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# $B$ physics at the DØ experiment

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**Abstract.** First results reveal good capabilities of DØ experiment to study $B$ physics. A new tracking system, high reconstruction rate and efficient trigger allow the selection of many interesting $B$-hadron decay modes such as semileptonic decays and final states involving $J/\psi$. This talk presents preliminary measurements of $B$-hadron properties in these modes, together with future plans and perspectives of $B$ physics in DØ.

## 1 Introduction

Experiments at hadron colliders provide excellent opportunities to study $B$ physics. The production cross section of $b\bar{b}$ pairs at Tevatron (2 TeV) is about 150 $\mu b$, which is significantly higher than the cross section at $e^+e^-$ colliders: 7 nb for $e^+e^- \to Z^0 \to b\bar{b}$ and 1 nb for $e^+e^- \to \Upsilon(4S) \to b\bar{b}$. Contrary to $\Upsilon(4S)$ $B$-factories, where only the ground $B_u$ and $B_d$ states are produced, experiments at hadron colliders can study all other $B$-hadrons, such as $B_s$, $\Lambda_b$, $B_c$, as well as $b$-quark resonances, like $B^{**}$. However, much higher background, $\sigma_{tot} = 75$ mb, imposes more sophisticated selection of interesting events.

Due to these advantages, the $B$ physics program at hadron collider includes:

- discovery and study of new particles: $B_c$, $\Xi_b$, $\Omega_b$, etc.;
- spectroscopy of $B$-hadrons;
- precise measurement of lifetime and masses of $B$-hadrons;
- $B_d$ and $B_s$ mixing, $\Delta\Gamma(B_s)$;
- CP-violation in the $B_d$ and $B_s$ systems;
- properties of $B$-hadron decay;

Some of these measurements, e.g., the physics of $B_s$, are possible only at hadron colliders, and the precision of many others, like the lifetime and masses of $B$-hadrons, is comparable to that of $\Upsilon(4S)$ factories, so that the $B$-physics at hadron colliders can be rich, productive and complementary to the measurements at $e^+e^-$ machines.

**Table 1.** Performance of the DØ initial state tagging methods

| | Jet Charge | Opposite Muon |
|---|---|---|
| efficiency ($\epsilon$) | $55 \pm 4\%$ | $8 \pm 2\%$ |
| dilution (D) | $21 \pm 11\%$ | $64 \pm 30\%$ |
| $\epsilon D^2$ | $2.4 \pm 1.7\%$ | $3.3 \pm 1.8\%$ |

## 2 Upgraded DØ detector

The DØ detector [1] was considerably upgraded [2] for the Run II operation. Its new layout is shown in Fig. 1. The most important modification, essential for all $B$-physics studies, is the new tracking system. It includes a 2 Tesla solenoid, 8 layers of silicon vertex detector (SMT), 16 silicon micro-strip disks, placed perpendicularly to the beam direction, 8 cylinders of scintillating fibre tracker (CFT), and preshower detectors, which aid in electron identification. The detailed view of the DØ tracking system is shown in Fig. 2.

The full length of the tracking system along the beam is $\simeq$2.7 m and the outer radius of the CFT is $\simeq$52 cm. Such a compact tracking system nevertheless allows the measurement of the momentum of charged particles with a precision of $\Delta p_T/p_T^2 \simeq 0.002/(\mathrm{GeV/c})$. The precision of track impact parameter is about 13 $\mu$m for tracks with $p_T > 10$ GeV/c, see Fig. 3. The tracking acceptance extends up to the track pseudo-rapidity $|\eta| < 3.5$.

Since the decay products of $B$ hadrons have fairly low momentum, e.g., $\sim$200 MeV/c in channels involving $D^{*+}$, the tracking system should efficiently reconstruct such particles. This capability of the DØ tracking system is illustrated by the reconstruction of decays $\Xi^\pm \to \Lambda\pi^\pm$ and $\Omega^\pm \to \Lambda K^\pm$, shown in Fig. 4. Additionally, observation of these decays with low background opens interesting possibilities of $b$-baryon physics at DØ.

Another modification of the DØ detector is the enhanced trigger system. Only the single muon and di-muon trigger were used for the $B$-physics studies so far. These triggers select muons with pseudo-rapidity $|\eta| < 2$ and transverse momentum $p_t > (2-3.5)$ GeV/c. Recently, the matching of reconstructed tracks and muons was added to the triggers, significantly improving their performance.

