Study of $B^+ \to \pi^+\pi^0\pi^0$ at Belle

12TH SAGA-YONSEI WORKSHOP

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Contents

Introduction

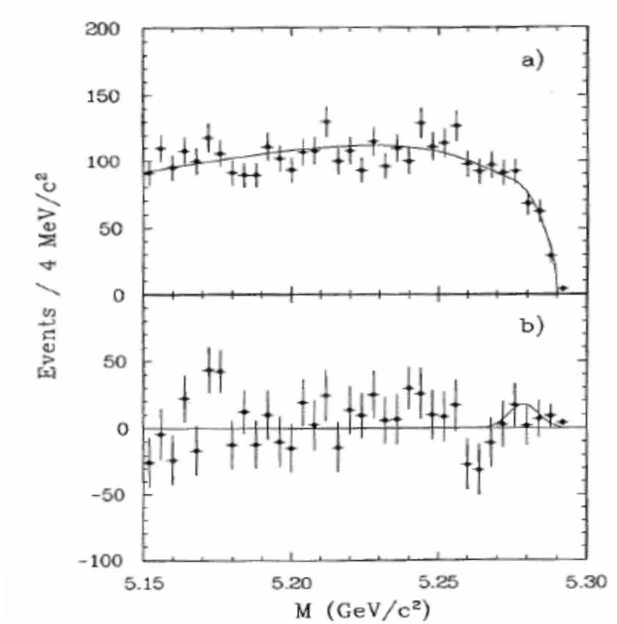
In the Standard Model (SM), b→c and b→u transitions are allowed via electroweak interaction.

- Due to the CKM suppression, b→u transitions are comparably less observed than b→c transitions.

The purpose of my research process is to search for the yet unobserved $B^+ \to \pi^+\pi^0\pi^0$ decay

- Its experimental limit on the branching fraction at 90% confidence level(C.L.) obtained by the ARGUS experiment is $\Gamma(B^+ \to \pi^+\pi^0\pi^0)/\Gamma_{total} < 8.9 \times 10^{-4}$
  - It is based on a data sample of 214 pb^{-1} from $\Upsilon(4S)$ resonance and 93 pb^{-1} in the continuum, on the ARGUS detector at the DORIS II storage ring.

We plan to search with a much larger amount of B mesons, corresponding to 772M $\Upsilon(4S)$ processes, at the Belle experiment.



Invariant mass distribution of all B candidate with 2 or 3 pions in final states
a) At the $\Upsilon(4S)$
b) After subtraction of the continuum contribution

Reference : ARGUS Collaboration, *Search for hadronic b→u decays*, Phys.Lett. B241 (1990) 278-282

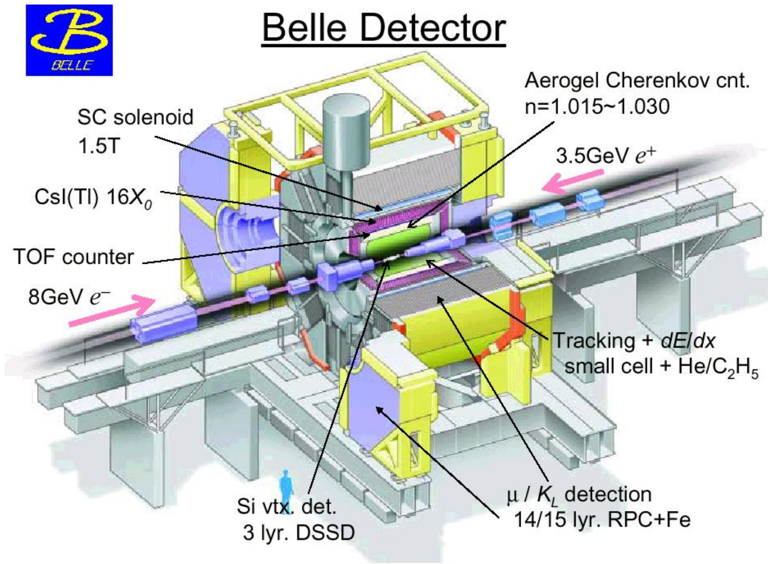
Belle Detector

The data sample used in this analysis was collected with the Belle detector at the KEKB asymmetric-energy e^+e^- collider.

