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Isolated e and μ in Events with missing transverse momentum at HERA

Gilles Frising

I. Phys. Institut, RWTH Aachen

H1 Collaboration

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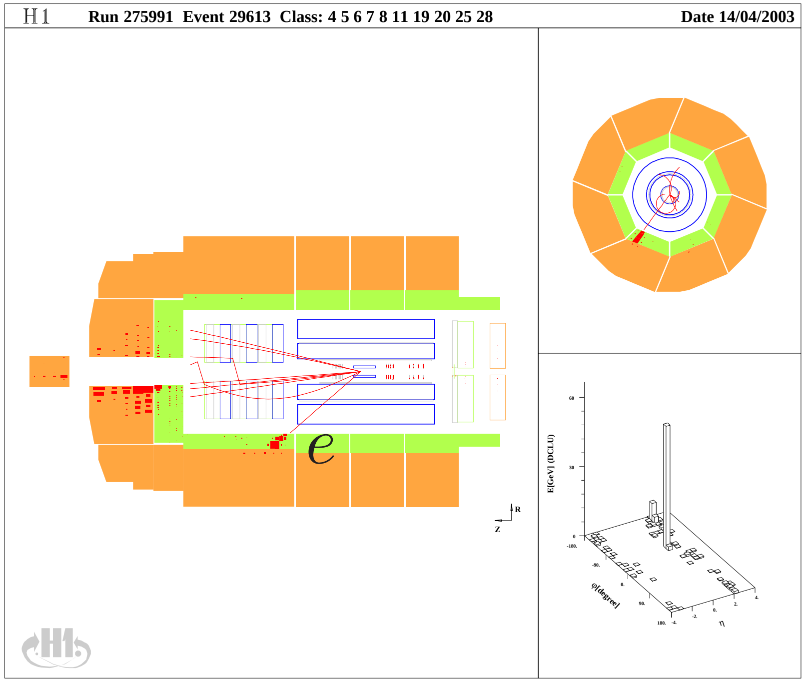
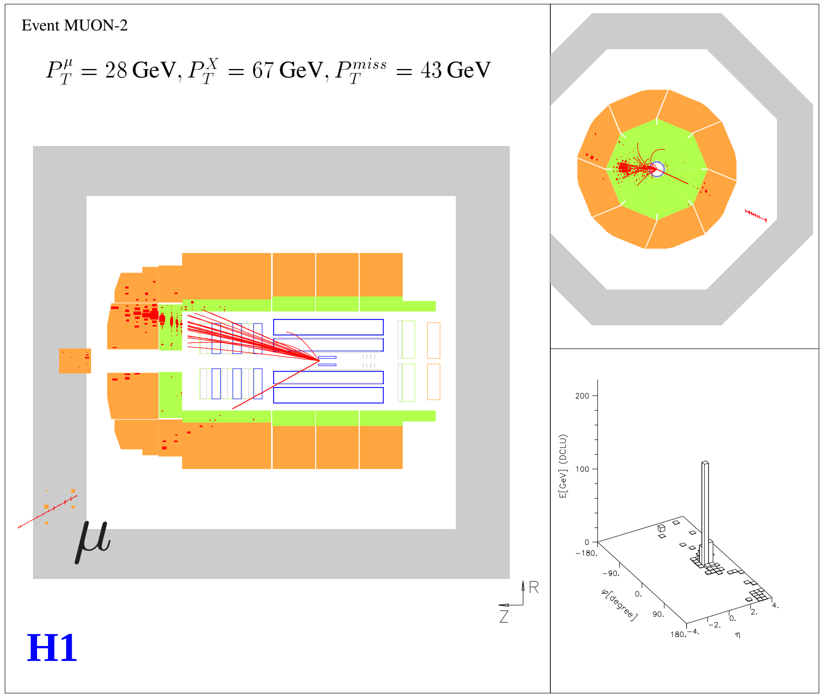
- Introduction
- Search Strategy and Results
- Hadronic decay channel
- Summary and Outlook

