Search for Bc → Bs π decay

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Winter student
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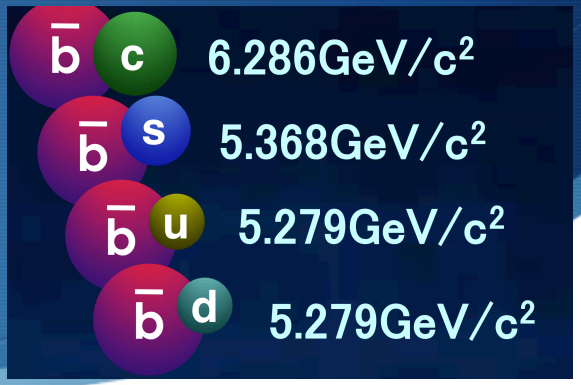
Introduction



- The properties of Bc meson are not completely understood
- Bc is the heaviest meson except for bb

  →BR: good benchmark to verify the theory

- Bc almost decays where Bs meson is involved in the final state

Br (Bc → Bs X) ~ 64%

Br (Bc → Bs π) ~ 16%

→ Not discovered!!

My Goal: Estimate the number of the signal and the BG of Bc → Bs (→J/Ψ φ) π (→KK)

How do we find Bc → Bs π?

Neural network (NN) approach

If we had more time, ……

1. Pre-selection
2. First NN to select Bs decays
3. NN optimal cut
4. Second NN to select Bc decays (using first NN optimal cut)
5. Estimate S/N of Bc → Bs π

This time, we had only 10 days……

Using Bs MC & data@10fb^{-1},,,

1. Pre-Selection
2. NN to optimize Bs → J/Ψ ϕ

Using Bc MC & data@3.3fb^{-1} ,,,

3. Pre-Selection
4. NN to optimize Bc decays
5. Estimate S/N of Bc → Bs π

- no trigger confirmation
- no MC distribution correction

Bs → J/ ψ ϕ

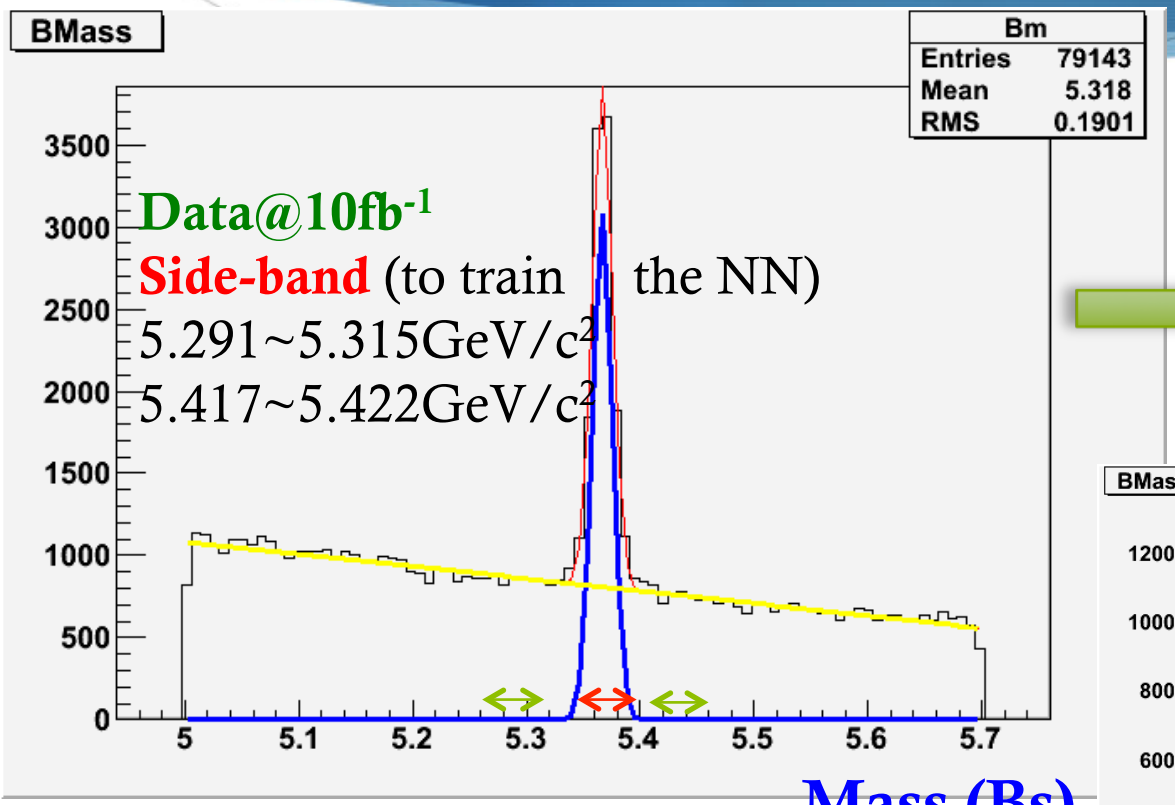
- data sample: p0-p38 10fb^{-1} dimuon trigger (JPSI)
- MC: Pythia
- use new Bstntuple (v90)

Pre-Selection

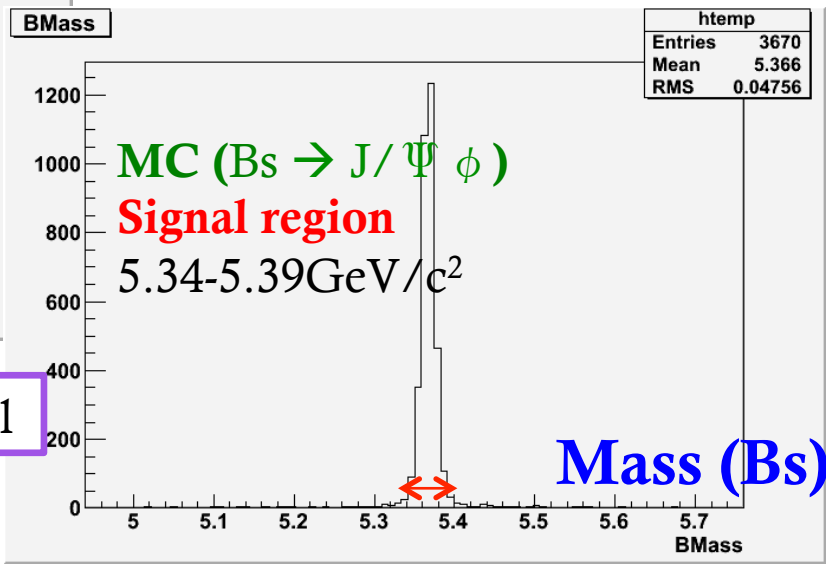
- Track quality : >9 axial and >9 stereo COT hits and > 3 Si hits for all tracks
- $5.0 GeV/c^2 < M(Bs) < 5.7 GeV/c^2$
- $3.014 GeV/c^2 < M(J/\psi) < 3.174 GeV/c^2$
- $1.009 GeV/c^2 < M(\phi) < 1.028 GeV/c^2$
- $Pt(\phi) > 1.0 GeV/c$
- $Pt(K) > 0.4 GeV/c$
- $\chi 2(Bs) < 23$
- $LL_{\mu\mu} > 0$

