Measurement of Bc differential cross-section and lifetime

Xianyou Wang, Guoming Chen, Xiangwei Meng, Zhenxia Zhang

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

Outline

- Motivation
- Experimental status
- Event generation
- Theoretical cross-section parameters
- New approach(estimate the cross-section of Bc)
- Analysis strategy
- Acceptance and trigger efficiency
- Latest analysis result
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Motivation

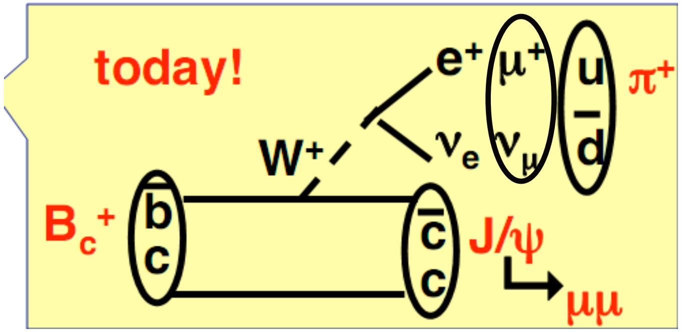
- Measure the differential cross-section of Bc->$J/\psi\mu\nu$ and Bc->$J/\psi\pi$ in 100pb^{-1}.

- Test the theory-predictions:
- Bc production in hadron collider: many theoretical uncertainties!
- σ (Bc) ~ 10^{-3} σ(other B-mesons) [E.g:Chang&Wu,EPJC38,267]

- Bc mass
- Potential: 6.2-6.4 GeV/c2

pQCD: 6326+29−9 MeV/c2
Lattice QCD: 6278(6)(4) MeV/c2
PDG'08: 6276$\pm$4 MeV/c2

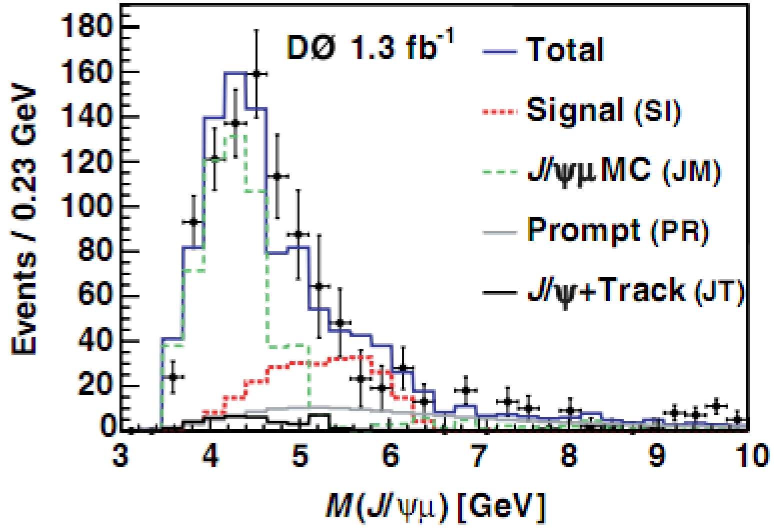
- Measure the mass and life time through Bc->$J/\psi\pi$.



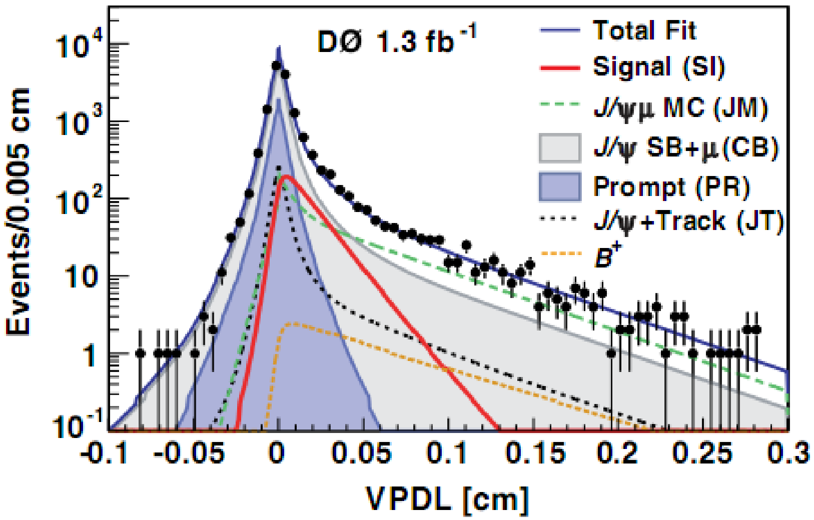
Experimental status

Collab.	L_{int}[pb^{-1}]	Mode	Signal event	Mass[MeV/c^2]	Lifetime[ps]
CDF	110	$J/\psi\, l^+ \nu$	$20.4^{+6.2}_{-5.5}$	$6400 \pm 390 \pm 130$	$0.46^{+0.18}_{-0.16} \pm 0.03$
D0	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	360	$J/\psi\, \pi^+$	14.6 ± 4.6	$6285.7 \pm 5.3 \pm 1.2$	—
CDF	360	$J/\psi\, e^+ \nu_e$	238	—	$0.463^{+0.073}_{-0.065} \pm 0.36$
CDF	2400	$J/\psi\, \pi^+$	108 ± 15	$6275.6 \pm 2.9 \pm 2.5$	—
D0	1300	$J/\psi\, \pi^+$	54 ± 12	$6300 \pm 14 \pm 5$	—
D0	1300	$J/\psi\, \mu^+ X$	881 ± 80	—	$0.448^{+0.038}_{-0.036} \pm 0.032$

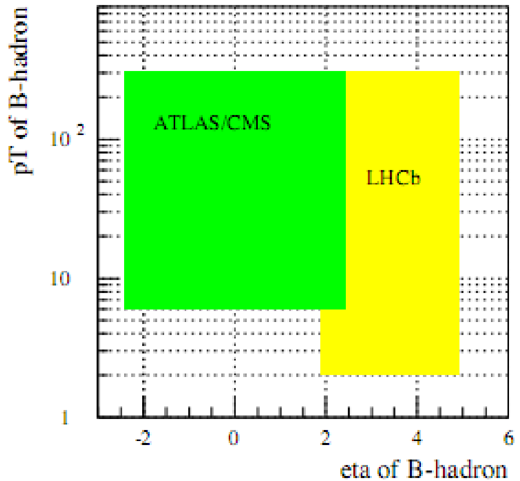
D0 Result

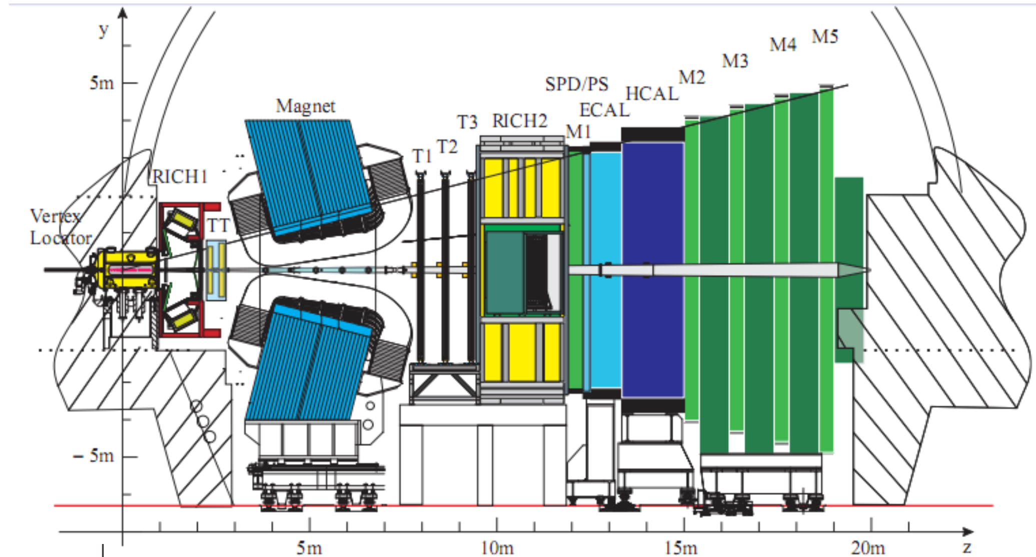


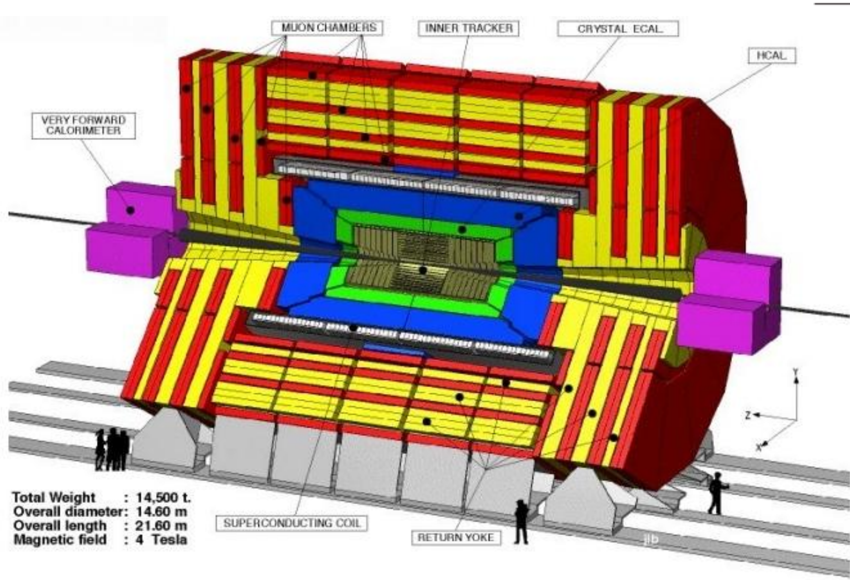
DØ 1.3 fb^{-1}
Total
Signal (SI)
J/ψμ MC (JM)
Prompt (PR)
J/ψ+Track (JT)
Events / 0.23 GeV
M(J/ψμ) [GeV]



