

# $\eta'$ meson rediscovery - update

Stefano Lacaprara

`stefano.lacaprara@pd.infn.it`

INFN Padova

Phys Perf meeting,  
SpeakApp, 8 November 2018

## Light meson in Belle II - Phase II

- **Update on  $\eta'$  rediscovery in Phase2 data**
  - ▶ Previous presentation 25/10/2018
  - ▶ JIRA ticket is **BIIPH2-62**
- **What is new:**
  - ▶ better MC phase2: use  $q\bar{q}$  (previously using only  $B\bar{B}$  - mixed events)
  - ▶ now  $\eta' \rightarrow \eta(\rightarrow \pi^+\pi^-\pi^0)\pi^+\pi^-$  visible in MC also (was not)
  - ▶ allowed to tune a bit better cut for  $\eta' \rightarrow \rho\gamma$
  - ▶  $\eta' \rightarrow \rho(\rightarrow \pi^+\pi^-)\gamma$  in Data!
- note not completed yet (sorry)

This presentation

Collect the work done so far

## particle list

- ✓  $\pi^0 \rightarrow \gamma\gamma$  (25/10/2018)
- ✓  $\rho \rightarrow \pi^+\pi^-$  (25/10/2018)
- ✓  $f_0(975) \rightarrow \pi^+\pi^-$  (25/10/2018)
- ✓  $K_S^0 \rightarrow \pi^+\pi^-$  (25/10/2018)
- ✓  $\phi \rightarrow K^+K^-$  (25/10/2018)
- ✓  $\eta \rightarrow \gamma\gamma$  (25/10/2018)
- ✓  $\eta \rightarrow \pi^+\pi^-\pi^0$  (25/10/2018)
- ✓  $\eta' \rightarrow \eta(\rightarrow \gamma\gamma)\pi^+\pi^-$  (better MC)
- ✓  $\eta' \rightarrow \eta(\rightarrow \pi^+\pi^-\pi^0)\pi^+\pi^-$  (now ok in MC)
- ✓  $\eta' \rightarrow \rho(\rightarrow \pi^+\pi^-)\gamma$  (new)

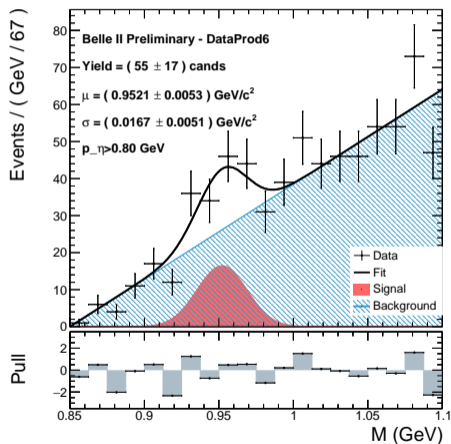
- MC phase II (new)
  - ▶ MC10 BGx1
  - ▶ [ $q\bar{q}$  for  $q$  in u d s c] Prod 4779 4780 4781 4782
  - ▶ Previously only mix MC (not  $c\bar{c}$  as wrongly reported)
- Data
  - ▶ exp3, Prod6, skim Hadron `[[nTracksLE>=3] and [Bhabha2Trk==0]]`
  - ▶ Runs: 529:5613: Lumi: 491.5  $\text{pb}^{-1}$
- Data Challenge - MC phase 3
  - ▶ skim TDCPV (ProdID 5142)
  - ▶ skim TDCPV Confluence page

### Selection:

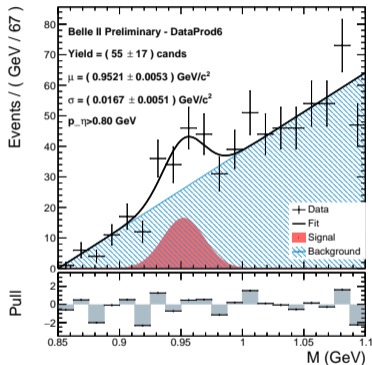
- $\eta \rightarrow \gamma\gamma$ 
  - ▶  $E_9/E_{25} > 0.75$
  - ▶ Cluster:  $N_{hits} > 5$ ,  $E_9/E_{21} > 0.93$
  - ▶  $E_\gamma > 400$  MeV
  - ▶  $0.52 < M_{\gamma\gamma} < 0.56$  GeV
  - ▶  $p_\eta > 800$  MeV
- $\pi^\pm$ 
  - ▶  $|d_0(\pi)| < 2$  cm,  $|z_0(\pi)| < 4$  cm
  - ▶  $PionID > 0.5$ ,  $KaonID < 0.5$
  - ▶  $p_\pi > 400$  MeV
- VertexFit with  $\eta \rightarrow \gamma\gamma$  mass constrained