Ref: CDF10722

After pre-selection before NN



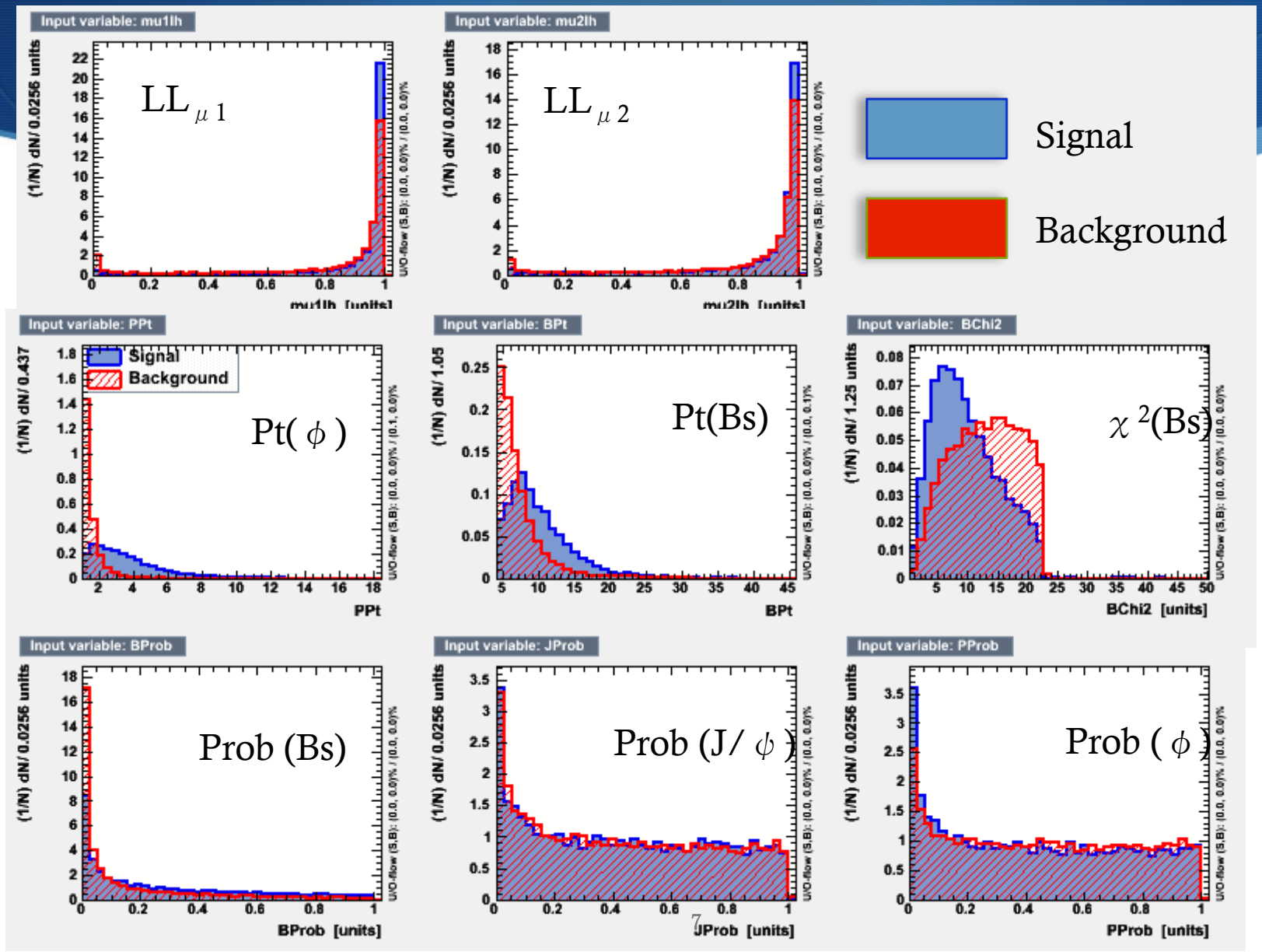
To train the NN,
Signal: 6685 events
BG: 6538events



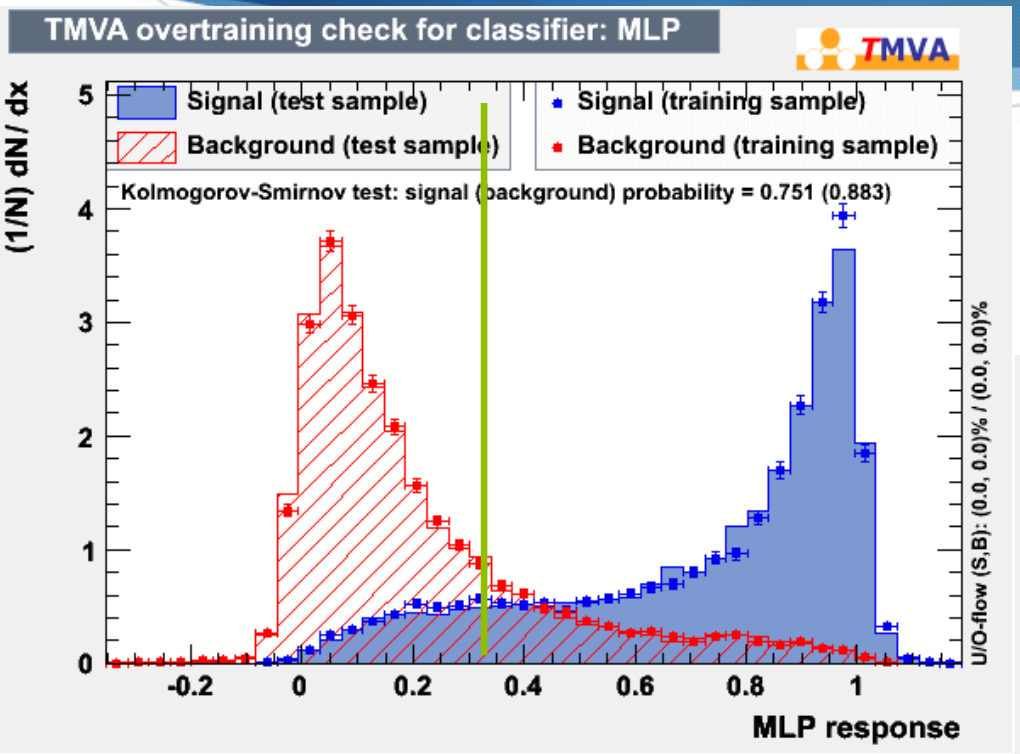
Fit function: gaussian + second order polynomial

