Searches for excited neutrinos with H1 at HERA

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DIS 2006
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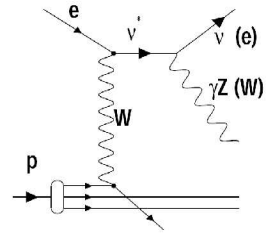
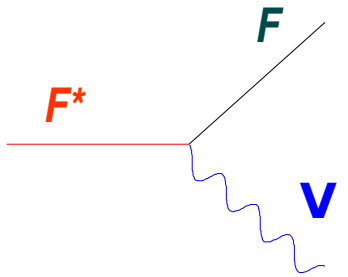


Excited states

- If found, direct proof of compositness:
  - "Trivial", "historical", "non-innovative" approach to BSM



- Excited fermions F* with magnetic transition to ground state

$$\mathcal{L}_{\text{eff}} = \sum_{V=\gamma,Z,W^{\pm}} \frac{e}{\Lambda}\bar{F}^{*}\sigma^{\mu\nu}(C_{VF^{*}F} - D_{VF^{*}F}\gamma_5)F\partial_{\mu}V_{\nu} + h.c.$$

- From g-2 and no EDM: |C|=|D| (and real) F.M. Renard, Phys.Lett.B116:264,1982
- F* organized in iso-doublets $(e^{*},\nu^{*})_{L,R}$ => interaction lagrangian:

Hagiwara et al, ZPC 29 (1985) 115.
Boudjema et al, ZPC 57 (1993) 425.

SU(2) U(1) SU(3)

$$\mathcal{L}_{int} = \frac{1}{2\Lambda}\bar{F}^{*}_{R}\sigma^{\mu\nu}[g f\frac{\tau^{a}}{2}W^{a}_{\mu\nu} + g' f'\frac{Y}{2}B_{\mu\nu} + g_s f_s\frac{\lambda^{a}}{2}G^{a}_{\mu\nu}]F_L$$

- Compositness scale Λ, internal dynamics stored in f,f',f_s couplings

Another approach: contact interactions (suppose common constituents)

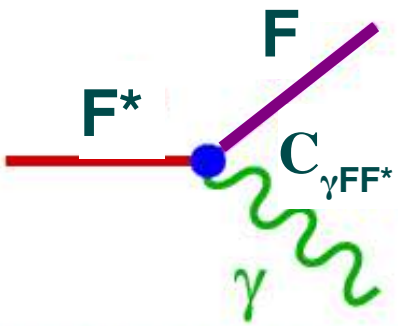
$$\mathcal{L} \alpha \frac{4\pi}{\Lambda^2}(\bar{e^{*}}\gamma^{\mu}e)(\bar{q}\gamma_{\mu}q)$$

Baur et al,PRD 42(1990) 815

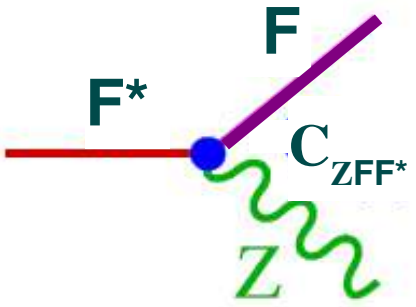
same pheonomenology, different normalisation

The VFF* couplings

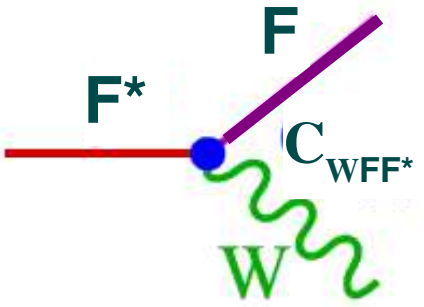
• γFF* vertex:



• ZFF* vertex:



• WFF* vertex:



$$C_{\gamma FF^*} = \frac{1}{2}\left(f I_3 + f' \frac{Y}{2}\right) \qquad C_{ZFF^*} = \frac{1}{2}\left(f I_3 \cot\theta_W - f' \frac{Y}{2}\tan\theta_W\right) \qquad C_{WFF^*} = \frac{f}{2\sqrt{2}\sin\theta_W}$$

- I_3: third component of isospin
- Y: hypercharge
- θ_W: Weinberg angle

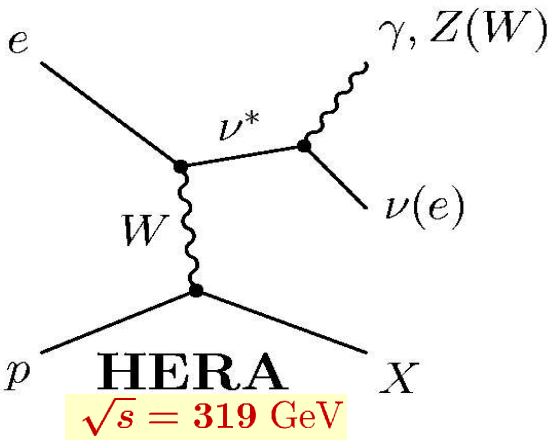
$$C_{\gamma\nu\nu*} = \frac{1}{4}(f - f') = 0|_{f=f'}$$

$$C_{\gamma ee*} = -\frac{1}{4}(f + f') = 0|_{f=-f'}$$

Photons couple to νν* if f≠f', maximal if f=-f'

Excited neutrino states can be excited from charged leptons via charged currents (if f≠0)
or produced in association with anti-neutrinos from γ/Z

