Institute of High Energy Physics
Chinese Academy of Sciences

BESIII上粲介子强子衰变振幅分析

报告人：卢泽辉

2024.5.11

目录

粲介子强子衰变振幅分析

✓ **检验非微扰QCD理论**

- 测量两体衰变 PP, VP, VV, SP, AP等分支比
- 研究 CP 破坏和SU(3)味道对称性破缺

✓ **理解强子谱**

- 为深入探讨轻标量介子提供实验支持

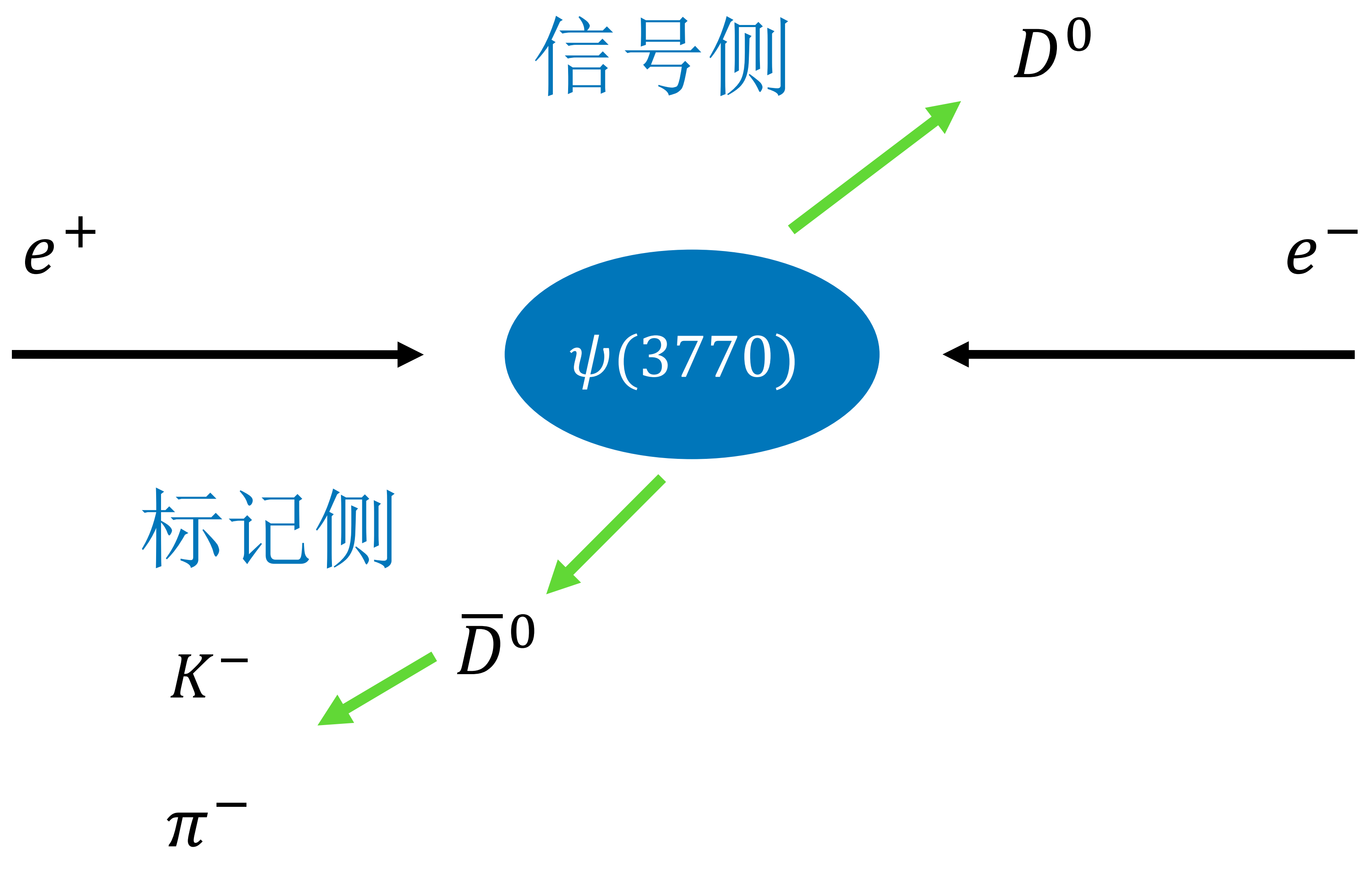
✓ **为其他测量提供重要衰变模型**

- 强相位测量等

✓ **BESIII上的粲介子强子衰变振幅分析**

- 成果丰富：二十余篇已发表
- 覆盖面广：三、四与五体分析
- 意义重要
  - $D^+ \to K_S^0 \pi^+ \eta$
  - $D^0 \to \pi^+ \pi^- \eta$ & $D^0 \to \pi^+ \pi^0 \eta$
  - $D_s^+ \to \pi^+ \pi^0 \eta$
  - $D_s^+ \to K_S^0 K_S^0 \pi^+$
  - $D_s^+ \to K_S^0 K^+ \pi^0$
  - …

分析策略和数据集



数据集:

$D^{0/+}$：收集于2011，2022-2024，共20 fb^{-1} @ $E_{\mathrm{cm}} = 3.773$ GeV

D_s^+：收集于2013-2017，共7.33 fb^{-1} @ $E_{\mathrm{cm}} = 4.128 - 4.226$GeV

单标记方法 (ST) : 仅重建标记侧 D介子

— 相对高的本底

— 更高的 效率

双标记方法 (DT) : 同时重建信号和标记侧 D介子

— 低本底 以研究不同衰变过程

— 标记侧系统误差 几乎被抵消

振幅构造:

