# Flavour physics at the precision frontier

*Using b-hadron decays to probe the Standard Model and seek for New Physics*

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High energy physics seminar

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UNIVERSITY OF CAMBRIDGE

# Talk outline

## Introduction

## Theoretical framework

- $b \to s\ell^+\ell^-$ effective Hamiltonian
- form factors definition

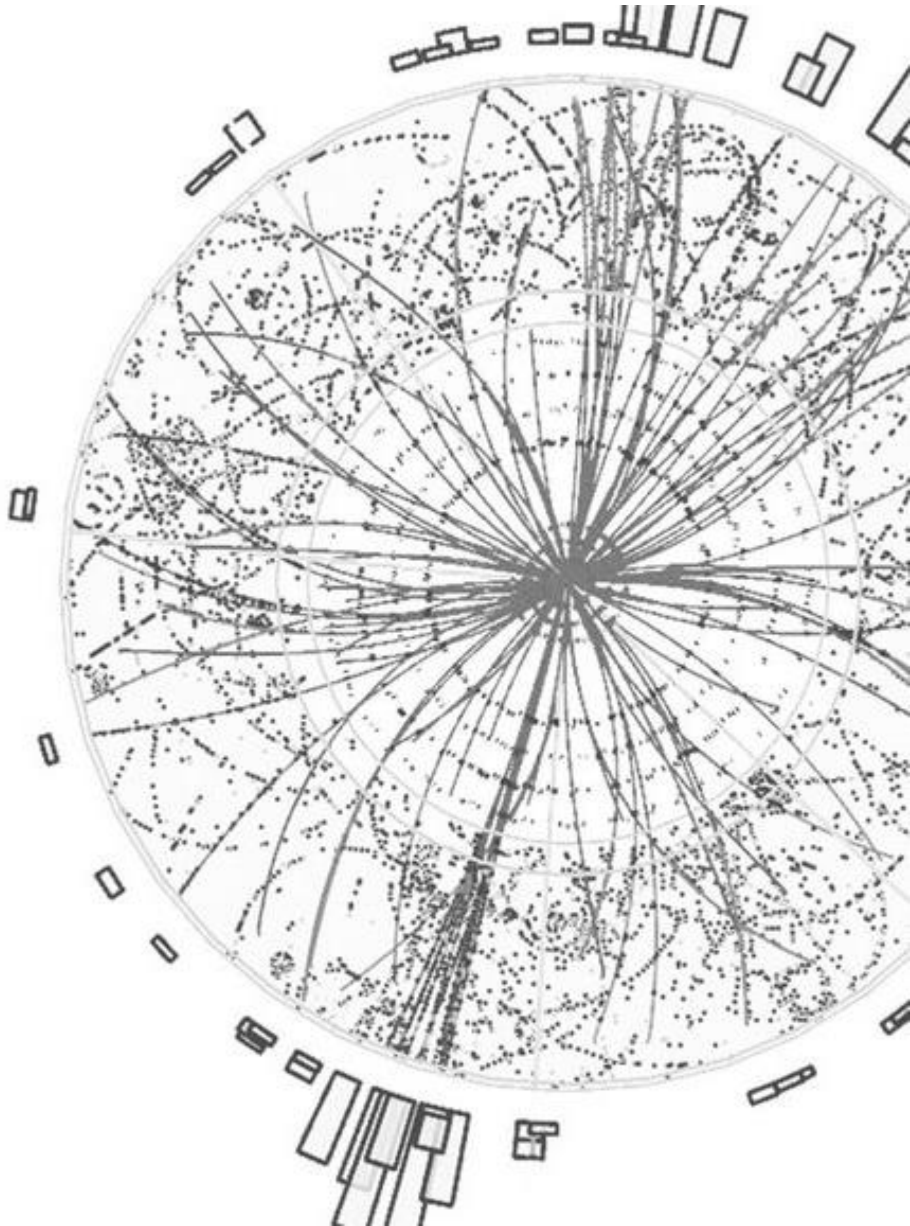
## Local and non-local form factors

- calculation
- analysis and results

## SM predictions

- comparison between SM predictions and data
- global fit to $b \to s\mu^+\mu^-$

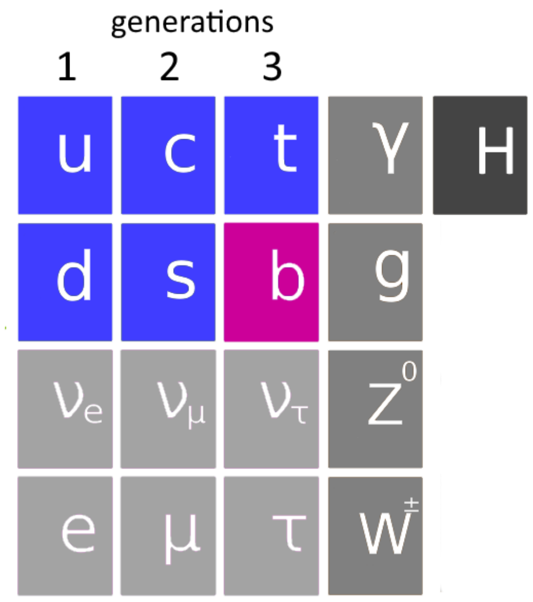
## Summary and outlook



# Introduction

# The beauty of the Standard Model

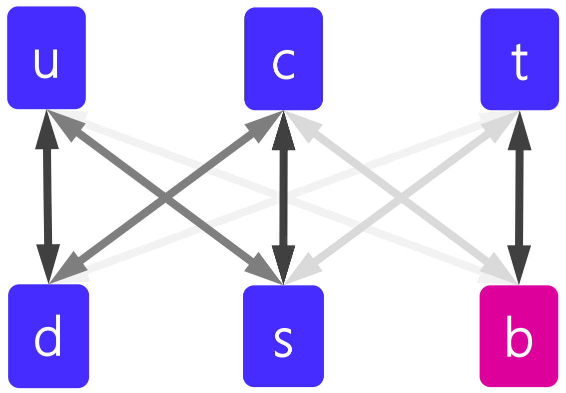





SM: 6 quark flavours and 6 lepton flavours

Flavour physics investigates the properties, the transitions, and the spectrum of the different quark and lepton flavours

Transitions between different (flavours) mediated by $W^{\pm}$




Why is the *b* quark interesting?

- third generation quark
- heaviest fermion that forms bound states ($m_b \gg \Lambda_{\text{QCD}}$)
- lighter than the $t$ quark
  $\Longrightarrow$ decays in quarks of another generation
  $\Longrightarrow$ CKM suppressed decay

# New Physics (**NP**) searches

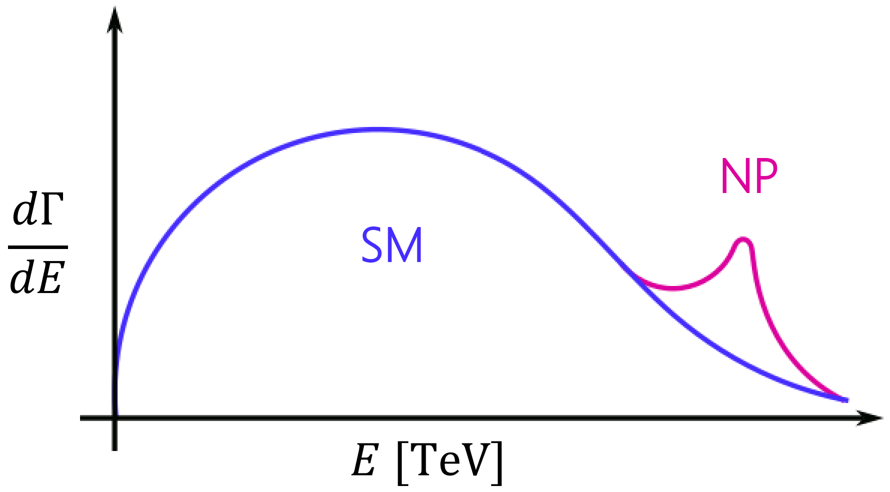
## Direct searches

LHC has reached its maximum energy

**No NP evidence** so far (too heavy?)

**Next experiments** will probably focus on **precision**

Direct NP discovery difficult in coming decades

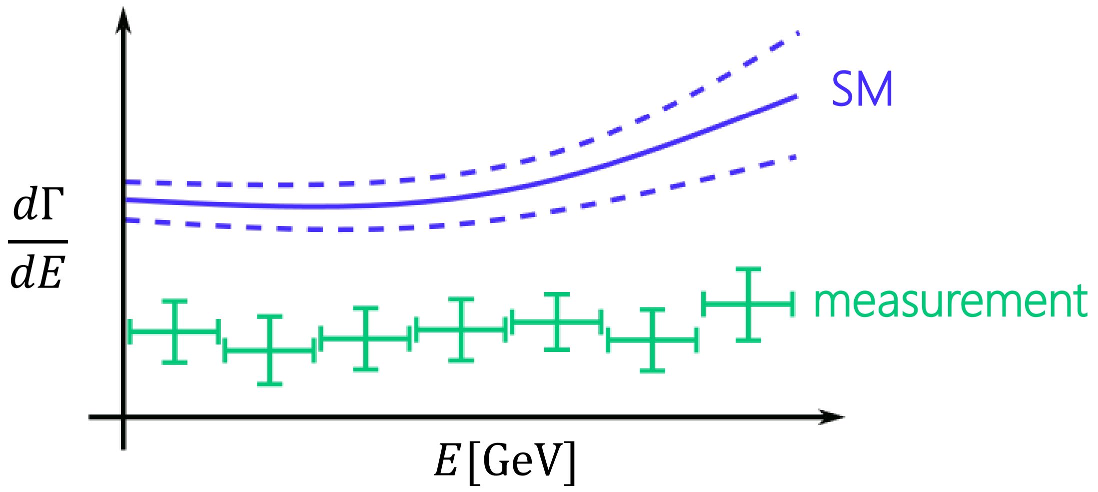



## Indirect searches (with flavour)

Probe the SM at **higher energies** than direct searches

**Compare precise measurements and calculations** of flavour observables

$\Longrightarrow$ obtain constraints on NP (or new discovery?)



