Study of $D^0 \to \pi^+\pi^-\eta'$

Belle II Winter School 2026

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Motivation

Precise branching fraction

- Measure $\mathcal{B}(D^0 \to \pi^+\pi^-\eta')$.
- CLEO: $\mathcal{B}(D^0 \to \pi^+\pi^-\eta') = (4.5 \pm 1.6 \pm 0.5) \times 10^{-4}$.
- Total relative uncertainty: 37.3%.

CLEO, Phys. Rev. D 77, 092003 (2008).

Light hadron spectroscopy

Study $f_0(500) \to \pi^+\pi^-$ and $\rho^0(770) \to \pi^+\pi^-$.

Charm CP violation

Search for CP violation in this singly Cabibbo suppressed decay.

Data Set and Software

Data

Run1 + Run2, $\mathcal{L} = 570$ fb^{-1}.

Software

basf2 `light-2607-kasei`.

MC samples

- Generic MC: `MC16rd`.
- Signal MC for signal shapes and efficiencies.

Signal MC channel	Generated events
$D^0 \to \pi^+\pi^-\eta'$	2 000 000
$D^0 \to K^-\pi^+\eta'$	2 000 000

Event Selection

Reconstruction

$$D^{*+} \to D^0 \, \pi^+_{\text{slow}},$$

$$D^0 \to \pi^+\pi^-\eta', \qquad D^0 \to K^-\pi^+\eta',$$

$$\eta' \to \pi^+\pi^-\eta, \qquad \eta \to \gamma\gamma.$$

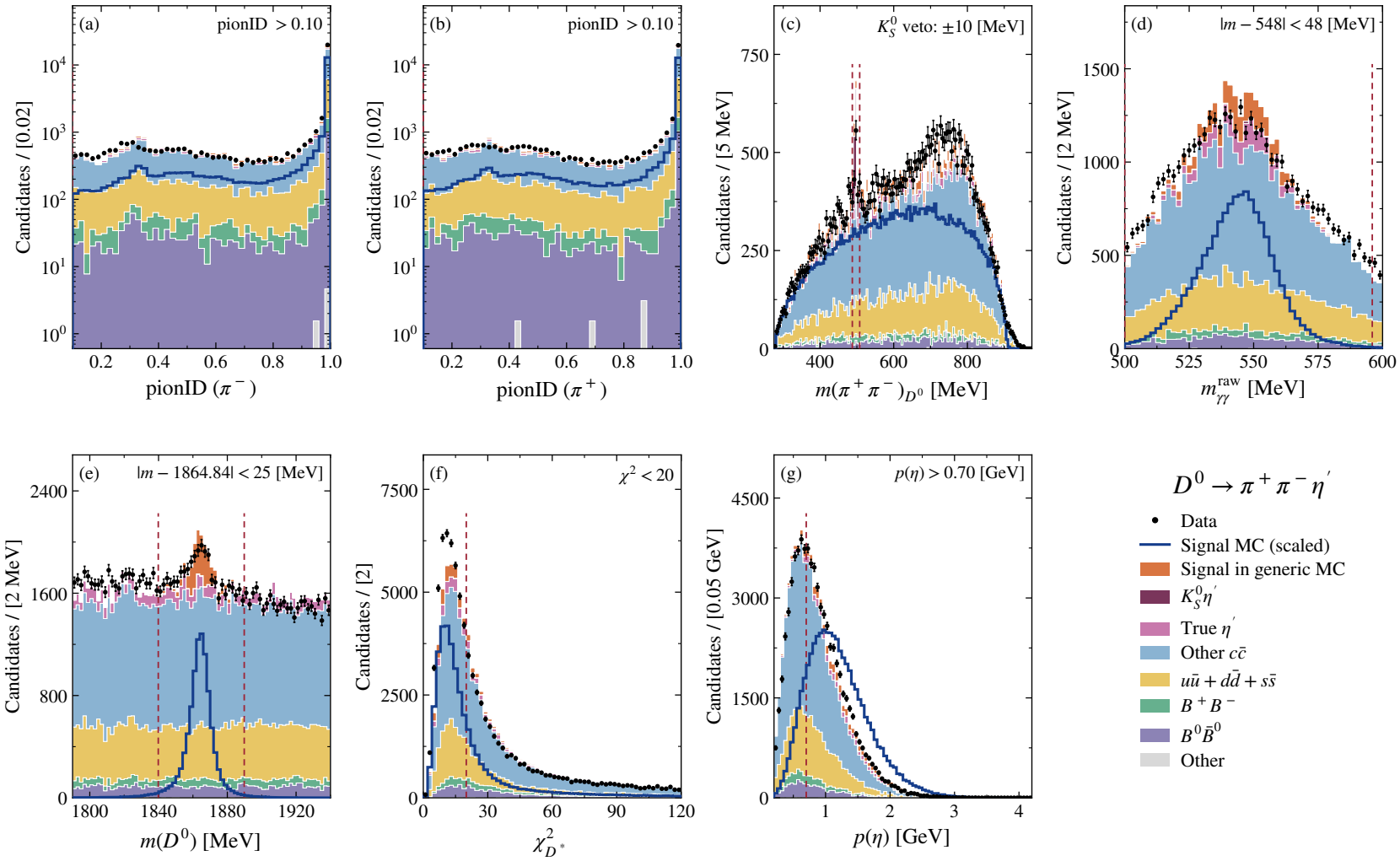
Reconstruction selections

- Tracks: `thetaInCDCAcceptance`, $|d_r| < 0.5$ cm, $|d_z| < 2$ cm.
