A Flavor of BESIII Physics

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KEK Flavor Physics Workshop

Tsukuba

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*Full disclosure: member of CLEO-c / BESIII / BelleII

Outline

Introduction

Open Charm Physics

The $Z_c(3900)$ & Friends

The Future

Conclusion

Introduction

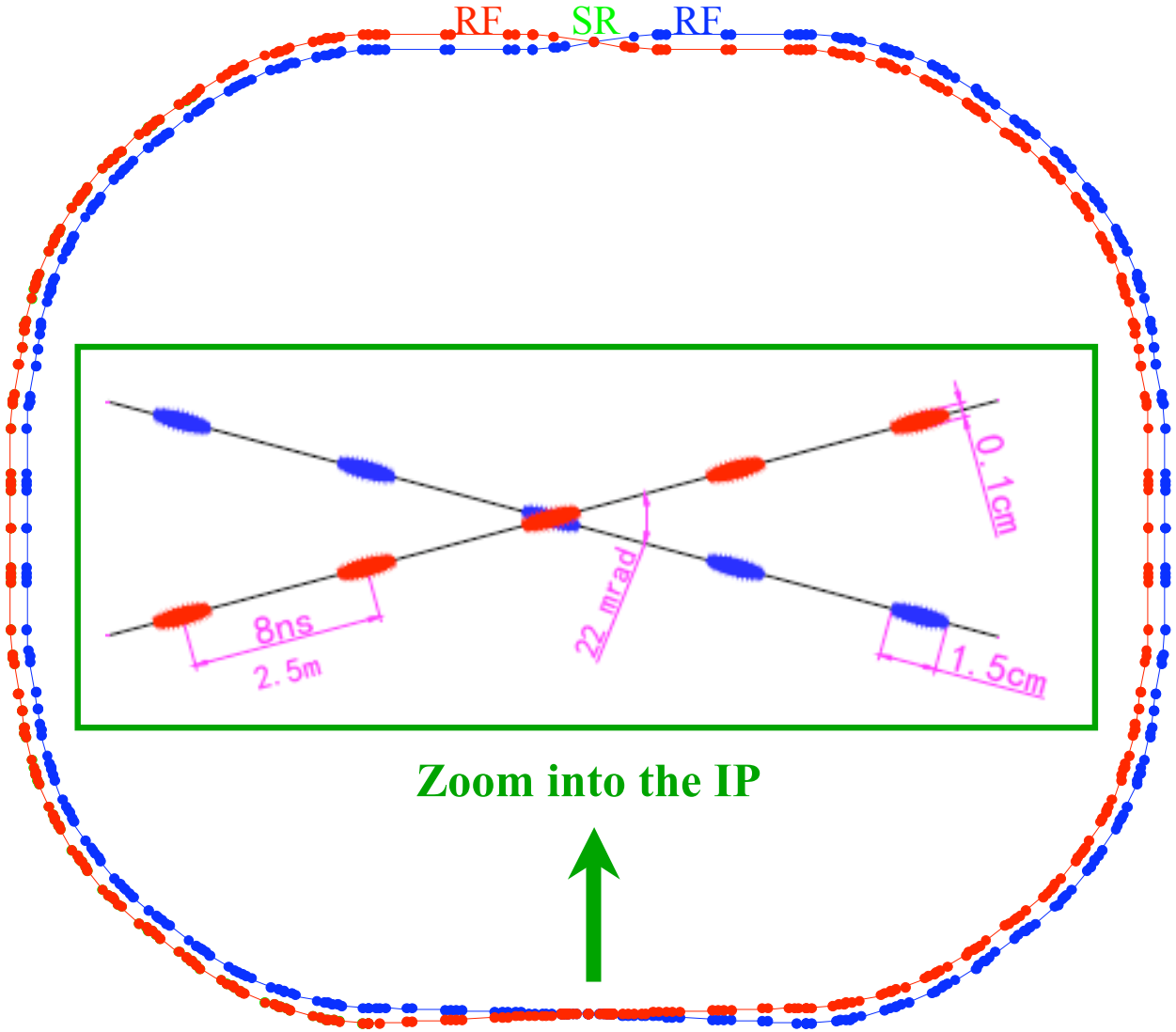
BEPCII Accelerator
BESIII Detector
Our Datasets
Physics Overview

IHEP, Beijing

~13 km due west of Tiananmen Square

BEPCII

Two-ring, large crossing angle, multi-bunch, high-current



- Design -

Beam energy:
1 - 2.3 GeV

Luminosity:
1×10^{33} $cm^{-2}s^{-1}$

Optimum energy:
1.89 GeV

Energy spread:
5.16×10^{-4}

No. of bunches:
93

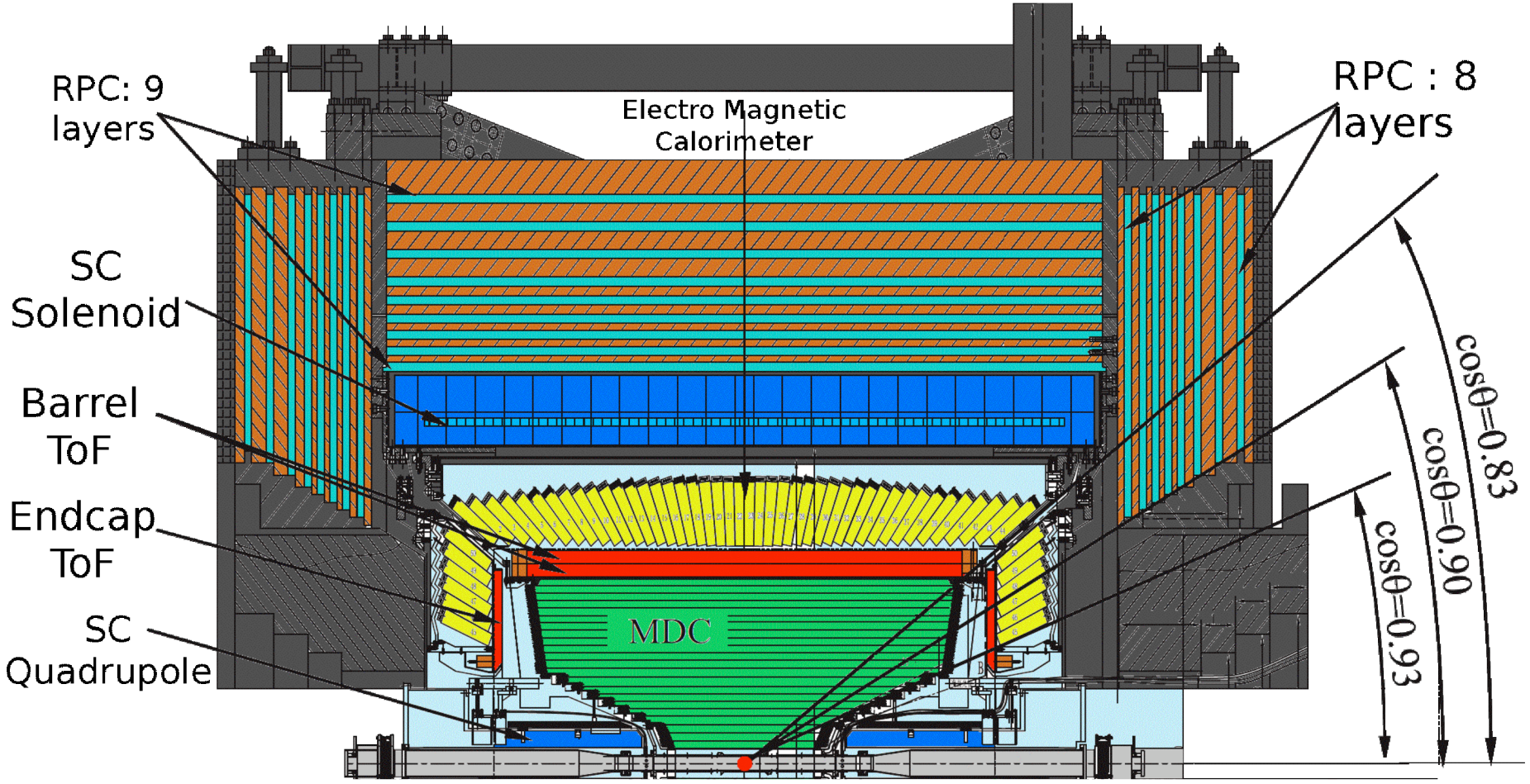
Bunch length:
1.5 cm

Total current:
0.91 A

SR mode:
0.25A @ 2.5 GeV

BESIII

53 institutions total
22 outside China



Wire tracker (no Si); TOF + dE/dx for PID; CsI Ecal ; RPC muon

e^+e^- & Charmonium

Direct, high-statistics production of $J^{PC} = 1^{--}$ charmonium

J/ψ ψ' [$^{2s+1}\mathcal{L}_J = {}^3S_1$ states]

also: $\psi(3770)^*$ $Y(4260)$

σ_{eff} ~ 2500 nb for J/ψ ; ~4x smaller for ψ'

Depends on beam energy spread

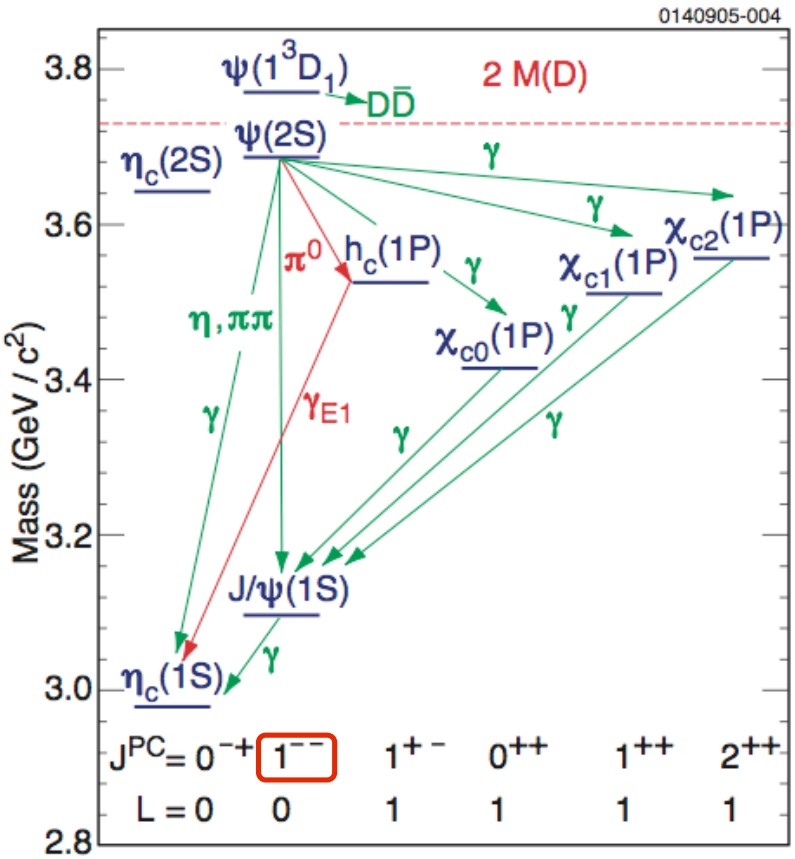
(BEPCII a bit narrower than CESR-c)

Radiative (γ, π^0 , $\pi\,\pi$, η) transitions give access to other states:

χ_{cJ} h_c η_c

$^3P_{0,1,2}$ $^1P_1$ $^1S_0$

(more on $\psi(3770)$ & D physics later)



Physics Runs

July 2008: First collisions w/ detector in place

New BEPCII accelerator & New BESIII detector

2009: First physics data

Many machine studies, brief physics runs

2010: First publications

3 papers in 2010 ; increased to 25 in 2013

2010-2014:

"Standard" physics runs

About 6 months, starting ~Dec. of previous year

Peak Luminosity: 0.7×10^{33} (70% design)

lower currents than design…

Data Sets

1.3×10^9	J/ψ	2009 + 2012	[2009 only: 0.225×10^9]
0.4×10^9	ψ'	2009 + 2012	[2009 only: 0.106×10^9]

2.9 fb^{-1} @ $\psi(3770)$	2010 + 2011	D pairs
0.48 fb^{-1} @ 4009 MeV	2011	D_s pairs &

1.92 fb^{-1} @ 4230, 4260 MeV	2013
0.54 fb^{-1} @ 4360 MeV	2013
0.46 fb^{-1} (total) @ 9 other energies	2013

3.4 fb^{-1} @ "high E" (incl. 4009 MeV)

Also, τ threshold mass scan

2014: discussed @ end of talk…

Breadth of Physics

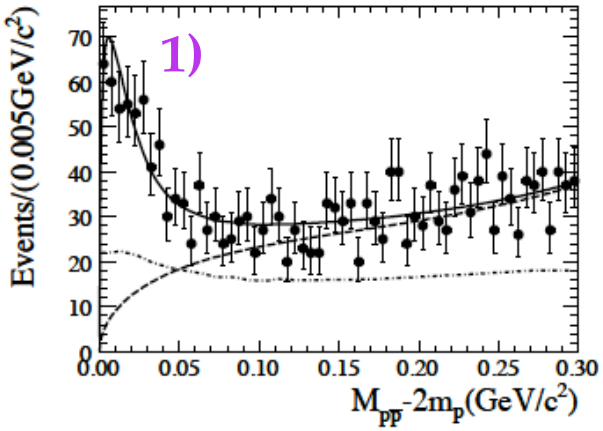
61 published / accepted papers, + 6 advanced drafts

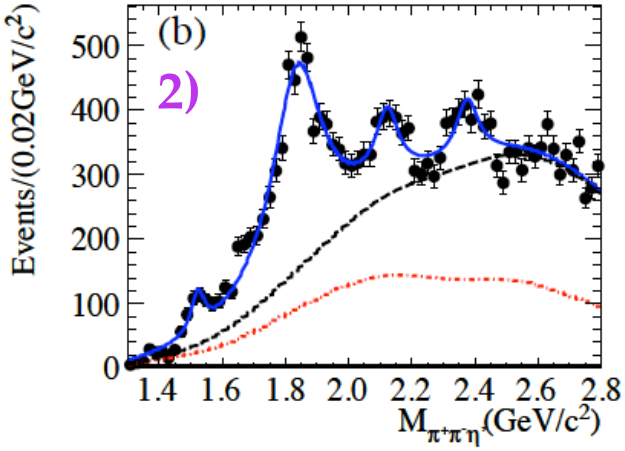
(My personal classification)

