



Excited fermions and other searches at HERA

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Overview and introduction

High pt taus

The high-pt lepton physics offers a very clean environment where looking for deviation from the SM.

Following the interesting results in the e and μ channel I'll present a search of high pt taus detected in their one prong hadronic decay.

Excited fermions

ep collisions are very suited to look for new states which decay in ordinary fermions and gauge bosons. Such states are foreseen by compositeness model which aim to explain the three family structure of the SM.

Results on excited electrons and neutrinos will be presented and compared with limits from other colliders

Results based on HERA I data:

$L \approx 110 \text{ pb}^{-1}$ for positron

$L \approx 15 \text{ pb}^{-1}$ for electron

HERA II running just started
factor ~ 10 expected in 5 years

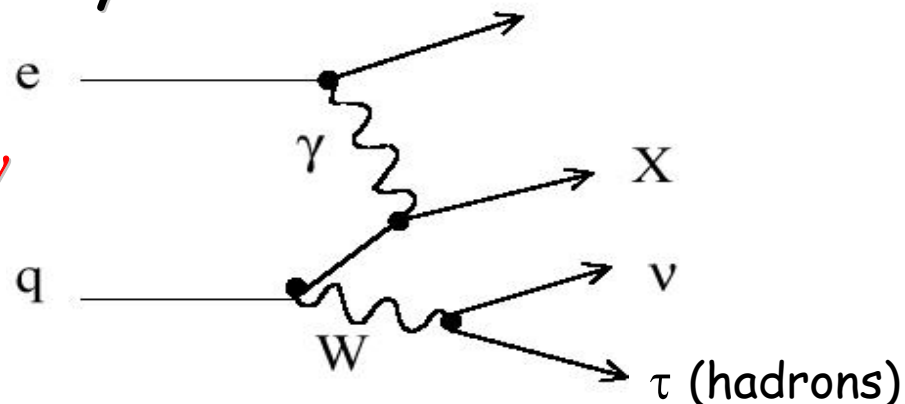
Search for high-pt isolated taus

- High-pt isolated track selection as for the e and μ channel single top analysis (missing CAL $P_t > 20$ GeV)
- Apply tau finder to high P_t tracks not identified as μ or e

➔ Multiobservable discrimination technique exploits the tau hadronic jet properties (hadronic Br $\sim 65\%$) in order to discriminate tau from QCD jets

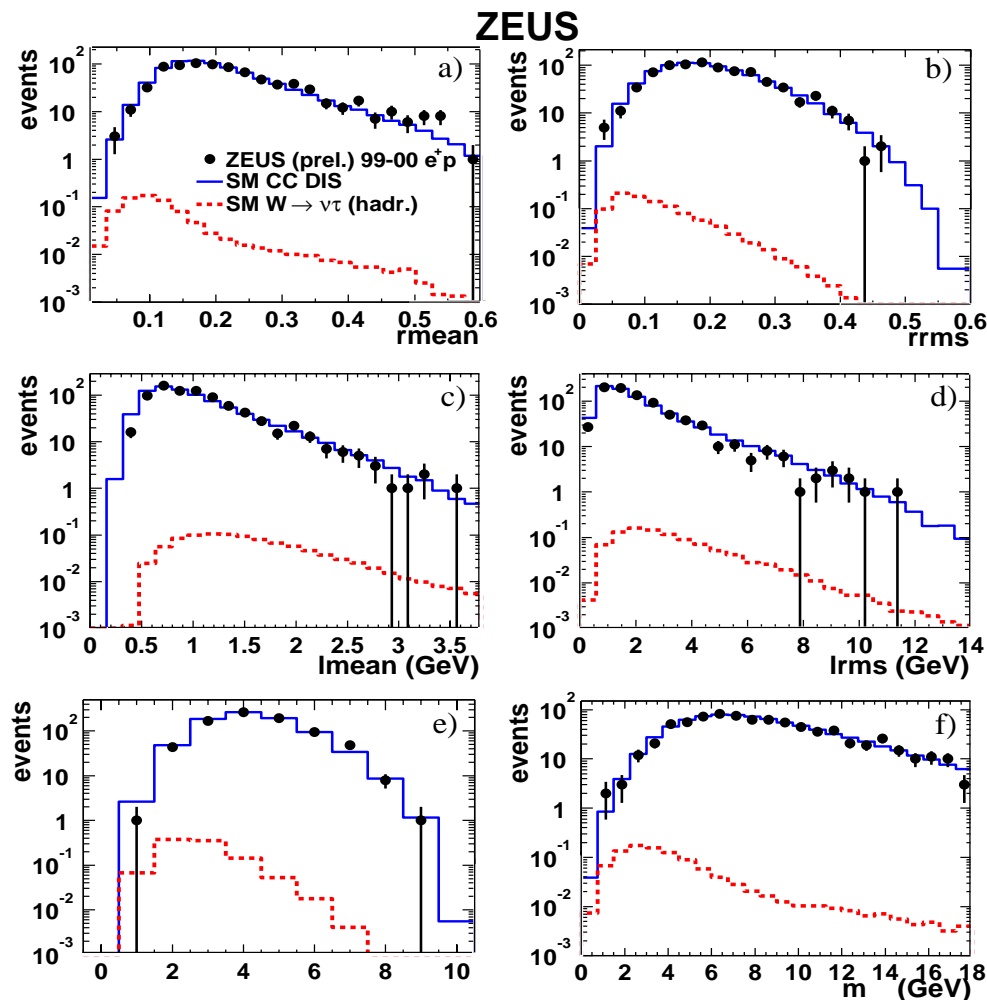
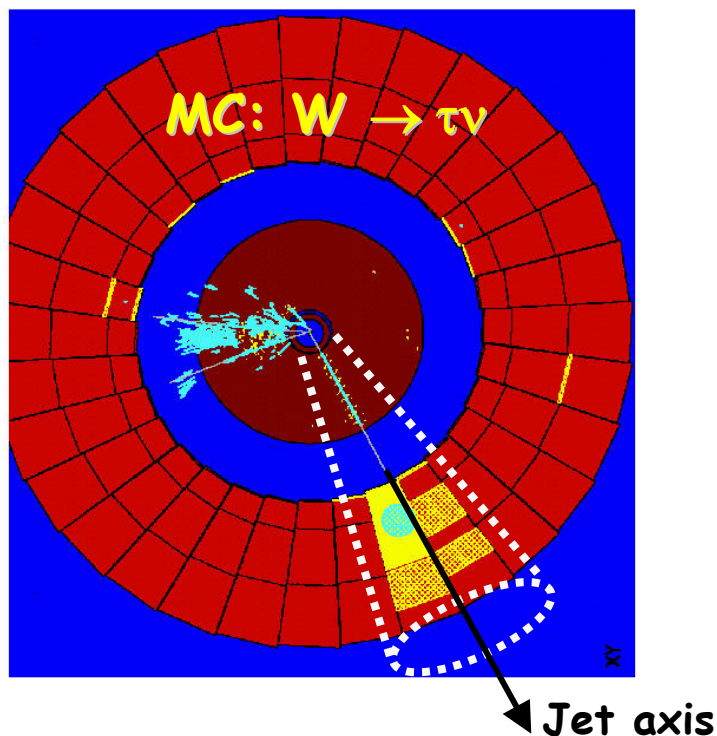
- Collimated (pencil like) jet
- Low charged particle multiplicity

