Angular analysis of $B^+ \rightarrow K^{*+} \rho^0$ decays in Belle data

Belle II - Italia
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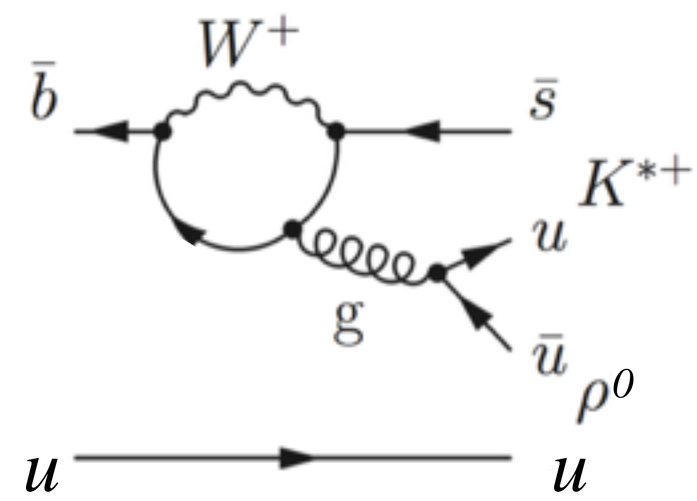
Introduction

$B^+ \rightarrow \rho^0 K^{*+}$
- $K^{*+} \rightarrow \pi^+ K^0$, $K^0 \rightarrow \pi^+\pi^-$
- $\rho^0 \rightarrow \pi^+\pi^-$

$B^+ \rightarrow \rho^0 K^{*+}$
- $K^{*+} \rightarrow K^+\pi^0$, $\pi^0 \rightarrow \gamma\gamma$
- $\rho^0 \rightarrow \pi^+\pi^-$



Full Belle dataset (711 fb^{-1}) analysed with the Belle II software

Observables:

- Br, A_{CP} and f_L (partial angular analysis -> integration over the azimuthal angle)

Motivations:

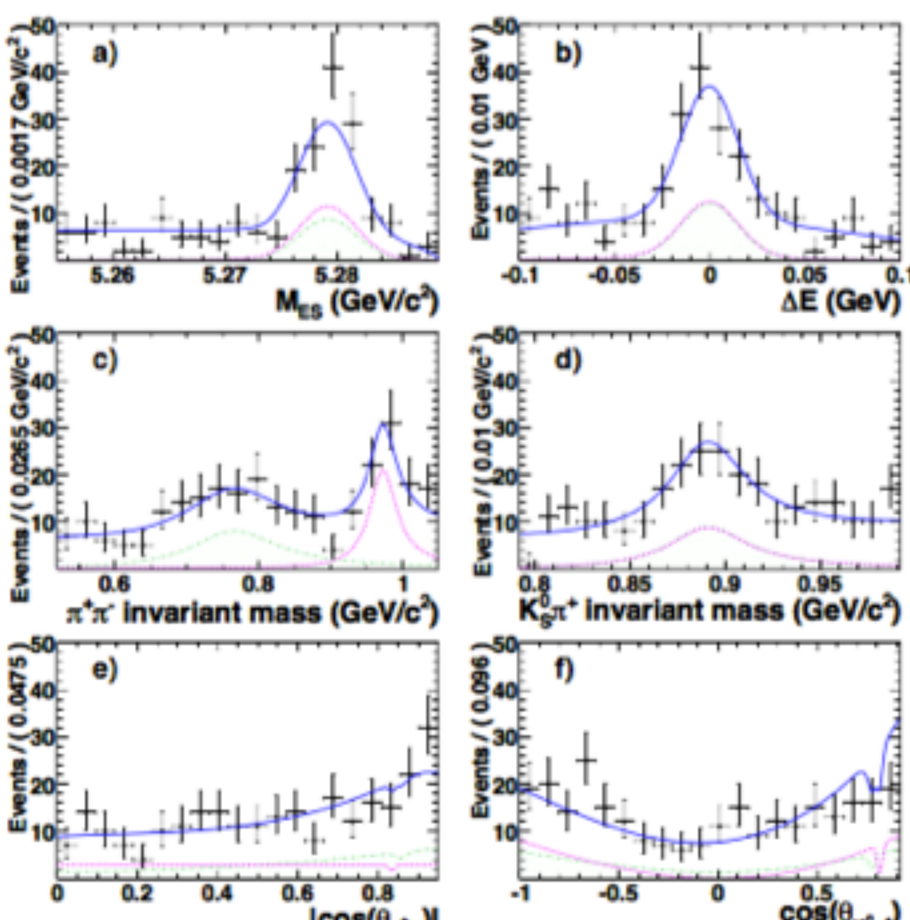
* Experimental test of B→VV helicity structure, test of enriched penguin contribution
  - Phys. Rev. D78:094001, 2008 Phys. Rev. Lett. 96:141801,2006
  - NLO predictions: arXiv:hep-ph/0612290
* DCPV in K*ρ system (intriguing anomalies from $K\pi$ modes)
  - Phys. Rev. D 87, 031103(R)
* Coming from a background of hadron collisions we aim to
  - Get familiar with B factories analysis in preparation for Belle II data
  - Contribute to Belle II software development/validation