- Integrated luminosity of 711 fb^{-1} or 772×10^6 $B\bar{B}$ pairs
- Collected on the $\Upsilon(4S)$ resonance at a center-of-mass (CM) energy ($\sqrt{s}$) of 10.58 GeV.

The structures of Belle detector

- Silicon vertex detector (SVD)
- 50-layer central drift chamber (CDC)
- Aerogel threshold Cherenkov counters (ACC)
- Array of a barrel-like arrangement of time-of-flight scintillation counters (TOF)
- Electromagnetic calorimeter comprised of 8736 CsI(Tl) crystals (ECL)
- Superconducting solenoid coil that provides a 1.5T
- Iron flux return located outside of the coil to detect K_L^0 mesons and to identify muons (KLM)



Research Strategy

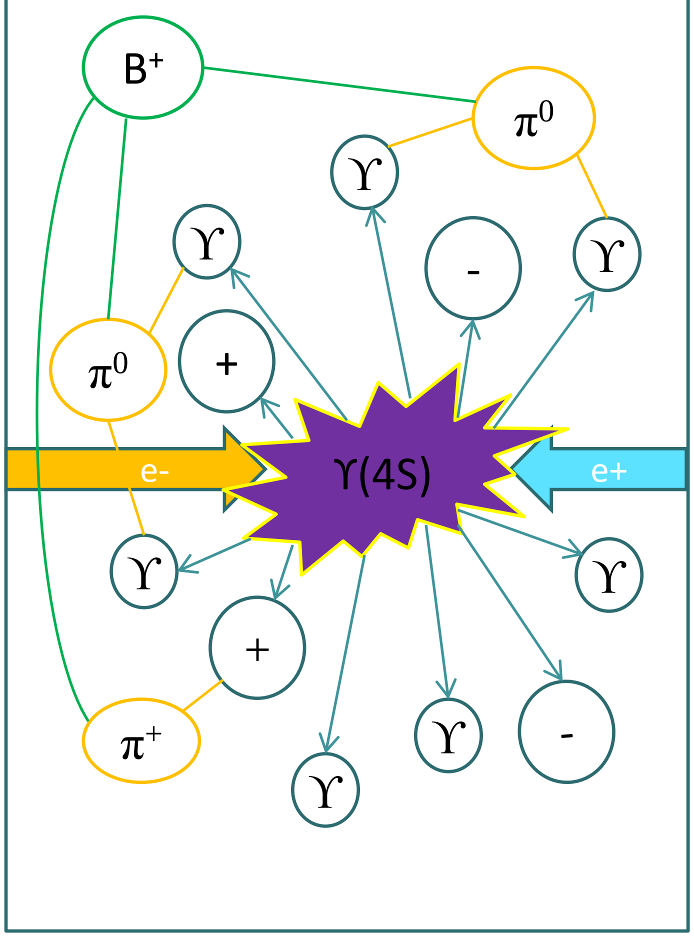
Perform a blind analysis with Monte Carlo (MC) samples based on

- EVTGEN event generator
- GEANT3 detector simulation

At the current process, we study the nature of non-resonant 3 body decay of $B^+ \rightarrow \pi^+\pi^0\pi^0$

- Using a large MC sample with 1M events generated in total
- In MC sample, reconstruct B meson by using 1 charged pion and 2 neutral pions.
    - Charged pion is selected from detected charged particle.
    - Neutral pions are reconstructed from detected gammas.
    - Another detected particles are regarded as them from other side B.
- By using MC sample, just try to calculate how much the branching fraction is.

In the final state,



B Meson Quality Control

After reconstruction of B meson using one charged pion and two neutral pions, we estimate a quality of the reconstructed B meson according to the following variables

- The beam constrained mass (M_{bc})
- The energy difference to the half of the beam energy in the center of mass (CM) frame (ΔE)

$$M_{bc} = \sqrt{E_{CM}^2 - p_B^2}$$

$$\Delta E = E_B - E_{CM}$$

E_{CM} : Beam energy in CM frame
p_B^2 : The momentum of reconstructed B in CM frame
E_B : The energy of reconstructed B in CM frame

To limit our study near the region relevant to the signal, we apply cuts in M_{bc} and ΔE :

