Sensitivity Estimation of the Super*B* Experiment to $D^0 \to Vl^+l^-$ Signals

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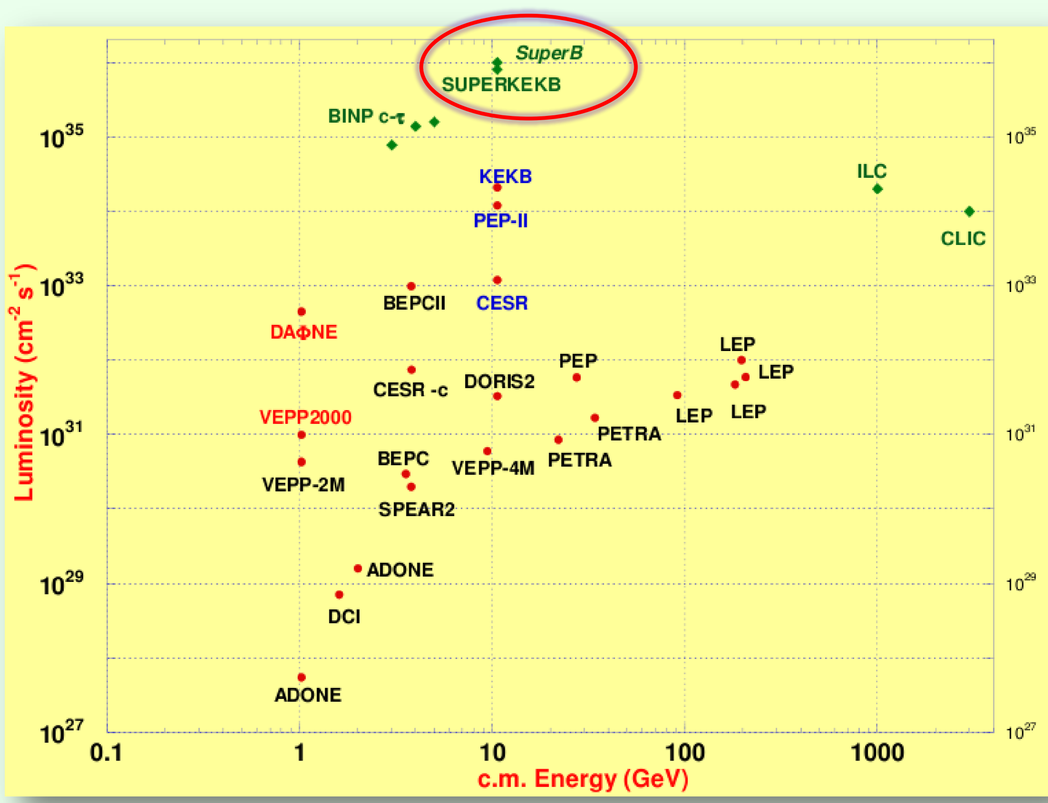
Flavor factories provide a way to study new physics through observation of rare decays occurring via loop diagrams, which lead to processes that are too rare to be directly observable in the current generation of colliders. The proposed Super*B* Factory will provide 100 times more integrated luminosity than current B factories, enabling the measurement and study of rare decays that have never been previously observed. The rare decay $D^0 \to Vl^+l^-$, where V is a vector boson, is one of the promising candidates for new physics signal discoveries due to the small and calculable Standard Model contribution. We present a description of the Super*B* facility and a study of the experiment's statistical sensitivity for these decay modes.

