

*Measurement of  $b$ - $b\bar{b}$   
correlations at the LHC with  
ATLAS*

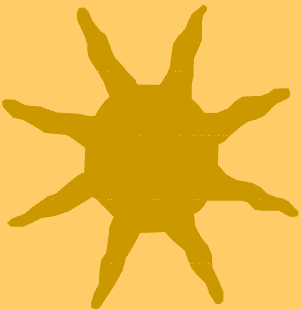
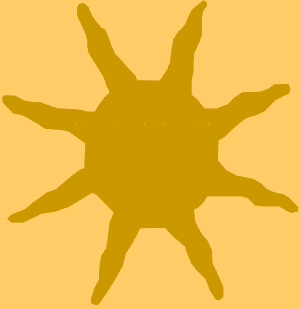
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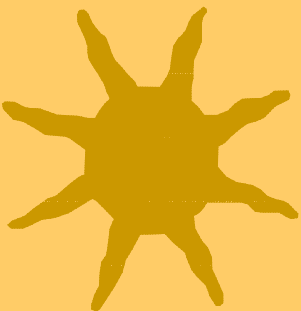
*HERA-LHC Workshop III: Heavy Quarks, 11-13  
October 2004, CERN*



## Outline

- ★ **b** production measurements in hadron collisions and QCD
- ★ ATLAS detector performance for **b** channels with muons;
- ★ Muon and  $J/\psi \rightarrow \mu\mu$  reconstruction in medium  $p_T$  jet
- ★ Correlations **b**- $\bar{b}$  with exclusive channels  
 $B_d \rightarrow J/\psi K_s^0$ ,  $\bar{b} \rightarrow \mu X$  and  $B_s^0 \rightarrow J/\psi \phi$ ,  $\bar{b} \rightarrow \mu X$
- ★ **Conclusions**

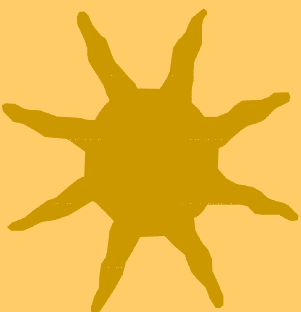
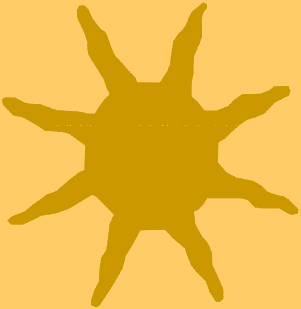




## *b production measurements*



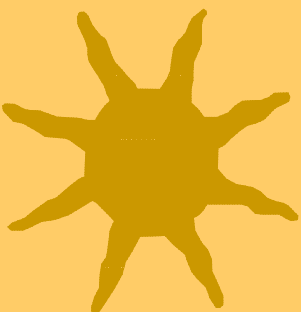
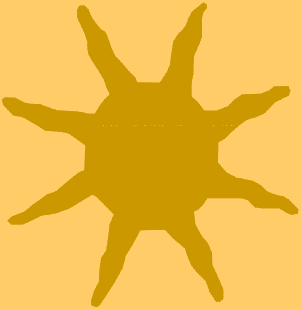
- ★  $b$  production measurements offer a test of perturbative QCD.
  - $b$ - $b$ bar correlations explicitly probe NLO terms.
- ★ Tevatron has measured  $b$ - $b$ bar correlations which are sensitive to production mechanisms, however the precision was limited by statistics.



