First studies on $B \to K^{(*)}\nu\nu$ at Belle-II

- with an eye to neutral reconstruction -

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Outline

- $B \to K^{(*)}\nu\nu$: theoretical and experimental status

- Analysis of MC samples
  - sample
  - pre-selection: distributions and efficiencies
  - discriminant variable distribution w and w/o machine bkg

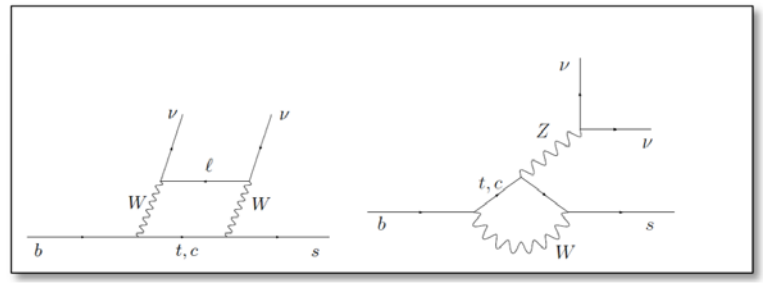
$B \to K^{(*)}\nu\nu$: THEORETICAL AND EXPERIMENTAL STATUS

$B \to K^{(*)}\nu\nu$: theoretical motivations

- SM predictions [JHEP 02 184,2015]:

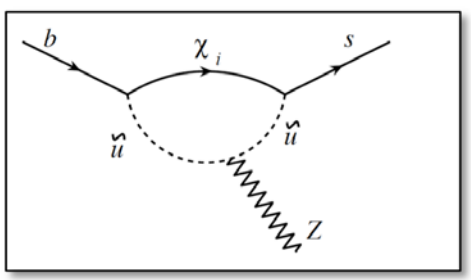
$$\mathrm{BR}(B^+ \to K^+\nu\bar{\nu})_{\mathrm{SM}} = (3.98 \pm \underline{0.43} \pm \underline{0.19}) \times 10^{-6},$$
$$\mathrm{BR}(B^0 \to K^{*0}\nu\bar{\nu})_{\mathrm{SM}} = (9.19 \pm \underline{0.86} \pm \underline{0.50}) \times 10^{-6},$$
$$F_L^{\mathrm{SM}} = 0.47 \pm \underline{0.03},$$

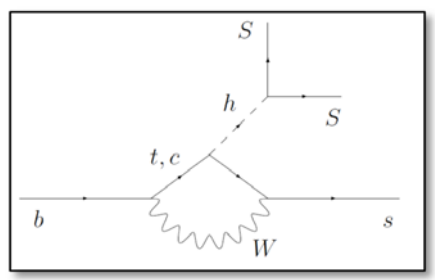
  - form factor error
    parametric error ($|V_{cb}|$-dominated)

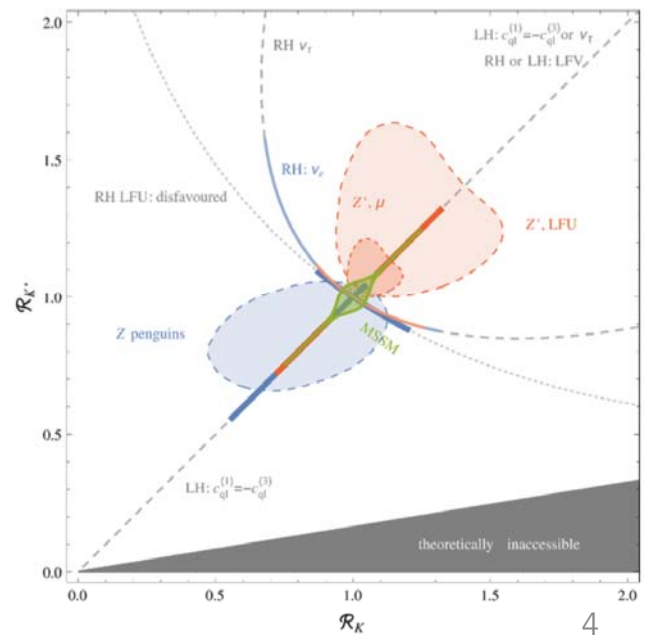


$R_{K^{(*)}}$ = $B \to K^{(*)}\nu\nu$ BR normalized to SM expectations [JHEP 02 184,2015]

- NP effects:
  - non standard Z-couplings
  - new sources of missing energy

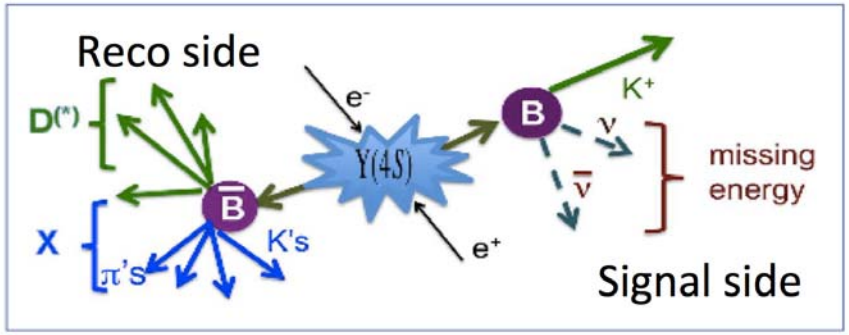






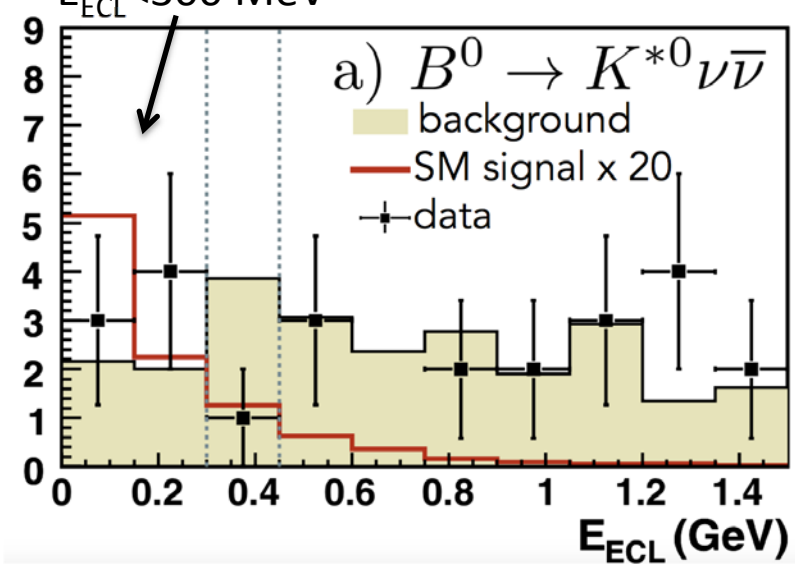
$B \to K^{(*)}\nu\nu$: experimental search (I)