Optimized to discriminate $W \rightarrow \tau\nu$ from CC-DIS background



Observables:

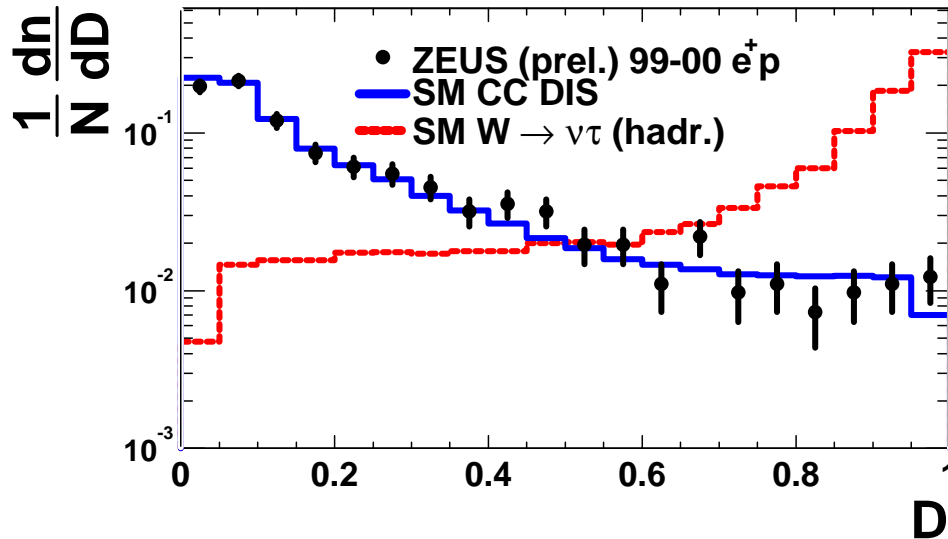
- radial jet energy distribution (mean and rms)
- longitudinal jet energy distribution (mean and rms)
- number of subjets
- jet mass



Optimization done using standard inclusive CC DIS selection

➔ Internal jet shape well described by the CC DIS MC

ZEUS



Discriminant defined by the density of bg and signal event in the 6-dim phase space.

$$D(\bar{x}) = \rho_{\text{sig}}(\bar{x}) / (\rho_{\text{bg}}(\bar{x}) + \rho_{\text{sig}}(\bar{x}))$$

Each jet has a D value, evaluated in the vicinity of the point \bar{x} that identify the jet. For each event the highest D is considered

DATA and CC DIS MC agree well

Requiring $D > 0.95$ and 1 track for the τ jet \rightarrow good separation between bg (CC DIS) and signal ($W \rightarrow \nu\tau$) and an acceptable efficiency ($\sim 24\%$) for the signal

After the tuning on CC DIS τ identification is applied to the isolated high-pt lepton selection \rightarrow

Isolated high-pt lepton selection:

- $p_{\top}^{\ell} > 20 \text{ GeV}$
- isolated ($D_{\text{track}} > 0.5$, $D_{\text{jet}} > 1.8$) track with $p_{\top} > 5 \text{ GeV}$

Tau identification:

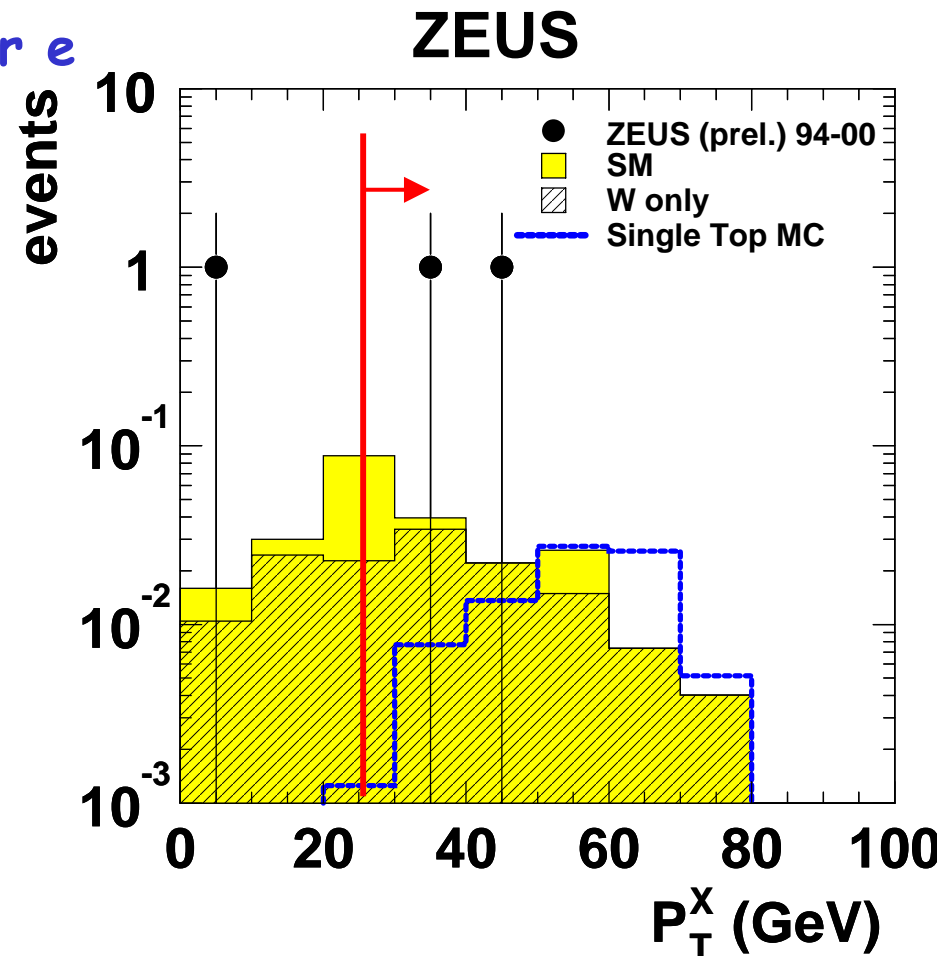
- Exclude tracks identified as μ or e
- $D > 0.95$

3 events observed
 0.23 ± 0.06 expected

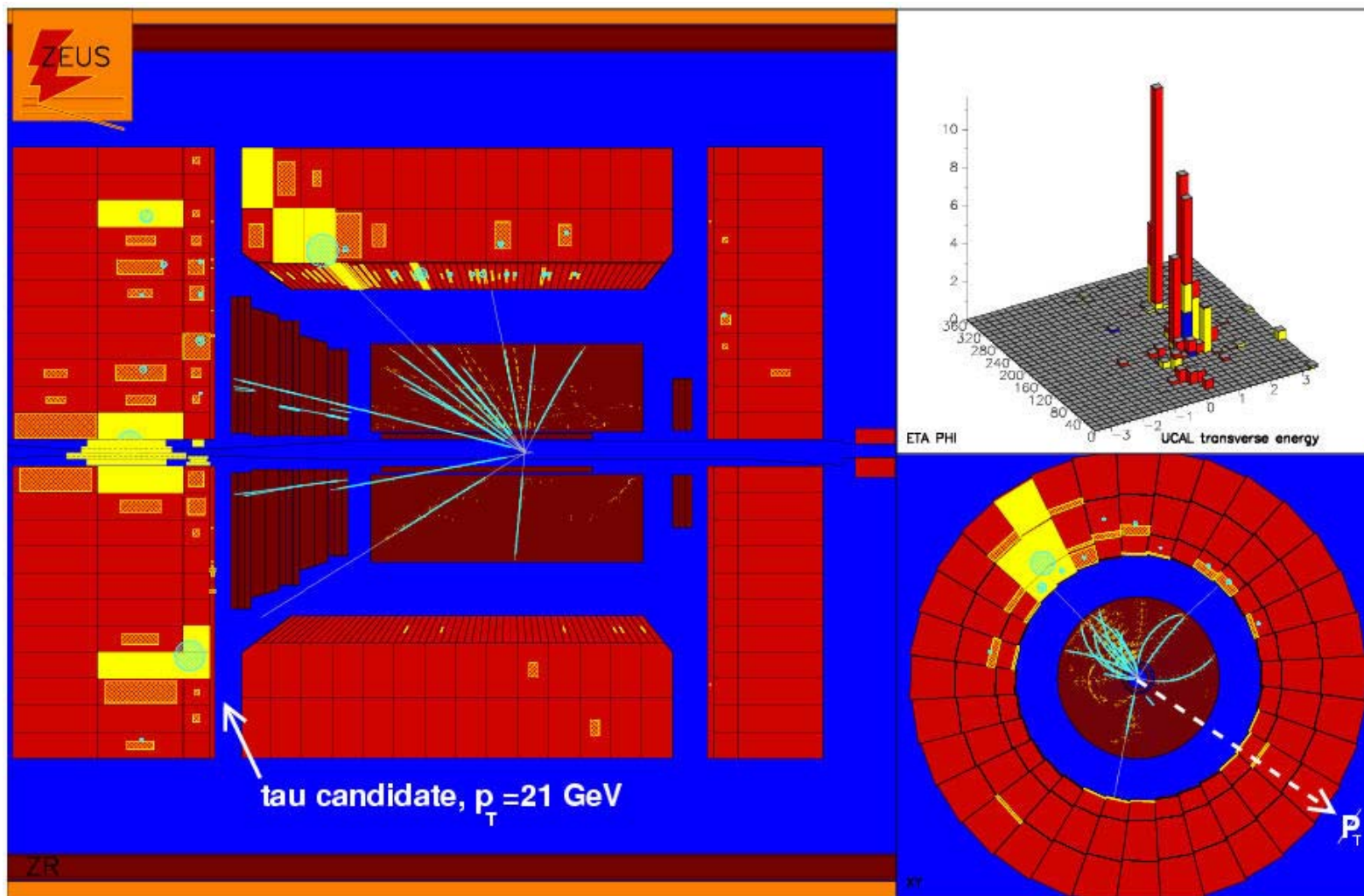
Optimizing hadronic Pt cut for single top signal:

- $P_{\top}^X > 25 \text{ GeV}$

2 events observed
 0.12 ± 0.02 expected



τ candidate 1 (1999 e^+ data)



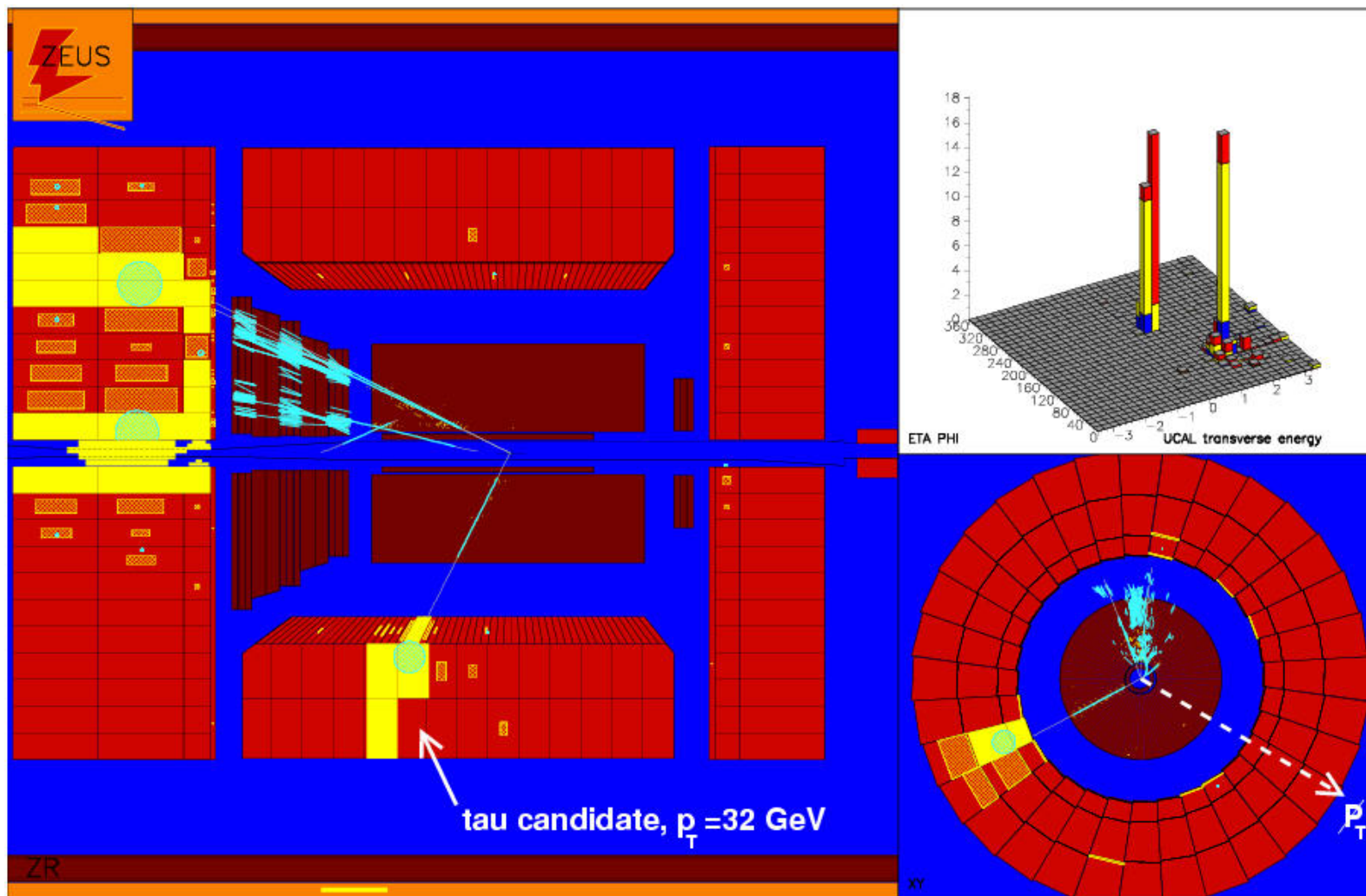
$$P_{T,CAL} = 37 \text{ GeV}$$

$$P_T^X = 48 \text{ GeV}$$

$$P_{T,\tau\text{jet}} = 21 \text{ GeV}$$

$$M_T = 32 \text{ GeV}$$

τ candidate 2 (1999 e^+ data)



$$P_{T,CAL} = 39 \text{ GeV}$$

$$P_T^X = 37 \text{ GeV}$$

$$P_{T,\tau\text{jet}} = 39 \text{ GeV}$$

$$M_T = 68 \text{ GeV}$$

Comparison with e and μ channels

ZEUS preliminary 1994-2000 $e^\pm p$ $\mathcal{L} = 130.5 \text{ pb}^{-1}$	Electrons obs./exp. (W)	Muons obs./exp. (W)	Taus obs./exp. (W)
$P_T^X > 25 \text{ GeV}$	1 / 1.14 ± 0.06 (1.10)	1 / 1.29 ± 0.16 (0.95)	2 / 0.12 ± 0.02 (0.10)
$P_T^X > 40 \text{ GeV}$	0 / 0.46 ± 0.03 (0.46)	0 / 0.50 ± 0.08 (0.41)	1 / 0.06 ± 0.01 (0.05)

