Search for Rare B Decays at DØ

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Workshop on

B Physics at the Tevatron

Run II and Beyond

Feb 24-26 2000

Processes studied:

- $B^0 \to K^*(896)\mu^+\mu^-$
- $b \to X_s\mu^+\mu^-$
- $B^0 \to \mu^+\mu^-$

Issues

- Expected signal rates
  - acceptance for different kinematic cuts
  - trigger rates
  - trigger efficiences
  - dependence on dimuon mass
  - signal rates with different analysis cuts
  - physics Bkgd rates

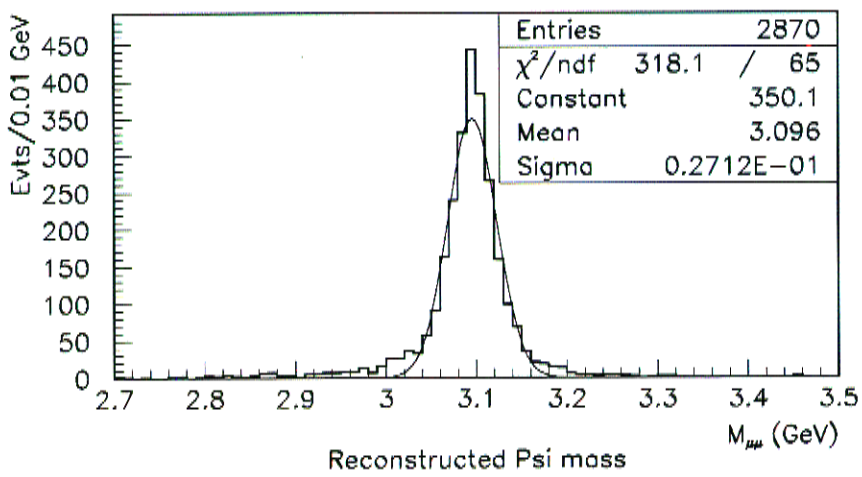
- Asymmetry studies for the $B^0 \to K^*(896)\mu^+\mu^-$ process

- Attempts to separate Signal from Background

- Conclusions

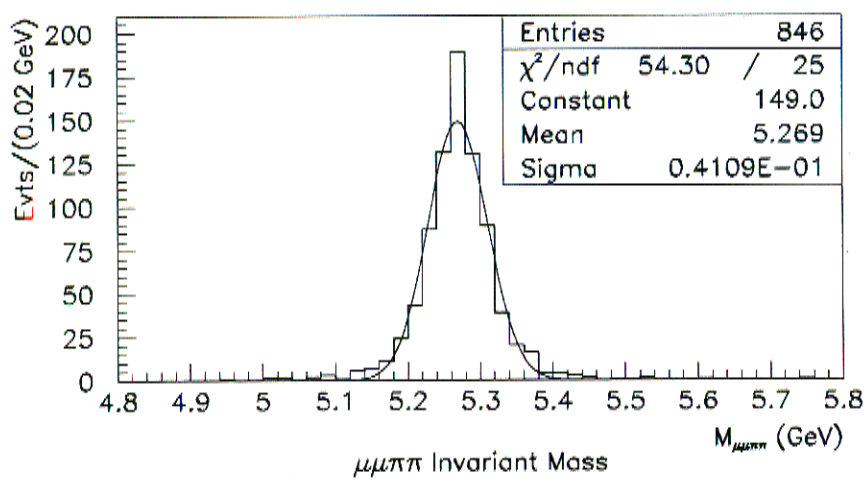
B Meson Reconstruction

- Reconstruction of J/ψ's produced in $B_d^\circ \to K_s^\circ + J/\psi$ events and decaying in $\mu^+\mu^-$. Both muons are required to have $p_T^\mu > 1.5$ GeV/c and $|\eta_\mu| < 2$.



27 MeV

- Reconstruction of B_d° candidates when demanding two pions with $p_T^\pi > 0.5$ GeV/c and $|\eta_\pi| < 2$.

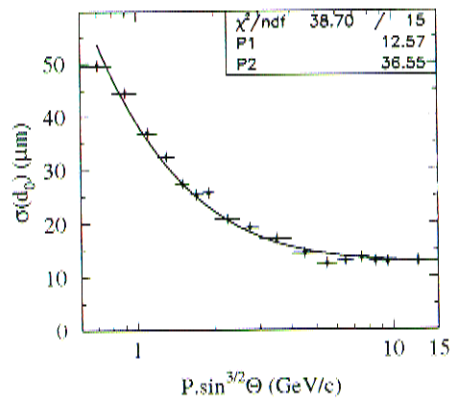


41 MeV
↓ mass constraints
15 MeV

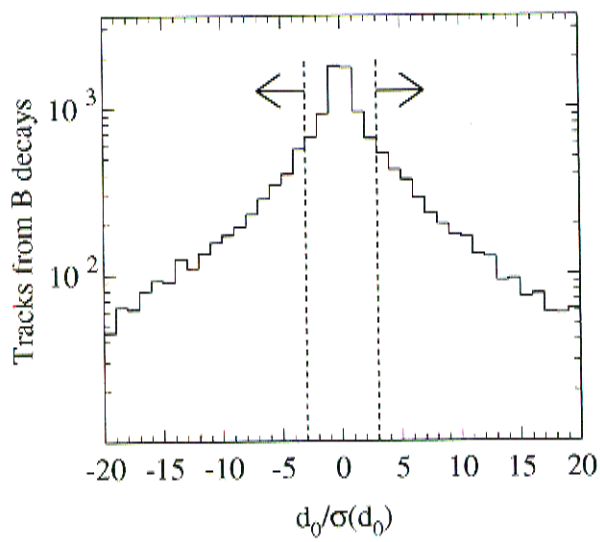
B-tagging

- The SMT will allow to tag B decays using displaced secondary vertices or tracks with large impact parameters.
- Impact parameter resolution in the transversal plane:

$$\sigma^2(d_0) = (12.6\ \mu\mathrm{m})^2 + \left(\frac{36.6}{p.\sin^{3/2}\theta}\right)^2 \qquad (1)$$



- For $B_d^\circ \to K_s + J/\psi$ events, more than 50% of the particles produced in B decays will have an impact parameter significance $d_0/\sigma(d_0)$ greater than 3.



Triggering on muons

- Investigate the trigger efficiency we could expect for $B^0 \to K^*(896)\mu^+\mu^-$ events given the Run II trigger scheme and the foreseen bandwidth limitations at level 1 (10 KHz) and level 2 (1 KHz).
- Samples of NLO QCD $b\bar{b}$ events and various signal processes generated with ISAJET. Events where both muons have $p_T > 1.5$ GeV/c and $|\eta_\mu| < 2$ sent to GEANT (80K generic $b\bar{b}$ evts). Simulation of the trigger response with the 1997 simulator.
- Results confirmed with the Feb. 2000 simulator for 2000 $B_d^\circ \to K_s + J/\psi$ evts.
- Background trigger rate simulation:
  1. QCD dijet events generated with ISAJET in 6 parton p_T bins: 2–5, 5–10, 10–20, 20–40, 40–80 and 80–500 GeV;
  2. Minimum bias interactions overlayed on the primary interaction to give a total of 2, 4, 6 or 8 interactions;
  3. Trigger rates computed with the assumptions of:
     - $\mathcal{L} = 2 \cdot 10^{32}$ cm^{-2}s^{-1};
     - beam crossing time = 132 ns.
- Studies need to be repeated with the new simulator.

