Rediscovery of η and η' in Proc9

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Intro

Rediscovery of η' in B2 data

- Similar work done for exp3, Prod6
  - Documented on BELLE2-NOTE-PH-2018-038
  - under review: got many comments, including request to update to newer processing
- End of year goal is to see $B^0 \to \eta' K^0_S$ in B2 Data
  - Considering $\eta' \to (\eta_{\gamma\gamma/3\pi}\pi^+\pi^-/\rho\gamma)$ $K^0_S \to \pi^+\pi^-$ final states:
  - $\mathcal{B}(B^0 \to \eta' K^0_S) \sim 1.27 \cdot 10^{-5}$
  - From BELLE2-NOTE-PH-2019-025, we have $n_{B\overline{B}} \sim 2.7 \cdot 10^6$
  - $n(B^0 \to \eta' K^0_S) = n_{B^0} \times \mathcal{B} \times \varepsilon \sim \mathcal{O}(1)$ events

Today

Rediscovery of η and η' in different final states using **Proc9** data for Phase III and Phase II

Technicalities

- Using **Proc9** data for Phase III and Phase II
- Release-03-02-02
- GT: **data_reprocessing_proc9**
- input **mdst** for `hlt_hadron` skims
- Exp3, Exp7, and Exp8 **4S**
- **Exp2** $L_{offline} = 0.495\ \text{fb}^{-1}$
- **Exp7** $L_{offline} = 0.643\ \text{fb}^{-1}$
  only $0.114\ \text{fb}^{-1}$ for final states with ρ
- **Exp8 4S** $L_{offline} = 1.980\ \text{fb}^{-1}$

✗ No MC comparison (yet)

particles list

- ✓ $\pi^0 \to \gamma\gamma$
- 🔧 $K^0_S \to \pi^+\pi^-$
- ✓ $\eta \to \gamma\gamma$
- ✓ $\eta \to \pi^+\pi^-\pi^0$
- ✓ $\eta' \to \eta(\to \gamma\gamma)\pi^+\pi^-$
- ✓ $\eta' \to \eta(\to \pi^+\pi^-\pi^0)\pi^+\pi^-$
- ✓ $\rho \to \pi^+\pi^-$
- ✓ $f_0(975) \to \pi^+\pi^-$
- ✓ $\eta' \to \rho(\to \pi^+\pi^-)\gamma$

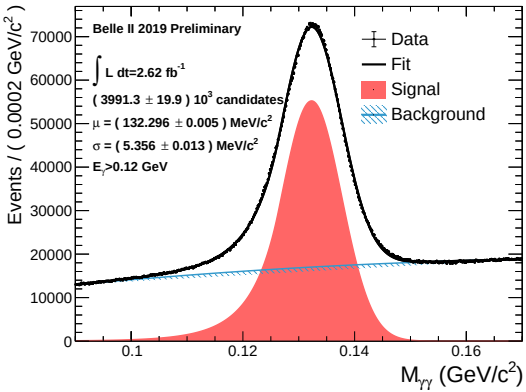
$\pi^0 \to \gamma\gamma$ reconstruction

Selection:

- `gamma:tight` from `stdPhotons`
  - $0.296706 < \theta_\gamma < 2.61799$
  - *clusterTimingError* $< 1e6$ and $[E_1/E_9 > 0.4$ or $E > 0.075$ GeV$]$
  - $E_{reg==1} > 0.05$ GeV
    $E_{reg==2} > 0.05$ GeV
    $E_{reg==3} > 0.075$ GeV
- Cluster: $N_{hits} > 1.5$, $E_9/E_{21} > 0.9$
- $E_\gamma > 120$ MeV

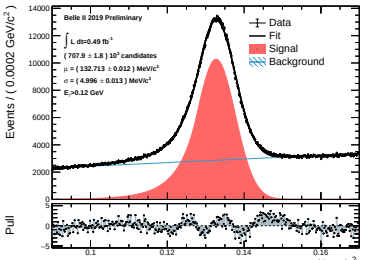
Binned-ML Fit with (CrystalBall + Gauss) + Chebychev[1]
Plot approved for LP:
BELLE2-NOTE-PL-2019-019

