Questions and answers - James Libby Lecture

The following questions were submitted through Google Form. Some / all may have been answered in the Q&A session already. Nevertheless, we request our lecturers to provide written answers here for the benefit of those who could not attend that session. Thank you!

Page 17(?) What would be the advantages, if any, of employing beam polarization at Belle II?

A it would expand the programme to allow EW measurements of A_{LR}, which is sensitive to sin2θ_{eff} at the mass of the Y(4S), Such a measurement allows the running to be seen as shown in the figure below. The predicted precision is shown in the table.

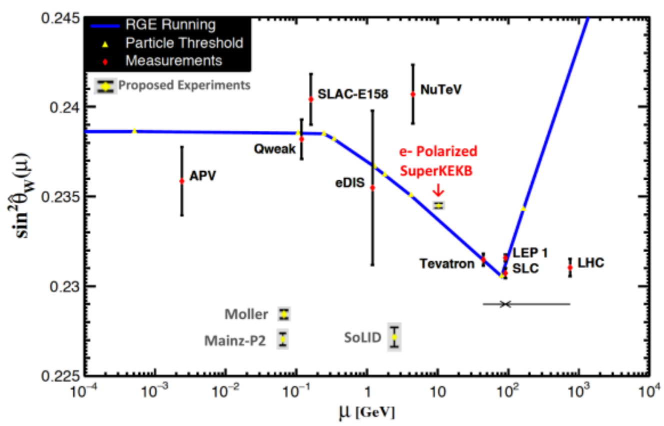

Figure 1: Determination of $\sin^2\theta_W$ at present and future experimental facilities as a function of energy scale, adapted from [3–5].

Final State Fermion	A_{LR}^{SM}	Relative A_{LR} Error (%)	g_V^f W.A.[1]	$\sigma(g_V^f)$ (20 ab^{-1})	$\sigma(g_V^f)$ (40 ab^{-1})	$\sigma(s^2\theta_W)$ (40 ab^{-1})
b-quark (eff.=0.3)	-0.020	0.4	-0.3220 $\pm$0.0077	0.002 improves x4	0.002	0.003
c-quark (eff.=0.15)	-0.005	0.5	+0.1873 $\pm$0.0070	0.001 improves x7	0.001	0.0008
tau (eff.=0.25)	-0.0006	2.4	-0.0366 $\pm$0.0010	0.001	0.0008	0.0004
muon (eff.=0.5)	-0.0006	1.5	-0.03667 $\pm$0.0023	0.0007 improves x3	0.0005	0.0003
electron (17nb acceptance, eff=.36)	+0.00015	2.0	-0.3816 $\pm$0.00047	0.0009	0.0006	0.0003

Table 1: For each fermion pair cleanly identifiable in Belle II for the given efficiency in column 1: column 2 gives the SM value of A_{LR}; column 3, the expected relative error on A_{LR} based on based on 40 ab^{-1} and a beam polarization at Belle II of 0.700 ± 0.003 with an error of ± 0.003; column 4, the current world average value of its neutral current vector coupling; column 5, the projected error on g_V^f with 20 ab^{-1} of data; column 6, the projected error on g_V^f with 40 ab^{-1} of data; and column 7, the projected SuperKEKB/Belle II error on $\sin^2\theta_W^{eff}$ with 40 ab^{-1} of polarized e^- beam data.

There is also potential to limit g-2 of the tau to 10^{-5} level, which is more precise than what is possible ultraperipheral heavy ion collisions at the LHC, but not at the level of expected enhancements if there is new physics in the muon g-2.

More details about the proposed polarization programme can be found in https://arxiv.org/abs/2205.12847

Page 21. I would naively think that the yellow band to intersect where green and blue bands intersect, and the slope represents the correlation between green and blue. Why is it not true? And what is the major reason for the correlation?

A These are the average of measurements from LHCb of V_{ub}/V_{cb} that use ratios of $\Lambda_b \to p l \nu$ and $\Lambda_b \to \Lambda l \nu$, as well as $B_s \to K l \nu$ and $B_s \to D_s l \nu$ It is hard to measure absolute rates at LHCb so it is use to normalize to another channel. So this band corresponds to the HFLAV average of $|V_{ub}/V_{cb}|=0.0838\pm0.0046$. More details available at https://hflav-eos.web.cern.ch/hflav-eos/semi/spring21/html/ExclusiveVub/exclVubVcb.html

As these are independent measurements there is no reason for them to overlap with the exclusive determinations of $|V_{cb}|$ and $|V_{ub}|$ directly. Further the $\Delta\chi^2$ on the bands is only one, so it is all compatible within 1.5 standard deviations.

