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Amplitude analysis of $B^0_s \to K^0_S K^\pm \pi^\mp$ decays

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Workshop on multi-body charmless *b*-hadron decays

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LHCb

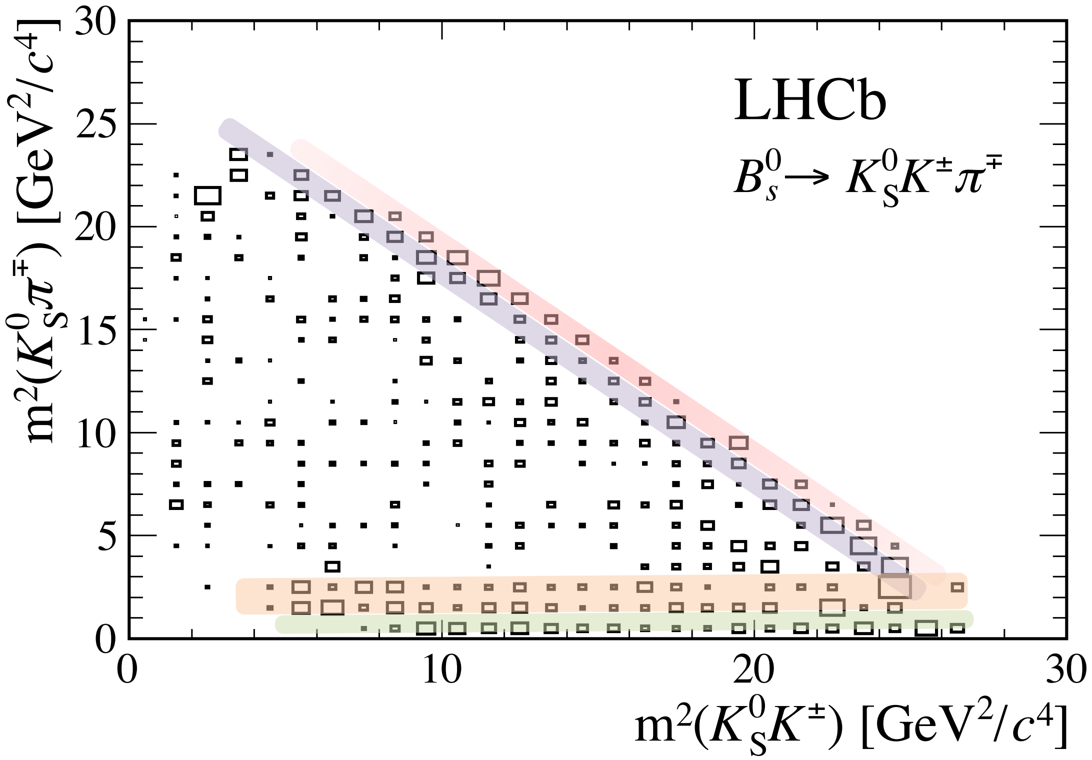
Amplitude analysis of $B^0_s \to K^0 K^{\pm}\pi^{\mp}$

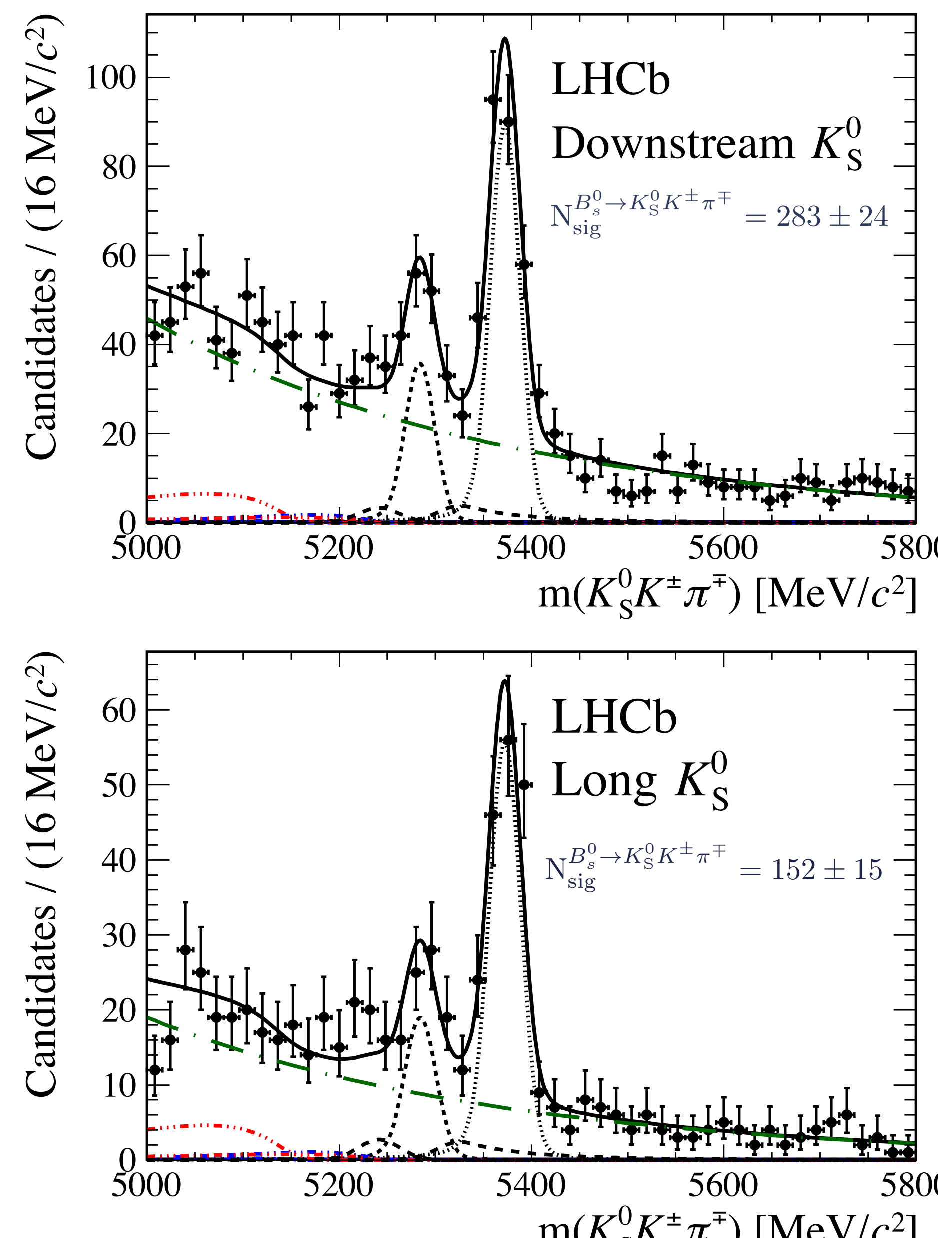
Search for ~~C~~P in charmless 3–body decays of neutral *B* mesons to final states containing a K^0 meson

- CKM angle γ using $B^0_s \to K^*K$ in an isospin analysis
- Non-zero $\Delta\Gamma_s$ allows effective lifetime measurement
- U-spin multiplet $B^0_s \to K^{*0}K^0 (K^{*0}K^0)$ to $B^0 \to K^*K$

Study of $B^0_{(s)} \to K^0_S h^+ h'^-$ decays with first observation of $B^0_s \to K^0_S K^{\pm}\pi^{\mp}$ and $B^0_s \to K^0_S \pi^+\pi^-$

JHEP 10 (2013) 143





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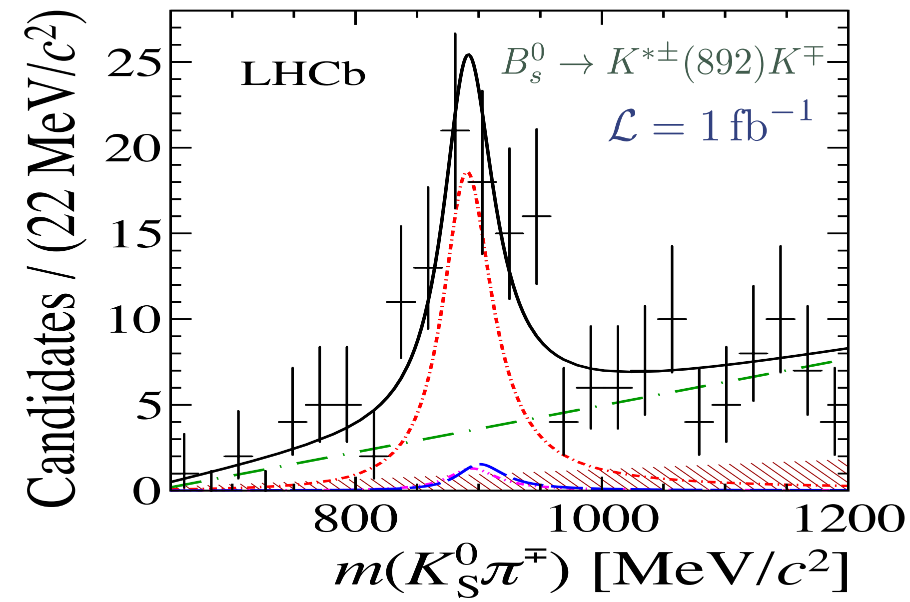
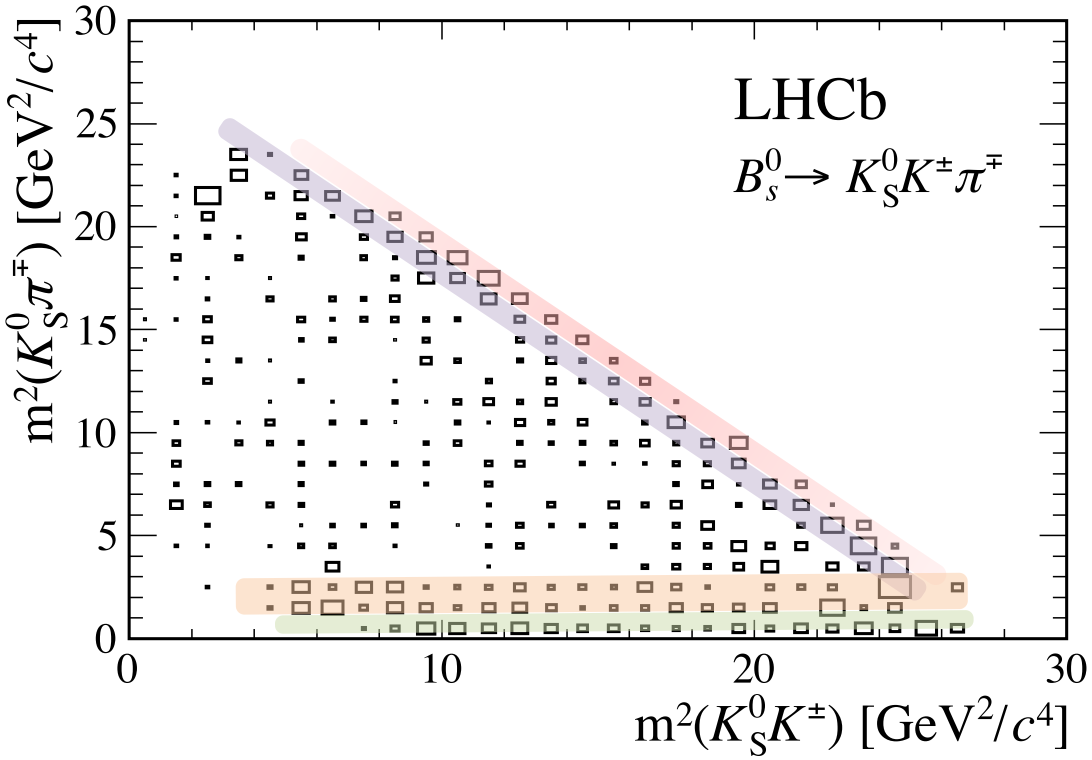
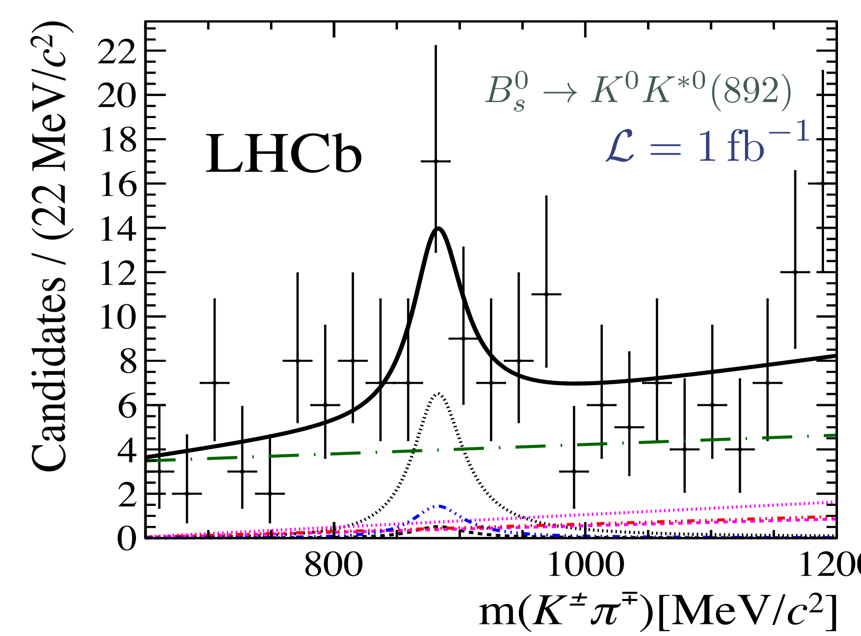
New J.Phys. 16 (2014) 12, 123001





