V 1.1

Search for W´ → eν

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- Introduction
- Monte Carlo Study
- Electron Identification
- Datasets & Selection Cuts
- Data – MC – Comparison
- Systematic Uncertainties
- Limit

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Heavy Gauge Bosons

Additional gauge bosons (W´ , Z´) are introduced in

many extensions to the SM : $SU(2)_L \, x \, SU(2)_R, \;\; SO(10), \;\; E_6, \;\; \ldots$

Parameters :

- mass, width

In addition :

- mixing W' – W etc ξ
- coupling W' – fermions g'
- CKM' – matrix U'

Make **assumptions** to reduce number of parameters :

⇨ mixing suppressed, $g' \equiv g_{SM}$, $U' \equiv U_{SM}$

Altarelli et al.,
Z. Phys. C45, 109 (1989)

⇨ width ~ mass

$$m_{W'} < 180\,GeV : \Gamma_{W'} = \frac{m_{W'}}{m_W} \cdot \Gamma_W$$

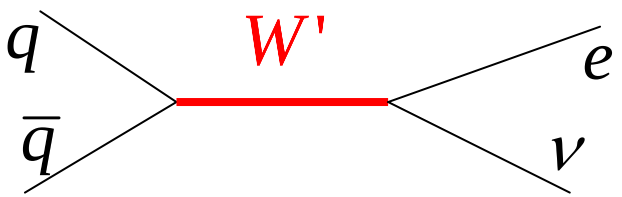
$$m_{W'} > 180\,GeV : \Gamma_{W'} = \frac{4}{3} \cdot \frac{m_{W'}}{m_W} \cdot \Gamma_W$$

Decay $W' \rightarrow tb$ allowed

Monte Carlo Study

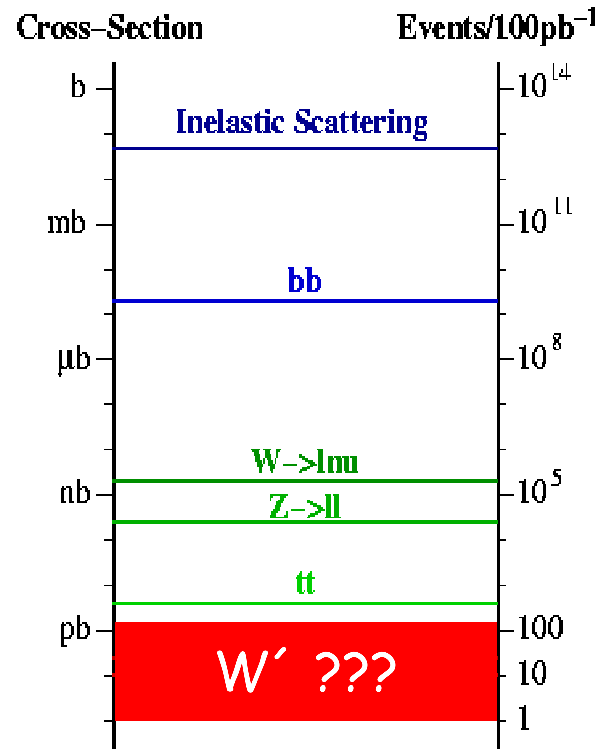
cross section

Production of W´ → eν MC



- PYTHIA + full detector simulation
- 5000 events each mass point
- XS in table are NNLO

m (W´) [GeV]	σ * Br [pb]
80	2600
500	2.44
600	0.84
700	0.30
800	0.11
900	0.044
1000	0.019
1100	0.0095
1200	0.0056



$K(m_{W'})$ for NNLO from

R. Hamberg, W.L. van Neerven and T. Matsuura, Nucl. Phys. B **359** (1991) 343; Erratum-ibid. B **644** (2002) 403

$$\sigma \cdot BR \sim 5 \cdot 10^{-3} \ldots 2\ pb$$

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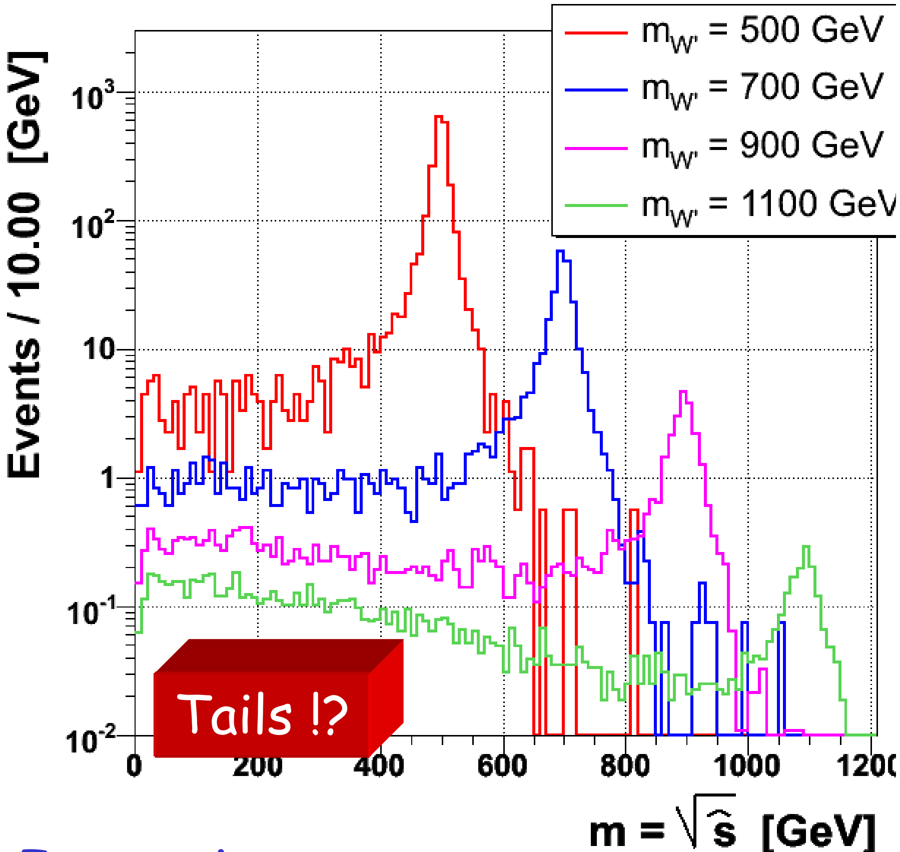
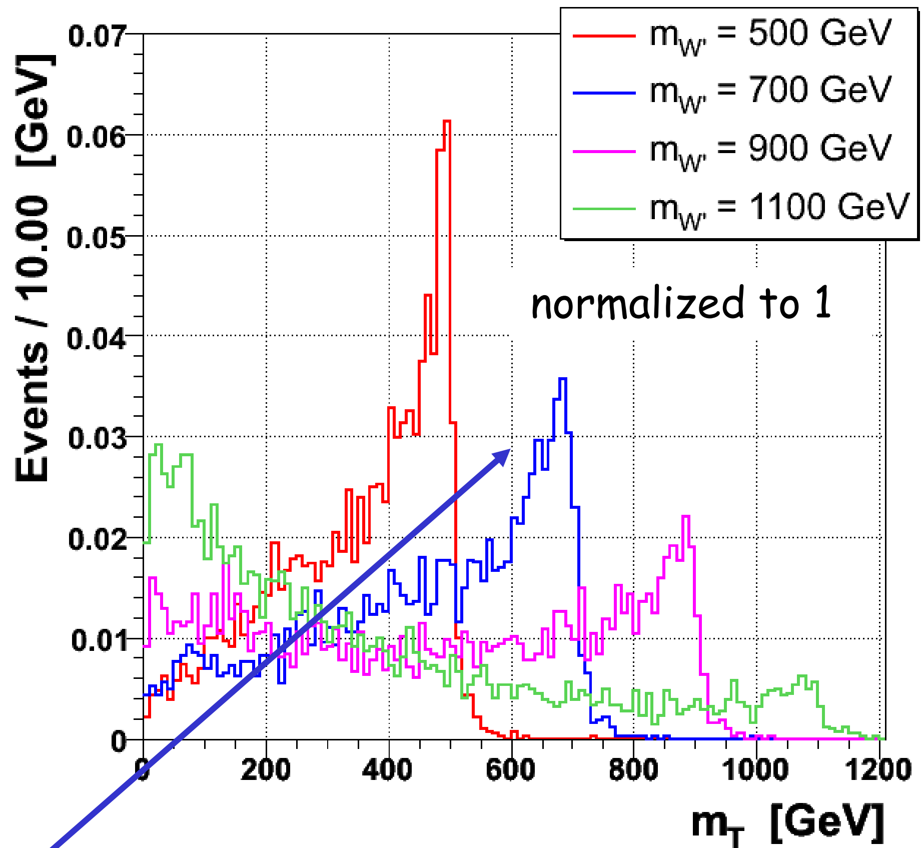
Monte Carlo Study