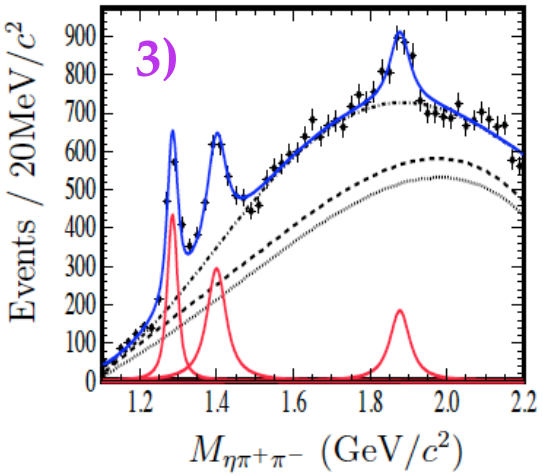
⋯▸	8	new low-energy resonances (incl. one null search)
	8	η, η' $(a_0\text{-}f_0)$ decays (mixing)
→	5	XYZ states
	3	$\psi(3770), \psi(4040)$ decays
	19	$J/\psi, \psi', \chi_{cJ}$ hadronic decays
	11	$J/\psi, \psi', \chi_{cJ}$ radiative / 2-photon / rare decays
	6	h_c, η_c, η_c' decays & parameters
	2	$\psi' \to J/\psi$ hadronic transition
→	2	D physics
	3	Luminosity, # $J/\psi, \psi'$

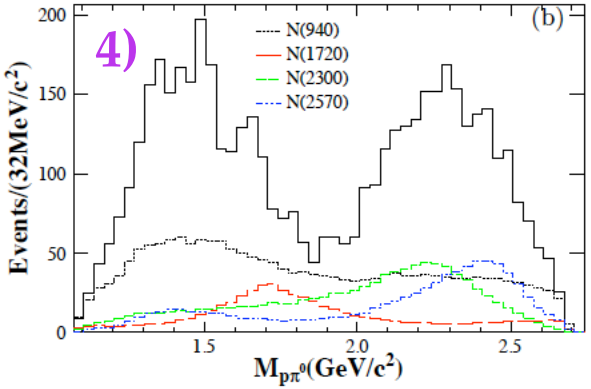
Low-E Resonance Gallery

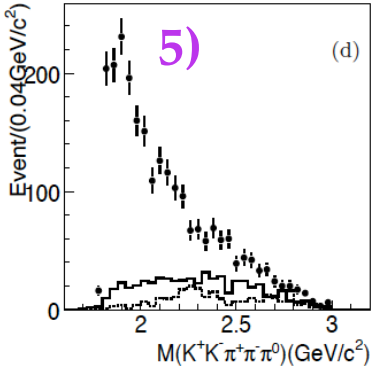
No time to discuss today!

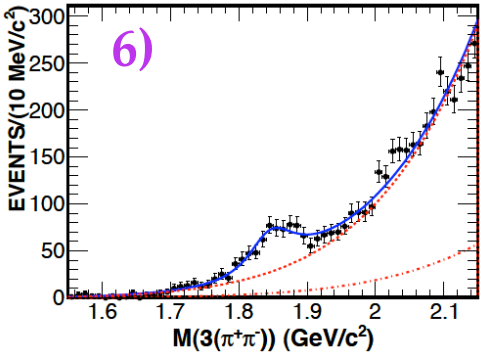












1)	$p\,p^{bar}$	in	J/ψ	$\rightarrow \gamma\, p\, p^{bar}$	CPC 34, 421 (2010); PRL 108, 102003 (2012)
2)	$\pi^+\pi^-\eta'$	in	J/ψ	$\rightarrow \gamma\, \pi^+\pi^-\eta'$	PRL 106, 072002 (2011)
3)	$\eta\,\pi^+\pi^-$	in	J/ψ	$\rightarrow \omega\,\eta\,\pi^+\pi^-$	PRL 107, 182001(2011)
4)	$p\,\pi^0$	in	ψ'	$\rightarrow p\,p^{bar}\pi^0$	PRL 110, 022001(2013)
5)	$\omega\,\phi$	in	J/ψ	$\rightarrow \gamma\,\omega\,\phi$	PRD 87 032008, (2013)
6)	$3(\pi^+\pi^-)$	in	J/ψ	$\rightarrow \gamma\, 3(\pi^+\pi^-)$	PRD 88, 091502(R) (2013)

NOTE:

There are *many* resonance and PWA papers from BESIII ! My goal here was to highlight the new, unexpected peaks only…

Open Charm Physics

Overview of D tags & Key Topics

$D^+ \to \mu\nu$

$D^0 \to \pi e\nu$, $Ke\nu$

Strong Phase $\delta_{K\pi}$

$D^+ \to K_S\pi^+\pi^0$ *

***Actually, more of a taste of our broad hadronic physics program**

D Physics @ ψ(3770)

ψ(3770): σ_{DD} ~ 6.6 nb

Only D pairs: no phase space for even *one* extra pion

Reconstruct one D in a set of hadronic "tag" modes:

Reduces backgrounds

Find the other D's direction (produce a "tagged D beam" !)

→ can now solve for a neutrino 4-vector, if needed…

"Familiar" tag variables (also used in B physics)

Conservation of momentum & energy

$$M_{bc} = (E_{beam}^2 - p_{cand}^2)^{1/2} \qquad \Delta E = E_{cand} - E_{beam}$$

("cand" is the candidate D: a sum over decay daughters)

Measure (# tags & signal) / (# tags) :

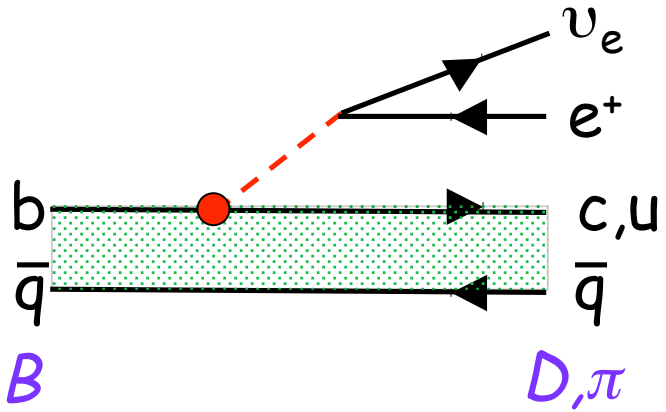
tag-side efficiency mostly cancels; tag systematics cancel

B Physics & Small CKM Elements

Usefulness is limited by theory

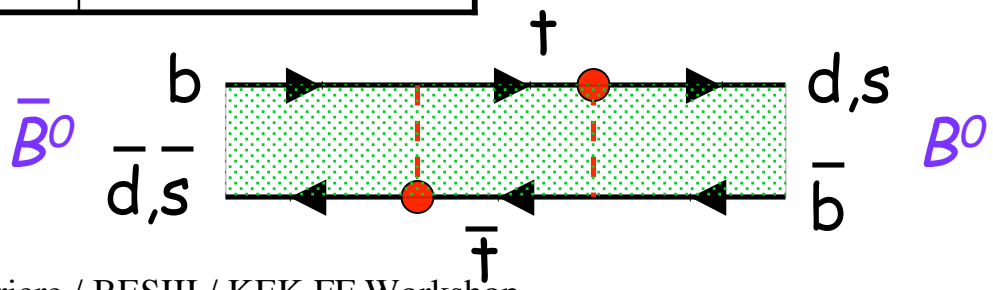
	d	s	b
u	1	λ	$A\lambda^3(\rho-i\eta)$
c	$-\lambda$	1	$A\lambda^2$
t	$A\lambda^3(1-\rho-i\eta)$	$-A\lambda^2$	1

Measure from B decays



Note the QCD "fog" (Isgur's "brown muck")

Measure from B^0-$\bar{B}^0$ mixing



Flavor Physics Connections

D^0, D^+, D_s^+ "golden mode" Branching Fractions

Hadronic: **Help normalize heavy flavor physics** **(base of unitarity triangle)**

e.g. , ***HQET-based V_{cb} involves D BF's***

[Systematics limited after CLEO-c; lower priority to check… but working on D* BF's]

Tests of Lattice QCD *(or V_{cd}, V_{cs} using LQCD)*

Leptonic: **D^+, $D_s \to \mu\nu, \tau\nu$ decay constants**

B^0, B^0_s decay constants enter in BB^{bar} mixing

Semileptonic: **$D \to K\, l\, \nu, \pi\, l\, \nu$ form factors**

Exclusive $B \to \pi\, l\, \nu$ also involves form factors

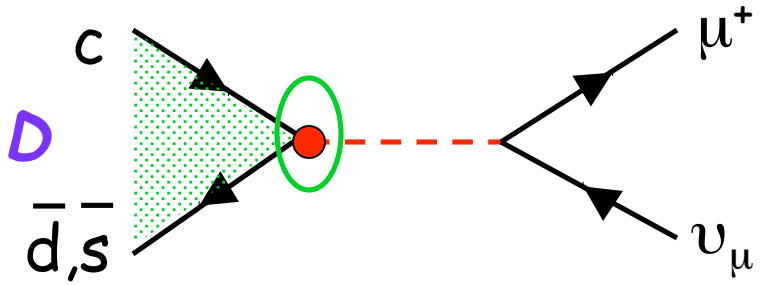
Strong Phases

Quantum Correlations: **allow access**

Improve & control systematics on CKM γ / ϕ_3 extraction

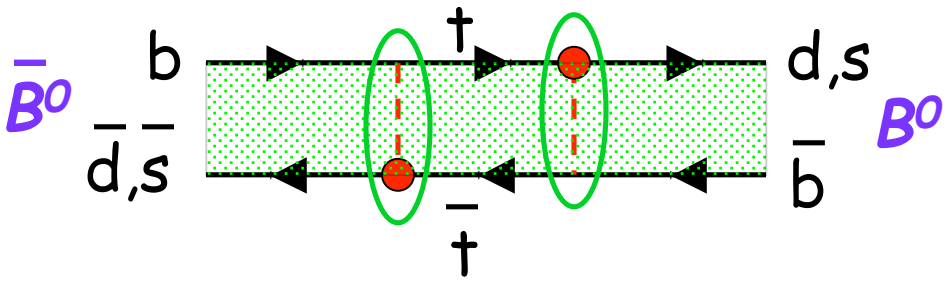
Interactions with all four small CKM elements accessed with B's
Plus, two more which are directly available in charm decays

Leptonic D Decays



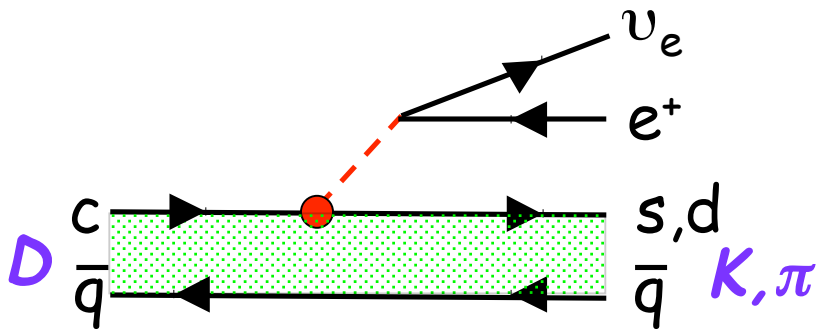
f_D is the decay constant :

"Chance that quarks overlap"
$\propto |\psi(0)|^2$: square of wave-function at origin



Decay constants also in Box Diagram
(W "exchange": really ~point-like four-fermi)

Semileptonic D Decays



Physics is all in the form factor :

"Chance c,qbar quarks bind" into final state ***K,π***

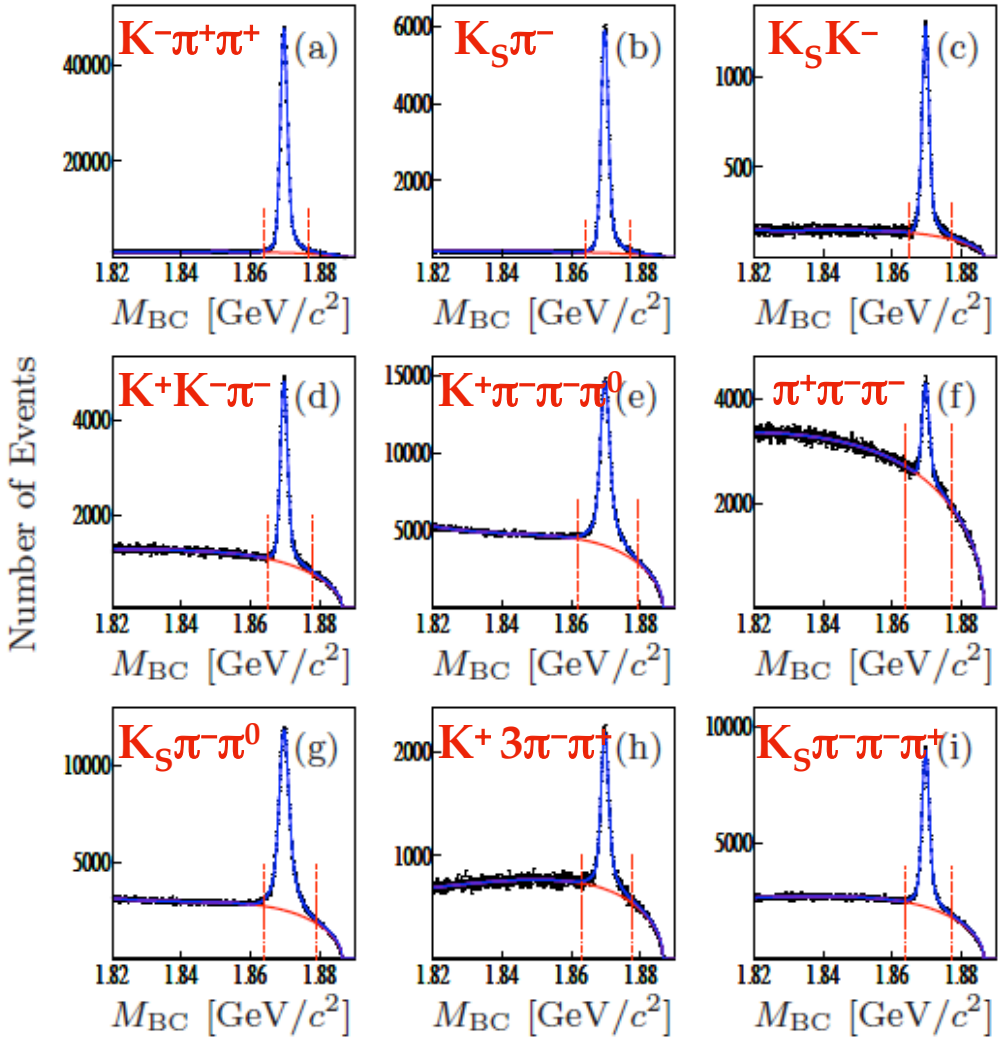
Similar form factors in semileptonic B decay

$D^+ \to \mu\nu$

BESIII 2.9 fb^{-1}
arXiv:1312.0374
Subm. To PRD

Uses 9 tag modes (for reference, CLEO-c used 6)

Even includes Cabibbo-suppressed modes !