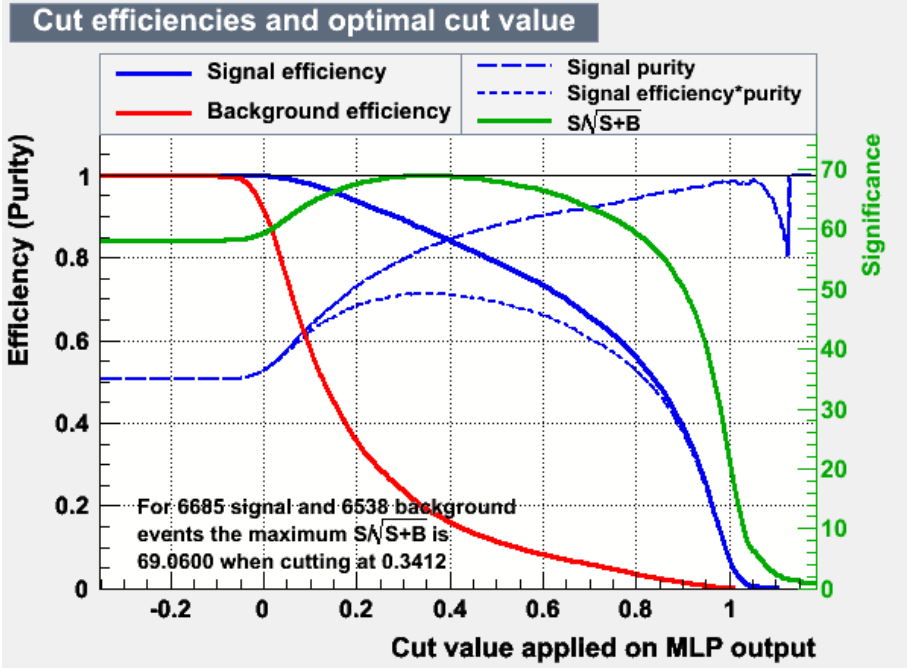
Mass(Bs): 5.366GeV/c^2

NN input variables



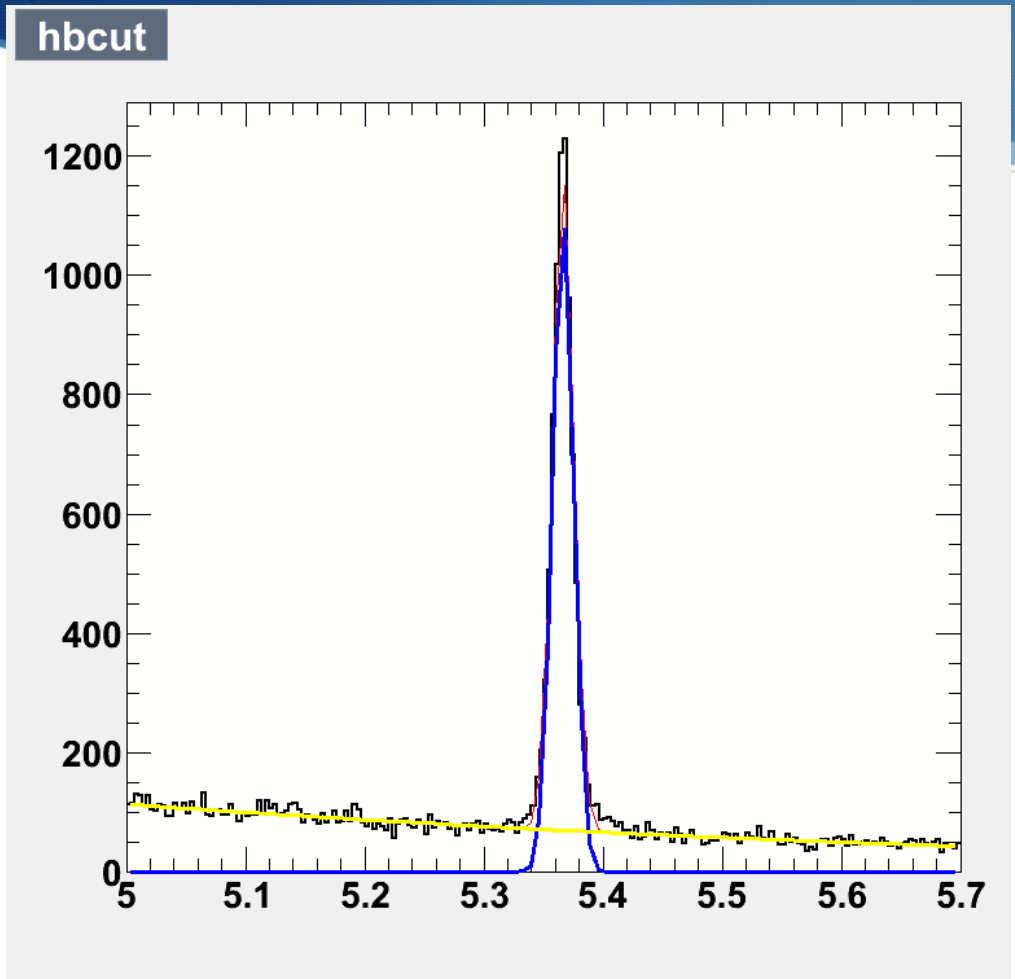
NN Output





Optimal cut : 0.3412

After NN optimal cut



Mass (Bs)

Expected (from NN):
Signal: 5822 events
BG: 1286events

Observed:
Signal: 6035±77 events
BG: 2278±51 events

Δ Signal(Obserbed-Expected)
= 212±123events (1.72 σ)

Δ BG(Obserbed-Expected)
= 962±51events

Bc → Bs π

- data sample: p0-p17 3.3fb^{-1} dimuon trigger (JPSI) (p18-p38 data cannot be available due to missing covariance block in xpmmsp dataset)
- MC: B generator
- use new Bstntuple (v90)

