

# $\eta$ and $\eta'$ meson rediscovery (plus $f_0$ )

Some preliminary look at MC10 and DataChallenge for  $B^0 \rightarrow \eta'(\rightarrow \eta(\rightarrow \gamma\gamma)\pi^+\pi^-)K_S^0(\rightarrow \pi^+\pi^-)$

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## Light meson in Belle II - Phase II

- Start looking into Data Challenge data for TDCPV  $B^0 \rightarrow \eta' K^0$ ;
- Some time ago Phil challenged me to look for  $\eta'$  on data;
  - ▶ JIRA ticket is **BIIPH2-62**
- General strategy is:
  - ▶ Define selection based on MC - phase II
  - ▶ test selection on large DataChallenge dataset
  - ▶ run on Data Phase2 (exp3, Prod6)

## This presentation

- Show  $\eta$  and  $\eta'$  in data
- very preliminary studies on  $B^0 \rightarrow \eta' K^0$  for MC10
  - ▶ and also on DC

## list of resonances studied

- ✓  $\pi^0 \rightarrow \gamma\gamma$  (backup)
- ✓  $\rho \rightarrow \pi^+\pi^-$
- ✓  $f_0(975) \rightarrow \pi^+\pi^-$
- ✓  $K_S^0 \rightarrow \pi^+\pi^-$  (backup)
- ✓  $\phi \rightarrow K^+K^-$  (backup)
- ✓  $\eta \rightarrow \gamma\gamma$
- ✓  $\eta \rightarrow \pi^+\pi^-\pi^0$
- ✓  $\eta' \rightarrow \eta(\rightarrow \gamma\gamma)\pi^+\pi^-$
- ✓  $\eta' \rightarrow \eta(\rightarrow \pi^+\pi^-\pi^0)\pi^+\pi^-$
- ✗  $\eta' \rightarrow \rho(\rightarrow \pi^+\pi^-)\gamma$

- MC phase II
  - ▶  $c\bar{c}$  events
  - ▶ Warning: non inclusive MC
  - ▶ BGx0: prodID 2218
  - ▶ BGx1: prodID 2264
- Data
  - ▶ exp3, Prod6, skim Hadron  $[[nTracksLE \geq 3] \text{ and } [Bhabha2Trk == 0]]$
  - ▶ Runs: 529:5613: Lumi:  $491.5 \text{ pb}^{-1}$
  - ▶ Also Prod6 available for comparison:
    - ★ exp3, Prod5, skim Hadron  $[[nTracksLE \geq 3] \text{ and } [Bhabha2Trk == 0]]$
    - ★ Runs: 529:5613: Lumi:  $472 \text{ pb}^{-1}$
- Data Challenge - MC phase 3
  - ▶ skim TDCPV (ProdID 5142)
  - ▶ N events (post skim) 59830371
  - ▶ Confluence page

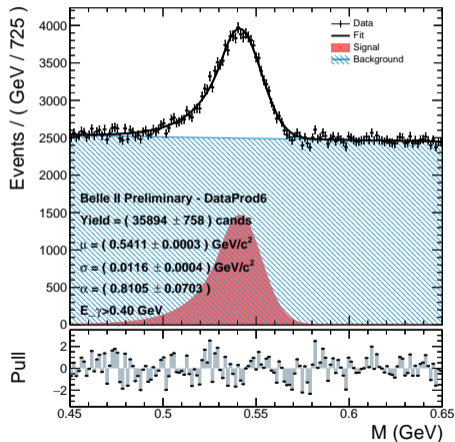
- git repo: `ssh://git@stash.desy.de:7999/~lacaprar/etaprime.git`
- `etaprime/Jupiter`
- Ntuple processing in `EtaProcessing.py`
- and in `EtaPrimeProcessing.py`
- analysis in `Pi0|Eta|EtaPrime....ipynb`
- Code is a messy shape, in case you want to reuse it, you might want to ask me

### Selection:

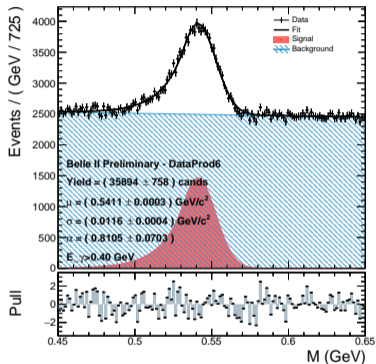
- $\text{gamma}:\text{pi}0$  from `stdPhotons`
  - ▶  $0.296706 < \theta_\gamma < 2.61799$
  - ▶  $|\text{clusterTiming}| < \text{clusterErrorTiming}$  or  $E > 0.1 \text{ GeV}$
  - ▶  $E_1/E_9 > 0.3$  or  $E > 0.1 \text{ GeV}$
- $50 \text{ MeV} < E_\gamma < 6 \text{ GeV}$
- $E_9/E_{25} > 0.75$
- Cluster:  $N_{\text{hits}} > 5$ ,  $E_9/E_{21} > 0.95$
- Varing  $E_\gamma > 300 - 500 \text{ MeV}$

UML Fit with CristalBall + Chebychev[1]

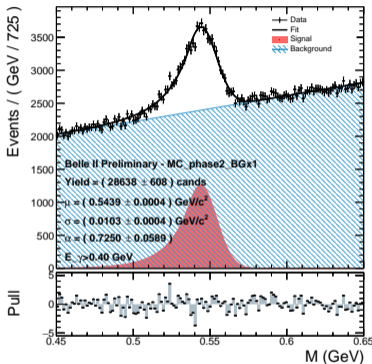
### Invariant Mass plot for Data Prod6, $500 \text{ nb}^{-1}$



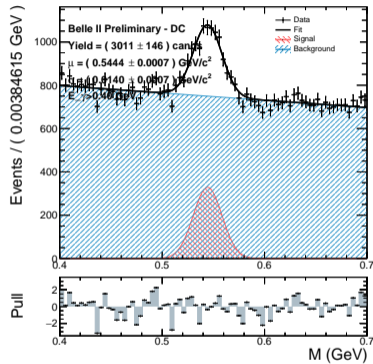
## Data - Phase 2



## MC - Phase 2 BGx1



## DC - Phase 3 BGx1



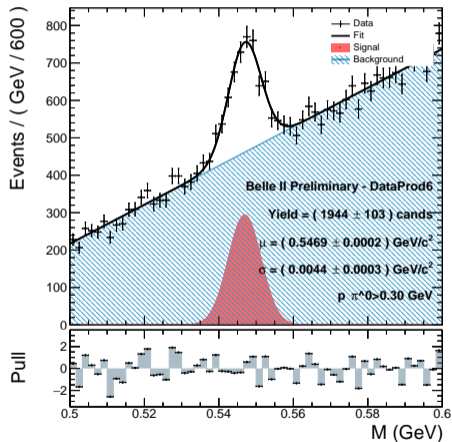
$\Delta\mu \sim 2 \text{ MeV}$ ,  $\Delta\sigma \sim 1 \text{ MeV}$ . **Warning:** MC only  $c\bar{c}$  bkg shape different.  
 Ph3-BGx1  $\sigma$  14 MeV (only fraction of full statistics - gauss fit)

### Selection:

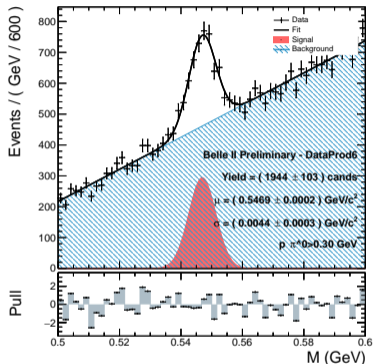
- $\pi^0 \rightarrow \gamma\gamma$ 
  - ▶  $|clusterTiming| < clusterErrorTiming$  or  $E > 0.1$  GeV
  - ▶  $50 \text{ MeV} < E_\gamma < 6 \text{ GeV}$
  - ▶ Cluster:  $N_{hits} > 1.5$ ,  $E_9/E_{21} > 0.9$
  - ▶  $100 < M_{\gamma\gamma} < 150 \text{ MeV}$
  - ▶  $p_{\pi^0} > 300 \text{ MeV}$
- $\pi^\pm$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

UML Fit with Gauss + Chebychev[1]

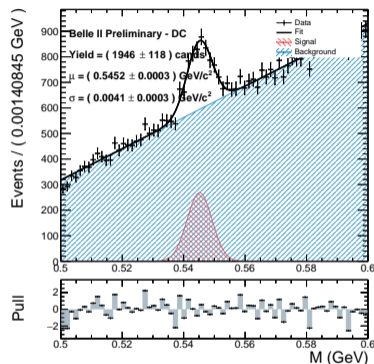
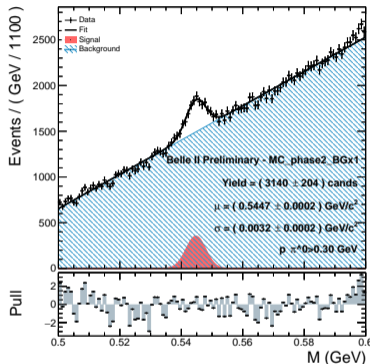
### Invariant Mass plot for Data Prod6, $500 \text{ nb}^{-1}$



## Data - Phase 2 - Prod6



## Montecarlo - Phase 2 BGx1MC - Phase 3 BGx1 - Data Challenge



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  $c\bar{c}$ )  
 On Ph3 (DC)  $\sigma \sim 4.1$  MeV, and S/B more similar to that of data.