- Recoil method:
  - reconstruct semileptonic or hadronic B decays on one side
  - look for K/K* + missing energy on the rest of the event (and ~ nothing else)



- Suppress qq and combinatoric BB background by using kinematic and event shape variables
- Crucial ingredients:
  - detector hermeticity and performing tracking: veto extra-tracks, low (→0) extra-energy in the calorimeter
  - particle identification: suppression of events with mis-identified K/π on both Reco and Signal sides
- Signal extraction: cut or fit to E_{ECL} distribution (extra-energy in the calorimeter)

here, signal region:
E_{ECL}<300 MeV



[Belle, PRL 99 221802, 2007]

$B \to K^{(*)}\nu\nu$: experimental search (II)

- Most recent experimental results:
  - Belle search for $B \to h^{(*)}\nu\nu$; 0.711 ab^{-1} [PRD RC 87, 111103(2013)]

Mode	Upper limit
$B^+ \to K^+\nu\bar{\nu}$	$< 5.5 \times 10^{-5}$
$B^0 \to K^0_S\nu\bar{\nu}$	$< 9.7 \times 10^{-5}$
$B^+ \to K^{*+}\nu\bar{\nu}$	$< 4.0 \times 10^{-5}$
$B^0 \to K^{*0}\nu\bar{\nu}$	$< 5.5 \times 10^{-5}$

  - BaBar search for $B \to K^{(*)}\nu\nu$; 0.429 ab^{-1} [PRD 87, 112005(2013)]

$BF(B^+ \to K^+\nu\bar{\nu})$	$< 1.6 \times 10^{-5}$
$BF(B^0 \to K^0\nu\bar{\nu})$	$< 4.9 \times 10^{-5}$
$BF(B \to K\nu\bar{\nu})$	$< 1.7 \times 10^{-5}$
$BF(B^+ \to K^{*+}\nu\bar{\nu})$	$< 6.4 \times 10^{-5}$
$BF(B^0 \to K^{*0}\nu\bar{\nu})$	$< 12.0 \times 10^{-5}$
$BF(B \to K^*\nu\bar{\nu})$	$< 7.6 \times 10^{-5}$

~ 1 order of magnitude far from SM expectation

$B \to K^{(*)}\nu\nu$: perspectives at Belle-II

- First extrapolation in BELLE2-NOTE-0021, assuming:
  - similar background to Belle
  - hadronic and semileptonic tag
  - SM prediction [JHEP 04 (2009) 022]:
    - $BR(B^- \to K^- \nu\nu) = 3.6 \times 10^{-6}$
    - $BR(B^0 \to K^{*0} \nu\nu) = 0.13 \times 10^{-6}$

$\mathcal{B}(B^+ \to K^+\nu\bar{\nu}) = (4.4 \pm 1.5) \times 10^{-6}$	
$0.711\ \mathrm{ab}^{-1}$ [Belle measurement]	$< 5.5 \times 10^{-5}$
$5\ \mathrm{ab}^{-1}$	$< 2.1 \times 10^{-5}$
$50\ \mathrm{ab}^{-1}$	$< 0.7 \times 10^{-5}$
$\mathcal{B}(B^0 \to K^0_S\nu\bar{\nu}) = (2.2 \pm 0.8) \times 10^{-6}$	
$0.711\ \mathrm{ab}^{-1}$ [Belle measurement]	$< 9.7 \times 10^{-5}$
$5\ \mathrm{ab}^{-1}$	$< 3.7 \times 10^{-5}$
$50\ \mathrm{ab}^{-1}$	$< 1.2 \times 10^{-5}$
$\mathcal{B}(B^0 \to K^{*0}\nu\bar{\nu}) = (6.8 \pm 2.0) \times 10^{-6}$	
$0.711\ \mathrm{ab}^{-1}$ [Belle measurement]	$< 5.5 \times 10^{-5}$
$5\ \mathrm{ab}^{-1}$	$< 2.1 \times 10^{-5}$
$50\ \mathrm{ab}^{-1}$	$< 0.7 \times 10^{-5}$

- What's (will be) new:
  - theo side: higher SM expectation for $BR(B^0 \to K^{*0} \nu\nu)$ (~ 9×10^{-6})
  - exp side: sensitivity study performed with Belle-II full simulation, more reliable estimates of
    - background contamination: e.g. higher pile-up reduced → discriminant power of E_{ECL} (study and optimization of ECL performances ongoing)
    - signal efficiency: lower boost → higher hermeticity (lower bkg, higher eff.), improved tracking and particle identification