transverse mass distribution





Increasing mass

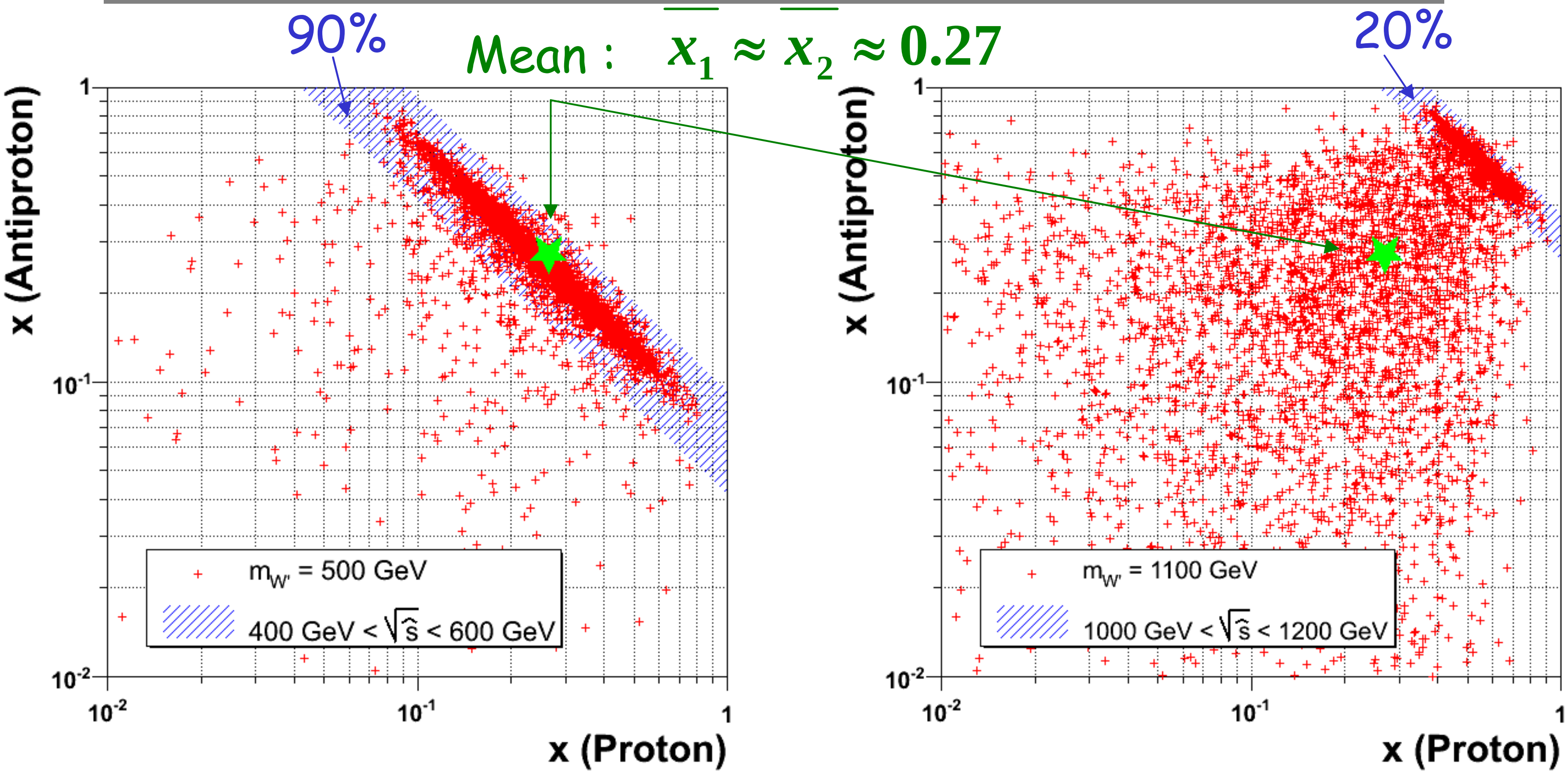
→ steeply decreasing cross section

→ smearing of Jacobian peak

→ distributions are flat → no peak search !

Monte Carlo Study

PDF influence



$$x \approx \frac{\sqrt{\hat{s}}}{\sqrt{s}} = \frac{500}{1960} = 0.26 \approx \overline{x}$$

$$\sqrt{\hat{s}} = \sqrt{x_1 x_2} \cdot \sqrt{s}$$

$$x \approx \frac{\sqrt{\hat{s}}}{\sqrt{s}} = \frac{1100}{1960} = 0.56 > \overline{x}$$

PDFs suppress on-mass-shell production of heavy gauge bosons

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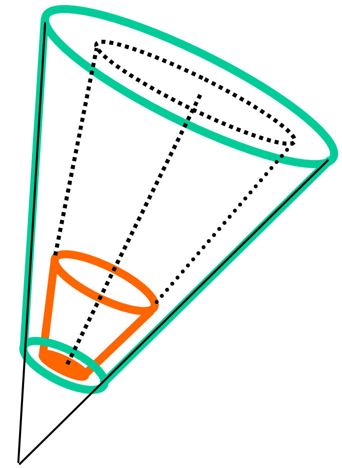
Electron Identification criteria

(1) Calorimeter

- huge energy fraction deposited in the EM layers $emf = \frac{E_{0.4}^{EM}}{E_{0.4}^{tot}} > 90\%$
- isolated shower $iso = \frac{E_{0.4}^{tot} - E_{0.2}^{EM}}{E_{0.2}^{EM}} \equiv$  < 0.2
- shower ‚electron-like' (χ^2 shower shape fit)

$$\chi^2_{\mathrm{HM}} < 12 \quad (N_{dof} = 7)$$



(2) Tracker

Thus: use tracker, but only direction

$$P(\chi^2) > 0.01 \qquad \chi^2 = \left(\frac{\Delta z}{\sigma_z}\right)^2 + \left(\frac{\Delta\phi}{\sigma_\phi}\right)^2$$

note: momentum resolution poor:

$Tracker:$	$\Delta p_T (p_T = 200\ GeV) \approx 80\ GeV$
$CAL:$	$\Delta E_{el} (E_{el} = 200\ GeV) \approx 9\ GeV$

