Graduate Students Seminar

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Search for Excited Quarks

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Search for Excited Quarks

- Framework
  - Excited fermions and compositeness
  - Phenomenological framework
  - Production of excited fermions
  - Production and decay of excited fermions at HERA
- q^* analysis
  - Overview of the q^* analysis
  - H1 detector and the q^* decay signature
  - Standard model background processes
- Present results and limits
  - Present results: Search for e^* at Zeus
  - Present results: Search for e^* at H1
  - Present results: Search for q^* at H1
  - Present limits for q^*
- Conclusion and outlook

Excited fermions and compositeness

Family structure and masses of fermions

Quarks	u (up)	c (charm)	t (top)
	d (down)	s (strange)	b (beauty)
Leptons	e (electron)	μ (muon)	τ (tau)
	ν_e (e neutrino)	ν_μ (μ neutr.)	ν_τ (τ neutr.)

Masses getting bigger $\longrightarrow$

Explanation: Compositeness of Quarks and Leptons ?

Consequence:

Existence of excited States of Quarks and Leptons

Compositeness Scale:	TeV region
Excited Fermion Masses:	TeV region
Lowest excitation states:	few hundred GeV

HERA (H1 and Zeus) allows

center of mass energies up to 320GeV

Phenomenological framework

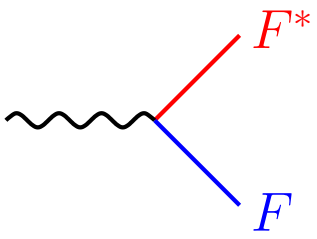
Assumption: Excited fermion F^* is composite of a scalar and a spin $\frac{1}{2}$ constituent

In our case: (lowest excitation) F^* has spin $\frac{1}{2}$, isospin spin $\frac{1}{2}$

Effective Theory: effective Lagrangian (low energy region)

Coupling of the excited fermion

Gauge boson $(g,\ Z/\gamma,\ W_{\pm})$



SM couplings (↘) new couplings (↙)

$$\mathcal{L}_{eff} = \frac{1}{2\Lambda}\,\bar{F}^*_R\,\sigma^{\mu\nu}\ \Big(\ g\ \ f\ \frac{\tau^a}{2}\,W^a_{\mu\nu} \leftarrow \text{SU(2)}$$
$$+\ g'\ \ f'\ \frac{Y}{2}\,B_{\mu\nu} \leftarrow \text{U(1)}$$
$$+\ g_s\ \ f_s\ \frac{\lambda_a}{2}\,G^a_{\mu\nu} \leftarrow SU(3)_C$$
$$\Big)\ F_L\ +\ h.c.$$

(Λ: compositeness scale)

Coupling constant:

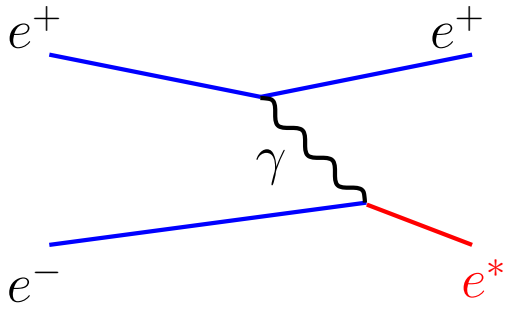
$$c_{\gamma f^* f} = \frac{1}{2}\,(f\ I_3 + f'\frac{Y}{2})$$

$\Rightarrow$ limits for f (or $f\ /\ \Lambda$)