$$A(p_j) = F^L_{D_s} F^L_r P^L S^L$$

$F^L_{D_s,r}$： Blatt-Weisskopf barrier factors

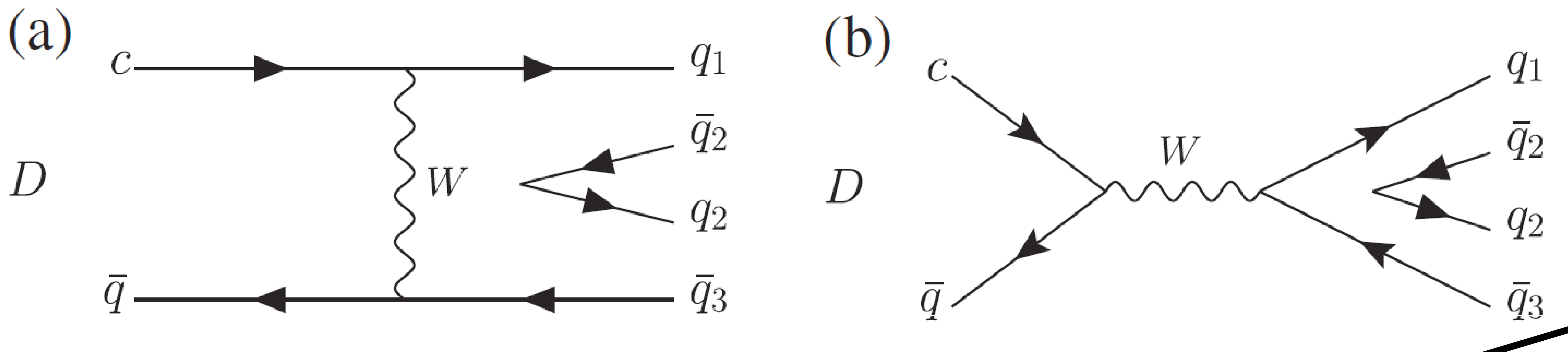
P^L： Propagator

S^L： Spin-dependent angular term

Eur. Phys. J. A 16 (2003) 537

Observation of $D^+ \to K_S^0 a_0(980)^+$

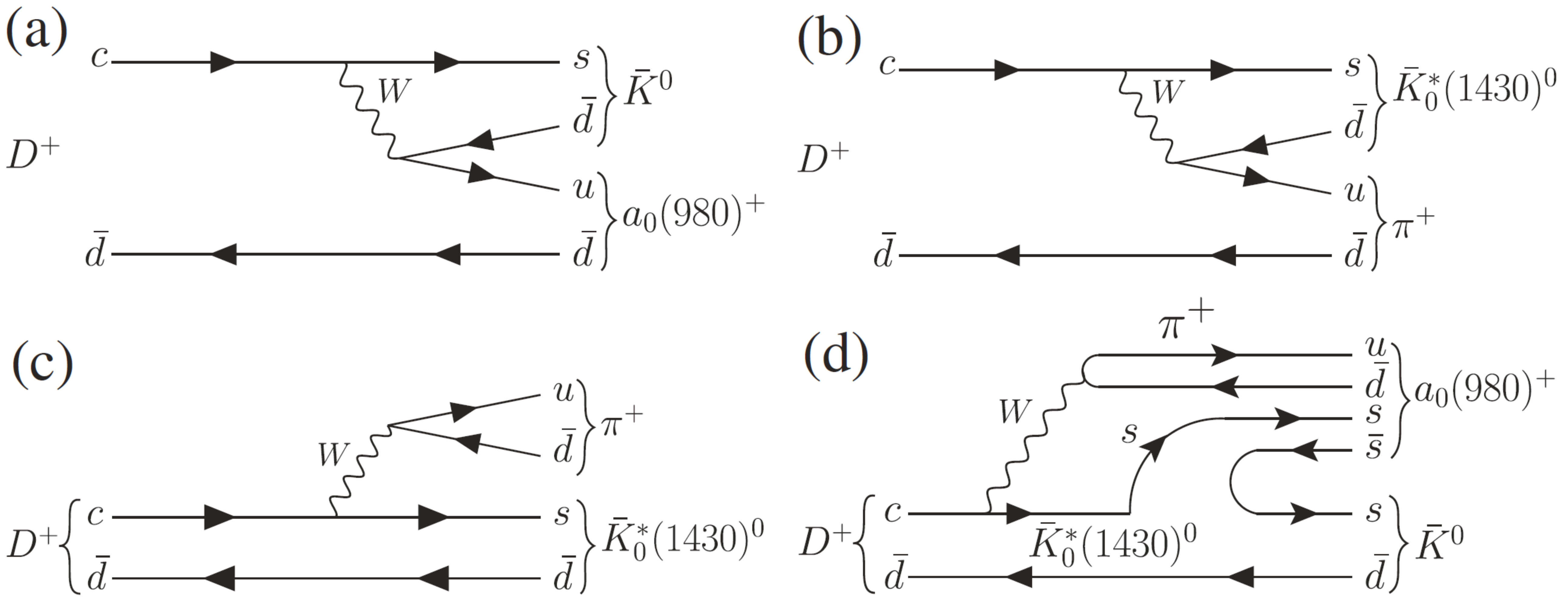
Phys. Rev. Lett. 132, 131903 (2024)



D^+：无法单独形成一个$\bar{K}^0$

Decay	Amplitude $D \to SP$
$D^+ \to f_0\pi^+$	$\frac{1}{\sqrt{2}}\alpha V_{cd}^* V_{ud}(T + C' + A + A') + \beta V_{cs}^* V_{us} C'$
$\to f_0 K^+$	$V_{cd}^* V_{us}\left[\frac{1}{\sqrt{2}}\alpha(T + A') + \beta A\right]$
$\to a_0^+ \overline{K}^0$	$V_{cs}^* V_{ud}(T' + C)$
$\to a_0^0 \pi^+$	$\frac{1}{\sqrt{2}} V_{cd}^* V_{ud}(-T - C' - A + A')$
$\to \sigma\pi^+$	$\frac{1}{\sqrt{2}}\beta V_{cd}^* V_{ud}(T + C' + A + A') - \alpha V_{cs}^* V_{us} C'$
$\to \bar{\kappa}^0 \pi^+$	$V_{cs}^* V_{ud}(T + C')$
$\to \bar{\kappa}^0 K^+$	$V_{cs}^* V_{us} T + V_{cd}^* V_{ud} A$
$D^0 \to f_0 \pi^0$	$\frac{1}{2}\alpha V_{cd}^* V_{ud}(-C + C' - E - E') + \frac{1}{\sqrt{2}}\beta V_{cs}^* V_{us} C'$
$\to f_0 \overline{K}^0$	$V_{cs}^* V_{ud}[\frac{1}{\sqrt{2}}\alpha(C + E) + \beta E']$
$\to a_0^+ \pi^-$	$V_{cd}^* V_{ud}(T' + E)$
$\to a_0^- \pi^+$	$V_{cd}^* V_{ud}(T + E')$
$\to a_0^+ K^-$	$V_{cs}^* V_{ud}(T' + E)$
$\to a_0^0 \overline{K}^0$	$V_{cs}^* V_{ud}(C - E)/\sqrt{2}$
$\to a_0^- K^+$	$V_{cd}^* V_{us}(T + E')$
$\to \sigma\pi^0$	$\frac{1}{2} V_{cd}^* V_{ud}\beta(-C + C' - E - E') - \frac{1}{\sqrt{2}}\alpha V_{cs}^* V_{us} C'$

无E和A贡献



四夸克态下的$a_0(980)^+$

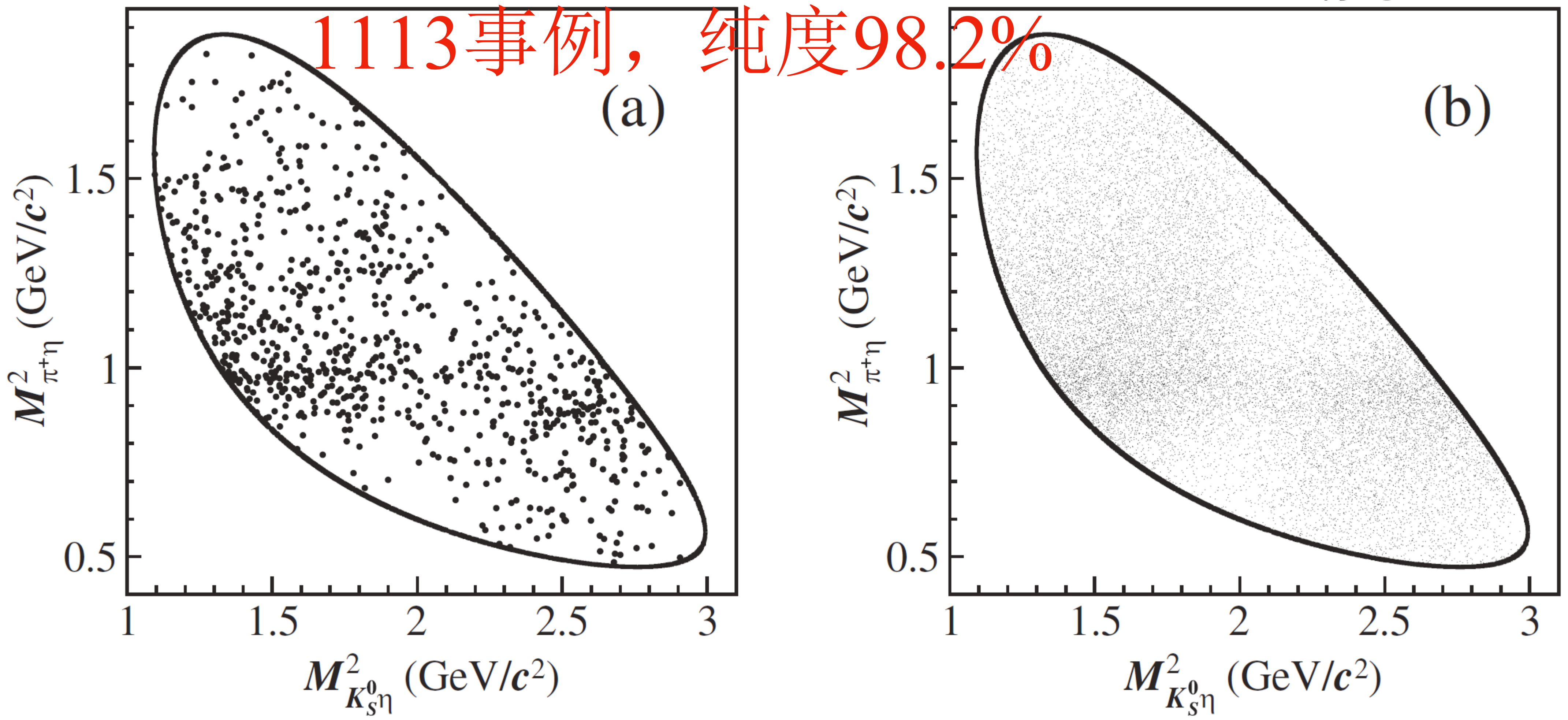
- 为图方法研究$D \to SP$过程提供重要参考
- 理解$D \to a_0(980)P$理论与实验不一致
- 帮助研究$a_0(980)$性质

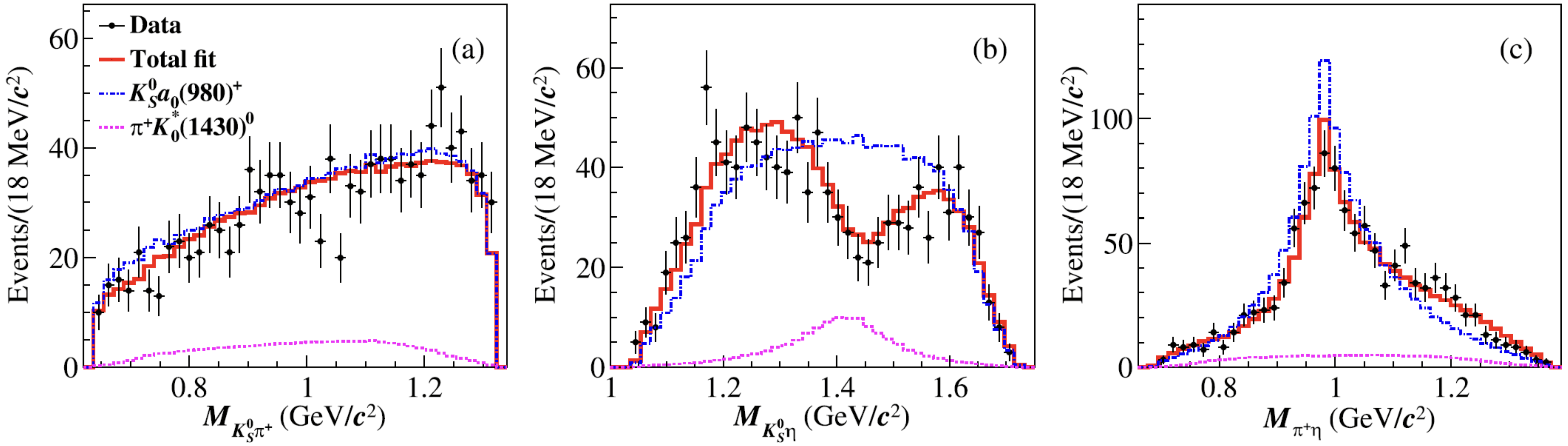
Observation of $D^+ \to K_S^0 a_0(980)^+$

