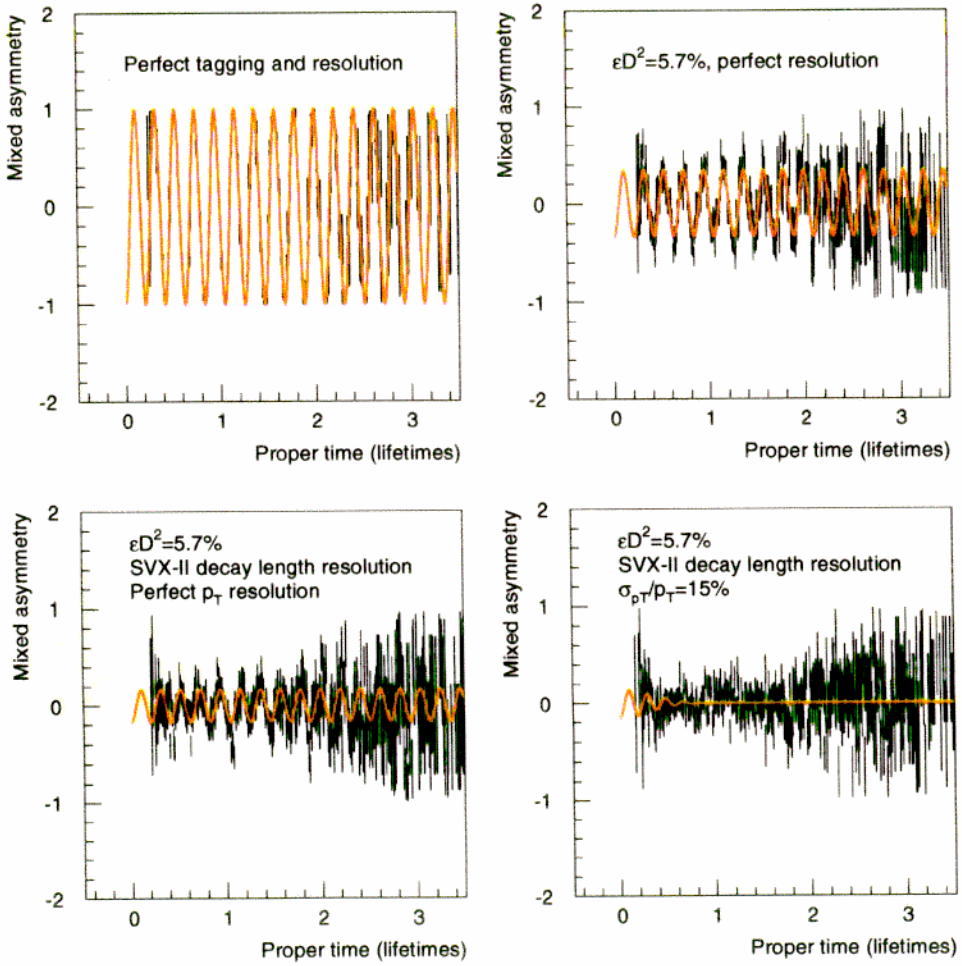
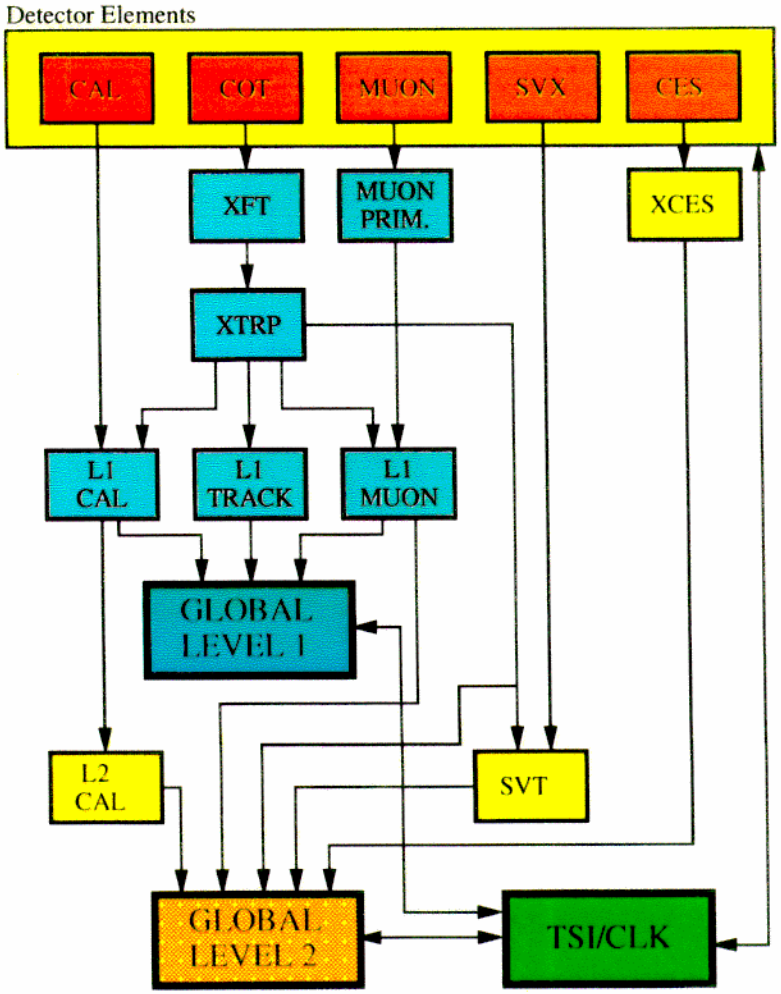
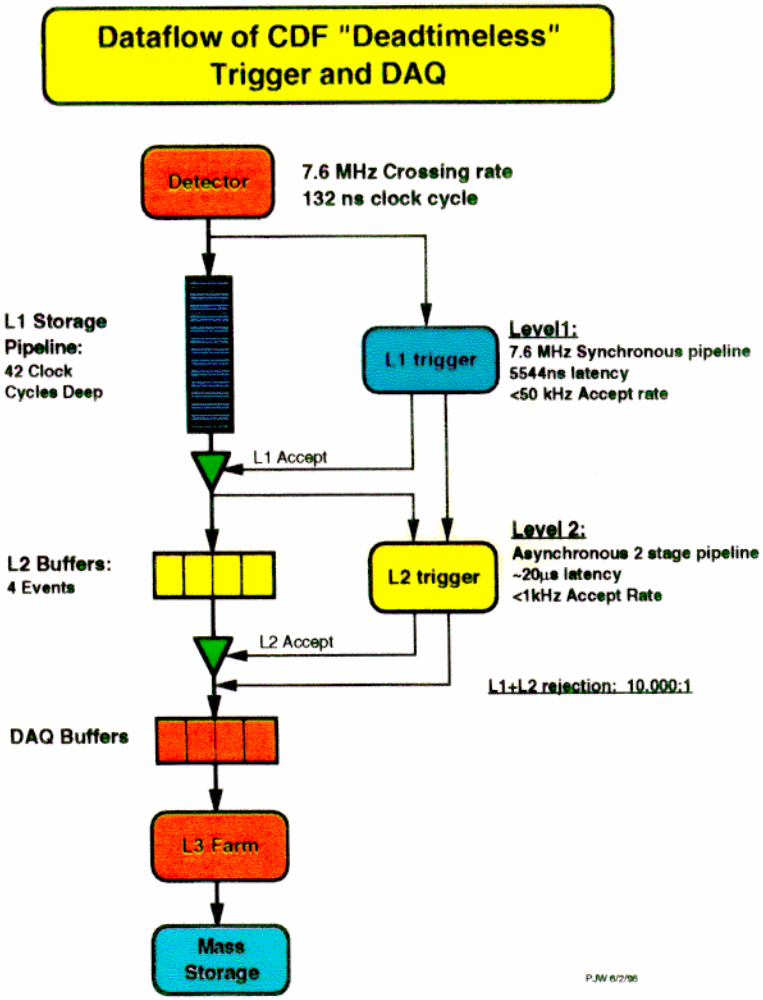
Illustration of $B_s^0 - \bar{B}_s^0$ Oscillations (Example: $x_s = \Delta m_s \tau_{B_s} = 30$)



Conclusion: to go beyond current limit need *fully* reconstructed B_s^0

RUN II TRIGGER SYSTEM





PJW 9/23/96

Trigger Elements for CDF II

Level 1

- EM calorimeter cluster
- Track stub in μ chamber
- Tracks (XFT) for $p_T > 1.5$ GeV/c
  - $\delta p_T / p_T^2 = 0.015$ (GeV/c)$^{-1}$
  - $\delta \phi_6 = 0.0015$ rad

Level 2

- Partial event reconstruction with Alpha Processors
- Silicon information available (SVT)
  to trigger on impact parameter and/or displaced vertex