Dataset & Selection Cuts

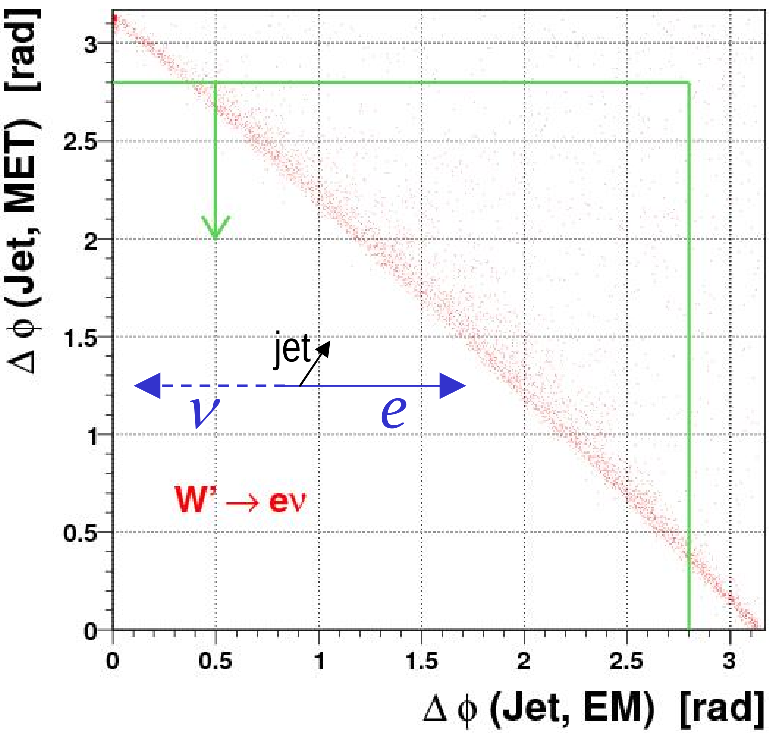
Luminosity ~ 1 fb^{-1}

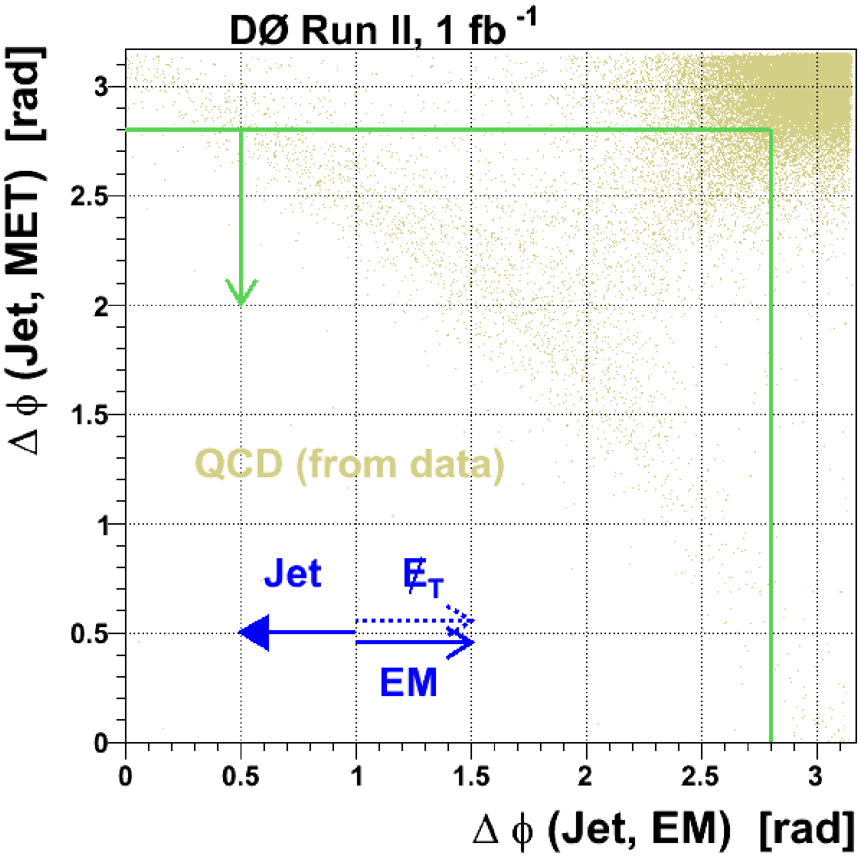
Run IIa dataset (August 2002 – February 2006)

- electron trigger requirement, quality cuts
- **Neutrino**
  - missing transverse energy MET > 30 GeV
- **Electron**
  - (at least) 1 electron candidate (calorimeter and tracker)
  - Central Calorimeter : $|\eta_{det}| < 1.1$
  - $E_T > 30$ GeV
- **Jets** (if present in the event with $E_T > 15$ GeV)
  - $\Delta\phi$ (jet, electron) < 2.8
  - $\Delta\phi$ (jet, MET) < 2.8
- Further cleaning cut

  $0.6 < E_T$ / MET < 1.4

Dataset & Selection Cuts   kinematic cuts

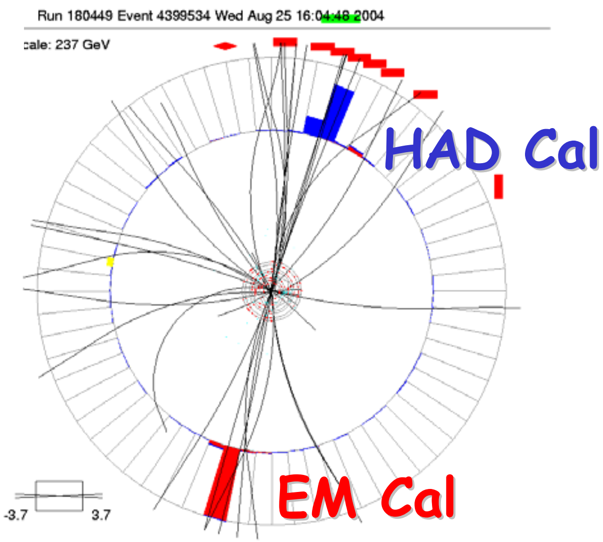


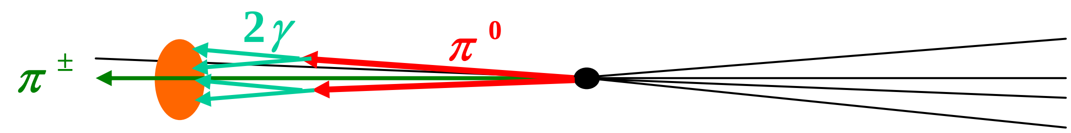


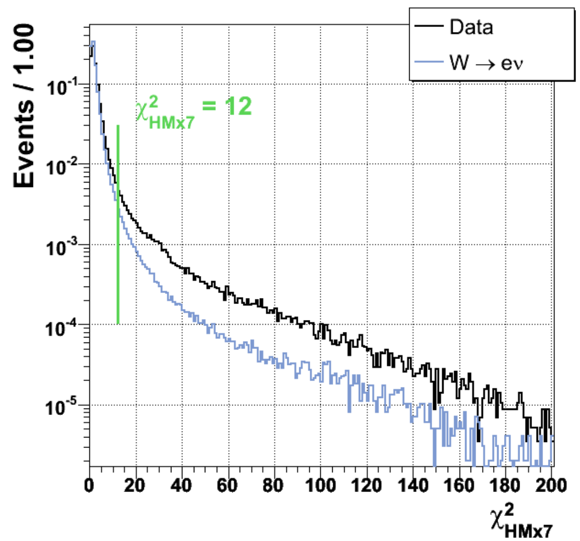
rejection of background events **with jets**