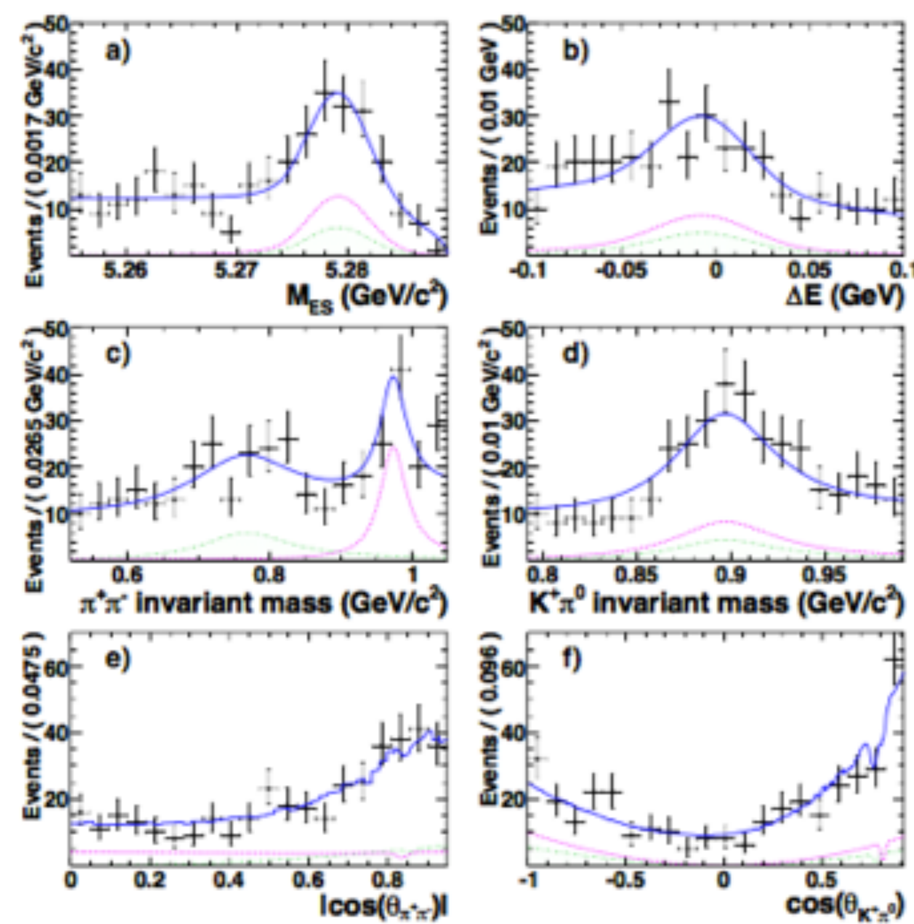
Experimental status

BaBar results: Phys. Rev. D83:051101,2011 arXiv:1012.4044v1

Mode	Y	ε(%)	S(σ)	B(x10^{-6})	f_L	A_{CP}
$B^+ \to \rho^0 K^{*+}$			5.3	4.6 ± 1.1	0.78 ± 0.12	0.31 ± 0.13
$K^{*+} \to K^0_S \pi^+$	85 ± 24	17.1	4.1	4.6 ± 1.3	0.74 ± 0.13	0.25 ± 0.14
$K^{*+} \to K^+ \pi^0$	67 ± 31	9.9	3.3	4.4 ± 2.1	0.94 ± 0.27	0.59 ± 0.31

Uncertainties dominated by the statistical component





Prospects

Rough estimation of expected number of events using existing Belle and BaBar yields in a similar channel:

$$N^{exp}(\rho^0 K^{*+}) = N^{BaBar}(\rho^0 K^{*+}) \times \frac{N^{Belle}(K^{*0}K^{*+})}{N^{BaBar}(K^{*0}K^{*+})}$$

	BaBar			Belle		
	$\mathcal{L}(fb^{-1})$	Nsignal		$\mathcal{L}(fb^{-1})$	Nsignal	
$B^+ \to K^{*0} K^{*+}(\to K^0_s \pi^+)$	426	6,9 arXiv:0901.1223	+4.5−3.5	711	15,8 arXiv:1502.00381	+7.2−6.1
$B^+ \to K^{*0} K^{*+}(\to K^+ \pi^0)$	426	13,9	+7.6−6.4	711	16,7	+7.6−6.5
$B^+ \to \rho^0 K^{*+}(\to K^0_s \pi^+)$	426	85 arXiv:1012.4044	±24	711	expected:	100-300
$B^+ \to \rho^0 K^{*+}(\to K^+ \pi^0)$,	426	67	±31	711	expected:	50-150

Potential for world leading result

Experimental challenges

- Get the analysers used with B-factory physics

Angular analysis with low-rate signal and large continuum background:

- Need effective background suppression that keeps to a minimum the biases on the angular observables

Wide ρ peak:

- Need to take into account cross-feed from many peaking backgrounds.
- Have to include $B \to K^* f_0$ as a signal

Analysis flow

1. Data preparation

2. Optimisation of the selection

3. Development and MC validation of the sample composition fit

4. Fit validation on a control sample of data

5. Fit on data and systematic uncertainties

Data Preparation

* Generation of signal and background MC using BASF framework

Standard Belle procedure for MC production. Generation with EvtGen + custom decay table

* Conversion of data, signal MC and generic MC to BASF2 format

Standard scripts of B2BII framework

Low signal, high background ⇒ selection is essential

HadronBJ Belle events, convert them to Basf2-compatible events and save those with candidates passed skim criteria

BASELINE SELECTION

$M(B^+)$	$\in[4.8, 5.5]GeV/c^2$
$M(\rho^0)$	$\in[0.5, 1.2]GeV/c^2$
$M(K^{*+})$	$\in[0.692,1.092]GeV/c^2$
π PID	>0.3
$M(J/\psi)$	$\in[2.95,3.25]GeV/c^2$
μ PID	>0.3

