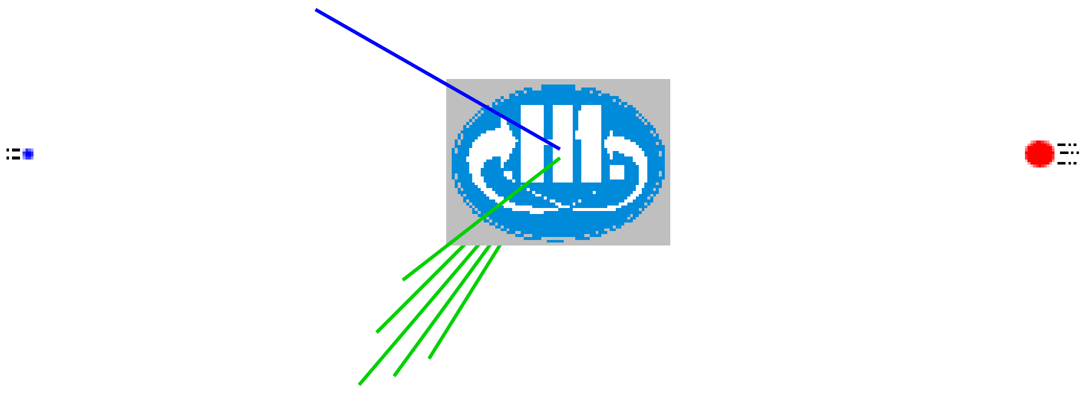
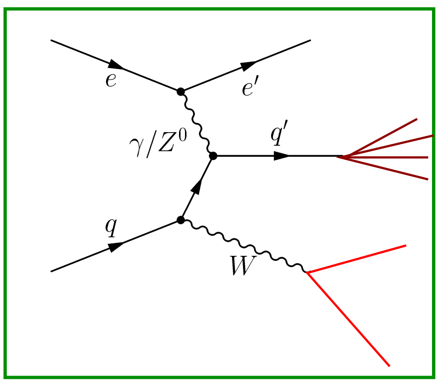
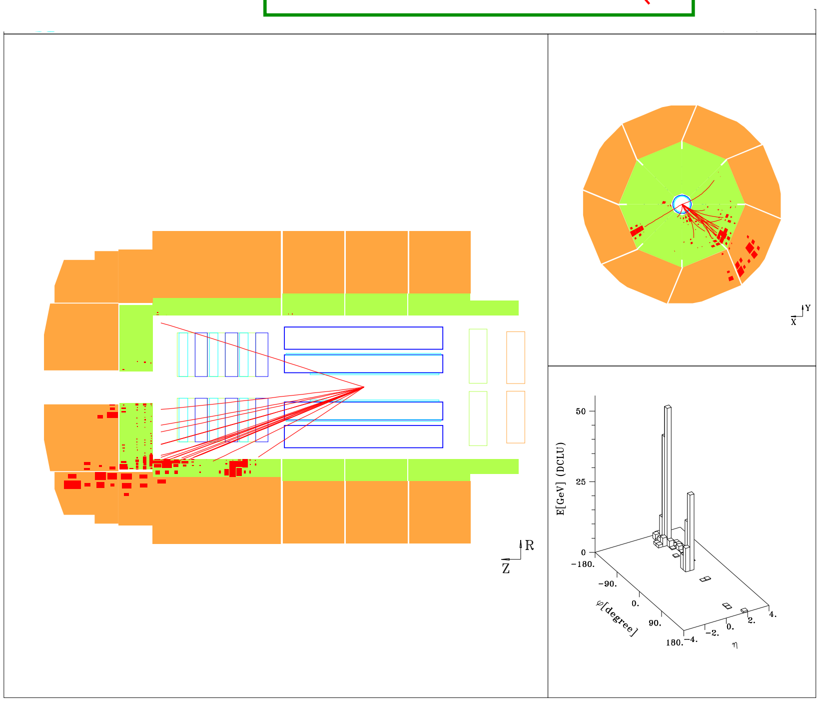
Events with high P_T isolated leptons and missing transverse energy



- Introduction
- $\ell + P_T^{miss}$ events and W production
- Search for anomalous top production
- Conclusions

Standard Model $\ell + P_T^{miss}$ events





- **W mostly photo-produced → low(ish) P_T**
  P_T^W is measured from hadrons $= P_T^X$
- **Standard Model (QCD LO) $\sigma(ep \to eW^{\pm}X) \simeq 1.2pb^{-1}$**
- **HERA experiments accumulated 120 pb^{-1}/exp.**
  ~ 30 events already produced in each detector