Prospect for Bc → Bs π

$$\frac{\sigma(p\bar{p} \to B_c X) BR(B_c \to J/\psi \iota\nu)}{\sigma(p\bar{p} \to B_u X) BR(B_u \to J/\psi \mathrm{K})} = 0.282 \pm 0.038(stat) \pm 0.074(syst)$$

$$BR(B_u \to J/\psi \mathrm{K}) = (1.01 \pm 0.04) \times 10^{-3}$$ (PDG)

From $BR(B_c \to J/\psi \iota\nu) = 0.019$ → $\frac{\sigma(p\bar{p} \to B_c X)}{\sigma(p\bar{p} \to B_u X)} = 0.0150 \pm 0.0045$

From $\frac{\sigma(p\bar{p} \to B_s X)}{\sigma(p\bar{p} \to B_u X)} = 0.28 \pm 0.04$ → $\frac{\sigma(p\bar{p} \to B_c X)}{\sigma(p\bar{p} \to B_s X)} = 0.053 \pm 0.018$

From $BR(B_c \to B_s \pi) = 0.164$ → $\frac{\sigma(p\bar{p} \to B_c X) BR(B_c \to B_s \pi)}{\sigma(p\bar{p} \to B_s X)} = 0.0088 \pm 0.0029$

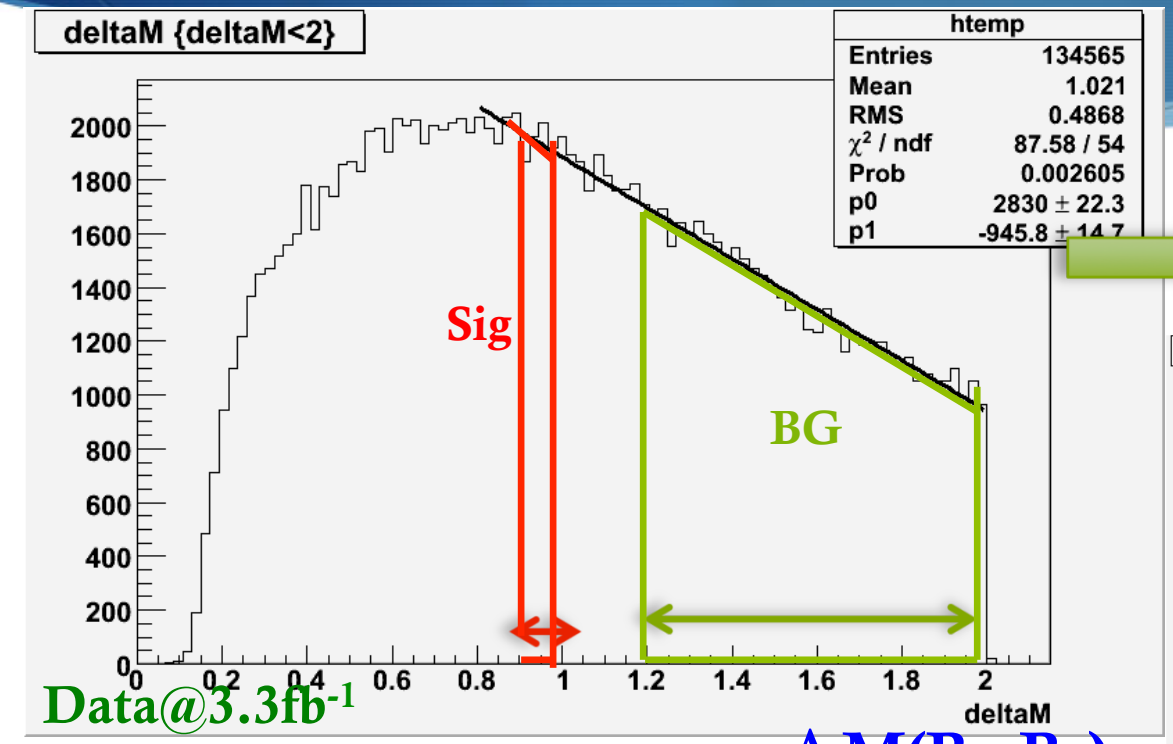
If we use CDF data of 10fb-1, there are 11000 J/Ψ φ events

If we use CDF data of 10fb-1, 97± 32 $B_c \to B_s \pi$ events are prospected!!!

Pre-Selection

- Track quality : >9 axial and >9 stereo COT hits and > 3 Si hits for all tracks
- $5.34 GeV/c^2 < M(Bs) < 5.39 GeV/c^2$
- $3.014 GeV/c^2 < M(J/\psi) < 3.174 GeV/c^2$
- $1.009 GeV/c^2 < M(\phi) < 1.028 GeV/c^2$
- $Pt(\phi) > 1.0 GeV/c$
- $Pt(K) > 0.4 GeV/c$
- $\chi^2(Bs) < 23$
- $LL_{\mu\mu} > 0$
- $Pt(Bs) > 4.0 GeV/c$
- $D0(\pi) < 0.12$
- $\chi 2(Bc) < 40$

After pre-selection before NN



Data@3.3fb^{-1}

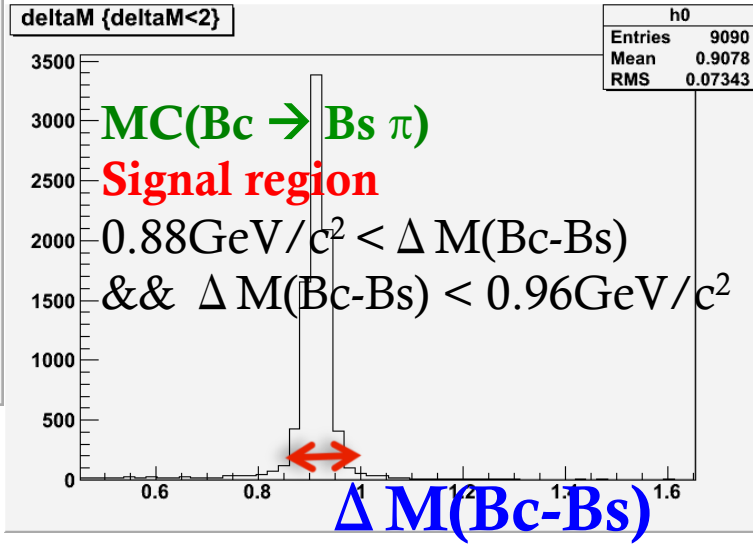
Side-band

1.2GeV/c^2 < ΔM(Bc-Bs) <2.0GeV/c^2

ΔM(Bc-Bs)

To train the NN,
Signal: 30 events
BG: 7092 events

BG=Sig∗BG/(Sig + BG)



ΔM(Bc-Bs)

Why ΔM not Mass(Bc)?
- Mass(Bc) depends on Mass(Bs)

