Excited fermions and other searches at HERA

International Conference on High Energy Physics
Amsterdam 24-31 July 2002

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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 compositness 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 pb^{-1} for positron

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

HERA II running just started
factor $\sim$ 10 expected in 5 years

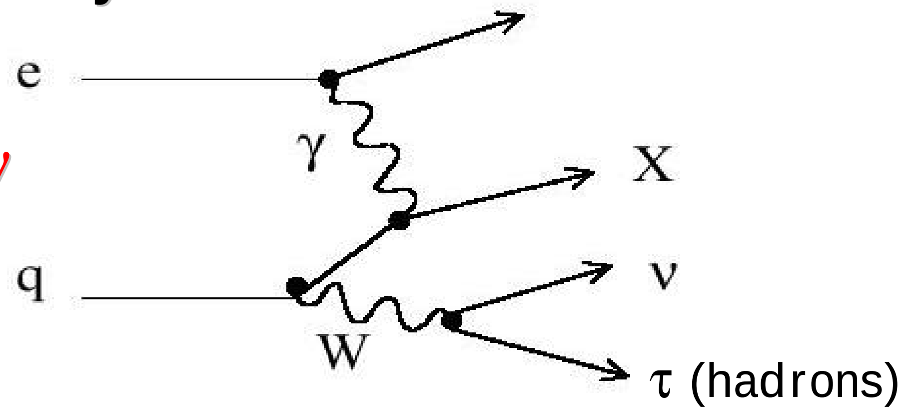
Search for high-pt isolated taus

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

➡ Multiobservable discrimination technique exploits the tau hadronic jet properties (hadronic Br ~ 65%) in order to discriminate tau from QCD jets

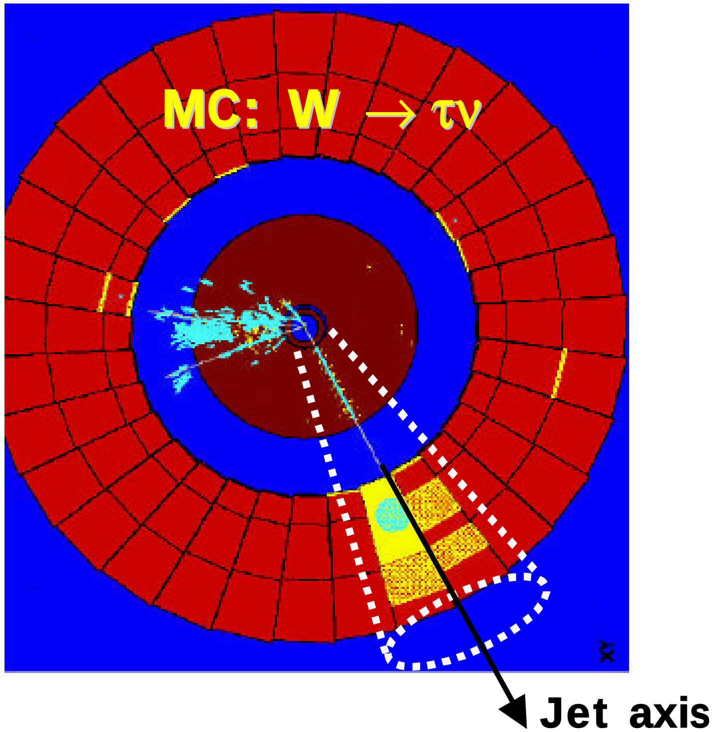
- Collimated (pencil like) jet
- Low charged particle multiplicity

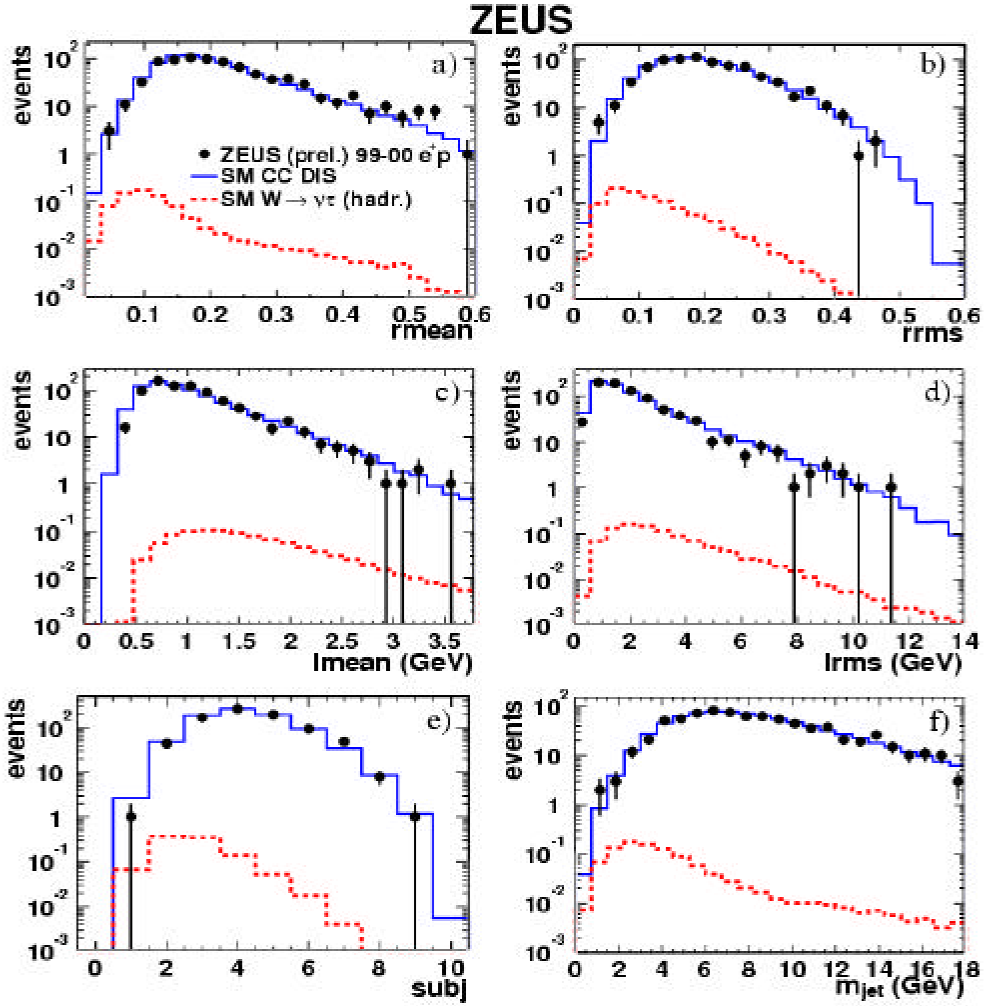
Optimized to discriminate W $\rightarrow \tau\nu$ from CC-DIS background