# Flavour changing currents

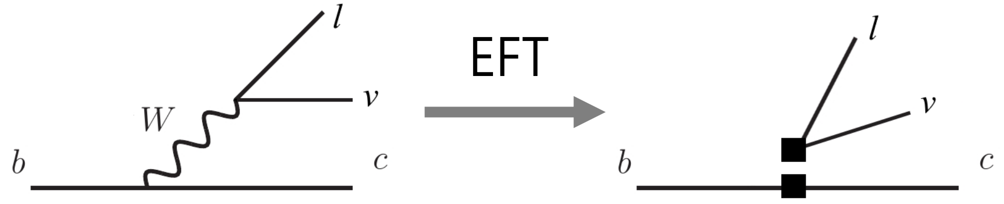


Flavour changing charged currents (FCCC) occur at tree level (mediated by $W^{\pm}$) in the SM

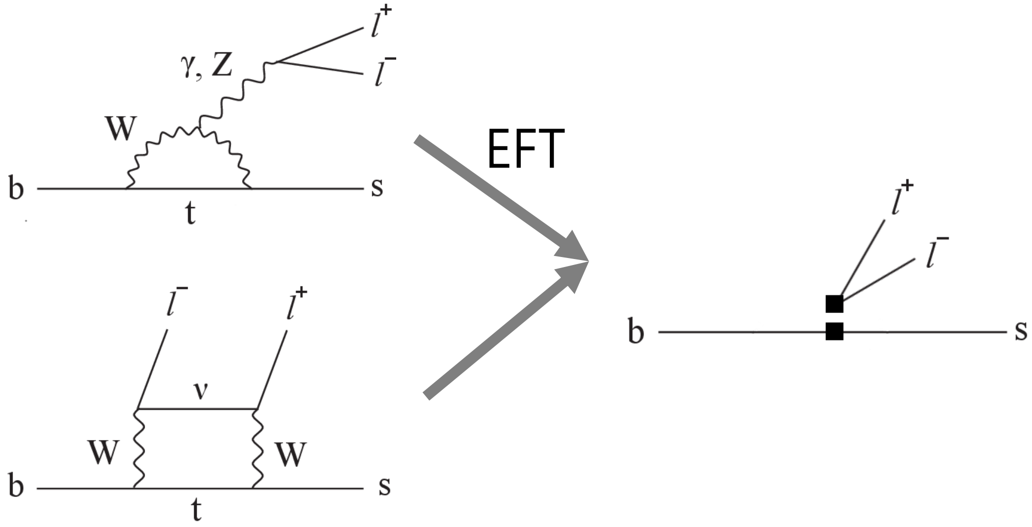
Flavour changing neutral currents (FCNC) absent at tree level in the SM. Focus on $b \to s\ell^+\ell^-$
FCNC are loop, GIM and CKM **suppressed in the SM**

FCNC **sensitive to new physics** contributions
Ideal for **indirect searches**

Integrate out DOF heavier than the $b$
⇓
**Weak effective field theory**




FCCC

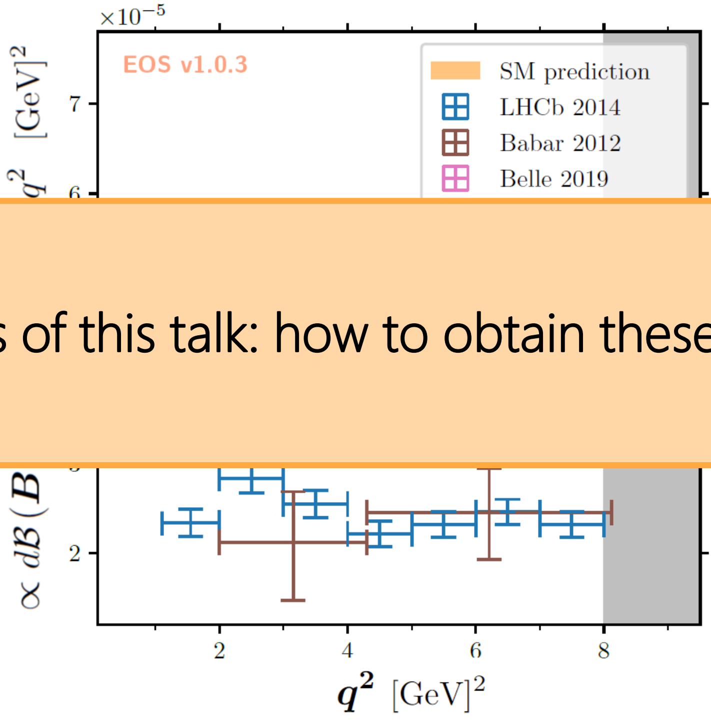


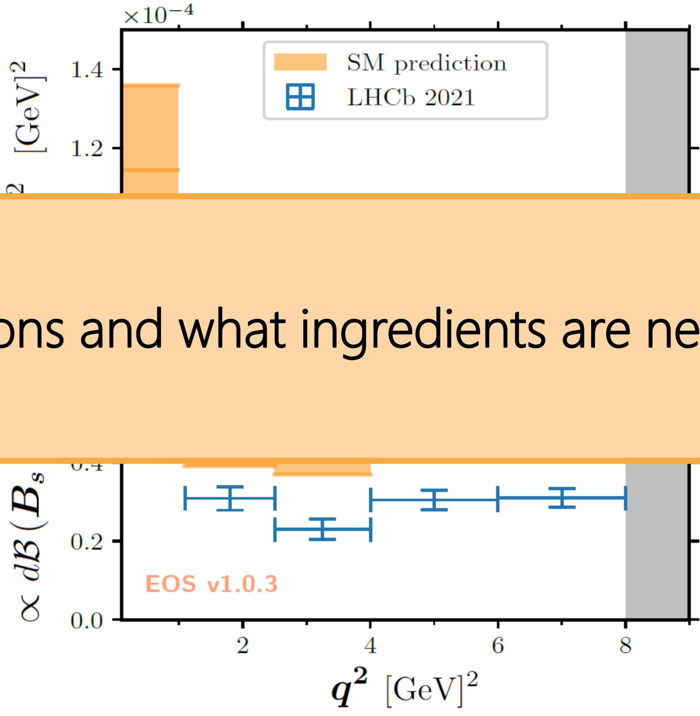

FCNC

# Indirect searches with $b \to s\mu^+\mu^-$



Test the SM and constrain NP with $B \to K^{(*)}\ell^+\ell^-$ and $B_s \to \phi\ell^+\ell^-$ decays




Focus of this talk: how to obtain these SM predictions and what ingredients are needed

Agreement between theory and experiment for LFU ratios $R_K$ and $R_{K^*}$,

but **tension (or anomalies) remains for** $B \to K^{(*)}\mu^+\mu^-$ and $B_s \to \phi\mu^+\mu^-$ observables

$\Longrightarrow$ need to understand this tension

# Importance of theory predictions



1. Tensions in $b \to s\ell^+\ell^-$:
   NP or misestimated QCD effects?

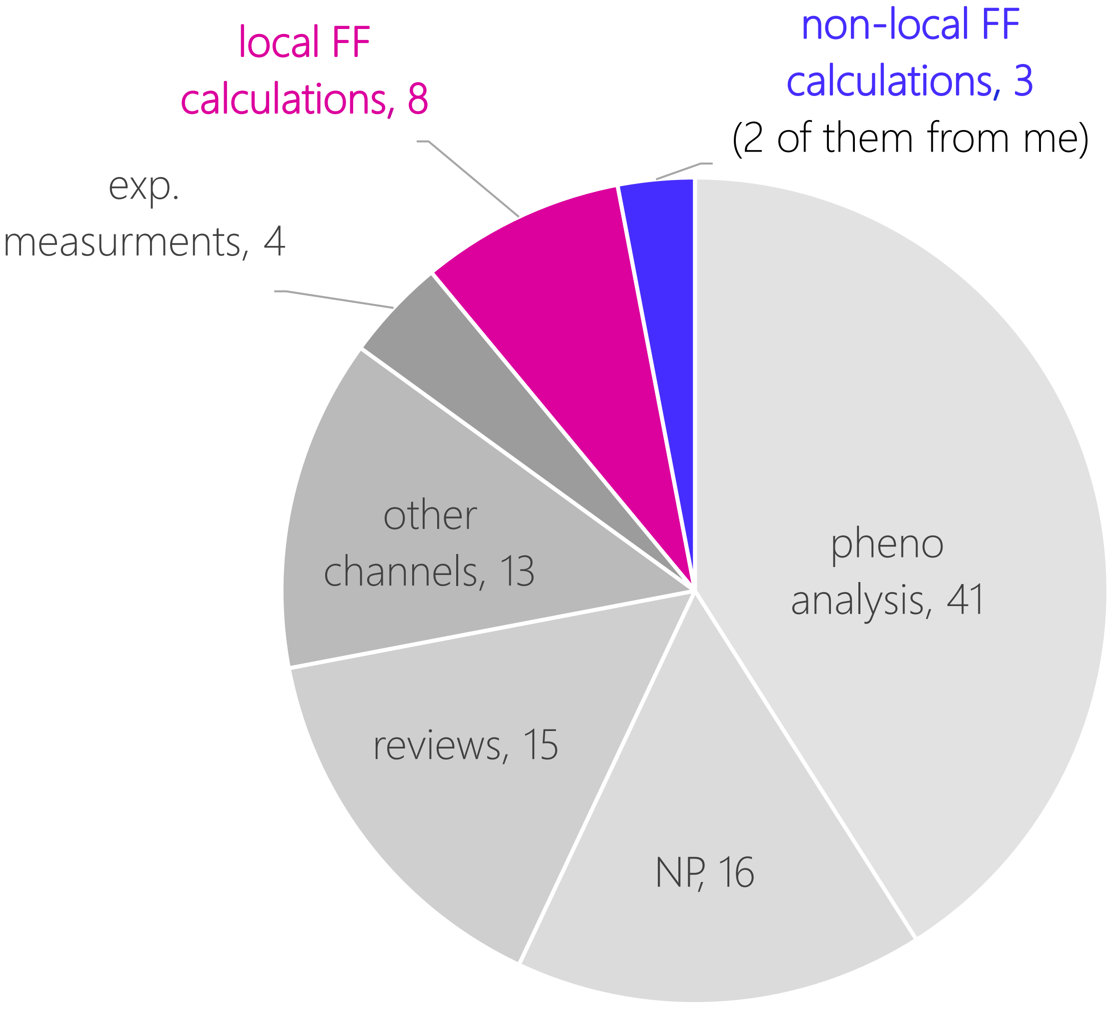
2. Constrain physics beyond the SM
   (SMEFT Wilson coefficients)