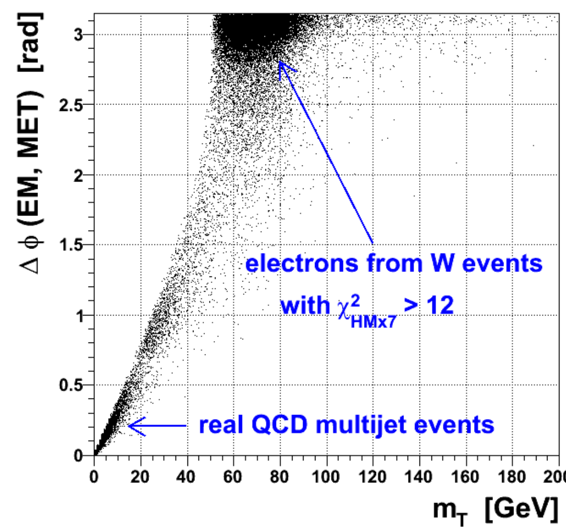
Dataset & Selection Cuts

QCD background



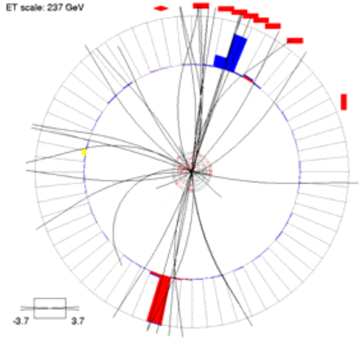


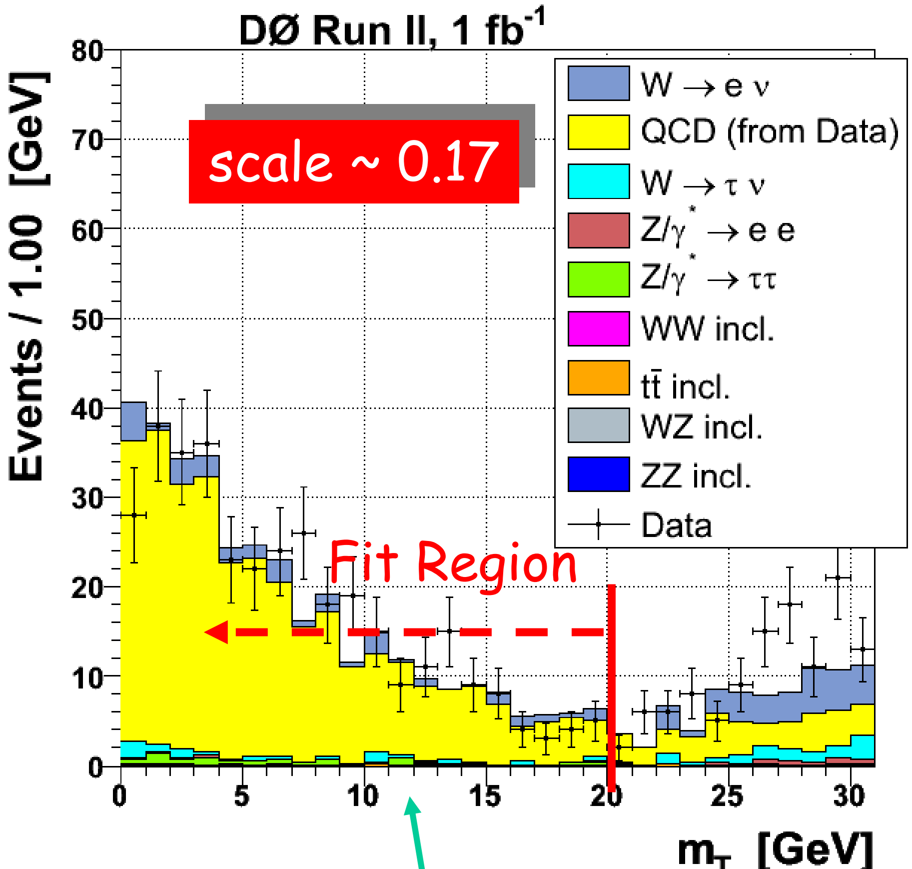


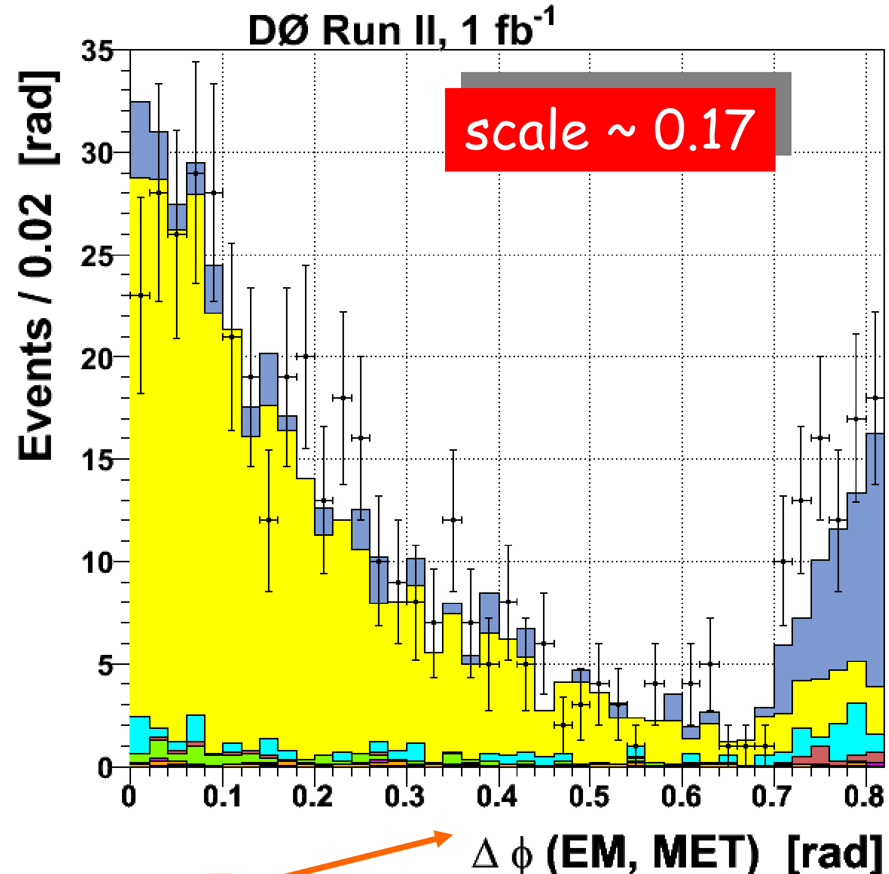


Estimate QCD contribution
from data:
-> invert Hmatrix cut

Determination of QCD Background







$$m_T = \sqrt{2 E_T^{el} \not{E}_T \left(1 - \cos \Delta\phi(el, MET)\right)}$$

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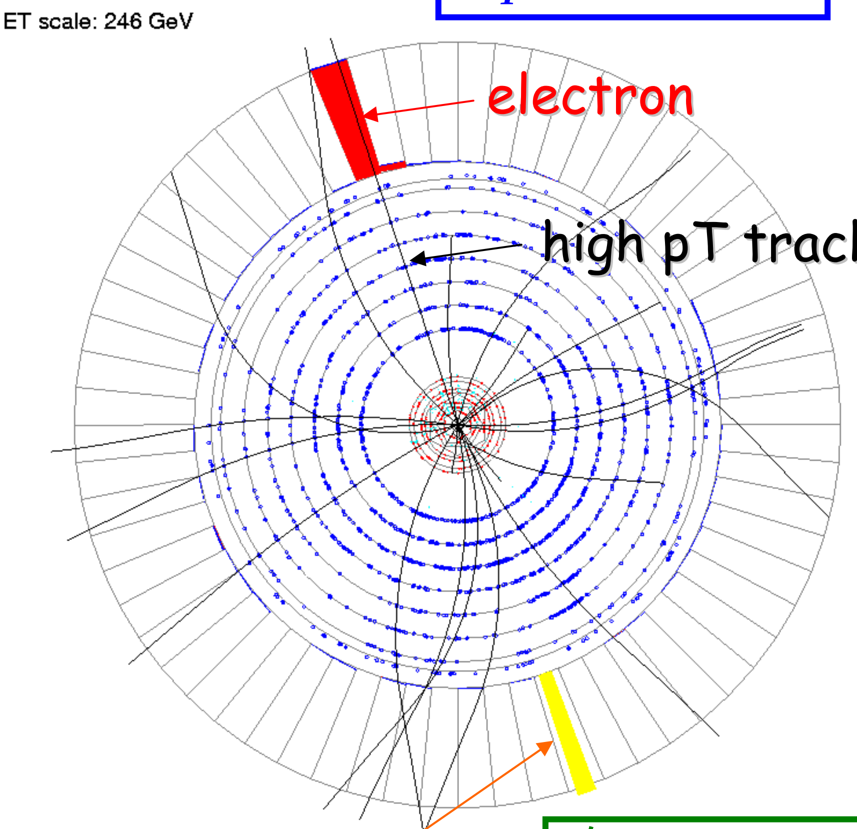
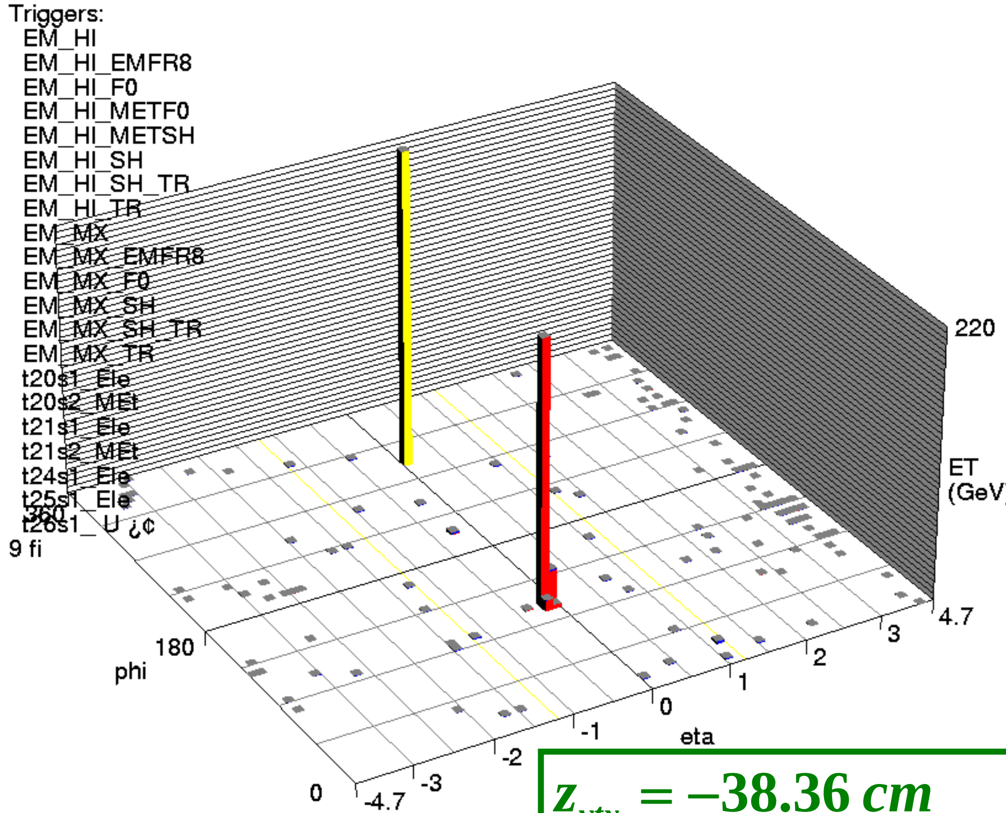
Event Display