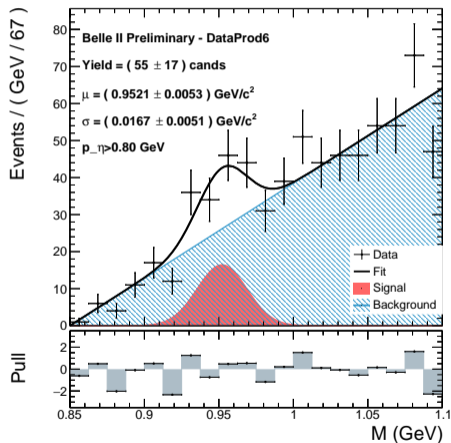


### Selection:

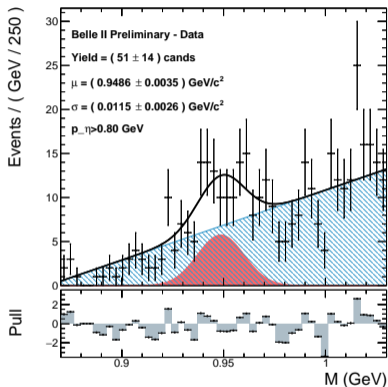
- $\eta \rightarrow \gamma\gamma$ 
  - ▶  $E_9/E_{25} > 0.75$
  - ▶ Cluster:  $N_{hits} > 5$ ,  $E_9/E_{21} > 0.93$
  - ▶  $E_\gamma > 400$  MeV
  - ▶  $0.52 < M_{\gamma\gamma} < 0.56$  GeV
  - ▶  $p_\eta > 800$  MeV
- $\pi^\pm$ 
  - ▶  $|d_0(\pi)| < 2$  cm,  $|z_0(\pi)| < 4$  cm
  - ▶  $PionID > 0.5$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

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

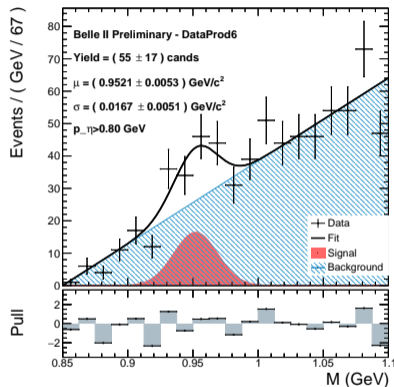
### Invariant Mass plot for Data Prod6, $500 \text{ nb}^{-1}$



### Data - Phase 2 -Prod5

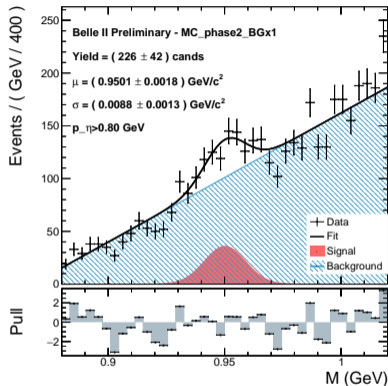


### Data - Phase II - Prod6

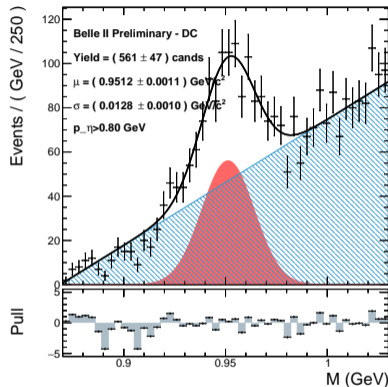


Maybe is a signal. Visible also in Prod5, width smaller.  
 Fit is rather unstable and statistics - if any - small

## Montecarlo - Phase 2 BGx1



## Montecarlo - Phase 3 BGx1 - Data Challenge

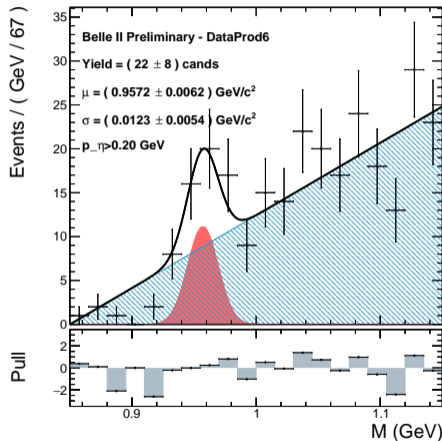


Better signal (even better with BGx0 - backup). "Peak" position is  $\Delta \sim 2 \text{ MeV}$ ,  
 $\sigma \sim 9 \text{ MeV}$  is way smaller than data (17 MeV)  
 DC nice peak  $\sigma \sim 13 \text{ MeV}$  (not full stat)

### Selection:

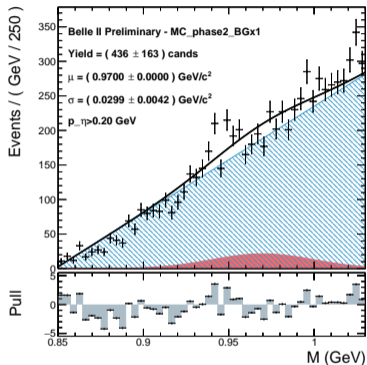
- $\pi^0 \rightarrow \gamma\gamma$ 
  - ▶ Cluster:  $N_{hits} > 5$ ,  $E_9/E_{21} > 0.91$
  - ▶  $E_\gamma > 50$  MeV
  - ▶  $125 < M_{\pi^0} < 150$  MeV
  - ▶  $p_{\pi^0} > 100$  MeV
- $\pi^\pm$ 
  - ▶  $|d_0(\pi)| < 2$  cm,  $|z_0(\pi)| < 4$  cm
  - ▶  $PionID > 0.5$ ,  $KaonID < 0.5$
  - ▶  $p_\pi > 100$  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, $500 \text{ nb}^{-1}$

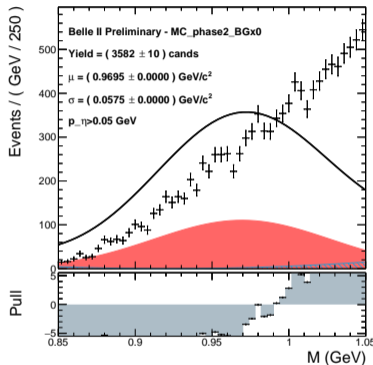


maybe, very maybe ... (similar in Prod5 - Backup)

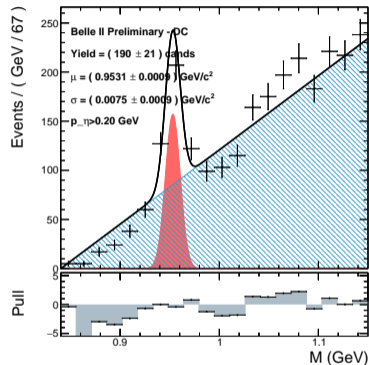
### Montecarlo - Phase 2 - BGx1



### Montecarlo - Phase 2 - BGx0



### Montecarlo - Phase 3 - BGx1



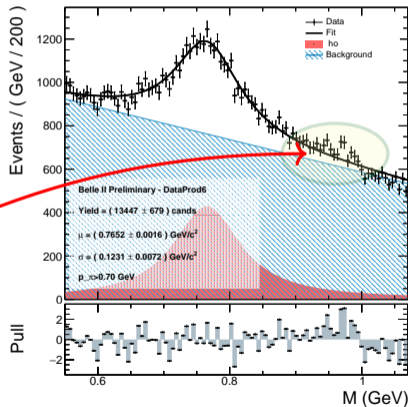
Almost no signal in the MC - ph2 (even before the cuts, MC truth) Wrong MC sample?  
 Ok for DC, quite narrow ( $\sigma \sim 7.5 \text{ MeV}$  vs  $12.8 \text{ MeV}$  for  $\gamma\gamma$ ) also 200  $\eta'_{3\pi}$  vs 560  $\eta'_{\gamma\gamma}$   
 to de understood

### Selection:

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

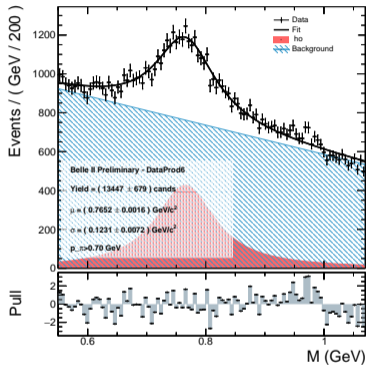
UML Fit with Breit-Wigner + Chebychev[1]

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

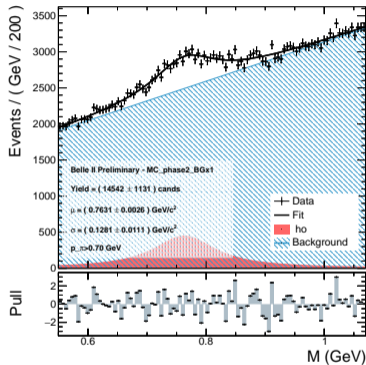


Hint of  $f_0 \rightarrow \pi^+ \pi^-$  at  $M_{\pi^+ \pi^-} \approx 0.98 \text{ GeV}$  ?