2.93 fb^{-1}

Phys. Rev. Lett. 132, 131903 (2024)

1113事例，纯度98.2%





Amplitude	Phase ϕ (rad)	FF (%)	Significance
$D^+ \to K_S^0 a_0(980)^+$	0.0 (fixed)	$105.00 \pm 0.94 \pm 1.04 \pm 0.07$	$>10\sigma$
$D^+ \to K_0^*(1430)^0 \pi^+$	$2.58 \pm 0.06 \pm 0.09 \pm 0.01$	$10.83 \pm 1.50 \pm 1.27 \pm 0.08$	$>10\sigma$

首次观测

考虑了干涉效应

相消干涉：$(15.83 \pm 1.53 \pm 1.65)\%$

$$\mathcal{B}(D^+ \to K_S^0 \pi^+ \eta) = (1.27 \pm 0.04 \pm 0.03)\%$$

$$\mathcal{B}(D^+ \to K_S^0 a_0(980)^+, a_0(980)^+ \to \pi^+\eta) = (1.33 \pm 0.05 \pm 0.04)\%$$

$$\mathcal{B}(D^+ \to \bar{K}_0^*(1430)\pi^+, \bar{K}_0^*(1430) \to K_S^0\eta) = (0.14 \pm 0.02 \pm 0.02)\%$$

Observation of $D \to a_0(980)\pi$

arXiv:2404.09219

$A(D_s^+ \to a_0(980)^+\pi^0) = -A(D_s^+ \to a_0(980)^0\pi^+)$

$\mathcal{B}(D_s^+ \to a_0(980)^{+(0)}\pi^{0(+)}, a_0(980)^{+(0)} \to \pi^{+(0)}\eta$
$= (1.46 \pm 0.15 \pm 0.23)\%$ Phys. Rev. Lett. 123, 112001 (2019)

比其它WA过程大
一个数量级 ➡ 末态相互作用

Observation of a a_0-like state $a_0(1817)^+$ in $D_s^+ \to K_S^0 K^+\pi^0$ Phys. Rev. Lett. 129, 182001 (2022)

可能是$a_0(980)^{+(0)}$的激发态

$a_0(980)^{+(0)}$性质研究：

- 四夸克态
- 分子态
- $K^{(*)}\bar{K}^{(*)}$分子态

?

$r_{+/-} = \mathcal{B}(D^0 \to a_0(980)^+\pi^-)/\mathcal{B}(D^0 \to a_0(980)^-\pi^+)$<0.05

- $a_0(980)^\pm\pi^\mp$在$D^0 \to K_S^0 K^\pm\pi^\mp$中误差巨大
- 在$D^0 \to \pi^+\pi^-\eta$中仅观察到峰状结构无法确定其存在

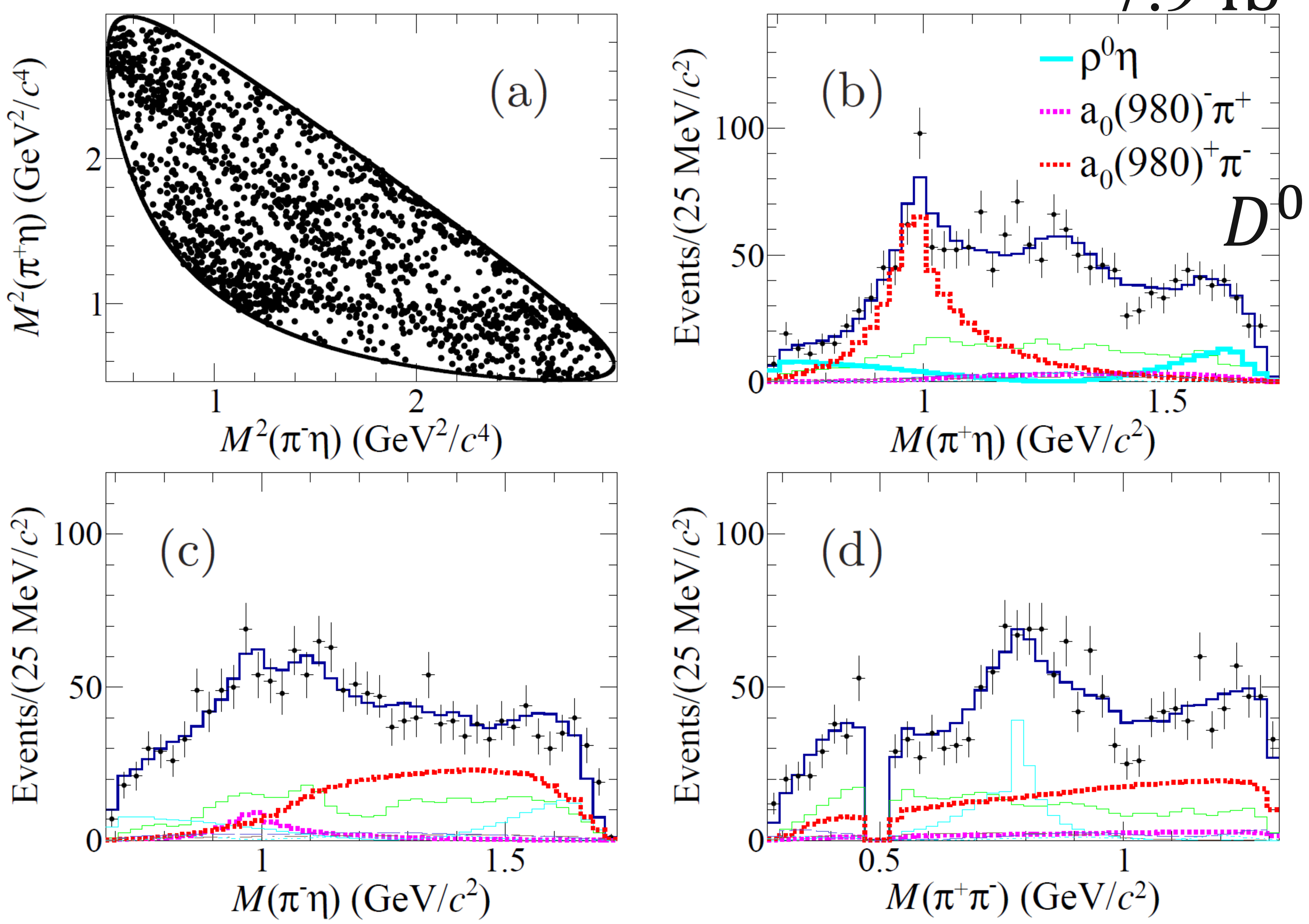
$r_{+/0} = \mathcal{B}(D^+ \to a_0(980)^+\pi^0)/\mathcal{B}(D^+ \to a_0(980)^0\pi^+)$

