Update on $B^0 \to \varphi K^0$ and first glance at $B^0 \to \eta' K^0$ time-dependent CP analysis

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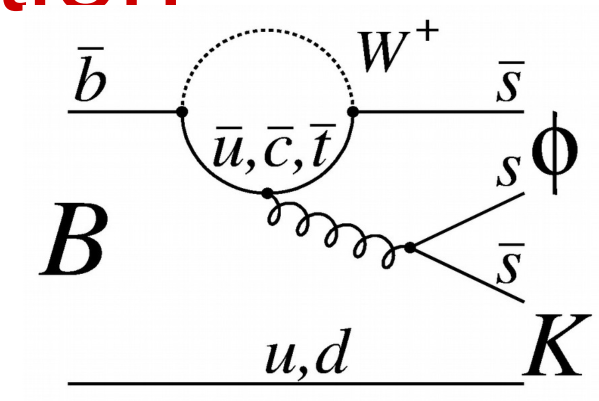
Outline

- $B^0 \to \varphi K^0$
  - Introduction and motivation
  - Analysis strategy
    - Helicity
  - Background with 100 fb^{-1} (BG0X and BG1X)
  - Impact of machine background on reconstruction
- $B^0 \to \eta' K^0$
  - First glance: efficiency and time resolution
- Summary and outlook

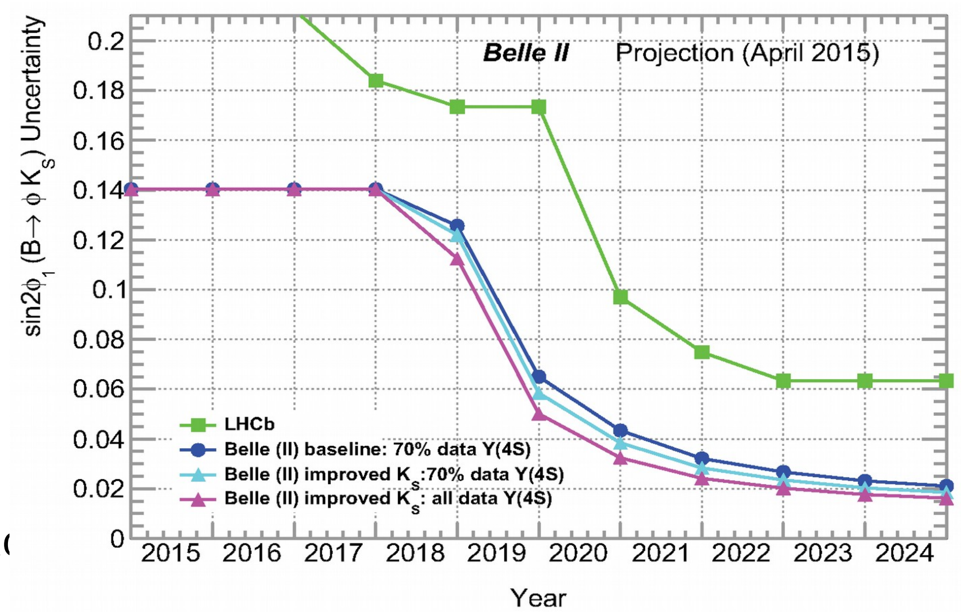
Introduction/Motivation

- This is a sensitivity study for the time-dependent CP-violation analysis of $B^0 \to \varphi K^0$;
  - Time-dependent CP asymmetry is little affected by "wrong-phase amplitudes", so it's expected to be tightly related to $\sin2\beta/\varphi_1(\psi K^0)$ (and V_{ub});
  - NP can enter in the loop, shifting CPV parameters from $B^0 \to cc\, K^0$ more than SM prediction (small);



- A good channel for early data:
  - Competition with LHCb
  - Errors dominated by statistics, quick progress wrt Belle/BaBar.
- Good channel for detector commissioning
  - Vtx, B-flavour tag, PID, ...

P. Urquijo (BELLE2-NOTE-PH-2015-004)

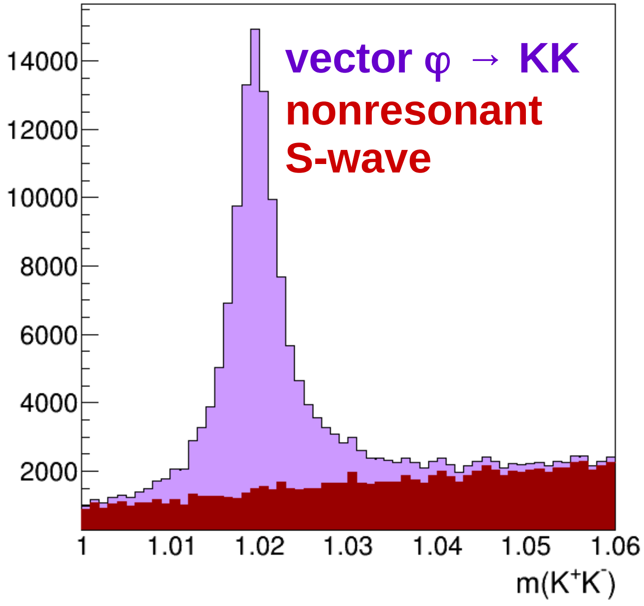


Analysis strategy

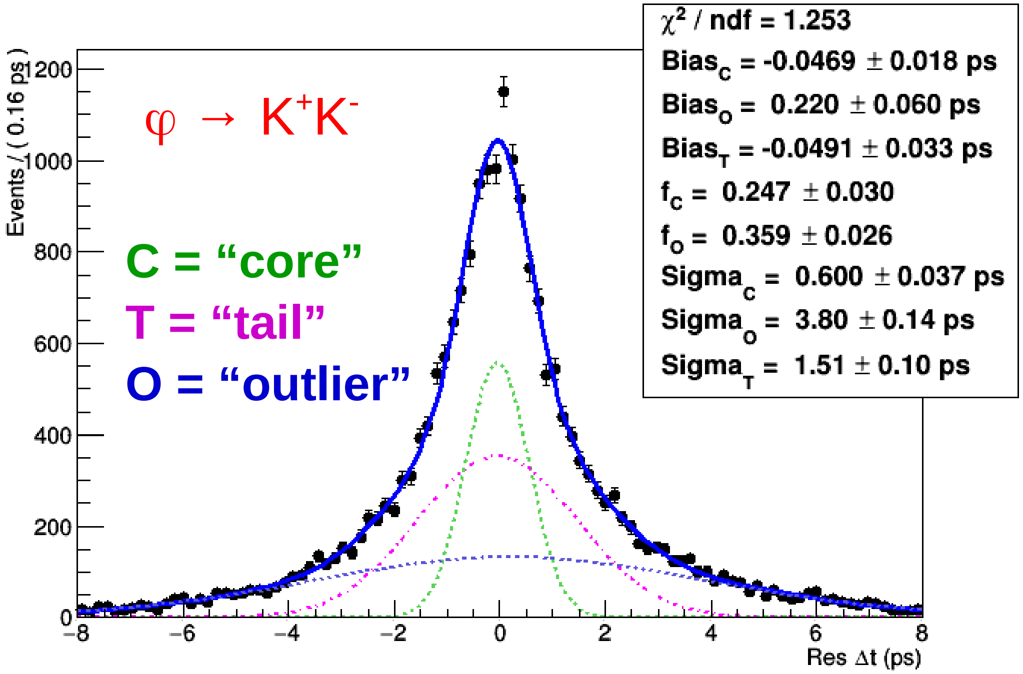
- The most complete approach for this channel is a Dalitz plot analysis of $K^+K^-K^0$ BaBar: PRD 85, 112010 (2012) Belle: PRD 82, 073011 (2010)
- Start with a simpler quasi-two body approach, restricting the K^+K^- invariant mass range around the φ mass;
  - $\varphi\ (K^+K^-)\quad K_S\ (\pi^+\pi^-)$
  - $\varphi\ (K^+K^-)\quad K_S\ (\pi^0\pi^0)$
  - $\varphi\ (\pi^+\pi^-\pi^0)\ K_S\ (\pi^+\pi^-)$
  - $\varphi\ (K^+K^-)\quad K_L$ (not yet)

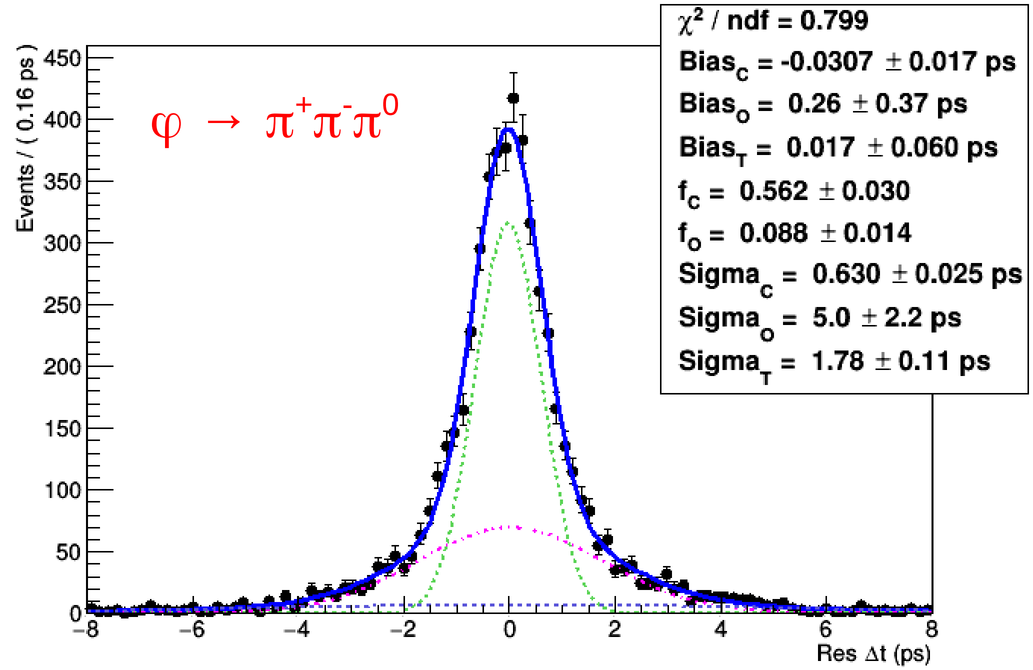
Not studied at BaBar/Belle:
- ✗ Low $\varphi \to 3\pi$ branching fraction (15%);
- ✗ Higher background;
- ✔ Better Δt resolution (higher p track);
- ✔ Practice for ωK^0.

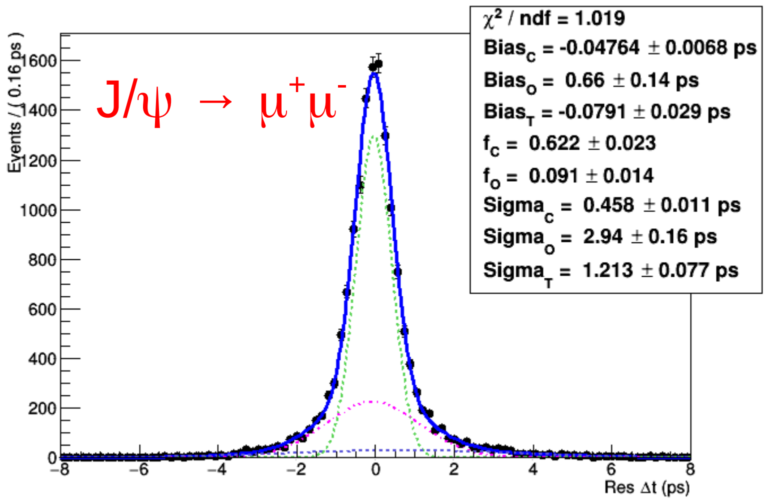
- Need to separate vector component (φ) from scalar:
  - helicity analysis
- Background



Efficiency and Δt resolution





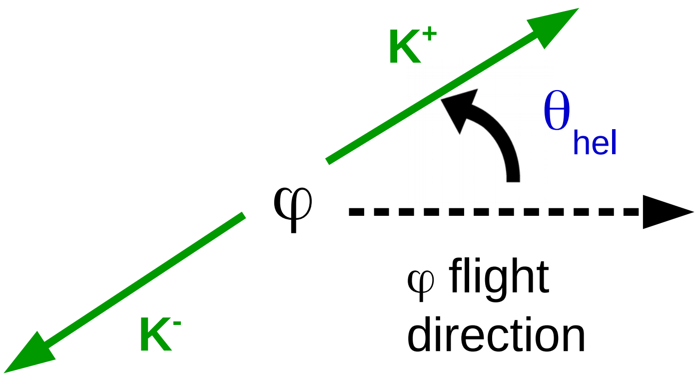


	Selection ε	Δt resolution
$\phi(K^+K^-) K_S$	35.2% $\pi^+\pi^-$ 13.7% $\pi^0\pi^0$	2.11 ps
$\phi(\pi^+\pi^-\pi^0)K_S(\pi^+\pi^-)$	28.3%	1.42 ps
$J/\psi(\mu^+\mu^-)K_S$		0.90 ps

