Heavy Flavour Physics at the other Facilities

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Abstract. The latest results concerning the Flavour Physics at facilities other than B-factories are reviewed. Included here are the results from LEP, CESR, RHIC, HERA and Tevatron and to conclude the prospects at LHC. The goal of this review is to show that Heavy Flavour Physics is one of the most promising place to explore beyond the standard model and also that this is not (anymore) the privileged physics topic of the B-factories.

1. Introduction or why heavy flavour physics is so appealing.
The Heavy Flavour Physics (HFP) labeled for long time “B Physics” is closely related to the CKM matrix representation and to the electron-positron facilities that were thought for long to be “the” facilities to study this physics topic [1]. This presentation aims to demonstrate that this field extends far beyond that from both the theoretical and experimental points of view.

HFP is QCD, electroweak and Beyond the Standard Model (BSM) Physics. HFP is a puzzle for many different reasons and heavy flavour objects are probes for New Physics. Heavy b- and c-quarks have a measurable lifetime; they both hadronize and couple with all the other quarks. Heavy flavours are produced in e⁺e⁻, ep, pp and in the heavy ion collisions. Thanks to HFP and to the experimentalists’ prowess, hadron colliders, called once upon the time “discovery machines” became high precision machines and are now competitors to e⁺e⁻ facilities especially B-factories in this field of research.

HFP is QCD Physics because heavy flavour production processes, bound states and lifetimes, decays and branching ratios are calculable by theory. The study of heavy-light bound states at all facilities provides accurate test of QCD predictions or new inputs to it. Moreover heavy flavours are probes for quark gluon plasma (QGP).

HFP is electroweak physics because for instance the study of Bₐ or D⁰ mixing and CP violation are tests of the fundamental properties of the electroweak interactions. HFP is BSM Physics because CP violations in B, or D⁰ systems are very sensitive to BSM. Rare B (D) decays are very sensitive to BSM as well. HF processes are physics backgrounds for new Physics. HF objects are key objects in new physics signatures. This is why HFP is becoming more and more appealing.

2. Heavy Flavour Physics at LEP: the legacy and latest results
The high energy electron positron colliders, LEP at CERN and SLC at SLAC explored all the Heavy Physics topics, sometimes in a pioneering way and an impressive harvest of results have been collected at LEP and SLC too. Among the major legacy two main results should be pointed out. LEP and SLC devoted a lot of efforts in searching for Bₐ oscillations. ALEPH experiment pioneered the analysis procedure and LEP and SLC experiments were very close to success. Indeed frequencies of less than 14.9 ps⁻¹ were excluded at 95% C.L. and the expected limit i.e. 19.5 ps⁻¹ is substantially higher because the amplitude values different from zero and one are found in the frequency range 16
to 20 ps$^{-1}$ [2]. Another important legacy from LEP is the measurement of the Forward/Backward Asymmetry at the $Z^0$ pole measured with a 2.5 $\sigma$ discrepancy with respect to the SM prediction (a sign for new physics?) [HFAG2007].

There are still important new results coming up from LEP. The nature of b-quark fragmentation has been studied at LEP and SLC. These are the only experimental facilities that allow studying B-fragmentation. Results exist from ALEPH (semi leptonichannels), OPAL and SLD (inclusive analysis). There is still an ongoing study in the DELPHI collaboration (inclusive analysis as well) that will improve the present achieved results and be the last word on the topic from LEP. The other result is the measurement of the cross-section for the open b-quark production in two photons interactions. A new result from ALEPH was presented at this conference [2] stating that
\[
\sigma(e^+e^-\rightarrow e^+e^- bb X) = 5.4 \pm 0.8\text{(stat.)} \pm 0.8\text{(syst.) pb}.
\]
It agrees with the next-to-leading order (NLO) QCD expectations but is barely consistent with the previous experimental results (e.g. L3 found a value of 12.8$\pm1.7$ (stat.)$\pm 2.3$(syst.) pb). LEP and SLC have been extremely valuable in exploring this physics domain.

3. Heavy Flavour Physics at the Cornell electron storage ring: THE charm place for ever

The Cornell electron-positron storage ring (CESR) produces $e^+e^-$ collisions at a center of mass (c.m.) energy of 9 to 12 GeV and a peak luminosity of $1.2 \times 10^{33}$ cm$^{-2}$ s$^{-1}$. Among the main assets of this facility is the fact that D and anti-D mesons are pair-produced at threshold, providing a huge amount of low multiplicity clean data. Very interesting new results from CLEO-c on hadronic, leptonic and semileptonic decays of D-mesons were produced this year and much more data are still to come [3].

The study of hadronic decays of the D mesons is performed studying the process: $e^+e^-\rightarrow \Psi(3770)$ with $\Psi\rightarrow D^+D^-$ and the following decays: $D^+\rightarrow K\pi\pi$ and $D\rightarrow K'\pi\pi$. Also considered is the decay $D^0\rightarrow K\pi+$. These decay branching ratios (Br) have been measured with a high accuracy. For instance a precision of $\partial B/B=2.9\%$ and 2.3\% is respectively achieved for these two processes. The mass of $D^0\rightarrow K\pi$ with $\Phi\rightarrow K^0s$ has been precisely determined and found to be $\text{M}(D^0) = 1864.847 \pm 0.150 \text{(stat.)} \pm 0.095 \text{(syst.) MeV}$. Moreover absolute $D_s$ hadronic branching ratios were measured using the first 195 pb$^{-1}$ data (still preliminary) with CLEO-c and at 4170 MeV beam energy. The $D_s$ decays into the five modes plotted in Fig.1 were evaluated and compared with the PDG06 results. The hadronic decays of $D_s$, Cabibbo suppressed, e.g. $K\pi^0$, $K\eta$, $K\eta'$ and $K^0\pi^+$, have been compared to Cabibbo favoured $D_s$ decays, e.g. $\pi\eta$, $\pi\eta'$ and $K^0\pi^+$. In particular the ratio ($D_s\rightarrow\pi^+\pi^0$)(Cabibbo forbidden)/($D_s\rightarrow K^0\pi^0$)(Cabibbo favoured) is found to be less than 0.04; it thus compares well with a $(V_{cd}/V_{cs})^2$ value of 1/20.

These errors are still statistics dominated; more data are coming soon.

The study of leptonic and semileptonic decays is schematized in Fig.2 here below.

