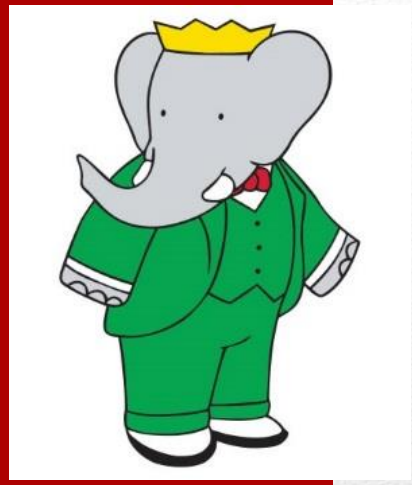
Study of scalar meson production in 3-body η_c decays at *BABAR*

arXiv:2106.05157



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on behalf of the BABAR Collaboration

Mexico City, July 28th, 2021

Università degli Studi di Messina

HADRON 2021

Charmonium decays and light spectroscopy

- The η_c resonance is strongly coupled to scalar mesons
- New information on meson properties: identification of the scalar glueball
- The η' meson is supposed to contain a significant gluonic contribution

Bass and Moskal, RMP91, 015003 (2019)

JPAC, EPJC81, 7, 647 (2021)

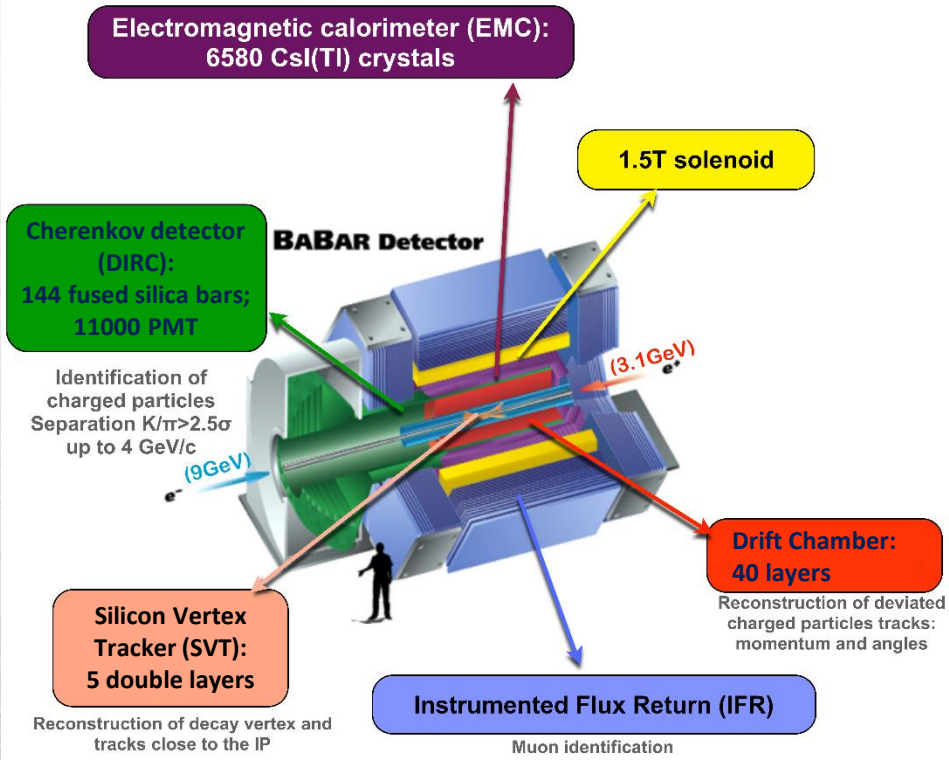
- It is of interest to compare study $\eta_c \to \eta^{(\prime)} \boldsymbol{f_0} (\to \pi^+\pi^-, K^+K^-)$
- Compare with results from J/ψ radiative decays

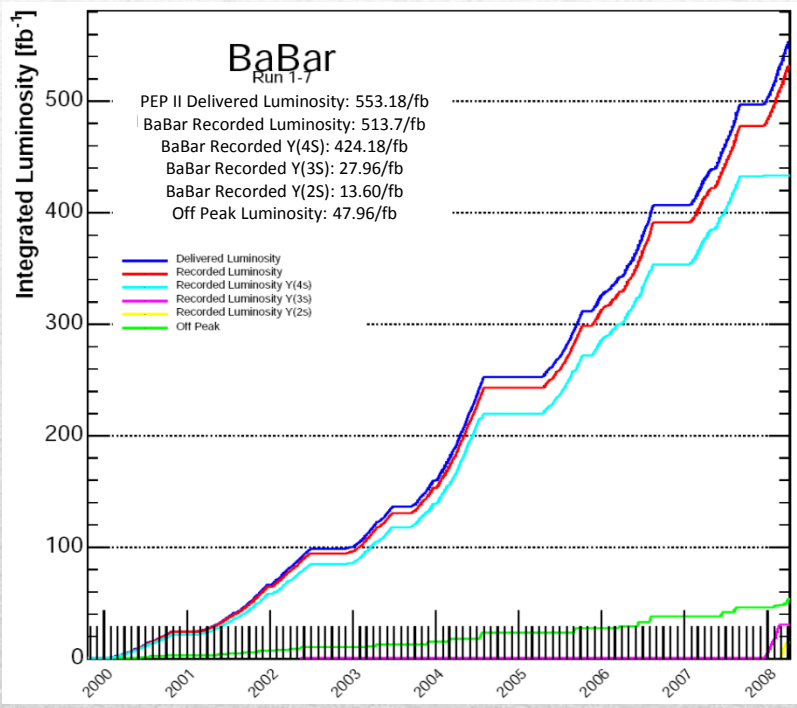
See Talks on Monday Meson Spectroscopy parallel session

