Tau leptons at HERA

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On behalf of the H1 collaboration

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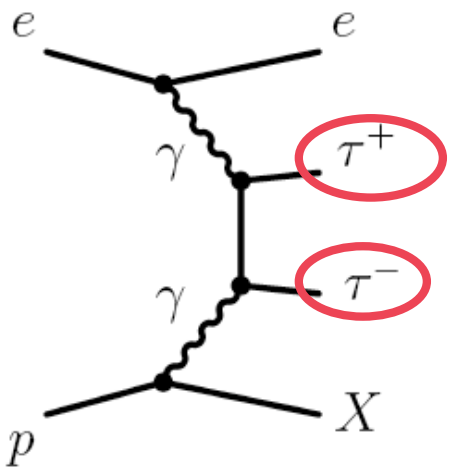
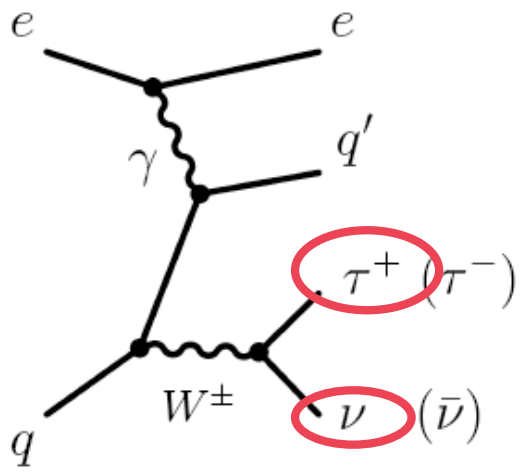
Production of τ leptons in $e^{\pm}$ p collisions at HERA

τ lepton pair production



Dominant source of τ leptons within SM : $\sigma\ (p^{T}_{\tau} > 2\ \text{GeV}) \approx 20$ pb

Events with large missing p_T and a high p_T isolated τ



Very rare process within SM : σ . Br ($W \to \tau\nu$) ≈ 0.1 pb

In this talk:

- Final results on study of tau lepton production on HERA I data : hep-ex/0604022 , DESY-06-029 , H1-150
- Preliminary results on HERA II data

Properties of τ leptons

Mass	1777.0 ± 0.3 MeV
$c\tau$	87.11 ± 0.33 μm

Only decay products observed in detector, Decay vertex difficult to reconstruct

Leptonic decay modes

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

Very difficult to distinguish from e/μ from primary interaction

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%

Collimated jets of low particle multiplicity

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%

Non isolated τ leptons experimentally not accessible

$\tau \equiv$ Isolated τ

Study of $\tau^+\tau^-$ production : Strategy

Study elastic production of $\tau^+\tau^-$ events

Use the following decay modes:

- $\tau \to e$ $\tau \to \mu$ (leptonic) $\approx$ 6%
- $\tau \to e/\mu$ $\tau \to$ hadrons (semileptonic) $\approx$ 45% , clean
- $\tau \to$ hadrons $\tau \to$ hadrons (hadronic) $\approx$ 42% , adds statistics, less clean $\rightarrow$ tau identification

For τ hadronic decay modes use a Neural Network analysis to distinguish:

- Hadronic 1-prong and 3-prong τ decays from quark/gluon jets ($L_{1\text{-prong}}$, $L_{3\text{-prong}}$)
- Hadronic 1-prong τ decays from unidentified electrons and muons (L_e , L_μ)

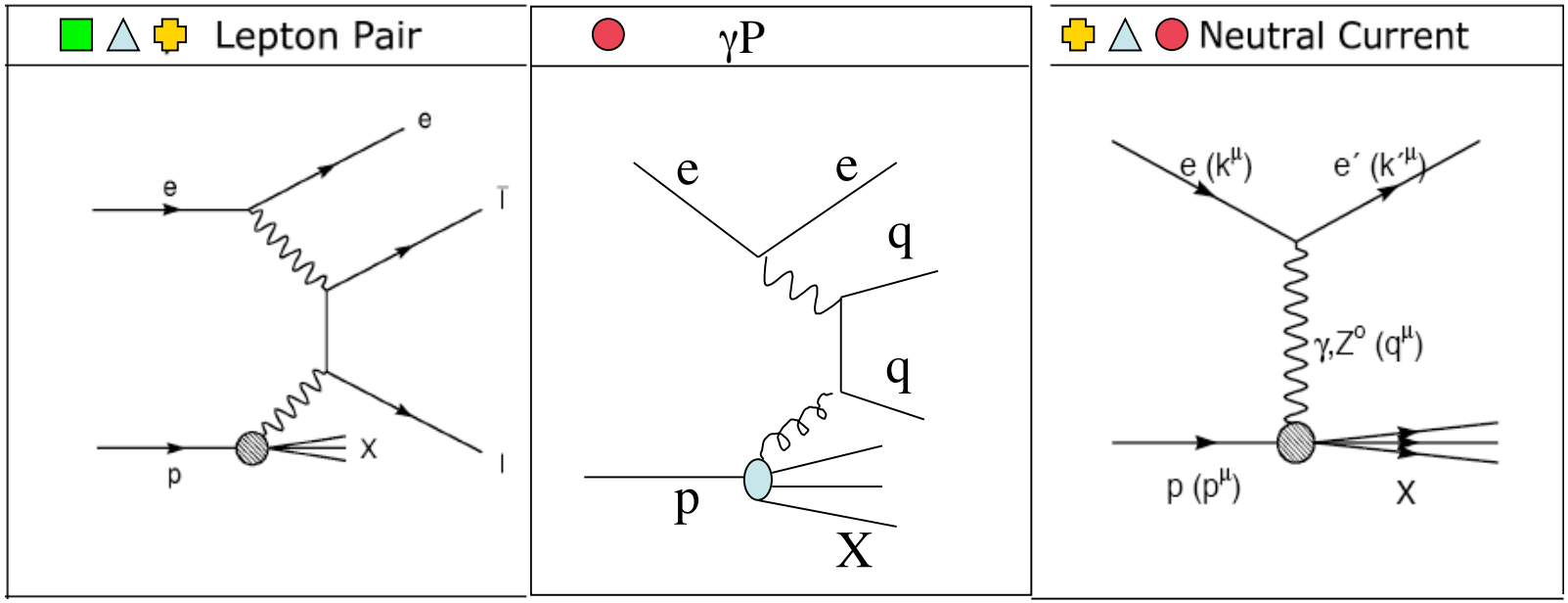
$L \in [0,1]$ with Background $\rightarrow 0$ and Signal (τ) $\rightarrow 1$

