Measurement of Bc^+, B^+ production Cross Section at 7 TeV pp collision at CMS

ICTP-NCP school on LHC Physics

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On behalf of CMS Collaboration

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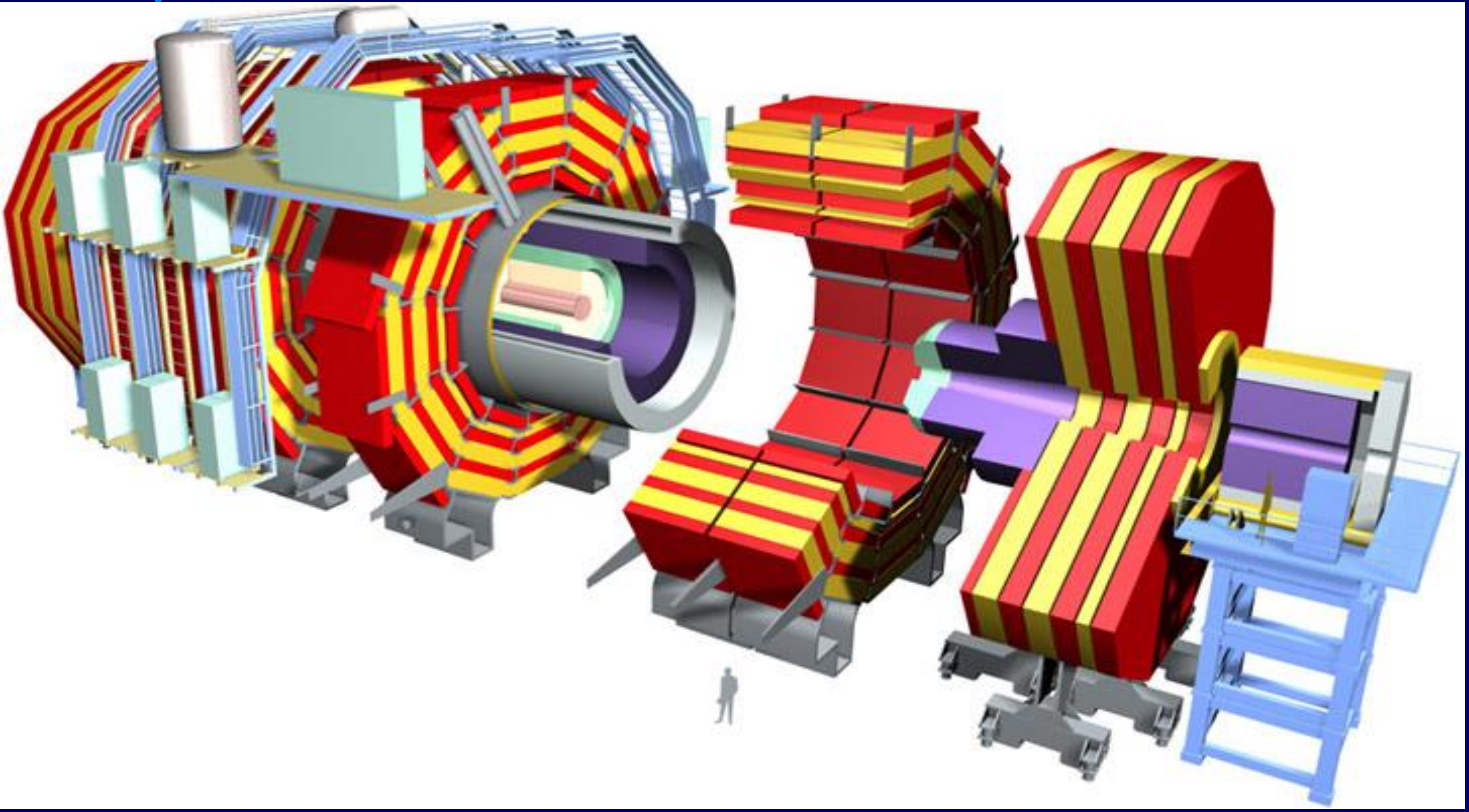
CMS Detector



Particle categorization

- Charged particles measured by tracking

  Stable or long-lived charged particles(e.g $e^{\pm}$,$\mu^{\pm}$,$\pi^{\pm}$,$K^{\pm}$,$P^{\pm}$)

- Charged particles measured by Calorimetery

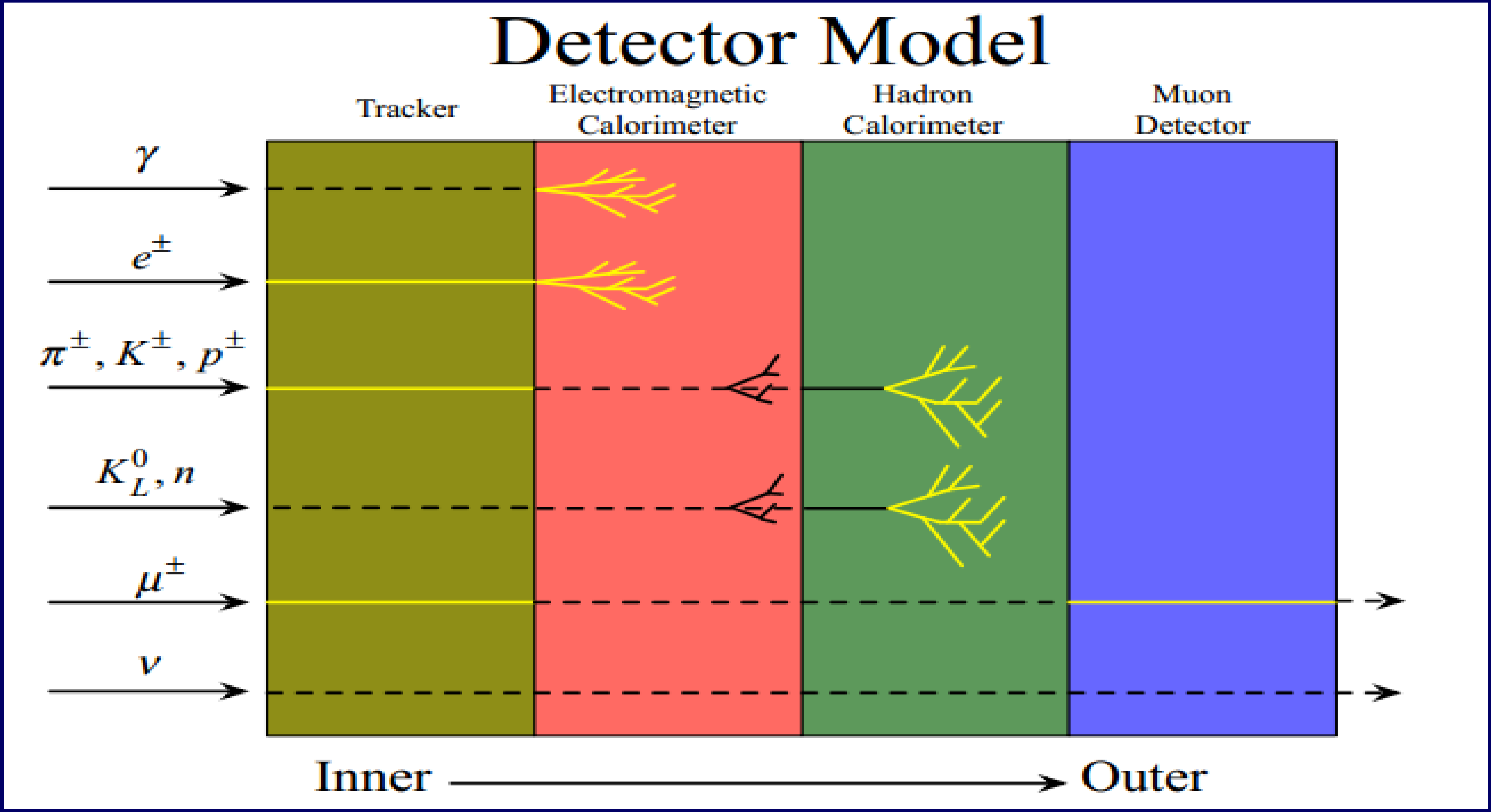
  Stable or long-lived neutral particle(e.g γ, k_L^0 , Neutrons)

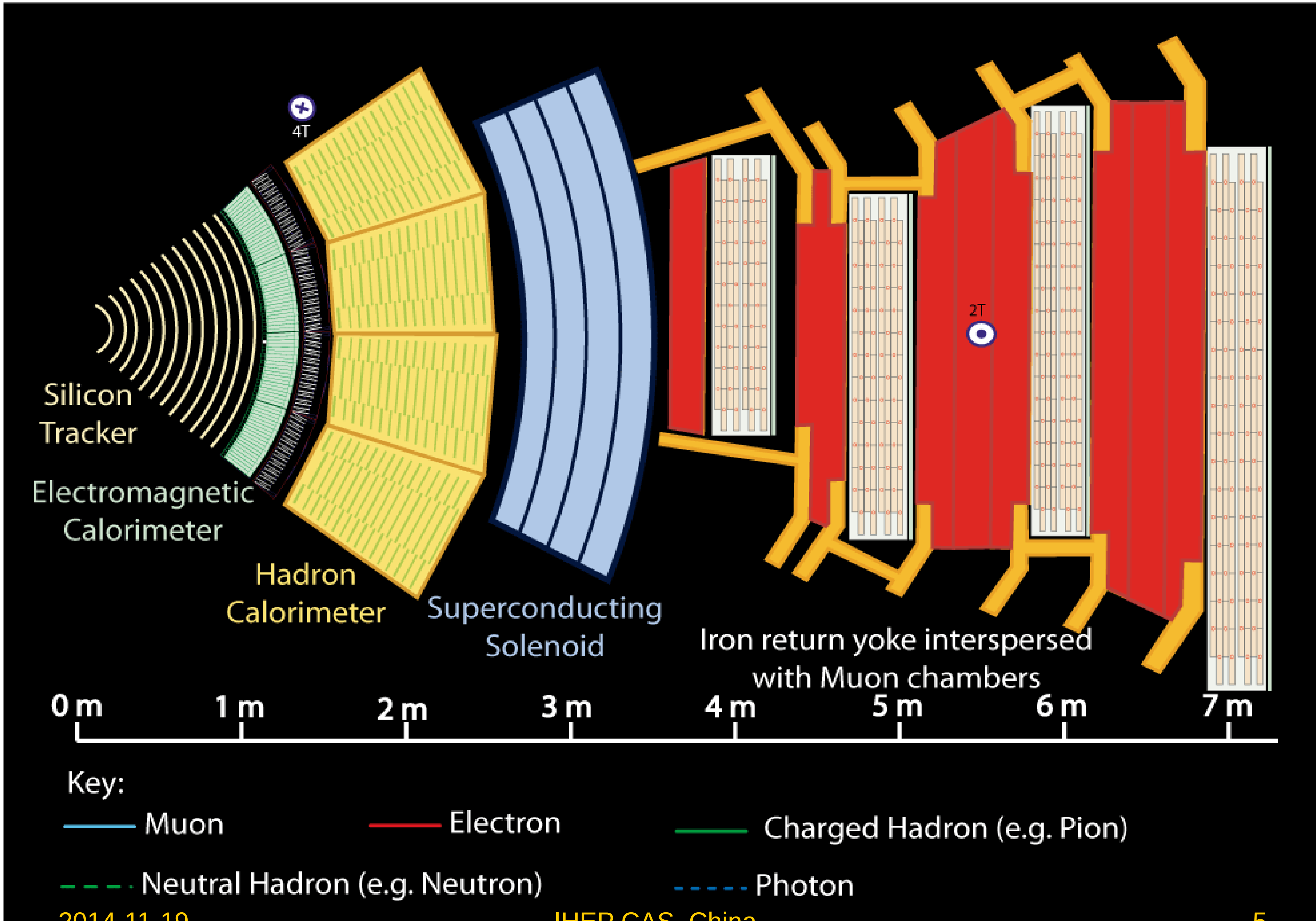
Unstable particles detected by their decay products:
(Ks, Λ and π^0)

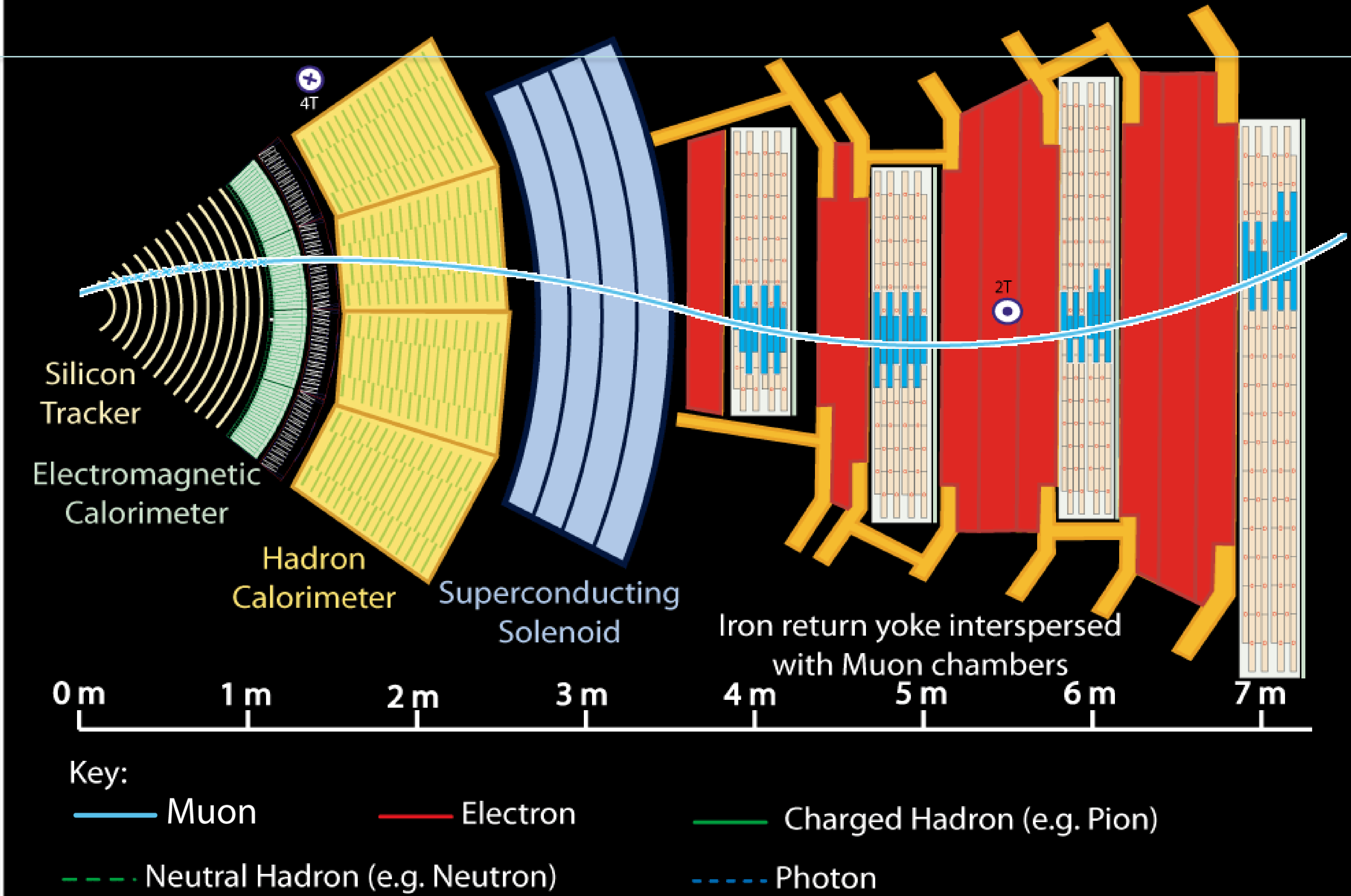
$$\pi^0 \rightarrow \gamma\gamma$$

$e^{\pm}$	Infinite
$\mu^{\pm}$	$c\tau_{\mu} = 660\,\mathrm{m}$
$\pi^{\pm}$	$c\tau_{\pi} = 7.8\,\mathrm{m}$
$K^{\pm}$	$c\tau_{K} = 3.7\,\mathrm{m}$.
$p^{\pm}$	Infinite

