RUN2BWS WG2 Meeting Feb,25,2000
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Rare b Decays at CDF

Contents

Run II Trigger

- 8 GeV electron (same as Run I)
  - 50 B_d / 2 fb^{-1} : $S/B > 1.5$
  - 25 B_s / 2 fb^{-1} : $S/B > 5$
  - Chance to observe Λ_b

  $\rightarrow$ Level 2 trigger rate is higher than the bandwidth (prescale or higher threshold)

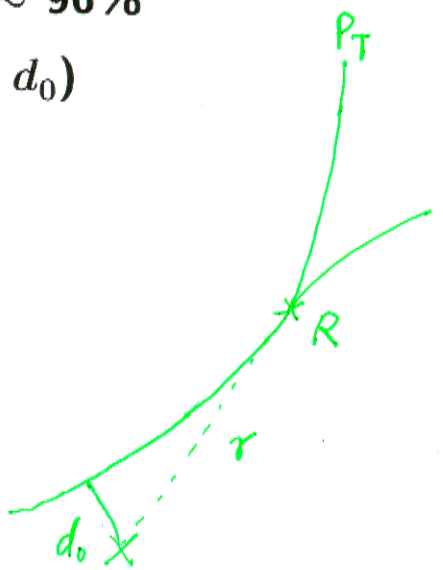
- 3 $\sim$ 4 GeV electron from conversion
  + 2 GeV track with $d_0 > 120$ μm from s-hadron decays
  - 200 B_d / 2 fb^{-1} : $S/B < 1.5$ (1000 events on tape)
  - 100 B_s / 2 fb^{-1} : $S/B < 5$ (400 events on tape)
  - Low efficiency for Λ_b (SVT needs $\geq$ 4 Hits)
    $\rightarrow$ electron + opposite side track will be useful

- 2.5 $\sim$ 3 GeV dielectron
  - two electrons from conversion are asymmetric ($p_T(e1) >> P_T(e2)$)
  - XFT is inefficient for displaced track

Run II Extrapolation

Run I → Run II

- **Accelerator : 75 pb^{-1} → 2 fb^{-1} ($\times$ 27)**
- **Detector**
  - **No central calorimeter upgrade**
  - **Vertex detector coverage :**
    $|Z| <$ 30 cm → 45 cm ($\times$ 1.4)
    $|R| <$ 8 cm → 20 cm (Conversion and Λ)
  - **Radiators : 6% → 8% ($\times$ 1.3)**
  - **Time of flight (improve S/B)**
- **Track trigger**
  - **COT track (XFT) at L1 (p_T and ϕ)**
    $\sigma_{p_T}/p_T^2 \sim$ 0.01 (GeV/c)$^{-1}$, efficiency $\sim$ 96%
  - **Silicon track (SVT) at L2 (p_T, ϕ, and d_0)**
    $\sigma_{d_0} \sim$ 35 μm, efficiency $\sim$ 75%
- **Electron trigger**
  - **Match track to Calorimeter at L1**
  - **Match track to Shower max at L2**



Note: XFT is inefficient for large d_0 tracks (>1cm)

conversion track impact parameter

d_0 **(mm)** $= 4.8$ **(mm)** $\times [R$ **(cm)**$/30]^2 \times 4/p_T$ **(GeV/c)**