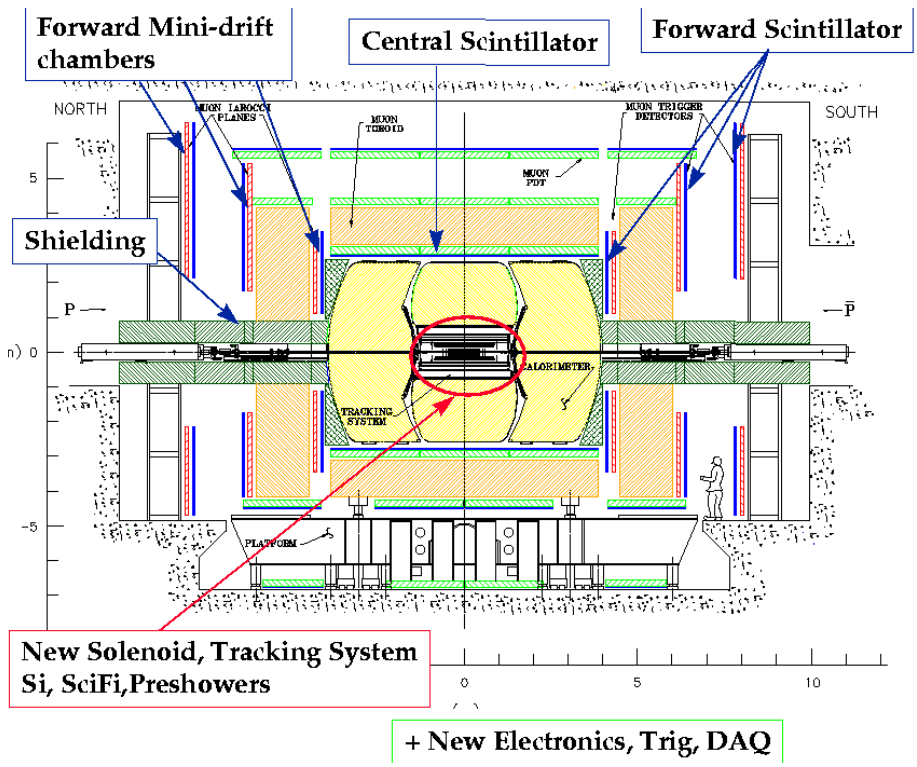


**Fig. 1.** The Upgraded DØ detector

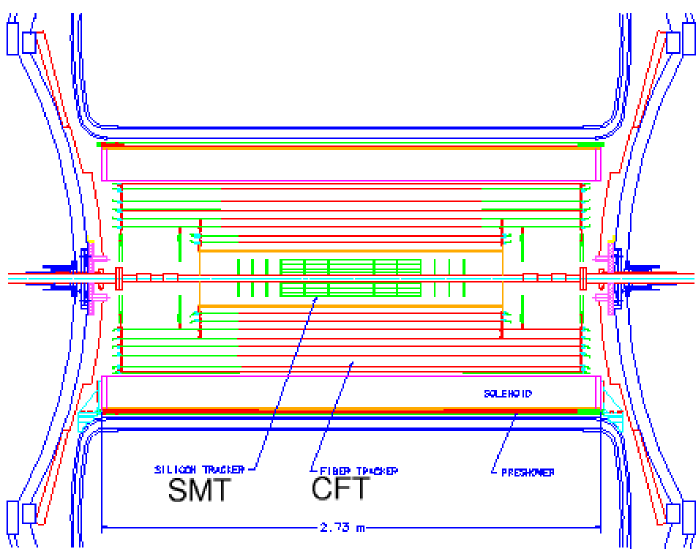


**Fig. 2.** The DØ tracking system

## 3 Current DØ analyses

A basic measurement for $B$ physics is the $b$-quark production cross section. It is important for understanding quark dynamics and tuning theoretical models, which describe quark interactions in hadron collisions. The $b$-jet cross section as a function of the jet energy measured in DØ experiment is shown in Fig. 5. Although only a small part (3.4 pb$^{-1}$) of available data is used, this measurement has a reasonable precision, comparable with theoretical uncertainties. The cross section is compatible with the DØ Run-I result [3] and is about 2 times higher than the theoretical expectations.

