Search for Inclusive Decay $b \to X_s \mu^+ \mu^-$ at DØ

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Workshop on

B Physics at the Tevatron

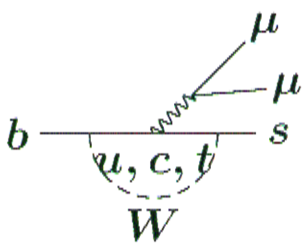
Run II and Beyond

Sep 23-25 1999

Outline

- DØ Run I analysis (PL 423, 419 (1998))
- CLEO measurement
- DØ muon triggers for Run II
- Preliminary MC studies

SM: FCNC decay forbidden to 1st order
allowed through 2nd order diagrams

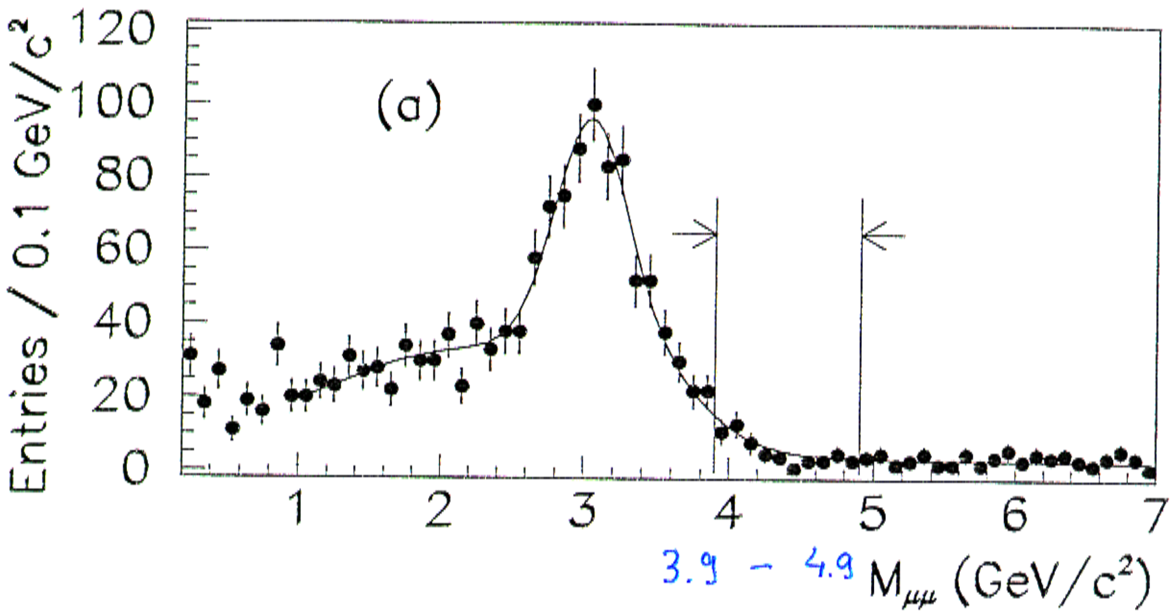


SM: $B(b \rightarrow s\mu^+\mu^-) = (6 \pm 1)10^{-6}$

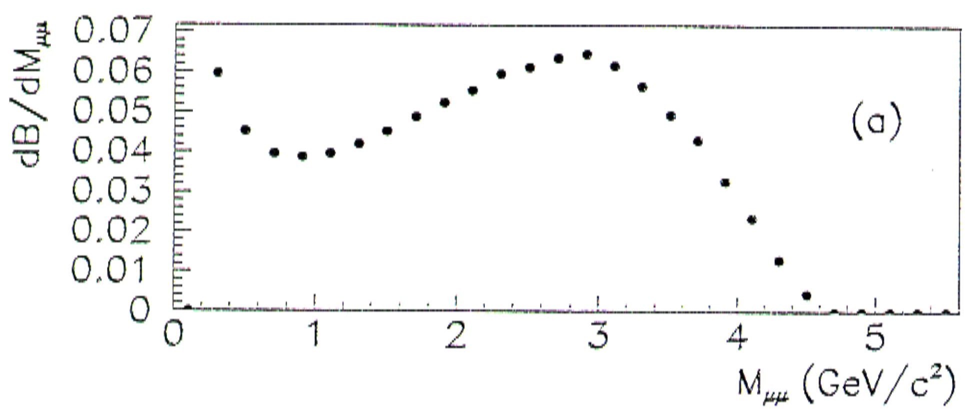
Interest in $b \rightarrow sl^+l^-$:

- In SM, with m_t known, measurement of $B(b \rightarrow s\mu^+\mu^-)$ is tantamount to measurement of $|V_{ts}|^2/|V_{cb}|^2$.
- Sensitivity to non-SM physics
  - charged Higgs boson
  - new gauge bosons
  - supersymmetric particles

Study of $b \to s \mu^+ \mu^-$ at DØ



DØ data



theoretical distribu[tion] of $M_{\mu\mu}$ from $b \to s \mu^+ \mu^-$

Event selection:

- Dimuon trigger, central region; $\mathcal{L} = (50.0 \pm 2.7)\ pb^{-1}$
- $p_T^{\mu\mu} > 5$ GeV, $|\eta^{\mu\mu}| < 0.6$, $p_T^{\mu} > 3.5$ GeV
- calorimeter confirmation; $N_{hits} \geq 6$
- 'global fit' for each muon

1564 events @ $M_{\mu\mu} < 7$ GeV

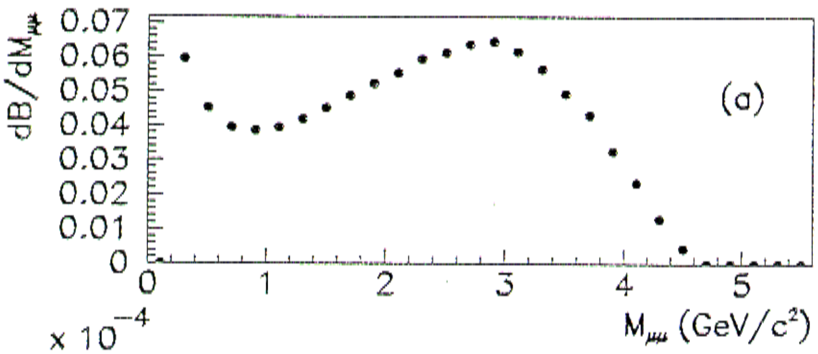
Efficiency for $b \to s \mu^+ \mu^-$

$$\varepsilon = A \times \varepsilon_{det}$$

A: kinematic acceptance for $p_T^{\mu} > 3$ GeV, $3.9 < M_{\mu\mu} < 4.9$ GeV { $p_T^b > 6$ GeV/c }