H1: 1994-1997 e^+p data

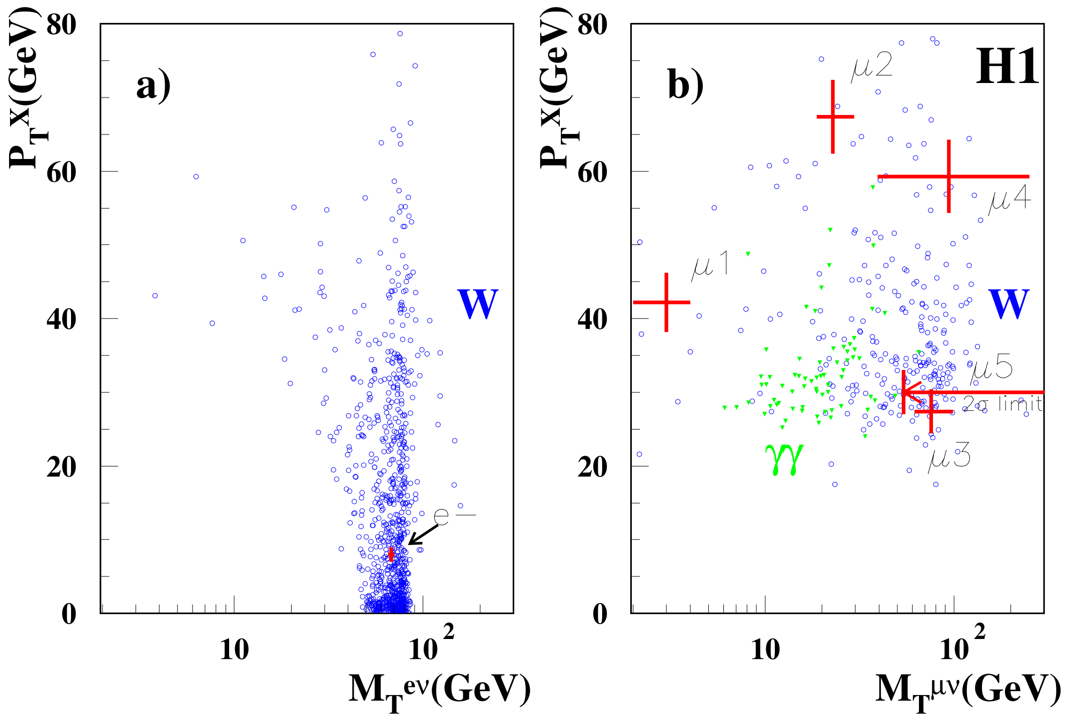
Searches for events with isolated leptons and missing P_T
Lumi (data)=36.5 pb^{-1}

$P_T^{calo} > 25$ GeV and $P_T^{\ell} > 10 GeV$

1 e^- cf 2.4 ± 0.5 SM

5 $\mu^{\pm}$ cf 0.8 ± 0.2 SM

Lumi (MC) $= 500\times$ Lumi(Data)



3 atypical events @ high P_T^X ; first one already seen in 1994

Optimized search for $\ell + P_T^{miss}$ (W)

Basic Cuts

Variable	Requirement
Lepton transverse momentum P_T^ℓ	> 10 GeV
Lepton polar angle θ_ℓ	$5^o < \theta_l < 145^o$
$\eta - \phi$ distance to closest jet D_{jet}	> 1.0
Calorimetric P_T^{calo}	> 12 GeV
P_T^{miss}	> 12 GeV

μ channel restricted to $P_T^X > 12$ GeV (trigger)

Backgrounds for $\ell + P_T^{miss}$ search

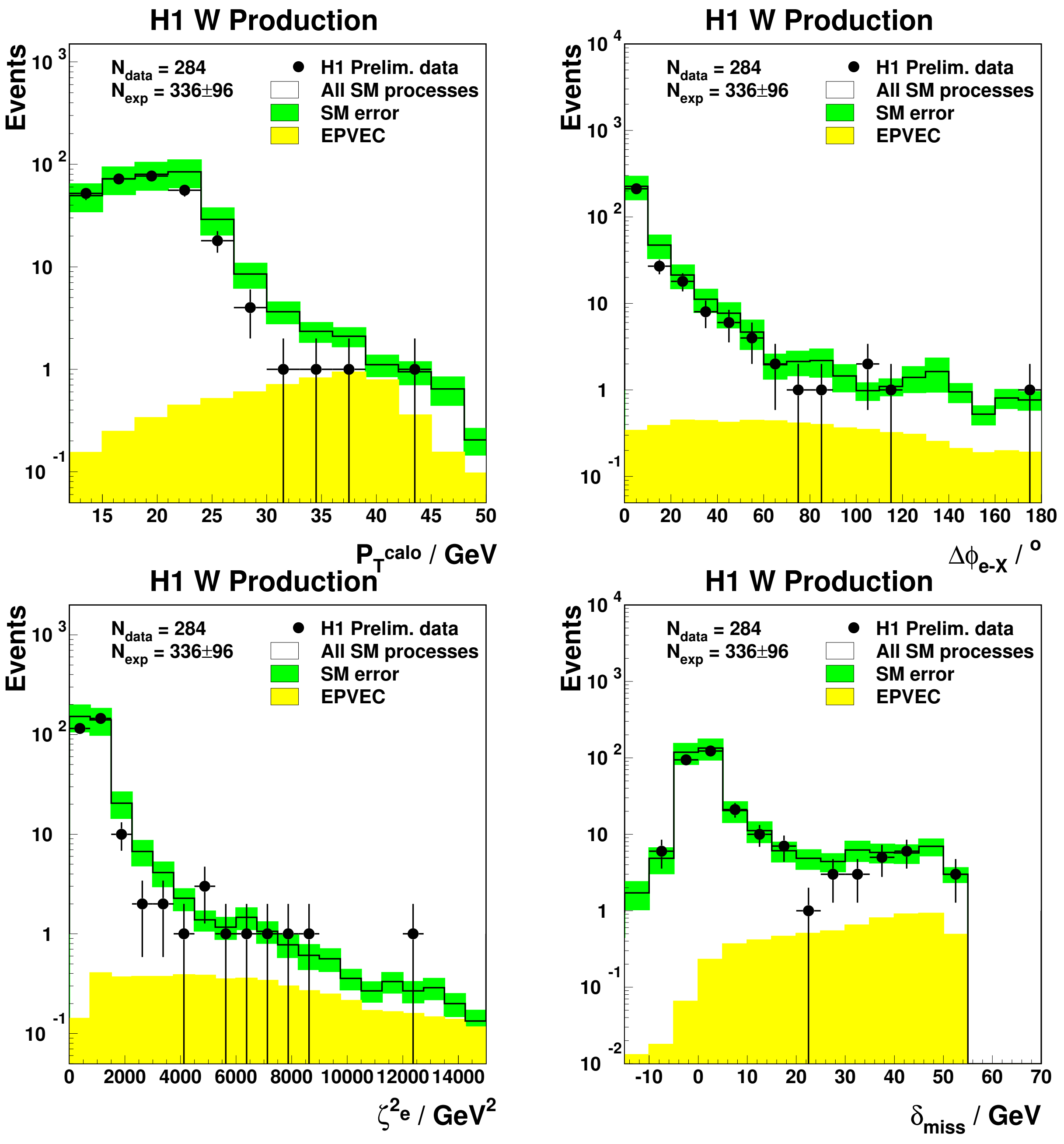
- No P_T^{miss} but true leptons: NC, $\gamma\gamma \to \ell^+\ell^-$, $\gamma - p$
- No lepton but genuine P_T^{miss} : CC