JHEP 1601 (2016) 012



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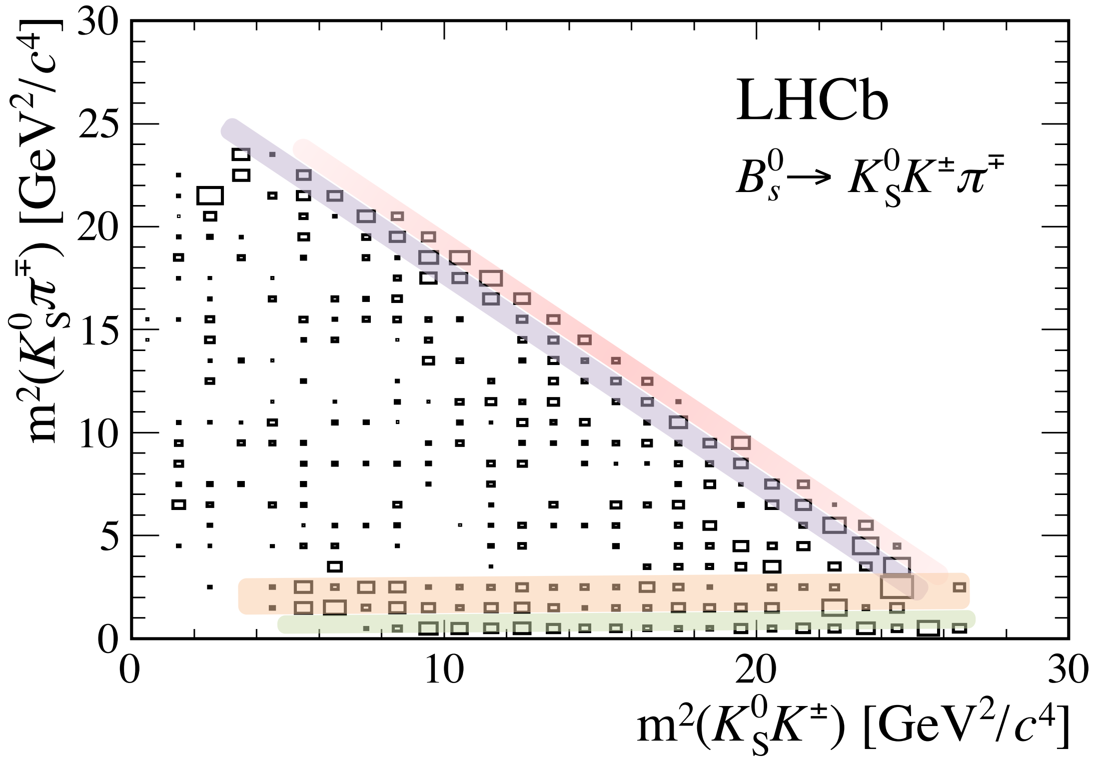
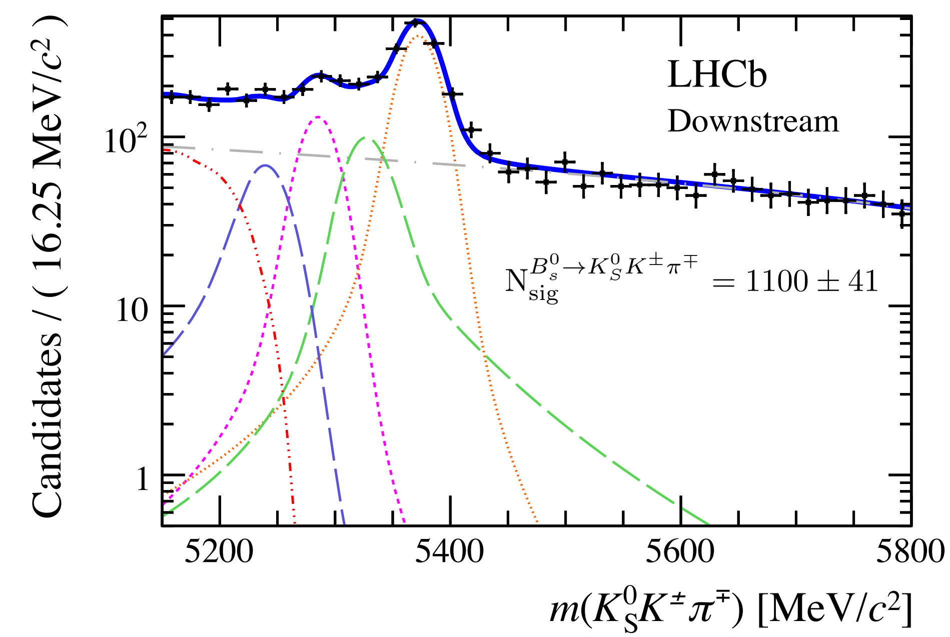
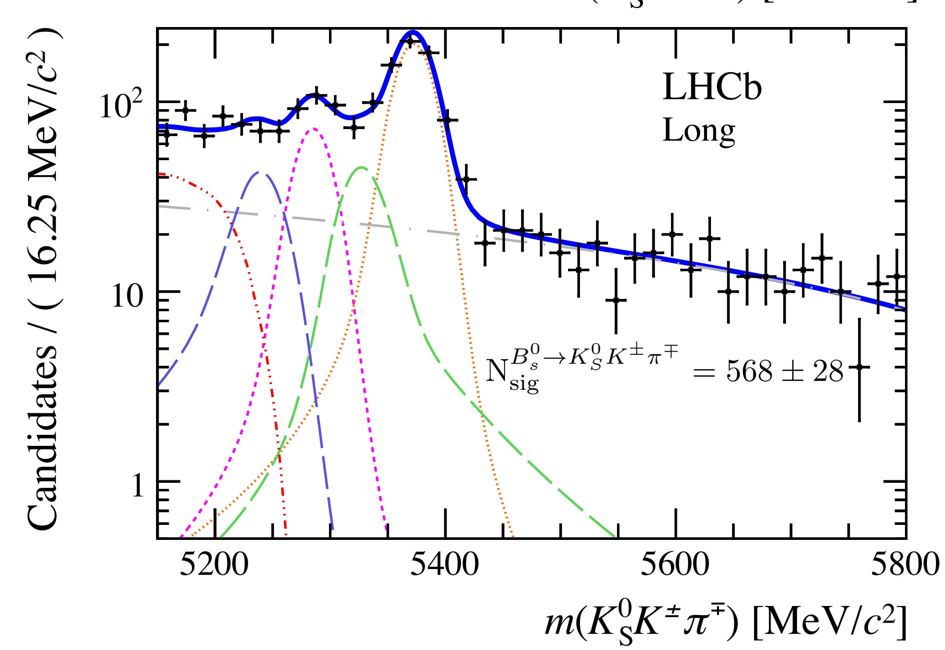


Updated branching fraction measurements of $B^0_{(s)} \to K^0_S h^+ h'^-$ decays

JHEP 11 (2017) 027





Overview of the analysis status

This talk covers some aspects of the first Dalitz analysis of $B^0_s \to K^0_S K^{\pm}\pi^{\mp}$ decays

[$3\,\mathrm{fb}^{-1}$ Run-I (2011/12) at 7/8 TeV]

- "Effective" untagged time-integrated Dalitz-Plot analysis strategy has been used

  [limited statistics for flavour tagging]

- Dataset selection, efficiency and background modelling common to all $K^0_S h^+ h^-$ modes

  [optimised FoM for DP analysis]

- Dalitz-plot fitting results and systematics

  [BR measurements and first observations of the $K\pi$ S-wave contribution]

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Amplitude fit model features for $B^0_s \to K^0_S K^{\pm} \pi^{\mp}$ decays

[Non-public results]: $\mathcal{L} = 3\text{fb}^{-1} - 2011 + 2012$ dataset

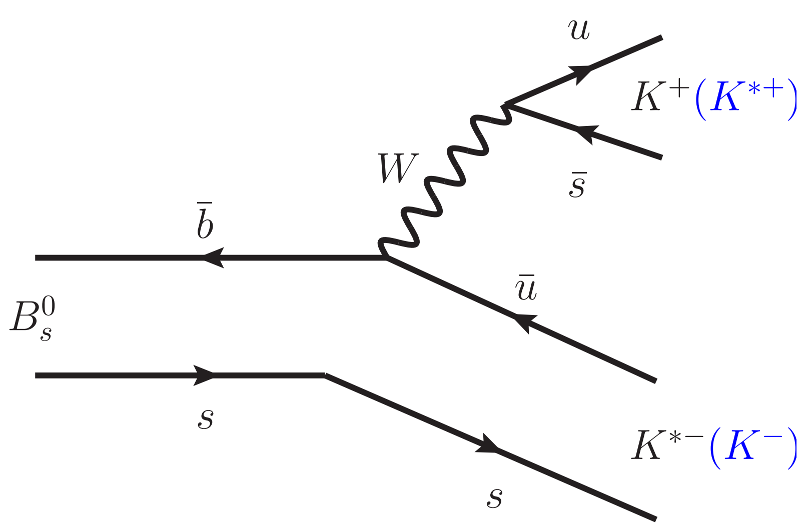
Method: effective untagged time-integrated analysis

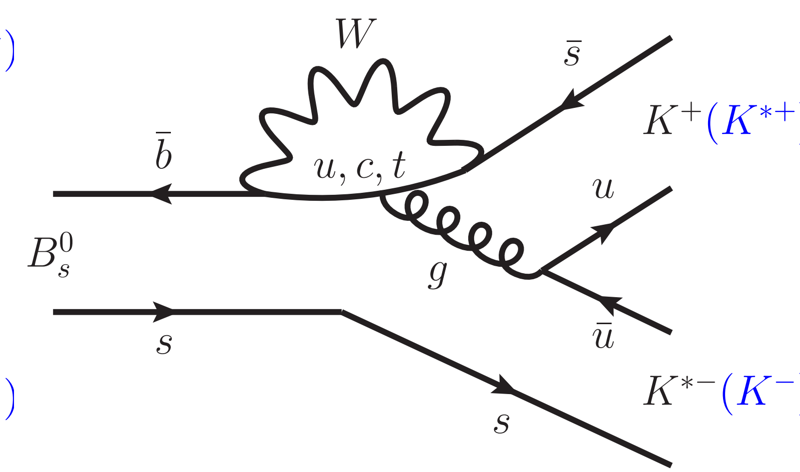
[LHCb-ANA-2014-045]

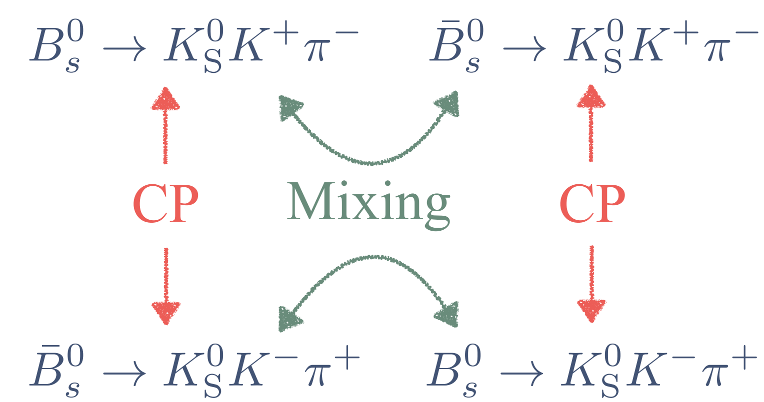
$B^0_s \to K^0K^{\pm}\pi^{\mp}$ decay features

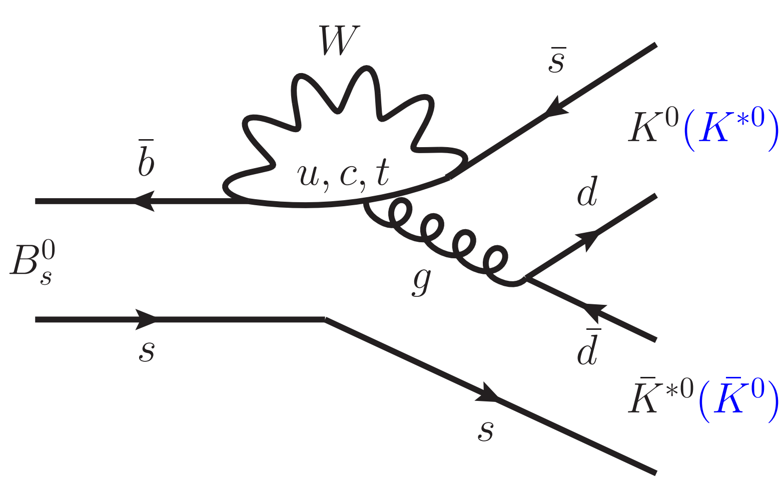
Decay channel $B^0_s \to K^0_S K^{\pm}\pi^{\mp}$ corresponds in fact to four different DP's:
$B^0_s(\bar{B}^0_s) \to K^0_S K^+\pi^-$ and $B^0_s(\bar{B}^0_s) \to K^0_S K^-\pi^+$ final states.

Leading diagrams are dominated by either K*(892) or K*(1430) contributions:









$\bar{B}^0_s \to \bar{K}^0K^+\pi^-$	Reference PRD 89 (074025)	arXiv:1401.5948	$\bar{B}^0_s \to \bar{K}^0K^-\pi^+$	Reference PRD 89 (074025)	arXiv:1401.5948
$K^{*0}\bar{K}^0$	$1.5^{+2.4}_{-0.9}$	$0.7^{+1.7}_{-0.5}$	$\bar{K}^{*0}K^0$	$3.8^{+0.8}_{-0.7}$	$2.3^{+0.6}_{-0.5}$
$K^{*-}K^+$	$3.5^{+0.7}_{-0.7}$	$2.3^{+0.6}_{-0.5}$	$K^{*+}K^-$	$2.6^{+2.7}_{-1.1}$	$1.3^{+2.0}_{-0.9}$
$K_0^{*0}(1430)\bar{K}^0$	$0.6^{+0.9}_{-0.4}$	$0.5^{+1.2}_{-0.4}$	$\bar{K}_0^0(1430)K^0$	$14.5^{+3.3}_{-2.9}$	$16.6^{+5.1}_{-4.3}$
$K_0^{*-}(1430)K^+$	$14.5^{+3.2}_{-2.9}$	$15.5^{+4.5}_{-3.9}$	$K_0^{*+}(1430)K^-$	$1.0^{+1.0}_{-0.4}$	$0.9^{+1.4}_{-0.5}$
Non resonant	$23.8^{+9.9}_{-6.7}$	$12.3^{+12.6}_{-6.3}$	Non Resonant	$24.2^{+0.9}_{-5.1}$	$12.9^{+13.2}_{-6.6}$
Total	$35.3^{+15.7}_{-9.8}$	$33.7^{+20.9}_{-12.0}$	Total	$36.7^{+14.9}_{-9.0}$	$34.2^{+21.1}_{-12.0}$

Theory predictions

$B^0_s \to K^0 K^\pm \pi^\mp$ decay-time formalism

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The decay-time distribution for B^0_s and $\bar{B}^0_s$ meson decays to a final state f (e.g. $B^0_s \to K^0_S K^+ \pi^-$) can be written as:

$$\frac{d}{dt}\Gamma_{\bar{B}^0_s \to f}(t) = \frac{\mathcal{N}_f e^{-t/\tau(B^0_s)}}{2\tau(B^0_s)} \left[\cosh\left(\frac{\Delta\Gamma_s t}{2}\right) + S_f \sin(\Delta m_s t) - C_f \cos(\Delta m_s t) + A_f^{\Delta\Gamma_s} \sinh\left(\frac{\Delta\Gamma_s t}{2}\right)\right]$$

$$\frac{d}{dt}\Gamma_{B^0_s \to f}(t) = \frac{\mathcal{N}_f e^{-t/\tau(B^0_s)}}{2\tau(B^0_s)} \left[\cosh\left(\frac{\Delta\Gamma_s t}{2}\right) - S_f \sin(\Delta m_s t) + C_f \cos(\Delta m_s t) + A_f^{\Delta\Gamma_s} \sinh\left(\frac{\Delta\Gamma_s t}{2}\right)\right]$$

$$S_f \equiv \frac{2\Im(\lambda_f)}{1+|\lambda_f|^2} \qquad C_f \equiv \frac{1-|\lambda_f|^2}{1+|\lambda_f|^2} \qquad A_f^{\Delta\Gamma_s} \equiv -\frac{2\Re(\lambda_f)}{1+|\lambda_f|^2} \qquad \lambda_f = \left|\frac{\bar{\mathcal{A}}_f}{\mathcal{A}_f}\right| e^{i(\phi_s^f + \delta_f)}$$

In the case of B^0_s decays, the integration between zero and infinity leads to :

$$\mathcal{N}_f = \left(|A_f|^2 + |\bar{A}_f|^2\right) \times \frac{1-y^2}{1+yA_f^{\Delta\Gamma_s}}$$

Premise: additional information on the phases between amplitudes from the $A^{\Delta\Gamma}$ term.