Page 23. What measurements are used in fits to give form factor?

So from the paper https://arxiv.org/pdf/2310.20286 the external measured branching fraction, angular 8 of the 12 angular coefficients (the other four are expected to be zero in the SM, which is compatible with the measurements). In addition, the lattice predictions for the form factors are also included in the fit, as well as the total rate. Form factor parameters and V_{cb} are determined simultaneously.

The full differential distribution is below

$$\frac{\mathrm{d}\Gamma(\bar{B}\to D^*\ell\bar{\nu}_\ell)}{\mathrm{d}w\,\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_\mathrm{V}\,\mathrm{d}\chi} = \frac{2G_\mathrm{F}^2\eta_\mathrm{EW}^2|V_\mathrm{cb}|^2 m_B^4 m_{\mathrm{D}^*}}{2\pi^4}\times\Big(J_{1s}\sin^2\theta_\mathrm{V}+J_{1c}\cos^2\theta_\mathrm{V}$$
$$+(J_{2s}\sin^2\theta_\mathrm{V}+J_{2c}\cos^2\theta_\mathrm{V})\cos 2\theta_\ell + J_3\sin^2\theta_\mathrm{V}\sin^2\theta_\ell\cos 2\chi$$
$$+J_4\sin 2\theta_\mathrm{V}\sin 2\theta_\ell\cos\chi + J_5\sin 2\theta_\mathrm{V}\sin\theta_\ell\cos\chi + (J_{6s}\sin^2\theta_\mathrm{V}+J_{6c}\cos^2\theta_\mathrm{V})\cos\theta_\ell$$
$$+J_7\sin 2\theta_\mathrm{V}\sin\theta_\ell\sin\chi + J_8\sin 2\theta_\mathrm{V}\sin 2\theta_\ell\sin\chi + J_9\sin^2\theta_\mathrm{V}\sin^2\theta_\ell\sin 2\chi\Big).$$

And the fits are shown here

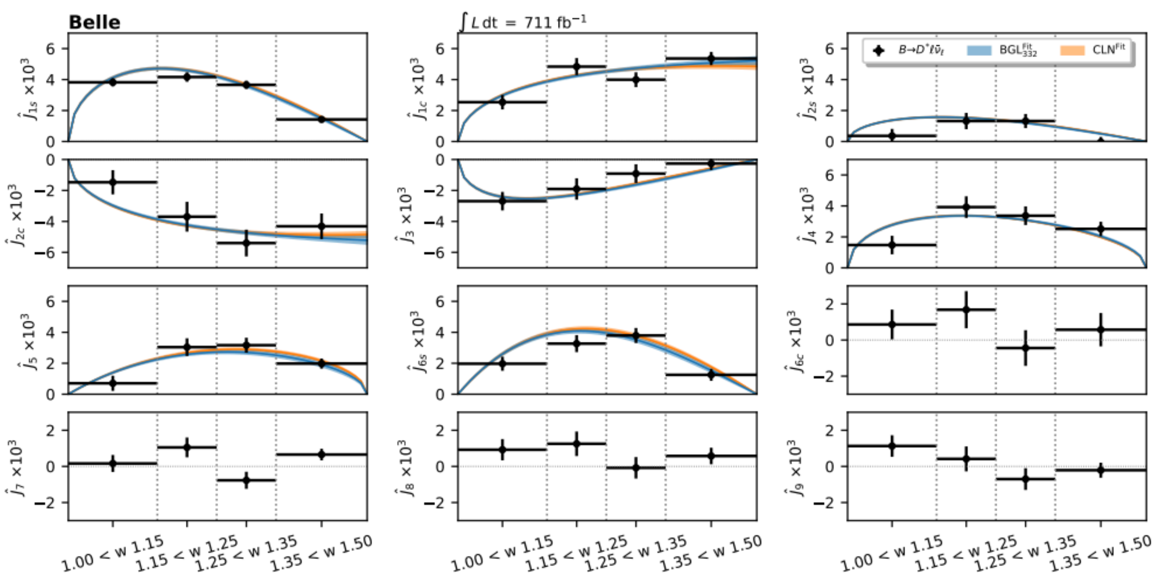

FIG. 1. The data points correspond to the averaged central values of the four measured normalized angular coefficients described in the text, with the uncertainties including statistical and systematic uncertainties. The vertical dotted lines indicate the binning in w. The blue (orange) curves correspond to the BGL_{332} (CLN) fit described in the text, with the 1σ uncertainty band. The angular coefficients J_{6c}, J_7, J_8, J_9 are not fitted, and expected to be zero in the SM.