Study of $\tau^+\tau^-$ production : Selection

Isolated e	$20° < \theta_e < 140°$ $p^e_T > 3$ GeV
Isolated μ	$20° < \theta_\mu < 140°$ $p^\mu_T > 2$ GeV
Isolated jet	$20° < \theta_{jet} < 120°$ $p^{jet}_T > 2$ GeV $L_{1\text{-prong}} \,\|\|\, L_{3\text{-prong}} > 0.75$
$\tau^+\tau^-$ pair	Two isolated e or μ or jets of opposite charges
Elastic Production	Nothing else
Veto NC DIS	E-Pz < 50 GeV
Veto $e^+ e^-$	$L_e > 0.75$ if final state has isolated e and 1-prong jet
Veto $\mu+ \mu-$	$L_\mu > 0.75$ if final state has isolated μ and 1-prong jet

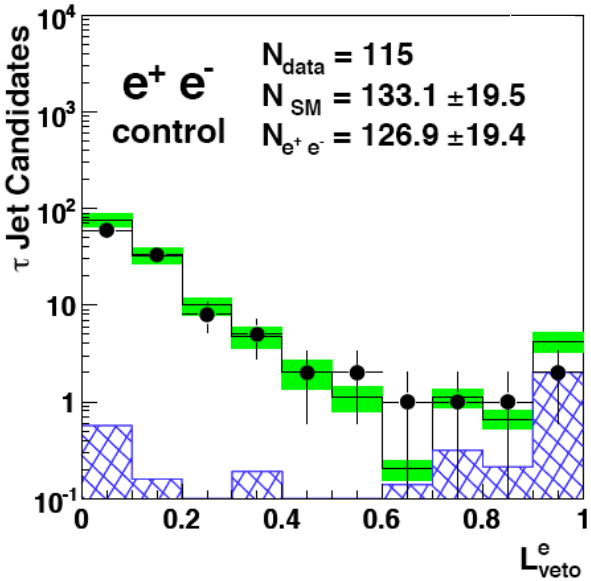
Signal eff. 50%
Background rej. 0.5%, 4%

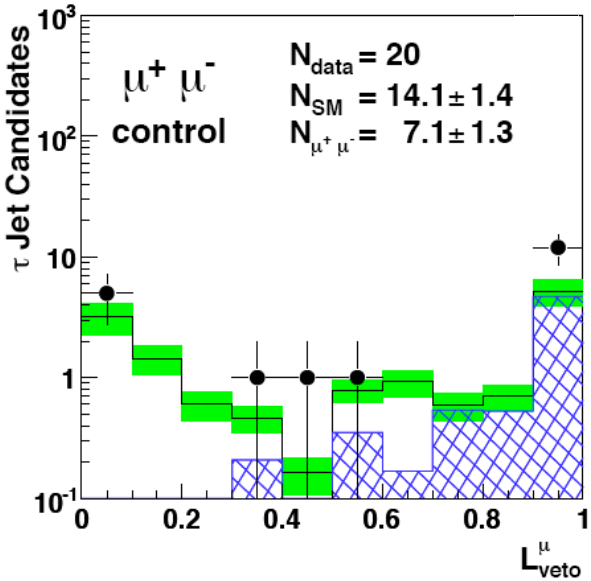
Study of $\tau^+\tau^-$ production : Backgrounds

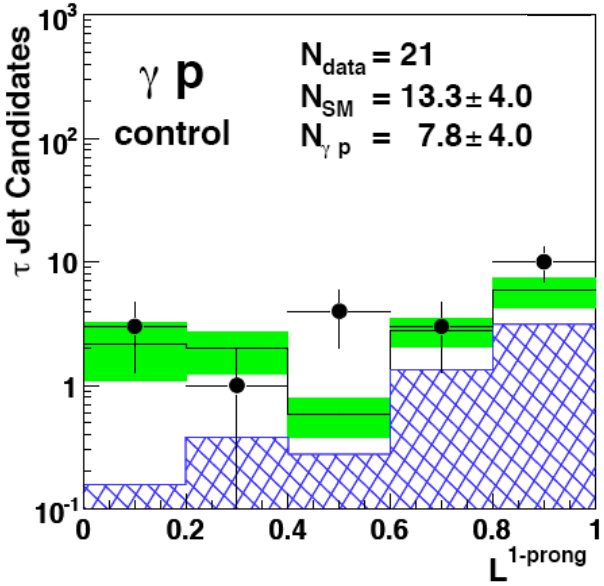


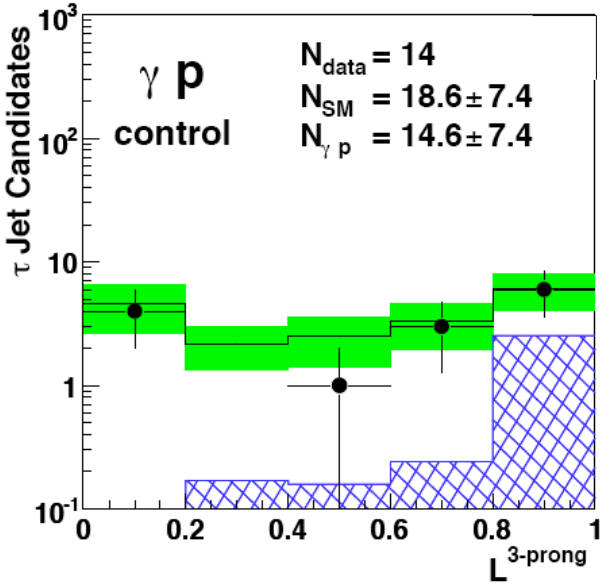
- q/g jet misidentified as τ jet
- unidentified e misidentified as 1-prong τ jet
- unidentified μ misidentified as 1-prong τ jet
- e/μ interpreted as $\tau \rightarrow$ e/μ

Study of $\tau^+\tau^-$ production : Background control samples





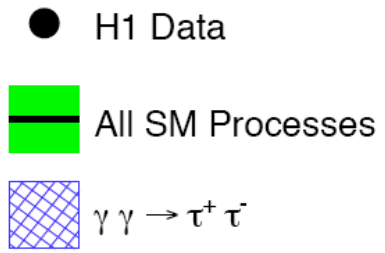




Main backgrounds :

$\gamma\gamma \rightarrow e^+e^-$, $\mu^+\mu^-$
NC , γP

Dedicated control samples selected to study background description and tau identification



Study of $\tau^+\tau^-$ production : Results Hera I (106 pb^{-1})

Number of events passing $\tau^+\tau^-$ selection

Decay channel	Leptonic eμ	Semileptonic		Hadronic τ-jet τ-jet	Total
		e τ-jet	μ τ-jet		
H1 Data	7	2	10	11	30
SM	2.9±0.4	6.3±0.9	7.0±1.3	11.0±2.0	27.1±4.1
$\tau^+\tau^-$	56%	47%	85%	50%	59%