Signal side: ONE track !

Veto on extra tracks,
and un-matched showers
with E > 300 MeV

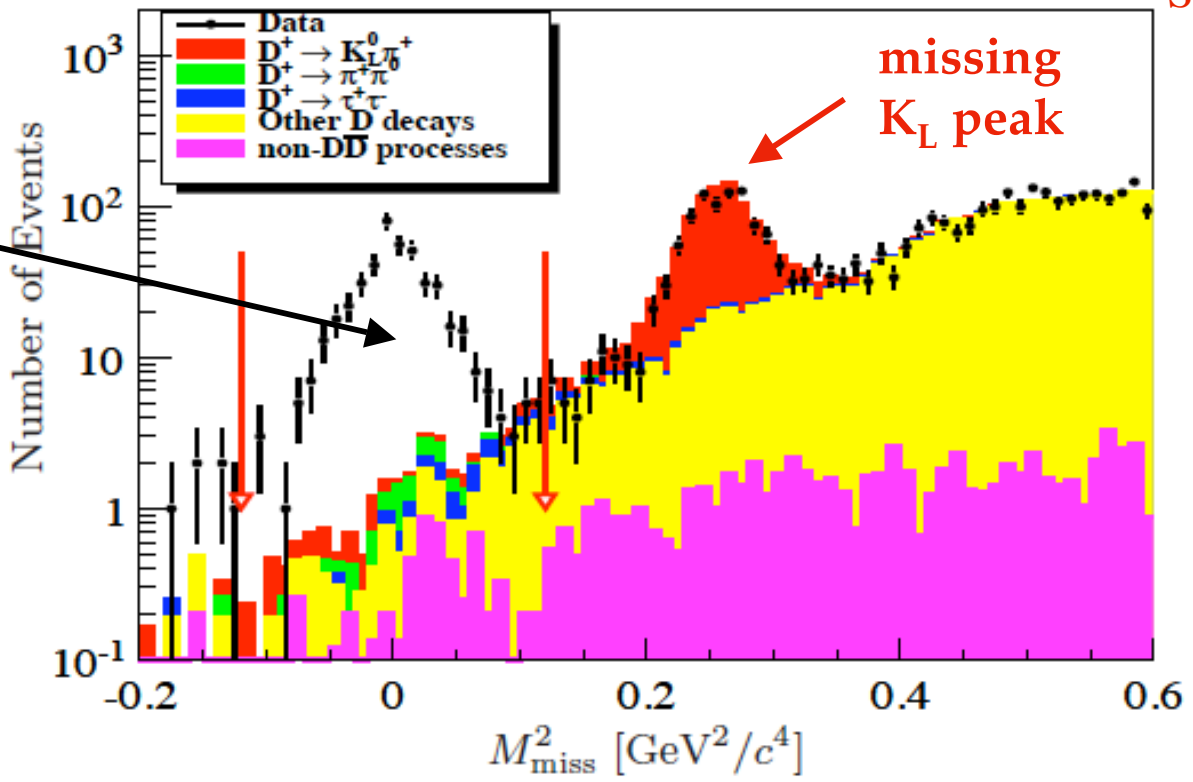
Reconstruct " MM^2 "
= (missing-mass)^2

presumably just a neutrino:
∴ signal peaks at 0

$D^+ \to \mu\nu$

BESIII 2.9 fb^{-1}
arXiv:1312.0374
Subm. To PRD

Clean Signal
(log plot!)



Result:

377.3 ± 20.6 ± 2.6 events above background

B($D^+ \to \mu\nu$) = (3.71 ± 0.19 ± 0.06) x 10^{-4}

Combining with V_{cd} , G_F , τ_D , m_D :

f_D = (203.2 ± 5.3 ± 1.8) MeV (± 2.6 ± 0.9)% ***most precise !***

previous best: (207.6 ± 9.3 ± 2.5) MeV (CLEO-c, τν floating)
(205.8 ± 8.5 ± 2.5) MeV (CLEO-c, including τν fixed to SM ratio)

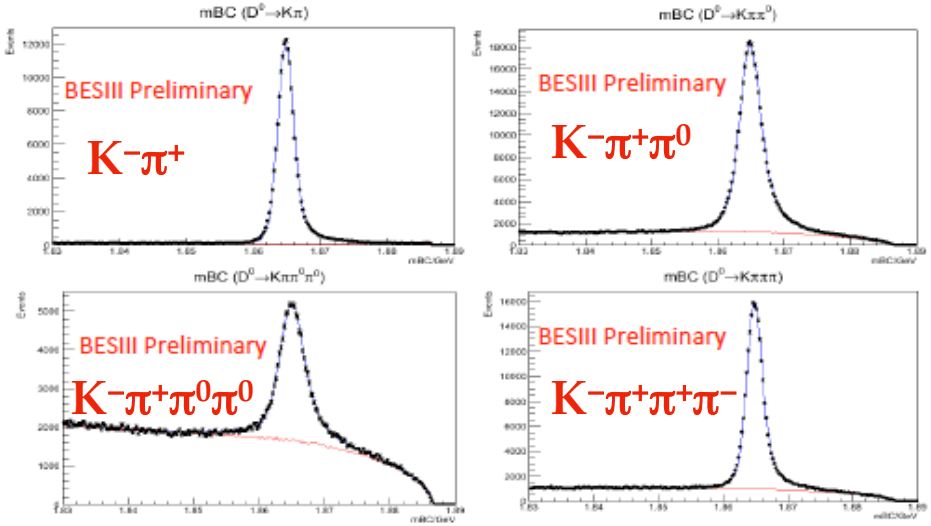
$D^0 \to Ke\nu,\ \pi e\nu$

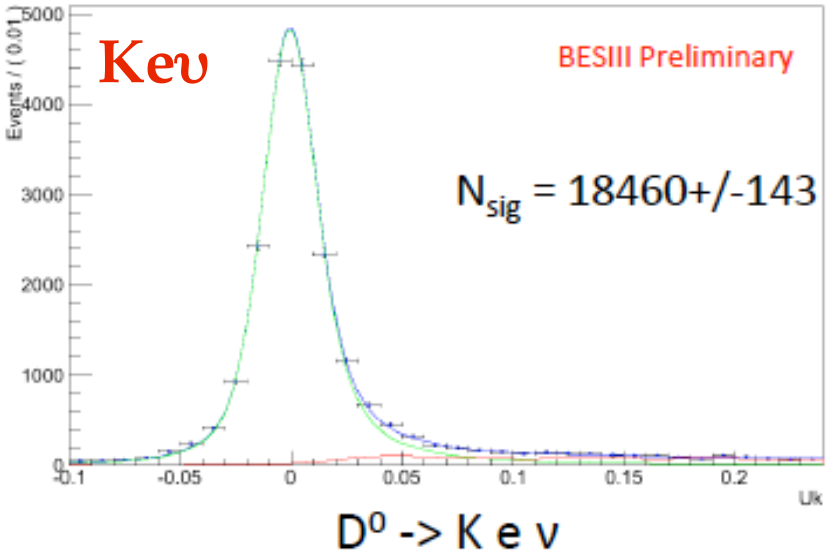
BESIII 0.9 fb^{-1}
CHARM2012
arXiv: 1207.1171

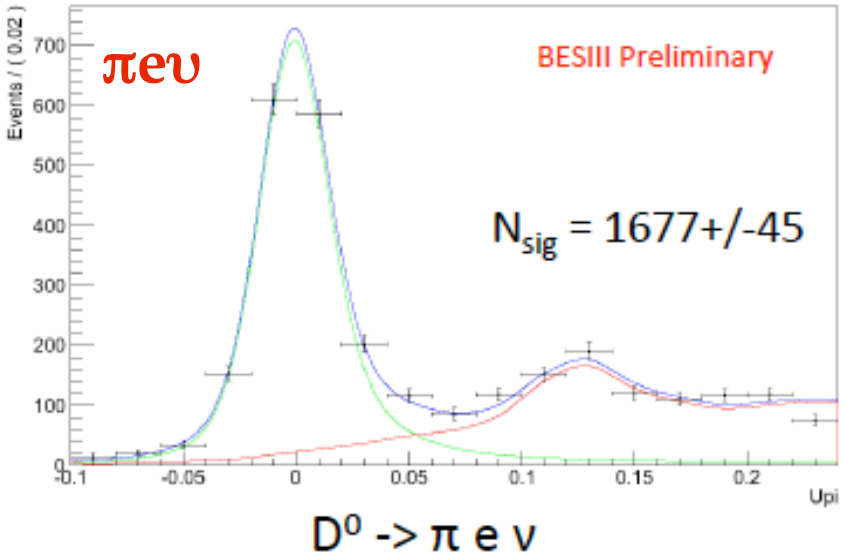
Use 4 hadronic tag modes

Signal side:
two tracks, e & K/π

Signal variable:
$U = E_{miss} - p_{miss}$
(peaks @ zero, similar to MM^2)





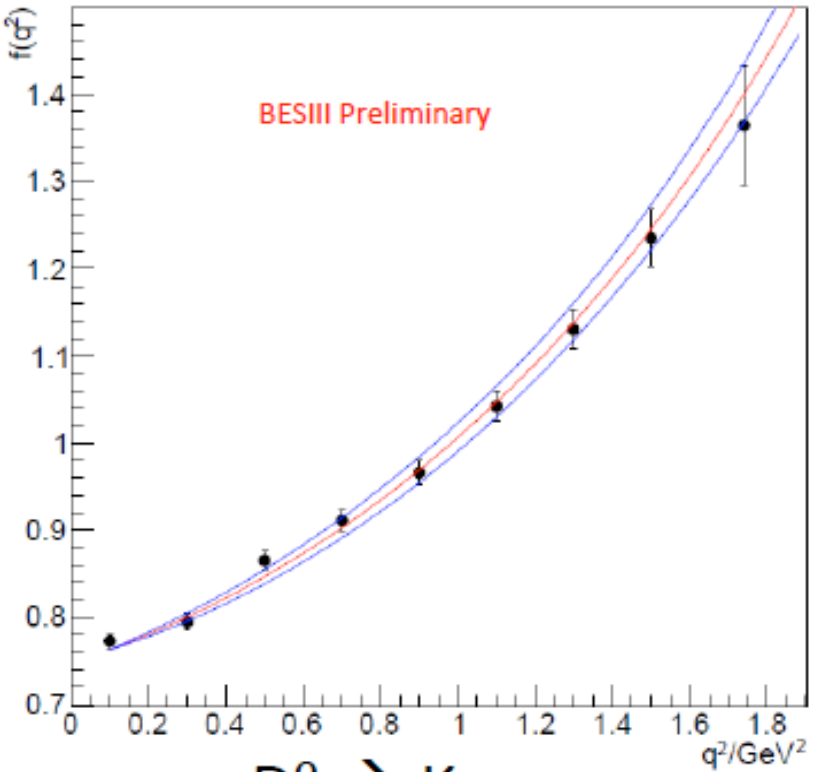


$D^0 \to K e \nu$, $\pi e \nu$

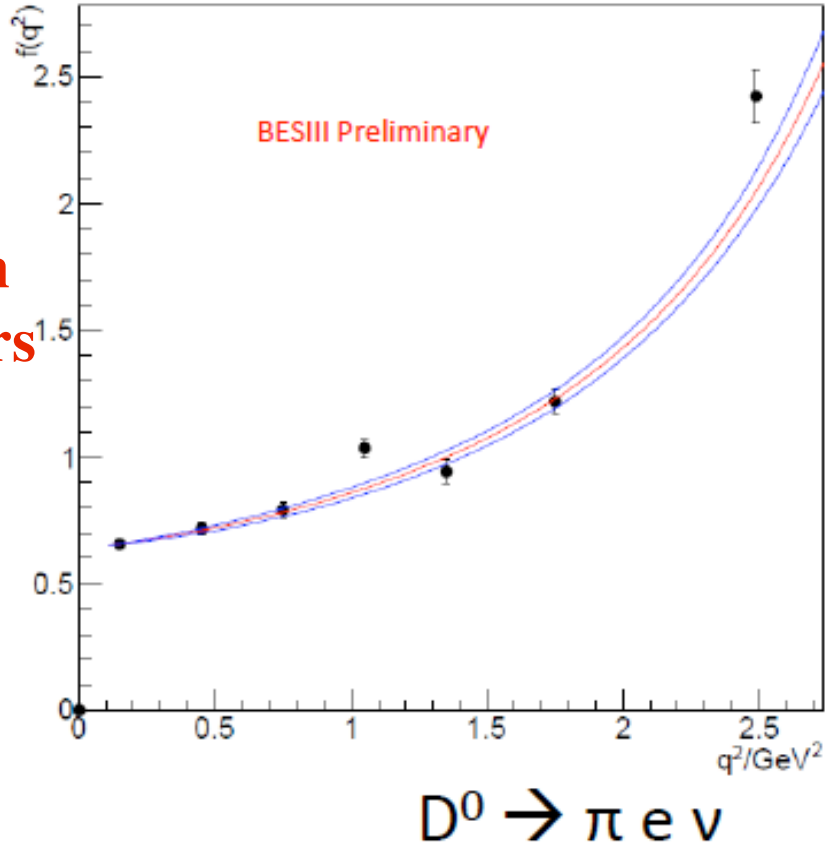
BESIII 0.9 fb^{-1}
CHARM2012
arXiv: 1207.1171

- Points: data with stat. error only
- Curves: from Fermilab-MILC within one stat. error, preliminary, **arXiv:1111.5471** (XXIX International Symposium on Lattice Field Theory);
- Other theoretical work: HPQCD, arXiv:1111.0225
- Comparing shape only here ($f_+(0)$ not known)

Slide directly from CHARM2012, for illustration
No attempt to update Lattice QCD…



Form Factors $f(q^2)$



$D^0 \to Ke\nu,\ \pi e\nu$

BESIII 0.9 fb^{-1}
CHARM2012
arXiv: 1207.1171

Numerical results
Only 1/3 of current data !

