Events with isolated high P_T leptons and missing E_T detected with the H1 detector at HERA.
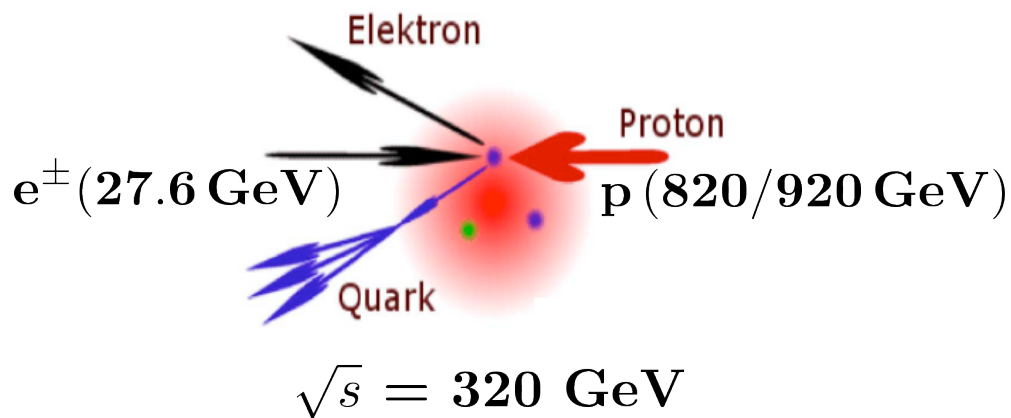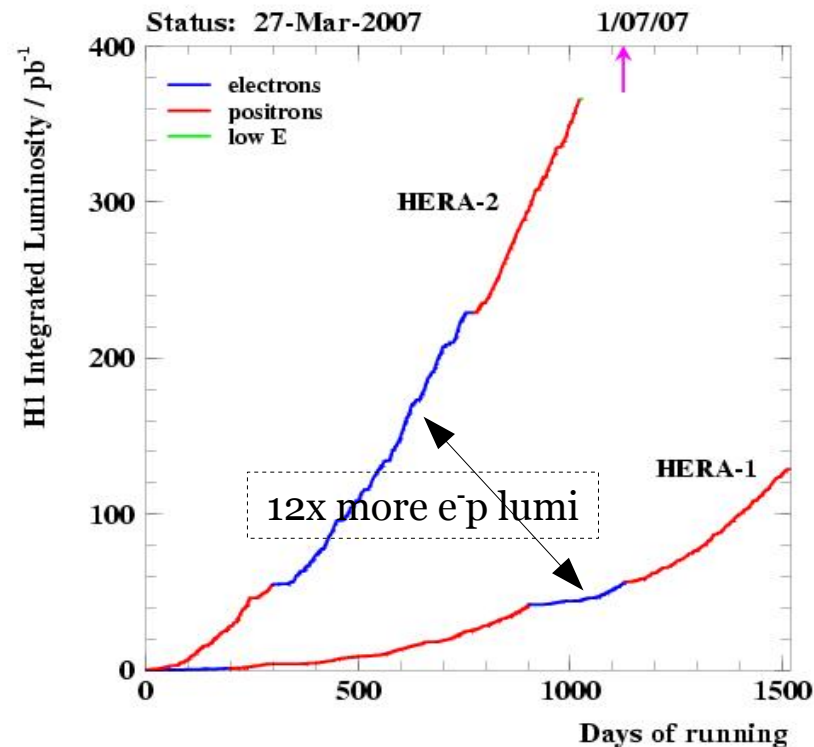
Ytsen de Boer (ITEP)

On behalf of the H1 collaboration.

- HERA and H1
- Electron/Muon channel
- Results
- Comparison H1 and ZEUS
- Tau channel
- Results
- Summary

DIS 2007
April 16-20, 2007, Munich, Germany

XV International Workshop on Deep-Inelastic Scattering and Related Subjects

HERA and H1

Status: 27-Mar-2007   1/07/07

- electrons
- positrons
- low E

HERA-2

HERA-1

12x more e⁻p lumi

$e^{\pm}\,(27.6\,\text{GeV})$ $p\,(820/920\,\text{GeV})$

Elektron

Proton

Quark

$$\sqrt{s} = 320\ \text{GeV}$$

HERA I (1994-2000)   HERA II (2003-2007)

· $e^{+}p \sim 105\ \text{pb}^{-1}$ · $e^{+}p \sim 188\ \text{pb}^{-1}$

· $e^{-}p \sim\ 14\ \text{pb}^{-1}$ · $e^{-}p \sim\ 170\ \text{pb}^{-1}$
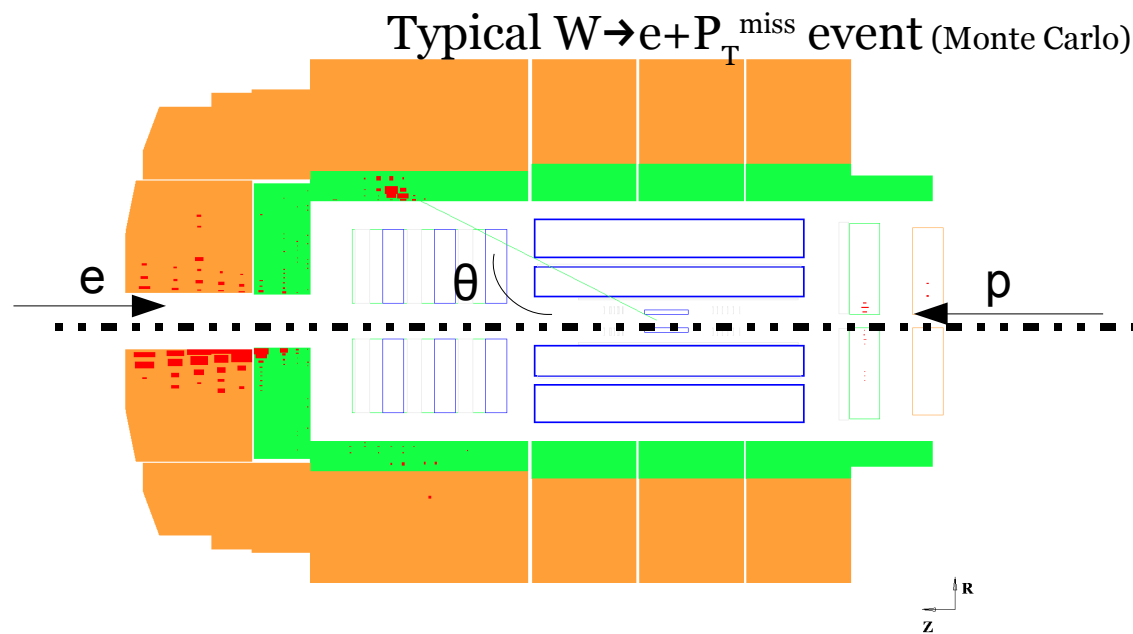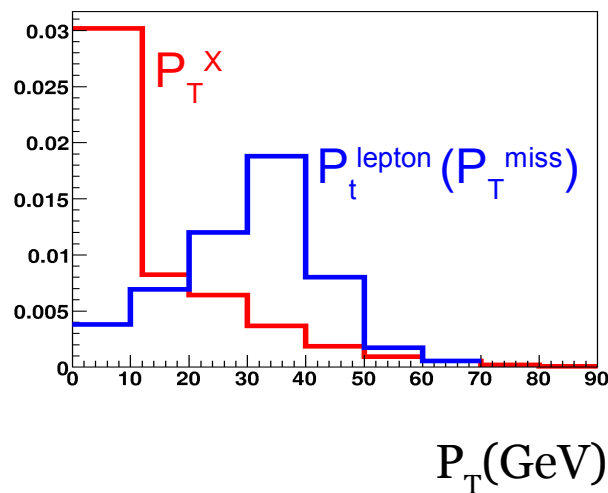
Total lumi ~ 478 pb⁻¹