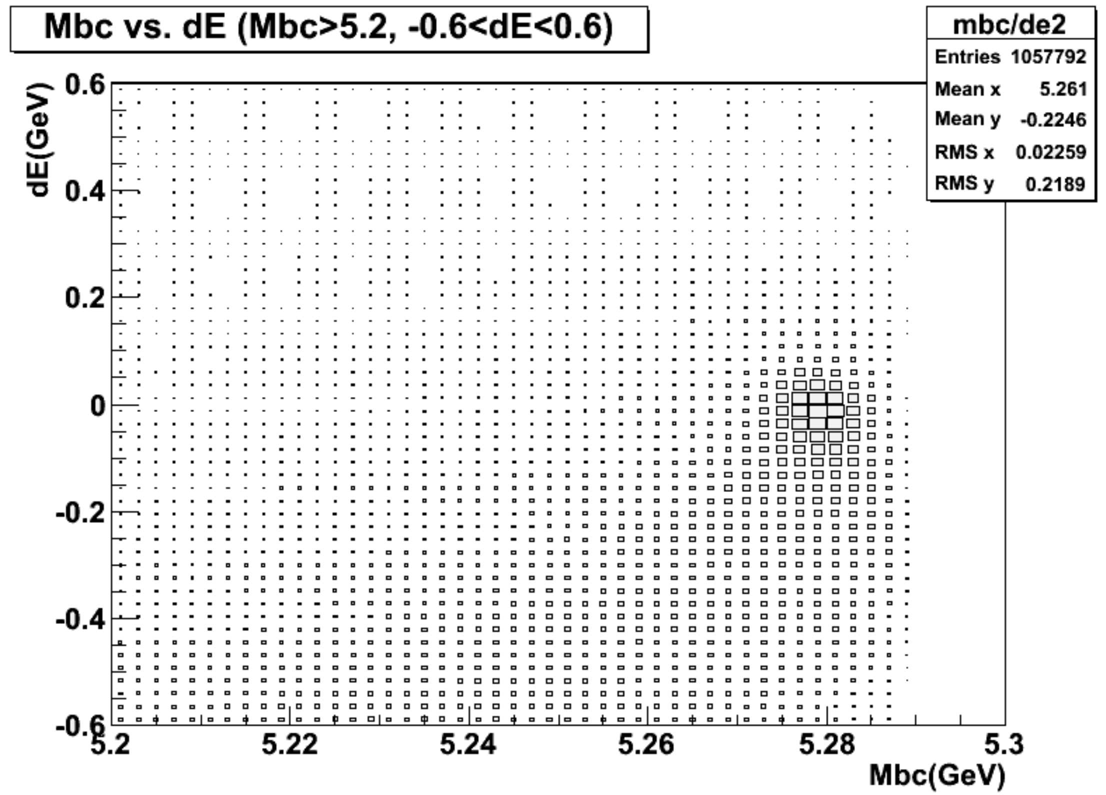
$$5.2\text{GeV}/c^2 < M_{bc} < 5.29\text{GeV}/c^2$$