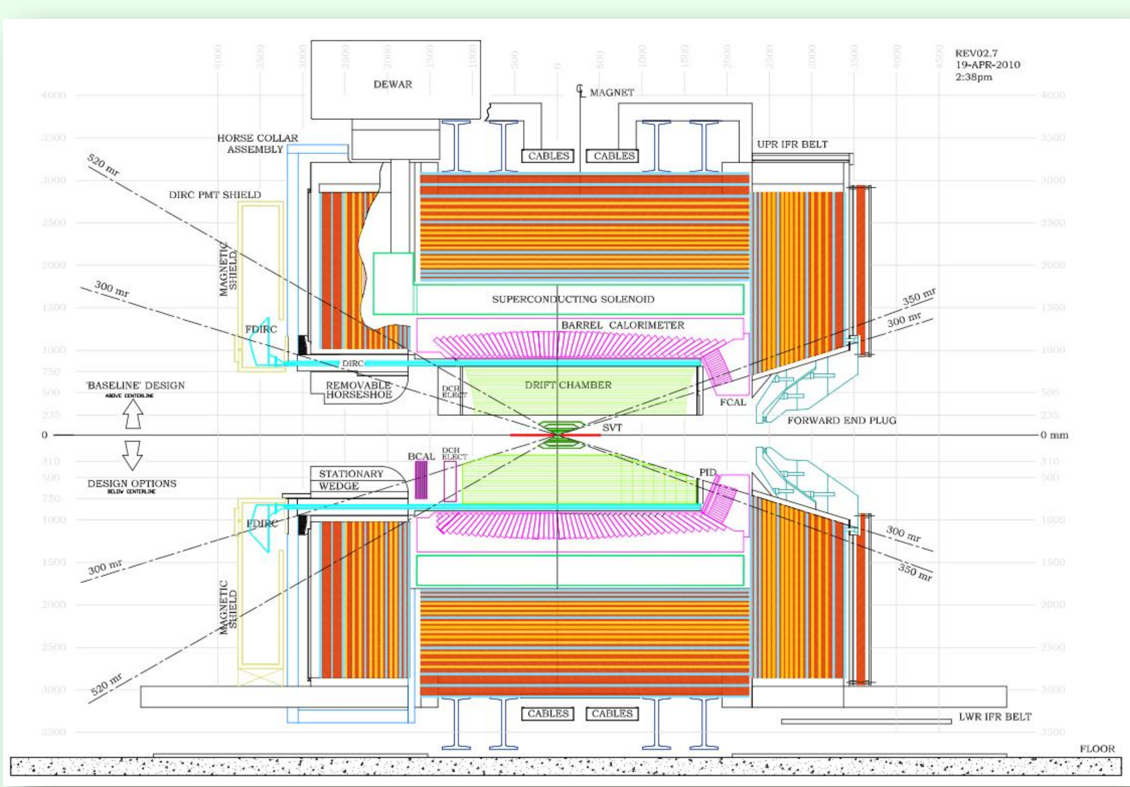
Super*B* Experiment

- Over the last decade, the asymmetric flavor factories PEP-II (*BABAR* detector) and KEKB (*Belle* detector) produced a wealth of flavor-physics results, including precision measurements of standard-model parameters and stringent test of the theory.



Evolution of e^+e^- collider luminosities

- The Super*B* flavor factory[1] will make use of improved accelerator technologies to provide 100 times higher luminosity, reaching $10^{36}\ cm^{-2}s^{-1}$. The integrated luminosity during 5 years of operation will reach 75 ab^{-1}. Super*B* is planned to start running in Frascati, Rome during the second half of the decade.

