

Light meson rediscovery

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nowhere, 25 September 2018

B-physics at CMS

- goal of this work is to rediscover η and η' particles in Phase2 data
- JIRA ticket is **BIIPH2-62**
- General strategy is:
 - ▶ Define selection based on MC
 - ▶ test selection on large DataChallenge dataset (inclusive MC w/o MC truth)
 - ▶ run on Data Phase2 (exp3, Prod5)

This presentation

Collect the work done so far

particle list

- $\pi^0 \rightarrow \gamma\gamma$
- $\rho \rightarrow \pi^+\pi^-$
- $K_S^0 \rightarrow \pi^+\pi^-$
- $\phi \rightarrow K^+K^-$
- $\eta \rightarrow \gamma\gamma$
- $\eta \rightarrow \pi^+\pi^-\pi^0$
- $\eta' \rightarrow \eta(\rightarrow \gamma\gamma)\pi^+\pi^-$
- $\eta' \rightarrow \eta(\rightarrow \pi^+\pi^-\pi^0)\pi^+\pi^-$
- $\eta' \rightarrow \rho(\rightarrow \pi^+\pi^-)\gamma$

- MC exclusive

- ▶ $B^0 \rightarrow \eta' \rightarrow \eta(\rightarrow \gamma\gamma)\pi^+\pi^-\text{K}_S^0(\rightarrow \pi^+\pi^-)$
- ▶ $B^0 \rightarrow \eta' \rightarrow \eta(\rightarrow \pi^+\pi^-\pi^0)\pi^+\pi^-\text{K}_S^0(\rightarrow \pi^+\pi^-)$
- ▶ $B^0 \rightarrow \eta' \rightarrow \rho(\rightarrow \pi^+\pi^-)\gamma\text{K}_S^0(\rightarrow \pi^+\pi^-)$

- MC inclusive

- ▶ Mixed
- ▶ $c\bar{c}$

- DC

- ▶ skim TDCPV (ProdID 5142)
- ▶ N events (post skim) 59830371
- ▶ Confluence page

- Data

- ▶ exp3, Prod5, skim Hadron $[[nTracksLE \geq 3] \text{ and } [Bhabha2Trk == 0]]$
- ▶ Runs: 529:5613: Lumi: 472 pb^{-1}
- ▶ exp3, Prod6, skim Hadron $[[nTracksLE \geq 3] \text{ and } [Bhabha2Trk == 0]]$
- ▶ Runs: 529:5613: Lumi: 491.5 pb^{-1}

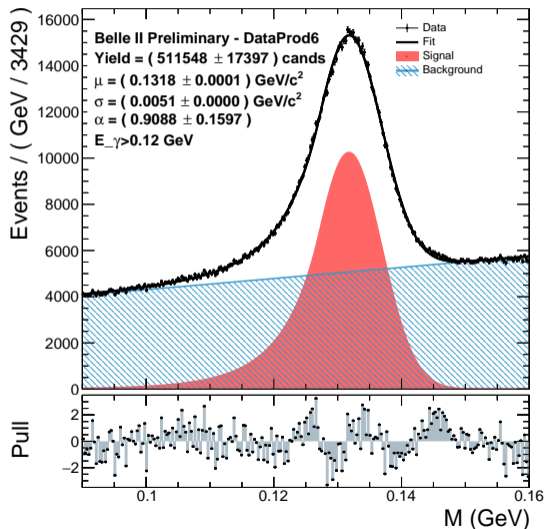
- git repo: `ssh://git@stash.desy.de:7999/~lacaprar/etaprime.git`
- `etaprime/Jupiter`
- processing in `EtaProcessing.py|ipynb`
- analysis in `Pi0|Eta|EtaPrime....ipynb`

Selection:

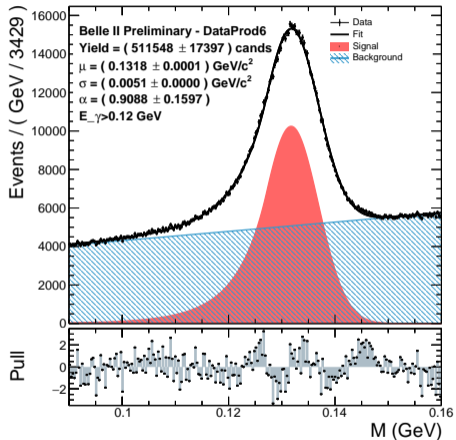
- `gamma:pi0` from `stdPhotons`
 - ▶ $0.296706 < \theta_\gamma < 2.61799$
 - ▶ $|clusterTiming| < clusterErrorTiming$ or $E > 0.1$ GeV
 - ▶ $E_1/E_9 > 0.3$ or $E > 0.1$ GeV
- $50 \text{ MeV} < E_\gamma < 6 \text{ GeV}$
- $E_9/E_{25} > 0.75$
- Cluster: $N_{hits} > 1.5$, $E_9/E_{21} > 0.9$
- Varing $E_\gamma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

UML Fit with CristalBall + Chebychev[1]

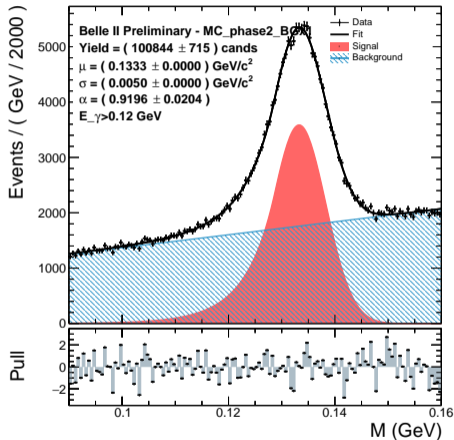
Invariant Mass plot for Data Prod6, $\sim 200 \text{ nb}^{-1}$



