



$J/\psi \rightarrow \omega\pi^0$ **analysis**
event selection, MC and backgrounds

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Event selection

$$J/\psi \rightarrow \omega\pi^0$$

$$e^+e^- \rightarrow \omega\pi_1^0 \rightarrow \pi^+\pi^-\gamma\gamma\gamma\gamma$$



$$\pi^+\pi^-\pi_2^0$$

vertex reconstruction from $\pi^+\pi^-$
 ω reconstruction through $\pi^+\pi^-\pi^0$
 π^0 identification through $\gamma\gamma$

$$\text{BR}_{\text{PDG}}(J/\psi \rightarrow \omega\pi^0) = (4.5 \pm 0.5) \times 10^{-4}$$

$$\text{BR}_{\text{PDG}}(\pi^0 \rightarrow \gamma\gamma) = 0.98823 \pm 0.00034$$

$$\text{BR}_{\text{PDG}}(\omega \rightarrow \pi^+\pi^-\pi^0) = 0.893 \pm 0.006$$

P.A. Zyla et al. (Particle Data Group), Prog. Theor. Exp. Phys. 2020, 083C01 (2020)

Charged tracks (MDC):
 Origin: $V_r < 1.0$ cm,
 $|V_z| < 10.0$ cm
 $|\cos\theta| < 0.93$

Neutral tracks (EMC):
 Endcap: $0.86 < |\cos\theta| < 0.92$
 $E_{\text{endcap}} > 50$ MeV
 Barrel: $|\cos\theta| < 0.8$
 $E_{\text{barrel}} > 25$ MeV

Event selection

m2gg events

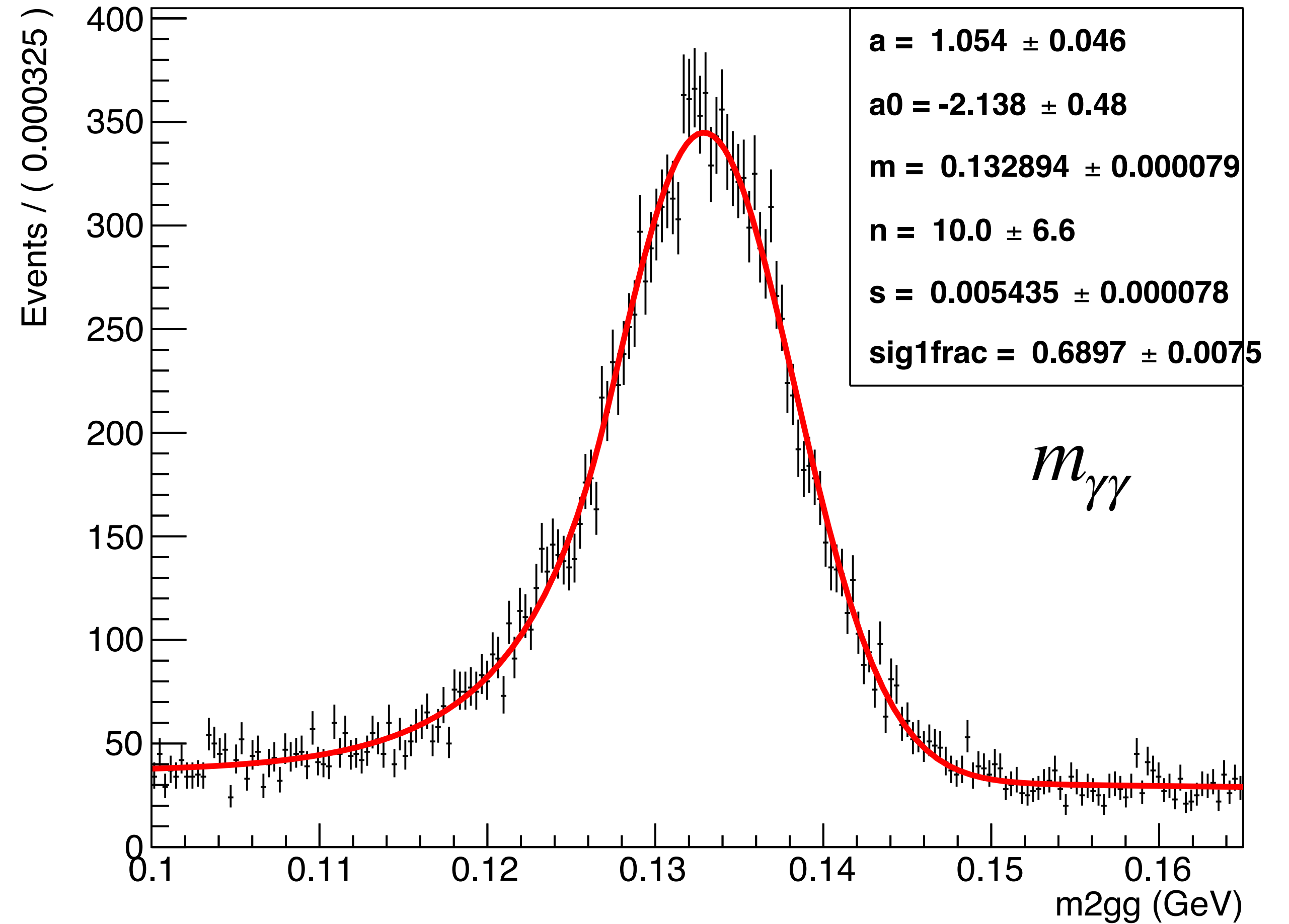
Signal exclusive MC 20k

Crystal-ball plus polynomial fit on the $\gamma\gamma$ distribution

We obtain

$$\sigma_{\pi^0} = 5.45 \text{ MeV}/c^2$$

From the FWHM sigma



our choice

Signal MC 20k samples

Selection "C4P2"

Kalman fit with 4 constraints:

- CM 4-momentum

+

Minimization of $\chi_{\pi^0\pi^0}^2$

$$\chi_{\pi^0\pi^0}^2 = \frac{(m(\gamma_1\gamma_2) - m_{\pi^0}^{\text{PDG}})^2}{\sigma_{\pi^0}^2} + \frac{(m(\gamma_3\gamma_4) - m_{\pi^0}^{\text{PDG}})^2}{\sigma_{\pi^0}^2}$$

$$\sigma_{\pi^0} \simeq 5.45 \text{ MeV}/c^2$$

Selected events: **6650**

C4

P2

Selection "C6"

Kalman fit with 6 constraints:

- CM 4-momentum
- π_1^0 resonance from $\gamma\gamma$
- π_2^0 resonance from $\gamma\gamma$

Selected events: **6238**

Selection "C7"

Kalman fit with 7 constraints:

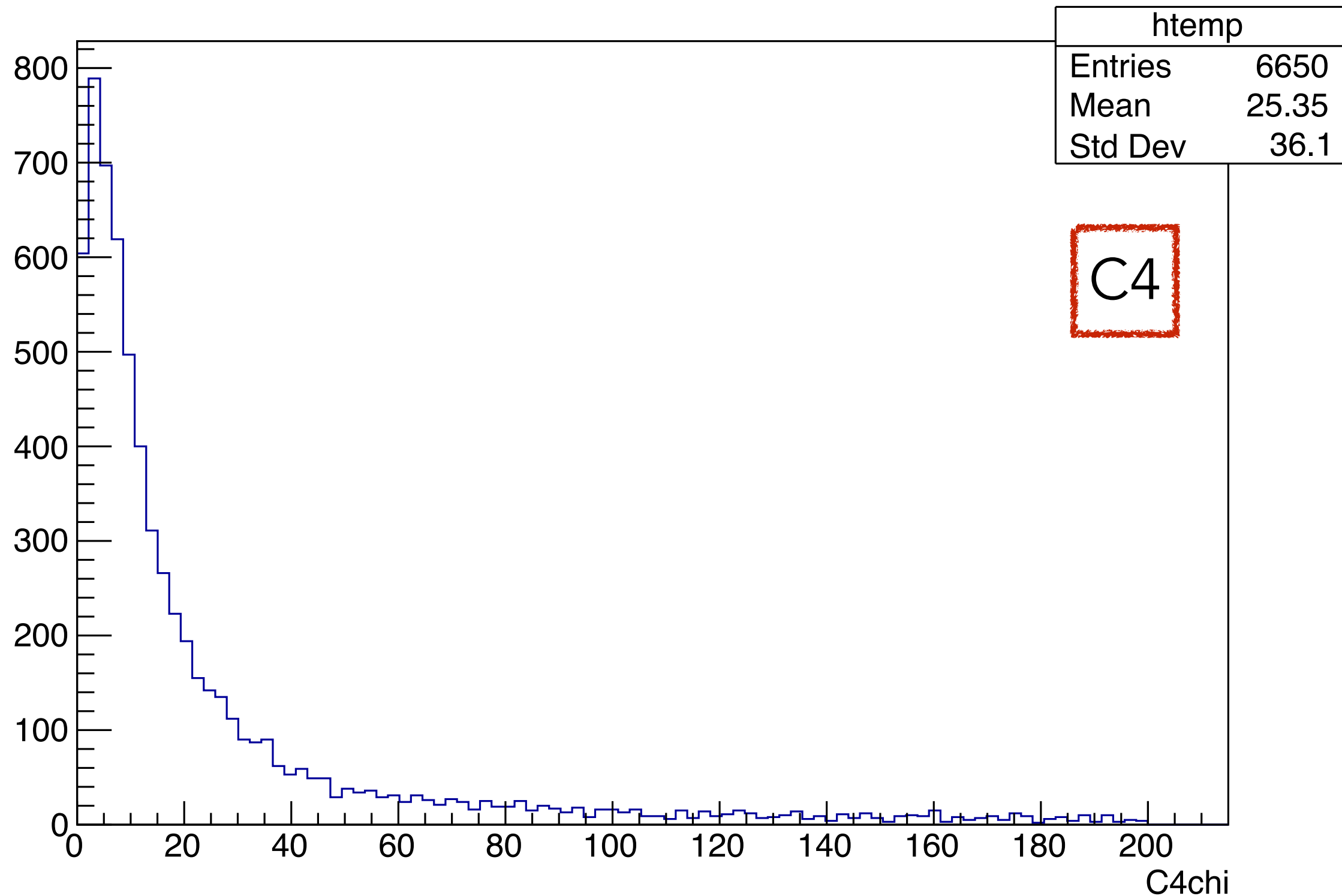
- CM 4-momentum
- π_1^0 resonance from $\gamma\gamma$
- π_2^0 resonance from $\gamma\gamma$
- $\pi_2^0\pi^+\pi^-$ resonance from $\gamma\gamma\pi^+\pi^-$

Selected events: **5818**

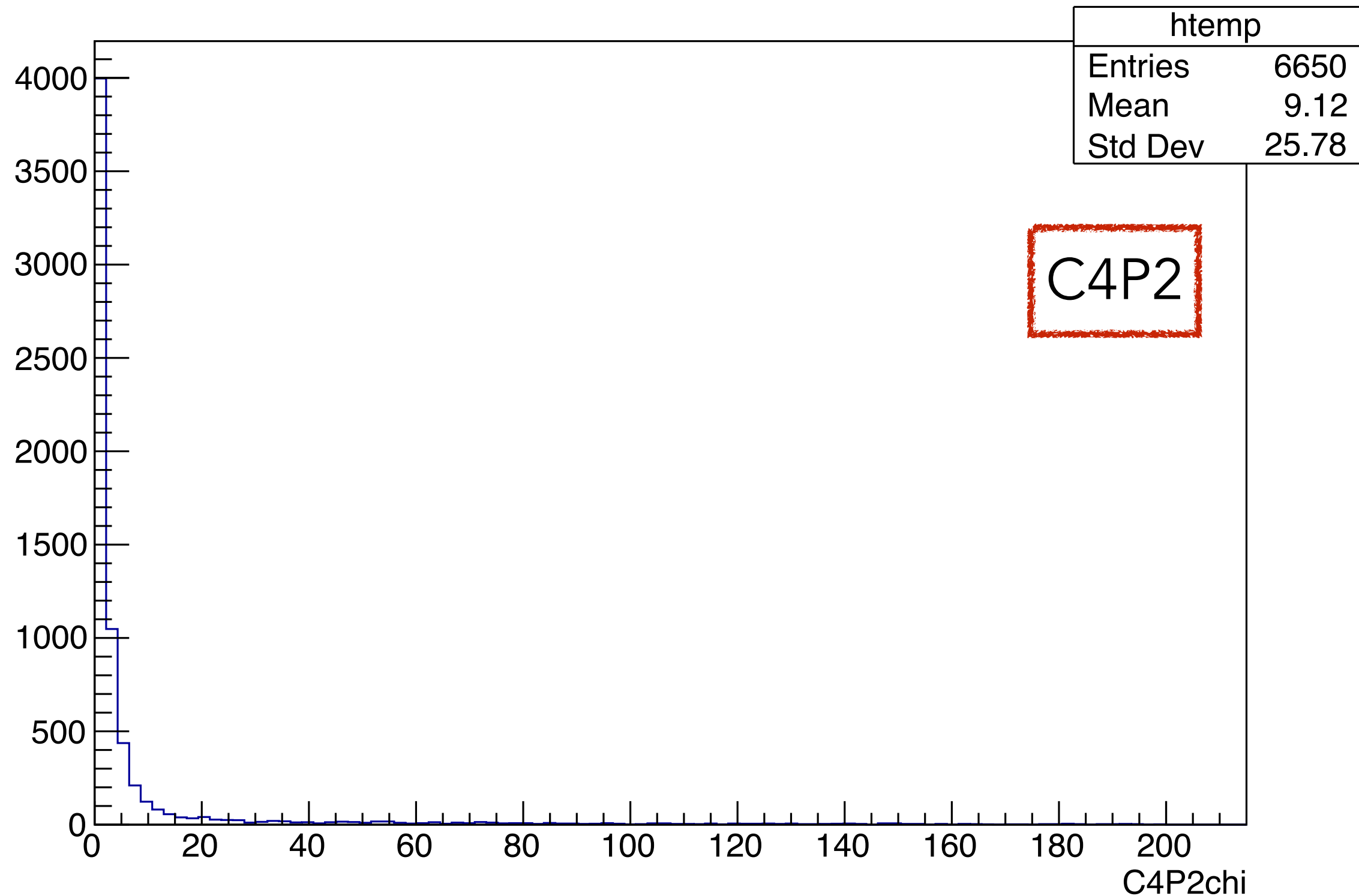
Efficiency of C4P2 $\sim 33.25\%$

χ^2 comparison

C4chi

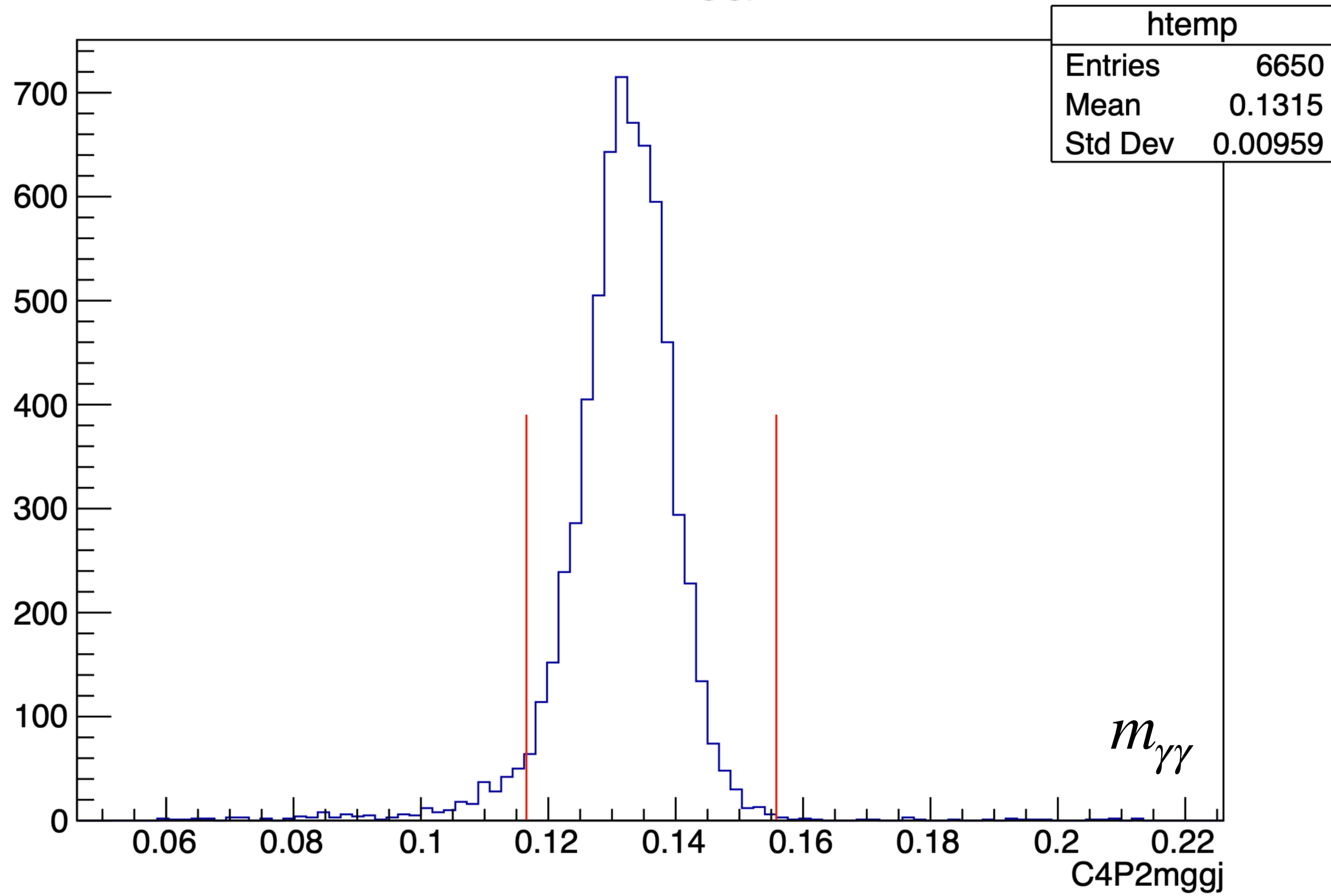


C4P2chi

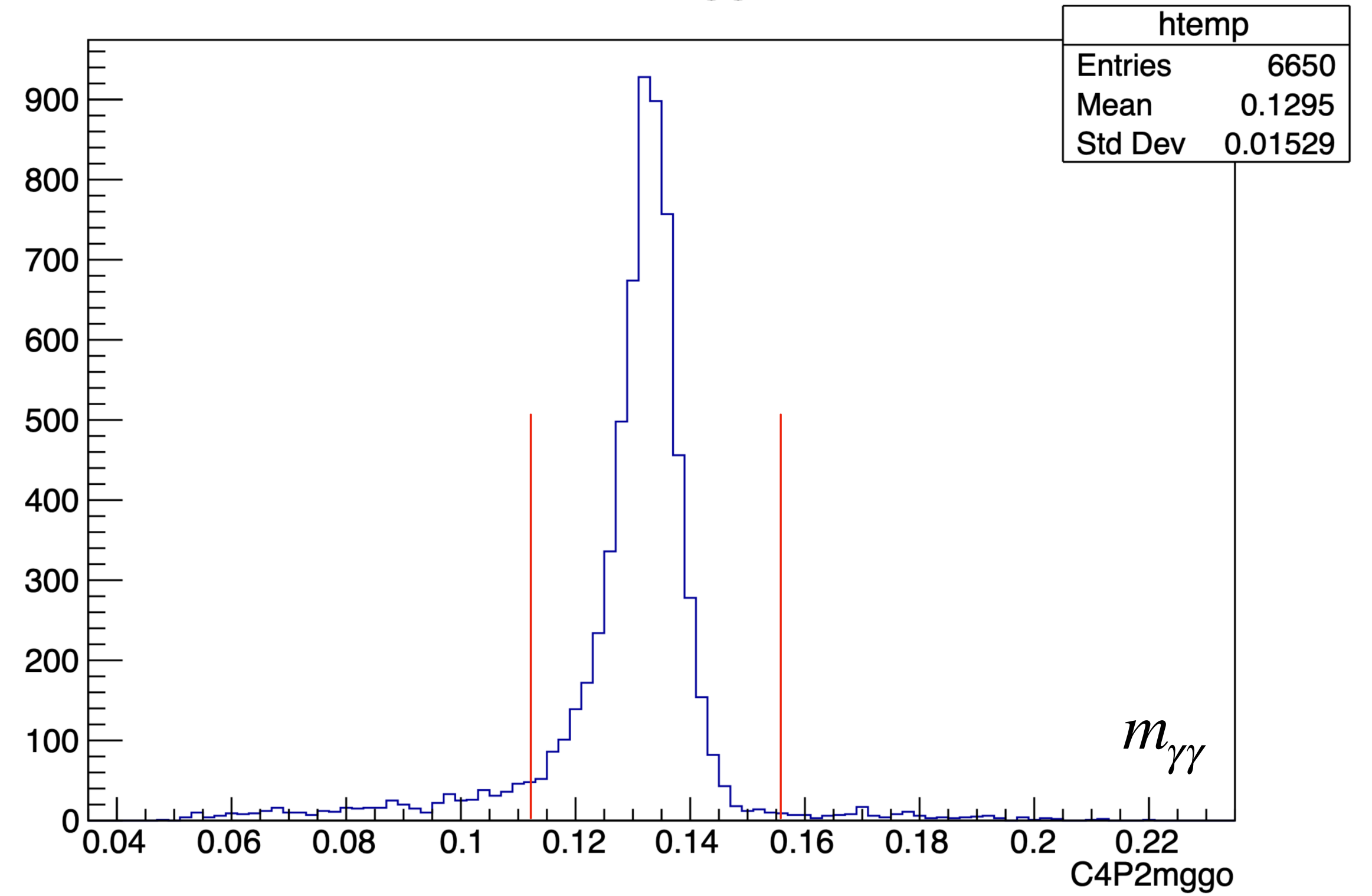


$$e^+e^- \rightarrow \omega\pi_1^0 \rightarrow \pi^+\pi^-\pi_2^0(\gamma\gamma)\pi_1^0(\gamma\gamma)$$

