



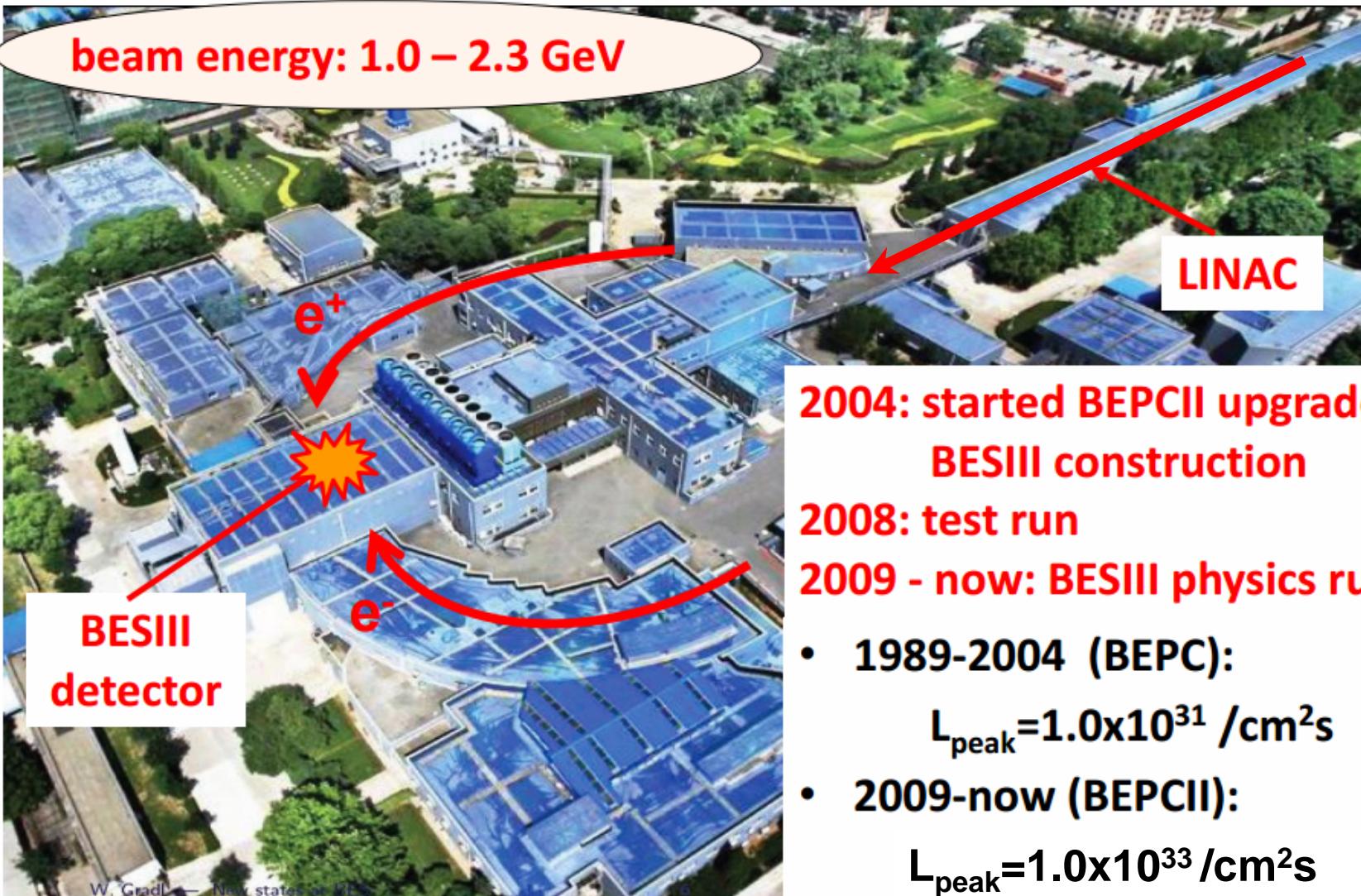
D Physics @ BESIII

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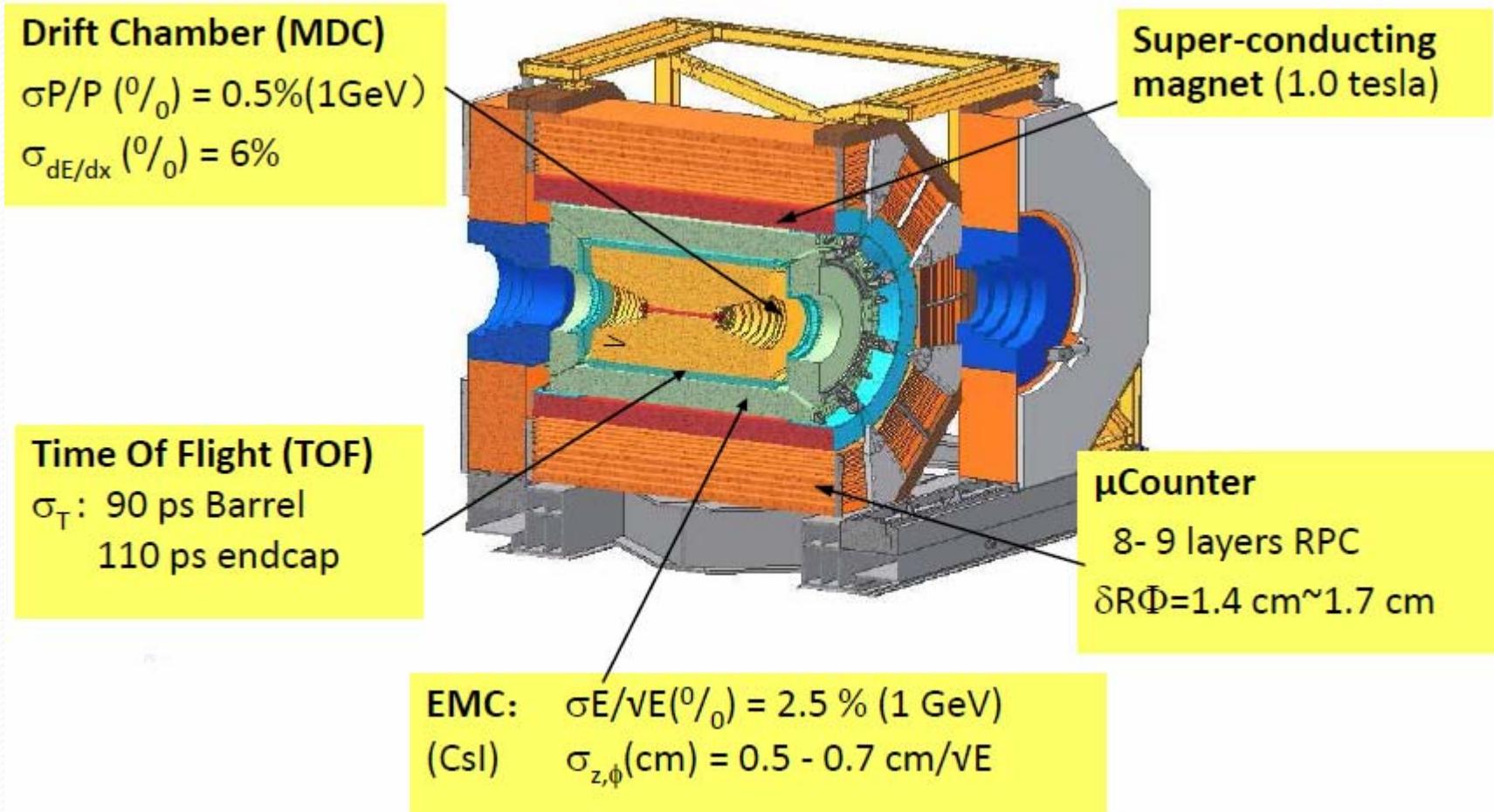
Outline