TRIGGERING on MUONS

Using a sample of 1812 (B -> J/Psi + Ks) events for Pt>0 and |eta|<~3

	Preselection	Pt(dimuon) > 2 GeV	Pt(each muon) > 1.5 GeV	|h (each muon)| < 1.6
	Trigger	Efficiencies		
2μ	mtm10=MUO(2,2,A,M)	(27.2 ± 2.7)%		
	mtm11=MUO(2,2,W,M)	(27.2 ± 2.7)%		
single μ	mtm5=MUO(1,4,A,M)	(33.3 ± 2.8)%		
	mtm6=MUO(1,4,A,T)	(15.4 ± 2.2)%		
	mtm11 OR mtm5	(41.2 ± 2.9)%		
OR	mtm11 OR mtm6	(32.3 ± 2.8)%		
	Preselection	Pt(dimuon) > 5 GeV	Pt(each muon) > 1.5 GeV	|h (each muon)| < 1.6
	Trigger	Efficiencies		
2μ	mtm10=MUO(2,2,A,M)	(46.4 ± 4.7)%		
	mtm11=MUO(2,2,W,M)	(46.4 ± 4.7)%		
single μ	mtm5=MUO(1,4,A,M)	(68.8 ± 4.4)%		
	mtm6=MUO(1,4,A,T)	(32.1 ± 4.4)%		
	mtm11 OR mtm5	(71.4 ± 4.3)%		
OR	mtm11 OR mtm6	(55.4 ± 4.7)%		
	Preselection	Pt(dimuon) > 5 GeV	Pt(each muon) > 3.0 GeV	|h (each muon)| < 1.6

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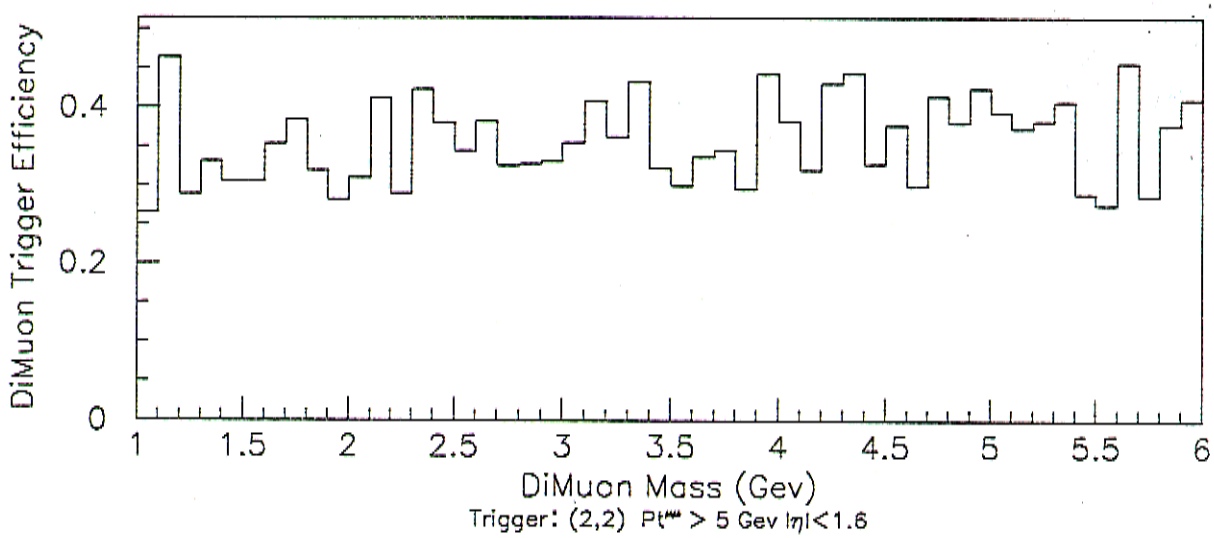
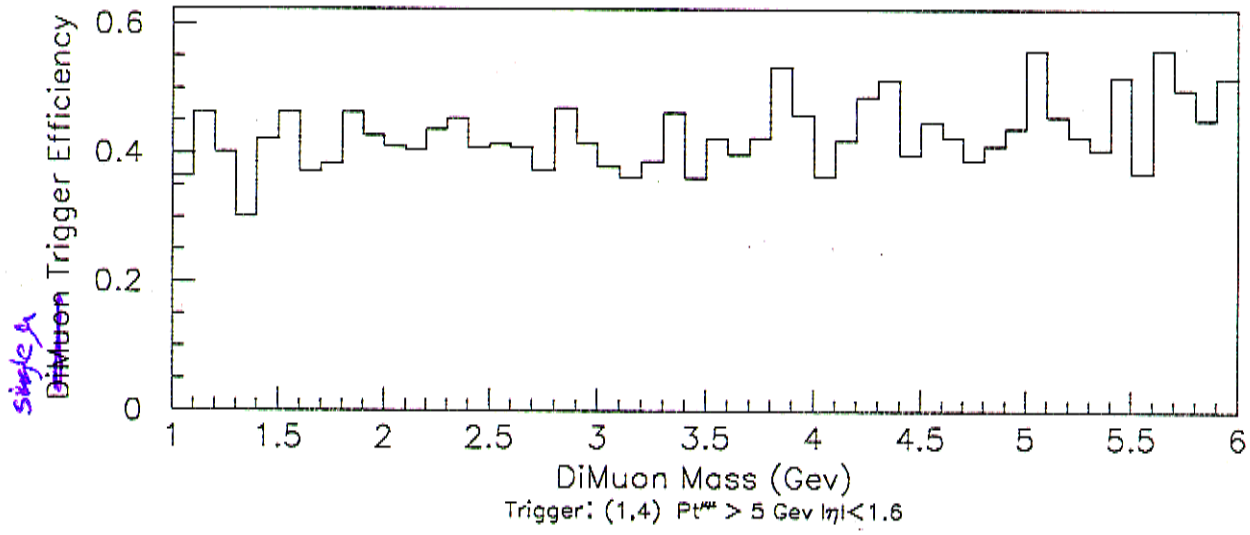
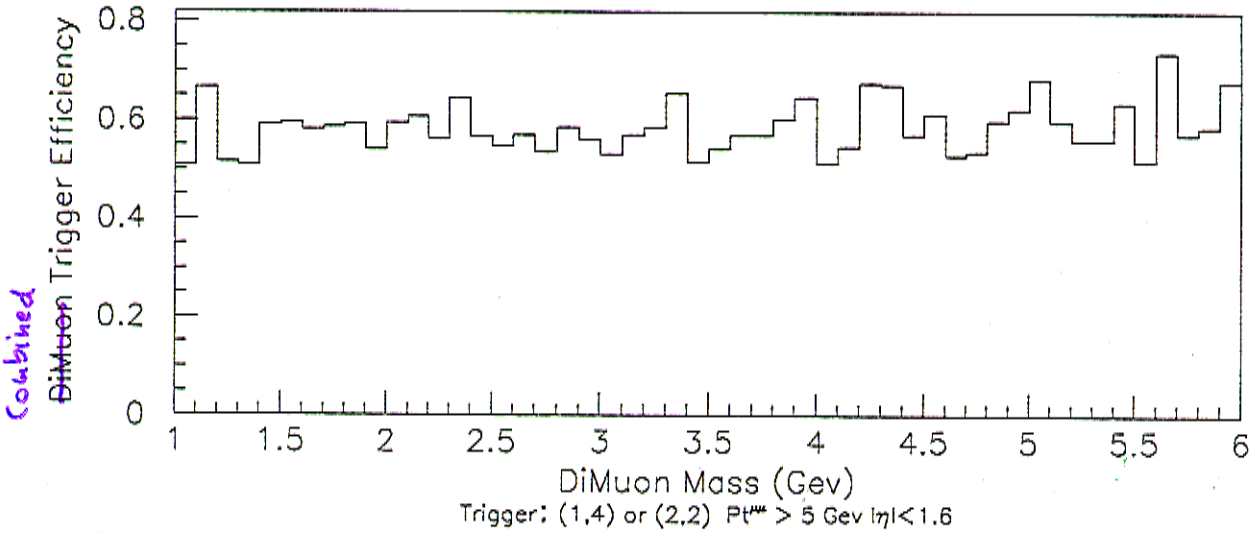


