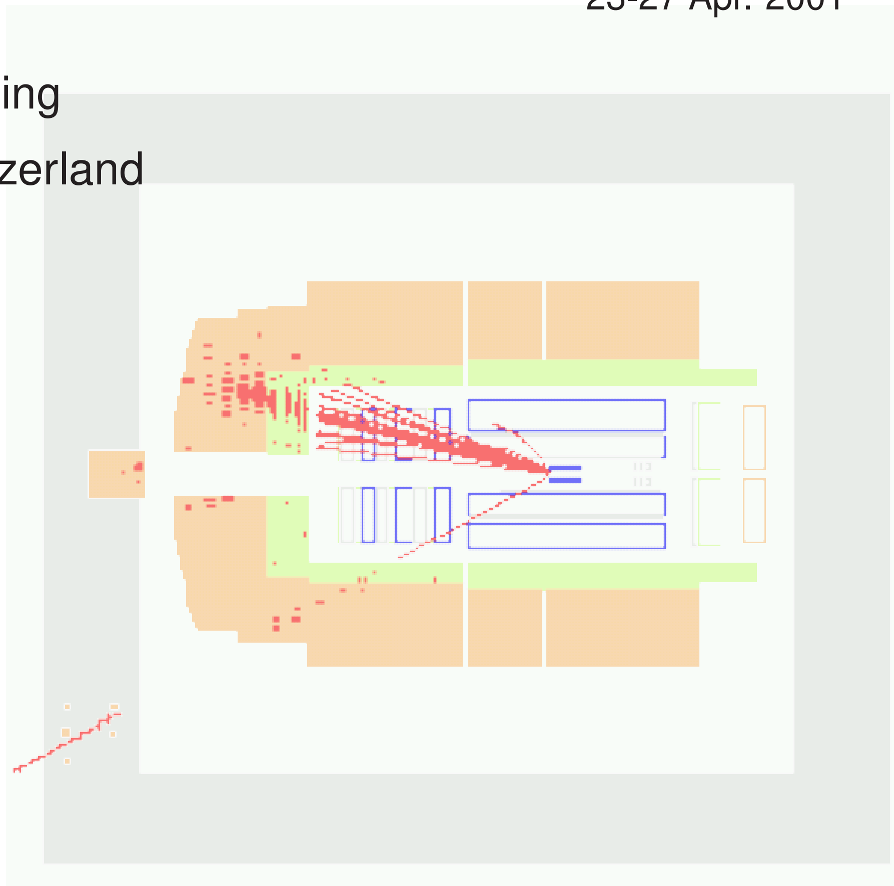
Search for Single Top Production in ep Collisions at HERA

on behalf of the H1 collaboration

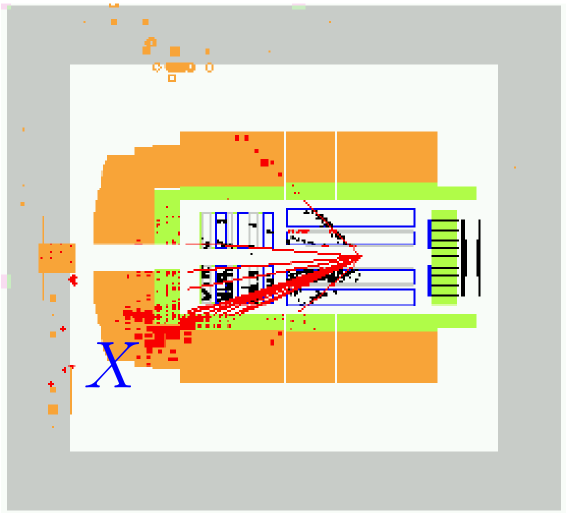
St.Petersburg
DIS Workshop
23-27 Apr. 2001

André Schöning
ETH Zürich, Switzerland



- Introduction
- Semileptonic Channels
  $\longrightarrow$ isolated leptons
- Hadronic (3-jet) Channel
- Results

Historical Introduction



- First exciting isolated lepton event seen in H1 1994

  DESY preprint 94-248 (1994)

- data from 1994-1997 (36.5 pb^{-1})

  observed ($p_t^X > 25$ GeV): 1 e and 5 μ (3.2)

  $\Rightarrow$ excess published Eur.Phys.J. C5 (1998)

- analysis of all HERA I data (118.3 pb^{-1}), accepted by *Phys. Lett.* **B**

  observed: 4 e and 6 μ (2.9) $p_t^X > 25$ GeV (1994-2000)

  0 e and 4 μ (0.8) $p_t^X > 25$ GeV (1994-1997)

- look for anomalous top production in FCNC Fritzsch and Holtmannspotter 1999

  (SM prediction for top production small $\approx$ 1fb)