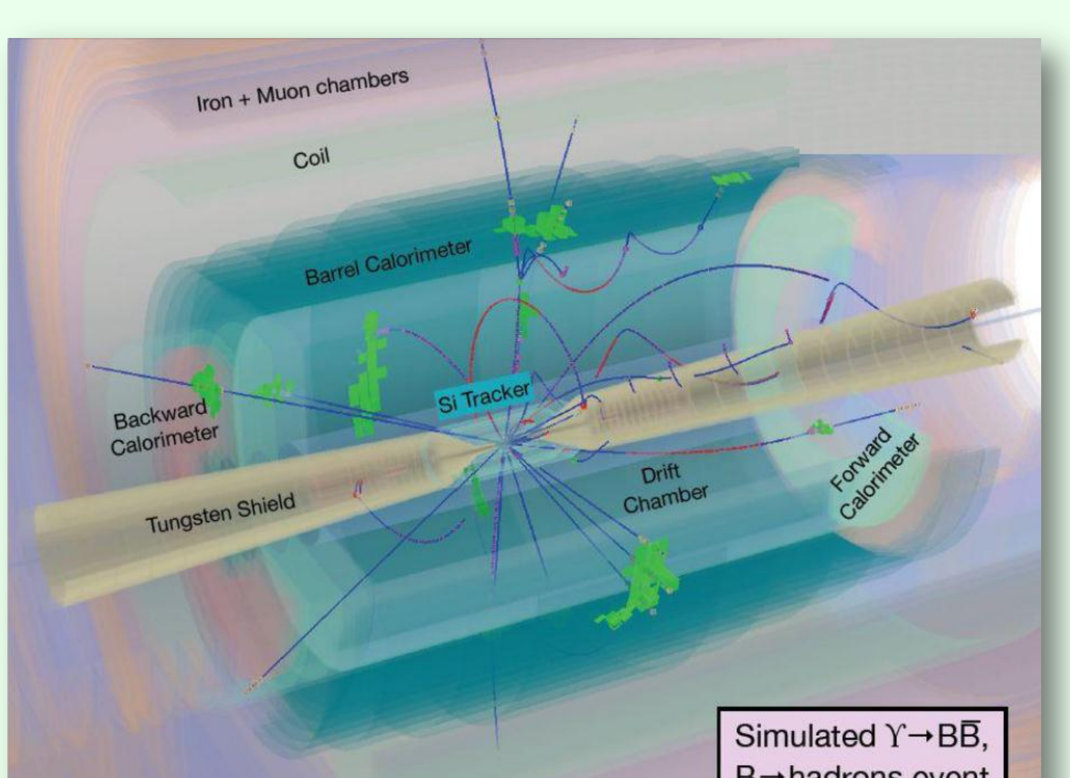


SuperB detector layout. Configurations: Minimal (bottom) and with all the optional parts (top)

- SuperB will run at the energy of $\Upsilon(4S)$ resonance (10.58 GeV), which decays almost exclusively to two B mesons, providing unprecedented statistics for rare b-quark decay research.

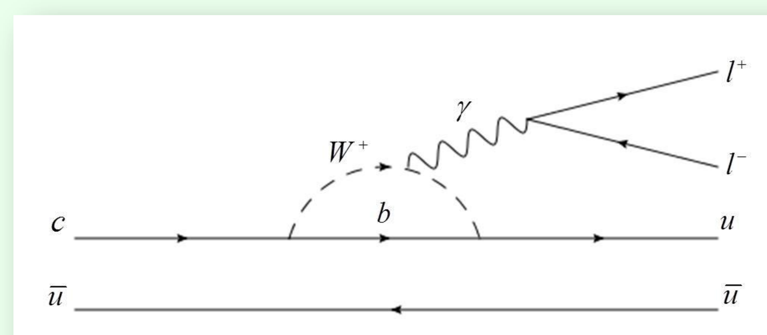
- Super*B* will also generate many $c\bar{c}$ pairs (about 1.03×10^9 per ab^{-1}), allowing new research in c-quark physics through D mesons. In addition, search for signs of lepton number violation through τ decay (about 10^9 per ab^{-1}) will be a major objective at Super*B*.

- Extensive simulations are performed to estimate the potential of Super*B* to discover and study new physics, in various new-physics scenarios.