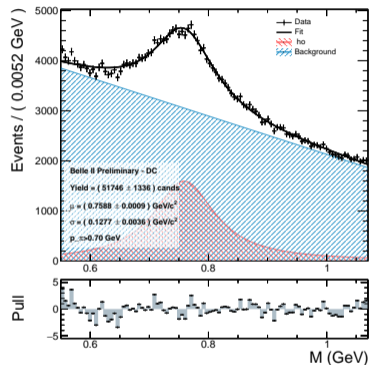
## Data - Phase 2



## Montecarlo - Phase 2 BGx1



## Data Challenge - Montecarlo



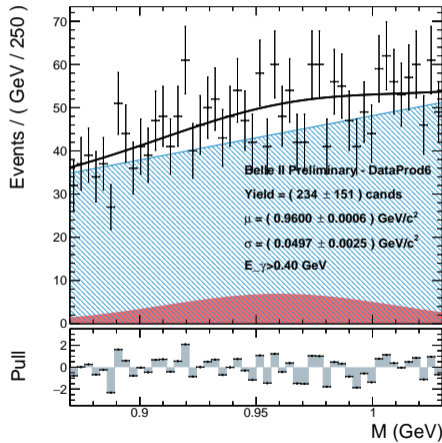
All seems fine: large intrinsic width. PDG 150 MeV, my fit 125 MeV  
 Background on DC similar to that of Data, no  $f_0(975)$  (not simulated)

## 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
  - ▶  $.73 < M_\rho < 0.8$  GeV after fit
- $\gamma$ 
  - ▶ gamma:pi0 from stdPhotons
  - ▶ Cluster:  $N_{hits} > 5$ ,  $E_9/E_{21} > 0.95$
  - ▶  $E_\gamma > 100$  MeV
  - ▶ **Pi0Veto**
    - \*  $|M_{\gamma\gamma} - M_{\pi^0}| > 20$  MeV with the  $\gamma$  from ROE with  $M_{\gamma\gamma}$  closest to  $M_{\pi^0}$  **and**
    - \*  $N < 2$   $\gamma$  in ROE with  $|M_{\gamma\gamma} - M_{\pi^0}| < 20$  MeV
- VertexFit with  $\rho$  mass constrained

UML Fit with Gauss + Chebychev[1]

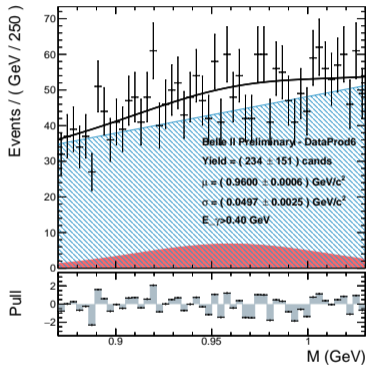
## Invariant Mass plot for Data Prod6, $500 \text{ nb}^{-1}$



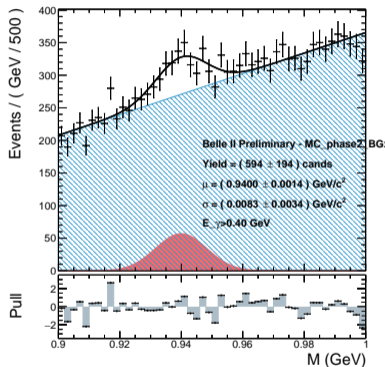
Nope (yet)



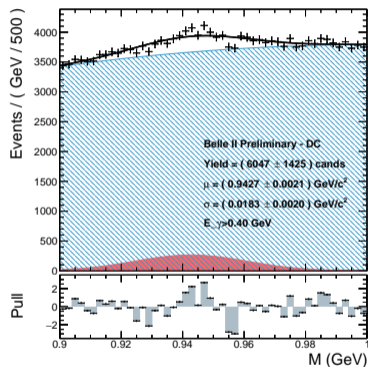
### Data Prod6 - Phase 2



### MC phase 2 BGx1



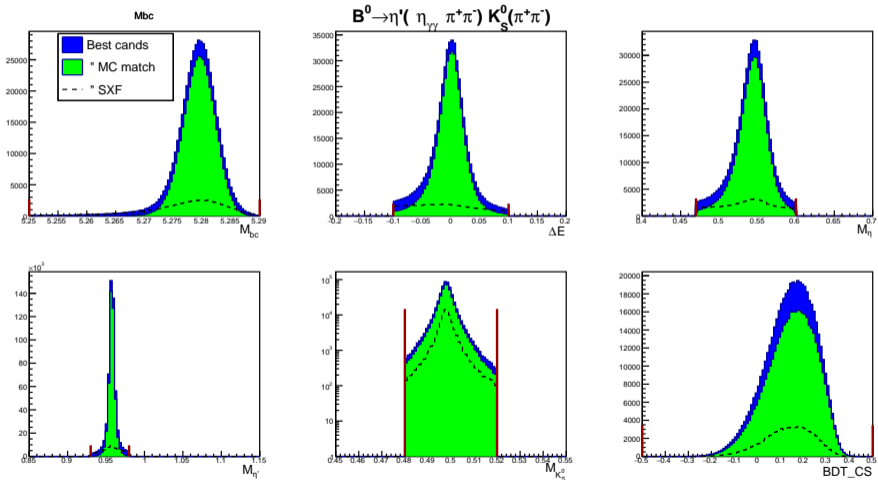
### DC phase 3 BGx1



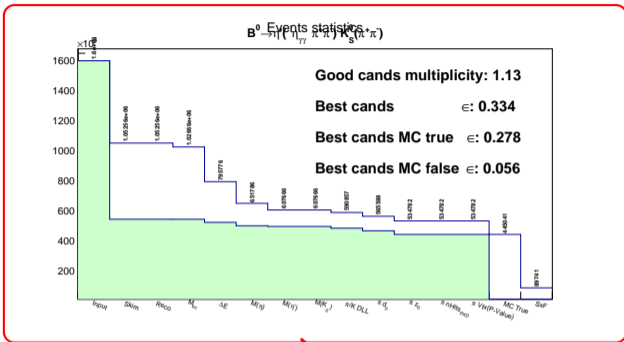
Good signal in MC phase 2. More work needed on Data, same also for DC

## Motivation

- Data Challenge analysis
  - ▶ demonstrate capability to perform full analysis on  $1 \text{ ab}^{-1}$  of “data”
  - ▶ crucial to demonstrate phase 3 readiness
- twofold blind analysis:
  - ▶ do not look at signal before analysis freezing
  - ▶ some “new physics” has been included in DC <sup>[Phill - several times]</sup>
- first step is to redo the old full exercise (The Belle II Physics Book) with up-to-data software and data
- start with MC10 datasets;
  - ✓ signal
  - ✗ continuum ( $u\bar{u}, d\bar{d}, c\bar{c}, s\bar{s}$ , mixed, charged)  $0.8 \text{ ab}^{-1}$ 
    - ▶ I realized while writing these slides that I processed phase2 continuum and generic BB, no wonder  $\sim$ no events survived!
- eventually apply on DC;
  - ▶ 1/abinv: TDCPV skims N events:  $5.672E6$  (pre-skim) events:  $59830371$  (post skim)

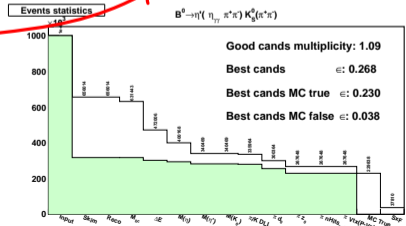


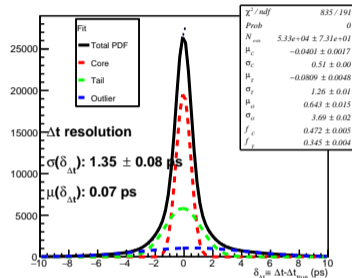
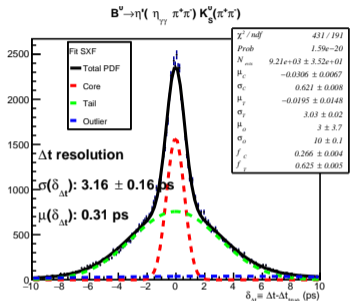
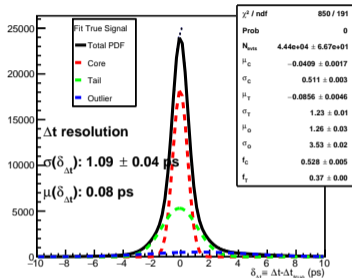
- Selection unchanged wrt to work for B2TIP
  - ▶ including SxF BDT not re-trained on new MC!
- just applying the old selection out of the box



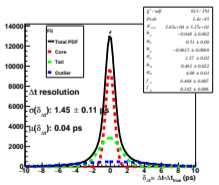
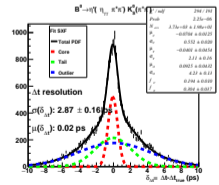
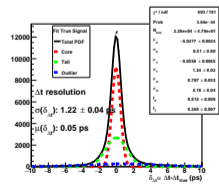
Dataset	$\epsilon$ %	SxF%	cand/ev
MC10 BGx1	27.8	5.6	1.13
B2TIP BGx0	30.1	2.3	1.06
B2TIP BGx1	23.0	3.8	1.09