2 interesting events but:

- Single top hypothesis largely disfavoured by $e/\mu/\text{jet}$ analysis
- any exotic explanation should produce excess in τ but not in μ or e

Definitely HERA II data needed
to solve the puzzle

Excited fermions

Compositeness models, predicts excited fermion states which decay into ordinary fermions and gauge bosons through magnetic type couplings.

The HERA experiments perform their analysis in the framework of the Hagiwara-Zeppenfeld-Komamiya Model which allows to evaluate excited fermion properties via the following effective lagrangian which describes the transition between excited and ordinary fermions:

$$L_{F^*F} = \frac{1}{\Lambda} \bar{F}_R^* \sigma^{\mu\nu} \left(g \cdot f \frac{\vec{\tau}}{2} \partial_\mu \vec{W}_\nu + g' \cdot f' \frac{Y}{2} \partial_\mu B_\nu + g_s \cdot f_s \frac{\lambda_a}{2} \partial_\mu G_\nu^a \right) F_L$$

Λ =compositeness scale ($\sim O(\text{TeV})$)

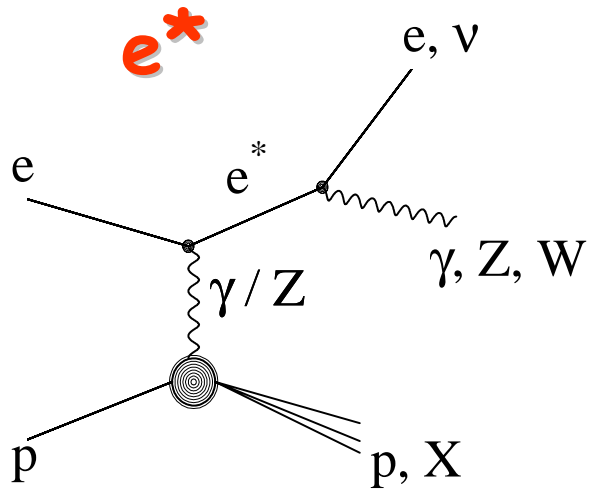
f, f', f_s =form factors for the different gauge groups

Assuming relation between f, f', f_s , branching ratios and production cross sections depends only of the f^* mass and f/Λ

At HERA no sensitivity to gluon mediated f^* production

→ $f_s=0$ assumed

Direct production of excited leptons at HERA 11



$$e^* \rightarrow e\gamma \quad \text{Br} \rightarrow 0 \text{ if } f \rightarrow -f'$$

Two isolated em clusters with large E_T

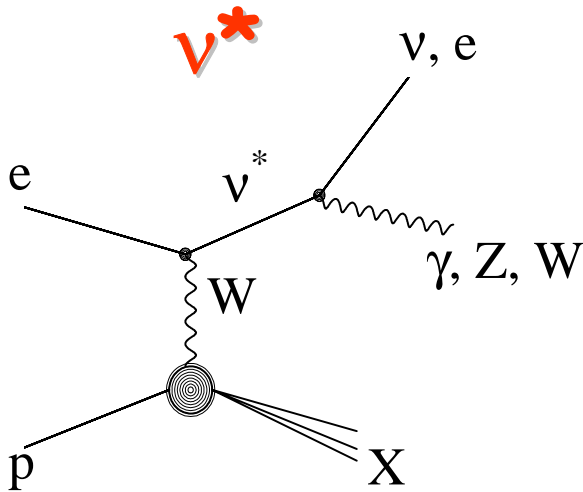
$$e^* \rightarrow eZ \quad Z \rightarrow q\bar{q}$$

At least two high E_T jets + high energy electron

$$e^* \rightarrow \nu W \quad W \rightarrow q\bar{q}'$$

At least two high E_T jets + large \cancel{P}_T

Due to W exchange much higher cross section for e-p



$$\nu^* \rightarrow \nu\gamma \quad \text{Br} \rightarrow 0 \text{ if } f \rightarrow f'$$

