Studies of Semileptonic Rare B Decays at ATLAS and CMS

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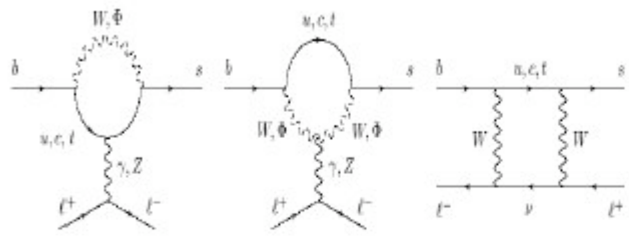
- on behalf of ATLAS and CMS collaborations

Outline

- Introduction
- Semileptonic rare decays in ATLAS
  - dimuon signature:
    - $B_d \rightarrow K^{0*}\mu^+\mu^-$, $B_s \rightarrow \Phi\ \mu^+\mu^-$, $B^+ \rightarrow K^+\mu^+\mu^-$, $B^+ \rightarrow K^{+*}\mu^+\mu^-$, $\Lambda_b \rightarrow \Lambda^0\mu^+\mu^-$
  - the trigger strategy
  - offline analysis
- Semileptonic rare decays in CMS: studies started, but not official yet
  - see CMS general talk by Starodumov on Monday session
- Conclusions

Introduction

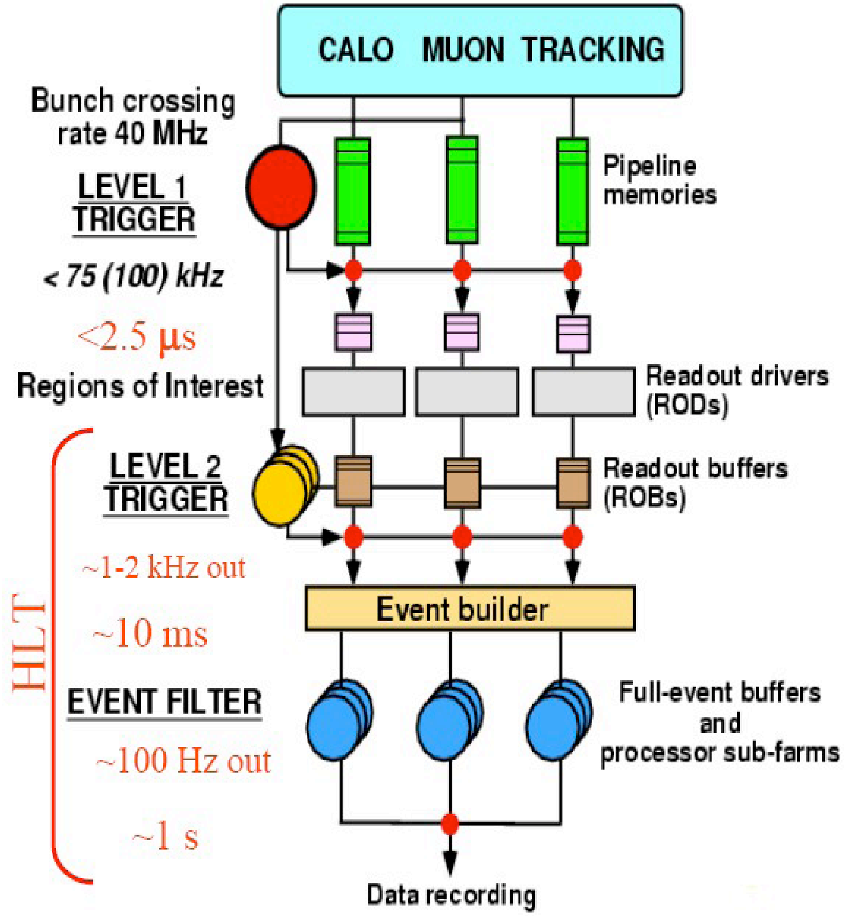
- $b \to s(d)l^+l^-$ FCNC transitions in SM
  - forbidden at the tree level, at lowest order occur through one-loop penguin and box diagrams
  - branching ratios ~ $10^{-6} \div 10^{-7}$