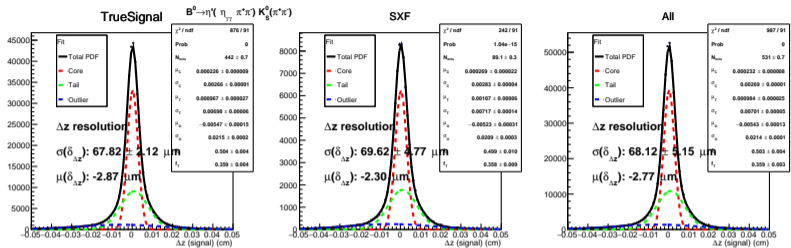
Efficiency improvement is mostly in reconstruction





Dataset	True	SxF	All
MC10 BGx1	1.09	3.16	1.35
B2TIP BGx1	1.22	2.87	1.45
B2TIP BGx0	0.91	-	-





**Signal side B2TIP**

True  $\sigma = 69 \mu\text{m}$

SxF  $\sigma = 70 \mu\text{m}$

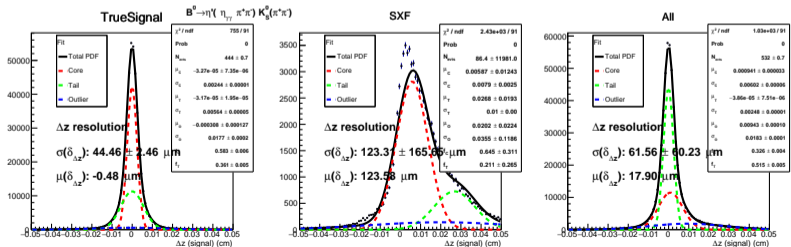
All  $\sigma = 69 \mu\text{m}$

Compatible

True Signal

SxF

All



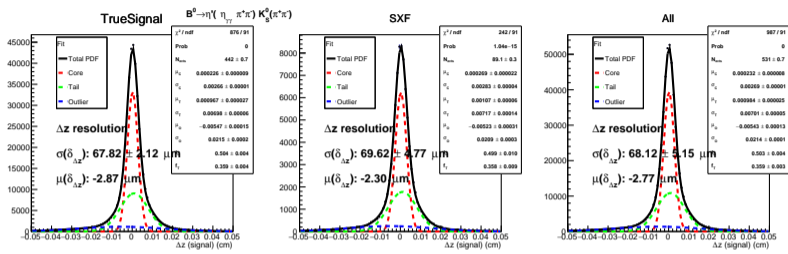
**Tag side B2TIP**

True  $\sigma = 52 \mu\text{m}$

SxF  $\sigma = 141 \mu\text{m}$

All  $\sigma = 67 \mu\text{m}$

Improved!



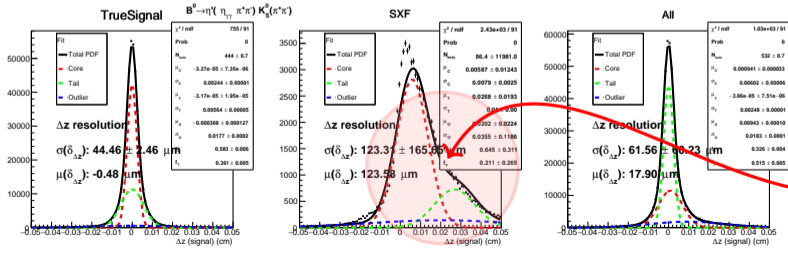
## Signal side B2TIP

True  $\sigma = 69 \mu\text{m}$   
 SxF  $\sigma = 70 \mu\text{m}$   
 All  $\sigma = 69 \mu\text{m}$   
**Compatible**

### True Signal

### SxF

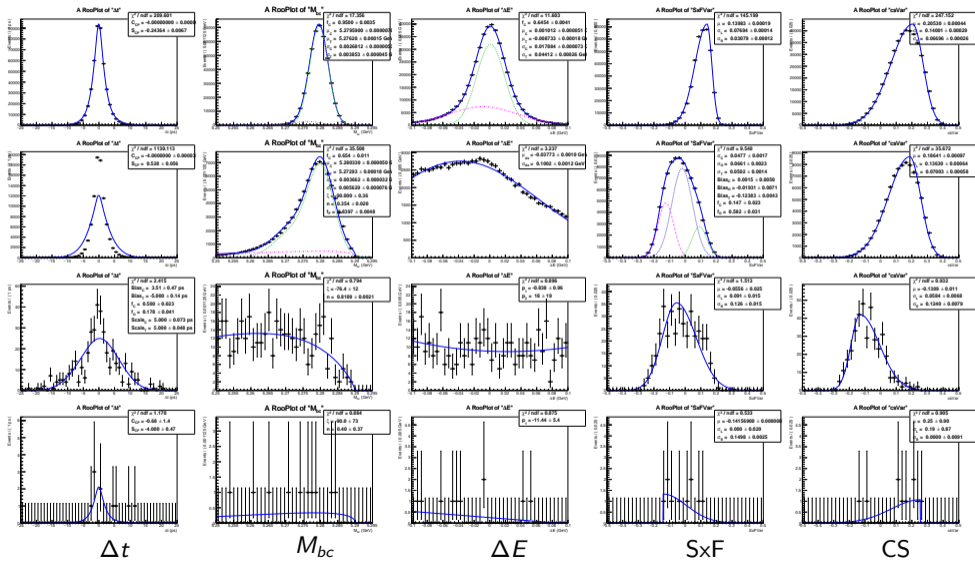
### All



## Tag side B2TIP

True  $\sigma = 52 \mu\text{m}$   
 SxF  $\sigma = 141 \mu\text{m}$   
 All  $\sigma = 67 \mu\text{m}$

**Improved!**  
 Shoulder for SxF  
 also present: bug of physics?



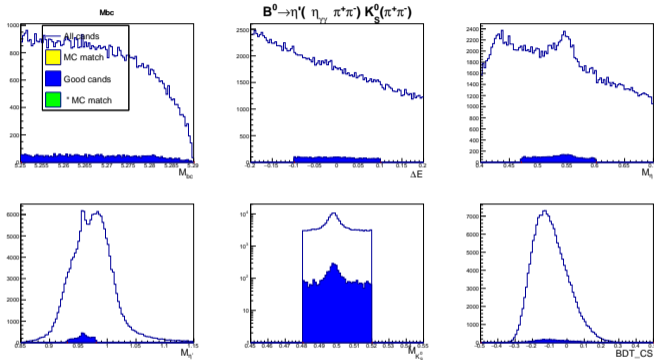
Signal

SxF

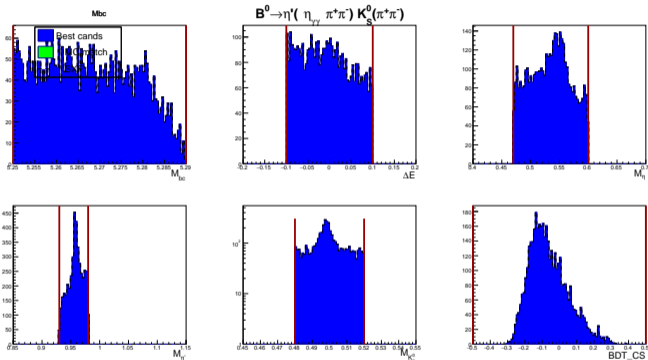
Continuum -  
phase 2 MC!

Peaking -  
phase 2 MC!





$\eta, \eta'$  and  $K_S^0$  ok.



$\eta$ ,  $\eta'$  and  $K_S^0$  ok. Where are the  $B^0$ ?? Expected  $\mathcal{O}(1000)$

- **Some  $\eta$  and  $\eta'$  final states rediscovered on Data**
  - ▶ agreement with MC is decent, not perfect
  - ▶ still things to understand both in MC and Data
  - ▶ Belle 2 note in preparation
- **started looking at  $B^0 \rightarrow \eta'(\eta_{\gamma\gamma}\pi^\pm)K_S^0$  with MC10**
  - ▶ Signal eff is larger than B2TIP, but also SxF
    - ★ BDT not retrained yet
  - ▶  $\Delta z$  improved on tag-side
  - ▶ generic BB and continuum to be processed
    - ★ NOTE TO SELF it is a smart idea to look at the right MC!
  - ▶ first look at DC: where are my  $B^0$ ?
- Lot of work to do

## 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**
- ✗  $\eta' \rightarrow \rho(\rightarrow \pi^+\pi^-)\gamma$  **working**

Additional or backup slides

## candidate selection: main cuts

- Reconstruct decay chain with mass constrains for  $\pi^0$ ,  $\eta$ ,  $\eta'$ ,  $K_S^0$ ,
  - ▶ vertex only (w/o mass) for  $B^0$  (more later)
    - $\pi^0, \eta_{\gamma\gamma}$ :
      - ▶  $0.06 < E_\gamma < 6 \text{ GeV}, E_9/E_{25} > 0.75$
      - ▶  $M(\pi^0) \in [100, 150] \text{ MeV}$
      - ▶  $M(\eta_{\gamma\gamma}) \in [0.52, 0.57] \text{ GeV};$
    - $\eta' \rightarrow \eta_{\gamma\gamma} \pi^+ \pi^-$ :
      - ▶  $d_0(\pi^\pm) < 0.08 \text{ mm}; z_0(\pi^\pm) < 0.1 \text{ mm};$
      - ▶  $N \text{ hits}_{PXD}(\pi^\pm) > 1, \text{ PID}$
      - ▶  $M(\eta') \in [0.93, 0.98] \text{ GeV};$
  - $\eta' \rightarrow \eta_{3\pi} \pi^+ \pi^-$ :
    - ▶  $M(\eta') \in [0.93, 0.98] \text{ GeV};$
  - $K_S^0 \rightarrow \pi^+ \pi^-$ :
    - ▶  $M(K_S^0 \rightarrow \pi^+ \pi^-) \in [0.48, 0.52] \text{ GeV};$
  - $B^0 \rightarrow \eta' (\rightarrow \eta_{\gamma\gamma} \pi^+ \pi^-) K_S^{0+-}$ 
    - ▶  $M_{bc} > 5.25 \text{ GeV};$
    - ▶  $|\Delta E| < 0.1 \text{ GeV};$
  - $B^0 \rightarrow \eta' (\rightarrow \eta_{3\pi} \pi^+ \pi^-) K_S^{0+-}$ 
    - ▶  $|\Delta E| < 0.15 \text{ GeV};$

if  $N_{cands} > 1$ , keep all of them!

