Searches at HERA

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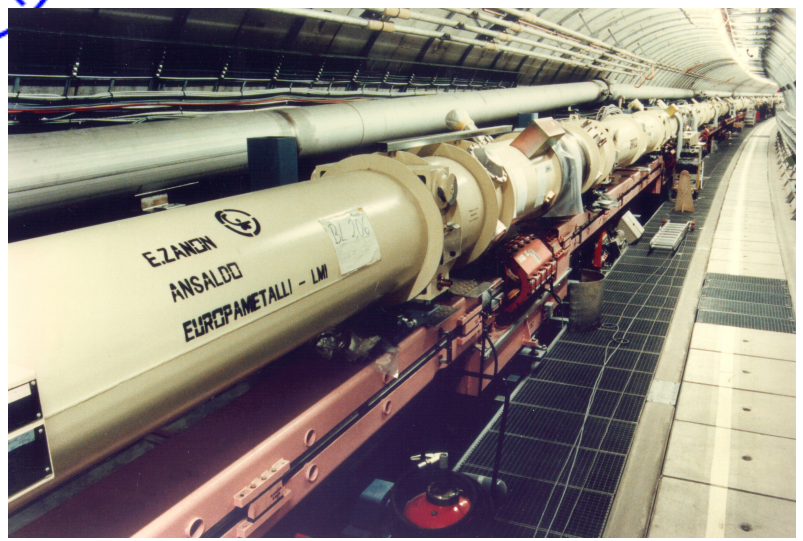
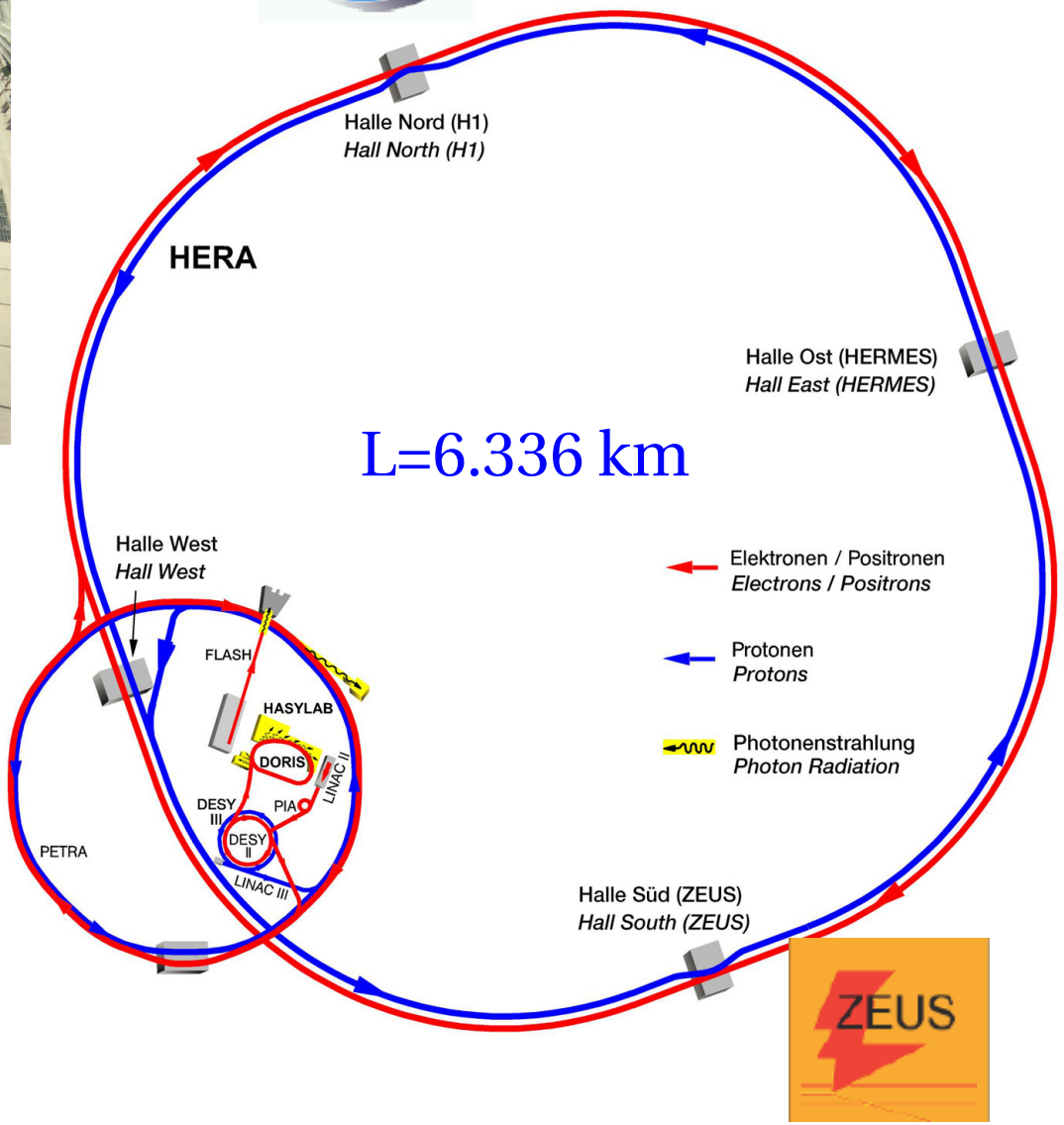
DESY

Aspen 2008 Winter Conference

- HERA
- Inclusive signatures
- Model-based searches
- Lepton signatures
- General search
- Summary

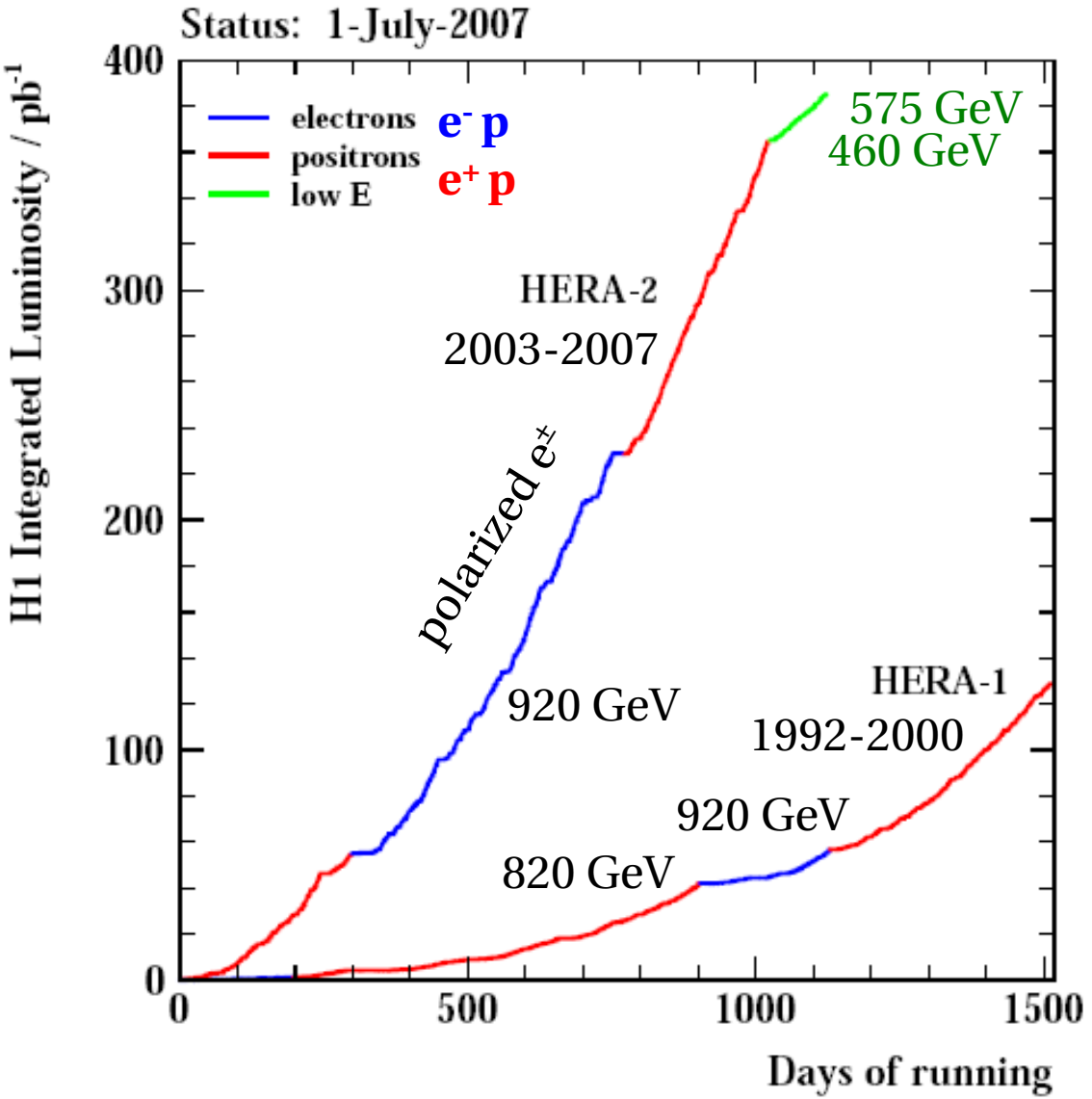
Hadron Elektron Ring Anlage HERA





- World's only ep accelerator and collider
- Operated 1992 - 2007
- p: 460-920 GeV, 110 mA
- e: 27.6 GeV, 45 mA
- 2 ep collider experiments: H1 and ZEUS.

Luminosity collection

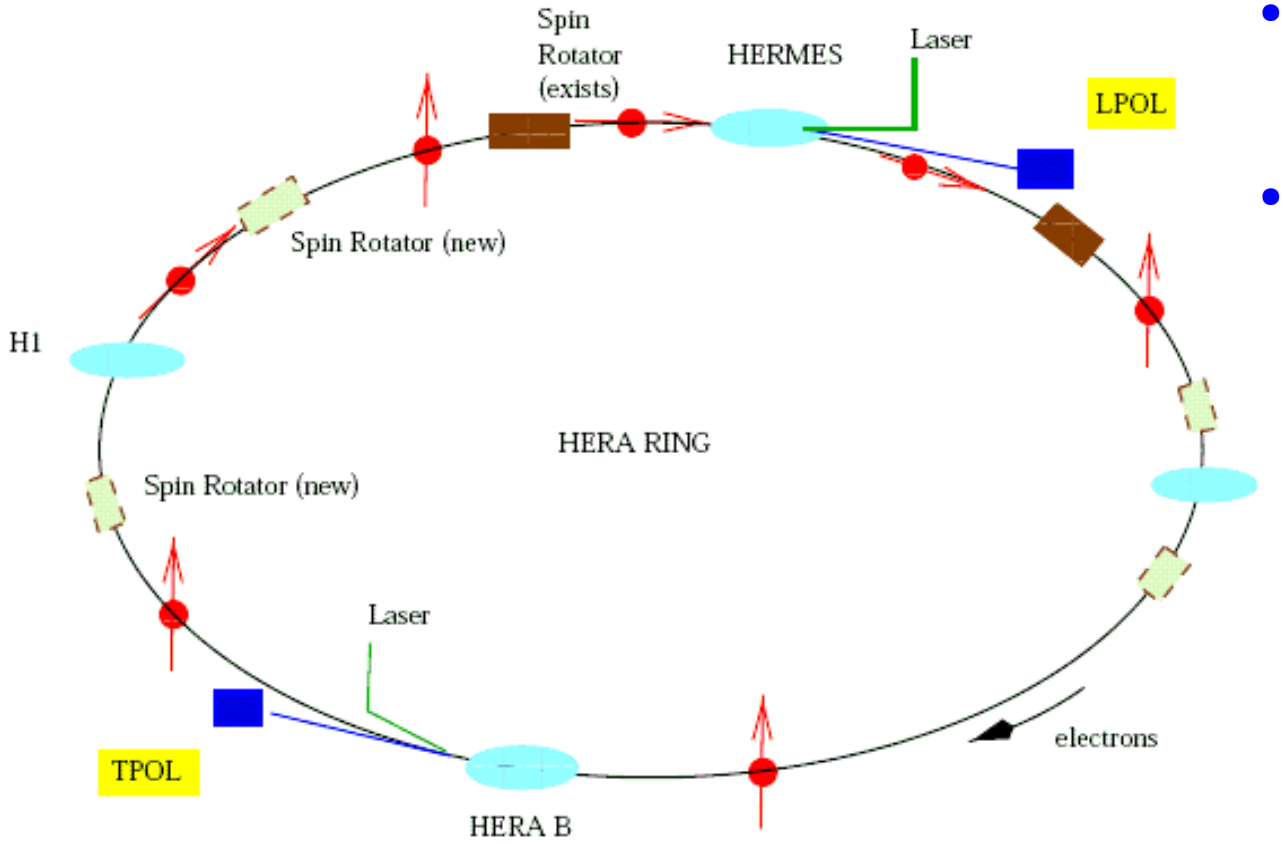


- H1 and ZEUS each have collected 0.5 fb^{-1} of high quality physics data, balanced in e^+ and e^-.
- 72% of the luminosity is from HERA II, with longitudinally polarized $e^\pm$ beams.
- The detectors have been operated successfully and efficiently, including all upgrades.