- Photons: `inCDCAcceptance`, $E_\gamma > 0.05$ GeV, $E_9/E_{21} > 0.6$.
- Tree fit with IP and η mass constraints.

Further Selection

Variable	Signal	Reference
$p_{\text{lab}}(\pi_{\text{slow}})$	< 1 GeV	
π^- `pionID` or K^- `kaonID`	> 0.10	
π^+ `pionID`	> 0.10	
$\lvert m^{\text{raw}}_{\gamma\gamma} - m^{\text{PDG}}_{\eta}\rvert$	< 48 MeV	
$\lvert m(D^0) - m^{\text{PDG}}_{D^0}\rvert$	< 25 MeV	
D^* tree fit χ^2	< 20	
$p(\eta)$	> 0.70 GeV	
$\lvert m(\pi^+\pi^-) - m^{\text{PDG}}_{K^0_S}\rvert$	> 10 MeV	/

Further Selection: Distributions



Cut Flow

Selection	Signal (%)		Reference (%)	
	Absolute	Relative	Absolute	Relative
Generated	100.0	100.0	100.0	100.0
Pre-selection	12.8	12.8	13.5	13.5
π^- `pionID` or K^- `kaonID`	12.8	100.0	13.5	100.0
π^+ `pionID`	12.8	100.0	13.5	100.0
η mass window	12.8	99.8	12.6	93.5
D^0 mass window	12.2	95.4	12.3	98.0
Tree fit χ^2	8.4	68.8	8.3	67.7
$p(\eta)$	7.2	85.7	7.2	86.2
K^0_S veto	6.9	96.5	/	/
2D fit region	6.9	99.1	7.1	99.1

Background Study

Double peaking background

$D^0 \to K^0_S \eta', \quad K^0_S \to \pi^+\pi^-$

- Veto: $|m(\pi^+\pi^-) - m^{\mathrm{PDG}}_{K^0_S}| > 10$ MeV.
- Neglect this channel's contribution after the veto.