$B \to K^{(*)}\nu\nu$ MC studies

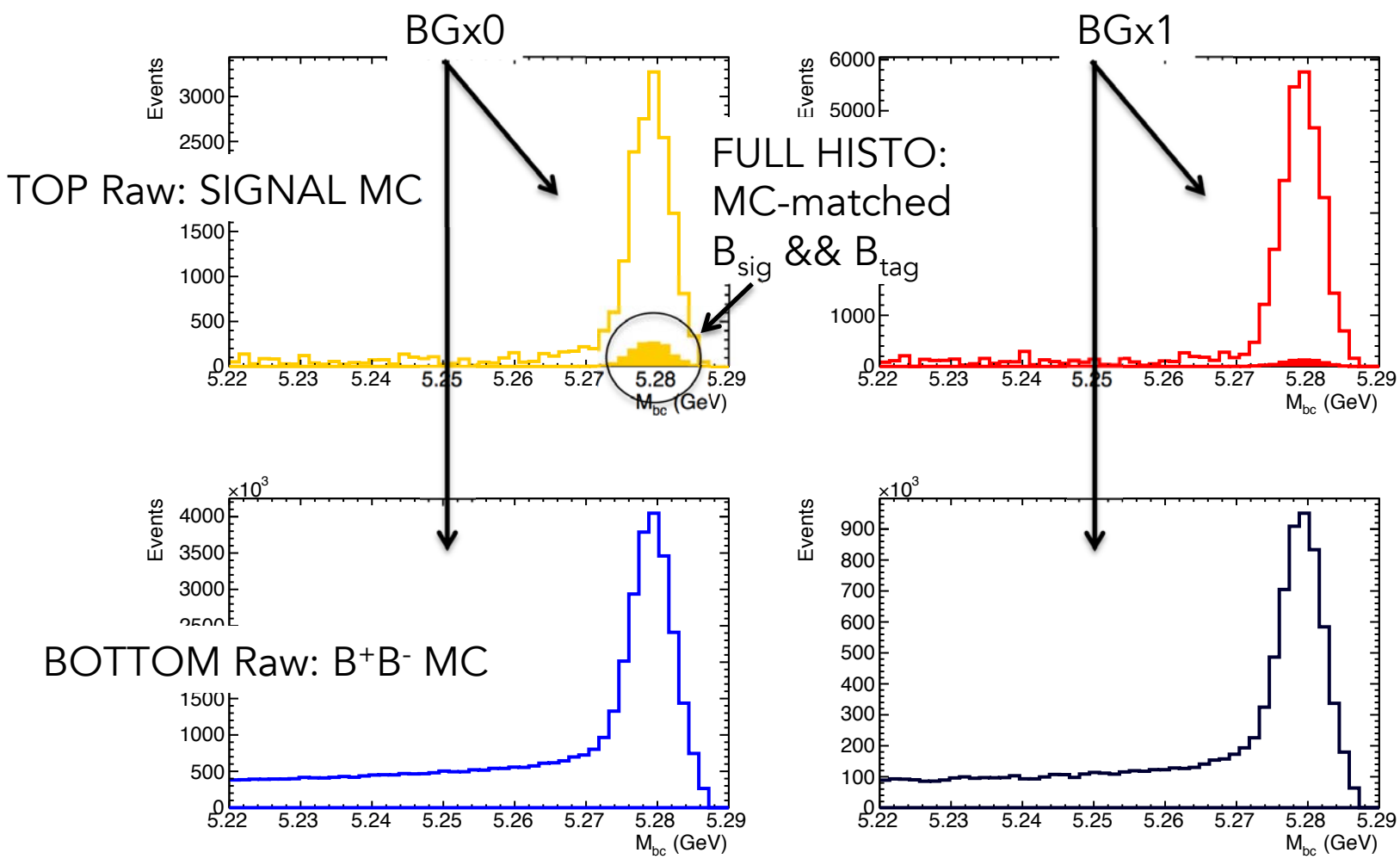
Samples

- SIGNAL SAMPLES:
  - 1002000 evts for BGx0 and BGx1 configs (private production with release-00-05-03)
  - reconstruct charged channel only: $K^{*+} \rightarrow K^{+}\pi^{0}$, $K_{s}\pi^{+}$

- $B^{+}B^{-}$ generic: (MC5 production, release-00-05-03)
  - ~11×10^{6} evt for BGx1 config
  - ~43×10^{6} evt for BGx0 config

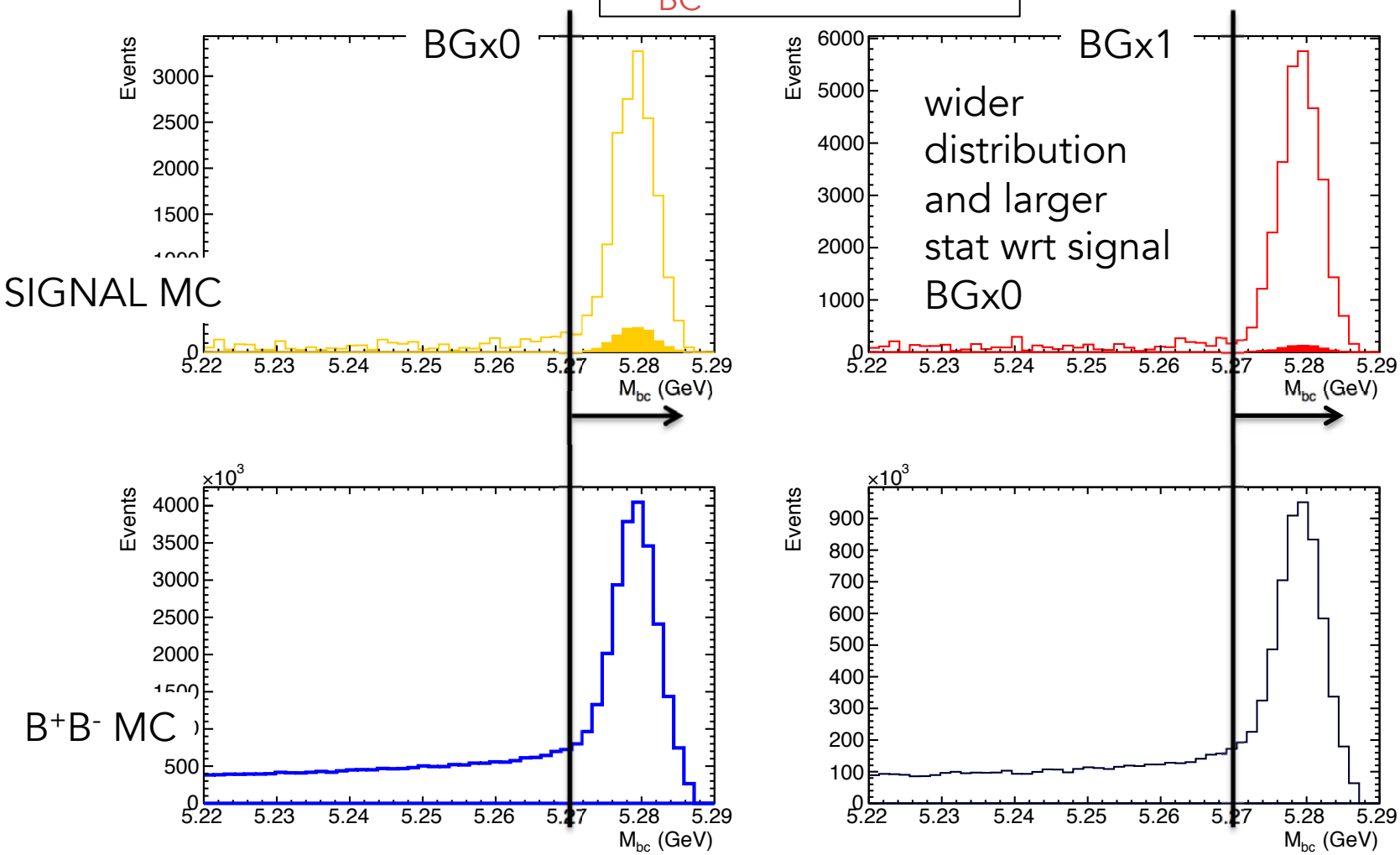
- @ reco level: same cuts discussed by Mario

