

Measurement of $\mathcal{B}(D^0 \rightarrow K^- \pi^+)$ at BABAR

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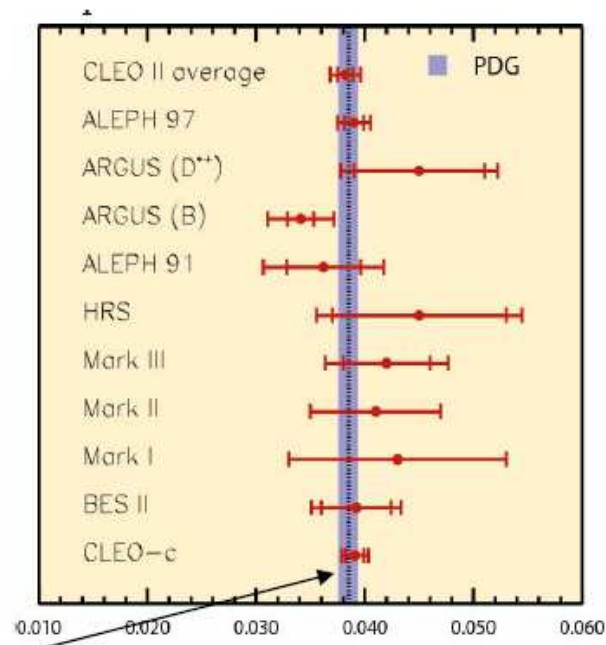
Motivations

- **How important to measure a precise absolute $\mathcal{B}(D^0 \rightarrow K^- \pi^+)$?**
 - **The absolute $\mathcal{B}(D^0 \rightarrow K^- \pi^+)$ is commonly used for normalizing many D decay modes : D^0, D^+ and D_s^+**
 - ↪ **It is particularly important in heavy flavor physics**
 - ↪ **Determination of $|V_{cb}|$ requires knowledge of $\mathcal{B}(D^0 \rightarrow K^- \pi^+)$**
 - ↪ **It improves our knowledge of D and B mesons properties**
 - **We present a precise measurement of $\mathcal{B}(D^0 \rightarrow K^- \pi^+)$**
 - ↪ **using partial reconstruction of the decay $\bar{B}^0 \rightarrow D^{*+} X \ell^- \bar{\nu}_\ell$**
 - **The recent precise measurement of $\mathcal{B}(D^0 \rightarrow K^- \pi^+)$ is done by CLEO-c**
 - ↪ **published in Phys. Rev. Lett. 95, 121801 (2005)**

Experimental Results

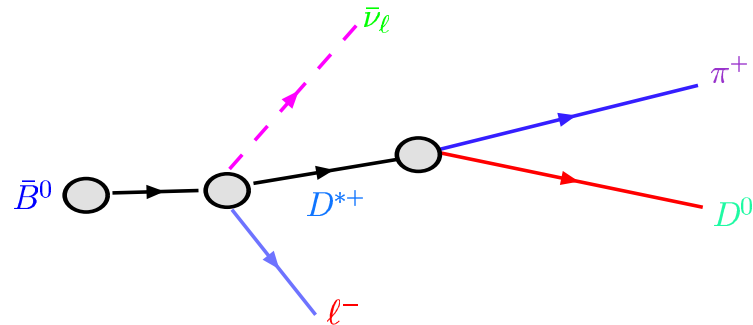
Sources	$\mathcal{B}(D^0 \rightarrow K^- \pi^+)(\%)$	Precision
ALEPH '96	$3.90 \pm 0.09 \pm 0.12$	3.8 %
CLEO '98	$3.81 \pm 0.15 \pm 0.16$	5.6 %
CLEO average	$3.82 \pm 0.07 \pm 0.12$	3.6 %
CLEO-c '05	$3.91 \pm 0.08 \pm 0.09$	3.1 %
PDG '06	3.80 ± 0.07 (average)	1.8 %

□ Comparison of $\mathcal{B}(D^0 \rightarrow K^- \pi^+)$ results :



Partial Reconstruction

□ $\bar{B}^0 \rightarrow D^{*+} X \ell^- \bar{\nu}_\ell$ ($D^{*+} \rightarrow D^0 \pi_s^+$) : D^{*+} is identified by π_s^+ only



- D^0 is collected without reconstructing a particular D^0 decay mode
- We are not biased by poorly known decay of $B \rightarrow D^* n(\pi) \ell \bar{\nu}_\ell$
- This sample is labeled as “inclusive sample”

□ **Observable Missing Mass Squared**

$$\mathcal{M}_\nu^2 \equiv (E_{\text{beam}} - E_{D^*} - E_\ell)^2 - (\vec{p}_{D^*} + \vec{p}_\ell)^2$$

