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B PHYSICS AT CDF

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From 1992 to 1995 the CDF experiment has taken 110 pb^{-1} of $\mathrm{p\overline{p}}$ collisions at a center-of-mass energy of 1.8 TeV. These data gave rise to a variety of important B physics measurements. Most importantly B mass, lifetime and mixing measurements, the observation of the last missing meson, the $\mathrm{B_c}$, and a measurement of the CP violation parameter $\sin 2\beta$. The highlights of those results are described and a perspective for the upcoming Run II period is given.

1 Introduction

From 1992-1995 CDF has collected 110 pb^{-1} of $\mathrm{p\overline{p}}$ collisions at a center-of-mass energy of 1.8 TeV. A large number of B physics measurements have been performed and the highlights will be summarized in Section 2. Measurements of B hadron masses, lifetimes and mixing, competitive with the LEP experiments have established the CDF experiment in the realm of B physics. The measurement of the CP violation parameter $\sin 2\beta$, which is still competitive with the first preliminary results of BaBar and Belle[1], demonstrates that CDF will contribute in a significant way when Run II will start in March 2001.

In the first two years the Tevatron will deliver 2 fb^{-1} to each, CDF and DØ, and an anticipated total of about 15 fb^{-1} each will be accumulated until the end of the program. Apart from the increased statistics, CDF will further enhance the B physics potential due to the upgrade of the triggering, tracking and particle identification systems. Apart from measurements of $\mathrm{B_u}$ and $\mathrm{B_d}$ mesons, CDF and DØ are in a unique position[a] to study heavier B hadrons like $\mathrm{B_s}$, Λ_B and $\mathrm{B_c}$. These measurements complement the program at the B factories and apart from just improving the understanding of CP violation they have a potential to observe effects of new physics beyond the Standard Model. In Section 3 the detector upgrades and the prospects for Run II are discussed.

[a] HERA-B will probably also observe $\mathrm{B_s}$ mesons but with lower statistics.

2 Run I Highlights

Due to the large number of B physics results from Run I this report restricts itself mostly to measurements of B hadron masses, lifetimes, mixing and CP violation. B hadron data sample from Run I are obtained by triggering on leptons. Semileptonic B decays have the advantage that the trigger rate is significantly reduced through the clean charged lepton signal. On the other hand the neutrino production decreases the quality of the proper decay length reconstruction.

B hadron mass and lifetime measurements are straightforward and CDF has measured the masses and lifetimes of all B mesons and the Λ_B baryon. CDF governs the world average of the heavy B hadrons since they are not produced at the $\mathrm{e^+e^-}$ machines at the $\Upsilon(4\mathrm{S})$ resonance. The masses of those heavy hadrons are

$$m(\mathrm{B_s}) = 5.3699 \pm 0.0023 \pm 0.0013\ \mathrm{GeV}\,,$$
$$m(\Lambda_\mathrm{B}) = 5.621 \pm 0.004 \pm 0.003\ \mathrm{GeV}\,,$$
$$m(\mathrm{B_c}) = 6.40 \pm 0.39 \pm 0.13\ \mathrm{GeV}\,,$$

together with their lifetimes as measured and published by CDF

$$\tau(\mathrm{B_s}) = 1.36 \pm 0.10\ \mathrm{ps}\,,$$

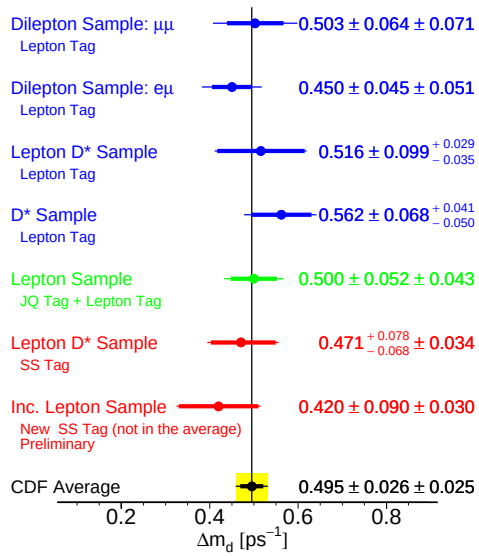

Figure 1. Summary of B_d mixing measurements.

$$\tau(\Lambda_B) = 1.32 \pm 0.17 \text{ ps},$$
$$\tau(B_c) = 0.46 \pm 0.17 \text{ ps}.$$

B mixing and CP violation are both due to the weak transitions between quarks and depend on the complex elements of the well known Cabibbo-Kobayashi-Maskawa matrix. Those measurements are particularly challenging since they require the identification of the flavor of the B meson at production. In Run I identification of the flavor at production or B flavor tagging has been mostly based on opposite side lepton and jet charge tags and on same side pion tags. A summary of the B_d mixing results is listed in Figure 1. A limit on B_s mixing has been determined to be $\Delta m_s > 5.8$ ps^{-1} at 95% confidence level. To determine the CP violation parameter $\sin 2\beta$, the asymmetry

$$A(t) = \frac{N_{B_d \to J/\psi K_S} - N_{\overline{B}_d \to J/\psi K_S}}{N_{B_d \to J/\psi K_S} + N_{\overline{B}_d \to J/\psi K_S}}$$

in the gold plated decay $B_d \to J/\psi K_S$ is measured. The asymmetry in the Standard Model is given by $-\sin 2\beta \sin \Delta m_d t$ and is