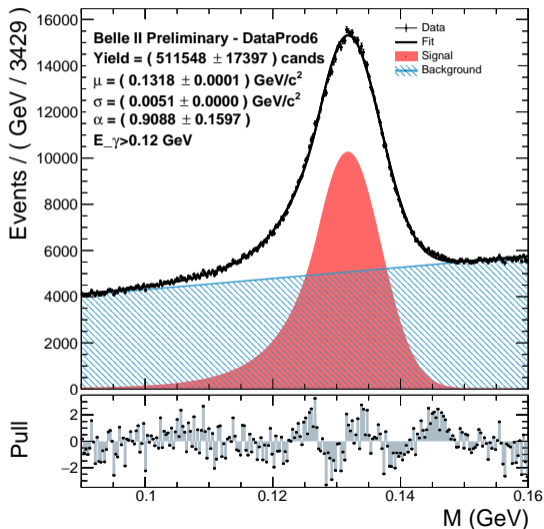
- $BR(\eta' \rightarrow \eta \pi^+ \pi^-) = 0.429$ 
  - ▶  $BR(\eta \rightarrow \gamma\gamma) = 0.3941$
  - ▶  $BR(\eta' \rightarrow \eta(\rightarrow \gamma\gamma)\pi^+\pi^-) = 0.169$
  - ▶  $BR(\eta \rightarrow \pi^+\pi^-\pi^0) = 0.3268$
  - ▶  $BR(\eta' \rightarrow \eta(\rightarrow \pi^+\pi^-\pi^0)\pi^+\pi^-)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

### Selection:

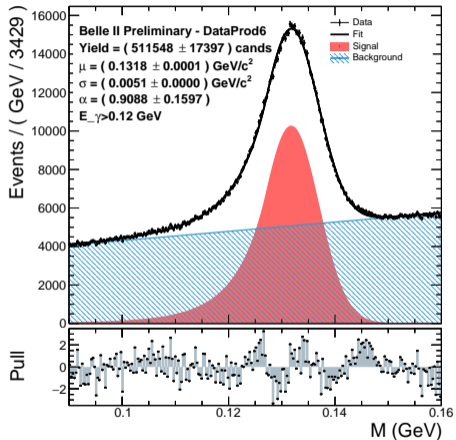
- `gamma:pi0` from `stdPhotons`
  - ▶  $0.296706 < \theta_\gamma < 2.61799$
  - ▶  $|clusterTiming| < clusterErrorTiming$   
or  $E > 0.1$  GeV
  - ▶  $E_1/E_9 > 0.3$  or  $E > 0.1$  GeV
- $50 \text{ MeV} < E_\gamma < 6 \text{ GeV}$
- $E_9/E_{25} > 0.75$
- Cluster:  $N_{hits} > 1.5$ ,  $E_9/E_{21} > 0.9$
- Varing  $E_\gamma > 60 - 160$  MeV

UML Fit with CristalBall + Chebychev[1]

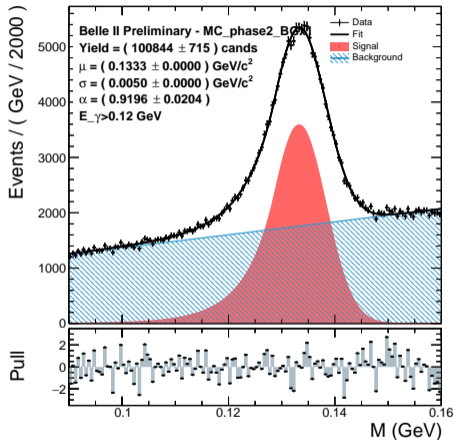
### Invariant Mass plot for Data Prod6, $\sim 200 \text{ nb}^{-1}$



## Data - Phase 2 Prod 6



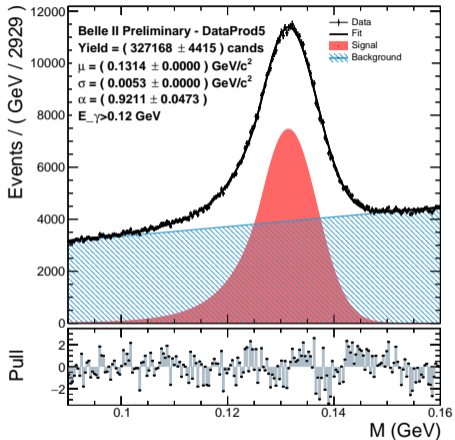
## Montecarlo - Phase 2 BGx1



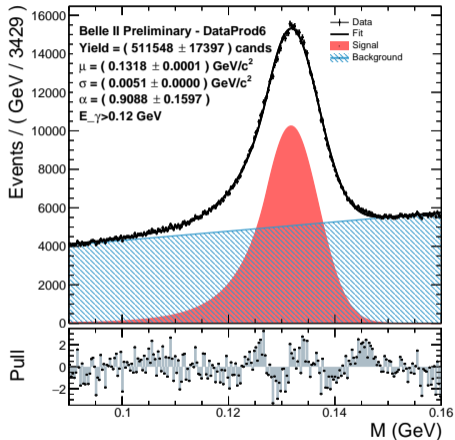
Nice agreement on  $\sigma$ , on MC peak is a bit shifted wrt Data



## Data - Phase 2 Prod 5

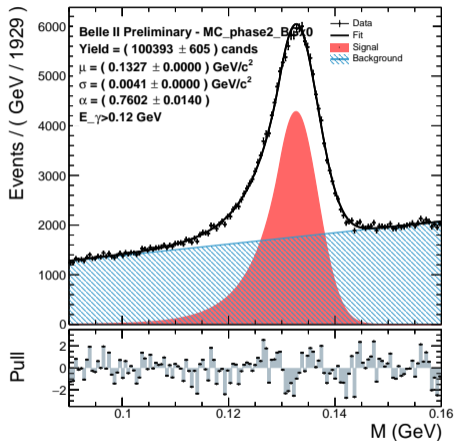


## Data - Phase 2 Prod 6

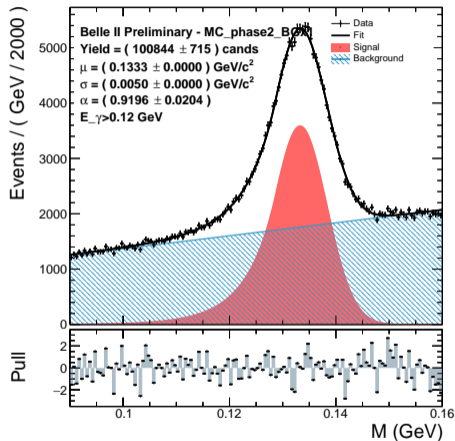


Peak position unchanged ( $\Delta \sim 0.4 \text{ MeV}$ ), width: Prod6 5.1 MeV, Prod5 5.3 MeV, so 4% improvement.