# *b production measurements*



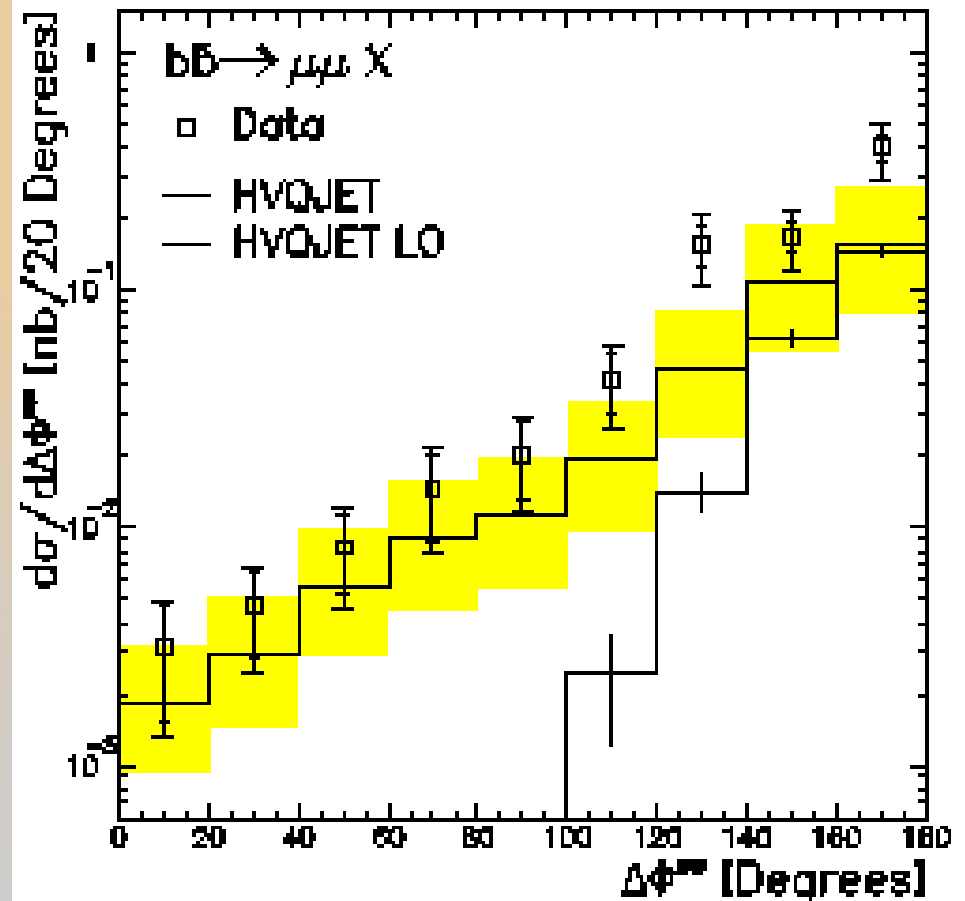
- ★ In experiments with limited statistics b-bbar correlations are measured using inclusive modes. Typical is the method of the  $\mu$ - $\mu$  angle
  - suffers from huge background (K/ $\pi$  decays cascade decays and charm)
  - demands isolation cuts e.g. on  $\mu$ - $\mu$  invariant mass that degrades an acceptance in the low  $\Delta\phi_{bb}$
  - requires model-dependent acceptance corrections to  $\Delta\phi_{\mu-\mu}$  distribution



# *b production measurements*



- ★ A measurement from D0 of the angular correlation,  $\Delta\phi_{\mu\mu}$ , compared with predictions from HVQJET. The points represent the D0 data, the solid histogram the NLO prediction and the yellow band the uncertainty on that prediction. The dotted curve represents the LO prediction.

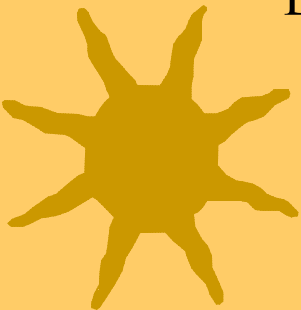




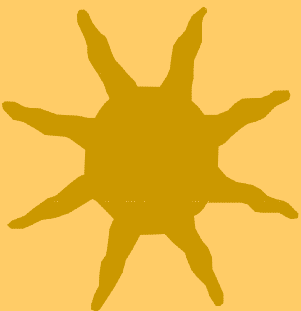
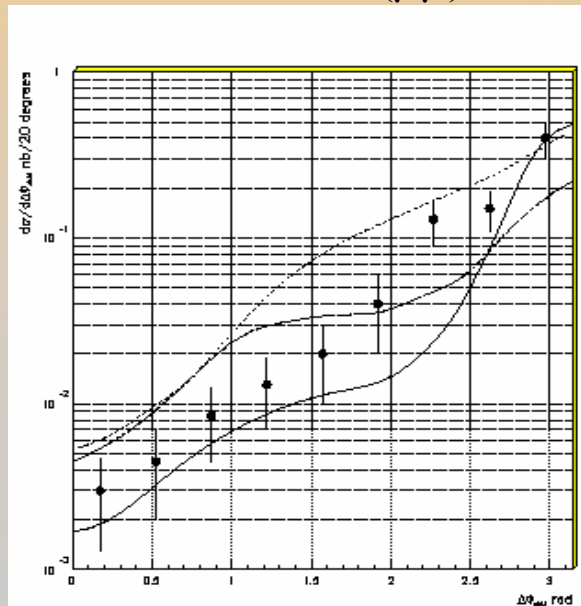
# *b production measurements*



