

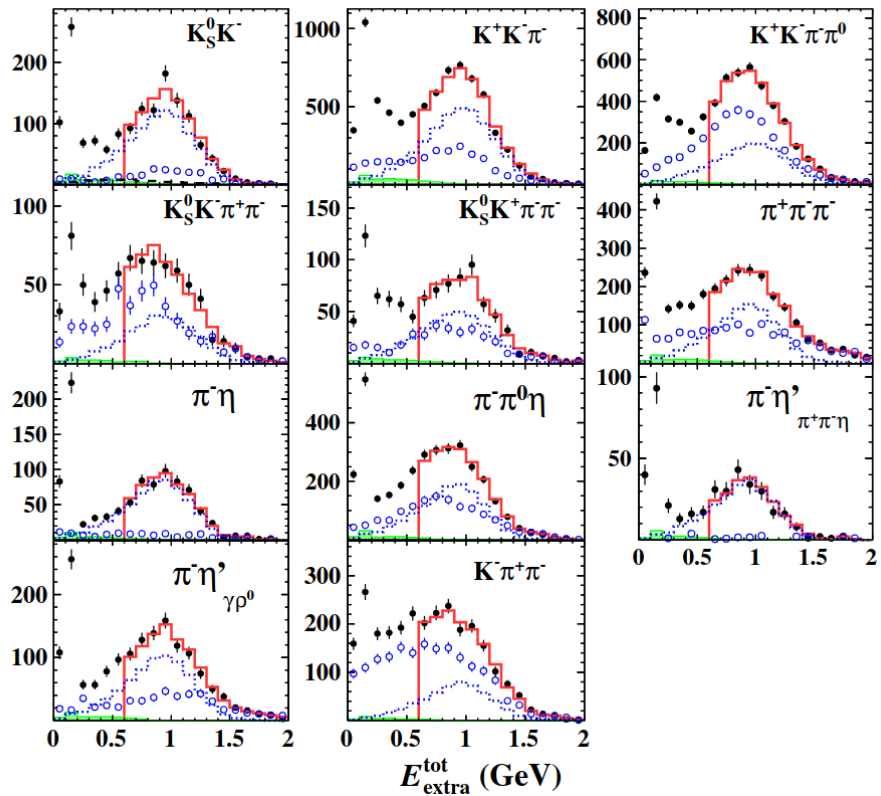
# Other Physics Opportunities @ BESIII

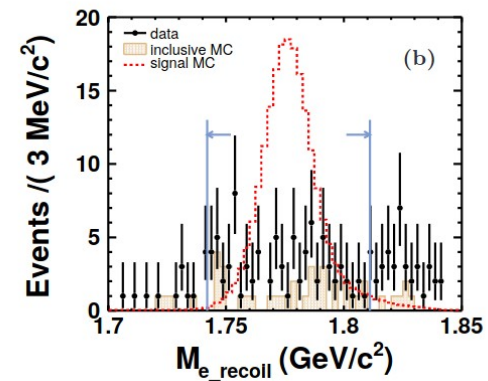
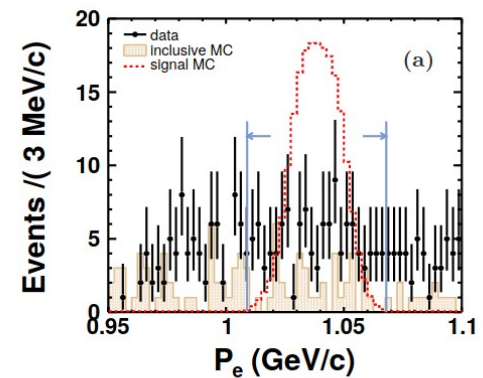
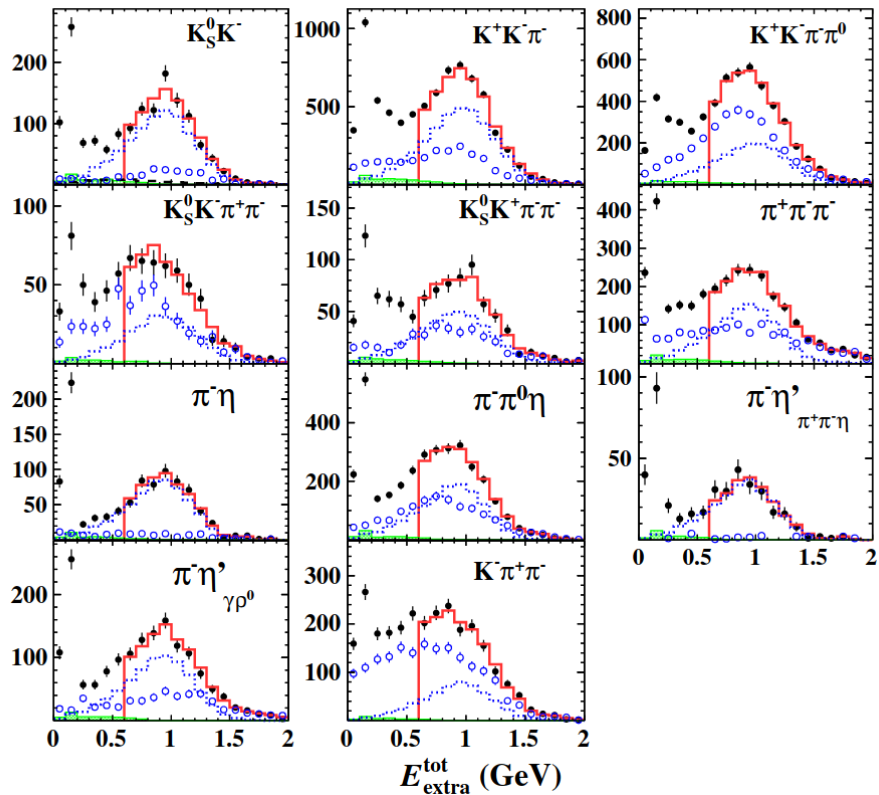


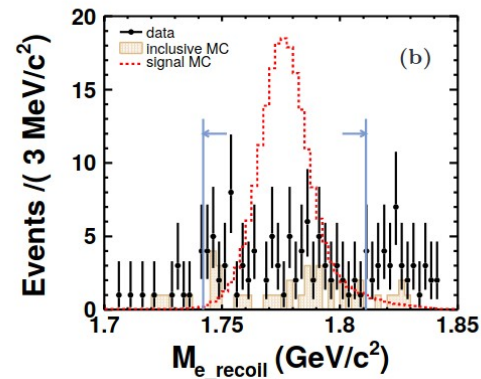
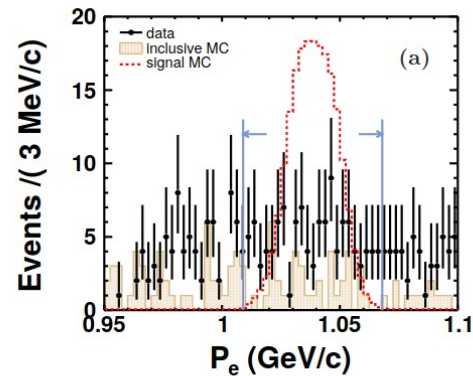
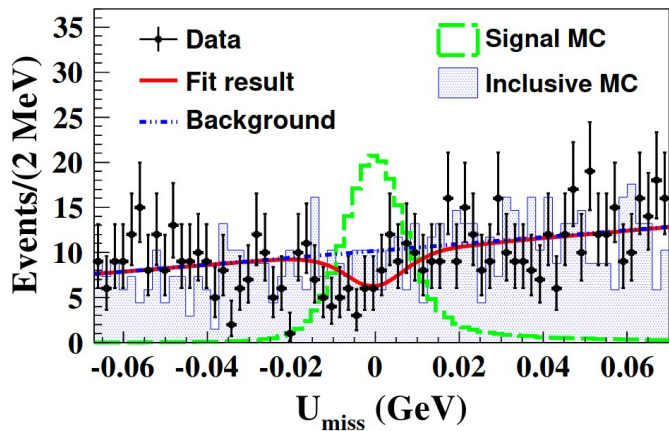
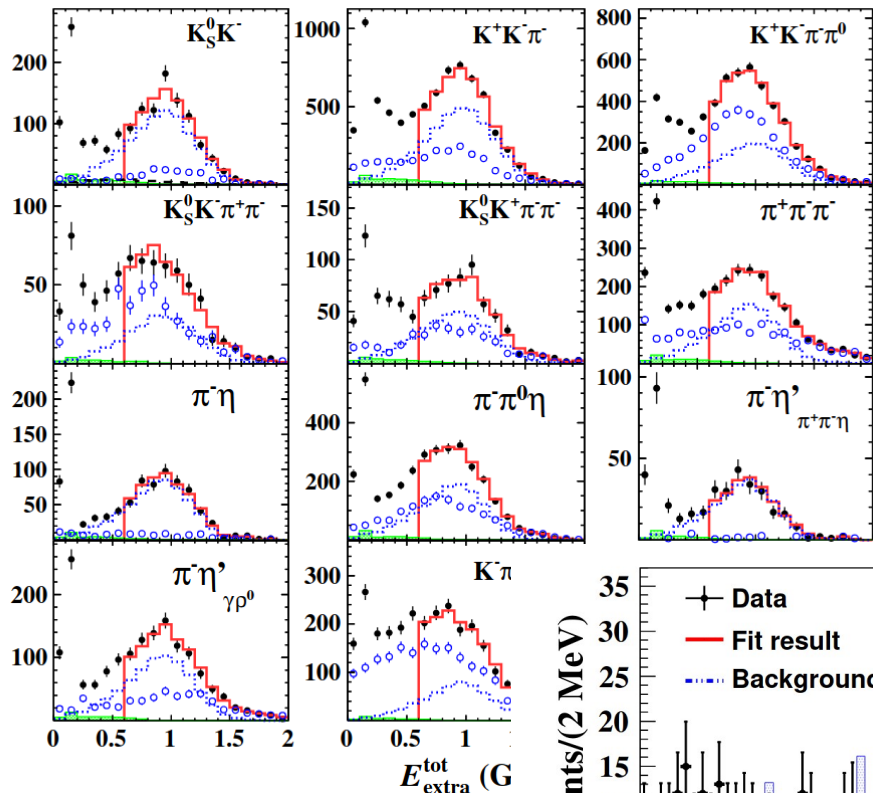
retreat