Purest final state

Total number of events observed is in agreement with SM expectation

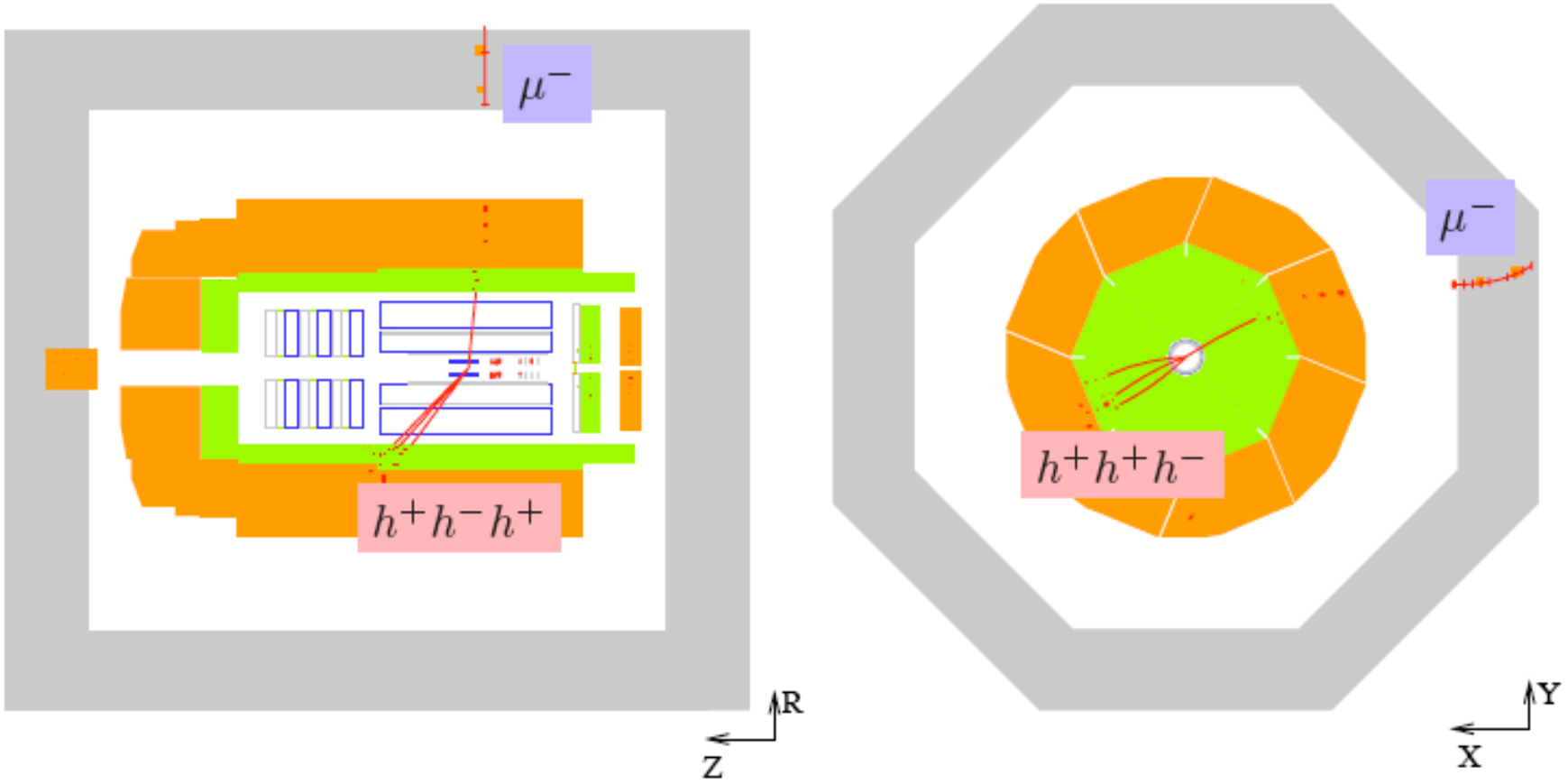
H1

TAU PAIR CANDIDATE

$$e^+p \longrightarrow e^+ \quad \tau^- \quad \tau^+p$$

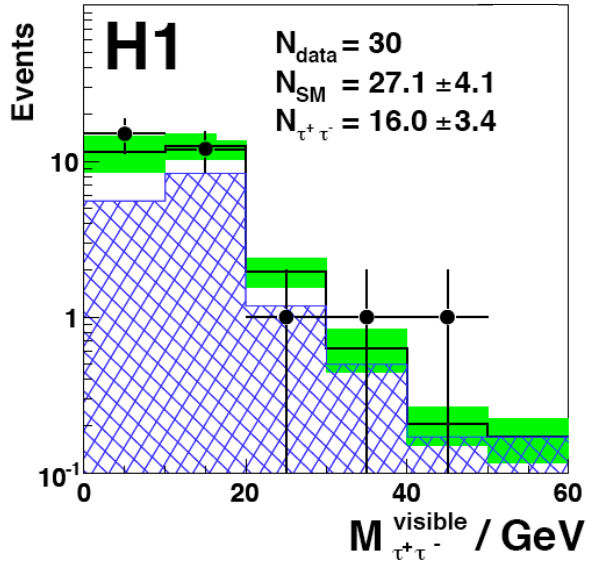
$$\tau^- \rightarrow \mu^- \quad \bar{\nu}_\mu \nu_\tau$$

$$\tau^+ \rightarrow h^+h^+h^- \quad \bar{\nu}_\tau$$



$\tau^+\tau^-$ Production Cross Section

First time at HERA!