BESIII Preliminary

Mode	measured branching fraction(%)	PDG	CLEOc
$\bar{D}^0 \to K^+ e^- \bar{\nu}$	3.542 $\pm$0.030$\pm$0.067	3.55 $\pm$0.04	3.50 $\pm$0.03 $\pm$0.04
$\bar{D}^0 \to \pi^+ e^- \bar{\nu}$	0.288 $\pm$0.008$\pm$0.005	0.289 $\pm$0.008	0.288 $\pm$0.008$\pm$0.003

BESIII Preliminary

Simple Pole	$f_+(0)\lvert V_{cd(s)}\rvert$	m_{pole}	
$D^0 \to Ke\nu$	0.729$\pm$0.005$\pm$0.007	1.943$\pm$0.025$\pm$0.003	
$D^0 \to \pi e\nu$	0.142$\pm$0.003$\pm$0.001	1.876$\pm$0.023$\pm$0.004	
Modified Pole	$f_+(0)\lvert V_{cd(s)}\rvert$	α	
$D^0 \to Ke\nu$	0.725$\pm$0.006$\pm$0.007	0.265$\pm$0.045$\pm$0.006	
$D^0 \to \pi e\nu$	0.140$\pm$0.003$\pm$0.002	0.315$\pm$0.071$\pm$0.012	
2 par. series	$f_+(0)\lvert V_{cd(s)}\rvert$	r_1	
$D^0 \to Ke\nu$	0.726$\pm$0.006$\pm$0.007	$-$2.034$\pm$0.196$\pm$0.022	
$D^0 \to \pi e\nu$	0.140$\pm$0.004$\pm$0.002	$-$2.117$\pm$0.163$\pm$0.027	
3 par. series	$f_+(0)\lvert V_{cd(s)}\rvert$	r_1	r_2
$D^0 \to Ke\nu$	0.729$\pm$0.008$\pm$0.007	$-$2.179$\pm$0.355$\pm$0.053	4.539$\pm$8.927$\pm$1.103
$D^0 \to \pi e\nu$	0.144$\pm$0.005$\pm$0.002	$-$2.728$\pm$0.482$\pm$0.076	4.194$\pm$3.122$\pm$0.448

Strong Phase $\delta_{K\pi}$

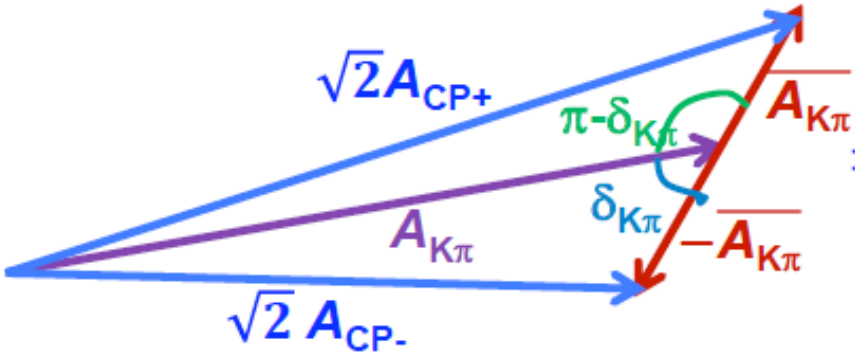
BESIII 2.9 fb^{-1}
Preliminary

A simple picture:
(simple = no mixing)

$$\frac{\langle K\pi|\overline{D^0}\rangle}{\langle K\pi|D^0\rangle} \equiv \frac{\overline{A_{K\pi}}}{A_{K\pi}} \equiv r_{K\pi}e^{i\delta_{K\pi}}$$

CF ± DCSD

$$\langle K\pi|D_{CP\pm}\rangle = (\langle K\pi|D^0\rangle \pm \langle K\pi|\overline{D^0}\rangle)/\sqrt{2} \Rightarrow \sqrt{2}A_{CP\pm} = A_{K\pi} \pm \overline{A_{K\pi}}$$



$$\Rightarrow \quad 2r_{K\pi}\cdot\cos\delta_{K\pi} \approx A_{CP\to K\pi} \equiv \frac{|A_{CP-}|^2 - |A_{CP+}|^2}{|A_{CP-}|^2 + |A_{CP+}|^2}$$

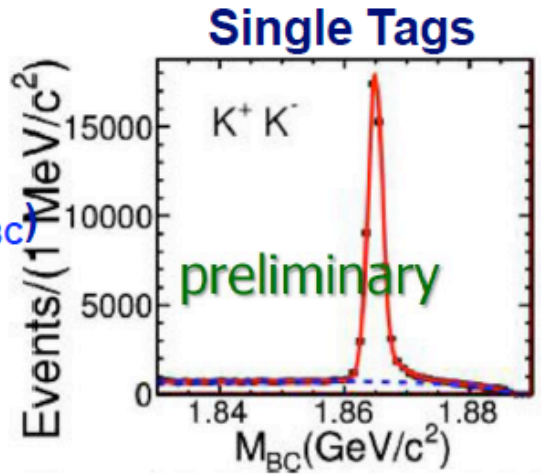
$$= \frac{Br(D_{CP-}\to K\pi) - Br(D_{CP+}\to K\pi)}{Br(D_{CP-}\to K\pi) + Br(D_{CP+}\to K\pi)}$$

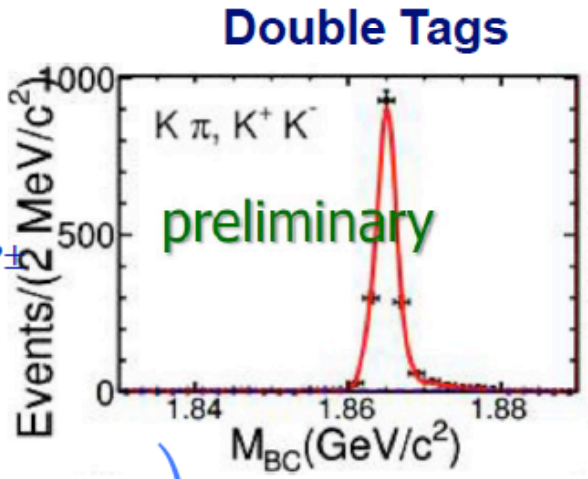
- Measuring $\delta_{K\pi}$ from rate differences if using external $r_{K\pi}$
- Reconstructed modes:
  - Flavor tags: $K^-\pi^+$, $K^+\pi^-$
  - CP+ tags (5 modes): K^-K^+, $\pi^+\pi^-$, $K^0_S\pi^0\pi^0$, $\pi^0\pi^0$, $\rho^0\pi^0$
  - CP- tags (3 modes): $K^0_S\pi^0$, $K^0_S\eta$, $K^0_S\omega$

Strong Phase $\delta_{K\pi}$

BESIII 2.9 fb^{-1}
Preliminary

- **Signal reconstruction:**
  - Single Tag (ST): CP tags
  - Double Tag (DT) : Kπ + CP Tag
  - Kinematic variable: Beam Constrained Mass (M_{BC})
  - Singal shape: σ⊗MC-truth
  - Background shape: ARGUS function
- $Br(D_{CP\pm} \to K\pi) = \frac{n_{K\pi,CP\pm}}{n_{CP\pm}} \cdot \frac{\varepsilon_{CP\pm}}{\varepsilon_{K\pi,CP\pm}}$
  - $n_{K\pi,CP\pm}$ and $n_{CP\pm}$ are event yields for DT and ST from M_{BC} fit
  - $\varepsilon_{K\pi,CP\pm}$ and $\varepsilon_{CP\pm}$ are detection efficiencies of DT and ST from MC simulation
  - Most systematics cancelled for ratio $\varepsilon_{CP\pm}/\varepsilon_{K\pi,CP\pm}$





BES III preliminary:

$$A_{CP\to K\pi} = \left(12.77 \pm 1.31(\text{Stat.})\ ^{+0.33}_{-0.31}\ (\text{sys.})\right)\%$$

Strong Phase $\delta_{K\pi}$

BESIII 2.9 fb^{-1}
Preliminary

- If we don't ignore the mixing effect
- $2r_{K\pi}\cos\delta_{K\pi} + y = (1 + R_{WS}) \cdot A_{CP\to K\pi}$
  - $R_{WS} \equiv \frac{\Gamma(D^0\to K^+\pi^-)}{\Gamma(D^0\to K^-\pi^+)} = r_{K\pi}^{\ 2} + r_{K\pi}y' + \frac{(x^2+y^2)}{2}$
- External inputs from HFAG2013 and PDG
  - $r_{K\pi}^{\ 2} = 0.347 \pm 0.006\%$,
  - $y = 0.66 \pm 0.09\%$,
  - $R_{WS} = 0.380 \pm 0.005\%$
- BESIII preliminary results:

$$\cos\delta_{K\pi} = 1.03 \pm 0.12 \pm 0.04 \pm 0.01$$

(Uncertainty is dominated by the statistical error.)

All $\delta_{K\pi}$ slides courtesy of Yangheng Zheng, CHARM2013

Other Quantum Correlation Work

Coherence factors: feed into CKM γ/ϕ_3 B analyses

(the "alphabet techniques" : GLW, ADS, GGSZ, …)

$K_S \pi^+ \pi^-$ most advanced: binned analysis ("CLEO-style")

$K^- \pi^+ \pi^0$, $\pi^+ \pi^- \pi^0$ } likely to pursue both model-ind't analyses, and also detailed Dalitz analyses

+ other modes (e.g., $K^-\pi^+\pi^+\pi^-$ & $K_S K^+\pi^-$ have been done by CLEO-c)

Mixing analyses: statistics-limited at $\psi(3770)$

(Too bad: neat effect @ $\psi(3770)$ where DCSD cancels for conjugate final states)

Luminosity x cross-section much higher @ B factories, LHCb

But… We do have a y_{CP} analysis in the works

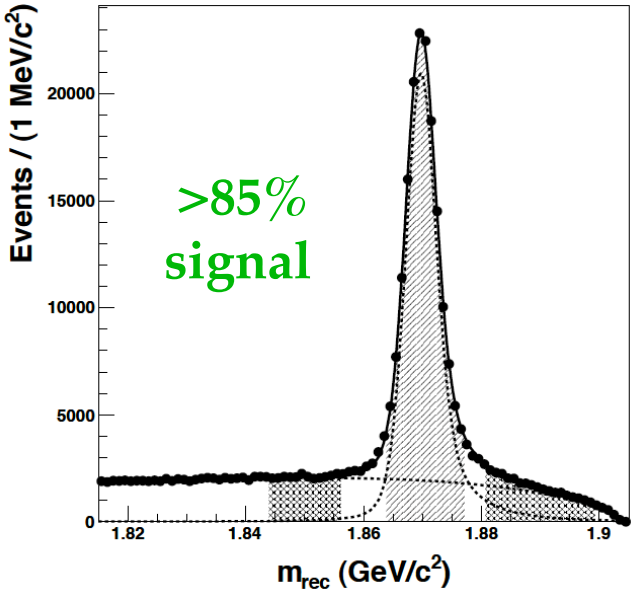
$D^+ \to K_S\pi^+\pi^0$ Dalitz

BESIII 2.9 fb^{-1}
arXiv 1401-3083
To appear in PRD

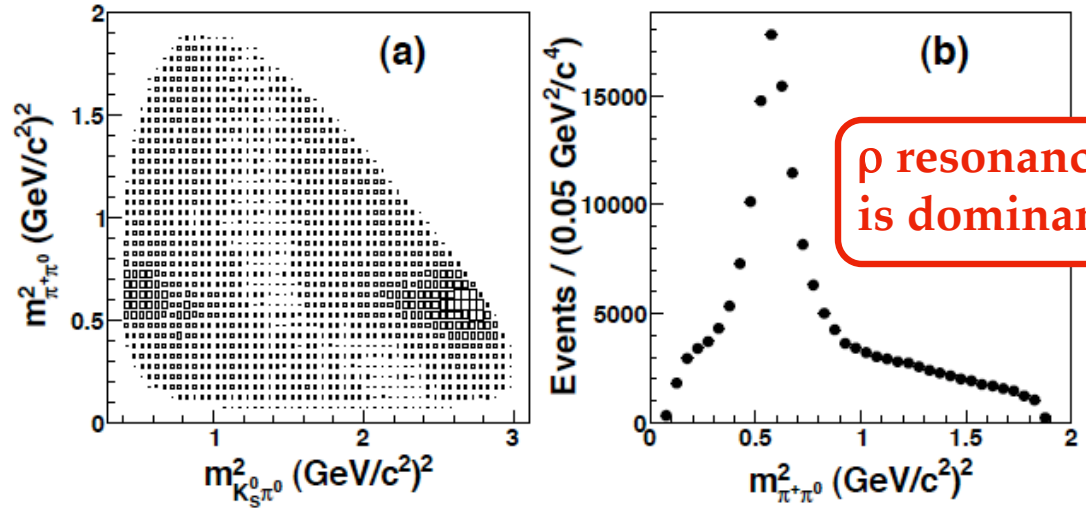
Good channel for $K_S\pi^0$ S-wave studies

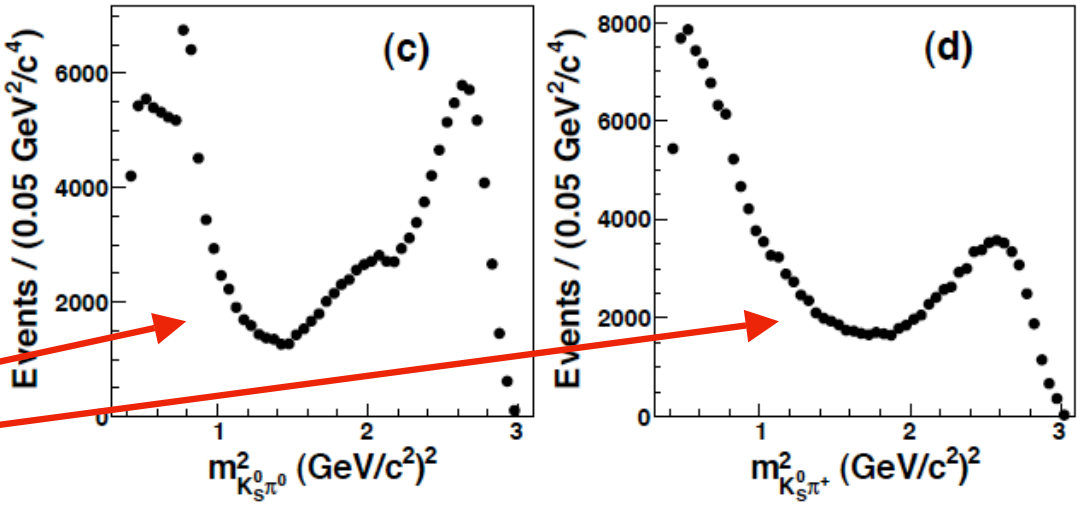
Signal via Recoil Mass :

- Constrain $K_S\pi^+\pi^0$ to m_D
- 4 vector of e^+e^- and D give recoil mass



Resulting Dalitz Plot :





