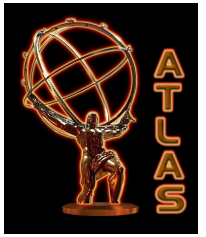
Bc Performance Studies at ATLAS



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Partikeldagarna

Outlines

- B-physics program in ATLAS
- B_c properties and purpose in ATLAS
- Current studies based on Monte Carlo Samples
- Facing to the early running and plans

B Physics at ATLAS

- Large $b\bar{b}$ production at LHC
  Estimated cross-section ~ 500 μb
- ATLAS
  Excellent muon systems and trackers, large |η| acceptance, triggers
- Large variety of B-physics topics at ATLAS

  Production cross-section of beauty and charm hadrons and heavy-flavour quarkonia

  Properties of B meson family and B baryons (B_d, B^+, B_s, B_c, Λ_b ...)

  Measurement of weak B hadron decays

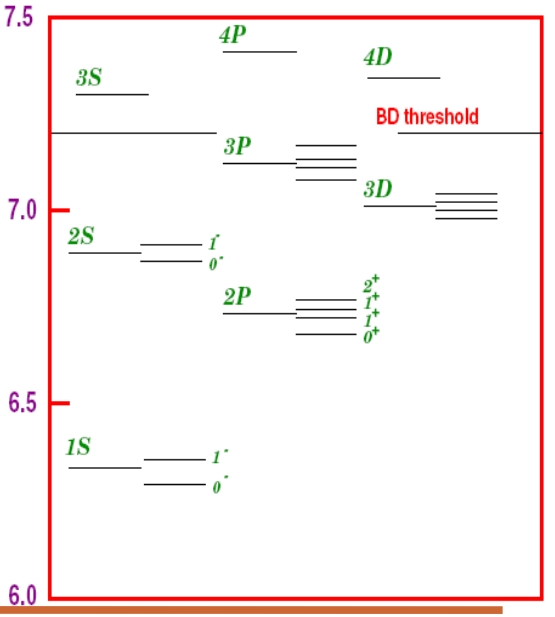
  New physics
- At LHC early running, favourable lower luminosity for B-physics
  (up to 10^{33} cm^{-2} s^{-2})

Bc Meson Properties

- Unique system: $B_c^+ = \bar{b}\,c \quad B_c^- = b\,\bar{c}$
  Bound state of two heaviest quarks, c and b, suppress relativistic effects
  Carry flavour, heavy-quark dynamics different from cc & bb quarkonia

- Mass predictions
  Theoretical predictions: potential models, QCD sum rules, Lattice QCD
  6150 ~ 6500 MeV/c² with large uncertainties

- Mass Spectrum of Bc family
  Below the threshold of decaying into BD pair, theory predicts 16 narrow (bc) states, not annihilate via strong force, instead, have cascade radiative transitions into the ground state by emitting photons and pion-pion pairs



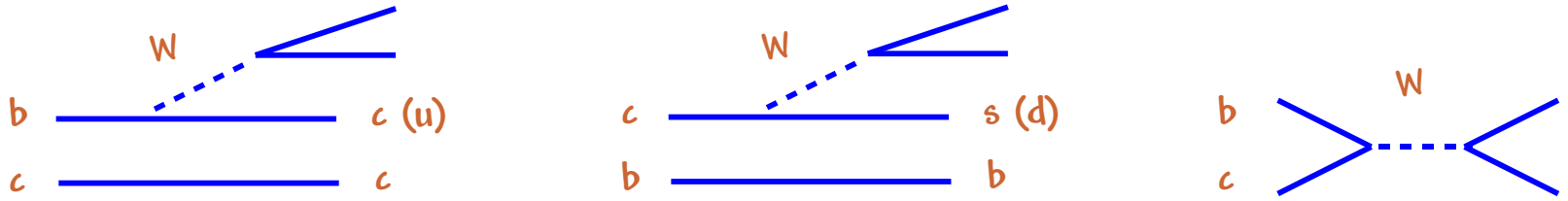
Bc Meson Properties

- Predicted mass values from potential models.
- Mass differences are more tightly constrained than the precise mass values.
- The form of strong potential could be extracted by measuring excited states and ground state.