Isolated Electron/Muon Analysis
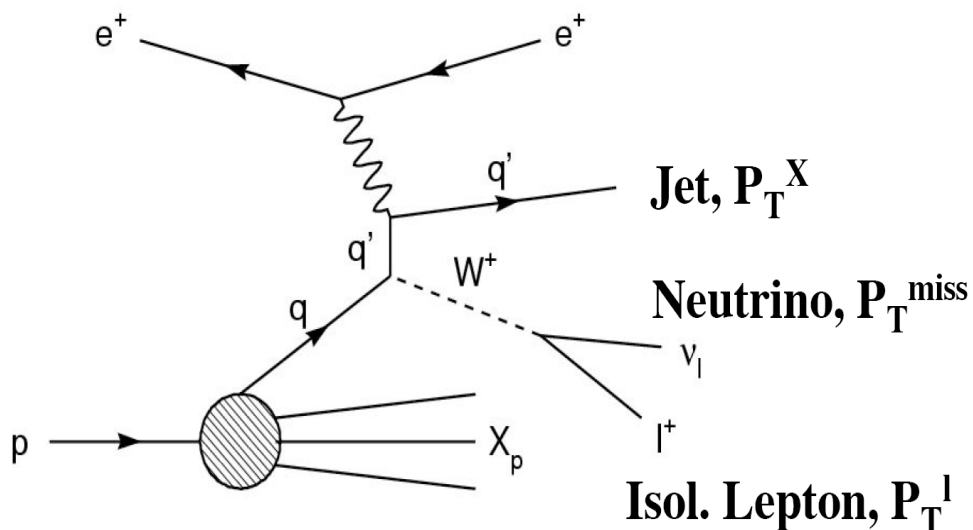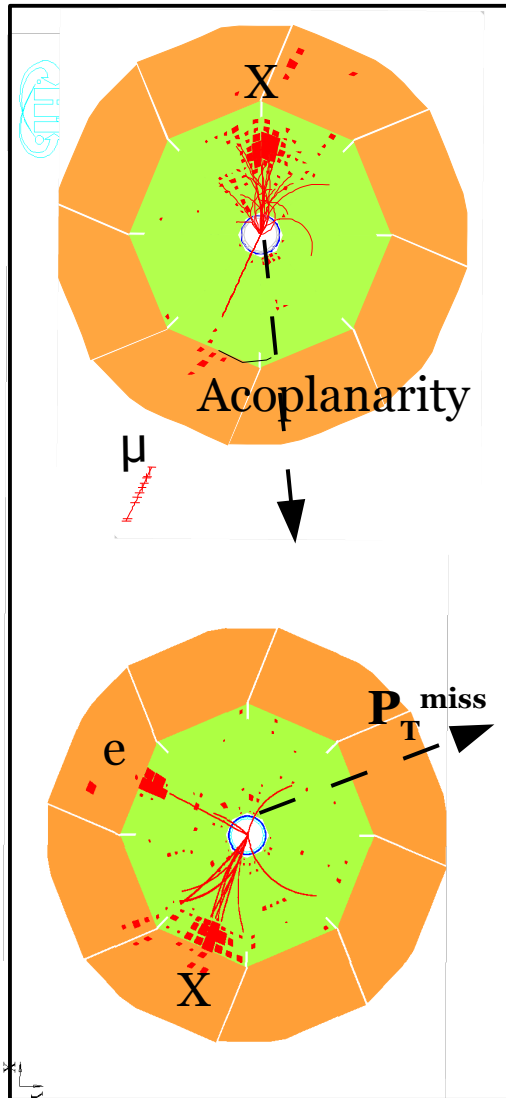
Main SM signal contribution:
- Real W production cross section ~ 1 pb
- W decays leptonically,
  branching ratio 10% per lepton

EPVEC Generator U.Baur at al.,
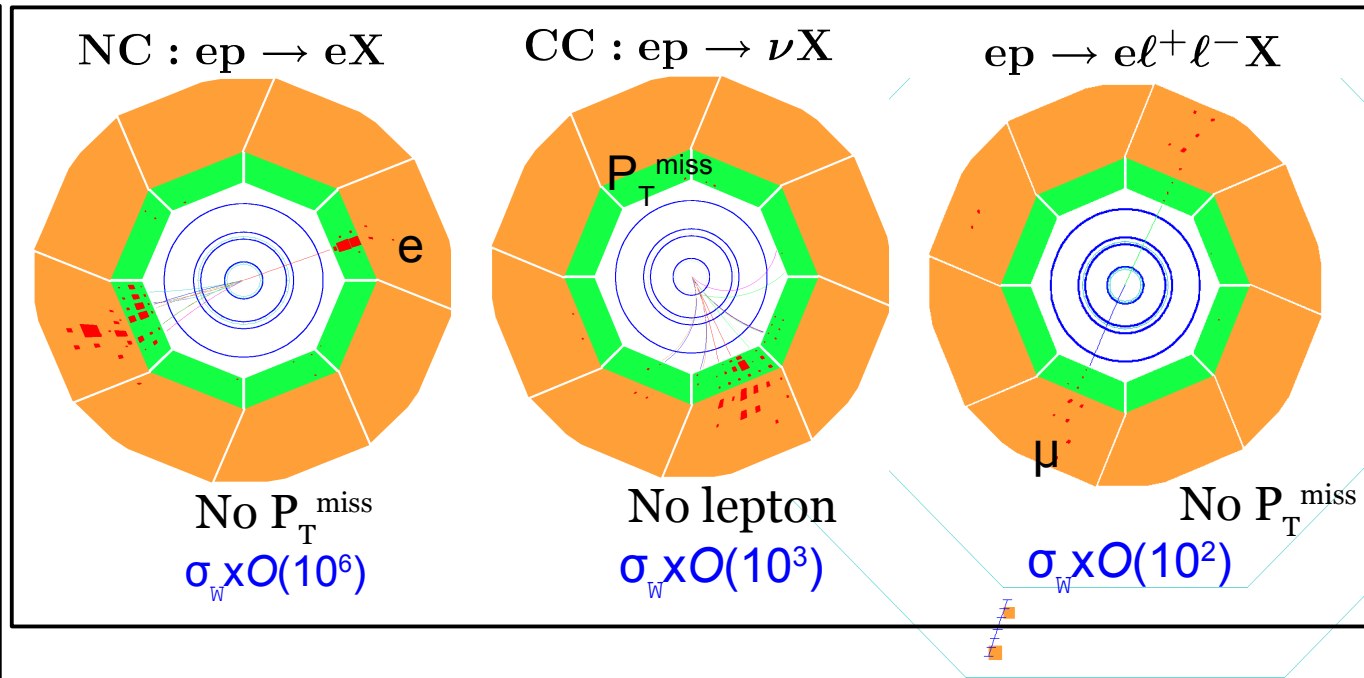**Nucl.Phys.B375:3(1992)**
+NLO K.P.Diener etal. EPJ.C25,405(2002))

Jet, P_T^X

Neutrino, P_T^{miss}

Isol. Lepton, P_T^l

Typical $W \to e + P_T^{miss}$ event (Monte Carlo)

