Search for $B \to K^{(*)}\nu\nu$ against hadronic tag

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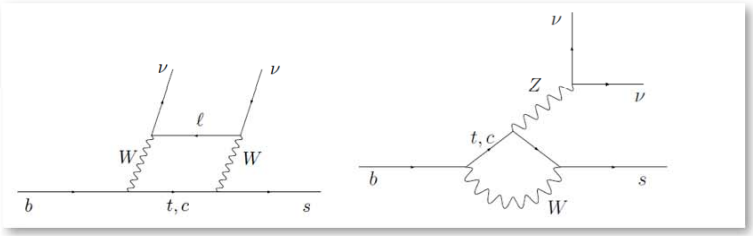
THEORETICAL AND EXPERIMENTAL STATUS

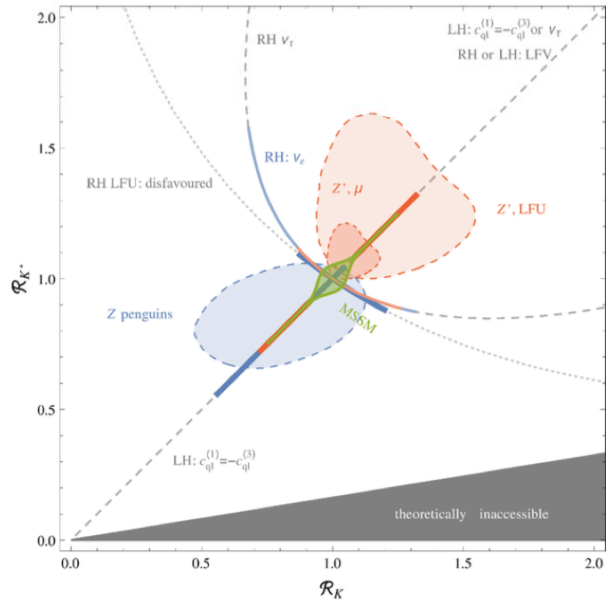
$B \to K^{(*)}\nu\nu$: theoretical motivations (I)

- SM predictions ([1] JHEP 02 184,2015) updated in D. M. Straub (BELLE2-MEMO-2016-007[2]):

Mode	$\mathcal{B}$ $[10^{-6}]$ Ref. [2]	$\mathcal{B}$ $[10^{-6}]$ Ref. [1]
$B^+ \to K^+\nu\bar{\nu}$	$3.98 \pm 0.43 \pm 0.19$	4.68 ± 0.64
$B^0 \to K^0_S\nu\bar{\nu}$	$1.85 \pm 0.20 \pm 0.09$	2.17 ± 0.30
$B^+ \to K^{*+}\nu\bar{\nu}$	$9.91 \pm 0.93 \pm 0.54$	10.22 ± 1.19
$B^0 \to K^{*0}\nu\bar{\nu}$	$9.19 \pm 0.86 \pm 0.50$	9.48 ± 1.10



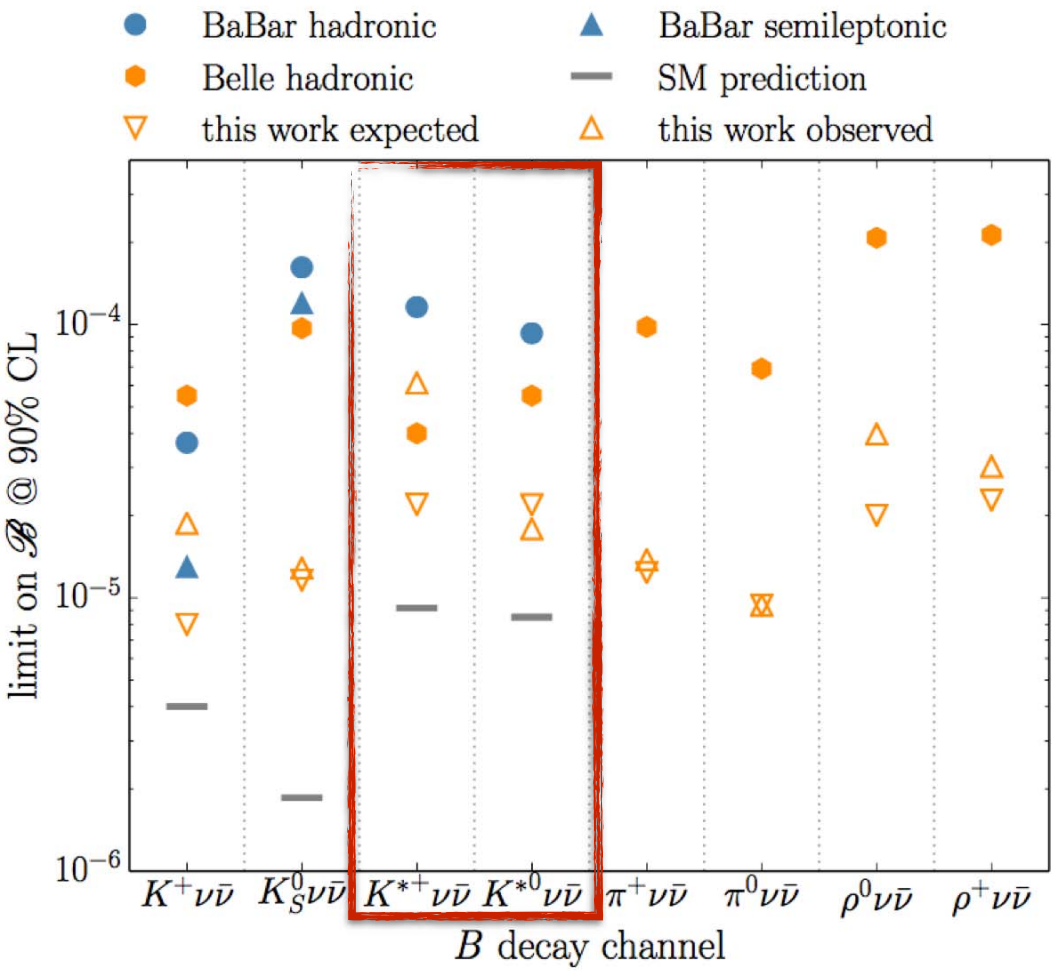
- NP effects:
  - non standard Z-couplings
  - new sources of missing energy



$R_{K^{(*)}}$ = $B \to K^{(*)}\nu\nu$ BR normalised to SM expectations [1]

- In connection to the the anomaly, wrt the SM expectation, in the $B \to K^*ll$ channels observed by LHCb, several NP models ([1], arXiv:1704.06188 [hep-ph]) foreseen deviations also in the $B \to K^{(*)}\nu\nu$ observables

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



Belle SL tagged analysis,
arXiv:1702.03224 [hep-ex]

~ 1/2 order of magnitude far from SM expectation

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

- We performed a cut-and-count analysis on MC5 samples reconstructing $B^+ \to K^{*+}(K^{+0}\pi)\nu\nu$, in order to test the different steps of the reconstruction/ selection and to evaluate the impact of machine background

- The reach of this simple and incomplete (missing K* modes) is well below the most recent Belle/BaBar measurements.
- For the B2TIP report, an extrapolation using the most recent measurement and assuming improvements in the hadronic B reconstruction have been computed

- In the near future, using MC8 we'll perform a more sophisticated analysis also adding the mission K* decay modes, both charged and neutrals.

