How to transfer experimental results to theorists?

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Current Situation

How is data used right now? - New Physics searches

- Altmannshofer,Straub [1308.1501] and within
  - Experimental errors Gaussian, measurements of same quantities by different experiments averaged (weighted average of symmetrised errors).
  - Form factor correlations included
- Beaujean,Bobeth,van Dyk [1310.2478] and within
  - Experimental errors if symmetric treated as Gaussian, if $>$ few% asymmetry use LogGamma.
  - Correlation info for lattice FFs, but not for LCSRs FFs nor LHCb data...
- Descotes,Matias,Virto [1307.5683] and within
  - Experimental errors Gaussian.
  - For exclusive decays LHCb data only, no $\mathcal{B}$s
  - Correlation info for data from “toys”
- Horgan,Liu,Meinel,Wingate [1310.3887]
  - Experimental errors Gaussian, measurements of same quantities by different experiments averaged (weighted average of symmetrised errors).

Current Situation

How is data used right now? - Form factors

- Beaujean,Bobeth,van Dyk [1310.2478] and within
  - combination of $B \to K^* \gamma$, $B \to K^* \ell^+ \ell^-$ helpful to fix non-factorizable power corrections
  - constraints on FFs, power corrections
- Hambrock,Hiller,Schacht,Zwicky [1308.4379] and within
  - Fit FFs from large q^2 data only
  - Experimental errors Gaussian
  - Only ratios of $B \to K^*$ angular observables

Binning of Angular Observables

- fine bins as used for $B^+ \to K^+\mu^+\mu^-$ analysis appear OK
  - basically 1GeV^2 steps, with slight adjusments
  - ϕ cut out
  - J/ψ, $\psi(2S)$ cut out
  - some reservations about cutting out ϕ (Sebastian)

Table 2: Differential branching fraction results for $B^+ \to K^+\mu^+\mu^-$

	Differential branching fraction ($\times 10^{-9}$)		
q^2 range (GeV$^2/c^4$)	central value	stat error	syst error
$0.1 < q^2 < 0.98$	33.2	1.8	1.7
$1.1 < q^2 < 2.0$	23.3	1.5	1.2
$2.0 < q^2 < 3.0$	28.2	1.6	1.4
$3.0 < q^2 < 4.0$	25.4	1.5	1.3
$4.0 < q^2 < 5.0$	22.1	1.4	1.1
$5.0 < q^2 < 6.0$	23.1	1.4	1.2
$6.0 < q^2 < 7.0$	24.5	1.4	1.2
$7.0 < q^2 < 8.0$	23.1	1.4	1.2
$11.0 < q^2 < 11.8$	17.7	1.3	0.9
$11.8 < q^2 < 12.5$	19.3	1.2	1.0
$15.0 < q^2 < 16.0$	16.1	1.0	0.8
$16.0 < q^2 < 17.0$	16.4	1.0	0.8
$17.0 < q^2 < 18.0$	20.6	1.1	1.0
$18.0 < q^2 < 19.0$	13.7	1.0	0.7
$19.0 < q^2 < 20.0$	7.4	0.8	0.4
$20.0 < q^2 < 21.0$	5.9	0.7	0.3
$21.0 < q^2 < 22.0$	4.3	0.7	0.2
$1.1 < q^2 < 6.0$	24.2	0.7	1.2
$15.0 < q^2 < 22.0$	12.1	0.4	0.6

Charmonium

- so far, vetoe windows J/ψ and $\psi(2S)$
- for further studies, also give results *within* existing charmonium vetoes
  - angular observables J_n should be fine
  - use similar bin size as in rest of the phase space
  - experiment: J/ψ tail is problematic due to detector effects
  - expierment: $\psi(2S)$ seems fine
- do not remove broad resonances, see previous session

Correlation and Likelihood

- So far experimental results do not provide information on:
  - Correlations between observables and their uncertainties arising from experimental effects such as background or detector acceptance
  - Confidence level intervals beyond 1σ
- Particularly in light of recent results/deviations it is crucial to provide both
- How exactly? Case dependent?