Trigger: (2,2) $Pt^{\mu\mu} > 5$ Gev $|\eta|<1.6$



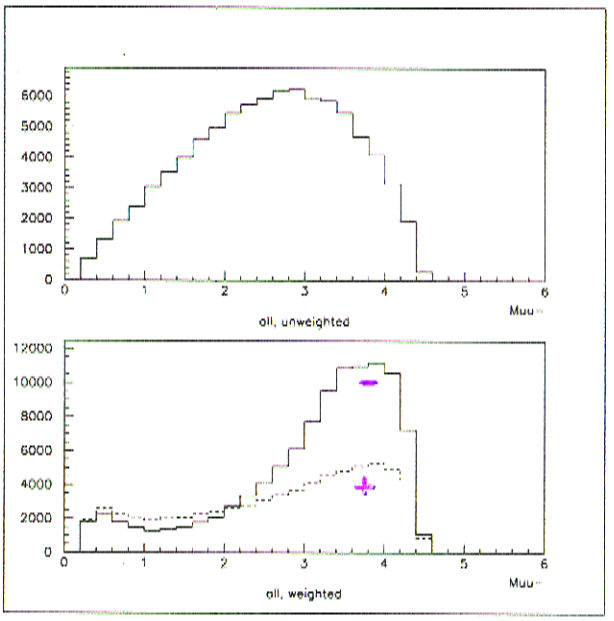
Trigger: (1,4) $Pt^{\mu\mu} > 5$ Gev $|\eta|<1.6$



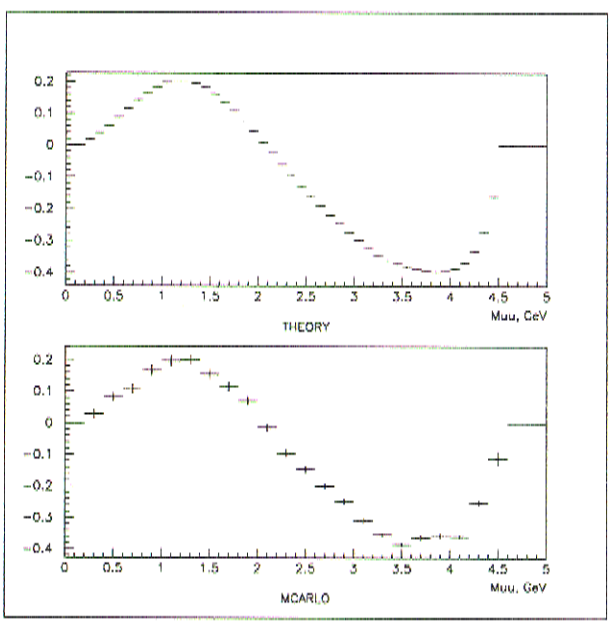
Trigger: (1,4) or (2,2) $Pt^{\mu\mu} > 5$ Gev $|\eta|<1.6$

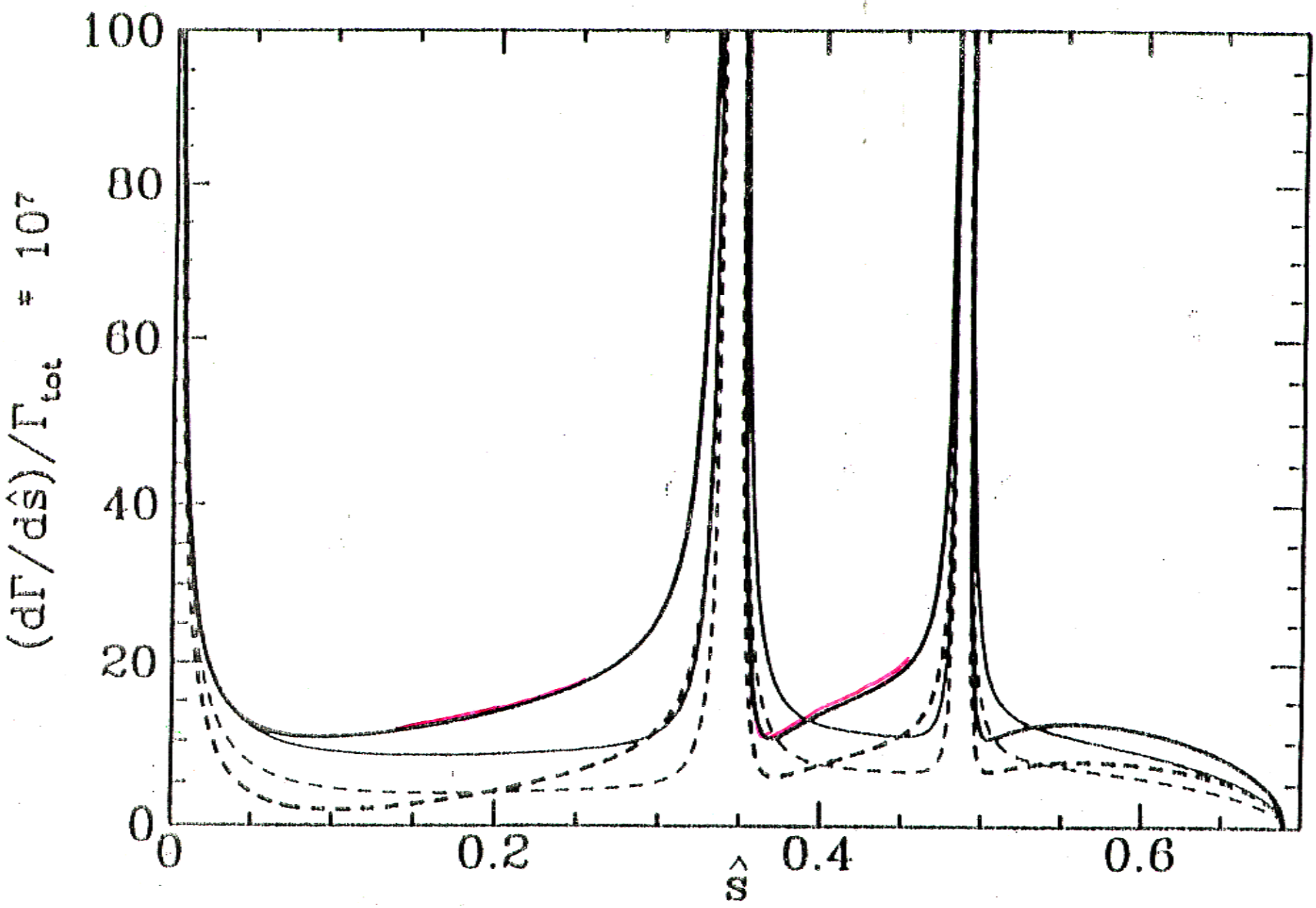
Asymmetry Studies for $B^0 \to K^*(896)\mu^+\mu^-$

- Monte Carlo based on paper by C. Greub et al. PL B 346 (1995) 149.
- ISAJET events weighted in bins of dimuon mass and E_{μ^-}



- Verified




100
80
60
40
20
0
0
0.2
0.4
0.6
$\hat{s}$
$(d\Gamma/d\hat{s})/\Gamma_{tot} = 10^7$

Expected number of events for $B^0 \to K^*(896)\mu^+\mu^-$

- Assumed luminosity 2 fb^{-1}
- Normalized to $\sigma(B^o) = 3\mu b$ for $p_T(B) > 6$ GeV, y(B)< 1
- Assumed BR($B^0 \to K^*(896)\mu^+\mu^-$) = 2 $\times 10^{-6}$
- Muons with $p_T(\mu) > 1.5(3.0)$ GeV and $\eta(\mu) < 1.6$