Only slow π_s and hard ℓ (e or μ) are detected

- $p_{\pi_s} < 190 \text{ MeV}/c$
- $p_\ell > 1.4 \text{ GeV}/c$

Branching Fraction

□ Signal Definition :

- $\bar{B}^0 \rightarrow D^{*+} \ell^- \bar{\nu}_\ell$, $D^{*+} \rightarrow D^0 \pi_s^+$ (primary) (70%)
- $\bar{B} \rightarrow D^* n(\pi) \ell \bar{\nu}_\ell$ (orbitally excited charm states) (15%)
- $\bar{B}^0 \rightarrow D^{*+} \gamma e^- \bar{\nu}_e$ (radiative B decay) (15%)

□ Branching Fraction Determination :

$$\mathcal{B}(D^0 \rightarrow K^- \pi^+) = \frac{N^{excl}}{N^{incl}} \times \frac{1}{\eta}$$

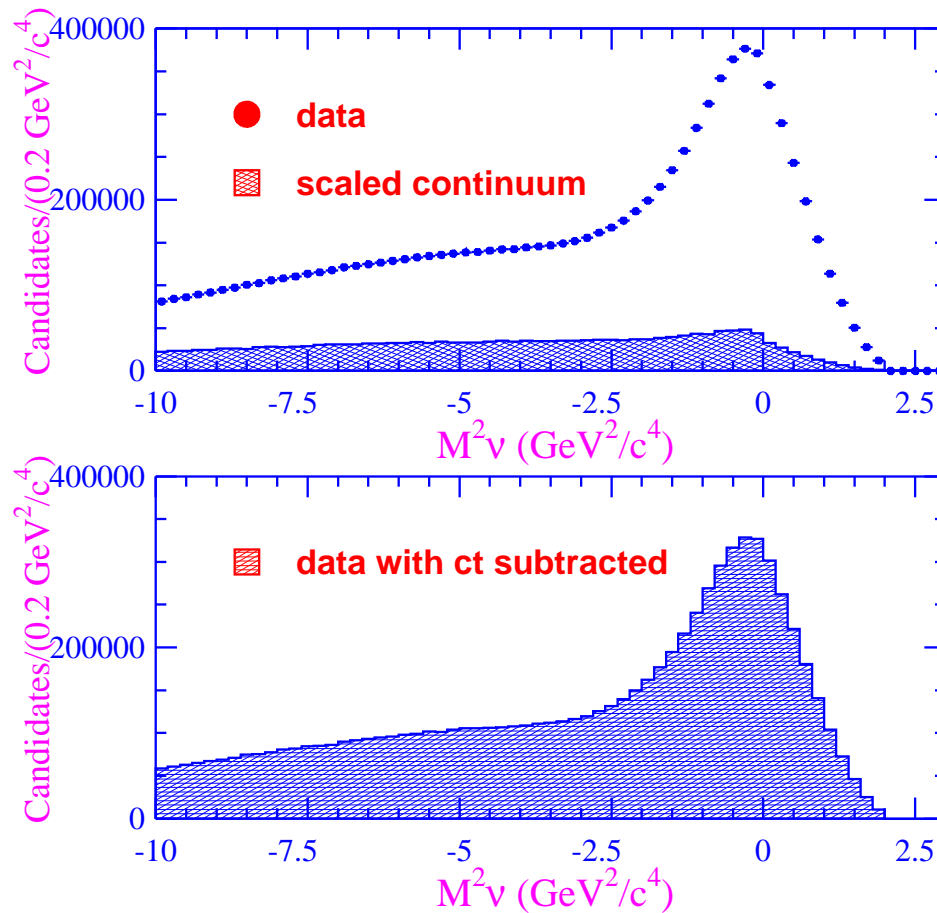
- the exclusive sample is a fully reconstructed D^0 (detail later)

$$\eta \equiv \varepsilon_{(K^- \pi^+)} \beta = \frac{N_{MC}^{excl}}{N_{MC}^{incl}} \times \frac{1}{\mathcal{B}_{MC}(D^0 \rightarrow K^- \pi^+)}$$

↪ $\varepsilon_{(K^- \pi^+)} = (34.78 \pm 0.10)\%$ (D^0 reconstruction efficiencies)