Introduction

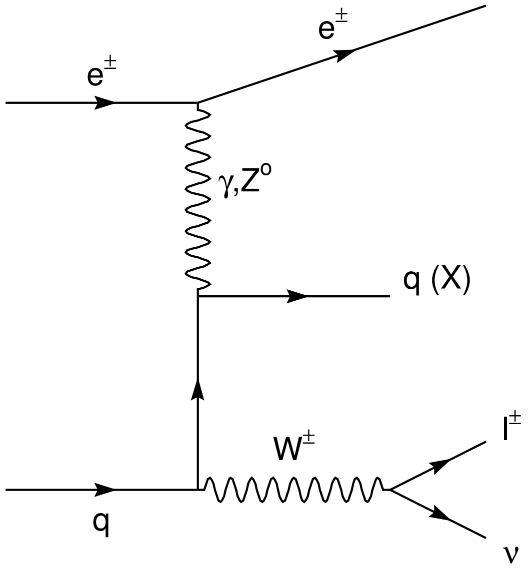
H1 observed an **excess of events** with a high P_T isolated lepton and missing P_T
[Eur. Phys. J. C **5** (1998) 575]





$\textit{New Publication}\ [\mathbf{hep-ex/0301030}] \Longrightarrow$ accepted by Phys. Lett. B

- Only significant contribution to this **signal** comes from SM W **production** with leptonic decay



Jet $\Longrightarrow P_T^X$
(Hadronic recoil)

Isol. lepton

Missing P_T

- Standard Model (LO) predicts $\sigma(ep \rightarrow eW^{\pm}X) \approx$1 pb

- **Branching ratio**
  W $\rightarrow$leptons$\approx 10.7\% \cdot 3$
  W $\rightarrow$hadrons$\approx 68\%$

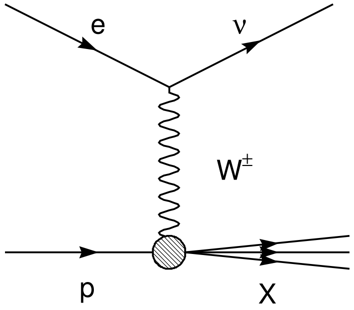
- NLO SM W calculations now available

  K. P. Diener, C. Schwanenberger, M. Spira, Eur. Phys. J. C **25** (2002) 405

  $\Longrightarrow$ talk of C. Schwanenberger

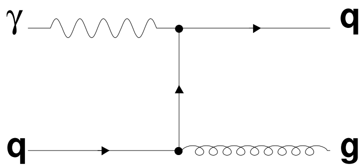
SM Background processes to W production

Charged Current (CC) processes :



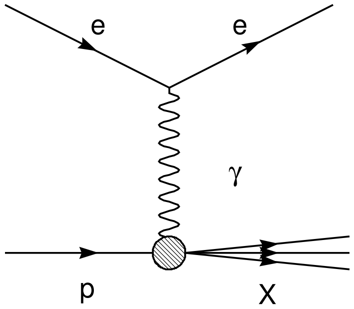
hadron or radiative photon can be misidentified as lepton

Photoproduction of jets $(\gamma \mathrm{p})$:



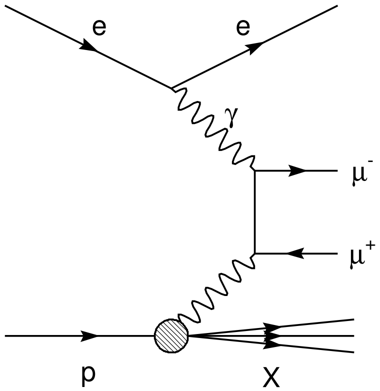
real or fake lepton from hadronic final state and P_T^{miss} from mismeasurement or non-containment

Neutral Current (NC) processes :



scattered lepton and P_T^{miss} from mismeasurement or non-containment can fake $W \rightarrow e\nu$ candidates

Lepton pair (LP) production :



One lepton is not detected

Search Strategy-W Event selection

Phase space

Polar Angle θ_l	$5^\circ < \theta_l < 140^\circ$
lepton transverse momentum P_T^l	> 10 GeV
missing transverse momentum P_T^{miss}	> 12 GeV