Single peaking backgrounds

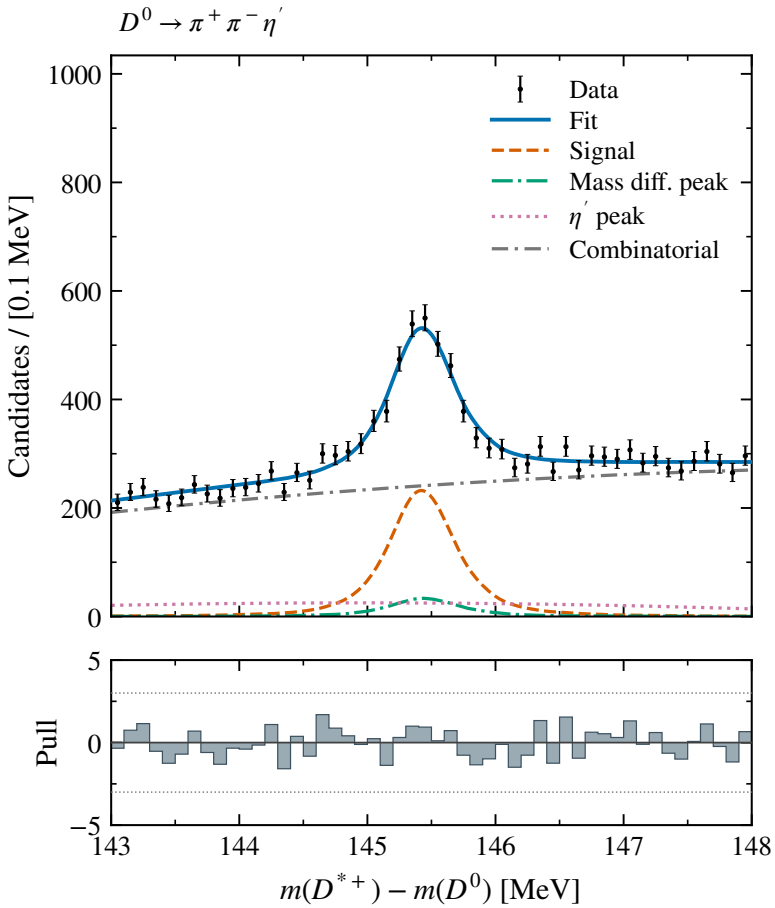
- True η' background: a peak in $m(\pi^+\pi^-\eta)$.
- Peak in $m(D^{*+}) - m(D^0)$: true D^* with a wrong pion assignment in η' reconstruction.