A new direction of $B$-physics studies in the DØ experiment, which was not possible in Run-I, is the study of exclusive $B$ decays and semi-exclusive $B$ decays, like decays involving $J/\psi \to \mu^+\mu^-$. About 130000 events con-

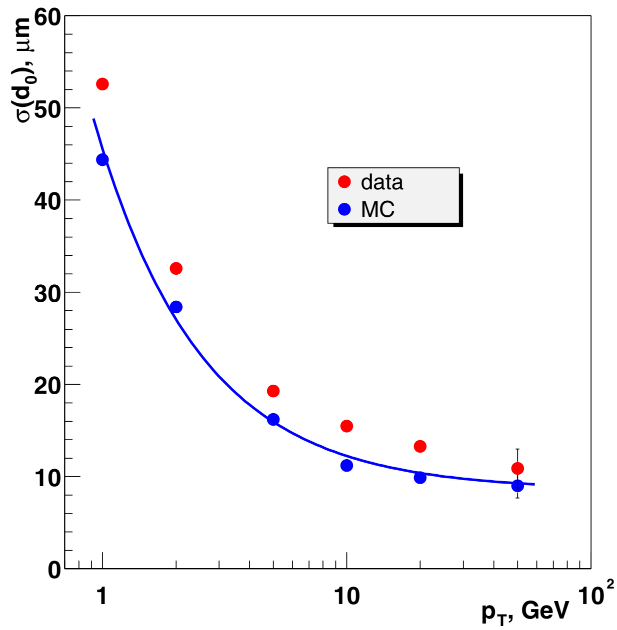


**Fig. 3.** Impact parameter precision versus track transverse momentum

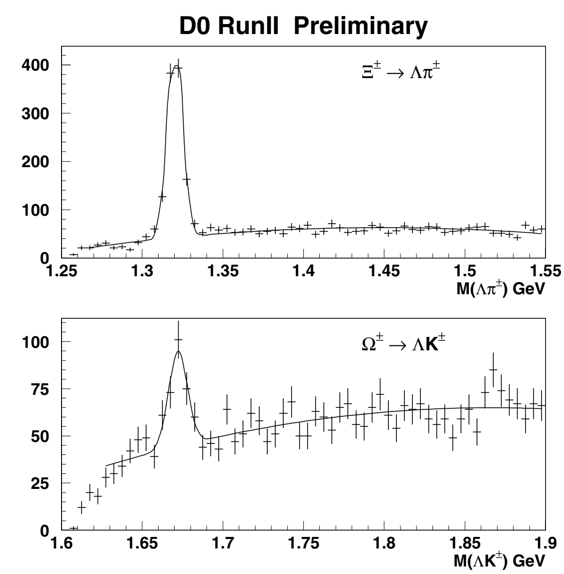


**Fig. 4.** $\Xi^{\pm} \to \Lambda\pi^{\pm}$ and $\Omega^{\pm} \to \Lambda K^{\pm}$ reconstructed in DØ experiment

taining a $J/\psi$ were selected in the first 47 $\mathrm{pb}^{-1}$ of data. Fig. 6 shows the invariant mass distributions of $J/\psi K^{+}$ and $J/\psi K^{*}(892)$ systems, where clear peaks of $B^{\pm}$ and $B_d$ are observed. These events are used to measure the lifetime of $B$-hadrons.

The DØ experiment measures both the inclusive average lifetime of all $B$-hadrons using the total $J/\psi$ sample, and the exclusive $B^{+}$ lifetime using decays $B^{\pm} \to J/\psi K^{\pm}$:

$$\tau_B = 1.561 \pm 0.024 \pm 0.074 \text{ ps (inclusive } B \text{ lifetime)}$$
$$\tau_B = 1.76 \pm 0.24 \text{ ps (Exclusive } B^{\pm} \text{ lifetime)}$$