- They provide a test of the SM and indirect search for signals of physics beyond the SM
  - differential cross-section sensitive to new physics
    - forward-backward asymmetry
    - dilepton invariant mass spectrum
  - provide information on long-distance QCD effects
  - one additional check to measure values of $|V_{ts}|$ and $|V_{td}|$ CKM matrix

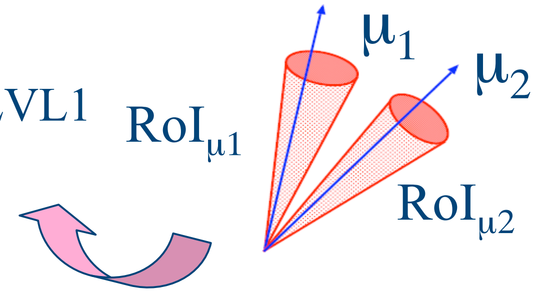
ATLAS Trigger Schema

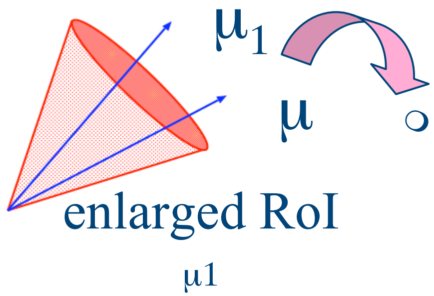
- LVL1
  - hardware-based, identifies Regions of Interest (RoI) for further processing
- LVL2
  - confirm LVL1 trigger
  - precision muon chamber and inner detector measurements in LVL1 RoI
- EF
  - refine LVL2 selection using offline-like algorithms
  - full event, alignment and calibration data available



Trigger for Semimuonic Rare B Decays - I

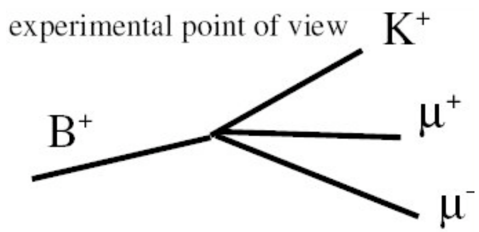
- B-Physics is accounted for 5÷10% of total trigger resources: it must be fast, efficient and selective
- Semileptonic decays: di-muon final state
- B-Trigger has two types of muon-based triggers
  - Topological triggers: based on two LVL1 muons confirmed at LVL2 (high luminosity period)

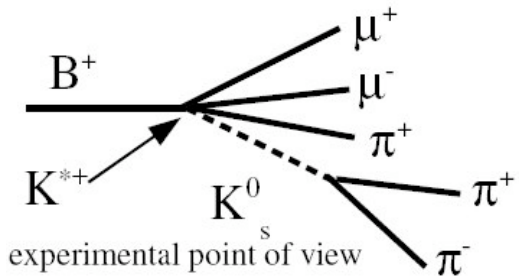




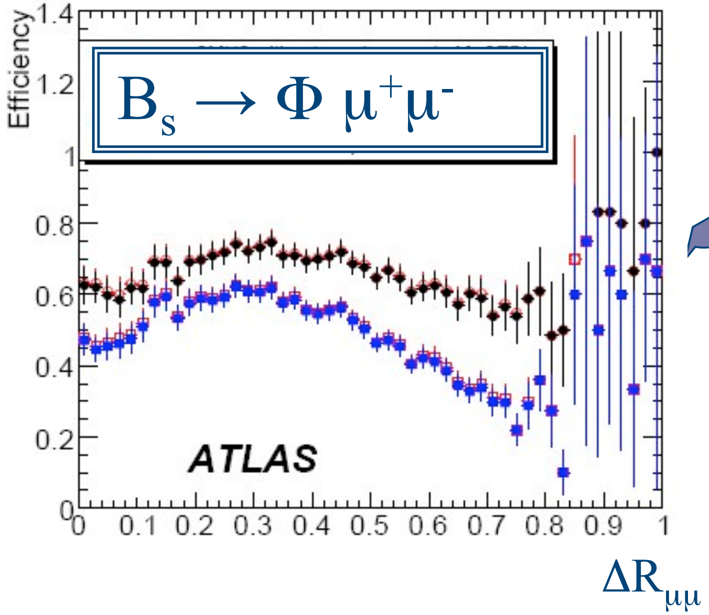
  - TrigDiMuon-based triggers where there is only one LVL1 muon and the second muon is found at the HLT stage (low luminosity period)