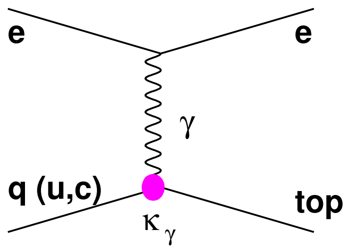
- Analysis on anomalous top production close to final $\longrightarrow$ paper submission soon

- Today report results status ICHEP 2002

Topology / Analysis Strategy

- anomalous production of top quarks at HERA:

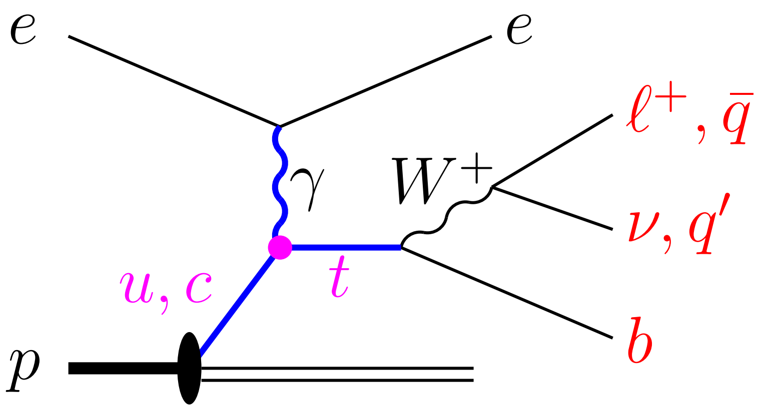
  study only magnetic κ_γ coupling to t and u, c quarks

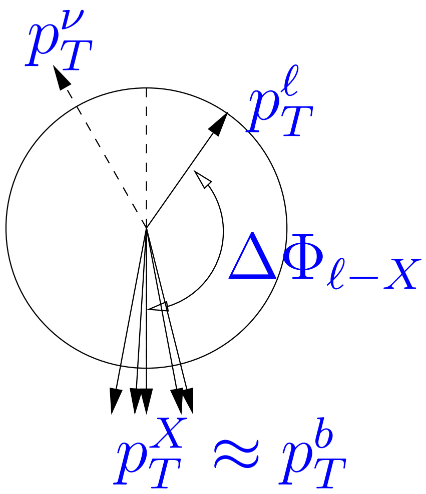


Z boson exchange negligible

implemented in ANOTOP MC generator

- semileptonic / hadronic decay:





- Search in semileptonic channel:
  - start from selected isolated lepton events with $p_t^X > 25$ GeV (status ICHEP 2002)
  - main background is SM W production (EPVEC MC generator)

Isolated Lepton Selection Cuts

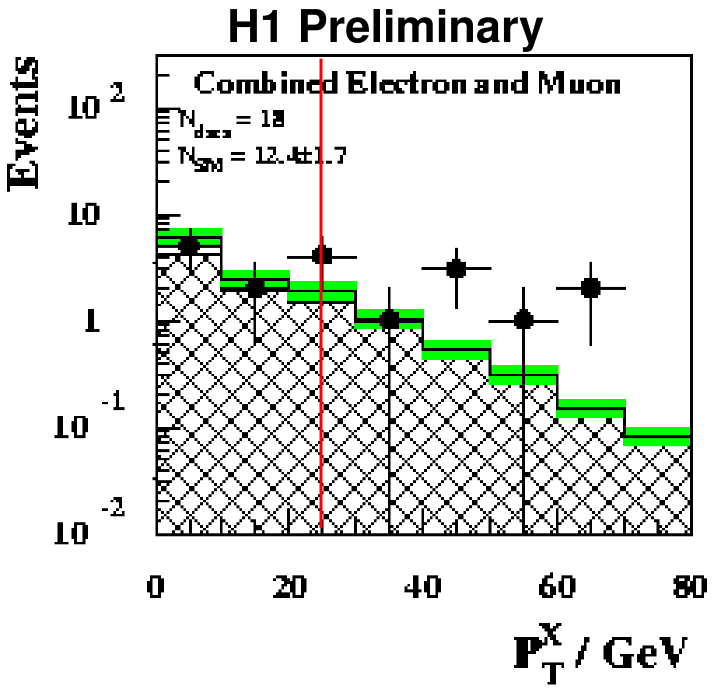
recent isolated lepton analysis $\longrightarrow$ talk by G.Frising