π^0

$E(\gamma)$	>0.1 GeV
$E(\pi^0)$	>0.25 GeV
$P(\pi^0)$	>0.4 GeV/c

K^0_s

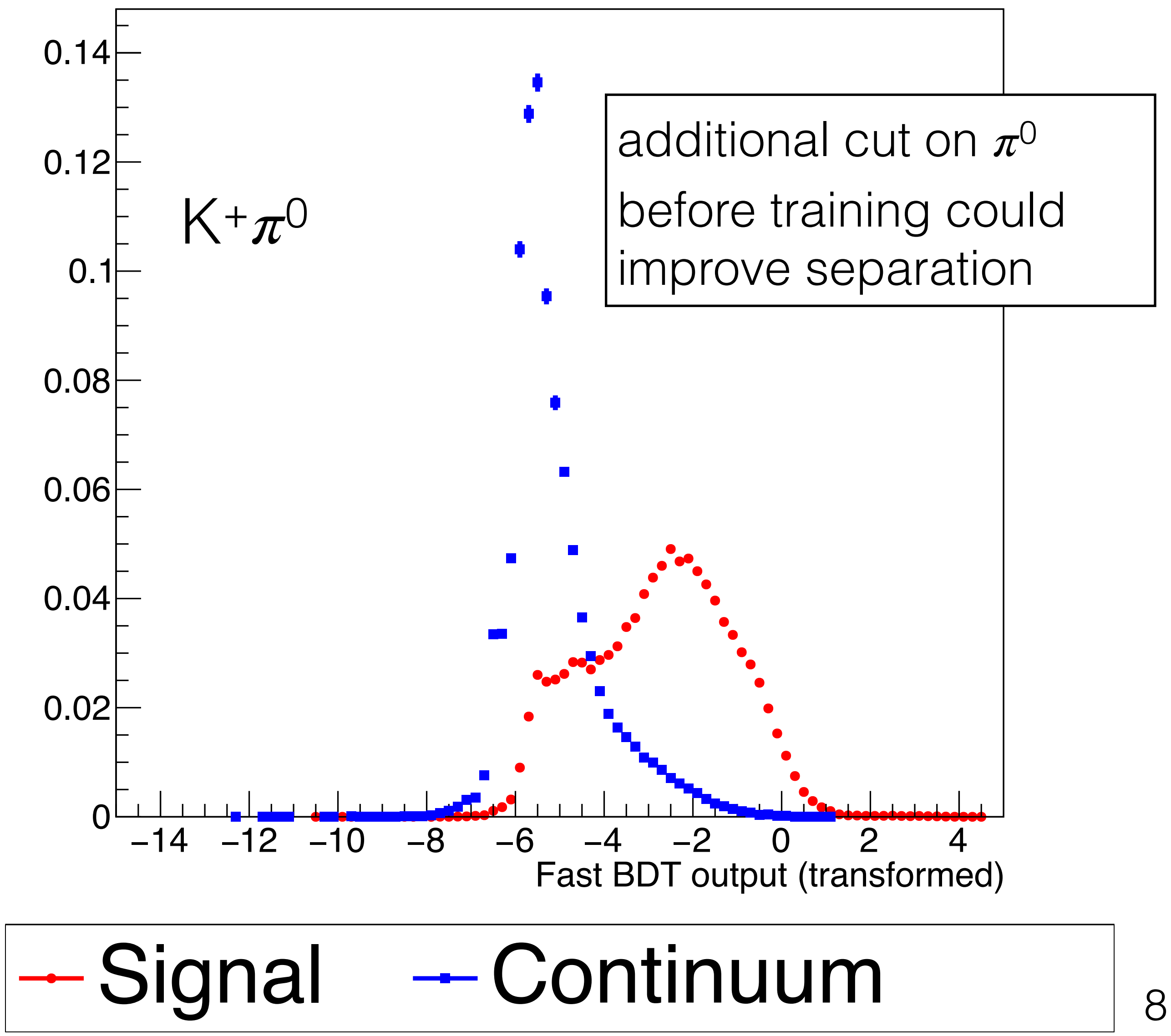
good K^0_s	VERO

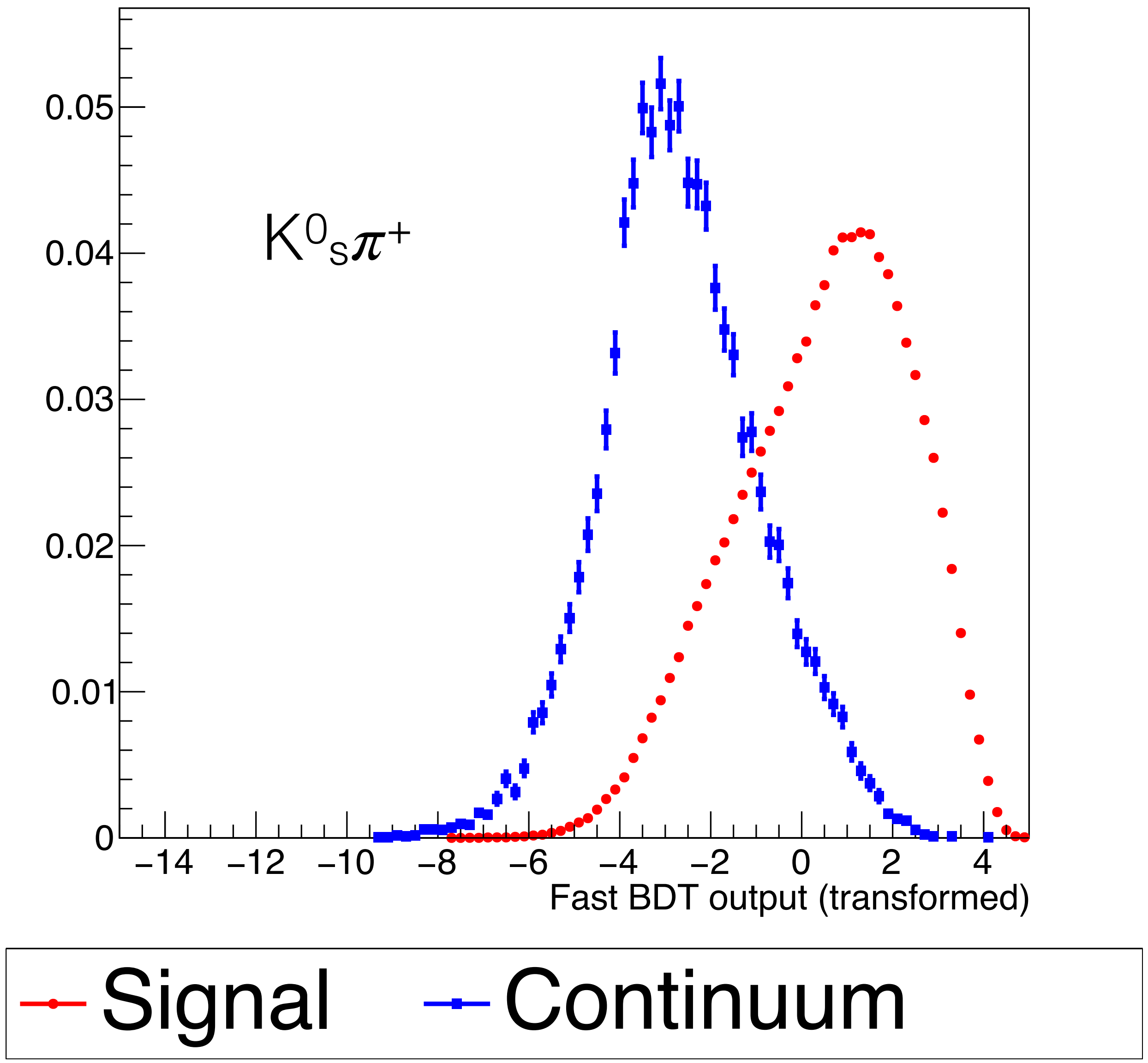
Need a dedicated selection tuning to suppress the background from the dominant continuum component and the several peaking contributions