C4P2mggj



C4P2mggo



Cut on $\gamma\gamma$ invariant mass

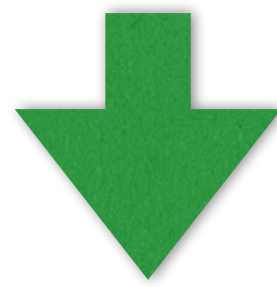
$$\sigma_{\pi^0} \simeq 5.45 \text{ MeV}/c^2$$

$$|m_{(\gamma\gamma)\pi^0} - m_{\pi^0}^{\text{PDG}}| < 4\sigma_{\pi^0}$$

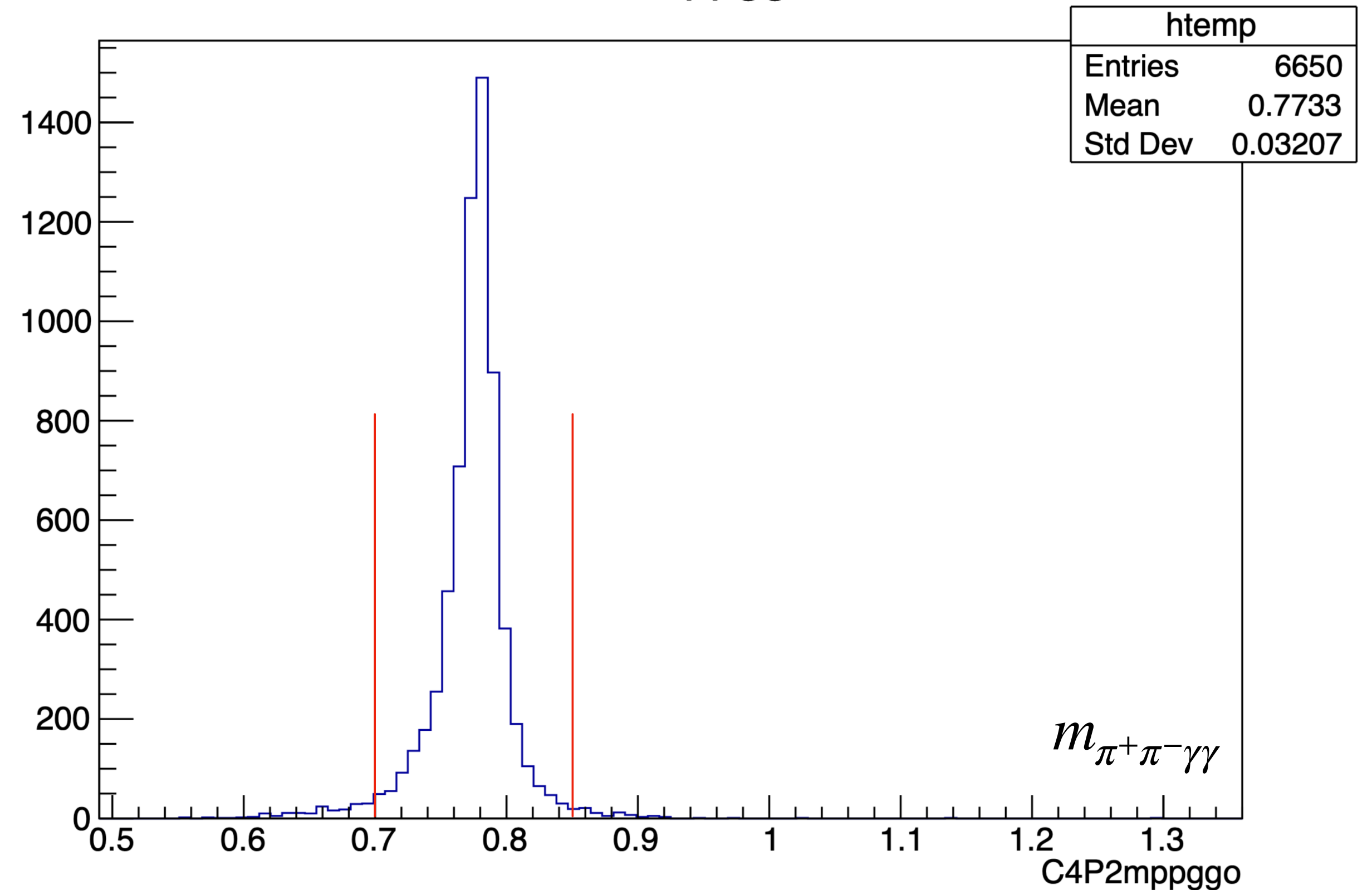
$$e^+e^- \rightarrow \omega\pi_1^0 \rightarrow \pi^+\pi^-\pi_2^0(\gamma\gamma)\pi_1^0(\gamma\gamma)$$

C4P2mppggo

Cut on $\pi^+\pi^-\gamma\gamma$ invariant mass



$$0.70 \text{ GeV} < m(\pi^+\pi^-(\gamma\gamma)\pi_2^0) < 0.85 \text{ GeV}$$



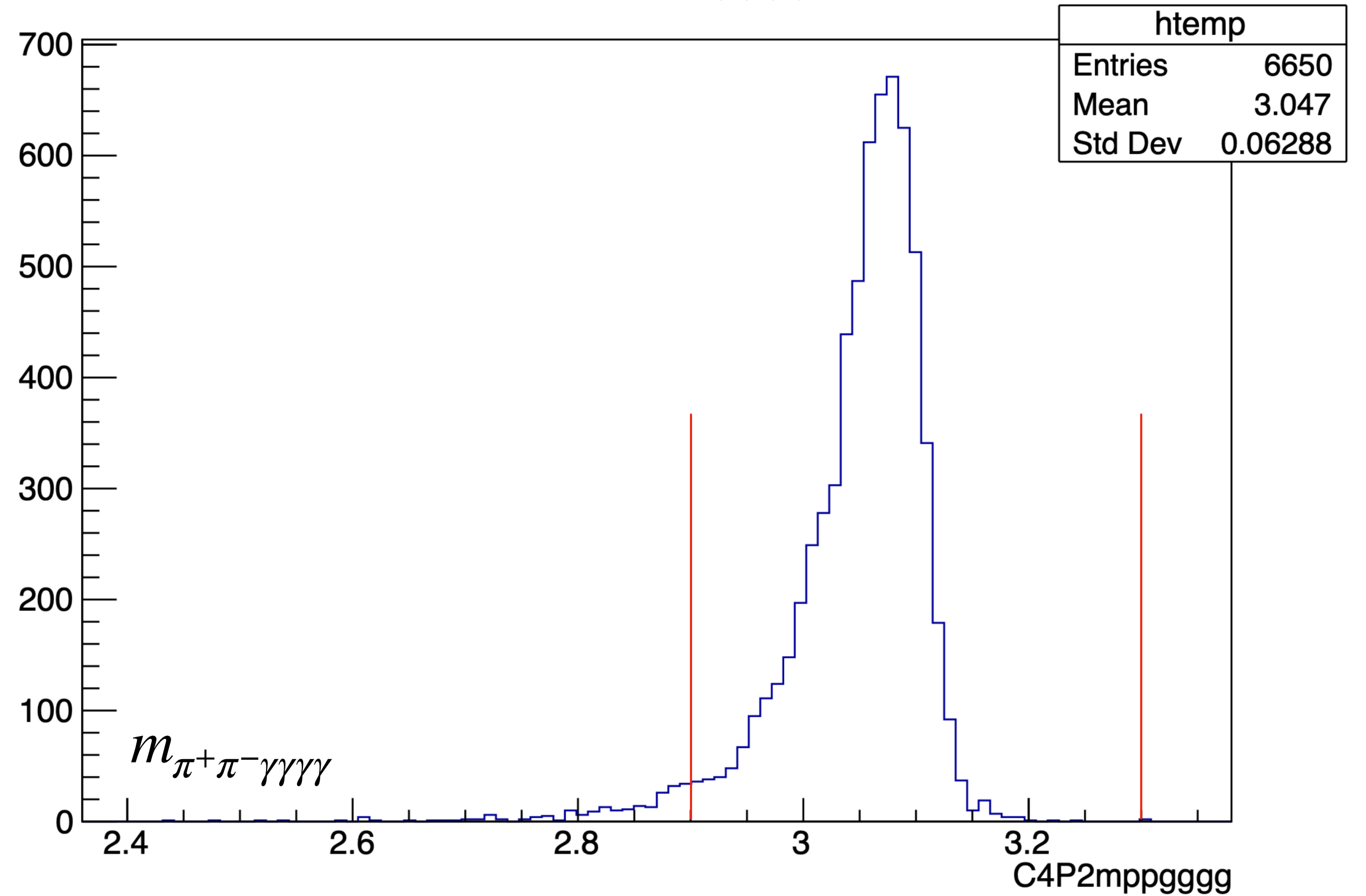
$$e^+e^- \rightarrow \omega\pi_1^0 \rightarrow \pi^+\pi^-\pi_2^0(\gamma\gamma)\pi_1^0(\gamma\gamma)$$

C4P2mppgggg

Cut on $\pi^+\pi^-\gamma\gamma\gamma\gamma$ invariant mass

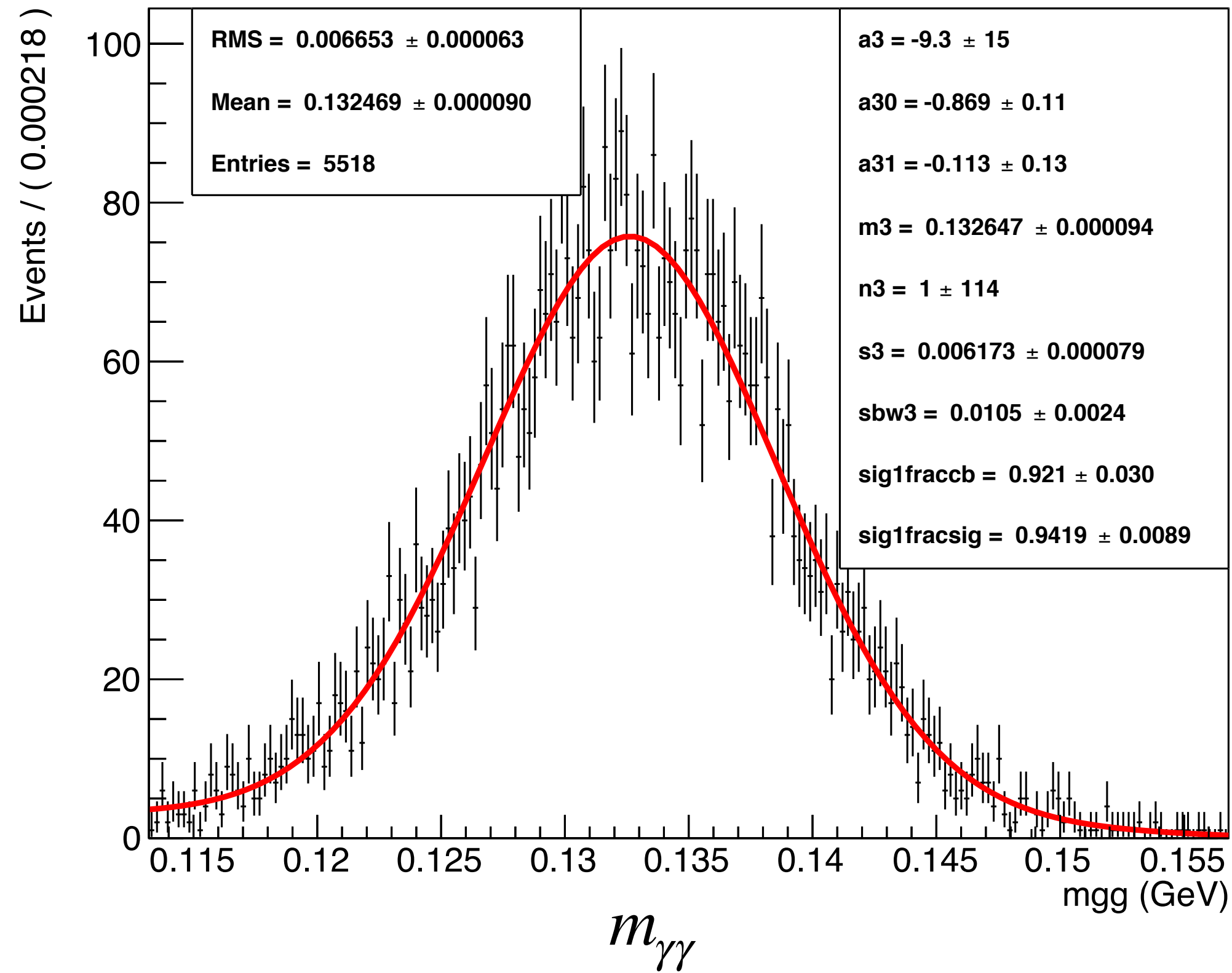


$$2.9 \text{ GeV} < m(\pi^+\pi^-\gamma\gamma\gamma\gamma) < 3.3 \text{ GeV}$$

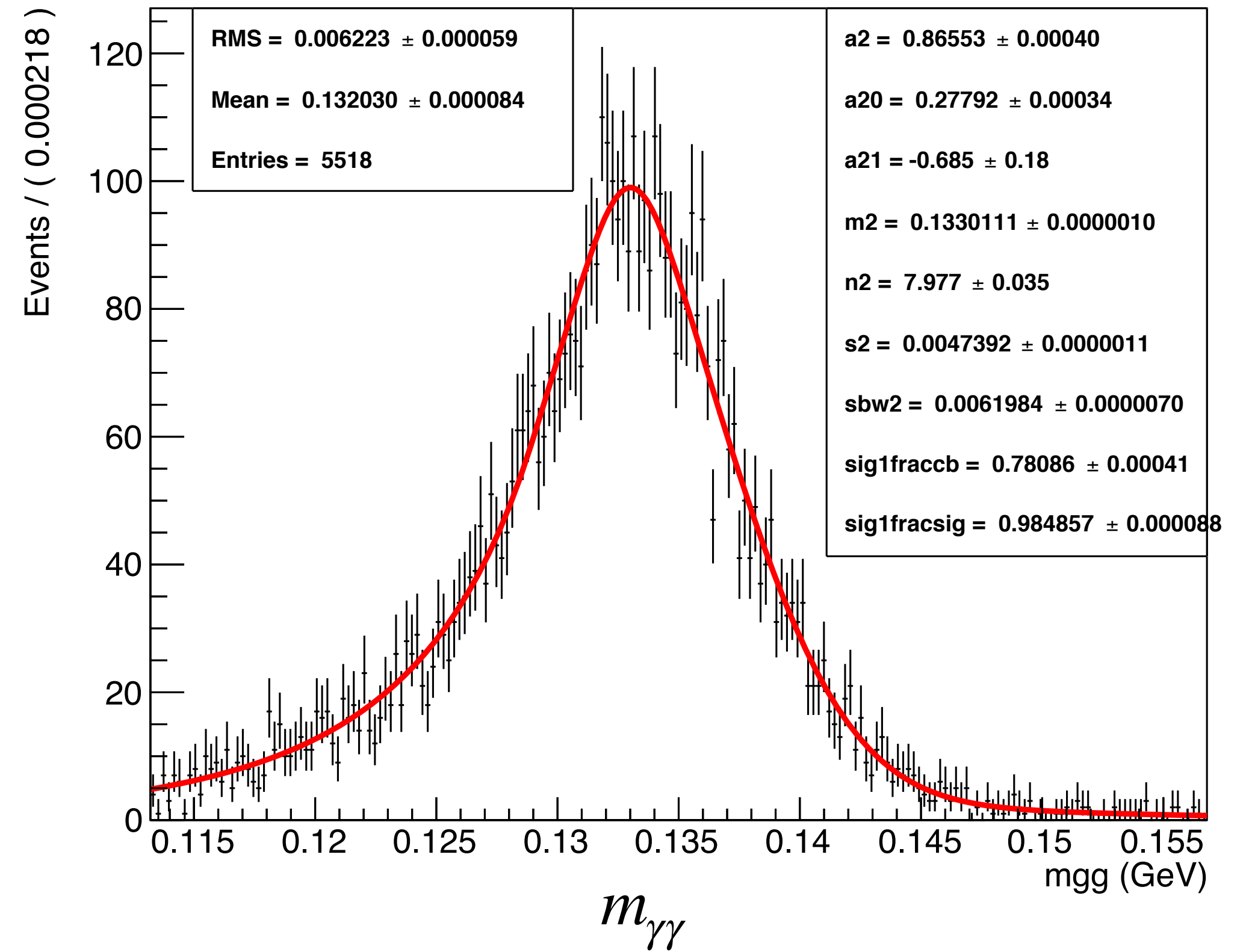


$$e^+e^- \rightarrow \omega\pi_1^0 \rightarrow \pi^+\pi^-\pi_2^0(\gamma\gamma)\pi_1^0(\gamma\gamma)$$

m_C4P2mggj



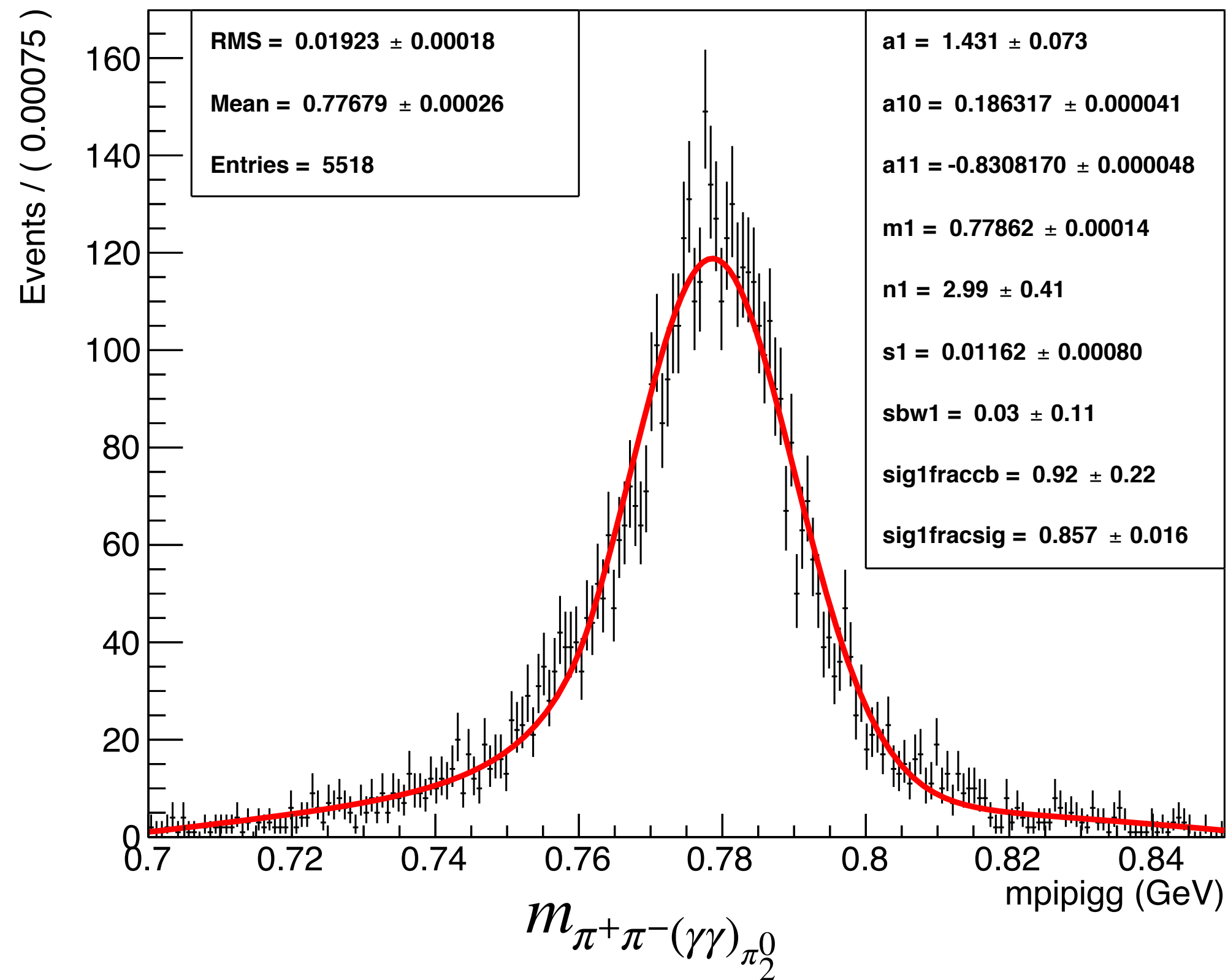
m_C4P2mggo



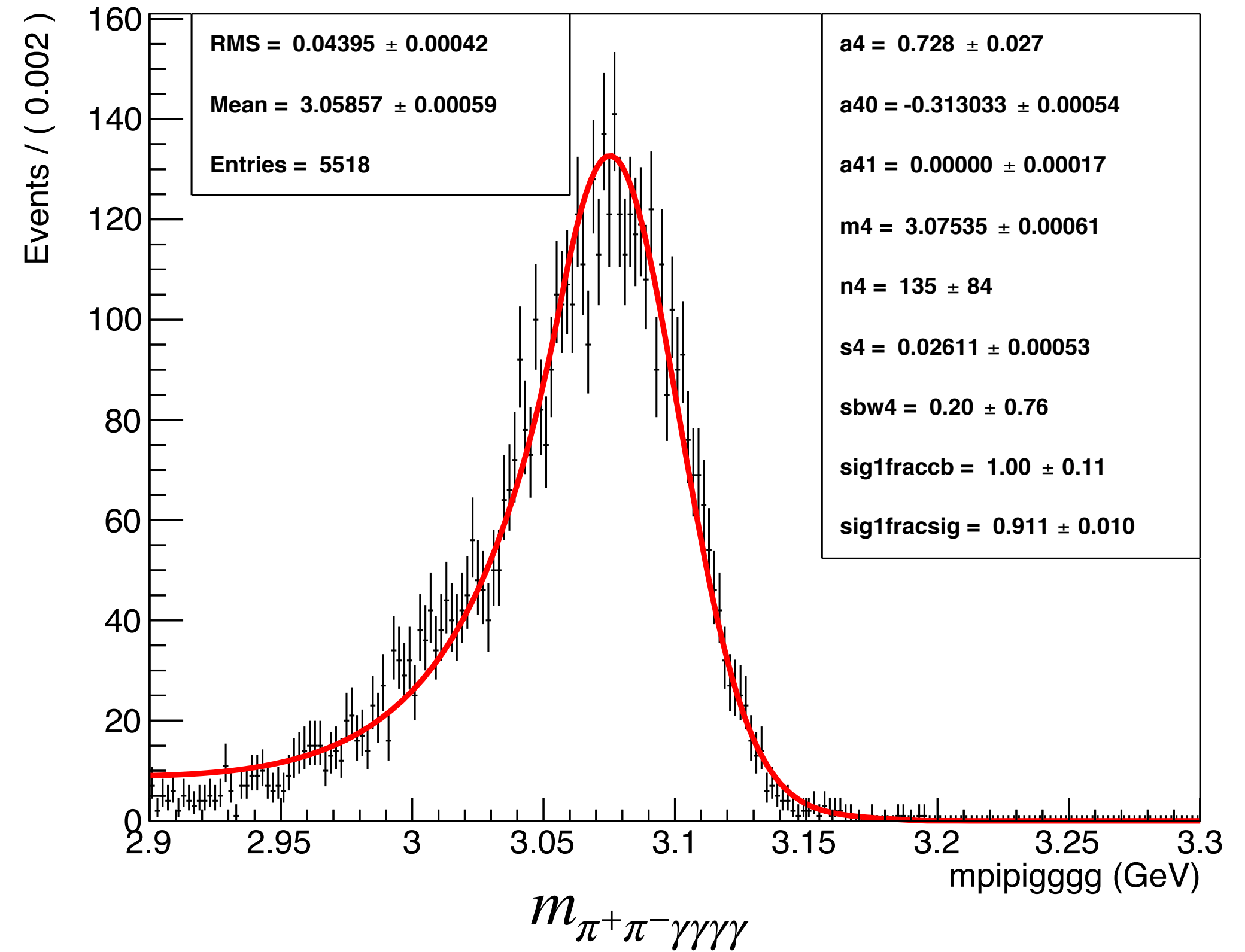
$$e^+e^- \rightarrow \omega\pi_1^0 \rightarrow \pi^+\pi^-\pi_2^0(\gamma\gamma)\pi_1^0(\gamma\gamma)$$