- Introduction
- Recent Charm Results
 - Observation of SCS decay $D^{+(0)} \rightarrow \omega\pi^{+(0)}$
 - Measurement of $D^+ \rightarrow \omega e^+\nu_e$ and Search for $D^+ \rightarrow \phi e^+\nu_e$
 - Analysis of $D^0 \rightarrow K^-/\pi^- e^+\nu_e$
 - Decay Dynamics and CP Asymmetry in $D^+ \rightarrow K_L e^+\nu_e$
 - Measurement $\text{Br}(D_s^+ \rightarrow \eta' X)$ and $\text{Br}(D_s^+ \rightarrow \eta' \rho^+)$
 - Search for $D^0 \rightarrow \gamma\gamma$ and improved measurement of $D^0 \rightarrow \pi^0\pi^0$
- Summary

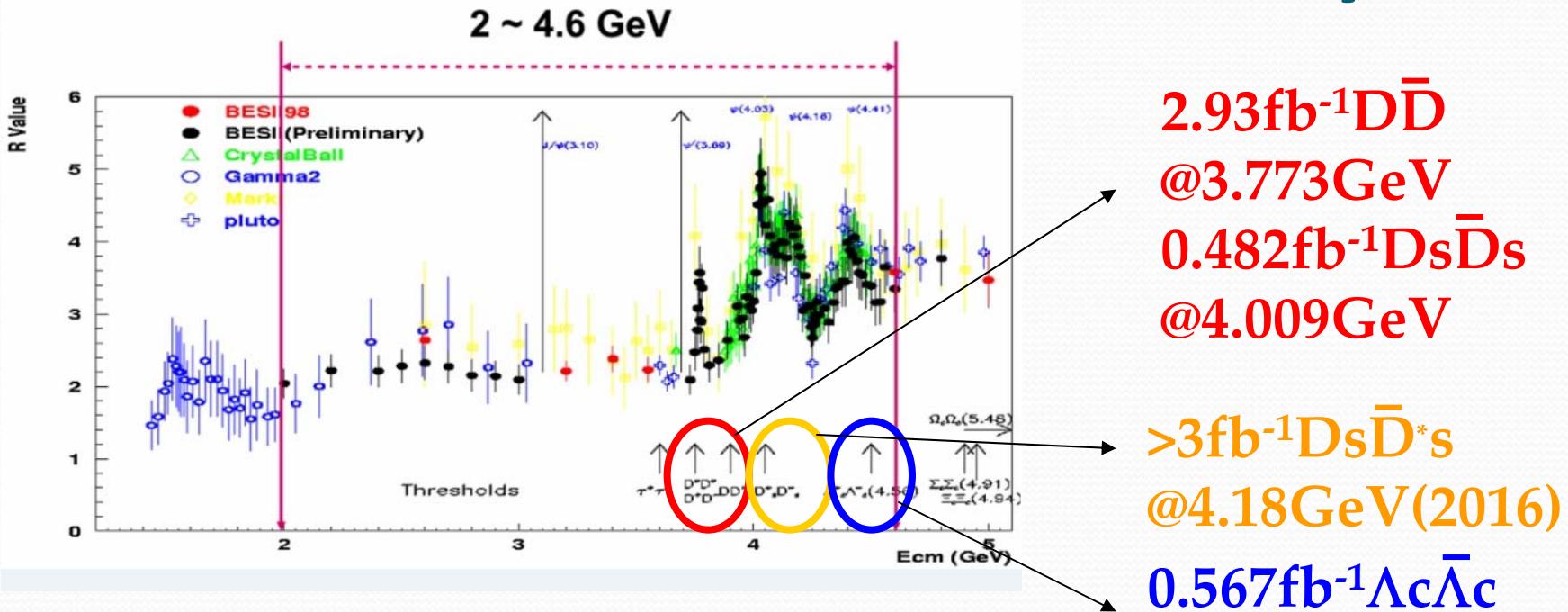
Beijing Electron Positron Collider



The BESIII detector

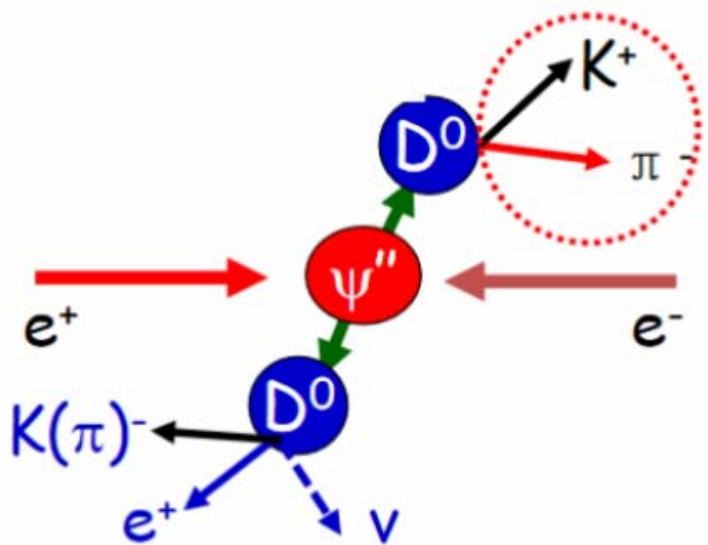


Charm Production and Charm Physics



- (Semi)leptonic and hadronic decays;
- Decay constant and form factors;
- CKM matrix: V_{cd}, V_{cs} ;
- Mixing and CPV;
- Rare and forbidden decays