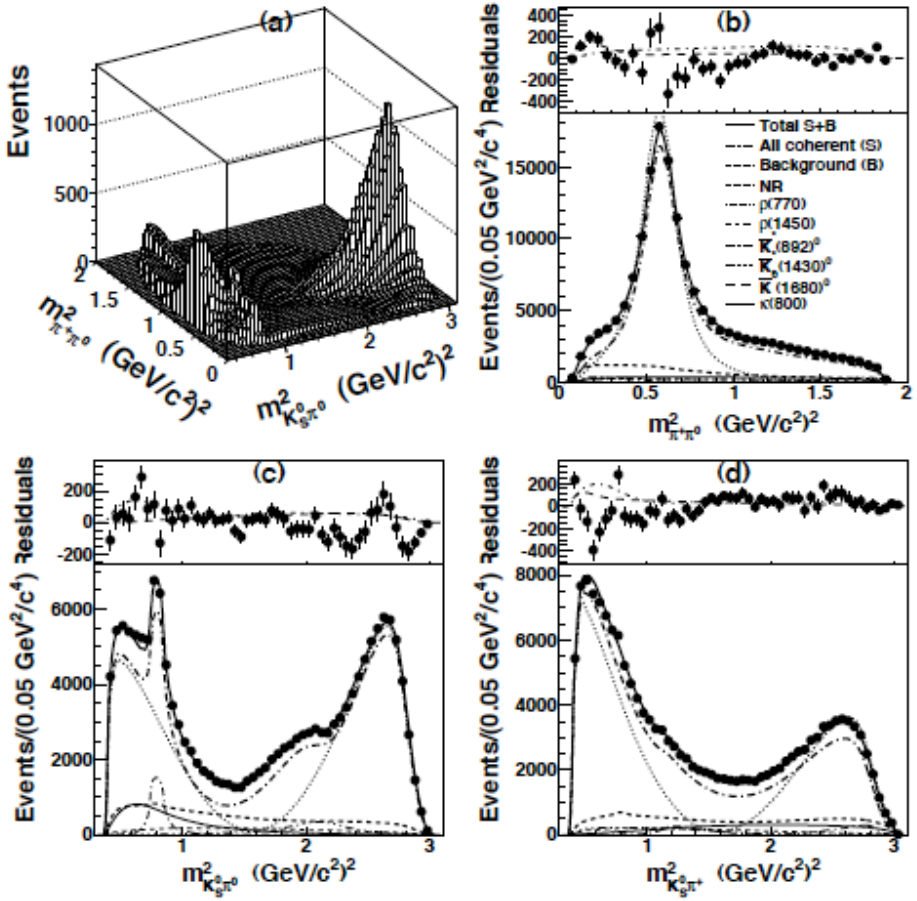
Other projections are dominated by "cos² shadow" of ρ

$D^+ \to K_S\pi^+\pi^0$ Dalitz

BESIII 2.9 fb^{-1}
arXiv 1401-3083
To appear in PRD

"Model D" Fit :

- Try many resonances
- Drop insignificant one
- Contains κ π (kappa) and non-resonant



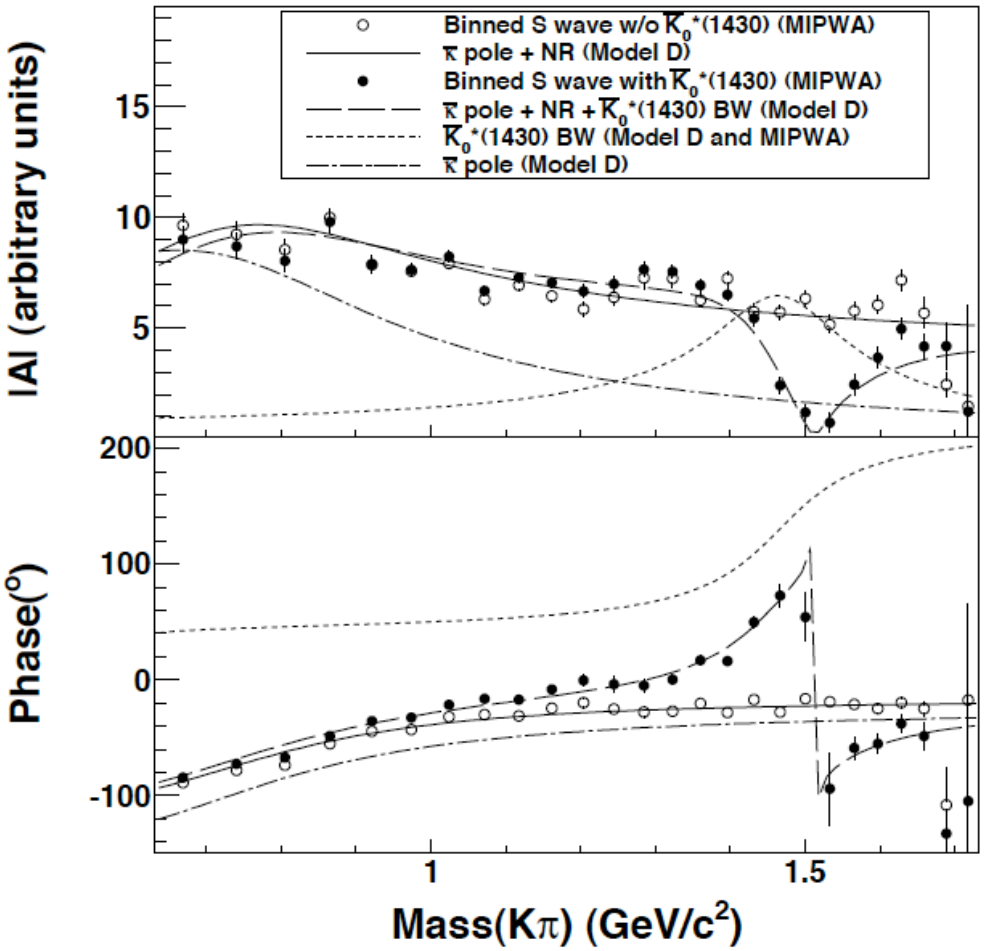
Decay Mode	Par.	Model D
Non-resonant	FF(%) $\phi(^\circ)$	6.1±0.9 276±6
$K^0_S\rho(770)^+$	FF(%) $\phi(^\circ)$	82.2±2.2 ← 0(fixed)
$K^0_S\rho(1450)^+$	FF(%) $\phi(^\circ)$	2.65±0.28 183.7±2.6
$\overline{K}^*(892)^0\pi^+$	FF(%) $\phi(^\circ)$	3.38±0.16 292.2±1.3
$\overline{K}^*(1410)^0\pi^+$	FF(%) $\phi(^\circ)$	
$\overline{K}^*_0(1430)^0\pi^+$	FF(%) $\phi(^\circ)$ mass(MeV) width(MeV)	3.7±0.6 339±5 1470±6 187±7
$\overline{K}^*_2(1430)^0\pi^+$	FF(%) $\phi(^\circ)$	
$\overline{K}^*(1680)^0\pi^+$	FF(%) $\phi(^\circ)$	1.05±0.09 255.3±2.0
$\overline{K}^*_3(1780)^0\pi^+$	FF(%) $\phi(^\circ)$	
$\overline{\kappa}^0\pi^+$	FF(%) $\phi(^\circ)$ $\Re$(MeV) $\Im$(MeV)	6.4±1.0 92±7 750±15 -230±21
$NR+\overline{\kappa}^0\pi^+$	FF(%)	19.2±1.8 ←
$K^0_S\pi^0$ S-wave	FF(%)	17.1±1.4
ΣFF(%)		105
$\chi^2/Ndof$		2068/1193
$-2\ln\mathcal{L}$		239807

$D^+ \to K_S\pi^+\pi^0$ Dalitz

BESIII 2.9 fb^{-1}
arXiv 1401-3083
To appear in PRD

We also perform a Model-Independent Partial-Wave Analysis (MIPWA) for the S-wave Kπ components : non-res. + κ + $K^*_0(1430)$)

Reduces model-dependence
(always a problem…)
Extract amplitude & phase of S-wave Kπ in mass bins



Conclusion:
Inclusion / omission of the $K^*_0(1430)$ resonance affects high-mass shape, but always significant phase motion at low masses (i.e., the κ region)

X, Y, Z Physics

Recall the Y(4260) …

$Z_c(3900)^{\pm} \rightarrow J/\psi\ \pi^{\pm}$

$Z_c(3885)^{\pm} \rightarrow (D^*D)^{\pm}$

$Z_c(4020)^{\pm} \rightarrow h_c\ \pi\ \pi$

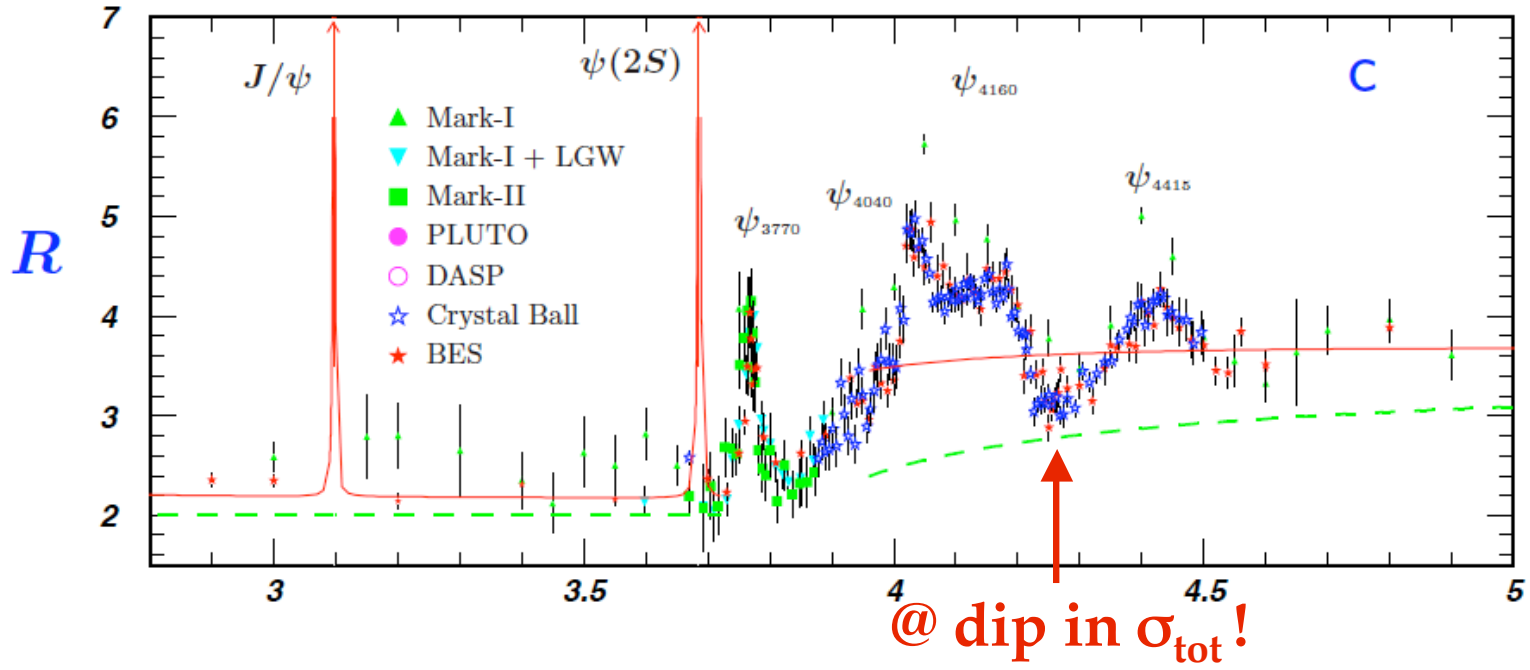
$Z_c(4025)^{\pm} \rightarrow (D^*D^*)^{\pm}$

$Y(4260) \rightarrow \gamma\ X(3872)$

Tetraquarks? Hybrids? Molecules? ⇒ ⇒ ⇒ no matter : FUN !!!

Y(4260) Data

2013: Large dataset at Y(4260)



Total charm cross-section @4260: ~4.3 nb (CLEO-c scan)

$e^+e^- \rightarrow J/\psi\,\pi\,\pi$ cross-section @4260: ~ 70 pb (BaBar/Belle)

PDG Y(4260) data: $\Gamma = (95 \pm 14)$ MeV

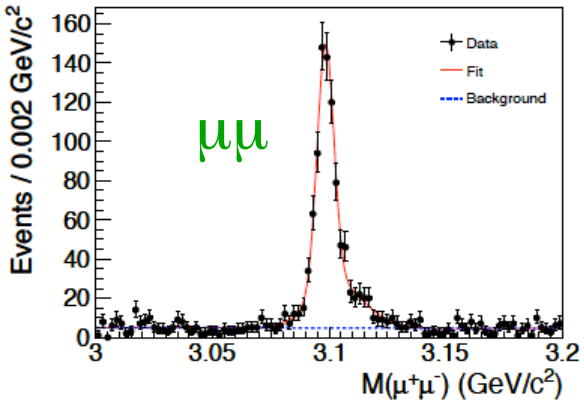
$\Gamma_{J/\psi\pi\pi}\,\Gamma_{ee}/\,\Gamma = 5.9\,^{+1.2}_{-0.9}$ eV

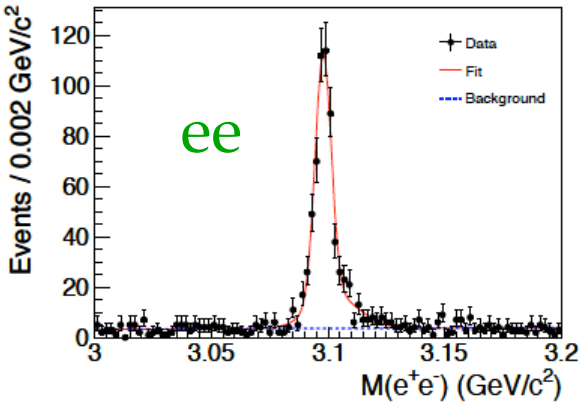
Y(4260) → π π J/ψ

BESIII 525 pb^{-1}
PRL 110,
252001(2013)

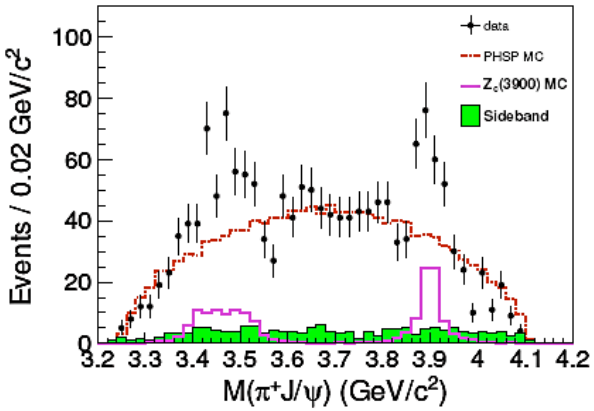
Study **525 pb^{-1}** collected at E_{cm} = 4260 MeV ;
look at well-known **J/ψ π π** decay of Y(4260)