Efficiency with selections $\sim 25.13\%$

m_C4P2mppggo

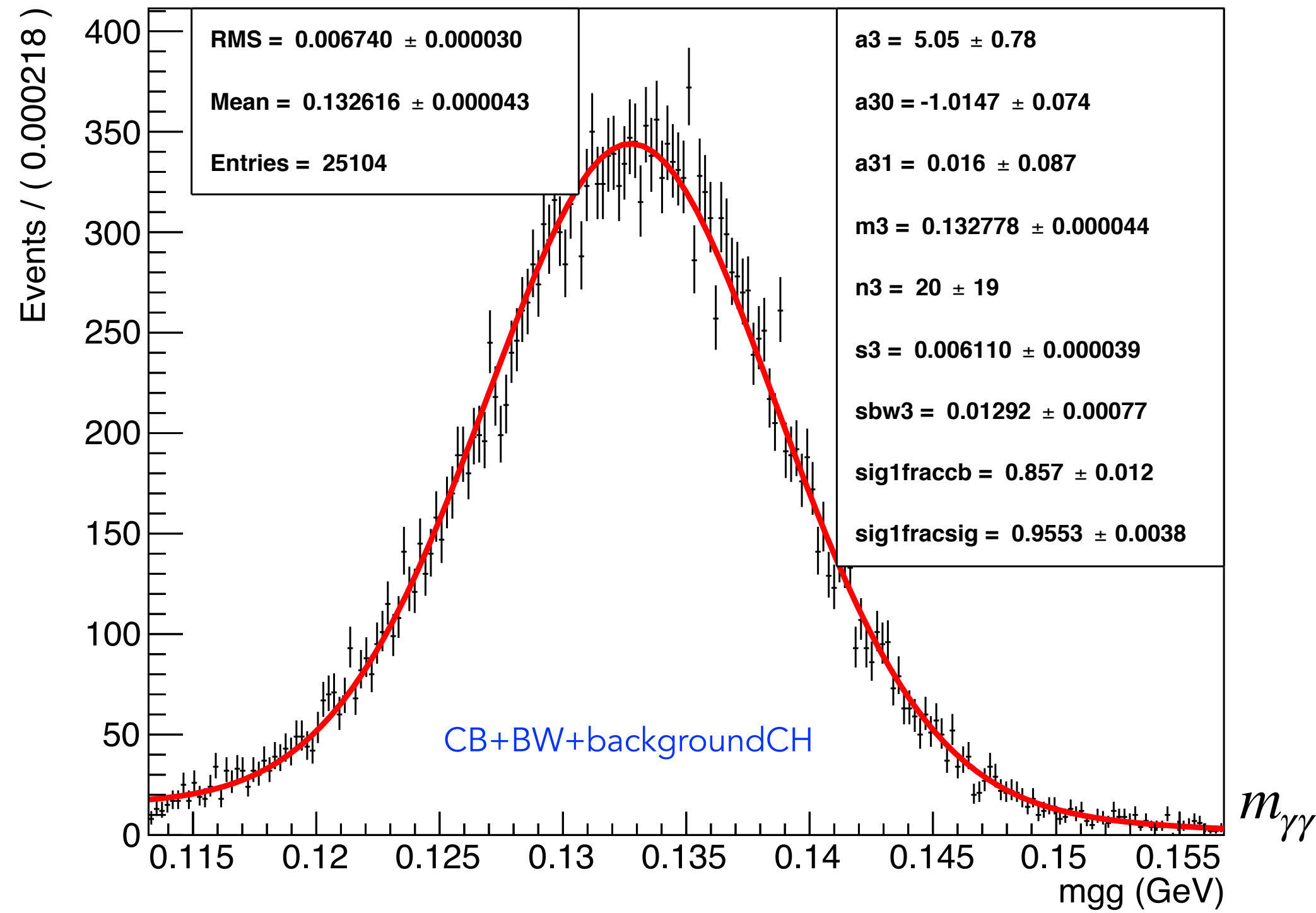


m_C4P2mppgggg

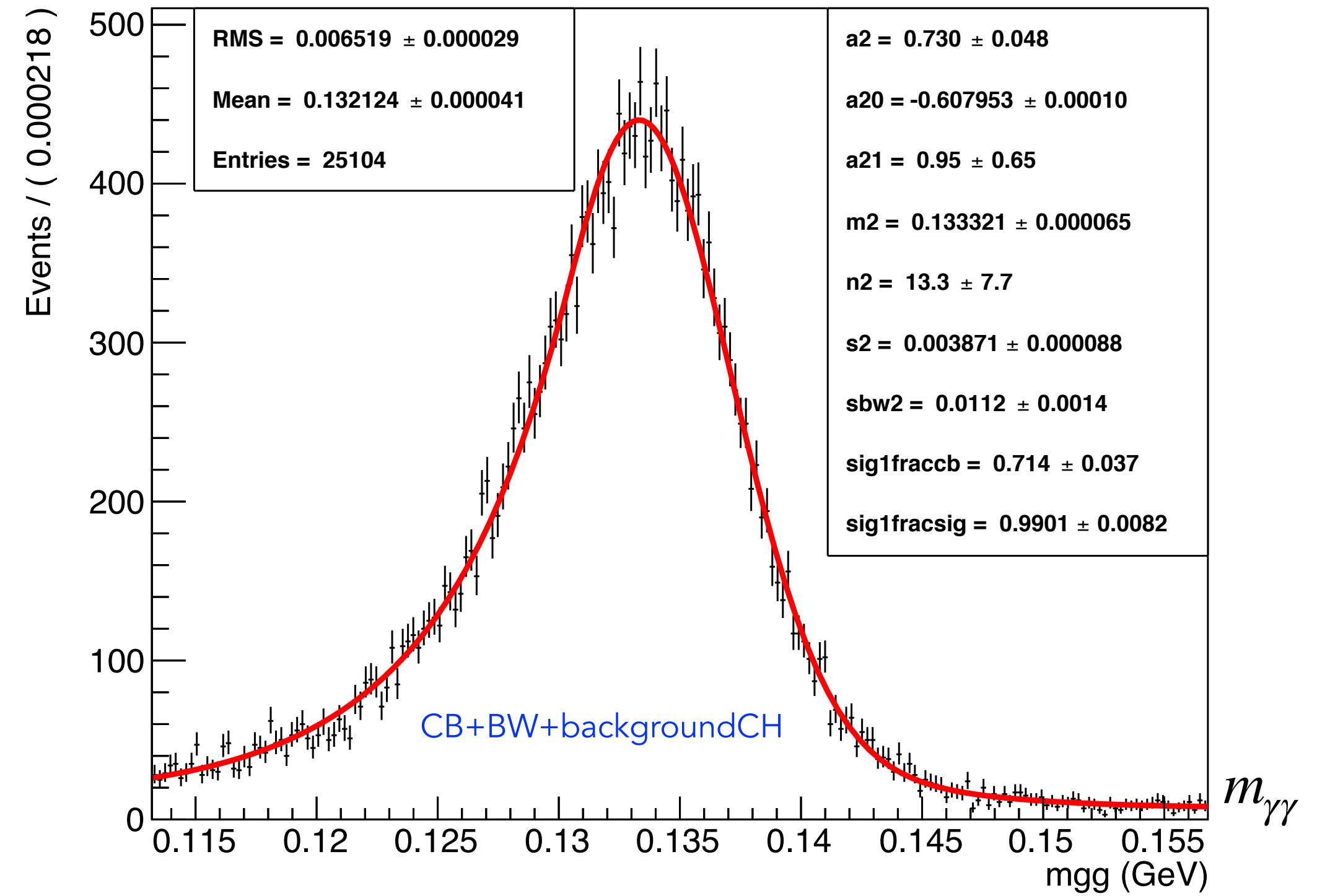


$0.70 \text{ GeV}/c^2 < m_{\pi^+\pi^-(\gamma\gamma)\pi_2^0} < 0.85 \text{ GeV}/c^2$
 $|m_{(\gamma\gamma)\pi^0} - m_{\pi^0}^{\text{PDG}}| < 4\sigma_{\pi^0}$
 $2.9 \text{ GeV}/c^2 < m_{\pi^+\pi^-\gamma\gamma\gamma} < 3.2 \text{ GeV}/c^2$

m_C4P2mggj



m_C4P2mggo

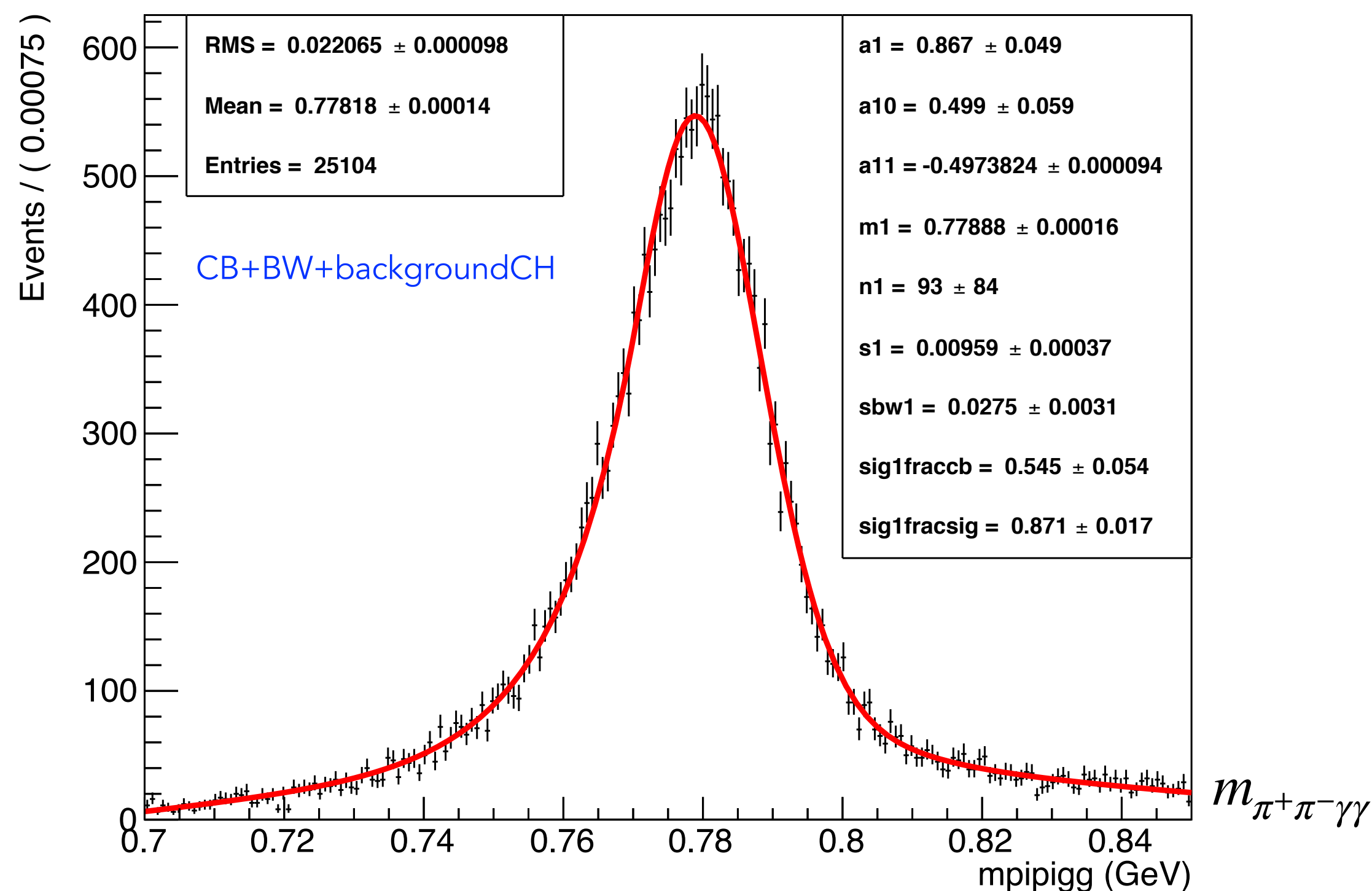


$$0.70 \text{ GeV}/c^2 < m_{\pi^+\pi^-(\gamma\gamma)\pi^0_2} < 0.85 \text{ GeV}/c^2$$

$$|m_{(\gamma\gamma)\pi^0} - m_{\pi^0}^{\text{PDG}}| < 4\sigma_{\pi^0}$$

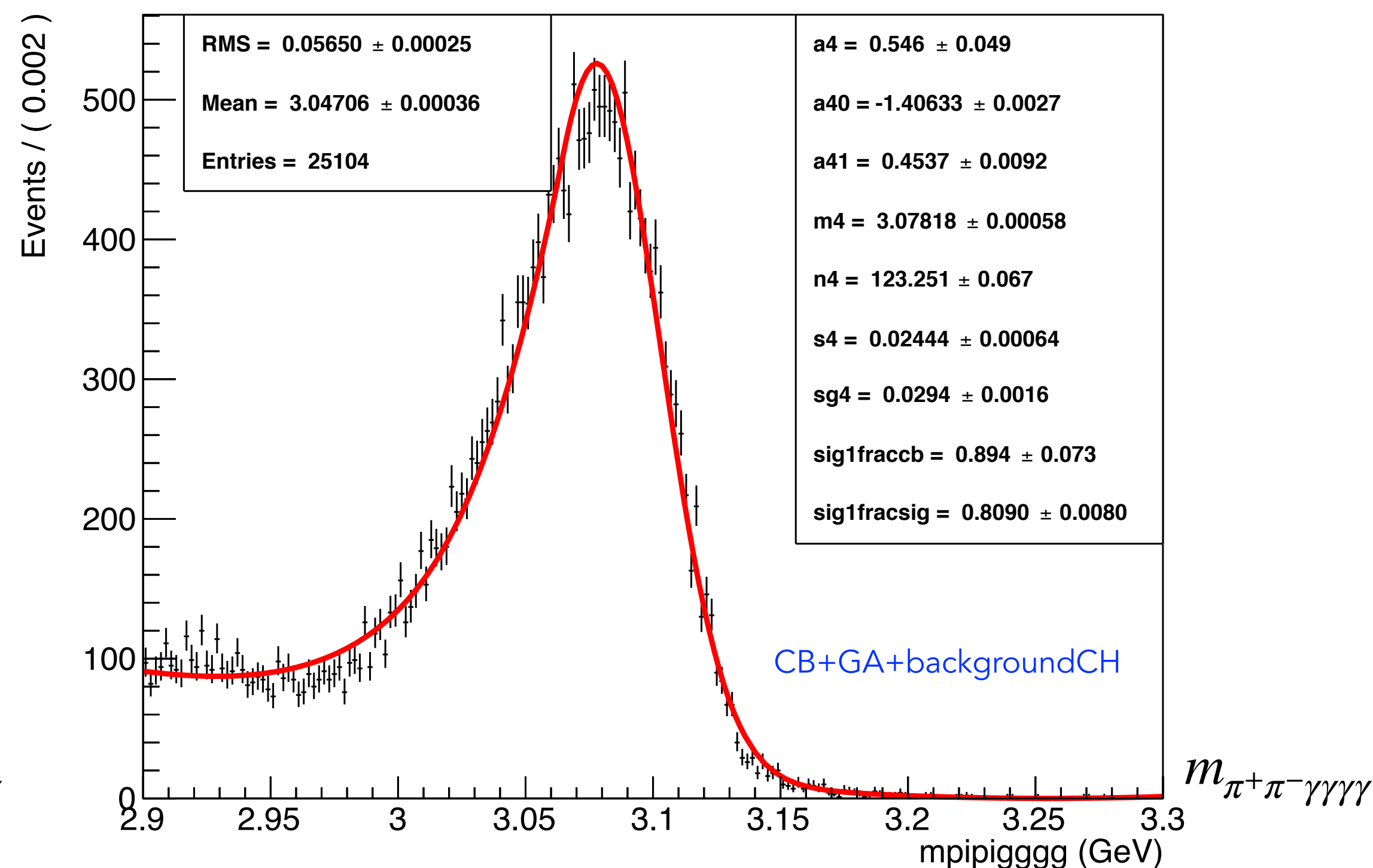
$$2.9 \text{ GeV}/c^2 < m_{\pi^+\pi^-\gamma\gamma\gamma\gamma} < 3.2 \text{ GeV}/c^2$$

m_C4P2mppggo



Expected events: $(101 \pm 11) \times 10^3$

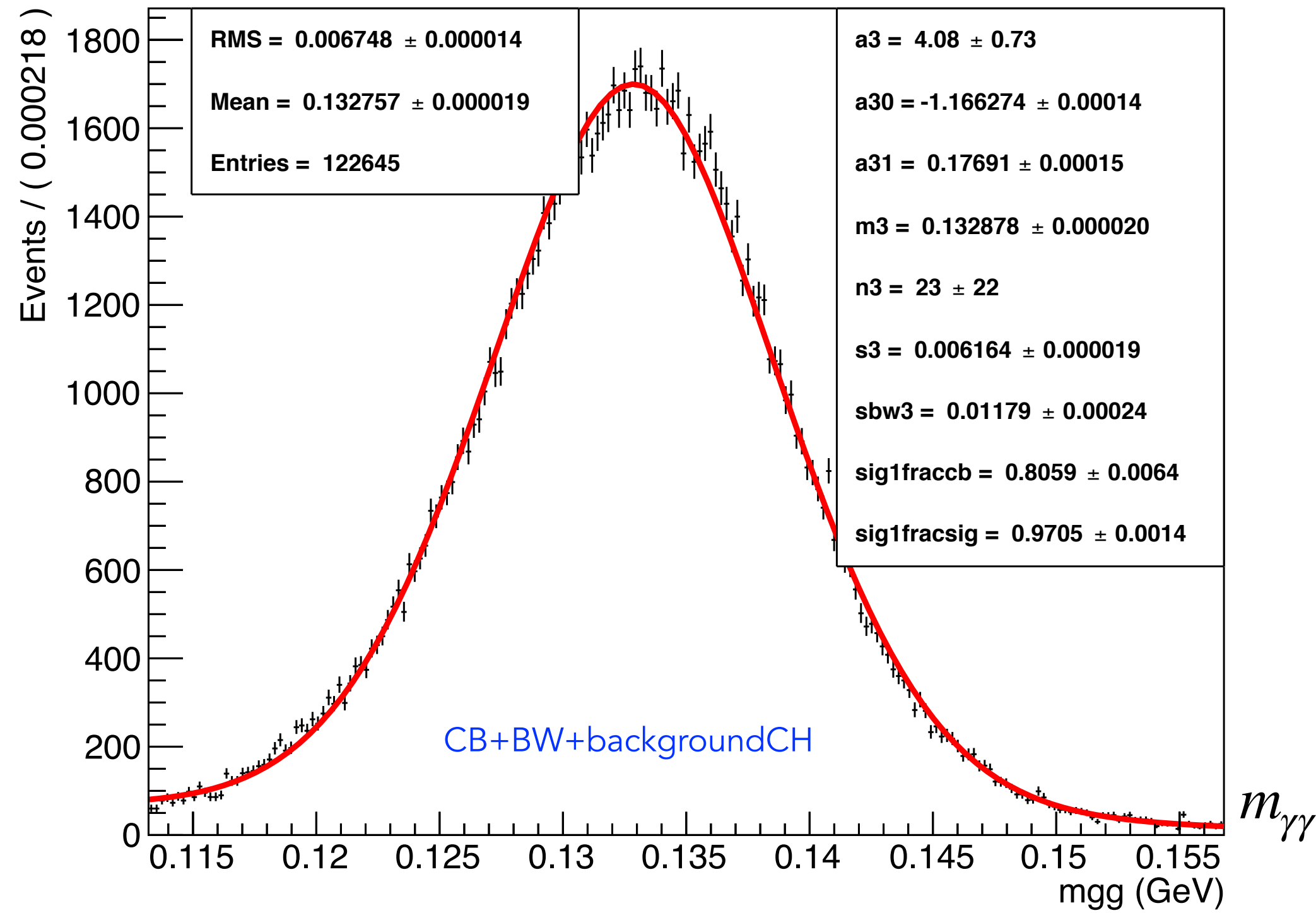
m_C4P2mppgggg



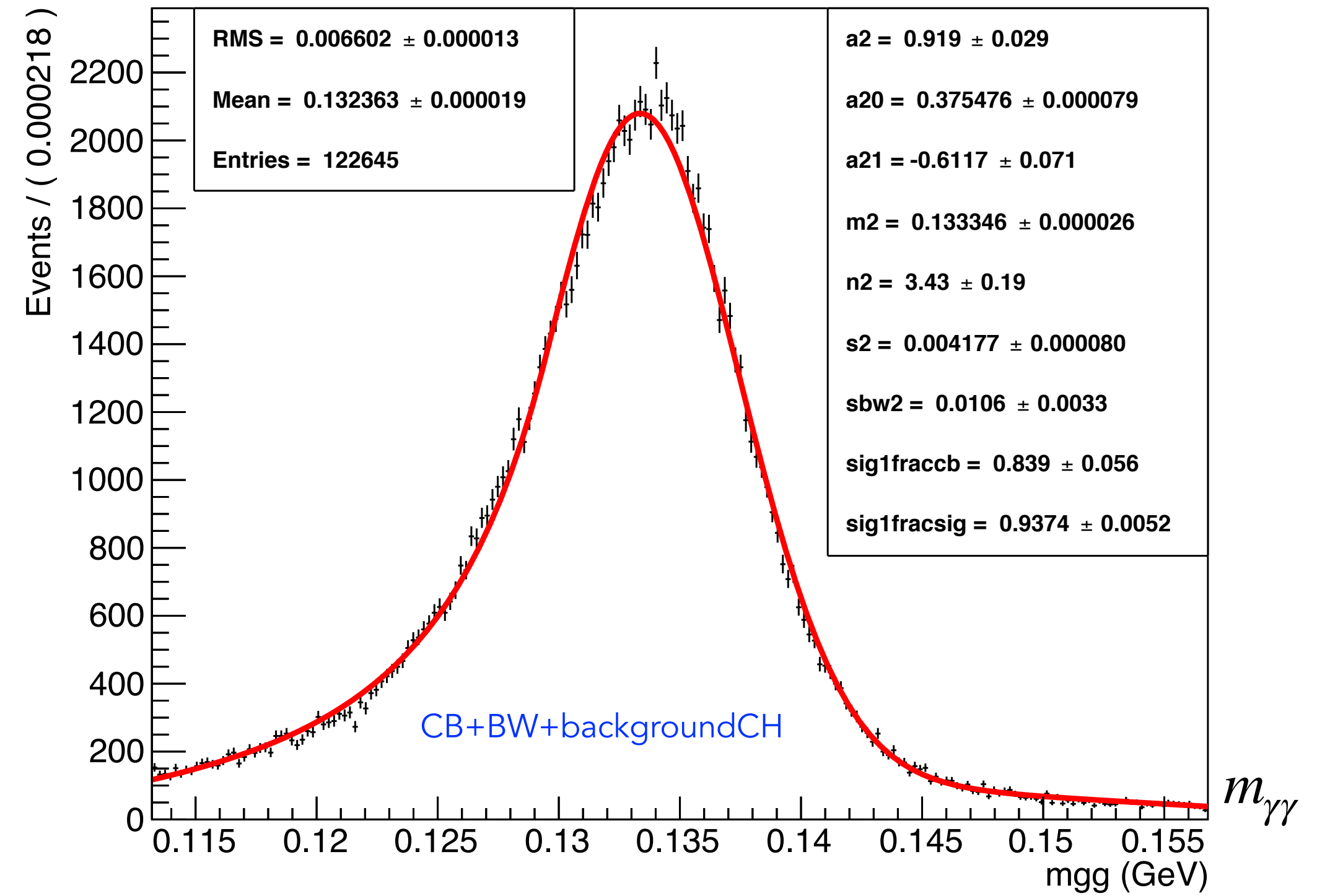
$$\frac{25104 \times 0.8090}{0.2513 \times \text{BR}_{\pi^0 \rightarrow \gamma\gamma}^2 \times \text{BR}_{\omega \rightarrow \pi^+\pi^-\pi^0}} = 92 \times 10^3$$