$^* y = \tau(B^0_s)\Delta\Gamma_s/2$

$B^0_s \rightarrow K^0 K^{\pm}\pi^{\mp}$ decay-time formalism

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The additional final state has a similar decay time equation. Hence, one can access:

$$\frac{\mathcal{N}_{\bar{f}}}{\mathcal{N}_f} = \frac{(|A_{\bar{f}}|^2 + |\bar{A}_{\bar{f}}|^2)(1-y^2)/(1+yA_{\bar{f}}^{\Delta\Gamma_s})}{(|A_f|^2 + |\bar{A}_f|^2)(1-y^2)/(1+yA_f^{\Delta\Gamma_s})}$$

$$= \frac{1+yA_f^{\Delta\Gamma_s}}{1+yA_{\bar{f}}^{\Delta\Gamma_s}} = \frac{1+R_f^2 - 2yR_f\cos(\phi_s^f+\delta_f)}{1+R_f^2-2yR_f\cos(\phi_s^f-\delta_f)}$$

- Even in absence of ~~CP~~ in decay, in general $N_f \neq N_{\bar{f}}$
- With no CP in decay, the asymmetry between N_f and $N_{\bar{f}}$ is limited to $2yR_f/(1+R^2_f)$
- If $\cos(\varphi_s+\delta) = \cos(\varphi_s-\delta) \rightarrow$ no ~~CP~~ in the interference between mixing and decay.

In this framework different Dalitz plot analyses can be performed:

Method I : Untagged and time integrated
Method II: Untagged and time-dependent
Method III: Tagged time-dependent

Sensitivity studies in a non-LHCb paper is being performed. Results for $B^0_s \rightarrow K^0_S\pi\pi$

C14-07-02 arXiv:1411.2018

$B^0_s \to K^0 K^\pm \pi^\mp$ Dalitz-plot analysis

Note that for $B^0_s \to K^0_S K^\pm \pi^\mp$ decays there are four amplitudes, which even in the absence of ~~C~~P, two independent amplitudes remain, A_f and $\bar{A}_f$.

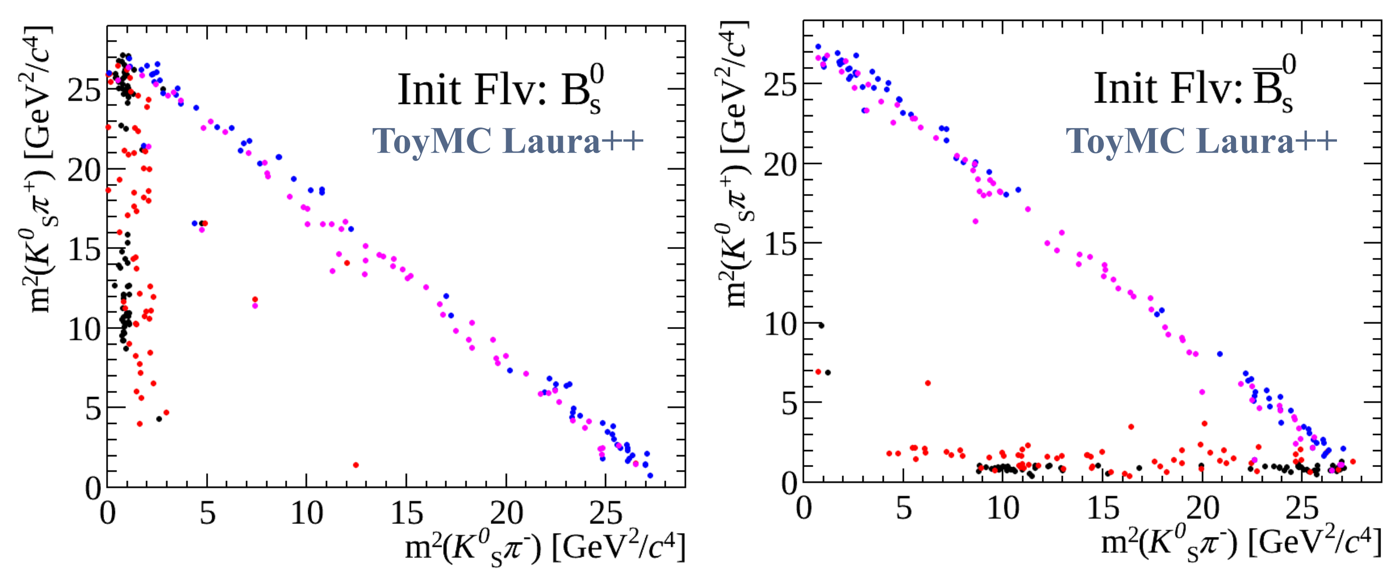
In an untagged analysis it is in general impossible to disentangle the two components, except:

- **[$B^0 \to K^+\pi^-\pi^0$]** - Final state assumed to be flavour-specific, so that one of the two possible contributions vanishes.

Phys.Rev. D83 (2011) 112010

- **[$B^0_{(s)} \to K^0_S\pi^+\pi^-$]** - In time-integrated DP analyses, resonances are either flavour specific (*e.g.* $K^{*+}\pi^-$) or self-conjugate (*e.g.* $K^0_S\rho^0$).

LHCb-PAPER-2017-033, arXiv:1712.09320



- **Remark:** cannot perform a untagged Dalitz-plot analysis of a non-self-conjugate, non-flavour-specific final state without some assumption on A_f and $\bar{A}_f$.

$B^0_s \longrightarrow K^0K^\pm\pi^\mp$ Dalitz-plot analysis

Consider an untagged decay-time-integrated Dalitz-plot analysis for $B^0_s \longrightarrow K^0_SK^\pm\pi^\mp$, the simplified combined decay time for a final state is given as

$$\Gamma_{\bar{B}^0_s \to f}(t) + \Gamma_{B^0_s \to f}(t) = \frac{\mathcal{N}_f e^{-t/\tau(B^0_s)}}{\tau(B^0_s)} \left[\cosh \frac{\Delta\Gamma_s t}{2} - A_f^{\Delta\Gamma_s} \sinh \frac{\Delta\Gamma_s t}{2}\right]$$

Integrating over time and inserting the definitions, the signal probability density function that can be used in a fit is determined to be

$$\mathcal{P}_f^{\rm sig}(s,t) = \frac{|\mathcal{A}_f|^2 + |\bar{\mathcal{A}}_f|^2 - 2\mathcal{D}{\rm Re}(\mathcal{A}_f^* \bar{\mathcal{A}}_f)}{\int\int_{DP} \; |\mathcal{A}_f|^2 + |\bar{\mathcal{A}}_f|^2 - 2\mathcal{D}{\rm Re}(\mathcal{A}_f^* \bar{\mathcal{A}}_f) \; ds\, dt}$$

$$\mathcal{D} = \frac{\int_0^\infty \epsilon(t) e^{-\Gamma_s t} \sinh \frac{\Delta\Gamma_s t}{2} dt}{\int_0^\infty \epsilon(t) e^{-\Gamma_s t} \cosh \frac{\Delta\Gamma_s t}{2} dt}$$

$$\mathcal{A}_f \leftrightarrow \bar{\mathcal{A}}_f$$
$$\mathcal{A}_f \to e^{i\phi}\mathcal{A}_f$$
$$\bar{\mathcal{A}}_f \to e^{-i\phi}\bar{\mathcal{A}}_f$$

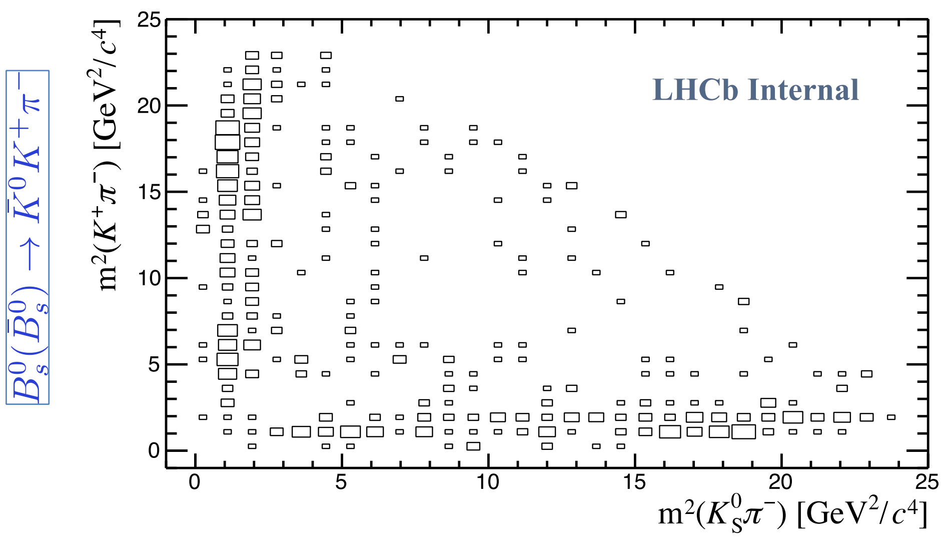
Conclusion: either time-dependent or independent analyses cannot be performed without the need of *flavour tagging* for $B^0_s \longrightarrow K^0_SK^\pm\pi^\mp$ decays.

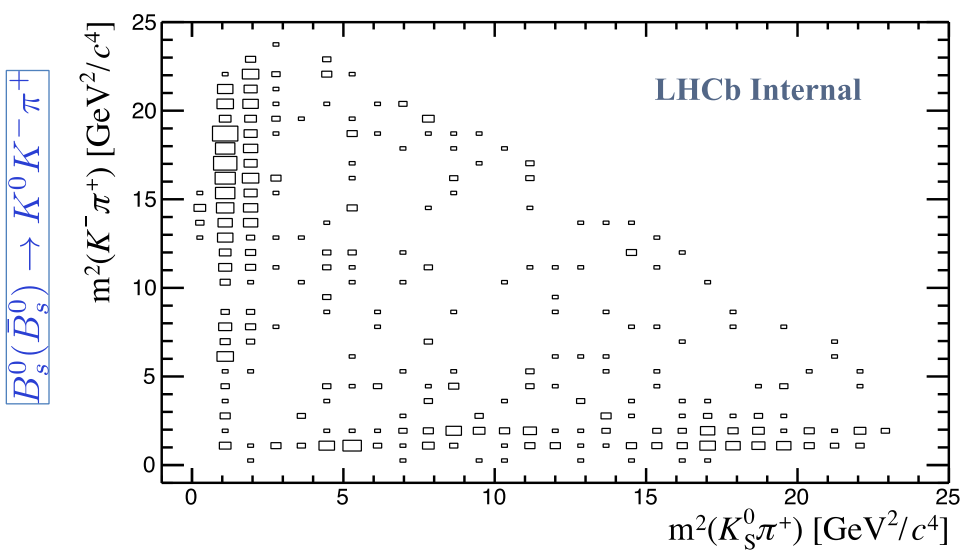
$B^0_s \to K^0 K^\pm \pi^\mp$ Dalitz-plot strategy

Flavour-tagging is unattractive with the current statistics, so an effective DP model is used:

$$\mathcal{P}^{\rm sig}_f(s,t) = \frac{|\mathcal{A}_f(s,t)|^2}{\int\int_{DP}\ |\mathcal{A}_f(s,t)|^2\ ds\,dt}$$

$$\widehat{FF}_j = \frac{\int\int_{DP} |c_j F_j(s,t)|^2\, dsdt + \int\int_{DP'} \left|\bar{c}_j \bar{F}_j(s',t')\right|^2 ds'dt'}{\int\int_{DP} \left|\sum_k c_k F_k(s,t)\right|^2 dsdt + \int\int_{DP'} \left|\sum_k \bar{c}_k \bar{F}_k(s',t')\right|^2 ds'dt'}$$





Although the presence of CP violation can be investigated, due to the approximations in the model, the complex coefficients obtained are not of trivial interpretation.