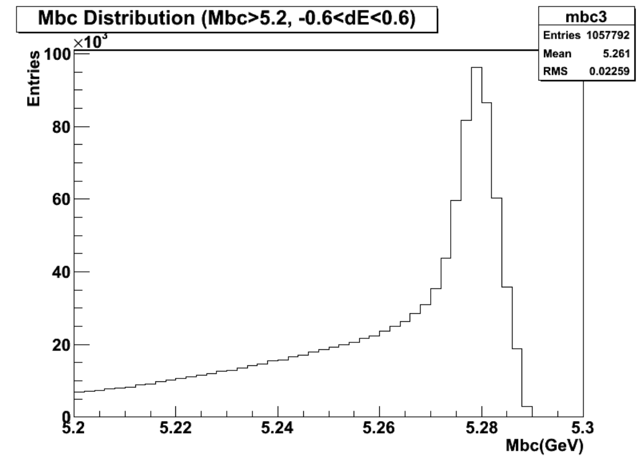
$$|\Delta E| < 0.6\text{GeV}$$

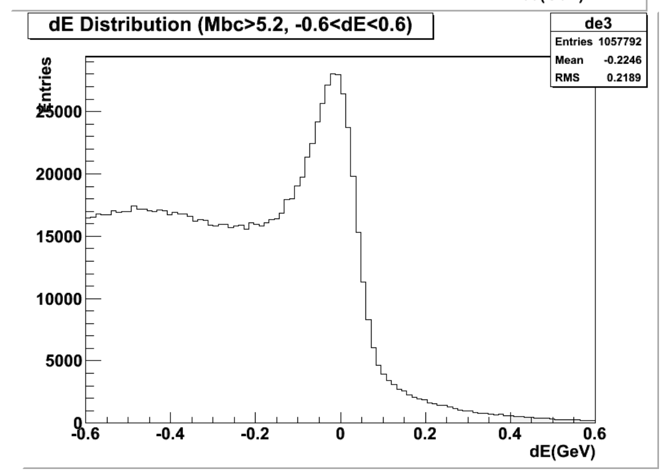
B Meson Quality Control

The 2-D plot of the signal MC sample M_{bc}-ΔE distribution and its projection in each variable

- $5.2 GeV/c^2 < M_{bc} < 5.29 GeV/c^2$, $|\Delta E| < 0.6 GeV$



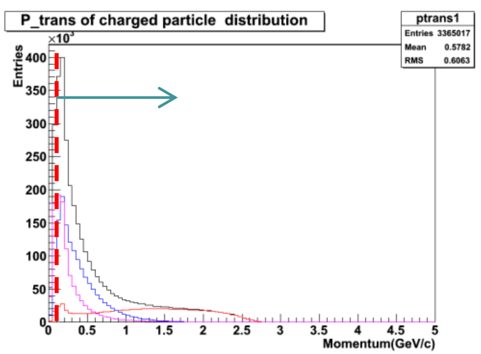


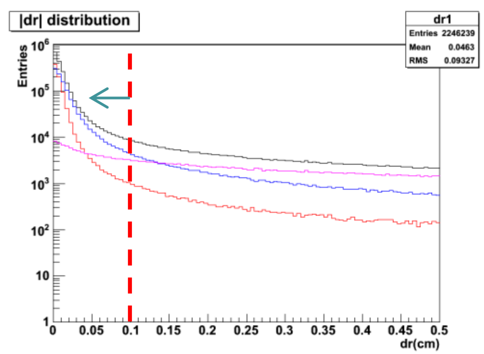


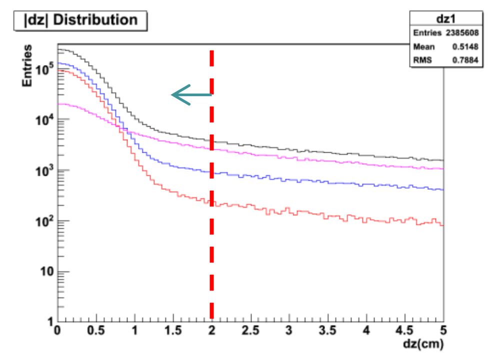
Best B candidate Selection

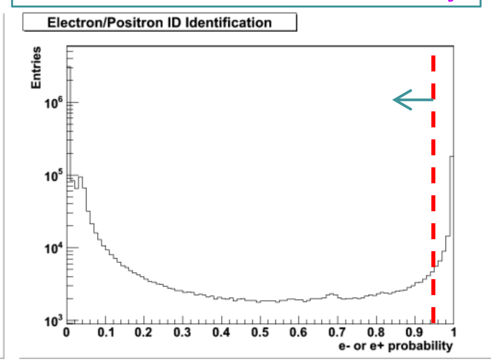
- To only take account of the B mesons reconstructed from good tracks, we apply the following cut :
  - Lab-frame transverse momentum (P_T) > 0.1 GeV/c
  - The distances from the interaction point to the B decay vertex in the plane
    - Perpendicular to the beam direction (dr) < 0.1cm
    - Along the beam direction (dz) < 2cm
  - Not identified as an electron/positron in particle identification : electron id < 0.95
  - If multiple selection is remained after applying these cuts, I choose $\min\left(\sqrt{(10 \cdot dr)^2 + (dz)^2}\right)$ as the best pi+
- In cases where there are multiple candidates reconstructed in an event, we decide which is the best by the quality of the pi0's used in the reconstruction:
  - Minimum value of sum of χ^2 in mass constraint fit of π^0
- After the best B candidate selection, 30% of the signal MC events have at least one well-reconstructed B.