Observables:

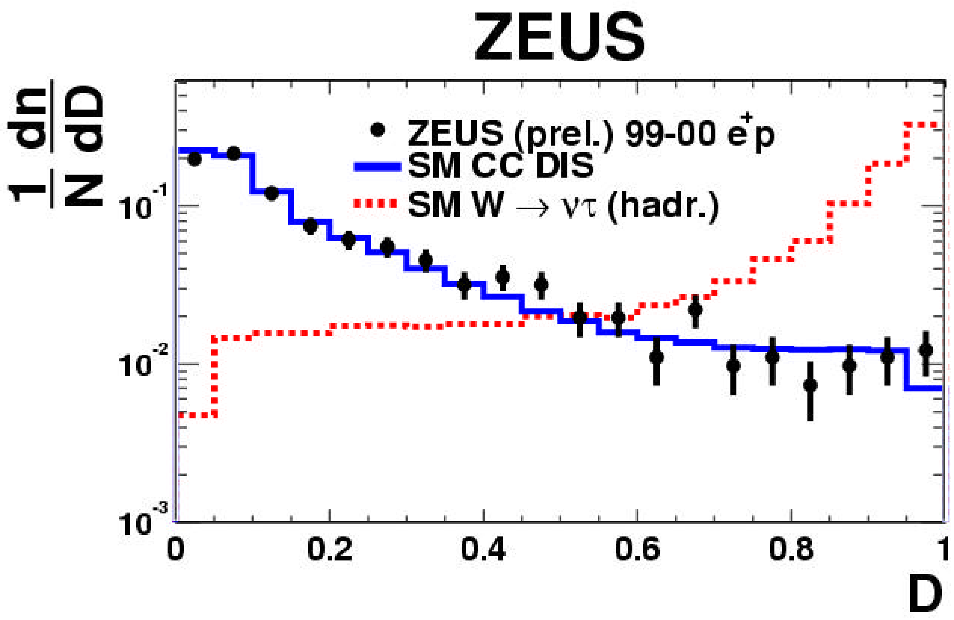
- radial jet energy distribution (mean and rms)
- longitudinal jet energy distribution (mean and rms)
- number of subjets
- jet mass





Optimization done using standard inclusive CC DIS selection

➡ **Internal jet shape well described by the CC DIS MC**



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

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

Each jet has a D value, 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 → good separation between bg (CC DIS) and signal (W→ντ) and an acceptable efficiency (~24%) for the signal

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

Isolated high-pt lepton selection:

- $\not{P}_t$ > 20 GeV
- isolated (D_{track}>0.5, D_{jet}>1.8) track with p_t > 5 GeV

Tau identification:

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

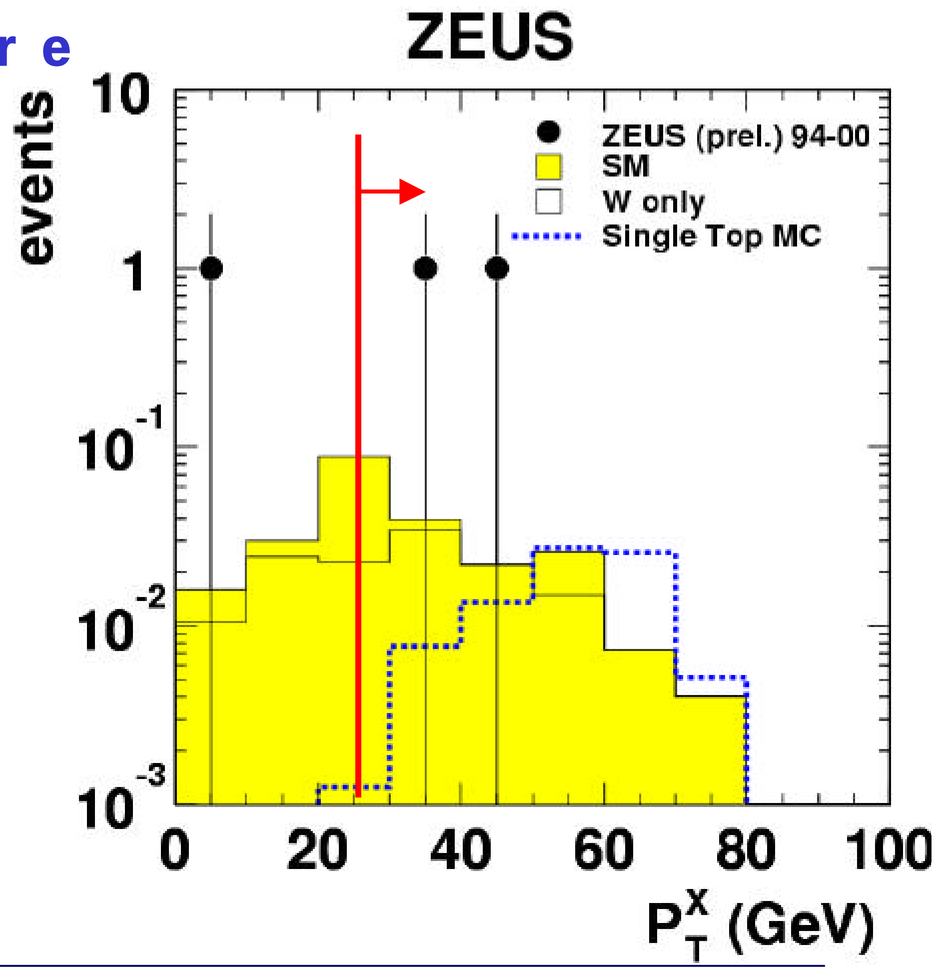
3 events observed
0.23 ± 0.06 expected

Optimizing hadronic Pt cut

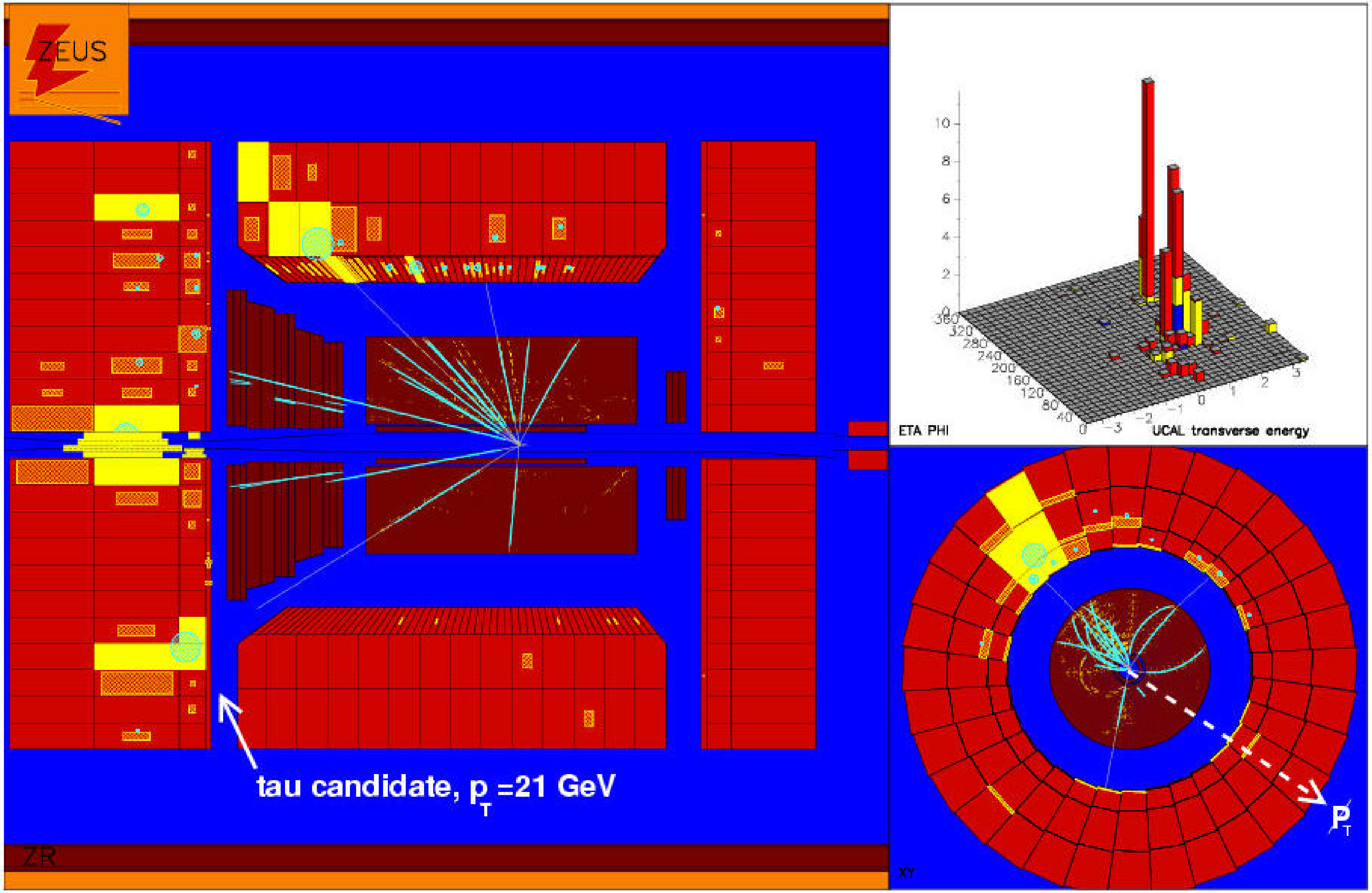
for single top signal:

- P_T^X > 25 GeV

2 events observed
0.12 ± 0.02 expected



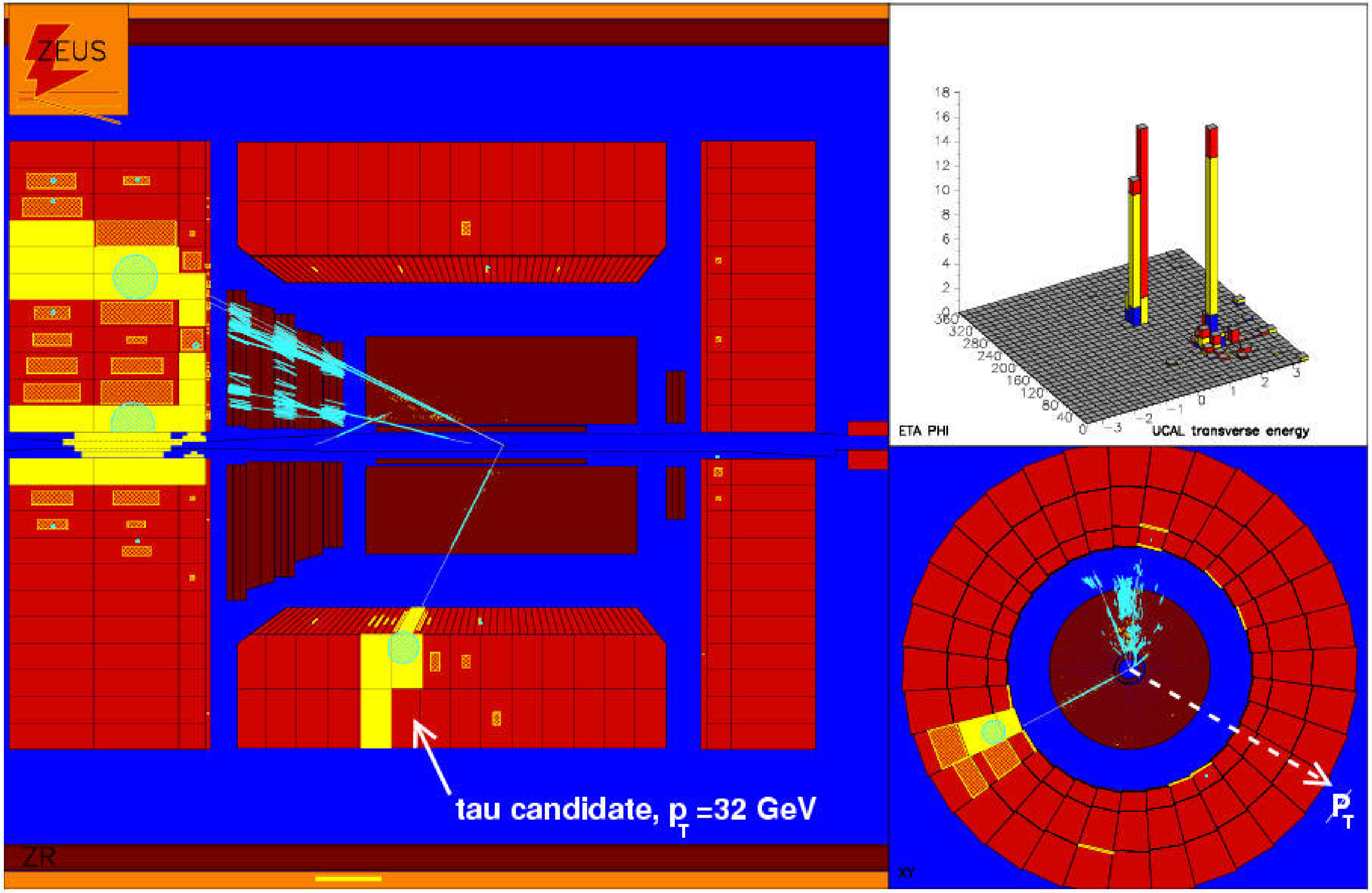
τ candidate 1 (1999 e^+ data)



$P_{T,CAL}$ = 37 GeV
P_T^X= 48 GeV

$P_{T,\tau jet}$= 21 GeV
M_T = 32 GeV

τ candidate 2 (1999 e^+ data)



$P_{T,CAL}$ = 39 GeV
P_T^X= 37 GeV

$P_{T,\tau jet}$= 39 GeV
M_T= 68 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)
$P_T^X > 25\,\text{GeV}$	$1 / 1.14 \pm 0.06$ (1.10)	$1 / 1.29 \pm 0.16$ (0.95)	$2 / 0.12 \pm 0.02$ (0.10)
$P_T^X > 40\,\text{GeV}$	$0 / 0.46 \pm 0.03$ (0.46)	$0 / 0.50 \pm 0.08$ (0.41)	$1 / 0.06 \pm 0.01$ (0.05)

2 interesting events but:

- **Single top hypothesis largely disfavoured by e/μ/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

Compositness 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:

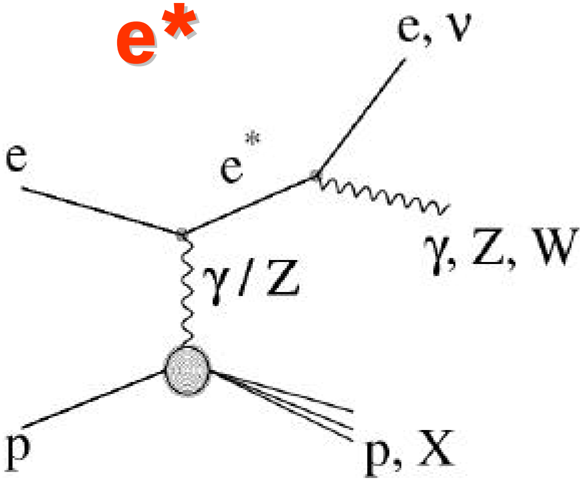
$$L_{eff} \propto \frac{1}{\Lambda}\left(f \cdot SU(2)_W + f' \cdot U(1)_Y + f_s \cdot SU(3)_c \right)$$

Λ=compositness scale ($\gtrsim$O(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

e*



$e^* \rightarrow e\gamma$ Br → 0 if f → -f'

Two isolated em clusters with large E_T

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

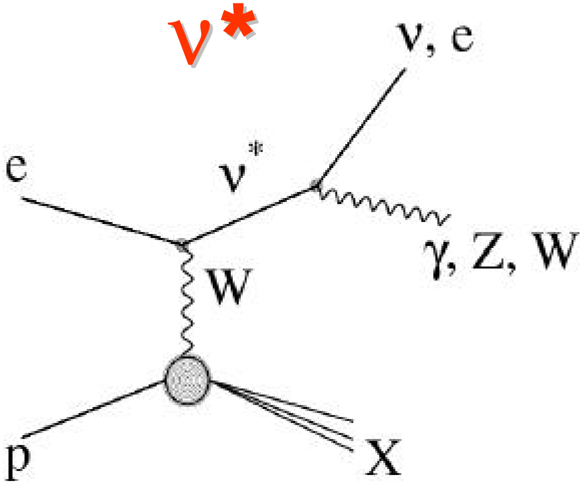
At least two high E_T jets + high energy electron