- global selection cuts:
  - Lumi: 101.6 pb^{-1}of e^+p and 13.6 pb^{-1}of e^-p scatt.
- removal of non-ep background
  - cuts on event timing and topology to reject cosmic bg
  - apply kinematic constraints
- selection of isolated electrons
  - deposition in EM calorimeters (LAr/Spacal) $\approx$ 98%
  - systematics checked with NC DIS and Compton
- selection of isolated muons:
  - identified in tracking system
  - signature in Forw. Muon system / Instr. Iron
  - and LAr calorimeter (mip)
- transv. momentum p_T^X of hadronic final state (b-jet):
  - from energy deposits in calorimeter and tracks

$p_T^\ell > 10$ GeV

$D_{\ell,\text{jet}} > 1$ GeV

$\Delta\Phi^{\text{aco}}_{e(\mu)-X} > 20(10)$ deg



$\Rightarrow$ 10 (2.8) events with $p_T^X > 25$

Top Selection Leptonic Channel

- jet transverse momentum cut:

  $p_T^{\mathrm{jet}} > 25$ GeV for $\Theta_{\mathrm{jet}} > 35^\circ$

  $p_T^{\mathrm{jet}} > 35$ GeV for $\Theta_{\mathrm{jet}} < 35^\circ$

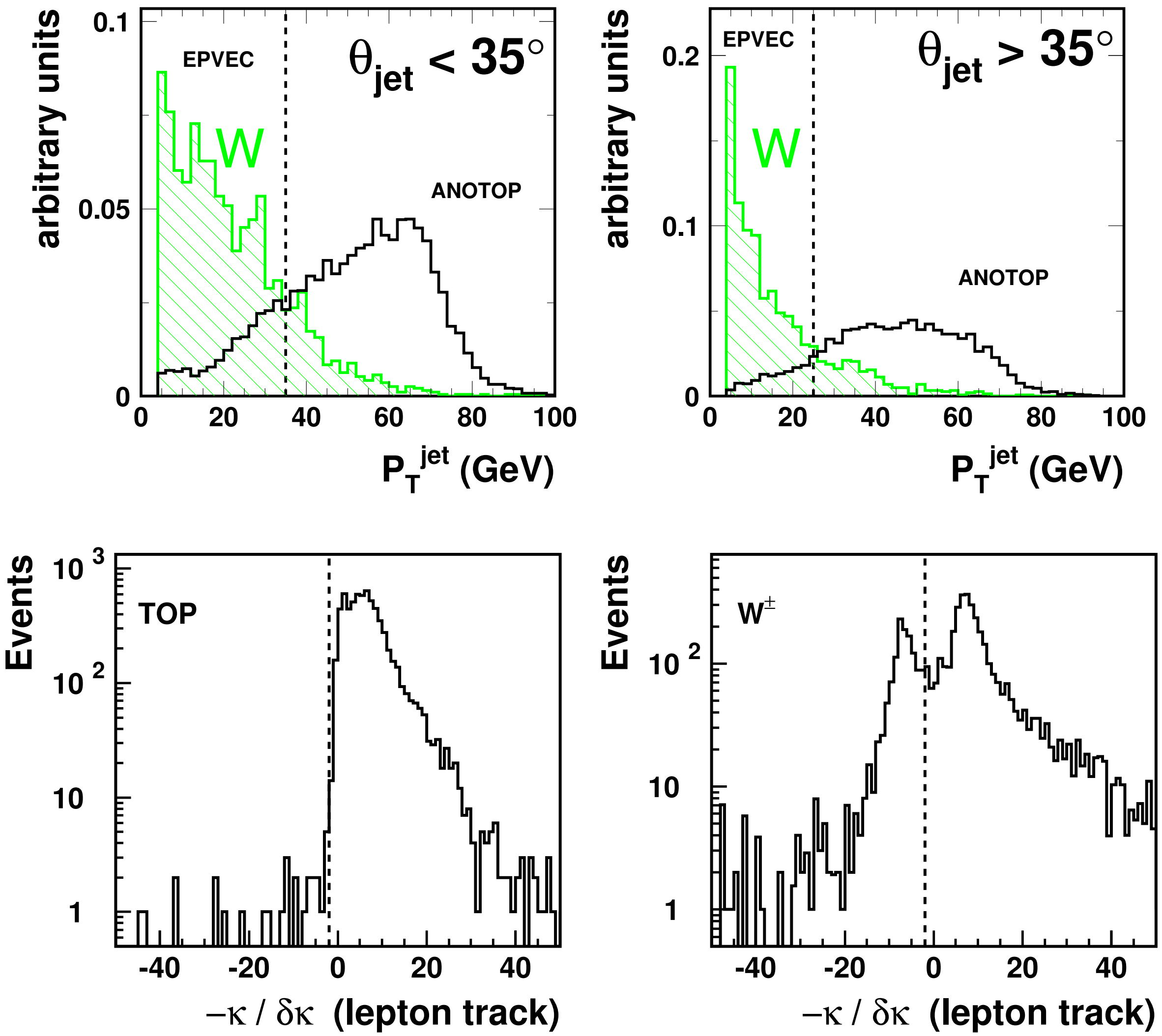
- minimum transverse mass:

  $M_T^{\ell\nu} > 10$ GeV

- top charge $(+\frac{2}{3})$ constraint:

  $\frac{-\kappa}{\Delta\kappa} > -2$

  (κ = curvature)



Event Yields Semileptonic Top Decay

e^+p data (101.6 pb^{-1}):

	W pre-selection		Top selectio n	
	Electron Channel	Muon Channel	Electron Channel	Muon Channel
Data	4	6	3	2
Standard Model	1.29 ± 0.33	1.54 ± 0.41	0.75 ± 0.18	0.77 ± 0.21
W only	1.05 ± 0.32	1.29 ± 0.39	0.51 ± 0.16	0.68 ± 0.19
Top efficiency	43%	51%	37%	45%

e^-p data (13.6 pb^{-1}):

	W pre-selection		Top selectio n	
	Electron Channel	Muon Channel	Electron Channel	Muon Channel
Data	0	0	0	0
Standard Model	0.26 ± 0.06	0.20 ± 0.07	0.13 ± 0.04	0.12 ± 0.03
W only	0.16 ± 0.05	0.18 ± 0.06	0.07 ± 0.02	0.10 ± 0.03
Top efficiency	43%	51%	37%	45%

Kinematic Reconstruction of $W \rightarrow \ell\nu$

- Tagged events (scattered electron detected):

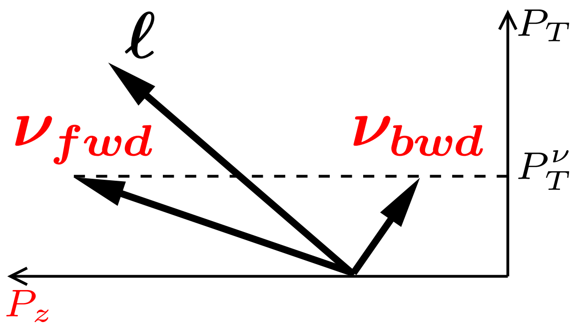
$$
\begin{aligned}
(E - p_z)^{\nu} &= 2E_e - (E - p_z)^{\text{vis}} \\
p_T^{\nu} &= p_T^{\text{miss}}
\end{aligned}
$$

$\Rightarrow$ neutrino directly reconstructed

- Untagged events (scattered electron and neutrino undetected):
  - W mass constraint $\Rightarrow$ in general two solutions for neutrino

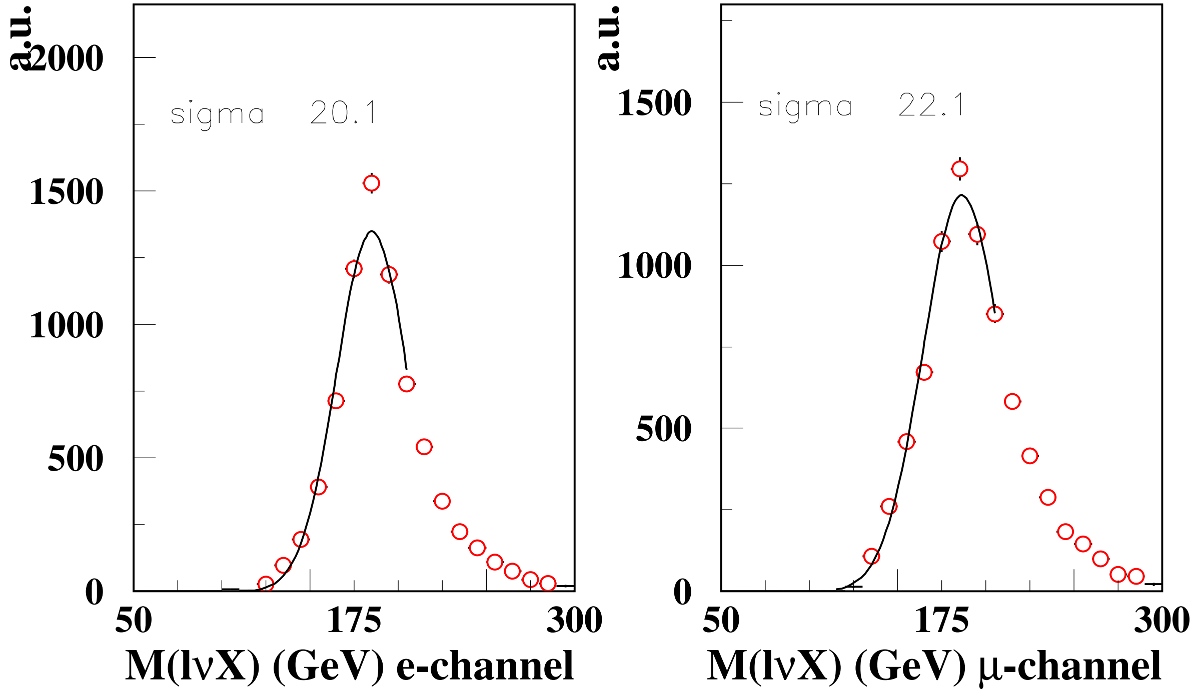
$$(M_W^2 + \vec{p}^{\,\ell}\vec{p}^{\,\nu})^2 = 4\,|\vec{p}^{\,\ell}|^2|\vec{p}^{\,\nu}|^2 \quad , \quad p_T^{\nu} = p_T^{\text{miss}}$$