- Hadron part trigger: now specific for each channel, track searched in the same RoI(s)





Trigger for Semimuonic Rare B Decays - II

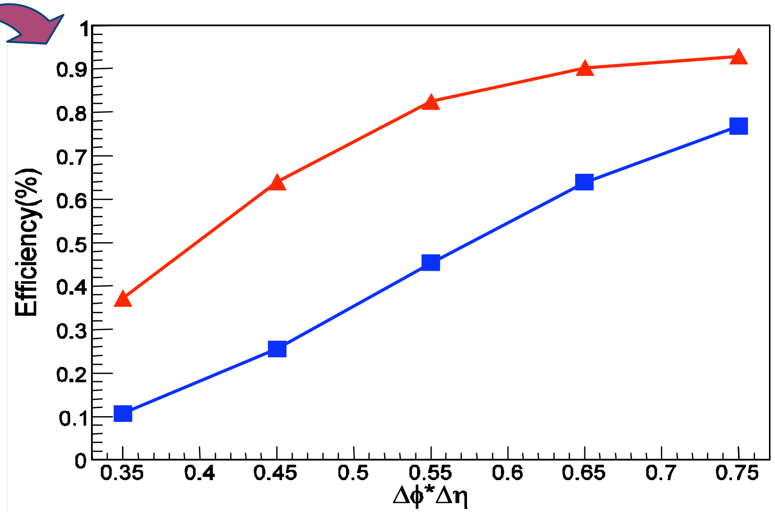


- LVL1 muons trigger efficiency vs. dimuon opening angle:
  - μ_1 and μ_2 $p_T > 4$ GeV (circles)
  - μ_1 and μ_2 $p_T > 6$ GeV (squares)

➯ Acceptance do not vanish in small opening angle region

- LVL2 TrigDiMuon-based trigger efficiency as a function of RoI size:
  - $\mu 1$ p_T>6GeV and $\mu 2$ p_T>3GeV
  - $\mu 1$ p_T>4GeV and $\mu 2$ p_T>2.5GeV

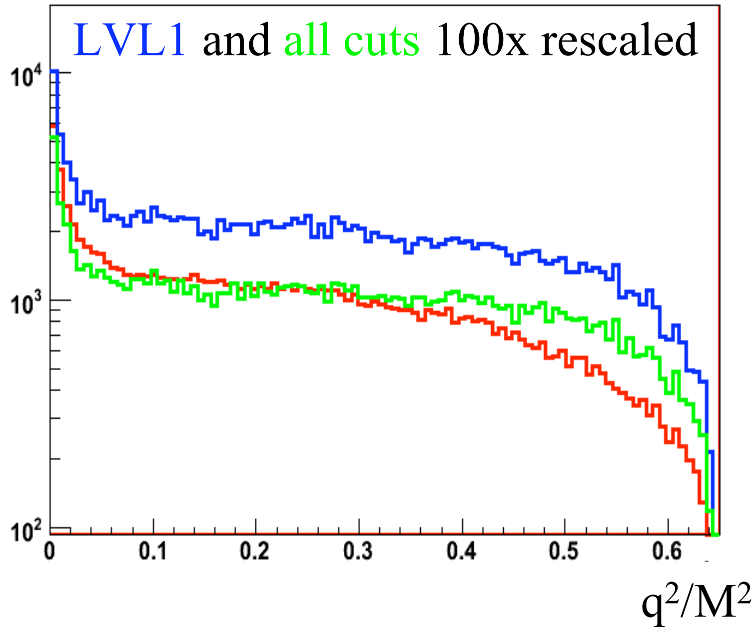
➯ Red curve shows saturation of efficiency as $\Delta\Phi \cdot \Delta\eta \geq 0.65$