Analysis selection in a nutshell

Remark: common strategy developed for all $K^0h^+h^-$ channels

Dataset, mass fit, efficiency and background maps

Dalitz-plot selection strategy

Series of studies to enhance the DP signal yield and/or the amplitude fit sensitivity

- Alternative MVA approaches investigated, (*e.g.* uBDT and Neurobayes using *s*Weights)
- PID criteria: DLL to ProbNN variables

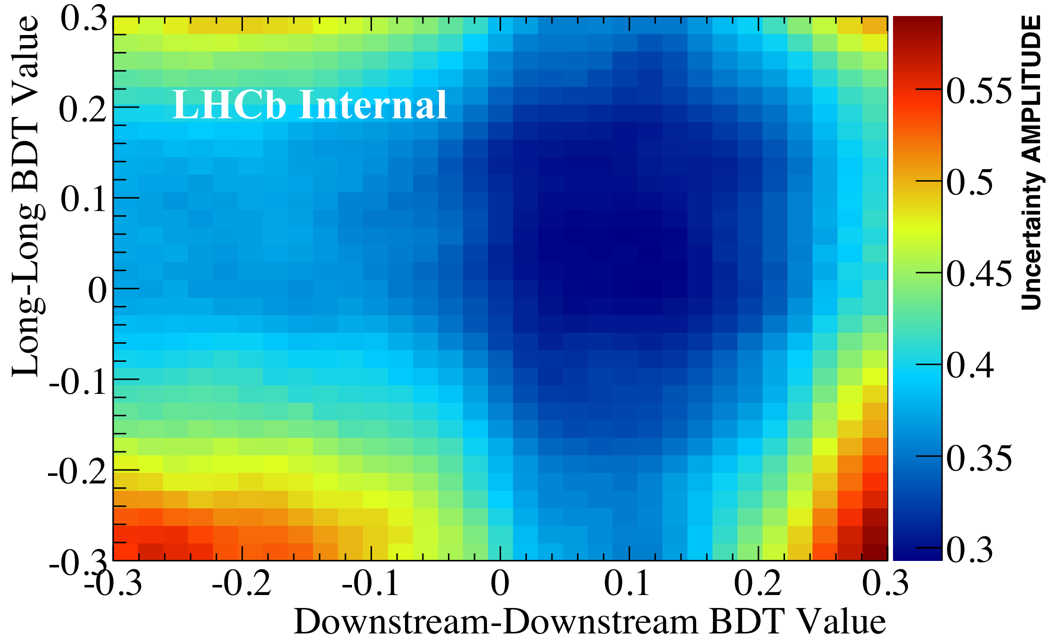
DP FoM optimisation for the optimal isobar parameter sensitivity (Stat+Syst effects)

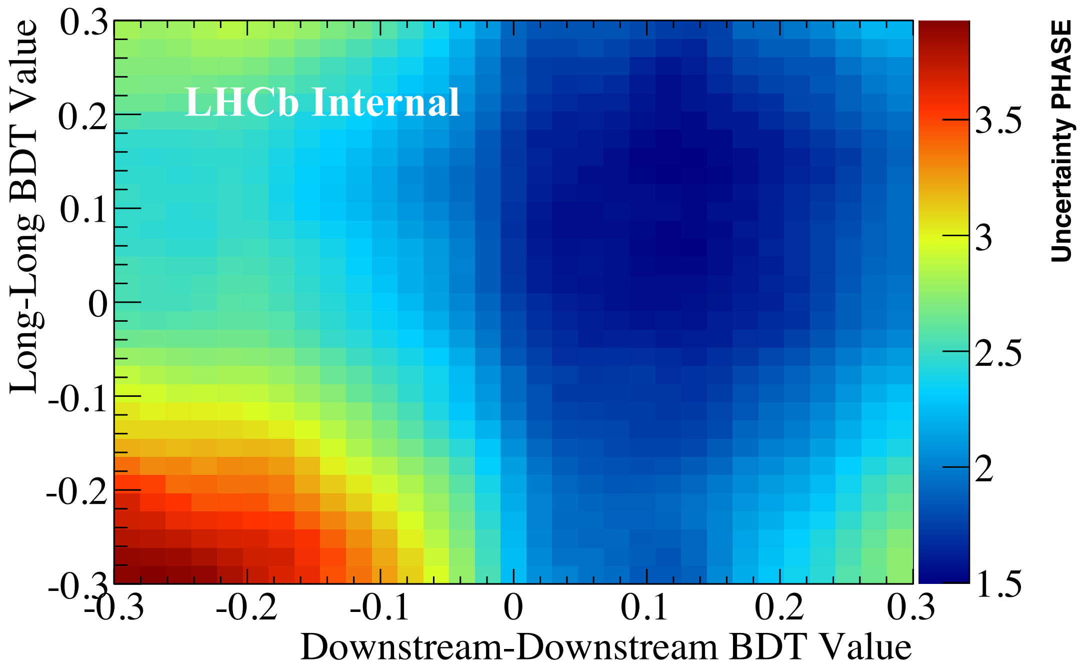
$$\mathrm{FoM}_1 = \frac{\mathrm{S}}{\sqrt{\mathrm{S}+\mathrm{B}}} \quad \mathrm{FoM}_2 = \frac{\mathrm{S}^2}{(\mathrm{S}+\mathrm{B})^{3/2}} \quad \mathrm{FoM}_3 = \frac{\epsilon_{\mathrm{sig}}}{\mathrm{a}/2+\sqrt{\mathrm{B}}}$$

Method: : series of ToyMC studies have been done to verify the uncertainties on the DP observables.

Results: FoM_2 seems to provide the best response

Selection technique for
$B_s^0 \to K_S^0 K^{\pm}\pi^{\mp}$ Dalitz plot optimisation
LHCb-INT-2015-003



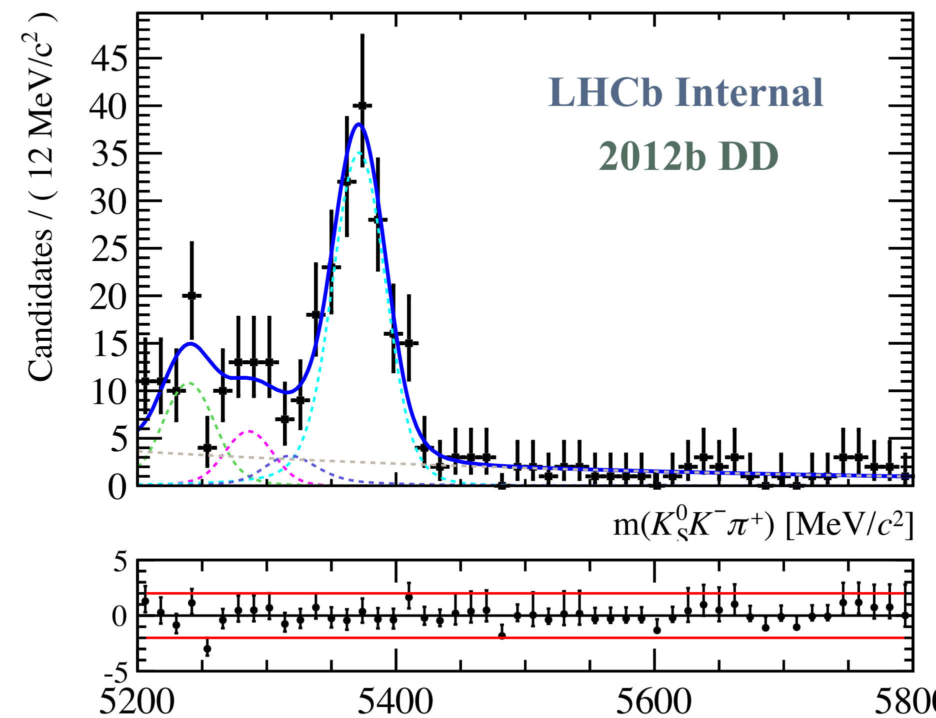


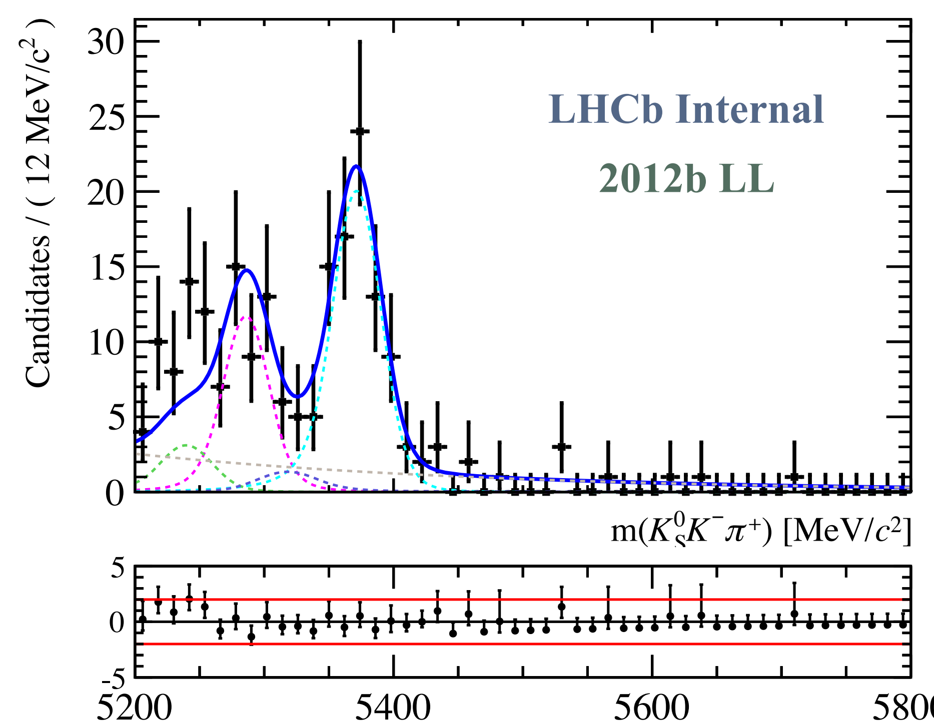
Mass fit model and results

Strategy similar to the BR paper, where a simultaneous fit of all *four* hypotheses combinations is performed splitting between DD/LL and 2011/2012a/2012b

- Split between the two final state charge types
- Total yields correspond to ~ 430 $K^0{}_S K^+ \pi^-$ and ~ 490 $K^0{}_S K^- \pi^+$ events

Final state	K^0_S	Year	B^0_s-signal 2.5 σ	B^0_s-signal Full fit	Combinatorial 2.5 σ	Combinatorial Full fit	Cross-feed 2.5 σ
$K^0_S K^+ \pi^-$	DD	2011	72.1	73.6 ± 10.6	22.1	108.3 ± 15.1	1.7
		2012a	45.7	48.2 ± 8.6	14.3	70.1 ± 12.1	1.1
		2012b	130.0	135.3 ± 13.6	17.9	87.4 ± 13.8	3.1
	LL	2011	74.6	76.2 ± 9.8	8.4	44.1 ± 9.8	1.8
		2012a	36.8	38.5 ± 7.7	11.2	58.8 ± 11.2	0.9
		2012b	71.9	73.5 ± 10.6	13.6	71.7 ± 13.1	1.7
$K^0_S K^- \pi^+$	DD	2011	71.4	72.8 ± 10.3	16.1	78.9 ± 12.7	1.3
		2012a	65.2	68.8 ± 9.6	9.5	46.2 ± 9.9	1.2
		2012b	158.6	165.1 ± 15.2	21.3	104.1 ± 15.0	2.9
	LL	2011	75.7	77.3 ± 9.8	7.4	39.0 ± 10.2	1.4
		2012a	38.5	40.3 ± 8.1	11.2	58.9 ± 11.9	0.7
		2012b	80.0	81.7 ± 10.4	9.5	50.1 ± 12.3	1.4





Efficiency map strategy and corrections

Similar approach used in similar Dalitz plot analyses (*e.g.* PRL 113 (2014) 162001):

DecProd cuts/Generator level

PIDCalib

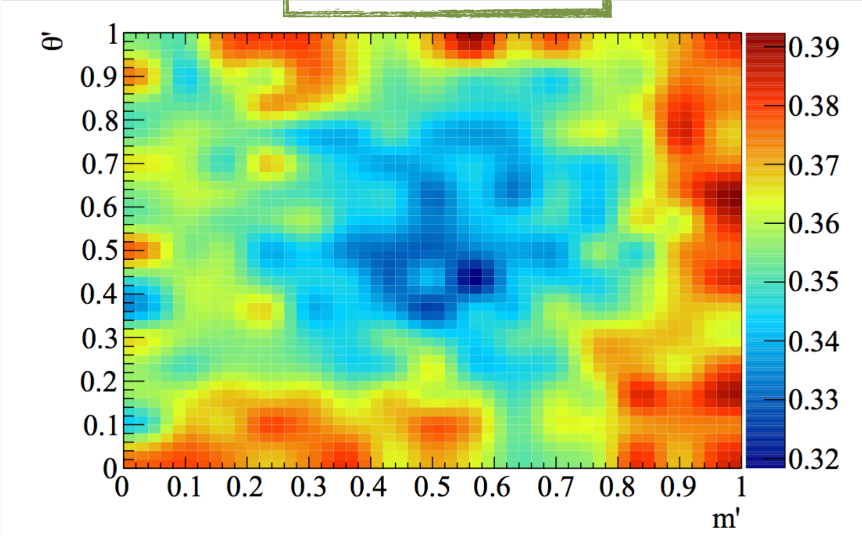
$$\epsilon^{Tot}_{B^0_{(s)}\to K^0_{\rm S}h^\pm h^\mp} = \epsilon^{Geom}_{B^0_{(s)}\to K^0_{\rm S}h^\pm h^\mp} \times \epsilon^{reco/trig/sel}_{B^0_{(s)}\to K^0_{\rm S}h^\pm h^\mp} \times \epsilon^{PID}_{B^0_{(s)}\to K^0_{\rm S}h^\pm h^\mp}$$

MC/data track correction

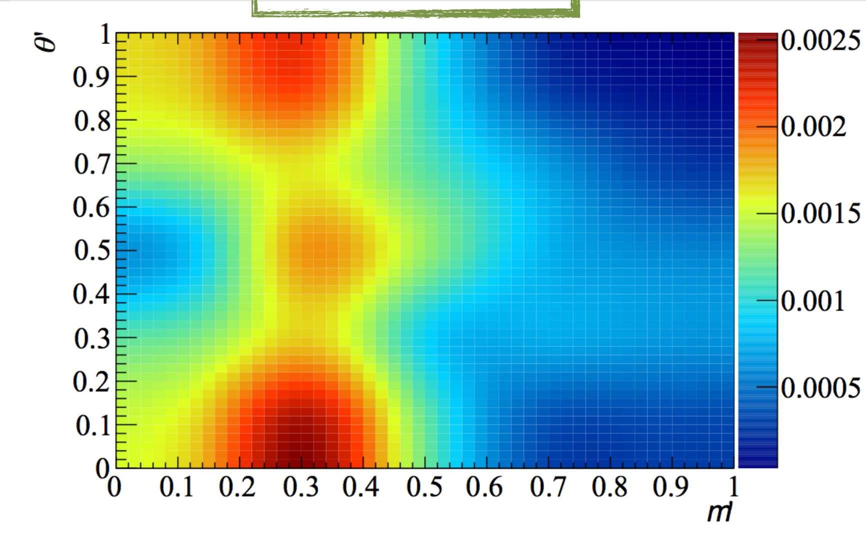
- L0 Hadron MC/data correction
- Overlap in the HCAL