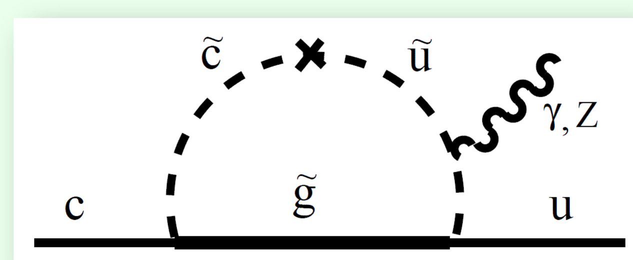


Simulation of an $\Upsilon(4S) \to B\bar{B}$ event in Super*B* detector

Rare Charm Meson Decays $D^0 \to Vl^+l^-$

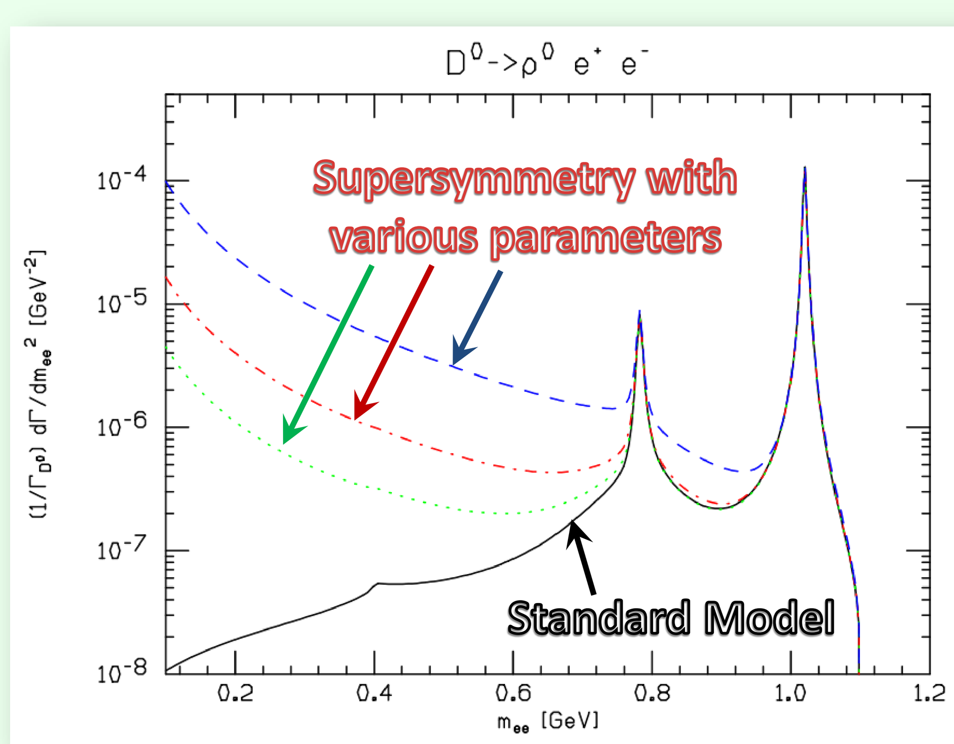


One of the SM loop diagrams contributing to $D^0 \to \rho^0 l^+ l^-$



One of the MSSM diagrams contributing to $D^0 \to \rho^0 l^+ l^-$

- In the Standard Model, the short-range (quark-mediated) contribution to $D^0 \to Vl^+l^-$ decays is highly suppressed, and the long-range (meson-mediated) contribution is expected to dominate. This will show up as resonant peaks in the $M_{l^+l^-}$ spectrum. By studying the spectrum, Super*B* could shed light on the role of long-distance interactions, which is theoretically not well understood.



- Several new-physics scenarios, such as supersymmetry (MSSM), predict potentially much larger branching fractions (relative decay probabilities) for these decays[2][3]. By studying $D^0 \to Vl^+l^-$ decays, Super*B* will help identify the flavor structure of the new physics theory.

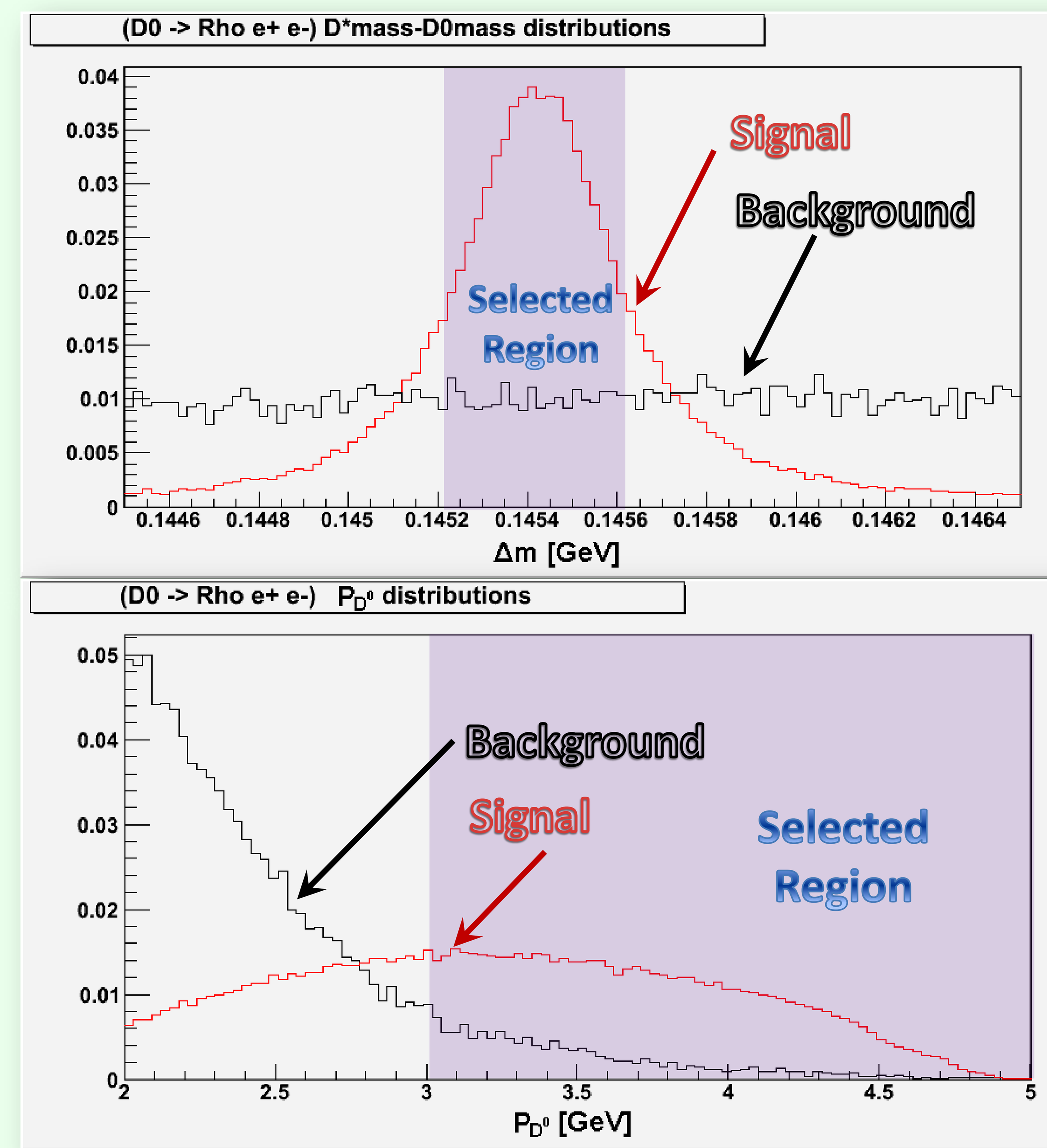
Decay Mode	Branching fractions		
	SM prediction[2]	MSSM prediction[2]	Experimental Limit (90% CL)
$D^0 \to \rho^0 e^+ e^-$	1.8×10^{-6}	1.3×10^{-5}	$< 1.2 \times 10^{-4}$ [4]
$D^0 \to \rho^0 \mu^+ \mu^-$	1.8×10^{-6}	8.7×10^{-6}	$< 2.5 \times 10^{-5}$ [4]
$D^0 \to \rho^0 e^+ \mu^-$	Forbidden	1.4×10^{-5}	$< 2.5 \times 10^{-4}$ [5]