- 对于D^+存在来自外/内发射树图贡献

Observation of $D \to a_0(980)\pi$

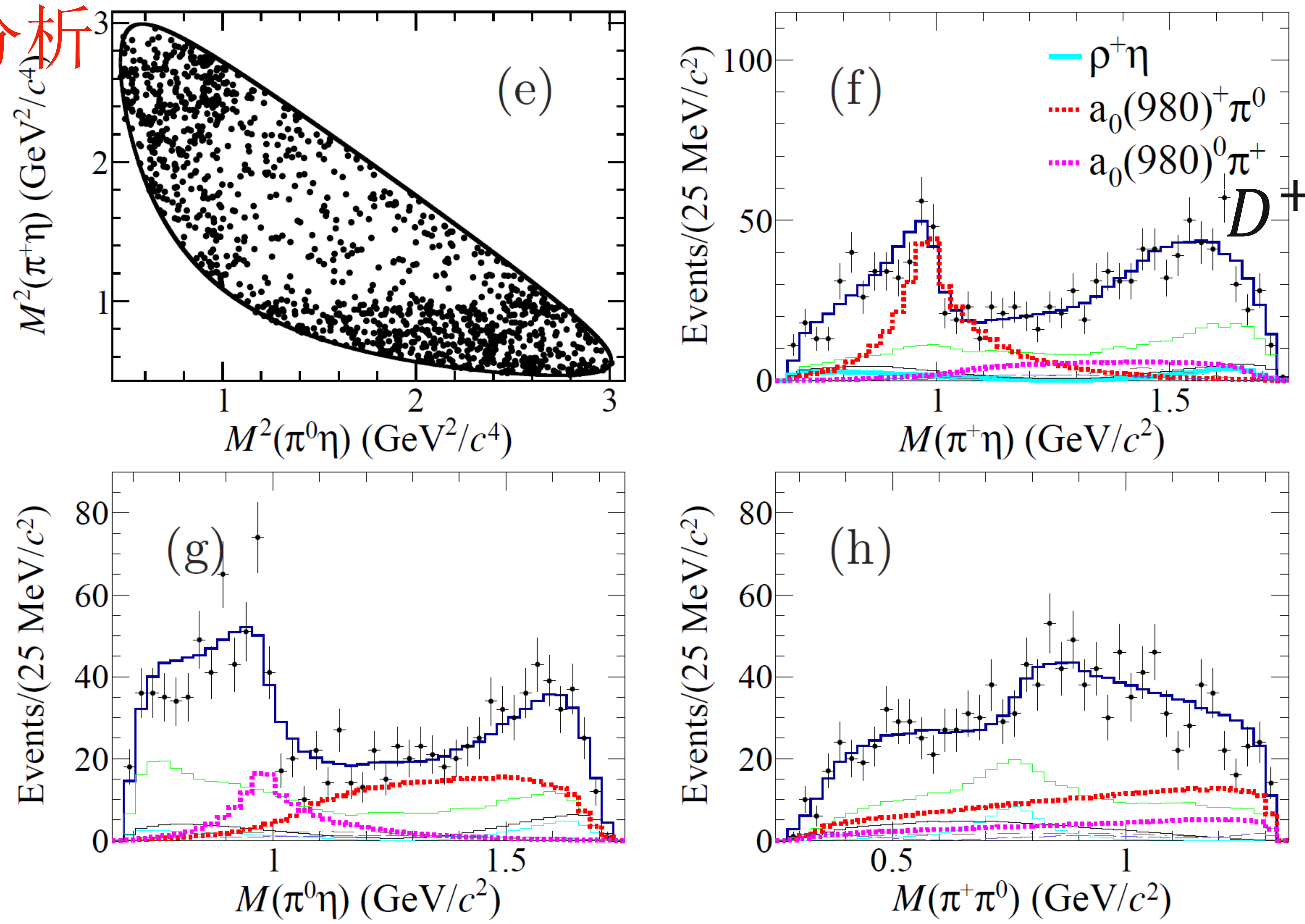
arXiv:2404.09219

$7.9\ \mathrm{fb}^{-1}$ 首次振幅分析



$D^0 \to \pi^+\pi^-\eta$

1678 事例
纯度74.1%



$D^+ \to \pi^+\pi^0\eta$

1226 事例
纯度65.7%

Amplitude	Phase (in unit rad)	FF (%)	Significance (σ)	BF ($\times 10^{-3}$)
$D^0 \to \rho^0\eta$	0 (fixed)	$15.2 \pm 1.7 \pm 1.0$	> 10	$0.19 \pm 0.02 \pm 0.01$
$D^0 \to a_0(980)^-\pi^+$	$0.06 \pm 0.16 \pm 0.12$	$5.9 \pm 1.3 \pm 1.0$	8.9	$0.07 \pm 0.02 \pm 0.01$
$D^0 \to a_0(980)^+\pi^-$	$-1.06 \pm 0.12 \pm 0.10$	$44.0 \pm 4.0 \pm 5.3$	> 10	$0.55 \pm 0.05 \pm 0.07$
$D^0 \to a_2(1320)^+\pi^-$	$-1.16 \pm 0.25 \pm 0.23$	$2.1 \pm 0.9 \pm 0.8$	4.5	$0.03 \pm 0.01 \pm 0.01$
$D^0 \to a_2(1700)^+\pi^-$	$0.08 \pm 0.17 \pm 0.23$	$5.5 \pm 1.8 \pm 2.7$	6.1	$0.07 \pm 0.02 \pm 0.03$
$D^0 \to (\pi^+\pi^-)_{S-\mathrm{wave}}\eta$	$-0.92 \pm 0.29 \pm 0.14$	$3.9 \pm 1.8 \pm 2.1$	5.3	$0.05 \pm 0.02 \pm 0.03$
$r_{+/-}$		$7.5^{+2.5}_{-0.8} \pm 1.7$	7.7^*	-
$D^+ \to \rho^+\eta$	$-4.03 \pm 0.19 \pm 0.13$	$9.3 \pm 3.0 \pm 2.1$	6.0	$0.20 \pm 0.07 \pm 0.05$
$D^+ \to (\pi^+\pi^0)_V\eta$	$-0.64 \pm 0.22 \pm 0.19$	$15.8 \pm 4.8 \pm 5.2$	4.7	$0.34 \pm 0.11 \pm 0.11$
$D^+ \to a_0(980)^+\pi^0$	0 (fixed)	$43.7 \pm 5.6 \pm 1.9$	9.1	$0.95 \pm 0.12 \pm 0.05$
$D^+ \to a_0(980)^0\pi^+$	$2.44 \pm 0.20 \pm 0.10$	$17.0 \pm 4.4 \pm 1.7$	7.9	$0.37 \pm 0.10 \pm 0.04$
$D^+ \to a_2(1700)^+\pi^0$	$0.92 \pm 0.20 \pm 0.14$	$4.2 \pm 2.1 \pm 0.7$	3.6	$0.09 \pm 0.05 \pm 0.02$
$D^+ \to a_0(1450)^+\pi^0$	$0.63 \pm 0.41 \pm 0.30$	$7.0 \pm 2.8 \pm 0.7$	4.7	$0.15 \pm 0.06 \pm 0.02$
$r_{+/0}$		$2.6 \pm 0.6 \pm 0.3$	4.0^*	-

* The significance is for the test hypothesis $r = 1.0$.

$K^*K \to a_0(980)\pi$
重散射的重要性

$\mathcal{B}(a_0(980)^+) > \mathcal{B}(a_0(980)^{-(0)})$

$r_{+/-} = 7.5^{+2.5}_{-0.8} \pm 1.7$

$r_{+/0} = 2.6 \pm 0.6 \pm 0.3$

$r_{+/-}$ → E图 > T图

$$\mathcal{B}(D^0 \to \pi^+\pi^-\eta) = (1.24 \pm 0.04 \pm 0.03) \times 10^{-3}$$
$$\mathcal{B}(D^+ \to \pi^+\pi^0\eta) = (2.18 \pm 0.12 \pm 0.05) \times 10^{-3}$$

Amplitude analysis of $D^+ \to K_S^0\pi^+\pi^0\pi^0$

JHEP09(2023)077

BESIII 2022: $\mathcal{B}\left(D^+ \to K_S^0\pi^+\pi^0\pi^0\right) = (2.904 \pm 0.062 \pm 0.087)\%$

Source	1	2	3	4	5	6	7	8
$N_{\rm ST}^{\rm tot}$	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
$(K/\pi)^\pm$ tracking	–	0.4	0.4	0.2	0.6	0.2	0.6	–
$(K/\pi)^\pm$ PID	–	0.4	0.4	0.2	0.6	0.2	0.6	–
K_S^0 reconstruction	1.6	1.6	–	1.6	1.6	1.6	–	3.2
π^0 reconstruction	2.1	2.1	1.4	1.4	0.7	2.1	1.4	0.7
2D fit	1.8	2.0	1.9	0.8	1.6	4.9	3.5	3.9
$\Delta E_{\rm sig}$ requirement	0.3	0.6	0.5	0.7	0.4	0.8	0.6	0.6
Quoted $\mathcal{B}$	0.12	0.10	0.10	0.10	0.08	0.12	0.07	0.14
MC modeling	1.8	0.6	1.2	1.6	2.9	0.8	0.3	–
MC statistics	0.7	0.8	0.9	0.6	0.8	0.9	0.6	0.5
QC effect	0.7	0.6	0.6	–	–	–	–	0.7
Total	3.8	3.3	3.4	3.0	4.0	5.8	4.0	5.2