$P_T(GeV)$

Signal/Background seperation

Signal

X

Acoplanarity

μ

↓

P_T^{miss}

e

X

Backgrounds

NC : ep → eX

No P_T^{miss}

$\sigma_W \times O(10^6)$

CC : ep → νX

P_T^{miss}

No lepton

$\sigma_W \times O(10^3)$

ep → eℓ⁺ℓ⁻X

μ

No P_T^{miss}

$\sigma_W \times O(10^2)$

Based on topologies define detection phase space:
$P_t^l > 10$ GeV, $P_T^{miss} > 12$ GeV, theta in $[5, 140]°$

Reduces most of the background

Further background supression using:
- lepton isolation D_{track}, D_{Jet}
- event balance (Acoplanarity)
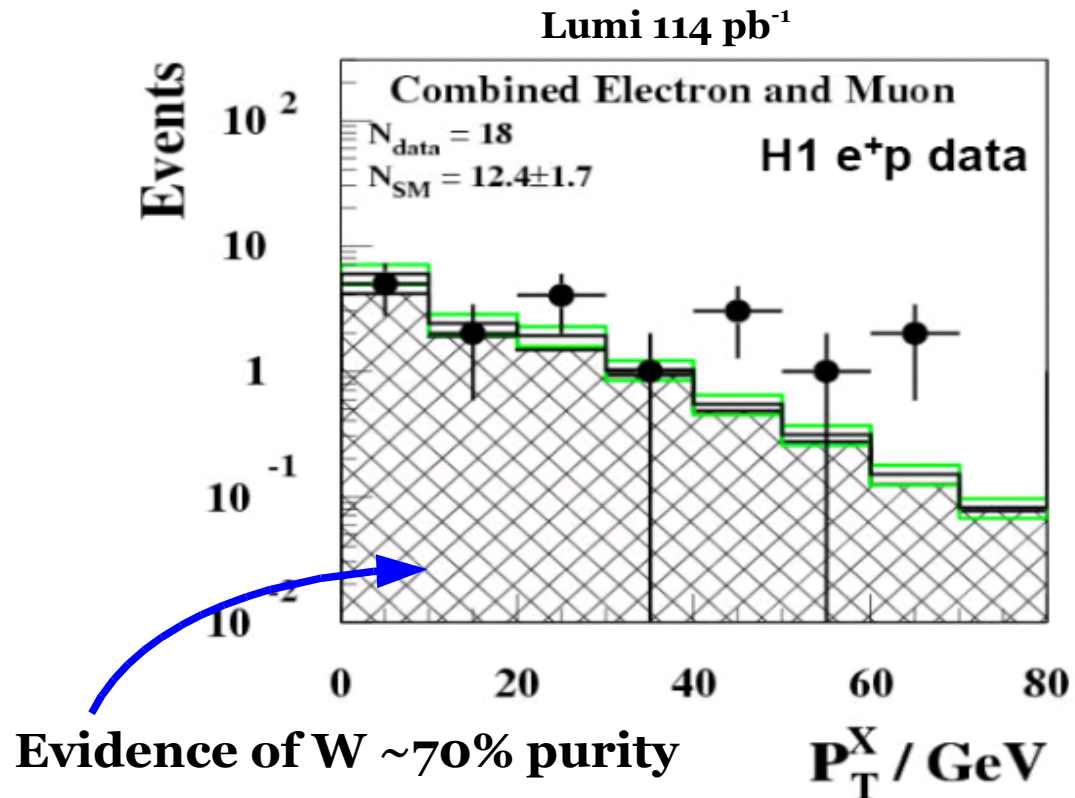- other kinematical and topological variables

Reminder: Main Results HERA I

Phys. Lett. B561 (2003) 241

In the e^+p data for $P_T^X > 25$ GeV (atypical of W)

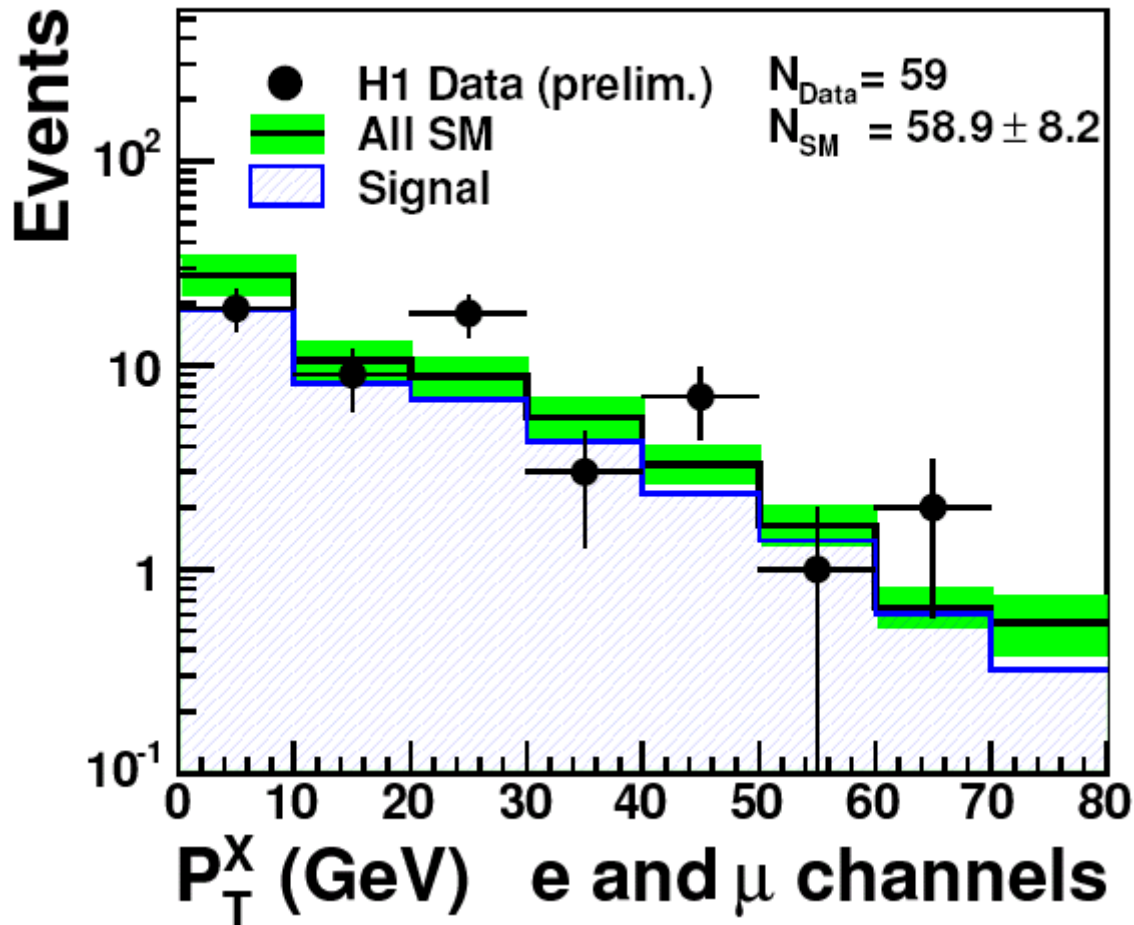**10 events observed**

**2.91 expected**

which corresponds to a 3 sigma excess.