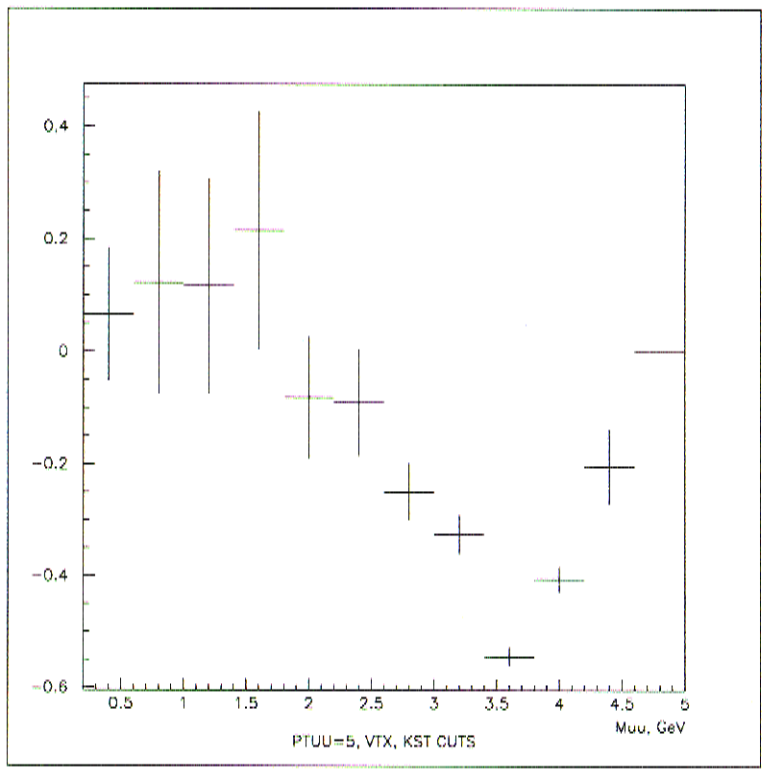
	$p_T^{\mu\mu} > 2$ GeV	$p_T^{\mu\mu} > 5$GeV ($p_T^{\mu} > 1.5$ GeV)	$p_T^{\mu\mu} > 5$GeV ($p_T^{\mu} > 3$ GeV)
Trigg. effic. (%)	32%	55%	60%
Recorded	6500	5200	1800
Vtx cut	2700	2500	900
$p_T(K^*) > 2$ GeV	1000	1000	400

proper decay distance of the $\mu\mu K\pi$ system in the transverse plane >100 μm

no $\mu^+\mu^-$ mass cuts

Asymmetry Studies for $B^0 \to K^*(896)\mu^+\mu^-$

- Expected signal in 2 fb^{-1} for:
  - after trigger requirement and
  - $p_T(\mu\mu) > 5$ GeV
  - proper decay distance of the $\mu\mu K\pi$ system > 100μm in the transverse plane
  - $p_T(K^*) > 2$ GeV
- 1000 events

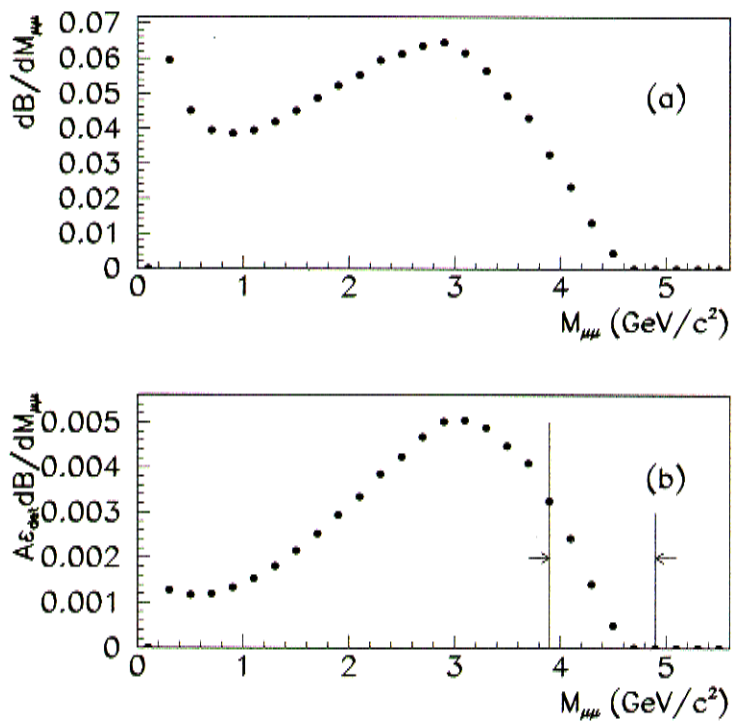


- Background not included. Difficult to estimate at this stage. Also perfect K, π identification

Search for $b \to X_s\mu^+\mu^-$ Decays

- Search for the decay process

$$b \to X_s\mu^+\mu^- \quad (\mathrm{BR(SM)} = 6 \times 10^{-6})$$



- In the mass window $3.9 < M_{\mu\mu} < 4.4$ GeV/c^2, only 5 % of the expected signal. Mass region below 3.9 GeV populated by sequential ($b \to c\mu X; c \to \mu Y$) decays.

$p_T^{\mu} > 2$ GeV/c

$|\eta^{\mu}| < 0.8$

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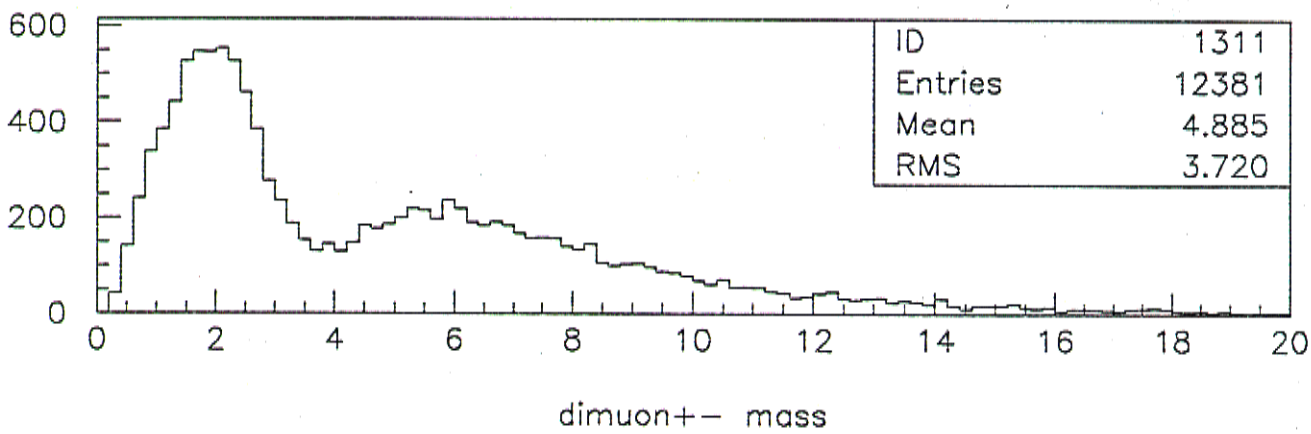
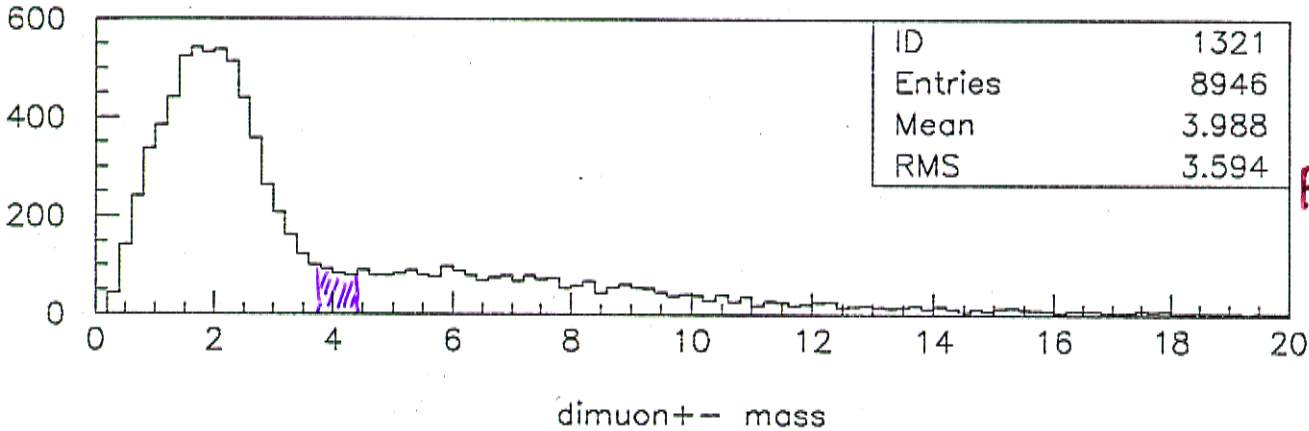
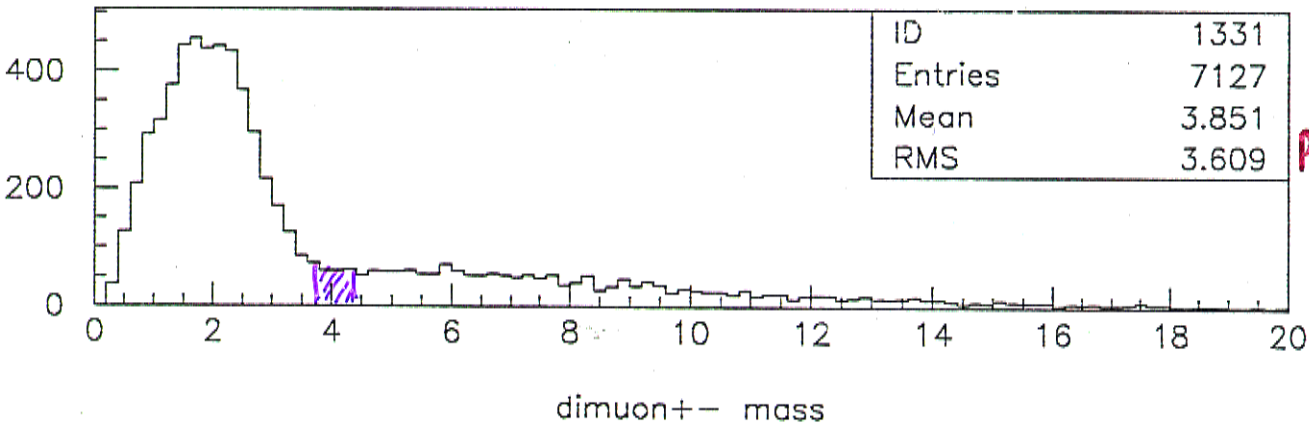