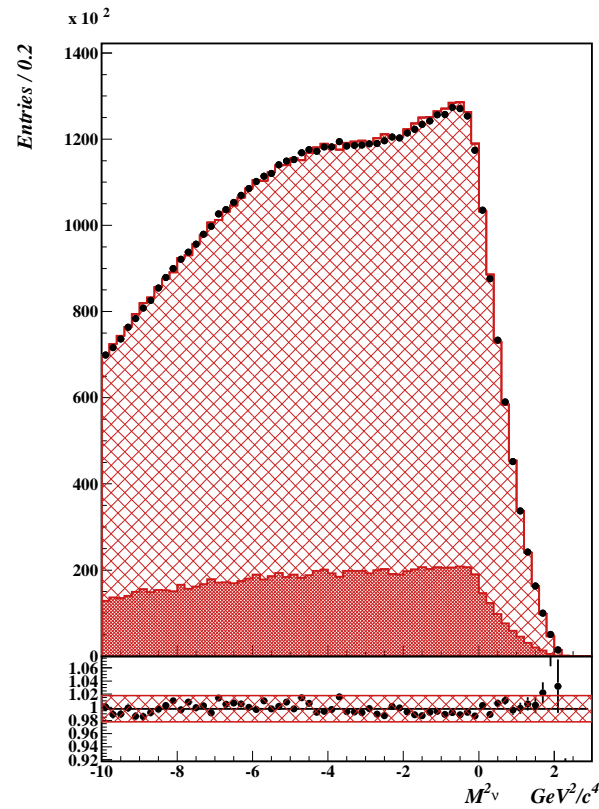
↪ $\beta = \frac{\mathcal{B}_{MC-truth}}{\mathcal{B}_{Gen}} = 1.0496 \pm 0.0016$ (analysis bias introduced by partial reco.)

Inclusive Sample



- **Data:** 210 fb^{-1} (230 million $B\bar{B}$) on-resonance and 22 fb^{-1} off-resonance for estimating the continuum background
- $\lambda_{cont} = 9.5 \hookrightarrow$ after correcting $\Delta(\text{Luminosity})$ and $\Delta(\text{CM energy})$

Wrong-charge Sample

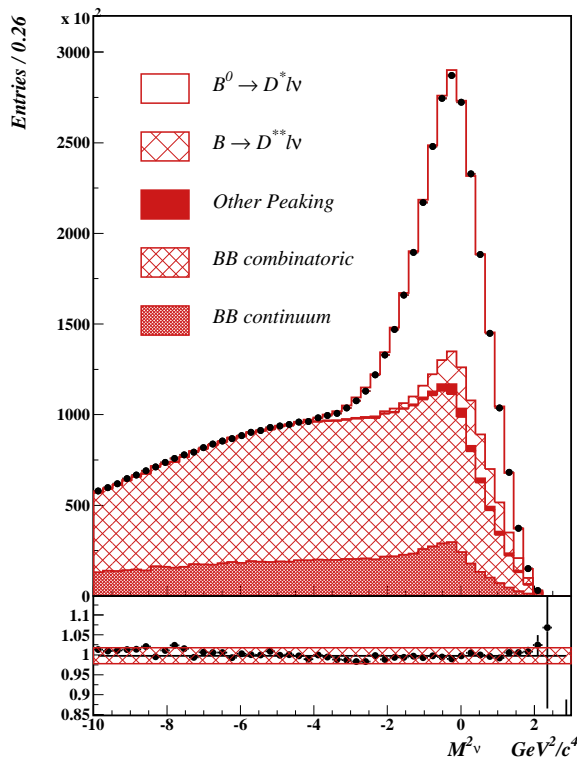


Source	Sideband region	Signal region
Data yield	2950×10^3	1700×10^3
Fitted yield	2949×10^3	1711×10^3
Difference	0.03%	0.6%

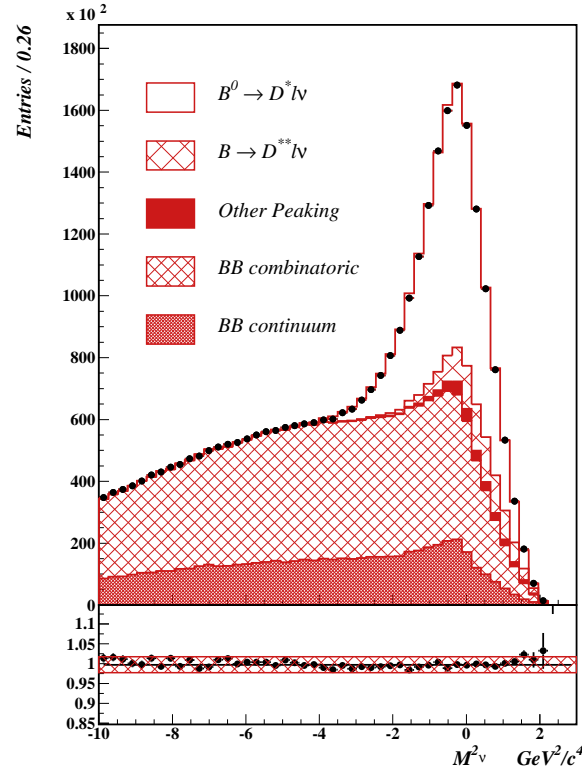
□ Signal region : $\mathcal{M}_\nu^2 > -2.0 \text{ GeV}^2/c^4$

