Brief Review of Rare Decay Studies at LHCb

1. $B_s \to \mu^+\mu^-$
2. $B \to X_{s,d}\,\gamma$
3. $B \to X_{s,d}\,l^+l^-$

Merely a summary of what *has* been studied, in order to give a flavour of what is possible.

Updated and extended studies expected soon!

Guy Wilkinson,
University of Oxford

10^{36} Workshop, SLAC May 2003

$B_s \rightarrow \mu^+\mu^-$ search

$B_s \rightarrow \mu^+\mu^-$ is the holy grail of Rare decays at hadron machines

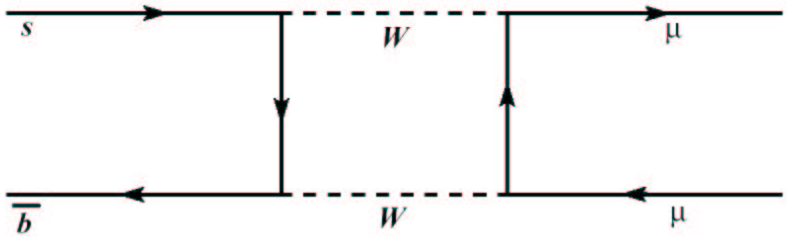
SM model prediction of BR has Small uncertainty:

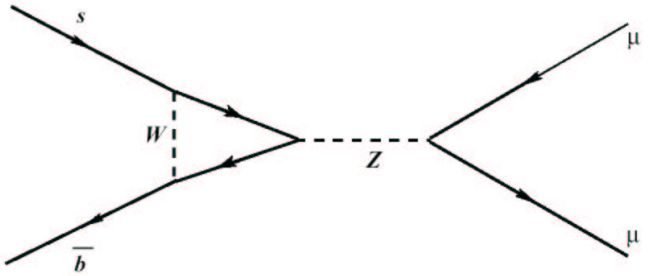
$(3.5 \pm 1.0) \times 10^{-9}$

Very small! Likely to be enhanced by New Physics

Careful feasibility study by LHCb. Very delicate – handful of events!

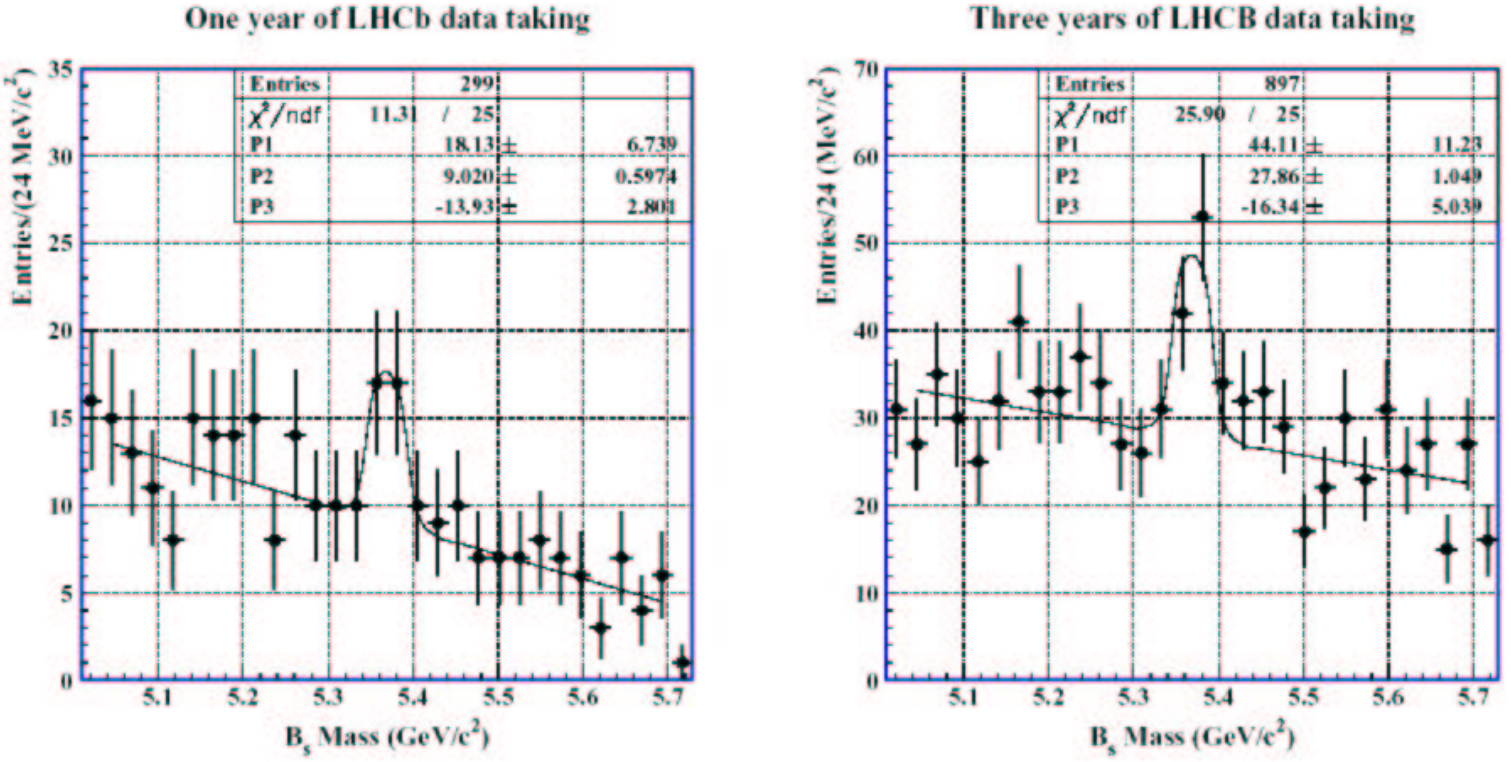
Distinctive trigger signature which Can be given "VIP" treatment