Invariant Mass plot for Data Proc9 Phase III Exp 7+8

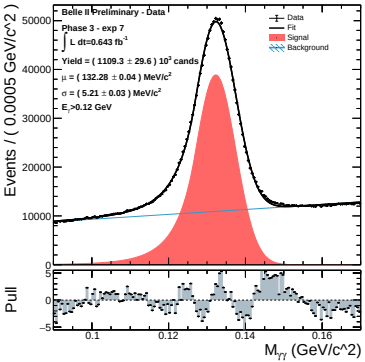


$\pi^0 \to \gamma\gamma$ Data Proc9 Exp7 - Exp8 comparison

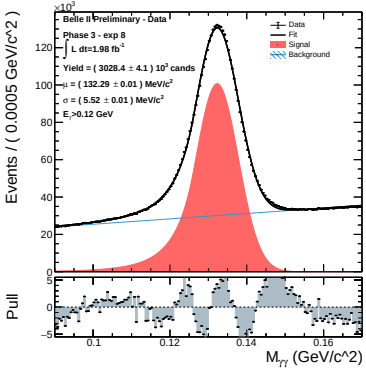
Data - Phase II Proc 9 - Exp3



Data - Phase III Proc 9 - Exp7



Data - Phase III Proc 9 - Exp8



$\mu = 132.7/132.3/132.3\,\text{MeV}$ (Exp3/7/8)
$\sigma = 5.0/5.2/5.5\,\text{MeV}$ $\sigma_{Exp8} > \sigma_{Exp7} > \sigma_{Exp3}$ Fit with single CB not optimal (θ, p dependent resolution and tails?)
Yield **does** scale with luminosity.

$\eta \to \gamma\gamma$ reconstruction

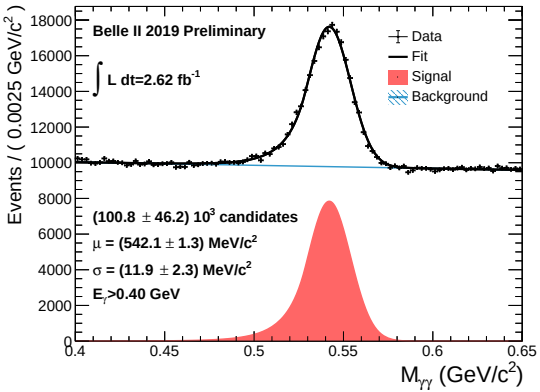
Selection:

- `gamma:tight` from `stdPhotons`
  - $0.296706 < \theta_\gamma < 2.61799$
  - *clusterTimingError* $< 1e6$ and $[E_1/E_9 > 0.4$ or $E > 0.075$ GeV$]$
  - $E_{reg==1} > 0.05$ GeV
    $E_{reg==2} > 0.05$ GeV
    $E_{reg==3} > 0.075$ GeV
- Cluster: $N_{hits} > 1.5$, $E_9/E_{21} > 0.9$
- $E_\gamma > 400$ MeV

Binned-ML Fit with CrystalBall + Chebychev[1]

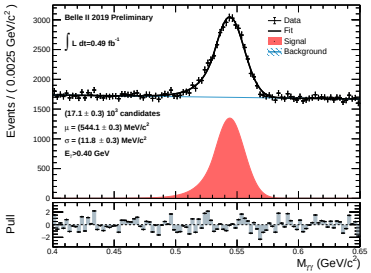
Plot approved for LP:
BELLE2-NOTE-PL-2019-019