Hadronic B Trigger Rates

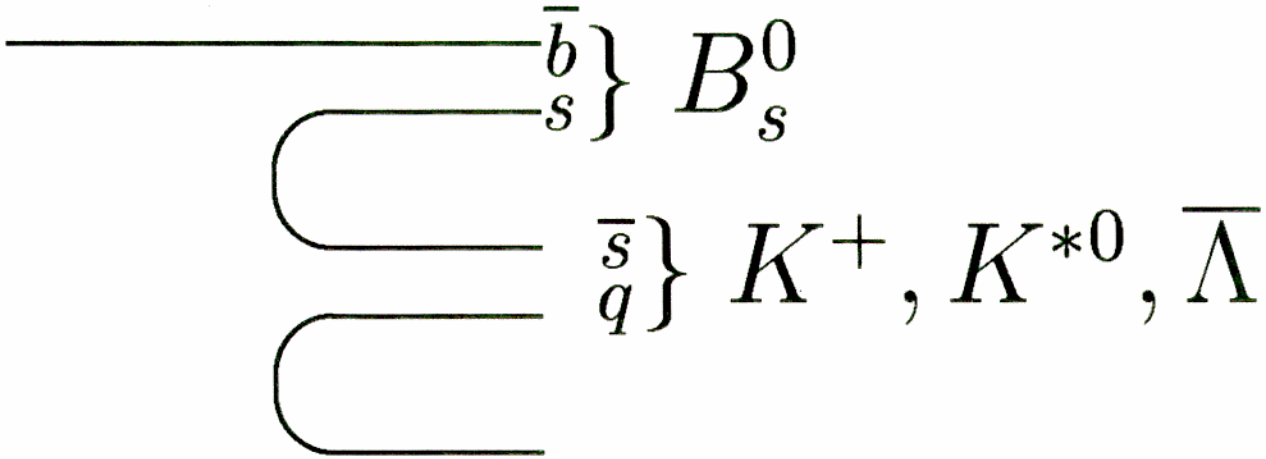
Scenario	T_{bunch} [ns]	$\mathcal{L}$ [$\text{cm}^{-2}\text{s}^{-1}$]	$\langle N_{p\bar{p}} \rangle$	L1 cross section [μb]	L1 rate [kHz]	L2 cross section [nb]	L2 rate [Hz]
A	396	0.7×10^{32}	2	252 ± 18	18	360 ± 100	25
B	132	2.0×10^{32}	2	152 ± 14	30	196 ± 74	39
C	396	1.7×10^{32}	5	163 ± 16	28	84 ± 48	14

Level 1 and Level 2 trigger cross sections and event rates for three operating scenarios of the Tevatron during Run II.

Scenario	B_s selection	include $\pi\pi$	L2 rate [Hz]	$D_s\pi^+$	$D_s\pi^+\pi^-\pi^+$
A	(394 ± 105) nb	(560 ± 125) nb	39	10,600	12,800
B	(280 ± 89) nb	(336 ± 97) nb	67	8400	10,400
C	(196 ± 74) nb	(224 ± 79) nb	38	7200	8100

Level 2 trigger cross sections for the collection of hadronic B_s decays and corresponding event rates including $\pi\pi$ data. as well as the B_s sample sizes expected in 2 fb^{-1} for the two B_s decay modes.

Principle of Same-Side Kaon Tagging for B_s

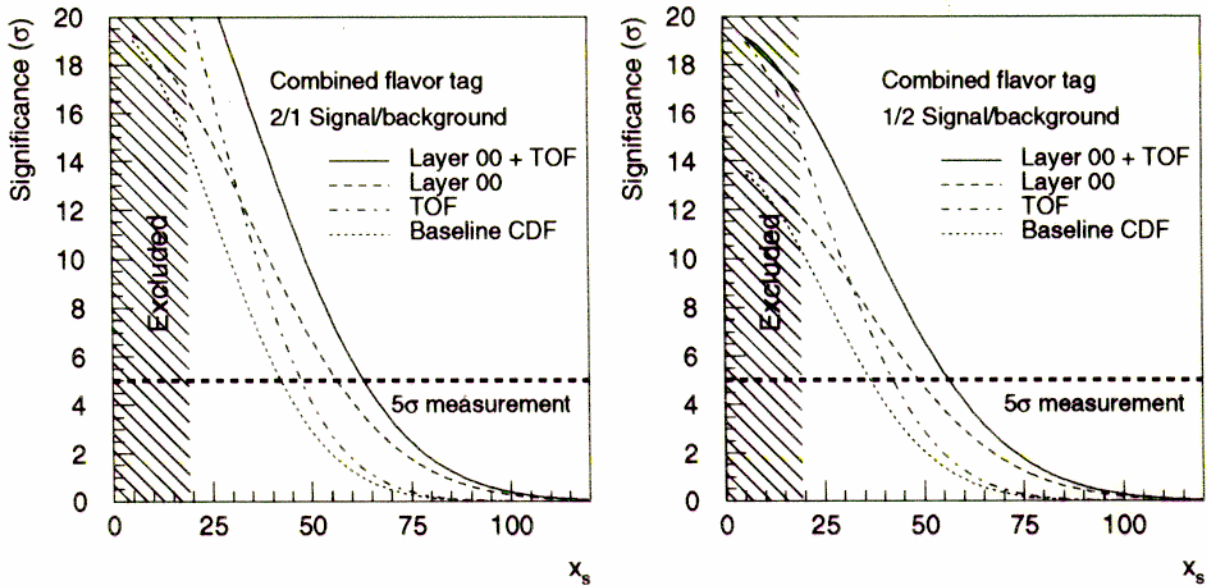


Expected Flavor Tagging in Run II B_s^0

$B_s^0 \to D_s^- \pi^+$		
	without TOF	**with TOF**
Same-Side (Kaon) Tag	1.0	4.2
Soft Lepton Tag (μ)	1.0	1.0
Soft Lepton Tag (e)	0.7	0.7
Jet Charge	3.0	3.0
Opposite-Side Kaon Tag	—	2.4
Total	5.7%	11.3%

$B_s^0/\bar{B}_s^0 \to J/\psi\ \phi$		
	without TOF	**with TOF**
Same-Side (Kaon) Tag	0.2	2.6
Soft Lepton Tag (μ)	1.0	1.0
Soft Lepton Tag (e)	0.7	0.7
Jet Charge	3.0	3.0
Opposite-Side Kaon Tag	—	2.4
Total	4.9%	9.7%

CDF II Reach for x_s



Effects of background levels on the Run II reach for x_s for the CDF II baseline upgrade and with the addition of L00 and TOF upgrades.

$N(B_S^0) = 20,000$ **events are assumed with signal-to-background ratios of 2:1 (left) and 1:2 (right).**

Decay length measurement uncertainty improves from 60 fs to 45 fs with inclusion of L00.

CDF II Reach for x_s

	S/B=2:1		S/B=1:2		$x_s = 30$		$x_s = 40$	
$N(B_s)$	Baseline	BTB	Baseline	BTB	Baseline	BTB	Baseline	BTB
5,000	30	49	21	39	2.20	0.24	—	0.53
10,000	37	56	30	49	0.52	0.11	—	0.21
20,000	42	63	37	56	0.21	0.05	0.99	0.10
30,000	45	67	40	60	0.13	0.03	0.50	0.06

Left: Maximum values of x_s for which an observation of B_s mixing could be made with at least 5σ significance. Values for signal-to-background ratios of 2:1 and 1:2 are shown.

Right: Minimum values of the signal-to-background ratio for which an observation of x_s mixing could be made with at least 5σ significance, for $x_s = 30$ and $x_s = 40$. The dashes indicate scenarios for which a 5σ observation could not be made even in the absence of any background.

BTB refers to the addition of the beyond-the-baseline detectors ToF plus L00.

Standard Model expectation: $18 < x_s < 27$ with (a 95% CL) limit of $x_s < 31$.
Current experimental limit: $x_s > 19$.

Polarization in $B \to V\,V$

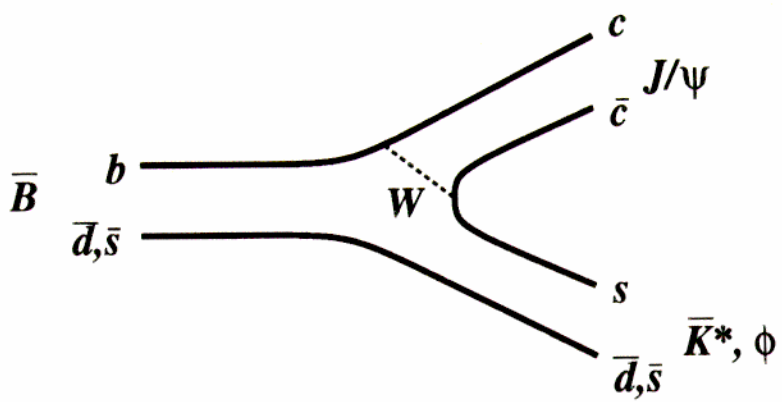
$B_d \to J/\psi\, K^*$
$\hookrightarrow K^+\pi^-$
$\hookrightarrow \mu^+\mu^-$

$B_s \to J/\psi\, \phi$
$\hookrightarrow K^+K^-$
$\hookrightarrow \mu^+\mu^-$

Motivations:

- **Probe the limits of the factorization ansatz used in extracting weak physics parameters from hadronic B decays.**
- **Relative importance of CP even and odd contributions to $B \to J/\psi\, K^*$; $K^* \to K_S\,\pi^0$ — useful information for B factories.**
- **Knowledge of relative importance of CP even and odd contributions to $B_s \to J/\psi\,\phi$ decays is important for searches for CP noninvariance in these decays — expected to be very small in Standard Model.**
- **Polarization analysis is an important step working towards a measurement of a lifetime difference for the heavy and light B_s^0 mesons using $B_s \to J/\psi\,\phi$.**

