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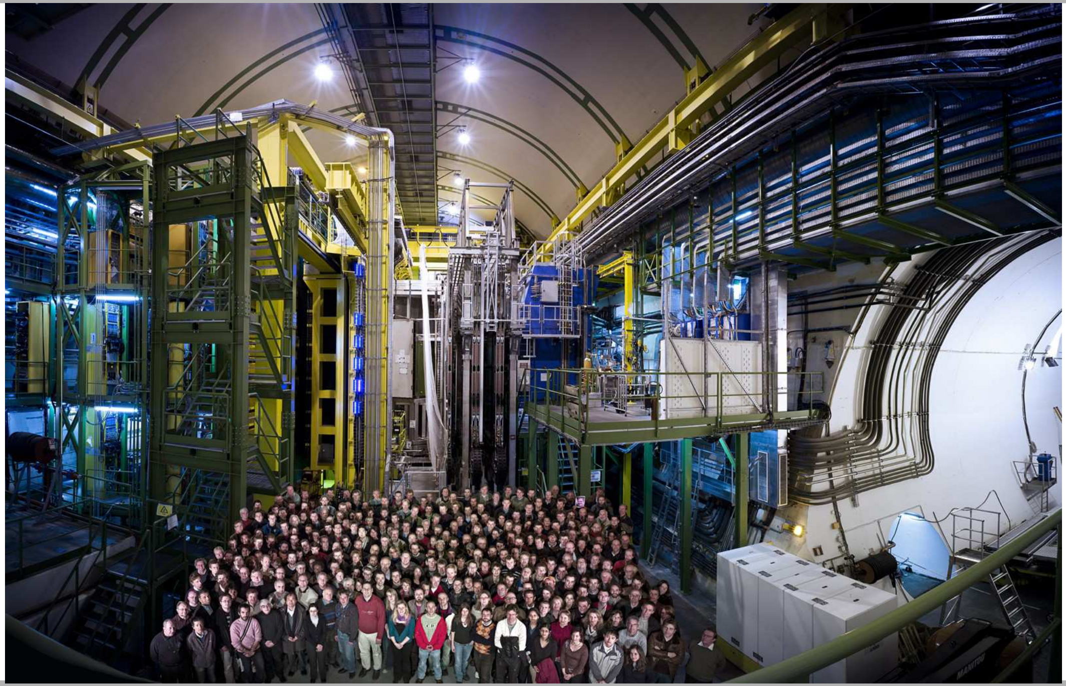
Latest results in rare decays at LHCb

M. Kreps on behalf of the LHCb Collaboration

Physics Department



Introduction

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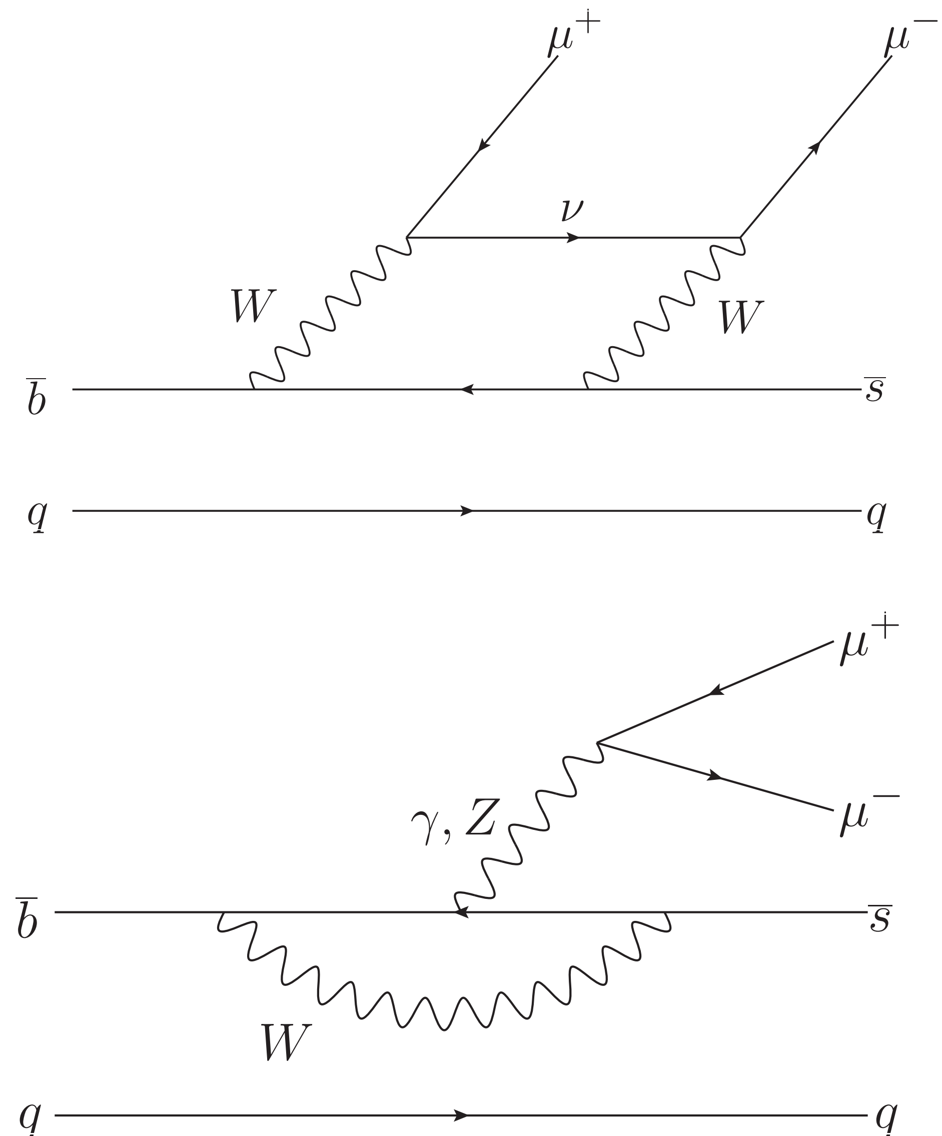
- In the SM, $b \to s$ FCNC decays
- SM BF of the order of 10^{-6}
- With angular analysis offers variety of observables
- Allows to test some underlying details of the NP
- Form factors make prediction of some observables less precise
- But many observables are free of form factor uncertainties
- Results shown today use 3 fb^{-1} of data



Typical q^2 spectrum

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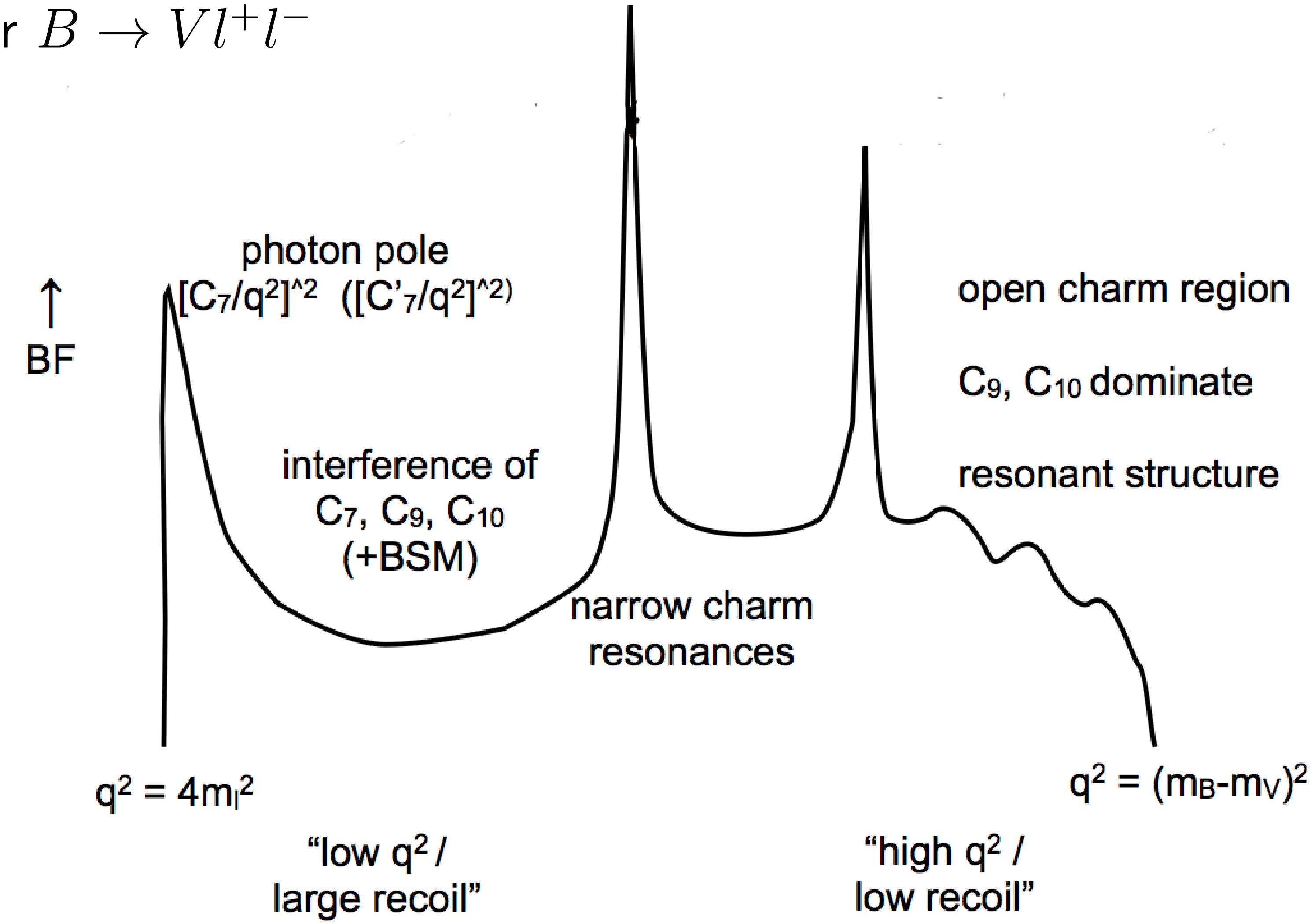
Valid for $B \to V l^+ l^-$



Different q^2 region sensitive to different contributions

From S. Jäger at Workshop on $b \to sll$ processes, 1-3 April 2014

Past excitement

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- Already existing measurements of many observables with 1 fb^{-1} of 2011 data
- Mostly consistent with SM
- Some discrepancies exists
  - Isospin asymmetry in $B \to K\mu^+\mu^-$
  - One of the angular observables (P_5') in $B^0 \to K^{*0}\mu^+\mu^-$
- Systematically update with 3 fb^{-1} of 2011+2012 data