  - reject unphysical solutions (energy-momentum conservation)
  - if no solutions $\Rightarrow$ find physical one by variation of errors within $\pm 2\sigma$
  - if two solutions $\Rightarrow$ take both solutions into account



Reconstruction of Top Quarks in Leptonic Channel

- b-jet from hadronic final state: sum up all energy deposits (exclude lepton)
- top mass resolution:

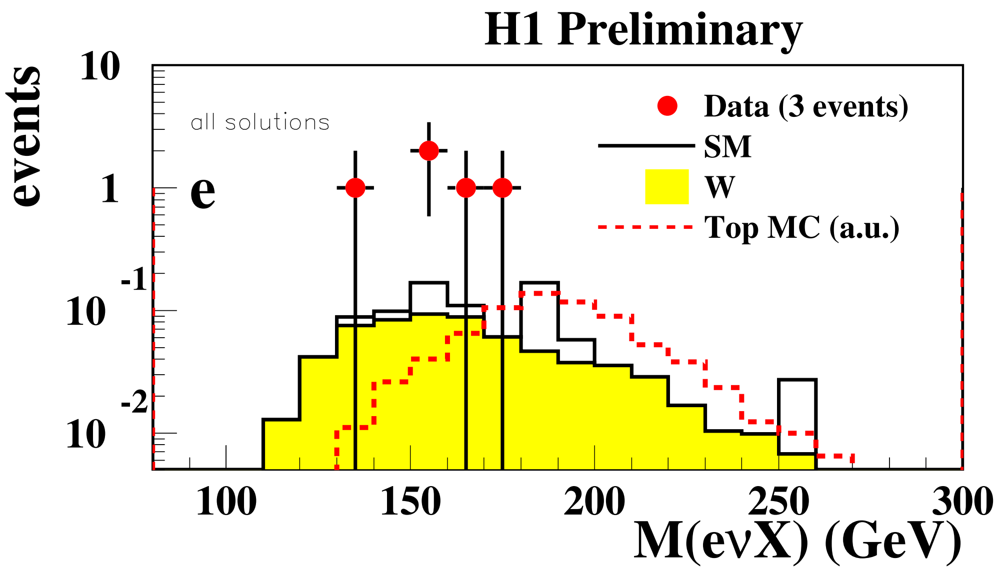


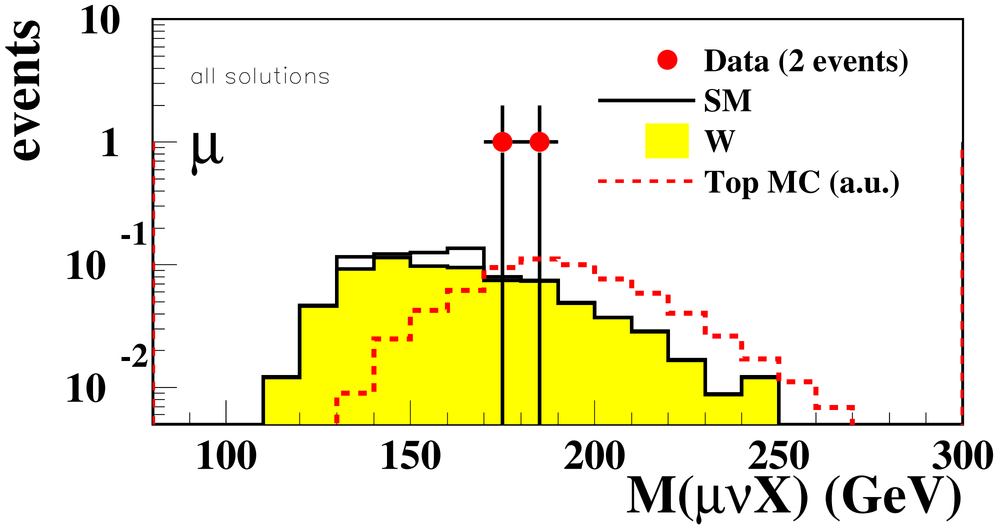
- correct neutrino choice: electrons=80% (95%) muons=65% (95%) untagged (tagged)