In (most of) the following pages:



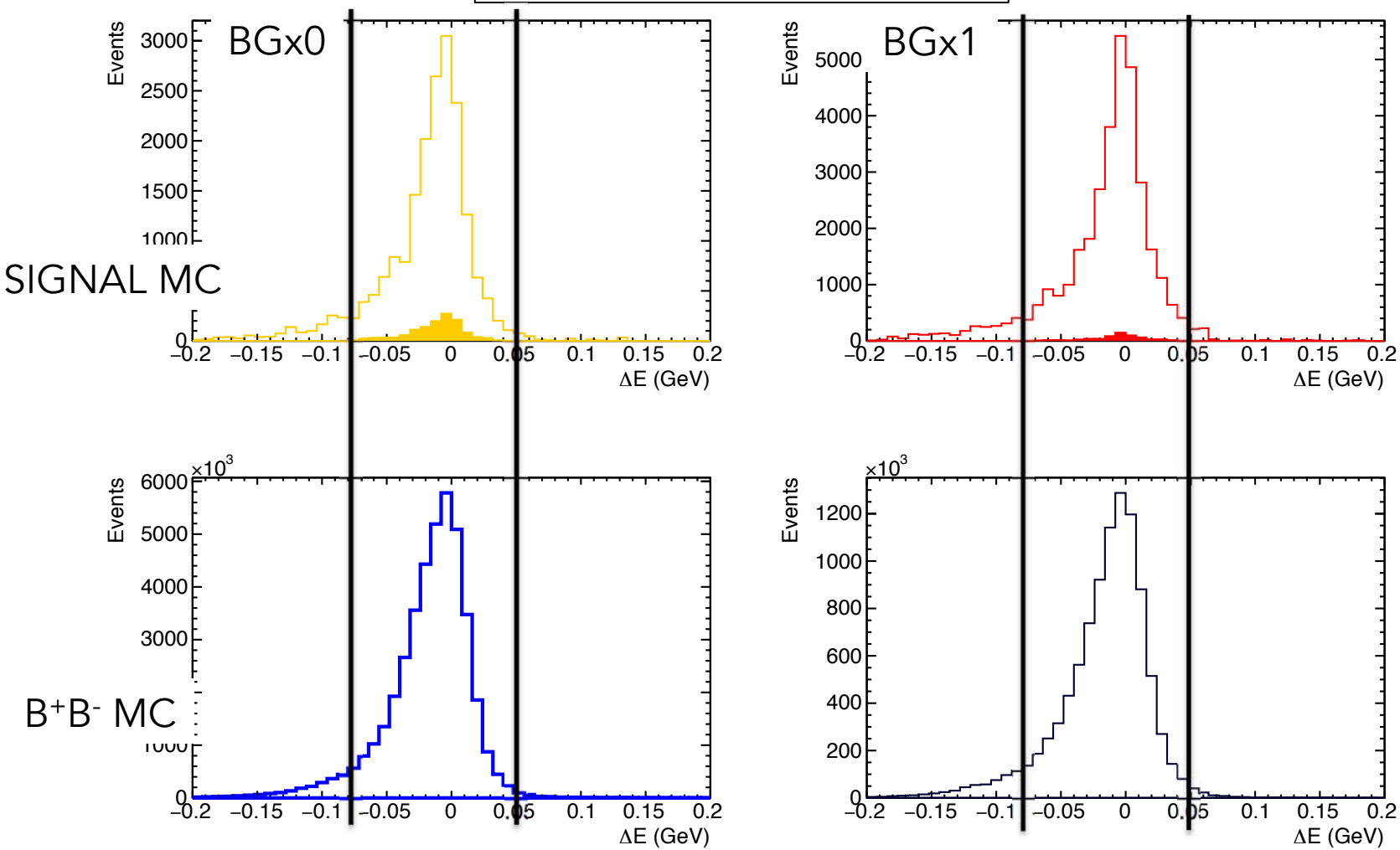
Tag side selection: m_{BC}

m_{BC}>5.27 GeV/c^2

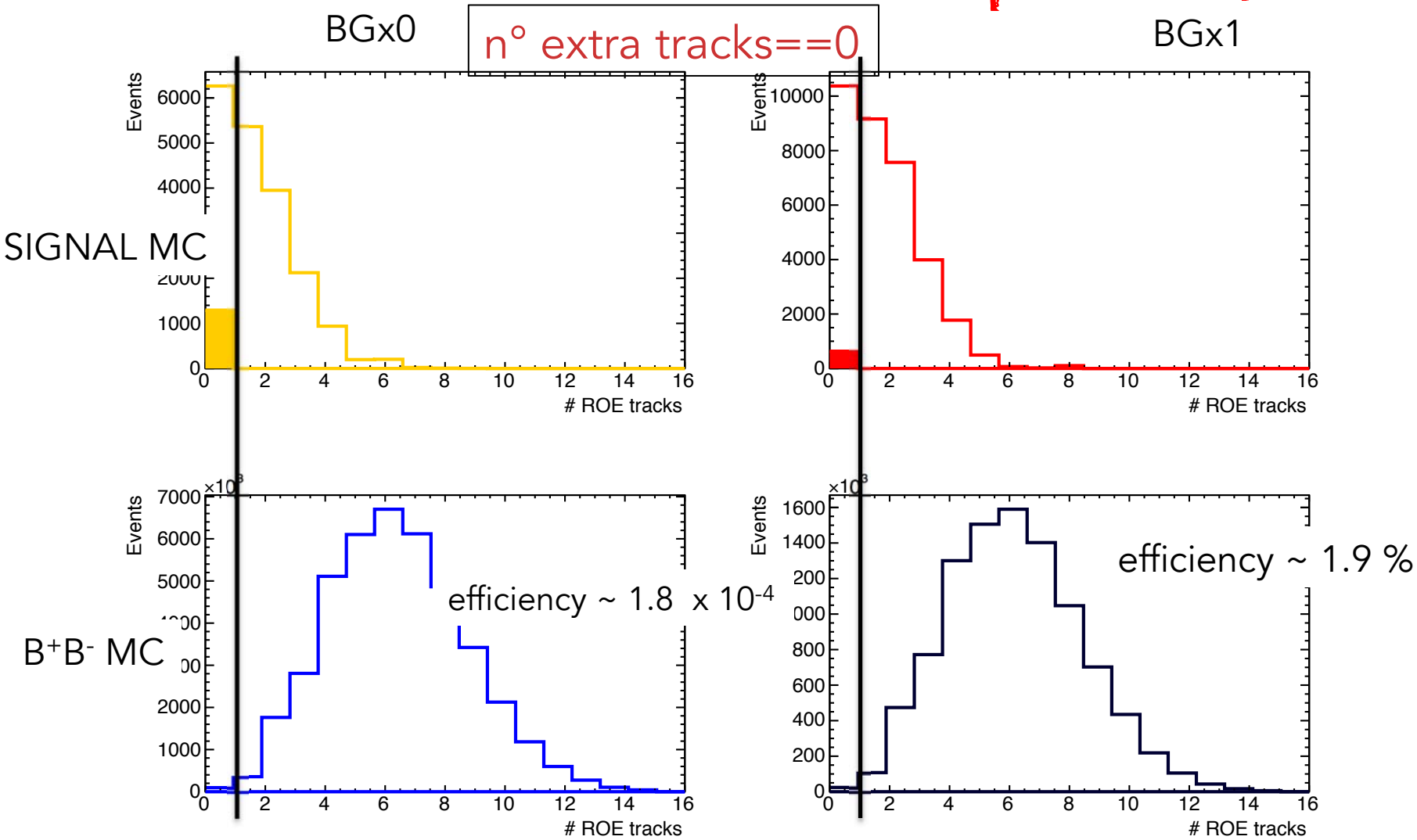


Tag side selection: ΔE

-0.08 < ΔE < 0.05 GeV



Signal side selection: extra-tracks multiplicity