state	Martin	BT
1^1S_0	6.253	6.264
1^1S_1	6.317	6.337
2^1S_0	6.867	6.856
2^1S_1	6.902	6.899
2^1P_0	6.683	6.700
$2P\ 1^+$	6.717	6.730
$2P\ 1'^+$	6.729	6.736
2^3P_2	6.743	6.747
3^1P_0	7.088	7.108
$3P\ 1^+$	7.113	7.135
$3P\ 1'^+$	7.124	7.142
3^3P_2	7.134	7.153
$3D\ 2^-$	7.001	7.009
3^5D_3	7.007	7.005
3^3D_1	7.008	7.012
$3D\ 2'^-$	7.016	7.012

Bc decays

- Three classes:
  1. $\bar{b}$ quark decay while c is spectator (~20%)
  2. c quark decay while $\bar{b}$ is spectator (~70%)
  3. annihilation channel $B_c^+ \to l^+ \nu_l (c\bar{s}, u\bar{s})$ (~10%)



- The total width is summed over the three partial widths

$$\Gamma(B_c \to X) = \Gamma(b \to X) + \Gamma(c \to X) + \Gamma(ann)$$

- Shorter lifetime τ ~ 0.5 ps

Prospects of Bc studies in ATLAS

- Bc has been observed by Tevatron experiment.
- At LHC energies, the dominant production will be gluon-gluon fusion. gg → Bc + anti-c+b. The summed cross section for the Bc meson production is about 10^{-3} of the total cross section of the bb production. With the luminosity of $L=10^{33}cm^{-2}s^{-1}$ one could expect 5×10^{9} events per year.
- We are focusing on mass measurements of several Bc states and differences relative to ground state.

$$B_c^+(2^1S_{0,1}) \rightarrow B_c^+(1^1S_0)\pi^+\pi^-$$

$$B_c^+(1^1S_0) \rightarrow J/\psi + \pi^+ \rightarrow \mu^+\mu^-\pi^+$$

Bc^+ Ground State Decay

- Studies have been done to reconstruct ground state decay

$$B_c^+(1^1S_0) \rightarrow J/\psi + \pi^+ \rightarrow \mu^+\mu^- + \pi^+$$

- Monte Carlo Samples

  Signal: $Bc^+ \rightarrow J/\Psi(\mu 6 \mu 3) + \pi^+$ (4550)

  PythiaB(PYTHIA implementation in ATLAS for B events) + EVTGEN(B decay)
  Full simulation and reconstruction with ATLAS geometry

  Background: ATLAS CSC production

  bb->Jpsi(μ6μ4)+X (~150K) other B decays

  pp->Jpsi(μ6μ4) (~150K) large prompt Jpsi production

"new magnetic field, misaligned geometry with material distortions"

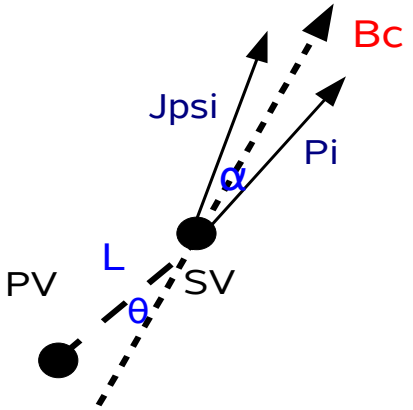
J/Ψ Selection

- Require muon tracks with one Pt>6GeV, one Pt>4GeV, |η|<2.5
- Form $\mu^+\mu^-$ pairs and fit to a common vertex
- Vertex Fit quality $\chi^2/ndf < 6$
- Invariant mass $| M_{J/\Psi} - M_{PDG} | < 200$ MeV

$J/\psi(\mu^+\mu^-)$ Cuts	Number of Selected Particles	Efficiency (%)
$\mu 4\mu 6, \|\eta\| < 2.5$	2990	
$\|\mathrm{Inv}(\mu^+\mu^-) - \mathrm{PDGMass}\| < 200\mathrm{MeV}$	2550	85.3
$\chi^2/\mathrm{ndf} < 6$	2476	97.1
refitted $\|\mathrm{InvMass} - \mathrm{PDGMass}\| < 200\mathrm{MeV}$	2476	100.0
Total Efficiency		82.8

Bc^+ Selection

- π^+ candidates:
  Positive charged tracks (excluding muons) with Pt>3GeV , $|\eta|<2.5$
  Not coming from primary vertex $|d_0|/\sigma_{d0} > 1$



- Make triplets from J/Ψ and π^+ candidates.
  Fit $\mu^+\mu^-$ and π^+ to a common vertex .
  $\mu^+\mu^-$ tracks are constrained to $M_{J/\Psi(PDG)}$