Invariant Mass plot for Data Proc9

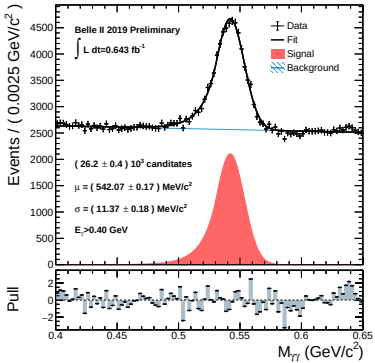


$\eta \to \gamma\gamma$ Data Proc9 Exp7 - Exp8 comparison

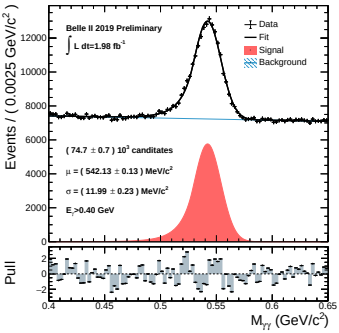
Data - Phase II Proc 9 - Exp3



Data - Phase III Proc 9 - Exp7



Data - Phase III Proc 9 - Exp8



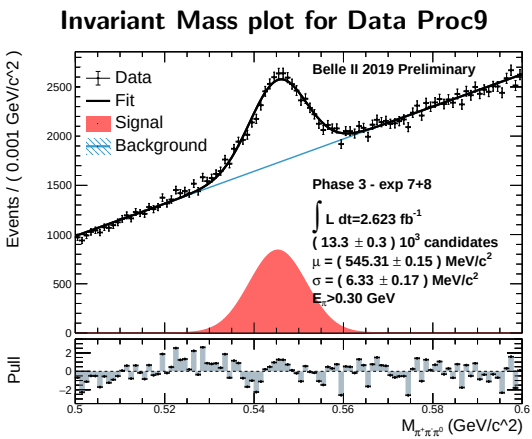
$\mu = 544.1/542.1/542.1\,\text{MeV}$ (Exp3/7/8)
$\sigma = 11.8/11.4/12.0\,\text{MeV}$ (Exp3/7/8)
Yield **does** scale with luminosity.

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

Selection:

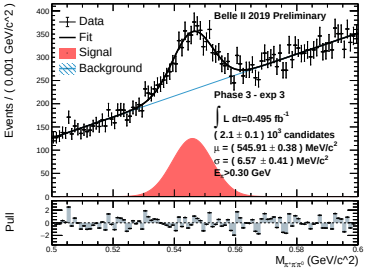
- π^0
  - Same as for π^0 earlier
  - $E_\gamma > 300$ MeV
  - $0.11 < M < 0.15$ MeV
- $\pi^\pm$
  - $p_\pi > 300$ MeV
- TreeFitter with π^0 mass constraint

Binned-ML Fit with CrystalBall + Chebychev[1]

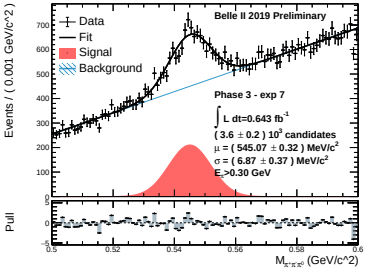


$\eta \to \pi^+\pi^-\pi^0$ vs experiment

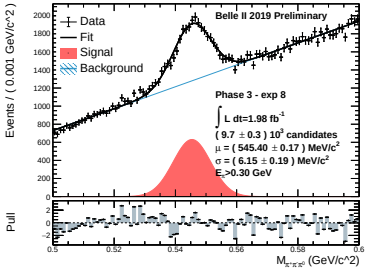
Phase II Proc 9 - Exp3



Phase III Proc 9 - Exp7



Phase III Proc 9 - Exp8



$\mu = 545.9/545.1/545.5\,\text{MeV}$ (Exp3/7/8) ($> M_{\eta\to\gamma\gamma} = 542\,\text{MeV}$)
$\sigma = 6.6/6.9/6.2\,\text{MeV}$ (Exp3/7/8)
Yield ok scale with luminosity.