The *BABAR* experiment

The *BABAR* detector was located at the interaction point of PEP II at SLAC

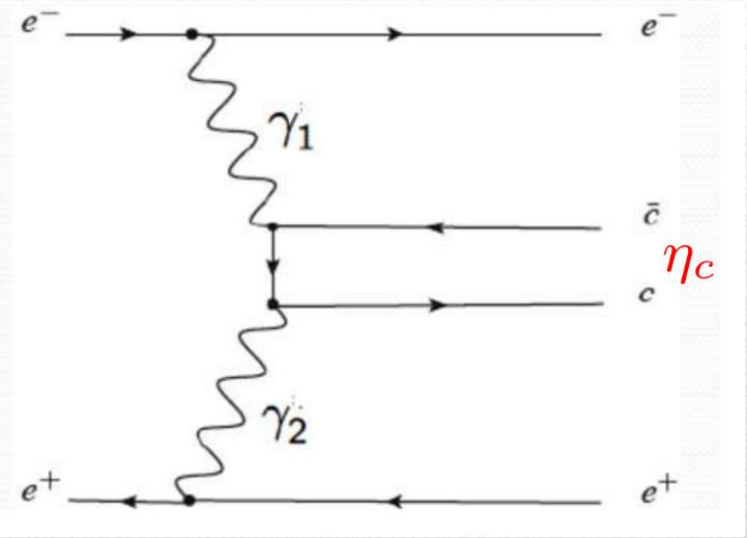
Asymmetric e^+e^- collider, mostly at $\sqrt{s} \sim 10.58$ GeV





$\int L\,dt \sim 519\ \text{fb}^{-1}$ close to the $\Upsilon(4S), \Upsilon(2S), \Upsilon(3S)$ peaks, $670 \times 10^6\ c\bar{c}$ pairs

η_c from $\gamma\gamma$ collisions



In two-photon interactions we select events where the e^+ and e^- are scattered at small angles and remain undetected

Only states with $J^{PC} = 0^{\pm+}, 2^{\pm+}, 3^{++}, 4^{\pm+}$ …

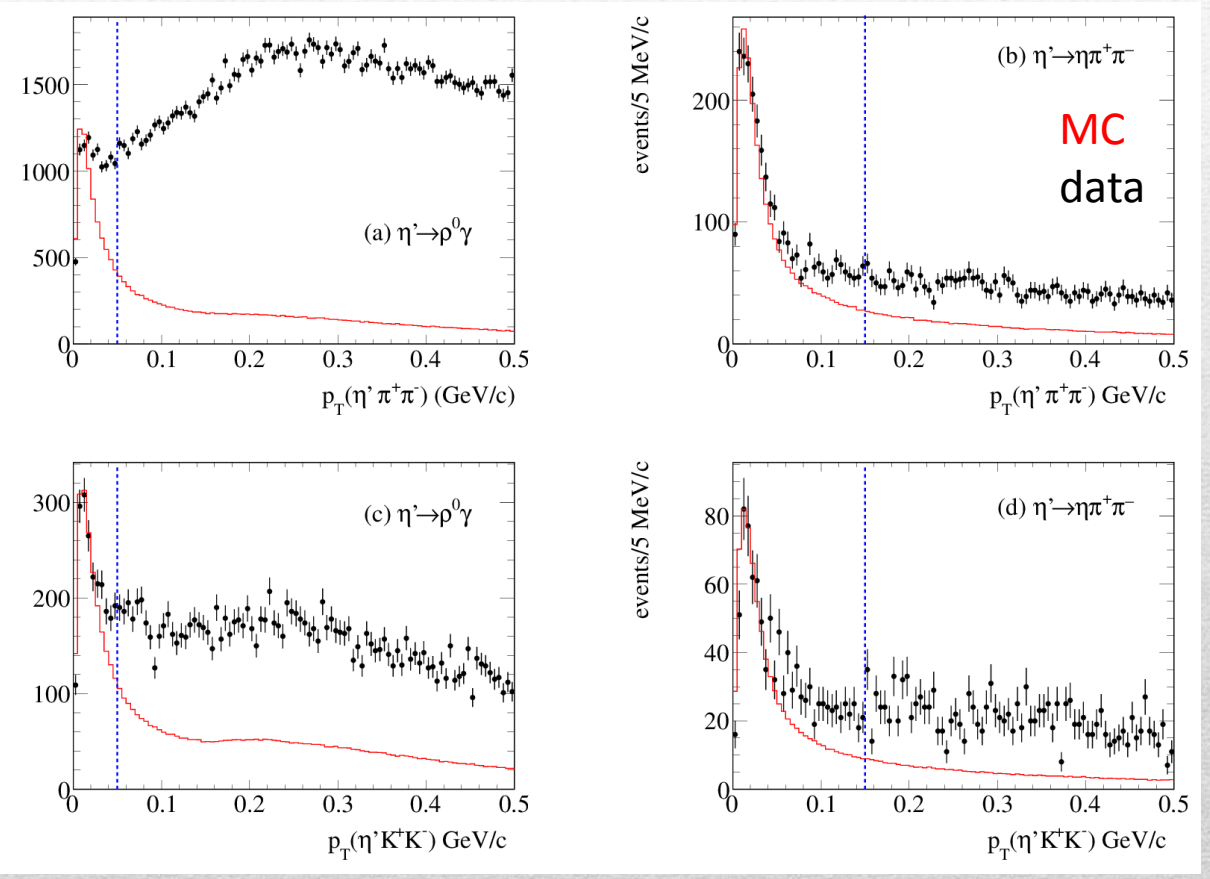
1. $\eta_c \to \pi^+\pi^-\eta'$
2. $\eta_c \to K^+K^-\eta'$ (first)
3. $\eta_c \to \pi^+\pi^-\eta$

