

# Measurement of the decay $B \rightarrow D^* \ell^+ \nu$ and determination of $|V_{cb}|$ at Belle

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Institute of High Energy Physics  
Austrian Academy of Sciences

on behalf of the Belle collaboration



ICHEP 2010,  
July 24, 2010



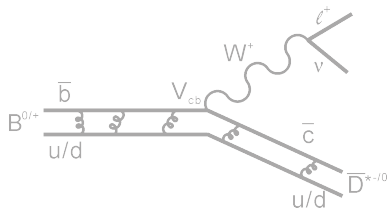
# Greetings from Belle!



# 日本茨城県つくば市大穂



# One way to determine $|V_{cb}|$ - Exclusive Decays



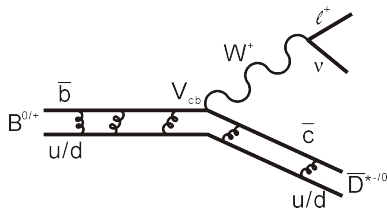
## Dominating effects

- Electroweak tree diagram
- Spectator quark
- And ... QCD effects

- Neutrino  $\rightarrow$  missing momentum
- QCD effects  $\rightarrow$  form factors



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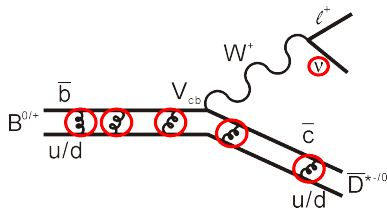


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## Results

- $\mathcal{F}_1 | V_{cb}|$
- Form factor parameters

## Considered final states

- Only signal is reconstructed
- $\bar{B} \rightarrow D^* \ell^- \bar{\nu}_\ell$ ,
  - $D^* \rightarrow D^0 \pi_S$ 
    - $D^0 \rightarrow K^- \pi^+$
    - $(D^0 \rightarrow K^- \pi^+ \pi^- \pi^+)$

## Systematics

- $B^0$  and  $B^+$  show different  $\pi_S$  systematic uncertainty

## Preliminary $B^+ \rightarrow \bar{D}^{*0} \ell^+ \nu$

- Shown at EPS09
- $\mathcal{L} = 141 \text{ fb}^{-1}$
- $N_{\text{signal}} = 27,106 \pm 367$

## $B^0 \rightarrow D^{*-} \ell^+ \nu$

- New result, ICHEP2010
- $\mathcal{L} = 711 \text{ fb}^{-1}$
- $N_{\text{signal}} = 123,427 \pm 636$

►  $B^+$  signal purity and background fractions

►  $B^0$  signal purity and background fractions



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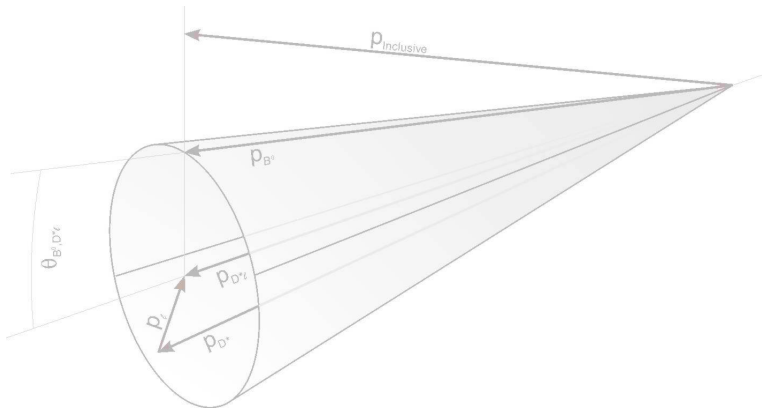
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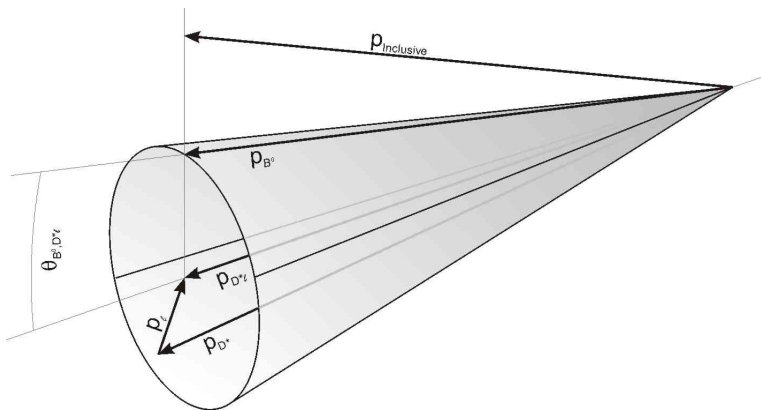
# Reconstruction of the $B$ rest frame



- $D^*l$  reconstruction yields 1D space of  $B$  candidates
- Combined with inclusive sum of remaining event: “best  $B$ ”



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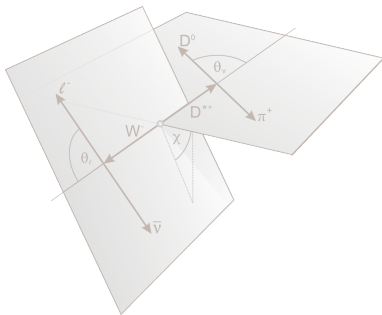
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# Differential decay width

## Kinematic variables

- $w = \frac{p_B^\mu \cdot p_{D^*} \cdot p_{\ell^+} \cdot p_{\nu_\ell}}{m_{B^0} m_{D^*}} = a + b q^2$
- $\cos \theta_\ell, \cos \theta_V, \chi$



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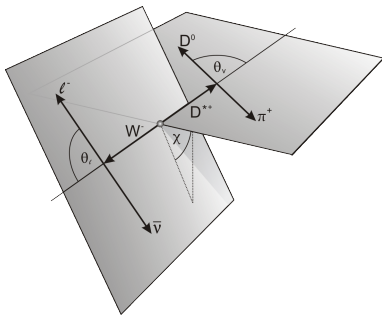
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 &= \frac{6m_B m_{D^*}^2}{8(4\pi)^4} \sqrt{w^2 - 1} (1 - 2wr + r^2) G_F^2 |V_{cb}|^2 \\
 & \times \{ (1 - \cos \theta_\ell)^2 \sin^2 \theta_V H_+^2(w) \\
 & \quad + (1 + \cos \theta_\ell)^2 \sin^2 \theta_V H_-^2(w) \\
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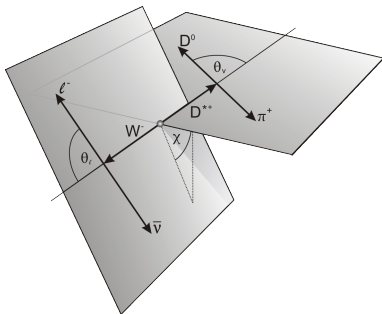
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# Investigation of $B^0$ background

## Background from $B$ decays

- Fake  $D^*$
- Fake Lepton
- Uncorrelated
- Signal correlated
- $B \rightarrow D^{**} \ell \nu, B \rightarrow D^* \pi \ell \nu$

## Off-resonance data

- Continuum:  $q\bar{q}$  decays

## General approach

- “Measure abundance of backgrounds”
- We calibrate MC using fit to real data

## Calibration of MC - HMCMLL, TFractionFitter

- Determine norm of MC components from fit to data
- Use 3D distribution  $\cos \theta_{B^0, D^* \ell}$  vs.  $\Delta m$  vs.  $p_\ell$



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# Background fractions and signal yield - $B^0$ analysis

	$141\text{fb}^{-1}, K\pi, e$	$141\text{fb}^{-1}, K\pi, \mu$	$274\text{fb}^{-1}, K\pi, e$	$274\text{fb}^{-1}, K\pi, \mu$
Num. Candidates	14802	14203	29217	26894
Signal events	$11609 \pm 181$	$11139 \pm 190$	$23029 \pm 280$	$21002 \pm 258$
Signal	$78.43 \pm 1.22$	$78.43 \pm 1.34$	$78.82 \pm 0.96$	$78.09 \pm 0.96$
$D^{**}$	$5.63 \pm 0.78$	$4.02 \pm 0.86$	$4.32 \pm 0.66$	$3.90 \pm 0.60$
Signal correlated	$1.07 \pm 0.17$	$1.41 \pm 0.25$	$1.33 \pm 0.16$	$1.71 \pm 0.19$
Uncorrelated	$7.24 \pm 0.35$	$6.01 \pm 0.40$	$7.19 \pm 0.31$	$6.31 \pm 0.29$
Fake $\ell$	$0.36 \pm 0.17$	$1.99 \pm 0.34$	$0.50 \pm 0.17$	$2.10 \pm 0.23$
Fake $D^*$	$2.59 \pm 0.12$	$2.81 \pm 0.13$	$3.07 \pm 0.11$	$2.96 \pm 0.10$
Continuum	$4.68 \pm 0.54$	$5.32 \pm 0.59$	$4.77 \pm 0.38$	$4.93 \pm 0.40$
	$189\text{fb}^{-1}, K\pi, e$	$189\text{fb}^{-1}, K\pi, \mu$	$107\text{fb}^{-1}, K\pi, e$	$107\text{fb}^{-1}, K\pi, \mu$
Num. Candidates	22056	20428	15871	14719
Signal events	$17301 \pm 240$	$15513 \pm 235$	$12365 \pm 189$	$11469 \pm 205$
Signal	$78.44 \pm 1.09$	$75.94 \pm 1.15$	$77.91 \pm 1.19$	$77.92 \pm 1.39$
$D^{**}$	$5.15 \pm 0.71$	$5.22 \pm 0.71$	$4.54 \pm 0.72$	$4.67 \pm 0.86$
Signal correlated	$1.56 \pm 0.27$	$2.07 \pm 0.37$	$2.01 \pm 0.26$	$2.73 \pm 0.43$
Uncorrelated	$6.35 \pm 0.35$	$6.01 \pm 0.33$	$7.33 \pm 0.38$	$6.30 \pm 0.40$
Fake $\ell$	$0.75 \pm 0.18$	$2.26 \pm 0.28$	$0.30 \pm 0.19$	$1.68 \pm 0.38$
Fake $D^*$	$2.86 \pm 0.12$	$2.69 \pm 0.11$	$2.89 \pm 0.13$	$2.80 \pm 0.14$
Continuum	$4.88 \pm 0.45$	$5.81 \pm 0.51$	$5.02 \pm 0.53$	$3.89 \pm 0.49$

# Investigation of low momentum tracks

## Track reconstruction efficiency at Belle

- Tracking is verified and well understood for  $p > 200\text{MeV}$
  - Low momenta: impact of material effects possible?
- Form the ratio between estimated signal events in data and signal events in MC, using one half of  $B^0$  samples
  - Six regions in  $p_{\pi_S}$  momentum are investigated
- We normalize to the value in the top most bin
  - Obtain ratio between efficiency in bin  $i$  and the highest momentum range,  $R_{i,max} = \epsilon_i / \epsilon_{max}$
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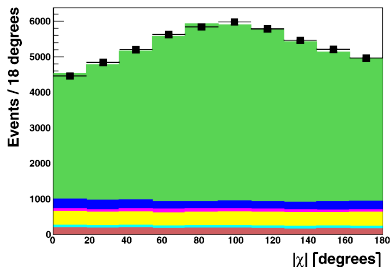
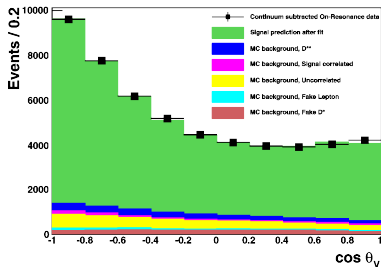
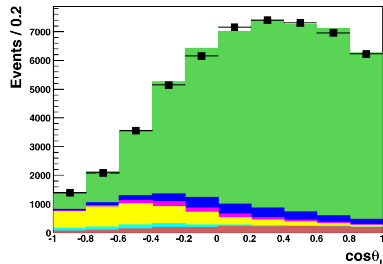
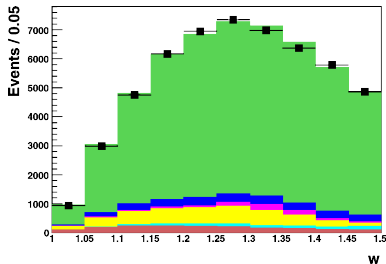
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Plots of results -  $B^0$ 

