Search for D^0 leptonic decays at Belle

Marko Starič

Jožef Stefan Institute
Ljubljana

ICHEP 2010

Outline

Search for FCNC decays $D^0 \to e^+e^-$ and $D^0 \to \mu^+\mu^-$
and for LFV decays $D^0 \to e^\pm\mu^\mp$

- Motivation
- Analysis steps
- Results
- Conclusions

Belle Collaboration, PRD 81 091102 (2010)

Motivation

Standard Model (SM):

- FCNC decays are highly suppressed in SM
- With long distance contributions $\mathcal{B} \sim 10^{-13}$
- LFV decays are forbidden in SM

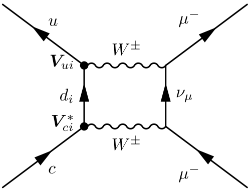
Some New Physics (NP) scenarios:

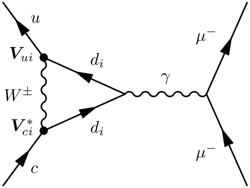
- FCNC branching fractions enhanced by many orders of magnitude
- R-parity violating SUSY: up to 10^{-8} $(\mu^+\mu^-)$
- Leptoquarks: $\mathcal{B}(D^0 \to \mu^+\mu^-) \sim 8 \times 10^{-7}$ (to explain f_{D_s} anomaly)

Charm FCNC and LFV decays probe couplings of up-quark sector in contrast to B and K.

$D^0 \to \mu^+\mu^-$

SM short distance

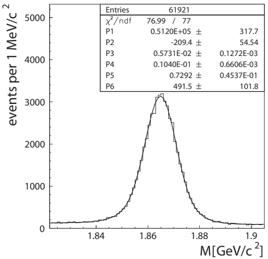




Method

- Our search based on 660 fb^{-1} taken at $\Upsilon(4S)$ and 60 MeV below.
- To suppress background:
  - we use high momentum D^0 from $D^{*+} \to D^0\pi^+$ decays
  - and only D^{*+} coming from continuum process $e^+e^- \to c\bar{c}$
- Measurement relative to well measured $D^0 \to \pi^+\pi^-$

$$\mathcal{B}(D^0 \to \ell^+\ell^-) = \frac{N_{\ell\ell}}{N_{\pi\pi}} \frac{\epsilon_{\pi\pi}}{\epsilon_{\ell\ell}} \mathcal{B}(D^0 \to \pi^+\pi^-)$$

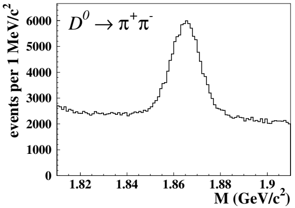


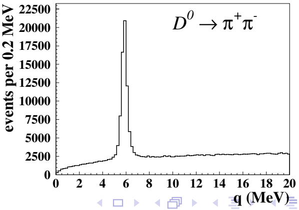
Normalization channel (data)

Fit of $m(\pi,\pi)$ distribution:
Double Gaussian + FSR tail + linear
$\sim 50 \times 10^3$ $D^0 \to \pi^+\pi^-$ decays

Event selection

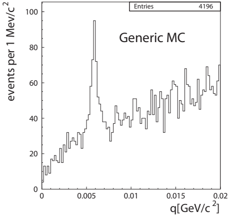
- Standard charged track selection
- Standard particle identification criteria
  - μ, e efficiencies $\sim$90%; pion mis-ID 1.5% (μ), 0.3% (e)
  - π efficiency $\sim$83%
- D^0 daughters fitted to common vertex (decay vertex)
- IP constrained fit of D^0 and π_{slow} to find D^0 production vertex
- $p^{D^{*+}}_{\rm cms} > 2.5$ GeV/c to suppress bkg. (also rejects D^0 from B)
- Candidate D^0 mesons selected using two kinematic observables:
  - invariant mass of D^0 daughters: $1.81 < M < 1.91$ GeV/c^2
  - energy released in D^{*+} decay: $q < 20$ MeV





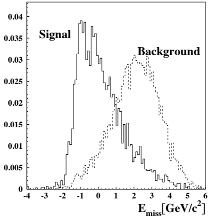
Background

- Background in $D^0 \to \ell^+\ell^-$ according to generic MC simulation
  - 80% from semileptonic B decays
  - 10% from D^0 decays
  - 10% other sources



- Can be grouped into:
  1. smooth combinatorial background
  2. peaking background from mis-ID of $D^0 \to \pi^+\pi^-$

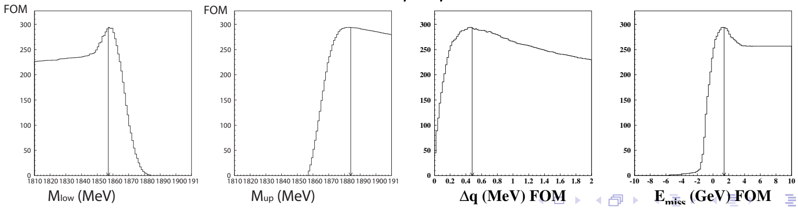
- To further suppress background:
  - requirements on signal region size in M and q
  - maximal allowed missing energy in the event $E_{\rm miss}$ to suppress bkg. from semileptonic B decays (undetected neutrinos!)



