Search for Events with isolated Leptons and large Missing Transverse Momentum

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Outline

Introduction

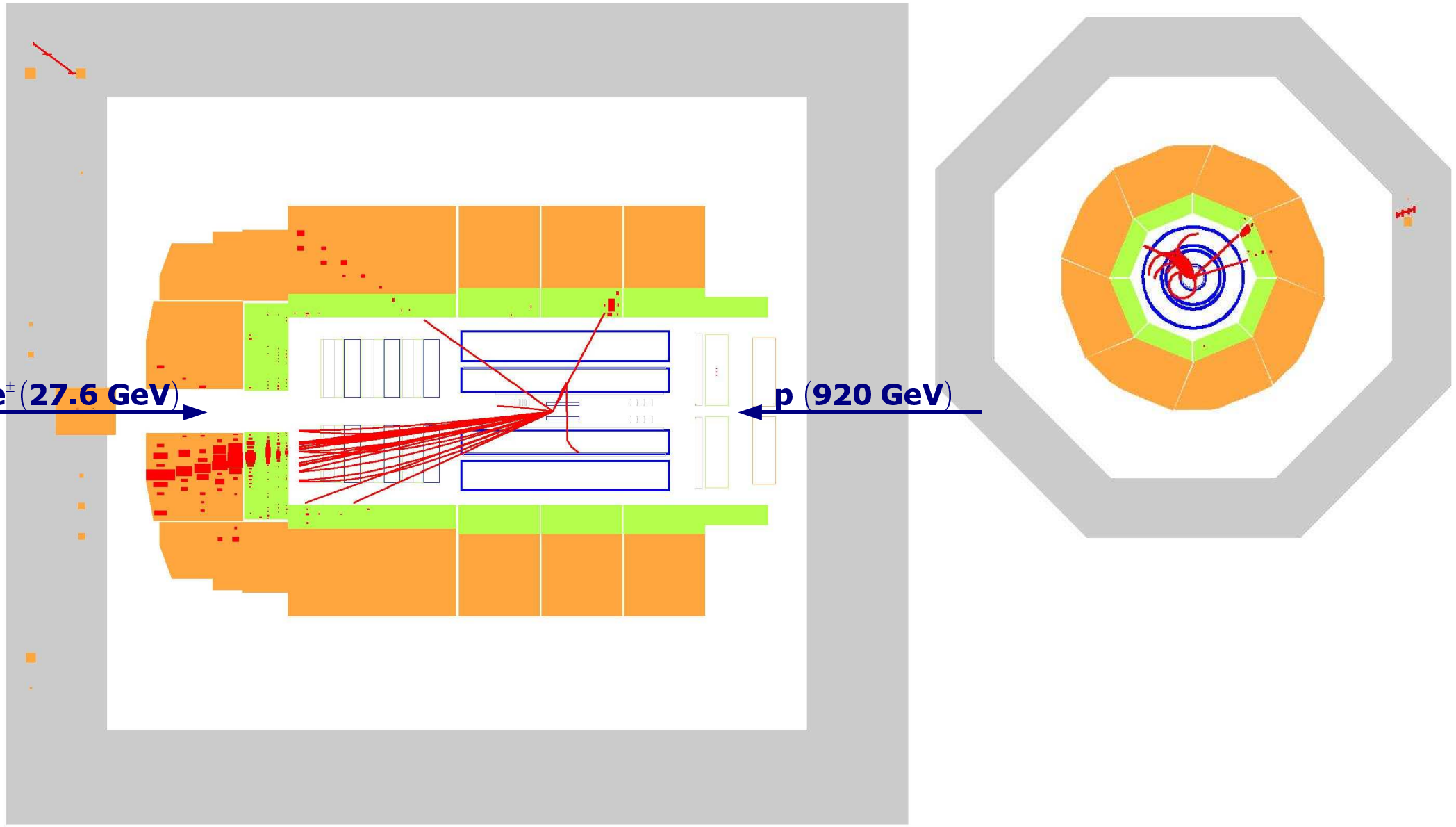
Summary of Results of HERA I Analysis

Preliminary Results of HERA II Analysis

Single top Production at HERA ?

