$B^0 \to DK^{*0}$ ADS

Kentaro Negishi (Tohoku Univ.)

Belle note 1160

Outline

1. Motivation
2. Event Selection
3. Suppression of qq Background
4. Signal Extraction
5. Fit on data
6. Summary and Plan

1. Motivation

- $B^0 \rightarrow DK^{*0}$
  - Can be used for measurement of ϕ_3.

I. Dunietz, Phys. Lett. B 270 75 (1991)

$$\mathcal{R}_{DK^{*0}} \equiv \frac{\Gamma(B^0 \to [K^-\pi^+]_D K^+\pi^-) + \Gamma(\bar{B}^0 \to [K^+\pi^-]_D K^-\pi^+)}{\Gamma(B^0 \to [K^+\pi^-]_D K^+\pi^-) + \Gamma(\bar{B}^0 \to [K^-\pi^+]_D K^-\pi^+)}$$
$$= r_S^2 + r_D^2 + 2k r_S r_D \cos(\delta_S + \delta_D) \cos \phi_3$$

Suspressed mode ($B^0 \rightarrow [K^-\pi^+]_D K^{*0}$)

Favored mode ($B^0 \rightarrow [K^+\pi^-]_D K^{*0}$)

$f = K^+\pi^-$

  - Time independent analysis, since B flavor tagged by K^{*0} decay.

- Possibility of more sensitivity by Dalitz analysis on $B^0 \rightarrow D\ K^+\ \pi^-$
  - T. Gershon Phys. Rev D 79, 051301 (2009)
  - T. Gershon and M. Williams Phys. Rev. D 80, 092002 (2009)

- I obtained the permission of suppressed mode at Aug. special BAM.
  - I report the result of R_{DK^*}.

2. Event selection

We reconstruct B meson by the following requirements.

(GeV)

Primary tracks	D^0	K^{*0}	B^0
•$\lvert\Delta r\rvert < 5$ mm	•K : $LR(K/\pi) > 0.4$	•K : $LR(K/\pi) > 0.7$	•$\lvert M_{bc} - m_{B0}\rvert < 0.008$
•$\lvert\Delta z\rvert < 5$ cm	•π : $LR(K/\pi) < 0.6$	•π : $LR(K/\pi) < 0.6$	
	•$\lvert M_{K\pi} - m_{D0}\rvert < 0.015$	•$\lvert M_{K\pi} - m_{K^{*}0}\rvert < 0.050$	

- To reduce the contamination from non-K^{*0} backgrounds, we apply tighter requirement for K from K^{*0}.
- Mass fit is applied to D^0.

Best candidate selection : based on M_{bc}

Background subtraction

D* event rejection : $\Delta M > 0.15$ GeV

ΔM : the mass difference between the $D^{*\pm}$ and D candidates

D* event have a peak $\Delta M \sim m_{\pi\pm}$.

$B^0 \to [K^{*0} K^-]D^- \pi^+$ (same final state for sup.) : $\lvert M_{K^{*}0K\pm} - m_{D\pm}\rvert > 0.018$ GeV

Helicity angle of K^{*0} cut : $\cos\theta_{K^*} < 0.8$ for favored mode

r_S Integrated regions for fav. and sup. mode are different due to $\cos\theta_{K^*}$ cut.

3. Suppression of qq background

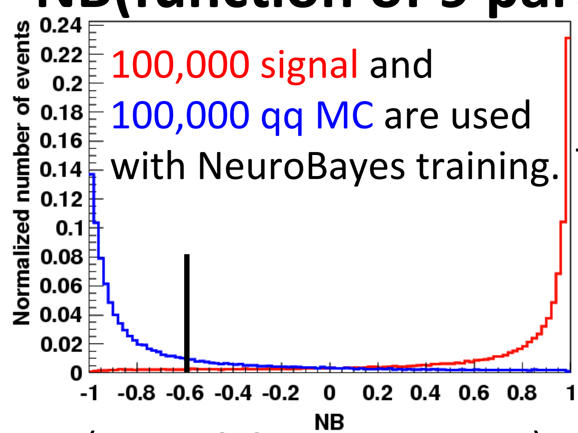
- For improving qq suppression, we use 9 parameters to be combined in neural network.
  - NeuroBayes package is employed.
  - The following parameters are input of NB.
  - NB is transformed in NB'for checking systematic uncertainty easier.
  - NB' is looked Gaussian like distribution.

•LR(KSFW) •$|qr|$
•$\cos\theta_{thr}$ •$|\cos\theta_B|$
•$\cos\theta^K{}_D$ •$\cos\theta^D{}_B$
•Δz •ΔQ
•Distance D K^{*0}

Each detail is discussed at backup pages.

Training

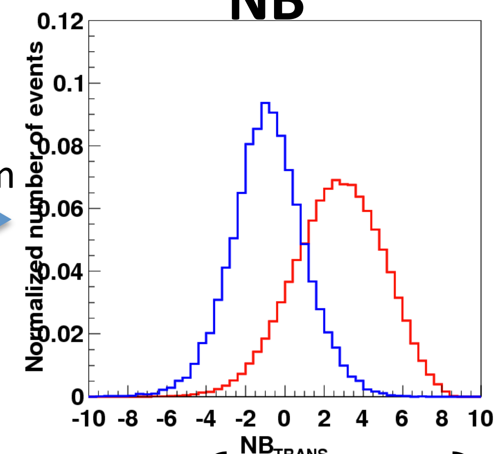
NB(function of 9 par.)



(NB < - 0.6 events are cut.)

Transform

NB'



$$NB' = \log\left(\frac{NB - NB_{low}}{NB_{high} - NB}\right)$$

$NB_{low} = -0.6$

$NB_{high} = 1.0$

4. Signal extraction

I perform ΔE NB' 2D fit.

PDF for ΔE

- Signal : a double Gaussian fixed from signal MC
- BB : free exponential and a Gaussian fixed from 4 st. BB MC
  - $\bar{D}^0\rho^0$: fixed from MC
  - Peaking BGs : fixed from MC
    - $[K^{*0}\pi^-]_{D-}$ K^+ for fav. mode
    - $[K^{*0}K^-]_{D-}$ π^+ for sup. mode
    - $[K^+K^-]_{D0}$ $\pi^+\pi^-$ for sup. mode
- qq : free 1st order chebychev

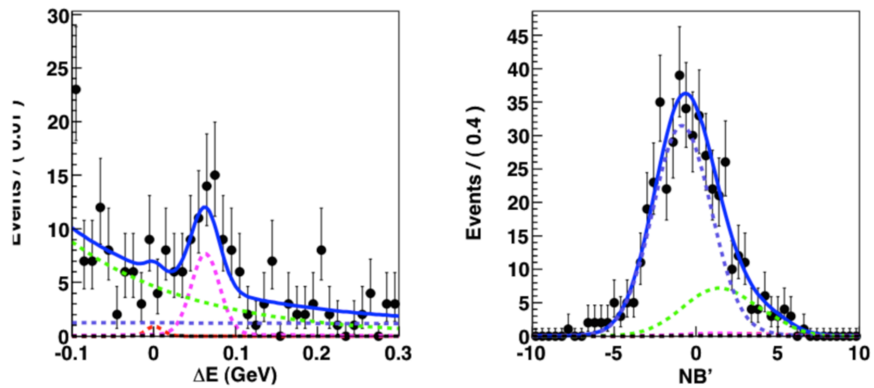
PDF for NB'

- Signal : a double Gaussian fixed from signal MC
- BB : a double Gaussian fixed from 4st. BB MC.
  - Peaking BGs : fixed from MC
- qq : a double Gaussian fixed from M_{bc} sideband of the data.

5. Fit on data

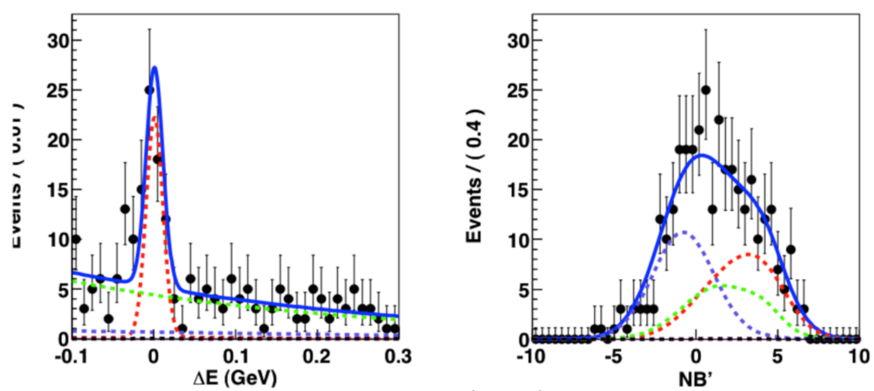
Exp 7 - 65

Suppressed mode



3 < NB' < 10 |ΔE| < 0.03

Favored mode



3 < NB' < 10 |ΔE| < 0.03

- Dots with err. bar : data
- Blue line : Total PDF
- Red dashed : Signal
- Magenta dashed : $D^0\rho^0$
- Black dashed : Peaking BGs
- Green dashed : BB
- Blue dashed : qq

- $N_{sup.} = 5.2 \,^{+10.3}_{-9.2}$
- $N_{fav.} = 128 \,^{+18}_{-17}$
- $R_{DK^*} = (3.4 \,^{+6.7}_{-6.0})*10^{-2}$
- $0.5\ \sigma$

6. Result of R_{DK^*}

Source	R_{DK^*} [10^{-2}]
PDFs parameterization	$^{+2.2}_{-1.5}$
Fit bias	± 0.2
Efficiency	± 0.1
Total	$^{+2.4}_{-1.8}$

Many syst. err. are canceled
by taking the ratio of sup. and fav. mode.

$$R_{DK^*} = \frac{N_{sup.}/\varepsilon_{sup.}}{N_{fav.}/\varepsilon_{fav.}}$$

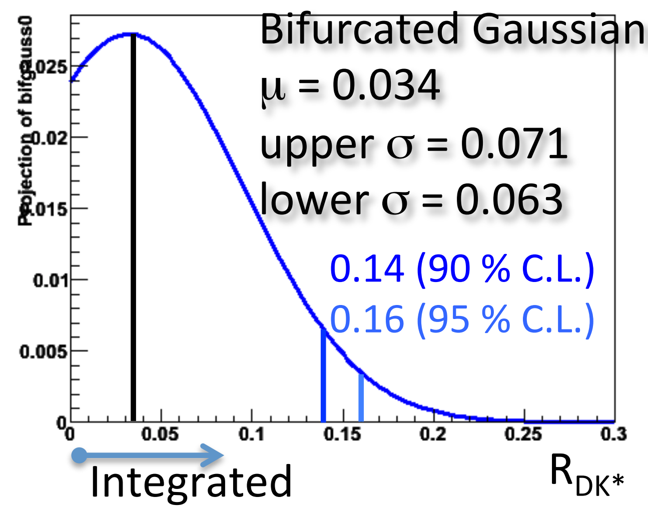
Fit par. : varying fixed parameter by ± 1 σ.
Fit bias : check 1000 pseudo-experiments.
Efficiency : MC statistics and PID correction.

- Obtain R_{DK^*} upper limit.
- $R_{DK^*} < 0.16$ (95 % C.L.)

[$\times 10^{-2}$]	$\mathcal{R}_{DK^{*0}}$	Stat. Err.	Syst. Err.	upper limit (95% C.L.)
This Analysis	3.4	$^{+6.7}_{-6.0}$	$^{+2.4}_{-1.8}$	16
Latest Result by BaBar	6.7	$^{+7.0}_{-5.4}$	±1.8	24

Stat. err. Syst. err.

$$R_{DK^*} = (3.4 \pm^{6.7}_{6.0} \pm^{2.4}_{1.8}) * 10^{-2}$$



7. Summary and Plan

- Summary
  - I obtained R_{DK^*}, and updated R_{DK^*} upper limit.

$$R_{DK^*} = (3.4 \underbrace{\pm^{6.7}_{6.0}}_{\text{Stat. err.}} \underbrace{\pm^{2.4}_{1.8}}_{\text{Syst. err.}}) * 10^{-2}$$

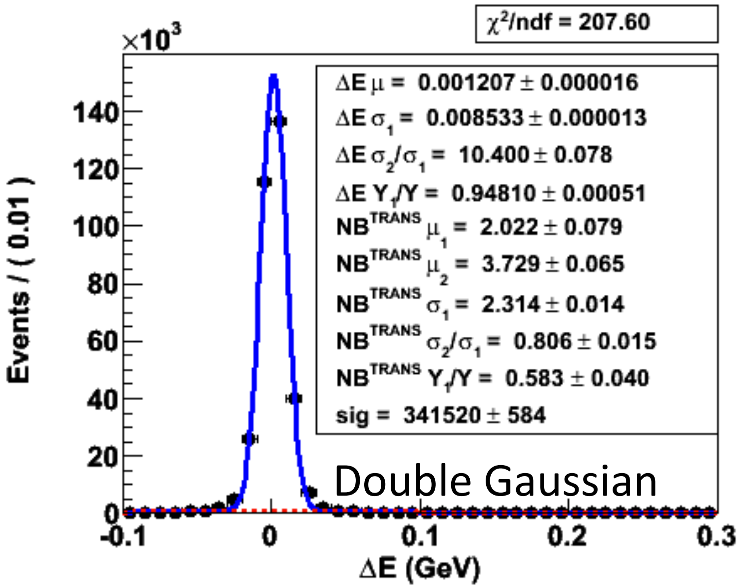
$$= 0.16 \text{ (95 \% C.L.)}$$

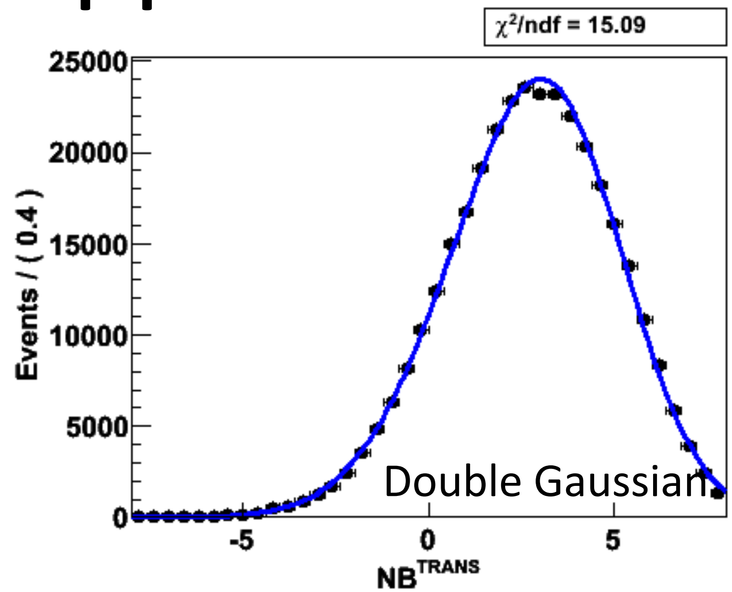
    - I'll updated R_{DK^*} upper limit.

- Plan
  - Obtain upper limit with likelihood.
  - Publish this result.

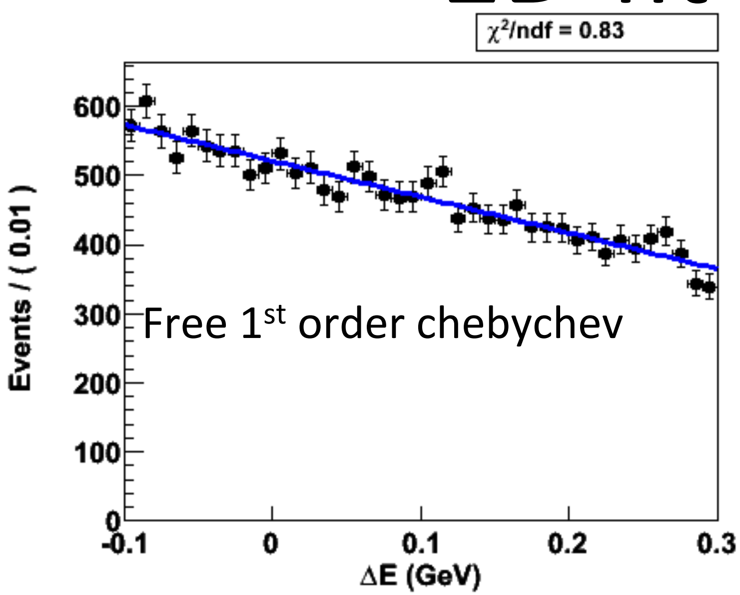
Back up

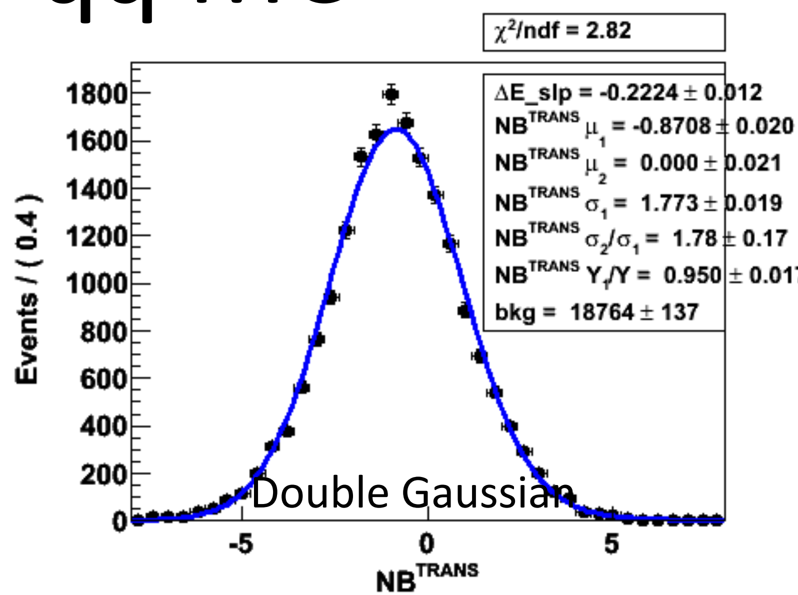
2D-fit to qq MC





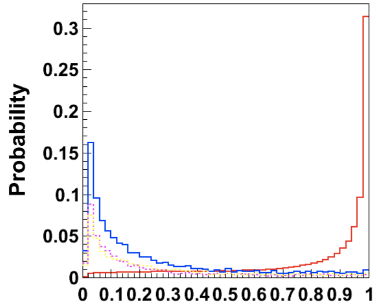
2D-fit to qq MC



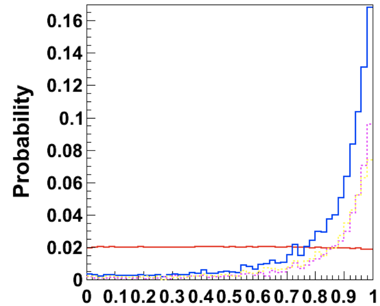


Input parameters

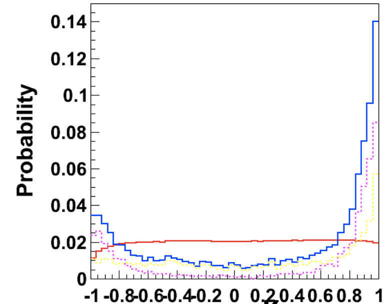
Red : Signal
Blue : qq BG
(Green : charm)
(Pink : uds)