UML Fit with Gauss + Chebychev[1]  
**maybe a signal**

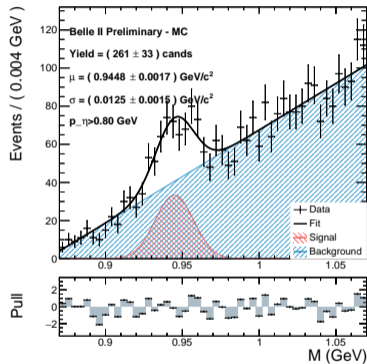
### Invariant Mass plot for Data Prod6, $500 \text{ nb}^{-1}$



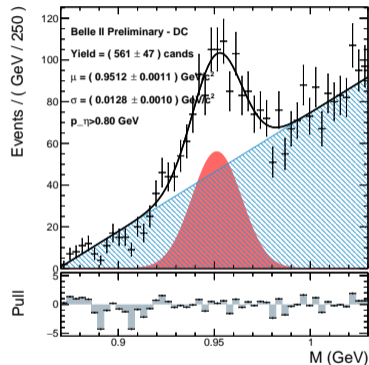
### Data - Phase 2



### MC - Phase 2 BGx1



### MC - Phase 3 BGx1 - DC



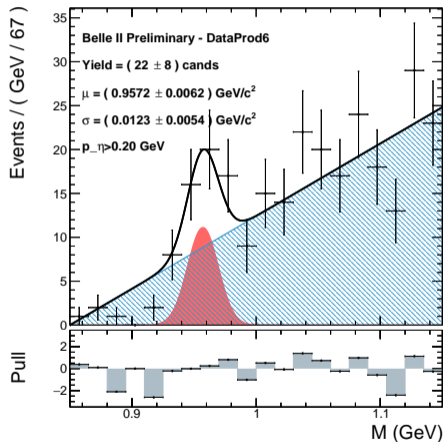
Better signal in MC: width is now 12 MeV (was 9)

### Selection:

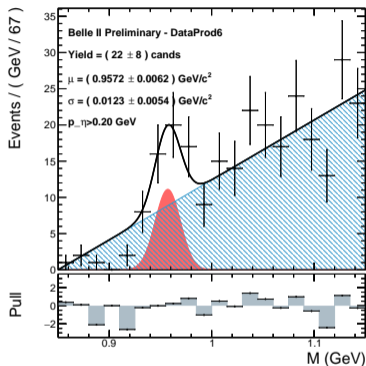
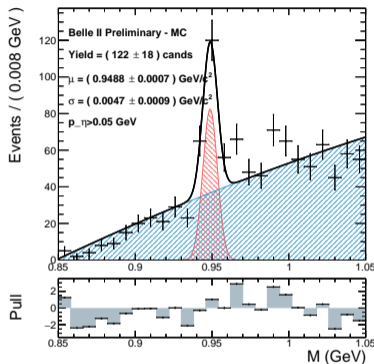
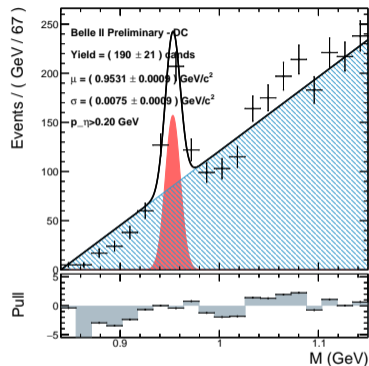
- $\pi^0 \rightarrow \gamma\gamma$ 
  - ▶ Cluster:  $N_{hits} > 5$ ,  $E_9/E_{21} > 0.91$
  - ▶  $E_\gamma > 50$  MeV
  - ▶  $125 < M_{\pi^0} < 150$  MeV
  - ▶  $p_{\pi^0} > 100$  MeV
- $\pi^\pm$ 
  - ▶  $|d_0(\pi)| < 2$  cm,  $|z_0(\pi)| < 4$  cm
  - ▶  $PionID > 0.5$ ,  $KaonID < 0.5$
  - ▶  $p_\pi > 100$  MeV
- $\eta$ 
  - ▶  $510 < M_\eta < 590$  MeV
  - ▶  $p_\eta > 200$  MeV
- VertexFit with  $\pi^0, \eta$  mass constrained

