$\Lambda_b ightarrow \Lambda(1520) \mu^+ \mu^-$ angular analysis

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Rare decays show deviations from the SM predictions



Differential branching ratios and angular observables



Only few measurements with *b*-baryon decays

Our favorite *b*-baryon decay : $\Lambda_b \rightarrow \Lambda(1520)\mu^+\mu^-$



Strong decay of $\Lambda^* \to pK^-$

		Overall	Status as seen in —			
Particle	J^P	status	$N\overline{K}$	$\Sigma \pi$	Other channels	
$\Lambda(1116)$	$1/2^{+}$	****			$N\pi$ (weak decay)	
$\Lambda(1380)$	$1/2^{-}$	**	**	**		
$\Lambda(1405)$	$1/2^{-}$	****	****	****		
$\Lambda(1520)$	$3/2^{-}$	****	****	****	$\Lambda\pi\pi,\Lambda\gamma$	
$\Lambda(1600)$	$1/2^{+}$	****	***	****	$\Lambda \pi \pi, \Sigma(1385)\pi$	
$\Lambda(1670)$	$1/2^{-}$	****	****	****	$\Lambda \eta$	
$\Lambda(1690)$	$3/2^{-}$	****	****	***	$\Lambda\pi\pi, \Sigma(1385)\pi$	
$\Lambda(1710)$	$1/2^{+}$	*	*	*		
$\Lambda(1800)$	$1/2^{-}$	***	***	**	$\Lambda \pi \pi, \Sigma(1385)\pi, N\overline{K}^*$	
$\Lambda(1810)$	$1/2^{+}$	***	**	**	$N\overline{K}_2^*$	
$\Lambda(1820)$	$5/2^{+}$	****	****	****	$\Sigma(1385)\pi$	
$\Lambda(1830)$	$5/2^{-}$	****	****	****	$\Sigma(1385)\pi$	
A(1890)	$3/2^{+}$	****	****	**	$\Sigma(1385)\pi, N\overline{K}^*$	
$\Lambda(2000)$	$1/2^{-}$	*	*	*		
$\Lambda(2050)$	$3/2^{-}$	*	*	*		
$\Lambda(2070)$	$3/2^{+}$	*	*	*		
$\Lambda(2080)$	$5/2^{-}$	*	*	*		
$\Lambda(2085)$	$7/2^{+}$	**	**	*		
A(2100)	$7/2^{-}$	****	****	**	$N\overline{K}^*$	
$\Lambda(2110)$	$5/2^{+}$	***	**	**	$N\overline{K}^*$	
$\Lambda(2325)$	$3/2^{-}$	*	*			
$\Lambda(2350)$	$9/2^{+}$	***	***	*		
A(2585)		*	*			

Rich Λ^* spectrum

Our favorite decay

Why do we focus on the $\Lambda(1520)$ resonance ?



arXiv:1912.08139v2 (top), arXiv:1507.03414 (bottom)

- Rare mode is statistically limited → full amplitude analysis not possible
- Λ(1520) resonance is dominating
- Standard Model prediction of angular distribution



Knowledge from tree-level decay $\Lambda_b \rightarrow pK^-J/\psi$: $\Lambda(1405)$ and $\Lambda(1600)$ under $\Lambda(1520)$ peak ! Our favorite decay

Selection of the $\Lambda_b \rightarrow \Lambda(1520)\mu^+\mu^-$ decay

Distinguish rare mode from $c\bar{c}$ resonances via $q^2 = (2m_\ell)^2$:



Decay topology :



Detached Λ_b decay vertex, where all the traces come from.

 $\begin{array}{c} q^2[{\rm GeV}/c^2] \in \\ \{[0.1,3],[3,6],[6,8],[1.1,6],[11,12.5],[15,16.8]\}\end{array}$

The rare mode is sensitive to New Physics !