1cm for R = 30cm, p_T = 2 GeV/c

$b \to s\gamma$

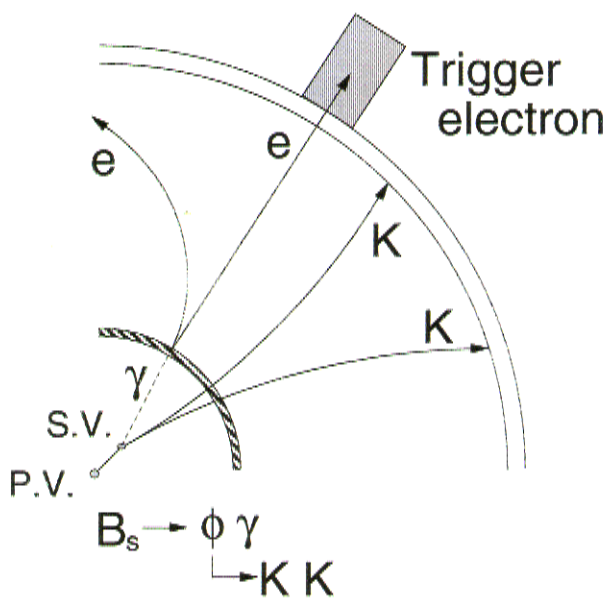
Run I Results

3 modes

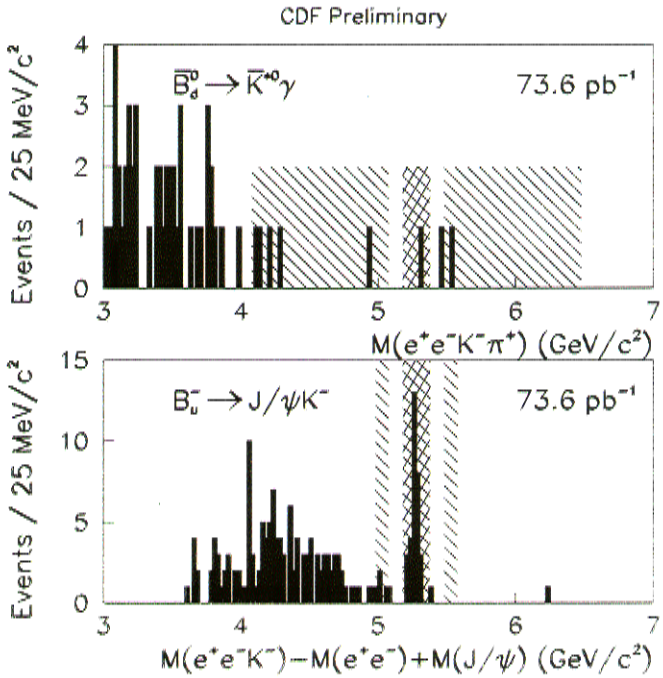
- $B_d \to K^{*0}\gamma$: observed by CLEO
- $B_s \to \phi\gamma$: not yet
  ($< 7 \times 10^{-4}$ at 90% CL by DELPHI)
- $\Lambda_b \to \Lambda\gamma$: not yet, no experimental result

Photon ID : photon conversion in detector

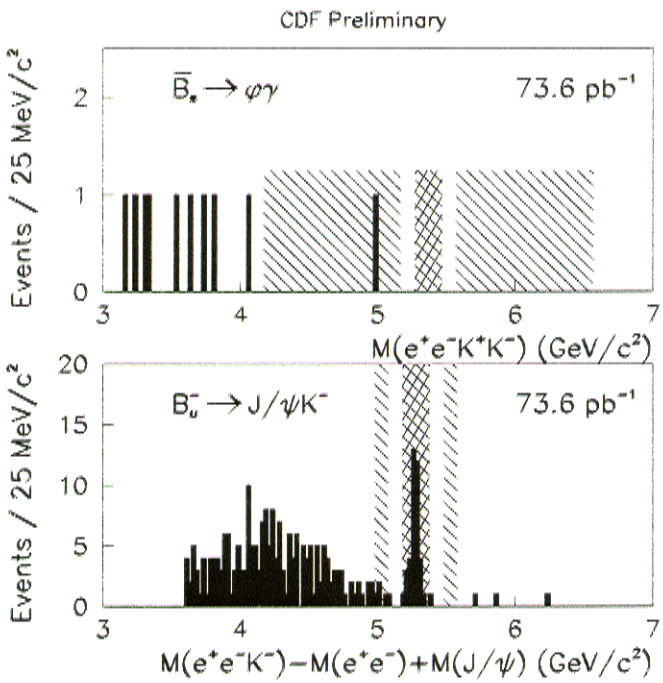
- Efficiency: 6%
- Good S/B and mass resolution ($\sigma M_B \sim$ 30 MeV/c^2)
- 8 GeV single electron trigger data (75 pb^{-1})
- $B_u \to J/\psi K$ for normalization



