Physics Reach of the BTeV Experiment

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Outline

- The BTeV Experiment -Goals
- The BTeV Detector - layout and unique features
- The Operating Parameters
- The Simulation
- Selected Final states
- Typical Sensitivities
- Status

BTeV's Physics Goals

- BTeV will begin to run well after the first measurements on CP violation in B decays have been made
- The fundamental question of whether the Standard Model's CKM mechanism for CP violation explains the complete pattern of CP violation in B decays will not yet have been answered
- BTeV is designed to look for new physics by
  - Checking the consistency of the Standard Model by making the very difficult measurements that will still be open circa 2006; and
  - Searching for rare and Standard Model violating decays of beauty and charm particles to look for deviations from the Standard Model

Summary of required measurements for CKM tests

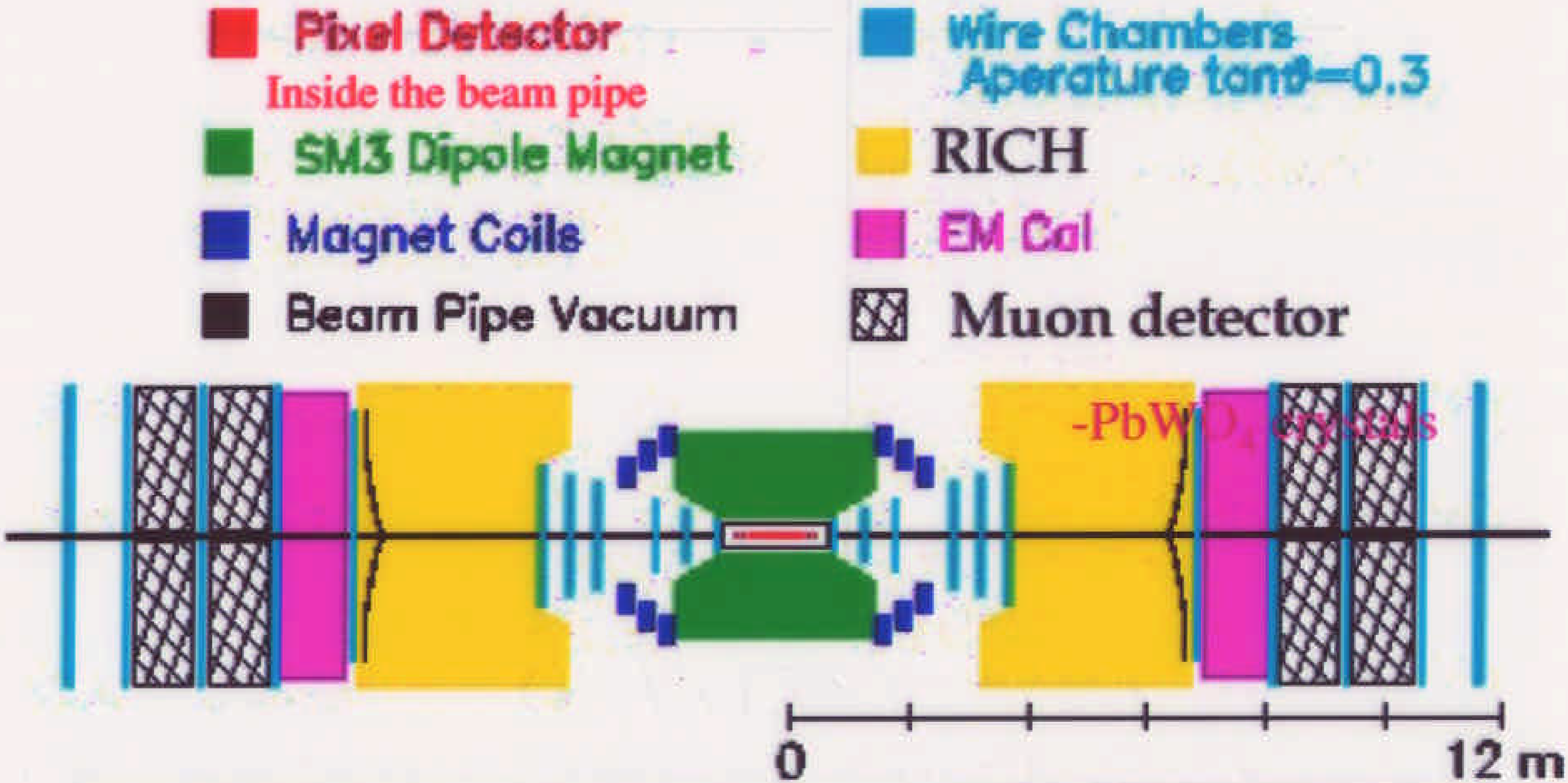
Physics Quantity	Decay Mode	Vertex Trigger	K/π sep	γ det	Decay time σ
$\sin(2\alpha)$	$B^o \to \rho\pi \to \pi^+\pi^-\pi^o$	✓	✓	✓	
$\sin(2\alpha)$	$B^o \to \pi^+\pi^-$ & $B_s \to K^+K^-$	✓	✓		✓
$\cos(2\alpha)$	$B^o \to \rho\pi \to \pi^+\pi^-\pi^o$	✓	✓	✓	
sign($\sin(2\alpha)$)	$B^o \to \rho\pi$ & $B^o \to \pi^+\pi^-$	✓	✓	✓	
$\sin(\gamma)$	$B_s \to D_s K^-$	✓	✓		✓
$\sin(\gamma)$	$B^- \to \bar{D}^o K^-$	✓	✓		
$\sin(\gamma)$	$B \to K\pi$	✓	✓	✓	
$\sin(2\chi)$	$B_s \to J/\psi\eta'$, $J/\psi\eta$		✓	✓	✓
$\sin(2\beta)$	$B^o \to J/\psi K_s$				
$\cos(2\beta)$	$B^o \to J/\psi K^*$ & $B_s \to J/\psi\phi$				
x_s	$B_s \to D_s\pi^-$	✓	✓		✓
$\Delta\Gamma$ for B_s	$B_s \to J/\psi\eta'$, K^+K^-, $D_s\pi^-$	✓	✓	✓	✓