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Fig.1: Br(CLEO)/Br(PDG06)

Fig 2: Schema of the leptonic and semileptonic decays of D-mesons
Using $V_{ud}$ and $V_{cs}$, the decay constants $f_D$ and $f_{D_s}$ can be determined from the leptonic decays of $D$ or $D_s$ into lepton plus neutrino. The measured decay constant of $D_s$ meson, $f_{D(s)}$, allows calibrating and validating the Lattice QCD (LQCD) calculations. Furthermore they impact HF Physics by constraining the CKM matrix, and moreover as the relative decays rate to different lepton flavours are well predicted by the Standard Model (SM) any measured deviations imply new physics. For instance the $D_s$ decays into $\mu\nu$ and $\tau\nu$ lead to two nice measurements of $f_{D(s)}$: CLEO has measured it with a precision of 5% compared to 8% in BABAR. The decay $D \to \mu\nu$ gives a fairly precise measurement of $f_D$ (8% precision). An impressive series of high precision results is provided by CLEO and a lot more have still to come with the data collected with the upgraded detector. Therefore not only standard Physics is being checked with high precision at this facility, but even and more importantly, it provides important inputs for the LQCD calculations and for looking for any possible deviation from the SM in the charm sector.

4. Heavy Flavour Physics at HERA, electron positron collider at DESY

This facility was running until June 30, 2007, with two major experiments, H1 and ZEUS. It delivered 500 $pb^{-1}$ of total luminosity per experiment, from 2002 to 2007, i.e. the duration of HERA II. A proton beam of 920 GeV was colliding with an electron beam of 27.5 GeV, providing $\sqrt{s} \sim 318$ GeV. The study of heavy quark production at this collider allows testing perturbative QCD due to the hard scale given by the heavy quark mass. It also provides a better understanding of the proton structure. Several interesting results were presented at this conference [4].

The production of charm mesons is studied in photoproduction process $\gamma p \to D^* X$ and in deep inelastic scattering (DIS). The cross-section of charm photoproduction as a function of $Q^2$ is measured by ZEUS. The ratio of $D^0$ and $D^+$ production rates, the strangeness suppression factor in charm fragmentation and the fraction of $D^+$ produced in a vector state is compared between various experiments or types of processes and machines, i.e. ZEUS DIS and photoproduction, H1 DIS and $e^+ e^-$ results as well as a previous ZEUS photoproduction result. All the results agree well between themselves for these three different variables. Likewise the fractions of $c$-quarks hadronising as $D^*$, $D^0$ and $D_s$ charm ground-state mesons, as $D^*$ mesons and $\Lambda_c$ baryons are compared between these different various cases. It is interesting to note that they agree well and that the HERA results are competitive with those of $e^+ e^-$ machines.

The charm fragmentation function is measured as a function of $z = (E+p_T)/E_T$ by ZEUS and H1 and compared to results from $e^+ e^-$ facilities, showing a nice agreement (Fig.3, left plot here below).

![Charm fragmentation function at HERA (H1 and ZEUS) and comparison with $e^+e^-$ results (left). Differential $b$-quark production cross-section as a function of $b$-quark transverse momentum (right).](image)

Charm spectroscopy is being studied with the new data by both experiments. For instance $D^*$ decay into $K\pi\pi$ can be double tagged by the slow $\pi$ and the $D^0$ in the final state, showing a nice $D^*$ peak in the mass spectrum [4].
Various measurements of the differential cross-sections of b-quark are performed as a function, for instance, of the b-quark transverse momentum (Fig.3, right) and show a general good agreement with the NLO QCD predictions and between the two experiments. From these preliminary studies one may expect interesting results in the HF sector from the full set of data recorded by HERA.

5. Heavy Flavour Physics at Relativistic Heavy Ion Collider RHIC

The RHIC facility at Brookhaven offers a presently unique variety of heavy ion collisions, namely: Cu-Cu, d-Au, at √s=200 GeV, Au-Au at 19.6, 62.4, 130 and 200 GeV and polarized proton-proton at 200 GeV. Various experiments are running at this facility with in particular PHENIX and STAR [5]. It is of interest to note that heavy flavours are probes for the QGP physics. The study of the energy loss of heavy quarks gives an independent way to extract properties of the medium. Due to their large mass, heavy quarks are primarily produced by gluon fusion. Thus the production rates can be computed by perturbative QCD (pQCD) and they are sensitive to the initial gluon distribution. The attenuation of heavy-flavoured particles in nucleus-nucleus collisions tests the microscopic dynamics of medium-induced parton energy loss and its dependence on the identity (color charge and mass) of the parent parton [5]. Heavy-quark energy loss is presently studied at RHIC using measurements of the nuclear modification factor $R_{AA}$ of non-photonic ($\gamma$-conversion and $\pi^0$-Dalitz subtracted) single electrons. Charm is dominating at low transverse momentum ($P_T$) and beauty at high transverse momentum and there is a large pQCD uncertainty on the $P_T$ position of c-decay with respect to b-decay. Distinguishing between b- and c-quark is thus important but experimentally very challenging to achieve especially in this particular environment.

A lot of work is going on in this field as stressed at this conference [5]. Among the main results, three are pointed out here that call for more data and/or explanation. Heavy spectroscopy is a nice achievement of both experiments. A combined $\Upsilon - \Upsilon' + \Upsilon''$ signal is measured by STAR consistent with NLO pQCD calculations and world data trend (Fig.4). PHENIX finds $J/\Psi$ signal disappearance in Au-Au collisions as compared to pp collisions: this is not yet explained. Hadronic and semi-leptonic decays of D mesons are studied by both experiments and found to be higher than NLO predictions, however STAR results are two times higher than those of PHENIX.

The forthcoming new data should hopefully help resolving these pending questions.

Fig.4 $J/\Psi$ production at STAR

6. Heavy Flavour Physics at hadron colliders with special emphasis on the Tevatron harvest

Over these last 20 years HFP at pp colliders witnessed a revolution that led to the fantastic results presently achieved at the Tevatron. The SppS proton-antiproton collider with the UA1 experiment at CERN was a precursor. UA1 was the first hadron collider experiment with a high precision tracking

Fig.5 Clear $J/\Psi$ signal at UA1(left), first CDF vertex detector (middle), $B$-signal at CDF I (right).
(drift chamber) in a magnetic field and with a muon detector, able to perform B-Physics in this environment. A nice \( J/\Psi \) signal was found in UA1 (Fig.5, left plot) with a first observation of B oscillations (B and \( B_s \) were mixed together) [6].