(NB that such decays very well suited to ATLAS/ CMS also)

$B_s \to \mu^+\mu^-$ results



With tight mass cut (eg. $\pm 1.5\ \sigma_{M(\mu\mu)}$):

2.9 σ significance in 1 year

5.7 σ significance in 3 years

$B \rightarrow X_{s,d}\,\gamma$

Feasibility in exclusive radiative Penguins has been demonstrated

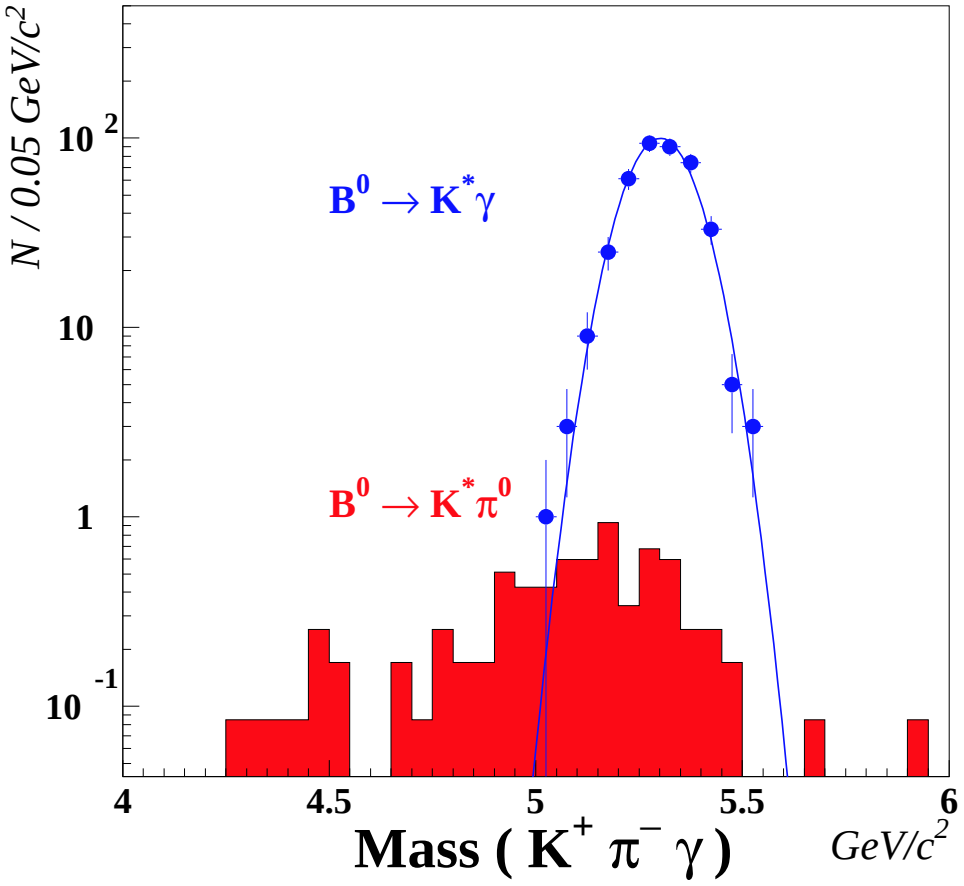
Yield benefits from high p_t photon trigger