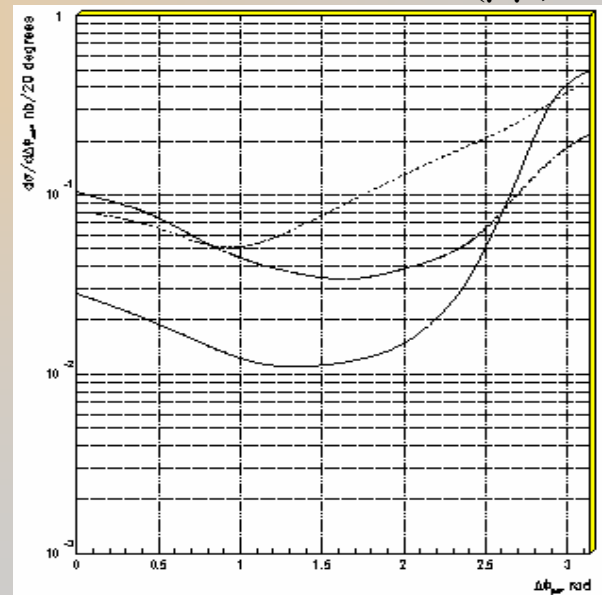
- ★ D0 di-muon data, comparison with models NLOQCD, Semihard model, Pythia
- ★ Limited statistics lead to choice of inclusive modes requiring isolation cuts,  $M(\mu\mu) > 6$  GeV in  $\mu\mu$  case, leading to bias not allowing fully explore  $\Delta\phi(bb) < 1.5$  rad region, as model differences are getting small after the cut.



Data and models with  $M(\mu\mu) > 6$  GeV



Models without  $M(\mu\mu)$  cut



Baranov, Smizanska, Phys. Rev. D62, 2000

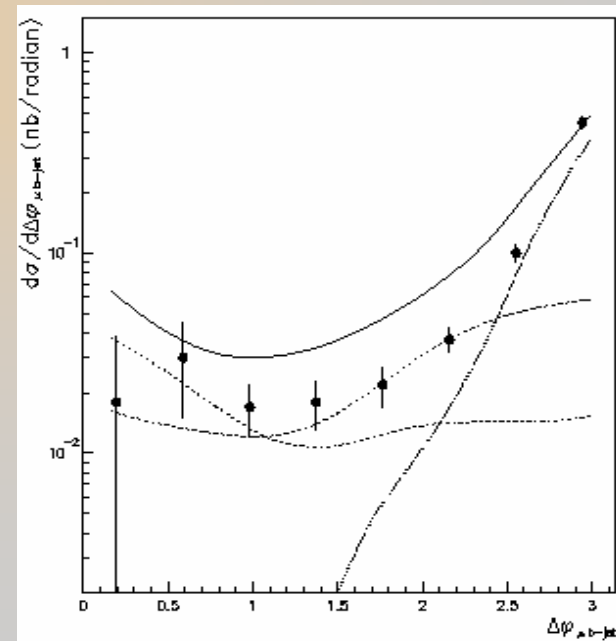
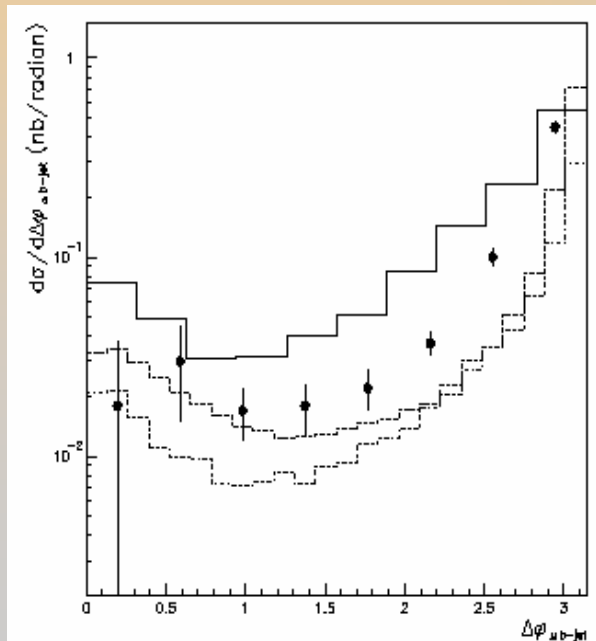


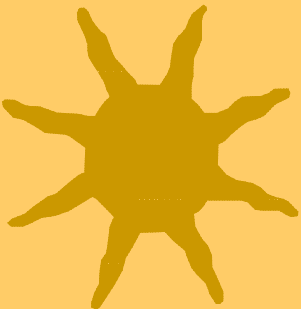
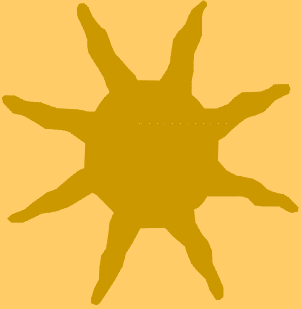
# *b production measurements*

- ★ CDF data  $\mu$ -bjet, comparison with models
- ★ Limited statistics lead to choice of inclusive modes, like  $bb \rightarrow \mu$  bjet requiring isolation cuts between  $\mu$  and b jet. Correction to cuts required model input (NLO was used). This lead to bias not allowing fully explore  $\Delta\phi(bb) < 1$  rad region.