The Run I at the Tevatron with the CDF detector is a pioneer. This is the first experiment in hadronic collisions that was successfully instrumented with a Silicon vertex detector (1992) as shown in Fig.5. Together with a high precision drift chamber in a high B-field, the vertex detector made CDF able to achieve a lot of B Physics studies and, by performing a full B event reconstruction in this framework, to pioneer CP violation studies in the B sector [6].

The Run II of the Tevatron with the upgraded CDF and D0 experiments opens a new era for HFP in hadron colliders. The LHC with ATLAS, CMS, LHCb and ALICE experiments should break new Physics frontiers. An important part of this review is dedicated to the impressive results achieved at the Tevatron over this last year. This was made possible, first with the very good functioning of the machine. At the time of EPS’07 a total luminosity of 3.2 fb\(^{-1}\) was delivered by the Tevatron, with 2.7 fb\(^{-1}\) recorded by each experiment, an average of 40 pb\(^{-1}\) per week and a peak luminosity of \( 2.85 \times 10^{32} \) cm\(^{-2}\)s\(^{-1}\). CDF and D0 performed nicely as well, especially for B-physics (see next section).

6.1. The experimental challenges to perform HFP at Tevatron.

HFP at Tevatron is characterized by three main facts; the good one is that the cross section of the production of b-quark pairs in pp collisions is of the order of five times higher at the Tevatron energy than in electron-positron collisions at \( \Upsilon(4S) \) or \( Z^0 \) pole. There is incoherent production of all b-hadrons, i.e. \( B^+, B^0, B^{0*}, \Lambda_b, \Sigma_b, \Xi_b \) … However the total inelastic cross-section is \( 10^3 \) times larger than \( \sigma(b \bar{b}) \) and the branching ratios for interesting processes are of order \( 10^{-6} \) lower of the later. The ugly fact is the messy environment with large combinatorial possibilities (Fig.6).

Very high detector performances are thus required in order to achieve HFP in this harsh environment. The key devices are the vertex detector, the tracking system, and highly selective triggers especially on heavy flavours. Identification of particles is another crucial asset.

CDF and D0 upgrades for Run II are instrumental to greatly improve these aspects [7]. D0 is characterized by excellent muon coverage and a tracking that covers down to a pseudo-rapidity \( \eta \) of 2. It has an excellent calorimeter and electron identification, a high efficiency muon trigger based on the \( P_t \) measurement at Level 1, namely one muon track trigger with a \( P_t \) threshold of 3 or 4.5 GeV/c and a two track muon trigger with a threshold of 2 GeV/c for each one. For Run II, D0 has replaced the TRD by a scintillating fibre based tracking and added a 2 Tesla solenoid field. The 1.8 T toroidal magnet part of the muon system is weekly reversed; this is very useful for estimating \( \mu \)-asymmetries systematic. In 2006 another Silicon layer was added at 1.6 cm from the beam axis just before the four layers of the vertex detector, made with four double-sided micro strip layers.

Based on the experience acquired in Run I, CDF built a third version of the vertex detector with five double sided Silicon microstrip layers plus a sixth single sided layer just at 1.4 cm of the beam pipe. A new drift chamber version able to work in the Run II conditions was built with an eXtremely
Fast Trigger (XFT) able to select tracks with a Pt threshold of 1.5 GeV/c in 1.9 µs, for every bunch crossing, and with $\sigma(1/P_t) = 1.7\%$ per GeV. A trigger (SVT) combining at Level 2 the information of the drift chamber (XFT) and the vertex detector was a grand premiere. It is able to reconstruct the impact parameter $d_0$ with an overall resolution $\sigma = 48 \mu m = 35 \mu m \oplus 33 \mu m$ (SVT plus beam resolutions). Both the XFT and SVT trigger systems were upgraded in order to cope with the increase in luminosity. The information of the axial layers was added to the one of the stereo layers in the XFT making it 3D device. The SVT was instrumented with faster FPGAs and much larger size associative memories (able to handle 512K patterns instead of 32K). This was achieved while continuing the data taking and the result is: good data at high luminosity, more data at low luminosity. The particle identification obtained by combining the time of flight (TOF) and the drift chamber dE/dX measurement is another crucial asset of CDF for HFP. CDF has thus three basic HFP triggers: the di-muon ($J/\psi$) trigger requiring $P_t(\mu)>1.5$ GeV/c, the displaced track plus lepton (e,µ) trigger for semi-leptonic modes and the two displaced track trigger essential for the fully hadronic modes (ex: CP asymmetry in 2-body charmless decays, $B_s$ mixing and charm physics); all ready at the Run II start.

It is thanks to this experimental prowess that an impressive series of results are being achieved both by CDF and D0. It is an important lesson for the forthcoming LHC experiments.

6.2. HF processes and QCD measurements
The hadron colliders are dominated by strong interaction processes and thus provide a vast training camp for testing many aspects of QCD especially in the HF domain. Many new results are provided by both experiments on this topic, this last year [8].

6.2.1 Understanding b cross-sections: The discrepancy between theory and experimental results in the cross-section of b-quark pairs, found by CDF in Run I, is now solved thanks to a community effort combining PDFs, fragmentation function, $\alpha_s$ parameters, better theoretical calculation (FONLL) and more accurate measurements [8].

6.2.2 b/c-jets and HF processes: Many fundamental processes require b- and c-jet identification. A lot of work is undertaken at Tevatron and was reported at this conference. W/Z+HF is not yet fully studied but promising preliminary results are reported on Z+b-jet (Fig.7, left plot) by CDF and on W+c-jet by D0 (Fig.7, right plot) [8].

CDF reported a new measurement of the $W+bb$ production cross section of 0.90±0.32 pb for $E_t(\text{jet})>20$ GeV and $\eta<2$ to be compared with 0.74±0.18 pb (leading order by ALPGEN Monte Carlo [8]). The b-jet energy scale is worked out at CDF with the process $Z^0\rightarrow bb$ and a new generation of heavy flavour taggers, based on neural networks are being developed at CDF and being tested in $Z+b$ and $Z+c$ measurements [8]. This work is essential for a lot of physics issues and allows, as a by-product, adjusting and improving Monte Carlo calculations.
6.3 Heavy Flavour Spectroscopy
Spectroscopy is, as already emphasized, another important aspect of HFP. Spectroscopy is not just about updating a number in the PDG. Indeed measuring the width (i.e. the lifetime) of decaying quarks bound into hadron states is related to the dynamics of the decay. The lifetime probes the interplay between the weak (decay) and strong (bounding) forces. Spectroscopy measurements also test QCD in non-perturbative regime, i.e. the validity of effective models for heavy-flavour quantities. New B-hadrons have been discovered this last year, new decays, mass and lifetimes have been measured with sometime puzzling results [9].

