Recent BaBar results on mixing in the charm sector

Alessandro Pilloni on behalf of the BaBar collaboration

Thomas Jefferson National Accelerator Facility, Newport News, VA 23608, USA.
INFN sez. di Roma, p.le A. Moro 2, 00185 Roma, Italy.

Introduction

A time-dependent amplitude analysis of the Dalitz-plot of $D^0 / \overline{D}^0$ decaying into self-conjugate final states gives a direct measurements the mixing parameters x and y

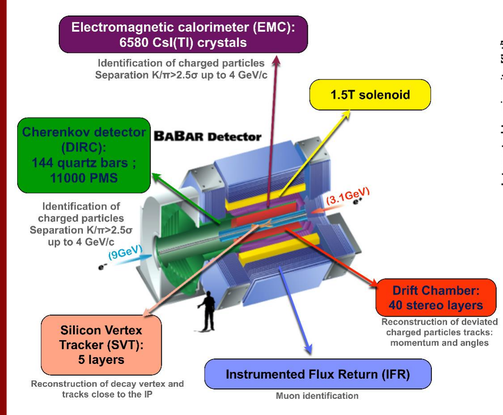
$$\left|\mathcal{M}\left(D^0\right)\right|^2 \propto \frac{1}{2} e^{-\Gamma_D t} \left\{ |A_f|^2 \left[\cosh\left(y\Gamma_D t\right) + \cos\left(x\Gamma_D t\right)\right] + \left|\frac{q}{p}\bar{A}_f\right|^2 \left[\cosh\left(y\Gamma_D t\right) - \cos\left(x\Gamma_D t\right)\right] \right.$$
$$\left. - 2\left[\mathrm{Re}\left(\frac{q}{p} A_f^* \bar{A}_f\right) \sinh\left(y\Gamma_D t\right) - \mathrm{Im}\left(\frac{q}{p} A_f^* \bar{A}_f\right) \sin\left(x\Gamma_D t\right)\right] \right\}$$

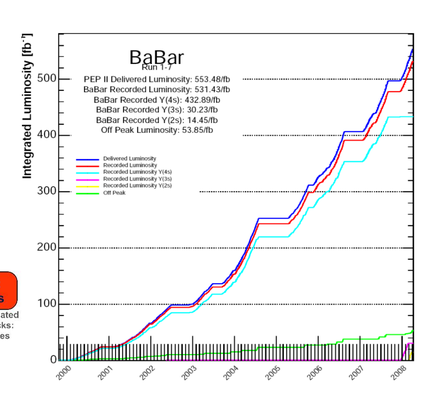
where $|D_{1,2}\rangle = p\left|D^0\right\rangle \pm q\left|\bar{D}^0\right\rangle$ and $x = \frac{m_1 - m_2}{\Gamma_D}, \quad y = \frac{\Gamma_1 - \Gamma_2}{2\Gamma_D}$

This is the first measurement of mixing parameters in the singly Cabibbo-suppressed channel $D^0 \to \pi^+\pi^-\pi^0$ [1]. At this level of precision, we neglect CP violations: $A_f(s_+, s_-) = \bar{A}_f(s_-, s_+), \quad \frac{q}{p} = 1$

The BaBar detector

The Babar detector was located at the interaction point of PEP II at SLAC Asymmetric e^+e^- collider, mostly at the $\Upsilon(4S)$ peak ~ 10.58 GeV