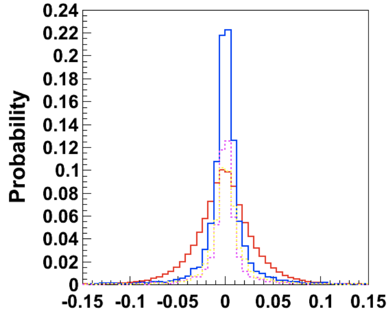
LR(KSFW)



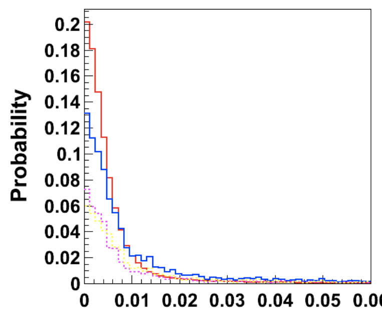
$|\cos\theta_{thr}|$



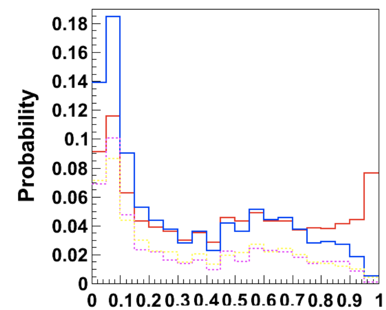
$\cos\theta^{K}_{D}$



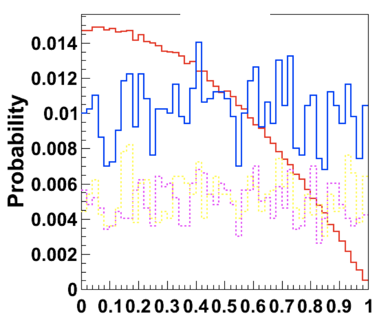
Δz



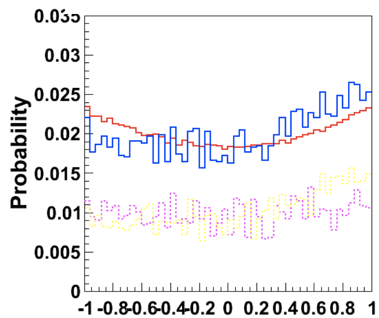
Distance D K^{*0}



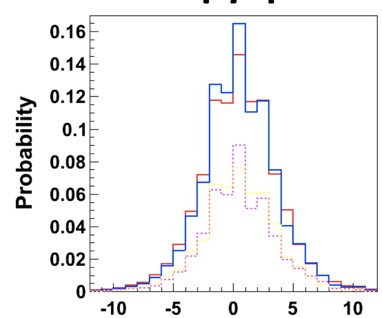
$|qr|$



$|\cos\theta_{B}|$

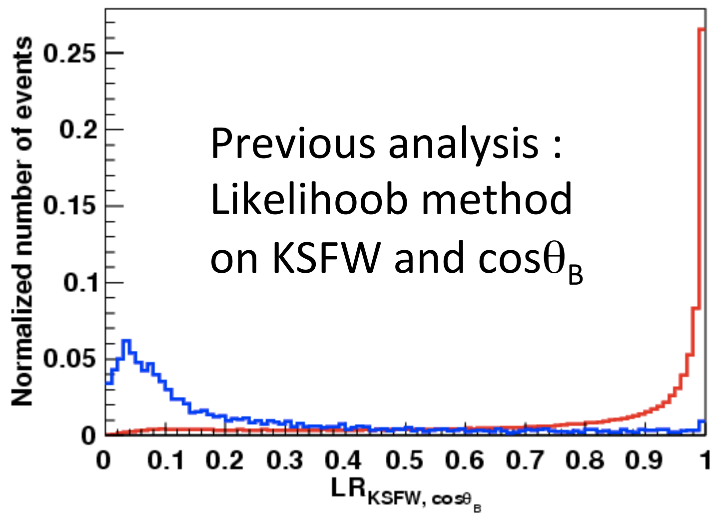


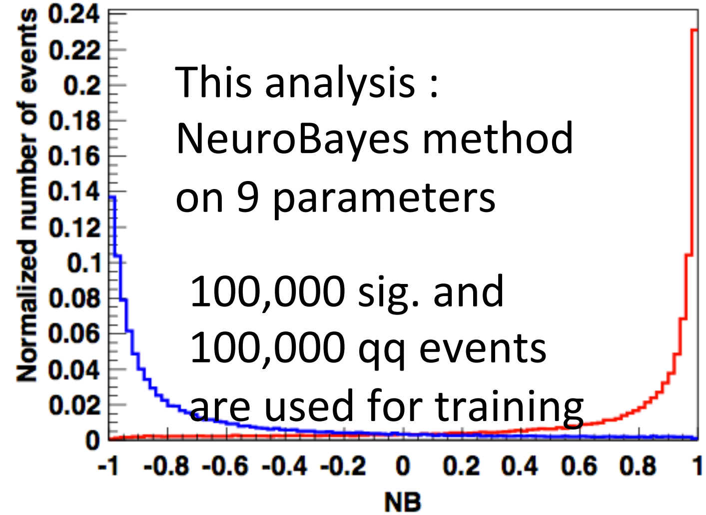
$\cos\theta^{D}_{B}$



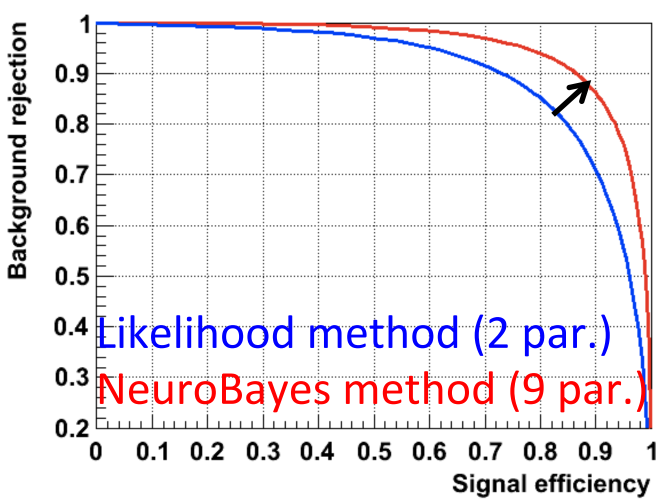
ΔQ

Comparison with previous analysis





For the numerical comparison, we obtain signal efficiency for background rejection at 99 % 95 % 90 % and 80 %.



Background rejection (%)	Signal efficiency (%)		Rate for signal efficiency
	Likelihood (2 par.)	NeuroBayes (9 par.)	
99	27.1	52.0	1.92
95	60.5	77.4	1.28
90	73.1	86.4	1.18
80	84.8	93.4	1.10

List of variables for NeuroBayes

Parameter	Signi. of single par.	Signi. loss	Global correl. (%)
LR(KSFW)	478	104	73
$\cos\theta_{thr}$	359	92	72
$\cos\theta^{K}{}_{D}$	328	154	43
Δz	213	110	29
Distance D K^{*0}	185	85	28
$\|qr\|$	151	55	23
$\|\cos\theta_B\|$	143	61	21
$\cos\theta^{D}{}_{B}$	53	23	13
ΔQ	25	4	10

Reasonable result

Significance of single parameter:

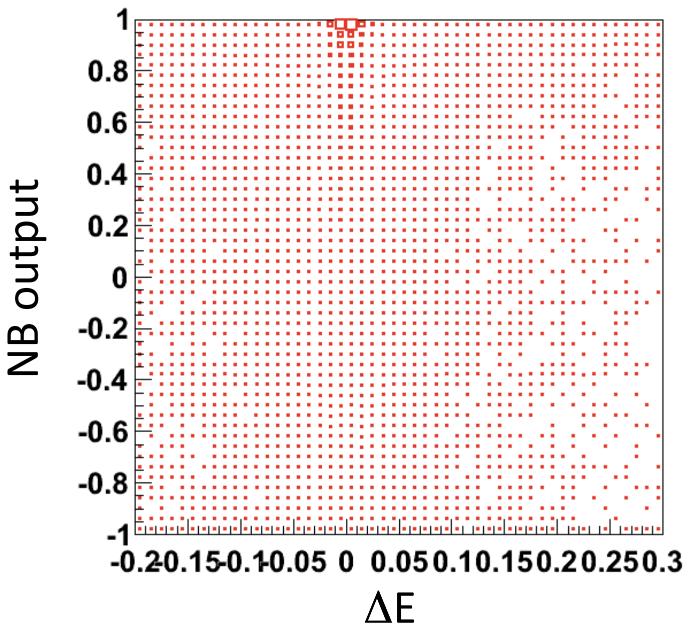
The correlation of a variable to the target multiplied by √(event number).

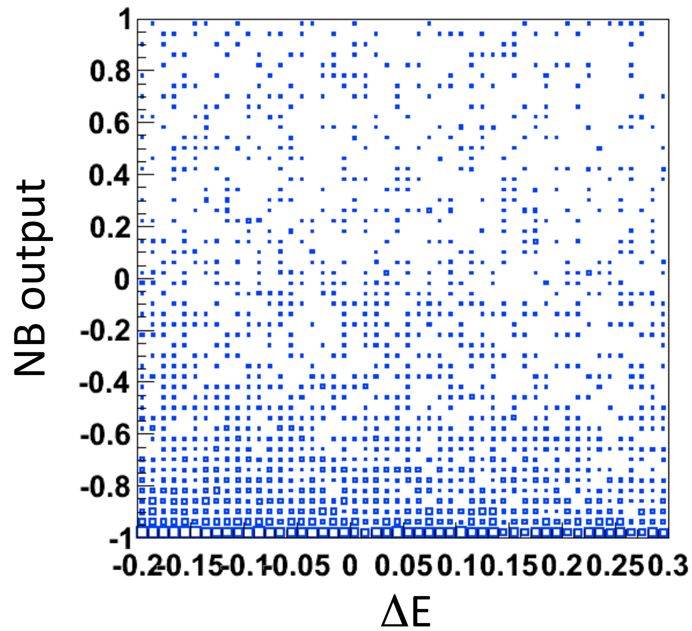
Significance loss when the variable is removed:

The loss of correlation multiplied by √(event number) when only this variable is removed from the input set and the total correlation to the target is re-computed

Signal extraction

- Strategy is to apply 2-D fit to ΔE and NB output.
- 2-D histograms are shown to reveal small correlation.



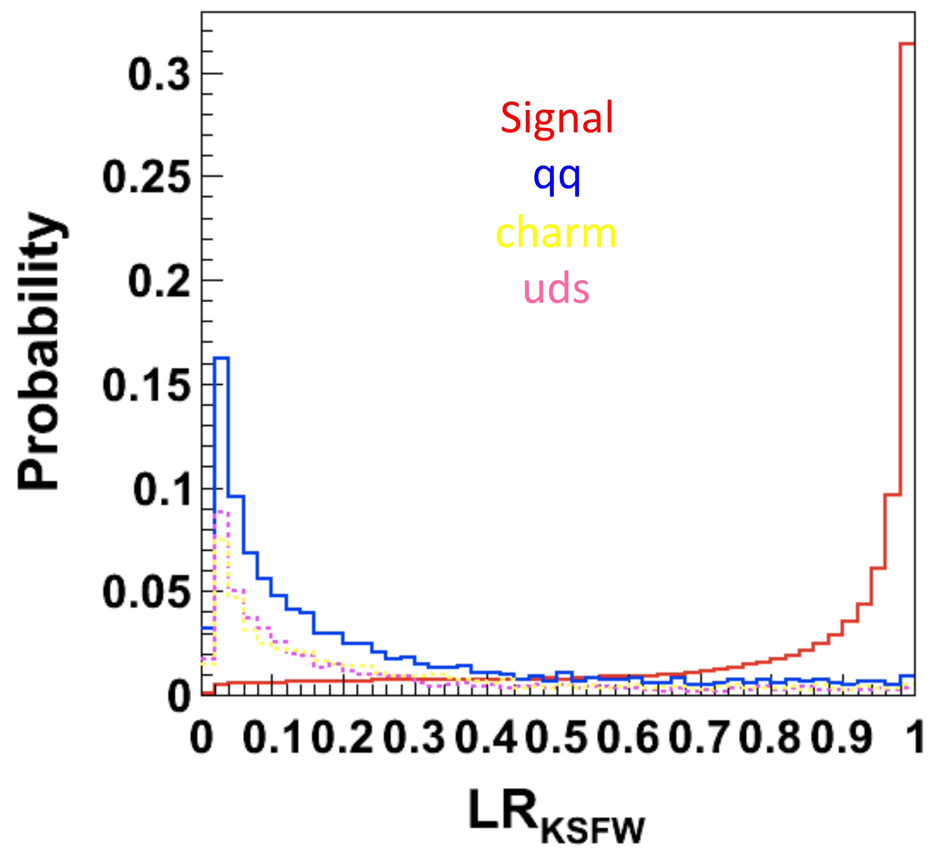


	Corr. factor
Signal	: -1.9 %
qq	: -1.5 %

We will obtain a 2-D PDF by taking a product of 1-D PDFs.

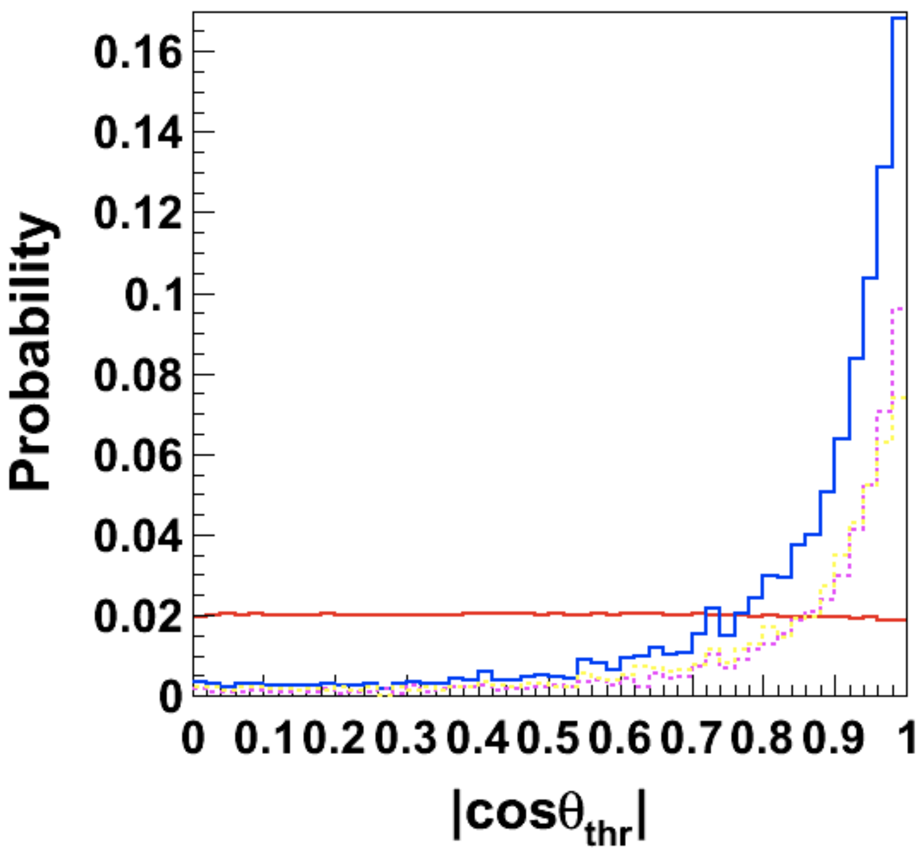
LR_{KSFW}

- LR_{KSFW} : Likelihood ratio of KSFW.
  - (I used this with cut base in previous analysis.)