High Energy Physics Detector




4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
0 m
1 m
2 m
3 m
4 m
5 m
6 m
7 m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon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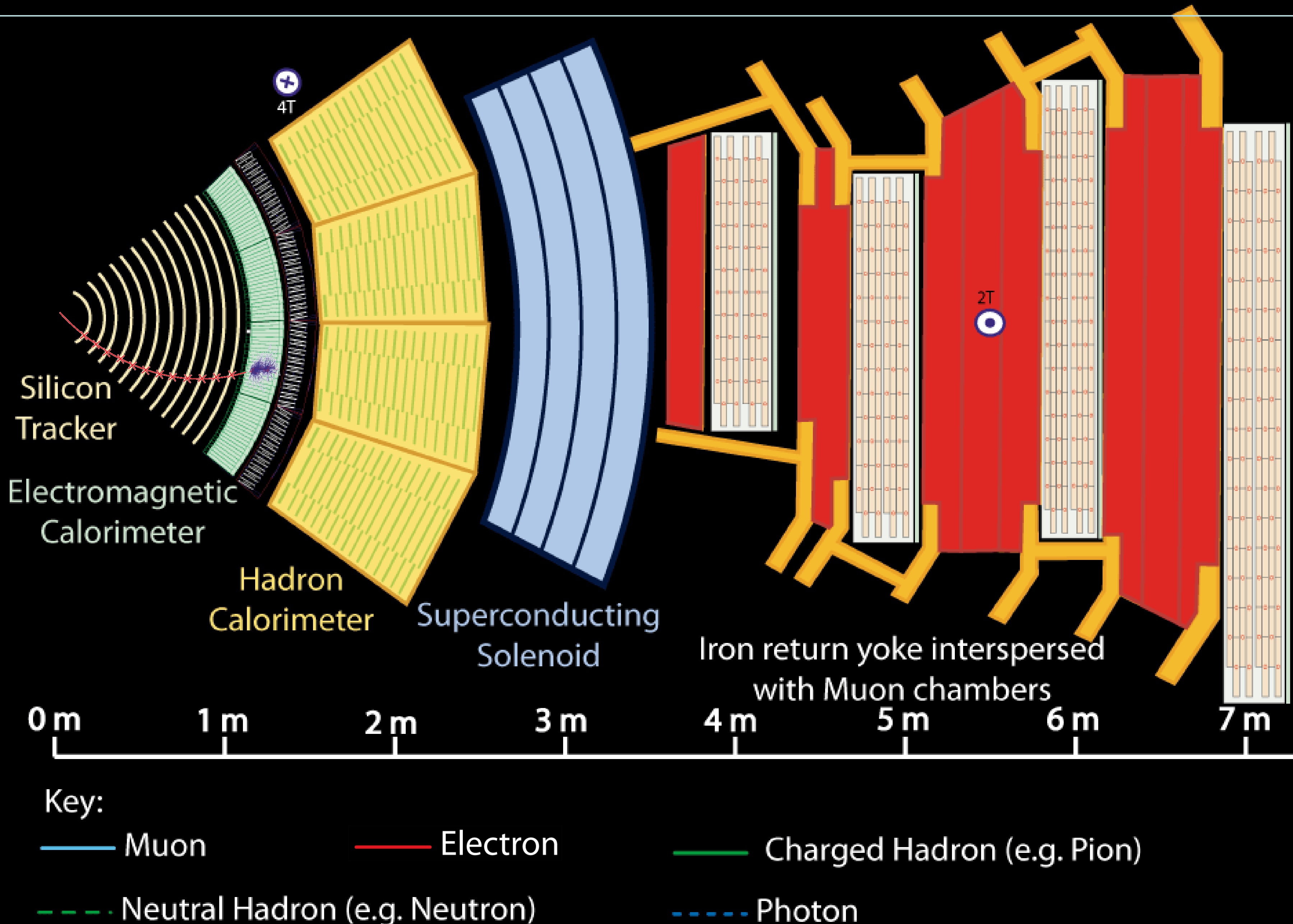
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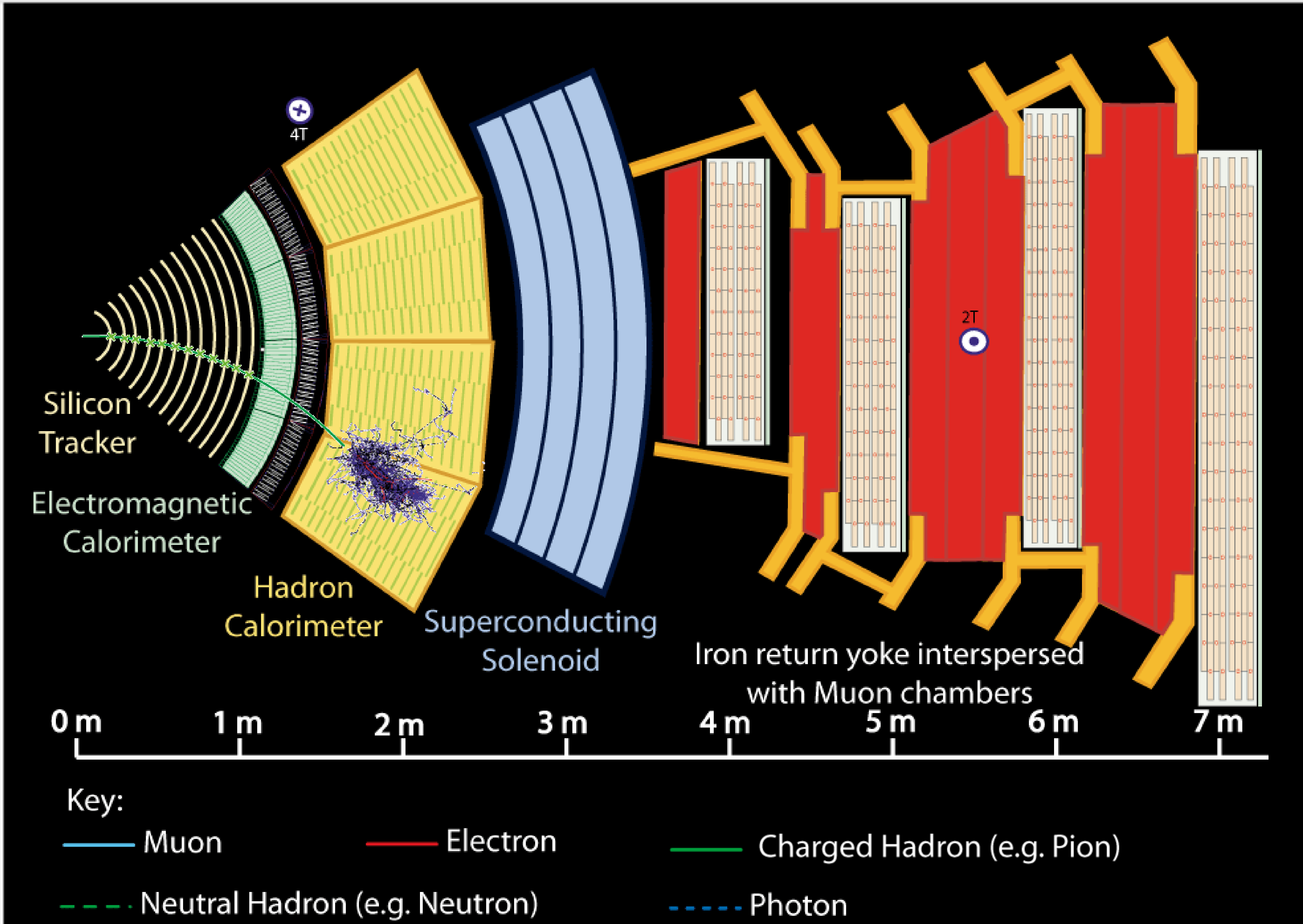
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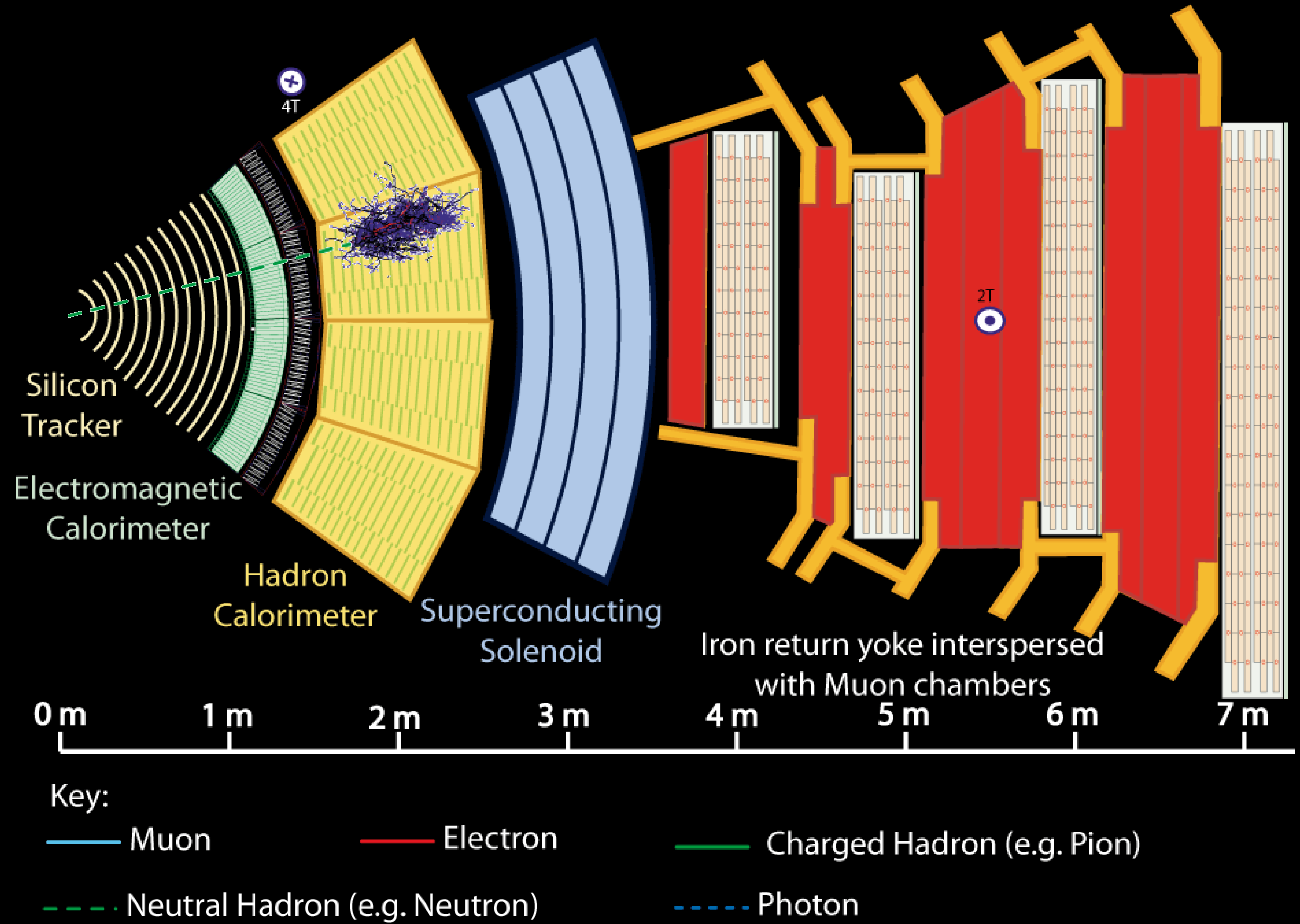
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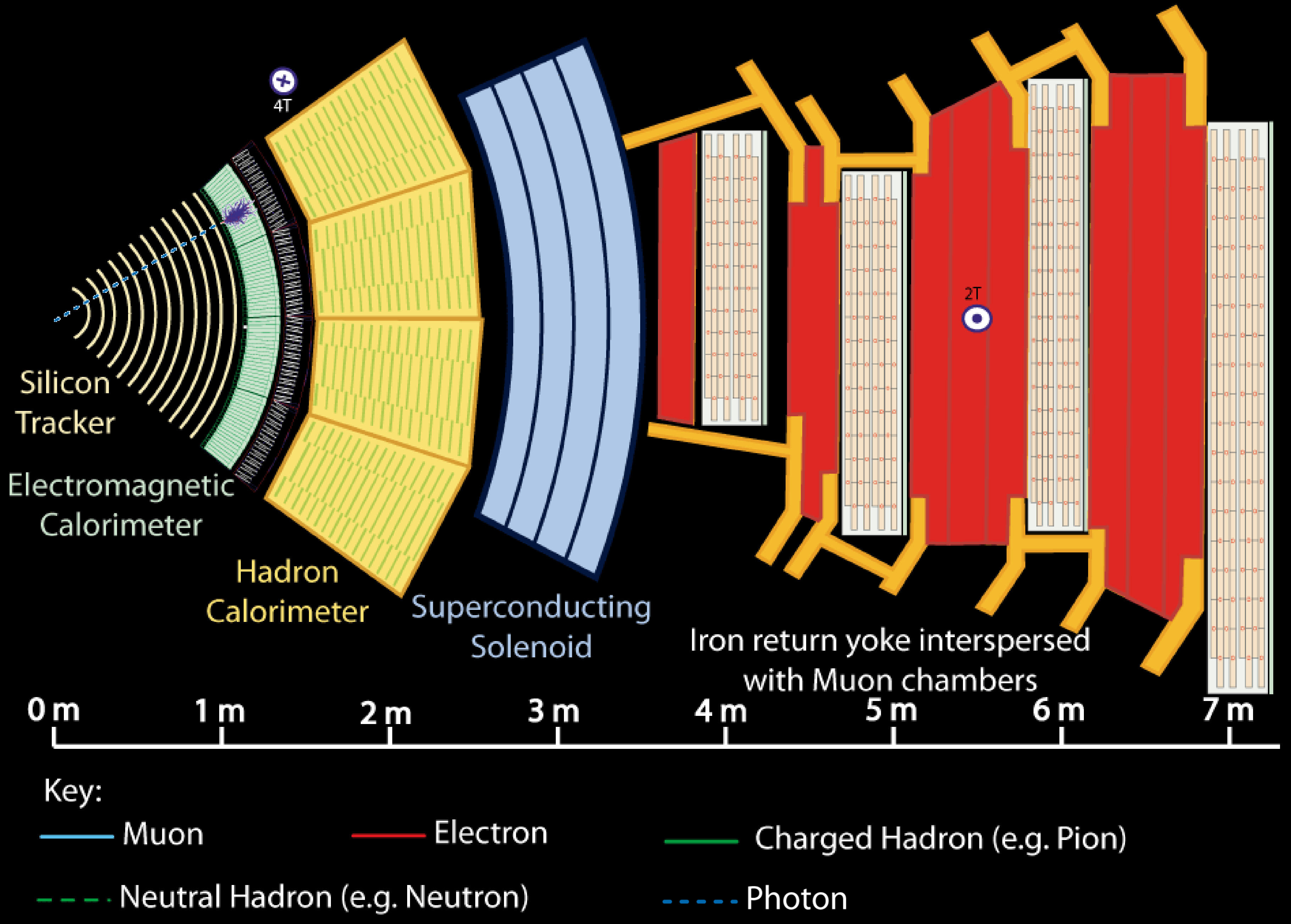
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B Meson Family

Particle	Symbol	Anti-particle	Quark content	Charge	Isospin (I)	Spin and parity (J^P)	Rest mass (MeV/c^2)	S	C	B'	Mean lifetime (s)
B meson	B^+	B^-	$u\bar{b}$	+1	½	0^-	5,279.15 ± 0.31	0	0	+1	$(1.638 \pm 0.011) \times 10^{-12}$
B meson	B^0	$\bar{B}^0$	$d\bar{b}$	0	½	0^-	5,279.53 ± 0.33	0	0	+1	$(1.530 \pm 0.009) \times 10^{-12}$
Strange B meson	B_s^0	$\bar{B}_s^0$	$s\bar{b}$	0	0	0^-	5,366.3 ± 0.6	−1	0	+1	$1.470^{+0.027}_{-0.026} \times 10^{-12}$
Charmed B meson	B_c^+	B_c^-	$c\bar{b}$	+1	0	0^-	6,276 ± 4	0	+1	+1	$(0.46 \pm 0.07) \times 10^{-12}$

$B_c^+(B^+) \to J/\psi\pi^+(K^+)$ Cross Section measurement

Measurement of B_c^+ and B^+ production Cross Section at 7 TeV pp collisions at CMS

Abstract

The results are presented for the measurement of the absolute differential production Cross Section of $B_c^+ \to J/\psi\pi^+$ and $B^+ \to J/\psi K^+$ process at $\sqrt{s} = 7$ TeV pp collision by the CMS experiment. The data-set was collected by the CMS detector in 2011, which corresponds to an integrated luminosity of 4.77 fb^{-1}. The B_c and B^+ differential cross sections are reported with respect to $B_c(B^+)$ p_T and rapidity (y). The integrated production Cross Section for B_c and B^+ with $p_T(B_c,\ B^+) > 10$ GeV/c and $|y(B_c,\ B^+)| < 1.5$ are measured to be $45.17 \pm 5.25^{+3.00}_{-3.12}$ pb and $6503.18 \pm 122.43 \pm 448.72$ pb respectively where the fist error is statistical and the second is systematic.

B Meson decays

B_c^+ DECAY MODES × B($\bar{b} \to B_c$)	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
The following quantities are not pure branching ratios; rather the fraction $\Gamma_i/\Gamma \times B(\bar{b} \to B_c)$.			
$J/\psi(1S)\ell^+\nu_\ell$ anything	$(5.2^{+2.4}_{-2.1}) \times 10^{-5}$		–
$J/\psi(1S)\pi^+$	$< 8.2 \times 10^{-5}$	90%	2372
$J/\psi(1S)\pi^+\pi^+\pi^-$	$< 5.7 \times 10^{-4}$	90%	2352
$J/\psi(1S)a_1(1260)$	$< 1.2 \times 10^{-3}$	90%	2171
$D^*(2010)^+\bar{D}^0$	$< 6.2 \times 10^{-3}$	90%	2468

B^+ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
Charmonium modes			
$\eta_c K^+$	$(9.1 \pm 1.3) \times 10^{-4}$		1753
$\eta_c K^*(892)^+$	$(1.2^{+0.7}_{-0.6}) \times 10^{-3}$		1648
$\eta_c(2S)K^+$	$(3.4 \pm 1.8) \times 10^{-4}$		1320
$J/\psi(1S)K^+$	$(1.014 \pm 0.034) \times 10^{-3}$		1683
$J/\psi(1S)K^+\pi^+\pi^-$	$(1.07 \pm 0.19) \times 10^{-3}$	S=1.9	1612
$h_c(1P)K^+ \times B(h_c(1P) \to J/\psi\pi^+\pi^-)$	$< 3.4 \times 10^{-6}$	CL=90%	1401
$X(3872)K^+$	$< 3.2 \times 10^{-4}$	CL=90%	1141
$X(3872)K^+ \times B(X \to J/\psi\pi^+\pi^-)$	$(9.5 \pm 1.9) \times 10^{-6}$	S=1.3	1141

J/ψ is reconstructed by its dimuon decay ($\mu^+\mu^-$)

Introduction

- With the discoveries of more and more b hadron states and their decay modes in last two decades, theoretical models provide rich predictions on b hadron production/decay: PYTHIA, perturbative QCD (BcVEGPY generation), … Need precise test by the high luminosity exp. Data.

- LHC/CMS is good exp. to perform the test:
  - Large production cross section of B hadron: Large B+ sample. Bc contains two different heavy quarks, production is much lower than $B_{u,d}$ hadron, nevertheless, LHC provided the largest Bc samples in the world.
  - CMS works in the central kinematic detection region : $0<|\eta|<2.4$, complementary with LHCb's measurement.