Continuum background

Dominant background: $q\bar{q}$ continuum

Exploring the discriminating power of a novel tool developed for Belle II, the multivariate "Fast BDT" classifier trained on the simulate signal and off-resonance data





Other backgrounds

Non-resonant modes:

$B^+ \to \pi^0\pi^+\pi^- K^+$

$B^+ \to \pi^+\pi^+\pi^- K^0_s$

$B^+ \to \rho^0 \pi^0 K^+$

$B^+ \to \rho^0 \pi^+ K^0_s$

$B^+ \to f_0 \pi^0 K^+$

$B^+ \to f_0 \pi^+ K^0_s$

$B^+ \to \pi^+\pi^- K^{*+} (\to \pi^0 K^+)$

$B^+ \to \pi^+\pi^- K^{*+} (\to \pi^+ K^0_s)$

Misidentification ($\pi \to K$):

$B^+ \to \pi^0\pi^+\pi^- \pi^+$

$B^+ \to \rho^+\rho^0$

$B^+ \to \eta' \pi^+$

(Contributing to π^0 mode)

Swapped hadron:

$B^+ \to \rho^+ K^{*0}$

(Contributing to π^0 mode)

Charmed modes:

$B^+ \to D^0 (\to K^+\pi^0\pi^-) \pi^+$

$B^+ \to D^0 (\to K^0_s\pi^+\pi^-) \pi^+$

(Contributing to both modes)

η' mode:

$B^+ \to \eta' (\to \pi^0\pi^+\pi^-) K^+$

(Contributing to π^0 mode)

Self cross feed: After selection, we expect significant fraction of multiple candidates (15-30% with the current simple baseline selection)

Strategy to reduce self cross feed:

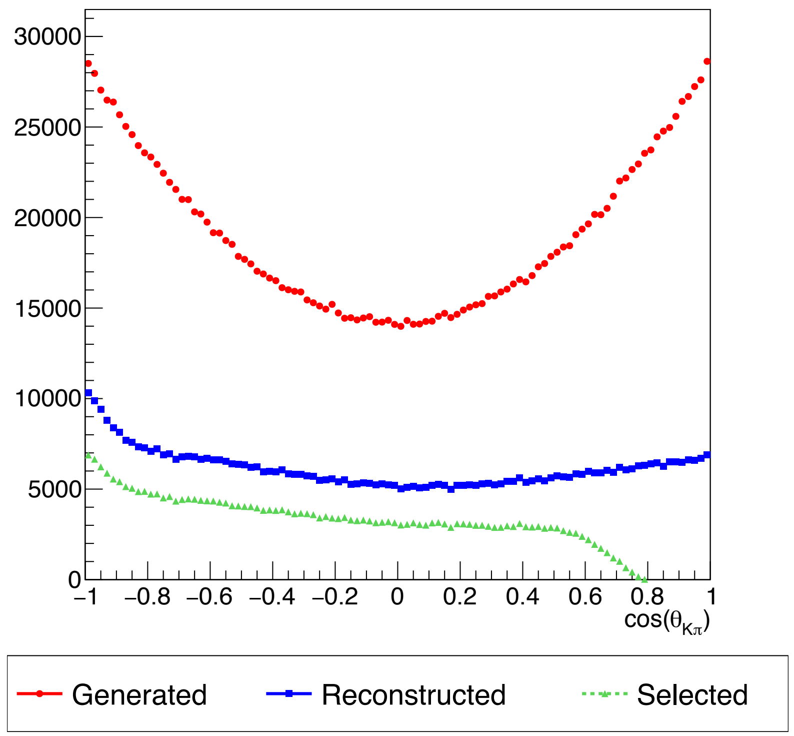
1. select best B-vertex fit

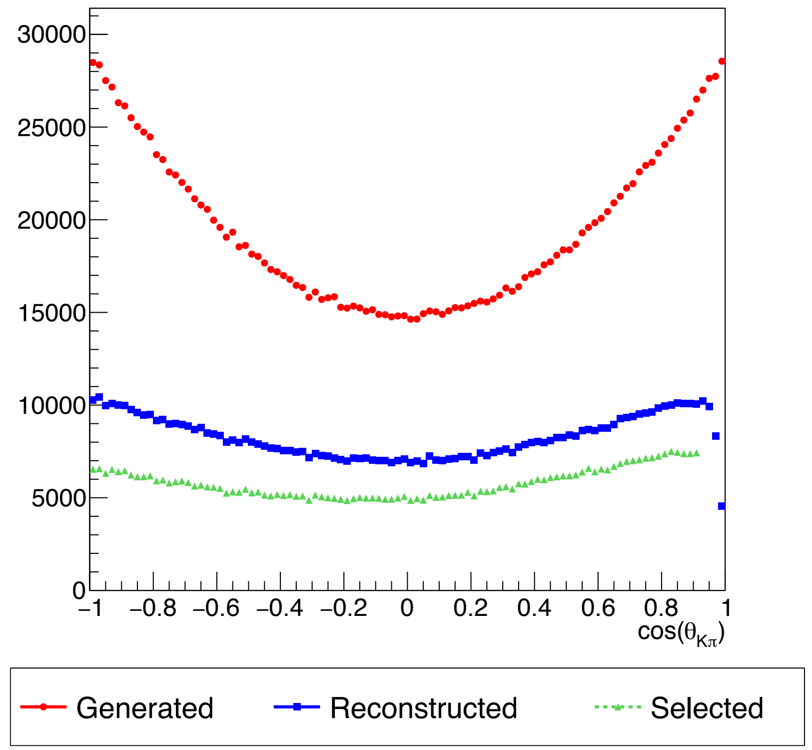
→ $(\varepsilon^{SIG} = 94\%, \varepsilon^{SxF} = 26\%)$