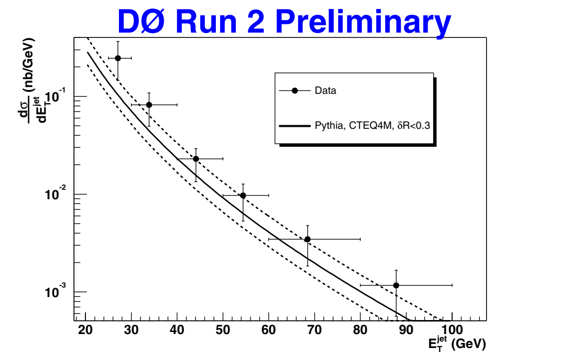


**Fig. 5.** $b$-jet cross section as a function of the jet energy

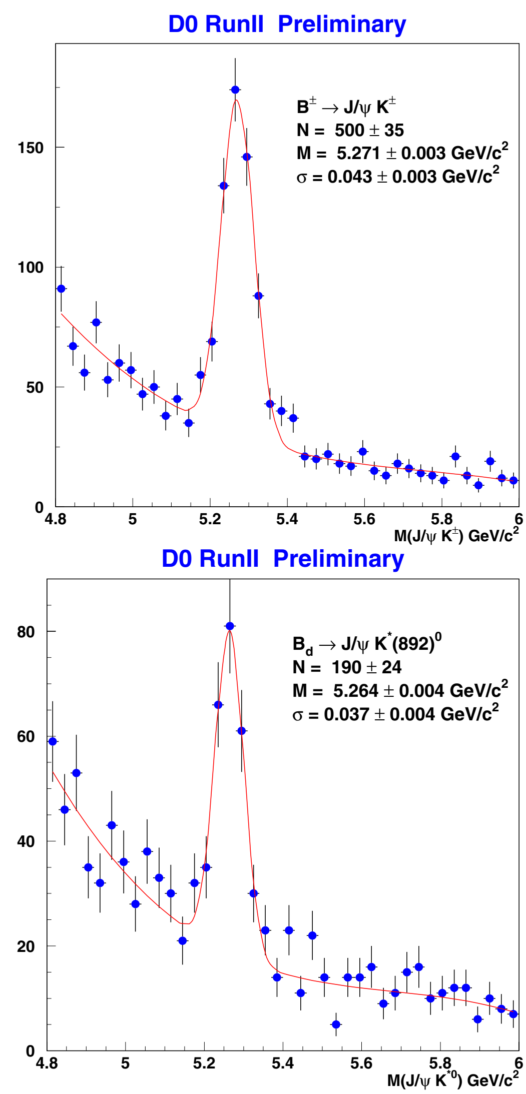


**Fig. 6.** Reconstruction of exclusive $B$ decays with $J/\psi$

Both measurements are consistent with the world average values [4]. An example of the lifetime fit to the $J/\psi K^{\pm}$ sample is shown in Fig. 7.

As an important step towards the measurement of $B_d$ and $B_s$ oscillations, The DØ collaboration has developed methods for tagging the initial state of the $B$ hadron. Cur-

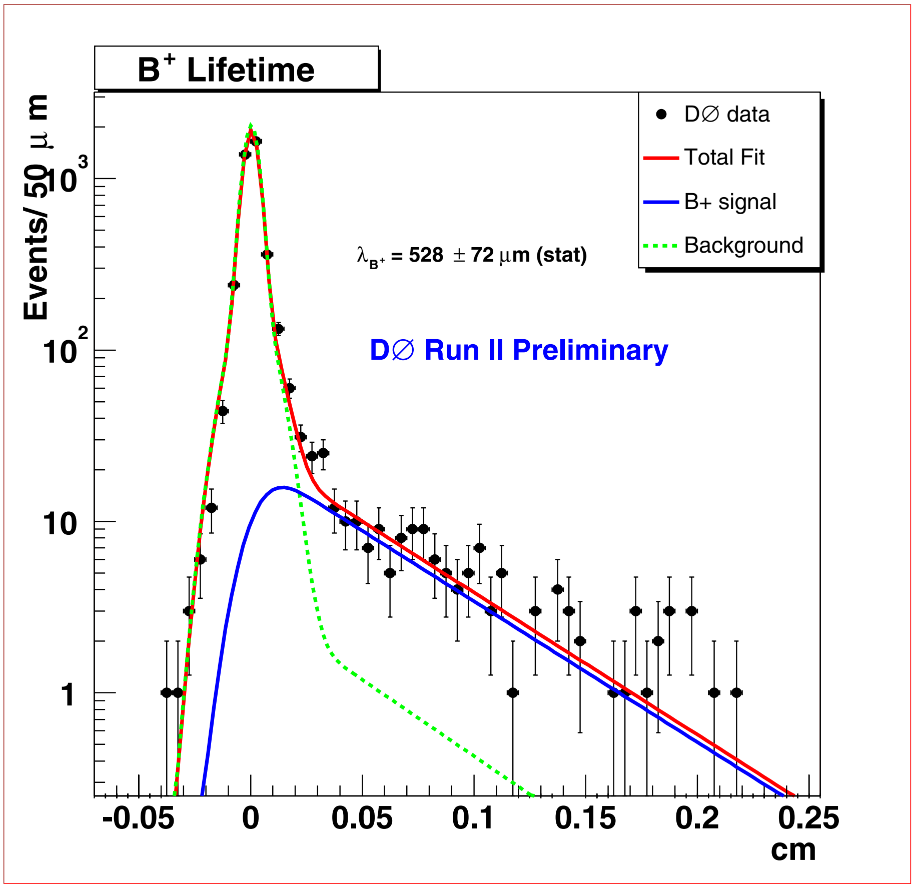


**Fig. 7.** Proper time distribution of $B^{\pm} \to J/\psi K^{\pm}$ events

rently, two complementary methods are pursued: the jet charge tagging and opposite muon tagging. The performance of both methods, given in Table 1, is determined directly in data using $B^{\pm} \to J/\psi K^{\pm}$ sample. For both methods it is close to expectations from simulation values.

