



KIRCHHOFF-
INSTITUT
FÜR PHYSIK



UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

One template to fit them all - Towards a universal fake photon background estimate

Trifels 18.07.2024
Prof. Schultz-Coulon, Rainer Stamen

Anniken Frønsdal Engedal
Tobias Heintz

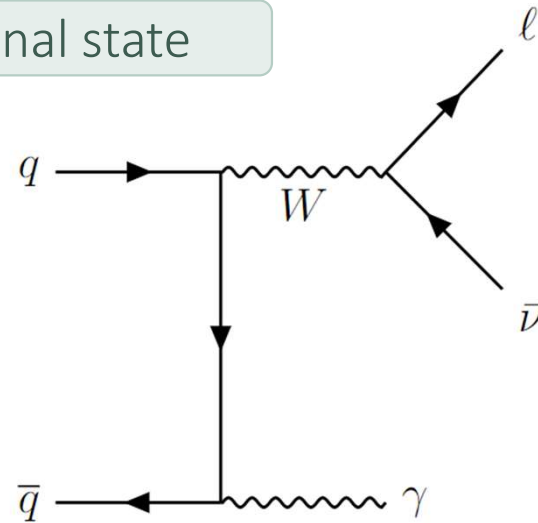
Motivation

Electro weak processes
with final state photon

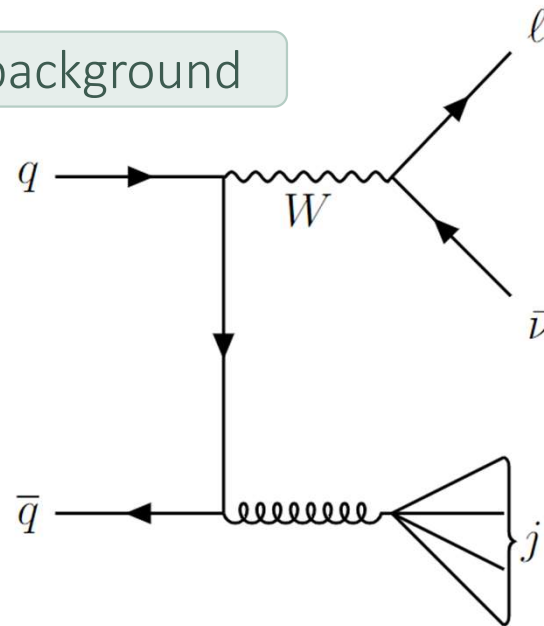


Dominating background
source: fake photons

Wy final state



Fake background



Fake photons from jets

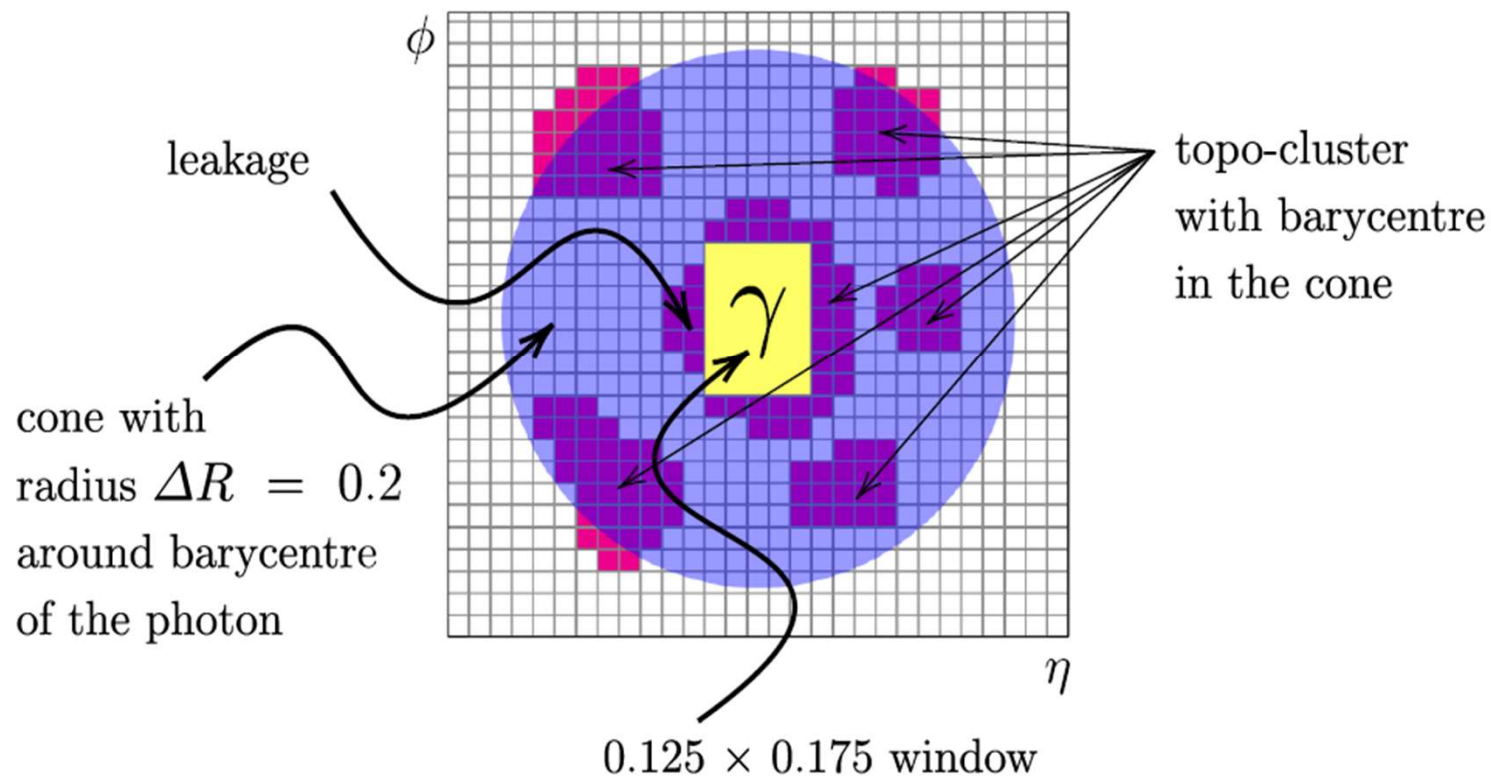
$$\pi^0 \rightarrow \gamma + \gamma$$

Motivation

Isolation energy



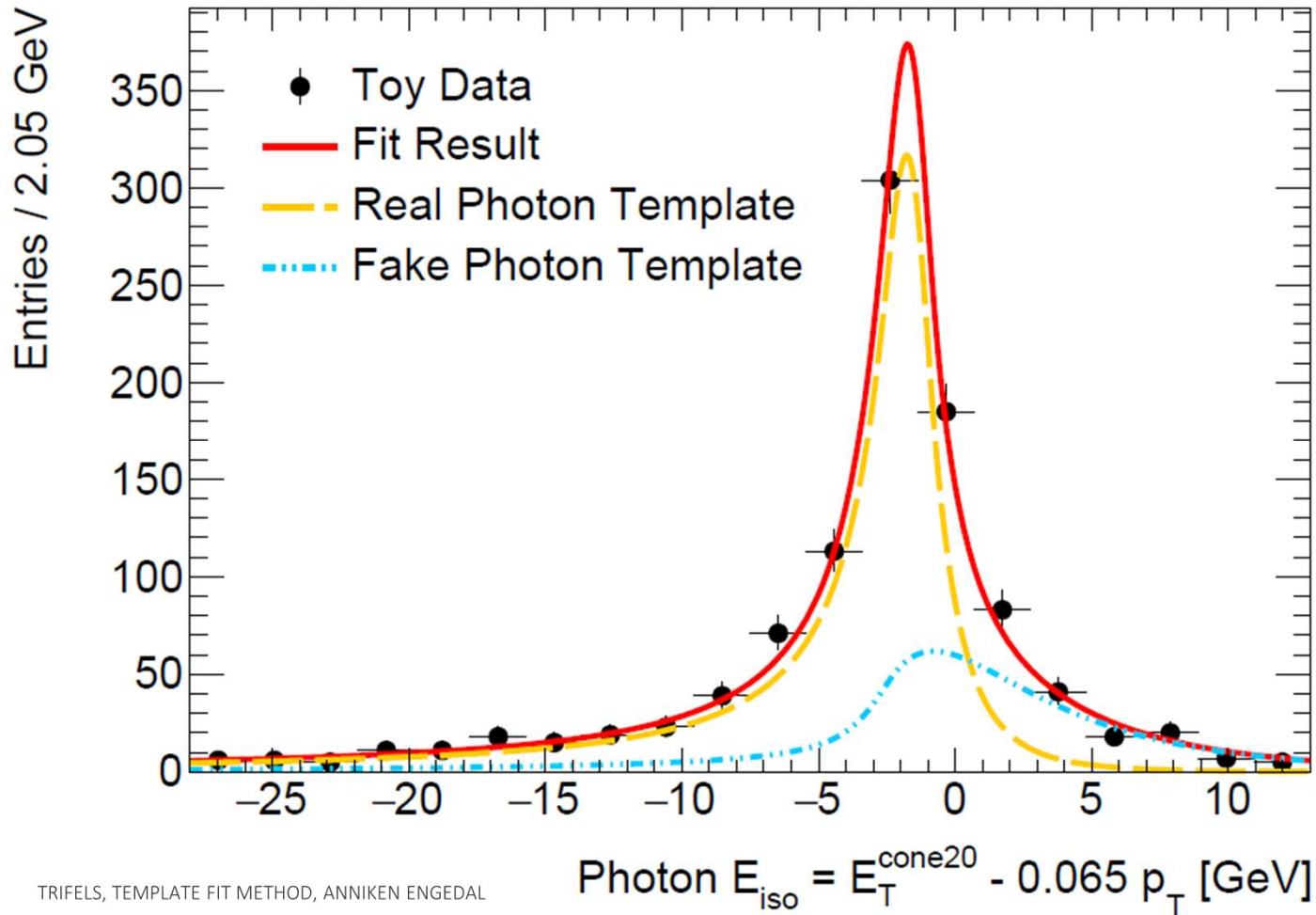
real or fake



$$E_T^{cone20} = E_{T,raw}^{cone20} - E_{T,core} - E_{T,leakage} - E_{T,pileup}$$