Angular observables



 $(\theta_\ell, \theta_\rho, \phi)$ in helicity basis

$$\begin{split} d\vec{\Omega} &= d\cos\theta_{\ell}d\cos\theta_{p}d\phi\\ \frac{d^{4}\Gamma}{dq^{2}d\vec{\Omega}} &= \sum_{i}\text{physics}_{i}\times\text{kinematics}_{i}\\ &= \frac{9\pi}{32}\sum_{i}L_{i}(q^{2},\mathcal{C},ff)\times f_{i}(\vec{\Omega}) \end{split}$$

 $\begin{aligned} \mathcal{C} &= \text{Wilson Coefficients} \rightarrow \text{short distance} \\ \text{part} \rightarrow \text{sensitive to NP} \\ ff &= \text{form factors} \rightarrow \text{long distance part} \end{aligned}$

Observables :

$$S_i = rac{L_i + ar{L}_i}{d(\Gamma + ar{\Gamma})/dq^2}, A_i = rac{L_i - ar{L}_i}{d(\Gamma + ar{\Gamma})/dq^2},
onumber \ A_{FB}^\ell = rac{3(L_{1c} + 2L_{2c})}{2(L_{1cc} + 2(L_{1ss} + L_{2cc} + 2L_{2ss} + L_{3ss}))}$$

Angular observables sensitive to New Physics (NP)

Observable predictions through flavio

• based on $\Lambda_b \rightarrow \Lambda(1520)\ell^+\ell^-$ phenomenology with lattice QCD or QM form-factors [arXiv:1903.00448, arXiv.1108.6129, arXiv:2009.09313]



Separation between Standard Model (SM) and New Physics model $C_9^{NP} = -1.11$. LHCb could start to be sensitive to NP with full Run1+2 data.

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Fit model

Angular PDF of $\Lambda_{3/2}$ (i.e. $\Lambda(1520)$) in HQlimit

Simplifications :

• Heavy quark limit $(m_b \to \infty)$

2 Normalization
$$(\frac{d\Gamma}{dq^2} = 1)$$
:
 $\frac{1}{2}L_{1cc} + L_{1ss} = 1$
 $A_{FB,3/2}^{\ell} = \frac{3}{4}L_{1c}$

③ CP-average $(L_i \rightarrow S_i)$

$$\begin{aligned} &\frac{8\pi}{3} \frac{d^4\Gamma}{dq^2d\cos\theta_\ell d\cos\theta_{\Lambda^*} d\phi} \\ &= \cos^2\theta_{\Lambda^*} \left(L_{1c}\cos\theta_\ell + L_{1cc}\cos^2\theta_\ell + L_{1ss}\sin^2\theta_\ell \right) \\ &+ \sin^2\theta_{\Lambda^*} \left(L_{2c}\cos\theta_\ell + L_{2cc}\cos^2\theta_\ell + L_{2ss}\sin^2\theta_\ell \right) \\ &+ \sin^2\theta_{\Lambda^*} \left(L_{3ss}\sin^2\theta_\ell\cos^2\phi + L_{4ss}\sin^2\theta_\ell\sin\phi\cos\phi \right) \\ &+ \sin\theta_{\Lambda^*}\cos\theta_{\Lambda^*}\cos\phi(L_{5s}\sin\theta_\ell + L_{5sc}\sin\theta_\ell\cos\theta_\ell) \\ &+ \sin\theta_{\Lambda^*}\cos\theta_{\Lambda^*}\sin\phi(L_{6s}\sin\theta_\ell + L_{6sc}\sin\theta_\ell\cos\theta_\ell), \end{aligned}$$

arXiv:1903.00448, arXiv:2005.09602

$$\begin{aligned} \frac{8\pi}{3} \frac{\mathrm{d}^{4}\Gamma}{\mathrm{d}q^{2}\mathrm{d}\cos\theta_{\ell}\mathrm{d}\cos\theta_{\rho}\mathrm{d}\phi} &\simeq \frac{1}{4}\left(1+3\cos^{2}\theta_{\rho}\right)\left(\left(1-\frac{1}{2}\boldsymbol{S}_{1cc}\right)\left(1-\cos^{2}\theta_{\ell}\right)\right.\\ &+ \left.\boldsymbol{S}_{1cc}\cos^{2}\theta_{\ell} + \frac{4}{3}\boldsymbol{A}_{FB,3/2}^{\ell}\cos\theta_{\ell}\right)\end{aligned}$$

Angular PDF is only dependent on $\cos \theta_{\ell}$ and $\cos \theta_{p}$. ϕ integration, instead of using the HQlimit, is under investigation.