$m_T = 530\ GeV$



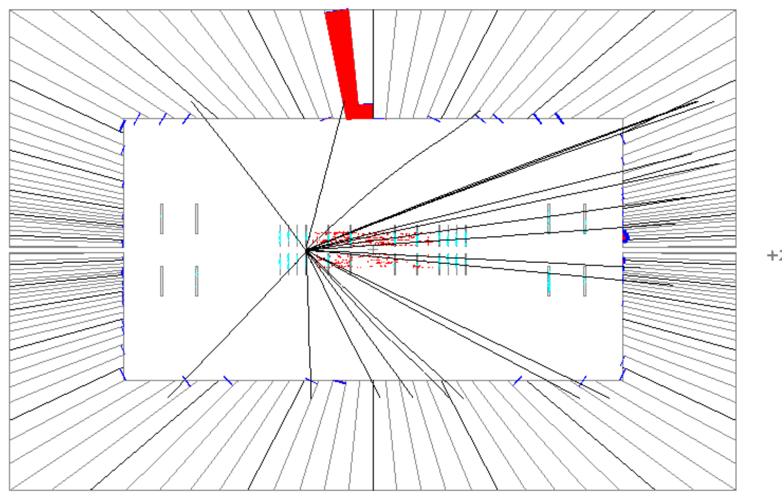


$z_{vtx} = -38.36\ cm$

$|z_{vtx} - z_e| = 0.04\ cm$

$\not{E}_T = 265\ GeV$

$E_T^{el} = 265\ GeV$



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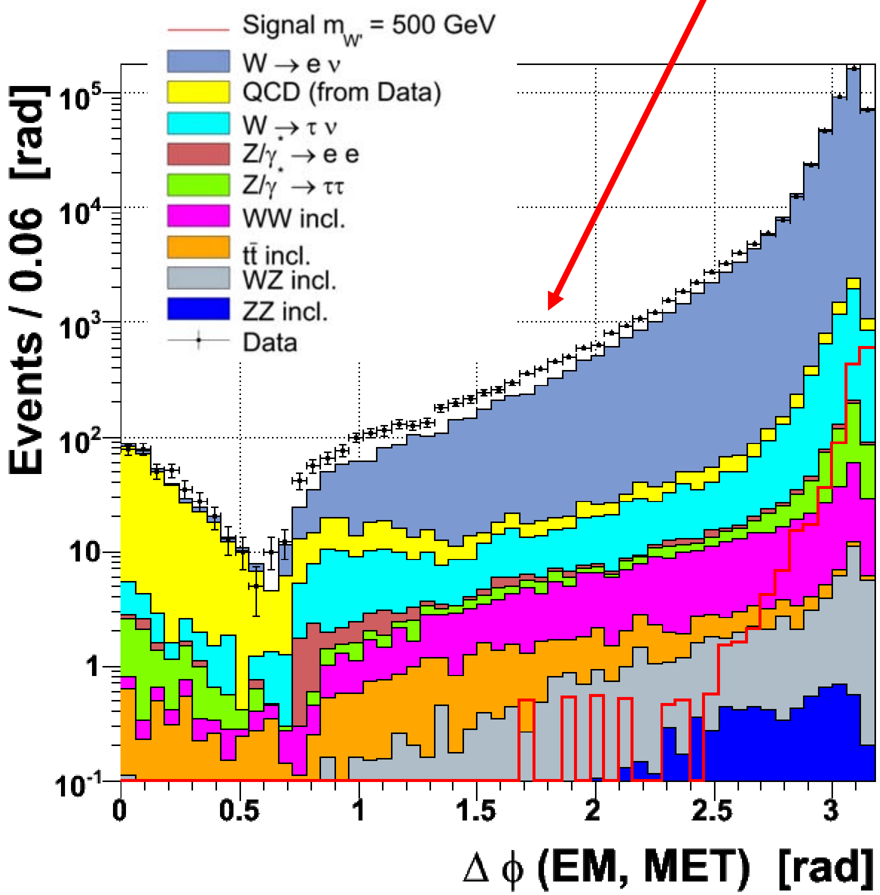
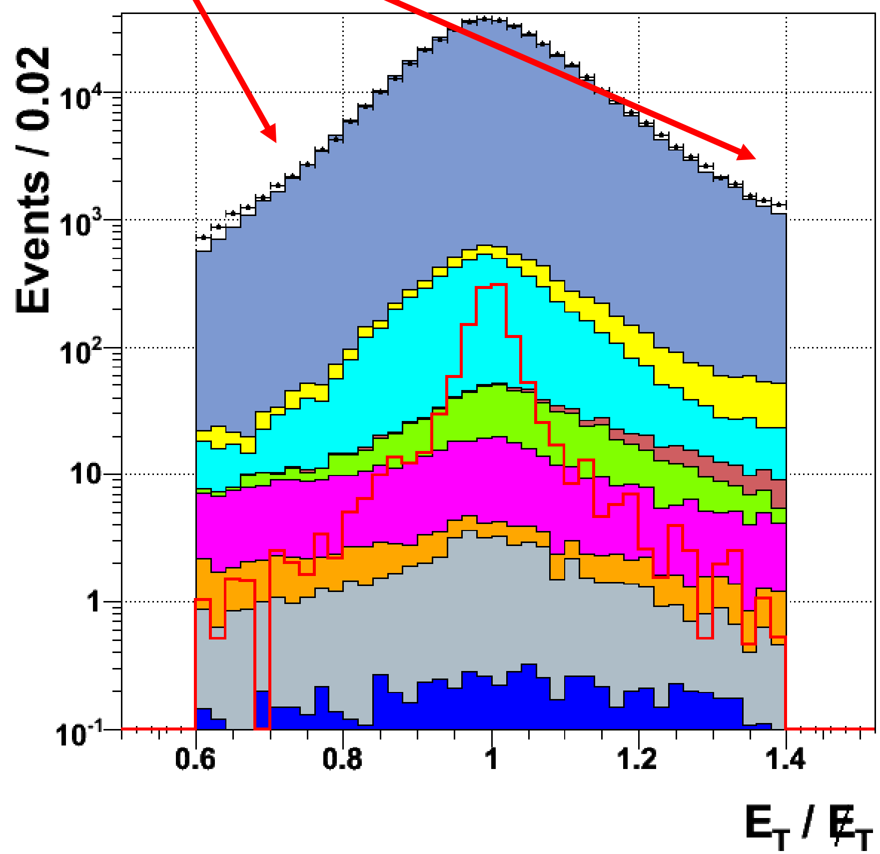
Discrepancies

Note : PYTHIA is a parton shower generator

Presence of jets = higher order effects ??





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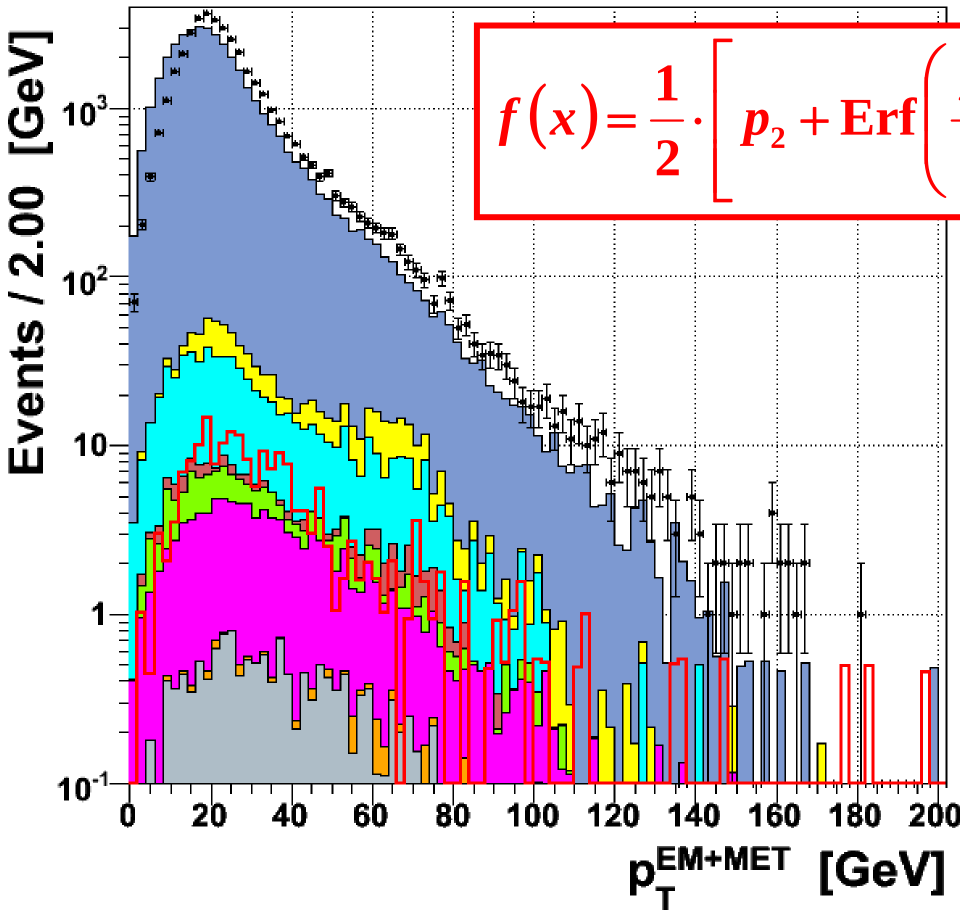
W events with 1 jet

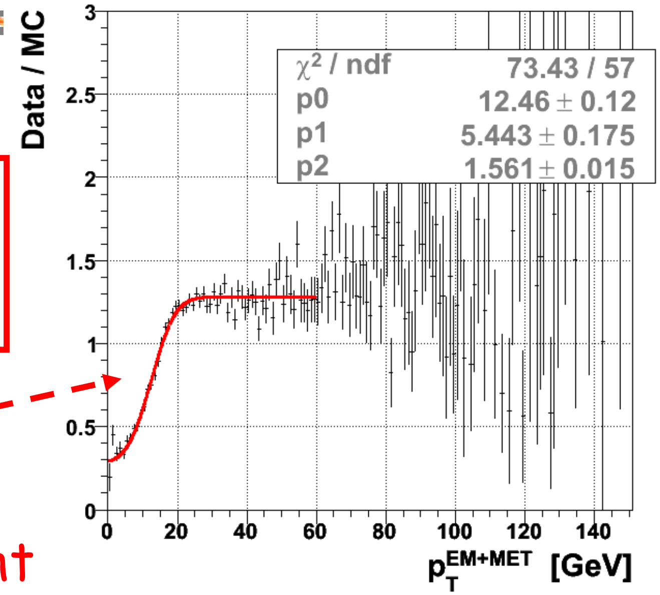
Very good agreement for event with 0 jets !