UML Fit with Gauss + Chebychev[1]

### Invariant Mass plot for Data Prod6, $500 \text{ nb}^{-1}$



maybe, very maybe ...

**Data - Prod6**

**MC - Phase 2 - BGx0**

**MC - Phase 3 - BGx1**


Now nice peak in MC, but very narrow (5 MeV) also shifted wrt data 8 MeV- narrow in DC also: maybe a fit problem. Previously no peak at all (wrong MC)

Yield  $N(\eta'_{\gamma\gamma}) \sim 2 \cdot N(\eta'_{3\pi})$

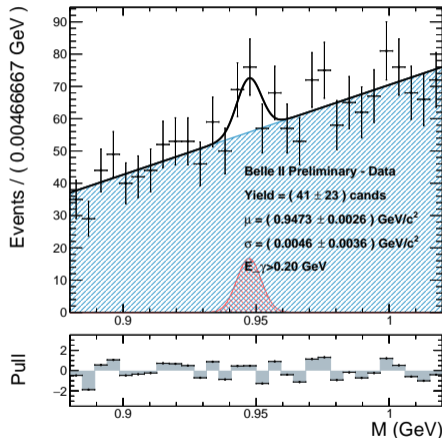
to de understood

### Selection:

- $\rho \rightarrow \pi^+\pi^-$ 
  - ▶  $PionID > 0.5$ ,  $KaonID < 0.5$
  - ▶  $p_\pi > 0.4$  GeV
  - ▶  $0.470 < M_\rho < 1.07$  GeV before fit
  - ▶  $0.7 < M_\rho < 0.85$  GeV after fit (was strickter)
- $\gamma$  gamma: pi0 from stdPhotons
  - ▶ Cluster:  $N_{hits} > 5$ ,  $E_9/E_{21} > 0.95$
  - ▶  $E_\gamma > 200$  MeV (was 100)
  - ▶ **Pi0Veto**
    - \* NO  $\gamma$  in ROE with  $|M_{\gamma\gamma} - M_{\pi^0}| < 20$  MeV (was  $N < 2$ )
- $p_{\eta'} > 1$  GeV (new)
- VertexFit with  $\rho$  mass constrained

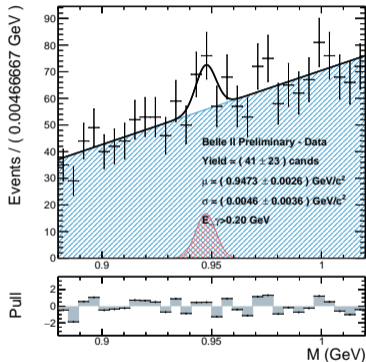
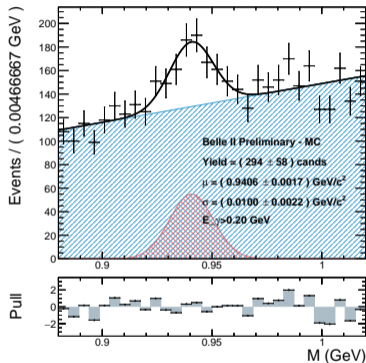
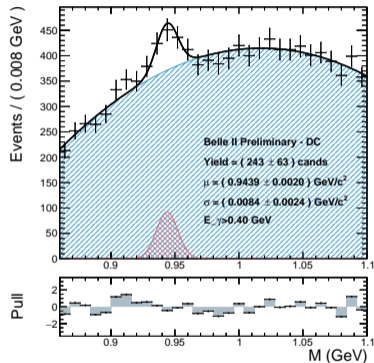
UML Fit with Gauss + Chebychev[1]

