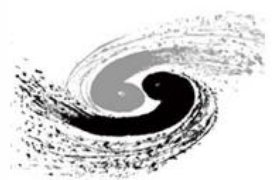


$B_c \rightarrow J/\psi \mu \mu$ analysis

Xianyou Wang, Guoming Chen, Xiangwei Meng,
Junquan Tao, Jianguo Bian, Zheng Wang, Jian Wang

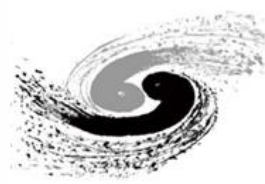
Institute of High Energy Physics, CAS, Beijing
Institute of theoretical physics, CQU, CQ

Outline



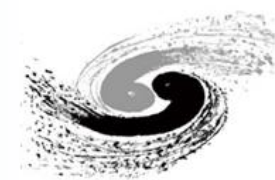
- Motivation
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 - Experimental status
 - Event generation
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- Event selection
 - Event selection strategy
 - Generate and Reconstruction
 - The Cuts:
 - Bc candidate mass window
 - Jpsi candidate mass window
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 - The third muon pt
 - High level trigger
 - Jpsi nominalized χ^2
 - Bc candidate Pt
 - Bc nominalized χ^2
- The results
 - The efficiency of the cuts
 - Invariant mass of Bc candidate

Motivation



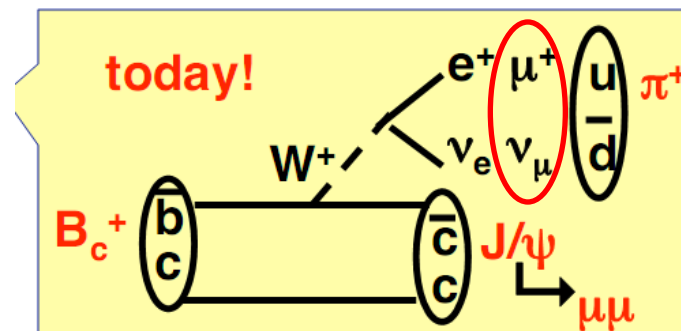
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Theoretical status

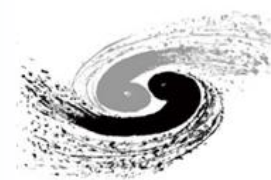


- Goal: measure mass and lifetime of Bc-meson with CMS
- Theory-predictions:
- Bc production in hadron collider: many theoretical uncertainties!
- $\sigma(\text{Bc}) \sim 10^{-3} \sigma(\text{other B-mesons})$ [E.g:Chang&Wu,EPJC38,267]
- Bc mass: $M=6.24 \pm 0.05 \text{ GeV}$ See e.g: [Kwong,Rosner, PRD44, 212]
[Eichten, Quigg, PRD49, 5845]
- Bc decay (only weak!):
- b-decay with c as spectator: 20-25%
- c-decay with b as spectator: 64-72%
- annihilation decays: 6.6-7.2%

ground state of bc
unique properties!!



Experimental status



Collab.	$\mathcal{L}_{\text{int}}$ [pb $^{-1}$]	Mode	Signal event	Mass [MeV/ c^2]	Lifetime [ps]
CDF[24][25]	110	$J/\psi \ell^+ \nu$	$20.4^{+6.2}_{-5.5}$	$6400 \pm 390 \pm 130$	$0.46^{+0.18}_{-0.16} \pm 0.03$
D0[26] [†]	210	$J/\psi \mu^+ X$	$95 \pm 12 \pm 11$	$5950^{+140}_{-130} \pm 340$	$0.45^{+0.12}_{-0.10} \pm 0.12$
CDF[27]	360	$J/\psi \pi^+$	14.6 ± 4.6	$6285.7 \pm 5.3 \pm 1.2$	—
CDF[30]	360	$J/\psi e^+ \nu_e$	238	—	$0.463^{+0.073}_{-0.065} \pm 0.036$
CDF[28] [‡]	2400	$J/\psi \pi^+$	108 ± 15	$6275.6 \pm 2.9 \pm 2.5$	—
D0[29] [†]	1300	$J/\psi \pi^+$	54 ± 12	$6300 \pm 14 \pm 5$	—
D0[31] [†]	1300	$J/\psi \mu^+ X$	881 ± 80	—	$0.448^{+0.038}_{-0.036} \pm 0.032$

[†]: D0 preliminary

[‡]: CDF preliminary

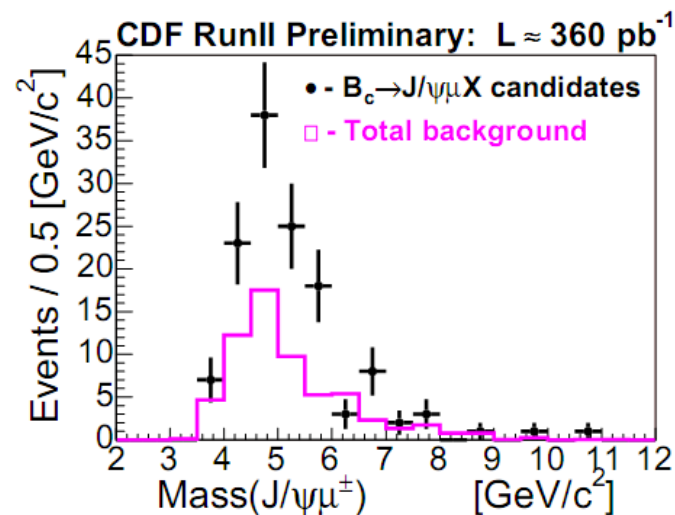
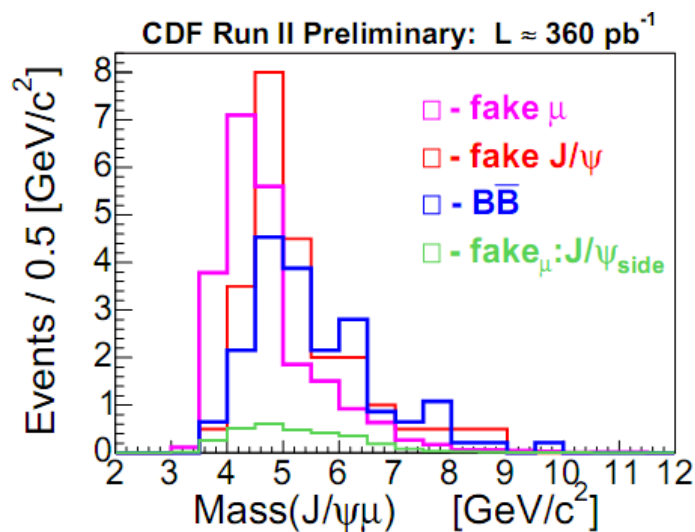
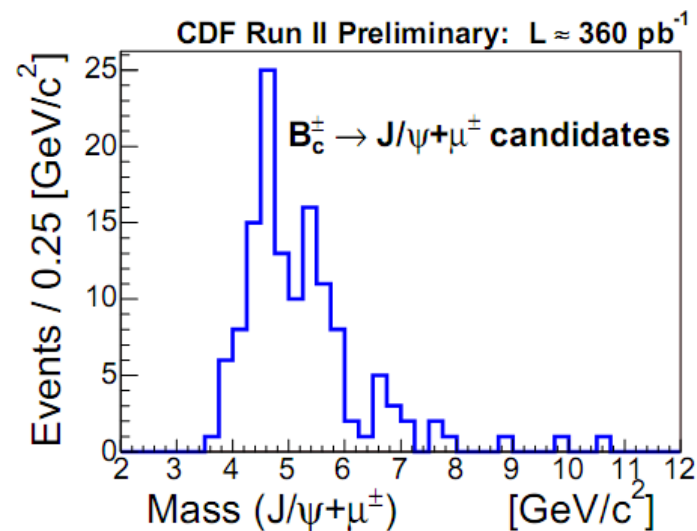
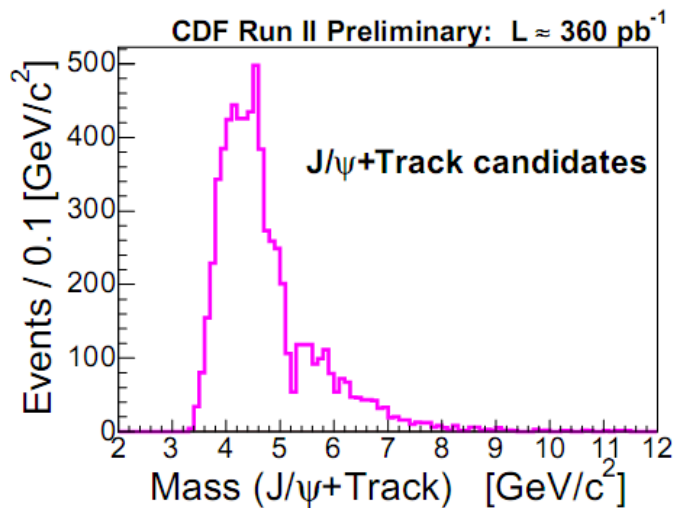
LHC: p-p collisions at ECM = 14.0 TeV,