# Table of results

	$B^+ \rightarrow \bar{D}^{*0} \ell \nu$	$B^0 \rightarrow D^{*-} \ell \nu$
$\rho^2$	$1.376 \pm 0.074 \pm 0.056$	$1.214 \pm 0.034 \pm 0.009$
$R_1(1)$	$1.620 \pm 0.091 \pm 0.092$	$1.401 \pm 0.034 \pm 0.018$
$R_2(1)$	$0.805 \pm 0.064 \pm 0.036$	$0.864 \pm 0.024 \pm 0.008$
$\mathcal{B}(B \rightarrow D^* \ell^+ \nu_\ell)$	$(4.84 \pm 0.04 \pm 0.56)\%$	$(4.56 \pm 0.03 \pm 0.26)\%$
$\mathcal{F}(1)  V_{cb}  \times 10^3$	$35.0 \pm 0.4 \pm 2.2$	$34.5 \pm 0.2 \pm 1.0$
$R_{K3\pi/K\pi}$	$2.072 \pm 0.023$	
$P_{\chi^2}$	3.7%	28.2%

▶ Subsamples -  $B^0$

▶ Systematic error -  $B^0$

▶ Correlations -  $B^0$

▶ Subsamples -  $B^+$

▶ Systematic error -  $B^+$

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# Systematic uncertainty, $B^0$ analysis

	$\rho^2$	$R_1(1)$	$R_2(1)$	$\mathcal{F}(1) V_{cb}  \times 10^3$	$\mathcal{B}(B^0 \rightarrow D^* \ell \nu)$
Value	1.214	1.401	0.864	34.5	4.56
Statistical Error	0.034	0.034	0.024	0.2	0.03
Systematic Error	0.009	0.018	0.008	1.0	0.26
Fast track efficiency				0.78	0.205
Slow track efficiency	0.002	0.003	0.004	0.28	0.059
$\rho_{\pi_S}$ stability	0.001	0.001	0.000	0.03	0.003
LeptonID	0.002	0.006	0.002	0.38	0.099
Norm $D^{**}$	0.001	0.001	0.001	0.03	0.008
Norm Signal Corr.	0.002	0.003	0.002	0.02	0.006
Norm Uncorr	0.002	0.008	0.003	0.02	0.001
Norm Fake $\ell$	0.003	0.003	0.001	0.01	0.003
Norm Fake $D^*$	0.001	0.001	0.000	0.00	0.003
Norm Continuum	0.002	0.002	0.001	0.00	0.003
$D^{**}$ composition	0.004	0.009	0.003	0.10	0.025
$D^{**}$ shape	0.003	0.005	0.002	0.04	0.011
$N(\Upsilon(4S))$				0.24	0.062
$f_{+-}/f_{00}$	0.004	0.009	0.003	0.24	0.062
$B^0$ life time				0.10	0.027
$\mathcal{B}(D^{*+} \rightarrow D^0 \pi_S^+)$				0.13	0.034
$\mathcal{B}(D^0 \rightarrow K\pi)$				0.22	0.058

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Norm Uncorr	0.002	0.008	0.003	0.02	0.001
Norm Fake $\ell$	0.003	0.003	0.001	0.01	0.003
Norm Fake $D^*$	0.001	0.001	0.000	0.00	0.003
Norm Continuum	0.002	0.002	0.001	0.00	0.003
$D^{**}$ composition	0.004	0.009	0.003	0.10	0.025
$D^{**}$ shape	0.003	0.005	0.002	0.04	0.011
$N(\Upsilon(4S))$				0.24	0.062
$f_{+-}/f_{00}$	0.004	0.009	0.003	0.24	0.062
$B^0$ life time				0.10	0.027
$\mathcal{B}(D^{*+} \rightarrow D^0 \pi_S^+)$				0.13	0.034
$\mathcal{B}(D^0 \rightarrow K\pi)$				0.22	0.058

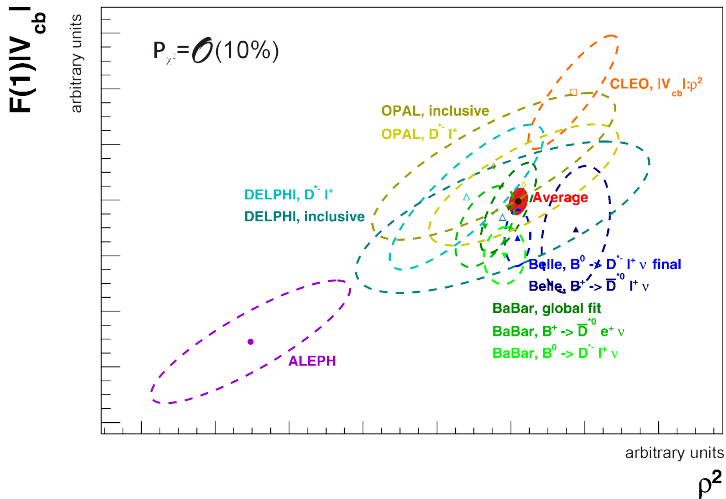
← Back to results page

# Systematic uncertainty, $B^0$ analysis

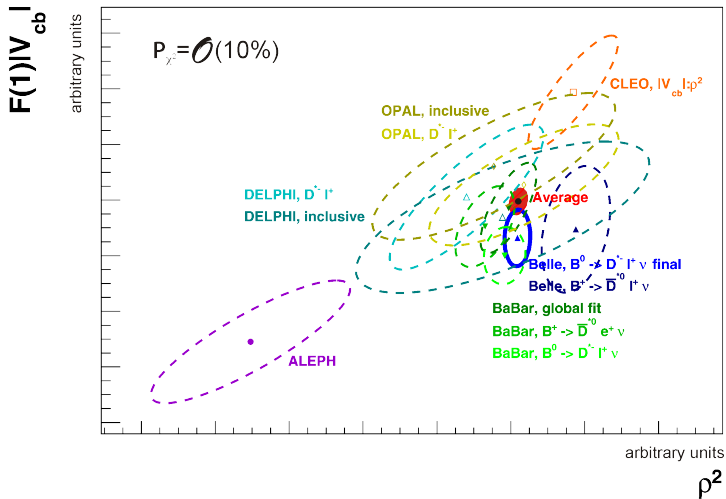
	$\rho^2$	$R_1(1)$	$R_2(1)$	$\mathcal{F}(1) V_{cb}  \times 10^3$	$\mathcal{B}(B^0 \rightarrow D^* \ell \nu)$
Value	1.214	1.401	0.864	34.5	4.56
Statistical Error	0.034	0.034	0.024	0.2	0.03
Systematic Error	0.009	0.018	0.008	1.0	0.26
Fast track efficiency				0.78	0.205
Slow track efficiency	0.002	0.003	0.004	0.28	0.059
$\rho_{\pi_S}$ stability	0.001	0.001	0.000	0.03	0.003
LeptonID	0.002	0.006	0.002	0.38	0.099
Norm $D^{**}$	0.001	0.001	0.001	0.03	0.008
Norm Signal Corr.	0.002	0.003	0.002	0.02	0.006
Norm Uncorr	0.002	0.008	0.003	0.02	0.001
Norm Fake $\ell$	0.003	0.003	0.001	0.01	0.003
Norm Fake $D^*$	0.001	0.001	0.000	0.00	0.003
Norm Continuum	0.002	0.002	0.001	0.00	0.003
$D^{**}$ composition	0.004	0.009	0.003	0.10	0.025
$D^{**}$ shape	0.003	0.005	0.002	0.04	0.011
$N(\Upsilon(4S))$				0.24	0.062
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[← Back to results page](#)

# Glimpse on the world average



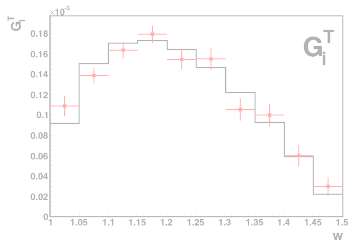
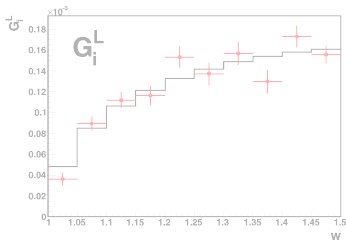
# Glimpse on the world average



# Explicit test of the parametrization - $B^0 \rightarrow \bar{D}^{*+} l \nu$

## Idea:

- Extract shapes of longitudinal and transversal helicity amplitudes from a 2D fit
- We find good agreement with parametrized result



(The statistical error is shown in these plots)

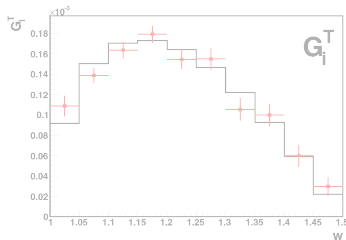
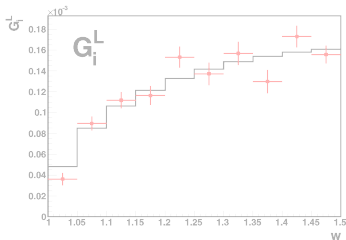




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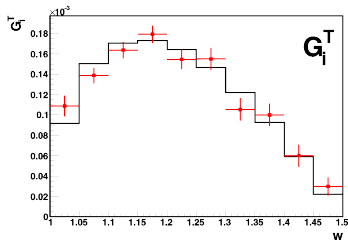
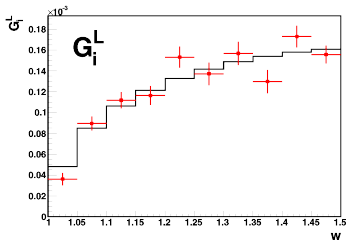
(The statistical error is shown in these plots)



# Explicit test of the parametrization - $B^0 \rightarrow \bar{D}^{*+} \ell \nu$

## Idea:

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- We find good agreement with parametrized result



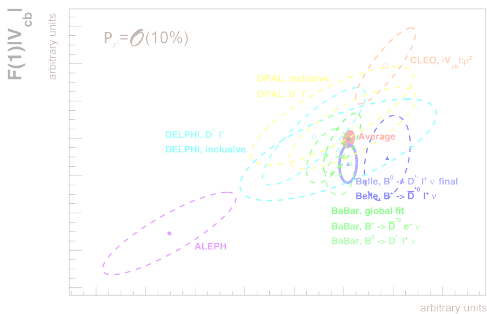
(The statistical error is shown in these plots)





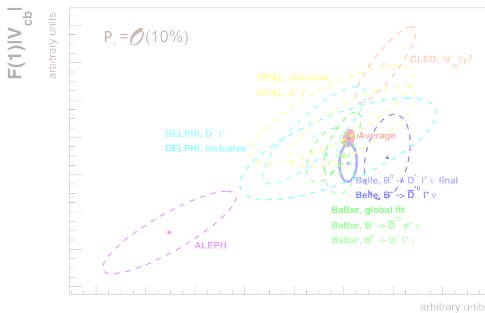
$B^0 \rightarrow D^{*-} \ell^+ \nu$  and  $B^+ \rightarrow \bar{D}^{*0} \ell^+ \nu$  at Belle