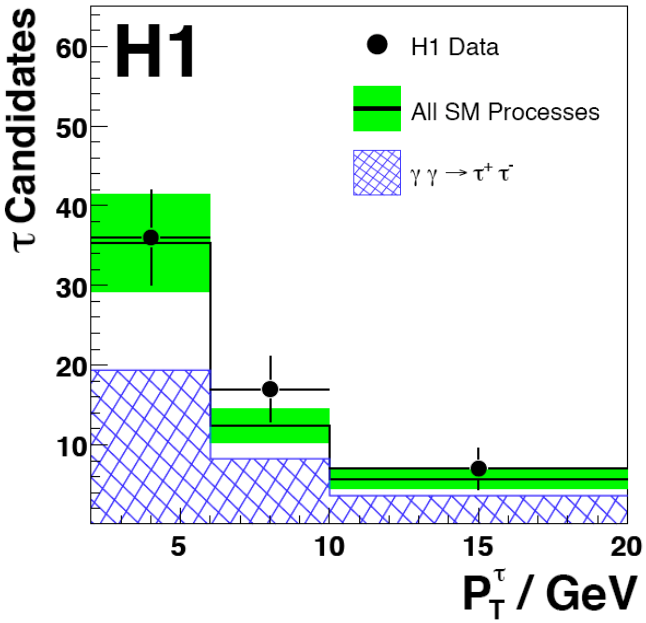


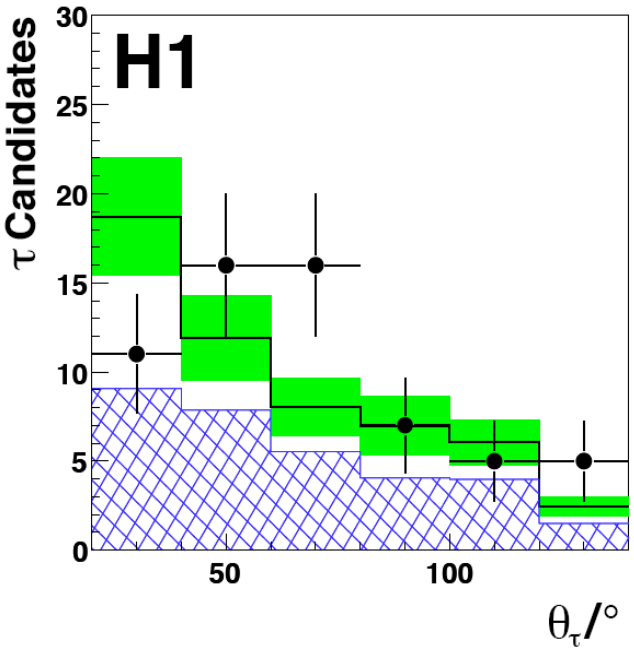
Phase space definition : elastic events with two τ leptons of

- $p^{\tau}_T > 2$ GeV acceptance ≈1%
- $20° < \theta_\tau < 140°$

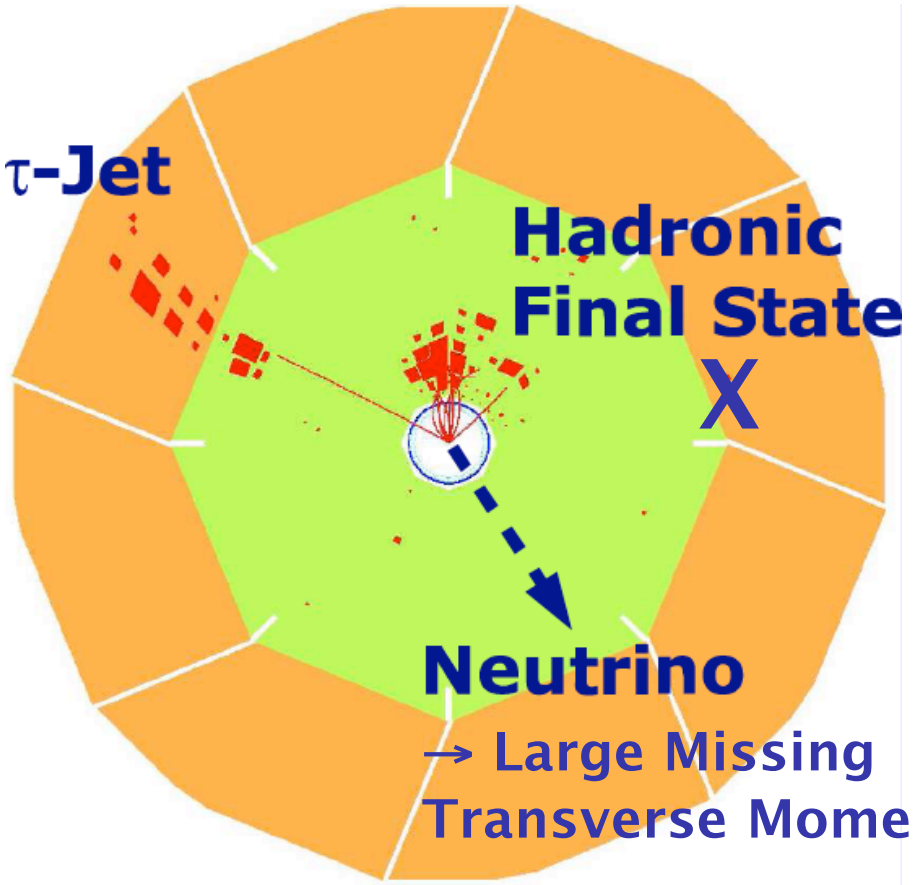
$$\sigma_{measured} = 13.6 \pm 5.7 \text{ pb}$$

$$\sigma_{expected} = 11.2 \pm 0.3 \text{ pb}$$



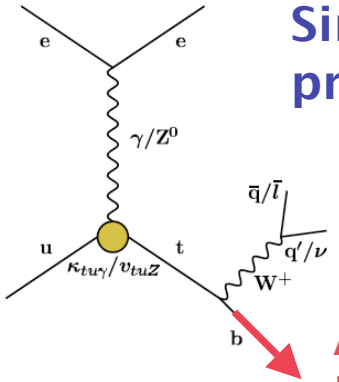


Search for events with an isolated τ and large missing p_T



Search motivated by excess observed at high p_T^X in the search for Isolated electrons and muons (see D.South, this conference)

An excess at high p_T^X could be a sign of new physics E.g.



Single top production

Additional high p_T jet → Large p_T^X

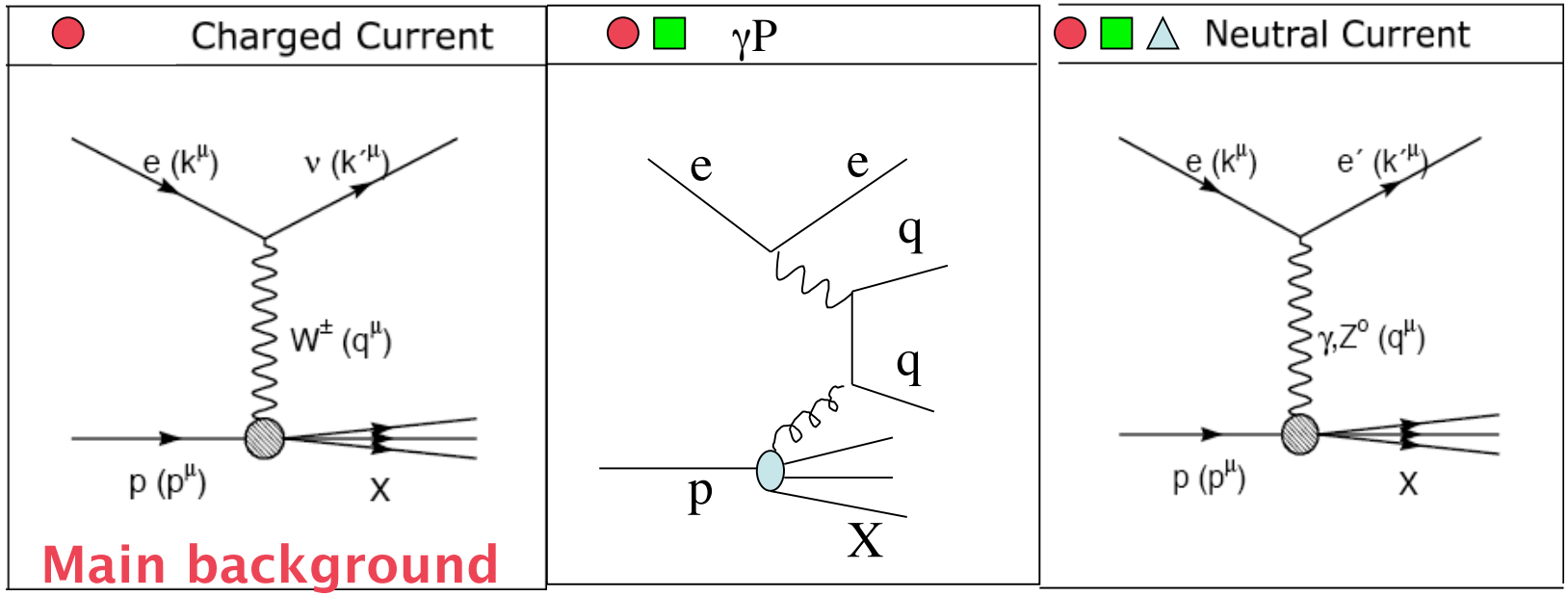
Search for τ + large p_T^{miss} : Selection