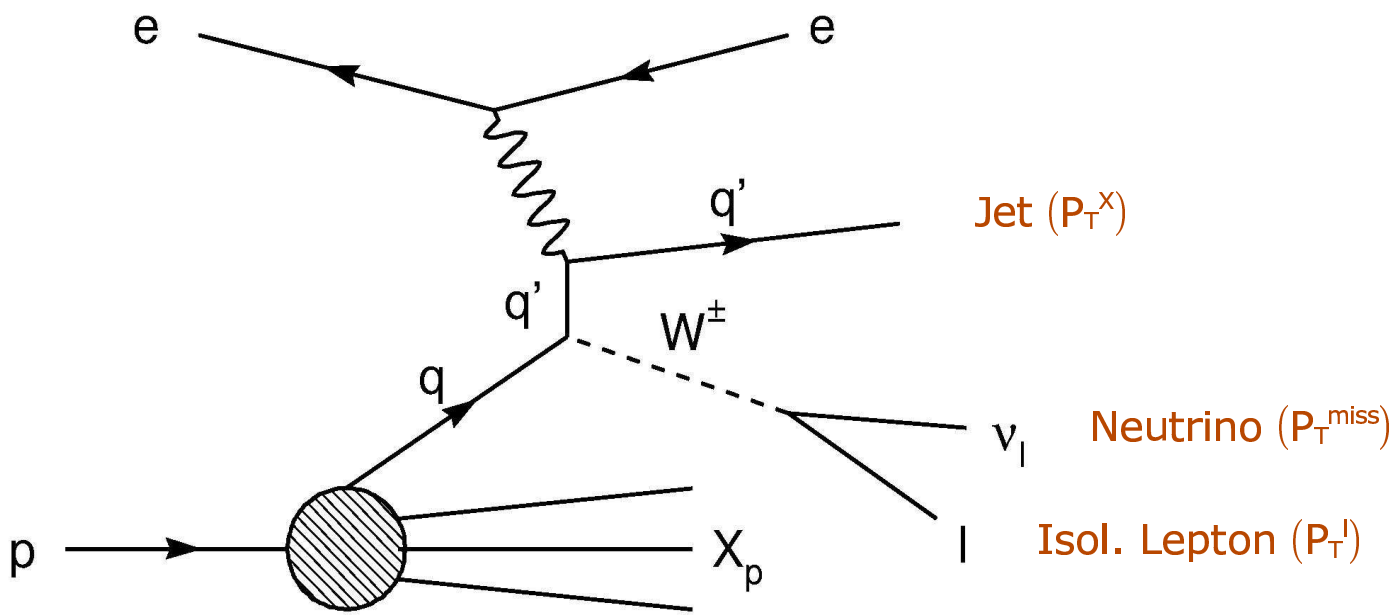
Summary

Introduction to the "Isolated Lepton" Analysis



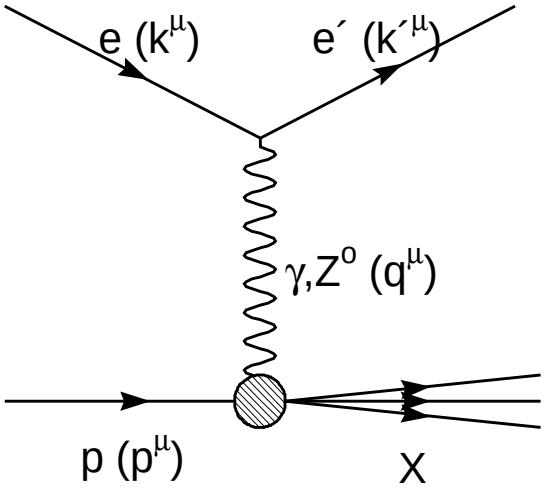
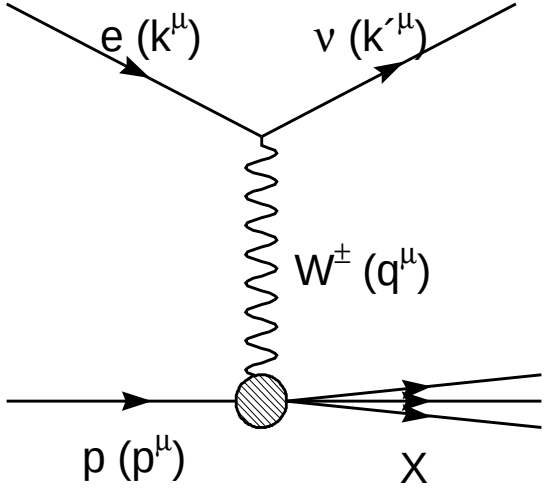
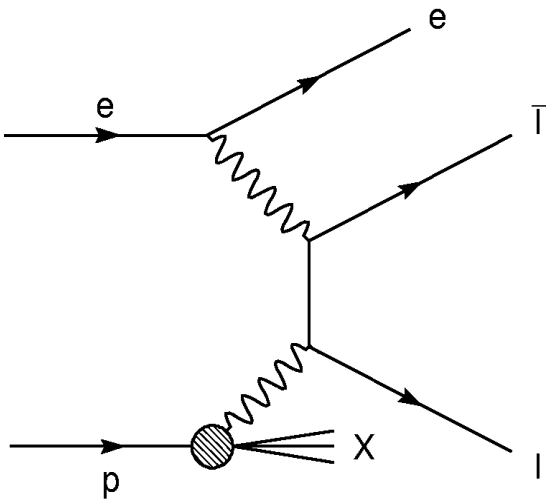
SM Signal

SM Signal: Production of real W Bosons



- Cross-Section $\sigma(ep \rightarrow eWX) \approx 1pb$ (at NLO)
- Branching Fraction $W \rightarrow l\nu \approx 10\%$ each for e,μ,τ

SM Background

e: Neutral Current	e,μ,τ: Charged Current	μ: Lepton Pair
		
genuine Electron & fake P_T^{miss} due to Mismeasurement	misidentified Electron/ Muon/Tau-Jet & genuine P_T^{miss}	genuine Muon & fake P_T^{miss} due to Mismeasurement

Event Selection

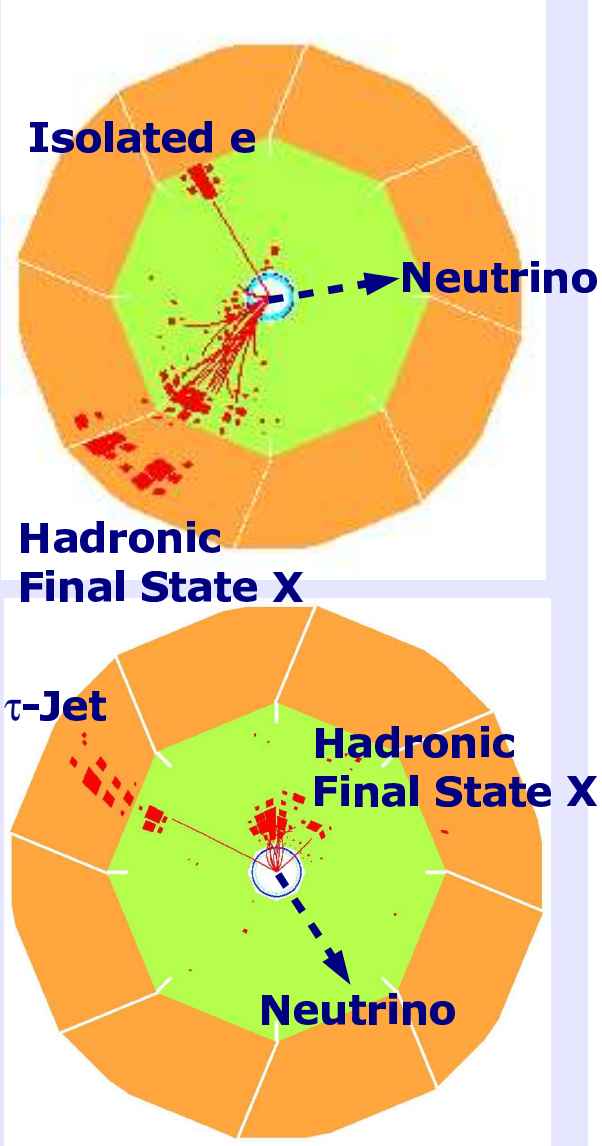
Selection of e,μ Events

Lepton within Detector Acceptance	$5^\circ < \theta_l < 140^\circ$
High Transverse Momentum of Lepton	$P_T^l > 10$ GeV
Lepton Isolation w.r.t. other Particles	$D_{jet} > 1$, $D_{track} > 0.5$
Large Missing Transverse Momentum	$P_T^{miss} > 12$ GeV
Acoplanarity	$\Delta\varphi_{\mu\text{-}X} < 170^\circ$ $\Delta\varphi_{e\text{-}X} < 160^\circ$