Very active field of research

$\Updownarrow$

Tremendous experimental efforts
LHCb, CMS, ATLAS, Belle (II)

Need more theory calculations
to fully exploit experimental work




*Example: distribution of first 100 citations of [NG/van Dyk/Virto 2020]*

# Theoretical framework

# $b \to s\ell^+\ell^-$ effective Hamiltonian



Transitions described by the **effective Hamiltonian**

$$\mathcal{H}(b \to s\ell^+\ell^-) = -\frac{4G_F}{\sqrt{2}} V_{tb}V_{ts}^* \sum_{i=1}^{10} C_i(\mu) O_i(\mu) \qquad \mu = m_b$$

Main contributions to $B \to K^{(*)}\mu^+\mu^-$ in the SM given by operators $O_7, O_9, O_{10}$

$$O_7 = \frac{e}{16\pi^2} m_b (\bar{s}_L \sigma^{\mu\nu} b_R) F_{\mu\nu} \qquad O_9 = \frac{e^2}{16\pi^2} (\bar{s}_L \gamma^\mu b_L) \textstyle\sum_\ell (\bar{\ell}\gamma_\mu \ell) \qquad O_{10} = \frac{e^2}{16\pi^2} (\bar{s}_L \gamma^\mu b_L) \textstyle\sum_\ell (\bar{\ell}\gamma_\mu \gamma_5 \ell)$$

Additional contributions given by operators $O_1, O_2$

$$O_2 = (\bar{s}_L T^a \gamma^\mu c_L)(\bar{c}_L T^a \gamma^\mu b_L) \qquad O_2 = (\bar{s}_L \gamma^\mu c_L)(\bar{c}_L \gamma^\mu b_L)$$

# $B \to K^{(*)}\ell^+\ell^-$ decay amplitude



Calculate decay amplitudes precisely to probe the SM

$$\langle K^{(*)}\ell^+\ell^- | O_{\mathrm{eff}} | B\rangle = \langle \ell\ell | \mathcal{O}_{\mathrm{lep}} | 0\rangle \langle K^{(*)} | O_{\mathrm{had}} | B\rangle + \text{non-fact.}$$

Analogous formulas apply to $B_s \to \phi\ell^+\ell^-$ decays

# $B \to K^{(*)}\ell^+\ell^-$ decay amplitude



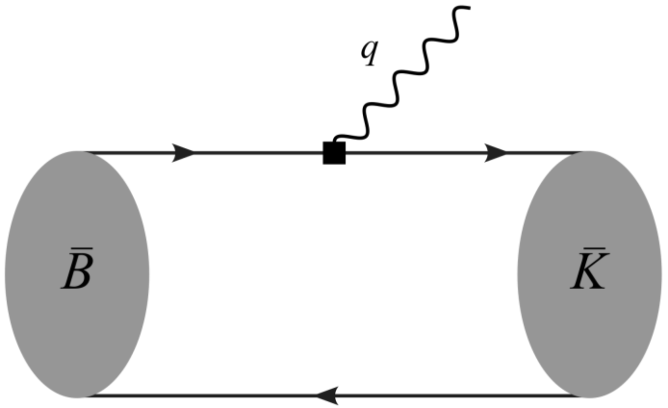
Calculate decay amplitudes precisely to probe the SM

$$\mathcal{A}(B \to K^{(*)}\ell^+\ell^-) = \mathcal{N}\left[\left(C_9 L_V^\mu + C_{10} L_A^\mu\right)\mathcal{F}_\mu - \frac{L_V^\mu}{q^2}\left(C_7\,\mathcal{F}_{T,\mu} + \mathcal{H}_\mu\right)\right]$$

Easily obtain the (differential) branching ratio and angular observables from the amplitude

$$\frac{d\mathcal{B}}{dq^2} = \frac{1}{\Gamma_{\text{tot}}}\frac{d\Gamma}{dq^2} \propto |\mathcal{A}|^2$$

$q^2$ is the momentum transfer squared



# $B \to K^{(*)}\ell^+\ell^-$ decay amplitude



Calculate decay amplitudes precisely to probe the SM

$$\mathcal{A}(B \to K^{(*)}\ell^+\ell^-) = \underbrace{\mathcal{N}\left[\left(C_9 L_V^\mu + C_{10} L_A^\mu\right)\right.}\mathcal{F}_\mu - \underbrace{\frac{L_V^\mu}{q^2}\left(C_7\right.}\mathcal{F}_{T,\mu} + \left.\left.\mathcal{H}_\mu\right)\right]$$

Wilson coefficients, leptonic matrix elements (and constants $\boldsymbol{\alpha}$, $\boldsymbol{V_{CKM}}$...)

↓

perturbative objects, small uncertainties

# $B \to K^{(*)}\ell^+\ell^-$ decay amplitude



Calculate decay amplitudes precisely to probe the SM

$$\mathcal{A}(B \to K^{(*)}\ell^+\ell^-) = \mathcal{N}\left[\left(C_9 L_V^\mu + C_{10} L_A^\mu\right) \mathcal{F}_\mu - \frac{L_V^\mu}{q^2}\left(C_7\ \mathcal{F}_{T,\mu} + \mathcal{H}_\mu\right)\right]$$

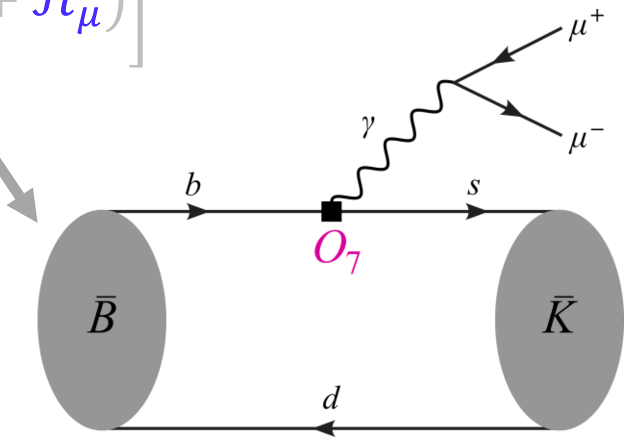
Local hadronic matrix elements

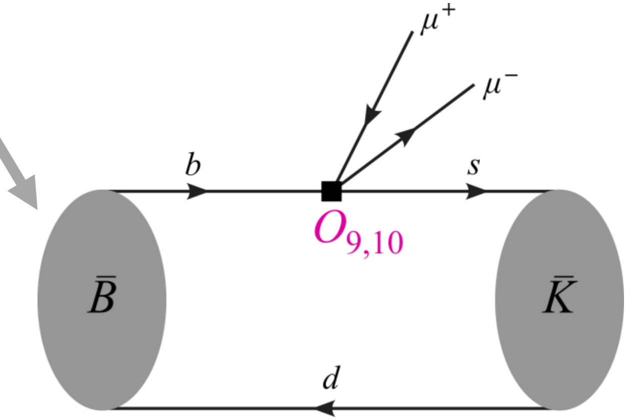
$$\mathcal{F}_\mu = \langle K^{(*)} | O_{7,9,10}^{\text{had}} | B \rangle \qquad O_{7,9,10}^{\text{had}} = (\bar{s}\,\Gamma\, b)$$

leading hadronic contributions

non-perturbative QCD objects
$\Longrightarrow$ calculate with lattice QCD (or LCSR)

moderate uncertainties $(3\% - 15\%)$



# $B \to K^{(*)}\ell^+\ell^-$ decay amplitude



Calculate decay amplitudes precisely to probe the SM

$$\mathcal{A}(B \to K^{(*)}\ell^+\ell^-) = \mathcal{N}\left[\left(C_9 L_V^\mu + C_{10} L_A^\mu\right) \mathcal{F}_\mu - \frac{L_V^\mu}{q^2}\left(C_7\, \mathcal{F}_{T,\mu} + \mathcal{H}_\mu\right)\right]$$

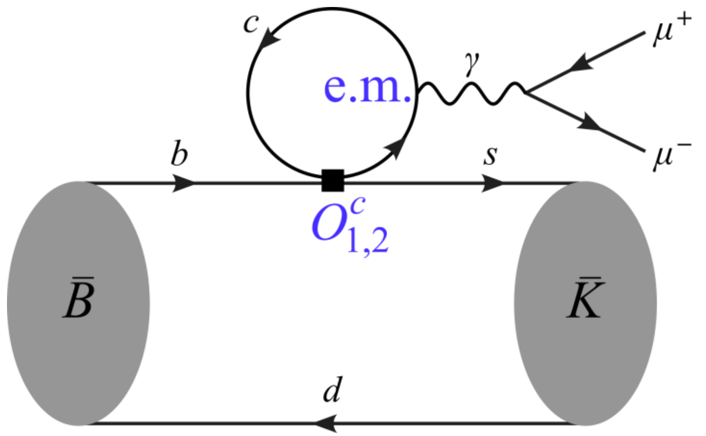
Non-local hadronic matrix elements

$$\mathcal{H}_\mu = i \int d^4x\, e^{iq\cdot x} \langle K^{(*)} | T\{j_\mu^{\mathrm{em}}(x), O_{1,2}^c(0)\} | B \rangle$$

subleading (?) hadronic contributions

non-perturbative QCD objects
$\Longrightarrow$ very hard to calculate

large uncertainties



# Form factors definitions



**Form factors** (FFs) **parametrize hadronic matrix elements**

FFs are functions of the momentum transfer squared $\boldsymbol{q^2}$

Local FFs

$$\mathcal{F}_\mu(k,q) = \sum_\lambda \mathcal{S}_\mu^\lambda(k,q)\,\mathcal{F}_\lambda(q^2)$$

computed with **lattice QCD** and light-cone sum rules with good precision $\mathbf{3\% - 20\%}$