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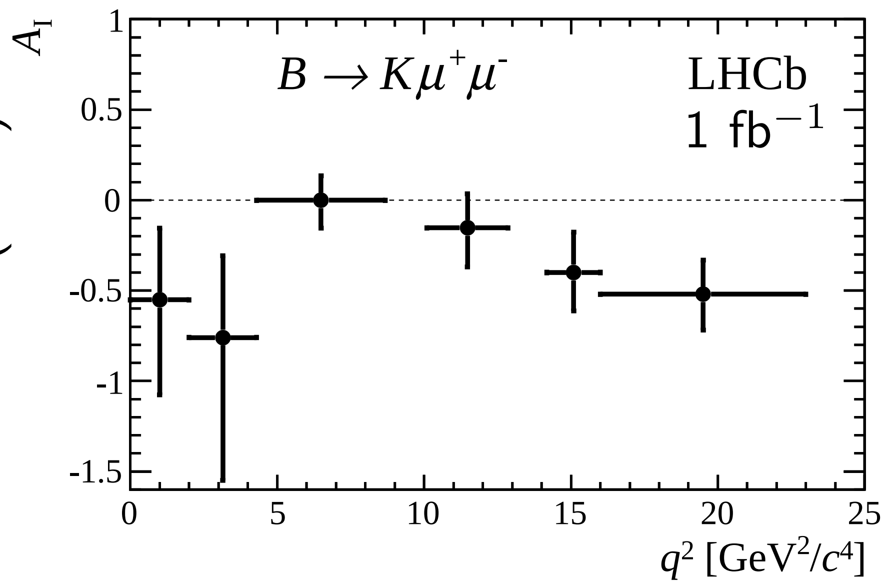

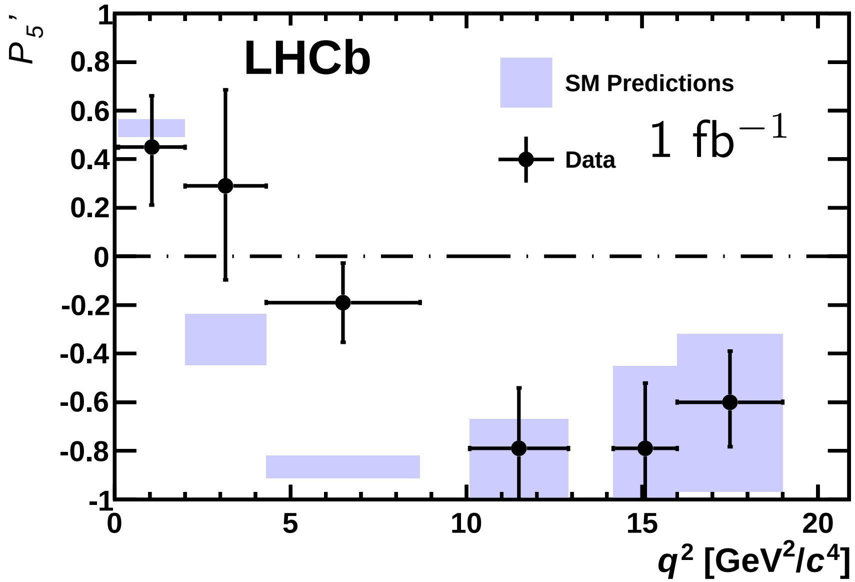

PRL 111 (2013) 191801

$B \to K^{(*)}\mu^+\mu^-$ sample

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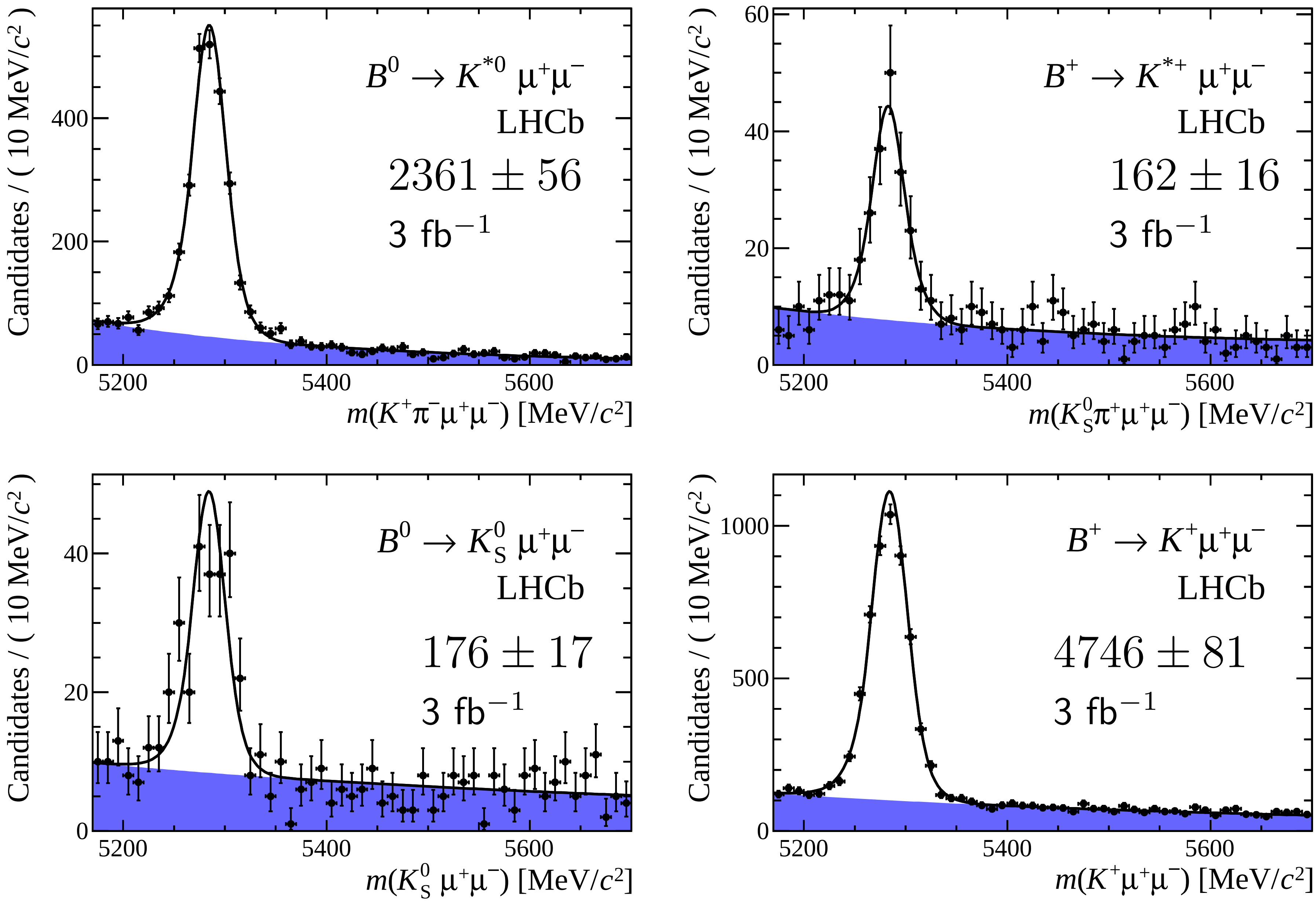

arXiv:1403.8044

Differential BF

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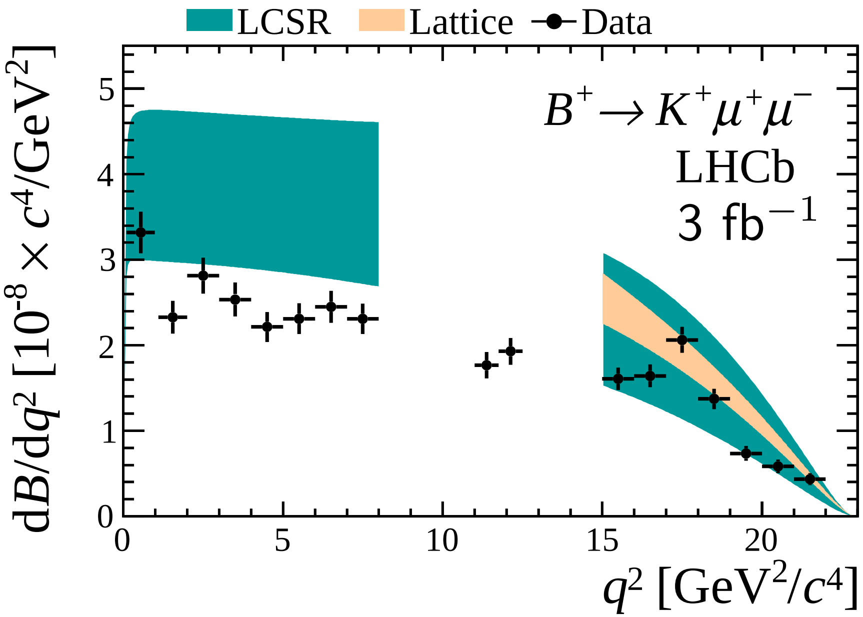