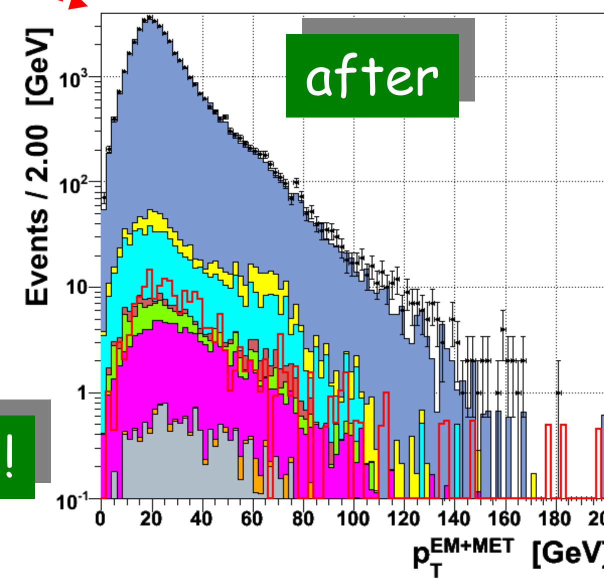
Jet recoils against W



$$f(x) = \frac{1}{2} \cdot \left[p_2 + \mathrm{Erf}\left(\frac{x - p_0}{\sqrt{2}\, p_1} \right) \right]$$

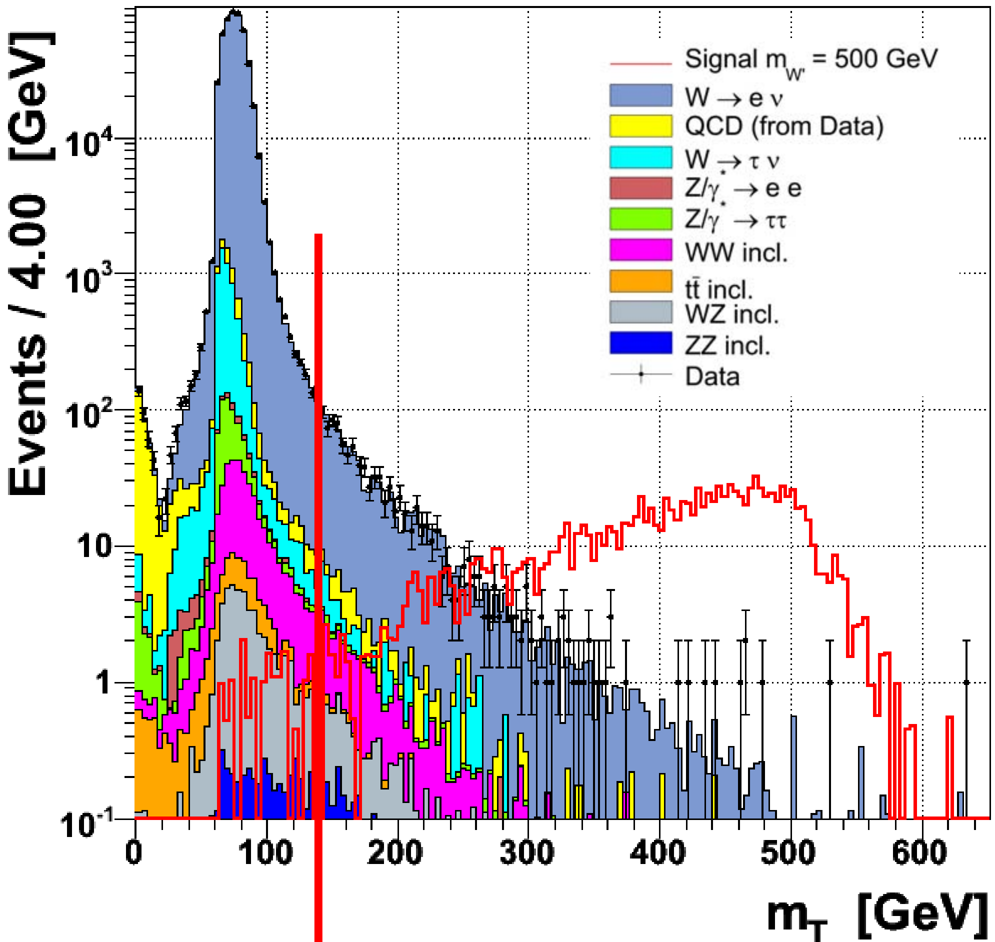
Fit & reweight





After reweighting good agreement everywhere !

W Sample



Data :
452984

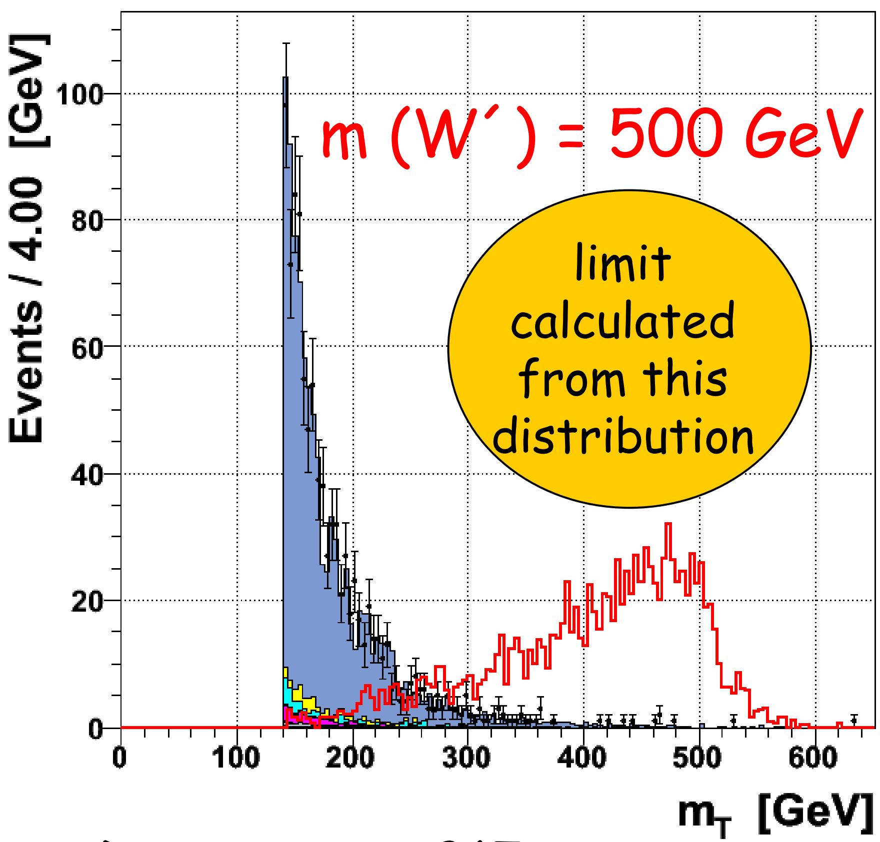
Background :
454000 ± 500 (stat) ± 35000 (sys)