### Invariant Mass plot for Data Prod6, $500 \text{ nb}^{-1}$



Maybe



**Data Prod6 - Phase 2**

**MC phase 2 BGx1**

**MC phase 3 BGx1**


Maybe a signal in Prod6, ok in MC and DC (note  $E_\gamma > 400$  MeV in DC vs 200 MeV in phase2)

- All  $\eta'$  final states rediscovered on Data (maybe)
- agreement with MC is better by using a more inclusive MC
- all seen also in Data Challenge MC
- Belle 2 note still in preparation

## Light meson rediscovered

- ✓  $\pi^0 \rightarrow \gamma\gamma$
- ✓  $\rho \rightarrow \pi^+\pi^-$
- ✓  $f_0(975) \rightarrow \pi^+\pi^-$  **new**
- ✓  $K_S^0 \rightarrow \pi^+\pi^-$
- ✓  $\phi \rightarrow K^+K^-$
- ✓  $\eta \rightarrow \gamma\gamma$  **already seen w/ lower stat**
- ✓  $\eta \rightarrow \pi^+\pi^-\pi^0$  **new**
- ✓  $\eta' \rightarrow \eta(\rightarrow \gamma\gamma)\pi^+\pi^-$  **new**
- ✓  $\eta' \rightarrow \eta(\rightarrow \pi^+\pi^-\pi^0)\pi^+\pi^-$  **new**
- ✓  $\eta' \rightarrow \rho(\rightarrow \pi^+\pi^-)\gamma$  **new**

Additional or backup slides

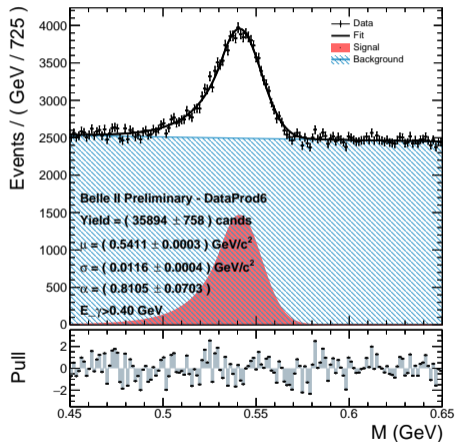
- $BR(\eta' \rightarrow \eta \pi^+ \pi^-) = 0.429$ 
  - ▶  $BR(\eta \rightarrow \gamma\gamma) = 0.3941$
  - ▶  $BR(\eta' \rightarrow \eta(\rightarrow \gamma\gamma)\pi^+ \pi^-) = 0.169$
  - ▶  $BR(\eta \rightarrow \pi^+ \pi^- \pi^0) = 0.3268$
  - ▶  $BR(\eta' \rightarrow \eta(\rightarrow \pi^+ \pi^- \pi^0)\pi^+ \pi^-) = 0.140$
- $BR(\eta' \rightarrow \rho\gamma) = 0.291$ 
  - ▶  $BR(\rho \rightarrow \pi^+ \pi^-) = 1$

### Selection:

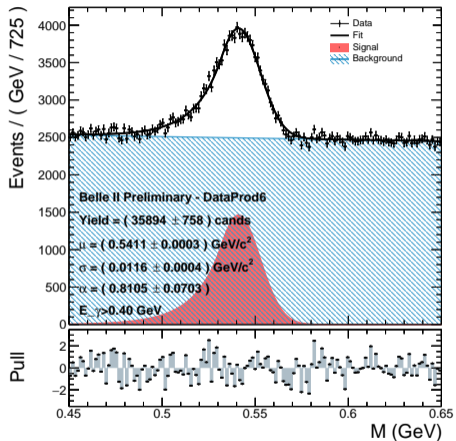
- $\text{gamma:pi0}$  from `stdPhotons`
  - ▶  $0.296706 < \theta_\gamma < 2.61799$
  - ▶  $|\text{clusterTiming}| < \text{clusterErrorTiming}$  or  $E > 0.1 \text{ GeV}$
  - ▶  $E_1/E_9 > 0.3$  or  $E > 0.1 \text{ GeV}$
- $50 \text{ MeV} < E_\gamma < 6 \text{ GeV}$
- $E_9/E_{25} > 0.75$
- Cluster:  $N_{\text{hits}} > 5$ ,  $E_9/E_{21} > 0.95$
- Varing  $E_\gamma > 300 - 500 \text{ MeV}$