PYTHIA, NLO, Semihard

PYTHIA  $gg \rightarrow bb$ ,  $gb \rightarrow gb$ ,  $g \rightarrow bb$





# *b* production at LHC

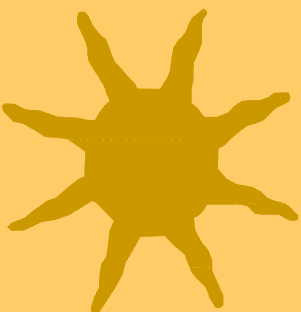
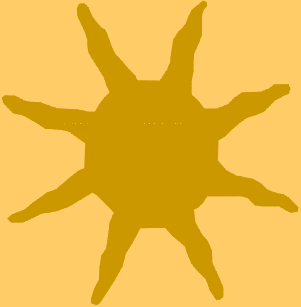


- ★ Very high rates of *b* quark production at LHC
  - 1 % of all events are *b*-*b*bar
  - High statistics of *b* hadron decays in ATLAS
    - ca.  $10^8$  reconstructed events (3 yr, low lumi)
  - Potential for high-quality measurements of *b*-*b*bar correlations

## Semi-inclusive and exclusive channels (statistics 3 yrs)

Inclusive channels	Events	Exclusive channels with the same lepton content	Events
$bb \rightarrow J/\psi(\mu\mu)X + \mu$	$2.8 \times 10^6$	$bb \rightarrow J/\psi(\mu\mu)X$ (excl) + $\mu$	$2.1 \times 10^5$
$bb \rightarrow J/\psi(\mu\mu)X + e$	$3.6 \times 10^6$	$bb \rightarrow J/\psi(\mu\mu)X$ (excl) + $e$	$2.1 \times 10^5$
$bb \rightarrow J/\psi(ee)X + \mu$	$0.6 \times 10^6$	$bb \rightarrow J/\psi(ee)X$ (excl) + $\mu$	$0.9 \times 10^5$