B_d and B_s



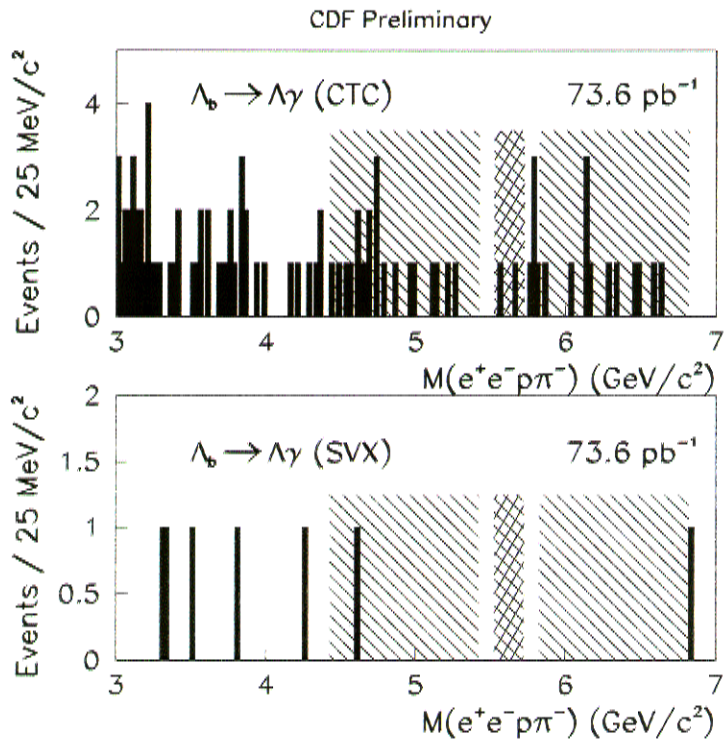
Candidate 1
BG 0.6
Signal expectation 1



Cand 0
BG 0.1
Sig 0.5

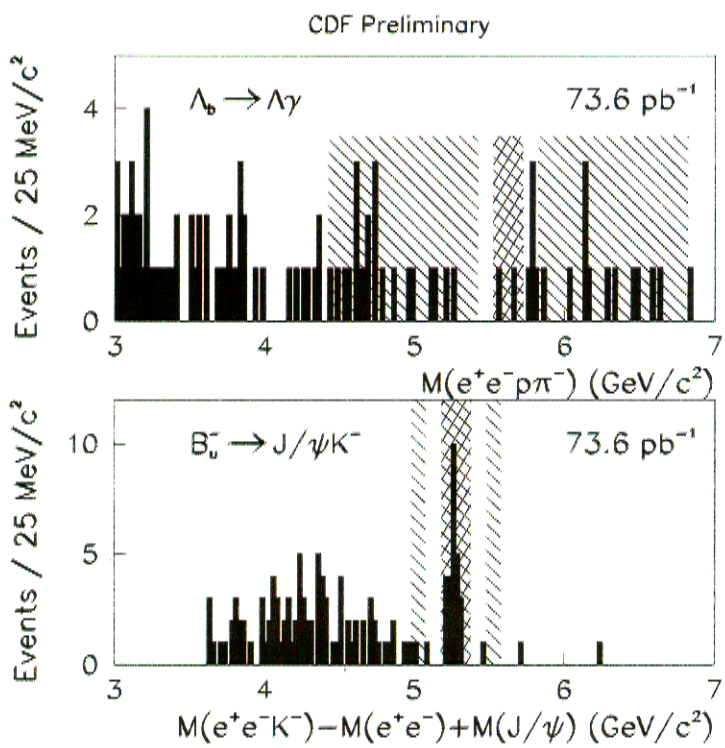
90% CL limit

- $Br(B_d \to K^{*0}\gamma) < 2.6 \times 10^{-4}$
- $Br(B_s \to \phi\gamma) < 3.4 \times 10^{-4}$



Cand 2
BG 3.3
Sig 0.13

Cand 0
BG 0.1
Sig 0.02



90% CL limit

- $Br(\Lambda_b \to \Lambda\gamma) < 6.5 \times 10^{-4}$

$b \to s\mu\mu$

Run I Results

- Run I dimuon trigger data without $M_{\mu\mu}$ cut (88 pb^{-1})
- $B_u \to \mu\mu K$ (published in PRL)
- $B_d \to \mu\mu K^{*0}$ (published in PRL)
- $B_s \to \mu\mu\phi$ is ongoing
- $\Lambda_b \to \mu\mu\Lambda$ is possible