Additional variables used against backgrounds:

		W	Non-W
Acoplanarity	$\Delta\phi(\ell - X)$	flat	$\simeq 0$ (NC,γp,$\gamma\gamma$)
Balance in z direction	$\delta = 2 * E_e^0 - (E - Pz)$	flat	$\simeq 0$ (NC,$\gamma\gamma$)
Fraction of energy in the $\vec{P_T}^{miss}$ direction	V_{ap}/V_p	$\simeq 0$	$\simeq 0.5$ (NC,γp)
ζ^2	$= Q^2$ (e channel)	flat	small (NC)
Calo isolation (e)	$E_h^{coneR=1}/E_e$	$\simeq 0$	> 0 (CC,γp)
Track isolation	D_{track}	flat	small (CC,γp)

Control sample in electron channel

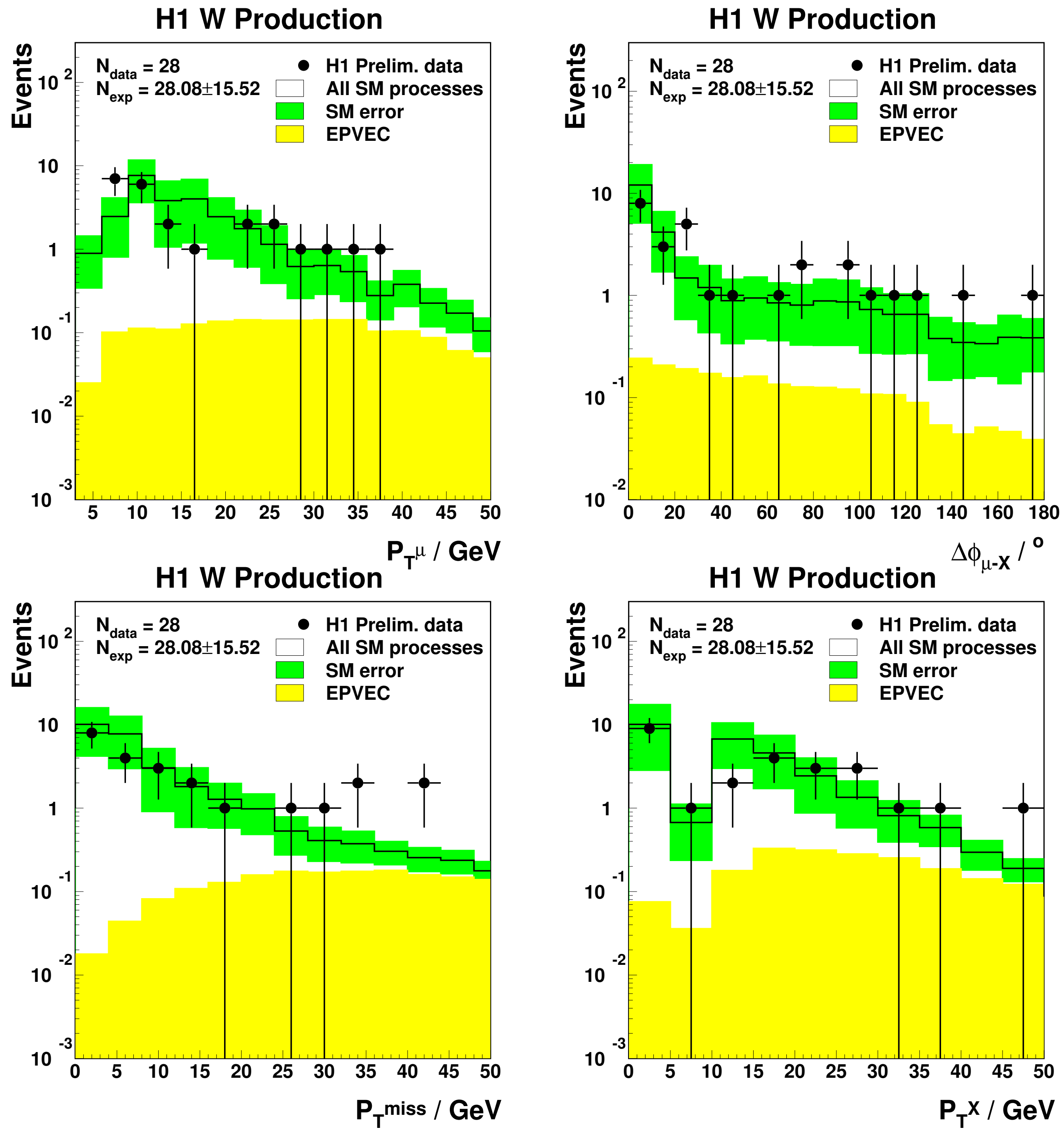
Selection: Basic cuts and $V_{ap}/V_p < 0.15$ for $P_T^e < 25$ GeV