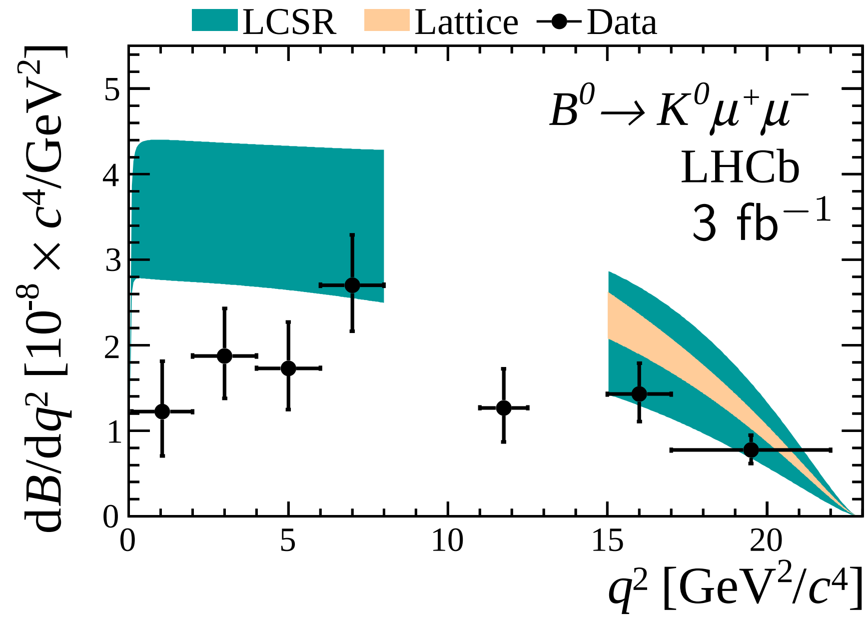

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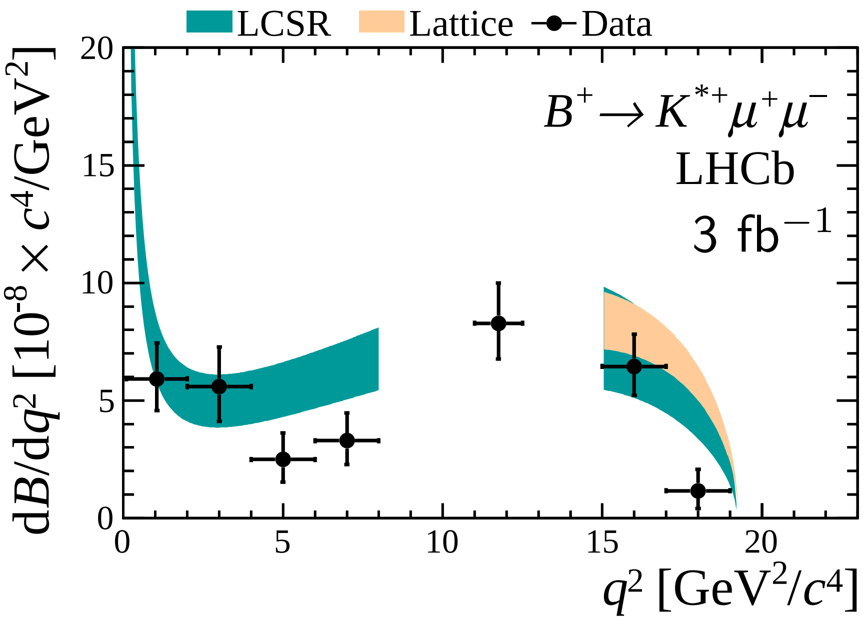
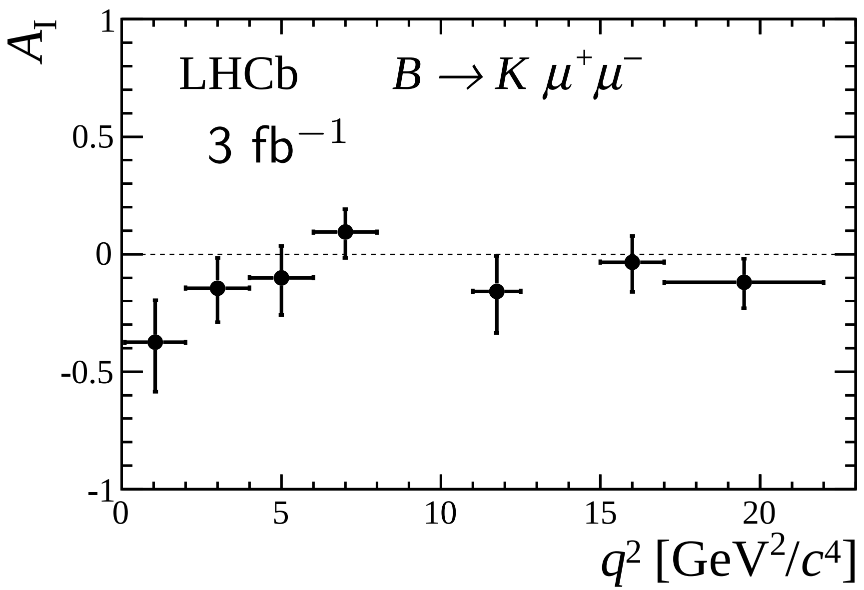


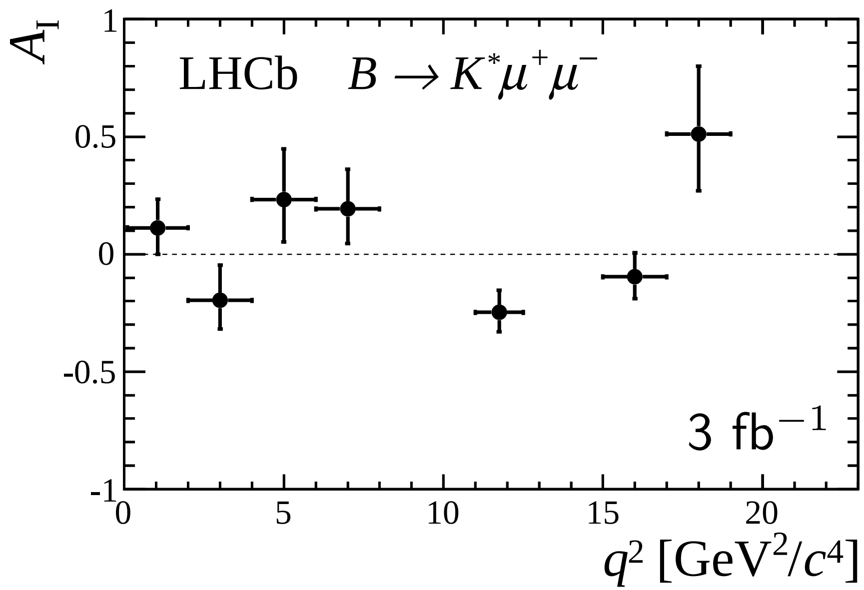
- Normalize with respect to decay through J/ψ
- Overall branching fraction below theory
- But all bins tend to be below theory (refs. in paper)

Isospin asymmetry

$$A_I = \frac{\Gamma(B^0 \to K^{(*)0}\mu\mu) - \Gamma(B^+ \to K^{(*)+}\mu\mu)}{\Gamma(B^0 \to K^{(*)0}\mu\mu) + \Gamma(B^+ \to K^{(*)+}\mu\mu)}$$

- In SM expect A_I close to zero
- Test simple hypothesis of uniform A_I
- $B \to K^*\mu\mu$ p-value of 80%
- $B \to K\mu\mu$ p-value of 11% (1.5σ)





arXiv:1403.8044

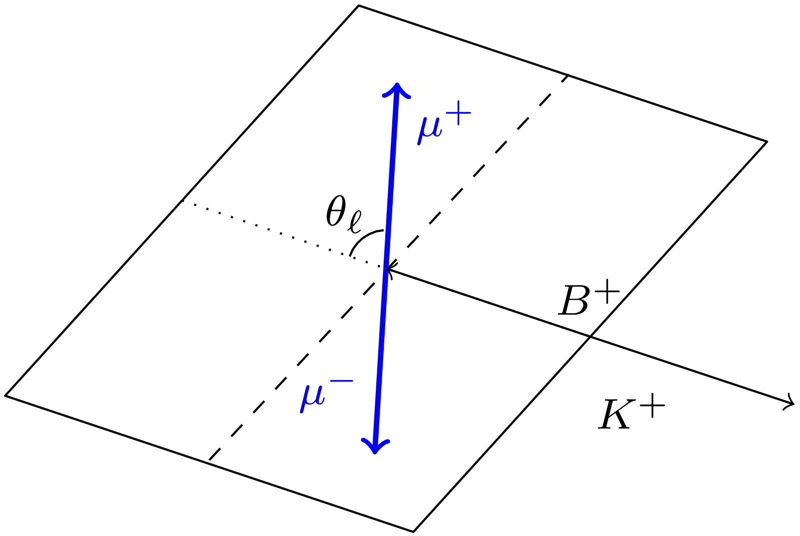
Angular analysis

- Start updates with $B \to K\mu^+\mu^-$
- Angular distribution for B^+

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_l} = \frac{3}{4}(1 - F_H)(1 - \cos^2\theta_l) + \frac{1}{2}F_H + A_{FB}\cos\theta_l$$

- Positive in boundaries $0 \leq F_H \leq 3$ and $|A_{FB}| \leq F_H/2$
- As B^0 is not self-tagging, A_{FB} not accessible

$$\frac{1}{\Gamma}\frac{d\Gamma}{d|\cos\theta_l|} = \frac{3}{2}(1 - F_H)(1 - \cos^2\theta_l) + F_H$$



Typical q^2 spectrum

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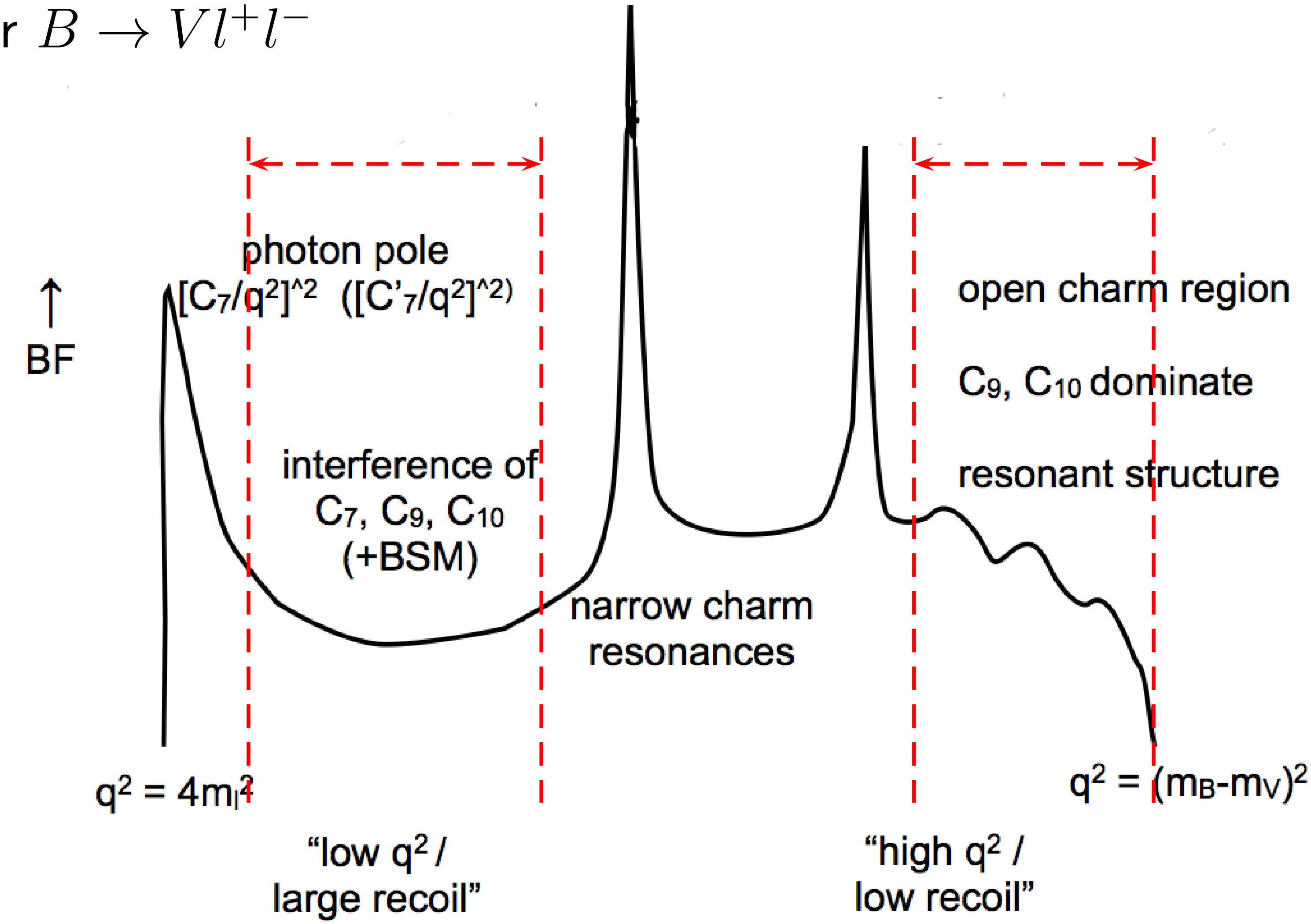
Valid for $B \to V l^+ l^-$