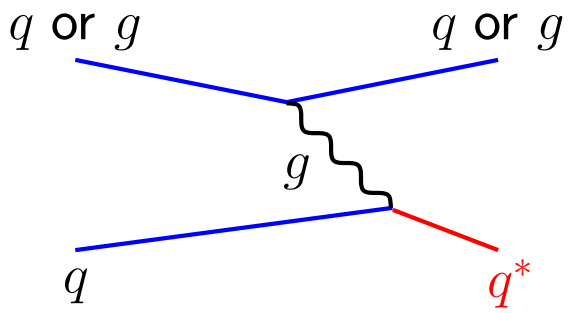
Production of excited fermions

- Single production

LEP: e^+e^- Collider

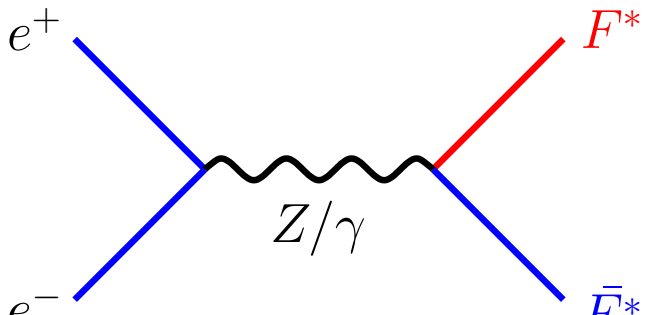


CDF: $p\bar{p}$ Collider

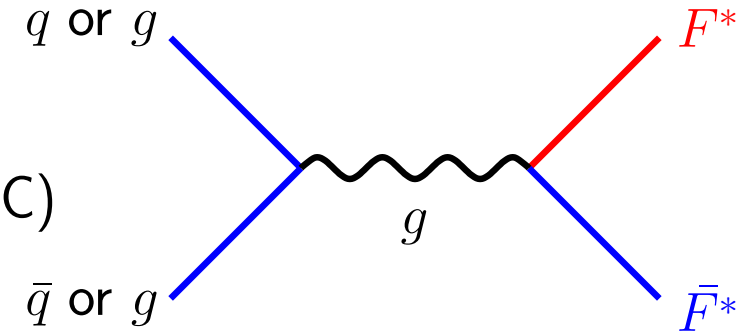


- Pair production

LEP: e^+e^- Collider

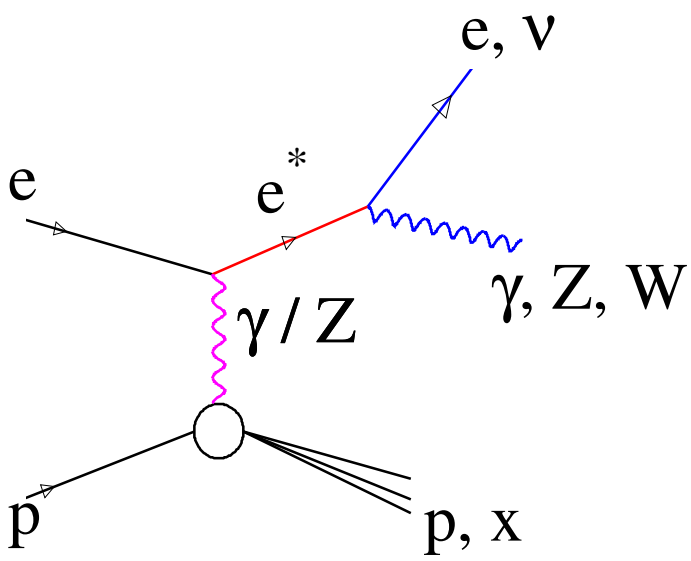


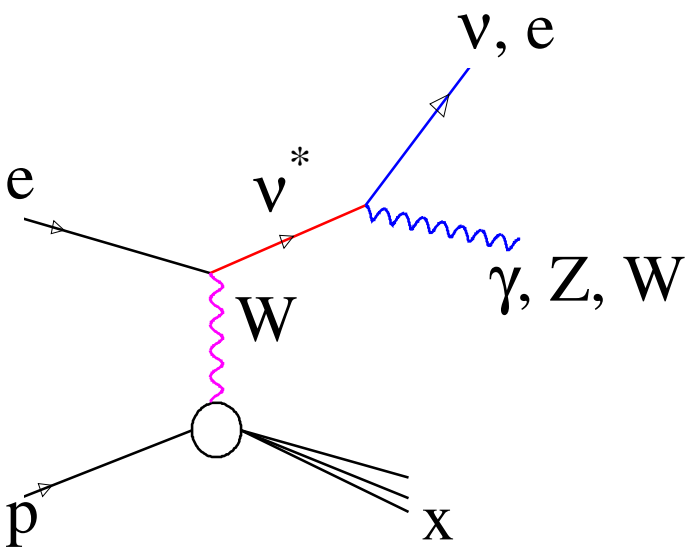
CDF: $p\bar{p}$ Collider
with gluons (e.g. LHC)