Analysis Technique



D^-

$$\begin{aligned} D^- &\rightarrow K^+ \pi^- \pi^- \\ D^- &\rightarrow K^+ \pi^- \pi^- \pi^0 \\ D^- &\rightarrow K_S^0 \pi^- \\ D^- &\rightarrow K_S^0 \pi^- \pi^0 \\ D^- &\rightarrow K_S^0 \pi^- \pi^+ \pi^- \\ D^- &\rightarrow K^+ K^- \pi^- \end{aligned}$$

D^0

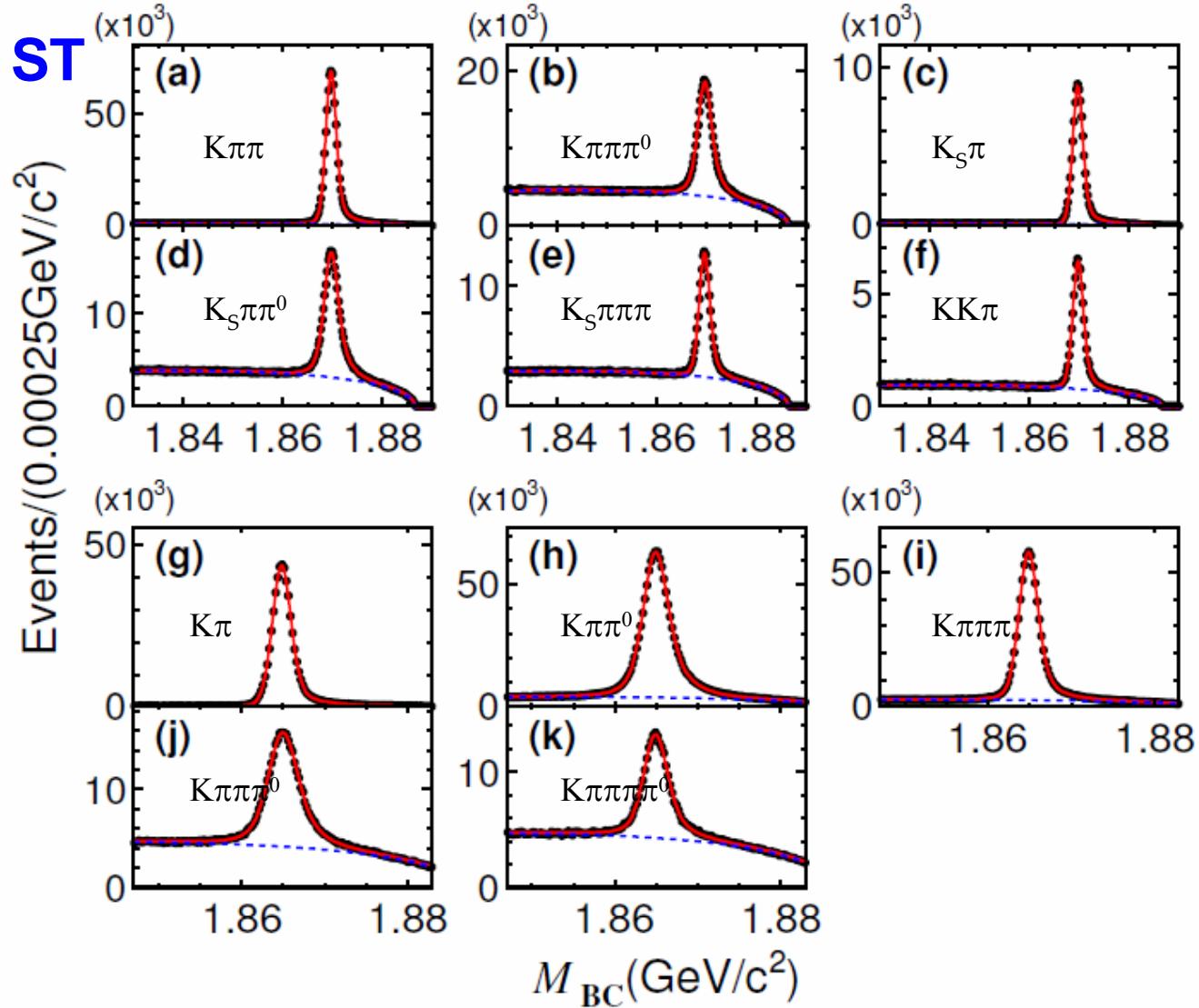
$$\begin{aligned} D^0 &\rightarrow K^- \pi^+ \\ D^0 &\rightarrow K^- \pi^+ \pi^0 \\ D^0 &\rightarrow K^- \pi^+ \pi^+ \pi^- \\ K_S^0 &\rightarrow \pi^+ \pi^- \\ \pi^0 &\rightarrow \gamma \gamma \end{aligned}$$

D_s^-

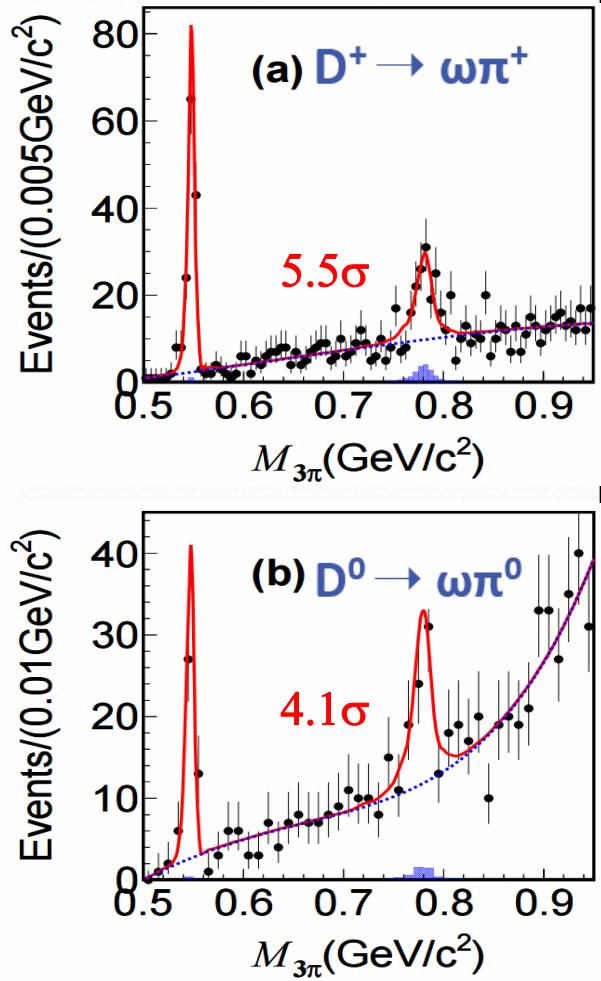
$$\begin{aligned} D_s^- &\rightarrow K_S^0 K^- \\ D_s^- &\rightarrow K^+ K^- \pi^- \\ D_s^- &\rightarrow K^+ K^- \pi^- \pi^0 \\ D_s^- &\rightarrow K_S K^+ \pi^- \pi^- \\ D_s^- &\rightarrow \pi^+ \pi^- \pi^- \\ D_s^- &\rightarrow \pi^- \eta \\ D_s^- &\rightarrow \pi^- \eta' (\eta' \rightarrow \pi^+ \pi^- \eta) \\ D_s^- &\rightarrow \pi^- \eta' (\eta' \rightarrow \rho^0 \gamma) \\ D_s^- &\rightarrow \pi^- \pi^0 \eta \end{aligned}$$