	$B^+$	$B^0$
$\rho^2$	$1.376 \pm 0.074 \pm 0.056$	$1.214 \pm 0.034 \pm 0.009$
$R_1(1)$	$1.620 \pm 0.091 \pm 0.092$	$1.401 \pm 0.034 \pm 0.018$
$R_2(1)$	$0.805 \pm 0.064 \pm 0.036$	$0.864 \pm 0.024 \pm 0.008$
$\mathcal{B}(B \rightarrow D^* \ell^+ \nu_\ell)$	$(4.84 \pm 0.04 \pm 0.56)\%$	$(4.56 \pm 0.03 \pm 0.26)\%$
$\mathcal{F}(1)  V_{cb}  \times 10^3$	$35.0 \pm 0.4 \pm 2.2$	$34.5 \pm 0.2 \pm 1.0$



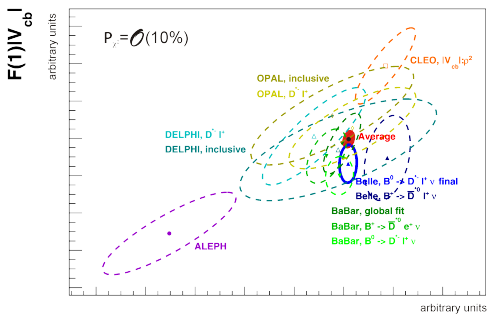
# $B^0 \rightarrow D^{*-} \ell^+ \nu$ and $B^+ \rightarrow \bar{D}^{*0} \ell^+ \nu$ at Belle

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Thanks for your attention!



# Measurement of the decay $B \rightarrow D^* \ell^+ \nu$ and determination of $|V_{cb}|$ at Belle

Wolfgang Dungel

Institute of High Energy Physics  
Austrian Academy of Sciences

on behalf of the Belle collaboration



ICHEP 2010,  
July 24, 2010





## The Belle Collaboration



## International Collaboration: Belle

Budker Institute Novosibirsk  
Charles U., Prague  
Chiba U.  
EPF Lausanne  
Fu Jen Catholic U.  
Gyeongsang National U.  
Hanyang U.  
Henryk Niewodniczanski Inst.  
Hiroshima Inst. of Tech.  
I. of Math. Sciences, Chennai  
IHEP, Beijing  
IHEP, Moscow  
IHEP, Vienna

Indian Inst. of Tech. Guwahati  
Indian Inst. of Tech. Madras  
INFN Torino  
ITEP, Moscow  
Jozef Stefan Inst.  
Kanagawa U.  
KEK  
Korea U.  
Kyoto U.  
Kyungpook National U.  
MPI Munich  
Nagoya U.  
Nara Women's U.

National Central U.  
National Taiwan U.  
National United U.  
Niigata U.  
Nippon Dental U.  
Novosibirsk State U.  
Osaka City U.  
Osaka U.  
Panjab U.  
Peking U.  
Princeton U.  
Riken  
Saga U.  
Seoul National U.  
Shinshu U.  
Sungkyunkwan U.  
Tata Institute  
Toho U.  
Tohoku Gakuin U.

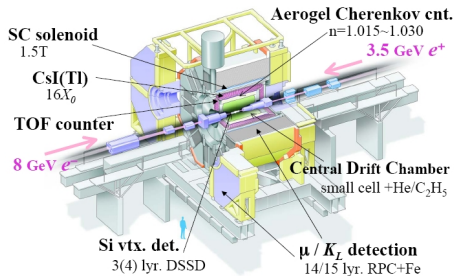
Tohoku U.  
Tokyo Metropolitan U.  
Tokyo U. of Agri. and Tech.  
Toyama NCMT  
U. of Cincinnati  
U. of Giessen  
U. of Hawaii  
U. of Illinois  
U. of Karlsruhe  
U. of Ljubljana  
U. of Maribor  
U. of Melbourne  
U. of Novo Gorica  
U. of Sydney  
U. of Tokyo  
USTC China  
Virginia PI  
Wayne State U.  
Yonsei U.





16 countries, 60 institutes, ~370 collaborators

# Belle and the KEK-B accelerator



New record, 2009/06/19!

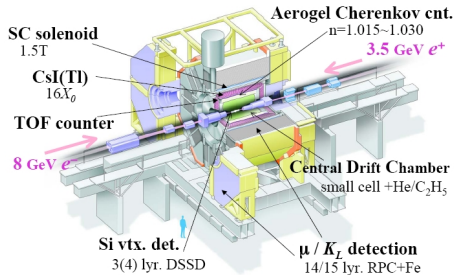
$$\mathcal{L}_{peak} = 2.1 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$$

Integrated luminosity, final

$$\bullet \mathcal{L} \approx 1050 \text{ fb}^{-1}$$



# Belle and the KEK-B accelerator



New record, 2009/06/19!

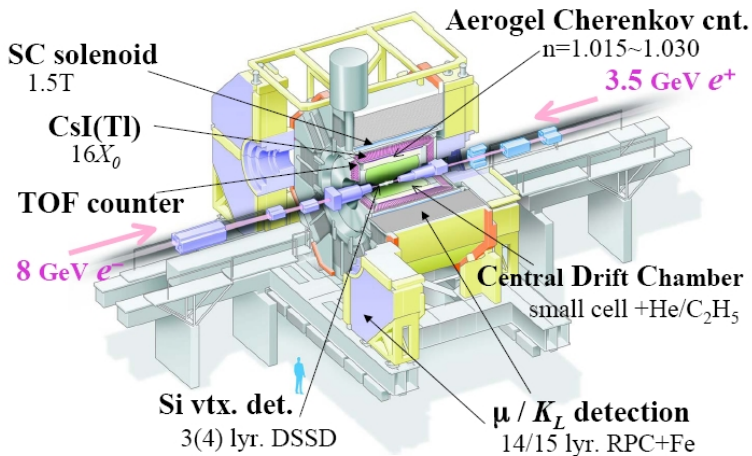
$$\mathcal{L}_{peak} = 2.1 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$$

Integrated luminosity, final

$$\bullet \mathcal{L} \approx 1050 \text{ fb}^{-1}$$



# The Belle Detector



# Tags at Belle

Efficiency



Purity



## Untagged

- Only signal reconstructed
- High efficiency

## Semileptonic tag

- Good statistics, clean events
- Kinematics not fully determined

## Full reconstruction tag

- Kinematics fully determined
- Low statistics



# Tags at Belle

Efficiency



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# Tags at Belle

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# Nobel prize 2008

## 2008年ノーベル物理学賞受賞！小林益川理論とは？

**Q クォークとは何ですか？**  
自然界の物質は原子で構成されています。原子は原子核と電子で構成されています。原子核は陽子と中性子で構成されています。陽子はクォークとグルーオンで構成されています。中性子はクォークとグルーオンで構成されています。クォークは素粒子の一種で、物質の構成要素です。



**Q 反粒子とは何ですか？**  
物質の構成要素であるクォークやレプトンには、質量が等しい反粒子が存在します。反粒子は、粒子の電荷や色荷が反対の性質を持っています。反クォークや反レプトンもクォークやレプトンと同じように物質の構成要素として存在します。



**Q どうしてクォークが6種類あるのですか？**  
クォークは、色荷という性質を持っています。色荷は赤、緑、青の3種類あります。クォークは、色荷を中和するために、反対の色荷を持つ反クォークと結合して、無色荷の物質を形成します。クォークの種類は、色荷の種類とフレーバーの種類によって決まります。

## 待ちに待った実験結果！ B ファクトリーによる検証

**Q どうしてクォークが6種類あるのですか？**  
クォークは、色荷という性質を持っています。色荷は赤、緑、青の3種類あります。クォークは、色荷を中和するために、反対の色荷を持つ反クォークと結合して、無色荷の物質を形成します。クォークの種類は、色荷の種類とフレーバーの種類によって決まります。

**Q CP 破綻性の検証、とは何ですか？**  
CP 破綻性とは、粒子と反粒子の振る舞いの違いを指します。自然界には、CP 対称性が破れていることが知られています。これは、物質と反物質の生成量の差を説明するために重要です。

**Q 小林益川理論とは何ですか？**  
小林益川理論は、クォークの混合を説明する理論です。これは、異なるフレーバーのクォークが互に変換し合うことを示しています。この理論は、CP 破綻性を説明するために重要な役割を果たしています。

**Q どうしてクォークが6種類あるのですか？**  
クォークは、色荷という性質を持っています。色荷は赤、緑、青の3種類あります。クォークは、色荷を中和するために、反対の色荷を持つ反クォークと結合して、無色荷の物質を形成します。クォークの種類は、色荷の種類とフレーバーの種類によって決まります。

**Q CP 破綻性の検証はどのように行われたのですか？**  
CP 破綻性の検証は、B ファクトリーでの実験によって行われました。B ファクトリーは、B 粒子と反B 粒子の生成と崩壊を観測するための実験装置です。実験結果は、CP 破綻性の存在を示しています。

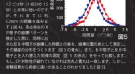
**Q B ファクトリー（工場）とは何ですか？**  
B ファクトリーは、B 粒子と反B 粒子を大量に生成するための実験装置です。これは、CP 破綻性の検証に不可欠な装置です。B ファクトリーは、加速器によって生成された電子と陽子の衝突によって稼働します。



**Q 東京のBファクトリーについて教えてください**  
東京のBファクトリーは、KEK（高エネルギー加速器研究機構）に設置されています。これは、日本の最先端の加速器施設です。東京のBファクトリーは、CP 破綻性の検証に重要な役割を果たしています。

**Q 大阪のBファクトリーについて教えてください**  
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**Q 小林益川理論は磁石を説明できるのですか？**  
小林益川理論は、クォークの混合を説明する理論です。これは、異なるフレーバーのクォークが互に変換し合うことを示しています。この理論は、CP 破綻性を説明するために重要な役割を果たしています。

**Q 大阪のBファクトリーの中で、最先端の技術を実験に使っていますか？**  
大阪のBファクトリーは、最先端の技術を実験に活用しています。これは、CP 破綻性の検証に重要な役割を果たしています。最先端の技術は、実験の精度を向上させています。



# 小林益川理論が正解だった！ Bファクトリーが放った決定打

東京のBファクトリーは、KEK（高エネルギー加速器研究機構）に設置されています。これは、日本の最先端の加速器施設です。東京のBファクトリーは、CP 破綻性の検証に重要な役割を果たしています。

大阪のBファクトリーは、KEK（高エネルギー加速器研究機構）に設置されています。これは、日本の最先端の加速器施設です。大阪のBファクトリーは、CP 破綻性の検証に重要な役割を果たしています。

**Bファクトリー実験に貢献している研究機関**

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# HQET and parametrization

## Helicity amplitudes

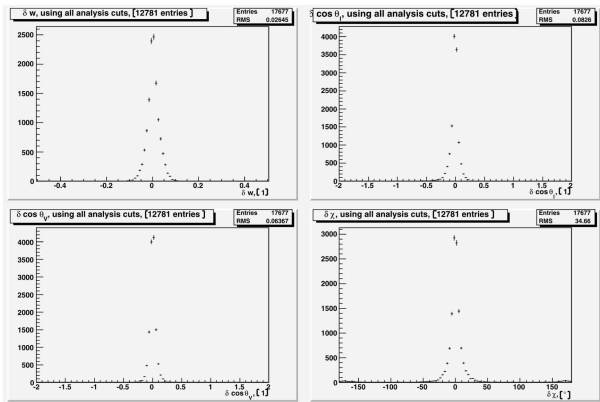
- $H_{\pm} = f_{\pm}(w) h_{A_1}(w) \left( 1 \mp \sqrt{\frac{w-1}{w+1}} R_1(w) \right)$
- $H_0 = f_0(w) h_{A_1}(w) \left( 1 + \frac{w-1}{1 - \frac{m_{D^*}^2}{m_B^2}} \left( 1 - R_2(w) \right) \right)$