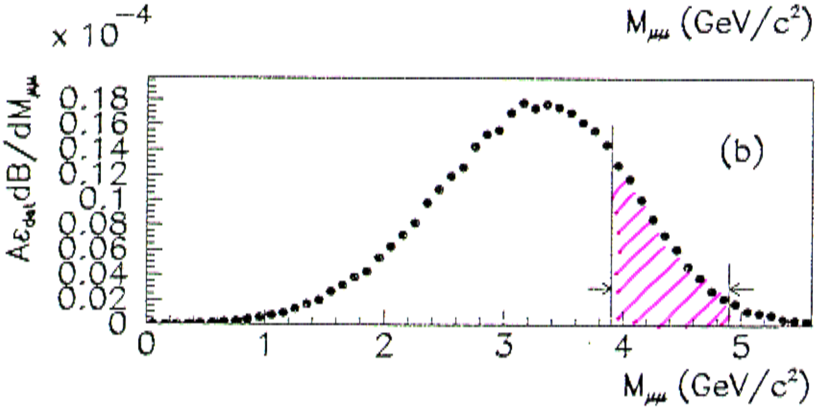
ε_{det}: trigger + offline eff. for accepted events

$$\varepsilon = (7.0 \pm 2.0) \times 10^{-5}$$



Theoretical distribution of $M_{\mu\mu}$

Baer & Pott PRD 55, 1684 (97)



DØ response (including kin. accept., detection efficiency and mass resolution)

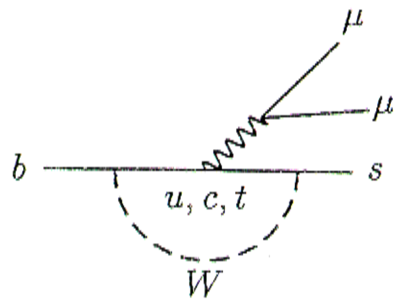
$$A = (7.0 \pm 1.4) \times 10^{-3}$$

$$\varepsilon_{det} = (1.0 \pm 0.2) \times 10^{-2}$$

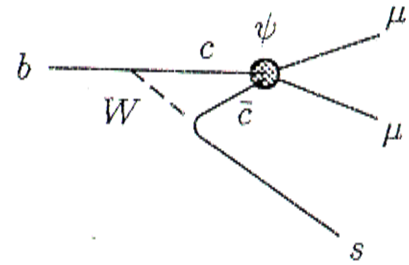
(Efficiency for $b \to s\mu^+\mu^-$ ctd.)

No major event simulation program includes the decay $b \to s\mu^+\mu^-$.

$b \to s\mu^+\mu^-$:



$b \to s\psi$
$\hookrightarrow \mu^+\mu^-$



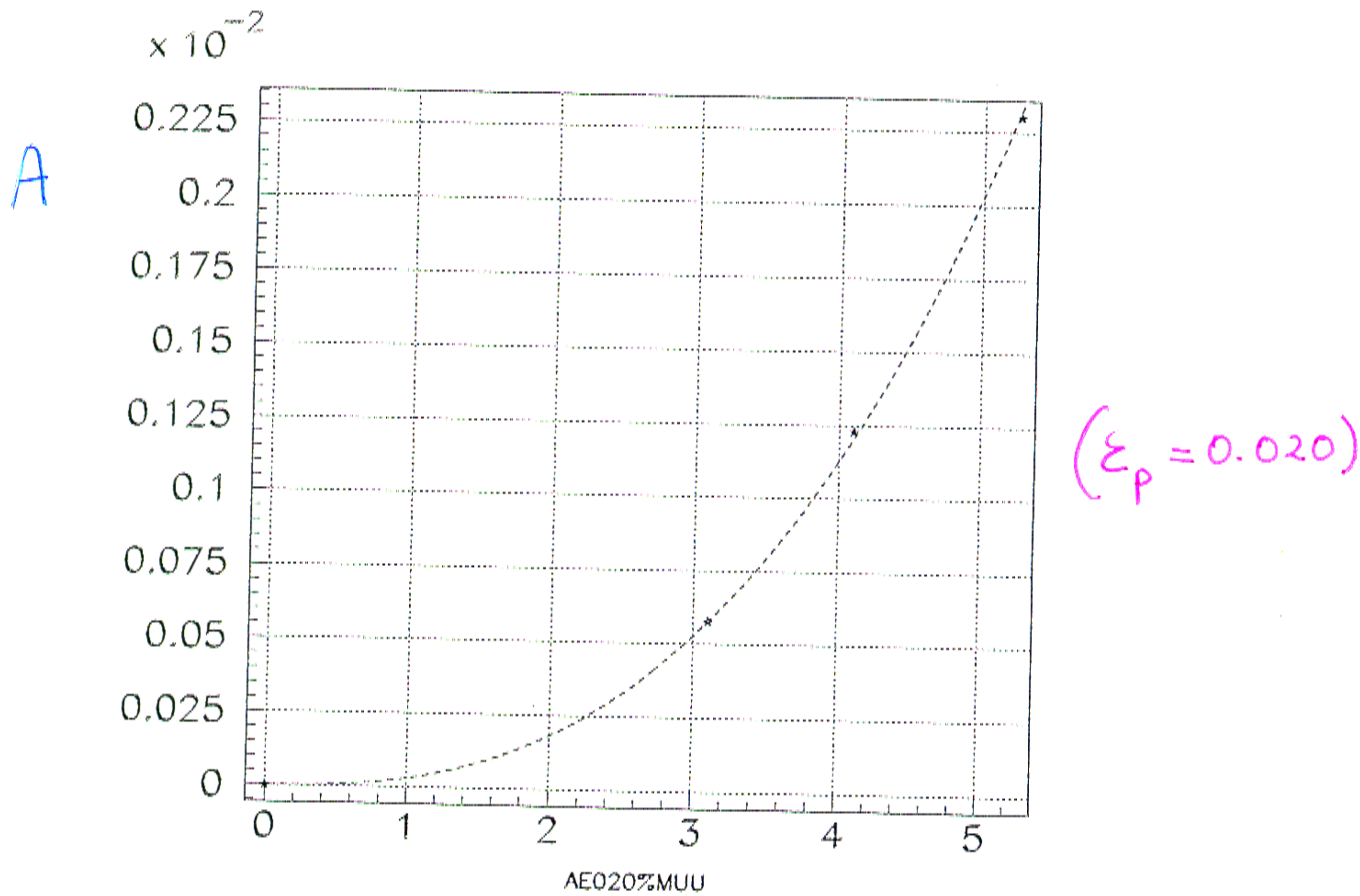
We use $b \to B$, $B \to X_s \psi$, $\psi \to \mu^+\mu^-$ simulated by Isajet (in LO QCD) as a model;

To calculate $A(M_{\mu\mu})$ we substitute $M_{\mu\mu}$ for M_ψ by hand.