$0.70 \text{ GeV}/c^2 < m_{\pi^+\pi^-(\gamma\gamma)\pi_2^0} < 0.85 \text{ GeV}/c^2$
 $|m_{(\gamma\gamma)\pi^0} - m_{\pi^0}^{\text{PDG}}| < 4\sigma_{\pi^0}$
 $2.9 \text{ GeV}/c^2 < m_{\pi^+\pi^-\gamma\gamma\gamma} < 3.2 \text{ GeV}/c^2$

m_C4P2mggj

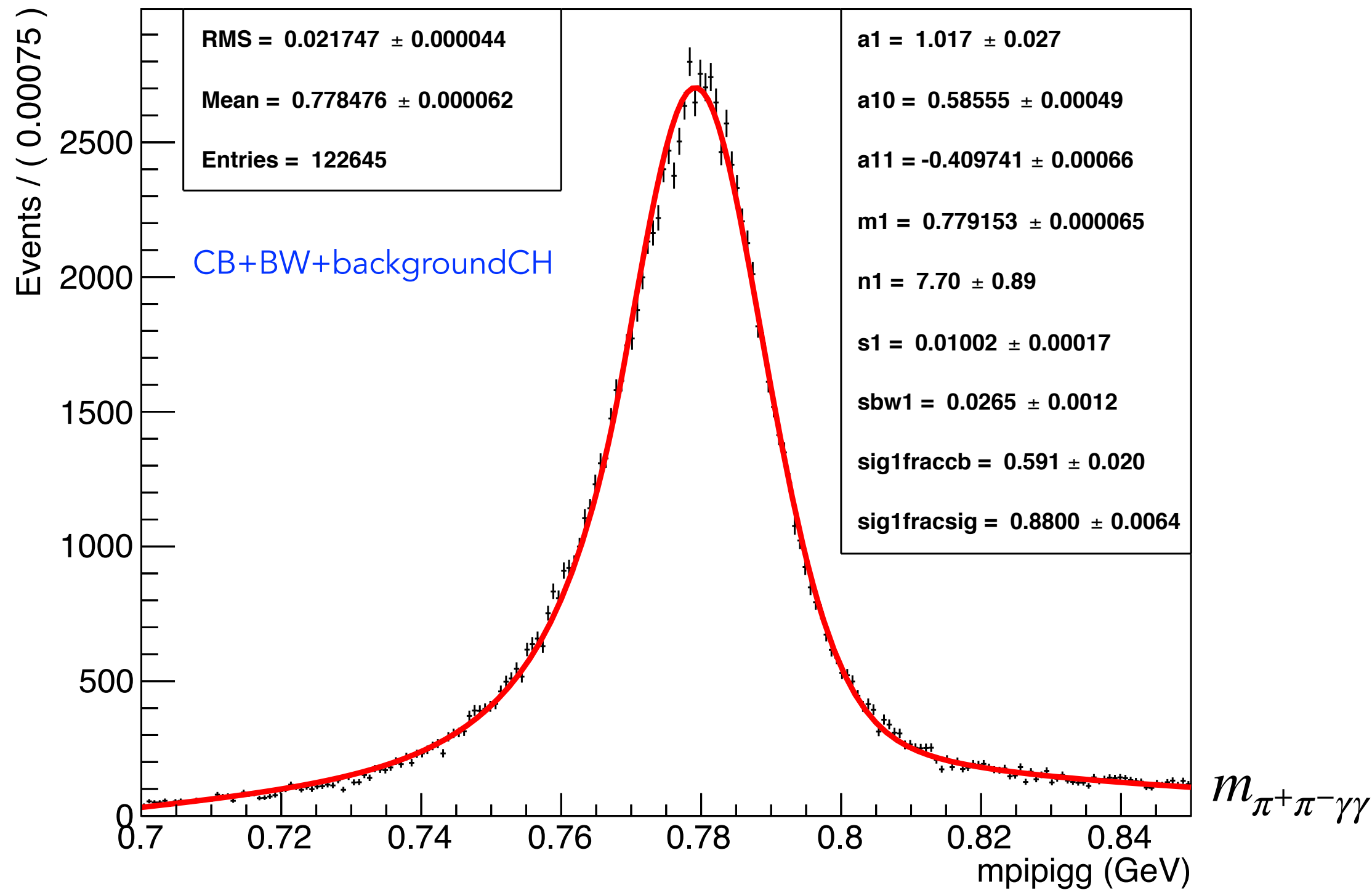


m_C4P2mggo



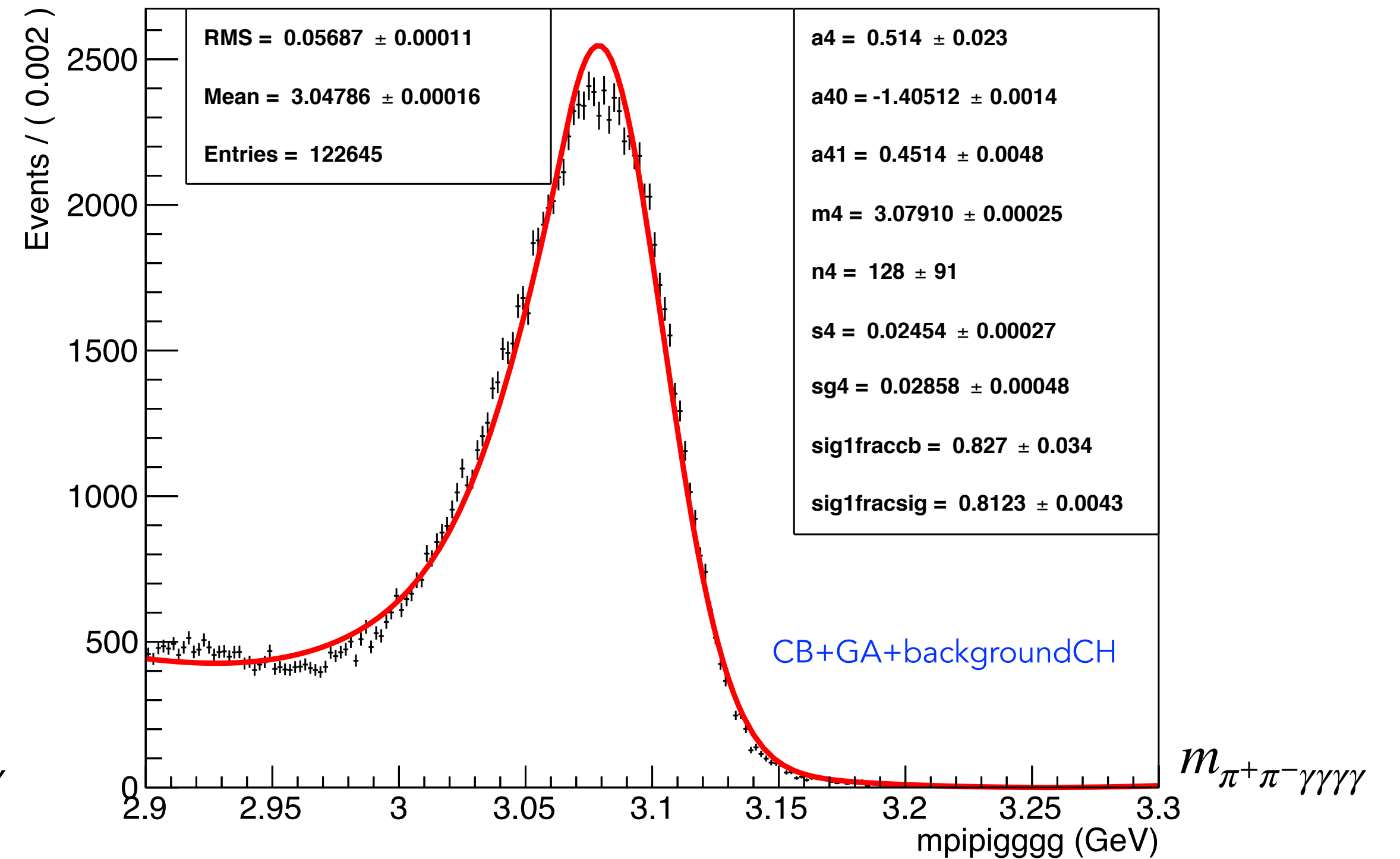
$0.70 \text{ GeV}/c^2 < m_{\pi^+\pi^-(\gamma\gamma)\pi_2^0} < 0.85 \text{ GeV}/c^2$
 $|m_{(\gamma\gamma)\pi^0} - m_{\pi^0}^{\text{PDG}}| < 4\sigma_{\pi^0}$
 $2.9 \text{ GeV}/c^2 < m_{\pi^+\pi^-\gamma\gamma\gamma\gamma} < 3.2 \text{ GeV}/c^2$

m_C4P2mppggo



Expected events: $(489 \pm 54) \times 10^3$

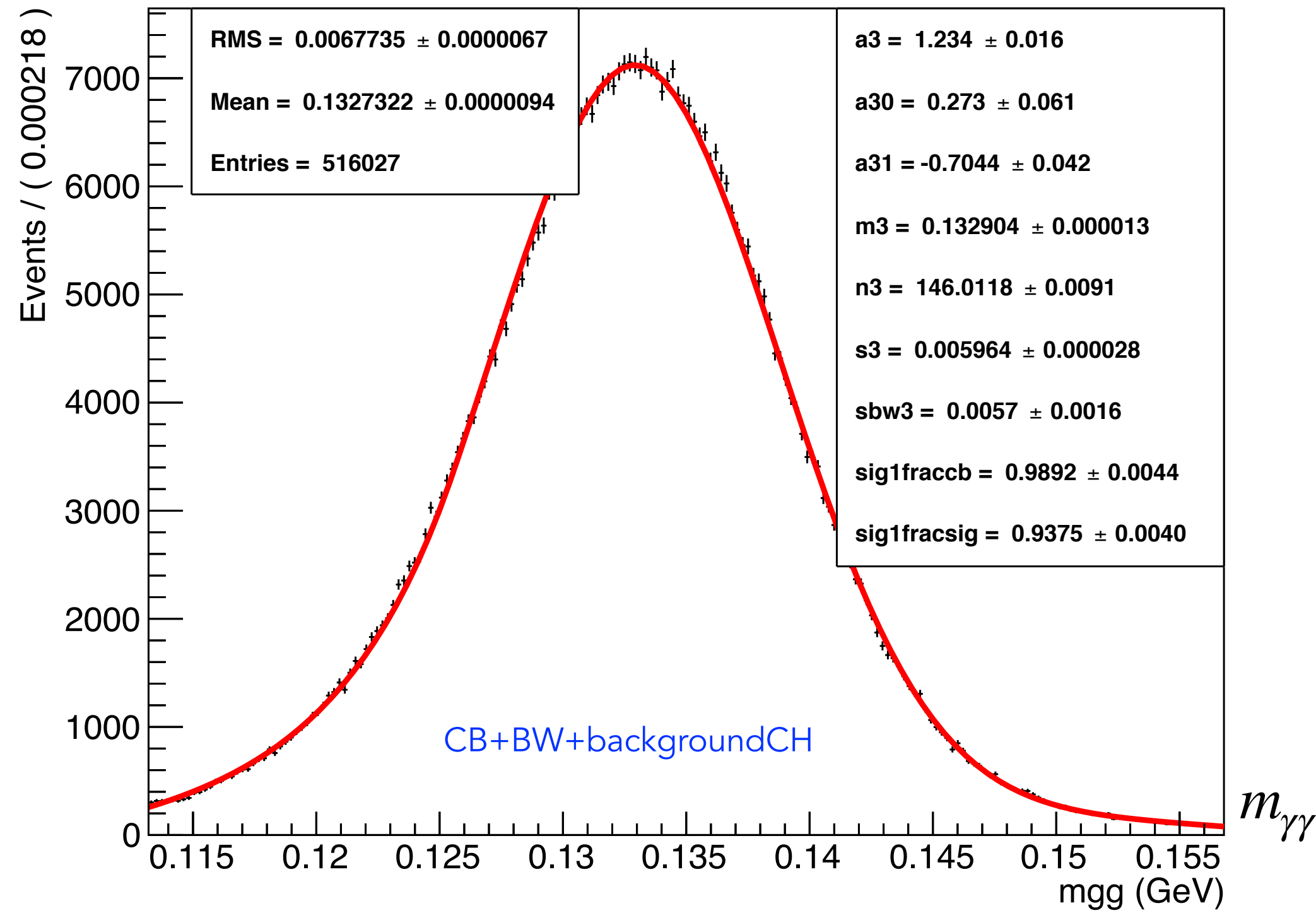
m_C4P2mppgggg



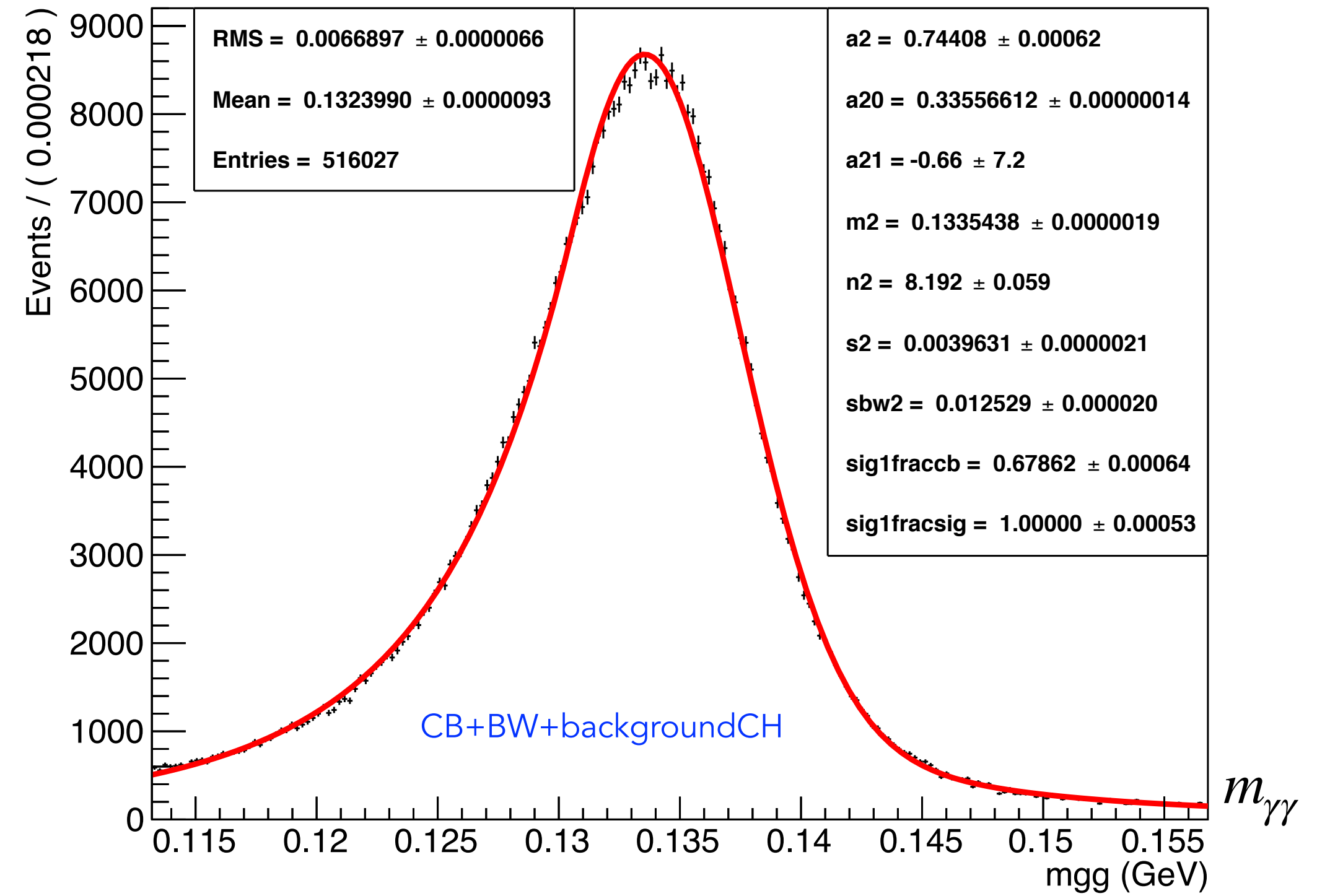
$$\frac{122645 \times 0.8123}{0.2513 \times \text{BR}_{\pi^0 \rightarrow \gamma\gamma}^2 \times \text{BR}_{\omega \rightarrow \pi^+\pi^-\pi^0}} = 455 \times 10^3$$

$0.70 \text{ GeV}/c^2 < m_{\pi^+\pi^-(\gamma\gamma)\pi_2^0} < 0.85 \text{ GeV}/c^2$
 $|m_{(\gamma\gamma)\pi^0} - m_{\pi^0}^{\text{PDG}}| < 4\sigma_{\pi^0}$
 $2.9 \text{ GeV}/c^2 < m_{\pi^+\pi^-\gamma\gamma\gamma\gamma} < 3.2 \text{ GeV}/c^2$

m_C4P2mggj

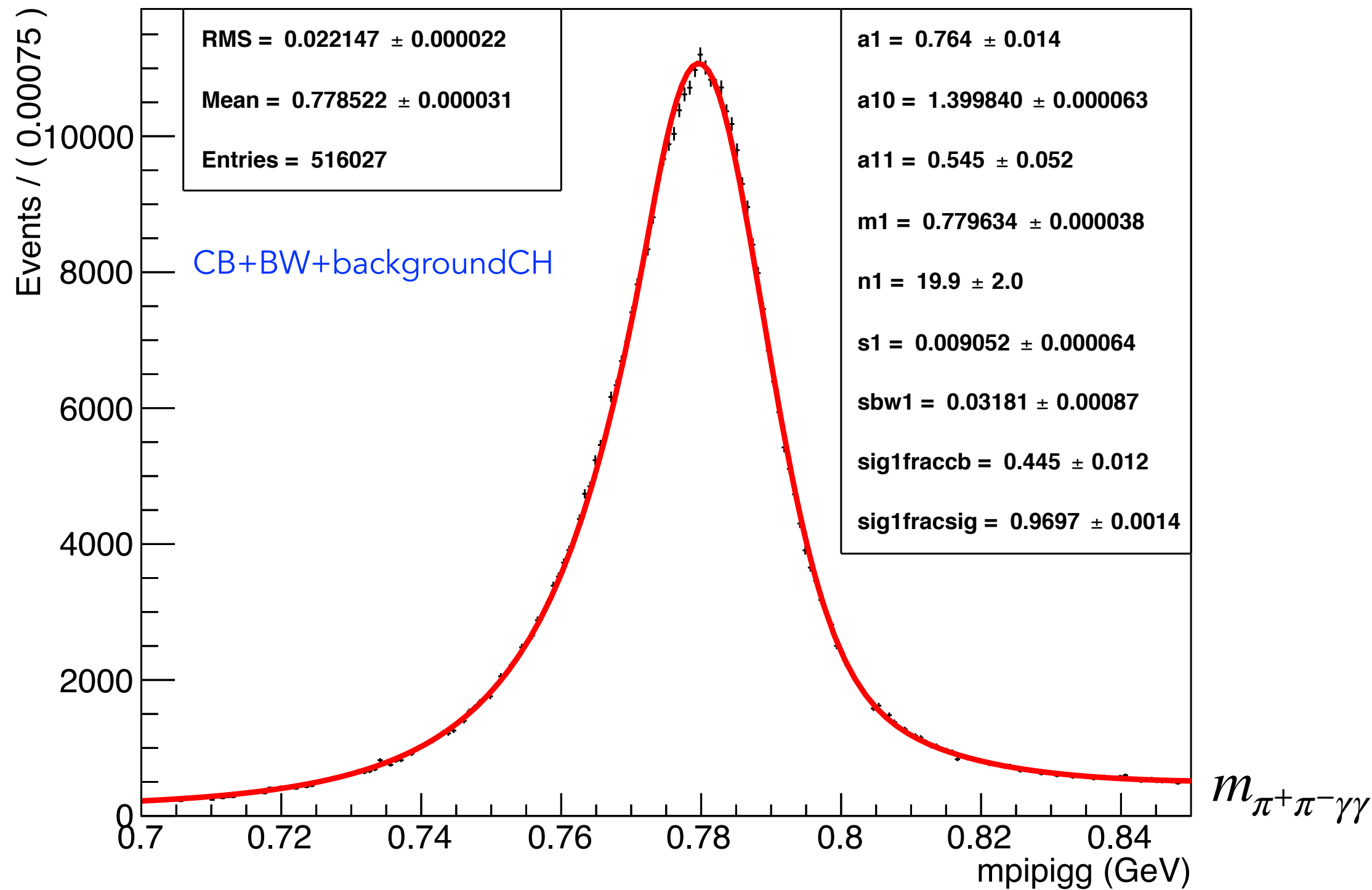


m_C4P2mggo



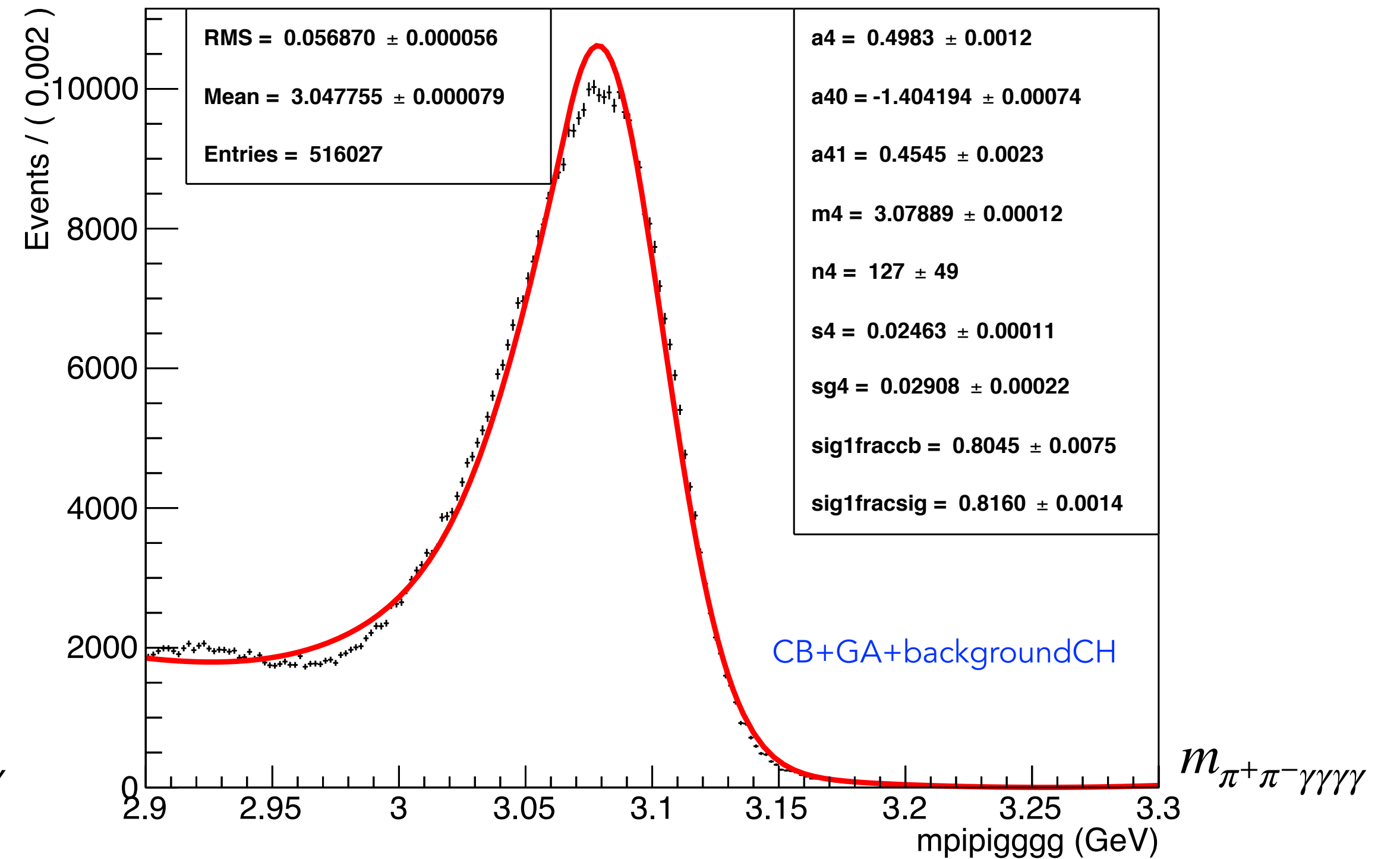
$0.70 \text{ GeV}/c^2 < m_{\pi^+\pi^-(\gamma\gamma)\pi_2^0} < 0.85 \text{ GeV}/c^2$
 $|m_{(\gamma\gamma)\pi^0} - m_{\pi^0}^{\text{PDG}}| < 4\sigma_{\pi^0}$
 $2.9 \text{ GeV}/c^2 < m_{\pi^+\pi^-\gamma\gamma\gamma\gamma} < 3.2 \text{ GeV}/c^2$