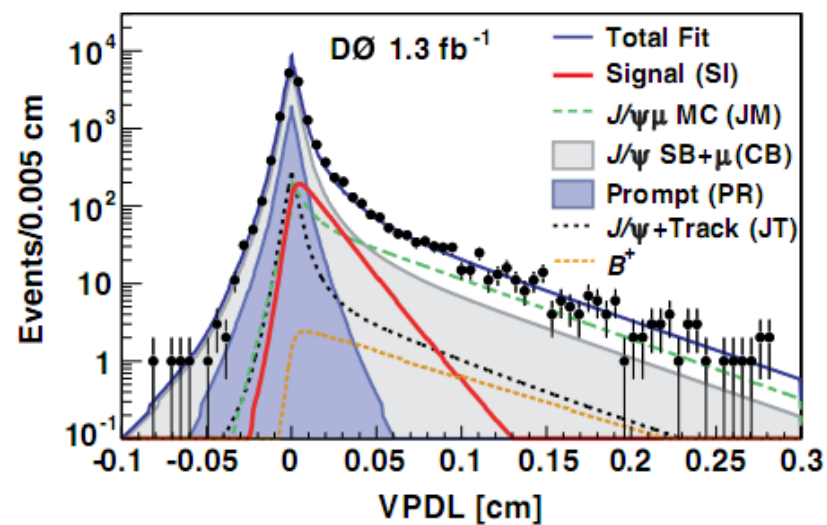
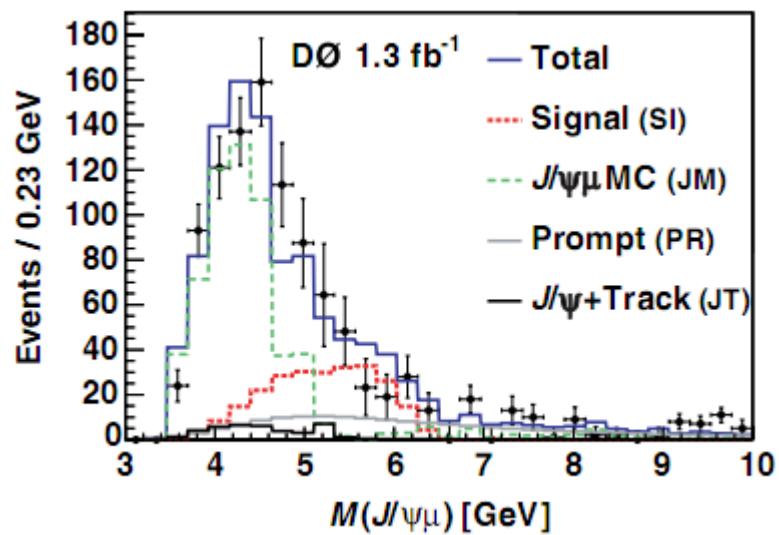
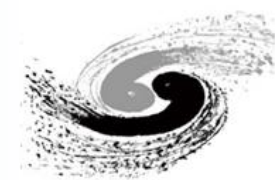
Initial L $\sim 2 \times 10^{32}$ cm $^{-2}$ s $^{-1}$, nominal L $\sim 1 \times 10^{34}$ cm $^{-2}$ s $^{-1}$

CMS: Competition with ALICE, LHCb, (ATLAS)...

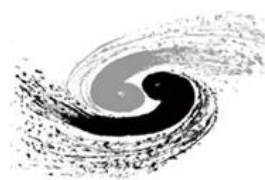
but...CMS has excellent muon system, tracker, large acceptance!

Most analyses here based on medium and high PT muons





Event generation



- Signal: $B_c \rightarrow J/\psi \mu$, $J/\psi \rightarrow \mu\mu$ generated with BCVEGPY 2.1 generator

[Chang&Wu, EPJC38:267,2004]

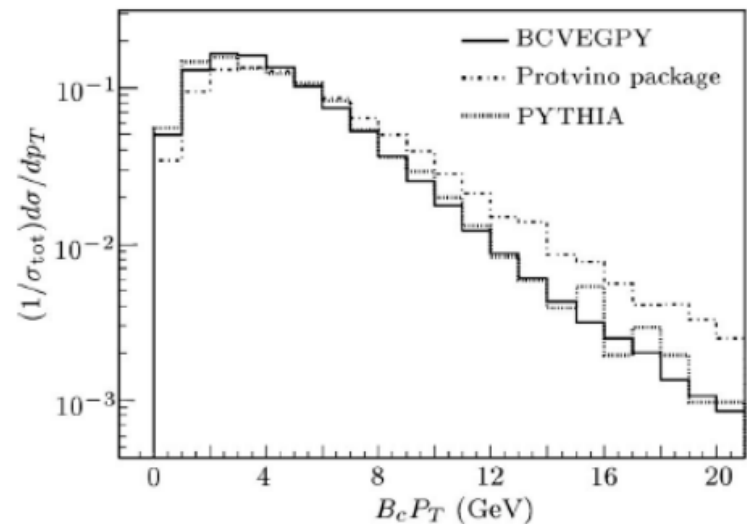
GeneratorInterface/GenExtension(BCVEGPY 2.1) in CMSSW_3_1_x

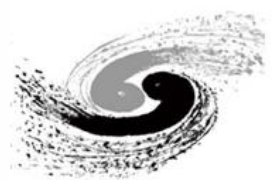
<https://twiki.cern.ch/twiki/bin/view/CMS/BcGenerator>

<http://indico.cern.ch/getFile.py/access?contribId=8&resId=0&materialId=slides&confId=52322>

I generate and analyze the signal
in CMSSW_2_2_3

- Generator cuts (simulate L1 and HLT trigger):
 - μ pair (from J/ψ) $p_T \geq 2.5 \text{ GeV}$ $|\eta| \leq 2.5$
 $\text{InvMass}(3.096 \text{ GeV}, 3.098 \text{ GeV})$
 - Third μ (μ from B_c) $p_T \geq 2.5 \text{ GeV}$ $|\eta| \leq 2.5$