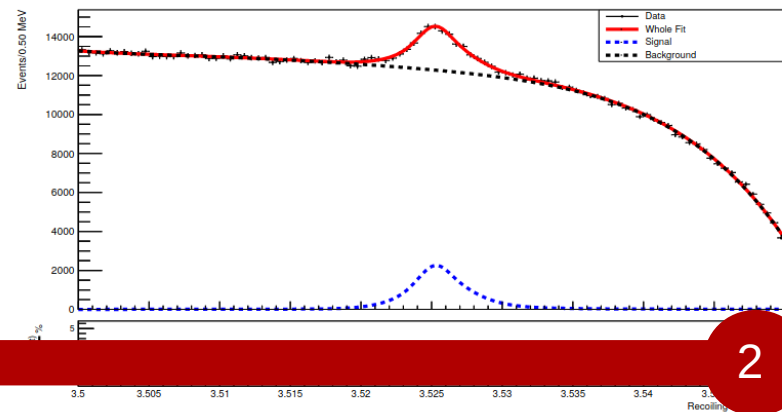
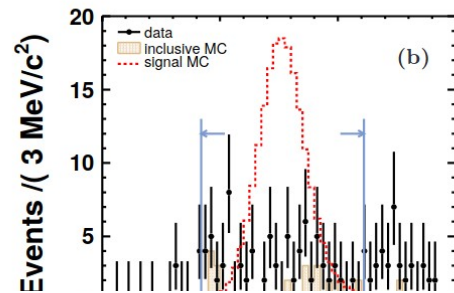
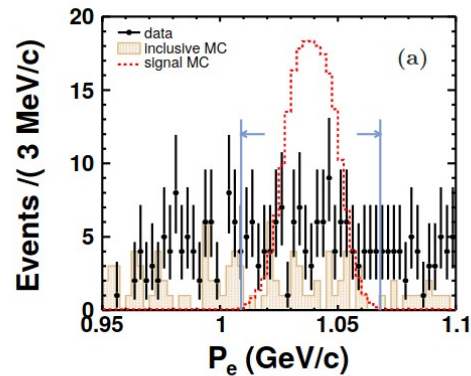
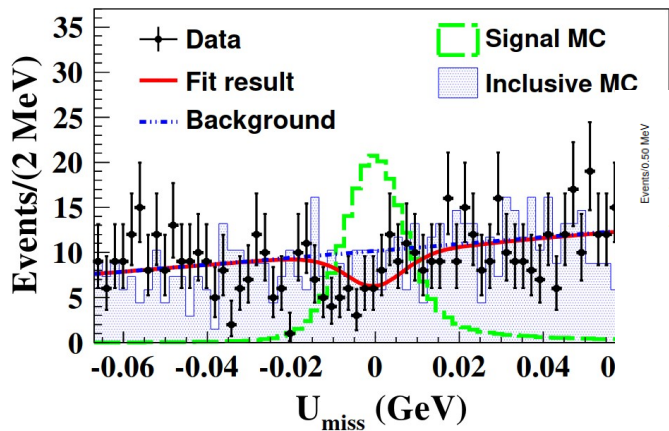
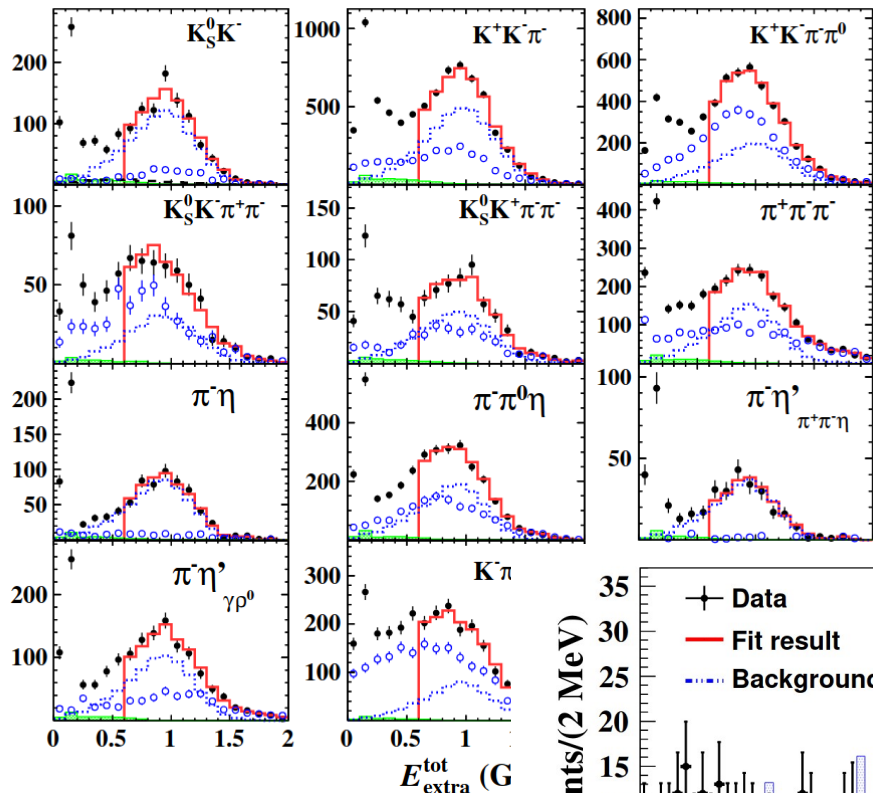
08/09/2021