6.3.1 Orbitally excited $B^{°**, B^{0**}}$. Why to study the spectroscopy of heavy-light systems? Because they are just like the H-atoms, namely bound by strong interaction. It is like a hyperfine structure but in QCD (Fig.8); $B^{**}$ probes the potential in a new regime [9]. For $B^{**}$ both CDF and D0 find the corresponding $B_1$ and $B^{°2}$ structures in the mass spectrum with very accurate measurement of the corresponding masses. The discrepancy between the two experiments is in the study of $B^{°2}$ where CDF finds $B_1$ (with 6.3 $\sigma$ significance) and $B^°2$ whereas only $B^{°2}$ is significant in D0 (Fig.8).

6.3.2 $B$ mesons lifetime: Updated values are provided by CDF and D0 on the measurement of the $B^{°}$ and $B^{0}$ lifetimes thus leading to the determination of

$$\frac{\tau(B^{°})}{\tau(B^{0})} = 1.080 \pm 0.016 \text{(stat.)} \pm 0.014 \text{(syst.)} \ (D0)$$

$B^{0}$ lifetime

$$\tau(B^{0}) = 1.420 \pm 0.043 \text{(stat.)} \pm 0.057 \text{(syst.)} \ (D0)$$

All these values are world best measurements to date [9].

6.3.3 Heavy flavoured baryon $Λ_b$ lifetime. D0 has determined with 1.3 $fb^{-1}$ data the $Λ_b^{°}$ lifetime in the semi leptonic and hadronic decay modes and compared with the $B^{0}$ lifetime, the world average, the QCD expectations and the CDF results. The presently available results [9] are listed here below.

| Item (experiment) | Decay mode | results |
|------------------|------------|---------|
| $Λ_b^{°}$ lifetime in ps (D0) | Semi-leptonic decay mode: $Λ_b^{°} \rightarrow μνΛ_c \ X$ Hadronic decay mode: $Λ_b^{°} \rightarrow J/Ψ(\rightarrow μμ)Λ_c^{0}(\rightarrow π^+π^-)$ | $1.290^{+0.119}_{-0.110} \text{(stat.)}^{+0.087}_{-0.091} \text{(syst.)}$ |
| $Λ_b^{°}$ lifetime in ps (D0) | Combined decay modes | $1.218^{+0.130}_{-0.115} \text{(stat.)}^{+0.042}_{-0.043} \text{(syst.)}$ |
| $B^{0}$ lifetime in ps (D0) | $B^{0} \rightarrow J/Ψ(\rightarrow μμ)K^0_s(\rightarrow π^+π^-)$ | $1.593^{+0.083}_{-0.079} \text{(stat.)}^{+0.050}_{-0.052} \text{(syst.)}$ |
| $τ(Λ_b^{°})/τ(B^{0})$ (D0) | | $0.811^{+0.096}_{-0.090} \text{(stat.)}^{+0.042}_{-0.045} \text{(syst.)}$ |
| $τ(Λ_b^{°})/τ(B^{0})$ (CDF) | | $1.018^{+0.062}_{-0.063} \text{(stat.)}^{+0.007}_{-0.008} \text{(syst.)}$ |

The D0 results are in good agreement with the world average and the QCD expectations. The CDF results are obtained with 1$fb^{-1}$ data and based on fully reconstructed $Λ_b^{°} \rightarrow J/Ψ \ Λ_c^{0}$, events.CDF gives...
the world best measurement but the $\tau(\Lambda^0_b)/\tau(B^0)$ ratio is about 3σ away from the world average and the QCD expectation (e.g. 0.88±0.05). This is a puzzling result under investigation in CDF, with higher statistics and looking for other decay channels [9].

6.3.4 New heavy flavoured baryons: discoveries of $\Sigma_b$ and $\Xi_b$. One year ago the only found heavy b-hadrons were B, seen by UA1, $\Lambda^0_b$ seen by LEP and CDF I and large samples of $\Lambda^0_b$ baryons produced at Tevatron II. The first heavy baryon to look for is: $\Sigma_b \to \Lambda^0_b \pi^\pm$, with $\Lambda^0_b \to \Lambda^+_c \pi^-$; $\Lambda^+_c \to pK^-$(see decay diagram on the left here below).

$\Sigma_b^*$ was observed by CDF for all 4 expected states with 5σ significance and masses in MeV/c²

$M(\Sigma_b^*) = 5807.7^{+2.0}_{-2.2}$ (stat.)±1.7 (syst.),
$M(\Sigma_b^*) = 5815.2^{+1.0}_{-1.7}$ (stat.)±1.7 (syst.),
$M(\Sigma_b^{*+}) = 5829.2^{+1.6}_{-1.8}$ (stat.)±1.7 (syst.),
$M(\Sigma_b^{*-}) = 5836.4^{+2.0}_{-1.7}$ (stat.)±1.7 (syst.).

These results show the high precision reachable by these experiments [9].

The $\Xi_b$ was discovered in its triple scoop cascade b decay (Fig.9) by D0 with CDF back to back. The cascade decays includes the following steps:

$\Xi_b \to J/\Psi \Xi$; $J/\Psi \to \mu^+\mu^-; \Xi \to \Lambda \pi; \Lambda \to p\pi^-$. D0 applies simple selection cuts on particles transverse momentum and lifetime significance and finds a clear excess at 5780 MeV/c.

Fig 9: Triple scoop $\Xi_b$ cascade b-decay schema (left), tracks in CDF (middle), mass spectrum (right).

The CDF analysis makes use of 15 x 10^6 $J/\Psi$ triggered sample in 1.9 fb⁻¹ recorded data and searches for the signals in sequence of the cascade decay in a straightforward way. There is a fairly complicated pair of displaced vertices: $\Xi$ lives a long time (cτ = 4.9 cm); $\Lambda$ lives 7.9 cm. The analysis coalesces measured tracks into a new object, $\Xi$ track (see Fig.9 middle view), which is treated as any other track. The obtained results by CDF and D0 are consistent with each other:

$M(\Xi_b) = 5774 \pm 11$(stat) ±15 (syst) MeV (D0), and
$M(\Xi_b) = 5792.9 \pm 2.5$(stat) ±1.7 (syst.) MeV (CDF),

and with theory (Fig.9, right). CDF momentum precision sets the current standard for B mass measurement [9].
6.4 B_s mixing: from the discovery to the exploration of the B_s sector.