$$E_{iso} := E_T^{cone20} - 0.065 \cdot p_T < 0$$

Template fit method



TRIFELS, TEMPLATE FIT METHOD, ANNIKEN ENGEDAL

Extract **real** and **fake** templates from MC



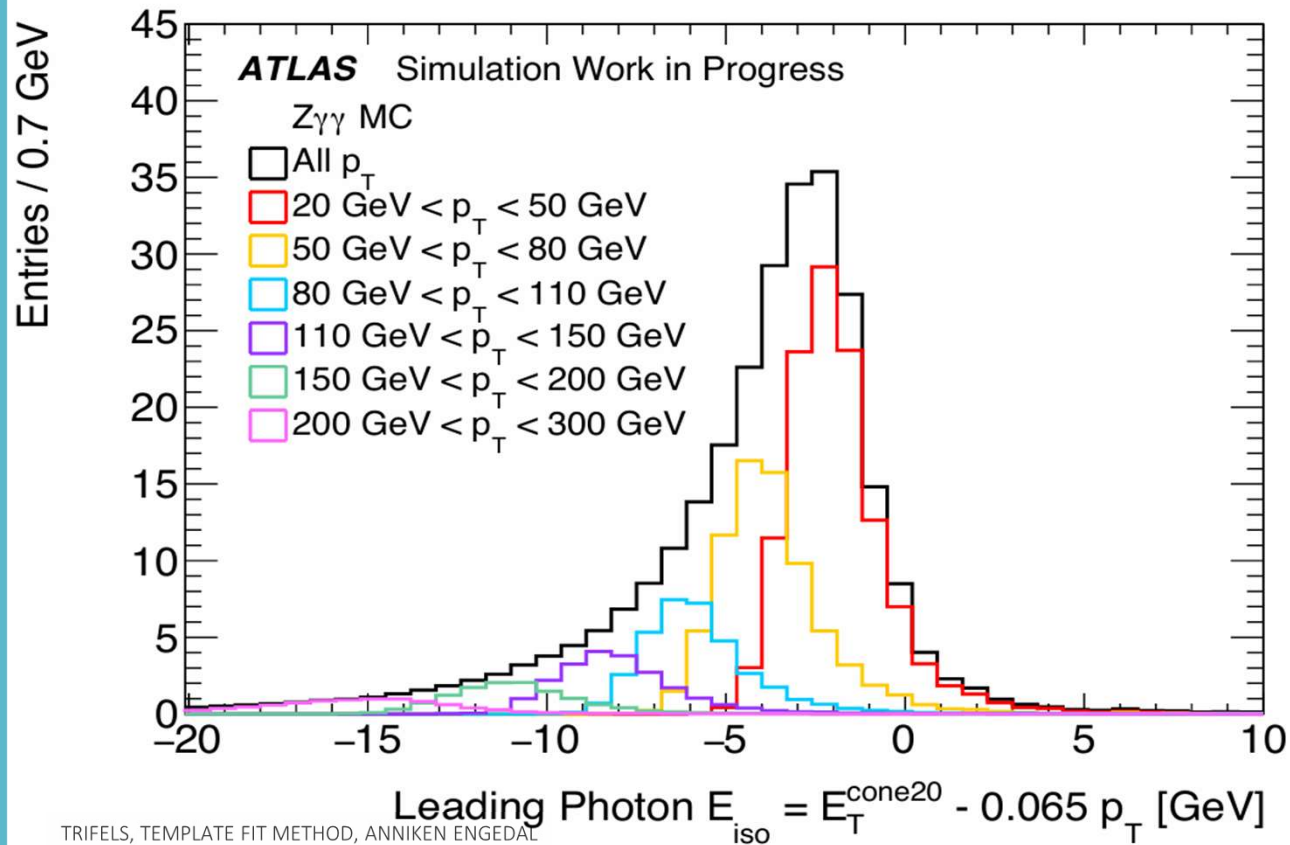
Combined fit on data



Estimate contributions

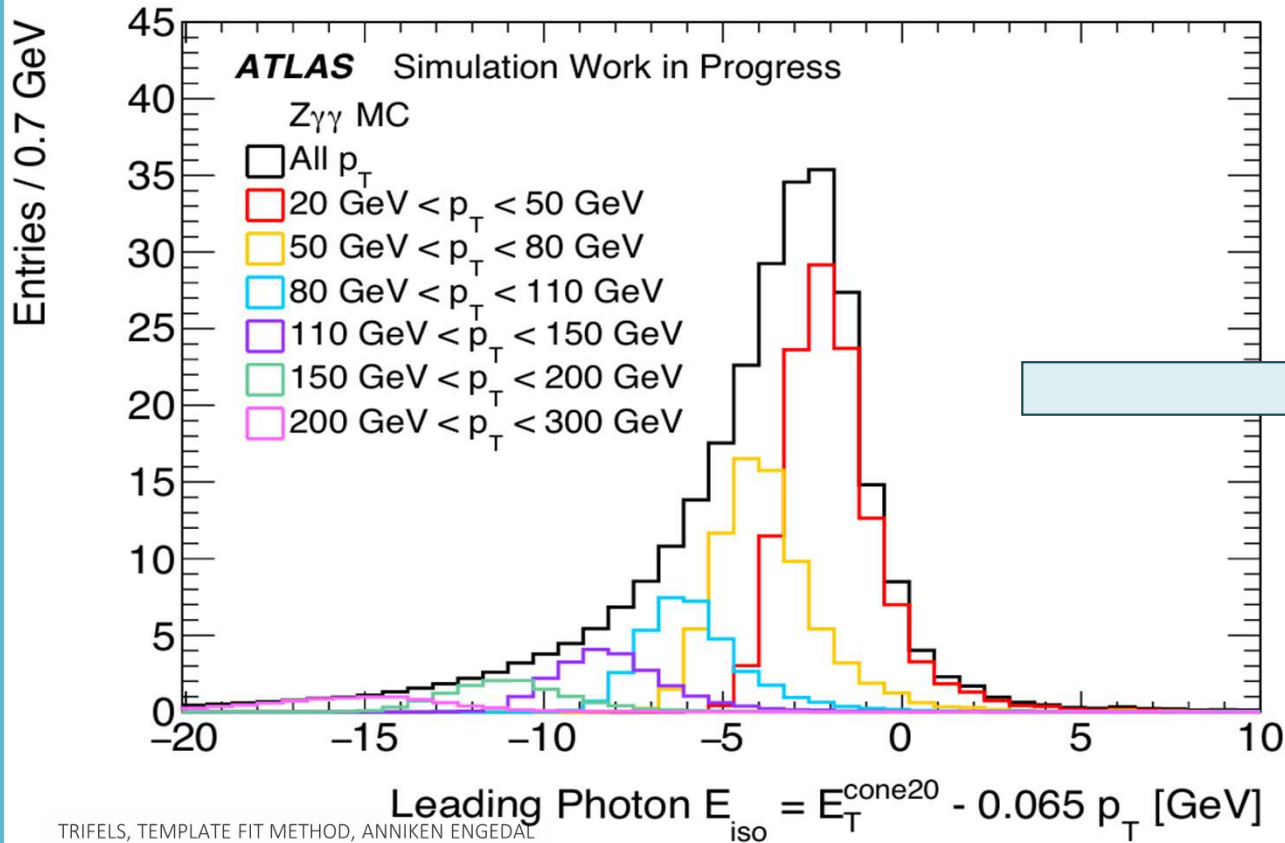
Template fit method

Challenge of p_T dependence



Template fit method

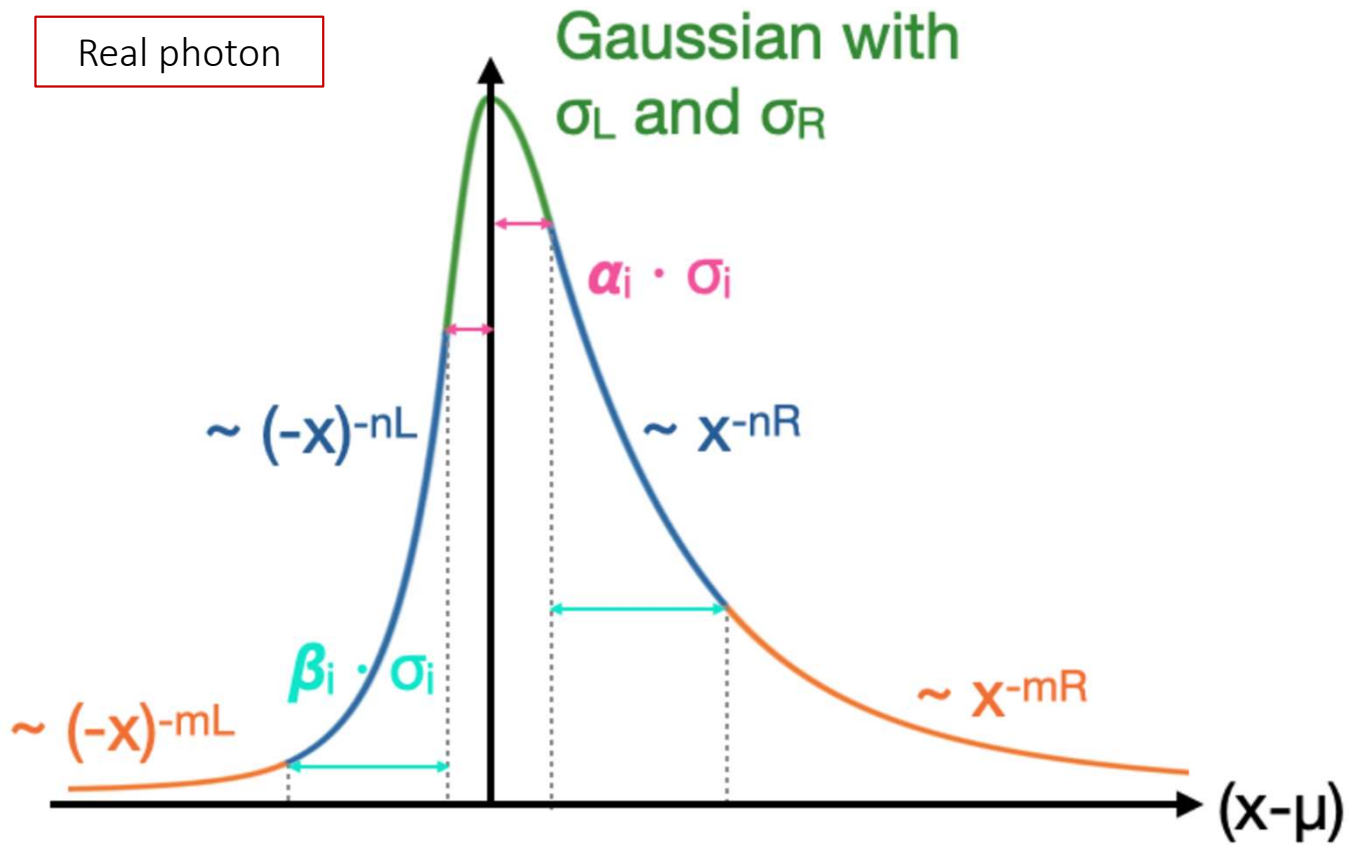
Challenge of p_T dependence



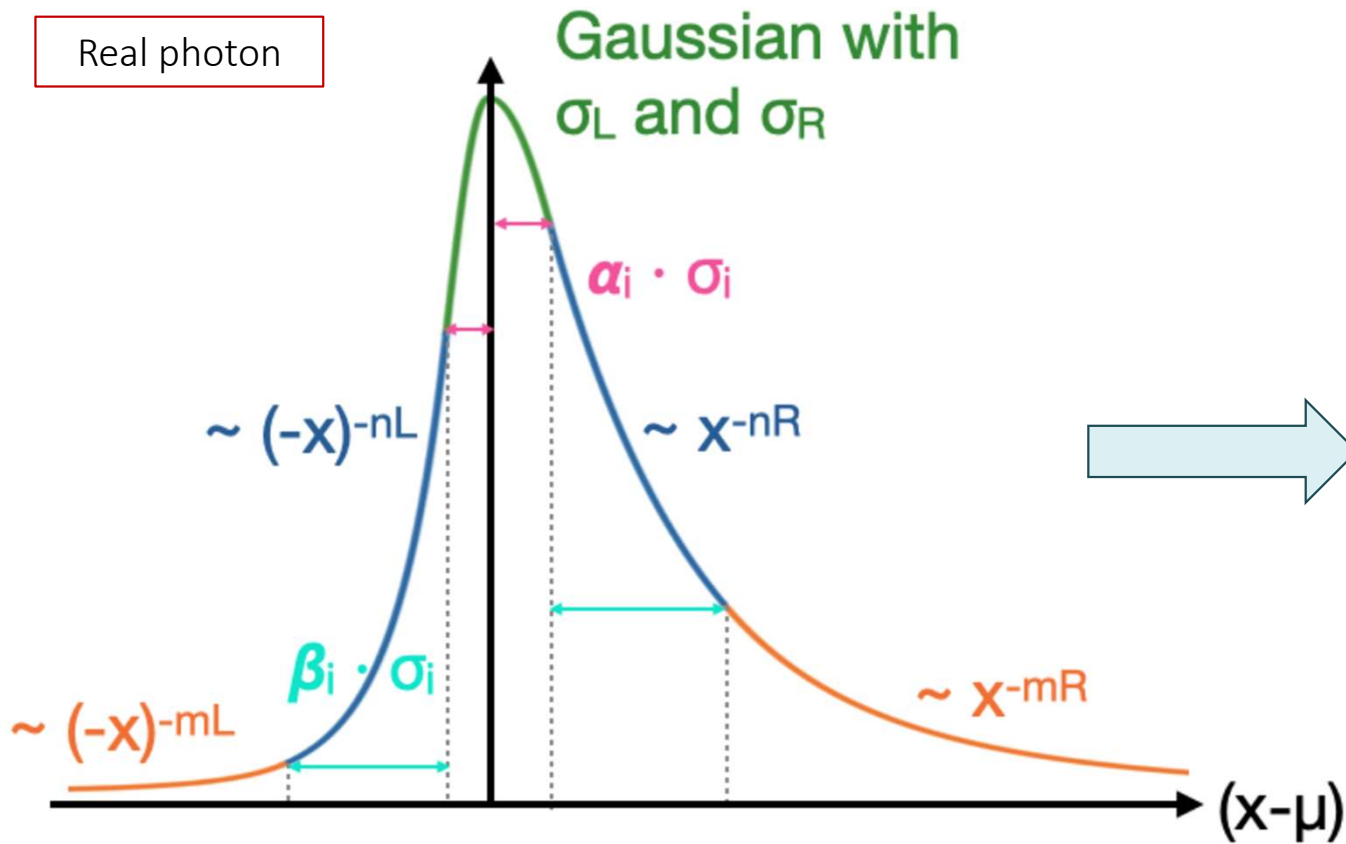
Generalisation of templates

$$\underbrace{T_{\gamma,j}(E_{\text{iso}}, p_T | \vec{\theta})}_{\text{generic}} \times \underbrace{f_X(p_T)}_{\text{specific}}$$

Generic isolation templates



Generic isolation templates

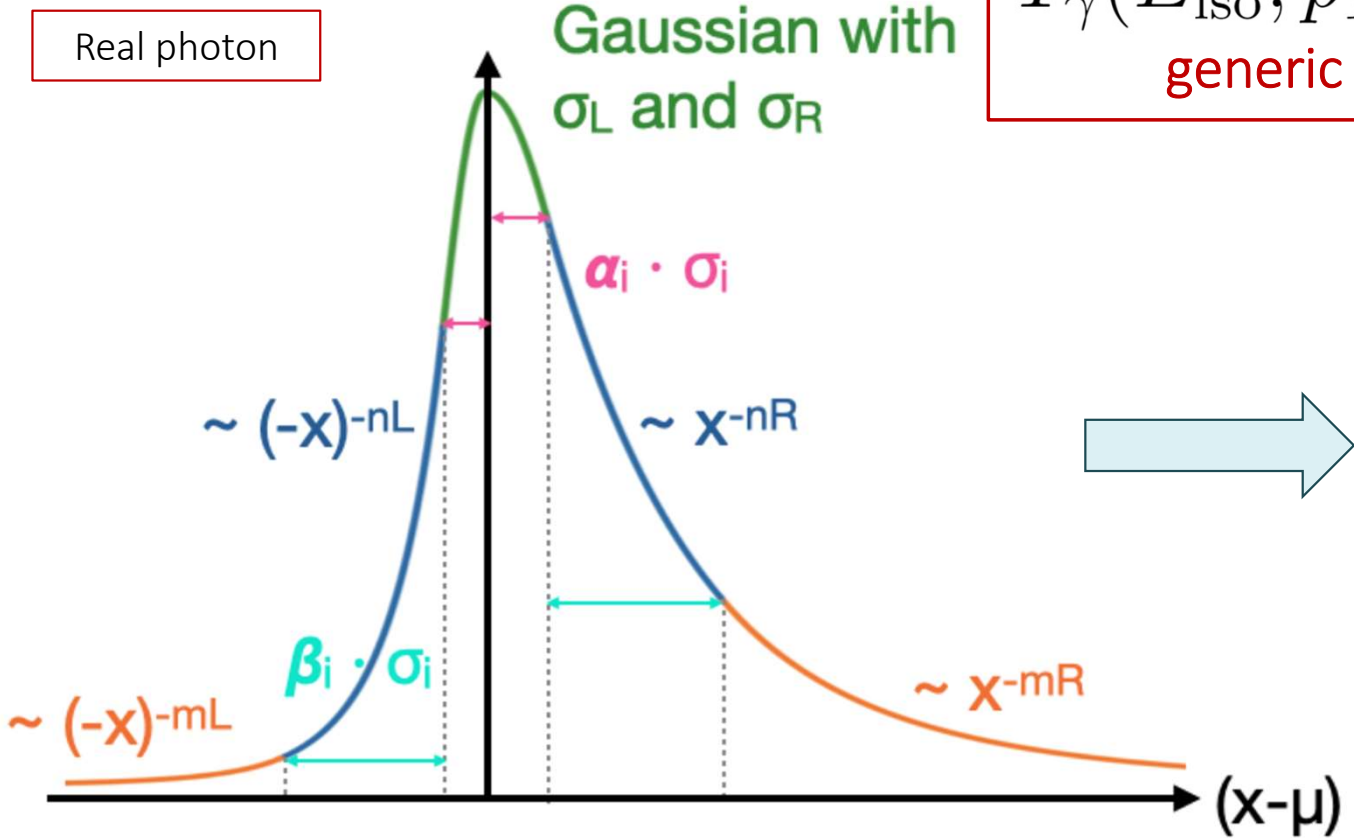


Determine p_T dependence of parameters $\vec{\theta}$

Generic isolation templates

$$T_\gamma(E_{\text{iso}}, p_T | \vec{\theta}) \times f_X(p_T)$$

generic
specific

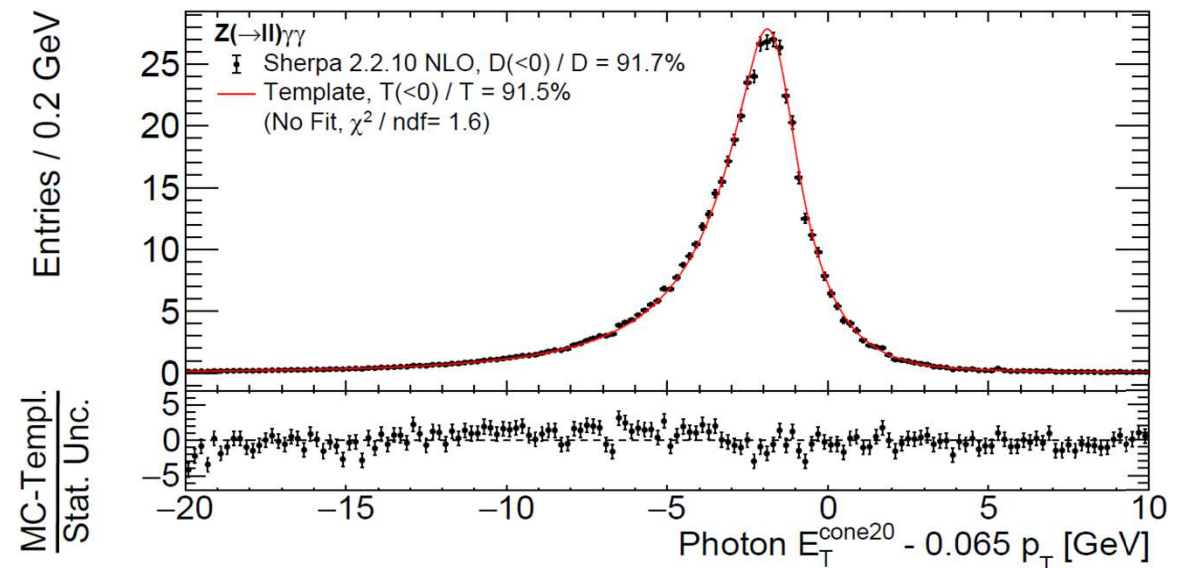
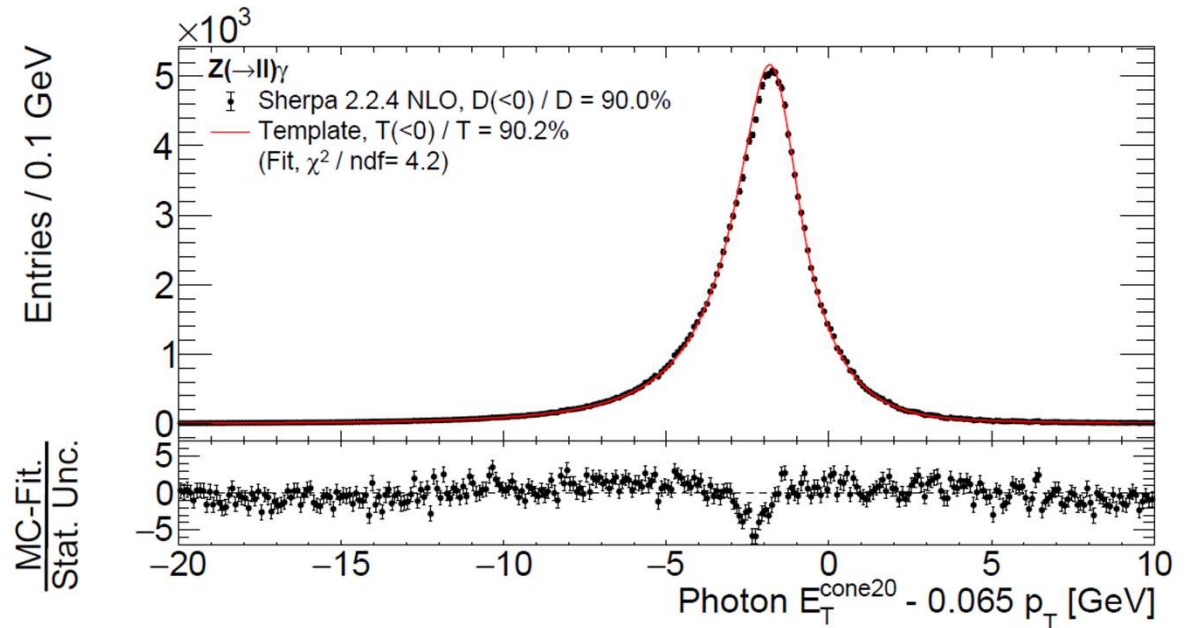


Determine p_T dependence of parameters $\vec{\theta}$

Extraction
of real
template



comparison



$$\underbrace{T(E_{\text{iso}}, p_{\text{T}} | \vec{\theta})}_{\text{2D template}} \cdot \underbrace{f_X(p_{\text{T}})}_{\substack{p_{\text{T}} \text{ distribution of} \\ \text{corresponding} \\ \text{phase space } X}}$$

Application for both Zy
and Zyy Run-2

$$T(E_{\text{iso}}, p_{\text{T}} | \vec{\theta}) \cdot f_X(p_{\text{T}})$$

2D template

p_{T} distribution of
corresponding
phase space X

?

Application for both Zy
and Zyy Run-2

Application for Run-3
processes?

Wy

Wyy

Zyy

Zy

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$$\underbrace{T(E_{\text{iso}}, p_{\text{T}} | \vec{\theta})}_{\text{2D template}} \cdot \underbrace{f_X(p_{\text{T}})}_{\substack{p_{\text{T}} \text{ distribution of} \\ \text{corresponding} \\ \text{phase space } X}}$$

?

Application for both Zy
and Zyy Run-2

Application for Run-3
processes?

