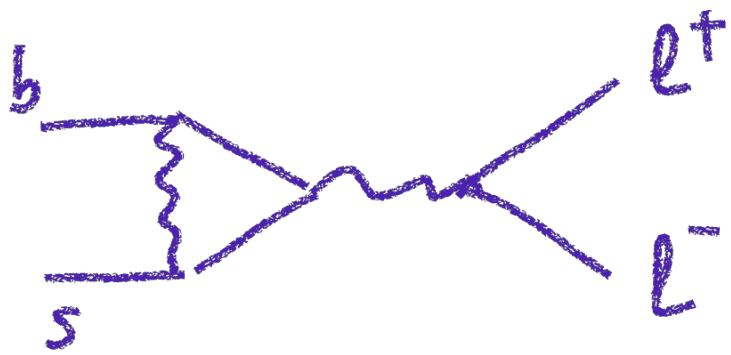
$B^0 \rightarrow K^{*0} e^+ e^-$ angular analysis in LHCb

Fabrice Desse

Arles

16:30 - 16:45



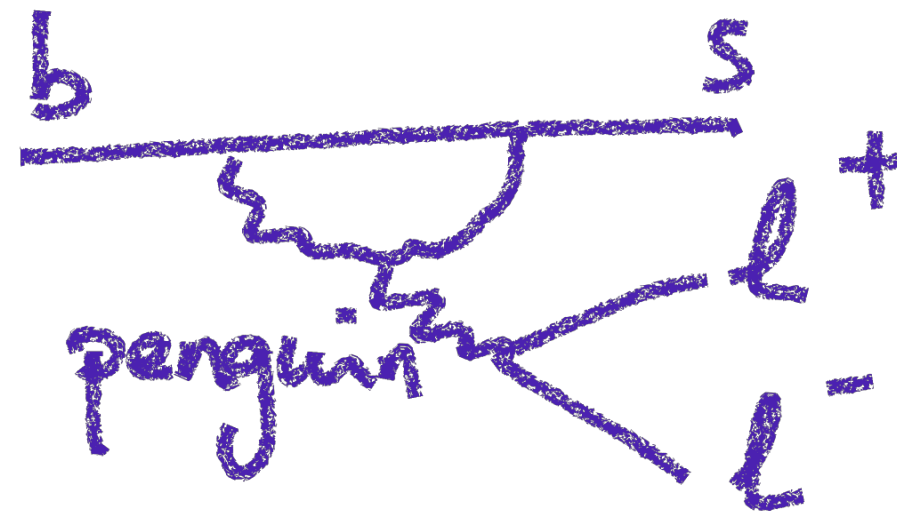


Rare heavy mesons decays to leptons

Arles

Cédric Méaux

12:25 - 12:40



Tests of Lepton Flavor Universality using semitauonic decays at LHCb

Arles

Dawid Gerstel

14:20 - 14:35

Testing the Lepton Universality in b-baryon decays

Arles

Vitalii LISOVSKIY

16:45 - 17:05



Determination of angular distribution



Study of the $\Lambda_b \rightarrow \Lambda^{*0} (K N) \ell \ell \ell$ decay

Martín Novoa Brunet

Arles

14:00 - 14:20

Interpretations

A gauged horizontal SU(2) symmetry and RK(*)