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

At least two high E_T jets + large $\not{P}_T$

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

ν*



$n^* \rightarrow n\gamma$ Br → 0 if f → f'

High energy photon + large $\not{P}_T$

$n^* \rightarrow eq\bar{q}'$

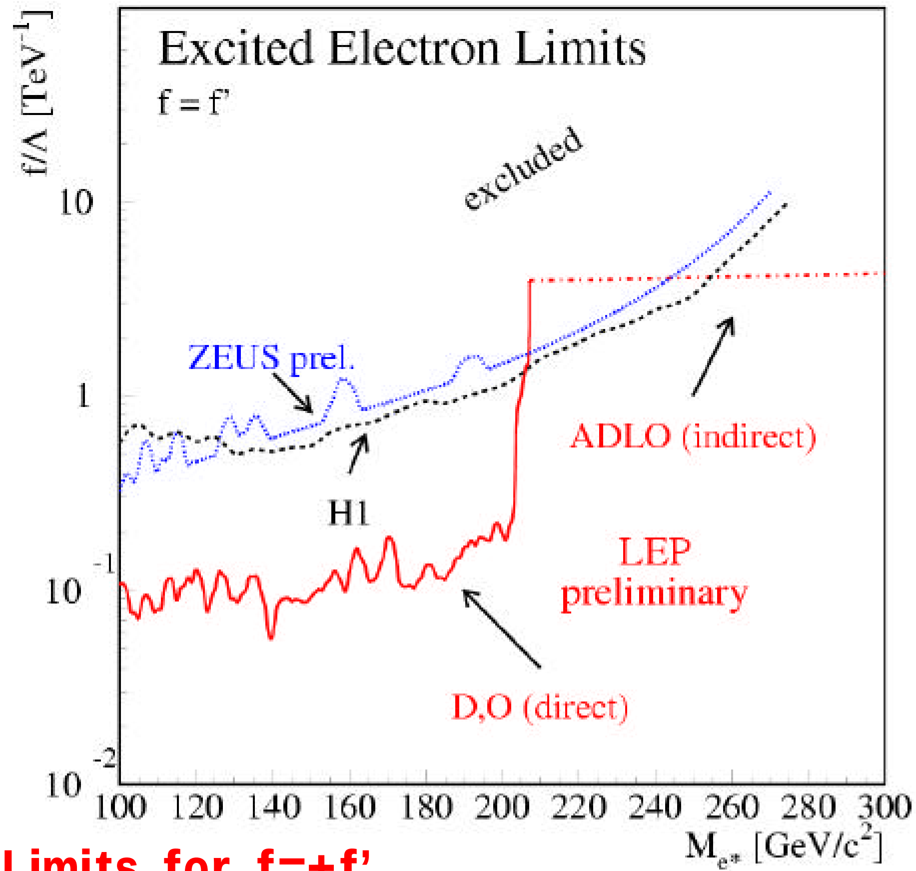
$n^* \rightarrow nq\bar{q}$

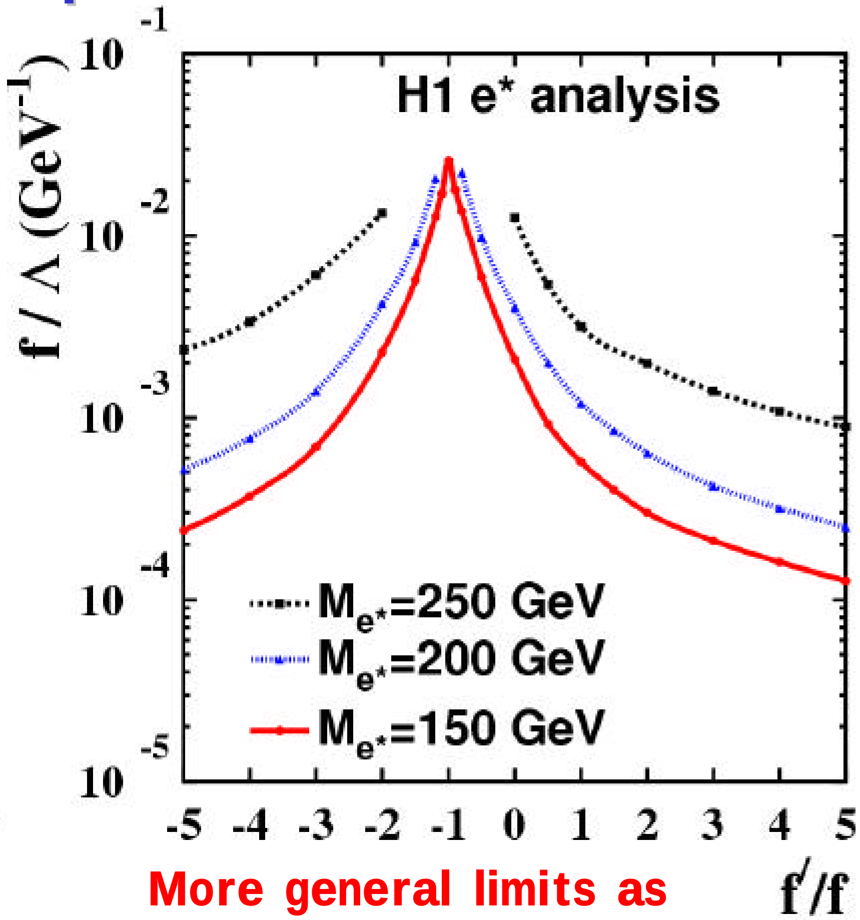
Signatures as in the respective e* channels