High energy photon + large \cancel{P}_T

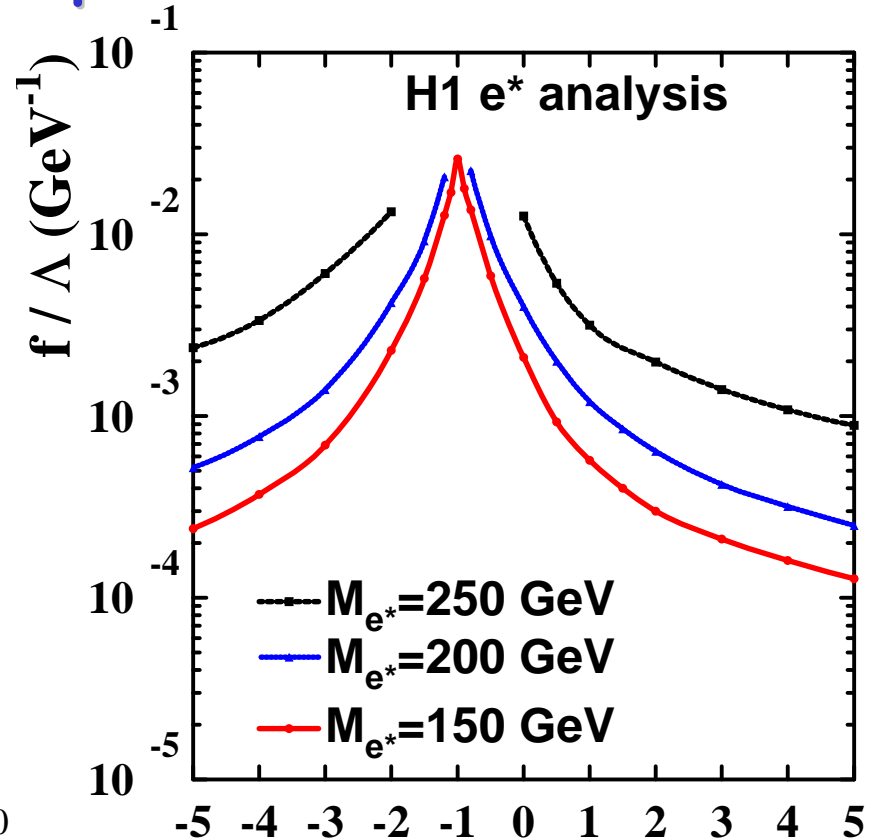
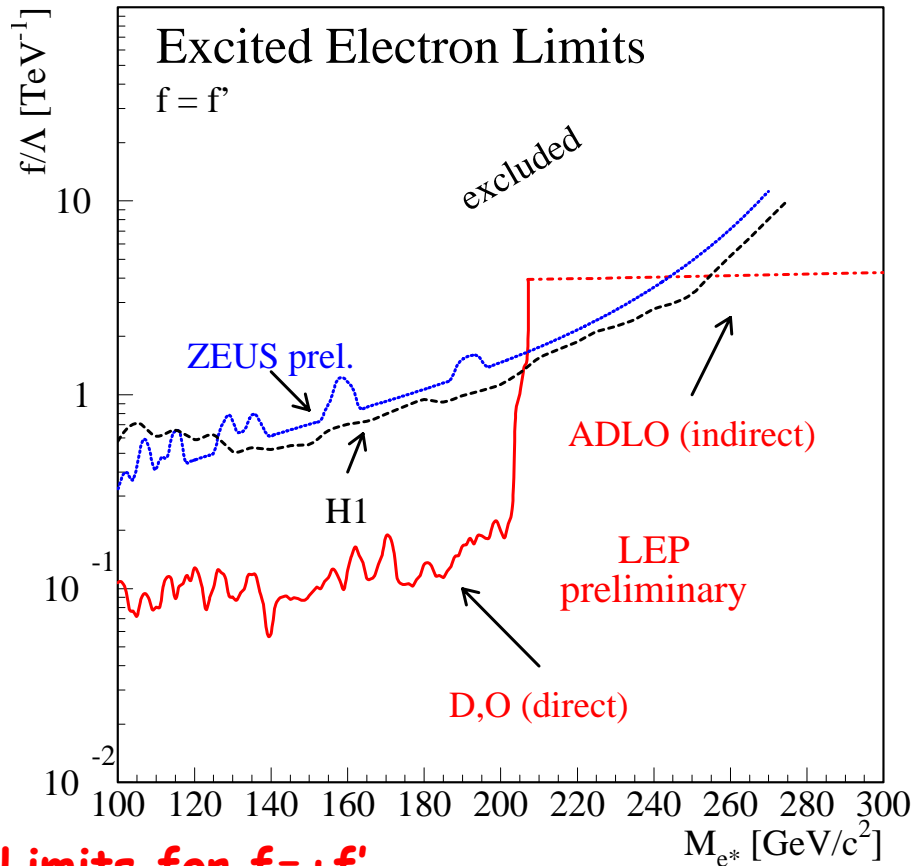
$$\nu^* \rightarrow e q \bar{q}'$$

$$\nu^* \rightarrow \nu q \bar{q}$$

Signatures as in the respective e^* channels

→ Signature: peak in the fermion-boson invariant mass

→ 95% CL limits on f/Λ (depend on the assumed model)