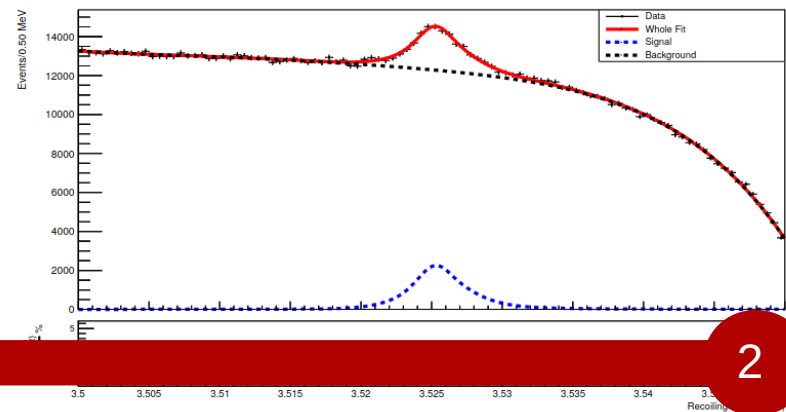
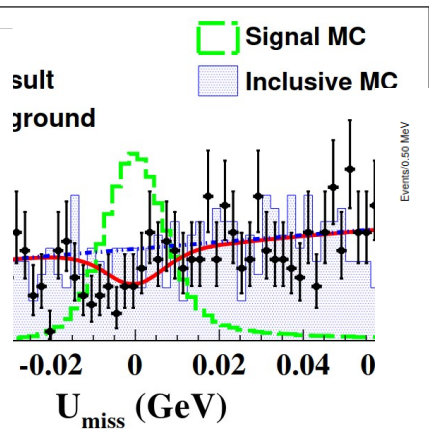
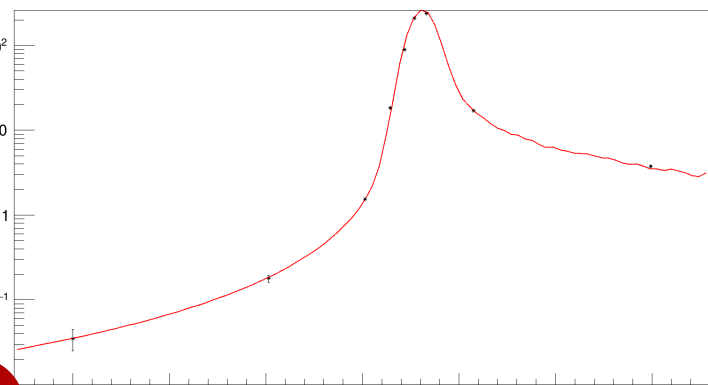
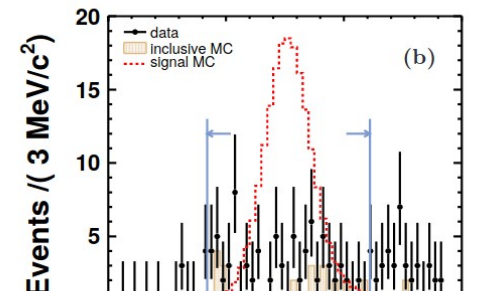
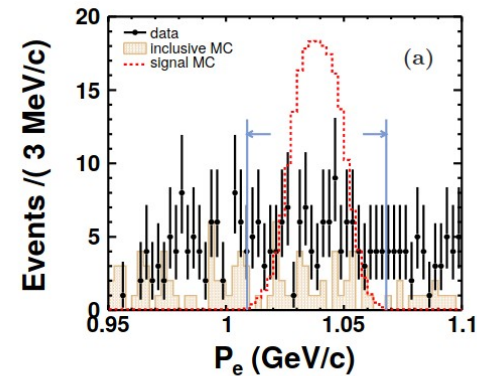
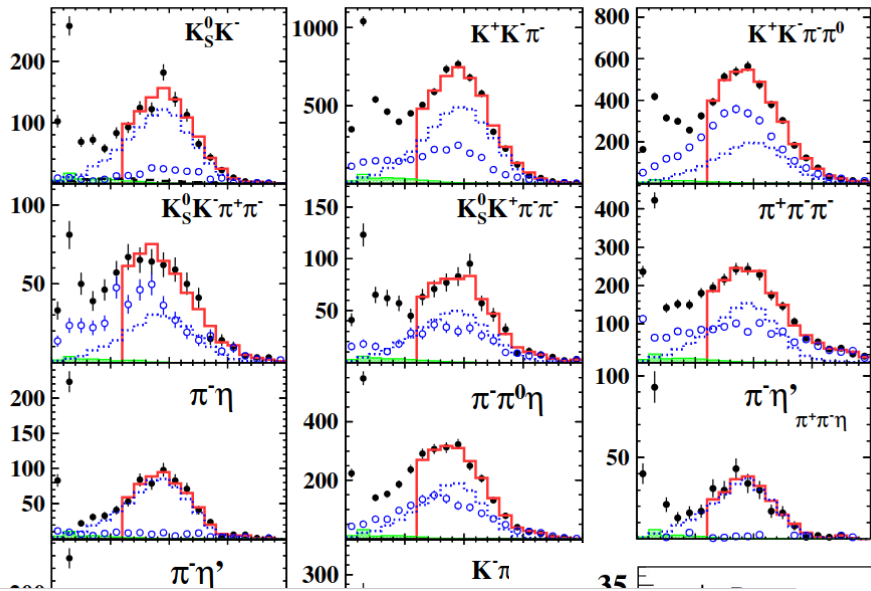
Giulio Mezzadri

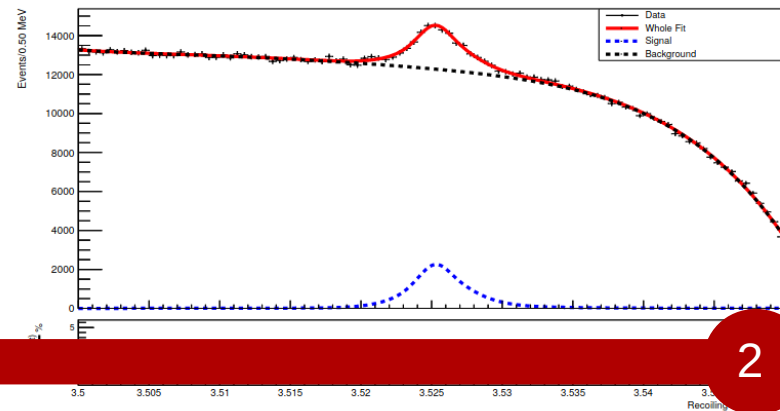
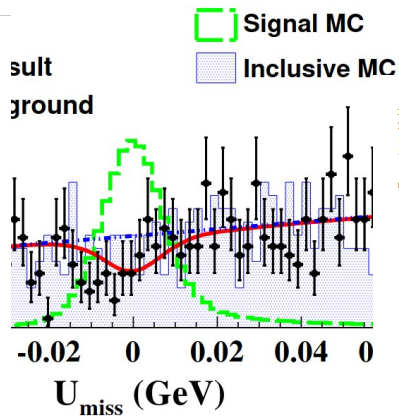
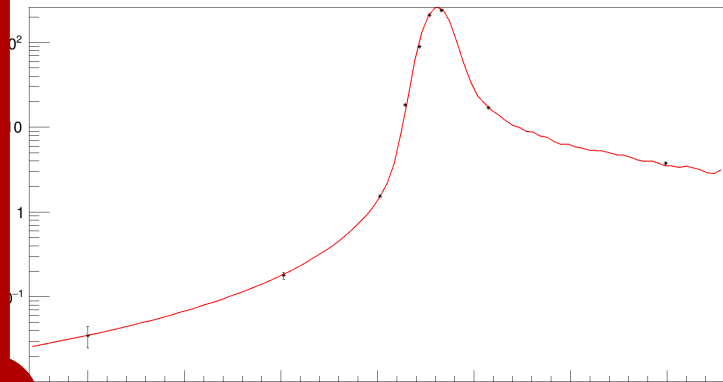
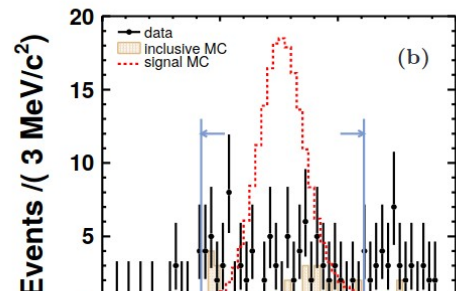
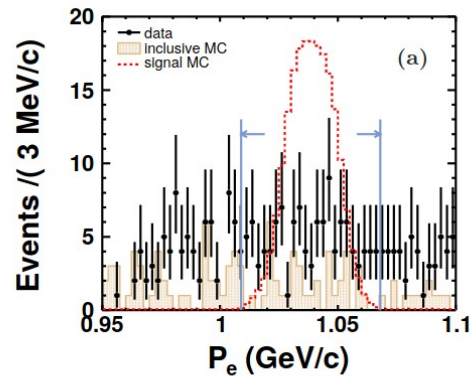
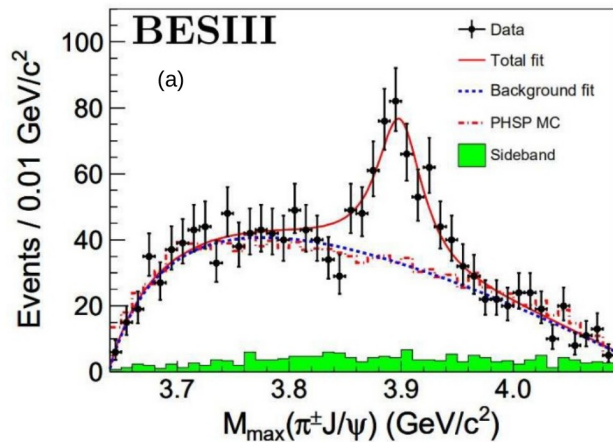
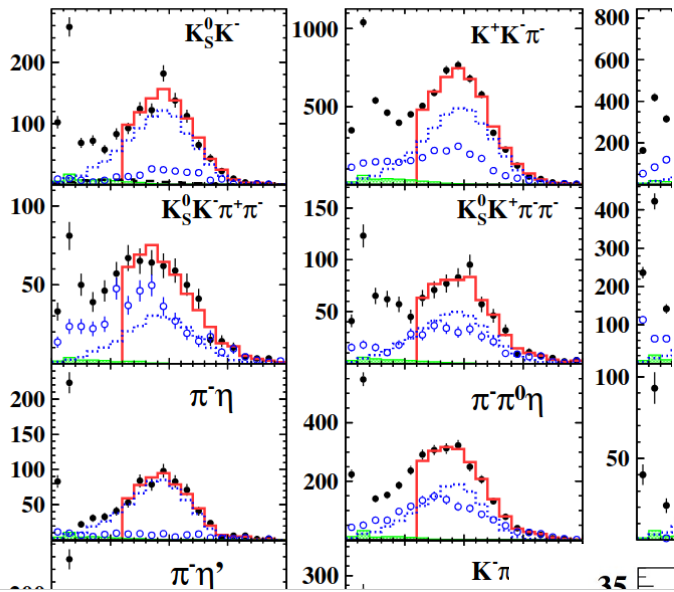