Branching fraction predictions of some rare charm decays and current experimental limits

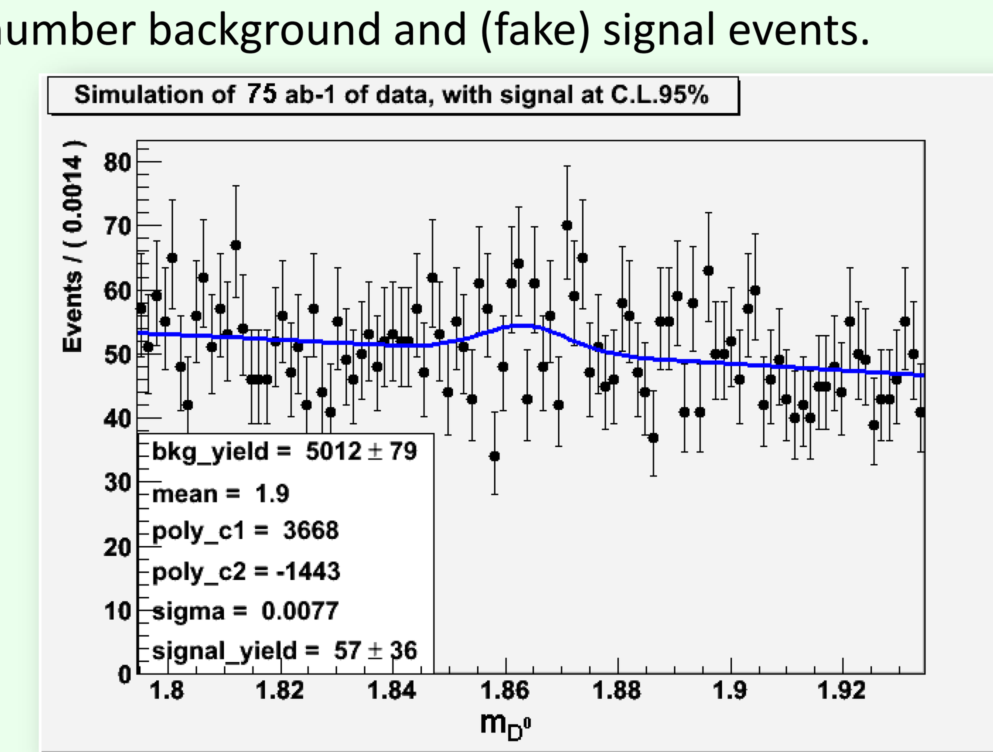
Sensitivity Estimation

In order to estimate the Super*B* sensitivity for these decays, the following steps were performed:

- Simulate signal and background mode using the Super*B* detector model. To obtain clean signal we use $D^* \to D^0\pi$ mode for D^0 creation.
- Optimize cuts on several kinematic parameters to provide the best $sig/\sqrt{bkg}$ ratio. For example:

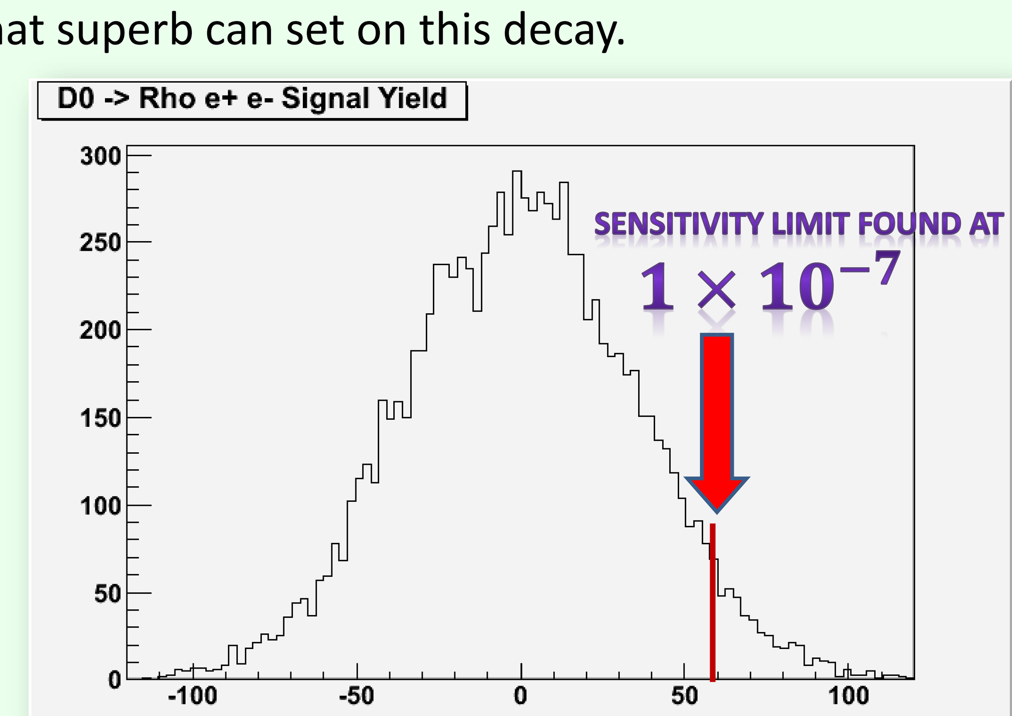


- Fit the m_{D^0} distribution of the selected signal (background) events to a Gaussian (a polynomial).
- Using the background m_{D^0} shape. Generate a large number of parameterized Monte Carlo experiments containing background only, each corresponding to 5 years of Super*B* operation.
- Fit the m_{D^0} distribution of each decay mode to obtain the number background and (fake) signal events.



A 5-year SuperB parameterized experiment with fake signal found at 95% confidence level

- The fake signal yield of the 95th percentile of all experiments gives the 95% confidence-level upper limit that superb can set on this decay.



Distribution of number of $D^0 \to \rho^0 e^+ e^-$ signal events found in background-only parameterized experiments

Super*B* could rule out the MSSM and the SM predictions at more than 95% CL.

If signal is found, the MSSM hypothesis can be tested against the SM hypothesis using the predicted difference in the $M_{l^+l^-}$ spectrum. Work is ongoing to determine the sensitivity for differentiating between the two hypotheses.

The results will be part of the SuperB Technical Design Report, which will be submitted to funding agencies for SuperB funding approval.

[1] SuperB Progress Reports, SuperB Collaboration, (2010), arXiv:1007.4241.
[2] G. Burdman, E. Golowich et al., Phys. Rev. D66, 014009, (2002).
[3] S. Fajfer, S. Prelovsek and P. Singer, Phys. Rev. D64, 114009 (2001).
[4] E.M. Aitala et al., E791 Collaboration, Phys.Rev.Lett.86, 3969, (2001).
[5] K. Kodama et al., E653 Collaboration, Phys. Lett. B 345, 85, (1995).