

High Level Trigger for rare decays at LHCb



Kim Vervink On behalf of the LHCb collaboration



17th of July 2009



LHCb

2

Detector fully equipped and commissioned.

Physics goal: search for New Physics in B decays in LHCb.

See also talk at plenary by A. Golutvin "LHCb" - Wednesday 22nd at 14h30

LHCb trigger environment 17/07/09



BR of interesting B decays: typically < 10^{-5} O(1)Hz

LHCb

3

Trigger is essential!!!



LO trigger



LHCD







• Muon: single μ with $p_{\tau} > 1.0 \text{ GeV} \rightarrow 200 \text{ kHz}$



LO output is large: 1 MHz

Pictures: Readout Network (Switch)



LHCb THCp

6

K. Vervink 17/07/09





8

HIt2 trigger example:

K. Vervink 17/07/09

the inclusive ϕ alley

~30 kHz

1. tracks from pattern recognition (no fitting) - apply "robust" cuts: P_T , distance to IP, ϕ mass...

800 Hz

3. Now with a reduced rate below 1000 Hz, we can apply the PID algorithm



2000 Hz

2. fancier tracking algorithm applied on reduced rate: Kalman fit tracks and apply cuts on track and vertex resolutions.

Hlt2 Incl. φ efficiency on offline selected events.

$B_s \rightarrow \phi \gamma$	75%
$B_s \rightarrow J/\psi(\mu\mu)\phi$	45%
$B_s \rightarrow J/\psi(ee)\phi$	55%
$B_s \rightarrow \phi \phi$	82%
$B_s \rightarrow D_s D_s$	40%
$B_s \rightarrow D_s \pi$	25%

Channels will also be triggered by other incl. trigger lines



Trigger performance on rare decays: 1.) $B^{0} \rightarrow K^{*} \mu \mu$ 2.) $B_{s} \rightarrow \phi \gamma$

See also: Search for New Physics at LHCb: CP violation in Charm sector and rare decays of B hadrons (M. H. Schune) II Flavour Physics - Friday 17th at 10h00

NOTE: trigger efficiencies quoted for offline selected events.

Lнср гнср 10

$$B^{o} \rightarrow K^{*}$$
μμ

- FCNC decay which proceeds through a b→s transition. New Physics can enter in the loops of the diagram.
- Decay described by three angles (θ_l , ϕ , θ_k) and di- μ invariant mass q².
- By measuring angular distribution asymmetries, the uncertainty from B⁰→K*µµ transition form-factors cancel.
- Start with forward-backward asymmetry $A_{\rm FE}$ of θ_l distribution and compare with the SM prediction.
- Analysing simultaneously the three angular distributions as function of q² gives sensitivity to each of its Wilson coefficient.



K* $\mu\mu$ through the trigger: μ and hadron alley

• The muon alleys are main trigger line but beware of soft muon signal.

LHCb ГНСр

11

• Cuts on P_{τ} affects the angular distribution.



N + (Di) Muon alley: Muon + track alley: Hadron alley:	- \textbf{P}_{τ} cut, IP (and di-muon mass) - 2^{nd} μ can have low \textbf{P}_{τ}	#lt1 eff: ~83% eff: ~80% eff: ~20%	#lt2t eff: 80% eff: 85% eff: 80%
--------------------------------------------------------------------	--------------------------------------------------------------------------------------------------	---------------------------------------------	-------------------------------------------

LO x Hlt1 x Hlt2 efficiency on offline selected events: 80%.

Distortion of acceptance function K. Vervink

Trigger and offline selection and the detector resolution affects the angular distribution θ_l . •Zero-crossing point of A_{fb} stays intact!!

Parameterize the acceptance function

- 1. MC simulation: The momentum distribution of B_d needs to be accurately generated. Cross check with $B^o \rightarrow J/\psi K^*$.
- 2. Control sample: $B^{\circ} \rightarrow J/\psi$ K*: triggered and selected by the same filters as the signal -- but 20 times more statistics and no A_{fb} asymmetry.



[2] arXiv:0804.3908v1



17/07/09

LHCD

12



Trigger performance on rare decays: 1.) $B^{o} \rightarrow K^{*} \mu \mu$ 2.) $B_{s} \rightarrow \phi \gamma$

LHCb THCp

$$B_s \rightarrow \phi \gamma$$



Probe New Physics in loop which would modify the photon polarisation.