Lumi 114 pb^{-1}

Combined Electron and Muon

$N_{data} = 18$
$N_{SM} = 12.4 \pm 1.7$

H1 e^+p data

Events

P_T^X / GeV

Evidence of W ~70% purity

HERA I+II Results

I+P_T^{miss} events at HERA I+II ($e^{\pm}p$, 478 pb^{-1})

- H1 Data (prelim.) N_{Data} = 59
- All SM N_{SM} = 58.9 ± 8.2
- Signal

Events

10^2

10

1

10^{-1}

0 10 20 30 40 50 60 70 80

P_T^X (GeV)   e and μ channels

- Full H1 data set analysed 478 pb^{-1}
- Good overall agreement with SM
- Continue to see high P_T^X events

e   e

X

H1 data event
HERA II: P_T^X = 45 GeV
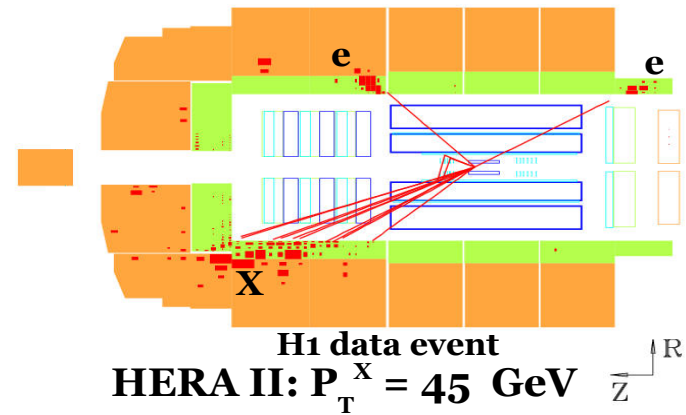
HERA I+II Results e⁻p and e⁺p
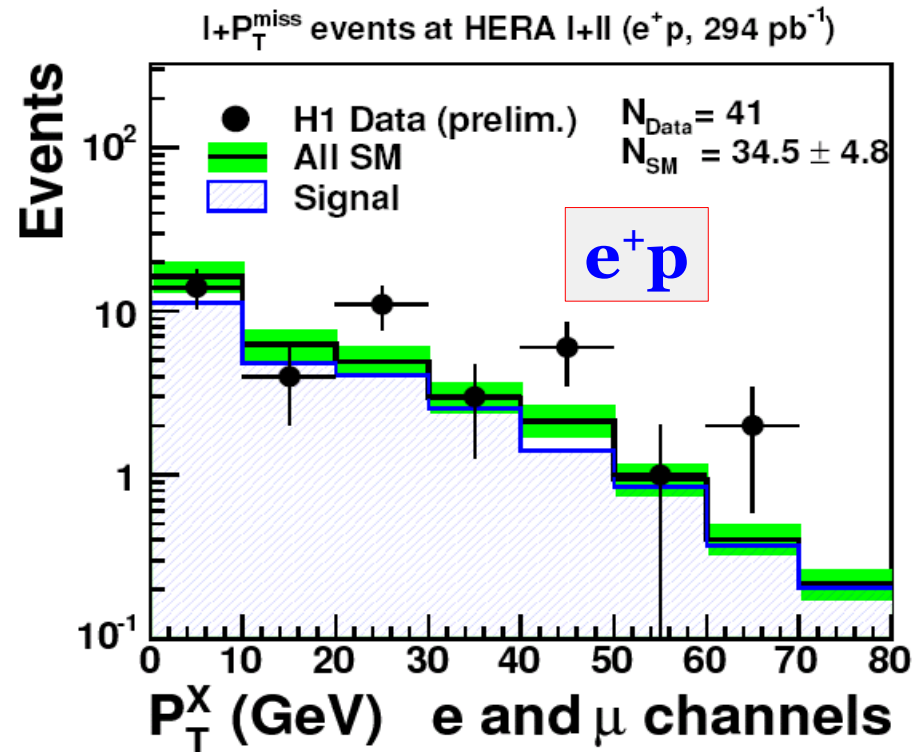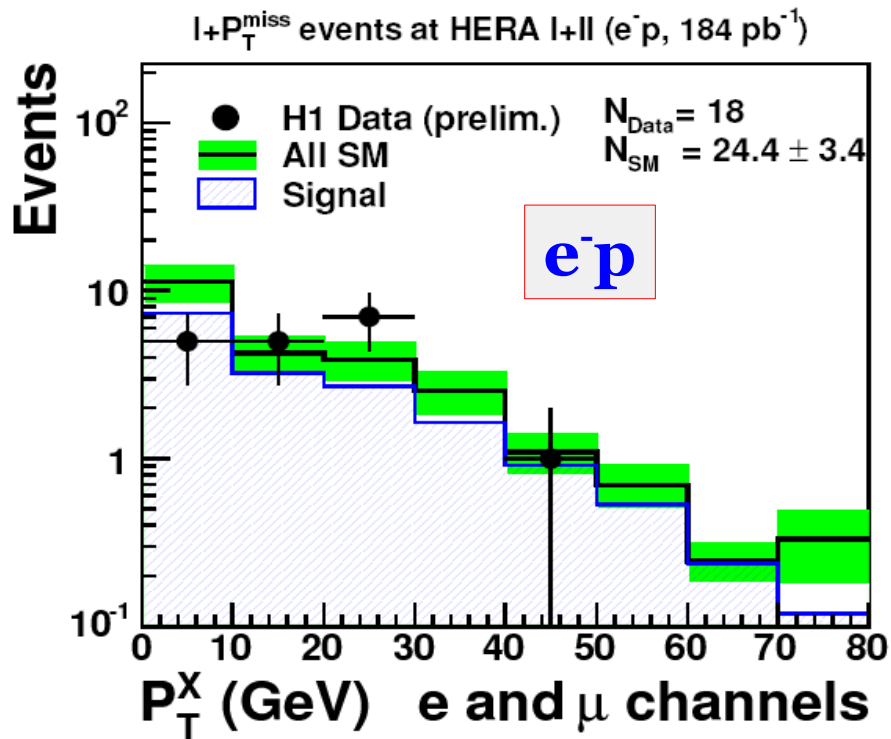
- Now 184 pb⁻¹ of e⁻p available and analysed
- Good agreement with SM

- Good over all agreement with SM
- Still see excess at high P_T^X

HERA I+II Results

H1 Preliminary $l+P_T^{miss}$ events at HERA I+II		Electron obs./exp. (Signal contribution)	Muon obs./exp. (Signal contribution)	Combined obs./exp. (Signal contribution)	
e^+p	Full Sample	26 / 27.3 ± 3.8 (71%)	15 / 7.2 ± 1.1 (85%)	41 / 34.5 ± 4.8 (74%)	
294 pb^{-1}	$P_T^X > 25$ GeV	11 / 4.7 ± 0.9 (75%)	10 / 4.2 ± 0.7 (85%)	21 / 8.9 ± 1.5 (80%)	3.0 sigma
e^-p	Full Sample	16 / 19.4 ± 2.7 (65%)	2 / 5.1 ± 0.7 (78%)	18 / 24.4 ± 3.4 (68%)	
184 pb^{-1}	$P_T^X > 25$ GeV	3 / 3.8 ± 0.6 (61%)	0 / 3.1 ± 0.5 (74%)	3 / 6.9 ± 1.0 (67%)	
$e^\pm p$	Full Sample	42 / 46.7 ± 6.5 (69%)	17 / 12.2 ± 1.8 (82%)	59 / 58.9 ± 8.2 (72%)	
478 pb^{-1}	$P_T^X > 25$ GeV	14 / 8.5 ± 1.5 (68%)	10 / 7.3 ± 1.2 (79%)	24 / 15.8 ± 2.5 (73%)	

- Good over all agreement in both data sets and both lepton channels
- Excess observed in both the electron and muon channel for e$^+$p data
- Excess amounts to a 3.0 sigma fluctuation.