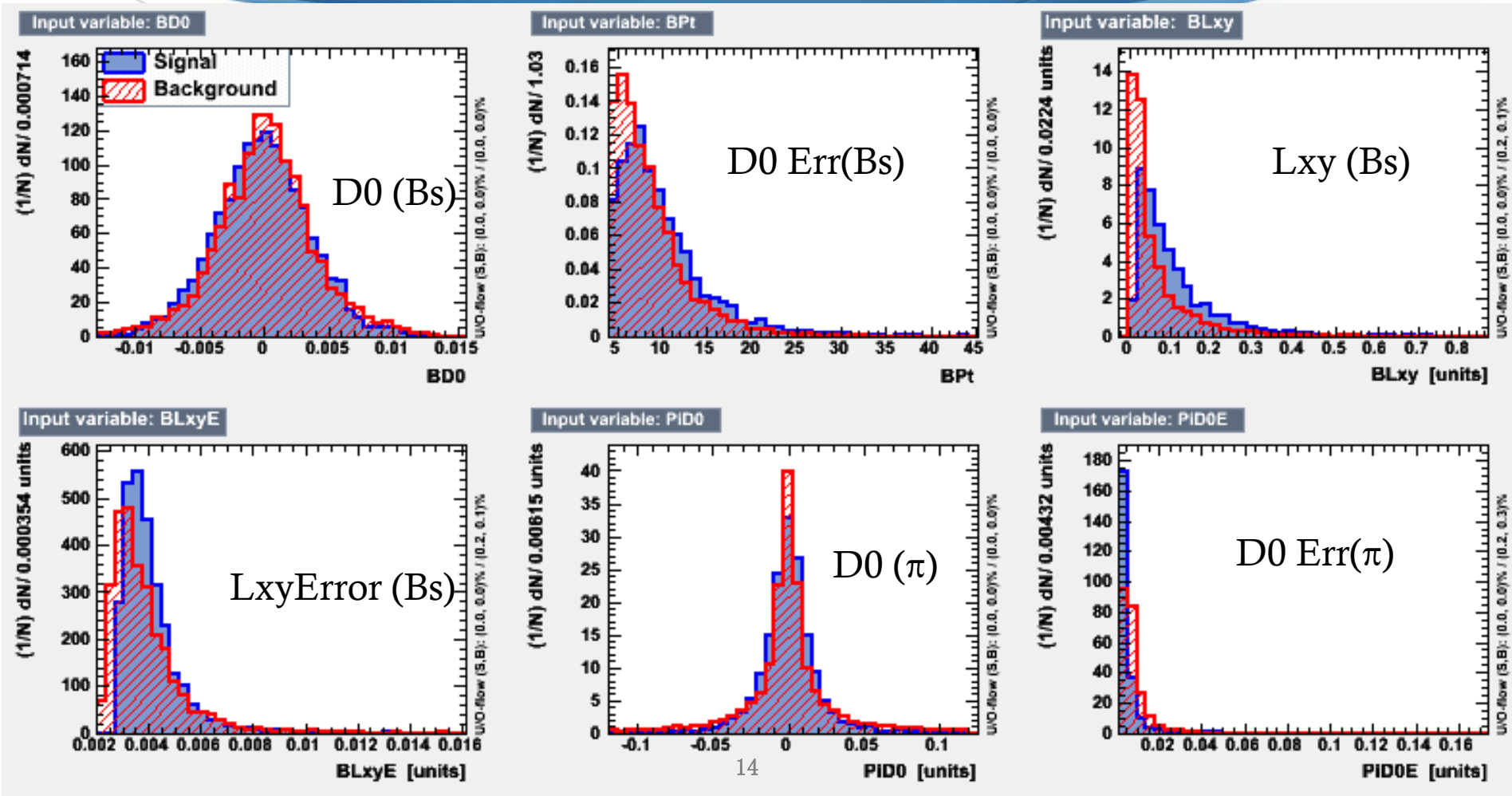
→ Use of ΔM gives much better mass resolution!!