Note: $\chi = \mathrm{ARG}\left[-\frac{V_{cs}^* V_{cb}}{V_{ts}^* V_{tb}}\right]$

Key Design Features of BTeV

- ❶ A dipole located ON the IR, gives BTeV TWO spectrometers - - one covering the forward proton rapidity region and the other covering the forward antiproton rapidity region.
- ❷ A precision vertex detector based on planar pixel arrays
- ❸ A vertex trigger at Level I which makes BTeV especially efficient for states that have only hadrons. The tracking system design has to be tied closely to the trigger design to achieve this.
- ❹ Strong particle identification based on a Ring Imaging Cerenkov counter. Many states that will be of interest in this phase of B physics will only be separable from other states if this capability exists. It also allows one to use charged kaons for tagging.
- ❺ A lead tungstate electromagnetic calorimeter for photon and π^0 reconstruction
- ❻ A very high capacity data acquisition system which frees us from making excessively specific choices at the trigger level

The BTeV Detector



This detector, its trigger and its data acquisition system, will be capable of addressing whatever problems are likely to arise in bottom and charm quark physics.

The Tevatron as a b & c source

property	Value
Luminosity	2×10^{32}
b cross-section	100 μb
# of b-pairs per 10^7 sec	2×10^{11}
b fraction	10^{-3}
c cross-section	>500 μb
Bunch Spacing	132 ns
Luminous region length	$\sigma_z = 30$ cm
Luminous region width	$\sigma_x \sim \sigma_y \sim 50$ μm
Interactions/crossing	<2.0>

GEANT3 Simulation

- Tried to make a realistic implementation of the detector
- Generated & tracked all primary and secondaries from interactions and decays
- Used a Poisson distribution with a mean of 2 interactions /crossing
- Ran on 50 LINUX CPUS

Trigger Simulation

- Trigger is based on using the pixel detector at the lowest level to inspect every crossing -- 7.6 million/sec -- to look for evidence of particles detached from the primary interaction vertex. BASED on 2 tracks with > 3σ detachment from nearby primary. Accepts ≈ 1% of crossings:

Level 1 Efficiency on Interesting Physics States

Process	Eff. (%)	Monte Carlo
Minimum bias	1	BTeVGeant
$B_s \to D_s^+ K^-$	74	BTeVGeant
$B^0 \to D^{*+} \rho^-$	64	BTeVGeant
$B^0 \to \rho^0 \pi^0$	56	BTeVGeant
$B^0 \to J/\psi K_s$	50	BTeVGeant
$B_s \to J/\psi K^{*o}$	68	MCFast
$B^- \to D^0 K^-$	70	MCFast
$B^- \to K_s \pi^-$	27	MCFast
$B^0 \to$ 2-body modes $(\pi^+\pi^-, K^+\pi^-, K^+K^-)$	63	MCFast

Level I trigger: profile of the 1% of the events which pass :

❶ 4% are from b-quark -- including 50-70% of all "analyzable" events

❷ 10% are from c-quark

❸ 40% are from s-quark

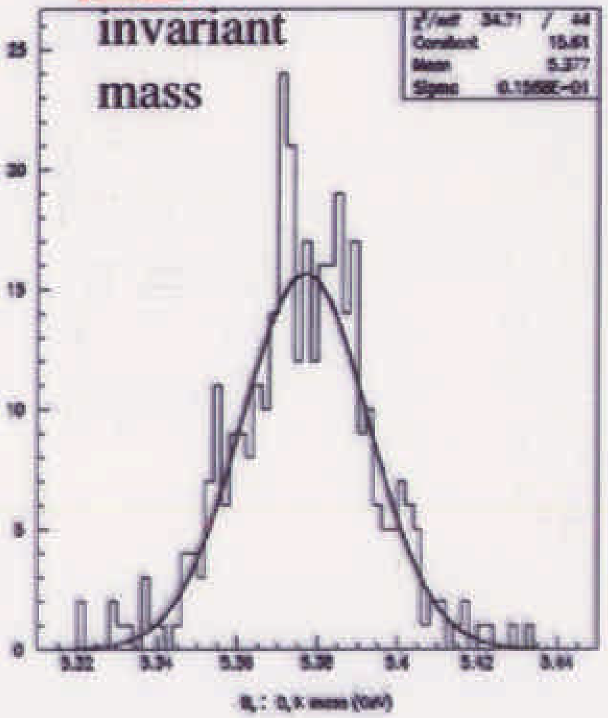
❹ 45% pure fakes (secondaries, etc)

Measurements of the CKM angle γ

- All methods are challenging either experimentally, theoretically, or both. Need to do it more than one way
- So far we have studied:

Final State	$\sigma(\gamma)$
$B_s \to D_s K$	7^0
$B^- \to K^- D^0$	10^0
$B \to K\pi$	$< 5^0$