H1/ZEUS Results Comparison at high P_T^X

| $P_T^X > 25$ GeV			electrons Data/SM	muons Data/SM
e^+p	H1	294 pb^{-1}	11/4.7±0.9	10/4.2±0.7
	ZEUS	228 pb^{-1}	1/3.2±0.4	3/3.1±0.5
e^-p	H1	184 pb^{-1}	3/3.8±0.6	0/3.1±0.5
	ZEUS	204 pb^{-1}	5/3.8±0.6	2/2.2±0.3

- ZEUS: good agreement with the Standard Model
- H1: overshoot at high P_T^X in e^+p data in both lepton channels
- H1 and ZEUS have slightly different acceptances

Comparison H1 and ZEUS Acceptances
Electron channel

Detection phase space	Electron Channel H1	Electron Channel ZEUS
$P_T^\ell \geq$	10	10
$P_T^{miss} \geq$	12	12
$P_T^X \geq$	0	12
θ	$5^o - 140^o$	$17^o - 86^o$

- **H1 has acceptance to lowest P_T^X**
- **High P_T^X events observed by both H1/ZEUS**
- **At higher P_T^X acceptances similar,**
  H1 higher due to wider theta range
- **Most (not all) H1 events in ZEUS acceptance**
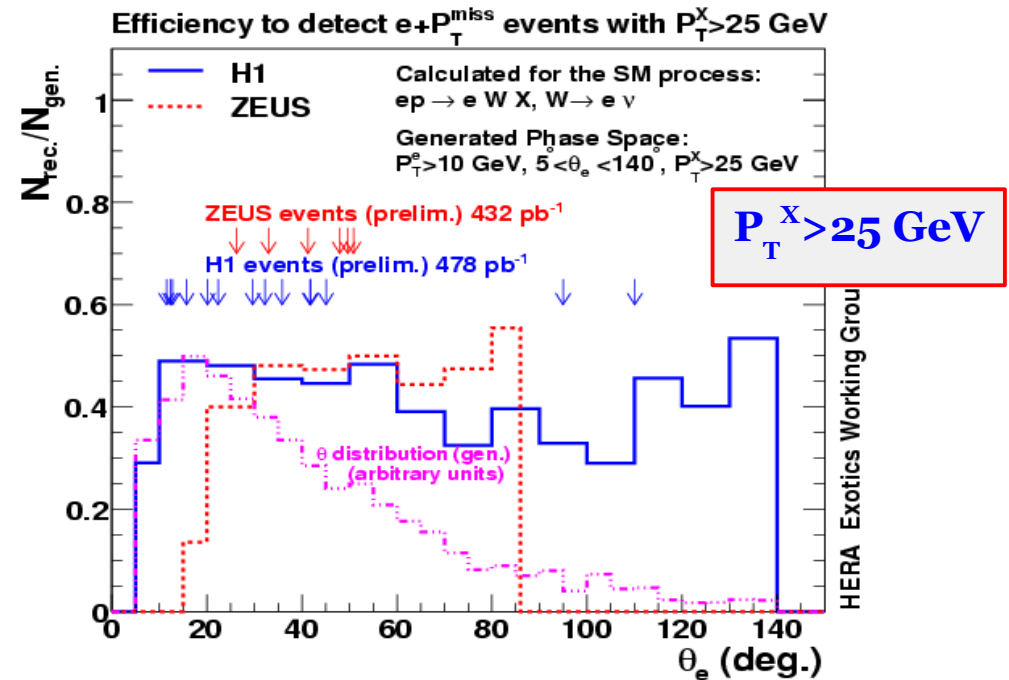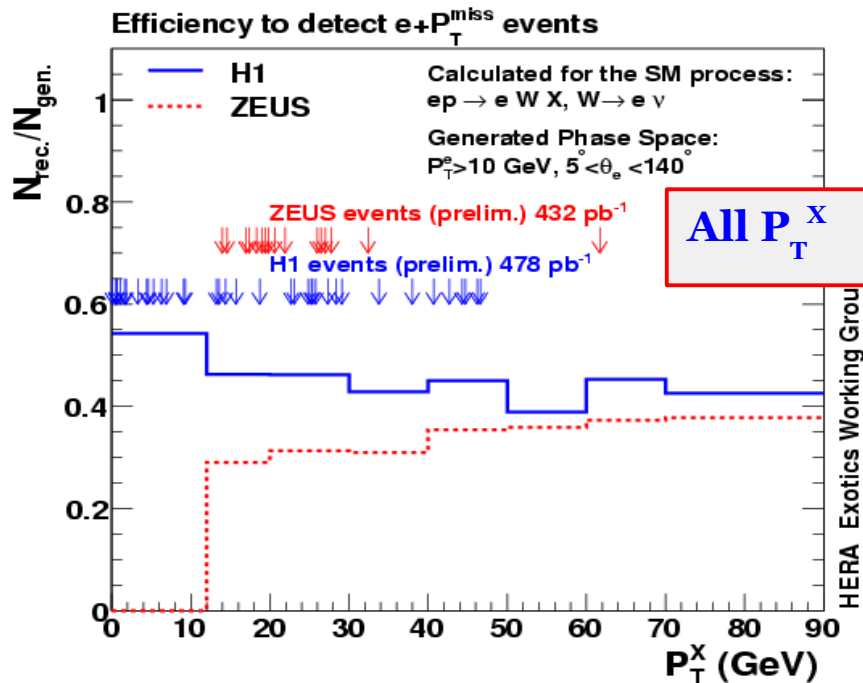
Comparison H1 and ZEUS Acceptances
Muon channel

Detection phase space		Muon Channel	
		H1	**ZEUS**
P_T^ℓ	$\geq$	10	10
P_T^{miss}	$\geq$	12	12
P_T^X	$\geq$	12	12
θ		$5^\circ - 140^\circ$	$17^\circ - 115^\circ$