2. include self cross feed shape into our fit model

Optimisation

Angular variables before and after reconstruction and selection:





we need to optimise selection without biasing too much the angular distributions

Possible strategy:

- optimisation by empirically finding the dependence of the average expected fractional total uncertainty on the polarisation fraction σ_{f_L}/f_L on signal and background yields
- maximise the resulting figure of merit keeping the angular variables unbiased

First tests with the fitter

$B^+ \rightarrow \rho^0 K^{*+}$ yield and longitudinal fraction given by an unbinned maximum likelihood

Our first goal is to have a running fit machinery. Hence assume various simplifications:

* 6 observables: B mass, ρ^0 mass, ρ^0 helicity angle, delta E, K* mass, K* helicity angle

* only 2 components:
  - Signal $B^+ \rightarrow \rho^0 K^{*+}$
  - continuum uds background

* variables initially assumed independent ("Babar-like") - we will investigate impact of dependences once the selection is frozen

* Assume cross-feed-free sample

* testing the fit without any selection to decouple the issues associated with the fit machinery to those associated with the possible non-independence of the pdf on each other

TESTS DONE:

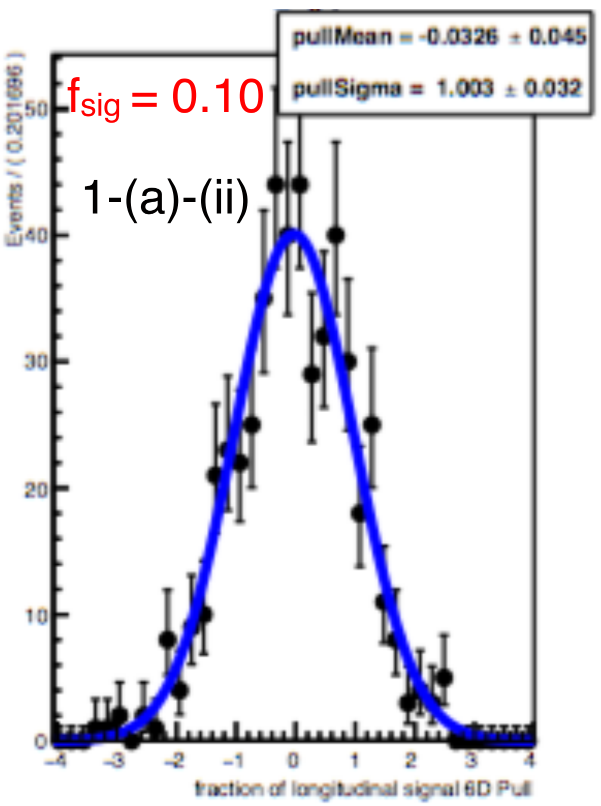
1. toy MC studies (draw events from the pdf and fit them under various configurations)
2. fit simulated signal and uds background MC without any selection applied

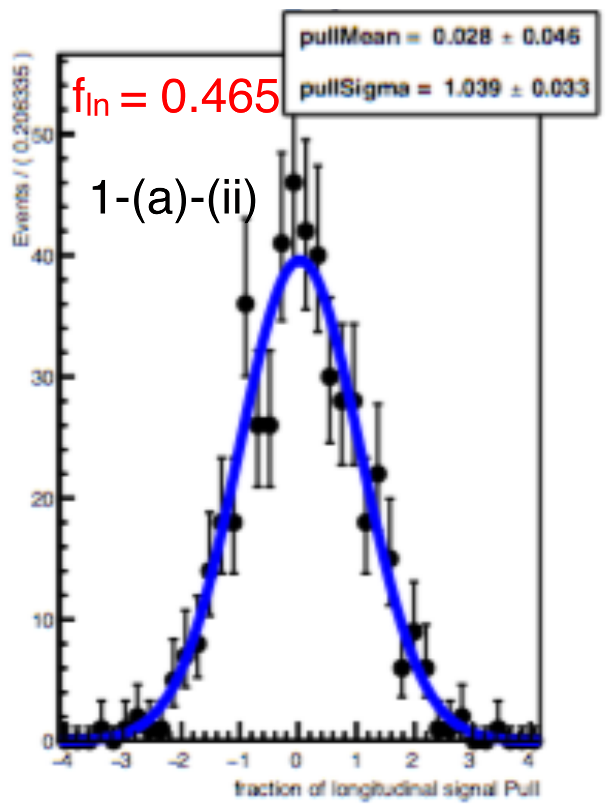
6D fit -> 2 floating parameters: the fraction of signal: f_{sig}, f_{ln}

