

B_s to mu mu gamma from B_s to mu mu

Francesco Dettori, Diego Guadagnoli, Ménil Reboud

Cern, LAPTh

March 29, 2017

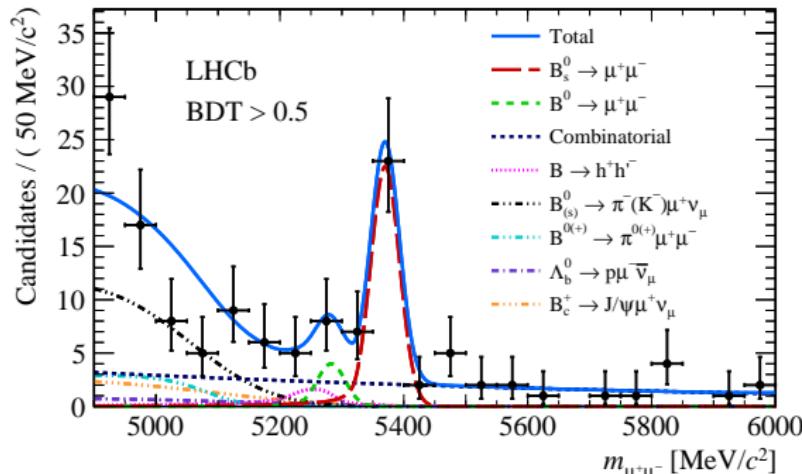


[Dettori, Guadagnoli, Reboud]

$B_s \rightarrow \mu\mu$

- “Golden channel” for the search of NP in FCNC
- Strong limit on Wilson coefficients C_9^{NP} and C_{10}^{NP}
- Recent update of LHCb result:

$$\mathcal{B}(B_s \rightarrow \mu\mu) = (3.0 \pm 0.6^{+0.3}_{-0.2}) \times 10^{-9}$$



[LHCb]

Status of Flavor Anomalies

- Look at the other presentations for a detailed description.
- We need other channels to infirm/confirm these results.

$B_s \rightarrow \mu\mu\gamma$

- Sensitive to C_9 , C_{10} and C_7 (in the low q^2 region)

- No experimental results

- SM:

$$\mathcal{B}(B_s \rightarrow \mu^+ \mu^- \gamma) \approx 5 \mathcal{B}(B_s \rightarrow \mu^+ \mu^-)$$

- Measurement strategies

- Direct measurement

- + Probe all the dilepton mass range $\rightarrow C_7, C_9, C_{10}$
 - Start from scratch, photon reconstruction

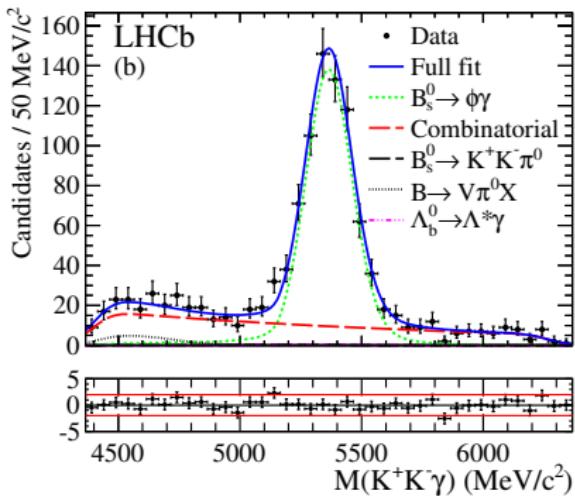
- Indirect measurement

- + Background of $B_s \rightarrow \mu\mu$, no photon reconstruction
 - Only probe the high dilepton mass range $M_{\mu\mu} \sim M_{B_s} \rightarrow C_9, C_{10}$

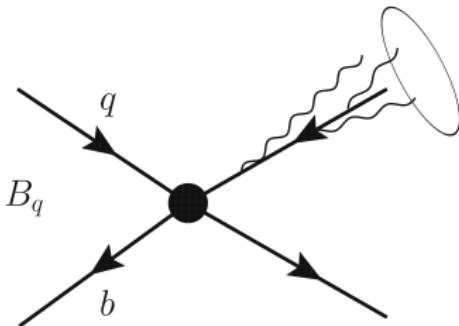
[Melikhov, Nikitin]