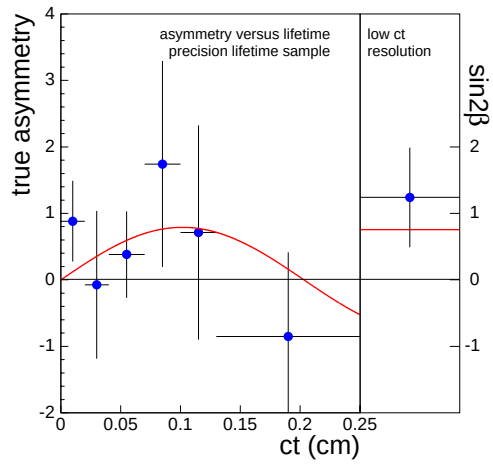

Figure 2. CP asymmetry measurement in $B_d \to J/\psi K_S$.

measured by CDF to be[3]

$$\sin 2\beta = 0.79 \pm 0.39 \pm 0.16$$

which translates to $\sin 2\beta$ being positive at the 93% confidence level. The corresponding time dependent asymmetry is shown in Figure 2. This result has the same statistical precision as, and is consistent with, the results from BaBar and Belle. All measurements so far agree with the Standard Model expectation of about 0.7.

3 Prospects for Run II

The Run II program is going to start in March 2001 providing 2 fb^{-1} to each of the Tevatron experiments in the first two years. CDF is presently preparing for the commissioning run which will allow to see first collisions from September to November 2000.

3.1 Detector Upgrades

To improve the overall detector performance CDF has undergone a major upgrade[2] in the last 5 years. Most important for B physics

- The silicon detector with five layers of two sided readout extending from 2.4 cm to

10.7 cm radius with an expected point resolution of 12 μm. Two additional similar silicon layers at 20 cm and 28 cm and a single sided layer at 1.6 cm radius bring the proper time resolutions for B hadrons decaying hadronically to 45 fs. The silicon detector covers a range of $|\eta| < 2$.

- A new time-of-flight detector consisting of Bicron plastic scintillators readout at both ends with 19-staged Hamamatsu PMT's. They are installed inside the solenoid magnet on top of the central outer tracker. The TOF system provides a 2σ separation between pions and kaons for momenta smaller 1.6 GeV being complementary with the dE/dx measurement in the tracker.
- The new trigger system including a track trigger at Level-1 with transverse momenta as low as 1.5 GeV and a secondary vertex trigger at Level-2. The combination of both will allow to trigger on purely hadronic B decays.
- The muon detector coverage has been doubled to cover a range of $|\eta| < 2$.

*3.2 **B**-Physics Prospects*

CP violation and B mixing analyses are in the spotlight for Run II. Both critically depend on the flavor tag. Apart from the increased statistics and the improved impact parameter resolutions, the improvement of the B flavor tagging significantly enhances the CDF B physics sensitivity. Depending on the analysis the effective event statistics improves by a factor of up to two just due to the particle identification capability of the new time-of-flight detector. Expectations for some interesting measurements in Run II based on 2 fb^{-1} follow:

- CDF will collect $\approx 10k$ $\mathrm{B_d} \to \mathrm{J}/\psi\,\mathrm{K_S}$ events resulting in a measurement of $\sin 2\beta$ with an error of ± 0.07.
- The CP violation parameter γ will be measured in a combination of $\mathrm{B_d} \to \pi^-\pi^+$ and $\mathrm{B_s} \to \mathrm{K^-K^+}$ modes with roughly 5k and 10k events, respectively. They allow a measurement of γ with an error better than $\pm 10^{\mathrm{o}}$. This result has been obtained assuming the signal to background ratio is as good as 1:2. This number has a large uncertainty which might increase the error of this measurement.
- $\mathrm{B_s}$ mixing is measured from $\mathrm{B_s} \to \mathrm{D_s^-}\,\pi^+$ decays and with 23k events CDF will be sensitive up to $x_\mathrm{s} \approx 65$ which is well above the Standard Model expectation. Probably $\mathrm{B_s}$ mixing (x_s= 20-30) will be observed in the first few month of data taking as shown in Figure 3.
- $\Delta\Gamma_\mathrm{s}/\Gamma_\mathrm{s}$ has been studied in $\mathrm{B_s} \to \mathrm{J}/\psi\,\phi$ decays. An event sample of 4k events will allow to obtain a precision of ± 0.05.

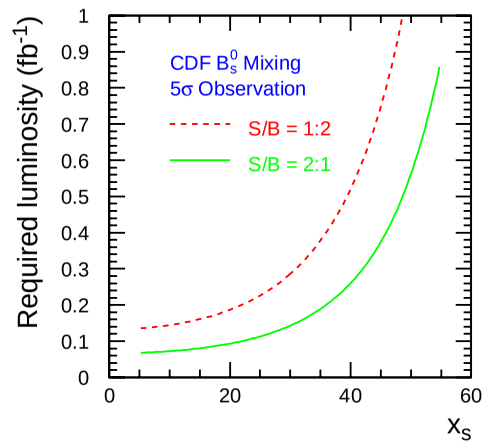

Figure 3. Required luminosity for a five sigma observation of $\mathrm{B_s}$ mixing.

References

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