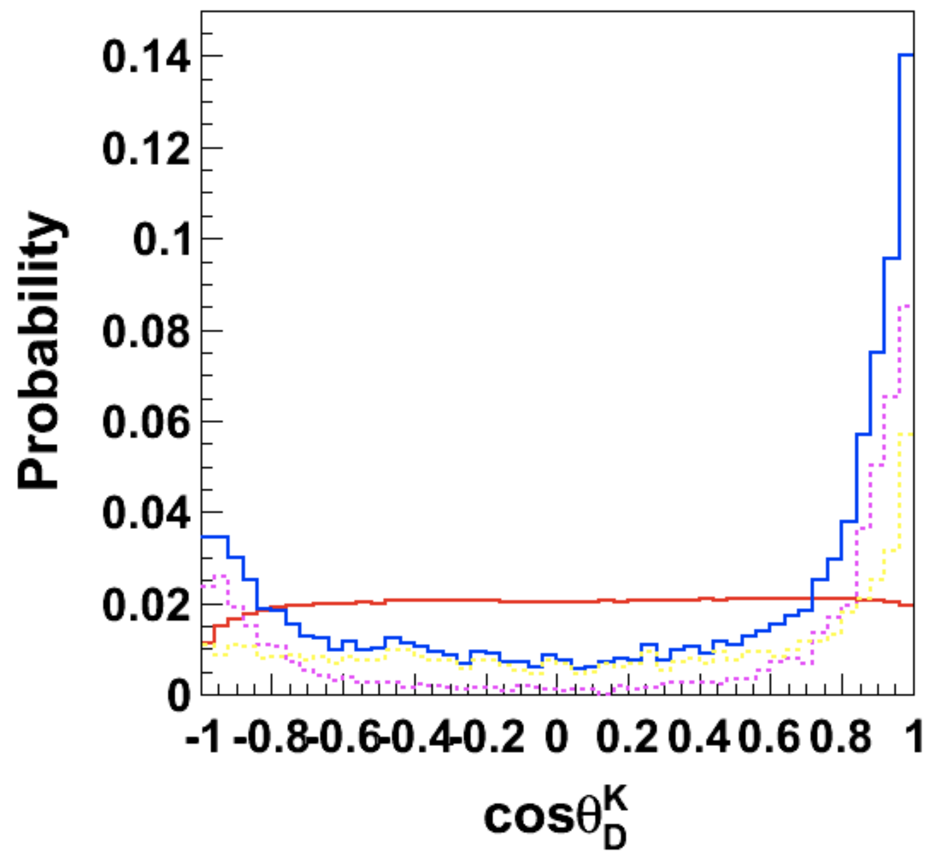
$|\cos\theta_{thr}|$

- $|\cos\theta_{thr}|$: the absolute value of the cosine of the angle in CM frame between the thrust axis of the B decay and the one of the detected remains.



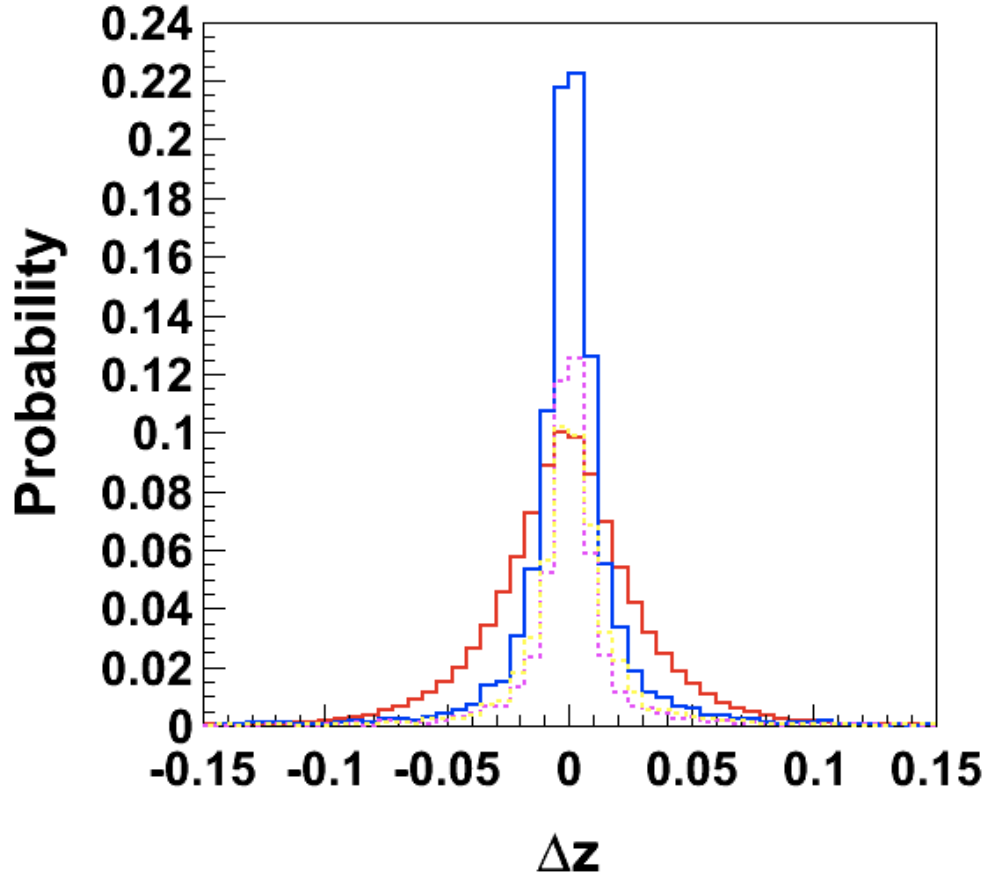
$\cos\theta^K_D$

- $\cos\theta^K_D$: the cosine of the angle between the daughter K direction and the opposite direction to B in the D-rest frame.



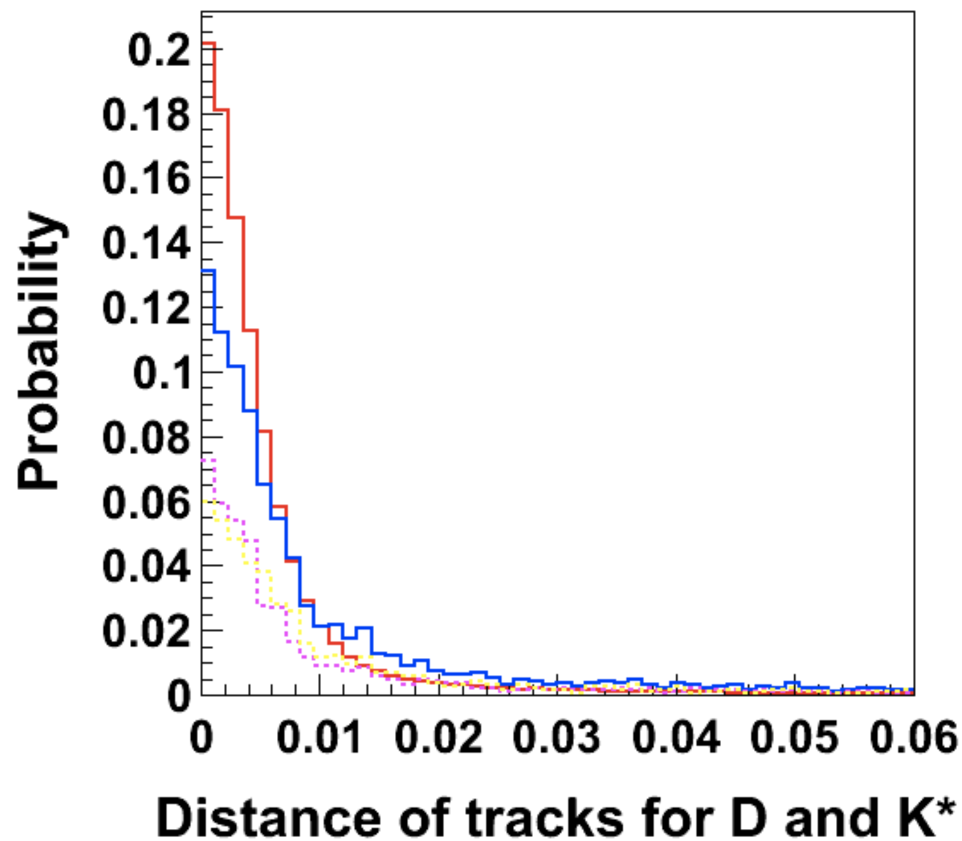
Δz

- Δz : the distance of the reconstructed and tag-side B vertices.



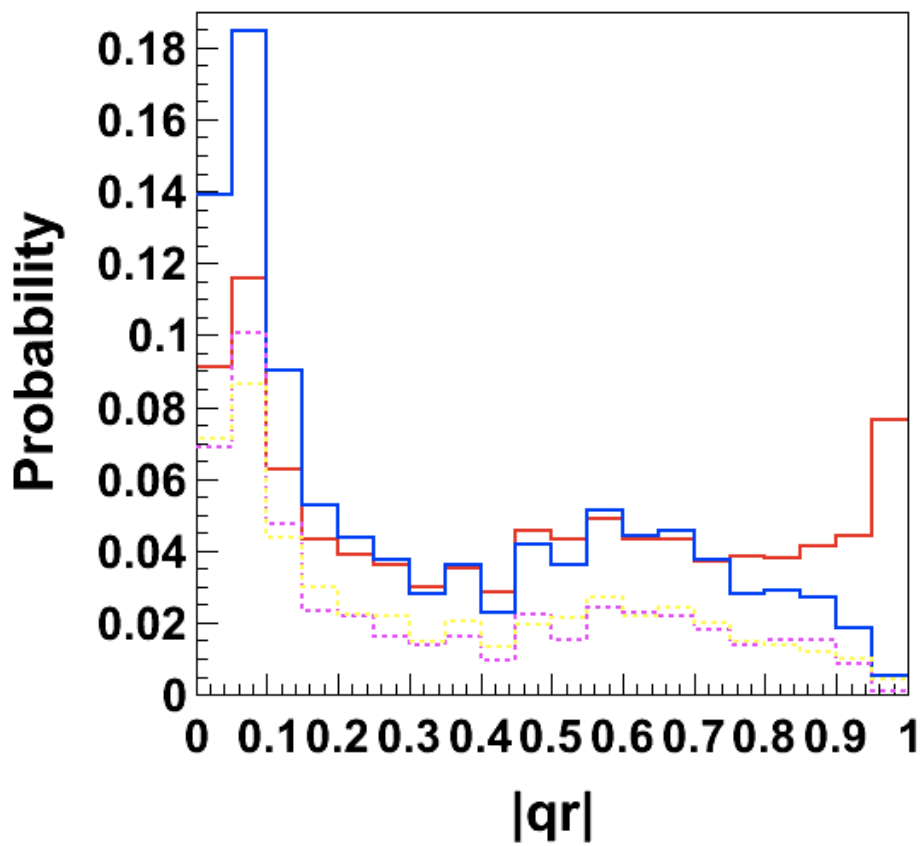
Distance of D K*

- Distance of D K* : the distance of closest approach between the K* track and the trajectory of the D candidate.



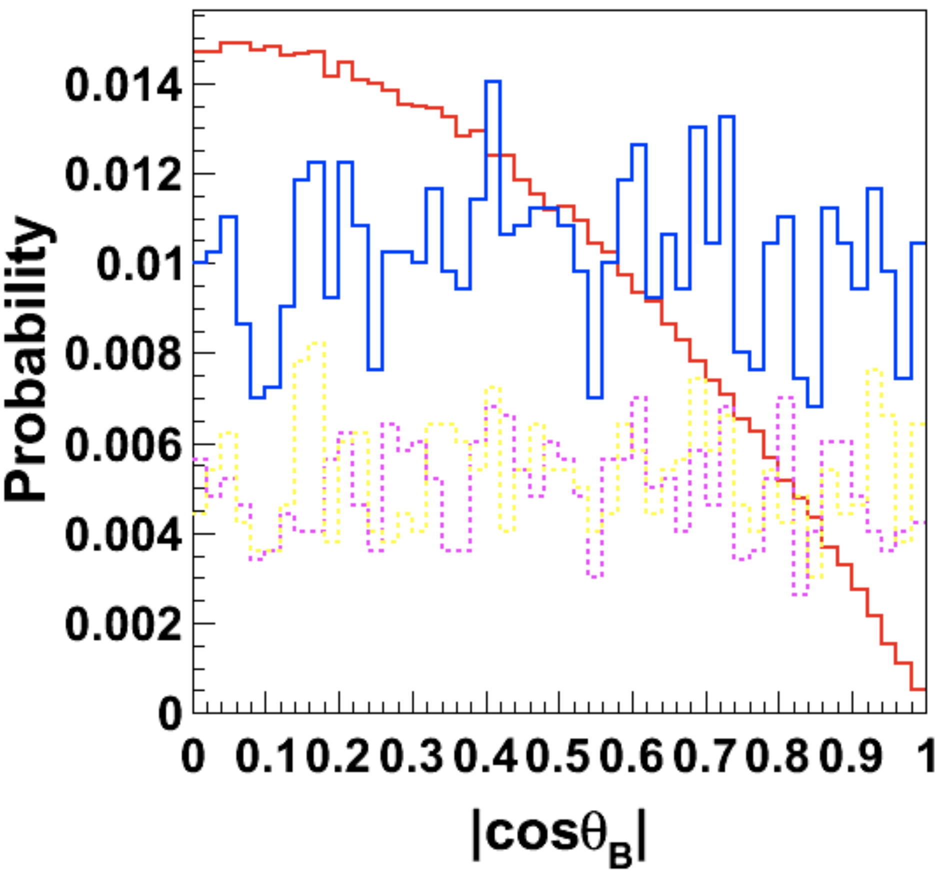
$|qr|$

- $|qr|$: the absolute value of the flavor tagging information qr, where q indicates the b-flavor and r indicates the quality of tagging.



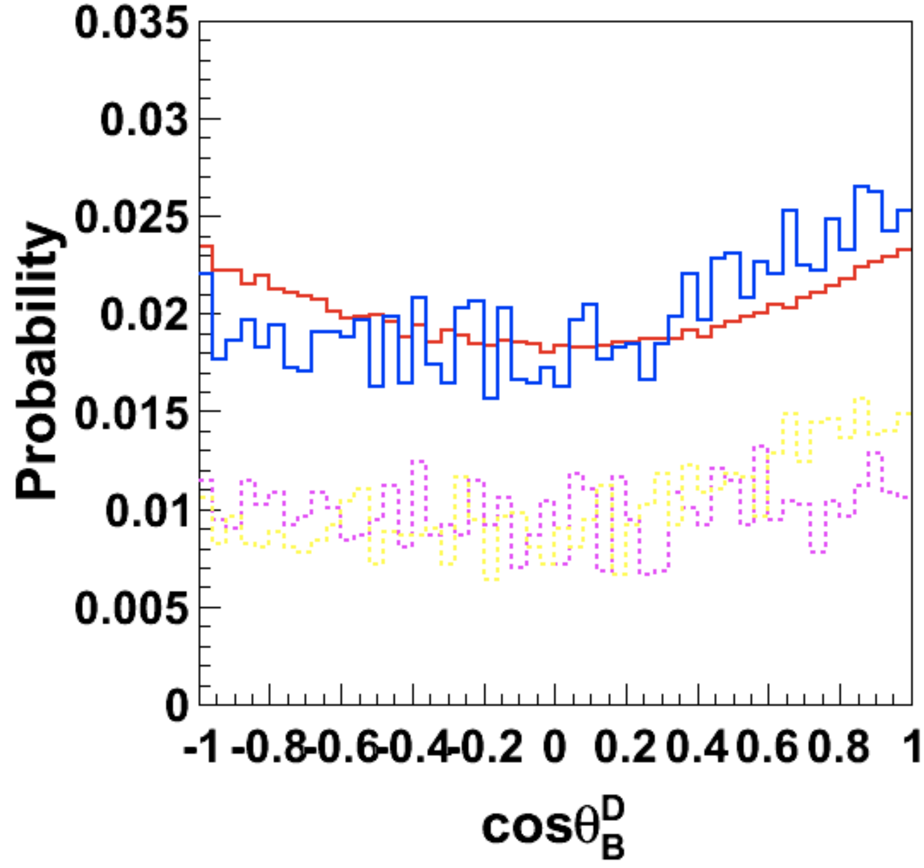
$|\cos\theta_B|$

- $|\cos\theta_B|$: the absolute value of cosine of the angle between the B-flight and the beam axis.



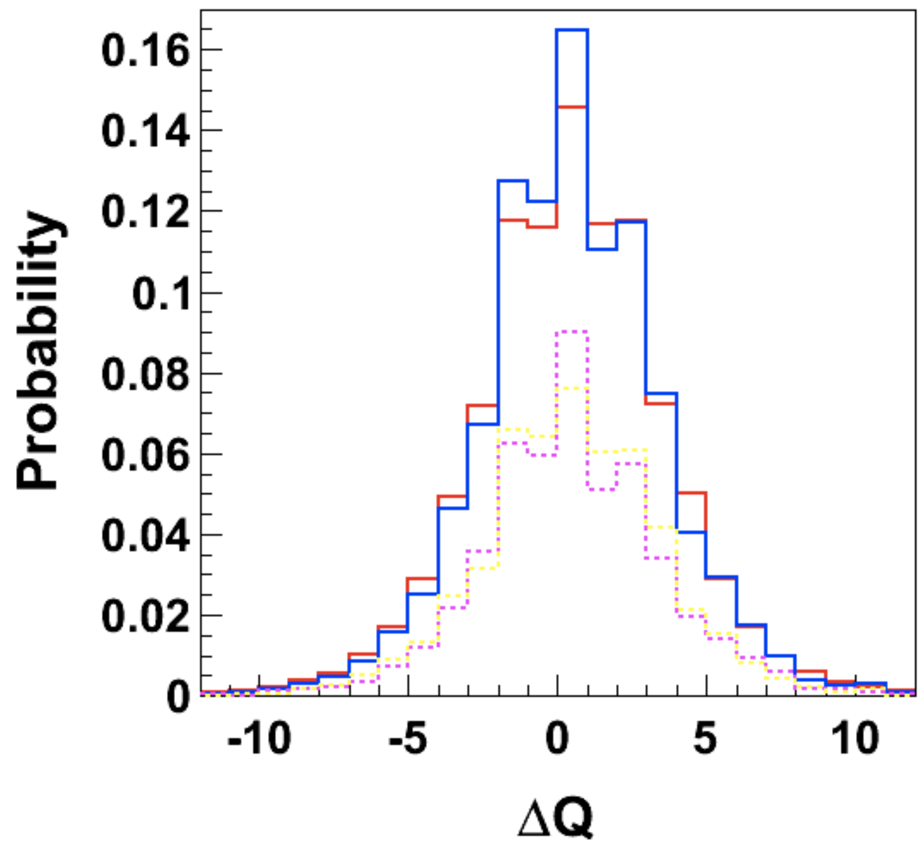
$\cos\theta^D_B$

- $\cos\theta^D_B$: the cosine of the angle between the D direction and the opposite direction to $\Upsilon(4S)$ in the B-rest frame.