m_C4P2mppggo



Expected events: $(2070 \pm 230) \times 10^3$

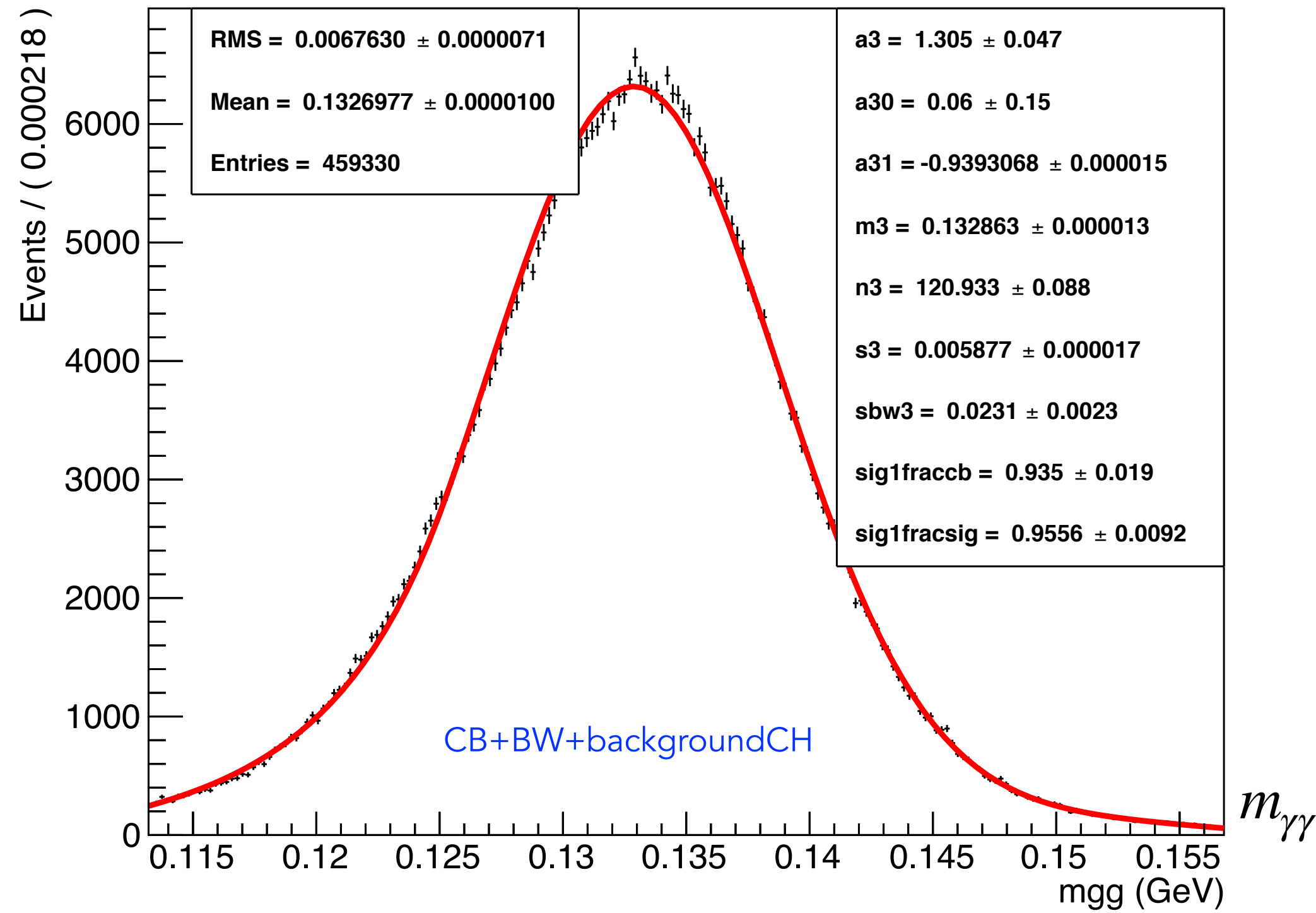
m_C4P2mppgggg



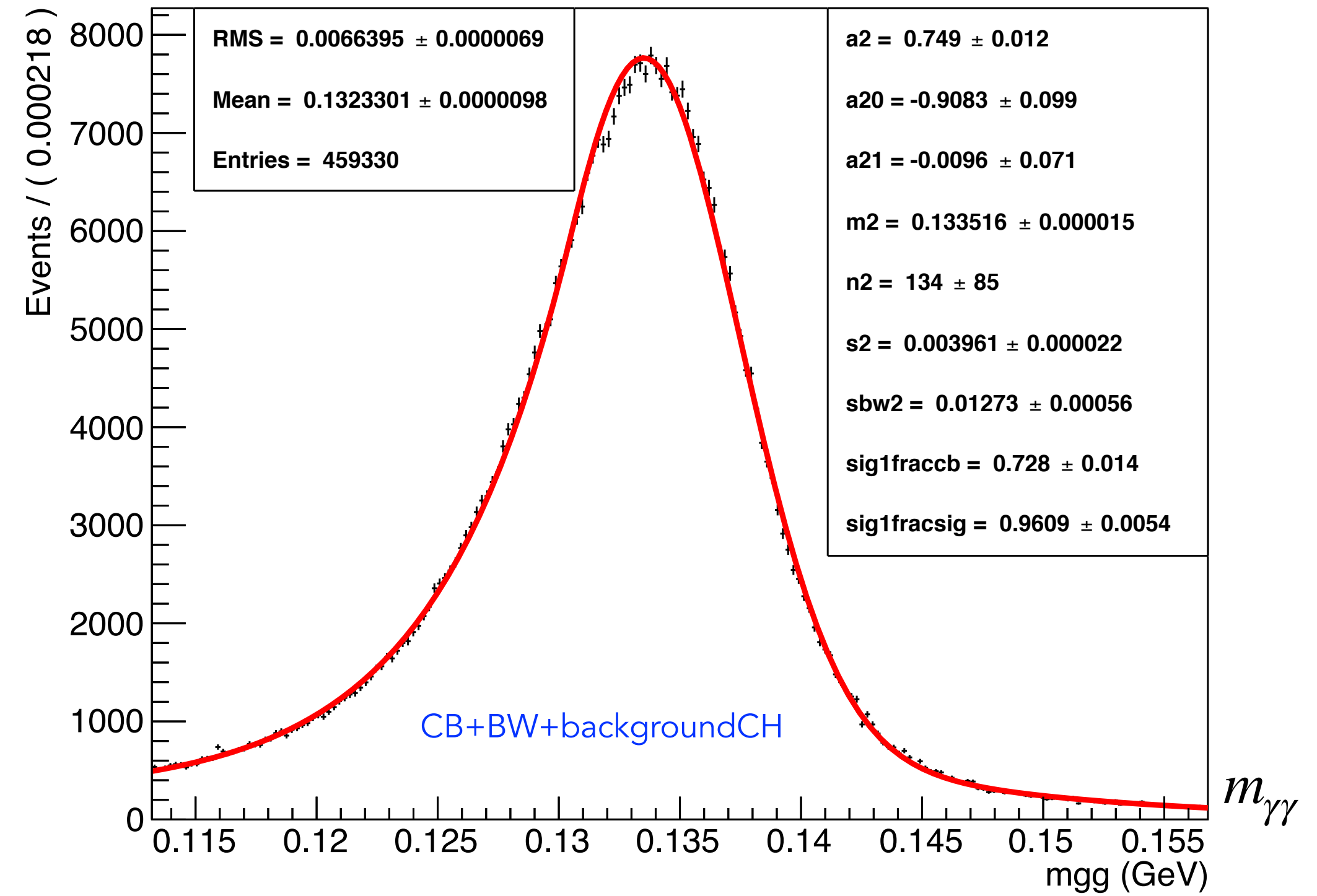
$$\frac{516027 \times 0.8160}{0.2513 \times \text{BR}_{\pi^0 \rightarrow \gamma\gamma}^2 \times \text{BR}_{\omega \rightarrow \pi^+\pi^-\pi^0}} = 1922 \times 10^3$$

$0.70 \text{ GeV}/c^2 < m_{\pi^+\pi^-(\gamma\gamma)\pi_2^0} < 0.85 \text{ GeV}/c^2$
 $|m_{(\gamma\gamma)\pi^0} - m_{\pi^0}^{\text{PDG}}| < 4\sigma_{\pi^0}$
 $2.9 \text{ GeV}/c^2 < m_{\pi^+\pi^-\gamma\gamma\gamma\gamma} < 3.2 \text{ GeV}/c^2$

m_C4P2mggj

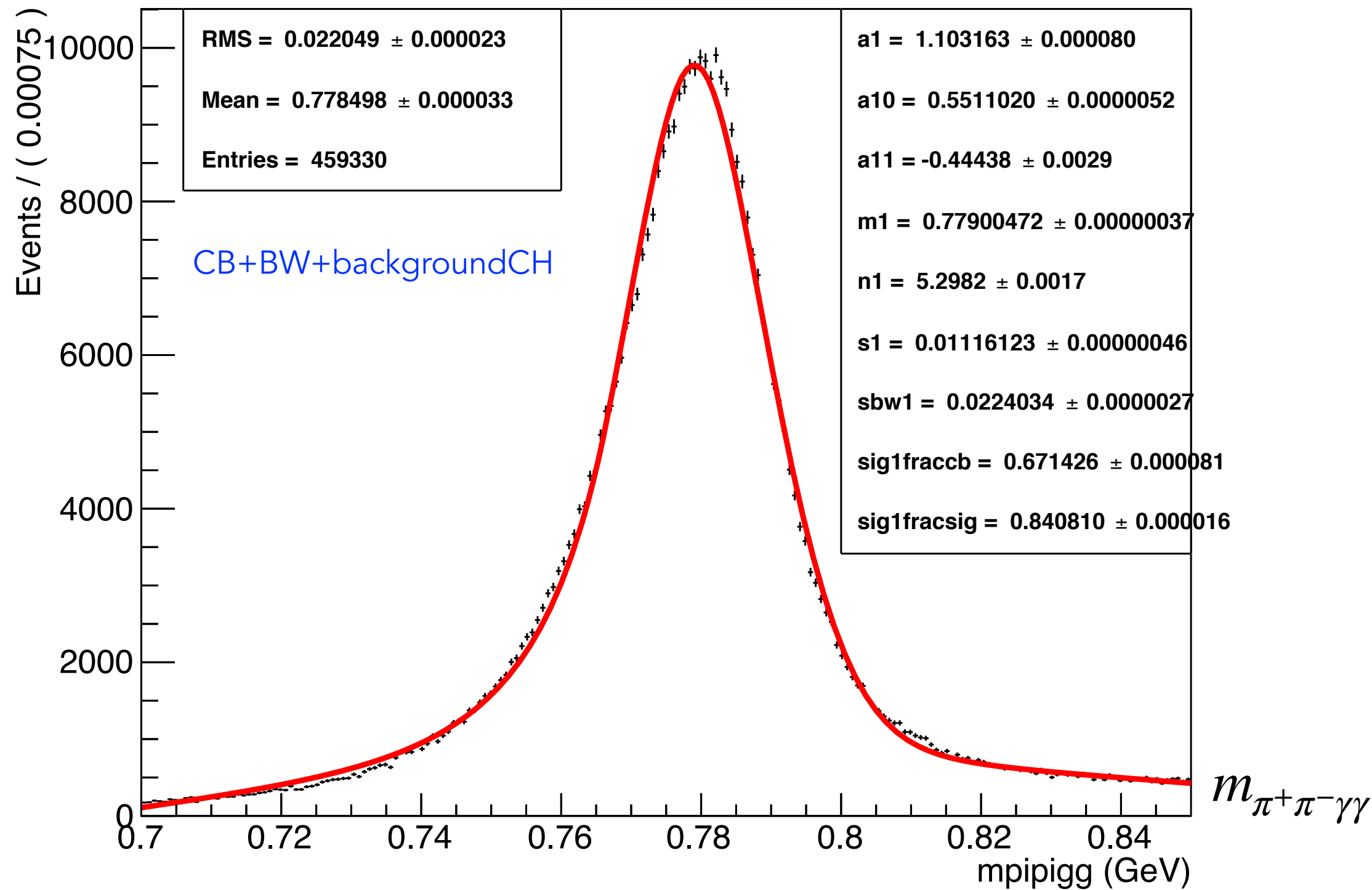


m_C4P2mggo

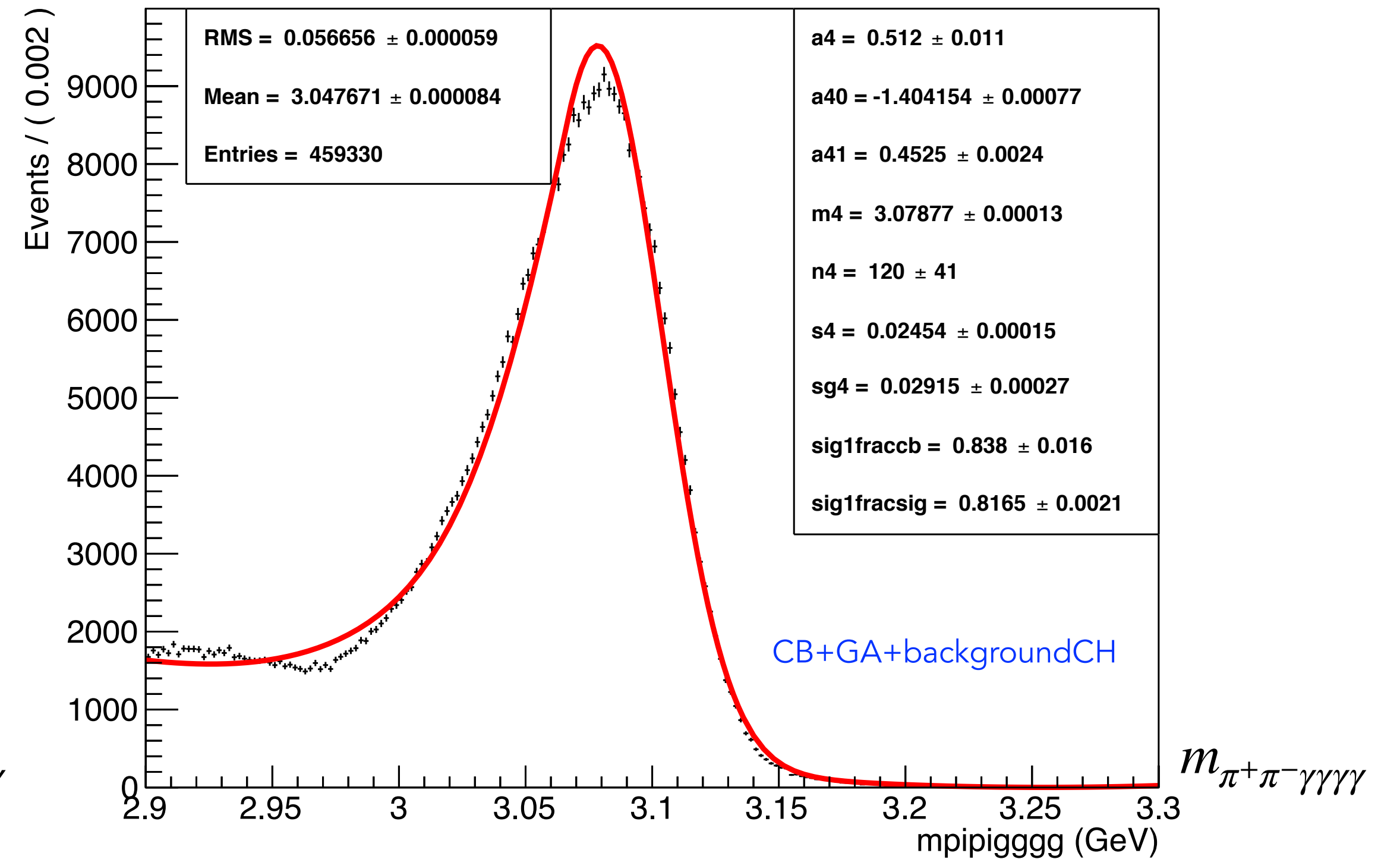


$0.70 \text{ GeV}/c^2 < m_{\pi^+\pi^-(\gamma\gamma)\pi^0_2} < 0.85 \text{ GeV}/c^2$
 $|m_{(\gamma\gamma)\pi^0} - m_{\pi^0}^{\text{PDG}}| < 4\sigma_{\pi^0}$
 $2.9 \text{ GeV}/c^2 < m_{\pi^+\pi^-\gamma\gamma\gamma\gamma} < 3.2 \text{ GeV}/c^2$

m_C4P2mppggo



m_C4P2mppgggg



Expected events: $(1845 \pm 205) \times 10^3$

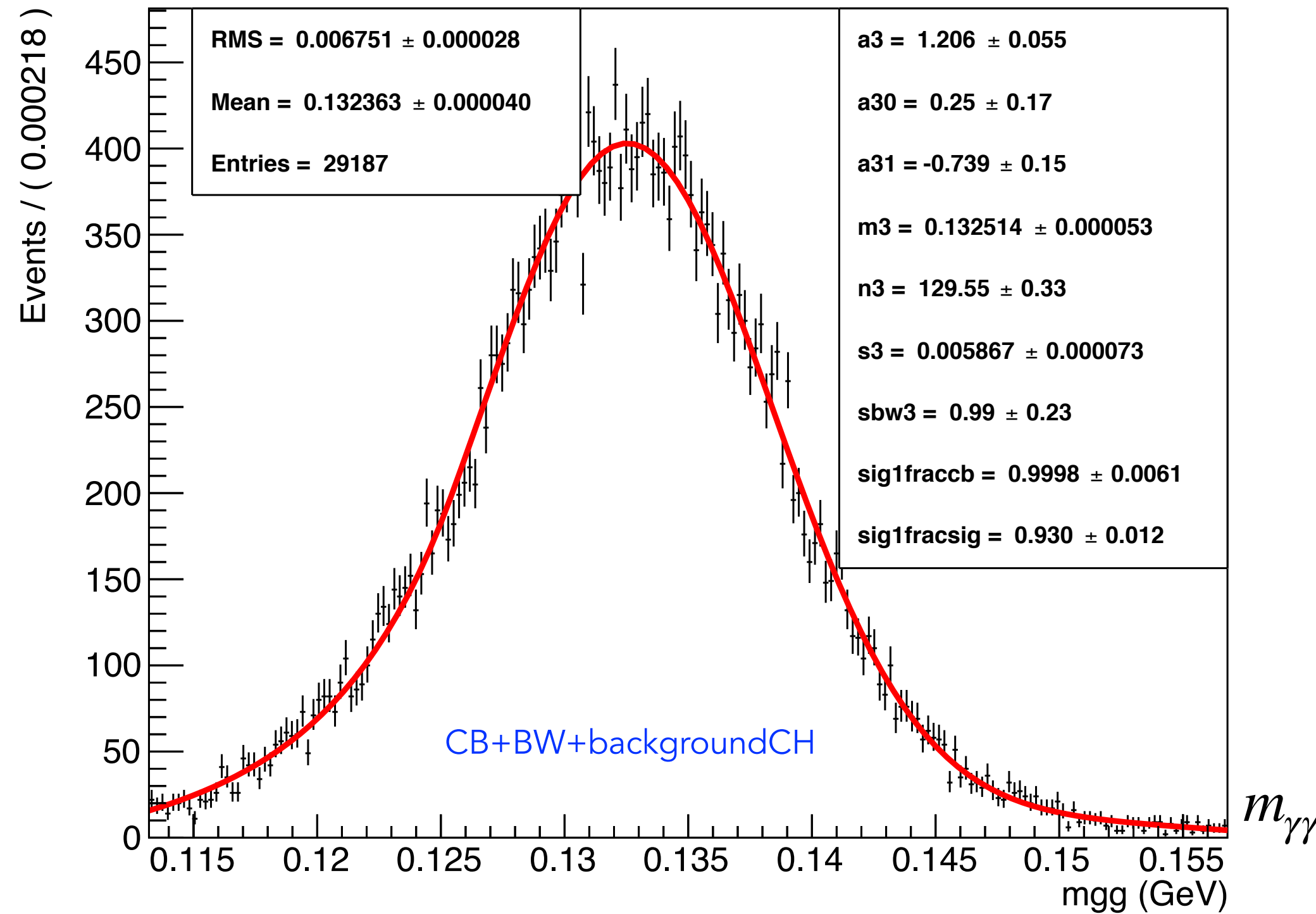
$$\frac{459330 \times 0.8165}{0.2513 \times \text{BR}_{\pi^0 \rightarrow \gamma\gamma}^2 \times \text{BR}_{\omega \rightarrow \pi^+\pi^-\pi^0}} = 1711 \times 10^3$$

$$0.70 \text{ GeV}/c^2 < m_{\pi^+\pi^-(\gamma\gamma)\pi_2^0} < 0.85 \text{ GeV}/c^2$$

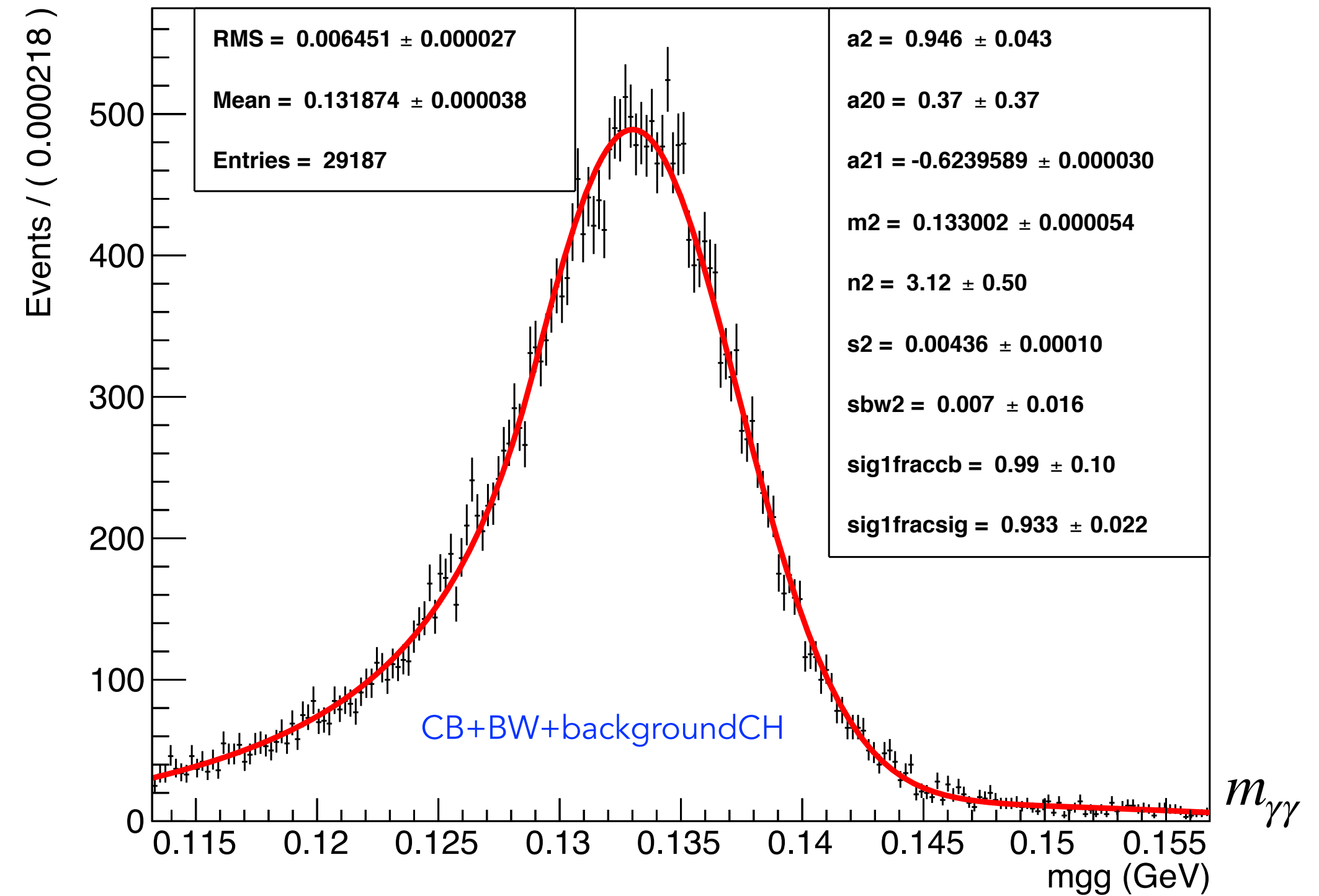
$$|m_{(\gamma\gamma)\pi^0} - m_{\pi^0}^{\text{PDG}}| < 4\sigma_{\pi^0}$$