Another direction of the DØ $B$-physics program is the study of $CP$-violation in $B$-hadron decays. The new tracking system allows the reconstruction of the "golden" channels: $B_d \to J/\psi K_S^0$ and $B_s \to J/\psi\phi$, see Fig. 8. It should be stressed that the measurement of $CP$-asymmetry in $B_s$ decays is possible only at hadron colliders. The DØ experiment has good sensitivity to this channel, and $62 \pm 12$ $B_s \to J/\psi\phi$ decays were reconstructed in the first 47 pb$^{-1}$ of data with relatively low background, so that $\sim 2000$ $B_s \to J/\psi\phi$ decays can be expected in $1 fb^{-1}$ of data.

The DØ experiment has also selected $\Lambda_b$ baryon in decays $\Lambda_b \to J/\psi\Lambda$. The properties of $b$-baryons are poorly known at the moment, and DØ expects to make important contribution in the measurement of their mass, lifetime, decay rates etc. Fig. 9 shows the mass distribution of the $J/\psi\Lambda$ system, where the signal of $\Lambda_b$ is observed.

$B$ hadrons in DØ are also selected using the single muon trigger. It allows the detection of their semileptonic decays. The preliminary analysis of a small amount of available data shows very large rate of reconstructed semileptonic $B$-decays available for study. Fig. 10 shows the mass distribution of $K^-\pi^+$ system associated with additional muon in the same jet. A clear signal of $D^0$ from $B \to \mu^- D^0 X$ decay is observed with a reconstruction rate up to 400 events/pb$^{-1}$. Such a strong and clean source of $B$-hadrons opens interesting possibilities for various measurements, including the lifetime of different $B$ hadrons and mixing of $B_d$ and $B_s$. In addition, this sample can be used for different technical studies, like further development of $b$-tagging, initial flavour tagging etc.

## 4 Conclusions

The DØ experiment is a newcomer in $B$ physics and its tracking system became fully operational just about one year ago. Some time will be required to understand and tune the detector performance and adjust the new software for optimized track reconstruction. However, the first preliminary results show excellent capabilities of the DØ experiment for $B$ physics, as the detector can precisely and efficiently measure tracks starting from very low momenta.

Analysis techniques develop very quickly in the DØcollaboration, already at this stage it is able to select almost all important $B$ decays with high rate, so that a large sample of $B$ events is expected for the projected Run-II luminosity. In addition, further improvements in