Non-local FFs

$$\mathcal{H}_\mu(k,q) = \sum_\lambda \mathcal{S}_\mu^\lambda(k,q)\mathcal{H}_\lambda(q^2)$$

Calculated using an **Operator Product Expansion (OPE)** or QCD factorization or …

large uncertainties $\Longrightarrow$ reduce uncertainties for a better understanding of rare $\boldsymbol{B}$ decays

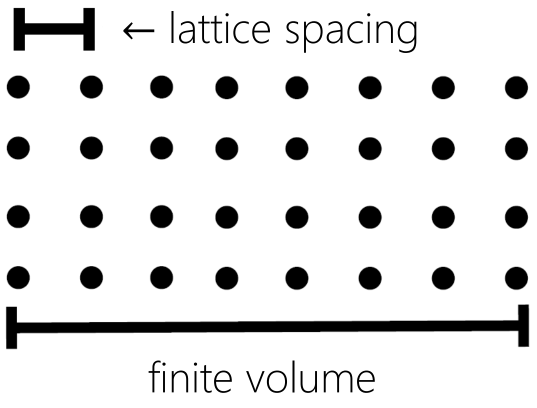
# Local form factors

# Methods to compute FFs

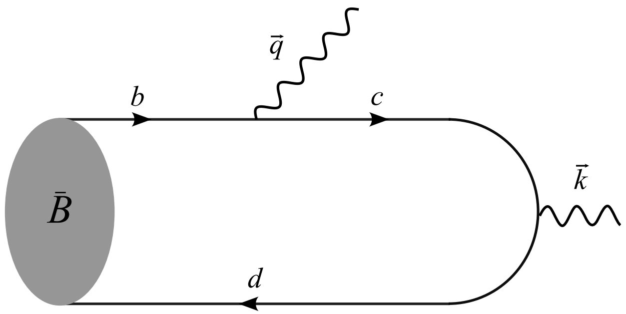


**Non-perturbative techniques** are needed to compute FFs

1. Lattice QCD (LQCD)
   more efficient usually at **high $q^2$**




2. Light-cone sum rules (LCSRs)
   only applicable at **low $q^2$**



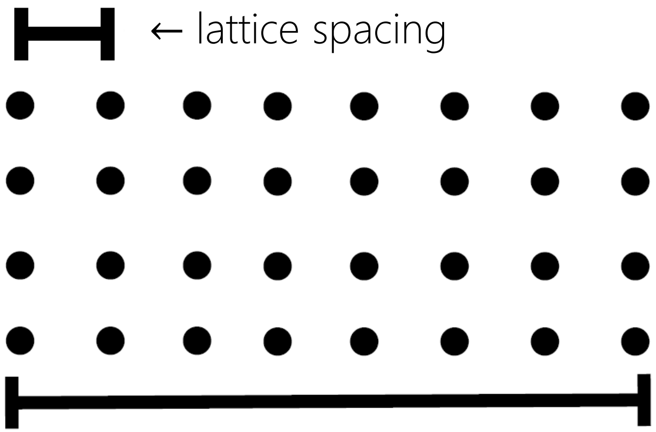

**Complementary** approaches to calculate FFs

# Lattice QCD in a nutshell



LQCD = evaluating path integrals numerically

$$\text{matrix element} = \int \prod_i \mathrm{d}\phi_i \,(\text{correlator})$$




To perform the calculation approximations are needed

1. nonzero lattice spacing
2. finite volume
3. Euclidian space time

## Pros

first principles calculations

reducible systematic uncertainties

## Cons

nonlocal matrix elements and unstable states, are still work in progress

computationally very expensive

# LCSRs in a nutshell



LCSRs are a method to calculate hadronic matrix elements

Method based on:

dispersion relation

quark-hadron duality assumption

Operator Product Expansion

## Pros

compute hadronic matrix elements
not accessible yet with LQCD

complementary w.r.t. LQCD

relatively faster

## Cons

need universal non-perturbative inputs
(QCD condensates or distribution
amplitudes)

non-reducible (but quantifiable) systematic
uncertainties

# Local form factors predictions



Available theory calculations for local FFs $\mathcal{F}_\lambda$

$B \to K$ :

- LQCD calculations at **high** $q^2$
  [HPQCD 2013/2023] [FNAL/MILC 2015]
  and in the **whole** semileptonic region
  [HPQCD 2023]
- LCSR at **low** $q^2$
  [Khodjamirian/Rusov 2017] [NG/Kokulu/van Dyk 2018]

$B \to K^*$ and $B_s \to \phi$ :

- LQCD calculations at **high** $q^2$
  [Horgan et al. 2015]
- LCSR calculation at **low** $q^2$
  [Bharucha et al. 2015] [NG/Kokulu/van Dyk 2018]

$B \to K$ **FFs excellent** status (need independent calculation at low $q^2$ )

**More LQCD results needed for vector states** (for high precision $K^*$ width cannot be neglected)

How to **combine** different calculations and obtain result **whole** semileptonic region?

# Map for local FFs



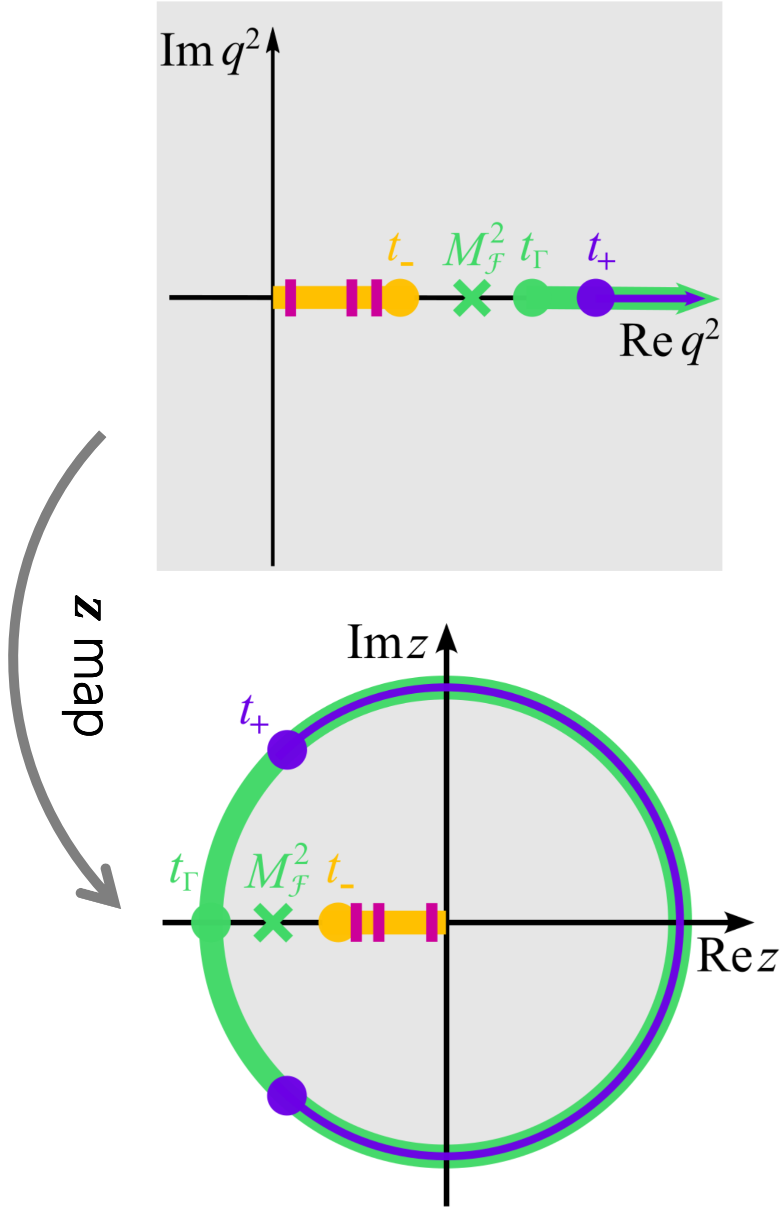
Obtain local FFs $\mathcal{F}_\lambda$ in the whole semileptonic region
by **combining all LQCD** (and **LCSRs**) results

$\mathcal{F}_\lambda$ analytic functions of $q^2$ except for isolated $s\bar{b}$ poles
and a branch cut for $q^2 > t_\Gamma = \left(M_{B_s} + (2)\, M_\pi\right)^2$

Branch cut differs from the pair production threshold:
$t_\Gamma \neq t_+ = \left(M_B + M_{K^{(*)}}\right)^2$ contrary to, e.g., $B \to \pi$

define the map

$$z(q^2) = \frac{\sqrt{t_\Gamma - q^2} - \sqrt{t_\Gamma}}{\sqrt{t_\Gamma - q^2} + \sqrt{t_\Gamma}}$$



# Parametrization for $\mathcal{F}_\lambda$



$\mathcal{F}_\lambda$ analytic in the open unit disk $\Longrightarrow$ **expand $\mathcal{F}_\lambda$ in a Taylor series in $z$**

We propose a **new parametrization** [Gopal/NG 2024]

$$\mathcal{F}_\lambda = \frac{1}{\mathcal{P}(z)\phi(z)} \sum_{k=0}^{\infty} c_k\, z^k \qquad\qquad \sum_{k=0}^{\infty} |c_k|^2 < 1$$

$\mathcal{P}(z)$ and $\phi(z)$ are known functions, **fit $c_k$** coefficients to LQCD (and LCSR) results

First parametrization that is simultaneously:

- valid for $t_\Gamma \neq t_+$
- **unitarity bounded**

Supersede BGL (approximates $t_\Gamma = t_+$ ) $\Longrightarrow$ **non-quantifiable systematic uncertainties**

# Local form factors predictions



$$\mathcal{A}(B \to K^{(*)}\ell^+\ell^-) = \mathcal{N}\left[\left(C_9 L_V^\mu + C_{10} L_A^\mu\right) \mathcal{F}_\mu - \frac{L_V^\mu}{q^2}\left(C_7\, \mathcal{F}_{T,\mu} + \mathcal{H}_\mu\right)\right]$$

