



Results on tau physics from HERA

Junpei Maeda
(Tokyo Institute of Technology)

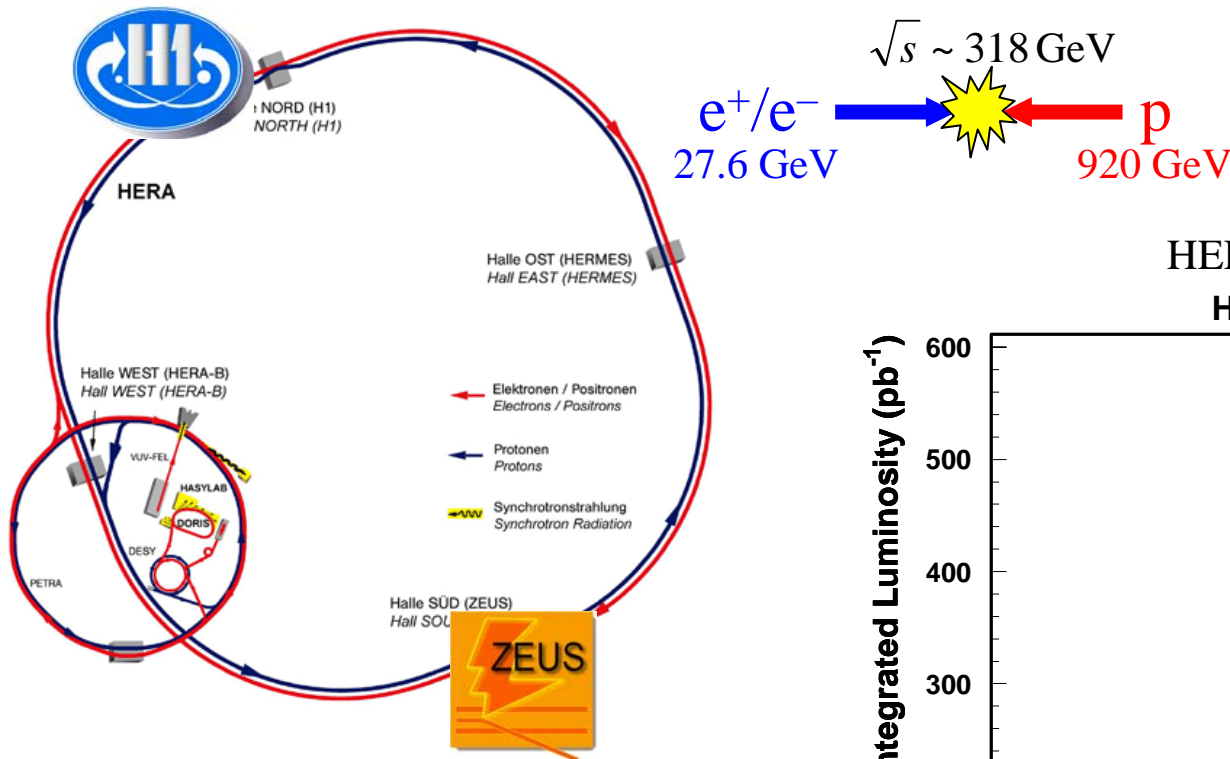


On behalf of
the H1 and ZEUS collaborations

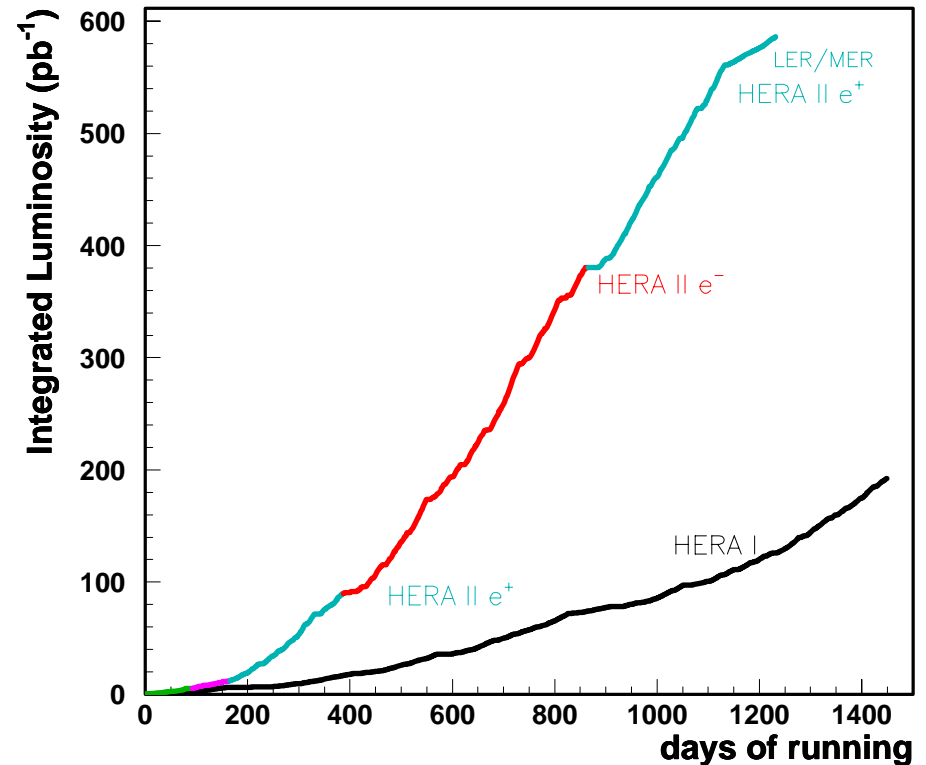


10th Int. Workshop on Tau Lepton Physics (TAU08)
September 22–25, 2008
Novosibirsk, Russia

HERA: World's Only ep Collider



HERA laid to rest on 30 June 2007.
HERA delivered



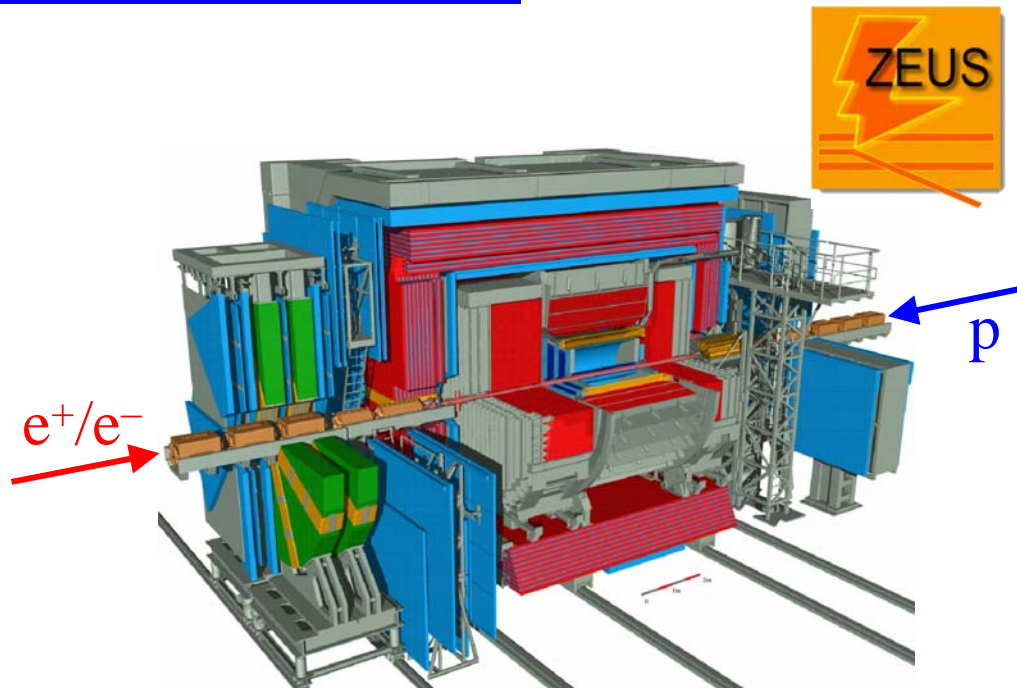
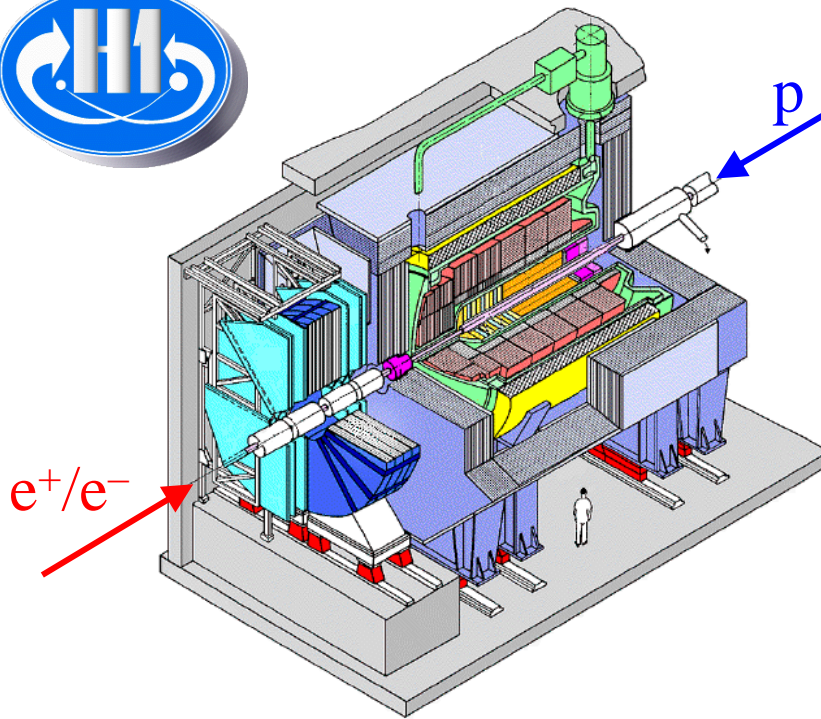
HERA-I (1992~2000) : $L \sim 120 \text{ pb}^{-1}/\text{exp.}$

HERA-II (2002~2007) : $L \sim 350 \text{ pb}^{-1}/\text{exp.}$

- luminosity upgraded
- longitudinally polarized lepton beam
- detector upgrades

→ 0.5 fb^{-1} data for each experiment!

H1 and ZEUS detector



Liquid Argon Calorimeter

fine granularity, excellent tracking

$$\sigma(E)/E = 12\% / \sqrt{E} \text{ for electrons}$$

$$\sigma(E)/E = 50\% / \sqrt{E} \text{ for hadrons}$$

Uranium–scintillator Calorimeter

good hadronic energy resolution

$$\sigma(E)/E = 18\% / \sqrt{E} \text{ for electrons}$$

$$\sigma(E)/E = 35\% / \sqrt{E} \text{ for hadrons}$$

Tau Production at HERA

Tau lepton production is a rare process at HERA!

- $\tau^+\tau^-$ pair-production events
- Isolated τ lepton with missing transverse momentum(P_T^{miss}) events
- Double charged Higgs Search
- Lepton Flavour Violation

→ Tau lepton is important in exotic search.

