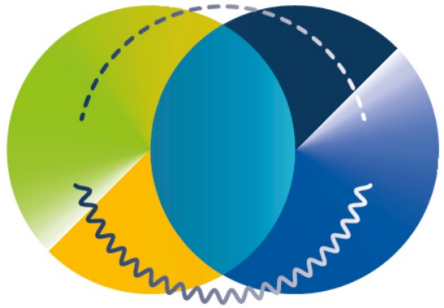


color meets flavor

Searching for new phenomena in weak and strong interactions

RA2 Kickoff, 23.10.2025

J. Albrecht

UNIVERSITÄT BONN

technische universität dortmund

UNIVERSITÄT SIEGEN

JÜLICH Forschungszentrum

From the proposal

- Objective 2: Stress test the Standard Model with weak decays
  - A clear advance would be to clarify the origin of the flavor anomalies and possibly to reveal new ones. Should these anomalies turn into evidence for a new phenomenon, CmF will be in a leading position to determine its physics origin. Such a breakthrough discovery in the field of particle physics could pave the way to a more fundamental theory of Nature.

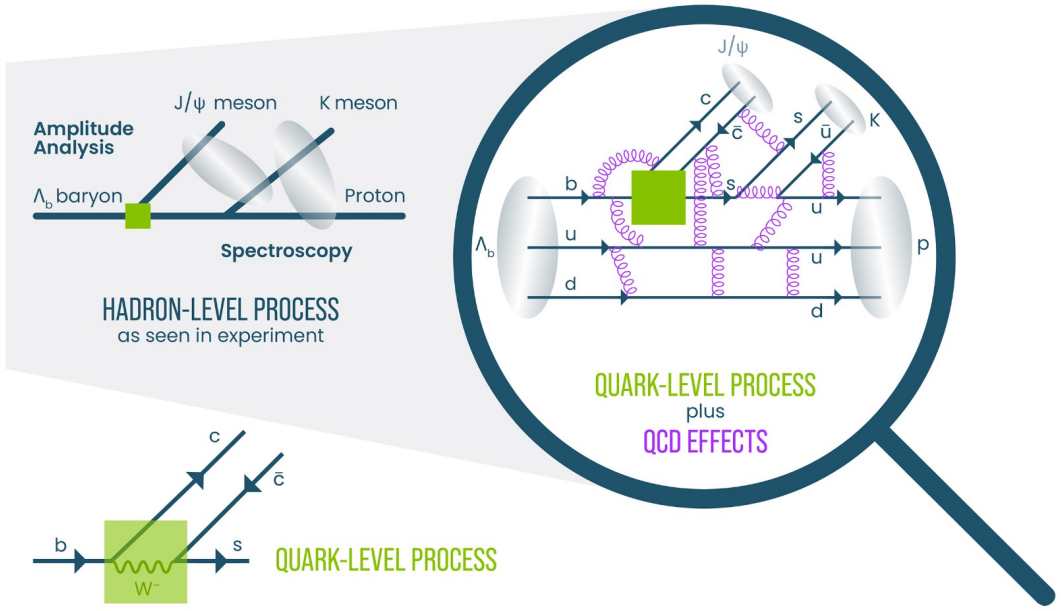


Figure 4.3.3: *The weak baryon decay* $\Lambda_b \to p K J/\psi$.

Ulrike Thomas and Andrey Sarantsev added to LHCb as "theory affiliates"