→ **Signature: peak in the fermion-boson invariant mass**

No excess in fermion-boson invariant mass

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





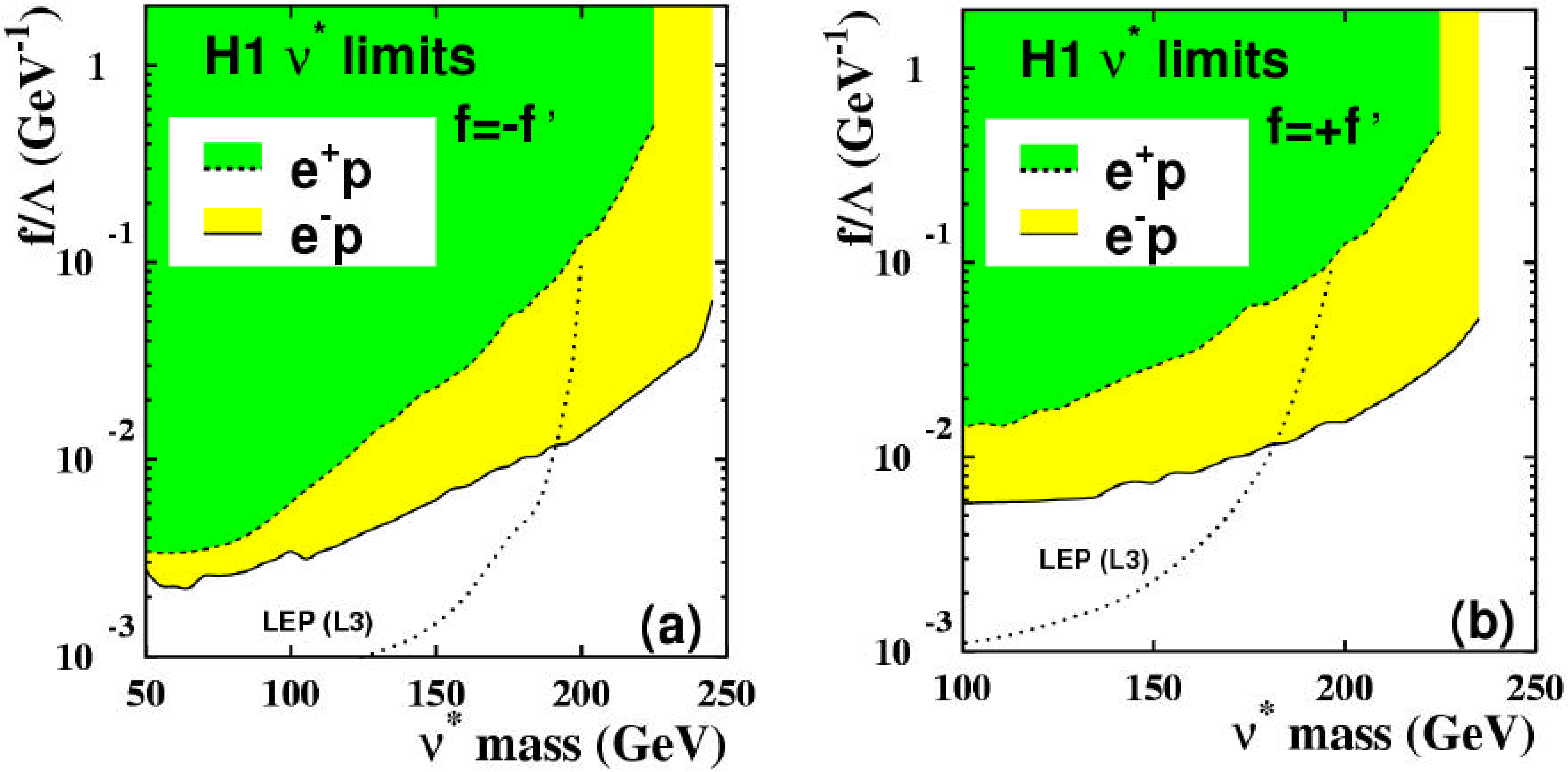
Limits for f=+f'

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 $f \to -f'$ is clearly visible

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



Zeus has similar results……..

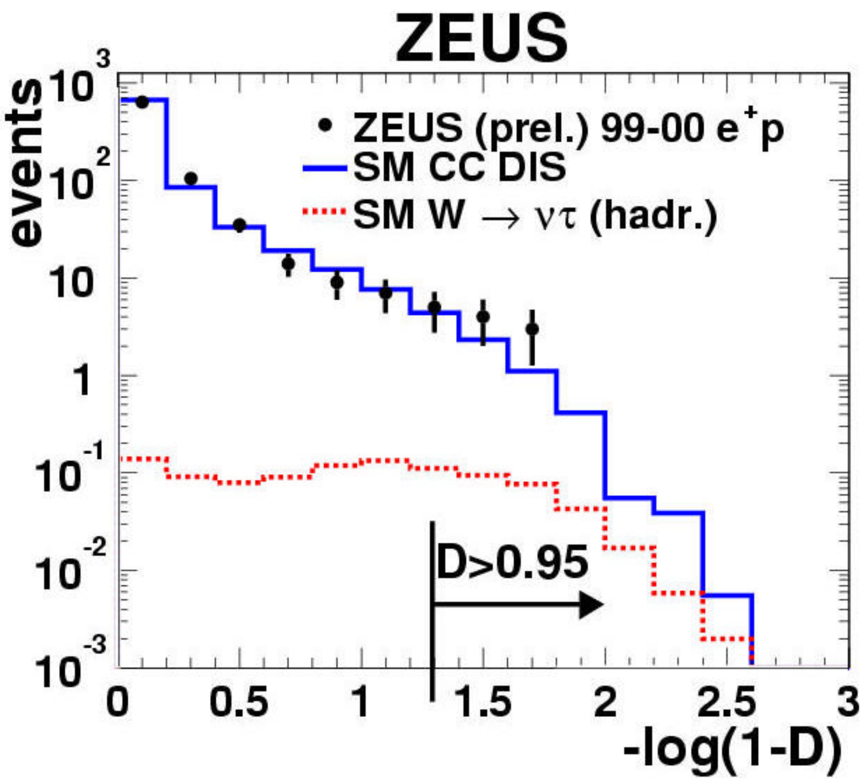
e^-p gives a much larger contribution

➡ 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 ~ 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 $M_{\varepsilon*} \lesssim 260$ GeV.
In the ν^* case the HERA experiments give best limits as soon as $M_{\nu*}$ approaches the LEP c.m.e.
These results (especially for the ν^* case) are expected to substantially improve with HERA II data