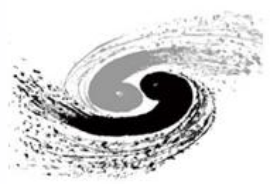


Related parameters

- $\text{Br}(b \rightarrow Bc) = 1.3 \cdot 10^{-3}$ [from HERWIG. Phys. Lett. B 266, 142 (1991).]
[E.g:Chang&Wu,EPJC38,267]
- $\text{Br}(\text{QCD} \rightarrow b\bar{b}) = 1.16\%$
- Bc cross section $51.56 \text{ mb} \cdot 0.0116 \cdot 0.001 \cdot 2 = 0.00119619 \text{ mb} \approx 1000 \text{ nb}$
- $\text{Br}(Bc \rightarrow J\psi \mu \mu) = 1.9 \%$
- $\text{Br}(J \rightarrow \mu \mu) = 6 \%$ $= 5.93 \pm 0.06 \%$
- so three muon Branch $= 5.93 \% \cdot 2 \% \approx 0.0012$
- $1000 \text{ nb} \cdot 0.0012 = 1.2 \text{ nb} = 1.2 \cdot 10^6 \text{ fb}$
- After filter.
- Signal cross section $1000 \text{ nb} \cdot 0.0012 \cdot 0.057 = 0.0684 \text{ nb} = 68400 \text{ fb}$
- So I asked for generate 2 fb^{-1} data in official

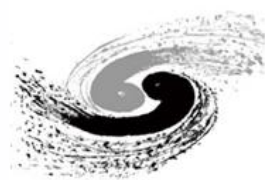
Filter efficiency

Event selection

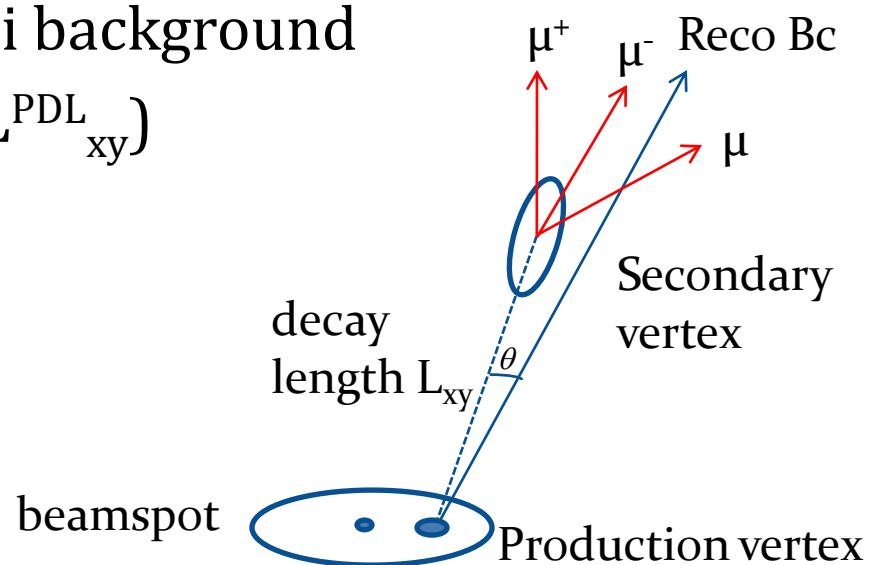


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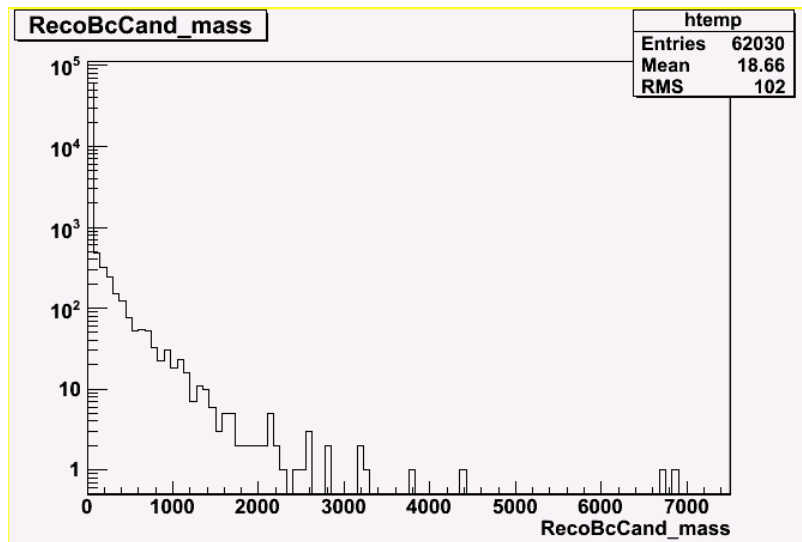
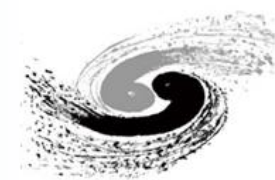
Event selection



- Step 0: trigger(Level 1 and High level trigger)
- Step 1: J/psi candidates:
2 muons, same vertex, different charge, M_{inv} (3.0,3.2) GeV
- Step 2: Bc candidates:
Find the third muon and fit vertex with J/psi candidates, M_{inv} (3.0,7.0) GeV
- Step 3: Suppress prompt J/psi background
Cut on proper decay length (L_{xy}^{PDL})
and significance ($L_{xy}^{PDL} / \sigma_{xy}$)



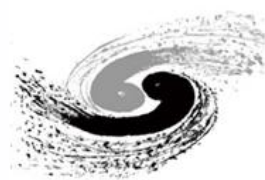
Generate and Reconstruction



- Generator cuts (simulate L1 and HLT trigger):
- Dimuon (from JPsi) $p_T \geq 2.5 \text{ GeV}$ $|\eta| \leq 2.5$
InvMass(3.096GeV, 3.098GeV)
- Third μ (μ from Bc) $p_T \geq 2.5 \text{ GeV}$ $|\eta| \leq 2.5$

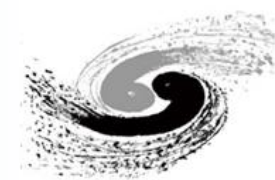
	Signal		B $\rightarrow$ J/ ψ $\mu\mu$ background	
	Events	Efficiency	Events	Efficiency
Generation	2.4*10 ⁶	-		
Gen-Sim-Reco	136610	0.057	2434076	
Dimuon select and vertex fit The three muon vertex fit	62030	0.454	47578	0.020