$\eta' \to \gamma\,\rho^0(\to \pi^+\pi^-)$ or $\to \pi^+\pi^-\eta(\to \gamma\gamma)$
$\eta \to \gamma\gamma$ or $\to \pi^+\pi^-\pi^0(\to \gamma\gamma)$

$\eta_c \to K^+K^-\eta$ was studied in BaBar, PRD89, 112004 (2014)

$\eta_c \to \eta' h^+ h^- \quad (h = \pi, K)$

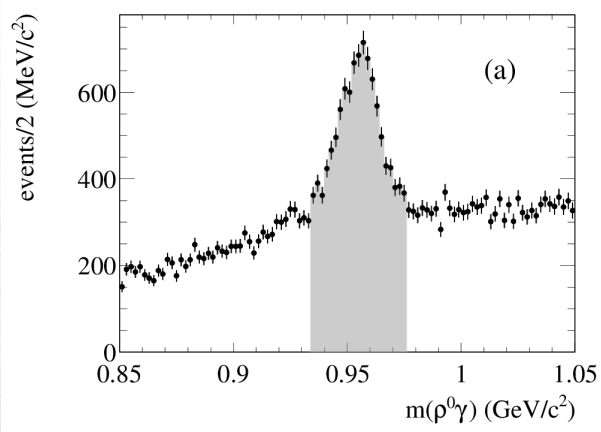
- Cuts on $p_T(2h^+2h^-)$ and M^2_{miss} remove the bkg from ISR and $\gamma\gamma \to 2h^+2h^-$
- Two-photon events isolated by cuts on $p_T(\eta' h^+ h^-)$ for $m(\eta' h^+ h^-) > 2.7$ GeV