→ make projects, see later

RA2: promises

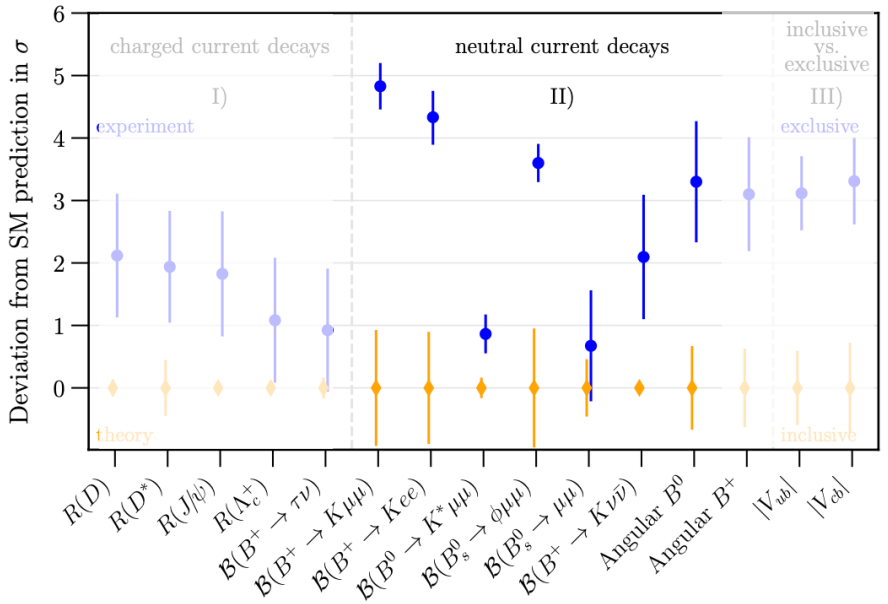
4.5.2 RESEARCH AREA 2: DECAYS OF BOTTOM, CHARM, AND STRANGE QUARKS

Key Researchers	Albrecht, Bell, Bernlochner, Dingfelder, Feldmann, Hanhart, Hiller, Huber, Kilian, Kubis, Lenz, Mannel, Meißner, Mitzel, Prim, Stamou, Stefkova, Witzel
Coop. Partners	Humair, Jüttner, Ligeti, Peláez, Schune, Urquijo, Vos, Wilkinson
Objectives	• Search for new phenomena in weak decays, in close collaboration with hadronic structure investigations in RA1. • Clarify the origin of the flavor anomalies. • Combine theoretical and experimental efforts for stringent tests of the SM to identify new phenomena in bottom and charm decays.
Cluster Professors	W2 Flavor Physics at LHCb (EXP) W3 BSM Phenomenology (TH), together with RA3

Consciesly integrate our international partners

Dortmund / LHCb B-flavor activities

- Rare decays
  - b->sll flavor anomalies → LHCb to measure cleanly
    → many TH projects, not clear which direct synergies we find
  - CmF: add more complex hadronic systems:
    L_b->pKμμ: one of the main examples of the proposal,
    suggest to start a CmF funded joint team here
    B^+→Kππμμ → who can help to understand the Kππ system?
  - New EN group at HISKP: N. Gubernari with focus (partly)
    on b→sll anomalies ? → synergies with LHCb?
  - Can we do any auxiliary measurements to understand
    the BR calculations?

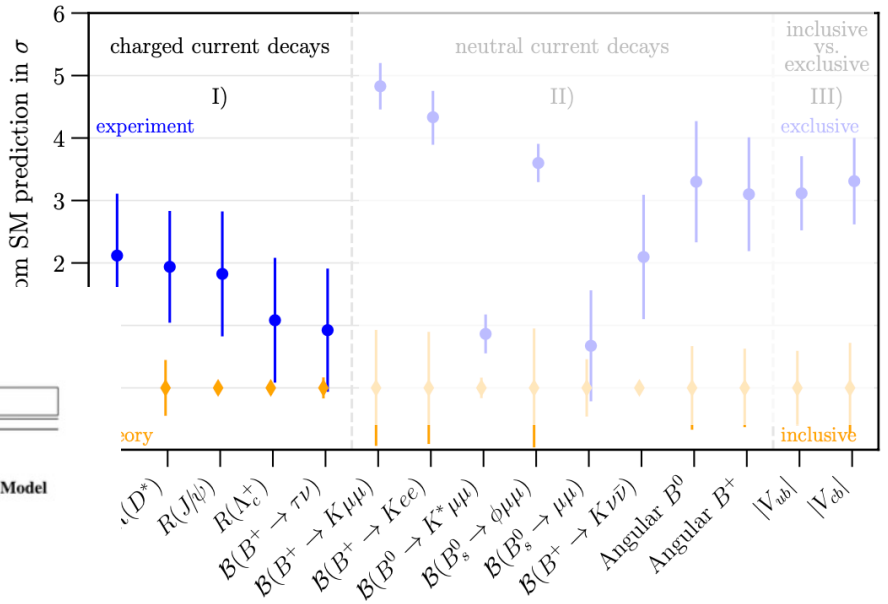


- From my team: Meet Mick Mulder

(New junior faculty @TUDO working on LHCb rare decays)