Result: $A(M_{\mu\mu}) \approx 2.9 \cdot 10^{-3} M_{\mu\mu}^{2.64}$

Integrate the product of $A(M_{\mu\mu})$ and theor. distrib. over the search window $3.9 \div 4.9$ GeV to obtain A.

$$A(M_{\mu\mu}) = 2.9 \times 10^{-3} M_{\mu\mu}^{2.64}$$

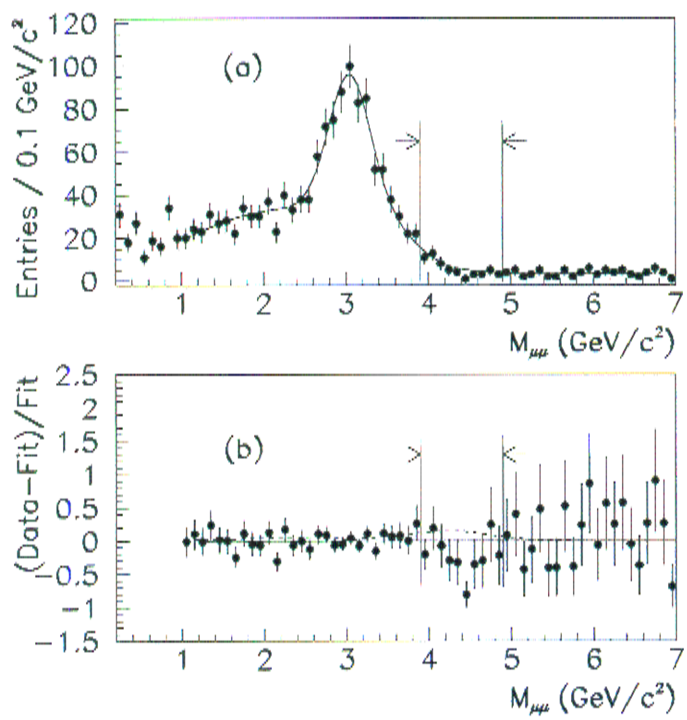


systematic uncertainty:
the acceptance depends on the 'Peterson' fragmentation parameter, ε_p, used in $b \to B$ simulation. We use the ε_p range compatible with CDF data on $\frac{d\sigma(b\to\mu)}{dp_T^\mu}$.

Search for Rare B Meson Decays

- Search for the decay process

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



- In the mass window $3.9 < M_{\mu\mu} < 4.9$ GeV/c^2, one observes 56 events where $68 \pm 2(\mathrm{stat.}) \pm 4(\mathrm{syst.})$ are expected from the fit.

- Limits at 90% confidence level:

$$\boxed{\mathrm{BR}(b \to X_s \mu^+ \mu^-) < 3.2 \times 10^{-4}}$$

Summary of limits on $B(b \to s\mu^+\mu^-)$

DØ: $B(b \to s\mu^+\mu^-) < 3.2 \times 10^{-4}$

UA1 (1991): $B(b \to s\mu^+\mu^-) < 5.0 \times 10^{-5}$

(but based on eff. overestimated by a large factor)

CLEO (1997, ~~submitted to PRL~~) PRL 80, 2289 (98):

$B(b \to s\mu^+\mu^-) < 5.8 \times 10^{-5}$

$B(b \to s\ell^+\ell^-) < 4.2 \times 10^{-5}$

n.b.: CLEO, indep. of DØ, finds the UA1 acceptance to be overestimated by at least ×3 (using PYTHIA)

SM: 6×10^{-6}

CLEO Collab: PRL 80, 2289 (1998)

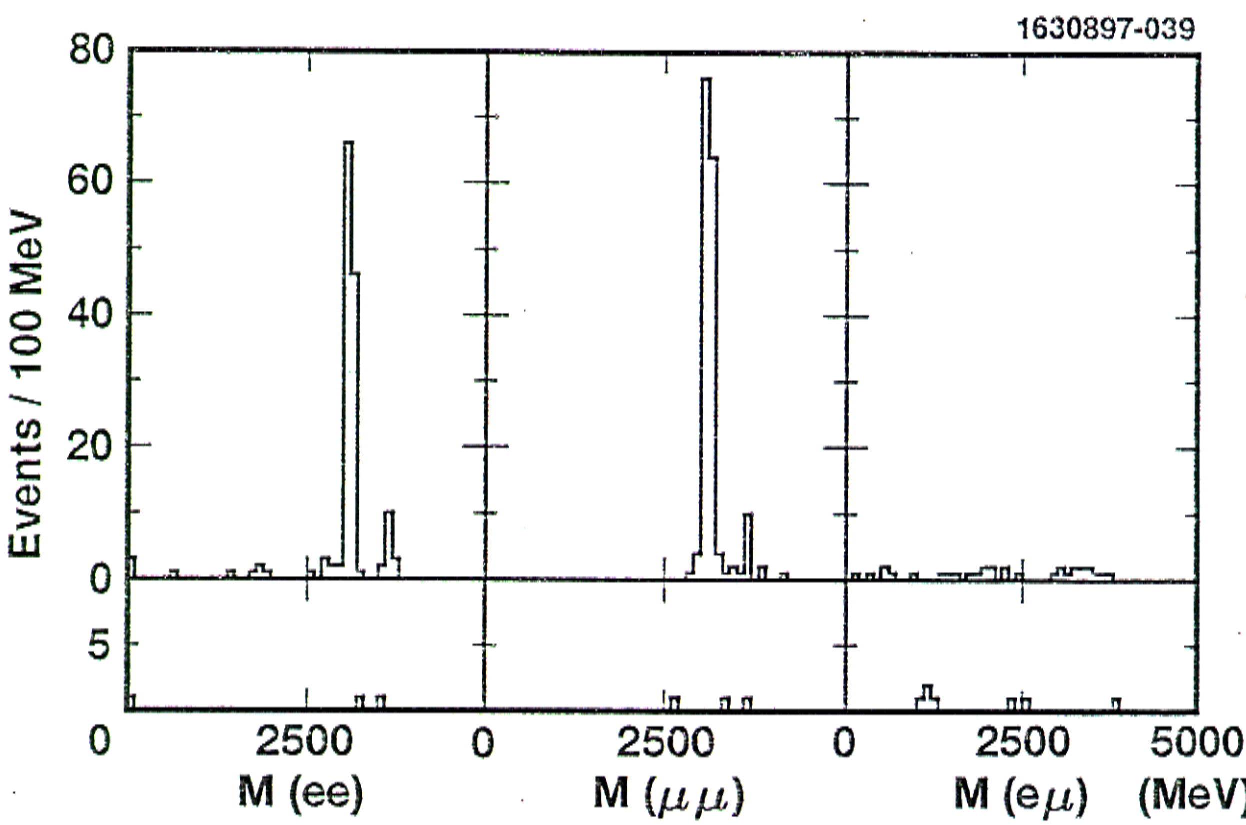
Look for: $B \to X_s l^+ l^-$, $l = e$ or μ

$X_s = K + (0 \div 4)\pi$

$(3.30 \pm 0.06) \times 10^6$ $B\bar{B}$ pairs

$$\chi_B^2 = \left(\frac{M_B - 5.279}{\sigma_M}\right)^2 + \left(\frac{E_B - E_{beam}}{\sigma_E}\right)^2 < 6$$