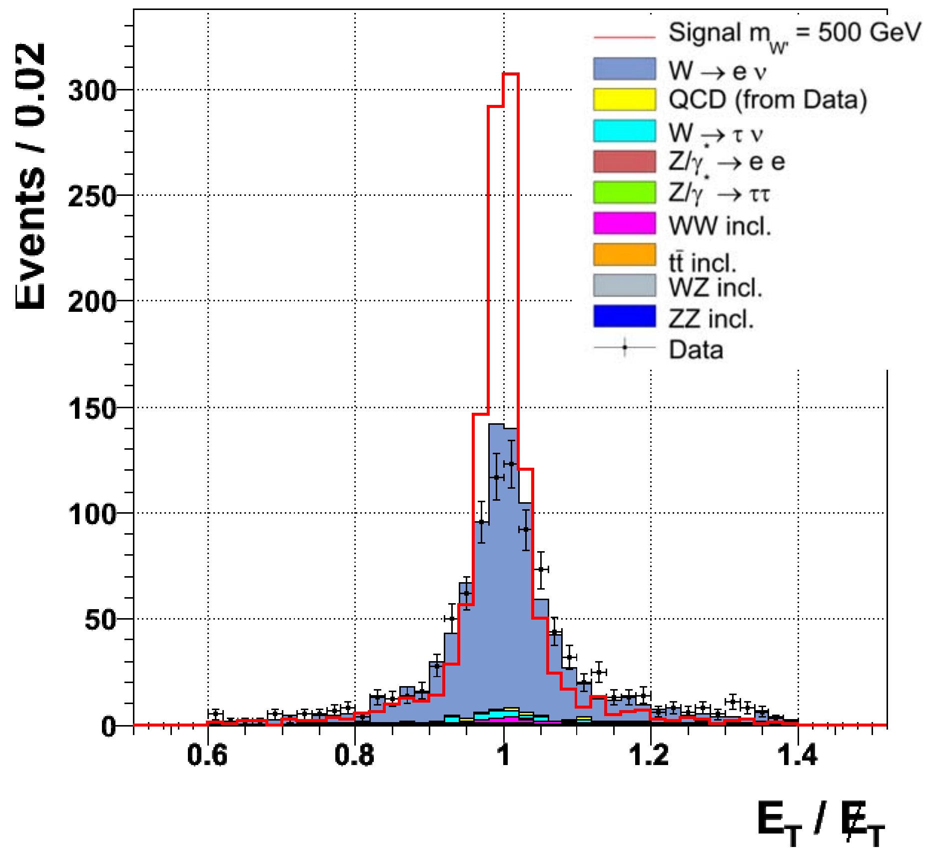
m_T spectrum with m_T > 140 GeV will be used for limit calculation (binned likelihood, shapes !)

Search Sample

data vs MC

Good agreement between data and background !





Data : 967

Background : 959 ± 21 (stat) ± 90 (sys)

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Systematic Uncertainties

Global Normalization

- Cross sections
  4 – 10 %
- luminosity (= scaling)
  4 %
- efficiency correction
  ~ 2 %
- QCD scaling
  7 %

Shape Changing (m_T distribution)

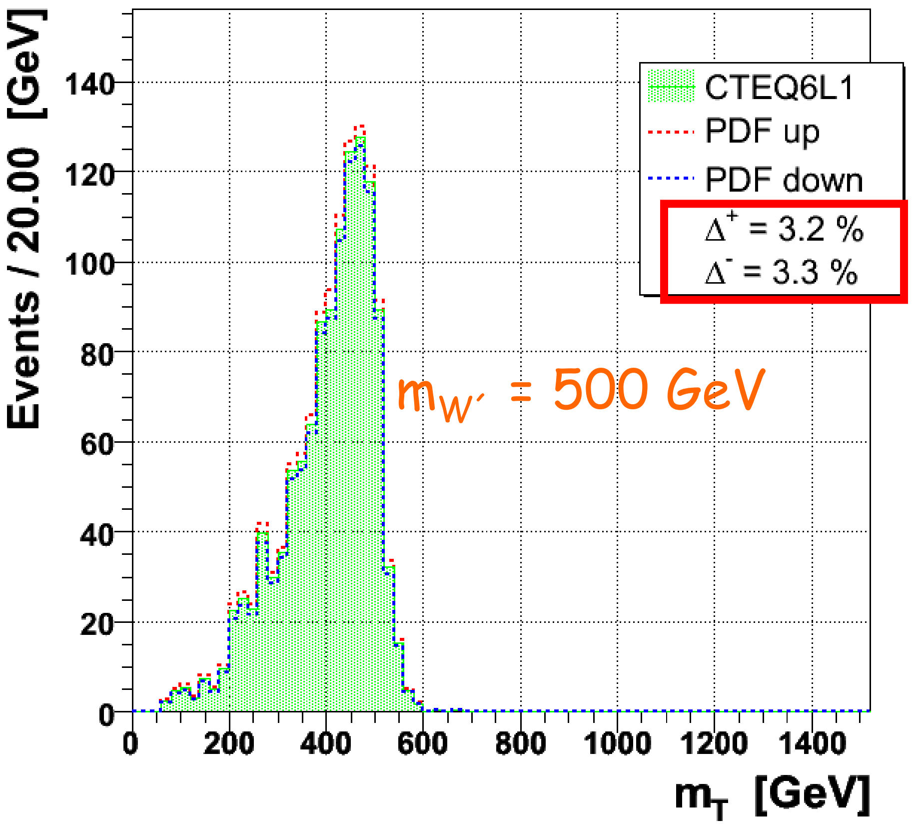
- Electron energy scale
  W´ : < 1 %
- Electron energy resolution
  W´ << 1 %
- PDF uncertainty
  W´ : 3 – 8 %
- Uncertainty of Γ_W
  W : 4 %

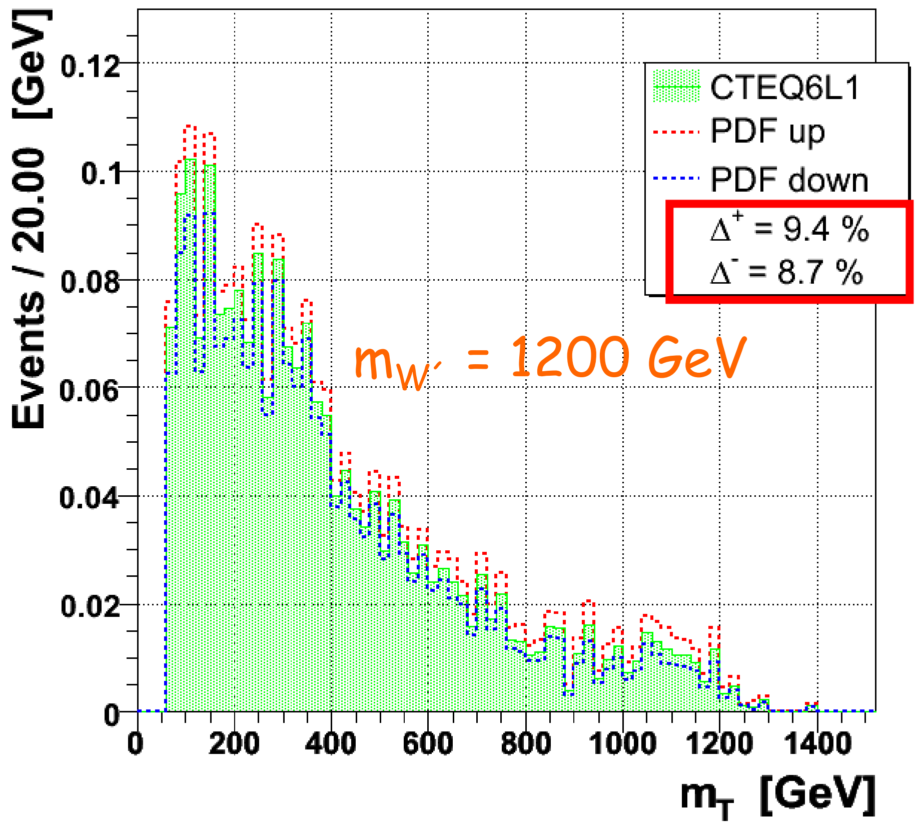
JES, W p_T reweighting
W,W´ < 1 %

Events m_T > 140 GeV

Make use of binned likelihood and
- take global and shape changing uncertainties into account
- take bin correlations into account