Main discriminating variables to obtain a high purity and a high efficiency

		W-Signal	Background
D_{track}	Isolation of lepton wrt to tracks	flat	small (CC,γp)
D_{jet}	Isolation of lepton wrt to jets	flat	small (CC,γp)
$\Delta\Phi(l-X)$	Acoplanarity	flat	$\approx 180^o$ (NC,γp,$\gamma\gamma$)
$\frac{Vap}{Vp}$	Ratio of anti-parallel to parallel final state particle momentum wrt to $\vec{P}_T^{\mathrm{miss}}$	≈ 0	≈ 0.5 (NC,γp)
ζ_l^2	$= Q^2$ e-channel	flat	small (NC)
δ_{miss}	Longitudinal Balance	flat	≈ 0 (NC)
$E_h^{\mathrm{cone}=1}/E_e$	Calorimetric isolation (e)	≈ 0	> 0 (CC,γp)

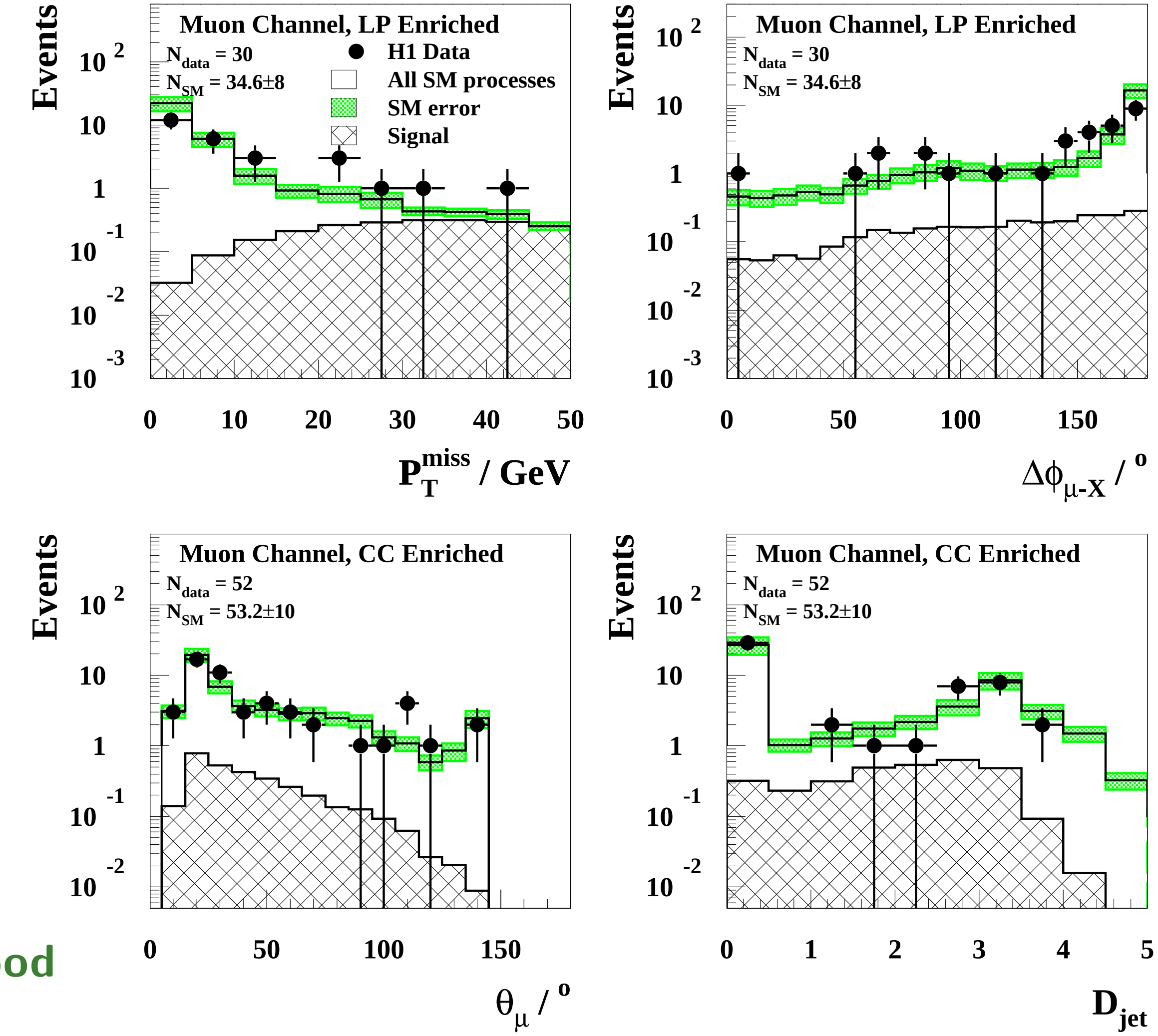
Background studies

$\longrightarrow$ Define *different background samples*, each enriched with important background processes