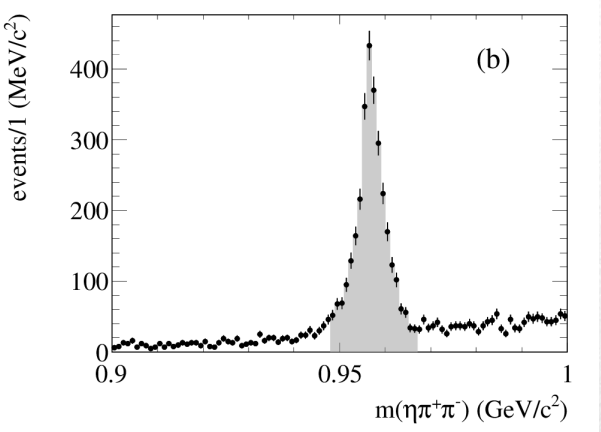


p_T selection optimized to the η_c signal

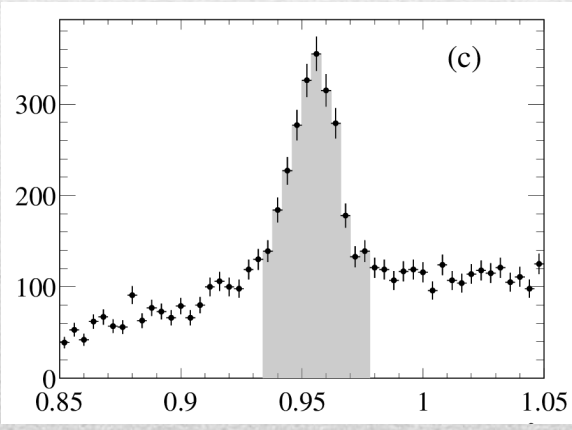
η' reconstruction

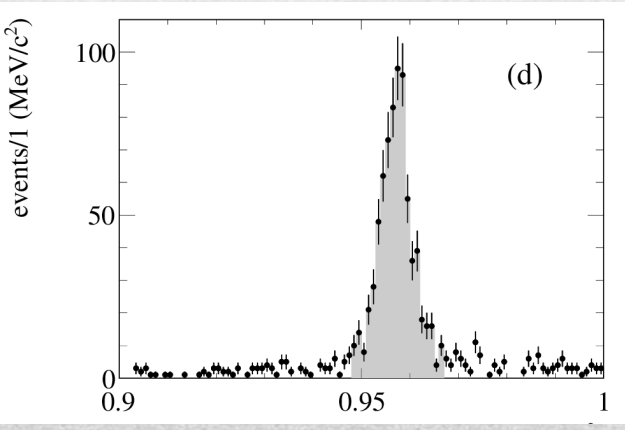
- From $\eta_c \to \eta' \pi^+ \pi^-$





- From $\eta_c \to \eta' K^+ K^-$

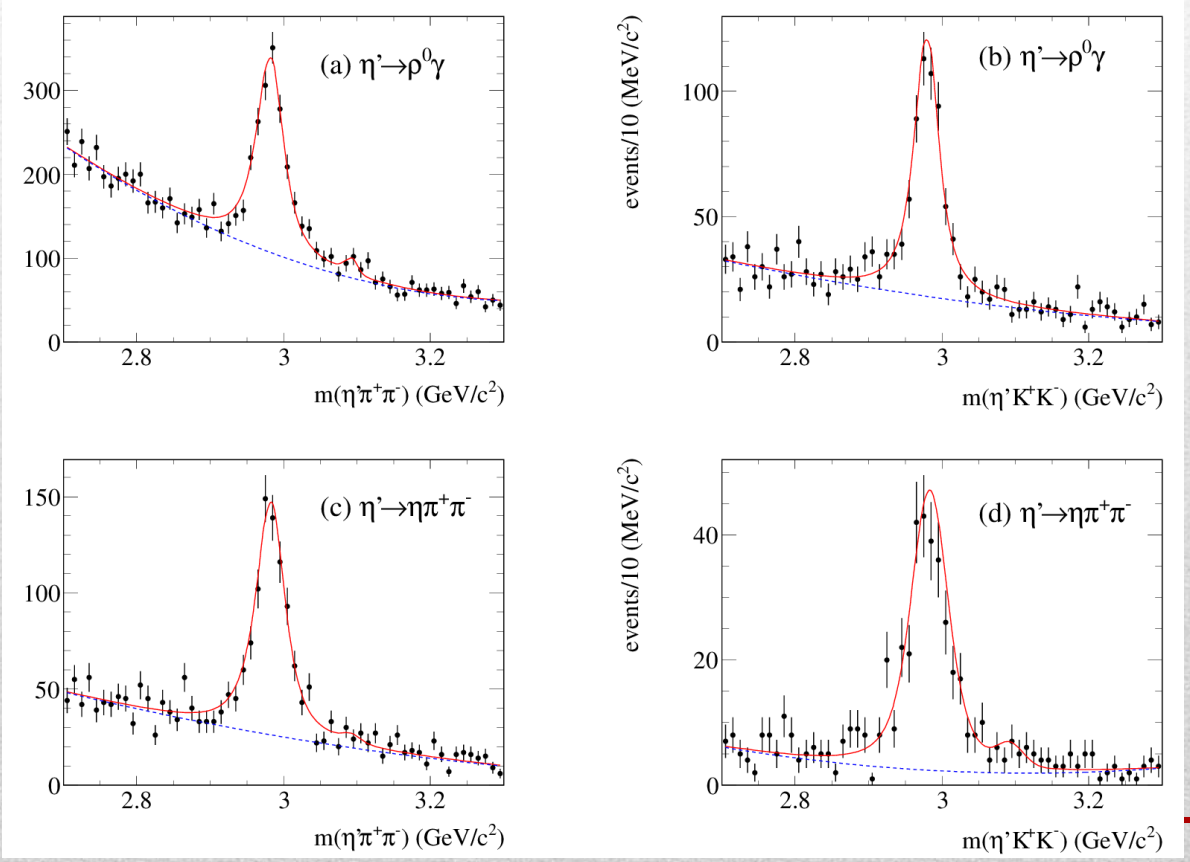




Then a mass constrained fit of η' is performed

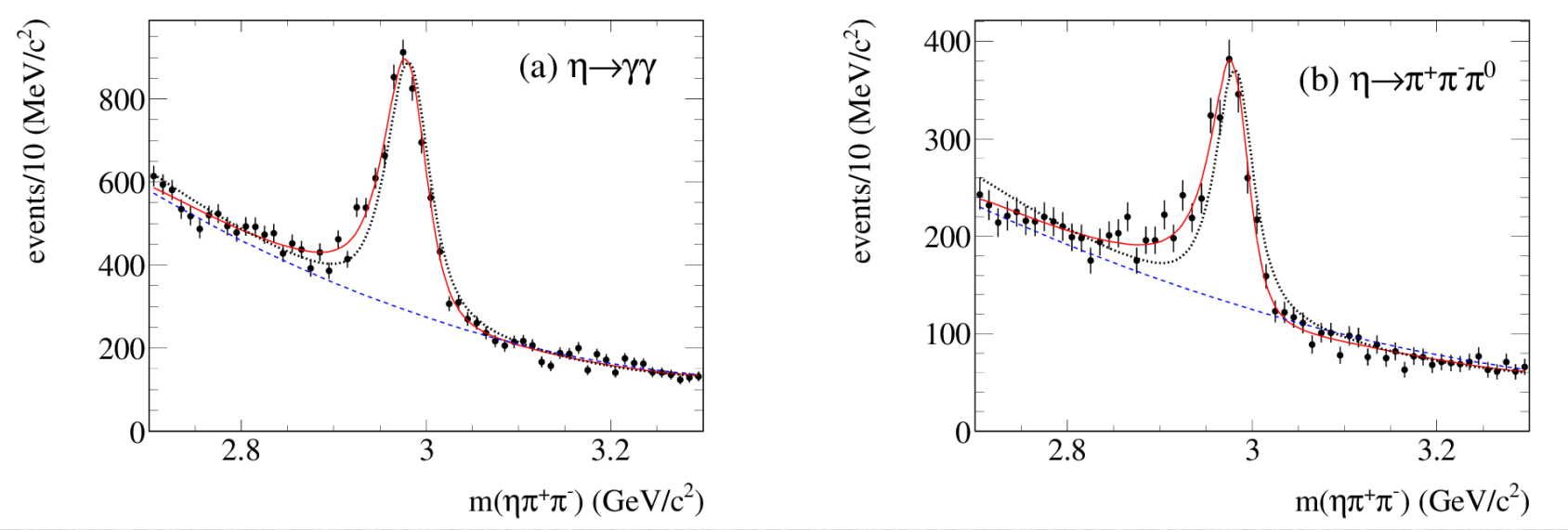
$\eta_c \to \eta' h^+ h^-$ reconstruction