MC - Phase 2 BGx0

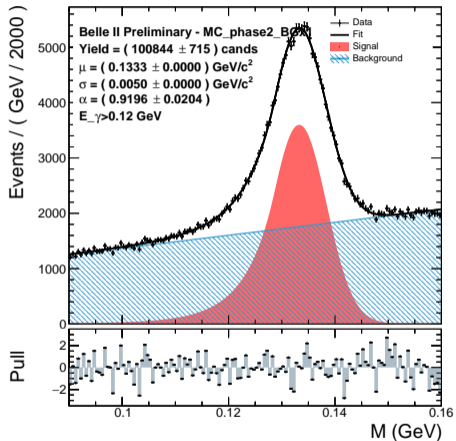


MC - Phase 2 BGx1

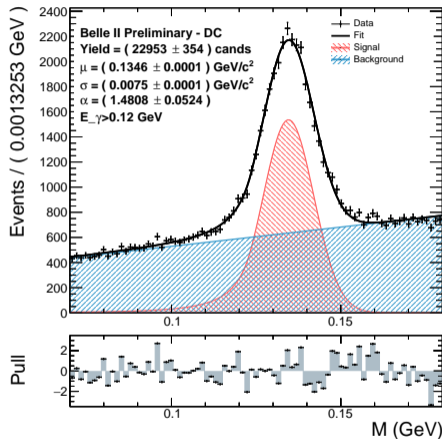


Peak position shift by 1 MeV, width increase by 1 MeV

### MC - Phase 2 BGx1



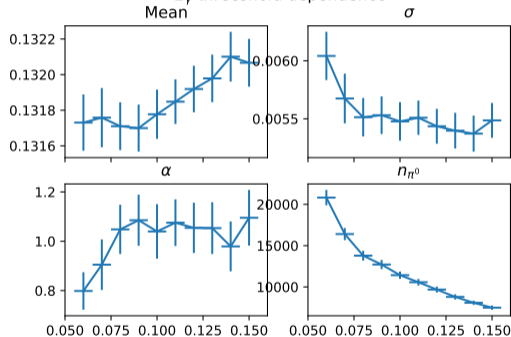
### Data Challenge - Phase 3 BGx1



Peak position shift further by 1 MeV, width increase from 5.3 to 7.5 MeV

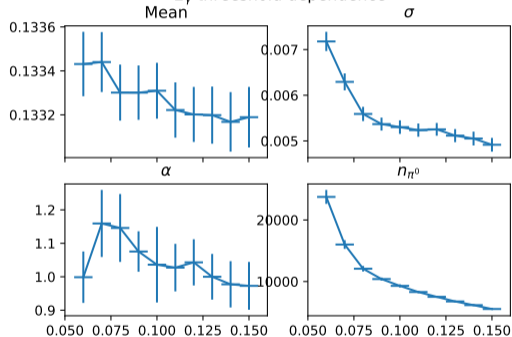
### Data Prod5- Phase 2

$E_{\gamma}$  threshold dependence

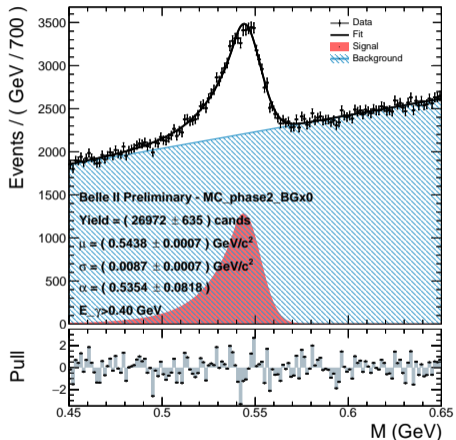


### Montecarlo - Phase 2 BGx1

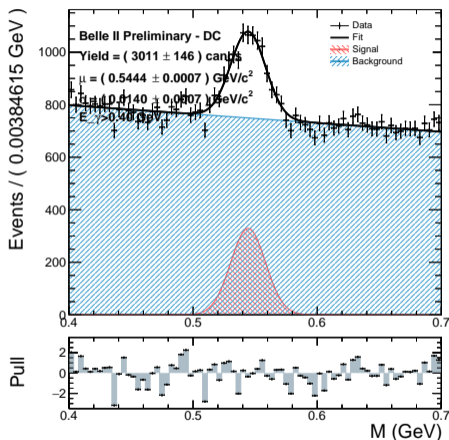
$E_{\gamma}$  threshold dependence



## BGx0 MC Phase 2



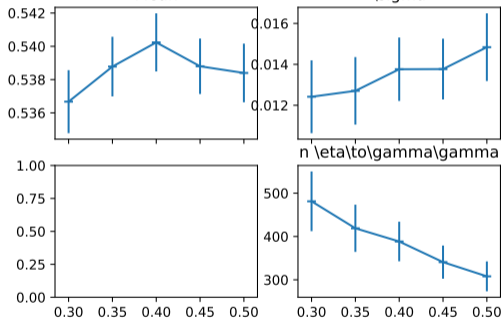
## BGx1 MC Phase 3 Data Challenge



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

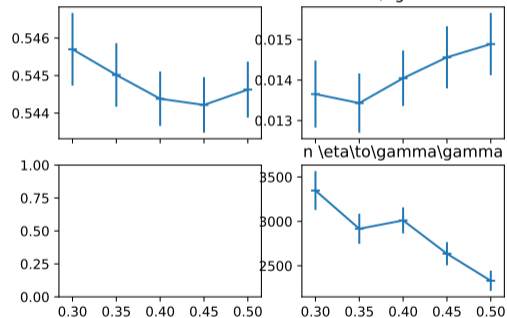
### Data - Phase 2

$E_\gamma$  threshold dependence  
Mean  $\sigma$



### Data Challenge - Montecarlo

$E_\gamma$  threshold dependence  
Mean  $\sigma$

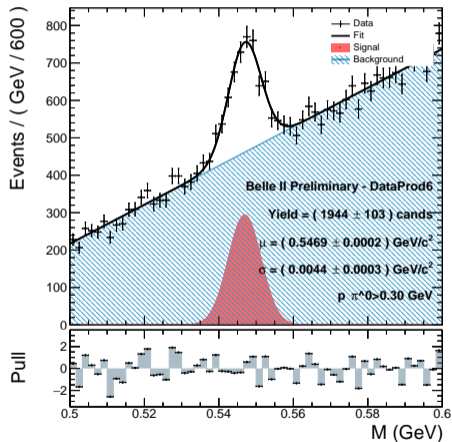


### Selection:

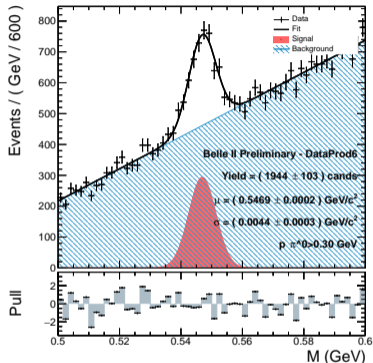
- $\pi^0 \rightarrow \gamma\gamma$ 
  - ▶  $|clusterTiming| < clusterErrorTiming$  or  $E > 0.1$  GeV
  - ▶  $50 \text{ MeV} < E_\gamma < 6$  GeV
  - ▶ Cluster:  $N_{hits} > 1.5$ ,  $E_9/E_{21} > 0.9$
  - ▶  $100 < M_{\gamma\gamma} < 150$  MeV
  - ▶  $p_{\pi^0} > 300$  MeV
- $\pi^\pm$ 
  - ▶  $|d_0(\pi)|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

UML Fit with Gauss + Chebychev[1]

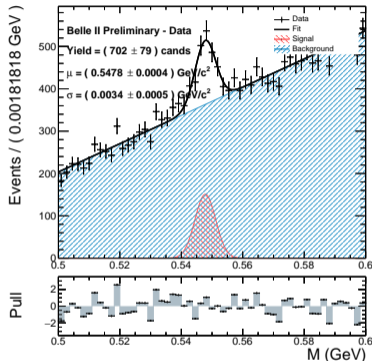
### Invariant Mass plot for Data Prod6, $500 \text{ nb}^{-1}$



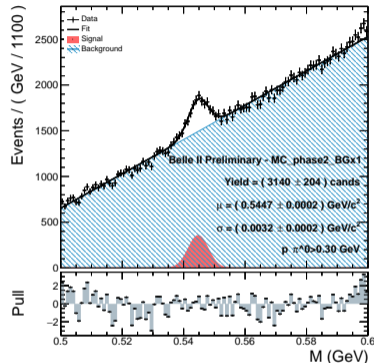
## Data - Phase 2 - Prod6



## Data - Phase 2 - Prod5



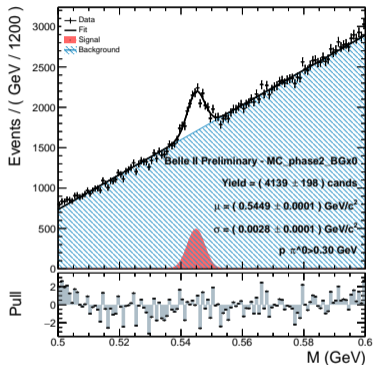
## Montecarlo - Phase 2 BGx1



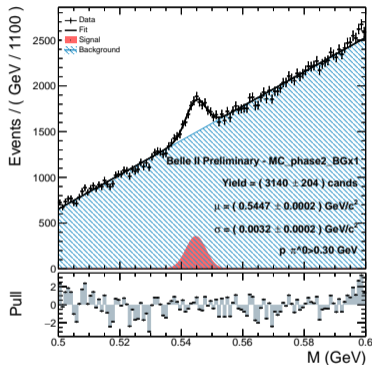
Peak on MC  $\sim 2$  MeV higher than data. Width significantly larger on Data (4.4 vs 3.2 MeV).  
 S/B very different (MC only  $c\bar{c}$ )  
 Prod6  $\sigma \sim 3.4$  MeV vs 3.2 on Prod5 (not full stat)



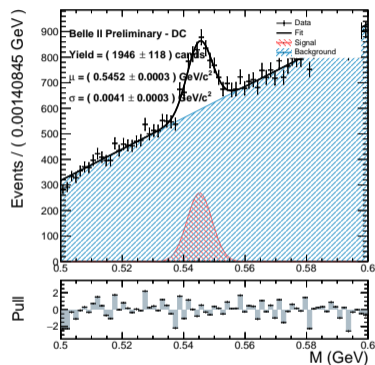
## MC - Phase 2 BGx0



## MC - Phase 2 BGx1



## MC - Phase 3 BGx1 - Data Challenge



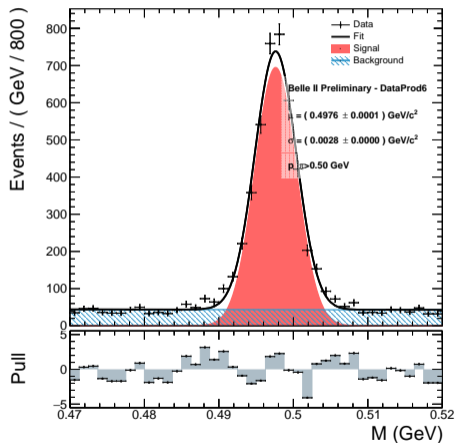
Width increases from 2.8 to 3.2 MeV with BGx1  
 On Ph3 (DC)  $\sigma \sim 4.1 \text{ MeV}$ , and S/B more similar to that of data.