$$M_B = \sqrt{E_{beam}^2 - P_B^2}$$

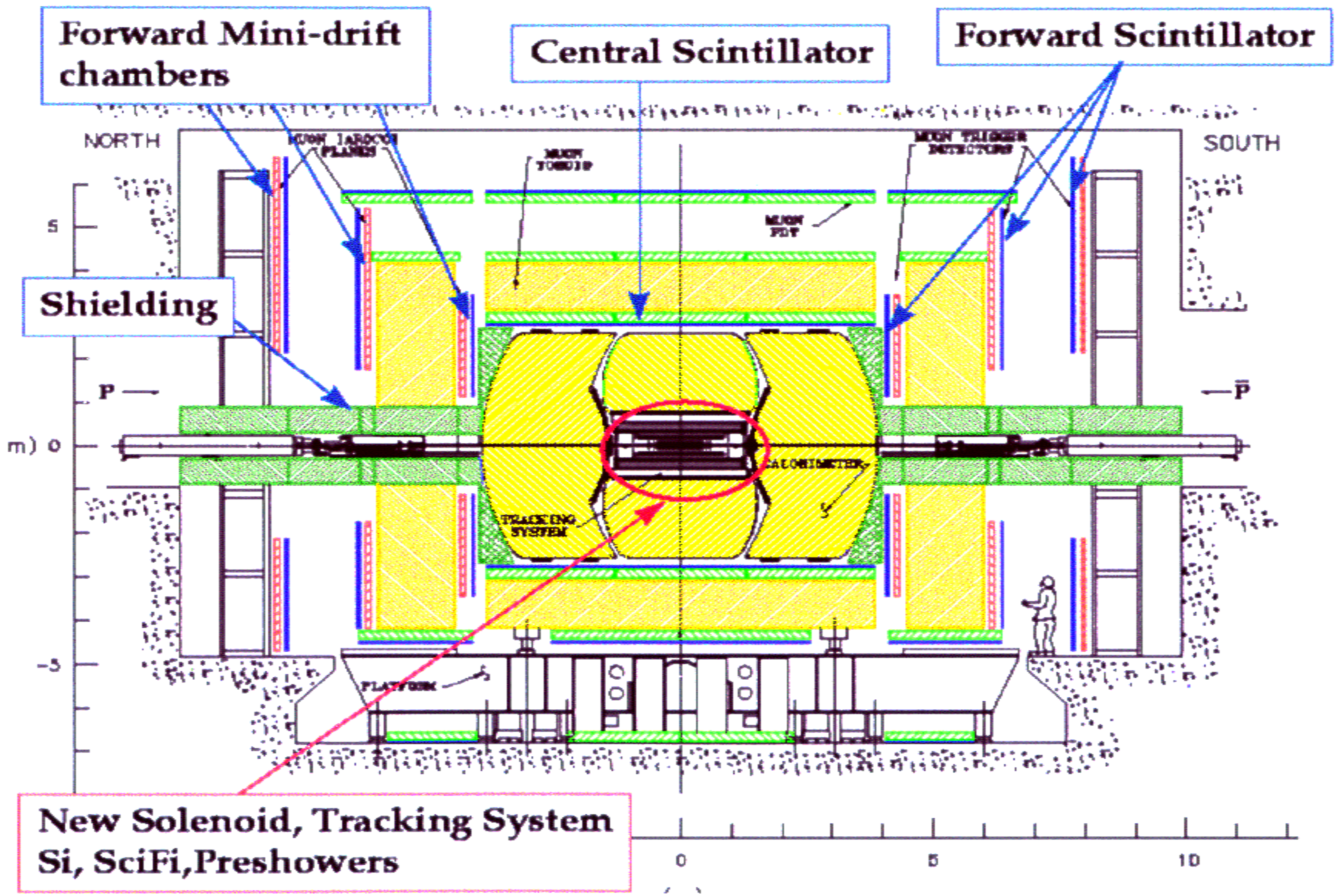


Υ(4S)

contin

	M (ee)	M (μμ)	M (eμ)
outside J/ψ, ψ′	10 ± 5	12 ± 5	18 ± 8
expected	9 ± 1	16 ± 2	39 ± 3