$284/336 \pm 96$ **Non-W contribution dominated by NC process**

Control sample in muon channel

Selection: Basic cuts without P_T^{miss} cut and with $P_T^{\mu} > 5$ GeV



$28/28 \pm 15$ Non-W contribution dominated by $\gamma\gamma \to \mu^+\mu^-$

Selection Requirement specific to each channel

Variable	Electron	Muon
ζ^2	> 500 GeV^2 > 5000 GeV^2 for $P_T^{\rm calo} < 25$ GeV	- -
$\frac{V_{ap}}{V_p}$	< 0.5 (< 0.15 for $P_T^e < 25$ GeV)	< 0.4 (< 0.15 for $P_T^{\rm calo} < 25$)
D_{track}	> 0.5 for $\theta_e \geq 45^o$ > 0.5 for $\frac{E_{cone}}{E^l} > 0.05$	> 0.5
P_T^X	-	> 12 GeV
$\Delta\phi_{e-X}$	$> 20^o$	$> 10^o$ for ≤ 2 central tracks
# μ	0	1
δ_{miss}	> 5 GeV †	-

† *if only one e candidate is detected, which has the same charge as the beam lepton.*

Results

New Data since Osaka: extra 20 pb^{-1} e^+p @ $\sqrt{s} = 320$ GeV
4 new W candidates in e-channel (1e$^+$ @ $P_T^X > 25$ GeV)

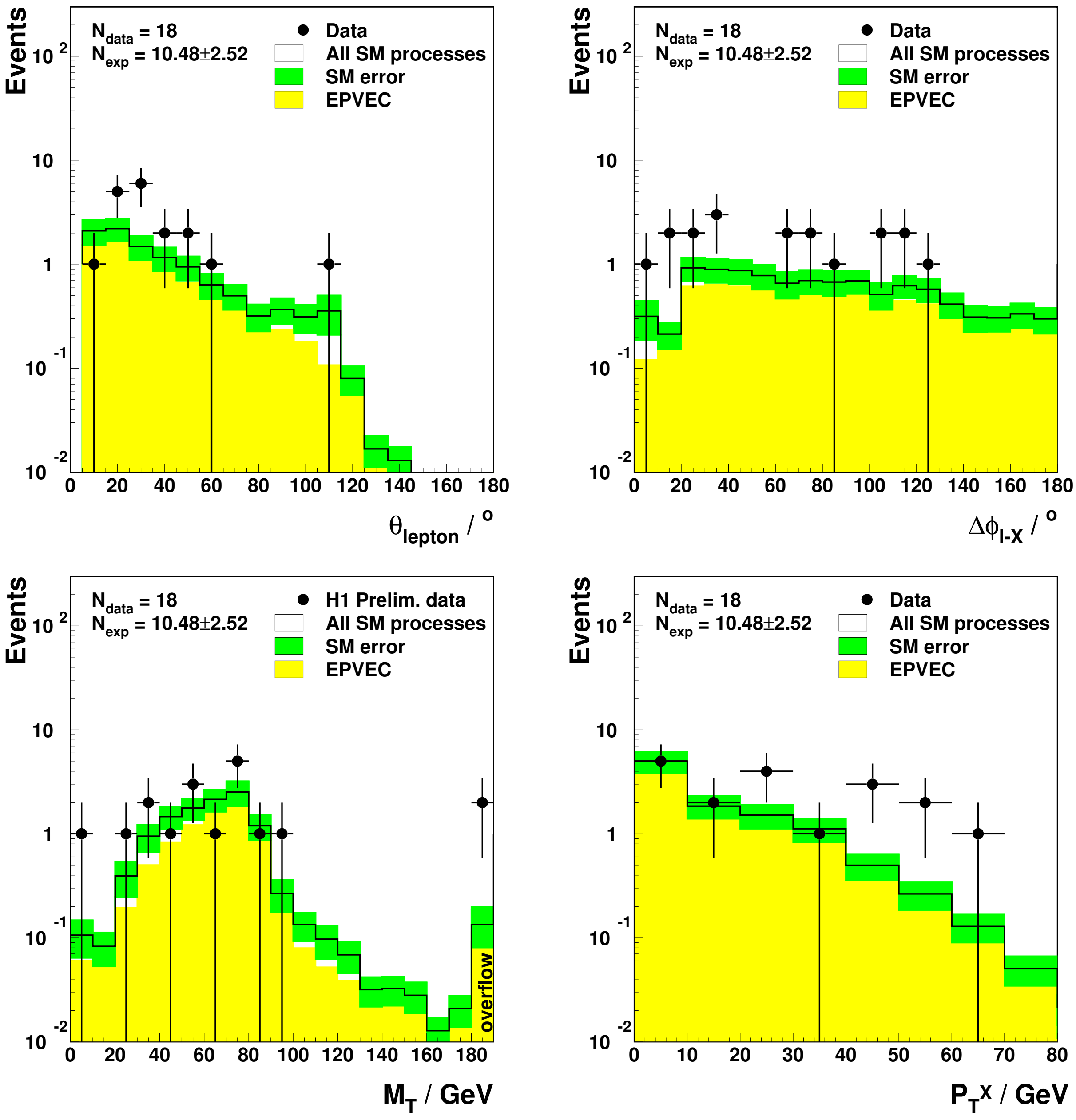
H1 94-00 e+p 101.6 pb^{-1}	Electrons	Muons	e+μ combined
$P_T^X > 0$ GeV	10 / 7.9 ± 1.9 6_{Osaka}	8 / 2.6 ± 0.7	18 / 10.5 ± 2.5 (only W 8.2)
$P_T^X > 12$ GeV	5 / 2.6 ± 0.7 4_{Osaka}	8 / 2.6 ± 0.7	13 / 5.1 ± 1.3 (only W 4.2)
$P_T^X > 25$ GeV	4 / 1.3 ± 0.3 3_{Osaka}	6 / 1.5 ± 0.4	10 / 2.8 ± 0.7 (only W 2.3)
$P_T^X > 40$ GeV	2 / 0.4 ± 0.1 2_{Osaka}	4 / 0.6 ± 0.2	6 / 1.0 ± 0.3 (only W 0.93)