Selection of τ Events

Tau-Jet within Detector Acceptance	$20^\circ < \theta_{jet} < 120^\circ$
High Transverse Momentum of Lepton	$P_T^{jet} > 7$ GeV
One-Prong Tau Decay	$R_{jet} < 0.12$, only 1 Track
Lepton Isolation w.r.t. other Particles	implicit
Large Missing Transverse Momentum	$P_T^{miss} > 12$ GeV
Acoplanarity	$\Delta\varphi_{jet\text{-}X} < 170^\circ$

Simulated Signal



HERA I Results

e^+p (1994-2000) 105 pb^{-1}

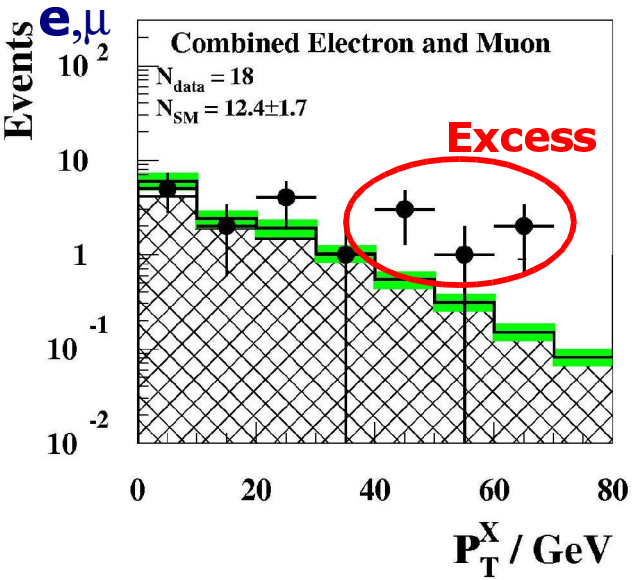
	Electron obs./exp. (W)	Muon obs./exp. (W)
All P_T^X	10/9.85 ± 1.27 (73%)	8/2.55 ± 0.44 (88%)
P_T^X > 25 GeV	4/1.48 ± 0.25 (86%)	6/1.44 ± 0.25 (90%)

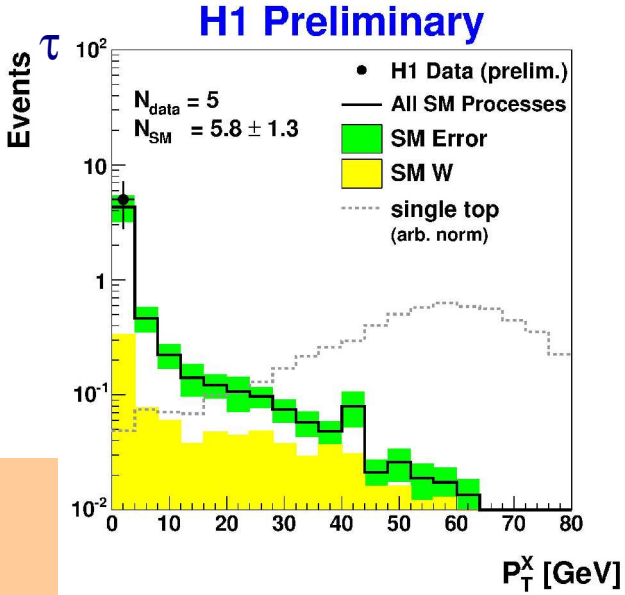
e^-p (1998/99) 14 pb^{-1}

All P_T^X	1/1.69 ± 0.22 (59%)	0/0.37 ± 0.06 (78%)
P_T^X > 25 GeV	1/0.28 ± 0.04 (64%)	0/0.24 ± 0.04 (75%)

$e^\pm p$ (1996-2000) 108 pb^{-1}

	Tau obs./exp. (W)
All P_T^X	5/5.81 ± 1.36 (15%)
P_T^X > 25 GeV	0/0.53 ± 0.10 (49%)





➡ In e^+p Collisions, Excess of Events observed at large hadronic Transverse Momenta in e and μ Channels
no Evidence for Excess seen in e^-p Collisions and in τ Channel

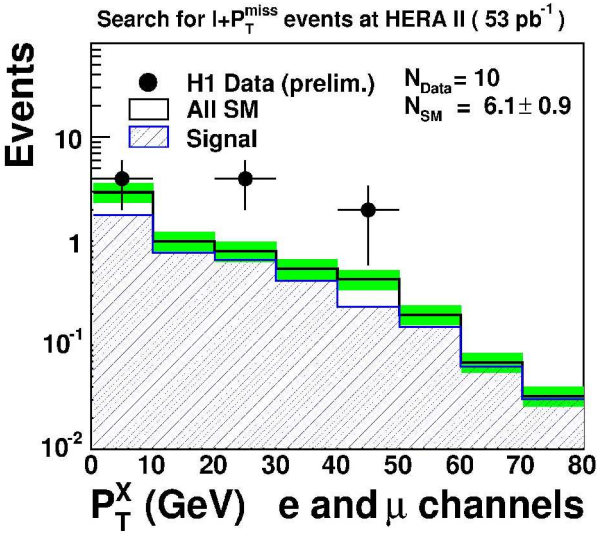
HERA II Results

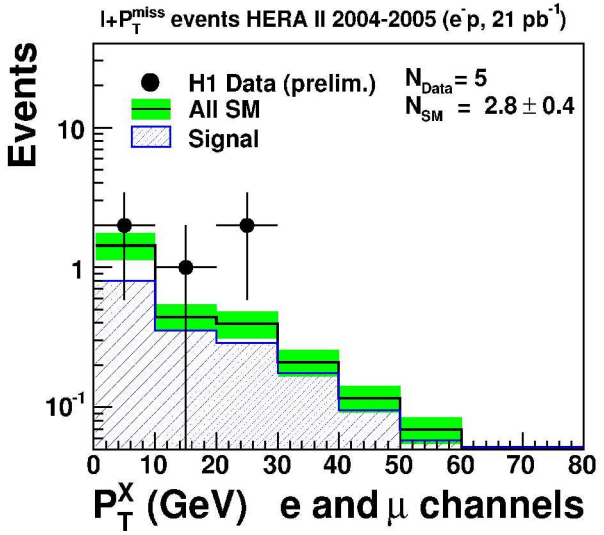
e^+p (2003/04) 53 pb^{-1}

	Electron obs./exp. (W)	Muon obs./exp. (W)
All P_T^X	9/4.75 ± 0.76 (65%)	1/1.33 ± 0.19 (77%)
P_T^X > 25 GeV	5/0.84 ± 0.19 (69%)	0/0.85 ± 0.13 (74%)