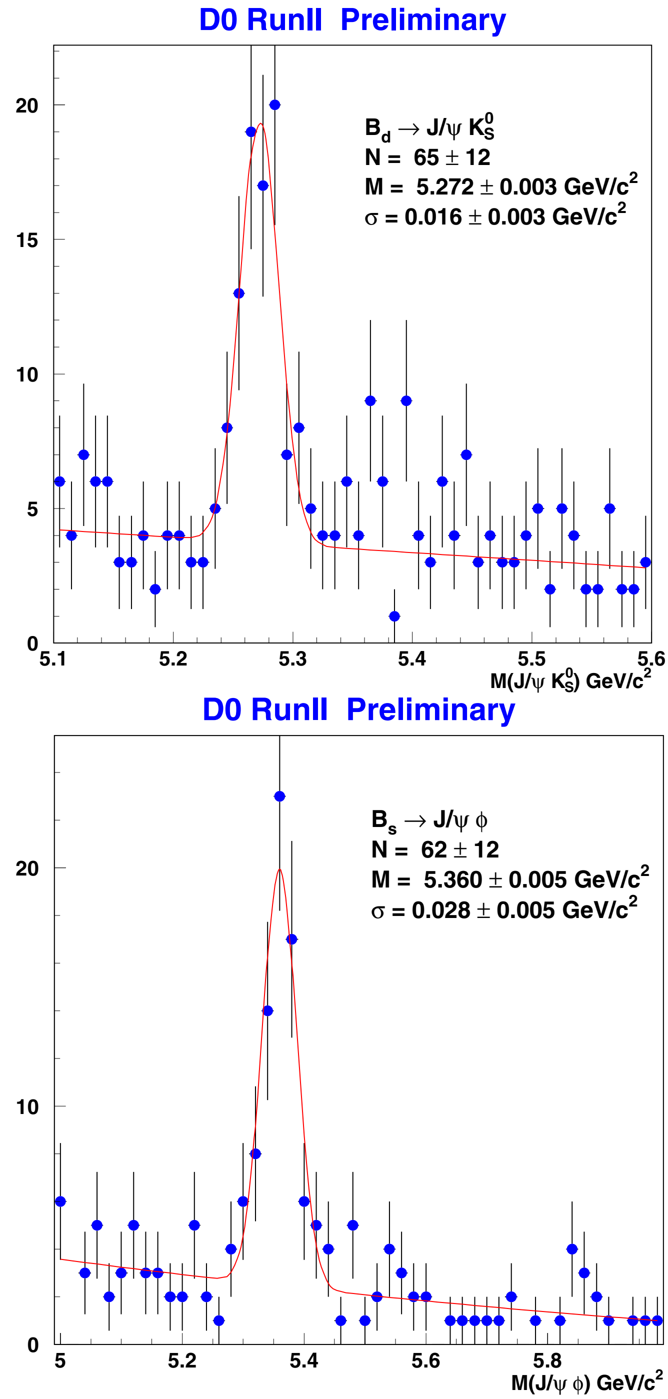


**Fig. 8.** Reconstruction of exclusive $B$ decays with $J/\psi$

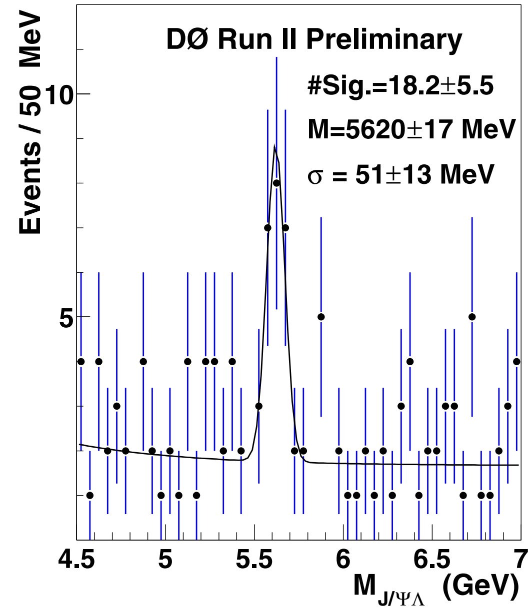


**Fig. 9.** Reconstruction of the $\Lambda_b \to J/\psi\Lambda$ decay

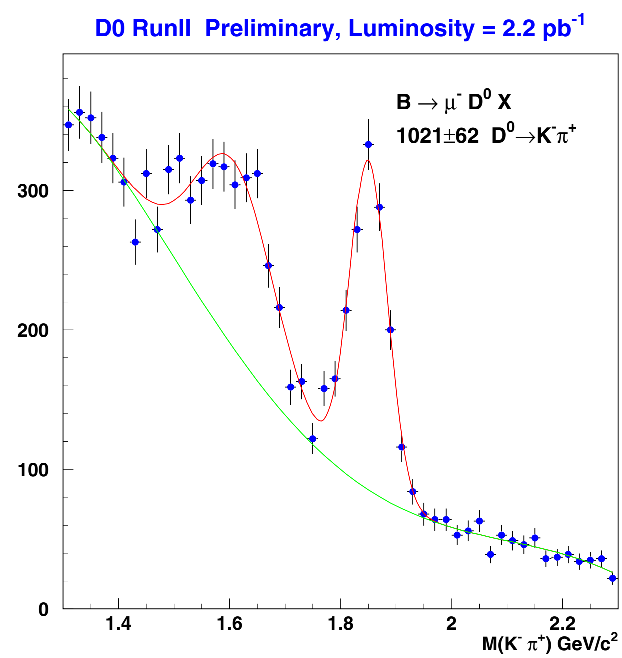


**Fig. 10.** Reconstruction of $D^0 \to K^-\pi^+$ in $B \to \mu^- D^0 X$ decays

the trigger, track reconstruction and event selection, resulting in even better overall performance, are expected soon.

The main direction of the $B$ physics program currently include the study of the $B$-hadron properties in exclusive and semi-exclusive decays involving muons.

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