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Baryons rare decays

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- Talk is only about Λ_b and Λ_c
- I'm experimentalist and while I touch theory, I'm not expert in it
- The aim is to stimulate discussion rather then giving you real overview

Motivation for baryons

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- Production rate of Λ_b is only about 25% of B^0 production rate
- Clearly just adding Λ_b for statistics increase is not very useful
- For real motivation we need access to something which we cannot access in B^0
- The added value comes from spin-$1/2$ initial state
  - More sensitivity to helicity structure of underlying theory
  - As far as I know there is not much of detailed discussion about it
  - Would be nice to have few specific examples where Λ_b decays allow to distinguish models when B^0 itself could not
- In following I concentrate on final states with muons, which are easier for hadron colliders
- Electrons certainly can be done, but probably not as first attempt
- Taus would be probably nice, but with number of neutrinos (2-4) and practically unknown Λ_b decays this is bit beyond chance right now

$\Lambda_b \to \Lambda\mu^+\mu^-$ - Experiment

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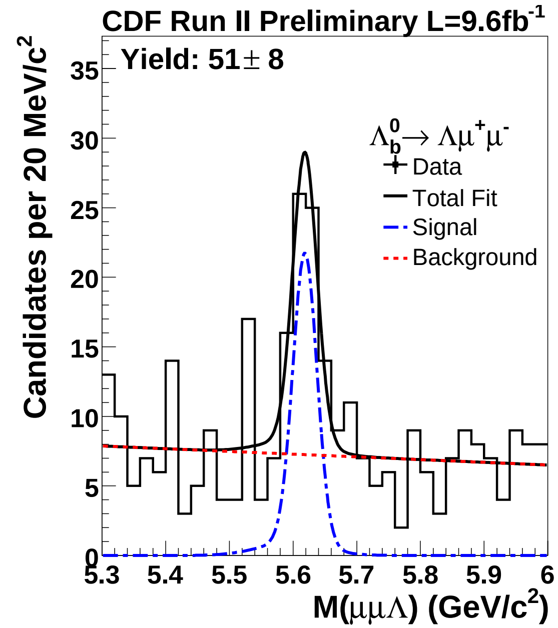
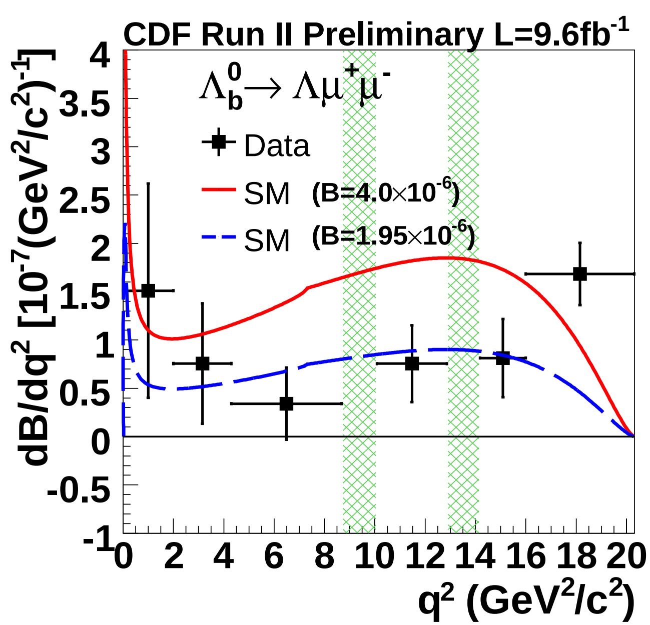
- Only measurement up to now done by CDF experiment
- Observe 51 ± 7 signal events
- Significance of the signal is 7.6σ
- Also measured differential branching fraction
- Do not see any real signal below $c\bar{c}$ resonances
- Most of the signal in highest q^2 bin
- For branching fraction, CDF extracts: $B(\Lambda_b^0 \to \Lambda\mu\mu)/B(\Lambda_b^0 \to J/\psi\Lambda) = [2.75 \pm 0.48(stat) \pm 0.27(syst)] \times 10^{-3}$ $B(\Lambda_b^0 \to \Lambda\mu\mu) = [1.95 \pm 0.34(stat) \pm 0.61(syst)] \times 10^{-6}$
- LHCb is working on measurement, expect result sometimes in winter (crude estimate about 90 events)