Raw selection efficiencies

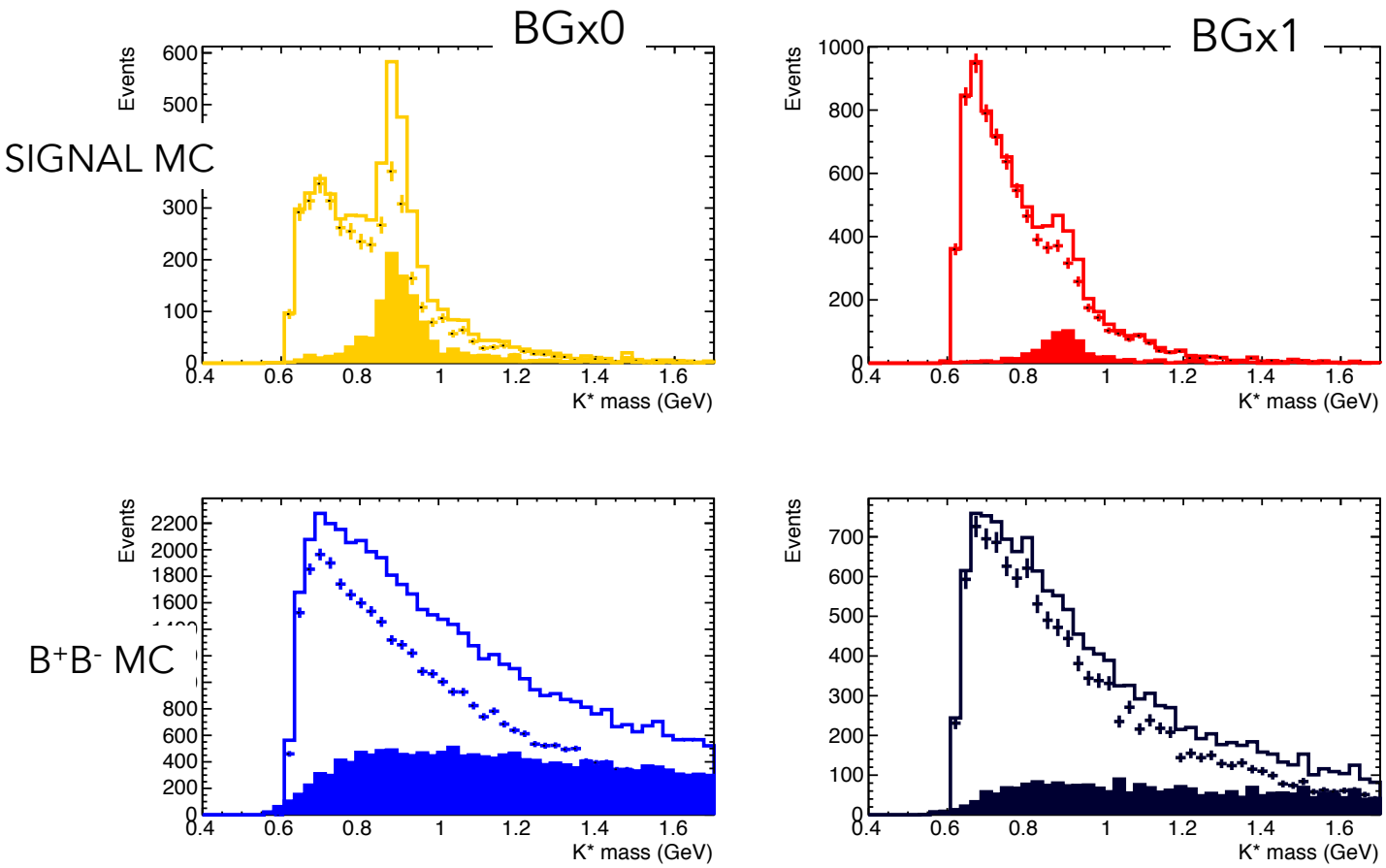
- Preselection cuts
  - $m_{BC} > 5.27$ GeV/c^2
  - $-0.08 < \Delta E < 0.05$ GeV
  - 0 extra tracks

	B^+B^-generic		$B \to K^{*+}nn$	
	BGX0	BGX1	BGx0	BGx1
efficiency (10^{-4})	~ 1.88	~ 0.99	~ 23	~ 16