Introduction

- Bc^+/B^+ cross section ratio and B^+ absolute cross section measurements published so far by the LHC experiments for pp collisions at 7 TeV.
- CMS two publications: Phys.Rev.Lett. 106 (2011) 112001 (5.8pb^{-1}, 2010 data) and CMS-PAS-BPH-12-011 (Bc/B^+, 2011 data) . ATLAS 2.4fb^{-1}: JHEP10(2013)042.

This analysis select the similar decay topology of Bc and B^+, $Bc^+ \rightarrow J/\psi\pi^+$ and $B^+ \rightarrow J/\psi K^+$, to measure the absolute cross section $d\sigma/dp_T$ and $d\sigma/d|y|$; Use the same analysis strategy.

$Bc^+ \rightarrow J/\psi\pi^+$ absolute production cross section measurement for the first time.

Measurement Strategy

$$\frac{d\sigma(pp \to B_c^+(B^+)\,X)}{dp_T^{B_c^+/B^+}} \cdot Br(B_c^+(B^+) \to J/\psi\pi^+(K^+)) = \frac{N_{sig}}{2 \cdot \varepsilon \cdot Br(J/\psi \to \mu\mu) \cdot \Delta p_T(|y|) \cdot \mathcal{L}}$$

- **Nsig**: Observed $Bc^{\pm}(B^{\pm}) \to J/\psi\pi^{\pm}(K^{\pm})$ event number in the given pT or |y| bin.
- **ε**: the full measurement efficiencies of $Bc^{\pm}(B^{\pm}) \to J/\psi\pi^{\pm}(K^{\pm})$ process。
- **L**: $4.77\times(1\pm4\%)$ fb^{-1}.
- **$Br(J/\psi\to\mu\mu)$** = $(5.93\pm0.06)\times10^{-2}$ (PDG);
- **$\Delta p_T(|y|)$**: bin width
- **2 :** accounts for our choices of quoting the Bc^+ (B^+) cross section..

Event selection

Data sample and trigger paths

Sample	Run range	Number of events	$\mathcal{L}(pb^{-1})$	trigger menu
/MuOnia/Run2011A-PromptReco-v4/AOD	165071-168437	26987206	970	1E33+1.4E33
/MuOnia/Run2011A-PromptReco-v5/AOD	170053-172619	8202804	357	2E33
/MuOnia/Run2011A-PromptReco-v6/AOD	172620-175770	9501198	706	2E32+3E33
/MuOnia/Run2011B-PromptReco-v1/AOD	175832-180296	27752865	2741	3E33+5E33

Cert_160404-180252_7TeV_PromptReco_Collisions11_JSON.txt

- Used data taken in 2011, start from 1E33 trigger menu.
- Total integrated luminosity: 4.77(1±4%) fb^{-1}
- Data are pre-selected by the muon displaced trigger with the evolution of trigger menu in 2011 data taking.

Run range	Menu	Trigger path	$\mathcal{L}(pb^{-1})$	L1 seed
163269-163869	5e32	HLT_Dimuon6p5_Jpsi_Displaced_v1	174.7	L1_DoubleMu0
165088-167043	1e33	HLT_Dimuon7_Jpsi_Displaced_v1	709.0	L1_DoubleMu0
166346-166346	1e33	HLT_Dimuon7_Jpsi_Displaced_v2	4.3	L1_DoubleMu0
167078-167913	1.4e3	HLT_Dimuon7_Jpsi_Displaced_v3	244.7	L1_DoubleMu0
170249-172868	2e33	HLT_DoubleMu3p5_Jpsi_displaced_v2	824.5	L1_DoubleMu0
173236-177053	3e33	HLT_DoubleMu4_Jpsi_displaced_v1	2071	L1_DoubleMu0_HighQ
178421-179889	5e33	HLT_DoubleMu4_Jpsi_displaced_v4	697.4	L1_DoubleMu0_HighQ
179959-180252	5e33	HLT_DoubleMu4_Jpsi_displaced_v5	113.0	L1_DoubleMu0_HighQ

The data sets are consistent with Muon T-P analysis of CMS AN-2011-417

Muon and J/ψ Selection

Use the standard T-P muon selection, and displaced J/ψ trigger definition of CMS B group to reconstruction J/ψ decaying from Bc and B^+, keep long life time signal, remove the prompt J/ψ background.

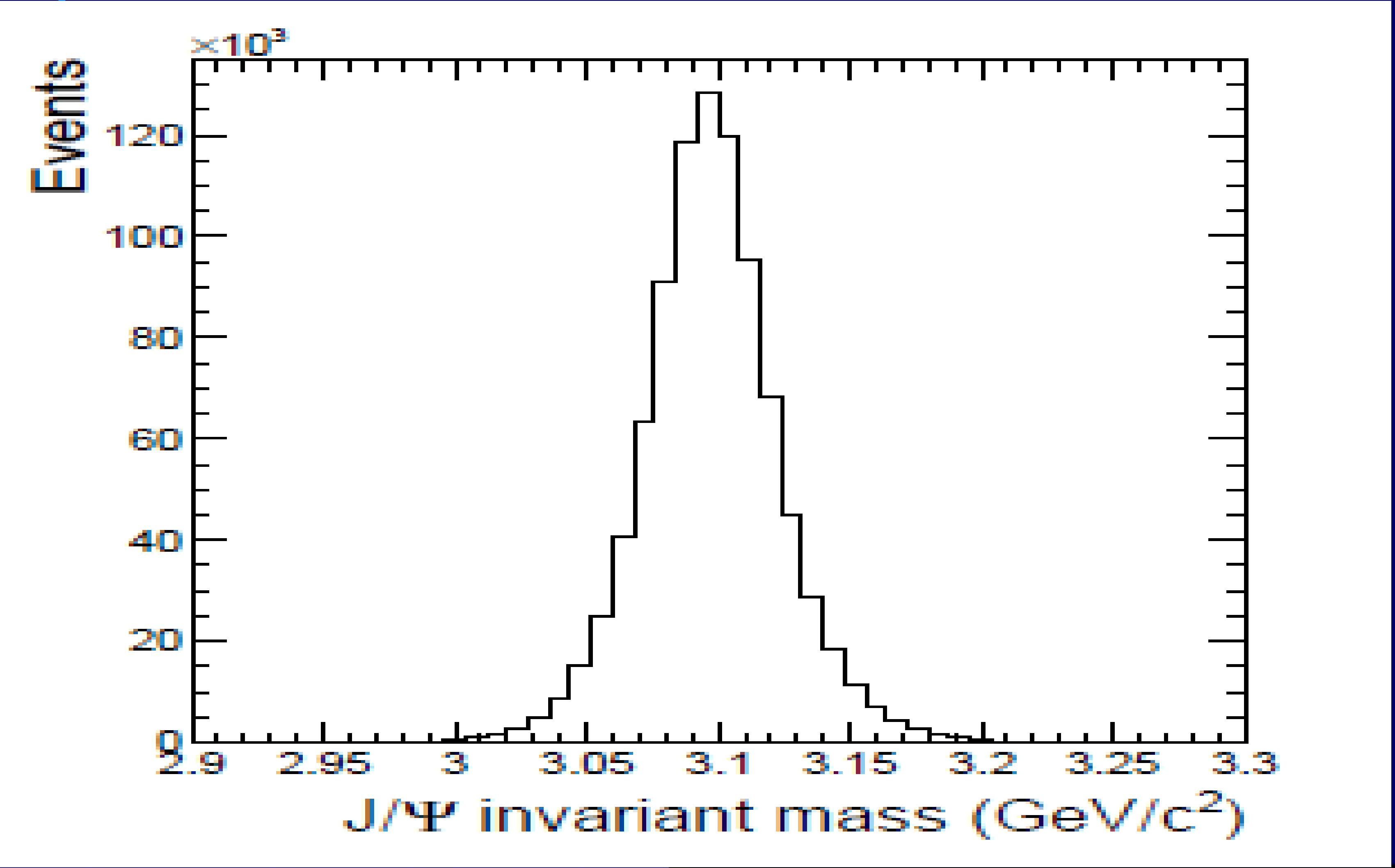
- Muon selection as the same as Muon T-P analysis: CMS AN AN-11-417) .

numberOfValidHits >10
χ^2/ndof<1.8 (track fit)
TrackerMuonArbitrated
TMOneStationTight
pixelLayersWithMeasurement > 1
|dB|< 3.0 cm and |dz | <15cm
numberOf ValidMuonHits > 0 (Gmuon)
Norm global track χ^2/ndof<20(Gmuon)

- After the pre-selected by the muon displaced trigger with the evolution of trigger, offline J/ψ reconstruction with cuts of HLT_DoubleMu4_Jpsi_displaced_v1(v4,v5)
- Keep all the J/$\psi(\mu^+\mu^-)$ combination.

J/ψ mass	(2.98, 3.22)
J/ψ p_T	> 6.9 GeV/c
J/ψ Cosα	> 0.9
J/ψ Lxy/σ	>3
J/ψ LxyDCA	< 0.5
J/ψ VtxCL	> 0.15

J/ψ Signal peak



$J/\psi\pi^{\pm}(K^{\pm})$ reconstruction

Pion(kaon), muon kinematic selection

- $p_T(\pi,K)>2.3$ GeV/c
- $N_{hit}(\pi,K)>10$, $P_{hit}(\pi,K)>1$, π/K Norm$\chi^2<3$.
- $p_T(\mu)>4$GeV/c. $|\eta(\mu)|<2.2$

The track and J/ψ candidate are subjected to the combined vertex and kinematic fit (kinematicConstrainedVertexFitter).

VtxPro($J/\psi\pi$,K)>0.03, Lxy/σ($J/\psi\pi$,K)>4.0

$J/\psi\pi^{\pm}(K^{\pm})$ requirement:

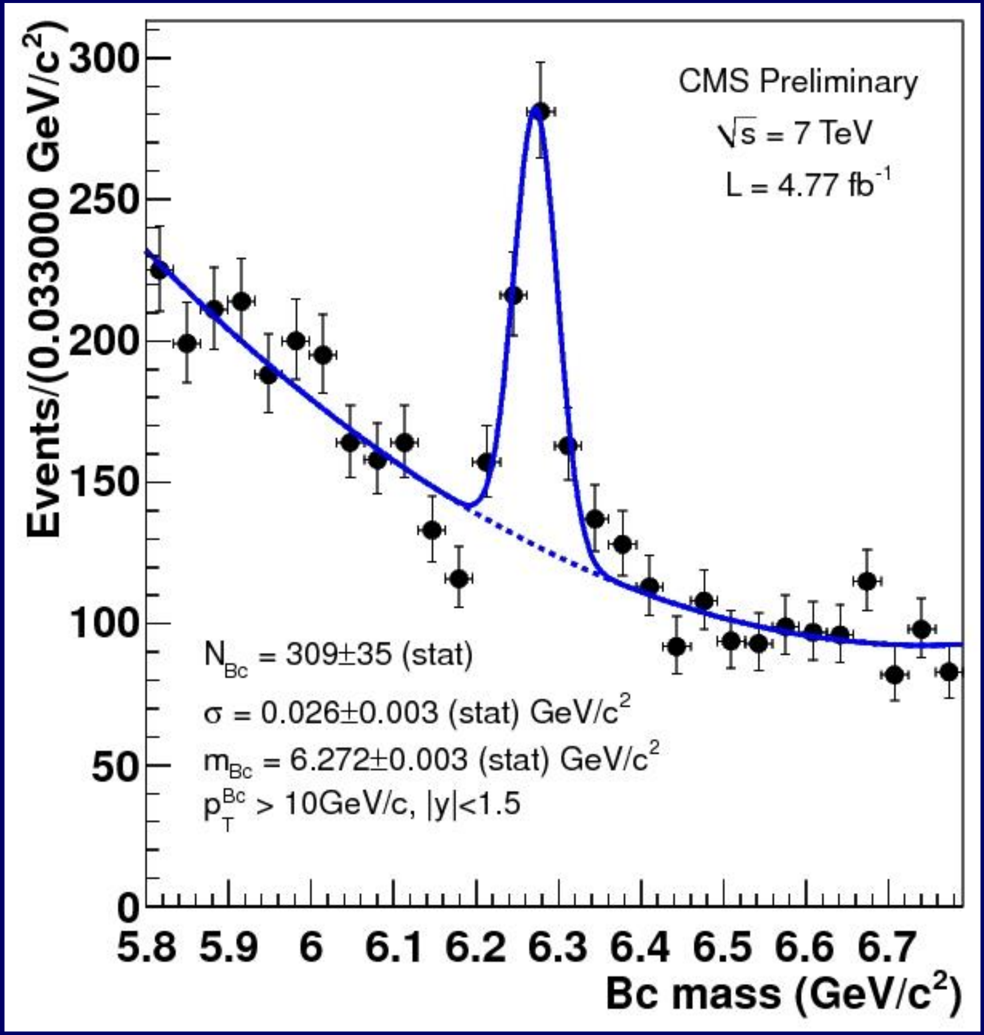
- Cosα($J/\psi\pi$,K)>0.98
- $|Y(J/\psi\pi,K)|<1.5$, $p_T(J/\psi\pi,K)>10$
- 5.6< M(Bc) <6.8; 5.0< M($B^{\pm}$) <5.55;

Checked the data/MC consistency, as well as each cut efficiencies ,significance with the Bc MC and real data samples.

Bc±(J/ψπ±) mass and fit

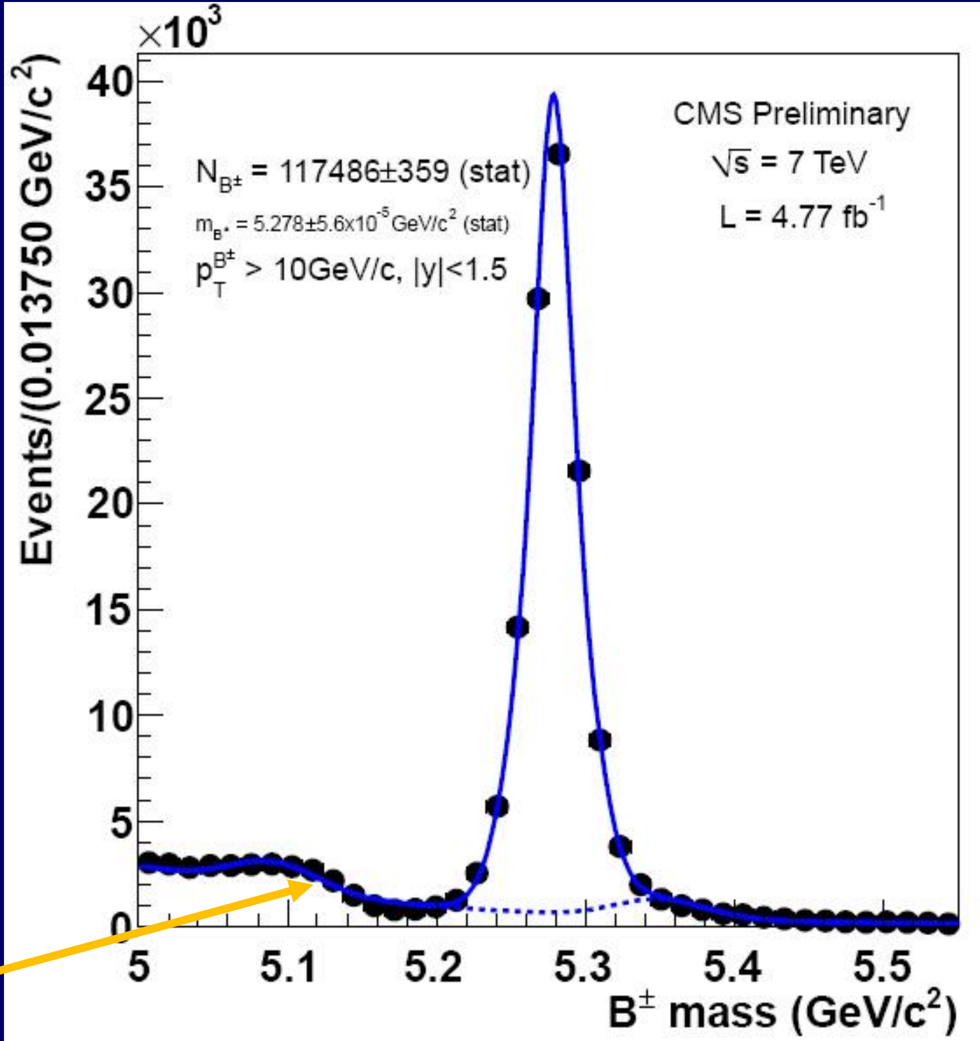
- Gaussian for the signal.
- 2nd order chybeshev polynomial for BG.
- Significance

$$S/\sqrt{S+B} = 11.4$$



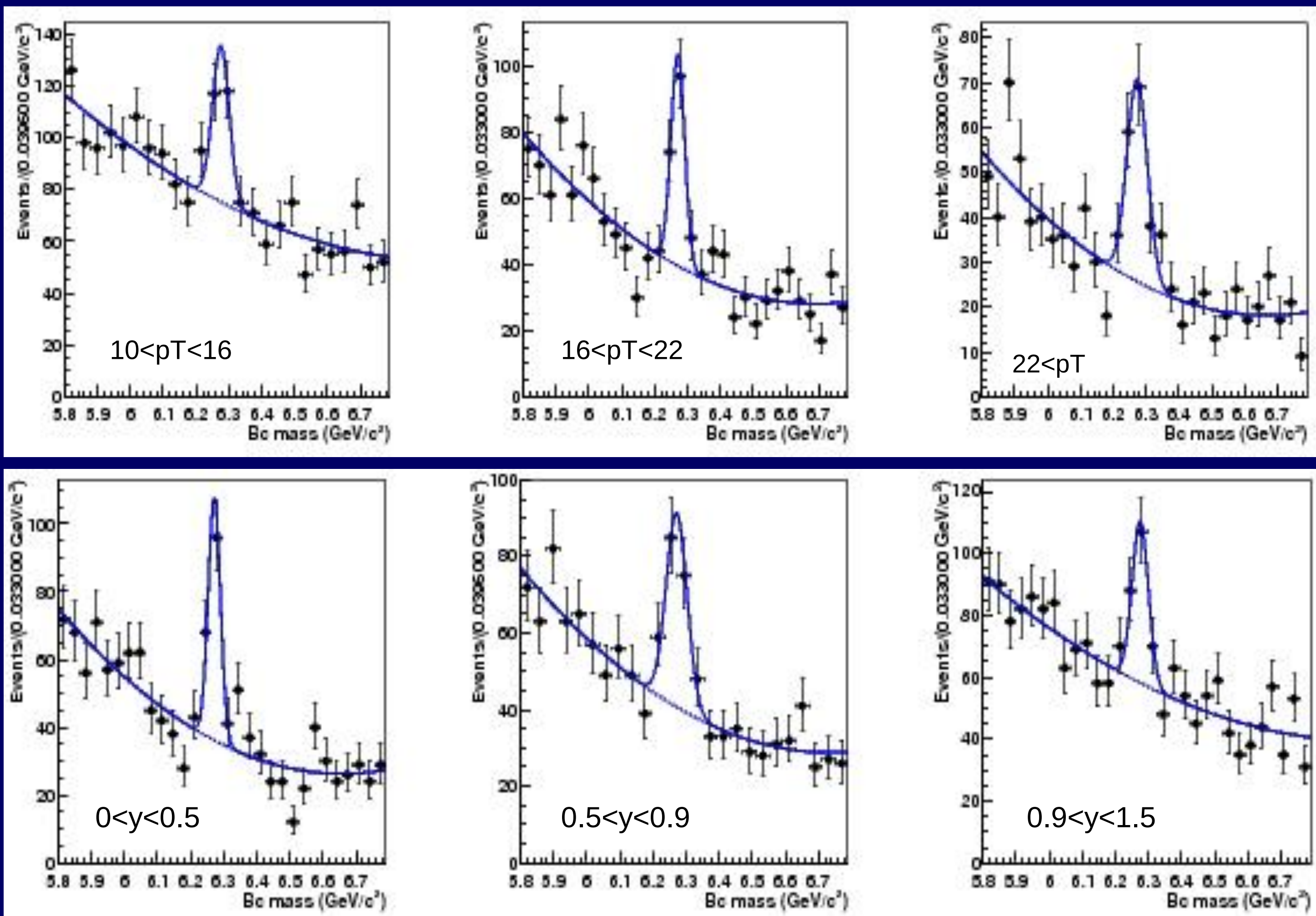
$B^{\pm}$ ($J/\psi K^{\pm}$) mass and fit