Wy

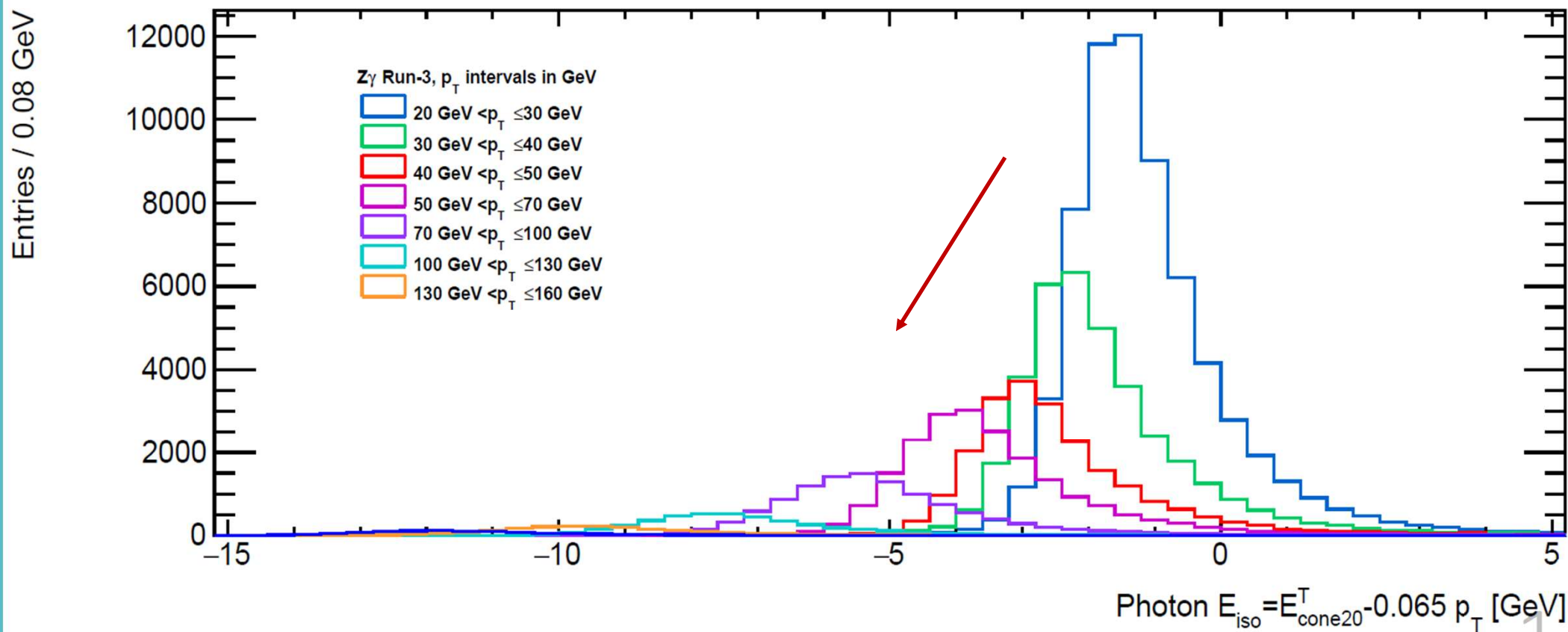
Wyy

Zyy

Zy

Z γ Run-3: Isolation energy

p_T dependence

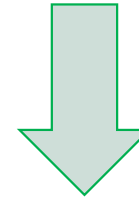


Real template extraction

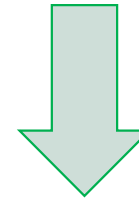
General fit procedure

$$T_{\gamma,j}(E_{\text{iso}}, p_T | \vec{\theta}) \times f_X(p_T)$$

Real template
developed empirically

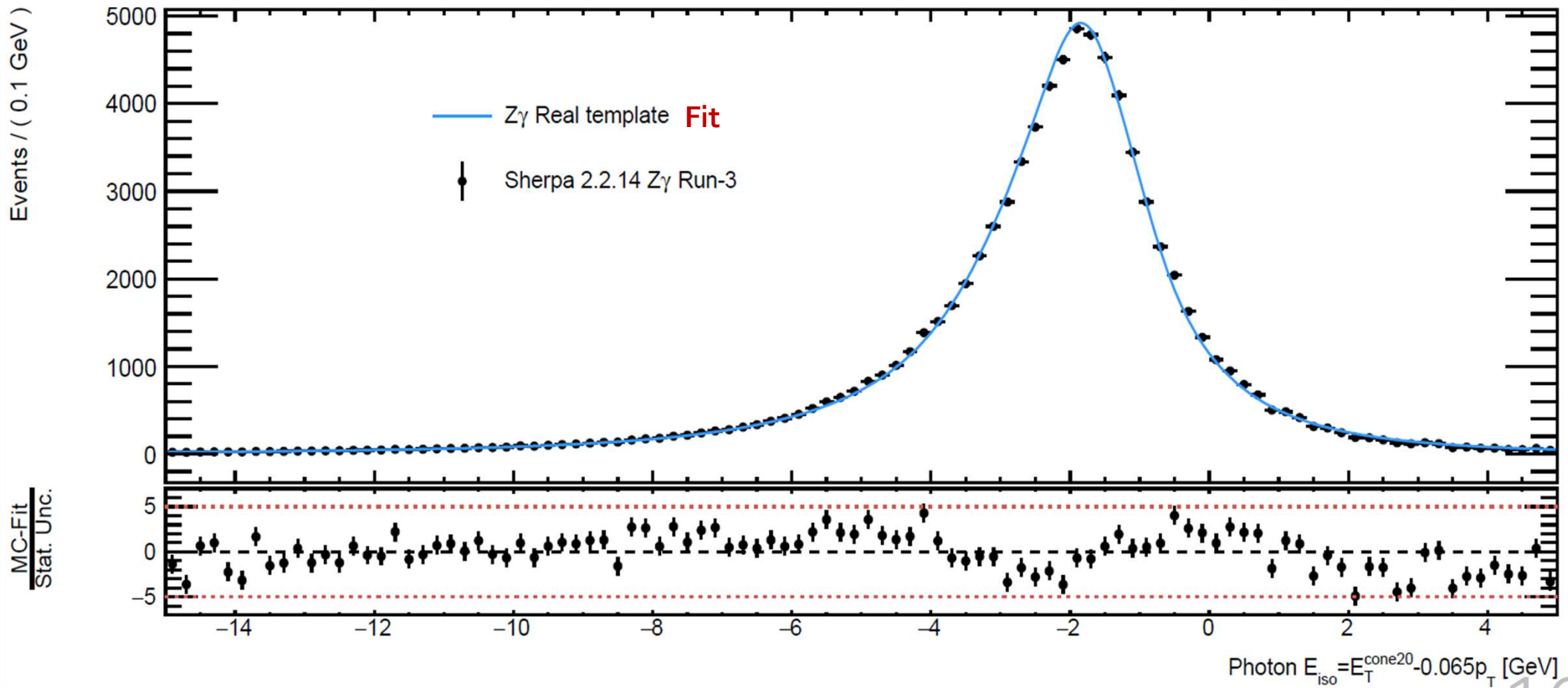


2D max. likelihood fit

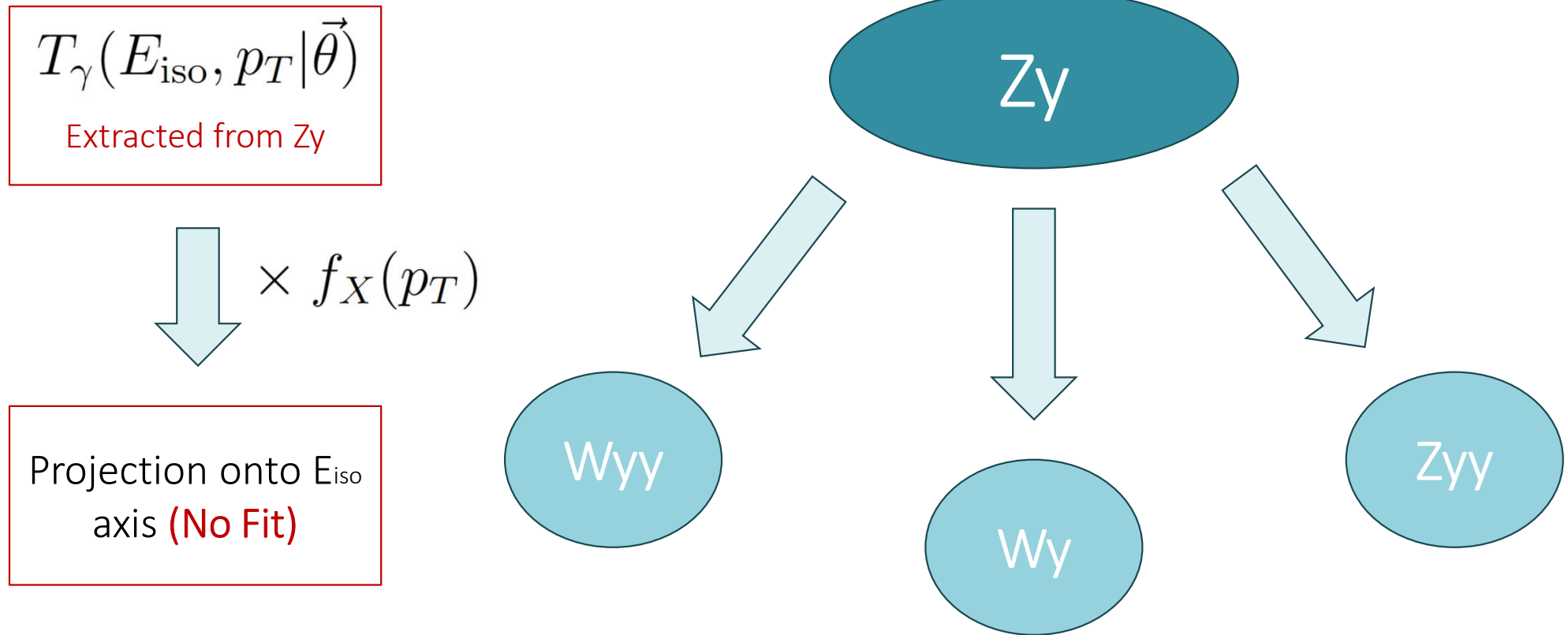


Projection onto E_{iso} axis

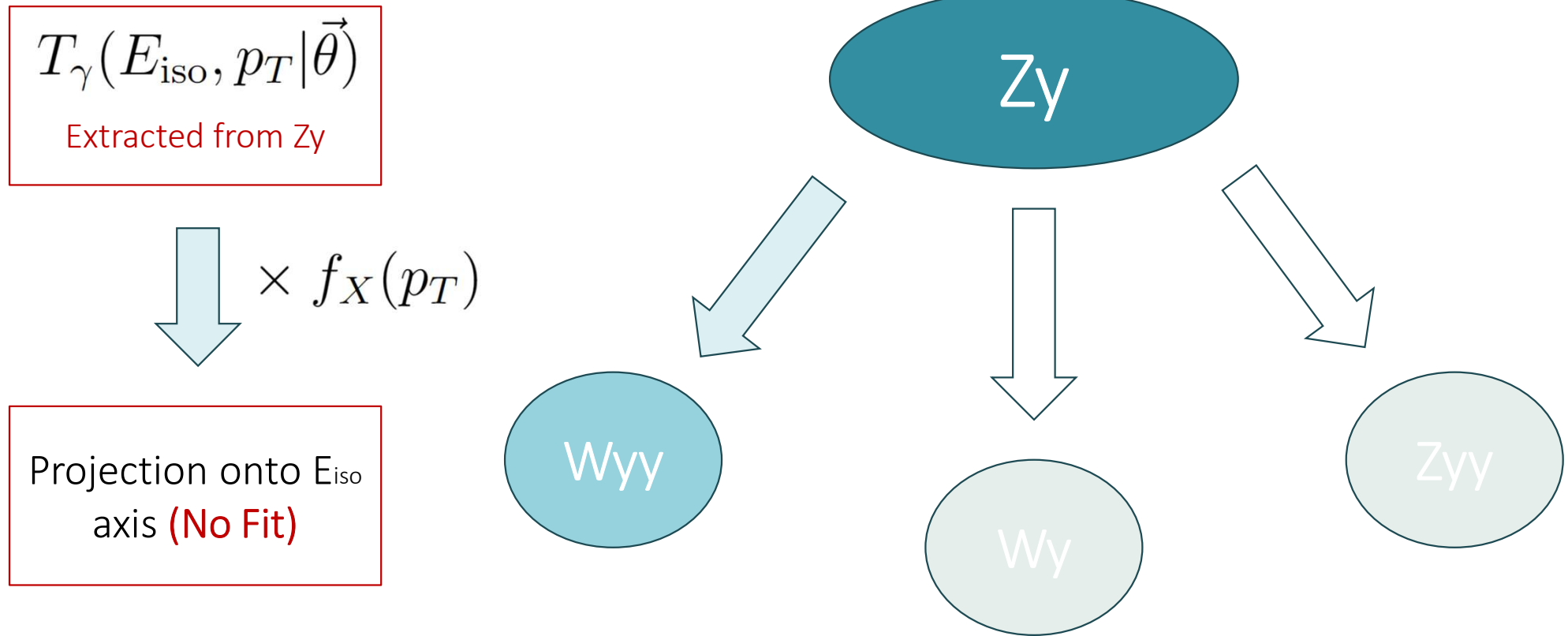
Z γ Run-3: Real template extraction



Comparison of Zy real template



Comparison of Zy real template

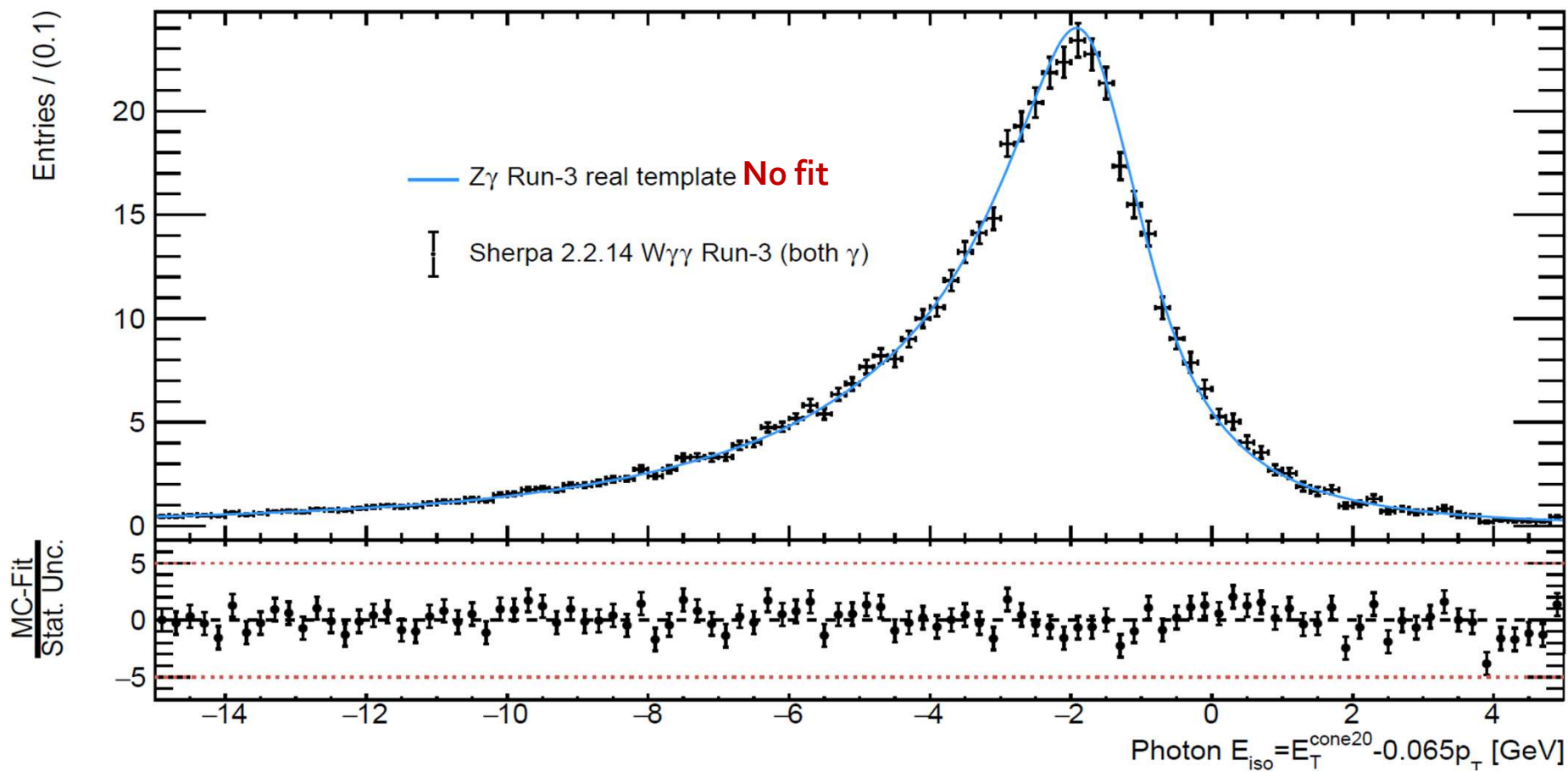


Z γ template

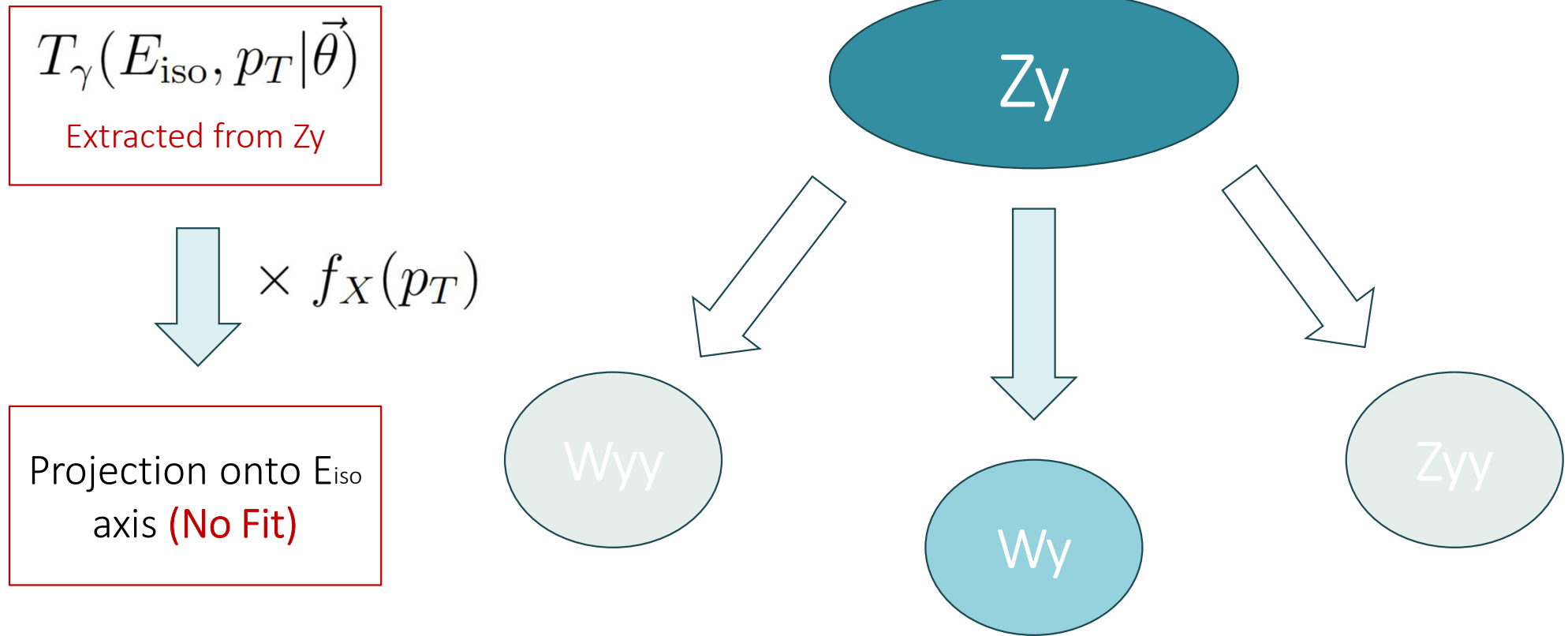


W γ (both γ)