Total entries
Particle from direct B decay
Particle from other decay
Particle not from decay







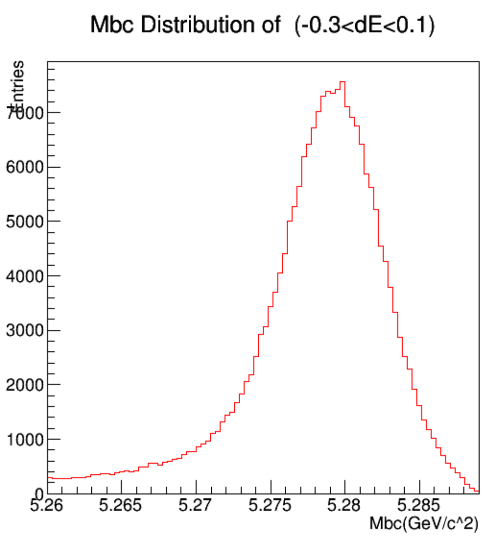


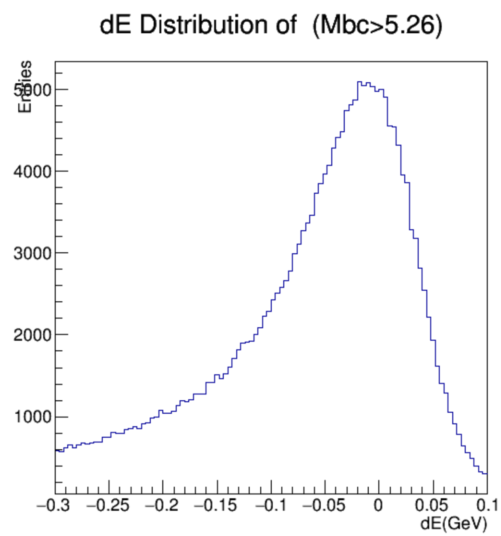
2D Fitting of M_{bc} vs. ΔE Distribution

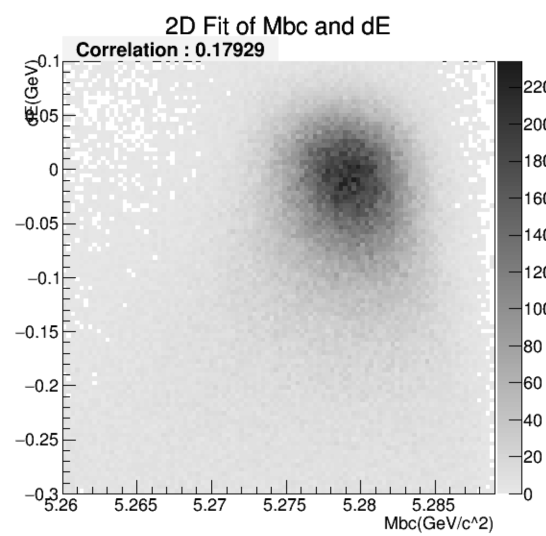
To utilize in the future in order to obtain the signal yield, an unbinned 2 dimensional ML fit in the M_{bc} vs. ΔE plane is performed.

Tighter cut applied for suppressing the effect of the combinatorial background events

- $5.26 GeV/c^2 < M_{bc} < 5.29 GeV/c^2$, $-0.3 GeV < ΔE < 0.1 GeV$
- Correlation factor between M_{bc} and ΔE : 0.17929. → It is not easy to obtain 2D PDF by taking direct product of the M_{bc} and ΔE PDFs.