Direct Measurement

- Challenging: soft photon, high background, softer muons...
- Ongoing with LHCb data...
- Radiative decays already measured with LHCb: $B_s \rightarrow \phi\gamma$, $B \rightarrow K^*\gamma$



Soft photons emission



■ Analytical point of view

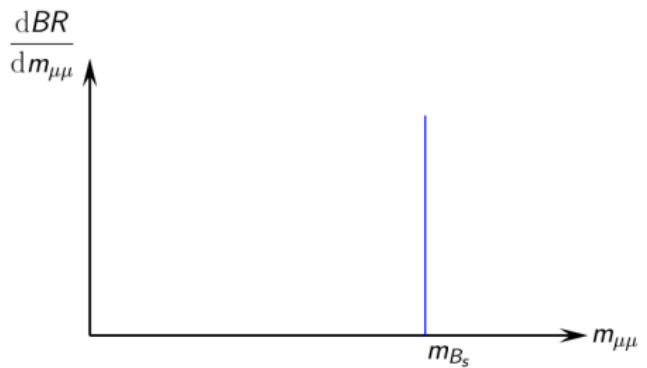
$$\begin{aligned}\mathcal{B}^{\text{phys}}(E_{\max}) &= \mathcal{B}(B_s \rightarrow \mu\mu + n\gamma)_{\sum E_\gamma \leq E_{\max}} \\ &= \omega(E_{\max}) \times \underbrace{\mathcal{B}^{(0)}}_{\text{NR decay}}\end{aligned}$$

$$\text{with } \omega(E_{\max}) \sim \left(\frac{2E_{\max}}{m_{B_s}}\right)^{\frac{2\alpha_{em}}{\pi} b} \text{ and } \omega(60 \text{ MeV}) \approx 0.89$$

[Isidori et al, Weinberg]

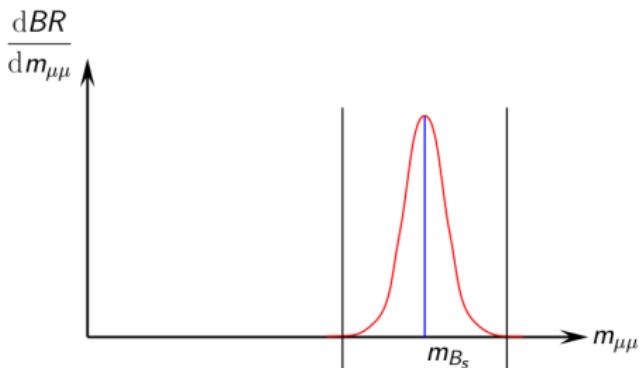
$B_s \rightarrow \mu\mu$

- Ideal case, negligible intrinsic width



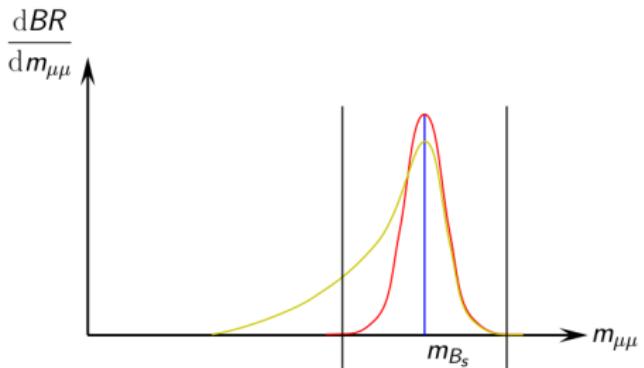
$B_s \rightarrow \mu\mu$

- Ideal case, negligible intrinsic width
- Experimental uncertainty on $m_{\mu\mu}$