Relevant Phenomenolgy



Decays are
Pseudoscalar to Vector Vector

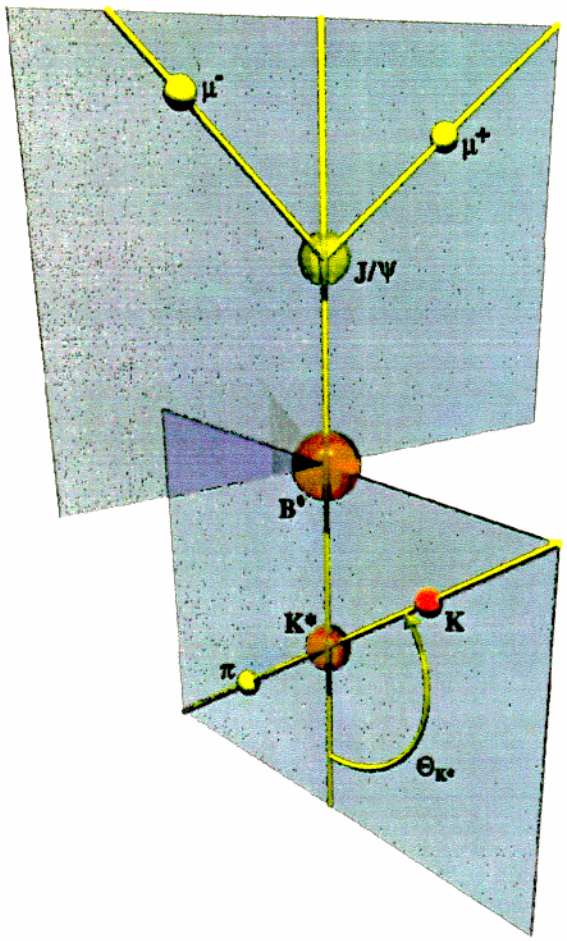
Can label states multiple ways:
Helicity: H_0, H_+, H_-
Partial Waves: S, P, D
Transversity: A_0, $A_\parallel$, $A_\perp$

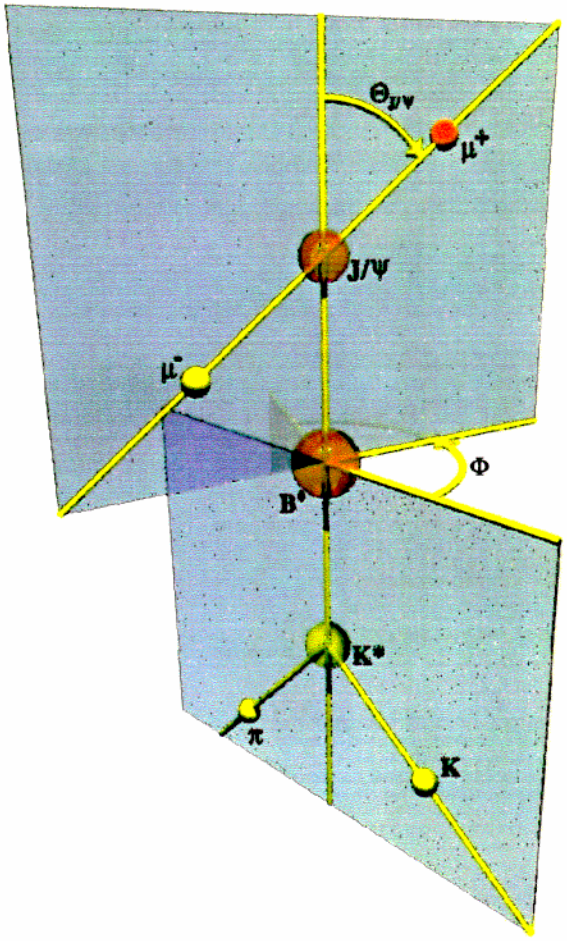
Phase space of decay has three dimensions:
Decay angles:
Helicity basis: Θ_{K^*}, $\Theta_{J/\psi}$, ϕ, or
Transversity basis: Θ_{K^*}, Θ_T, Φ_T

Analysis Method:

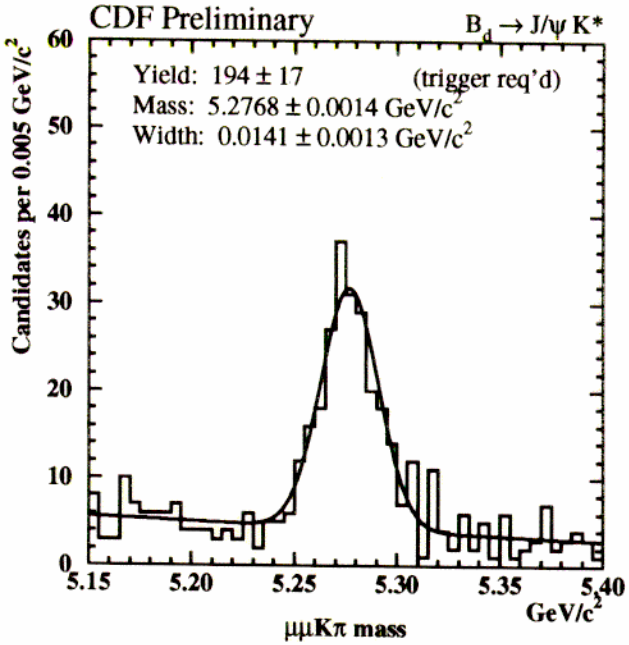
- Perform analysis in transversity basis to extract the parity even and odd amplitudes.

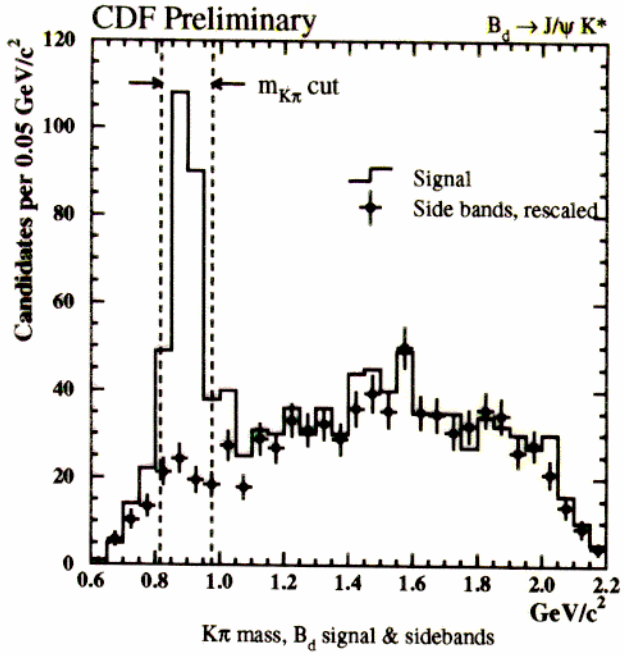
Definition of Helicity Angles Θ_{K^*} and $\Theta_{J/\psi}$





$B^0 \to J/\psi\ K^{*0}$

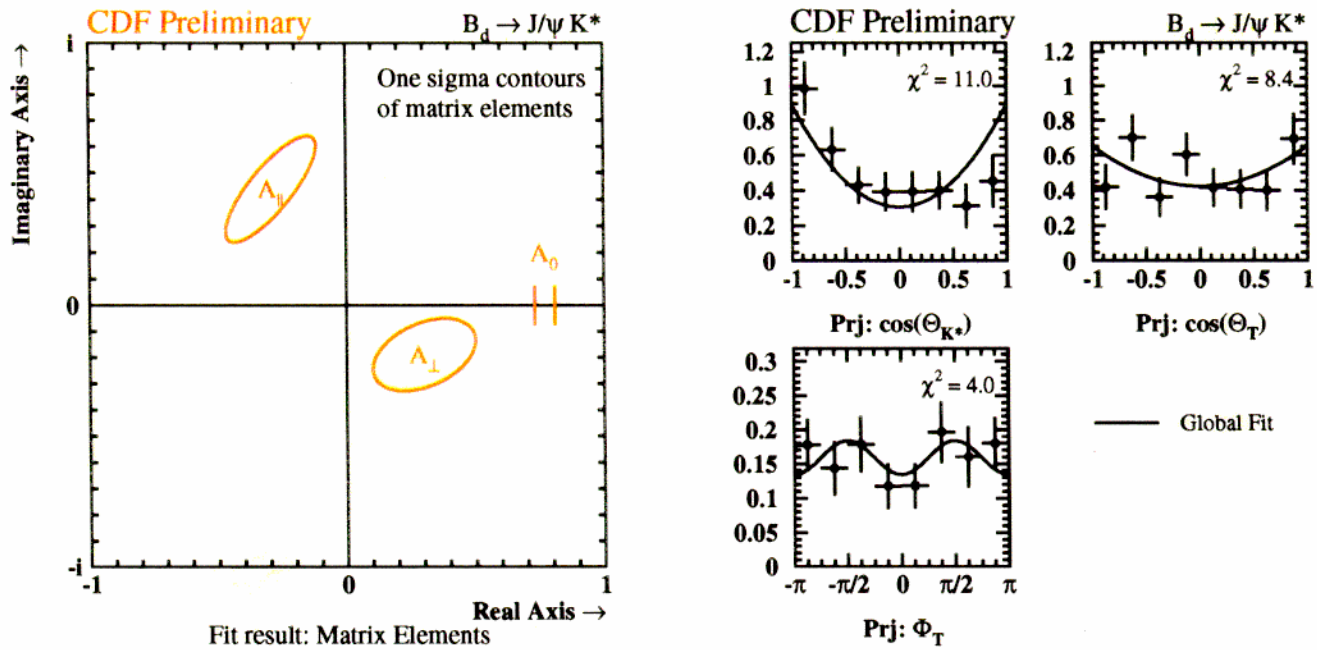




Selection criteria:

1. **Four track vertex; 2 of 4 in SVX.**
2. **J/ψ muons must satisfy trigger.**
3. $p_T(B) > 6\ \mathrm{GeV}/c$; $c\tau \geq 100\ \mu\mathrm{m}$.
4. **Require isolation.**
5. **Require** $|m_{K\pi} - m_{K^*}^{PDG}| < 80\ \mathrm{MeV}/c^2$; $p_T(K\pi) > 2\ \mathrm{GeV}/c$.
6. **Choose K and π mass assignment which gives best K^* mass.**

Polarization Result for $B_d \to J/\psi\ K^{*0}$



Left: **Fit results for decay $B_d \to J/\psi\ K^{*0}$.**
Arbitrary overall phase; $\to$ require $A_0 \in \Re, > 0$.
Statistical error only.