Observation of SCS decay $D^+(0) \rightarrow \omega\pi^+(0)$

PRL116,082001(2016)



DT



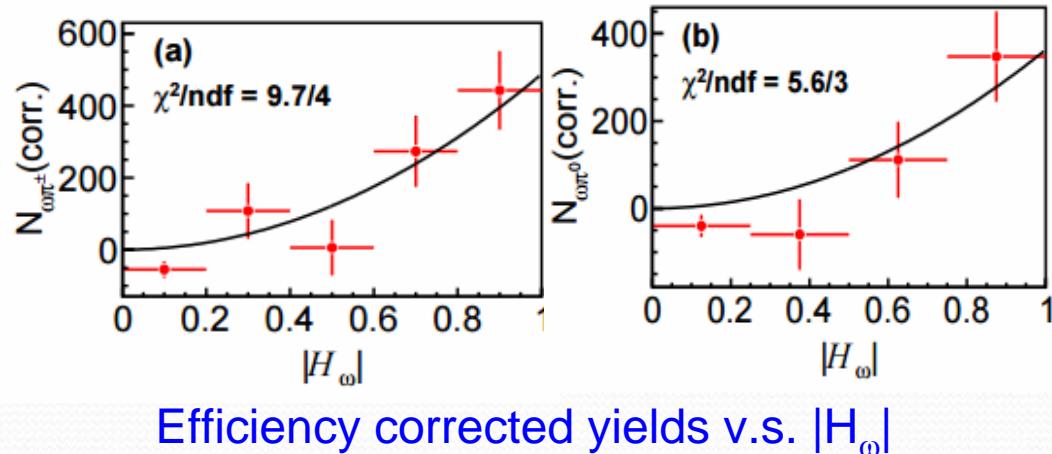
Observation of SCS decay $D^{+(0)} \rightarrow \omega\pi^{+(0)}$

PRL116,082001(2016)

CLEO-c(281pb^{-1}) did not observe
PRL96(2006)081802

Theory predicts $\sim 10^{-4}$ due to the
destructive interference between
color-suppressed diagrams

PRD81(2010)074021



Mode	This work	Previous measurements
$D^+ \rightarrow \omega\pi^+$	$(2.79 \pm 0.57 \pm 0.16) \times 10^{-4}$	$< 3.4 \times 10^{-4}$ at 90% C.L.
$D^0 \rightarrow \omega\pi^0$	$(1.17 \pm 0.34 \pm 0.07) \times 10^{-4}$	$< 2.6 \times 10^{-4}$ at 90% C.L.
$D^+ \rightarrow \eta\pi^+$	$(3.07 \pm 0.22 \pm 0.13) \times 10^{-3}$	$(3.53 \pm 0.21) \times 10^{-3}$
$D^0 \rightarrow \eta\pi^0$	$(0.65 \pm 0.09 \pm 0.04) \times 10^{-3}$	$(0.68 \pm 0.07) \times 10^{-3}$

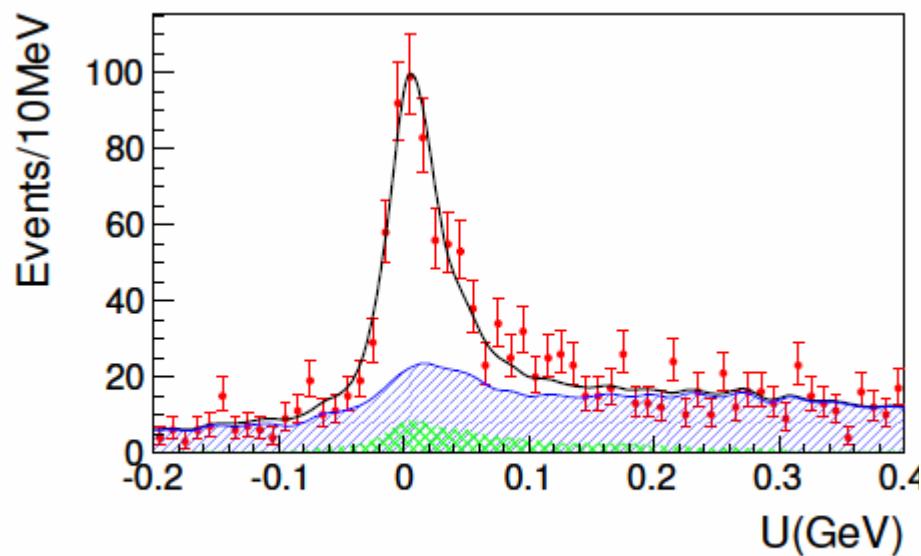
Improved understanding of U-spin and SU(3)-flavor symmetry breaking effects in D decays

BESIII first observation:

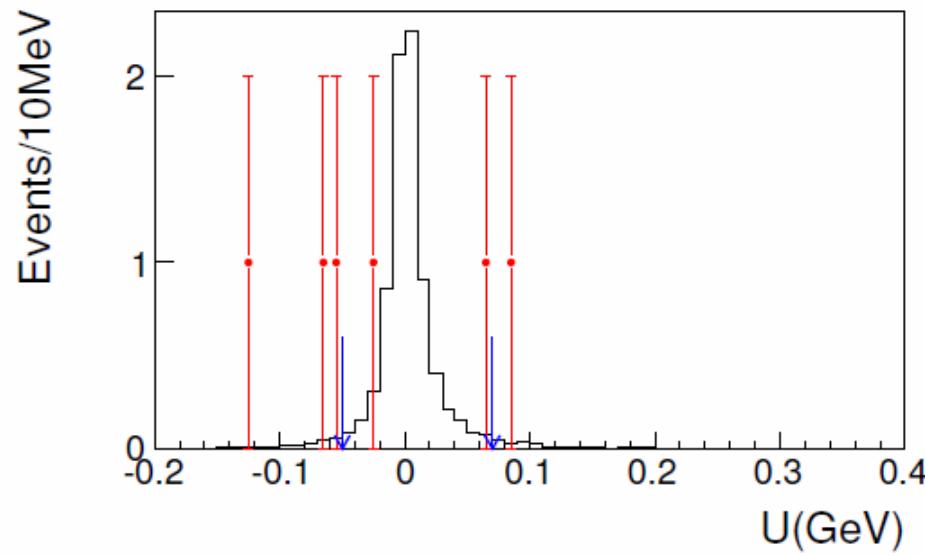
- Consistent with theory prediction
- ω helicity angle $\sim \cos^2\theta$ distribution
- $\text{Br}(D \rightarrow \eta\pi)$ consistent previous measurement