- Signal: three Gaussians.
- Bg: Gaussian for B^0 et al. Exponential for flat BG.
- $B^{\pm} \to J/\psi \pi^{\pm}$ is fixed to the parameters obtained from MC.



$B^0 \to J/\psi K^0(K\pi)$ et, al.

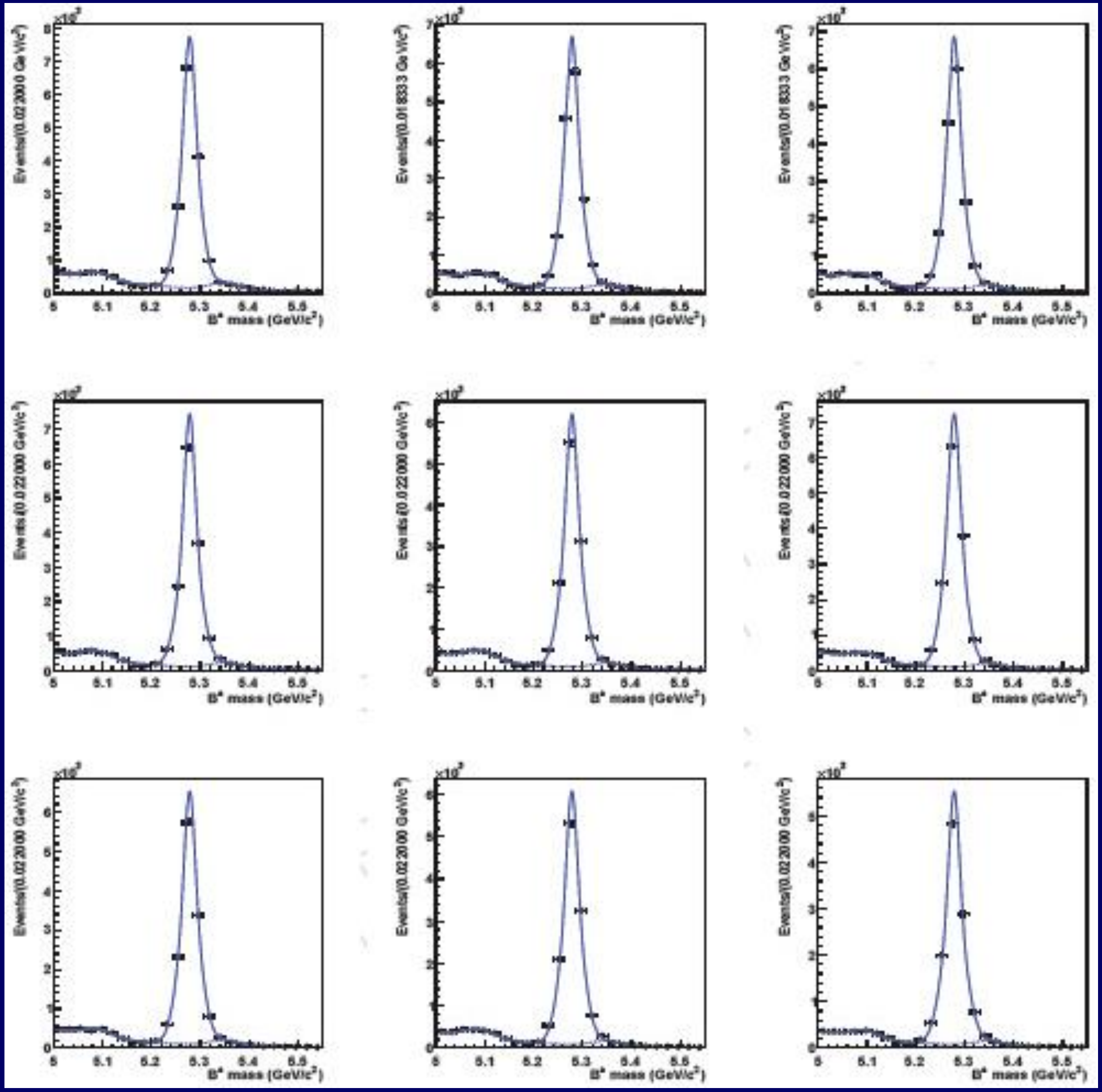
Bc mass in pT/|y| bin



- To calculate the differential cross section we divide into 3 p_T and 3 |y| bins for Bc , 9 p_T and 9 |y| bins for B^+. Partitioning of pT and |y| bins is done to keep the number of events and statistical close within all bins.
- Mass is fixed, resolution is free.

$B^{\pm}$ mass in 9 pT bins

$p_T^{B_c}$	n_{sig}
10-14	14277.3 ± 128.1
14-16	14752.0 ± 129.7
16-18	15148.2 ± 121.5
18-20	13612.1 ± 118.7
20-22	11573.4 ± 111.8
22-25	13493.9 ± 120.9
25-29	12353.7 ± 110.3
29-36	11596.1 ± 111.3
36-120	10721.0 ± 109.3

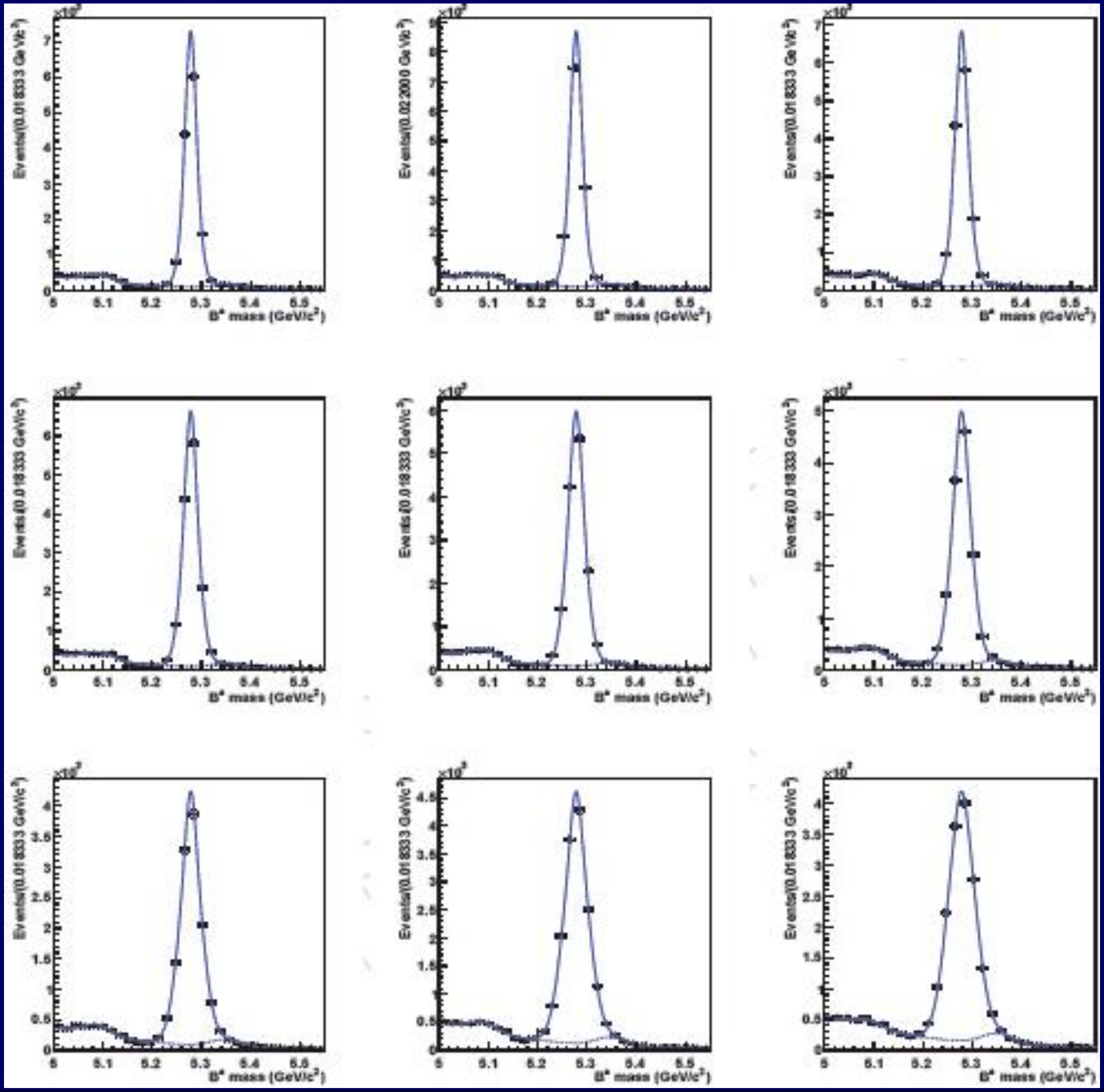


Mass is fixed, resolution is free.

Binning selection keep the stat. error of the data/MC samples be in same order with sys. Error.

$B^{\pm}$ mas in 9 |y| bin

$\lvert y^{B_c} \rvert$	n_{sig}
0-0.15	12637.7 ± 113.2
0.15-0.3	12745.3 ± 116.4
0.3-0.45	12993.2 ± 116.5
0.45-0.6	13583.0 ± 119.0
0.6-0.75	13561.3 ± 120.8
0.75-0.9	12438.3 ± 117.6
0.9-1.05	11492.5 ± 247.0
1.05-1.25	14075.1 ± 126.3
1.25-1.5	14603.2 ± 133.6
	n_{sig}
Total bins	117486.38 ± 359.44



Mass is fixed, resolution is free.

Binning selection keep the stat. error of the data/MC samples be in same order with sys. Error.

$Bc(B^{\pm}) \rightarrow J/\psi\pi(K^{\pm})$ efficiency

Efficiencies are computed from a combination of data-driven technique(T&P) and MC simulation.

$$\text{Efficiency} = \text{Acc} \times \varepsilon_{\text{Total\_MC}} \times \alpha_{2\mu} \times \alpha_{\text{Disp-trigger}}$$

- **Acc**: acceptance。
- $\varepsilon_{\text{Total-MC}}$: MC efficiency except acceptance。
- α_{2mu}: : Correction factor for muon trigger, ID , quality requirements. It is the ratio between real data muon T-P efficiency and MC Muon T-P efficiency.
- α_{Disp}: Correction factor for the displaced J/ψ requirement in the analysis. It is the efficiency ratio of displaced J/ψ cuts between the real data and MC sample.

MC samples

Sample	Events	ε_{filter}	$\sigma(pb)$	$\mathcal{L}(pb^{-1})$
/BctoJPsipi_Bcvegpy_Sum12/xywang-BctoJPsiPi_HLTBPH2011_RECO-0a2dd2255eed315a6c242ad2b584c6d9/USER	1490439		301162	
/BpToPsiMuMu_2MuPEtaFilter_Tight_7TeV-pythia6-evtgen/Fall11-HLTBPh2011_START42_V14B-v2/AODSIM	8380592	3.188×10^{-4}	2.98×10^{7}	842

- MC samples are used to calculate the acceptance and parts of efficiencies.
- Bc are generated by BCVEGPY, $B^{\pm}$ are generated by PYTHIA.
- Samples are published and available at DBS.
- Muon Tag&Probe samples of 2011 data were used to calculated the muon efficiency and correction.

Acceptance: Acc

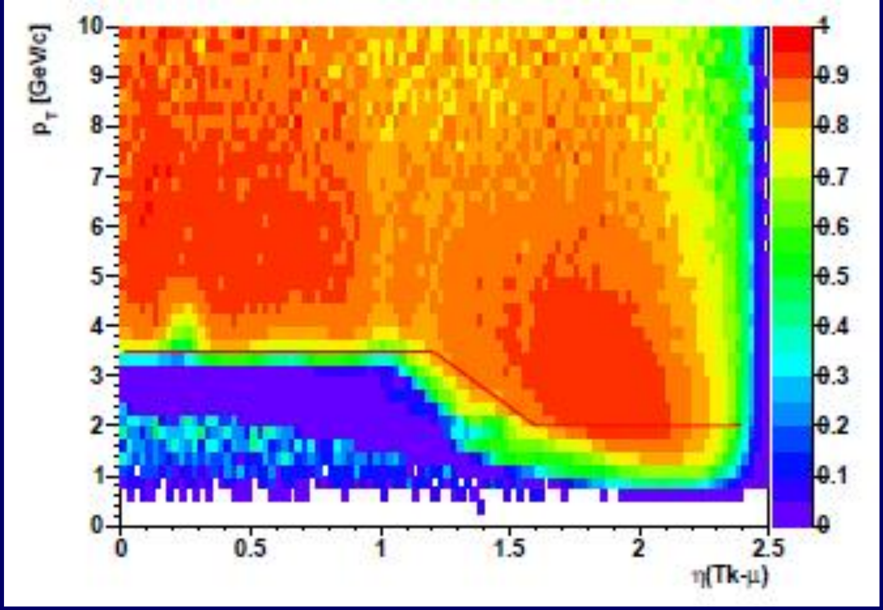
Use the MC sample without reconstruction, without any kinematic filter.

$$Acc = \frac{N^{gen}(B^{B\to J/\psi\pi(K)}_{PassedAcc.cut})}{N^{gen}(B^{B\to J/\psi\pi(K)}_{BeforeAcc.cut})}$$

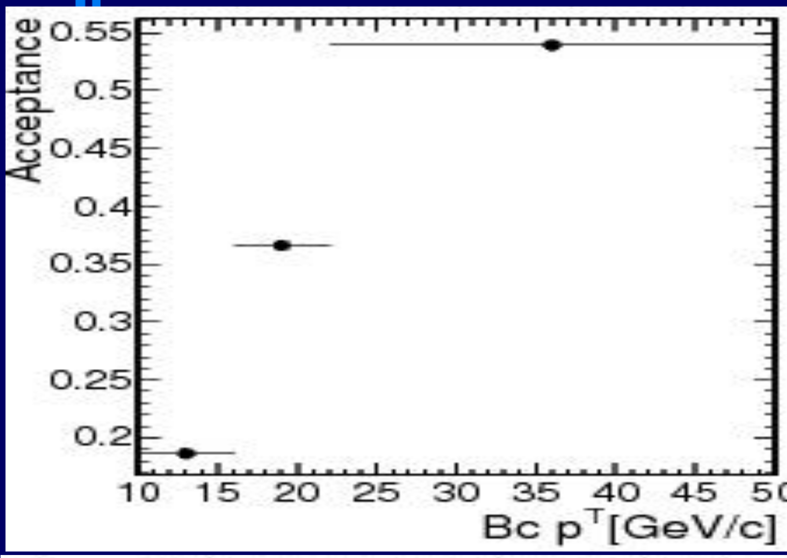
$$Acc. = \frac{N\{B_c(p_T > 10\ GeV/c;, |y| < 1.5), J/\psi(p_T > 6.9\ GeV/c;), \mu(acc.);\}}{N\{B_c(p_T > 10\ GeV/c;, |y| < 1.5)\}}$$