$D_s K$ invariant mass

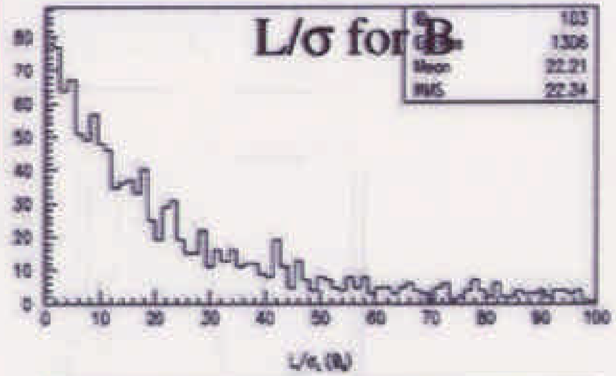


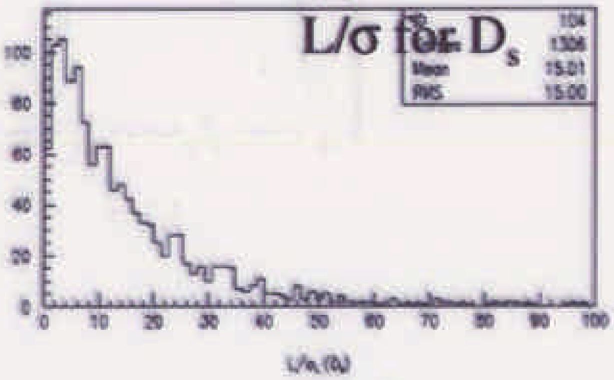
$\sigma_m = 15 MeV/c^2$

Use $D_s \to \phi \pi^+$, $\phi \to K^+K^-$

$\to K^* K^+$, $K^* \to K^-\pi^+$

$S/B = 7$





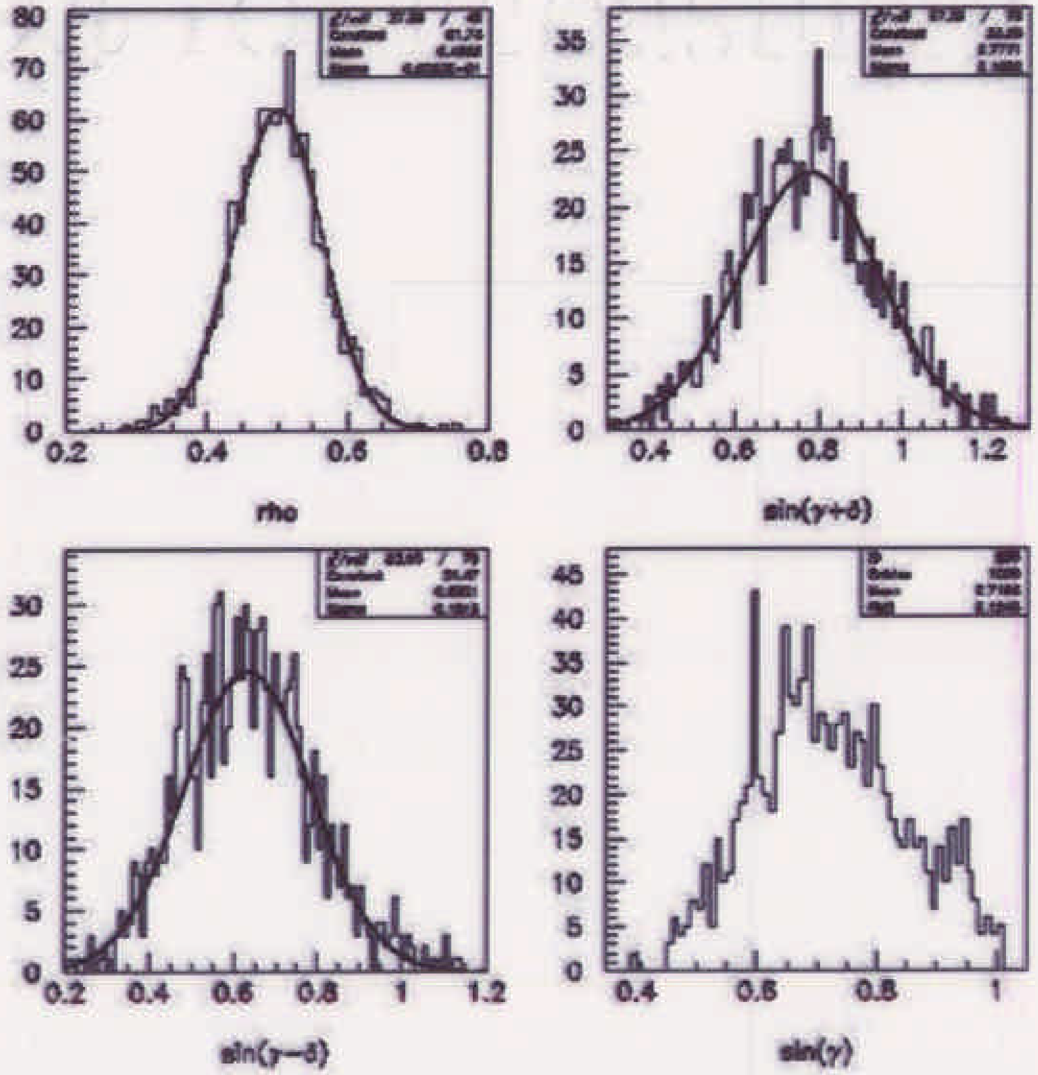
$\sigma_{\tau_{proper}} = 43$ fs

$B \to D_s K$

Fitted Values of ρ, $\sin(\gamma+\delta)$, $\sin(\gamma-\delta)$, and $\mathrm{Sin}(\gamma)$ for $\gamma = 45^o$.