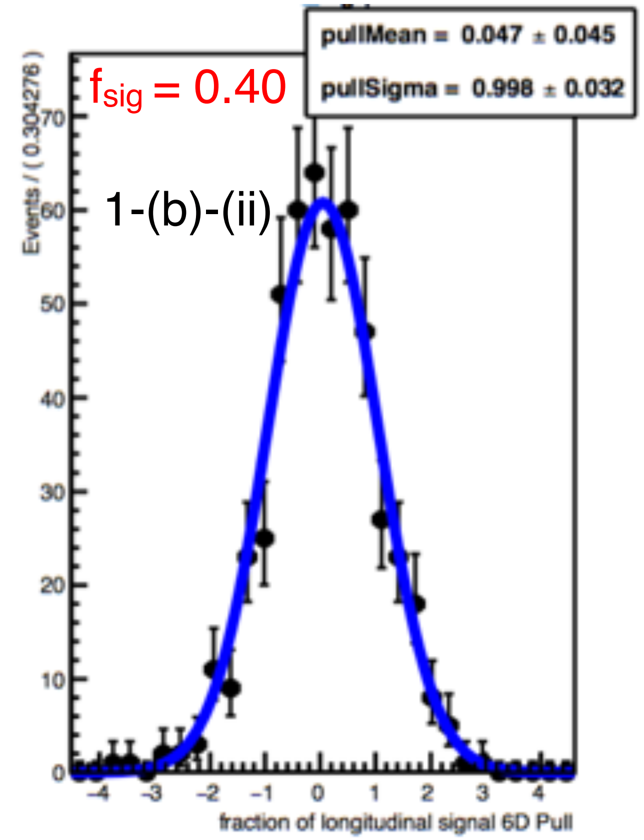
toy MC - pull distributions

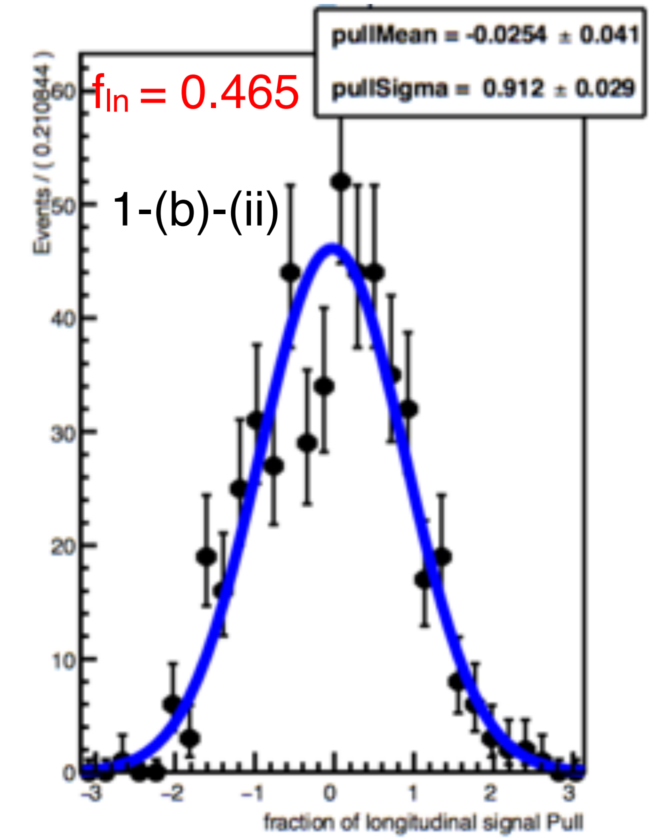
just an example

Generated 500 sets of 10^5 events with fixed fraction of signal (fsig = 0.1, 0.4, 0.9) and fixed fln (=0.465)







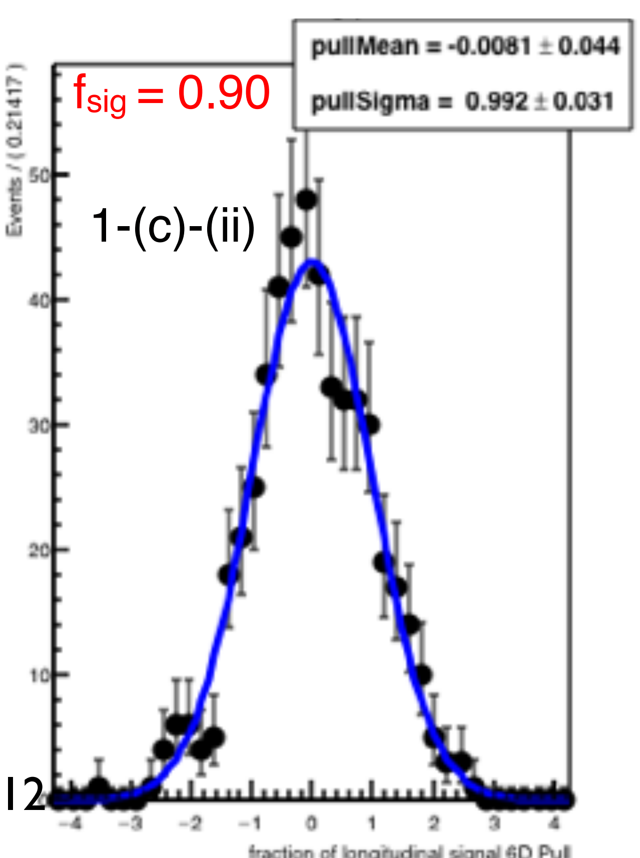


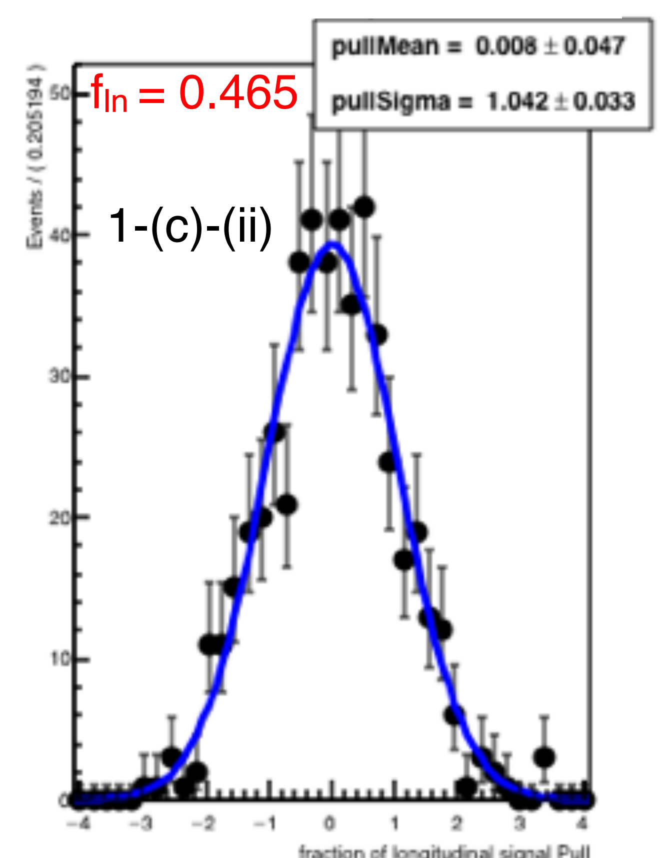
mean and sigma of pull distribution of fsig