Trigger for Semimuonic Rare B Decays - III

- Impact of trigger cuts on $\Lambda_b \rightarrow \Lambda^0\mu^+\mu^-$: LVL1 muon cuts, p_T>0.5GeV hadron cut and acceptance $|\eta|<2.5$
  - trigger cuts prefer higher dimuon invariant mass
  - suppression of $|A_{FB}|$ in low q^2/M^2 region

Di-muons invariant mass

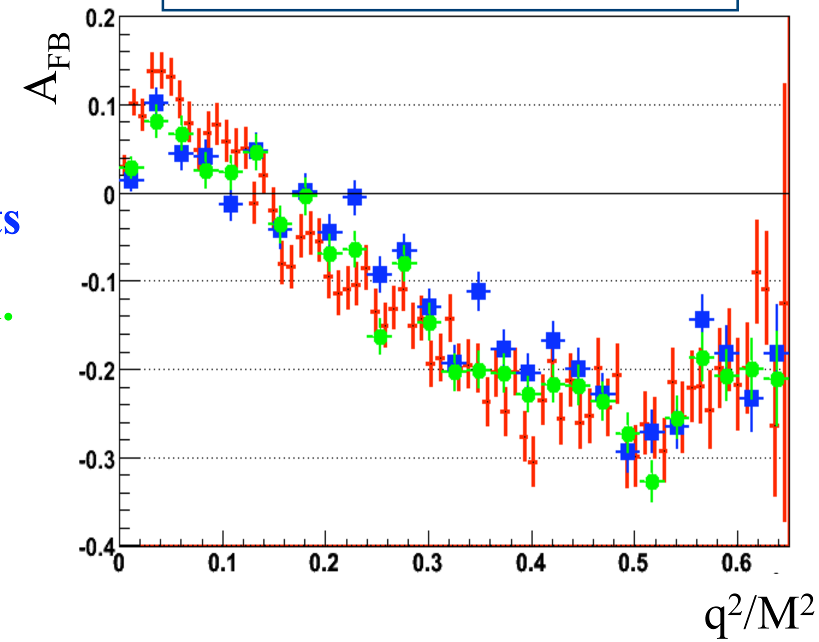


No cuts

LVL1 cuts

HLT had. cuts

Forward-Backward Asymmetry



Offline Analysis - I

- $B_d \rightarrow K^{0*}\mu^+\mu^-$, $B_s \rightarrow \Phi\, \mu^+\mu^-$, $B^+ \rightarrow K^+\mu^+\mu^-$, $B^+ \rightarrow K^{+*}\mu^+\mu^-$, $\Lambda_b \rightarrow \Lambda^0\mu^+\mu^-$
- Analysis variables:
  - good dimuon vertex with χ^2/NDF<3
  - dimuon mass in kinematical allowed window and J/Ψ and Ψ(2S) areas excluded $m_{\mu\mu} \notin [m_\Psi \pm 3\sigma]$
  - secondary hadron reconstruction with vertex χ^2/NDF<2, p_T>3GeV and mass in $m_h \pm 3\sigma$
  - good B meson vertex with χ^2/NDF<2
  - b-hadron mass in $m_B \pm 3\sigma$ and proper time>0.5ps

Decay Channel	Theo. Br.Ratio	Cross-Section	Events in 30 fb^{-1}
$B_d \rightarrow K^{0*}\mu^+\mu^-$	$1.3 \cdot 10^{-6}$	2.5 pb	2500
$B_s \rightarrow \Phi\, \mu^+\mu^-$	$\sim 10^{-6}$	0.57 pb	900
$B^+ \rightarrow K^+\mu^+\mu^-$	$3.4 \cdot 10^{-7}$	2.0 pb	4000
$B^+ \rightarrow K^{+*}\mu^+\mu^-$	$\sim 10^{-6}$	2.1 pb	2300
$\Lambda_b \rightarrow \Lambda^0\mu^+\mu^-$	$2.0 \cdot 10^{-6}$	1.2 pb	800