K* mass

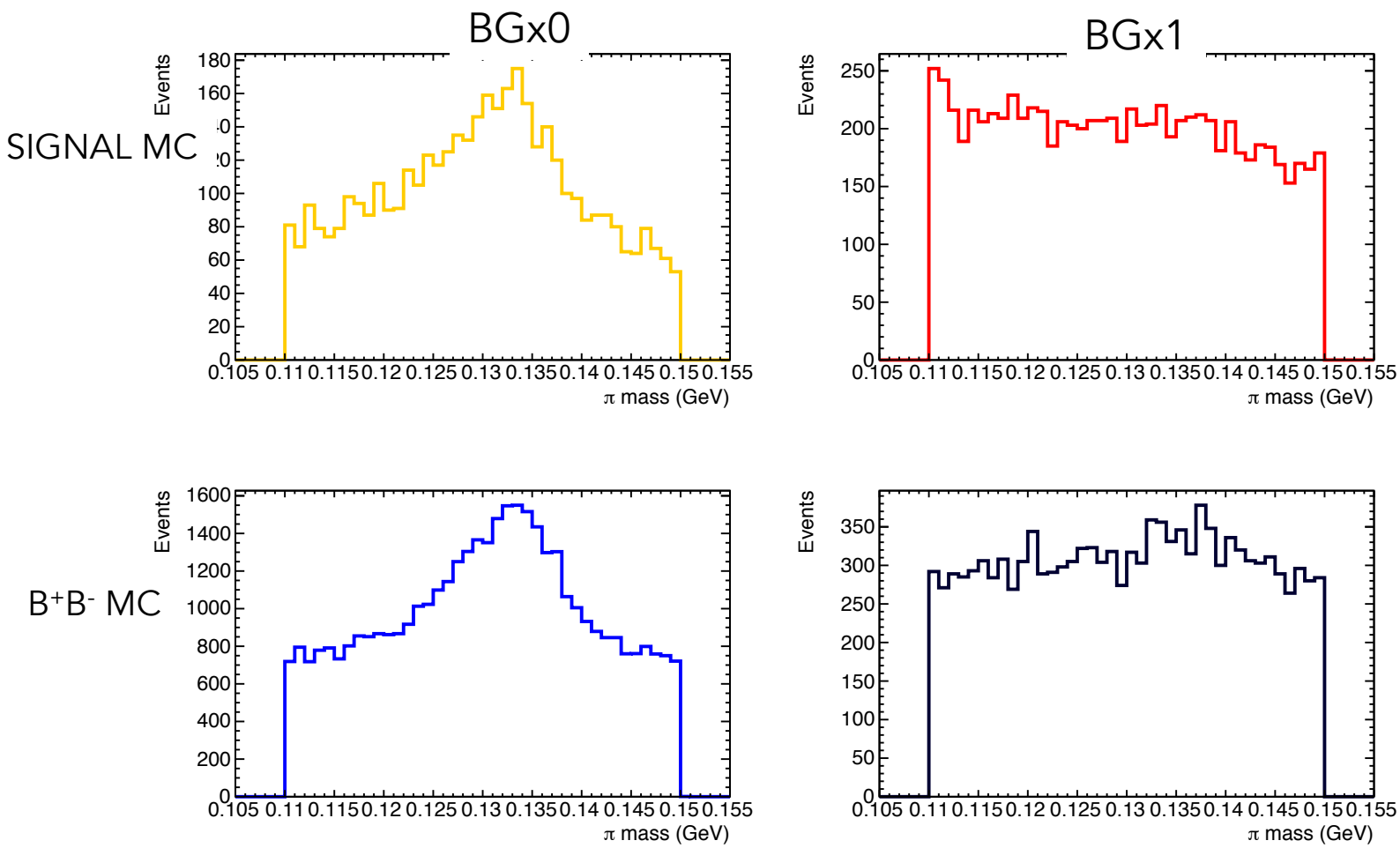
- In these plots:
  - full histo: $K_s\pi$ mode
  - dots: $K\pi^0$ mode

Peak at ~ 700 MeV/c^2 probably due to problem in ECL cluster energy calibration which results in shifted π^0 mass peak position, more details in tomorrow ECL software talk



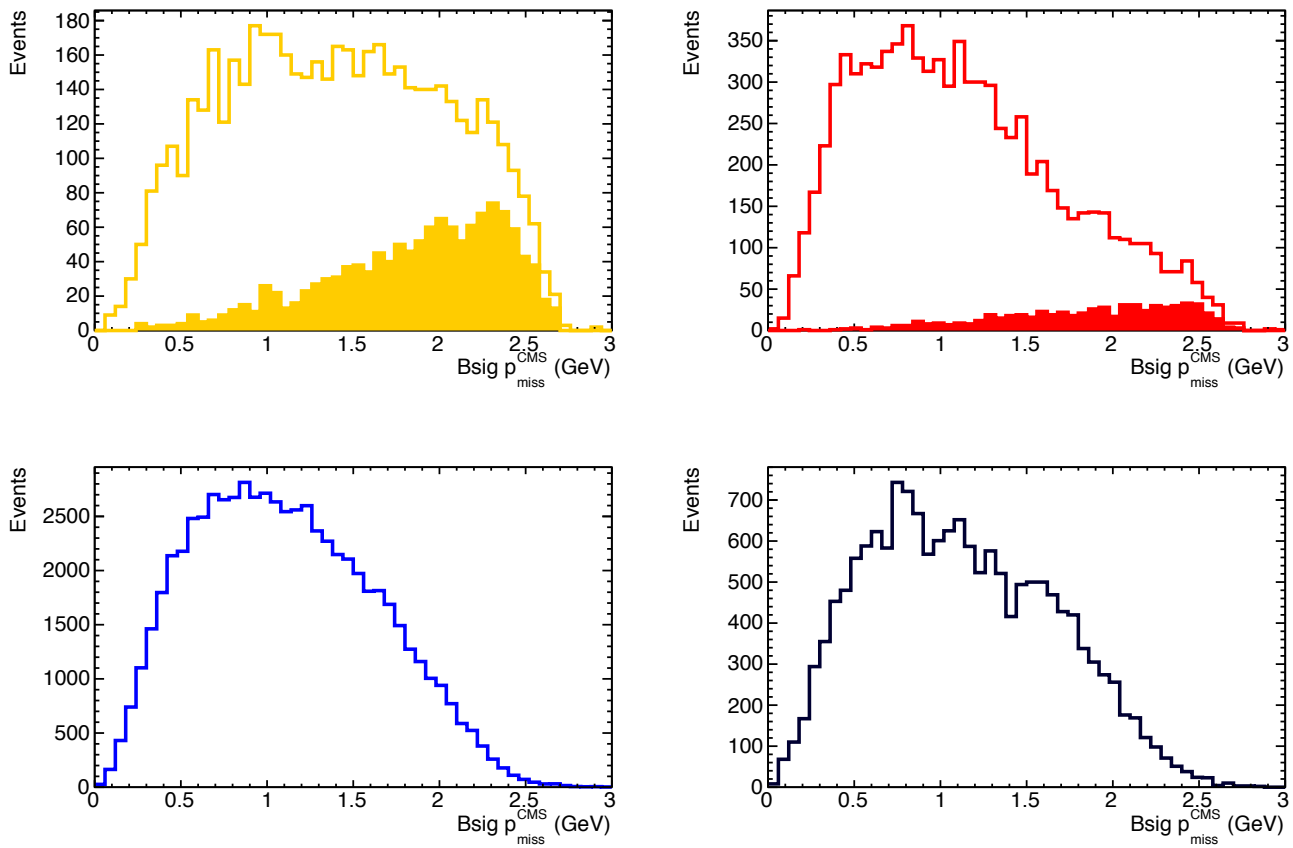
π^0 (from signal side K*) mass

- machine bkg has a big impact in π^0 mass, further investigation and improvement in reconstruction needed