Sideband region : $-10 < \mathcal{M}_\nu^2 < -4 \text{ GeV}^2/c^4$

Inclusive Fitting Results



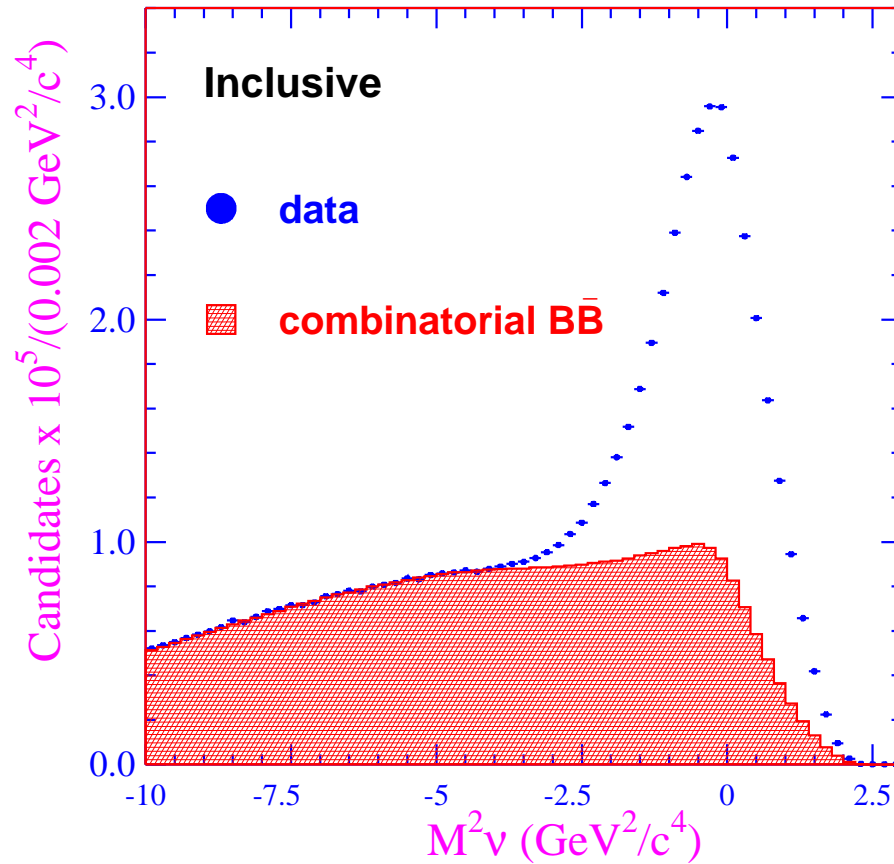
$(e^{\mp} - \pi_s^{\pm})$



$(\mu^{\mp} - \pi_s^{\pm})$

- χ^2 binned fit to data w/ signal MC + continuum + combinatoric + other $B\bar{B}$ peaking + $D^* \pi \ell \bar{\nu}_\ell$ production
- \hookrightarrow Bottom plot : ratio data/fit and fitting with a constant