Different q^2 region sensitive to different contributions

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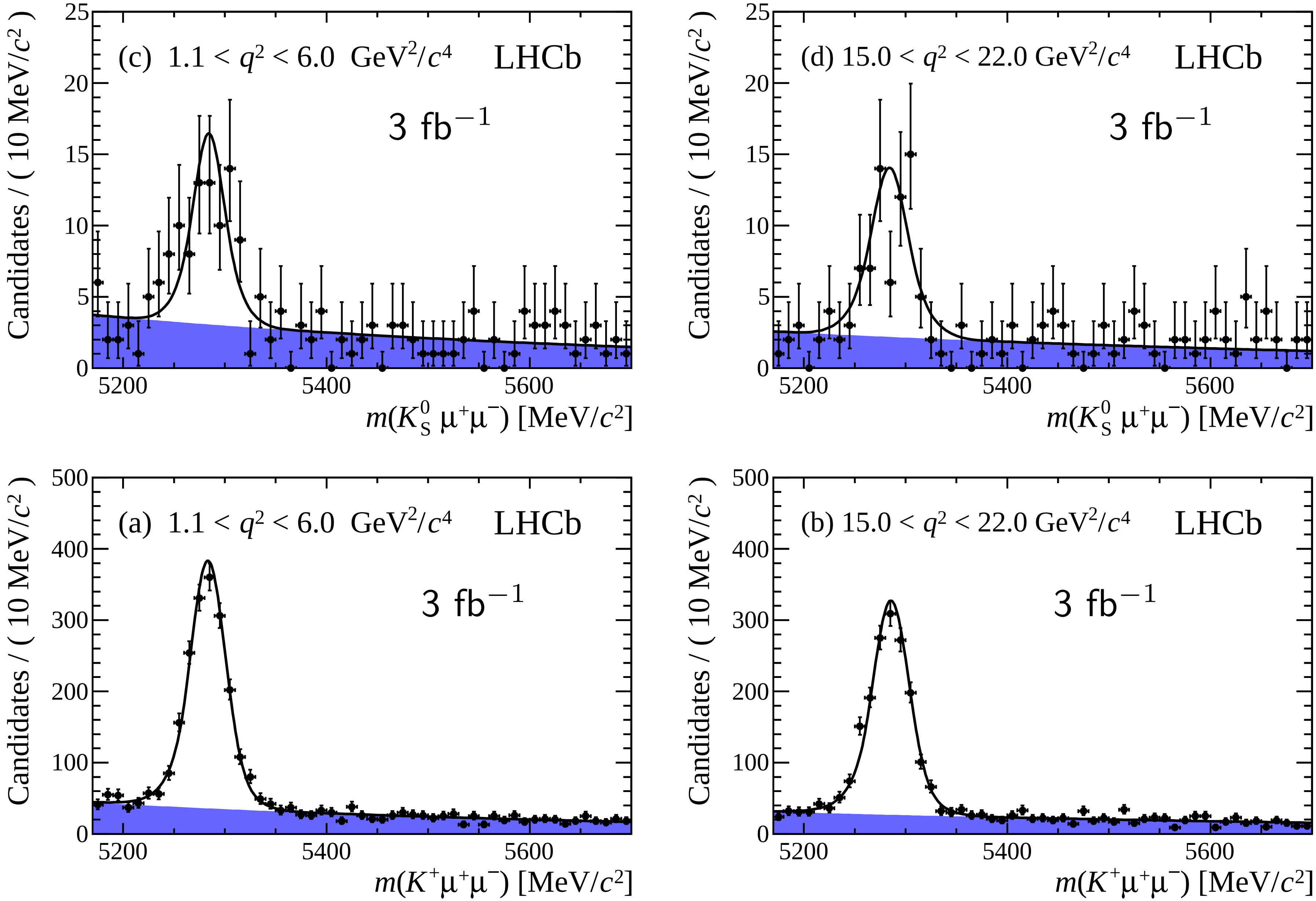
Sample



arXiv:1403.8045

Angular distributions

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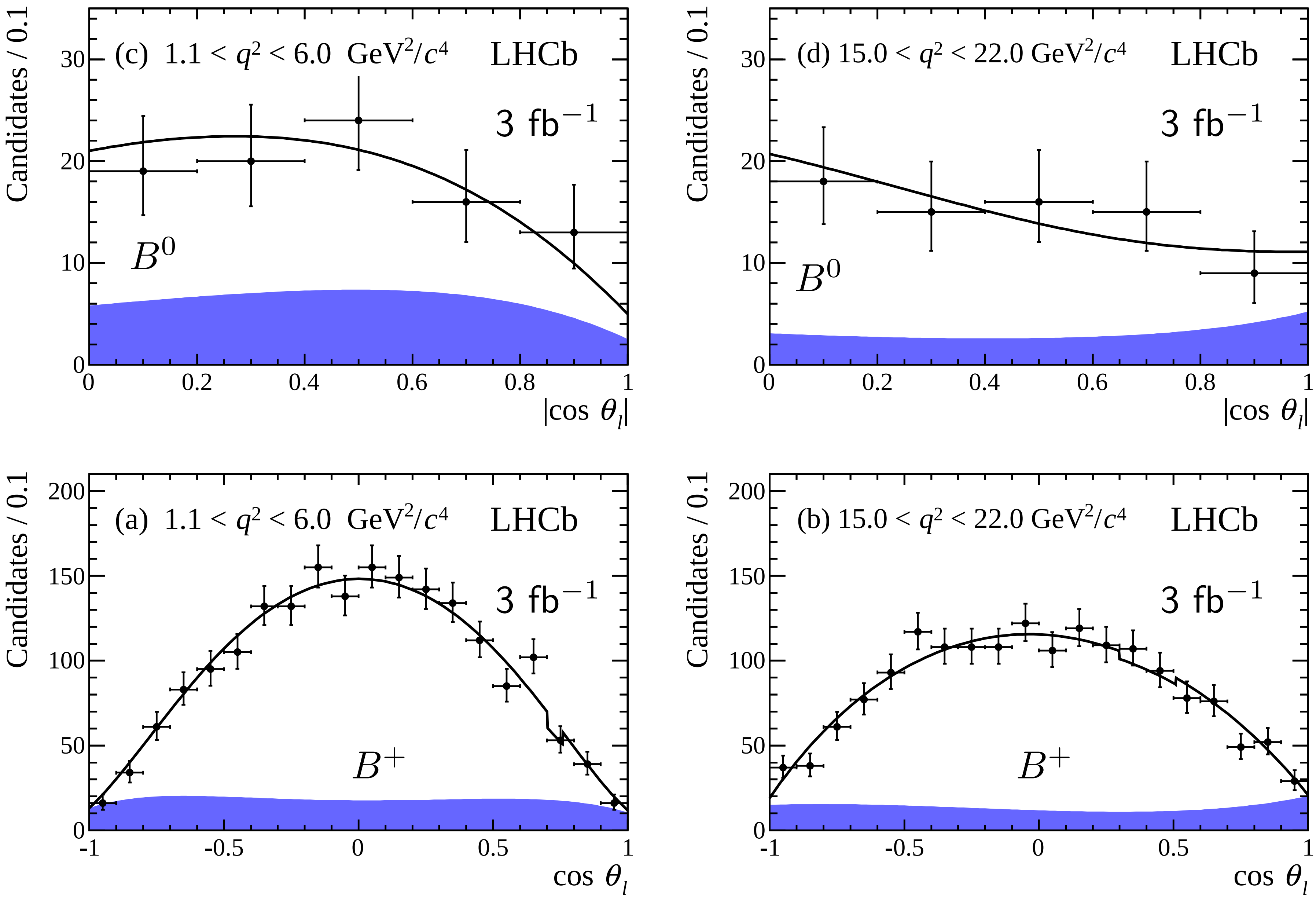

arXiv:1403.8045

$B^+ \to K^+\mu^+\mu^-$ results

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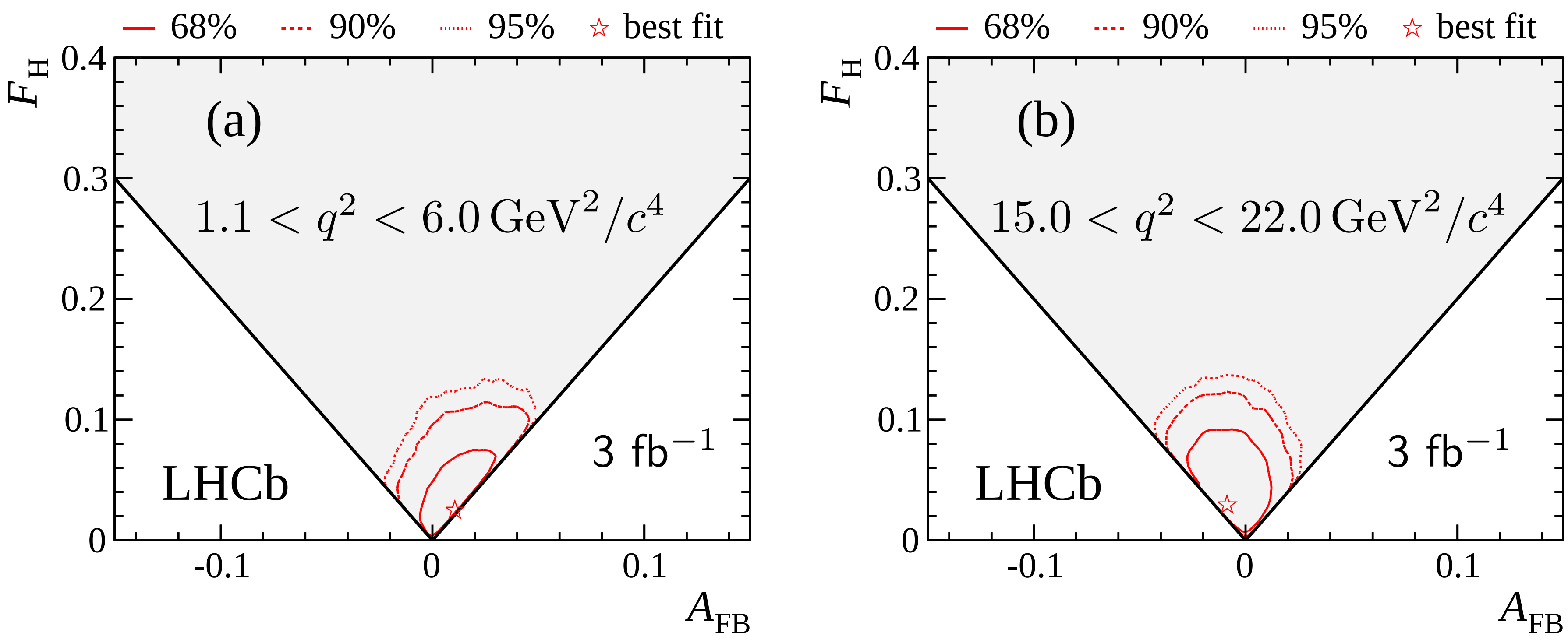


