Studies of sin(2β) via $B \to J/\psi + K_S$ at DØ

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Introduction
lepton triggering
offline reconstruction
δ(Sin(2β)) estimation

MCFAST and
Full GEANT/Reco

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Introduction

Asymmetry (in the Standard Model) is directly related to sin2β:

$$A_{CP}(t) = \frac{\Gamma\left(\overline{B^0} \rightarrow J/\psi K_S^0\right) - \Gamma\left(B^0 \rightarrow J/\psi K_S^0\right)}{\Gamma\left(\overline{B^0} \rightarrow J/\psi K_S^0\right) + \Gamma\left(B^0 \rightarrow J/\psi K_S^0\right)} = \sin(2\beta)\sin(\Delta m_d t)$$

This is a very good channel due to:

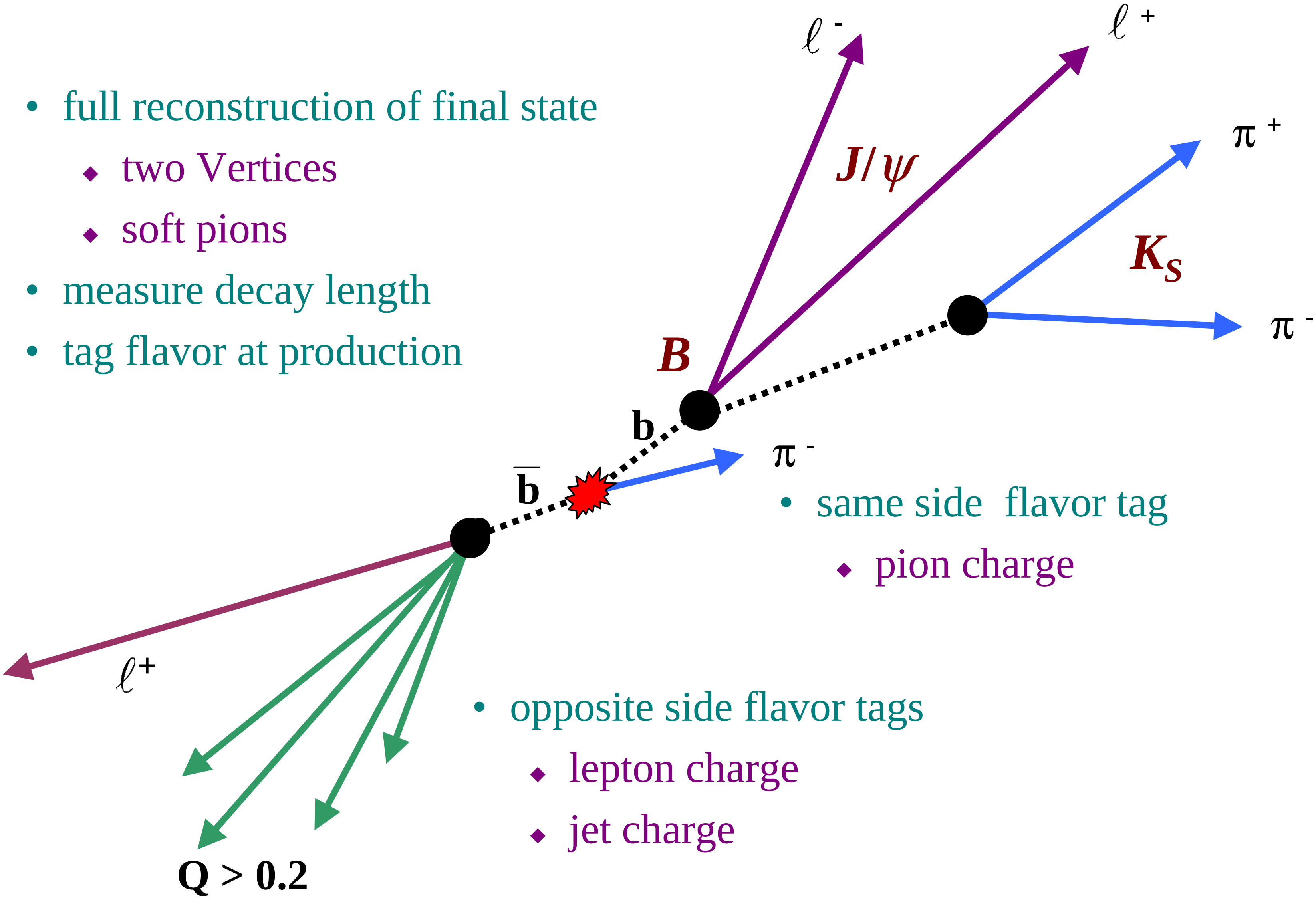
- readily accessible final states with small background
- relatively large branching ratio
- negligible theoretical uncertainty
    - penguin amplitude is expected to be small since cc pair must be popped from vacuum
    - penguin diagram contribution to the asymmetry has the same phase as tree level