B_s is special as contrary to any other system it has a very high frequency of oscillation between B_s and anti-B_s meson states making it experimentally very challenging. In the B_s-antiB_s meson system, the flavour eigenstates are not the same as the mass eigenstates. The mass difference $\Delta M_s=M_{H}-M_{L}$ between the heavy ($B_{s0}$) and the light ($B_{sL}$) mass eigenstates determines the frequency of oscillation of the B_s mesons. One main experimental issue was to measure $\Delta M_s$ and to verify if it is compatible with SM expectation. New Physics predicts possible additional contribution to the SM process and thus an higher $\Delta M_s$ value.

Furthermore the decay rates $\Gamma_H$ and $\Gamma_L$ of these two mass eigenstates are two more quantities that affect the time evolution of the B_s system. The difference $\Delta \Gamma=\Gamma_L-\Gamma_H$ is also related to a further quantity, the CP violating phase $\Phi_s$. This phase describes the mixing induced CP violation and is related to the angle $\beta$, in the nearly degenerated unitarity triangle obtained from the multiplication of the second and third column of the CKM triangle. The SM expectation value for the $\Phi_s$ phase is very small. Any deviation from SM expectations on B_s oscillation frequency $\Delta \Gamma$ and thus $\Phi_s$ would be an indication of new physics.

It took about two decades to achieve the discovery of B_s mixing. It was among one of the highest priority at Tevatron II. The search was previously performed at various facilities. As seen in previous sections LEP, SLD, UA1 and CDFI [10]. Finally CDFII was able to achieve this discovery thanks to the work on several crucial aspects of the detector upgrade (trigger, particle identification) and thanks to the analysis that exploits at best all the detector assets.

6.4.1 Discovery and measurement of the $B_s$ mixing: The discovery of the B_s mixing and the high precision measurement of the B_s oscillations were reported last year, leading to the result:

$$\Delta M_s=17.77 \pm 0.10\text{(stat)} \pm 0.07 \text{(syst.)} \text{ps}^{-1} [10],$$

with $8 \times 10^{-8}$ probability that a random fluctuation mimics the signal i.e. 5.4 $\sigma$ significance. It gives the following results for the value of $V_{td}$ and of $V_{ts}$ CKM matrix elements:

$$|V_{td}|/|V_{ts}|=0.2060 \pm 0.0007 \text{(stat)} \pm 0.0004 \text{(syst.)} \text{[lat. QCD]}.$$

This result is quite striking as the overall experimental error is about 10 times lower than the theoretical one! Indeed to explore a still possible non standard physics effect, one has to wait for more precise lattice QCD calculations. The current theoretical uncertainty on $\Delta M_s$ is about 14%, how much time and effort it will take to go down to 1 or 2%?

Meanwhile both CDF and D0 are pursuing the exploration of the B_s mixing sector in various different ways by trying to measure the other two related parameters of the B_s mixing sector, namely $\Delta \Gamma$ and $\Phi_s$, in particular by studying the B_s decay mode into $J/\psi\mu^+\mu^-$ $\phi$ ($\rightarrow K^+K^-$) as briefly discussed in the next section.

6.4.2 The $B_s$ lifetime and CP violating phase measurement. D0 investigates in several interesting ways this sector evaluating $\Delta \Gamma_s$ and $\Phi_s$ with different measurements: i) analysis of the time evolution of the polarisation amplitudes in $B_s \rightarrow J/\psi\phi$; ii) measurement of the branching ratio of the decay: $B_s \rightarrow D_s^{(*)}\phi$; iii) measurement of semi leptonic charge asymmetry $A_{SL}$ in $B_s$ decay [10].

i) A direct measurement of $\Delta \Gamma_s$ is performed by D0 based on the process $B_s \rightarrow J/\psi\phi$ with a final state which contains both CP-even and CP-odd amplitudes. Thus the two CP-eigenstates can be separated by their different angular distributions. By assuming the CP violating phase equal to zero, D0 finds:

$$\Delta \Gamma_s=0.12^{+0.08}_{-0.06} \pm 0.02 \text{ ps}^{-1}$$

and,

$$\tau_s=1.52\pm 0.07 \text{ ps}$$

(where $\tau_s$ is the mean lifetime)

The measurement of the CP violating phase is performed by D0 using the $B_s \rightarrow J/\psi\phi$ process, without tagging the initial B_s state. The interference of CP-even and CP-odd amplitudes gives a contribution proportional to $\sin \Phi_s$ provided there is a large width
Likewise CDF is pursuing the exploration of the B_s mixing sector with the study of the process B_s → J/Ψ ϕ in order to determine the B_s lifetime and the CP violating phase. One week after the EPS, the CDF results were delivered based on the complete set of available data, i.e. 1.7 fb^{-1} [10]. CDF has performed a mass-lifetime-angle fit to measure the lifetime difference \( \Delta \tau_s \) between the B_s mass eigenstates; by setting \( \phi_s = 0 \) in the fit, the following results are obtained:

\[
\Delta \tau_s = 0.076^{+0.059}_{-0.063}(\text{stat.}) \pm 0.006(\text{syst.}) \text{ ps}^{-1}
\]

and

\[
\tau_s = 456 \pm 13(\text{stat.}) \pm 7(\text{syst.}) \mu \text{m}
\]

where \( \tau_s \) is the extracted mean B_s lifetime [10]. This is currently the most precise measurement and it agrees well with the world average B^0 lifetime as predicted by theory. Because of the biased fit result, a confidence region following the procedure suggested by Feldman and Cousins is shown in Fig.10, instead of the point estimate for \( \Delta \tau_s \) and \( \phi_s \).