UML Fit with CristalBall + Chebychev[1]

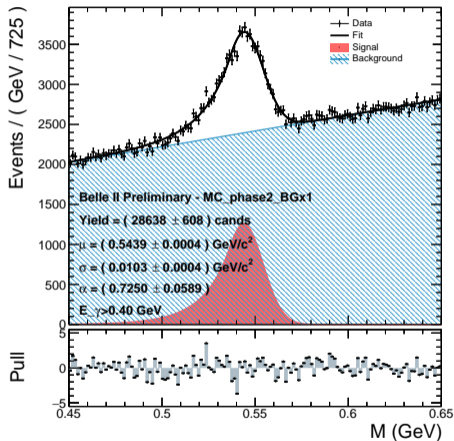
### Invariant Mass plot for Data Prod6, $500 \text{ nb}^{-1}$



## Data - Phase 2

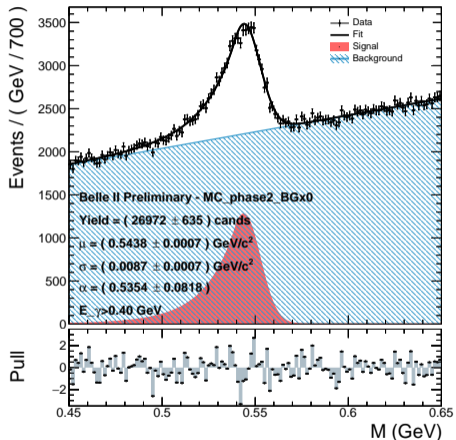


## Montecarlo - Phase 2 BGx1

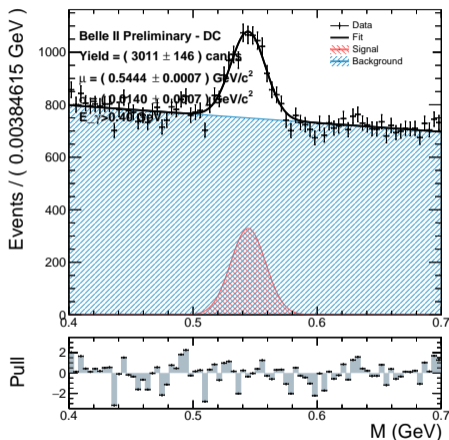


$\Delta\mu \sim 2 \text{ MeV}$ ,  $\Delta\sigma \sim 1 \text{ MeV}$ . **Warning:** MC only  $c\bar{c}$  bkg shape different

## BGx0 MC Phase 2



## BGx1 MC Phase 3 Data Challenge



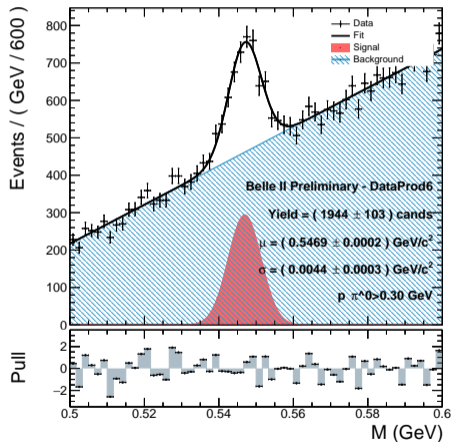
Ph2: BGx1  $\sigma$ 10.3 MeV vs BGx0 8.7 MeV vs Ph3-BGx1 14 MeV

