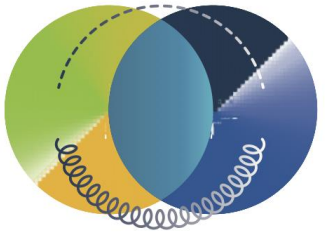
Cross-functional-team 1

Mick Mulder, Nico Gubernari

Rotationsgebäude, Bonn

28 April 2026



color meets flavor

RA2-2: Excited Lambda spectrum in rare B decays (Albrecht, Thoma)

RA2-7: Phenomenology of Bs to 4 leptons (Albrecht, Stamou)

RA2-9: Light Cone distribution amplitudes of B hadrons (Feldmann, Gubernari)

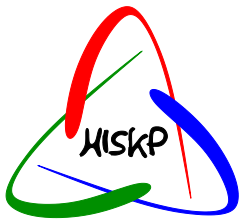
RA2-10: Analytic Properties of the charm contribution in b to s ll (Gubernari, Kubis)

CFT FCNC Semileptonics

Bastian Kubis

HISKP (Theorie), BCTP

Universität Bonn



RA2 Cross-Functional Teams

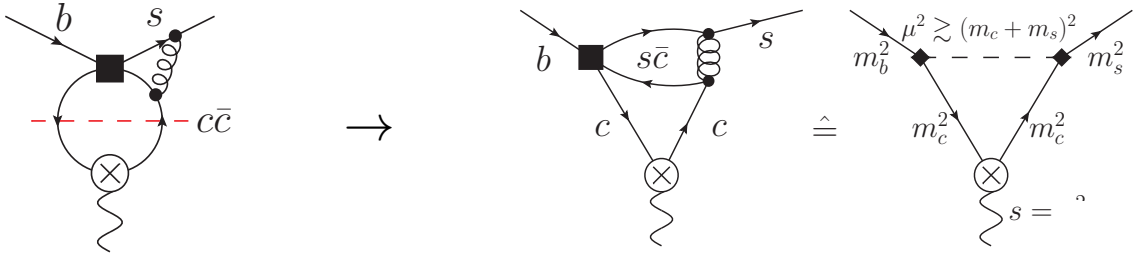
Bonn, April 28, 2026

based on arXiv:2604.01284

with essential input from Simon Mutke

$b \to s\ell\ell$ at partonic two-loop order; anomalous thresholds

- Light-quark / charm loops hadronize into triangle topologies; at two loops:



- Additional **anomalous thresholds** (“triangle singularity”)

- Want **dispersion relation** (“DR”) to confirm suspected **analytic structures**

$$F_{2,(c)}^{(7)}(s) = F_{2,(c)}^{(7)}(0) + \frac{s}{2\pi \mathrm{i}} \int_{s_{\text{thr}}=4m_c^2}^{\infty} \mathrm{d}s' \, \frac{\operatorname{disc} F_{2,(c)}^{(7)}(s')}{s'(s'-s)}$$

- Discontinuity determined by **triangle diagram**

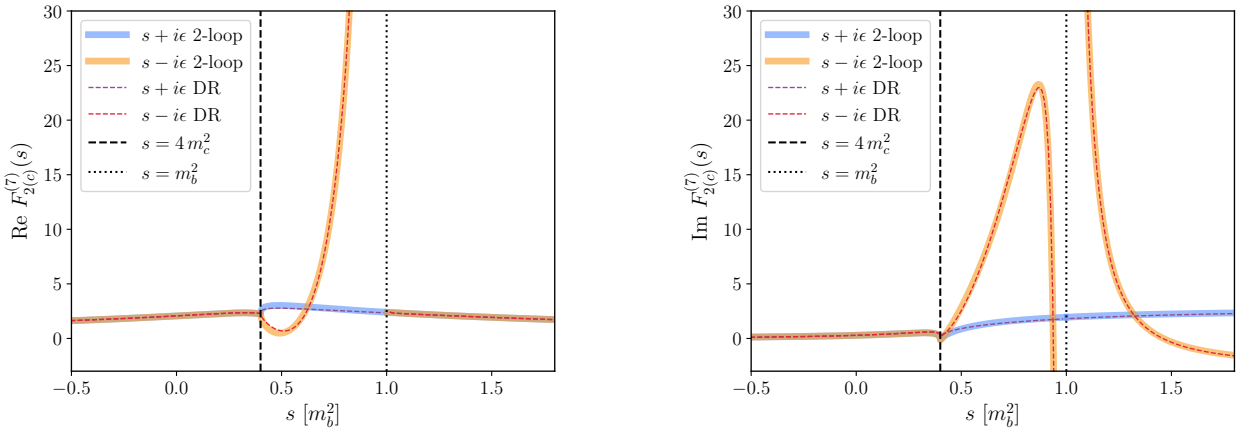
  $\hookrightarrow$ allow for $\mu^2 \geq \mu_{\text{thr}}^2 = (m_c + m_s)^2$ via spectral function