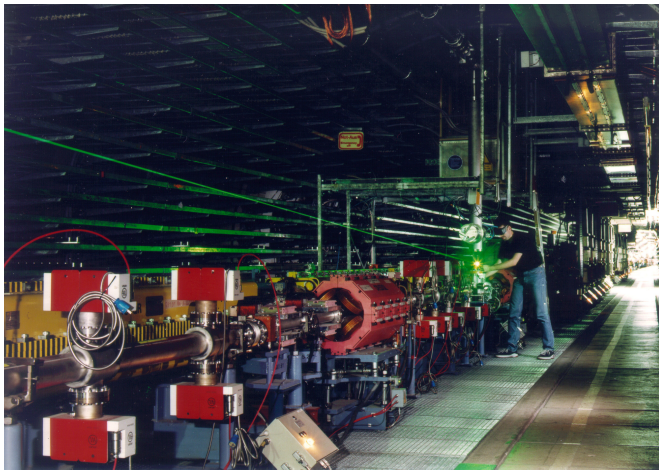
Polarized $e^{\pm}$

e beam acquires transverse polarization by the Sokolov-Ternov effect (magnetic moment couples to the dipole B field, spin flip by synchrotron radiation emission).

Spin rotators provide longitudinal polarization at the experiments (Hermes since 1995, H1 and ZEUS since 2003).

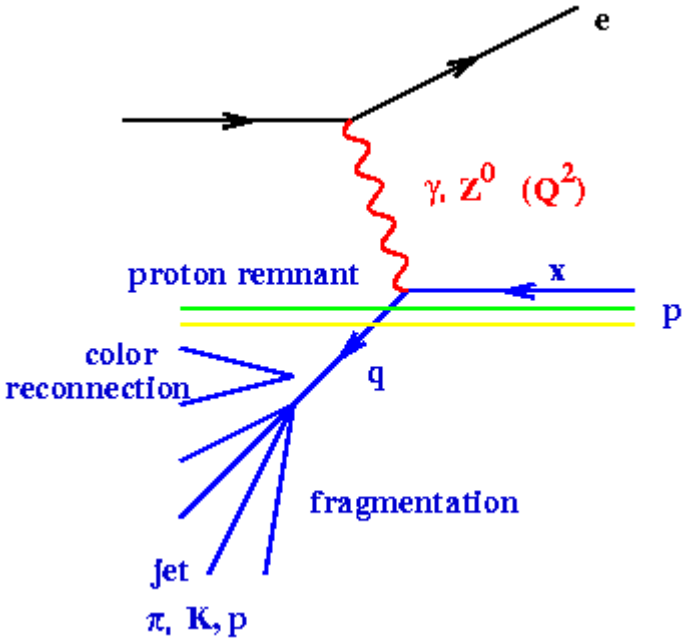


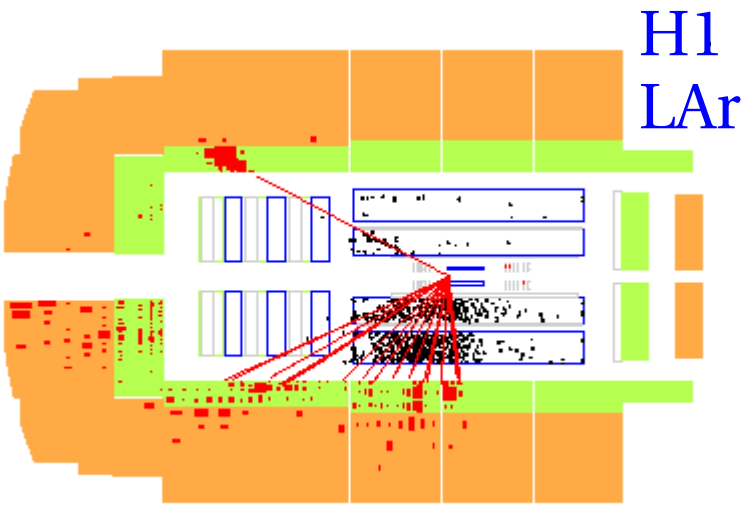
- Polarization typically 30-40%.
- Polarization monitored by Compton backscattering of laser beams.



Deep inelastic scattering

Neutral current: γ or Z exchange

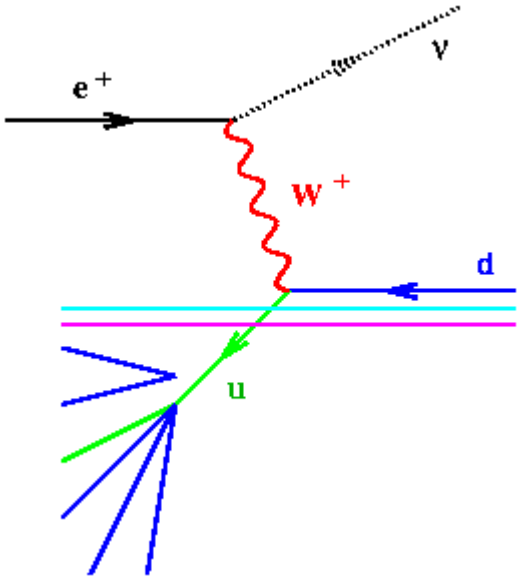




jet balanced by e in E_t: good for calibration.
1% jet energy scale uncertainty above 20 GeV.

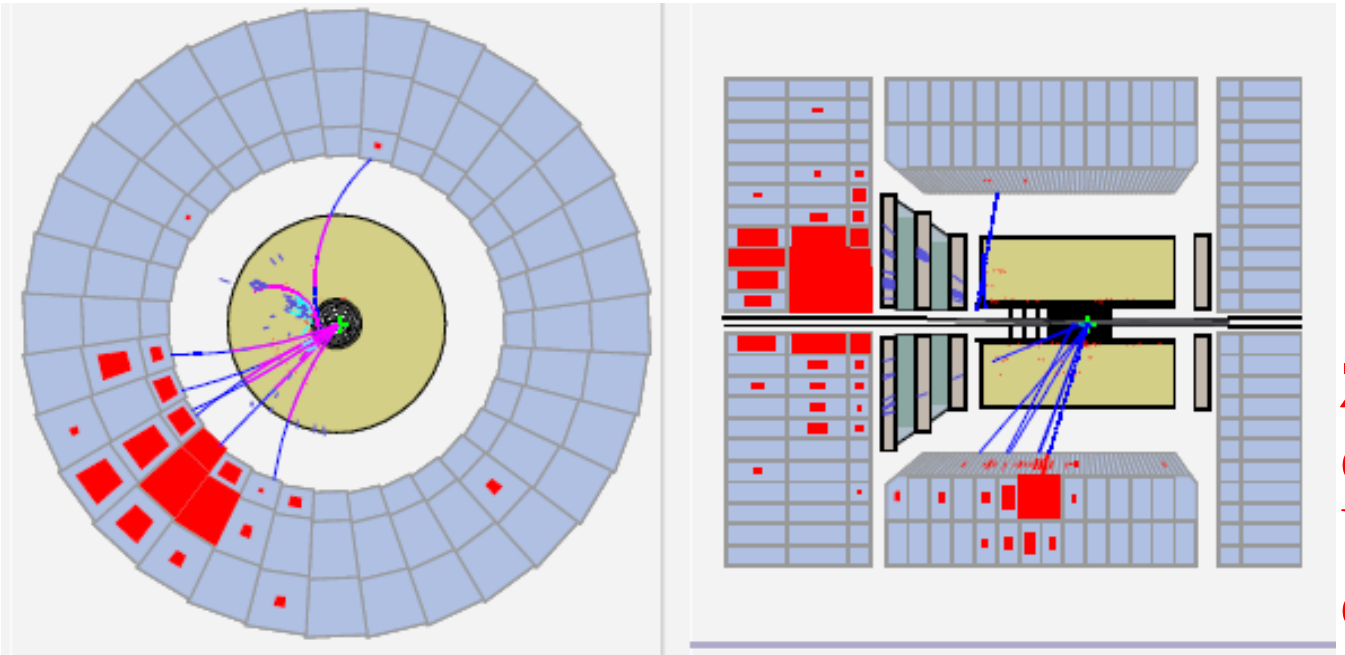
- Q^2: 4-momentum transfer from e to q by boson.
- x = momentum fraction quark/proton.
- $s = 4E_eE_p = 101400$ GeV^2.
- $y = Q^2/sx$ = inelasticity = ½(1-cosθ^*) eq cms angle.

Charged current: W± exchange



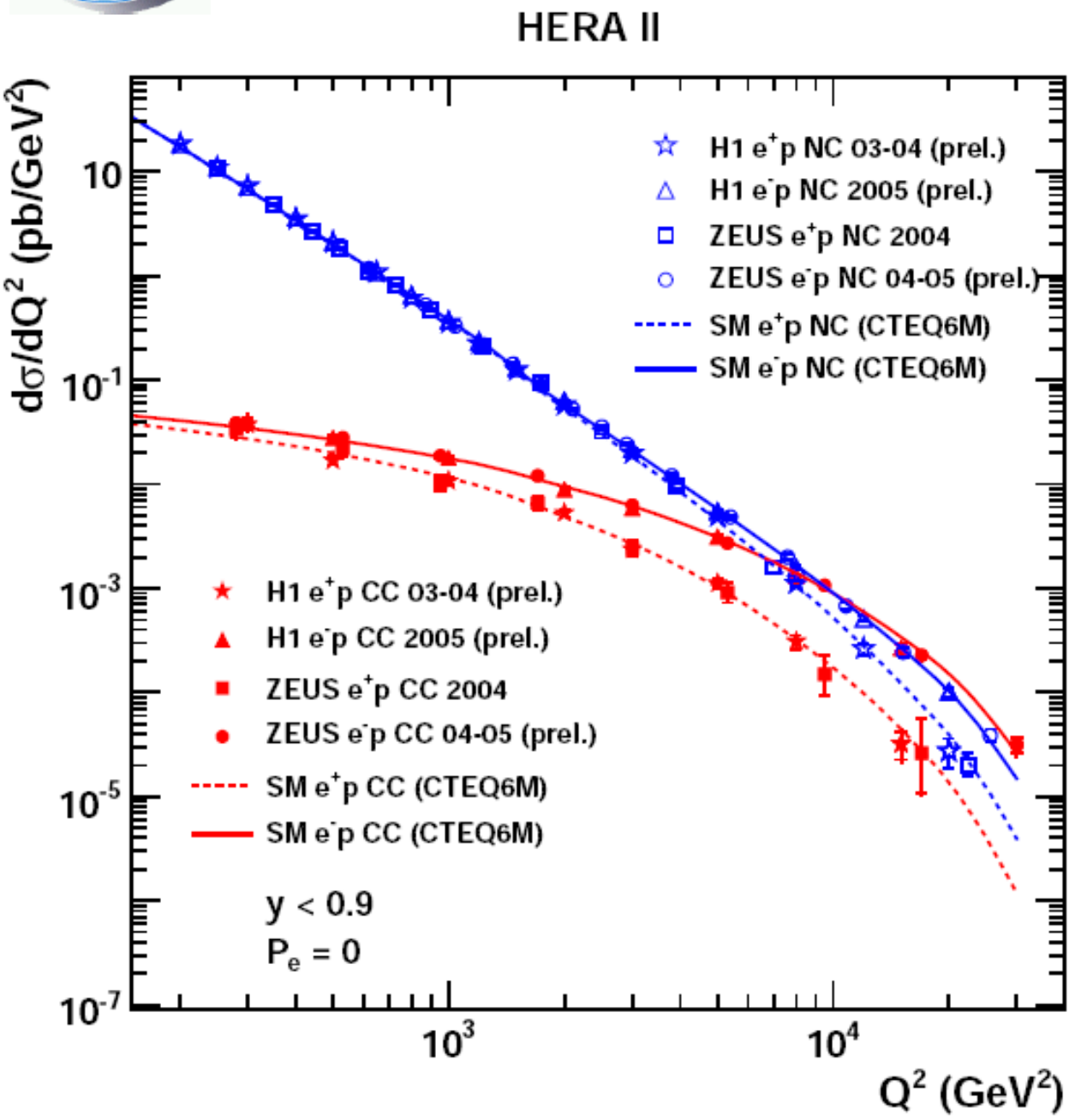
Q^2, x, y can be reconstructed from the hadronic final state.