## Parametrization by CLN

- $h_{A_1}(w) = h_{A_1}(1) (1 - 8\rho^2 z + (53\rho^2 - 15)z^2 - (231\rho^2 - 91)z^3)$   
 $z = \frac{\sqrt{w+1} - \sqrt{2}}{\sqrt{w+1} + \sqrt{2}}$
- $R_1(w) = R_1(1) - 0.12(w - 1) + 0.05(w - 1)^2$
- $R_2(w) = R_2(1) + 0.11(w - 1) - 0.06(w - 1)^2$

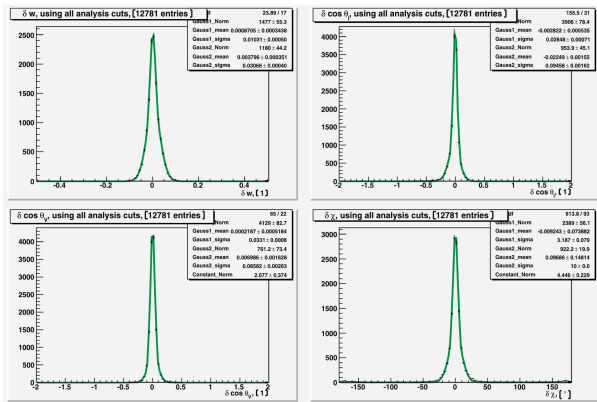


## Resolutions in kinematic variables



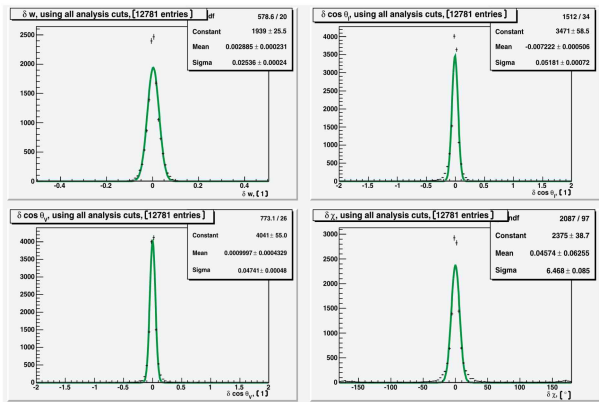
- Resolutions are approximately double Gaussians
- Almost identical for  $B^0$  and  $B^+$

## Resolutions in kinematic variables

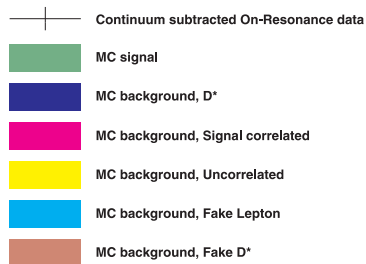
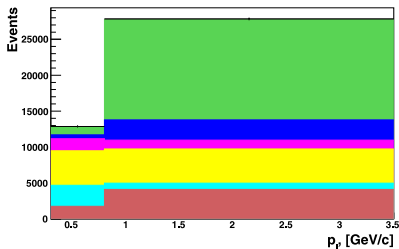
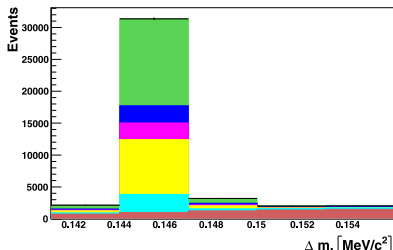
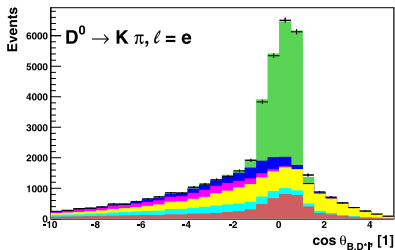


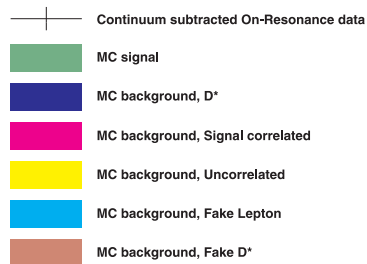
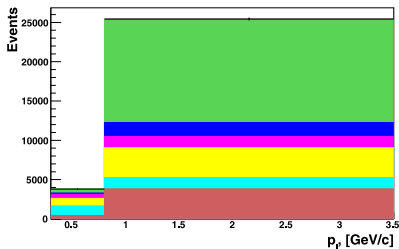
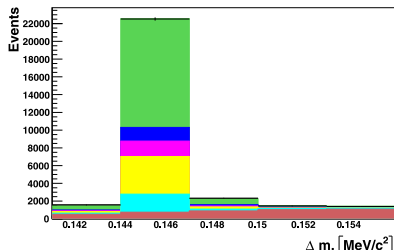
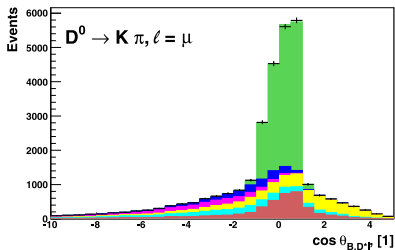
- Resolutions are approximately double gaussians
- Almost identical for  $B^0$  and  $B^+$

## Resolutions in kinematic variables

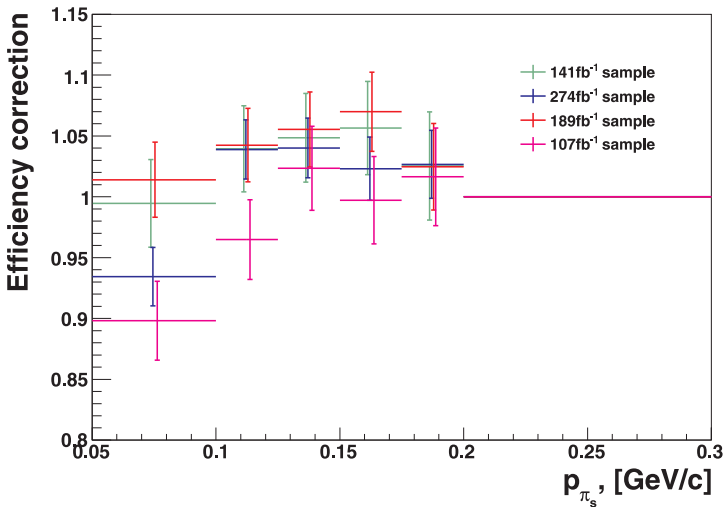


- For easier comparison: Gaussian assumption
- $\delta_w = 0.025$ ,  $\delta_{\cos \theta_\ell} = 0.052$ ,  $\delta_{\cos \theta_\nu} = 0.047$ ,  $\delta_\chi = 6.47^\circ$

Plots of  $B^0$  background calibration - e channels

Plots of  $B^0$  background calibration -  $\mu$  channels

# Efficiency correction due to low momentum tracks



# Covariances between bins of the marginal distributions

## Covariances

$$\text{Cov}_{ij} = \text{Cov}(n_i, n_j) = N \cdot (p_{ij} - p_i p_j), \quad \forall i \neq j$$

- $N$ : Total number of events
- $n_{ij}$ : Bin content of the bin  $(i, j)$  of 2d histogram
- $n_k$ : Bin content of the bin  $k$  of a 1d histogram
- $p_x = \frac{n_x}{N}$

## Special cases

- Independent variables:  $p_{ij} = p_i p_j \rightarrow \text{Cov}_{ij} \equiv 0$
- Perfect anti-correlation:  $n_{ij} = 0 \rightarrow \text{Cov}_{ij} < 0$
- Positive correlation:  $p_{ij} > p_i p_j \rightarrow \text{Cov}_{ij} > 0$





# Data sample for $B^0 \rightarrow D^{*-} \ell^+ \nu$ analysis

## Sub-samples

- Belle data has been recorded with several detector setups, tracking algorithms etc.
  - To make sure we don't introduce systematic problems, we investigate four subsamples
- 
- Sample A -  $141 \text{fb}^{-1}$
  - Sample B -  $274 \text{fb}^{-1}$
  - Sample C -  $189 \text{fb}^{-1}$
  - Sample D -  $107 \text{fb}^{-1}$



# Analysis procedure for $B^0$

- Four experiment ranges, in each both  $e$  and  $\mu$
- Therefore, we have a total of 8 samples

## Analysis steps and data samples

- Background estimation
  - In each of the 8 samples
- Calculation of  $\pi_S$  corrections
  - In each of the 4 experiment ranges
- Fit to the samples, calculation of syst. uncertainty
  - In each of the 4 experiment ranges
- Final result as average of the 4 results
  - Using the algorithm used for HFAG world average



Results for  $B^0$  subsamples - 1

Sample A (141fb <sup>-1</sup> )	$D^0 \rightarrow K\pi, \ell = e$	$D^0 \rightarrow K\pi, \ell = \mu$	total sample
$\rho^2$	$1.248 \pm 0.102 \pm 0.022$	$1.285 \pm 0.114 \pm 0.028$	$1.259 \pm 0.076 \pm 0.019$
$R_1(1)$	$1.317 \pm 0.099 \pm 0.041$	$1.577 \pm 0.131 \pm 0.036$	$1.436 \pm 0.078 \pm 0.030$
$R_2(1)$	$0.804 \pm 0.076 \pm 0.017$	$0.768 \pm 0.093 \pm 0.020$	$0.795 \pm 0.058 \pm 0.015$
$ \mathcal{F}(1)V_{cb}  \times 10^3$	$34.7 \pm 0.5 \pm 1.2$	$34.5 \pm 0.6 \pm 1.2$	$34.6 \pm 0.4 \pm 1.2$
$\chi^2 / \text{n.d.f}$	32.2 / 36.0	31.6 / 36.0	70.9 / 76.0
$P_{\chi^2}$	0.651	0.676	0.643

Sample B (274fb <sup>-1</sup> )	$D^0 \rightarrow K\pi, \ell = e$	$D^0 \rightarrow K\pi, \ell = \mu$	total sample
$\rho^2$	$1.169 \pm 0.079 \pm 0.011$	$1.167 \pm 0.088 \pm 0.016$	$1.168 \pm 0.059 \pm 0.011$
$R_1(1)$	$1.411 \pm 0.079 \pm 0.026$	$1.449 \pm 0.090 \pm 0.028$	$1.427 \pm 0.059 \pm 0.022$
$R_2(1)$	$0.902 \pm 0.054 \pm 0.011$	$0.859 \pm 0.061 \pm 0.013$	$0.882 \pm 0.041 \pm 0.010$
$ \mathcal{F}(1)V_{cb}  \times 10^3$	$34.3 \pm 0.4 \pm 1.1$	$33.8 \pm 0.4 \pm 1.1$	$34.1 \pm 0.3 \pm 1.1$
$\chi^2 / \text{n.d.f}$	22.7 / 36.0	36.5 / 36.0	60.7 / 76.0
$P_{\chi^2}$	0.958	0.443	0.900