$$\operatorname{disc} F_{2,(c)}^{(7)}(s) = \int_{\mu_{\text{thr}}^2}^{\infty} \mathrm{d}\mu^2 \, \rho(\mu^2) \operatorname{disc} F_{2,(c)}^{(7)}(s;\mu^2)$$

Reconciling partonic and hadronic analyticity

- Fit $\rho(\mu^2)$ to match discontinuity of 2-loop results

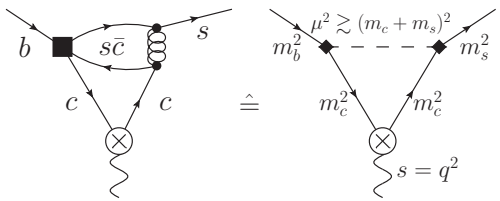
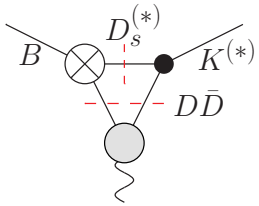
cf. Asatrian, Greub, Virto 2019



- **hadronic** and **partonic levels** share **same analytic structure!**

  ↪ differences: mass effects & hadronization

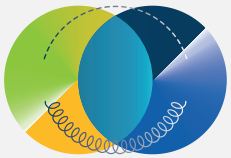
Hoferichter, BK, Mutke 2026

Partonic picture	**Hadronic picture**
	
$s_{\text{thr}} = 4m_c^2 \simeq 0.4\, m_b^2$	$s_{\text{thr}} = 4M_D^2 \simeq 0.5\, M_B^2$
$\mathbf{s}_{\text{anom}} \simeq m_b^2$	$\mathbf{s}_{\text{anom}} \simeq (0.85 - 0.3\text{i})\, M_B^2$

$B_{d,s} \to 4\ell$

Targeting LHCb's strengths

Emmanuel Stamou



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RA2 meeting
CFT kick-off

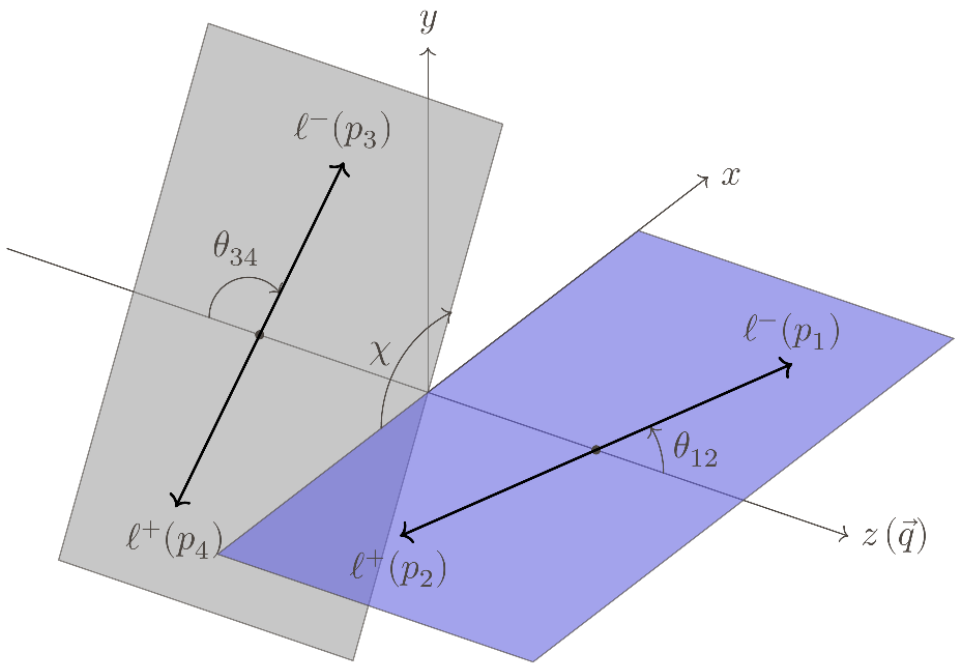
28.04.2026

$B_{s,d} \to 4\ell$

[with J. Albrecht and J. Wagner and help required]