Analysis of $D^+ \rightarrow (\omega, \phi) e^+ \nu_e$

PRD92,071101(2015)



$$D^+ \rightarrow \omega e^+ \nu_e$$

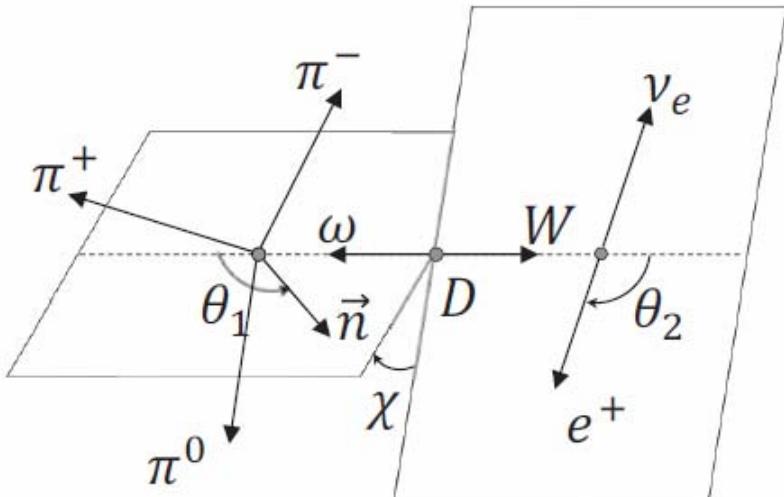


$$D^+ \rightarrow \phi e^+ \nu_e$$

Mode	This work	CLEO-c
$\omega e^+ \nu_e$	$(1.63 \pm 0.11 \pm 0.08) \times 10^{-3}$	$(1.82 \pm 0.18 \pm 0.07) \times 10^{-3}$
$\phi e^+ \nu_e$	$< 1.3 \times 10^{-5}$ (90% C.L.)	$< 9.0 \times 10^{-5}$ (90% C.L.)

Analysis of $D^+ \rightarrow (\omega, \phi) e^+ \nu$

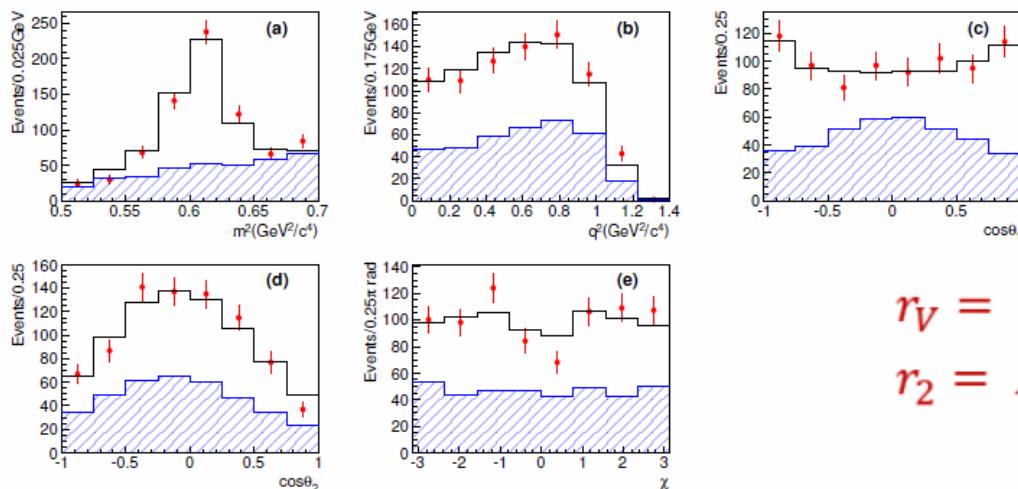
PRD92,071101(2015)



$$\frac{d\Gamma}{dq^2 d \cos \theta_1 d \cos \theta_2 d\chi dm_{\pi\pi\pi}} = \\ \mathcal{F}(V(q^2), A_{1,2}(q^2) \dots)$$

A five-dimensional maximum likelihood fit is performed in the space of m^2 , q^2 , $\cos \theta_1$, $\cos \theta_2$ and χ .

Amplitude analysis of $D^+ \rightarrow \omega e^+ \nu$ is performed for the first time