$\Lambda_b \to \Lambda\mu^+\mu^-$ - Exp. issues

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- Generally, difficulties at low q^2
  - Λ get large fraction of Λ_b momentum
  - With long lifetime, many Λs at low q^2 will decay after tracking detectors
- Λ_b has non-zero spin and in principle can be produced polarized
  - In fact for Λ, production polarization was observed
  - With polarized production, we need to take it into account for angular analysis
  - Even branching fraction could be affected by polarization
  - Up to now we have low statistics and are fine with crude uncertainties, but at some point we will have to get better in this
- For angular analysis and measurement of quantities like A_{FB} we cannot do real q^2 dependence as all signal seems to be at high q^2
- I think we will have to do angular analysis first in q^2 bins where we have signal and see what we can learn

Other rare Λ_b decays

- One of the experimental difficulty is long lifetime of Λ
- Could avoid it by looking to pK^- final state, which mostly comes through excited Λs
- For B^0 we have about 10 times more events in $K^{*0}\mu\mu$ than $K_S\mu\mu$
- Scaling expect $\Lambda_b \to \Lambda\mu\mu$ would give large signal
- Probably will be less efficient as p/K separation is not as good as π/K
- Issues expected:
  - Nobody ever looked even to decays to $J/\psi pK^-$, so we should not start right with rare decays
  - Λ^* states are not that far apart and their parameters are often not well measured
  - Might require full 4-body final state analysis to disentangle different Λ^* states
- At LHCb we are working on this, but will have some delay compared to $\Lambda_b \to \Lambda\mu\mu$

$\Lambda_b \to \Lambda\mu\mu$ theory

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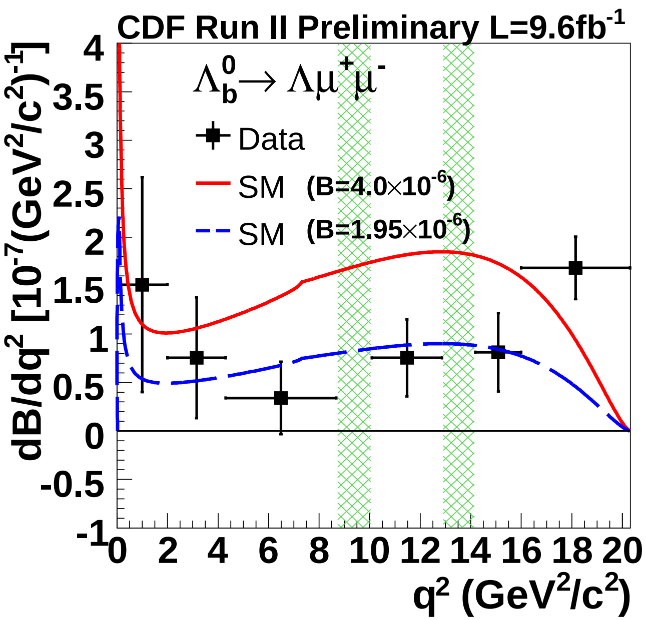
- Governed by $b \to s\mu\mu$ transition
- Theory starts from same quark level effective Hamiltonian as for B^0 decays
- Real difference is in form factors and perhaps to some extent Wilson coefficients
- My feeling is that form factors (hadronic part) for Λ_b baryons is much behind b-mesons
- Are there measurements on other Λ_b decays, which experimentalist can do in order to help theory to do calculations?
- In following I show few predictions, but certainly not exhaustive list
- What I'm showing is more as an example to bring up some points
- Unless we experimentally proof that Λ_b is produced unpolarized, it would be useful to keep production polarization in equations (reflects to angular distributions)