### Selection:

- $\pi^0 \rightarrow \gamma\gamma$ 
  - ▶  $|clusterTiming| < clusterErrorTiming$  or  $E > 0.1$  GeV
  - ▶  $50 \text{ MeV} < E_\gamma < 6 \text{ GeV}$
  - ▶ Cluster:  $N_{hits} > 1.5$ ,  $E_9/E_{21} > 0.9$
  - ▶  $100 < M_{\gamma\gamma} < 150 \text{ MeV}$
  - ▶  $p_{\pi^0} > 300 \text{ MeV}$
- $\pi^\pm$ 
  - ▶  $|d_0(\pi)| < 2 \text{ cm}$ ,  $|z_0(\pi)| < 4 \text{ cm}$
  - ▶  $PionID > 0.5$ ,  $KaonID < 0.5$
  - ▶  $0.296706 < \theta_\gamma < 2.61799$
- $p_\eta > 100 \text{ MeV}$
- VertexFit for decay chain (mass constrained for  $\pi^0$ )

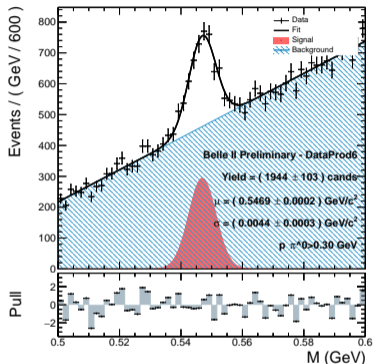
UML Fit with Gauss + Chebychev[1]

### Invariant Mass plot for Data Prod6, $500 \text{ nb}^{-1}$

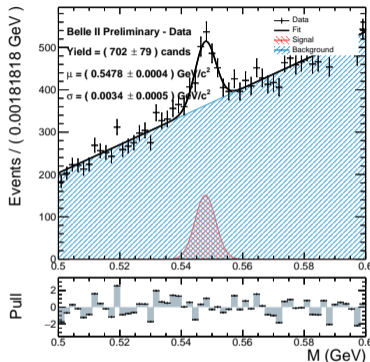




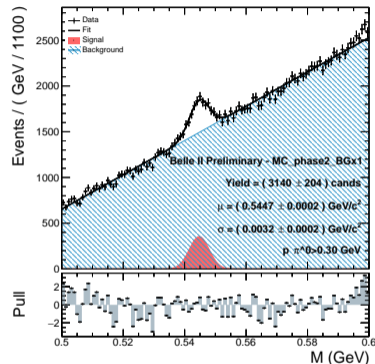
## Data - Phase 2 - Prod6



## Data - Phase 2 - Prod5

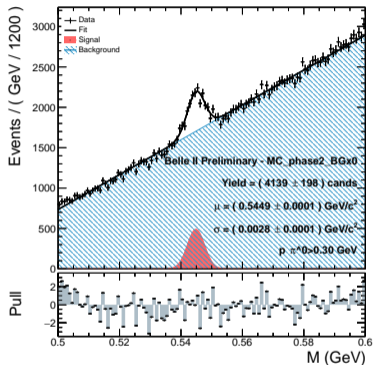


## Montecarlo - Phase 2 BGx1

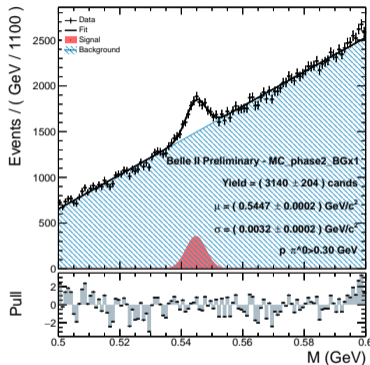


Peak on MC  $\sim 2$  MeV higher than data. Width significantly larger on Data (4.4 vs 3.2 MeV).  
 S/B very different (MC only  $c\bar{c}$ )  
 Prod6  $\sigma \sim 3.4$  MeV vs 3.2 on Prod5 (not full stat)

