# Toy Monte Carlo: Dimuon Decay

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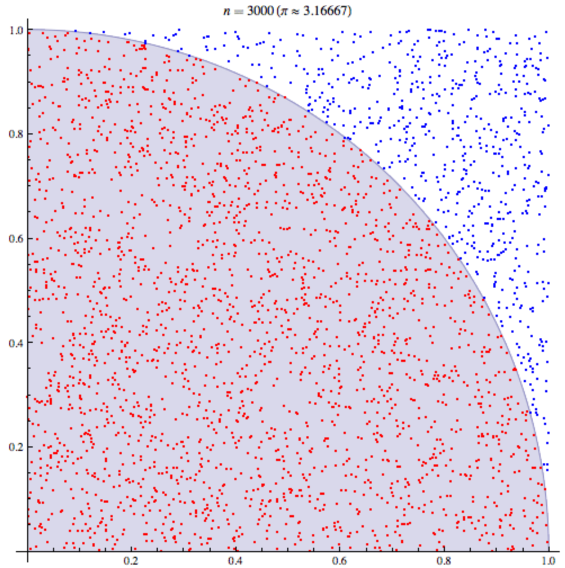
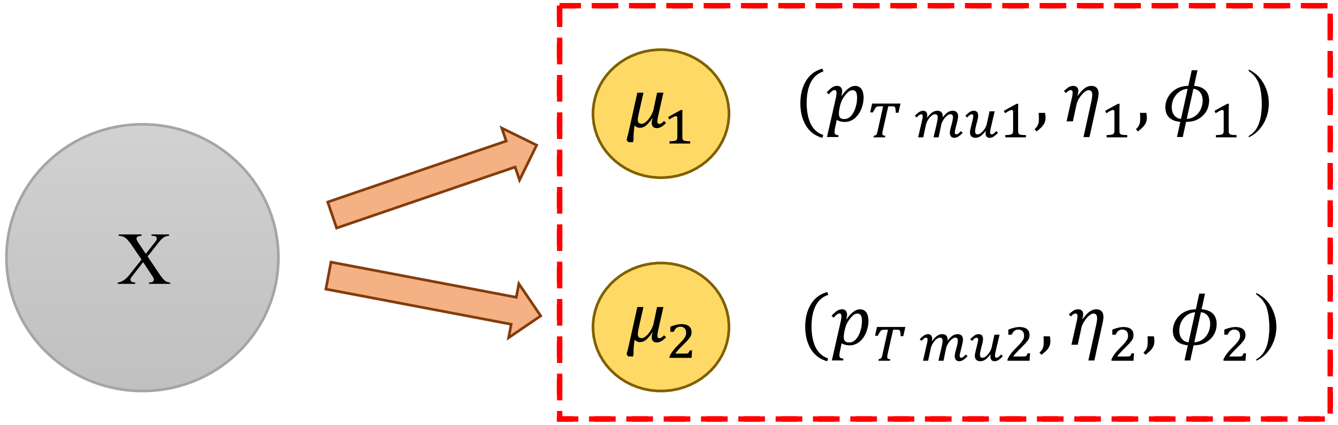
# Toy Monte Carlo

- Monte Carlo method : a computational algorithm use randomness to solve problems that might be deterministic in principle.
- We use it to simulate the process during particle scattering from the high energy collision statistically.
- I analysis the data (analogy with the process of muons decay from specific particle after the collision) constructed by some random variables obeys some particular distributions.



# Toy Monte Carlo

- Here, a "event" is defined by each unknown (for me) mass particle decays into two muons.