MC5 studies on $B^+ \to K^{*+}\nu\nu$ and B2TIP extrapolation

Samples & strategy

- SIGNAL SAMPLES:~1M evts for BGx1 and BGx0 configs (private production with release-00-05-03), $K^{*+} \rightarrow K^{+}\pi^{0}$ only
- GENERIC MC SAMPLES: (MC5 production, release-00-05-03) corresponding to 1 ab^{-1} both for BGx0 and BGx1

- @ reco level:
  - Hadronic tag side reconstructed with FEI algorithm (B_{tag} signal probability > 0.05%)
  - Best Y candidate selected according to highest Btag signal probability and K* with smallest $|m_{K^*,reco}-m_{K^*,PDG}|$
  - dedicated clustering cleaning <u>optimised on BGx1 sample</u>

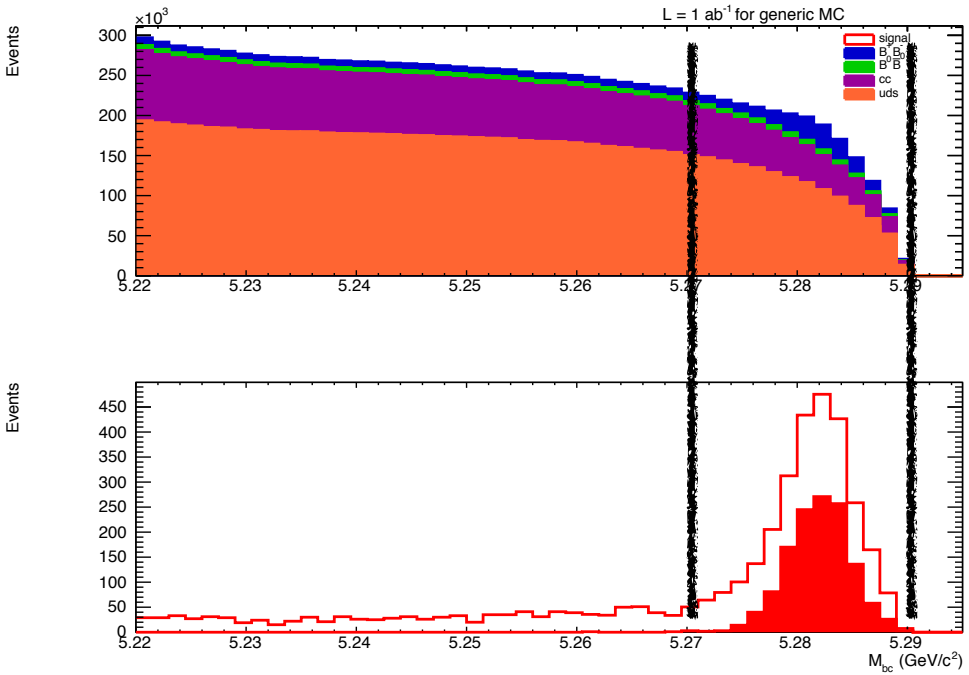
- Apply pre-selection cuts on m_{BC}, ΔE; optimise cuts on R2, m_{K^*} using S/sqrt(B) as figure of merit; apply cuts on $\cos^*\theta_{miss}$, $cp^*_{miss}+E^*_{miss}$
- Define a signal window on E_{extra} and evaluate signal efficiency and expected number of background events
- Estimate UL with Bayesian approach and extrapolate at higher luminosities