missing transverse momentum: neutrino



ZEUS compensating U-scintillator calorimeter

$e^+ p$ and $e^- p$ cross sections vs Q^2

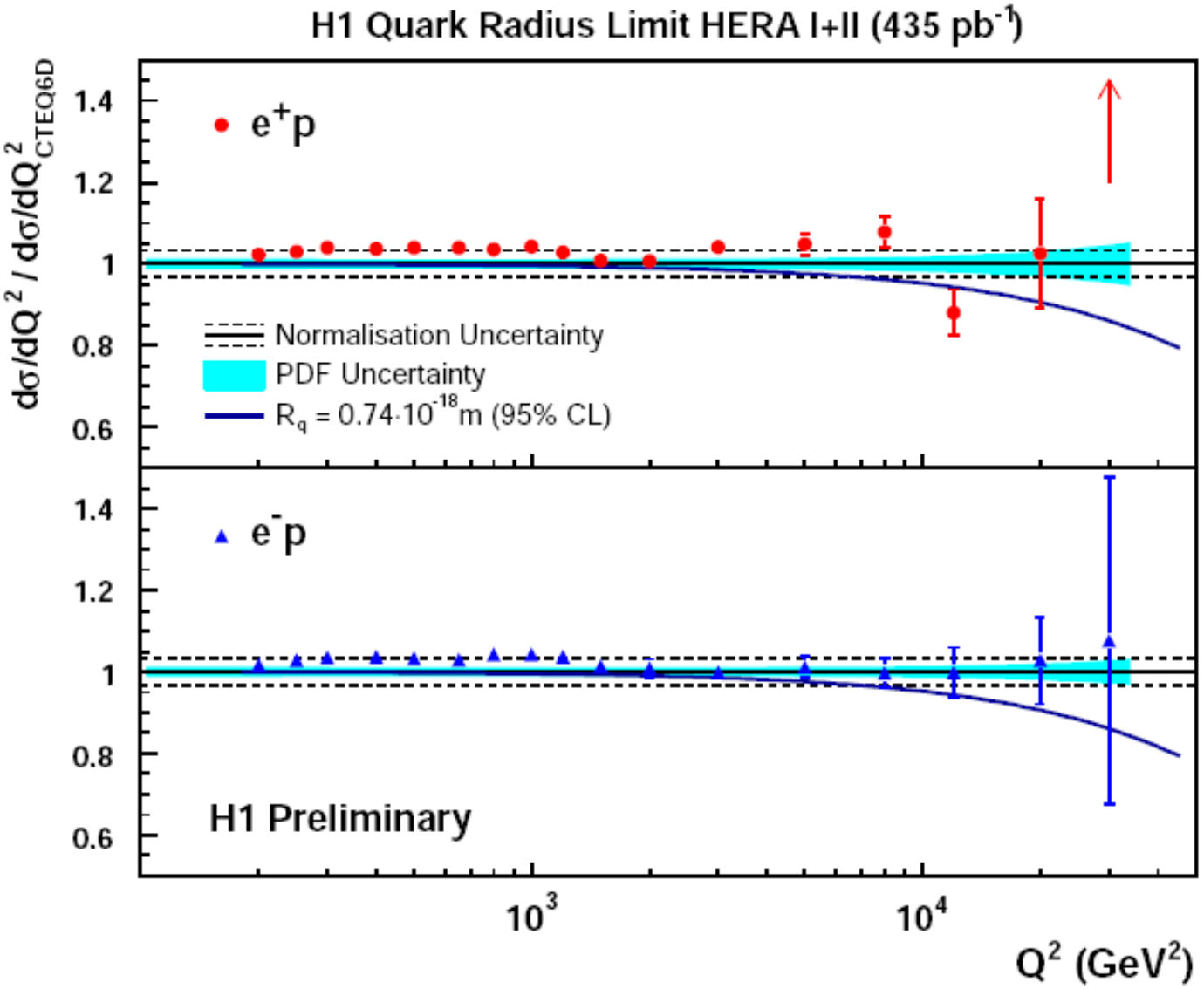


- Destructive and constructive γZ interference in Neutral Current.
- Charged Current:

  e^-u enhanced

  e^+d suppressed.
- Electroweak unification at $Q^2 \sim m_W^2$.
- A textbook measurement from HERA.

Quark radius limit

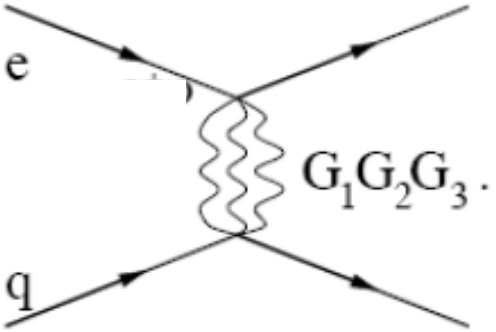


Quark radius form factor: $(1 - R_q^2 Q^2/6)$

H1 limit: $R_q < 0.74 \cdot 10^{-18}$ m

ZEUS limit: $R_q < 0.67 \cdot 10^{-18}$ m

Large extra dimensions?

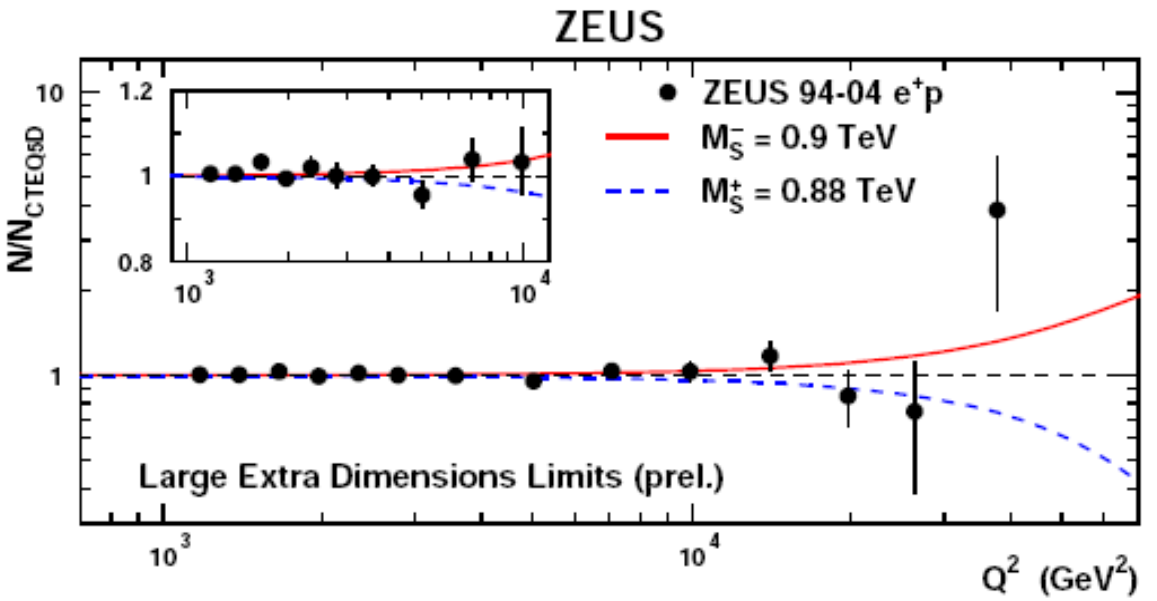


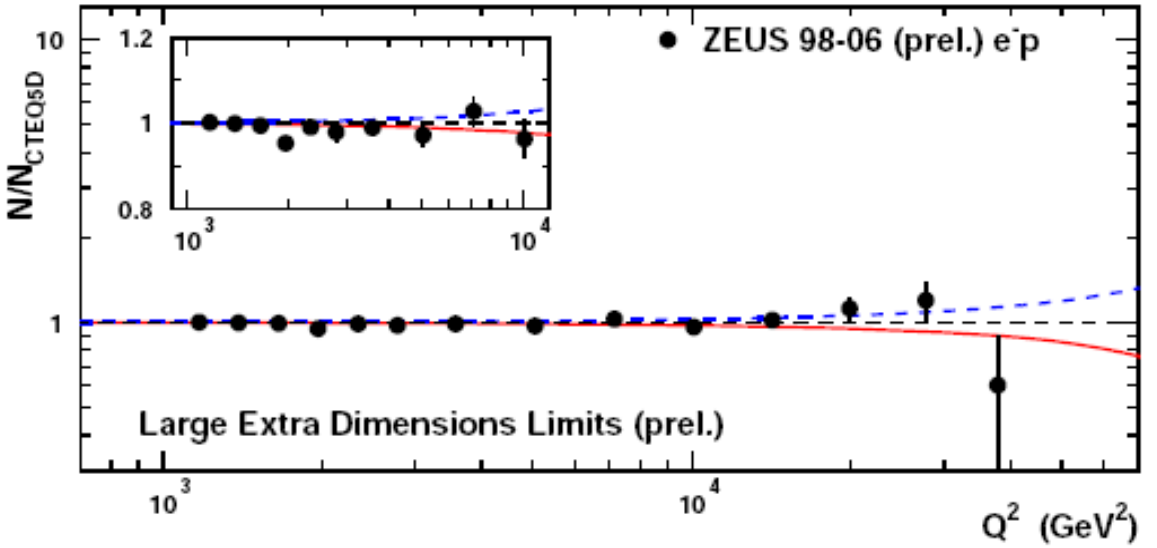
Limit on the contribution of graviton exchange in theories with large extra dimensions at scale $M_S^{\pm}$,

Destructive or constructive interference with standard model:

$M_S^- > 0.9$ TeV

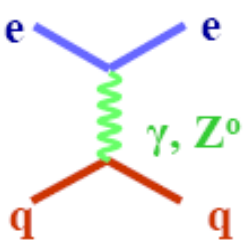
$M_S^+ > 0.88$ TeV

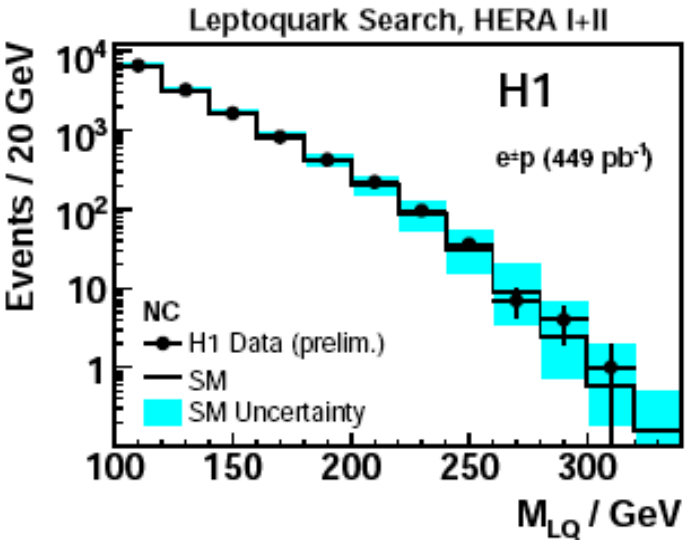


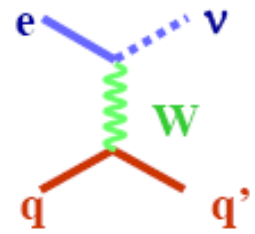


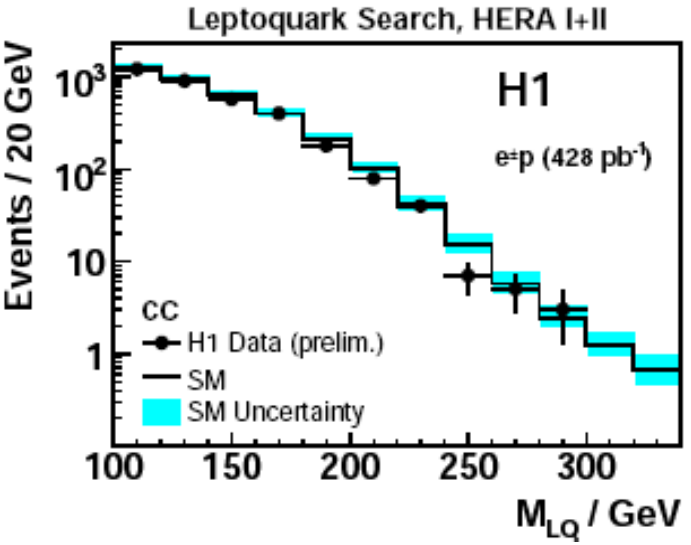
1st generation Leptoquarks?

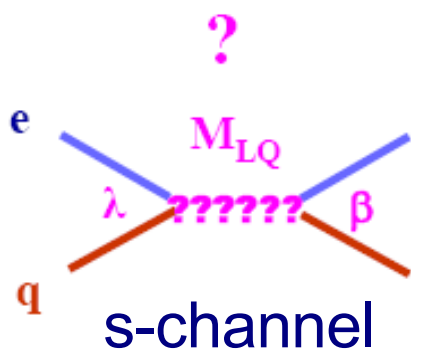
Mass peak at $\sqrt{x}\sqrt{s}$?

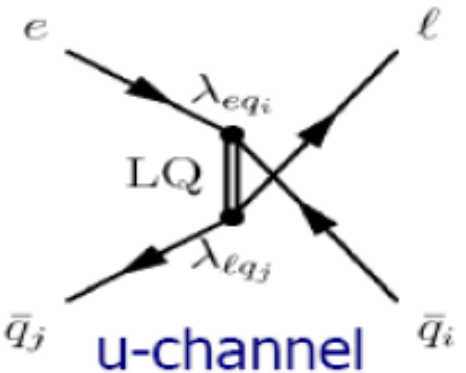


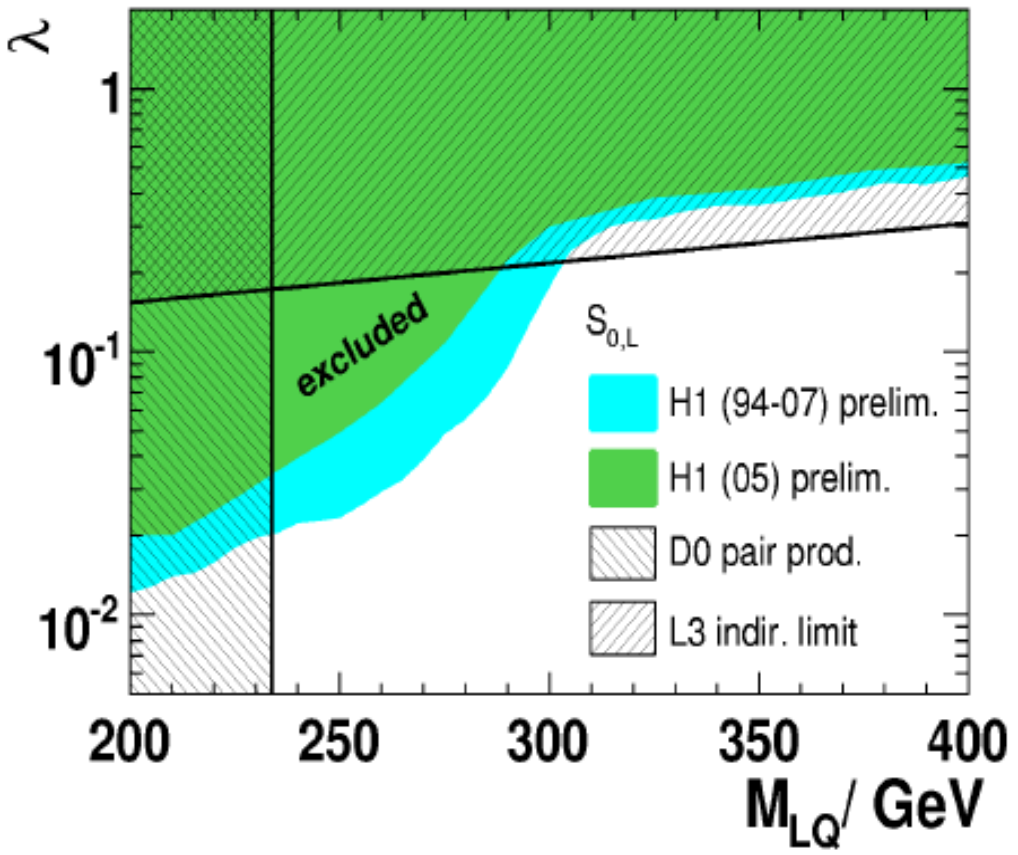




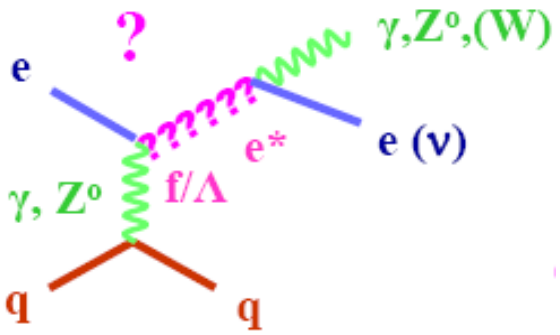






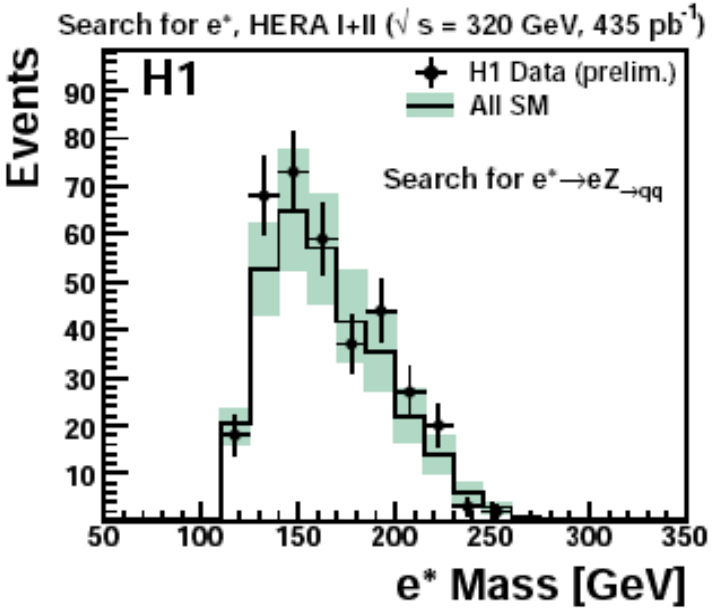


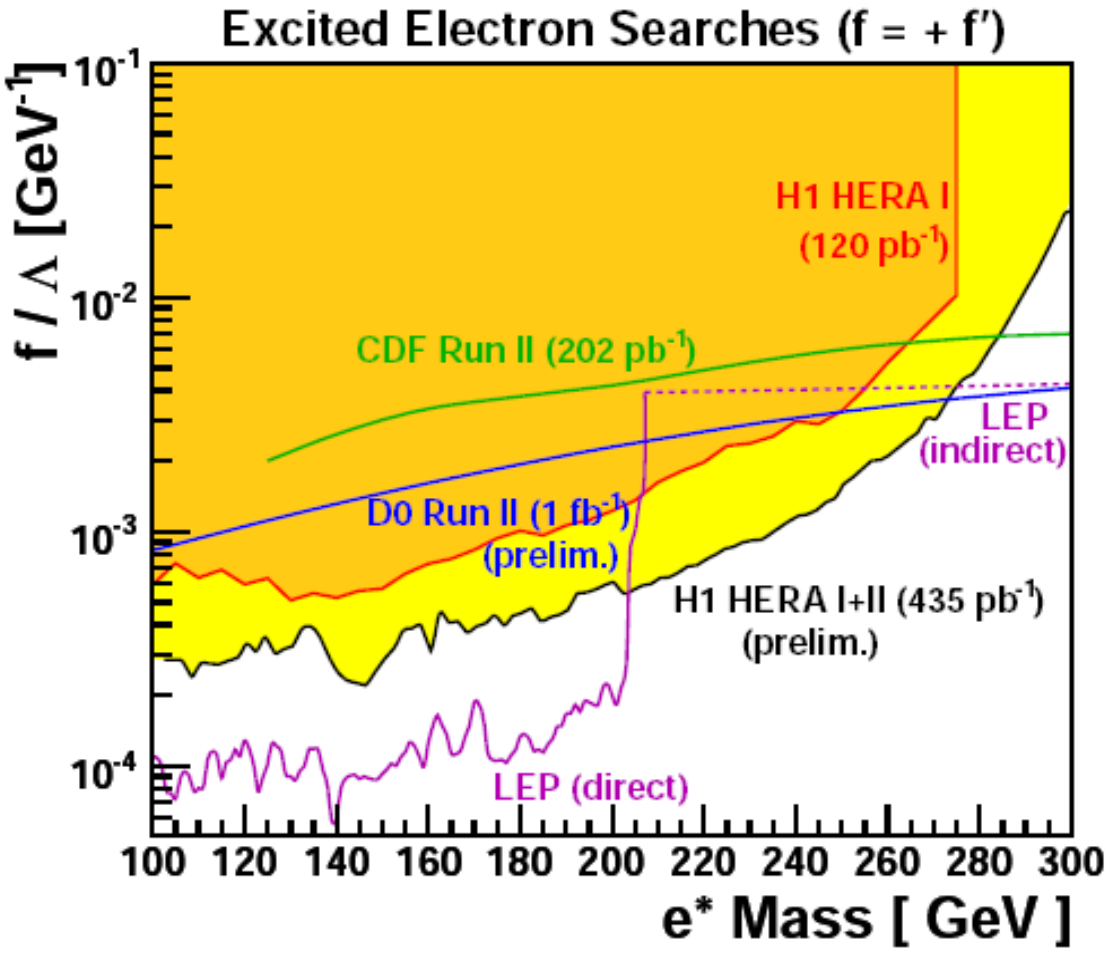
Excited electrons?



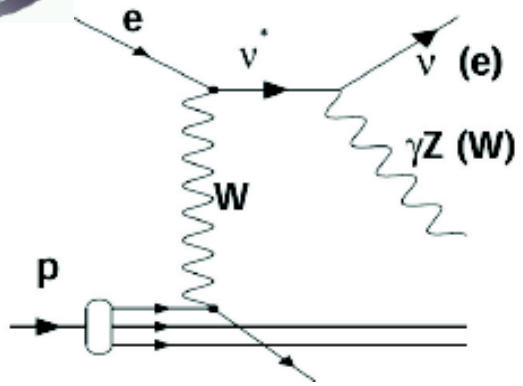
Hagiwara model of gauge mediation:
U(1) coupling f
SU(2) coupling f'.