DØ Upgraded Detector Performance

- Good Momentum resolution:
  - $dp_T/p_T^2 = 0.002$ (Silicon+Fiber tracker)
- High tracking efficiency:
  - at least 95 % $|\eta| < 3.5$ (disks)
- Vertex Reconstruction:
  - primary vertex: $\sigma^{vertex} = 15\text{-}30\ \mu m\ (r\text{-}\phi)$
  - secondary vertex: $\sigma^{vertex} = 40\ \mu m\ (r\text{-}\phi)$, $100\ \mu m\ (r\text{-}z)$
- Excellent lepton coverage, trigger and ID efficiency:
  - muons: $p_T > 1.5$ GeV, $|\eta| < 2$
  - electrons: $p_T > 1.5$ GeV, $|\eta| < 2.5$
- Impact parameter trigger

Sin(2β) via $B \rightarrow J/\psi + K_S$

- full reconstruction of final state
  - two Vertices
  - soft pions
- measure decay length
- tag flavor at production



- same side flavor tag
  - pion charge
- opposite side flavor tags
  - lepton charge
  - jet charge

Strength of DØ

Depend on lepton identification and triggering:

- Electron ID and triggering:
  - excellent calorimetry and coverage
  - new central scintillating fiber tracker (CFT)
  - pre-shower detectors

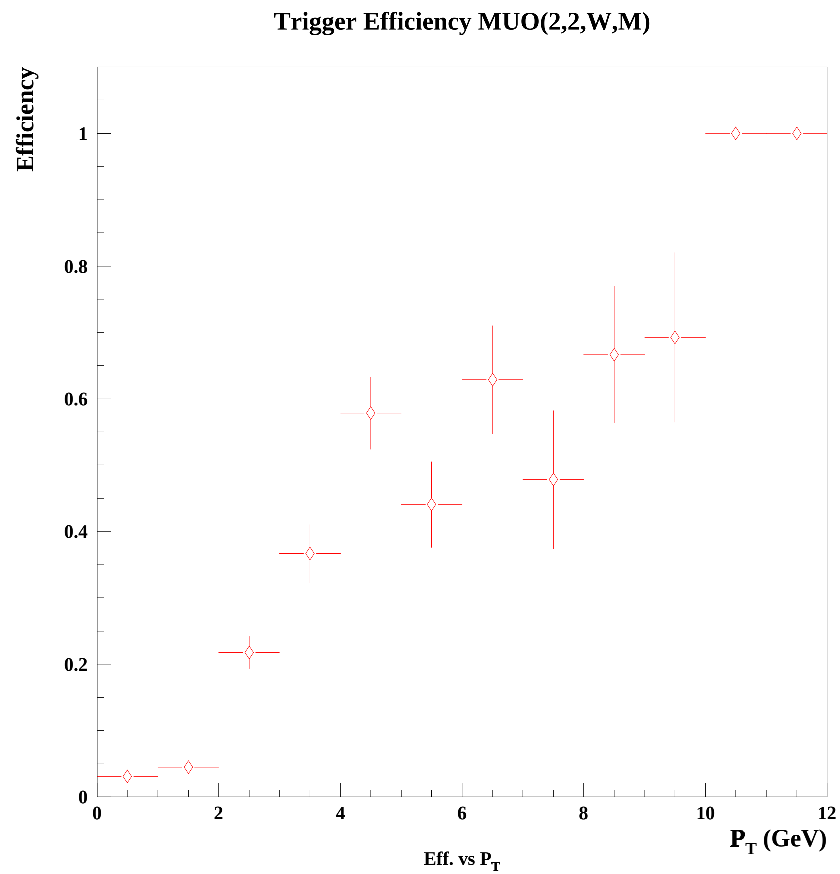
- Muons :
  - good muon coverage and purity
  - enhanced muon triggering using track seeds from CFT

Muon Triggers

$P_T(B) > 4$ GeV and $|\eta| < 3$

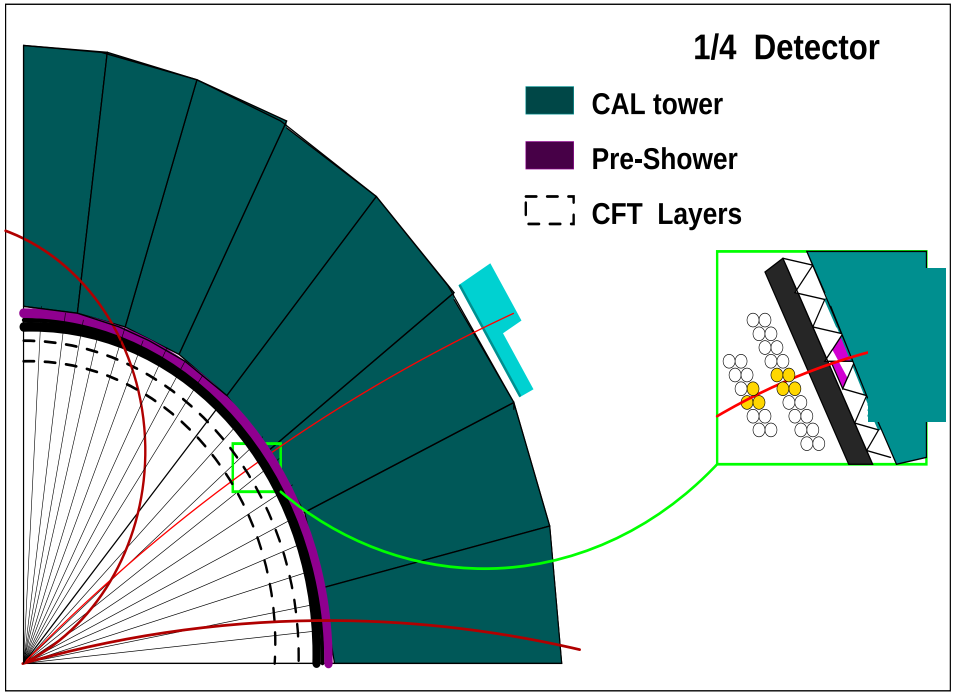
Trigger	Level 2 backg. (Hz)	$B \to J/\psi K_S$ efficiency (%)
Single μ: (T1) $P_T > 4$ (loose)	~39	24±1
$P_T > 4$ (tight)		11±1
Dimuon: (T2) $P_T > 2, 2$	~272	12±1
Overall (T1) or (T2)		27±1