• Measure the time-dependent decay rate:

$$\Gamma(\overset{(-)}{B_s} \to \phi\gamma) = |A|^2 e^{-\Gamma_s t} \Big[\cosh(\Delta\Gamma_s t/2) + A_s^{\Delta} \sinh(\Delta\Gamma_s t/2) \pm C_s \cos(\Delta m_s t) \mp S_s \sin(\Delta m_s t) \Big]$$

$$C_{s} \approx 0 \qquad S_{s} \approx \sin 2\psi \sin 2\phi \approx 0$$
$$\sin \varphi_{s} \stackrel{SM}{\approx} 0$$

- Decay described by proper-time (t) but not by tagging
- Reliable theoretical prediction at NNLO





- Decay described by proper-time (t) but not by tagging
- Reliable theoretical prediction at NNLO



LO x #lt1 efficiency: ~60%

LHCD

16



* on offline selected events (which passed LO (+ #lt1) trigger)

(b)

9

[ps]

Distortion of the proper-time distribution

- Both trigger selection and offline selection cut on IP distance of φ to reduce the prompt background.

[a.u.]

0.08

0.06

0.04

0.02

2

3

• Affects the B_s proper-time distribution



- Acceptance function: $\varepsilon = \varepsilon(t)$
 - Use control sample $\textbf{B^{0}}{\longrightarrow}\textbf{K^{*}}(\textbf{K^{+}}\pi^{-})\gamma$
 - Follows the same trigger flow

as the signals.

• Statistics are ~factor 6 higher.

 $\frac{2 \text{ fb}^{-1}}{\text{Expect 11x10^3 selected signal events}}$ stat. error on $A^{\Delta} = ~0.2$

5

K. Vervink

17/07/09

Belle [1]: 18⁺⁶-5 signal events on 24 fb⁻¹ BF (B_s $\rightarrow \phi \gamma$)= 57⁺¹⁸-15(stat)⁺¹²-11(syst) 10⁻⁶ [1]PRL 100, 121801 (2008)

K. Vervink 17/07/09

18

Trigger during first data

Trigger settings has to allow for trigger commissioning

1. Random event selector trigger

- Monitor the distributions at LO entrance
- 2. LO trigger + Random event selector in Hlt1:
 - Monitor the distributions of variables we will cut on in Hlt
- 3. Events passing the full trigger:
 - Monitor the online environment using offline reconstruction
 - Trigger efficiencies vs.
 offline



K. Vervink 17/07/09

LHCb THCP

19

Summary

- Critical aspect of LHCb is isolating rare decays in the LHC environment.
- Trigger consist of
 - $\, \circ \,$ a hardware trigger which search for high P_{\tau} events.
 - and a software "High Level Trigger" based on software algorithms in a CPU farm.
- Trigger efficiencies of 80% and 60% for $B^0 \rightarrow K^* \mu \mu$ and $B_s \rightarrow \phi \gamma$ respectively are obtained.
- With control samples we can study and correct for the introduced biases on acceptance function or lifetime distribution.
- Finally strategy for trigger commissioning is discussed

We are ready for data...

K. Vervink 17/0	7/09	
-----------------	------	--

Other LHCb talks at EPS

- Commissioning and performance of LHCb vertex detector (T. Bowcock)
 - IV Detectors & accelerators Thursday 16th at 10h00
- Measurements of CP violation and CKM matrix at LHCb (M. Calvi)
 - II Flavour Physics Thursday 16th at 11h30
- New Physics sensitivity of the rare decay mode B->Kl⁻l⁺ (T. Hurth)
 - II Flavour Physics Friday 17th at 9h30
- Search for New Physics at LHCb: CP violation in Charm sector and rare decays of B hadrons (M. H. Schune)
 - II Flavour Physics Friday 17th at 10h00
- Nonleptonic charmless Bc decays and their search at LHCb (S. Descotes Genon)
 - II Flavour Physics Saturday 18th at 10h05
- LHCb (A. Golutvin) -
 - Plenary session Wednesday 22nd at 14h30