The Cuts



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Select Criteria



- Jpsi selection

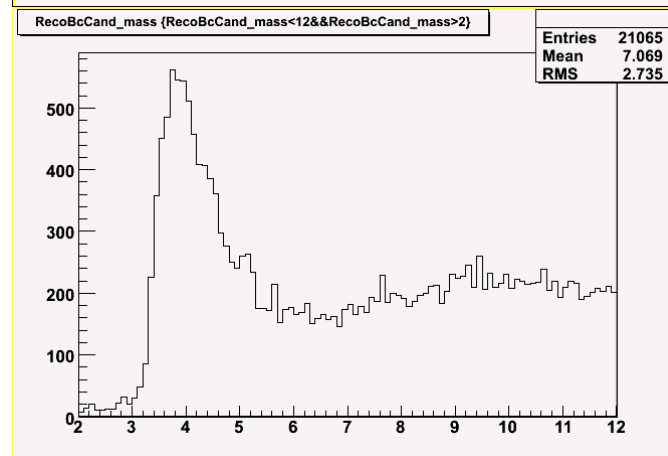
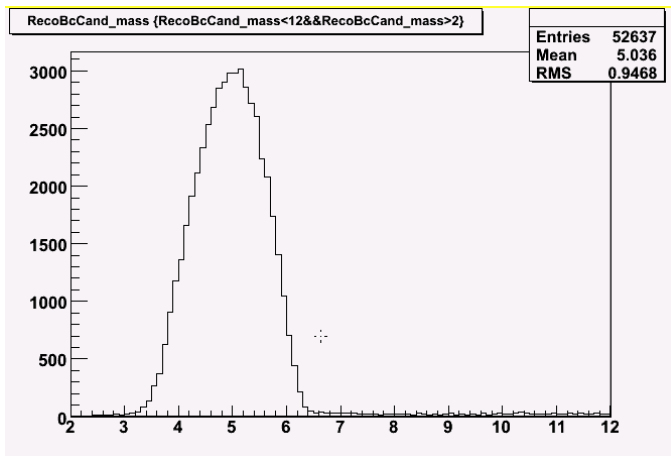
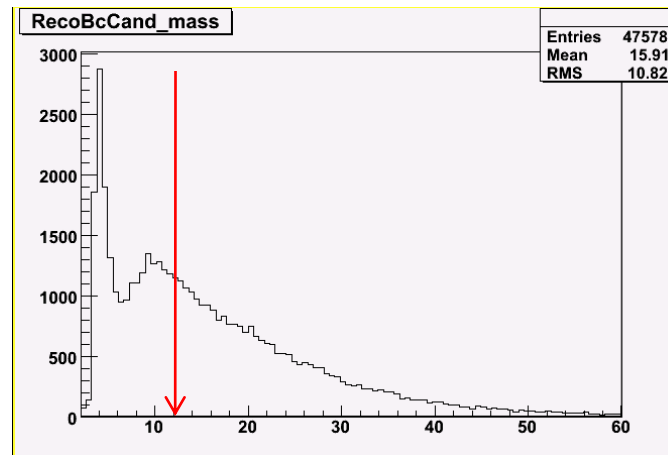
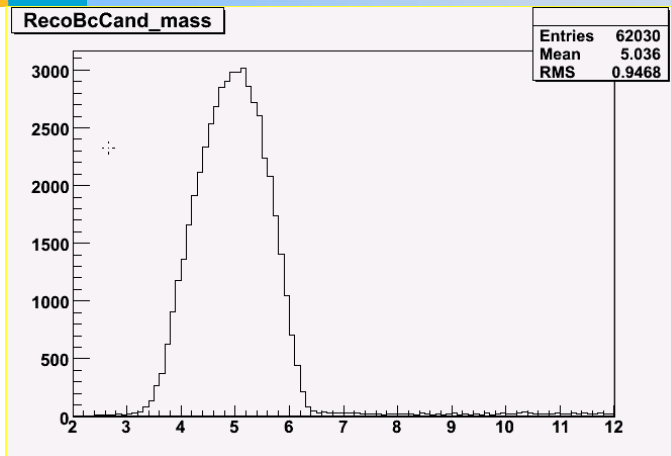
track	$p_T > 1.5 \text{ GeV/c}$ 3 or more Si $r - \phi$ hits 2 or more axial COT SL 2 or more stereo COT SL
CMU muon	$\chi^2 < 9$
CMX muon	$\chi^2 < 9$
opposite charge	$q_1 \cdot q_2 = -1$

- Third muon selection

track quality	Si hits: ≥ 3 , COT Ax/St hits: ≥ 25
J/ψ	within $\pm 50 \text{ MeV/c}^2$ around peak
third track	$p_T > 3.0 \text{ GeV/c}$ no track within 40 cm at CMU surface fiducial to CMUP
J/ψ + track vertex	J/ψ mass constrained $\text{prob}(\chi^2) > 1\%$ lifetime $c\tau > 60\mu$
kinematic	$\Delta\phi < \pi/2$
third muon	above quality requirements must be CMUP muon $\text{CMU } \chi_x^2 < 9$
remove $B^+ \rightarrow J/\psi K^+$	$ M(J/\psi + K) - M(B^+) > 50 \text{ MeV/c}^2$

- My cut
- [Bc candidate mass window\(2,12\)](#)
- [Jpsi candidate mass window\(3.047,3.147\)](#)
- [Dimuon muon pt\(>2.5Gev/c\)](#)
- [The third muon pt\(>3.0Gev/c\)](#)
- [High level trigger\(HLT MU3\)](#)
- [Jpsi nomalized \$\chi^2\(<8\)\$](#)
- [Bc candidate Pt\(>3.0Gev/c\)](#)
- [Bc nomalized \$\chi^2 \(<8\)\$](#)

Bc candidate mass window



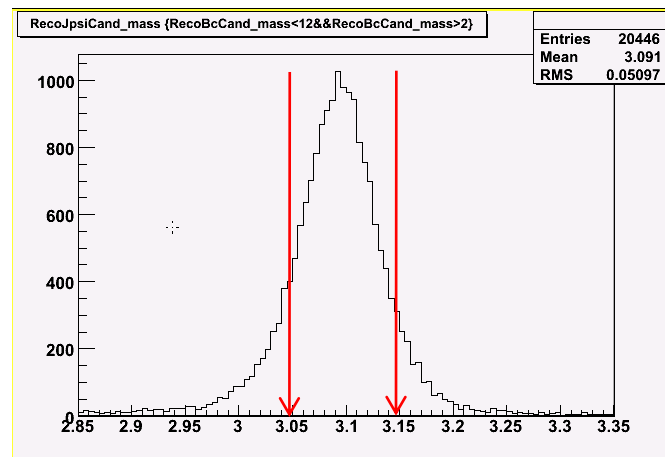
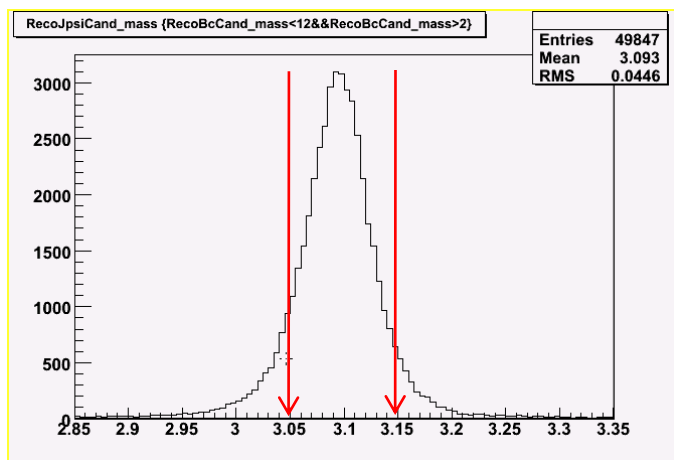
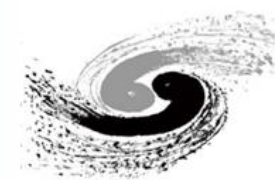
- Select condition:
- 1) Inverse charge dimuon, the best one.
- 2) kalman vertex fit



- Select Criteria :
- 3) Bc mass window(2,12)