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

D>0.95, 1 track

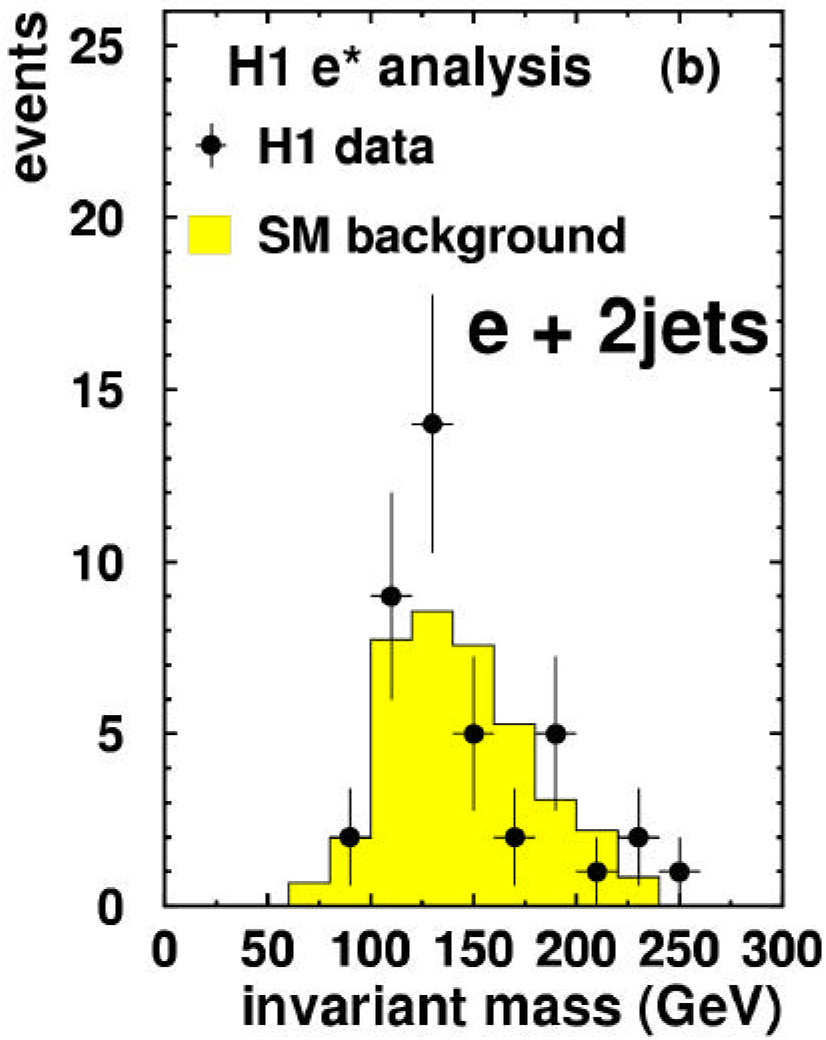
Efficiency : $\varepsilon = N_{\tau,sel} / N_{\tau} = 24\%$

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

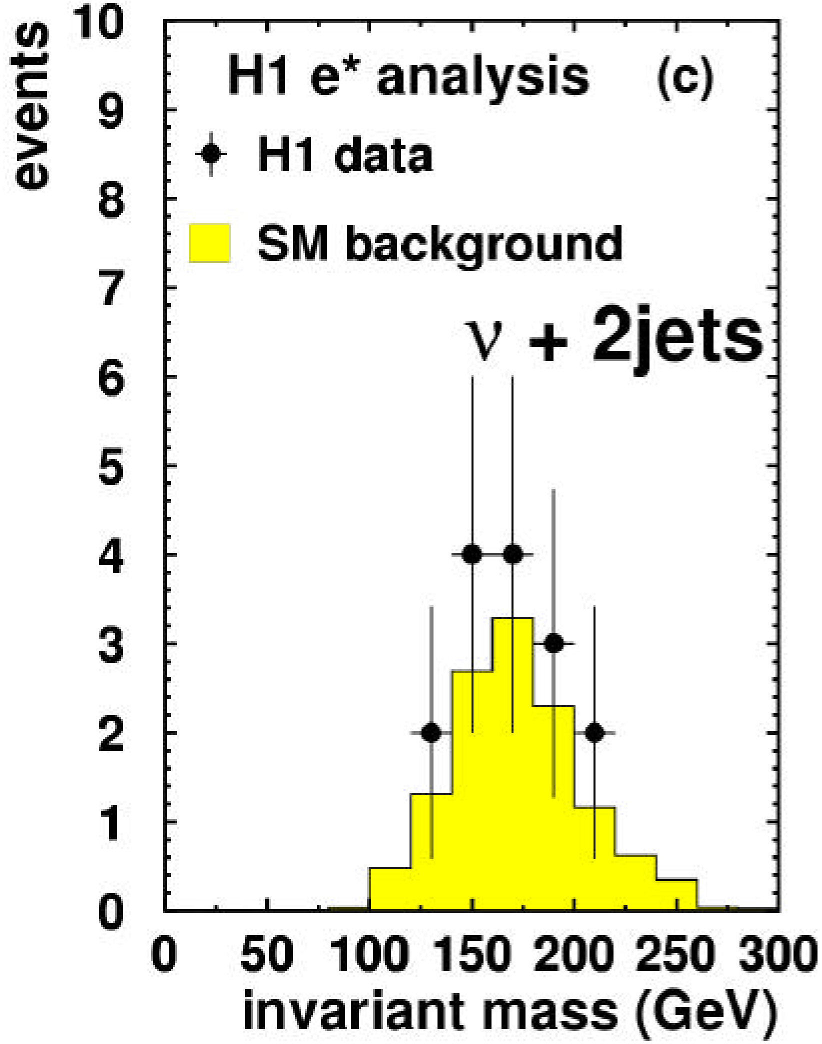
Separation: $S = R \times S = 132$

e*→ eZ→eq$\bar{q}$

e*→ eW→νq$\bar{q}$'