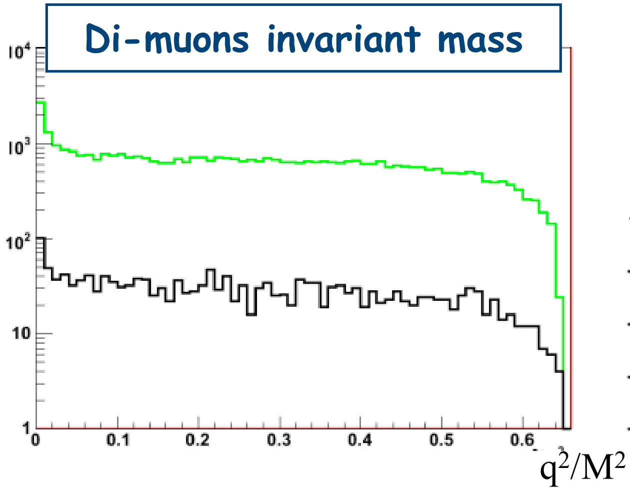
Number of expected events after analysis cuts

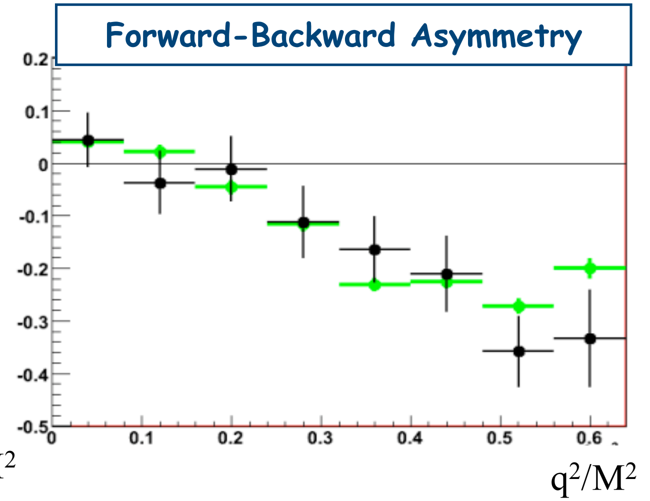
Offline Analysis - II

$\Lambda_b \rightarrow \Lambda^0\mu^+\mu^-$

simulated events

reconstructed events

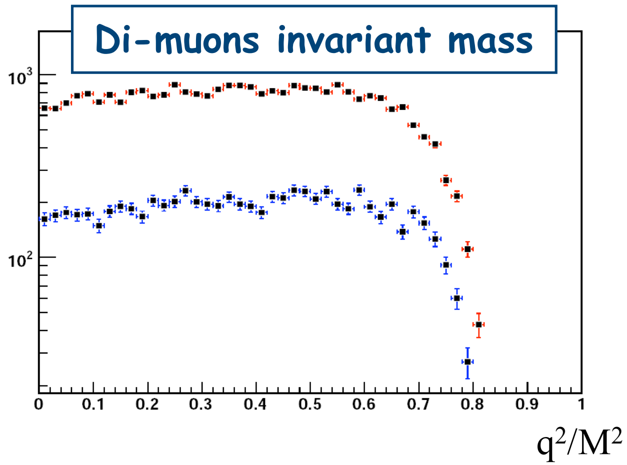


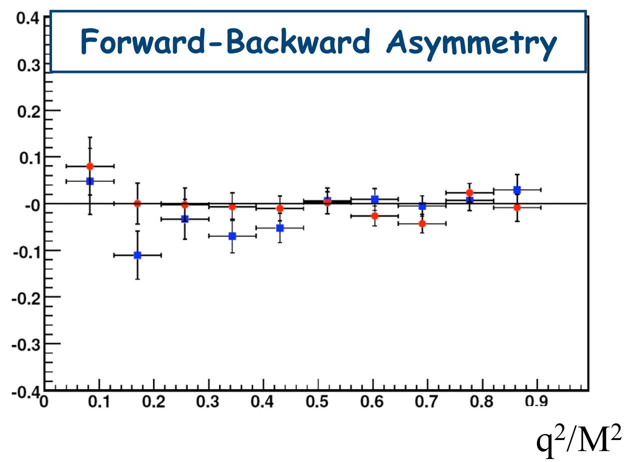


$B^+ \rightarrow K^+\mu^+\mu^-$

simulated events

reconstructed events



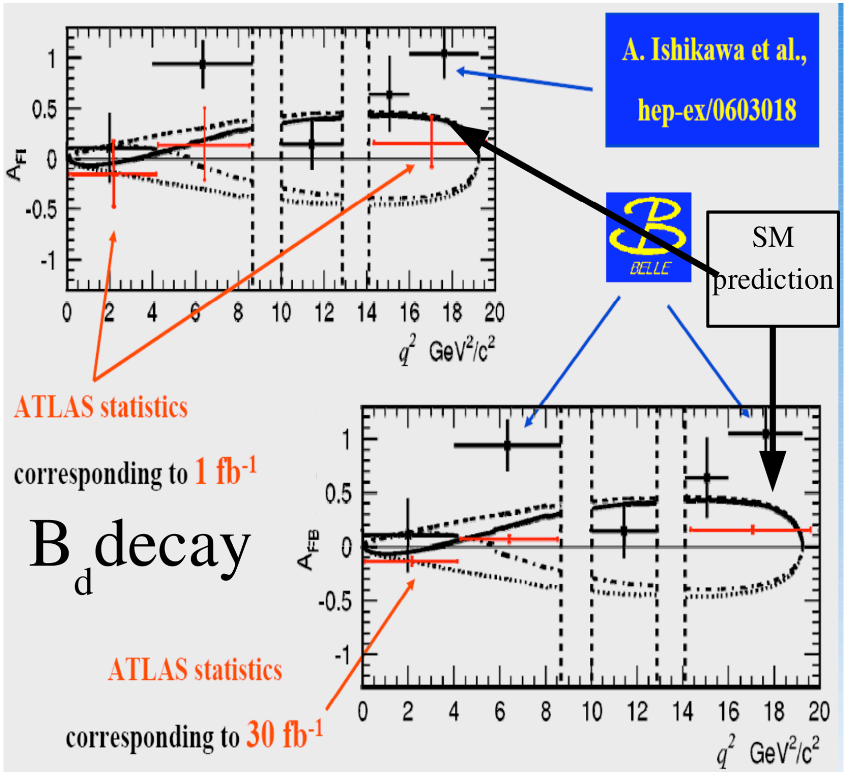


Offline analysis cuts do not introduce additional effects on dimuon invariant mass spectrum and A_{FB}

Expected precisions

- Plot is from Belle hep-ex/0603018:
  - ✓ Solid and dashed lines are SM; dotted and dot-dashed lines are NP; black crosses are Belle measurements
  - ✓ Red crosses are ATLAS expectations, with statistical errors only (B_d decay)

Decay Channel ($30\ fb^{-1}$)	δA_{FB} (1-6)GeV
$B_d \rightarrow K^{0*}\mu^+\mu^-$	4.8 %
$B_s \rightarrow \Phi\ \mu^+\mu^-$	6.0 %
$B^+ \rightarrow K^+\mu^+\mu^-$	3.0 %
$B^+ \rightarrow K^{+*}\mu^+\mu^-$	5.2 %
$\Lambda_b \rightarrow \Lambda^0\mu^+\mu^-$	6.0 %



➲ Good sensitivity to measure forward-backward asymmetry in semileptonic rare decays

Conclusions

- LHC potential for semileptonic rare decay physics is enormous

- ATLAS and CMS will use this potential for precise measurements of quantities sensitive to New Physics
  - after 3 years of data taking at $L=(1\div3)\cdot10^{33}cm^{-2}s^{-1}$ there will be enough statistics to find deviations from SM predictions and to set strong limits on New Physics beyond SM
  - will study methods to continue even at nominal luminosity ($L\cong 10^{34}cm^{-2}s^{-1}$) the rare decay program thanks to final state muons