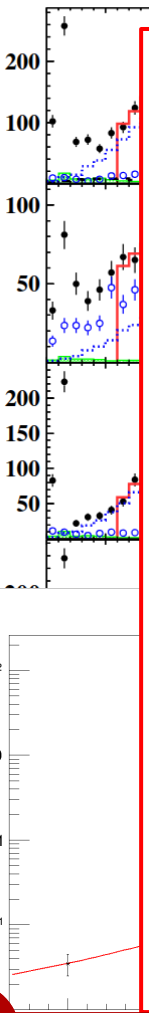




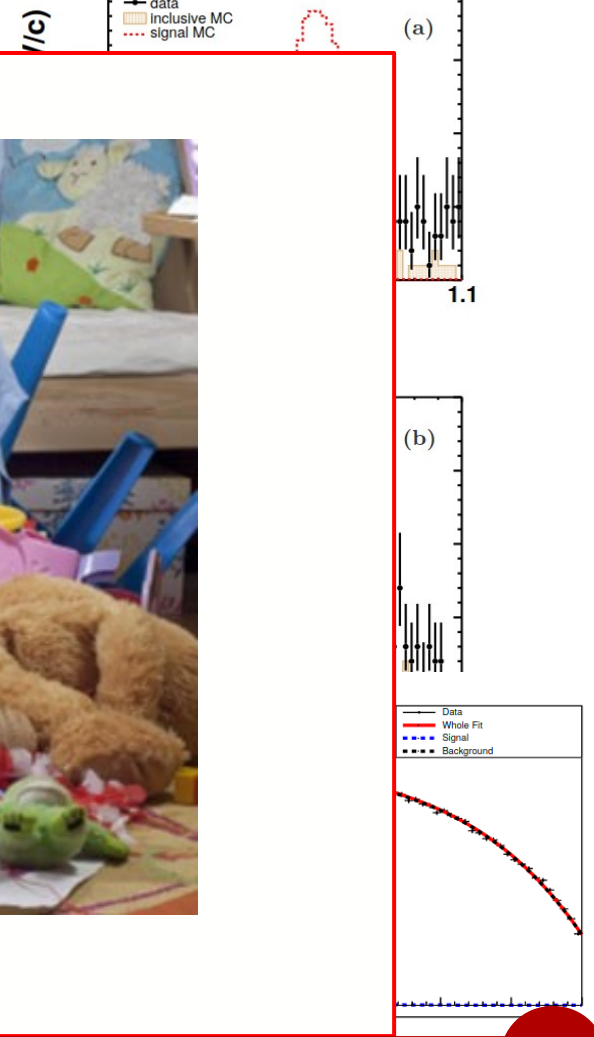


BESIII

20



C'è rischio di fare confusione!





BESIII

+

Data

Total fit

20

data  
Inclusive MC  
signal MC

(a)

1.1

(b)

Data  
Whole Fit  
Signal  
Background



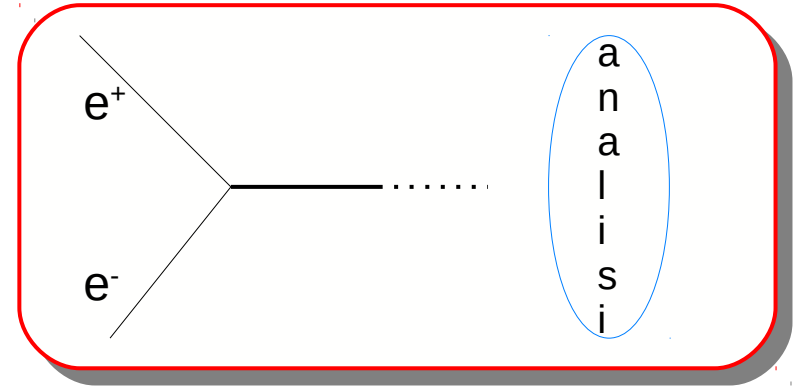
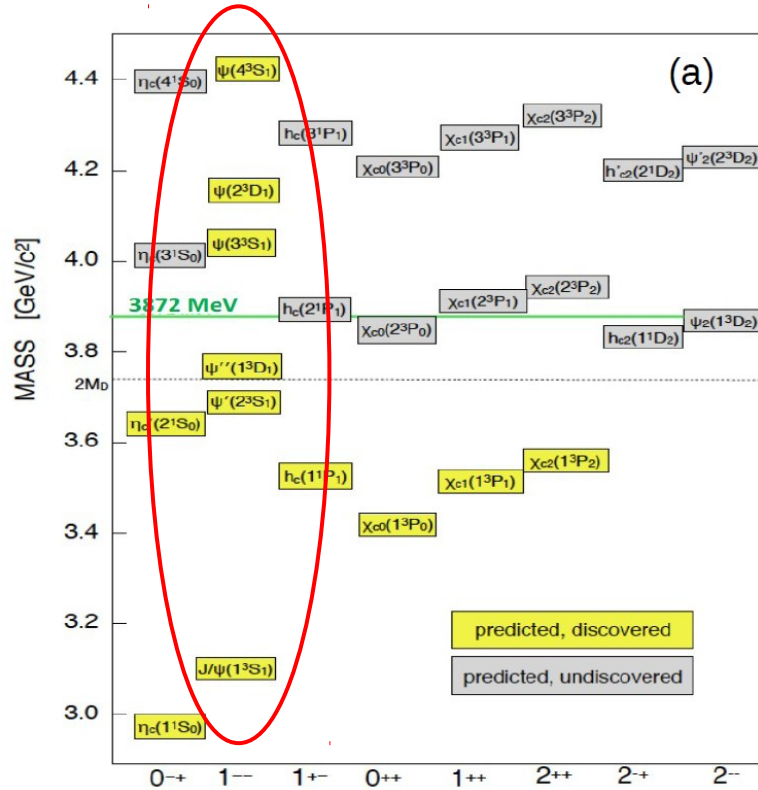
C'è rischio di fare confusione!