- Resolution as Gaussian+Crystal Ball, lineshape as Breit-Wigner
- Binned χ^2 fits, parameters fixed but consistent with PDG values
- Bkg described by quadratic polynomial, residual J/ψ from ISR



$$\frac{B(\eta_c \to \eta' K^+ K^-)}{B(\eta_c \to \eta' \pi^+ \pi^-)} = 0.644 \pm 0.039 \pm 0.032$$

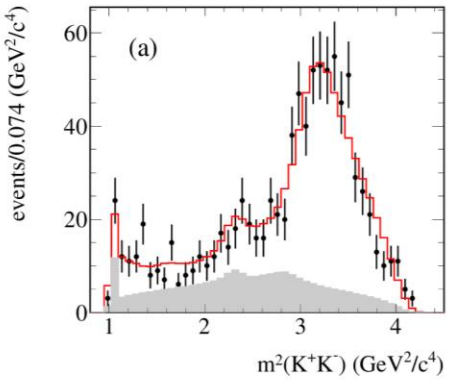
$\eta_c \to \eta\pi^+\pi^-$ reconstruction

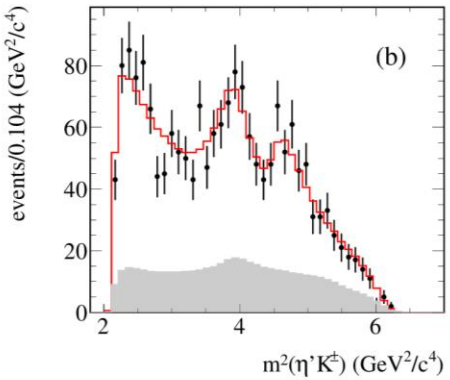


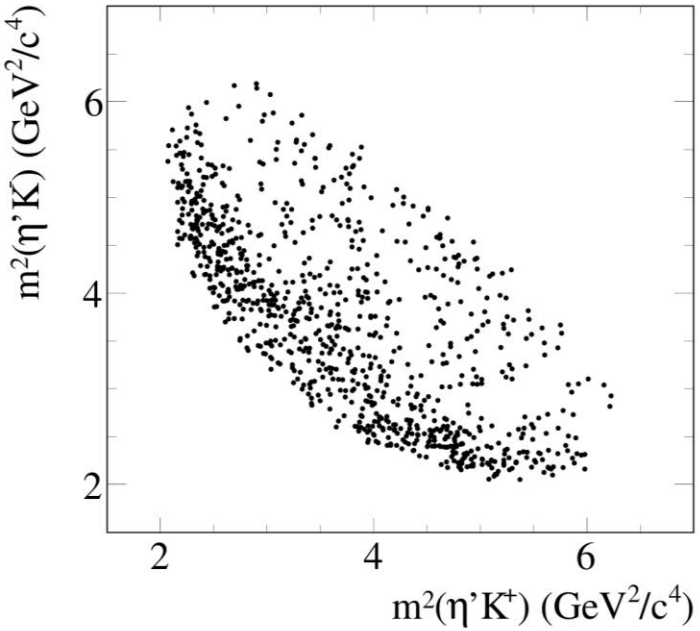
- Mass shifted down by 10 MeV, interference with bkg is introduced
- χ^2/ndf improves dramatically from 2.5 to 1

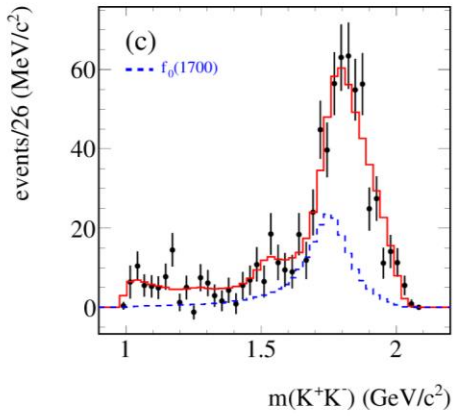
$\eta_c \to \eta' K^+ K^-$ Dalitz plot analysis

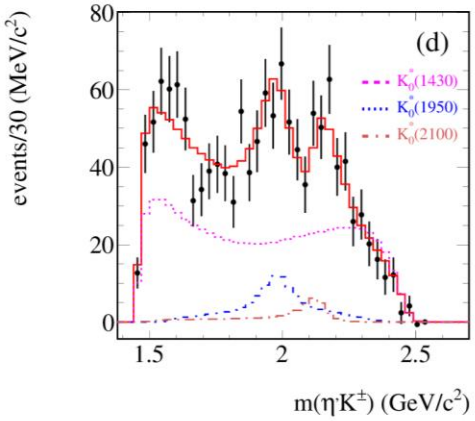
- Combined for all η' channels
- Bkg from sidebands











- Presence of $f_0(1700)$, $K_0^*(1430)$, $K_0^*(1950)$ and possibly a $K_0^*(2130)$