Right: **Background subtracted data projected onto decay angles; points corrected for acceptance/efficiency. Curves from global fit.**

Polarization Results

CDF Run IB result for $B_d \to J/\psi\ K^*$ (90 pb^{-1}):

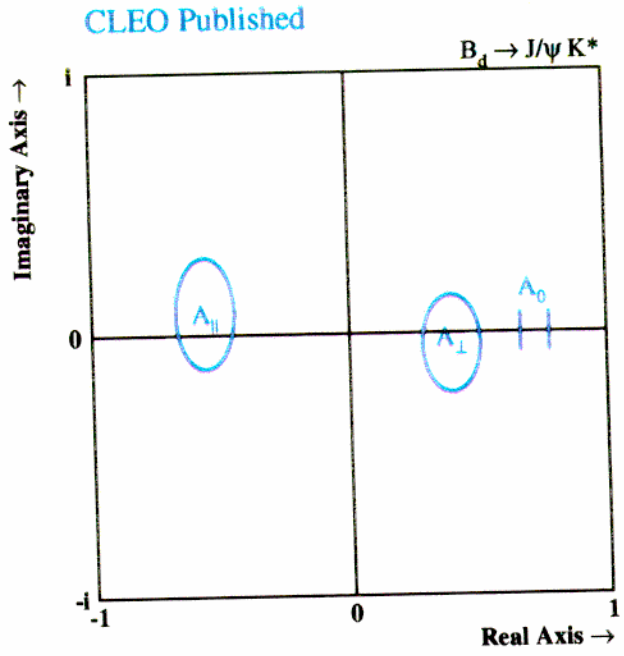
$$\begin{aligned} A_0 &= 0.770 \pm 0.039 \pm 0.012 \\ A_{\|} &= (0.530 \pm 0.106 \pm 0.034)e^{(2.16\pm0.46\pm0.10)i} \\ A_{\perp} &= (0.355 \pm 0.156 \pm 0.039)e^{(-0.56\pm0.53\pm0.12)i} \end{aligned}$$

and

$$\begin{aligned} \frac{\Gamma_L}{\Gamma} = |A_0|^2 &= 0.593^{+0.059}_{-0.061} \pm 0.018 \\ \frac{\Gamma_\perp}{\Gamma} = |A_\perp|^2 &= 0.126^{+0.121}_{-0.093} \pm 0.028 \end{aligned}$$

Comparison with CLEO:

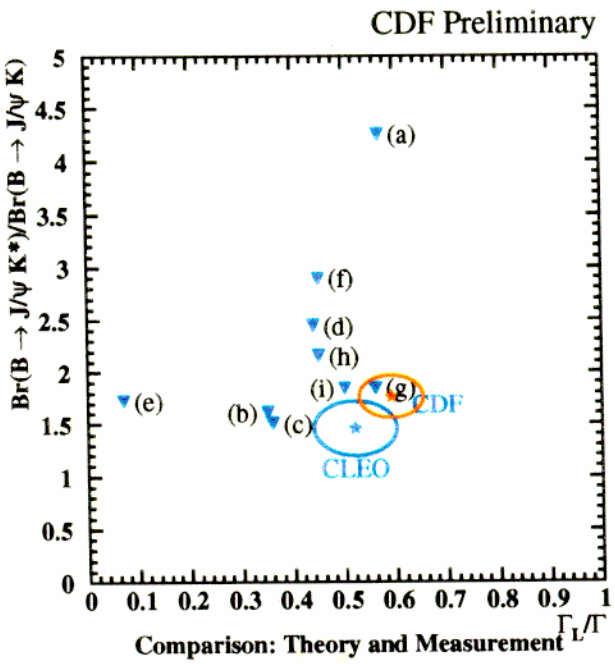
$$\begin{aligned} \phi(A_{\|}) &= 3.00 \pm 0.37 \pm 0.04 \\ \phi(A_{\perp}) &= -0.11 \pm 0.46 \pm 0.03 \\ \frac{\Gamma_L}{\Gamma} = |A_0|^2 &= 0.52 \pm 0.07 \pm 0.04 \\ \frac{\Gamma_\perp}{\Gamma} = |A_\perp|^2 &= 0.16 \pm 0.08 \pm 0.04 \end{aligned}$$



CLEO Result for $B_d \to J/\psi\ K^*$

Plot assumes no correlations in error matrix.

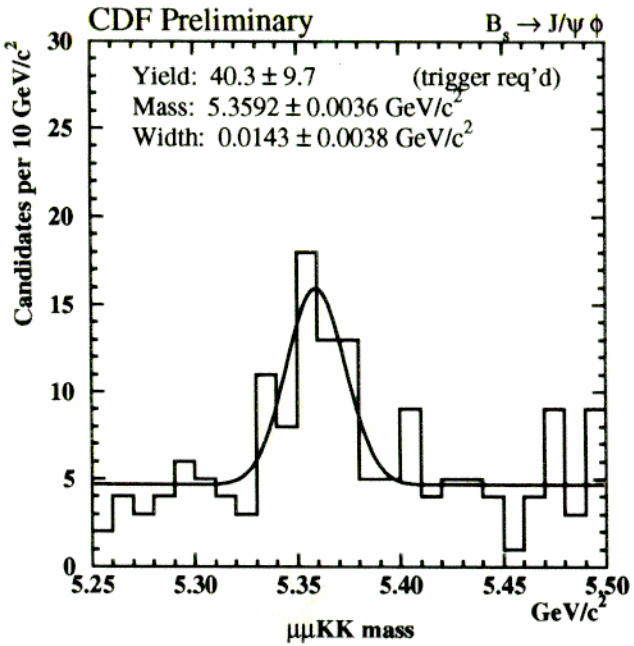
$B \to VV$ Polarization: Theory and Latest Experimental Results

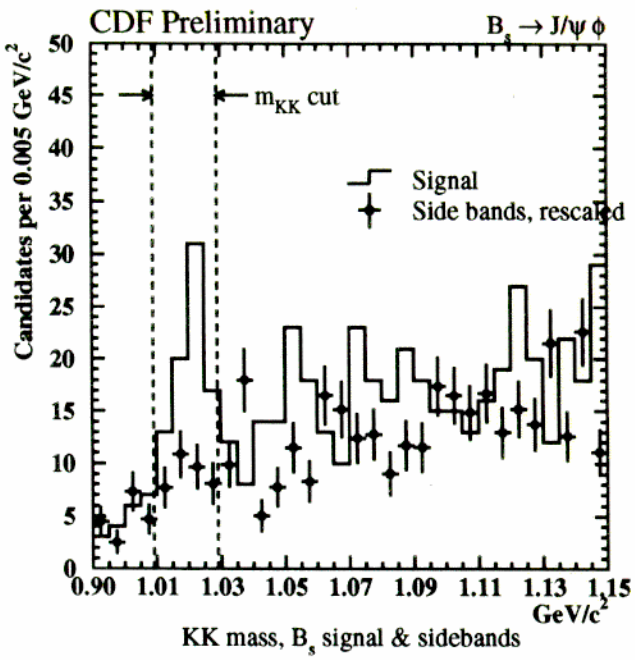


Gourdin, Kamal, Pham
PRL 73, 19 Dec, 1994, p. 3355:
(a) "BSW I", (b)"BSW II",
(c) "CDDFGN", (d) "JW"
Cheng
Phys. Lett. B, 1997, p. 345
(e) "ISGW", (f) "IW(i)",
(g) "IW(ii)", (h) "IW(iii)",
(i) "LF"

Comparison of predictions and measurements for the ratio of branching fractions for B decays to VP ($J/\psi K^{\pm}$) and VV ($J/\psi K^{*}$) states vs. the longitudinal polarization in VV decays.