$e^* \to e\,\gamma$
$e^* \to e\,Z,\ Z \to q\bar{q}$
$e^* \to \nu\,W,\ W \to qq'$





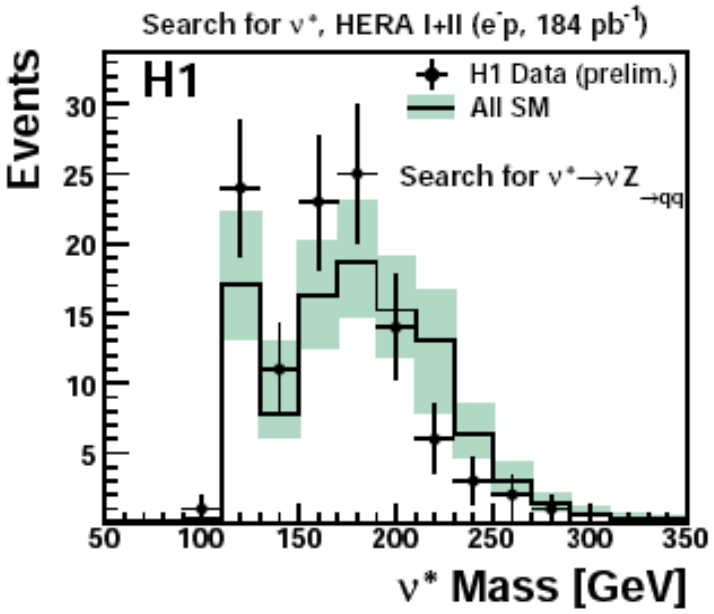
Excited neutrinos?



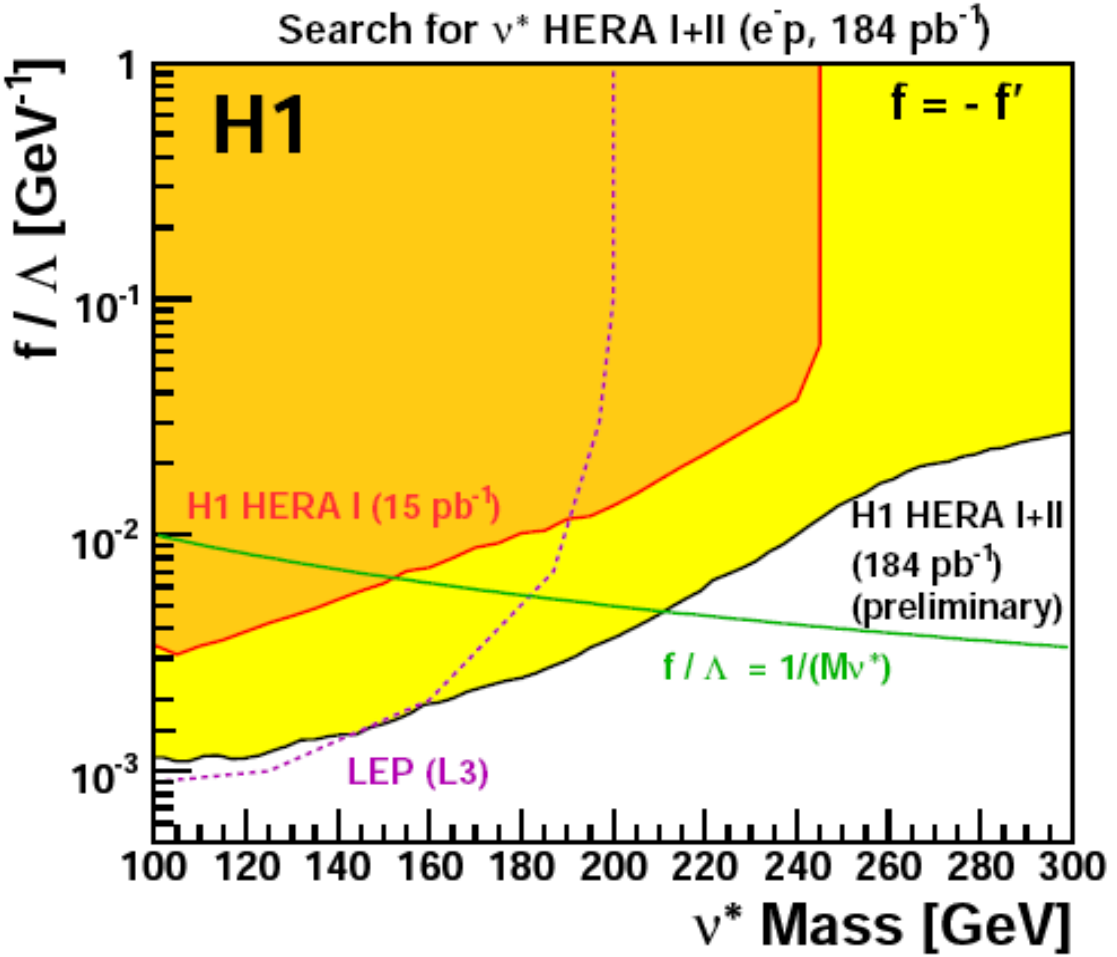
$\nu^* \to \nu\,\gamma$

$\nu^* \to \nu\,Z,\ Z \to q\bar{q}$

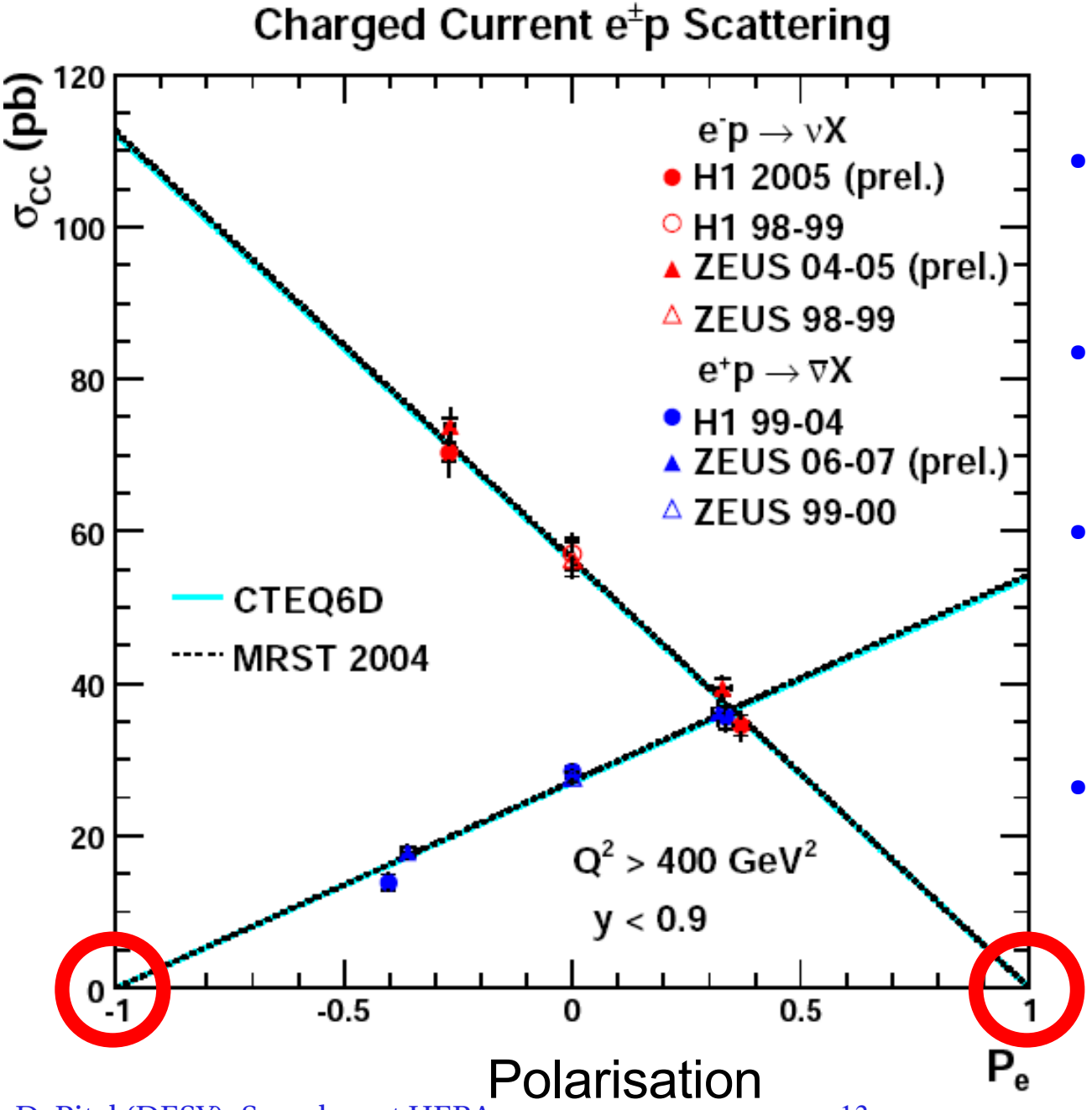
$\nu^* \to e\,W,\ W \to qq'$



e⁻ p data used: enhanced charged current cross section.



Charged current with polarized e±



- Standard model:

  $\sigma = (1 \pm P) \cdot \sigma_0$

- Extrapolation to $P = \pm 1$:

  σ consistent with zero.

- limit on right-handed W:

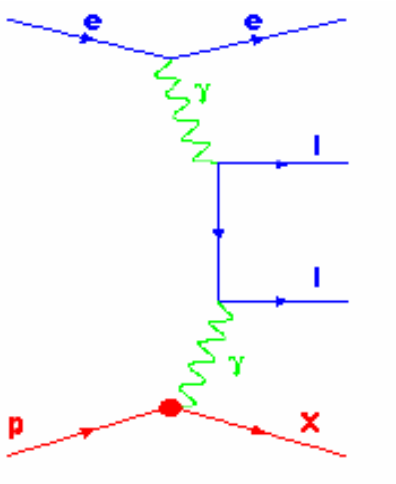
  $M(W_R) > 208$ GeV.

- CDF:

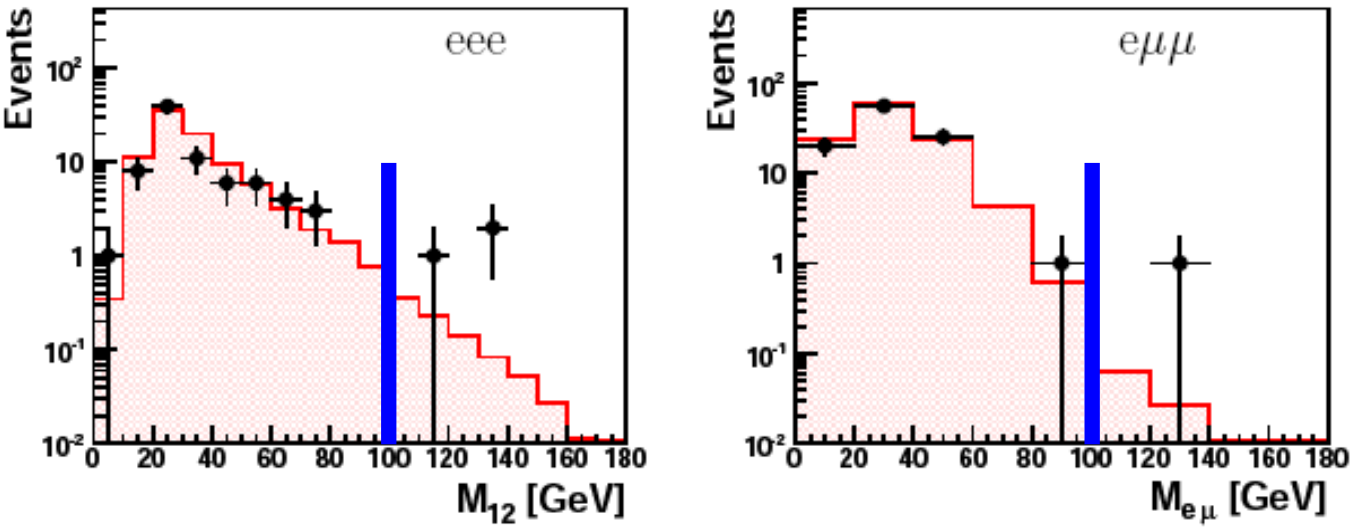
  $M(W_R) > 790$ GeV.