signal
B^+B^-
$B^0\bar{B}^0$
$c\bar{c}$
uds

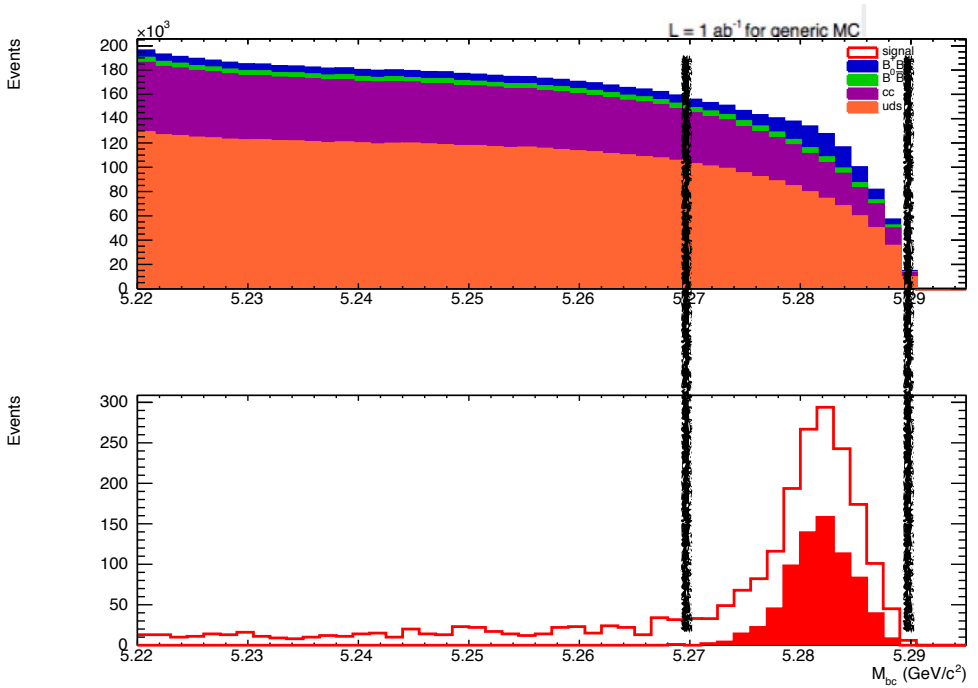
m_{BC} cut

$5.27\ GeV/c^2 < m_{BC} < 5.29\ GeV/c^2$

BGx0



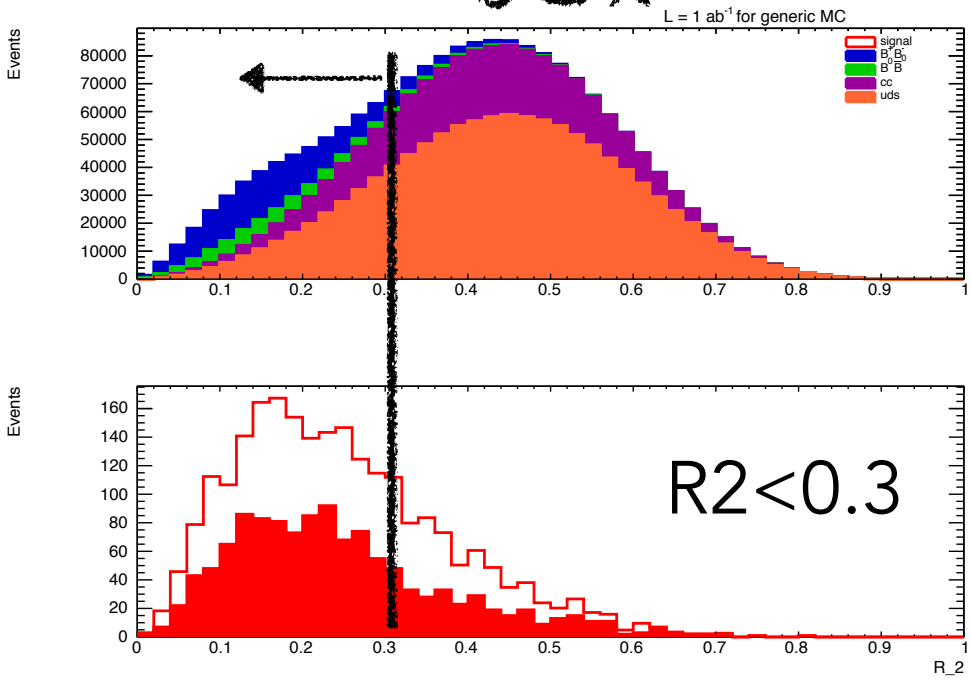
BGx1

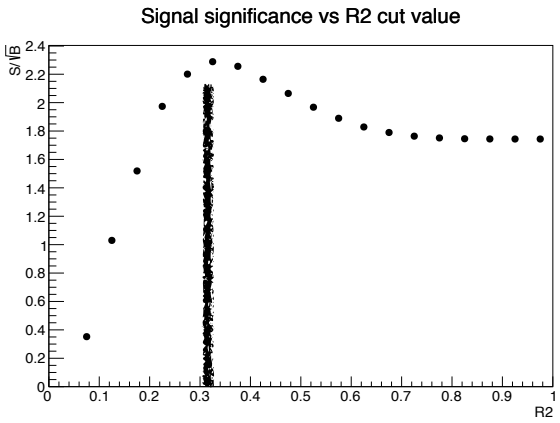


signal
B_0B_0
B^+B^-
cc
uds

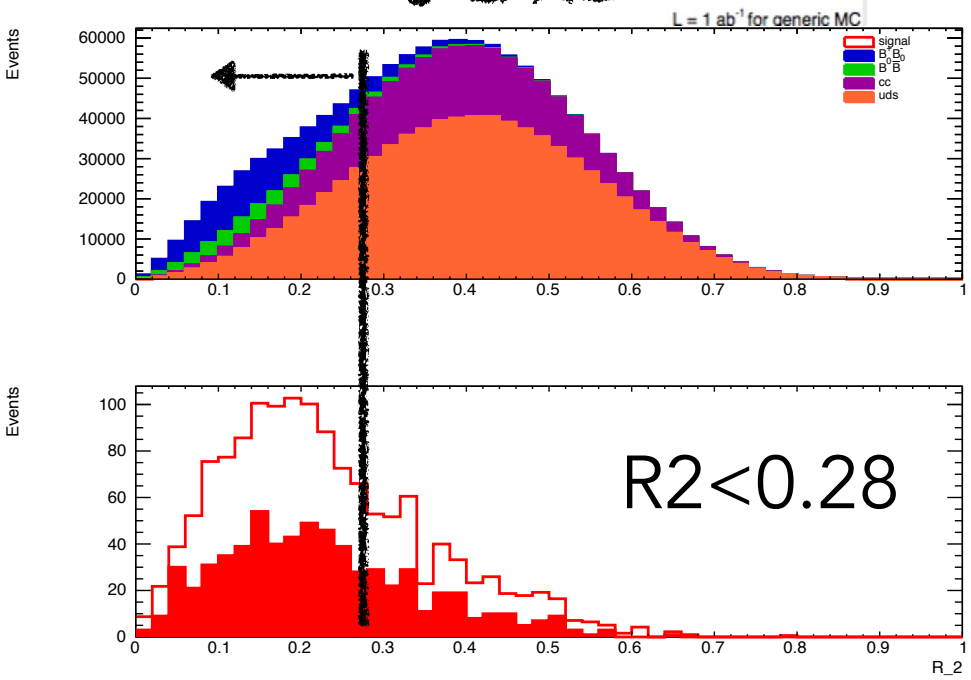
R2 cut

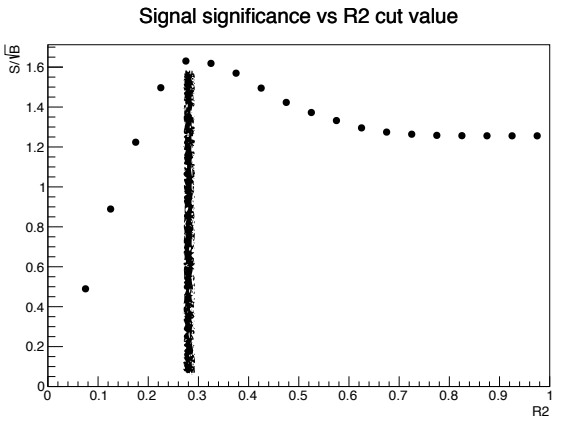
BGx0





BGx1



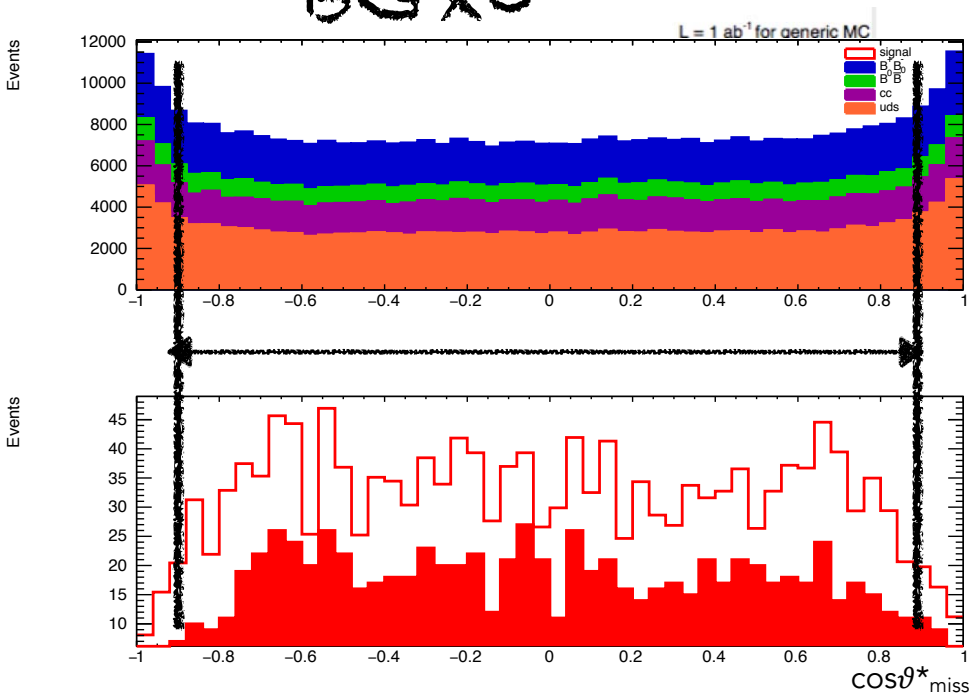


$\cos\theta^*_{miss}$ cut

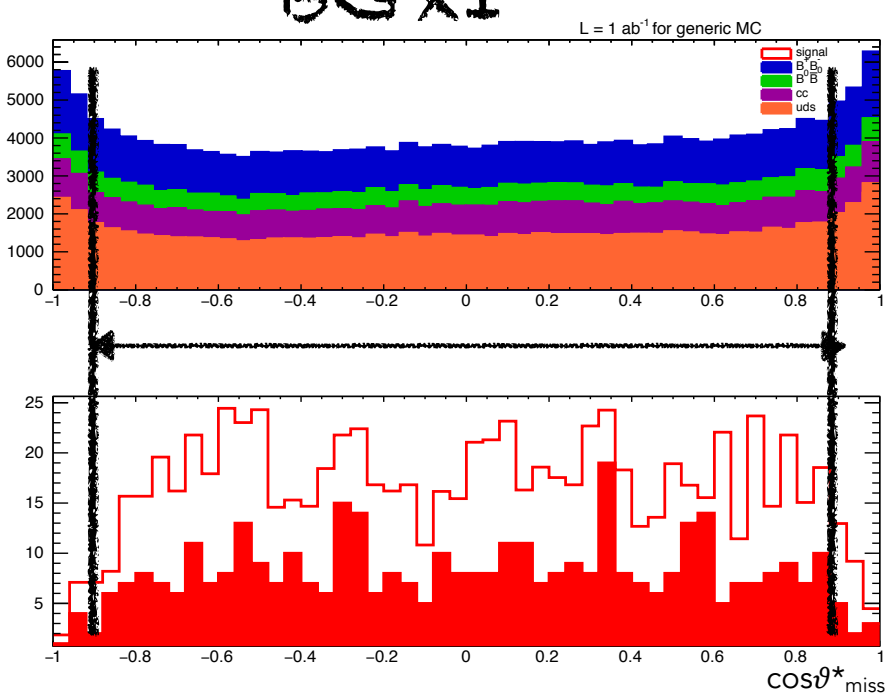
- Missing momentum in CM frame:
  - $P^*_{MISS} = P^*_{Y4S} - P^*_{Btag} - P^*_{K^*}$
  - At reco level, # extra tracks = 0 is required

  →missing momentum related to extra neutrals only
- Cut not optimised with significance scan, $|\cos\vartheta^*_{miss}|<0.85$