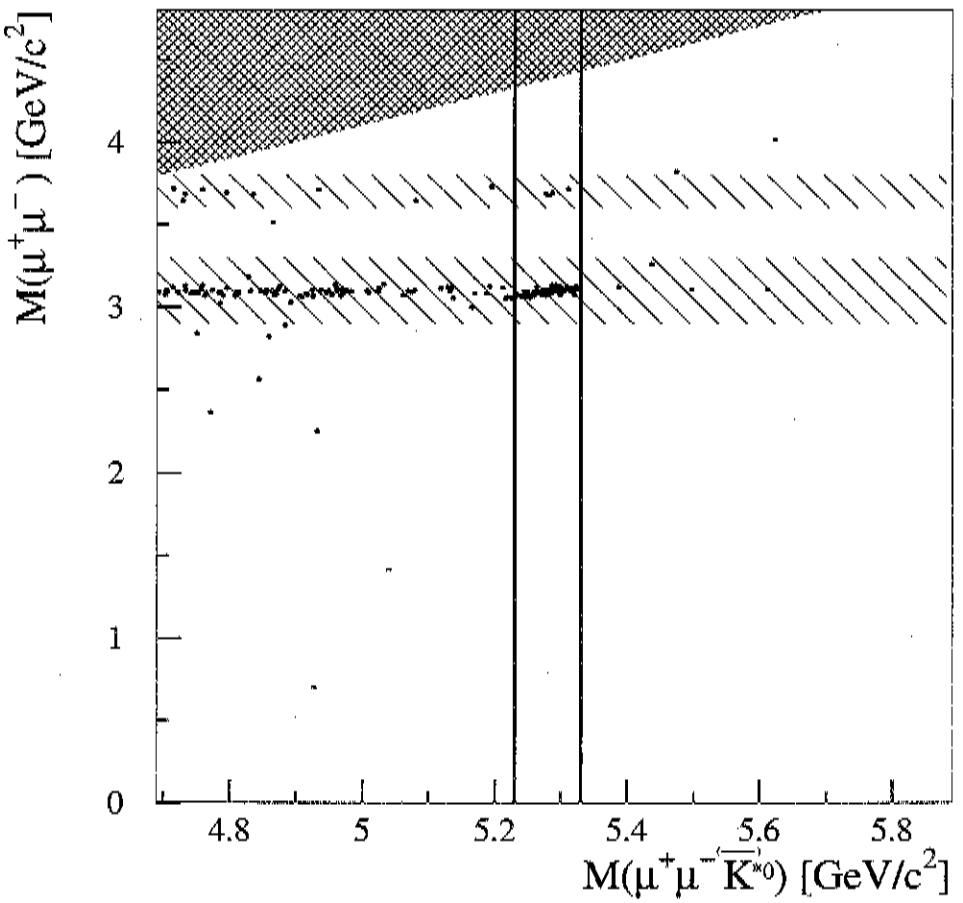
- $B \to J/\psi K^{(*)}$ for normalization

$$\frac{N_{\mu\mu K^*}}{N_{J/\psi K^*}} = \frac{Br(B_d \to \mu\mu K^*)}{Br(B_d \to J/\psi(\to \mu\mu)K^*)} \times \frac{\epsilon_{\mu\mu K^*}}{\epsilon_{J/\psi K^*}}$$
$$= \frac{1 \sim 3 \times 10^{-6}}{8 \times 10^{-5}} \times 0.65 = \frac{1}{40 \sim 120}$$

$\longrightarrow$ We expect $1\ \mu\mu K^*$
in the data with $40 \sim 120\ J/\psi K^*$

After optimized selection cut,

- $\mu\mu K^*$: **0 events**
- $J/\psi K^*$: **75 events (0.6 – 2 events signal expectation)**



90% CL limit

- $Br(B_u \to \mu\mu K) < 5.2 \times 10^{-6}$
- $Br(B_d \to \mu\mu K^{*0}) < 4.0 \times 10^{-6}$

Run II extrapolation

Run I $\rightarrow$ Run II

- 88 pb^{-1} $\rightarrow$ 2 fb^{-1} ($\times$ 23)
- Muon detector upgrade
- Vertex detector coverage :
  $|Z| <$ 30 cm $\rightarrow$ 45 cm ($\times$ 1.4)
- Time of flight (improve S/B)
- Track trigger
  - COT track (XFT) at L1 (p_T and ϕ)
    $\sigma_{p_T}/p_T^2 \sim$ 0.01 (GeV/c)$^{-1}$, efficiency $\sim$ 96%
  - Silicon track (SVT) at L2 (p_T, ϕ, and d_0)
    $\sigma_{d_0} \sim$ 35 μm, efficiency $\sim$ 75%
- Muon trigger
  - Match track to muon detector at L1