Dimuon pairs

- Goals

Goals

Find out the unknown mass particle

Plot $p_T$ distribution of pure signal

# Toy Monte Carlo : Steps

Reconstruct Mass distribution

Find out the unknown mass particle

Fitting

Get the mass window

## Sideband Subtraction

Draw $p_T$ distribution of total signal (under the mass window) & background (outside the mass window)

## Fitting Method

Different $p_T$ ranges: Reconstruct Mass distribution

Fitting

$p_T$ distribution of pure signal

# Reconstruct Mass Distribution

- Conservation of Relativistic Energy

$$E_{total} = \sqrt{(p_{z\,mu1} sinh\,\eta_1\,)^2 + p_{T\,mu1}{}^2 + m_{mu1}{}^2} + \sqrt{(p_{z\,mu2} sinh\,\eta_2\,)^2 + p_{T\,mu2}{}^2 + m_{mu2}{}^2}$$

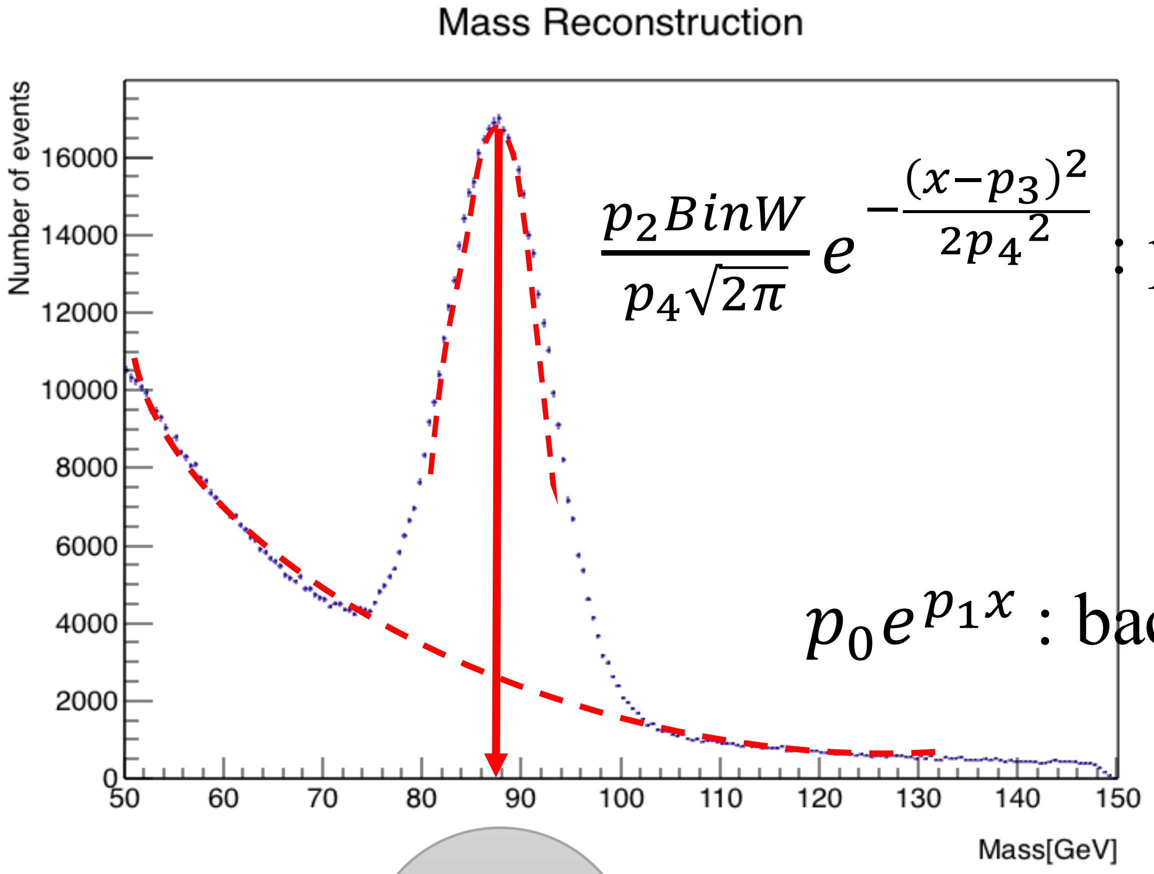
- Conservation of Relativistic Momentum

$$P_{total} = \sqrt{P_x{}^2 + P_y{}^2 + P_z{}^2} \text{ with } \begin{cases} P_x = p_{T\,mu1} cos\phi_1 + p_{T\,mu2} cos\phi_2 \\ P_y = p_{T\,mu1} sin\phi_1 + p_{T\,mu2} sin\phi_2 \\ P_z = p_{T\,mu1} sinh\,\eta_1 + p_{T\,mu2} sinh\,\eta_2 \end{cases}$$

- Conservation of Relativistic Momentum

$$\mathrm{m} = \sqrt{E_{total}{}^2 - P_{total}{}^2}$$

# The Results of Mass Distribution



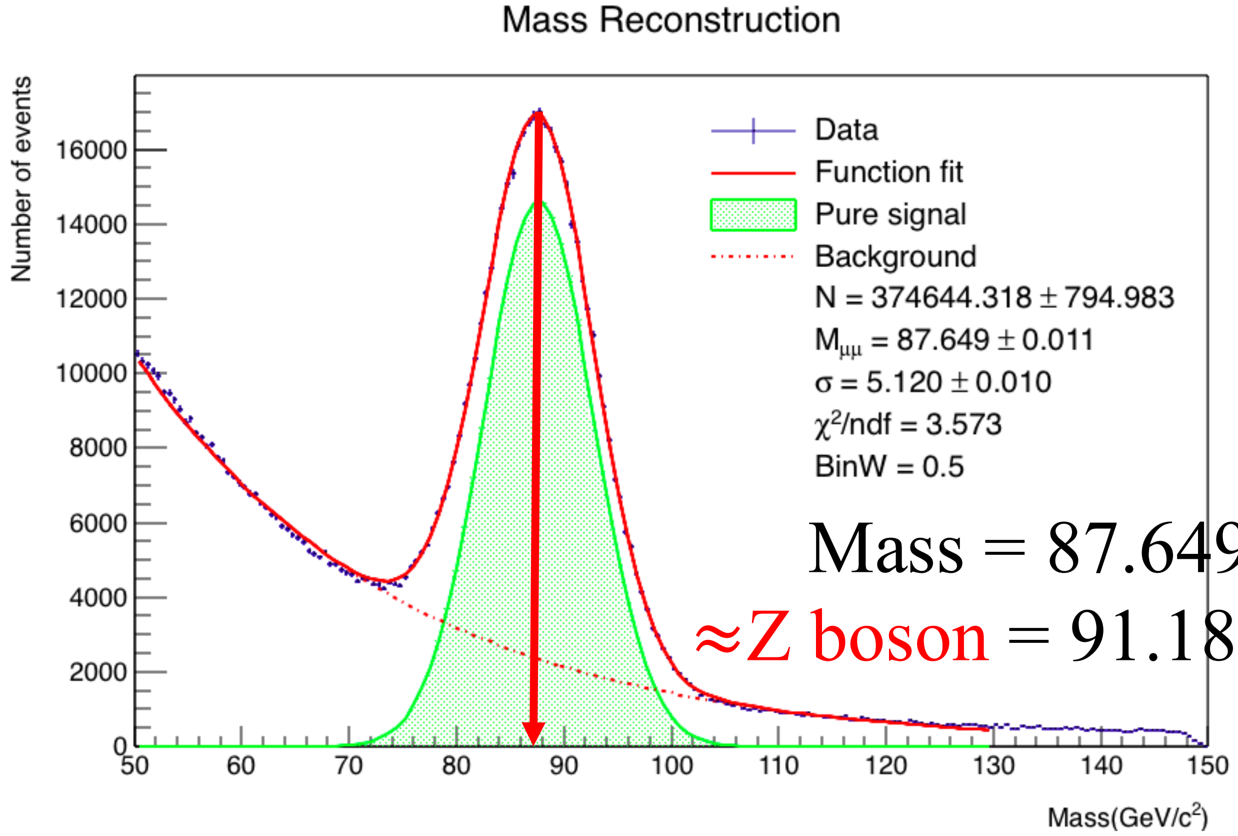

$$\frac{p_2 BinW}{p_4\sqrt{2\pi}} e^{-\frac{(x-p_3)^2}{2{p_4}^2}}$$ : pure signal

$p_0 e^{p_1 x}$ : background

X

M = ?