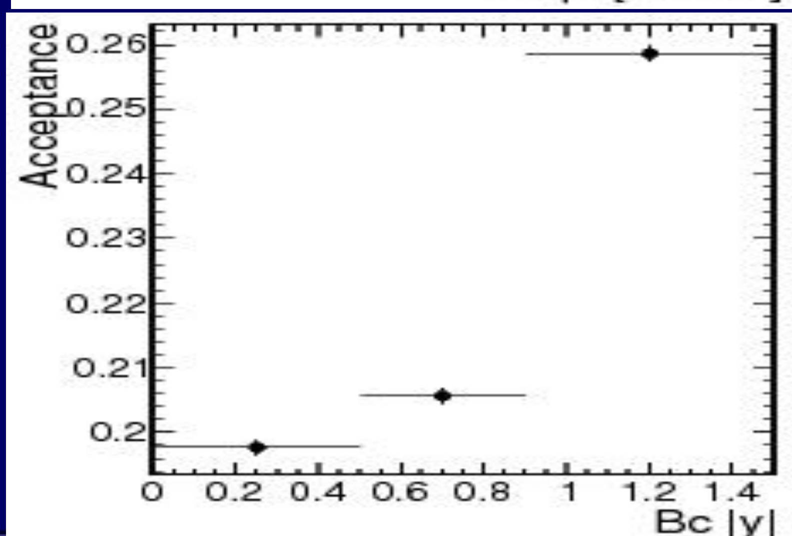
$\lvert\eta\rvert < 1.2:$	$p_{T,min} = 3.5\ \mathrm{GeV}/c$
$1.2 < \lvert\eta\rvert < 1.6:$	$p_{T,min} = 3.5 \to 2.0\ \mathrm{GeV}/c$
$1.6 < \lvert\eta\rvert < 2.4:$	$p_{T,min} = 2\ \mathrm{GeV}/c$

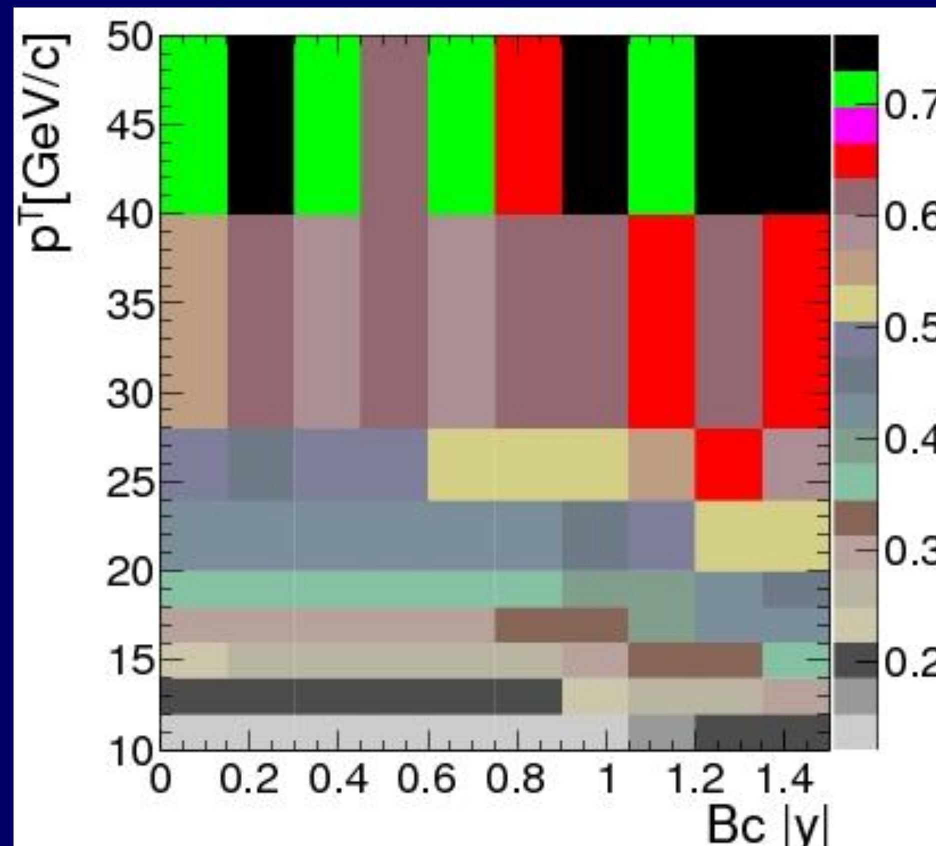
- Use the muon acc. cut "track50" in of muon T-P note AN2011-417.
- Corresponding T-P samples were used in the analysis for the Moun T-P efficiency calculation.



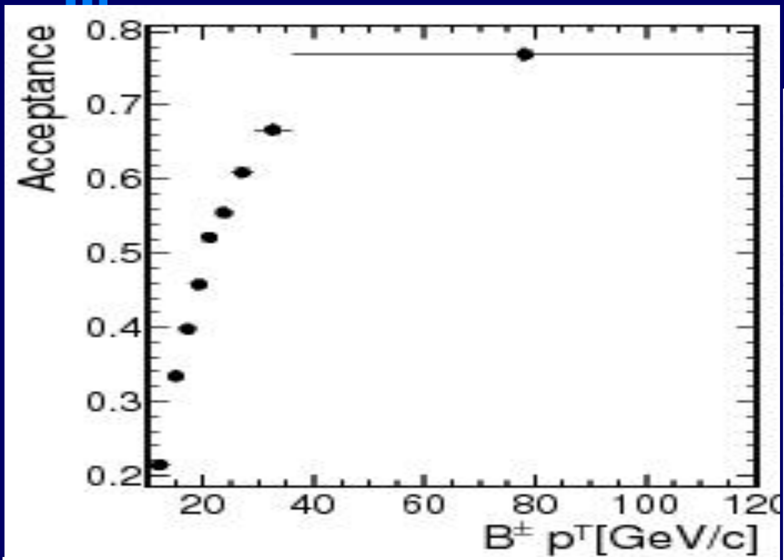
Bc→J/ψπ acceptance

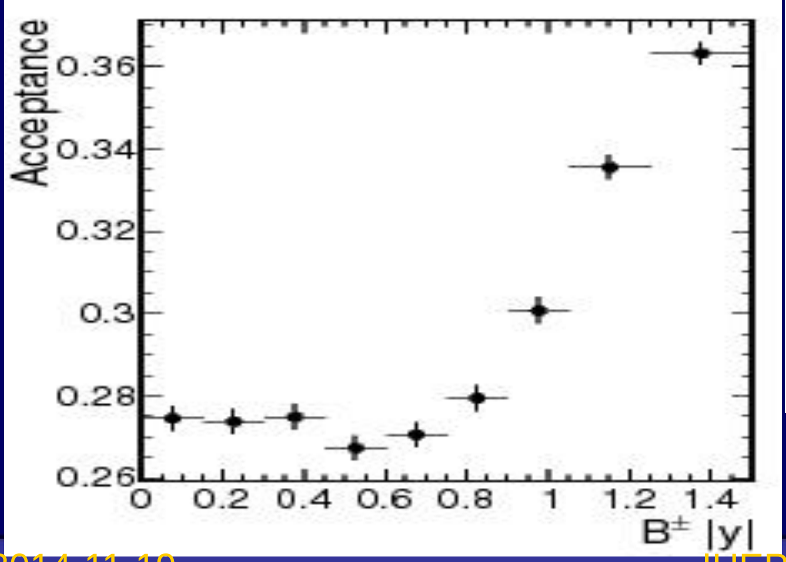


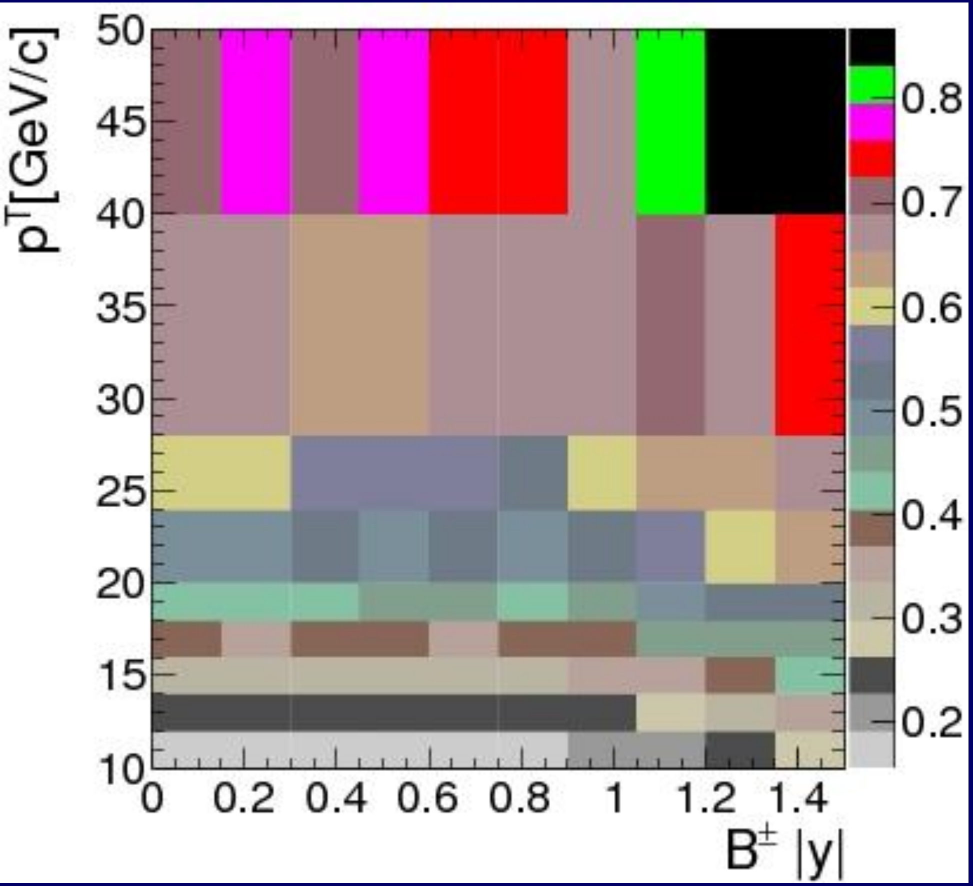




$B^+ \to J/\psi K^+$ Acceptance

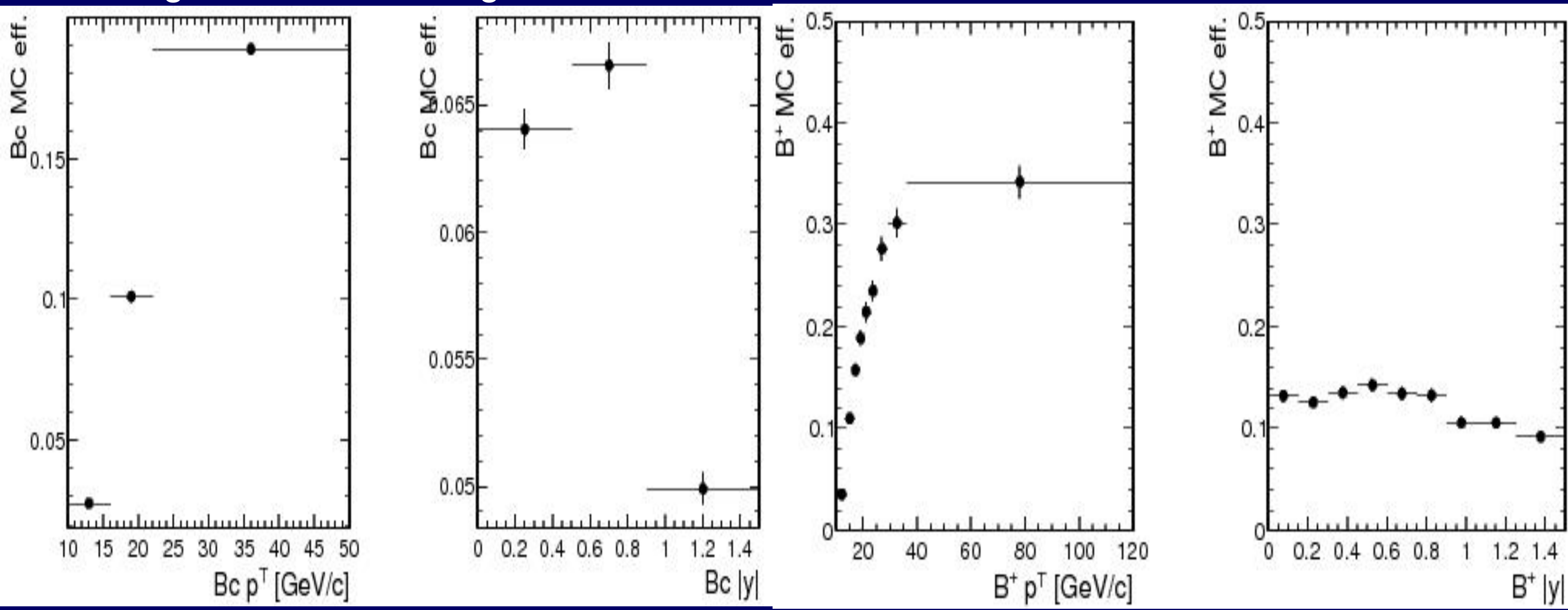






$$\varepsilon_{Total\_MC} = \frac{N^{reco\_match(fit)}(B^{B\to J/\psi\pi(K)}_{Passed\_all\_cuts})}{N^{gen}(B^{B\to J/\psi\pi(K)}_{Passed\_Acc.\_cut})}$$

- $N^{gen}(B^{B\to J/\psi\pi(K)}_{Passed\_Acc.cut})$: MC generated Bc, B^+ events after the Acc.
- $N^{reco\_match(fit)}(B^{B\to J/\psi\pi(K)}_{Passed\_all\_cut})$: Bc, B^+ events after all the cuts, ΔR matched with generated Bc using ΔR.



Muon Correction Factor

$$\alpha_{muonT-P} = \frac{\varepsilon^{B\to J/\psi\pi(K)}(2\mu\_T\&P\_Data)}{\varepsilon^{B\to J/\psi\pi(K)}(2\mu\_T\&P\_MC)}$$

Correction factor for the muon trigger, ID , quality requirement. Ratio between the real data muon T-P efficiency and MC Muon T-P efficiency.

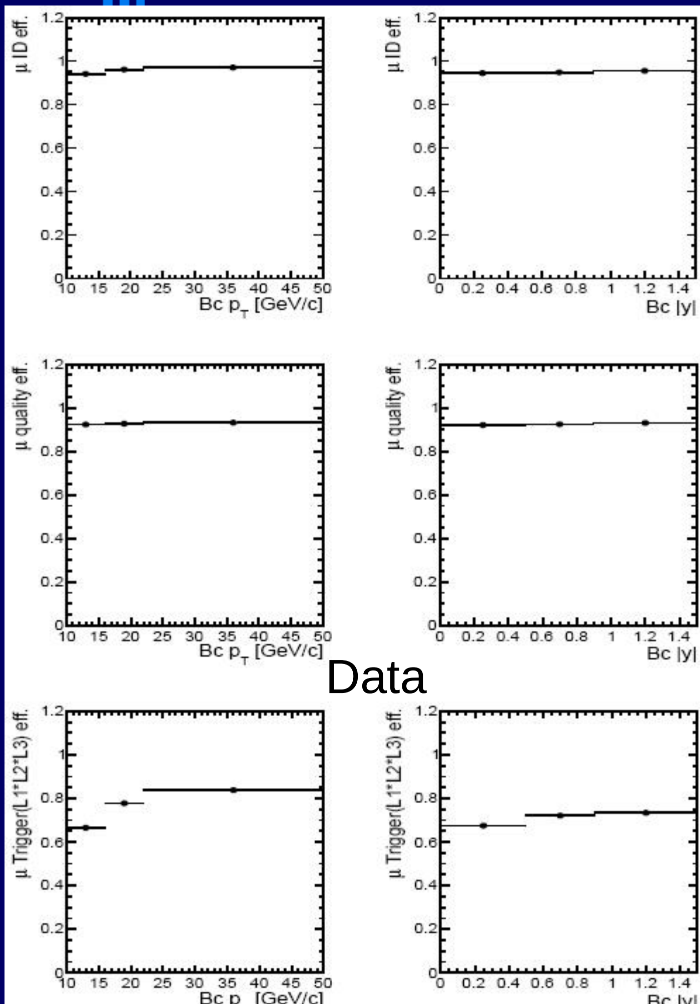
$$\varepsilon_{\mu} = \varepsilon_{tracking} \times \varepsilon_{ID} \times \varepsilon_{Qual} \times \varepsilon_{L1.L2} \times \varepsilon_{L3}$$

$$\varepsilon_{D\mu} = \varepsilon_{\mu_1} \times \varepsilon_{\mu_2}$$

$$\varepsilon_{2\mu}(p_T,\ |y|) = N(p_T,\ |y|) / \sum_{i=0}^{i=N(p_T,\ |y|)} \frac{1}{\varepsilon_{D\mu,\ i}}$$

N(pT, |y|): the number of signal events with two muons within acceptance in Bc ($B^{\pm}$) p_T or |y| bins.