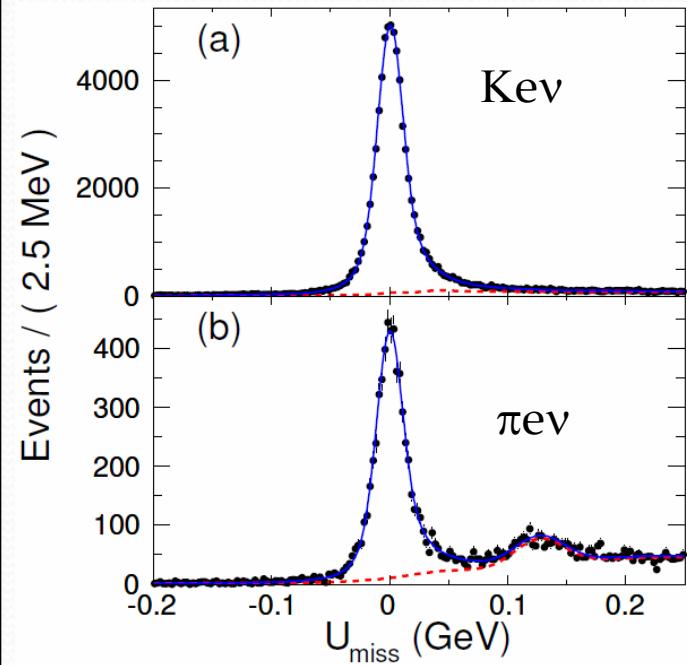


$$r_V = V(0)/A_1(0) = 1.24 \pm 0.09 \pm 0.06$$

$$r_2 = A_2(0)/A_1(0) = 1.06 \pm 0.15 \pm 0.05$$

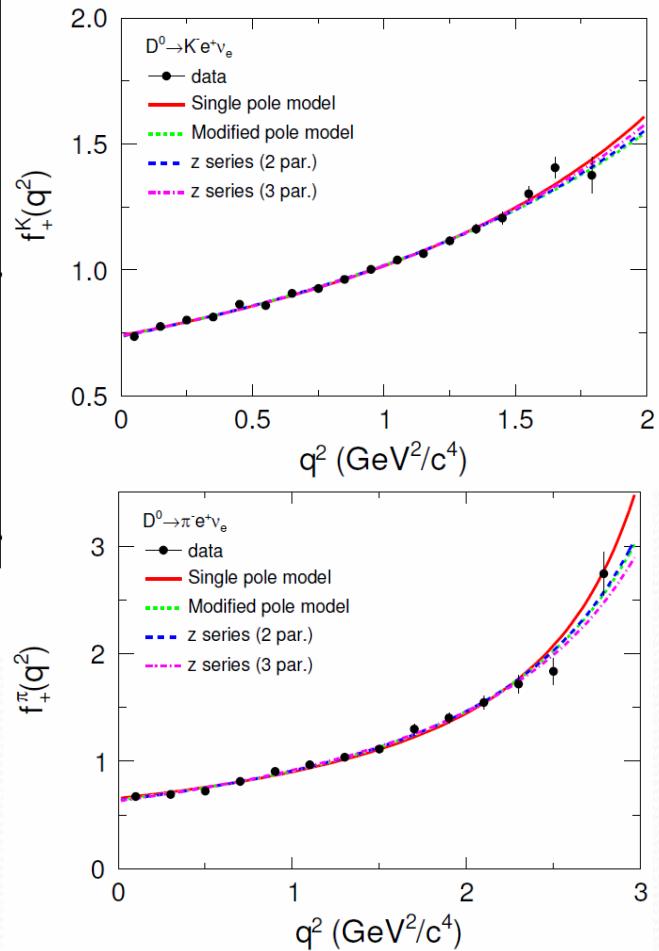
Analysis of $D^0 \rightarrow (K^-/\pi^-) e^+ \nu_e$

PRD92,072012(2015)



$$BF(D^0 \rightarrow K^- e^+ \nu_e) = (3.505 \pm 0.014 \pm 0.033)\%$$

$$BF(D^0 \rightarrow \pi^- e^+ \nu_e) = (0.295 \pm 0.004 \pm 0.003)\%$$



$$\frac{d\Gamma}{dq^2} = \frac{G_F^2}{24\pi^3} |V_{cs}(d)|^2 |\vec{p}_{K^-(\pi^-)}|^3 |f_+^{K(\pi)}(q^2)|^2$$

$$f_+(q^2)$$

Simple pole model:

$$= \frac{f_+(0)}{1 - \frac{q^2}{M_{pole}^2}}$$

Modified pole model:

$$= \frac{f_+(0)}{(1 - \frac{q^2}{M_{pole}^2})(1 - \alpha \frac{q^2}{M_{pole}^2})}$$

Series expansion:

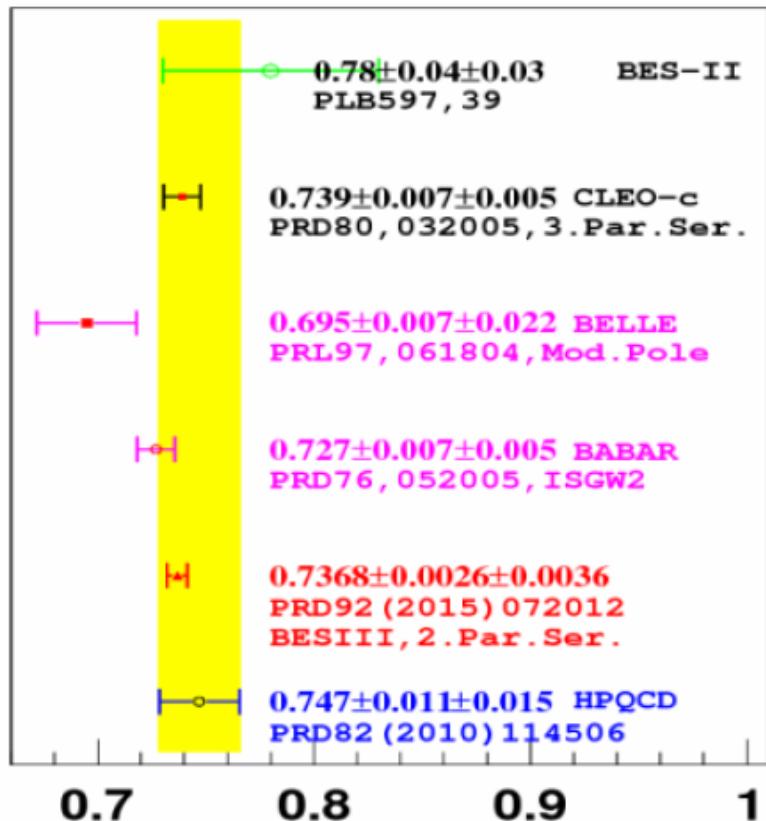
$$= \frac{1}{P(t)\Phi(t,t_0)} a_0(t_0) \times (1 + r_1(t_0)[z(t, t_0)])$$

Analysis of $D^0 \rightarrow (K^-/\pi^-)e^+\nu_e$

PRD92,072012(2015)

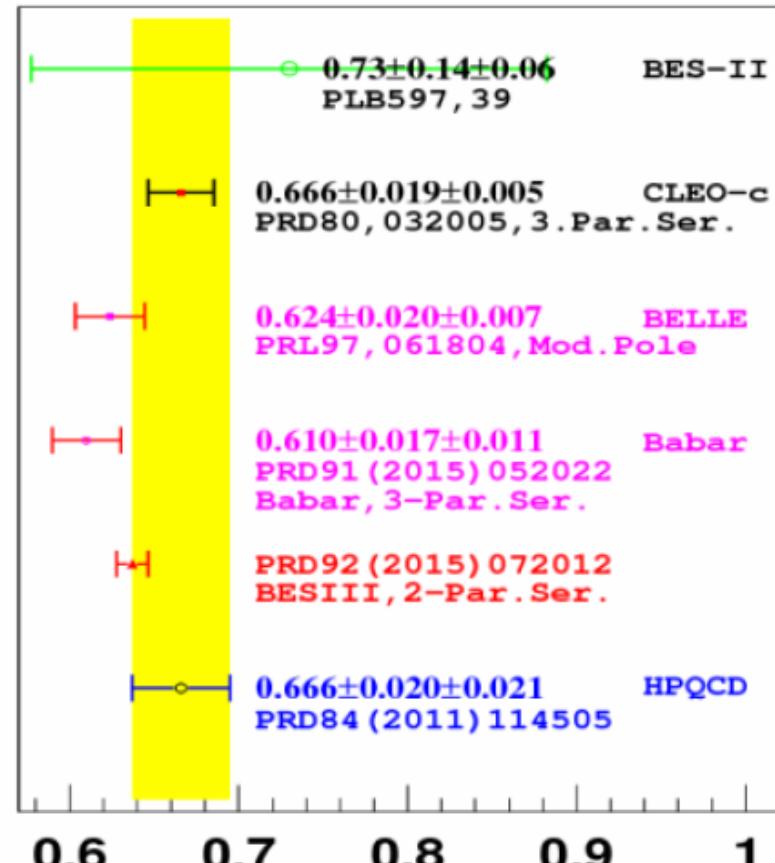
$$|V_{cs(d)}|f_+^{D^0 \rightarrow (K^-/\pi^-)e^+\nu_e}(0) \rightarrow f_+^{D^0 \rightarrow (K^-/\pi^-)e^+\nu_e}(0)$$