# Fitting




Mass = $87.649 \pm 0.011 \mathrm{GeV}/c^2$

≈Z boson = $91.1876 \pm 0.0021$ GeV/$c^2$

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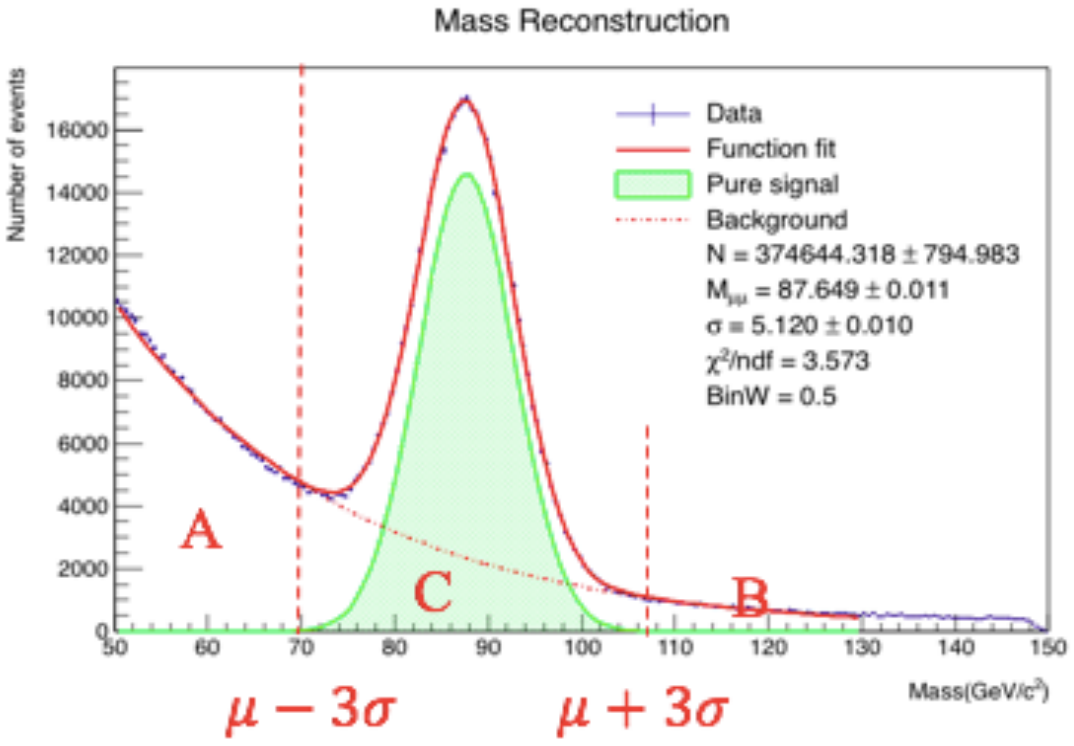
FCN=553.867 FROM MIGRAD     STATUS=CONVERGED      626 CALLS       627 TOTAL
                     EDM=1.01432e-07     STRATEGY= 1       ERROR MATRIX ACCURATE
 EXT PARAMETER                                    STEP         FIRST
 NO.   NAME        VALUE            ERROR          SIZE       DERIVATIVE