BGx0



BGx1

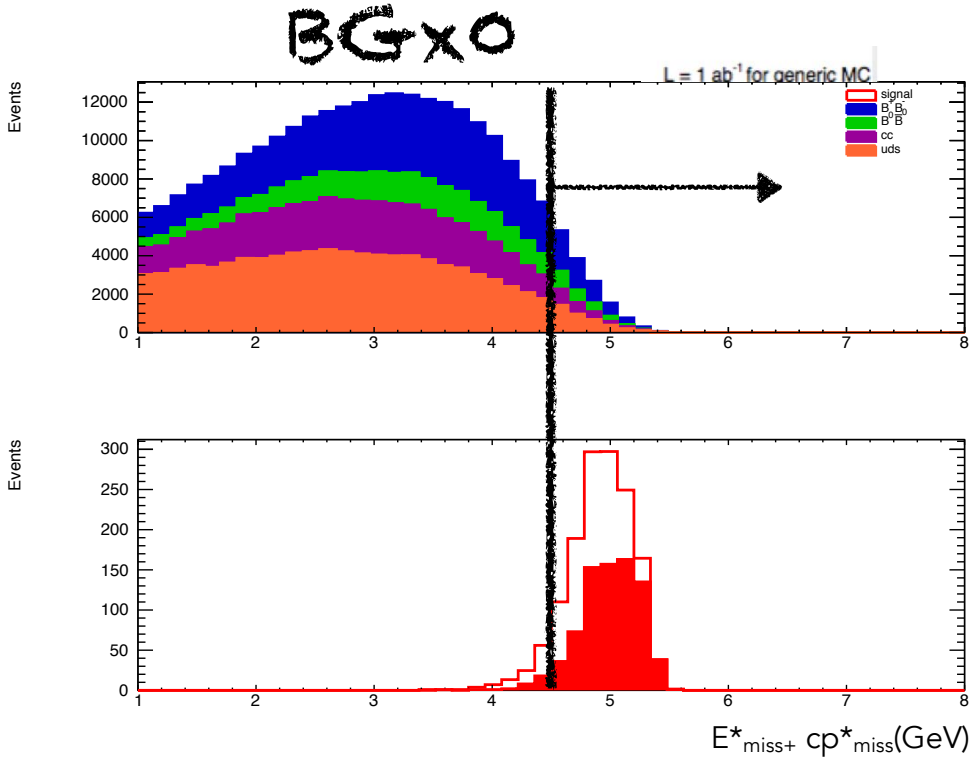


signal
$B_0\bar{B}_0$
B^+B^-
cc
uds

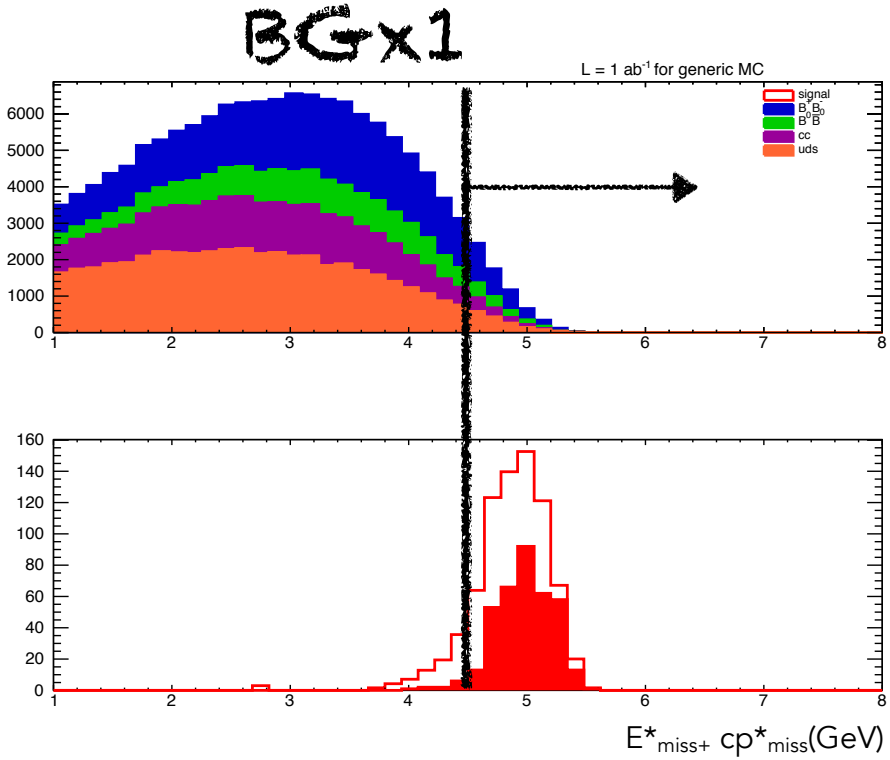
cp^*_{miss} + E^*_{miss} (I)

- Cut not optimised with significance scan, $E^*_{miss}+cp^*_{miss}> 4.5$ GeV

BGx0



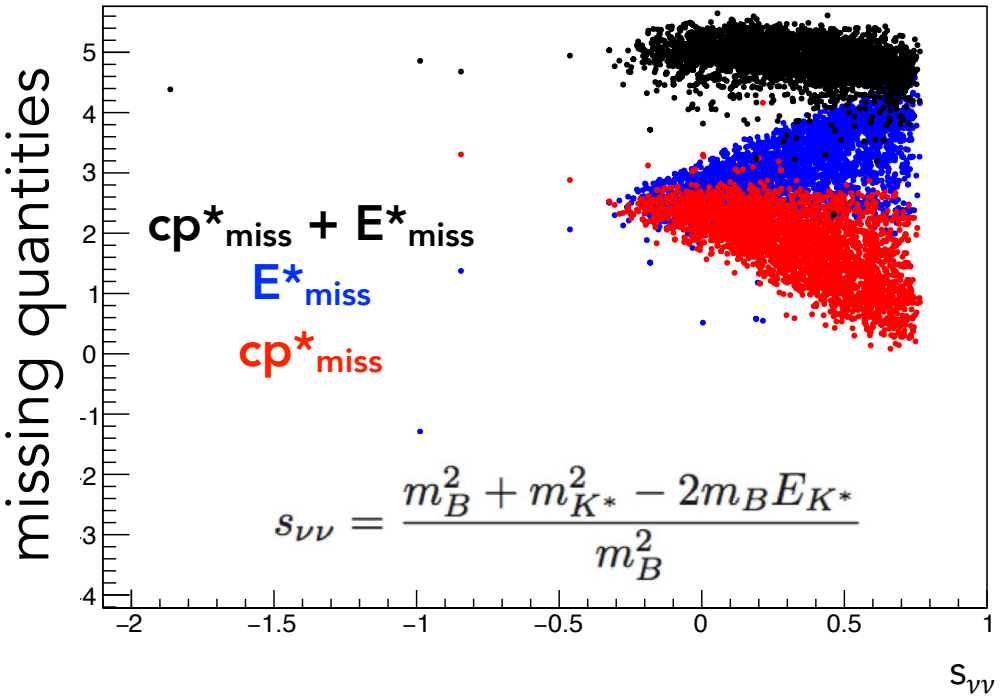
BGx1

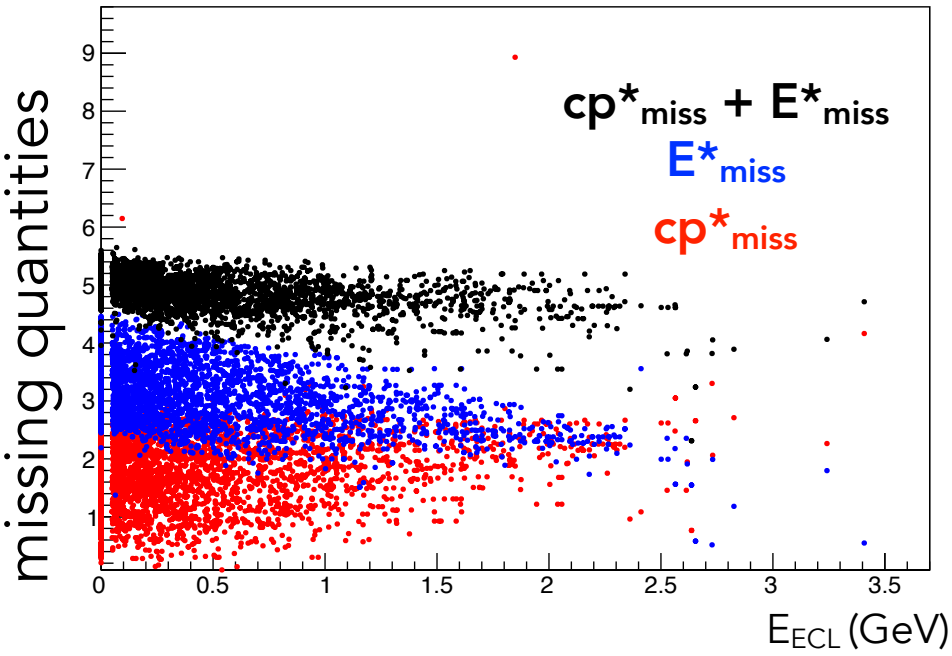


cp^*_{miss} + E^*_{miss} (II)