Jpsi candidate mass window



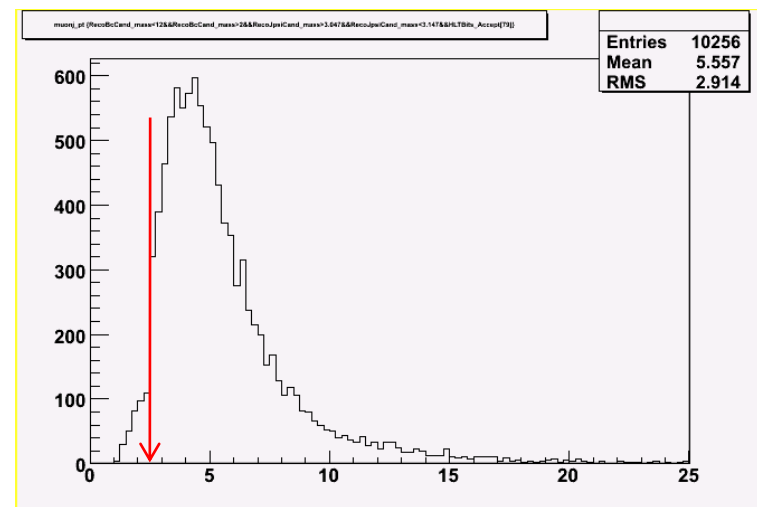
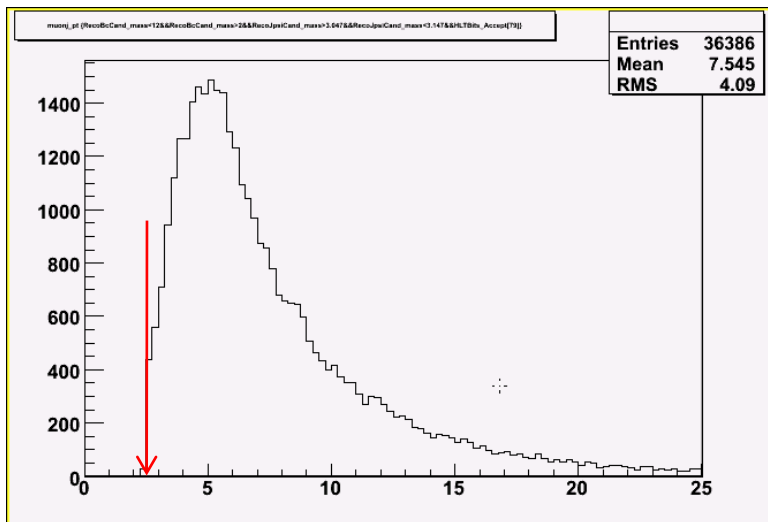
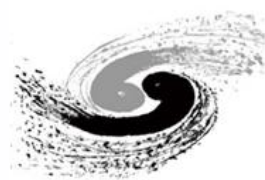
- This is the reference to CDF



- Select Criteria :
- 3)Jpsi mass window(3.047,3.147)



Dimuon pt



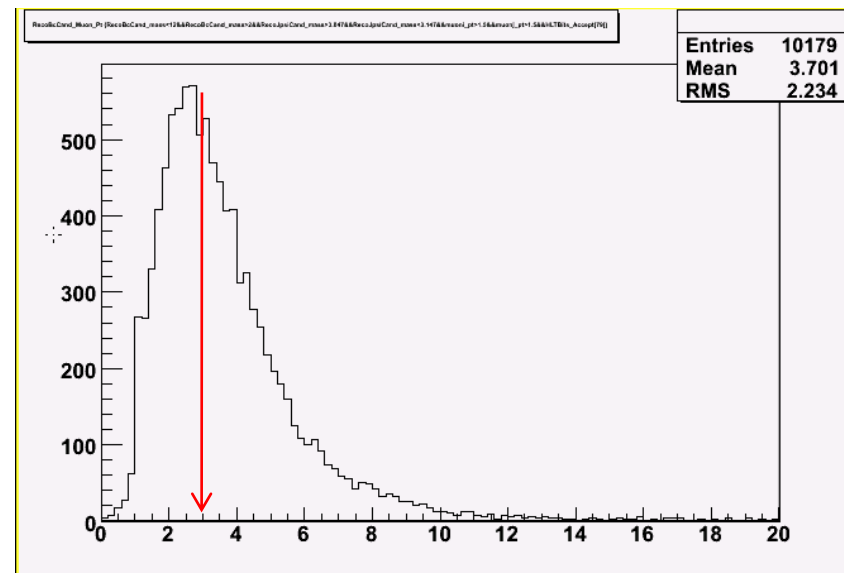
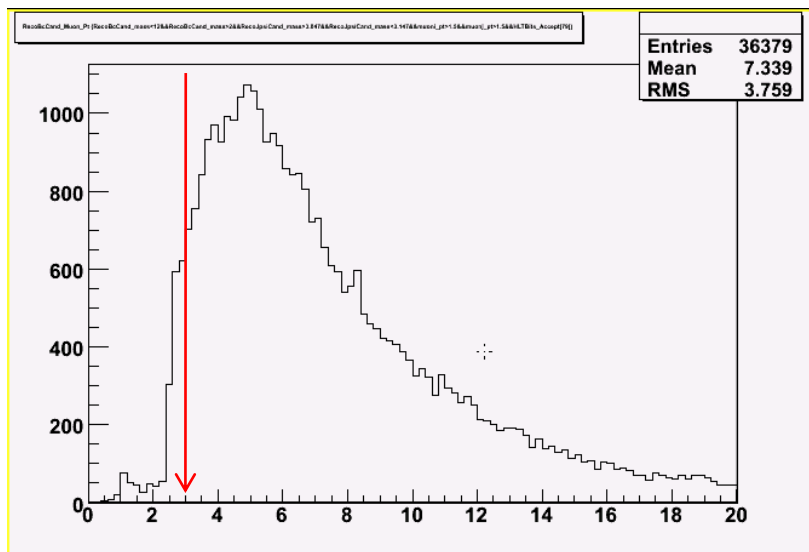
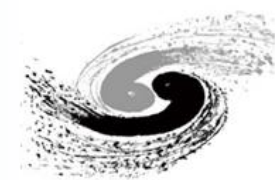
- Select condition:
- 1) Inverse charge dimuon, the best one.
- 2) kalman vertex fit
- 3) Bc mass window(2,12)