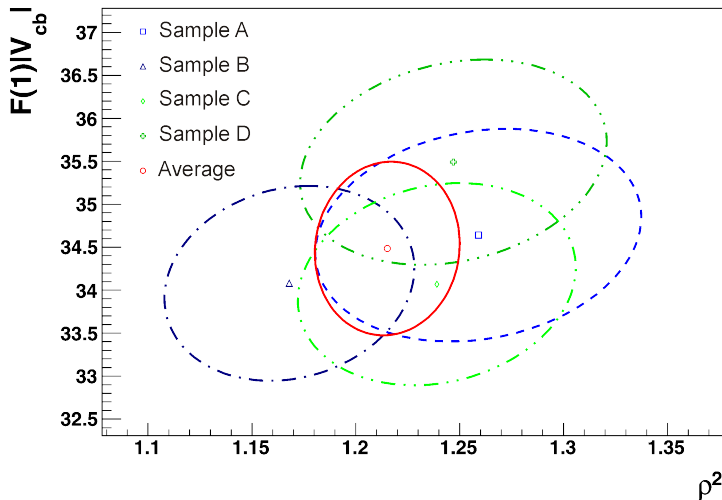
[◀ Back to results page](#)[▶ Other subsample results](#)

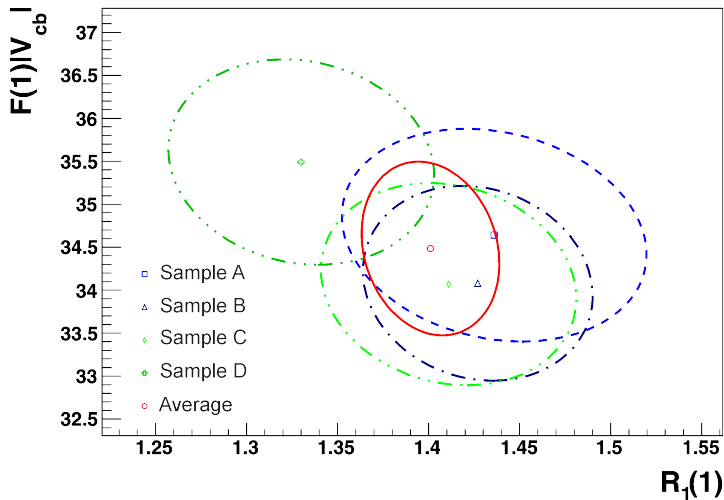
Results for  $B^0$  subsamples - 2

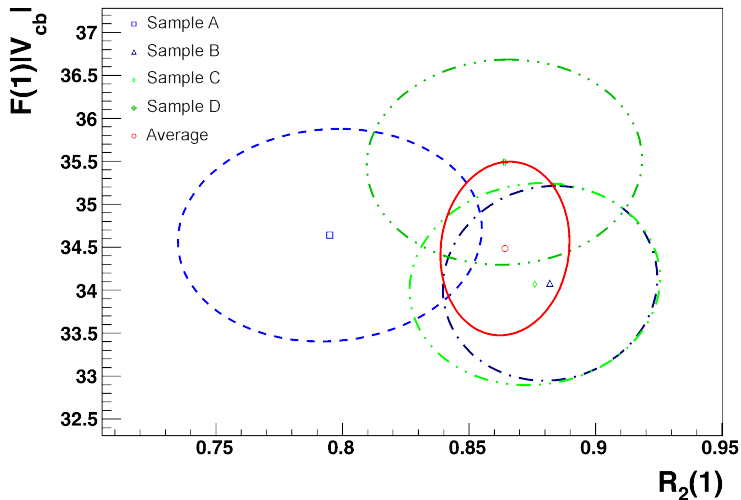
Sample C (189fb <sup>-1</sup> )	$D^0 \rightarrow K\pi, \ell = e$	$D^0 \rightarrow K\pi, \ell = \mu$	total sample
$\rho^2$	$1.226 \pm 0.088 \pm 0.011$	$1.262 \pm 0.101 \pm 0.016$	$1.239 \pm 0.066 \pm 0.011$
$R_1(1)$	$1.363 \pm 0.086 \pm 0.026$	$1.480 \pm 0.107 \pm 0.033$	$1.411 \pm 0.066 \pm 0.023$
$R_2(1)$	$0.891 \pm 0.062 \pm 0.012$	$0.851 \pm 0.076 \pm 0.015$	$0.876 \pm 0.048 \pm 0.012$
$ \mathcal{F}(1)V_{cb}  \times 10^3$	$34.3 \pm 0.5 \pm 1.1$	$33.8 \pm 0.5 \pm 1.1$	$34.1 \pm 0.3 \pm 1.1$
$\chi^2 / \text{n.d.f}$	38.6 / 36.0	38.2 / 36.0	81.4 / 76.0
$P_{\chi^2}$	0.352	0.370	0.314

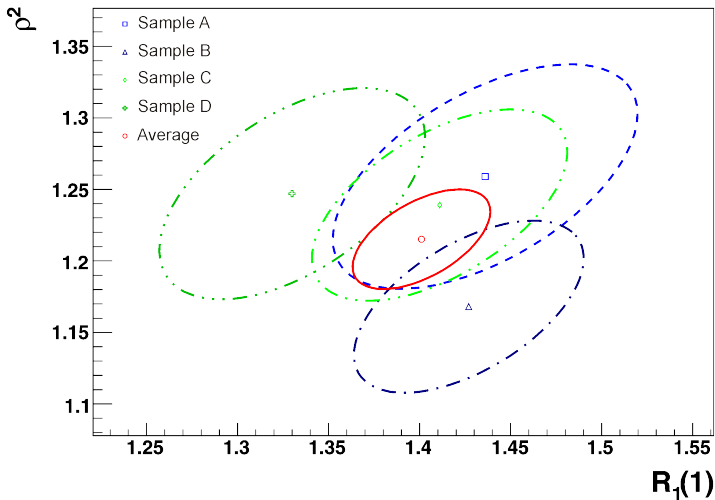
Sample D (107fb <sup>-1</sup> )	$D^0 \rightarrow K\pi, \ell = e$	$D^0 \rightarrow K\pi, \ell = \mu$	total sample
$\rho^2$	$1.321 \pm 0.102 \pm 0.019$	$1.174 \pm 0.106 \pm 0.020$	$1.247 \pm 0.073 \pm 0.014$
$R_1(1)$	$1.448 \pm 0.109 \pm 0.041$	$1.230 \pm 0.089 \pm 0.031$	$1.330 \pm 0.069 \pm 0.027$
$R_2(1)$	$0.791 \pm 0.081 \pm 0.019$	$0.931 \pm 0.071 \pm 0.015$	$0.864 \pm 0.053 \pm 0.014$
$ \mathcal{F}(1)V_{cb}  \times 10^3$	$35.3 \pm 0.6 \pm 1.2$	$35.6 \pm 0.6 \pm 1.2$	$35.5 \pm 0.4 \pm 1.2$
$\chi^2 / \text{n.d.f}$	25.1 / 36.0	42.0 / 36.0	70.1 / 76.0
$P_{\chi^2}$	0.913	0.226	0.669

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Plots of the  $B^0$  average

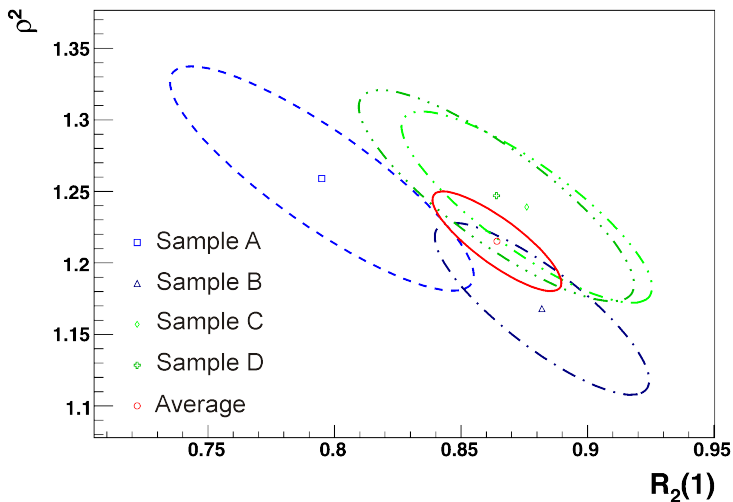
Plots of the  $B^0$  average

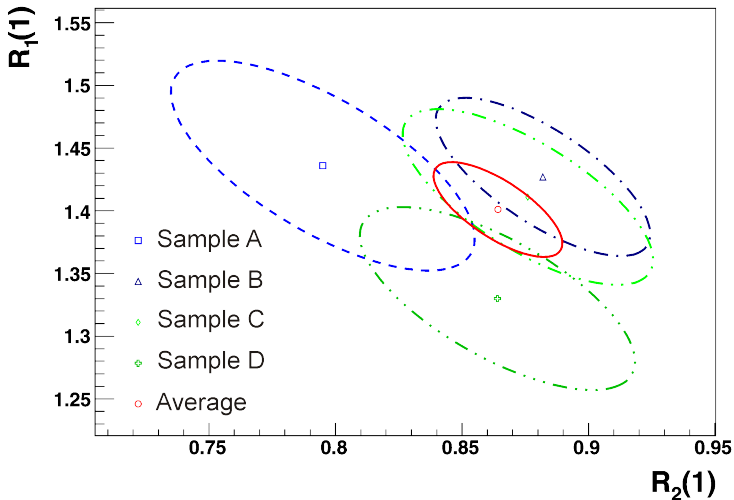
Plots of the  $B^0$  average

Plots of the  $B^0$  average



# Plots of the $B^0$ average



Plots of the  $B^0$  average

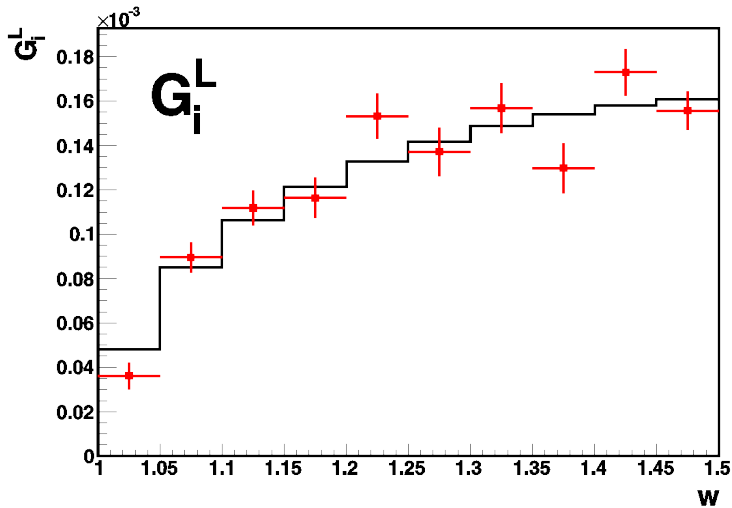
# Correlations in $B^0$ analysis

- Table shows statistical correlation coefficients

	$\mathcal{F}(1) V_{cb} $	$\rho^2$	$R_1(1)$	$R_2(1)$
$\mathcal{F}(1) V_{cb} $	1.000	0.625	-0.122	-0.206
$\rho^2$		1.000	0.575	-0.872
$R_1(1)$			1.000	-0.697
$R_2(1)$				1.000