DØ 1.3 fb^{-1}
Total Fit
Signal (SI)
J/ψμ MC (JM)
J/ψ SB+μ(CB)
Prompt (PR)
J/ψ+Track (JT)
B$^+$
Events/0.005 cm
VPDL [cm]







CMS: Competition complement with LHCb

CMS Most analyses here based on medium and high PT muons

Event generation

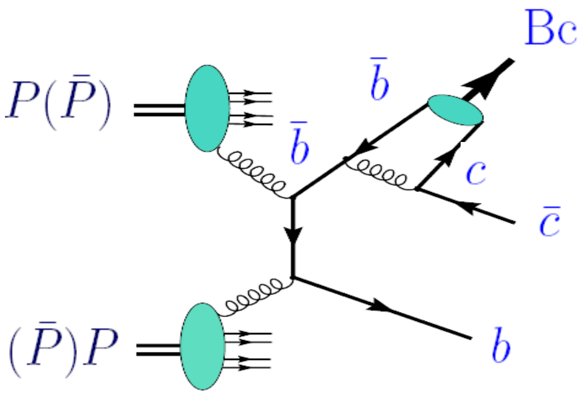
- Signal: Bc→J/ψ μ, J/ψ → μμ generated with BCVEGPY 2.1 generator [Chang&Wu, EPJC38:267,2004]

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

- Generator cuts:
  - μ pair (from JPsi) pT≥2.5GeV |η|≤2.5
  - Third μ(μ from Bc) pT≥2.5GeV |η|≤2.5



Bc theoretical cross-section

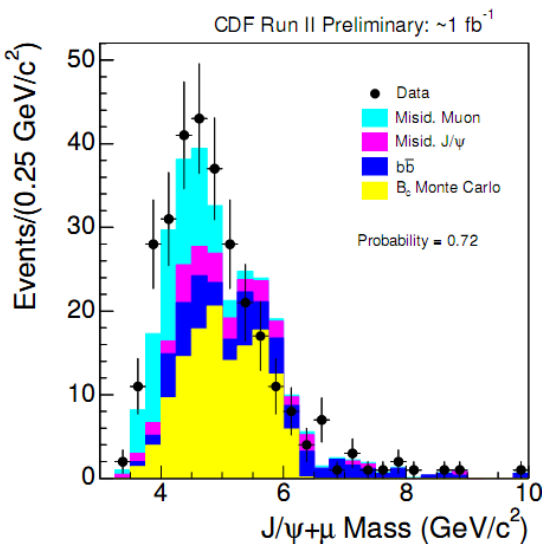
- Br (b->Bc) =1.3*10^{-3} [from HERWIGM. Phys. Lett. B 266, 142 (1991).]
- Br (QCD->bb(bar))=1.16%
- Bc cross section 51.56 mb*0.0116*0.001*2=0.00119619 mb≈1000 nb

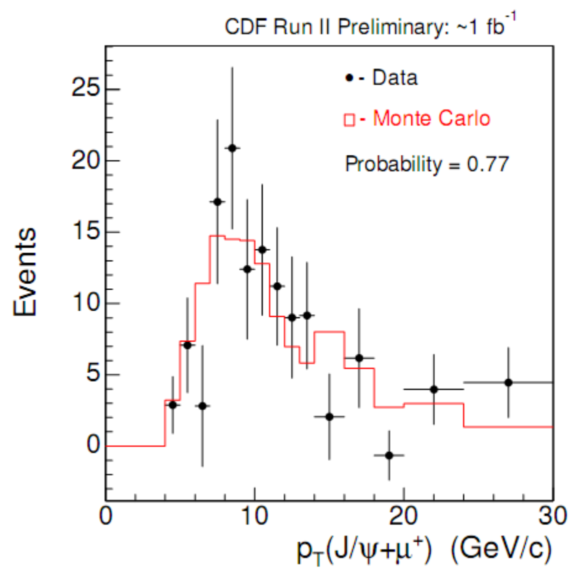
- Br (Bc2JPsiMuNu) = 1.9 %
- Br (J2MuMu = 6 %) = 6 %
- so three muon Branch = 6 %*2 % = 0.0012
- 1000 nb*0.0012 = 1.2 nb(σ Bc$\rightarrow$J/$\psi\mu\nu$)
- This result is come from the fragment mechanics

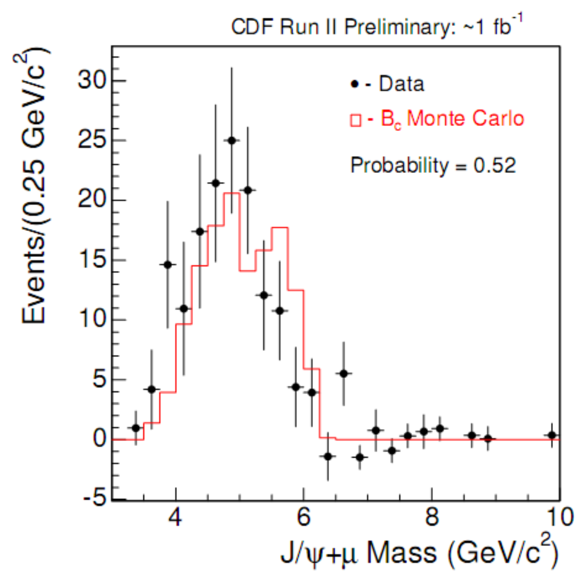
- The Bc cross-section calculated by Bcvegpy2.1 is different from this result , it's about 360nb when$\sqrt{s}$ =10eV (σ Bc$\rightarrow$J/$\psi\mu\nu$ is 0.4nb).

CDF Public Note 9740 09-03-05

Final results	$p_T(B) > 4$ GeV/c	$p_T(B) > 6$ GeV/c
$N(B_c^+ \to J/\psi + \mu^+ + \nu)$	117.6 ± 17.2 (stat) $^{+8.3}_{-6.4}$ (sys)	107.1 ± 16.7 (stat) $^{+7.9}_{-6.1}$ (sys)
$N(B^+ \to J/\psi + K^+)$	2333 ± 55 (stat)	2299 ± 53 (stat)
ϵ_{rel}	5.867 ± 0.068 (stat) $^{+0.554}_{-0.450}$ (sys) ± 0.720 (spectrum)	4.872 ± 0.060 (stat) $^{+0.420}_{-0.278}$ (sys) ± 0.298 (spectrum)
$\frac{\sigma(B_c^+) * BR(B_c^+ \to J/\psi + \mu^+ + \nu)}{\sigma(B^+) * BR(B^+ \to J/\psi + K^+)}$	0.295 ± 0.040 (stat) $^{+0.033}_{-0.026}$ (sys) ± 0.036 (spectrum)	0.227 ± 0.033 (stat) $^{+0.024}_{-0.017}$ (sys) ± 0.014 (spectrum)







The monte carlo simulation generator is Bcvegpy1.0(only s-wave)

New approach(estimate the cross-section of Bc$^+$)

- The "signal" events are then passed through the detector and trigger simulation with all analysis cuts applied and a requirement that pT ($J/\psi+\mu^+$) > 4 (6) GeV/c.

Efficiencies	$p_T(B) > 4$ GeV/c	$p_T(B) > 6$ GeV/c
$\epsilon_{B_c^+}$ (%)	0.0551	0.1232
ϵ_{B^+} (%)	0.3231	0.6005

For p_T>4Gev/c we obtain

$$\sigma^{CDF}\left(B_c^+\right) * BR\left(B_c^+ \to J/\psi\left(\mu^-\mu^+\right) + \mu^+ + \nu\right) = \frac{N_{signal}}{\int Ldt \times \varepsilon_{B_C^+}}$$

$$= \frac{117.6}{1\text{fb}^{-1} \times 0.000551} = 213\,430 \text{ fb} \pm 30\,583\text{fb}\left(stat\right)^{+16274.5(fb)}_{-12549.0(fb)}\left(sys\right)$$

This result was calculated by us, the uns

$$\sigma^{Est}_{\sqrt{s}=10TeV}\left(B_c^+\right) * BR\left(B_c^+ \to J/\psi\left(\mu^+\mu^-\right) + \mu^+ + \nu\right)$$

$$= \sigma^{CDF}\left(B_c^+\right) * BR\left(B_c^+ \to J/\psi\left(\mu^+\mu^-\right) + \mu^+ + \nu\right) * \frac{\sigma^{MC}_{\sqrt{s}=10TeV}\left(B_c^+\right)}{\sigma^{MC}_{\sqrt{s}=1.96TeV}\left(B_c^+\right)}$$

$\sigma^{MC}_{\sqrt{s}=10TeV}\left(B_c^+\right)$ $\sigma^{MC}_{\sqrt{s}=1.96TeV}\left(B_c^+\right)$ are the cross-section calculated by Bcvegpy2.1 in whole phase space.

$\sigma^{MC}_{\sqrt{s}=10TeV}\left(B_c^+\right) = 184671.84\,pb$ $\sigma^{MC}_{\sqrt{s}=1.96TeV}\left(B_c^+\right) = 8984.48\,pb$

So at last the cross-section of $B_c^+ \to J/\psi\left(\mu\mu^+\right) + \mu^+ + \nu$

$$\sigma^{Est}_{\sqrt{s}=10TeV}\left(B_c^+\right) * BR\left(B_c^+ \to J/\psi\left(\mu^+\mu^-\right) + \mu^+ + \nu\right) = 213.43\,pb * 20.55 \approx 4000\,pb$$

- Cross-section of $Bc^+ \to J/\psi(\mu^+\mu^-)\mu^-$ in theoretical it should be 1.2 nb.

- After filtrate(muon P_T>2.5GeV/c ,$|\eta|<2.5$).
- Signal cross section 1.2nb*0.057 = 68.4 pb
- In 100 pb^{-1} there will be 6840events.

- From the way we used above Cross-section of $Bc \to J/(\mu^+\mu^-)\mu^-$ should be 8.0nb.
- After filtrate(muon P_T>2.5GeV/c ,$|\eta|<2.5$).
- Signal cross section 8.0nb*0.057 = 456 pb
- In 100 pb^{-1} there will be 45600events.