$$T_{\gamma}(E_{\text{iso}}, p_T | \vec{\theta}) \times f_{W\gamma\gamma}(p_T)$$



Comparison of Zy real template

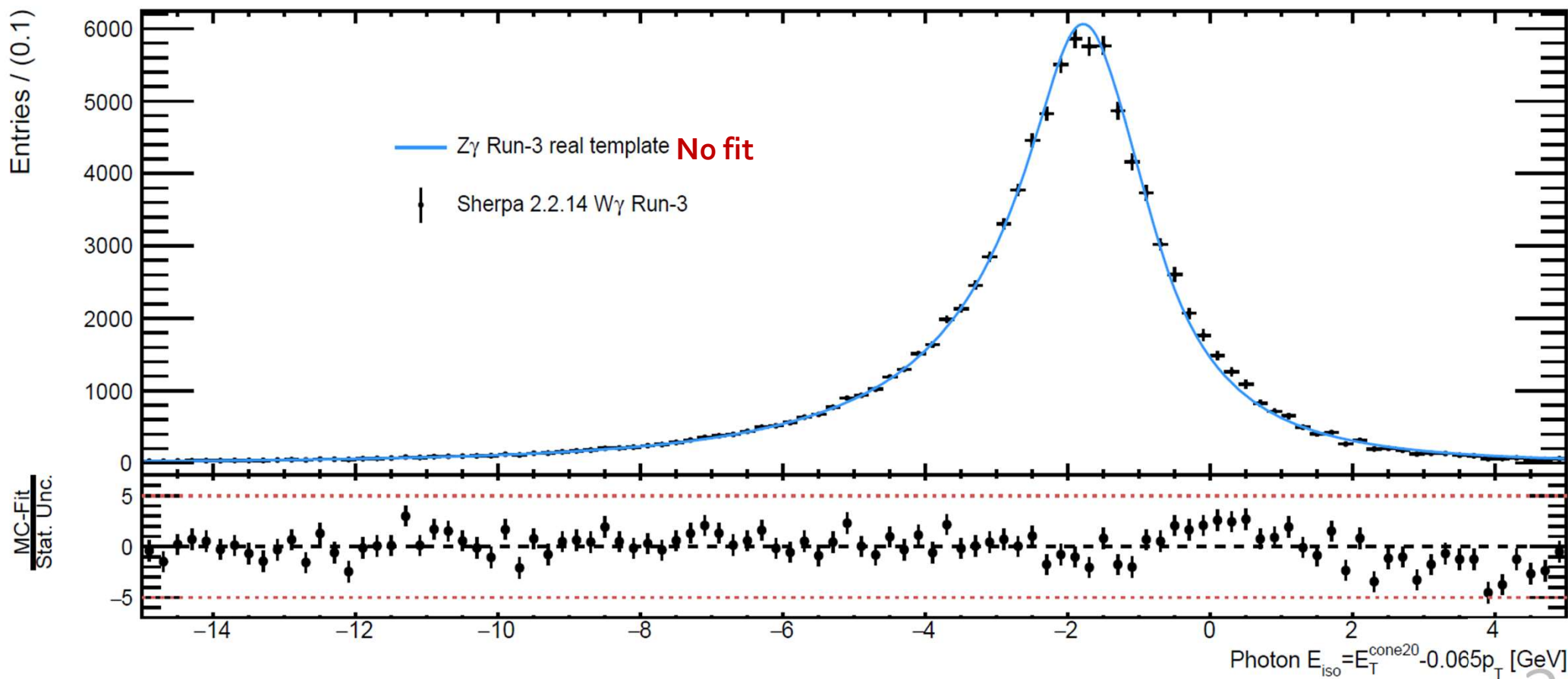


Z γ template



W γ

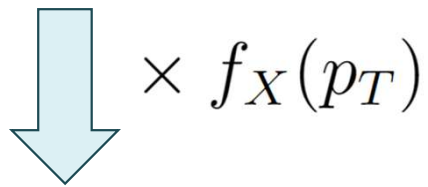
$$T_{\gamma}(E_{\text{iso}}, p_T | \vec{\theta}) \times f_{W\gamma}(p_T)$$



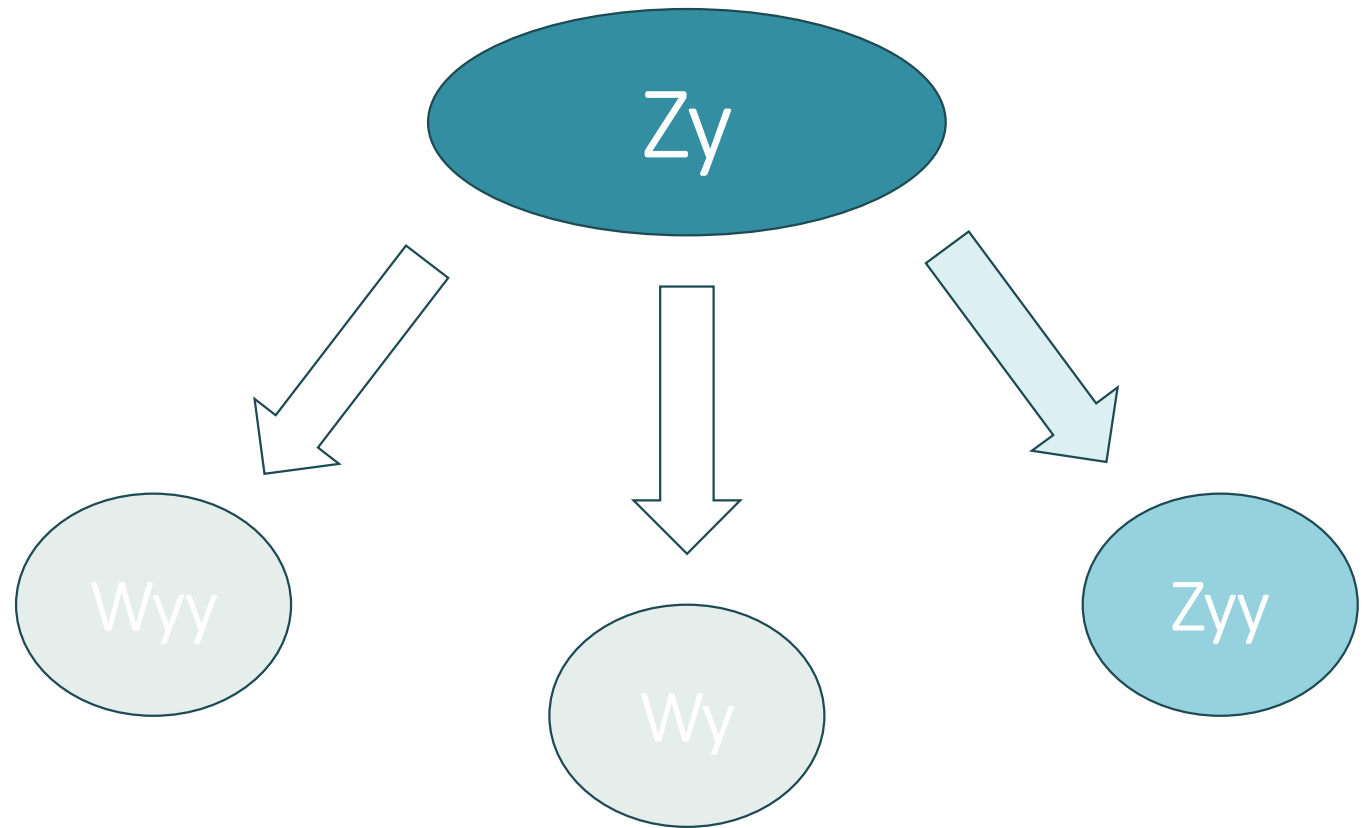
Comparison of Zy real template

$$T_\gamma(E_{\text{iso}}, p_T | \vec{\theta})$$

Extracted from Zy



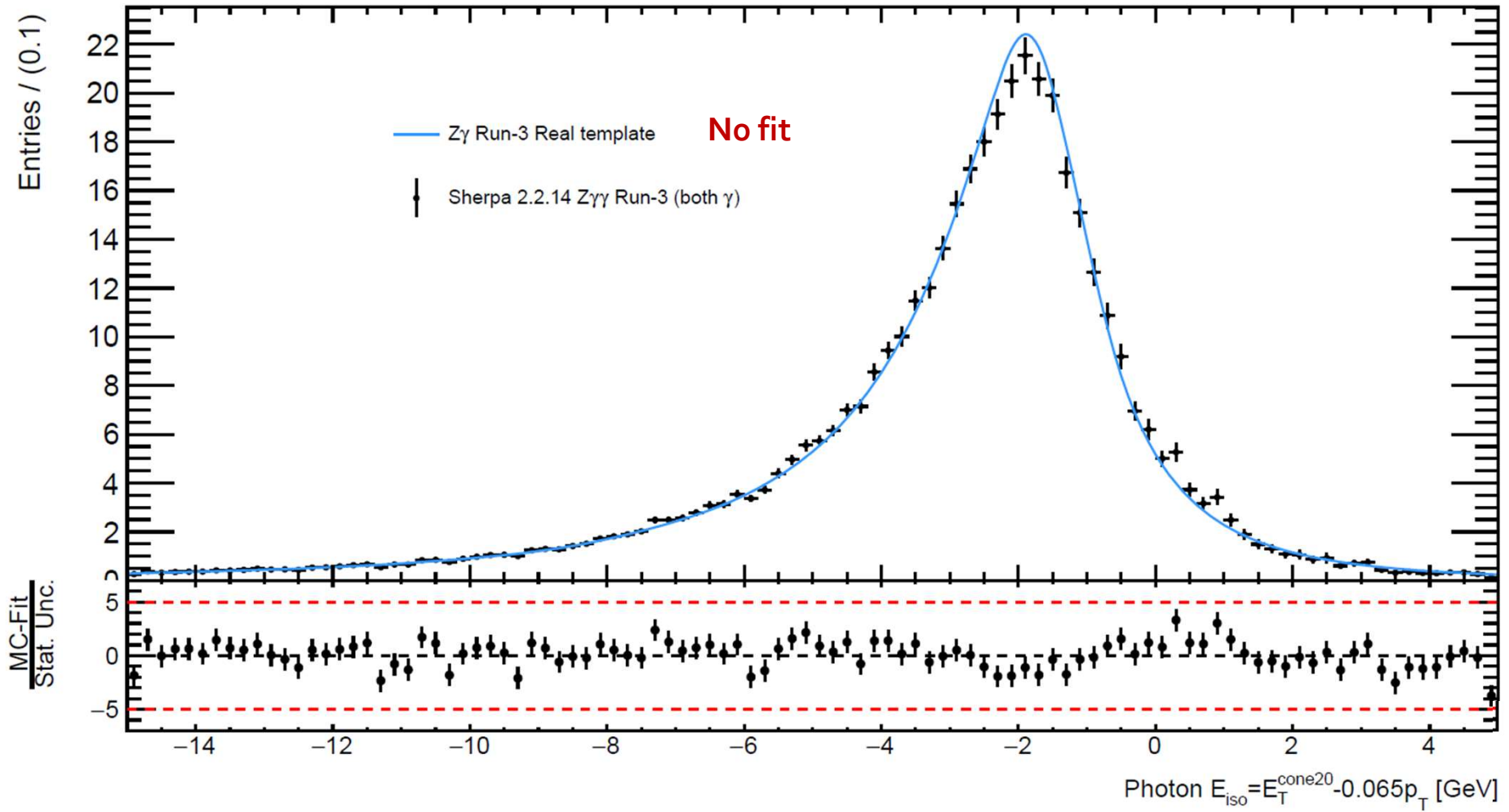
Projection onto E_{iso} axis (No Fit)



Z γ template



Z $\gamma\gamma$ (both γ)



Summary

$$T_{\gamma}(E_{\text{iso}}, p_T | \vec{\theta}) \times f_X(p_T)$$

Improved template fit method with Run-3

Real templates Z_y, W_y, W_{yy}, Z_{yy} ✓

Summary

$$T_{\gamma}(E_{\text{iso}}, p_T | \vec{\theta}) \times f_X(p_T)$$

Improved template fit method with Run-3

Real templates $Z\gamma$, $W\gamma$, $W\gamma\gamma$, $Z\gamma\gamma$ ✓

Thank you for listening, any questions?

Back ups

Run-2

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Real template: modified DSCB

$$M_\gamma(E_{\text{iso}}|\vec{\theta}_0) = \begin{cases} \exp\left(-\frac{1}{2} \cdot \left[\frac{E_{\text{iso}} - \mu}{\sigma_i}\right]^2\right), & \text{for } 0 \leq \mp\left(\frac{E_{\text{iso}} - \mu}{\sigma_i}\right) \leq \alpha_i, \\ A_i \cdot \left(B_i \mp \frac{E_{\text{iso}} - \mu}{\sigma_i}\right)^{-n_i}, & \text{for } \alpha_i < \mp\left(\frac{E_{\text{iso}} - \mu}{\sigma_i}\right) \leq \alpha_i + \omega_i, \\ C_i \cdot \left(D_i \mp \frac{E_{\text{iso}} - \mu}{\sigma_i}\right)^{-m_i}, & \text{for } \alpha_i + \omega_i < \mp\left(\frac{E_{\text{iso}} - \mu}{\sigma_i}\right) \leq \infty, \end{cases}$$

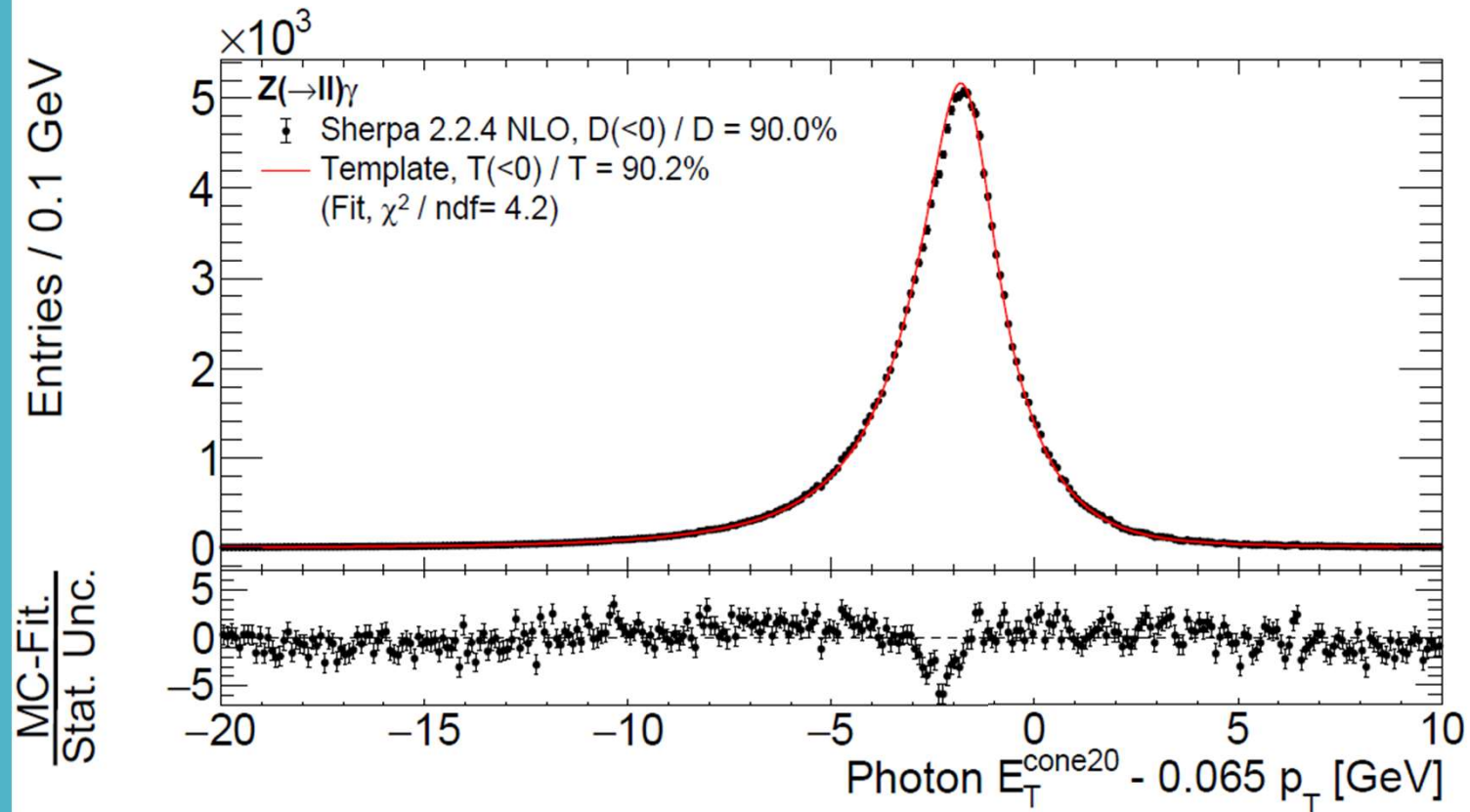
$$A_i = \left(\frac{n_i}{|\alpha_i|}\right)^{n_i} \cdot \exp\left(-\frac{|\alpha_i|^2}{2}\right) \quad \text{and} \quad B_i = \frac{n_i}{|\alpha_i|} - |\alpha_i|,$$

$$D_i = \frac{m_i}{n_i} (B_i + \alpha_i + \omega_i) - (\alpha_i + \omega_i) \quad \text{and} \quad C_i = A_i (B_i + \alpha_i + \omega_i)^{-n_i} (D_i + \alpha_i + \omega_i)^{m_i}$$