- In order to have a model-independent analysis, variables correlated with $\nu\nu$ kinematics shouldn't be used (e.g. K* momentum)
- A 2-D fit to extra neutral energy & missing quantities can be use to extract signal and bkg yield, small correlation among the two variables is desirable

BGx1, $K^{*+} \to K^+ \pi^0$



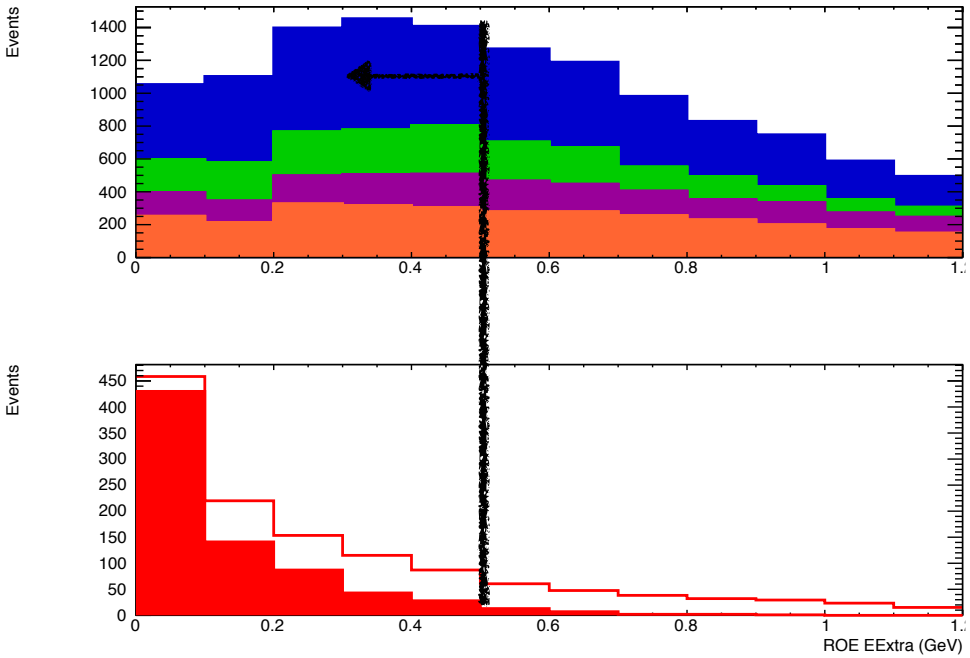


signal
$B_0\bar{B}_0$
B^+B^-
cc
uds

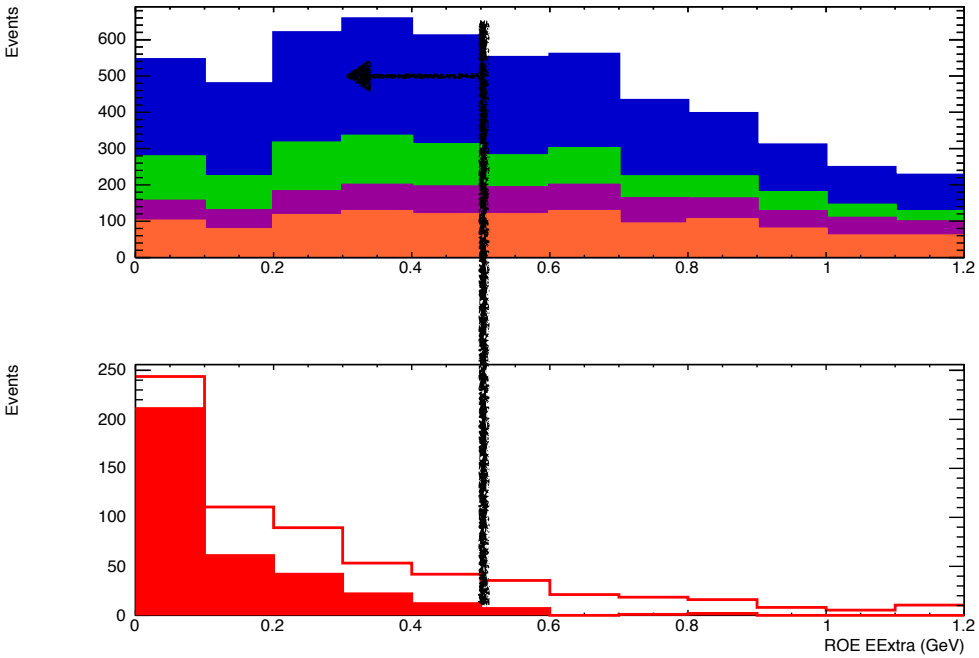
Extra neutral energy before cut

- Cut not optimised with significance scan, ROE $E_{extra} < 0.5$ GeV

BGx0

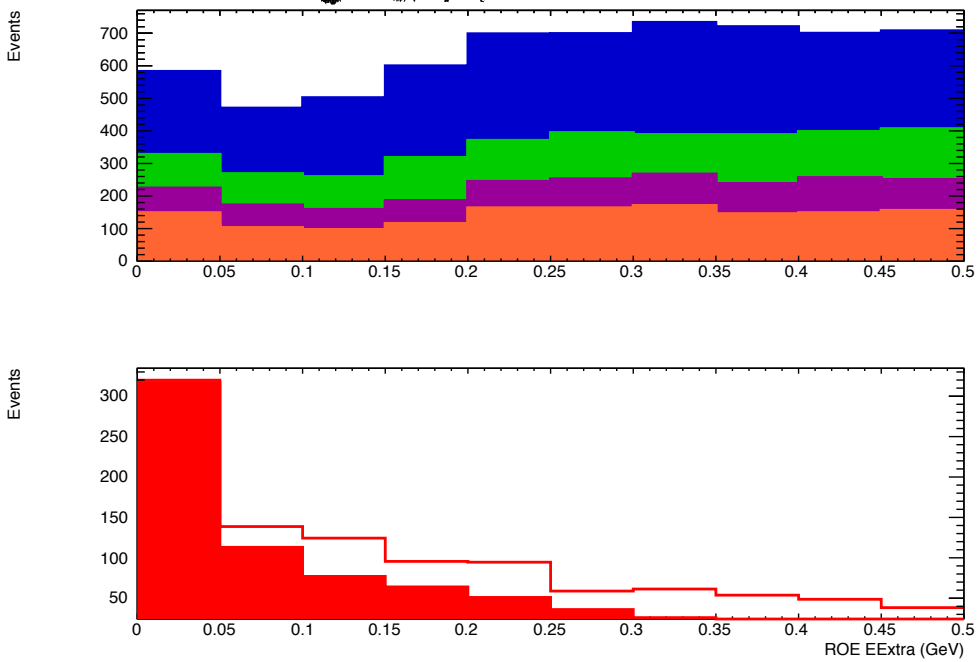


BGx1

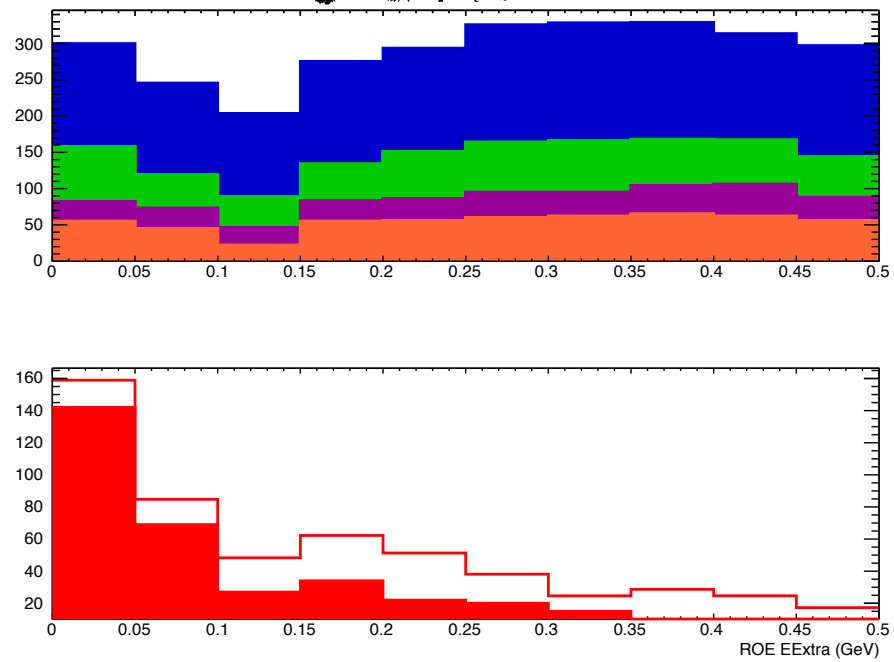


Extra neutral energy after cut (I)