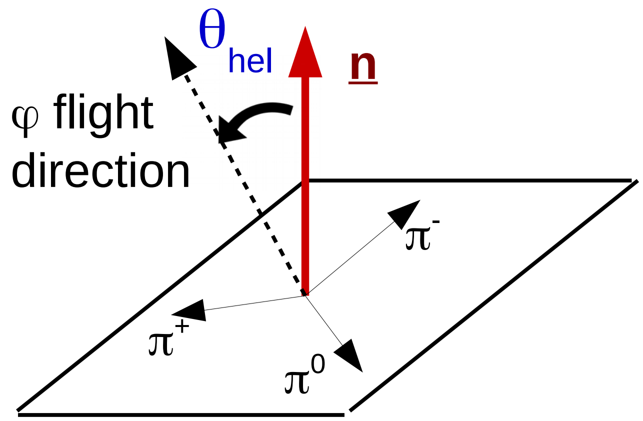
π^0 reconstruction likely to improve

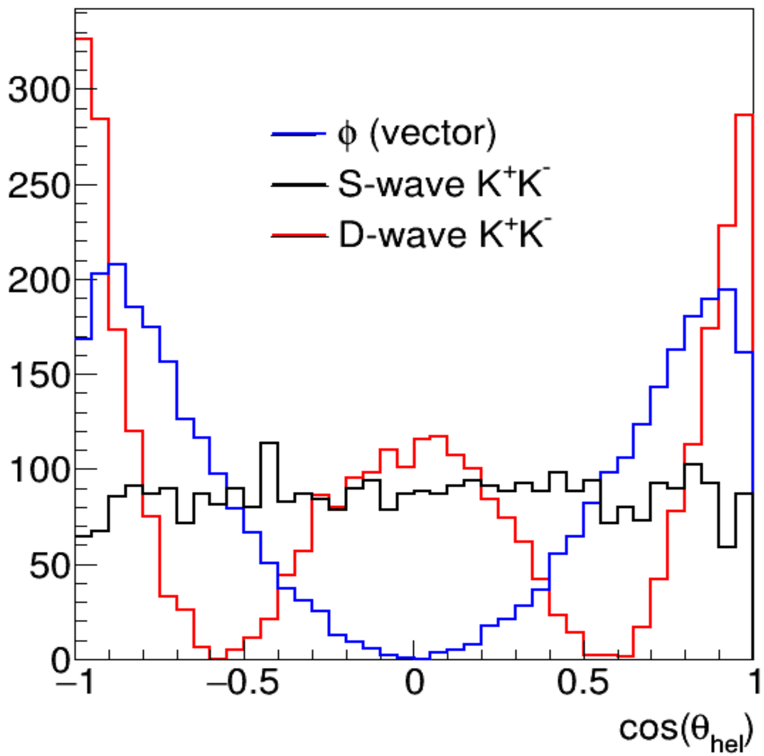
Event selection in backup

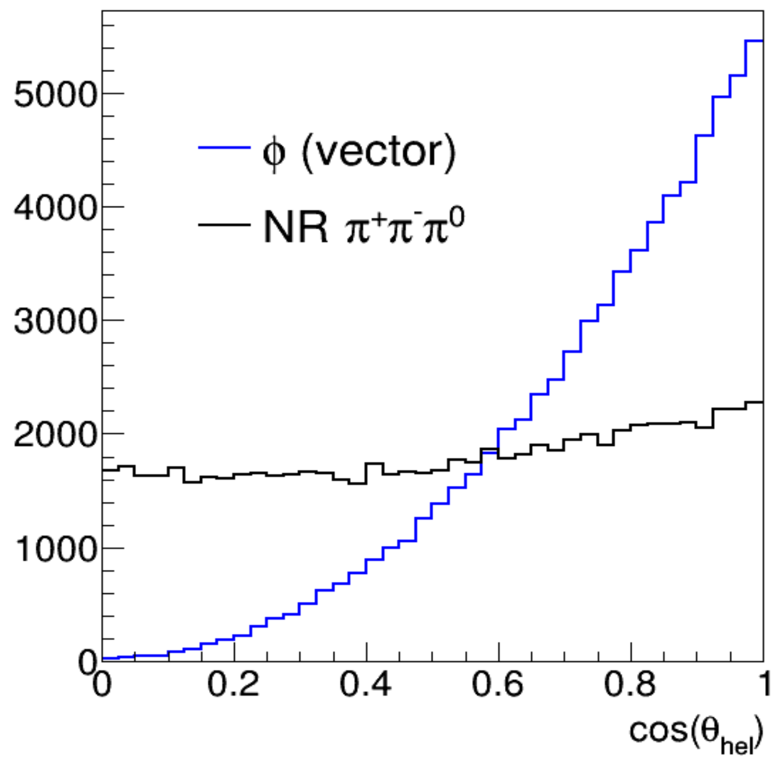
Helicity angles



The angles are measured in the φ rest frame







Multidimensional fit

- The extraction of the parameters of interest (mostly S and C), is done performing a multi-dimensional maximum likelihood fit, using the variables:
  - Δt;
  - ΔE;
  - M_{bc};
  - M(φ);
  - φ helicity; (new)
  - Continuum suppression variable. (new)

The pdf is of the form:

$$\mathcal{P}_j^i \equiv \mathcal{T}_j \underbrace{\left(\Delta t^i, \sigma_{\Delta t}^i, \varphi^i\right)}_{\text{time dependent part}} \cdot \prod_k \underbrace{\mathcal{Q}_{k,j}(x_k^i)}_{\text{time integrated}}$$

- Right now I'm using the old package RooRarFit, updated to cope with the newer version of ROOT/RooFit.
  - We would like to maintain and develop this tool also for the other (time-dependent) analyses.
    - Integrating **RooRarFit** in BASF2 w/ Luigi Di Gioi

Multidimensional fit

ΔE

M_{bc}

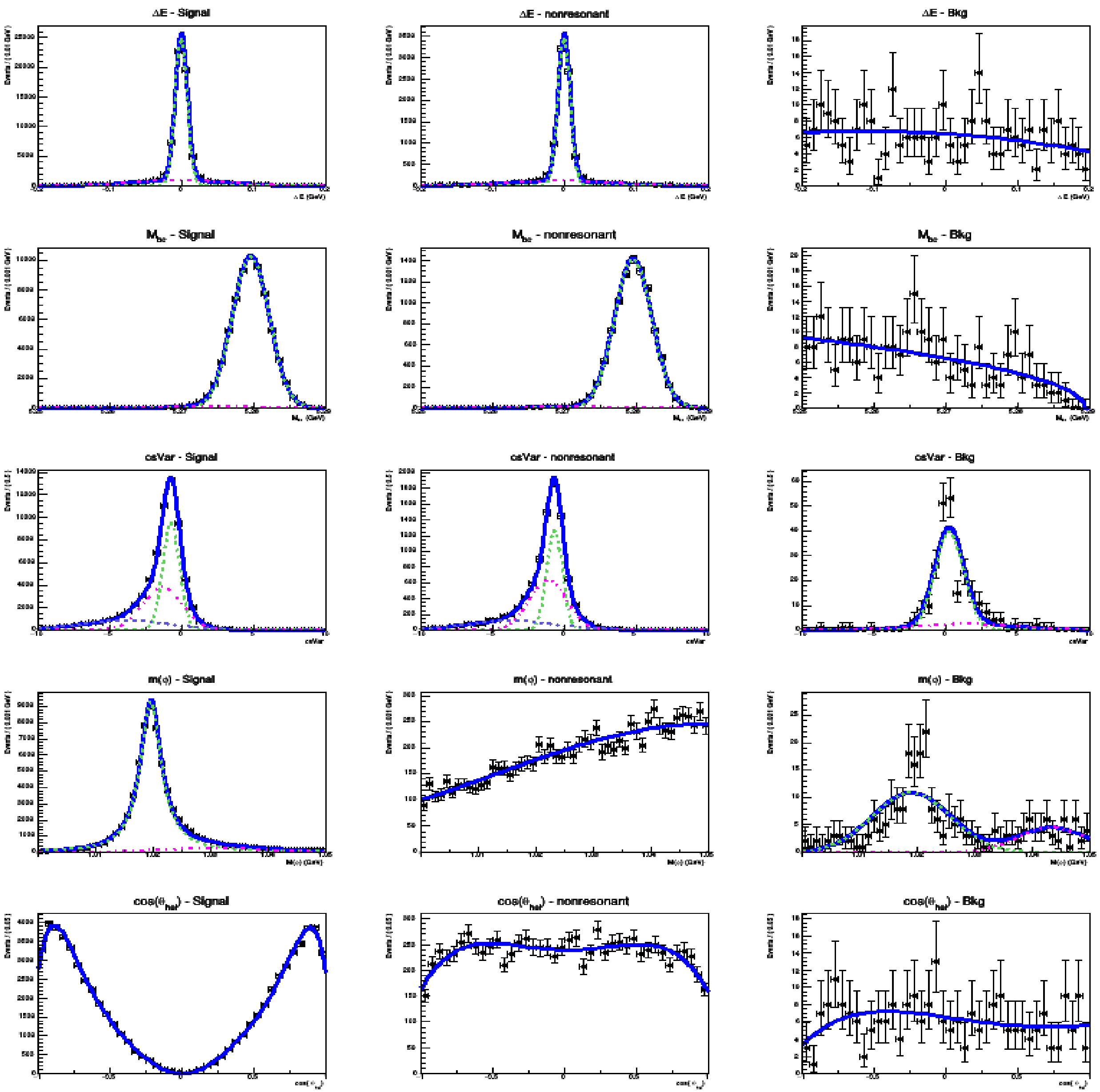
Continuum suppression variable

New

$M(\varphi)$

$\cos(\theta_{hel})$

New



Signal | NR $K^+K^-K_S$ | Combinatorial Bkg.

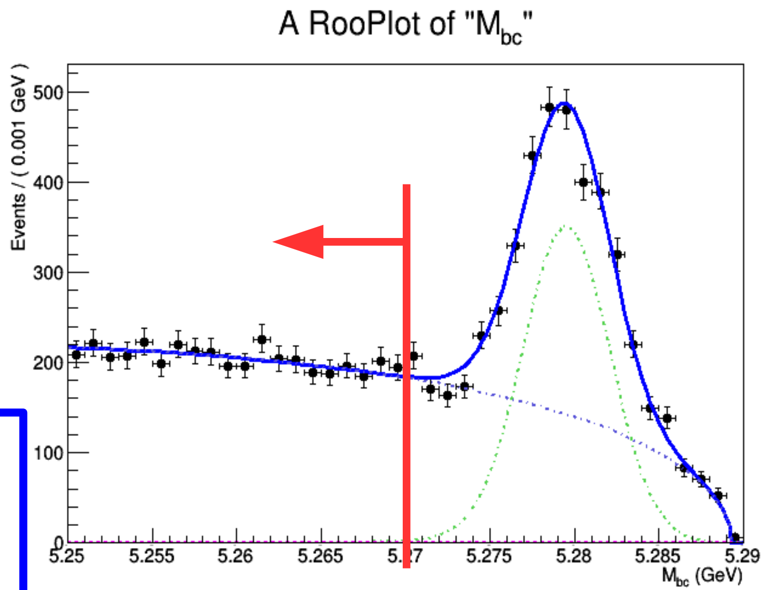
Not full MC yet

Backgrounds

Two main background sources:

1) Combinatorial: dominated by continuum ($e^+e^- \rightarrow u\bar{u}, d\bar{d}, s\bar{s}, c\bar{c}$) events.

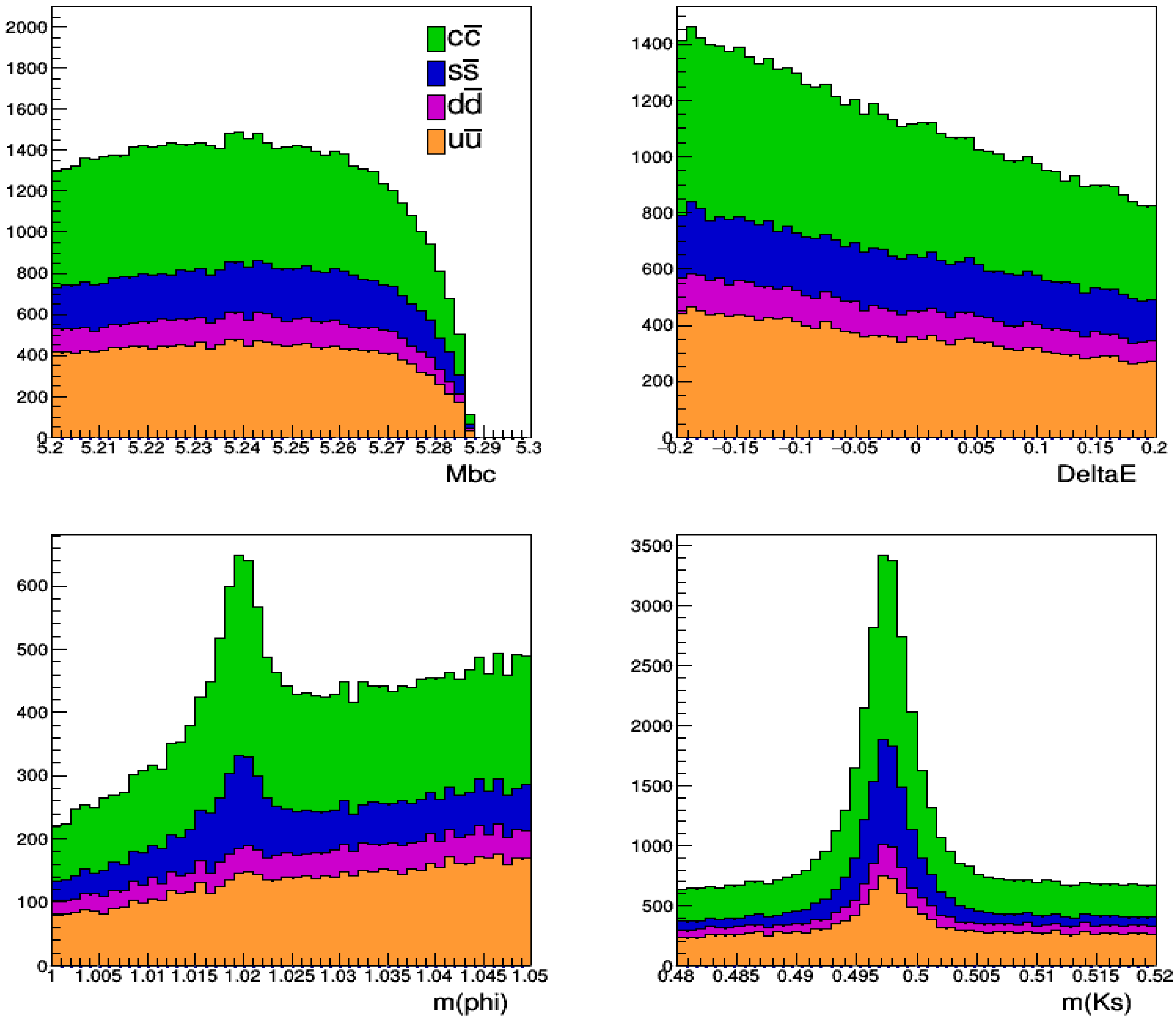
- On a real analysis this is modeled on the data from the M_{bc} sideband.