max level 2 rate for all DØ triggers is 1000 Hz

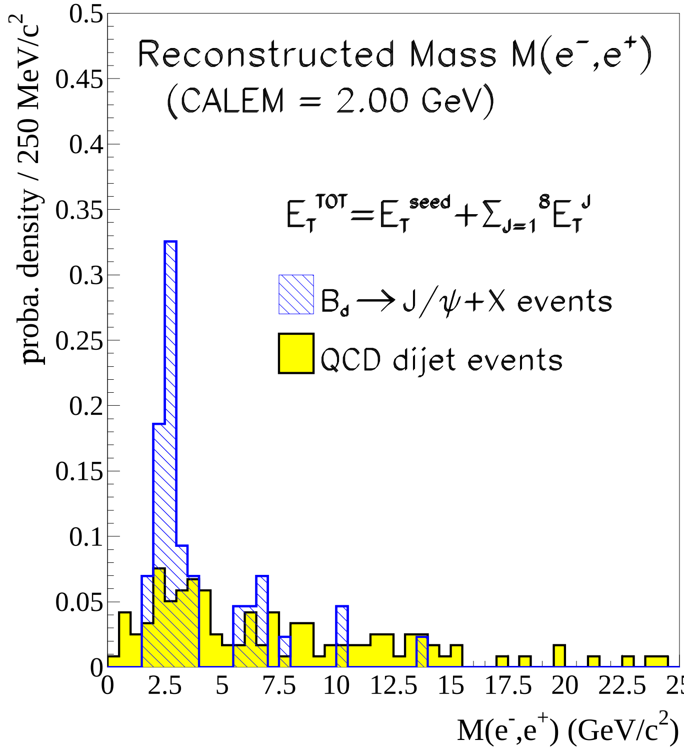


DØ GEANT/Trig. Sim.

Di-electron Trigger



di-electron mass cut at level 2



Two electrons each with p_T > 2 GeV/c

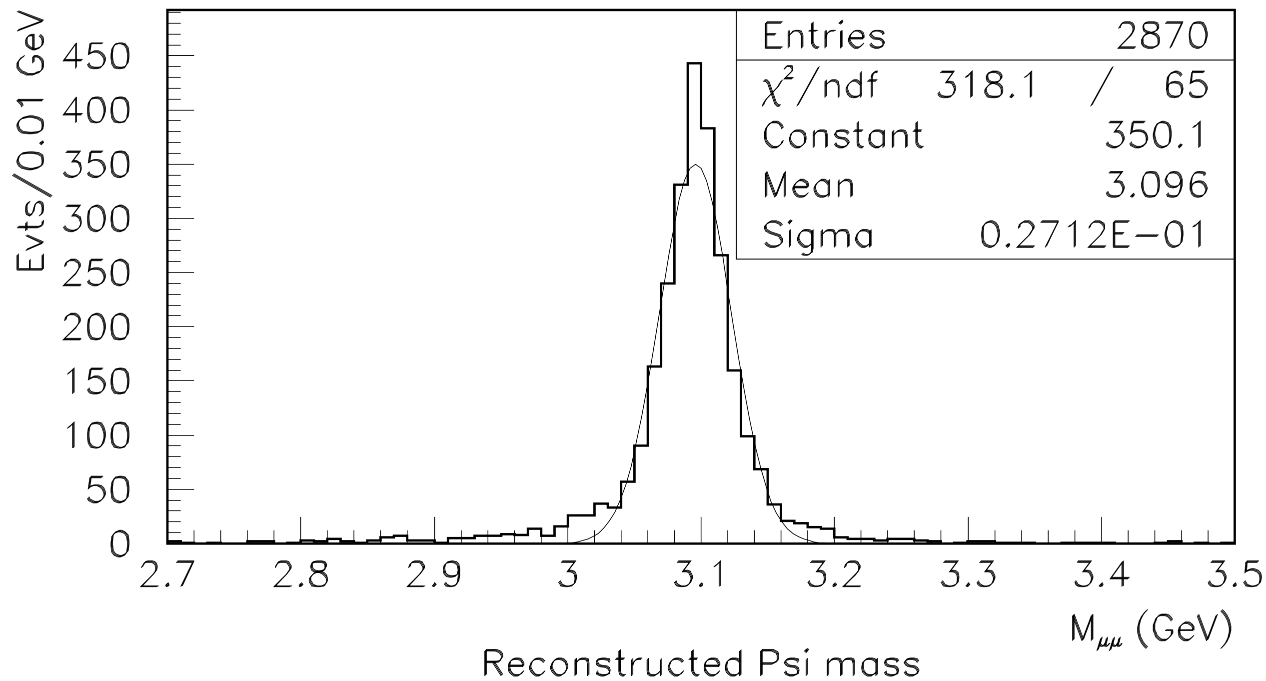
- relies on pre shower - CAL match to reduce background
- also cut on opposite sign, ΔR, and invariant mass at level 2
- level 2 rate ~ 200 Hz and efficiency ~20%