@ high $P_T^X > 25$ GeV : 10/2.82±0.73

94-97 data	36.5 pb^{-1}	5 events	5μ $(2^+, 2^-, 1^?)$
99-00 data	65.1 pb^{-1}	5 events	4 e$^+$ and 1 μ^+

H1 98-99 e^-p (13.6 pb^{-1}) Data: 0 SM: 1.78
(e:1.46 ± 0.30 μ:0.32 ± 0.09)

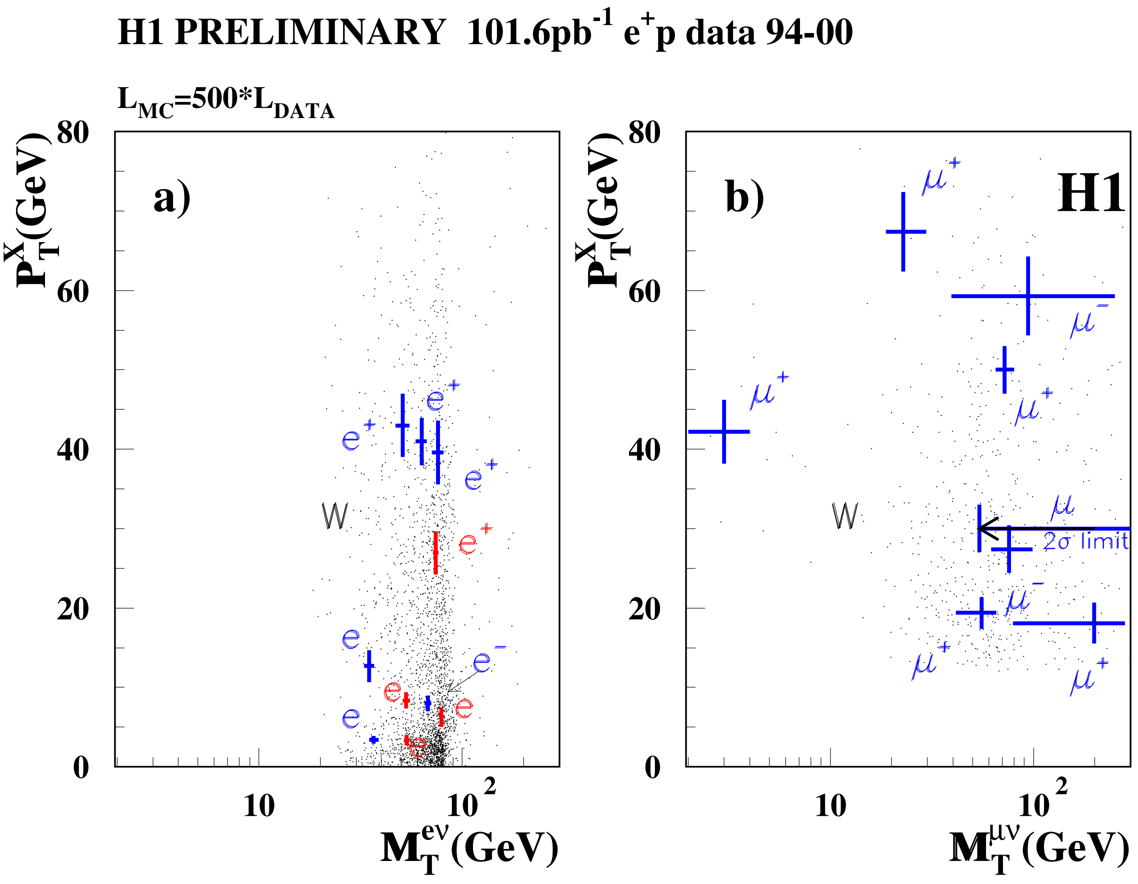
W candidates (e and μ)



@ $P_T^X > 25$ GeV: 10 events (2.8 expected)