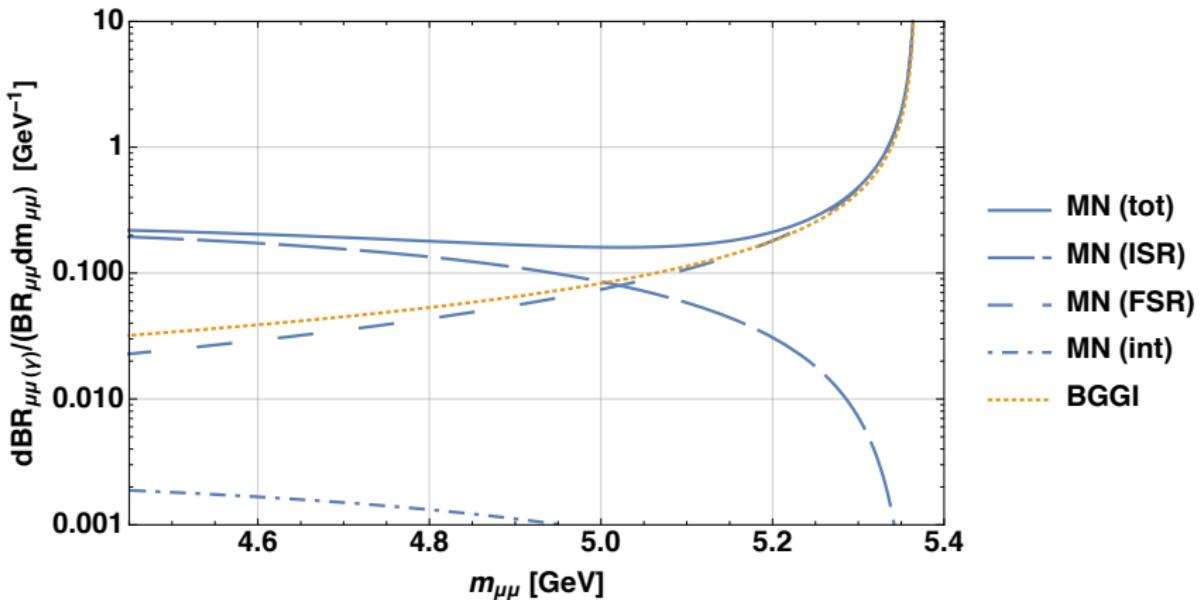


$B_s \rightarrow \mu\mu$

- Ideal case, negligible intrinsic width
- Experimental uncertainty on $m_{\mu\mu}$
- Soft photons emission



$B_s \rightarrow \mu\mu\gamma$ in the SM

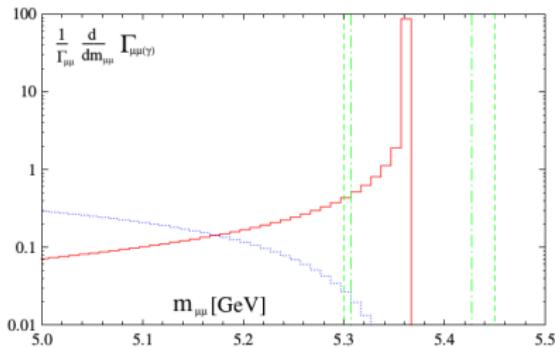


$$\Gamma_{B_s \rightarrow \mu\mu\gamma} \approx \Gamma_{B_s \rightarrow \mu\mu\gamma}^{ISR} + \Gamma_{B_s \rightarrow \mu\mu\gamma}^{FSR}$$

[Buras et al.]

