Observation of New Hadronic $\psi(2S)$ Decays at CLEO

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- Introduction
- Event selection
- Preliminary results
- Summary

Motivation

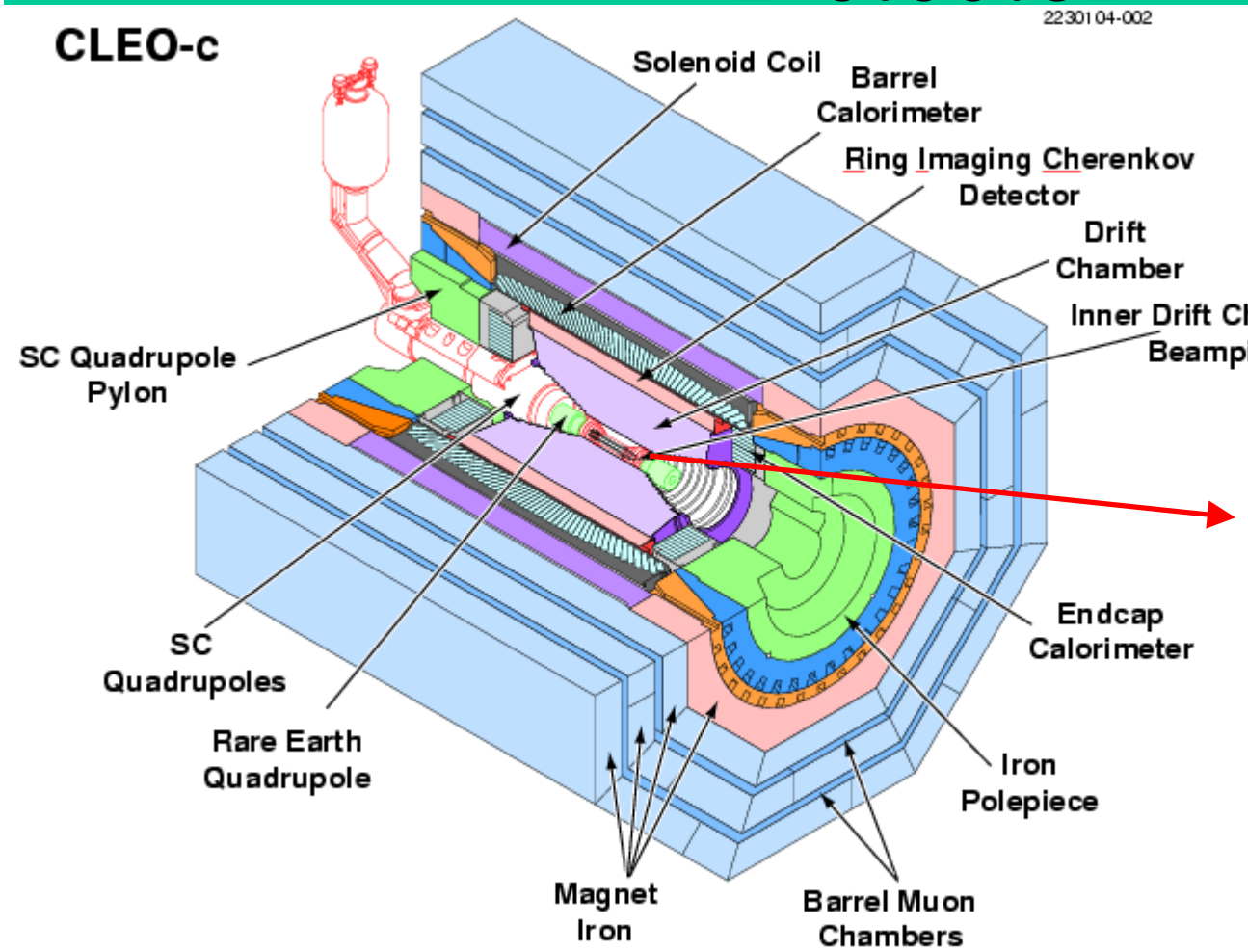
- $\psi(2S)$: the "12% rule"?

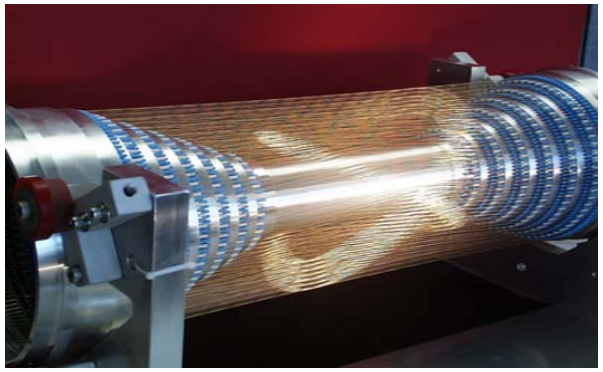
For the charmonium system ($c\bar{c}$ annihilation), decay rate ~ $|\Psi(0)|^2$,

$$Q_h = \frac{B(\psi(2S) \to h)}{B(J/\psi \to h)} = \frac{B(\psi(2S) \to l^+l^-)}{B(J/\psi \to l^+l^-)} \approx (12.7 \pm 0.5)\%$$

- Information on resonant vs. non-resonant in multi-body final state.
- S-D mixing (with $\psi(3770)$ analysis)

Detector





6-layer all-stereo

1.0 T magnetic field, silicon detector replaced by inner drift chamber.

Performance: tracking $\delta p/p \approx 0.6\%$ at p=1GeV/c for 93% of 4π

calorimeter $\delta E/E \approx 2.2\%$ at E=1GeV for 93% of 4π

Strategy

- Data Used: 5.5 pb^{-1} $\Psi(2S)$ CLEO3 + CLEOc, 3M decays,
  20.5 pb^{-1} continuum @ 3.67 GeV
- Scale continuum data for non-resonant subtraction
- Use sideband to subtract fake events
- Measure BRs of $\psi(2S)$ relative to $\pi^+\pi^- J/\psi$, $J/\psi \to \mu\mu$,

$$\frac{B(\psi(2S)\to X)}{B(\psi(2S)\to\pi^+\pi^- J/\psi, J/\psi\to\mu^+\mu^-)} = \frac{N^{obs,\psi(2S)} - N^{cont} \times f_{cont \to 2S}}{N(\pi^+\pi^-\mu^+\mu^-) \,/\, \varepsilon(\pi^+\pi^-\mu^+\mu^-)}$$