e.g: muon channel: same phase space $5^\circ < \theta_\mu < 140^\circ$, $P_T^\mu > 10$ GeV and $P_T^{\text{calo}} > 12$ GeV

LP enriched sample:
require at least one isolated muon

CC enriched sample:
require at least one muon,
$\frac{Vap}{Vp} < 0.15$

$\Longrightarrow$ **background well understood**



Isolated leptons and missing P_T

- **H1 e^+p data (105 pb^{-1})**, full HERA I data 1994-2000 – 10 electron & 8 muon combined :

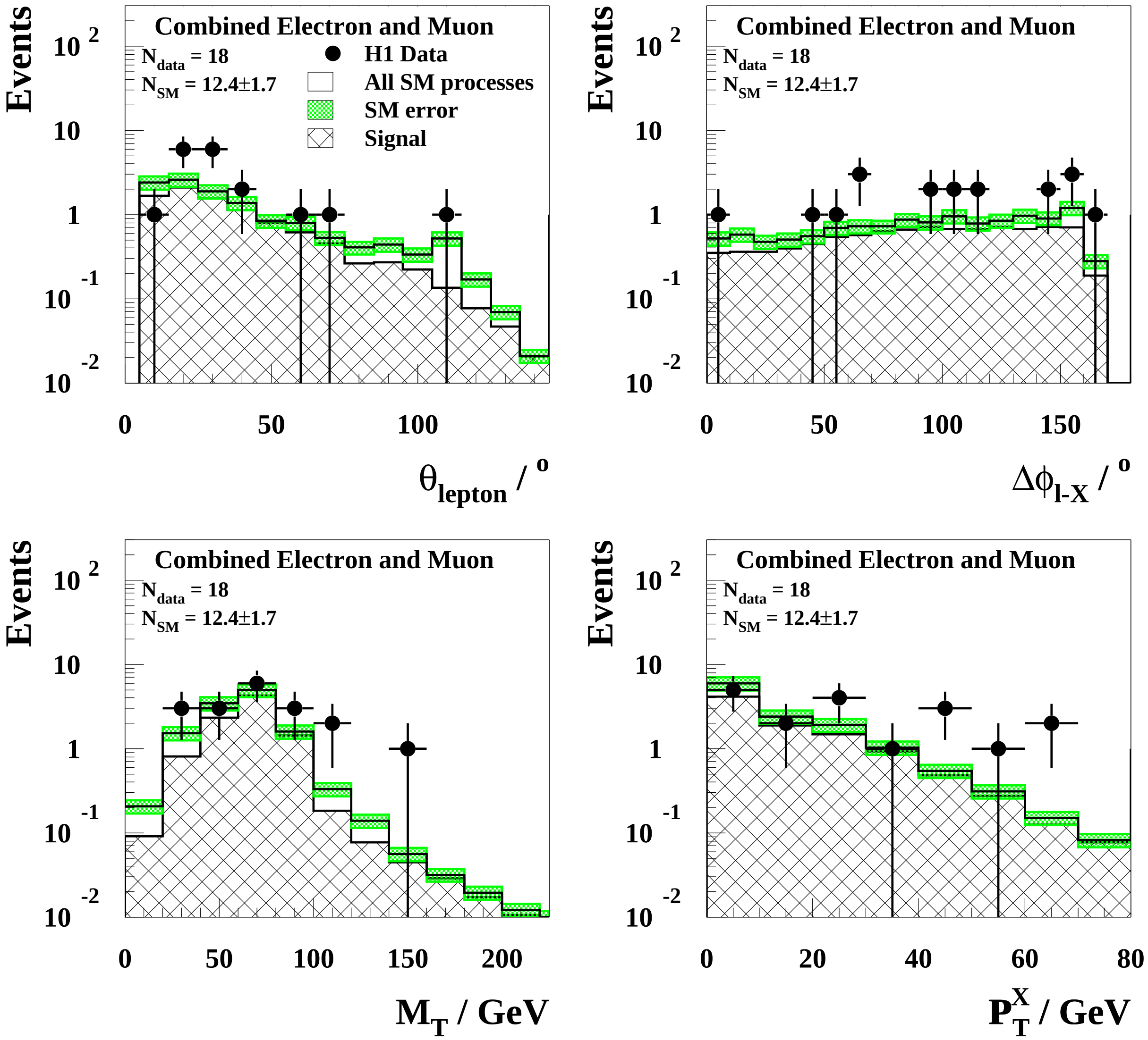
Electron and Muon	H1 Data	SM Total	W Signal	Other SM processes
$P_T^X < 12$ GeV	5	6.40 ± 0.79	4.45 ± 0.70	1.95 ± 0.36
$12 < P_T^X < 25$ GeV	3	3.08 ± 0.43	2.40 ± 0.40	0.68 ± 0.14
$25 < P_T^X < 40$ GeV	4	1.83 ± 0.27	1.59 ± 0.26	0.24 ± 0.06
$P_T^X > 40$ GeV	6	1.08 ± 0.22	0.96 ± 0.22	0.12 ± 0.04