Summary of Semileptonic Top Decay Selection

H1 Preliminary	PT(X) (GeV)	Untagged Solution 1 Mass (GeV)	Untagged Solution 1 $E-P_z$ (GeV)	Untagged Solution 2 Mass (GeV)	Untagged Solution 2 $E-P_z$ (GeV)	Tagged Solution Mass (GeV)
e^+ top cand.	41	159 ± 7	61	136 ± 6	21	–
e^+ top cand.	43	–	–	166 ± 8	54	165 ± 6
e^+ top cand.	39	178 ± 5	39	156 ± 7	21	–
e^+	27	234 ± 15	65	199 ± 14	38	–
μ^+	42	–	–	146 ± 7	19	–
μ^-	27	152 ± 12	53	129 ± 6	34	156 ± 10
$\mu^-(1\sigma)$	59	180	67	188	37	–
$\mu\ (2\sigma)$	30	157	53	139	22	–
μ^+ top cand.	67	–	–	181 ± 10	19	–
μ^+ top cand.	50	–	–	174 ± 12	39	–

Reconstructed Top Mass





Preselection for the Hadronic Top Decay

Preselection:

- three jets j with $p_T^j > 25, 20, 15$ GeV
- acceptance $-0.5 < \eta_{\rm jet} > 2.5$
- rejection of electrons (against NC DIS)