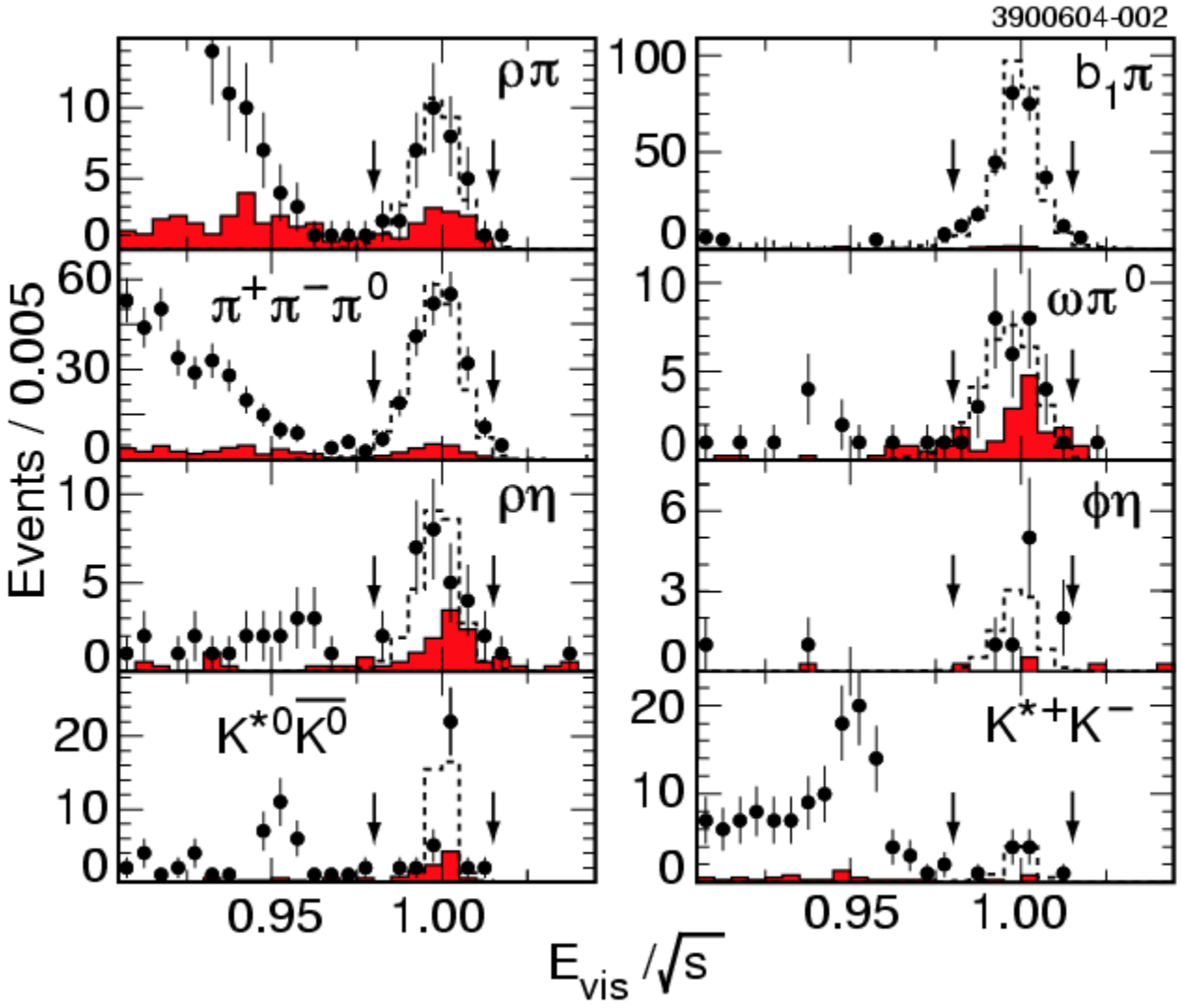
then convert into absolute branching fractions using
$BR(\psi(2S)\to\pi^+\pi^- J/\psi)=(32.3\pm1.3)\%$, $BR(J/\psi\to\mu^+\mu^-)=(5.88\pm0.10)\%$