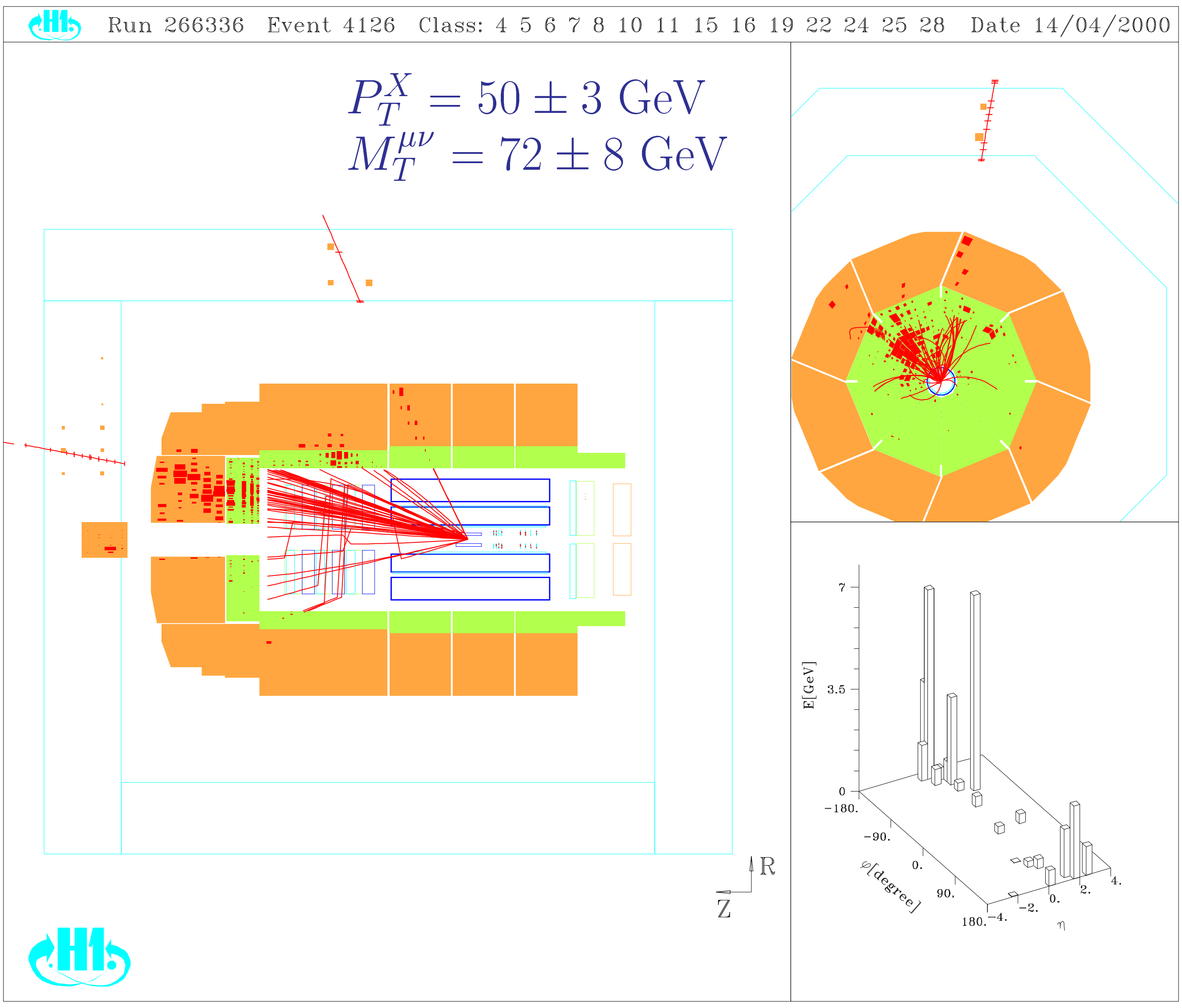
Selected events compared with W production in $M_T^{\ell\nu}$–P_T^X plane

$$M_T^{\ell\nu} = \sqrt{(|\vec{P_T^\ell}| + |\vec{P_T^\nu}|)^2 + (\vec{P_T^\ell} + \vec{P_T^\nu})^2}$$