$B \to J/\psi K_S$ Reconstruction

$J/\psi \to \mu^+ \mu^-$

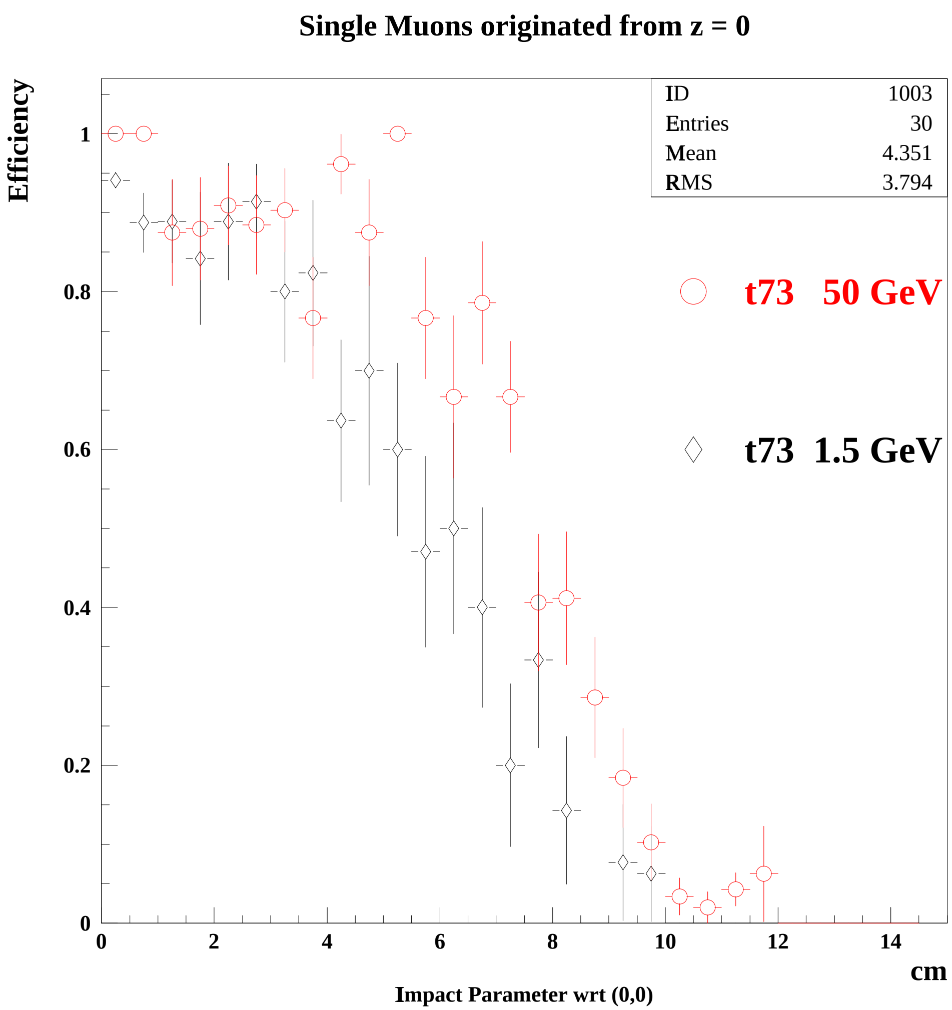
- two muon tracks
  - $p_T > 1.5$ GeV
  - $|\eta| < 2$
  - 85% efficiency