Production and decays of excited fermions at HERA

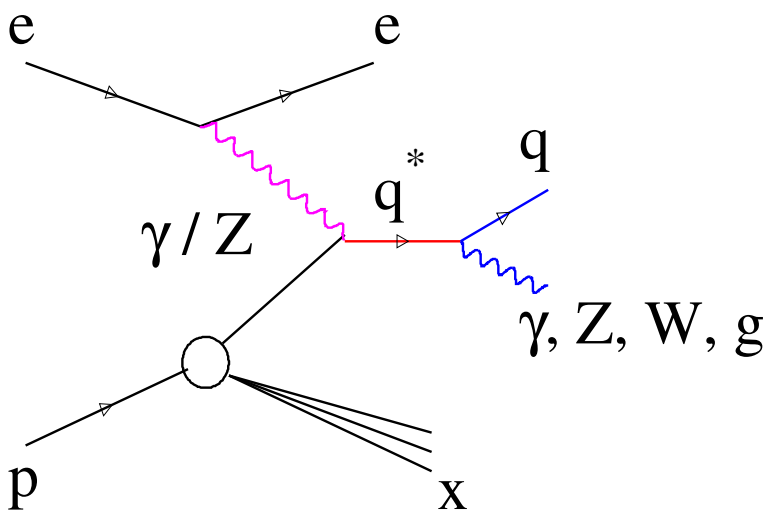
m_{e^*}





m_{ν^*}

m_{q^*}



Overview of the q^* search analysis

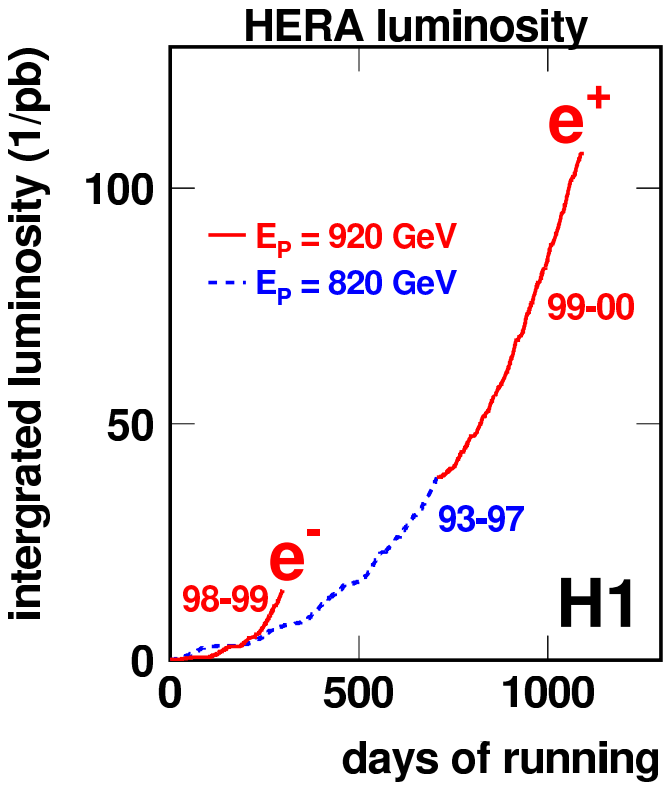
MC signal sample:

- Event Generator FERMION (Marie-Claude Cousinou)
- Simulated detector response from H1Sim

MC background sample:

- NC DIS events with generator DJANGOH
- Photoproduction events with generator PYTHIA

H1 data:



- Last analysis on q^* used $37\ pb^{-1}$ integrated luminosity of data
- Now is more then $100\ pb^{-1}$ integrated luminosity of data available

Find cuts to separate signal and background

Derive limits

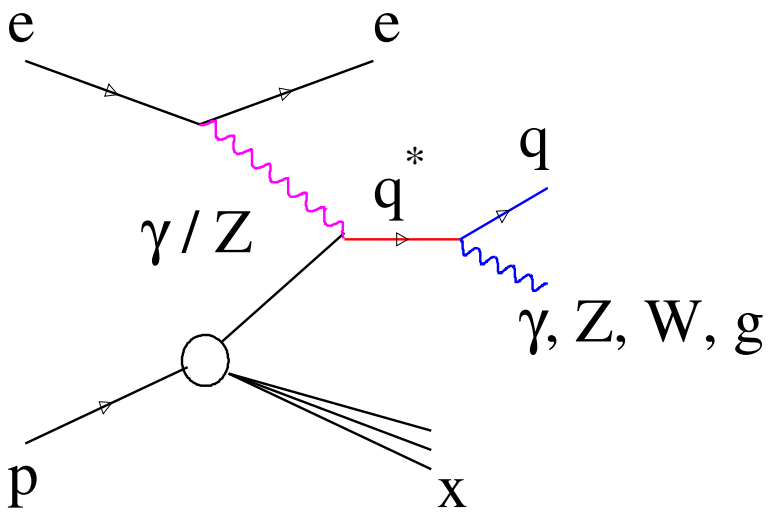
H1 detector and the q^* decay signature

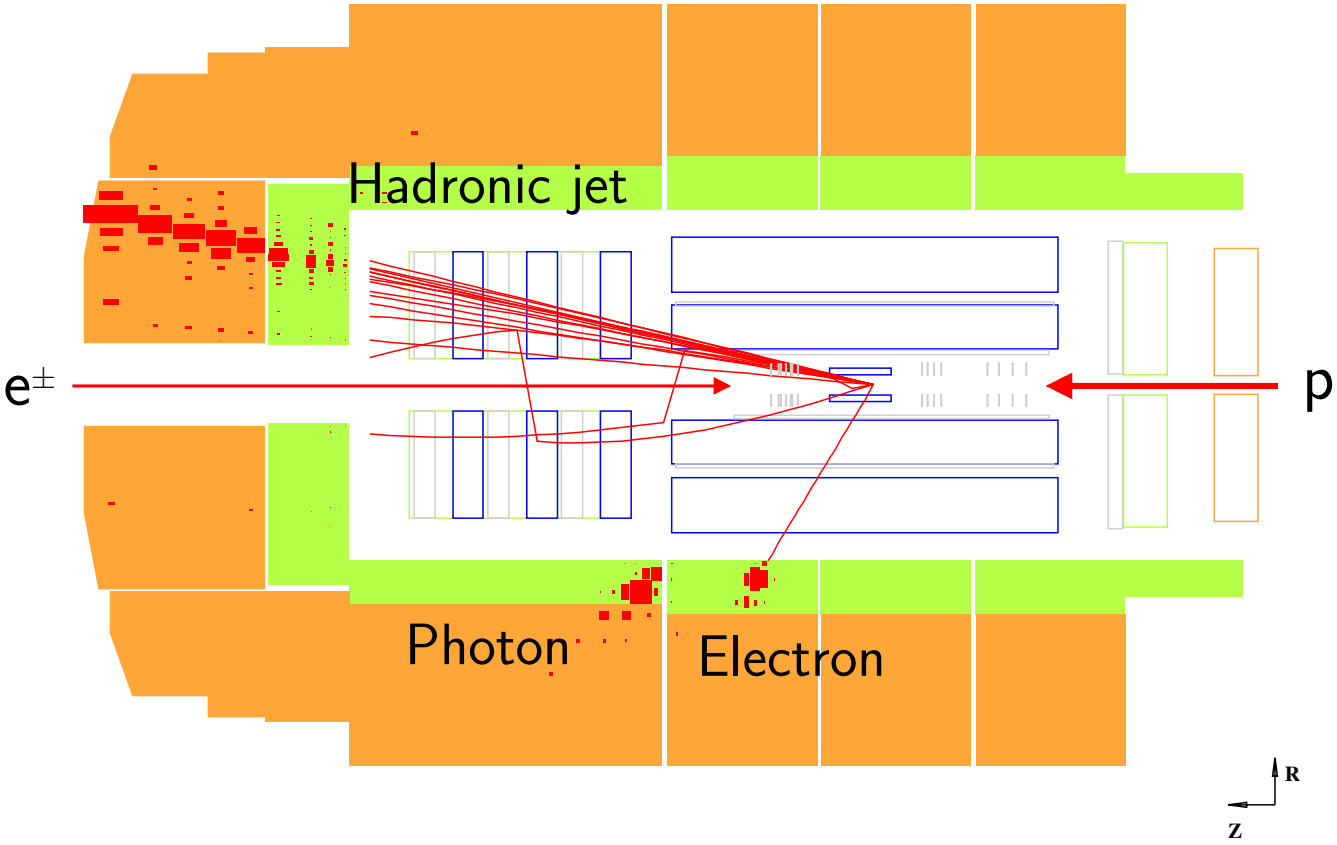
Signature:

1 hadronic jet

1 photon

1 electron
(can be at low angle)





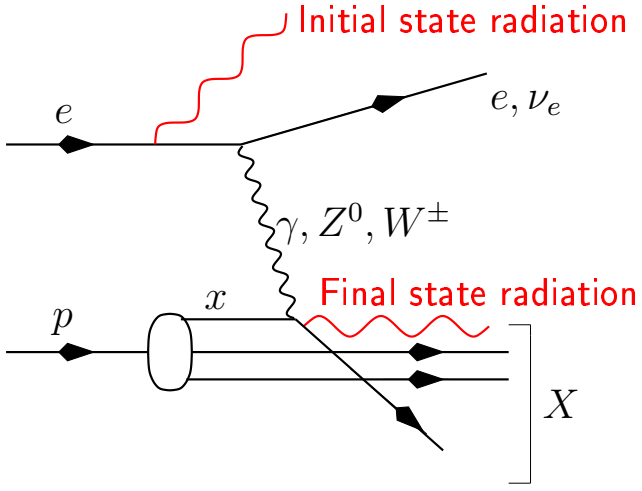
Important parts of the detector:

- LAr Calorimeter
- Tracking system

Standard model background processes

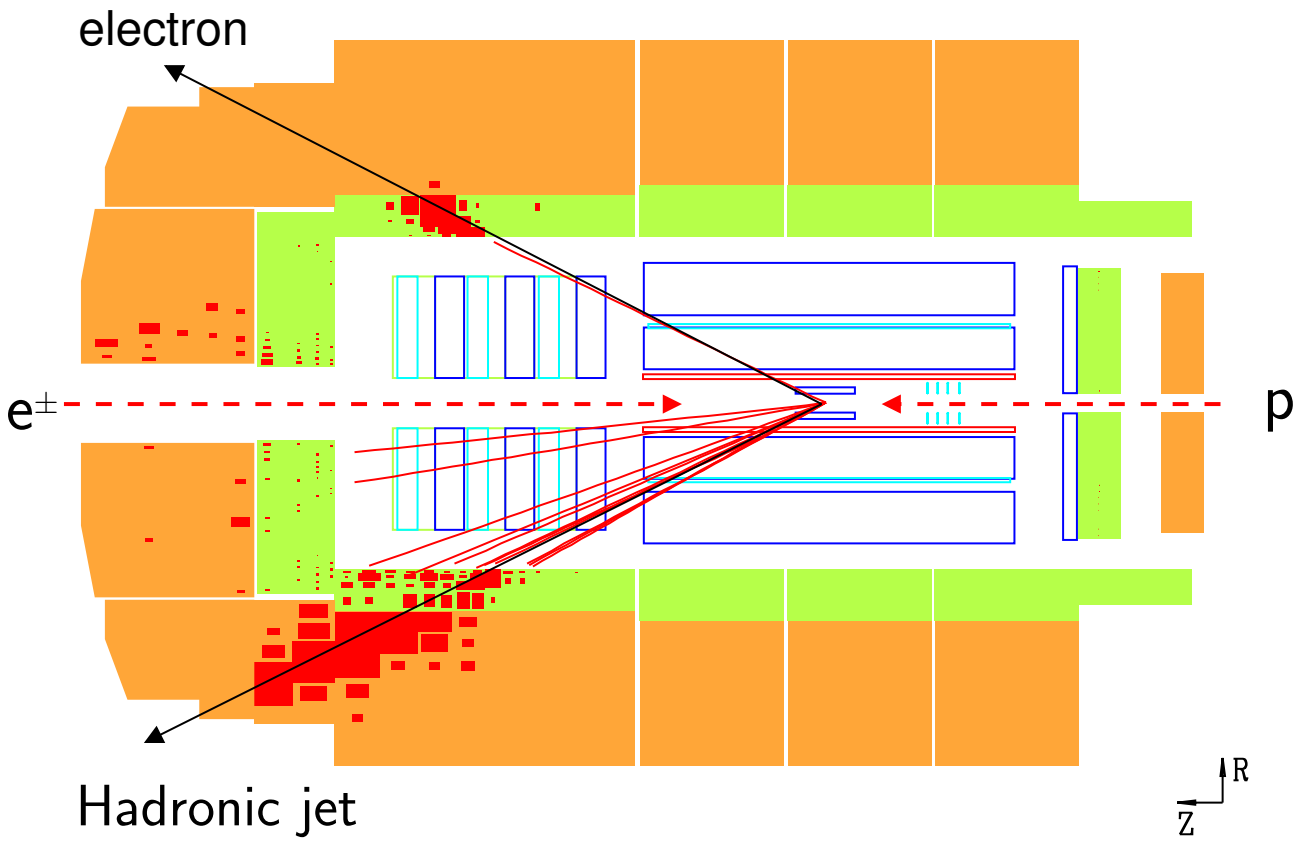
Neutral current DIS: Z^0 exchange

- Isolated scattered electron