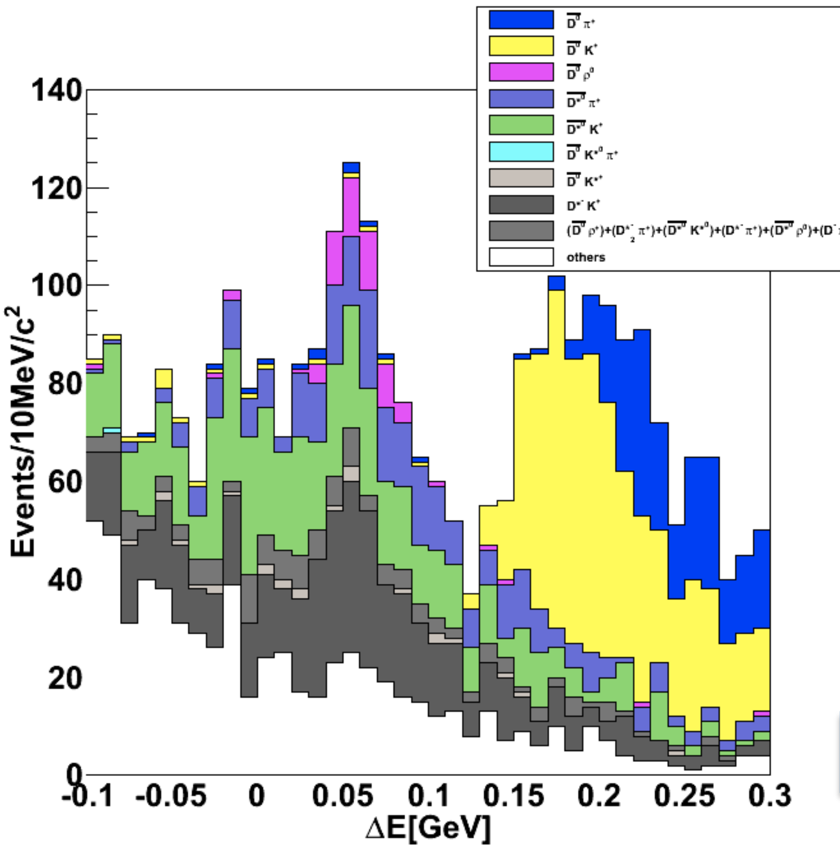


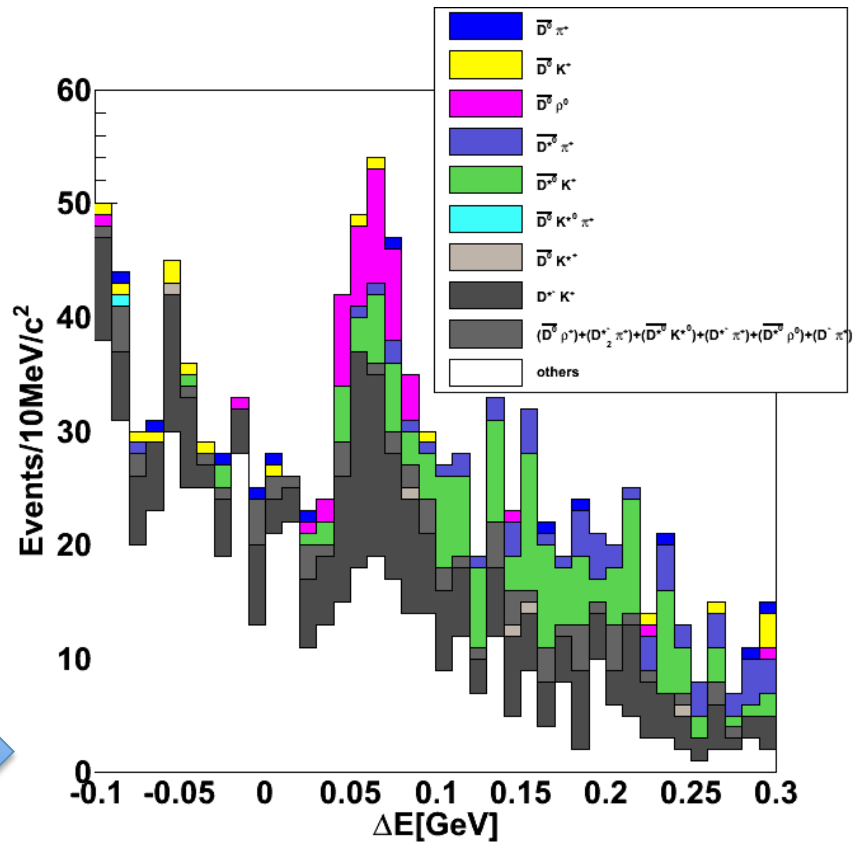
ΔQ

- ΔQ : the charge difference between the sum of the charges of particles in the D hemisphere and the one on the opposite hemisphere, excluding the particles used for the reconstruction of B meson.



4st. BB MC



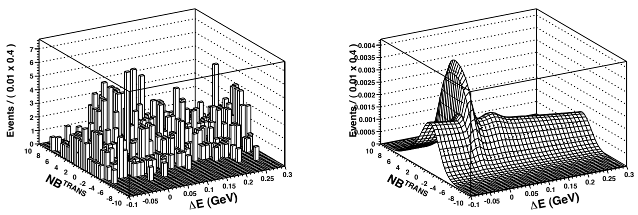


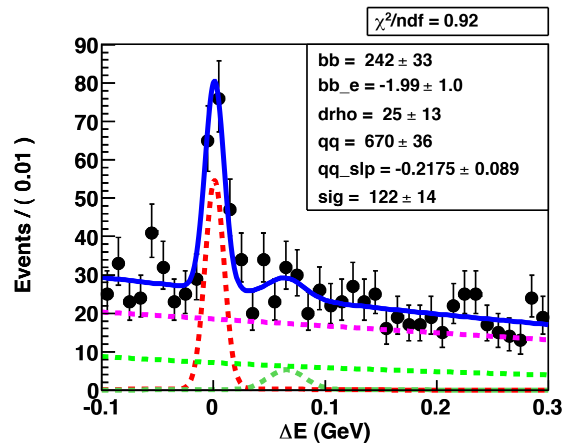
$\cos\theta_{K*} < 0.8$

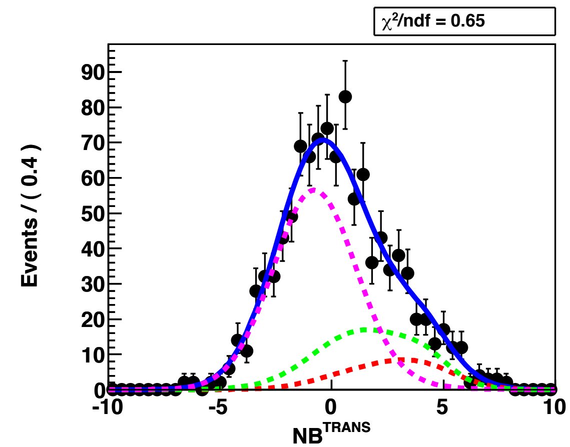
$\cos\theta_{K^*}$

mode \ $\cos\theta_{K^*}$ cut		< 0.75	< 0.80	< 0.85	< 0.90	< 0.95
Signal (Efficiency (%))		76.7	**81.1**	85.9	91.3	95.4
Background rejection (%)						
BB		43.7	**35.1**	28.3	18.5	8.3
	$D^0\rho^0$	39.8	**30.7**	22.2	13.5	4.6
	$D^0\pi^+$	97.7	**96.7**	95.4	78.0	43.1
	D^0K^+	99.5	**98.5**	86.2	66.1	34.3
	$D^{*0}\pi^+$	89.1	**71.1**	67.5	50.1	25.2
	$D^{*0}K^+$	84.5	**75.3**	63.4	46.8	23.2
	$D^{*-}\pi^+$	87.9	**81.1**	71.0	55.2	28.1
qq		14.3	**11.4**	8.4	5.2	2.1

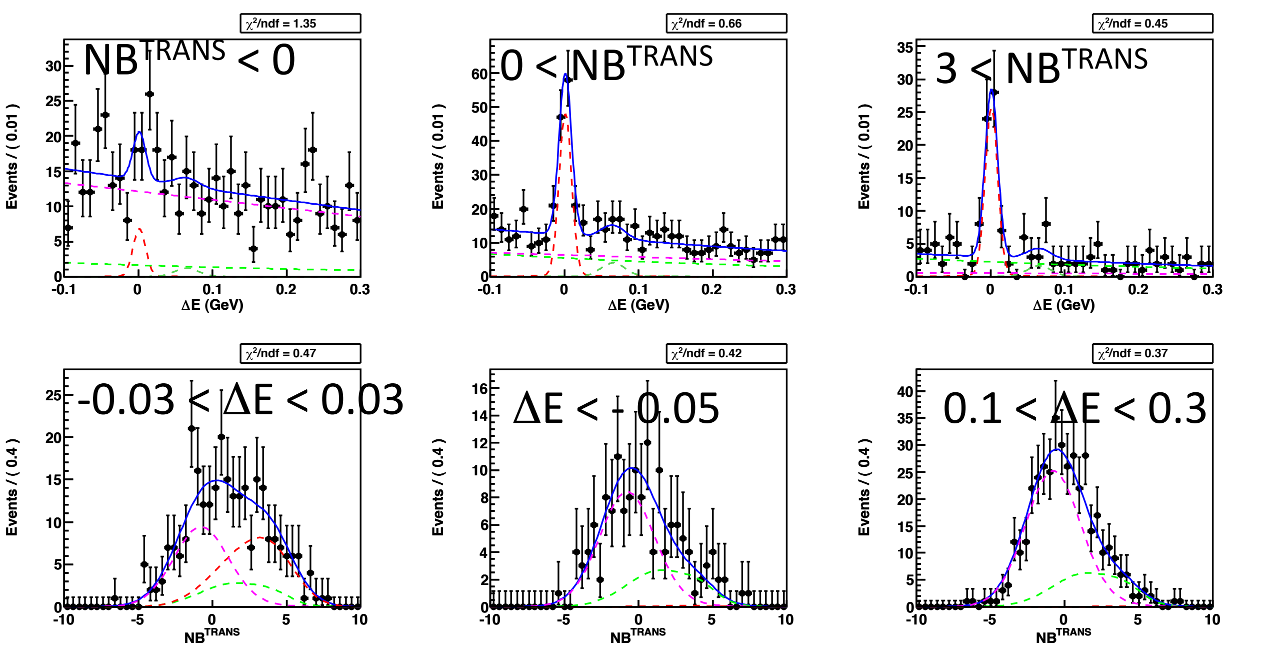
Fit to favored mode on MC(1)



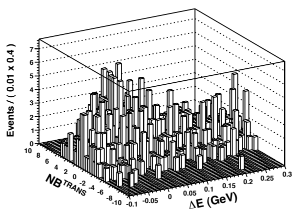


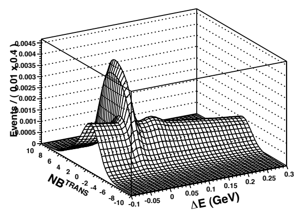


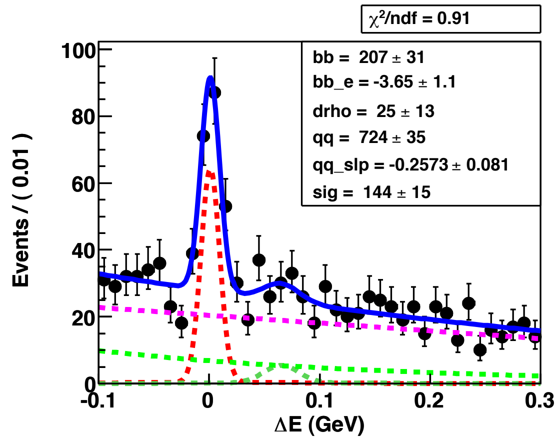
$N_{sig.}$ = 133 from generator info.

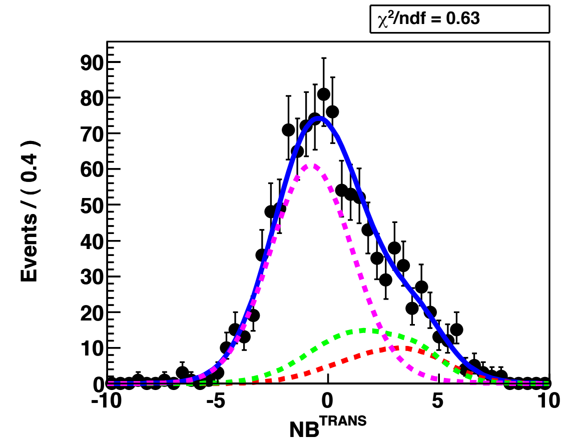


Fit to favored mode on MC(2)

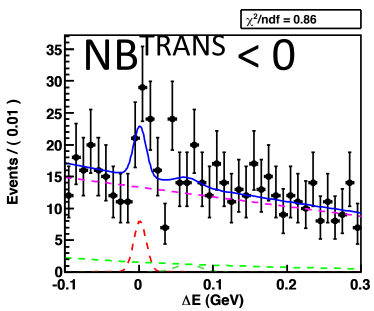


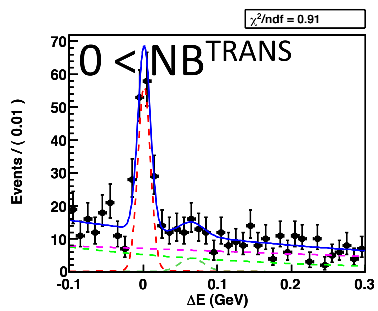


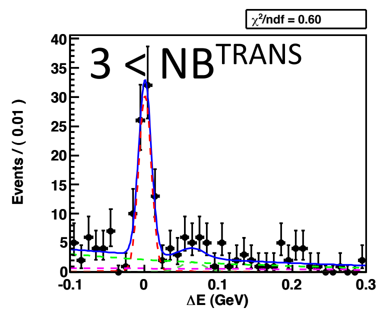


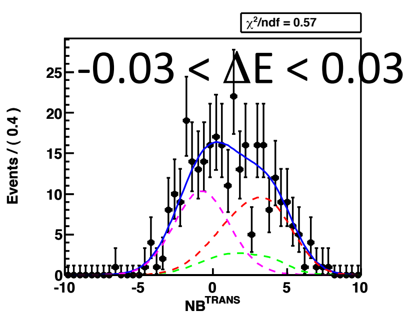


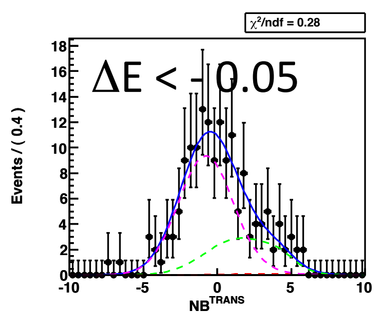
$N_{sig.}$ = 133 from generator info.

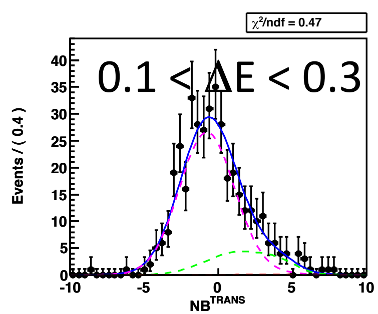




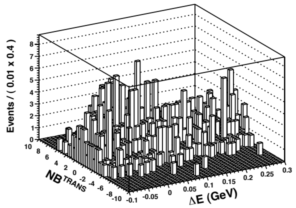


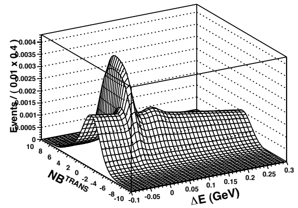


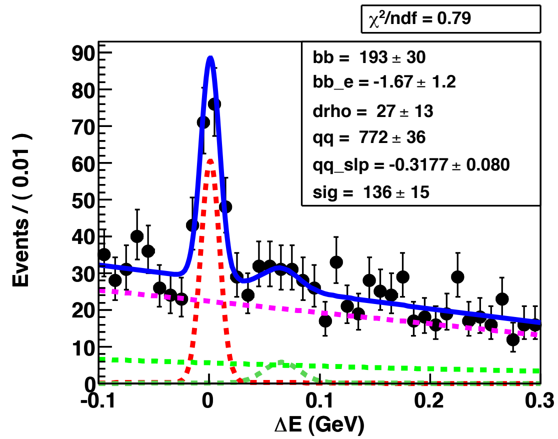


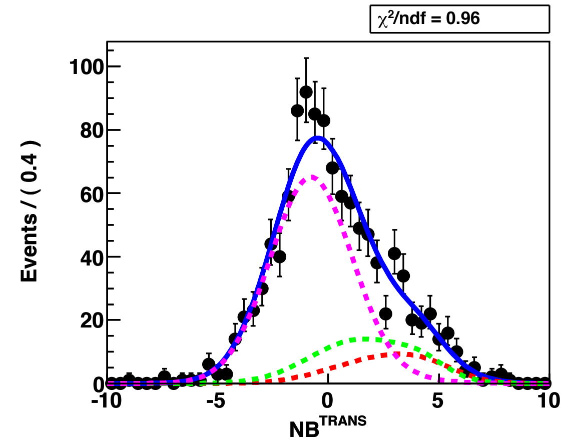


Fit to favored mode on MC(3)

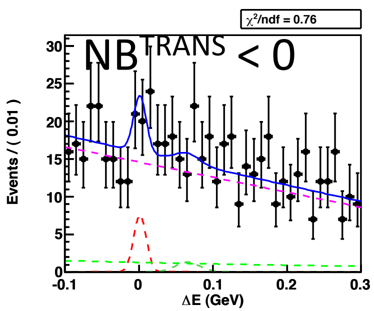


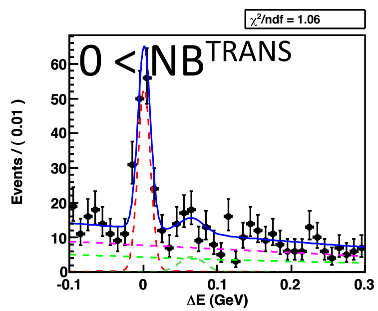


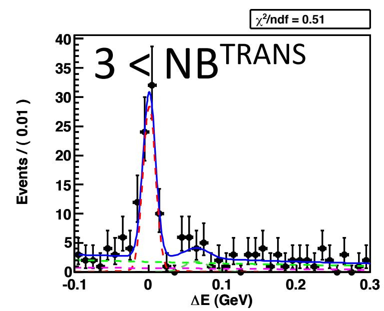


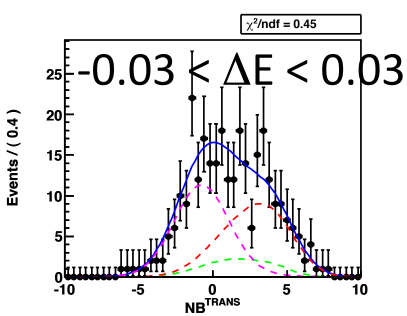


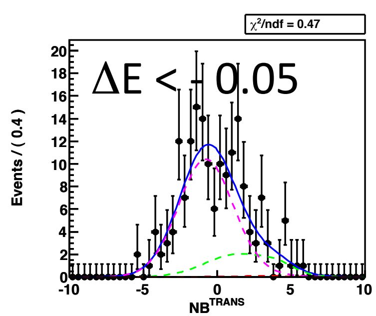
$N_{sig.}$ = 133 from generator info.