Facciamo un po' di ordine!

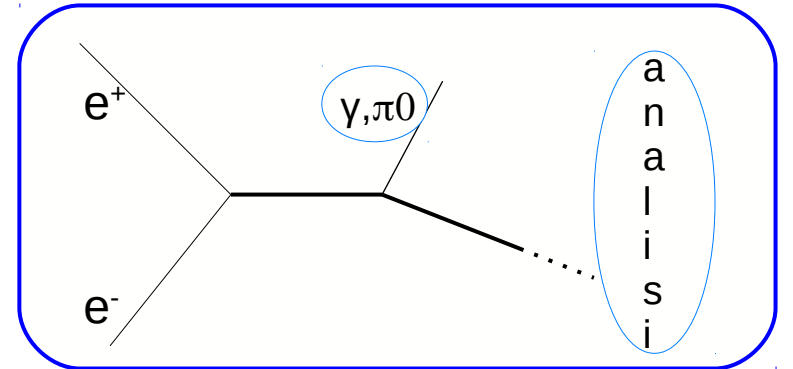
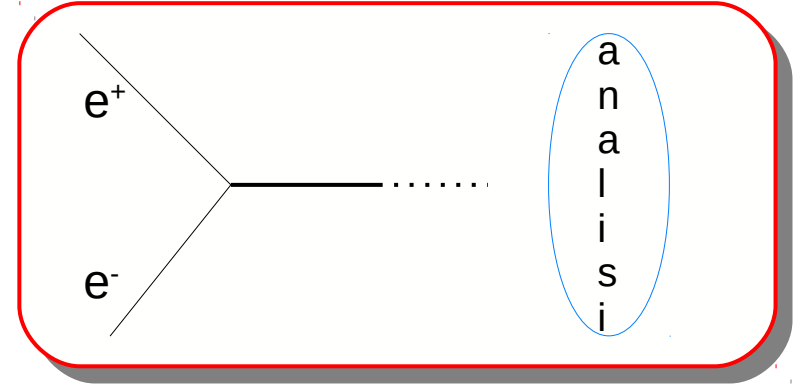
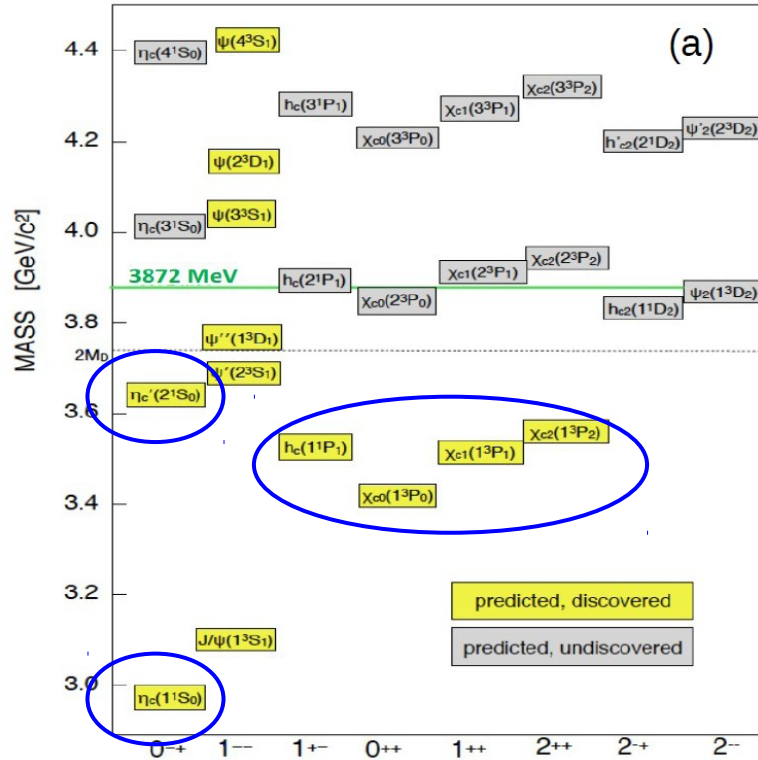


<https://arxiv.org/pdf/1912.05983.pdf>

# Studio di decadimenti e transizioni del charmonio



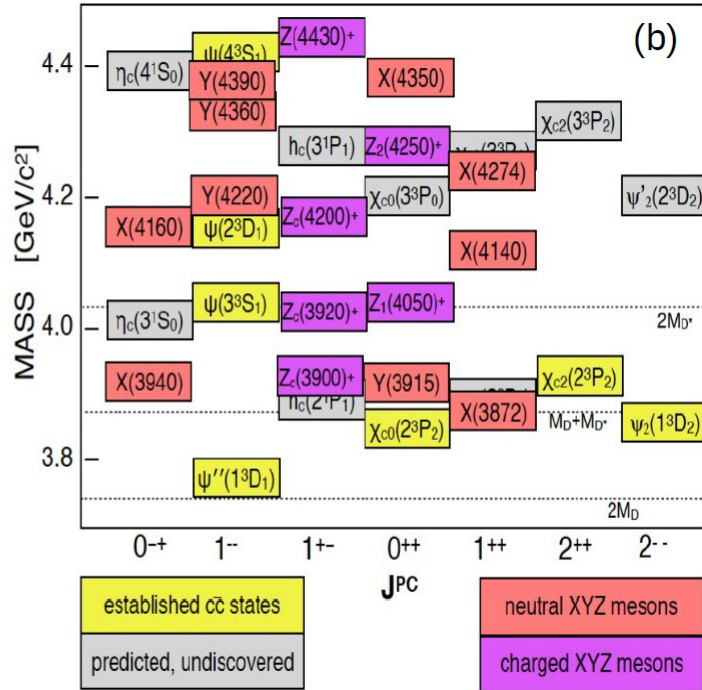
# Studio di decadimenti e transizioni del charmonio



# Studio di stati esotici



# Studio di stati esotici

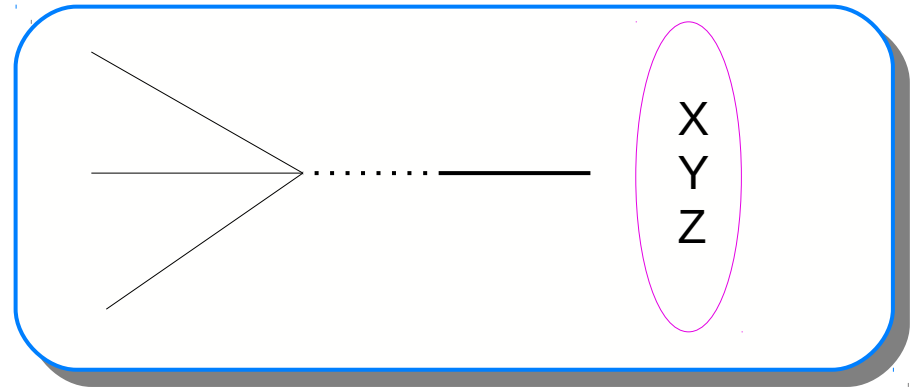


Una nuova famiglia di stati del charmonio:

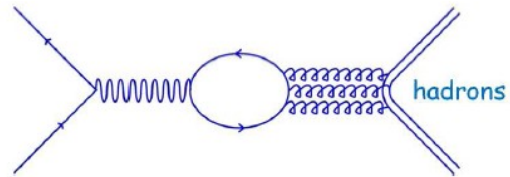
Y - Stati neutri vettoriali

Z - Stati carichi (a quattro quark)

X - Stati neutri non vettoriali

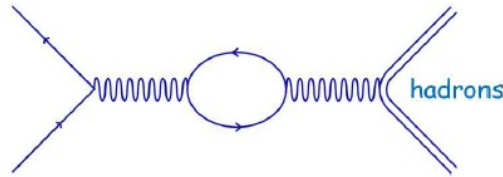


# Studio della fase relativa tra le ampiezze di decadimento forte ed elettromagnetica del charmonio

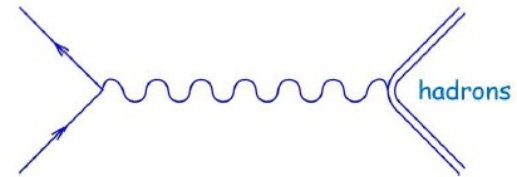


(a)