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 $\Lambda_b \rightarrow \Lambda(1520)\mu^+\mu^-$

Angular PDF of $\Lambda_{1/2}$ (i.e. $\Lambda(1405)$, $\Lambda(1600)$)

Simplifications :

- Strong decay : $\alpha = 0$
- Over the set of the s

OP-average

 $K(q^2,\cos\theta_\ell,\cos\theta_\Lambda,\phi) \equiv \frac{8\pi}{3} \frac{\mathrm{d}^4\Gamma}{\mathrm{d}q^2\,\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_\Lambda\,\mathrm{d}\phi}\,,$

which can be decomposed in terms of a set of trigonometric functions,

$$\begin{split} K(q^2,\cos\theta_\ell,\cos\theta_\Lambda,\phi) &= \left(K_{1ss}\sin^2\theta_\ell + K_{1cc}\cos^2\theta_\ell + K_{1c}\cos\theta_\ell\right) \\ &+ \left(K_{2ss}\sin^2\theta_\ell + K_{2cc}\cos^2\theta_\ell + K_{2c}\cos\theta_\ell\right)\cos\theta_\Lambda \\ &+ \left(K_{3sc}\sin\theta_\ell\cos\theta_\ell + K_{3s}\sin\theta_\ell\right)\sin\theta_\Lambda\sin\phi \\ &+ \left(K_{4sc}\sin\theta_\ell\cos\theta_\ell + K_{4s}\sin\theta_\ell\right)\sin\theta_\Lambda\cos\phi \,. \end{split}$$

arXiv:1410.2115

$$\begin{split} \frac{8\pi}{3} \frac{\mathsf{d}^4 \Gamma}{\mathsf{d} q^2 \mathsf{d} \cos \theta_\ell \mathsf{d} \cos \theta_\rho \mathsf{d} \phi} &\simeq \frac{1}{2} \left(1 - \mathcal{K}_{1cc} \right) \left(1 - \cos^2 \theta_\ell \right) + \mathcal{K}_{1cc} \cos^2 \theta_\ell \\ &+ \frac{2}{3} \mathcal{A}_{FB,1/2}^\ell \cos \theta_\ell \end{split}$$

Angular PDF is only dependent on $\cos \theta_{\ell}$. K parameter encode information about $\Lambda_{1/2}$ resonances in m_{pK} window.

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 $\Lambda_b \rightarrow \Lambda(1520)\mu^+\mu^-$

Fit strategy / physics PDF

Fit pK⁻ mass spectrum with

 $\mathsf{PDF}_{\mathsf{mass}} = f_{3/2} |\mathsf{BW}_{\mathsf{rel}}(M_{\rho K}, \frac{M_{\Lambda(1520)}}{M_{\Lambda(1520)}}, \Gamma_{\Lambda(1520)})|^2 + (1 - f_{3/2})\mathsf{Polynomial}_{o3}(M_{\rho K}, a_1, a_2, a_3)$

by fixing $M_{\Lambda(1520)}$ and $\Gamma_{\Lambda(1520)}$ to their PDG value, $L_{\Lambda_b \to \Lambda^* \mu \mu} = 1$, $L_{\Lambda^* \to pK} = 2$, $r_{\Lambda_b} = 5 \text{ GeV}^{-1}$, $r_{\Lambda^*} = 3 \text{ GeV}^{-1}$

- Extract f_{3/2}
- Solution Fit angles $(\cos \theta_{\ell}, \cos \theta_{p})$ with

 $\mathsf{PDF}_{ang} = f_{3/2}\mathsf{PDF}_{ang,3/2}(A^{\ell}_{FB,3/2}, S_{1cc}) + (1 - f_{3/2})\mathsf{PDF}_{angular,1/2}(A^{\ell}_{FB,1/2}, K_{1cc})$