- **H1 e^-p data (14 pb^{-1}) :**

  1 electron event for 1.69 ± 0.22 exp.
  0 muon event for 0.37 ± 0.06 exp.

$\Longrightarrow$ **Overall agreement**

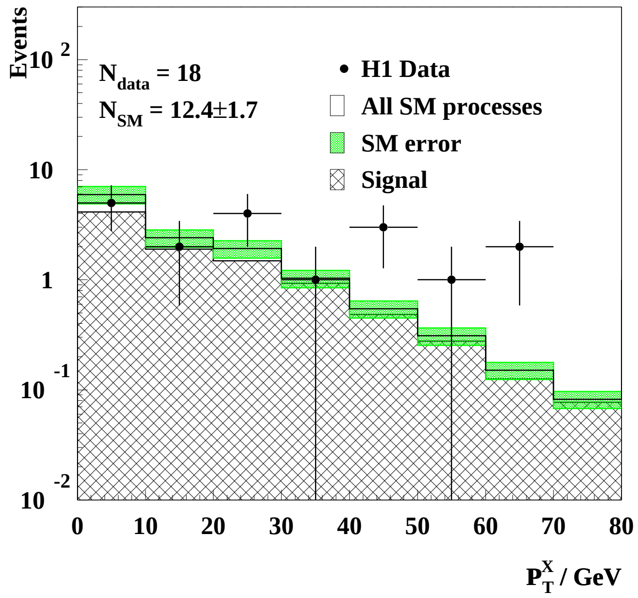
Isolated leptons and missing P_T



Isolated leptons and missing P_T – H1 Excess at high P_T^X

Electron and Muon	H1 Data	SM Total	W Signal	Other SM processes
$25 < P_T^X < 40$ GeV	4	1.83 ± 0.27	1.59 ± 0.26	0.24 ± 0.06
$P_T^X > 40$ GeV	6	1.08 ± 0.22	0.96 ± 0.22	0.12 ± 0.04

$\Longrightarrow$ **H1** sees largest excess at large P_T^X
where background is very small



ZEUS data compatible with expectation in whole P_T^X-range:

ZEUS preliminary 94-00 $e^{\pm}p$ 130 pb^{-1}	Electrons Obs./exp. (W)	Muons Obs./exp. (W)
$P_T^X > 25$ GeV	$2 / 2.90^{+0.59}_{-0.32}$ (45%)	$5 / 2.75^{+0.21}_{-0.21}$ (50%)
$P_T^X > 40$ GeV	$0 / 0.94^{+0.11}_{-0.10}$ (61%)	$0 / 0.95^{+0.14}_{-0.10}$ (61%)

Isolated lepton production cross section

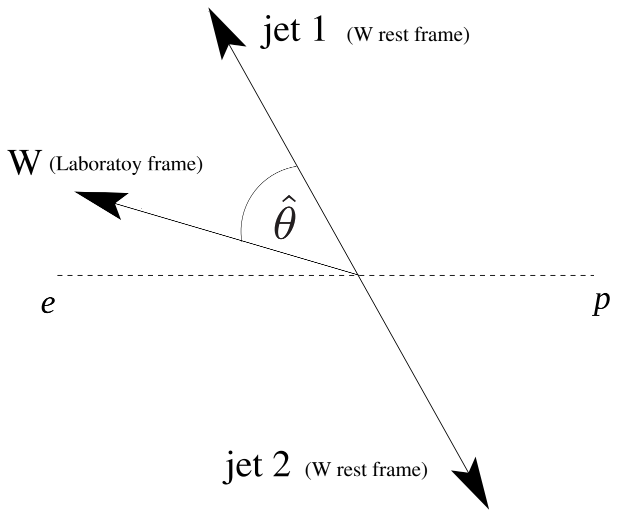
- σ **for all processes** yielding **genuine isolated electrons or muons and** P_T^{miss}
- defined for the **kinematic region** $5^\circ < \theta_l < 140^\circ$, $P_T^l > 10$ GeV, $P_T^{\mathrm{miss}} > 12$ GeV and $D_{jet} > 1.0$ at $\sqrt{s} = 312$ GeV
- **Acceptance** A calculated with W Monte Carlo (EPVEC) accounting for trigger, detection efficiencies, migrations

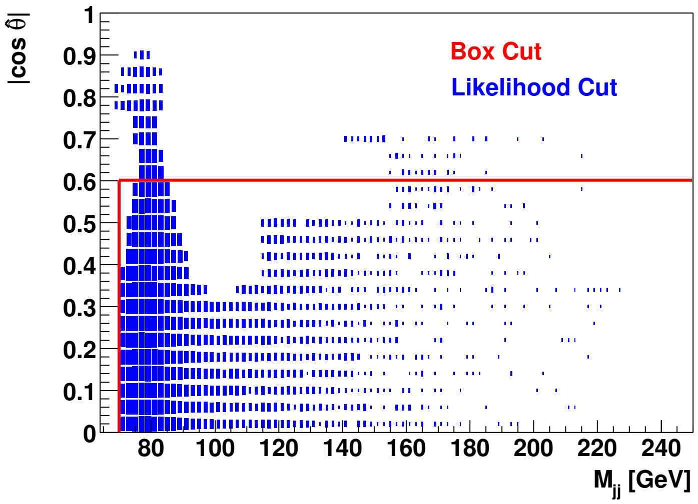
$$\sigma = \frac{(\mathrm{N_{data}} - \mathrm{N_{bgd}})}{\mathcal{L}A}$$