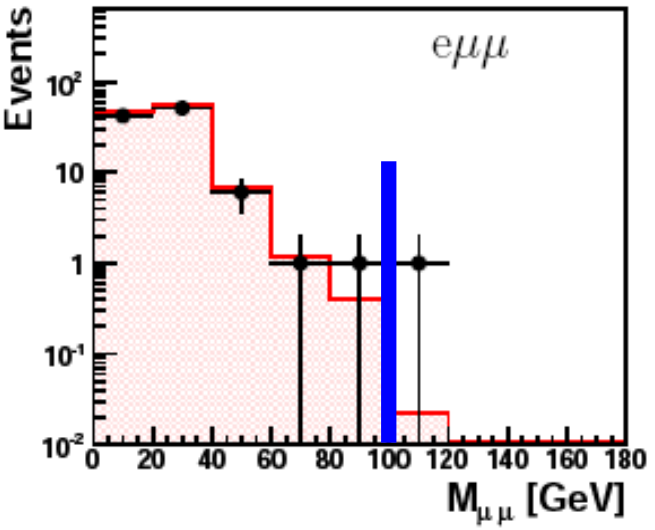
Multi-leptons

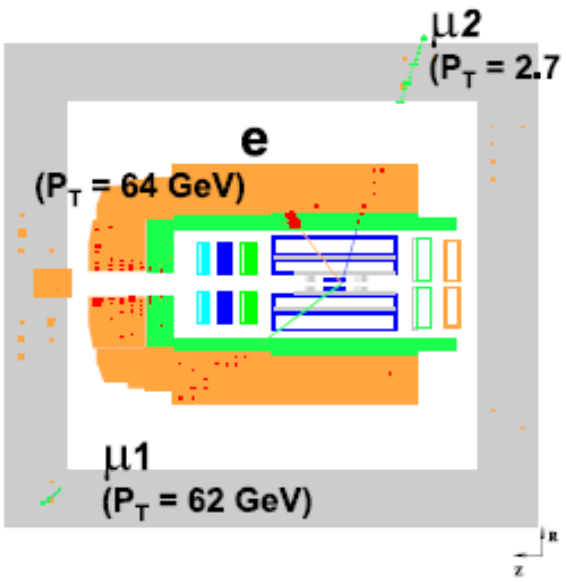
example: tri-lepton mass spectra:



2 or 3 e/μ observed







H1 Data (prelim.)
DIS+Compton
Pair Production

H1 observes 9 events with $M_{ij} > 100$ GeV, for 2.2 expected in e^+p.

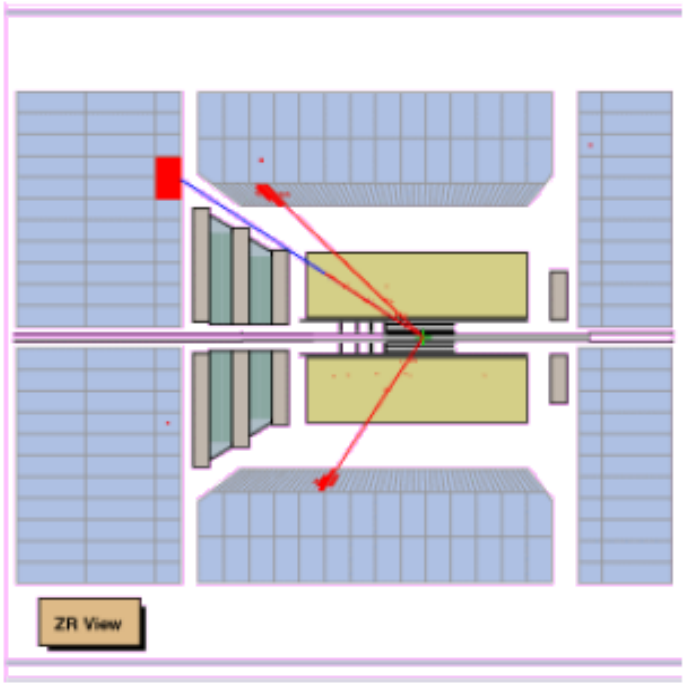
Multi-electrons

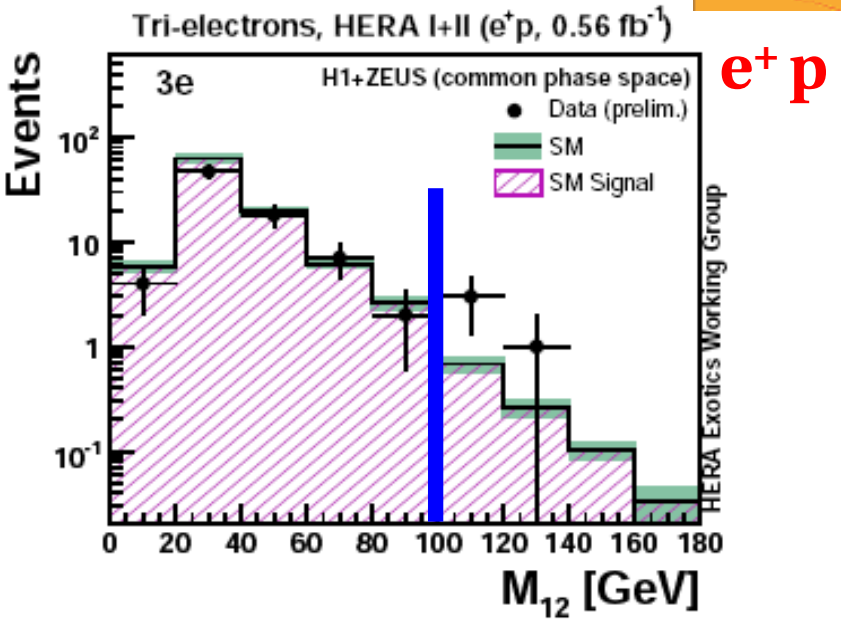
H1 and ZEUS combined in common phase space for $M_{12} > 100$ GeV:

$e^+ p$: 8 for 3.1 expected

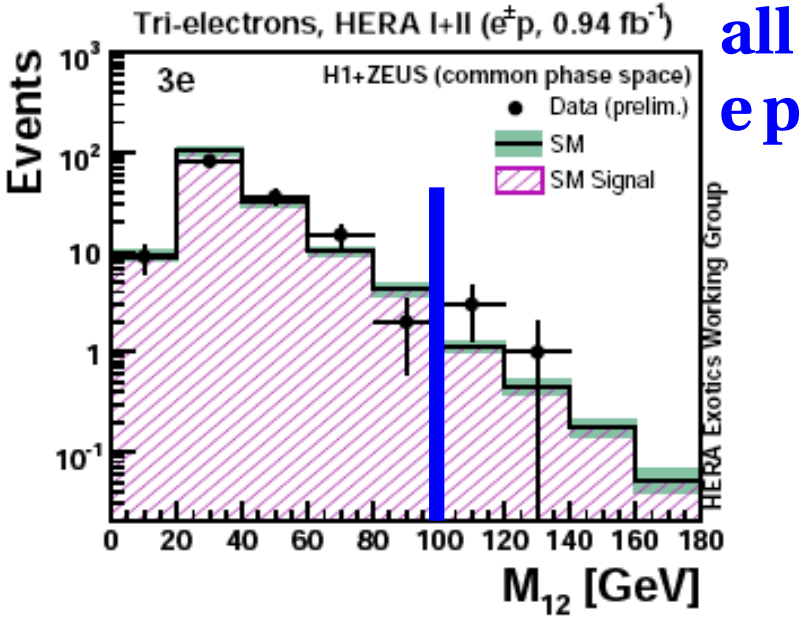
all ep: 9 for 5.3 expected.

A 3-electron event in ZEUS:



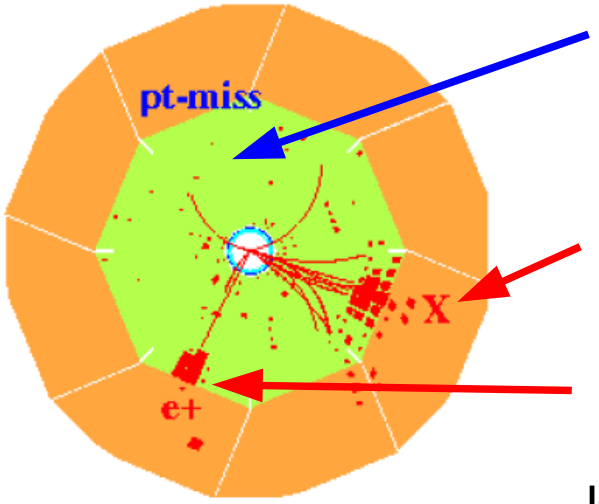


$e^+ p$



all e p

High p_t leptons and missing p_t

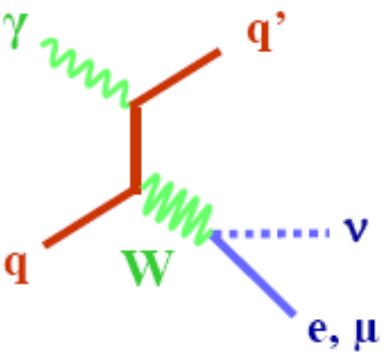


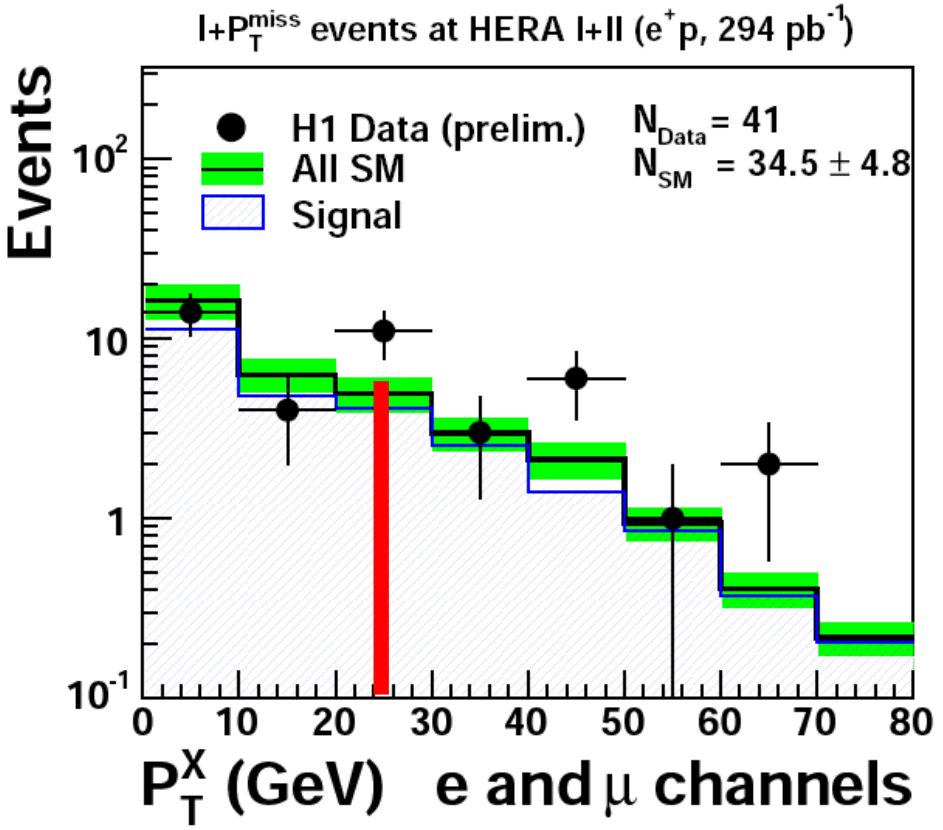
Missing momentum

Hadronic system X

Isolated high p_t e or μ

Standard model:
W production, ~1 pb.
but: expect small P_T^X

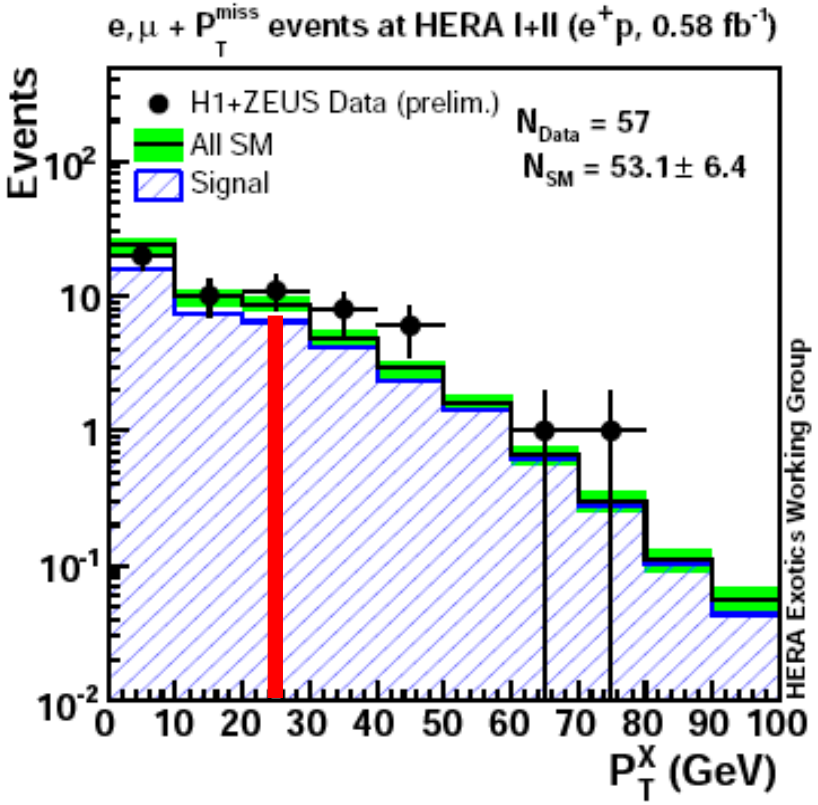




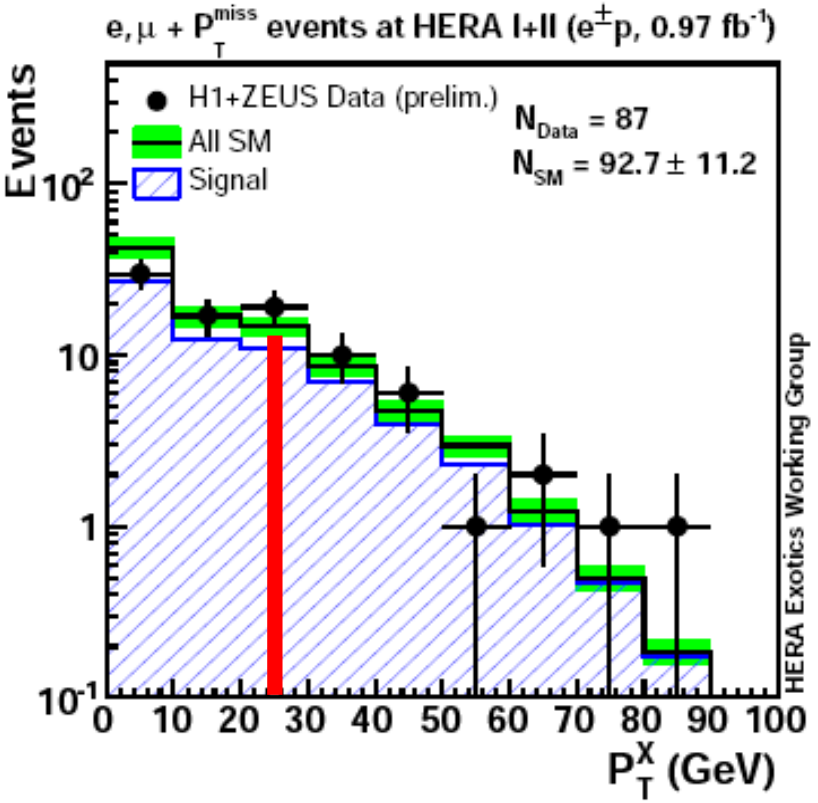
in **$e^+ p$**,
for $P_T^X > 25$ GeV:
H1 sees 21 events for
9±1.5 expected: **3.0 σ**.

High p_t leptons and missing p_t

H1 and ZEUS combined in a common phase space:



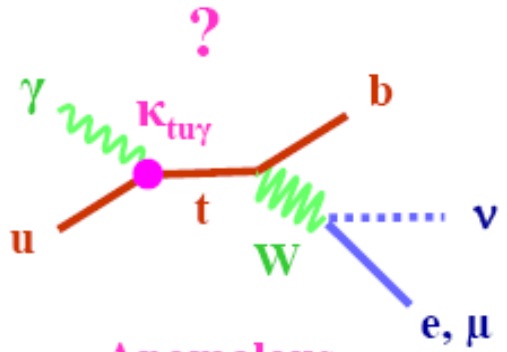
in **e^+ p**, for $P_T^X > 25$ GeV:
H1 and ZEUS combined
see 23 events for 15±2
expected: **1.8 σ**.

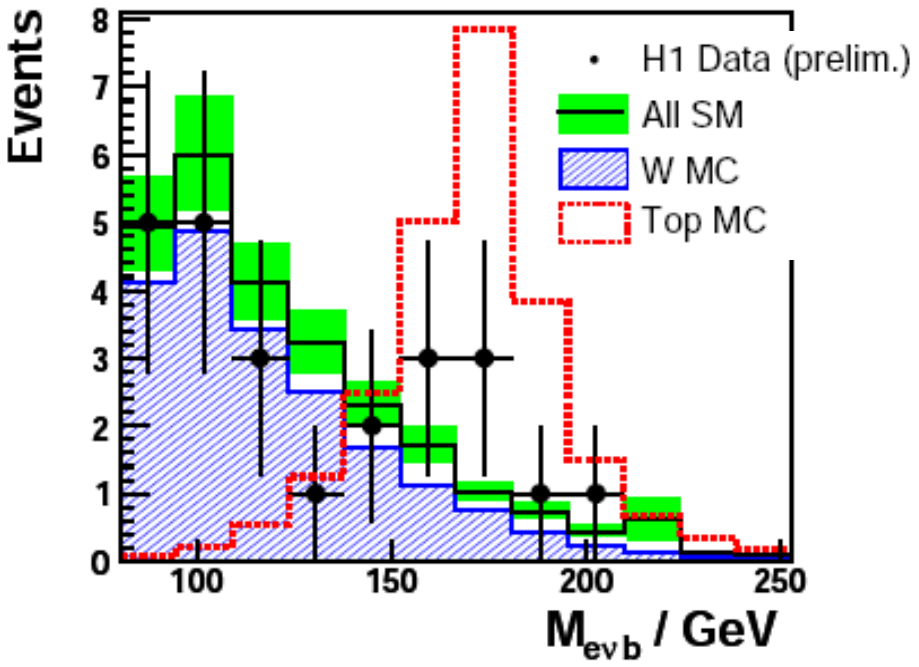


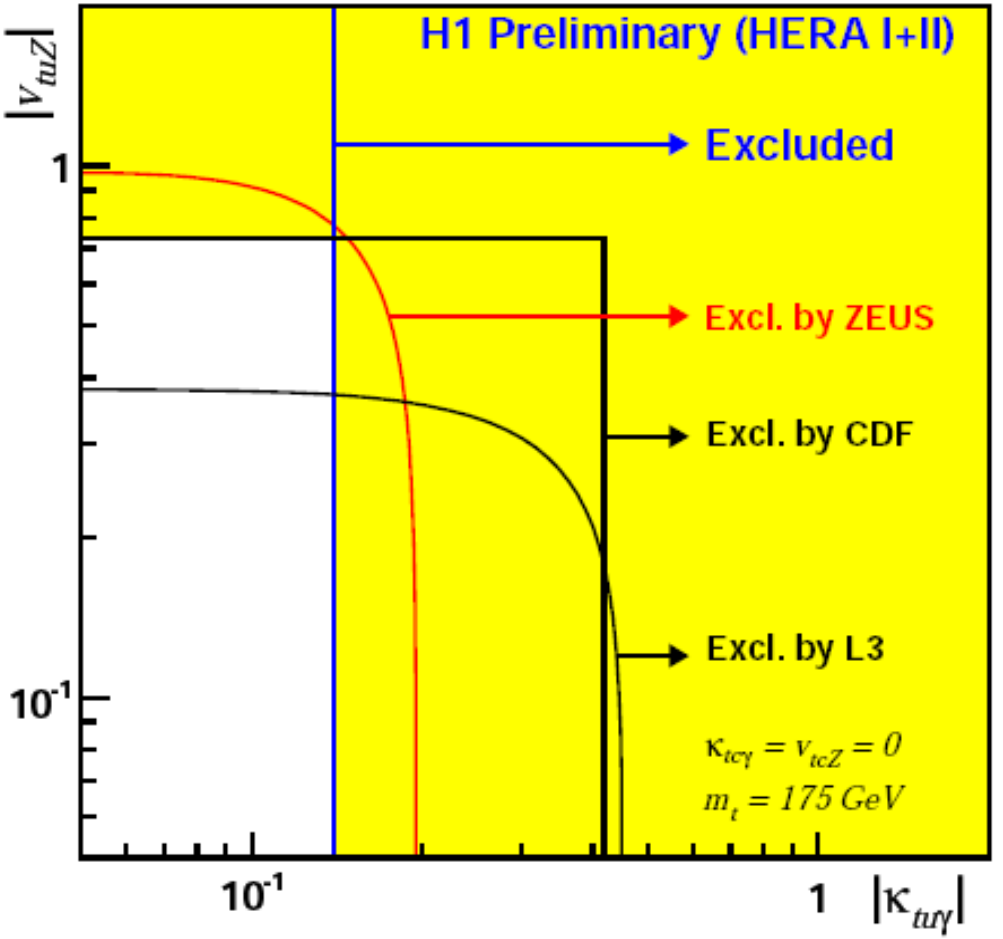
all ep, for $P_T^X > 25$ GeV:
H1 and ZEUS combined
see 29 events for 25±3
expected.

Anomalous top production?

Single top at HERA: ~1 fb.