QED+QCD



(b)



(c)

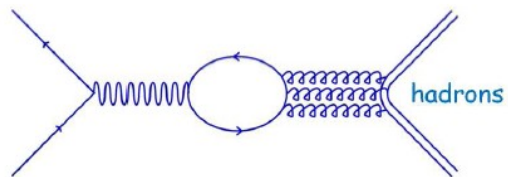
QED

Tutto noto, calcolabile

Scan attorno ad una risonanza del charmonio

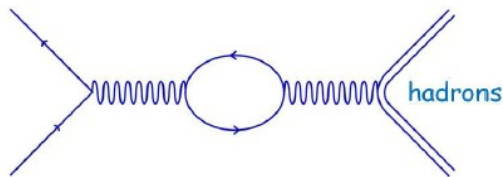
Dall'informazione di come varia la sezione d'urto attorno al picco determino se c'è interferenza

# Studio della fase relativa tra le ampiezze di decadimento forte ed elettromagnetica del charmonio

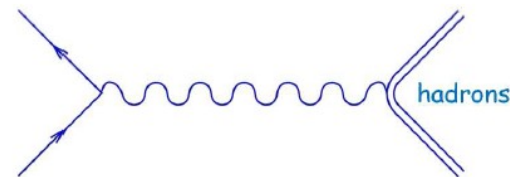


(a)

QED+QCD



(b)



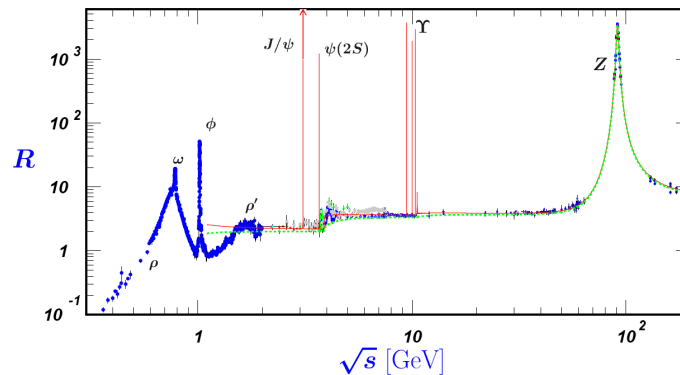
(c)

QED

Tutto noto, calcolabile

Scan attorno ad una risonanza del charmonio

Dall'informazione di come varia la sezione d'urto attorno al picco determino se c'è interferenza

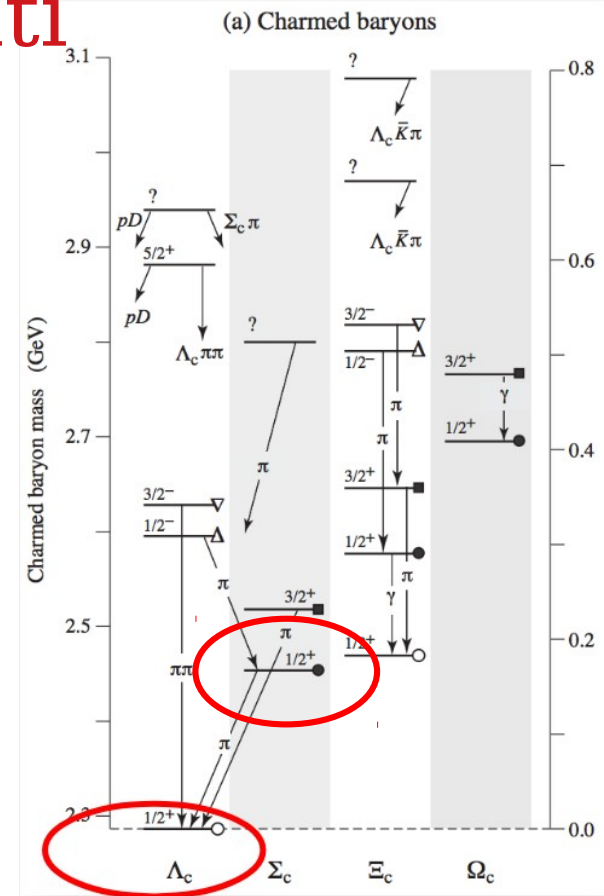
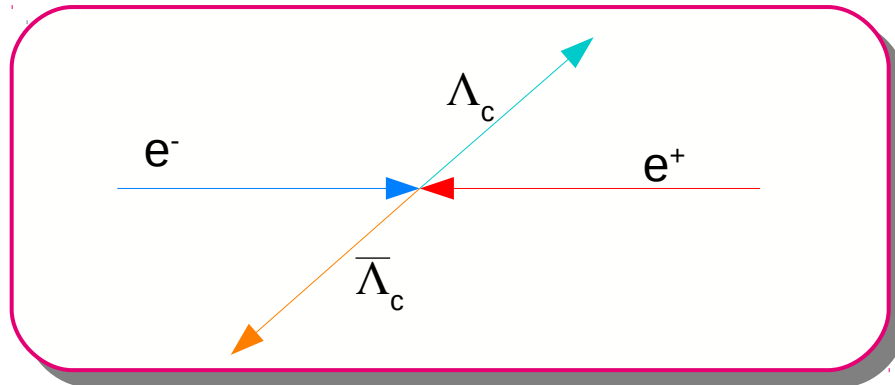




# Studio di decadimenti di mesoni e di barioni charmati

State	$J^P$	Mass (MeV)	Width (MeV)	Experiments	Observed Modes
$D^0$	$0^-$	$1864.83 \pm 0.05$	$(410.1 \pm 1.5) \times 10^{-15}$ s	Mark I [328]	$K\pi$ and $K3\pi$
$D^\pm$	$0^-$	$1869.58 \pm 0.09$	$(1040 \pm 7) \times 10^{-15}$ s	Mark I [329]	$K2\pi$
$D^{*0}$	$1^-$	$2006.85 \pm 0.05$	$< 2.1$	Mark I [330]	$e^+e^- \rightarrow DD^*$
$D^{*\pm}$	$1^-$	$2010.26 \pm 0.05$	$(83.4 \pm 1.8) \times 10^{-3}$	Mark I [330]	$e^+e^- \rightarrow DD^*$

State	$J^P$	Mass (MeV)	Width (MeV)	Experiments	Observed Modes
$D_s$	$0^-$	$1968.27 \pm 0.10$	$(500 \pm 7) \times 10^{-15}$ s	DASP [360]	$\eta\pi^\pm$
$D_s^*$	$1^-$	$2112.1 \pm 0.4$	$< 1.9$	DASP [360]	$D_s\gamma$
$D_{s0}^*(2317)$	$0^+$	$2317.7 \pm 0.6$	$< 3.8$	BaBar [112]	$D_s^+\pi^0$





Opportunità vicine

# Studio di decadimenti e transizioni del charmonio

Opportunità:  $\psi(2S) \rightarrow \tau^+\tau^-$

$$R_{\tau/\ell}^V \equiv \frac{\Gamma(V \rightarrow \tau^+\tau^-)}{\Gamma(V \rightarrow \ell^+\ell^-)}, \quad (V = \psi, \Upsilon; \ell = e, \mu),$$

$V(nS)$	SM prediction	Exp. value $\pm \sigma_{\text{stat}} \pm \sigma_{\text{syst}}$
$\Upsilon(1S)$	$0.9924 \pm \mathcal{O}(10^{-5})$	$1.005 \pm 0.013 \pm 0.022$
$\Upsilon(2S)$	$0.9940 \pm \mathcal{O}(10^{-5})$	$1.04 \pm 0.04 \pm 0.05$
$\Upsilon(3S)$	$0.9948 \pm \mathcal{O}(10^{-5})$	$1.05 \pm 0.08 \pm 0.05$
$\psi(2S)$	$0.390 \pm \mathcal{O}(10^{-4})$	$0.39 \pm 0.05$

Iniziato da Isabella, con giusto supporto si può utilizzare il 1B di  $\psi(2S)$  per confrontare contro la predizione del Modello Standard