- Showing results based on the 100 fb^{-1} (**uu, dd, ss, cc)** equivalent production of continuum MC.
- 80 fb^{-1} w/o machine background **BGx0**
- 20 fb^{-1} w/ machine background **BGx1**

1) Peaking: not yet

Background composition – $K^+K^- \pi^+\pi^-$



at "preselection" level:

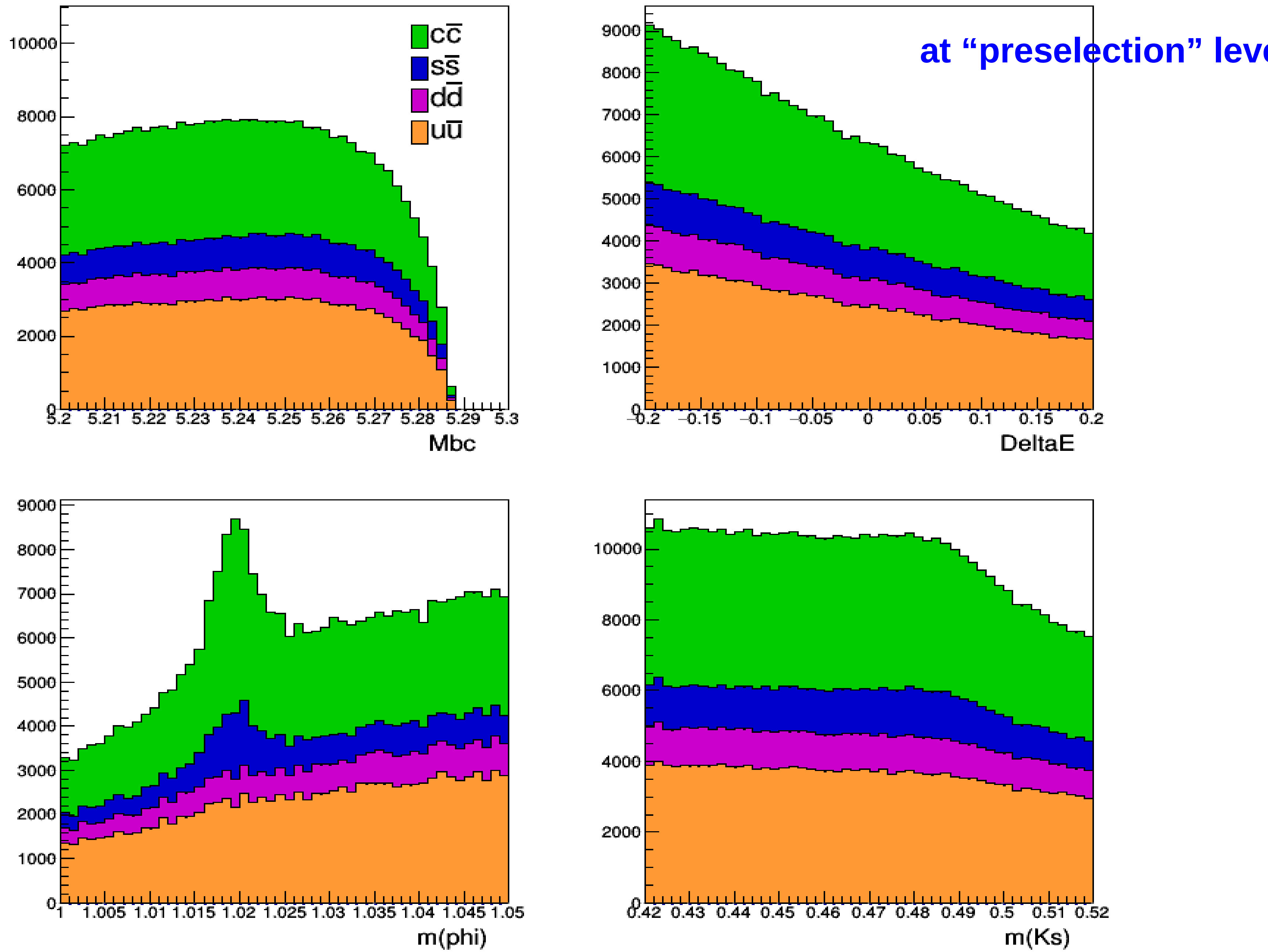
Decay candidate reconstructed

Before selection cuts

20 fb^{-1}
BGx1

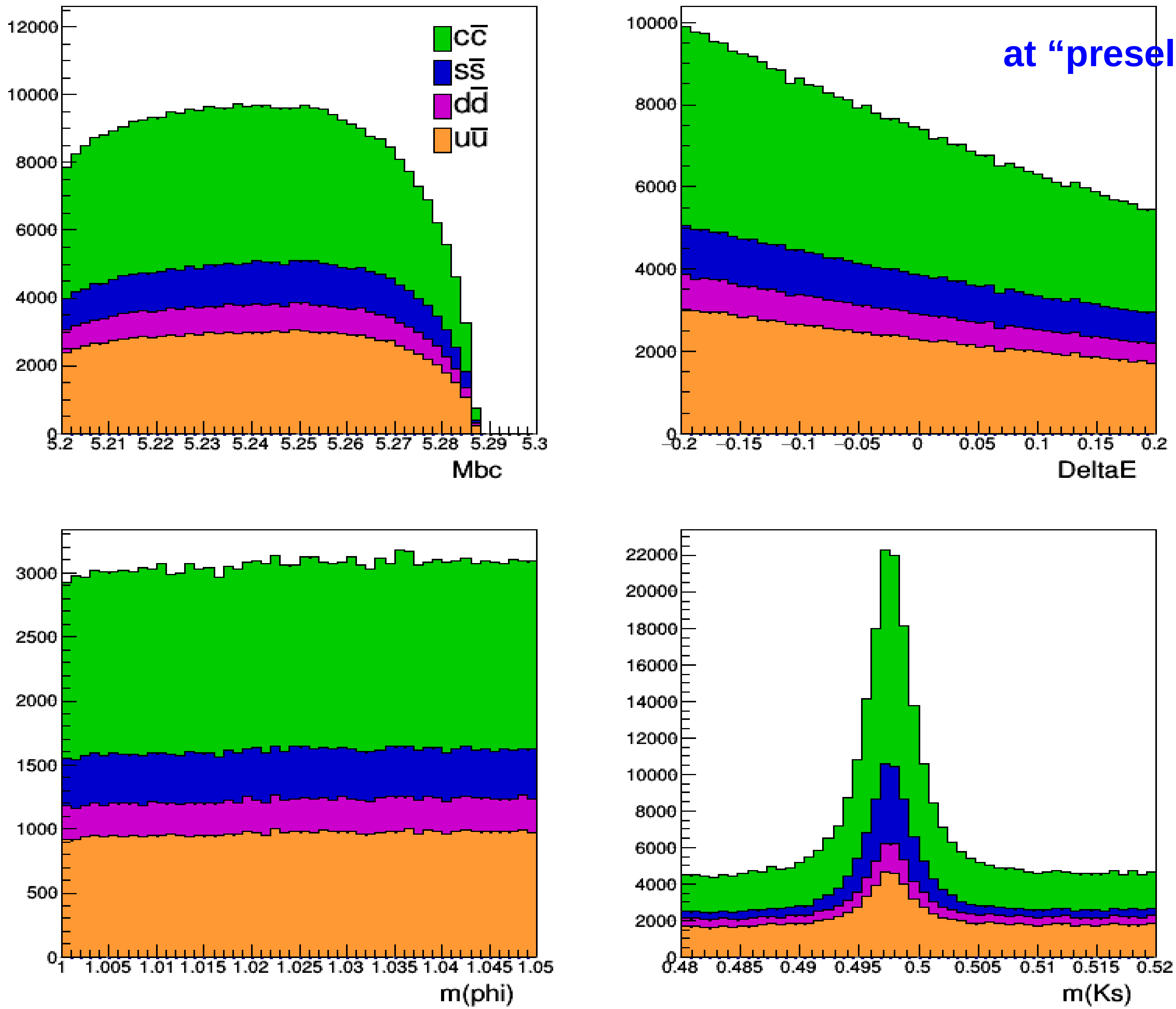
Background composition – $K^+K^- \pi^0\pi^0$

at "preselection" level



Background composition – $\pi^+\pi^-\pi^0\ \pi^+\pi^-$

at "preselection" level

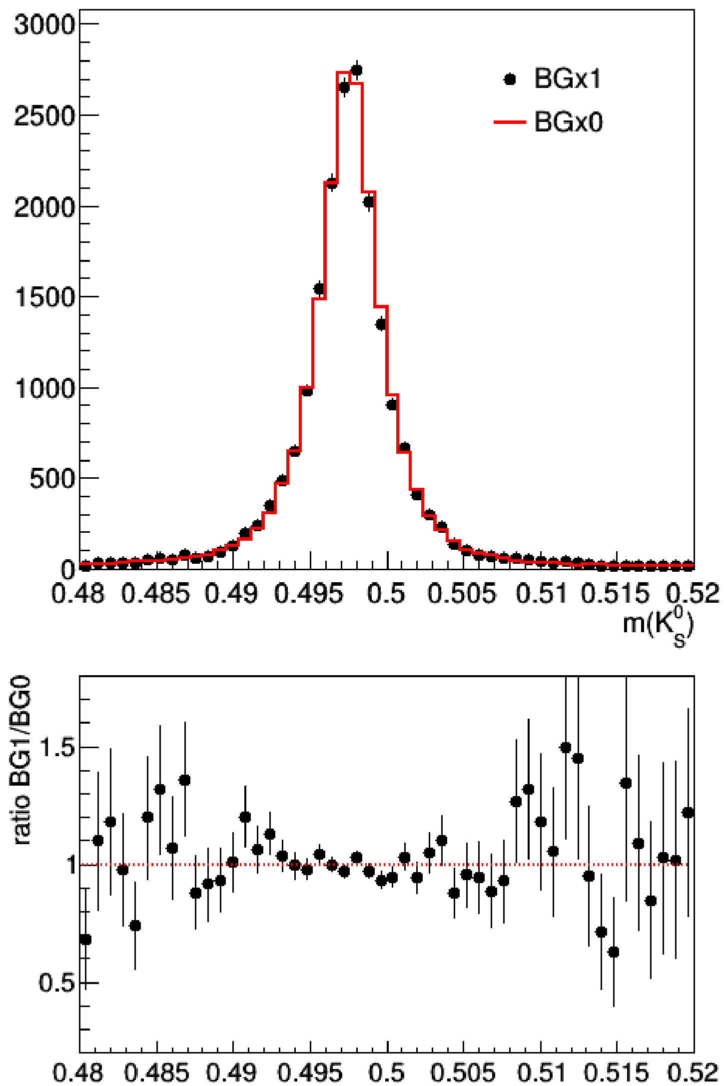


Background rejection

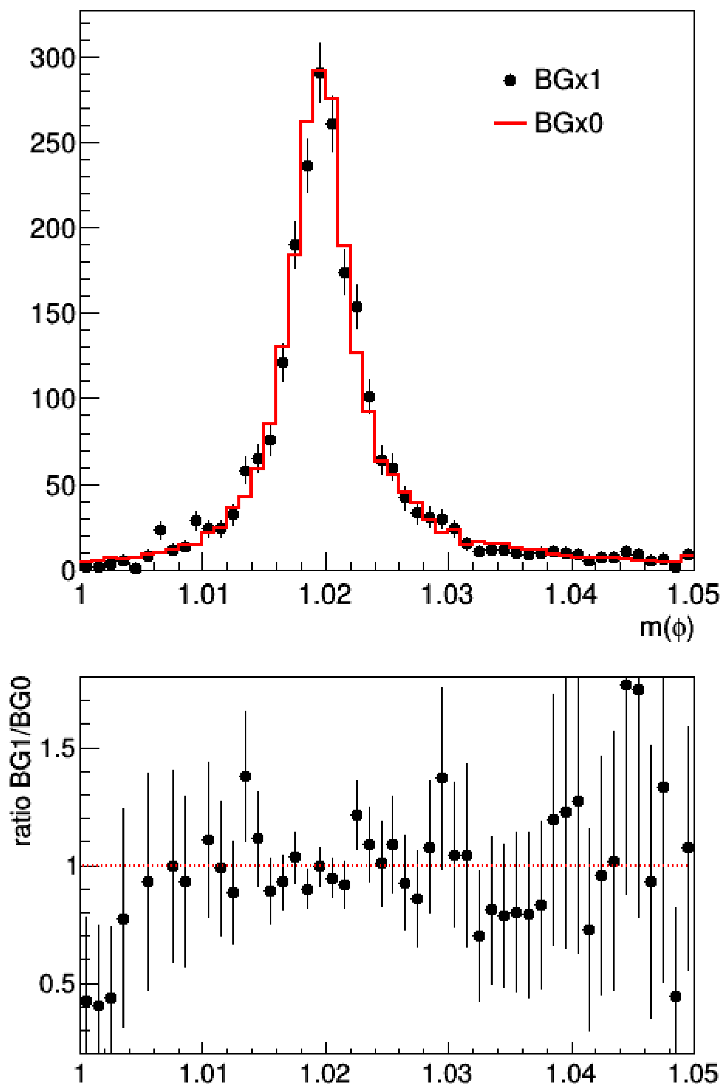
Sgn	$K^+K^- \pi^+\pi^-$		$K^+K^- \pi^0\pi^0$		$\pi^+\pi^-\pi^0 \ \pi^+\pi^-$	
	Selection efficiency [all cuts] (x 10^{-6})					
	BGx0	**BGx1**	**BGx0**	**BGx1**	**BGx0**	**BGx1**
$u\bar{u}$	8.8 ± 0.2	6.4 ± 0.4	1.78 ± 0.12	1.39 ± 0.20	658.3 ± 2.3	469.8 ± 3.7
$d\bar{d}$	7.6 ± 0.5	5.7 ± 0.8	1.47 ± 0.21	0.75 ± 0.31	717.3 ± 4.7	515.6 ± 8.0
$s\bar{s}$	50.6 ± 1.3	39.4 ± 2.2	9.53 ± 0.56	7.70 ± 1.00	952.3 ± 5.6	699.1 ± 9.5
$c\bar{c}$	25.3 ± 0.5	20.8 ± 0.9	5.05 ± 0.22	3.31 ± 0.35	1049.3 ± 6.3	759.4 ± 5.3

- NB no cut on continuum suppression variable (yet)
  - Likely very powerful, still some problems (see backup for details).
- Less background rejection from $s\bar{s}$ and $c\bar{c}$ (φ)
- $\varphi \to 3\pi$ has much more background than $\varphi \to KK$
- w/o machine background higher probability to pass the selection.
  - Most likely as the signal (not yet done)
  - The difference arises from several different sources.