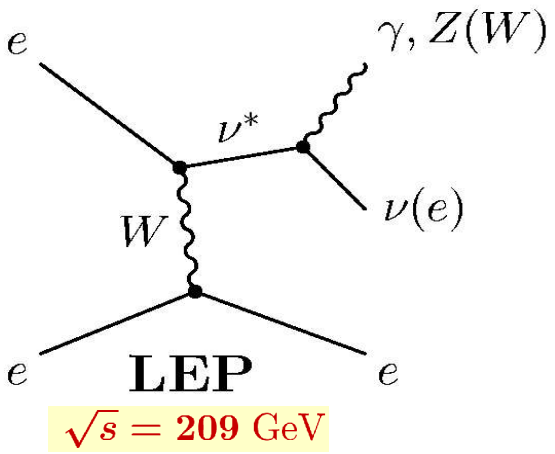
Search for ν* at colliders



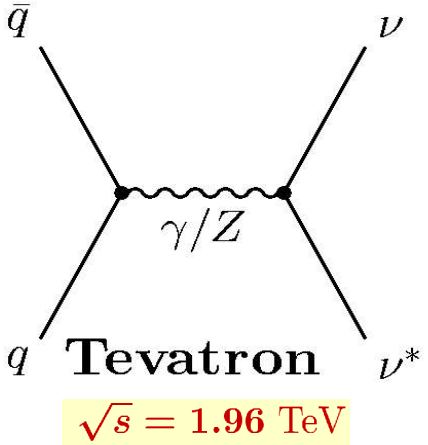
Signature: neutral lepton-boson resonance

- **HERA: Produced in CC-like interactions**
  - **Extra jets in the events, besides ν* decay products**
  - **Cross section much larger in e- p (O(10^2)) due to favourable valence u-quarks and helicity enhancement (CC-like)**

$$\sigma_{CC}^{e^{\pm}p} \sim Y_+\binom{d}{u} \mp Y_-\binom{d}{u} \qquad Y_{\pm} = 1 \pm (1-y)^2$$



- **LEP: similar production mechanism, larger cross sections and generally smaller background**



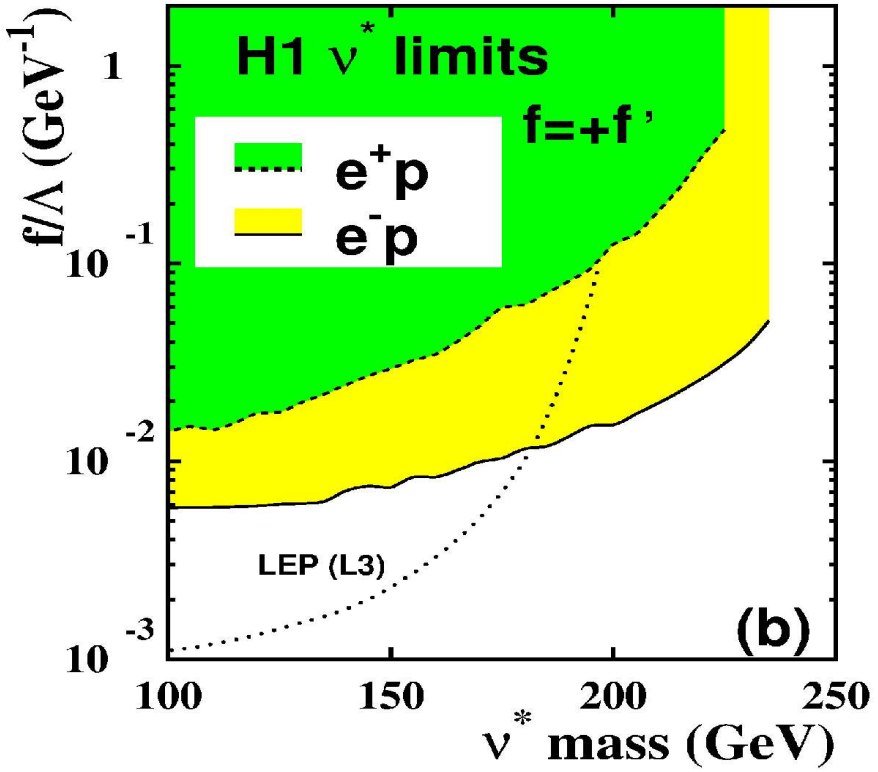
- **Tevatron: photon or jets with missing P_T**
  - **final state already investigated (LED, SUSY)**
  - **ν* analysis not yet done**