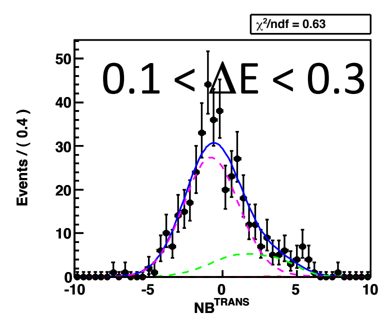




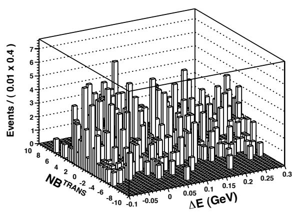


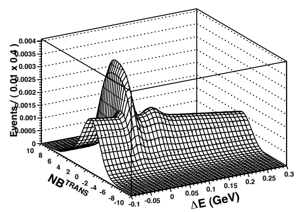


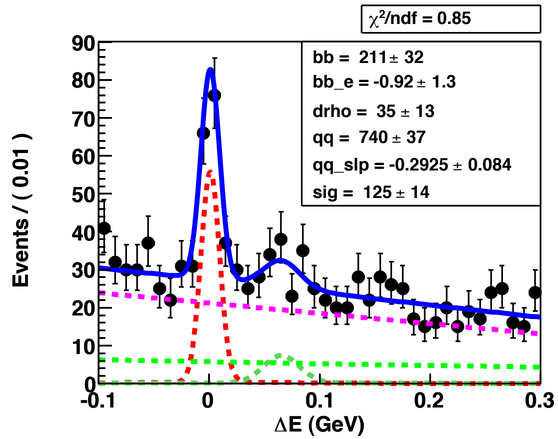


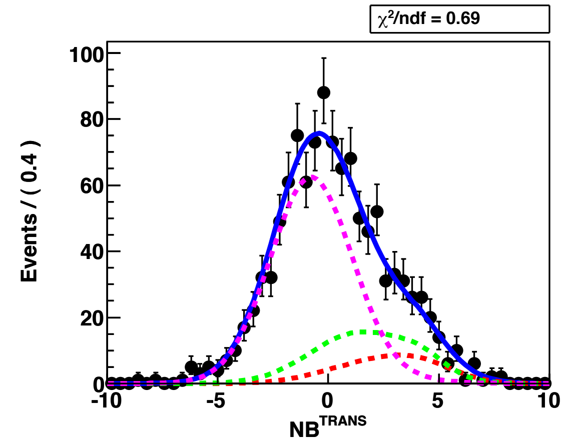


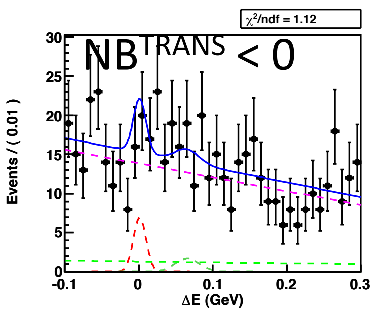
Fit to favored mode on MC(4)

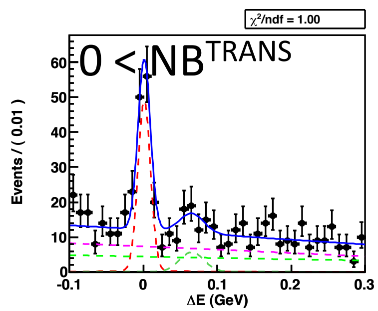


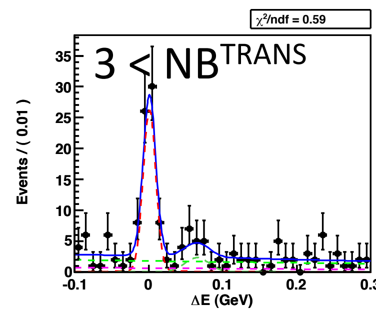


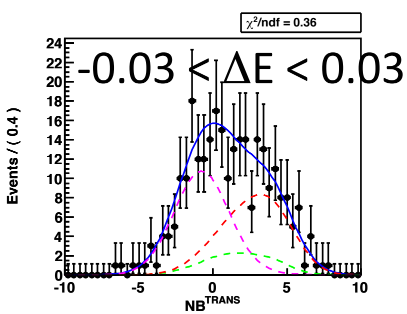


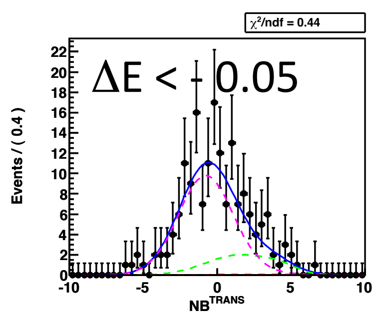


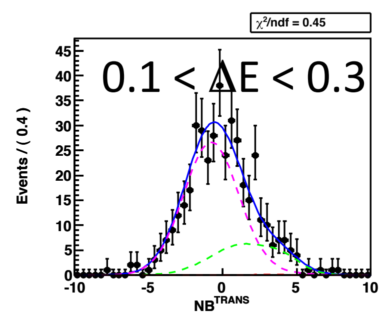




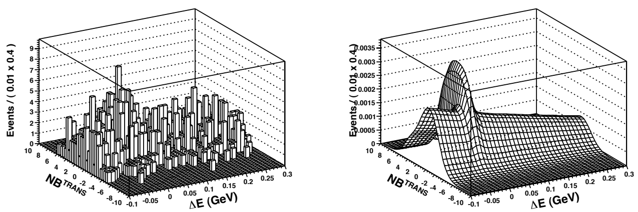




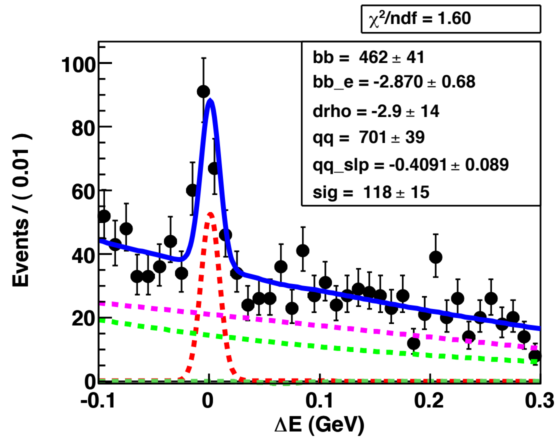


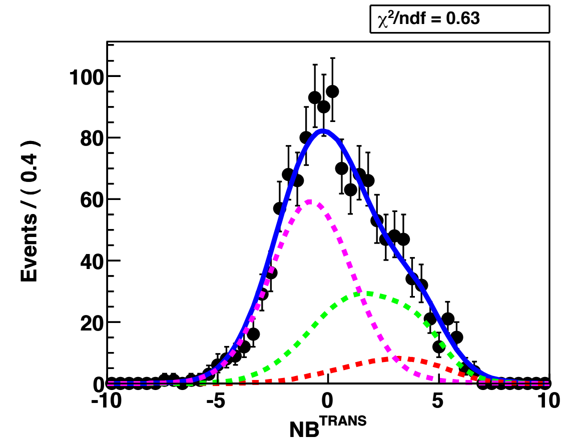


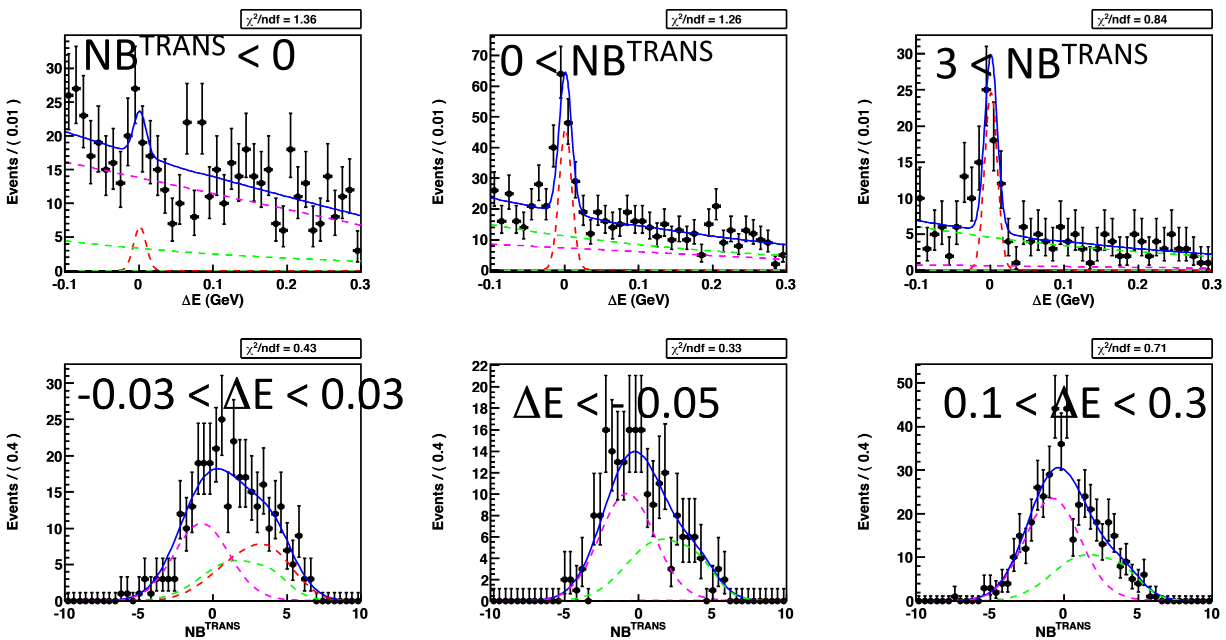
Fit to favored mode on the data



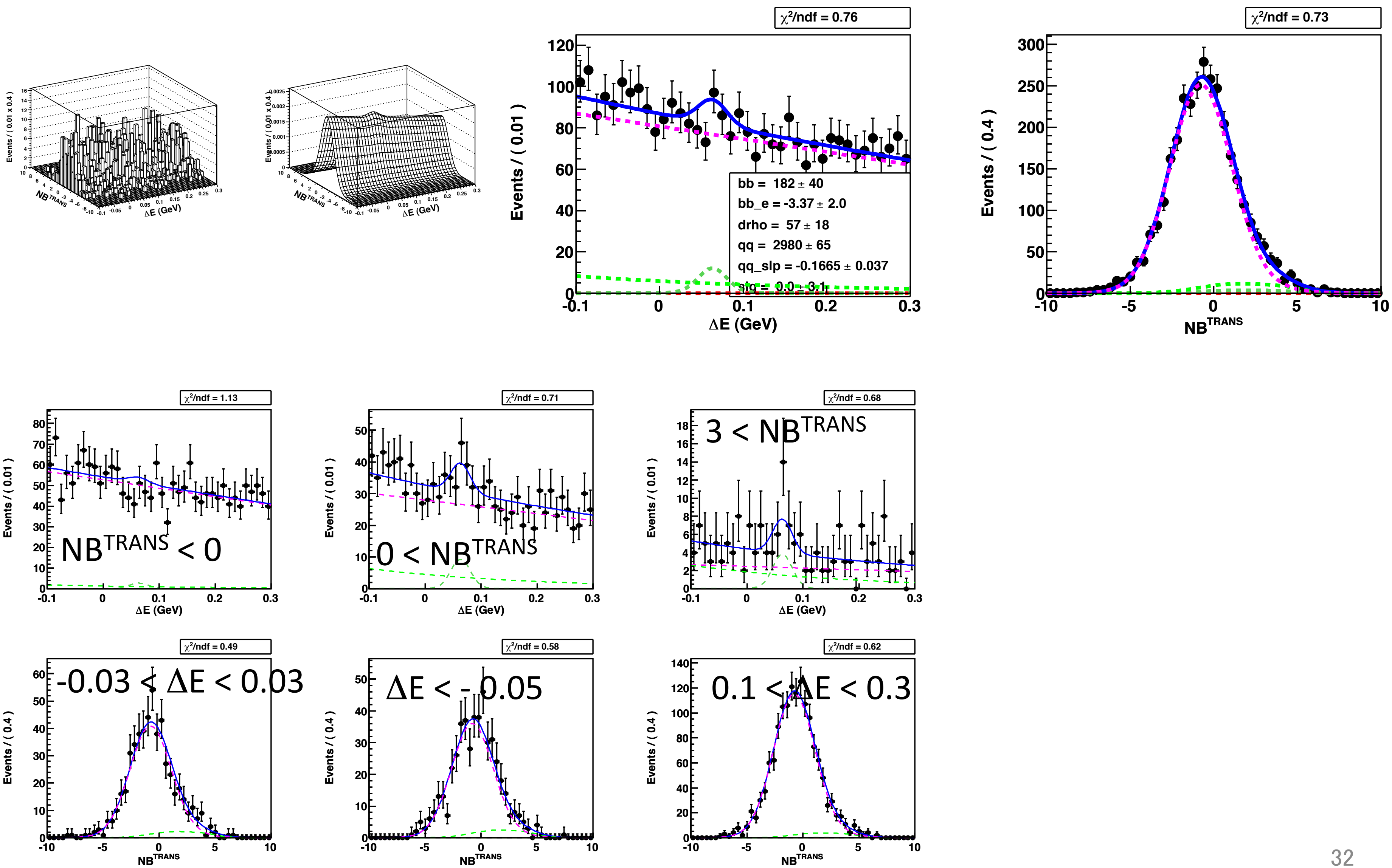
$N_{sig.}$ = 133 from generator info.



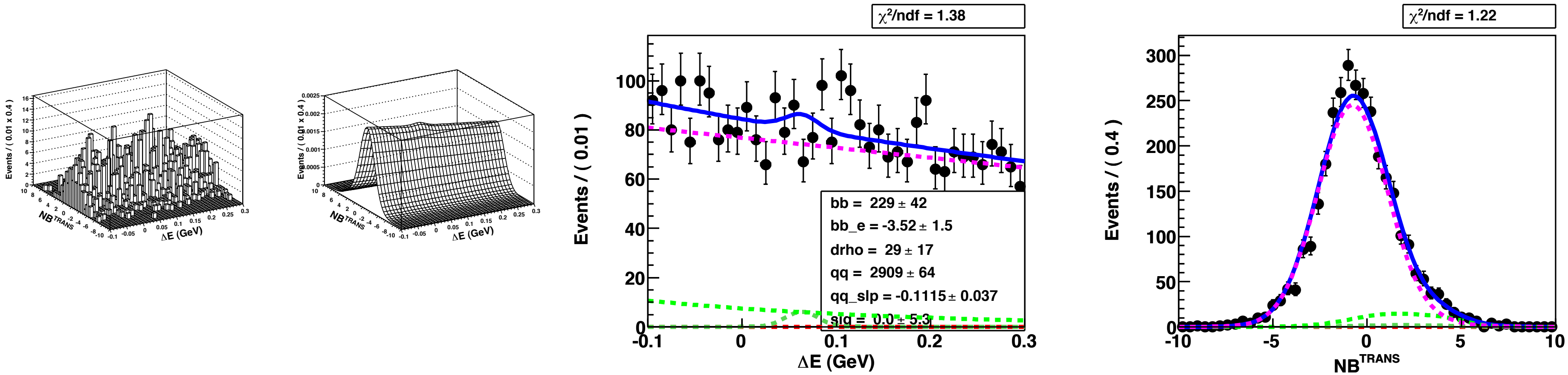


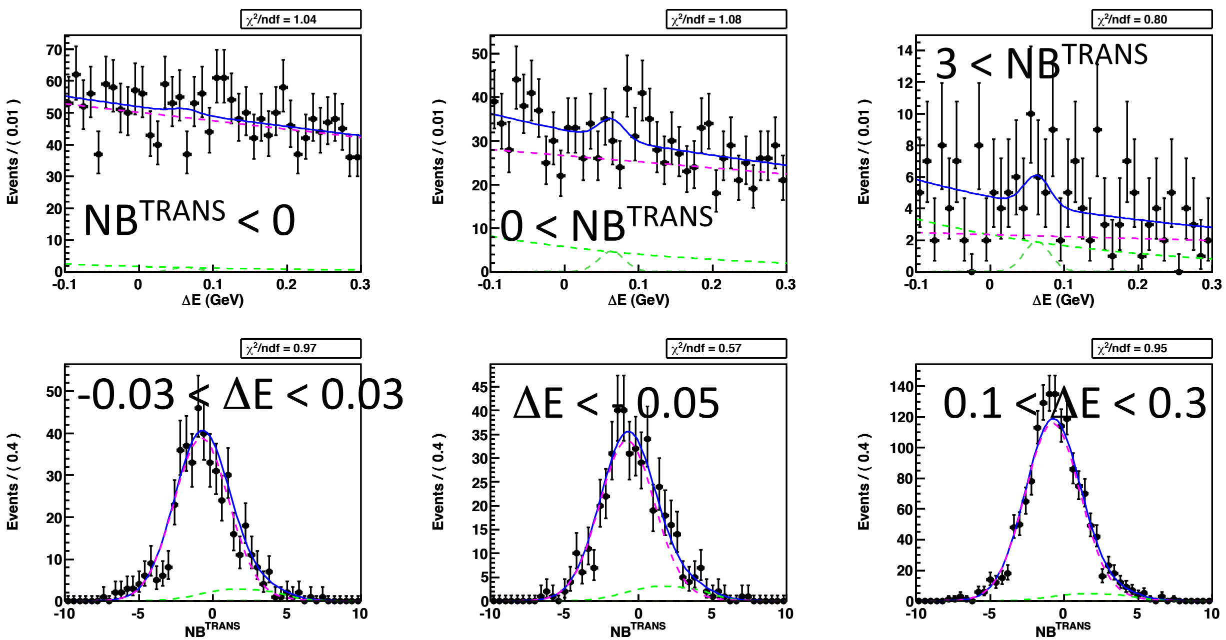


Fit to suppressed mode on MC (1)