- One or more central jets
- Proton remnant energy around beampipe

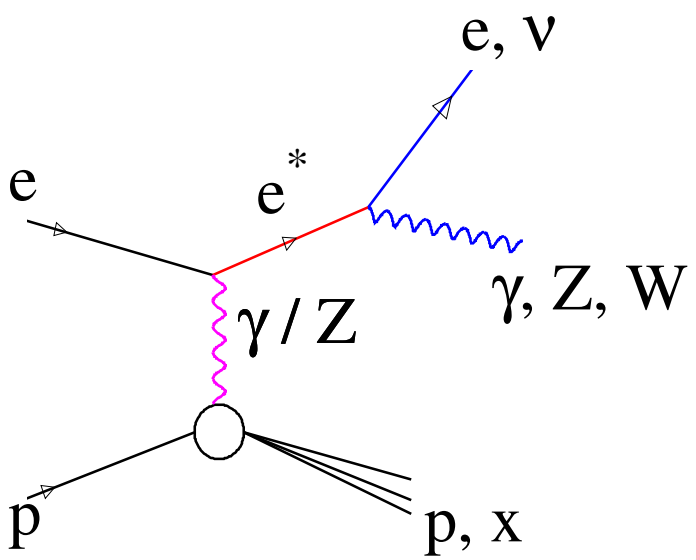


NC DIS with initial or final state radiation:

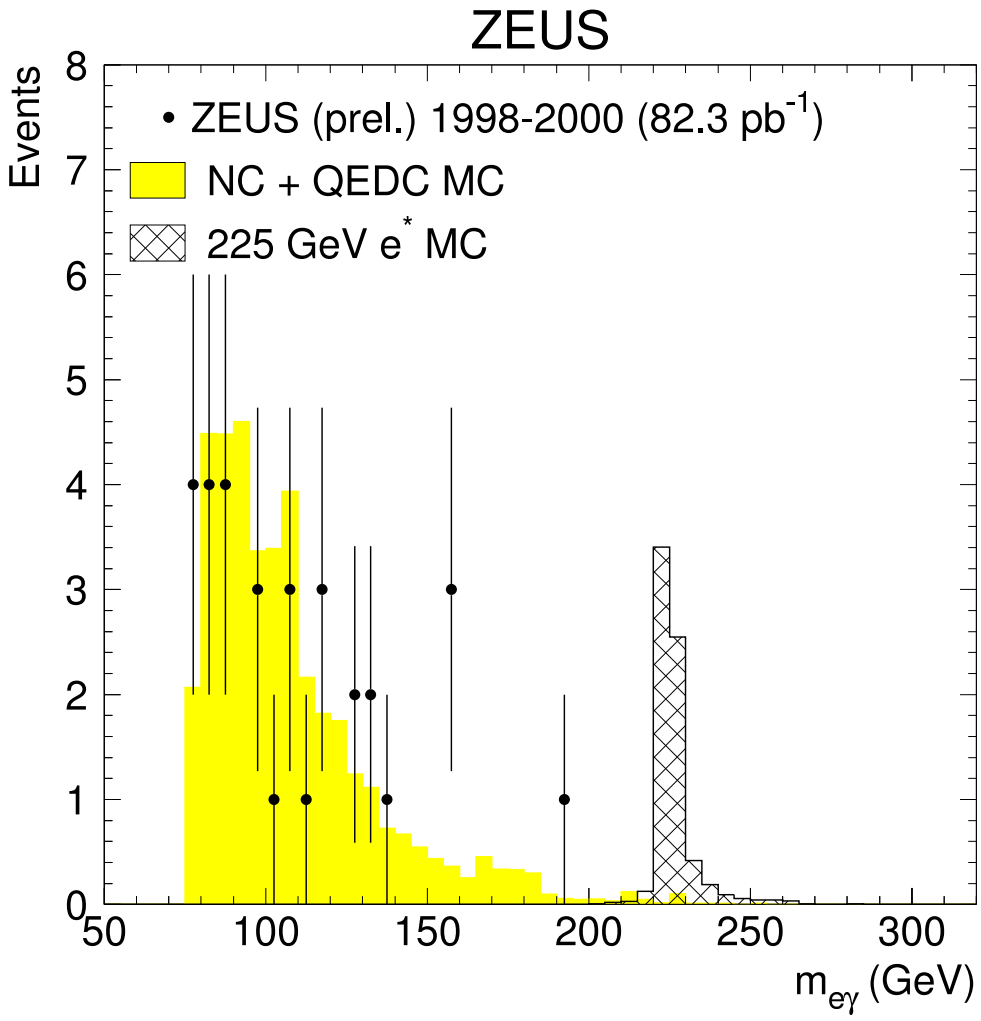
- Extra photon coming from initial or final state
- Problem if electron vanishes through beampipe