The exploration of the B_s sector has to be further pursued with more data and in all the available ways.
6.4.3  **Direct CP violation in B^±→J/ΨK^±** The SM predicts a small direct CP violation, of about 1%, in this decay process, through b→ccs, due to the interference between the two amplitudes here below:

\[ A_{CP}(B^+\rightarrow J/ΨK^+) = \frac{\Gamma(B^+\rightarrow J/ΨK^-) - \Gamma(B^+\rightarrow J/ΨK^+)}{\Gamma(B^+\rightarrow J/ΨK^-) + \Gamma(B^+\rightarrow J/ΨK^+)} \]

D0 has measured this asymmetry using 1.6 fb\(^{-1}\) recorded data and a large sample of B→J/Ψ(→νν) K data (Fig.11) and found that:

\[ A_{CP}(B^+\rightarrow J/Ψ(1S)K^+) = 0.0067\pm0.0074\text{(stat.)} \pm 0.0026\text{(syst.), world’s best result} [11]. \]

6.4.4  **A first look to the D^0 Mixing sector** CDF has claimed a few weeks after this conference a 3.8 \(\sigma\) evidence for the D^0 mixing [12]. D0 mixing was discovered a few months ago by BABAR followed by BELLE [1]. This evidence is comparable to the one of the B factories and indeed it shows with other interesting results presented at this conference that the charm sector is not anymore a "chasse gardée" of B factories. This is indeed a very promising HF sector at hadron colliders.

6.5  Rare decays and CP violation studies

Rare decays are a rich source of potential new physics effects that more often than not predict much higher decay rates than the Standard Model. Any measured deviation will be a precious indication of new physics. They require very high precision measurements and high luminosity.

6.5.1  **Search for B_{d,s} decay into two muons** In the SM, the Flavour Changing Neutral Current (FCNC) mechanism (here below) is heavily suppressed and predicted to have a branching ratio Br(B \(\rightarrow\) υν) of \((3.42\pm0.54) \times 10^{-9}\). The decay B_{d,s} \(\rightarrow\) μμ is further suppressed by \((V_{td}/V_{ts})^2\) and expected to be \((1.00\pm0.14) \times 10^{-10}\).

Thus SM expects to see zero events at the Tevatron (CDF plus D0), but sizeable new Physics enhancement could be observed induced for instance by Supersymmetry which predicts the branching ratio to be boosted by two orders of magnitude. Both CDF and D0 have looked for such possible deviations. D0 has reported new results on B_{s} \(\rightarrow\) μμ with two analyzed samples of data, one is with 1.25 fb\(^{-1}\) (Run IIa), the second one with 0.75 fb\(^{-1}\) (RunIIb) corresponding to data with the new Silicon layer added near the beam pipe. The D0 result with 2 fb\(^{-1}\) is: Br(B_{s} \(\rightarrow\) μμ) < 7.5 (9.3) \times 10^{-8} at 90% (95%) C.L. Thanks to the good mass resolution, CDF can resolve B_{s} \(\rightarrow\) μμ from B_{d} \(\rightarrow\) μμ. The results from both experiments are: no signal found so far (i.e. with 2fb\(^{-1}\) data). The new CDF result on Br(B_{s} \(\rightarrow\) μμ) is less than \(4.7\times10^{-8}\) at 90% (95%) C.L. This is a factor 17 higher than SM prediction. The B_{d} limit from CDF is of \(1.5(1.8)\times10^{-8}\) at 90% (95%) C.L. This is about 200 times higher than SM prediction and must also be compared to the limit from BABAR: of \(8.3\times10^{-8}\) at 90% C.L. The results of CDF with 2fb\(^{-1}\) are the world’s best limits [13].
\( \mu \mu \) is proportional to \((\tan \beta)^6\) where \(\tan \beta\) is the ratio of vacuum expectation values of the two neutral CP-even Higgs fields. If \(\tan \beta\) is large, such decay could be observed at the Tevatron. For Minimal Flavour Violating (MFV) models \(B_d \to \mu \mu\) remains suppressed relative to \(B_s \to \mu \mu\). This may not be true for non MFV models such as R-parity violating (RPV) SUSY [13]. Thus a simultaneous observation of \(B_{ds} \to \mu \mu\) decays can be important in determining the flavour structure of new Physics. Furthermore, these decays have a strong correlation with the anomalous muon magnetic moment, dark matter nucleon scattering cross-sections and Higgs mass. This shows the importance of studying them and of being able to disentangle \(B_s\) from \(B_d\), not very easy to achieve experimentally.

6.5.2 Search for non resonant decay of \(B\) into \(\mu \mu\) plus hadron. The non-resonant decay of \(B_{u,d,s}\) into a pair of muons plus one hadron via box or penguin diagrams would allow new physics to be observed through interference with SM amplitudes. BABAR and BELLE have already observed \(B_u\) decay into \(\mu \mu K\) and \(B_d\) into \(\mu \mu K^*\). Still missing the observation of \(B_s\) decay into \(\mu \mu \phi\) which is predicted to be with a branching ratio of \(1.6 \times 10^{-6}\) by the SM. The goal at the Tevatron is to re-establish the \(B_{u,d}\) signals in the Tevatron data and to discover \(B_s\) into \(\mu \mu \phi\). Based on 1 \(\text{fb}^{-1}\) data, CDF has identified these decays and measured their corresponding \(Br\) to be:

\[
Br(B^+ \to \mu^+ \mu^- K^+) = [0.60 \pm 0.15(\text{stat.}) \pm 0.04(\text{syst.})] \times 10^{-6} \text{ with 45 events yield (4.5 } \sigma \text{ significance)}
\]

\[
Br(B^0 \to \mu^+ \mu^- K^*) = [0.82 \pm 0.31(\text{stat.}) \pm 0.10(\text{syst.})] \times 10^{-6} \text{ with 18 events yield (2.9 } \sigma \text{ significance).}
\]

They are in good agreement and with comparable uncertainties to those obtained by the B-factories. CDF and D0 have searched for the decay \(B_s\) into \(\mu \mu \phi\) [13]. The reported results are on 450 \(\text{pb}^{-1}\) data for D0 and 920 \(\text{pb}^{-1}\) data for D0. The results are summarized in the plots here below; D0 does not find a signal when expecting 1.6\(\pm \)0.6 events. CDF finds 11 events when expecting 3.5\(\pm \)1.5 events.

---

**Fig 12:** the evolution of the 95\%CL limits on \(Br(B_s \to \mu \mu)\) with time (left); latest results from D0 and CDF in the study of this decay channel both with 2\(\text{fb}^{-1}\) data. (right plots)

**Fig 13:** Invariant mass \((\mu \mu \phi)\) distribution in D0 (left) and CDF (right)
This corresponds to a 2.4σ significance and leads to \( \text{Br}(B_s \to \mu^+ \mu^-) < 2.4 \times 10^{-6} \) at 90% C.L. In a Bayesian approach the \( \text{Br} \) is \((1.16 \pm 0.56 \pm 0.42) \times 10^{-6} \).