Result:

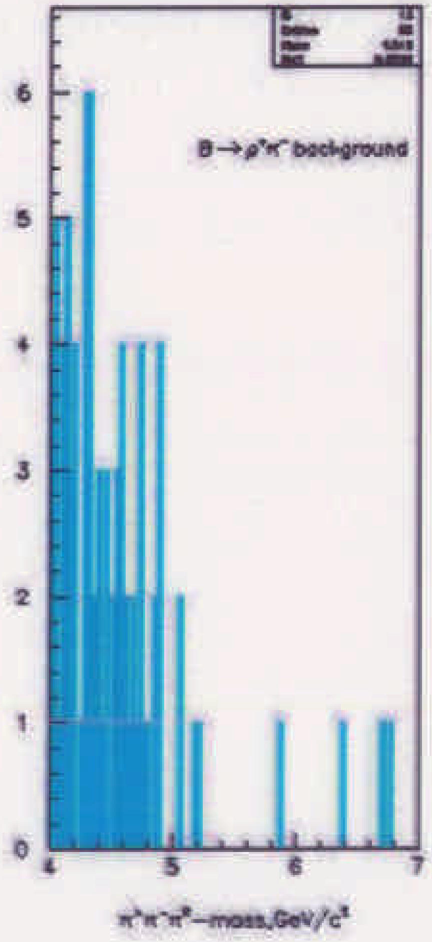
$\gamma = 46^{+0.8}_{-0.7}$ degrees

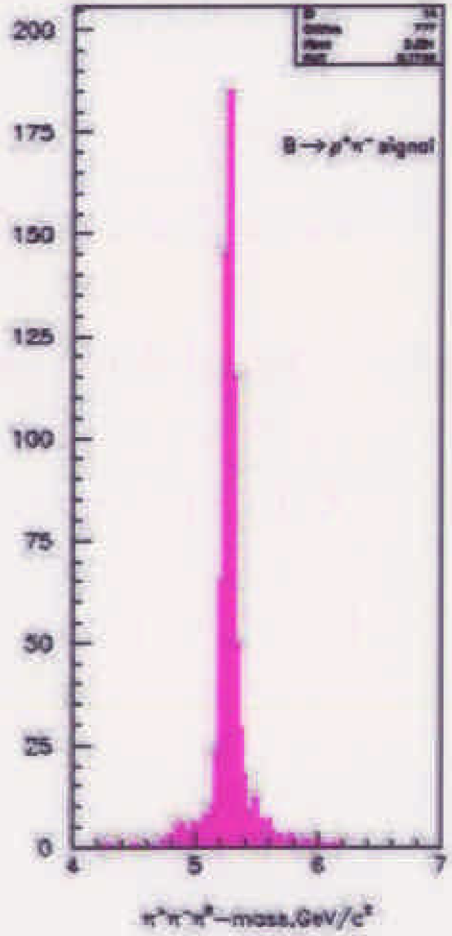


Notes:
① ρ is ratio of the two competing weak decay diagrams
② γ is the CKM ∠
③ δ is the strong phase shift
④ $x_s \to 20$ (to 40)

$B^o \to \rho\pi$ for Measuring α

$B^o \to \rho^+\pi^-$





Physics Reach (CKM) in 10^7 s

Reaction	$\mathcal{B}$ (B)(x10^{-6})	# of Events	S/B	Parameter	Error or (Value)
$B^o \to \pi^+\pi^-$	4.3	24,000	3	Asymmetry	0.024
$B_s \to D_s K^-$	300	13,100	7	γ	7°
$B^o \to J/\psi K_S$, $J/\psi \to \mu^+\mu^-$	445	80,500	10	$\sin(2\beta)$	0.025
$B_s \to D_s \pi^-$	3000	103,000	3	x_s	(75)
$B^- \to D^o (K^+\pi^-) K^-$	0.17	300	1		
$B^- \to D^o (K^+K^-) K^-$	1.1	1,800	>10	γ	10°
$B^- \to K_S \pi^-$	12.1	8,000	1		
$B^o \to K^+\pi^-$	18.8	108,000	20	γ	<5°
$B^o \to \rho^+\pi^-$	28	9,400	4.1		
$B^o \to \rho^o\pi^o$	5	1,350	0.3	α	~10°
$B_s \to J/\psi \eta$,	330	1,920	15		
$B_s \to J/\psi \eta'$ $J/\psi \to \mu^+\mu^-$	670	7,280	30	χ	0.033