e^-p (2004/05) 21 pb^{-1}

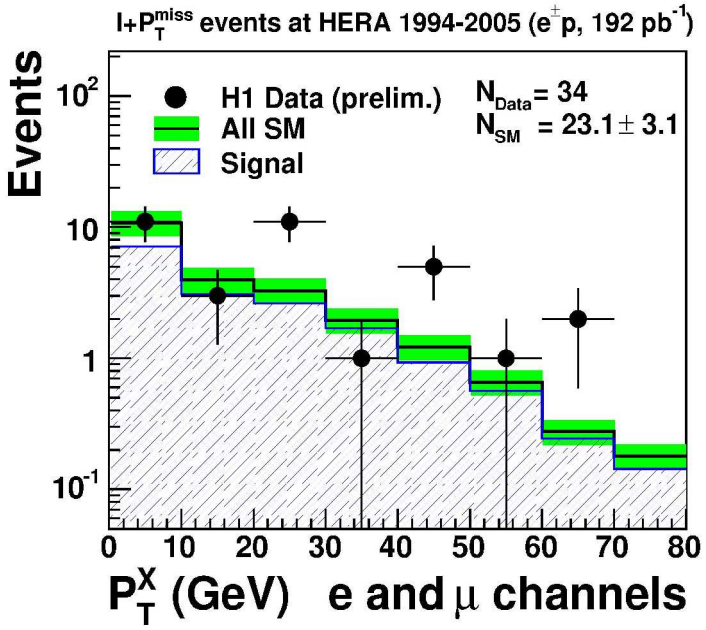
All P_T^X	5/2.15 ± 0.33 (63%)	0/0.59 ± 0.09 (76%)
P_T^X > 25 GeV	1/0.30 ± 0.05 (77%)	0/0.36 ± 0.06 (72%)





➞ Excess of outstanding Events observed in e^+p and e^-p Collisions (concentrated in e Channel)
no Results for τ Channel yet

Combined HERA I + II Results



e$^{\pm}$p data (1994-2005) 192 pb^{-1}

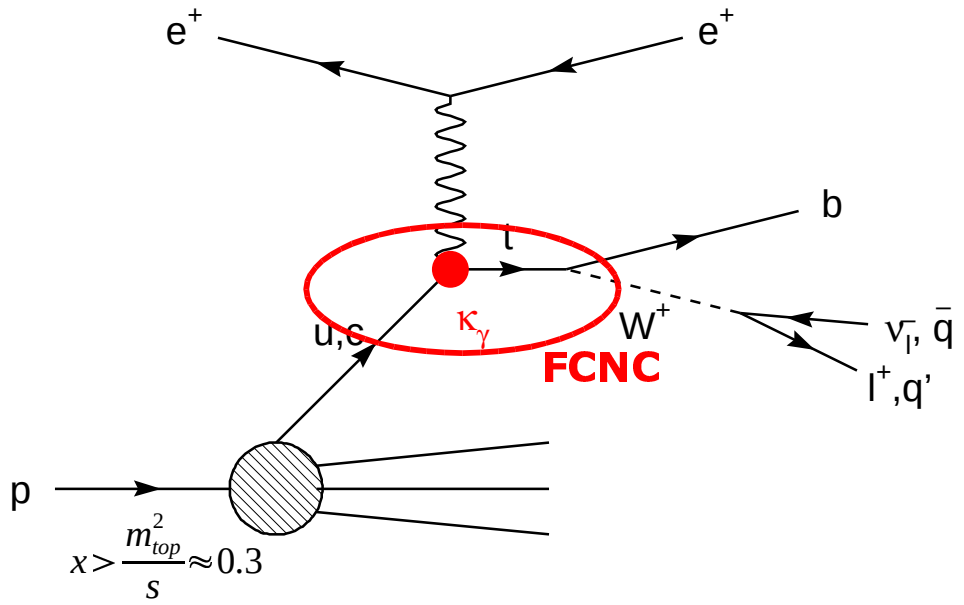
	Electron obs./exp. (W)	Muon obs./exp. (W)	Tau① obs./exp. (W)
All P_T^X	25/18.3 ± 2.5 (70%)	9/4.8 ± 0.8 (85%)	5/5.8 ± 1.4 (15%)
P_T^X > 25 GeV	11/3.0 ± 0.6 (81%)	6/3.0 ± 0.6 (86%)	0/0.5 ± 0.1 (49%)

① e$^{\pm}$p (1996-2000) 108 pb^{-1}

Production of single top Quarks at HERA ?