$$2.9 \text{ GeV}/c^2 < m_{\pi^+\pi^-\gamma\gamma\gamma} < 3.2 \text{ GeV}/c^2$$

m_C4P2mggj

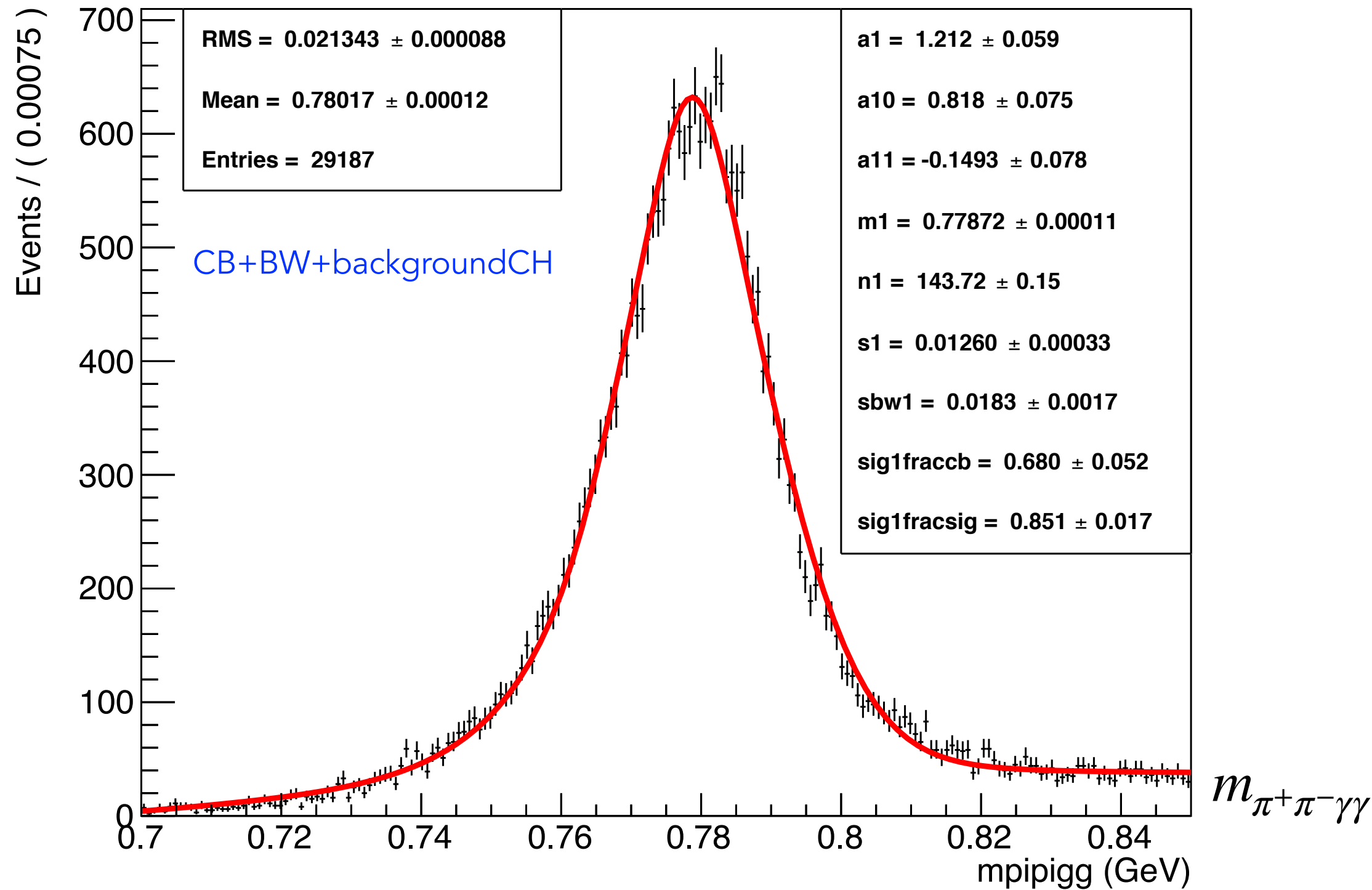


m_C4P2mggo



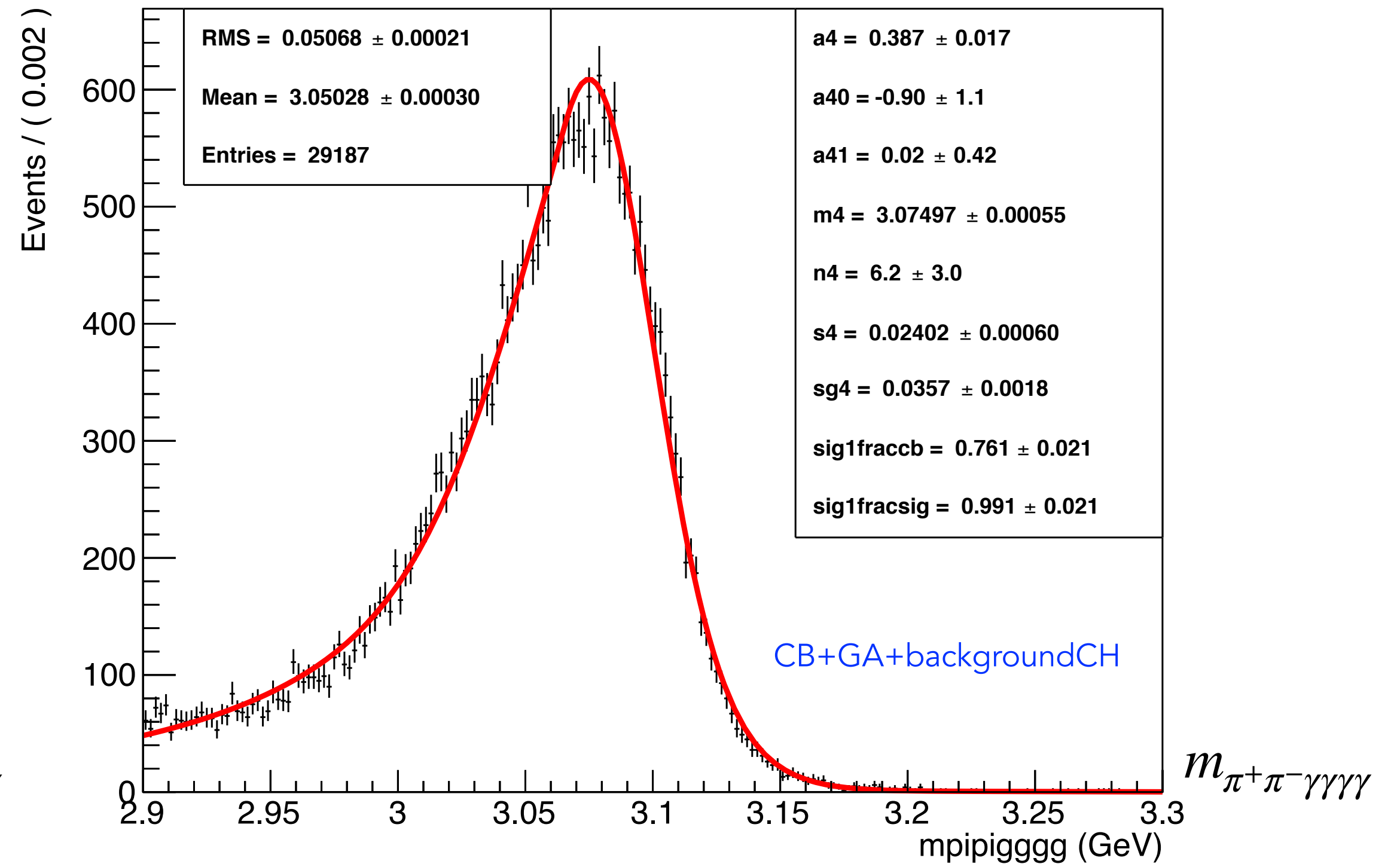
$0.70 \text{ GeV}/c^2 < m_{\pi^+\pi^-(\gamma\gamma)\pi_2^0} < 0.85 \text{ GeV}/c^2$
 $|m_{(\gamma\gamma)\pi^0} - m_{\pi^0}^{\text{PDG}}| < 4\sigma_{\pi^0}$
 $2.9 \text{ GeV}/c^2 < m_{\pi^+\pi^-\gamma\gamma\gamma\gamma} < 3.2 \text{ GeV}/c^2$

m_C4P2mppggo



Expected events: $(101 \pm 11) \times 10^3$

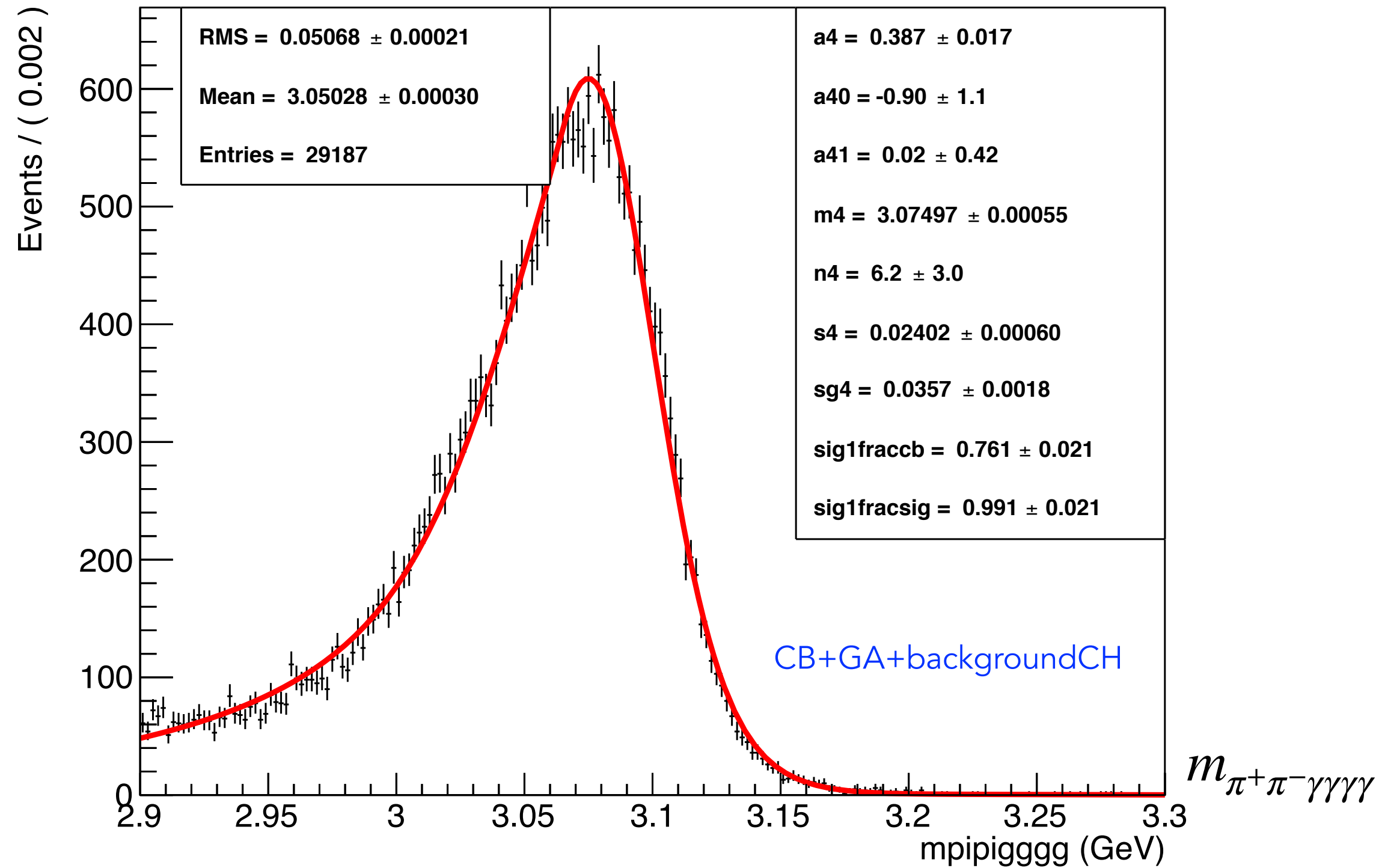
m_C4P2mppgggg



$$\frac{29187 \times 0.991}{0.2513 \times \text{BR}_{\pi^0 \rightarrow \gamma\gamma}^2 \times \text{BR}_{\omega \rightarrow \pi^+\pi^-\pi^0}} = 132 \times 10^3$$

$$0.70 \text{ GeV}/c^2 < m_{\pi^+\pi^-(\gamma\gamma)\pi_2^0} < 0.85 \text{ GeV}/c^2 \quad |m_{(\gamma\gamma)\pi^0} - m_{\pi^0}^{\text{PDG}}| < 4\sigma_{\pi^0} \quad 2.9 \text{ GeV}/c^2 < m_{\pi^+\pi^-\gamma\gamma\gamma} < 3.2 \text{ GeV}/c^2$$

m_C4P2mppgggg



Expected events: $(101 \pm 11) \times 10^3$

$$\frac{29187 \times 0.991}{0.2513 \times \text{BR}_{\pi^0 \rightarrow \gamma\gamma}^2 \times \text{BR}_{\omega \rightarrow \pi^+\pi^-\pi^0}} = 132 \times 10^3$$

$$\text{BR}_{\text{PDG}}(J/\psi \rightarrow \omega\pi^0) = (5.89 \pm 0.13^{\text{stat}}) \times 10^{-4}$$

$$\text{BR}_{\text{PDG}}(J/\psi \rightarrow \omega\pi^0) = (4.5 \pm 0.5) \times 10^{-4}$$

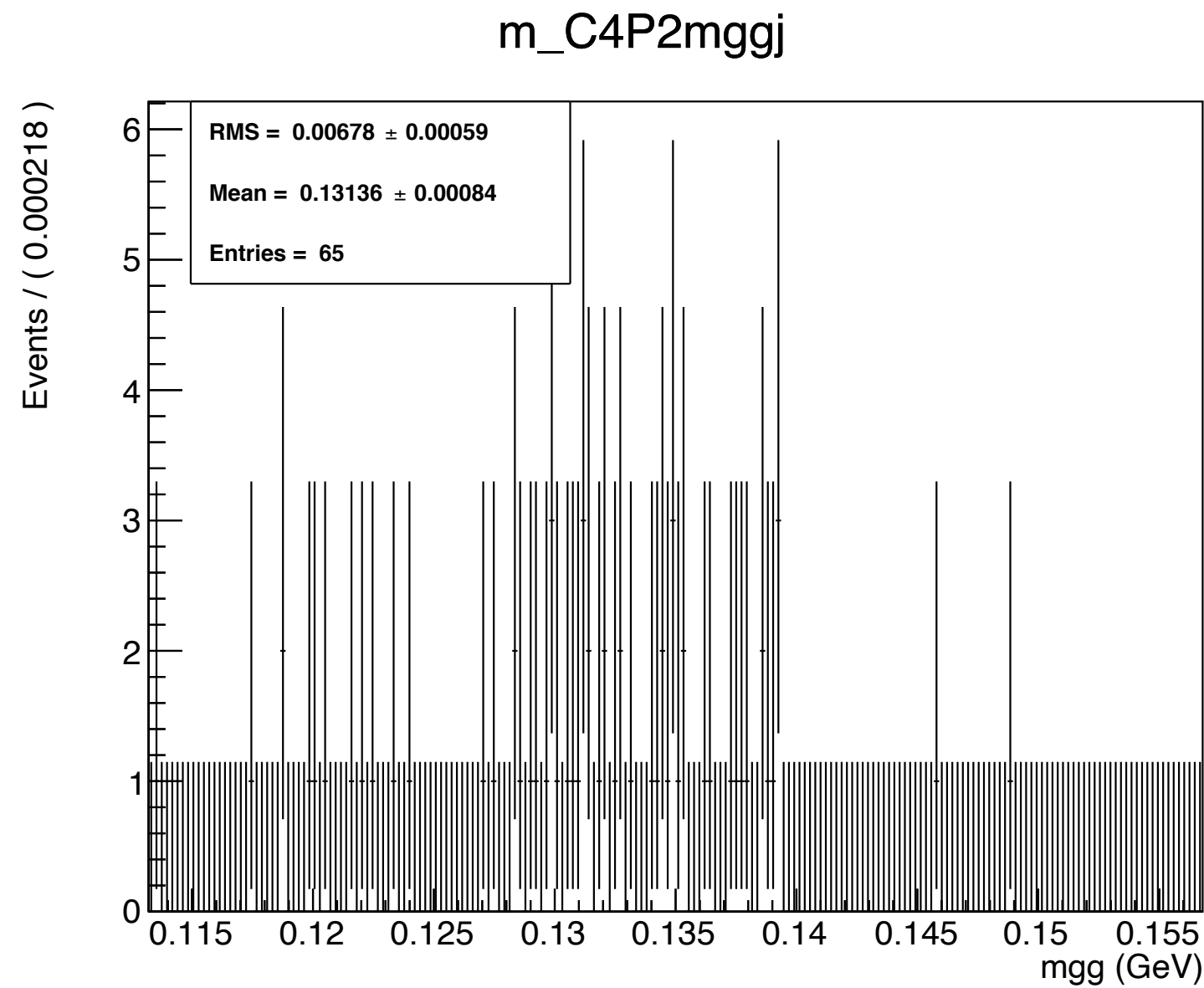
Principal backgrounds

Exclusive MC 20k samples

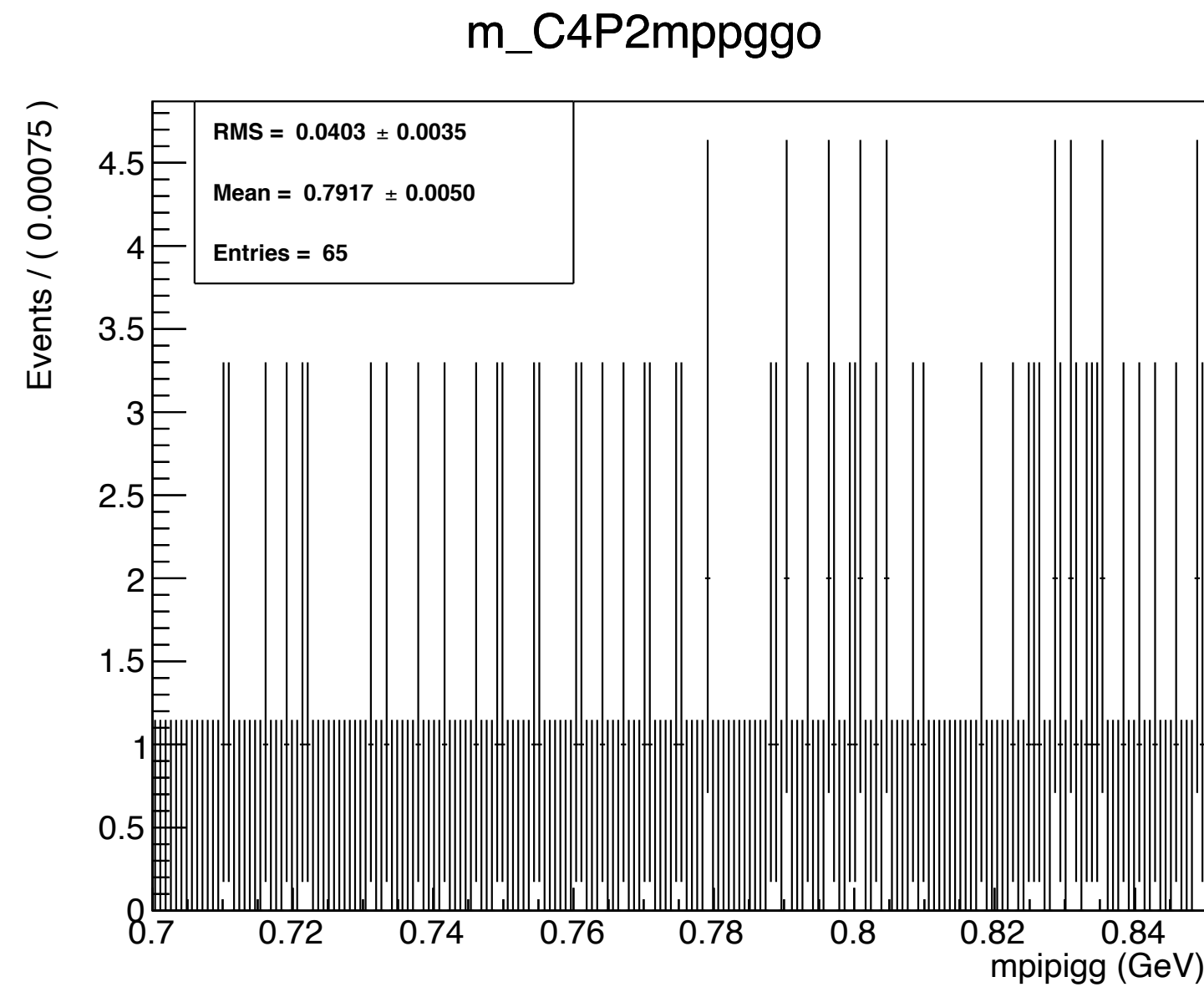
$e^+e^- \rightarrow \pi^+\pi^-\pi^0\pi^0$	Event selected: 65	Efficiency: 0,33% Signal/background: 85
$e^+e^- \rightarrow \omega\pi^0\pi^0 \rightarrow \pi^+\pi^-\pi^0\pi^0\pi^0$	Event selected: 21	Efficiency: 0,11% Signal/background: 263
$e^+e^- \rightarrow \rho^0\pi^0\pi^0 \rightarrow \pi^+\pi^-\pi^0\pi^0$	Event selected: 19	Efficiency: 0,10% Signal/background: 290
$e^+e^- \rightarrow \rho^+\pi^-\pi^0 \rightarrow \pi^+\pi^-\pi^0\pi^0$	Event selected: 28	Efficiency: 0,14% Signal/background: 197
$e^+e^- \rightarrow \rho^-\pi^+\pi^0 \rightarrow \pi^+\pi^-\pi^0\pi^0$	Event selected: 23	Efficiency: 0,12% Signal/background: 240
$e^+e^- \rightarrow \pi^+\pi^-\pi^0\pi^0\pi^0$	negligible	