Possible Run II trigger options

- 3 GeV + 1.5 GeV dimuon
- 2 track (for hadronic B decays)
  $d_0 >$ 120 μm, $p_T >$ 2 GeV, $p_T(1) + p_T(2) >$ 5.5 GeV
- 3–4 GeV lepton + 2 GeV track with $d_0 >$ 120 μm
  (for semileptonic B decays)

Extraction of the $A_{FB}(M_{\mu\mu}) = 0$

Significance of the asymmetry (no background case)

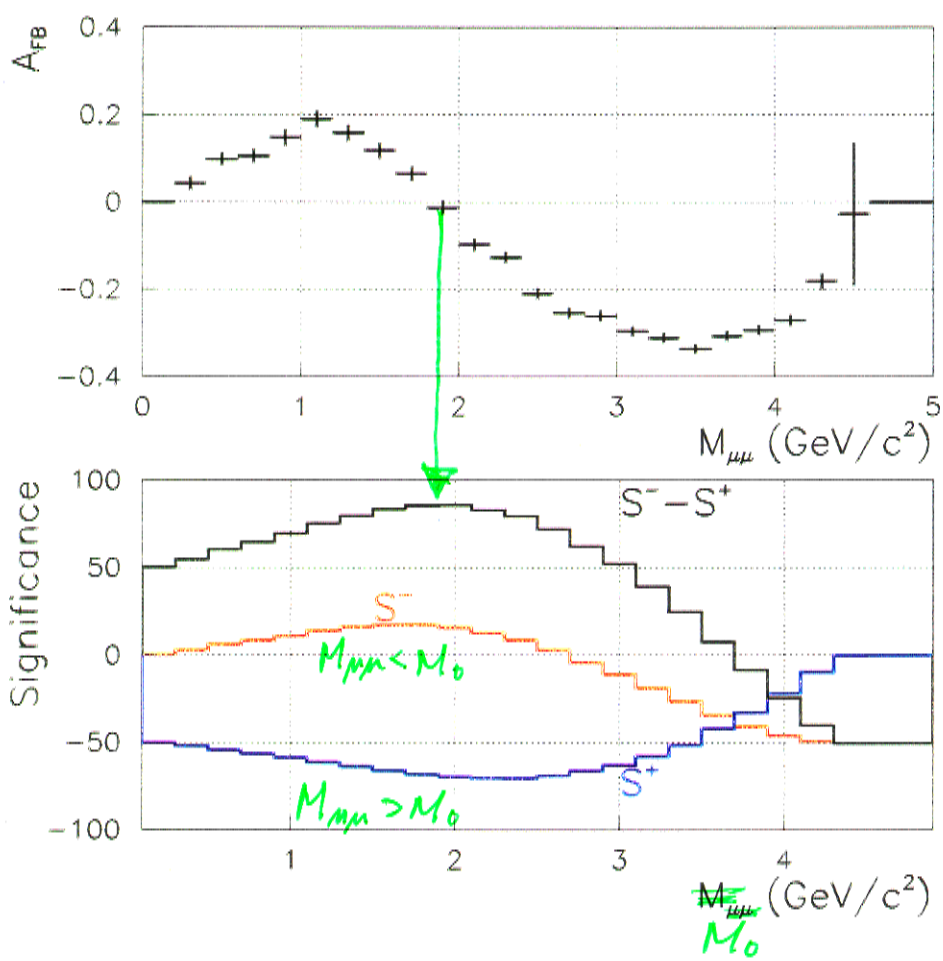
$$\mathcal{S}_{A_{FB}} = \frac{N_F - N_B}{\sqrt{N_F + N_B}}$$

is positive and negative for the forward and backward events, respectively. A function,