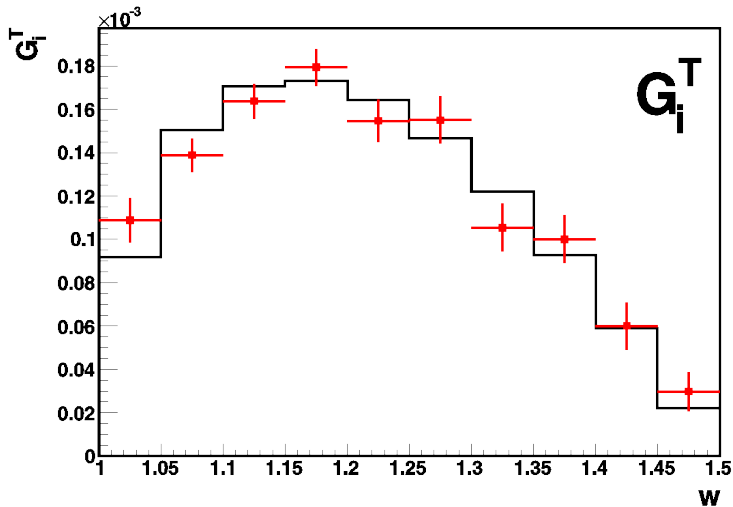
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Check of  $G_L$  in  $B^0$  analysis

Check of  $G_L$  in  $B^0$  analysis

	$D^0 \rightarrow K\pi, \ell = e$	$D^0 \rightarrow K\pi, \ell = \mu$
$G_1^L, [1]$	$(0.405 \pm 0.083 \pm 0.027) \times 10^{-4}$	$(0.283 \pm 0.090 \pm 0.019) \times 10^{-4}$
$G_2^L, [1]$	$(0.878 \pm 0.096 \pm 0.054) \times 10^{-4}$	$(0.935 \pm 0.099 \pm 0.061) \times 10^{-4}$
$G_3^L, [1]$	$(1.102 \pm 0.109 \pm 0.068) \times 10^{-4}$	$(1.124 \pm 0.112 \pm 0.073) \times 10^{-4}$
$G_4^L, [1]$	$(1.230 \pm 0.128 \pm 0.077) \times 10^{-4}$	$(1.123 \pm 0.133 \pm 0.071) \times 10^{-4}$
$G_5^L, [1]$	$(1.232 \pm 0.137 \pm 0.074) \times 10^{-4}$	$(1.787 \pm 0.151 \pm 0.112) \times 10^{-4}$
$G_6^L, [1]$	$(1.479 \pm 0.149 \pm 0.087) \times 10^{-4}$	$(1.281 \pm 0.159 \pm 0.078) \times 10^{-4}$
$G_7^L, [1]$	$(1.426 \pm 0.152 \pm 0.086) \times 10^{-4}$	$(1.727 \pm 0.171 \pm 0.106) \times 10^{-4}$
$G_8^L, [1]$	$(1.458 \pm 0.154 \pm 0.083) \times 10^{-4}$	$(1.107 \pm 0.165 \pm 0.067) \times 10^{-4}$
$G_9^L, [1]$	$(1.678 \pm 0.146 \pm 0.100) \times 10^{-4}$	$(1.794 \pm 0.154 \pm 0.111) \times 10^{-4}$
$G_{10}^L, [1]$	$(1.592 \pm 0.125 \pm 0.097) \times 10^{-4}$	$(1.527 \pm 0.122 \pm 0.100) \times 10^{-4}$
	fit to total sample	central value of parametrized fit
$G_1^L, [1]$	$(0.361 \pm 0.060 \pm 0.025) \times 10^{-4}$	$0.480 \times 10^{-4}$
$G_2^L, [1]$	$(0.895 \pm 0.069 \pm 0.056) \times 10^{-4}$	$0.849 \times 10^{-4}$
$G_3^L, [1]$	$(1.118 \pm 0.078 \pm 0.070) \times 10^{-4}$	$1.061 \times 10^{-4}$
$G_4^L, [1]$	$(1.164 \pm 0.091 \pm 0.073) \times 10^{-4}$	$1.213 \times 10^{-4}$
$G_5^L, [1]$	$(1.532 \pm 0.102 \pm 0.094) \times 10^{-4}$	$1.328 \times 10^{-4}$
$G_6^L, [1]$	$(1.372 \pm 0.110 \pm 0.082) \times 10^{-4}$	$1.417 \times 10^{-4}$
$G_7^L, [1]$	$(1.568 \pm 0.114 \pm 0.095) \times 10^{-4}$	$1.486 \times 10^{-4}$
$G_8^L, [1]$	$(1.298 \pm 0.112 \pm 0.076) \times 10^{-4}$	$1.540 \times 10^{-4}$
$G_9^L, [1]$	$(1.730 \pm 0.105 \pm 0.104) \times 10^{-4}$	$1.580 \times 10^{-4}$
$G_{10}^L, [1]$	$(1.557 \pm 0.085 \pm 0.095) \times 10^{-4}$	$1.608 \times 10^{-4}$

Check of  $G_T$  in  $B^0$  analysis

Check of  $G_T$  in  $B^0$  analysis

	$D^0 \rightarrow K\pi, \ell = e$	$D^0 \rightarrow K\pi, \ell = \mu$
$G_1^T, [1]$	$(1.187 \pm 0.148 \pm 0.075) \times 10^{-4}$	$(0.982 \pm 0.142 \pm 0.067) \times 10^{-4}$
$G_2^T, [1]$	$(1.514 \pm 0.112 \pm 0.102) \times 10^{-4}$	$(1.239 \pm 0.104 \pm 0.081) \times 10^{-4}$
$G_3^T, [1]$	$(1.594 \pm 0.116 \pm 0.104) \times 10^{-4}$	$(1.685 \pm 0.116 \pm 0.115) \times 10^{-4}$
$G_4^T, [1]$	$(1.809 \pm 0.122 \pm 0.113) \times 10^{-4}$	$(1.760 \pm 0.128 \pm 0.115) \times 10^{-4}$
$G_5^T, [1]$	$(1.649 \pm 0.136 \pm 0.105) \times 10^{-4}$	$(1.484 \pm 0.141 \pm 0.102) \times 10^{-4}$
$G_6^T, [1]$	$(1.511 \pm 0.145 \pm 0.097) \times 10^{-4}$	$(1.572 \pm 0.165 \pm 0.104) \times 10^{-4}$
$G_7^T, [1]$	$(1.135 \pm 0.156 \pm 0.069) \times 10^{-4}$	$(0.974 \pm 0.161 \pm 0.063) \times 10^{-4}$
$G_8^T, [1]$	$(0.933 \pm 0.159 \pm 0.060) \times 10^{-4}$	$(1.072 \pm 0.156 \pm 0.070) \times 10^{-4}$
$G_9^T, [1]$	$(0.631 \pm 0.163 \pm 0.038) \times 10^{-4}$	$(0.571 \pm 0.151 \pm 0.036) \times 10^{-4}$
$G_{10}^T, [1]$	$(0.254 \pm 0.141 \pm 0.025) \times 10^{-4}$	$(0.324 \pm 0.122 \pm 0.038) \times 10^{-4}$
	fit to total sample	central value of parametrized fit
$G_1^T, [1]$	$(1.088 \pm 0.102 \pm 0.069) \times 10^{-4}$	$0.919 \times 10^{-4}$
$G_2^T, [1]$	$(1.388 \pm 0.077 \pm 0.092) \times 10^{-4}$	$1.505 \times 10^{-4}$
$G_3^T, [1]$	$(1.637 \pm 0.081 \pm 0.108) \times 10^{-4}$	$1.706 \times 10^{-4}$
$G_4^T, [1]$	$(1.794 \pm 0.085 \pm 0.113) \times 10^{-4}$	$1.733 \times 10^{-4}$
$G_5^T, [1]$	$(1.547 \pm 0.097 \pm 0.101) \times 10^{-4}$	$1.642 \times 10^{-4}$
$G_6^T, [1]$	$(1.552 \pm 0.109 \pm 0.100) \times 10^{-4}$	$1.466 \times 10^{-4}$
$G_7^T, [1]$	$(1.054 \pm 0.111 \pm 0.065) \times 10^{-4}$	$1.222 \times 10^{-4}$
$G_8^T, [1]$	$(1.000 \pm 0.110 \pm 0.064) \times 10^{-4}$	$0.926 \times 10^{-4}$
$G_9^T, [1]$	$(0.600 \pm 0.110 \pm 0.035) \times 10^{-4}$	$0.589 \times 10^{-4}$
$G_{10}^T, [1]$	$(0.297 \pm 0.091 \pm 0.029) \times 10^{-4}$	$0.221 \times 10^{-4}$



# Comparison of preliminary results - 2008 and 2010

## Changes in the analysis

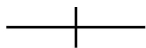
- Data sample ( $140\text{fb}^{-1} \rightarrow 711\text{fb}^{-1}$ ),  $D^0$  modes
- Enhanced background calibration
- Soft  $\pi$  investigation
- Newer PDG numbers for  $D$  branching ratios etc.

	$B^0 \rightarrow D^{*-} \ell \nu$ , ICHEP08	$B^0 \rightarrow D^{*-} \ell \nu$ , ICHEP2010
$\rho^2$	$1.293 \pm 0.045 \pm 0.029$	$1.214 \pm 0.034 \pm 0.009$
$R_1(1)$	$1.495 \pm 0.050 \pm 0.062$	$1.401 \pm 0.034 \pm 0.018$
$R_2(1)$	$0.844 \pm 0.034 \pm 0.019$	$0.864 \pm 0.024 \pm 0.008$
$\mathcal{B}(B \rightarrow D^{*} \ell^+ \nu_\ell)$	$(4.42 \pm 0.03 \pm 0.25)\%$	$(4.56 \pm 0.03 \pm 0.26)\%$
$\mathcal{F}(1)  V_{cb}  \times 10^3$	$34.4 \pm 0.2 \pm 1.0$	$34.5 \pm 0.2 \pm 1.0$
$R_{K3\pi/K\pi}$	$2.153 \pm 0.011$	
$P_{\chi^2}$	82.0%	28.2%





# Color scheme



**(OnRes - Continuum) data**



**Signal**



**MC background, Sig.corr.**



**MC background, D\*\***



**MC background, Uncorr.**



**MC background, Fake Lepton**



**MC background, Comb D\***



**MC background, Fake D<sup>0</sup>**



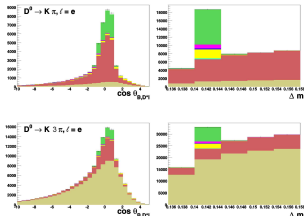
# $B^+$ background investigation

## Investigated using MC

- Fake  $D^0$
- Combinatoric  $D^{*}$
- Fake Lepton
- Uncorrelated
- $B \rightarrow D^{**} \ell \nu, B \rightarrow D^{*} X \ell \nu$
- Signal correlated

## Off-resonance data

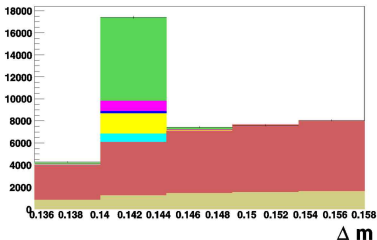
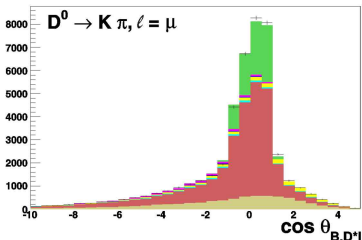
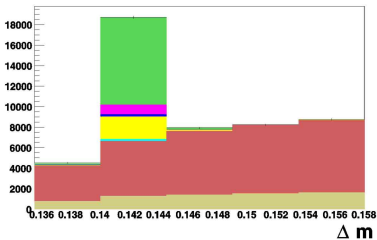
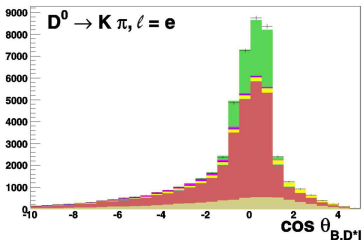
- Continuum:  $q\bar{q}$  decays