$B_s \to J/\psi\ \phi$

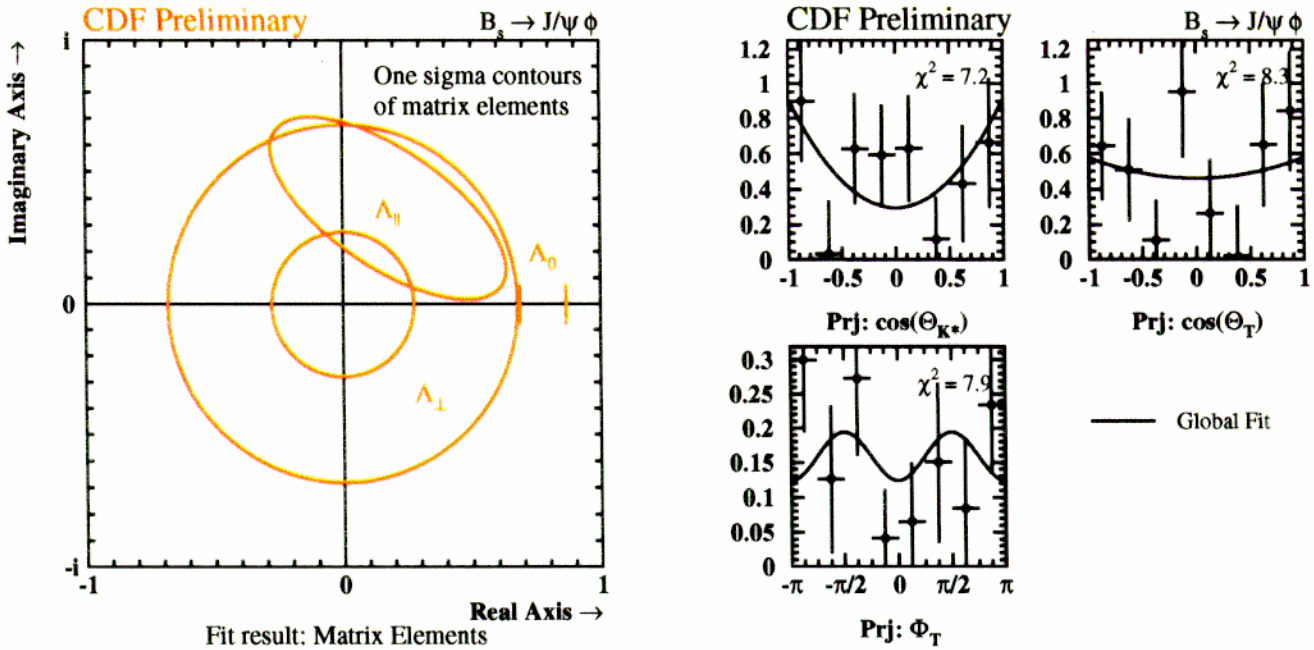




Selection criteria:

1. **Four track vertex; 2 of 4 in SVX.**
2. **J/ψ muons must satisfy trigger.**
3. $p_T(B) > 4.5\,\mathrm{GeV}/c$; $c\tau \geq 50\ \mu\mathrm{m}$.
4. **Require isolation.**
5. **Require** $|m_{KK} - m_\phi^{PDG}| < 10\,\mathrm{MeV}/c^2$; $p_T(KK) > 1.5\,\mathrm{GeV}/c$.

Polarization Result for $B_s \to J/\psi\ \phi$



Left: **Fit results for decay $B_s \to J/\psi\ \phi$.**
Arbitrary overall phase; $\to$ require $A_0 \in \Re, > 0$. No Phase information for $A_\perp$.
Statistical error only.

Right: **Background subtracted data projected onto decay angles;**
points corrected for acceptance/efficiency. Curves from global fit.

Polarization Results, Cont'd

CDF Run 1B result for $B_s \to J/\psi\ \phi$ (90 pb^{-1}):

$$
\begin{aligned}
A_0 &= 0.778 \pm 0.090 \pm 0.012 \\
A_{\parallel} &= (0.407 \pm 0.232 \pm 0.034)e^{(1.12 \pm 1.29 \pm 0.11)i} \\
|A_{\perp}| &= 0.478 \pm 0.202 \pm 0.040
\end{aligned}
$$

and

$$
\begin{aligned}
\frac{\Gamma_L}{\Gamma} = |A_0|^2 &= 0.606 \pm 0.139 \pm 0.018 \\
\frac{\Gamma_{\perp}}{\Gamma} = |A_{\perp}|^2 &= 0.229 \pm 0.188 \pm 0.038
\end{aligned}
$$

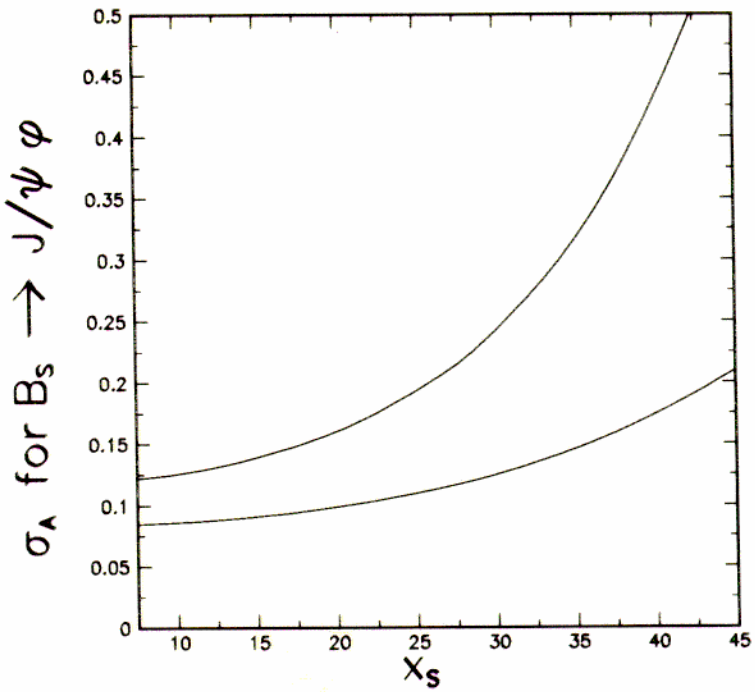
Polarization in $B \to V\,V$ decays

Measurement of full matrix elements for both $B^0 \to J/\psi\ K^*$ and $B_s \to J/\psi\ \phi$ decays in hand.

Final state interactions could still be significant ; naive Factorization appears to be insufficient.

Parity odd component of $B \to V\,V$ decay amplitudes is small; could be consistent with zero.

Search for CP Violation in $B_s \to J/\psi\ \phi$ Decays



- **Assumes 6000 $B_s^0/\bar{B}_s^0 \to J/\psi\ \phi$ events**
- **Lower curve with L00 and TOF; upper curve without (CDF II baseline)**

Projected uncertainty on the CP asymmetry in $B_s \to J/\psi\ \phi$ decays vs. $x_s = \Delta m_s \tau_{B_s}$

Small asymmetry expected in the Standard Model $\propto \lambda^2 \eta$

Significant asymmetry is unambiguous sign of new physics

The B_S^0 meson exists in two CP-conjugate states:

$|B_S^0\rangle = |\bar{b}s\rangle$ **and** $|\bar{B}_S^0\rangle = |b\bar{s}\rangle$

and there are two mass eigenstates (H = 'heavy' and L = 'light'):

$$|B_S^H\rangle = 1/\sqrt{2}\,(\,|B_S^0\rangle - |\bar{B}_S^0\rangle\,) \quad \text{and} \quad |B_S^L\rangle = 1/\sqrt{2}\,(\,|B_S^0\rangle + |\bar{B}_S^0\rangle\,).$$

with mass and lifetime differences:

$$\Delta m \equiv m_H - m_L, \quad \Delta\Gamma \equiv \Gamma_L - \Gamma_H, \quad \text{and} \quad \Gamma = 1/2\,(\Gamma_H + \Gamma_L),$$

Δm **and** $\Delta\Gamma$ **are taken to be positive.**

The B_S^H **state is long-lived and** CP **odd and**

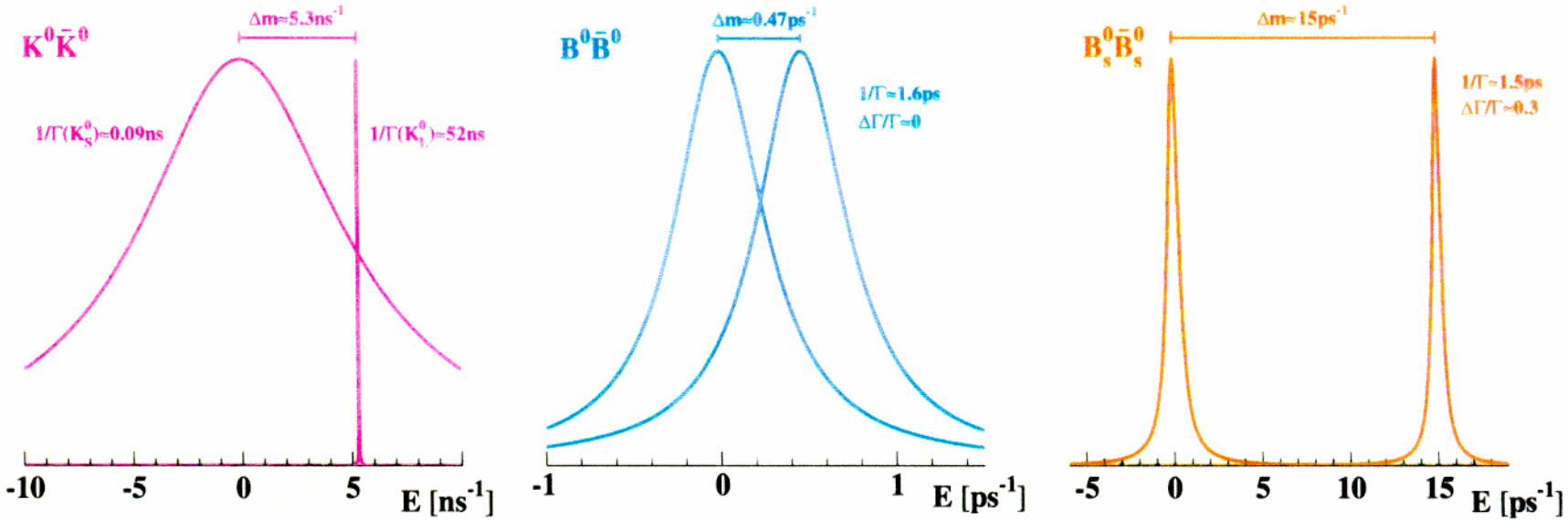
the B_S^L **state is short-lived and** CP **even.**

Unlike the B^0 meson, the width difference in the B_S^0 system is expected to be large: $\Delta\Gamma/\Gamma$ to be on the order of 10-20%.