$B_s \rightarrow \mu\mu$ analysis

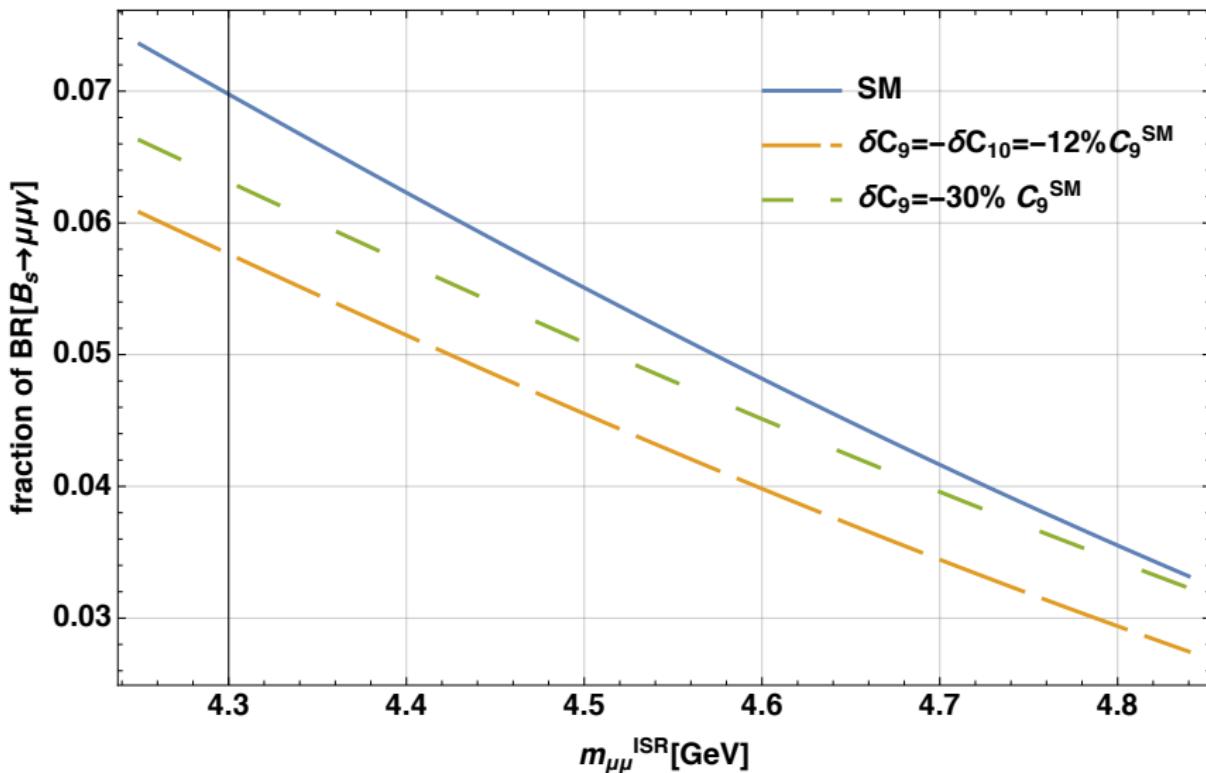
- $B_s \rightarrow \mu\mu\gamma$ is a background of $B_s \rightarrow \mu\mu$
- The FSR part is corrected in the $B_s \rightarrow \mu\mu$ analysis (via MC simulations)
- The ISR part is negligible in the mass window and absorbed in other backgrounds (Combinatorial and partially reconstructed B decays)



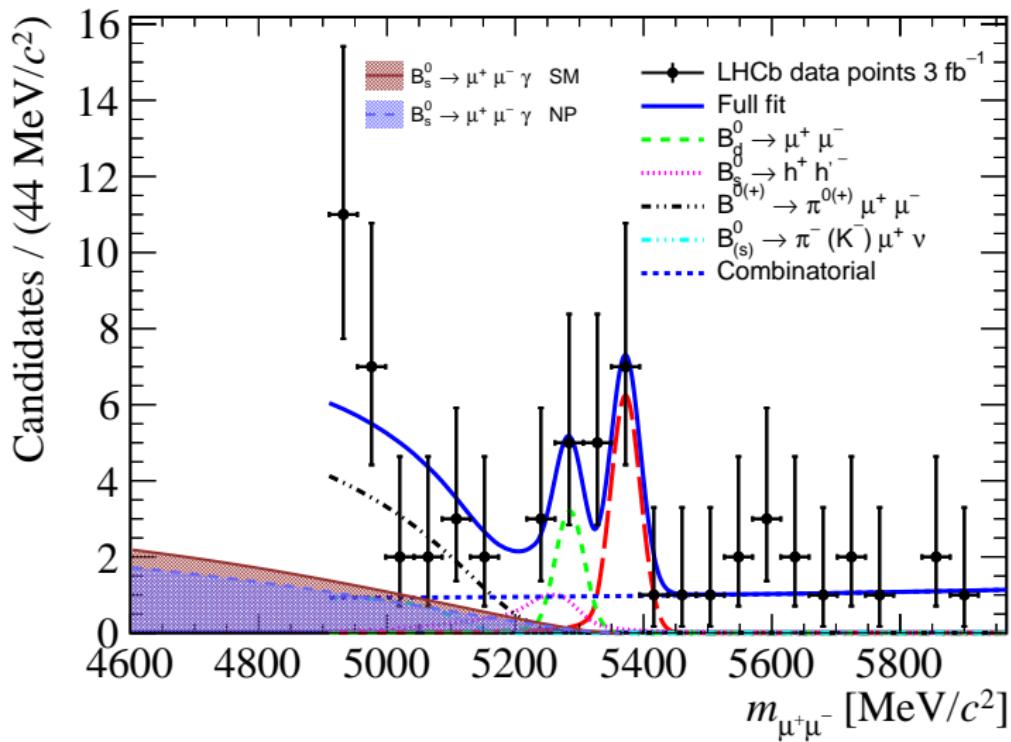
- $B_s \rightarrow \mu\mu\gamma$ decays can be searched as a contamination of the $B_s \rightarrow \mu\mu$ distribution

[Bobeth et al.]