Event yield in $B \rightarrow K^{*0}\gamma$

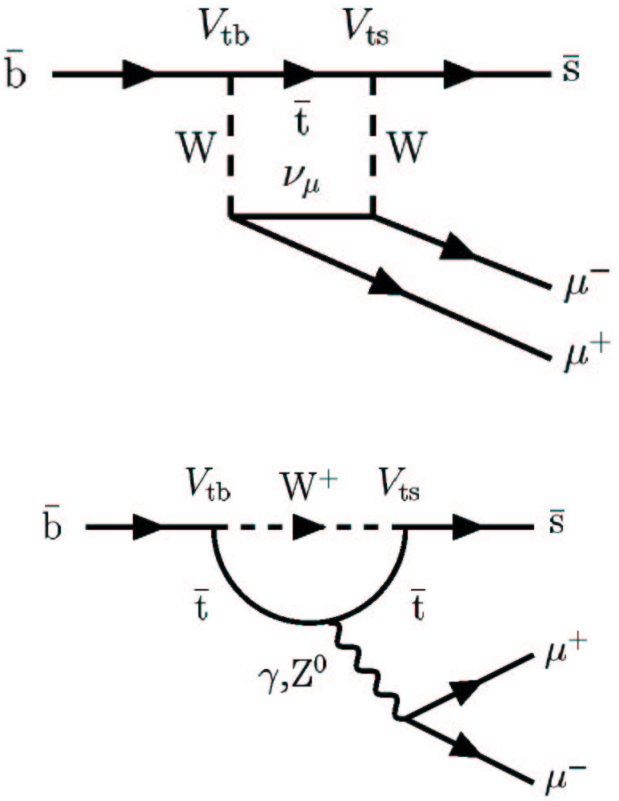
20 k / year

Other decays under study

Inclusive reconstruction not yet investigated



$B \rightarrow X_{s,d}\, l^+l^-$



Decays $B \rightarrow X_{s,d}\, l^+l^-$ have high interest in B physics.

Measurement of $|V_{td}| / |V_{ts}|$ which is complementary to mixing method

Many observables sensitive to NP:

- Cross-section
- Forward backward asymmetry
- Non-zero CP violation?

LHCb feasibility studies have been conducted (show here). Are being Revised for optimised detector.

Reconstruction Strategy

Look only in $\mu^+\mu^-$ channel, as Bremsstrahlung makes J/ ψ and $\psi(2S)$ rejection inefficient for $e+e^-$ (Use cut $1 \leq m_{\mu\mu} \leq 2.45$ GeV)

Benefit from high trigger efficiency for di-muons & good precision on deplaced vertex

Perform analysis with charged tracks only, and K^0_s

Inclusive reconstruction. Form B with:

- One di-muon
- Up to two kaons
- Up to four pions

RICH invaluable!

Reconstruction Performance

Yield in $B^0 \to X_s\ \mu^+\mu^-$

24k events / year

With $m(\mu^+\mu^-)$ cut:
9k events / year
S/B = 5.7 ± 1.5

Yield in $B^0 \to X_d\ \mu^+\mu^-$

550 events / year

With $m(\mu^+\mu^-)$ cut:
200 events / year
S/B = 0.9 ± 0.6

Calculation of inclusive BR has uncertainty from trigger.
More importantly from theory error. Statistical precisions:

$$\sigma\ BR(B^0 \to X_s\ \mu^+\mu^-)/BR = 1.8\ \%$$

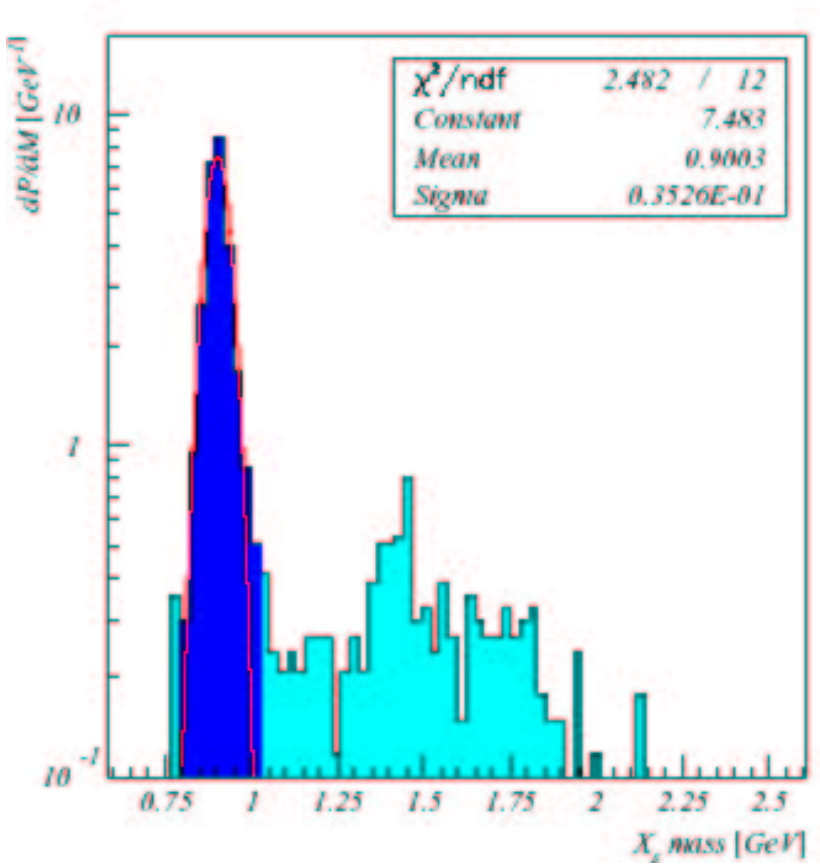
$$\sigma\ BR(B^0 \to X_d\ \mu^+\mu^-)/BR = 22\ \%$$

Exclusive Yields

Mass window applied to $X_{d,s}$ system gives

- 8000 $B^{\pm} \rightarrow \mu\mu K^{\pm}$
- 9000 $B^{0} \rightarrow \mu\mu K^{*0}$
- 700 $B^{\pm} \rightarrow \mu\mu K^{*\pm}$
- 300 $B^{\pm} \rightarrow \mu\mu\pi^{\pm}$
- 200 $B^{0} \rightarrow \mu\mu p$