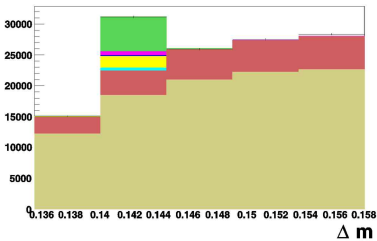
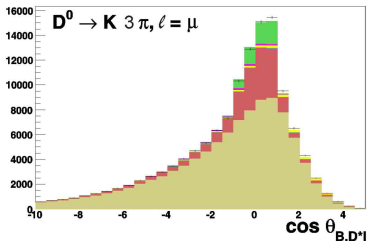
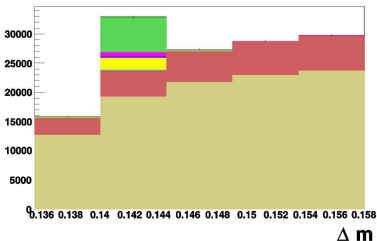
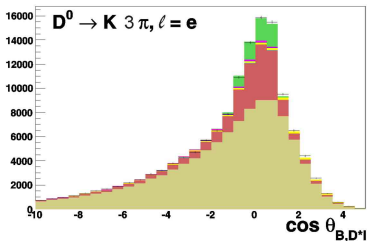


## HMCMLL, TFractionFitter

- Determine norm of MC components from fit to data
- Use 2D distribution  $\cos \theta_{B^0, D^* \ell}$  vs.  $\Delta m$

# Plot of TFractionFitter result - $B^+, D^0 \rightarrow K\pi$ modes



Plot of TFractionFitter result -  $B^+$ ,  $D^0 \rightarrow K3\pi$  modes

Background and signal purity,  $B^+$ 

## Fractions of the components

	$K\pi, e$	$K\pi, \mu$	$K3\pi, e$	$K3\pi, \mu$
Raw yield	13035	12262	16989	16350
Signal events	$8133 \pm 205$	$7447 \pm 201$	$5987 \pm 229$	$5539 \pm 222$
Signal	$(62.39 \pm 1.57)\%$	$(60.73 \pm 1.64)\%$	$(35.24 \pm 1.35)\%$	$(33.88 \pm 1.36)\%$
Signal correlated	$(1.27 \pm 0.31)\%$	$(1.46 \pm 0.32)\%$	$(1.16 \pm 0.26)\%$	$(1.34 \pm 0.31)\%$
$D^{**}$	$(0.77 \pm 0.98)\%$	$(0.73 \pm 0.98)\%$	$(0.39 \pm 0.50)\%$	$(0.36 \pm 0.47)\%$
Uncorrelated	$(4.97 \pm 0.54)\%$	$(4.25 \pm 0.45)\%$	$(3.48 \pm 0.41)\%$	$(3.30 \pm 0.38)\%$
Fake $\ell$	$(0.31 \pm 0.10)\%$	$(1.94 \pm 0.59)\%$	$(0.18 \pm 0.06)\%$	$(0.95 \pm 0.29)\%$
Combinatoric $D^{*0}$	$(24.76 \pm 0.51)\%$	$(24.30 \pm 0.48)\%$	$(16.35 \pm 0.69)\%$	$(15.19 \pm 0.67)\%$
Fake $D^0$	$(2.91 \pm 0.25)\%$	$(3.12 \pm 0.23)\%$	$(38.53 \pm 0.50)\%$	$(39.45 \pm 0.51)\%$
Continuum	$(2.63 \pm 0.43)\%$	$(3.46 \pm 0.51)\%$	$(4.68 \pm 0.50)\%$	$(6.14 \pm 0.56)\%$

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Results for all subsamples,  $B^+$ 

	$D^0 \rightarrow K\pi, \ell = e$	$D^0 \rightarrow K\pi, \ell = \mu$	$D^0 \rightarrow K3\pi, \ell = e$
$\rho^2$	$1.199 \pm 0.125 \pm 0.051$	$1.370 \pm 0.129 \pm 0.057$	$1.723 \pm 0.162 \pm 0.062$
$R_1(1)$	$1.507 \pm 0.135 \pm 0.095$	$1.568 \pm 0.158 \pm 0.089$	$1.840 \pm 0.271 \pm 0.110$
$R_2(1)$	$0.868 \pm 0.093 \pm 0.036$	$0.839 \pm 0.110 \pm 0.032$	$0.585 \pm 0.198 \pm 0.049$
$R_{K3\pi/K\pi}$	2.072	2.072	2.072
$\mathcal{B}(B^+ \rightarrow \bar{D}^{*0} \ell^+ \nu_\ell)$	$4.91 \pm 0.05 \pm 0.58$	$4.77 \pm 0.05 \pm 0.57$	$4.83 \pm 0.07 \pm 0.57$
$\mathcal{F}(1) V_{cb}  \times 10^3$	$34.3 \pm 0.6 \pm 2.2$	$35.0 \pm 0.6 \pm 2.3$	$36.5 \pm 1.0 \pm 2.4$
$\chi^2/\text{ndf.}$	48.3 / 36	40.6 / 36	39.6 / 36
$P_{\chi^2}$	8.3 %	27.5 %	31.3 %

	$D^0 \rightarrow K3\pi, \ell = \mu$	Fit to total sample
$\rho^2$	$1.434 \pm 0.209 \pm 0.086$	$1.376 \pm 0.074 \pm 0.056$
$R_1(1)$	$1.813 \pm 0.273 \pm 0.107$	$1.620 \pm 0.091 \pm 0.093$
$R_2(1)$	$0.764 \pm 0.191 \pm 0.052$	$0.805 \pm 0.064 \pm 0.037$
$R_{K3\pi/K\pi}$	2.072	$2.072 \pm 0.023$
$\mathcal{B}(B^+ \rightarrow \bar{D}^{*0} \ell^+ \nu_\ell)$	$4.83 \pm 0.07 \pm 0.58$	$4.84 \pm 0.04 \pm 0.57$
$\mathcal{F}(1) V_{cb}  \times 10^3$	$34.8 \pm 1.0 \pm 2.3$	$35.0 \pm 0.4 \pm 2.2$
$\chi^2/\text{ndf.}$	44.2 / 36	187.8 / 155
$P_{\chi^2}$	16.3 %	3.7 %

Breakdown of the preliminary systematic error,  $B^+$ 

	$\rho^2$	$R_1(1)$	$R_2(1)$	$\mathcal{F}(1) V_{cb}  \times 10^3$	$\mathcal{B}(B^+ \rightarrow \bar{D}^{*0} \ell^+ \nu_\ell)$
Value	1.376	1.620	0.805	34.98	4.841
Statistical Error	0.074	0.091	0.064	0.37	0.044
$\pi_s^0$ & tracking	<b>0.027</b>	0.025	0.012	<b>1.97</b>	<b>0.491</b>
LeptonID	0.012	0.024	0.011	0.39	0.096
Norm - Signal Corr.	0.007	0.002	0.007	0.13	0.038
Norm - $D^{**}$	0.005	0.023	0.002	0.04	0.041
Norm - Uncorr	0.014	<b>0.074</b>	<b>0.025</b>	0.28	0.023
Norm - Fake $\ell$	0.017	0.028	0.010	0.05	0.024
Norm - Comb $D^{*0}$	0.008	0.014	0.008	0.11	0.028
Norm - Fake $D^0$	0.009	0.014	0.007	0.06	0.020
Norm - Continuum	0.004	0.005	0.001	0.00	0.003
Shape - Uncorr	0.014	0.003	0.005	0.10	
Shape - Comb $D^{*0}$	<b>0.027</b>	0.005	0.008	0.21	
Shape - Fake $D^0$	0.024	0.003	0.008	0.17	
$\mathcal{B}(D^0 \rightarrow K\pi)$				0.32	0.089
$\mathcal{B}(D^{*0} \rightarrow D^0 \pi^0)$				0.82	0.227
$B^+$ life time				0.12	0.033
$N(\Upsilon(4S))$				0.14	0.040
$f_{+-} / f_{00}$	0.003	0.006	0.003	0.15	0.043

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# Correlations in $B^+$ analysis

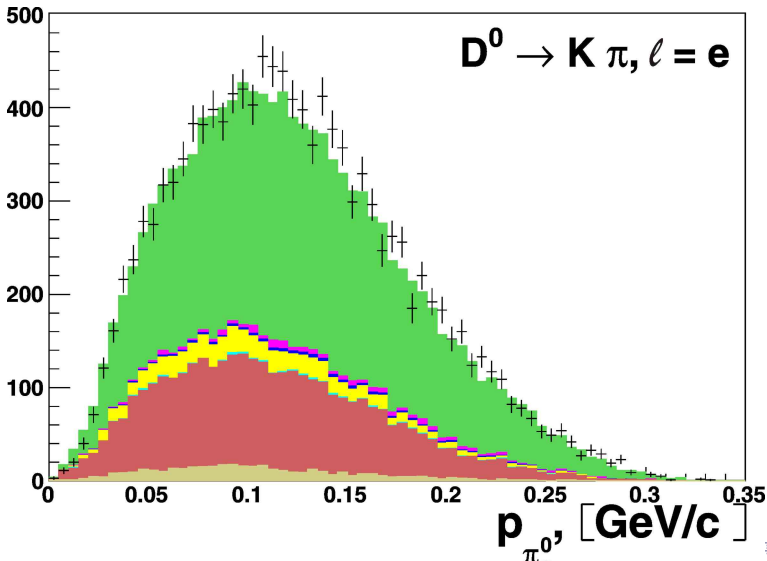
- Table shows statistical correlation coefficients

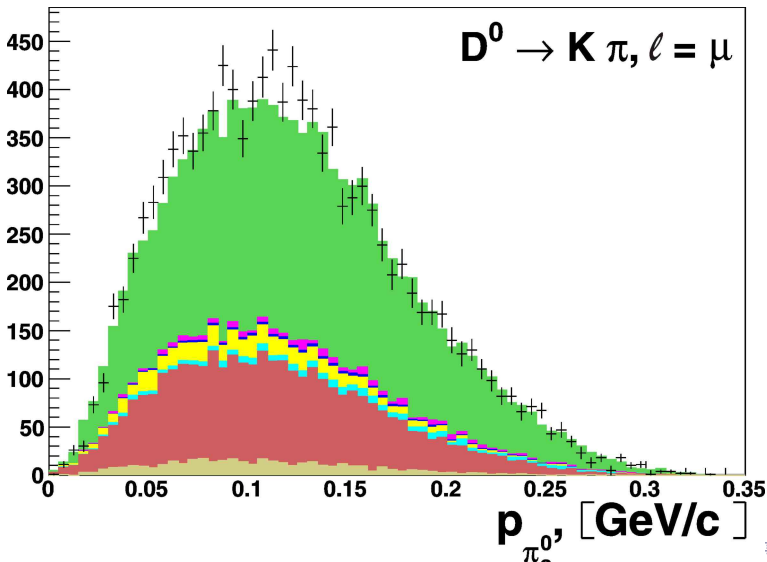
	$\mathcal{F}(1) V_{cb} $	$\rho^2$	$R_1(1)$	$R_2(1)$
$\mathcal{F}(1) V_{cb} $	1.000	0.455	-0.222	-0.054
$\rho^2$		1.000	0.648	-0.889
$R_1(1)$			1.000	-0.749
$R_2(1)$				1.000