Input $V_{cs(d)}$ of CKM Fitter



$f_+^K(0)$

- The most precise form factor measurement to calibrate the LQCD

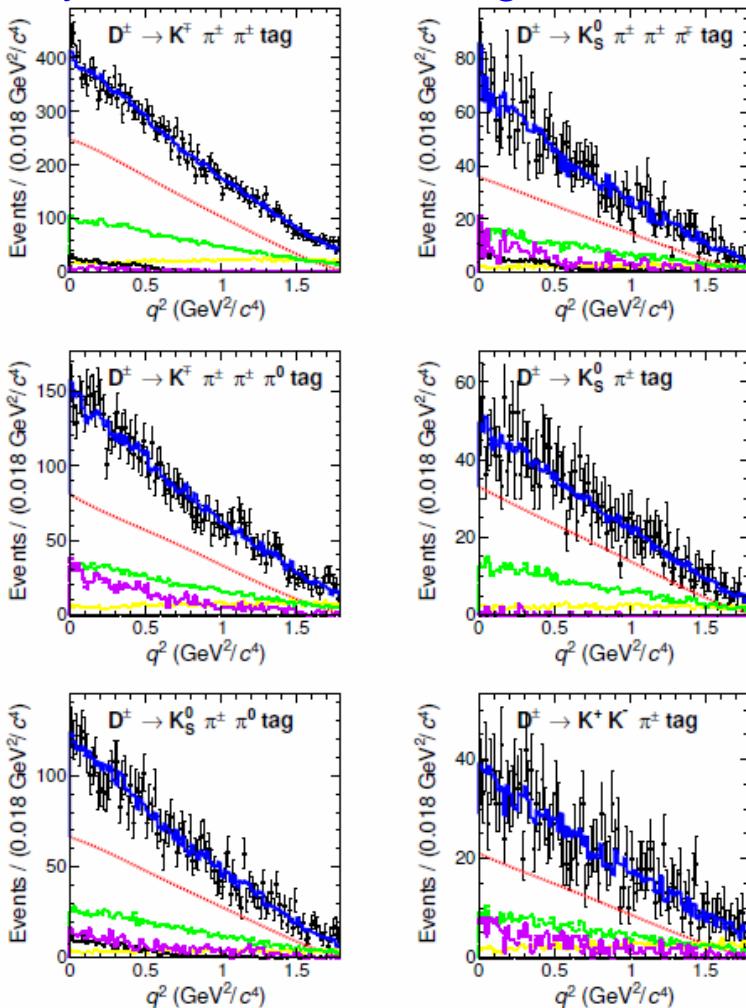


$f_+^\pi(0)$

Decay Dynamics and CP Asymmetry in $D^+ \rightarrow K_L e^+ \nu_e$

PRD92,112008(2015)

Simultaneous Fit to observed DT
yields, red dash is signal



- Regardless of long flight distance, K_L interact with EMC and deposit part of energy → give position information
- Constraint K_L with $U_{miss}=0$

The first measurement of $\text{BF}(D^+ \rightarrow K_L e^+ \nu_e)$

$$\begin{aligned}\mathcal{B}(D^+ \rightarrow K_L e^+ \nu_e) &= \\ (4.454 \pm 0.038 \pm 0.102)\% &\end{aligned}$$

$$\begin{aligned}\mathcal{B}(D^- \rightarrow K_L e^- \bar{\nu}_e) &= \\ (4.507 \pm 0.038 \pm 0.104)\% &\end{aligned}$$

$|V_{CS}| = 0.975 \pm 0.008 \pm 0.015 \pm 0.025$ (with LQCD input $f_+^K(0)$), consistent with 0.986 ± 0.016 (PDG)

$$A_{CP} \equiv \frac{\text{BF}(D^+ \rightarrow K_L e^+ \nu_e) - \text{BF}(D^- \rightarrow K_L e^- \bar{\nu}_e)}{\text{BF}(D^+ \rightarrow K_L e^+ \nu_e) + \text{BF}(D^- \rightarrow K_L e^- \bar{\nu}_e)} = (-0.59 \pm 0.60 \pm 1.48)\%$$

Measurement $\text{Br}(\text{D}_s^+ \rightarrow \eta' X)$ and $\text{Br}(\text{D}_s^+ \rightarrow \eta' \rho^+)$ (II)

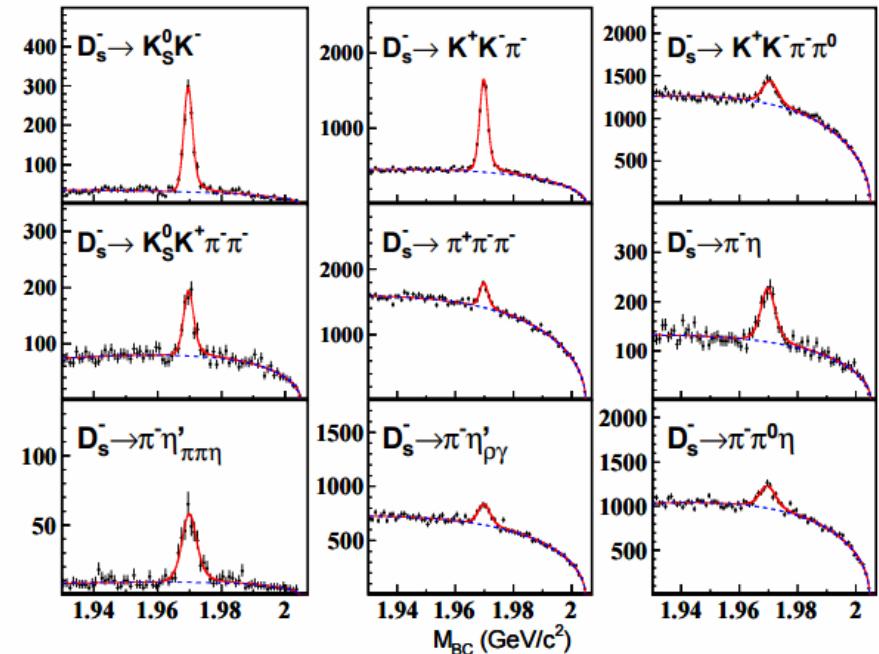
About 15.6 K ST D_s^- events by

using 9 ST modes

use 4.009GeV data

PLB750(2015)466

$N(\text{D}_s^+ \rightarrow \eta' X) = 68 \pm 14$ events



$$\text{BF}(\text{D}_s^+ \rightarrow \eta' X) = (8.8 \pm 1.8 \pm 0.5)\%$$

Consistent with CLEO-c ($(11.7 \pm 1.7 \pm 0.7)\%$) in 1σ PRD79(2009)112008

$$\text{BF}(\text{D}_s^+ \rightarrow \eta' \rho^+) = (5.8 \pm 1.4 \pm 0.4)\%$$

$$\text{Br}^{\text{exp}}(\text{D}_s^+ \rightarrow \eta' \rho^+) = (3.0 \pm 0.5)\% \quad \text{PRD84(2011)074019}$$