BGx0

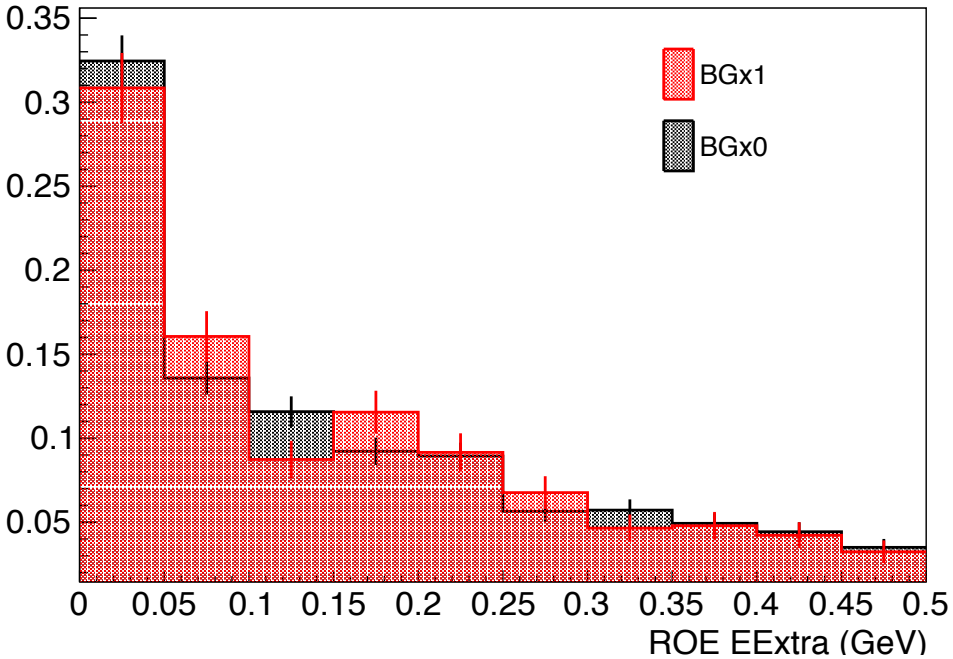


BGx1

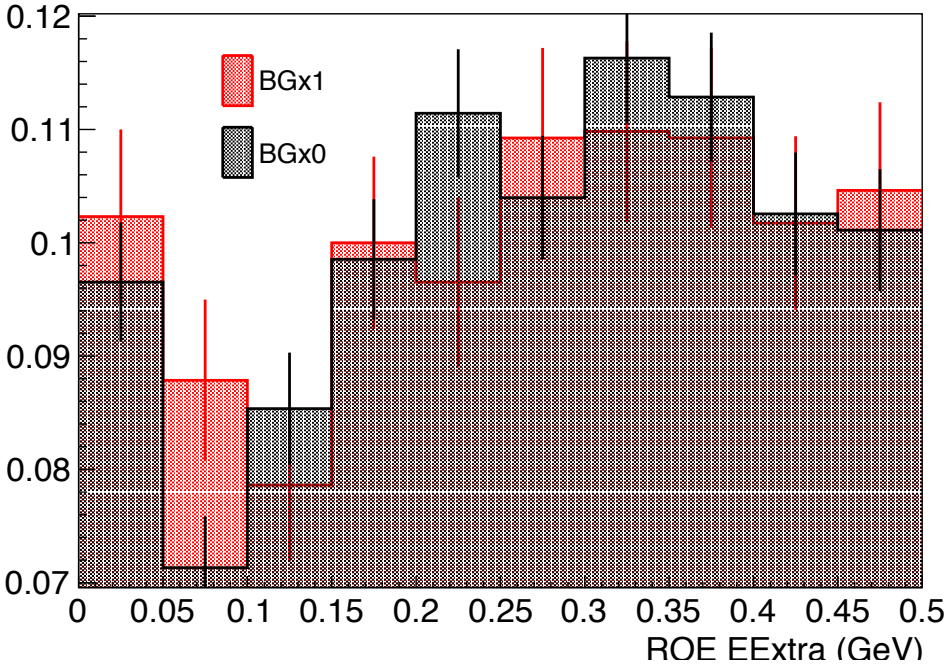


Extra neutral energy after cut (II)