Data - Phase 2 Prod 6

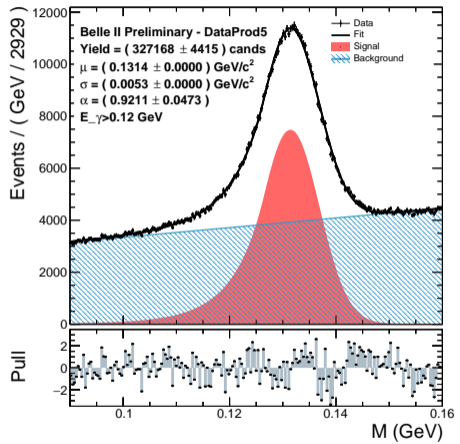


Montecarlo - Phase 2 BGx1

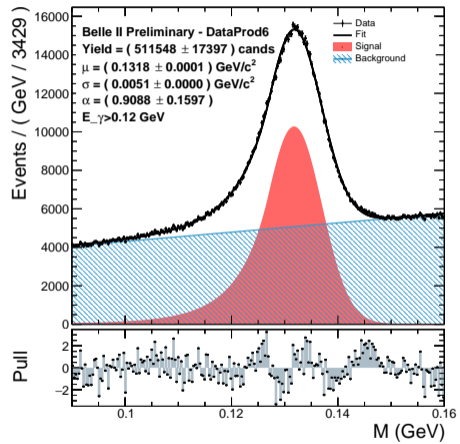


Nice agreement on σ , on MC peak is a bit shifted wrt Data

Data - Phase 2 Prod 5

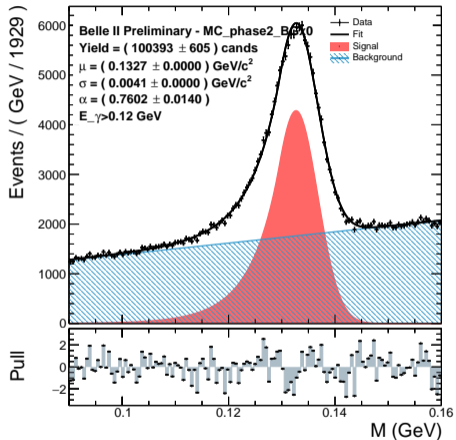


Data - Phase 2 Prod 6

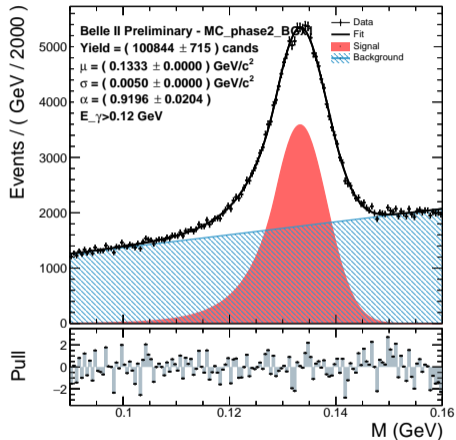


Peak position unchanged ($\Delta \sim 0.4 \text{ MeV}$), width: Prod6 5.1 MeV, Prod5 5.3 MeV, so 4% improvement.

MC - Phase 2 BGx0

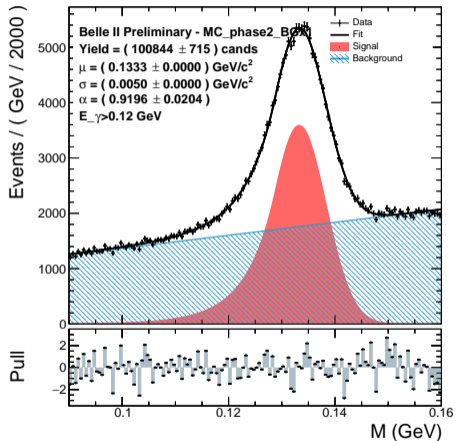


MC - Phase 2 BGx1

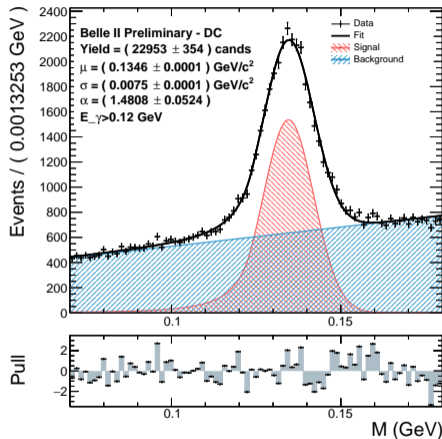


Peak position shift by 1 MeV, width increase by 1 MeV

MC - Phase 2 BGx1



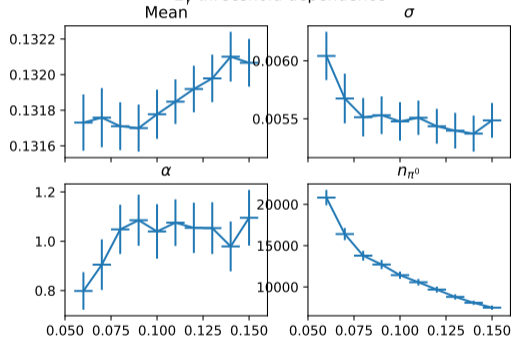
Data Challenge - Phase 3 BGx1



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

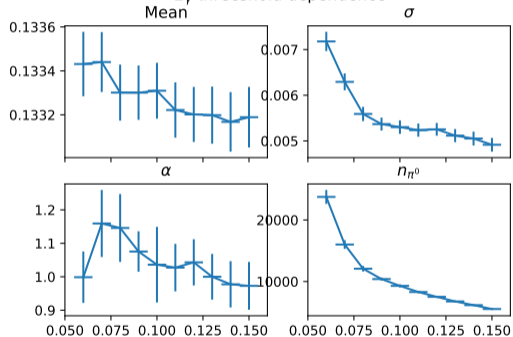
Data Prod5- Phase 2

E_{γ} threshold dependence



Montecarlo - Phase 2 BGx1

E_{γ} threshold dependence

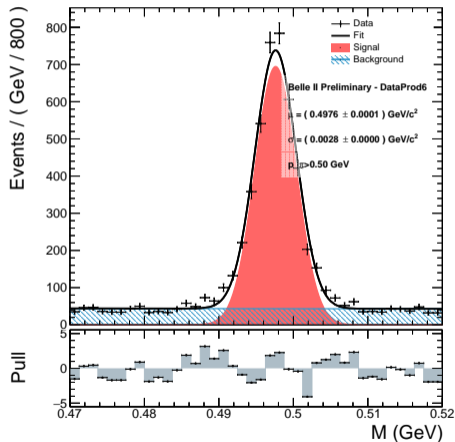


Selection:

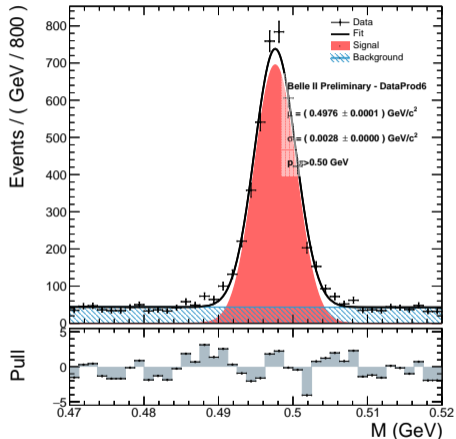
- stdPi (good)
 - ▶ $0.296706 < \theta_\pi < 2.61799$
 - ▶ $|d_0(\pi)| < 2 \text{ cm}$
 - ▶ $|z_0(\pi)| < 4 \text{ cm}$
 - ▶ $PionID > 0.5, KaonID < 0.5$
- or $p < 0.5 \text{ dr} > 0.05, dz < 0.8, \cos \Delta\phi > 0.955$
- or $0.5 < p < 1.5 \text{ dr} > 0.03, dz < 1.8, \cos \Delta\phi > 0.995$
- or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