$\mu\mu K\pi$ mass spectrum



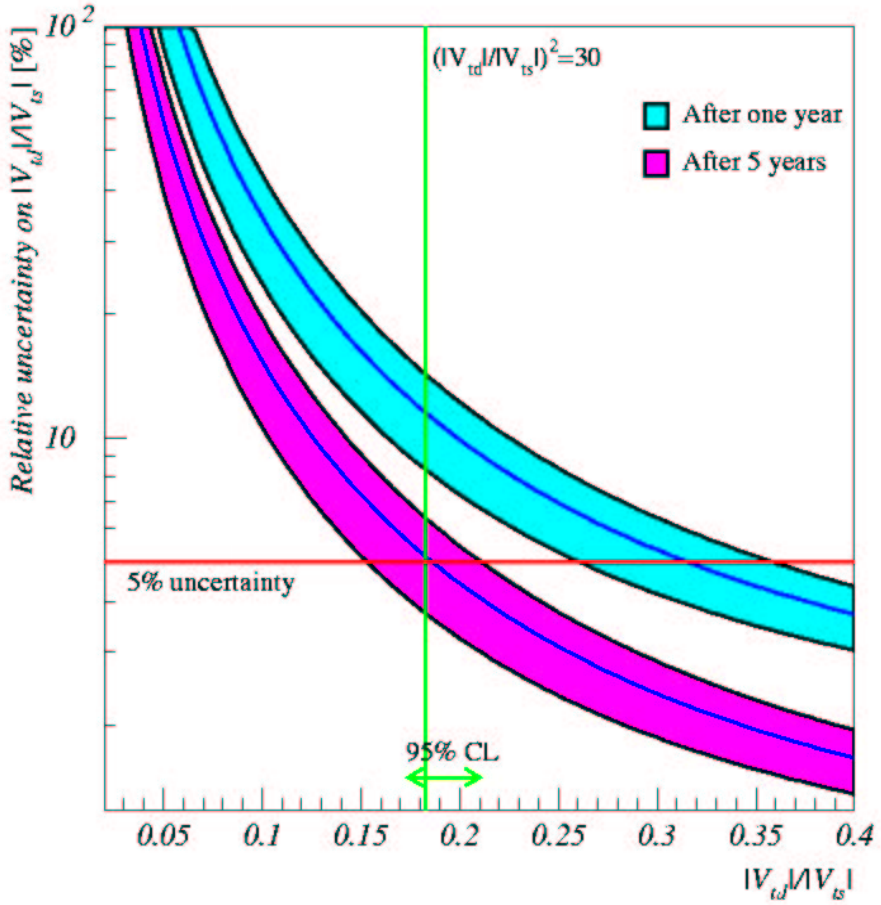
Determination of $|V_{td}|/|V_{ts}|$

As for BR measurements,
Reweight observed events
in dimuon mass range, for
isospin conjugated final states

Uncertainty coming from
invisible high multiplicity
events needs to be investigated

Statistical uncertainty:
- Between 8-14 % after 1 year
- Reach 5 % after 5 ± 3 years

Very interesting complementarity
with oscillation based extraction



Forward Backward Asymmetry (A_{FB})

A_{FB} of angle θ of μ^+ to X_s in $\mu\mu$ frame is very selective between the SM and some SUSY models

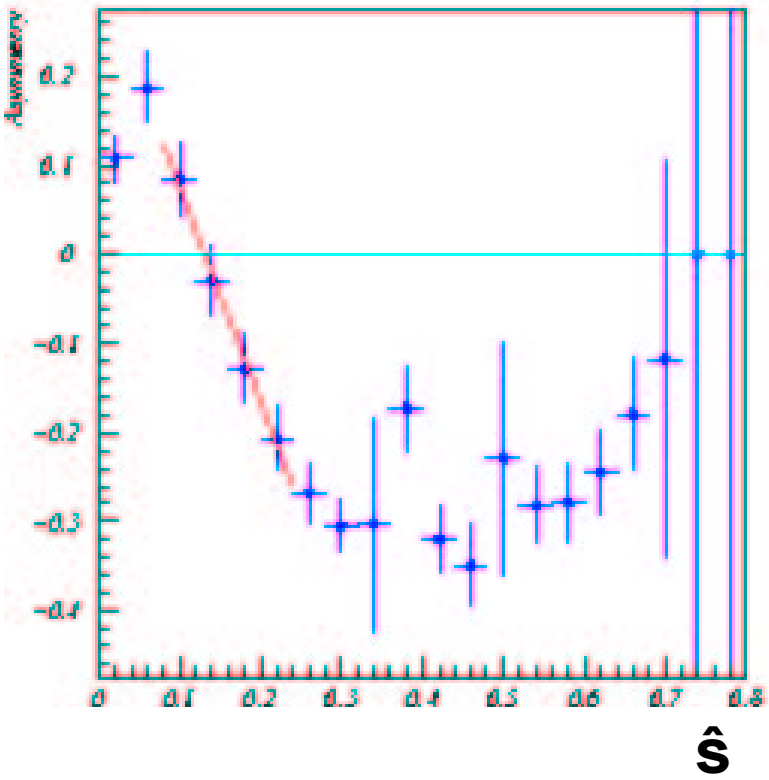
Study dependence vs $\hat{s} = (m_{\mu\mu}/m_B)^2$

A_{FB} expected to be 0 and $\hat{s}$ independent for $\mu\mu K$

$|A_{FB}| \leq 0.6$ % (90% C.L.)
$0 \leq \hat{s} \leq 0.32$ in 10 years

Variation with $\hat{s}$ for $\mu\mu K^*$

Error on zero intercept ~ 10^{-5} in one year's running



Conclusions

- Studies conducted so far show LHCb has powerful potential in rare decays, with demonstrated sensitivity down to 10^{-9}
- $B \rightarrow X_{s,d} l^+ l^-$ looks very promising
- Capabilities encompass modes with leptons, hadrons and neutrals (but .ge. 2 charged tracks a must!)
- This is an area which we should devote more attention to.