Tau Production at HERA

- $\tau^+\tau^-$ pair-production events
 - Leptonic channel ($\tau^+\tau^- \rightarrow e^\pm \mu^\mp$)
 - Semi-leptonic channel ($\tau^+\tau^- \rightarrow e^\pm had^\mp, \mu^\pm had^\mp$)
 - Hadronic channel ($\tau^+\tau^- \rightarrow had^\pm had^\mp$)
- Isolated τ lepton with missing transverse momentum(P_T^{miss}) events
- Double charged Higgs Search
- Lepton Flavour Violation

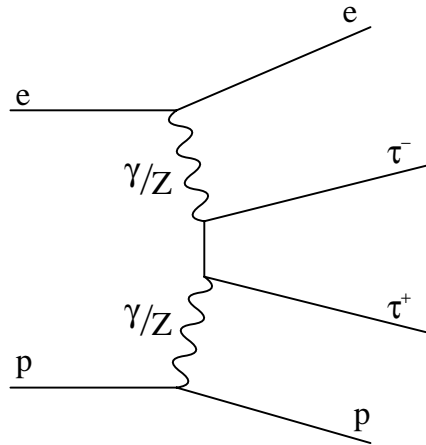
$\tau^+\tau^-$ pair-production (only leptonic) @ ZEUS

$ep \rightarrow \tau^+\tau^-(ep)$

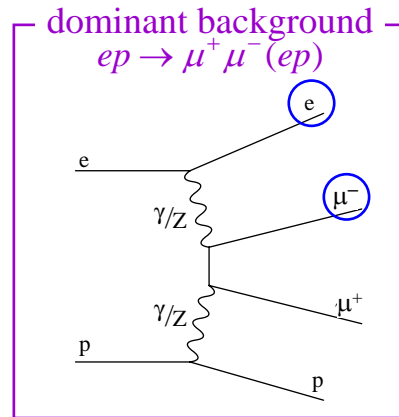
HERA-II e^-p data $L=135 \text{ pb}^{-1}$

ZEUS

ZEUS-prel-06-017

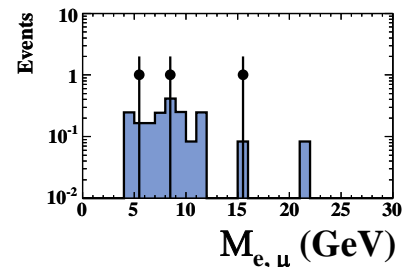
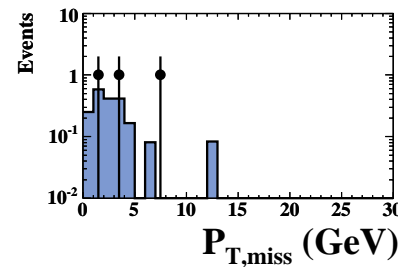
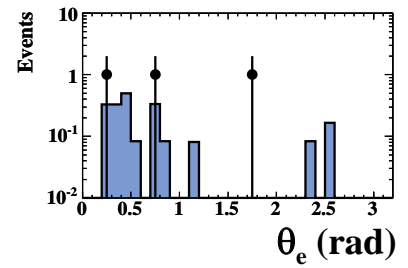
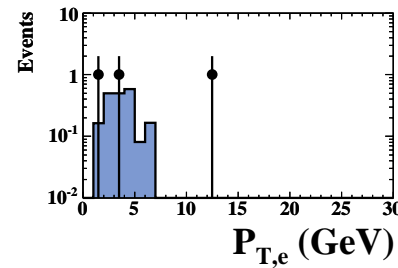
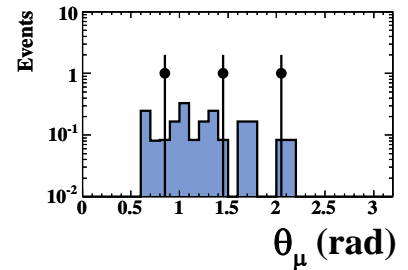
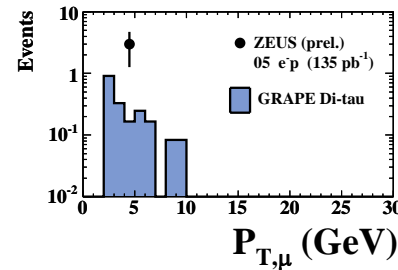


searched for $\tau^+\tau^- \rightarrow e^\pm \mu^\mp$
(leptonic decay)



selection criteria

electron	muon
$E_e > 4 \text{ GeV}$	$p_T^\mu > 2 \text{ GeV}$
$\theta_e < 2.6 \text{ rad}$	$0.6 \text{ rad} \leq \theta_\mu \leq 2.8 \text{ rad}$
	(Acceptance of central tracking detector)
elastic requirements <ul style="list-style-type: none"> Number of tracks in event : 1~3 No energy deposit in "forward" calorimeter region 	



ZEUS e^-p 135 pb⁻¹ (prel.)

Data	$\tau^+\tau^-$	$\mu^+\mu^-$
3	2.0 ± 0.8	< 0.2

→ Data agree with SM expectation.

$\tau^+\tau^-$ pair-production (incl. hadronic) @ ZEUS

$ep \rightarrow \tau^+\tau^-(ep)$

HERA-II $e^\pm p$ data $L=364 \text{ pb}^{-1}$

ZEUS-prel-08-009

To study hadronically-decayed τ identification, searched for:

$$\tau^+\tau^- \rightarrow \begin{cases} e^\pm + h^\mp + \nu_\tau + \dots & (\text{BR} : \sim 23\%) \\ h^\pm + h^\mp + \nu_\tau + \dots & (\text{BR} : \sim 42\%) \end{cases}$$

more statistics than $e\mu$ channel ($\sim 6\%$)

Hadrons from τ decay is identified by "jet".

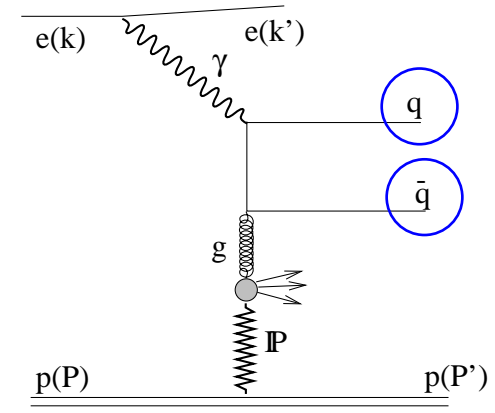
The most difficult thing : separate a τ -jet from quark/gluon induced jets

$\sigma \sim 10 \text{ pb}$ ($P_T^\tau > 5 \text{ GeV}$)

There are many kinds of large background...

e.g.) diffractive-photoproduction

$\sigma \sim 300 \text{ nb}$ (2 jets w/ $E_T > 4 \text{ GeV}$)



electron	jet
$p_T^e > 5 \text{ GeV} \ \& \ -2 < \eta_e < 2$ matched track ($p_{T^{\text{track}}} > 3 \text{ GeV}$)	$p_T^{\text{jet}} > 5 \text{ GeV} \ \& \ -2 < \eta^{\text{jet}} < 2$ at least one associated tracks, electron rejection cut
elastic requirements : No energy deposit in forward calorimeter region, Low track multiplicity	

τ -jet ID for $\tau^+\tau^-$ pair-production @ ZEUS

τ -ID using PDE Range Searching (discriminant)

had τ -ID

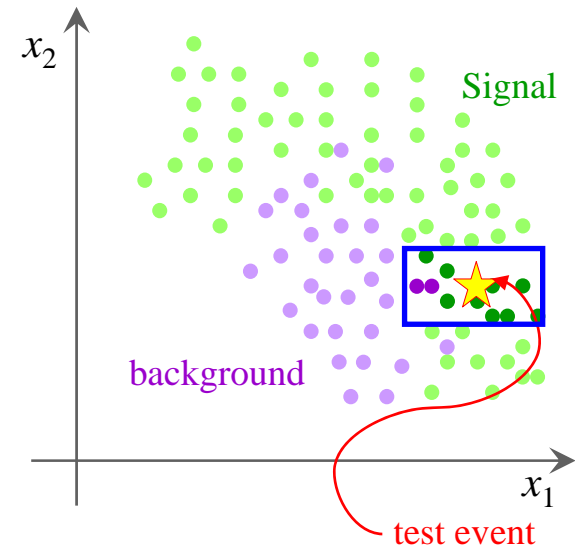
suggested by T.Carli, B.Koblitz.
NIMA501(2003)576

- Generalization of one-dimensional PDE approach to n dimensions
 - Counts number of signal and background events (training sample) in "vicinity" V of the test event
 - Implemented in **TMVA**

$$D(i_{\text{event}}, V) = \frac{\frac{\text{\#signal events in } V}{N_S}}{\frac{\text{\#signal events in } V}{N_S} + \frac{\text{\#background events in } V}{N_B}}$$

Diagram illustrating the components of the discriminant formula:

- Discrimination value $D(i_{\text{event}}, V)$
- #signal events in V $\rightarrow n_S(i_{\text{event}}, V)$
- #all signal events $\rightarrow N_S$
- #background events in V $\rightarrow n_B(i_{\text{event}}, V)$
- #all background events $\rightarrow N_B$



- 6 variables are inputted to discriminant, then evaluate discrimination value. (next slide)

τ -jet ID for $\tau^+\tau^-$ pair-production @ ZEUS

had τ -ID

ZEUS

6 variables are prepared for discriminant.

Rmean, Rrms : 1st and 2nd moment of radial extension

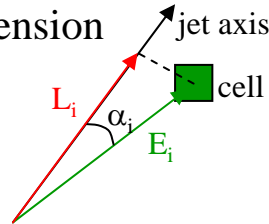
$$R_{mean} = \langle R \rangle = \frac{\sum_i \{E_i \cdot R_i\}}{\sum_i E_i} \quad R_{rms} = \sqrt{\frac{\sum_i E_i \cdot (\langle R \rangle - R_i)^2}{\sum_i E_i}}$$

Mass : invariant mass of clustered CAL cells

$$Mass = \sqrt{(\sum_i E_i)^2 - (\sum_i p_{i,x})^2 - (\sum_i p_{i,y})^2 - (\sum_i p_{i,z})^2}$$

Lmean : 1st moment of longitudinal extension

$$L_{mean} = \langle L \rangle = \frac{\sum_i E_i \cdot \cos \alpha_i}{\sum_i E_i}$$

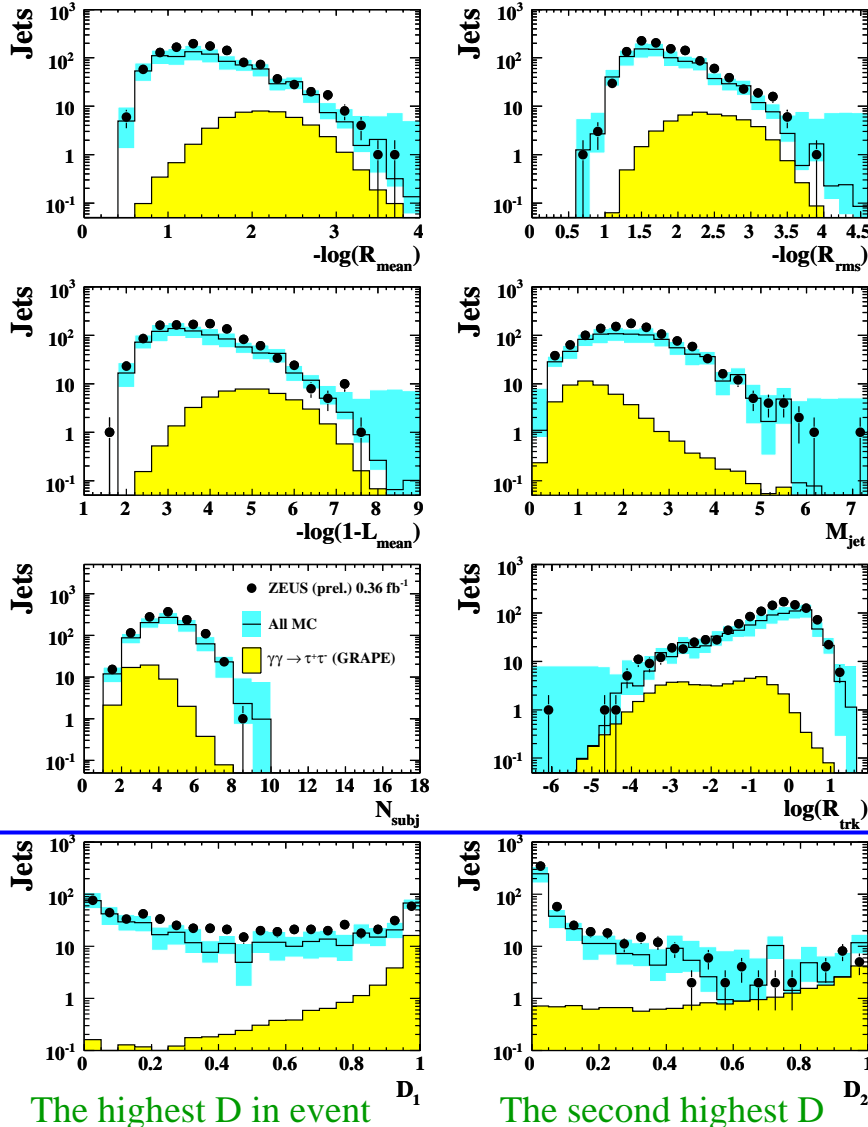


Rtrk : The sum of distance between the jet axis and the tracks associated with the jet

$$R_{trk} = \sum_i^{N_{trk}} \sqrt{(\Delta \eta_i^2 + \Delta \phi_i^2)}$$

Nsubj : Number of subjects ($y_{cut} = 5 \times 10^{-4}$)