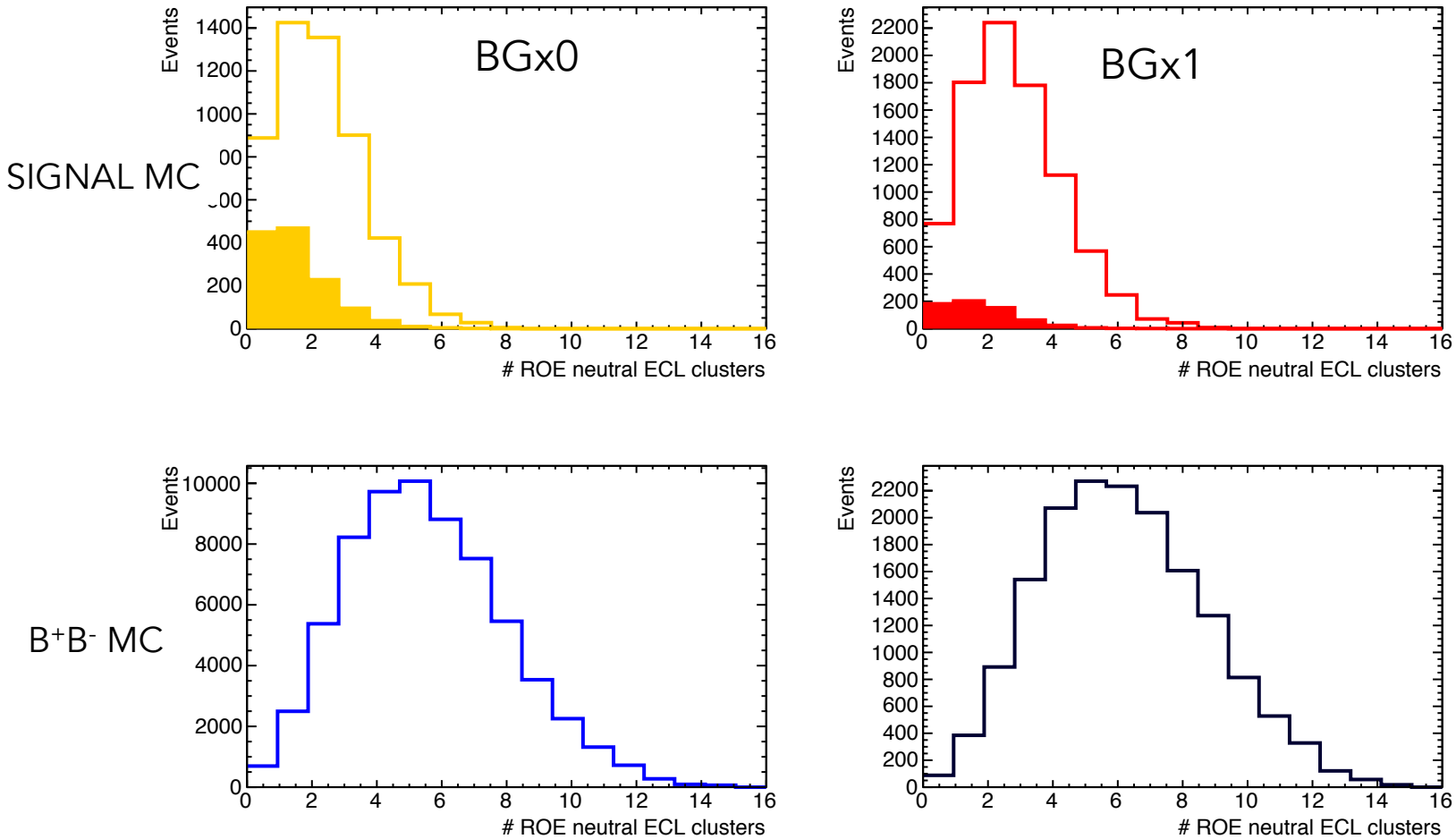


Neutrino pair properties

- Missing 4-momenutm = Y(4) 4-momentum – 4-momentum of all tag and signal side particle momenta
- One example: missing 3-momentum in CM frame