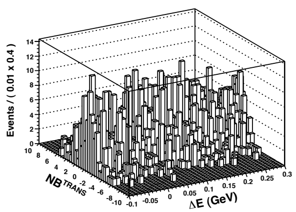


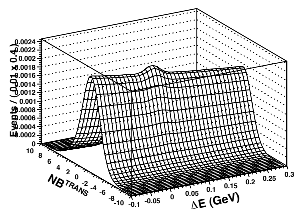
Fit to suppressed mode on MC (2)

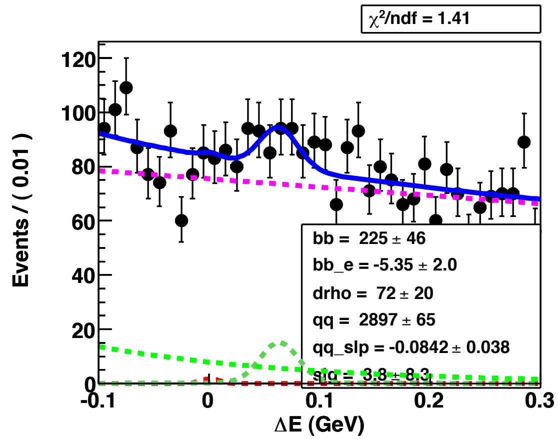


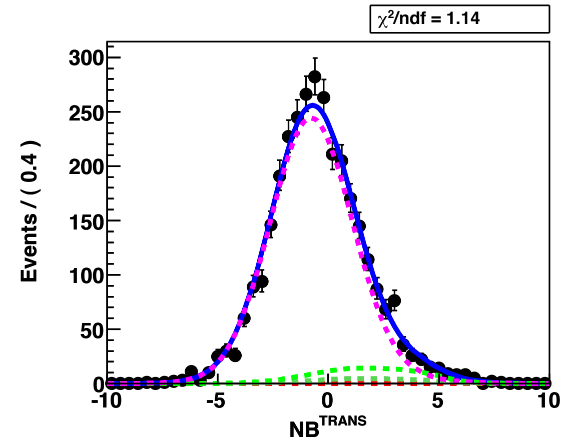


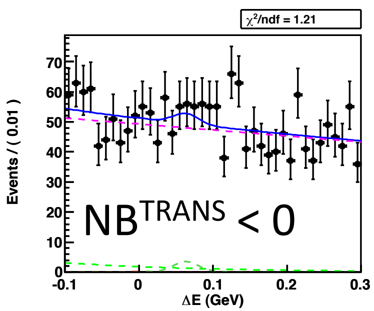
Fit to suppressed mode on MC (3)

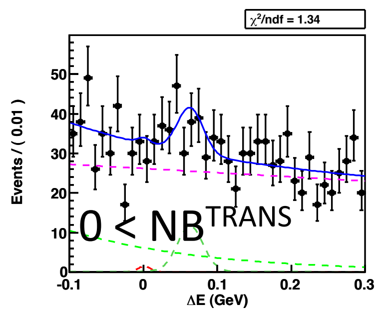


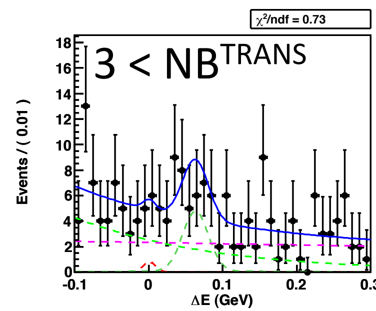


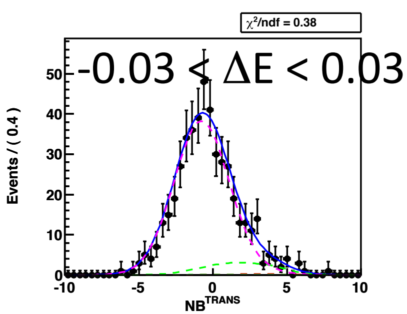


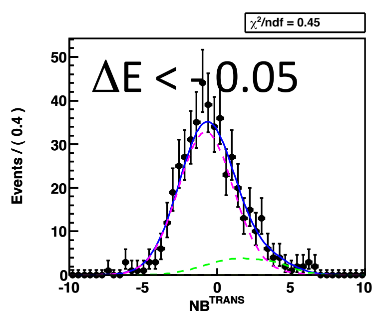


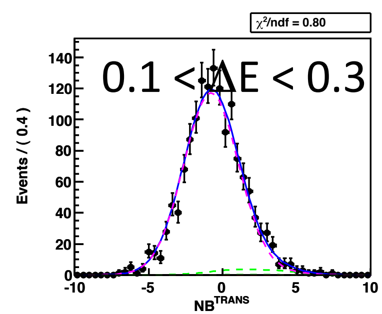




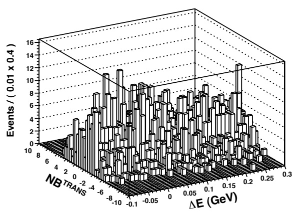


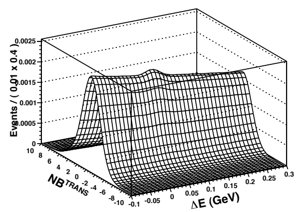


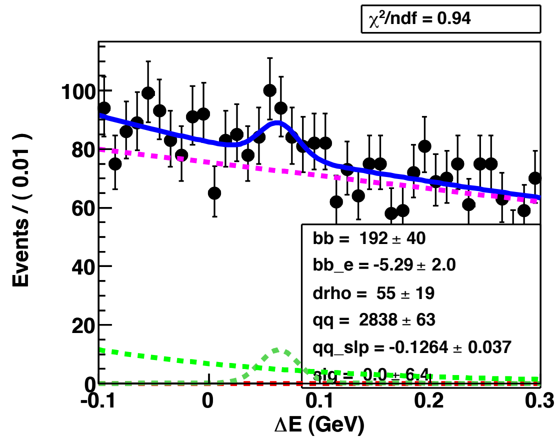


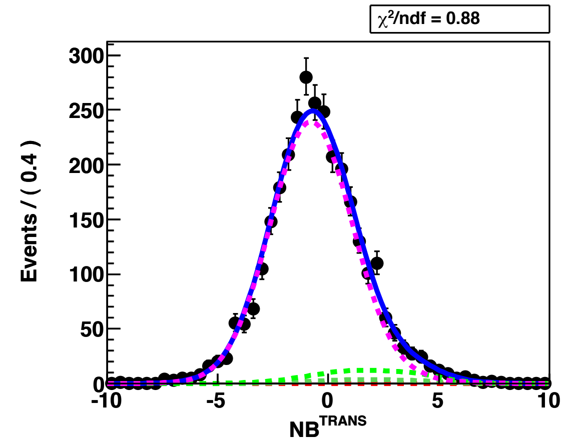


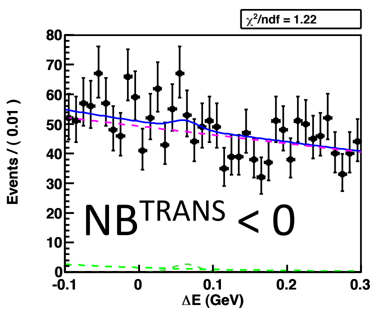
Fit to suppressed mode on MC (4)

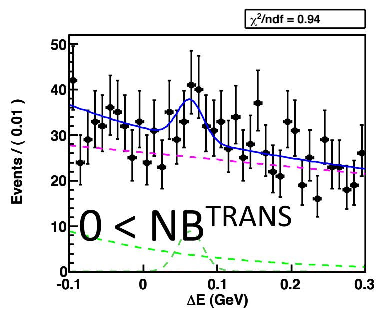


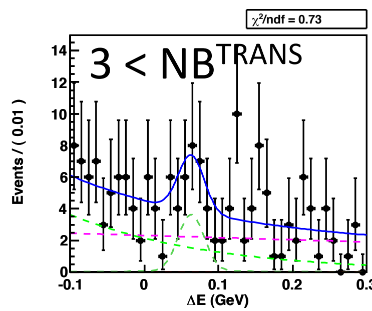


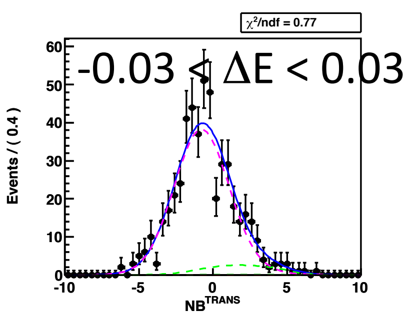


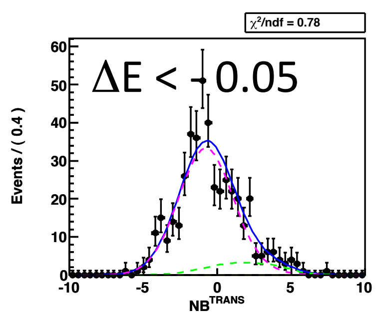


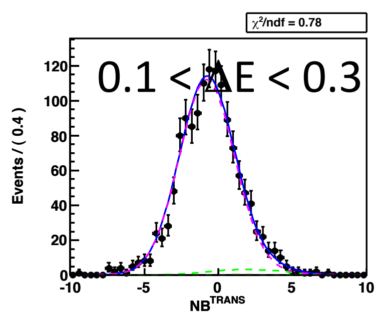






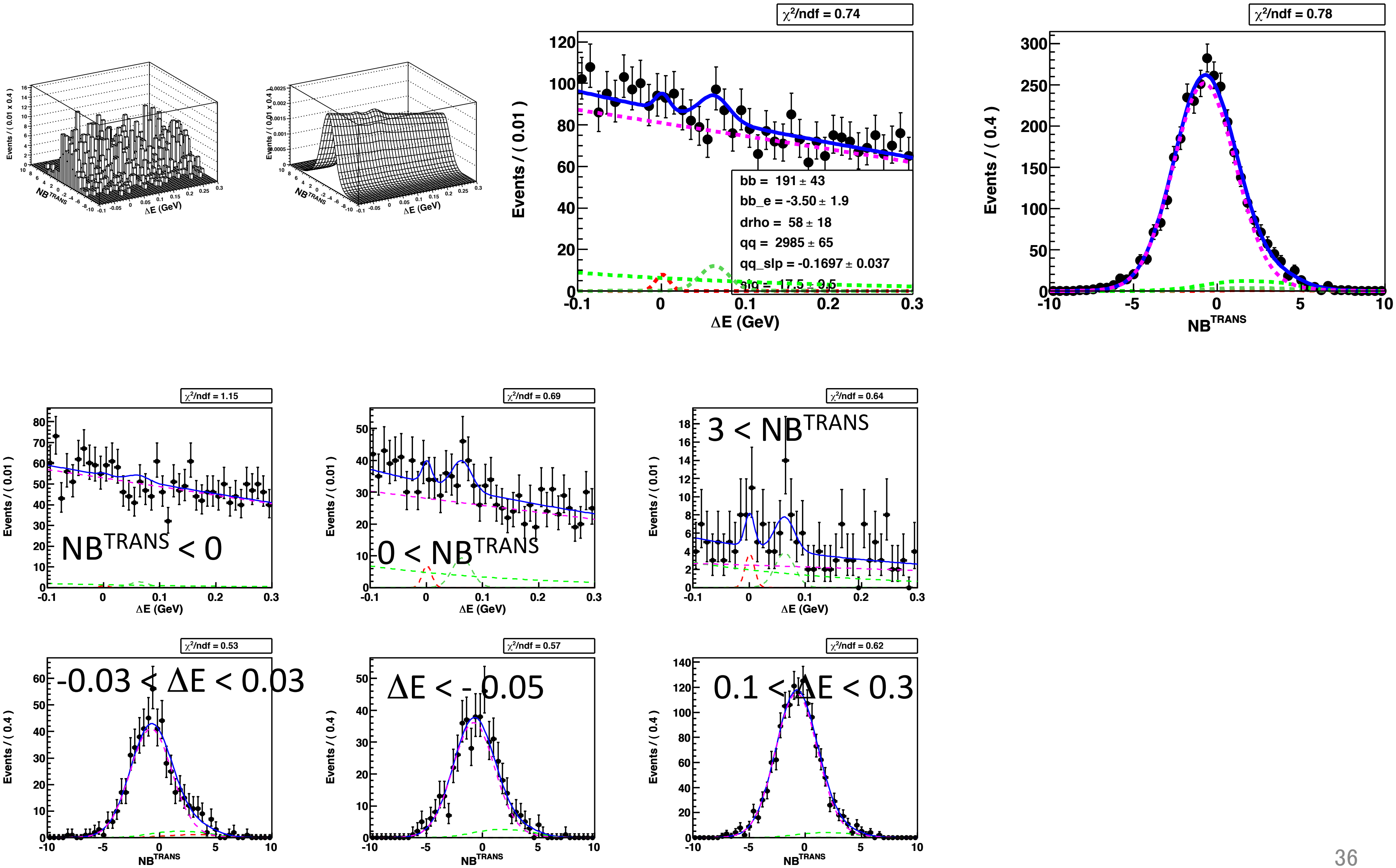






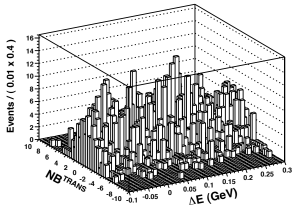
Fit to suppressed mode on MC (1)

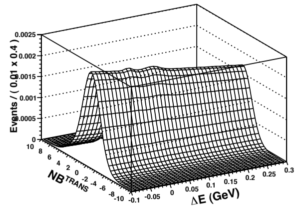
with 33 signal events.

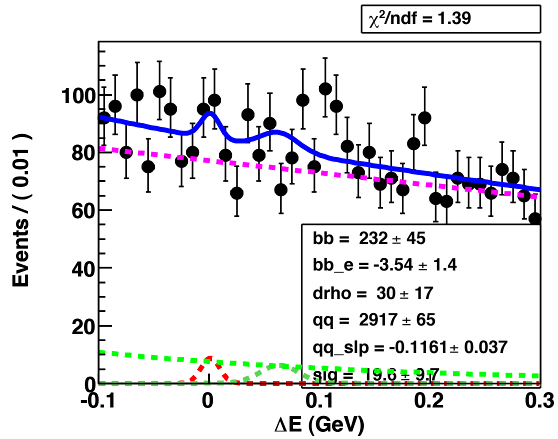


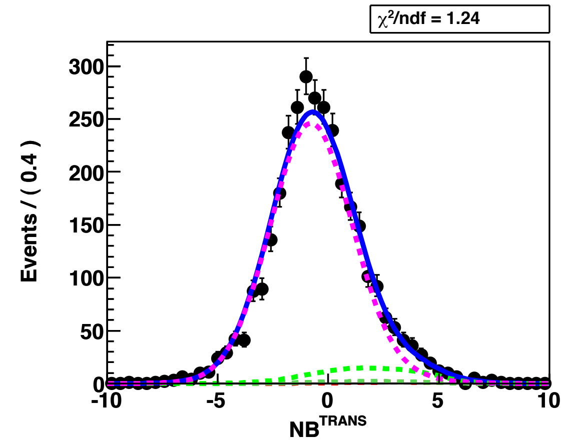
Fit to suppressed mode on MC (2)

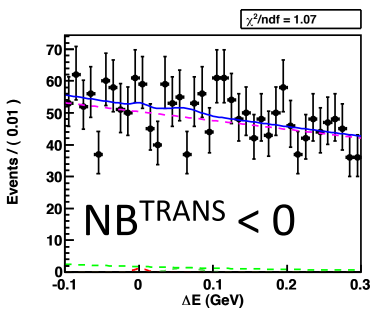
with 33 signal events.