Muon efficiency

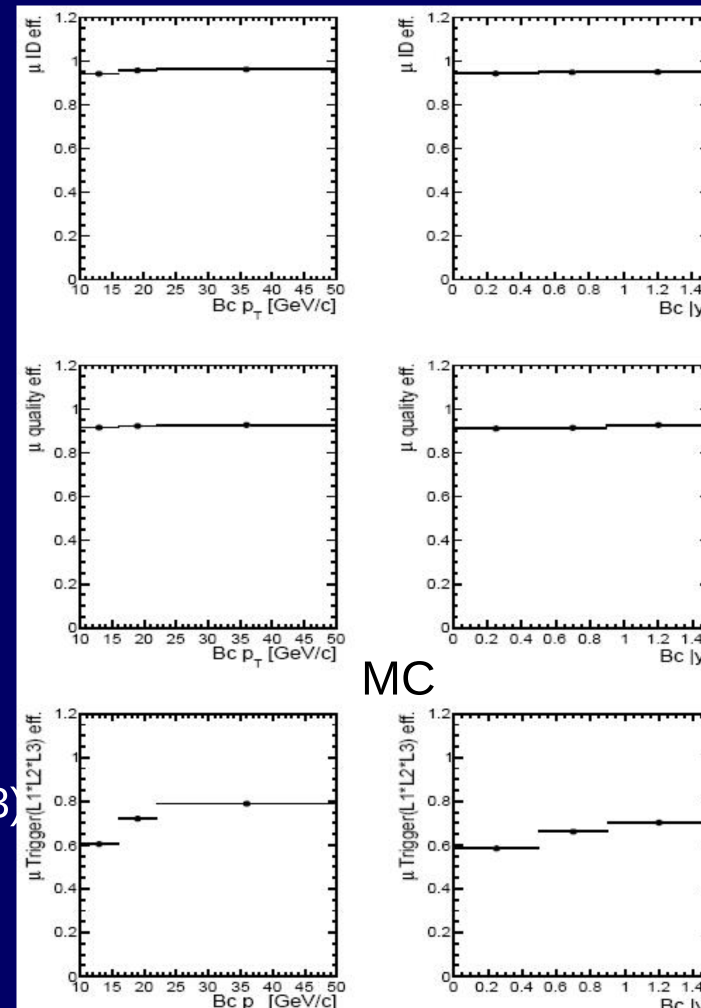


Muon ID efficiency

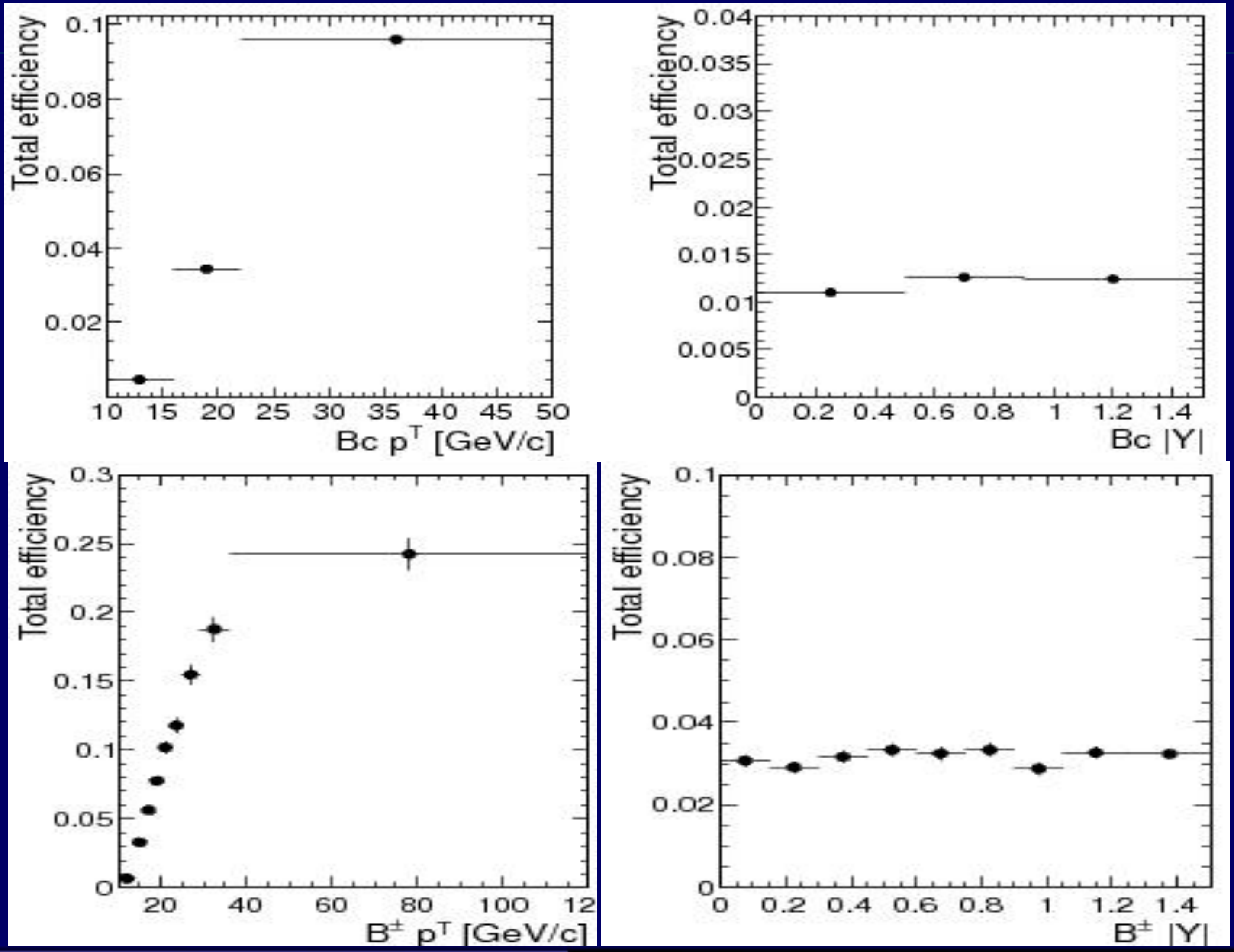
Muon quality efficiency

Muon trigger(L1,2,3) efficiency

Muon tracking eff. 99.0(1±0.01)%



Efficiency = Acc × ε_{Total_MC} × $\alpha_{2\mu}$ × $\alpha_{Disp\text{-}trigger}$



Systematic errors

$$\frac{d\sigma(pp \to B_c^+(B^+)X)}{dp_T^{B_c^+/B^+}} \cdot Br(B_c^+(B^+) \to J/\psi\pi^+(K^+)) = \frac{N_{sig}}{2 \cdot \varepsilon \cdot Br(J/\psi \to \mu\mu) \cdot \Delta p_T(|y|) \cdot \mathcal{L}}$$

Dependence on efficiency: Truth matching; Life time, recon eff., hadronic,Muon tracking; T-P eff. Mialignment. Stat. of MC samples.

Others: Lumi.; Br(J/ψ→μμ);

Dependence on signal evt. abstraction: signal model; Bg. model, pT/y binning

Systematic errors

- **Signal PDF**: Bc: 1(2) Gaussian
  B+: 2(3) Gaussian.

- **Bg PDF**: Bc: 2nd Chebyshev polynomial(exponential)
  B+: Gaussian+exp.
  (2 gaussian+ 2nd Chebyshev polynomial)

- **p_T/|y| binning:** in each bin, the difference of MC sample fitting results between events number in generator level .

- **MC truth matching $\Delta R(B^{reco}, B^{gen})$:** difference between event yields between the ΔR match and fitting result. we also study the effect of the deltaR matching and we came with a difference of 76 events (16896 and 16820 after all the cuts with i)deltaR ii)without deltaR)) which is quite small.

Systematic errors

- **Stat . Error of T-P samples and Bc(B^+) MC samples**: Errors of muon T-P samples are propagated in the Muon correction factor calculation.

- Hadron **tracking efficiency**: 3.9%; Muon tracking: 0.5%.
  CMS PAS TRK-10-002

- **Misalignment** : 1%. (PRL106(2011)252001, B0$\rightarrow$J/ψK^0)

- Br(J/$\psi\rightarrow\mu\mu$): 1% (PDG). L: 4%.
- **Bc Life time : The life time** PDG(Bc) = 0.452 ± 0.041 ps

We reweight our MC sample for 0.411 ps and 0.493 ps .
The difference in efficiencies of Bc in both samples is considered to be systematic of Bc life time (after all the cuts)

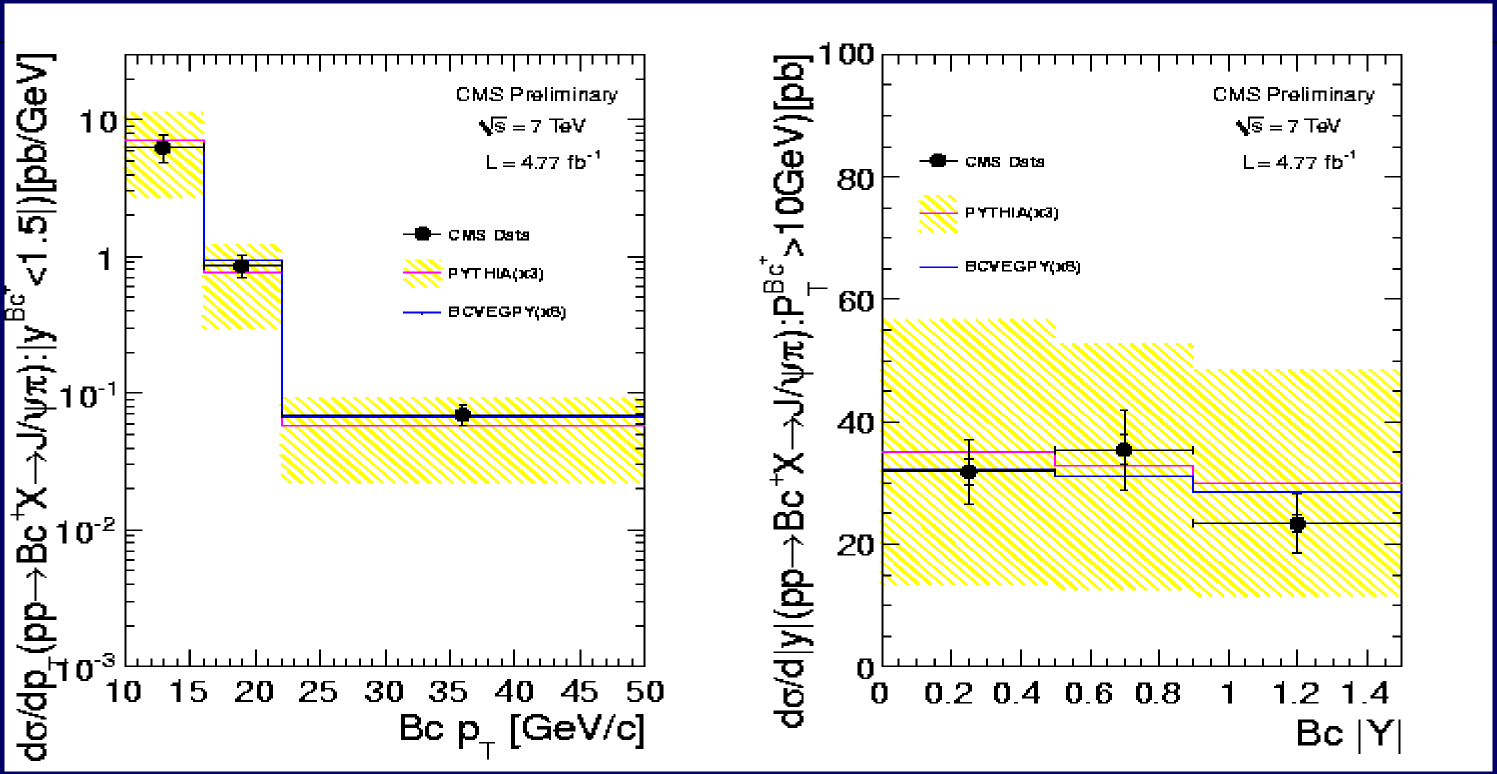
Systematic errors

The sys. Uncertainties due to the statistic of muon Tag&Probe sample, Bc, B± MC samples are not listed in the table. They are included in efficiency error calculation, and taken as the stat. error in the cross section results.

Source	p_T Bin1	p_T Bin2	p_T Bin3	$\lvert y \rvert$ Bin1	$\lvert y \rvert$ Bin2	$\lvert y \rvert$ Bin3	single Bin
Signal model	0.8	6.4	0.9	0.5	0.7	0.3	2.4
Bg. model	0.4	0.9	1.4	0.8	0.9	0.3	0.2
Truth Matching	0.1	0.3	0.2	0.4	0.2	0.2	0.3
p_T/y binning	0.6	0.2	0.3	0.1	0.1	0.1	0.1
Hadron tracking Efficiency	3.9	3.9	3.9	3.9	3.9	3.9	3.9
Muon kinematic	0.9	0.6	0.1	1.5	1.3	0.7	0.1
Muon Tracking	0.5	0.5	0.5	0.5	0.5	0.5	0.5
recon. eff.	0.4	0.3	0.5	0.4	0.3	0.4	0.2
Misalignment	1.0	1.0	1.0	1.0	1.0	1.0	1.0
B_c life time	$^{+2.0}_{-3.4}$	$^{+2.1}_{-2.7}$	$^{+1.6}_{-2.2}$	$^{+2.0}_{-2.6}$	$^{+1.8}_{-2.9}$	$^{+2.3}_{-2.8}$	$^{+1.9}_{-2.8}$
$Br(J/\psi \to \mu^+\mu^-)$	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Luminosity	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Total	$^{+6.3}_{-6.9}$	$^{+9.0}_{-9.1}$	$^{+6.3}_{-6.4}$	$^{+6.4}_{-6.6}$	$^{+6.3}_{-6.7}$	$^{+6.3}_{-6.5}$	$^{+6.6}_{-6.9}$

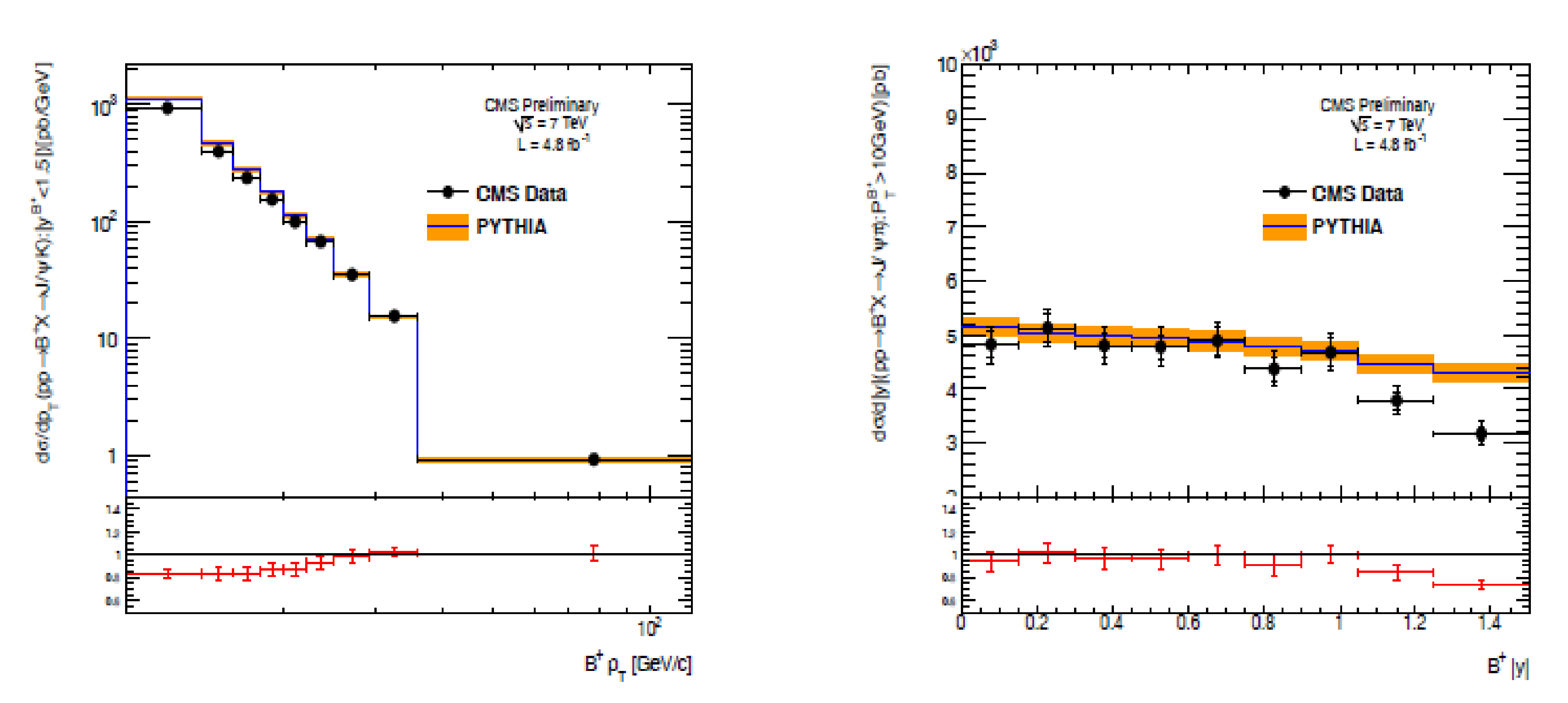
source	p_T Bin1	Bin2	Bin3	Bin4	Bin5	Bin6	Bin7	Bin8	Bin9	$\lvert y \rvert$ Bin1	Bin2	Bin3	Bin4	Bin5	Bin6	Bin7	Bin8	Bin9	One Bin
Signal model	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Bg. model	2.4	3.9	6.0	5.8	3.9	3.5	4.5	4.3	5.3	4.0	3.2	3.5	4.6	3.1	4.5	4.1	4.0	4.0	3.8
Truth Matching	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.3
p_T/y binning	0.6	0.6	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Hadron track Eff.	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
Muon kinematic	0.9	0.9	0.6	0.6	0.6	0.1	0.1	0.1	0.1	1.5	1.5	1.5	1.3	1.3	1.3	0.7	0.7	0.7	0.1
Muon Tracking	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
recon. eff.	0.4	0.4	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.4	0.4	0.4	0.2
Misalignment	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
$Br(J/\psi \to \mu^+\mu^-)$	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Luminosity	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Total	6.4	7.1	8.4	8.2	7.0	6.8	7.4	7.2	7.9	7.2	6.8	6.9	7.5	6.7	7.5	7.1	7.1	7.1	6.9

$Bc^+ \to J/\psi\pi^+$ Cross section result



- For Bc p_T>10 GeV, |y|<1.5.
- Errors are stat. errors of real data, MC sample and Muon Tag&proble samples, sys. error respectively.
- Br(Bc→Jψ/π)=0.0013 in the generator. (Large Br. theor. Uncertainty 0.1%-2%)
- Error of BCVEGPY and PYTHIA is the Br(Bc→Jψ/π) theoretical error of 0.0013±0.0008 in PRD81,014015(2010).

$B^+ \to J/\psi K^+$ Cross section result



- For B+ p_T>10 GeV, |y|<1.5.
- Errors are stat. errors of the real data, MC sample and Muon Tag&proble samples; sys. Error respectively.
- Error of PYTHIA is the Br($B+ \to J/\psi K+$) error of 0.001014 ± 0.000034 in PDG.