Bc: 6.277GeV/c^2
Bs: 5.366GeV/c^2
Δ = 0.911GeV/c^2

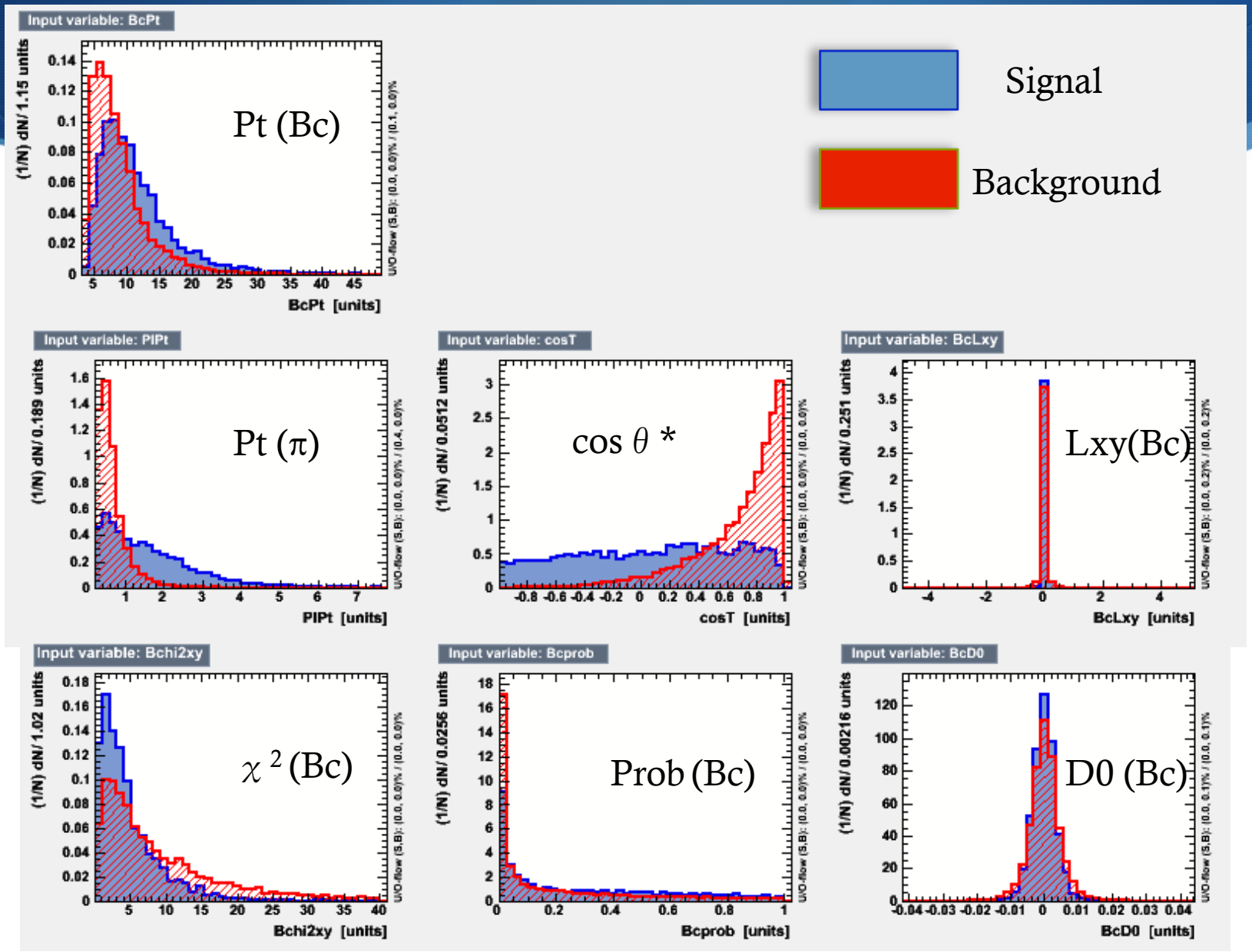
NN Input 1

Signal

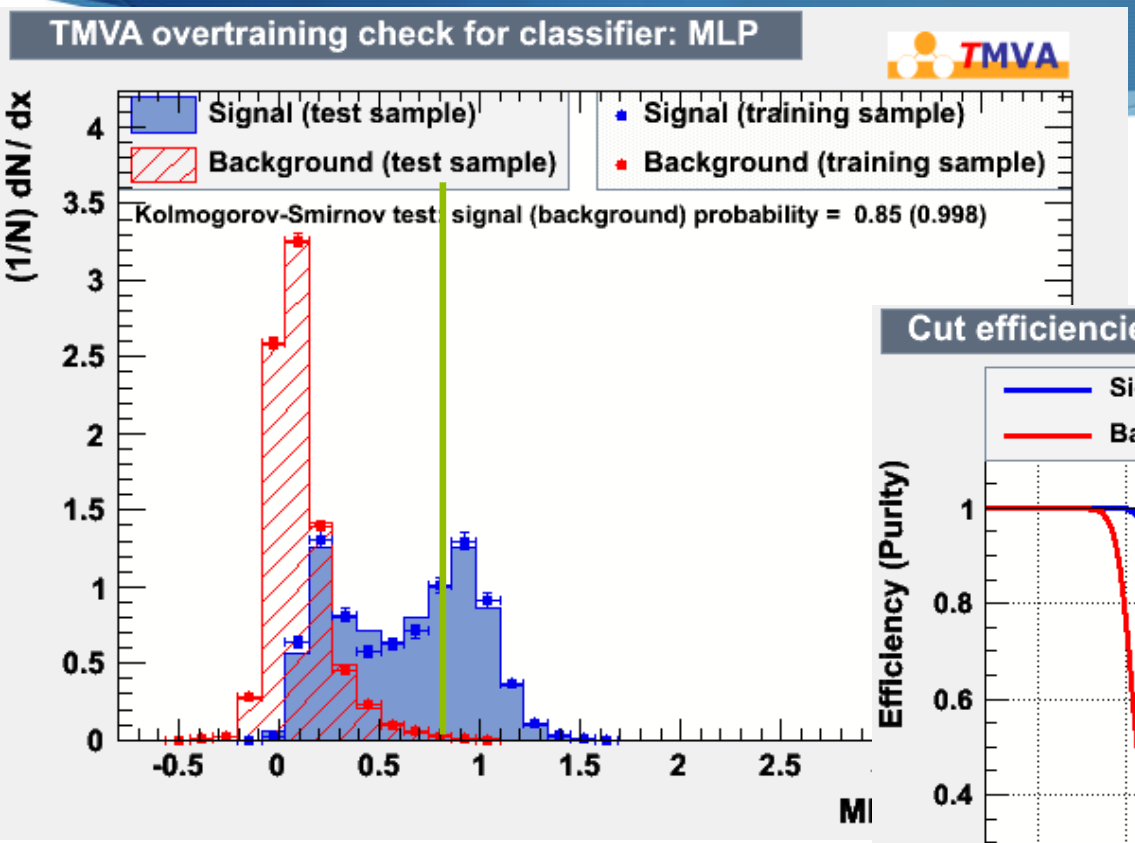
Background

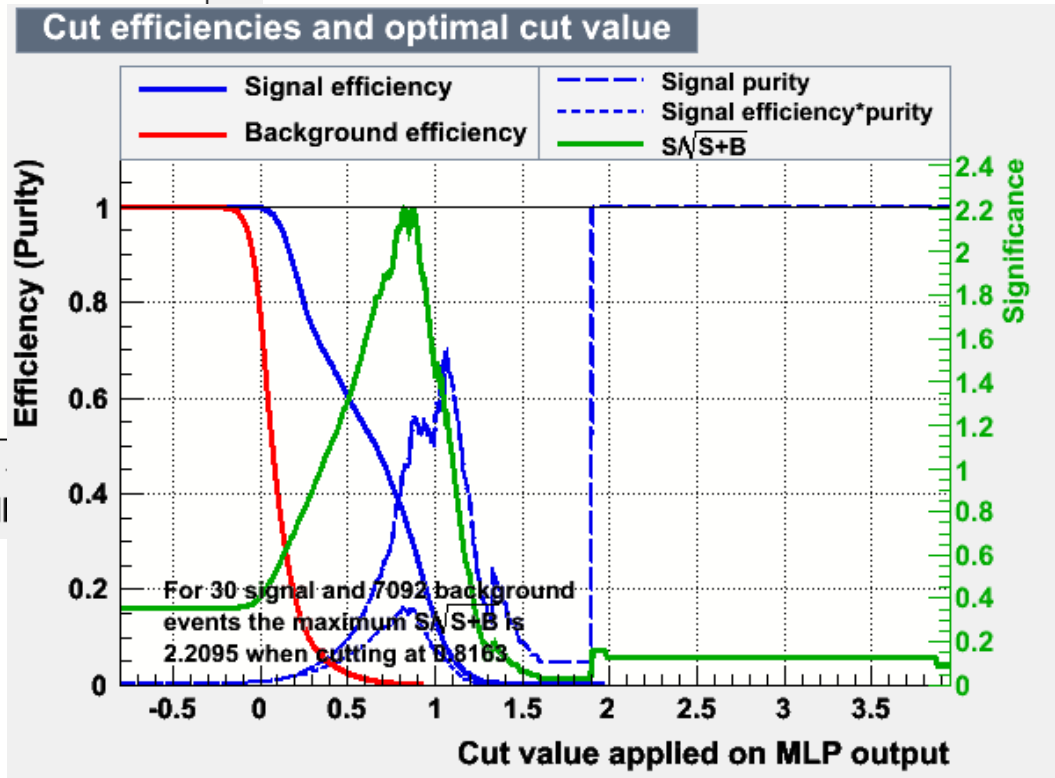


NN Input2


Input variable: BcPt
Pt (Bc)
BcPt [units]
Signal
Background
Input variable: PIPt
Pt (π)
PIPt [units]
Input variable: cosT
cos θ *
cosT [units]
Input variable: BcLxy
Lxy(Bc)
BcLxy [units]
Input variable: Bchi2xy
χ 2 (Bc)
Bchi2xy [units]
Input variable: Bcprob
Prob (Bc)
Bcprob [units]
Input variable: BcD0
D0 (Bc)
BcD0 [units]