Extraction of real and fake templates

From Zy Run-2

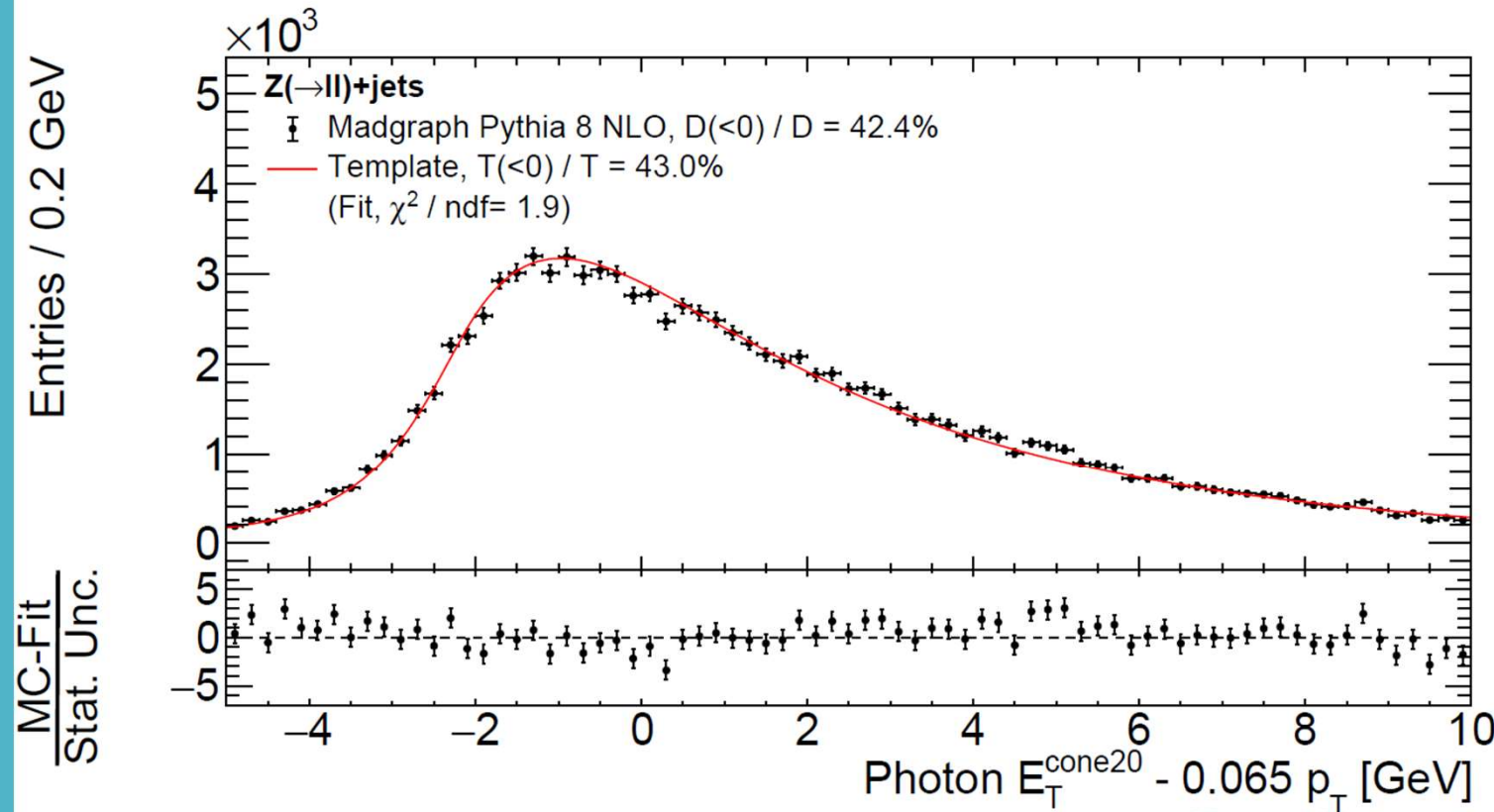
Real photon



Extraction of real and fake templates

From Zy Run-2

Fake photon

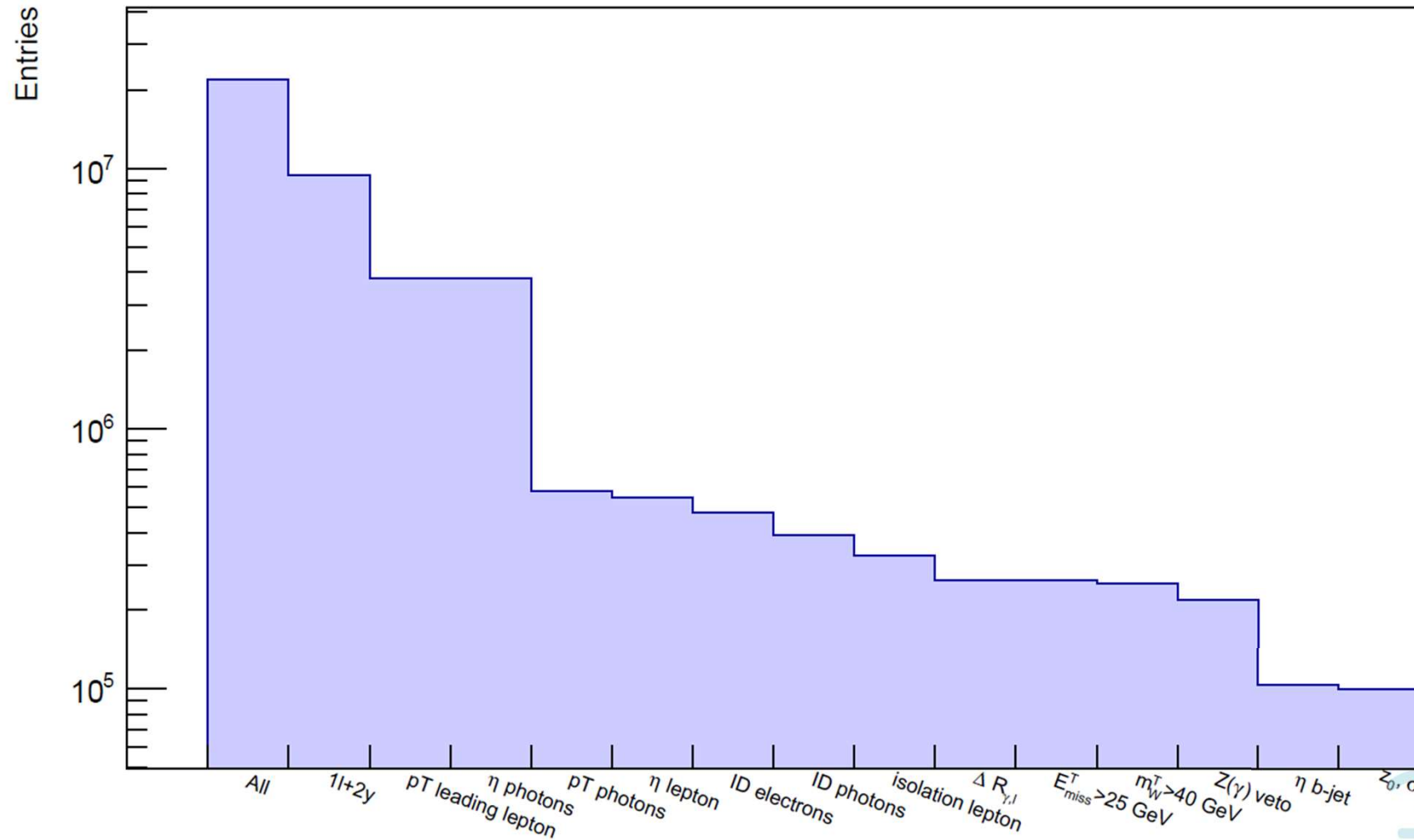


Wy Run-3

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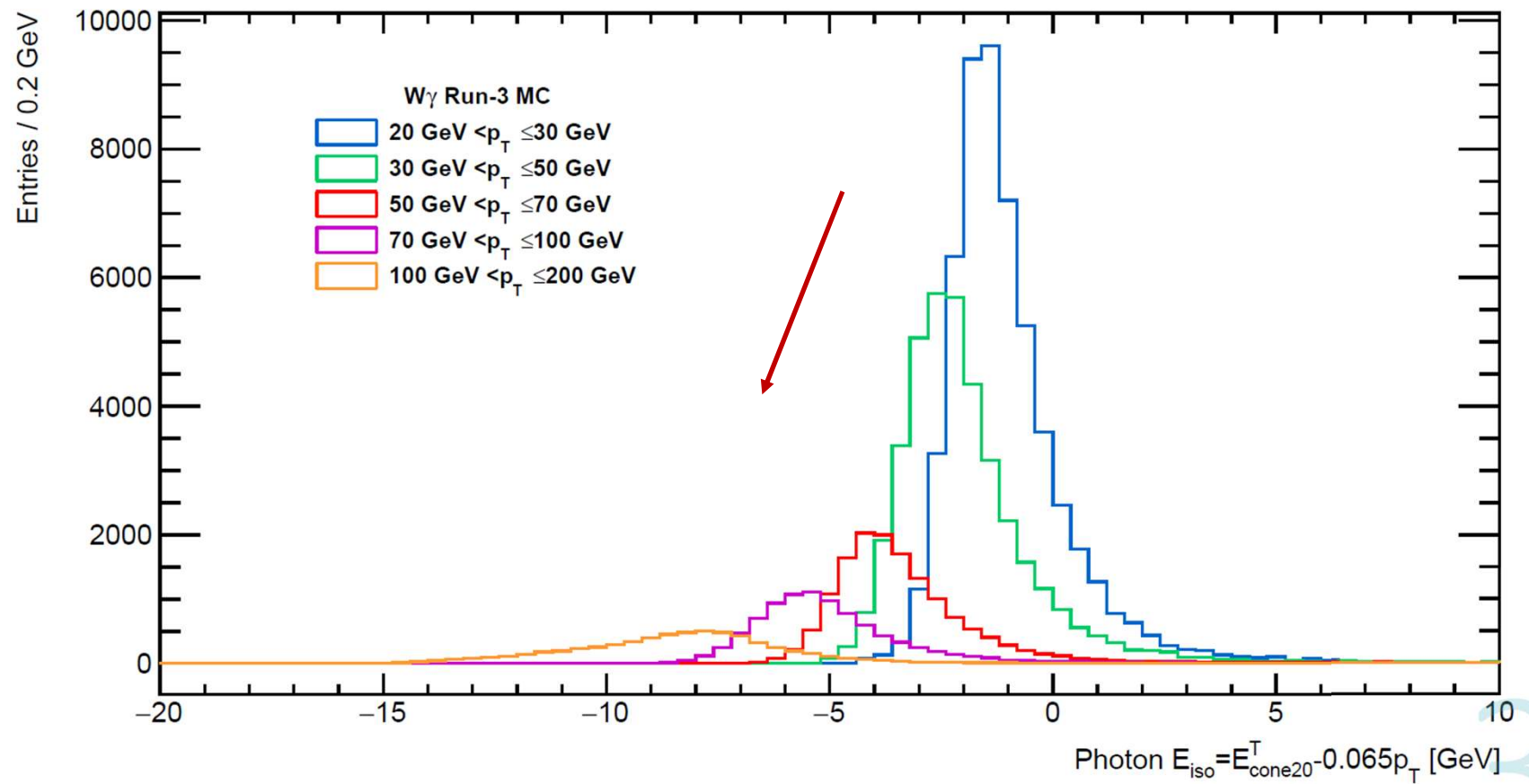
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Cutflow diagram of $W\gamma$ Run-3 MC