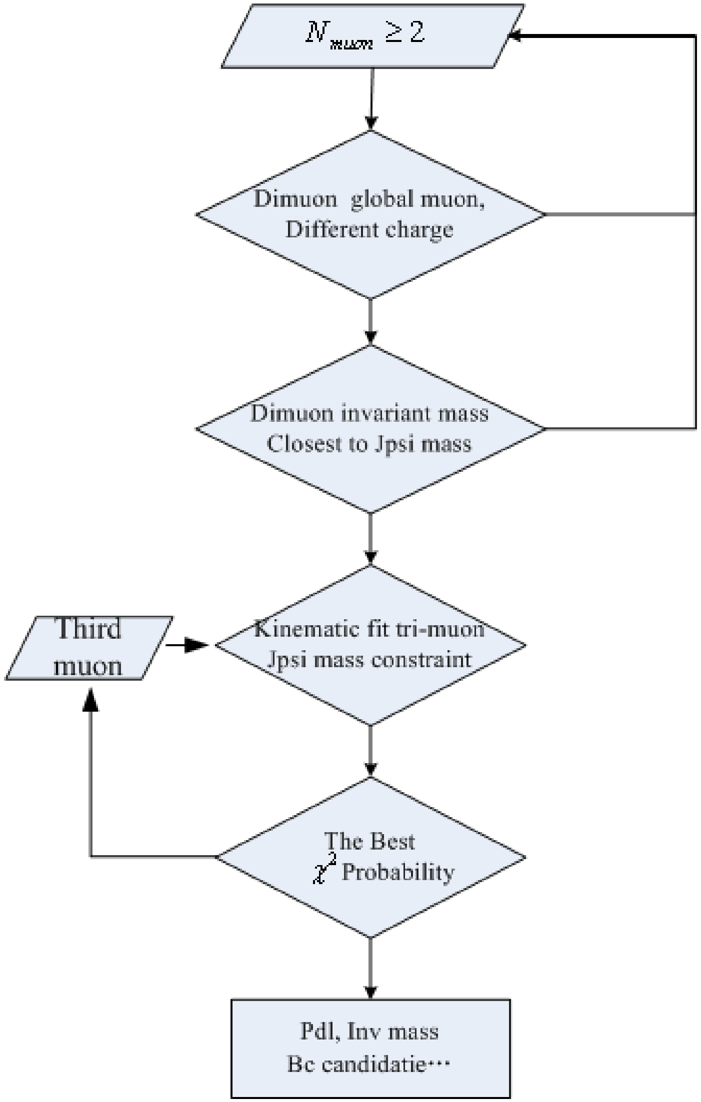
- There will be 1/3 events be Reconstructed.

Data sample

- Signal(muon P_T>1GeV/c ,$|\eta|$<2.5):
- Bc2JpsiMuNu(signal) 502 972 ~200pb^{-1}

- Background:
- B2JpsiMuMu(Inclvsive B) 10 778 551 ~100pb^{-1}
- Jpsi2MuMu(Prompt Jpsi) 11 369 136 ~10pb^{-1}
- ppmumux (QCD) 1016158 ~1pb^{-1}

Analysis strategy



- Calculate the trigger efficiency $\varepsilon_{Trigger}$.
- Calculate the efficiency of the selection strategy.
- Add different cut and calculate the efficiency.
- Product select efficiency and the cuts efficiency as the Reconstructed efficiency ε_{Reco} .

$$\frac{d\sigma}{dp_T} \times Br\left(Bc \to J/\psi\ \mu\nu\right) \times Br\left(J/\psi \to \mu\mu\right)$$

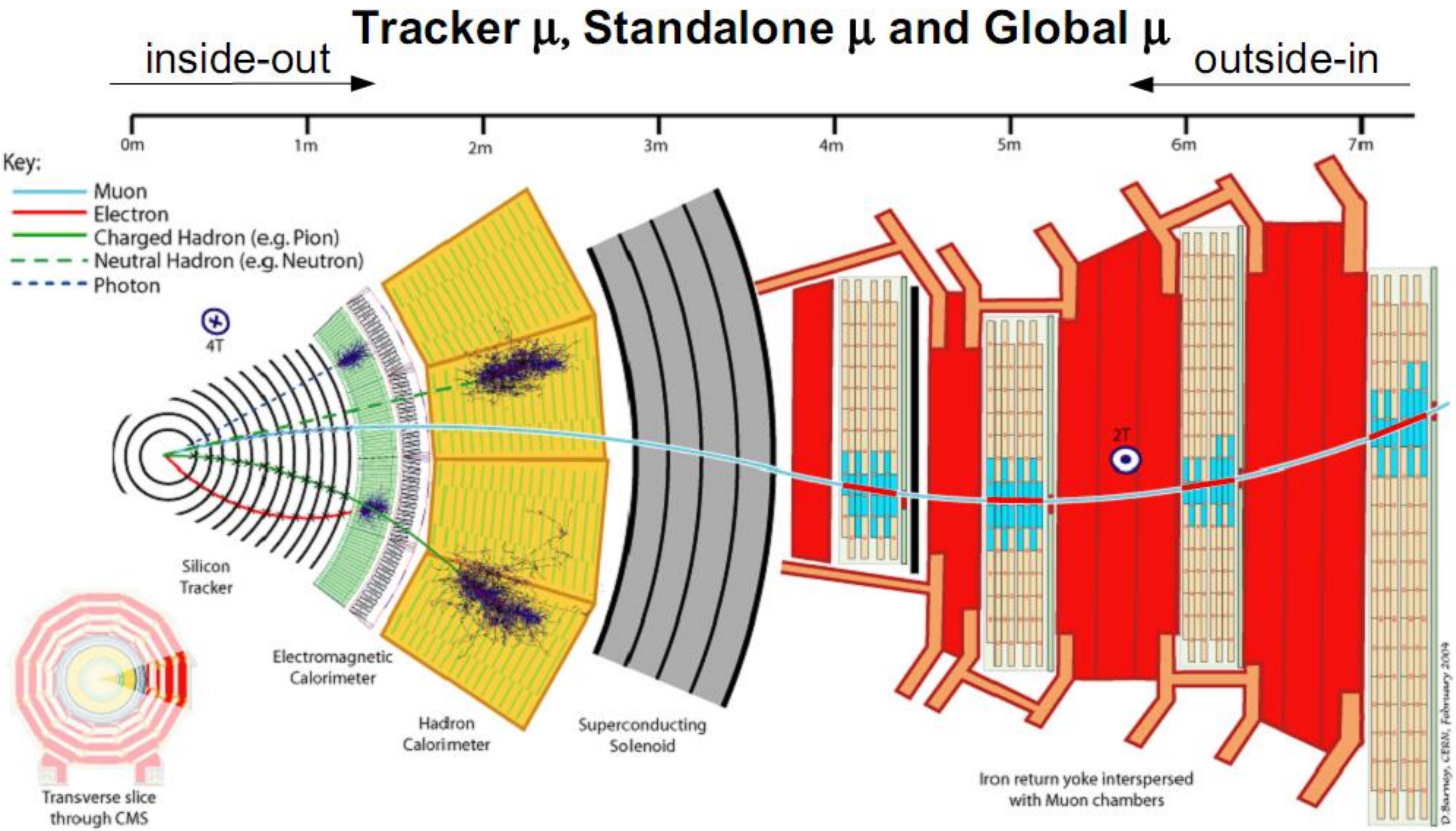
$$= f\left(\Delta P_T\right) \times \frac{N_{\Delta p_T}^{Bc}\left(A, \varepsilon_{Trigger}, \varepsilon_{\mathrm{Reco}}, \lambda_{Trigger}^{corr}, \lambda_{\mathrm{Reco}}^{corr}\right)}{\int Ldt.\Delta P_T}$$

- $\int Ldt$ Integral luminosity.
- f fraction for Bc-> $J/\psi\mu\nu$
- $\lambda_{Trigger}^{corr}, \lambda_{\mathrm{Reco}}^{corr}$ correction on trigger and reco efficiency from Tag&probe

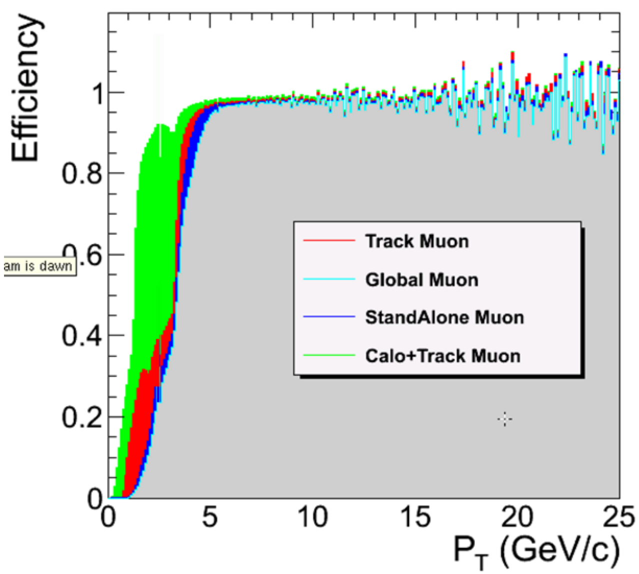
3 Muon types in CMSSW

Two independent approaches for muon reconstruction leading to **three different types of muon candidates**:

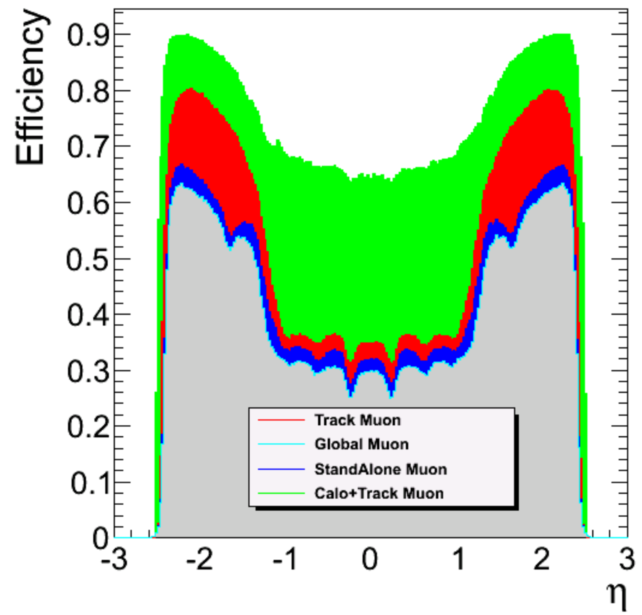
Tracker μ, Standalone μ and Global μ



Muon reconstruction efficiency

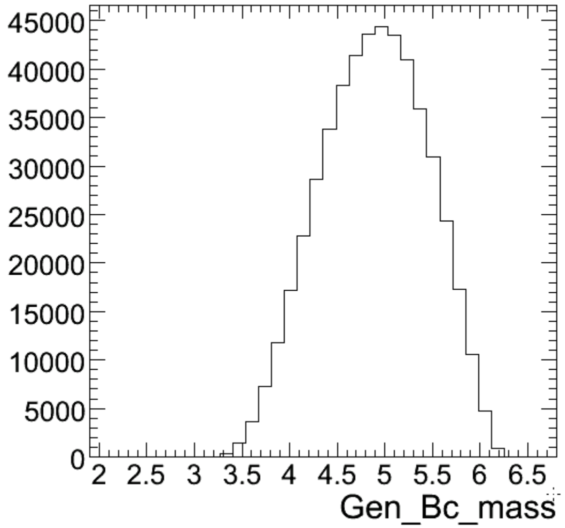


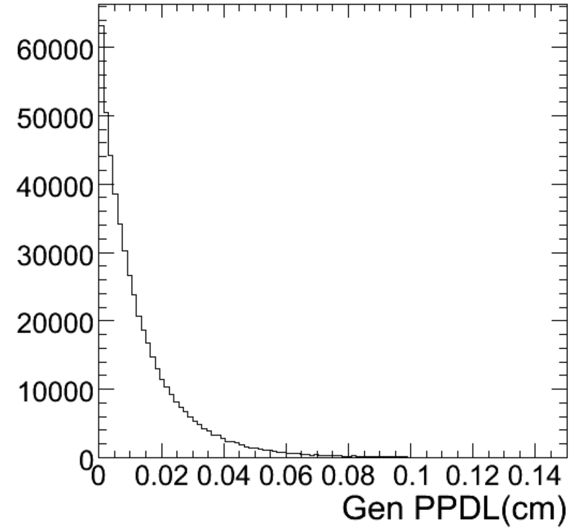
$$\varepsilon_{acc} = N_{Re-macthed}\left(p_t\right) / N_{Gen}\left(P_t\right)$$



$$\varepsilon_{acc} = N_{Re-macthed}\left(\eta\right) / N_{Gen}\left(\eta\right)$$

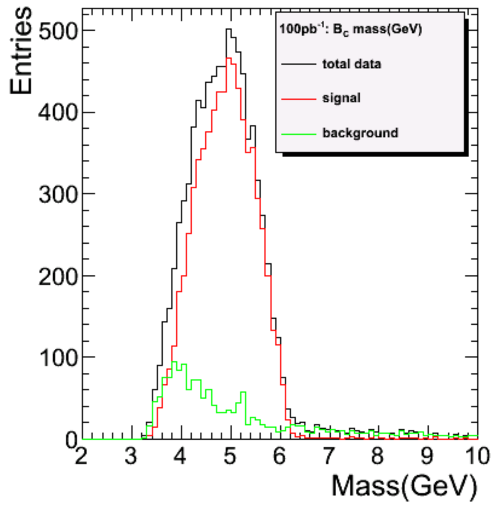
Invariant mass and decay length distribution

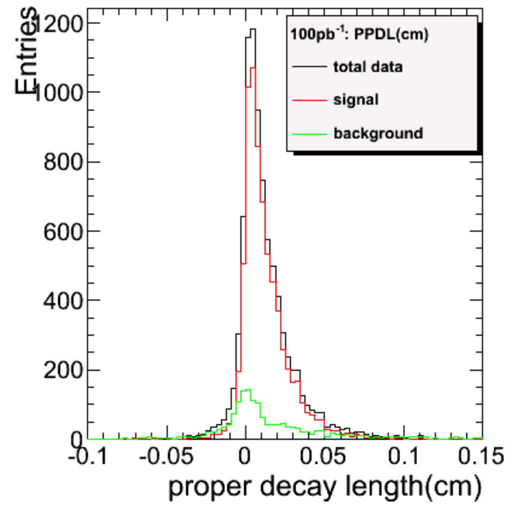


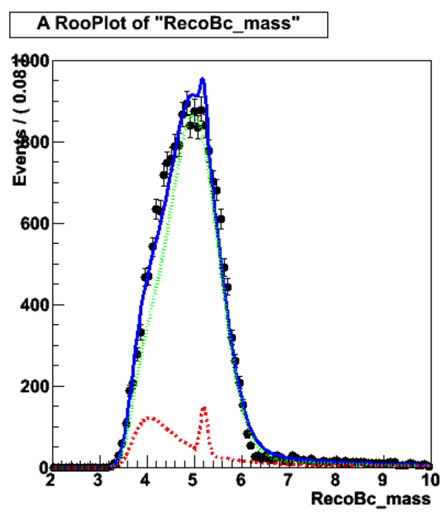


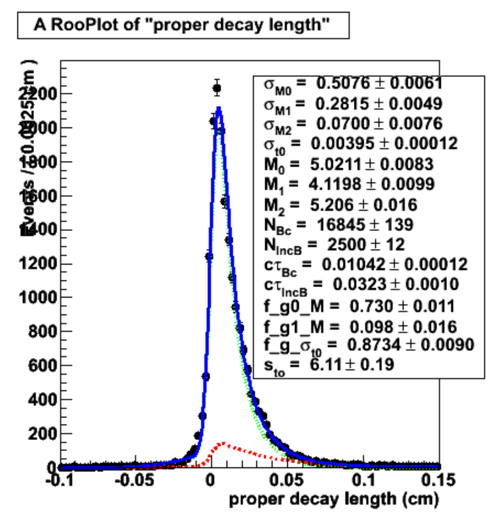
Reconstruction and fit result

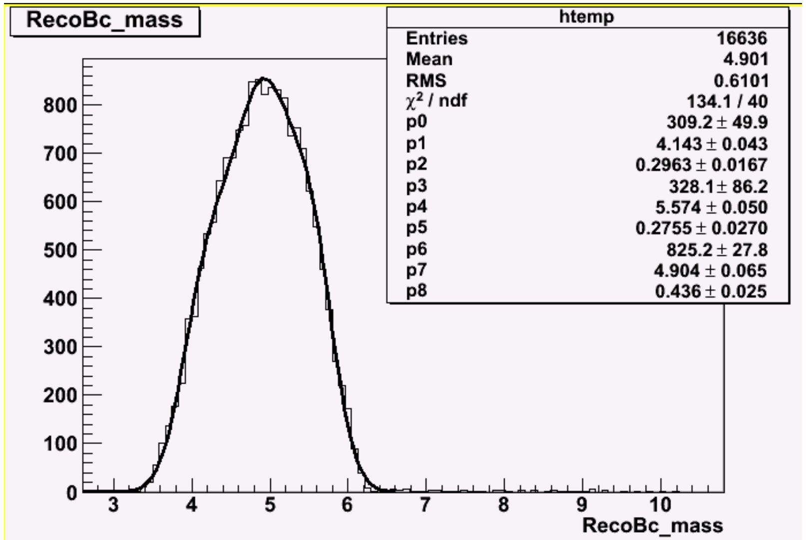
- Event selection
- All global muon
- pt(>2Gev/c)
- Trigger: HLTDoubleMu0
- Final states:
  Mass (2,10)
  χ^2 /ndf(<10)
- Jpsi selection
- Pt(>2.0Gev/c)
  mass (2.85,3.35)
- The third muon:
  χ^2 /ndf(<1.9)
  Nhits (>10)
- ΔR between J/ψ and Third muon (<1.5)