- No treatment of interference between $\Psi(2S)$ and continuum

Event selection

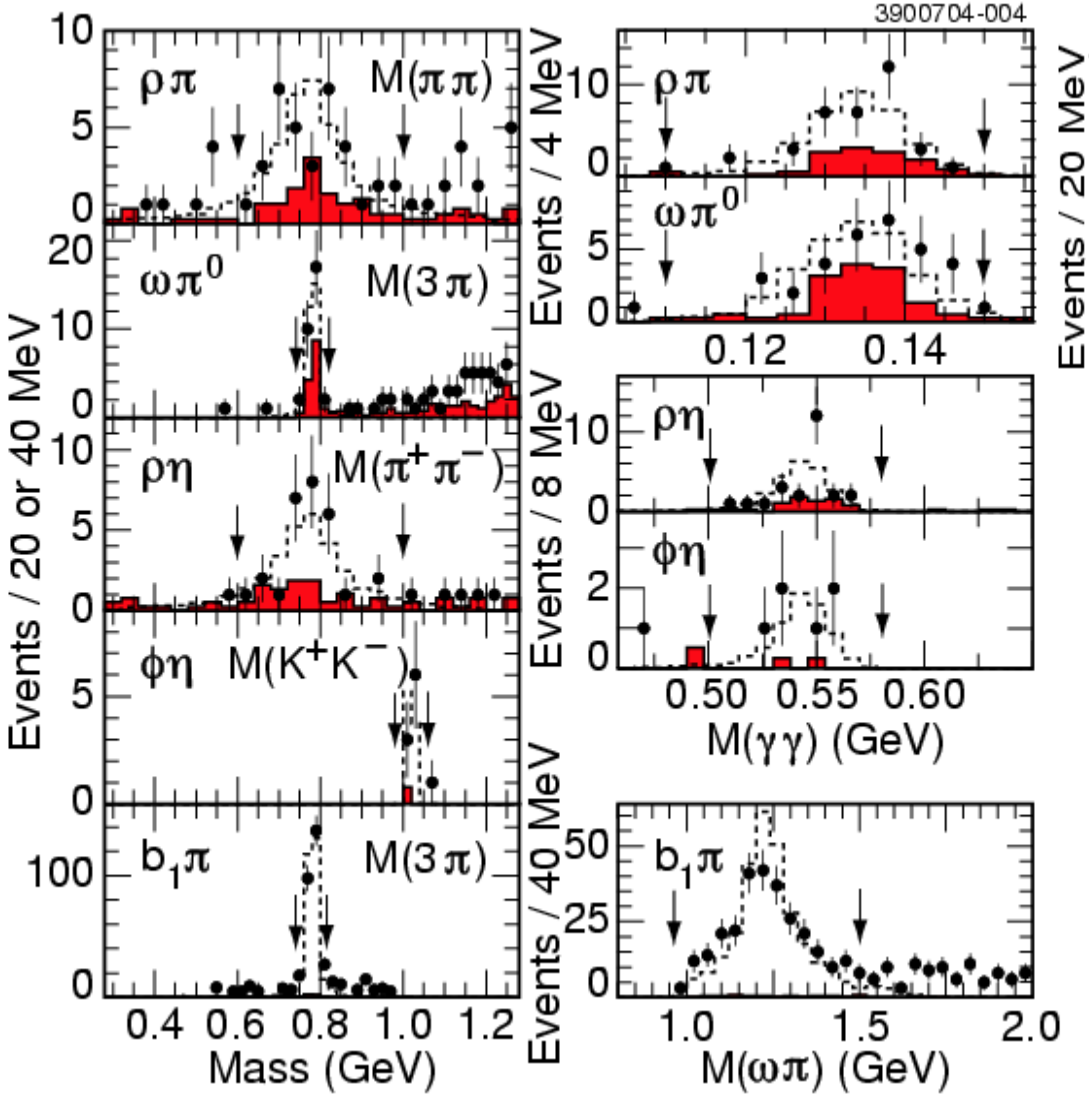
- Standard track quality requirement
- Charge balance: net charge=0
- Energy conservation: 0.98, 0.99<E_{vis}/E_{cm}<1.01, 1.02
- Momentum conservation: $|\sum \vec{p}| / E_{beam} < 0.04$
- PID with combined RICH-dE/dx
  (efficiency > 90%, fake rate < 5%)
- Suppress $\pi^+\pi^- J/\psi$, $\pi^0\pi^0 J/\psi$ with recoil mass cuts
- $\Lambda \to p\pi$, π^0 & $\eta \to \gamma\gamma$ constrained fitting
- Mass window for intermediate resonance states