$p_T^{\mu\mu} > 4$ GeV/c



$p_T^{\mu\mu} > 5$ GeV/c

QQNLO MONTE CARLO (ISAJET 7.22)

$p_T^{\mu} > 2\ GeV/c$

$|\eta^{\mu}| < 1.6$

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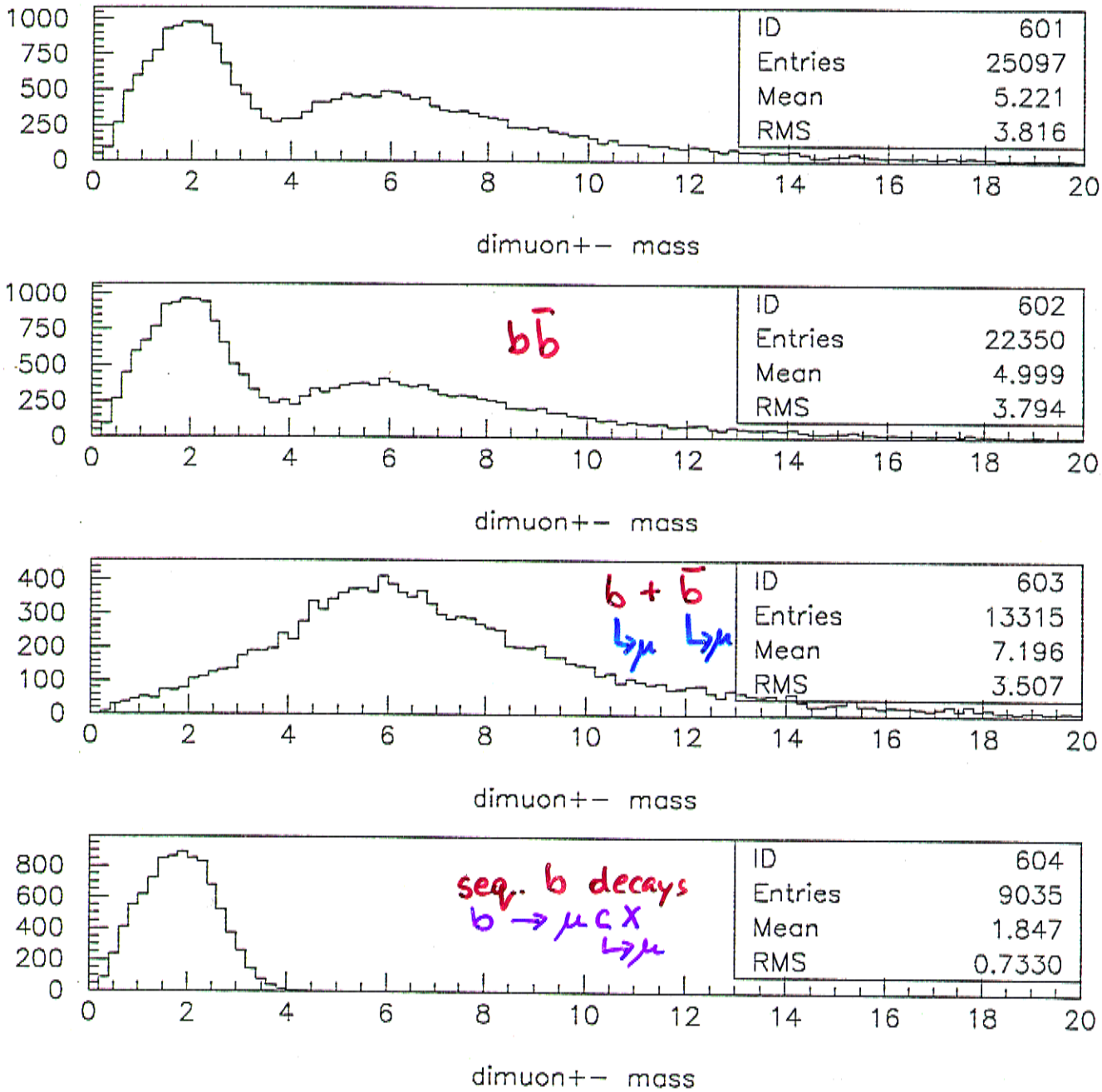

MASS $\mu^+\mu^-$, GeV

Signal - NLO QCD Bkgd Separation

- Vertex Separation.
- Event topology.
- Jet Properties.