PDF Uncertainty





Reweight the Monte Carlo samples

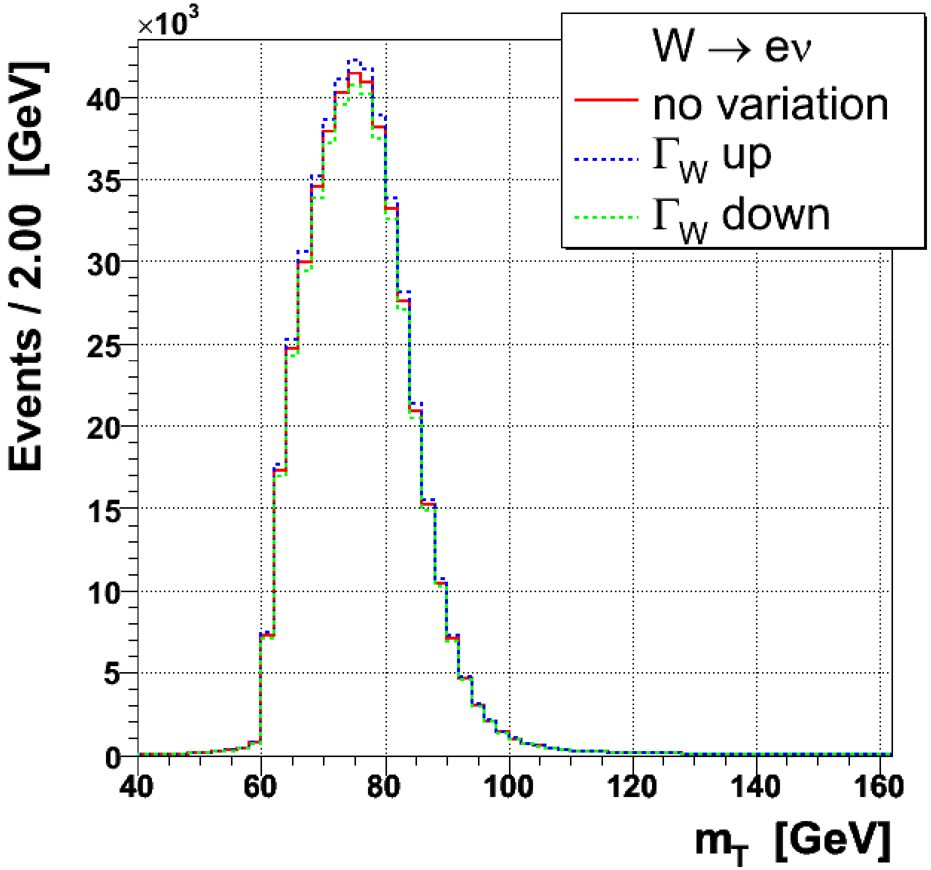
CTEQ6L1 -> CTEQ6.1M and CTEQ6.1M.xx (xx = 1 ... 40) error functions

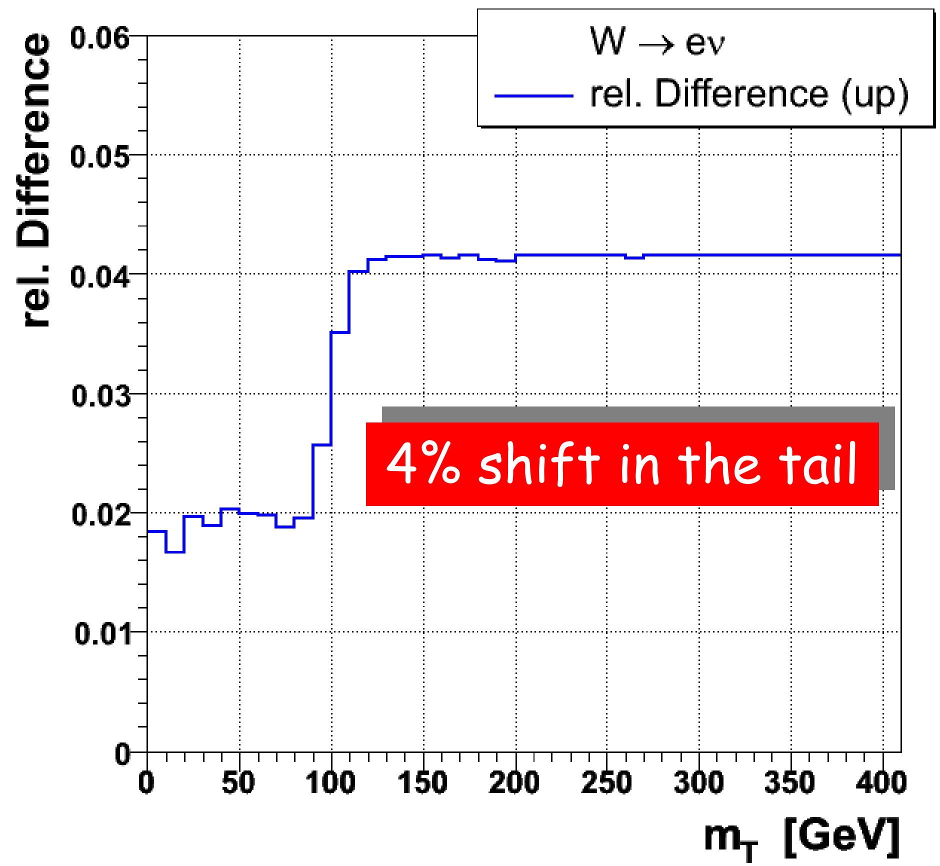
Width of the W boson

Γ_W known at 2% level → Impact on W ??

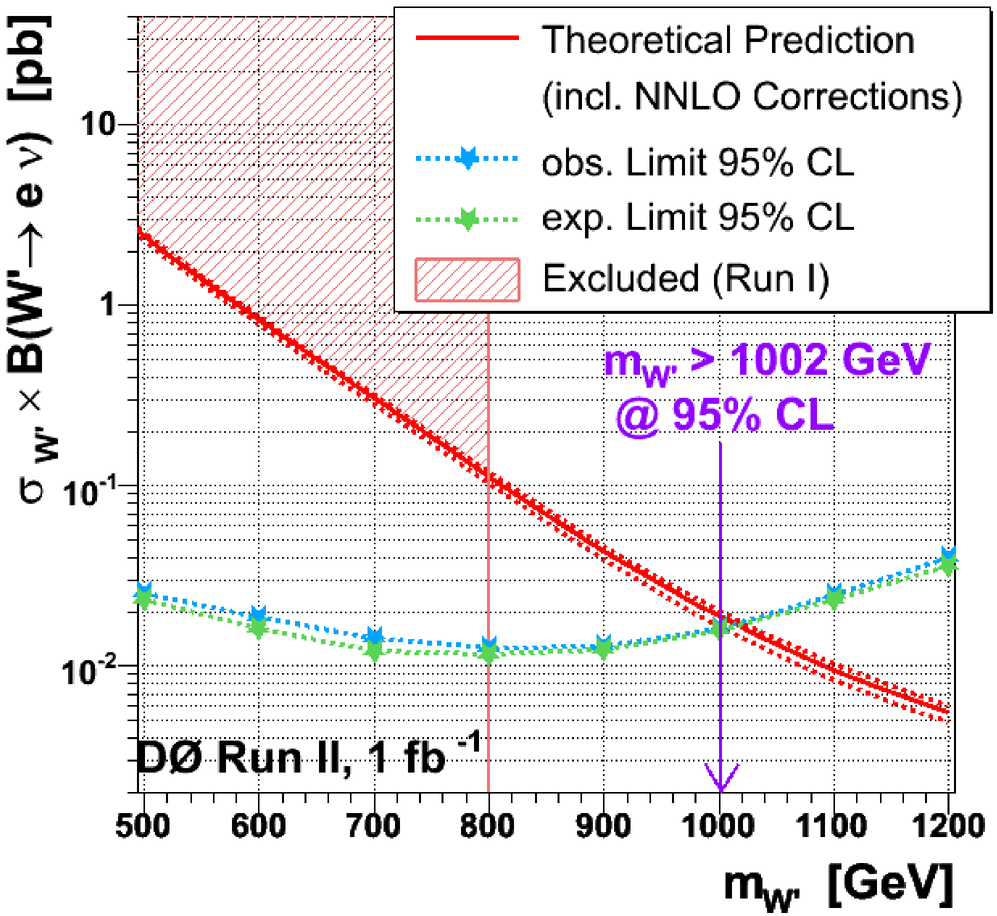
Idea : Reweight events with Breit-Wigner

$$w^{\pm} = \frac{BW(m, M_W, \Gamma_W \pm \Delta\Gamma_W)}{BW(m, M_W, \Gamma_W)}$$





Limit (from m_T distribution)



Result ($W' \to e\nu$, L = 1 fb^{-1}) :

$m_{W'}$ > 1002 GeV @ 95% CL

mT >	Data	Standard Model
140 GeV	967	959 ± 21 (stat) ± 90 (sys)
200 GeV	241	242 ± 9 (stat) ± 18 (sys)
300 GeV	37	31 ± 2 (stat) ± 5 (sys)
400 GeV	10	9 ± 1 (stat) ± 1 (sys)
500 GeV	2	2 ± 1 (stat) ± 1 (sys)

CDF Run IIa ($W' \to e\nu$, 205 pb^{-1}) :
$m_{W'}$ > 788 GeV @ 95% CL

Summary

- ✓ Presented search for W′ → eν using the full Run IIa dataset until February 2006 (~1 fb^{-1})
- ✓ good agreement between data & background prediction
- ✓ shapes and overall numbers agree
- ✓ systematic uncertainties under control

- ✓ ☹ no evidence for New Phenomena
- ✓ limit set on production cross section x branching fraction

- ✓ most stringent direct limit to date : $m_{W'} > 1002$ GeV
  (assuming Standard Model couplings)

- ✓ PhD thesis submitted
- ✓ analysis currently under review for publication in PRL