signal MC

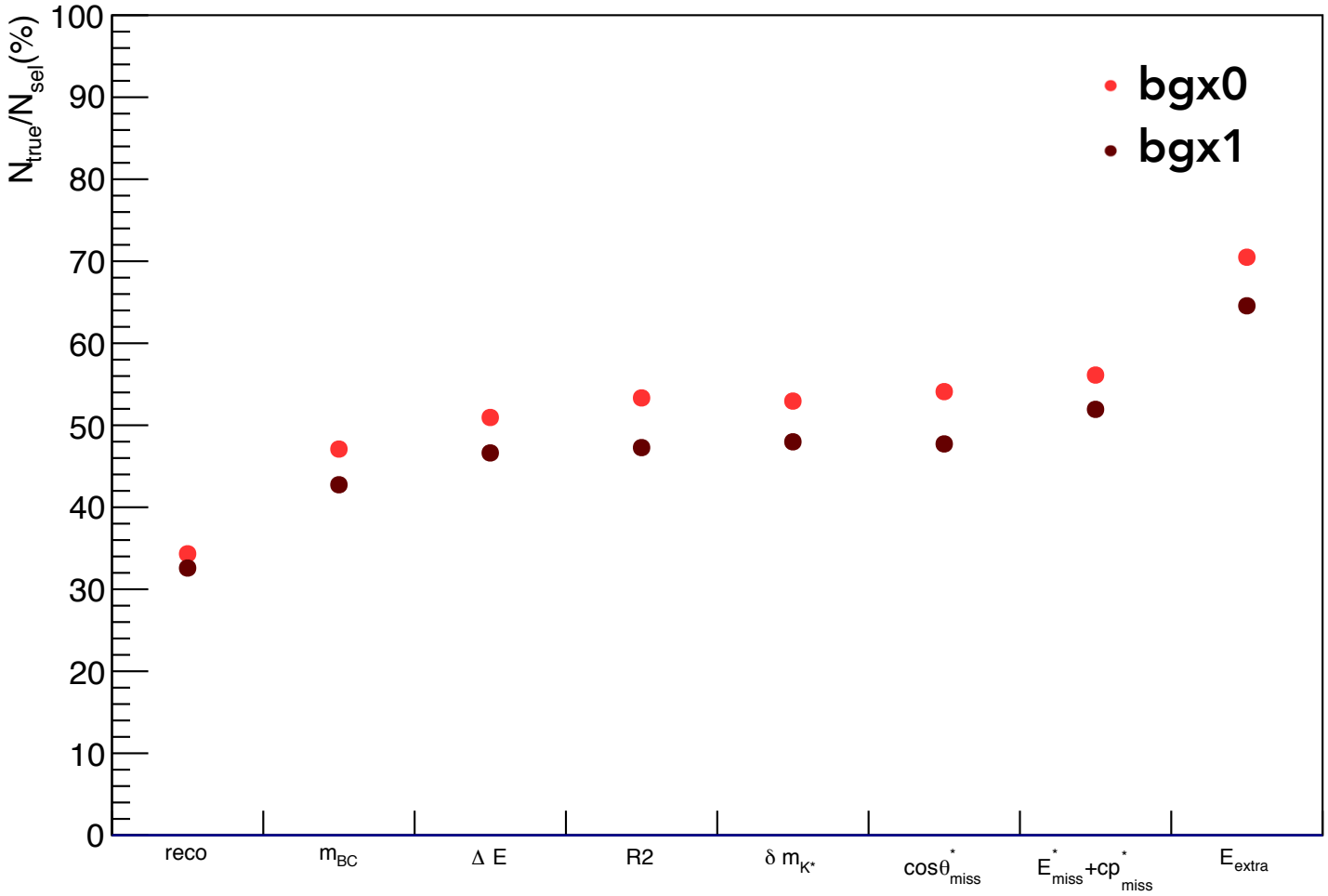


charged



Purity trend: BGx0 vs BGx1

signal MC



Summary and UL using MC5 sample

	BGx0	BGx1
Lumi (ab^{-1})	1	1
$N_{exp,\ bkg}$	6415 ± 80	3687 ± 61
signal eff (10^{-4})	10.3 ± 0.3	5.38 ± 0.23
N_{sig}/sqrt(B)	0.16	0.15
UL @ 90% C.L.	2.6×10^{-4}	3.8×10^{-4}
	U.L. extrapolation	
5 ab^{-1}	1.12×10^{-4}	1.7×10^{-4}
50 ab^{-1}	3.9×10^{-5}	2.6×10^{-5}

Extrapolation for the B2TIP report

- Consider SL and HAD tag Belle analysis, assume two times better hadronic tagging

- Expected precision on the Branching fraction :

	$B^+ \to K^+ \nu\nu$	$B^0 \to K^{*0} \nu\nu$
5 ab^{-1}	38%	35%
50 ab^{-1}	12%	11%

- Measurement of fraction of longitudinally polarised K*, sensitive at NP [2], feasible @ 10% level with full statistics

- Numbers and text in process of being finalised.

Conclusions

- SM prediction for $B^+ \to K^{*+} \nu\nu$ branching fraction at 10^{-5} level
  - latest Belle searches 1/2 order of magnitude away from SM expectation
  - for someNP scenarios, connection with $B^+ \to K^{*+}$ ll channels and anomalies measured at LHCb

- Impact of machine background evaluated on MC5 samples using $K^{*+} \to K^+\pi^0$ channel
  - Cut-And-Count analysis with reconstruction cuts optimised on BGx1 sample
  - higher signal efficiency and expected bkg on BGx0, higher N_{sig}/sqrt(B) for BGx0
  - (bkg rejection on BGx0 could be improved by optimising reconstruction cuts)
  - machine bkg for MC5 production has a small effect on both UL and extra neutral energy distribution

- Extrapolation based on most recent Belle measurement for B2TIP report
  - 10% level precision on branching fraction with full statistics