	pull mean	pull sigma
f_{sig}= 0.1	-0.03 +-0.05	1.003 +-0.032
f_{sig}= 0.4	-0.047 +-0.045	0.998 +-0.032
f_{sig}= 0.9	-0.0081 +-0.044	0.992 +-0.031

mean and sigma of pull distribution of fln

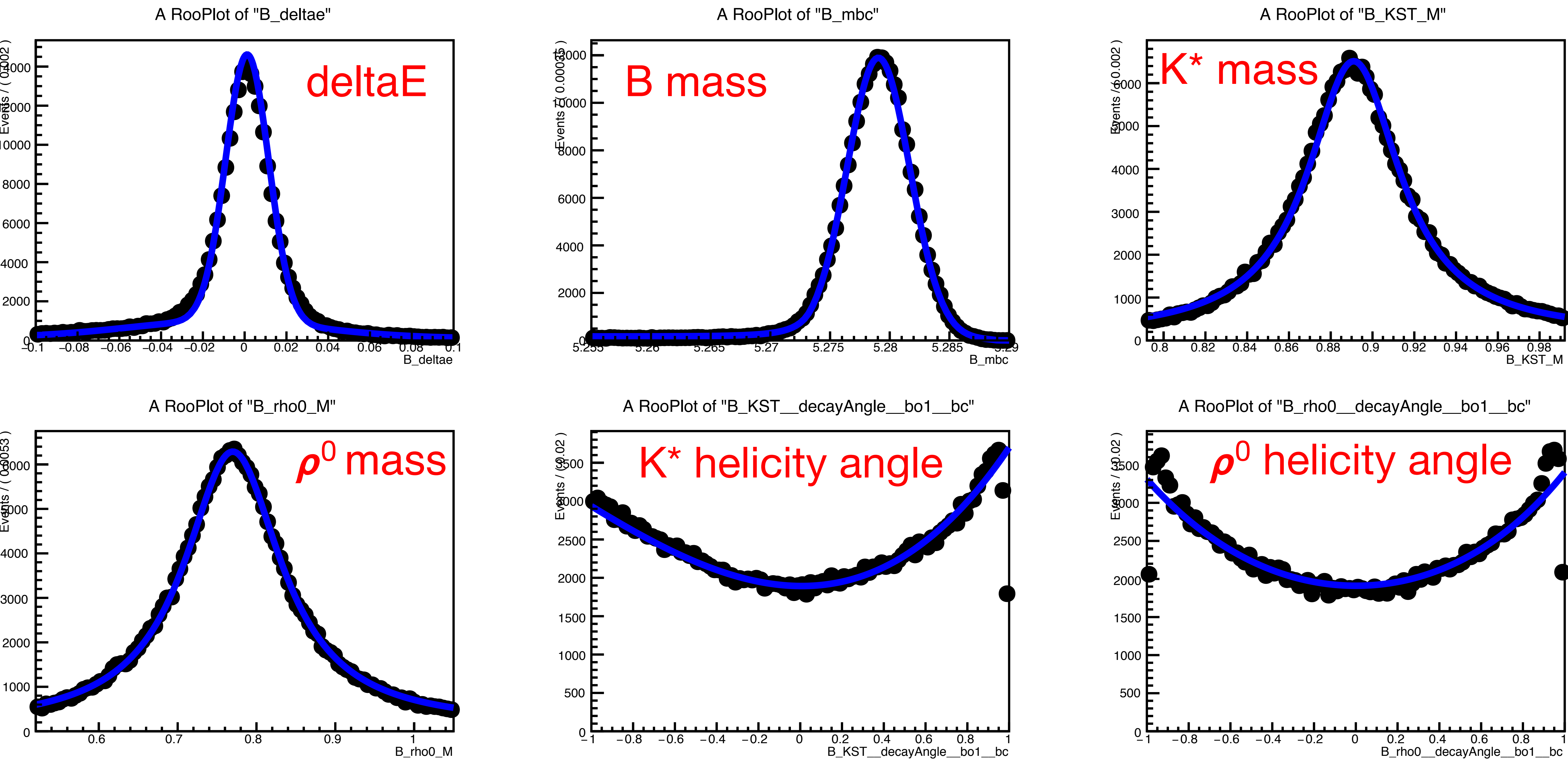
	pull mean	pull sigma
f_{sig}= 0.1	0.028 +-0.05	1.039 +-0.033
f_{sig}= 0.4	-0.0254 +-0.041	0.912 +-0.029
f_{sig}= 0.9	0.008 +-0.047	1.042 +-0.033





6D fit signal + uds background

projections of the 6 observables:



Floating Parameter	InitialValue	FinalValue +/- Error
f_ln	5.0000e-01	4.5642e-01 +/- 1.34e-03
f_sig_6D	5.0000e-01	9.4904e-01 +/- 5.88e-04