Present results: Search for e^* at Zeus

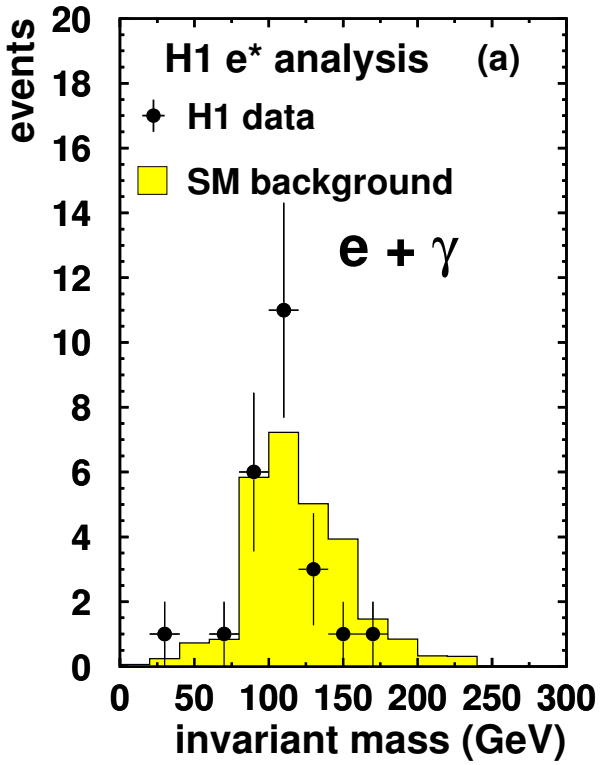


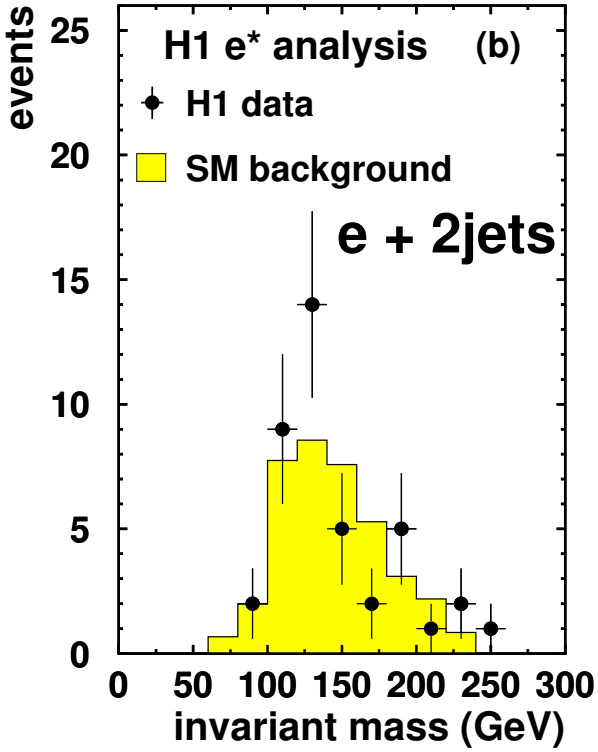
Invariant mass of detected electron and photon