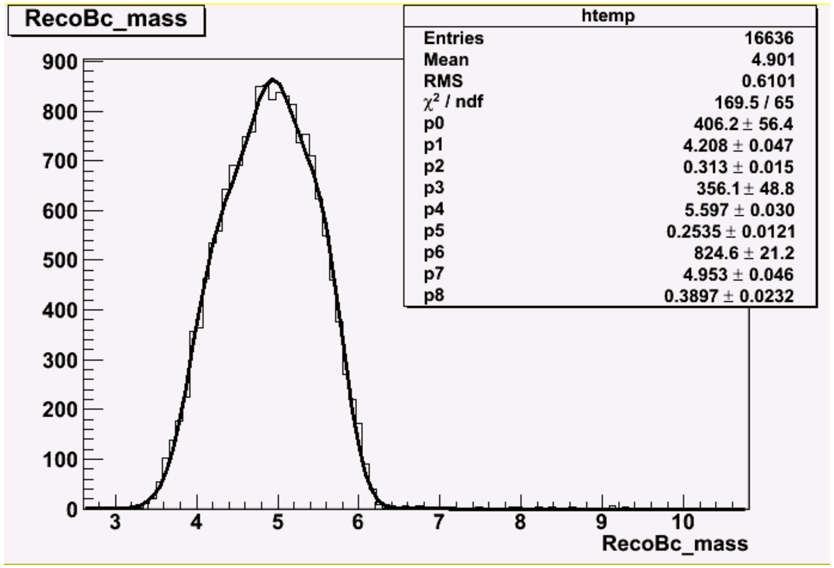


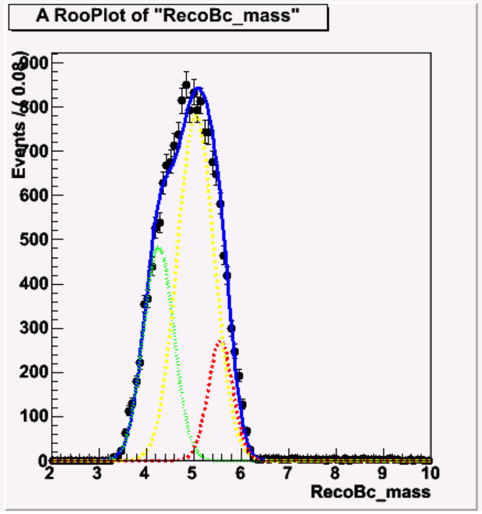


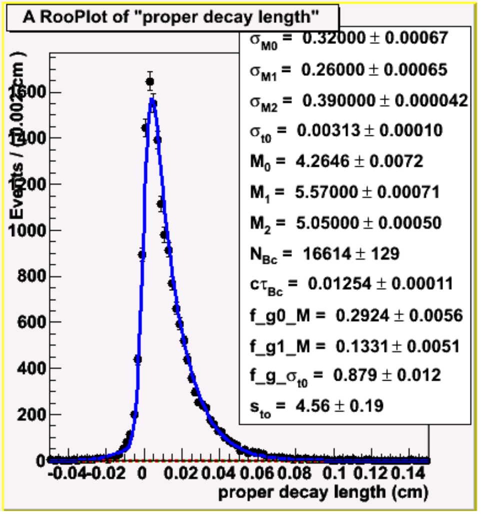




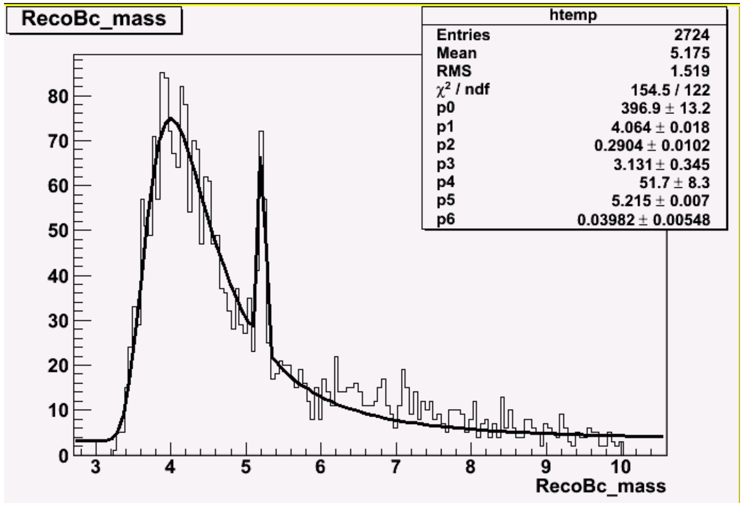

RecoBc_mass
htemp
Entries 16636
Mean 4.901
RMS 0.6101
χ² / ndf 134.1 / 40
p0 309.2 ± 49.9
p1 4.143 ± 0.043
p2 0.2963 ± 0.0167
p3 328.1 ± 86.2
p4 5.574 ± 0.050
p5 0.2755 ± 0.0270
p6 825.2 ± 27.8
p7 4.904 ± 0.065
p8 0.436 ± 0.025
RecoBc_mass


RecoBc_mass
htemp
Entries 16636
Mean 4.901
RMS 0.6101
χ² / ndf 169.5 / 65
p0 406.2 ± 56.4
p1 4.208 ± 0.047
p2 0.313 ± 0.015
p3 356.1 ± 48.8
p4 5.597 ± 0.030
p5 0.2535 ± 0.0121
p6 824.6 ± 21.2
p7 4.953 ± 0.046
p8 0.3897 ± 0.0232
RecoBc_mass

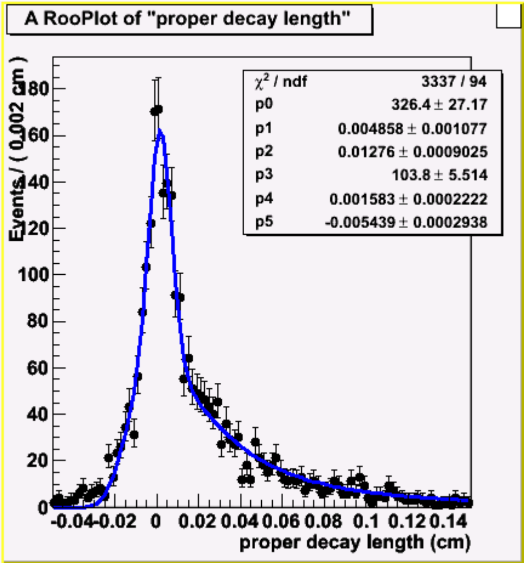

A RooPlot of "RecoBc_mass"
Events / (0.08)
RecoBc_mass


A RooPlot of "proper decay length"
Events / (0.002 cm)
σ_M0 = 0.32000 ± 0.00067
σ_M1 = 0.26000 ± 0.00065
σ_M2 = 0.390000 ± 0.000042
σ_t0 = 0.00313 ± 0.00010
M_0 = 4.2646 ± 0.0072
M_1 = 5.57000 ± 0.00071
M_2 = 5.05000 ± 0.00050
N_Bc = 16614 ± 129
cτ_Bc = 0.01254 ± 0.00011
f_g0_M = 0.2924 ± 0.0056
f_g1_M = 0.1331 ± 0.0051
f_g_σ_t0 = 0.879 ± 0.012
s_t0 = 4.56 ± 0.19
proper decay length (cm)

Inclusive B



RecoBc_mass
htemp
Entries 2724
Mean 5.175
RMS 1.519
χ² / ndf 154.5 / 122
p0 396.9 ± 13.2
p1 4.064 ± 0.018
p2 0.2904 ± 0.0102
p3 3.131 ± 0.345
p4 51.7 ± 8.3
p5 5.215 ± 0.007
p6 0.03982 ± 0.00548
RecoBc_mass

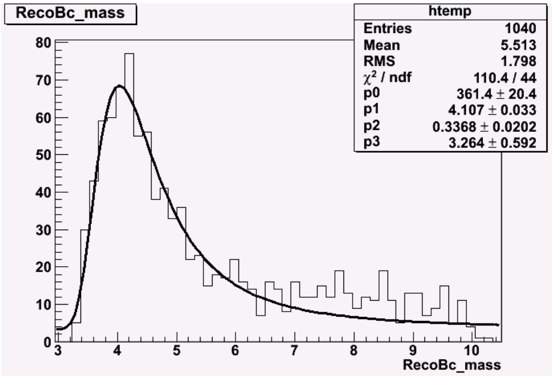


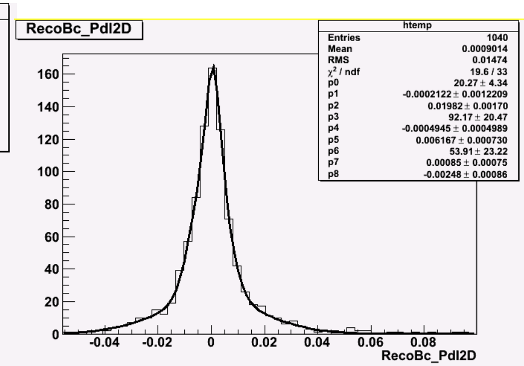
A RooPlot of "proper decay length"
χ² / ndf 3337 / 94
p0 326.4 ± 27.17
p1 0.004858 ± 0.001077
p2 0.01276 ± 0.0009025
p3 103.8 ± 5.514
p4 0.001583 ± 0.0002222
p5 -0.005439 ± 0.0002938
Events / (0.002 cm)
proper decay length (cm)

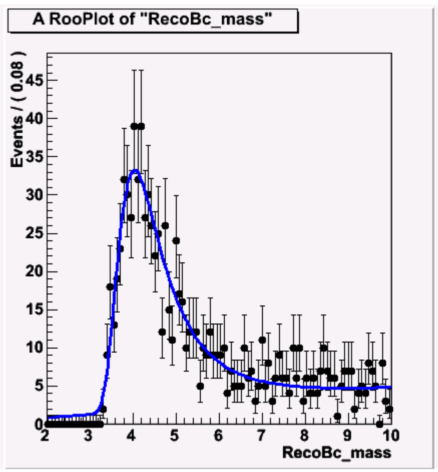
Prompt J/ψ background toy mc

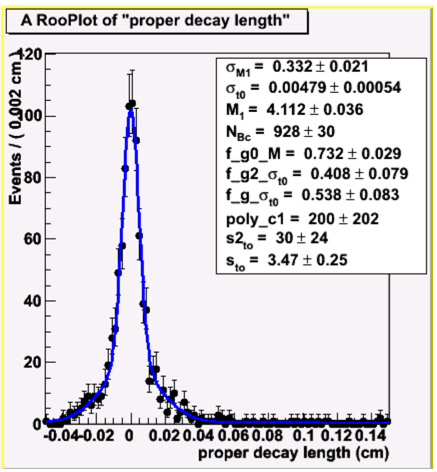
- Event selection
- All global muon
- Trigger: HLTDoubleMuOpen
- Final states: Mass (2,10)

- Jpsi selection
- Pt(>2.0Gev/c)
  mass (2.85,3.35)
- The third muon:
- Pt(>1.3Gev/c)