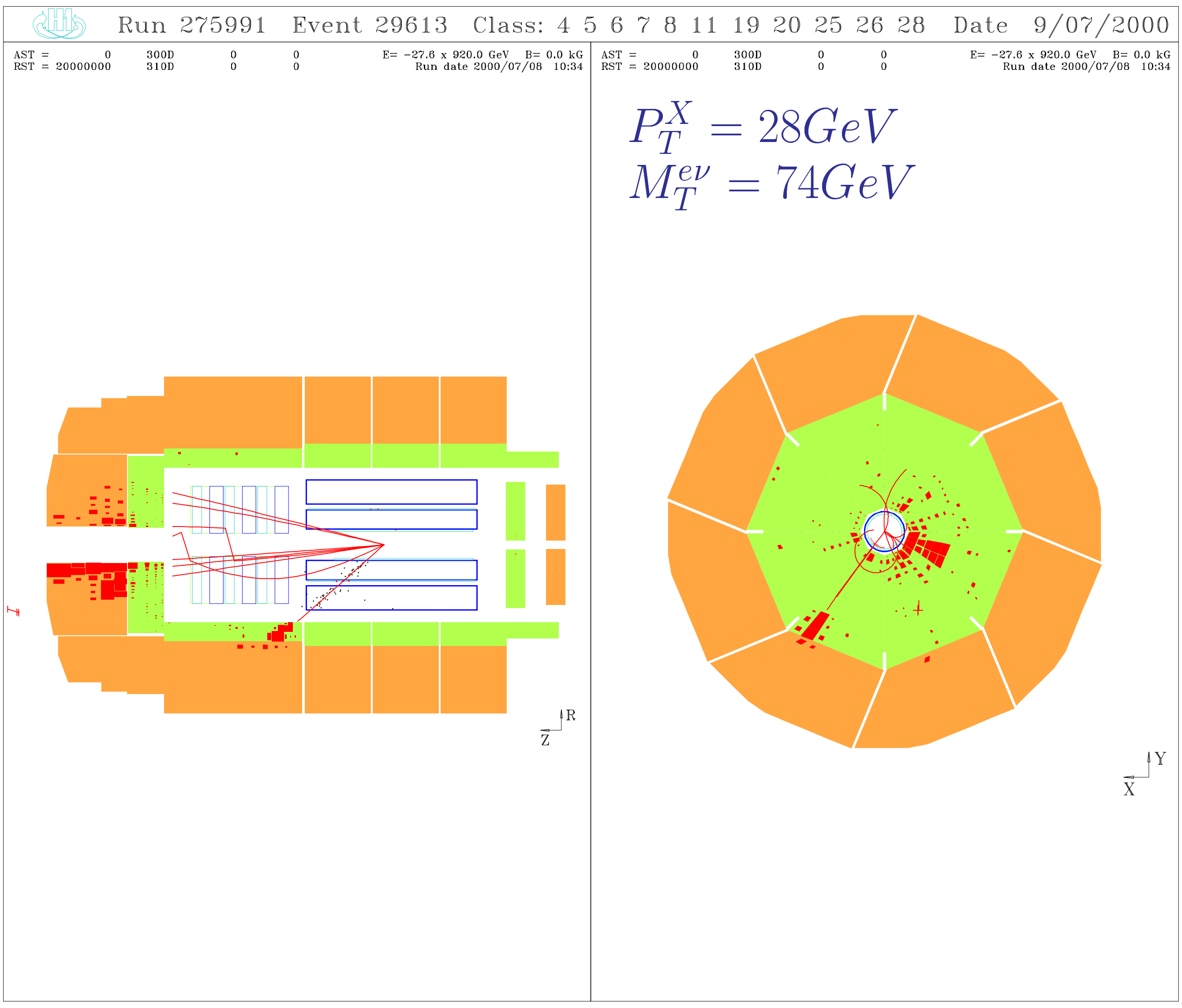


C.Diaconu C.P.P.Marseille

2000 Data $W \to \mu\nu$ candidate @ high P_T

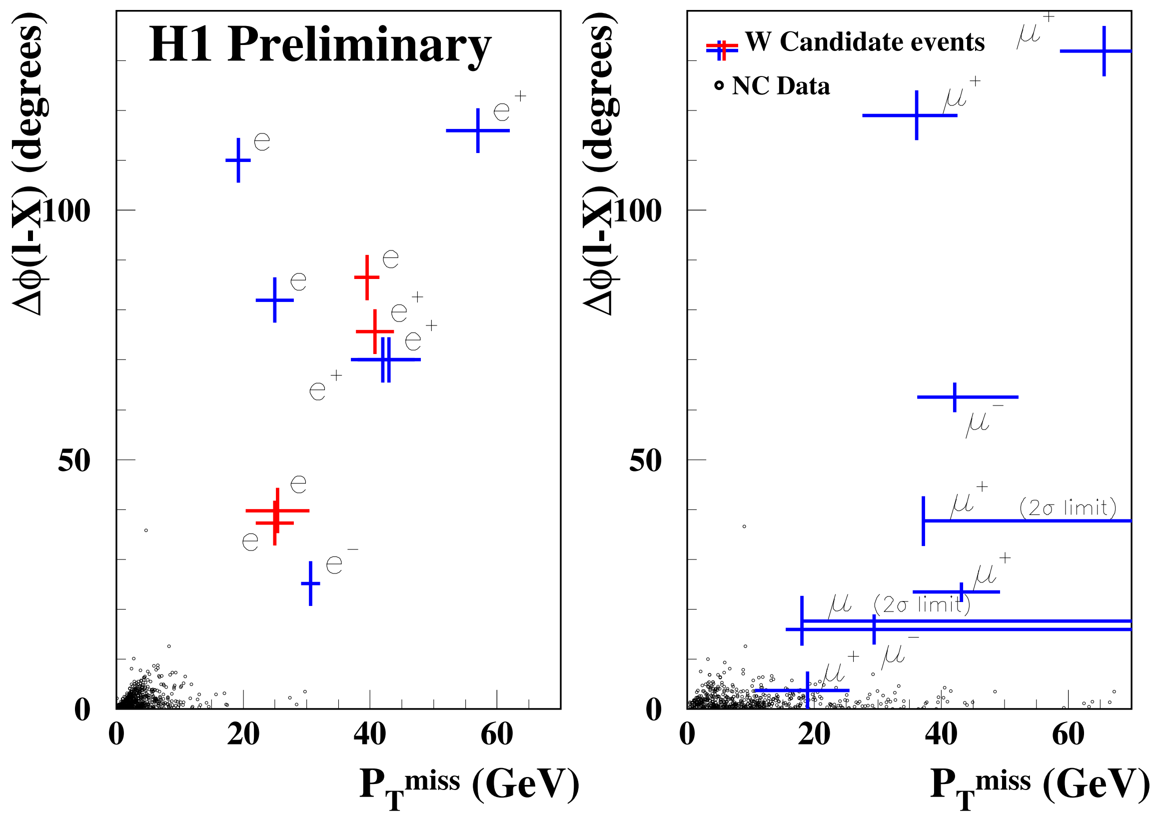


New $W \to e\nu$ candidate @ high P_T



Genuine missing particle?
A resolution study with data

Resolution study using NC data



Comparison ZEUS-H1

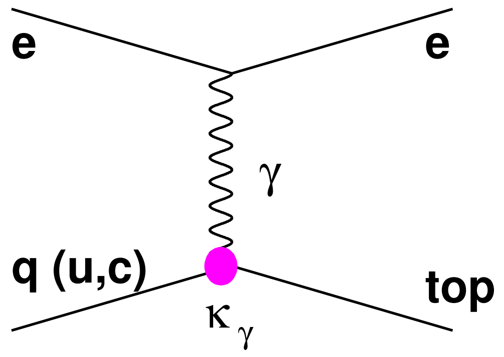
H1	(101.6 pb^{-1}) e^+p data **only**	18/10.5 (8.2 from W only)	High Purity/Efficiency for $\ell + P_T^{miss}$ events
H1	(115.2 pb^{-1}) $e^{\pm}p$ data	18/12.3 (9.4 from W only)	
ZEUS	(130 pb^{-1}) $e^{\pm}p$ data	17/16.4 (4.0 from W only)	Inclusive sample of lepton events

When the same phase space is selected @ $P_T^X > 25$ GeV, same angular range (H1) and Inforced non-W rejection (ZEUS)

H1	(82 pb−1 Osaka)	9/1.8 (1.5 from W)
ZEUS	(130 pb^{-1})	2/2.4 (2.1 from W)

- **SM expectations are in agreement**
  we do expect same rate of $\ell + P_T^{miss}$ SM events
- **H1 sees more events at high P_T^X**
  ZEUS has the acceptance to detect such events
- **Statistical fluctuation? More data soon...**
- **Events with interesting topology and kinematics observed by both H1 and ZEUS.**