arXiv:1403.8045

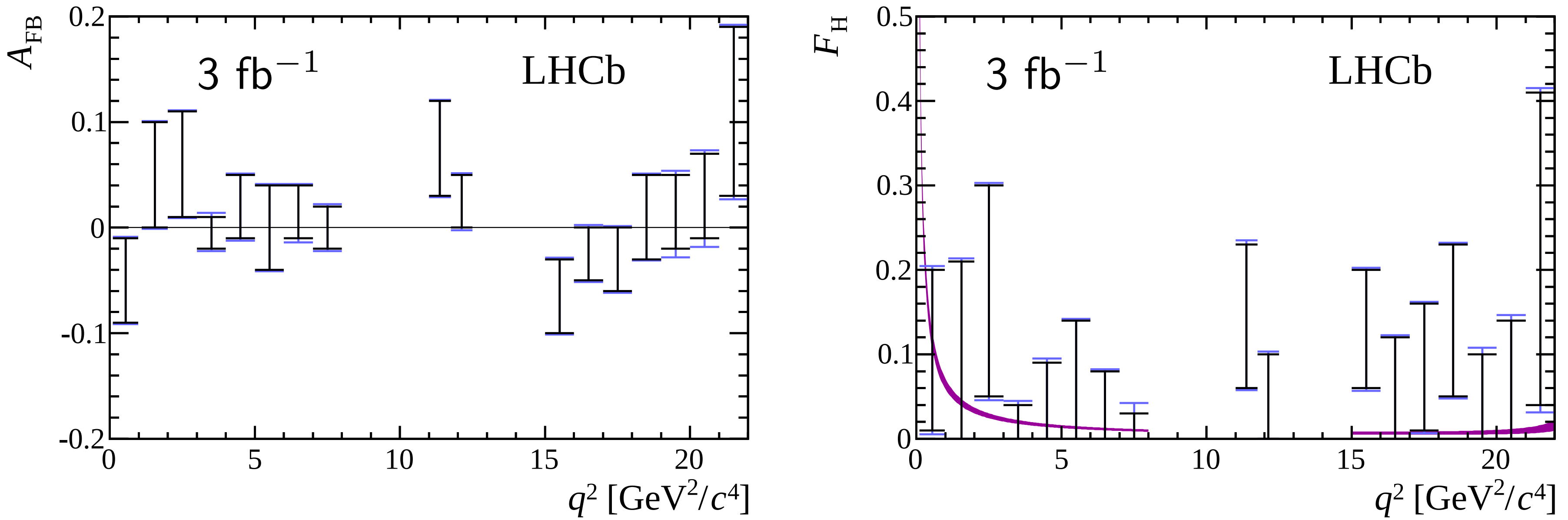
- Angular distribution for B^+

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_l} = \frac{3}{4}(1-F_H)(1-\cos^2\theta_l) + \frac{1}{2}F_H + A_{FB}\cos\theta_l$$

- Positive in boundaries $0 \leq F_H \leq 3$ and $|A_{FB}| \leq F_H/2$

$B^+ \to K^+\mu^+\mu^-$ results

- Expect $A_{FB} \approx 0$ in the SM, F_H close to zero as well
- Measurement dominated by statistical uncertainties
- Consistent with SM
- In 1D results, other parameter is treated as nuisance, but remember they are correlated



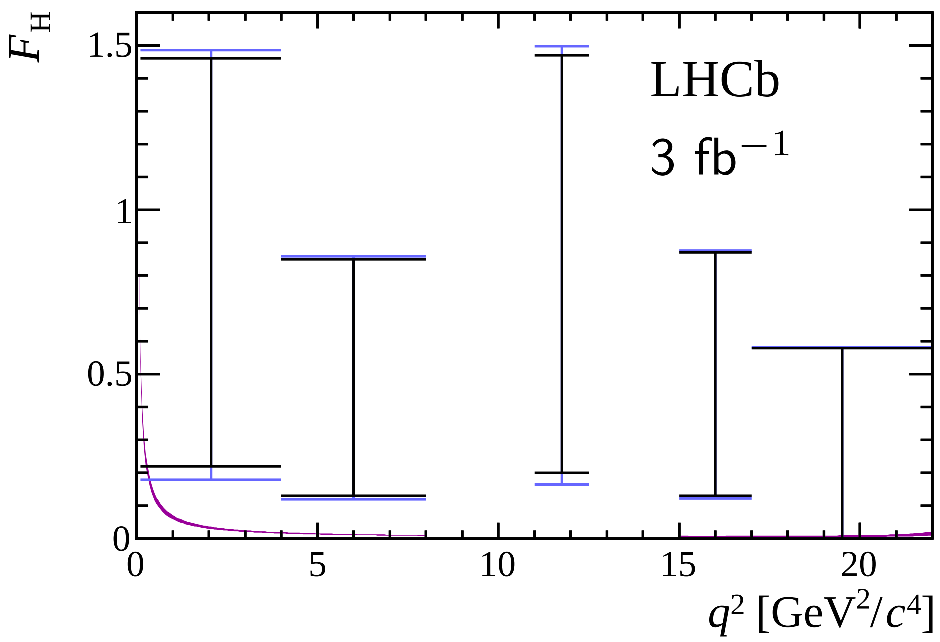
arXiv:1403.8045

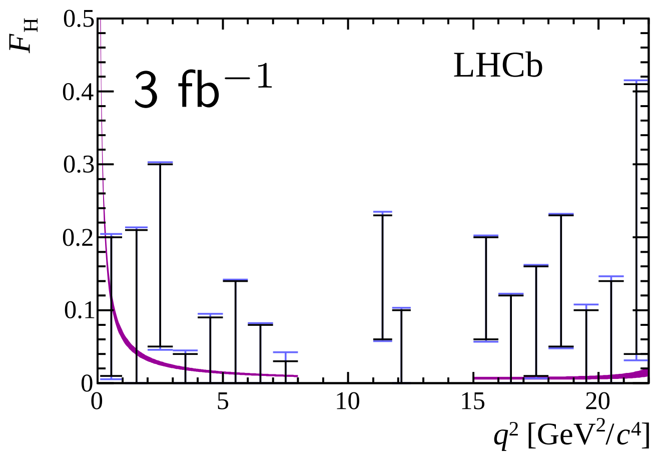
$B^0 \to K_S\mu^+\mu^-$ result

- Statistics for $B^0 \to K_S\mu^+\mu^-$ still low
- Within large uncertainties consistent with SM
- Also consistency between B^+ and B^0
- Both decays together put constraint on tensor amplitudes

$\rightarrow$ Rule out large cancellation between left- and right-handed couplings in $B_s \to \mu^+\mu^-$

arXiv:1403.8045





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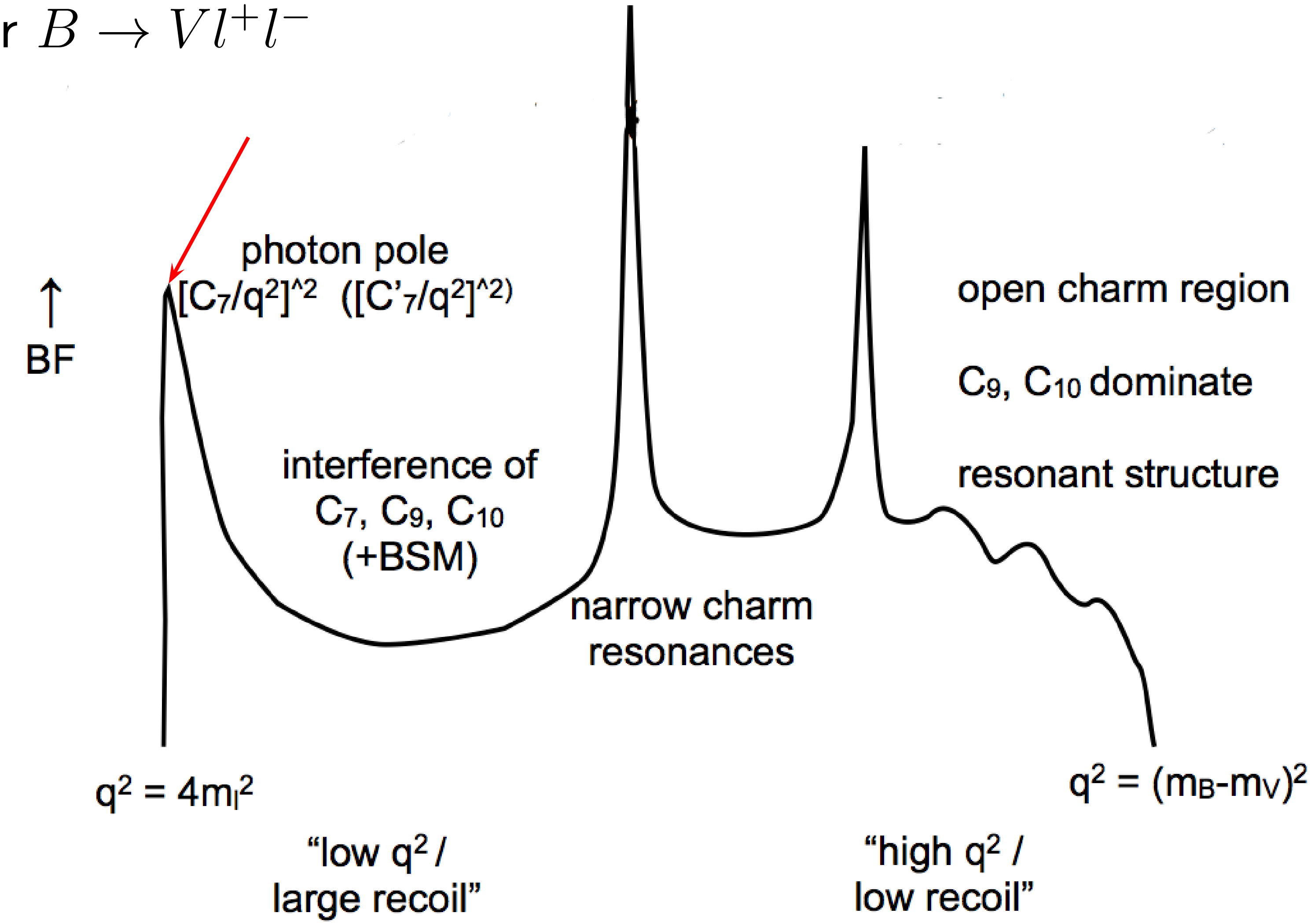