In summary, *e.g.* $B^0_s \to K^0_S K^+\pi^-$ DD 2011:

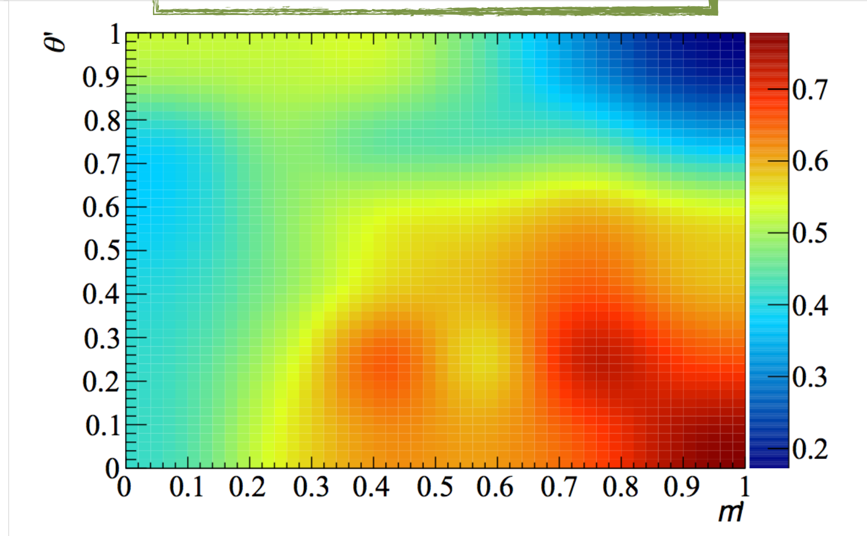
Geometry



Selection



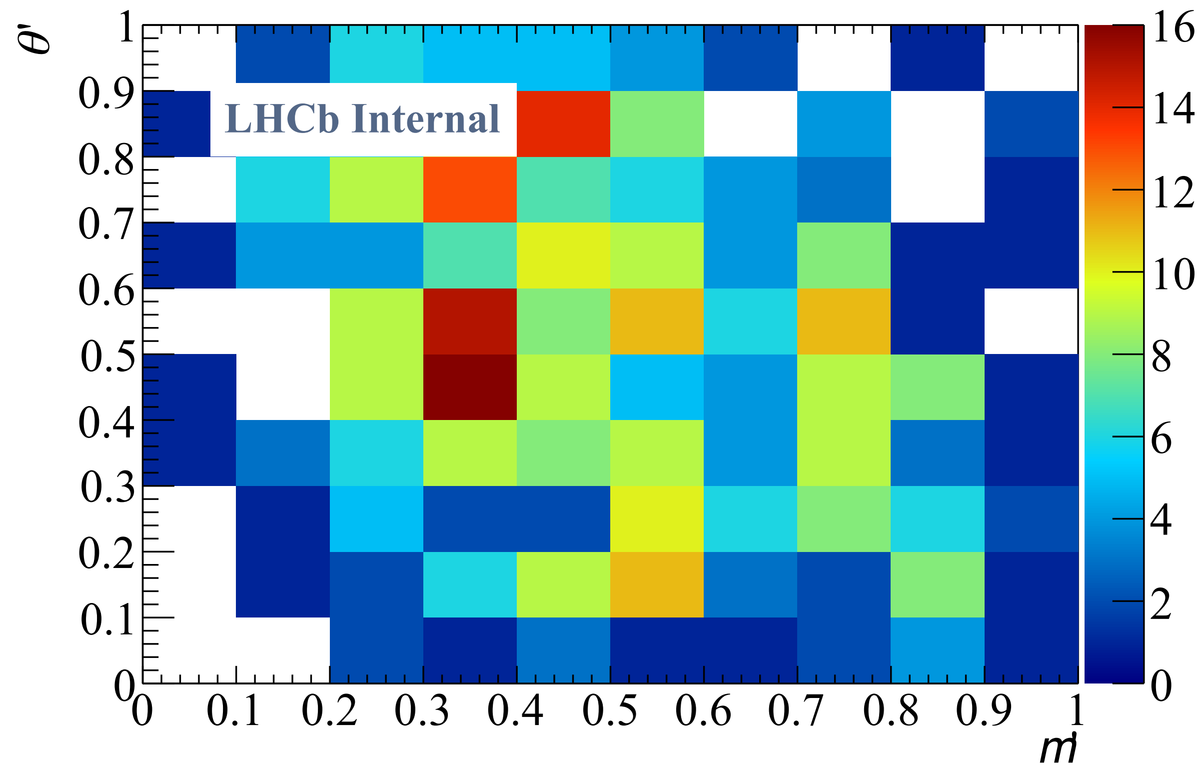
Particle identification



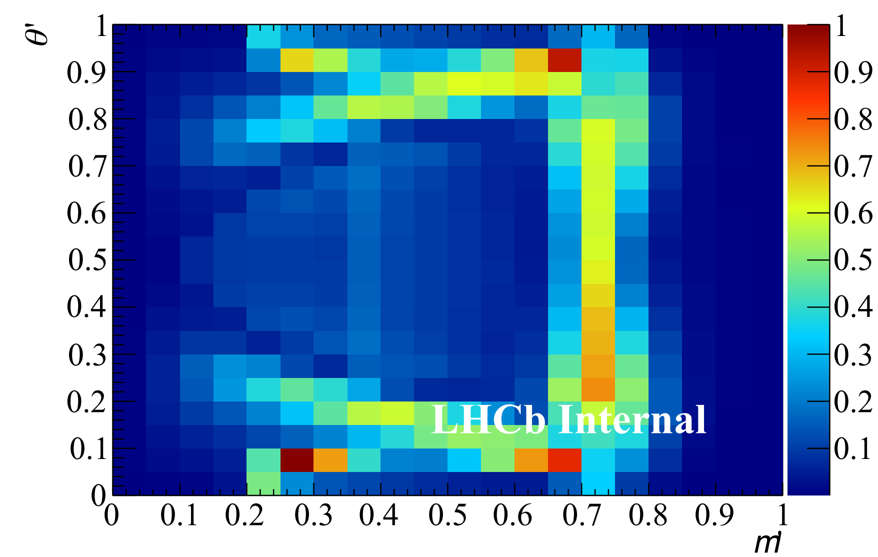
Background distributions

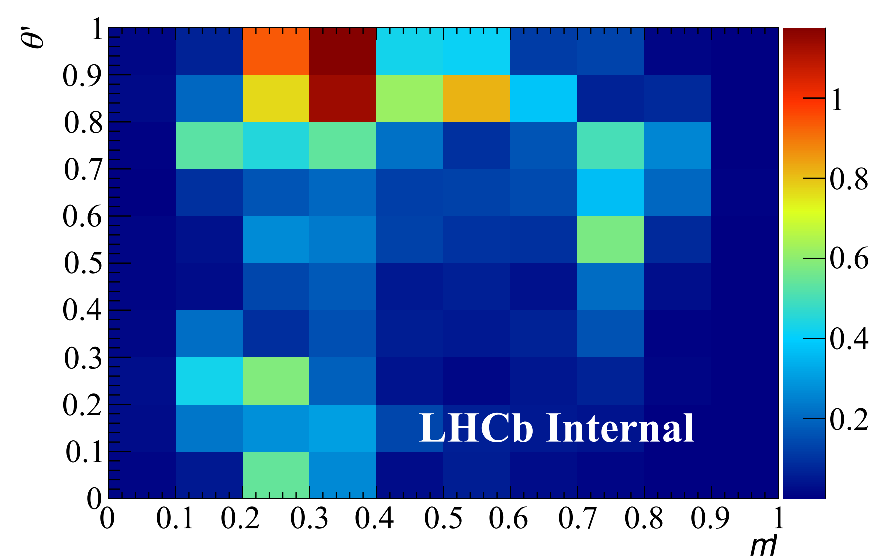
Two main contributions are considered in the model: combinatorial (~10%) and cross-feed from from $B^0 \to K^0_S \pi^+ \pi^-$decays (3%).

Combinatorial bkg: right side-band is statistically limited after the full selection (loose selection)



Crossfeed: re-weight MC samples using ToyMC inspired by BaBar model





Dalitz-Plot fit machinery and results

[Non-public results]: $\mathcal{L} = 3\text{fb}^{-1} - 2011 + 2012$ dataset

First amplitude analysis of $B^0_s \to K^0 K^{\pm} \pi^{\mp}$ decays using an Isobar approach

Dalitz-plot fitting

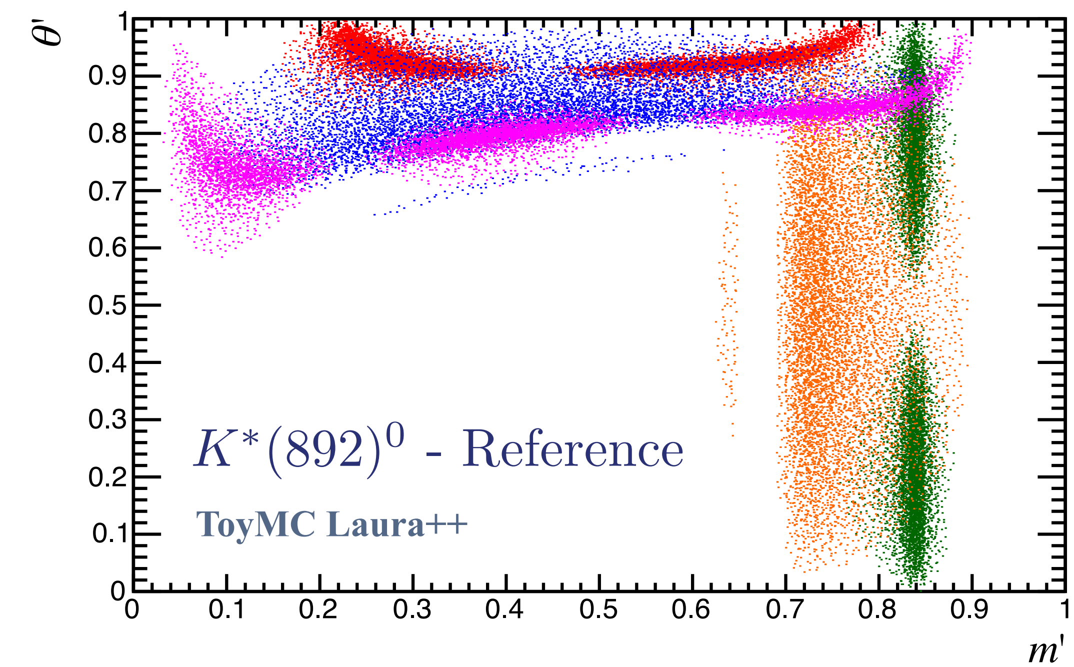
Simultaneous unbinned DP fit based on the JFit [arXiv:1409.5080] framework is performed for each event i and signal/background k component as

$$\mathcal{L} = \prod_i^{N_c} \left[\sum_k N_k \mathcal{P}_k \left(m_i^2(K^{\pm}\pi^{\mp}), m_i^2(K_S^0\pi^{\mp}) \right) \right]$$

$$m' \equiv \frac{1}{\pi} \arccos\left(2 \frac{m_{K^{\pm}\pi^{\mp}} - m_{K^{\pm}\pi^{\mp}}^{\min}}{m_{K^{\pm}\pi^{\mp}}^{\max} - m_{K^{\pm}\pi^{\mp}}^{\min}} - 1 \right)$$

$$\theta' \equiv \frac{1}{\pi} \theta_{K^{\pm}\pi^{\mp}}$$

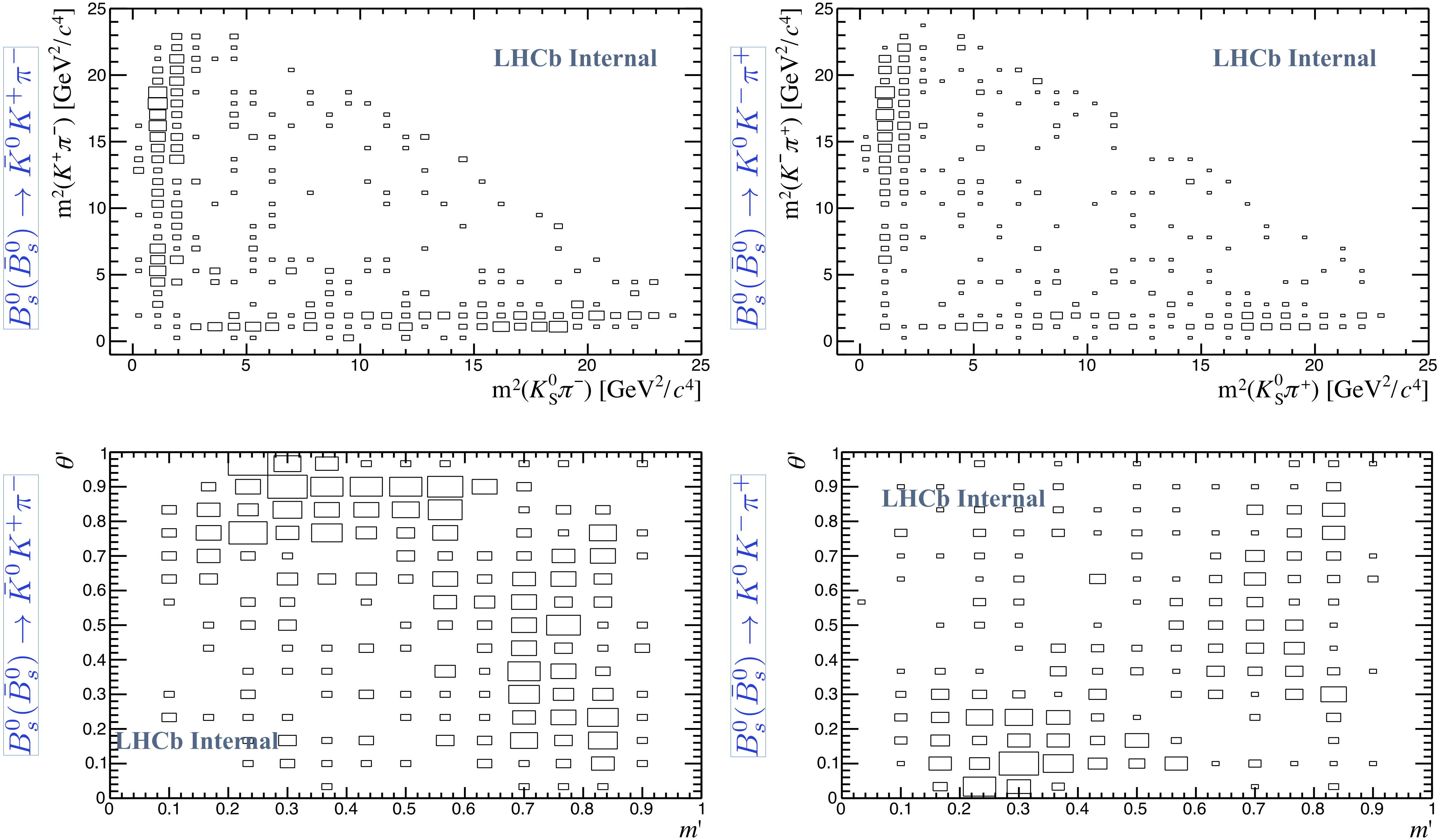
Resonance	Spin	Model	Mass (MeV/c^2)	Width (MeV)
$K^*(892)^0$	1	Rel BW	895.81 ± 0.19	47.4 ± 0.6
$K^*(892)^{\pm}$	1	Rel BW	891.66 ± 0.26	50.8 ± 0.9
$K_0^*(1430)^0$	0	LASS	1425 ± 50	270 ± 80
$K_0^*(1430)^{\pm}$	0	LASS	1425 ± 50	270 ± 80
$K_2^*(1430)^0$	2	Rel BW	1432.4 ± 1.3	109 ± 5
$K_2^*(1430)^{\pm}$	2	Rel BW	1425.6 ± 1.5	98.5 ± 2.7