### Selection:

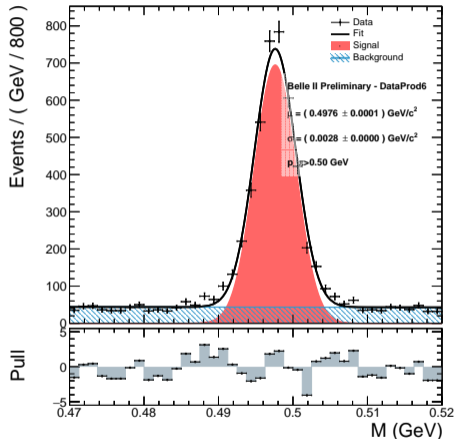
- stdPi (good)
  - ▶  $0.296706 < \theta_\pi < 2.61799$
  - ▶  $|d_0(\pi)| < 2 \text{ cm}$
  - ▶  $|z_0(\pi)| < 4 \text{ cm}$
  - ▶  $PionID > 0.5, KaonID < 0.5$
- or  $p < 0.5 \text{ dr} > 0.05, dz < 0.8, \cos \Delta\phi > 0.955$
- or  $0.5 < p < 1.5 \text{ dr} > 0.03, dz < 1.8, \cos \Delta\phi > 0.995$
- or  $p > 1.5 \text{ dr} > 0.02, dz < 2.8, \cos \Delta\phi > 0.9955$
- $NHits_{CDC} > 15$  (and  $NHits_{SVD} = 0$  for DC)
- $p_\pi > 0.3 - 1.3 \text{ GeV}$

UML Fit with Gauss + Chebychev[1]

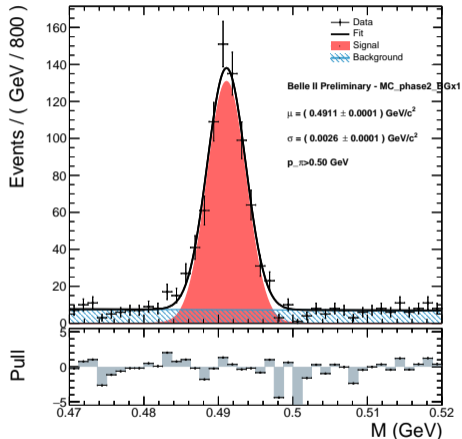
### Invariant Mass plot for Data Prod6, $500 \text{ nb}^{-1}$



## Data - Phase 2

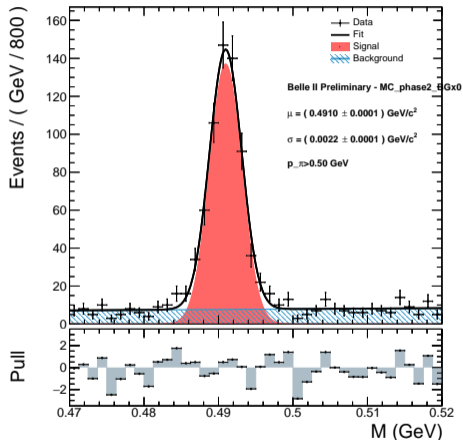


## Montecarlo - Phase 2 BGx1

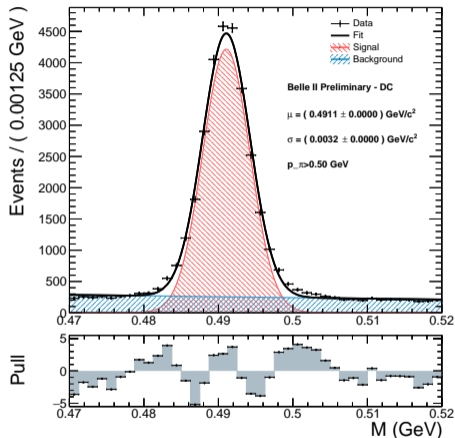


Significan shift in peak position, width similar (large on Data)

## Montecarlo - Phase 2 BGx0



## Montecarlo - Phase 3 Data Challenge



Peak shift not due to BGx1, only larger width. DC BGx1 has even larger width.

### Selection:

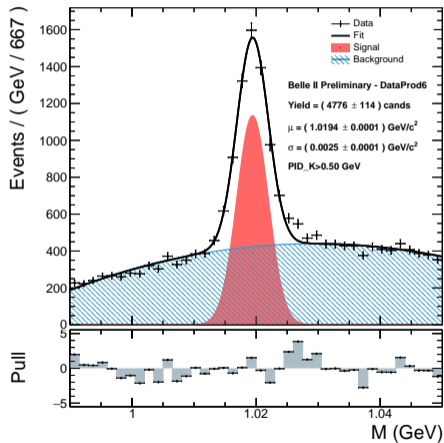
- stdK(good)

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

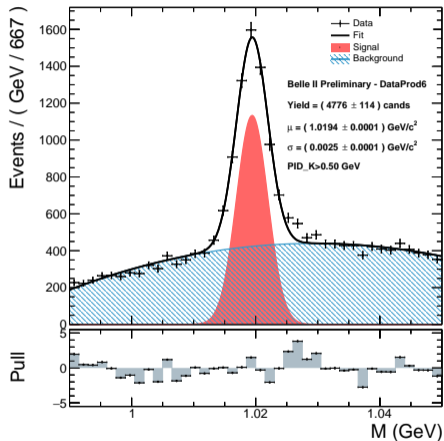
- $p_K > 0.3 \text{ GeV}$

UML Fit with Gauss + Chebychev[1]

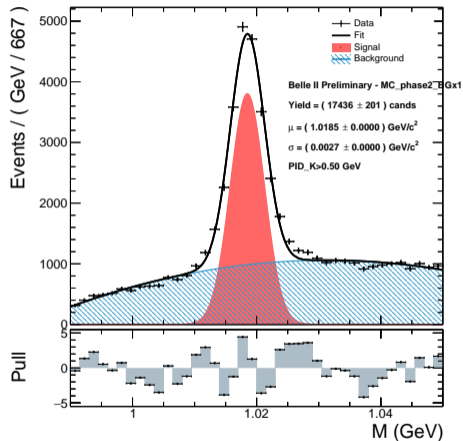
### Invariant Mass plot for Data Prod6, $500 \text{ nb}^{-1}$