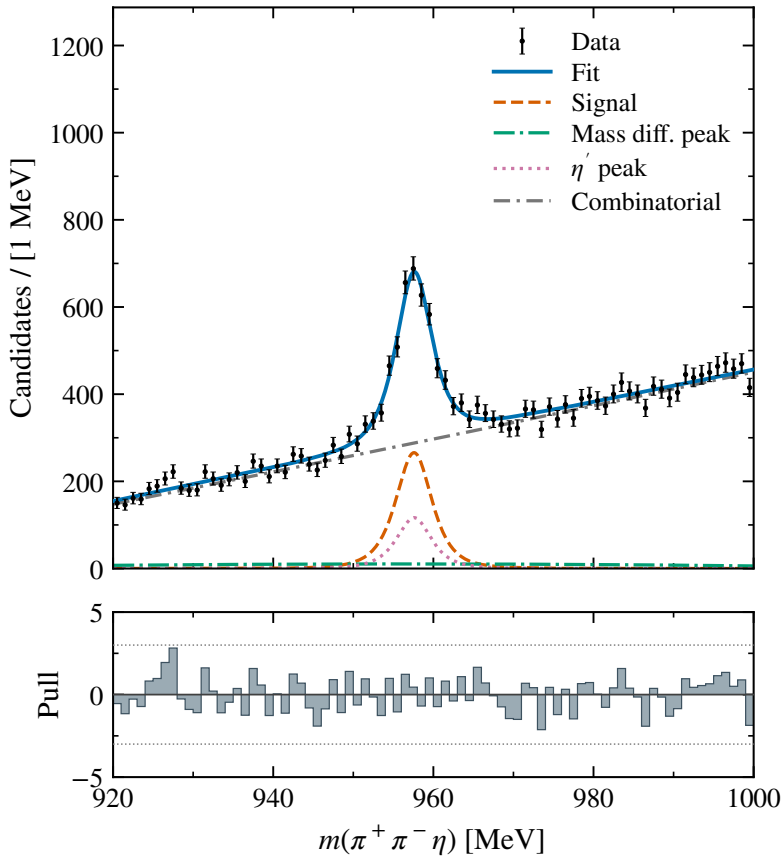
Fit Model

2D fit in $m(D^{*+}) - m(D^0)$ and $m(\pi^+\pi^-\eta)$.

Component	Shape
Signal	2D MC shape $\otimes$ Gaussian resolution
Mass difference peak	MC shape $\times$ 2nd order polynomial
η' peak	2nd order polynomial $\times$ MC shape
Combinatorial	2nd order polynomial $\times$ 2nd order polynomial