Inclusive Yield



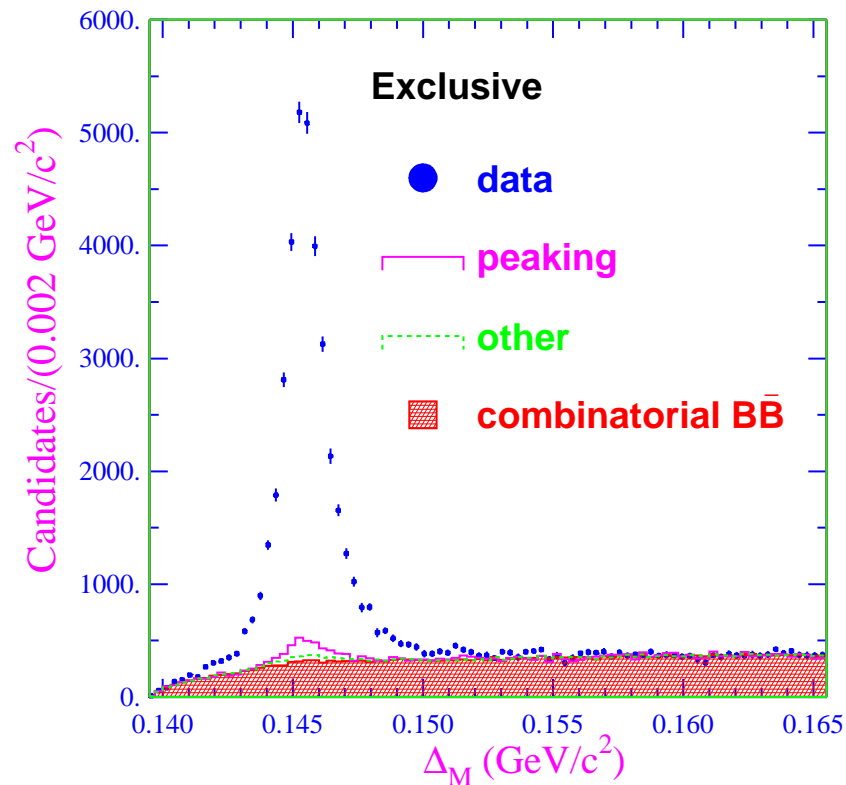
- We are using MC sample to estimate the combinatoric background

$$\text{Inclusive yield} \equiv N^{incl} = (2157.5 \pm 2.9(stat)) \times 10^3$$

Exclusive Selection

- We select ($D^0 \rightarrow K^- \pi^+$) within the signal region of the inclusive sample ($\mathcal{M}_v^2 > -2.0 \text{ GeV}^2/c^4$) to reduce the background
- We combine pairs of opposite charged tracks to compute the invariant mass of $M_{K^- \pi^+}$, where K^- has charged opposite to slow π_s^+
- We then select the events in mass range of $1820 < M_{K\pi} < 1910 \text{ MeV}/c^2$ which contains more than 95% of our signal candidates
- Finally we combine each D^0 candidate with the slow π_s^+ and reject events with mass difference $\Delta_M \equiv M_{K\pi, \pi_s^+} - M_{K\pi} > 162.5 \text{ MeV}/c^2$
- We apply kaon-PID selection to reduce the background
- We look for signal events in the interval: $142.4 < \Delta_M < 149.9 \text{ MeV}/c^2$