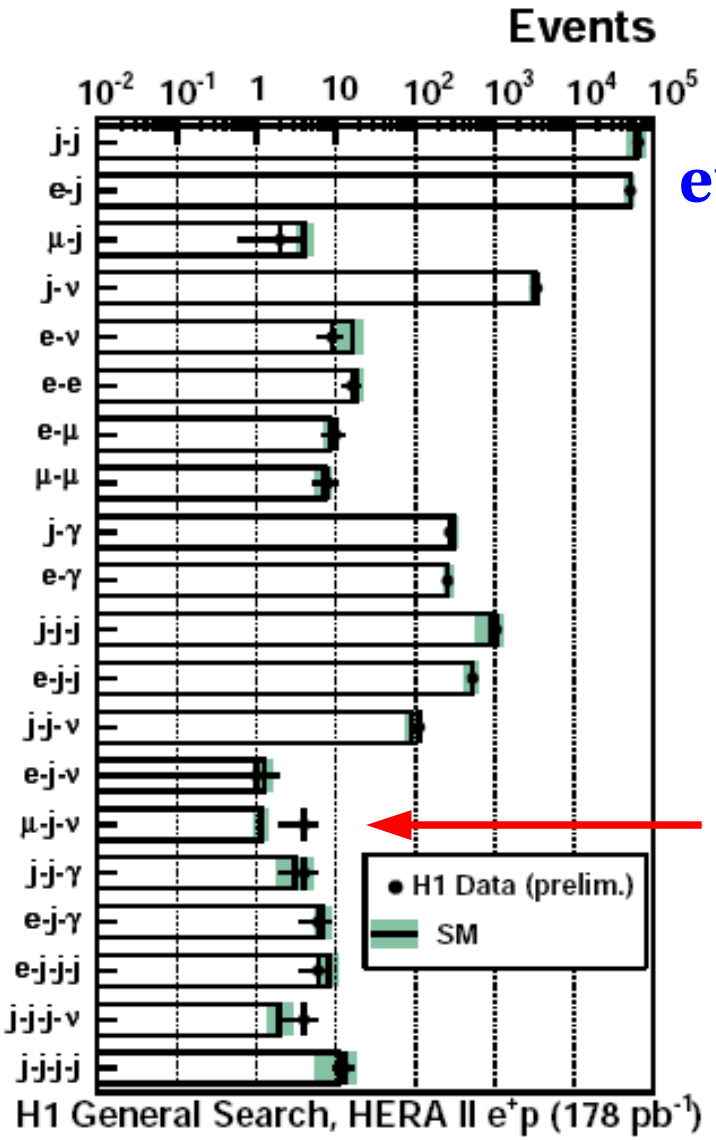




H1 has most stringent limit on t-u-γ coupling.

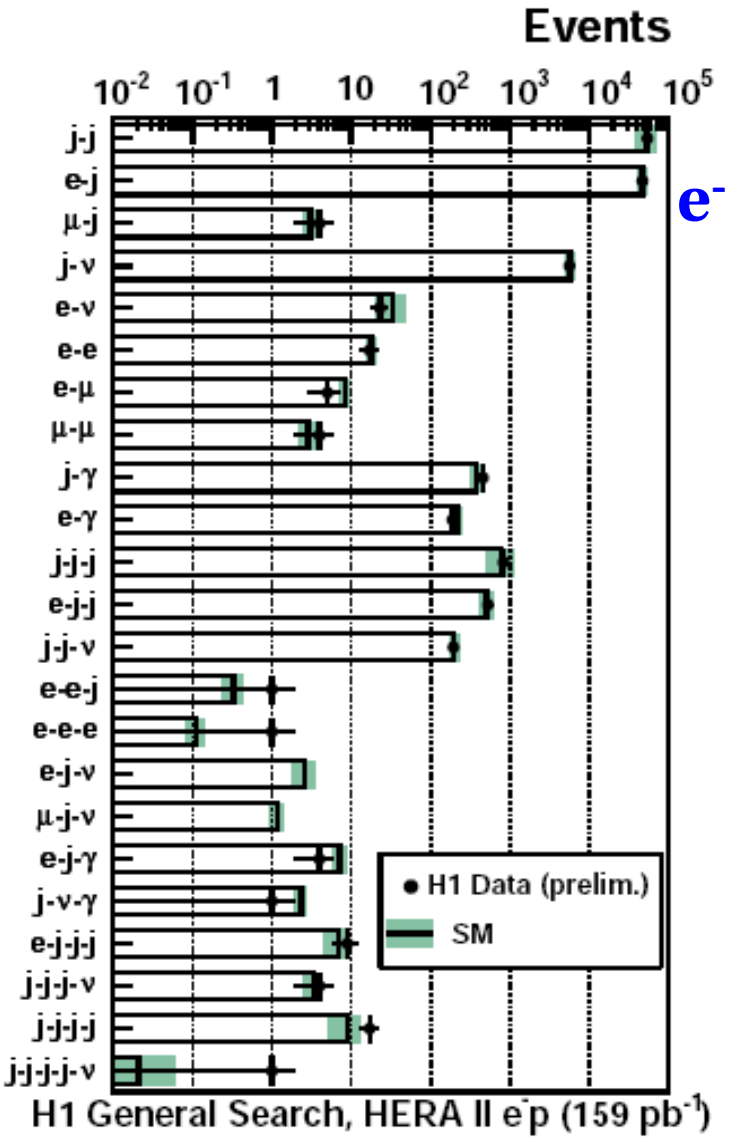
General search with high p_t objects

e, μ, γ, jets, ν with $p_t > 20$ GeV



$e^+ p$

largest fluctuation: μ-jet-ν.

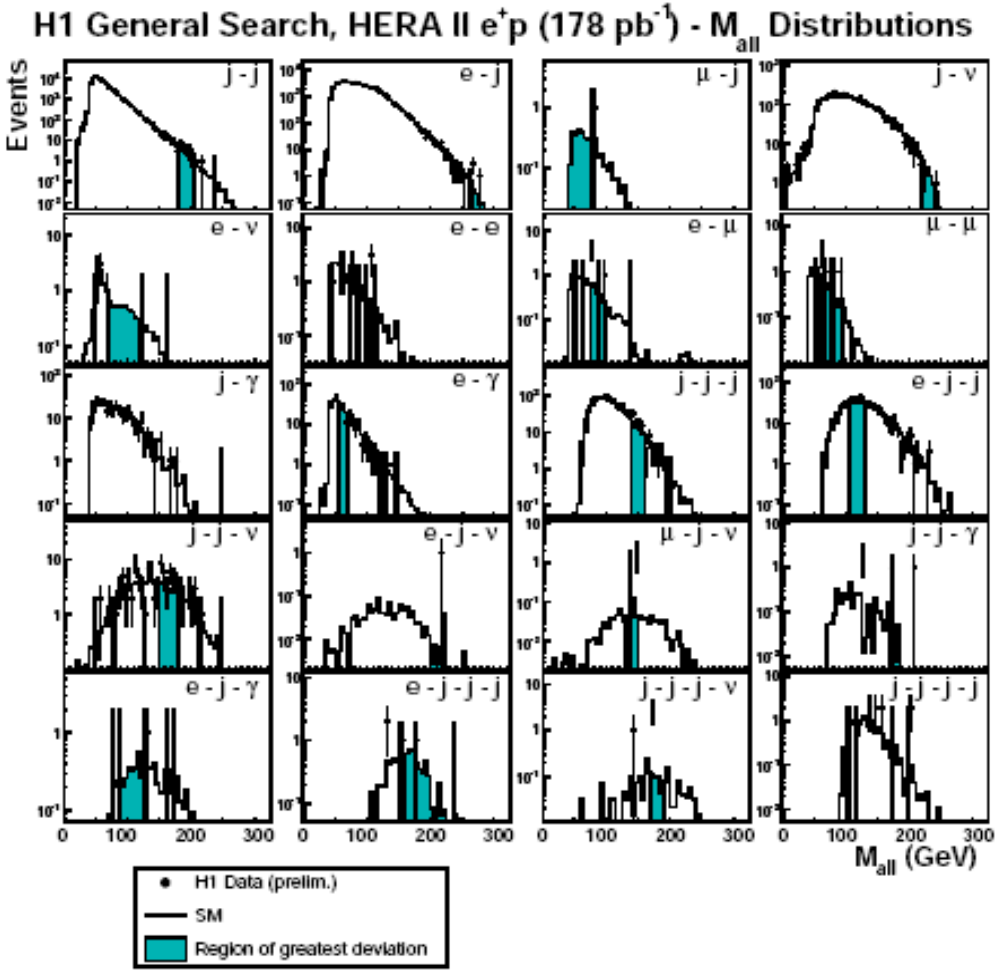


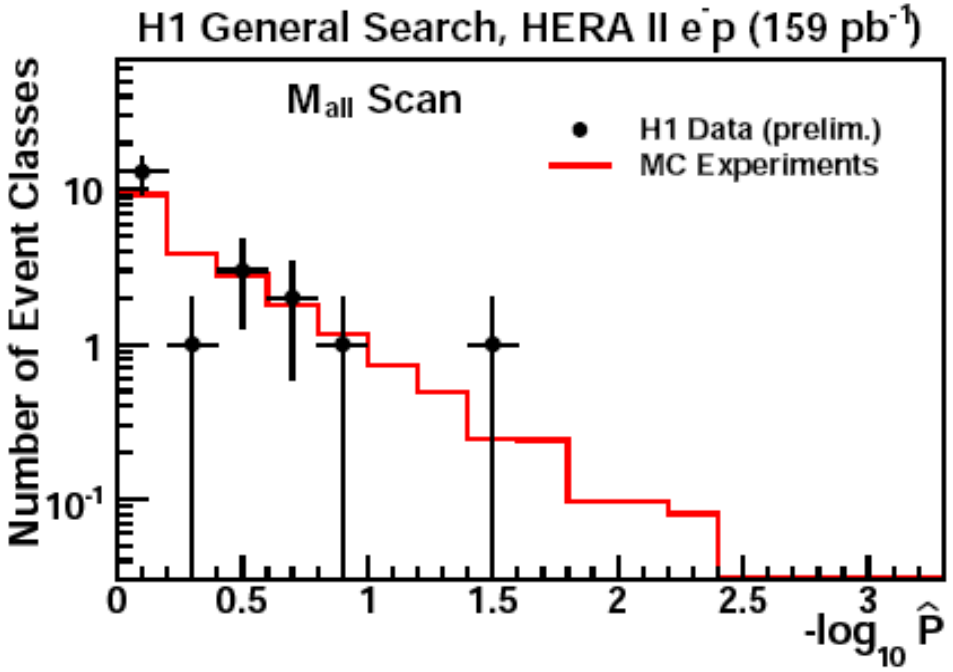
$e^- p$

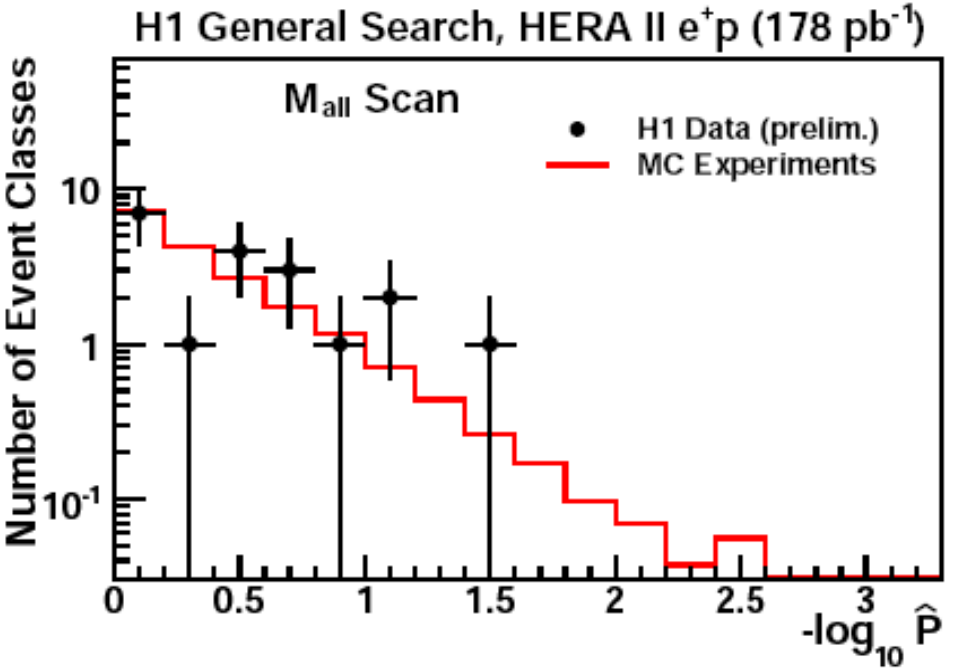
All channels described by Standard Model physics.

General search with high p_t objects

Search for largest deviation
in mass spectra in each class,
calculate P-values.







Summary

- HERA ep beams ended on June 30, 2007, after 15 years of successful operation.
- Each collider experiment has collected close to 0.5 fb^{-1} of high quality data with precision detectors.
- A comprehensive search for new physics phenomena using all data and combining H1 and ZEUS is underway.
- Preliminary results show no significant deviation from the standard model.