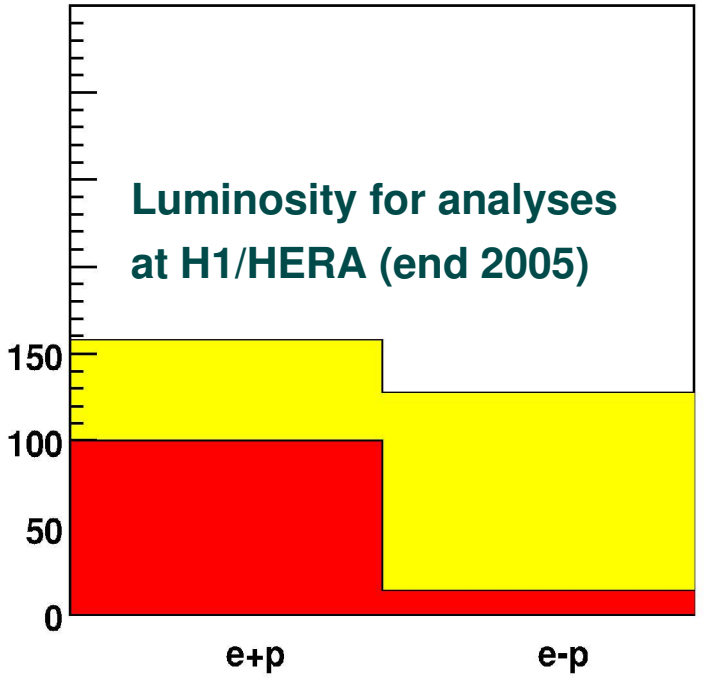
Searches for ν* at HERA

H1 HERA I Result $L(e^-p) = 14\ pb^{-1}$ **(Best sensitivity)**

Phys. Lett. B525 (2002) 9

$L(e^+p) = 102\ pb^{-1}$



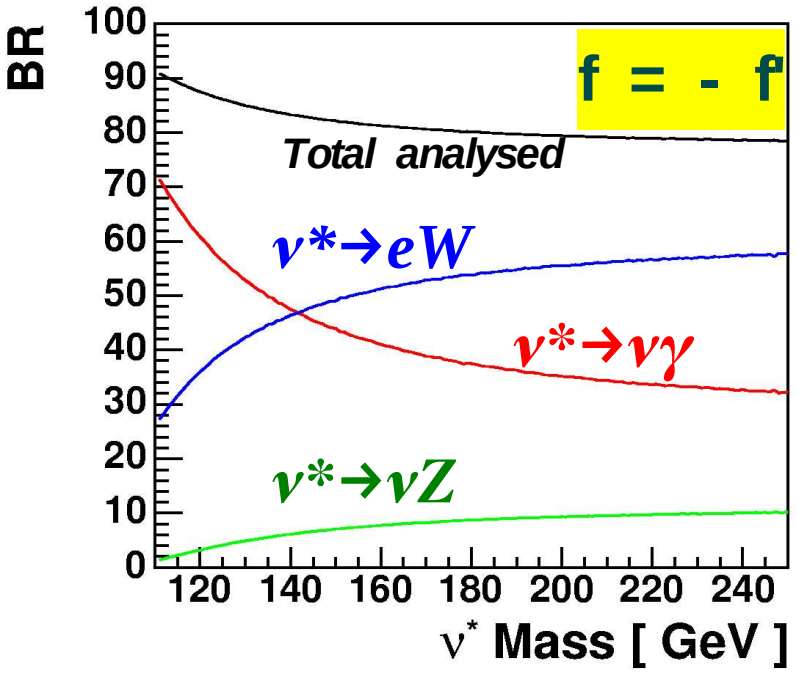


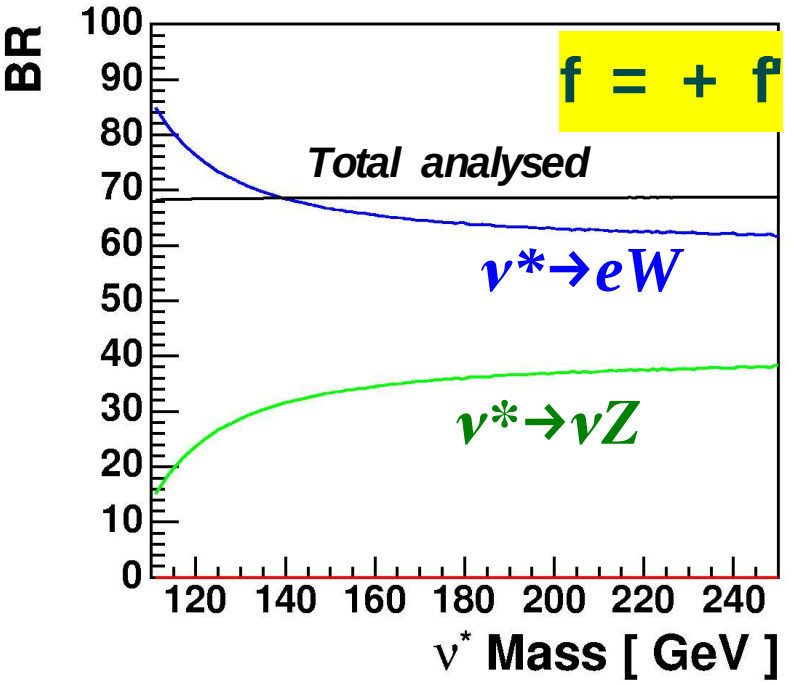
- **Large data sample in e- p mode collected at present**
  - **factor 8 more than the publication**
- **New preliminary result: H1 Search for ν* using $L(e^-p) = 114\ pb^{-1}$**

The decays and their signatures

Decay	Signature	Main SM Background
$\nu \to \nu\gamma$	Photon+P_T^{miss}	Radiative CC
$\nu \to eW$ (W→jets)	e+multijet	NC (multijet)
$\nu \to \nu Z$ (Z→jets)	P_t^{miss}+multijet	CC (multijet)

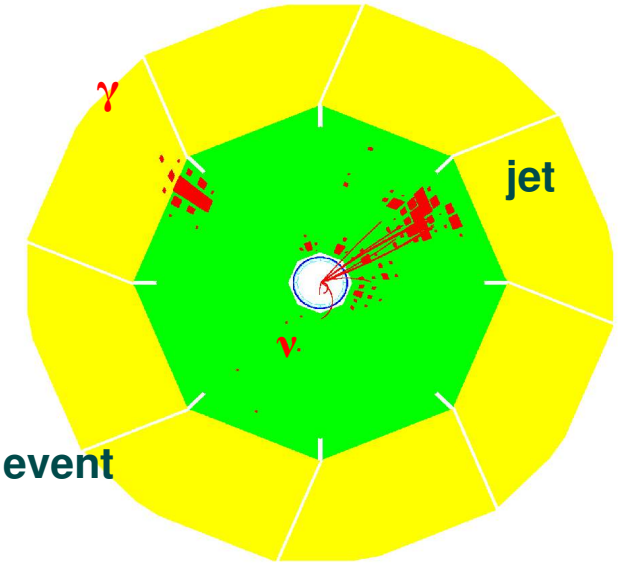
(leptonic decays of W/Z not considered at present)