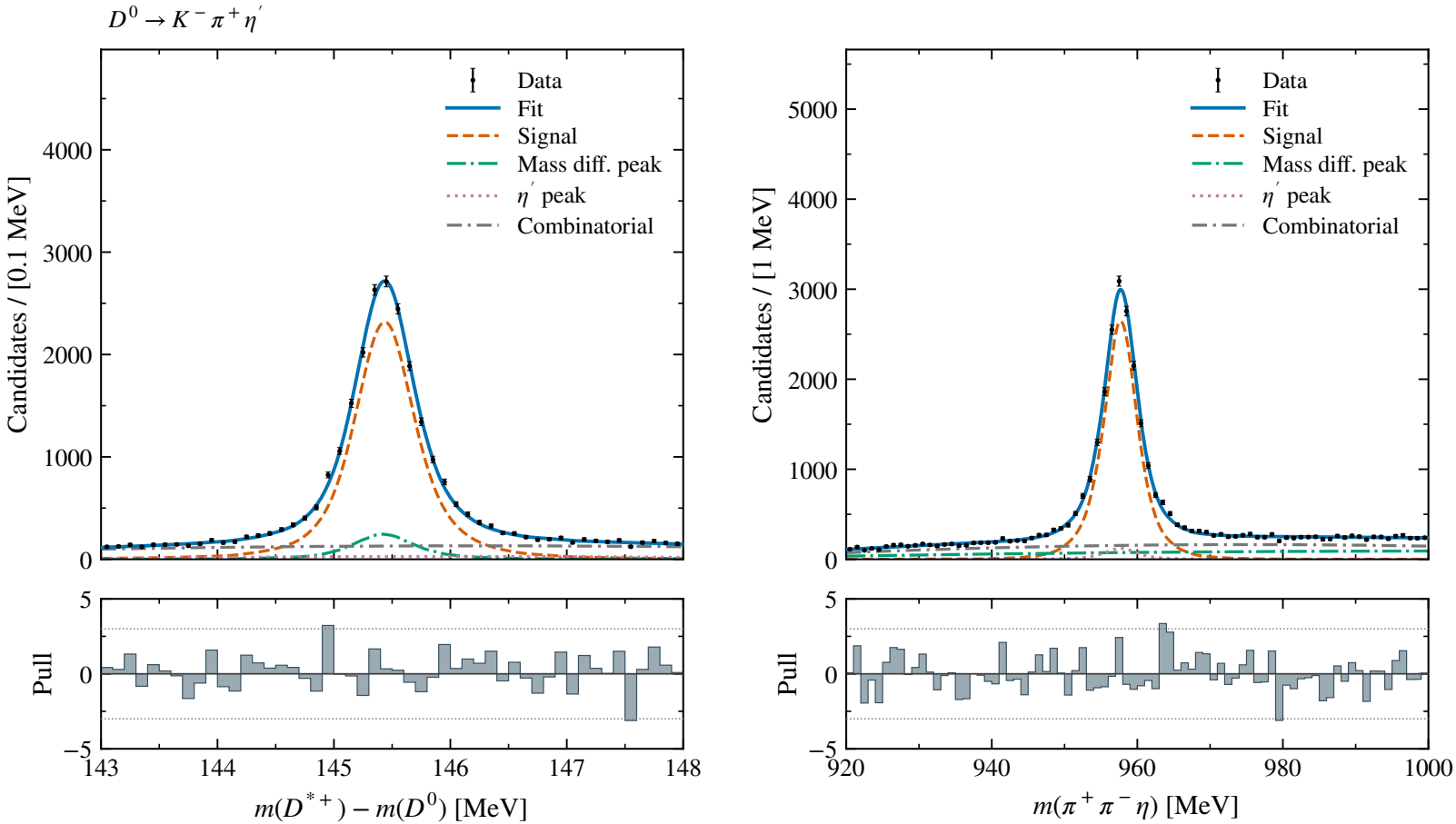
Fit Results: $D^0 \to \pi^+\pi^-\eta'$





$$N_{\text{sig}} = 1740 \pm 85$$

Fit Results: $D^0 \to K^-\pi^+\eta'$



$$N_{\text{ref}} = 17618 \pm 191$$

Relative Branching Fraction

$$R \equiv \frac{\mathcal{B}(D^0 \to \pi^+\pi^-\eta')}{\mathcal{B}(D^0 \to K^-\pi^+\eta')} = \frac{N_{\text{sig}}}{N_{\text{ref}}} \frac{\epsilon_{\text{ref}}}{\epsilon_{\text{sig}}}.$$

Quantity	Signal	Reference
Fitted yield	1740 ± 85	17618 ± 191
Generated MC	2 000 000	2 000 000
Selected MC	137 419	142 391
Efficiency	6.87%	7.12%

$$\boxed{R = (10.23 \pm 0.51_{\text{stat.}}) \times 10^{-2}}$$

Absolute Branching Fraction

$$\mathcal{B}(D^0 \to \pi^+\pi^-\eta') = R\,\mathcal{B}(D^0 \to K^-\pi^+\eta').$$

Reference branching fraction

$\mathcal{B}(D^0 \to K^-\pi^+\eta') = (6.43 \pm 0.34) \times 10^{-3}$.

$$\boxed{\mathcal{B}(D^0 \to \pi^+\pi^-\eta') = (6.58 \pm 0.33_{\text{stat.}} \pm 0.35_{\mathcal{B}_{\text{ref}}}) \times 10^{-4}}$$

Comparison with CLEO

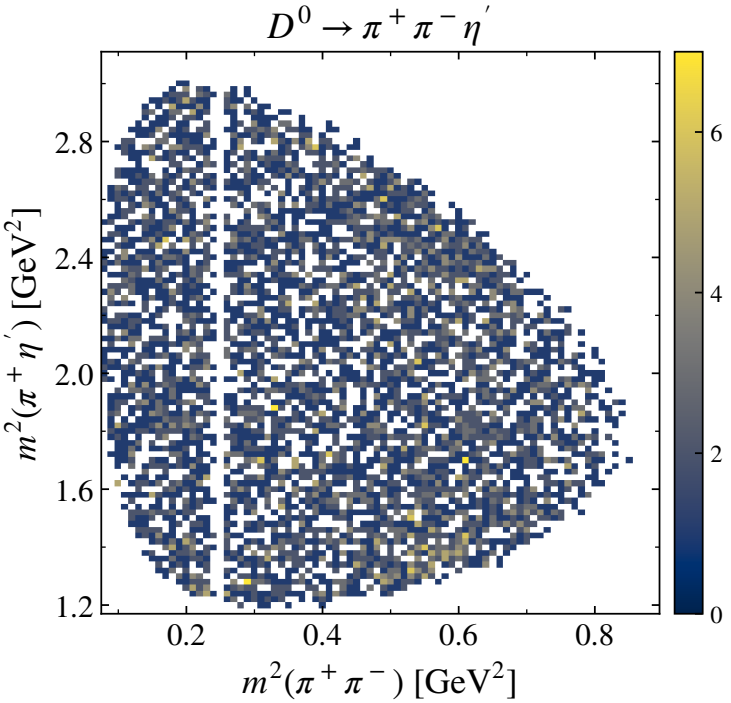
$\mathcal{B}(D^0 \to \pi^+\pi^-\eta') = (4.5 \pm 1.6_{\text{stat.}} \pm 0.5_{\text{syst.}}) \times 10^{-4}$.