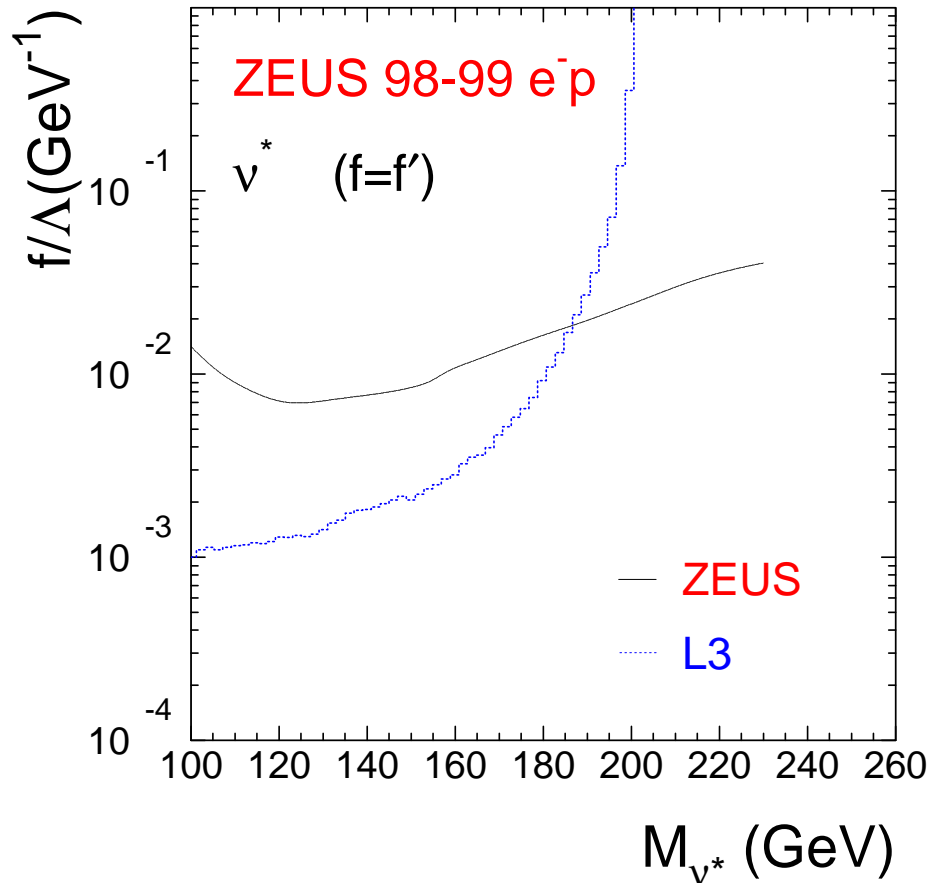
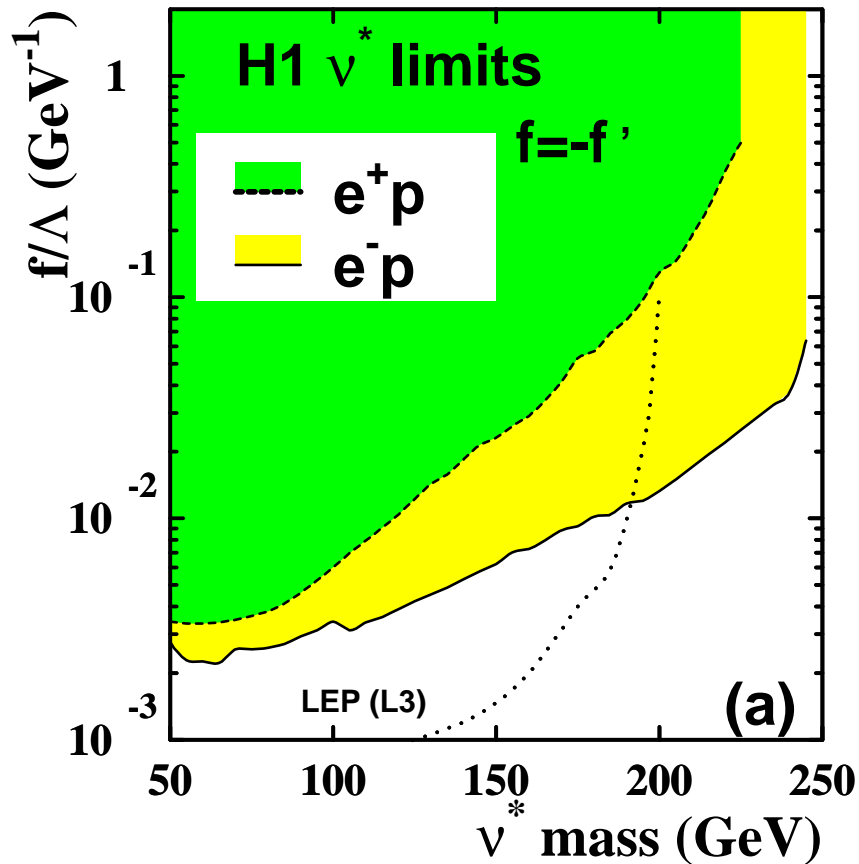
Limits for $f = +f'$

HERA results extends the excluded region to higher masses respect to previous direct searches and improves on LEP indirect limits for $M_{e^*} \lesssim 260$ GeV

More general limits as a function of f/f'

The effect of vanishing em coupling when $f \rightarrow -f'$ is clearly visible

In the ν^* case HERA experiments give best limits as soon as M_{ν^*} approaches the LEP c.m.e.



Due to W exchange, e^-p gives much better limits (u-quark density in the proton involved and helicity suppression in e^+p)

➔ substantial improvement expected with HERA II

Conclusions

The search for high-pt leptons was extended to the tau channel. Two clean and interesting events have been selected while the SM expectation is ~ 0.1 ($P \sim 0.6\%$).

Anyway the single top interpretation for such result is largely disfavoured by limits on the other channels.