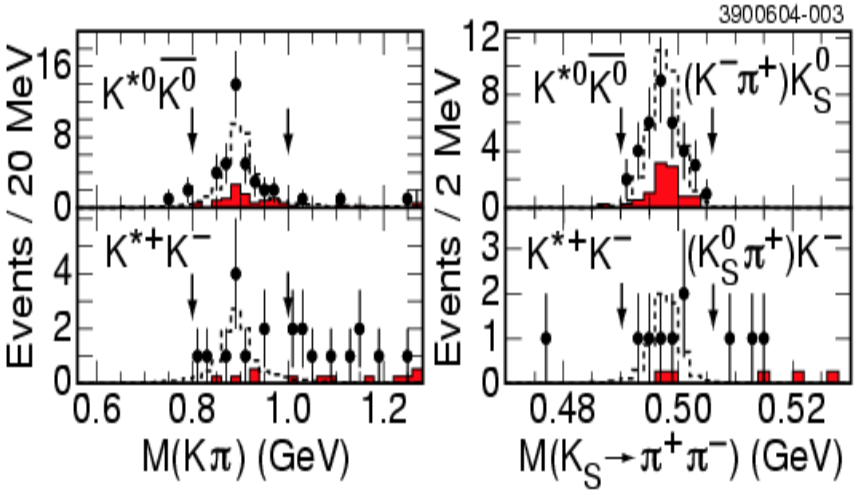
2-body modes: energy conservation



In the plots: dot - data, histogram - MC, shaded - scaled continuum

2-body modes: resonance mass





In the plots: dot - data,
histogram - MC,
shaded - scaled continuum

ψ(2S) 2-body modes

Branching ratios and Q_h values

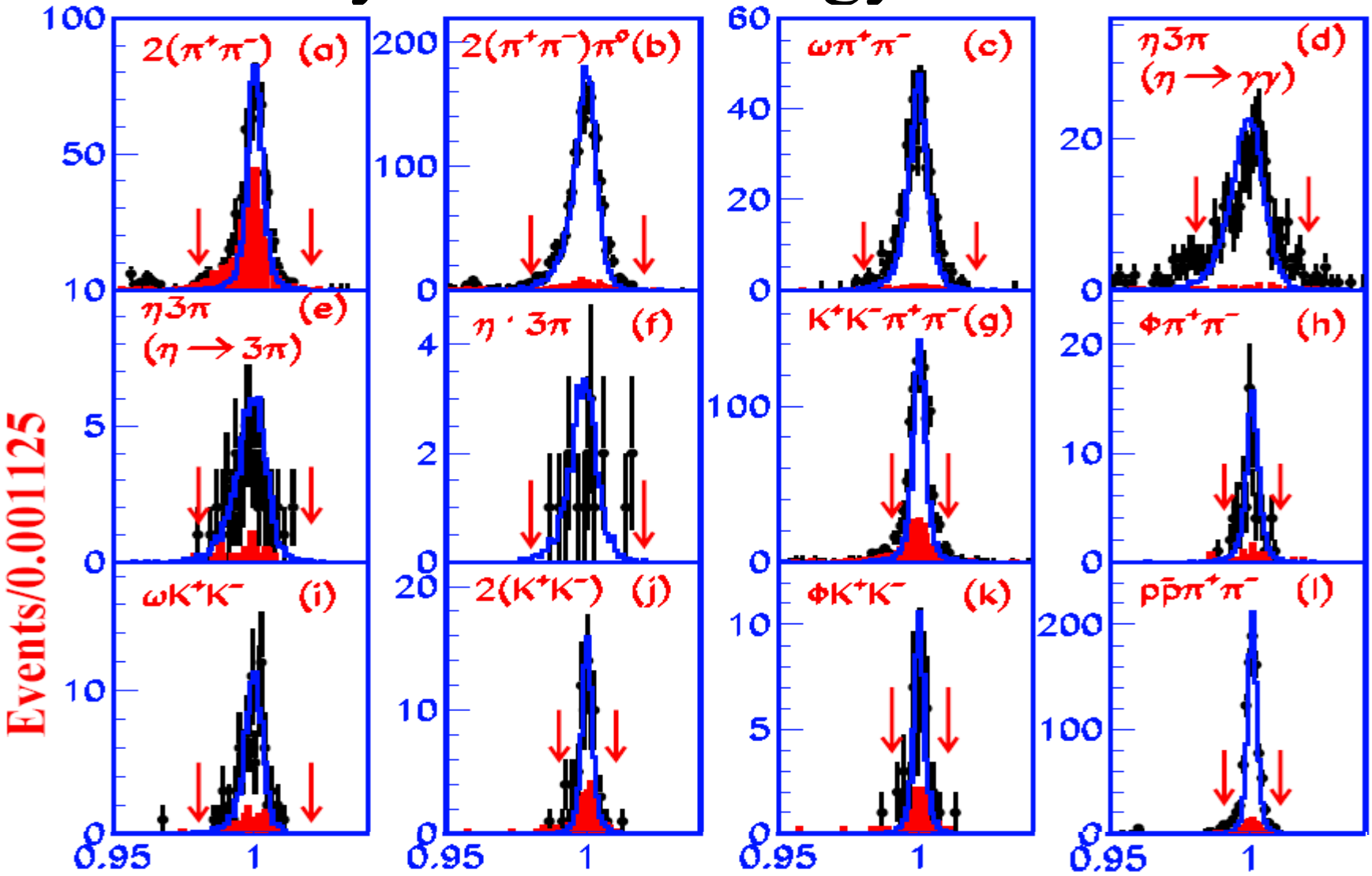
hep-ex/0407028
submitted to PRL

Mode	CLEO (10^{-5})	PDG/BES(10^{-5})	Q_h (%)
$\pi^+\pi^-\pi^0$	$17.7^{+1.5}_{-1.3} \pm 2.7$	$15.1 \pm 1.8 \pm 1.9$	0.8 ± 0.1
$\rho^0\pi^0$	$0.9^{+0.4}_{-0.4} \pm 0.1$		0.2 ± 0.1
$\rho^+\pi^-$	$1.0^{+0.6}_{-0.5} \pm 0.1$		0.1 ± 0.1
$\rho\pi$	$2.0^{+0.7}_{-0.6} \pm 0.2$	$5.1 \pm 0.7 \pm 0.8$	0.2 ± 0.1
$\omega\pi$	$2.3^{+1.1}_{-0.9} \pm 0.2$	$1.88 \pm .64 \pm .32$	5.6 ± 2.7
$\phi\pi$	< 0.6	< 0.3	
$\rho\eta$	$2.7^{+0.9}_{-0.8} \pm 0.2$	$1.78 \pm .65 \pm .22$	13.8 ± 5.0
$\omega\eta$	< 1.0	< 1.1	
$\phi\eta$	$1.8^{+1.5}_{-1.0} \pm 0.4$	$3.5 \pm 1.0 \pm 0.6$	2.8 ± 2.3
$K^{*0}\bar{K}^0$	$8.7^{+2.5}_{-2.1} \pm 0.8$	$15.0 \pm 2.1 \pm 1.9$	2.1 ± 0.6
$K^{*+}K^-$	$1.0^{+0.9}_{-0.6} \pm 0.2$	$2.9 \pm 1.3 \pm 0.4$	0.2 ± 0.2
$b_1^0\pi^0$	$20.5^{+4.4}_{-3.8} \pm 2.9$		8.9 ± 3.0
$b_1^+\pi^-$	$36.8 \pm 4.0 \pm 7.4$	32 ± 8	12.3 ± 2.5
$b_1\pi$	$56.6^{+5.5}_{-5.3} \pm 10.8$		10.7 ± 1.9

(BES: newly presented at ICHEP04, Beijing)