$p_T^{\mu\mu} > 5\ GeV/c$

$|\eta^{\mu}| < 1.6$

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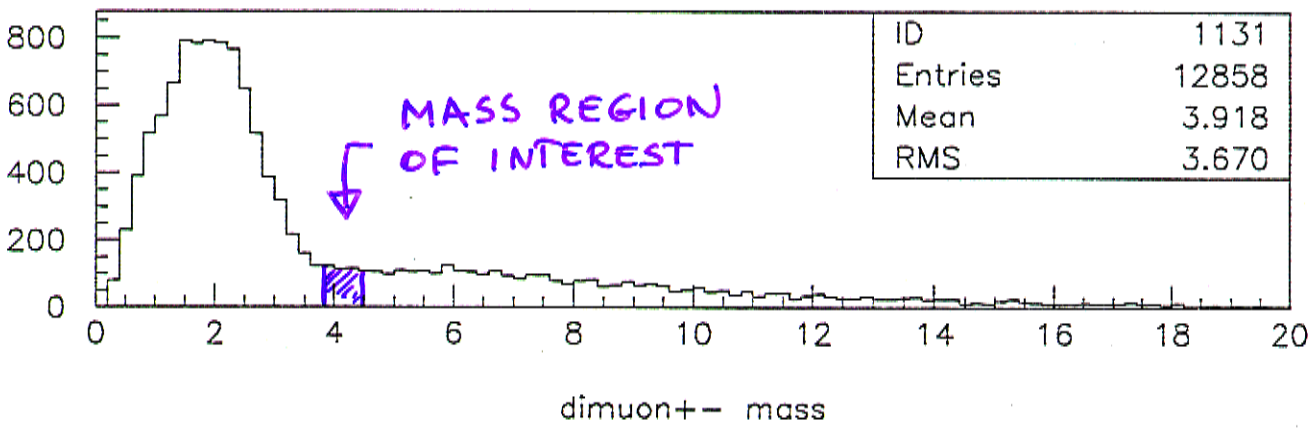
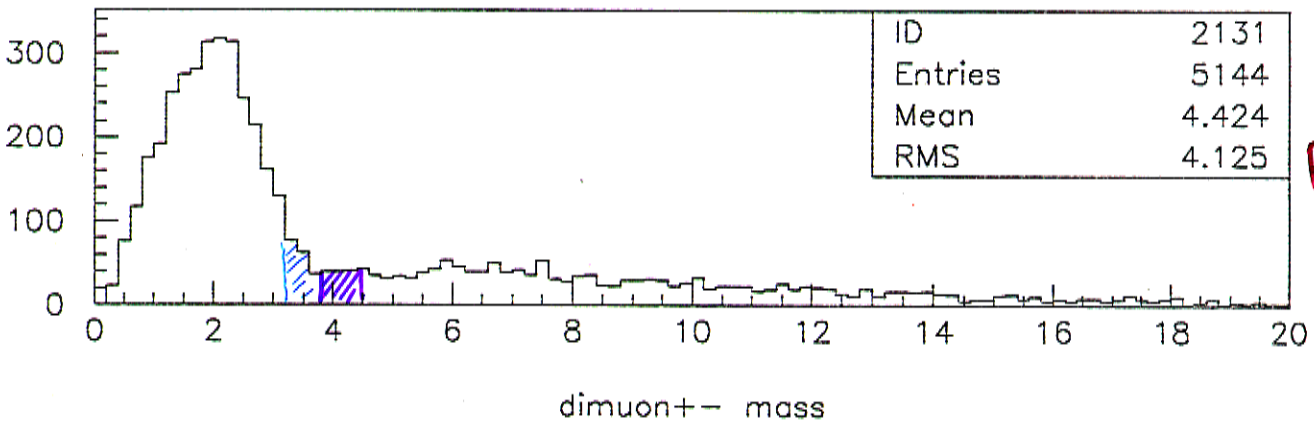
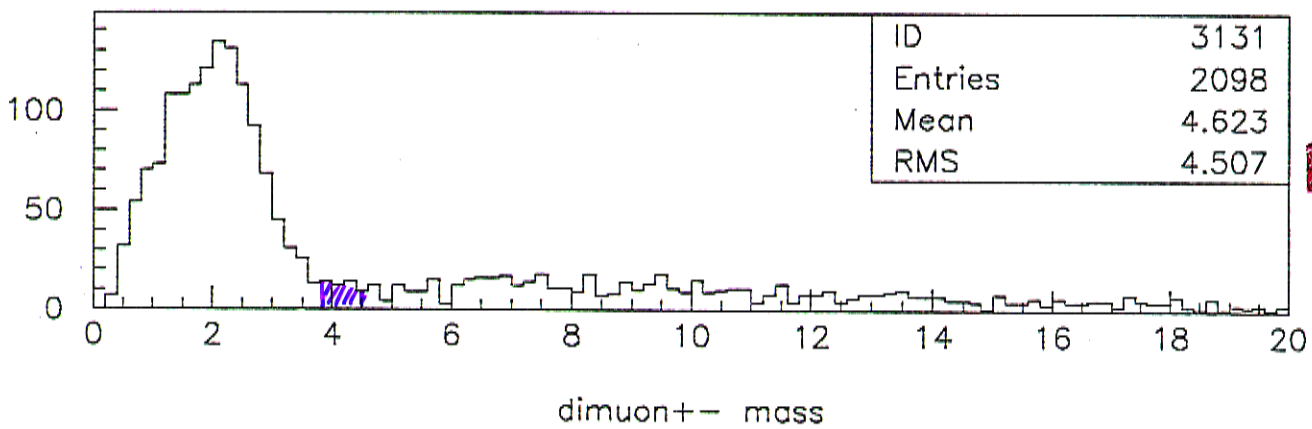


$p_T^{\mu} > 2\ GeV/c$



$p_T^{\mu} > 3\ GeV/c$



$p_T^{\mu} > 4\ GeV/c$

$q \to b\bar{b}$

$3.2 < M_{\mu\mu} < 4.8$ GeV

$p_T^{\mu} > 2$ GeV/c

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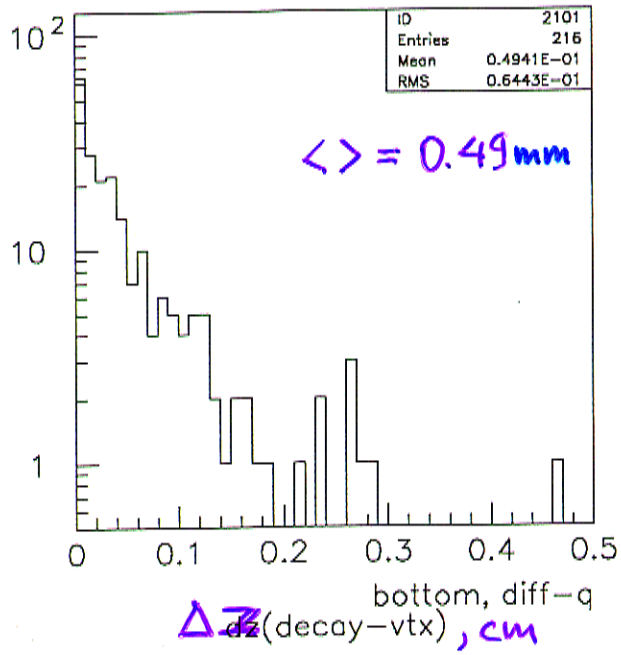