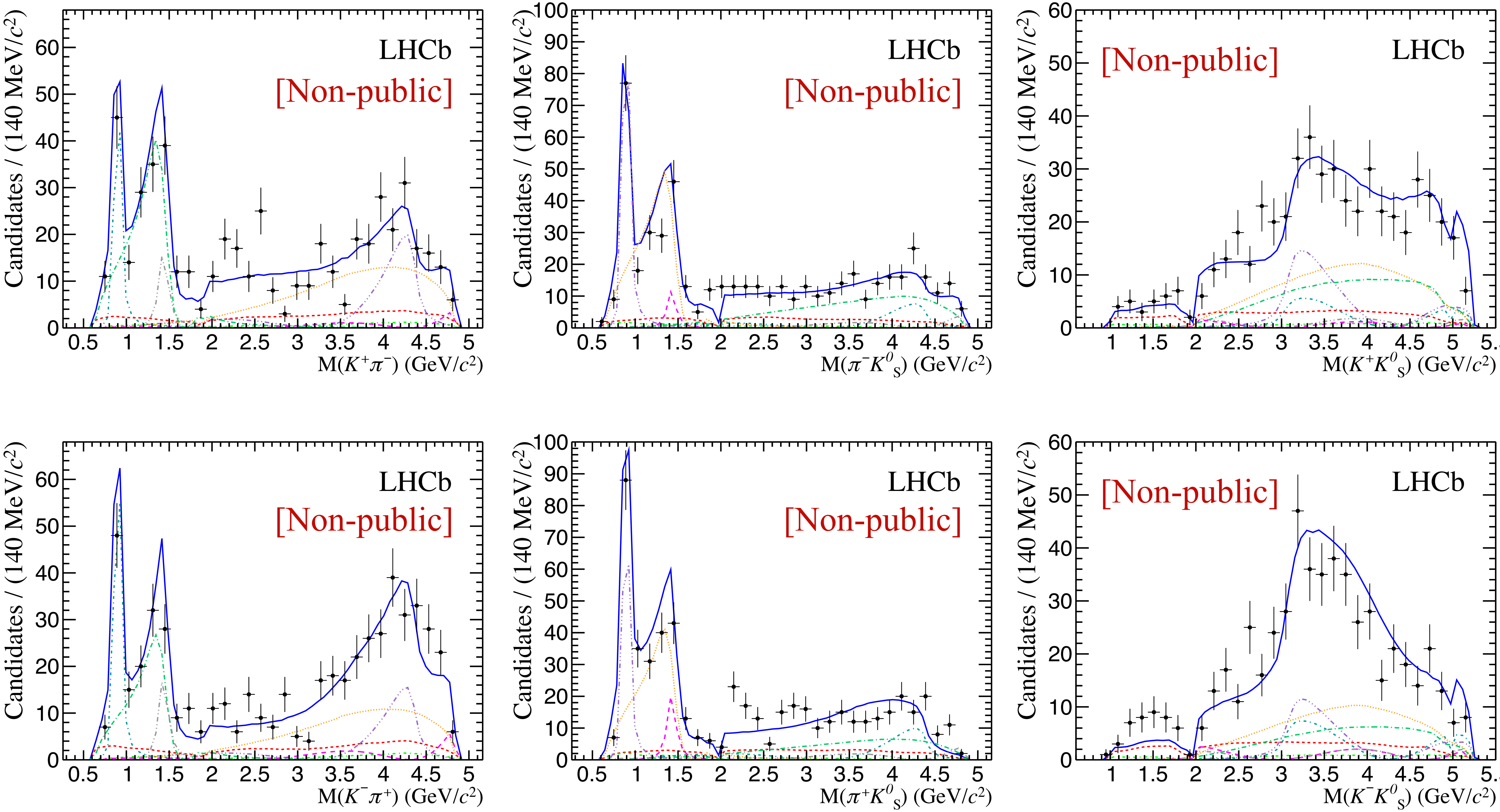
Multiple solutions :

- It is possible the during the process of minimisation the fit finds multiple solutions.
- To ensure a global minimum, each fit is repeated **100** times with randomised values
- The solution with the smallest negative log-likelihood is taken as the default result.

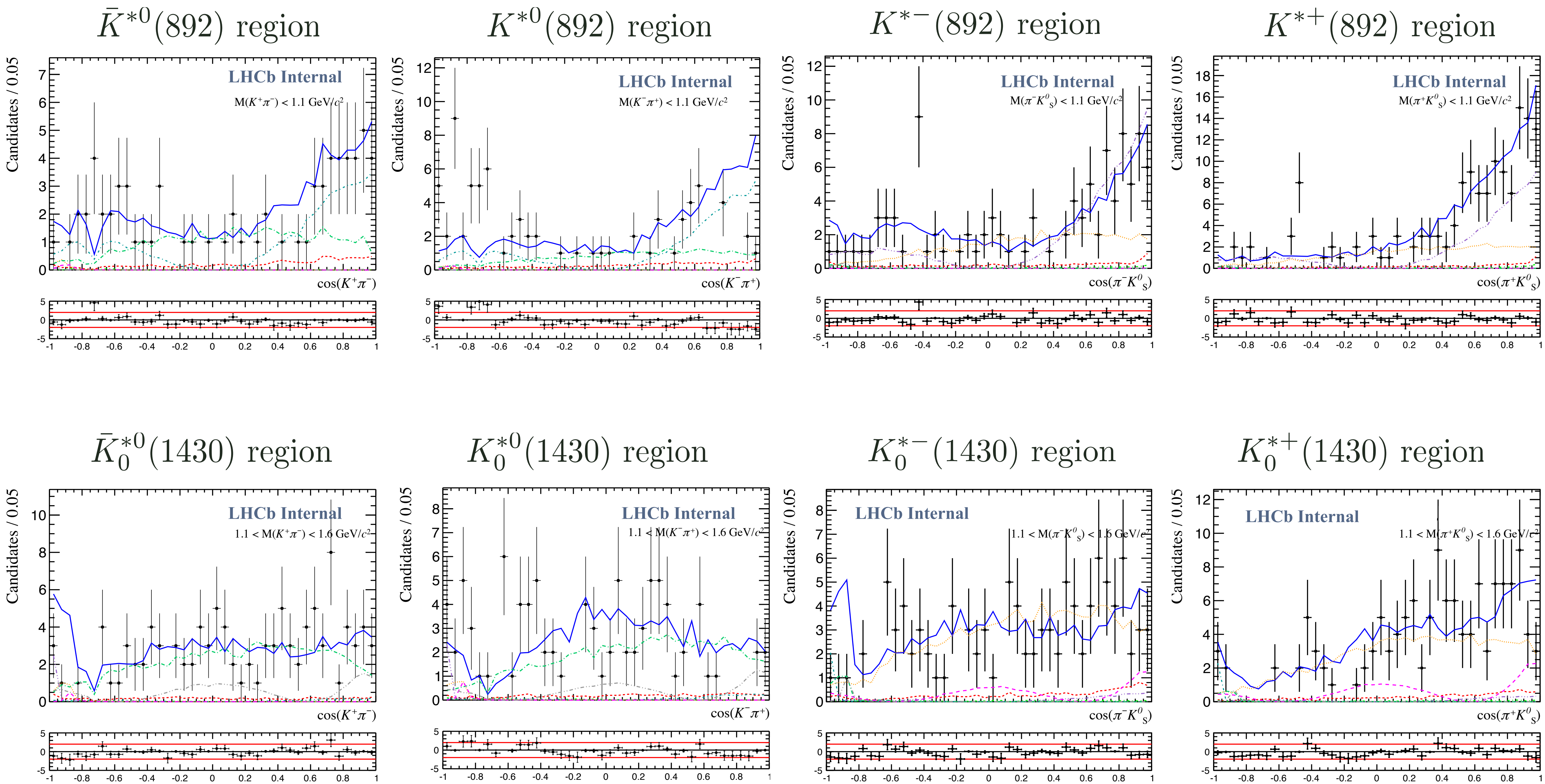
Phase-space distributions



Fit results - Invariant mass projections



Fit results - helicity angle projections



Fit results - isobar parameters

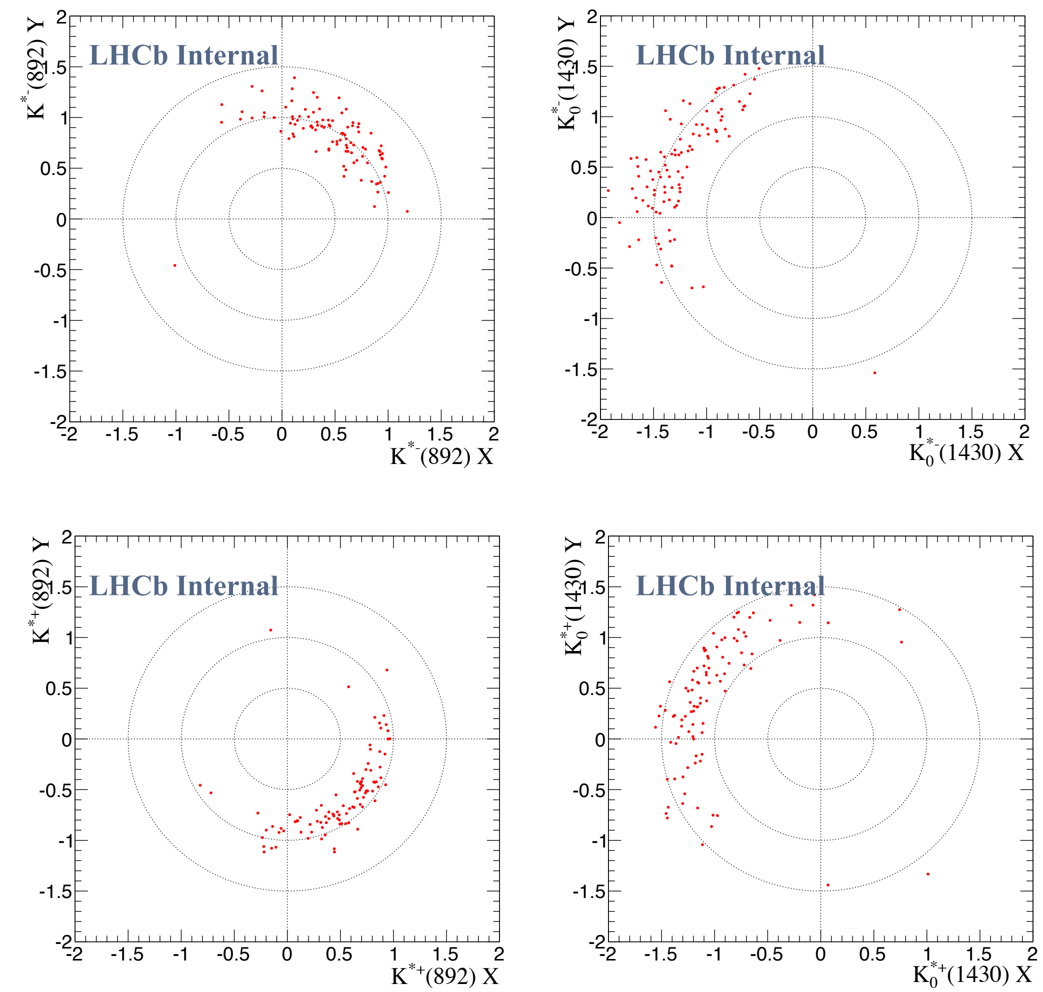
$B_s^0(\bar{B}_s^0) \to K_S^0 K^+ \pi^-$

Resonance	Fit fraction (%)	Isobar model coefficients Real part	 Imaginary part
$\bar{K}^*(892)^0$	13.2 ± 2.4	1.00	0.00
$\bar{K}_0^*(1430)^0$	33.9 ± 2.9	-1.33 ± 0.24	0.90 ± 0.31
$\bar{K}_2^*(1430)^0$	5.9 ± 4.0	0.01 ± 0.20	-0.67 ± 0.15
$K^*(892)^-$	15.6 ± 1.5	0.28 ± 0.48	1.05 ± 0.19
$K_0^*(1430)^-$	30.2 ± 2.6	-1.45 ± 0.24	0.42 ± 0.58
$K_2^*(1430)^-$	2.9 ± 1.3	0.05 ± 0.19	-0.47 ± 0.14
Total fit fraction	102		