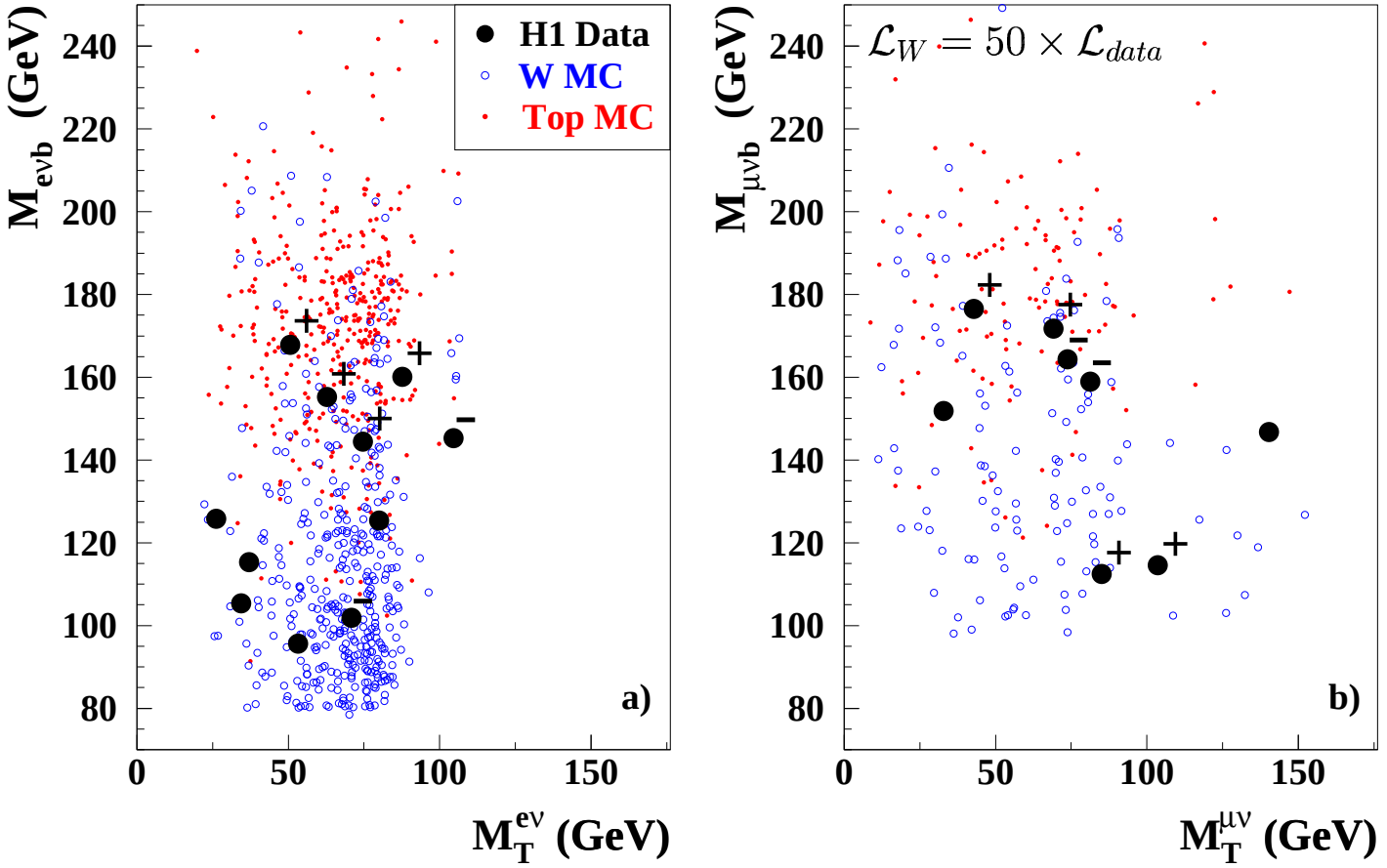
Motivation: explains the large hadronic Transverse Momenta observed in the "Isolated Lepton" Events

as P_T of b-Jets resulting from t ➞ bW Decays



- SM single top Production highly suppressed $(\sigma < 1\text{fb})$
- Flavour-Changing Neutral Current (FCNC) Interactions may yield observable Cross-Sections

Why single top Decays ?



b-Quark Reconstruction

b-Jet not tagged, but reconstructed from sum of all Jets

Neutrino Reconstruction

apply W Mass Constraint $M_{l\nu}=\sqrt{P_l^2+P_\nu^2+2P_lP_\nu}\approx\sqrt{2P_lP_\nu}=M_W$