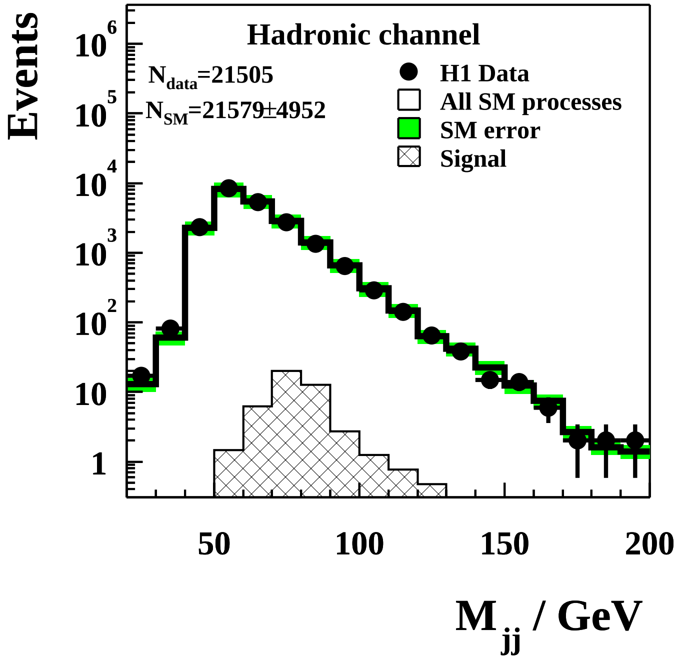
	Cross Section / pb			
	Measured	**SM NLO**	SM LO Diener *et al.*	SM LO Baur *et al.*
$P_T^X < 25$ GeV	$0.146 \pm 0.081 \pm 0.022$	0.194 ± 0.029	0.147 ± 0.044	0.197 ± 0.059
$P_T^X > 25$ GeV	$0.164 \pm 0.054 \pm 0.023$	0.043 ± 0.007	0.041 ± 0.012	0.049 ± 0.015
$P_T^X > 0$ GeV	$0.31 \pm 0.10 \pm 0.04$	0.237 ± 0.036		

Search for W Production in the hadronic channel

- **Assume enhanced W production** can explain the excess $\Longrightarrow$ search in *hadronic* channel
- Large QCD background
- $-0.5 < \eta^{\text{Jet}} < 2.5$
  $p_T^{\text{Jet1,2}} > 25, 20$ GeV
  $p_T^{\text{Jet3}} > 5$ GeV (if 3rd Jet used in M_{jj})
- 2D Likelihood analysis in $(M_{jj}, |\cos\hat{\theta}|)$-plane