UML Fit with Gauss + Chebychev[1]

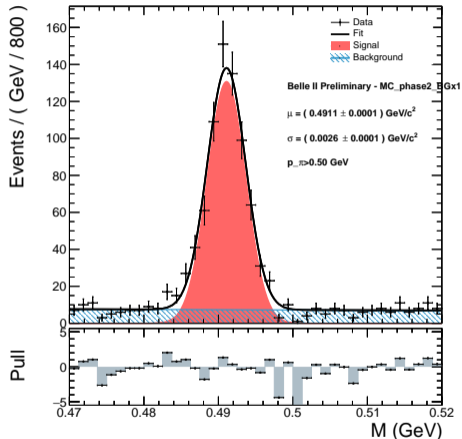
Invariant Mass plot for Data Prod6, 500 nb^{-1}



Data - Phase 2

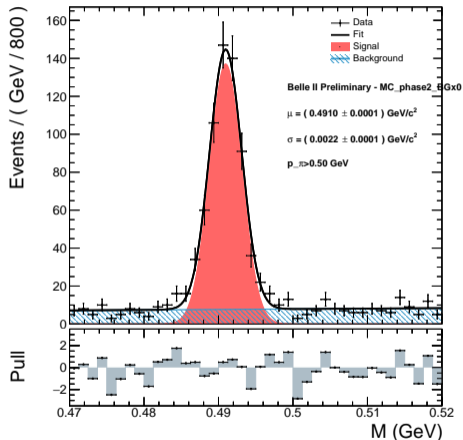


Montecarlo - Phase 2 BGx1

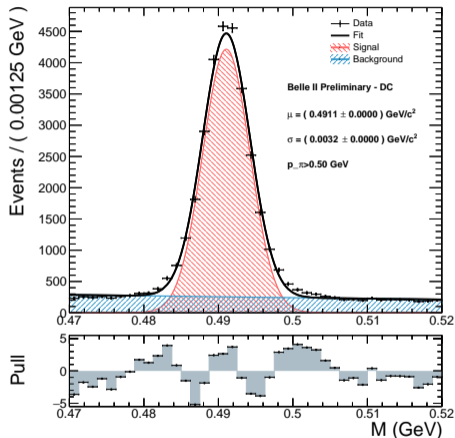


Significan shift in peak position, width similar (large on Data)

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:

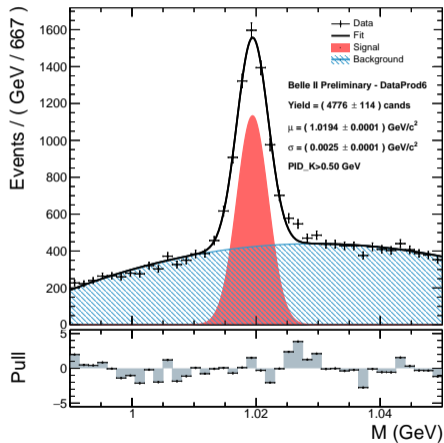
- stdK(good)

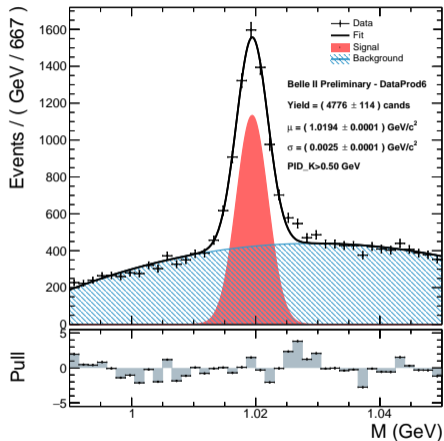
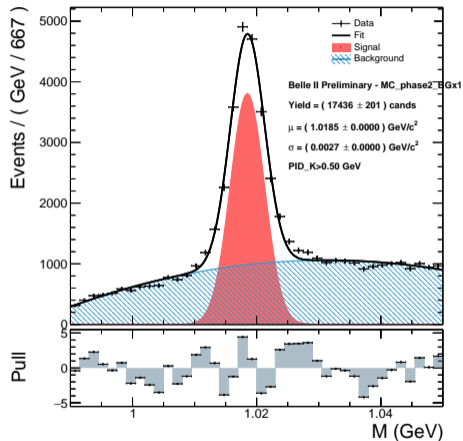
- ▶ $0.296706 < \theta_\pi < 2.61799$
- ▶ $|d_0(\pi)| < 2 \text{ cm}$
- ▶ $|z_0(\pi)| < 4 \text{ cm}$
- ▶ $PionID < 0.5$
- ▶ $KaonID > 0.5$
- ▶ $NHits_{CDC} > 15$

- $p_K > 0.3 \text{ GeV}$

UML Fit with Gauss + Chebychev[1]

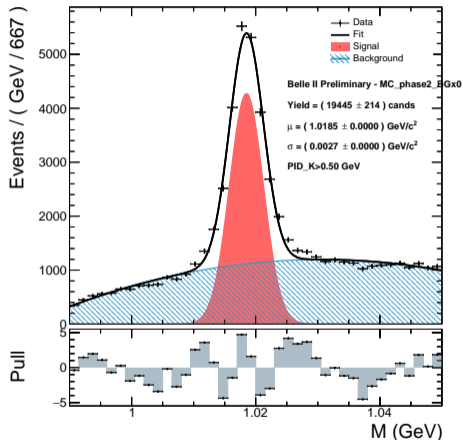
Invariant Mass plot for Data Prod6, 500 nb^{-1}