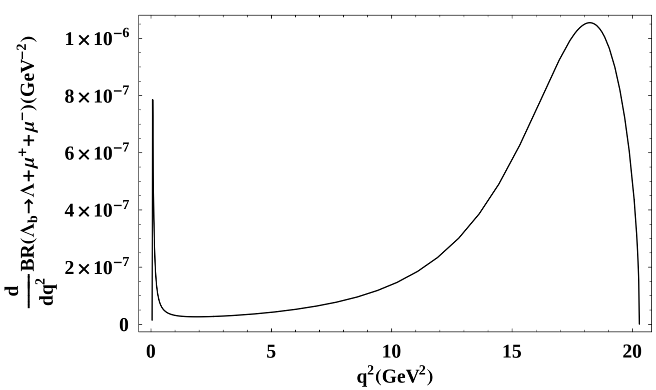
$\Lambda_b \to \Lambda\mu\mu$ $\mathbf{d}\mathcal{B}/\mathbf{d}q^2$

- As said, they start from same effective Hamiltonian, so can differ only in Wilson coefficients and form factors used
- One from JHEP 05 (2006) 001 is my own implementation of formulas from paper
- Real question, which one is best or whether their spread reflects our uncertainty
- There seems to be also difference at low q^2, also compared to B^0

PRD 81, 056006



EPJ C59, 861



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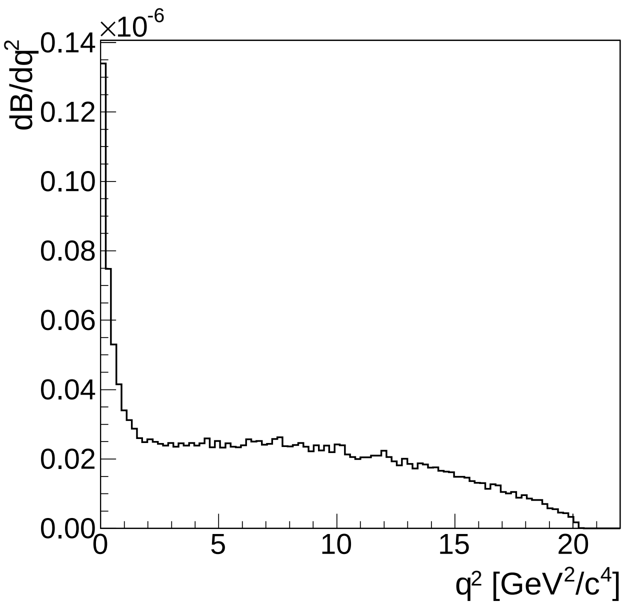

$\Lambda_b \to \Lambda\mu\mu\ A_{FB}$

- A_{FB} is another quantity usually predicted
- Even comparing two predictions which would give most of the rate at high q^2 gives inconsistent prediction of size of A_{FB}
- While there are few more things predicted, this is not done generally
- Rarely one could find full 5D expression (q^2 plus 4 angles) to evaluate other possible quantities
- Rarely production polarization taken into account