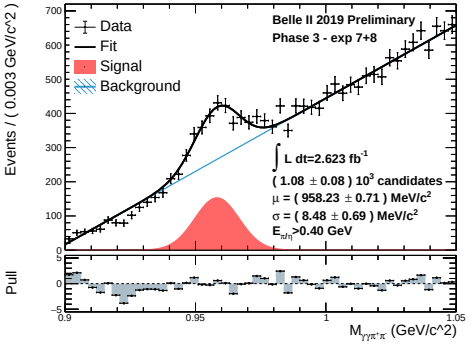
$\eta' \to \eta(\to \gamma\gamma)\pi^+\pi^-$ reconstruction

Selection:

- $\eta \to \gamma\gamma$
  - Same as for π^0
  - $0.48 < M < 0.58$ MeV
  - $p_\eta > 400$ MeV
- $\pi^\pm$
  - $p_\pi > 400$ MeV
- TreeFitter with η mass constraint

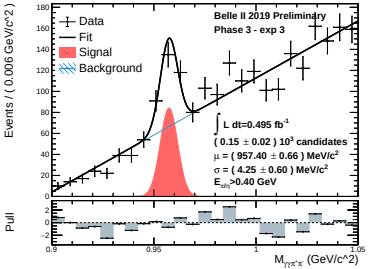
UML Fit with Gauss + Chebychev[1]

Invariant Mass plot for Data Proc9

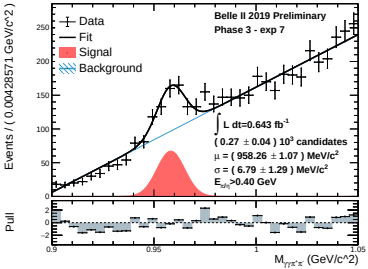


$\eta' \to \eta(\to \gamma\gamma)\pi^+\pi^-$ vs experiment

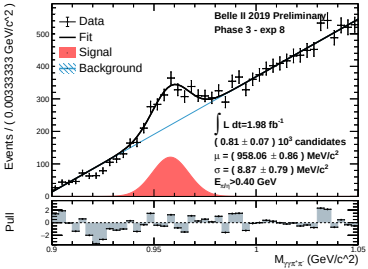
Data - Phase II Proc 9 - Exp3



Data - Phase III Proc 9 - Exp7



Data - Phase III Proc 9 - Exp8



$\mu = 958.1/958.3/957.4$ MeV (Exp3/7/8)
$\sigma = 4.25/6.8/8.9/$ MeV (Exp3/7/8)
Exp3 peak quite narrow, maybe statistics or fit?
was $\sigma = 12$ MeV with Prod6, comparable with MC (10 MeV). Yield with Prod6 was 87 ± 21 vs 150 ± 20 candidates (see backup)

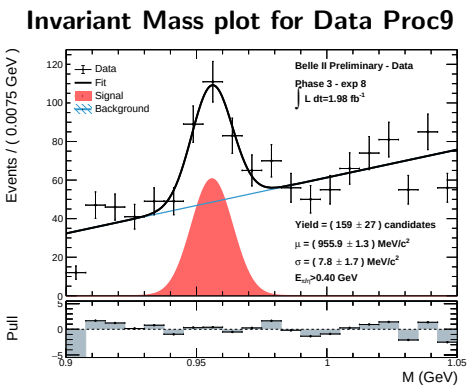
$\eta' \to \eta(\to \pi^+\pi^-\pi^0)\pi^+\pi^-$ reconstruction

Selection:

- $\eta \to\to \pi^+\pi^-\pi^0$
  - γ: same as for π^0
  - $E_\gamma > 0.400$ MeV
  - $0.51 < M < 0.58$ MeV
  - $p_\eta > 400$ MeV
- $\pi^\pm$
  - $p_\pi > 400$ MeV
- TreeFitter with π^0 and η mass constraint

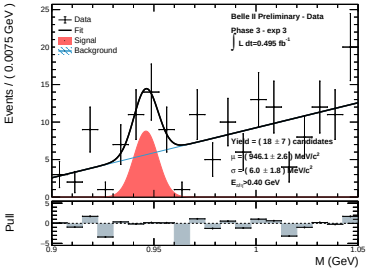
UML Fit with Gauss + Chebychev[1]