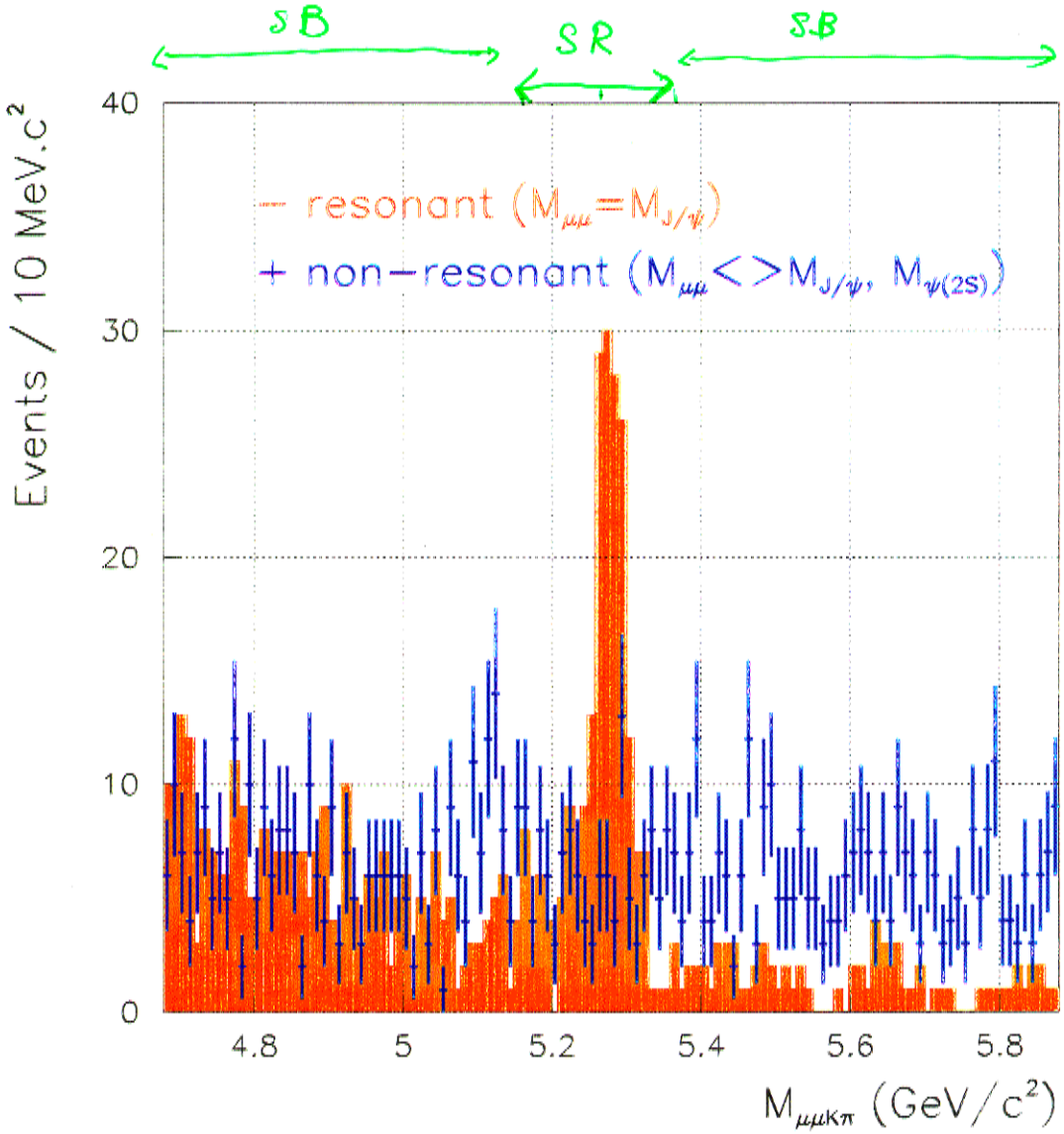
$$\mathcal{S}_{A_{FB}}(M_{\mu\mu} < M_0) + (-\mathcal{S}_{A_{FB}}(M_{\mu\mu} > M_0)),$$