## *b-bbar correlations with ATLAS*



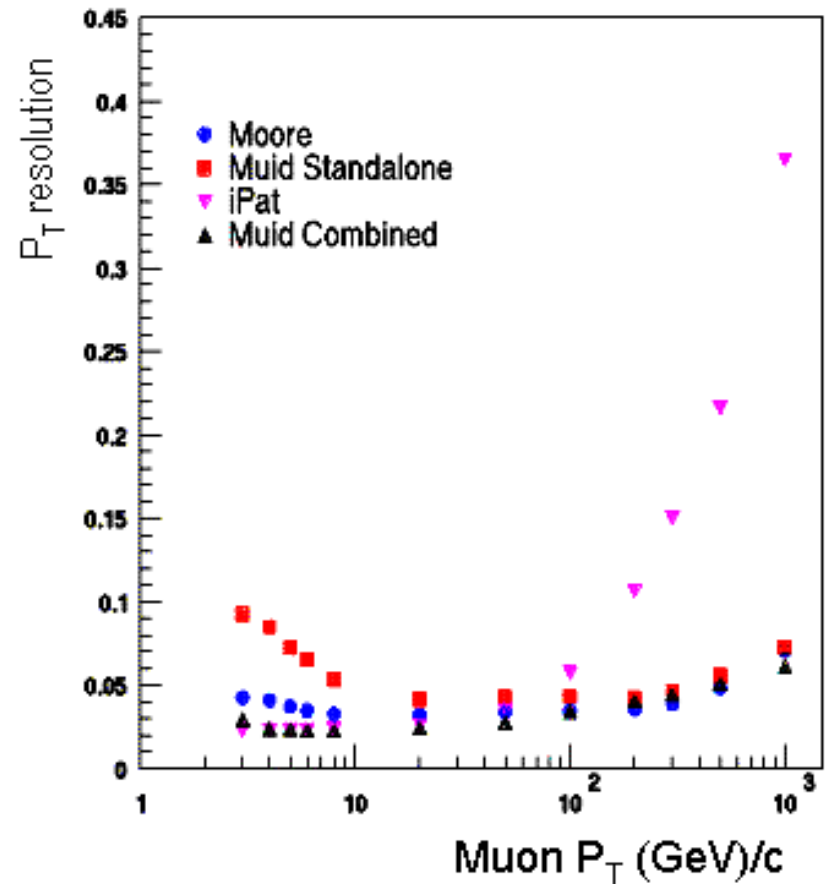
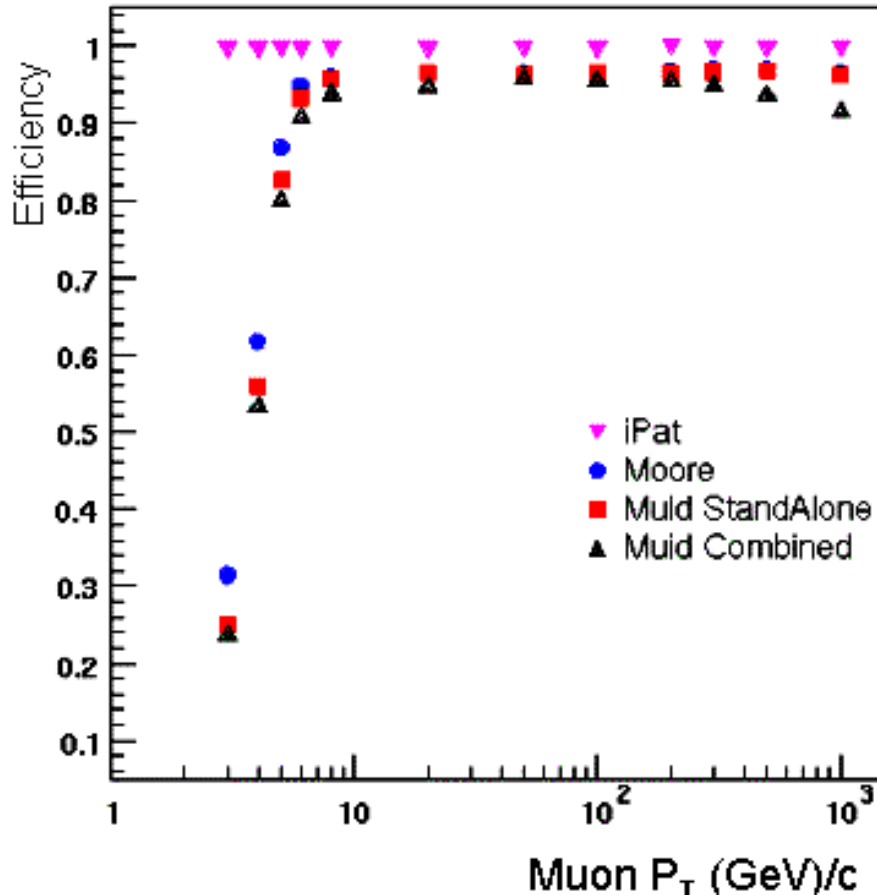
- ★ We want to investigate angular correlations in b-bbar production.
- ★ Investigating using
  - $b \rightarrow J/\psi X \rightarrow \mu\mu X$
  - $b\bar{b} \rightarrow \mu X$
  - $J/\psi - \mu$  angle measurements
    - Smaller backgrounds due to  $J/\psi$  constraint
- ★ The ATLAS detector performance is very good for these channels and provides interesting data for this type of measurements.



# ATLAS Muon Combined Reconstruction



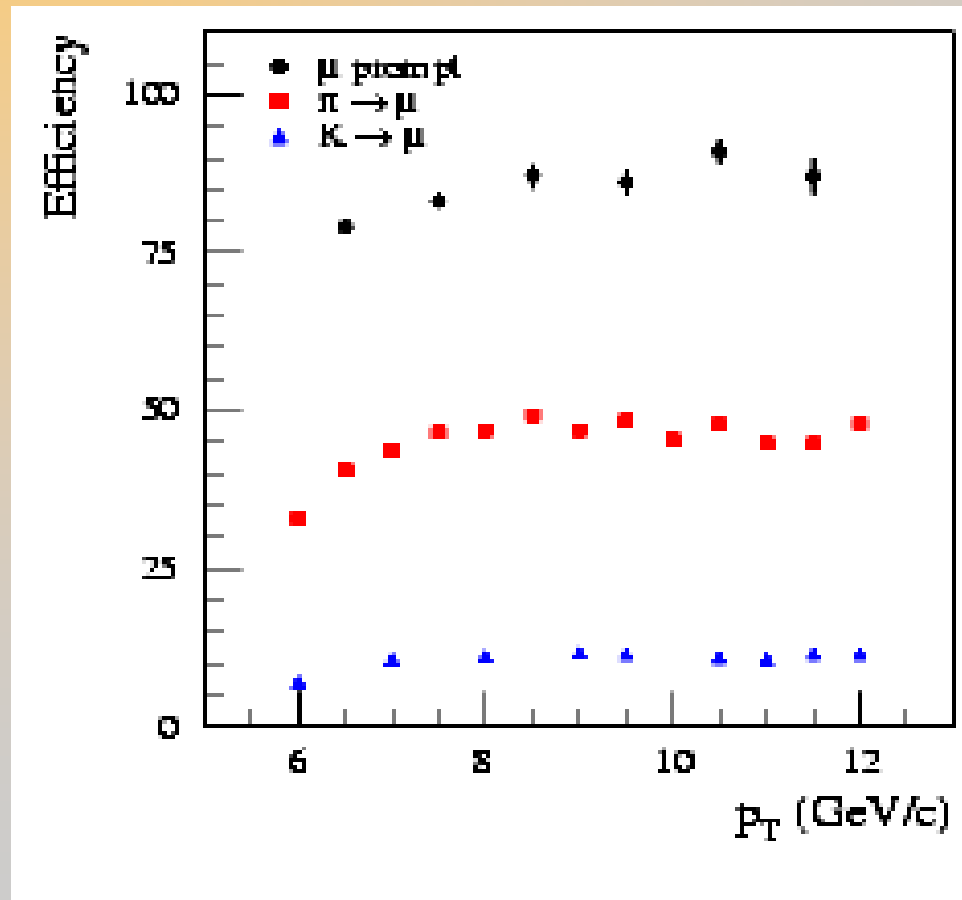
Full simulation studies show excellent reconstruction of muons (Muon System + Inner Detector).