Ménil Reboud

Arles

17:05 - 17:25



Flavour anomalies and (fundamental) partial compositeness

Peter Stangl

Arles

14:35 - 14:55



Sébastien



Marie-Hélène



Peter

Radiative corrections

**In one line: TH error in flavour anomalies far from settled.
Would deserve dedicated session(s)**

EFT understanding

**If new physics heavy, it must show up as EFT shifts first.
Are we being general enough? Accurate enough?**

Model building

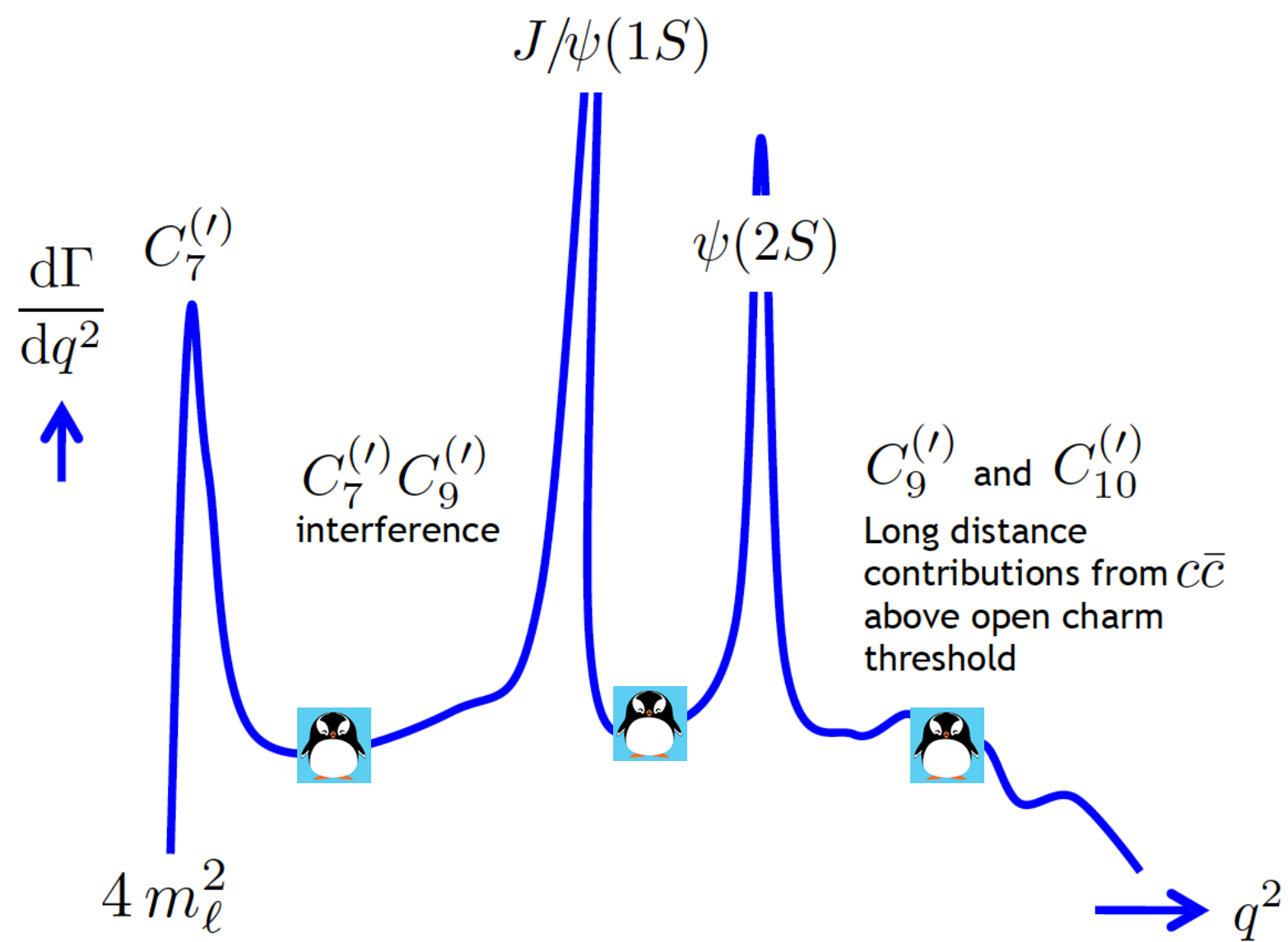
**Do proposed models point to something that makes sense?
Connections with other NP hints (DM, $g-2$, ...)?**