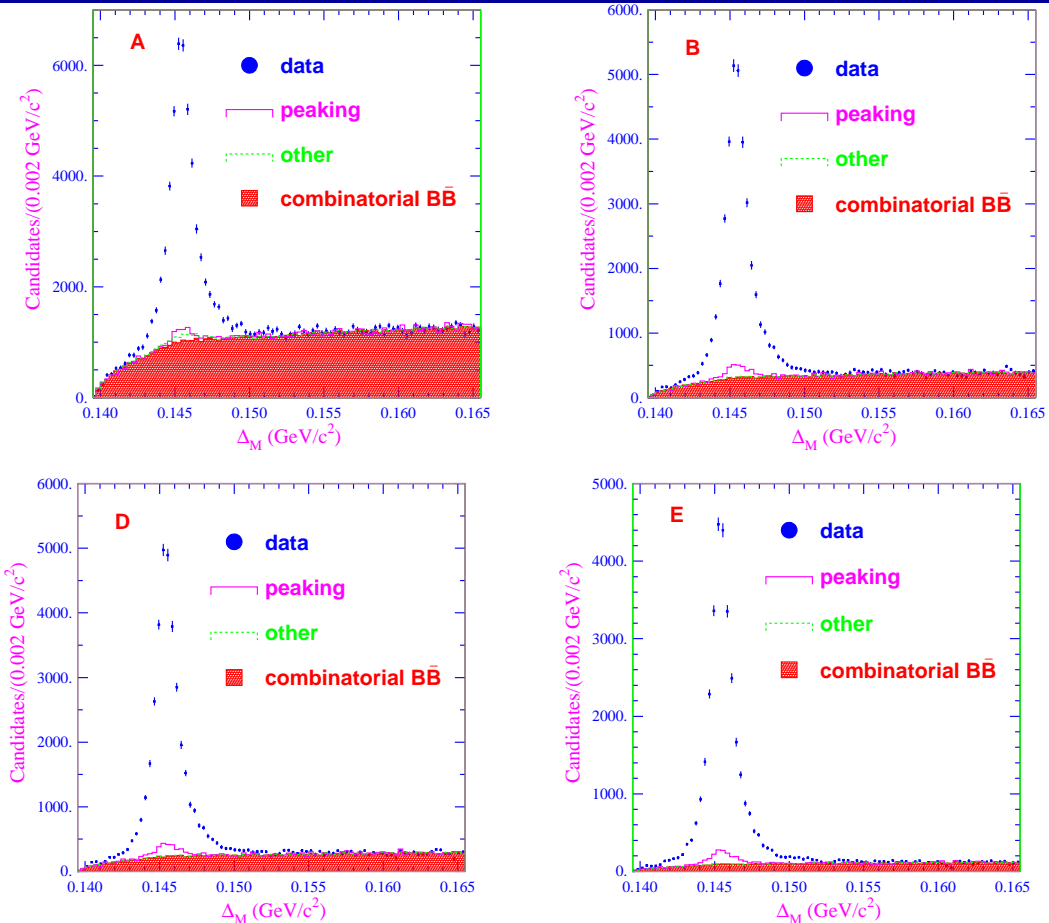
Exclusive Sample



- D^0 peaking \equiv uncorrelated background where the true D^0 pairs with the true soft π_s^+ (both from D^{*+}) but the D^{*+} and ℓ^- are coming from a different B

Exclusive yield $\equiv N^{excl} = (31.7 \pm 0.28(stat)) \times 10^3$

Cross-check Samples



- A. Loose D^0 mass selection (page 10 with no K-PID)**
- B. $|M_{K\pi} - m(D^0)_{PDG}| < 25 \text{ MeV}/c^2$**
- C. Sample A + K-PID (final result)**
- D. Sample B + $\Pi(Vtx(K\pi)) > 1\%$**
- E. Sample B + $\Pi(Vtx(K\pi)) > 1\%$ + K-PID**

Alternative Results

□ Summary of all exclusive samples :

Source	$\eta \equiv \varepsilon_{(K^-\pi^+)}\beta(\%)$	$\mathcal{B}(D^0 \rightarrow K^-\pi^+)(\%)$
Exclusive A	40.3 ± 0.11	4.067 ± 0.047 (stat)
Exclusive B	36.3 ± 0.10	3.999 ± 0.039 (stat)
Exclusive C	36.5 ± 0.10	4.025 ± 0.038 (stat)
Exclusive D	35.7 ± 0.10	3.965 ± 0.038 (stat)
Exclusive E	32.8 ± 0.10	3.962 ± 0.036 (stat)

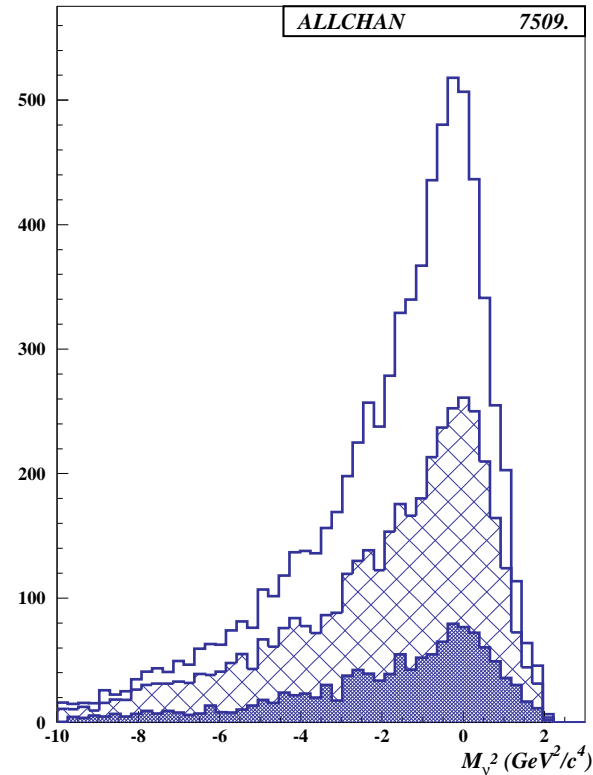
□ Comparison of the inclusive and exclusive samples :

Source	Inclusive	Exclusive
Data	3887550 ± 1970	43920 ± 210
Continuum	408960 ± 1970	2940 ± 170
Combinatoric $B\bar{B}$	1321250 ± 580	7410 ± 50
Peaking	1370 ± 80
Other	510 ± 10
Total	2157530 ± 2850	31700 ± 280

Analysis Bias

- We compare $\mathcal{B}(D^0 \rightarrow K^- \pi^+)$ in MC-truth table ($\mathcal{B}_{MC-truth}$) with its branching fraction in our MC generation production (\mathcal{B}_{Gen})
- We consider several final states such as $KK, \pi\pi, K e \nu, K \mu \nu, K \pi \pi$
- The main sources of the analysis bias (as independent effects):
 - the inclusive event selection: $(2.4 \pm 1.2)\%$
 - the soft pion reconstruction: $(2.5 \pm 1.2)\%$
- We take half of the deviation from unity and add them in quadrature
↪ the systematic error due to the analysis bias : $\sigma_\beta = 1.7\%$
- We are working to improve this bias for final publication