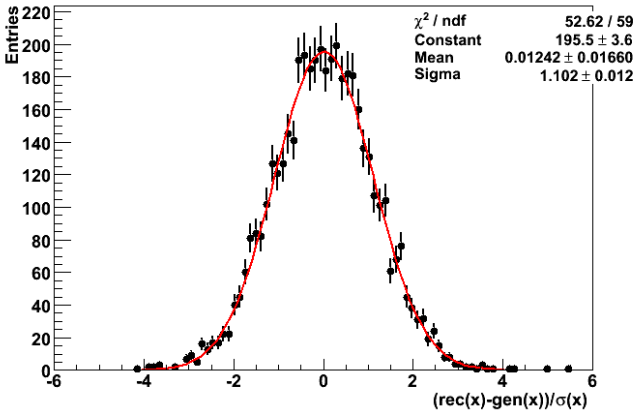
- Bc^+ candidates:
  vertex fitting $\chi^2/ndf < 5$
  Proper Decay Length
  $\lambda = c\tau = Lxy*M_B/P_T > 0.1mm$
  $\cos(\alpha) > 0.7$, $\cos(\theta)>0.99$
  $|M_{Bc}-M_{PDG}| < 180$ MeV

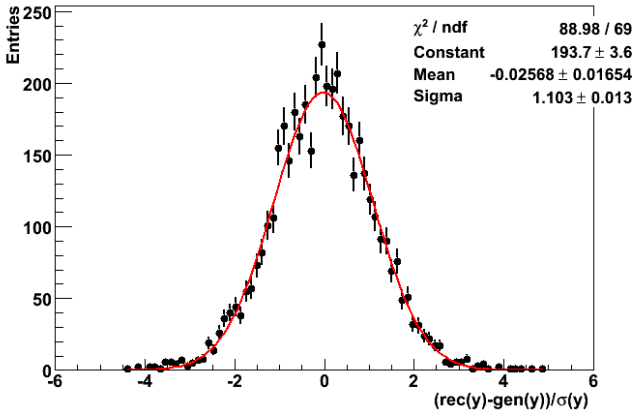
Signal: B_c Cuts	Selected $B_c \to J/\Psi\pi^+$ (NEvt: 4550)	Selection Efficiency (%)
$J/\Psi\pi^+$ triplets	2507	55.1
$\lvert\text{InvMass} - \text{PDGMass}\rvert < 500\text{MeV}$	828	33.0
$\chi^2/\text{ndf} < 5$	784	94.7
$\lambda > 0.1\text{mm}$	458	58.4
opening angle $\cos(\alpha) > 0.7$	457	98.3
pointing angle $\cos(\theta) > 0.99$	450	98.5
truth match	445	98.9
refitted $\lvert\text{InvMass} - \text{PDGMass}\rvert < 180\text{MeV}$	432	97.1
Total Efficiency		9.5

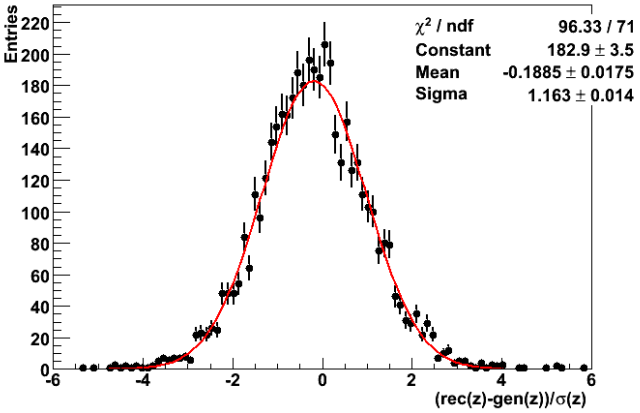
Vertex Reconstruction

$(x_{Rec} - x_{True})/error(x_{Rec})$ $(y_{Rec} - y_{True})/error(y_{Rec})$ $(z_{Rec} - z_{True})/error(z_{Rec})$