$B_s^0(\bar{B}_s^0) \to K_S^0 K^- \pi^+$

Resonance	Fit fraction (%)	Isobar model coefficients Real part	 Imaginary part
$K^*(892)^0$	19.2 ± 2.3	1.00	0.00
$K_0^*(1430)^0$	27.0 ± 4.1	1.13 ± 0.17	-0.38 ± 0.34
$K_2^*(1430)^0$	7.7 ± 2.8	-0.48 ± 0.18	0.41 ± 0.21
$K^*(892)^+$	13.4 ± 2.0	-0.59 ± 0.32	0.59 ± 0.32
$K_0^*(1430)^+$	28.5 ± 3.6	1.17 ± 0.23	-0.32 ± 0.57
$K_2^*(1430)^+$	5.8 ± 1.9	-0.16 ± 0.25	0.52 ± 0.14
Total fit fraction	102		

Stability checks for observed differences in the isobar parameters indicated good determination of fit fractions



Systematic uncertainties

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Signal/background yields from mass fit

- Statistical: propagate using covariance matrix RMS from ensemble of 100 fits
- Fixed Parameters: similar to stat errors
- Alternative model: 1-CB and constraints on the background shape (nominal diff)

Background modelling

- Histograms are varied 100x and the data is refitted RMS from ensemble

Efficiency mapping

- Maps: similar to background model
- PIDCalib: different binning scheme

Fit intrinsic bias

- Pseudo-experiments

Fixed parameters in the DP fit

- Mass and widths of all resonances
- Blatt-Weisskopf radius parameters
- LASS parameters r and a
- Fit is repeated varying each of these and RMS of distribution is examined

Kπ S-wave model

- EFKLLM model is examined

Addition/removal marginal components

- Examples: insertion of insertion of the $a_2(1320)^{\pm}$ resonance

"Effective" flavour average approach

- Time-dependent toys to assign mis-modelling of the model approximation

Systematic uncertainties summary

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The results for the various sources of systematic uncertainties are given below:

	Fit fraction (%) uncertainties							
Resonance	Yields	Eff.	Bkg. SDP	Fit Bias	Add. Res.	Fixed Par.	Model Alt.	Total
$K^*(892)^-$	0.19	0.52	0.18	0.19	0.03	0.71	5.40	5.48
$K_0^*(1430)^-$	0.12	0.63	0.23	0.34	0.06	2.12	22.00	22.1
$K_2^*(1430)^-$	0.14	0.29	0.12	0.58	0.10	1.82	2.20	2.94
$\overline{K}^*(892)^0$	0.22	0.40	0.18	0.92	0.02	0.35	7.00	7.09
$\overline{K}_0^*(1430)^0$	0.16	0.89	0.34	0.36	0.06	4.38	3.30	5.58
$\overline{K}_2^*(1430)^0$	0.13	0.69	0.31	1.30	0.20	4.42	3.60	5.90
$K^*(892)^+$	0.39	0.62	0.12	0.46	0.12	0.75	1.10	1.60
$K_0^*(1430)^+$	0.47	0.69	0.38	0.76	0.16	6.44	13.00	14.6
$K_2^*(1430)^+$	0.07	0.41	0.20	0.24	0.15	4.13	4.50	6.14
$K^*(892)^0$	0.37	0.39	0.34	0.25	0.25	0.51	3.00	3.13
$K_0^*(1430)^0$	0.36	0.62	0.43	0.79	0.67	0.90	3.90	4.22
$K_2^*(1430)^0$	0.14	0.37	0.23	0.80	0.06	1.04	5.50	5.67

Dominant uncertainties come from the $K\pi$ S-wave model, e.*g*. the choice of the alternative line shapes to the LASS model for the $K^{*\pm,0}(1430)$ states

Slice in m($K^{\pm}\pi^{\mp}$) region: 1.1 - 1.6 GeV

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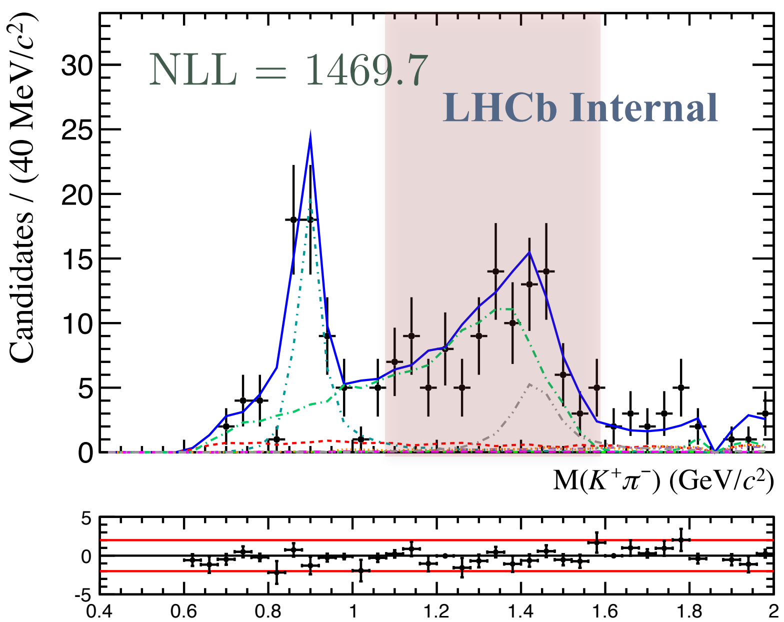
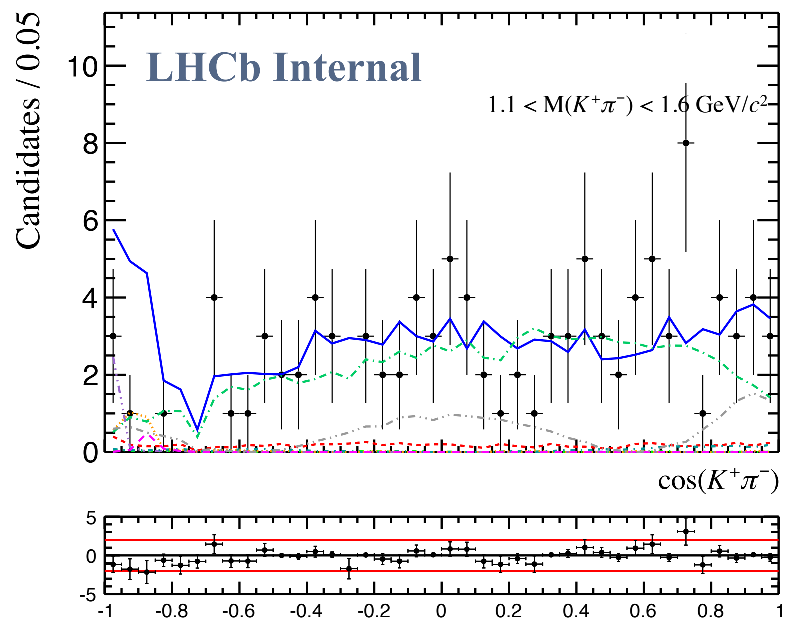
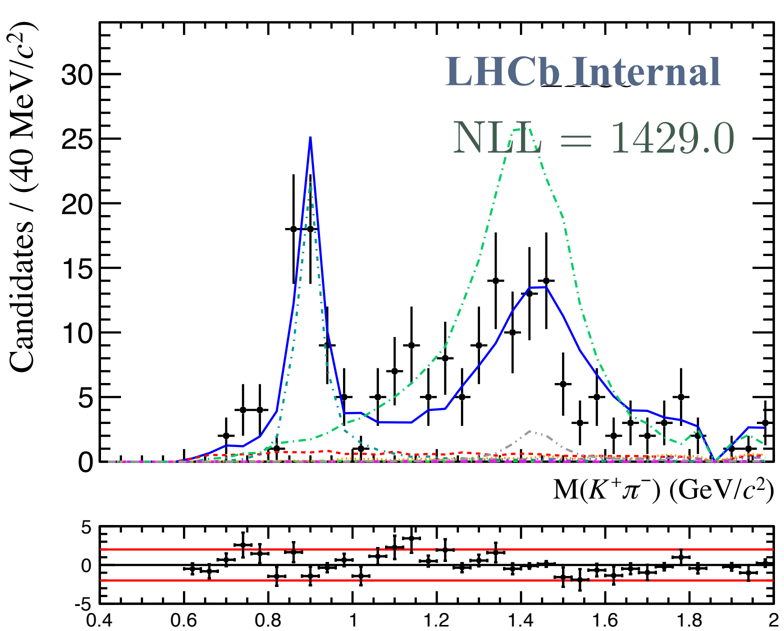
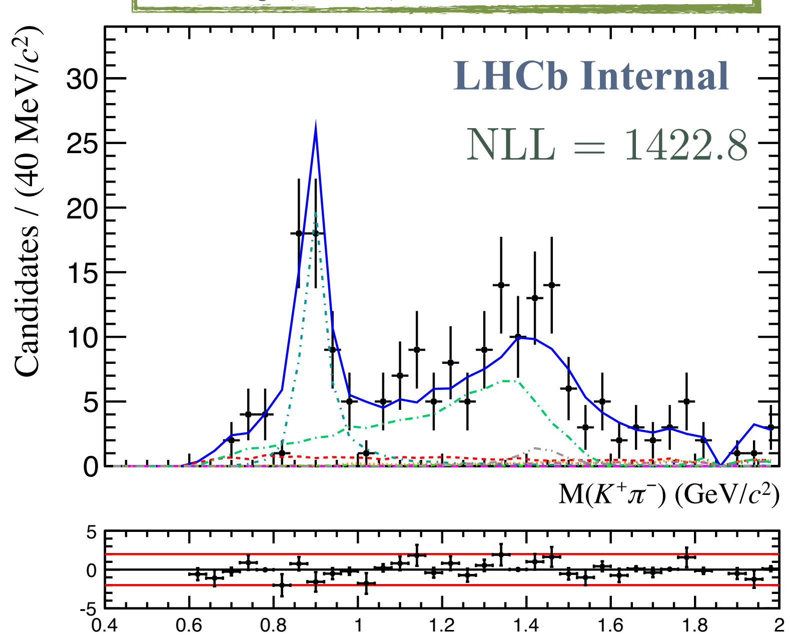




$K_0^*(1430)$ - LASS float



Phys. Rev. D 83, 039903 (2011)
$K_0^*(1430)$ - EFKLLM



The Kπ spectrum is modelled:

- **K*(892)** [Rel BW]
- **K^*_0(1430)** [LASS fixed]
- **K^*_2(1430)** [Rel BW]

Many alternative scenario have been investigated:

EFKLLM is used as alternative lineshape model (large systematics)

Significance of the $K^{*(\pm,0)}(1430)$ states

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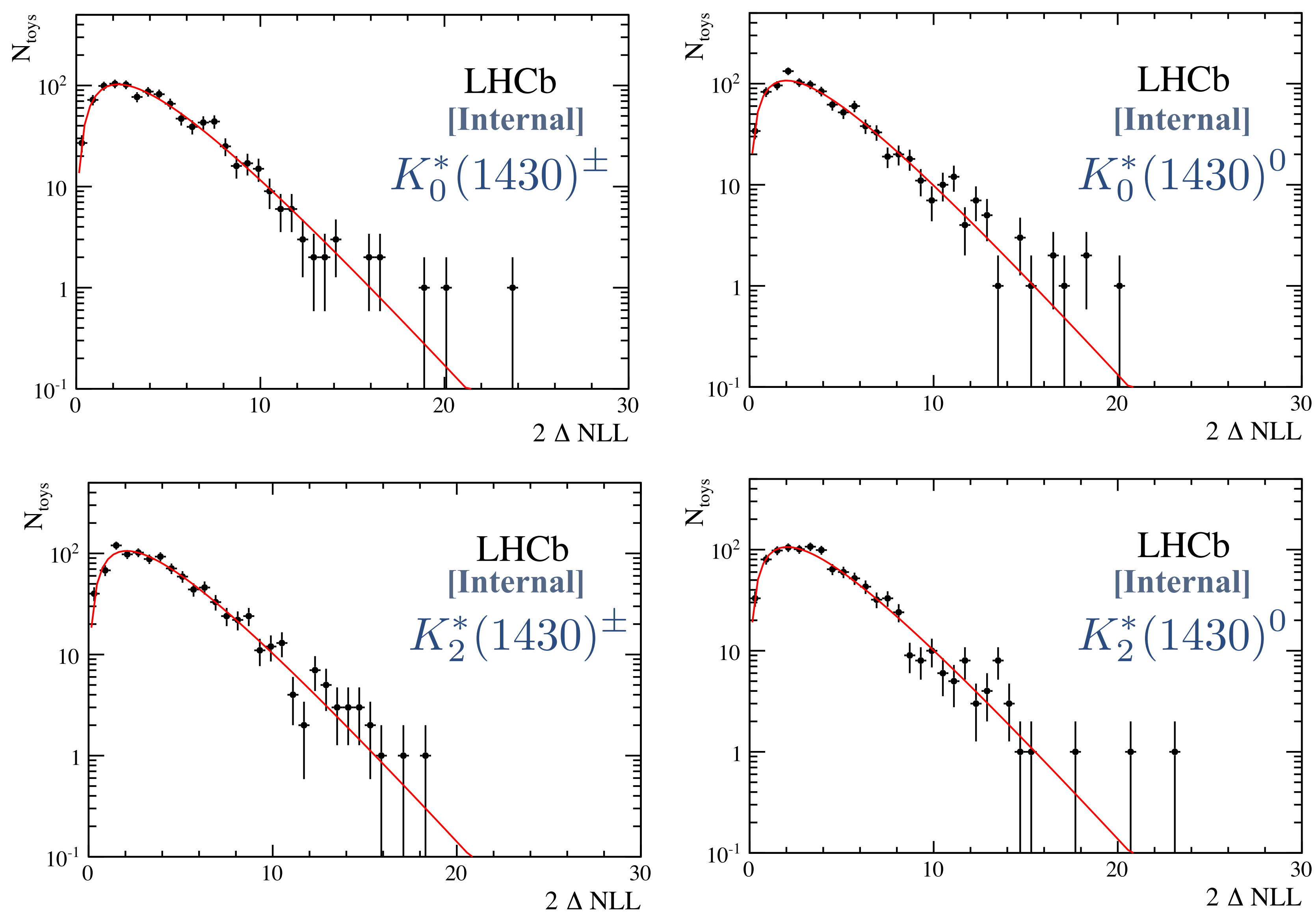
Series of ensembles were generated and fitted with and without the resonance included