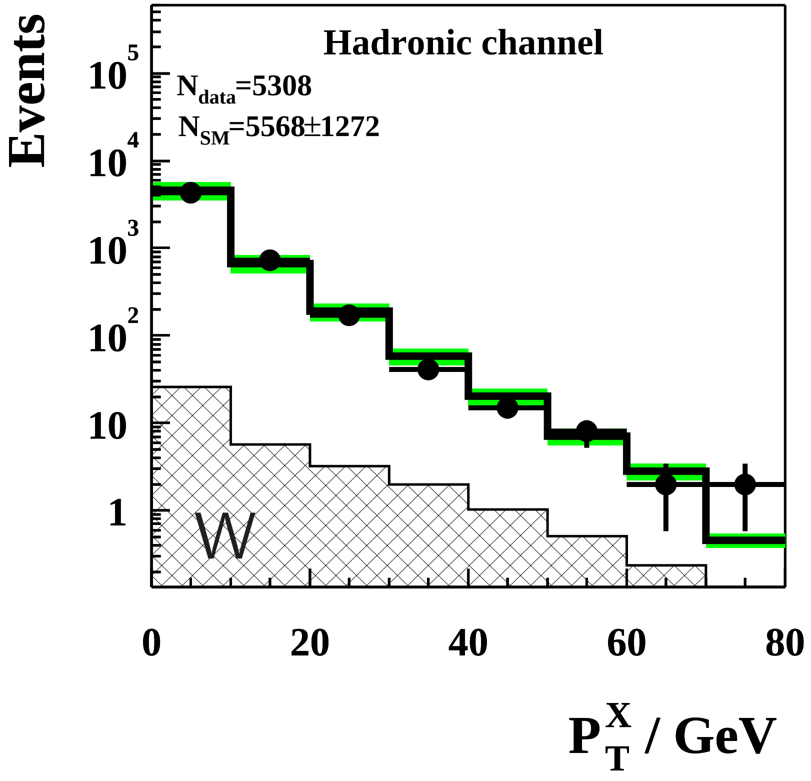




$\Longrightarrow M_{jj} > 70$ GeV and $|\cos\hat{\theta}| < 0.6$

Search for W Production in the hadronic channel

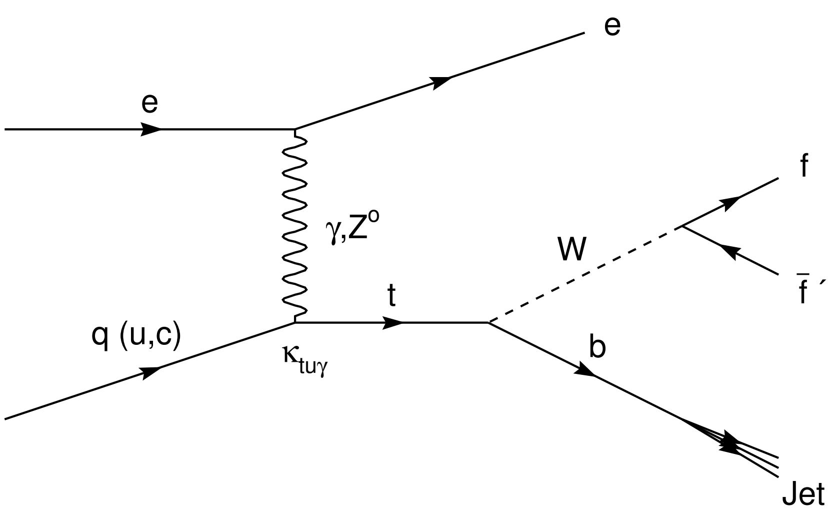
- Good agreement in shape between data and SM over whole P_T^X range
- Normalisation of background derived in *non-signal* region (factor 1.2)
- Increasing sensitivity with increasing P_T^X
- At $P_T^X > 40$ GeV 27 events for 30.9±6.7 expected (1.9±0.4 expected from W production) with an efficiency of 30 %
- No evidence for *enhanced W production* with present statistics
- compatibility between leptonic and hadronic channels at 1.7σ level

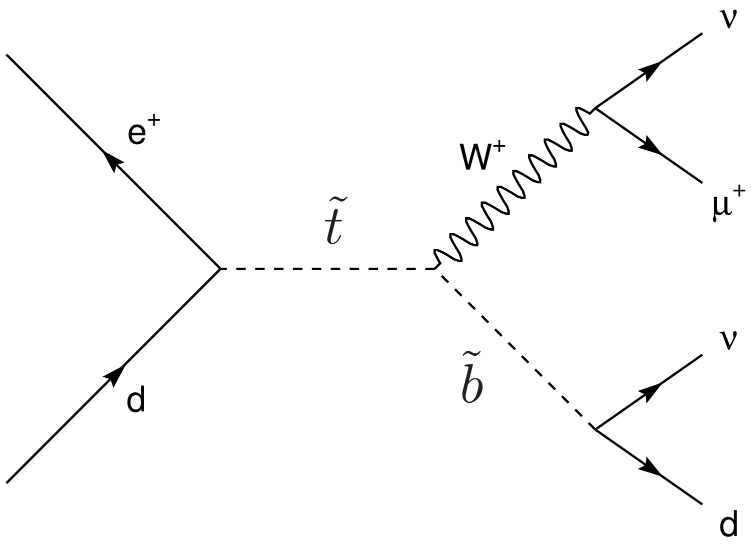


Interpretation?

Beyond the SM, other processes have similar topology, e.g.

FCNC single top production | $R\!\!\!/_p$ **supersymmetry stop production**





$\Longrightarrow$ Both examples expect large hadronic recoil

$\longrightarrow$ see talks on top production (e.g. A. Schöning)

Summary and Outlook

- full HERA I data have been analysed
- Overall number of isolated lepton events agrees with the expectation. However at high P_T^X H1 observes an excess.
- **cross section** for processes yielding genuine electrons and muons and P_T^{miss} has been measured
- No indication of anomalies in the hadronic W decay channel
- Increased Luminosity at HERA II ($leptonic$ and $hadronic$ channels) will help to clarify whether the excess arises from **new physics** or **statistical fluctuation**