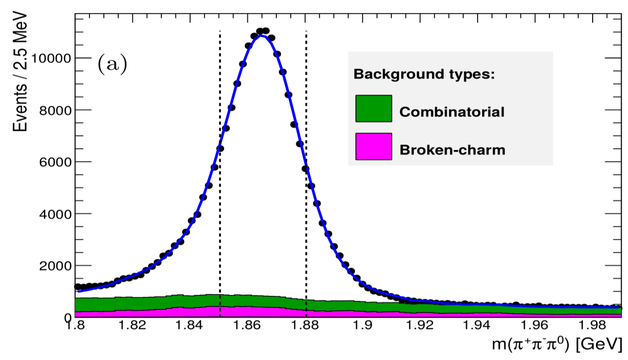


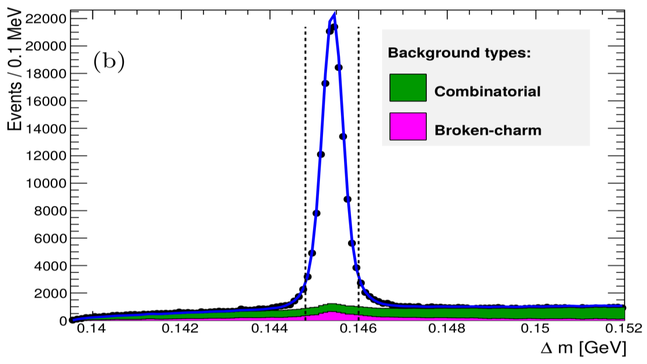
This analysis uses 468.1 fb^{-1} of data, both on- and off-peak

Event selection

- Reconstructed $D^{*+} \to \pi_s^+ D^0$ to select flavor
- Vetoes on $D^0 \to K^-\pi^+$, $D^0 \to K^-\pi^+\pi^0$, $D^0 \to K_S\,\pi^+\pi^0$, $D^0 \to K_S\,\pi^0$
- $E_{\mathrm{lab}}(\pi^0) > 350$ MeV
- $p_{\mathrm{cms}}(D^0) > 2.8$ GeV to remove $B \to D$ events
- $-2 < t(D^0) < 3$ ps, $\sigma_t < 0.8$ ps
- $P(\chi^2) > 0.1\%$ for the D^* candidates
- $\left|m(D^0) - m_{\mathrm{PDG}}\right| < 15$ MeV, $\left|\Delta m - \Delta m_{\mathrm{PDG}}\right| < 600$ keV

138k events, 91% purity

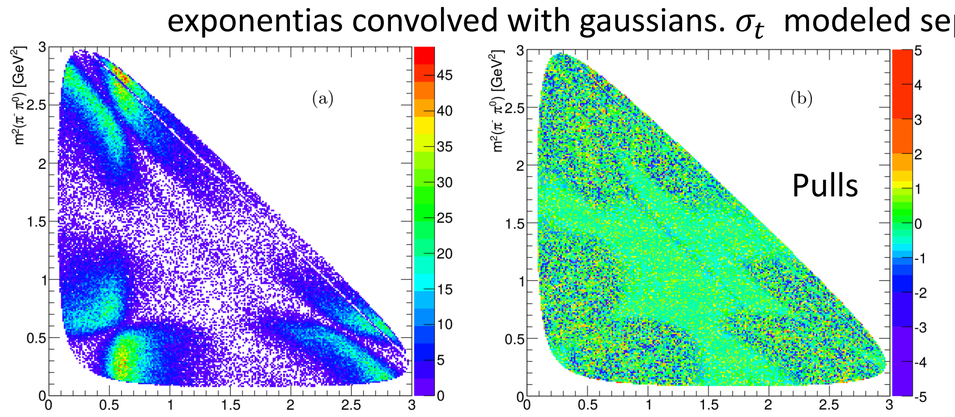


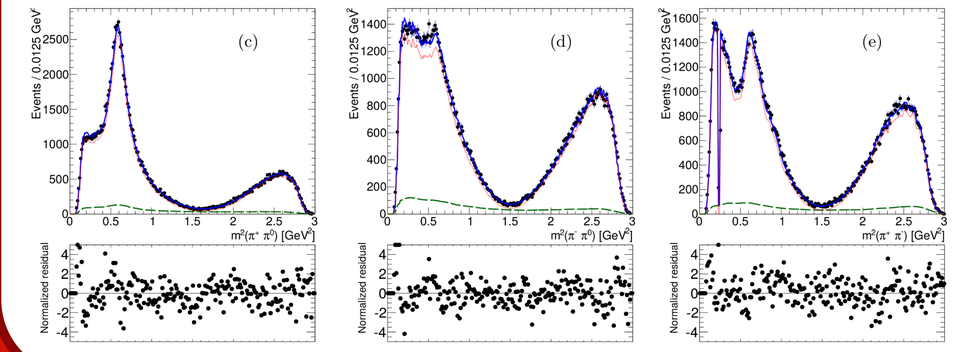


Fit model and results

An unbinned maximum-likelihood fit is performed to extract the parameters using **`GooFit`** [2]