$K^*_0(1430)$ resonances are seen with more than 15 standard deviations

Branching ratio results

The fit fractions of the resonant components can be converted into quasi-two-body BF:

$$\mathcal{B}\left(B_s^0 \to K^* K\right) = \widehat{FF}_j \times \mathcal{B}\left(B_s^0 \to \overset{(-)}{K}{}^0 K^\pm \pi^\mp\right)$$

$$\mathcal{B}(B_s^0 \to \overset{(-)}{K}{}^0 K^\pm \pi^\mp) = (73.6 \pm 5.7 \pm 6.9 \pm 3.0) \times 10^{-6}$$

$$\begin{aligned}
\mathcal{B}\left(B_s^0 \to K^*(892)^\pm K^\mp\right) &= (18.6 \pm 1.2 \pm 0.8 \pm \ \ 2.8 \pm 2.0) \times 10^{-6} \\
\mathcal{B}\left(B_s^0 \to K_0^*(1430)^\pm K^\mp\right) &= (31.3 \pm 2.3 \pm 0.7 \pm 17.8 \pm 3.3) \times 10^{-6} \\
\mathcal{B}\left(B_s^0 \to K_2^*(1430)^\pm K^\mp\right) &= (10.3 \pm 2.5 \pm 1.1 \pm 11.5 \pm 1.1) \times 10^{-6} \\
\mathcal{B}\left(B_s^0 \to \overset{(-)}{K}{}^*(892)^0 \overset{(-)}{K}{}^0\right) &= (19.8 \pm 2.8 \pm 1.2 \pm \ \ 3.0 \pm 2.1) \times 10^{-6} \\
\mathcal{B}\left(B_s^0 \to \overset{(-)}{K}{}_0^*(1430)^0 \overset{(-)}{K}{}^0\right) &= (33.0 \pm 2.5 \pm 0.9 \pm \ \ 6.1 \pm 3.5) \times 10^{-6} \\
\mathcal{B}\left(B_s^0 \to \overset{(-)}{K}{}_2^*(1430)^0 \overset{(-)}{K}{}^0\right) &= (16.8 \pm 4.5 \pm 1.7 \pm 14.8 \pm 1.8) \times 10^{-6}
\end{aligned}$$

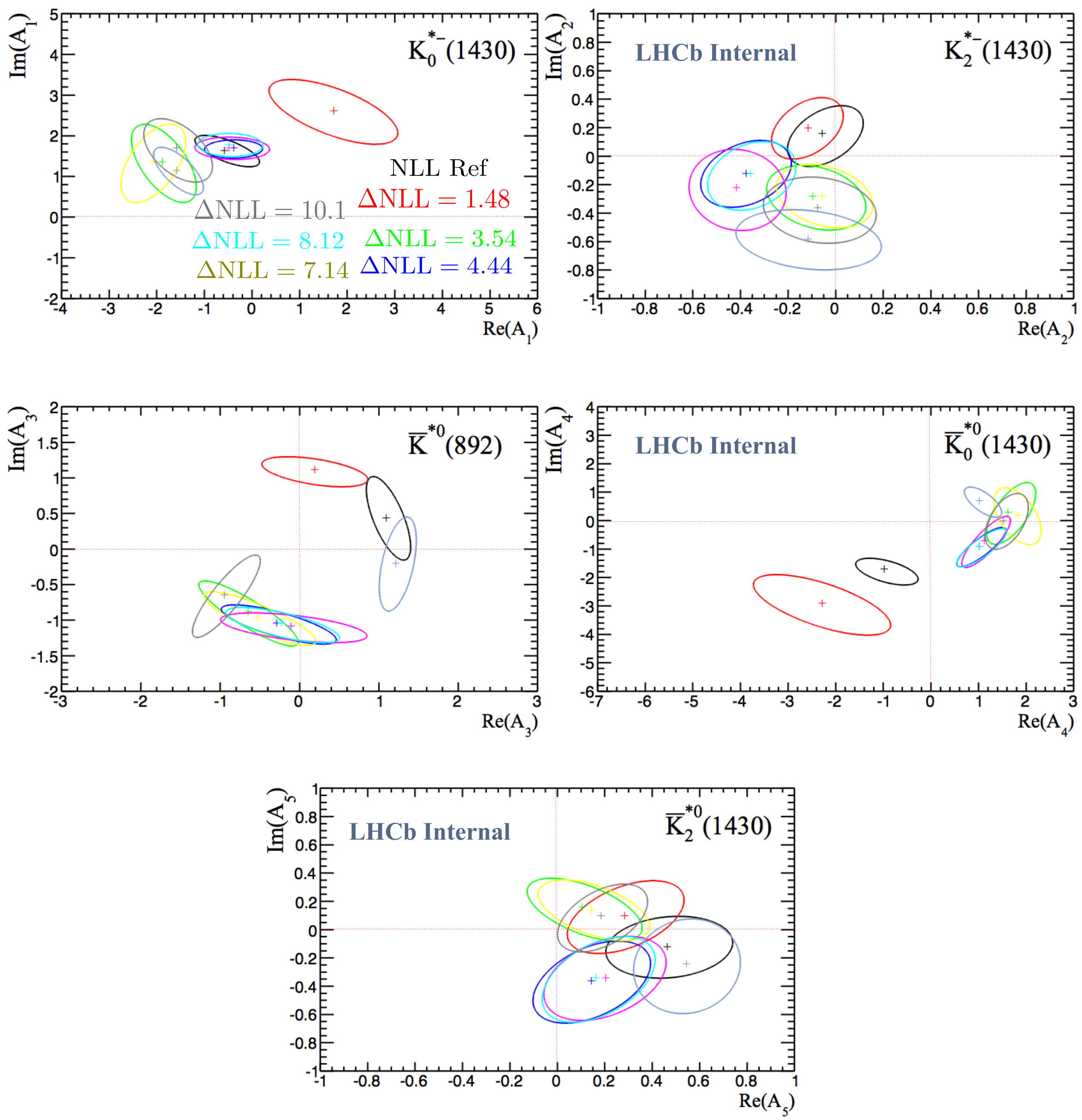
- Results are in good agreement with, and more precise than, the previous measurements
- Measurements for K*±0(1430) are largely dominated by S-wave modelling

Summary

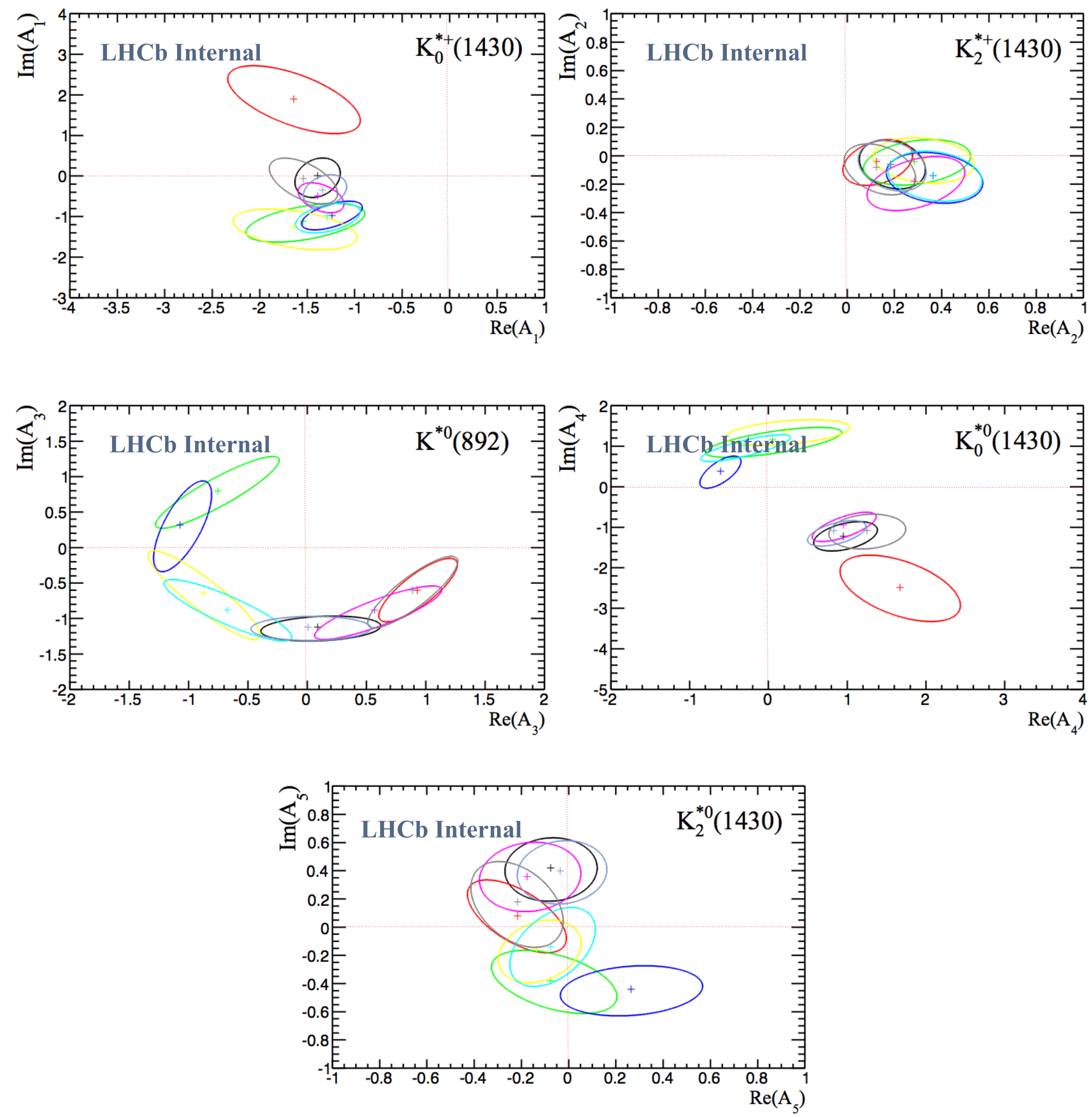
- Due to the approximations in the amplitude model, an untagged time independent approach can only provide information about the fit fractions
- All the steps of the analysis are finalised and paper draft is close to completion
  - Results for $K^{*0,\pm}(892)$ resonances indicate a good agreement with previous measurements
  - Systematics related to the $K^{*}(1430)$ resonances are currently the limiting factor in the measurement
  - Nevertheless, first observation of the $K^{*}(1430)$ states is obtained
- Full potential (e.g. ~~CP~~) of this channel will be only possible in LHCb Run 3-4

Secondary minima

Isobar parameters for $K^0_S K^+ \pi^-$

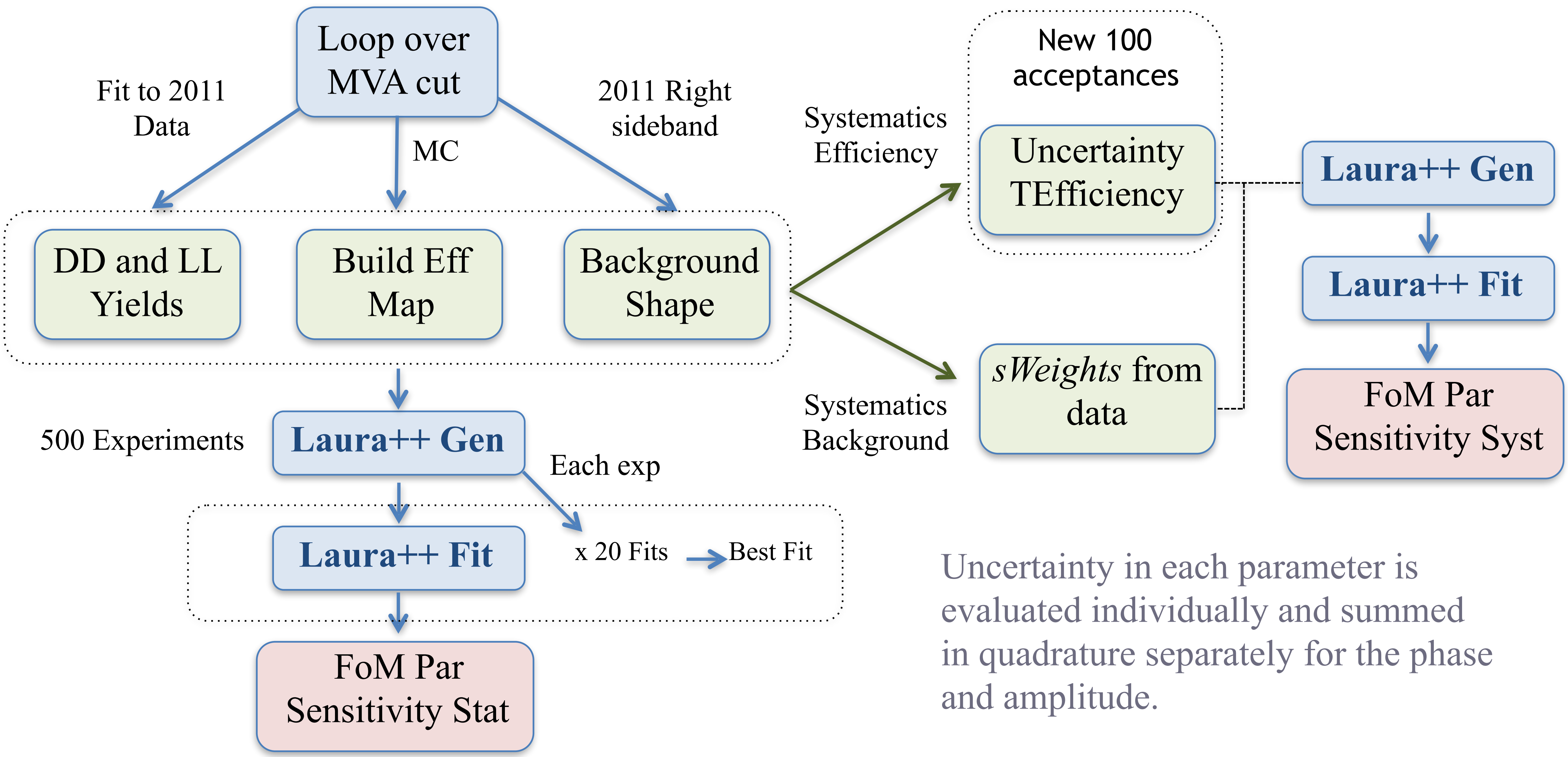


Isobar parameters for $K^0_S K^- \pi^+$



FoM selection optimisation framework

Framework : machinery developed to extract inputs from data and MC and provide to Laura++ to produce Toy MC's.



Uncertainty in each parameter is evaluated individually and summed in quadrature separately for the phase and amplitude.