Large missing momentum	$P_T^{miss} > 12$ GeV
Isolated jet	$20° < \theta_{jet} < 120°$ $p^{jet}_T > 7$ GeV
Veto NC DIS	$E-Pz < 50$ GeV
Veto NC and γP	$\Delta\phi$ (τ – X) < 170° Vap/Vp < 0.5 (Vap/Vp <0.15 iff PtCalo<25 GeV)
τ Identification Veto CC	Only 1 charged track in isolated jet Rjet < 0.12 $p_T^{track} > 5$ GeV

Signal eff. ≈ 80%
Background rej ≈ 1%

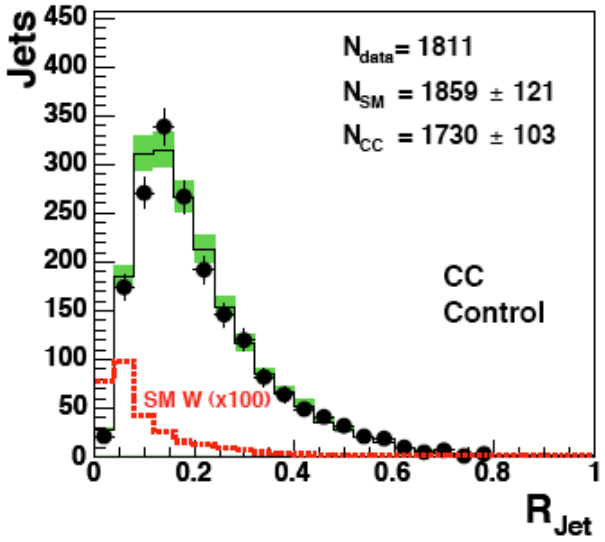
R_{jet} = Radius of the jet =
Energy weighted distance in (η,ϕ)
of each hadron in the jet from the jet axis

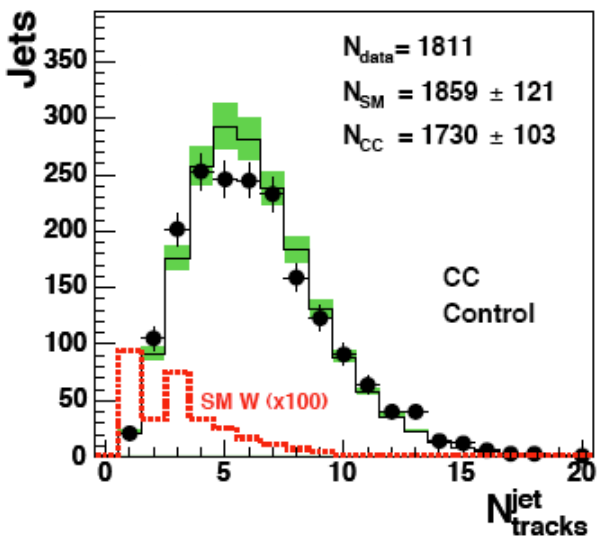
Search for τ + large p_T^{miss} : Backgrounds



- q/g jet misidentified as τ jet
- e misidentified as 1-prong τ jet
- P_T^{miss} due to mismeasurement

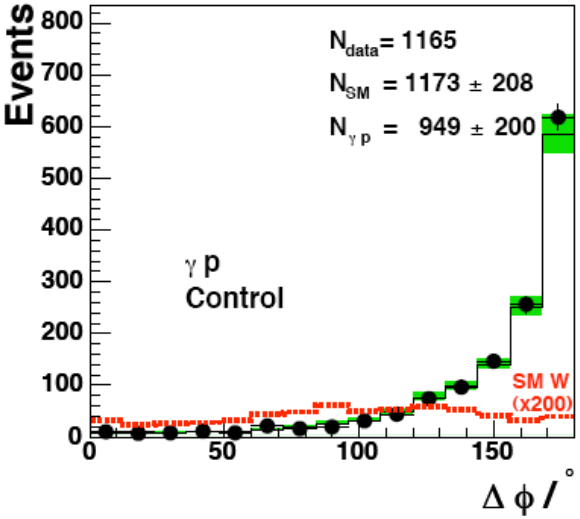
Search for τ + large p_T^{miss} : Background control samples

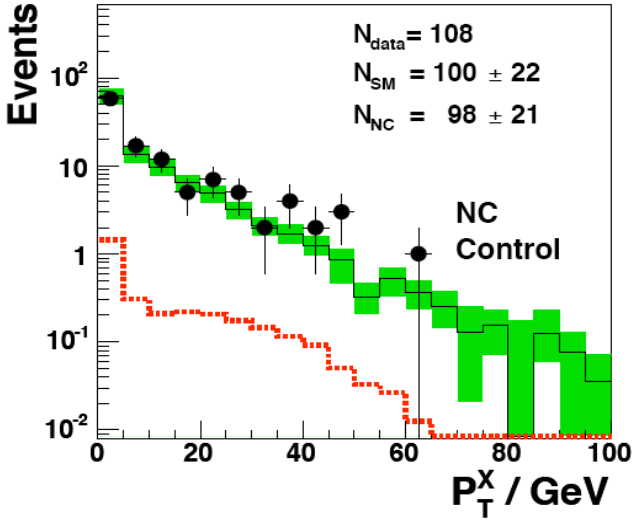


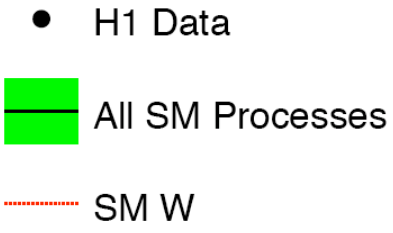


Main backgrounds :
CC, γP, NC

Dedicated control samples selected to study background description and tau identification