Impact of machine background

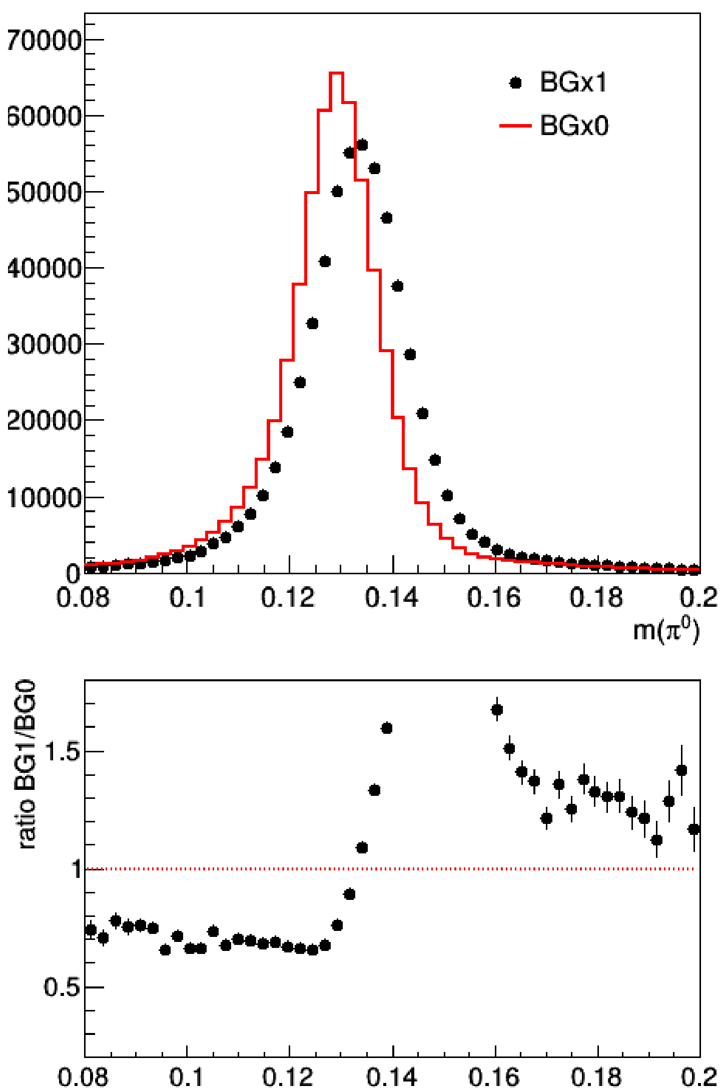


Real $K_s \rightarrow \pi^+\pi^-$ candidates

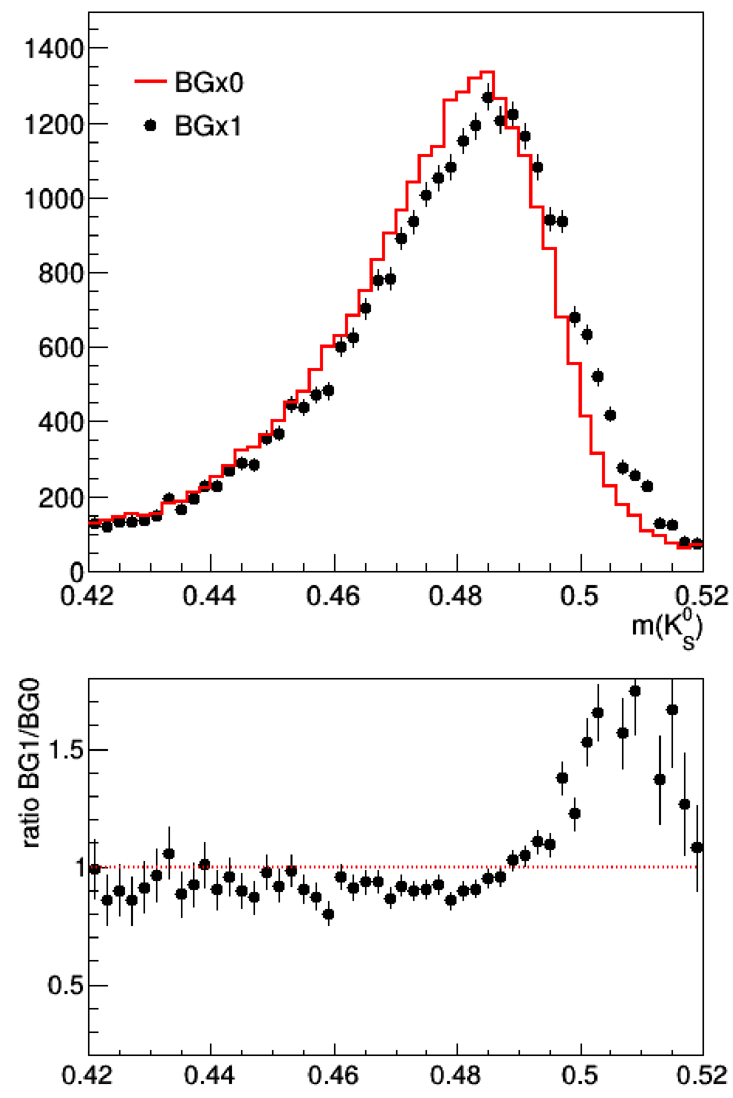


Real $\varphi \rightarrow K^+K^-$ candidates

Impact of machine background

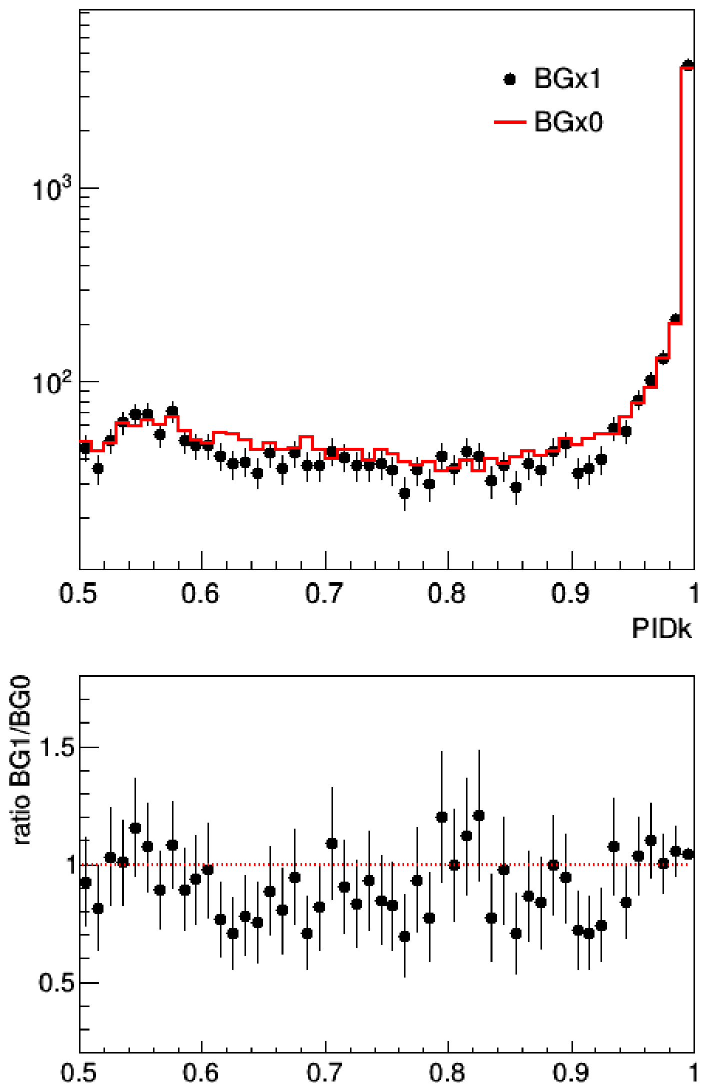


Real π^0 candidates

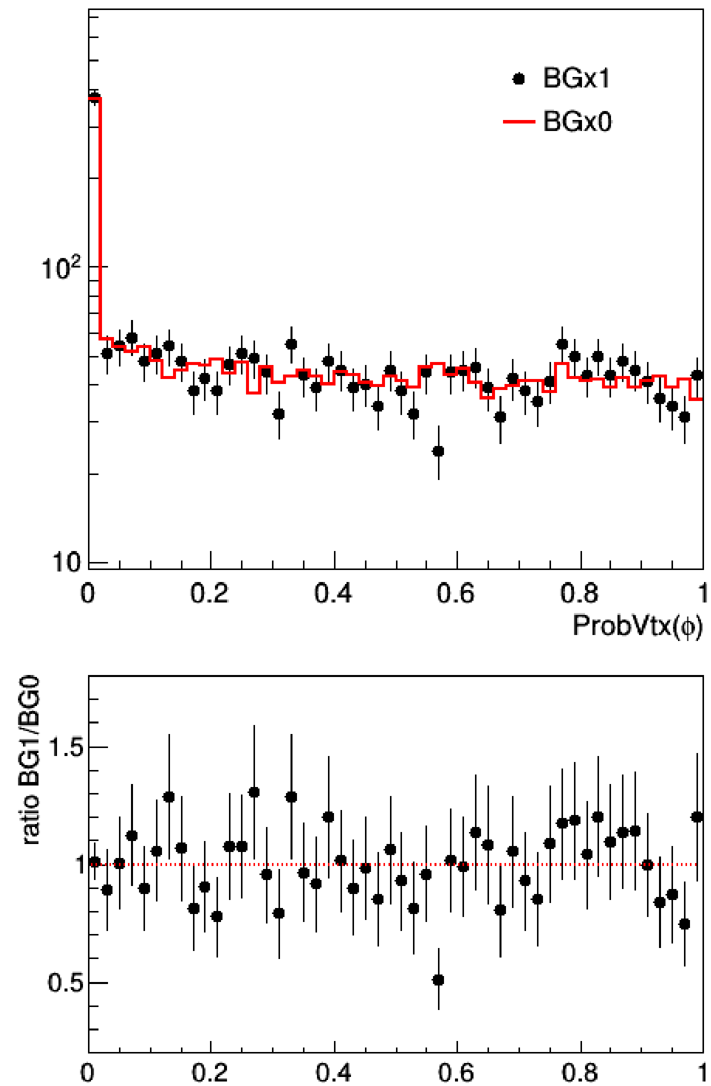


Real $K_S \rightarrow \pi^0\pi^0$ candidates

Impact of machine background

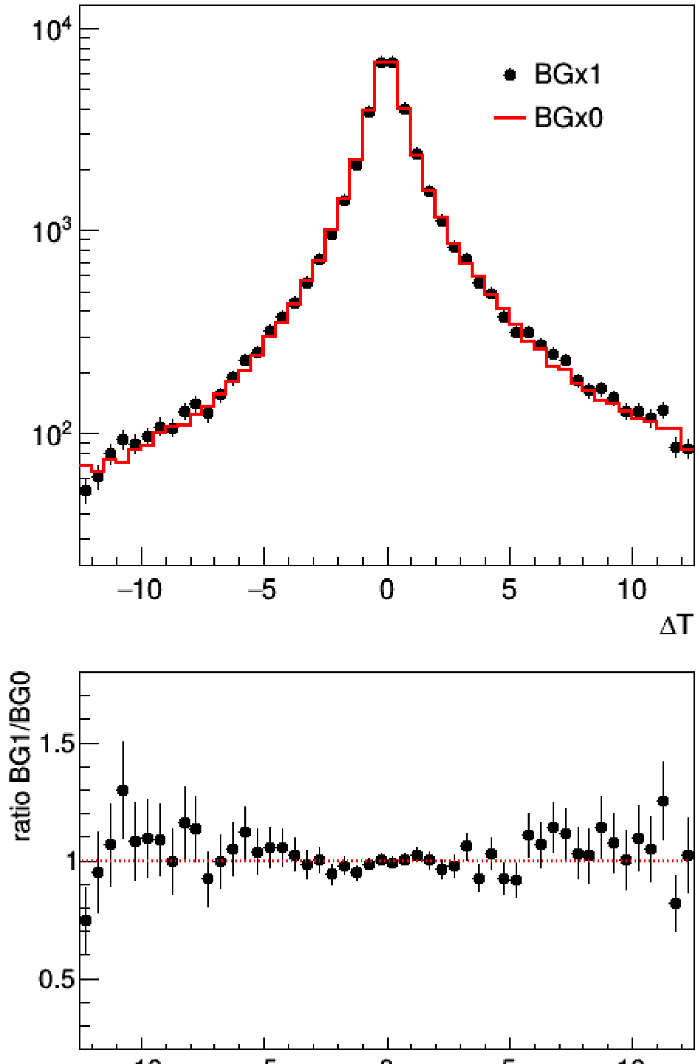


PIDk LR probability (real kaons)

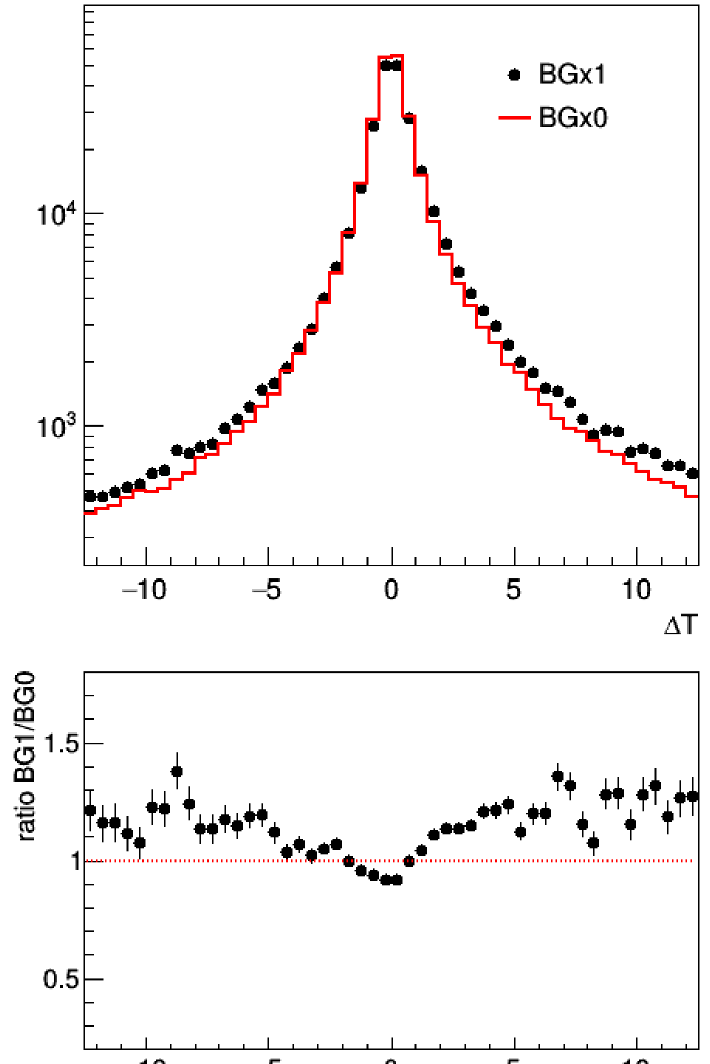


$\varphi \rightarrow K^+K^-$ vertex probability (real φ's)

Impact of machine background



$\varphi \to K^+K^-, K_s \to \pi^+\pi^-$
(loose selection)



$\varphi \to \pi^+\pi^-\pi^0, K_s \to \pi^+\pi^-$
(loose selection)