- High P_T^X events observed by both H1/ZEUS
- At higher P_T^X acceptances similar, H1 higher due to wider theta range
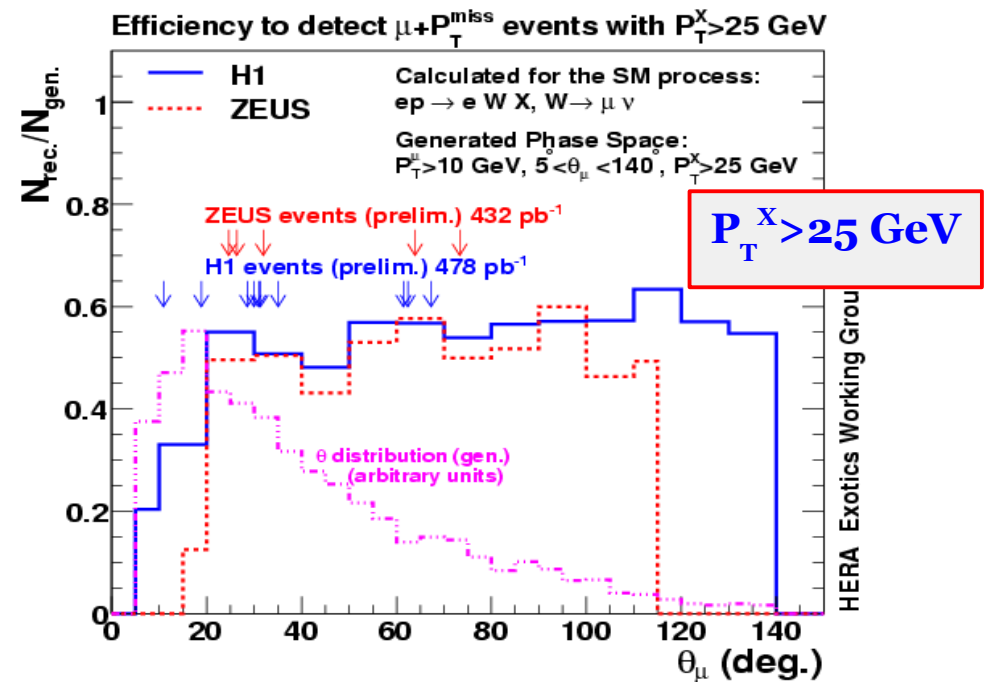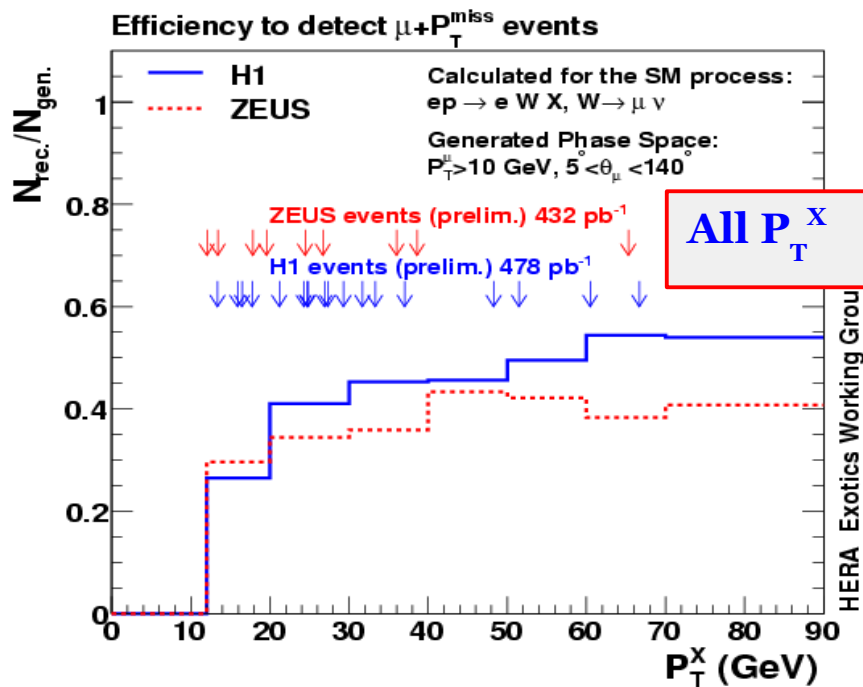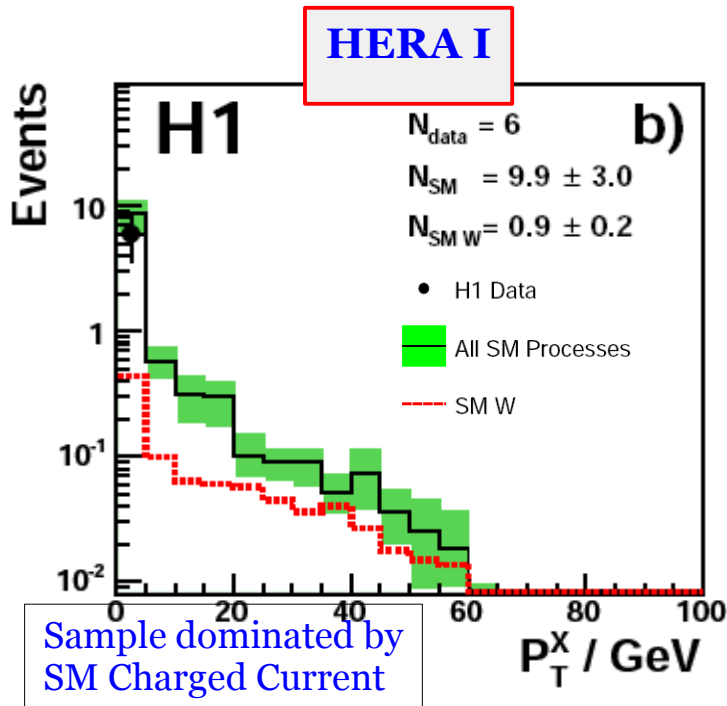- Most (not all) H1 events in ZEUS acceptance

Isolated Tau Analysis

- **Cross check results in elec/muon chann**
- **Look for:**
  - **events with P_t^{miss} miss**
  - **narrow jets ("1-prong")**

"1-prong"

tau

tau neutrino

HERA I

H1 b)

$N_{data} = 6$

$N_{SM} = 9.9 \pm 3.0$

$N_{SM\ W} = 0.9 \pm 0.2$

- H1 Data
- ▮ All SM Processes
- --- SM W

Sample dominated by SM Charged Current
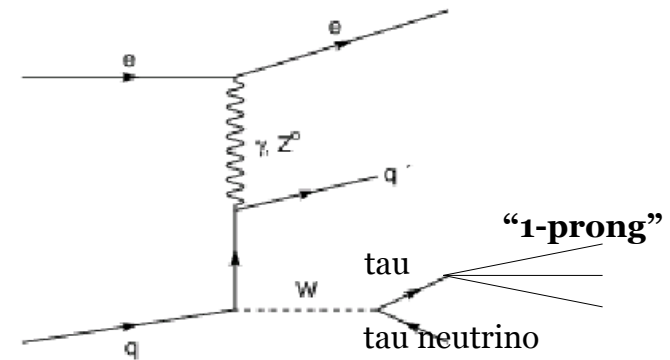
W production cross section ~ 1 pb
Tau branching ratio ~ 43% (1-prong)