The $K_0^*(1430)$

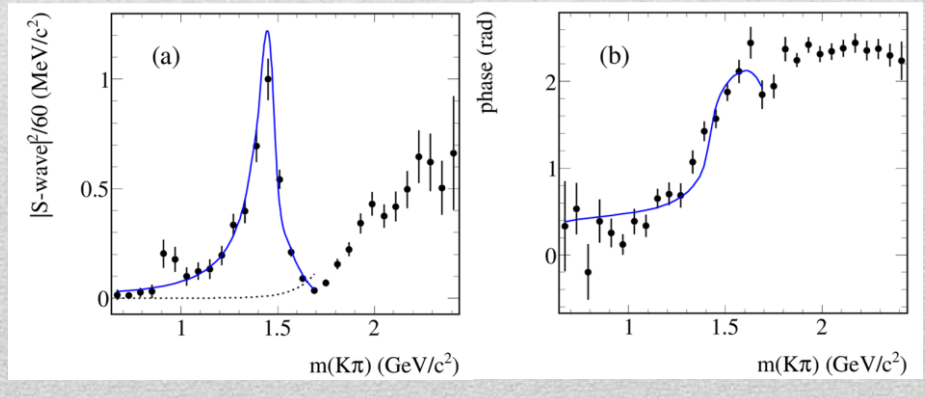
$$BW(m) = 1/\left(m_0^2 - m^2 - i\left(\rho_{1(m)}^2\, g_{\pi K}^2 + \rho_{2(m)}^2\, g_{\eta' K}^2\right)\right)$$

Coupled-channel
Flatté-like

Initally fitted to the MIPWA of BaBar, PRD93, 012005 (2016) ,
but ratio of couplings not compatible with other determinations

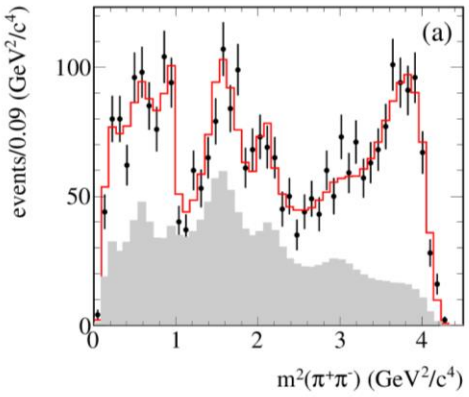
If the latter is imposed, the agreement with MIPWA is still good,
and one gets

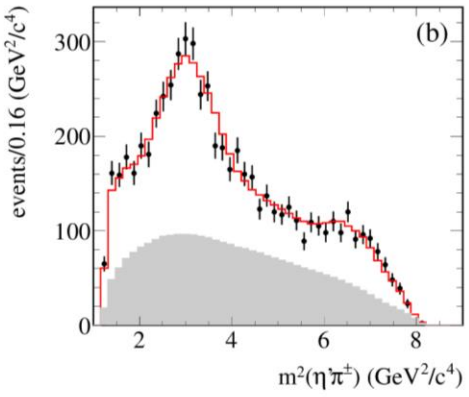
$$m(K_0^*(1430)) = 1453 \pm 22_{\rm stat} \pm 6_{\rm sys} {\rm MeV}/c^2,$$
$$g_{K\pi}^2 = 0.462 \pm 0.036_{\rm stat} \pm 0.048_{\rm sys}\ {\rm GeV}^2/c^4,$$
$$\frac{g_{\eta' K}^2}{g_{\pi K}^2} = 1.66 \pm 0.27_{\rm stat} \pm 0.29_{\rm sys}.$$

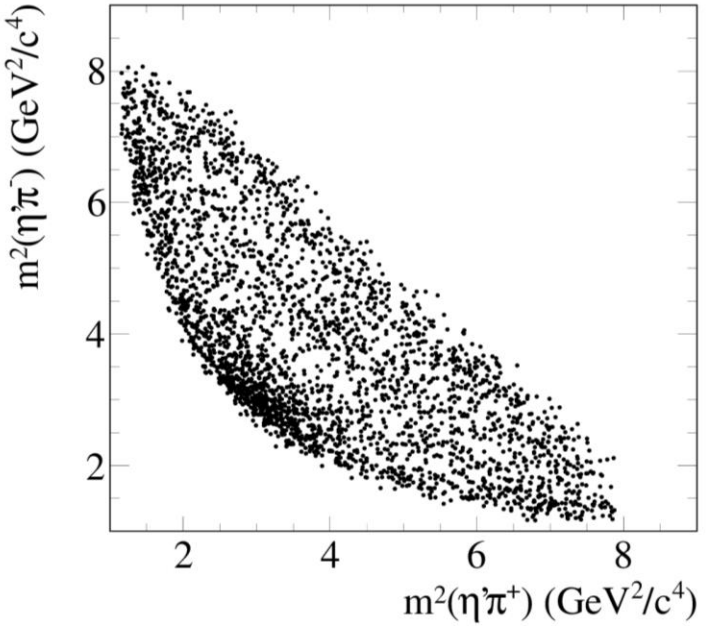


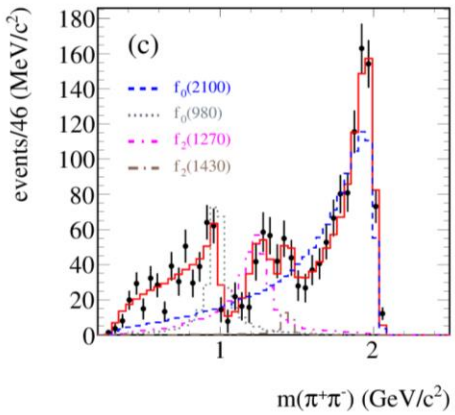
$\eta_c \to \eta'\pi^+\pi^-$ Dalitz plot analysis