to be compared with (12.7±0.5)%

multi-body modes: energy conservation



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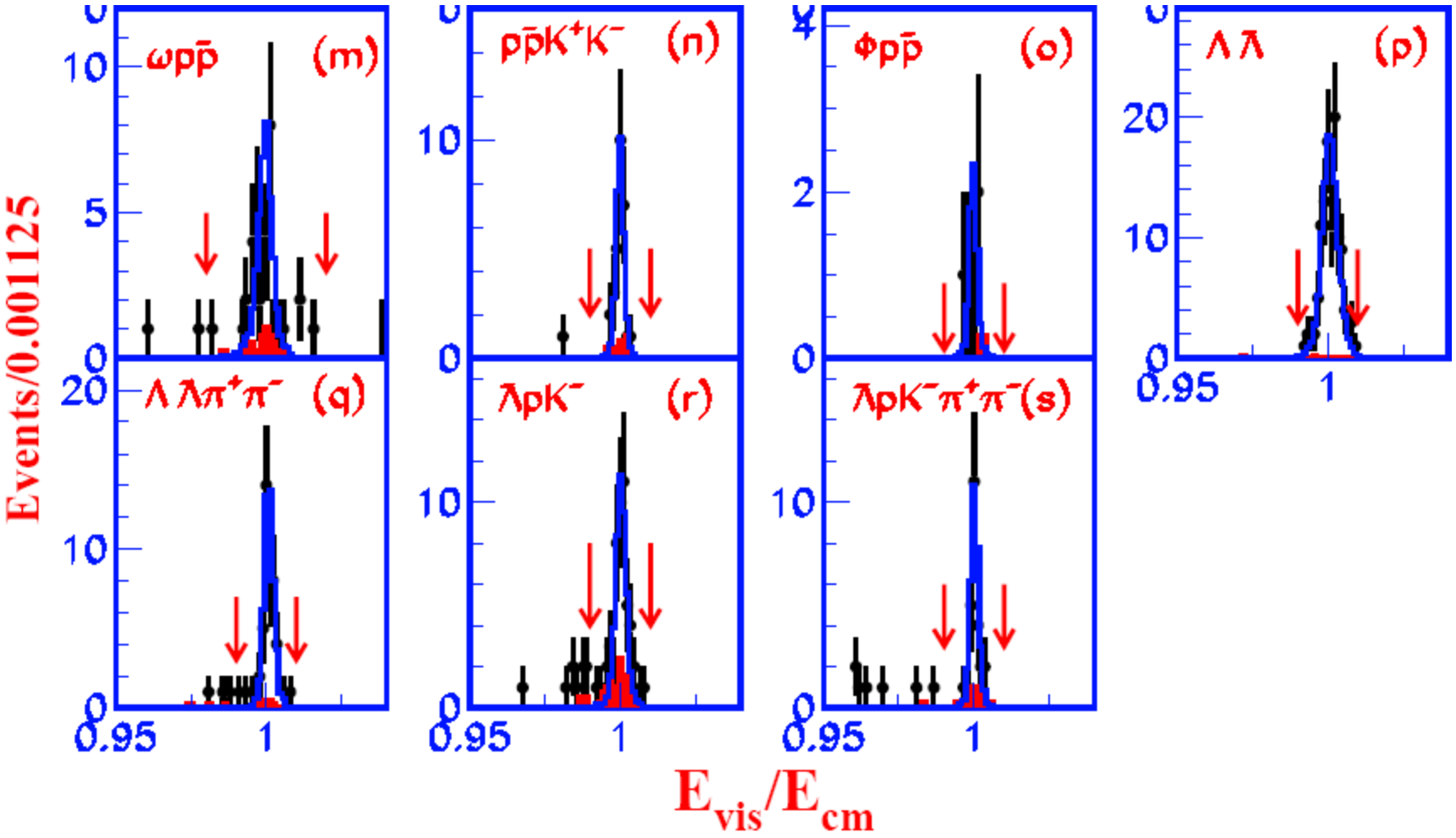
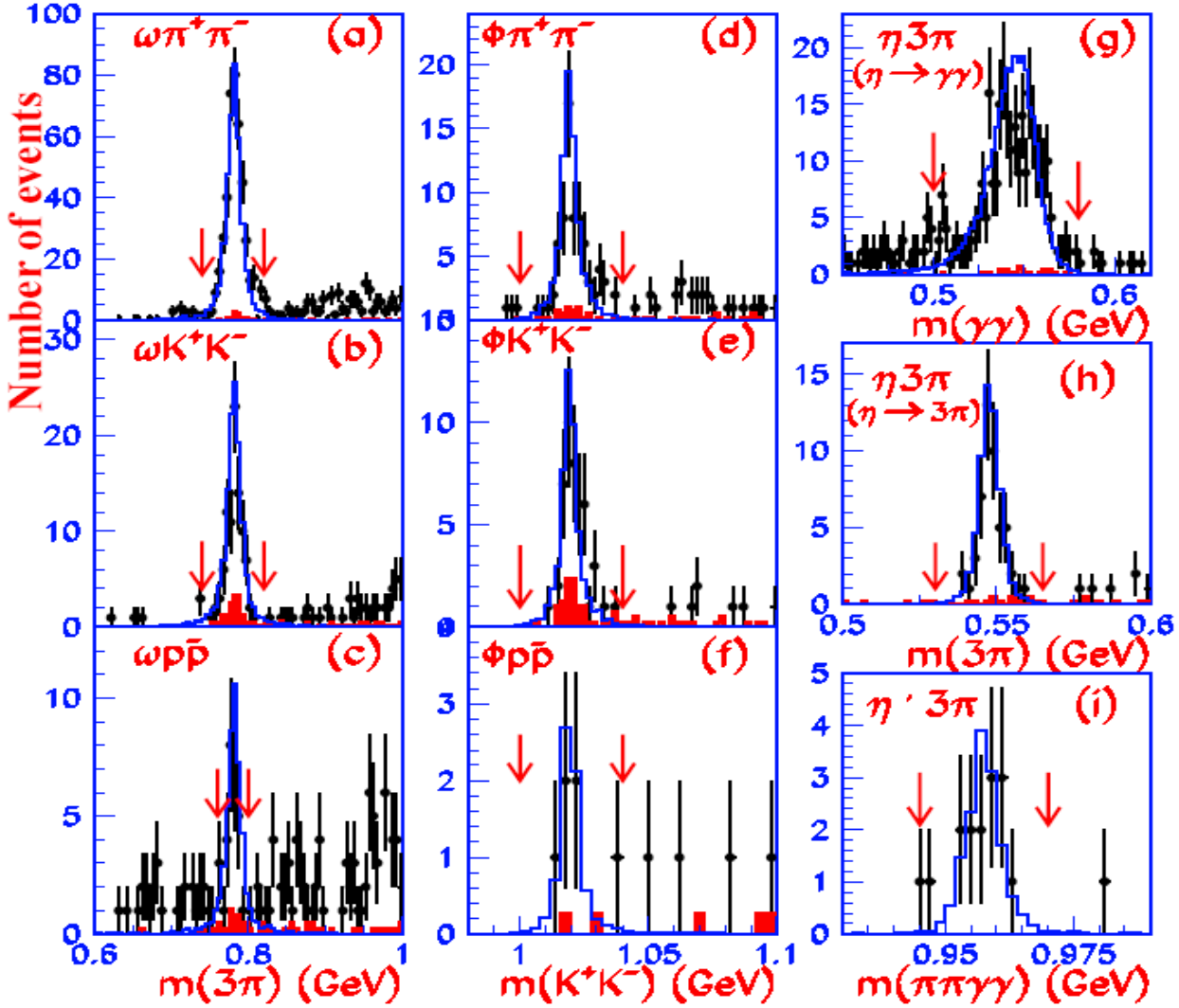
multi-body modes: energy conservation