Semi-Leptonic Decay Channel $t \to bW^+ \to bl^+\nu$

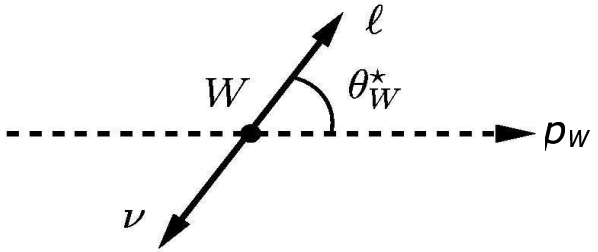
Multivariate Likelihood Analysis

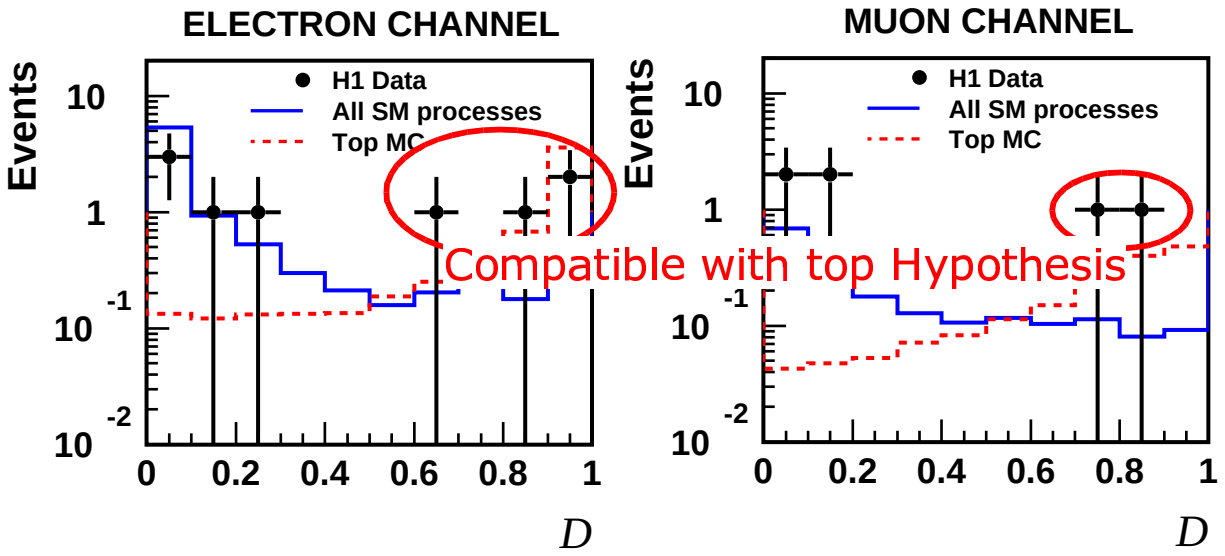
based on the Discriminant Function

$$D(V)=\frac{P^{signal}}{P^{signal}+P^{background}}, P=C(V)\prod_i p_i$$

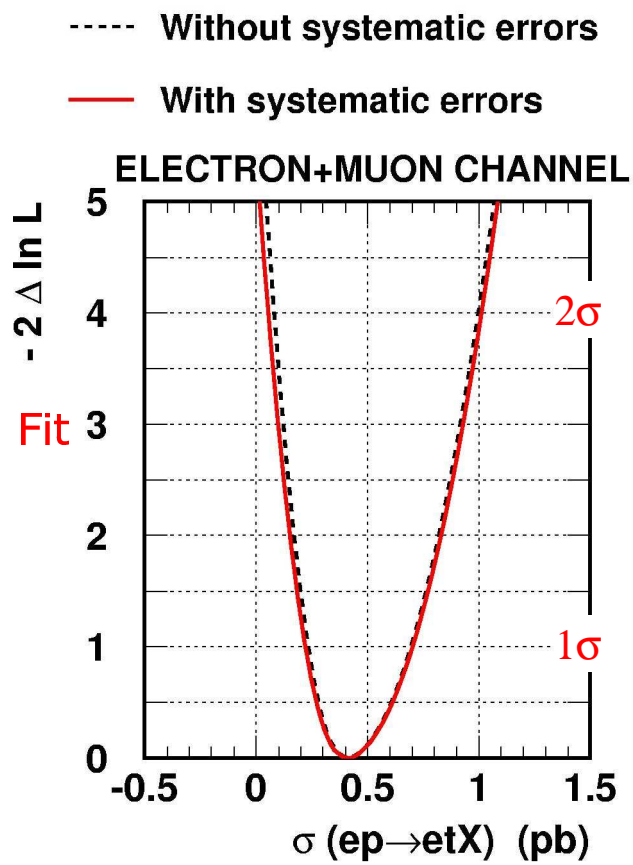
using the Variables

$V = \{P_T^b, M_{l\nu b}, \cos\theta_W^*\}$





Likelihood Fit



Hadronic Decay Channel $t \to bW^+ \to bqq'$

Preselection

$P_T^{jet1} > 40$ GeV, $P_T^{jet2} > 30$ GeV, $P_T^{jet3} > 15$ GeV

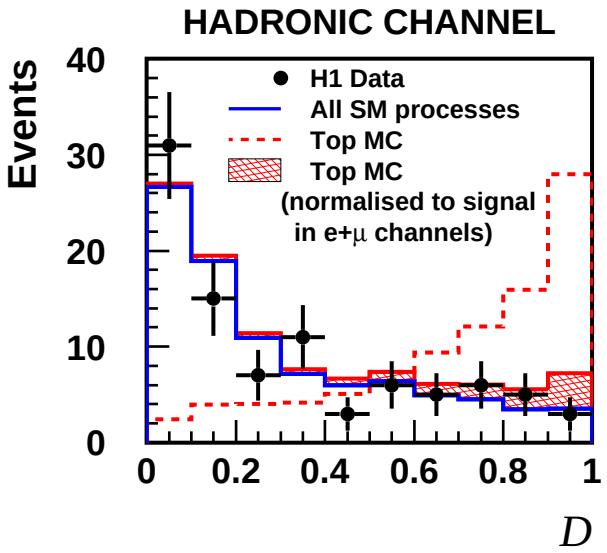
$E_T^{tot} > 110$ GeV

$65 \text{ GeV} < M_{ij} < 95 \text{ GeV}$ for any two jets i,j

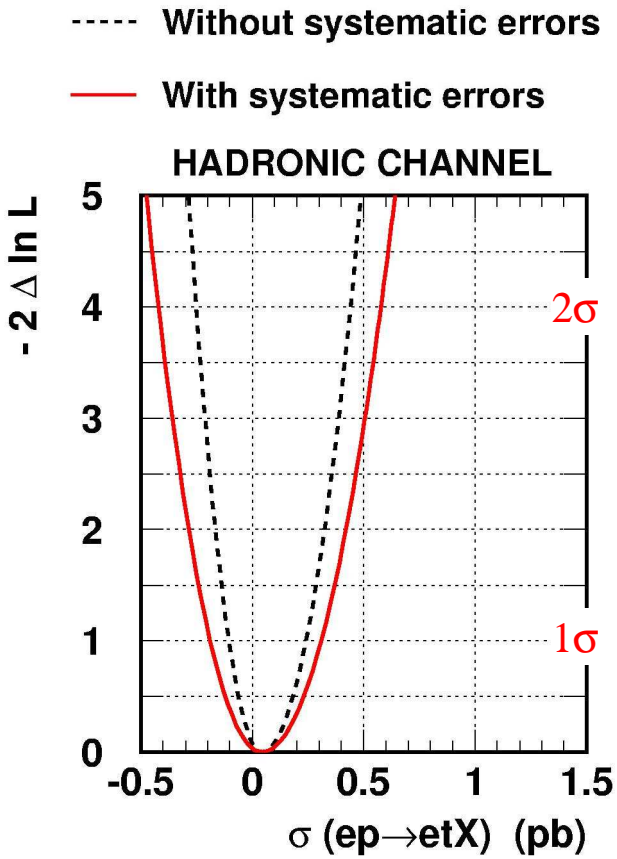
Likelihood Analysis

similar to semi-leptonic Channel,
using the Variables

$V = \{P_T^b, M_{jets}, \cos\theta_W^*\}$



Likelihood Fit



Exclusion Limits for anomalous top Production

Semi-leptonic Channel

$\sigma = 0.41^{+0.29}_{-0.19}$ pb

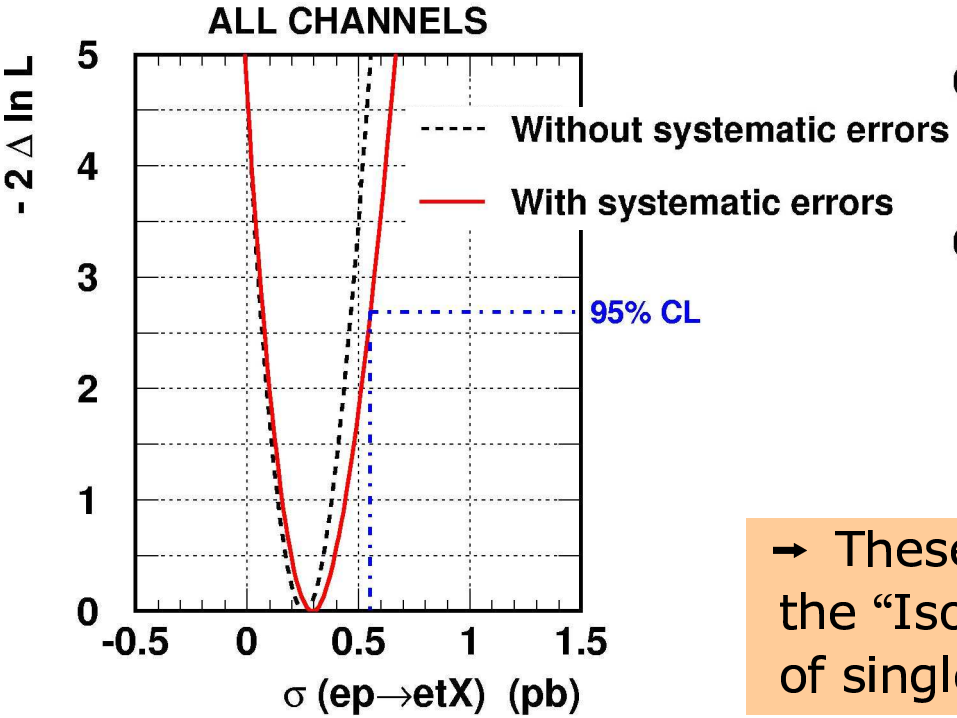
Hadronic Channel

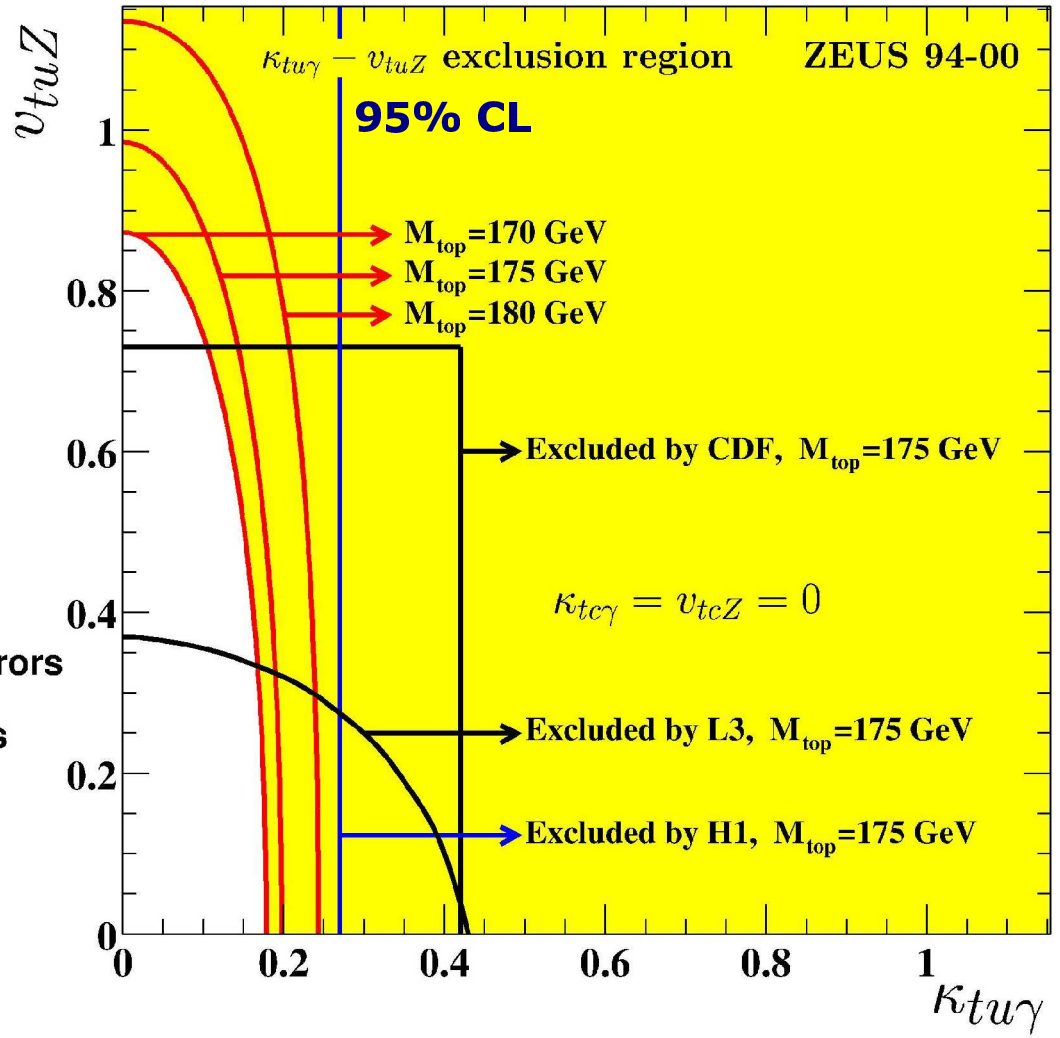
$\sigma = 0.04^{+0.27}_{-0.23}$ pb

Combined Channel

$\sigma = 0.29^{+0.15}_{-0.14}$ pb

$\kappa_{tu\gamma} = 0.20^{+0.05}_{-0.06}$



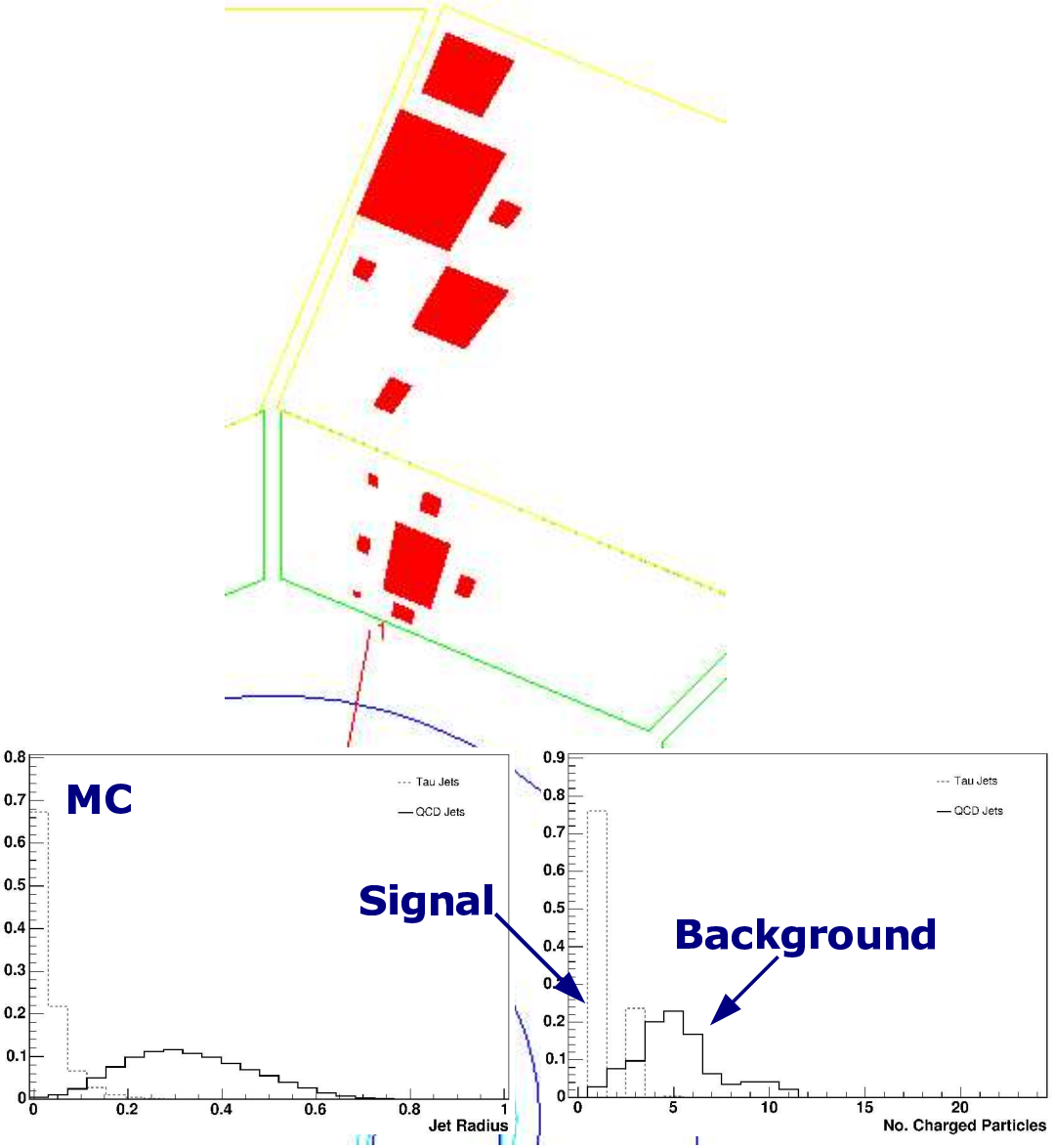


➡ These Limits do not exclude the Interpretation of the "Isolated Lepton" Events as resulting from Decays of single top Quarks produced by FCNC Interactions