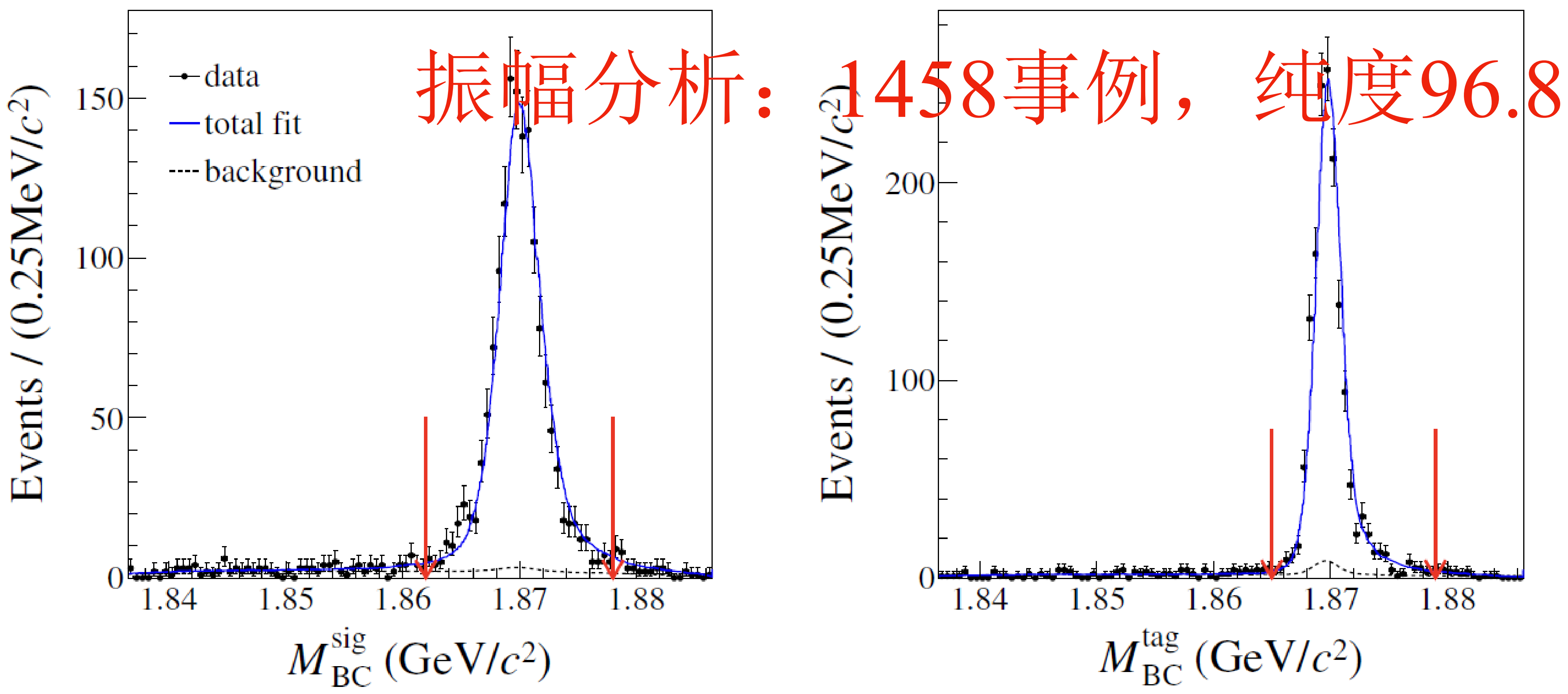
MC 模型是系统误差的主要来源

丰富的中间过程：

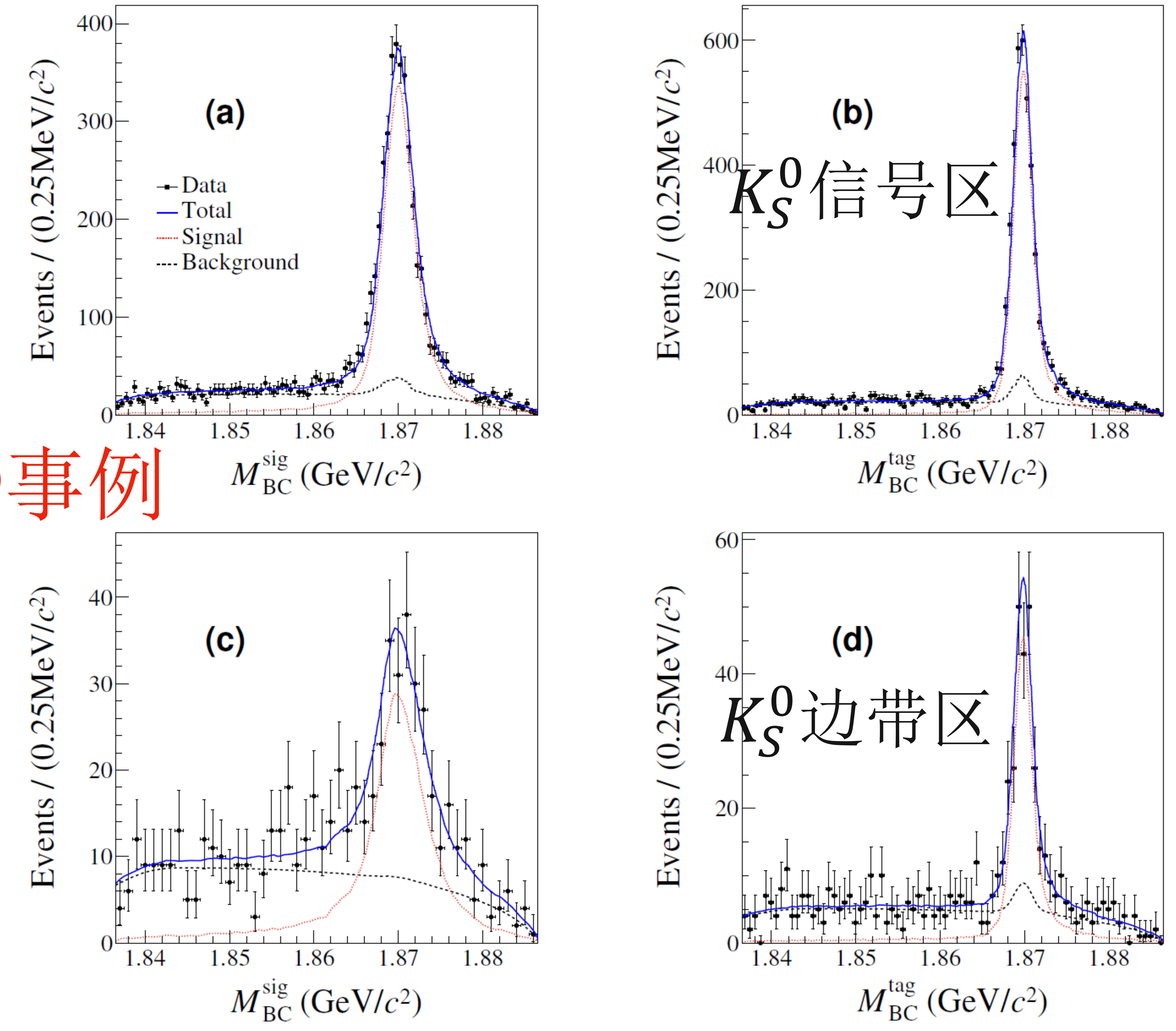
$\bar{K}^{*0}, \rho^+, a_1(1260), K_1(1270), K_1(1400)\ \ldots$