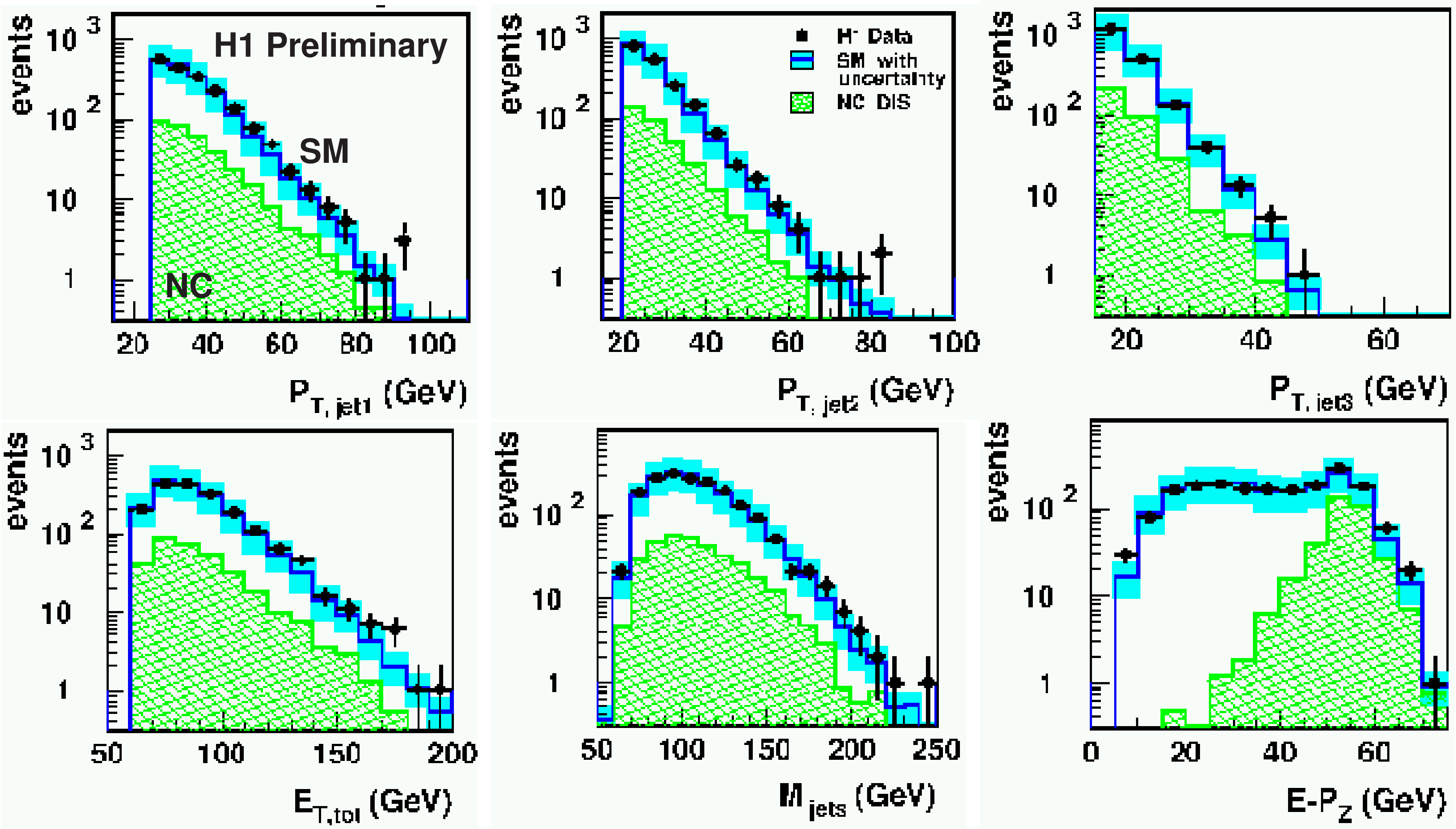
$\Rightarrow$ $\approx$ 1500 events

SM expectation:

- RAPGAP $Q^2 > 4$ GeV (NC DIS)
- PYTHIA $Q^2 < 4$ GeV (photoproduction)

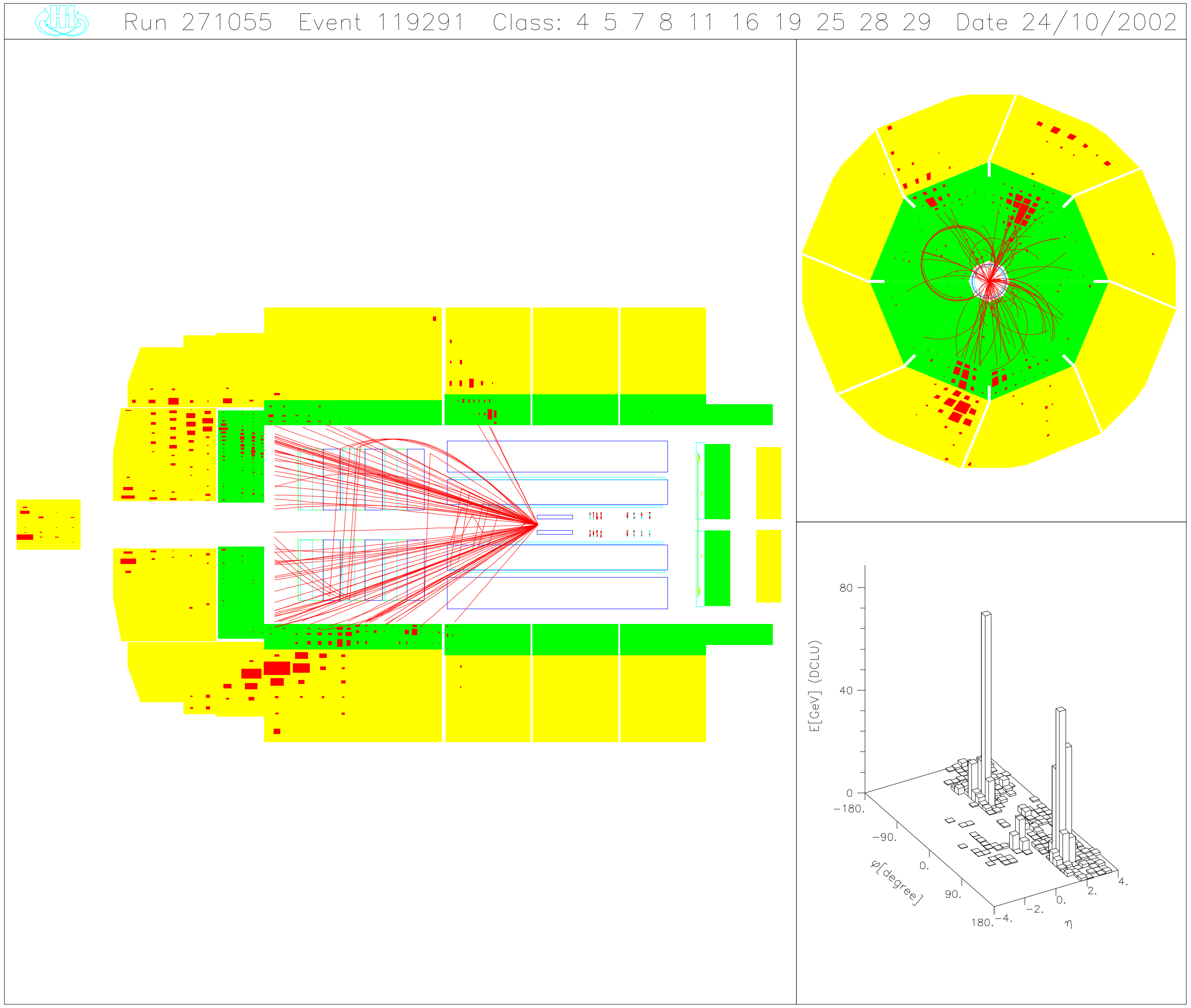
$\Rightarrow$ data-MC comparison

Hadronic Channel Control Plots



- normalisation factor 1.25 (lack of higher order QCD corrections for background)