Search for τ + large p_T^{miss} : Results Hera I (115 pb^{-1})

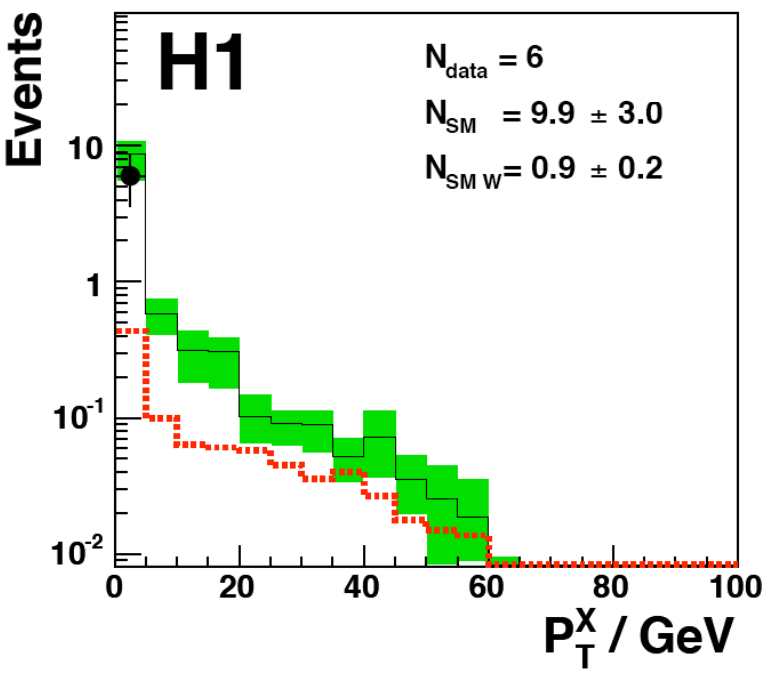
Number of events passing τ + large p_T^{miss} selection

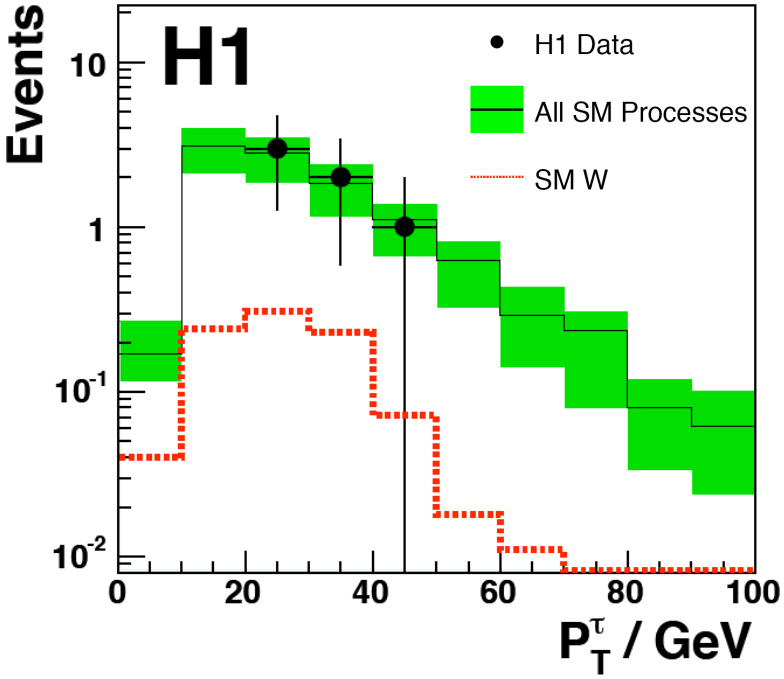
	H1 Data	Total SM expectation	SM signal (W)	Other SM Processes
Total	6	9.9 ± 3.0	0.89 ± 0.20	9.0 ± 3.0
$P_T^X > 25$ GeV	0	0.39 ± 0.10	0.20 ± 0.05	0.19 ± 0.09

Number of events observed is compatible with SM expectation

No event observed at high p_T^X

Cross section limit for $\tau + p_T^{miss}$ processes





Cross section upper limit at 95% C.L. for $p_T^X > 25$ GeV

Phase space definition

- $p^\tau_T > 10$ GeV
- $5° < \theta_\tau < 140°$
- $p_T^{miss} > 12$ GeV

Accept. ≈8%

$\sigma(p_T^X > 25\ \text{GeV}) < 0.31$ pb

Compatible with results on isolated e/μ : Phys.Lett.B561 (2003) 241

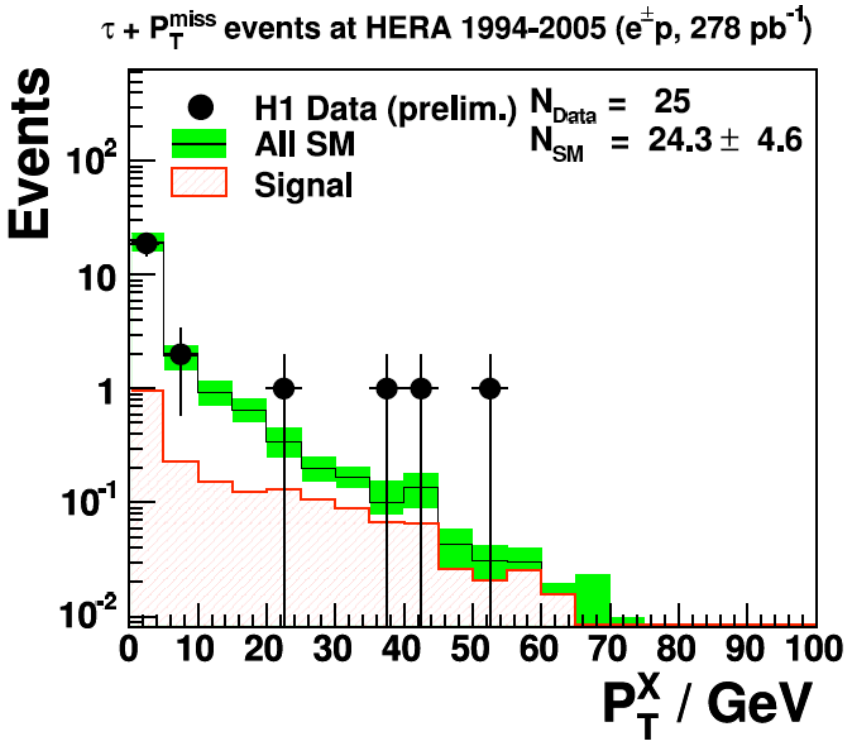
Search for τ + large p_T^{miss} : Results Hera I + II (278 pb^{-1})