First glance at $B^0 \to \eta' K^0$

- Same studies as for $B^0 \to \varphi K^0$

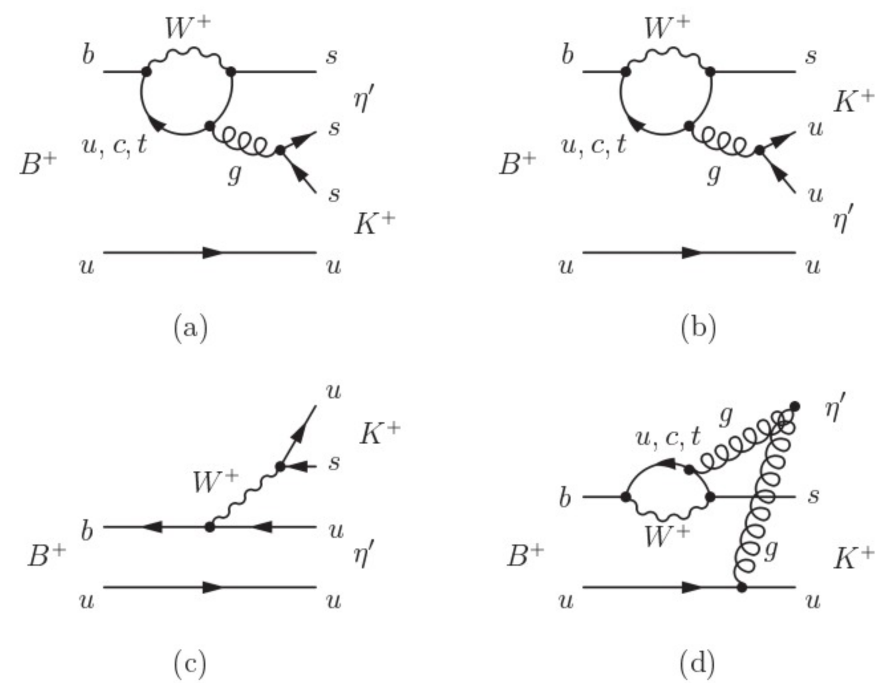
BaBar: PRD 79, 052003,
Belle: PRL 98, 031802

  – $B^0 \to \eta' K^0$ has large BR 6.6×10^{-5}

    CLEO, PRL 81, 1786 (98)

    ~10x BR($B^0 \to \varphi K^0$)

    - Constructive interference between penguin diagrams

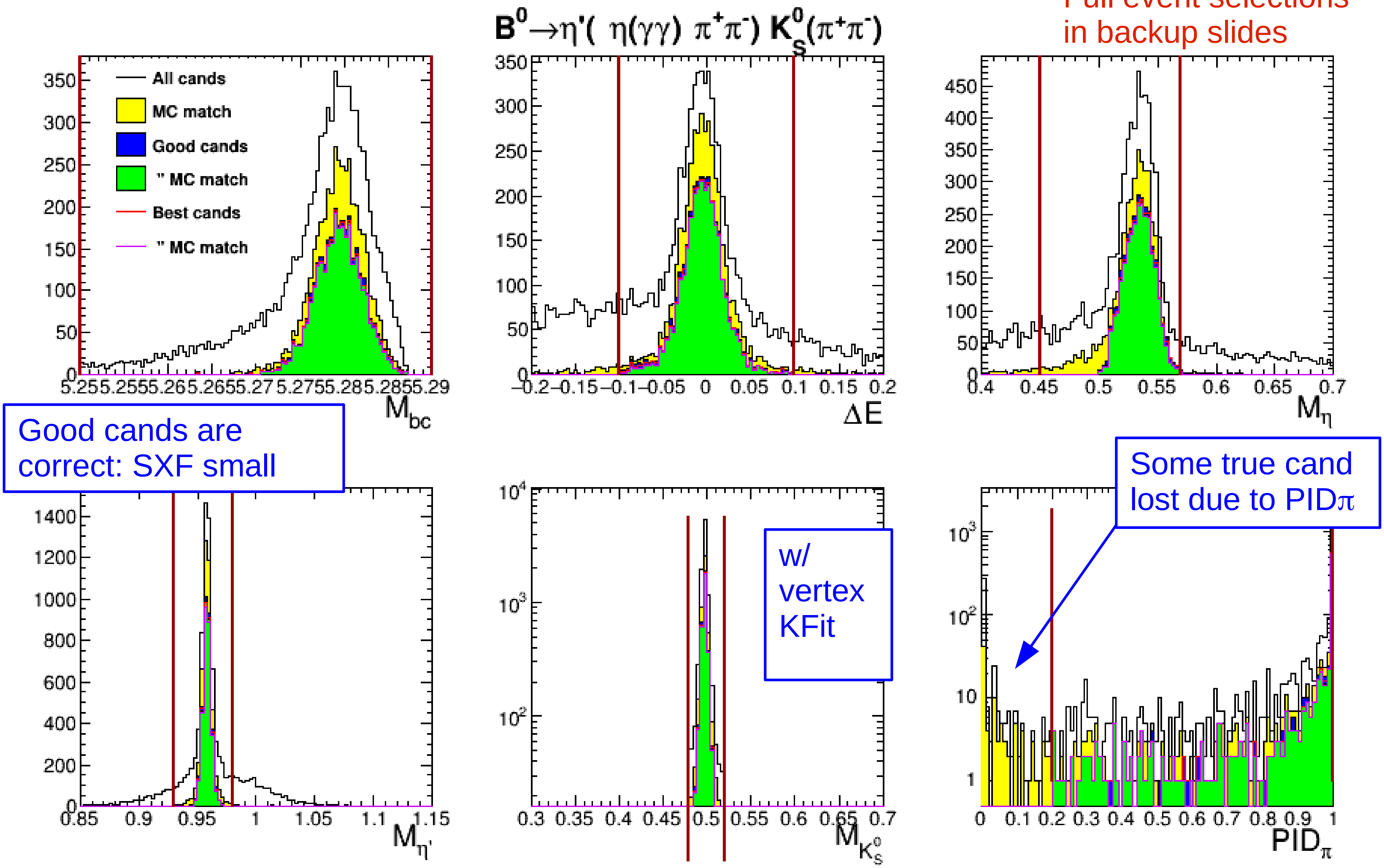


  – CPV first observed in 2006 by BaBar
    - Statistically limited (~1500 $\eta' K^0_S$)
  – Many decay channels:
    - $B^0 \to \eta' (\rho\gamma)\ K^0_S$ (Not yet) BR: 29%
    - $B^0 \to \eta' (\eta\ (\gamma\gamma)\ \pi^+\pi^-)\ K^0_S (\pi^+\pi^-)$ BR: .43*.40*.7 =12%
    - $B^0 \to \eta' (\eta\ (\gamma\gamma)\ \pi^+\pi^-)\ K^0_S (\pi^o\pi^o)$ BR: .43*.40*.3 = 5%
    - $B^0 \to \eta' (\eta\ (\pi^+\pi^-\pi^o)\ \pi^+\pi^-)\ K^0_S (\pi^+\pi^-)$ BR: .43*.23*.7 = 7%
    - $B^0 \to \eta' (\eta\ (\pi^+\pi^-\pi^o)\ \pi^+\pi^-)\ K^0_S (\pi^o\pi^o)$ BR: .43*.23*.3 = 3%
    - $B^0 \to \eta' K^0_L$ (Not yet)
  – Large combinatorial background

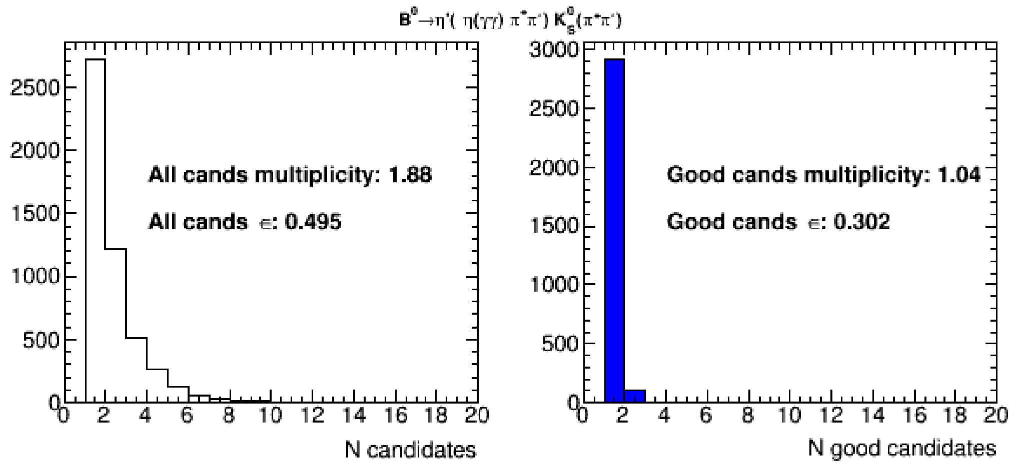
BR_{Tot} ($\eta' \to (\eta\pi^+\pi^-)K^0_S$)=27%

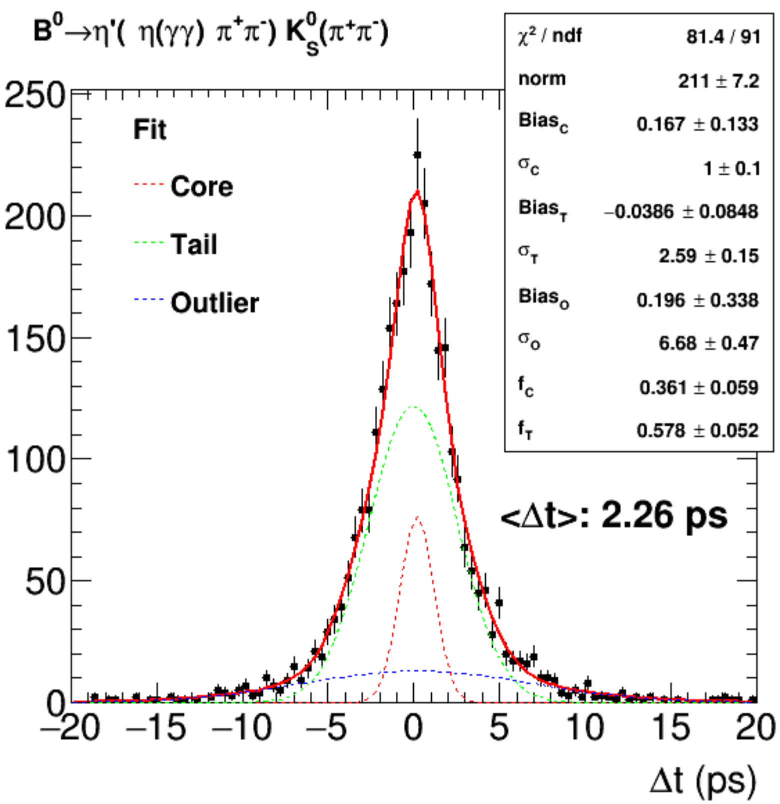
$B^0 \rightarrow \eta' (\eta\ (\gamma\gamma)\ \pi^+\pi^-)\ K^0_S\ (\pi^+\pi^-)$ distributions