$$e^+e^- \rightarrow \pi^+\pi^-\pi^0\pi^0$$

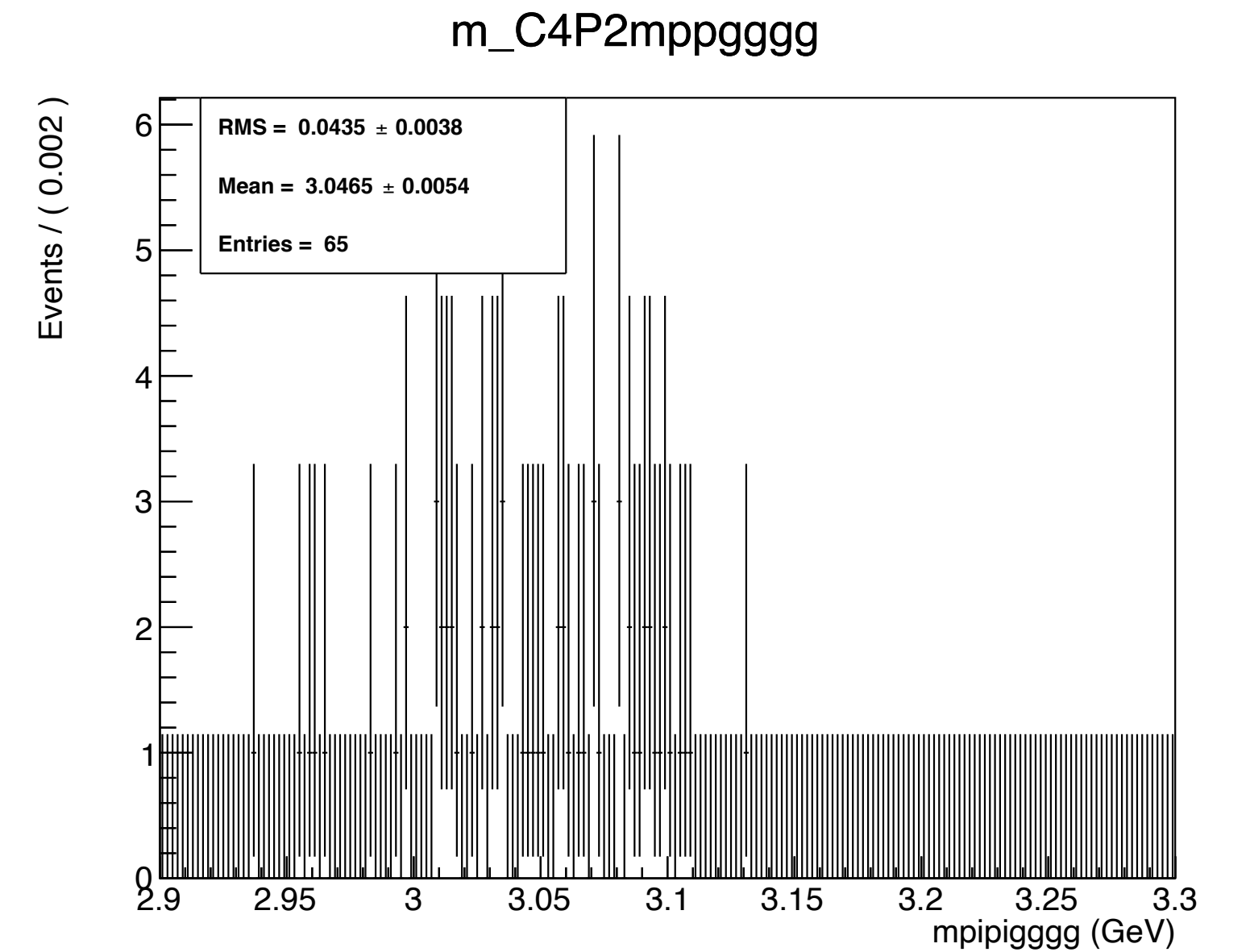
Event selected: 65



$$m_{(\gamma\gamma)\pi_1^0}$$



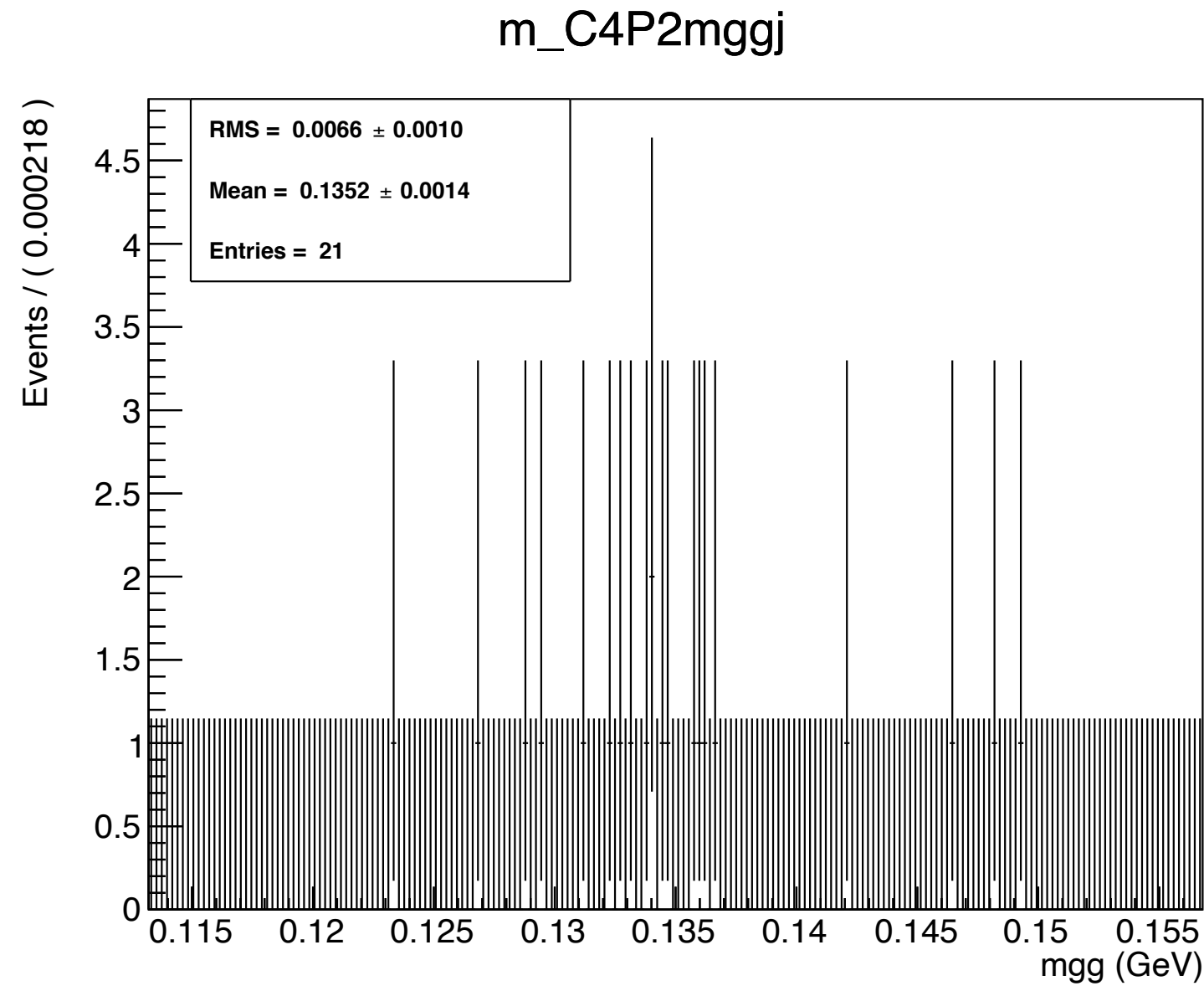
$$m_{\pi^+\pi^-(\gamma\gamma)\pi_2^0}$$



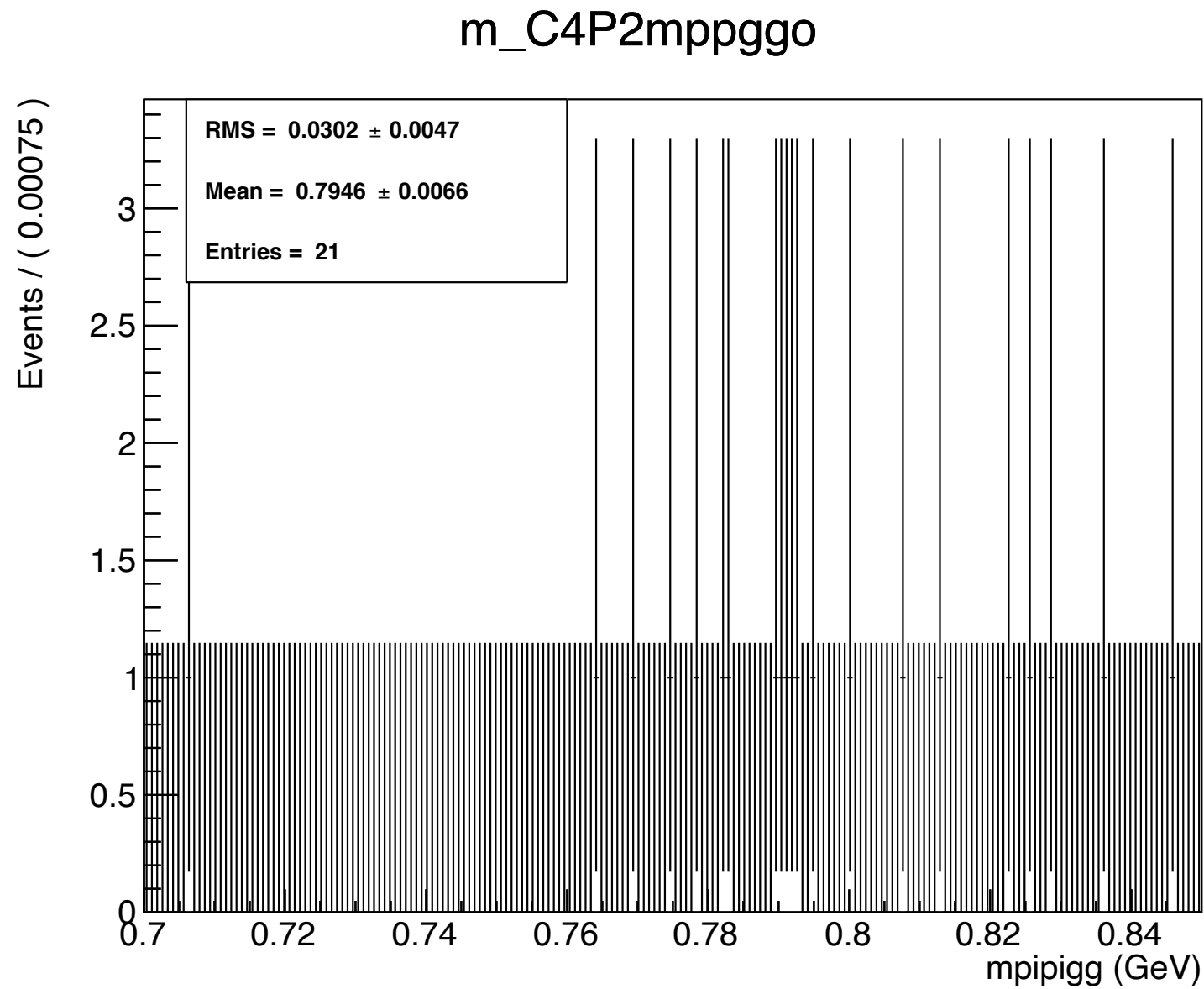
$$m_{\pi^+\pi^-\gamma\gamma\gamma\gamma}$$

$$e^+e^- \rightarrow \omega\pi^0\pi^0 \rightarrow \pi^+\pi^-\pi^0\pi^0\pi^0$$

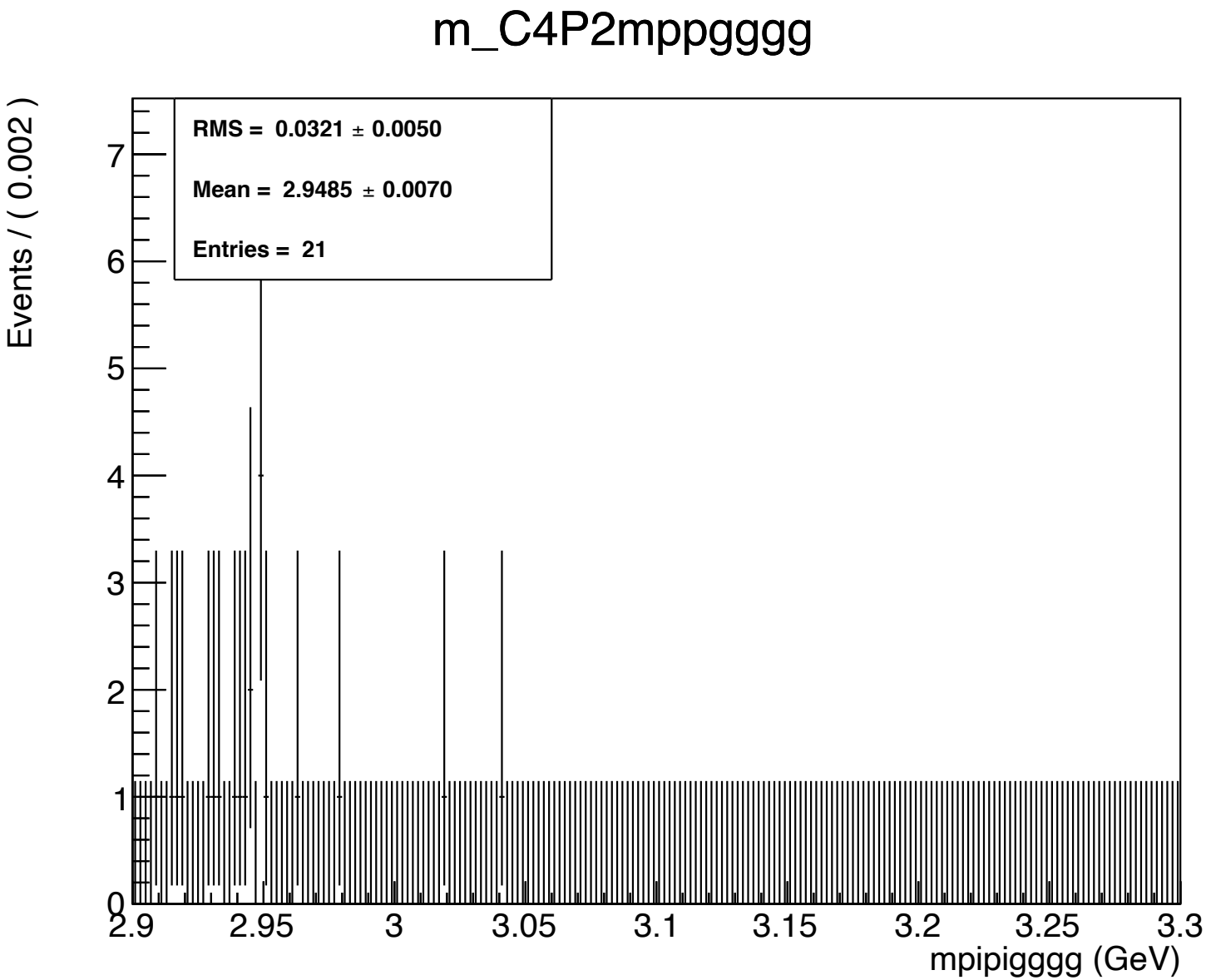
Event selected: 21



$$m_{(\gamma\gamma)\pi_1^0}$$



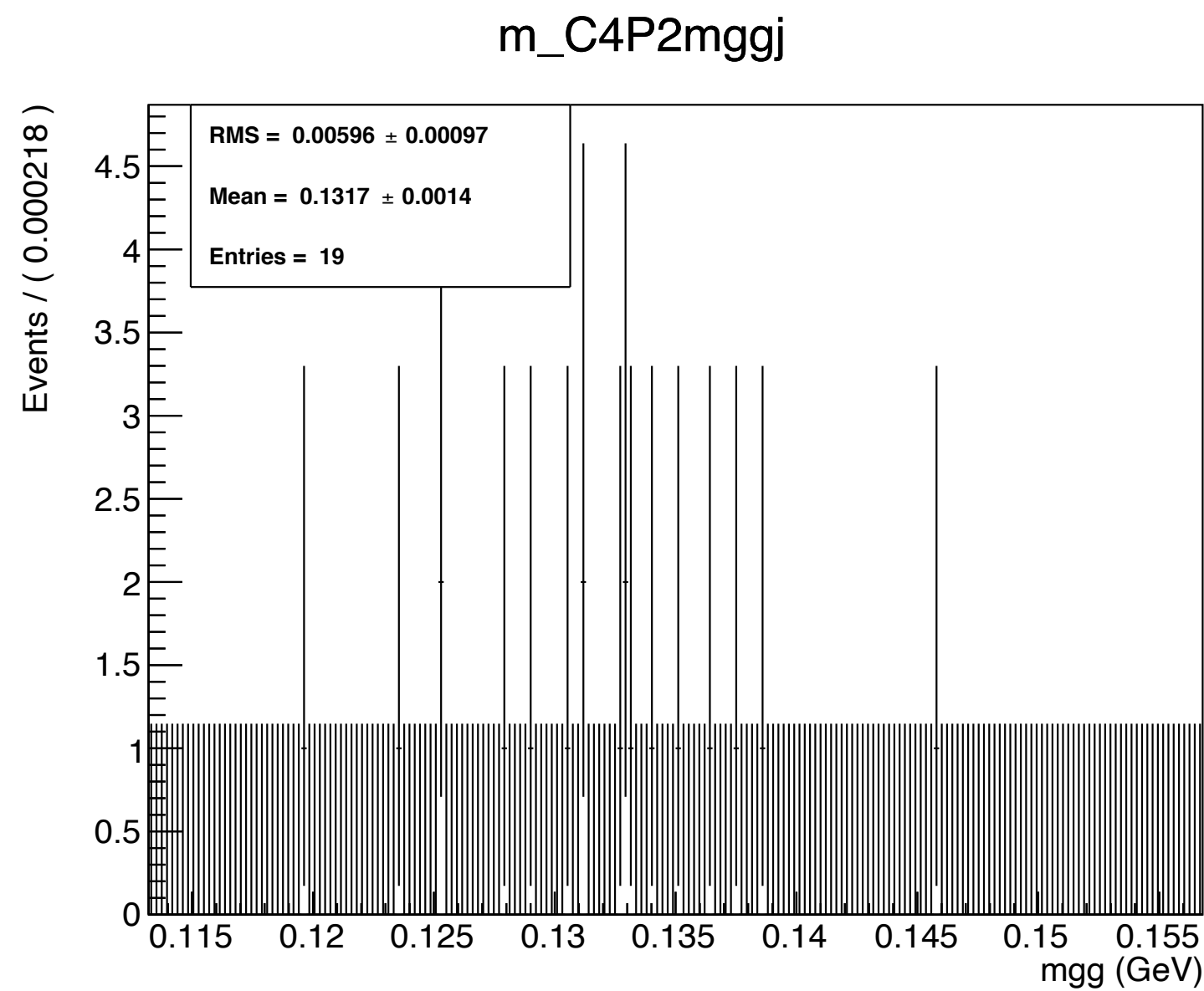
$$m_{\pi^+\pi^-(\gamma\gamma)\pi_2^0}$$



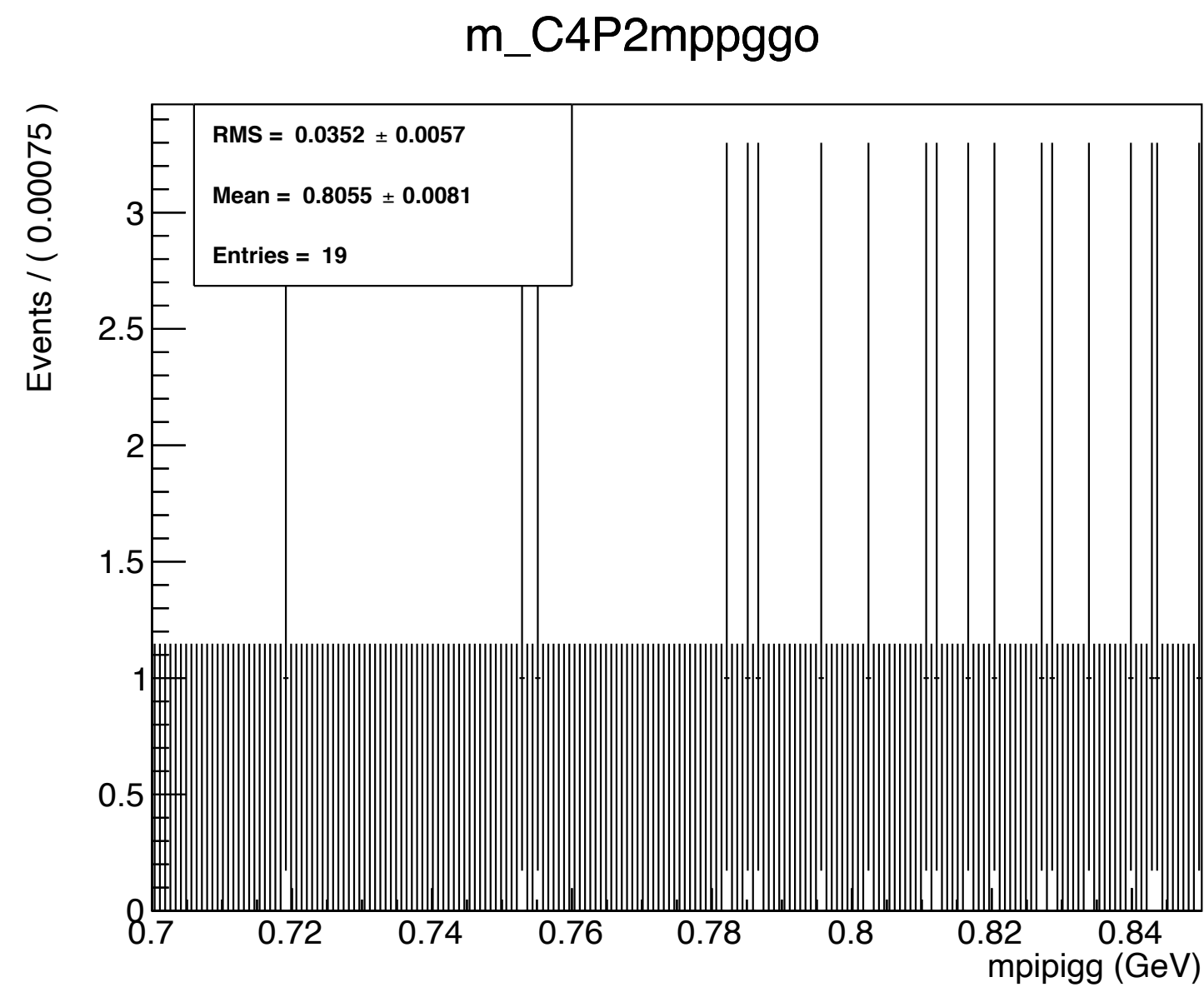
$$m_{\pi^+\pi^-\gamma\gamma\gamma\gamma}$$