e^+p and e^-p samples, 278 pb^{-1}

New H1 preliminary result

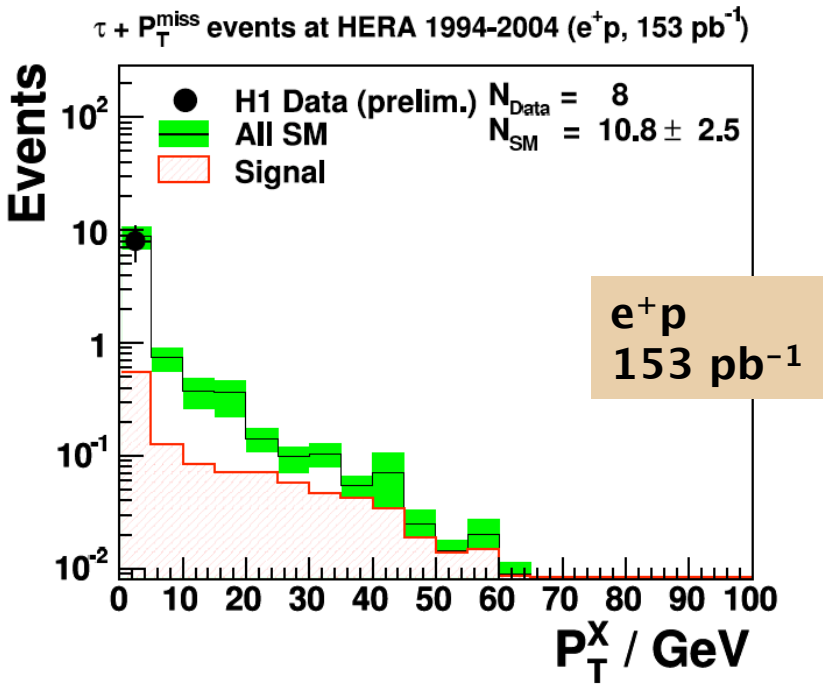
on Hera I and Hera II data

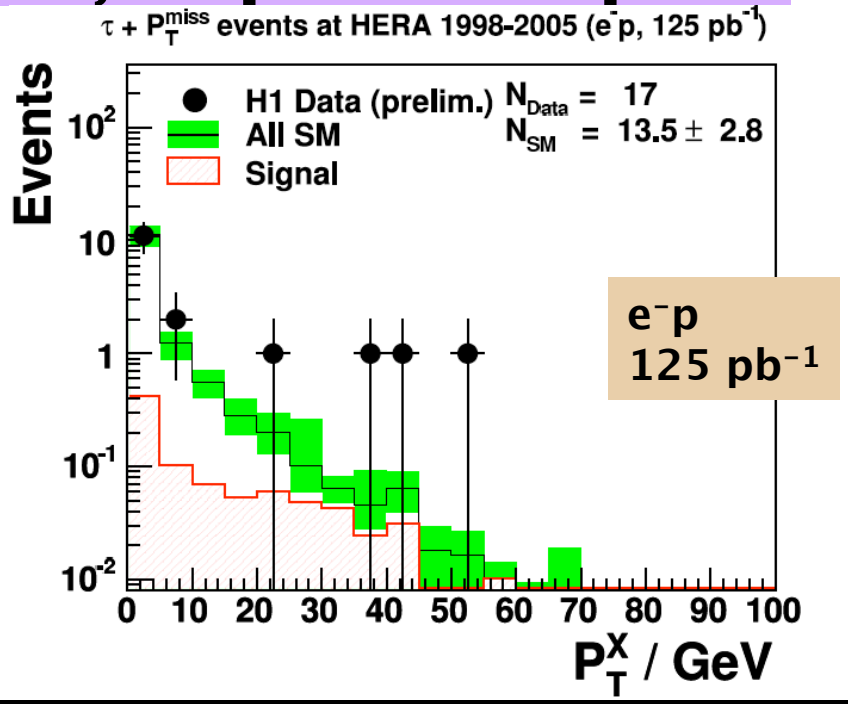
→e^+p and e^-p samples have now comparable sizes



H1 Preliminary		H1 Data	Total SM expectation	SM signal (W)	Other SM Processes
94-05 $e^{\pm}p$ 278 pb^{-1}	Total	25	24.2 ± 5.0	2.0 ± 0.37	22.2 ± 5.0
	P_T^X>25 GeV	3	0.74 ± 0.18	0.44 ± 0.08	0.31 ± 0.16