← Outputted discrimination value



ZEUS-prel-08-009

Results of $\tau^+\tau^-$ pair-production @ ZEUS

$ep \rightarrow \tau^+\tau^-(ep)$ HERA-II $e^\pm p$ data $L=364 \text{ pb}^{-1}$

ZEUS-prel-08-009

Discriminant threshold is given for each topology

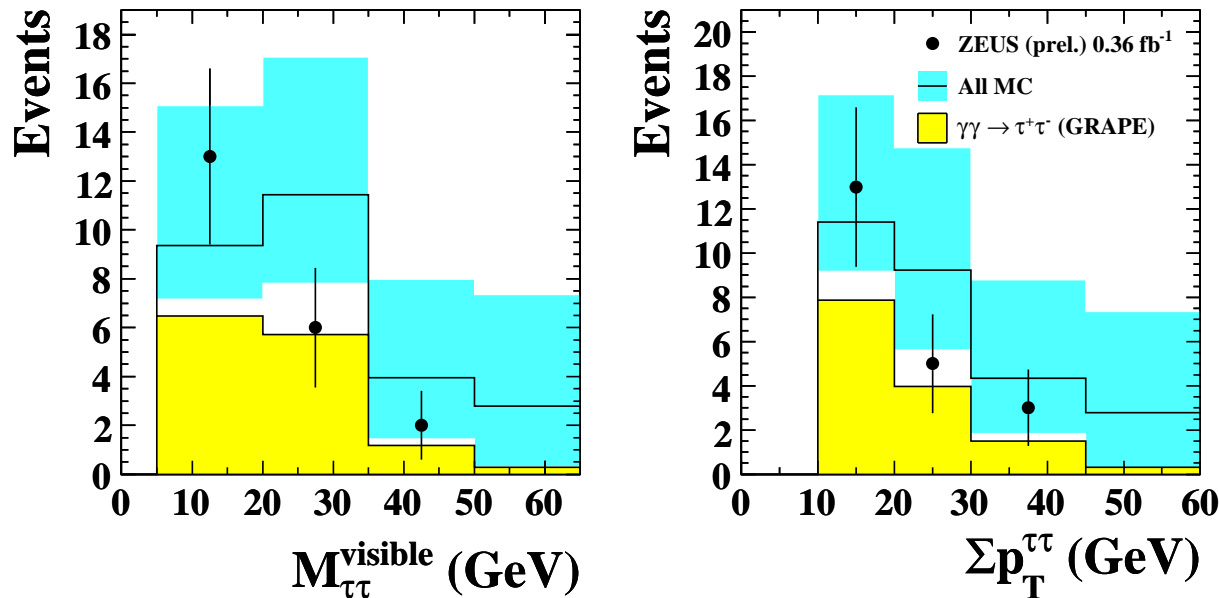
ZEUS ditau events HERA II data ($L=0.36 \text{ fb}^{-1}$)

Topology	All	jet-jet	e-jet-jet	e-jet	e-e-jet
D cut		0.80	0.50	0.90	0.90
Data	21	14	3	4	0
Total SM	$27.2^{+7.1}_{-6.3}$	$20.2^{+6.8}_{-5.7}$	$1.4^{+3.3}_{-0.2}$	$4.9^{+3.1}_{-1.3}$	$0.7^{+4.4}_{-0.1}$
ditau MC	$13.2^{+0.6}_{-1.0}$	$9.1^{+0.4}_{-0.8}$	1.4 ± 0.1	2.2 ± 0.1	0.5 ± 0.1
(purity)	(49%)	(45%)	(97%)	(46%)	(74%)

Large uncertainty due to {

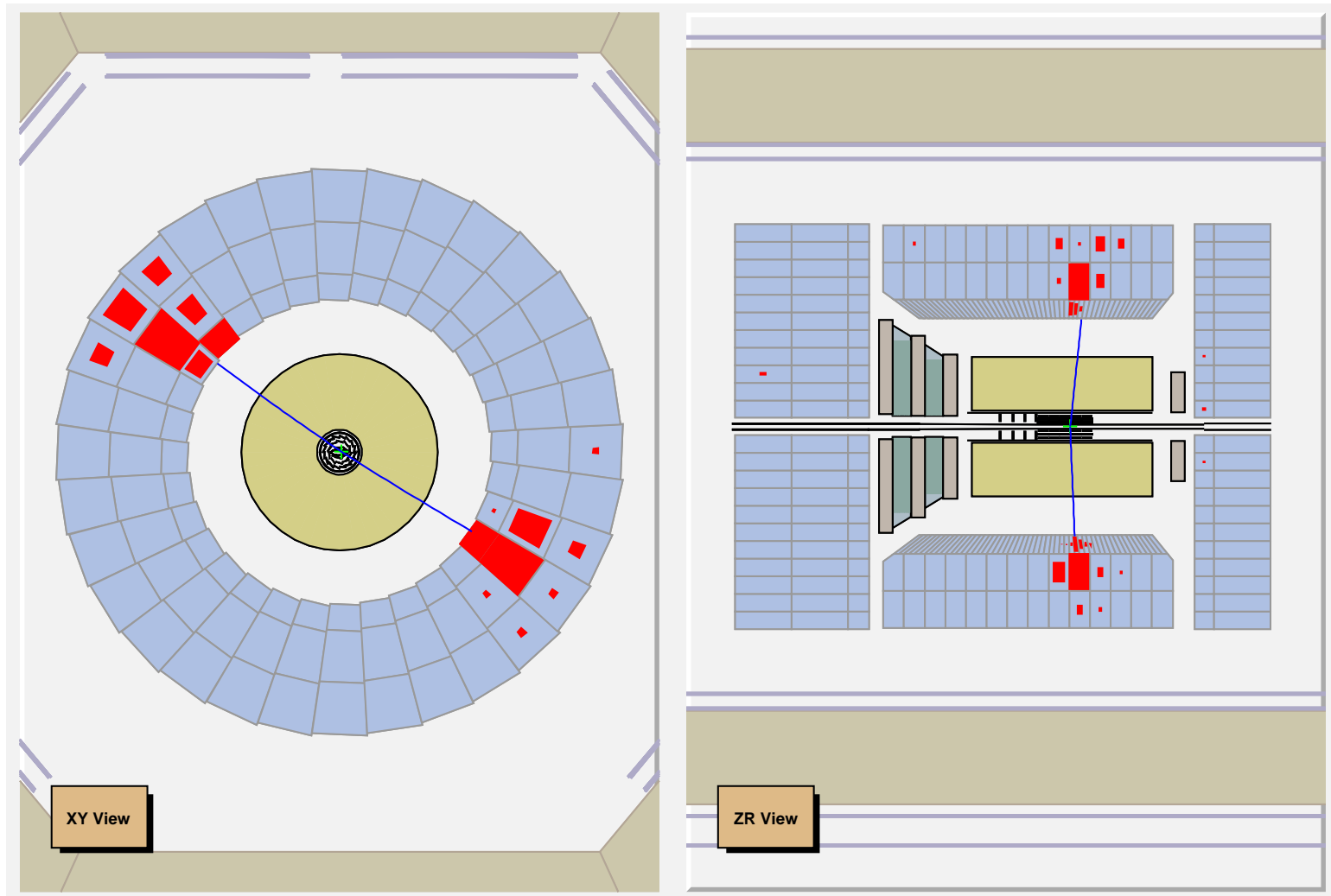
- MC statistics
- PHP scale normalization

ZEUS



Data are in reasonable agreement with SM expectation.

The highest $M_{\tau\tau}^{\text{visible}}$ event ($M_{\tau\tau}^{\text{visible}}=40$ GeV)



$\tau^+\tau^-$ pair-production @ H1

$ep \rightarrow \tau^+\tau^-(ep)$ HERA-I $e^\pm p$ data $L=106 \text{ pb}^{-1}$

Eur. Phys. J. C48 (2006) 699–714

look for all topologies to be able to identify $\tau^+\tau^-$ events

- leptonic($e\mu$), semi-leptonic(e -jet, μ -jet), hadronic(jet-jet) decay
- look at the jets from low P_T
 - exactly required 1 or 3-tracks in the jet
 - using neural network to identify τ -jet
- the first measurement of $\tau^+\tau^-$ cross section at ep -collider

Neural Network based tau-ID

had τ -ID

- To distinguish hadronic 1-prong, 3-prong τ decays from quark/gluon jets ($L_{1\text{-prong}}$, $L_{3\text{-prong}}$)
- To distinguish hadronic 1-prong τ decays from misidentified electrons/muons (L_{veto}^e , L_{veto}^μ)
 - multiplicities of neutral clusters / invariant mass / number of tracks / 1st moment of energy deposits...

electron	muon	jet
$p_T^e > 3 \text{ GeV}$	$p_T^\mu > 2 \text{ GeV}$	$p_T^{\text{jet}} > 2 \text{ GeV}$ $L_{1\text{-prong}} \parallel L_{3\text{-prong}} > 0.75$
Two isolated e or μ or jets of opposite charges		
elastic requirements : No additional tracks/clusters, No activity in forward regions		
NC/di-e/di- μ rejection : $E-P_z < 50 \text{ GeV}$, $L_{\text{veto}}^e > 0.75$, $L_{\text{veto}}^\mu > 0.75$		