Summary

- The $Bc^+ \to J/\psi\pi^+$ and $B+ \to J/\psi K^+$ differential production cross section $d\sigma/dp_T$, $d\sigma/d|y|$ are measured at CMS with $4.8fb^{-1}$ 7 TeV data.

For pT(Bc^+,B^+)>10 GeV, |y(Bc+,b+)|<1.5,

$$\sigma(\mathrm{Bc}^+ \to \mathrm{J}/\psi\pi^+) = 45.17 \pm 5.25(\mathrm{stat})\,^{+3.0}_{-3.12}(sys)\,pb$$

$\sigma(B^+ \to J/\psi K^+)$ =6503.18±122.43(stat.)±448.72(sys.)pb

- The B^+ cross section measurement are consistent with PYTHIA prediction. Bc $d\sigma/dp_T$,$d\sigma/d|y|$ shapes are consistent with PYHTIA and BCVEGPY, the cross section values are 3 and 8 times larger than PYTHIA and BCVEGPY (assume $Br(Bc \to J\psi/\pi)$=0.0013.)

Summary

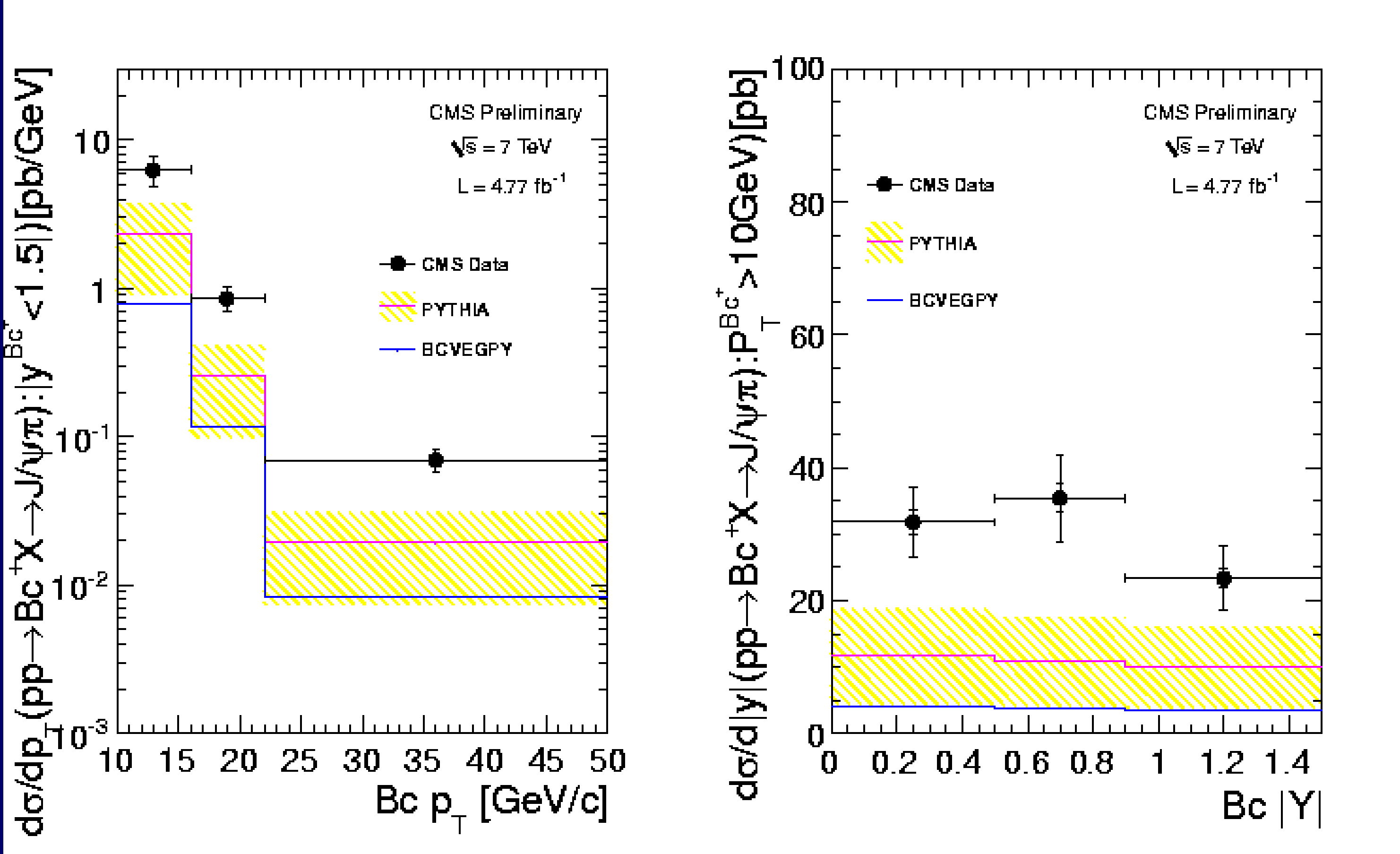
We wish these measurements will be helpful to understand Bc (B^+) meson production and decay mechanism.

- The $Bc^+ \to J/\psi\pi^+$ branching ratio (2%-0.1%);
- The contributions of the Next leading order Bc production calculation.

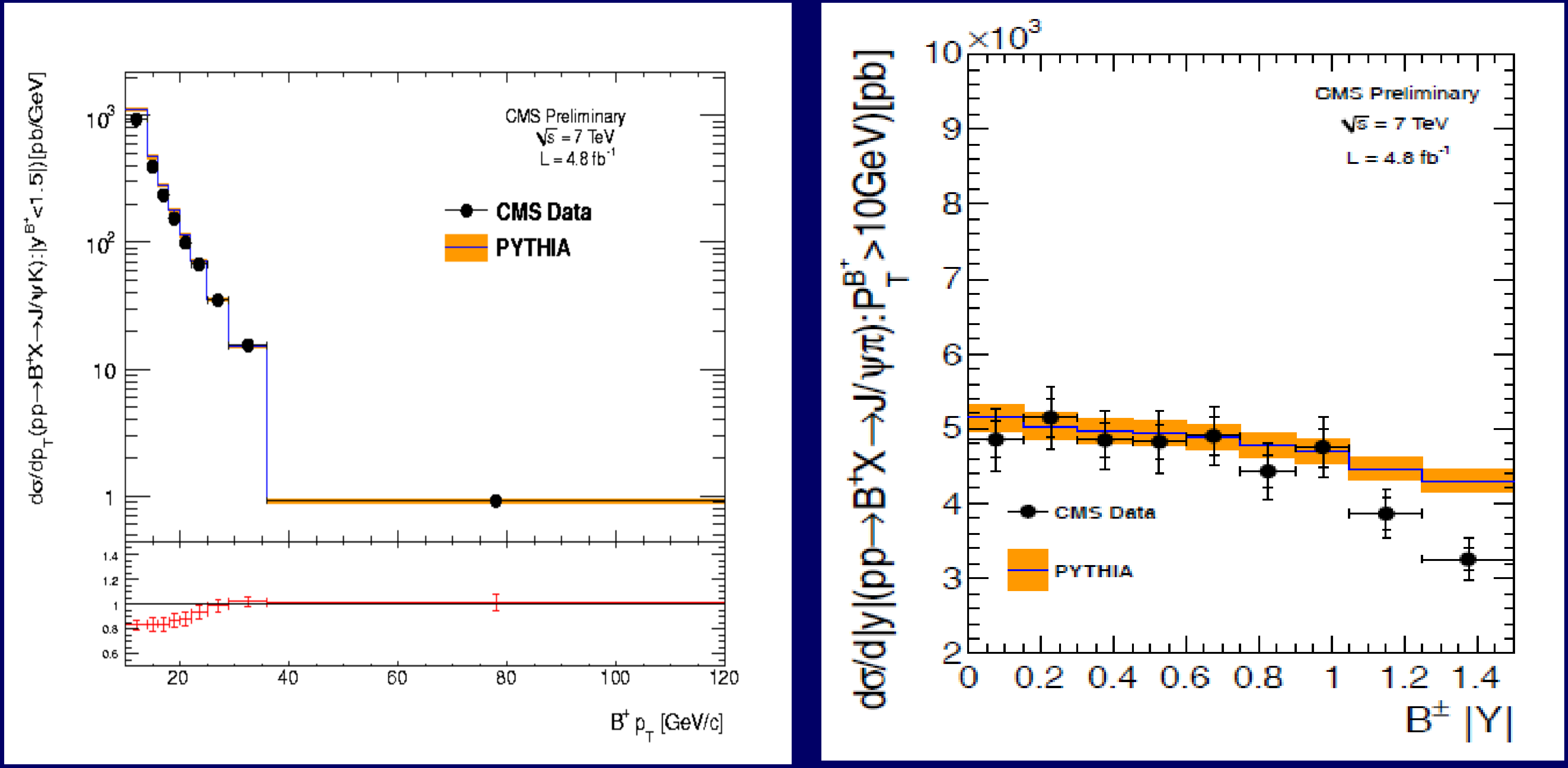
Thanks !

Back up

Bc cross section Results



B+ cross section results



T-P samples

$99.0 \pm 1.0\%$ as recommended by muon POG. The Tag&Probe data files (seen in the link [24]) of the single muon efficiency we used for ε_{ID} and ε_{Qual} calculations are the follows,

- MuonID_pt_abseta_runA_inclMay10_TrkCuts_15Nov2011_corrected.root
- MuonQual_pt_abseta_runA_inclMay10_TrkCuts_15Nov2011_corrected.root

- L1L2Dimuon0Jpsi_pt_abseta_cowboys_TrkCuts_6Nov2011_corrected.root
- L1L2Dimuon0Jpsi_pt_abseta_seagulls_run1_TrkCuts_12Nov2011_corrected.root
- L3Dimuon0Jpsi_pt_abseta_cowboys_TrkCuts_6Nov2011_corrected.root
- L3Dimuon0Jpsi_pt_abseta_seagulls_run1_TrkCuts_12Nov2011_corrected.root
- L1L2_pt_abseta_MC_cowboys_TrkCuts_20Oct2011_corrected.root
- L3_pt_abseta_MC_cowboys_TrkCuts_20Oct2011_corrected.root

$$\alpha_{Displaced\_J/\psi\_cut} = \frac{\varepsilon^{B\to J/\psi\pi(K)}(Displaced\_J/\psi\_Data)}{\varepsilon^{B\to J/\psi\pi(K)}(Displaced\_J/\psi\_MC)}$$

Data

Displaced trigger eff.	163269 – 167913	170249 – 172868	173236 – 180252	Average
$J\psi p_T :< 10.0GeV$	0.955 ± 0.002	0.916 ± 0.006	0.861 ± 0.005	0.892 ± 0.003
$J\psi p_T : 10.0 - 12.0GeV$	0.967 ± 0.002	0.926 ± 0.005	0.884 ± 0.004	0.911 ± 0.003
$J\psi p_T : 12.0 - 15.0GeV$	0.974 ± 0.001	0.933 ± 0.005	0.880 ± 0.004	0.911 ± 0.003
$J\psi p_T : 15.0 - 20.0GeV$	0.975 ± 0.002	0.929 ± 0.006	0.894 ± 0.005	0.919 ± 0.003
$J\psi p_T : 20.0 - 30.0GeV$	0.978 ± 0.002	0.927 ± 0.008	0.899 ± 0.006	0.922 ± 0.004
$J\psi p_T :> 30.0GeV$	0.979 ± 0.004	0.897 ± 0.017	0.910 ± 0.011	0.924 ± 0.007
$J\psi\|\eta\| : 0.0 - 0.4GeV$	0.973 ± 0.002	0.938 ± 0.005	0.902 ± 0.004	0.925 ± 0.003
$J\psi\|\eta\| : 0.4 - 0.8GeV$	0.970 ± 0.002	0.940 ± 0.005	0.898 ± 0.004	0.922 ± 0.003
$J\psi\|\eta\| : 0.8 - 1.2GeV$	0.974 ± 0.002	0.930 ± 0.006	0.889 ± 0.005	0.916 ± 0.003
$J\psi\|\eta\| : 1.2 - 1.6GeV$	0.966 ± 0.002	0.922 ± 0.006	0.862 ± 0.005	0.897 ± 0.003
$J\psi\|\eta\| : 1.6 - 2.2GeV$	0.964 ± 0.002	0.896 ± 0.007	0.858 ± 0.006	0.889 ± 0.004

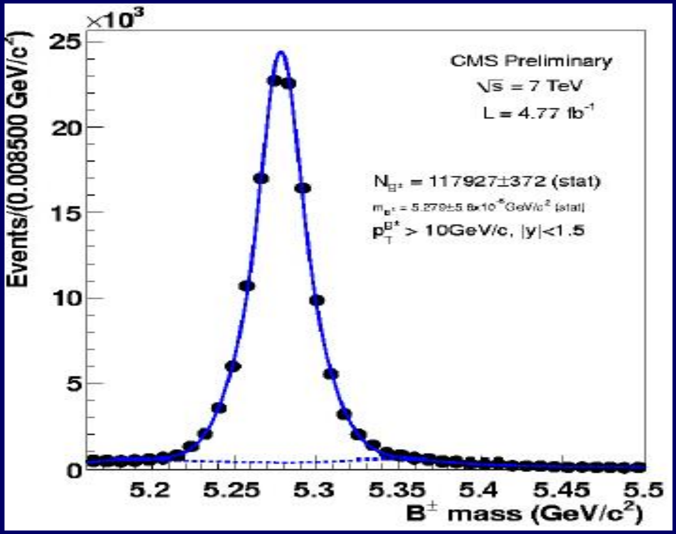
Bc MC

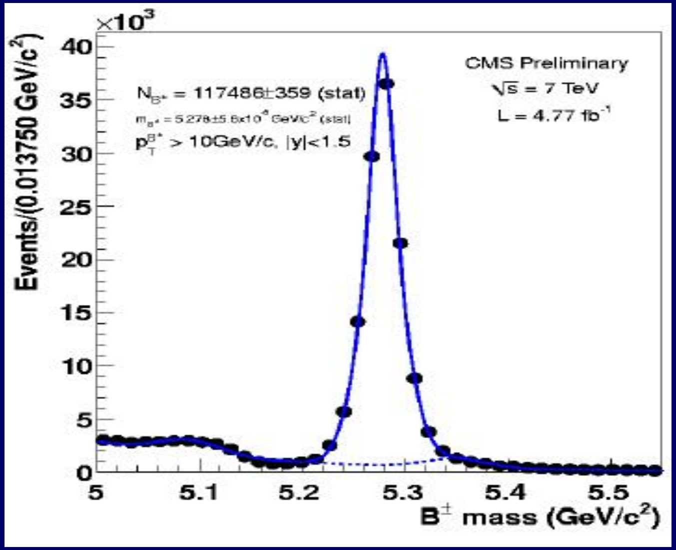
Displaced trigger eff.	Dimu7	Doublemu3p5	Doublemu4	Average
$J/\psi\ p_T :< 10.0GeV$	0.915 ± 0.002	0.893 ± 0.004	0.862 ± 0.004	0.879 ± 0.003
$J/\psi\ p_T : 10.0 - 12.0GeV$	0.934 ± 0.002	0.909 ± 0.003	0.883 ± 0.003	0.898 ± 0.002
$J/\psi\ p_T : 12.0 - 15.0GeV$	0.940 ± 0.002	0.918 ± 0.003	0.889 ± 0.003	0.904 ± 0.002
$J/\psi\ p_T : 15.0 - 20.0GeV$	0.943 ± 0.002	0.919 ± 0.003	0.895 ± 0.004	0.909 ± 0.002
$J/\psi\ p_T : 20.0 - 30.0GeV$	0.948 ± 0.003	0.921 ± 0.005	0.896 ± 0.006	0.912 ± 0.004
$J/\psi\ p_T :> 30.0GeV$	0.950 ± 0.007	0.927 ± 0.011	0.898 ± 0.013	0.914 ± 0.008
$J/\psi\ \|\eta\| : 0.0 - 0.4GeV$	0.954 ± 0.002	0.934 ± 0.003	0.907 ± 0.003	0.922 ± 0.002
$J/\psi\ \|\eta\| : 0.4 - 0.8GeV$	0.942 ± 0.002	0.920 ± 0.003	0.894 ± 0.003	0.909 ± 0.002
$J/\psi\ \|\eta\| : 0.8 - 1.2GeV$	0.927 ± 0.002	0.900 ± 0.003	0.874 ± 0.004	0.890 ± 0.002
$J/\psi\ \|\eta\| : 1.2 - 1.6GeV$	0.927 ± 0.002	0.899 ± 0.004	0.872 ± 0.004	0.888 ± 0.003
$J/\psi\ \|\eta\| : 1.6 - 2.2GeV$	0.919 ± 0.003	0.895 ± 0.004	0.869 ± 0.005	0.884 ± 0.003