6.5.3 Search for \( D \) decay into \( \mu \mu \nu \). The rare decays in the \( D^0 \) sector are also very interesting. D0 experiment has searched for this decay \([13]\).

Fig.14 Feynman diagrams for the various possible decays; invariant(\( \pi \mu \mu \)) mass distribution at D0.

Up-type FCNC process as shown on the left diagrams here above, is enhanced in the case of RPV supersymmetry processes or of little Higgs models and thus is a good place to look for new physics. D0 has searched for \( D^+ \to \mu^+ \mu^- \pi^+ \). The branching ratio upper limit is normalized with respect to the process \( D_s^0 \to \phi \pi^+ \to \mu^+ \mu^- \) and \( \text{Br}(D_s^0 \to \phi \pi^+ \to \mu^+ \mu^-) \times \text{Br}(\phi \to \mu^+ \mu^-) = 0.46 \) at 90% C.L.. By using the central values for the normalizing fractions D0 obtains: \( \text{Br}(D^+ \to \mu^+ \mu^-) \leq 4.7 \times 10^{-6} \) at 90% C.L. If compared with the \( e^+e^- \) facilities, FOCUS, CLEO and BABAR, in the \( e^+e^- \pi^+ \pi^- \) channel, D0 result is the world best result.

6.5.4 Search for \( B \) and \( B_s \) decay into hadrons. Thanks to its sophisticated tracking triggering system CDF is pioneering the study of fully reconstructed hadronic decays such as \( B^0, B^0_s \), into a pair of charged hadrons. This is a useful tool for probing the CKM matrix. These decays are sensitive to new physics contributions through the Penguin diagrams and also via anomalous CP asymmetries (\( A_{\text{CP}} \)). CDF observed three new rare decay modes using 1fb\(^{-1}\) (Fig.15) with the following number of events \( N_{\text{raw}} \):

\[
\begin{align*}
N_{\text{raw}}(B_{s}^0 \to K^- \pi^+) &= 230 \pm 34 \text{(stat.)} \pm 16 \text{(syst.)}, 8\sigma \text{ significance}, \\
N_{\text{raw}}(\Lambda_{b}^0 \to p \pi^-) &= 110 \pm 18 \text{(stat.)} \pm 16 \text{(syst.)}, 6\sigma \text{ significance}, \\
N_{\text{raw}}(\Lambda_{b}^0 \to p K^-) &= 156 \pm 20 \text{(stat.)} \pm 11 \text{(syst.)}, 11\sigma \text{ significance}.
\end{align*}
\]

and the upper limits on the annihilation modes

\[
\begin{align*}
B^0 \to \pi^- \pi^+ \quad \text{and} \quad B_{s}^0 \to K^- K^+ \text{are extracted from:}
\end{align*}
\]

\[
\begin{align*}
&f_\pi BR(B^0 \to \pi^- \pi^+) = 0.007 \pm 0.004 \text{(stat.)} \pm 0.005 \text{(syst.)} \\
&f_\pi BR(B^0 \to K^- K^+) = 0.020 \pm 0.006 \text{(stat.)} \pm 0.008 \text{(syst.)}
\end{align*}
\]

It gives:

\[
\begin{align*}
\text{Br}(B^0 \to K^- K^+) = (0.39 \pm 0.16 \pm 0.12) \times 10^{-6} \text{ (} < 0.7 \times 10^{-6} \text{ at 90\% C.L.,}) \\
\text{Br}(B_{s}^0 \to \pi^- \pi^+) = (0.53 \pm 0.31 \pm 0.0) \times 10^{-6} \text{ (} < 1.36 \times 10^{-6} \text{ at 90\% C.L.)}.
\end{align*}
\]

Fig 15 Invariant \( \pi \pi \)-mass distribution.
These are the world’s best limits for $B^0_s \rightarrow \pi^+\pi^-$ while the resolution is the same than for the B-factories for $B^0 \rightarrow K^*K$ [13]. Both modes are annihilation dominated, not yet observed and hard to predict.

6.5.5 Direct CP asymmetry in $B^0$ and $B^0_s$: By studying the hadronic decays of $B^0$ and $B^0_s$, CDF checks if the observed direct CP violation observed in $B \rightarrow K\pi$ is due to new physics and also the SM prediction of equal violation in $B_s \rightarrow K\pi$.

In addition, SM expects a large $A_{CP}(B_s \rightarrow K\pi)$ of 0.37 and of opposite sign to $A_{CP}(B \rightarrow K\pi)$: this is tested as well

$$A_{CP} = \frac{N(B^0 \rightarrow K^-\pi^+) - N(B^0 \rightarrow K^+\pi^-)}{N(B^0 \rightarrow K^-\pi^+) + N(B^0 \rightarrow K^+\pi^-)} = -0.086 \pm 0.023 \text{(stat.)} \pm 0.009 \text{(syst.)}$$

$$A_{CP} = \frac{N(B_s \rightarrow K^-\pi^+) - N(B_s \rightarrow K^+\pi^-)}{N(B_s \rightarrow K^-\pi^+) + N(B_s \rightarrow K^+\pi^-)} = +0.39 \pm 0.15 \text{(stat.)} \pm 0.08 \text{(syst.)}$$

These results are the first measurements of CP violation in the $B_s$ system [13].

7. Concluding remarks

There has been impressive activity in the heavy flavour Physics sector this past year at many different facilities and experiments other than at B-factories, with very important results. It confirms that HFP is becoming a major domain to look for BSM Physics and that HF objects are crucial probes to achieve this exploration. The results obtained in these experiments including in heavy ions are instrumental for the forthcoming experiments at LHC, i.e. ATLAS CMS, LHCb and ALICE. The expertise acquired at hadron colliders will serve not only LHCb but also ATLAS and CMS. HFP embraces QCD, electroweak and BSM Physics it is thus not restricted to only dedicated “B Physics” experiments or facilities. However it is very demanding from the point of view of detecting capabilities as it requires very high precision measurements especially on the detector parts related to the identification and measurement of heavy flavour objects. This means that the actual LHC experiments will have to undergo serious upgrades in order to be able to probe in depth the heavy flavoured world. This is just a beginning…

8. Acknowledgments

There are a lot of people to be thanked for their help in providing the information and results I tried to summarize in this review. It was indeed a much wider topic than anticipated and I should apologize for all the results I was not able to include in this review, especially those from BES and KLOE and other very experimental results in the reviewed topics. All my thanks to the Physics conveners, the B Physics conveners and the spoke persons of H1 and ZEUS, CDF and D0, PHENIX and STAR, CLEO and LHC and to all the speakers in the parallel sessions that did a superb job and gave great talks that provided me with all this impressive material. This talk is very much indebted to all of them and also the work of so many people in these various experiments, without forgetting the theoreticians.