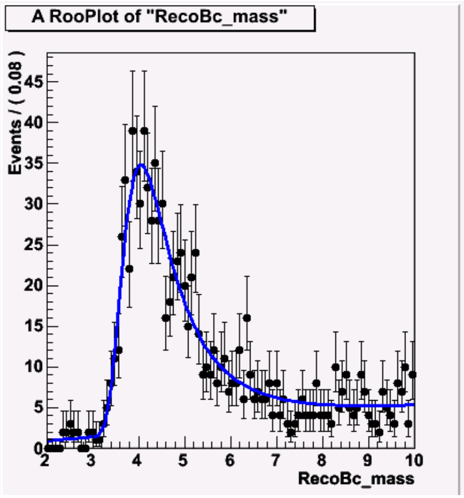


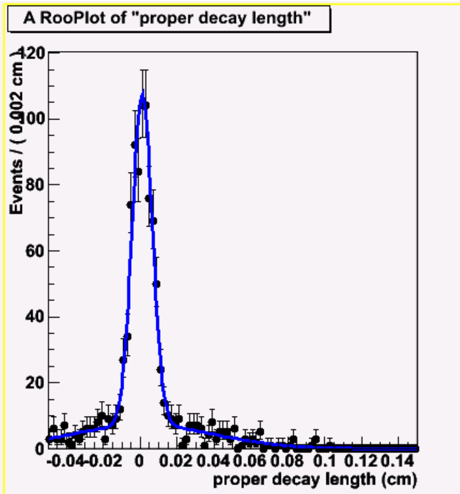






Roofit fit result



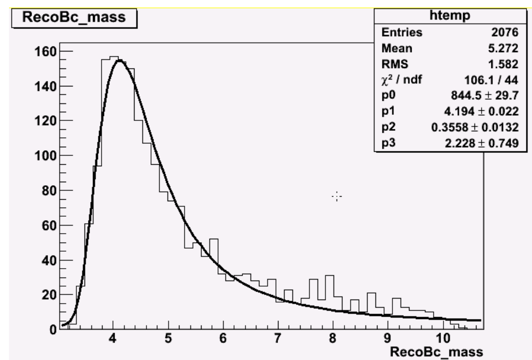


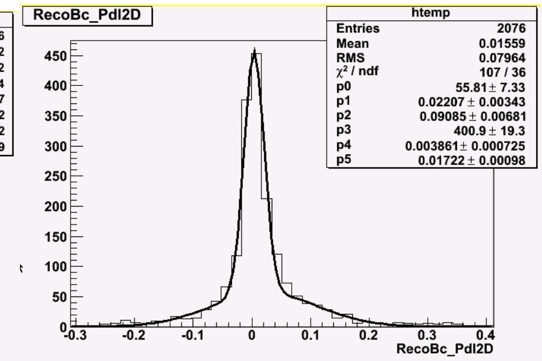
After Toy MC(1000)

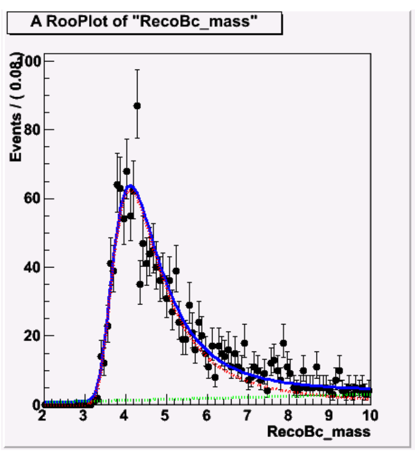
QCD background toy mc

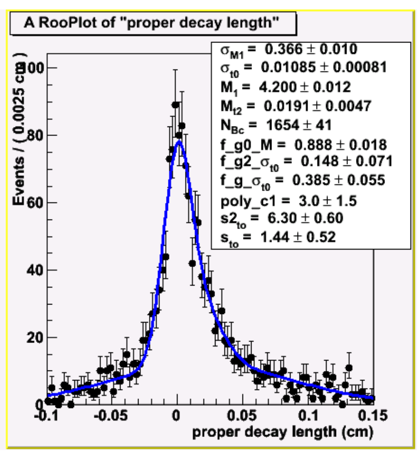
- Event selection
- One traker muon
- Trigger: HLTDoubleMuOpen

- Final states: Mass (2,10)
- Jpsi selection
- Pt(>2.0Gev/c) mass (2.85,3.35)

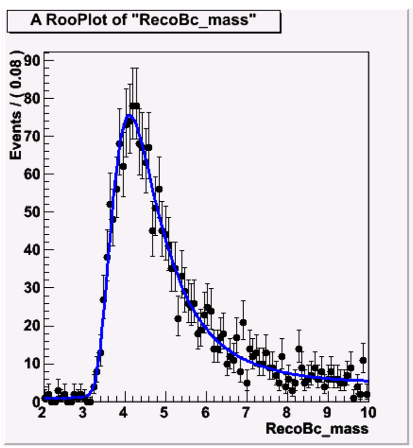


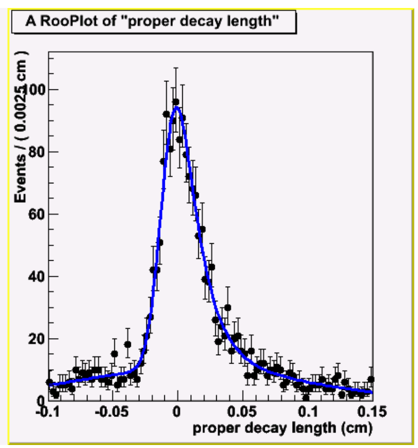






Roofit fit result





After Toy MC(2000)

	No filter	trigger	$P_T>2$	global	$\chi^2<1.9$	$N_{hits}>10$	Vertex $\chi^2<10$	Dimuon global	Dimuon $P_T>2$
Prompt J/ψ	119555	26502	6936	2071	24912	21156	22760	22531	24104
QCD	10597	3891	2408	2390	3744	3317	2663	1004	2029

	ε_{Reco}	ε_{HLT}	ε_{TPt}	ε_{Ttype}	ε_{Txisq}	ε_{Thits}	$\varepsilon_{vtexxisq}$	$\varepsilon_{dimutype}$	ε_{dimuPt}	ε_{total}
Prompt J/ψ	1	0.2217	0.2617	0.0781	0.94	0.7983	0.8588	0.8502	0.9095	0.0023
QCD	1	0.3672	0.6189	0.6142	0.9622	0.8525	0.6844	0.2580	0.5215	0.0105

- ε_{HLT} HLTrig efficiency
- ε_{TPt} Muon from Bc Pt cut(>2.0Gev/c)
- ε_{Ttype} Muon from Bc type (global muon)
- ε_{Txisq} Muon from Bc $\chi^2<1.9$
- ε_{Thits} Muon from Bc $N_{hits}>10$
- $\varepsilon_{vtexxisq}$ Vertex fit $\chi^2<10$
- $\varepsilon_{dimutype}$ Dimuon type (global muon)
- ε_{dimupt} Dimuon Pt cut(>2.0Gev/c)
- $\varepsilon_{total}= \varepsilon_{HLT} * \varepsilon_{TPt} * \varepsilon_{Ttype} * \varepsilon_{Txisq} * \varepsilon_{Thits} * \varepsilon_{vtexxisq} * \varepsilon_{dimutype} * \varepsilon_{dimupt}$

PT(GeV/c)	total	(5,12)	(12,15)	(15,18)	(18,21)	(21,25)	(25,30)	(30,36)	(>36)
Prompt J/ψ	26502	18909	3188	1410	643	339	153	68	37
QCD	3891	2461	393	208	95	74	27	13	14

PT(GeV/c)	total	(5,12)	(12,15)	(15,18)	(18,21)	(21,25)	(25,30)	(30,36)	(>36)
Prompt J/ψ ε_{bin}	1	0.713	0.12	0.053	0.024	0.012	0.0058	0.0025	0.0014
QCDε_{bin}	1	0.632	0.1	0.053	0.024	0.019	0.0069	0.0033	0.0036

The Integrated luminosity of the sample
Jpsi2MuMu(Prompt Jpsi) 10862911/(1.15*10^6)=9.4Pb^{-1}
Ppmumux(QCD) 1016158/(1.103384*10^6)=0.920Pb^{-1}

- So we got in 100 pb^{-1} Integrated luminosity background
$N_{background}=N_{sample}*\varepsilon_{Total} * \varepsilon_{bin} *100\ Pb^{-1}/\int Ldt$

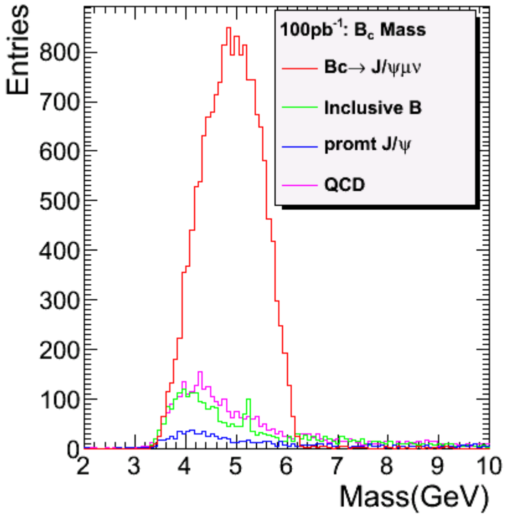
PT(GeV/c)	(5,12)	(12,15)	(15,18)	(18,21)	(21,25)	(25,30)	(30,36)	(>36)
Prompt J/ψ ($N_{J/\psi}$)	2085	351	155	70	35	16	7	4
QCD(N_{QCD})	7643	1209	641	290	229	83	40	40

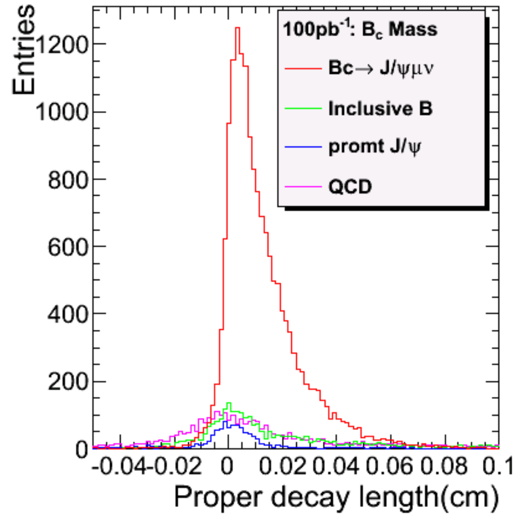
Number of Signal and background in different Pt bin(100pb^{-1})