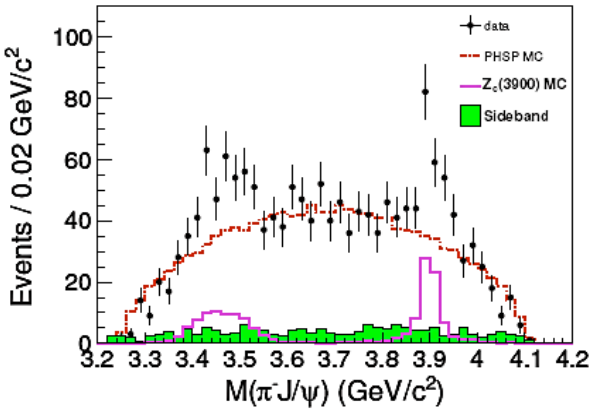
J/ψ di-lepton peaks:

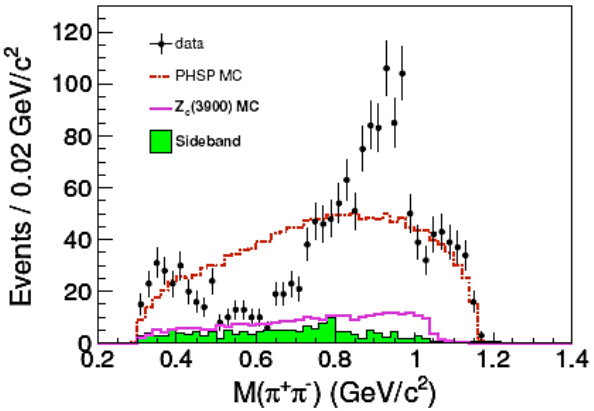




Pair-wise invariant masses: (of *π π J/ψ*)





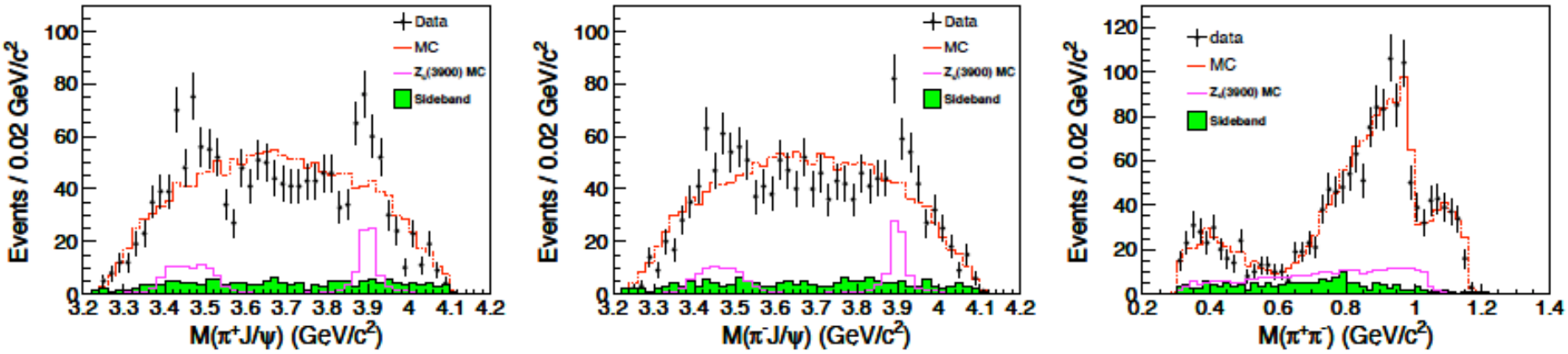


Shift focus ! → $Z_c^+(3900)$

BESIII 525 pb^{-1}
PRL 110,
252001(2013)

Peak(s) in J/ψ π masses:
really only one (next page)
in both π charges
not due to π π structure
(not even if D-wave π π)

Structure in di-pion mass:
well-modeled via
$f_0(980)$ + σ(500) + non-res.



Now, red curve is MC w/ π π structure

$Z_c^+(3900)$

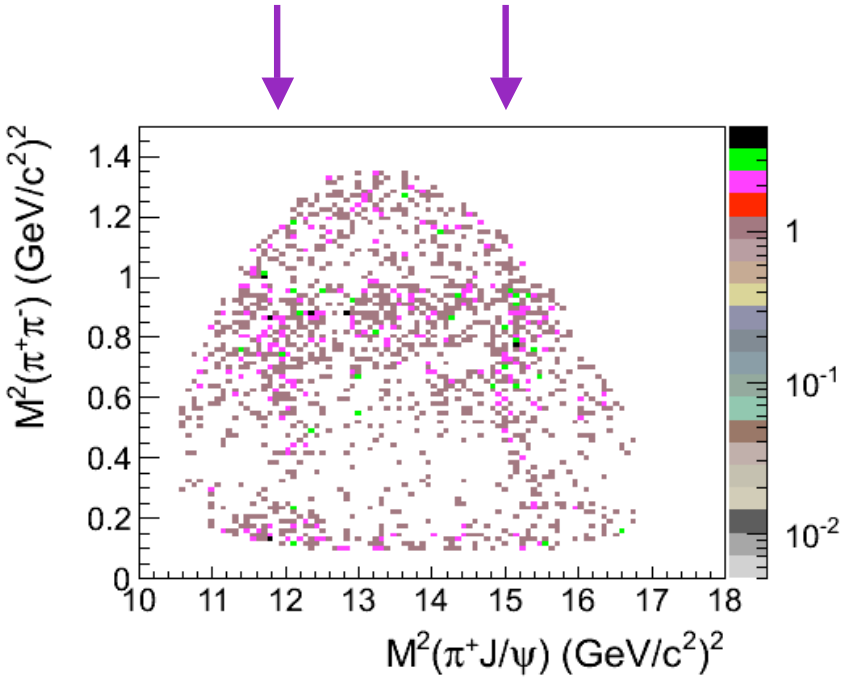
BESIII 525 pb^{-1}
PRL 110,
252001(2013)

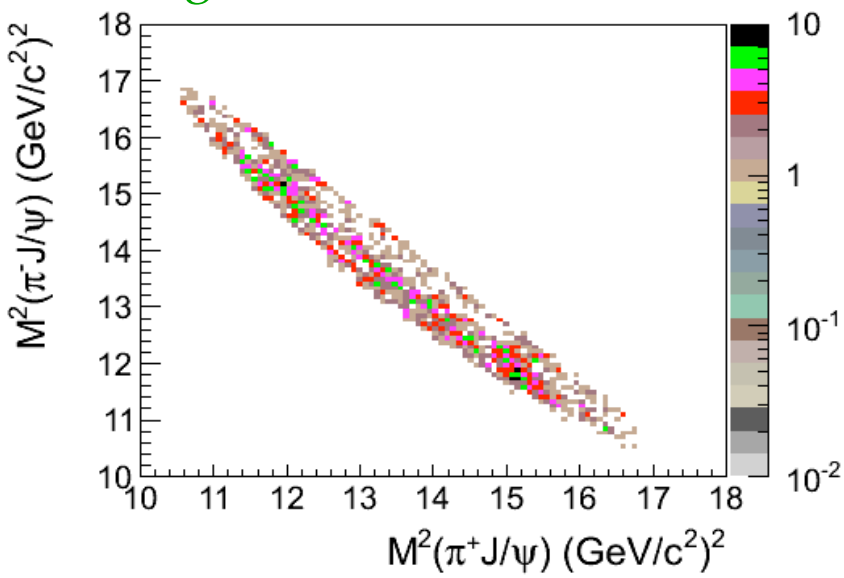
Dalitz Plots

Two stripes in J/ψ π mass
one is a reflection of the other:
correlation in two J/ψ π axes

Fold over Dalitz plot !
[plot "M_{max}(J/ψ π)"]

high in one ↔ low in other



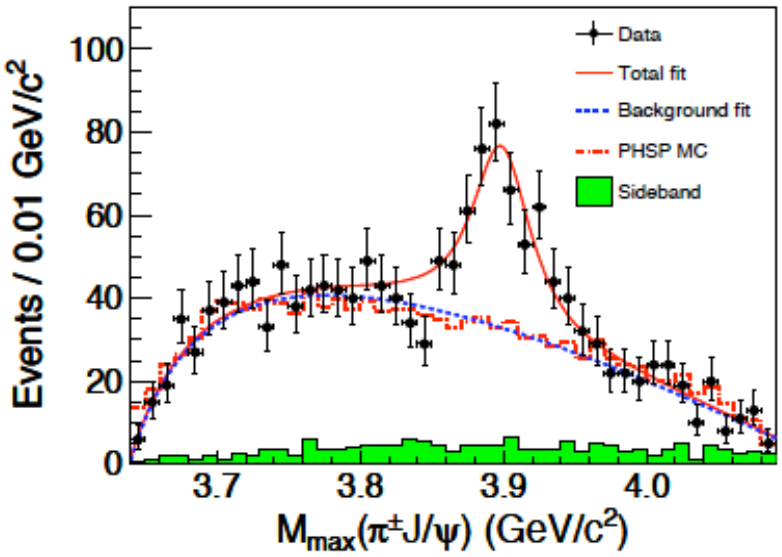


$Z_c^+(3900)$

BESIII 525 pb^{-1}
PRL 110,
252001(2013)

Fit To:

S-wave BW + MC resolution
+ empirical background
function (4 parameters)



Total rate:

$e^+e^- \to \pi\,\pi\,J/\psi$ Born-level cross-section = (62.9 ± 1.9 ± 3.7) pb

Consistent with Y(4260)

$Z_c^+(3900)$ peak in π^+ J/ψ :

M = (3899.0 ± 3.6 ± 4.9) MeV Γ = (46 ± 10 ± 20) MeV

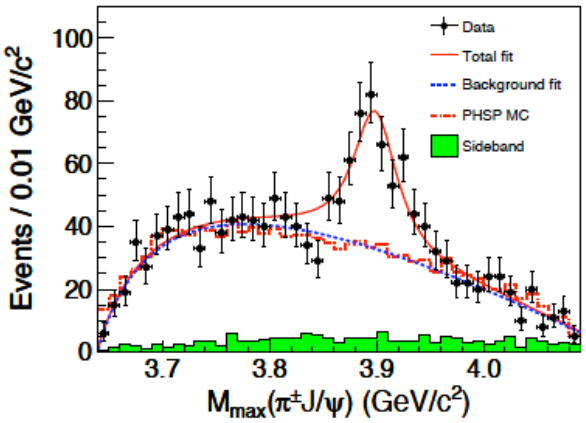
Fractional rate of $Z_c^+(3900)$ peak :

$$R = \frac{\sigma(e^+e^- \to \pi^\pm Z_c(3900)^\mp \to \pi^+\pi^- J/\psi))}{\sigma(e^+e^- \to \pi^+\pi^- J/\psi)} = (21.5 \pm 3.3 \pm 7.5)\,\%$$

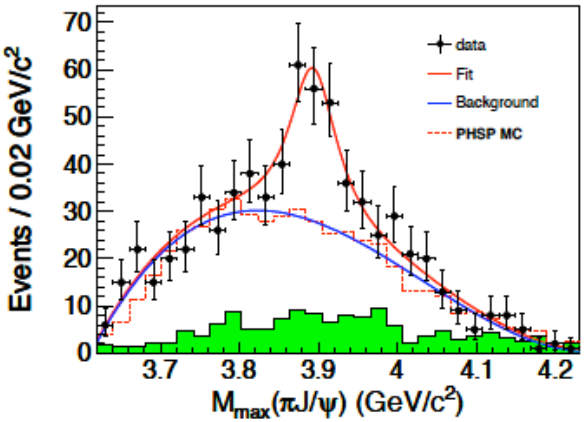
BESIII, Belle, NWU

We present : the (Z_c) ^{3}

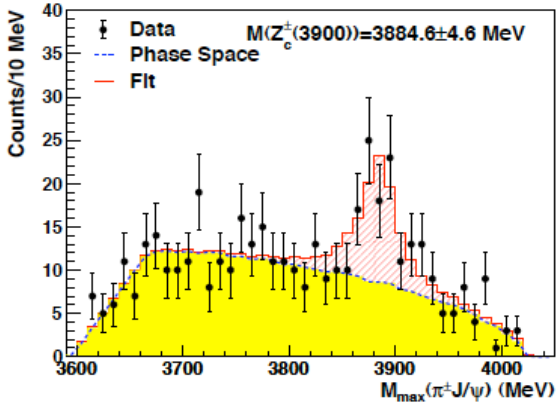
BESIII $Z_c^+(3900)$
PRL 110, 252001 (2013)



Belle $Z_c^+(3895)$
PRL 110, 252002 (2013)



Northwestern U.
$Z_c^+(3900)$
PLB 727, 366 (2013)



Note horizontal range differences !