Summary

- Excess of Events with isolated Electrons/Muons and large Missing Transverse Momentum observed in H1 HERA I Data (118 pb^{-1})
- Excess continued to be seen in H1 HERA II Data (74 pb^{-1})
- A possible Explanation for the observed Excess may be the Production of single top Quarks by Flavour-Changing Neutral Current Interactions
- Need more HERA II Data to clarify Origin of observed Excess

Signature of τ-Leptons



Mass	1777.0 ± 0.3 MeV
Lifetime τ	290.6 ± 1.1 fs
cτ	87.11 ± 0.33 μm

Leptonic decay modes

$\tau \rightarrow e\nu$	≈ 17%
$\tau \rightarrow \mu\,\nu$	≈ 18%

Hadronic "1-Prong" Decay Modes

$\tau \rightarrow \pi^{\pm}\,\nu$	≈ 11%
$\tau \rightarrow \rho^{\pm}\,\nu \rightarrow \pi^{\pm}\ \pi^{0}\,\nu$	≈ 25%
$\tau \rightarrow \pi^{\pm}\ \pi^{0}\,\pi^{0}\,\nu$	≈ 9%

Hadronic "3-Prong" Decay Modes

$\tau \rightarrow \pi^{\pm}\,\pi^{\pm}\,\pi^{\pm}\,\nu$	≈ 10%
$\tau \rightarrow \pi^{\pm}\,\pi^{\pm}\,\pi^{\pm}\,\pi^{0}\,\nu$	≈ 4%

H1 – ZEUS τ-Channel Comparison

$e^{\pm}p$ data (1994-2004) 108 pb^{-1}

	Data observed	All SM Processes expected	SM W expected	Single Top Eff. • BR
All P_T^X	5	5.81 ± 1.36	0.87 ± 0.15	0.52%
$P_T^X > 25$ GeV	0	0.53 ± 0.10	0.26 ± 0.05	0.49%

$e^{\pm}p$ data (1994-2000) 130 pb^{-1}