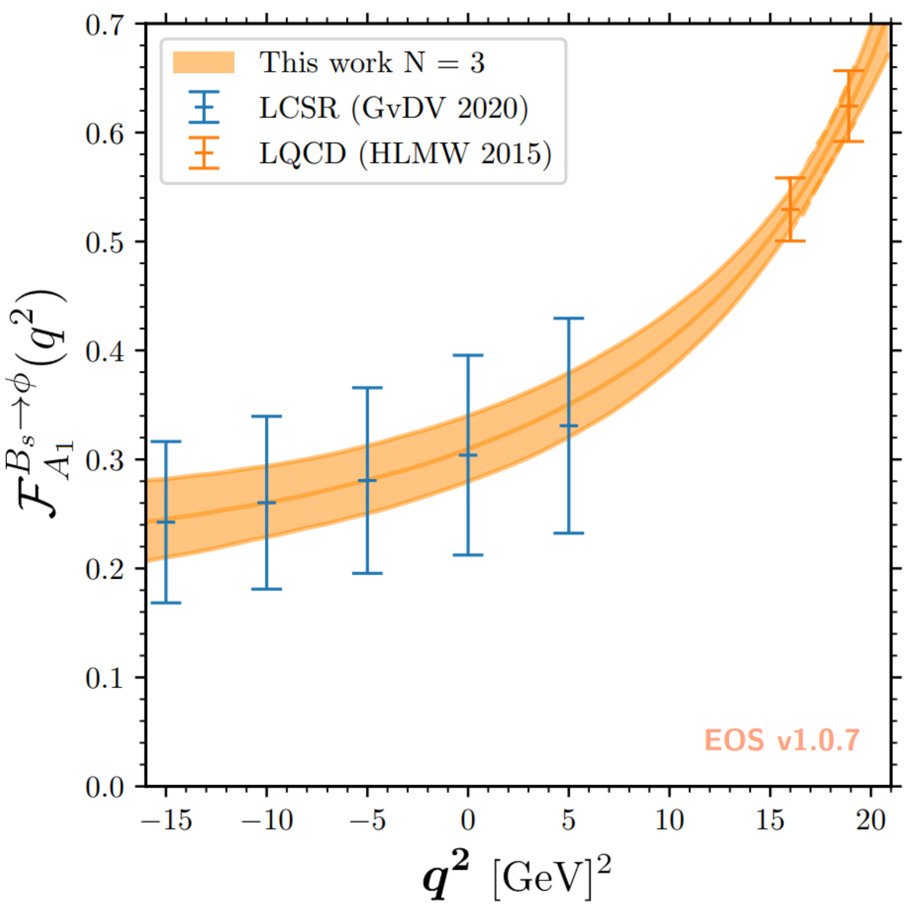
Fit available inputs to

$$\mathcal{F}_\lambda = \frac{1}{\mathcal{P}(z)\phi(z)} \sum_{k=0}^{3} c_k\, z^k \qquad \sum_{k=0}^{3} |c_k|^2 < 1$$

Obtain numerical results for $B \to K^{(*)}$ and $B_s \to \phi$ in the whole semileptonic region

Agreement between LQCD and LCSRs

Fit done in [NG/Reboud/van Dyk/Virto 2023]
Update with new parametrization



# Non-local form factors

# Methods to calculate non-local FFs



Non-perturbative techniques are needed to compute non-local FFs $\mathcal{H}_\lambda(q^2)$

- lattice QCD $\Longrightarrow$ work in progress

- QCD factorization:
  factorize hard and soft contributions
  $\Longrightarrow$ double expansion in $1/m_b$ and $1/E_{K^{(*)}}$
  valid for $q^2 < 7\ \mathrm{GeV}^2$
  How to calculate power corrections? How extend to $\Lambda_b$ decays?
  Is the perturbative treatment of the charm loop reliable close to threshold?

- light-cone operator product expansion (LCOPE) $\Longrightarrow$ see next slide

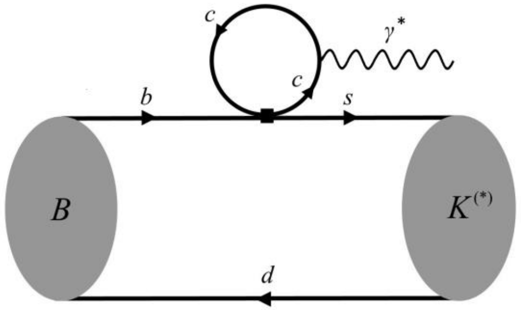
# Obtaining theoretical predictions for $\mathcal{H}_\lambda$



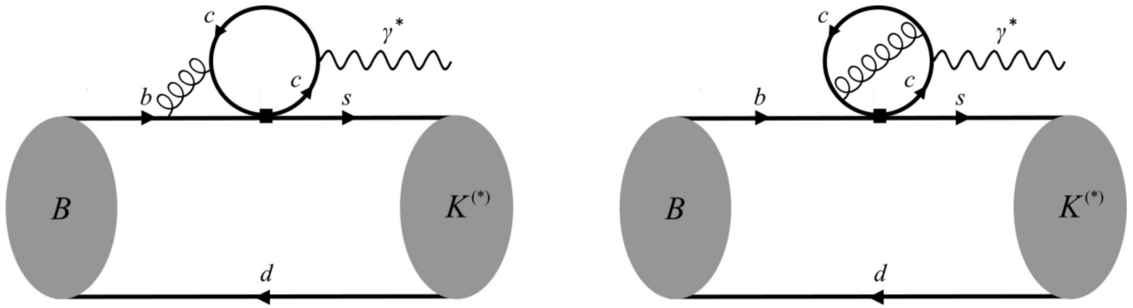
1. Calculate non-local FFs $\mathcal{H}_\lambda$ using a LCOPE at negative $q^2$

$$\mathcal{H}_\lambda(q^2) = \mathcal{C}_\lambda(q^2)\mathcal{F}_\lambda(q^2) + \tilde{\mathcal{C}}_\lambda(q^2)\mathcal{V}_\lambda(q^2) + \cdots$$

leading power (LO in $\alpha_s$)

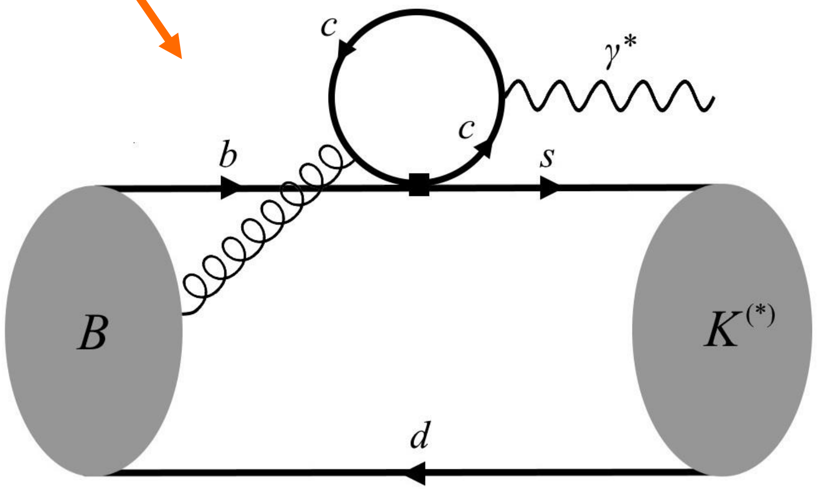



+ hard gluons $(\alpha_s)$ corrections




[Bell/Huber 2014] [Asatrian/Greub/Virto 2019]

soft gluon correction
non-perturbative
$\Longrightarrow$ not $\alpha_s$ suppressed




[Khodjamirian et al. 2010]
[NG/van Dyk/Virto 2020]

# Obtaining theoretical predictions for $\mathcal{H}_\lambda$



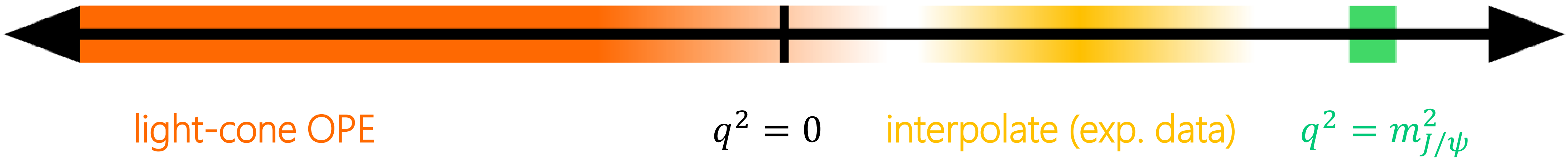
1. Calculate non-local FFs $\mathcal{H}_\lambda$ using a LCOPE at negative $q^2$

$$\mathcal{H}_\lambda(q^2) = C_\lambda(q^2)\mathcal{F}_\lambda(q^2) + \tilde{C}_\lambda(q^2)\mathcal{V}_\lambda(q^2) + \cdots$$

2. Extract $\mathcal{H}_\lambda$ at $q^2 = m^2_{J/\psi}$ from $B \to K^{(*)}J/\psi$ and $B_s \to \phi\, J/\psi$ measurements (decay amplitudes independent of the local FFs)

3. **New approach: interpolate** these two results to obtain theoretical predictions in the low $q^2$ $(0 < q^2 < 8\ \mathrm{GeV}^2)$ region $\Longrightarrow$ compare with experimental data

Need a parametrization to interpolate $\mathcal{H}_\lambda$: which is the optimal parametrization?