Different q^2 region sensitive to different contributions

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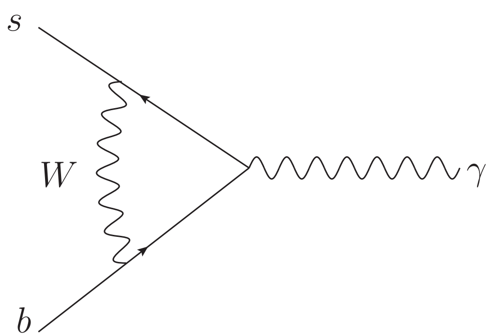
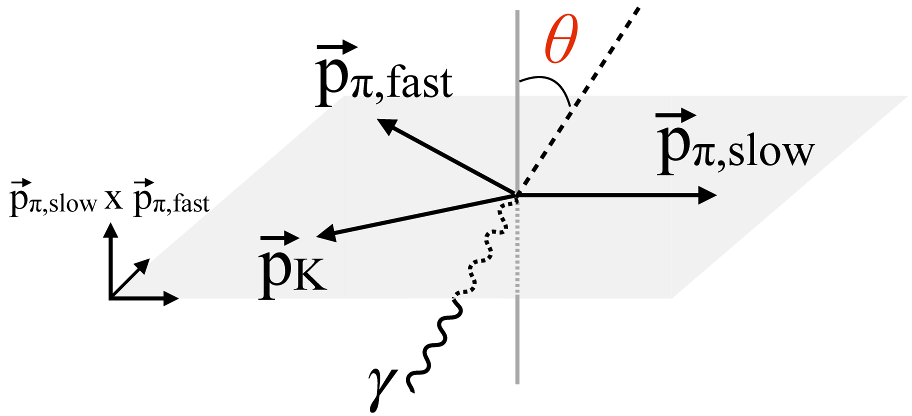
Photon polarization

- One way of accessing photon polarization is to look to $b \to s\gamma$ decays
- In the SM, decay proceeds through $b \to s$ penguin
- As $W^{\pm}$ couples only to left-handed fermions, dominantly we get left-handed photon
- Right-handed contribution proportional to m_s/m_b
- New physics does not necessarily have same restriction
- Experimentally study angular distribution in $B^+ \to K^+\pi^-\pi^+\gamma$

$$\sum_{i=0,2,4} a_i(s, s_{13}, s_{23}) \cos^i\theta + \lambda_\gamma \sum_{j=1,3} a_j(s, s_{13}, s_{23}) \cos^j\theta$$

- Measure up-down asymmetry A_{UD}, which is proportional to photon polarization λ_γ





Photon polarization

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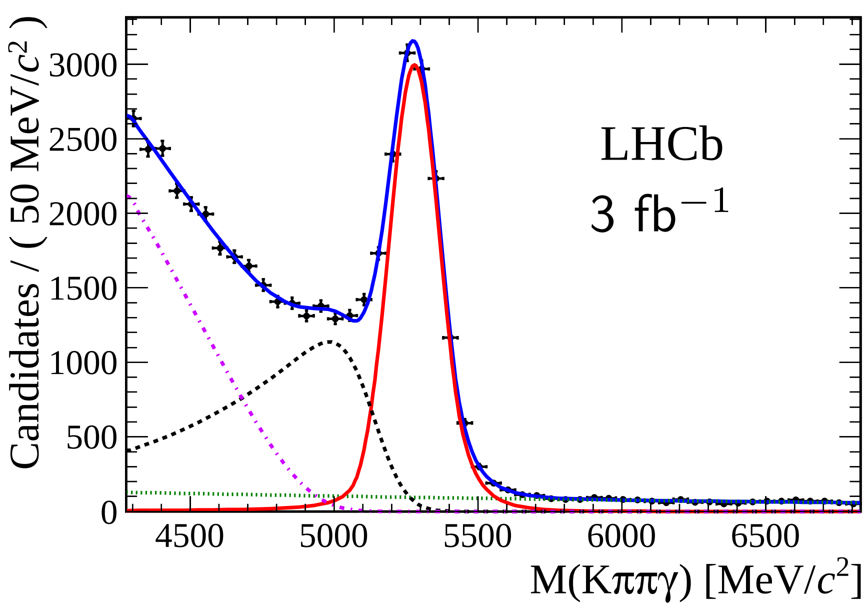
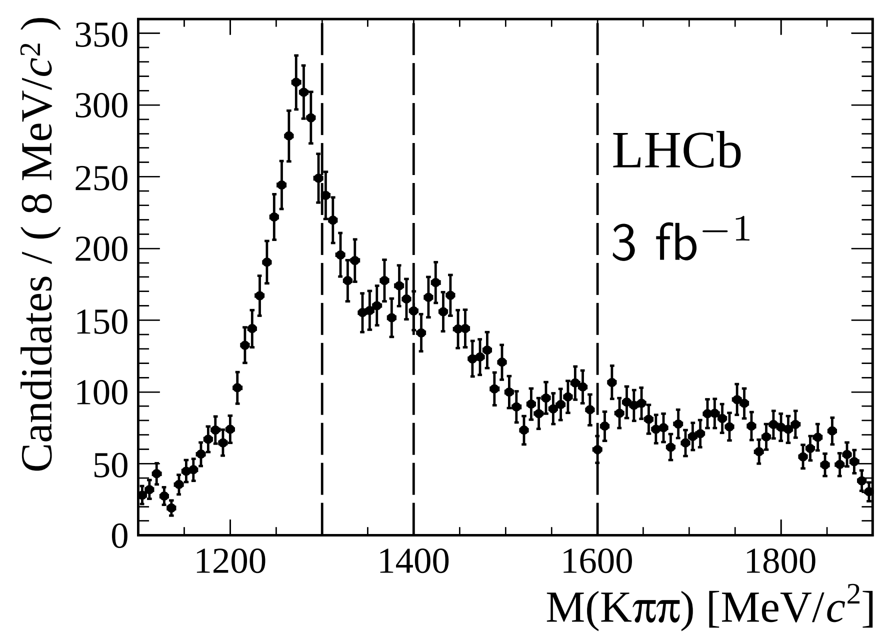
- Challenge from photon energy resolution
- Background from decays with missing π not as well separated
- About 14000 signal decays
- For photon polarization itself, non-zero A_{UD} implies non-zero polarization
- $K\pi\pi$ mass spectrum with lot of contributions $\Rightarrow$ conversion to photon polarization non-trivial





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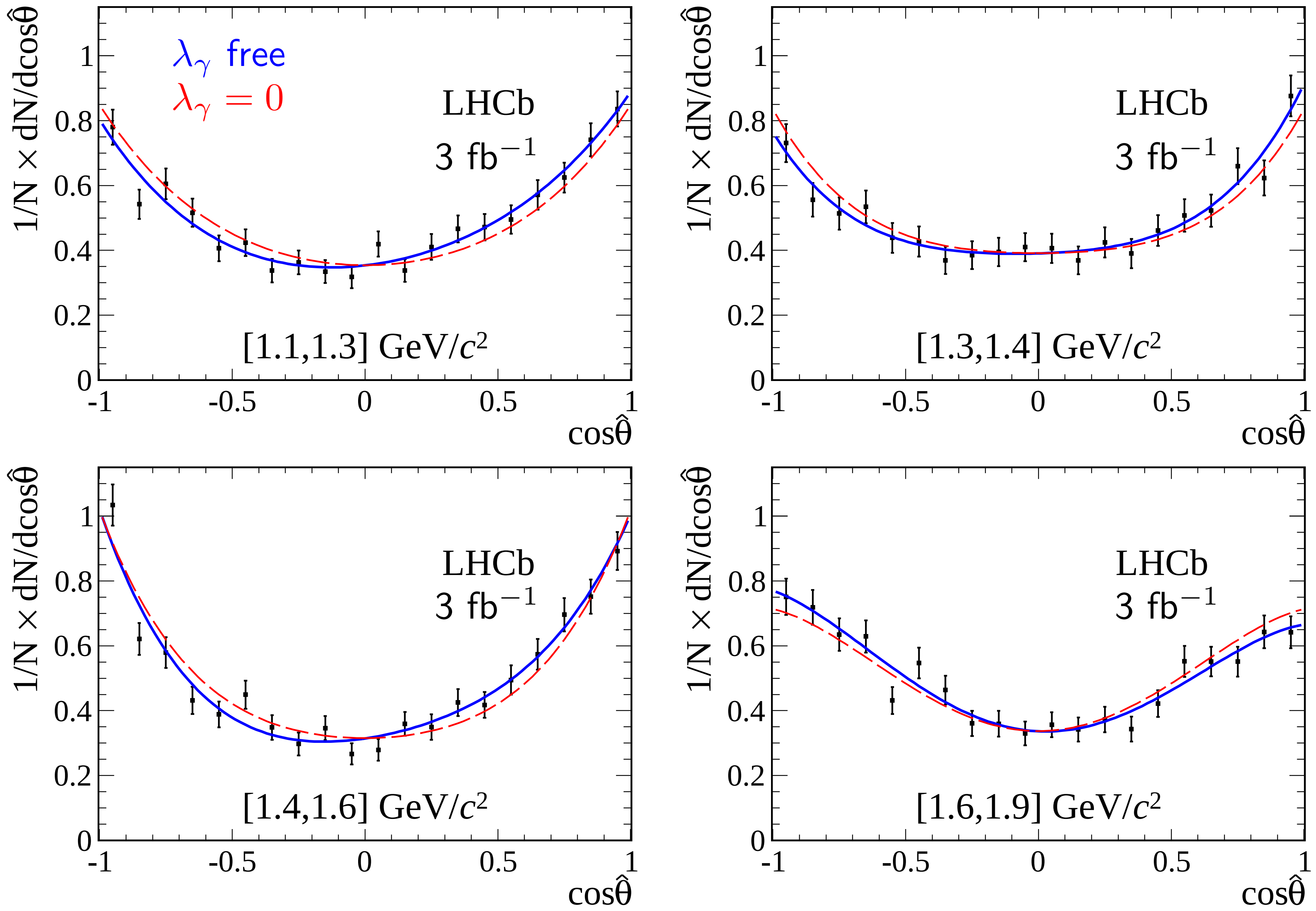
$B \to K\pi\pi\gamma$ angular dist