$f_{ln\ expected} = 0.476$

$f_{sig\ expected} = 0.973$

Biases are due presumably to the known mismodelings

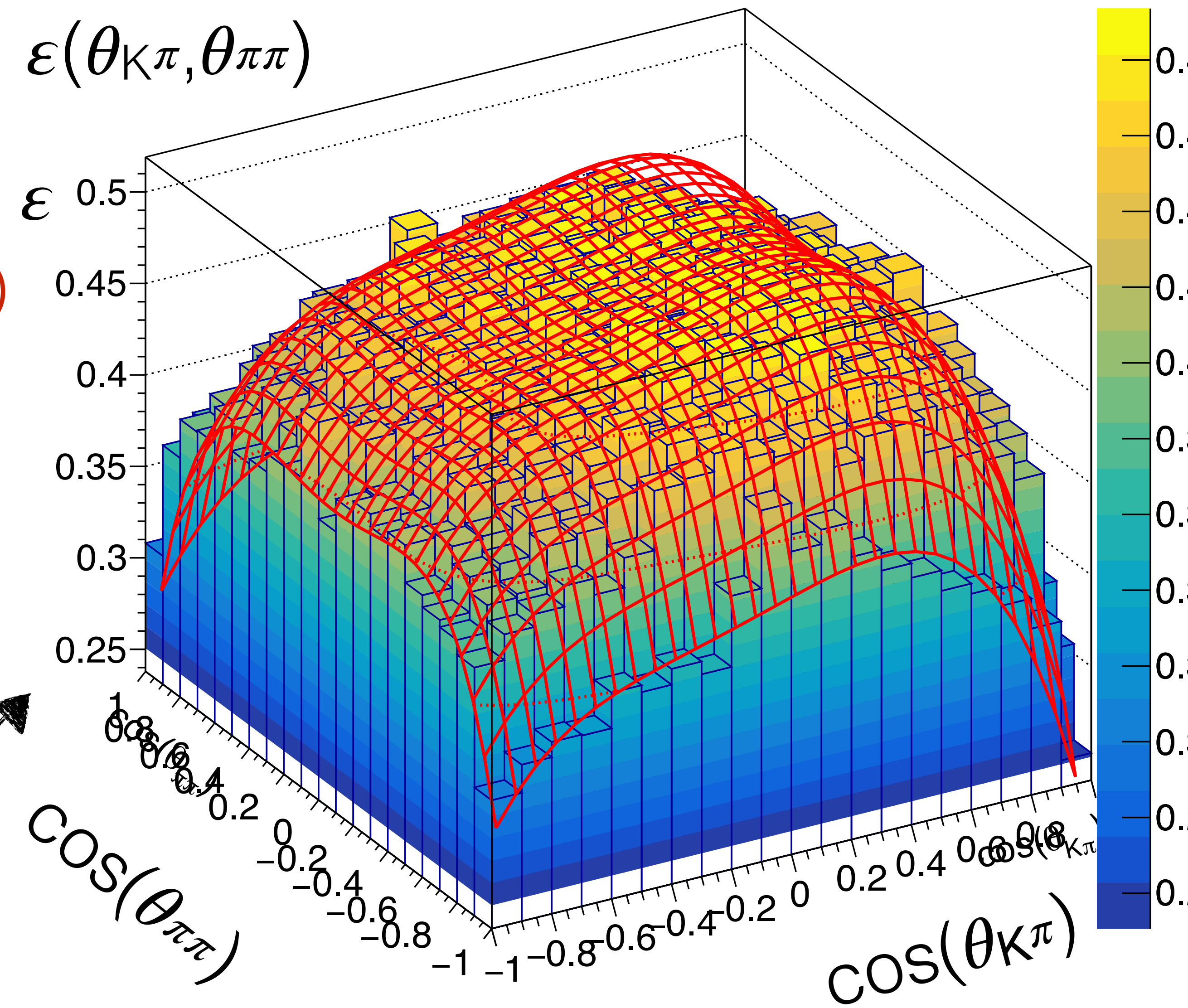
Correlations

We are now expanding our fitter to include the effect of correlated efficiencies and acceptances. The final treatment requires the selection to be frozen, but we are already exercising the machinery of parametrising correlated acceptances

- Physics correlations are known, but nontrivial acceptance/efficiency correlations are introduced by the selection.

$\text{PDF} = \text{PDF}(M_{K\pi}, M_{\pi\pi}, M_{bc}, \Delta E) \times \text{PDF}(\theta_{K\pi}, \theta_{\pi\pi})$

$\text{PDF}(\theta_{K\pi}, \theta_{\pi\pi}) = \text{PDF}^{GEN}(\theta_{K\pi}, \theta_{\pi\pi}) \times \varepsilon(\theta_{K\pi}, \theta_{\pi\pi})$



empirical efficiency function $\varepsilon(\theta_{K\pi}, \theta_{\pi\pi})$ has to be extracted from simulation

B2BII technical details

B2BII: technical details

Questions? ilya.komarov@ts.infn.it

- What?
  B2BII package allows for usage of BASF2 for analysis of Belle data/MC providing conversion of Belle MDST to Belle II MDST.

- Why?
  You don't know Belle software or you want to ensure swift transition of your analysis to Belle II.

- How?
  First, check B2BII Confluence page
  Second, check examples

- Missing conversions?
  CDC hit pattern

B2BII: tricks

Questions? ilya.komarov@ts.infn.it

- In converted mdst, neutral pions and kaons are stored in pi0:mdst and K_s0:mdst containers

- If you want to refit candidate containing neutral, make sure you refit the neutral first:

```
copyParticles('K_S0:my', 'K_S0:mdst', False)
massVertexRave('K_S0:my', 0, ‘')
```

- Working with Belle centrally-produced dataset you might want to skim them first. This can be done by adding filter sequence to Convert.py script.

- Recently we added set of scripts automatising job submission for full Belle data/MC samples.

Summary

- We started working on the $B^+ \to \rho^0 K^{*+}$ analysis
- We analyse the full Belle data set with the Belle II software
- Potential is there for a world's best measurement
- We have got decent control of the technical tools associated with data and MC production and processing
- We are now:
    - attacking the optimisation of the selection
    - developing the fitter
- We plan to get results by fall (and have gained some familiarity with B-factory analysis meanwhile)