# ATLAS Muon Combined Reconstruction

- Efficient rejection of muons from  $\pi/K$  to  $\mu$



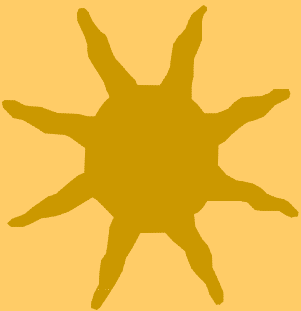
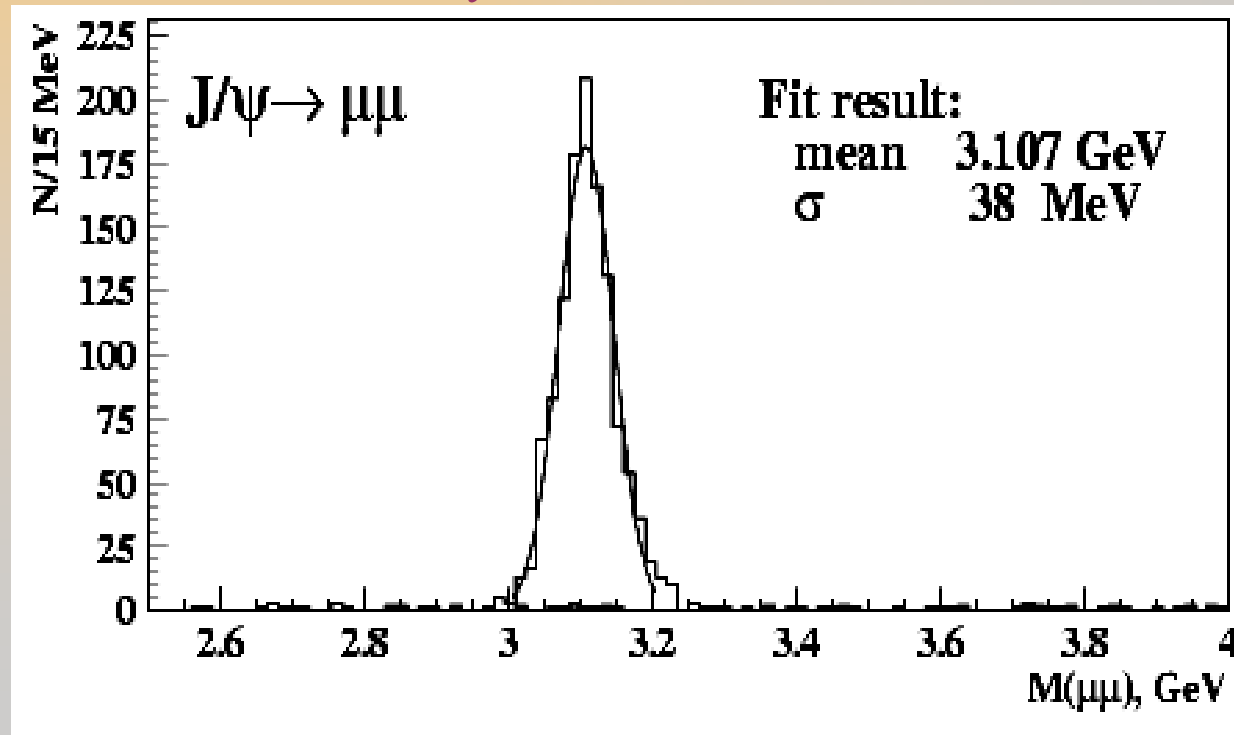