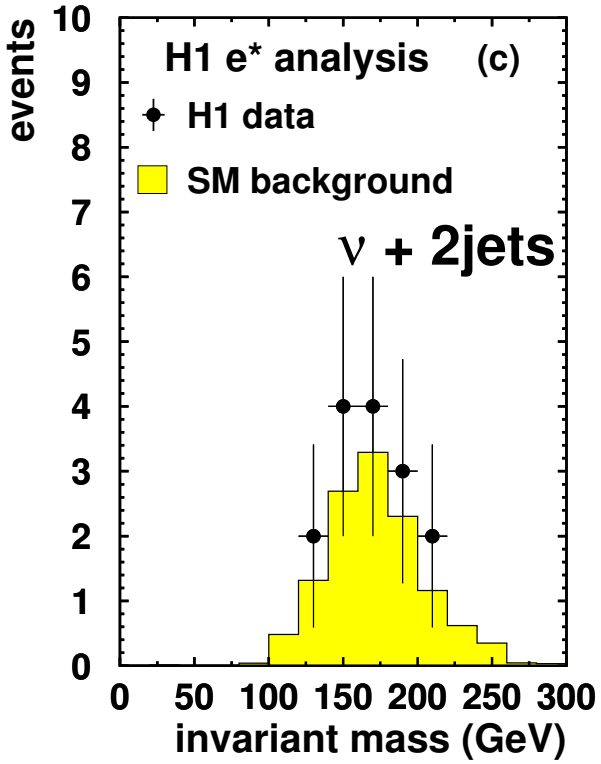


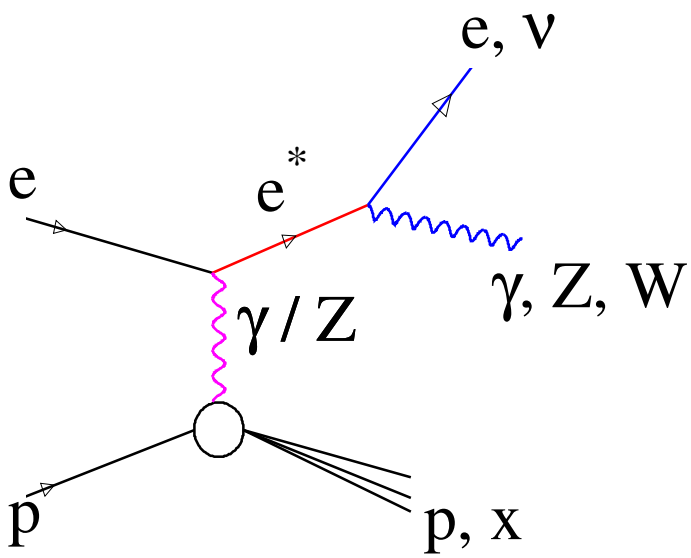
Present results: Search for e^* at H1

Invariant masses for different decay channels

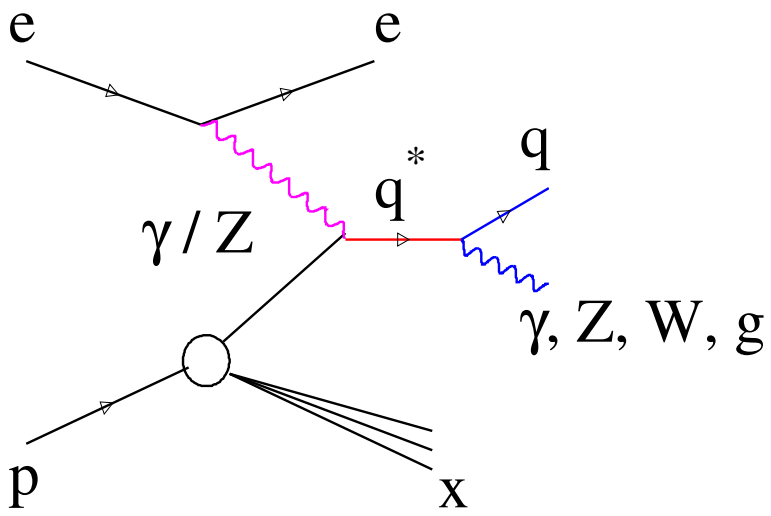




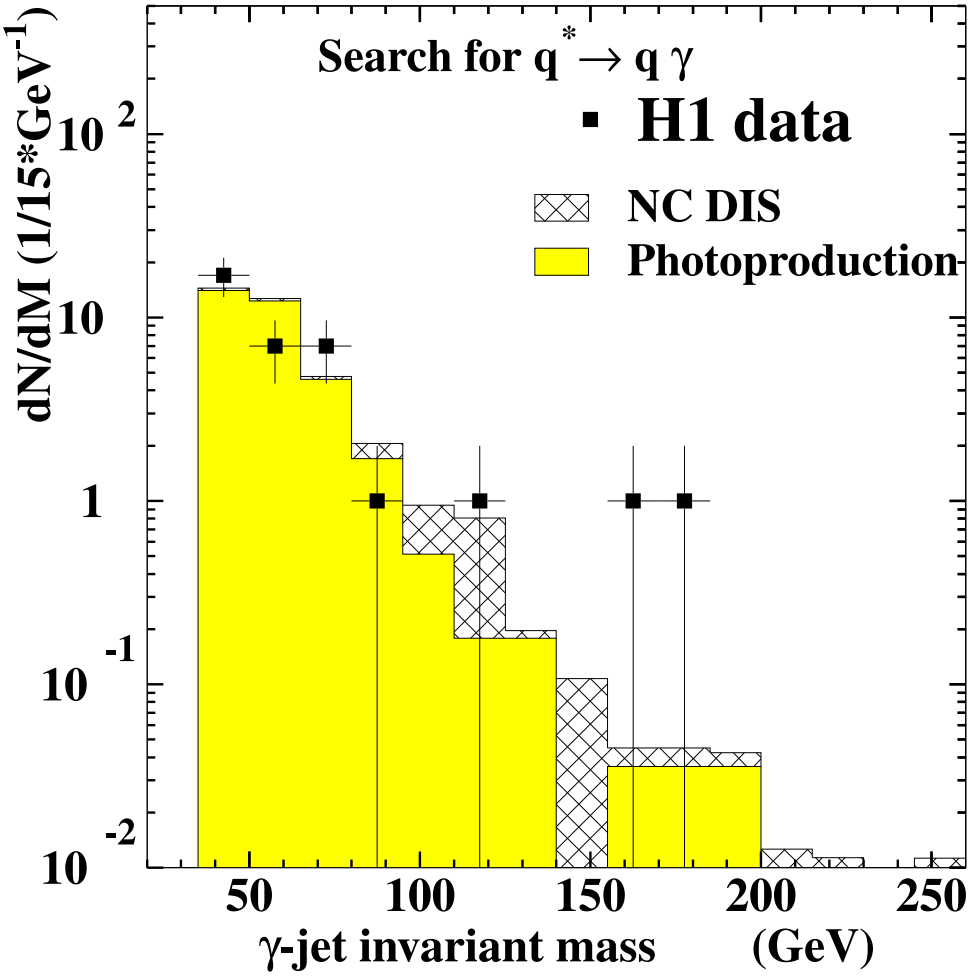




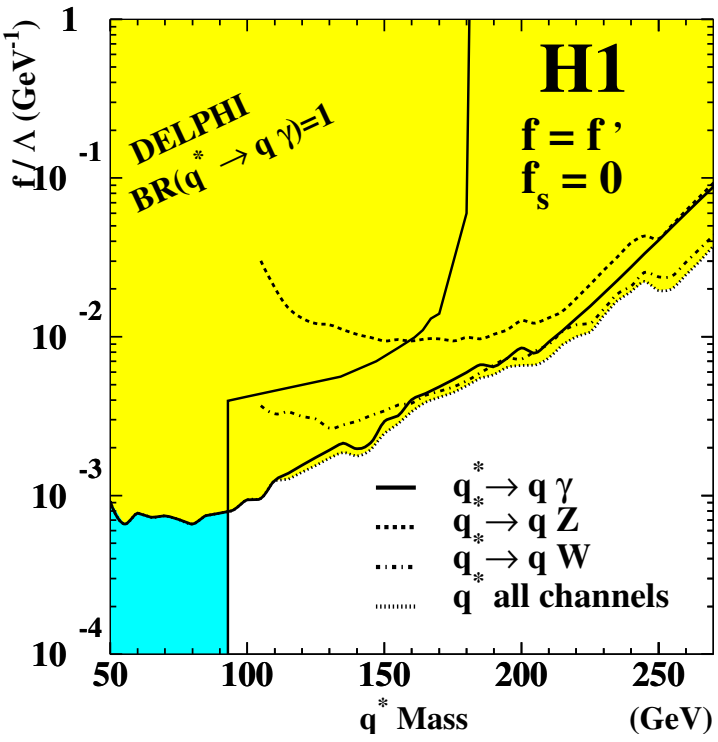
Present results: Search for q^* at H1



Invariant mass of detected jet and photon



Present limits: Search for q^* at H1

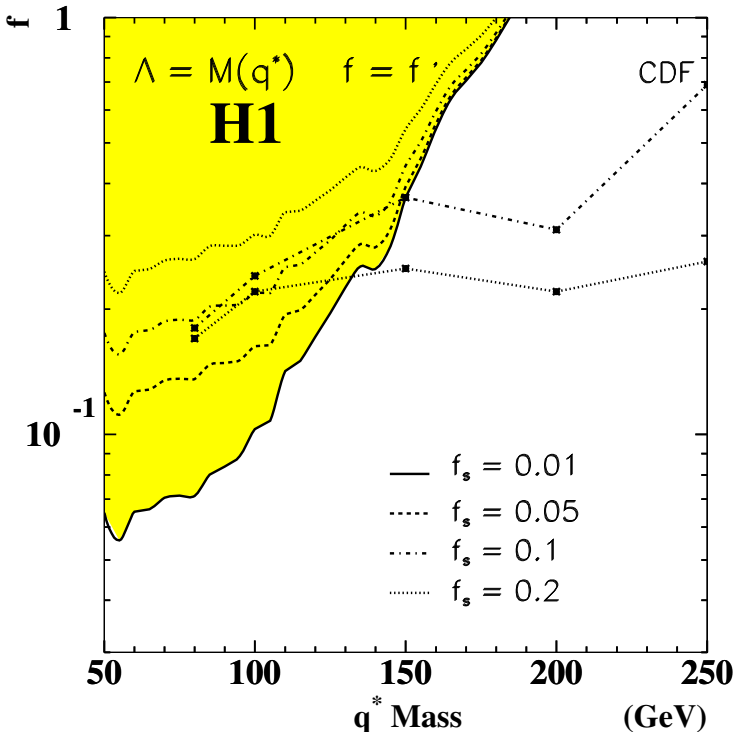


Assumption:

$f = f'$ and $f_s = 0$

no strong coupling

Extension of results from DELPHI by H1



Assumption:

$f = f'$ and $\Lambda = M(q^*)$

Results CDF (TeVatron)

strong coupling in generation process

H1 is more sensitive for small f_s than CDF

Conclusion and outlook

- H1 can contribute limits at regions of

  small q^* masses

  and

  small f_s

- q^* analysis should be pushed at H1

  because CDF will deliver new results

  in the near future, too

- A lot of work ahead