Search for τ + large p_T^{miss} : Results Hera I + II, e^+p and e^-p

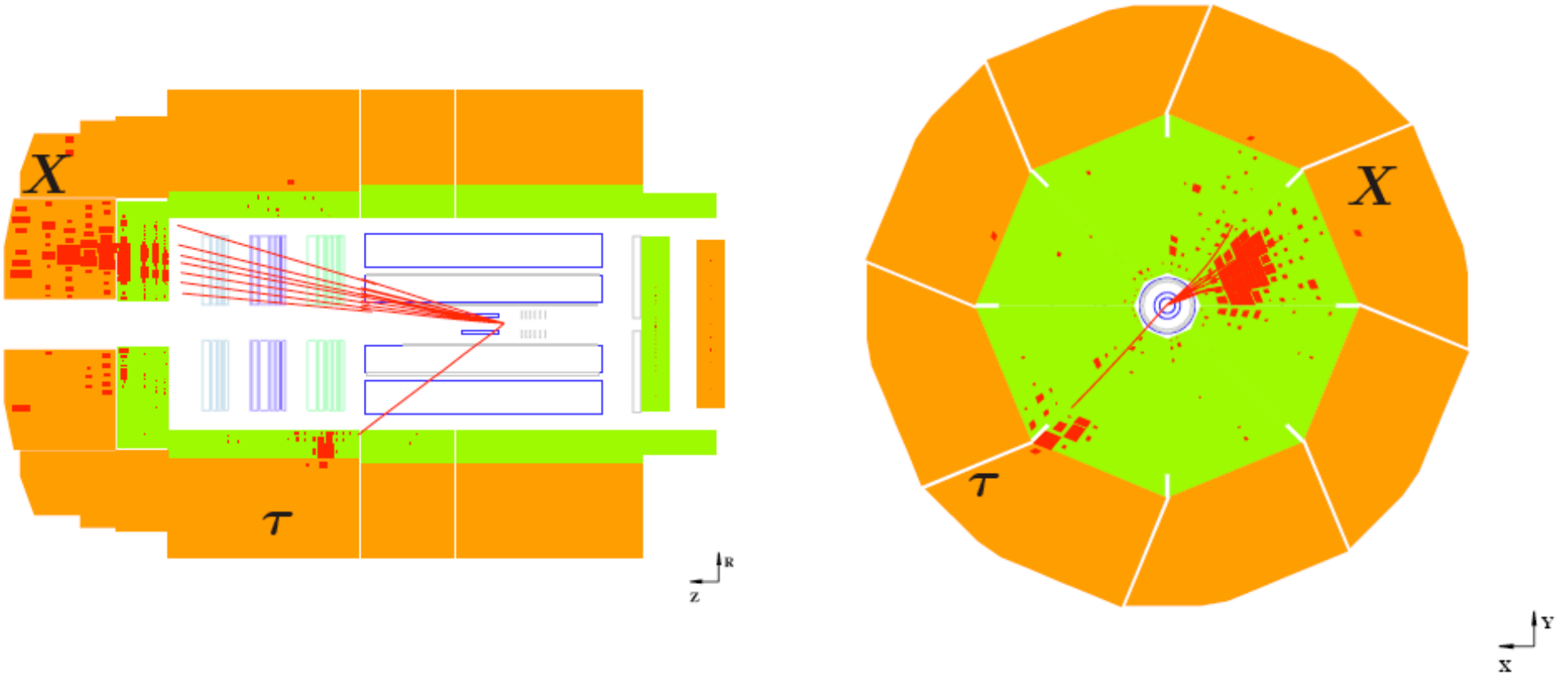




H1 Preliminary		H1 Data	Total SM expectation	SM signal (W)	Other SM Processes
94-04 e^+p 153 pb^{-1}	Total	8	10.6 ± 2.9	1.1 ± 0.23	9.5 ± 2.9
	P_T^X>25 GeV	0	0.40 ± 0.10	0.24 ± 0.05	0.15 ± 0.09
98-05 e^-p 125 pb^{-1}	Total	17	13.5 ± 2.6	0.9 ± 0.15	12.6 ± 2.6
	P_T^X>25 GeV	3	0.35 ± 0.09	0.19 ± 0.03	0.16 ± 0.09

H1 preliminary

H1 $\tau + \mathrm{P_T^{miss}}$ candidate with large $\mathrm{P_T^X}$



$$P_T^{miss} = 28 \text{ GeV} \quad P_T^{\tau} = 13 \text{ GeV} \quad P_T^{X} = 39 \text{ GeV}$$

Summary

The production of tau pairs in ep collisions has been studied for the first time at HERA, with 106 pb^{-1} of data.
The measured cross section is
$\sigma_{\tau^+\tau^-} = 13.6 \pm 5.7$ pb
compatible with the expected value of 11.2 ± 0.3 pb

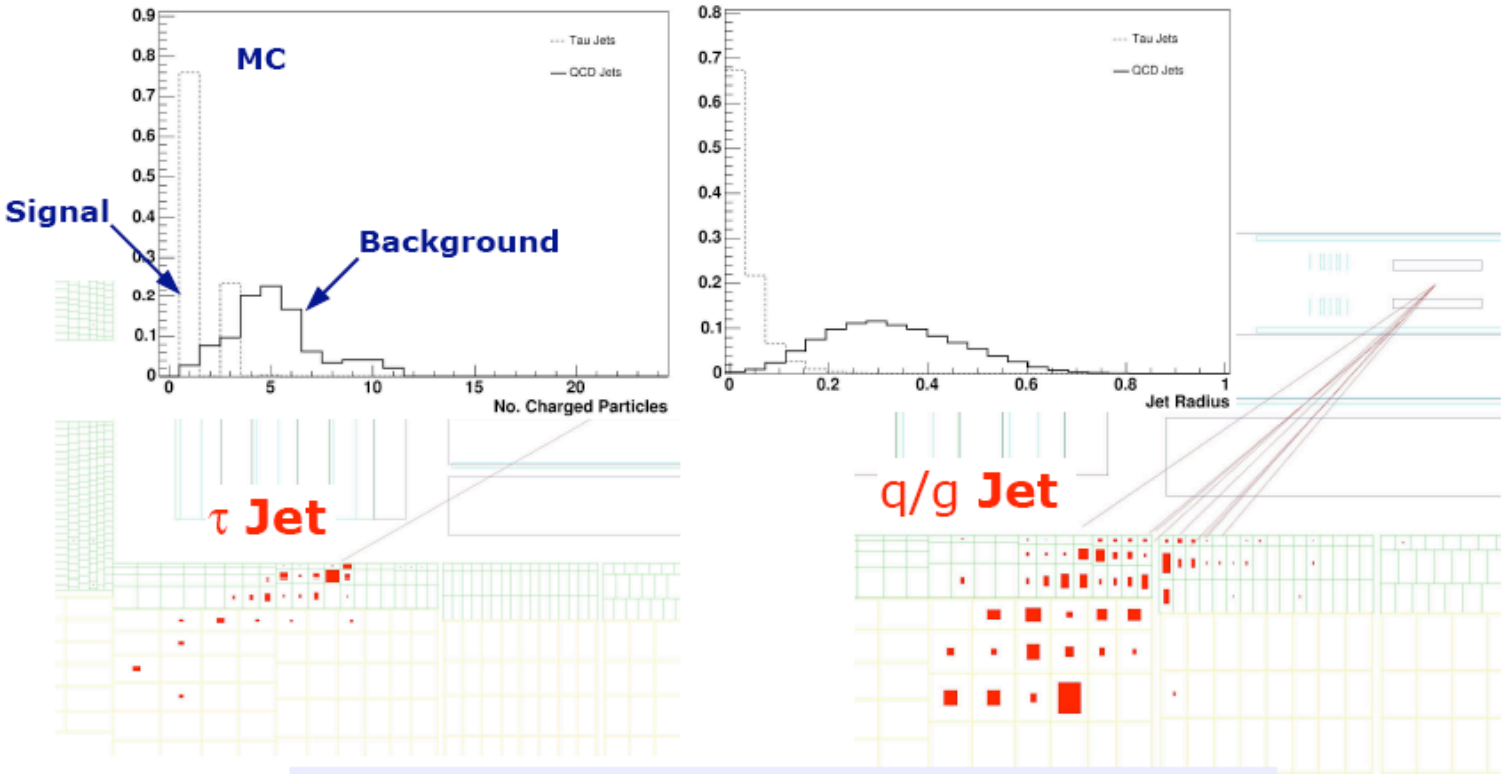
The search for isolated tau leptons in events with large missing momentum has been finalized on 115 pb^{-1} of data.

Both results are summarized in the publication hep-ex/0604022, DESY-06-029 , H1-150

Preliminary results on 278 pb^{-1} of data on the search for isolated $\tau + p_T^{miss}$ are also reported.
At $p_T^X > 25$ GeV , 3 events are observed,
for 0.74 ± 0.18 expected from SM processes

backup

Hadronic τ decays



A hadronic τ decay originates a jet with very specific charateristics : collimated energy deposits in Calorimeter and few charged particles in Tracking detectors