Optimization of selection criteria

- For optimization we select:
  - signal region size ($M_{\rm low}$, $M_{\rm up}$, Δq)
  - maximal allowed $E_{\rm miss}$
- Optimized to obtain the best upper limits
- Figure-of-merit: $\mathcal{F} = \epsilon_{\ell\ell}/N_{UL}$
  - $\epsilon_{\ell\ell}$ ... efficiency obtained from tuned signal MC
  - N_{UL} ... Poisson average of Feldman-Cousins 90% C.L. upper limits obtained with expected bkg. and no signal, using generic MC
- Each leptonic decay channel optimized separately

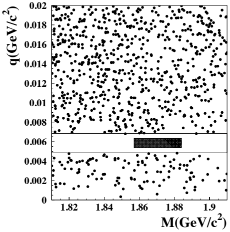
$$D^0 \to \mu^+\mu^-$$



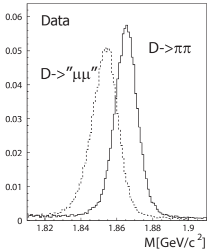
Background estimation

To estimate background inside the signal region we rely (almost) exclusively on experimental data

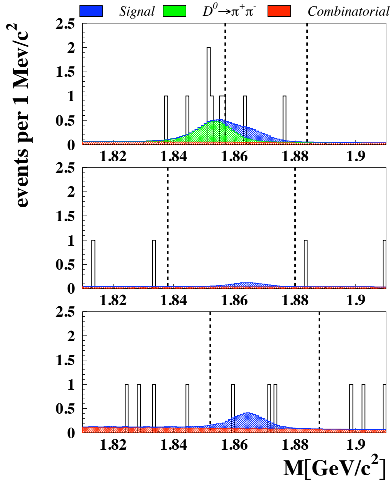
- Combinatorial background (smooth)
  - estimated from 2D sideband in q
  - shape: $f(M,q) \propto (1 - aM)\sqrt{q}$
  - parameter a determined from fit to MC sample



- Peaking background (mis-ID of $D^0 \to \pi^+\pi^-$)
  - estimated from reconstructed $D^0 \to \pi^+\pi^-$ by replacing pion mass with lepton mass and by wighting each event with mis-ID probability
  - mis-ID probabilities measured using $D^{*+} \to D^0\pi^+, D^0 \to K^-\pi^+$
  - resulting distribution normalized absolutely



Results



Channel	events	estim. bkg
$D^0 \to \mu^+\mu^-$	2	3.1±0.1
$D^0 \to e^+e^-$	0	1.7±0.2
$D^0 \to e^\pm\mu^\mp$	3	2.6±0.2

Number of observed events consistent with estimated background

dashed lines are borders of signal region

Upper limits on branching fractions

- Upper limits calculated using program `pole.f`
  - extension of Feldman-Cousins method by inclusion of systematic errors
- Found nearly the same results as with standard Feldman-Cousins

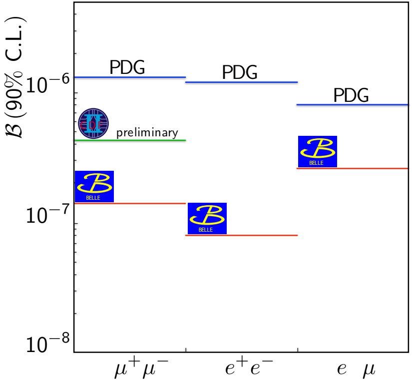
90% C.L. upper limits

$\mathcal{B}(D^0 \to \mu^+\mu^-) < 1.4 \times 10^{-7}$

$\mathcal{B}(D^0 \to e^+e^-) < 7.9 \times 10^{-8}$

$\mathcal{B}(D^0 \to e^\pm\mu^\mp) < 2.6 \times 10^{-7}$

New best upper limits



Conclusions

- We have searched for the FCNC decays $D^0 \to \mu^+\mu^-$ and $D^0 \to e^+e^-$, and the LFV decays $D^0 \to e^\pm\mu^\mp$.
- We found no evidence of these decays.
- We set new upper limits on branching fractions for these decays.
- Our results can further constrain the size of certain R-parity violating couplings.
- The upper limit for $D^0 \to \mu^+\mu^-$ (1.4×10^{-7}) strongly disfavors a leptoquark contribution as the explanation for the f_{D_s} anomaly (prediction: $\mathcal{B} \sim 8 \times 10^{-7}$, I. Dorsner et al., PLB 682, 67 (2009)).