# Map for non-local FFs



Similar situation with respect to $\mathcal{F}_\lambda$

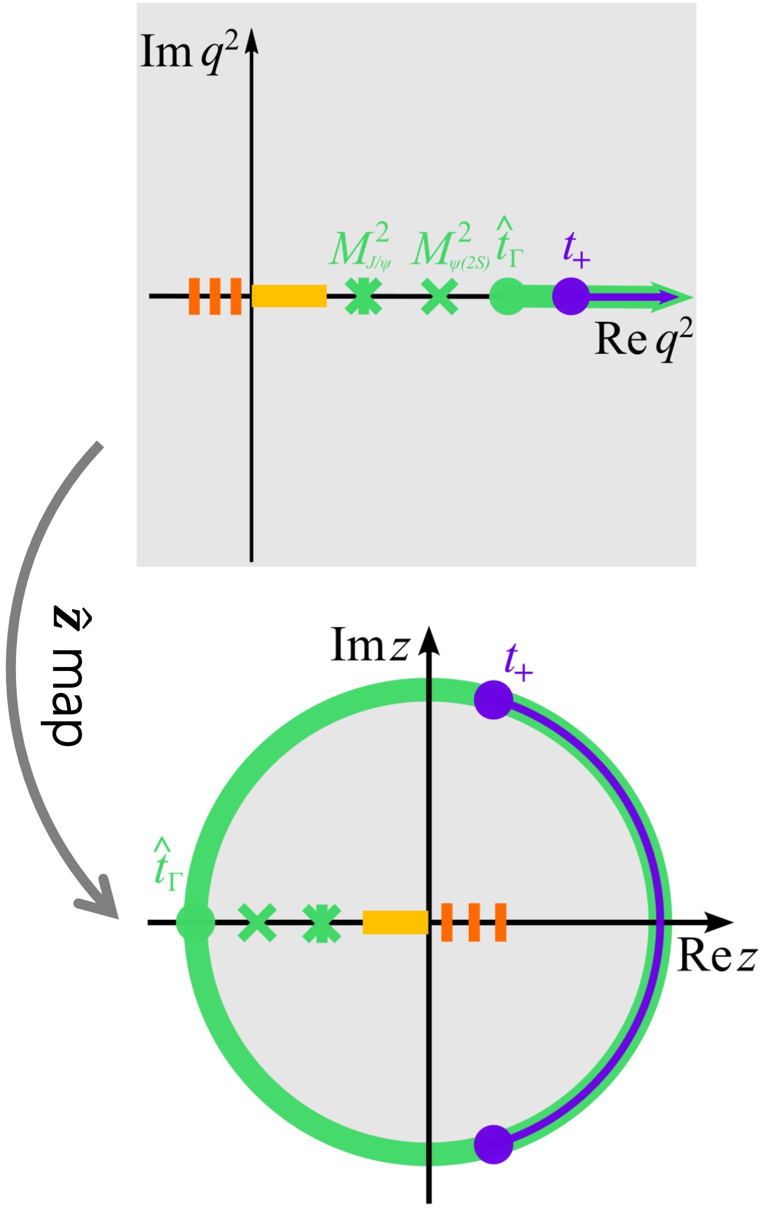
$\mathcal{H}_\lambda$ analytic functions of $q^2$ except for isolated $c\bar{c}$ poles ($J/\psi$ and $\psi(2S)$) and a branch cut for $q^2 > \hat{t}_\Gamma = 4M_D^2$

Branch cut differs from the pair production threshold:

$$t_\Gamma \neq t_+ = \left(M_B + M_{K^{(*)}}\right)^2$$

Define the map

$$\hat{z}(q^2) = \frac{\sqrt{\hat{t}_\Gamma - q^2} - \sqrt{\hat{t}_\Gamma}}{\sqrt{\hat{t}_\Gamma - q^2} + \sqrt{\hat{t}_\Gamma}}$$




**Anomalous cuts will be discussed later!** (neglected for the moment being)

# Non-local form factors predictions



$$\mathcal{A}(B \to K^{(*)}\ell\ell) = \mathcal{N}\left[\left(C_9 L_V^\mu + C_{10} L_A^\mu\right) \mathcal{F}_\mu - \frac{L_V^\mu}{q^2}\left(C_7\, \mathcal{F}_{T,\mu} + \mathcal{H}_\mu\right)\right]$$

Obtain numerical results for the non-local FFs $\mathcal{H}_\lambda$

$$\mathcal{H}_\lambda(\hat{z}) \propto \sum_{n=0}^{5} \beta_n p_n(\hat{z}) \qquad \sum_{n=0}^{\infty} |\beta_n|^2 < 1$$

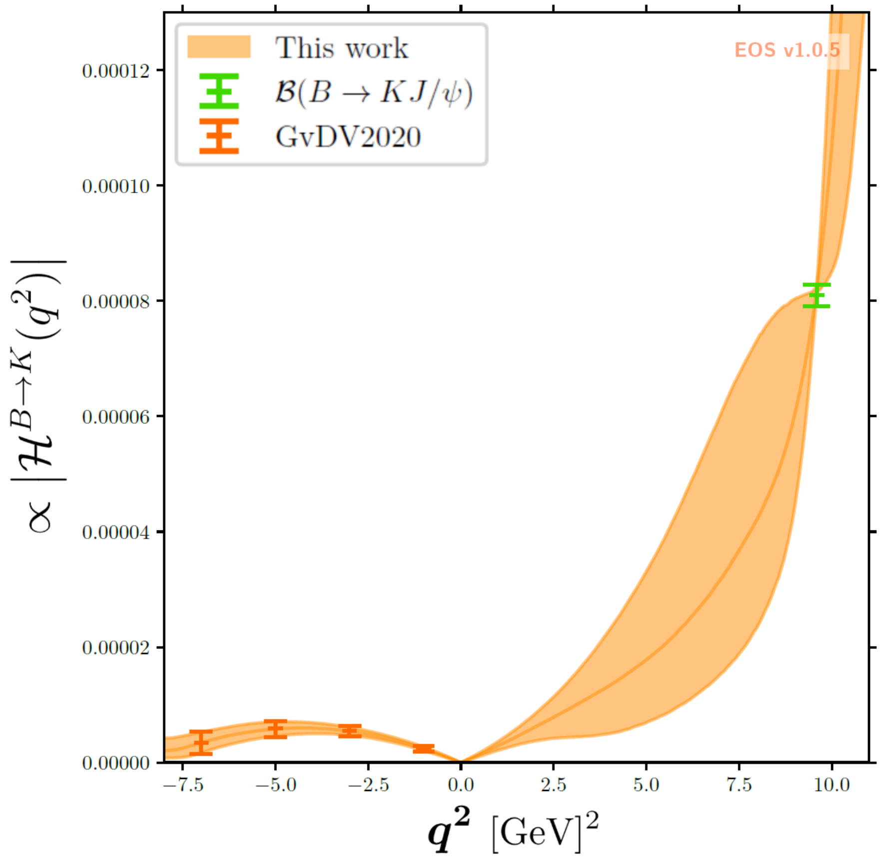
Fit the $\hat{z}$ parametrization

- light-cone OPE calculation at negative $q^2$

$$\mathcal{H}_\lambda(q^2) = C_\lambda(q^2)\mathcal{F}_\lambda(q^2) + \tilde{C}_\lambda(q^2)\mathcal{V}_\lambda(q^2) + \cdots$$

- $B \to K^{(*)} J/\psi$ and $B_s \to \phi\, J/\psi$ measurements at $q^2 = m_{J/\psi}^2$
- unitarity bound (derived for the first time)

Need to update including anomalous cuts!




[NG/Reboud/van Dyk/Virto 2022]

# SM predictions and confrontation with data

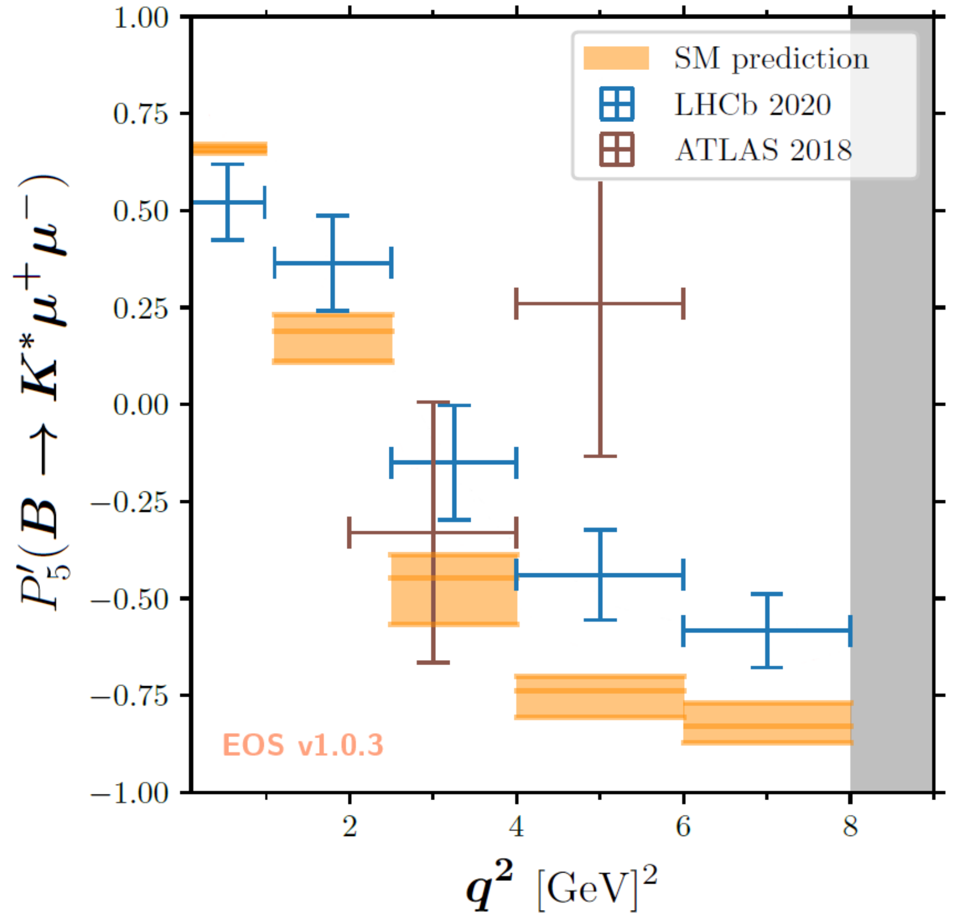
# SM predictions vs. data



Predict observables using our $\mathcal{F}_\lambda$ and $\mathcal{H}_\lambda$ results:

BRs and angular observables
for $B \to K^{(*)}\mu^+\mu^-$, and $B_s \to \phi\mu^+\mu^-$

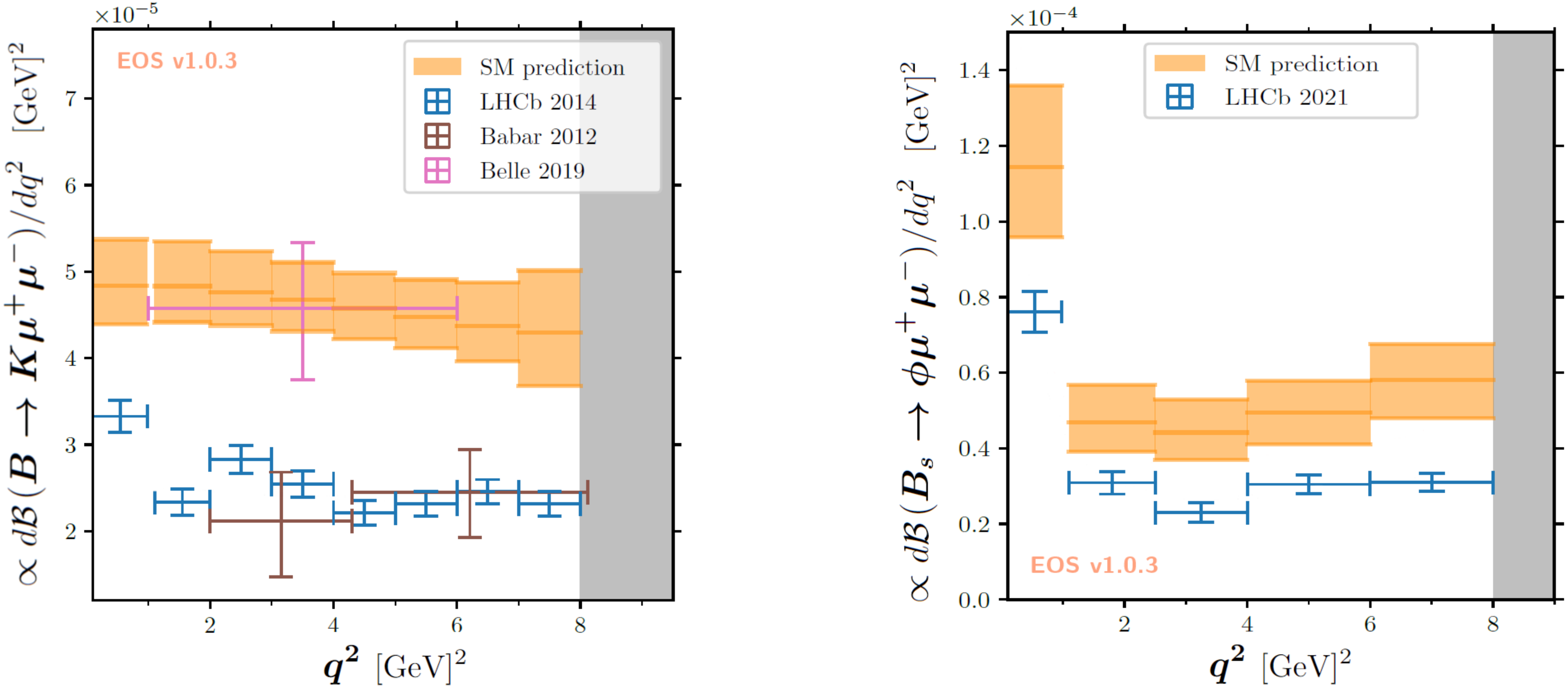
- theory uncertainties mostly due to $\mathcal{F}_\lambda$
- progress in $\mathcal{H}_\lambda$ calculations urgently needed
- more measurements on the way




[NG/Reboud/van Dyk/Virto 2022]

# SM predictions vs. data






[NG/Reboud/van Dyk/Virto 2022]

Coherent tensions between SM predictions and data

# Global fit to $b \to s\mu^+\mu^-$ (setup)



Use our predictions for the local and non-local FFs as priors

Fit the Wilson coefficients $C_9^{\mathrm{NP}}$ and $C_{10}^{\mathrm{NP}}$ to the available experimental measurements in $b \to s\mu^+\mu^-$ transitions
$(C_{9,10} = C_{9,10}^{\mathrm{SM}} + C_{9,10}^{\mathrm{NP}})$

We perform three fits, one for each set of the following set of experimental measurements:
(BRs, angular observables, binned and not binned)

- $B \to K\mu^+\mu^- + B_s \to \mu^+\mu^-$
- $B \to K^*\mu^+\mu^-$
- $B_s \to \phi\mu^+\mu^-$

Combined fit would be very challenging $\longrightarrow$ 130 nuisance parameter

# Global fit to $b \to s\mu^+\mu^-$ (results)



we **obtain good fits**, agreement between the three fits

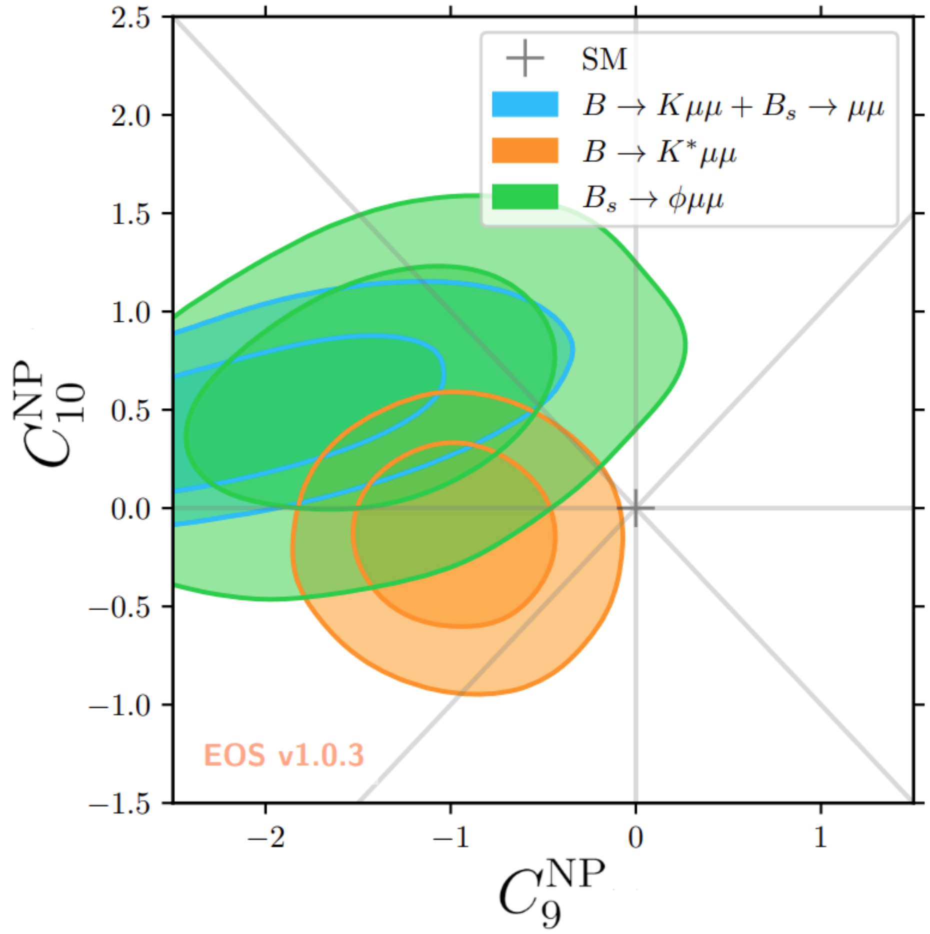
**Substantial tension w.r.t. SM** (in agreement with the literature)

Pulls ($p$ value of the SM hypothesis):

- $5.7\sigma$ for $B \to K\mu^+\mu^- + B_s \to \mu^+\mu^-$
- $2.7\sigma$ for $B \to K^*\mu^+\mu^-$
- $2.6\sigma$ for $B_s \to \phi\mu^+\mu^-$

Local FFs $\mathcal{F}_\lambda$ main uncertainties

**Non-local FFs $\mathcal{H}_\lambda$ cannot explain this tension**



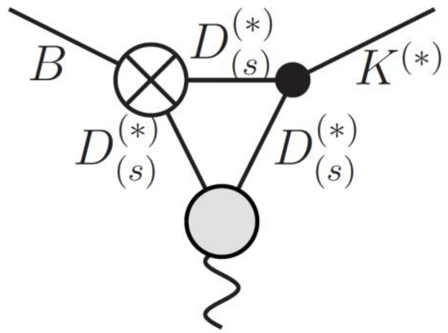
# Open issues

# Rescattering effects



**Missing contributions?**

Ciuchini et al. 2022 (also way before) claim that $B \to \bar{D}D_s \to K^{(*)}\ell^+\ell^-$ rescattering might have a sizable contribution $\Longrightarrow O(20\%)$ at amplitude level




**LCOPE contains (implicitly) rescattering effects**

**partonic** calculation does not yield large contribution (LP OPE and NLO $\alpha_s$)

$$\mathcal{H}_\lambda(q^2) = C_\lambda(q^2)\mathcal{F}_\lambda(q^2) + \tilde{C}_\lambda(q^2)\mathcal{V}_\lambda(q^2) + \cdots$$

$C_\lambda$ is complex valued for any $q^2$ value due to branch cut in $p^2 = M_B^2$ as expected

[Asatrian/Greub/Virto 2019]

Large quark-hadron duality violation?

Slow convergence of the LCOPE?