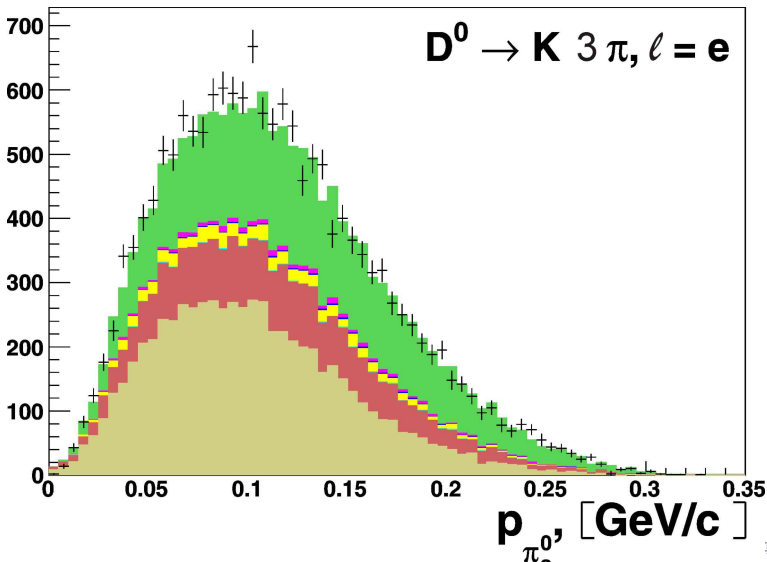
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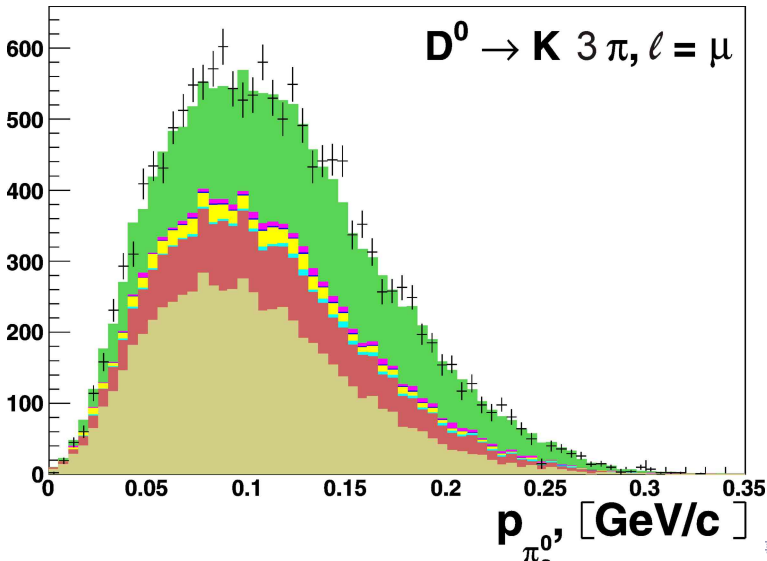


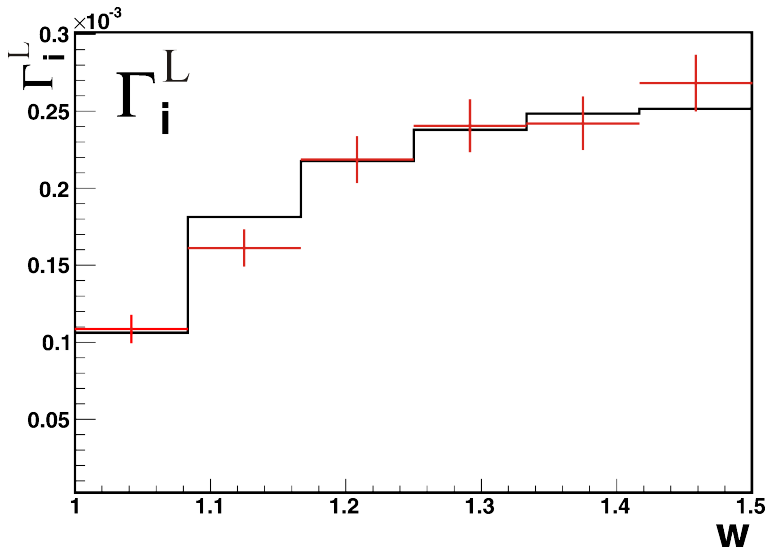


$B^+$ ,  $p_{\pi_S^0}$  distribution -  $K\pi$ ,  $e$  channel

$B^+$ ,  $p_{\pi_S^0}$  distribution -  $K\pi, \mu$  channel

$B^+$ ,  $p_{\pi_S^0}$  distribution -  $K3\pi$ ,  $e$  channel

$B^+$ ,  $p_{\pi_S^0}$  distribution -  $K3\pi, \mu$  channel

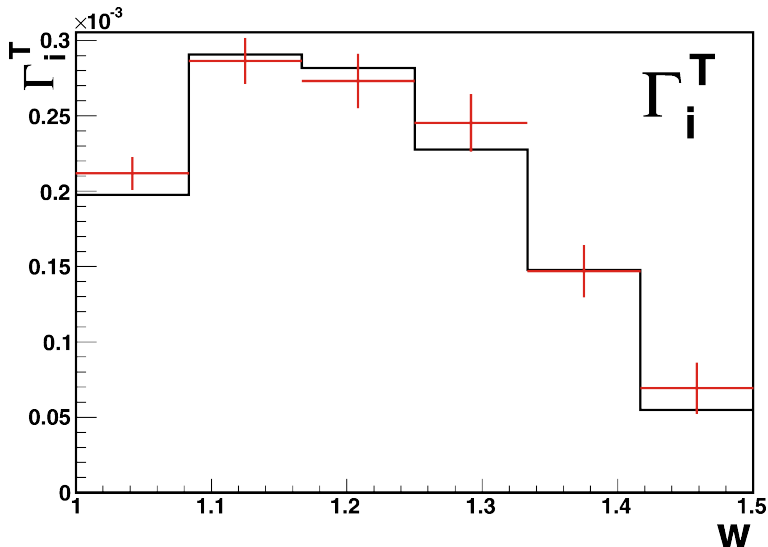
Check of  $G_T$  in  $B^+$  analysis

Check of  $G_L$  in  $B^+$  analysis

	$D^0 \rightarrow K\pi, \ell = e$	$D^0 \rightarrow K\pi, \ell = \mu$
$G^{00}, w \in (1, \frac{13}{12})$	$(1.025 \pm 0.119 \pm 0.120) \times 10^{-4}$	$(1.176 \pm 0.146 \pm 0.137) \times 10^{-4}$
$G^{00}, w \in (\frac{13}{12}, \frac{7}{6})$	$(1.544 \pm 0.165 \pm 0.176) \times 10^{-4}$	$(1.689 \pm 0.177 \pm 0.192) \times 10^{-4}$
$G^{00}, w \in (\frac{7}{6}, \frac{15}{12})$	$(2.238 \pm 0.213 \pm 0.237) \times 10^{-4}$	$(2.121 \pm 0.216 \pm 0.238) \times 10^{-4}$
$G^{00}, w \in (\frac{15}{12}, \frac{8}{6})$	$(2.677 \pm 0.244 \pm 0.268) \times 10^{-4}$	$(2.059 \pm 0.240 \pm 0.228) \times 10^{-4}$
$G^{00}, w \in (\frac{8}{6}, \frac{17}{12})$	$(2.406 \pm 0.235 \pm 0.256) \times 10^{-4}$	$(2.426 \pm 0.263 \pm 0.263) \times 10^{-4}$
$G^{00}, w \in (\frac{17}{12}, 1.5)$	$(2.907 \pm 0.250 \pm 0.301) \times 10^{-4}$	$(2.384 \pm 0.273 \pm 0.278) \times 10^{-4}$

	fit to total sample	central value of parametrized fit
$G^{00}, w \in (1, \frac{13}{12})$	$(1.087 \pm 0.092 \pm 0.123) \times 10^{-4}$	$1.062 \times 10^{-4}$
$G^{00}, w \in (\frac{13}{12}, \frac{7}{6})$	$(1.611 \pm 0.121 \pm 0.179) \times 10^{-4}$	$1.812 \times 10^{-4}$
$G^{00}, w \in (\frac{7}{6}, \frac{15}{12})$	$(2.186 \pm 0.151 \pm 0.238) \times 10^{-4}$	$2.175 \times 10^{-4}$
$G^{00}, w \in (\frac{15}{12}, \frac{8}{6})$	$(2.406 \pm 0.172 \pm 0.262) \times 10^{-4}$	$2.379 \times 10^{-4}$
$G^{00}, w \in (\frac{8}{6}, \frac{17}{12})$	$(2.421 \pm 0.175 \pm 0.258) \times 10^{-4}$	$2.483 \times 10^{-4}$
$G^{00}, w \in (\frac{17}{12}, 1.5)$	$(2.683 \pm 0.186 \pm 0.298) \times 10^{-4}$	$2.514 \times 10^{-4}$



Check of  $G_T$  in  $B^+$  analysis

Check of  $G_T$  in  $B^+$  analysis

	$D^0 \rightarrow K\pi.\ell = e$	$D^0 \rightarrow K\pi.\ell = \mu$
$\Gamma^T, w \in (1, \frac{13}{12})$	$(2.267 \pm 0.153 \pm 0.264) \times 10^{-4}$	$(1.939 \pm 0.152 \pm 0.228) \times 10^{-4}$
$\Gamma^T, w \in (\frac{13}{12}, \frac{7}{6})$	$(2.695 \pm 0.214 \pm 0.307) \times 10^{-4}$	$(3.015 \pm 0.216 \pm 0.348) \times 10^{-4}$
$\Gamma^T, w \in (\frac{7}{6}, \frac{15}{12})$	$(2.786 \pm 0.253 \pm 0.310) \times 10^{-4}$	$(2.678 \pm 0.261 \pm 0.299) \times 10^{-4}$
$\Gamma^T, w \in (\frac{15}{12}, \frac{8}{6})$	$(2.298 \pm 0.249 \pm 0.246) \times 10^{-4}$	$(2.673 \pm 0.295 \pm 0.290) \times 10^{-4}$
$\Gamma^T, w \in (\frac{8}{6}, \frac{17}{12})$	$(1.557 \pm 0.242 \pm 0.162) \times 10^{-4}$	$(1.369 \pm 0.250 \pm 0.144) \times 10^{-4}$
$\Gamma^T, w \in (\frac{17}{12}, 1.5)$	$(0.588 \pm 0.205 \pm 0.056) \times 10^{-4}$	$(0.862 \pm 0.284 \pm 0.099) \times 10^{-4}$

	fit to total sample	central value of parametrized fit
$\Gamma^T, w \in (1, \frac{13}{12})$	$(2.117 \pm 0.108 \pm 0.248) \times 10^{-4}$	$1.975 \times 10^{-4}$
$\Gamma^T, w \in (\frac{13}{12}, \frac{7}{6})$	$(2.865 \pm 0.152 \pm 0.327) \times 10^{-4}$	$2.908 \times 10^{-4}$
$\Gamma^T, w \in (\frac{7}{6}, \frac{15}{12})$	$(2.732 \pm 0.181 \pm 0.303) \times 10^{-4}$	$2.819 \times 10^{-4}$
$\Gamma^T, w \in (\frac{15}{12}, \frac{8}{6})$	$(2.454 \pm 0.191 \pm 0.263) \times 10^{-4}$	$2.276 \times 10^{-4}$
$\Gamma^T, w \in (\frac{8}{6}, \frac{17}{12})$	$(1.468 \pm 0.174 \pm 0.154) \times 10^{-4}$	$1.478 \times 10^{-4}$
$\Gamma^T, w \in (\frac{17}{12}, 1.5)$	$(0.693 \pm 0.170 \pm 0.070) \times 10^{-4}$	$0.547 \times 10^{-4}$





# Measurement of the decay $B \rightarrow D^* \ell^+ \nu$ and determination of $|V_{cb}|$ at Belle

Wolfgang Dungenl

Institute of High Energy Physics  
Austrian Academy of Sciences

on behalf of the Belle collaboration



ICHEP 2010,  
July 24, 2010