- Se va male → Misura di precisione di decadimenti del charmonio
- Se va (molto) bene → **Stoccolma!**

# Studio della fase alla $\psi(2S)$ in $\rho\pi$ , $p\bar{p}$

Prendendo un modello, si può calcolare, con i dati disponibili:

- $J/\psi$ 
  - VP (1 $\cdot$ 0 $\cdot$ ) (e.g.  $J/\psi \rightarrow \rho\pi$ ) fase =  $106^\circ \pm 10^\circ$
  - PP (0 $\cdot$ 0 $\cdot$ ) (e.g.  $J/\psi \rightarrow \pi\pi$ ) fase =  $89.6^\circ \pm 9.9^\circ$
  - BB ( $\frac{1}{2}$   $\frac{1}{2}$ ) (e.g.  $J/\psi \rightarrow p\bar{p}$ ) fase =  $89^\circ \pm 8^\circ$
- At  $\psi(2S)$ 
  - VP (1 $\cdot$ 0 $\cdot$ ) fase =  $159^\circ \pm 12^\circ$
  - PP (0 $\cdot$ 0 $\cdot$ ) fase =  $95^\circ \pm 11^\circ$

Per entrambe le analisi, abbiamo il codice di analisi (praticamente) già pronto!

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Differenza di fase in processi VP potrebbe essere origine del  $\rho\pi$  puzzle, una delle osservazioni fenomenologiche più "longeve" senza spiegazione

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Per entrambe le analisi, abbiamo il codice di analisi (praticamente) già pronto!

CAVEAT:

Questo lavoro è effettivamente la prima evidenza sperimentale diretta di buco nero



# Altre idee “mature”

Opportunità: Update di  $\psi(2S) \rightarrow \pi^0 h_c$

Opportunità: Studio di  $\psi(2S) \rightarrow \pi^0 h_c, h_c \rightarrow e^+e^-\eta_c$

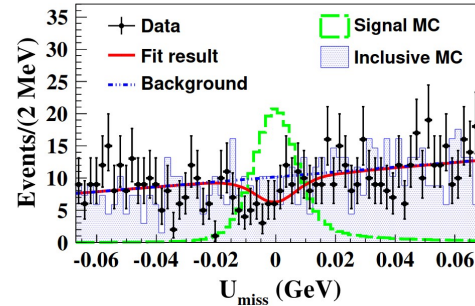
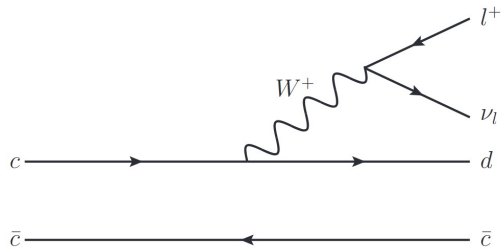
Opportunità: Ricerca di pentaquark in  $\Lambda_c \rightarrow p\phi\pi^0$



Opportunità  
per il futuro



# Studio del decadimento debole della J/psi



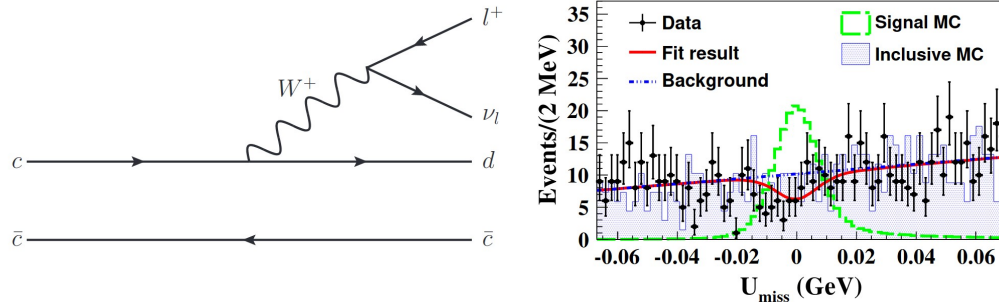
- $\Gamma_{298} D^- e^+ \nu_e + \text{c.c.}$
- $\Gamma_{299} \bar{D}^0 e^+ e^- + \text{c.c.}$
- $\Gamma_{300} D_s^- e^+ \nu_e + \text{c.c.}$
- $\Gamma_{301} D_s^{*-} e^+ \nu_e + \text{c.c.}$
- $\Gamma_{302} D^- \pi^+ + \text{c.c.}$
- $\Gamma_{303} \bar{D}^0 \bar{K}^0 + \text{c.c.}$
- $\Gamma_{304} \bar{D}^0 \bar{K}^{*0} + \text{c.c.}$
- $\Gamma_{305} D_s^- \pi^+ + \text{c.c.}$
- $\Gamma_{306} D_s^- \rho^+ + \text{c.c.}$

## Weak decays

$< 1.2$	$\times 10^{-5}$	CL=90%
$< 8.5$	$\times 10^{-8}$	CL=90%
$< 1.3$	$\times 10^{-6}$	CL=90%
$< 1.8$	$\times 10^{-6}$	CL=90%
$< 7.5$	$\times 10^{-5}$	CL=90%
$< 1.7$	$\times 10^{-4}$	CL=90%
$< 2.5$	$\times 10^{-6}$	CL=90%
$< 1.3$	$\times 10^{-4}$	CL=90%
$< 1.3$	$\times 10^{-5}$	CL=90%

Grazie ai 10B di eventi, è possibile ridurre di molto gli attuali limiti sperimentali sul decadimento debole della J/psi

# Studio del decadimento debole della J/psi



Grazie ai 10B di eventi, è possibile ridurre di molto gli attuali limiti sperimentali sul decadimento debole della J/psi

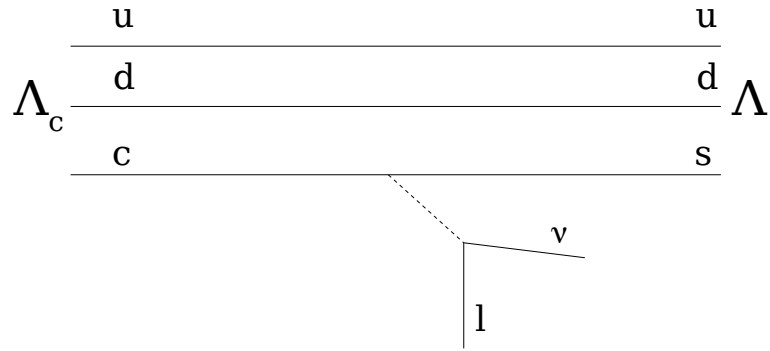
Specie i canali adronici, hanno limiti relativamente poco stretti e predizioni “quasi” accessibili

## Weak decays

$\Gamma_{298}$	$D^- e^+ \nu_e + \text{c.c.}$	< 1.2	$\times 10^{-5}$	CL=90%
$\Gamma_{299}$	$\bar{D}^0 e^+ e^- + \text{c.c.}$	< 8.5	$\times 10^{-8}$	CL=90%
$\Gamma_{300}$	$D_s^- e^+ \nu_e + \text{c.c.}$	< 1.3	$\times 10^{-6}$	CL=90%
$\Gamma_{301}$	$D_s^{*-} e^+ \nu_e + \text{c.c.}$	< 1.8	$\times 10^{-6}$	CL=90%
$\Gamma_{302}$	$D^- \pi^+ + \text{c.c.}$	< 7.5	$\times 10^{-5}$	CL=90%
$\Gamma_{303}$	$\bar{D}^0 \bar{K}^0 + \text{c.c.}$	< 1.7	$\times 10^{-4}$	CL=90%
$\Gamma_{304}$	$\bar{D}^0 \bar{K}^{*0} + \text{c.c.}$	< 2.5	$\times 10^{-6}$	CL=90%
$\Gamma_{305}$	$D_s^- \pi^+ + \text{c.c.}$	< 1.3	$\times 10^{-4}$	CL=90%
$\Gamma_{306}$	$D_s^- \rho^+ + \text{c.c.}$	< 1.3	$\times 10^{-5}$	CL=90%