- **Signal:** Dalitz plot distribution given by isobar model (coherent sum of Breit-Wigners); decay time distribution given by an exponential convolved with resolution (3 gaussians $\propto \sigma_t$). σ_t modeled separately in 6 regions of the Dalitz plot.
- **Wrong π_s^0 bkg:** ($< 1\%$) same Dalitz plot and decay time distributions as the signal, $\sim 50\%$ gives right flavor assignment (lucky pion)
- **Broken charm bkg:** misrecostructed D^0 (but peaks in Δm). Dalitz plot distribution from MC, decay time distributions given by two exponentials convolved with gaussians.
- **Combinatorial bkg:** Dalitz plot distribution from sidebands, decay time distributions given by two exponentias convolved with gaussians. σ_t modeled separately in 6 regions of decay time.





Large pull values near low and high values of m^2 in all projections
Similar effect in MC

Fitted values:

$$\tau_D = (410.2 \pm 3.8)\ \mathrm{fs}$$
$$x_{\mathrm{raw}} = (2.08 \pm 1.17)\%$$
$$y_{\mathrm{raw}} = (0.14 \pm 0.89)\%$$

To estimate any possible bias, the same fit is performed to MC samples with given $x = \pm 1\%, y = \pm 1\%$

The mean bias is
$\Delta x = 0.58\%, \Delta y = -0.05\%$

Systematic uncertainties

Dominant sources of systematics are:

- Amplitude-model variations, estimated removing the least relevant resonances
- Combinatorial DP distribution, when the MC is used instead than data
- Different decay time windows, and number of σ_t ranges
- Fit bias correction, taken as half of the bias measured from MC
- Effect of SVT misalignment, estimated creating MC signal samples with deliberately-wrong alignment files

Source	x [%]	y [%]
"Lucky" false slow pion fraction	0.01	0.01
Time resolution dependence on reconstructed D^0 mass	0.03	0.02
Amplitude-model variations	0.31	0.12
Resonance radius	0.02	0.10
DP efficiency parametrization	0.03	0.03
DP normalization granularity	0.03	0.04
Background DP distribution	0.21	0.11
Decay time window	0.18	0.19
σ_t cutoff	0.01	0.01
Number of σ_t ranges	0.11	0.26
σ_t parametrization	0.05	0.03
Background-model MC time distribution parameters	0.06	0.11
Fit bias correction	0.29	0.02
SVT misalignment	0.20	0.23
Total	0.56	0.46

Summary and conclusions

We present the first measurement of charm mixing in the singly Cabibbo-suppressed $D^0 \to \pi^+\pi^-\pi^0$ channel

$$x = (1.5 \pm 1.2 \pm 0.6)\%$$
$$y = (0.2 \pm 0.9 \pm 0.5)\%$$

to compare with the HFAG average [3]:

$$x = \left(0.49^{+0.14}_{-0.15}\right)\%$$
$$y = (0.61 \pm 0.08)\%$$

References

[1] J.P. Lees *et al.* [BaBar Collaboration], "Measurement of the neutral D meson mixing parameters in a time-dependent amplitude analysis of the $D^0 \to \pi^+\pi^-\pi^0$ decay", arXiv:1604.00857 [hep-ex].

[2] R. Andreassen *et al.*, "Implementation of a Thread-Parallel, GPU-Friendly Function Evaluation Library", IEEE Access 2, 160 (2014), code on http://github.com/GooFit/GooFit

[3] Y. Amhis et al. [HFAG Collaboration], "Averages of b-hadron, c-hadron, and τ-lepton properties as of summer 2014", arXiv:1412.7515

Contacts

alessandro.pilloni@roma1.infn.it

Ask the guy