BESIII: 525 pb^{-1} at E_{cm} = 4260 MeV
BelleII: ISR from ~10 GeV, cut on $4.15 < M(J/\psi\pi\pi) < 4.45$ GeV
(hence, higher upper endpoint on mass above…)
NWU: 586 pb^{-1} at E_{cm} = 4170 MeV (CLEO-c legacy data)

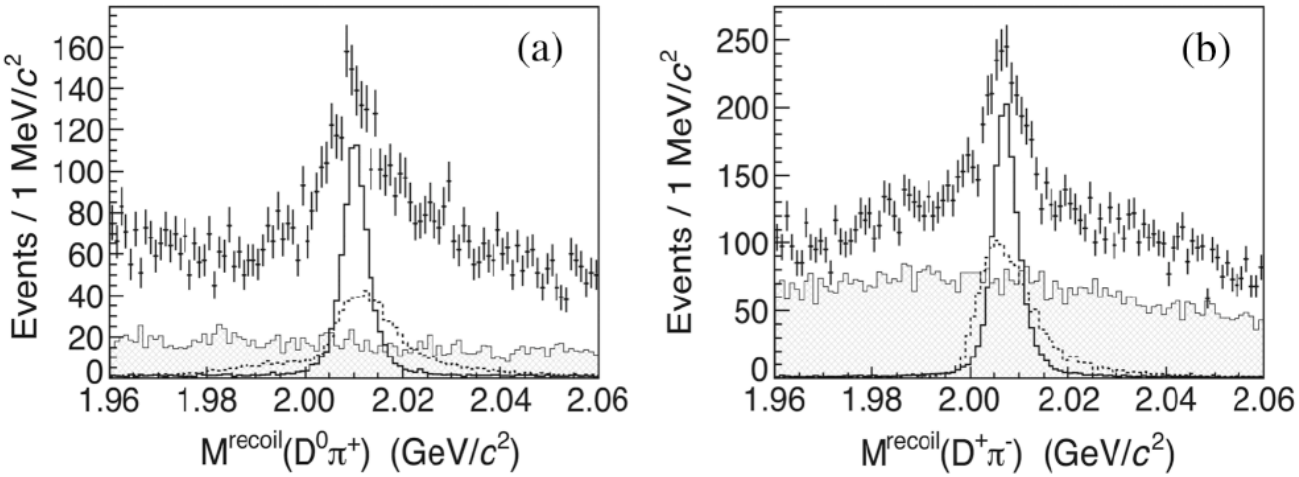
$Z_c(3885) \to (DD^*)^\pm$

BESIII 525 pb^{-1}
PRL 112,
022001(2014)

$e^+e^- \to D\ D^{*bar}\pi$ @ 4260 MeV

Two channels:

(a) $D^0\ D^{*-}\ \pi^+$ **(b) $D^+\ D^{*0bar}\ \pi^-$**



Reconstruct:

bachelor π and *one* of D^+ or D^0

D π recoil mass:

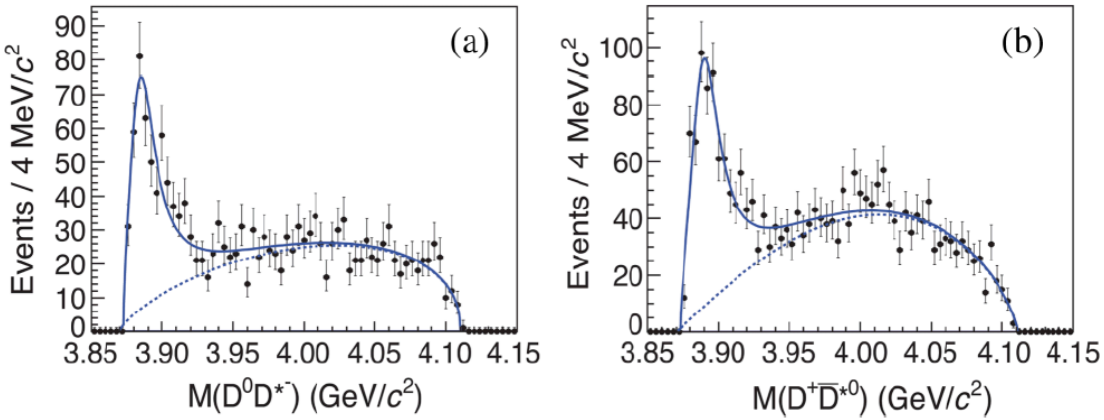
clear peak at D masses; cut on…*

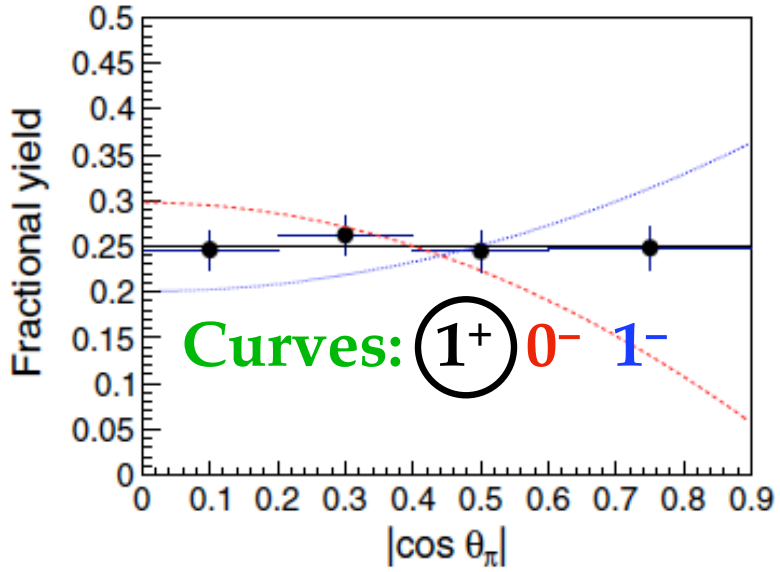
$Z_c(3885) \to (DD^*)^\pm$

BESIII 525 pb^{-1}
PRL 112,
022001(2014)

Plot DD*masses:

Clear excesses over phase-space near threshold





Peak parameters:

M = (3883.9 ± 1.5 ± 4.2) MeV

Γ = (24.8 ± 3.3 ± 11) MeV

about 2σ & 1σ lower than Zc(3900)

← Also determine J^P via **π angle**

$Z_c(4020)$ in $\pi^+\pi^- h_c$

BESIII 3.4 fb^{-1}
PRL 111,
242001(2013)

Use $h_c \to \eta_c \gamma$ Select events with :

$\pi^+\pi^-$ recoil mass near h_c

$\pi^+\pi^-\gamma$ recoil mass near η_c

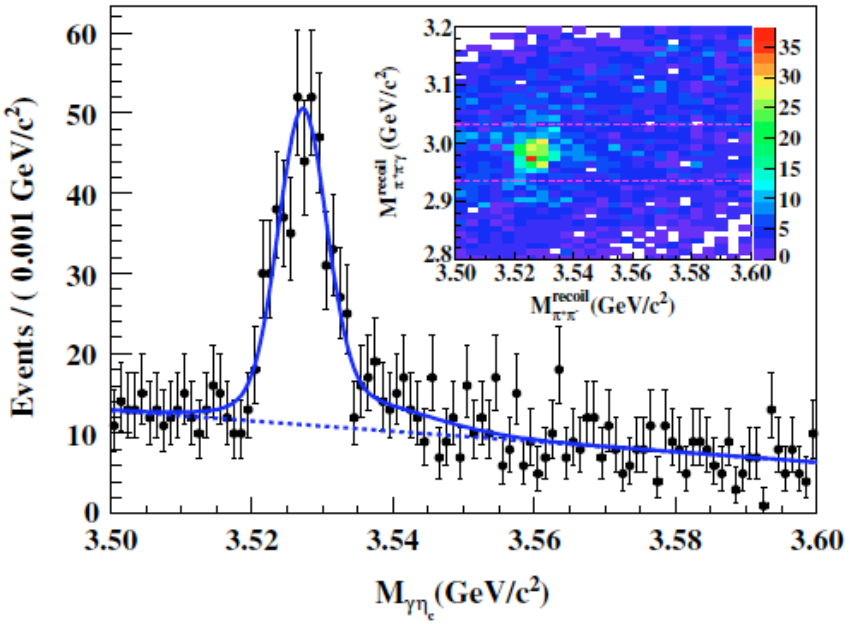
Then use 16 η_c decay modes

3.4 fb^{-1} @ 13 E_{cm} points
(~87% in 4 points)

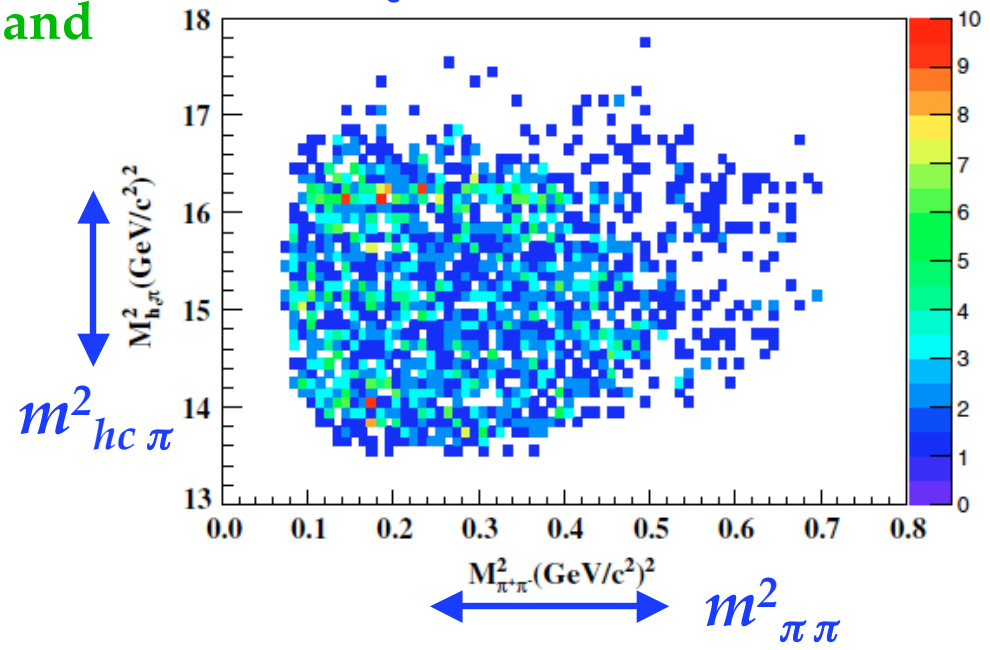
Inset: scatter plot of 2 recoil masses

1-D Projection:

h_c peak in mass($\gamma\,\eta_c$) from η_c band



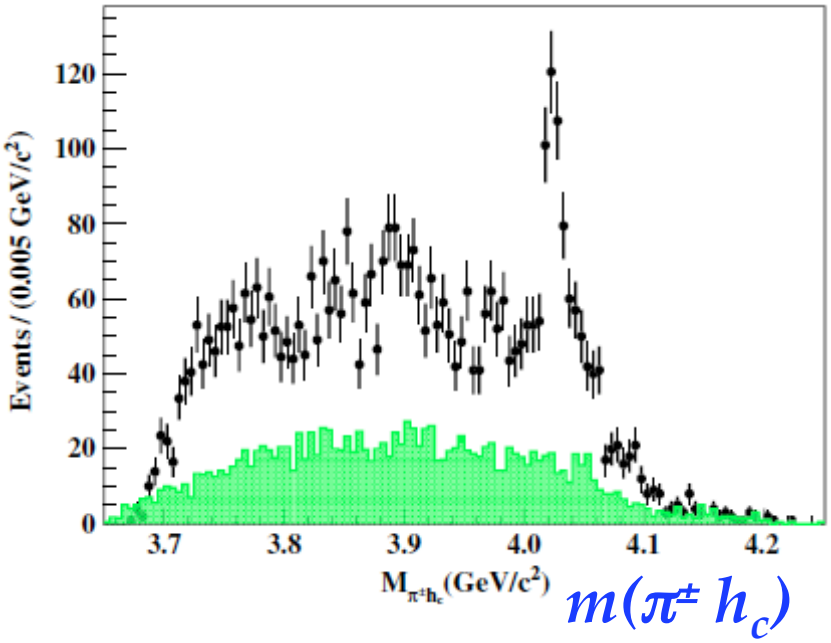
$h_c\,\pi^+\pi^-$ Dalitz Plot:



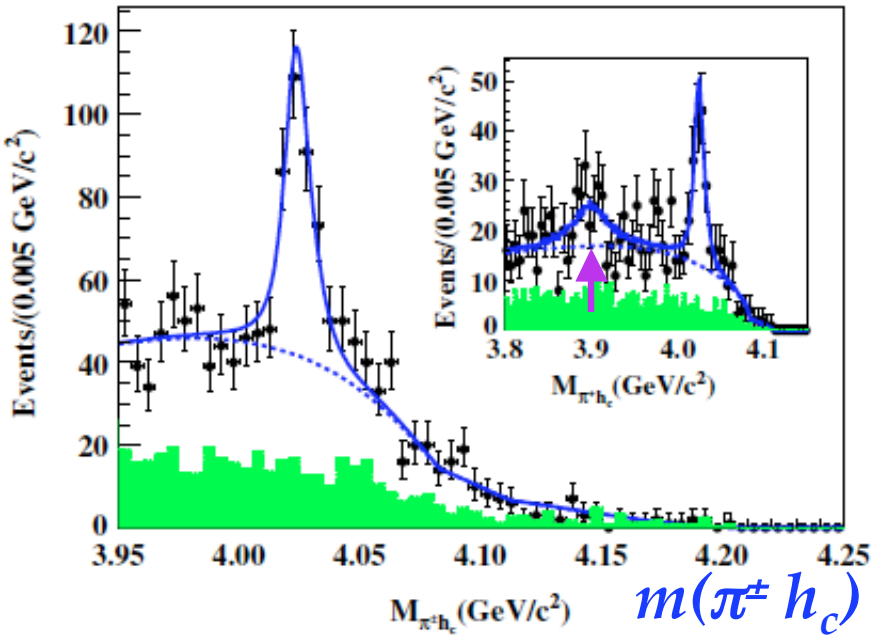
$Z_c(4020)$ in $\pi^+\pi^- h_c$

BESIII 3.4 fb^{-1}
PRL 111,
242001(2013)

Large, narrow peak in $\pi^\pm h_c$ mass !



Zoom in on a fit to peak



Inset shows insignificant $Z_c(3900)$

Parameters of *new* Peak:

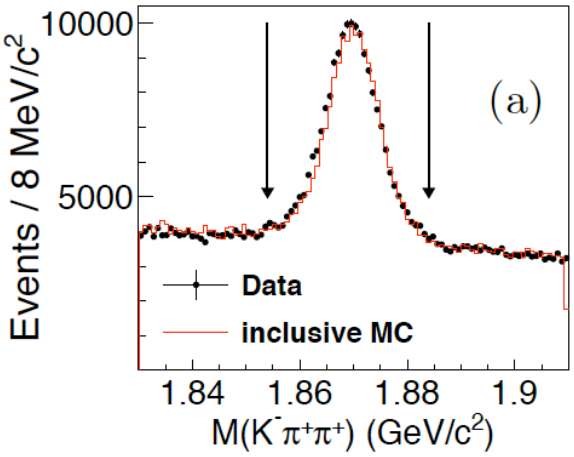
$M = (4022.9 \pm 0.8 \pm 2.7)$ MeV $\Gamma = (7.9 \pm 2.7 \pm 2.6)$ MeV

$Z_c(4025) \rightarrow (D^*D^*)^{\pm}$

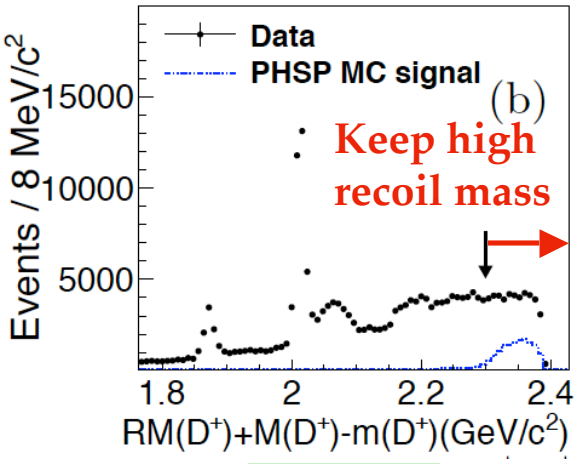
$e^+e^- \rightarrow D^*\ D^{*bar}\pi$ @ 4260 MeV