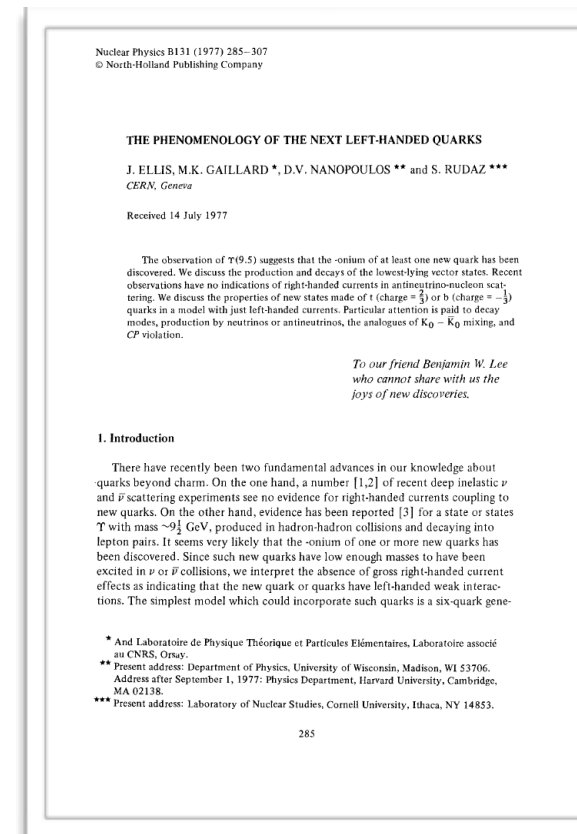
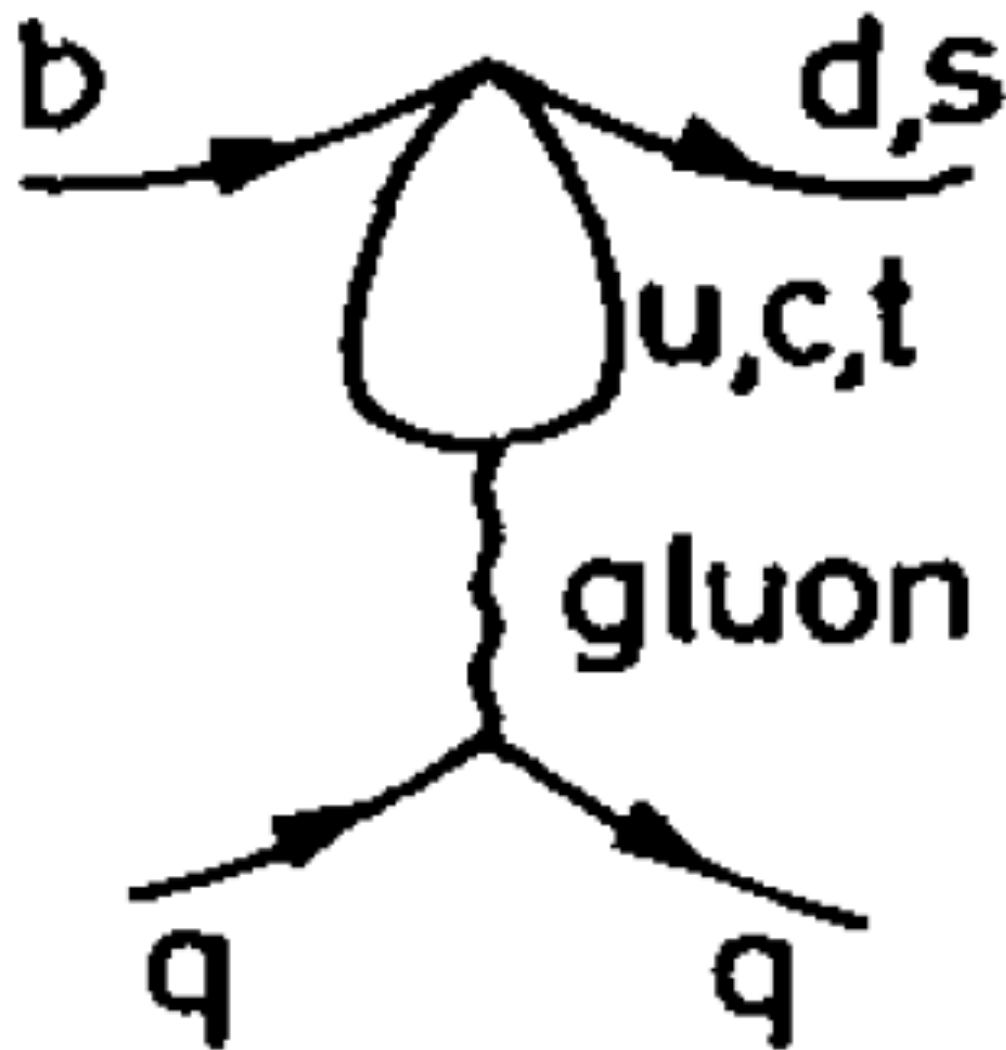
We did not forget:

- From Sebastien DG: Connections between the searches for lepton-flavour violating processes, lepton-flavour universality violating processes and NP models.
- From Olivier Leroy: Most sensitive observables to New Physics in $b \rightarrow c \ell \nu$ and $b \rightarrow u \ell$ transitions and their ratios ($\ell = e, \mu, \tau$). Experimental and theoretical aspects. All tests of LFU
- From MH Schune: Understanding the theoretical uncertainties in $R(D^*)$ in view of the recent papers (D^* width ...)
- From Marc Knecht: radiative corrections is an important item, given the precision expected on say, semileptonic decays of mesons at future B factories

Thank you!







The first penguin