- Select Criteria :
- 4) Dimuon pt > 2.5 GeV



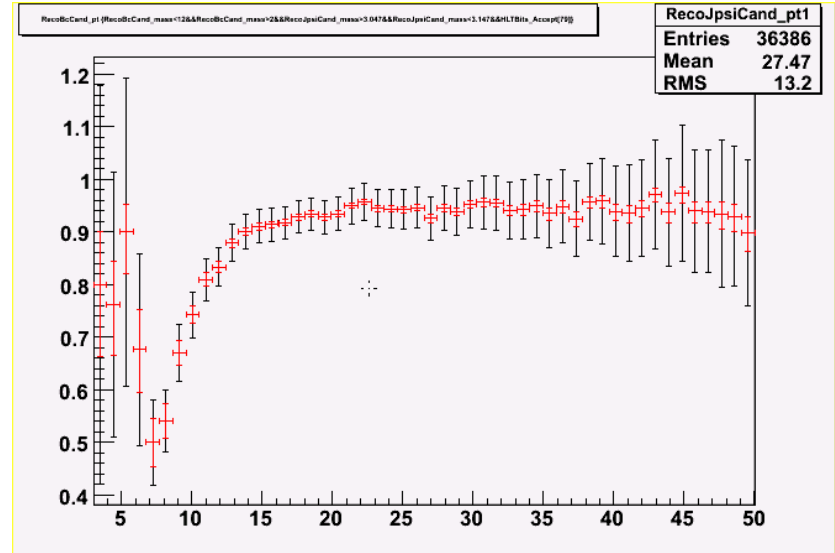
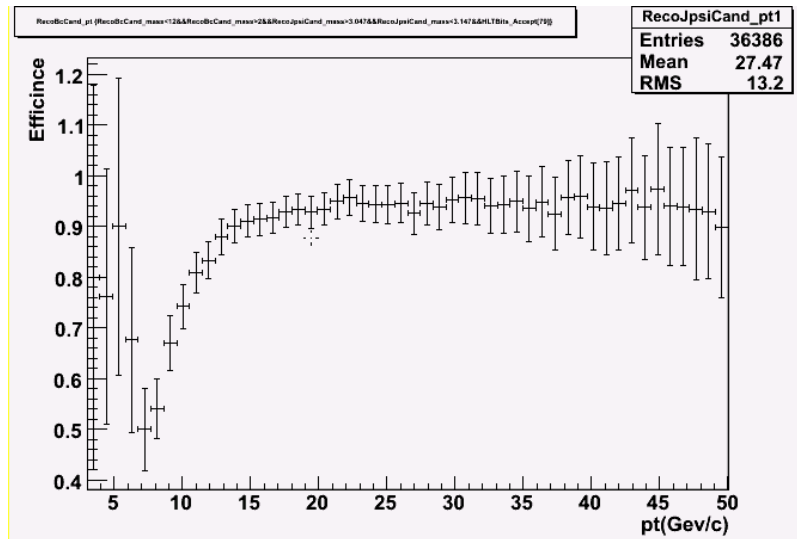
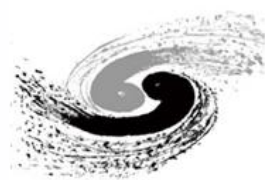
The third muon pt



- Select Criteria :
- 5) The third muon $pt > 3 \text{ GeV}/c$



High level trigger



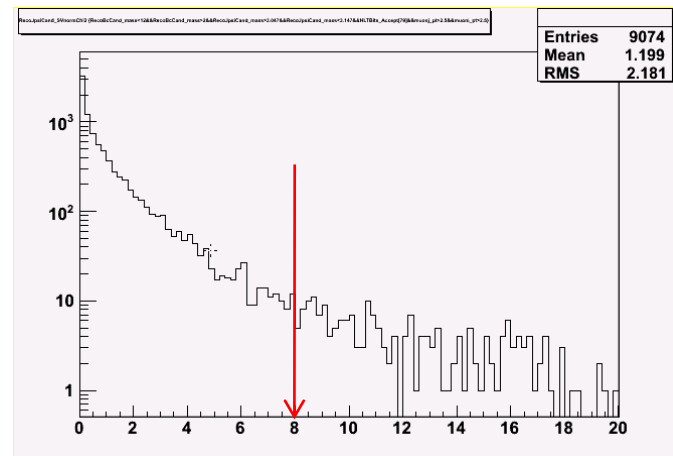
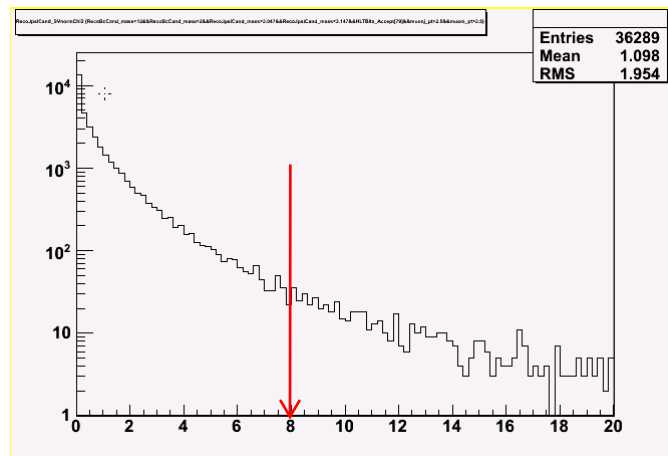
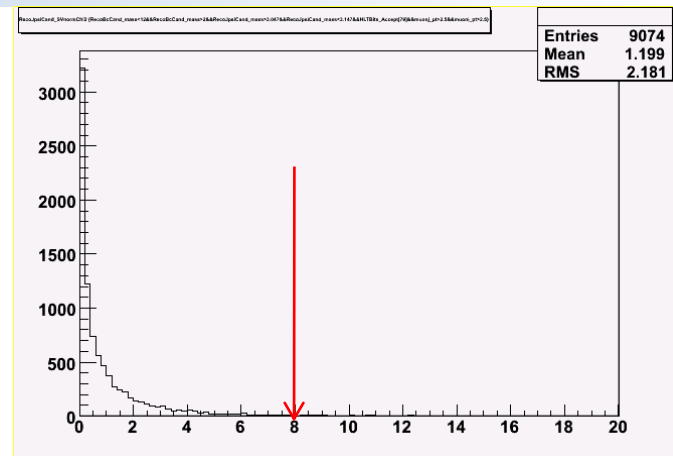
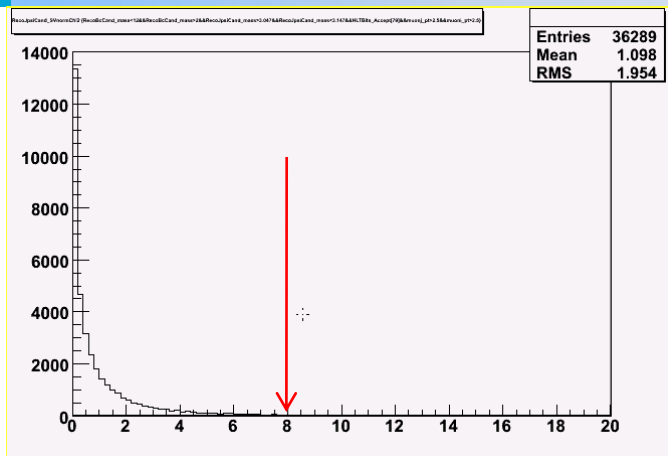
Bc High level trigger efficiency