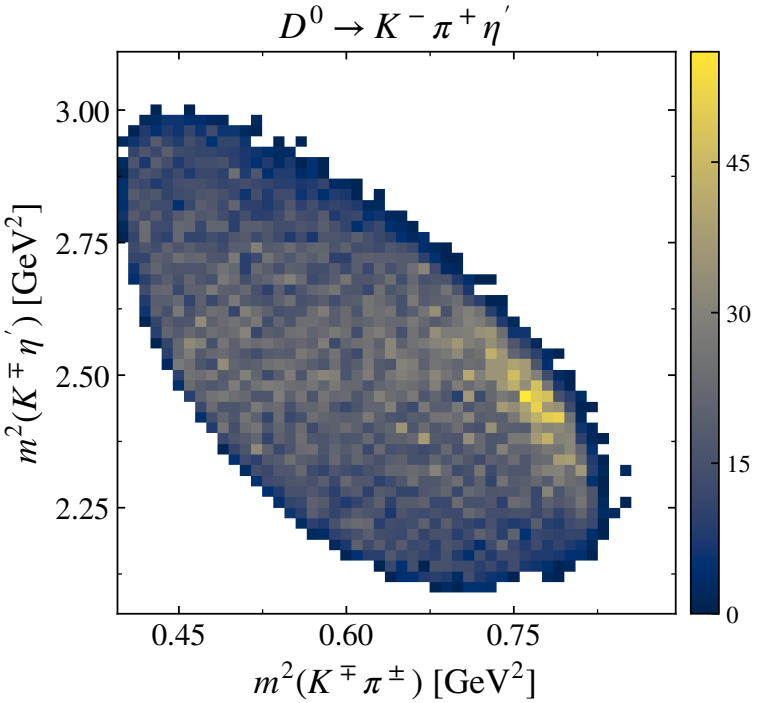
Relative statistical uncertainty
CLEO 35.6% This study 5.0%

The two central values differ by $1.2\,\sigma$.

Data Dalitz Distributions

$|m(D^0) - m_{D^0}^{\mathrm{PDG}}| < 15$ MeV, $\quad 950 < m(\pi^+\pi^-\eta) < 965$ MeV.





Summary and Next Steps

Branching fractions

$$\frac{\mathcal{B}(D^0 \to \pi^+\pi^-\eta')}{\mathcal{B}(D^0 \to K^-\pi^+\eta')} = (10.23 \pm 0.51_{\text{stat.}}) \times 10^{-2}$$

$$\mathcal{B}(D^0 \to \pi^+\pi^-\eta') = (6.58 \pm 0.33_{\text{stat.}} \pm 0.35_{\mathcal{B}_{\text{ref}}}) \times 10^{-4}$$

We reach 7.1 times CLEO's relative statistical precision.

Next steps

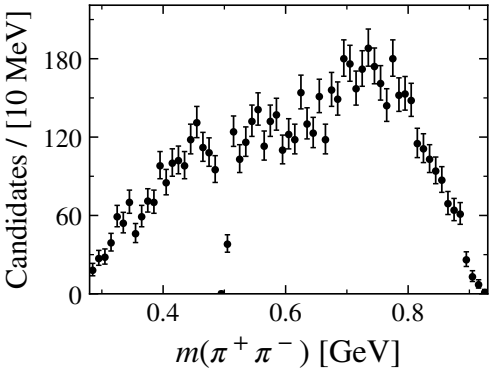
- Estimate peaking backgrounds, including $D^0 \to K^0_S\eta'$ decays that survive the veto.
- Apply PID efficiency corrections for pions and kaons.
- Evaluate the systematic uncertainties.