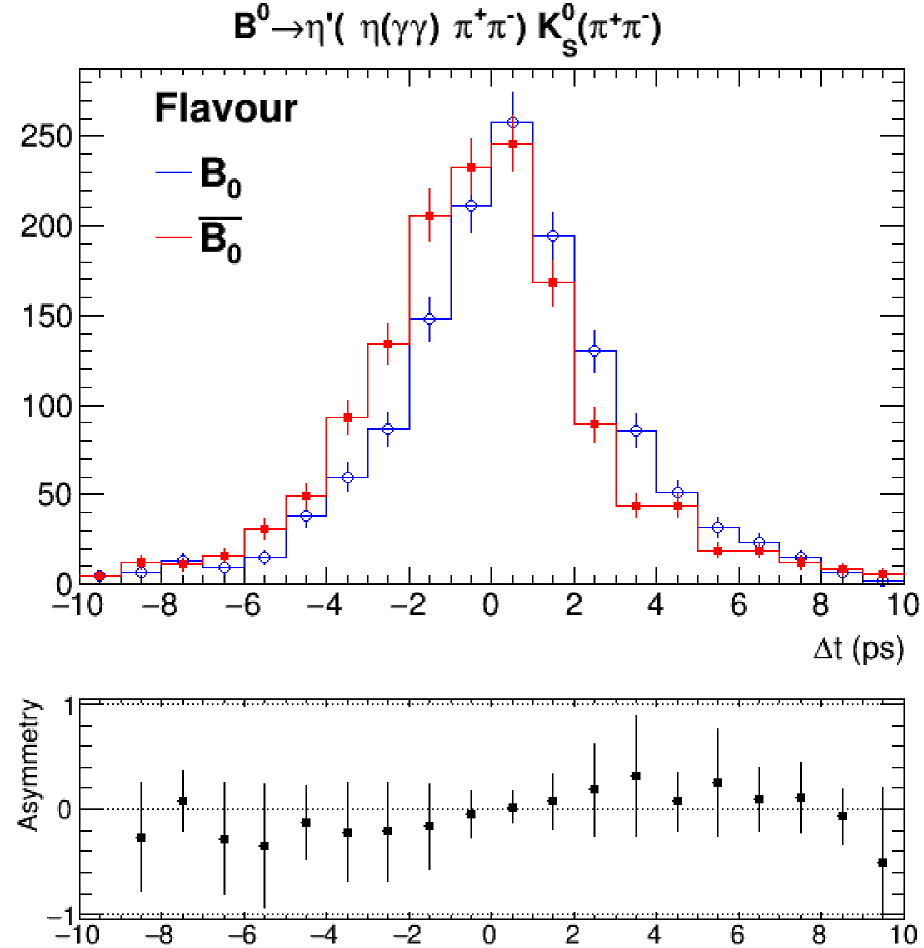
Full event selections in backup slides



$B^0 \rightarrow \eta' (\eta\ (\gamma\gamma)\ \pi^+\pi^-)\ K^0_S (\pi^+\pi^-)$





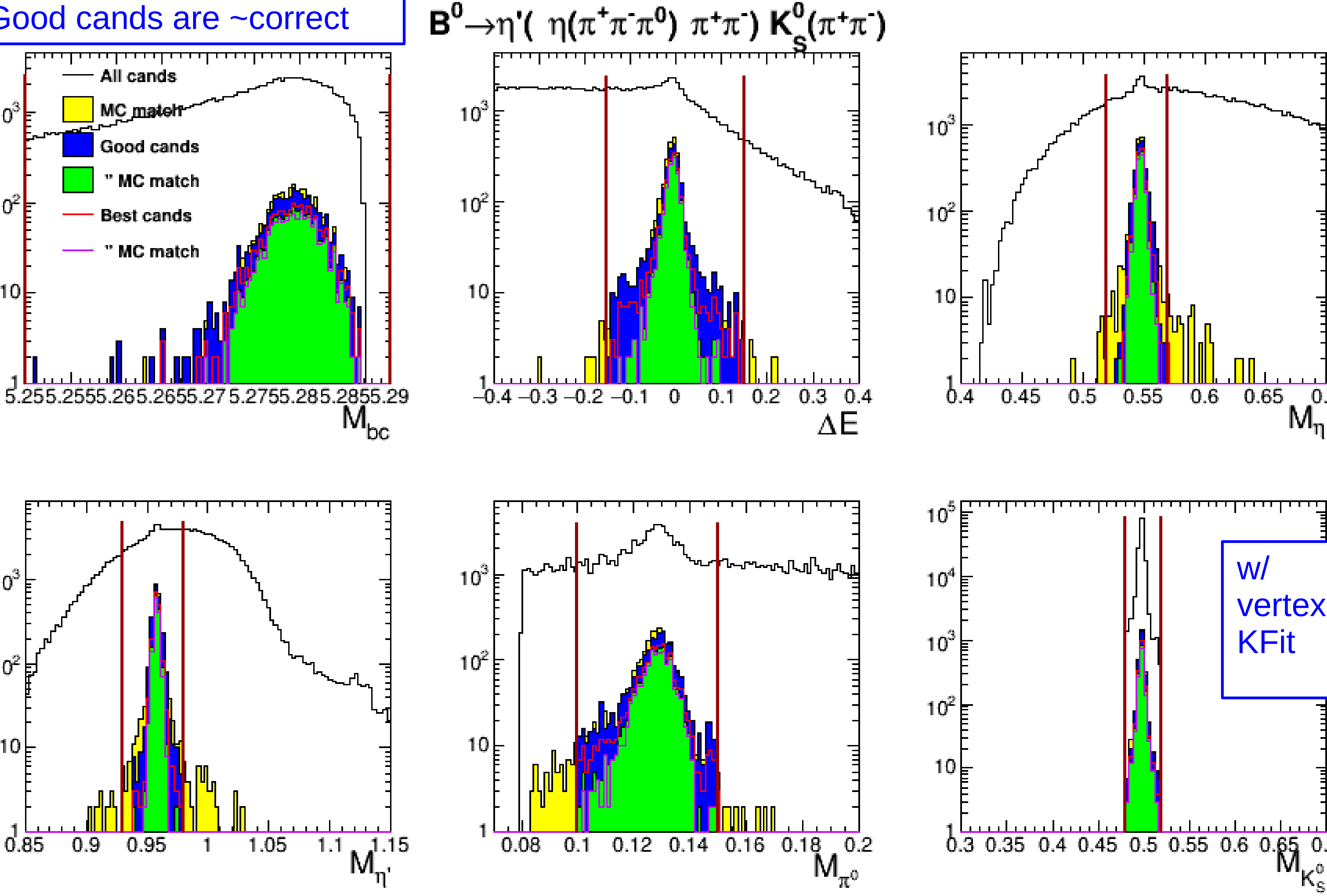


For $B^0 \rightarrow \eta' (\eta\ (\gamma\gamma)\ \pi^+\pi^-)\ K^0_S (\pi^0\pi^0)$

- Efficiency ~0.5x (as for φK^0)
- Same Δt resolution (see backup)

$B^0 \rightarrow \eta' (\eta (\pi^+\pi^-\pi^0) \pi^+\pi^-) K^0_S (\pi^+\pi^-)$ distributions

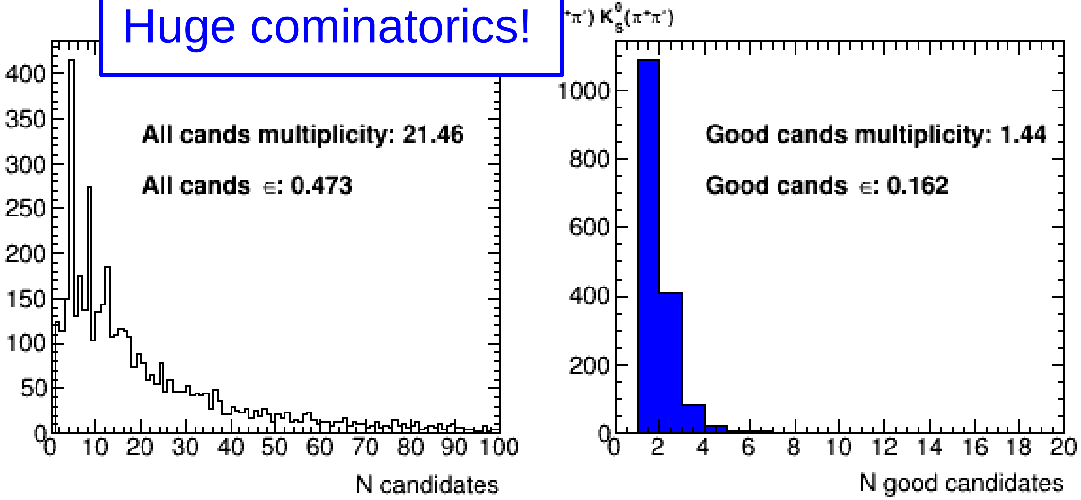
Huge cominatorics!
Good cands are ~correct

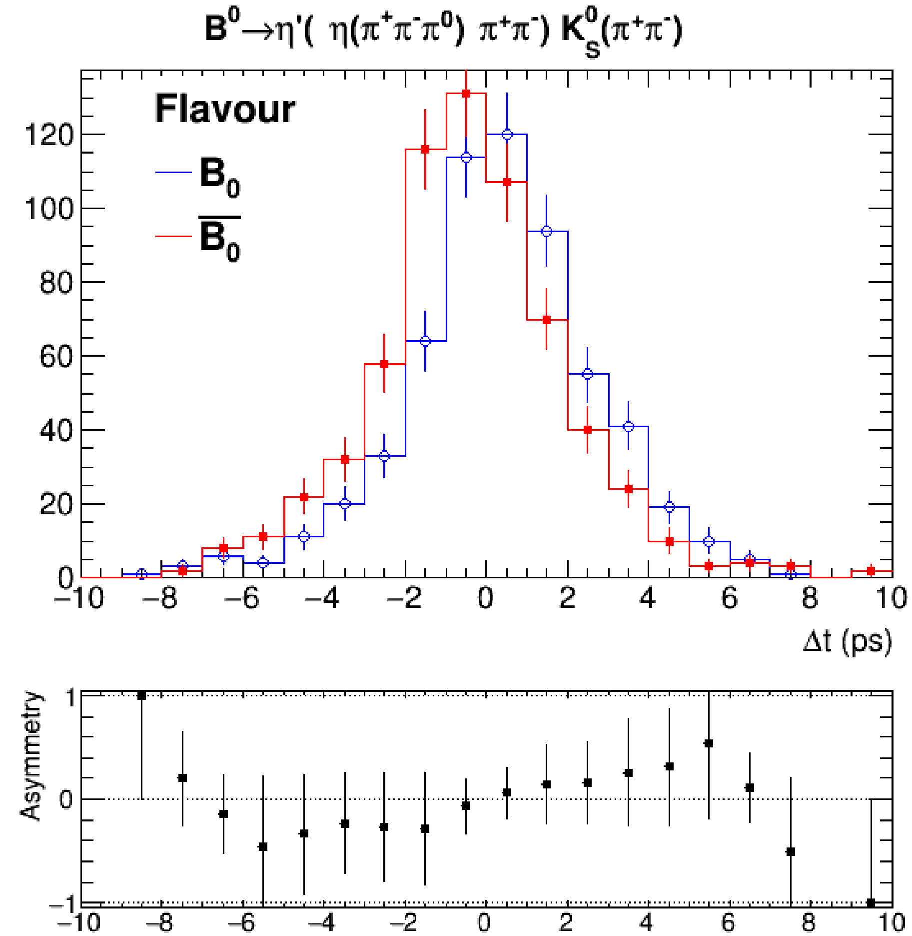


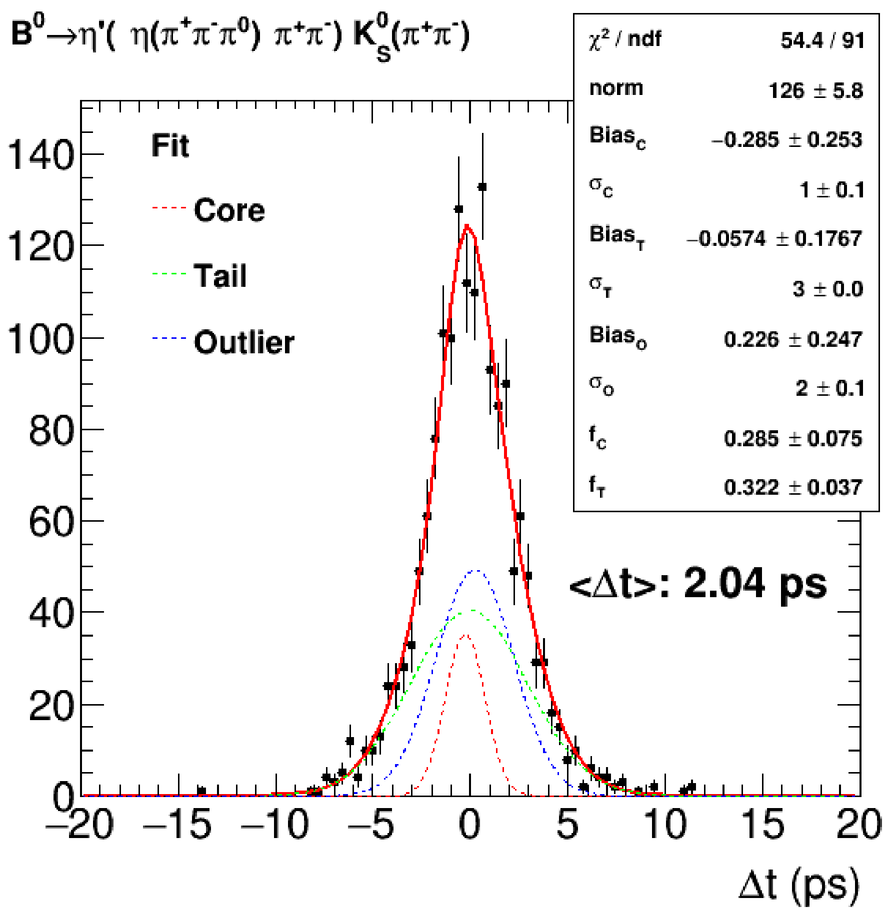
w/
vertex
KFit

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

Huge cominatorics!







$B^0 \rightarrow \eta' (\eta\ (\pi^+\pi^-\pi^0)\ \pi^+\pi^-)\ K^0_S (\pi^0\pi^0)$ under study: combinatorics will be interesting...

Channels summary

	BR 10^{-5}	Selection ε	Δt resolution
η' (η ($\gamma\gamma$) $\pi^+\pi^-$) K^0_s	1.1	29.6% $\pi^+\pi^-$ 12.5% $\pi^0\pi^0$	2.25 ps
η' (η ($\pi^+\pi^-\pi^0$) $\pi^+\pi^-$) K^0_s	0.6	13.2% $\pi^+\pi^-$ -- $\pi^0\pi^0$	2.04 ps
$\varphi(K^+K^-)$ K_s	0.35	35.2% $\pi^+\pi^-$ 13.7% $\pi^0\pi^0$	2.11 ps
$\varphi(\pi^+\pi^-\pi^0)K_s(\pi^+\pi^-)$	0.07	28.3%	1.42 ps
$J/\psi(\mu^+\mu^-)K_s$	52	--	0.90 ps

Conclusions / outlook

- $B^0 \rightarrow (\varphi\ /\ \eta') K^0_S$ channels studied for time-dependent CPV
  - Φ advanced, η' preliminary: both encouraging
  - η': more channels to be analyzed, background, ...
- Large samples of generic and signal MC have become available, thanks a lot to the people involved in the production!
  - Things so far look ok: the impact of the machine background on tracking, vertexing and PID is reasonably small (but visible);
  - Still some problem with event topology/continuum suppression: under investigation
- Use the MC that is going to be released soon for a full scale analysis exercise.

Backup Slides

Motivations

- $b \to s$ penguin dominated decays:
  - $B \to \eta' K^0$, ωK^S, $\pi^0 K^0$ are sensitive to $\sin 2\varphi_1$:

$$A_f(\Delta t) = \frac{\Gamma(\overline{B}^0(\Delta t) \to f) - \Gamma(B^0(\Delta t) \to f)}{\Gamma(\overline{B}^0(\Delta t) \to f) + \Gamma(B^0(\Delta t) \to f)} = -C_f \cos(\Delta m_B \Delta t) + S_f \sin(\Delta m_B \Delta t)$$

  - in case of pure penguin amplitude $S_f \approx \sin 2\varphi_1$
- Presence of color-suppressed tree amplitudes shift S_f from $\sin 2\varphi_1$ for a value of 0.01~0.1
  - Depending on decay mode
- Examining for a larger deviations of S_f from $\sin 2\varphi_1$ is an important test of the Standard Model

Event selection $B^0 \to \varphi K^0$

- $M_{bc} > 5.25$;
- $|\Delta E| < 0.2$ ($\varphi \to KK$, $K_S \to \pi^+\pi^-$);
- $-0.1 < \Delta E < 0.2$ ($\varphi \to KK$, $K_S \to \pi^0\pi^0$);
- $-0.4 < \Delta E < 0.2$ ($\varphi \to 3\pi$, $K_S \to \pi^+\pi^-$);
- $1.00 < M(K^+K^-) < 1.05$;
- $0.97 < M(\pi^+\pi^-\pi^0) < 1.04$;
- $d_0(K^\pm) < 0.08$;
- $z_0(K^\pm) < 0.3$;
- At least one PXD hit for each $K^\pm/\pi^\pm$ from φ decay;
- PIDk(K) > 0.2;
- VtxPvalue(K_S, φ, B) > 0.0001.

- $0.48 < M(K_S \to \pi^+\pi^-) < 0.52$;
- $0.10 < M(\pi^0) < 0.14$;
- $0.44 < M(K_S \to \pi^0\pi^0) < 0.51$;

$K^\pm$:	`K+:all`
K_S:	`stdKshorts`
π^0:	`stdPi0`

Selection efficiencies $B^0 \to \varphi K^0$

- In the next slides I'm showing the probability of background events to pass the cuts at two different stages:
  - Preselection: basically the output of the basf2 job that produces the root output file to be processed in the following stage;
  - Selection: this restricts to the events that are going to be used in the multidimensional time-dependent fit (*);

- Still considering only the channels:

  1) $\varphi\ (K^+K^-)$ $K_S\ (\pi^+\pi^-)$
  2) $\varphi\ (K^+K^-)$ $K_S\ (\pi^0\pi^0)$
  3) $\varphi\ (\pi^+\pi^-\pi^0)$ $K_S\ (\pi^+\pi^-)$

  (work on K_L mode yet to begin)

  (*) without including a cut on a very powerful continuum/BB discriminating variable, that will likely be introduced.