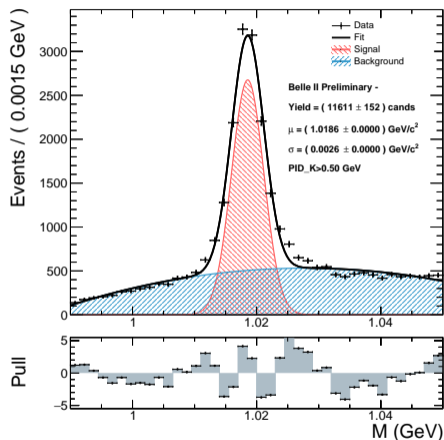
Data - Phase 2

Montecarlo - Phase 2 BGx1


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

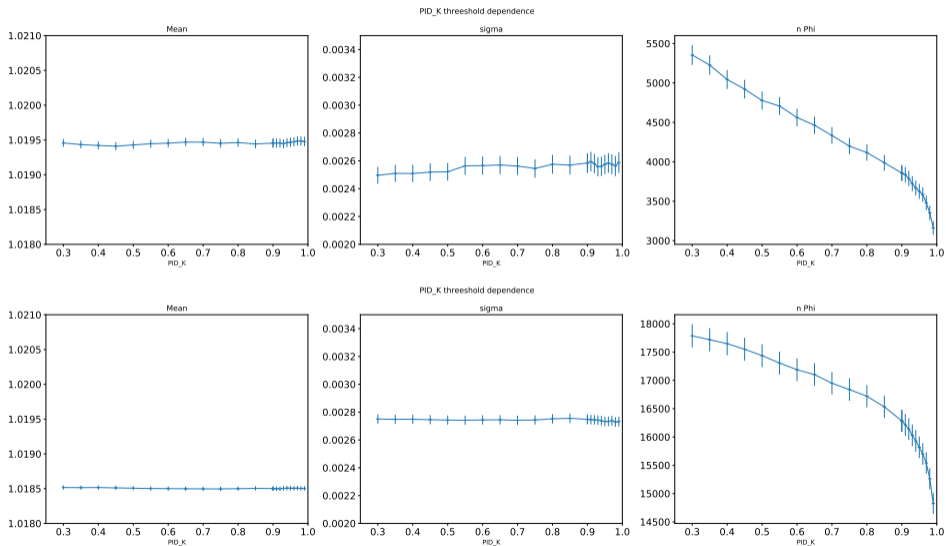
Montecarlo - Phase 2 BGx0



Montecarlo - Phase 3 BGx1 - Data Challenge



Phase 3 BGx1 better than Phase 2 BGx1 ?

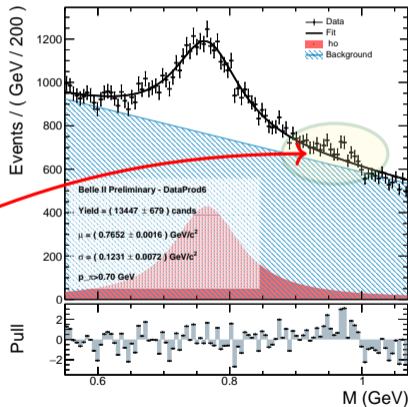


Selection:

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

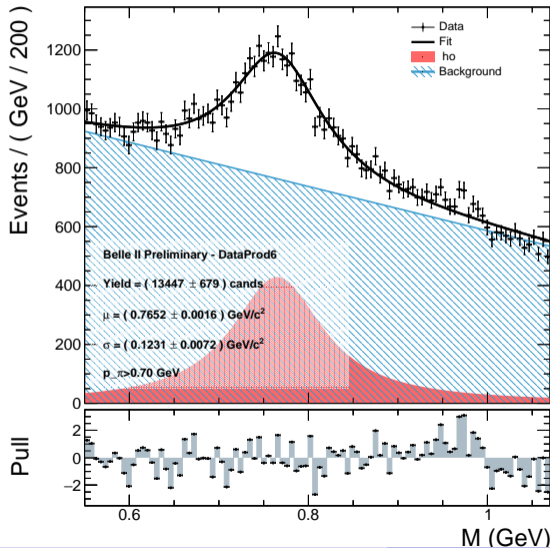
UML Fit with Breit-Wigner + Chebychev[1]

Invariant Mass plot for Data Prod6, 500 nb^{-1}

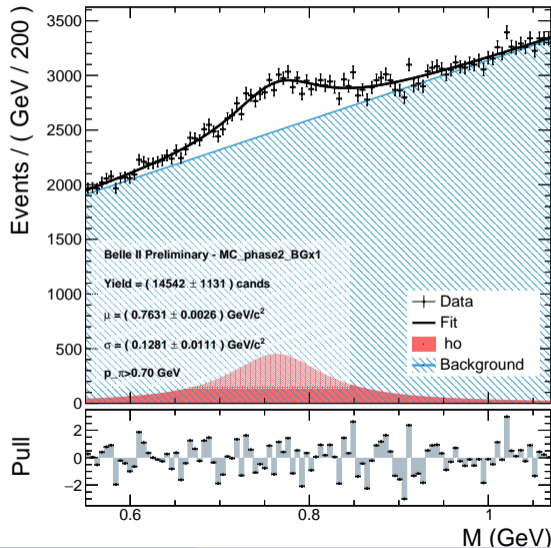


Hint of $f_0 \rightarrow \pi^+ \pi^-$ at $M_{\pi^+ \pi^-} \approx 0.98 \text{ GeV}$?