The DØ Upgrade

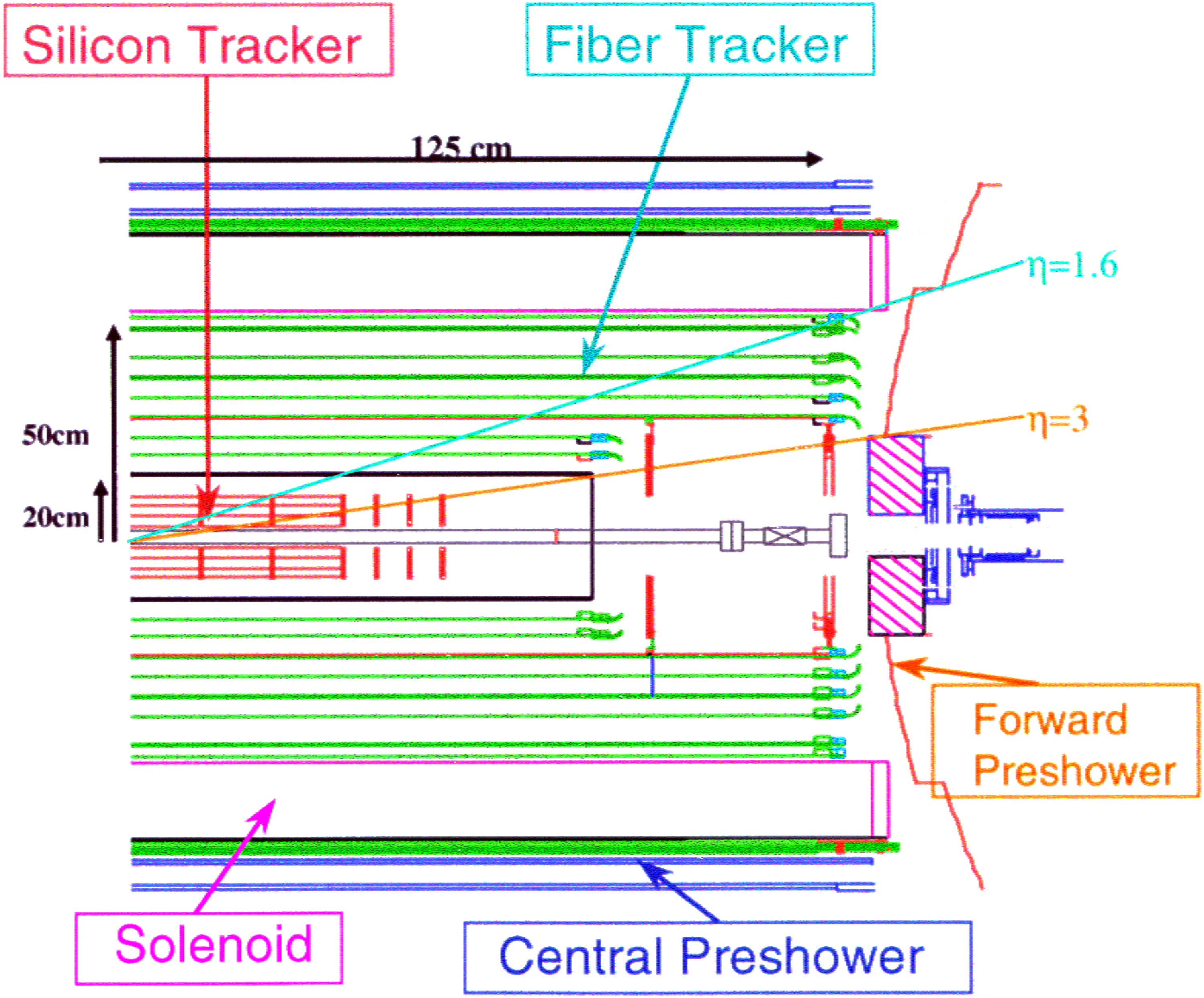


+ New Electronics, Trig, DAQ

DØ Upgraded Detector Performance

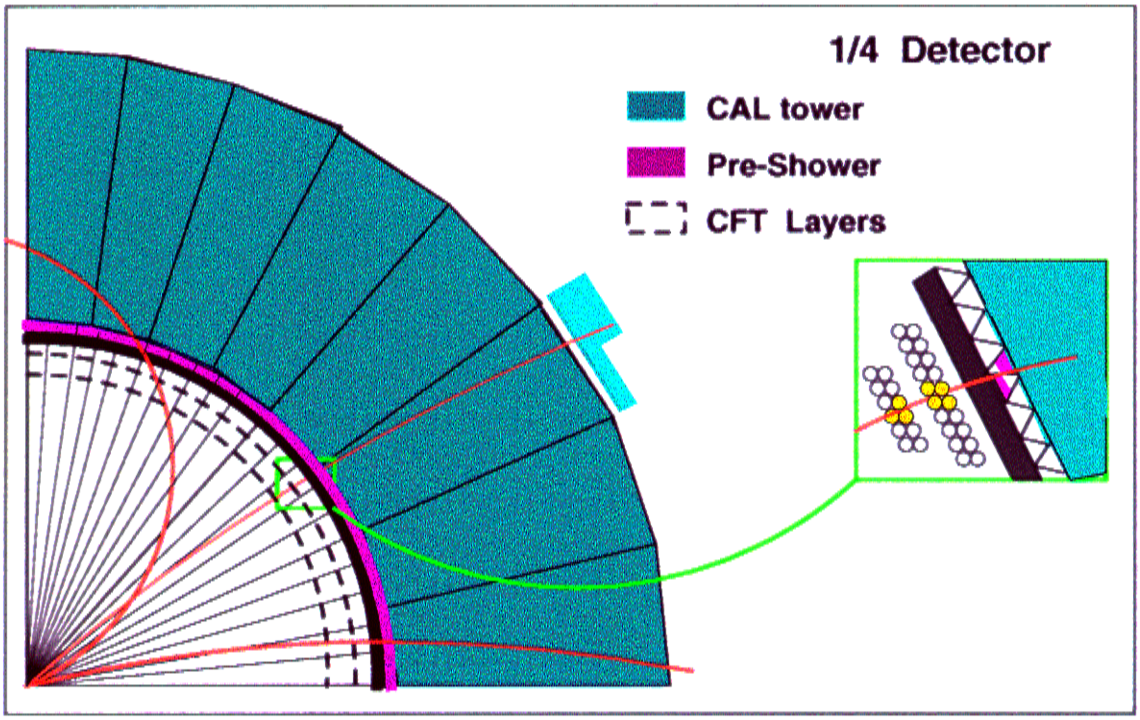
- Good Momentum resolution:
  - $dP_T/P_T^2 = 0.002$ (Silicon+Fiber tracker)
- High tracking efficiency:
  - at least 95 % $|\eta| < 3$ (disks)
- Vertex Reconstruction:
  - primary vertex: $\sigma^{vertex} = 15\text{-}30\ \mu m$ (r-ϕ)
  - secondary vertex: $\sigma^{vertex} = 40\ \mu m$ (r-ϕ) , $100\ \mu m$ (r-z)
- Excellent lepton coverage trigger and ID efficiency:
  - muons: $pT > 1.5$ GeV, $|\eta| < 2$
  - electrons: $pT > 1$ GeV, $|\eta| < 2.5$
- Impact parameter trigger

The DØ Inner Tracking System



DØ Electron Triggers

- Low E_T cut for in EM CAL (2.0 GeV)
- Low threshold PS clusters (2.0-.5.0 MIPs)
- Low p_T track / charge sign (1.5 GeV/c)



- Level 1 trigger:
  - Matching: Track - PS Cluster (+- 3 strips)
  - CAL - PS Cluster (quadrant)
- - Level-2 trigger:
  - - Matching: CAL - PS clusters in (η, Φ)
  - - EM fraction, ΔR(e-,e+), M(e-,e+), $\Delta\Phi$(e-,e+)

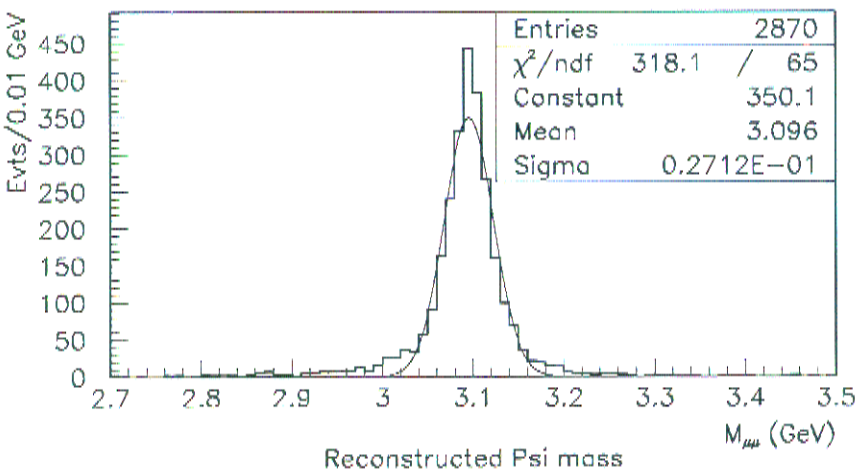
~~OUTLINE~~

97' MONTE CARLO TRIGGER STUDIES

- Motivation
  - time integrated CP asymmetry from $K_s + J/\psi$
  - B_s mixing in the x_s range 15 - 20
  - FCNC b decays etc
- Monte Carlo samples
  - NLO $Q\bar{Q}$; $2 < p_T < 80$ GeV/c; $\mu\mu$ and ee mode
  - $b \to J/\psi + X$; $J/\psi \to \mu\mu(ee)$
  - prompt J/ψ
  - $B_s \to D_s + \mu$ (two μ in the final state)
  - $B_s \to D_s + 3\pi$ (only one μ in the final state)
  - QCD background — 2 jets cuts 2-80 GeV in p_T bins, multiple inter, $\mathcal{L} = 2 10^{32}$
- Standard Triggers
  - nominal
  - modified single μ triggers
  - modified dimuon triggers
- STT Triggers
  - rates
  - efficiencies
- Expected event samples for selected processes
- Conclusions

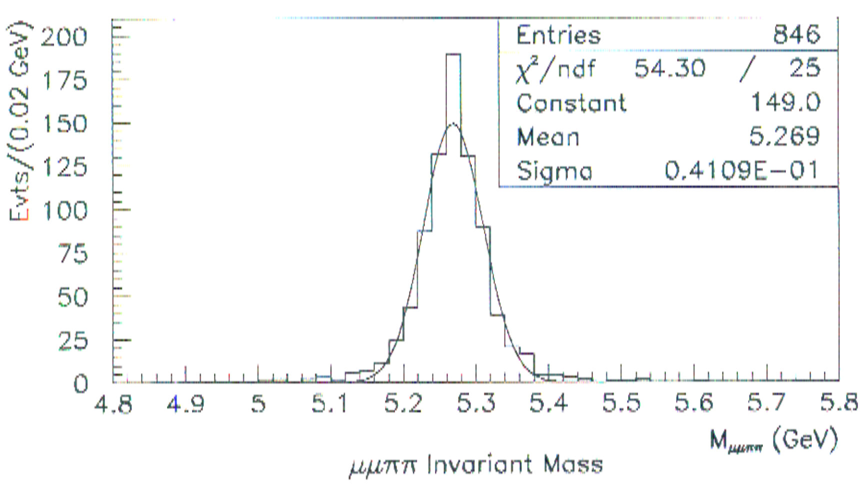
B Meson Reconstruction

- 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 $|\eta_\pi| < 2$.