Search for $\nu^* \rightarrow \nu\gamma$

- P_T^{Miss}>15 GeV, P_t^{jet}>5 GeV
- isolated photon
- reduce CC:
  - P_t^{photon}>20 GeV
  - extra kin. cuts E-P_z>45 for P_t^{γ}<50 GeV

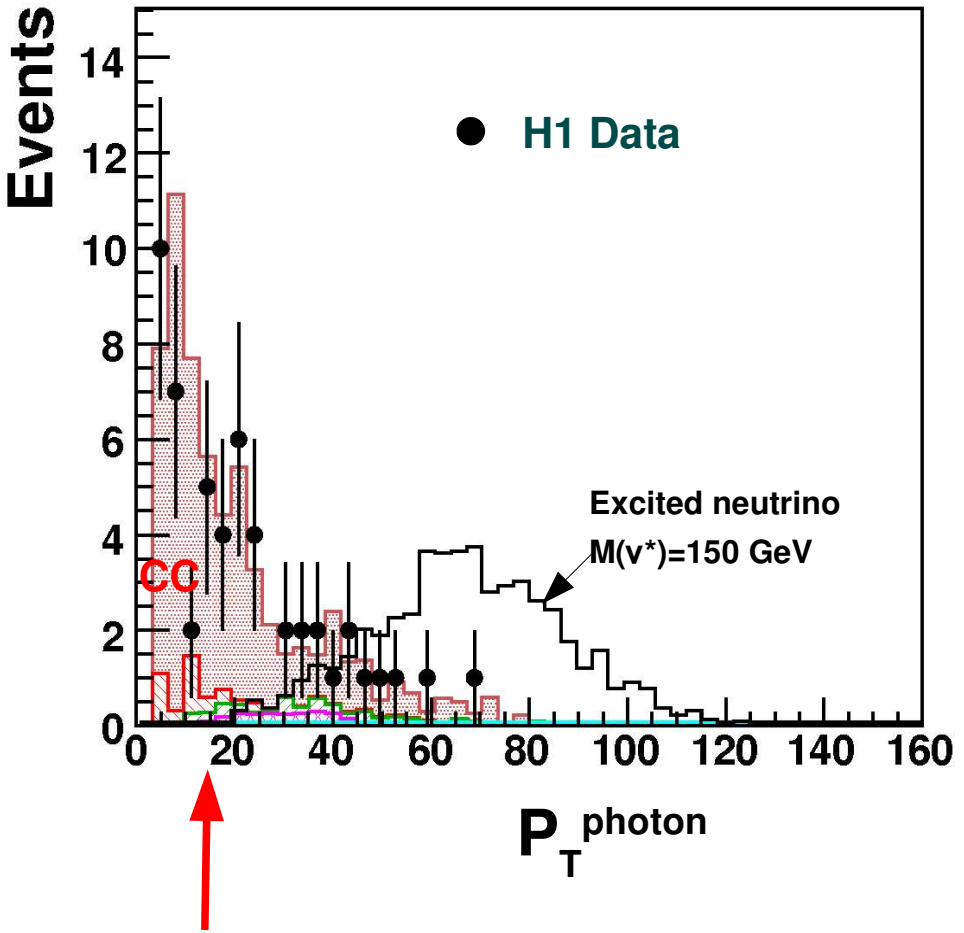


v* MC event

ν reconstructed from

P^{tot}_T=0 and E-P_z =2*E_e^{beam} constraints

Main background: radiative CC DIS



Search for ν* multi-jet decays

ν*→ν Z

P_T^{miss}>12 GeV

P_t^{jets}>20,15 GeV

CC dijets

+reduce CC

E-P_z>25 GeV

V_{ap}/V_p>0.1 ("open CC's")