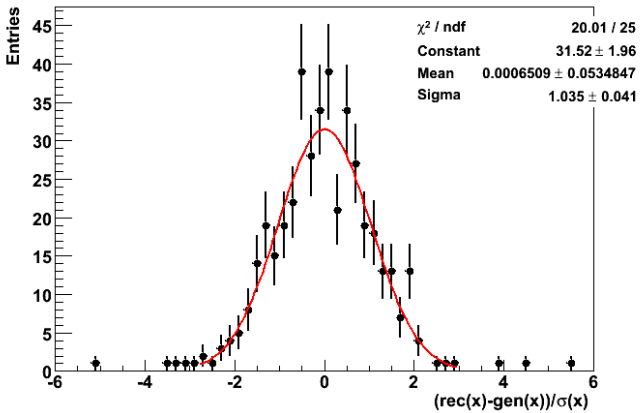
- Primary Vertex

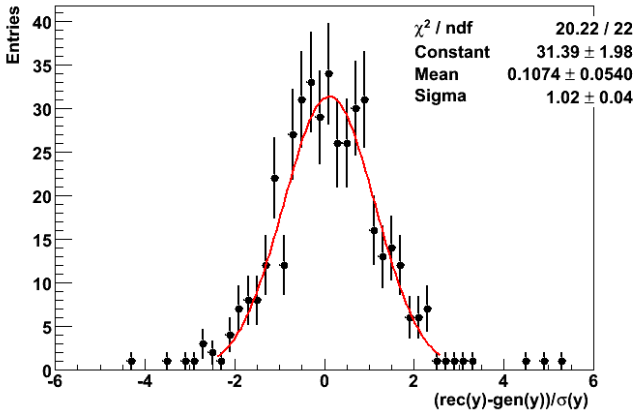


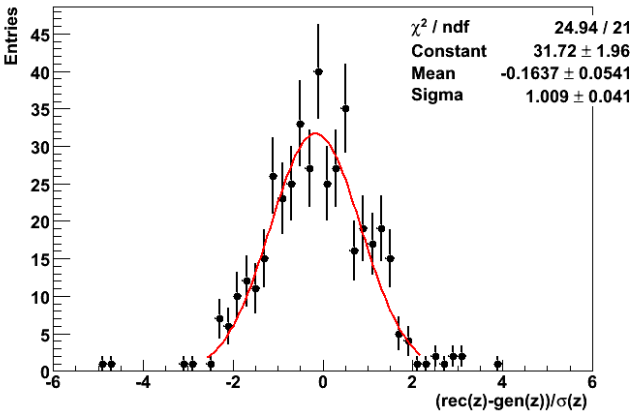




- Secondary Vertex

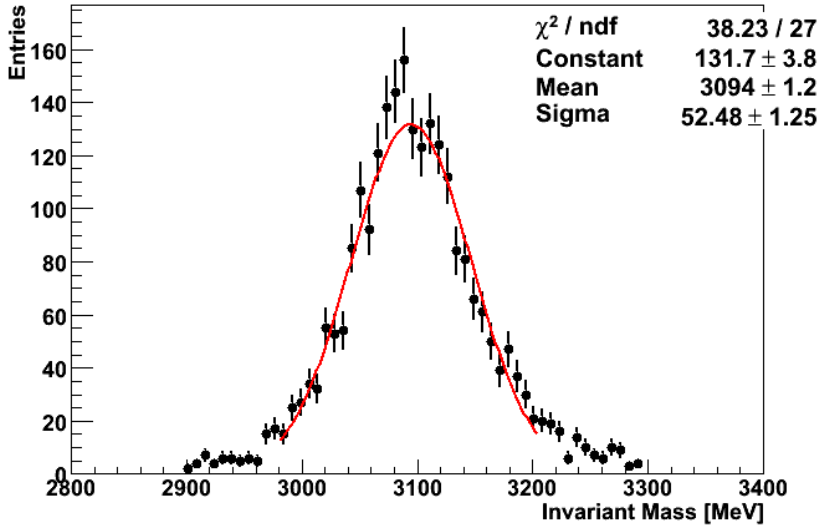




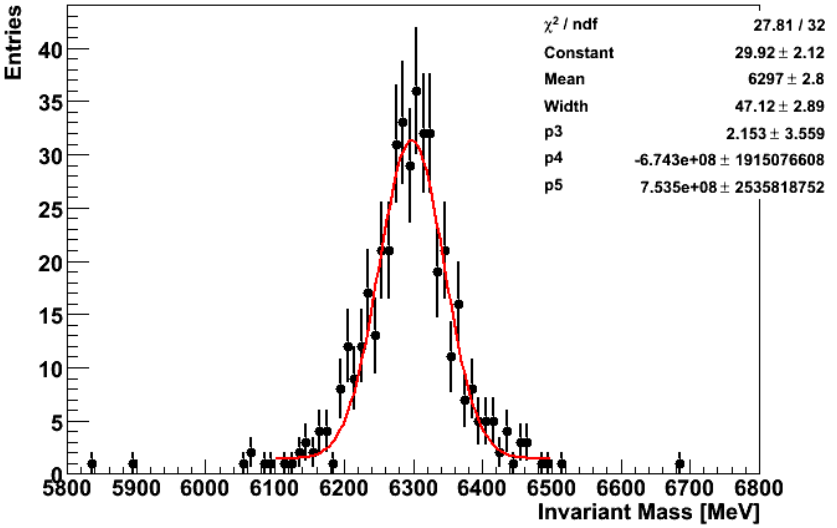


Reconstructed Invariant Mass

- Di-muon(J/Ψ) invariant mass



- Bc Invariant Mass after all the cuts apart from final mass cut



Mean Value ~ 6297 MeV

Mass resolution ~ 47 MeV

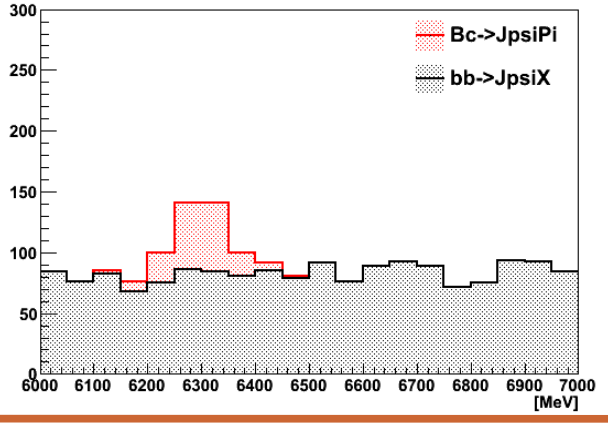
Mass in Gen. = 6300 MeV

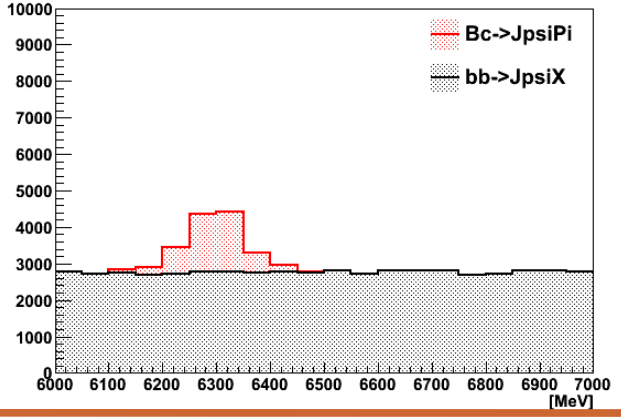
Combination of Samples

- Cross section of samples we are using:
  $Bc^+ \to J/\Psi(\mu 6 \mu 3) + \pi^+$ ~1.77pb
  bb->Jpsi(μ6μ4)+X ~ 11 nb
  pp->Jpsi(μ6μ4) ~ 23 nb
- Current λ > 0.1mm cut helps to reduce combinatorial background from prompt Jpsi. 3 events (out of 150K) fell into 6~7GeV mass range. Due to the limited sample statistics but the large actual production , we should still be careful when dealing with real data.
- Normalized both signal and background to different luminosities. Smear the background fluctuation

1 $(fb)^{-1}$

S/sqrt(B) ~ 7





30 $(fb)^{-1}$

S/sqrt(B) ~ 30

Conclusions

- Studies have been done with MC samples Bc(1S0)->Jpsi(μ6μ3)Pi (~1.77pb). The efficiency of our selection is ~ 10%. Background from the other B decay(bb->JpsiX) and prompt Jpsi has been investigated.
- Based on MC study, we expect that with the integrated luminosities of early running:
  a) 1 fb-1
  ~ 200 signal events after selection, we should see it.
  d) 10-30 fb-1 at 10^33
  ~ 2000 signal events, we should get some results.
- Excited States
  Also planning to measure the mass of 2S state.

$$B_c^+(2^1S_{0,1}) \rightarrow B_c^+(1^1S_0) + \pi^+ + \pi^-$$

  Will study on MC samples with similar strategy as ground state, sample production is ongoing.

Thanks !