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Up-Down Asymmetry

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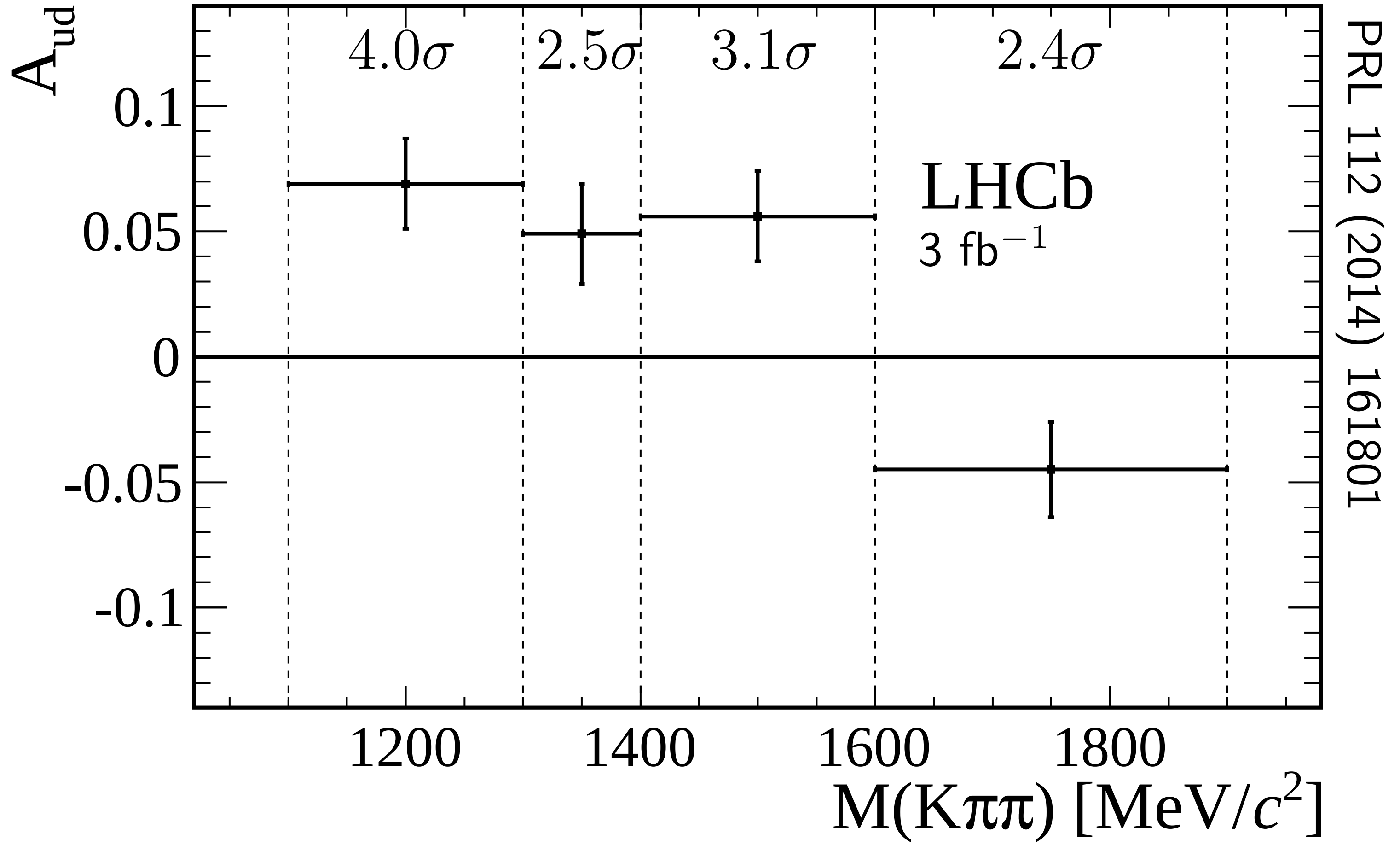

- Combined significance for non-zero photon polarization is 5.2σ
- Lot of work remains to understand hadronic system before extracting λ_γ

Conclusions

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- Rare $b \to s$ decays provide sensitive window to new physics
- Rich set of observables available
- Previous results with 1 fb^{-1} mostly compatible with SM
- We are on way of updating all measurements with 3 fb^{-1} of data
- Isospin asymmetry in $B \to K\mu^+\mu^-$ now better consistent with SM
- Differential branching fractions systematically $B \to K^{(*)}\mu^+\mu^-$ systematically bellow expectation
- First observation of photon polarization in $b \to s\gamma$
- Much more to come in near future

Backup

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LHCb detector

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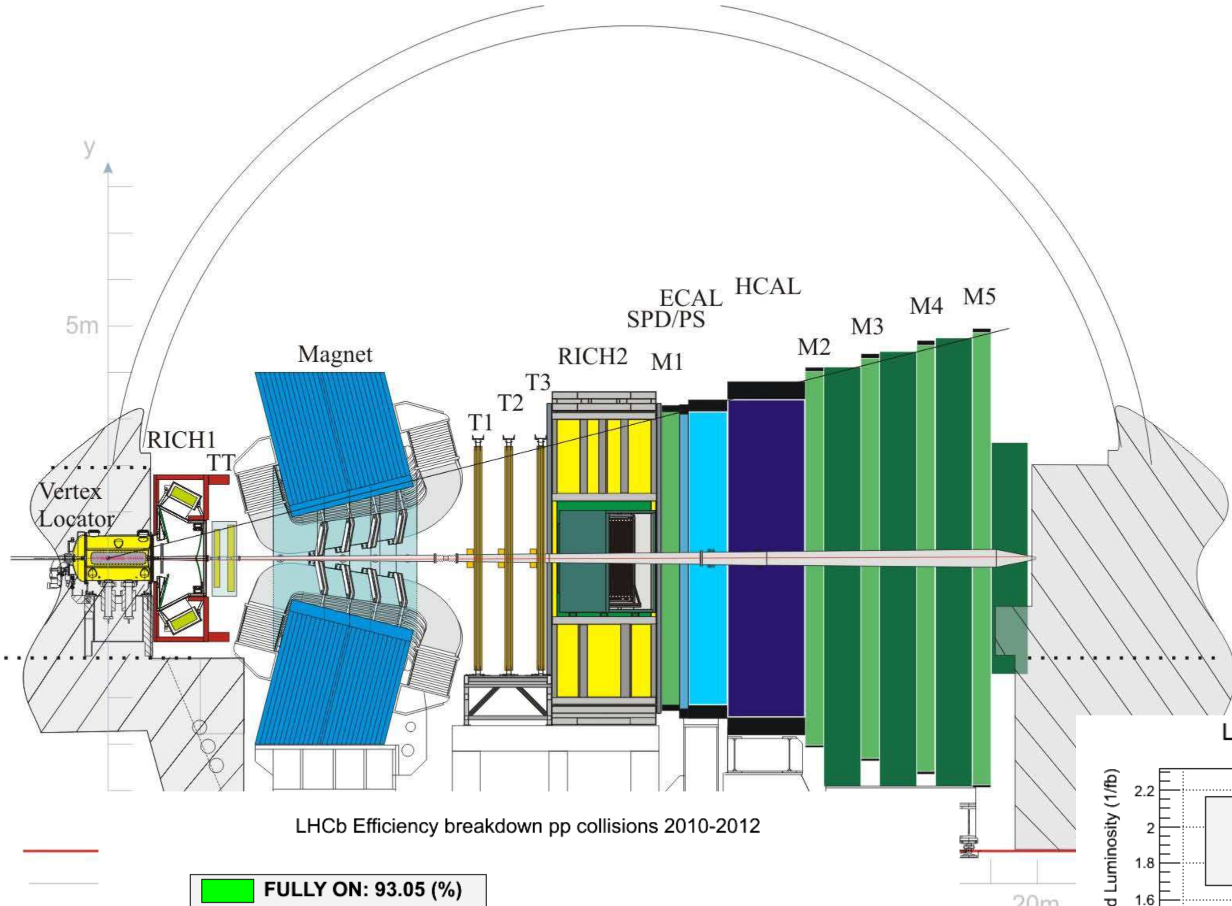
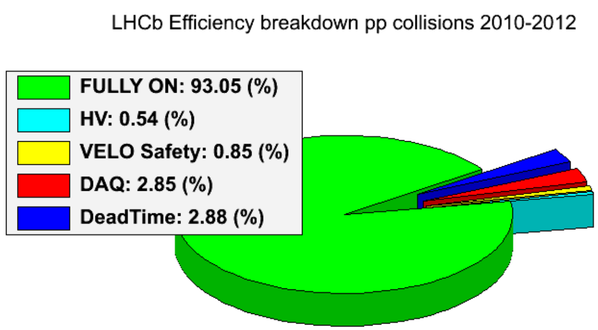
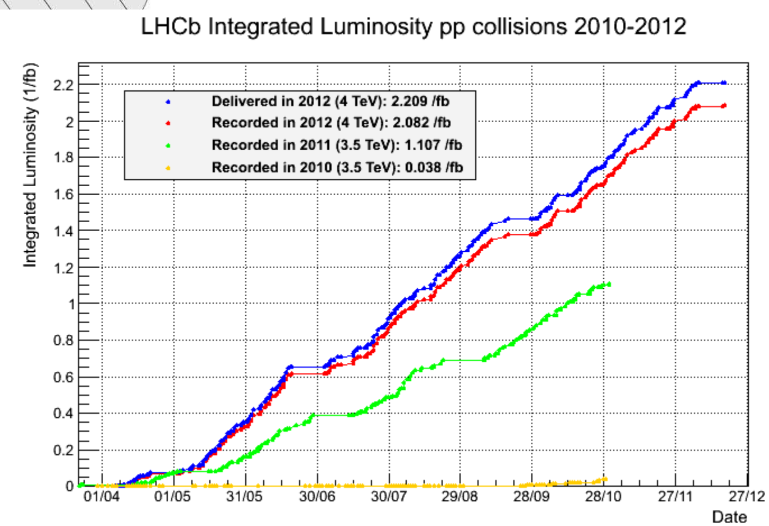
- Good mass resolution
- Good time resolution
- High trigger rate on c and b
- Uniform running conditions







$B^0 \to K^*\mu^+\mu^-$ ang. dist.

$$\frac{9}{32\pi}\Big[\frac{3}{4}(1-F_{\rm L})\sin^2\theta_K + F_{\rm L}\cos^2\theta_K + \frac{1}{4}(1-F_{\rm L})\sin^2\theta_K\cos 2\theta_\ell$$

$$- F_{\rm L}\cos^2\theta_K\cos 2\theta_\ell + S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi$$

$$+ S_4\sin 2\theta_K\sin 2\theta_\ell\cos\phi + S_5\sin 2\theta_K\sin\theta_\ell\cos\phi$$