ν*→eW

P_T^e>10 GeV

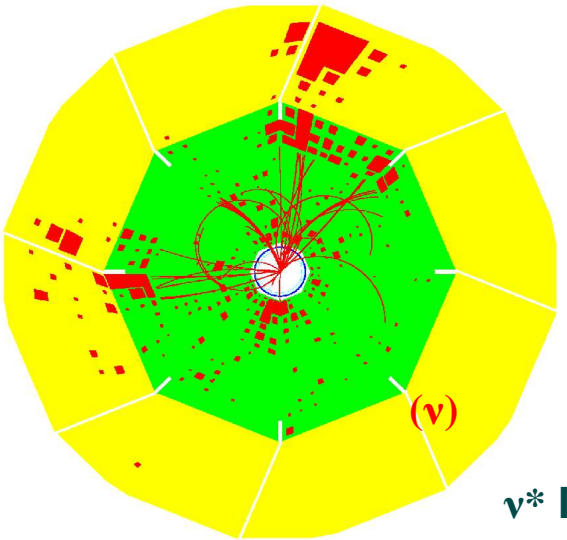
P_t^{jets}>20,15 GeV

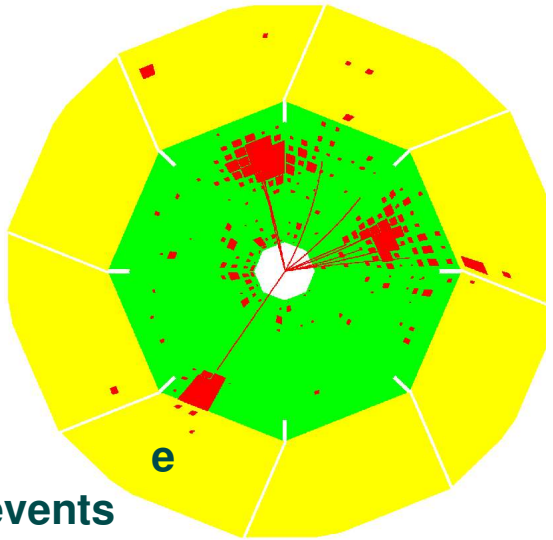
NC dijets

+ reduce NC

Q^2>2500 if P_t^e<25 GeV

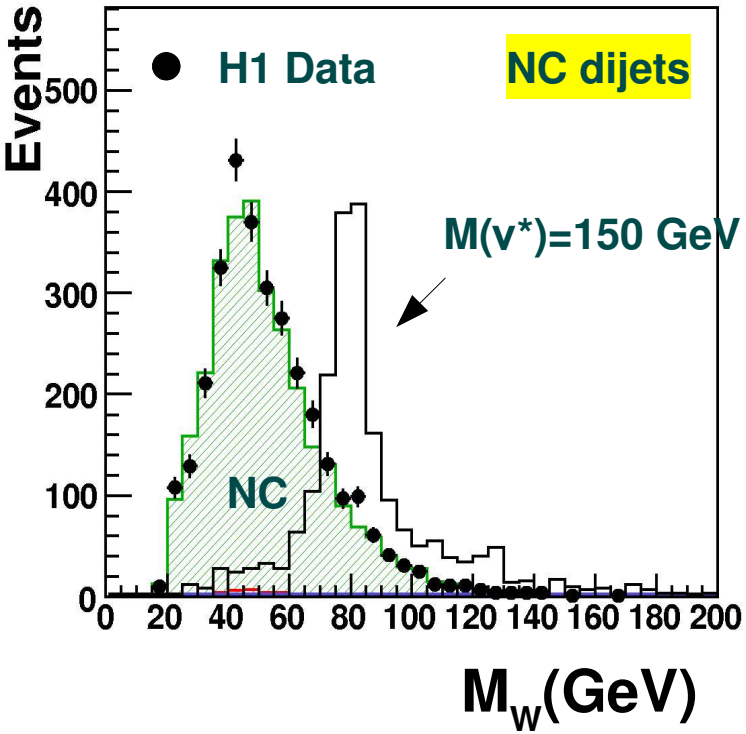
Form a W/Z candidate from 2 highest P_T jets





ν* MC events

ν reconstructed from P_T and E-P_z constraints



Results

H1 Preliminary 114 pb^{-1} (2005)

Selection	Data	SM	CC-DIS	NC-DIS	γp
$\nu^* \to eW_{\hookrightarrow qq}$	136	118 ± 22	$--$	112 ± 21	4.4 ± 1.2
$\nu^* \to \nu Z_{\hookrightarrow qq}$	88	81 ± 15	54 ± 13	5 ± 1.6	22 ± 5
$\nu^* \to \nu\gamma$	12	11.6 ± 2.5	9.1 ± 2.4	1.3 ± 0.3	0.4 ± 0.15