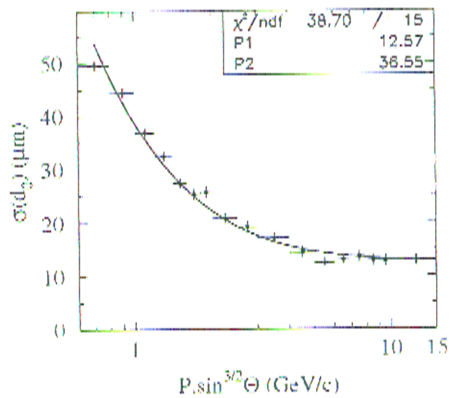


41 MeV → 15 MeV (mass constraints)

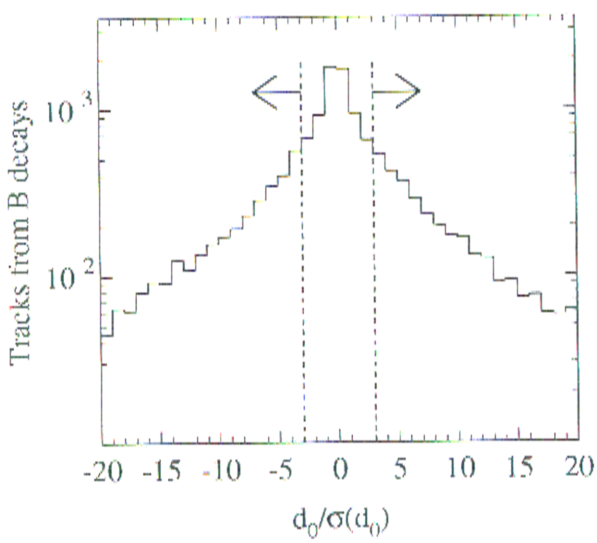
B-tagging

- 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:

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

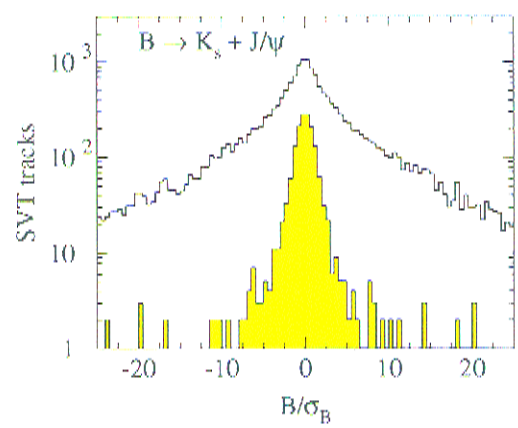


- For $B_d^\circ \rightarrow K_s + J/\psi$ events, more than 50% of the particles produced in B decays will have an impact parameter significance $d_0/\sigma(d_0)$ greater than 3.

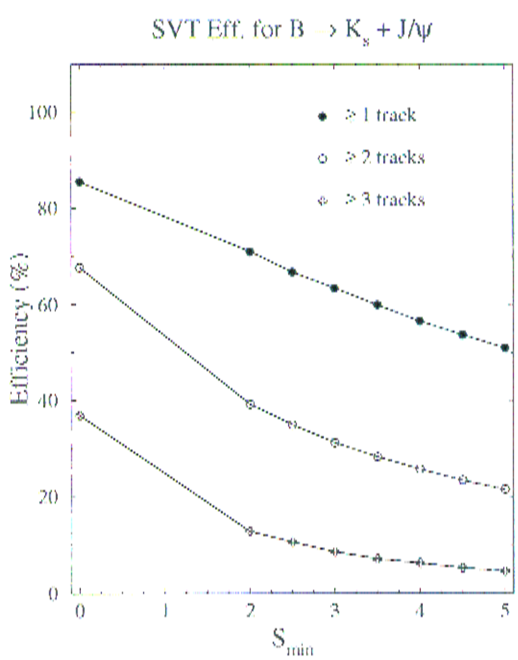


Silicon Vertex Trigger

- The Silicon Vertex Trigger relies on the presence of tracks with large impact parameters.
- For $B_d^\circ \to K_s + J/\psi$ events, more than 80% of the particles with $p_T > 1.5$ GeV/c and $|\eta| < 1.6$ come from B meson decays.



- A reasonable trigger efficiency can be achieved with a simple counting algorithm.

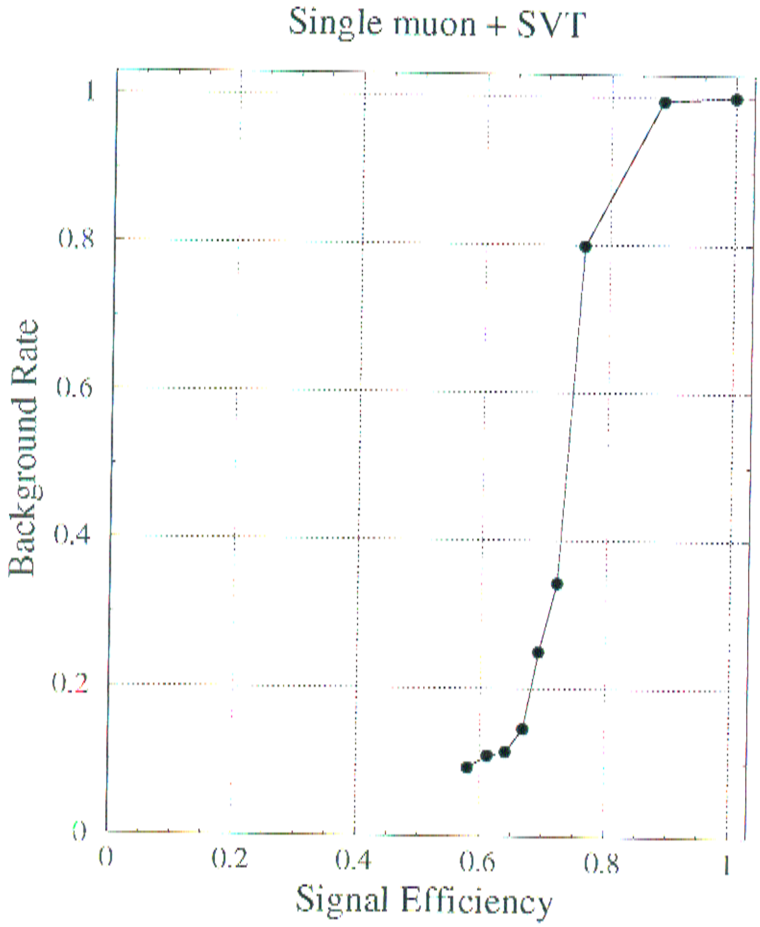


Single Muon Trigger

- Investigate various options of a single muon trigger.

Trigger Configuration	L2 Bgd. (Hz)	ψK_s (%)
• $p_T > 6$, $\mid \eta \mid < 2$	13.5	10.8
• $p_T > 4$, $\mid \eta \mid < 2$	38.6	23.9
• $p_T > 4$ + SVT	13.2	17.3

- In case the single muon trigger rate would need to be reduced, the SVT would be very helpful to preserve a good signal efficiency.