- Select Criteria :
- 6) High level trigger HLT_Mu3



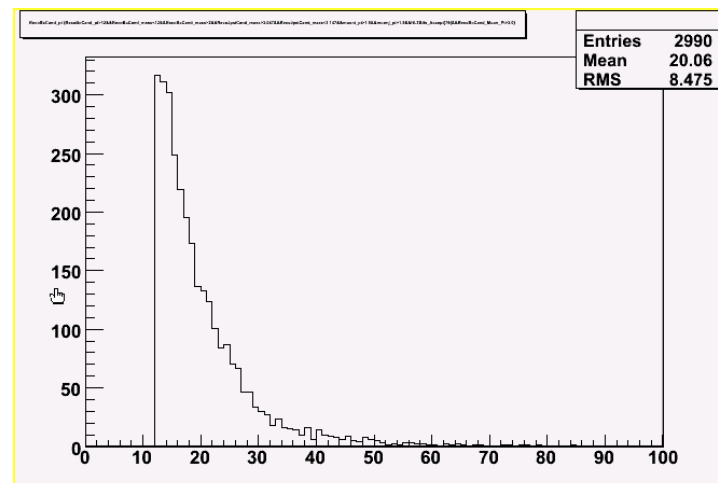
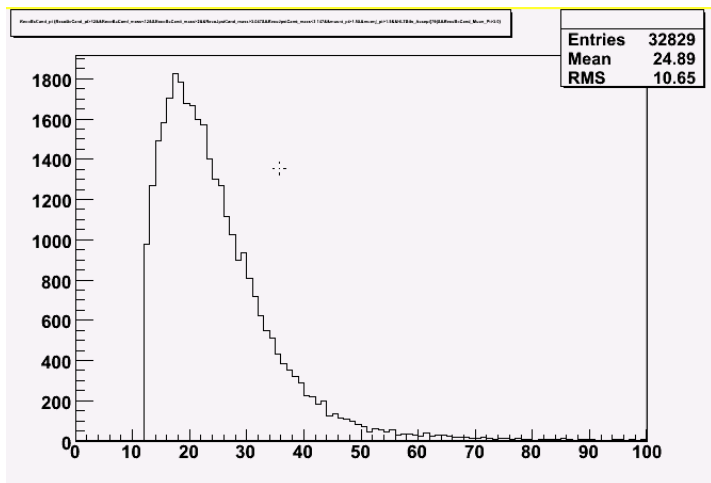
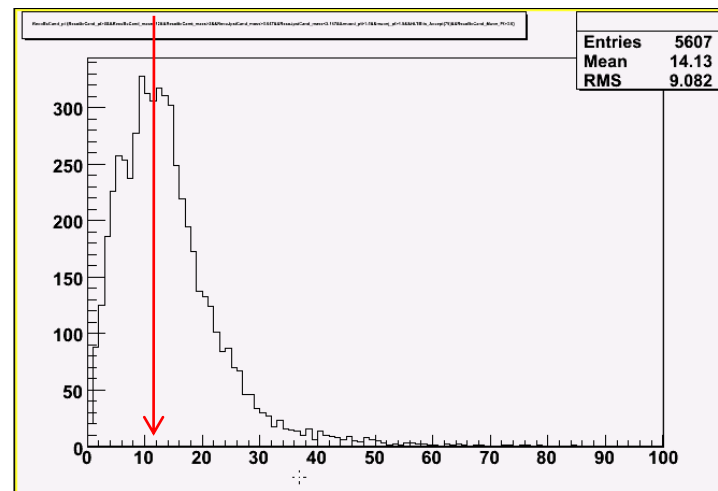
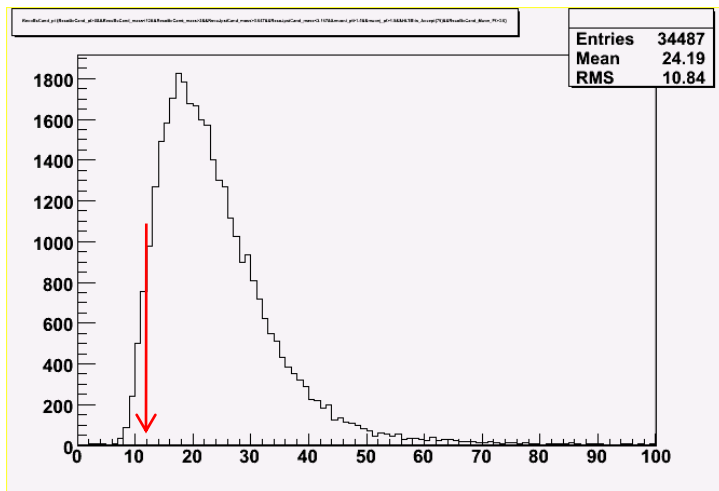
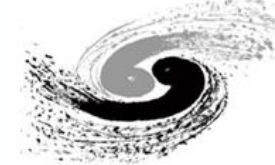
Jpsi normalized χ^2



- Select Criteria :
- 7) Jpsi normalized $\chi^2 < 8 (\chi^2/\text{ndof})$



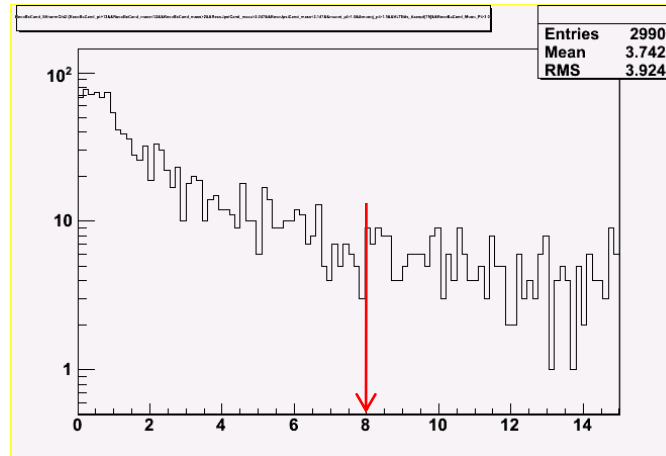
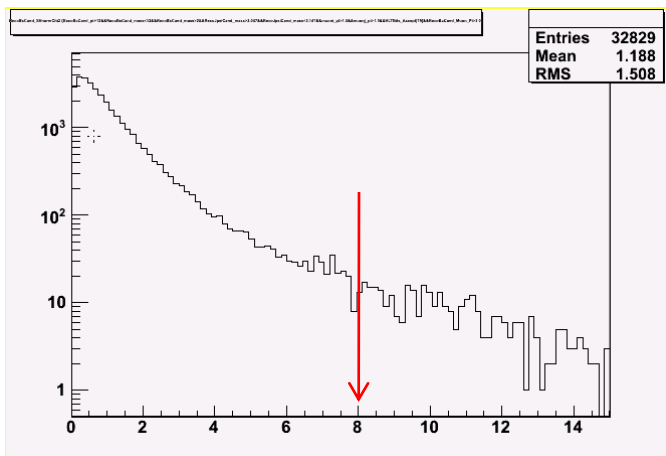
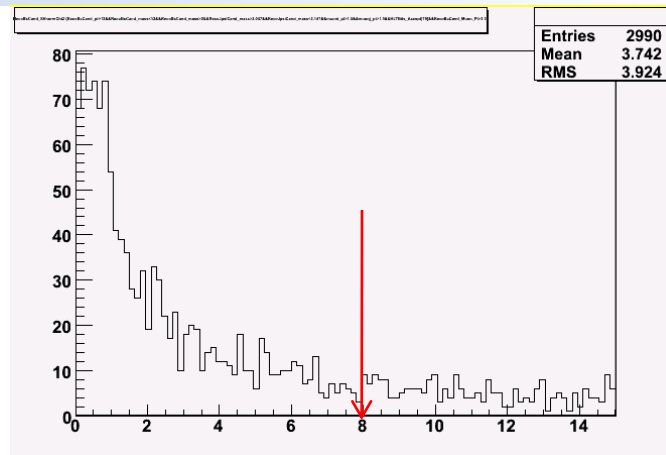
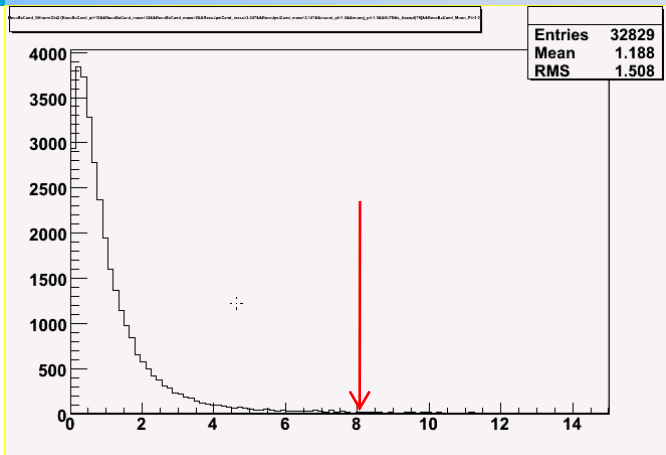
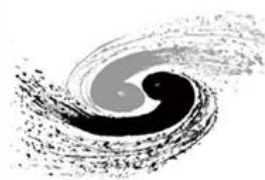
Bc candidate Pt