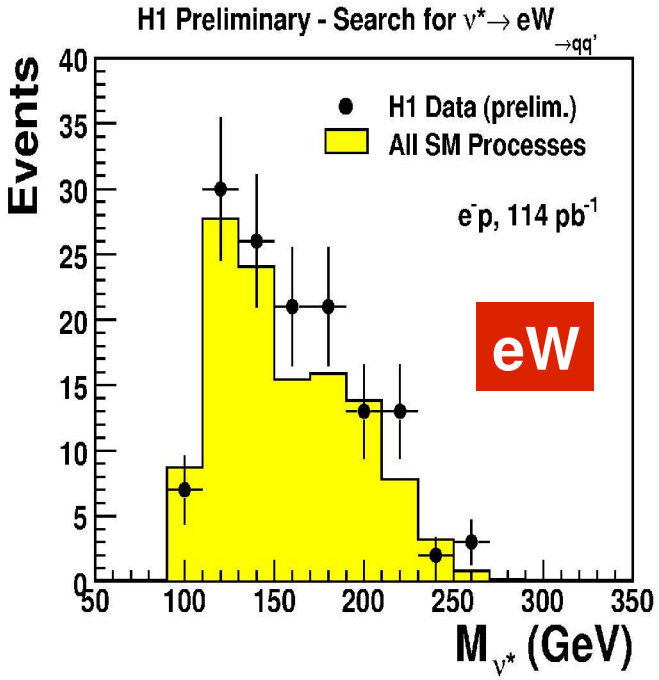
efficiency

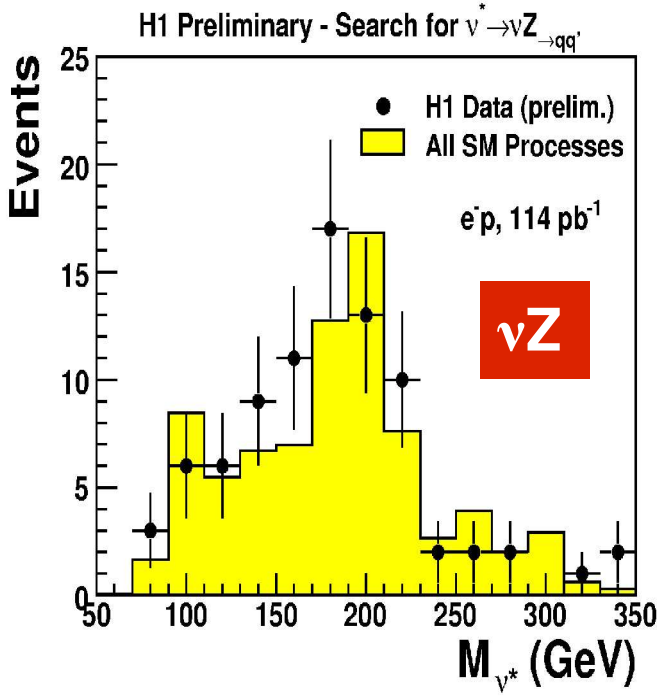
M_{ν^*}100-260 GeV

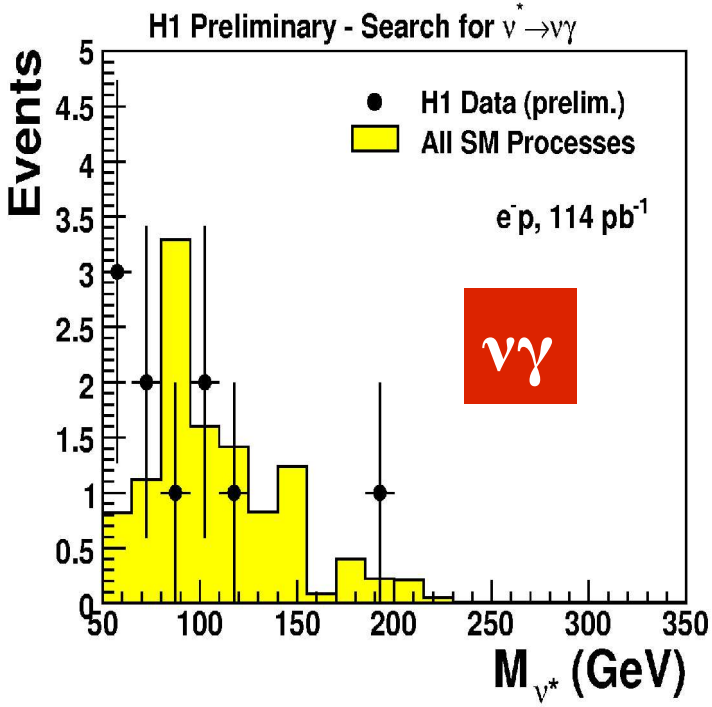
20-45%

20-35%

~50%







Mass resolution $\sigma(M_{\nu^*})$ ~15 GeV
(M_{ν^*}=260 GeV)