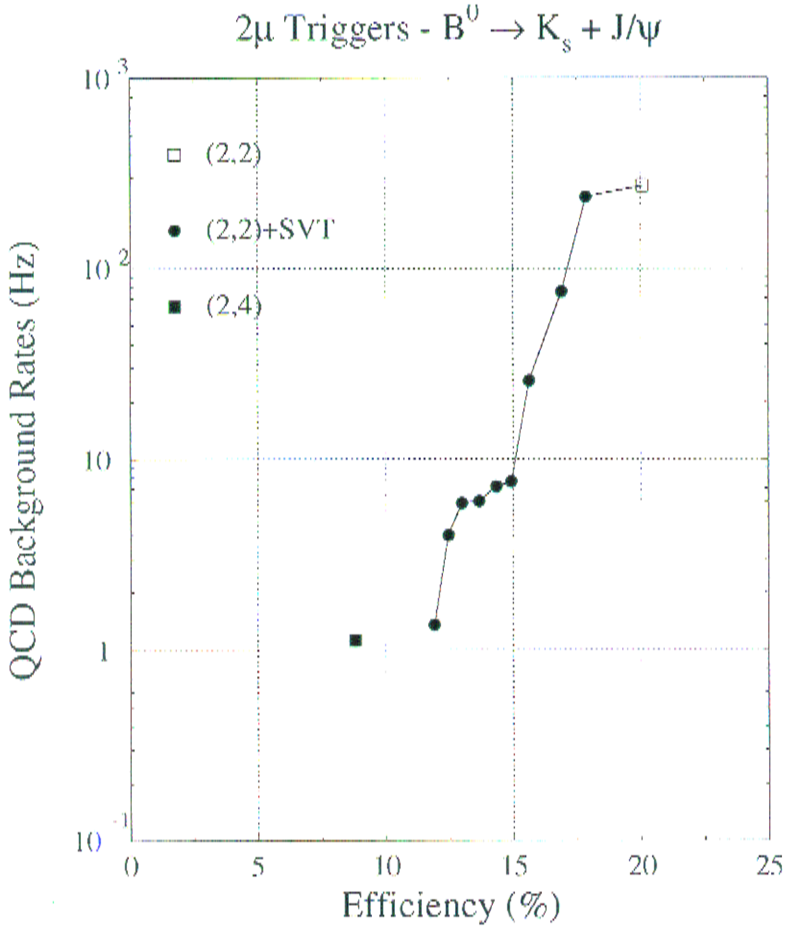


Dimuon Trigger

- Play with threshold on both legs of the J/ψ.

Trigger	L2 Bgd. (Hz)	ψK_s (%)
• (2 GeV, 4 GeV)	1.1	8.8
• (2 GeV, 2 GeV)	272	20.1
• (2,2) + SVT	7.6	14.9

- The SVT allows to reduce the rate of the low threshold trigger (2,2) while preserving a better efficiency than (2,4).

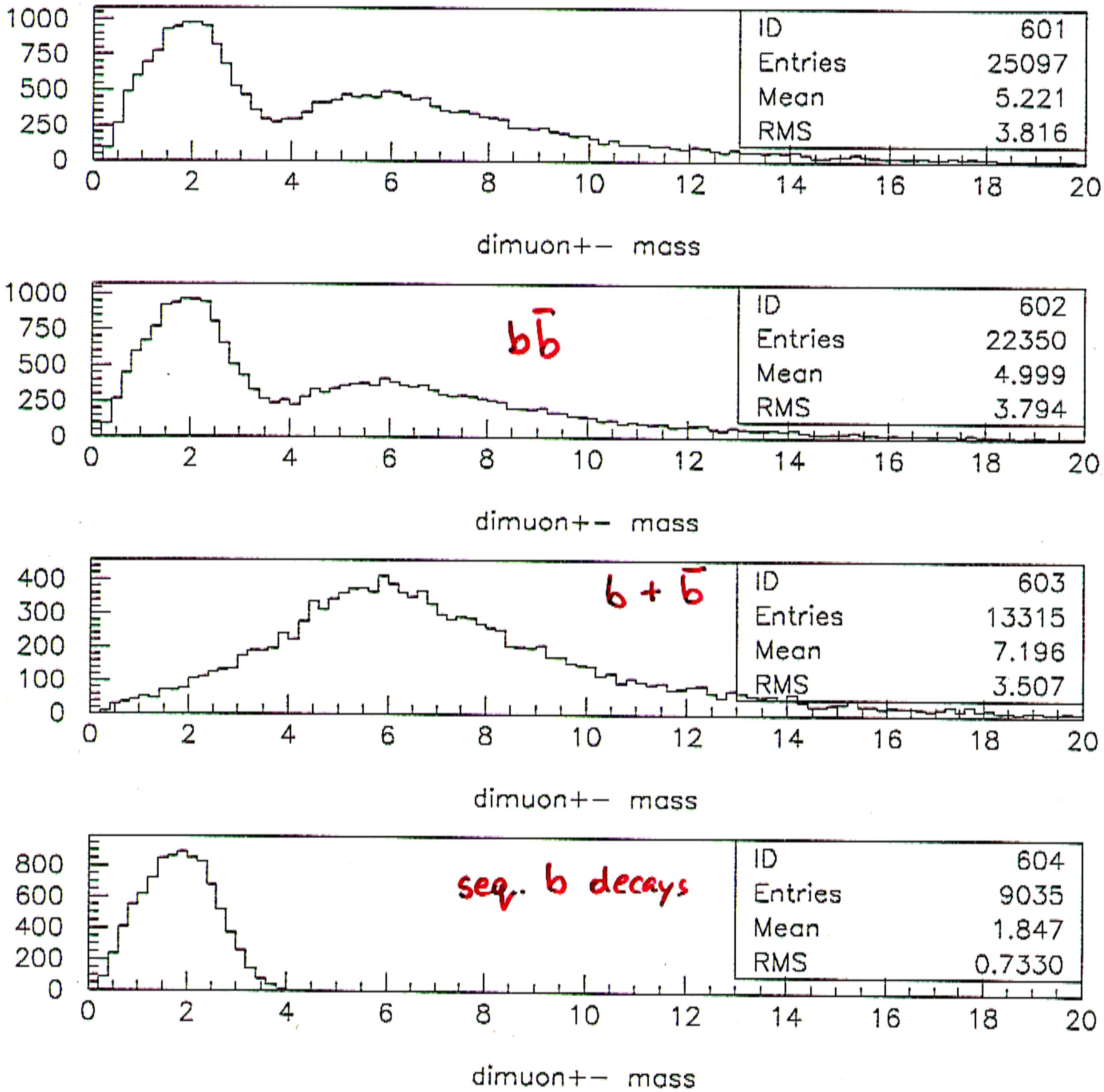


QQNLO MONTE CARLO (ISAJET 7.22)