$M_{\eta' \to \eta(\to\gamma\gamma)\pi^+\pi^-} = 958.2 \pm 0.7$ MeV

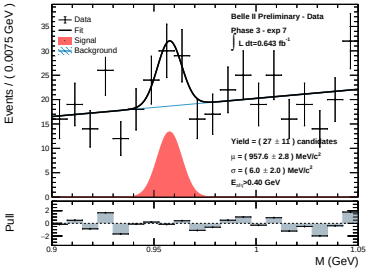


$\eta' \to \eta(\to \pi^+\pi^-\pi^0)\pi^+\pi^-$ vs experiment

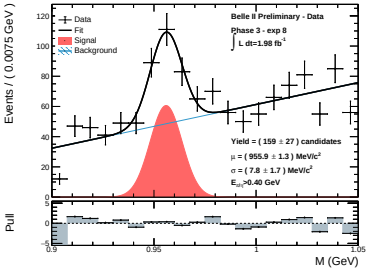
Data - Phase II Proc 9 - Exp3



Data - Phase III Proc 9 - Exp7



Data - Phase III Proc 9 - Exp8



$\mu = 946958/956\,\text{MeV}$ (Exp3/7/8) ($M_{\eta' \to \eta(\to\gamma\gamma)\pi^+\pi^-} = 958.2\,\text{MeV}$)

$\sigma = 6.0/6.0/7.8\,\text{MeV}$

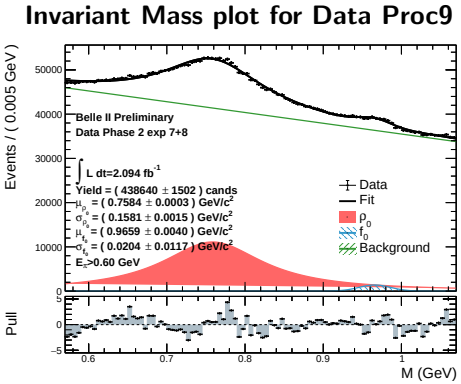
Exp3/Exp7 quite dubious peaks.

$\rho \to \pi^+\pi^-$) reconstruction

Selection:

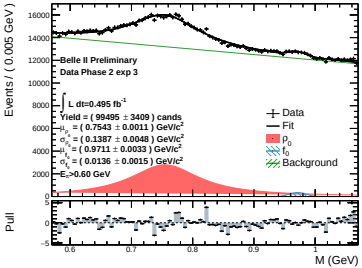
- $\rho \to \pi^+\pi^-$
  - $0.57 < M < 0.95$ MeV
  - $p_\pi > 600$ MeV

Possible structure at 970 MeV
$f_0(975) \to \pi^+\pi^-$?
Binned-ML Fit with BreitWigner ρ + Gauss $f_0(975)$ + Chebychev[1]

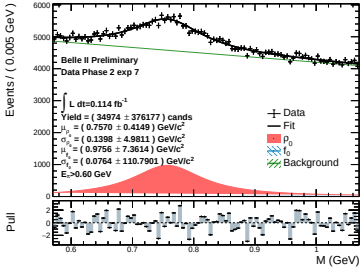


$\eta' \to \rho(\to \pi^+\pi^-)\gamma$ vs experiment

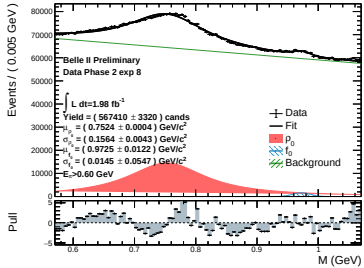
Data - Phase II Proc 9 - Exp3



Data - Phase III Proc 9 - Exp7



Data - Phase III Proc 9 - Exp8



Large background
$f_0(975)$ seen also in Exp3
Warning $L_{exp7} = 0.114\,\text{fb}^{-1}$ due to technical problems