- 极化测量
- 轴矢量介子研究
- …

2.93 fb^{-1}



绝对分支比测量：3679事例



Amplitude analysis of $D^+ \to K_S^0\pi^+\pi^0\pi^0$

首次振幅分析

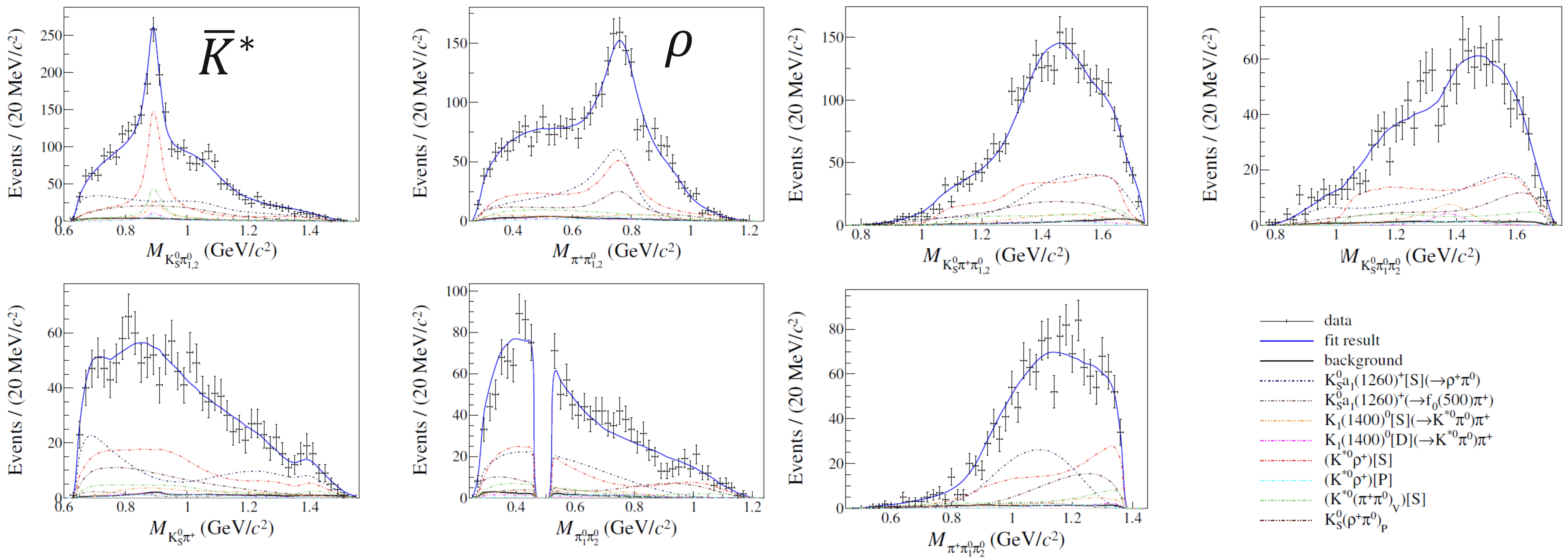
JHEP09(2023)077

Amplitude	Phase ϕ_n (rad)	FF (%)	Significance (σ)
$D^+ \to K_S^0 a_1(1260)^+[S](\to \rho^+\pi^0)$	0.0 (fixed)	$30.0 \pm 3.6 \pm 4.2$	>10
$D^+ \to K_S^0 a_1(1260)^+(\to f_0(500)\pi^+)$	$4.78 \pm 0.22 \pm 0.20$	$3.5 \pm 1.1 \pm 1.9$	6.9
$D^+ \to \bar{K}_1(1400)^0[S](\to \bar{K}^{*0}\pi^0)\pi^+$	$-3.01 \pm 0.12 \pm 0.16$	$6.0 \pm 1.2 \pm 0.3$	9.6
$D^+ \to \bar{K}_1(1400)^0[D](\to \bar{K}^{*0}\pi^0)\pi^+$	$4.29 \pm 0.16 \pm 0.20$	$2.4 \pm 0.6 \pm 0.2$	6.7
$D^+ \to \bar{K}_1(1400)^0(\to \bar{K}^{*0}\pi^0)\pi^+$	—	$8.0 \pm 1.2 \pm 0.4$	—
$D^+[S] \to \bar{K}^{*0}\rho^+$	$-3.33 \pm 0.10 \pm 0.17$	$31.8 \pm 2.7 \pm 1.3$	>10
$D^+[P] \to \bar{K}^{*0}\rho^+$	$-1.68 \pm 0.17 \pm 0.16$	$1.7 \pm 0.6 \pm 0.1$	5.0
$D^+ \to \bar{K}^{*0}\rho^+$	—	$33.6 \pm 2.7 \pm 1.4$	—
$D^+[S] \to \bar{K}^{*0}(\pi^+\pi^0)_V$	$-5.60 \pm 0.13 \pm 0.16$	$9.1 \pm 2.0 \pm 1.0$	9.4
$D^+ \to K_S^0(\rho^+\pi^0)_P$	$0.76 \pm 0.11 \pm 0.24$	$16.5 \pm 1.6 \pm 0.3$	>10

	This work	
$\bar{K}^{*0}\rho^+$	$(5.82 \pm 0.49 \pm 0.28)\%$	$(4.8 \pm 1.2 \pm 1.4)\%$[1]
$K_S^0 a_1[S], a_1 \to \rho^+\pi^0$	$(8.66 \pm 1.04 \pm 1.24) \times 10^{-3}$	$(11.97 \pm 0.62 \pm 1.20 \pm 0.44) \times 10^{-3}$[2]

[1] Phys. Rev.D 45 (1992) 2196 [2] Phys. Rev. D 100 (2019) 072008

- 存在$\bar{K}_1(1400)^0(\to \bar{K}^{*0}\pi^0)\pi^+$，无$K_1(1270)^+\pi^0$，与理论预期一致
- 与$D^+ \to K_S^0\pi^+\pi^+\pi^-$一致

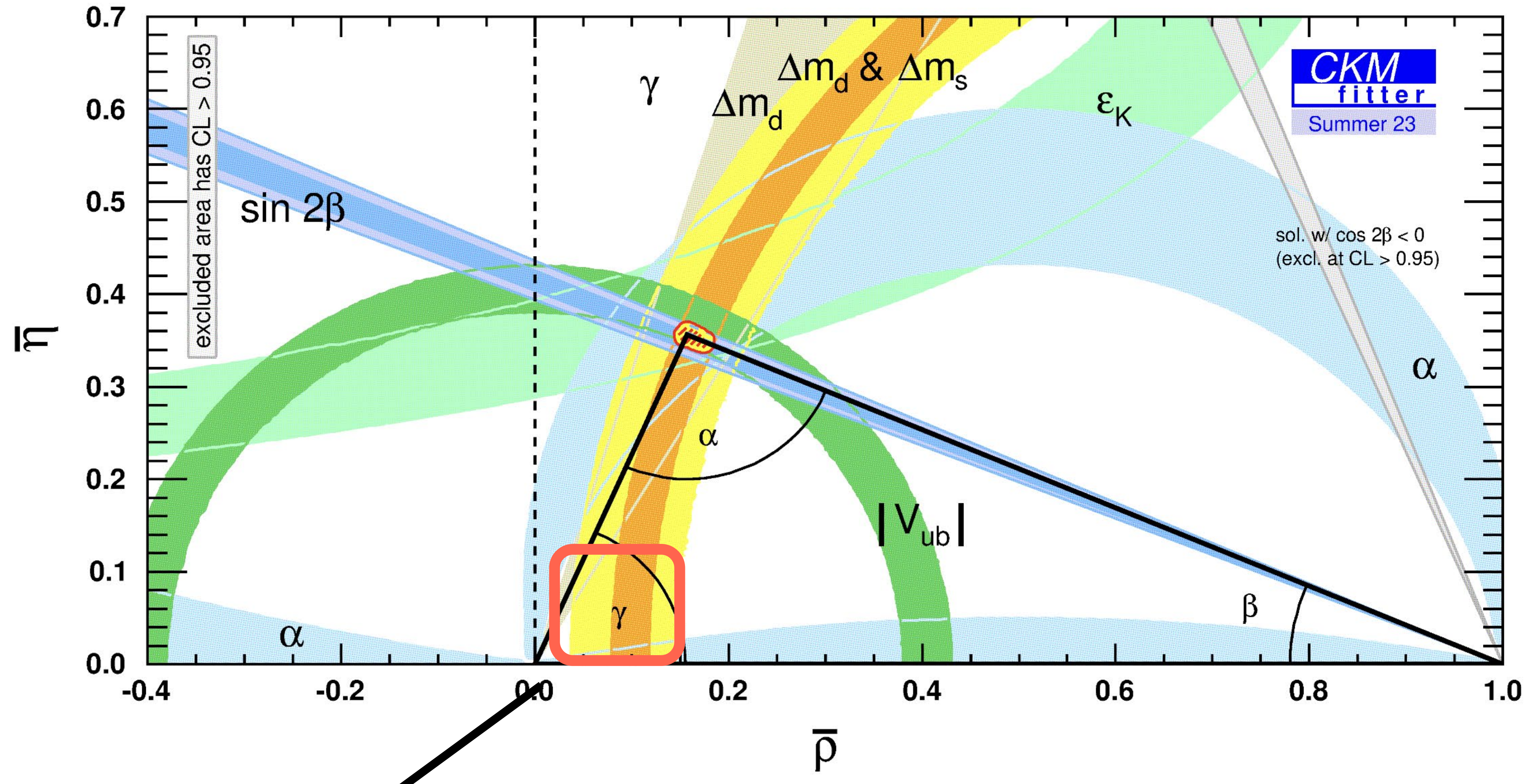


Source	Uncertainty (%)
ST yield	0.5
Tracking efficiency	0.1
PID efficiency	0.1
K_S^0 reconstruction	1.6
π^0 reconstruction	1.4
MC sample size	0.6
Quoted BFs	0.1
Amplitude model	0.6
2D fit	0.5
$\Delta E_{\rm sig}$ requirement	0.4
Total	2.4

$$\mathcal{B}(D^+ \to K_S^0\pi^+\pi^0\pi^0) = (2.888 \pm 0.058 \pm 0.069)\%$$

$D^0 \to \pi^+\pi^-\pi^+\pi^-$ & $D^0 \to \pi^+\pi^-\pi^0\pi^0$

Accepted by CPC



通过$B \to DK$测量CKM角γ检验CKM三角形幺正性 → D^0介子自共轭过程的CP-even比例等参数是重要输入 → $D^0 \to 4\pi$是提取CKM角γ的重要过程

需要可靠的$D^0 \to 4\pi$振幅分析模型为CKM角γ测量提供保障

$D^0 \to 4\pi$

- CP-even比例测量
- CP破坏寻找
- $D \to VV, AP$过程提取

$D^0 \to \pi^+\pi^-\pi^+\pi^-$

- FOCUS，~6000事例，本底~10%
- CLEO，~7000事例，本底~20%

$D^0 \to \pi^+\pi^-\pi^0\pi^0$

- 无振幅分析结果

$D^0 \to \pi^+\pi^-\pi^+\pi^-$ & $D^0 \to \pi^+\pi^-\pi^0\pi^0$

<u>**Accepted by CPC**</u>

Tag mode	$\bar{D}^0 \to K^+\pi^-$	$\bar{D}^0 \to K^+\pi^-\pi^0$	$\bar{D}^0 \to K^+\pi^-\pi^+\pi^-$
N^{ST}	549586 ± 778	914531 ± 1321	600316 ± 856
ϵ^{ST}	0.6762 ± 0.0004	0.2953 ± 0.0001	0.3365 ± 0.0002
$N^{\mathrm{DT}}_{\pi^+\pi^-\pi^+\pi^-}$	1719 ± 42	2560 ± 56	1520 ± 43
$\epsilon^{\mathrm{DT}}_{\pi^+\pi^-\pi^+\pi^-}$	0.2792 ± 0.0006	0.1187 ± 0.0002	0.1221 ± 0.0003
$N^{\mathrm{DT}}_{\pi^+\pi^-\pi^0\pi^0}$ (non-η)	721 ± 32	917 ± 39	562 ± 29
$\epsilon^{\mathrm{DT}}_{\pi^+\pi^-\pi^0\pi^0}$ (non-η)	0.0818 ± 0.0003	0.0319 ± 0.0001	0.0334 ± 0.0001
$\frac{2rR\cos\delta}{1+r^2}$	-0.114 ± 0.004 [31]	-0.067 ± 0.005 [32]	$-0.046^{+0.013}_{-0.011}$ [32]