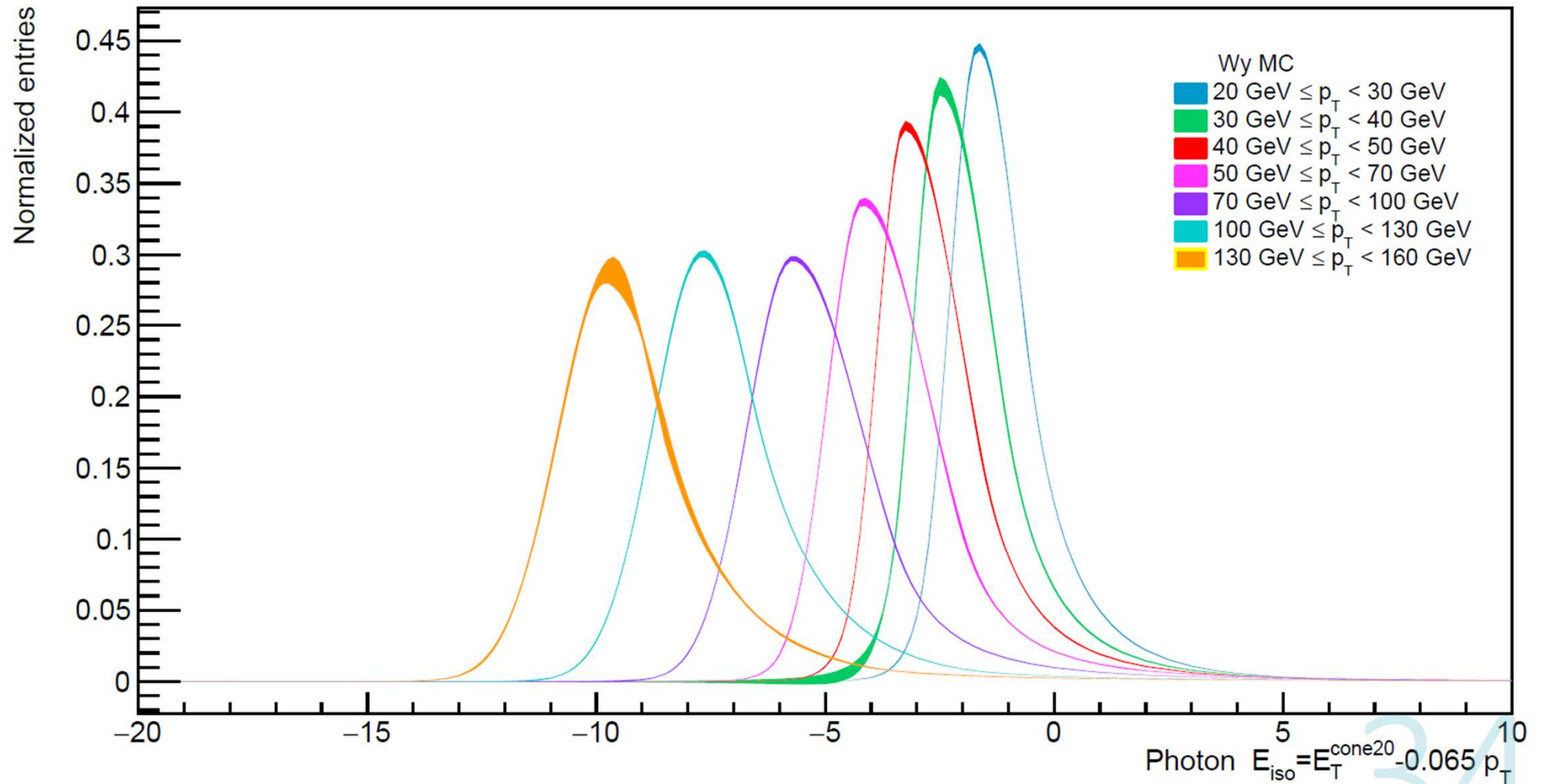


W γ Run-3: Isolation energy

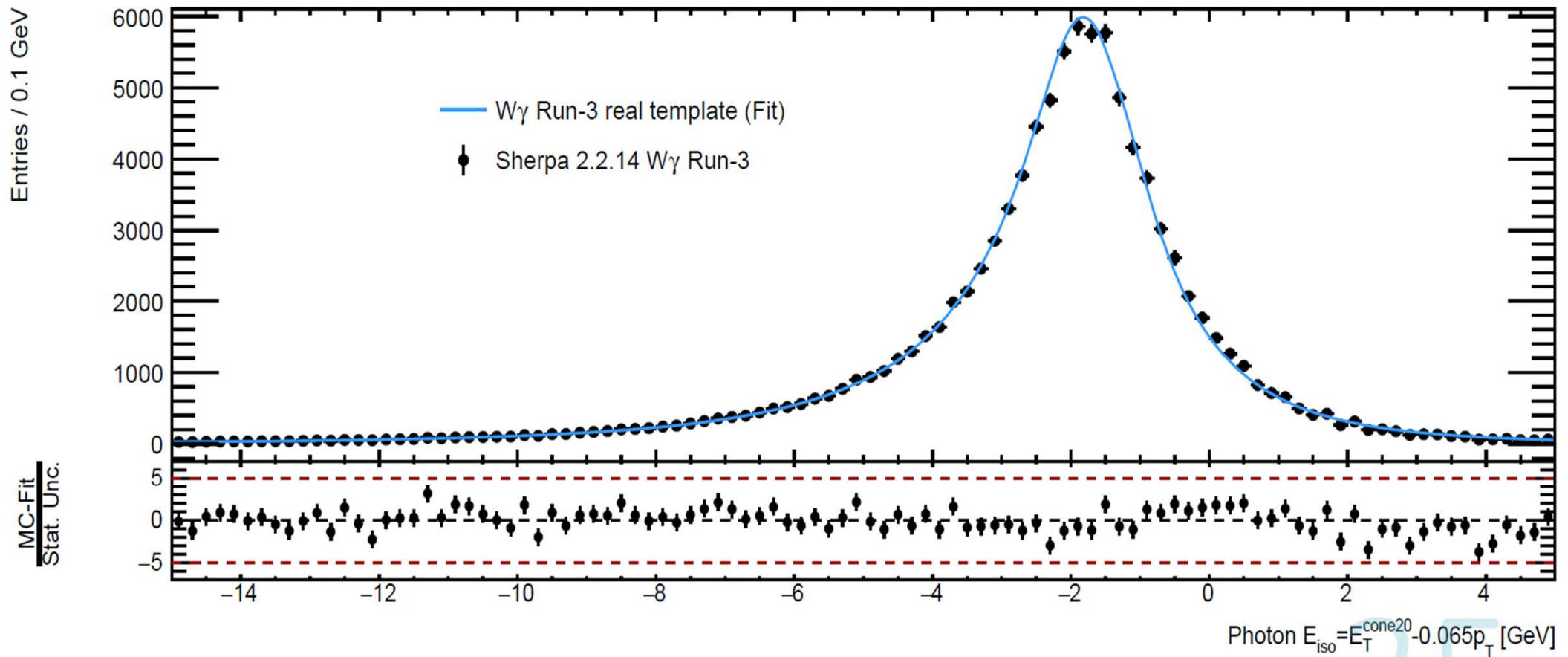
p_T dependence



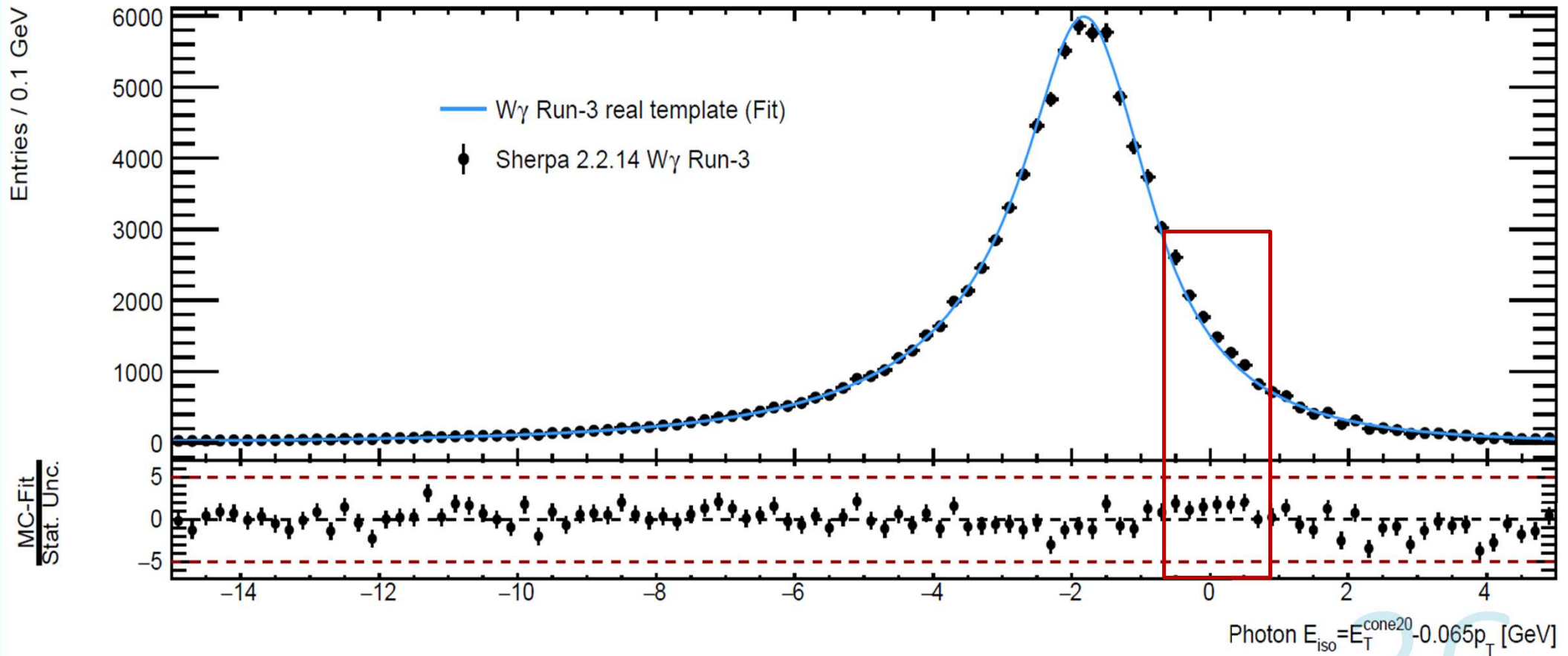
Wy Run-3: 1D fits for p_T intervals



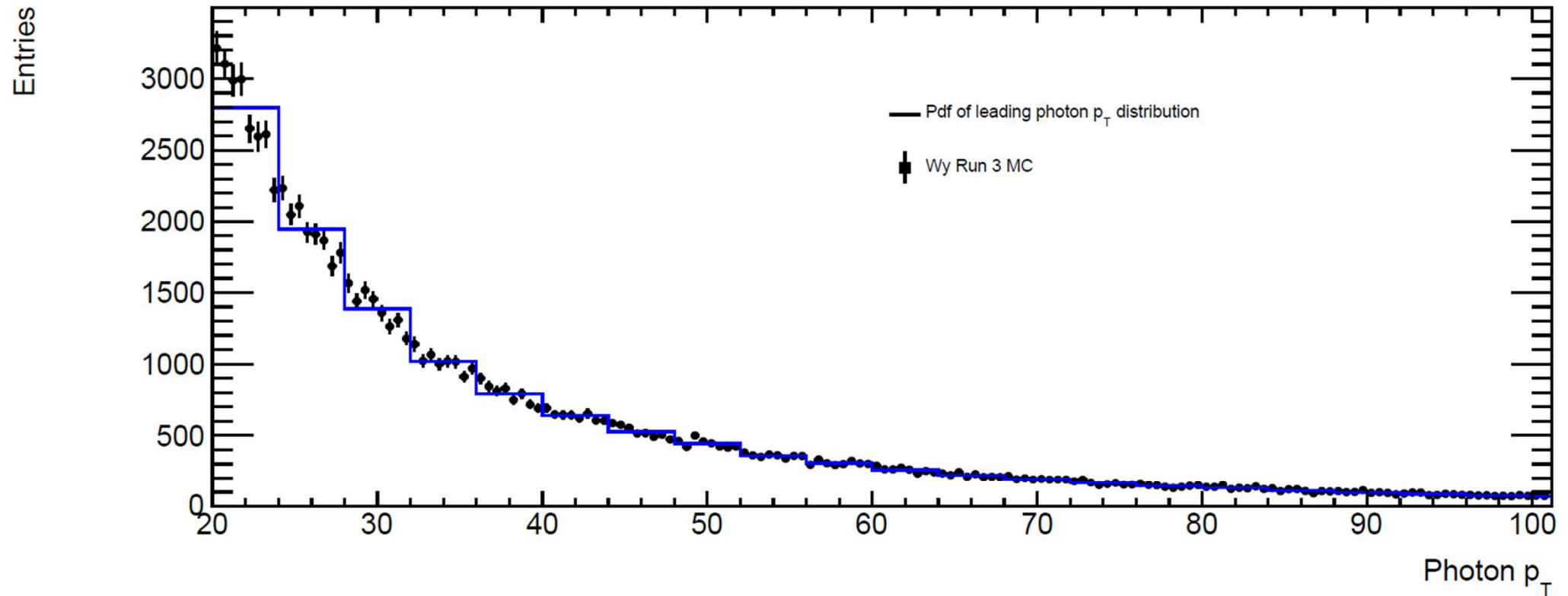
Wy Run-3: Real template extraction



W γ Run-3: Real template extraction

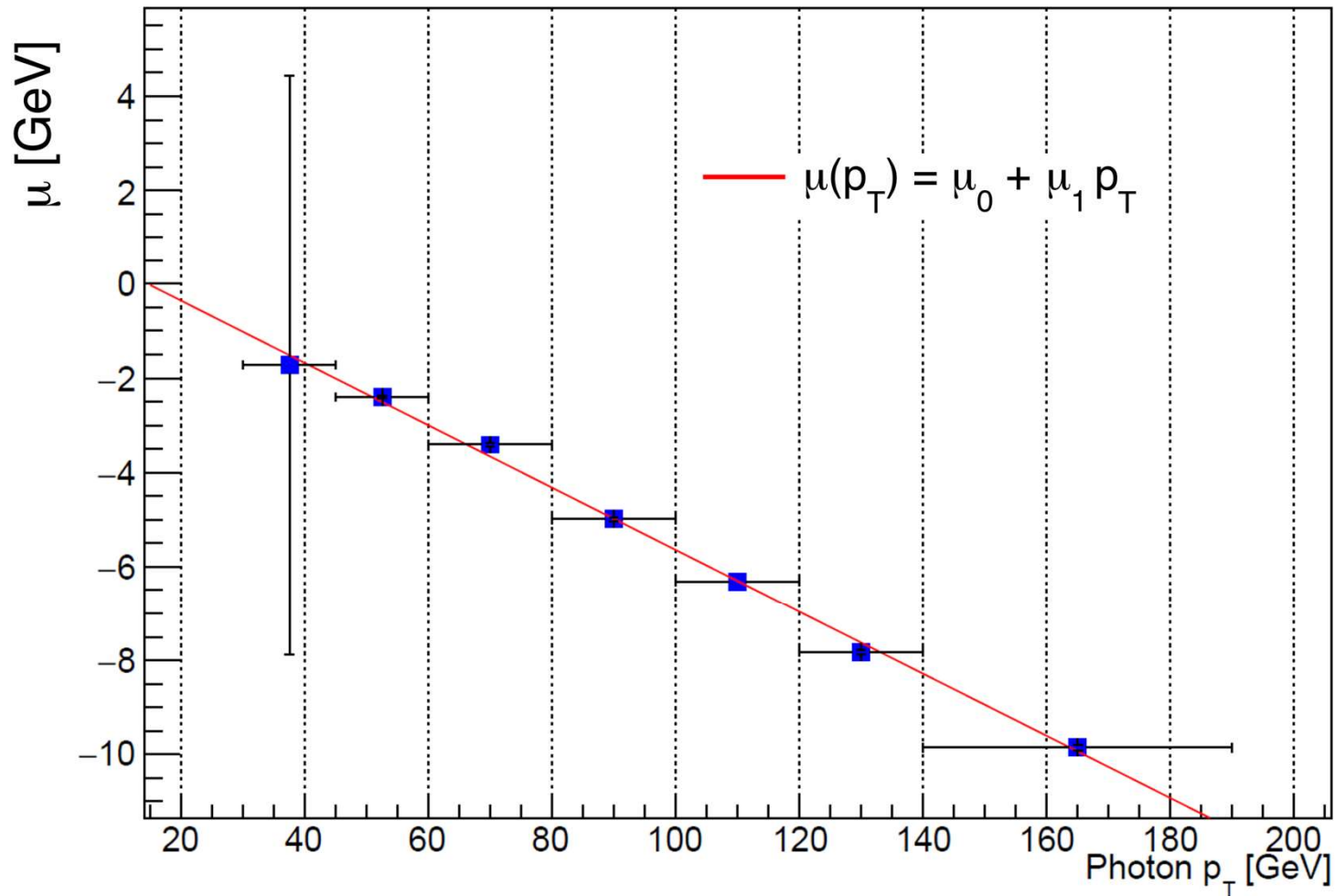


Wy Run-3: PT pdf distribution



Wy Run-3: p_T dependence of parameter μ

An example: $\mu(p_T) = \mu_0 + \mu_1 \cdot p_T$

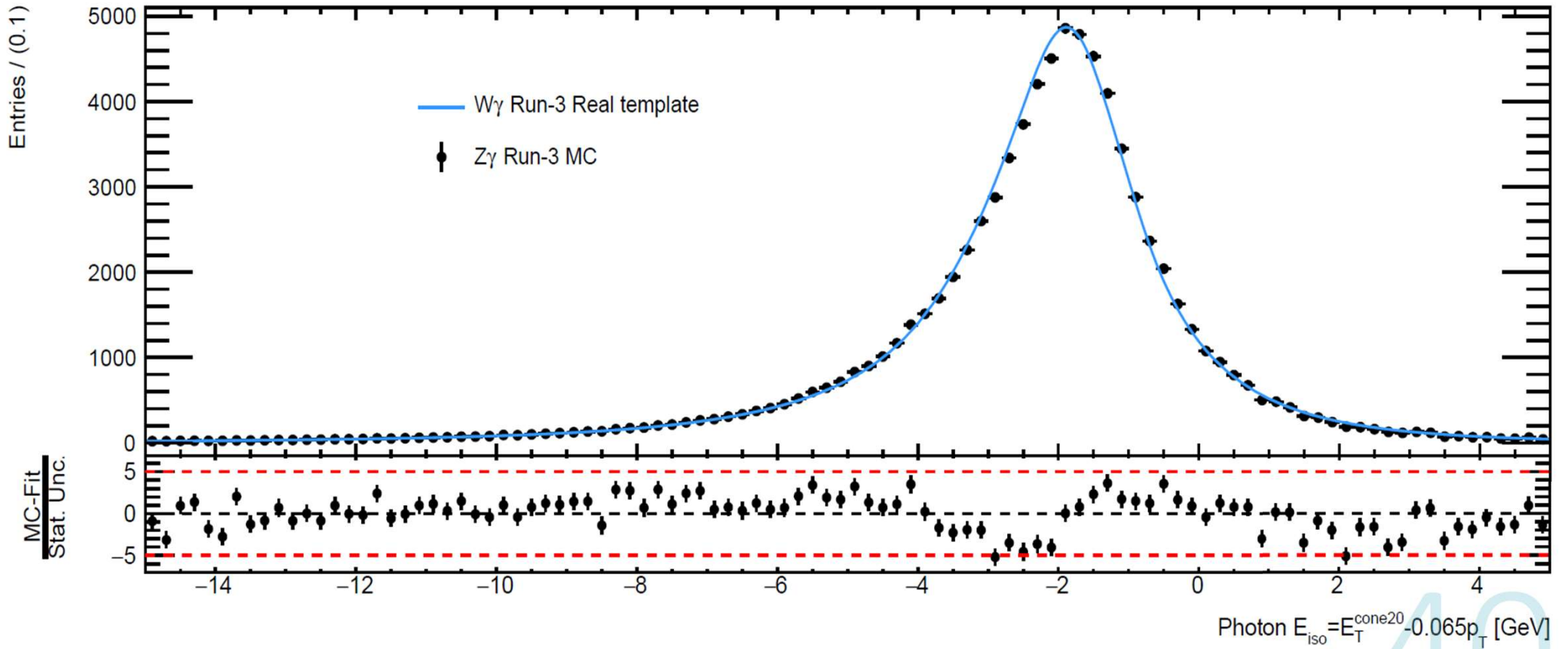


Wy template \rightarrow Zy, Wyy, Zyy

W γ template



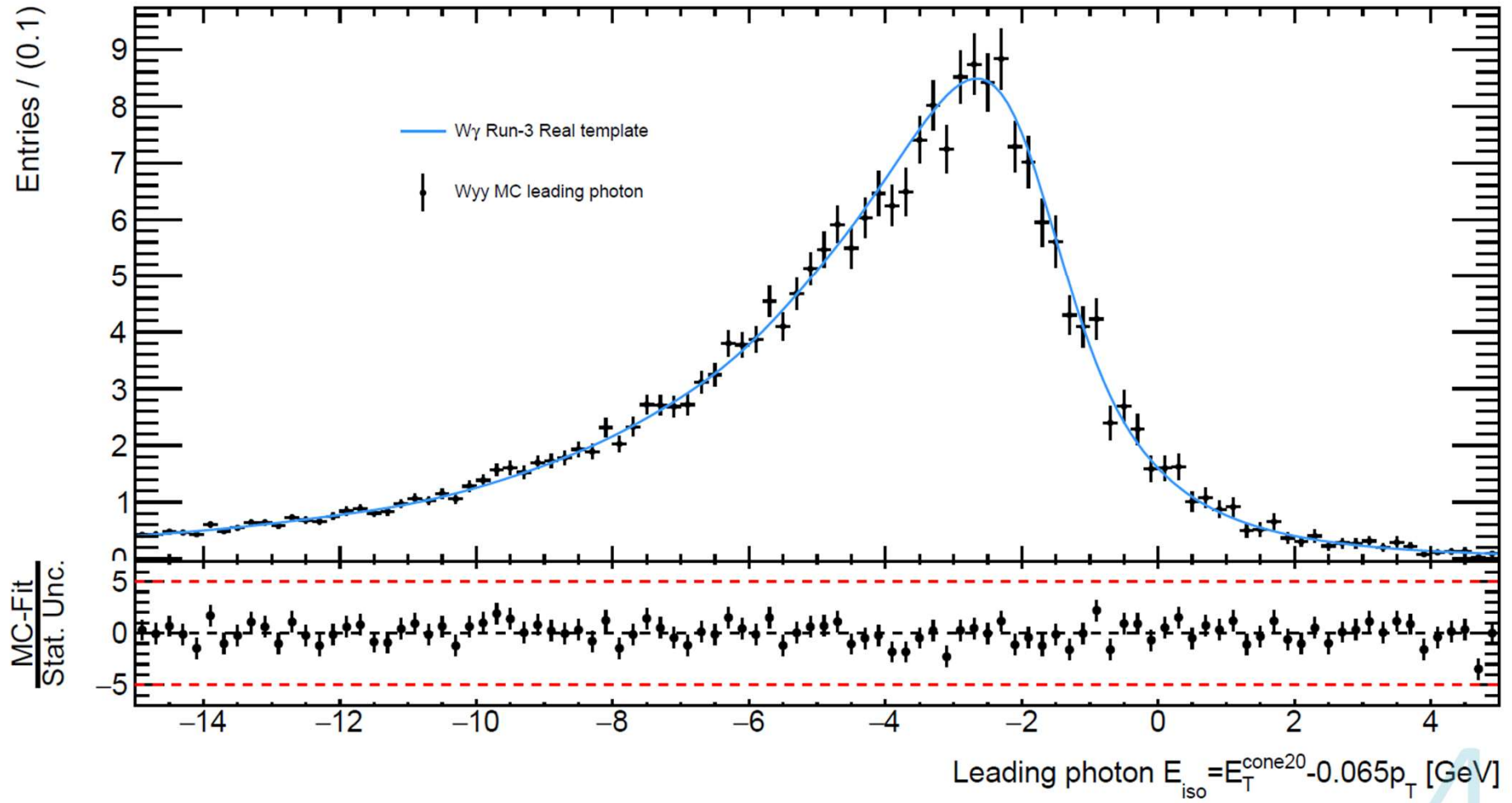
Z γ



W γ template



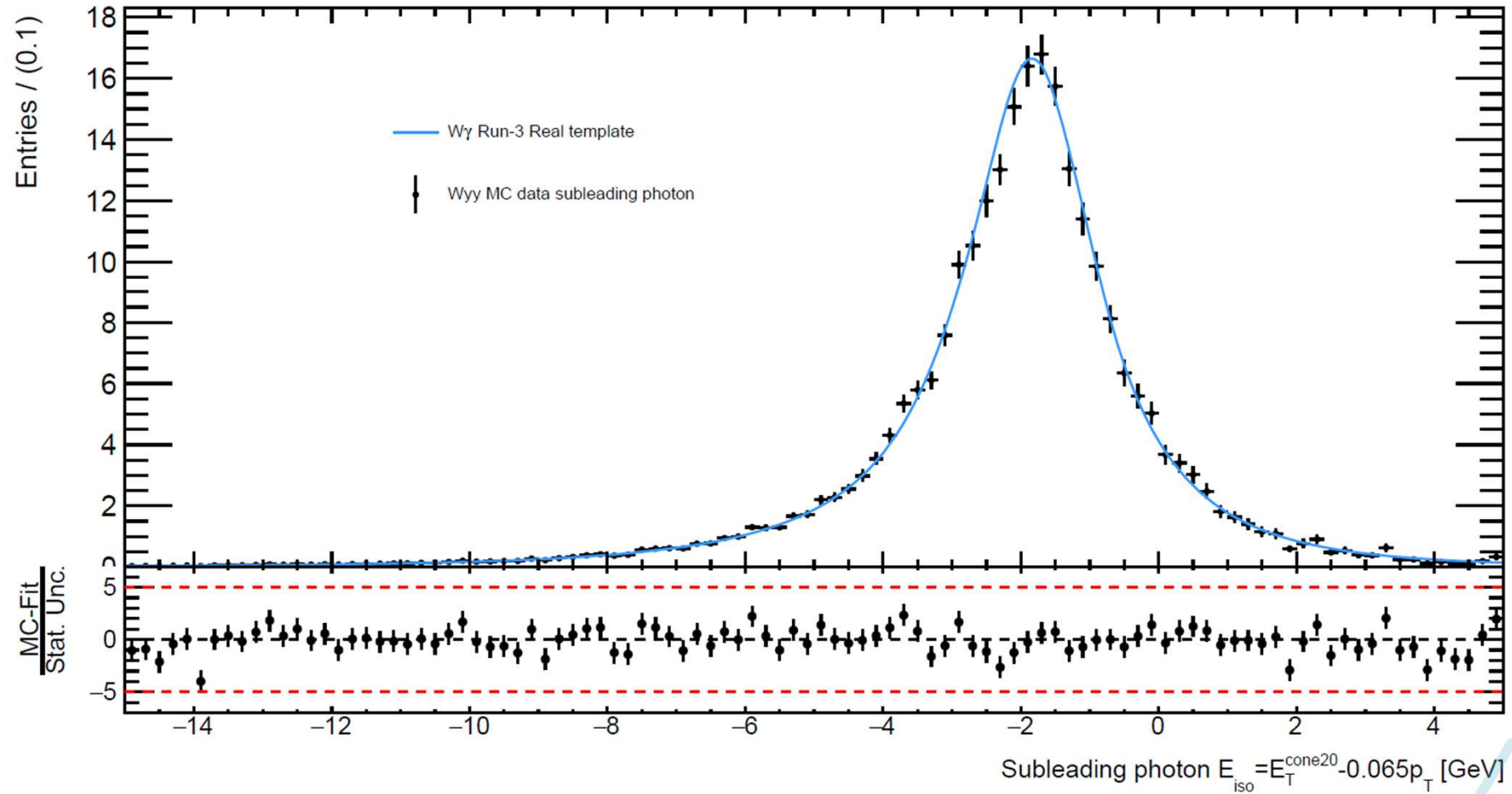
W $\gamma\gamma$ (leading)