$\eta' \to \rho(\to \pi^+\pi^-)\gamma$ reconstruction

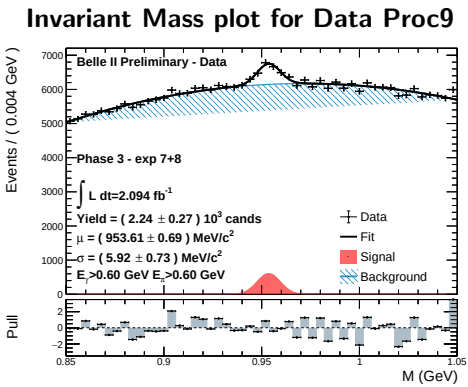
Selection:

- $\rho \to \pi^+\pi^-$
  - $0.57 < M < 0.95$ MeV
  - $p_\pi > 600$ MeV
- γ
  - same as for π^0
  - $E_\gamma > 600$ MeV
- TreeFitter with ρ mass constraint

UML Fit with Gauss + Chebychev[2]

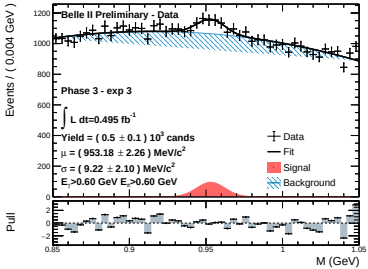
$M_{\eta' \to \eta(\to \gamma\gamma)\pi^+\pi^-} = 958.2 \pm 0.7$ MeV

$M_{\eta' \to \eta(\to \pi^+\pi^-\pi^0)\pi^+\pi^-} = 955.9 \pm 1.3$ MeV

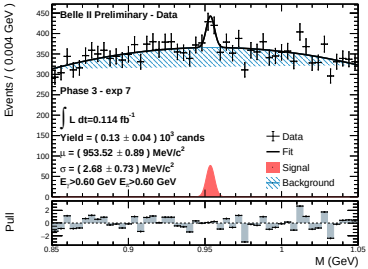


$\eta' \to \rho(\to \pi^+\pi^-)\gamma$ vs experiment

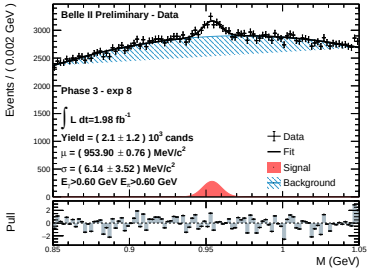
Data - Phase II Proc 9 - Exp3



Data - Phase III Proc 9 - Exp7



Data - Phase III Proc 9 - Exp8



$\mu = 953.2/953.5/953.9\,\text{MeV}$ (Exp3/7/8) ($> M_{\eta\to\gamma\gamma} = 542\,\text{MeV}$)
$\sigma = 9.2/2.7/6.1\,\text{MeV}$
exp7 peak significantly narrower, $L_{exp7} = 0.114\,\text{fb}^{-1}$
Very large background

Summary

All η' final states rediscovered on Data

TODO:

- update on BELLE2-NOTE-PH-2018-038
- Look $B^0 \to \eta' K^0_S$ and $B^\pm \to \eta' K^\pm$ ($\mathcal{B} = 7 \cdot 10^{-5}$) in data?
  - Do not expect any signal, but can study background
- Look at MC12
  - both for η and η' to compare with data
  - and $B^0 \to \eta' K^0_S$

Light meson rediscovered

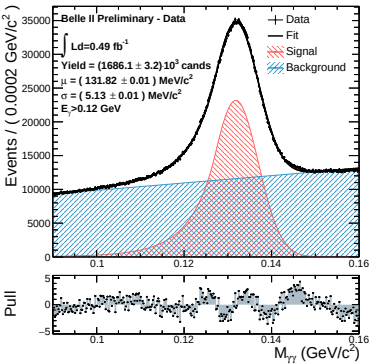
- ✓ $\pi^0 \to \gamma\gamma$
- $K^0_S \to \pi^+\pi^-$
- ✓ $\eta \to \gamma\gamma$
- ✓ $\eta \to \pi^+\pi^-\pi^0$
- ✓ $\eta' \to \eta(\to \gamma\gamma)\pi^+\pi^-$
- ✓ $\eta' \to \eta(\to \pi^+\pi^-\pi^0)\pi^+\pi^-$
- ✓ $\rho \to \pi^+\pi^-$
- ✓ $f_0(975) \to \pi^+\pi^-$
- ✓ $\eta' \to \rho(\to \pi^+\pi^-)\gamma$