Fit studies

Realistic samples

- Monte-Carlo generator developed by A.Beck, T.Blake and M.Kreps
- Full angular distribution of Λ* mass spectrum
- Resonances might have global complex phases between them
- Only phase differences are important
- Generate random phase combinations for phase differences $\Delta \psi_{1405/1600}$:

phase combination	$\Delta\psi_{ m 1405}$	$\Delta\psi_{1600}$
0	0.00 π	0.00 π
1	1.38π	1.93π
2	1.10π	1.61π
3	0.43π	0.62 π
4	0.06π	1.38π
5	1.41π	0.70π

Fit realistic samples

- Fit mixture of three individual resonances, namely the Λ(1405), Λ(1520) and Λ(1600)
 - No interference
 - \checkmark Validation of fit model without interferences
- It samples with random phase combinations
 - $\checkmark\,$ Interferences of $\Lambda(1405),\,\Lambda(1520)$ and $\Lambda(1600)$ are included
 - ✓ Adapt fit model

<u>Color code</u> : distribution of the $\Lambda(1520)$, $\Lambda(1405) + \Lambda(1600)$, total PDF

Fit mixture of three resonances without interference

Exemplary for one of the q^2 bins, but similar for the others :



Fits converge nicely and the projections look reasonable

Shape of realistic samples with interference



No impact of interferences on $m(pK^-)$ and $\cos \theta_{\ell}$, but changes shape of $\cos \theta_p$ even with few $\Lambda_{1/2}$ events !

Update angular fit model

Adding interference terms proportional to $\cos \theta_p$ and $\cos^2 \theta_p$ to the angular PDF of the $\Lambda_{1/2}$ resonances.

$$\begin{aligned} \mathsf{PDF}_{\mathsf{ang}} &= f_{3/2} \left(\left(1 - \frac{1}{2} \mathbf{S}_{1cc} \right) \left(1 - \cos^2 \theta_\ell \right) + \mathbf{S}_{1cc} \cos^2 \theta_\ell + \frac{4}{3} \mathbf{A}_{FB,3/2}^\ell \cos \theta_\ell \right) \\ & \times \left(\frac{1}{4} + \frac{3}{4} \cos^2 \theta_\rho \right) \\ & + (1 - f_{3/2}) \left(\frac{1}{2} \left(1 - K_{1cc} \right) \left(1 - \cos^2 \theta_\ell \right) + K_{1cc} \cos^2 \theta_\ell + \frac{2}{3} \mathbf{A}_{FB,1/2}^\ell \cos \theta_\ell \right) \\ & \times \left(\frac{3 - i_2}{3} + i_1 \cos \theta_\rho + i_2 \cos^2 \theta_\rho \right) \end{aligned}$$

<u>Color code</u> : distribution of the $\Lambda(1520)$, $\Lambda(1405) + \Lambda(1600)$, $\Lambda(1405) + \Lambda(1600) +$ interferences of 3 resonances, total PDF

Fit realistic samples with updated angular fit model

Phase combination 0:



New interference term can catch the asymmetric shape.

Fit realistic samples

Phase combination 1, 2, 3, 4 and 5:



Fraction of $\Lambda(1520)$ events $f_{3/2}$

<u>Aim:</u> Verification if the generated values are found by the fit unless the interferences



Uncertainties are linked to sample size \rightarrow not scaled Deviation of $f_{3/2}$ found in high q^2 bins

 $\Lambda_b \rightarrow \Lambda(1520)\mu^+\mu^-$

Angular observables



Fit values of angular observables are close to generated ones

Conclusion and outlook

- ✓ Validation of physics PDF without interference terms
- ✓ Include interference terms in the physics PDF
- $\checkmark\,$ Fit values of the angular observables find generated values
- □ Solve issue with fraction of $\Lambda(1520)$ events $f_{3/2}$ from $m(pK^-)$ fit
- □ Scaling the samples to Run 1+2 yields and redo the fit
- □ Add detector effects on the angular distribution (= angular acceptance)



Thank you for your attention !