References

(more details and updates in a hep-ph paper to appear on this contribution)

[1] Junji Haba, ‘Heavy Flavour Physics at B factories’, these Proceedings and references therein

[2] D. Albaneo, ‘Review of experimental searches for B, oscillations’, La Thuile 2001.

[3] T. Wengler, ‘Hadronic photon-photon decay at LEP’, these Proceedings

[4] Hanna Mahlke, contribution to the DIS 2007 conference; see DIS Proceedings.

[5] M. Artuso, D. Cassel, S. Stone, I. Shipsey these Proceedings.

[6] Olaf Behnke, ‘Experimental Tests of QCD’, these Proceedings and references therein.

[7] \(A.\) Y. Molina (ZEUS) & P. Bellan (ZEUS), M. Turcato, P. Thompson (H1), C. Niebuhr: these Proceedings.

[8] A. Dainese et al., Heavy Quark Energy Loss at RHIC and LHC, hep-ph0601107,
C. Salgado private communication
Jan Rak, ‘Heavy Ion Physics’, these Proceedings and references therein
J. Biecelik (STAR) and A. Dion (PHENIX): these proceedings and references therein.

[6] UA1 Collaboration, Phys. Lett. B, 256, 1991 and CDF Collaboration; PRL 68, 1992.

[7] V.M. Abazov et al., D0 collaboration, ‘The Upgraded D0 detector’, NIM A565:463-537, 2006
R.Blair et al., CDF Collaboration, The CDF II Detector, Technical Design Report, FERMILAB-Pub-96/390-E, and a list of NIM papers on the various sub detector upgrades, among which:
B. Ashmankas et al., The CDF Silicon Vertex Trigger, NIM A518:532-536, 2004
D. Acosta et al., A Time-Of-Flight Detector in CDF II, NIM A518:605-608, 2004
T. Affolder et al., CDF Collaboration, The CDF II Detector, Technical Design Report, FERMILAB-Pub-96/390-E, and a list of NIM papers on the various sub detector upgrades, among which:
B. Ashmankas et al., The CDF Silicon Vertex Trigger, NIM A518:532-536, 2004
D. Acosta et al., A Time-Of-Flight Detector in CDF II, NIM A518:605-608, 2004
T. Affolder et al., COT Central Outer Tracker, NIM A526:249, 2004
A. Annovi (CDF), S. de Cecco (CDF), A. Attal (CDF) and M. Ahsan (D0), these Proceedings.
M.L. Mangano et al., ALPGEN, a generator for hard multiparton processes in hadronic collisions, JEHP 0307:001, 2003, hep-ph/0206293.
[7] V.M. Abazov et al., D0 collaboration, ‘The Upgraded D0 detector’, NIM A565:463-537, 2006
R.Blair et al., CDF Collaboration, The CDF II Detector, Technical Design Report, FERMILAB-Pub-96/390-E, and a list of NIM papers on the various sub detector upgrades, among which:
B. Ashmankas et al., The CDF Silicon Vertex Trigger, NIM A518:532-536, 2004
D. Acosta et al., A Time-Of-Flight Detector in CDF II, NIM A518:605-608, 2004
T. Affolder et al., CDF Collaboration, The CDF II Detector, Technical Design Report, FERMILAB-Pub-96/390-E, and a list of NIM papers on the various sub detector upgrades, among which:
B. Ashmankas et al., The CDF Silicon Vertex Trigger, NIM A518:532-536, 2004
D. Acosta et al., A Time-Of-Flight Detector in CDF II, NIM A518:605-608, 2004
T. Affolder et al., COT Central Outer Tracker, NIM A526:249, 2004
A. Annovi (CDF), S. de Cecco (CDF), A. Attal (CDF) and M. Ahsan (D0), these Proceedings.
M.L. Mangano et al., ALPGEN, a generator for hard multiparton processes in hadronic collisions, JEHP 0307:001, 2003, hep-ph/0206293.
[8] A. Annovi (CDF), S. de Cecco (CDF), A. Attal (CDF) and M. Ahsan (D0), these Proceedings.
[9] A. Annovi (CDF), S. de Cecco (CDF), A. Attal (CDF) and M. Ahsan (D0), these Proceedings.
[10] A. Abulancia et al. CDF Collaboration, Observation of B0s - ϒμμ oscillations, Phys.Rev.Lett, 97:242003, 2006 and references therein.
M. Milnik, Bs Mixing and B Hadron lifetimes at CDF, these Proceedings, hep-ex 0710.3498v1.
P. Ball, Probing New Physics Through Bs Mixing, hep-ph0703245, and references therein
T. Kuhl (D0), K. Holubyev(D0), these Proceedings
V.M. Abazov et al., D0 Collaboration, Combined D0 measurements Constraining the CP-Violating Phase & Width Difference in the Bs System, Phys.Rev.D 76, 057101(2007)
T. Kuhr, ‘Lifetime Difference and CP asymmetry in the Bs→J/Ψφ decay at CDF’, in Proceedings of SUSY’07 Conference, July 2007, Karlsruhe (Germany).

CDF Collaboration, ‘Evidence for D0-antiD0 Mixing using the CDF II detector’, CDF Public Note, October 18, 2007 and CDF paper in preparation.

D0 collaboration, Measurement of Direct CP Violation in B+→J/Psi K+, 5405-CONF

M. Milnik (CDF), A. Maciel (D0), M. Morello (CDF). These Proceedings and also:
CDF Collaboration, Search for Bs→μμ and B0→μμ Decays in 2 fb^-1 of p#bar{p} collisions, with CDF II, CDF Public Note 8956, and references therein.
D0 Collaboration, A New Upper Limit for the Rare B^0→μμ Using 2fb^-1 of Run II data, 5344-CONF, (March 2007) and references therein.
CDF Collaboration, Search For the Rare Decays B^+→μμ K^+, B^0→μμ K^0 and B^0→μμ φ, Public Note 8543, Dec 2006, and references therein.
V.M. Abazov et al., D0 Collaboration, Search for FCNC D-Meson Decays, Submitted to PRL.
CDF Collaboration, Measurement of Branching Fractions and Direct CP Asymmetries of B^0→h+h^- decays in 1 fb^-1, Public Note 8479 and references therein.