EPVEC Generator U.Baur at al., Nucl.Phys.B375:3(1992) +NLO K.P.Diener etal. EPJ.C25,405(2002))
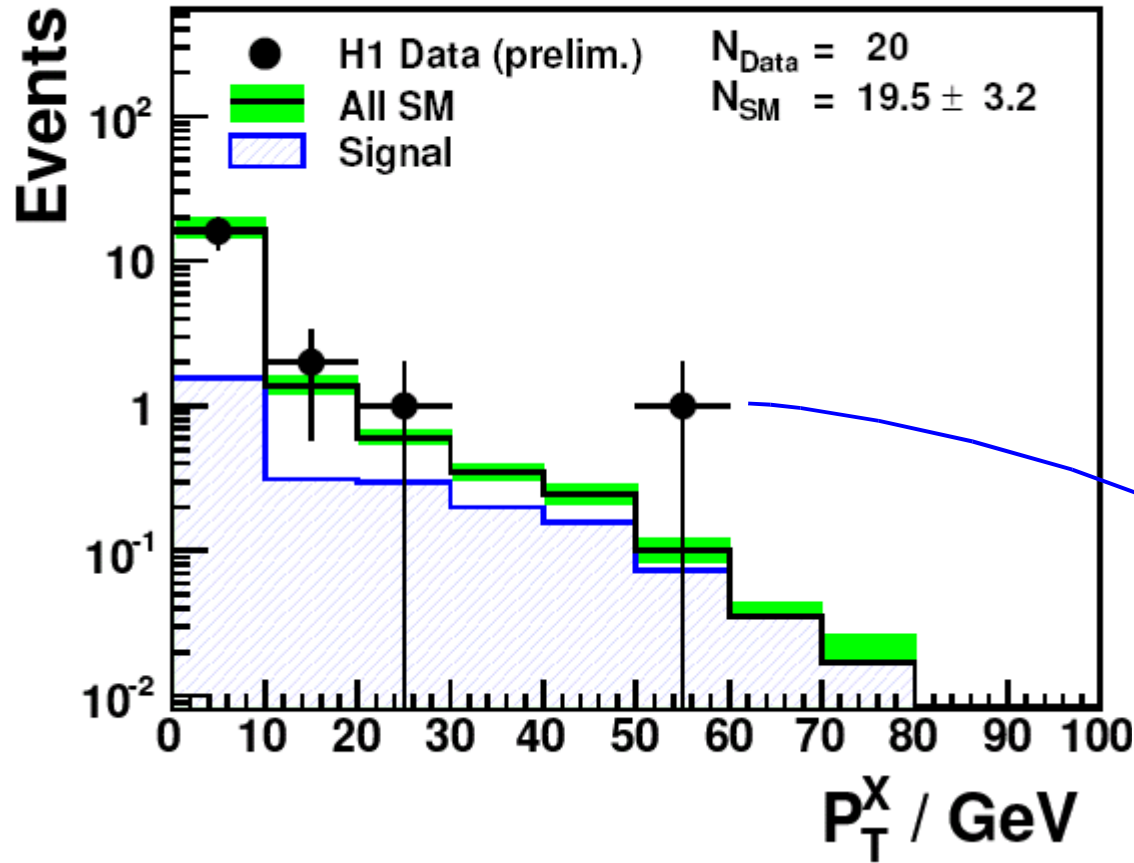
HERA I analysis in good agreement with the Standard Model:

- HERA I (118 pb^{-1}) Published: Eur.Phys.J.C48:699-714,2006

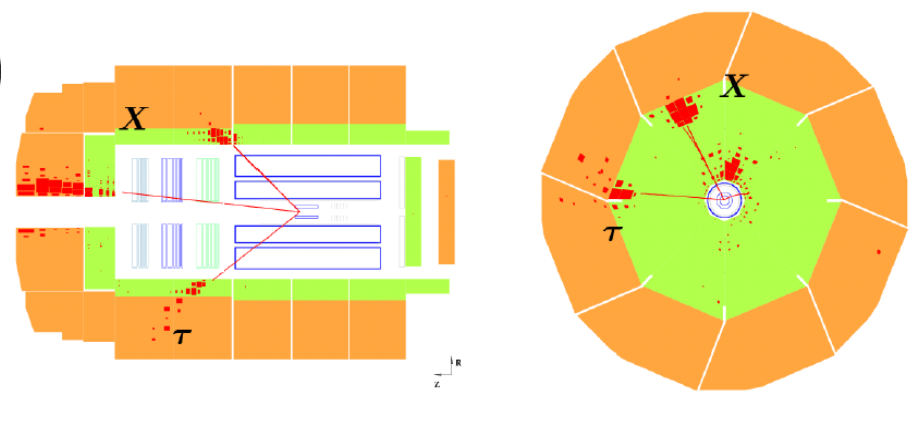Found 6, expected 9.9, signal 0.9, no events at $P_T^X > 25$ GeV

- **Improved track isolation: New analysis**
- **More lumi (from all H1 data 471 pb^{-1})**
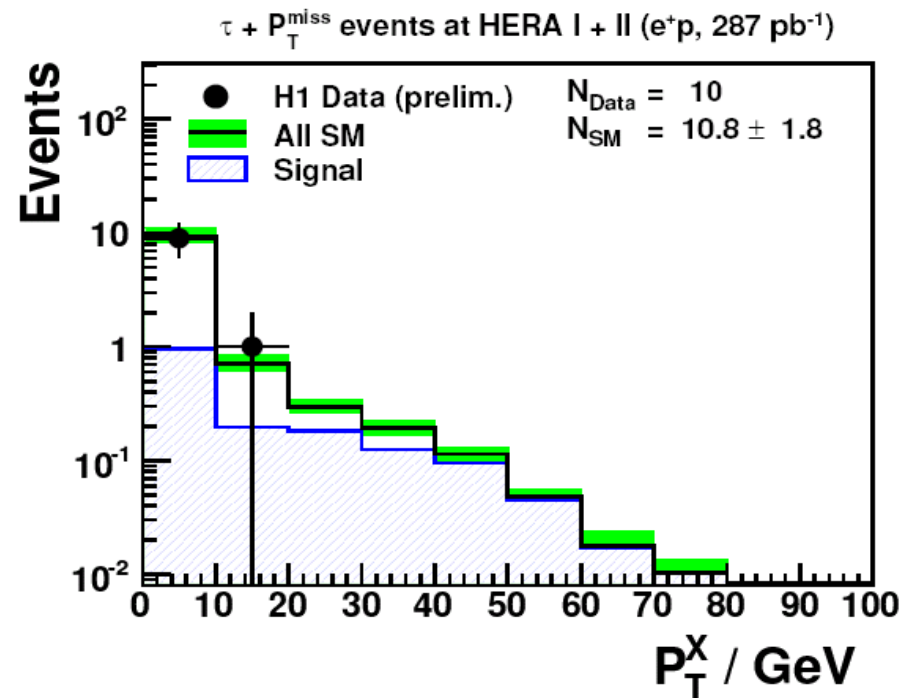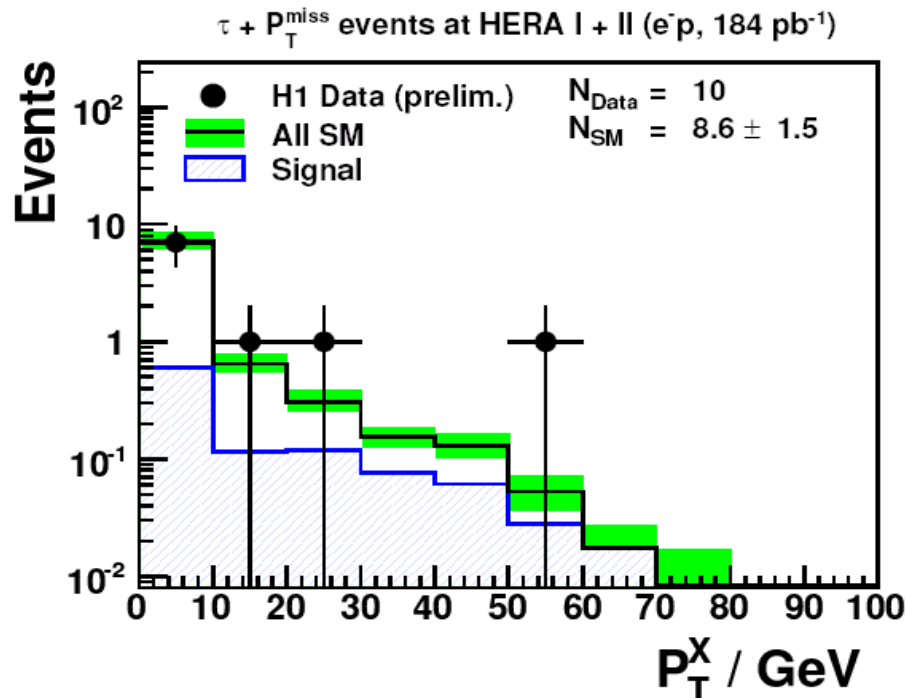
HERA I+II Tau Results