Modeling the $\Lambda(1520)$ mass peak

Difficulty to estimate fraction of $\Lambda(1520)$ events $f_{3/2}$ from an angular fit only \rightarrow get $f_{3/2}$ by fitting the $m(pK^-)$ mass spectrum

 $\Lambda_b \rightarrow \Lambda(1520) \mu^+ \mu^-$ MC underlines need of relativistic Breit-Wigner :

$$|\mathsf{BW}_{\mathsf{rel}}(M_{\rho\mathsf{K}}, M_{\Lambda^*}, \Gamma_{\Lambda^*})|^2 = \left[\left(\frac{q(M_{\rho\mathsf{K}})}{q(M_{\Lambda^*})} \right)^{L_{\Lambda_b \to \Lambda^* \mu\mu}} \left(\frac{p(M_{\rho\mathsf{K}})}{p(M_{\Lambda^*})} \right)^{L_{\Lambda^* \to \rho\mathsf{K}}} \times F_{\Lambda_b \to \Lambda^* \mu\mu}(q(M_{\rho\mathsf{K}}), q(M_{\Lambda^*}, r_{\Lambda_b})) \frac{F_{\Lambda^* \to \rho\mathsf{K}}(p(M_{\rho\mathsf{K}}), p(M_{\Lambda^*}), r_{\Lambda^*})}{M_{\Lambda^*}^{2} - M_{\rho\mathsf{K}}^2 - iM_{\Lambda^*}\Gamma(M_{\rho\mathsf{K}}, M_{\Lambda^*})} \right]^2 \\ \Gamma(M_{\rho\mathsf{K}}, M_{\Lambda^*}) = \Gamma_{\Lambda}^* \left(\frac{p(M_{\rho\mathsf{K}})}{p(M_{\Lambda^*})} \right)^{2L_{\Lambda^* \to \rho\mathsf{K}} + 1} \frac{M_{\Lambda^*}}{M_{\rho\mathsf{K}}} F_{\Lambda^* \to \rho\mathsf{K}}^2(p(M_{\rho\mathsf{K}}), p(M_{\Lambda^*}))$$

p, q Λ^*, K^- momentum in Λ_b, Λ^* restframeFBlatt-Weißkopf form factors

 $r_{\Lambda_b}, r_{\Lambda^*}$ Interaction radius of the Λ_b, Λ^*

 $L_{\Lambda^* \to pK}$ orbital angular momentum between p and K^- in the $\Lambda^* \to pK^-$ decay

 $L_{\Lambda_b \to \Lambda^* \mu \mu}$ orbital angular momentum between Λ^* and the dimuon system in the $\Lambda_b \to \Lambda^* \mu \mu$ decay $M_{\Lambda^*}, \Gamma_{\Lambda^*}$ pole mass and width of Λ^*

Blatt-Weißkopf form factors

$$\begin{split} B_0'(p,p_0,d) &= 1 \,, \\ B_1'(p,p_0,d) &= \sqrt{\frac{1+(p_0\,d)^2}{1+(p\,\,d)^2}} \,, \\ B_1'(p,p_0,d) &= \sqrt{\frac{9+3(p_0\,d)^2+(p_0\,d)^4}{1+(p\,\,d)^2}} \,, \\ B_2'(p,p_0,d) &= \sqrt{\frac{9+3(p_0\,d)^2+(p_0\,d)^4}{9+3(p\,\,d)^2+(p\,\,d)^4}} \,, \\ B_3'(p,p_0,d) &= \sqrt{\frac{225+45(p_0\,d)^2+6(p_0\,d)^4+(p_0\,d)^6}{225+45(p\,\,d)^2+6(p\,\,d)^4+(p\,\,d)^6}} \,, \\ B_4'(p,p_0,d) &= \sqrt{\frac{11025+1575(p_0\,d)^2+135(p_0\,d)^4+10(p_0\,d)^6+(p_0\,d)^8}{11025+1575(p\,\,d)^2+135(p\,\,d)^4+10(p\,\,d)^6+(p\,\,d)^8}} \,, \\ B_4'(p,p_0,d) &= \sqrt{\frac{893025+99225(p_0\,d)^2+6300(p_0\,d)^4+315(p_0\,d)^6+15(p_0\,d)^8+(p_0\,d)^{10}}{893025+99225(p\,\,d)^2+6300(p\,\,d)^4+315(p\,\,d)^6+15(p\,\,d)^8+(p\,\,d)^{10}}} \,, \end{split}$$

from LHCb-ANA-2013-053

 K_{1cc} and $A_{FB,1/2}^{\ell}$



Uncertainties are linked to sample size \rightarrow not scaled !