MC samples

- Showing results based on the 100 fb^{-1} equivalent production of continuum MC:

	BGx0		BGx1	
	# events (M)	**equiv. lumi (fb^{-1})**	**# events (M)**	**equiv. lumi (fb^{-1})**
$u\bar{u}$	128.40	80	32.10	20
$d\bar{d}$	32.08	80	8.02	20
$s\bar{s}$	30.64	80	7.66	20
$c\bar{c}$	106.32	80	26.58	20

- I also took a look at the very recently released signal MC:
  - Bd -> phiKS_K+K-pi+pi-, BGx0
  - Bd -> phiKS_K+K-pi0pi0, BGx0
  - Bd -> phiKS_2pi+2pi-pi0, BGx0

Selection efficiencies – $K^+K^- \pi^+\pi^-$

BGx0	Preselection efficiency (x 10^{-3})	Selection efficiency (x 10^{-6})
$u\bar{u}$	0.628 ± 0.002	8.8 ± 0.2
$d\bar{d}$	0.670 ± 0.005	7.6 ± 0.5
$s\bar{s}$	1.459 ± 0.007	50.6 ± 1.3
$c\bar{c}$	1.030 ± 0.003	25.3 ± 0.5

BGx1	Preselection efficiency (x 10^{-3})	Selection efficiency (x 10^{-6})
$u\bar{u}$	0.540 ± 0.004	6.4 ± 0.4
$d\bar{d}$	0.620 ± 0.009	5.7 ± 0.8
$s\bar{s}$	1.260 ± 0.013	39.4 ± 2.2
$c\bar{c}$	0.890 ± 0.006	20.8 ± 0.9

Events without background have a higher probability to pass the selection. The difference arises from several different sources.

Selection efficiencies – $K^+K^- \pi^0\pi^0$

BGx0	Preselection efficiency (x 10^{-3})	Selection efficiency (x 10^{-6})
$u\bar{u}$	10.694 ± 0.009	1.78 ± 0.12
$d\bar{d}$	11.806 ± 0.019	1.47 ± 0.21
$s\bar{s}$	13.729 ± 0.021	9.53 ± 0.56
$c\bar{c}$	13.907 ± 0.011	5.05 ± 0.22

BGx1	Preselection efficiency (x 10^{-3})	Selection efficiency (x 10^{-6})
$u\bar{u}$	9.343 ± 0.017	1.39 ± 0.20
$d\bar{d}$	10.475 ± 0.036	0.75 ± 0.31
$s\bar{s}$	12.283 ± 0.040	7.70 ± 1.00
$c\bar{c}$	12.501 ± 0.022	3.31 ± 0.35

Events without background have a higher probability to pass the selection.
The difference arises from several different sources.

Selection efficiencies – $\pi^+\pi^-\pi^0\ \pi^+\pi^-$

BGx0	Preselection efficiency (x 10^{-3})	Selection efficiency (x 10^{-6})
$u\bar{u}$	4.612 ± 0.006	658.3 ± 2.3
$d\bar{d}$	5.026 ± 0.012	717.3 ± 4.7
$s\bar{s}$	8.087 ± 0.016	952.3 ± 5.6
$c\bar{c}$	868.8 ± 0.009	1049.3 ± 6.3

BGx1	Preselection efficiency (x 10^{-3})	Selection efficiency (x 10^{-6})
$u\bar{u}$	3.507 ± 0.010	469.8 ± 3.7
$d\bar{d}$	3.917 ± 0.022	515.6 ± 8.0
$s\bar{s}$	6.249 ± 0.028	699.1 ± 9.5
$c\bar{c}$	6.705 ± 0.016	759.4 ± 5.3

Events without background have a higher probability to pass the selection. The difference arises from several different sources.

Event selection $B^0 \to \varphi K^0$

Main selection cuts:

- $M_{bc} > 5.25$;
- $|\Delta E| < 0.2$ ($\varphi \to KK$, $K_S \to \pi^+\pi^-$);
- $-0.1 < \Delta E < 0.2$ ($\varphi \to KK$, $K_S \to \pi^0\pi^0$);
- $-0.4 < \Delta E < 0.2$ ($\varphi \to 3\pi$, $K_S \to \pi^+\pi^-$);
- $1.00 < M(K^+K^-) < 1.05$;
- $0.97 < M(\pi^+\pi^-\pi^0) < 1.04$;
- $d_0(K^\pm) < 0.08$;
- $z_0(K^\pm) < 0.3$;

Objects:

$K^\pm$: `K+:all`

K_S: `stdKshorts`

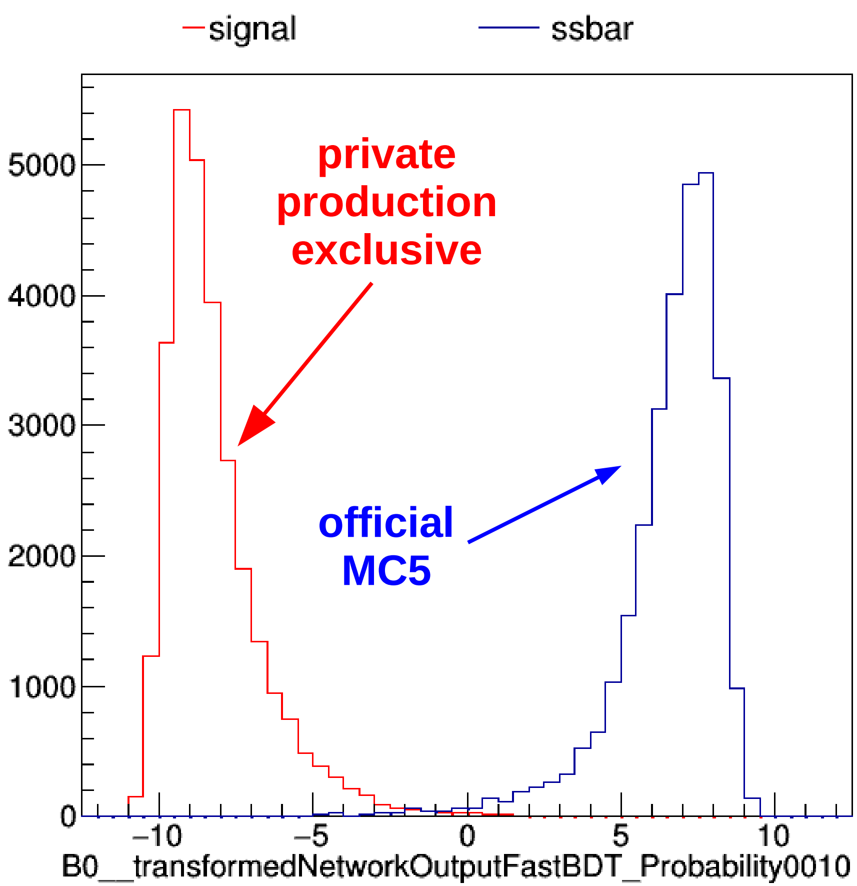
- $0.48 < M(K_S \to \pi^+\pi^-) < 0.52$;
- $0.10 < M(\pi^0) < 0.14$;
- $0.44 < M(K_S \to \pi^0\pi^0) < 0.51$;

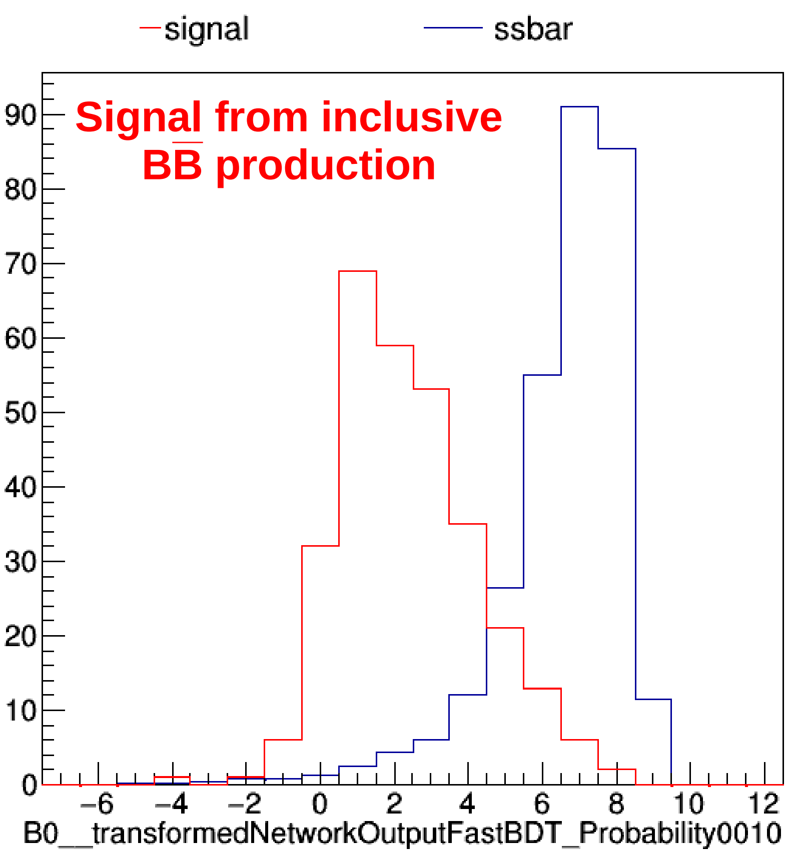
- At least one PXD hit for each $K^\pm/\pi^\pm$ from φ decay;
- PIDk(K) > 0.2;
- VtxPvalue(K_S, φ, B) > 0.0001.

Selection efficiencies look reasonable (see backup)

Puzzle: continuum suppression

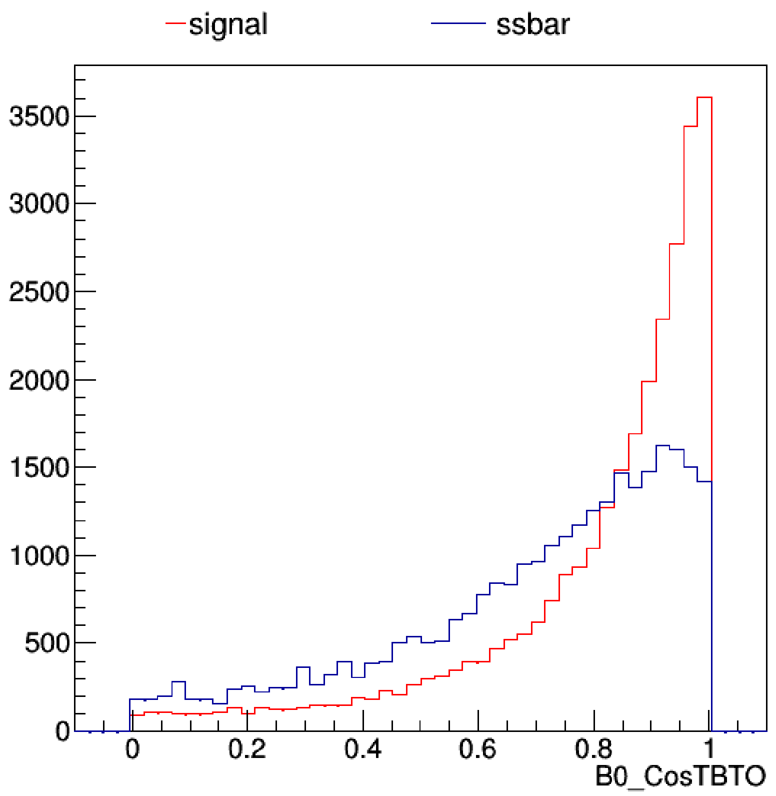
- The separation power is unrealistically high:
  - Esclusive production (private and official) very different wrt inclusive BBar production.





Puzzle: continuum suppression

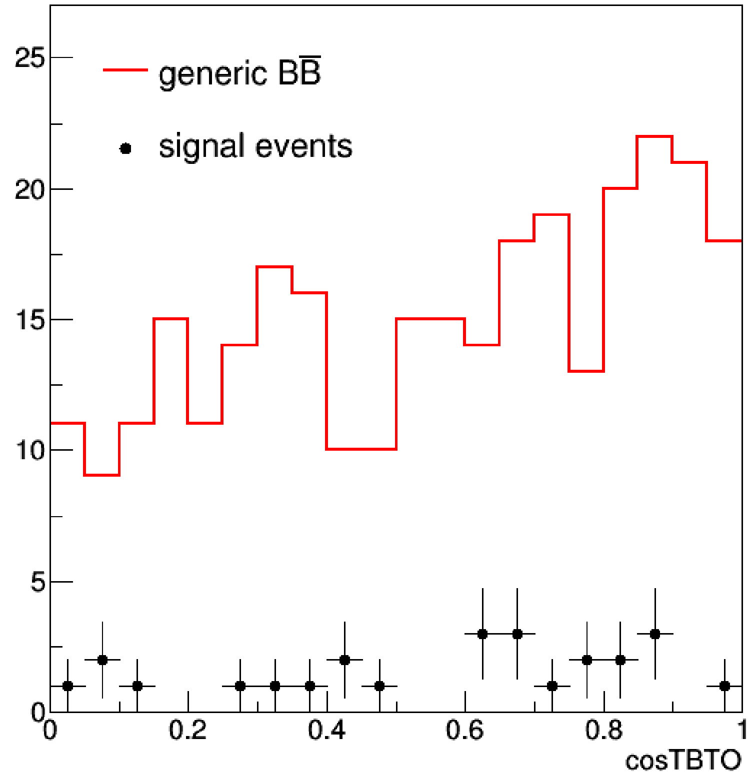
- Moreover, there seems to be a problem with the “event topology”: B decays are expected to be “spherical”, while continuum events are more “jet like”;
- One of the strongest variables that can separate between the two components is the angle between the thrust axis of the signal B candidate and the thrust axis of the rest of the event;
- I expect the distribution of CosTBTO to be ~flat for signal (and $B\bar{B}$ events) and strongly peaking at 1 for the continuum;

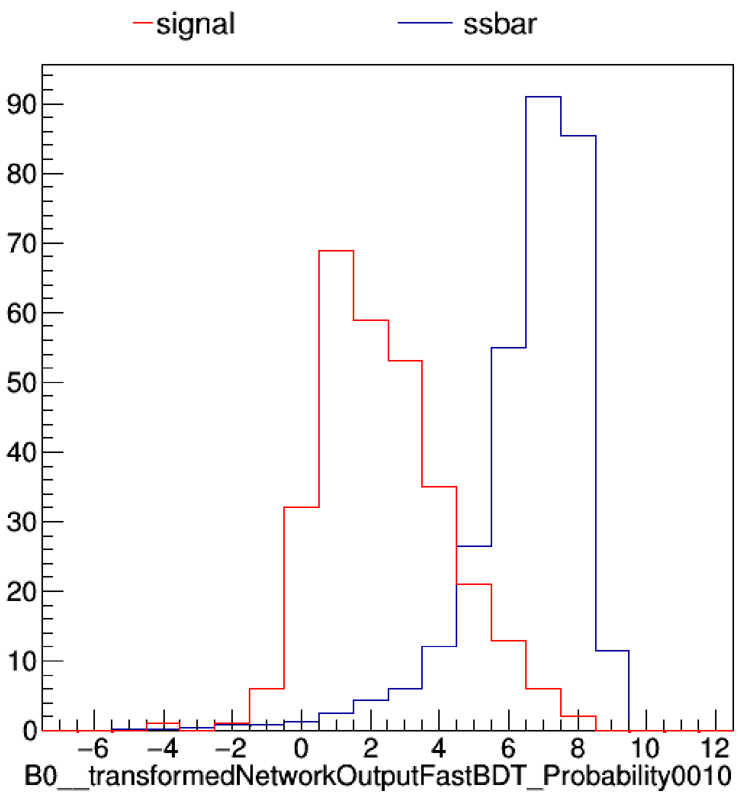


- Apparently I'm getting the opposite, so this points to either a bug in the computation of this variable or a problem in the generation of the signal samples.