MCFAST

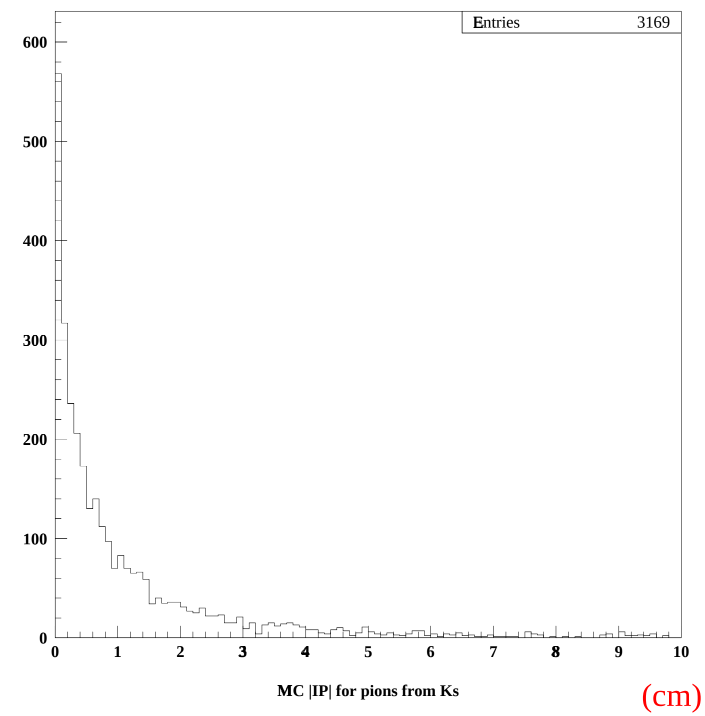


$B \to J/\psi K_S$ Reconstruction

It looks like we can reconstruct $K_S \to \pi^+\pi^-$.



DØ Run II GEANT



DØ GEANT/Trig. Sim.

$B \to J/\psi K_S$ Reconstruction

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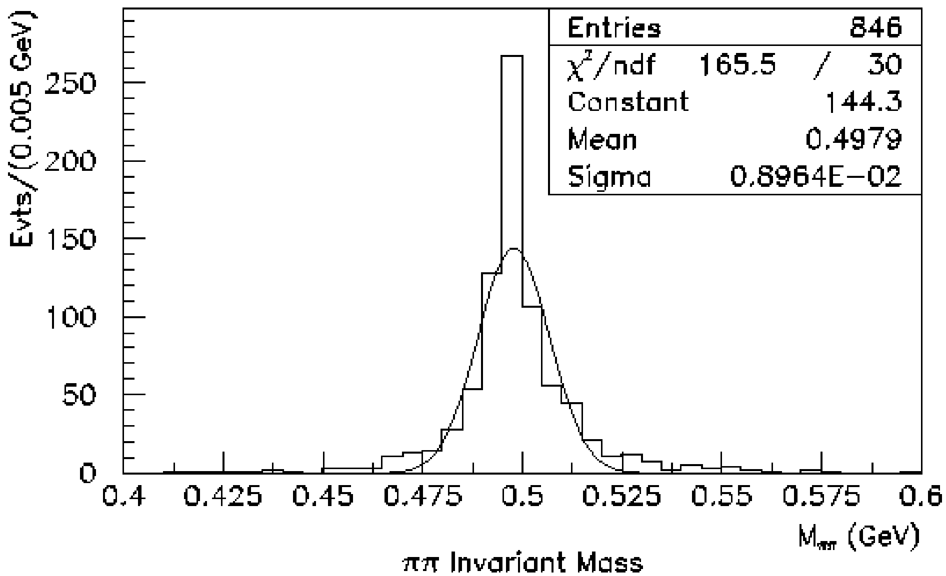
$K_S \to \pi^+ \pi^-$

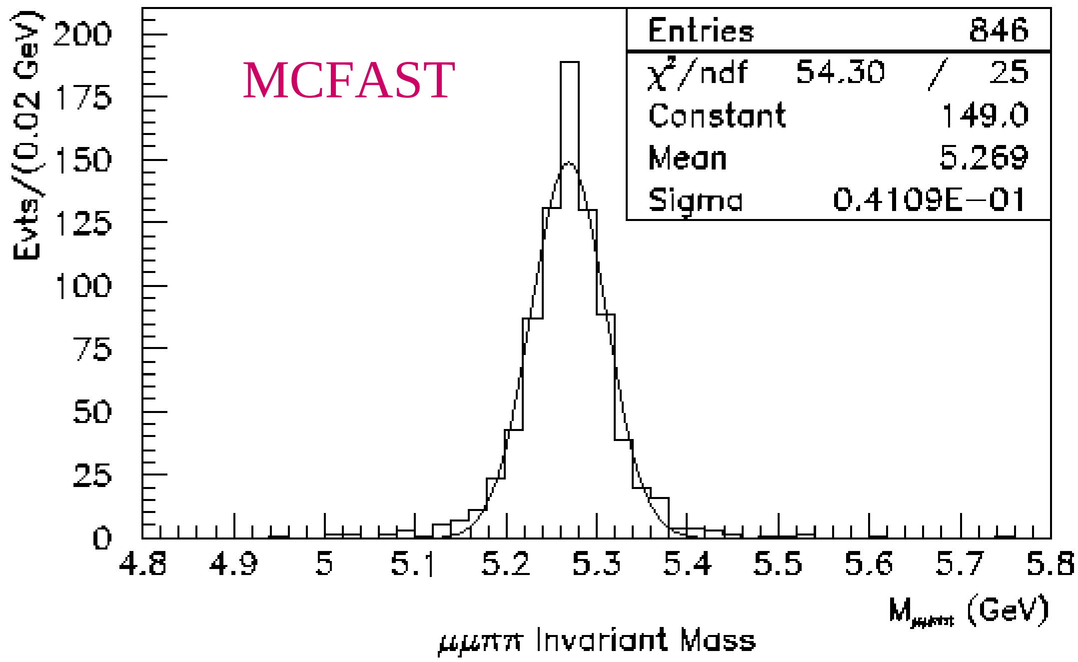
- $P_T(\pi) > 0.4$ GeV/c
- $|\eta_\pi| < 1.7$
- $L_{xy}/\sigma > 5$
- efficiency ~ 27 %



