Inclusive W and Z Production

$\Longrightarrow$ $p\bar{p} \to W + X$ $p\bar{p} \to Z + X$

$\Longrightarrow$ **detect W and Z via their leptonic decays**

- $W \to e\nu, Z \to ee$

trigger on events with:

$\Rightarrow$ **high p_T electron + large $\not{E}_T$ (W)**

$\Rightarrow$ **2 high p_T electrons (Z)**

- **cleaner signature**
- **lower background**

In addition to W or Z decay products have hadronic energy X in event due to $\rightarrow$

- **"recoil" to W or Z**
  - **if $p_T(W, Z) \neq 0$ then recoil quark(gluon) is also produced**
- **underlying event due to**
  - **multiple interactions in the event**
  - **spectator parton interactions**
  - **detector effects**

M_W - Quantities Measured

We measure quantities in calorimeter (set $|E| \equiv |\vec{p}|$!) (includes underlying event):

$\rightarrow$ **electron energy** $\vec{E}(e)$

$\rightarrow$ **missing transverse energy** ($\vec{\not{E}}_T$) **in calorimeter cells**

$$\vec{\not{E}}_T = -\Sigma_i E_i \sin\theta_i = -\Sigma_i \vec{E}_T^i$$

$\star$ **missing longitudinal energy not known because particles escape down beamline**

$\rightarrow$ **have** $\vec{\not{E}}_T \equiv \vec{E}_T(\nu) = -\vec{E}_T(e) - \vec{E}_T(R)$

Then can determine recoil and boson transverse energy $\vec{E}_T(R) \equiv -\vec{E}_T(W)$

From Measured Quantities:

$$\vec{E}(e), \vec{E}_T(\nu), \vec{E}_T(R), \vec{E}_T(W)$$

Cannot reconstruct W invariant mass

$$M_W^2 = (E^e + E^\nu)^2 - (\vec{E}^e + \vec{E}^\nu)^2$$

$\rightarrow$ **Instead measure M_T^W where $M_T^2 = M^2 + E_x^2 + E_y^2$**

$\star$ **transverse mass of W**

$$M_T^W = \sqrt{2E_T^e E_T^\nu (1 - \cos\varphi)}$$

$\star$ **invariant mass of Z**

$$M_Z = \sqrt{2E^{e1} E^{e2} (1 - \cos\varphi)}$$

M_W - Measurement Technique

No analytic description of the $M_T(W)$ distribution...

- **model data with fast Monte Carlo (MC) simulation**
  - model kinematic variables and detector effects

- **generate $M_T(W)$ distributions as a function of M_W**
  - do for 21 values of M_W, 100 MeV apart

- **extract value of M_W by doing event-by-event maximum-likelihood fit of data to MC simulation**

$\longrightarrow$ **largest error is due to calibration of electron energy scale, therefore**

$\longrightarrow$ **measure ratio of W/Z mass (reduces systematic errors):**

$$M_W = \frac{M_W^{meas}}{M_Z^{meas}} \cdot M_Z^{LEP}$$

use $M_Z^{LEP} = 91.1884 \pm 0.0024$ GeV

which is very precise combined value from the 4 experiments at LEP collider at CERN in Geneva, Switzerland

M_W - Monte Carlo Simulates:

- W production and decay $\longrightarrow$ to get $\vec{P}_T(e)$ & $\vec{P}_T(W)$ (and therefore can calculate $\vec{P}_T(\nu)$)
- electron and hadronic (recoil) energy scale
- energy & angular resolution
- additional energy due to underlying event
- selection biases & efficiencies
- kinematic cuts