Correlation and Likelihood

Take a typical tough case:

- Full angular fit of $B \to K^*$ involves large number of parameters
  - 8 to 24 per B flavour and q^2 region depending on parametrisation
- Cannot trivially sample the likelihood space
- Even if we could, likelihood parametrisation might not be ideal
  - e.g coefficients of amplitude ansatz
  - transforming likelihood to more user-friendly basis non-trivial
- Additionally fitting for J's or amplitudes results in non-Gaussian likelihood with level of non-Gaussian behaviour depending on fitting strategy
  - Cannot blindly provide error matrix of fit either
  - Devise methods to quantify/correct non-Gaussian behaviour

Correlation and Likelihood

Easy and user friendly solution:

- Provide stripped down LHCb dataset (background subtracted?)
  - e.g `ROOT` n-tuple with angles, q^2, B flavour, background fraction...
  - Provide continuous q^2 data for large and low recoil region(?)

- Helper classes that:
  - Build likelihood based on pdf with J's or amplitudes (or whatever else experimentalists use) with a full working example reproducing published result
  - Allows users to build their own likelihood with interfaces to `EOS`, `SuperIso`... (requires understanding of how data is used right now)
  - Provide tools that automatically add experimental nuisance parameters to a given likelihood

Fitting the $B \to K^*$ Amplitudes - How?

- fit transversity amplitudes instead of angular observables at $1\text{GeV}^2 \leq q^2 \leq 6\text{GeV}^2$
- parametrization: $\lambda = \perp, \|, 0$ transversity states, $\chi = L, R$ lepton chirality

$$A_\lambda^\chi = \frac{\alpha_\lambda^\chi}{q^2} + \beta_\lambda^\chi + \gamma_\lambda^\chi q^2$$

- amplitudes are complex $\Rightarrow$ parameters $\alpha, \beta, \gamma \in \mathbb{C}$
- 4 symmetry relations between amplitudes Matias,Mescia,Ramon,Virto [1202.4266]
- number of real-valued fit parameters N

$$N = (3 \times 2 \times 2 - 4) \times 3 = 24$$

- only usable with full correlation information

Fitting the $B \to K^*$ Amplitudes - Why?

- contains more information on q^2 dependence than large bins
- other reasons?

Fitting the $B \to K^*$ Amplitudes - Why Not?

- model bias, disregards A_S, A_t, tensor amplitudes
  - not yet excluded (scalars: Hurth,Mahmoudi [1312.5267], tensors: Bobeth,Hiller,van Dyk [1212.2312])
  - 2014 LHCb measurement of $B \to K\mu^+\mu^-$ might exclude scalars and tensors
- transversity basis is only one basis of amplitudes
  - some groups prefer helicity basis: Jäger,Camalich [1212.2263]
- correlation information needed: 24×24 *no S-wave contributions*
  - observables: 18×18 per bin, with S wave
  - virtually no inter-q^2-bin correlation
  - small bins provide also shape information

Fitting the $B \to K^*$ Amplitudes - ToDo

- is parametrization sufficient? back of an envelope!

$$A(q^2) = N(q^2) \times \left(C_9 \pm C_{10} + \frac{\mathcal{T}(q^2)}{\xi(q^2)} \right) \xi(q^2)$$

- norm N (modulo prefactors)

$$N(q^2) \sim \frac{\sqrt{q^2 \lambda(M_B^2, M_K^2, q^2)}}{M_B^3} = N_0 \sqrt{q^2} + N_1 \sqrt{q^2}^3 + N_2 \sqrt{q^2}^5 + \dots$$

- form factor ξ (asymptotically)

$$\xi(q^2) = \frac{1}{q^2 - M_B^2} = \xi_0 + \xi_1 q^2 + \xi_2 q^4 + \dots$$

- correlator $\mathcal{T}$ (C_7 only)

$$\frac{\mathcal{T}(q^2)}{\xi(q^2)} = \frac{M_B^2}{q^2} C_7 + \dots$$

- so shouldn't amplitudes be parametrized as

$$A(q^2) \simeq \sqrt{q^2} \left(\frac{\alpha}{q^2} + \beta + \gamma q^2 \right) \qquad ?$$