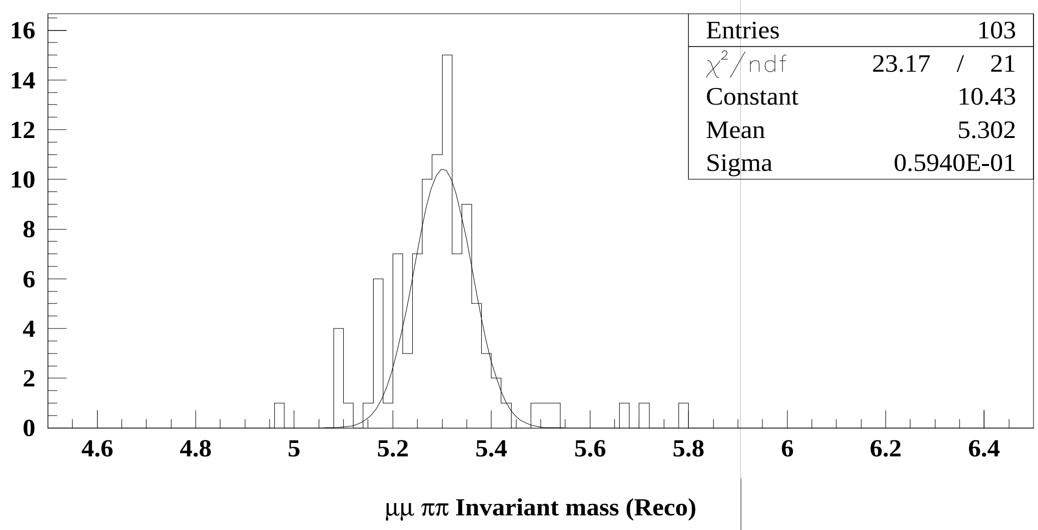
$B \rightarrow J/\psi K_S$ Reconstruction

Combined $\mu^+\mu^-\pi^+\pi^-$
invariant mass

(before fit)