2.93 fb^{-1}

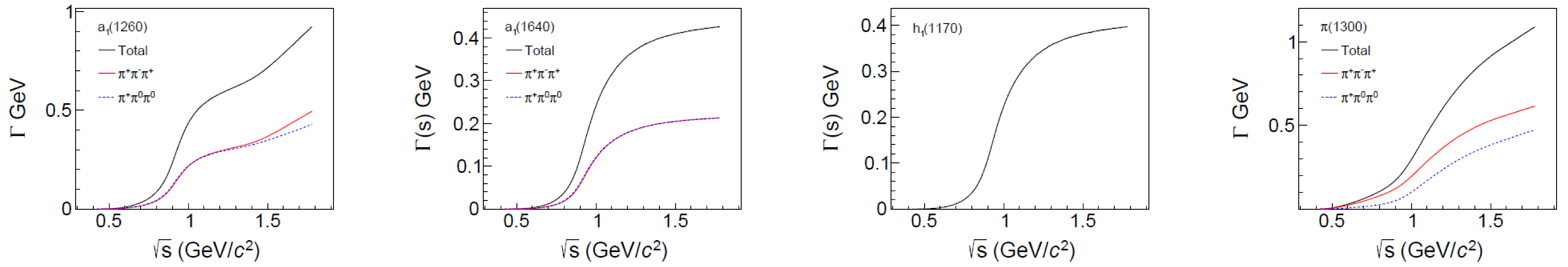
$D^0 \to \pi^+\pi^-\pi^+\pi^-$： ~ 5800事例，纯度~92%

$D^0 \to \pi^+\pi^-\pi^0\pi^0$：~2200事例，纯度~63%

能量依赖宽度：

$$\Gamma_{a\to bcd}(s) \propto \frac{m_0}{\sqrt{s}} \int \sum_{\mathrm{spin}} |A_{a\to bcd}|^2 \mathrm{d}\Phi_3$$

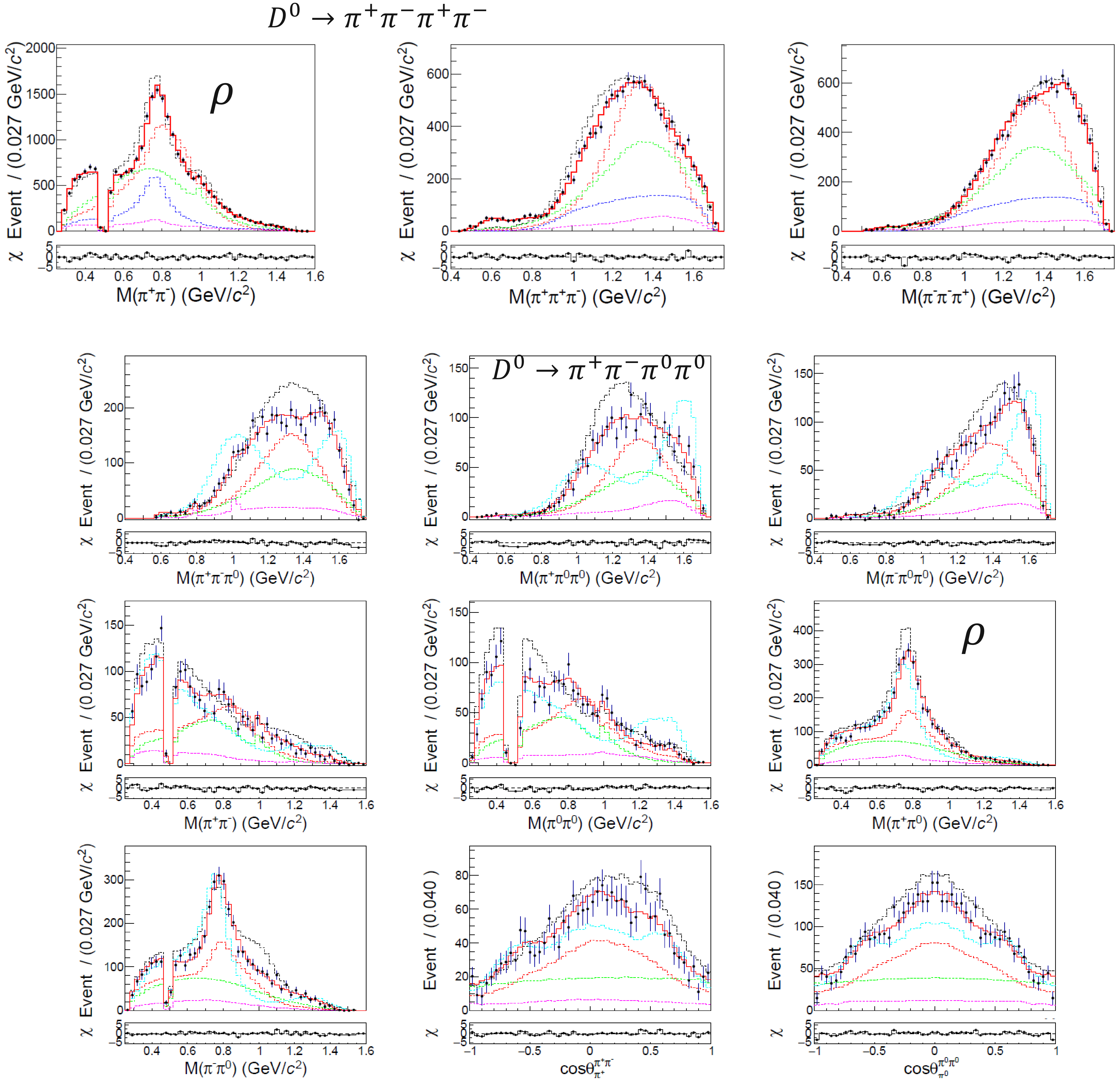
基于振幅分析模型结果



$D^0 \to \pi^+\pi^-\pi^+\pi^-$ & $D^0 \to \pi^+\pi^-\pi^0\pi^0$

Accepted by CPC

	Component	Branching fraction (%)	
		$\pi^+\pi^-\pi^+\pi^-$	$\pi^+\pi^-\pi^0\pi^0$
AP	$D^0 \to a_1(1260)^+\pi^-$	$0.566 \pm 0.024 \pm 0.008 \pm 0.110$	$0.546 \pm 0.027 \pm 0.011 \pm 0.069$
	$D^0 \to a_1(1260)^-\pi^+$	$0.071 \pm 0.010 \pm 0.001 \pm 0.017$	$0.068 \pm 0.011 \pm 0.001 \pm 0.021$
	$D^0 \to a_1(1260)^0\pi^0$	-	$0.313 \pm 0.031 \pm 0.007 \pm 0.082$
	$D^0 \to a_1(1640)^+\pi^-$	$0.012 \pm 0.003 \pm 0.000 \pm 0.006$	$0.010 \pm 0.003 \pm 0.000 \pm 0.007$
	$D^0 \to h_1(1170)^0\pi^0$	-	$0.012 \pm 0.006 \pm 0.000 \pm 0.010$
PP	$D^0 \to \pi(1300)^+\pi^-$	$0.222 \pm 0.018 \pm 0.003 \pm 0.031$	$0.148 \pm 0.014 \pm 0.003 \pm 0.025$
	$D^0 \to \pi(1300)^-\pi^+$	$0.162 \pm 0.016 \pm 0.002 \pm 0.028$	$0.108 \pm 0.011 \pm 0.002 \pm 0.021$
	$D^0 \to \pi(1300)^0\pi^0$	-	$0.221 \pm 0.027 \pm 0.005 \pm 0.033$
	$D^0 \to \pi_2(1670)^0\pi^0$	-	$0.010 \pm 0.002 \pm 0.000 \pm 0.004$
VV	$D^0 \to \rho(770)^0\rho(770)^0$	$0.193 \pm 0.013 \pm 0.003 \pm 0.022$	-
	$D^0 \to \rho(770)^0\rho(770)^0[S]$	$0.012 \pm 0.004 \pm 0.000 \pm 0.003$	-
	$D^0 \to \rho(770)^0\rho(770)^0[P]$	$0.067 \pm 0.007 \pm 0.001 \pm 0.006$	-
	$D^0 \to \rho(770)^0\rho(770)^0[D]$	$0.159 \pm 0.015 \pm 0.002 \pm 0.017$	-
	$D^0 \to \rho(770)^0\rho(1450)^0$	$0.017 \pm 0.006 \pm 0.000 \pm 0.008$	-
	$D^0 \to \rho(770)^0\rho(1450)^0[P]$	$0.007 \pm 0.003 \pm 0.000 \pm 0.003$	-
	$D^0 \to \rho(770)^0\rho(1450)^0[D]$	$0.010 \pm 0.006 \pm 0.000 \pm 0.008$	-
	$D^0 \to \rho(770)^+\rho(770)^-$	-	$0.864 \pm 0.040 \pm 0.018 \pm 0.075$
	$D^0 \to \rho(770)^+\rho(770)^-[S]$	-	$0.124 \pm 0.019 \pm 0.003 \pm 0.033$
	$D^0 \to \rho(770)^+\rho(770)^-[P]$	-	$0.186 \pm 0.013 \pm 0.004 \pm 0.019$
	$D^0 \to \rho(770)^+\rho(770)^-[D]$	-	$0.342 \pm 0.029 \pm 0.007 \pm 0.024$
	$D^0 \to \rho(770)^+\rho(1450)^-[D]$	-	$0.016 \pm 0.008 \pm 0.000 \pm 0.016$
	$D^0 \to \rho(770)^0(\pi\pi)_S$	$0.019 \pm 0.004 \pm 0.000 \pm 0.012$	$0.010 \pm 0.002 \pm 0.000 \pm 0.004$
	$D^0 \to (\pi^+\pi^-)_S(\pi\pi)_S$	$0.432 \pm 0.032 \pm 0.006 \pm 0.066$	$0.356 \pm 0.029 \pm 0.007 \pm 0.049$
TP	$D^0 \to f_2(1270)^0(\pi\pi)_S$	$0.012 \pm 0.003 \pm 0.000 \pm 0.008$	$0.010 \pm 0.002 \pm 0.000 \pm 0.008$
VP	$D^0 \to \omega(782)\pi^0$	-	$0.009 \pm 0.004 \pm 0.000 \pm 0.002$
	$D^0 \to \phi(1020)\pi^0$	-	$0.014 \pm 0.004 \pm 0.000 \pm 0.003$