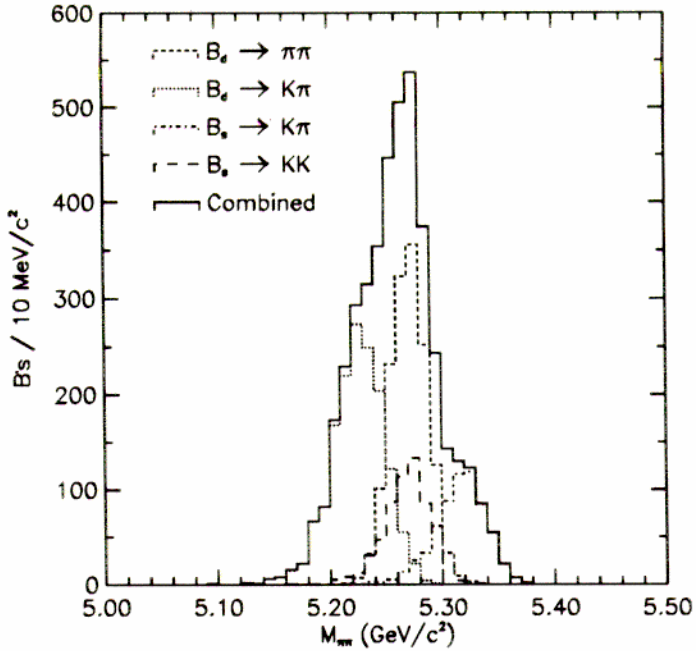
Using semileptonic B_s decays, CDF has looked for a lifetime difference and found:

$\Delta\Gamma/\Gamma = 0.34\ ^{+0.31}_{-0.34}$ **or a 95% limit of** $\Delta\Gamma/\Gamma < 0.83$.

In Run II the combined use of the semileptonic decays as well as $B_s \to J/\psi\ \phi$, augmented by knowledge of the polarization states, will allow a determination of $\Delta\Gamma$.


$K^0\bar{K}^0$
$\Delta m \approx 5.3 ns^{-1}$
$1/\Gamma(K^0_S) \approx 0.09 ns$
$1/\Gamma(K^0_L) \approx 52 ns$
-10
-5
0
5
E [ns^{-1}]
$B^0\bar{B}^0$
$\Delta m \approx 0.47 ps^{-1}$
$1/\Gamma \approx 1.6 ps$
$\Delta\Gamma/\Gamma \approx 0$
-1
0
1
E [ps^{-1}]
$B^0_s\bar{B}^0_s$
$\Delta m \approx 15 ps^{-1}$
$1/\Gamma \approx 1.5 ps$
$\Delta\Gamma/\Gamma \approx 0.3$
-5
0
5
10
15
E [ps^{-1}]

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



- **Mass distributions for**
  - $B^0 \to \pi^+\pi^-$
  - $B^0 \to K\pi$
  - $B_s \to K\pi,\ KK$
- **Equal BRs assumed**
- $\sigma(B_d) \sim 3\sigma(B_s)$
- **All charged kaons assumed to be pions**
- **~20 MeV/c² mass resolution assumed**
- **Vertical scale is arbitrary**

If $B \to \pi^+\pi^-$ branching fraction is 10^{-5}, 10,000 events (untagged) can be collected by CDF in 2 fb^{-1}.

Events must pass the SVT trigger; look at proper lifetime distribution starting at ≈ 1.5 lifetimes.

Flavor-tagging efficiency of 7.8% and $S/N = 1/4$ leads to uncertainty on $\sin(2\alpha)$ of 0.10 (modulo penguins)

what about γ

also desirable but not easy:

$B_s^0 \to D_s^- K^+$

expect ~ 700 events using 'two track' trigger
(smaller BR)

physics bckgnd 1:1 dE/dx + TOF
$(D_s^{(*)-} \pi^+)$

Combinatorics also helped by dE/dx + TOF
1:5

$\Rightarrow$ 1:6 S/B

Toy Monte Carlo estimates on extracting
$\sin(\gamma + \delta_{strong})$ vs. $\sin(\gamma - \delta_{strong})$

and uncertainty on $\sin(\gamma + \delta_{strong})$
~ 0.43

$B^{\pm} \to D K^{\pm}$ follow Atwood, Dunietz & Soni

200 - 300 events ($D \to K\pi$, $K 3\pi$)

Toy Monte Carlo:

resolution of $\sim 20^\circ$ on γ
if $60^\circ < \gamma < 100^\circ$

physics bckgnd 1:20 ($B^- \to D^0 \pi^-$)
dE/dx + TOF

combinatorics still to be studied

For several reasons we have focused so far on B physics at a particular hadron collider (Tevatron) and on CP/mixing studies using central (rapidity production).

Clearly this is not the full story, at least in principle.

1st: LHC pp @ $\sqrt{s} = 14$ TeV

$\sigma_{b\bar{b}} \cong 500\,\mu b$ $\quad (\mathcal{L} = 10^{32} \rightarrow 10^{34}\ cm^{-2} sec^{-1})$

vs. Tevatron $\bar{p}p$ @ $\sqrt{s} = 2$ TeV

$\sigma_{b\bar{b}} \simeq 110\,\mu b$ $\quad (\mathcal{L} = 5 \cdot 10^{31} \rightarrow 5 \cdot 10^{32}\ cm^{-2} sec^{-1})$

2nd: looking forward

polar angle Θ

$\cos\Theta = p_z / p$

$\eta = -\ln\left[\tan\left(\frac{\Theta}{2}\right)\right]$

Θ			
$\sim 40°$	~ 700 mr	$\eta \sim 1$	
$\sim 16°$	~ 275 mr	$\eta \sim 2$	BTeV, LHCb
$\sim 6°$	~ 100 mr	$\eta \sim 3$	BTeV, LHCb
$\sim 2°$	~ 35 mr	$\eta \sim 4$	BTeV, LHCb

HERA-B (see poster sessions)