Additional stuff

Additional or backup slides

Prod6 results on Phase II Exp3

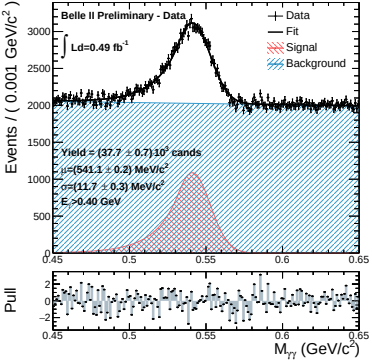
$\pi^0 \to 2\gamma$ Prod 6 - Exp3



Proc9 Exp3

$\mu = 132.71\,\text{MeV}$ $\sigma = 5.0\,\text{MeV}$

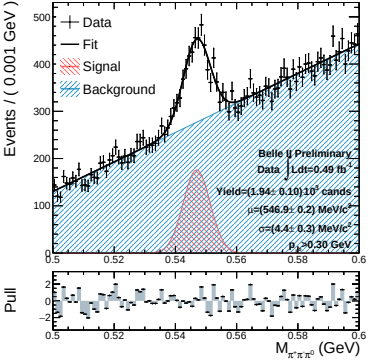
$\eta \to 2\gamma$ Prod 6 - Exp3



Proc9 Exp3

$\mu = 544.11\,\text{MeV}$ $\sigma = 11.8\,\text{MeV}$

$\eta \to 3\pi$ Prod 6 - Exp3

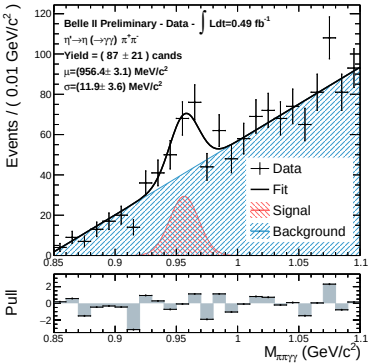


Proc9 Exp3

$\mu = 545.91\,\text{MeV}$ $\sigma = 6.6\,\text{MeV}$

Prod6 results on Phase II Exp3

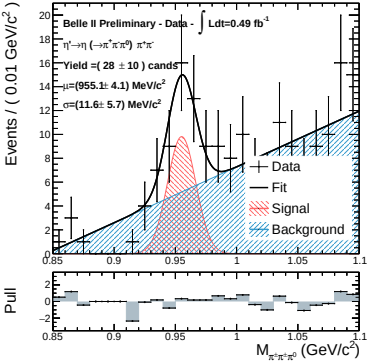
$\eta' \to \eta_{\to\gamma\gamma} 2\pi$ Prod 6 - Exp3



Proc9 Exp3

$\mu = 957.4\,\text{MeV}$ $\sigma = 4.25\,\text{MeV}$

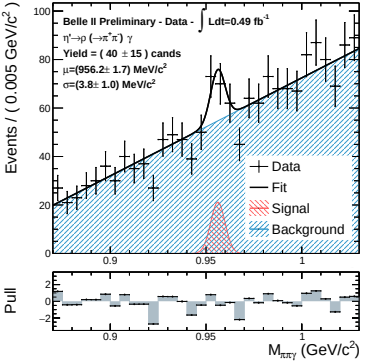
$\eta' \to \eta_{\to 3\pi} 2\pi$ Prod 6 - Exp3



Proc9 Exp3

$\mu = 946\,\text{MeV}$ $\sigma = 6\,\text{MeV}$

$\eta' \to \rho\gamma$ Prod 6 - Exp3



Proc9 Exp3

$\mu = 953.2\,\text{MeV}$ $\sigma = 9.2\,\text{MeV}$

Bibliography I