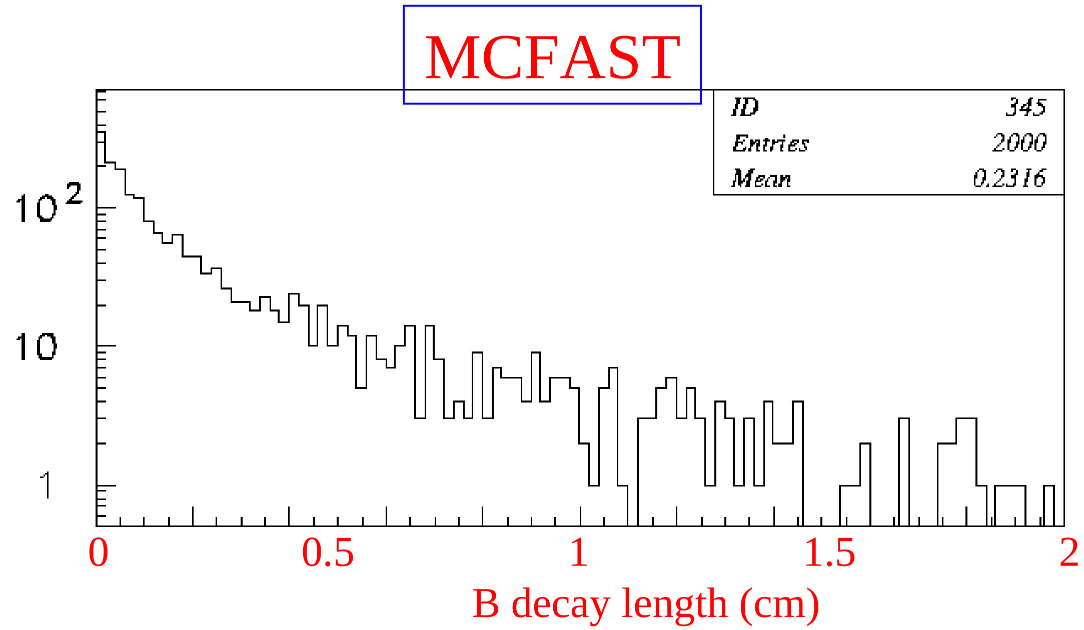
RECO

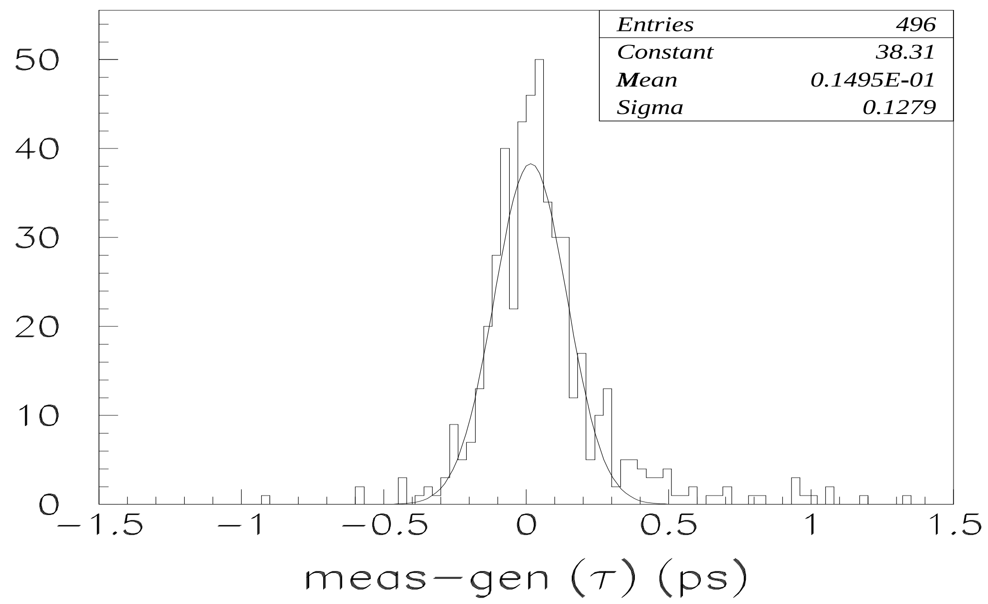


$B \rightarrow J/\psi K_s$ decay length reconstruction

- Two secondary two-track vertices
- Average *B* decay length: 2.3 mm
- Measured decay length resolution: 100 µm
- Measured time resolution:

120 ps



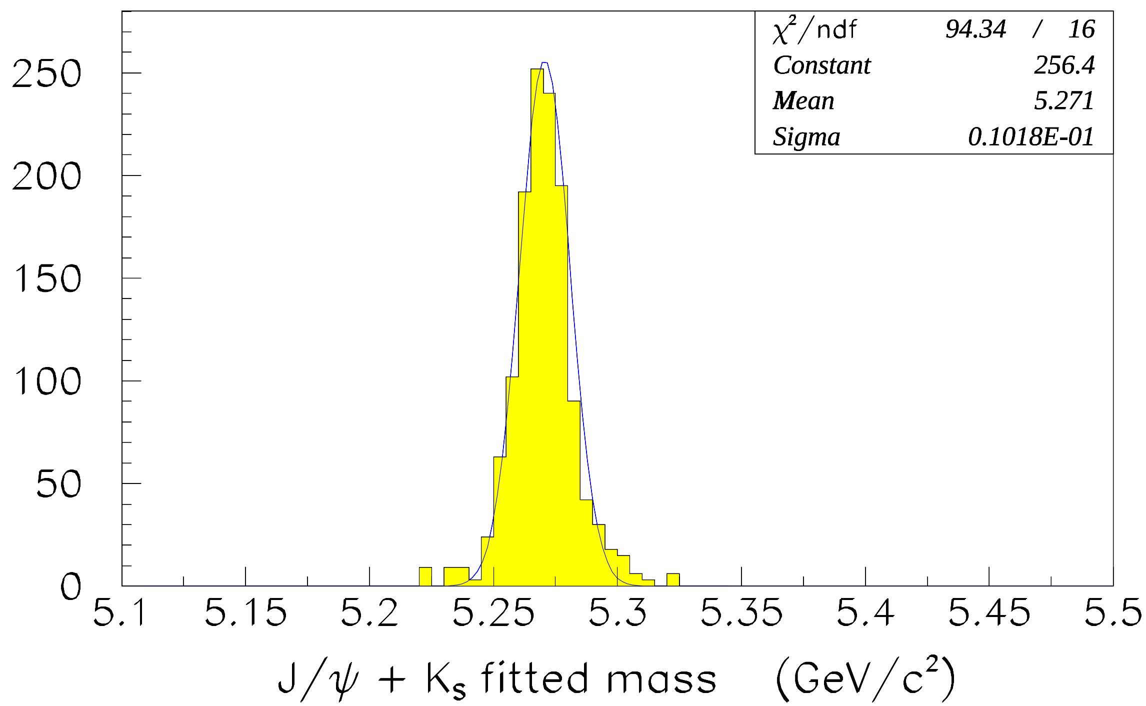


$B \to J/\psi K_S$ Reconstruction

- $J/\psi \to \mu^+\mu^-$ require two tracks with $p_T > 1.5$ GeV/c
- $K_S \to \pi^+\pi^-$ use long lifetime to reject background: $L_{xy}/\sigma > 5$
- Perform 4-track fit assuming $B \to J/\psi + K_S$
  - constrain $\pi\pi$ and $\mu\mu$ to mass of K_S and J/ψ respectively
  - force K_S to point to B vertex and B to point to primary