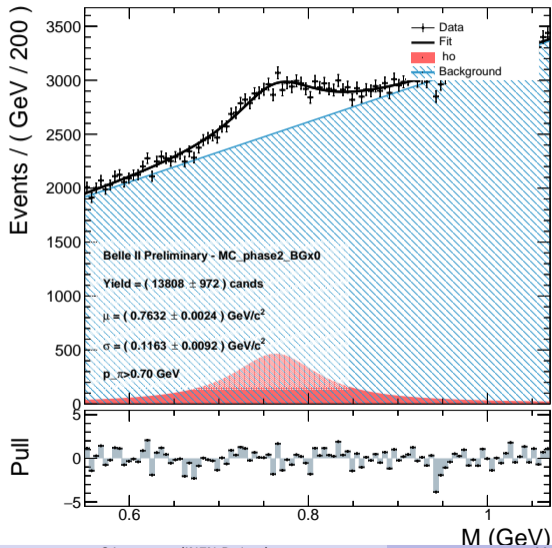
Data - Phase 2



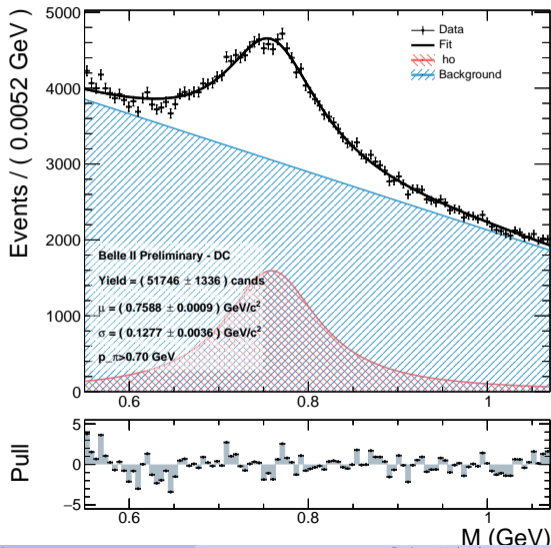
Montecarlo - Phase 2 BGx1



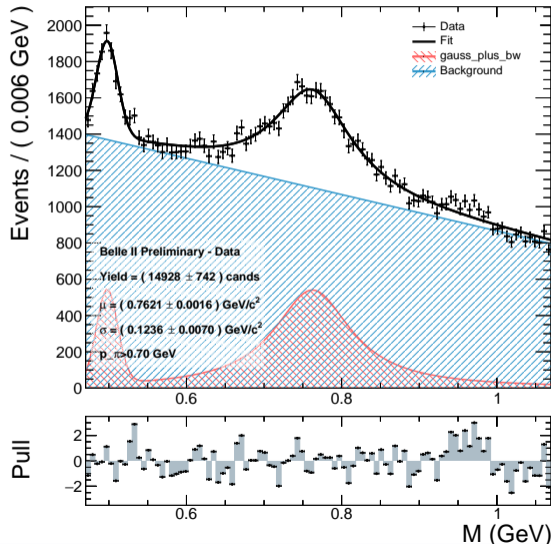
Montecarlo - Phase 2 BGx0



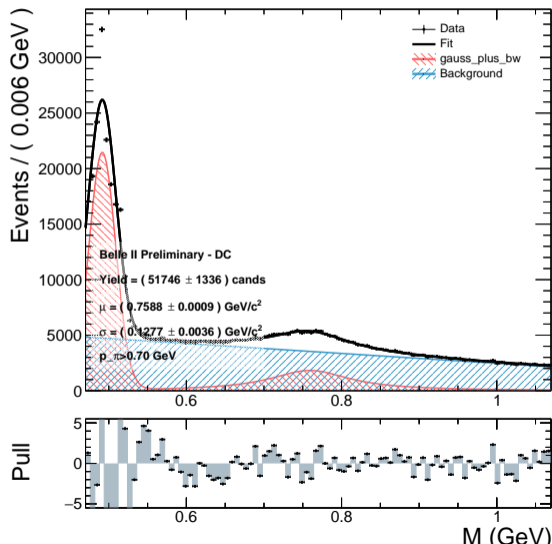
Data Challenge - Montecarlo



Data - Phase 2



Data Challenge - Montecarlo

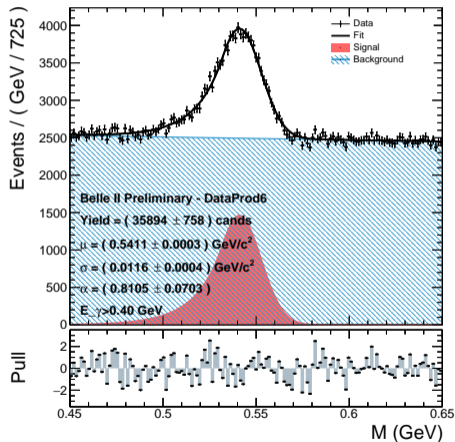


Selection:

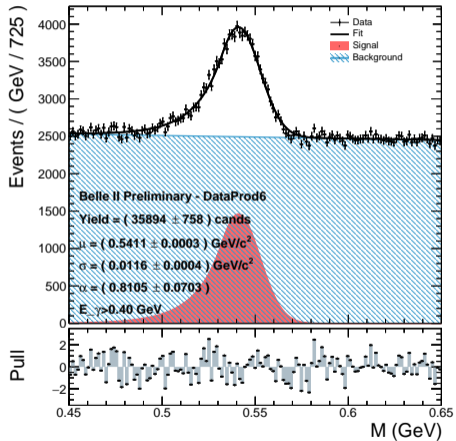
- $50 \text{ MeV} < E_\gamma < 6 \text{ GeV}$
- $E_9/E_{25} > 0.75$
- Cluster: $N_{hits} > 5$, $E_9/E_{21} > 0.95$
- $0.296706 < \theta_\gamma < 2.61799$
- Varing $E_\gamma > 300 - 500 \text{ MeV}$

UML Fit with CristalBall + Chebychev[1]

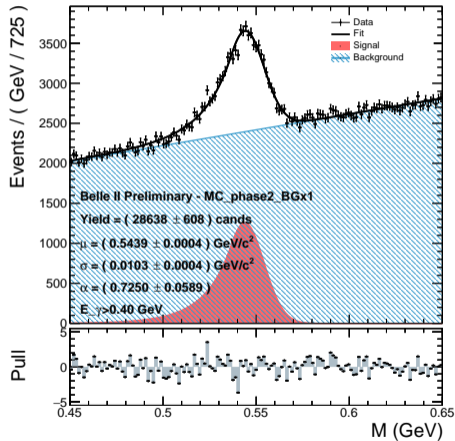
Invariant Mass plot for Data Prod6, 500 nb^{-1}