$D^0 \to \pi^+\pi^-\pi^+\pi^-$ & $D^0 \to \pi^+\pi^-\pi^0\pi^0$

Accepted by CPC

FF(%)	9	13
1. $D^0 \to a_1(1260)^+\pi^-$	-27.3 ± 2.1	5.2 ± 1.1
2. $D^0 \to a_1(1260)^-\pi^+$	-0.1 ± 0.1	3.4 ± 0.5
3. $D^0 \to a_1(1420)^+\pi^-$	0.1 ± 0.1	1.0 ± 0.2
4. $D^0 \to a_1(1640)^+\pi^-$	4.9 ± 0.7	-1.6 ± 0.6
5. $D^0 \to a_1(1640)^-\pi^+$	0.3 ± 0.1	-1.9 ± 0.5
6. $D^0 \to a_2(1320)^+\pi^-$	0.0 ± 0.0	-0.0 ± 0.0
7. $D^0 \to a_2(1320)^-\pi^+$	-0.0 ± 0.0	0.0 ± 0.0
8. $D^0 \to \pi(1300)^+\pi^-$	9.2 ± 1.5	-49.2 ± 4.1
9. $D^0 \to \pi(1300)^-\pi^+$	23.5 ± 2.3	-39.8 ± 3.9
10. $D^0 \to \rho(770)^0\rho(770)^0$		2.0 ± 0.5
11. $D^0 \to \rho(770)^0\rho(1450)^0$		-0.6 ± 0.3
12. $D^0 \to \rho(770)^0(\pi\pi)_S$		0.0 ± 0.0
13. $D^0 \to (\pi^+\pi^-)_S(\pi\pi)_S$		62.8 ± 4.6
14. $D^0 \to f_2(1270)^0(\pi\pi)_S$		

FF(%)	12	14	17
1. $D^0 \to a_1(1260)^+\pi^-$	-18.6 ± 1.8	-33.5 ± 1.8	2.4 ± 0.8
2. $D^0 \to a_1(1260)^-\pi^+$	-7.6 ± 1.0	-12.1 ± 1.1	2.0 ± 0.4
3. $D^0 \to a_1(1260)^0\pi^0$	0.7 ± 0.1	-34.3 ± 2.6	4.8 ± 1.1
4. $D^0 \to a_1(1420)^+\pi^-$	-0.3 ± 0.1	-0.4 ± 0.1	0.7 ± 0.1
5. $D^0 \to a_1(1640)^+\pi^-$	3.7 ± 0.6	3.0 ± 0.5	-1.3 ± 0.4
6. $D^0 \to a_1(1640)^-\pi^+$	1.7 ± 0.5	1.1 ± 0.4	-1.4 ± 0.4
7. $D^0 \to a_2(1320)^+\pi^-$	0.0 ± 0.0	-0.6 ± 0.2	-0.0 ± 0.0
8. $D^0 \to a_2(1320)^-\pi^+$	-0.0 ± 0.0	1.0 ± 0.2	-0.0 ± 0.0
9. $D^0 \to h_1(1170)^0\pi^0$	-0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
10. $D^0 \to \pi(1300)^+\pi^-$	-3.7 ± 0.4	-5.3 ± 0.7	-14.6 ± 1.2
11. $D^0 \to \pi(1300)^-\pi^+$	-3.1 ± 0.4	-1.9 ± 0.6	-11.1 ± 1.1
12. $D^0 \to \pi(1300)^0\pi^0$	23.2 ± 2.8	-5.3 ± 1.2	-21.5 ± 2.2
13. $D^0 \to \pi_2(1670)^0\pi^0$		-0.6 ± 0.2	-0.0 ± 0.0
14. $D^0 \to \rho(770)^+\rho(770)^-$		90.9 ± 3.9	-2.1 ± 1.0
15. $D^0 \to \rho(770)^+\rho(1450)^-[D]$			-1.0 ± 0.3
16. $D^0 \to \rho(770)^0(\pi\pi)_S$			0.0 ± 0.0
17. $D^0 \to (\pi^+\pi^-)_S(\pi\pi)_S$			37.4 ± 3.0
18. $D^0 \to f_2(1270)^0(\pi\pi)_S$			
19. $D^0 \to \omega(782)\pi^0$			
20. $D^0 \to \phi(1020)\pi^0$			

$D^0 \to a_1(1260)\pi, \pi(1300)\pi, \rho(770)\rho(770)$
及$2(\pi\pi)_S$间存在巨大干涉

	$F_+^{\pi^+\pi^-\pi^+\pi^-}$	$F_+^{\pi^+\pi^-\pi^0\pi^0}$(non-$\eta$)
This work (model-dependent)	$(75.2 \pm 1.1_{\text{stat.}} \pm 1.5_{\text{syst.}})\%$	$(68.9 \pm 1.5_{\text{stat.}} \pm 2.4_{\text{syst.}})\%$
CLEO-c (model-dependent)	$(72.9 \pm 0.9_{\text{stat.}} \pm 1.5_{\text{syst.}} \pm 1.0_{\text{model}})\%$ [13]	-
CLEO-c (model-independent, global)	$(73.7 \pm 2.8)\%$ [52]	-
CLEO-c (model-independent, binned)	$(76.9 \pm 2.1_{\text{stat.}} \pm 1.0_{\text{syst.}} \pm 0.2_{K_S\ \text{veto}})\%$ [6]	-
BESIII (model-independent, global)	$(73.4 \pm 1.5_{\text{stat.}} \pm 0.8_{\text{syst.}})\%$ [53]	$(68.2 \pm 7.7)\%$ [54]

$$\mathcal{B}(D^0 \to \pi^+\pi^-\pi^+\pi^-) = (0.688 \pm 0.010 \pm 0.010)\%$$
$$\mathcal{B}(D^0 \to \pi^+\pi^-\pi^0\pi^0) = (0.951 \pm 0.025 \pm 0.021)\%$$

其他粲介子强子衰变振幅分析测量

- ✓ $D_s^+ \to \pi^+\pi^0\pi^0$:**JHEP01(2022)052**
- ✓ $D_s^+ \to K^+\pi^+\pi^-$:**JHEP08 (2022) 196**
- ✓ $D_s^+ \to \pi^+\pi^+\pi^-\pi^0$: 待发表
- ✓ $D_s^+ \to \pi^+\pi^+\pi^-\pi^0\pi^0$: 待发表
- ✓ $D^0 \to K_S^0\pi^0\eta$: 待发表
- ✓ $D^+ \to K_S^0K_S^0\pi^+$: 待发表
- ✓ $D^+ \to \pi^+\pi^0\pi^0$: 待发表
- ✓ $D^+ \to K^+\pi^+\pi^-\pi^0$:待发表

……

总结

✓ **BESIII上粲介子强子衰变振幅分析研究成果丰富**

- 三、四与五体振幅分析的成功研究
- $D \to VP, SP, AP, VV$...等中间过程的精确测量
- $a_0(980)$性质研究

✓ **未来会有更多的重要结果**

- 20 fb^{-1}数据结果
- DCS振幅分析研究

谢谢各位老师、同学的聆听！