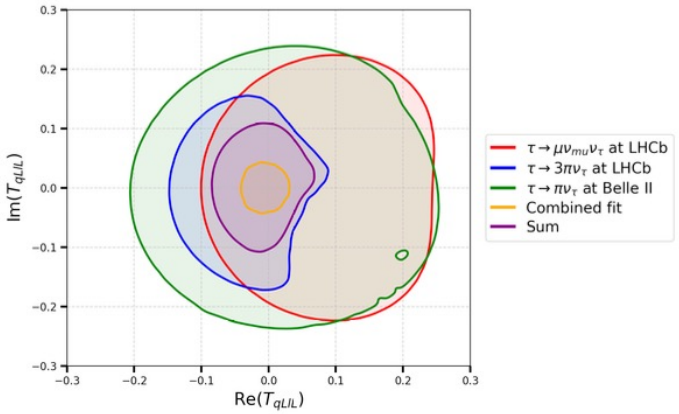
Dortmund / LHCb B-flavor activities

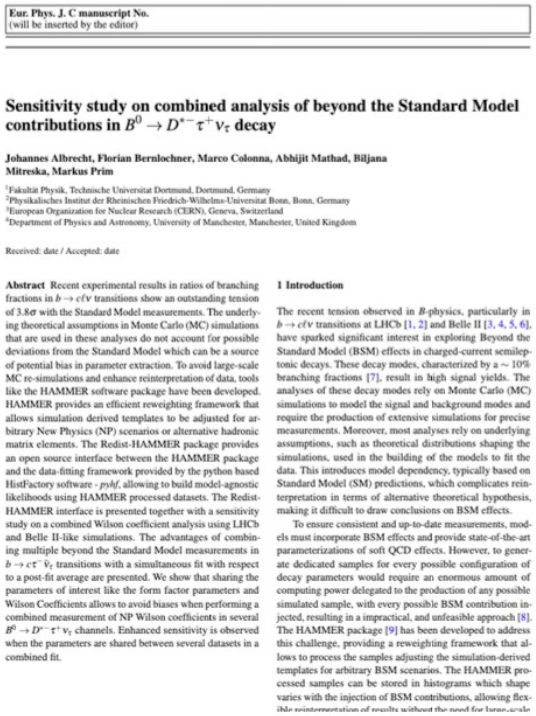
- Semileptonic decays
  - Preparation phase: started joint project with Florian / B2 (Marco Colonna)



The paper showing sensitivity studies in at **"refinements" stage**.

- Redist-HAMMER to combine (toy datasets):
  - $R(D^*)$—muonic measurement at LHCb;
  - $R(D^*)$—hadronic measurment at LHCb;
  - τ—helicity angle polarization measurment at Belle II.
- the combination **enhances the sensitivity**, **consistency** and **cures possible bias**.





Eur. Phys. J. C manuscript No.
(will be inserted by the editor)

Sensitivity study on combined analysis of beyond the Standard Model contributions in $B^0 \to D^{*-}\tau^+\nu_\tau$ decay

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Received: date / Accepted: date

Abstract Recent experimental results in ratios of branching fractions in $b \to c\ell\nu$ transitions show an outstanding tension of 3.8σ with the Standard Model measurements. The underlying theoretical assumptions in Monte Carlo (MC) simulations that are used in these analyses do not account for possible deviations from the Standard Model which can be a source of potential bias in parameter extraction. To avoid large-scale MC re-simulations and enhance reinterpretation of data, tools like the HAMMER software package have been developed. HAMMER provides an efficient reweighting framework that allows simulation derived templates to be adjusted for arbitrary New Physics (NP) scenarios or alternative hadronic matrix elements. The Redist-HAMMER package provides an open source interface between the HAMMER package and the data-fitting framework provided by the python based HistFactory software - *pyhf*, allowing to build model-agnostic likelihoods using HAMMER processed datasets. The Redist-HAMMER interface is presented together with a sensitivity study on a combined Wilson coefficient analysis using LHCb and Belle II-like simulations. The advantages of combining multiple beyond the Standard Model measurements in $b \to c\tau^-\bar{\nu}_\tau$ transitions with a simultaneous fit with respect to a post-fit average are presented. We show that sharing the parameters of interest like the form factor parameters and Wilson Coefficients allows to avoid biases when performing a combined measurement of NP Wilson coefficients in several $B^0 \to D^{*-}\tau^+\nu_\tau$ channels. Enhanced sensitivity is observed when the parameters are shared between several datasets in a combined fit.