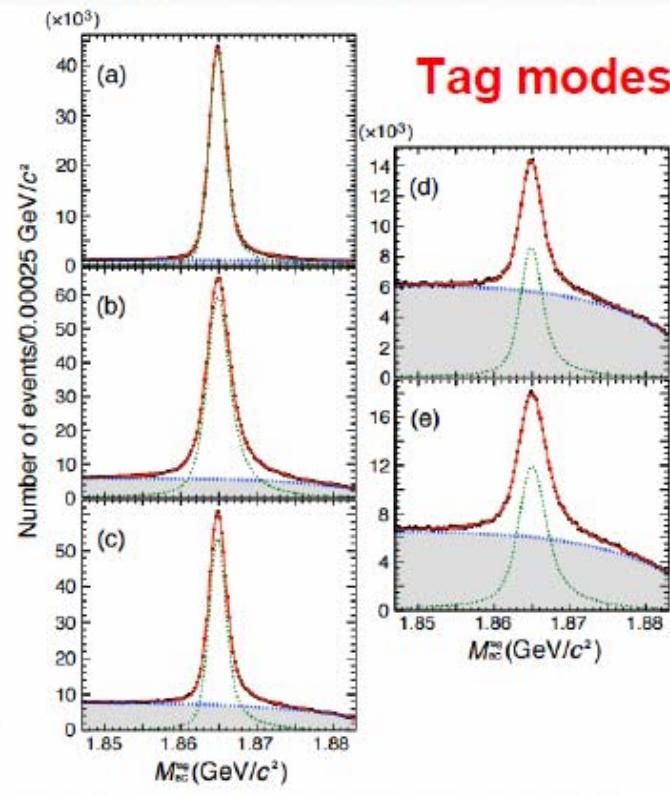
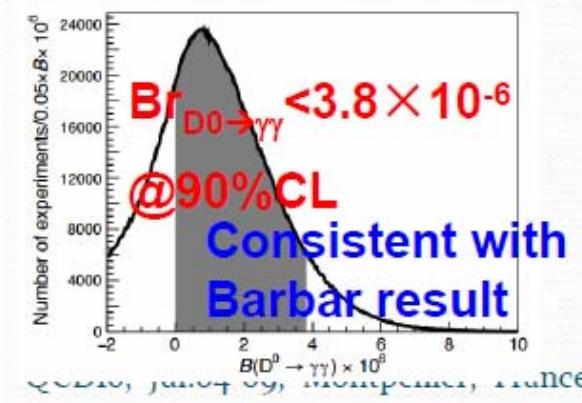
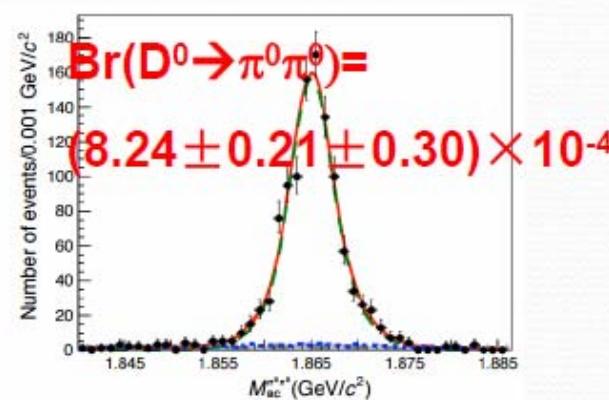
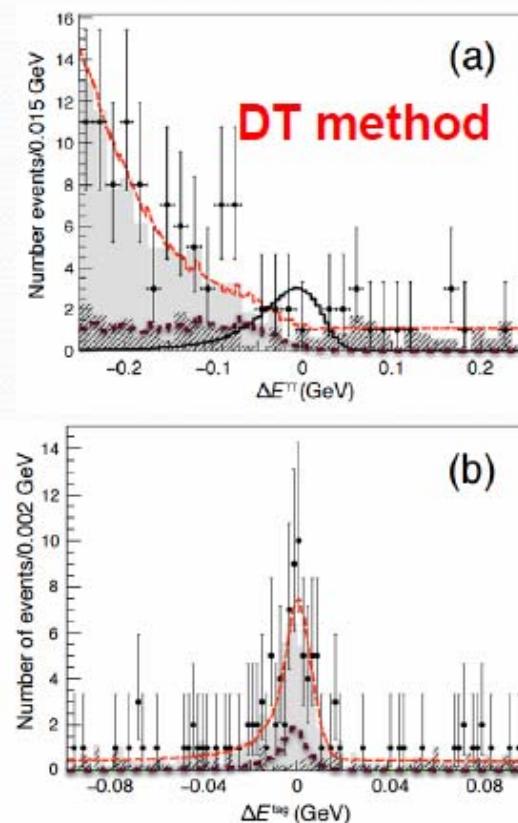
Resolve the disagreement between theoretical prediction and CLEO's measurement

$$\text{Br}(\text{D}_s^+ \rightarrow \eta' \rho^+) = (12.5 \pm 2.2)\% \quad \text{PRD58(1998)052002}$$

Search for $D^0 \rightarrow \gamma\gamma$ and improved measurement of $D^0 \rightarrow \pi^0\pi^0$

PRD91(2015)112015

- Flavor-Changing Neutral Current(FCNC) decay $D^0 \rightarrow \gamma\gamma$ is suppressed by GIM mechanism($\text{br} \sim 3 \times 10^{-11}$).
- Long-distance contributions → enhance the $\text{br} \sim 3 \times 10^{-8}$



Summary

- Form factor measurement in (semi)leptonic charm decays provide important test to LQCD calculations, CKM matrix unitary
- Hadronic charmed meson and baryon decays improve understanding of non-perturbative QCD;
- Other ongoing programs not covered in this talk:
Searches for rare/forbidden decays, and quantum correlated analysis, et al
- New data of $>3\text{fb}^{-1}$ $D_s D_s^*$ @4.180GeV are taken → benefit the understanding of physics related to D_s further!
- Many new exciting results are on their way!

Thank you!

The End