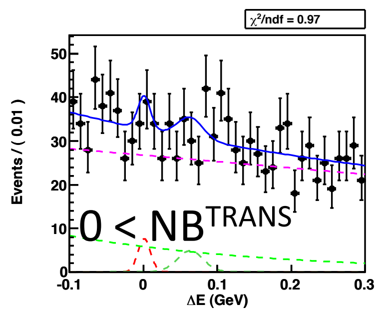


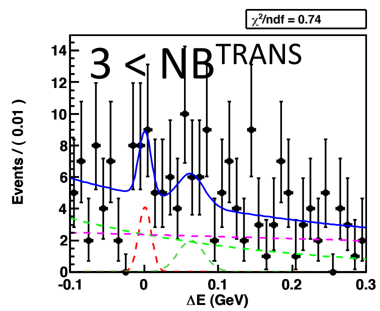


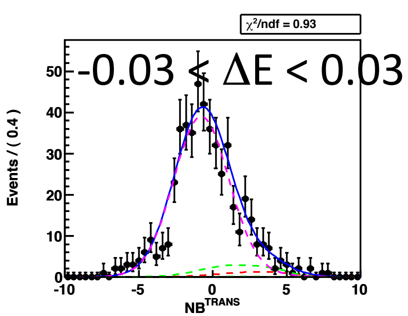


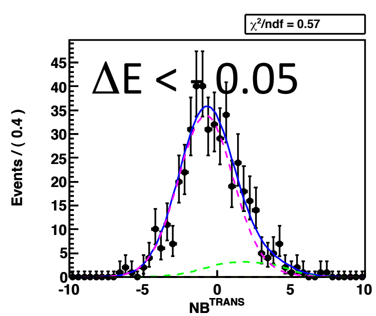


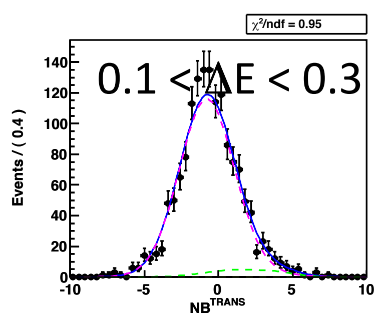






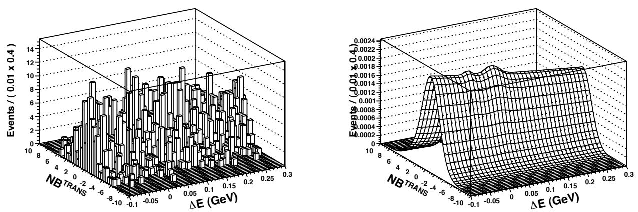


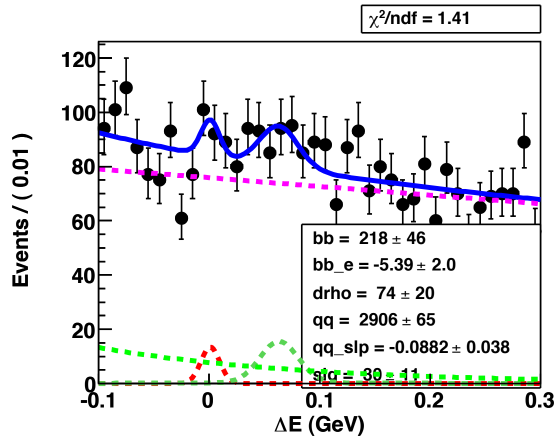


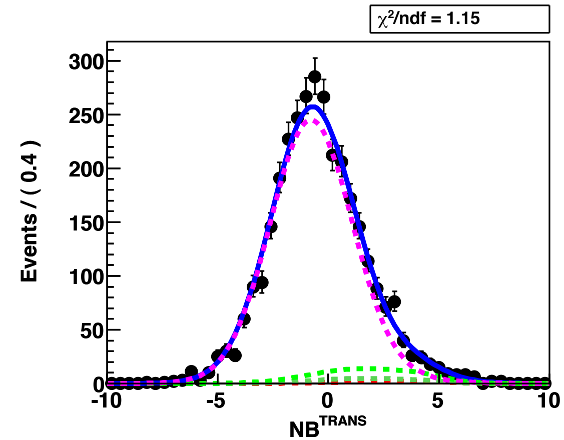


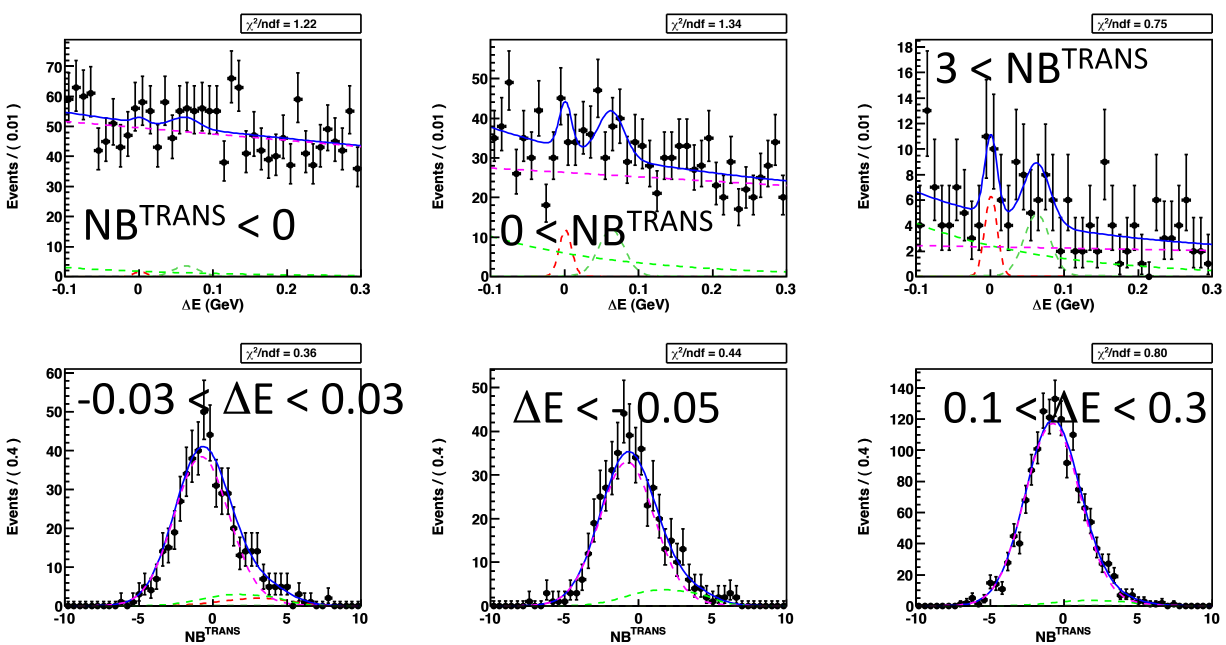
Fit to suppressed mode on MC (3)

with 33 signal events.



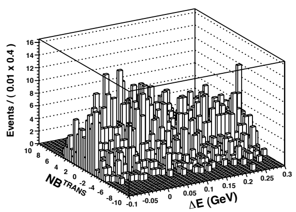


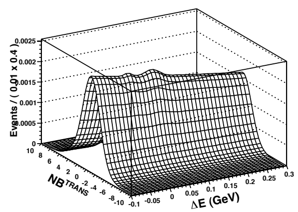


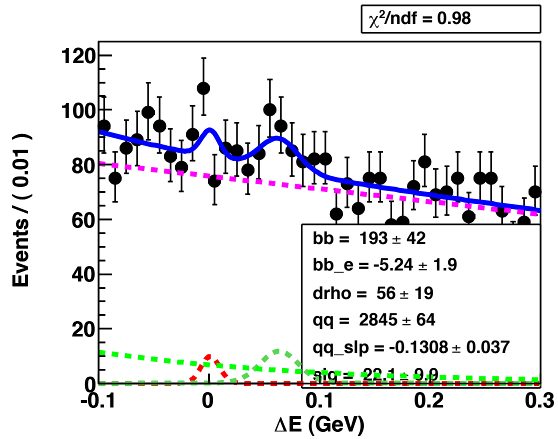


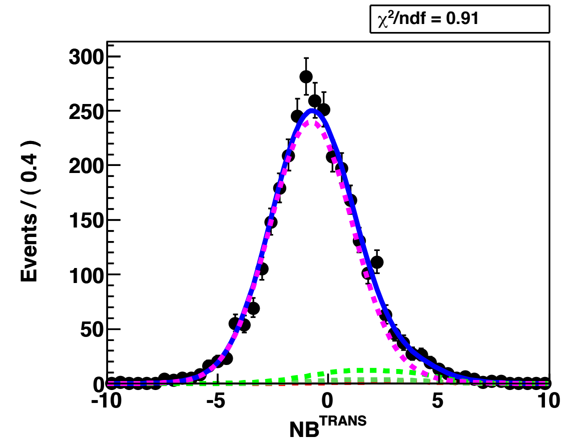
Fit to suppressed mode on MC (4)

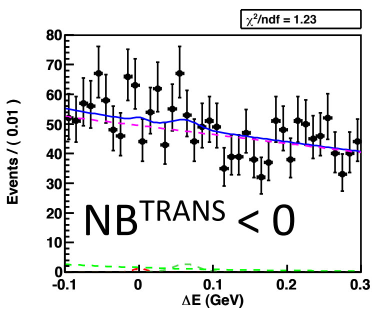
with 33 signal events.

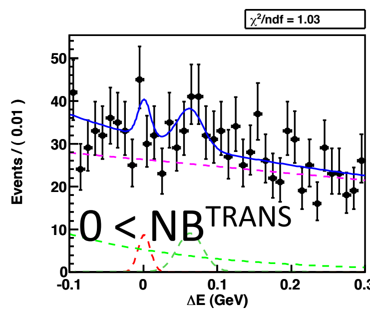


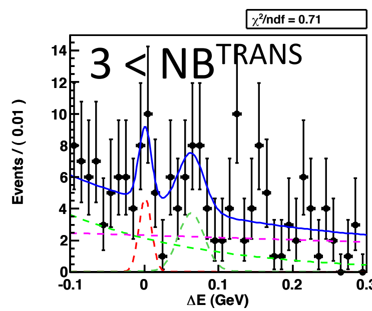


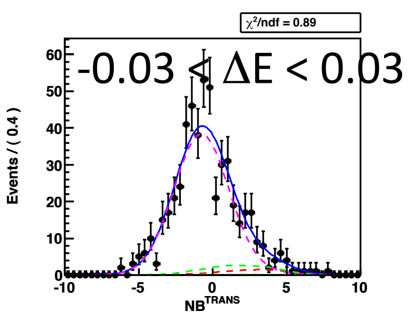


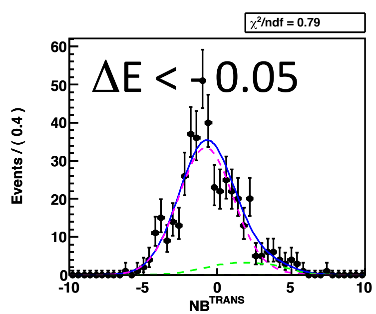


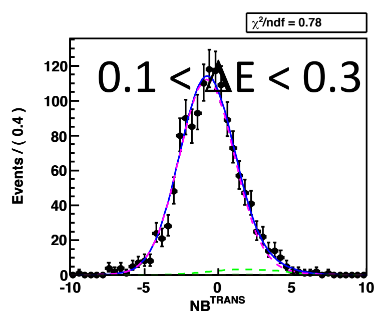




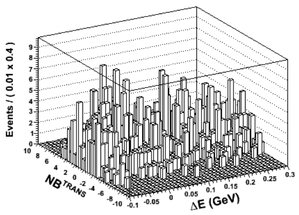


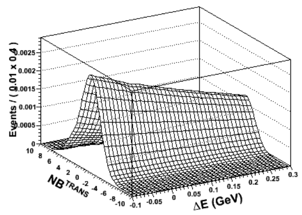


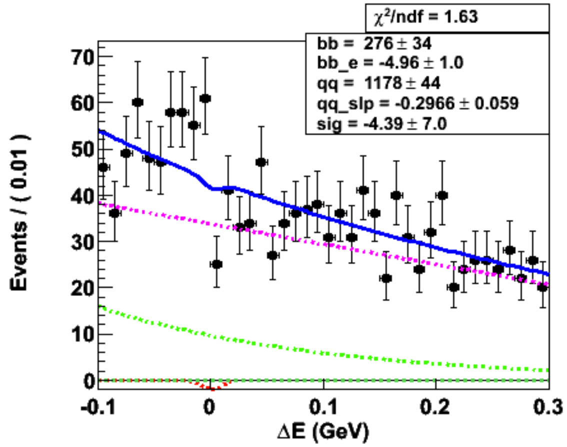


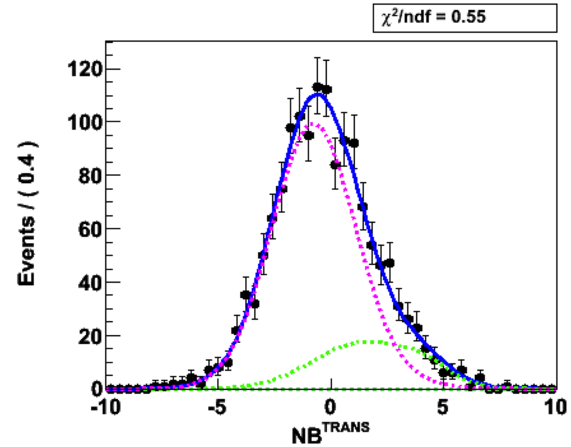


Fit to suppressed mode on D^0 sideband data

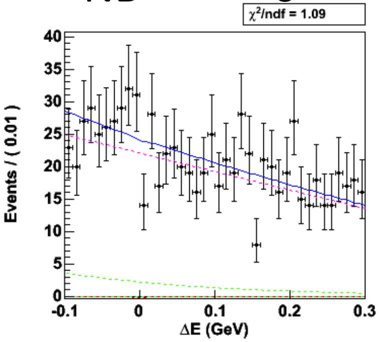




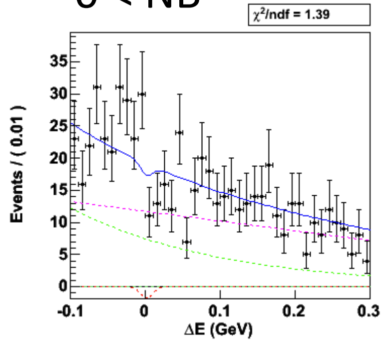




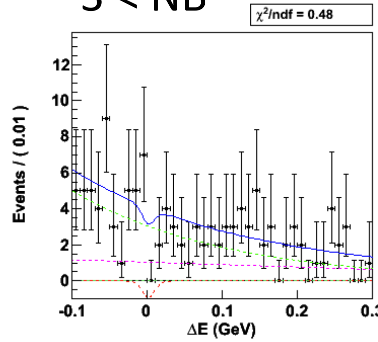
$NB^{TRANS} < 0$



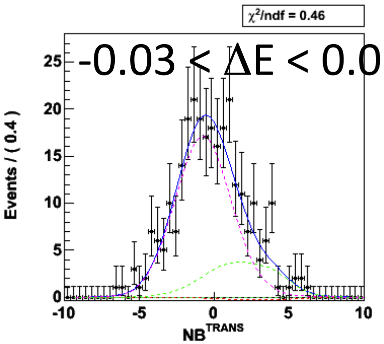
$0 < NB^{TRANS}$



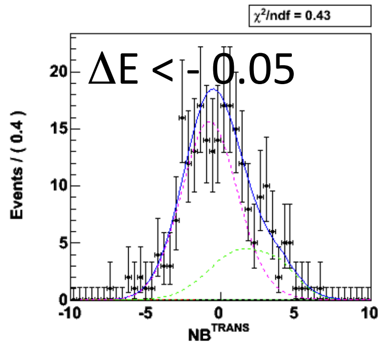
$3 < NB^{TRANS}$



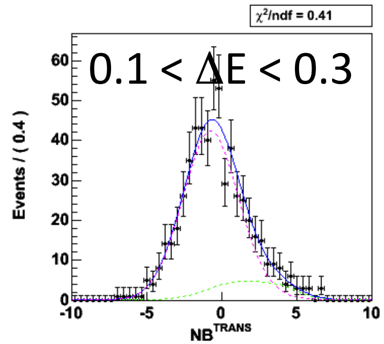
$-0.03 < \Delta E < 0.03$



$\Delta E < -0.05$

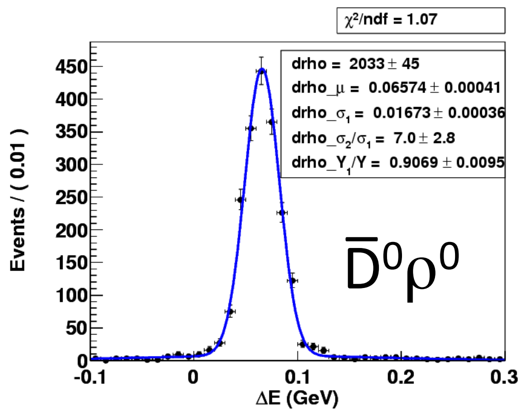


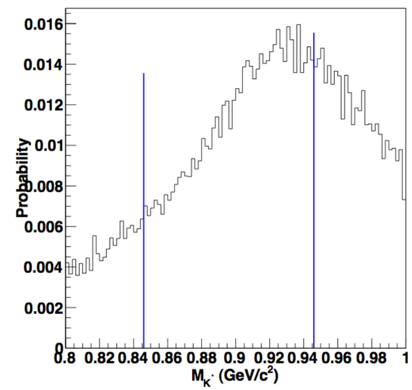
$0.1 < \Delta E < 0.3$



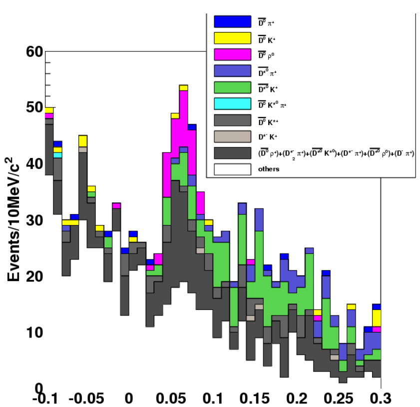
BB backgrounds

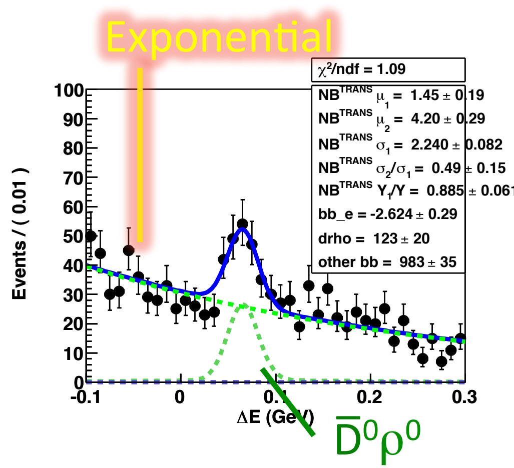
- BB background ΔE PDFs are fixed from MC.
  - I generated 1M events $\bar{D}^0\rho^0$ MC.
    - $\bar{D}^0\rho^0$ PDF shape is obtained from fit to MC.