Peaking Combinatoric Background



- $\bar{B} \rightarrow D(X)\ell^- \bar{\nu}_\ell$, $D \rightarrow Y\pi^+$, where π^+ mimics the soft pion from D^{*+} decays: e.g: $D^+ \rightarrow (\bar{K}^*/\omega/\rho)\pi^+$
- We varied these events contribution by $\pm 100\%$ in MC sample and obtained 0.34% syst error due to this background

Systematic Errors

Summary of the absolute systematic error for $\mathcal{B}(D^0 \rightarrow K^- \pi^+)$:

Sample	Source	$\delta(\mathcal{B})/\mathcal{B}$ (%)
N^{incl}	Analysis bias	1.70
	Non-peaking combinatorial bkg	0.75
	Peaking combinatorial bkg	0.34
	Soft pion decay in flight	0.10
	Fake leptons	0.08
	Cascade decay	0.08
	Monte Carlo events shape	0.08
	Continuum bkg	0.05
	D^{**} production	0.02
	Photon radiation	0.02
N^{excl}	Tracking efficiency	1.0
	D^0 invariant mass	0.8
	K^- identification	0.7
	Combinatorial bkg shape	0.3
	Combinatorial bkg normalization	0.27
	Other background	0.1
Total		2.43

The dominant syst error is due to the analysis bias (it will be improved)

Summary

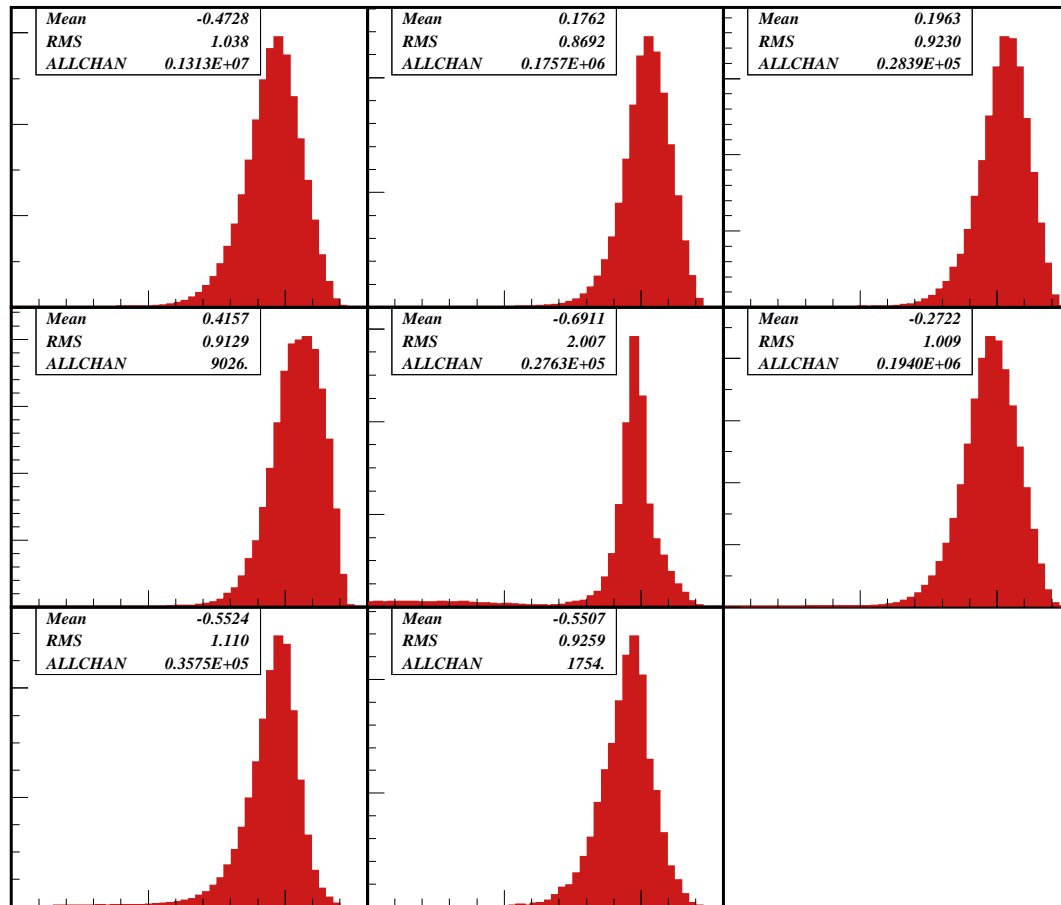
- **Inclusive yield** : $N^{incl} = (2157.5 \pm 2.9) \times 10^3$
- **Exclusive yield** : $N^{excl} = (31.7 \pm 0.28) \times 10^3$
- **The preliminary result:**

$$\mathcal{B}(D^0 \rightarrow K^- \pi^+) = (4.025 \pm 0.038_{stat} \pm 0.098_{syst})\%$$