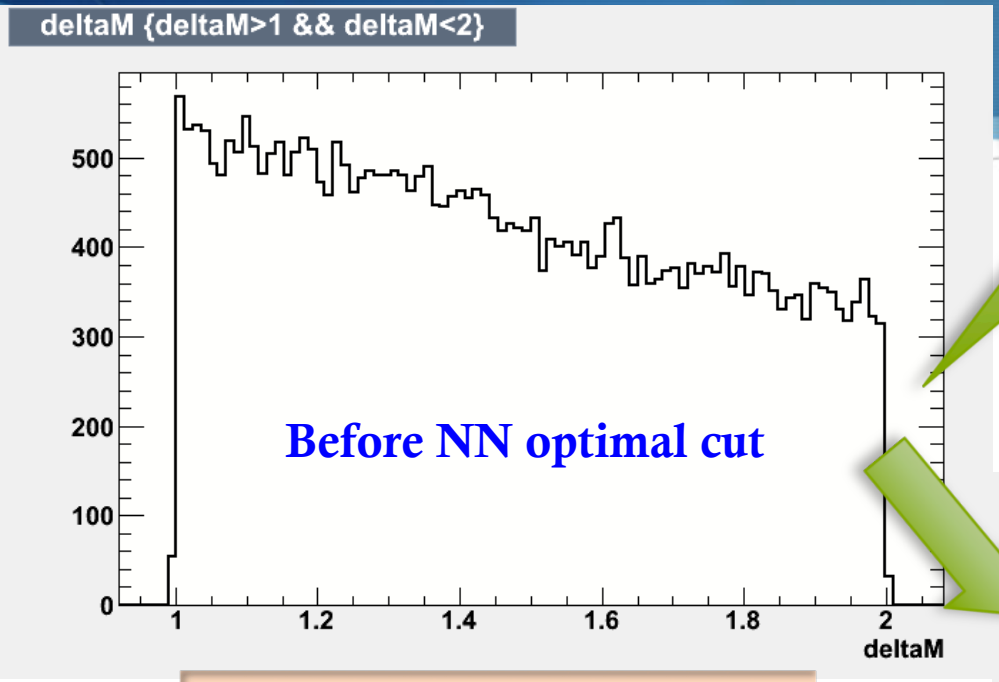
NN Output





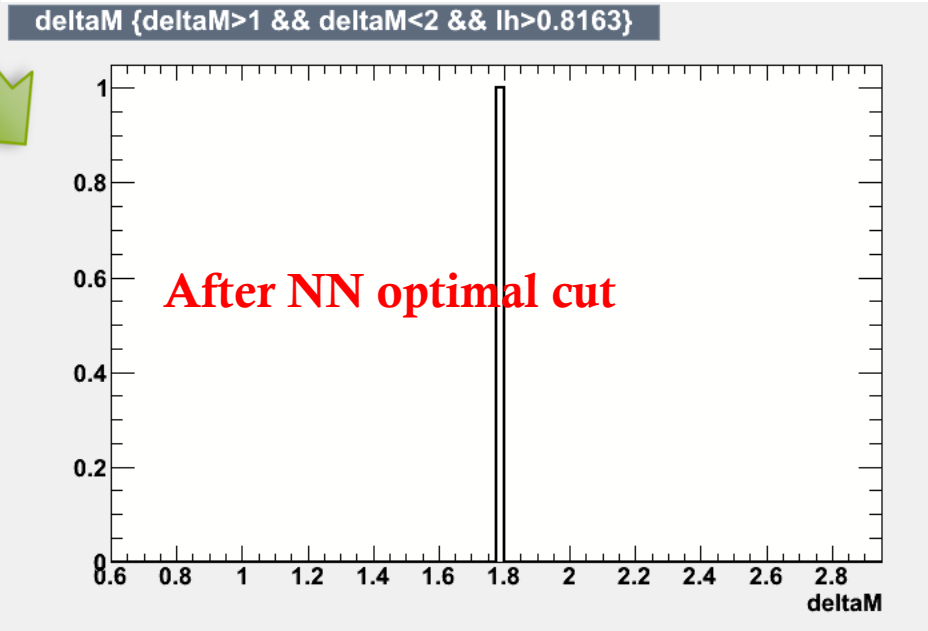
Optimal cut : 0.8163

After NN optimal cut



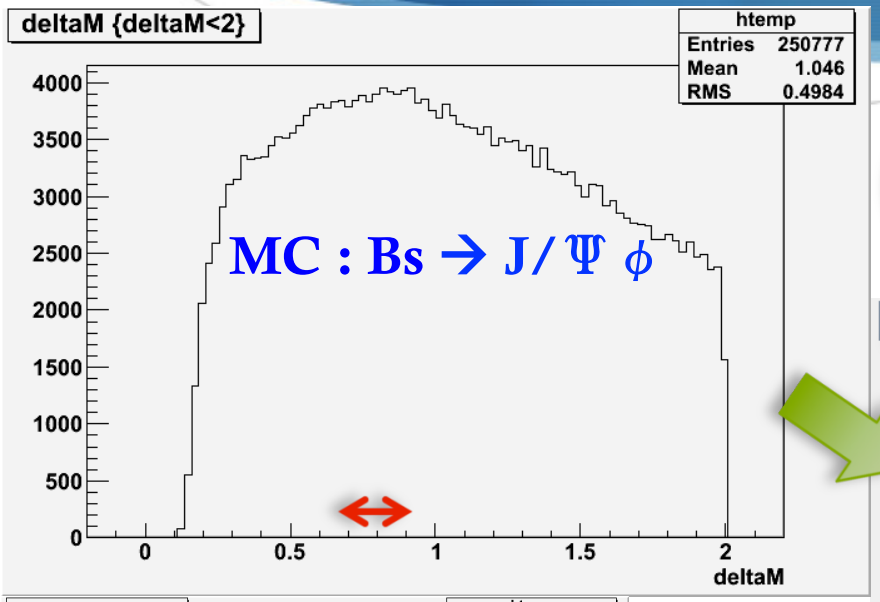
NN cut
lh>0.8163

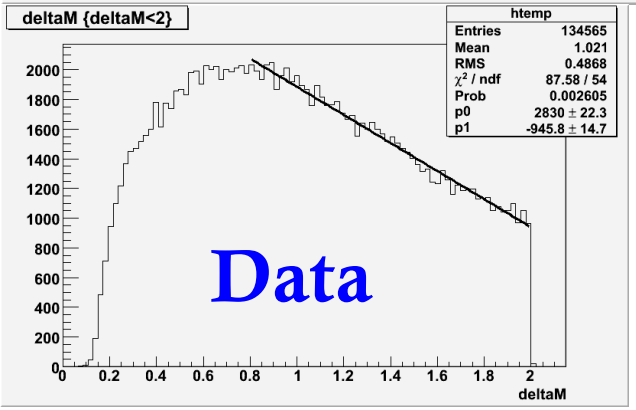
We could reduce BG!!



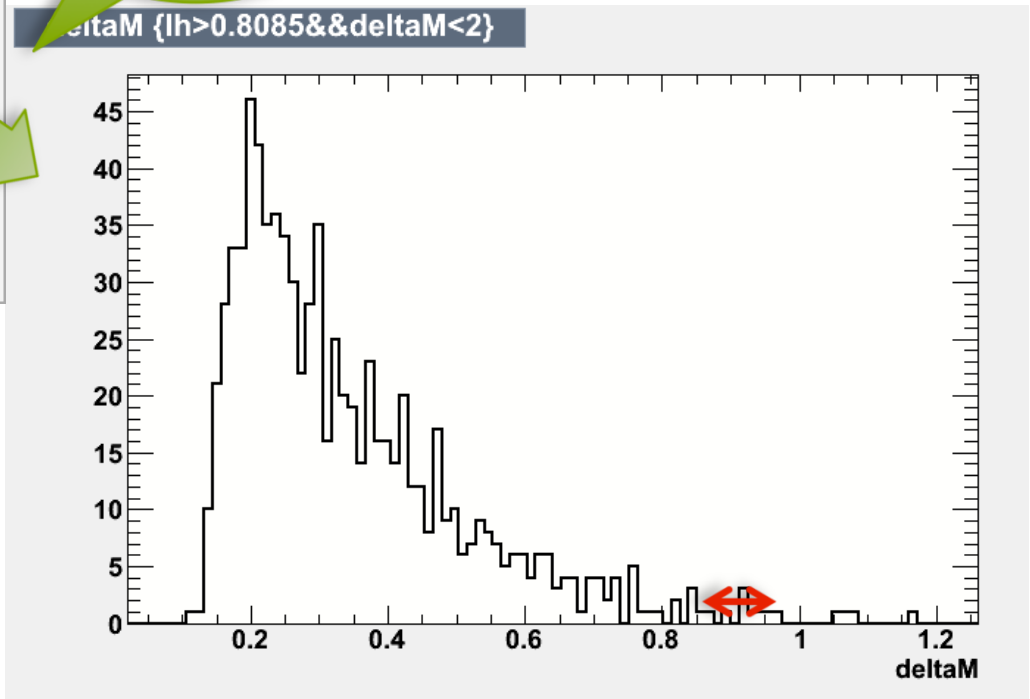
Expected:
Signal: 10.8 events
BG: 13.3 events

Main BG : prompt Bs → J/Ψ ϕ





NN cut
lh>0.8163



Summary

- I estimated the number of the signal and the BG of Bc → Bs π using NN (TMVA) @3.3fb^{-1}.

  Signal : 10.8events
  BG : 13.3 events

- Using NN can reduce the BG of prompt Bs→ J/Ψ ϕ

Back up

$$\frac{\sigma(p\bar{p} \to B_c X)\mathrm{BR}(B_c \to J/\psi \ell \nu)}{\sigma(p\bar{p} \to B_u X)\mathrm{BR}(B_u \to J/\psi K)} = 0.282 \pm 0.038(\mathrm{stat}) \pm 0.074(\mathrm{syst})$$

$\mathrm{BR}(B_u \to J/\psi K) = (1.01 \pm 0.04)\ \mathrm{x}\ 10^{-3}$　　ＰＤＧ

理論予言値　$\mathrm{BR}(B_c \to J/\psi \ell \nu) = 0.019$ を用いると、

$$\frac{\sigma(p\bar{p} \to B_c X)}{\sigma(p\bar{p} \to B_u X)} = 0.0150 \pm 0.0045$$　（理論予言値 $\approx 2\ \mathrm{x}\ 10^{-3}$）