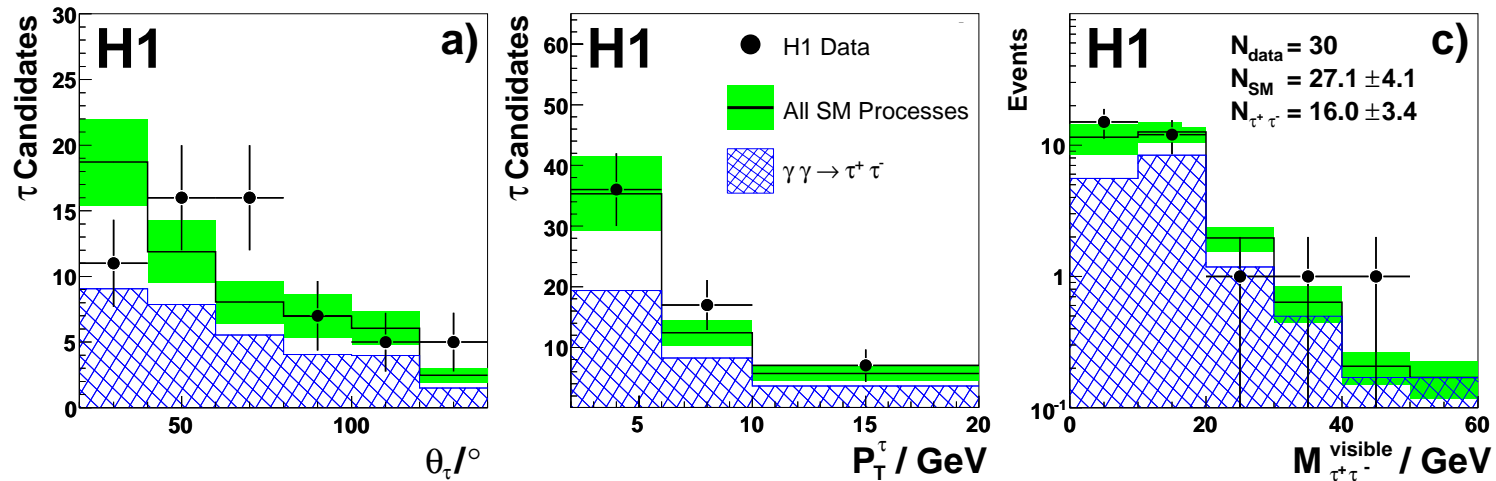
signal efficiency = 50%

misidentified probability = 0.5% (4%)

Results of $\tau^+\tau^-$ pair-production @ H1

$ep \rightarrow \tau^+\tau^-(ep)$ HERA-I $e^\pm p$ data $L=106 \text{ pb}^{-1}$

Eur. Phys. J. C48 (2006) 699–714



$\tau^+\tau^-$ Results					
Decay Channel	Leptonic $e\mu$	Semi-leptonic		Hadronic $\tau\text{-jet } \tau\text{-jet}$	Total
		$e\tau\text{-jet}$	$\mu\tau\text{-jet}$		
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%

Phase space definition

elastic events with two τ leptons of

- $p_T^\tau > 2 \text{ GeV}$
- $-20^\circ < \theta_\tau < 140^\circ$

(acceptance $\approx 1\%$)

Purest final state

$$\sigma_{\text{measured}} = 13.6 \pm 4.4 \pm 3.7 \text{ pb}$$

stat. syst.

$$\sigma_{\text{theory}} = 11.2 \pm 0.3 \text{ pb (GRAPE)}$$

first measurement at HERA !!

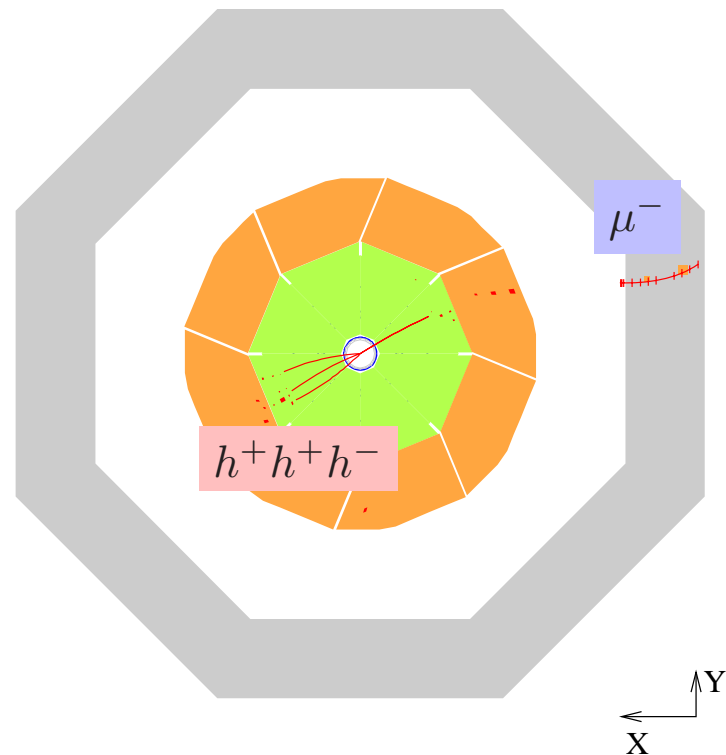
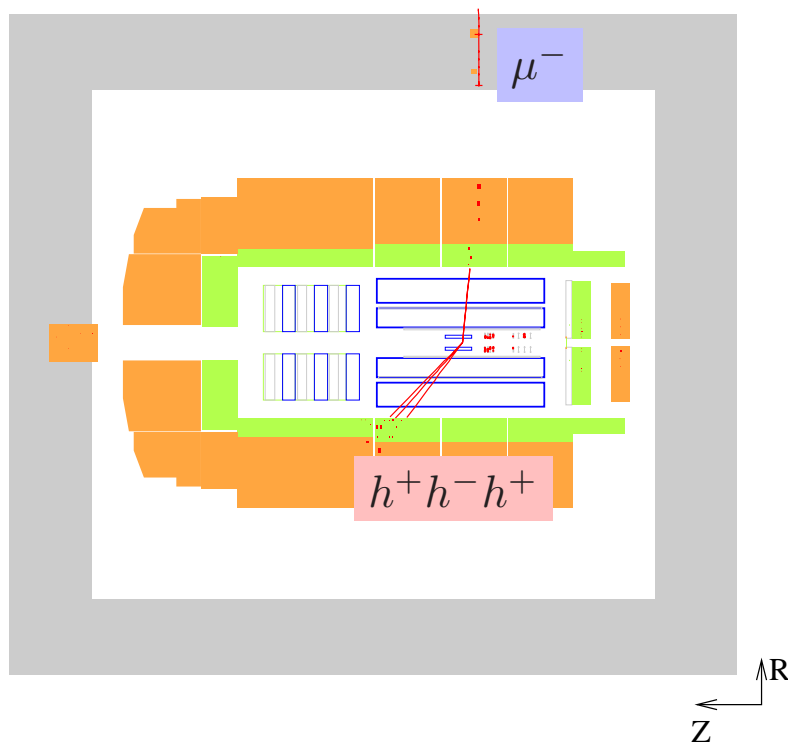
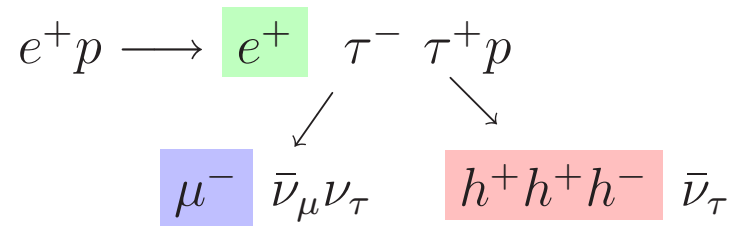
→ good agreement with SM expectation!

$\tau^+\tau^-$ candidate @ H1

Eur. Phys. J. C48 (2006) 699–714

H1

TAU PAIR CANDIDATE



Tau Production at HERA

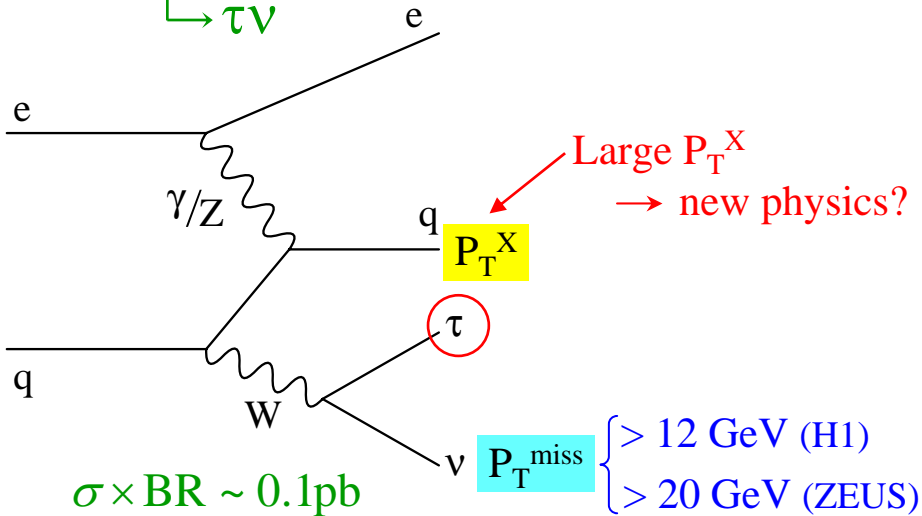
- $\tau^+\tau^-$ pair-production events
- Isolated τ lepton with missing transverse momentum(P_T^{miss}) events
- Double charged Higgs Search
- Lepton Flavour Violation

Isolated tau leptons + P_T^{miss} physics

ZEUS : Phys. Lett. B 583 (2004) 41

H1 : H1prelim-07-064

$$ep \rightarrow W(eX) \rightarrow \tau \nu$$

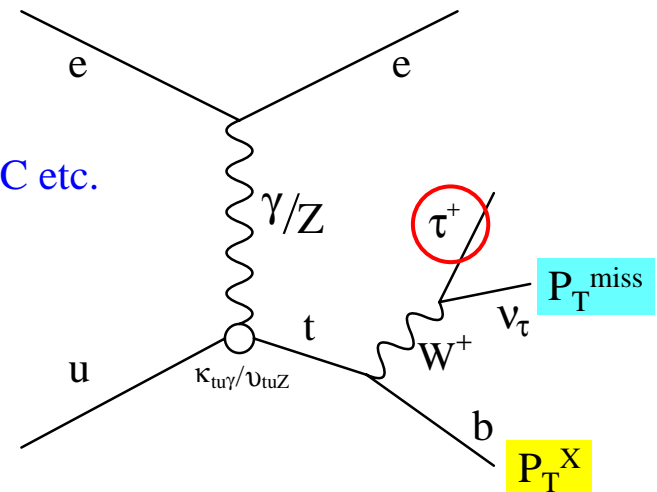


Rare process, but sensitive to new physics

- SM signal is single W boson production with subsequent decay $W \rightarrow \tau \nu$.
- Main background is CC events with narrow jets.
- A complement to isolated $e(\mu) + P_T^{\text{miss}}$ analysis
(There is a slight excess for $e(\mu)$ channel at H1.)

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

→ single top production via FCNC etc.



Additional high p_T jet

τ -ID for Isolated $\tau + P_T^{\text{miss}}$ analysis @ ZEUS

HERA-I $e^\pm p$ data $L=130 \text{ pb}^{-1}$

Phys. Lett. B 583 (2004) 41

ZEUS

had τ -ID

τ -ID using PDE Range Searching

- Same method as $\tau^+\tau^-$ analysis. (see above)
- Variable set is different.