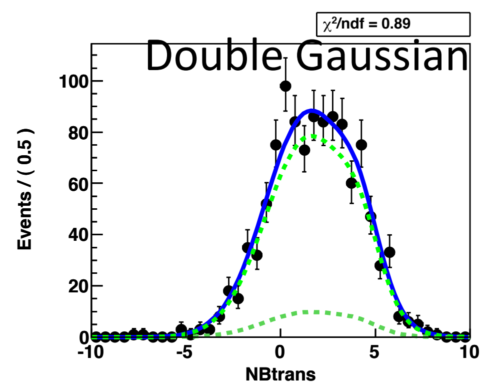




- Other BB

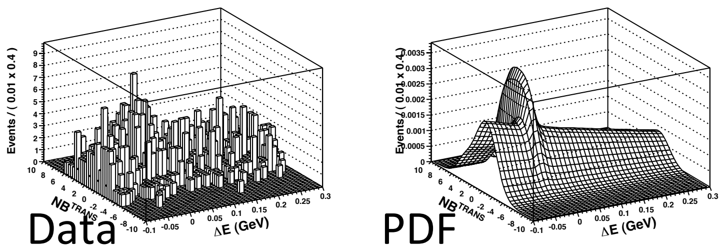






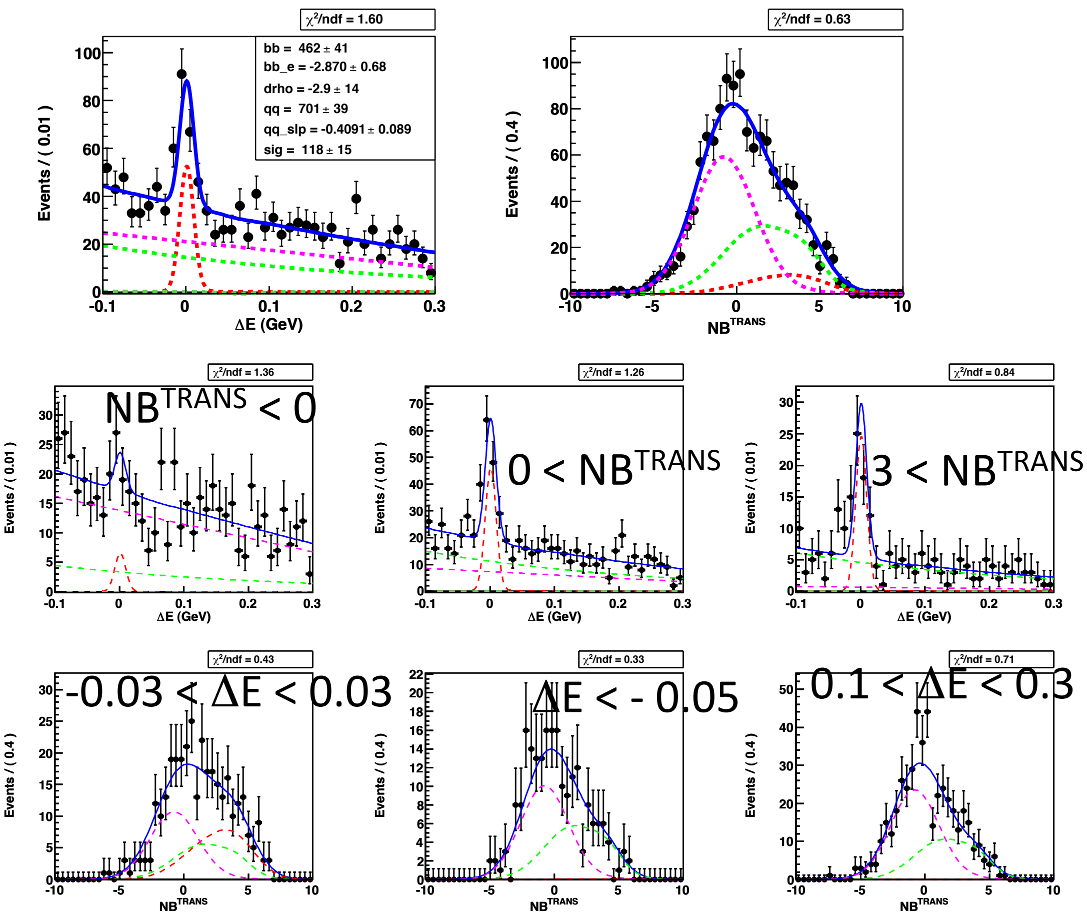
Fit to data on favored mode

Exp. 7-65



Blue	: Total
Red	: Signal
Green	: $\bar{D}^0\rho^0$
Yellow	: Other BB BG
Magenta	: qq

Blue	: Total
Red	: Signal
Yellow	: BB BG
Magenta	: qq



#Sig. = 118 ± 15

$Br(B^0 \rightarrow DK^{*0})_{fav.}$

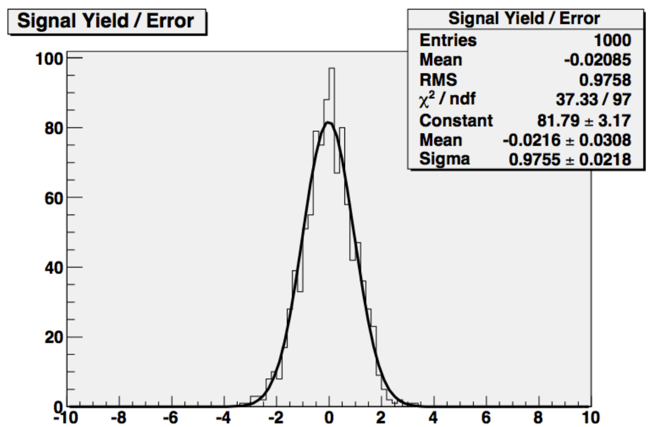
$= (3.68 \pm 0.48)*10^{-5}$

$Br_{PDF} = (4.2 \pm 0.6)*10^{-5}$

$-0.7\,\sigma$

6. Check the $Br(B^0 \to DK^{*0})_{fav.}$

Systematics source	(%)
Number of BB	± 1.4
Track efficiency	± 1.4
Signal efficiency	± 0.2
Uncertainty of $Br(D^0 \to K\pi)$	± 1.3
Fit parameterization	± 0.5
Fit bias	0.0
Total	**± 2.4**



Pull distribution for number of signal.

- $Br(B^0 \to DK^{*0})_{fav.} = (3.68 \pm 0.49 \pm 0.10) * 10^{-5}$

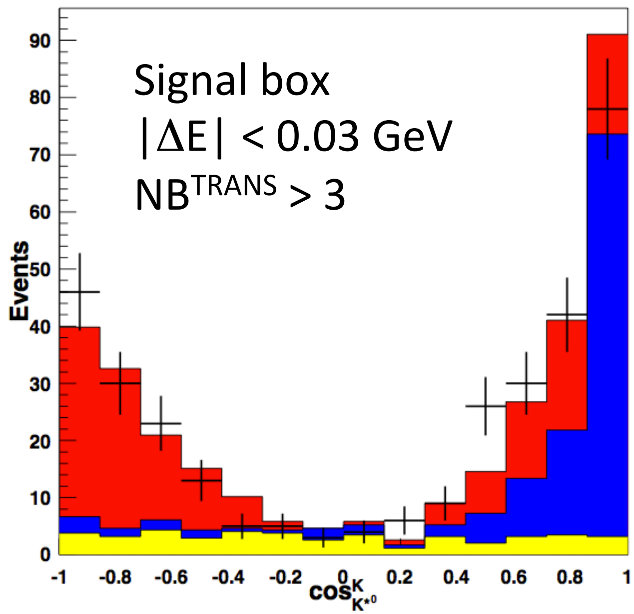
	$Br(B^0 \to D^0K^{*0})$ ($* 10^{-5}$)
This analysis	$3.68 \pm 0.49 \pm 0.10$
Belle @ 85M BB (PRL 90, 141802 (2003))	$4.8\ ^{+1.1}_{-1.0} \pm 0.5$
BaBar @ 226M BB (arXiv:0904.2112v2 [hep-ex] (2009))	$4.0 \pm 0.7 \pm 0.3$
PDG	4.2 ± 0.6

D^0 subdecay, $K\pi\pi^0$, $K\pi\pi\pi$ are included.

Check $\cos\theta_{K^{*0}}$ in signal box

- I check for $B^0 \to DK^+\pi^-$ non-resonant mode with $\cos\theta_{K^{*0}}$ in signal box.

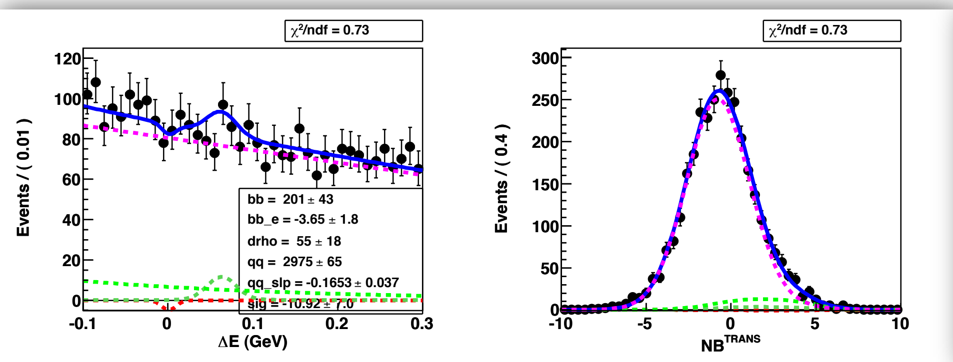
Dots with error bar : data
Histograms : MC
Red : Signal
Blue : BB
Yellow : qq



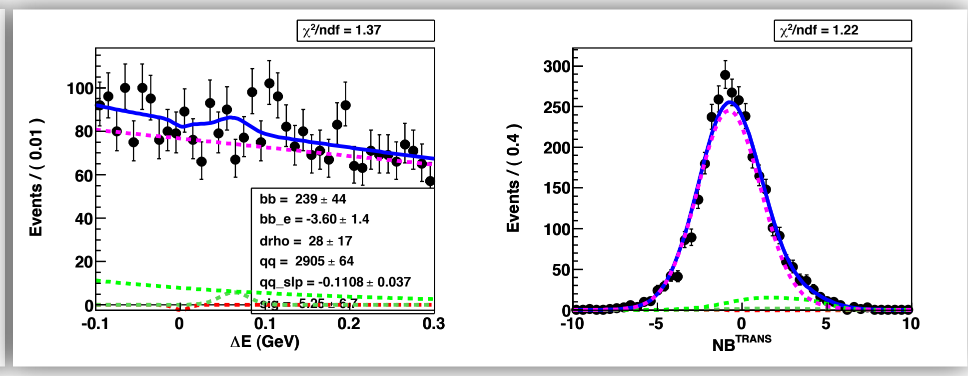
Non-resonant mode is negligible.

7. Fit to Suppressed Mode on 4 ensembles of 1 stream MC

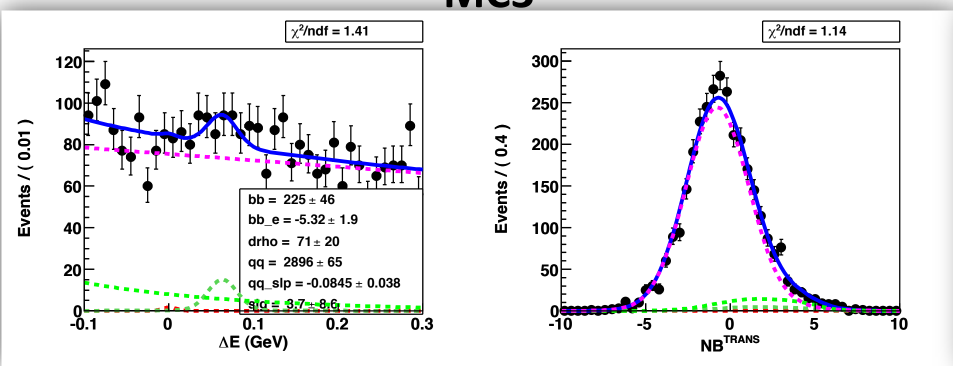
MC1



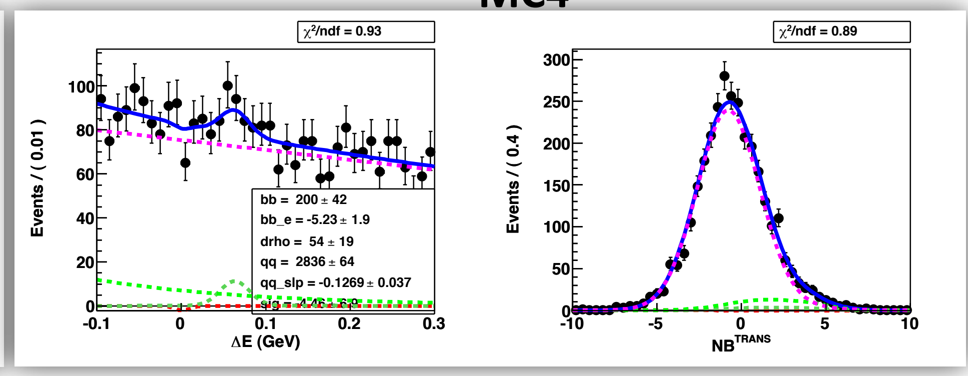
MC2



MC3

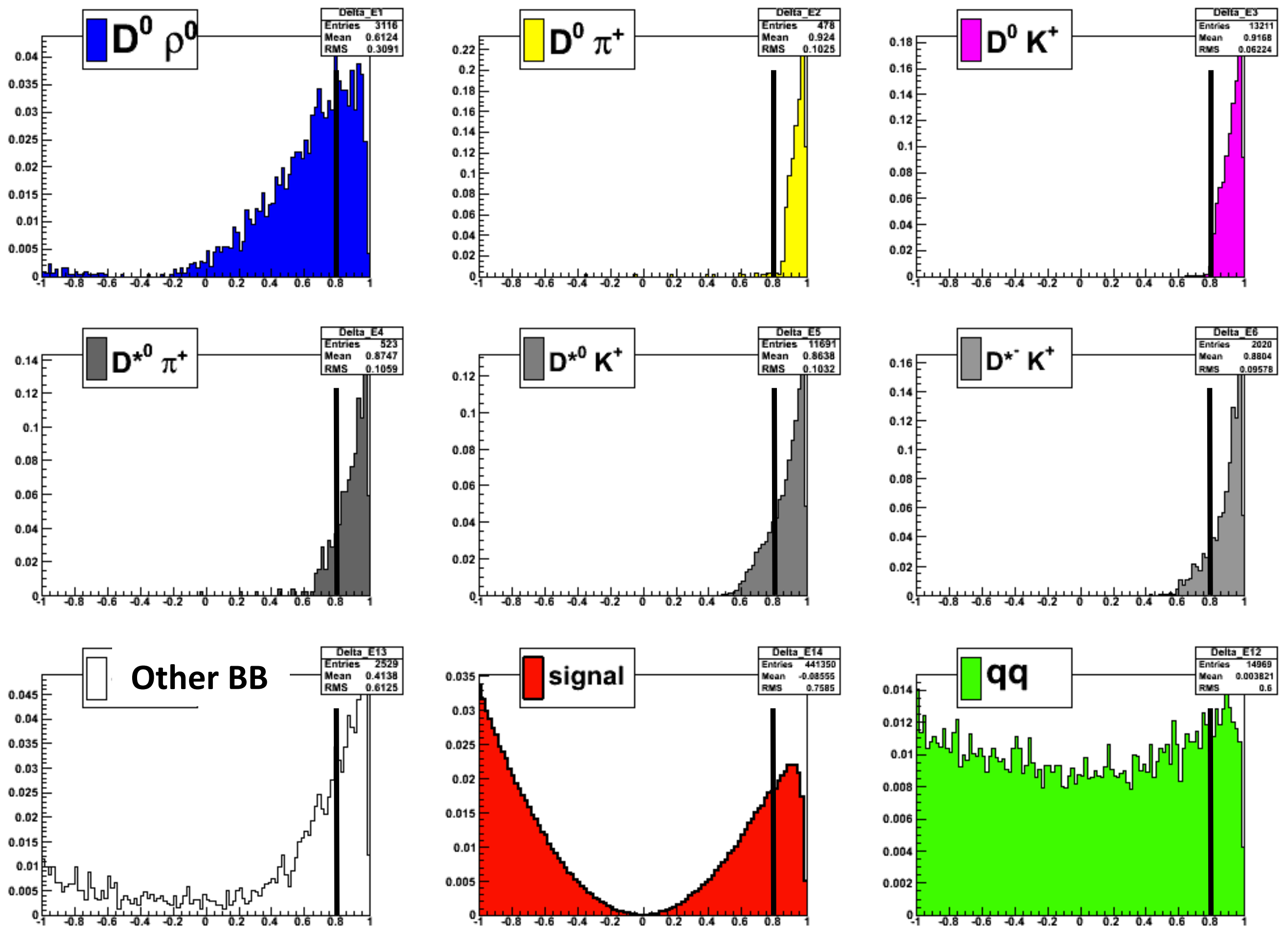


MC4



- I obtain $N_{sig.}$ = - 10.9 ± 7.2, - 5.3 ± 6.7, 3.7 ± 8.6, - 4.4 ± 8.9.
- $N_{sig.}$ = 0 from generator info.
- These are consistent results.

$\cos\theta_{K*}$ distributions of each mode



- Some BB backgrounds have a strong peak at $\cos\theta_{K*} \sim 1$.
- $\cos\theta_{K*} < 0.8$ cut for BB background suppression.