Pt(GeV/c)	Signal	Inclusive B	Prompt J/ψ(×10)	QCD (×100)
(5,12)	673	966	52	18
(12,15)	822	570	19	4
(15,18)	1072	411	9	3
(18,21)	970	275	6	4
(21,25)	1051	213	5	3
(25,30)	927	115	3	1
(30,36)	603	93	0	0
(36---)	653	80	1	0

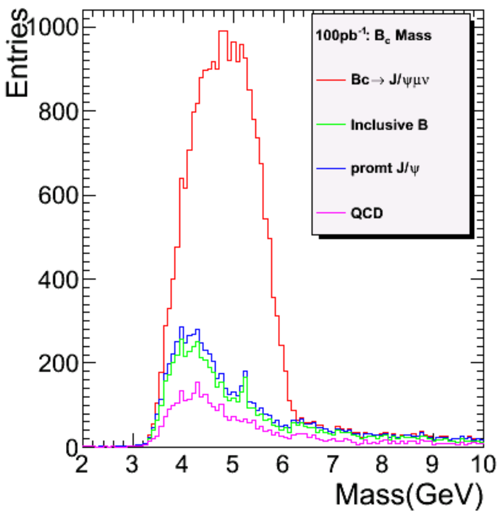
Total distribution of signal and background

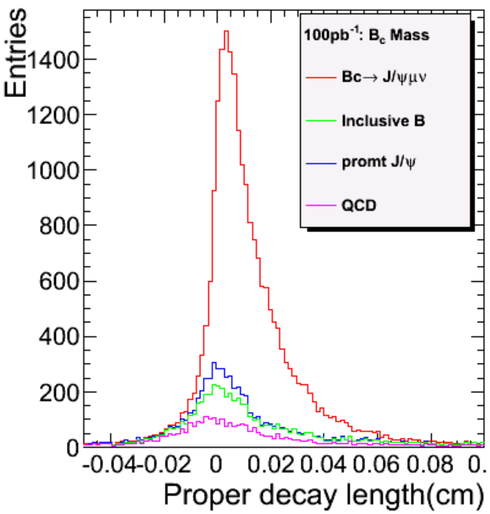
- No stack



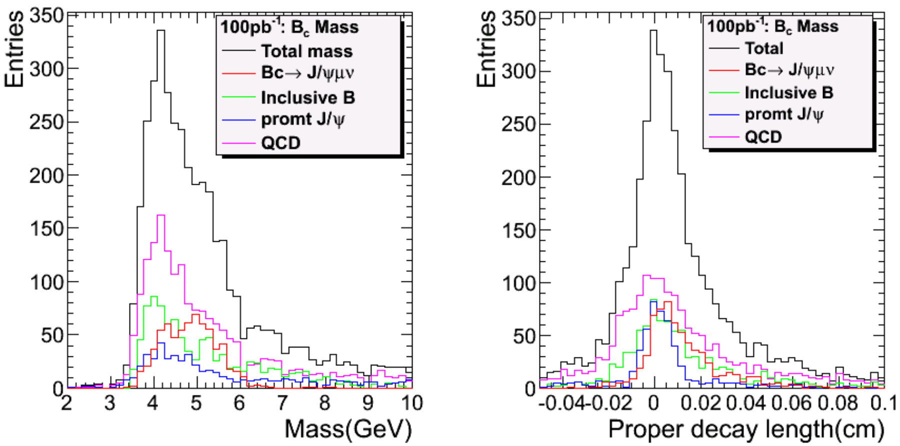


- After stack

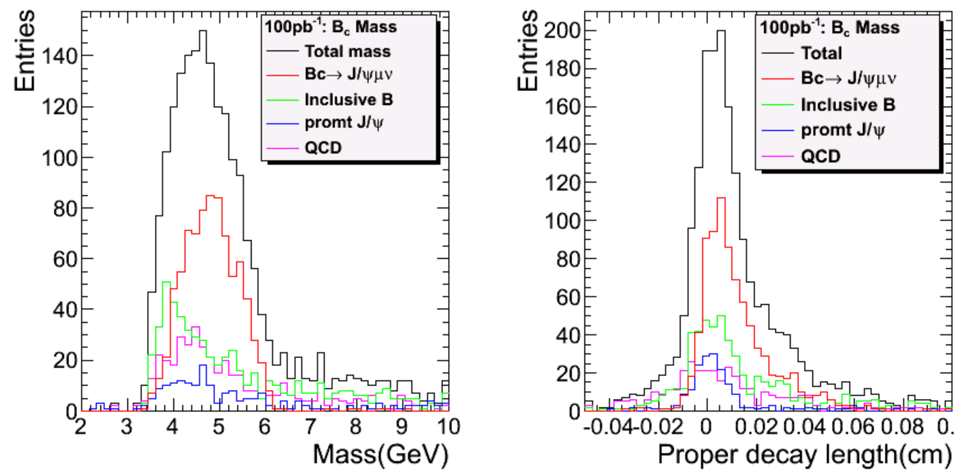




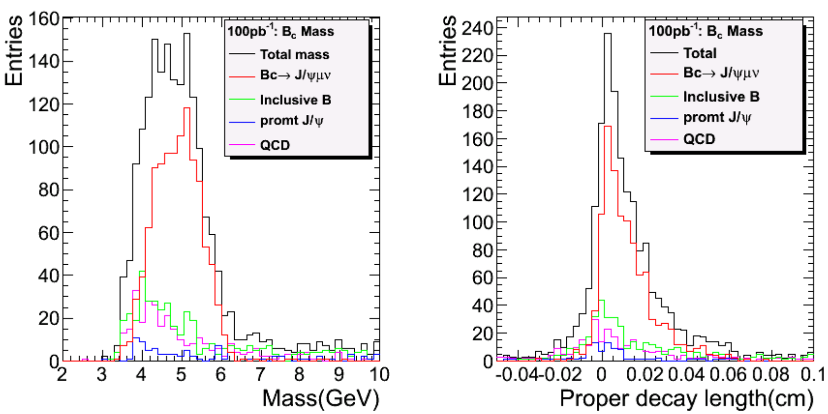
Distribution in different pt bin



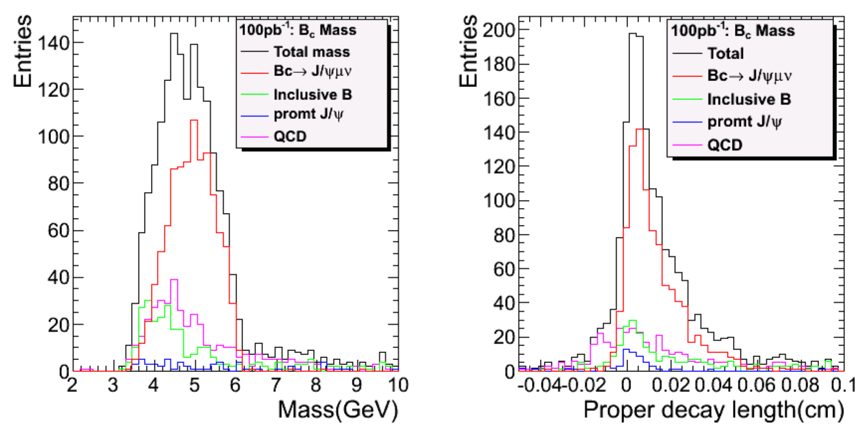
Pt(GeV/c)(5,12)



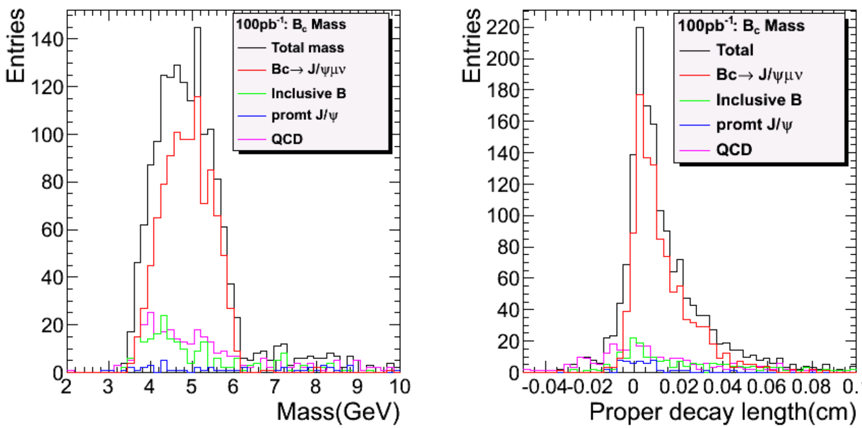
Pt(GeV/c)(12,15)



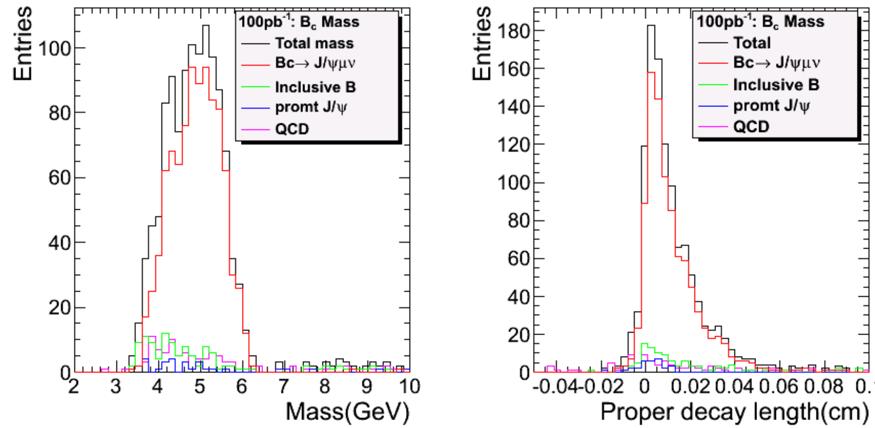
Pt(GeV/c)(15,18)