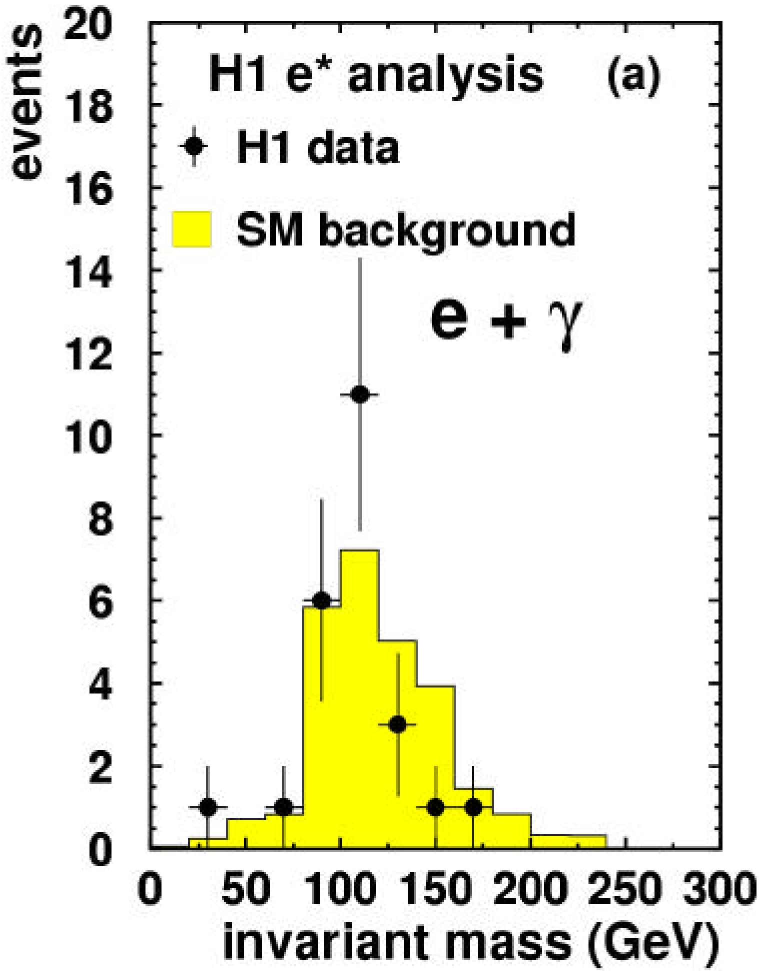


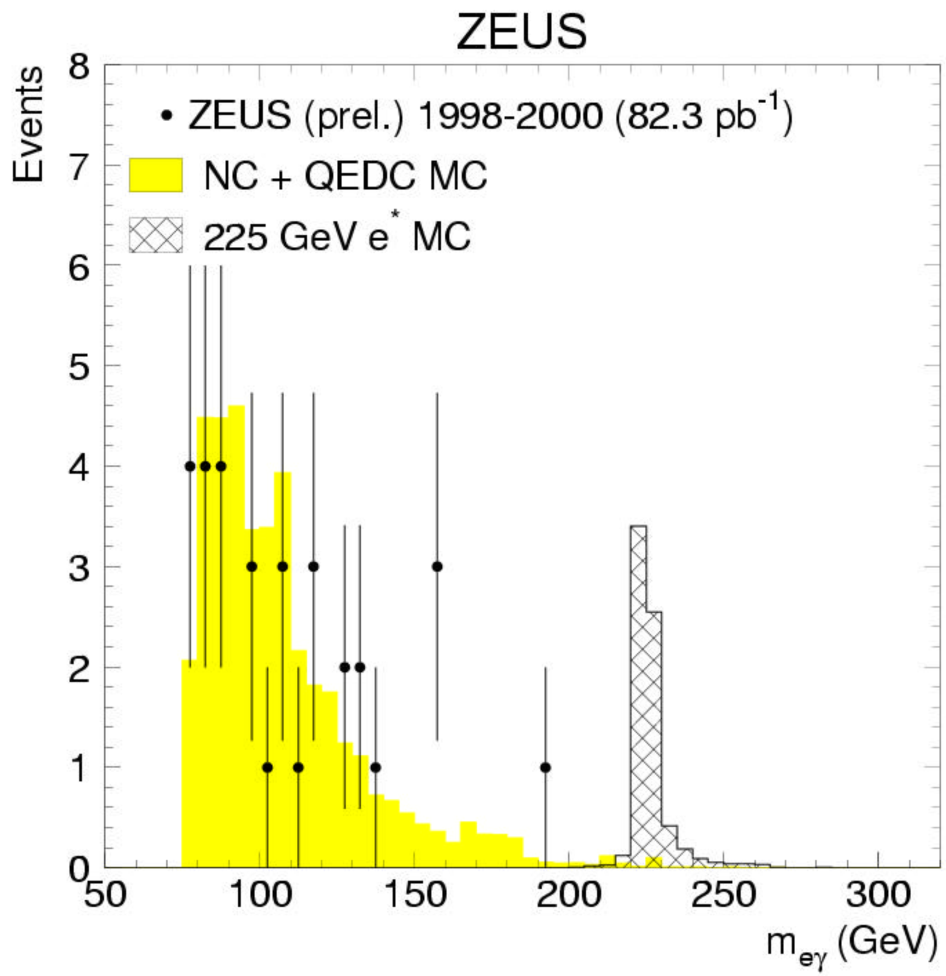
SM bg mainly due to NC DIS



SM bg mainly due to CC DIS

e*→ eγ Mass spectra





SM bg dominated by NC DIS, QED Compton and $\gamma\gamma \rightarrow ee$ process