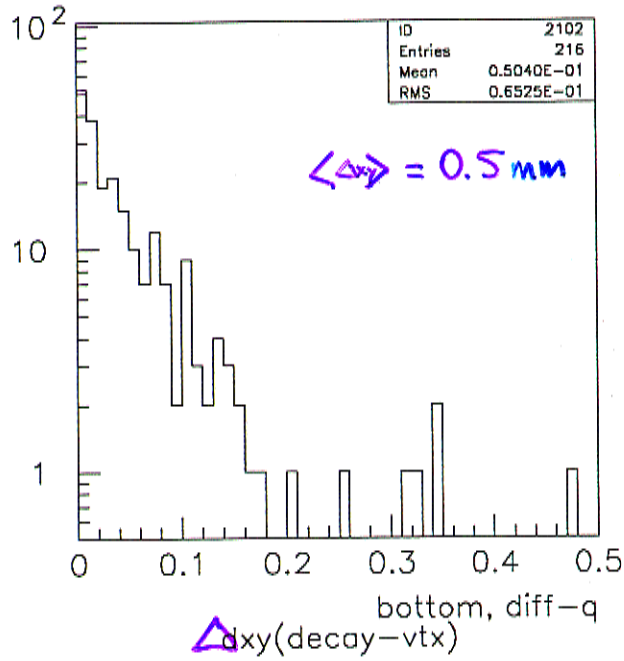

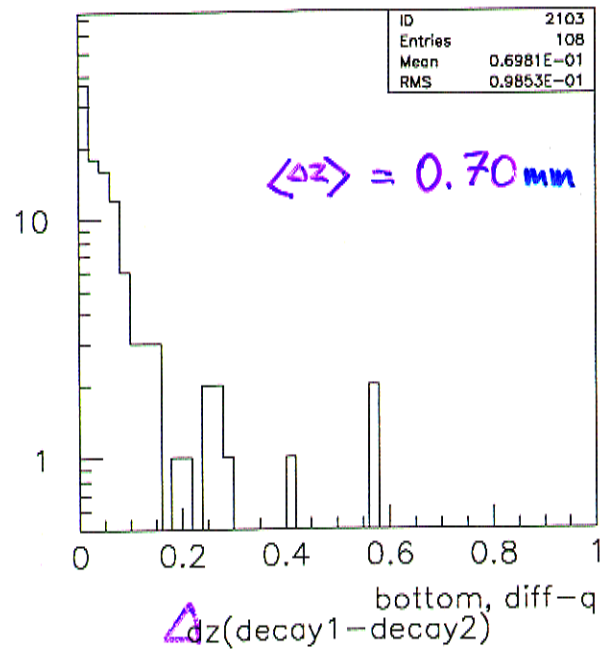

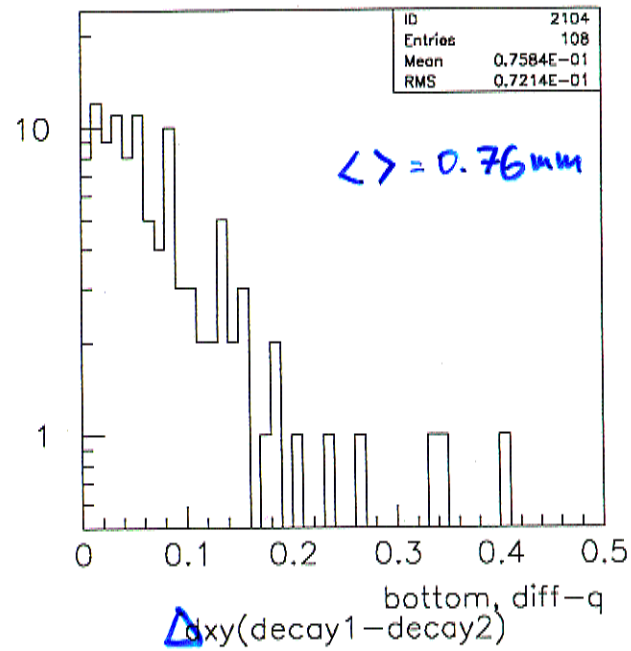

$\Delta\eta_{b\bar{b}}$ between jets

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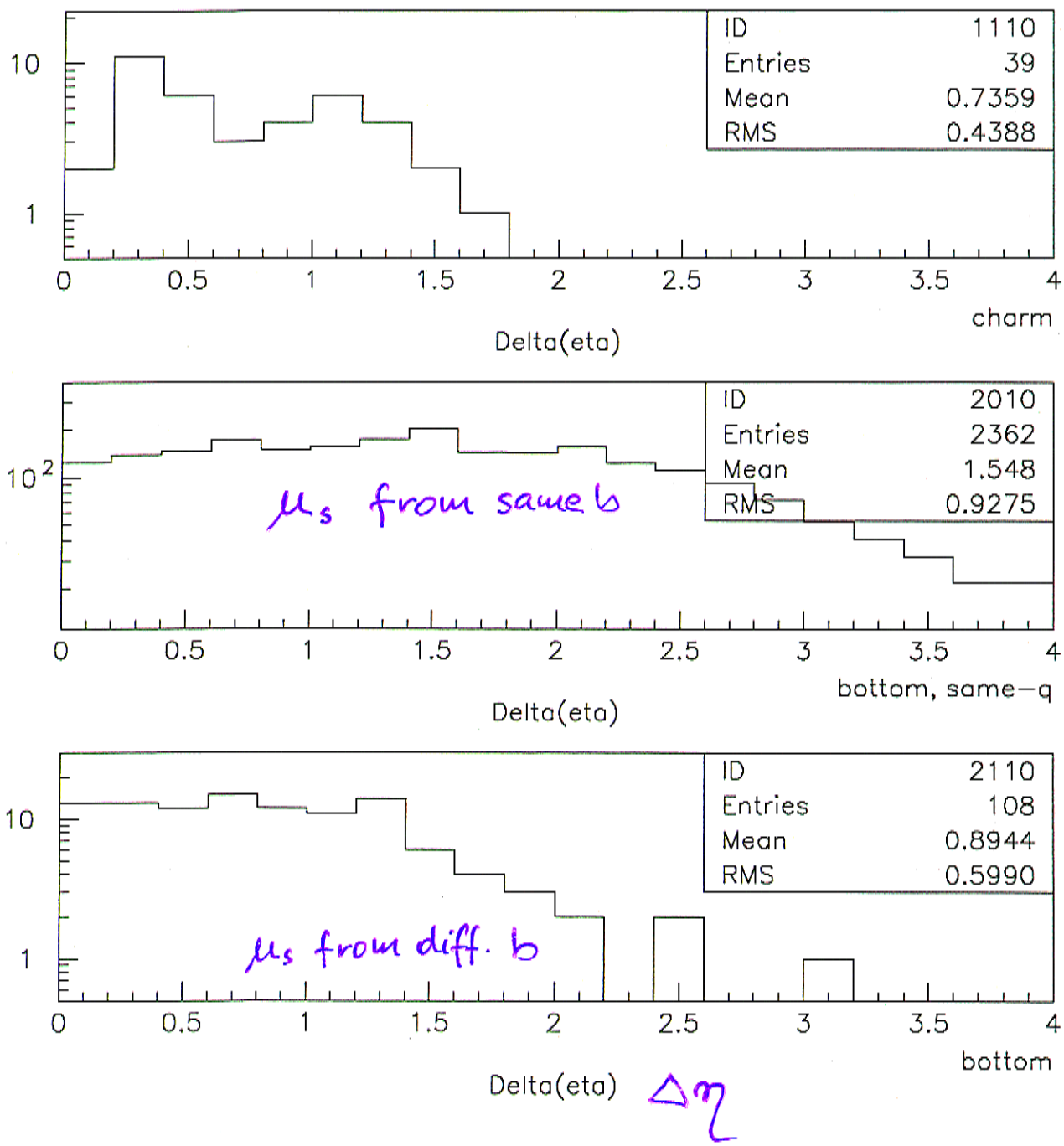

$\Delta\phi_{b\bar{b}}$

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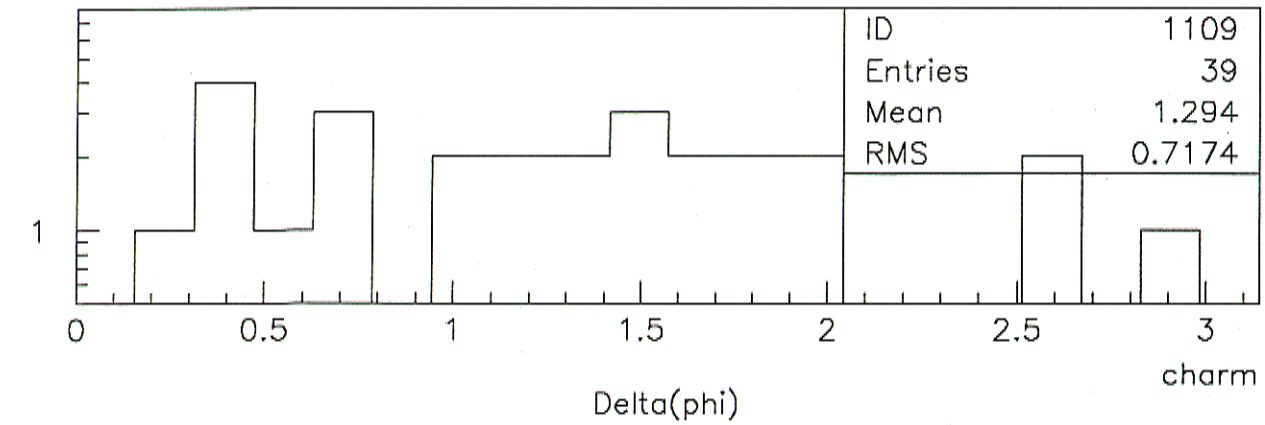