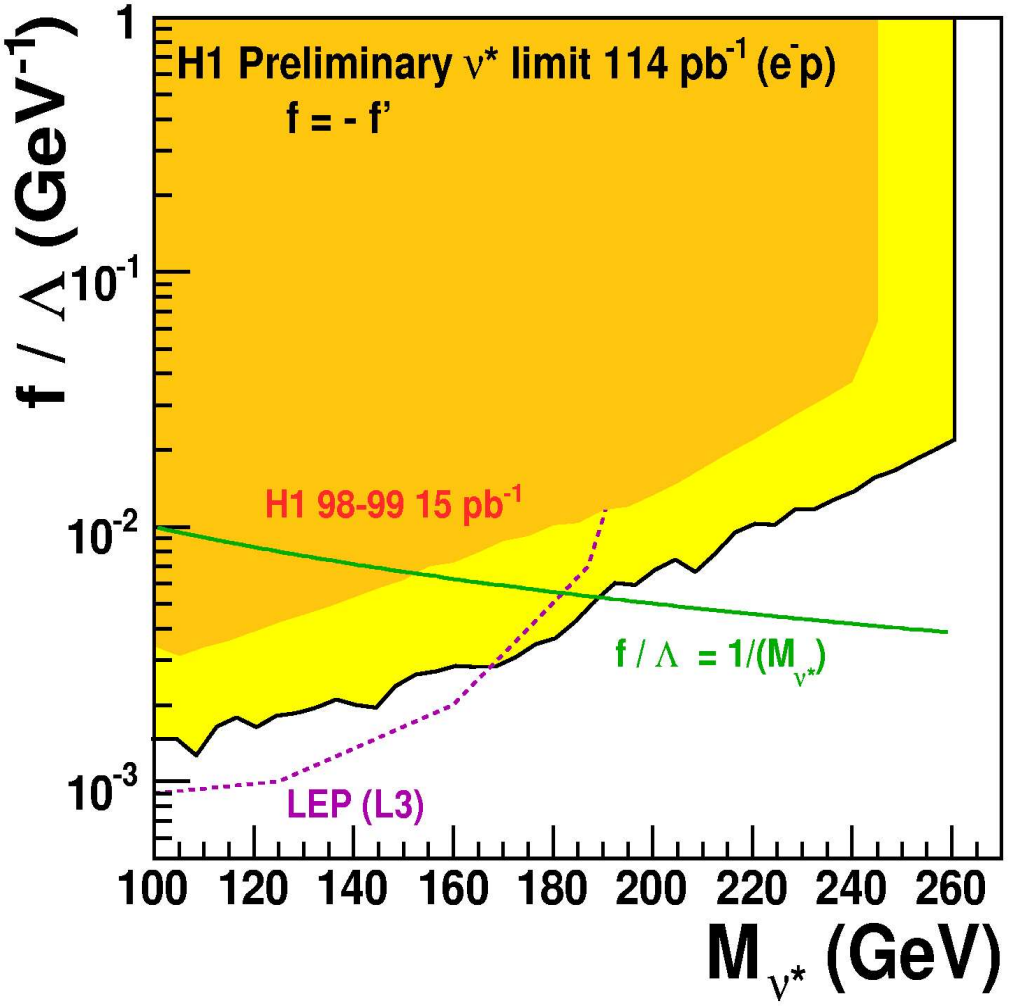
$\sigma(M_{\nu^*})$ =~18 GeV

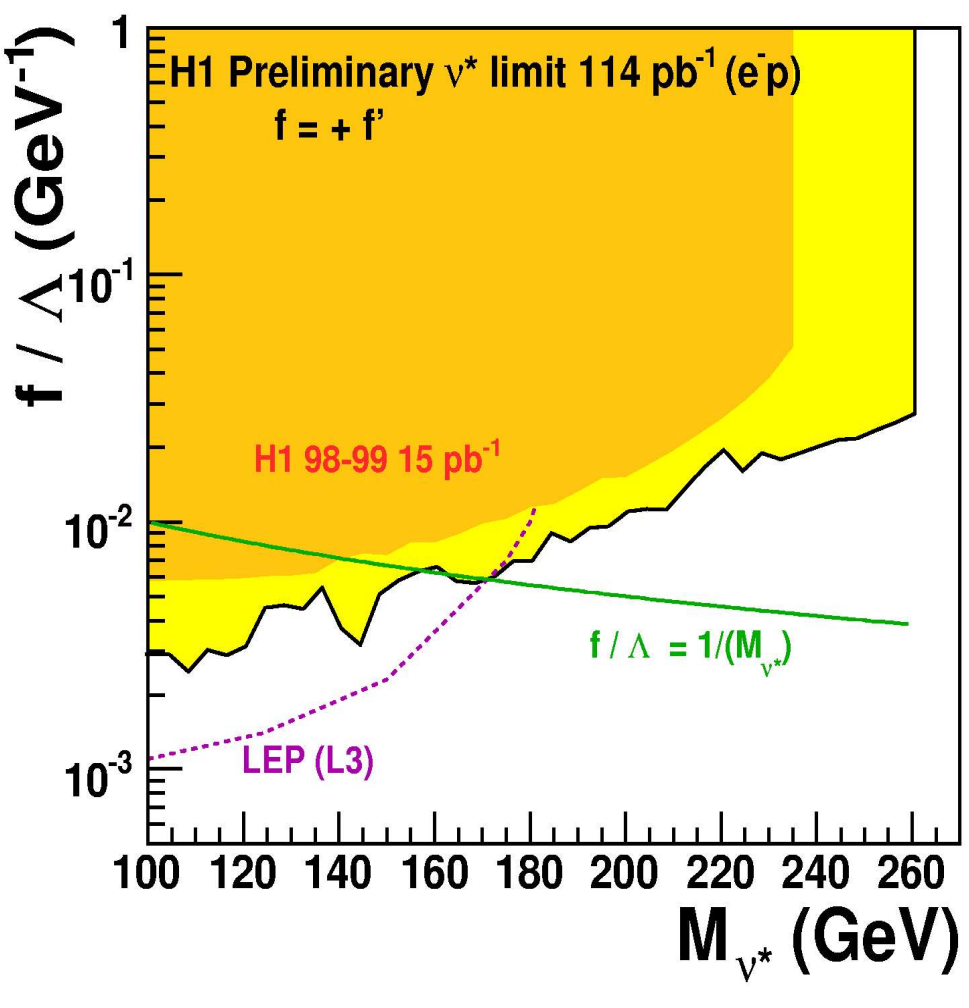
$\sigma(M_{\nu^*})$ ~4 GeV

No significant deviation from the SM prediction => exclusion regions ($f/\Lambda, M_{\nu^*}$)

New domains explored

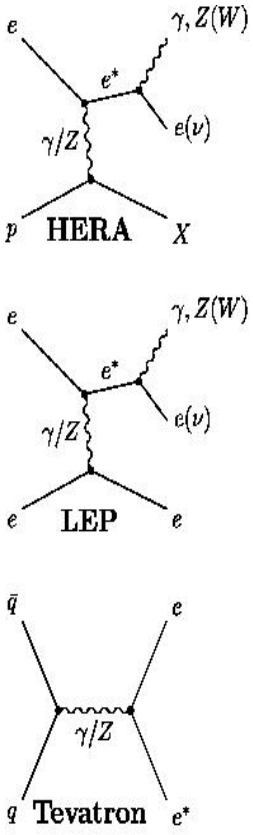
ν* has negligible width close to the sensitivity border