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

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

21/09/99 21.47



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

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

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

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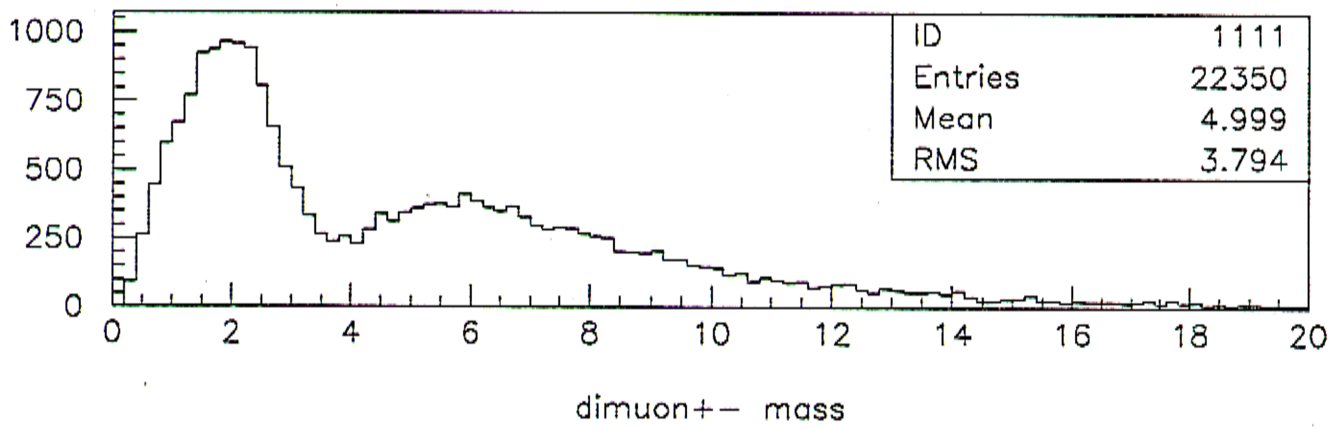
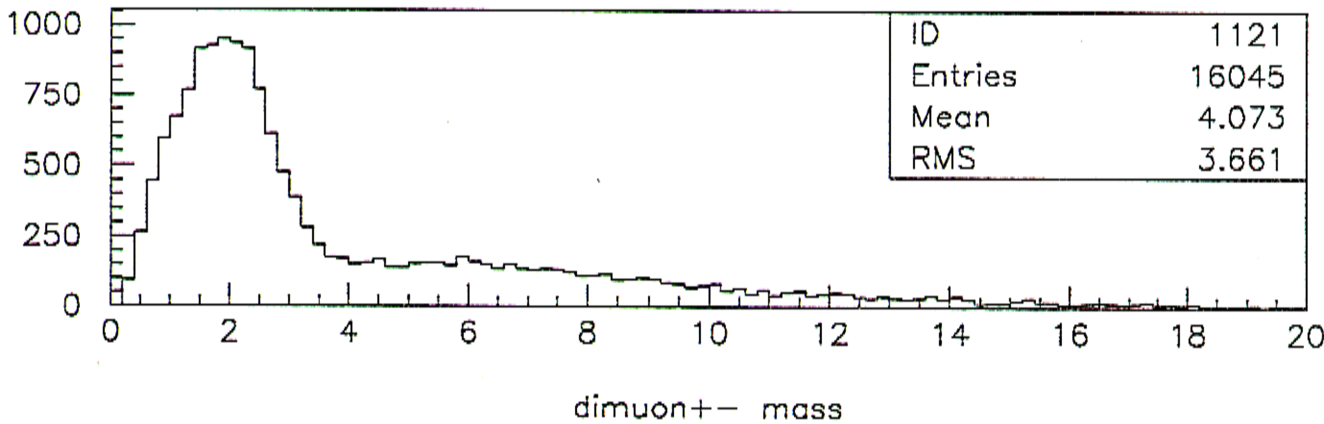
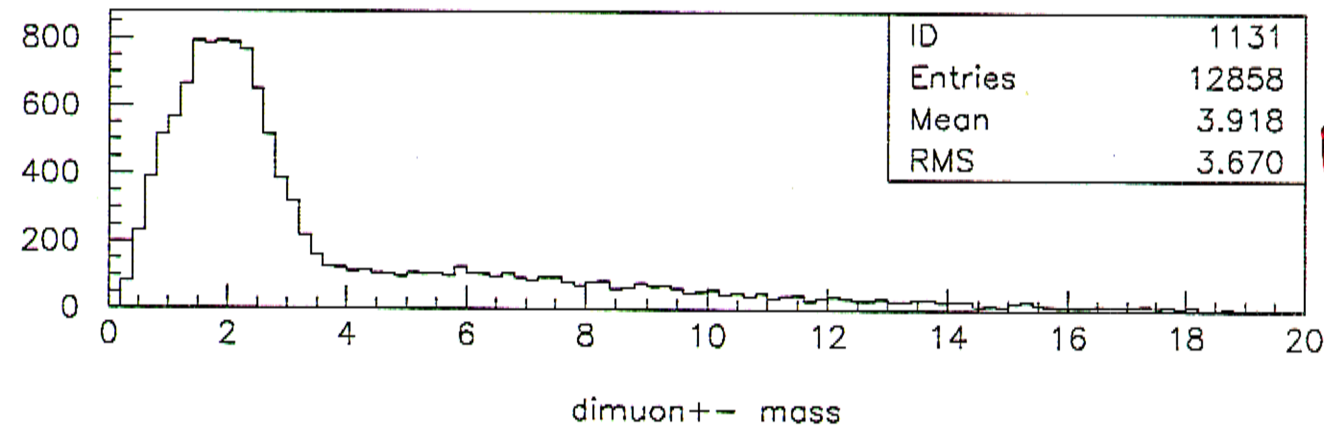




$p_T^{\mu\mu} > 4$ GeV/c



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

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

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

Run2 vs Run1 Comparison

	Run1	Run2
• $\int \mathcal{L} dt$	50 pb^{-1}	2 fb^{-1}
• $\sigma_M(J/\psi \to \mu^+\mu^-)$	~ 350 MeV/c^2	~ 27 MeV/c^2
• η coverage (μ)	~~0.6~~ 1.0	~~2.0~~ 1.6
• kinematic acceptance $p_T^b > 6$ GeV/c; $\lvert\eta^b\rvert < 1$ $p_T^\mu > 3$ GeV/c; $\lvert\eta^\mu\rvert < 1$; $M_{\mu\mu} > 3.9$ GeV	7×10^{-3}	7×10^{-3}
• trigger/off-line effic.	1%	25%
• background reduction		× ?? mass resol. search window same, displaced vtx μ's from b jets
• Signal (Events)	0	~~900~~ 600
• Background (Events)	68	~~25~~ 50,000
• S/$\sqrt{N}$	0	600/220

$p_T^{\mu\mu} > 5$ GeV/c
$p_T^{\mu} > 3$ GeV

CONCLUSIONS

IN RUN 2 (2 fb^{-1}) DØ will collect:

~ 600 $b \to X_s \mu^+ \mu^-$

$\sim 50{,}000$ $b\bar{b} \to \mu^+ \mu^- X$

for: $3.9 < M_{\mu\mu} < 4.4$ GeV

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

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

$|\eta^{\mu}| < 1.6$ GeV/c

QUESTION?

HOW MUCH ONE CAN REDUCE the $b\bar{b}$ PHYSICS BACKGROUND BY REQUIRING

- μs from same vtx
- kinematic cuts
- CLEO method?..

NUMBER of $b \to X_s \mu^+ \mu^-$ (observed) $\sim \times 3$ IF $p_T^{\mu} > 2$ GeV/c