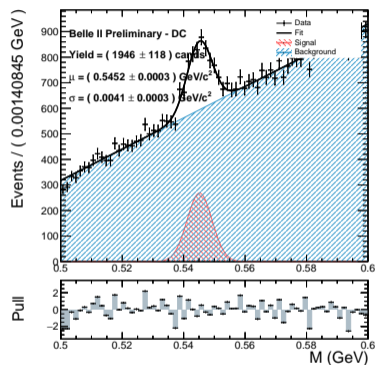
MC - Phase 2 BGx0



MC - Phase 2 BGx1



MC - Phase 3 BGx1 - Data Challenge



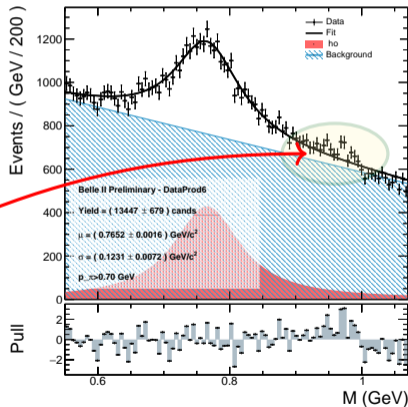
Width increases from 2.8 to 3.2 MeV with BGx1  
 On Ph3 (DC)  $\sigma \sim 4.1 \text{ MeV}$ , and S/B more similar to that of data.

### Selection:

- stdPi (good)
  - ▶  $0.296706 < \theta_\pi < 2.61799$
  - ▶  $|d_0(\pi)| < 2 \text{ cm}$
  - ▶  $|z_0(\pi)| < 4 \text{ cm}$
  - ▶  $PionID > 0.5$
- $KaonID < 0.5$
- $NHits_{CDC} > 15$
- $p_\pi > 0.3 \text{ GeV}$

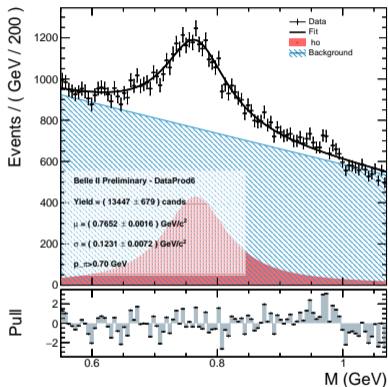
UML Fit with Breit-Wigner + Chebychev[1]

### Invariant Mass plot for Data Prod6, $500 \text{ nb}^{-1}$

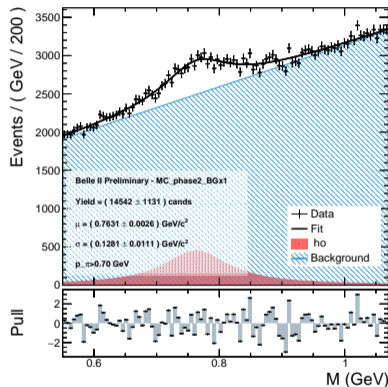


Hint of  $f_0 \rightarrow \pi^+ \pi^-$  at  $M_{\pi^+ \pi^-} \approx 0.98 \text{ GeV}$  ?

## Data - Phase 2

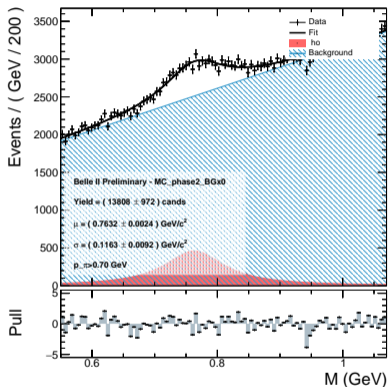


## Montecarlo - Phase 2 BGx1

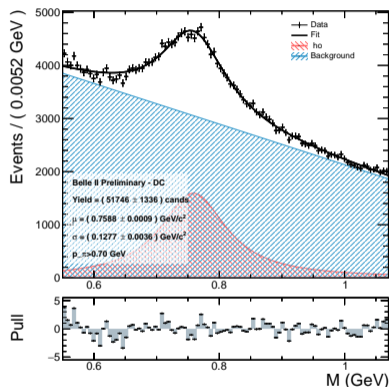


All seems fine: large intrinsic width. PDG 150 MeV, my fit 125 MeV)