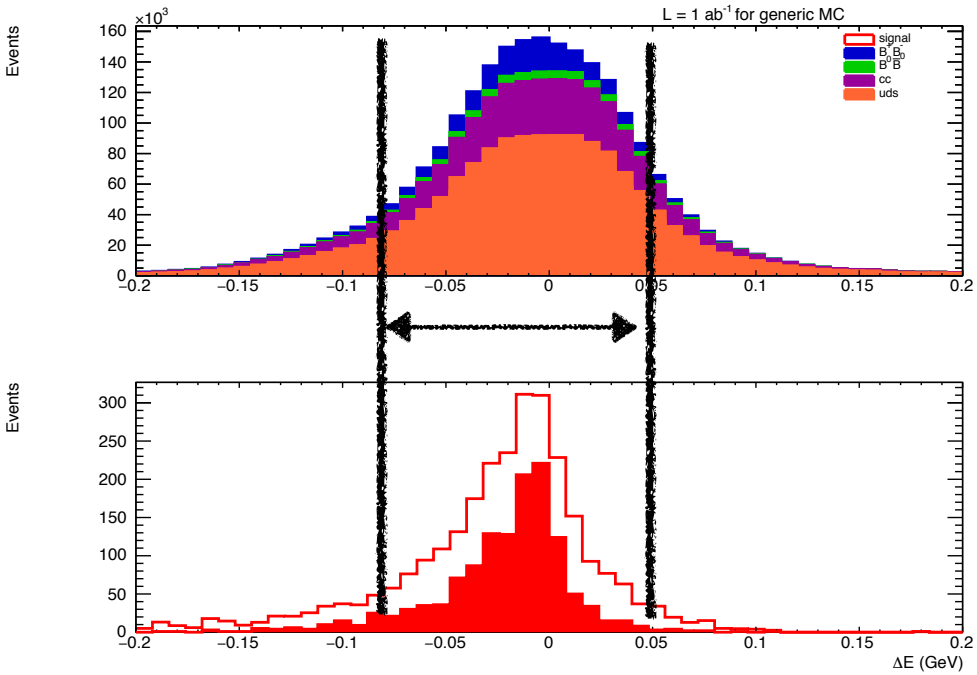
EXTRA SLIDES

signal
B^+B^-
$B^0\bar{B}^0$
$B\bar{B}$
cc
uds

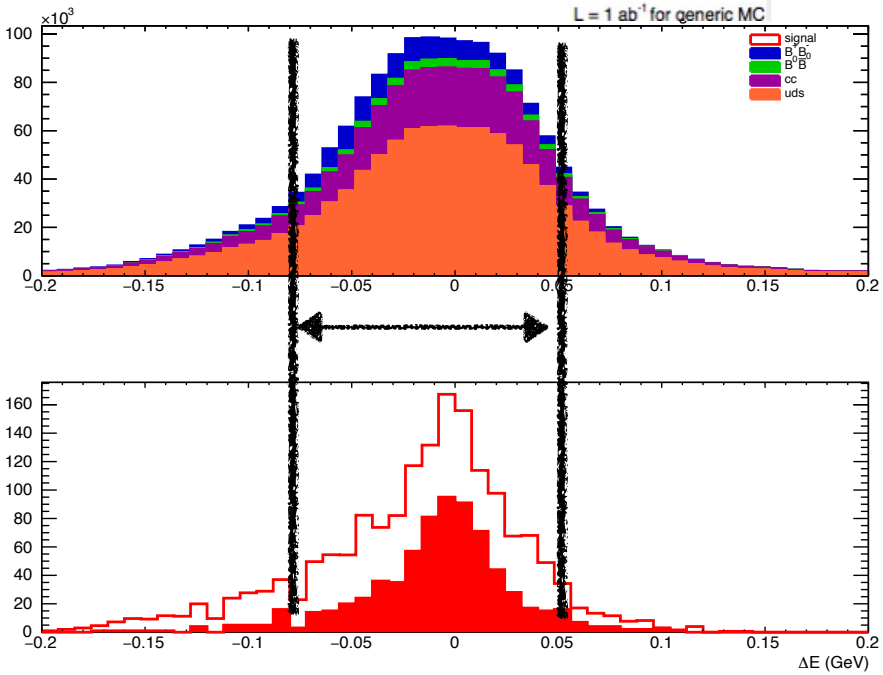
ΔE cut

-0.08 GeV < ΔE < 0.05 GeV

BGx0



BGx1

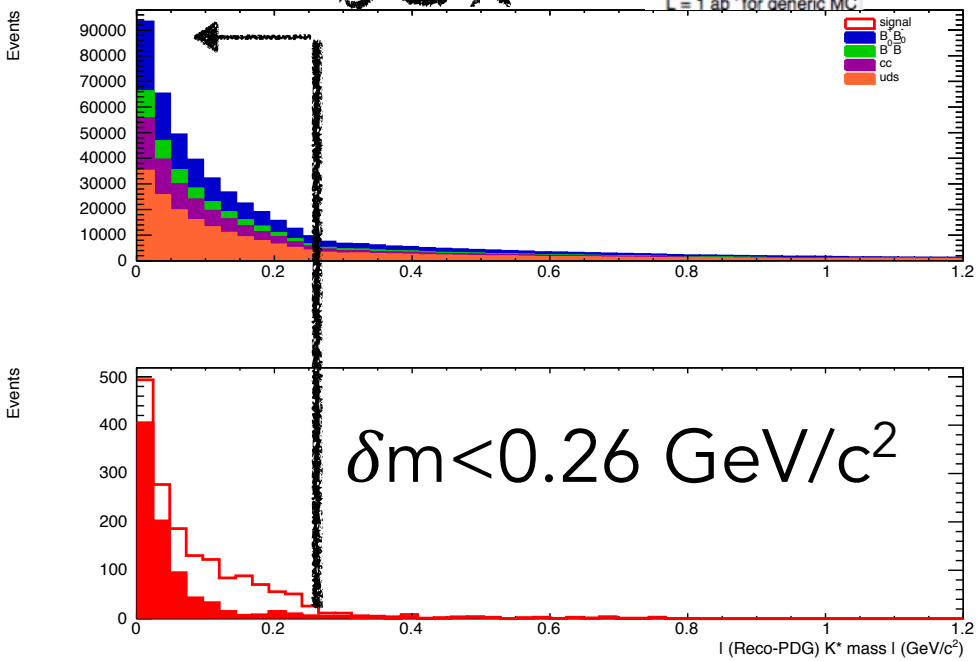


signal
$B_0\bar{B}_0$
B^-B^+
cc
uds

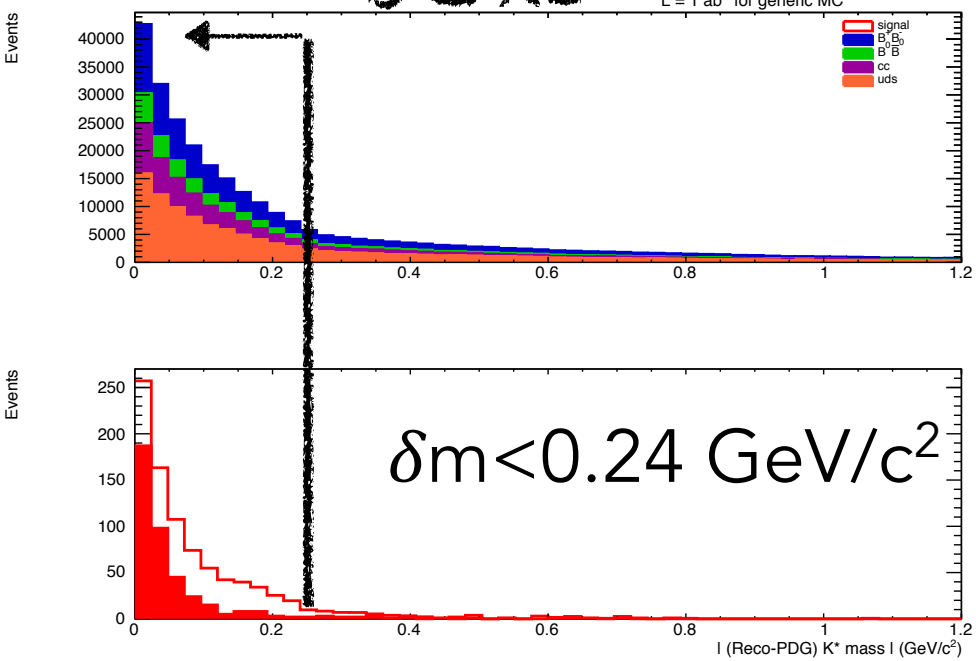
m_{K^*} cut

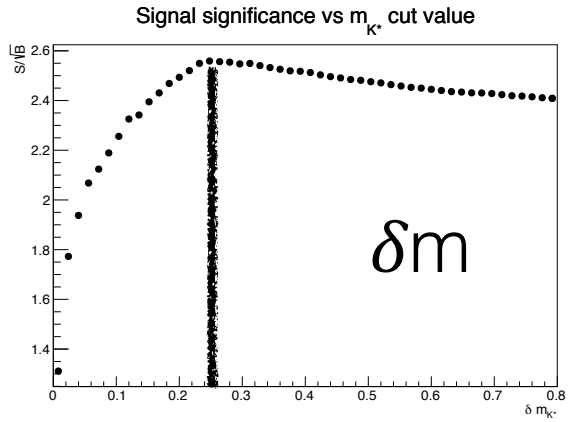
select a window of $m_{K^*}^{PDG}$ +/- δm

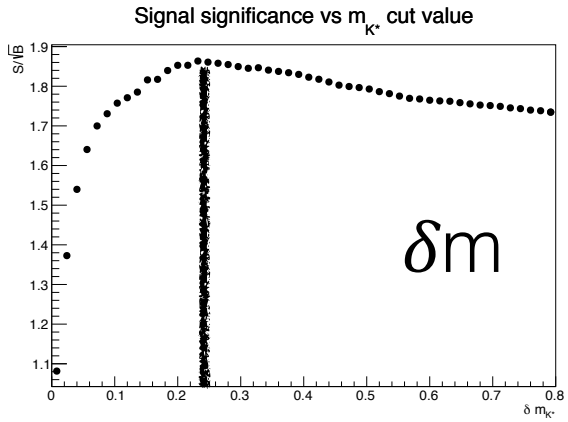
BGx0



BGx1



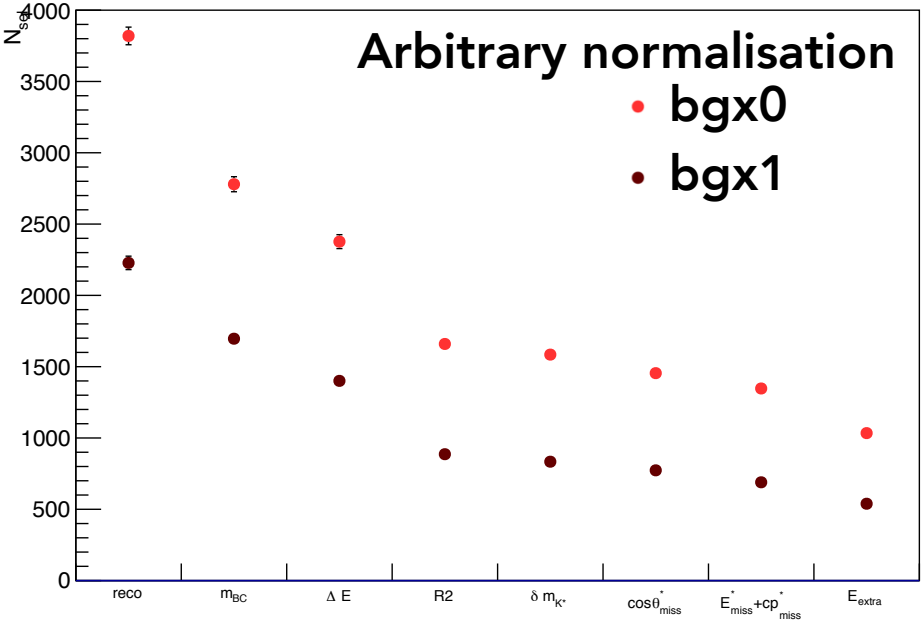


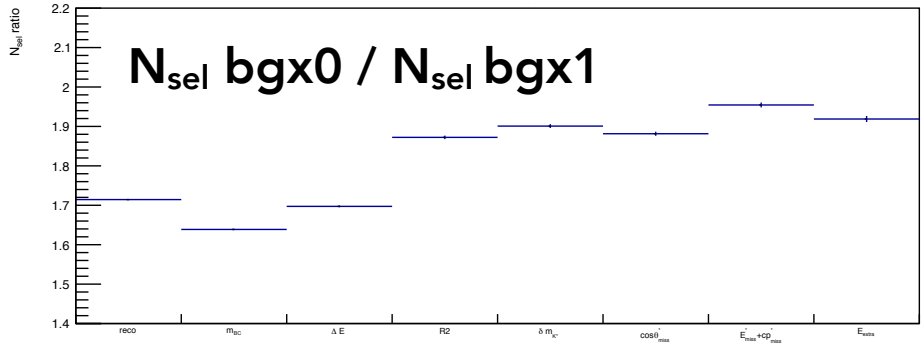


Selection summary: BGx0 vs BGx1

signal MC

Number of selected events





charged

Number of selected events