will be maximum at the $A_{FB}(M_0) = 0$

Test with the MC sample



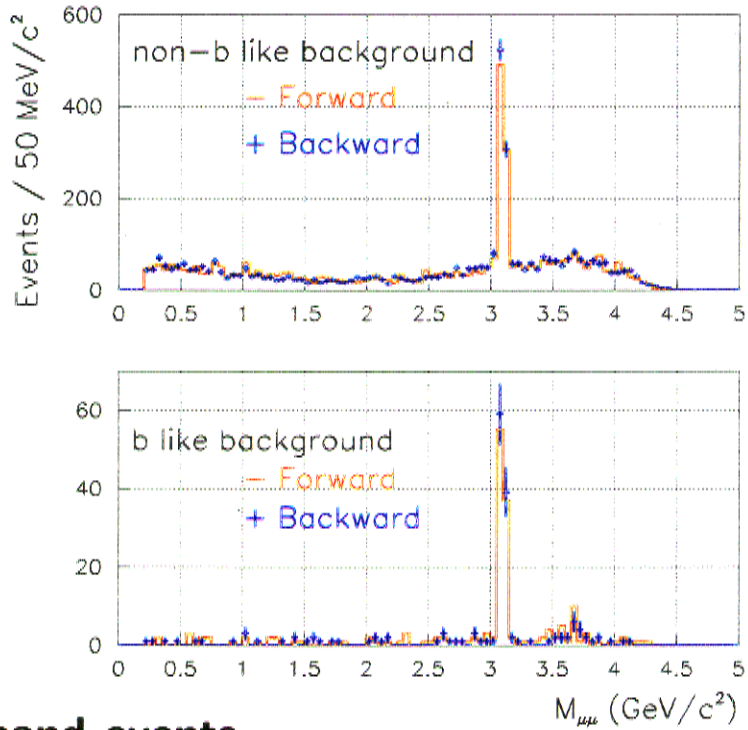
Background Study in Run I Data



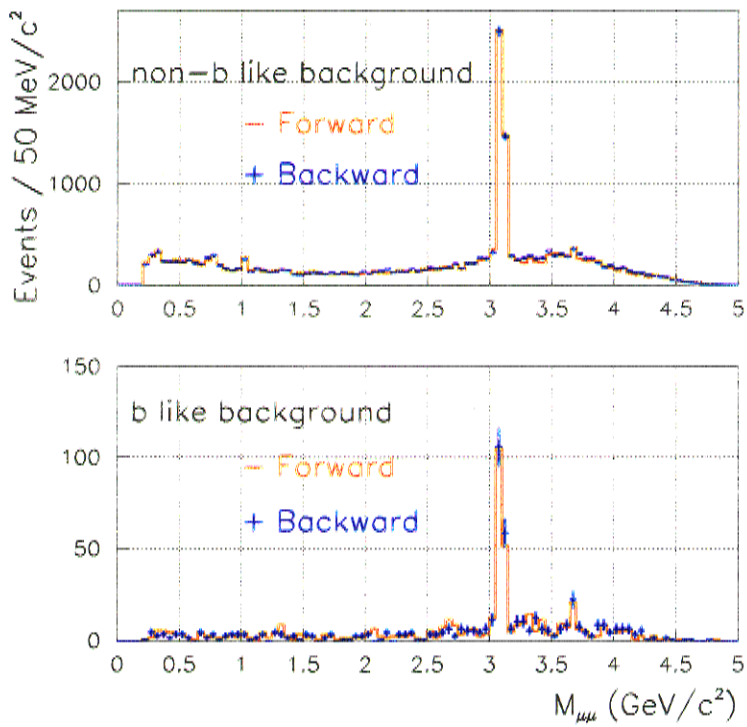
Check the A_{FB} distribution of the background events in the same dataset as the Run I $B_d \to K^{*0}\mu\mu$ search.

- **B like events :** $L_{xy}/\sigma > 2$, $d_0(\mu, K, \pi)/\sigma > 1$
- **non-B like events :** $L_{xy}/\sigma < 2$, $d_0(\mu, K, \pi)/\sigma < 2$
- **M_B signal region events:** $|M_{\mu\mu K\pi}$-$M_{B_d}|$<**100 MeV/c^2**
- **M_B sideband events :** **100** $<|M_{\mu\mu K\pi}$-$M_{B_d}|<$ **600 MeV/c^2**