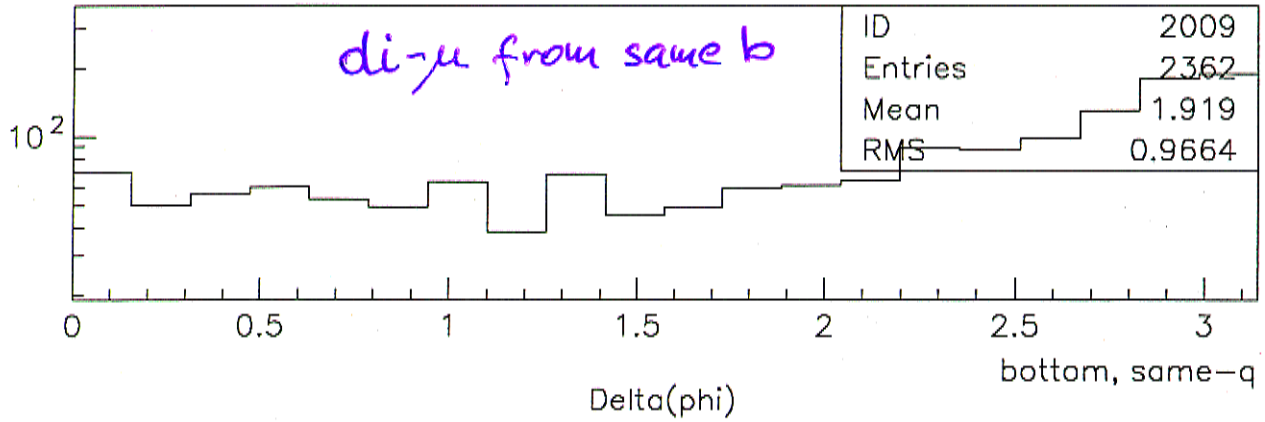

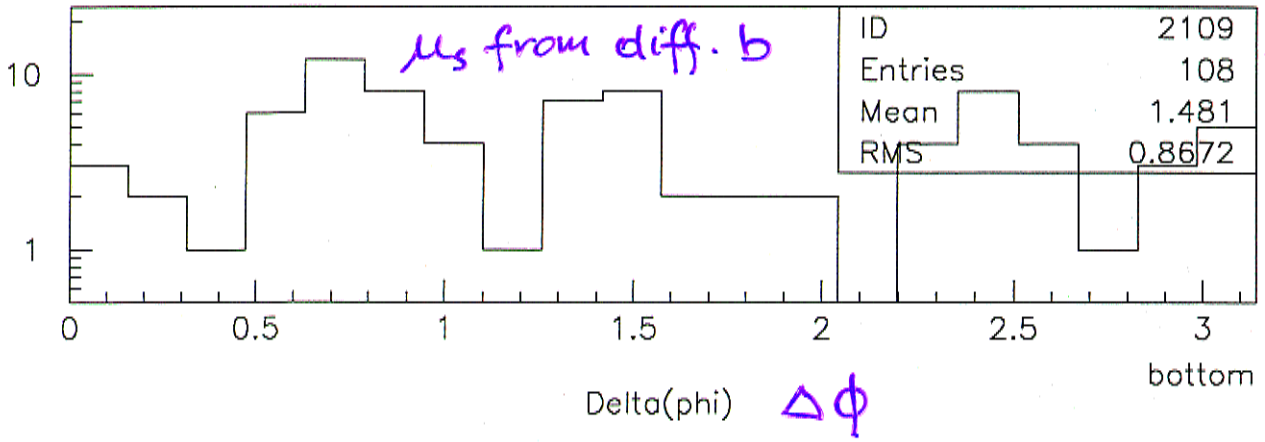

γ + charged multiplicy
no p_T cut

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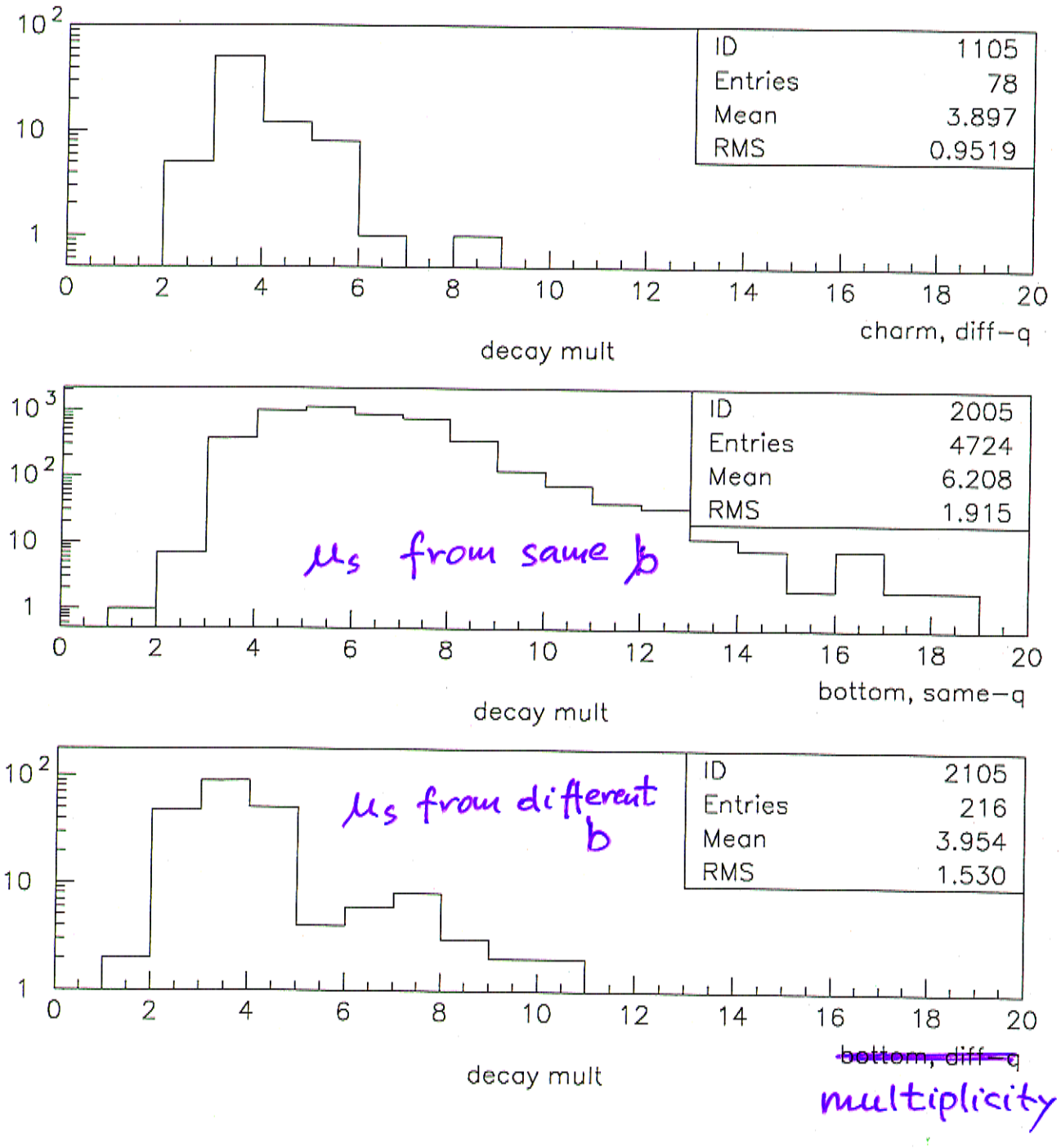

Conclusions

- Process $B^0 \to K^*(896)\mu^+\mu^-$
  - the most promesing.
  - Expect after analysis cuts: 1000 evnts.
  - Poor asymmetry measurement at small dimuon masses.

- Process $b \to X_s\mu^+\mu^-$
  - Only large dimuon mass region above 3.9 GeV available (5%).
  - Expect 1000 events.
  - Gluon Splitting background: S:B $\not\leq$ 1:50 before vertex cuts.

- Process $B^0 \to \mu^+\mu^-$
  - hopeless for the SM predictions.

- Signal - Background separation needs further work.