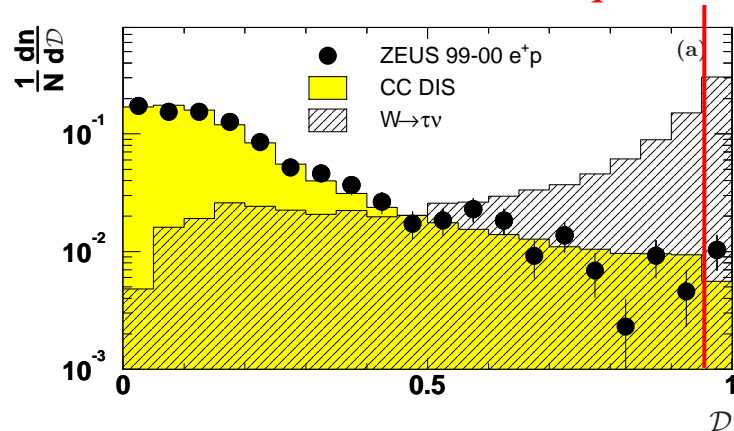
$$\log(R_{\text{trk}}) \rightarrow -\log(L_{\text{rms}})$$

L_{rms} : 2nd moment of longitudinal extension

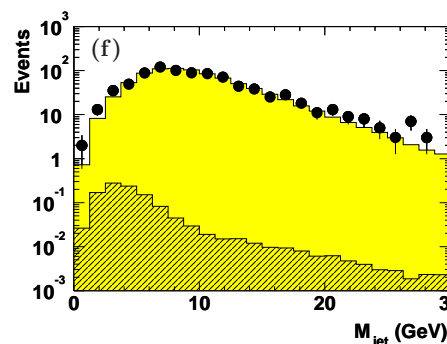
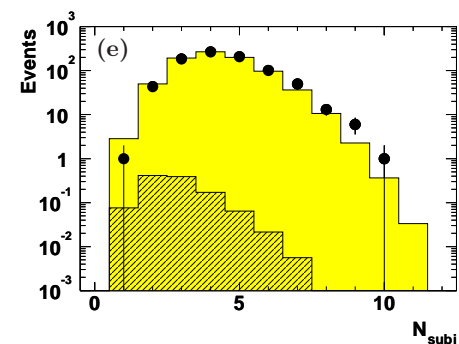
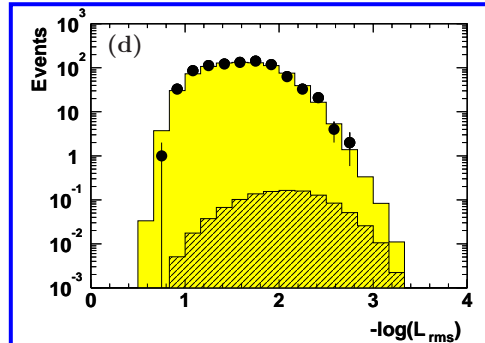
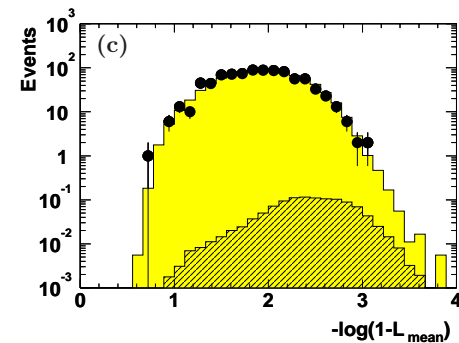
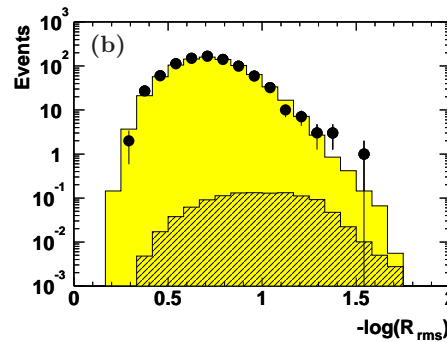
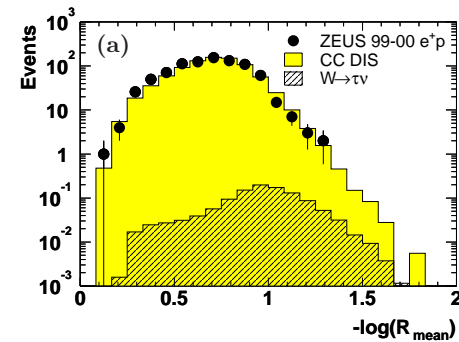
$$L_{\text{rms}} = \sqrt{\frac{\sum_i E_i (L_{\text{mean}} - \cos \alpha_i)^2}{\sum_i E_i}}$$

ZEUS

required $D > 0.95$



Good separation of signal from background!



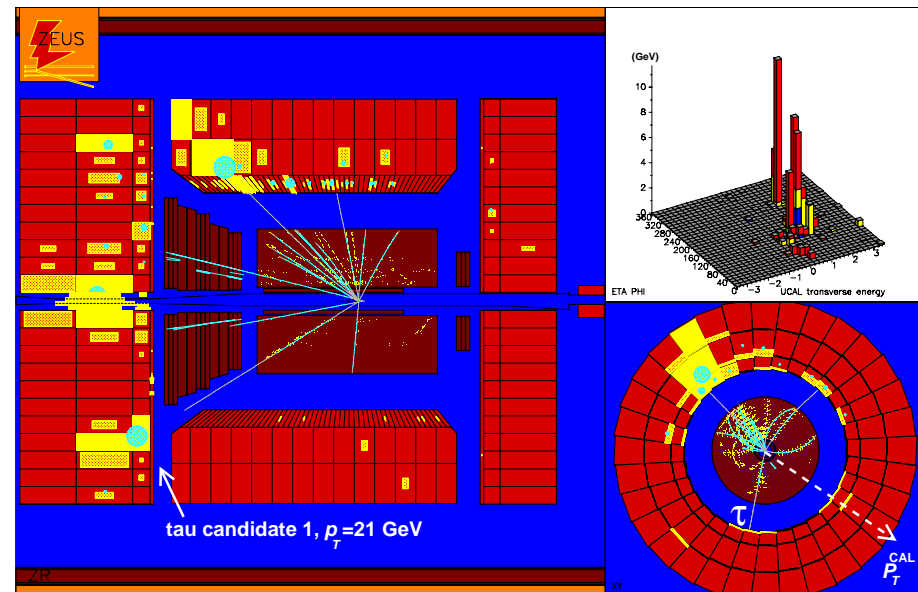
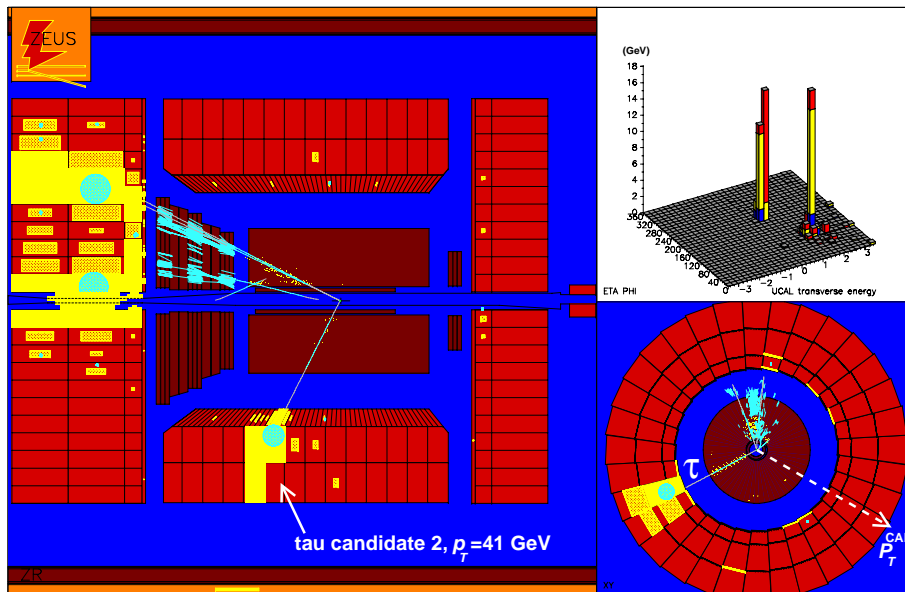
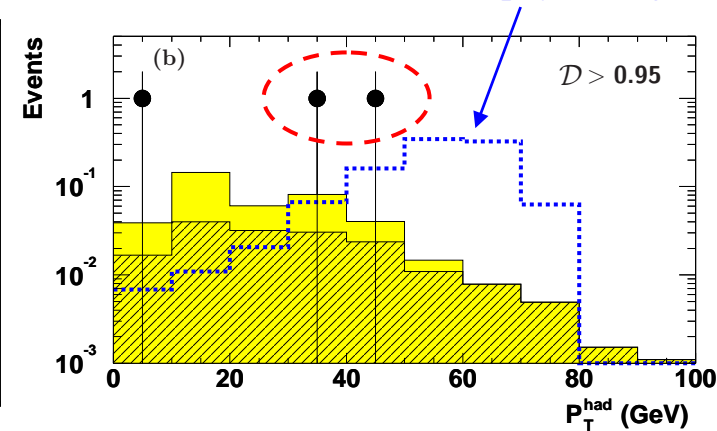
Result of isolated $\tau + P_T^{\text{miss}}$ @ ZEUS

Phys. Lett. B 583 (2004) 41

Interesting $\tau + P_T^{\text{miss}}$ events at large P_T^X are observed at ZEUS!

New physics signal

ZEUS 1994–2000 $e^\pm p$ $L = 130.1 \text{ pb}^{-1}$	ZEUS data	SM expectation	$W \rightarrow \tau \nu$ Contribution
Total	3	$0.40^{+0.12}_{-0.13}$	43%
$P_T^{\text{had}} > 25 \text{ GeV}$	2	0.20 ± 0.05	49%
$p_T^{\text{had}} > 40 \text{ GeV}$	1	0.07 ± 0.01	71%



Isolated tau leptons + P_T^{miss} @ H1

H1prelim-07-064

$$ep \rightarrow W(eX) \\ \downarrow \\ \tau \nu$$

- ZEUS HERA-I result has a slight excess for $\tau + P_T^{\text{miss}}$ events.
- H1 analyzed **all** HERA data. \longrightarrow **471 pb⁻¹**

had τ -ID

cut-based tau-ID

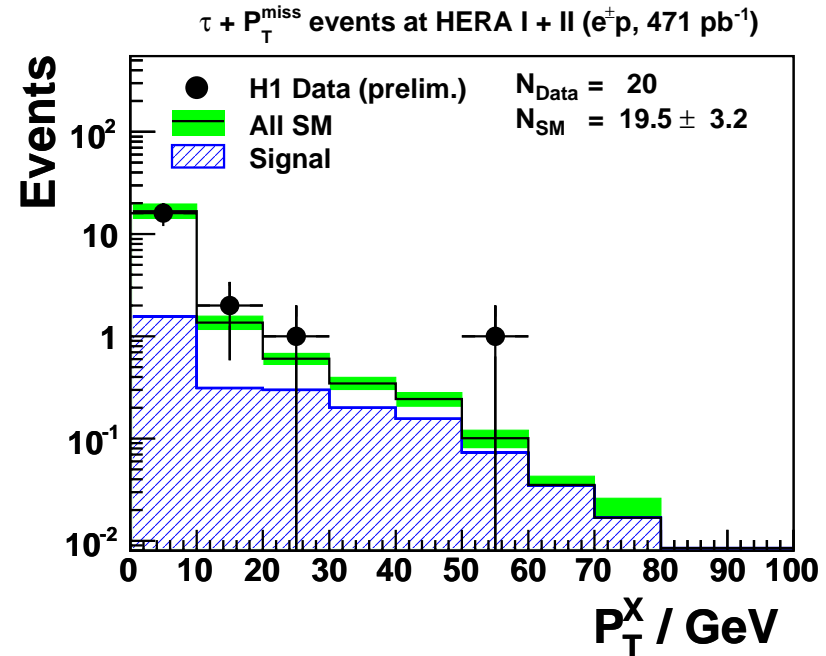
- look for jet in LAr calorimeter (cone radius = 1.0)
 $P_T^{\text{jet}} > 7 \text{ GeV}, 20^\circ < \theta^{\text{jet}} < 120^\circ$
- Isolation : Distance to other e, μ , jet in η - $\phi > 1.0$

Radial shower shape ("Jet radius") **< 0.12**

$$R_{\text{jet}} = \frac{1}{E_{\text{jet}}} \sum_h E_h \sqrt{\Delta\eta(\text{jet}, h)^2 + \Delta\phi(\text{jet}, h)^2}$$

- $N_{\text{jet}}^{\text{tracks}} = 1$ (**only 1-prong jet**)

\longrightarrow misidentification probability : **< 1%**



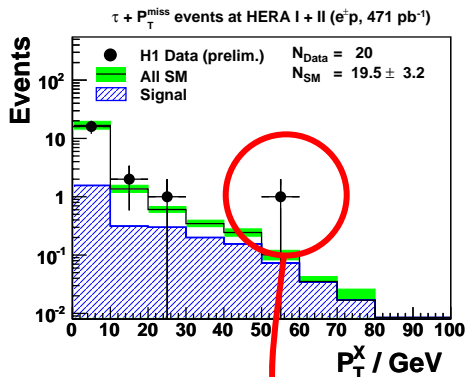
H1 Preliminary $\tau + P_T^{\text{miss}}$ events at HERA I+II		H1 Data	SM Expectation	SM Signal $W \rightarrow \tau \nu$	Other SM Processes
$e^\pm p$	Full Sample	20	19.5 ± 3.2	2.7 ± 0.4	16.8 ± 2.8
471 pb ⁻¹	$P_T^X > 25 \text{ GeV}$	1	0.99 ± 0.13	0.62 ± 0.10	0.37 ± 0.03

CC events are dominant.