$$e^+e^- \rightarrow \rho^0\pi^0\pi^0 \rightarrow \pi^+\pi^-\pi^0\pi^0$$

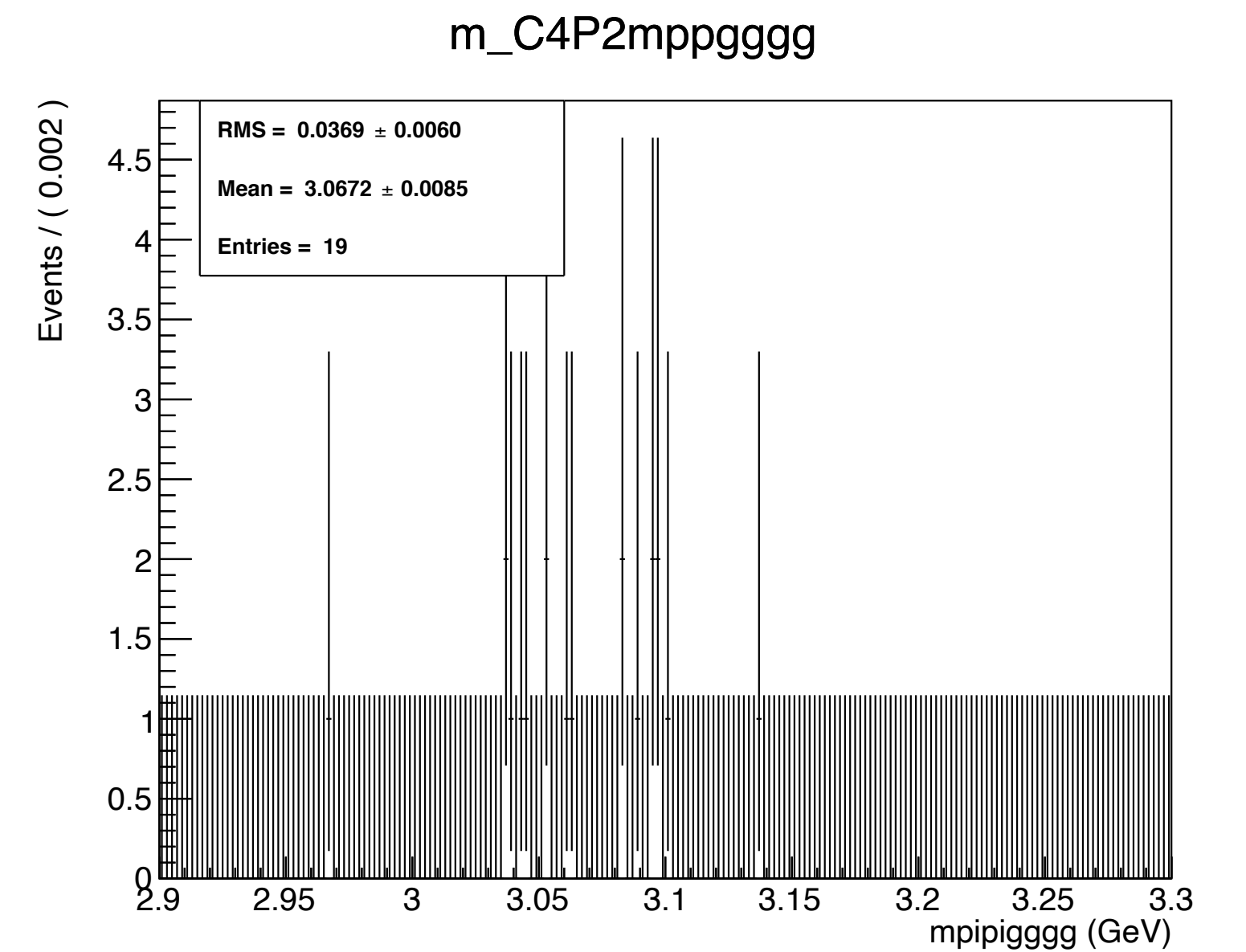
Event selected: 19



$$m_{(\gamma\gamma)\pi_1^0}$$



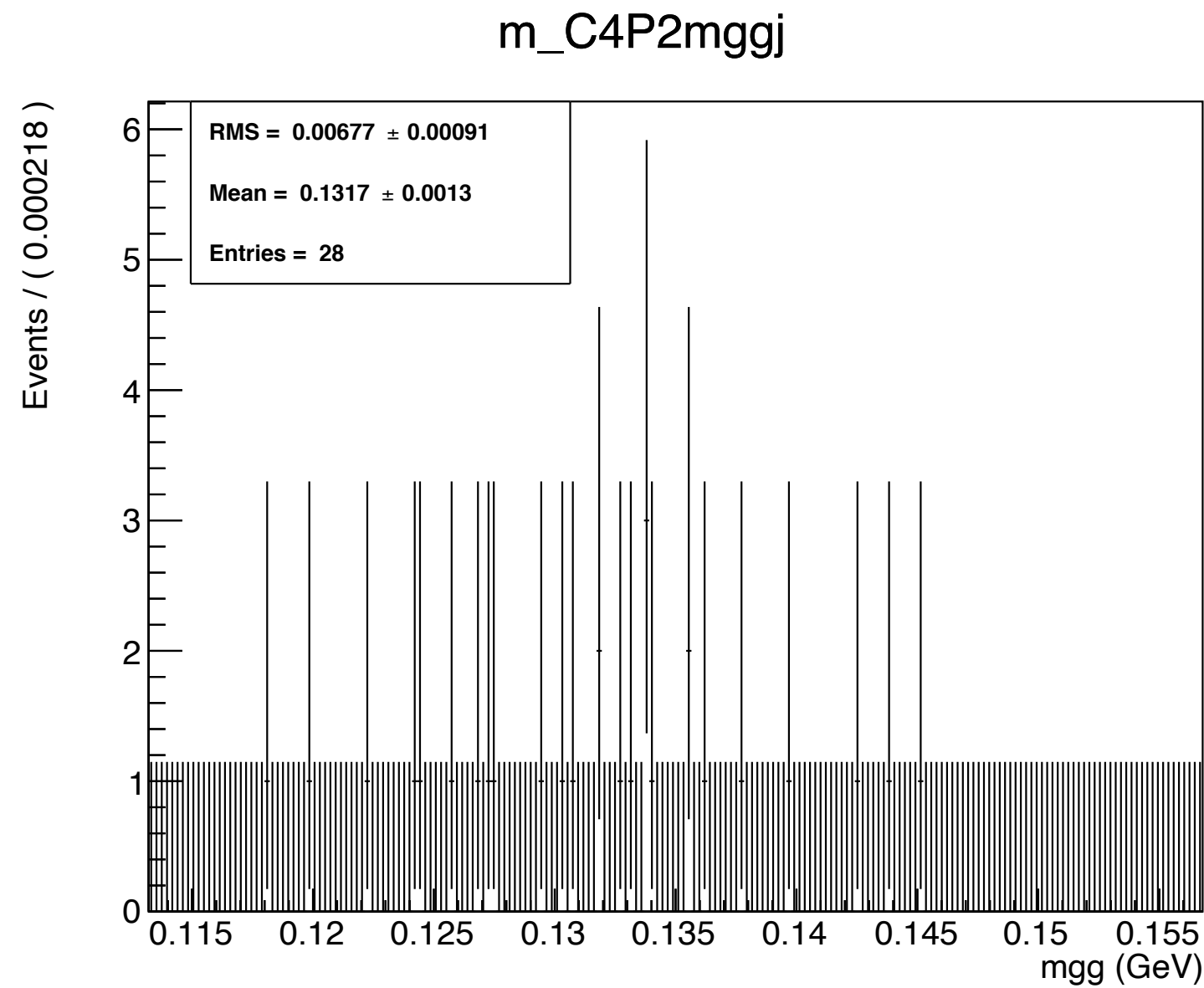
$$m_{\pi^+\pi^-(\gamma\gamma)\pi_2^0}$$



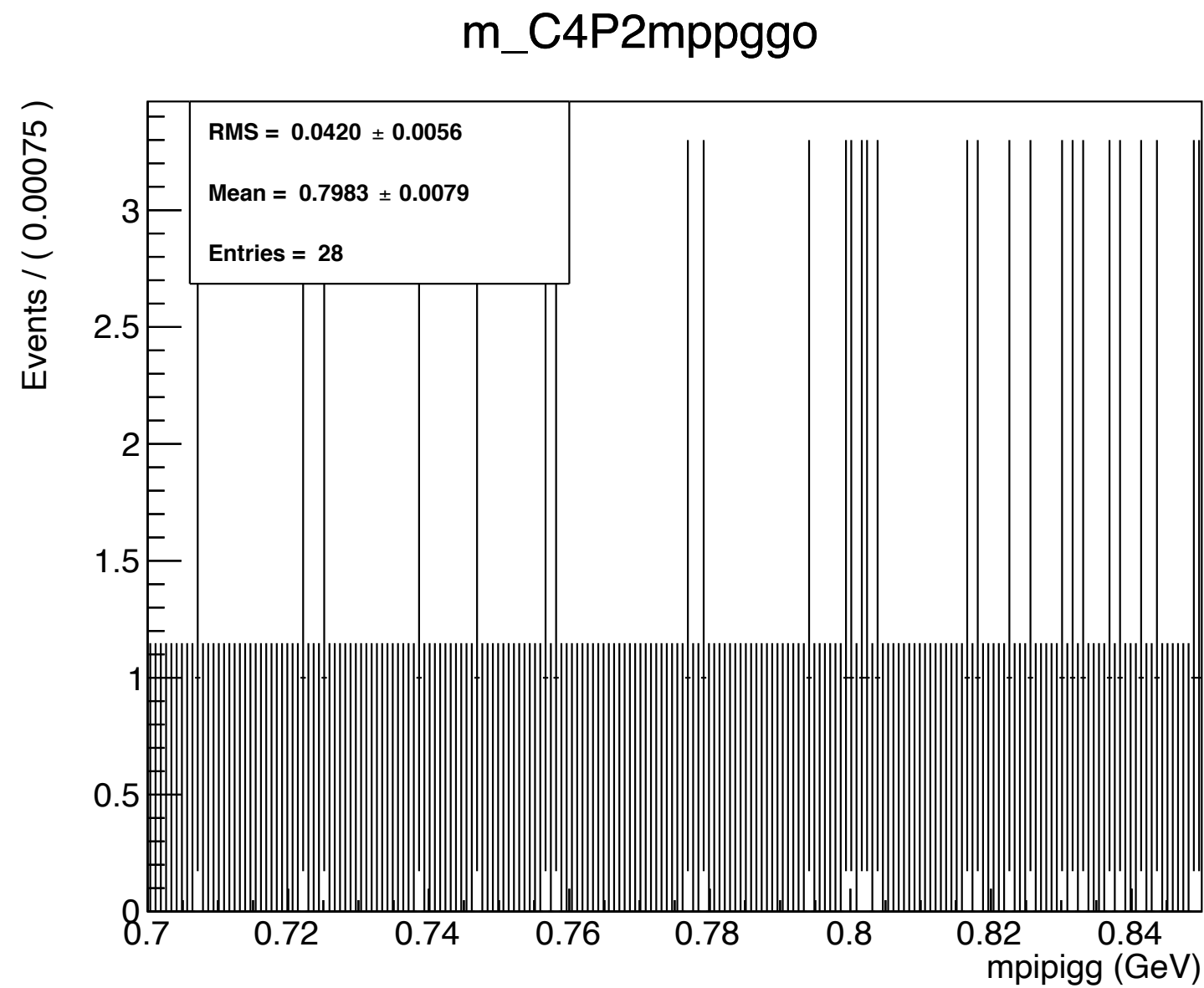
$$m_{\pi^+\pi^-\gamma\gamma\gamma\gamma}$$

$$e^+e^- \rightarrow \rho^+\pi^-\pi^0 \rightarrow \pi^+\pi^-\pi^0\pi^0$$

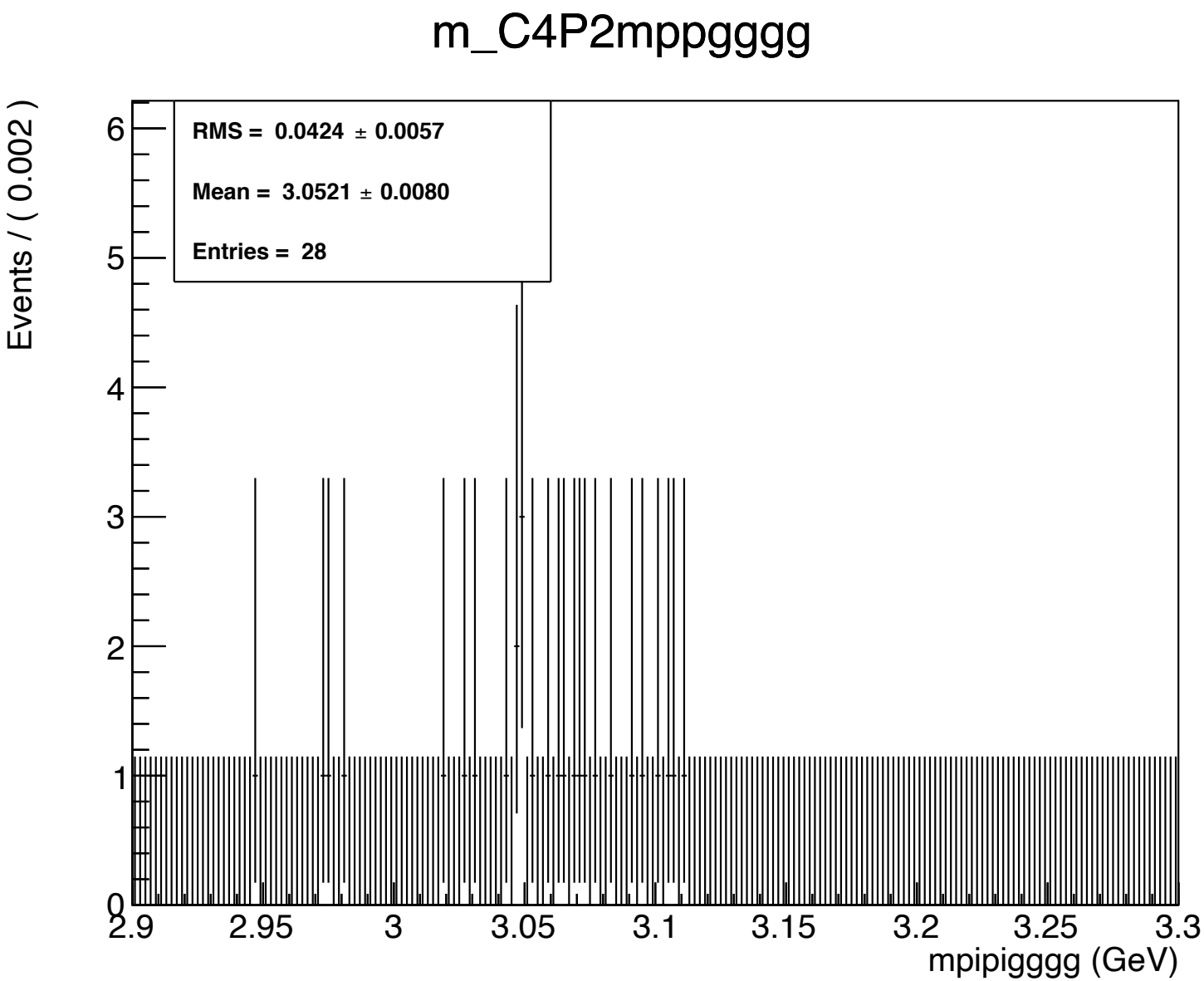
Event selected: 28



$$m_{(\gamma\gamma)\pi_1^0}$$



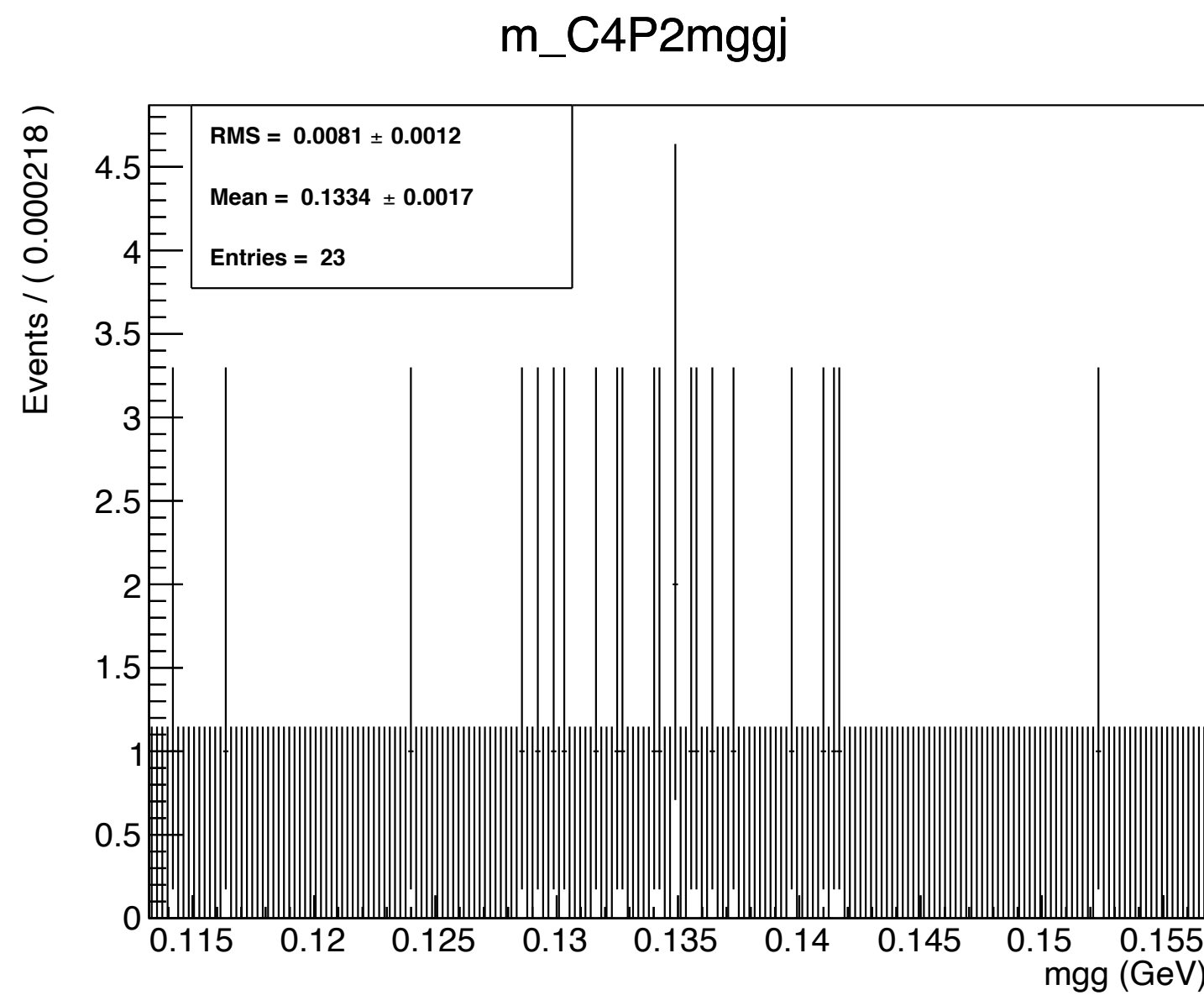
$$m_{\pi^+\pi^-(\gamma\gamma)\pi_2^0}$$



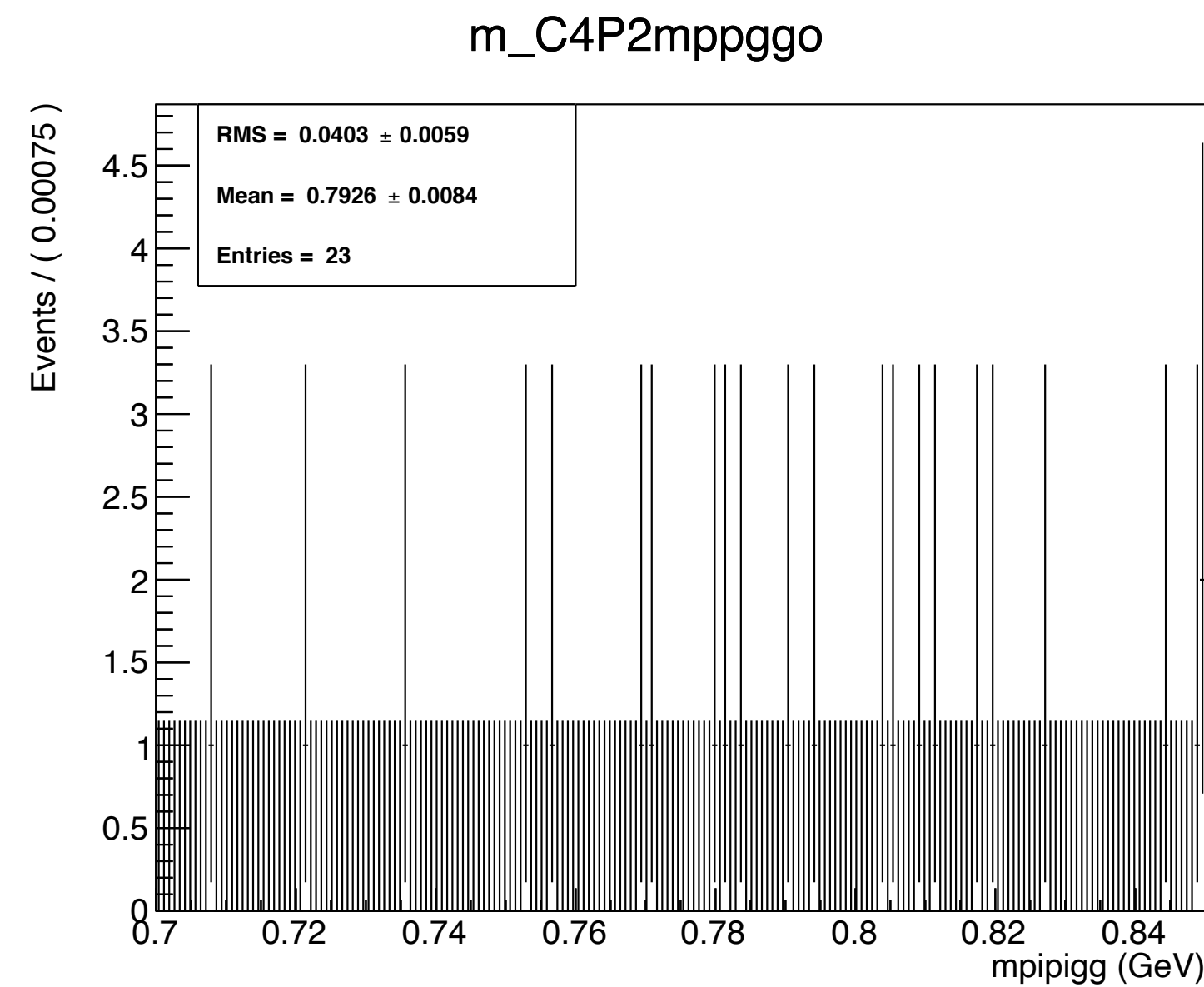
$$m_{\pi^+\pi^-\gamma\gamma\gamma\gamma}$$

$$e^+e^- \rightarrow \rho^- \pi^+ \pi^0 \rightarrow \pi^+ \pi^- \pi^0 \pi^0$$

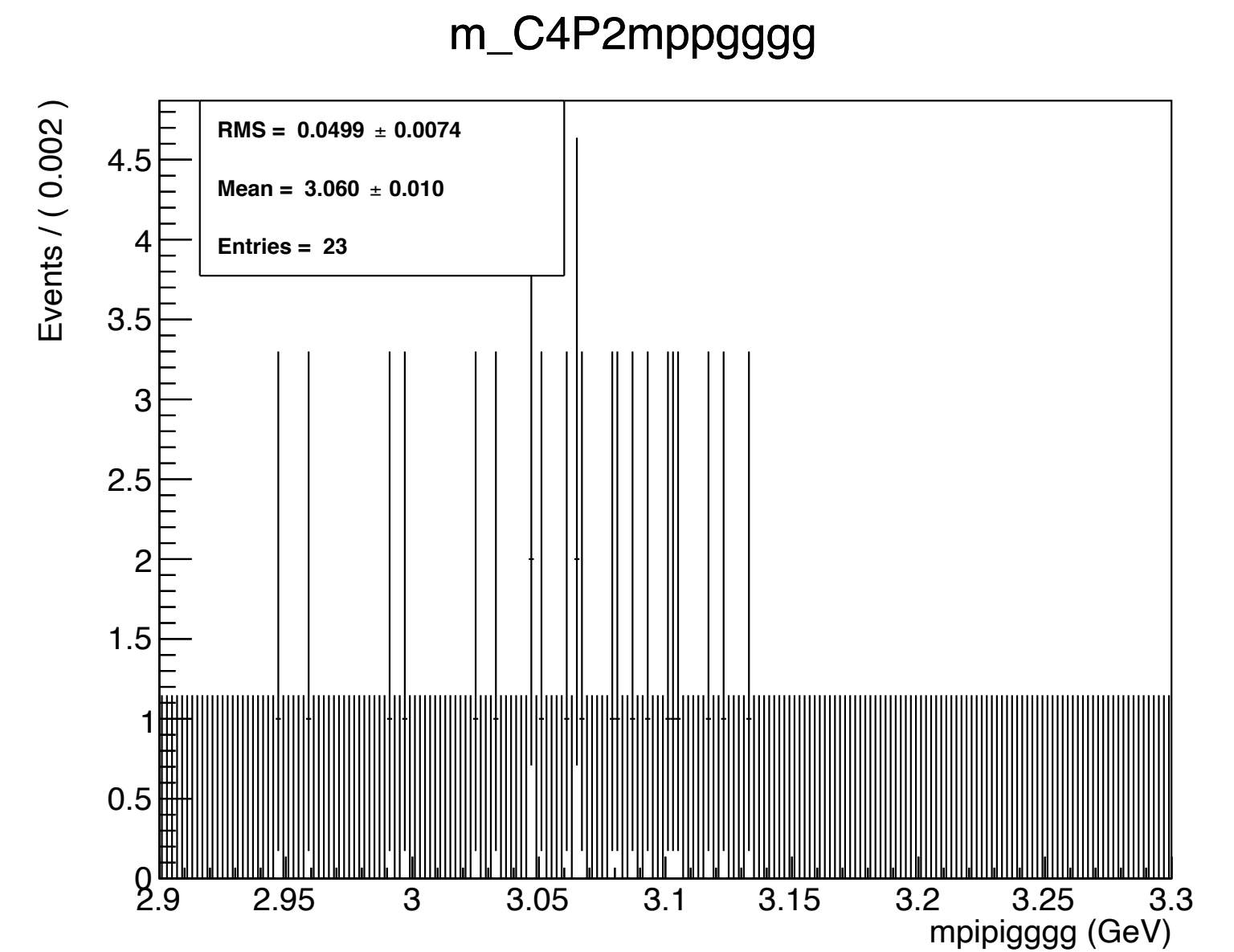
Event selected: 23



$$m_{(\gamma\gamma)\pi_1^0}$$



$$m_{\pi^+\pi^-(\gamma\gamma)\pi_2^0}$$



$$m_{\pi^+\pi^-\gamma\gamma\gamma\gamma}$$