B^+ MC

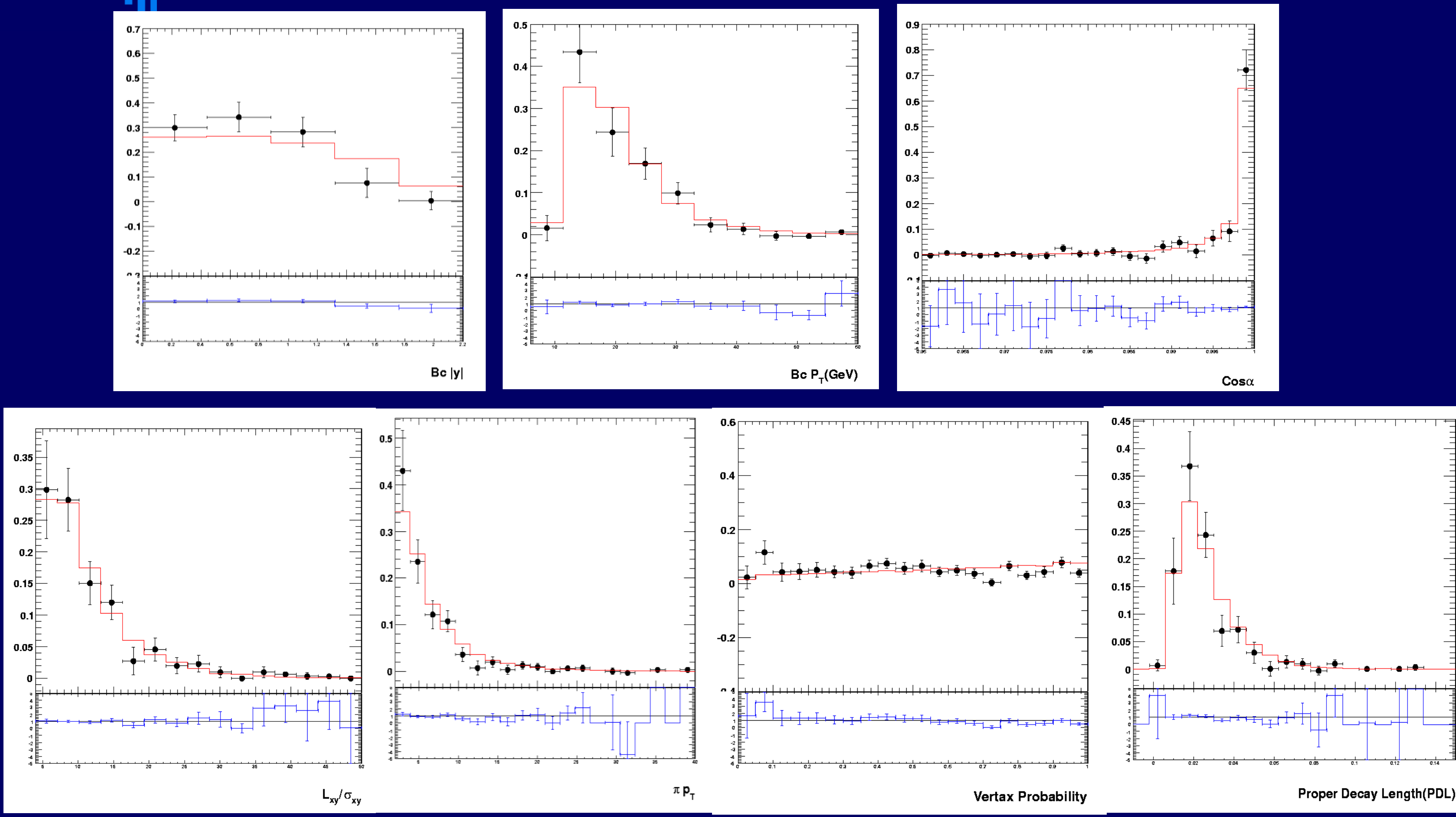
Displaced trigger eff.	Dimu7	Doublemu3p5	Doublemu4	Average
$J\psi p_T :< 10.0GeV$	0.966 ± 0.004	0.938 ± 0.007	0.915 ± 0.009	0.930 ± 0.005
$J\psi p_T : 10.0 - 12.0GeV$	0.976 ± 0.003	0.950 ± 0.006	0.925 ± 0.007	0.940 ± 0.004
$J\psi p_T : 12.0 - 15.0GeV$	0.976 ± 0.003	0.947 ± 0.005	0.922 ± 0.007	0.937 ± 0.004
$J\psi p_T : 15.0 - 20.0GeV$	0.981 ± 0.003	0.952 ± 0.006	0.931 ± 0.007	0.945 ± 0.004
$J\psi p_T : 20.0 - 30.0GeV$	0.970 ± 0.005	0.929 ± 0.009	0.905 ± 0.011	0.923 ± 0.007
$J\psi p_T :> 30.0GeV$	0.987 ± 0.006	0.969 ± 0.013	0.946 ± 0.017	0.958 ± 0.010
$J\psi\|\eta\| : 0.0 - 0.4GeV$	0.980 ± 0.003	0.956 ± 0.006	0.937 ± 0.007	0.949 ± 0.004
$J\psi\|\eta\| : 0.4 - 0.8GeV$	0.968 ± 0.003	0.948 ± 0.006	0.928 ± 0.007	0.940 ± 0.004
$J\psi\|\eta\| : 0.8 - 1.2GeV$	0.974 ± 0.003	0.943 ± 0.006	0.920 ± 0.008	0.936 ± 0.005
$J\psi\|\eta\| : 1.2 - 1.6GeV$	0.974 ± 0.003	0.934 ± 0.007	0.900 ± 0.009	0.921 ± 0.005
$J\psi\|\eta\| : 1.6 - 2.2GeV$	0.979 ± 0.003	0.947 ± 0.006	0.921 ± 0.008	0.937 ± 0.005

Background PDF systematics

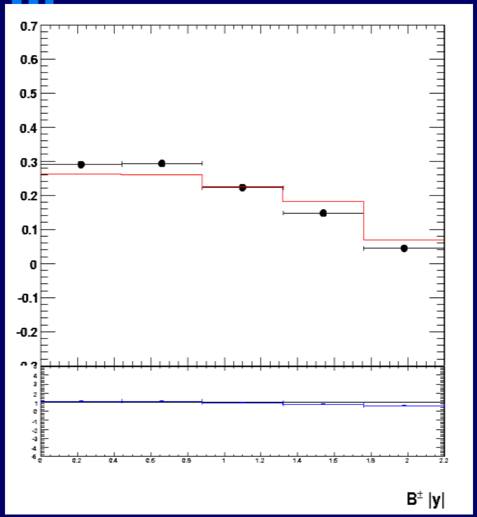


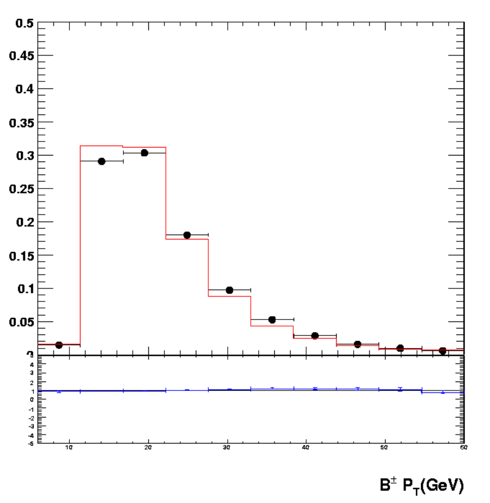


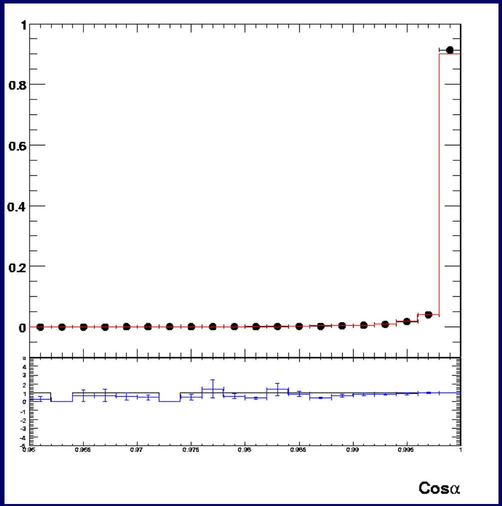
MC and real data(Bc)

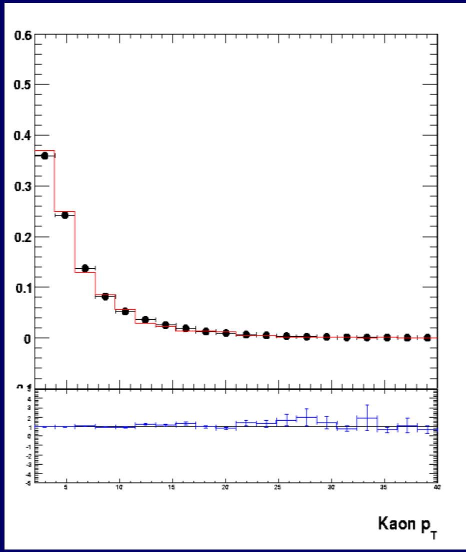


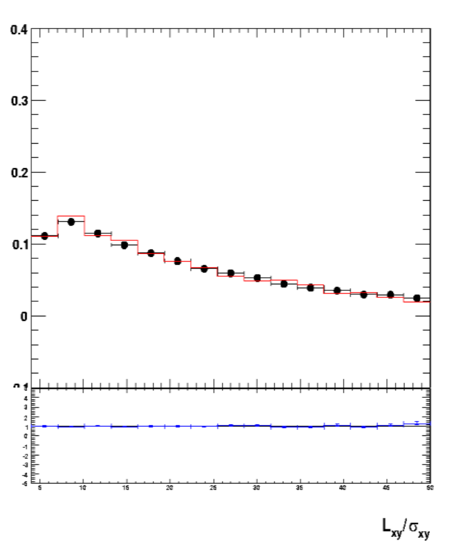
MC and real data(B+)

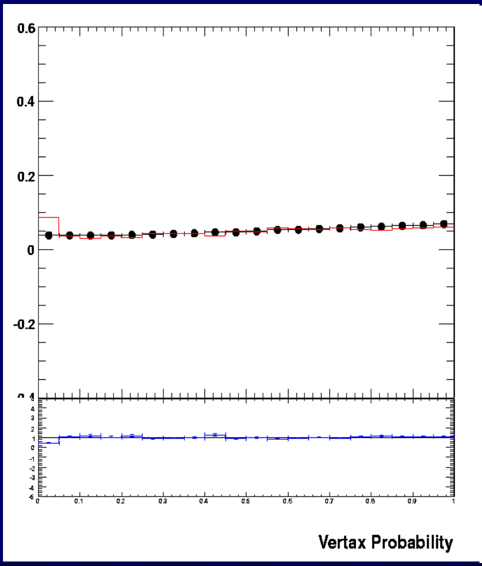


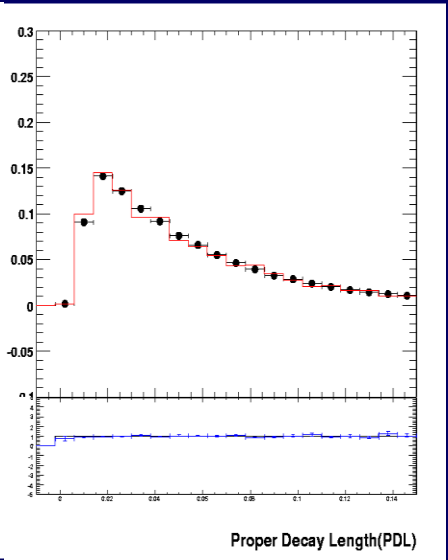






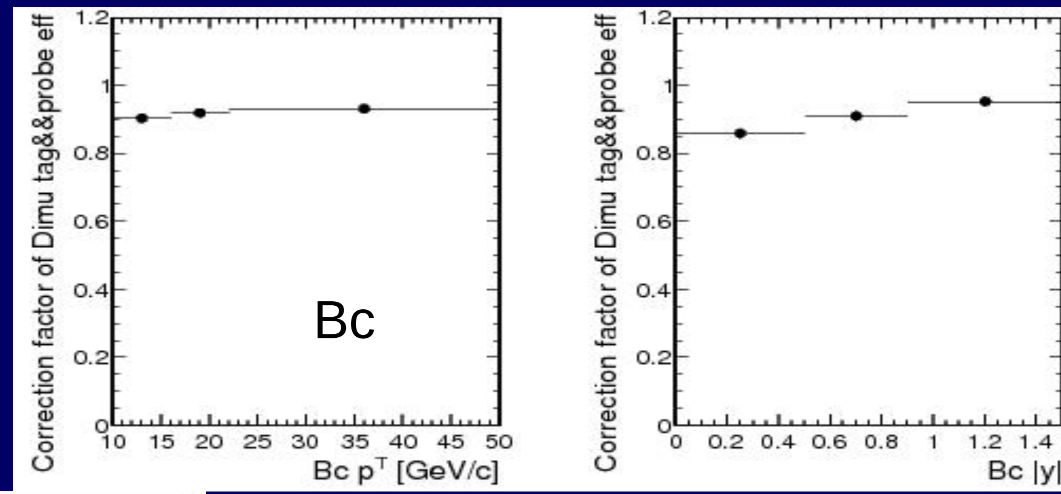


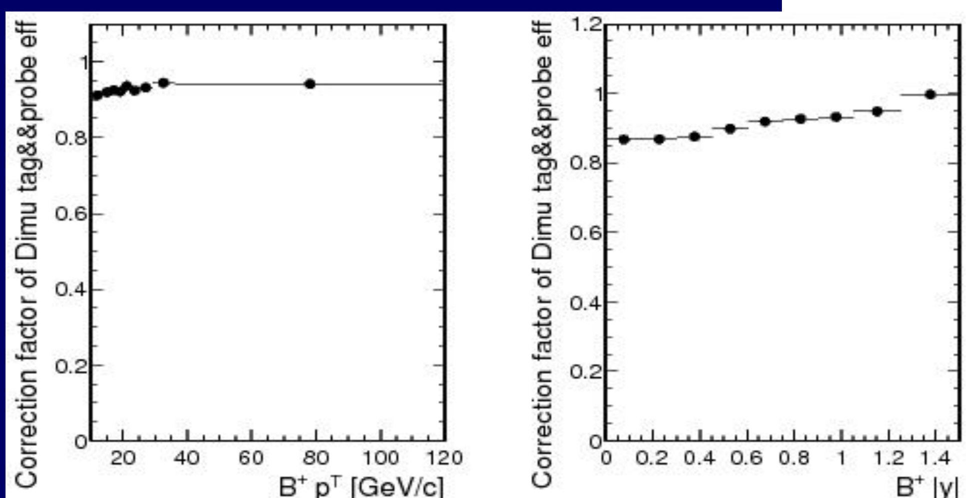




μ T-P efficiency correction

$$\alpha_{muonT-P} = \frac{\varepsilon^{B\to J/\psi\pi(K)}(2\mu\_T\,\&\,P\_Data)}{\varepsilon^{B\to J/\psi\pi(K)}(2\mu\_T\,\&\,P\_MC)}$$





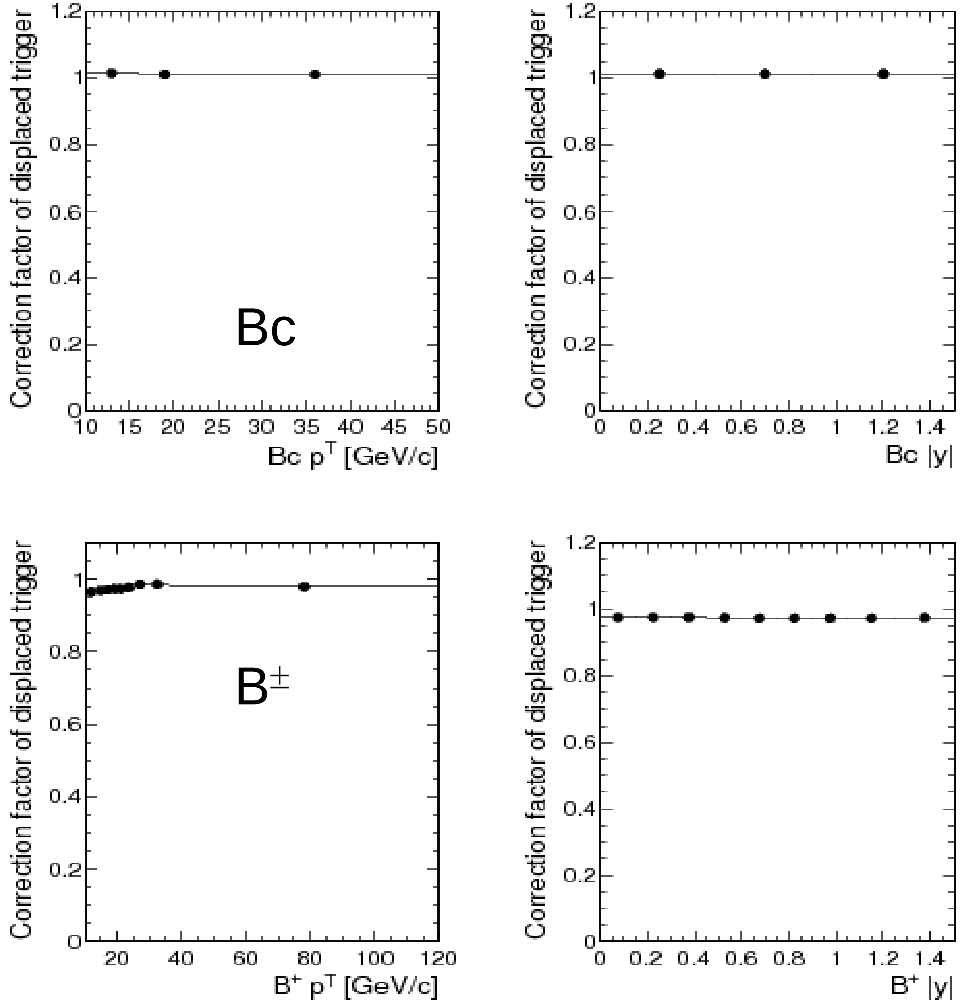
B$^\pm$

Correction for displaced trigger cut

$$\alpha_{Displaced\_J/\psi\_cut} = \frac{\varepsilon^{B\to J/\psi\pi(K)}(Displaced\_J/\psi\_Data)}{\varepsilon^{B\to J/\psi\pi(K)}(Displaced\_J/\psi\_MC)}$$

- Displaced eff. is calculated as the fraction of $J/\psi\to 2\mu$ events passed displaced J/ψ cuts and the events passing the prompt trigger.
- The average eff. weighted by the int. lumi. of each period run.

J/ψ displaced correction factor



$$\alpha_{Displaced\_J/\psi\_cut} = \frac{\varepsilon^{B\to J/\psi\pi(K)}(Displaced\_J/\psi\_Data)}{\varepsilon^{B\to J/\psi\pi(K)}(Displaced\_J/\psi\_MC)}$$