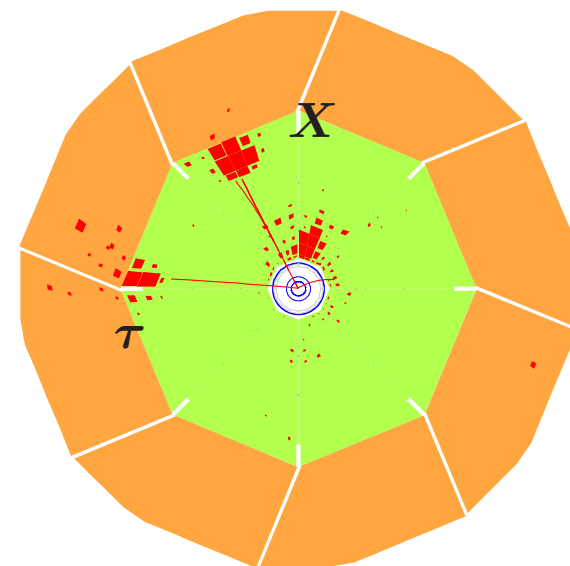
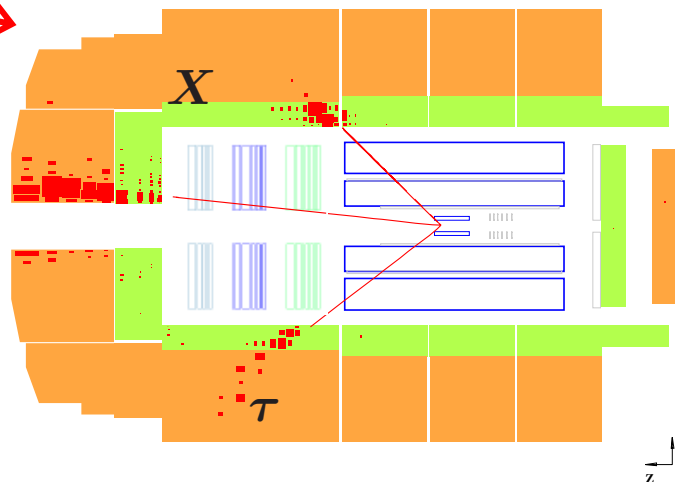
Data in good agreement with SM prediction!

$\tau + P_T^{\text{miss}}$ candidate event

H1prelim-07-064



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



$$P_T^{\text{miss}} = 59 \text{ GeV} \quad P_T^\tau = 14 \text{ GeV} \quad P_T^X = 51 \text{ GeV}$$

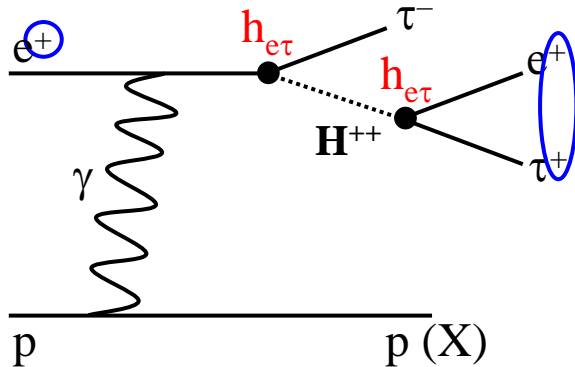
Tau Production at HERA

- $\tau^+\tau^-$ pair-production events
- Isolated τ lepton with missing transverse momentum(P_T^{miss}) events
- Double charged Higgs Search
- Lepton Flavour Violation

Doubly-charged Higgs search @ H1

Phys. Lett. B 638 (2006) 432

searched for H^{++} bosons using HERA-I e^+p data $L=88 \text{ pb}^{-1}$



Event class	$H^{++} \rightarrow e^+\tau^+$ final selection		
	N_{obs}	N_{bckg}	Signal fraction
$e\mu$	0	0.27 ± 0.02	6 %
eh	1	1.66 ± 0.48	12 %
ee	0	0.14 ± 0.04	7 %
total	1	2.07 ± 0.54	25 %

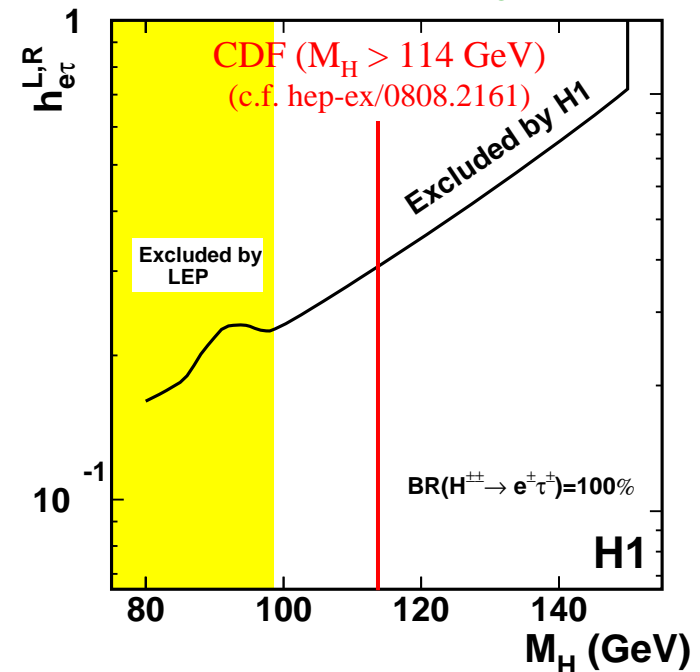
SM

signal efficiency

had τ -ID

cut-based tau-ID

e	μ	jet
$p_T^e > 10(5) \text{ GeV}$ Isolated	$p_T^\mu > 10(5) \text{ GeV}$ Isolated	$p_T^{\text{jet}} > 10(5) \text{ GeV}$ No other track within $0.15 < R < 1.5$
$P_T^{\text{miss}} > 8 \text{ GeV (e-e)} / P_T^{\text{miss}} > 11 \text{ GeV (e-jet)}$ Charge of Higgs decay product candidates = lepton beam charge		



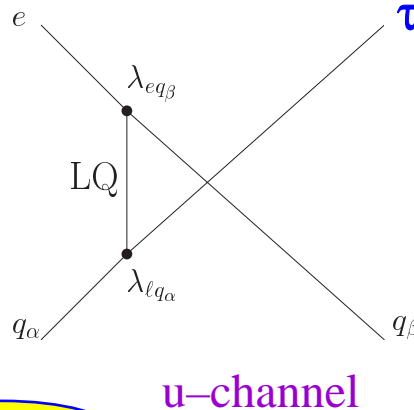
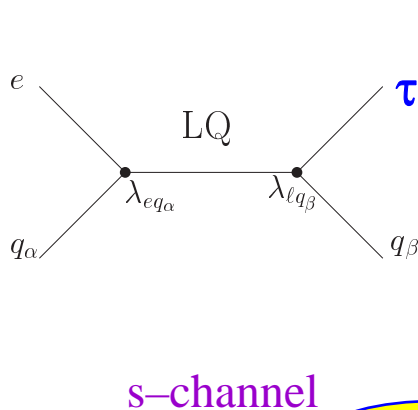
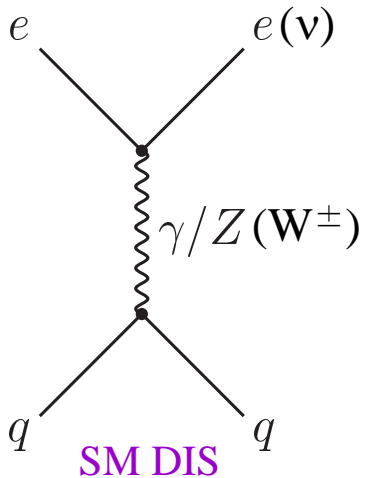
No evidence for $H^{++} \rightarrow e^+\tau^+$ decays

Lepton Flavour Violation @ H1/ZEUS

searched for Lepton Flavour Violation

H1 : Eur. Phys. J. C52 (2007) 833–847

ZEUS : Eur. Phys. J. C44 (2005) 463–479



Leptoquark(LQ)s couple to both quarks and leptons.

It carries both leptonic(L) and baryonic (B) numbers.



Neural Network based tau-ID

80% signal efficiency

95% quark/gluon induced jet rejection

like H1 $\tau^+\tau^-$ analysis

had τ -ID

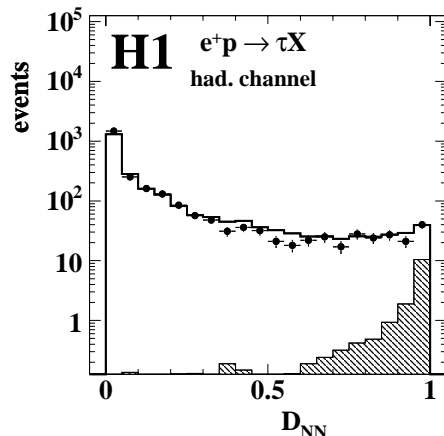
τ -ID using PDE Range Searching

same discriminant as in ZEUS $\tau + P_T^{\text{miss}}$ search

had τ -ID



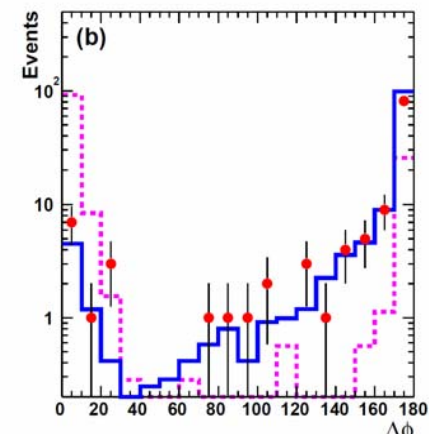
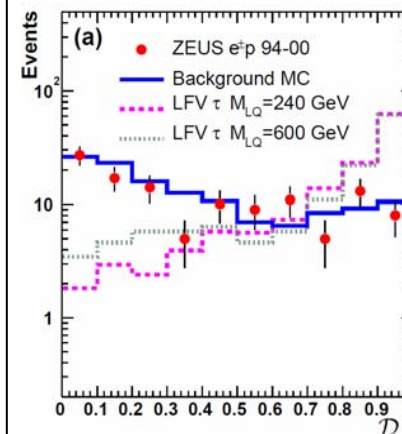
ZEUS



Required :

$P_{T^{\text{jet1}}} > 25\text{GeV}$, $P_{T^{\text{jet2}}} > 15\text{GeV}$
exactly 1 or 3 tracks in the jet

$D_{\text{NN}} > 0.8$ & ...