- **Current comparison results :**

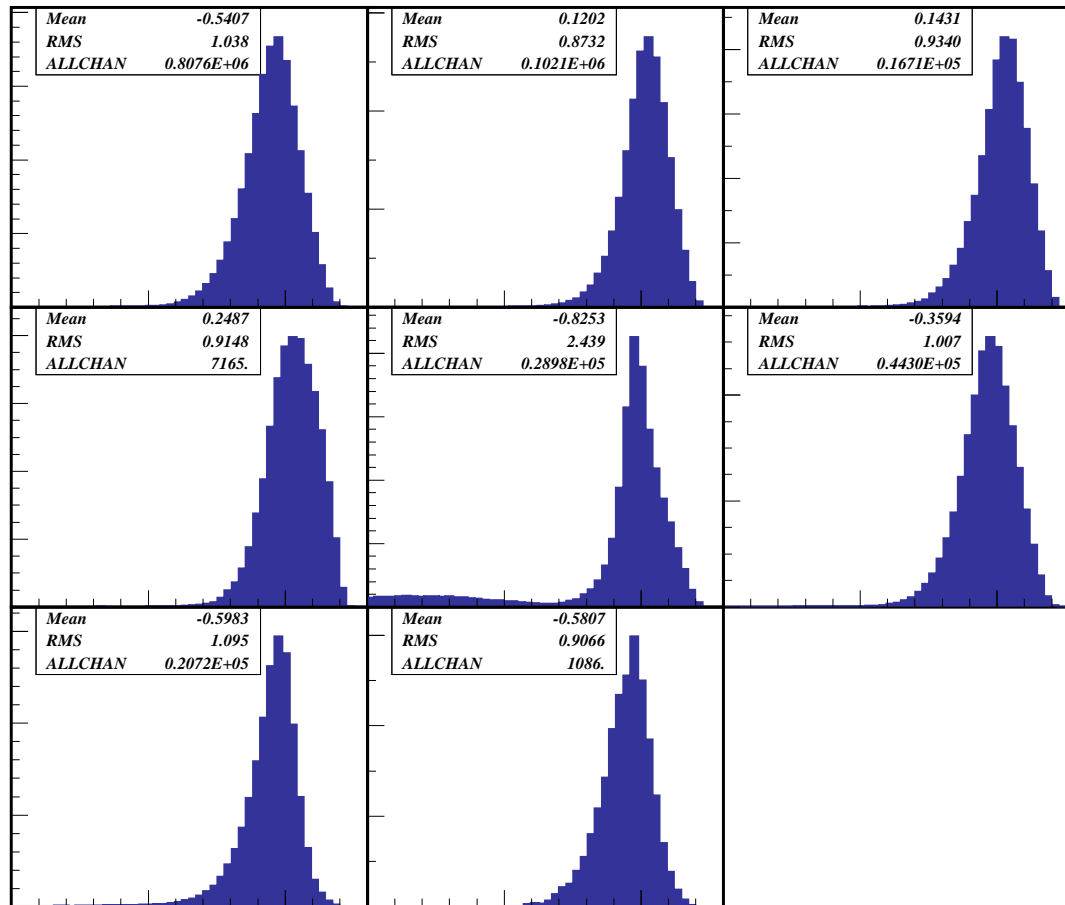
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CLEO average	$3.82 \pm 0.07 \pm 0.12$	3.6 %
CLEO-c '05	$3.91 \pm 0.08 \pm 0.09$	3.1 %
This analysis	$4.025 \pm 0.038 \pm 0.098$	2.6 %

Signal Events in Electron Sample (backup)



- Fake D^{*+} , resonant D^{**} , non-resonant D^{**} , cascade, fake e, radiative D^{**} , soft pion decay in flight, others
- We vary the individual event type by $\pm 30\%$ and refit them

Signal Events in Muon Sample (backup)



- Fake D^{*+} , resonant D^{**} , non-resonant D^{**} , cascade, fake μ , radiative D^{**} , soft pion decay in flight, others
- We vary the individual event type by $\pm 30\%$ and refit them