Wy template



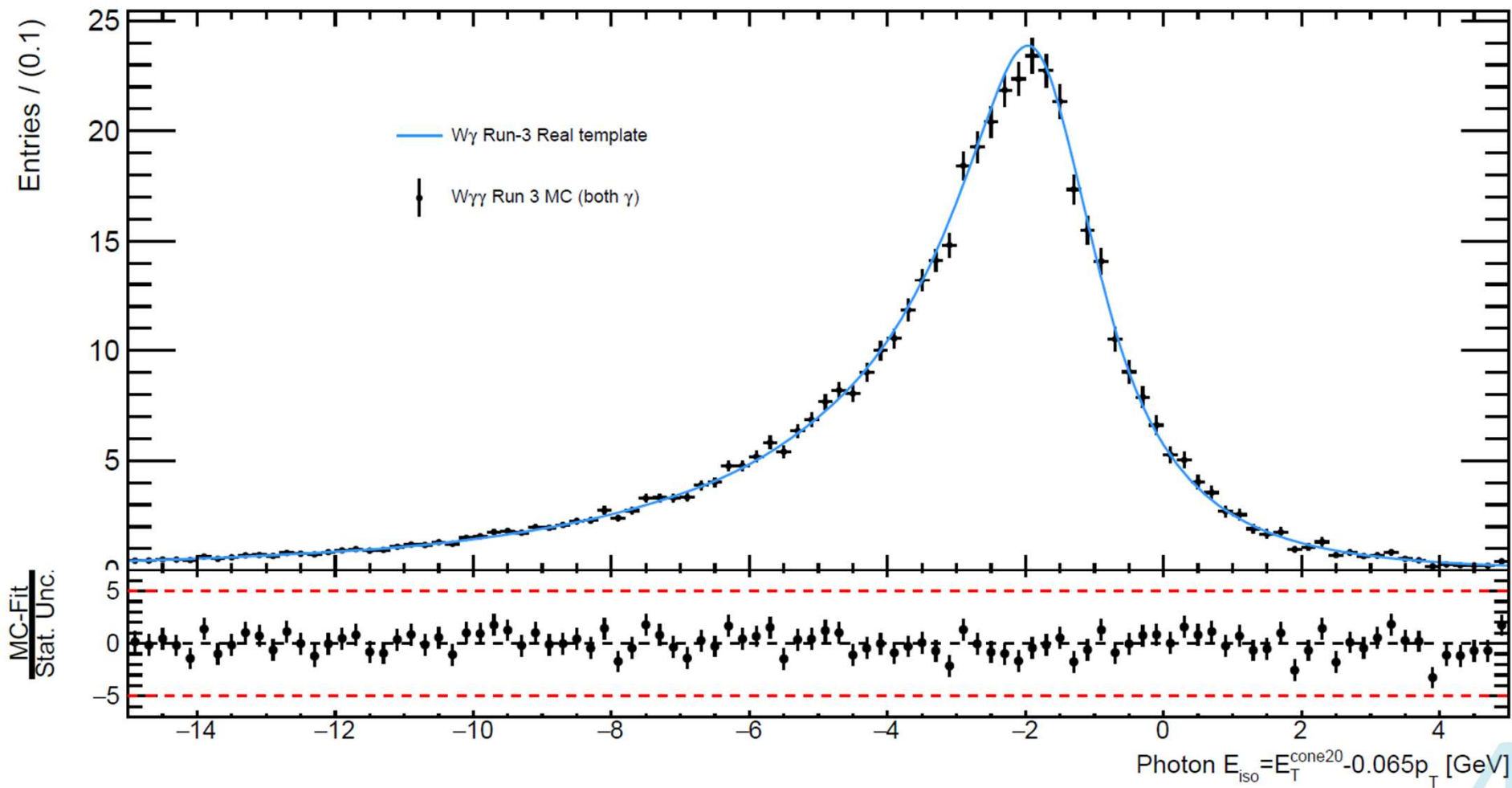
Wyy (subleading)



W γ template



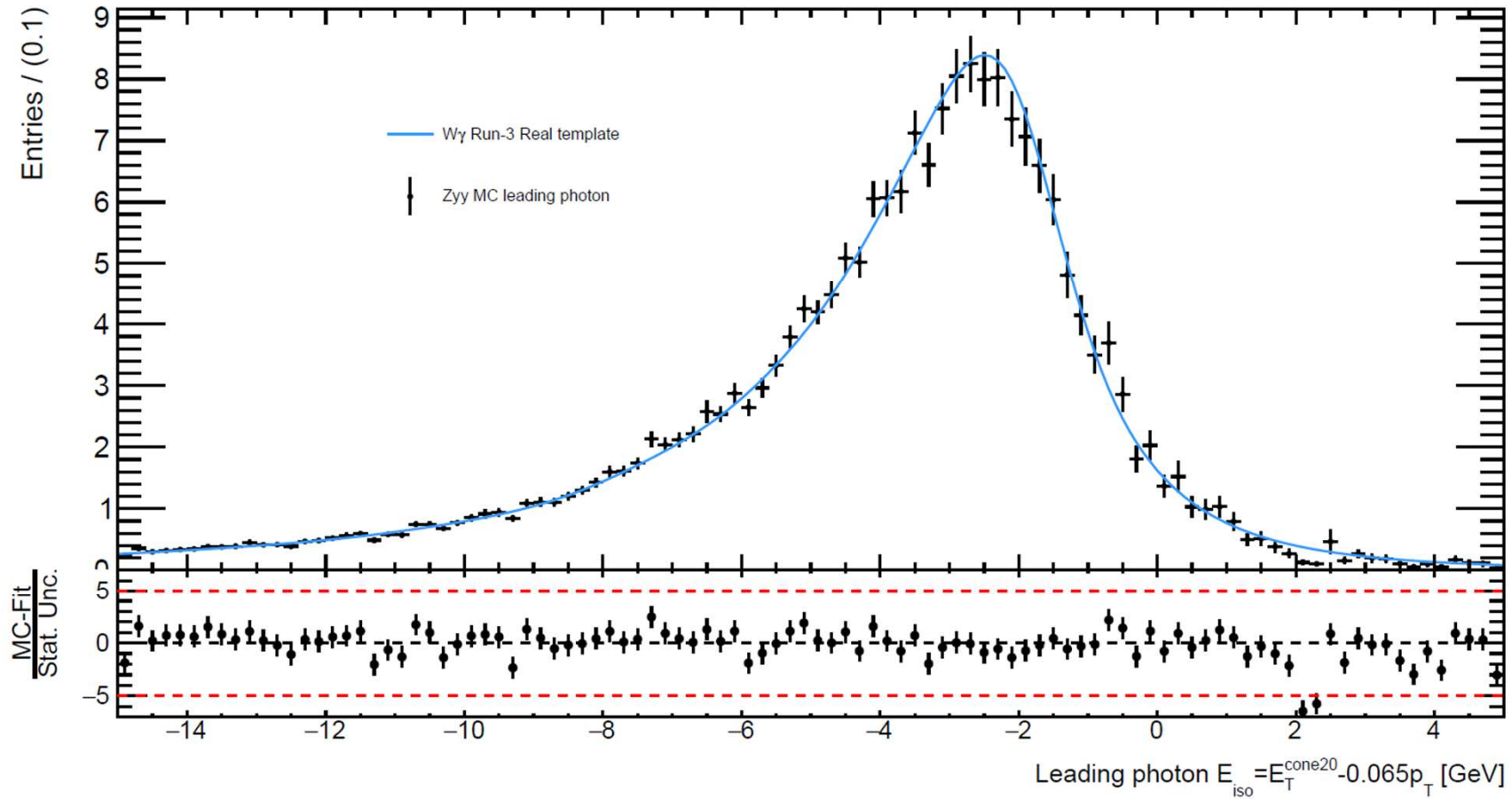
W $\gamma\gamma$ (both γ)



W γ template



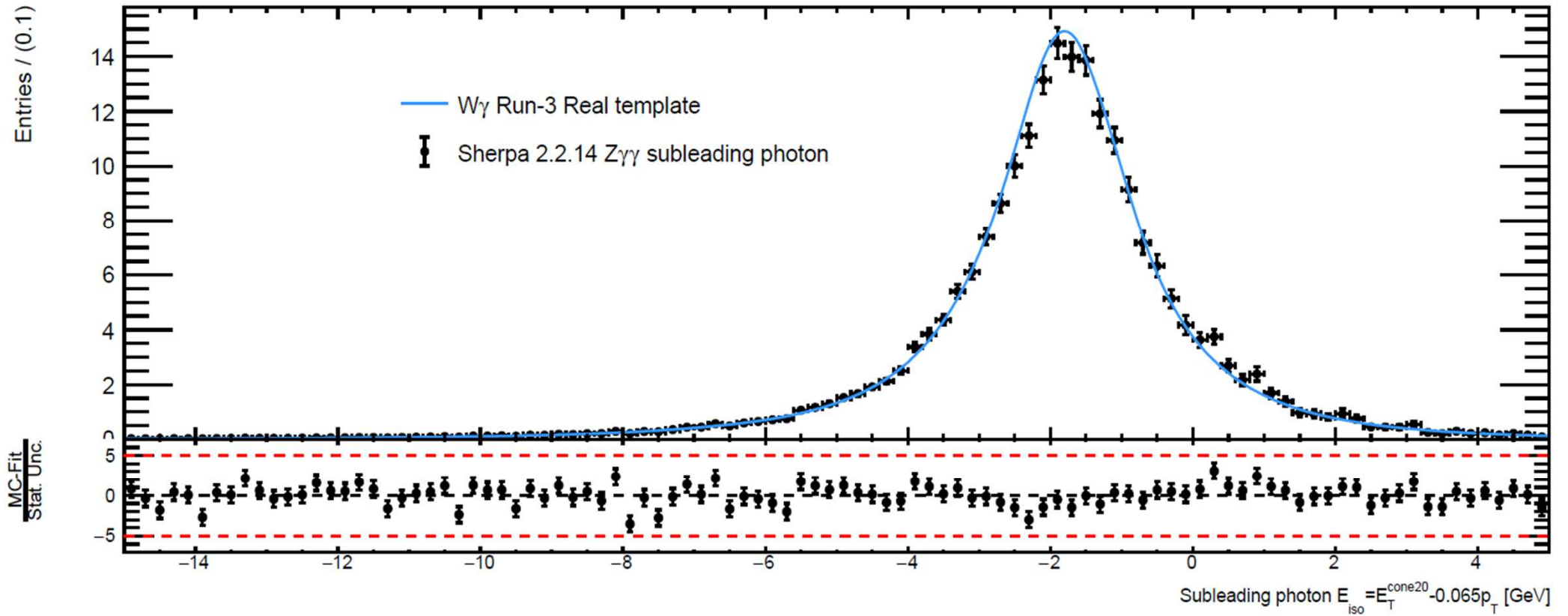
Z $\gamma\gamma$ (leading)



W γ template



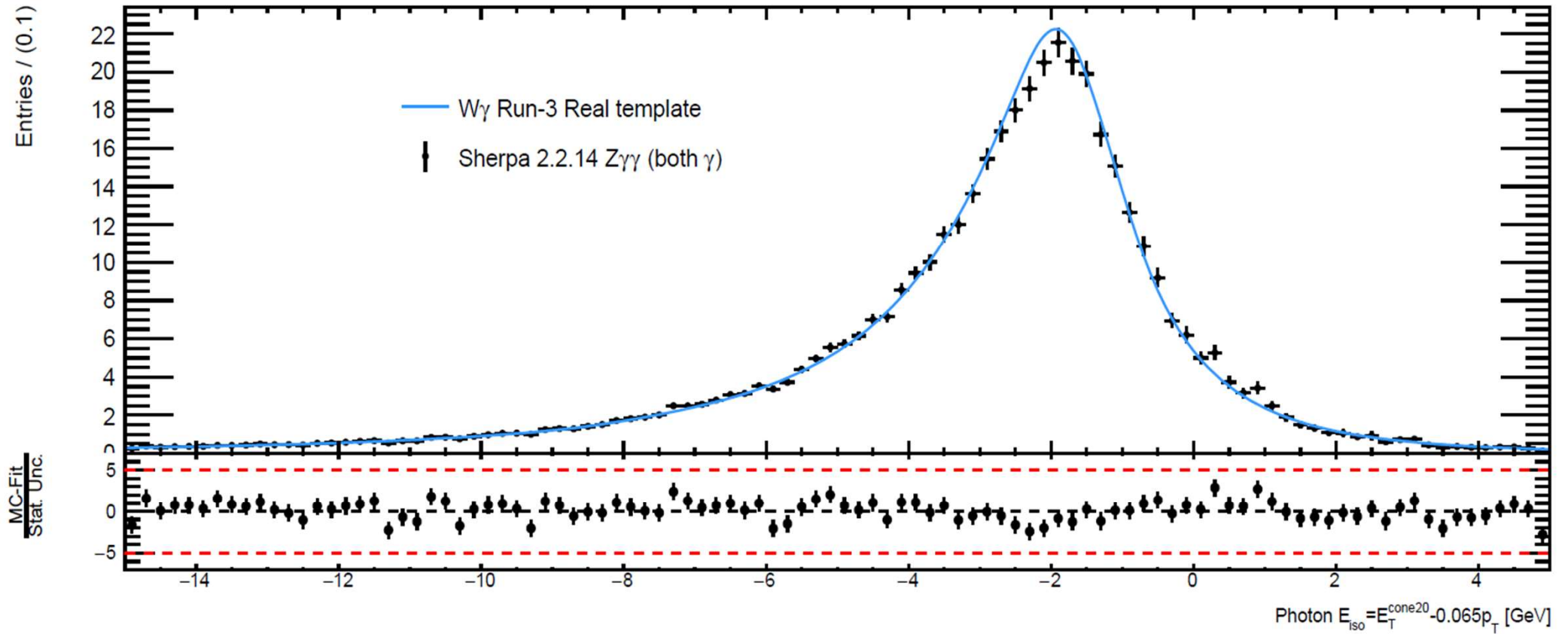
Z $\gamma\gamma$ (subleading)



W γ template



Zγγ (both photons)