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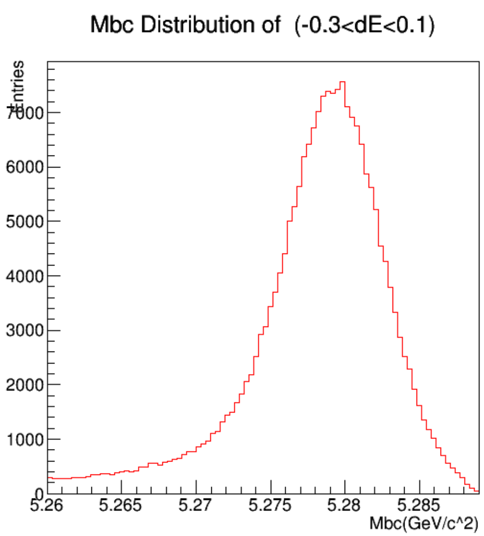
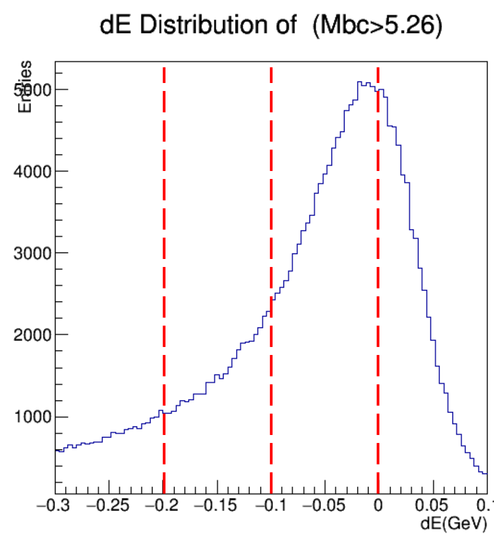
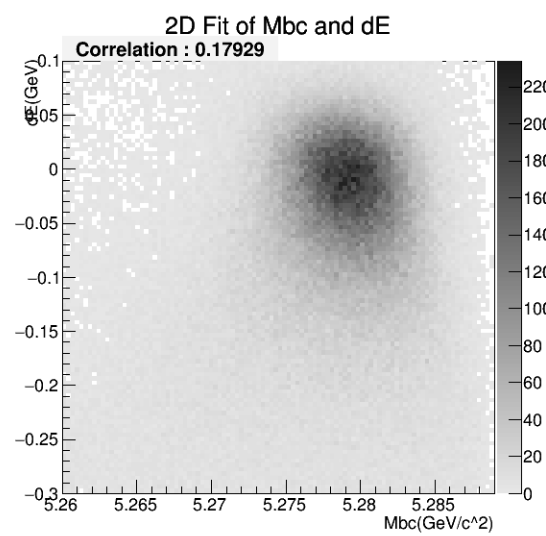
- Correlation factor between M_{bc} and ΔE : 0.17929. → It is not easy to obtain 2D PDF by taking direct product of the M_{bc} and ΔE PDFs.
- In order to model such correlated distribution, I plan to perform a fit in the shown cut ΔE region and obtain the parameters of the 1D PDF used to model M_{bc} as a function of ΔE.







Summary

- In the Standard Model (SM), b→c and b→u transitions are allowed via electroweak interaction. But b→u transitions are comparably less observed than b→c transitions.
- A preliminary study with a non-resonant 3-body decay signal MC was presented.
- The B mesons', reconstructed from the sets of a charged pion and a neutral pion, quality can be controlled via variables related to the B mesons' daughters, where the best B selection was done according to the χ^2 of the mass constrained fit used in reconstructing the neutral pions.
- Currently, working a parametric PDF modelling of the signal MC in the 2D plane of M_{bc} and ΔE.