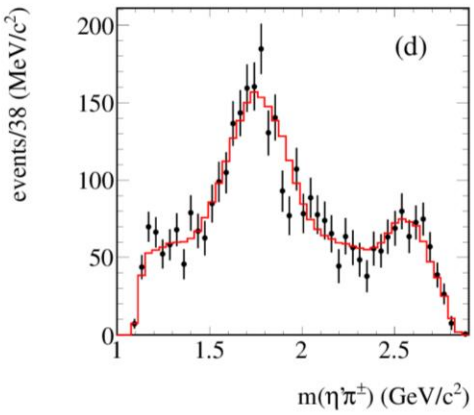
- Combined for all η' channels
- Bkg from sidebands







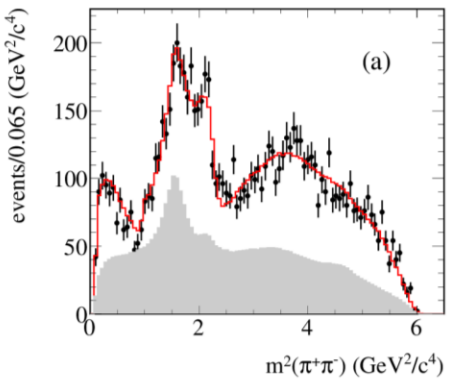


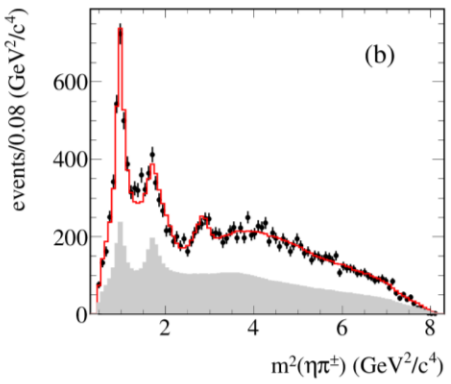


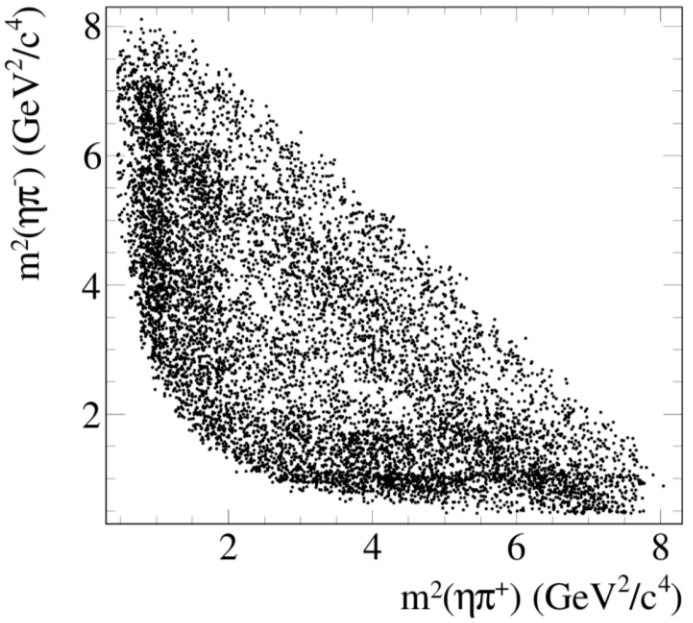
- Decay dominated by $f_0(2100)$

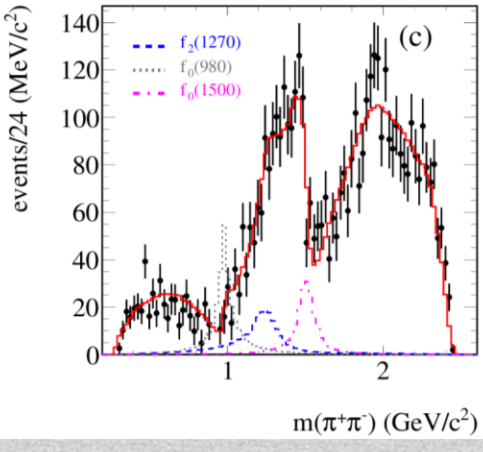
$\eta_c \to \eta\,\pi^+\pi^-$ Dalitz plot analysis

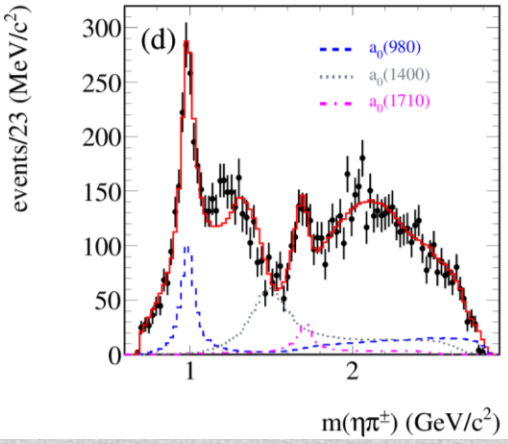
- Combined for all η channels
- Bkg from sidebands