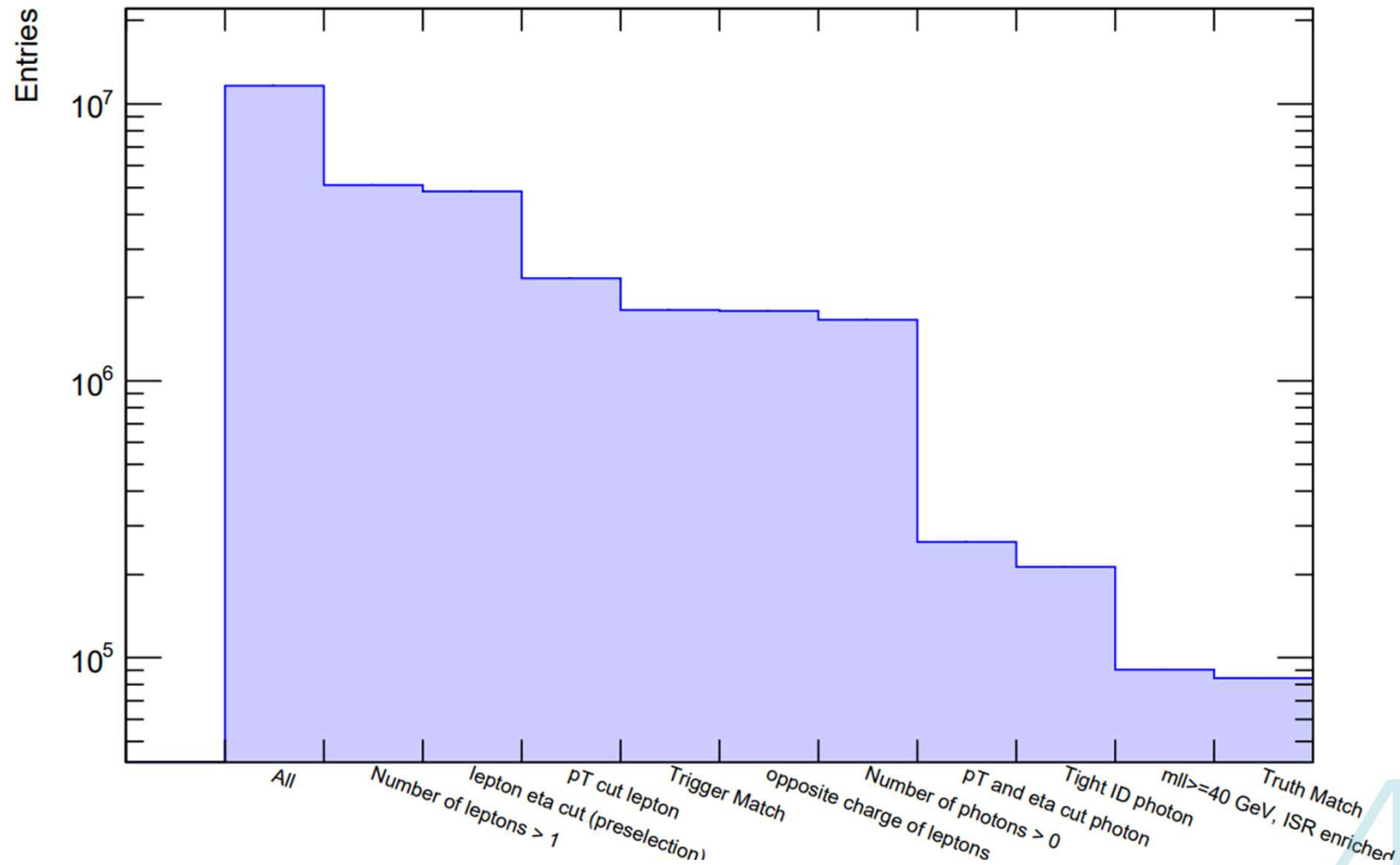


Zy Run-3

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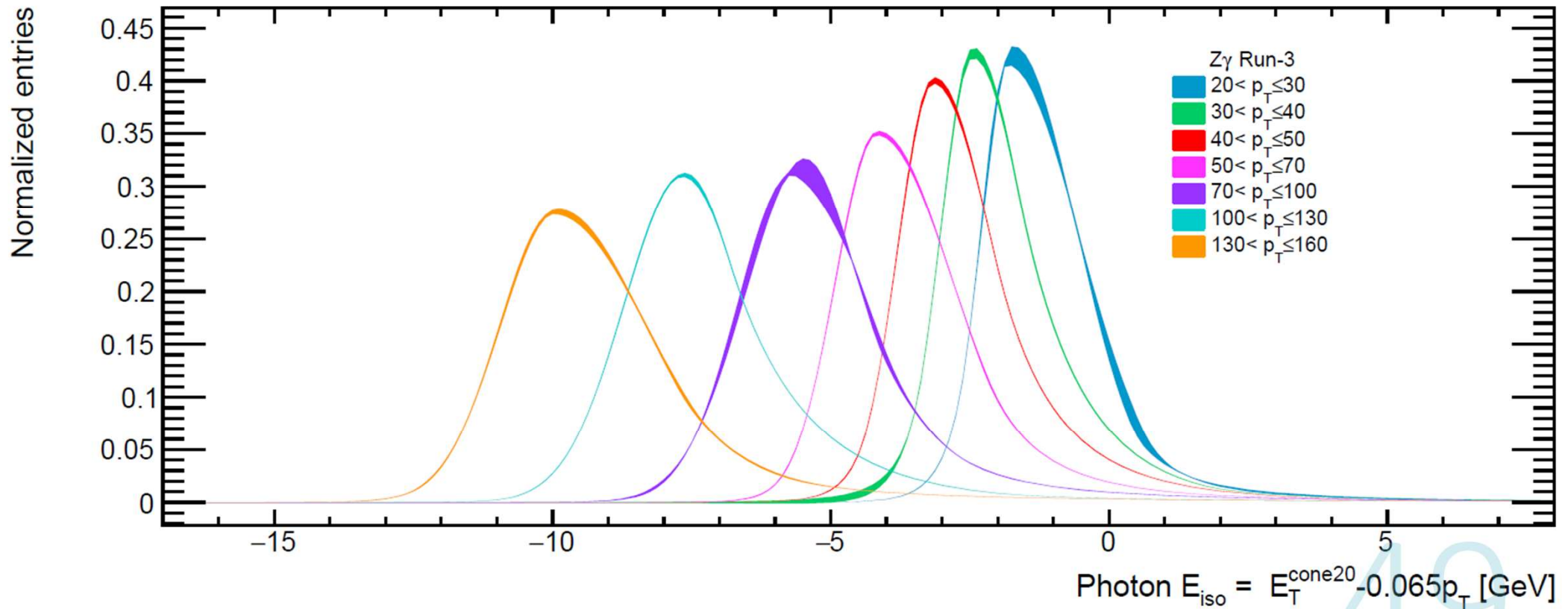
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Cutflow diagram of Zy Run-3 MC

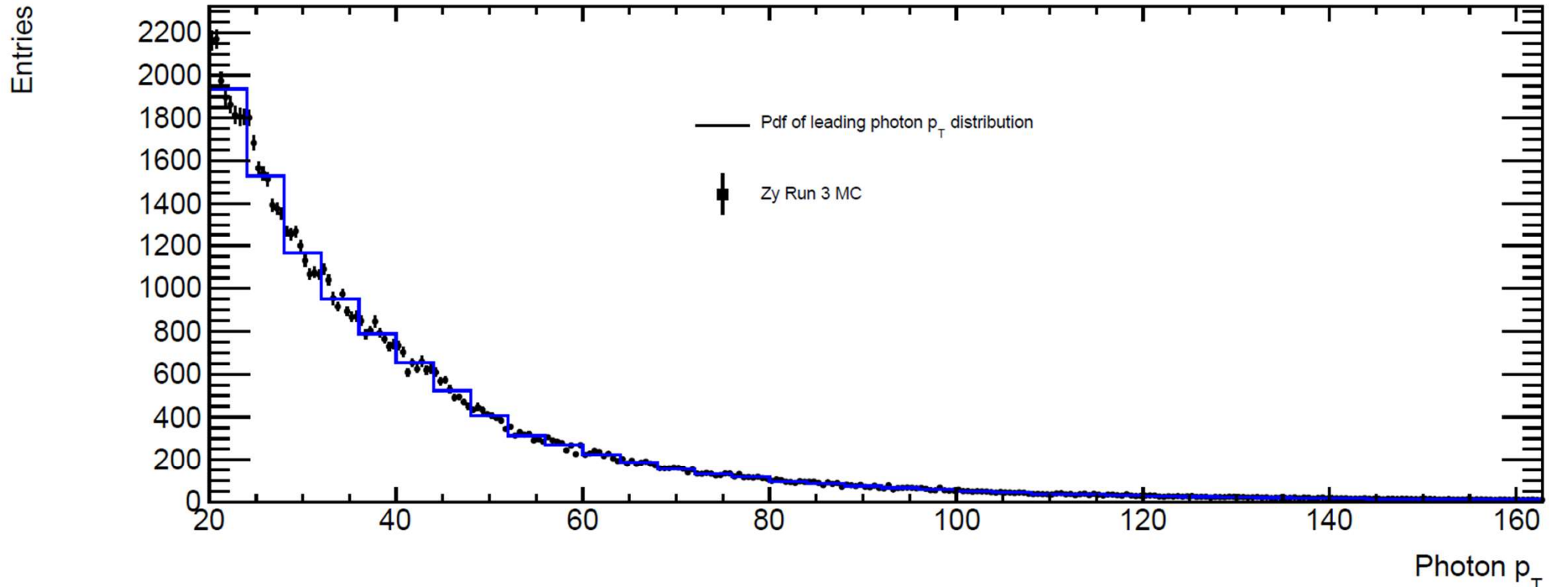


Wy Run-3: 1D fits for p_T intervals

p_T dependence



Zy Run-3: PT pdf distribution

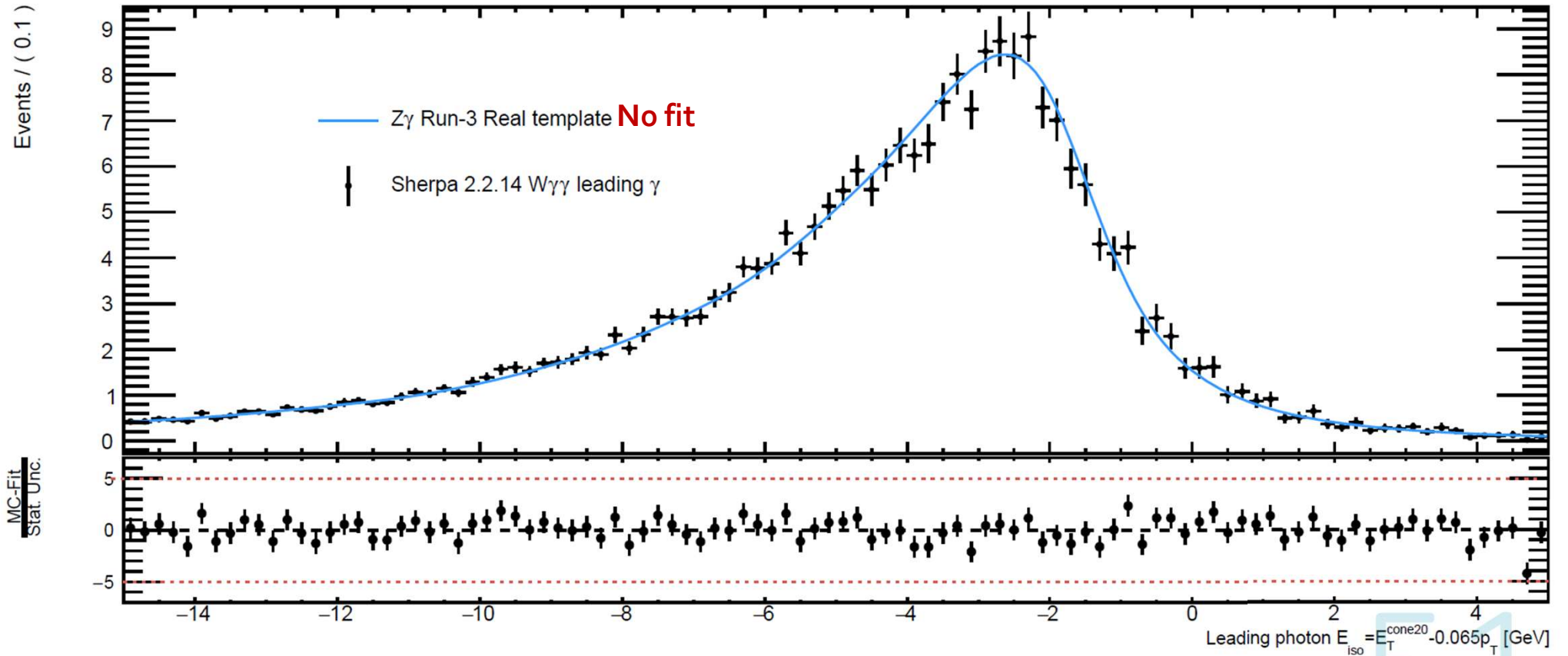


Z γ template



W $\gamma\gamma$ (leading γ)

$$T_\gamma(E_{\text{iso}}, p_T | \vec{\theta}) \times f_{W\gamma\gamma}(p_T)$$

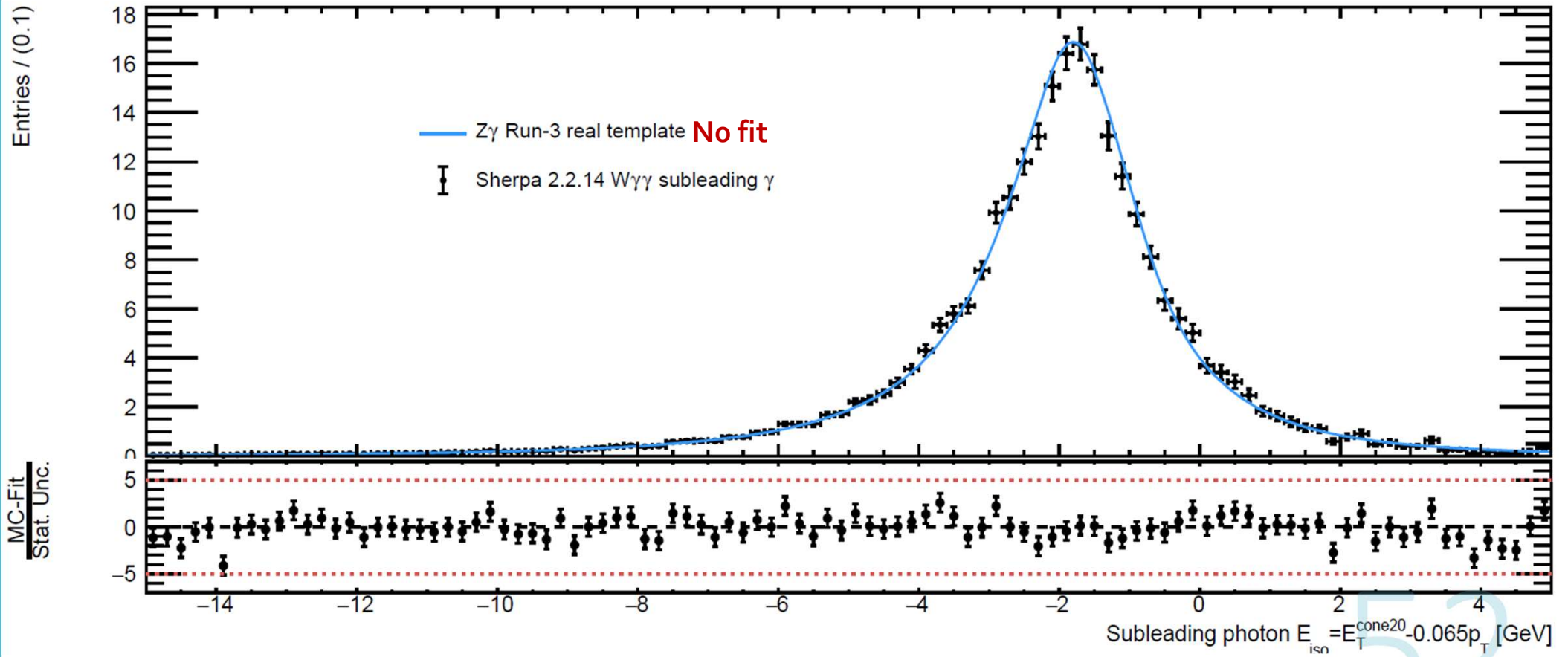


Z γ template



W $\gamma\gamma$ (subleading γ)

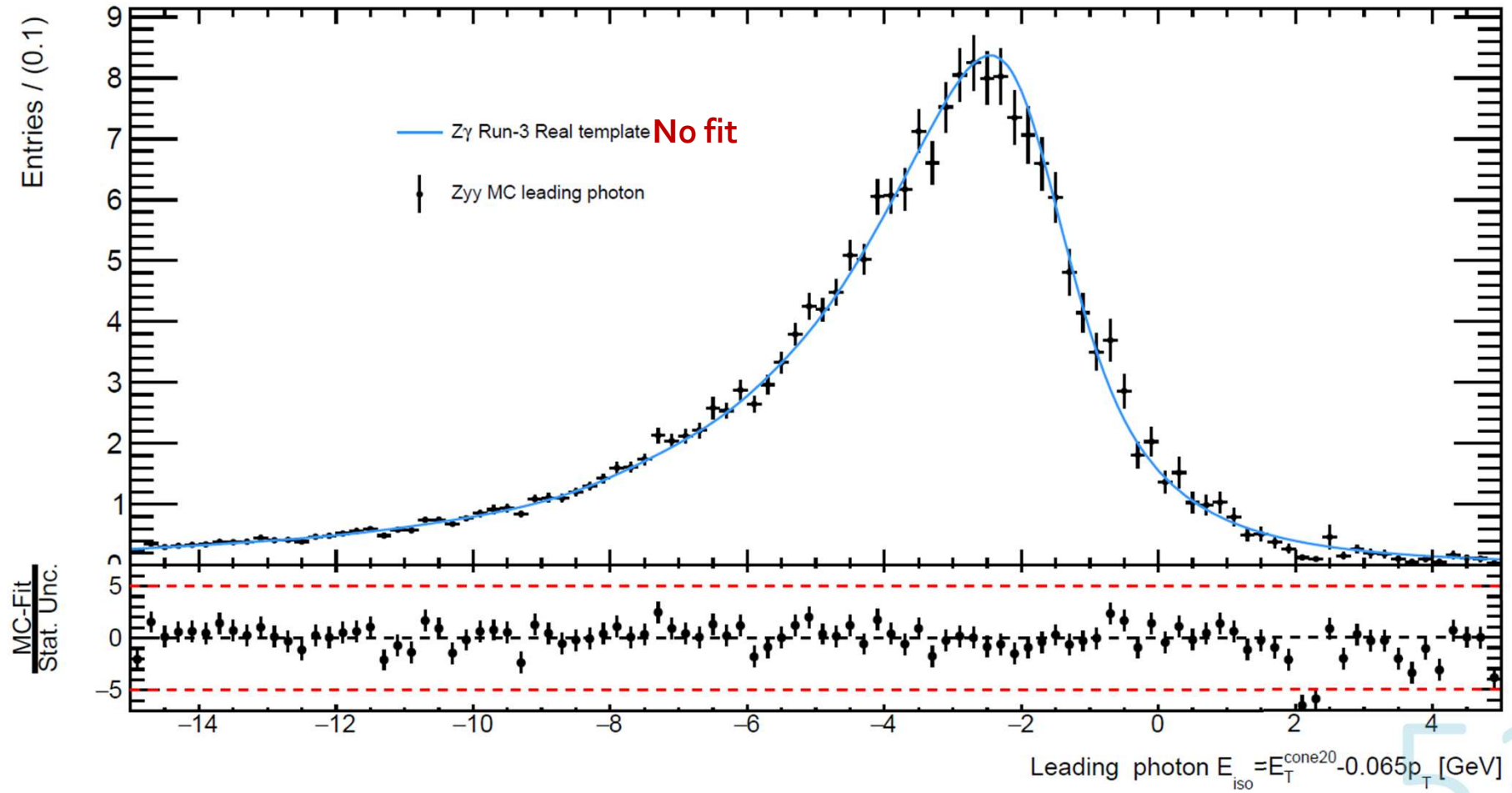
$$T_\gamma(E_{\text{iso}}, p_T | \vec{\theta}) \times f_{W\gamma\gamma}(p_T)$$



Zy template



Zyy (leading y)



Z γ template



Z $\gamma\gamma$ (subleading γ)