τ + P_T^{miss} events at HERA I + II ($e^{\pm}p$, 471 pb^{-1})

- H1 Data (prelim.) N_{Data} = 20
- All SM N_{SM} = 19.5 ± 3.2
- Signal

- Analysed 471 pb^{-1}
- Good agreement with the Standard Model

HERA I+II Tau Results e⁺p and e⁻p

τ + P_T^{miss} events at HERA I + II (e⁻p, 184 pb⁻¹)

- H1 Data (prelim.) N_{Data} = 10
- All SM N_{SM} = 8.6 ± 1.5
- Signal

τ + P_T^{miss} events at HERA I + II (e⁺p, 287 pb⁻¹)

- H1 Data (prelim.) N_{Data} = 10
- All SM N_{SM} = 10.8 ± 1.8
- Signal

H1 Preliminary τ+P_T^{miss} events at HERA I+II		H1 Data	SM Expectation	SM Signal	Other SM Processes
e^+p 287 pb⁻¹	Full Sample	10	10.8 ± 1.8	1.6 ± 0.3	9.2 ± 1.6
	$P_T^X > 25$ GeV	0	0.53 ± 0.07	0.38 ± 0.06	0.15 ± 0.01
e^-p 184 pb⁻¹	Full Sample	10	8.6 ± 1.5	1.0 ± 0.2	7.6 ± 1.4
	$P_T^X > 25$ GeV	1	0.47 ± 0.07	0.25 ± 0.04	0.22 ± 0.03
$e^\pm p$ 471 pb⁻¹	Full Sample	20	19.5 ± 3.2	2.7 ± 0.4	16.8 ± 2.8
	$P_T^X > 25$ GeV	1	0.99 ± 0.13	0.62 ± 0.10	0.37 ± 0.03

- **Analysed 184 pb⁻¹ of e⁻p and 287 pb⁻¹ of e⁺p data**
- **Good agreement with the Standard Model in both data sets**

Summary and Conclusions

- **For the presented results, use was made of the full H1 ep data set ~ 478 pb⁻¹**

- **<u>Electron/Muon Channel:</u>**
    - **Found good overall agreement with the Standard Model 59 found vs. 58.9 expected**
    - **The HERA I excess in e⁺p data at high P_T^X**

       continues to be seen 21 found vs. 8.9 expected The fluctuation remains a 3 sigma effect.

- **<u>Tau Channel:</u>**
    Found good agreement with SM
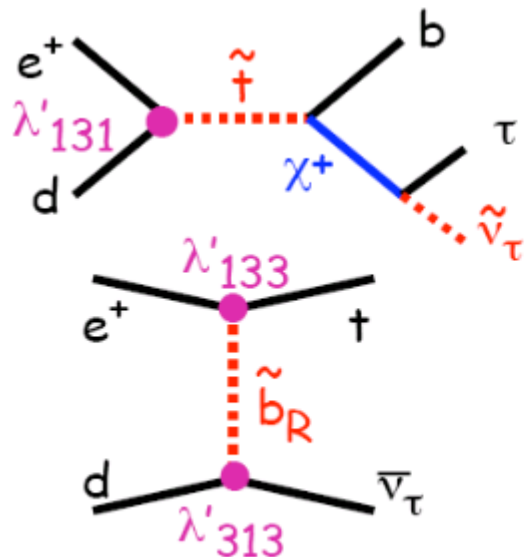   **20 found vs. 19.5 expected**

Backup slides

Interpretation

- Particle coupling to e-q with fermion number F=0 :
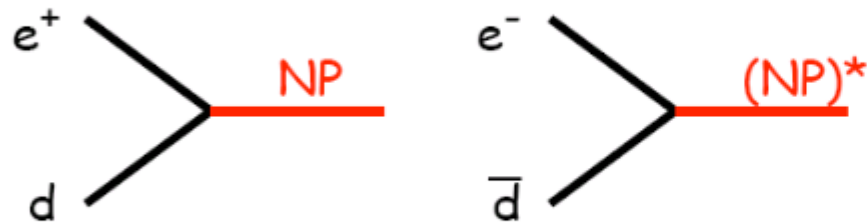
Large mass i.e. large x_{Bj}
$d >> \bar{d}$, hence $\sigma(e+) >> \sigma(e-)$

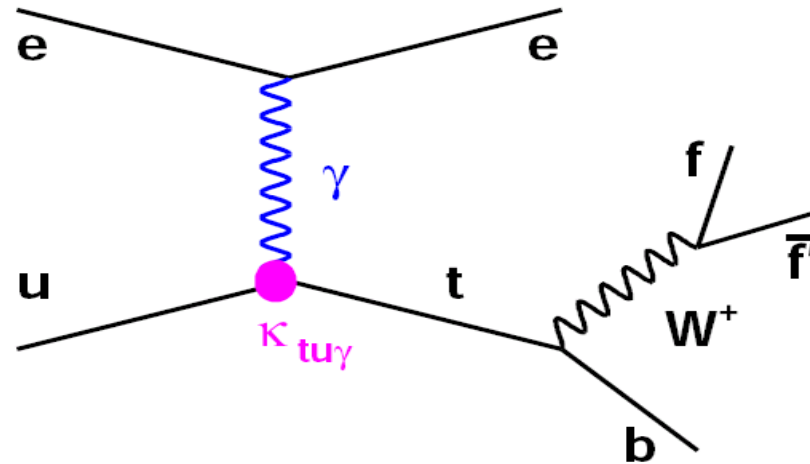- Another example : Squarks in R-parity violating SUSY

If LSP is $\tilde{\nu}_\tau$ and no large RpV coupling involving the τ : $\tilde{\nu}_\tau$ could be long-lived

RpV via couplings involving two 3rd generation fields, light sbottom. Large $M_{top} \rightarrow$ large x_{Bj}

HERA I Single Top Results

Eur. Phys. J. C33 (2004) 9

- **Standard Model Single top negligible cross section ~ 1 fb**
- **Consider anomalous (FCNC) single top production where W decays both leptonically and hadronically.**
- **Observed 5 events vs. 1.31 +/- 0.22 expected**
- **H1 Measured single top production X-sec 0.29 + 0.15 − 0.14 pb**
- **H1 set cross section limit of 0.55 pb at 95% confidence level**
- **Better description of data with anomalous (FCNC) single top**
- **Does not provide larger yield for e^+p over e^-p data**

Tau Event Selection

Tau Channel Selection	
Inclusive CC	$P_T^{\text{calo}} > 12 \text{ GeV}$
	$P_T^{\text{had}} > 12 \text{ GeV}$
	$P_T^{\text{miss}} > 12 \text{ GeV}$
	$\delta^{\text{miss}} > 5 \text{ GeV}$
	$V_{ap}/V_p < 0.5$
	$(< 0.15 \text{ if } P_T^{\text{miss}} < 25 \text{ GeV})$
Narrow Jets	$P_T^{jet} > 7 \text{ GeV}$
	$20° < \theta^{jet} < 120°$
	$R^{jet} < 0.12$
	$N_{tracks}^{jet} \geq 1, \max(P_T^{track}) > 5 \text{ GeV}$
Isolation	$D_{em,\mu,jet} > 1.0$
Acoplanarity	$\Delta\varphi(\tau, X) < 170° \text{ if } P_T^X > 5 \text{ GeV}$
1-Prong Jets	$N_{tracks}^{Djet<1.0} = 1$
Final Selection	$N_{\text{DTNV}}^{D_{track}<0.3} = 1$