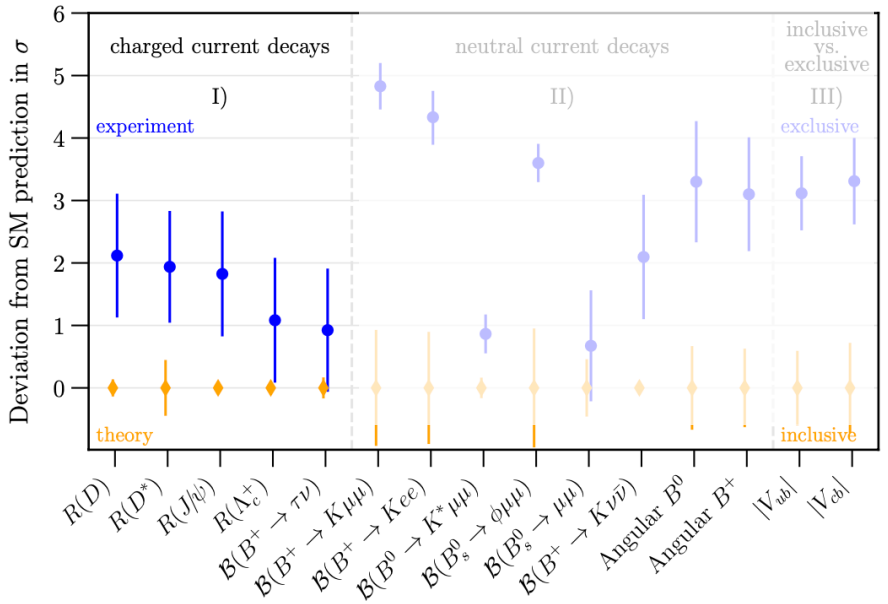
1 Introduction

The recent tension observed in B-physics, particularly in $b \to c\ell\nu$ transitions at LHCb [1, 2] and Belle II [3, 4, 5, 6], have sparked significant interest in exploring Beyond the Standard Model (BSM) effects in charged-current semileptonic decays. These decay modes, characterized by a $\sim 10\%$ branching fractions [7], result in high signal yields. The analyses of these decay modes rely on Monte Carlo (MC) simulations to model the signal and background modes and require the production of extensive simulations for precise measurements. Moreover, most analyses rely on underlying assumptions, such as theoretical distributions shaping the simulations, used in the building of the models to fit the data. This introduces model dependency, typically based on Standard Model (SM) predictions, which complicates reinterpretation in terms of alternative theoretical hypothesis, making it difficult to draw conclusions on BSM effects.

To ensure consistent and up-to-date measurements, models must incorporate BSM effects and provide state-of-the-art parameterizations of soft QCD effects. However, to generate dedicated samples for every possible configuration of decay parameters would require an enormous amount of computing power delegated to the production of any possible simulated sample, with every possible BSM contribution injected, resulting in a impractical, and unfeasible approach [8]. The HAMMER package [9] has been developed to address this challenge, providing a reweighting framework that allows to process the samples adjusting the simulation-derived templates for arbitrary BSM scenarios. The HAMMER processed samples can be stored in histograms which shape varies with the injection of BSM contributions, allowing flex-

Dortmund / LHCb B-flavor activities

- Semileptonic decays
  - Preparation phase: started joint project with Florian / B2 (Marco Colonna, 3rd year PhD)
  - We think we can prove now that a real, joint use of Belle 2 and LHCb datasets is beneficial
    → restart collaboration activities to get this approved
  - How to continue? Further joint CmF projects?



- Event interpretation: Tobias Knospe will joint Bonn group to learn event interpretation methods
  - Also work on joint SL analysis? Unclear
  - Work central in IAL / TA2

Dortmund / LHCb B-flavor activities

- CP Violation / time dependent
  - Gamma: Quentin Führing, now post-doc with me, waiting for fellow board. Ideas for new projects welcome
  - DMS / Bs -> Ds pi : measurement with LHCb run 3 in progress. Whats next here?
  - Decay specific asymmetries: publicaton imminent
    Jamie Gooding (finishing PhD student, will stay in LHCb)
    → Ideas and discussions for new projects welcome

Dortmund / LHCb light-flavor activities

- New Post-Doc Gabriele Martinelli, to start 02/2026
  - Has worked intensely on rare Kaon and Hyperon decays at LHCb, new projects, ideas and collaborations welcome
  - Novel Run 3 trigger system opens new paths

- Original measurement from my group was $\tau \rightarrow \mu\mu\mu$, will do for Run 3 again
  - I see this for CmF mostly relevant for the IAL, as the bakcground shapes are very diverse and fruitful to learn

- Axion / light NP related studies in multi-muon decays (Stamou/JA)
  - Doubly off shell form factors for B24mu needed
  - JA&Es+ Khodjamirian, Mannel et al ?
  - JA&ES + Vos et al ?

PHOTOS++

VII. QED RADIATIVE CORRECTIONS

To further enhance the precision of theoretical predictions, Quantum Electrodynamics (QED) radiative corrections must be considered. This involves developing a consistent framework that combines soft and collinear photons with process-dependent contributions. The state of the art is the simulation package *PHOTOS*, developed over 30 years ago, which estimates process-independent QED corrections. However, adapting this tool for bottom- and charm-hadron decays requires additional refinements, particularly incorporating real and virtual process-dependent contributions. Achieving these refinements necessitates close collaboration between experiment and theory. CmF brings together the expertise needed to implement both process-independent and process-dependent QED corrections, with the goal to establish a new standard tool.