# *ATLAS $J/\psi$ reconstruction in inclusive $b \rightarrow J/\psi X$ events*

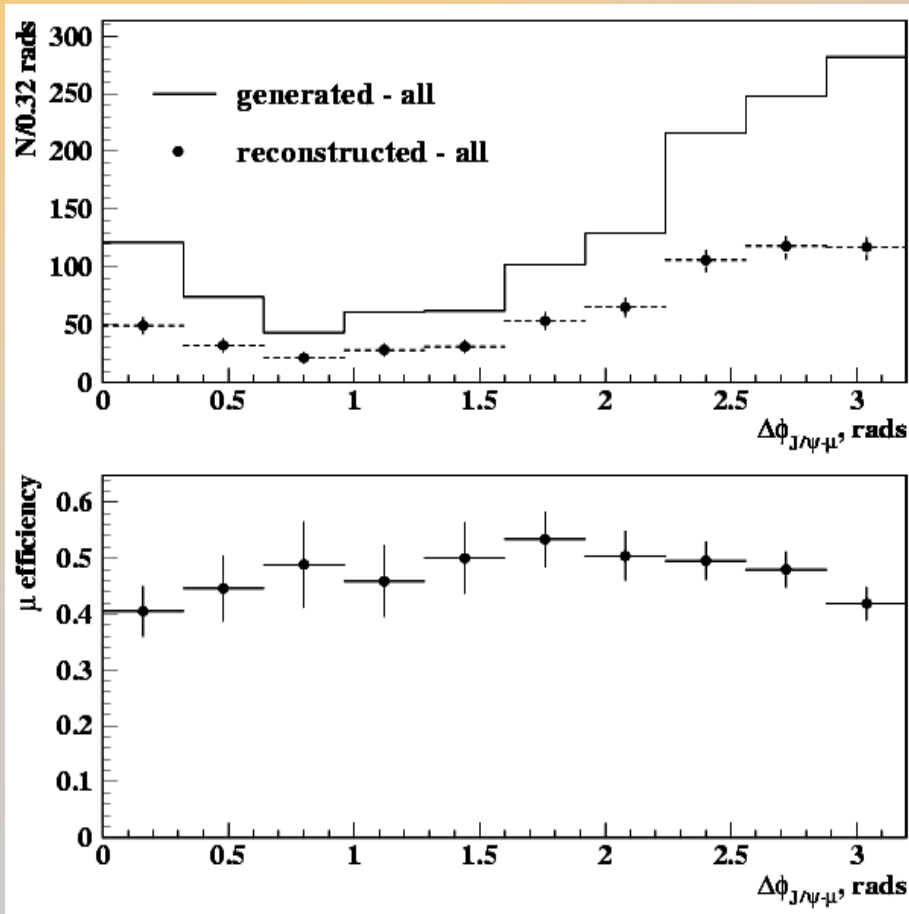
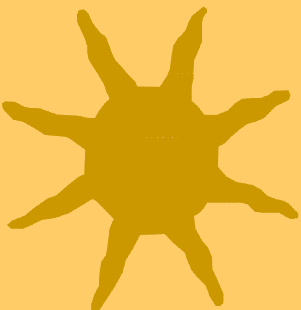
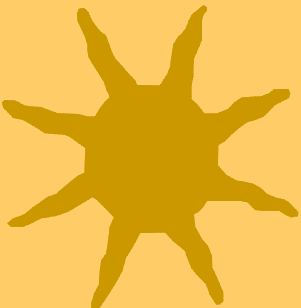


- ★  $J/\psi$  reconstruction resolution does not degrade even inside b-jets with  $p_T > 50 \text{ GeV}$

Phys. TDR-MUID



# ATLAS $b$ - $b\bar{b}$ correlations in $B_d^- \rightarrow J/\psi K_s^0, \bar{b} \rightarrow \mu X$



★ Efficiency does not drop significantly at small  $\Delta\phi < 1$ .