- Select Criteria :
- 8) Bc candidate pt > 12 GeV/c



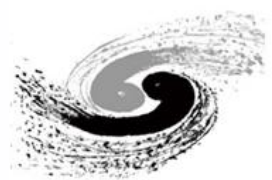
Bc normalized χ^2



- Select Criteria :
- 9) Jpsi normalized $\chi^2 < 8 (\chi^2 / \text{ndof})$

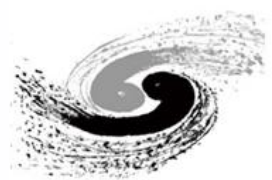


The results



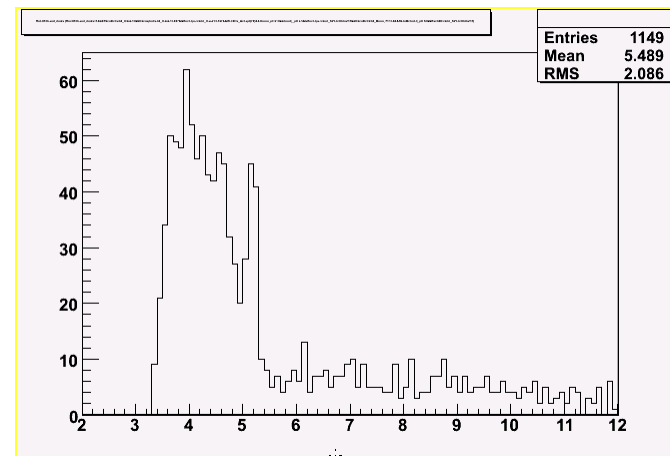
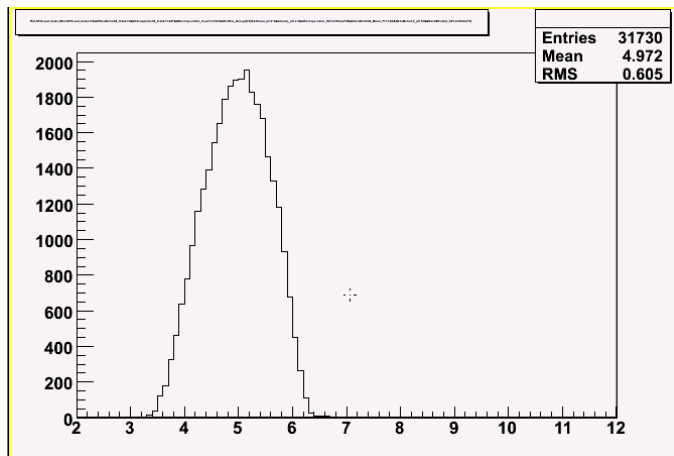
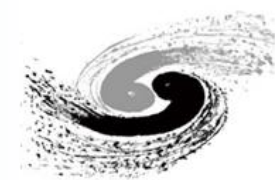
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The efficiency of the cuts



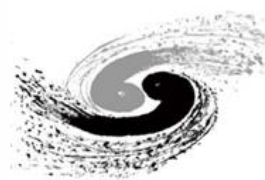
description	Selection Criteria	Signal		B→J/ψμμ background	
		Events	Efficiency	Events	Efficiency
Bc mass window	(2,12)	52637	0.38531	21065	0.00865
J/ψ mass window	(3.047,3.147)	39669	0.29038	14267	0.00586
HLTigger	HLT_Mu3	36386	0.26635	10256	0.00421
Dimuon pt	>2.5	36289	0.26564	9074	0.00373
J/ψ Nomalized χ^2	<8	35503	0.25989	8802	0.00362
Third muon pt	>3.0	33676	0.24651	4605	0.00189
Bc candidate pt	>12	32098	0.23496	2818	0.00116
Bc Nomalized χ^2	<8	31730	0.23227	1149	0.00047

Invariant mass of Bc candidate

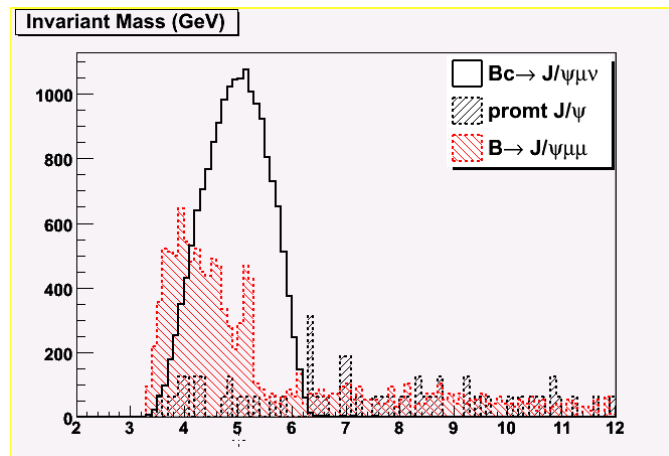
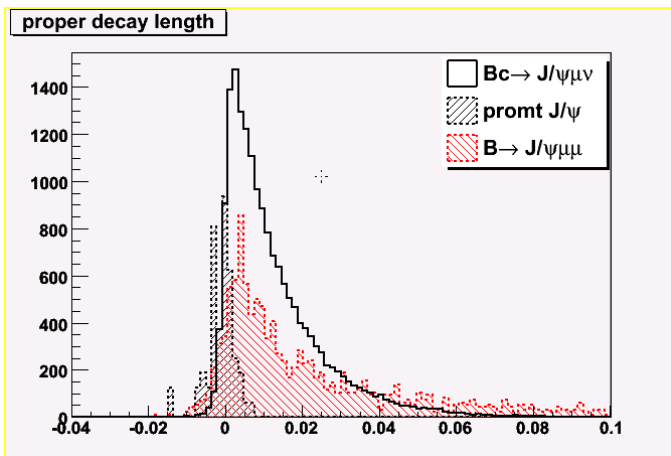


- Select Criteria :
- 1) Inverse charge dimuon, the best one.
- 2) Bc mass window(2,12)
- 3) Jpsi mass window(3.047,3.147)
- 4) Single muon $pt > 2.5 \text{ GeV}/c$
- 5) The third muon $pt > 3.0 \text{ GeV}/c$
- 6) High level trigger HLT_Mu3
- 7) Jpsi normalized $\chi^2 < 8 (\chi^2 / \text{ndof})$
- 8) Bc $pt > 12.0 \text{ GeV}/c$
- 9) Bc normalized $\chi^2 < 8 (\chi^2 / \text{ndof})$

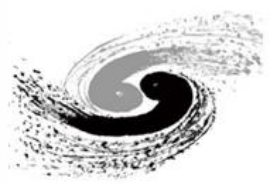
The results



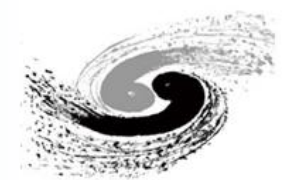
- Integrated in 1fb^{-1}



Next step



- Add QCD background.
- Add Criteria significance ($L^{\text{PDL}}_{xy} / \sigma_{xy}$)



Thank you!