Anomalous top production at HERA



$t \to bW(\to \ell\nu)$ $\longrightarrow$ **lepton+high P_T jet + P_T^{miss}**

$t \to bW(\to q\bar{q}')$ $\longrightarrow$ **3 high P_T jets**

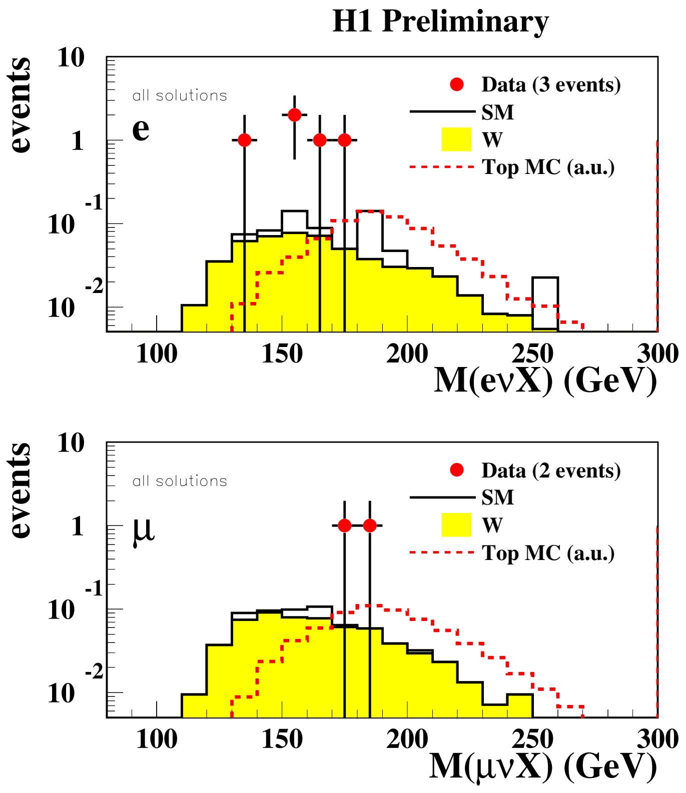
$$\mathcal{L} = \frac{e}{\Lambda}\left[\bar{t}\sigma_{\mu\nu}q^{\nu}\kappa_{\gamma ut}uA^{\mu}\right]$$

another convention $\kappa^0_{\gamma ut} = 1/q_u\kappa_{\gamma ut} = 3/2\kappa_{\gamma ut})$

Top: leptonic channel

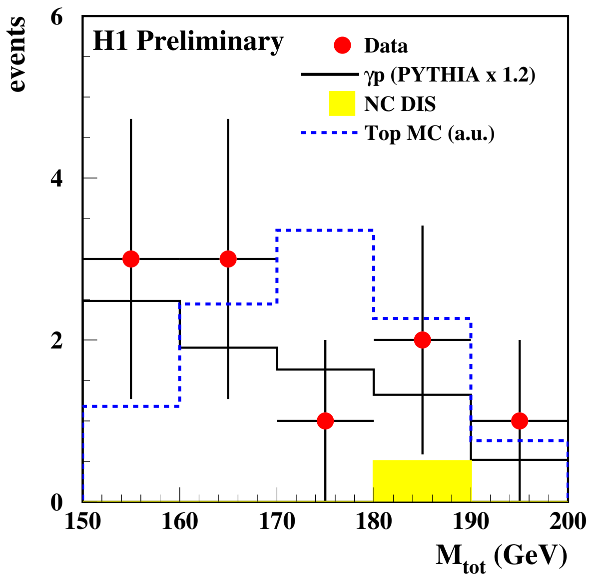
- $P_T(jet) > 35(25)$ GeV for $\theta(jet) < (>)35°$
- $M_T^{\ell\nu} > 10$ GeV
- Reject -ve charged leptons

5 top candidates (3e+2μ) for 1.4 ± 0.5 expected.



Top: hadronic channel

- **3 jets** $P_T(jet1,2,3) > 25, 15, 10$ **GeV and** $E_T(tot) > 120$ **GeV**
- $70 < M_{ij} < 90$ **GeV,** $150 < M(tot) < 190$ **GeV**



10 top candidates for $8.3^{+5.9}_{-4.6}$ **expected.**
From observed hadronic candidate events
$\longrightarrow N_{t\to\ell} < 10.0$ **@95% C.L. 5** ℓ **Observed**

Combining leptonic and hadronic channel

$\kappa_{\gamma ut} < 0.25$ **@ 95% C.L.**

Competitive with LEP (0.45 for $\kappa_Z = 0$**) and Tevatron (0.28).**

$((\kappa^0_{\gamma ut} = 3/2\kappa_{\gamma ut})\ \kappa^0_{\gamma ut} < 0.38(0.25)$ @ 95% C.L. in $\mathrm{H1}_{LO}(\mathrm{ZEUS}_{NLO}))$

Conclusions

- Events with isolated leptons and missing transverse momentum have been observed at HERA by both H1 and ZEUS.
- Most likely SM explanantion: W production
- 101.6 pb^{-1} e^+p data: 18 (e,μ) / 10.5 $\pm$2.5 (8.2 from W only)
  13.6 pb^{-1} e^-p data: 0 (e,μ) / 1.8 $\pm$0.4 expected
- @ $P_T^X > 25$ GeV : 10 / 2.8$\pm$0.7
- With similar acceptance at high $P_T^X > 25$ GeV ZEUS sees no excess 2/2.43.
- Search for anomalous top production
  HERA has discovery potential with respect to LEP and TEVATRON
  Competitive limit on $\kappa_{\gamma ut}$ electromagnetic coupling.
- Eagerly waiting for next hundreds of pb^{-1} at HERA...