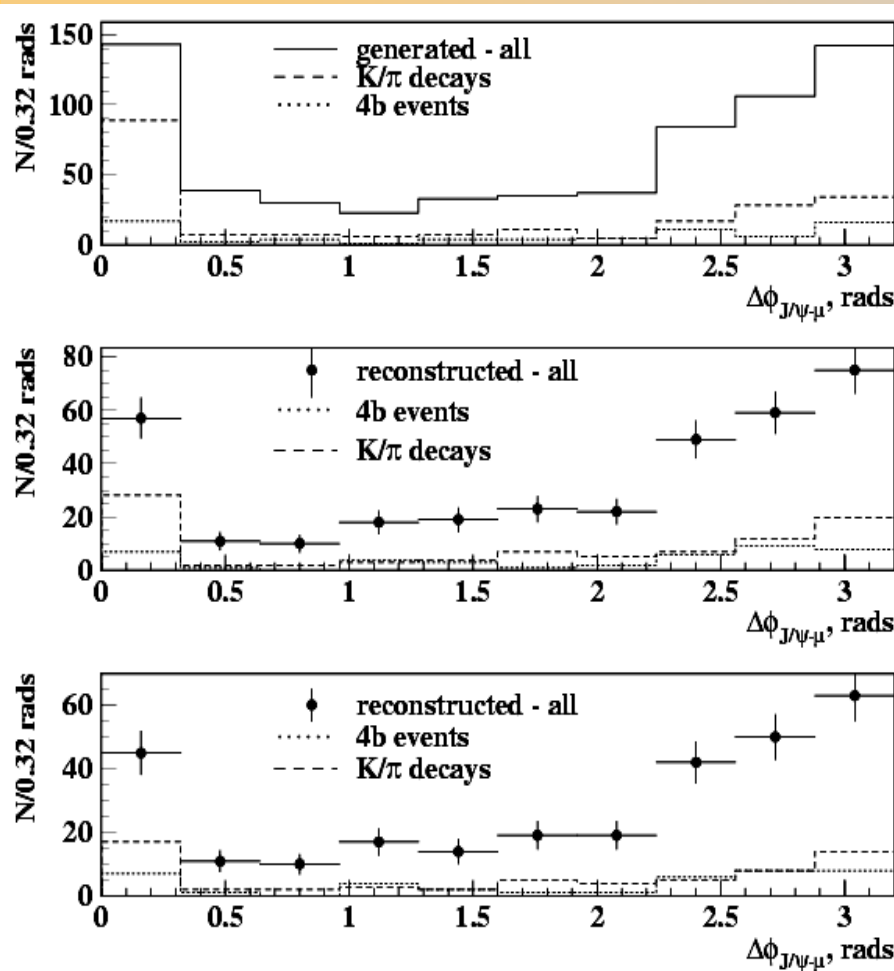
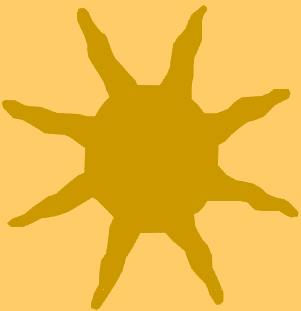
★ Selection cuts do not require any model dependent correction.



# ATLAS $b$ - $b$ correlations in

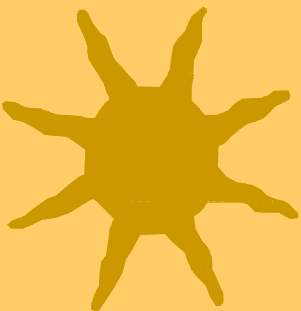


$$B_s^0 \rightarrow J/\psi \phi, \bar{b} \rightarrow \mu X$$



- ★ Background included within the event reconstruction
  - before and after application of K/π rejection

- ★  $B_s^0$  is more difficult than  $B_d$ 
  - correlated bgnd. from  $K^+ \rightarrow \mu$



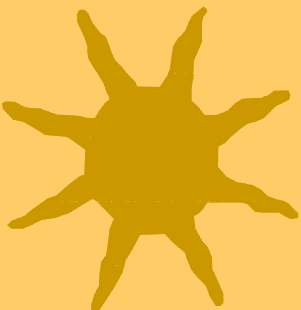
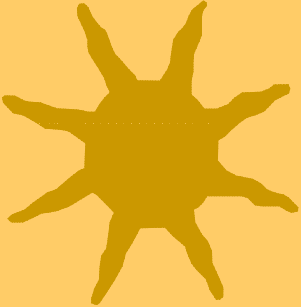
# *Conclusions I*



- ★ The high beauty production rate at LHC will allow to extend b-production measurements. Correlations between b and  $\bar{b}$  quarks and events with more than one heavy-quark pair,  $b\bar{b}b\bar{b}$ ,  $b\bar{b}c\bar{c}$ ,  $b\bar{b}s\bar{s}$ , that were difficult to access in previous experiments due to limited statistics, will be investigated in detail.
- ★ ATLAS can exploit the large statistics of B-hadron decays reconstructed exclusively allowing for precise b production measurements.



## Conclusions II



- ★ Good prospects for measurements of b-bbar correlations in muon channels.
- ★ In  $b\text{-}\bar{b} \rightarrow J/\psi (\mu\mu) X$ ,  $J/\psi$  event mass reconstruction is not degraded at b-jet even for medium momenta  $p_T > 50$  GeV.
- ★ For b-bbar correlations so far two exclusive channels were studied
  - $B_d \rightarrow J/\psi K_s^0$
  - $B_s^0 \rightarrow J/\psi \phi$looking for additional muon.
- ★ Need to understand b production
  - $b\bar{b}b\bar{b}$  as background to Higgs decays