MCFAST

$P_T(B) > 4$ GeV



Flavor Tagging

Opposite side tags:

- identify the flavor of the other *B* in the event
  - soft lepton tags $b \rightarrow l^- + X$
  - jet charge tags $Q_{jet} < 0$ for b

Same side tags:

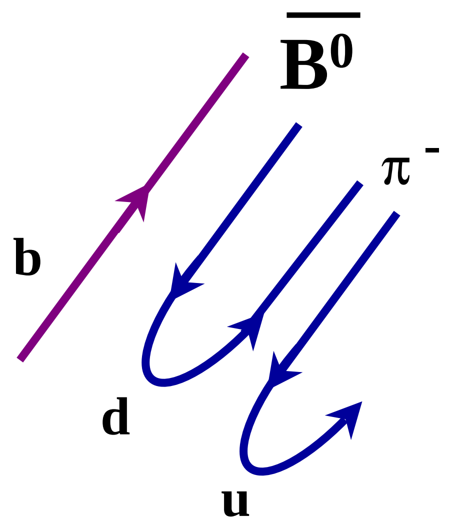
- correlation of flavor and charge of closest particle produced in fragmentation or decay

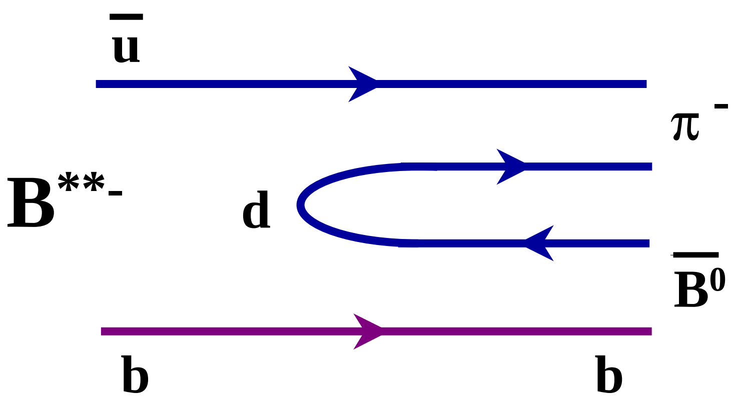
Efficiency ($\mathcal{E}$) and dilution factor ($\mathcal{D}$)

$\mathcal{D} = 2\mathcal{P} - 1$

$\mathcal{P}$ is the correct tag probability

$\mathcal{E}\mathcal{D}^2$ is the tag's effectiveness





Flavor Tagging

Tag	εD^2 (%) measured CDF Run I	εD^2 (%) expected CDF Run II	Relevant DØ difference	DØ capabilities
Same side	$1.8 \pm 0.4 \pm 0.3$	2.0	same	2.0
Soft lepton	$0.9 \pm 0.1 \pm 0.1$	1.7	μ , e ID coverage	3.1
Jet charge	$0.8 \pm 0.1 \pm 0.1$	3.0	forward tracking	4.7
Opp. side K		2.4	no ToF	none
Combined		9.1		9.8

How many B_d may we get ?

$$\sigma_{b\bar{b}} = 3.3 \times 48\,\mu b = 158\,\mu b$$

$$f(b \rightarrow B_d) = 0.42$$

$$\text{Acceptance} \quad : P_T(B) > \mathbf{4\ GeV/}\ \boldsymbol{c}\ , |\,y(B)\,| < 3.0 = 31\%$$

$$\sigma_B = \boldsymbol{\sigma}_{b\bar{b}} \cdot f \cdot \boldsymbol{Acc} = 21\mu b$$

$$BR = BR(B \rightarrow J/\psi + K_s, J/\psi \rightarrow \mu^+\mu^-, K_s \rightarrow \pi^+\pi^-)$$

$$= (5\times10^{-4})(0.06)(0.68) = (2\times10^{-5})$$

$$\varepsilon_{trigger} = 0.27$$

$$\boldsymbol{\varepsilon_{reco}} = 0.09$$

$$N = L \cdot 2 \cdot \sigma_B \cdot BR \cdot \varepsilon_{\text{trigger}} \cdot \boldsymbol{\varepsilon_{reco}} = 40\mathbf{K}$$

assuming luminosity ~ 2 fb^{-1}

Sin2β Expectations for 2fb^{-1}

For a ***time dependent*** analysis:

$$\sigma(\sin 2\beta) \approx e^{x_d^2\Gamma^2\sigma_t^2}\sqrt{\frac{1+4x_d^2}{2x_d}}\frac{1}{\sqrt{\varepsilon D^2 N}}\sqrt{1+\frac{B}{S}}$$

- (S/B ~ 0.75)
- εD^2 ~ 9.8 %
- σ_t ~ 128 fs

mode	$J/\psi \rightarrow \mu^+\mu^-$	$J/\psi \rightarrow e^+e^-$
trigger eff. (%)	**27**	**20**
reco'd events	**40,000**	**30,000**
σ(**sin2**β)	**0.04**	**0.05**
	0.03	

assuming luminosity ~ 2 fb^{-1}