4-body decay:
$B_q \to \ell^-(p_1)\ell^+(p_2)\ell^-(p_3)\ell^+(p_4)$

5 kinematic variables
- two dilepton energies: q^2, k^2
- three angles: $\theta_{12}, \theta_{34}, \chi$



- LHCb upper limits at 95% CL

$$\text{BR}(B_s \to \mu\mu\mu\mu) < 8.6 \times 10^{-10}$$
$$\text{BR}(B_d \to \mu\mu\mu\mu) < 1.8 \times 10^{-10}$$

- Main issue in experimental analysis (only phase-space, no form factors)

➜ Provide solid theory predictions and MC simulation thereof

[Danilina, Nikitin 2022; Albrecht, Wagner, ES in progress]

$B_{s,d} \to 4\ell$ – towards a SM prediction

- Operators contributing in SM

$$\mathcal{O}_7 = \frac{e}{16\pi^2} m_b \bar{b} \sigma^{\mu\nu} P_L q F_{\mu\nu} \qquad \mathcal{O}_{9(10)} = \frac{e^2}{16\pi^2} (\bar{b}\gamma^\mu P_L q)(\bar{\ell}\gamma_\mu(\gamma_5)\ell)$$

- Parametrisation of singly off-shell FFs (same as for $B \to \ell\ell\gamma$)

[Albrecht, ES, Ziegler, Zwicky 21]

$$M_5^\rho(q,k) \equiv \langle \gamma^*(k,\rho)|\bar{q}\gamma_5 b|\bar{B}_q(p_B)\rangle = i m_B R^\rho \, P^*(q^2,k^2) \,,$$

$$M_V^{\mu\rho}(q,k) \equiv \langle \gamma^*(k,\rho)|\bar{q}\gamma^\mu b|\bar{B}_q(p_B)\rangle = R_\perp^{\mu\rho} \, V_\perp^*(q^2,k^2) \,,$$

$$M_A^{\mu\rho}(q,k) \equiv \langle \gamma^*(k,\rho)|\bar{q}\gamma^\mu\gamma_5 b|\bar{B}_q(p_B)\rangle = R_\parallel^{\mu\rho} \, V_\parallel^*(q^2,k^2) + R_{\mathbb{L}}^{\mu\rho} V_{\mathbb{L}}^*(q^2,k^2) + \frac{2R_P^{\mu\rho}}{\hat{q}^2} P^*(q^2,k^2)$$

$$M_T^{\mu\rho}(q,k) \equiv \langle \gamma^*(k,\rho)|\bar{q} i q_\nu \sigma^{\mu\nu} b|\bar{B}_q(p_B)\rangle = R_\perp^{\mu\rho} \, T_\perp^*(q^2,k^2) \,,$$

$$M_{T_5}^{\mu\rho}(q,k) \equiv \langle \gamma^*(k,\rho)|\bar{q} i q_\nu \sigma^{\mu\nu}\gamma_5 b|\bar{B}_q(p_B)\rangle = -(R_\parallel^{\mu\rho} \, T_\parallel^*(q^2,k^2) + R_{\mathbb{L}}^{\mu\rho} T_{\mathbb{L}}^*(q^2,k^2))$$

Shortcomings:

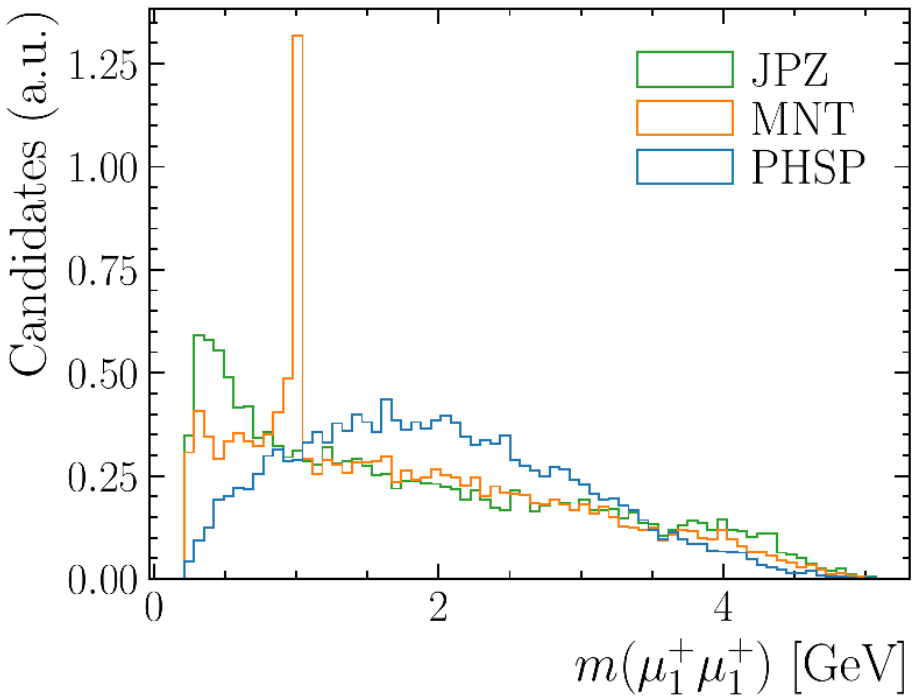
- missing topologies, mistakes in simulation implementation ✓
- full k^2–q^2 dependence missing in current theory estimates ✘

(only $(q^2,0)/(0,k^2)$ values from LSRs and VMD estimates for resonances used)

$B_{s,d} \to 4\ell$ – status

[with J. Albrecht and J. Wagner and help required]

- Computed full amplitude in helicity formalism + new EvtGen implementation with two FF models
- Comparison of FF and phase-space models



- main differences at low dilepton values
- improved efficiencies within uncertainty of LHCb's analysis
- (old EvtGen model gives unphysical results)

$B_{s,d} \to 4\ell$ – outlook

[with J. Albrecht and J. Wagner and help required]

Many open questions:

- Where can the FF approximation be trusted?

  (resonances, charm pollution,…)

- Which dilepton/angular distributions are free from large hadronic uncertainties?

  (design “optimal” observables for NP searches)

- Are there BSM models that have evaded detections so far but could first be seen in $B \to 4\ell$?

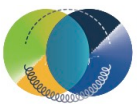
➜Input, help, and criticism welcome.

RA2-9:
Light-cone distribution amplitudes of b-hadrons

"RA2 meeting"
Bonn, 28.04.2026

Thorsten Feldmann (SI) and Nico Gubernari (BN)

Universität Siegen
TP1 Theoretical Particle Physics
CPPS Center for Particle Physics Siegen



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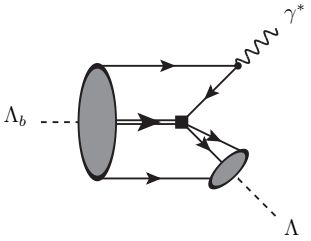
Light-cone distribution amplitudes (LCDAs):

- encode the relevant hadronic information
  in factorization approaches to exclusive b-hadron decays
  (QCD factorization à la BBNS; correlation functions for light-cone sum rules)

- genuinely non-perturbative objects,
  but difficult to constrain from lattice QCD
- non-trivial RG evolution $\rightarrow$ "radiative tail"
- fits to experimental data require
  sufficiently sophisticated parametrizations
- beyond leading power in $1/m_b$: new objects,
  "di-light-cone distribution amplitudes" (DLCDAs) show up

...

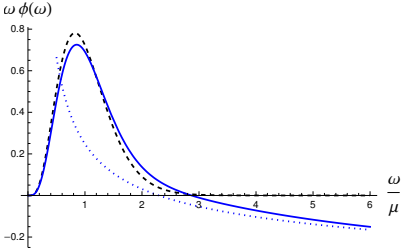
✓ di-light-cone LCDAs appearing in rare Λ_b decays



[Feldmann/Gubernari 2024]

...