	Data observed	All SM Processes expected	SM W expected	Single Top Eff. • BR
All P_T^X	3	0.40 ± 0.12	0.19 ± 0.04	0.27%
$P_T^X > 25$ GeV	2	0.20 ± 0.05	0.09 ± 0.02	0.27%

H1 – ZEUS e,μ,τ-Channel Comparison

$e^{\pm}p$ data (1994-2005) 192 pb^{-1}

	Electron obs./exp. (W)	Muon obs./exp. (W)	Tau① obs./exp. (W)
All P_T^X	25/18.3 ± 2.5 (70%)	9/4.8 ± 0.8 (85%)	5/5.8 ± 1.4 (15%)
P_T^X > 25 GeV	11/3.0 ± 0.6 (81%)	6/3.0 ± 0.6 (86%)	0/0.5 ± 0.1 (49%)

① $e^{\pm}p$ (1996-2000) 108 pb^{-1}

$e^{\pm}p$ data (1994-2000) 130 pb^{-1}

	Electron obs./exp. (W)	Muon obs./exp. (W)	Tau obs./exp. (W)
All P_T^X	24/20.6 $^{+1.7}_{-4.6}$ (17%)②	12/11.9 $^{+0.6}_{-0.7}$ (16%)②	3/0.40 ± 0.12 (43%)
P_T^X > 25 GeV	2/2.90 ± 0.6 (45%)	5/2.75 ± 0.21 (50%)	2/0.20 ± 0.05 (49%)

② Preselection

Likelihood Fit

Fit Distribution of Discriminant D observed in the Data
with Distributions expected for Standard Model Background
and single top Signal

Normalisation of Standard Model Background fixed/
Normalisation of single top Signal allowed to vary

➞ one Parameter Fit

Function to be maximized:

$$L = \prod_{k=1}^{n_{bin}} e^{-\mu_k} \frac{\mu_k^{n_k}}{n_k!}$$ (Product of Poisson Probabilities)

with $\mu_k = B_k + S_k$ Sum of Standard Model Expectation B_k
and single Top Contribution S_k in Bin k

➞ fitted Parameter $S = \Sigma_k S_k$ so as to best match the Data