	Decay type	Example	exp. sensitivity ( $\times 10^{-6}$ )	predicted $\mathcal{B}$ [7-10] ( $\times 10^{-10}$ )
$c \rightarrow s$	$D_{(s)}P$	$J/\psi \rightarrow D_s^- \pi^+$	9.9	2.00 ~ 8.74
		$J/\psi \rightarrow D^0 K^0$	13.0	0.36 ~ 2.80
	$D_{(s)}V$	$J/\psi \rightarrow D_s^- \rho^+$	2.0	12.60 ~ 50.50
		$J/\psi \rightarrow D^0 K^{*0}$	0.38	1.54 ~ 10.27
	$D_{(s)}^*V$	$J/\psi \rightarrow D_s^{*-} \rho^+$	1.7	52.60
$c \rightarrow d$	$D_{(s)}P$	$J/\psi \rightarrow D_s^- K^+$	9.8	0.16 ~ 0.55
		$J/\psi \rightarrow D^- \pi^+$	0.21	0.08 ~ 0.55
		$J/\psi \rightarrow D^0 \eta$	0.72	0.016 ~ 0.070
		$J/\psi \rightarrow D^0 \eta'$	0.25	0.003 ~ 0.004
		$J/\psi \rightarrow D^0 \pi^0$	0.48	0.024 ~ 0.055
	$D_{(s)}V$	$J/\psi \rightarrow D_s^- K^{*+}$	5.4	0.82 ~ 2.79
		$J/\psi \rightarrow D^- \rho^+$	0.35	0.42 ~ 2.20
		$J/\psi \rightarrow D^0 \rho^0$	0.77	0.18 ~ 0.22
		$J/\psi \rightarrow D^0 \omega$	0.35	0.16 ~ 0.18
	$D_{(s)}^*V$	$J/\psi \rightarrow D^0 \phi$	0.22	0.41 ~ 0.65
		$J/\psi \rightarrow D_s^{*-} K^{*+}$	4.5	2.6
		$J/\psi \rightarrow D_s^{*-} \rho^+$	0.083	2.8
		$J/\psi \rightarrow D_s^{*-} K^{*+}$	0.027	9.6

# Studio del decadimento semi-leptonico della $\Lambda_c$ con il neutrone



$$\Gamma_{72} \quad \Lambda e^+ \nu_e$$

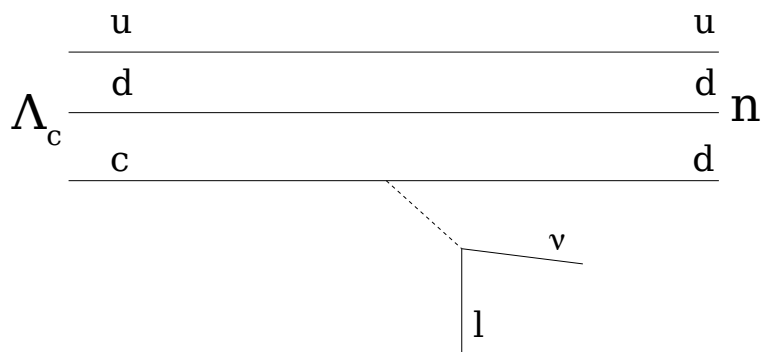
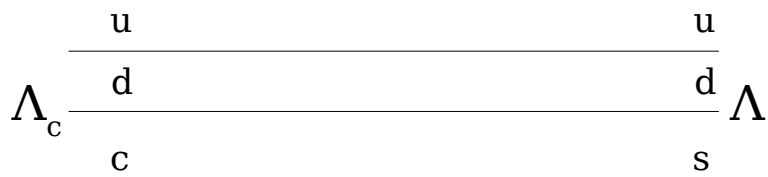
$$\Gamma_{73} \quad \Lambda \mu^+ \nu_\mu$$

Semileptonic modes

$$(3.6 \pm 0.4) \%$$

$$(3.5 \pm 0.5) \%$$

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Sarebbe la prima misura in assoluto di questo processo

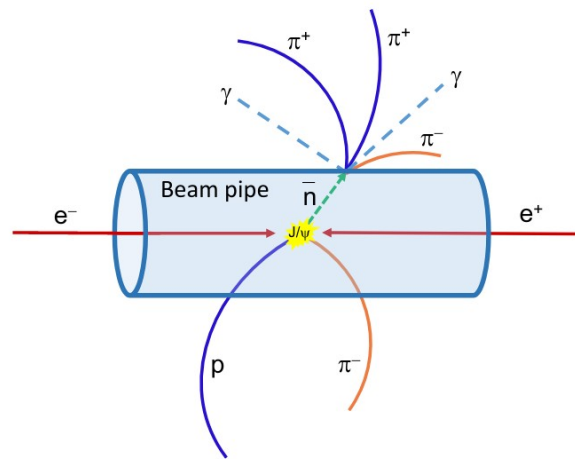
Difficoltà:

- è un processo soppresso rispetto al caso con la  $\Lambda$  nello stato finale
- ricostruire il neutrone e cercare il neutrino come massa mancante

Positivo: Abbiamo tantissimi dati!

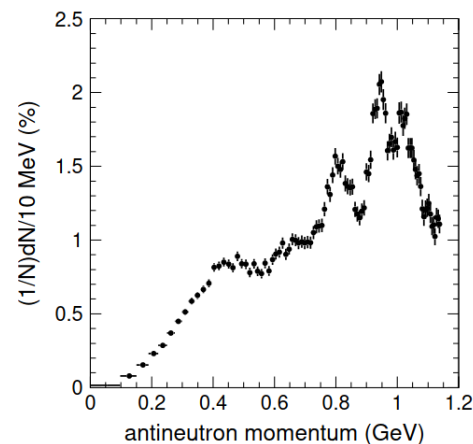
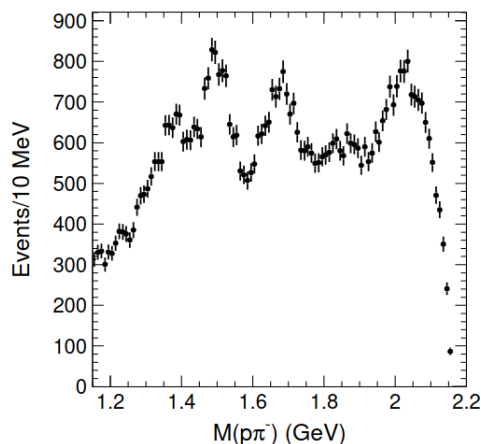
# Studio di interazioni nucleari con antineutroni

Phys.Rev.Lett. 127  
(2021) 1, 012003



Disponibili circa 8 milioni di antineutroni usando tutto il sample di  $J/\psi$  con processo  $n+Be$  o  $n+C$

Sorgente unica di anti-neutroni con processo  $J/\psi \rightarrow p\pi n$



Per la fisica, review di Tullio Bressani e Alessandra Filippi, Phys.Rept. 383 (2003) 213-297

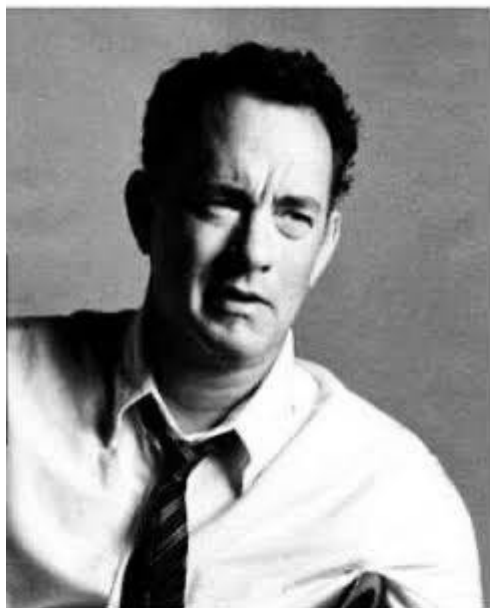
“Complementare” con Urania!

# Raccogliendo le idee

- BESIII continuerà a raccogliere dati fino al 2030
- Finestra unica per accedere a tantissime diverse analisi
- PiFE ha sviluppato una forte competenza nell'analisi, in particolare nel charmonio e negli adroni leggeri
- L'unico limite è l'immaginazione (ed il tempo per finire i lavori...

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**T.HANKS**



**T.hanks a lot**