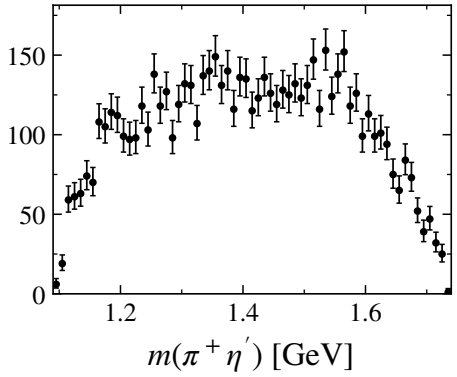
Thank you!

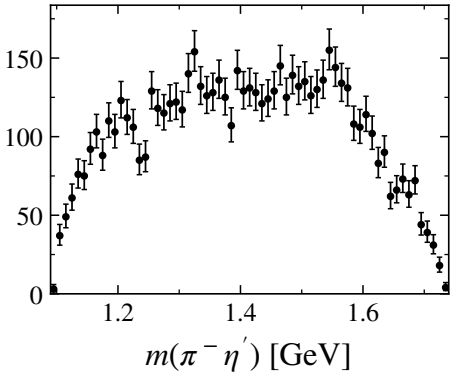
Data Dalitz Mass Projections

$$|m(D^0) - m_{D^0}^{\mathrm{PDG}}| < 15 \text{ MeV}, \qquad 950 < m(\pi^+\pi^-\eta) < 965 \text{ MeV}.$$

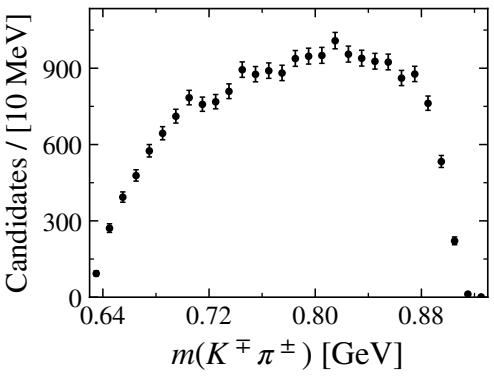
$D^0 \to \pi^+\pi^-\eta'$ 6,691 candidates

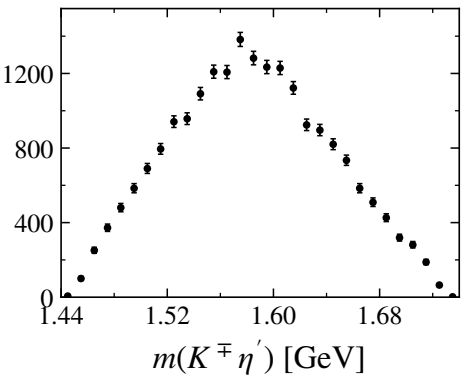


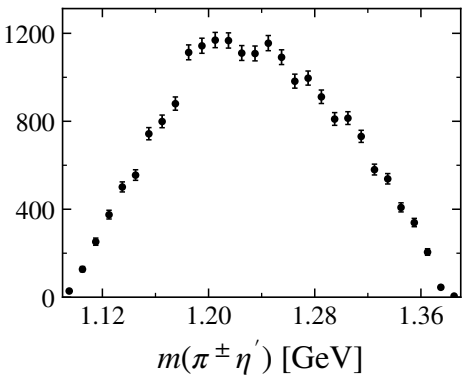




$D^0 \to K^-\pi^+\eta'$ 20,680 candidates







Backup 1