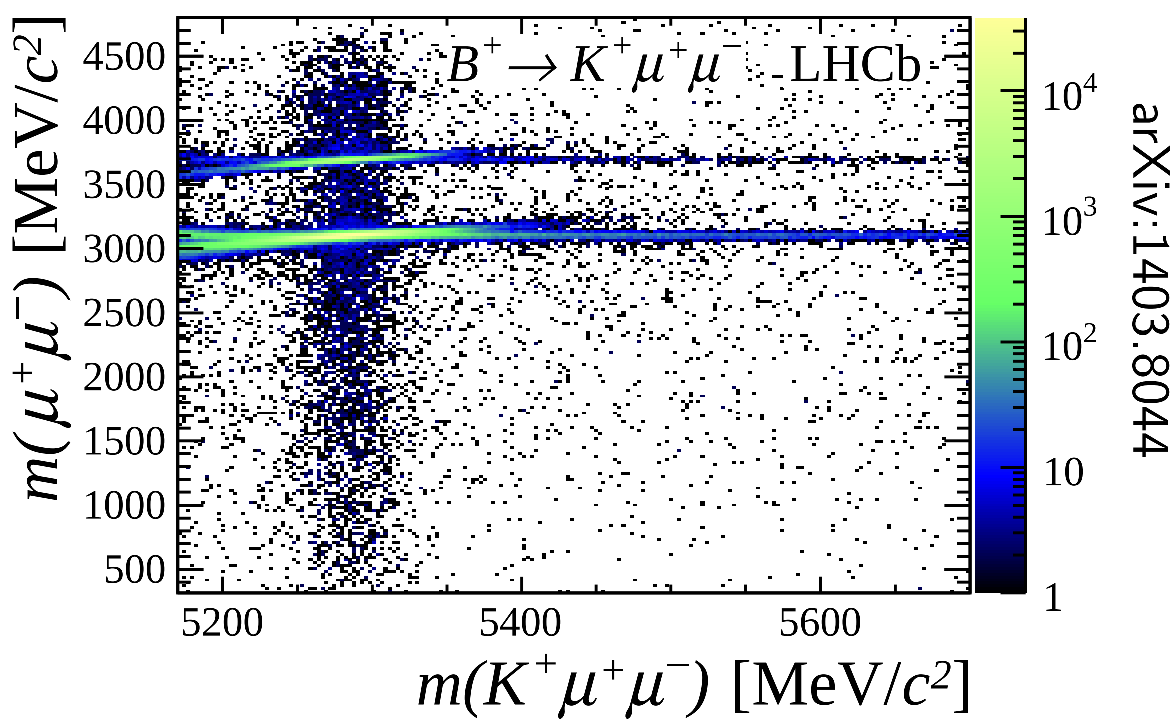
$$+ S_6\sin^2\theta_K\cos\theta_\ell + S_7\sin 2\theta_K\sin\theta_\ell\sin\phi$$

$$+ S_8\sin 2\theta_K\sin 2\theta_\ell\sin\phi + S_9\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi\Big]$$

$$P'_{i=4,5,6,8} = \frac{S_{j=4,5,7,8}}{\sqrt{F_{\rm L}(1-F_{\rm L})}}$$

Selection with dimuons

- Uses BDT to combine kinematic, topological and PID inputs
- Trained on resonant (J/ψ) signal in data/simulation
- Simplify $c\bar{c}$ resonances veto
- Decays via J/ψ used for normalization



Isospin asymmetry

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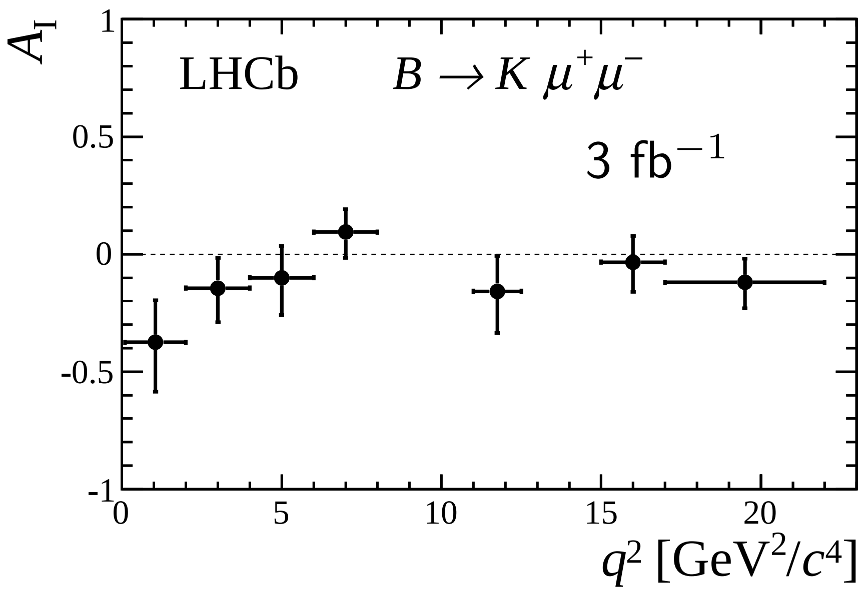
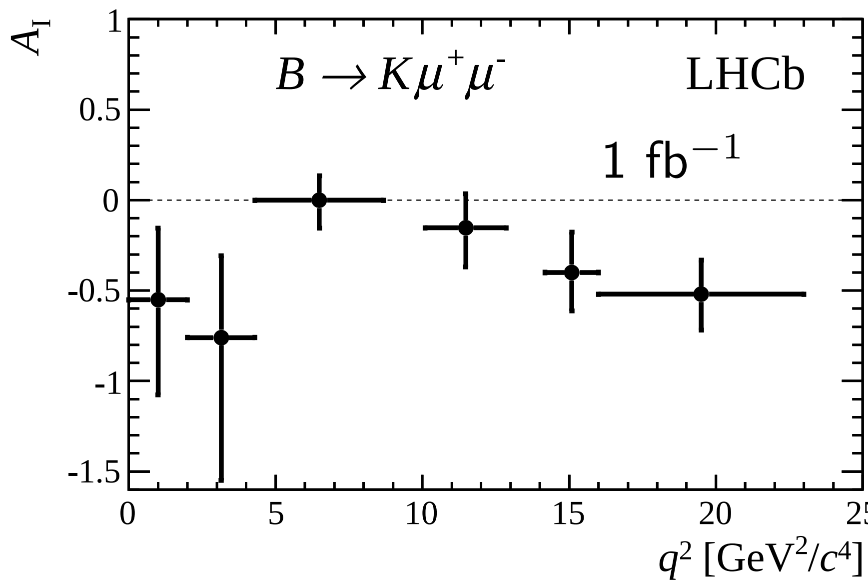
$$A_I = \frac{\Gamma(B^0 \to K^{(*)0}\mu\mu) - \Gamma(B^+ \to K^{(*)+}\mu\mu)}{\Gamma(B^0 \to K^{(*)0}\mu\mu) + \Gamma(B^+ \to K^{(*)+}\mu\mu)}$$

- In SM expect A_I close to zero
- Test simple hypothesis of uniform A_I
- $B \to K\mu\mu$ p-value of 11% (1.5σ)
- Compared to result in LHCb-PAPER-2012-011, more consistent with SM
- Change from different test, different normalization, reanalysis of 2011 data and difference between 2011 and 2012

arXiv:1403.8044





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Isospin asymmetry

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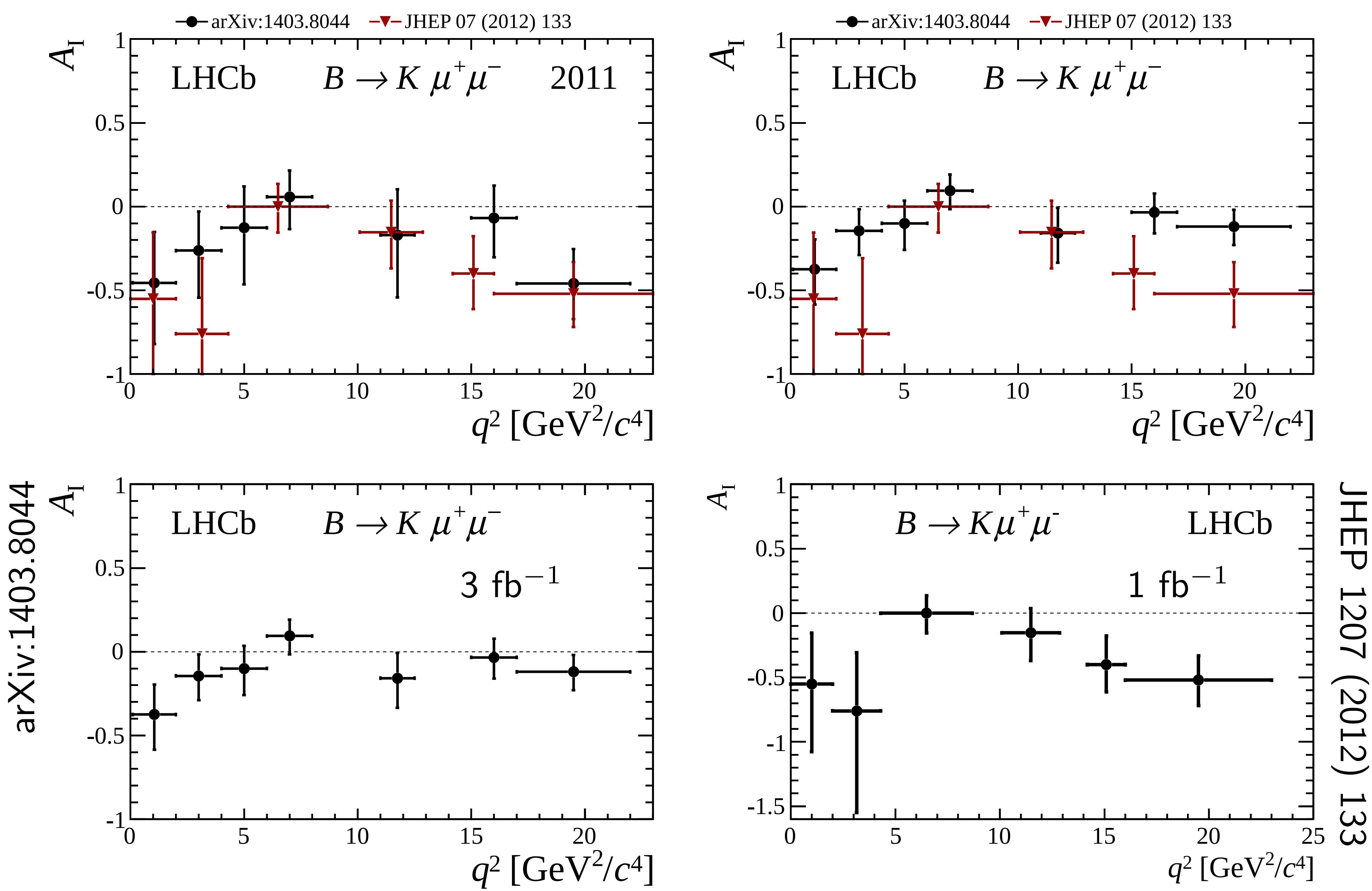

Angular efficiciency

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