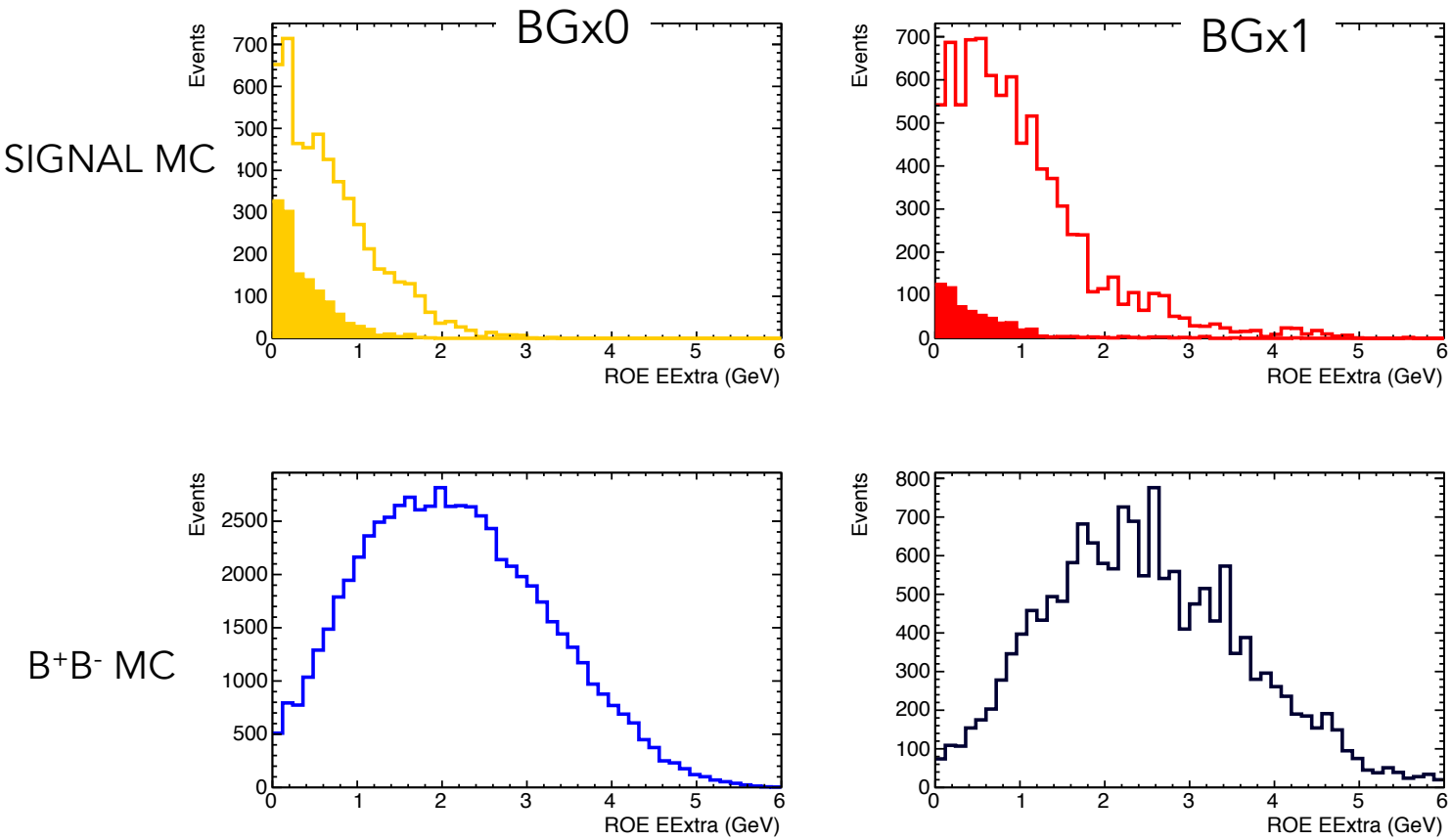
Extra neutral multiplicity



- Upper limit on extra neutral multiplicity may be required

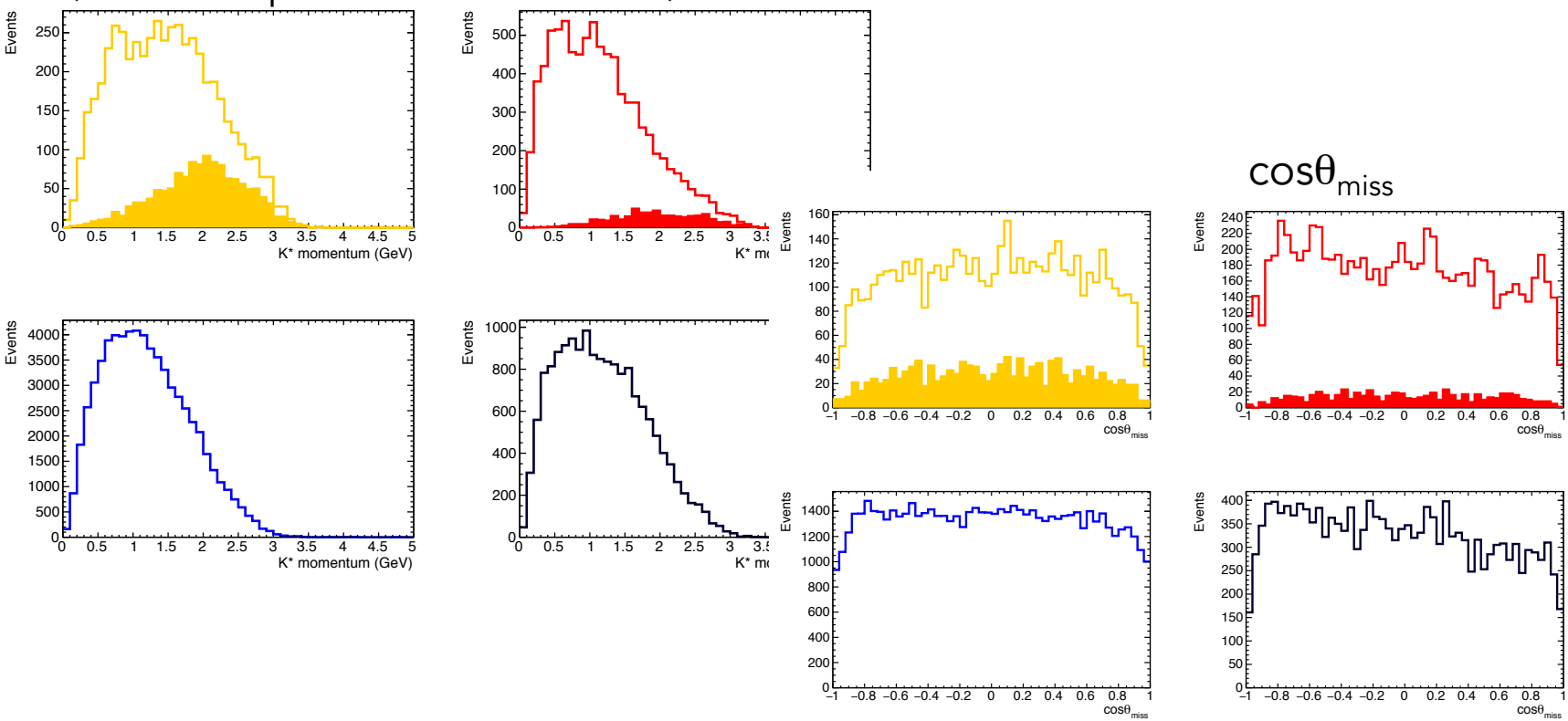
Extra neutral energy in ECL

- One of the most discriminant vars
  - studies on minimum gamma energy (now 50 MeV) and minimum Eextra energy (now 130 MeV) needed, machine bkg dependent



Other potentially useful variables

K* momentum
(model dependent distribution)



Event shape variables not investigated yet

Conclusions

- Experimental UL on $B \to K^{(*)}\nu\nu$ from B-factories 1 order of magnitude far from SM expectation
- First row extrapolation from Belle to Belle-II: SM BR measurable with full stat

- First investigation on signal and charged generic MC
  - reasonable distribution for discriminant variables
  - machine bkg has an impact, above all on neutral reconstruction

- Next steps:
  - run on qq and B0B0bar, reconstruct K^{*0}, K, K_S modes
  - perform background characterization
  - tune signal side selection and define signal extraction strategy
  - compare analysis reach with nominal FWD ECL (CsI(Tl)) and pure CsI FWD ECL

EXTRA-SLIDES

BGx0 vs BGx1: signal MC