M_B signal region events

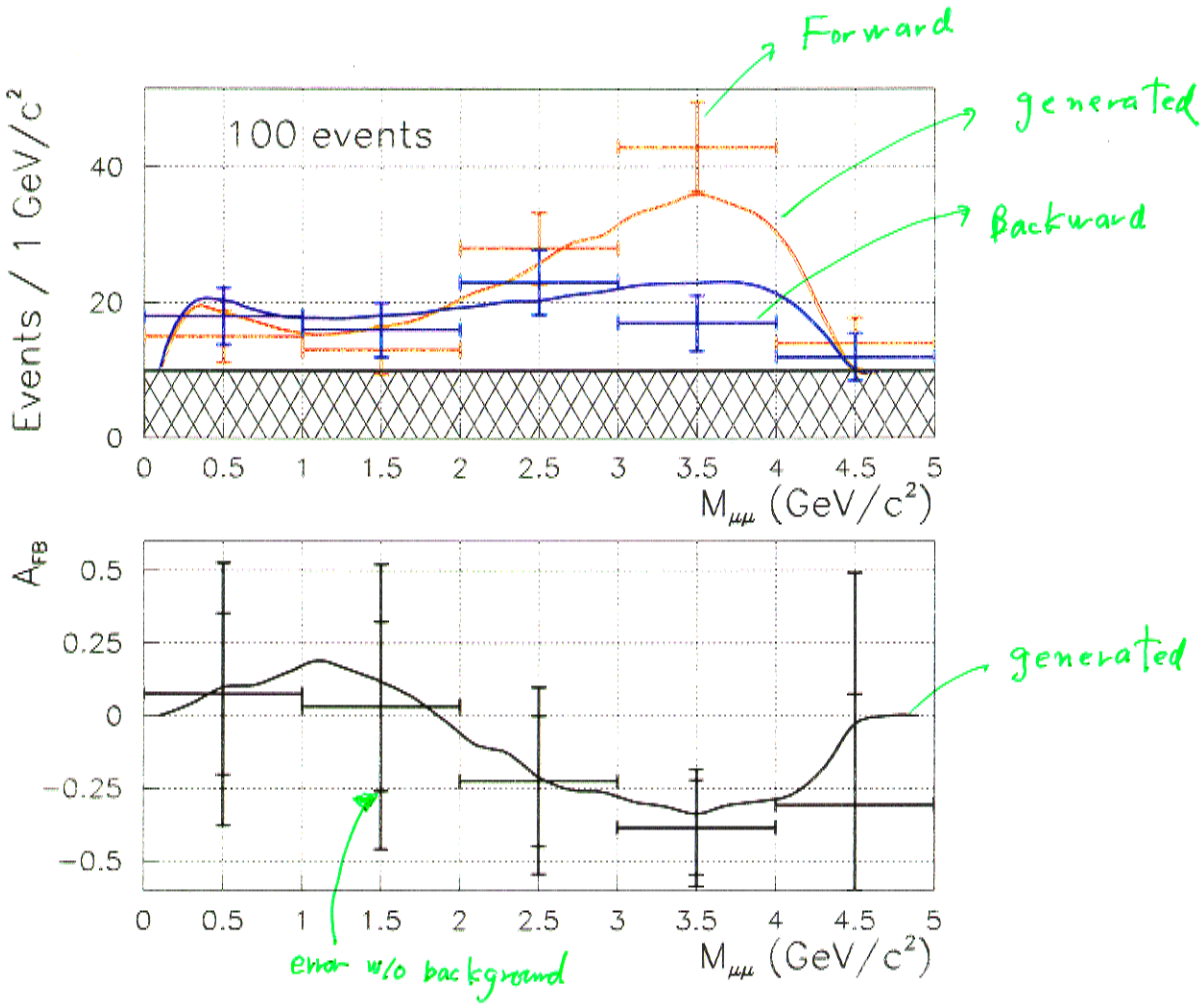


M_B sideband events



A_{FB} with 100 events

- **Apply the dimuon trigger and offline kinematical selection cuts**
- $S/B = 1$
  - **flat $M_{\mu\mu}$ distribution**
  - **no background asymmetry**



Summary

- **Run I CDF (90% CL Limit)**
  - $Br(B_d \to K^{*0}\gamma) < 2.6 \times 10^{-4}$
  - $Br(B_s \to \phi\gamma) < 3.4 \times 10^{-4}$
  - $Br(\Lambda_b \to \Lambda\gamma) < 6.5 \times 10^{-4}$
  - $Br(B_u \to \mu\mu K) < 5.2 \times 10^{-6}$
  - $Br(B_d \to \mu\mu K^{*0}) < 4.0 \times 10^{-6}$
- **We are designing the trigger for the rare $b \to sll$ and $b \to s\gamma$ decays**