さらに $\frac{\sigma(p\bar{p} \to B_s X)}{\sigma(p\bar{p} \to B_u X)} = 0.32 \pm 0.1$（ＣＤＦ８１４０）　を用いると

0.28±0.04 (PDG2011)

$$\frac{\sigma(p\bar{p} \to B_c X)}{\sigma(p\bar{p} \to B_s X)} = 0.0$$ .021

0.053±0.018

理論予言値　$\mathrm{BR}(B_c \to B_s \pi) = 0.164$ を用いると、

$$\frac{\sigma(p\bar{p} \to B_c X)\,\mathrm{BR}(B_c \to B_s \pi)}{\sigma(p\bar{p} \to B_s X)} = 0.0$$ .0034

0.0088±0.0029

現在 10 fb^{-1}のデータ解析で~11000個の $B_s \to J/\psi\phi$ 事象観測

(CDF8950　arXiv 0712.2348)

10 fb^{-1}で 97±32 個の $B_c \to B_s \pi\ (B_s \to J/\psi\phi)$ 事象の検出が期待される。

- > data sample: p0-p17 3.3fb-1 dimuon trigger (JPSI)
  > use new Bstntuple (v90)
  > p18-p38 data cannot be available due to missing covariance block in xpmmsp dataset
  > (also I see some other files are broken)
  >
  > Disclaimer:
  > I am a winter student from University of Tsukuba.
  > This is my first physics analysis and the purpose is
  > to roughly estimate the number of the signal and the background.
  > Indeed I have only 10 days for this study.
  > So I omit many details:
  > - no trigger confirmation
  > - no MC distribution correction