Puzzle: continuum suppression

- Took a peek at the MC5 generic B$\bar{B}$ (only the first 20 fb^{-1} chunk): ~300 events pass the selection and 25 of them are actual $B^0 \rightarrow \varphi K_S$ events;

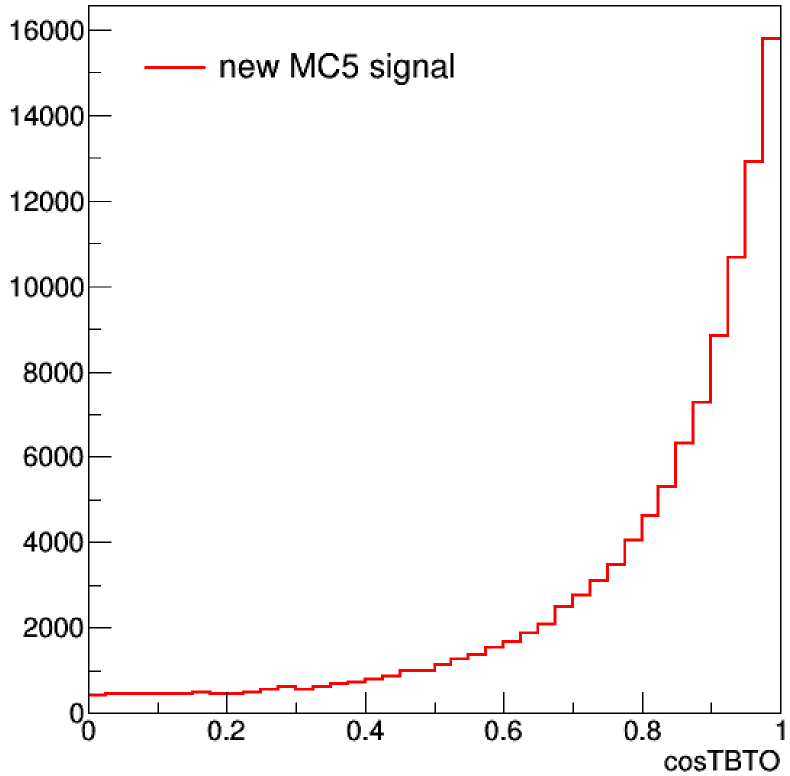




- Cannot draw strong conclusions, but it seems like the CosTBTO distribution is fine and separation power of the continuum suppression machinery is realistic.

A look at the newly released signal MC

- I immediately ran on the new official signal MC samples that have been released a few days ago;
- Same problem as in my private samples: the CosTBTO distribution strongly peaks at 1…;
- This is true for all the final states I am investigating;
- Looks like a problem in the generation of the signal sample (?);



- This is an open issue, so I appreciate any input from people who might have run into the same problem.

On backup slides I pasted the snippet of the steering file I have been using to build the continuum suppression.

Continuum Suppression

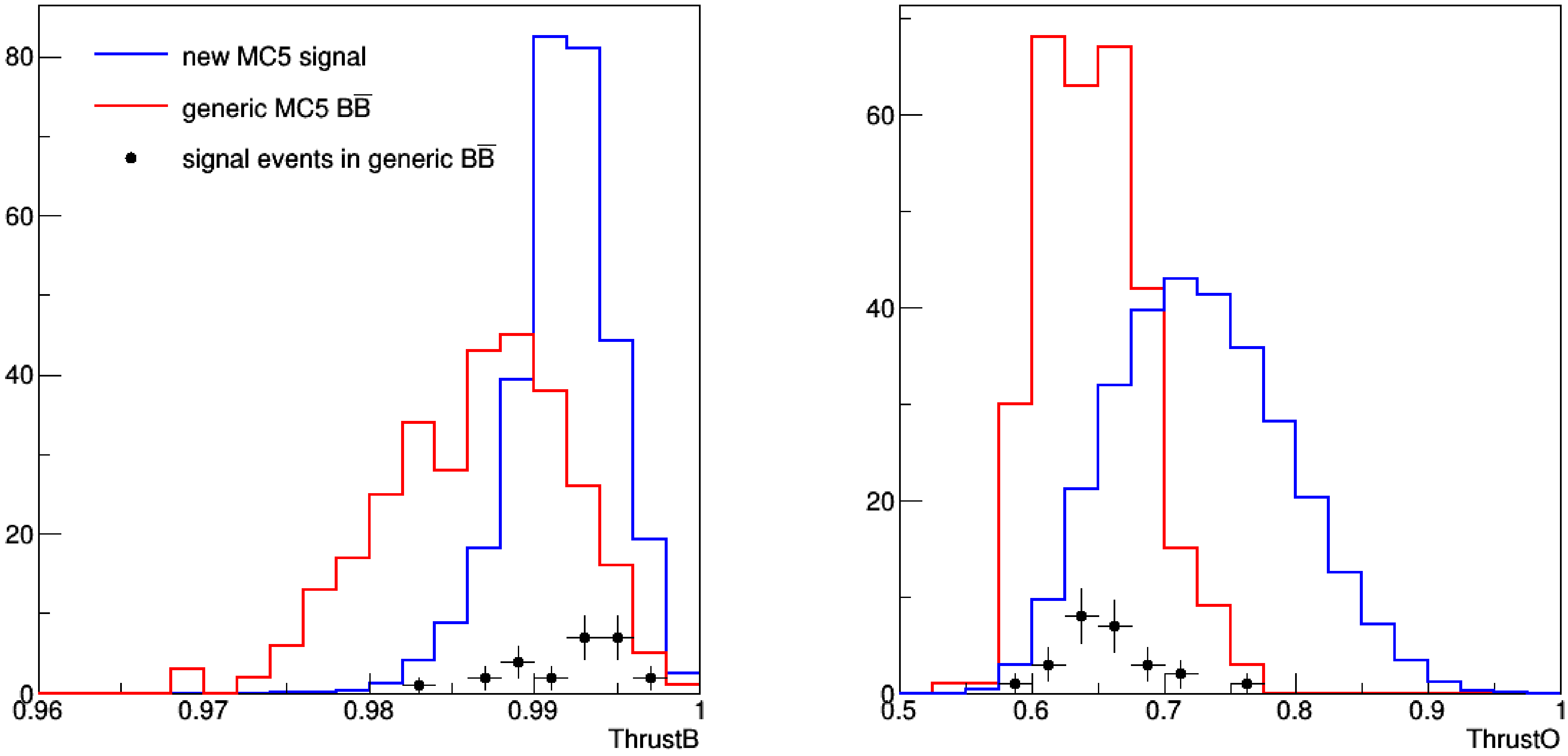
```
reconstructDecay('B0:ch1 -> phi:all K_S0:mdst',
                 'Mbc > 5.2 and abs(deltaE) < 0.2')
vertexRave('B0:ch1', 0.0, 'B0:ch1 -> [phi -> ^K+ ^K-] K_S0')
matchMCTruth('B0:ch1')

# get the rest of the event:
buildRestOfEvent('B0:ch1')

# get tag vertex ('breco' is the type of MC association)
TagV('B0:ch1', 'breco')

# get continuum suppression (needed for flavor tagging)
buildContinuumSuppression('B0:ch1')
```

Continuum suppression



Event selection

$B^0 \rightarrow \eta' (\eta (\gamma\gamma) \pi^+\pi^-) K^0_S (\pi^+\pi^-)$

- $M_{bc} > 5.25$;
- $|\Delta E| < 0.1$
- $0.45 < M(\eta \rightarrow \gamma\gamma) < 0.57$;
- $0.93 < M(\eta') < 0.98$;
- $0.48 < M(K^0_s \rightarrow \pi^+\pi^-) < 0.52$;
- PIDpi($\pi^\pm$)>0.2
- $d_0(\pi^\pm) < 0.08$;
- $z_0(\pi^\pm) < 0.1$;
- At least one PXD hit for each $\pi^\pm$ from η' decay;
- VtxPvalue(η, η', K_S, B_0) > 1.E-5

Event selection

$B^0 \rightarrow \eta' (\eta\ (\gamma\gamma)\ \pi^+\pi^-)\ K^0_S\ (\pi^0\pi^0)$

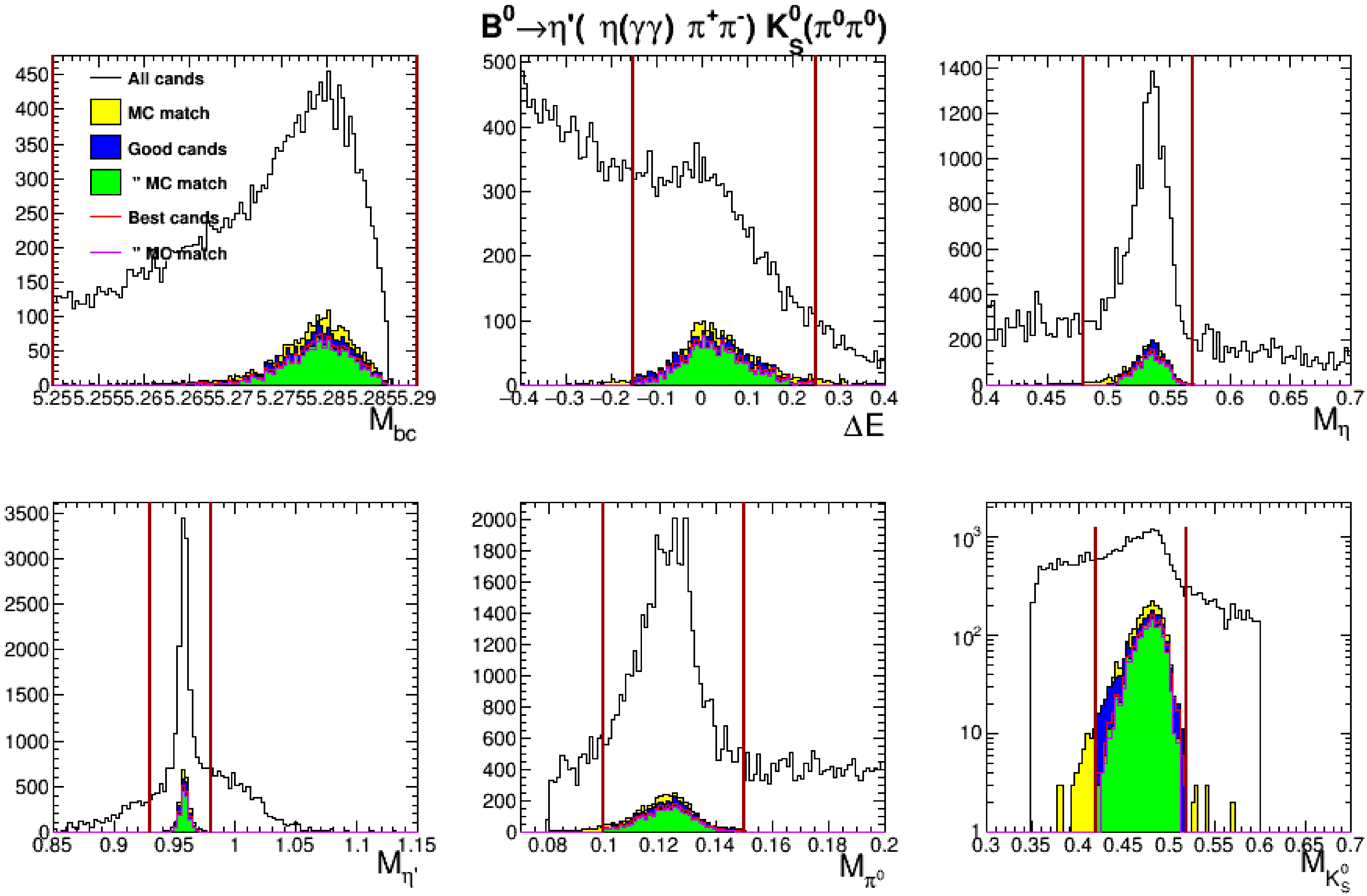
- $M_{bc} > 5.25$;
- $-0.15 < \Delta E < 0.25$
- $0.45 < M(\eta \rightarrow \gamma\gamma) < 0.57$;
- $0.93 < M(\eta') < 0.98$;
- $0.1 < M(\pi^0) < 0.15$;
- $0.42 < M(K^0_s \rightarrow \pi^0\pi^0) < 0.52$;
- PIDpi$(\pi^\pm)$>0.2
- $d_0(\pi^\pm) < 0.08$;
- $z_0(\pi^\pm) < 0.15$;
- At least one PXD hit for each $\pi^\pm$ from η' decay;
- VtxPvalue(η, η', B_0) > 1.E-5

Event selection

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

- $M_{bc} > 5.25$;
- $|\Delta E| < 0.15$
- $0.52 < M(\eta \rightarrow \pi^+\pi^-\pi^0) < 0.57$;
- $0.93 < M(\eta') < 0.98$;
- $0.1 < M(\pi^0) < 0.15$;
- $0.48 < M(K^0_s \rightarrow \pi^+\pi^-) < 0.52$;
- PIDpi$(\pi^\pm)>0.2$
- $d_0(\pi^\pm) < 0.08$;
- $z_0(\pi^\pm) < 0.15$;
- At least one PXD hit for each $\pi^\pm$ from η' decay;
- VtxPvalue(η, η', K_S, B_0) > 1.E-5

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



$B^0 \rightarrow \eta' (\eta\ (\gamma\gamma)\ \pi^+\pi^-)\ K^0_S\ (\pi^0\pi^0)$