Sensitivity



A last plot



Further remarks

- LHCb is just an example. This method can be applied to other experiments, but:
 - ATLAS and CMS have a worse dimuon mass resolution (25 MeV in LHCb, 30 to 100 MeV for ATLAS and CMS)
 - Belle II will rather perform the direct measurement

Further remarks

- LHCb is just an example. This method can be applied to other experiments, but:
 - ATLAS and CMS have a worse dimuon mass resolution (25 MeV in LHCb, 30 to 100 MeV for ATLAS and CMS)
 - Belle II will rather perform the direct measurement
- The method can be applied to any $M \rightarrow \ell\ell\gamma$ provided that the theoretical prediction is clean (e.g. difficulties with $D^0 \rightarrow \mu\mu\gamma$)

Further remarks

- LHCb is just an example. This method can be applied to other experiments, but:
 - ATLAS and CMS have a worse dimuon mass resolution (25 MeV in LHCb, 30 to 100 MeV for ATLAS and CMS)
 - Belle II will rather perform the direct measurement
- The method can be applied to any $M \rightarrow \ell\ell\gamma$ provided that the theoretical prediction is clean (e.g. difficulties with $D^0 \rightarrow \mu\mu\gamma$)
- The method can be applied to any $M \rightarrow \mu\mu X$ provided that:
 1. $\mathcal{B}(M \rightarrow \mu\mu X) \gtrsim \mathcal{B}(M \rightarrow \mu\mu)$
 2. Good theoretical prediction
 3. Low background

Conclusion

- $B_s \rightarrow \mu\mu\gamma$ is a good countercheck for the $B_s \rightarrow \mu\mu$ analysis
- The direct measurement is not easy
- One can estimate the high dilepton mass spectrum with the $B_s \rightarrow \mu\mu$ sample

Backup

Naive estimation of the branching ratio R_γ^ℓ

$$R_\gamma^\ell = \frac{\mathcal{B}(B_s \rightarrow \ell^+ \ell^- \gamma)}{\mathcal{B}(B_s \rightarrow \ell^+ \ell^-)}$$

1. $\frac{m_\ell^2}{M_{B_s}^2}$: helicity suppression of $B_s \rightarrow \ell^+ \ell^-$
2. α_{em} : additional γ -emission
3. 4π : phase space

[Melikhov, Nikitin]

Naive estimation of the branching ratio R_γ^ℓ

$$R_\gamma^\ell = \frac{\mathcal{B}(B_s \rightarrow \ell^+ \ell^- \gamma)}{\mathcal{B}(B_s \rightarrow \ell^+ \ell^-)} \sim \frac{M_{B_s}^2}{m_\ell^2} \frac{\alpha_{em}}{4\pi}$$

| | R_γ^e | R_γ^μ | R_γ^τ |
|------------------|--------------|----------------|-----------------|
| Naive estimation | 10^5 | 1 | α_{em} |
| Melikhov-Nikitin | 10^5 | 5 | 10^{-2} |

| m_ℓ | E_{min}^γ (MeV) | m_e | | | m_μ | | | m_τ | | |
|---|------------------------|-------|------|------|---------|------|------|----------|------|----|
| | | 20 | 50 | 80 | 20 | 50 | 80 | 20 | 50 | 80 |
| $Br(B_d \rightarrow \ell^+ \ell^- \gamma) \times 10^{10}$ [This work] | 3.95 | 3.95 | 3.95 | 1.34 | 1.32 | 1.31 | 3.39 | 2.37 | 1.87 | |
| $Br(B_s \rightarrow \ell^+ \ell^- \gamma) \times 10^9$ [This work] | 24.6 | 24.6 | 24.6 | 18.9 | 18.8 | 18.8 | 11.6 | 8.10 | 6.42 | |

[Melikhov, Nikitin]