Strength of interference terms



Interferences are treated as nuisance parameters

Minuit output

RooMinimizerFcn: Minimized function has error status. Returning maximum FCN so far (129656) to force MIGRAD to back out of this region. Error log follows. Parameter values: AFB=-0.250593 AFBOneHalf=-0.232013 K1cc=0.175359 S1cc=0.323543 i1=-0.981721 i2=-0.960783 PID28680/ RooRealMPFE::nll AngularPdf full data a136c70 MPFE5[arg=nll AngularPdf full data GOF5 vars=(AFB, AFBOneHalf, K1cc, S1cc, ThreeHalfFrac, 11, 12, ml, gSguared)] p.d.f value of (AngularPdf) is less than zero (-0.001624) for entry 2447 @ ! refCoefNorm=(), !pdfs=(dGThreeHalfPdf = 0.209557/1.33333,dGOneHalfPdf = 0.41232/0.906319), !coefficients=(ThreeHalfFrac = 0.727957 +/- 0.0049118) p.d.f value of (AngularPdf) is less than zero (-0.003250) for entry 3656 0 ! refCoefNorm=(), !pdfs=(dGThreeHalfPdf = 0.209557/1.33333.dGOneHalfPdf = 0.41232/0.906319), !coefficients=(ThreeHalfFrac = 0.727957 +/- 0.0049118) p.d.f value of (AngularPdf) is less than zero (-0.001624) for entry 2447 @ ! refCoefNorm=(). !pdfs=(dGThreeHalfPdf = 0.209557/1.33333,dGOneHalfPdf = 0.41232/0.906319). !coefficients=(ThreeHalfFrac = 0.727957 +/- 0.0049118) p.d.f value of (AngularPdf) is less than zero (-0.003250) for entry 3656 @ ! refCoefNorm=(), !pdfs=(dGThreeHalfPdf = 0.209557/1.33333,dGOneHalfPdf = 0.41232/0.906319), !coefficients=(ThreeHalfFrac = 0.727957 +/- 0.0049118) p.d.f value of (AngularPdf) is less than zero (-0.010652) for entry 840 0 ! refCoefNorm=(), !pdfs=(dGThreeHalfPdf = 0.209557/1.33333.dGOneHalfPdf = 0.41232/0.906319), !coefficients=(ThreeHalfFrac = 0.727957 +/- 0.0049118) p.d.f value of (AngularPdf) is less than zero (-0.009655) for entry 1407 @ ! refCoefNorm=(), !pdfs=(dGThreeHalfPdf = 0.209557/1.33333,dGOneHalfPdf = 0.41232/0.906319). !coefficients=(ThreeHalfFrac = 0.727957 +/- 0.0049118) p.d.f value of (AngularPdf) is less than zero (-0.010652) for entry 840 0 ! refCoefNorm=(), !pdfs=(dGThreeHalfPdf = 0.209557/1.33333.dGOneHalfPdf = 0.41232/0.906319), !coefficients=(ThreeHalfFrac = 0.727957 +/- 0.0049118) p.d.f value of (AngularPdf) is less than zero (-0.009655) for entry 1407 @ ! refCoefNorm=(), !pdfs=(dGThreeHalfPdf = 0.209557/1.33333.dGOneHalfPdf = 0.41232/0.906319). !coefficients=(ThreeHalfFrac = 0.727957 +/- 0.0049118) p.d.f value of (AngularPdf) is less than zero (-0.004703) for entry 532 0 ! refCoefNorm=(), !pdfs=(dGThreeHalfPdf = 0.209557/1.33333,dGOneHalfPdf = 0.41232/0.906319), !coefficients=(ThreeHalfFrac = 0.727957 +/- 0.0049118) p.d.f value of (AngularPdf) is less than zero (-0.004703) for entry 532 @ ! refCoefNorm=(), !pdfs=(dGThreeHalfPdf = 0.209557/1.33333.dGOneHalfPdf = 0.41232/0.906319), !coefficients=(ThreeHalfFrac = 0.727957 +/- 0.0049118) RooNLLVar::nll AngularPdf full data[paramSet=(AFB,AFBOneHalf,K1cc,S1cc,ThreeHalfFrac,i1,i2 ,ml,gSquared) function value is NAN @ paramSet=(AFB = -0.250593.AFBOneHalf = -0.232013.K1cc = 0.175359,S1cc = 0.323543,ThreeHalfFrac = 0.727957 +/- 0.0049118,i1 = -0.981721,i2 = -0.960783.ml = 0.gSquared = 7) MIGRAD MINIMIZATION HAS CONVERGED. MIGRAD WILL VERIFY CONVERGENCE AND ERROR MATRIX. COVARIANCE MATRIX CALCULATED SUCCESSFULLY FCN=88213.5 FROM MIGRAD STATUS=CONVERGED 522 CALLS 523 TOTAL EDM=7.81173e-86 STRATEGY= 2 FRROR MATRIX ACCURATE