In the plots: dot - data, histogram - MC, shaded - scaled continuum

multi-body modes: resonance mass



In the plots: dot - data, histogram - MC, shaded - scaled continuum

ψ(2S) multi-body modes

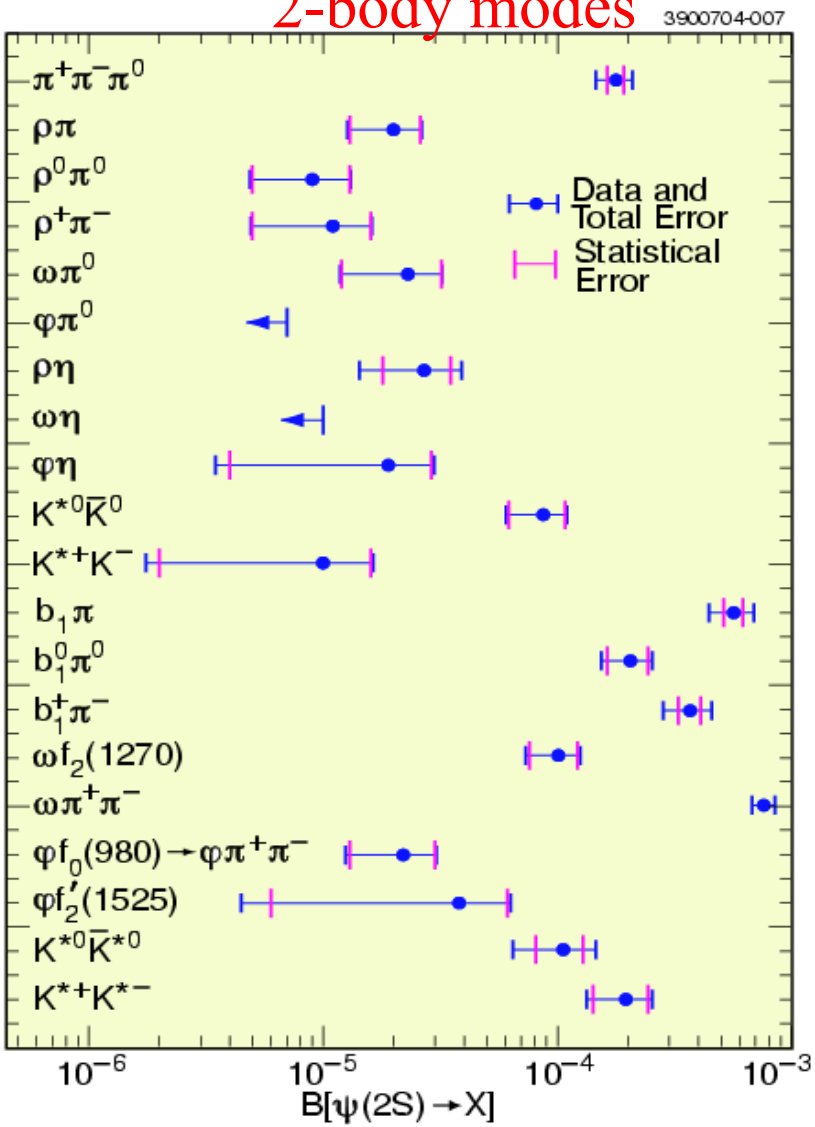
Preliminary results
ICHEP04 10-0753

mode h	$\mathcal{B}(\psi(2S) \to h)$ (10^{-4}) this work	PDG	$Br(J/\psi)$ (10^{-4}) PDG	Q_h (%) this work
$2(\pi^+\pi^-)$	2.0 ± 0.3	4.5 ± 1.0	40 ± 10	5.0 ± 1.5
$2(\pi^+\pi^-)\pi^0$	23.7 ± 3.3	30 ± 8	337 ± 26	7.0 ± 1.1
$\omega\pi^+\pi^-$	8.0 ± 1.2	4.8 ± 0.9	72 ± 10	11.1 ± 2.3
$\eta 3\pi$	8.5 ± 1.0	-	-	-
$\eta' 3\pi$	4.3 ± 2.0	-	-	-
$K^+K^-\pi^+\pi^-$	6.5 ± 0.9	16 ± 4	72 ± 23	9.0 ± 3.1
$\phi\pi^+\pi^-$	0.9 ± 0.2	1.50 ± 0.28	8.0 ± 1.2	11.4 ± 3.5
ωK^+K^-	1.9 ± 0.4	1.5 ± 0.4	19 ± 4	9.9 ± 2.9
$2(K^+K^-)$	0.6 ± 0.1	-	-	-
ϕK^+K^-	0.7 ± 0.2	0.60 ± 0.22	15.4 ± 2.1	4.7 ± 1.6
$p\bar{p}\pi^+\pi^-$	5.4 ± 0.7	8.0 ± 2.0	60 ± 5	9.0 ± 1.4
$\omega p\bar{p}$	0.5 ± 0.2	0.80 ± 0.32	13 ± 2.5	3.7 ± 1.9
$p\bar{p}K^+K^-$	0.2 ± 0.1	-	-	-
$\phi p\bar{p}$	$< 0.18(90\%\mathrm{CL})$	< 0.26	0.45 ± 0.15	-
$\Lambda\bar{\Lambda}$	3.0 ± 0.5	1.81 ± 0.34	13 ± 1.2	23.4 ± 4.6
$\Lambda\bar{\Lambda}\pi^+\pi^-$	2.7 ± 0.8	-	-	-
$\Lambda\bar{p}K^+$	0.7 ± 0.2	-	8.9 ± 1.6	7.9 ± 2.8
$\Lambda\bar{p}K^+\pi^+\pi^-$	1.2 ± 0.4	-	-	-