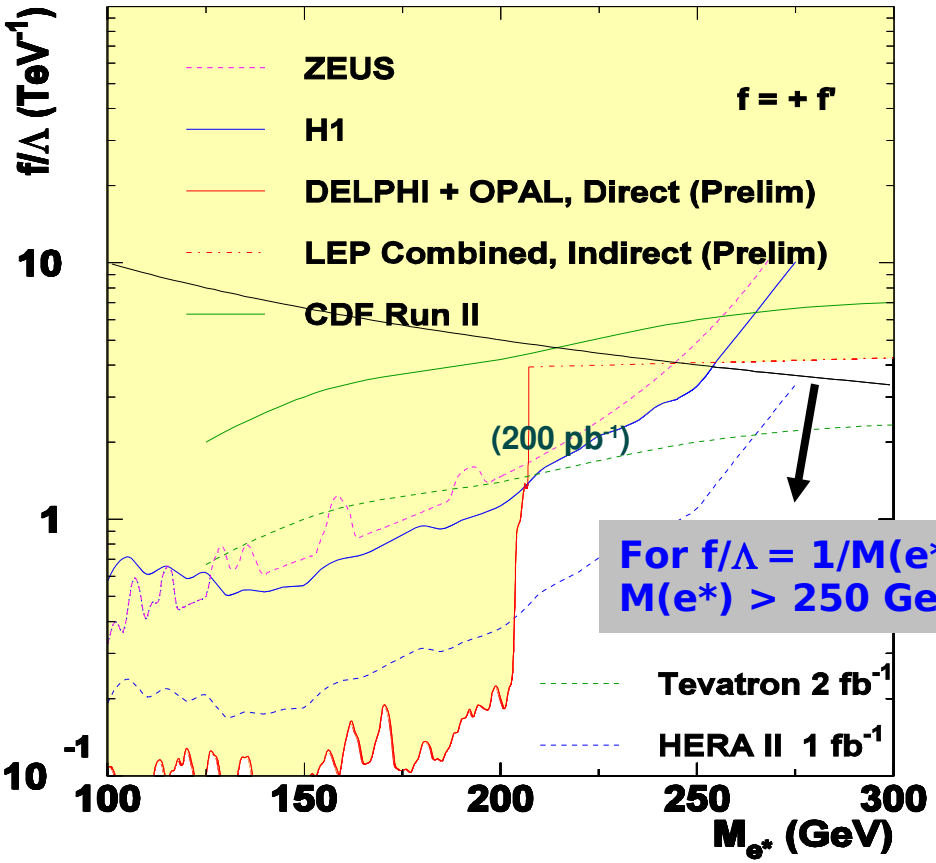


If f=-f' (maximal coupling to the photon) and $f/\Lambda = 1/M_{\nu*}$
$M_{\nu*} < 188 GeV$ excluded @ 95% C.L.

Status of other f* searches



e*



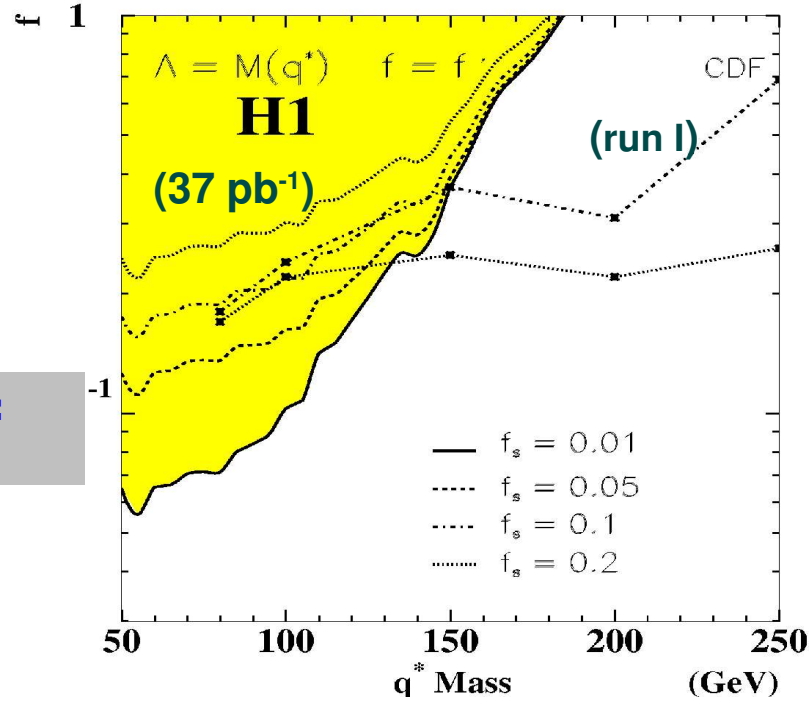
For f/Λ = 1/M(e*) : M(e*) > 250 GeV

q*

D0 (380 pb^{-1}):

q*→qZ(→ee) (f=f'=f_s=1, Λ=M_{q^*})

M_{q^*}<520 GeV excluded @95%CL



e*: HERA have an unique sensitivity up to M(e*)=300 GeV and f/Λ~10^{-3}(GeV^{-1})

q*: dominated by Tevatron, if strong sector also "excitable" (f_s>0)

HERA sensitive if f_s <<1 ; large increase in luminosity expected

Other excited fermions could be produced in pairs at Tevatron

(D0: Mμ*>680 GeV, Λ=1TeV, CI formalism)

Conclusions

- Search for excited neutrino has been performed using HERA II data
  - $L(e^-p)=114\ pb^{-1}$
- A new domain explored, but no positive signal found
- Neutrino masses up to 260 GeV ($f/\Lambda=1.10^{-2}$) excluded in the present analysis; for $f/\Lambda=1/M_{\nu^*}$ $M_{\nu^*}>188$ GeV @ 95% CL
- significant increase in analysed data sample expected
  - $L^{HERAtotal}(e^-p)$~factor 2 w.r.t. present analysis (ν^*)
  - $L^{HERAtotal}$ ~= factor 4-5 w.r.t. HERA I (e^*, q^*)

Search for lepton-boson resonances will continue at HERA!