COVARIANCE MATRIX CALCULATED SUCCESSFULLY
FCN=88213.5 FROM HESSE STATUS=0K 40 CALLS 563 TOTAL
EDM=7.81718e-06 STRATEGY= 2 ERROR MATRIX ACCURATE
EXT PARAMETER INTERNAL INTERNAL
NO. NAME VALUE ERROR STEP SIZE VALUE
1 AFB -2.38781e-01 4.01788e-03 2.33974e-05 -2.41111e-01
2 AFB0neHalf -2.38269e-01 8.37365e-03 4.77853e-05 -2.40584e-01
3 K1cc 1.70811e-01 6.72561e-03 9.94670e-05 -7.18662e-01
4 S1cc 3.51643e-01 6.51424e-03 7.75063e-05 -3.01250e-01
5 i1 -1.21203e+00 2.48641e-02 9.59349e-05 -6.51038e-01
6 i2 -7.72697e-01 2.58713e-02 8.60677e-05 -2.74492e+00
ERR DEF= 0.5
EXTERNAL ERROR MATRIX. NDIM= 25 NPAR= 6 ERR DEF=0.5
1,614e-05 -1,635e-05 8,415e-06 -1,628e-05 -2,670e-07 1,615e-08
-1.635e-05 7.012e-05 -3.610e-05 1.683e-05 7.111e-07 -2.382e-08
8,415e-06 -3,610e-05 4,524e-05 -2,098e-05 1,158e-06 2,142e-06
-1.628e-05 1.683e-05 -2.098e-05 4.244e-05 -8.081e-07 -1.823e-06
-2.670e-07 7.111e-07 1.158e-06 -8.081e-07 6.183e-04 4.267e-04
1.615e-08 -2.382e-08 2.142e-06 -1.823e-06 4.267e-04 6.694e-04
PARAMETER CORRELATION COEFFICIENTS
NO. GLOBAL 1 2 3 4 5 6
1 0.72477 1.000 -0.486 0.311 -0.622 -0.003 0.000
2 0.73741 -0.486 1.000 -0.641 0.308 0.003 -0.000
3 0.73471 0.311 -0.641 1.000 -0.479 0.007 0.012
4 0.72180 -0.622 0.308 -0.479 1.000 -0.005 -0.011
5 0.66336 -0.003 0.003 0.007 -0.005 1.000 0.663
6 0.66341 0.000 -0.000 0.012 -0.011 0.663 1.000
[#1] INFO:Minization RooMinimizer::optimizeConst: deactivating const optimization
>>> ANGULAR FIT RESULT :
Refit = False , Failed = False , Minuit Status = 0 , AtLimit = False

<u>RooFitResult</u>: minimized FCN value: 88213.5, estimated distance to minimum: 7.81718e-06 covariance matrix quality: Full, accurate covariance matrix Status: MIDIMIZE® HESSE=0

Floating Parameter	FinalValue +/-	Error
AFB	-2.3878e-01 +/-	4.02e-03
AFBOneHalf	-2.3827e-01 +/-	8.37e-03
K1cc	1.7081e-01 +/-	6.73e-03
S1cc	3.5164e-01 +/-	6.51e-03
i1	-1.2120e+00 +/-	2.49e-02
i2	-7.7270e-01 +/-	2.59e-02