@ DESY ep collider

HERA-B IS A FIXED TARGET EXPERIMENT

- THIN (50 x 500 μm) WIRES IN PROTON BEAM HALO
- 920 GeV/c p beam

$\sigma(pN \to bbX) \simeq 15$ nb / nucleon

$\sigma_{bb} / \sigma_{inel} \sim 10^{-6}$

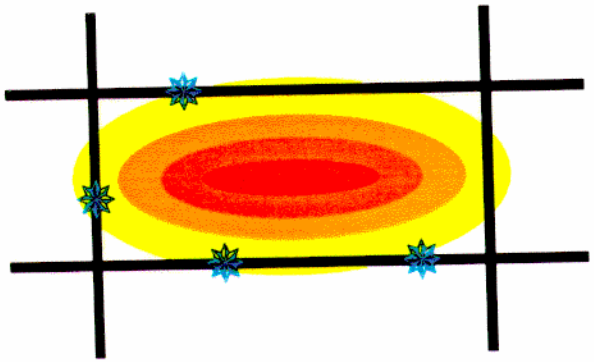
$\Rightarrow$ 40 MHz interaction rate

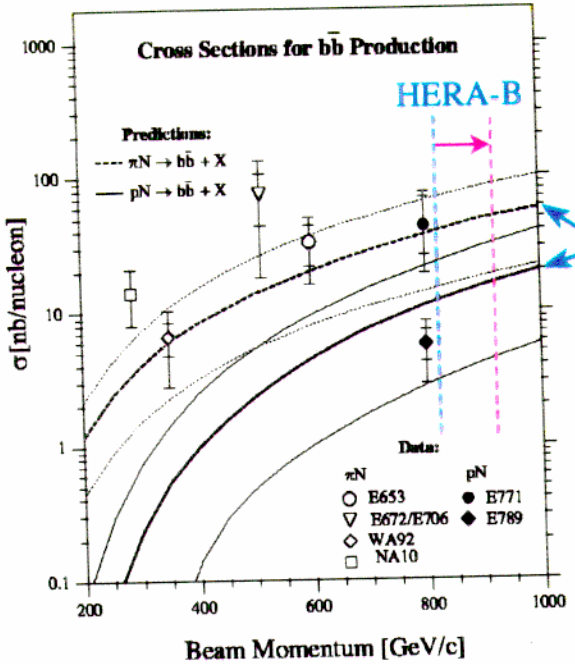
~ 4 interactions / crossing

Challenges to overcome in all aspects of triggering, tracking and reconstruction

Many of the technologies and methods under test are relevant to LHCb and BTeV

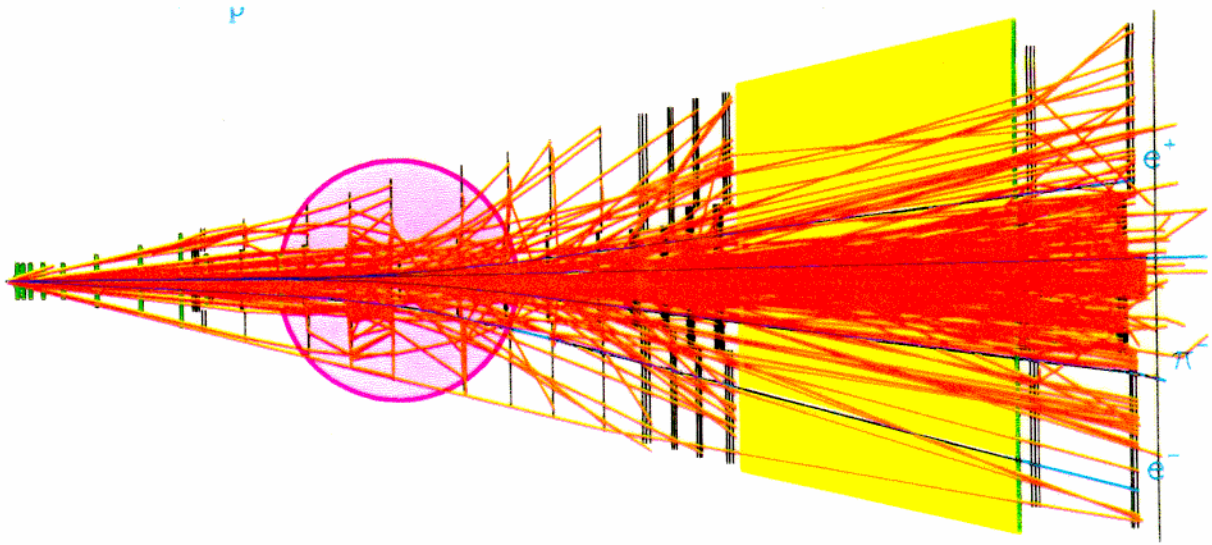
Wire Target and Cross Section at HERA-B





Nason, Dawson & Ellis, 1988-90

A Typical Event Expected at HERA-B



HERA-B

Detector has ~ 550 k channels

including:

136 k Si Strip

175 k GEM-MSCG *
(inner tracker)

32 k RICH ** (C_4F_{10} radiator)
multi cell PMT
Particle ID

'97, '98 engineering runs
'99 comissioning full detector
'00 physics

* in production, due for installation 12/99
** Commissioned: see recent CERN Courier

HERA-B expected $B^0 \to J/\psi K_S$ reach

- 10^7 sec operation ('nominal' year)
- 40 MHz interaction rate
- $\sigma_{b\bar{b}} \sim 12 \to 17$ nb

$\Rightarrow$ 1400 $\to$ 2000 $B^0 \to J/\psi K_S$

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

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

- tagging power $\sim 30\%$

$\Rightarrow$ $\sigma(\sin 2\beta) = 0.13 \to 0.11$

BTeV

Beyond Run II ($2\,fb^{-1}$) @ FNAL Tevatron

$C\phi$ int area ($D\phi$ @ $D\phi$, CDF @ $B\phi$)

2 arm (forward/backward) spectrometer

$(\pm 300\ mr)^2 * 2$ acceptance

tracking, particle ID : $1 < p < 100$ GeV/c

goal to run @ $\mathcal{L} = 2 \cdot 10^{32}\ cm^{-2} sec^{-1}$
132 nsec (crossings)

Particle ID robust

Key feature:

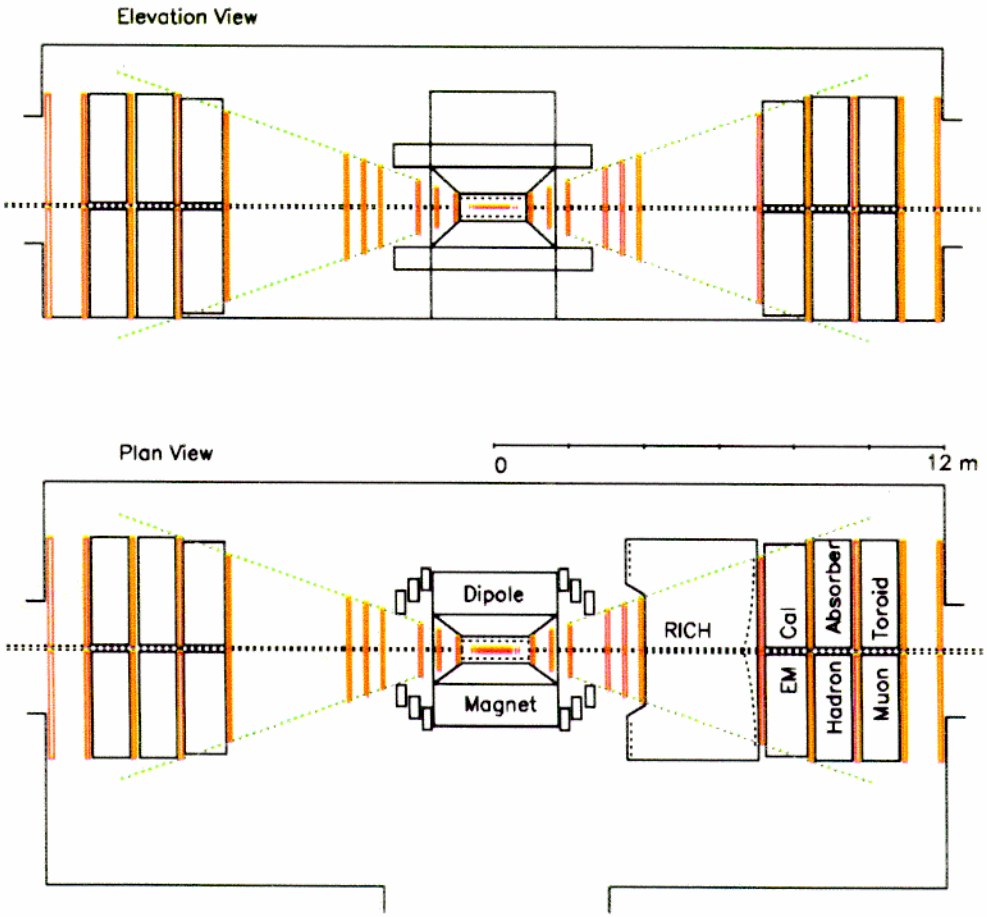
~30 10 cm x 10 cm triplet planes of PIXEL detectors (50 μm x 400 μm)

beam crossing drives highly parallel readout (clock speed > 25 MHz)

$r_{min} = 6\ mm$

Level 1 vertex trigger

The BTeV Detector



LHCb

- Day 1 LHC experiment (DELPHI HALL)
- reduced $\mathcal{L}$ IR ($1-2 \cdot 10^{32}\,cm^{-2}sec^{-1}$)
- single arm spectrometer

  $(\pm 330\ mr)^2$ acceptance

  robust particle ID

  ~20 layers of double layer Si-strip

  $r_{min} = 1\ cm$

FULL MENU OF B PHYSICS

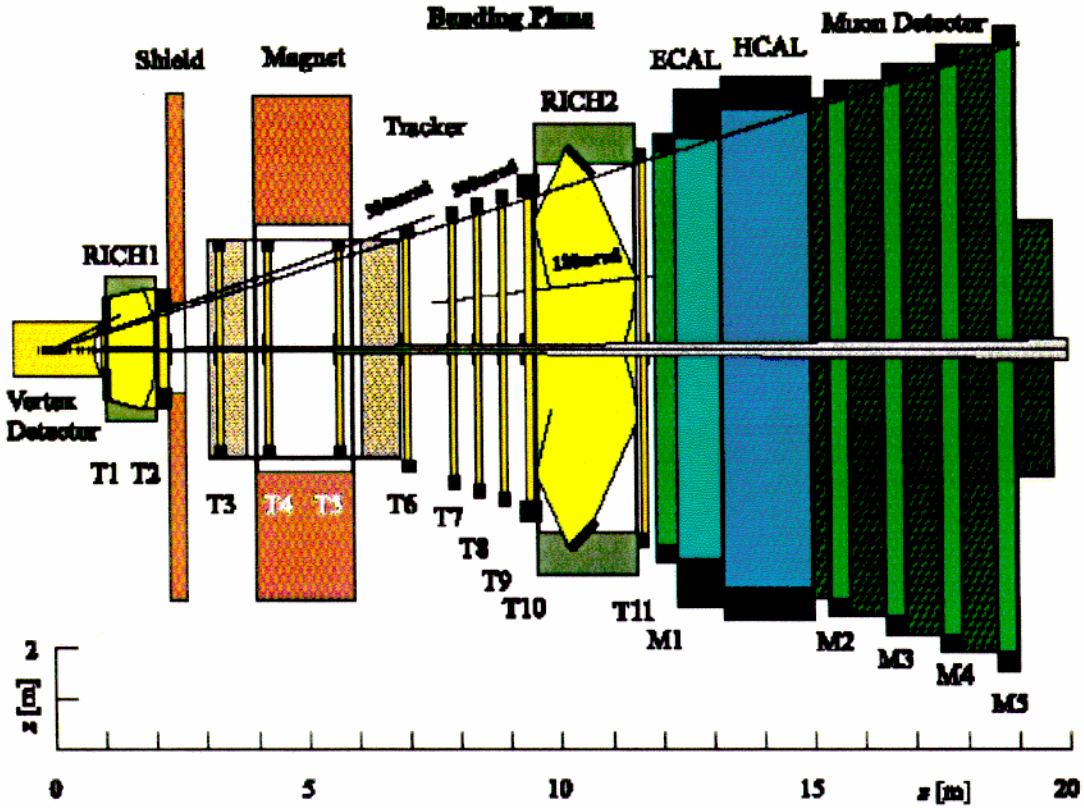
$\alpha, \beta, \gamma, \beta_s$

Δm_s, $\Delta\Gamma$, etc.