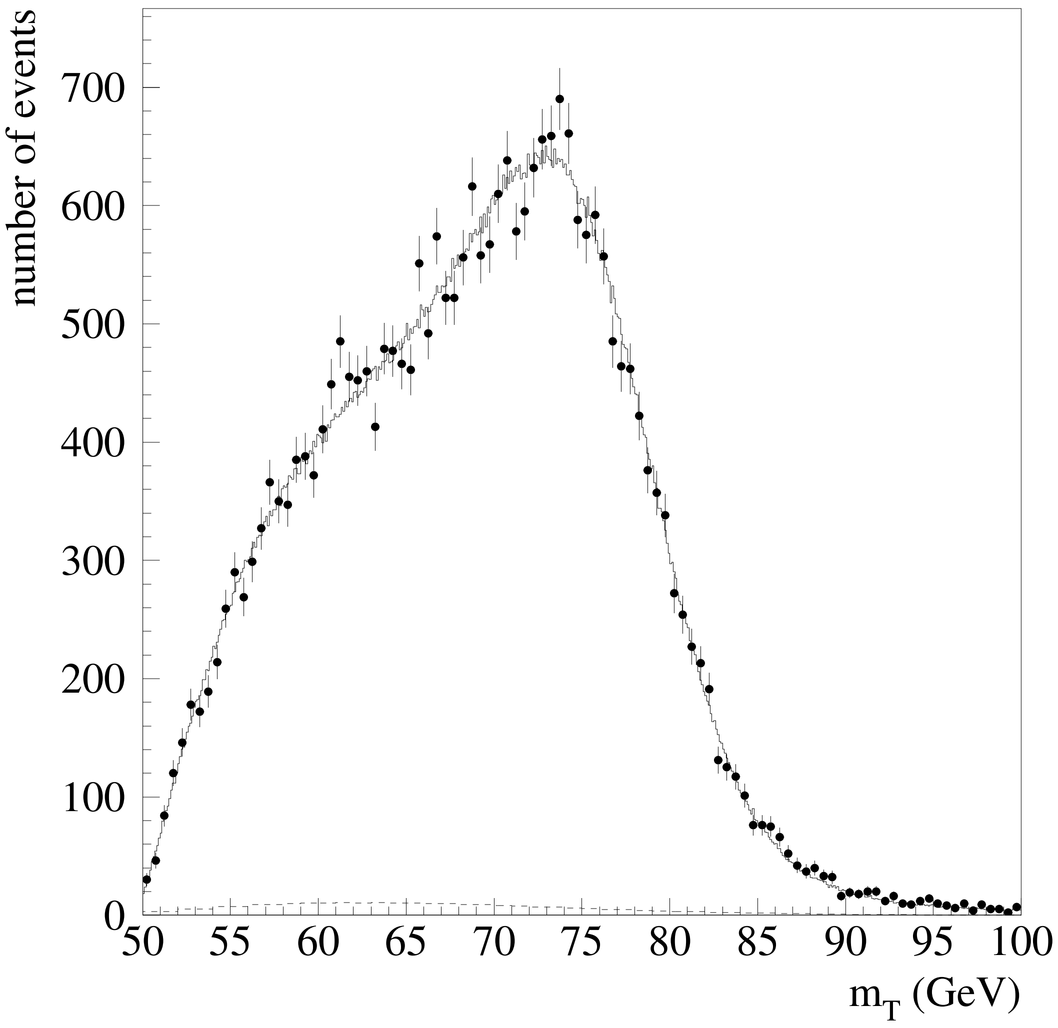
(Z events modelled in analagous way)

$\Rightarrow$ Points to Note!!

$\longrightarrow$ use $Z \rightarrow ee$ and other data to set most parameters in MC

$\longrightarrow$ systematic errors set using large statistics samples of MC data - vary parameter within its errors

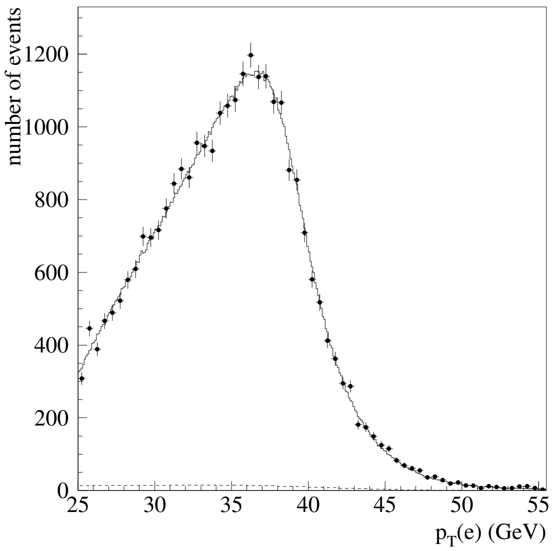
Run 1B, M_W - from Fit to $M_T(W)$

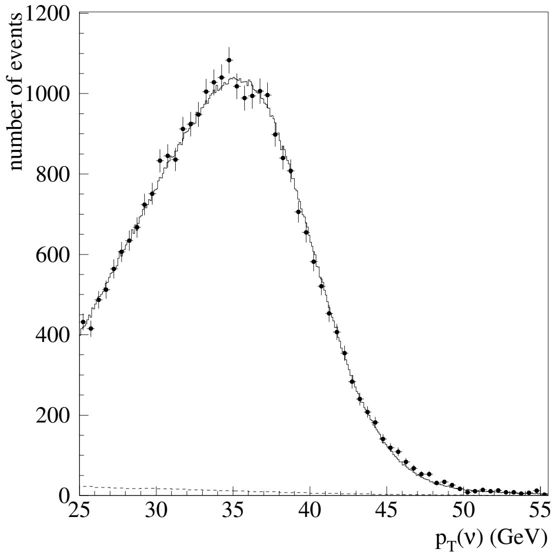


$$\boxed{M_W(\mathrm{Run1B}) = 80.45 \pm 0.07(stat)\ \mathrm{GeV/c^2}}$$

Run 1B: M_W - from P_T^e and P_T^ν fits

(Consistency Checks)





M_W **from** $P_T(e)$ **fit** $= 80.49 \pm 0.14\ \mathrm{GeV/c^2}$

M_W **from** $P_T(\nu)$ **fit** $= 80.42 \pm 0.18\ \mathrm{GeV/c^2}$