- ✓ di-light-cone LCDAs appearing in rare Λ_b decays [Feldmann/Gubernari 2024]
- ✓ radiative tail for (ordinary) 3-particle LCDAs of Λ_b baryon



[Feldmann/Vladimirov 2025]

...

- ✓ di-light-cone LCDAs appearing in rare Λ_b decays [Feldmann/Gubernari 2024]
- ✓ radiative tail for (ordinary) 3-particle LCDAs of Λ_b baryon [Feldmann/Vladimirov 2025]

- 3-particle dLCDAs for the B-meson
  - appear in sub-leading contributions to exclusive B-decays
  - complete classification of Dirac and Lorentz structures

$$\langle 0|\bar{q}(z_1 n)\, gG_{\mu\nu}(z_2 \bar{n})\, \Gamma h_v(0)|\bar{B}(v)\rangle = \ldots ?$$

[Bartocci,Böer,Feldmann,Ferré,Gubernari,Vladimirov, arXiv:2605.NNNNN]

...

✓ di-light-cone LCDAs appearing in rare Λ_b decays [Feldmann/Gubernari 2024]

✓ radiative tail for (ordinary) 3-particle LCDAs of Λ_b baryon [Feldmann/Vladimirov 2025]

- 3-particle dLCDAs for the B-meson
  - appear in sub-leading contributions to exclusive B-decays
  - complete classification of Dirac and Lorentz structures
  - relations to local matrix elements of dim-5 and dim-6
  - implementation of radiative tail for leading-twist

[Bartocci,Böer,Feldmann,Ferré,Gubernari,Vladimirov, arXiv:2605.NNNNN]

Further plans:

- applications of B-meson DLCDAs in LCSRs
- radiative tail of 3-particle DLCDAs for Λ_b-baryon
- 2-loop radiative tail for 2-particle B-meson LCDA
- connection between LCDAs and shape function ($\rightarrow$ inclusive b-decays)
- …

Siegen (TF):

- Björn Lange (permanent)
- Daniel Vladimirov (PhD, SFB until 12/2026)

$> 01/2027$: application for 3rd SFB funding period …

Bonn (NG):

- Eduard Costa (PhD, Emmy Noether until 12/2028)

External:

- Riccardo Bartocci (KA)
- Philipp Böer (CERN)
- Max Ferré (MZ)
- Danny van Dyk (Durham)

Status of RA2-2

Excited Lambda spectrum in rare b decays

(Albrecht, Thoma)

Introduction

- Overall goal: understand $\Lambda^* \to pK$ system

- Presently used in fits: data from various old Kp-scattering experiments
- Done so far: combined Kp-scattering data and $\Lambda_b^0 \to pK^-\gamma$ LHCb data within Bonn-Gatchina framework
  Observed nice agreement of existing BnGa-PWA solution with LHCb data!
- Future plan: use new data from INSIGHT@ELSA

- Kp-scattering data also analysed by ANL-Osaka, Kent groups,
  who extracted different resonance pole positions from data. Using their pole positions:
  - Fit with ANL-Osaka resonances does not describe LHCb data
  - Fit with Kent pole positions also compatible with LHCb data

- Main goal of RA2-2: add LHCb data from different systems to global fit
  - $\Lambda_b^0 \to pK^-\gamma$: already being combined in global fit with scattering data
  - $\Lambda_b^0 \to J/\psi(\to \mu^+\mu^-)pK^-$ (pentaquark mode): to be included in global fit
  - $\Lambda_b^0 \to pK^-\mu^+\mu^-$ (rare mode): use $\Lambda^* \to pK$ knowledge to constrain NP

Progress since October

- Global fit to pK scattering data and $\Lambda_b^0 \to pK^-\gamma$ LHCb data now also considers Kent University solutions:
  shows consistency with LHCb data → polarisation data (INSIGHT) required to distinguish between the solutions
- Work shown on April 10 in LHCb Amplitude Analysis forum, well received
- Next step: work on publication of results of this global fit

Outlook

- Publish results from global fit to pK scattering and $\Lambda_b^0 \to pK^-\gamma$ LHCb data
- Work on adding pentaquark and rare mode LHCb data
- Long-term: wealth of information from INSIGHT