envisioned for BOTH

LHCb & BTeV

The LHCb Detector



Facility	$\mathcal{L}$	$\sigma(B\bar{B})$	$\int \mathcal{L}dt$	$B\bar{B}$ pairs
Present facilities: (Stage I)				
CESR II e^+e^- $\Upsilon(4S)$	5×10^{32}	1.15 nb	9.5	5×10^6
LEP e^+e^- Z^0	1.6×10^{31}	6.7 nb	0.16	0.9×10^6
FNAL Run I ($p\bar{p}$)	2×10^{31}	100 μb	0.1	1×10^{10}
Next round facilities: (Stage II)				
PEPII e^+e^- $\Upsilon(4S)$	3×10^{33}	1.15 nb	30	3×10^7
also KEK				
PEPII e^+e^- $\Upsilon(5S)$	3×10^{33}	0.1 nb[a]	30	3×10^6
CLEO III e^+e^- $\Upsilon(4S)$	1.7×10^{33}	1.15 nb	17	2×10^7
CLEO III e^+e^- $\Upsilon(5S)$	1.7×10^{33}	0.1 nb[a]	17	2×10^6
FNAL Run II [b]($p\bar{p}$)	1×10^{32}	100 μb	1.0	1×10^{11}
HERA-B	40 MHz [c]	~10 nb	–	3×10^8
Facilities after 2003: (Stage III)				
BTeV FNAL ($p\bar{p}$)	2.0×10^{32}	100 μb	2.0	2×10^{11}
Upgraded PEPII e^+e^-	3×10^{34}	1.15 nb	300	3×10^8
CESR Phase IV e^+e^-	3×10^{34}	1.15 nb	300	3×10^8
LHC [d] pp ($\geq$2005)	1.5×10^{32}	500 μb	1.5	8×10^{11}

[a]Estimated $B_s\bar{B}_s$ based on arguments like those outlined in the text.
[b] Main Injector Design. Upgrades have been proposed.
[c] Interaction rate per second on 50 μm diameter C, Cu, or Al target.
[d] LHC-B reference design.

Table 6: Luminosity goals, cross sections, and rates of produced B's. The luminosity $\mathcal{L}$ is given in $cm^{-2}s^{-1}$. The integrated luminosity, $\int \mathcal{L}dt$, is given in fb^{-1}. For Stage I, the value given is for the cumulative data analyzed thus far. The numbers for LEP are representative of a single experiment. For Stages II and III, it is the projected amount for one year's (10^7s) running. The number of $B\bar{B}$ pairs is for a year's running.

$\sin 2\beta$			
	Precision	Technique	Comments
BaBar	± 0.059 @ 30 fb^{-1} ± 0.019 @ 300 fb^{-1}	$J/\psi K_S$, D^+D^-, etc.	Estimates from TDR [44]
CLEO			
CDF	± 0.08 @ 2 fb^{-1} ± 0.07 @ 2 fb^{-1}	$J/\psi K_S$ $J/\psi K_S$	Without time-of-flight. With time-of-flight. From CDF II TDR [45]
D0	± 0.16	$J/\psi K_S$	From [46]
HERA-B	± 0.13	$J/\psi K_S$	From [47]
BTeV	± 0.015	$J/\psi K_S$	From [48]
ATLAS	± 0.017	$J/\psi K_S$	From [42]
CMS	± 0.023	$J/\psi K_S$	From [43]
LHCb	$\pm(0.017 - 0.011)$	$J/\psi K_S$	From [49]

Table 9: Claims of the various experiments for their ability to measure $\sin 2\beta$.

$\sin 2\alpha$			
	Precision	Technique	Comments
BaBar	± 0.085 @ 30 fb^{-1}	$\pi^+\pi^-$, $\rho\pi$, $a_1\pi$, etc.	Estimates from TDR [44]. Measure α even with penguins.
CLEO			
CDF	± 0.10 @ 2 fb^{-1}	$\pi^+\pi^-$	With time-of-flight. Uses dE/dx from drift chamber. Measures asymmetry only [45].
D0			No K/π separation
HERA-B	± 0.22	$\pi^+\pi^-$	From [47] Measures asymmetry only.
BTeV	± 0.03	$\pi^+\pi^-$	From [48] Measures asymmetry only.
ATLAS	± 0.18	$\pi^+\pi^-$	From [42] Measures asymmetry only.
CMS	± 0.16	$\pi^+\pi^-$	From [43] Measures asymmetry only.
LHCb	± 0.05	$\pi^+\pi^-$	From [49] Measures asymmetry only.

Table 10: Claims of the various experiments for their ability to measure $\sin 2\alpha$ in $B \to \pi^+\pi^-$ itself. Because of the likely contribution from penguin diagrams, whose weak phase differs from that of the tree diagrams, the analysis is much more difficult than for $\sin 2\beta$. The asymmetry by itself does not determine $\sin 2\alpha$, though the precision indicated in the Table represents the uncertainty in $\sin 2\alpha$ computed as if there were no penguins. In principle, using isospin symmetry and measuring the time-dependent (tagged) decay to $\pi^+\pi^-$, together with the branching ratios to $\pi^0\pi^0$, $\pi^\pm\pi^0$, suffice to find α, up to discrete ambiguities, even in the presence of penguin amplitudes. CESR can contribute by measuring the decays without time dependence. Unfortunately, a very small branching ratio is expected for $B \to \pi^0\pi^0$, making this approach problematic. More promising is the use of $B \to \rho\pi$, though again a small branching ratio to $\rho^0\pi^0$ may impede this program and require extensive running. It is assumed that the hadron colliders will not measure modes with π^0's, although LHCb has begun consideration of the $\rho\pi$ channel [49].

$BR(B \to \pi^+\pi^-) = 10^{-5}$??

γ			
	Precision	Technique	Comments
BaBar			Similar to CLEO
CLEO	$\pm 30°$ @14fb^{-1} $\pm 15°$ @75fb^{-1} $\pm 10°$ @300fb^{-1}	$K\pi$ $K\pi$ $K\pi$	For theoretical uncertainties see Section 3.2.3.
CDF	$\pm$ 20-25° 2fb^{-1}	$B_s \to D_s K$,	$B^- \to DK^-$
D0			
HERA-B			
BTeV	$\sigma(\sin\gamma) \approx \pm 0.10$ $\sigma(\gamma) \approx \pm 8°$	$B_s \to D_s K^\pm$ $B^- \to \bar{D}^0 K^-$ $B \to K\pi$	Measures $\sin(\gamma \pm \delta)$ [50]
ATLAS	uncertain	$B \to DK$	Analysis in progress
CMS	unknown		
LHCb	$\sigma(\gamma) \approx \pm 10°$	$B_s \to D_s K^\pm$	[49]

Table 11: Claims of the various experiments for their ability to measure the angle γ in the unitarity triangle.

Δm_s and x_s			
	Precision	Technique	Comments
BaBar			
CLEO			
CDF	Measure if $x_s \leq$ ~~20~~ 40, 60	$B_s \to D_s n\pi$	[45] wo, w ToF + LOO
D0	Measure if $x_s \leq 16$	$B_s \to D_s n\pi$	[51]
HERA-B			
BTeV	Measure if $x_s \leq 40$ Measure if $x_s \leq 80$	$B_s \to D_s\pi$ $B_s \to D_s\pi$	EOI configuration Square hole pixel design
ATLAS	Measure if $x_s \leq 38$	$B_s \to D_s\pi, a_1$	[42]
CMS	Measure if $x_s \leq 38$	$B_s \to D_s\pi$	[43]
LHCb	Measure if $x_s \leq 91$	$B_s \to D_s\pi$	[49]

Table 12: Claims of the various experiments for their ability to measure the mass difference Δm_s and the corresponding mixing parameter x_s.

I have <u>not</u> covered everything

(i.e. rare or radiative decays, etc.)

especially with respect to hardware.

Many more details are accessible via web sites for each of the experiments

What I hope I have conveyed is that B physics relevant to CP violation in and beyond the SM

CAN BE DONE

HAS BEEN DONE

& WILL BE DONE

AT HADRON COLLIDERS

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Harry Lipkin*, Isi Dunietz, Jon Rosner & Boris Kayser

AND OWEN 'I got blisters on me fingers' LONG

* TRANSVERSITY

References for further reading:

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