BESIII 827 pb^{-1}
arXiv:1308.2760

$D^+ \rightarrow K^-\pi^+\pi^+$



D^+ recoil mass



Recon. - nominal
Improves resolution

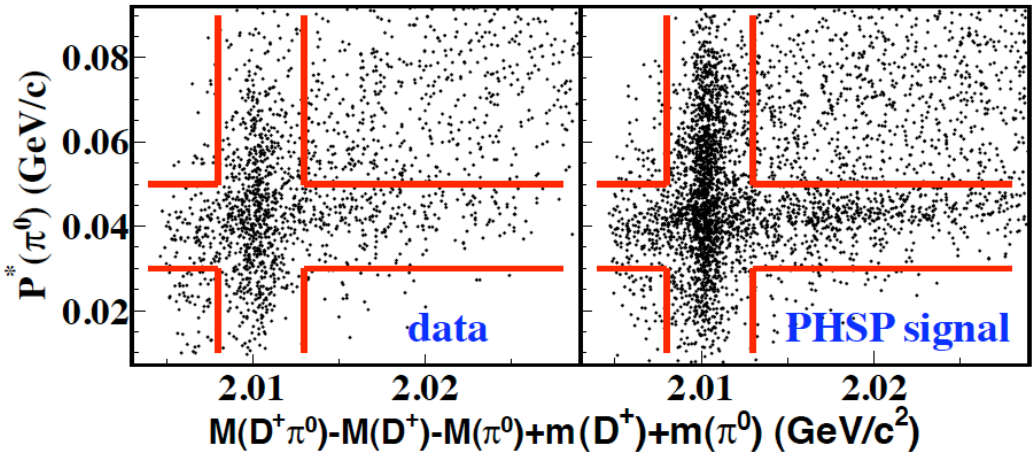
$D^{*+}\ D^{*0}\ \pi^-$ *with*

$D^{*+} \rightarrow D^+ \pi^0$

$D^{*0bar} \rightarrow D^{0bar} \pi^0$

Reconstruct:
D^+, π^-, one π^0

cut on D^+ mass, & recoil mass

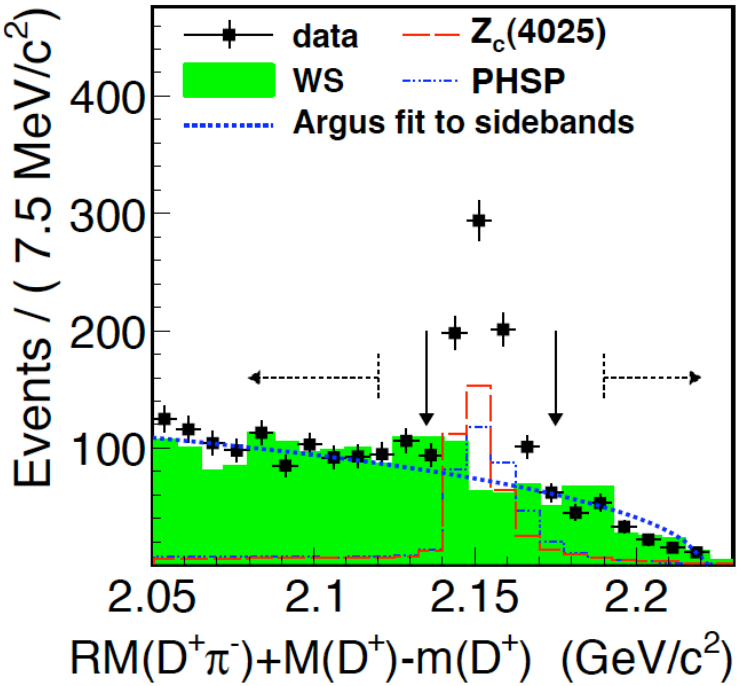


Vertical Band:
π^0 from D^{*+}

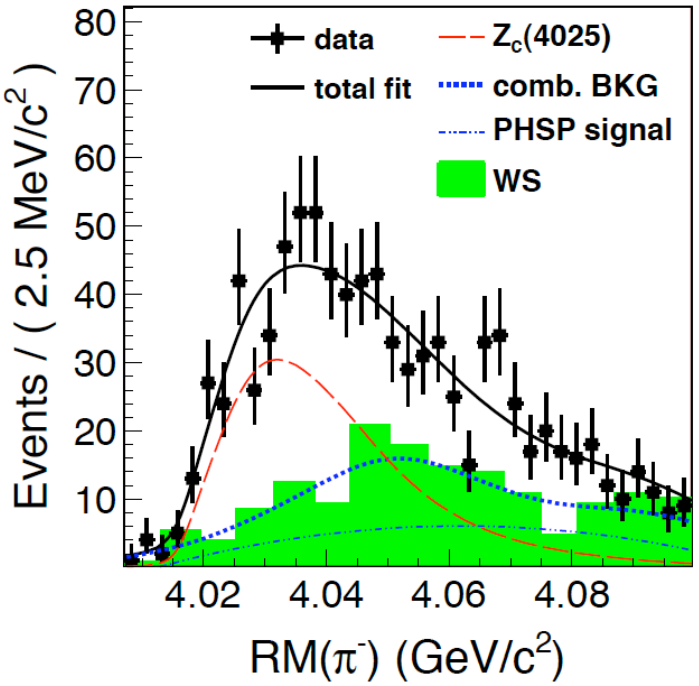
Horizontal Band:
π^0 from D^{*0bar}

$Z_c(4025) \to (D^*D^*)^\pm$

BESIII 827 pb^{-1}
arXiv:1308.2760



Peaks near sum of
D^{*0bar} & π^0 masses



π^- recoil mass: $D^{*+}D^{*0bar}$ mass
Inconsistent with phase-space

Parameters of new Peak: **(65 ± 9)% of all $D^{*+}\,D^{*0}\,\pi^-$**

M = (4026.3 ± 2.6) MeV Γ = (24.8 ± 5.6) MeV

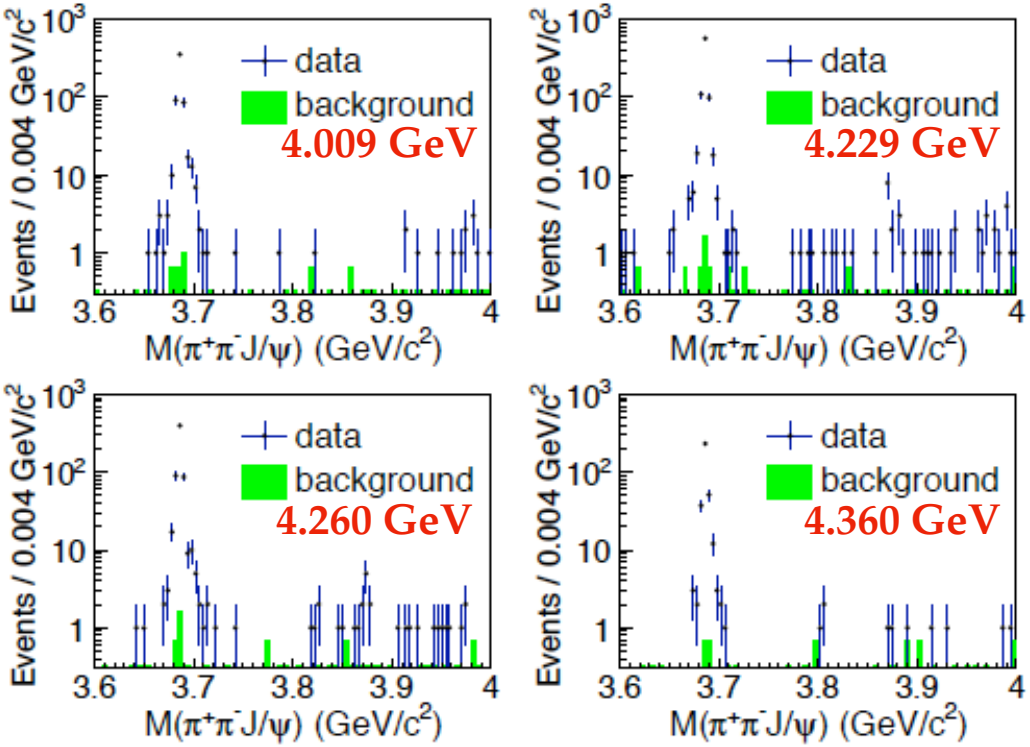
Same peak as previous h_c result ??? More work is needed…

Y(4260) → γ X(3872)

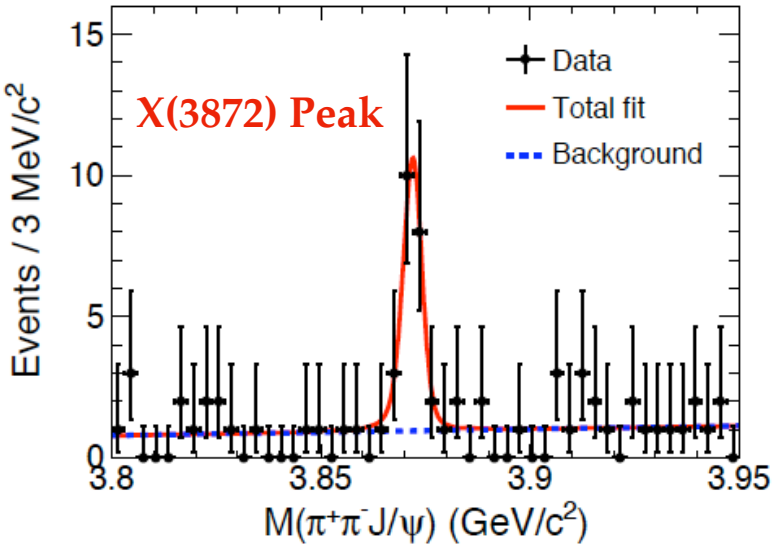
BESIII 2.9 fb^{-1}
arXiv:1310.4101

Analysis: Observe $e^+e^- \to \gamma$ X(3872) at several energies

Fit extracted σ(E) to resonance: does it look like Y(4260) ?



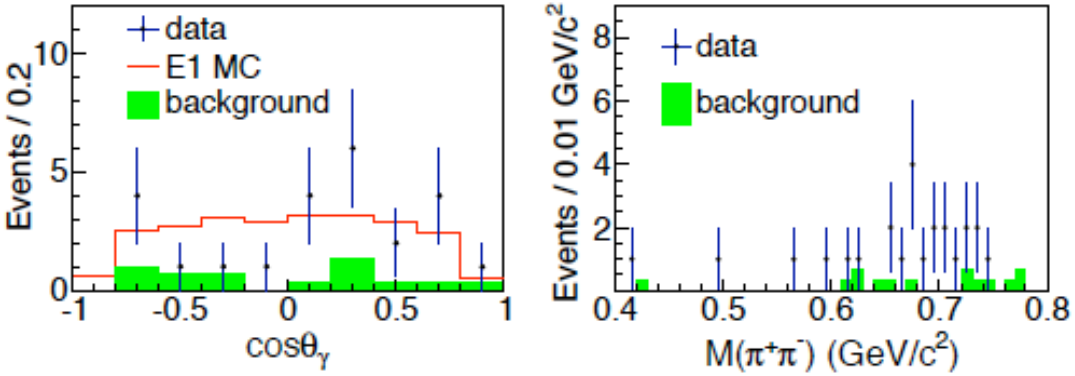
Summed over E_{cm}; zoomed in



6.3 σ X signal: M(X) = (3871.9 ± 0.7 ± 0.2) MeV Γ(X) < 2.4 MeV (90% CL)

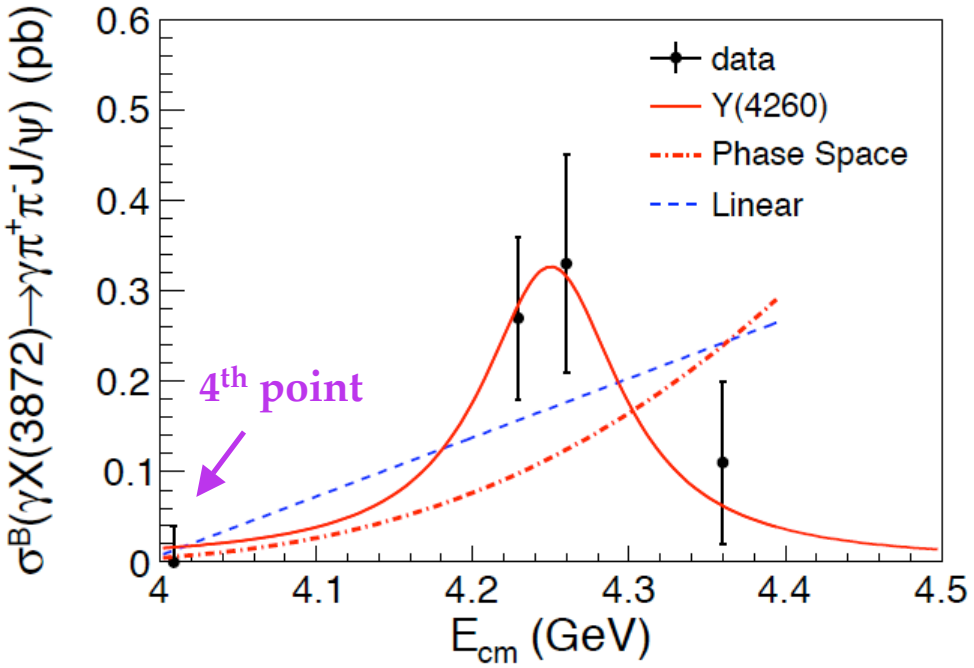
Y(4260) → γ X(3872)

BESIII 2.9 fb^{-1}
arXiv:1310.4101



Study of γππ structure :

- γ angle consistent with E1
- ππ consistent with ρ
  (as with CDF data)



Fit to cross-sections to :

- Y(4260) Resonance
- linear rise
- E1 phase space ($\propto E_\gamma^3$)
  no 4260

Y(4260) clearly best:

CL's in order: 92%, 6%, 3%

The Future

Running: Now & Later

So far this run:

>100 points for an "R scan" :

3.85 - 4.59 GeV

Mix of 5 & 10 MeV steps

~ 6 - 8 pb^{-1} per point

Current: working on 500 pb^{-1} per @ 4600 MeV

(not optimal for Λ_c pairs, but stay tuned…)

Future Runs: (no particular order)

- lower-energy R scan
- $D_s^* D_s$ data @ 4170 MeV
- More $\psi(3770)$, J/ψ, ψ'
- More "XYZ"

Easy to fill MANY years !

Conclusions

Precision D Physics is Underway

- (semi)leptonic: world's best; $D^+ \to \mu\nu$ unique to threshold
- Quantum Correlations also unique to threshold

Spectroscopy Very Active

- Much XYZ work discussed
- also many *other* analyses completed
  on new low-energy hadronic resonances

Many other facets to our program

- Charmonium states & transitions
- More low-energy hadron physics
- R_{had} scans (& charm decomposition!)
- Tau mass @ threshold (?Koide formula?)