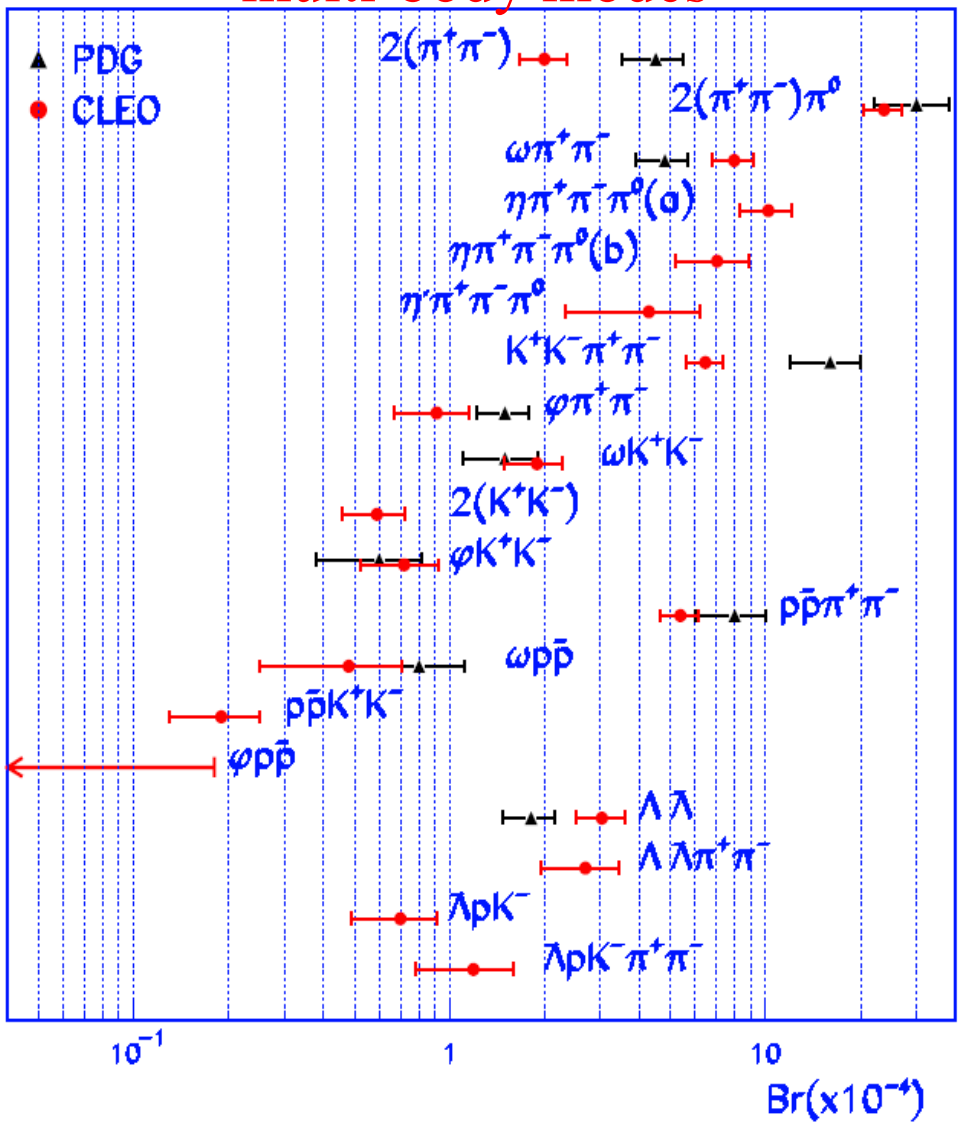
to be compared with (12.7±0.5)%

Display of ψ(2S) branching ratios

2-body modes

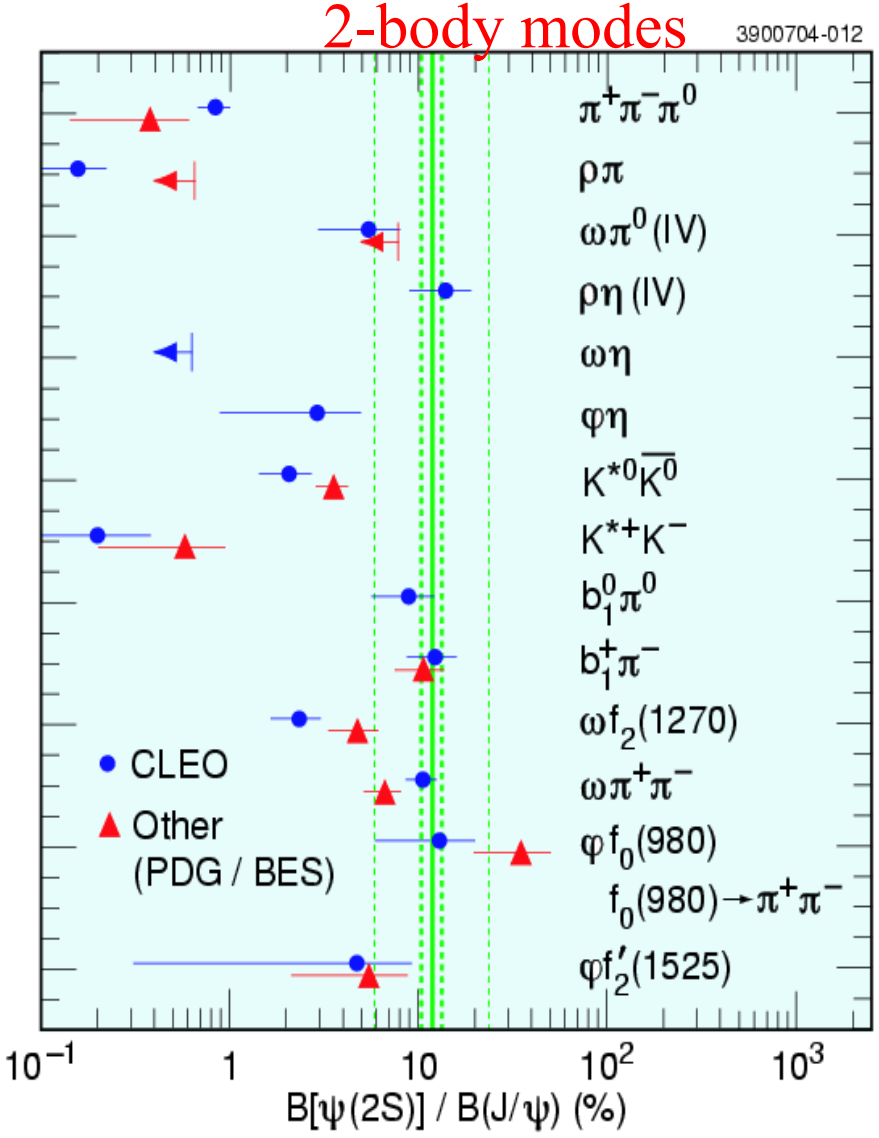


multi-body modes

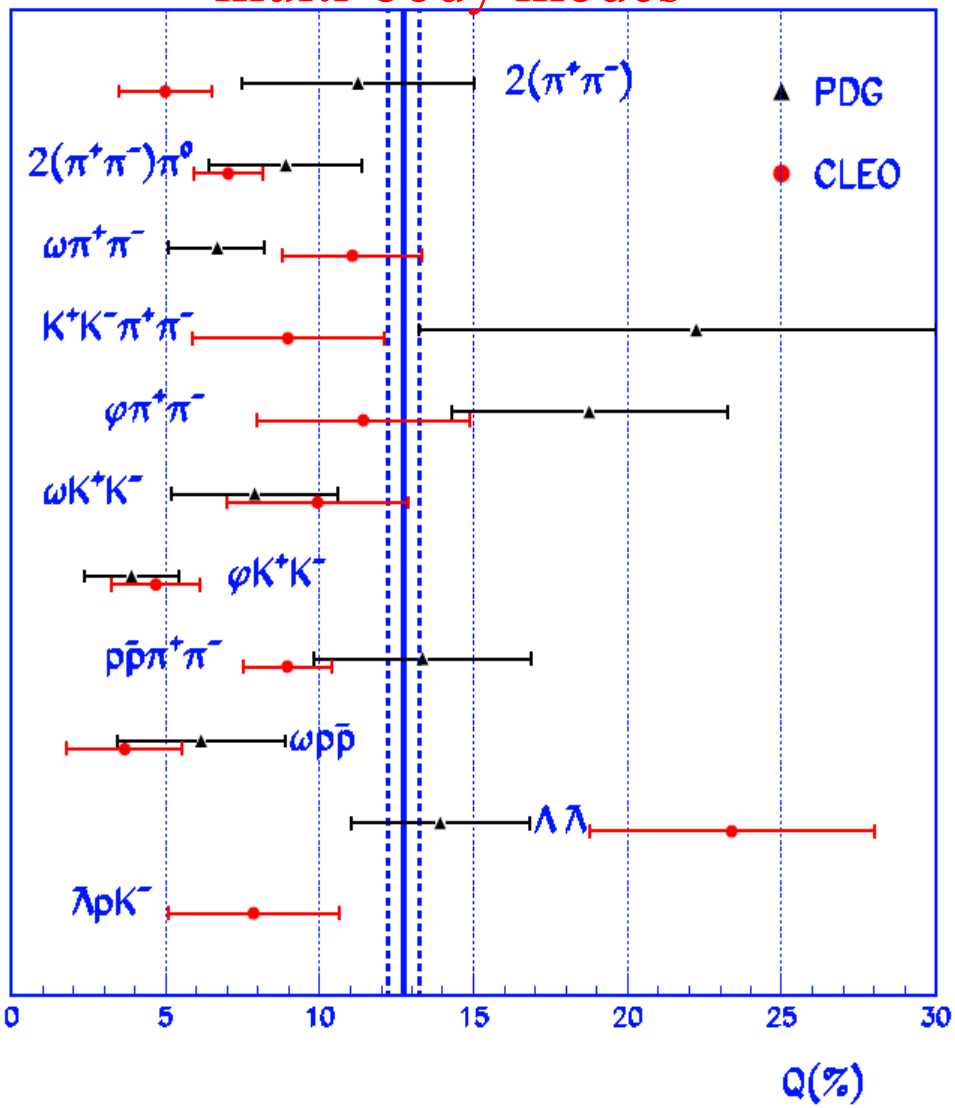


Display of Q_h values ($Q_h = B(\psi(2S)\to h)/B(J/\psi\to h)$)

2-body modes



multi-body modes



Summary

- 5 new, 4 previously observed $\psi(2S)$ 2-body decay modes (hep-ex/0407028, submitted to PRL)
- Deficit in other V+P modes ($\omega\eta$,$\phi\eta$, K^*K) besides $\rho\pi$
- Electromagnetic isospin violating modes ($\omega\pi$, $\rho\eta$) obey the 12% rule
- 8 new, 11 previously observed $\psi(2S)$ multi-body decay modes (Preliminary results, ICHEP04 10-0753)
- Reasonable agreement with the 12% rule for 11 multi-body modes
- Study of resonance structures is still ongoing.