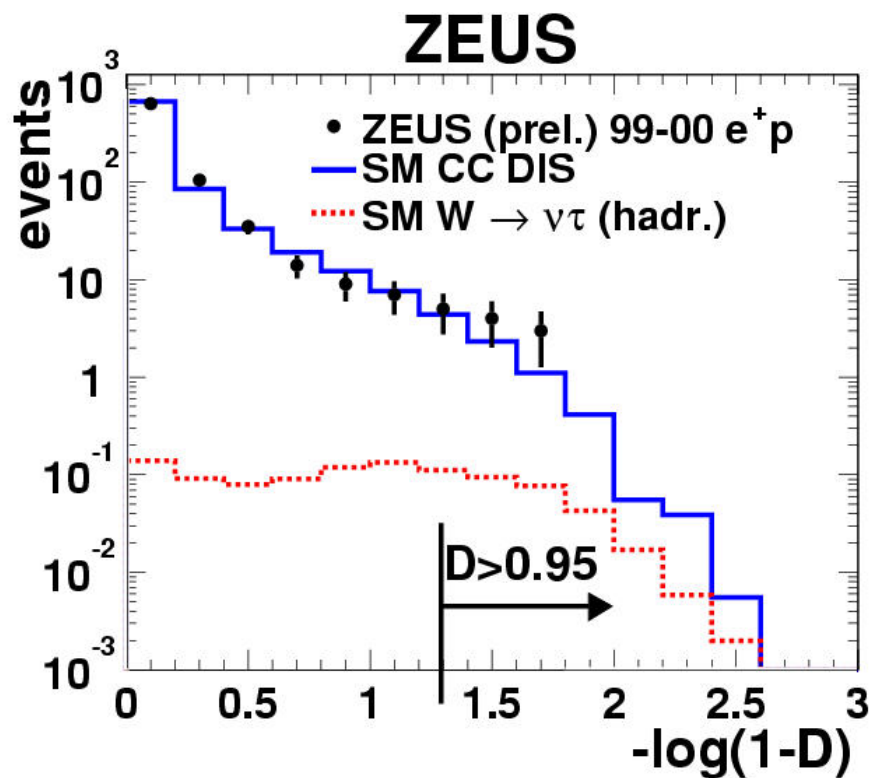
HERA II data needed to clarify the picture

New results on excited fermions based on the full HERA I data have been presented.

For the e^* HERA results extends the excluded region beyond LEP c.m.e. for direct searches and improves on indirect LEP limits for $M_{e^*} \lesssim 260$ GeV.

In the ν^* case the HERA experiments give best limits as soon as M_{ν^*} approaches the LEP c.m.e.

These results (especially for the ν^* case) are expected to substantially improve with HERA II data



$$D = N_{\text{sig}} / (N_{\text{bg}} + N_{\text{sig}})$$

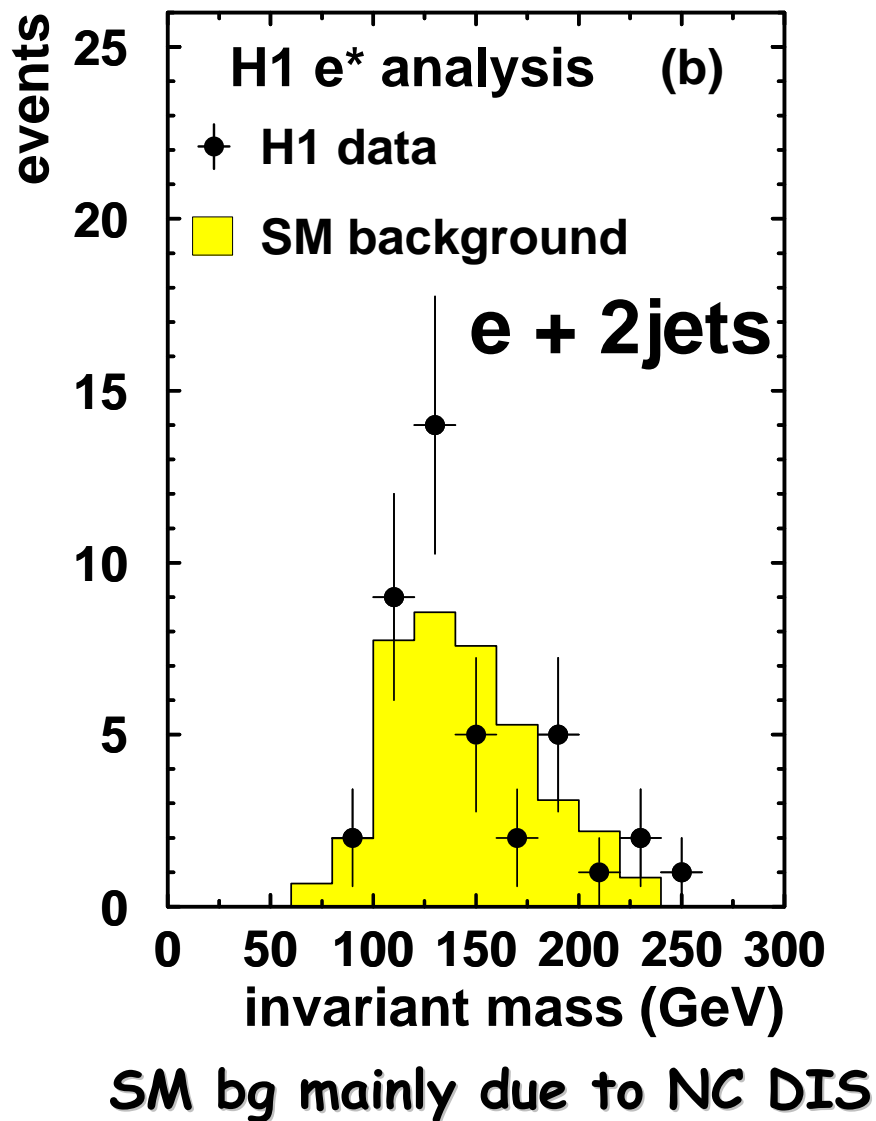
$D > 0.95$, 1 track

Efficiency : $\varepsilon = N_{\tau, \text{sel}} / N_{\tau} = 24\%$

Rejection : $R = N_{\text{QCD}} / N_{\text{QCD, sel}} = 561$

Separation: $S = R \times \varepsilon = 132$

$$e^* \rightarrow eZ \rightarrow eq\bar{q}$$



$$e^* \rightarrow eW \rightarrow \nu q\bar{q}'$$