## Montecarlo - Phase 2 BGx0

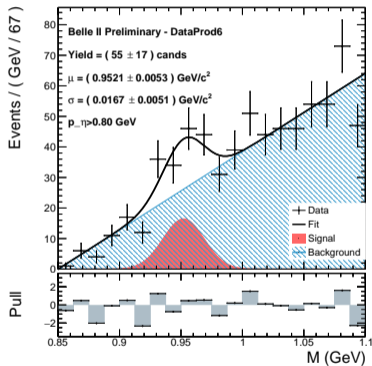


## Data Challenge - Montecarlo

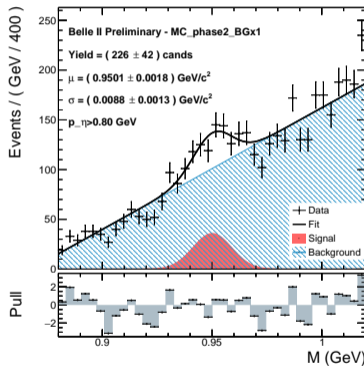


Background on DC similar to that of Data, no  $f_0(975)$  (not simulated)

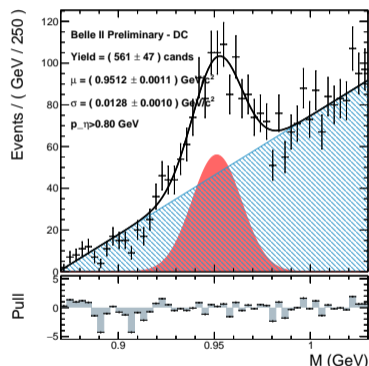
### Data - Phase II - Prod6



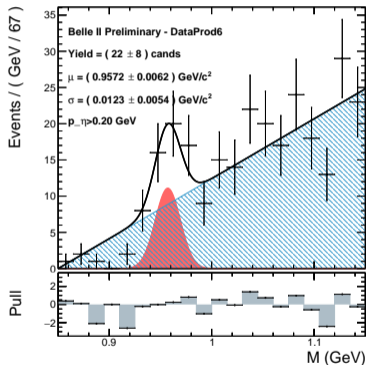
### Montecarlo - Phase 2 BGx1



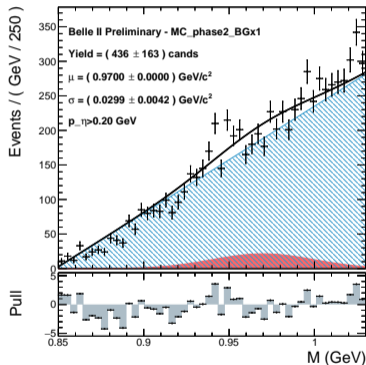
### Montecarlo - Phase 3 BGx1 - Data Ch



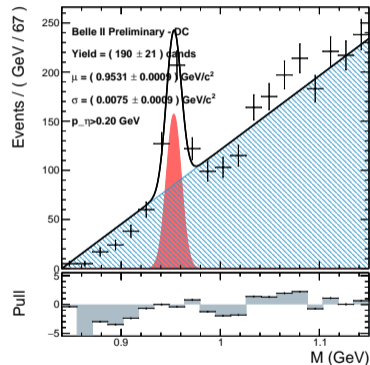
Data - Phase 2 Prod6



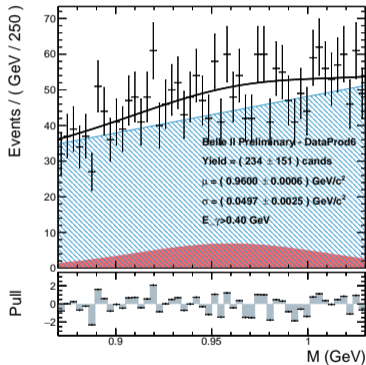
Montecarlo - Phase 2 - BGx1



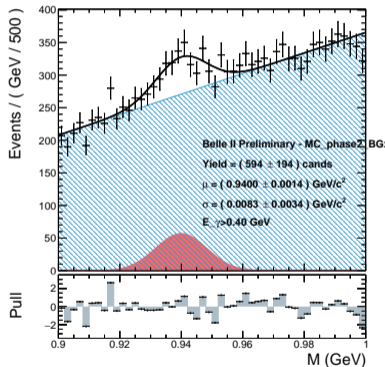
Montecarlo - Phase 3 - BGx1



Data Prod6 - Phase 2



Montecarlo phase 2 BGx1



Montecarlo phase 2 BGx1