- Complex resonant structures also in bkg
- A new $a_0(1700)$ found,
  $m = 1704 \pm 5 \pm 2$ MeV,
  $\Gamma = 110 \pm 15 \pm 11$ MeV

Results from Dalitz plot analyses

- $\eta_c \to \eta' K^+ K^-$

Final state	fraction (%)	phase (rad)
$f_0(1710)\eta'$	$30.0 \pm 5.3 \pm 1.6$	0.
$K_0^*(1430)^+ K^-$	$57.6 \pm 7.5 \pm 2.1$	$0.79 \pm 0.13 \pm 0.59$
$K_0^*(1950)^+ K^-$	$7.3 \pm 2.8 \pm 0.4$	$1.09 \pm 0.23 \pm 1.10$
$f_0(1500)\eta'$	$0.9 \pm 1.0 \pm 0.3$	$0.24 \pm 0.51 \pm 0.10$
$f_0(980)\eta'$	$4.8 \pm 3.0 \pm 0.4$	$-0.92 \pm 0.53 \pm 0.05$
$f_2(1270)\eta'$	$2.7 \pm 1.4 \pm 0.1$	$2.9 \pm 0.42 \pm 0.09$
$K_0^*(2130)^+ K^-$	$2.7 \pm 1.7 \pm 0.4$	$-0.48 \pm 0.38 \pm 0.06$
sum	$105.9 \pm 10.4 \pm 2.7$	

- $\eta_c \to \eta' \pi^+ \pi^-$

Final state	fraction (%)	phase (rad)
$f_0(2100)\eta'$	$74.9 \pm 7.5 \pm 3.6$	0.
$f_0(500)\eta'$	$4.3 \pm 2.3 \pm 0.7$	$-5.89 \pm 0.24 \pm 0.10$
$f_0(980)\eta'$	$16.1 \pm 2.4 \pm 0.5$	$-5.31 \pm 0.16 \pm 0.04$
$f_2(1270)\eta'$	$22.1 \pm 2.9 \pm 2.4$	$-3.60 \pm 0.16 \pm 0.03$
$f_2(1430)\eta'$	$1.9 \pm 0.7 \pm 0.1$	$-2.45 \pm 0.32 \pm 0.11$
$a_2(1710)\pi$	$3.2 \pm 1.9 \pm 0.5$	$-0.75 \pm 0.27 \pm 0.11$
$a_0(1950)\pi$	$2.5 \pm 1.1 \pm 0.1$	$-0.02 \pm 0.32 \pm 0.06$
$f_2(1800)\eta'$	$5.3 \pm 2.2 \pm 1.4$	$0.67 \pm 0.24 \pm 0.08$
sum	$130.5 \pm 9.5 \pm 4.7$	

- $\eta_c \to \eta \pi^+ \pi^-$

Final state	fraction (%)	phase (rad)
$a_0(980)\pi$	$12.3 \pm 1.2 \pm 0.9$	0.
$a_2(1310)\pi$	$2.5 \pm 0.7 \pm 0.6$	$-1.04 \pm 0.13 \pm 0.20$
$f_0(500)\eta$	$4.3 \pm 1.3 \pm 0.7$	$0.54 \pm 0.14 \pm 0.20$
$f_2(1270)\eta$	$4.6 \pm 0.9 \pm 0.4$	$-1.15 \pm 0.11 \pm 0.05$
$f_0(980)\eta$	$5.7 \pm 1.3 \pm 1.0$	$-2.41 \pm 0.09 \pm 0.04$
$f_0(1500)\eta$	$4.2 \pm 0.7 \pm 0.6$	$2.32 \pm 0.13 \pm 0.05$
$a_0(1450)\pi$	$15.0 \pm 2.4 \pm 2.1$	$2.60 \pm 0.09 \pm 0.11$
$a_0(1700)\pi$	$3.5 \pm 0.8 \pm 0.6$	$1.39 \pm 0.15 \pm 0.12$
$f_2(1950)\eta$	$4.2 \pm 1.0 \pm 0.6$	$-1.59 \pm 0.15 \pm 0.20$
sum	$56.3 \pm 3.7 \pm 2.9$	
NR	$172.7 \pm 8.0 \pm 10.0$	$1.67 \pm 0.07 \pm 0.03$

Summary

- First observation of $\eta_c \to \eta' K^+ K^-$
- Observation of a new $a_0(1700)$
- Evidence for $f_2(1430) \to \pi^+ \pi^-$
- Comparison between η_c decays to gluonium candidates

BaBar, arXiv:2106.05157

Final state	$f_0(1500)(\%)$	$f_0(1710)(\%)$	$f_0(2100)(\%)$
$\eta K^+ K^-$	$23.7 \pm 7.0 \pm 1.8$	$8.9 \pm 0.2 \pm 0.4$	
$\eta \pi^+ \pi^-$	$4.2 \pm 0.7 \pm 0.6$		$0.$
$\eta' K^+ K^-$	$0.9 \pm 1.0 \pm 0.3$	$30 \pm 5.3 \pm 1.6$	
$\eta' \pi^+ \pi^-$	0.3 ± 0.2		$74.9 \pm 7.5 \pm 3.5$

- This effect may point to an enhanced gluonic content of $f_0(1710)$ and $f_0(2100)$

Thank you!