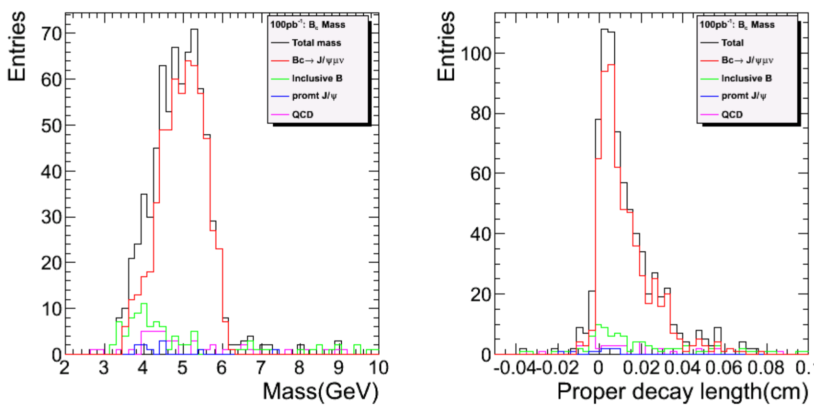
Pt(GeV/c)(18,21)



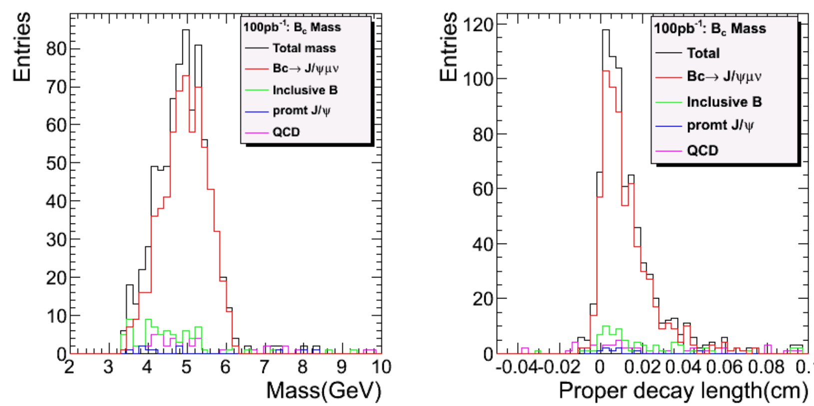
Pt(GeV/c)(21,25)



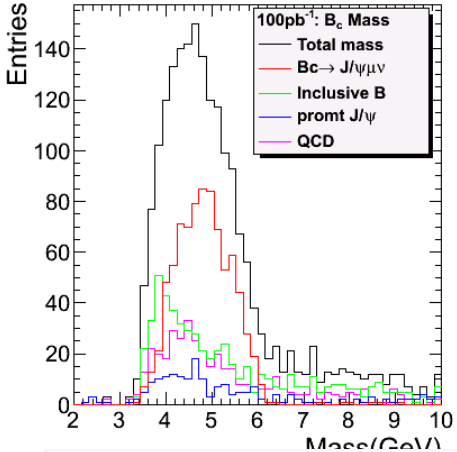
Pt(GeV/c)(25,30)



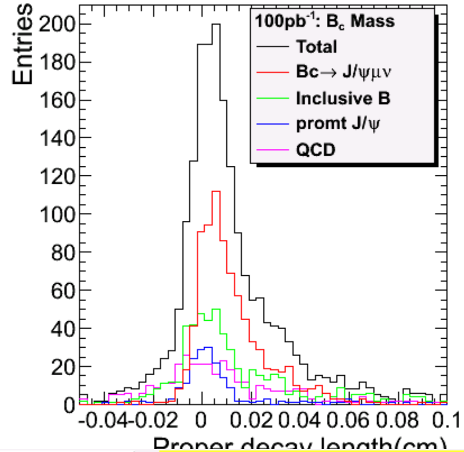
Pt(GeV/c)(30,36)



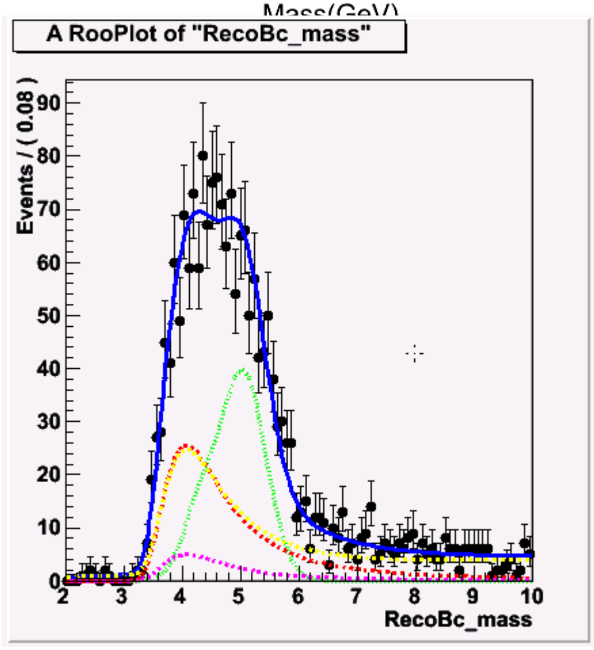
Pt(GeV/c)(>36)



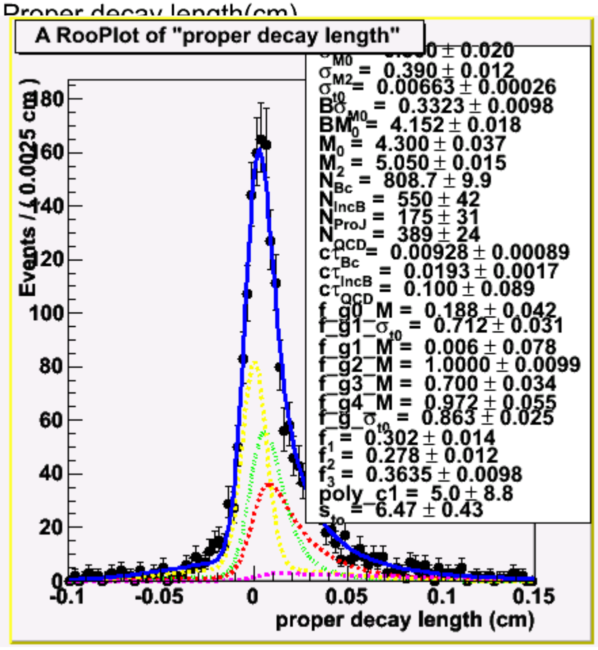
100pb⁻¹: B_c Mass
Total mass
Bc→ J/ψμν
Inclusive B
promt J/ψ
QCD
Entries
Mass(GeV)



100pb⁻¹: B_c Mass
Total
Bc→ J/ψμν
Inclusive B
promt J/ψ
QCD
Entries
Proper decay length(cm)



A RooPlot of "RecoBc_mass"
Events / (0.08)
RecoBc_mass



A RooPlot of "proper decay length"
σ_M2 = 0.390 ± 0.012
σ_t0 = 0.00663 ± 0.00026
Bσ_M0 = 0.3323 ± 0.0098
BM_0 = 4.152 ± 0.018
M_0 = 4.300 ± 0.037
M_2 = 5.050 ± 0.015
N_Bc = 808.7 ± 9.9
N_IncB = 550 ± 42
N_ProJ = 175 ± 31
N_QCD = 389 ± 24
cτ_Bc = 0.00928 ± 0.00089
cτ_IncB = 0.0193 ± 0.0017
cτ_QCD = 0.100 ± 0.089
f_g0_M = 0.188 ± 0.042
f_g1_σ_t0 = 0.712 ± 0.031
f_g1_M = 0.006 ± 0.078
f_g2_M = 1.0000 ± 0.0099
f_g3_M = 0.700 ± 0.034
f_g4_M = 0.972 ± 0.055
f_g_σ_t0 = 0.863 ± 0.025
f_1 = 0.302 ± 0.014
f_2 = 0.278 ± 0.012
f_3 = 0.3635 ± 0.0098
poly_c1 = 5.0 ± 8.8
s_t0 = 6.47 ± 0.43
Events / (0.0025 cm)
proper decay length (cm)

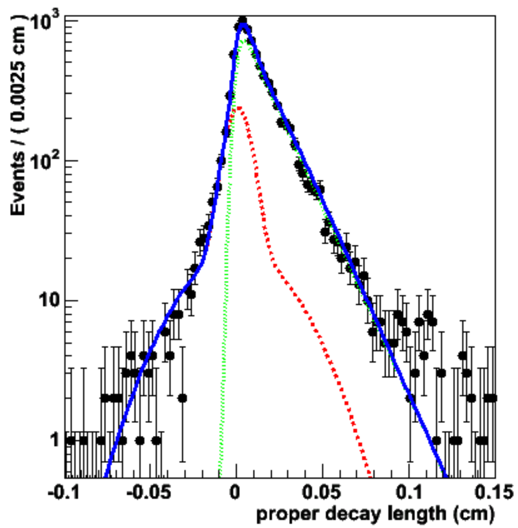
Next step

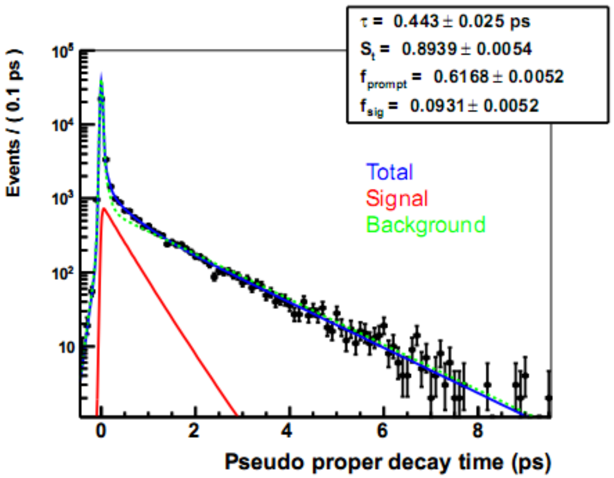
- Tow dimensional fit the mass and decay length in different pt bin.
- Fit validation.
- Tag-probe method based on the real data.
- Real data analysis strategy.

Thank you!

Backup

Decay length





- Our result on cms
- (MC)Analysis result on LHCb