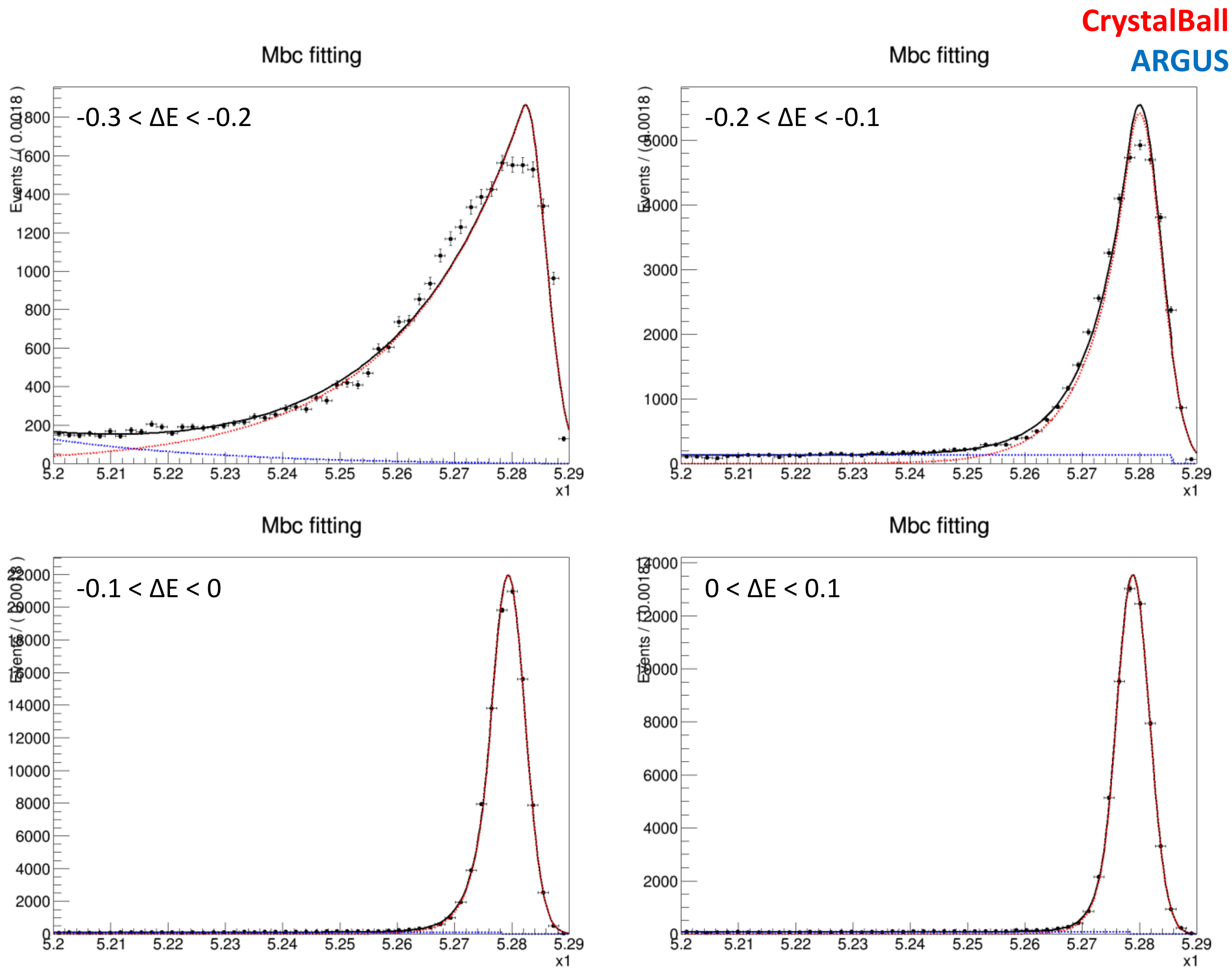
Thank you for listening.

Backup

M_{bc} Fitting on Each ΔE Region

Fitting with PDF of Crystal Ball function + ARGUS background function

- At low ΔE region, PDF does not fit with signal MC.



Crystal Ball function

$$f(x;\alpha,n,\bar{x},a) = N \cdot \begin{cases} \exp\left(-\frac{(x-\bar{x})^2}{2\sigma^2}\right) & \left(\text{for } \frac{x-\bar{x}}{\sigma} > -\alpha\right) \\ A \cdot \left(B - \frac{x-\bar{x}}{\sigma}\right)^{-n} & \left(\text{for } \frac{x-\bar{x}}{\sigma} \le -\alpha\right) \end{cases}$$

where

$$A = \left(\frac{n}{|\alpha|}\right)^n \cdot \exp\left(-\frac{|\alpha|^2}{2}\right)$$

$$B = \frac{n}{|\alpha|} - |\alpha|$$

Dalitz Plot Study

Dalitz plot study

- The kinematics of a three-body decay can be described by the masses of two combined particles in the process
- Dalitz plot is a 2 dimensional plot with a selection of the two possible pairs of such mass combination.
- We expect the Dalitz plot to be uniformly flat without angular correlations between the decay products(as our signal MC events are generated)
- When the resonant processes, e.g. $B^+ \to \rho^+(\pi^+\pi^0)\pi^0$, provide significant contribution, the Dalitz plot will show a non-uniform distribution with a peak around the mass of the resonance.

Dalitz Plot Study

Labeling particles after reconstructing a B meson

- The charged pion of our decay as particle 1
- The neutral pion yielding a larger mass when combined with the charged pion as particle 2
  - Then, we can determine the larger of the combined mass and present a Dalitz plot folded.
- The lastly left neutral pion as particle 3

All the possible B candidate combination with the B quality cuts applied in our signal sample are included in the figure at right.

We observe 2 peculiar peaks as circled in the figure at right.

- The peak near to the origin originates from the low momentum π^+
- The other around the $20 < M_{12} < 25$ GeV^2/c^4 originates from the low momentum π^0