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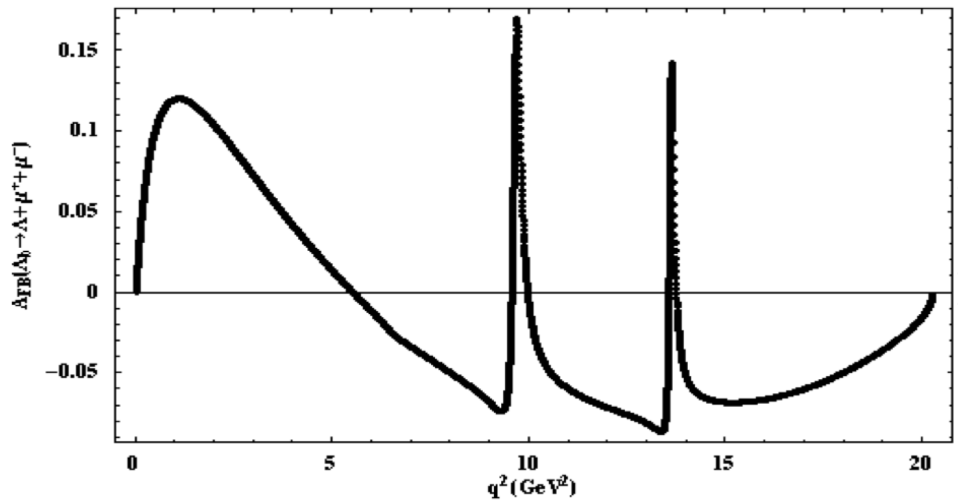
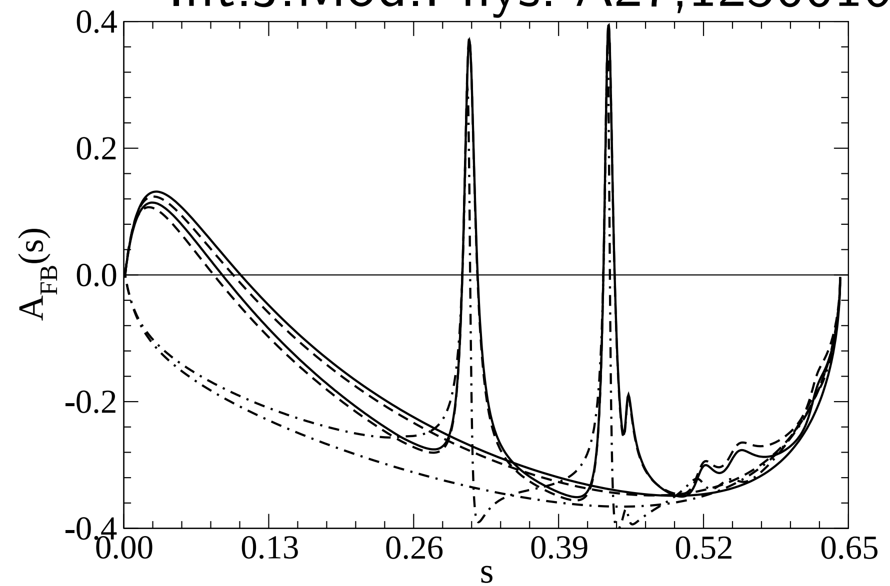
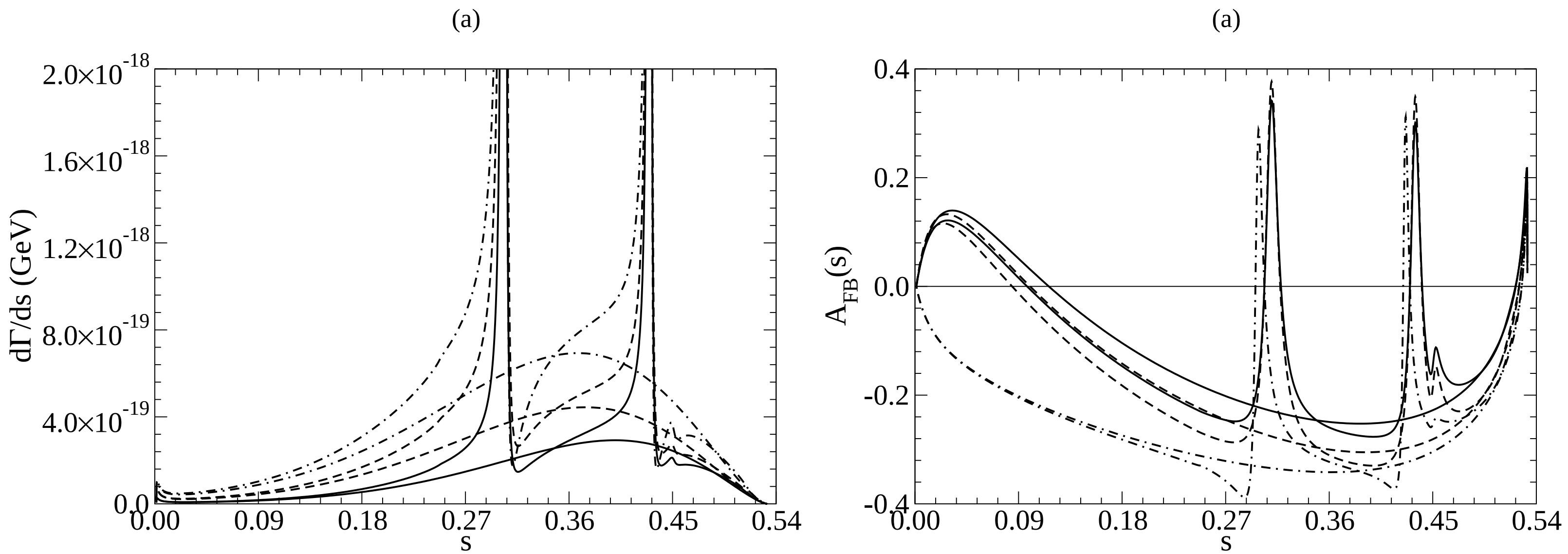