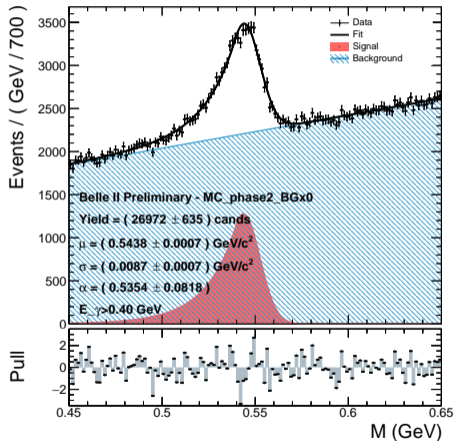
Data - Phase 2



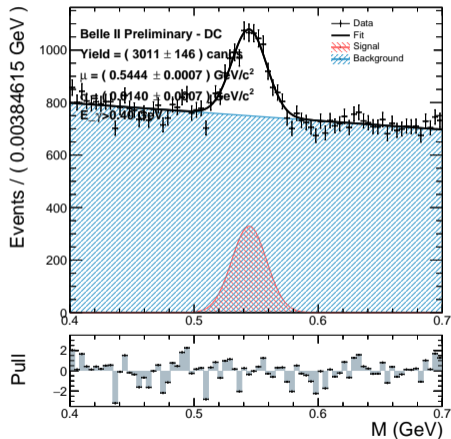
Montecarlo - Phase 2 BGx1



BGx0 MC Phase 2

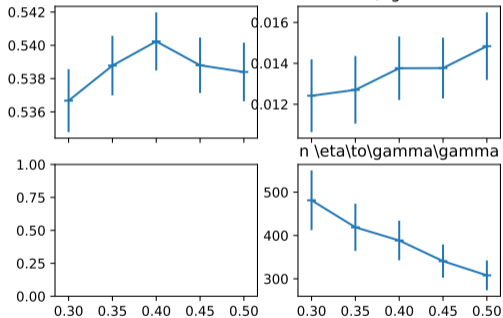


BGx1 MC Phase 3 Data Challenge



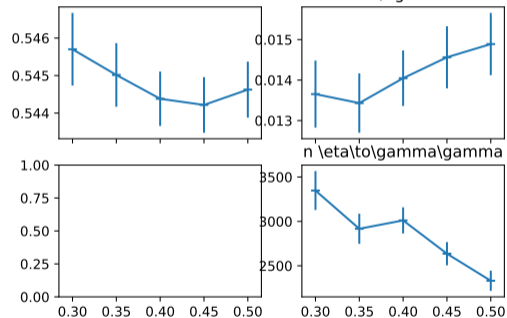
Data - Phase 2

E_γ threshold dependence
Mean



Data Challenge - Montecarlo

E_γ threshold dependence
Mean

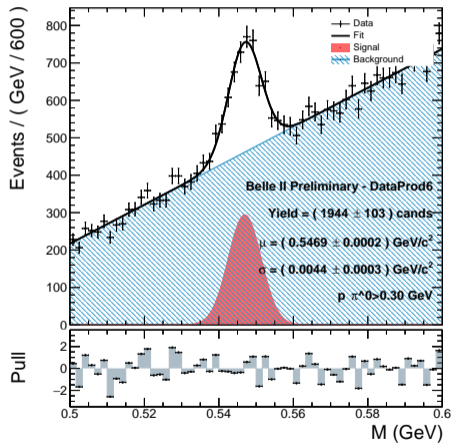


Selection:

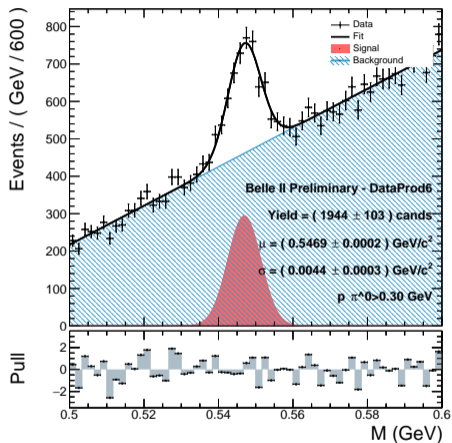
- $\pi^0 \rightarrow \gamma\gamma$
 - ▶ $50 \text{ MeV} < E_\gamma < 6 \text{ GeV}$
 - ▶ Cluster: $N_{hits} > 1.5, E_9/E_{21} > 0.9$
 - ▶ $100 < M_{\gamma\gamma} < 150 \text{ MeV}$
 - ▶ $p_{\pi^0} > 300 \text{ MeV}$
- π^\pm
 - ▶ $|d_0(\pi)| < 2 \text{ cm}, |z_0(\pi)| < 4 \text{ cm}$
 - ▶ $PionID > 0.5,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

UML Fit with Gauss + Chebychev[1]

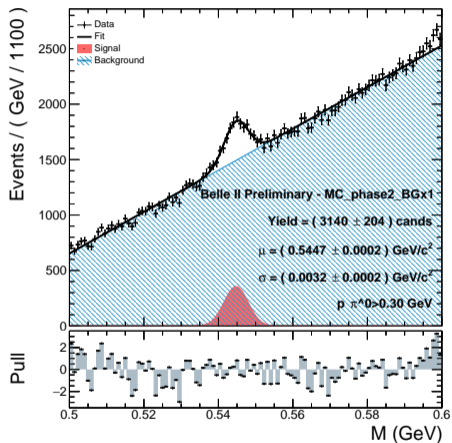
Invariant Mass plot for Data Prod6, 500 nb^{-1}



Data - Phase 2

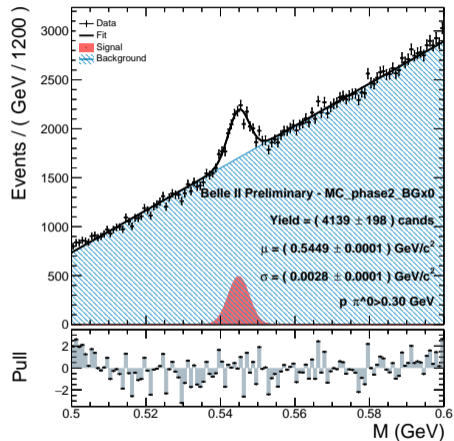


Montecarlo - Phase 2 BGx1

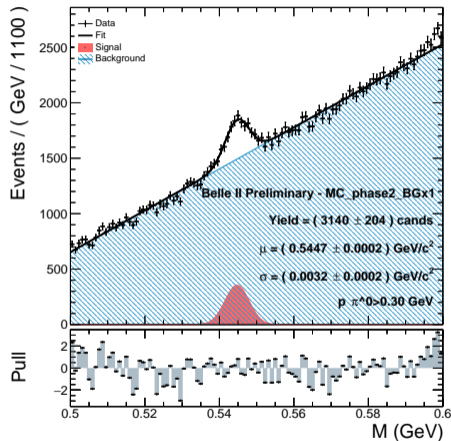


Peak on MC ~ 2 MeV higher than data. Width significantly larger on Data (4.4 vs 3.2 MeV).
 S/B very different (MC only $c\bar{c}$)

Montecarlo - Phase 2 BGx0

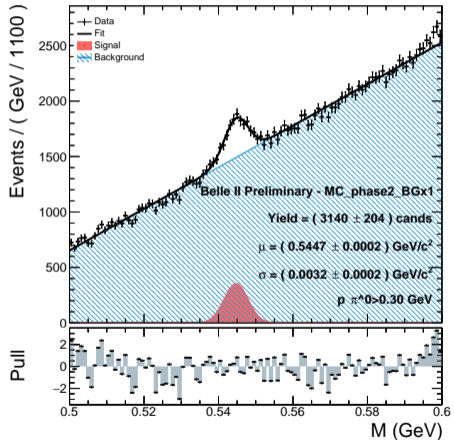


Montecarlo - Phase 2 BGx1

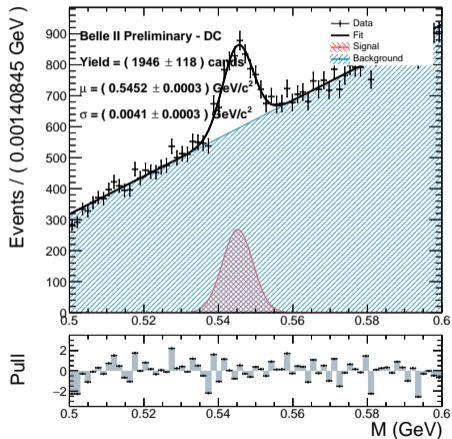


Width increases from 2.8 to 3.2 MeV with BGx1

Montecarlo - Phase 2 BGx1



Montecarlo - Phase 3 BGx1 - Data Challenge

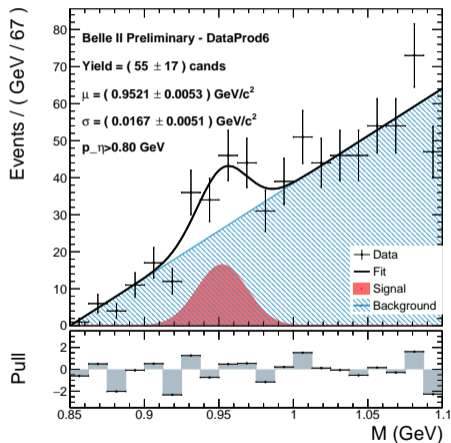


Selection:

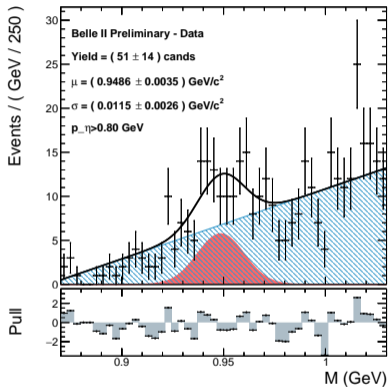
- $\eta \rightarrow \gamma\gamma$
 - ▶ $E_9/E_{25} > 0.75$
 - ▶ Cluster: $N_{hits} > 5$, $E_9/E_{21} > 0.93$
 - ▶ $E_\gamma > 400$ MeV
 - ▶ $0.52 < M_{\gamma\gamma} < 0.56$ GeV
 - ▶ $p_\eta > 0.8$ GeV
- π^\pm
 - ▶ $|d_0(\pi)| < 2$ cm, $|z_0(\pi)| < 4$ cm
 - ▶ $PionID > 0.5$, $KaonID < 0.5$
 - ▶ $p_\pi > 300$ MeV

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

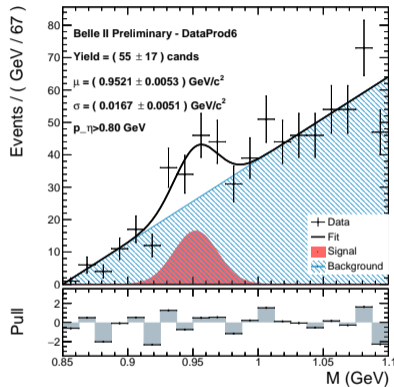
Invariant Mass plot for Data Prod5, 500 nb^{-1}



Data - Phase 2 -Prod5

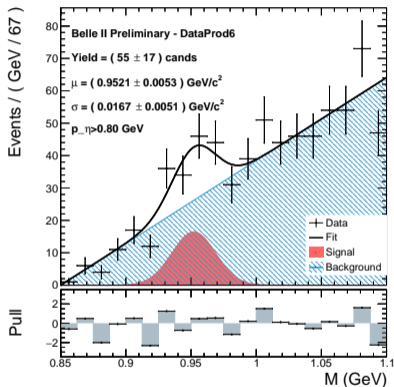


Data - Phase II - Prod6

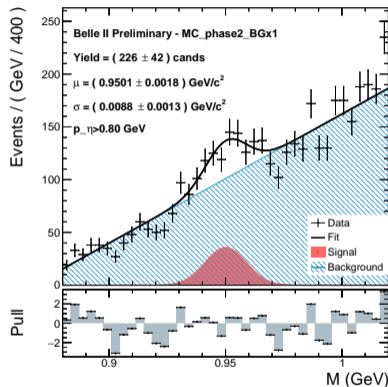


Maybe is a signal. Visible also in Prod5, width smaller (but fit is rather unstable and statistics - if any - small)

Data - Phase 2

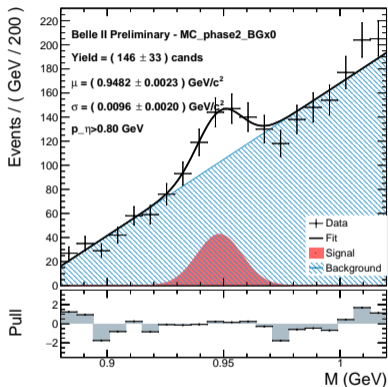


Montecarlo - Phase 2 BGx1

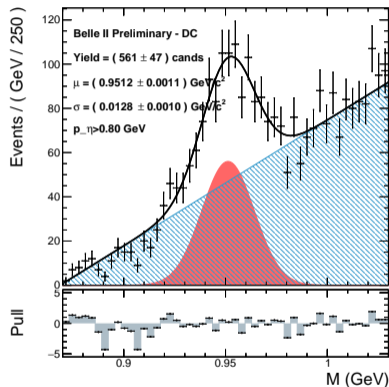


Maybe is a signal. "Peak" position is correct, $\sigma \sim 16 \text{ MeV}$ is larger than MC (10 MeV)

Montecarlo - Phase 2 BGx0



Montecarlo - Phase 3 BGx1 - Data Challenge



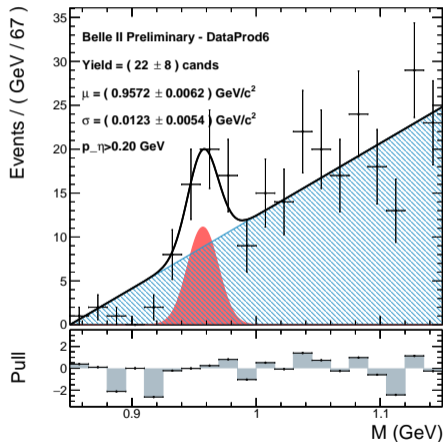
Maybe is a signal. "Peak" position is correct, $\sigma \sim 16$ MeV is larger than MC (10 MeV)

Selection:

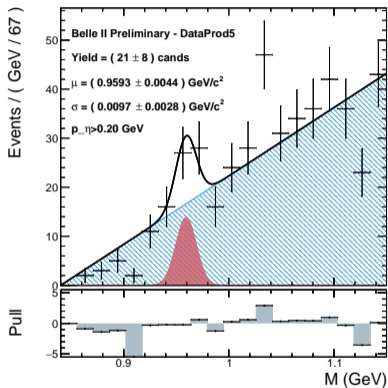
- $50 \text{ MeV} < E_\gamma < 6 \text{ GeV}$
- $-150 < T_{cluster} < 0 \text{ ns}$
- $E_9/E_{25} > 0.75$
- Cluster: $N_{hits} > 1.5, E_9/E_{21} > 0.9$
- $0.5 < \theta_{\gamma_0} < 2.5$
- $0.296706 < \theta_{\gamma_1} < 2.61799$
- $E_\gamma > 250 \text{ MeV}$