Alternative approach $\Longrightarrow$ directly calculate rescattering effects using hadronic methods

# Anomalous branch cuts



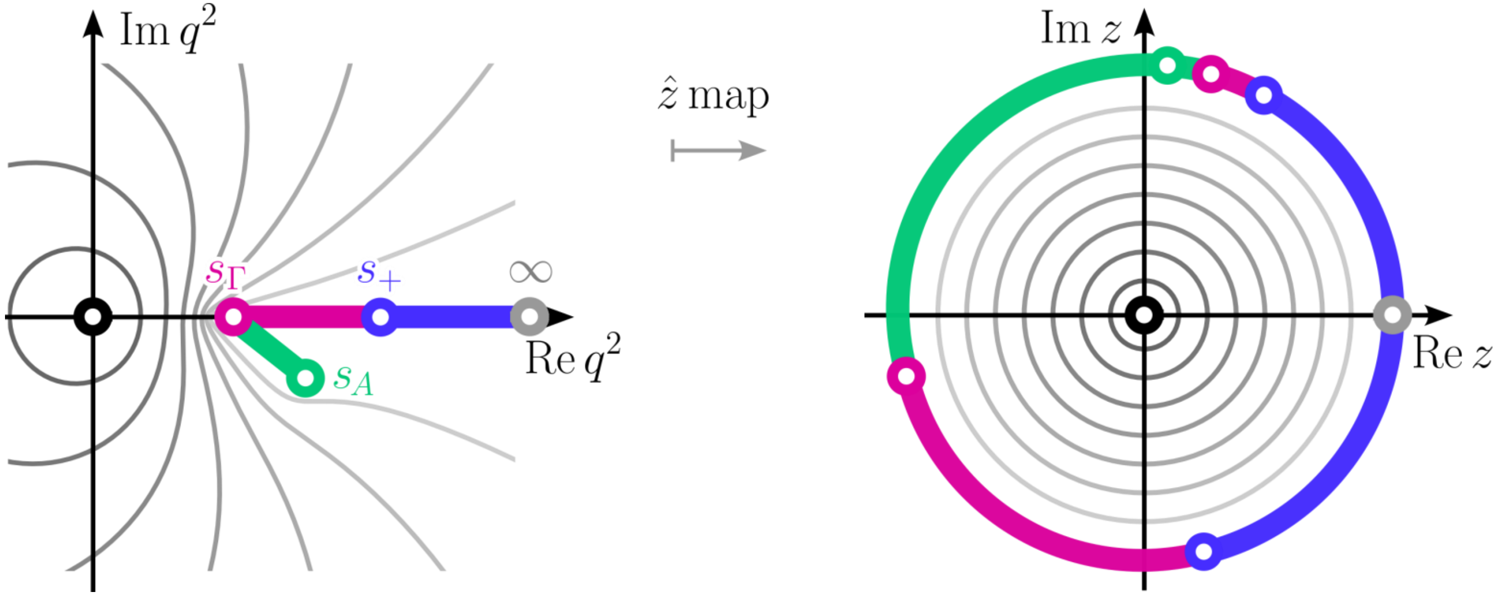
Non-local FFs may present have anomalous branch cuts that extend into the complex plane
Example $B \to D D_s^* \to K \ell^+ \ell^-$ rescattering

$$s_+ = (m_B + m_K)^2 \qquad s_\Gamma = (2m_D)^2 \qquad s_A = 24.1 - 3.5i$$

[Mutke et al. 2024]

Apply the same procedure as for the subthreshold branch cuts, but:

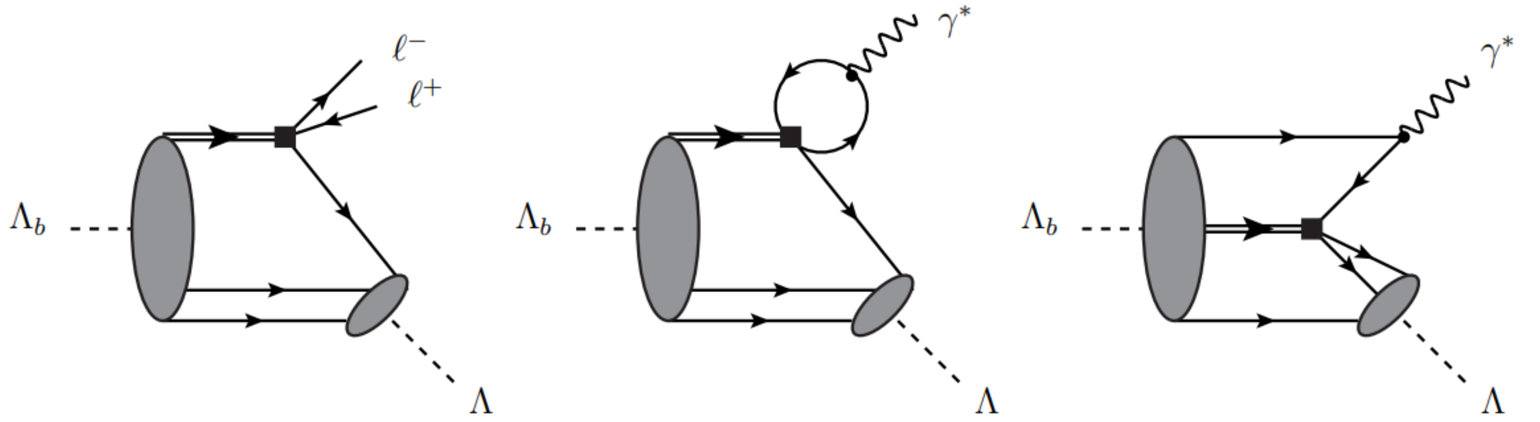
- $\hat{z}$ map is very hard to obtain (existence guaranteed by the Riemann Mapping Theorem)
- $\Delta\chi$ calculation extremely challenging




[Gopal/NG 2024]

# $\Lambda_b \to \Lambda\ell^+\ell^-$ decays






[Feldmann/NG 2023]

If $b \to s\mu^+\mu^-$ anomalies are due to New Physics $\Longrightarrow$ same shift expected in $\Lambda_b \to \Lambda\mu^+\mu^-$
but rescattering effects are different

Already measured by LHCb $\Longrightarrow$ new and more precise measurements on the way

Progress needed in theory calculations (no estimate of charm-loop beyond naïve factorization)

fFirst calculation of “annihilation” contributions in [Feldmann/NG 2024]

# Possible issues on local FFs



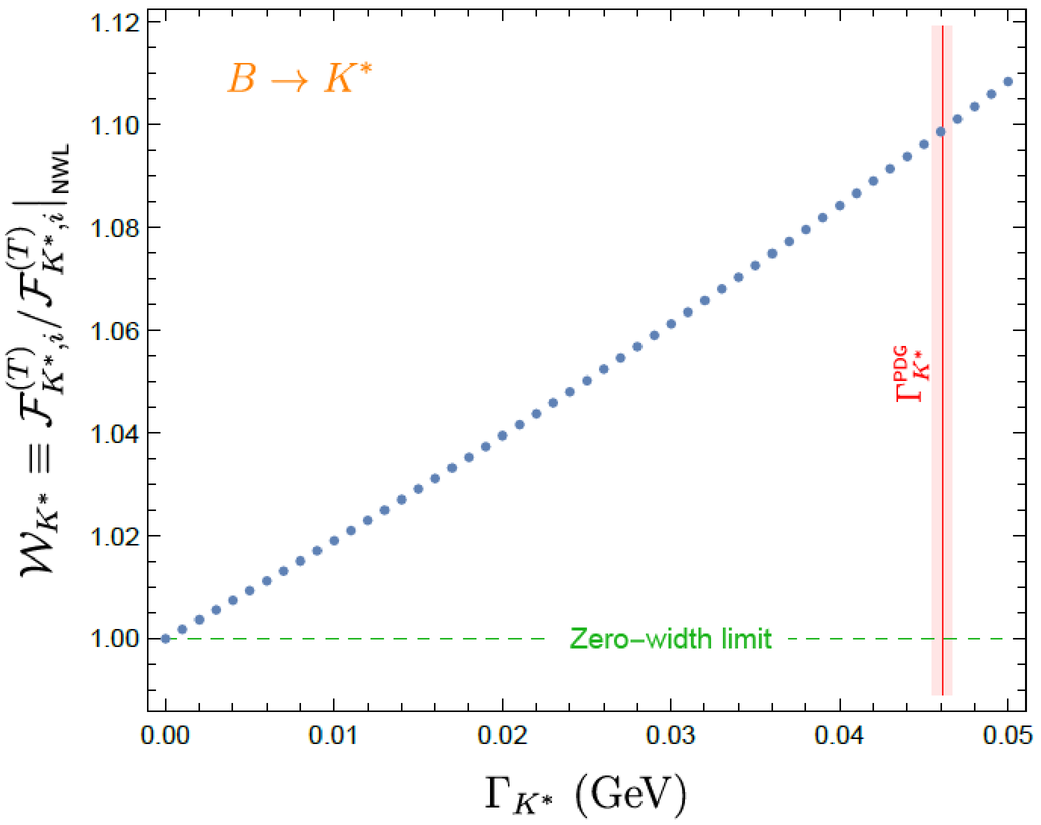
**Precise LQCD** calculations for local $\mathcal{F}_\lambda$ FFs at low $q^2$ are **essential** to have better theoretical predictions

Already available for $B \to K\ell^+\ell^-$ [HPQCD 2022]

w.i.p. for $B \to K^*\ell^+\ell^-$ and $B_s \to \phi\ell^+\ell^-$

$K^*$ has a sizable width
$\Longrightarrow$ $B \to K\pi\ell^+\ell^-$ local FFs calculation
first steps in [Descotes-Genon et al. 2019] using LCSRs

**Clear path** to solve these issues




[Descotes-Genon et al. 2019]

# Summary and outlook

# Summary and outlook



1. Improved parametrization for local FFs $\mathcal{F}_\lambda$ (consider below threshold branch cuts)

   Combine LQCD (and LCSRs) inputs to get results for $\mathcal{F}_\lambda$ in $B \to K^{(*)}\ell^+\ell^-$ and $B_s \to \phi\ell^+\ell^-$

2. Calculate $\mathcal{H}_\lambda$ with LCOPE and use unitarity bounds

   Need to include anomalous branch cuts

3. SM predictions for observables in $B \to K^{(*)}\ell^+\ell^-$ and $B_s \to \phi\ell^+\ell^-$ decays

   Coherent deviations between SM and data in $B \to K^{(*)}\ell^+\ell^-$ and $B_s \to \phi\ell^+\ell^-$ decays

4. **Progress on the theory side needed** more than ever

Thank you!