Motivations of a search for

$D^0 \rightarrow \mu^+\mu^-$ at LHCb

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Motivation and challenges

From SM calculations: $\mathcal{B}(D^0 \rightarrow \mu^+\mu^-) \sim 10^{-18}$ [short-distance processes], increasing to $\mathcal{B}(D^0 \rightarrow \mu^+\mu^-) \sim 10^{-13}$ when long-distance processes are included. *"This prediction is many orders of magnitude beyond the reach of the present generation of experiments. Considering the effects on $D^0 \rightarrow \mu^+\mu^-$ from a number of extensions to the Standard Model: R-parity violating SUSY, multiple Higgs doublets, extra fermions, extra dimensions, and extended technicolor, theorists find that the $D^0 \rightarrow \mu^+\mu^-$ branching ratio can be enhanced by orders of magnitude to the range of 10^{-8} to 10^{-10}, and in the case of R-parity violating SUSY, roughly to the level of the existing experimental limit. Similar enhancements can occur in K and B-decays, but* ***charm decays provide a unique laboratory to search for new physics couplings in the up-quark sector."*** (1)

(1) CDF, 2003 [hep-ex:0308059]

Present Experimental Knowledge

Current available limits @ 90% c.l. are from:

- CDF (hep-ex:0308059 (2003)): $\mathcal{B}(D^0 \rightarrow \mu^+\mu^-) < 2.5*10^{-6}$. pp experiment @ sqrt(s) = 1.96TeV; 65pb^{-1} data.
- BEATRICE (PL B408 469 (1997)): $\mathcal{B}(D^0 \rightarrow \mu^+\mu^-) < 4.1*10^{-6}$. 350GeV/c pions on tungsten/copper target
- E771 (PRL 77 2380 (1996)): $\mathcal{B}(D^0 \rightarrow \mu^+\mu^-) < 4.2*10^{-6}$. 800GeV/c proton silicon interactions

How many D^0 mesons?

Starting from "Rare charm decays in SM and beyond"(1) for calculations

(1)[hep-ph/0112235] (2001) (Burdman, Golowich, Hewett, Pakvasa)

$\mathcal{B}(D^0 \rightarrow \mu^+\mu^-)$: $O(10^{-13})$ [SM; LD effects]; $O(10^{-10})$ [NP];

$\not{R}_{parity}$ $O(10^{-6})$

$\mathcal{L}(\text{LHCb}) = 2 \cdot 10^{32}\ \text{cm}^{-2}\text{s}^{-1}$

$\sigma(c\bar{c}) \sim 6 \cdot \sigma(b\bar{b}) \sim 3\text{mb}$

Assuming $\mathcal{B}$ $O(10^{-10})$ in one year $O(10^3)$ evts [$O(10^{-5}$evts $s^{-1})$] can be produced

What can LHCb do on this channel?

Large background is expected (*see next slide*): how to reject it and select signal events with high efficiency?

- Apply μ-ID criteria
- Cut on μ impact parameter
- Cut on secondary vertex quality
- Cut on di-μ invariant mass
- Cut on D^0 flight length,
- Cut on D^0 impact parameter
- Cut on D^0, μ p_T

Assuming that the L0 trigger efficency for $B^0 \to \mu^+\mu^-$ is not much larger than that for $D^0 \to \mu^+\mu^-$ we can estimate the selection efficiency $\varepsilon_{sel}(D^0 \to \mu^+\mu^-)$ to be $O(1\%)$ ($B^0 \to \mu^+\mu^-$ ~2.5%)

Expected (per year): $O(10)$ reconstructed events (NP) ; NO events (SM)

Work in progress.....

A crucial study that we'd like to perform as soon as possible is to check the impact of various backgrounds on this measurement. Possible sources are:

1. $D^0 \rightarrow hh$ with $h \rightarrow \mu\, \nu$
2. Background from combinatorial (with contributions from double semileptonic decays $D^0 \rightarrow \mu X$)

We'd like also to understand better the contribution from $D^0 \rightarrow \mu^+\mu^-\gamma$ decays that can be high[(1)]:

$\mathcal{B}(D^0 \rightarrow \mu^+\mu^-\gamma)$: (1-3)*10^{-9} [SM; LD effects]; 5*10^{-8} [MSSM]

(1)"B($D^0 \rightarrow \mu^+\mu^-\gamma$) decay in SM and beyond", Fajfer,Singer,Zupan [hep-ph/0209250]

Future plans

- We've started looking for $D^0 \rightarrow \mu^+\mu^-$ directly from primary vertex: we need to decide if taking into account $B \rightarrow D^0 \rightarrow \mu^+\mu^-$ (cross section ~ 1/6; but higher p_T) will help.
- Generic MC events are being produced: we'll start soon to check-study them in order to have a better understanding of selection efficiencies and generator reliability.
- Background studies are crucial: selection algorithm performances will be highly dependent on the backgrounds.