UML Fit with Gauss + Chebychev[1] **maybe, very maybe ...**

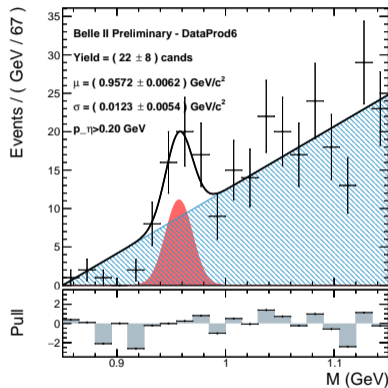
Invariant Mass plot for Data Prod6, 500 nb^{-1}



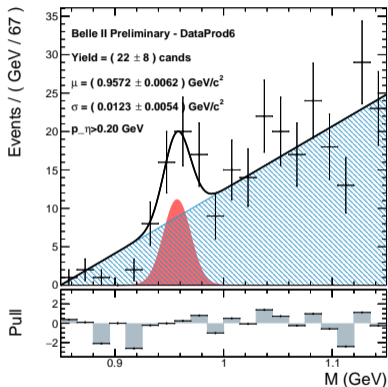
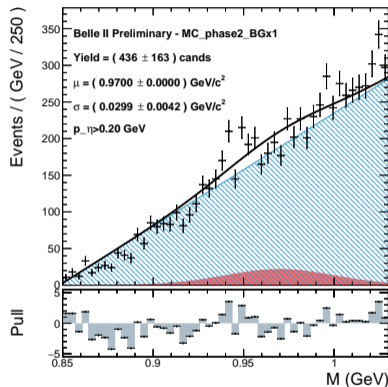
Data - Phase 2 Prod5



Data - Phase 2 Prod6

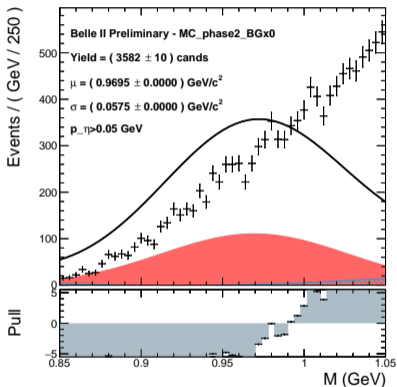


Very maybe both in Prod5 and Prod6

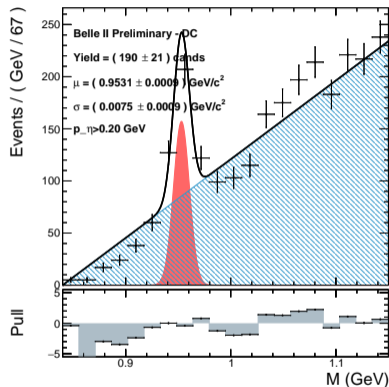
Data - Phase 2

Montecarlo - Phase 2 BGx1


Almost no signal in the MC (even before the cuts) Wrong MC?

Montecarlo - Phase 2 - BGx0



Montecarlo - Phase 3 - BGx1



Nice peak in DC (NB, the fit is UML, binned plot just for show)

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

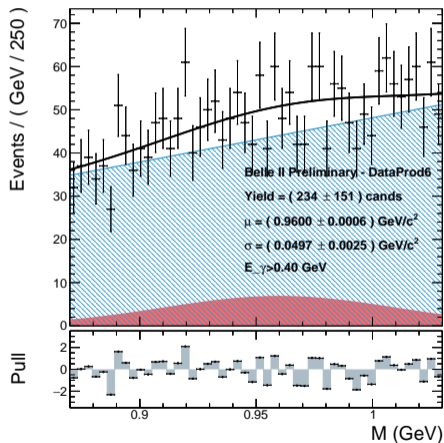
Selection:

- $\rho \rightarrow \pi^+\pi^-$
 - ▶ PionID_i0.5, KaonID_i0.5
 - ▶ $p_\pi > 0.5$ GeV
 - ▶ M_ρ KFit constrained: $0.75 < M_{nc} < 0.79$
- γ
 - ▶ gamma:pi0 from stdPhotons
 - ▶ Cluster: $N_{hits} > 1.5$, $E_9/E_{21} > 0.9$
 - ▶ $E_\gamma > 100$ MeV
 - ▶ $|M_{\gamma\gamma} - M_{\pi_0}| > 20$ MeV with the γ from ROE with $M_{\gamma\gamma}$ closest to M_{π_0} (pioVeto)

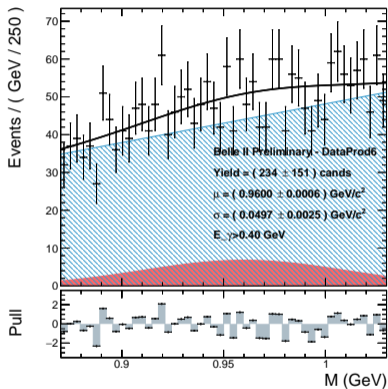
UML Fit with Gauss + Chebychev[1]

Not a signal

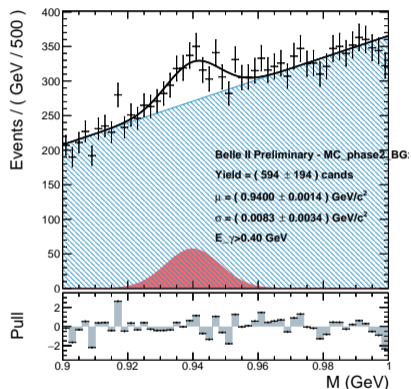
Invariant Mass plot for Data Prod6, 500 nb^{-1}



Data Prod6 - Phase 2

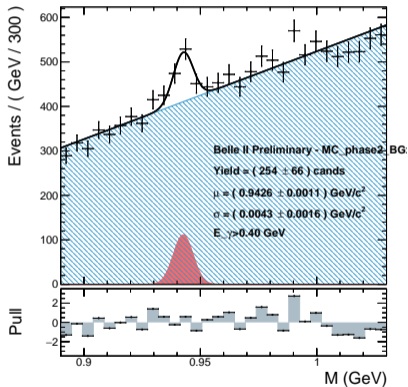


Montecarlo phase 2 BGx1

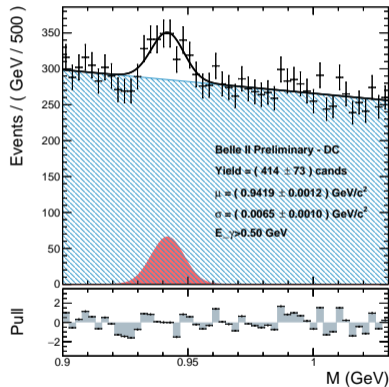


No signal seen

Montecarlo phase 2 BGx0



Montecarlo phase 3 BGx1 Data Challenge



Additional or backup slides