  1  p0            7.66784e+04   4.81169e+02   3.21517e-05  -1.18620e-01
  2  p1           -3.98058e-02   9.14167e-05   1.27720e-06  -3.07439e+00
  3  p2            3.74644e+05   7.94983e+02   1.65118e-05   3.65926e-03
  4  p3            8.76486e+01   1.10984e-02   1.29390e-05   2.04788e-01
  5  p4            5.12029e+00   1.01907e-02   5.96840e-06   4.58318e-01
```

# Sideband Subtraction

- Draw the $p_T$ distribution of pure signal from $p_T$ distribution of signal + background and background.

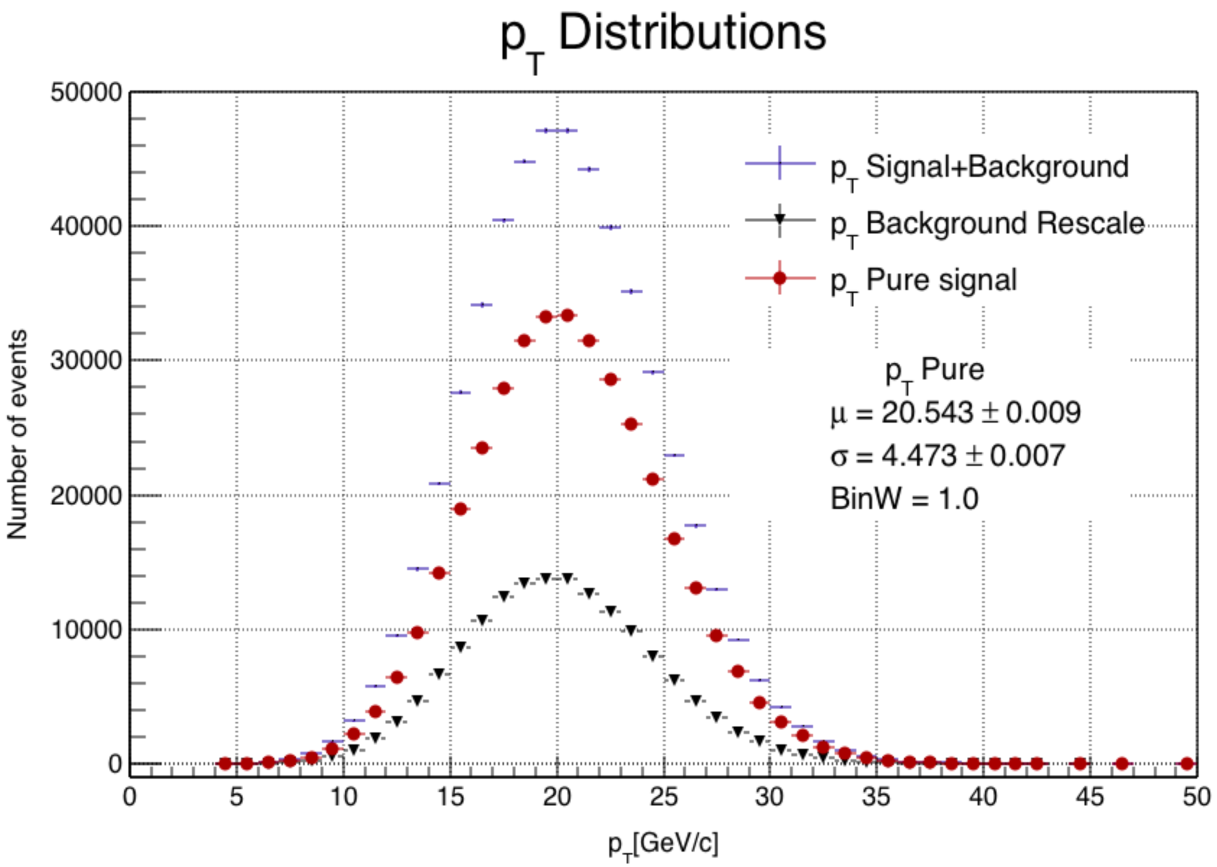



$$p_T\_\text{pure} = p_T\_\text{signal} - p_T\_\text{BG\_normalized}$$

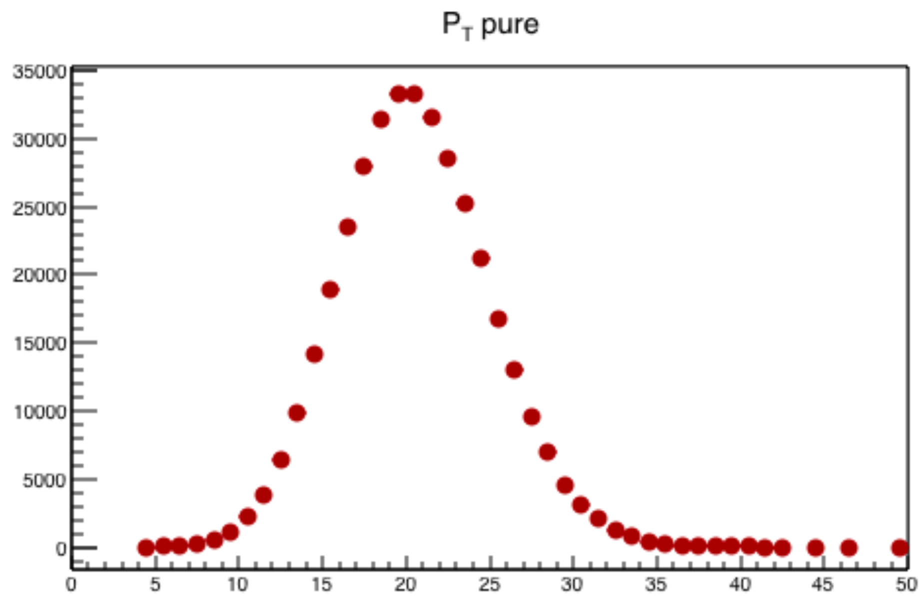
$$p_T\_\text{BG\_normalized} = factor \times p_T\_\text{BG}$$

$$factor = \frac{C}{A+B}$$

# The Results of Sideband Subtraction

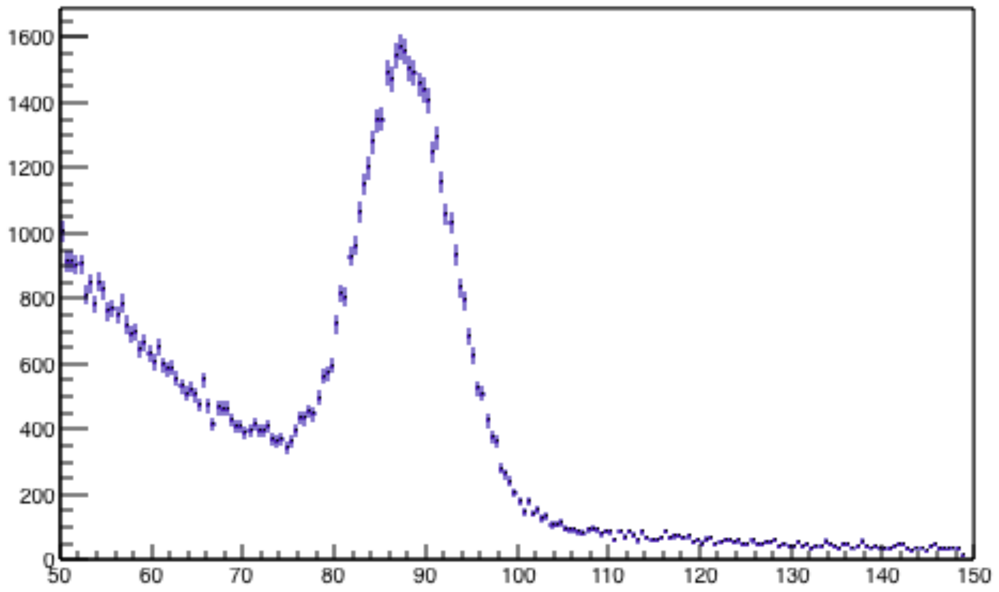


# Fitting Method




Choose $P_T$ range from 7 ~ 36 GeV/c

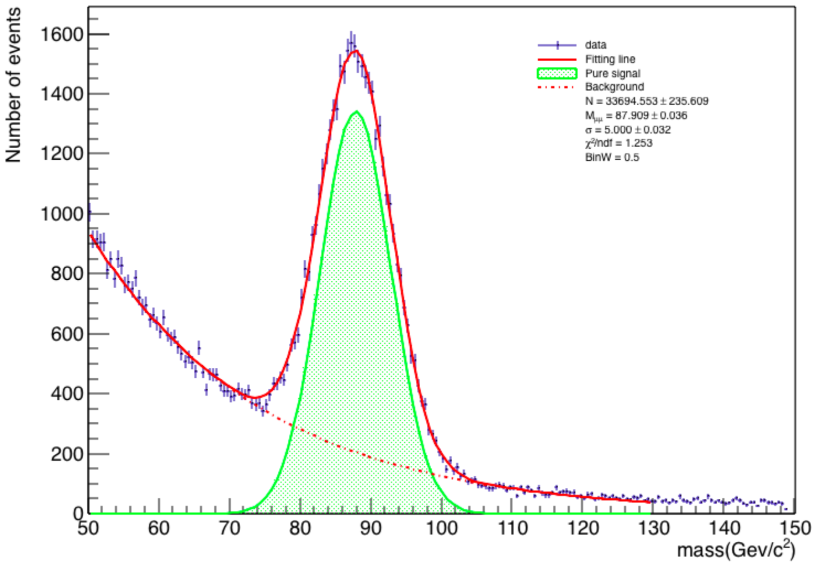
Cut the $P_T$ at range 1 GeV/c:
7~8, ……, 35~36 GeV/c




Mass distributions

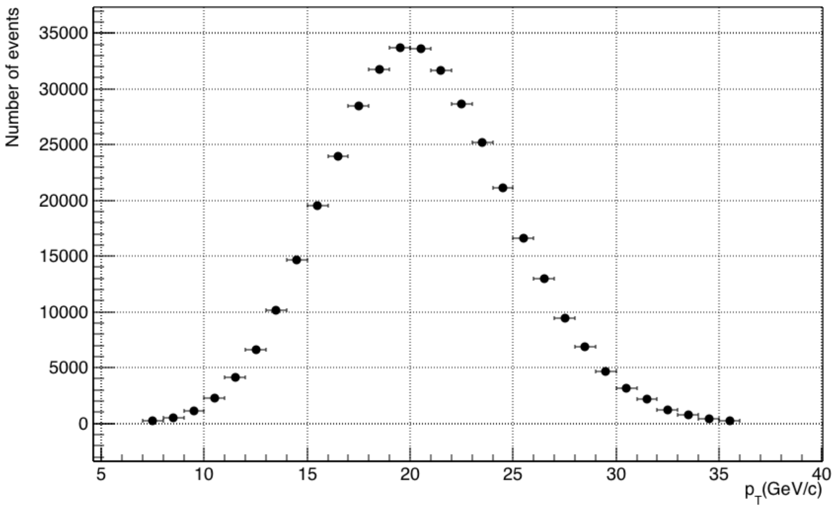
# Fitting Method

Fittings




×N

$P_T$ distribution




# of events of pure signal from $p_2$ in array:

$$Y = [\#1, \dots, \#N] \longrightarrow Yaxis$$

Middle points of $P_T$ range :

$$X = \left[\frac{1}{2} j(j+1)\right] \longrightarrow Xaxis$$

# Comparing Two Results of Methods

- The Monte Carlo data has $P_T$ dependence.
- They are pretty match from the ratio comparison.