Limits for LQs in the τ channel @ H1/ZEUS

Eur. Phys. J. C52 (2007) 833–847

HERA-I $e^\pm p$ data $L=80.2 \text{ pb}^{-1}$

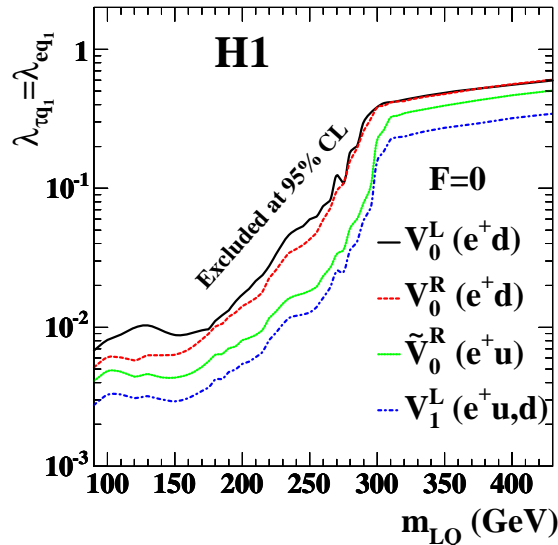
No significant deviation from SM found.

Limits were set on coupling to LQ
leading to Lepton Flavour Violation.



H1 e^-p : 13.7 pb^{-1} , e^+p : 66.5 pb^{-1}			
		Data	SM MC
$ep \rightarrow \tau X$	e^-p	0	0.75 ± 0.21
	e^+p	1	4.90 ± 0.85

→ No evidence for LFV



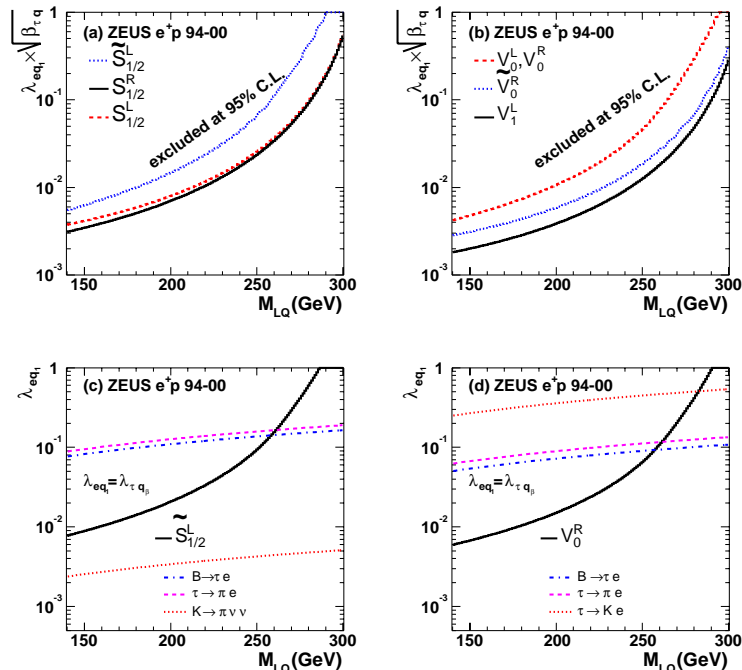
Eur. Phys. J. C44 (2005) 463–479

No candidate was found. Limits on LQ were set.

HERA-I $e^\pm p$ data $L=130 \text{ pb}^{-1}$

Data	0
SM	2.3 ± 0.5
sel. eff.	22~30% ($M_{LQ} < \sqrt{s}$)

ZEUS → No evidence for LFV

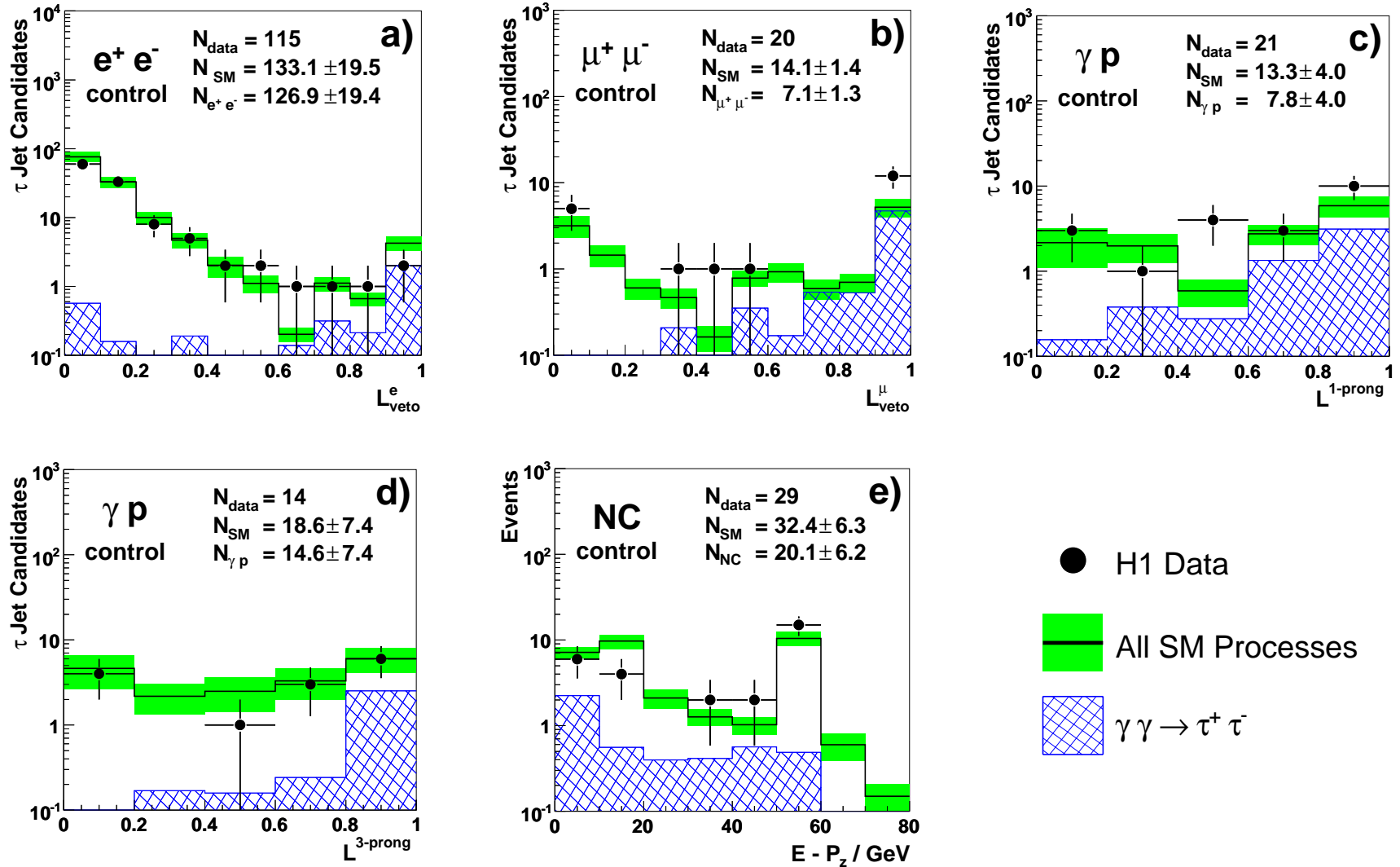


Summary

- Only a few taus have been seen at HERA.
 - Detecting taus at HERA is a challenging task.
- They are an important signature for new physics.
- Many tools for the identification of hadronically–decayed taus have been developed by **H1** and **ZEUS**.
- Results for $\tau^+\tau^-$ pair–production are in agreement with SM prediction (**H1/ZEUS**).
- New result of isolated $\tau + P_T^{\text{miss}}$ from **H1** is in agreement with SM expectation.
 - **ZEUS** result using HERA–I data has a slight excess.
- No evidence for $H^{++} \rightarrow e^+\tau^+$ decays (**H1**) and lepton flavour violation (**H1/ZEUS**)
- HERA data taking ended on June 30 2007 after 15 years successful operation:
 - Each experiment has collected $\sim 500 \text{ pb}^{-1}$ data.
 - Tau analyses have not finalized yet, still more to come for the next years!

backup slides

Background control sample for $\tau^+\tau^-$ pair-production @ H1



Event selection for isolated tau + P_T^{miss} @ H1

H1prelim-07-064

CC selection

$$P_T^{\text{miss}} > 12 \text{ GeV}$$

the ratio of the anti-parallel and parallel components
of the hadronic P_T

Tau-jet selection (cut-based)

look for jet in LAr calorimeter (cone radius = 1.0)

$$P_T^{\text{jet}} > 7 \text{ GeV}, 20^\circ < \theta^{\text{jet}} < 120^\circ$$

Isolation : Distance to other e, μ , jet in η - $\phi > 1.0$

Radial shower shape ("**Jet radius**")

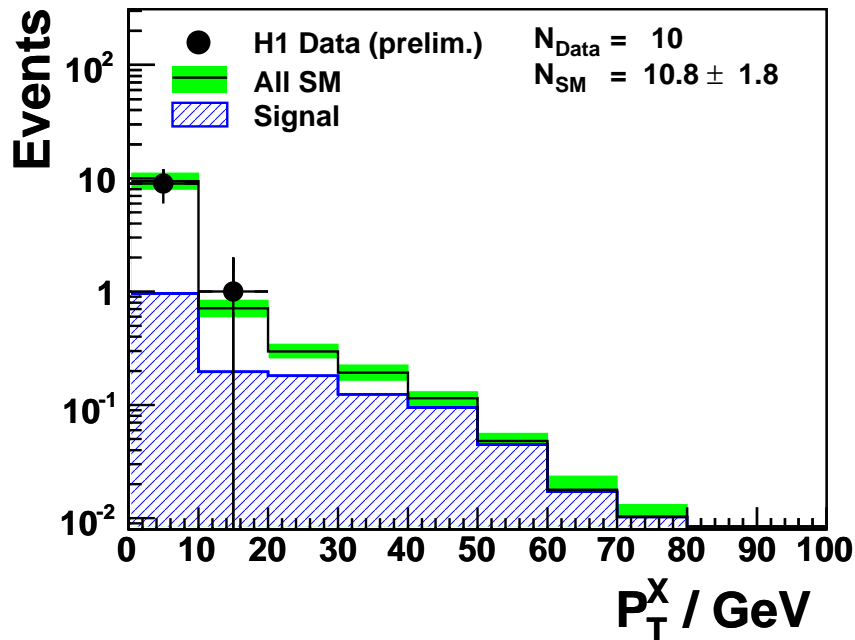
$$R_{\text{jet}} = \frac{1}{E_{\text{jet}}} \sum_h E_h \sqrt{\Delta\eta(\text{jet}, h)^2 + \Delta\phi(\text{jet}, h)^2}$$

only 1-prong jet \rightarrow (misidentification probability : $< 1\%$)