Data - Phase 2

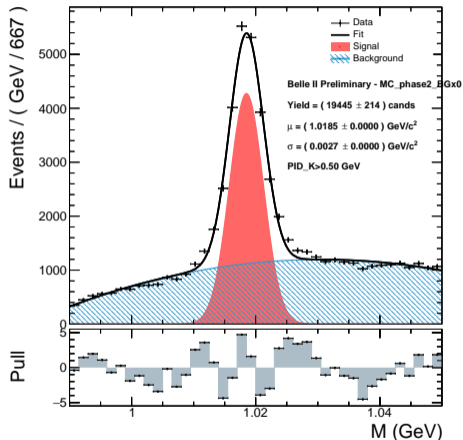


Montecarlo - Phase 2 BGx1

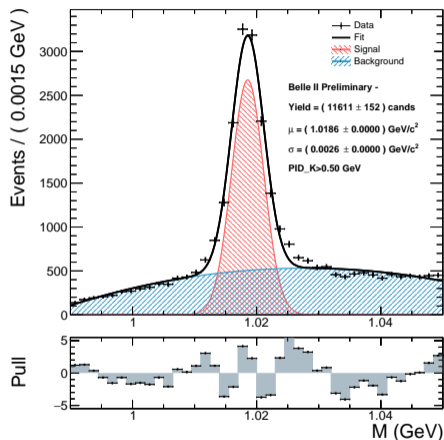


Peak position 1 MeV higher on Data than MC, width slightly smaller in Data

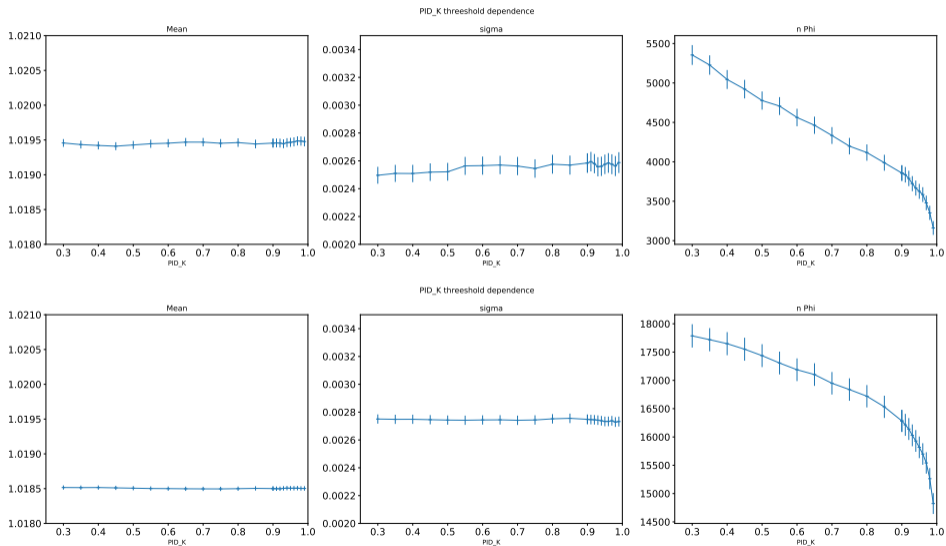
Montecarlo - Phase 2 BGx0



Montecarlo - Phase 3 BGx1 - Data Challenge

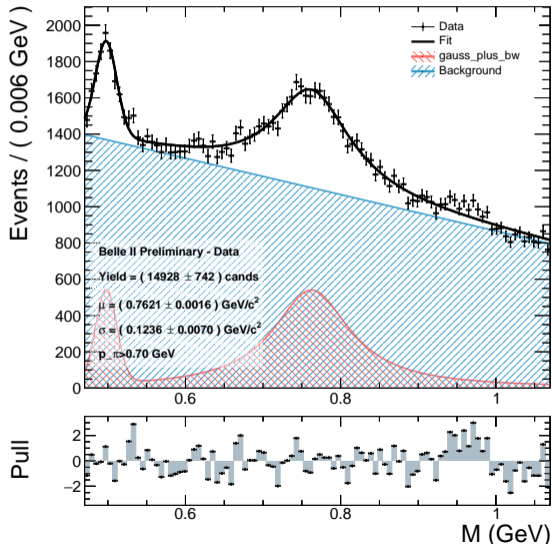


Phase 3 BGx1 better than Phase 2 BGx1 ?

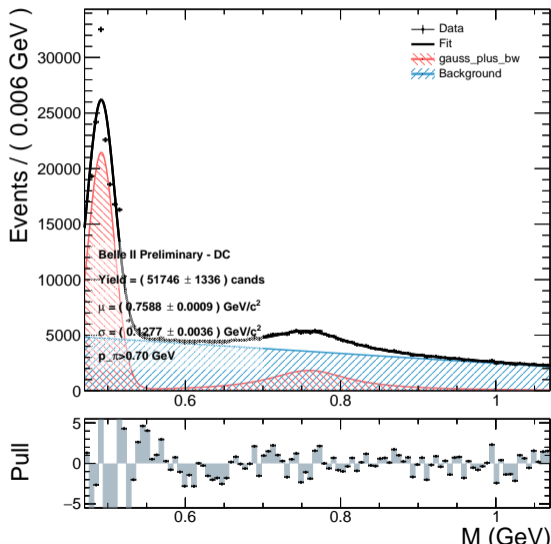




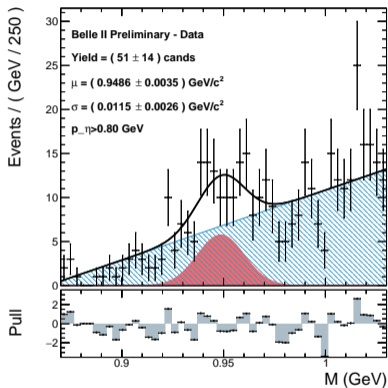
## Data - Phase 2



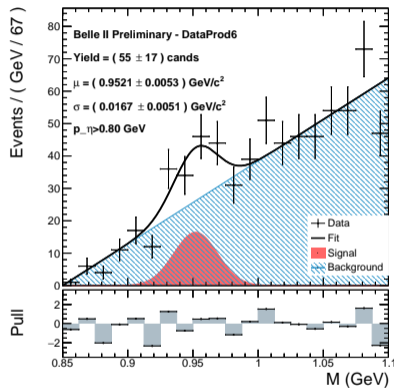
## Data Challenge - Montecarlo



## Data - Phase 2 -Prod5

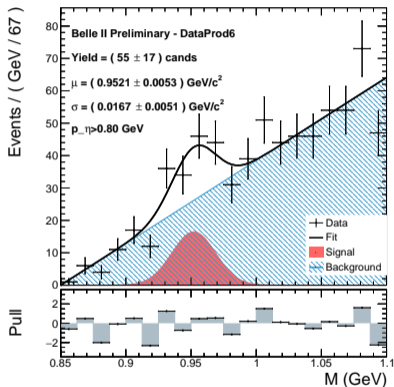


## Data - Phase II - Prod6

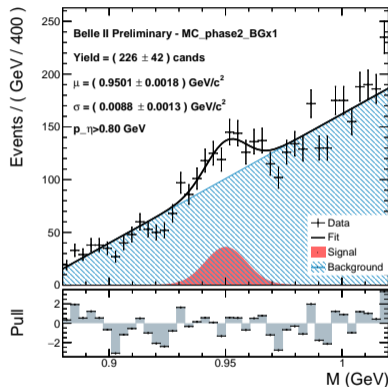


Maybe is a signal. Visible also in Prod5, width smaller.  
 Fit is rather unstable and statistics - if any - small

## Data - Phase 2

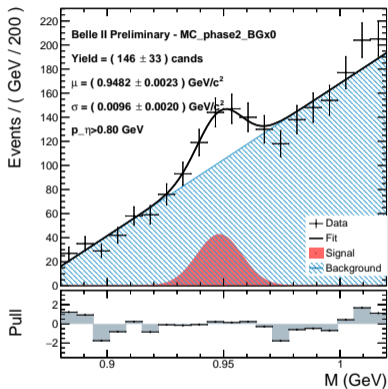


## Montecarlo - Phase 2 BGx1

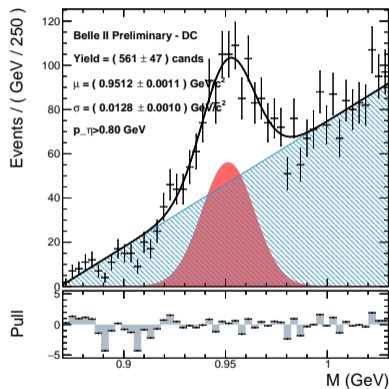


Maybe is a signal. "Peak" position is  $\Delta \sim 2 \text{ MeV}$ ,  $\sigma \sim 17 \text{ MeV}$  is larger than MC (9 MeV)

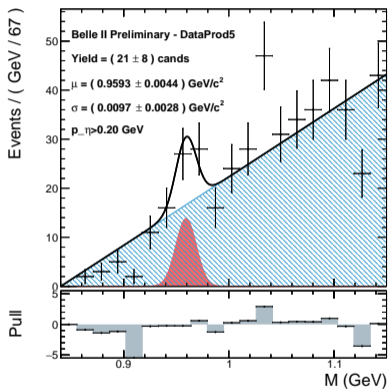
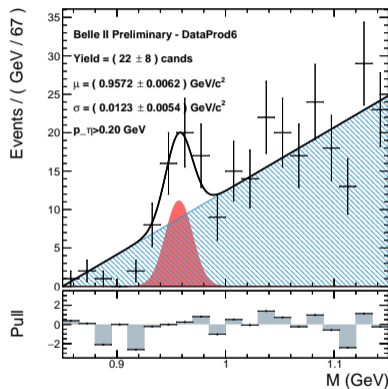
### Montecarlo - Phase 2 BGx0



### Montecarlo - Phase 3 BGx1 - Data Challenge

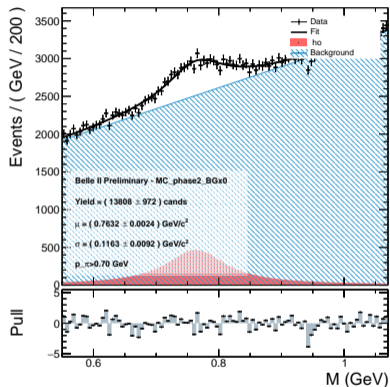


Nicer peak in MC phase2 BGx0 and in Data Challenge

**Data - Phase 2 Prod5**

**Data - Phase 2 Prod6**


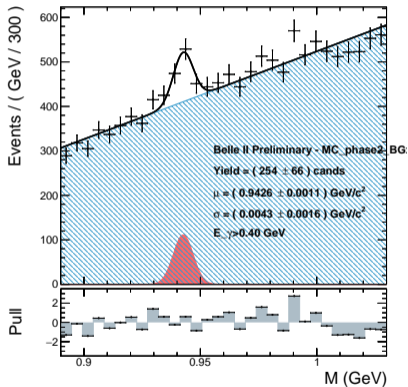
Very maybe both in Prod5 and Prod6

### Montecarlo - Phase 2 BGx0



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

### Montecarlo phase 2 BGx0



### Montecarlo phase 3 BGx1 Data Challenge