Int.J.Mod.Phys. A27,1250016



Decays to pK final states

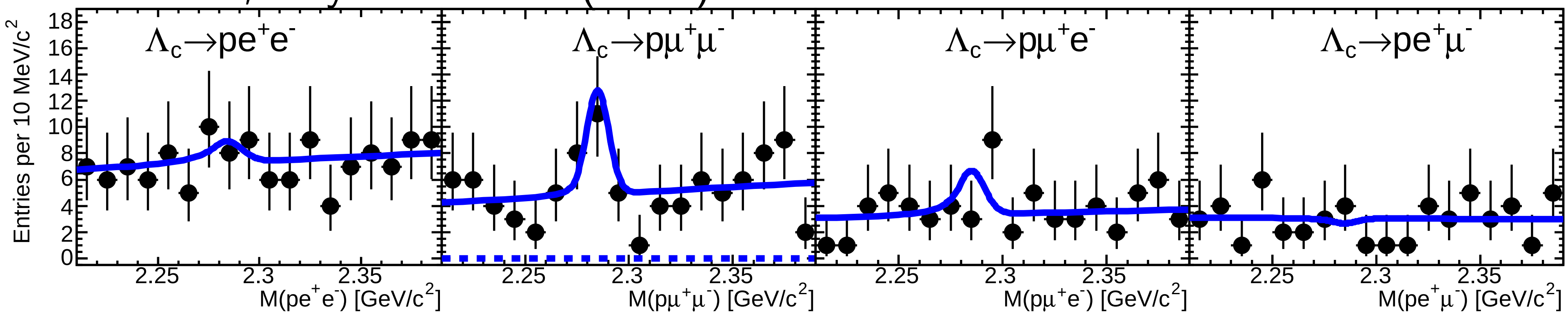
- I'm aware of only one prediction by Mott, Roberts in Int.J.Mod.Phys. A27, 1250016
- It provides prediction for rates, differential rates and A_{FB}
- Does not give full 5D distributions
  - In principle we can do measurement without it, it is possible to work out angular distributions and measure amplitudes
  - When doing measurement we might need to take interferences between different states into account



Λ_c^+ baryons

- In SM basically same diagrams as Λ_b, just swapping up type quarks for down type quarks
- Should be interesting, I guess also in connection to recent results in charm sector
- Rate of $\Lambda_c \to p\mu^+\mu^-$ is likely very small
- Best limit comes from Babar and is $< 4.4 \times 10^5$
- At LHCb we might be able to improve this (but I did not do any real calculation)
- Experimentally challenging because of Λ_c short lifetime

BABAR, Phys.Rev. D84 (2011) 072006



Questions and wishes

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- Example or two of how measurements on baryons provides more information than B^0
- Full 5D (q^2, 4 angles) distributions
  - In experiment we can live without it, but it would make our life easier
- What experiments should measure
  - Specially if we cannot do full angular analysis with existing statistics
- What about q^2 bins, at this point, experiments use same binning as for B mesons
- How well we know hadronic physics for baryons?
- Are there any measurements LHCb could do to help to constrain hadronic physics and improve prediction