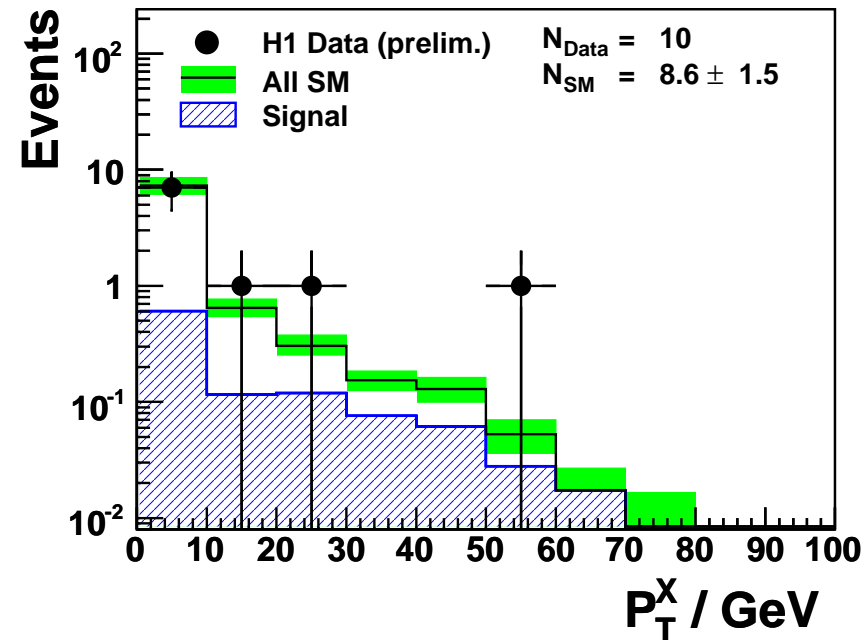
Inclusive CC	$P_T^{\text{calo}} > 12 \text{ GeV}$ $P_T^{\text{had}} > 12 \text{ GeV}$ $P_T^{\text{miss}} > 12 \text{ GeV}$ $\delta^{\text{miss}} > 5 \text{ GeV}$ $V_{ap}/V_p < 0.5$ (< 0.15 if $P_T^{\text{miss}} < 25 \text{ GeV}$)
Narrow Jets	$P_T^{\text{jet}} > 7 \text{ GeV}$ $20 < \theta^{\text{jet}}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

Isolated tau leptons + P_T^{miss} @ H1

$\tau + P_T^{\text{miss}}$ events at HERA I + II (e^+p , 287 pb^{-1})



$\tau + P_T^{\text{miss}}$ events at HERA I + II (e^-p , 184 pb^{-1})

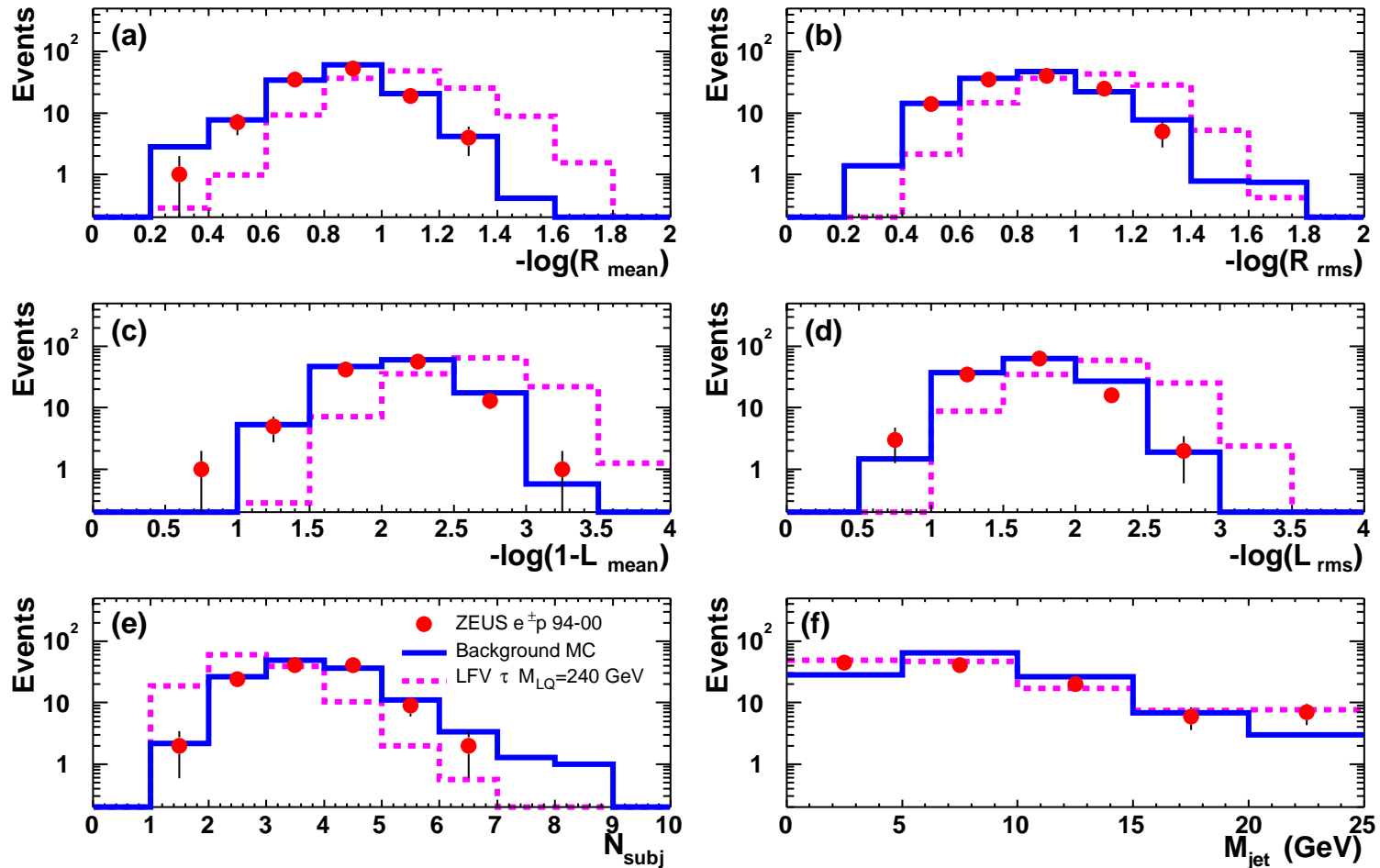


H1 Preliminary $\tau + P_T^{\text{miss}}$ events at HERA I+II		H1 Data	SM Expectation	SM Signal $W \rightarrow \tau \nu$	Other SM Processes
e^+p 287 pb^{-1}	Full Sample	10	10.8 ± 1.8	1.6 ± 0.3	9.2 ± 1.6
	$P_T^X > 25 \text{ GeV}$	0	0.53 ± 0.07	0.38 ± 0.06	0.15 ± 0.01
e^-p 184 pb^{-1}	Full Sample	10	8.6 ± 1.5	1.0 ± 0.2	7.6 ± 1.4
	$P_T^X > 25 \text{ GeV}$	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
	$P_T^X > 25 \text{ GeV}$	1	0.99 ± 0.13	0.62 ± 0.10	0.37 ± 0.03

H1prelim-07-064

Lepton Flavour Violation @ ZEUS

ZEUS



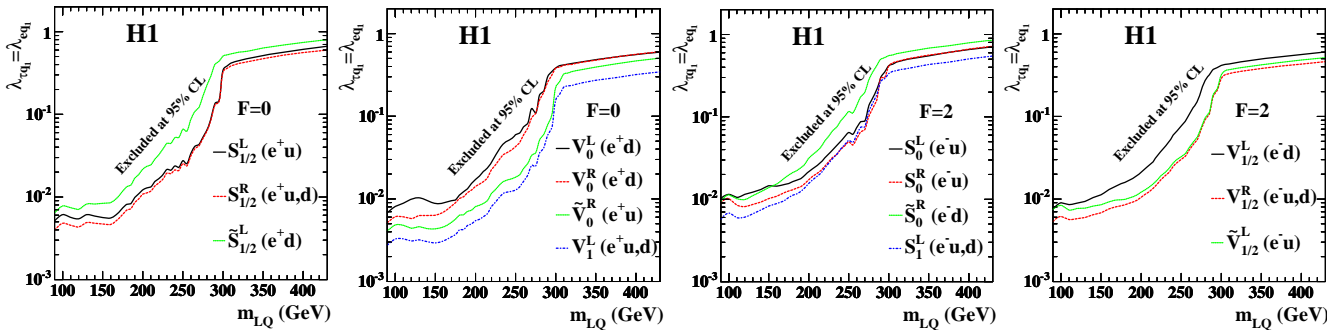
Limits for LQs in the τ channel @ H1/ZEUS

Eur. Phys. J. C52 (2007) 833–847

HERA-I $e^\pm p$ data $L=80.2 \text{ pb}^{-1}$

No significant deviation from SM found.

Limits were set on coupling to LQ leading to Lepton Flavour Violation.



H1 e^-p : 13.7 pb^{-1} , e^+p : 66.5 pb^{-1}			
		Data	SM MC
$ep \rightarrow \tau X$	e^-p	0	0.75 ± 0.21
	e^+p	1	4.90 ± 0.85

→ No evidence for LFV

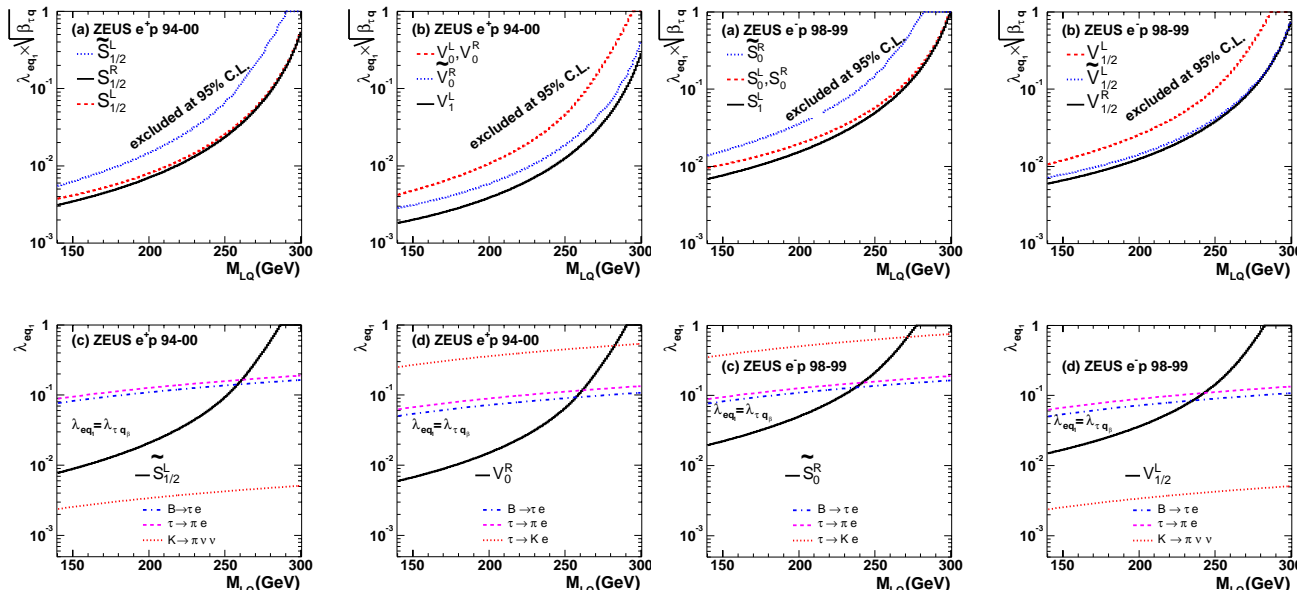


ZEUS

e^+p data

ZEUS

e^-p data



HERA-I $e^\pm p$ data $L=130 \text{ pb}^{-1}$

Data	0
SM	2.3 ± 0.5
sel. eff.	22~30% ($M_{LQ} < \sqrt{s}$)

No candidate was found.

Limits on LQ were set.

→ No evidence for LFV

Eur. Phys. J. C44 (2005) 463–479