Selected 3-jet Event

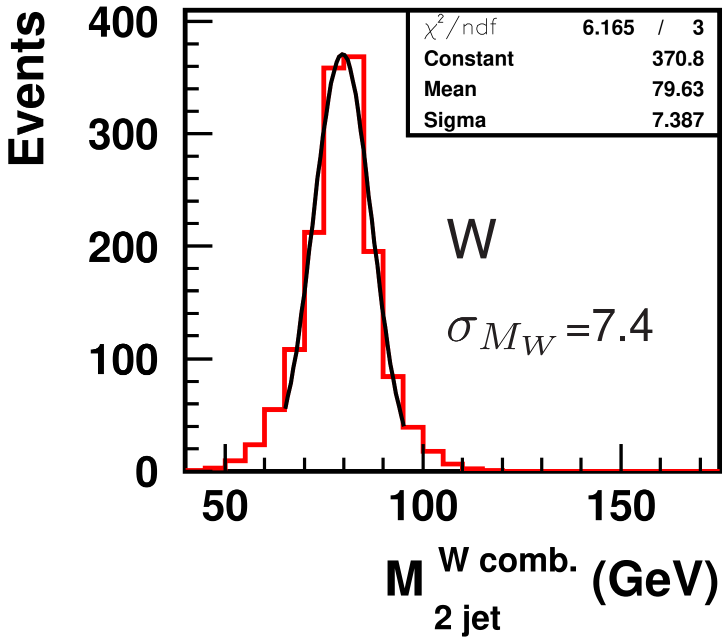


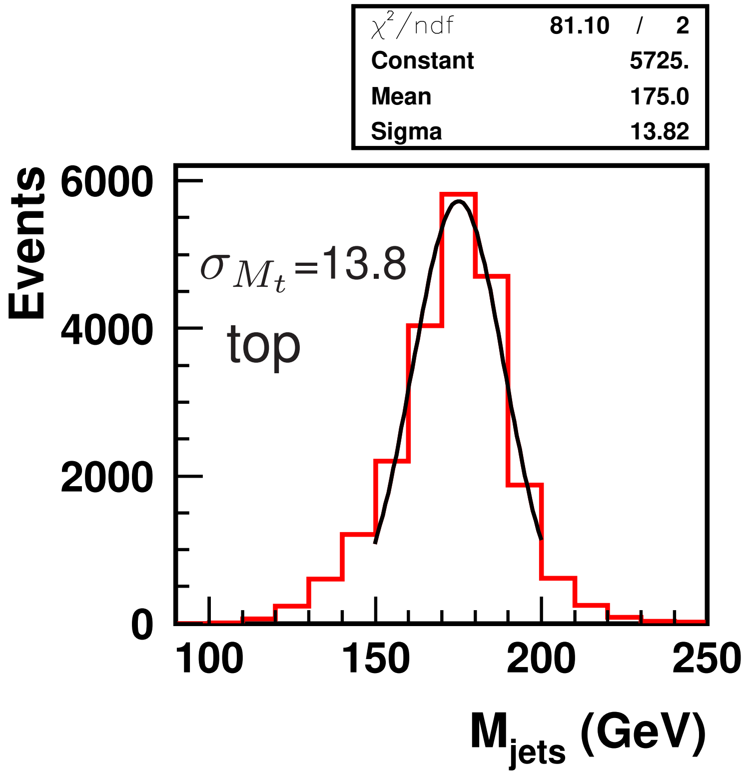
Reconstruction of the Hadronic Top Decay

Assignment of jets to W and top decay

- jets forming invariant mass closest to W are combined
- third jet assigned to b-quark

$\Rightarrow$ 70% correct

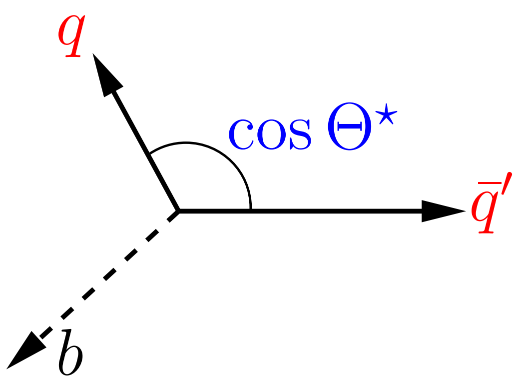




Selection of the Hadronic Top Decay

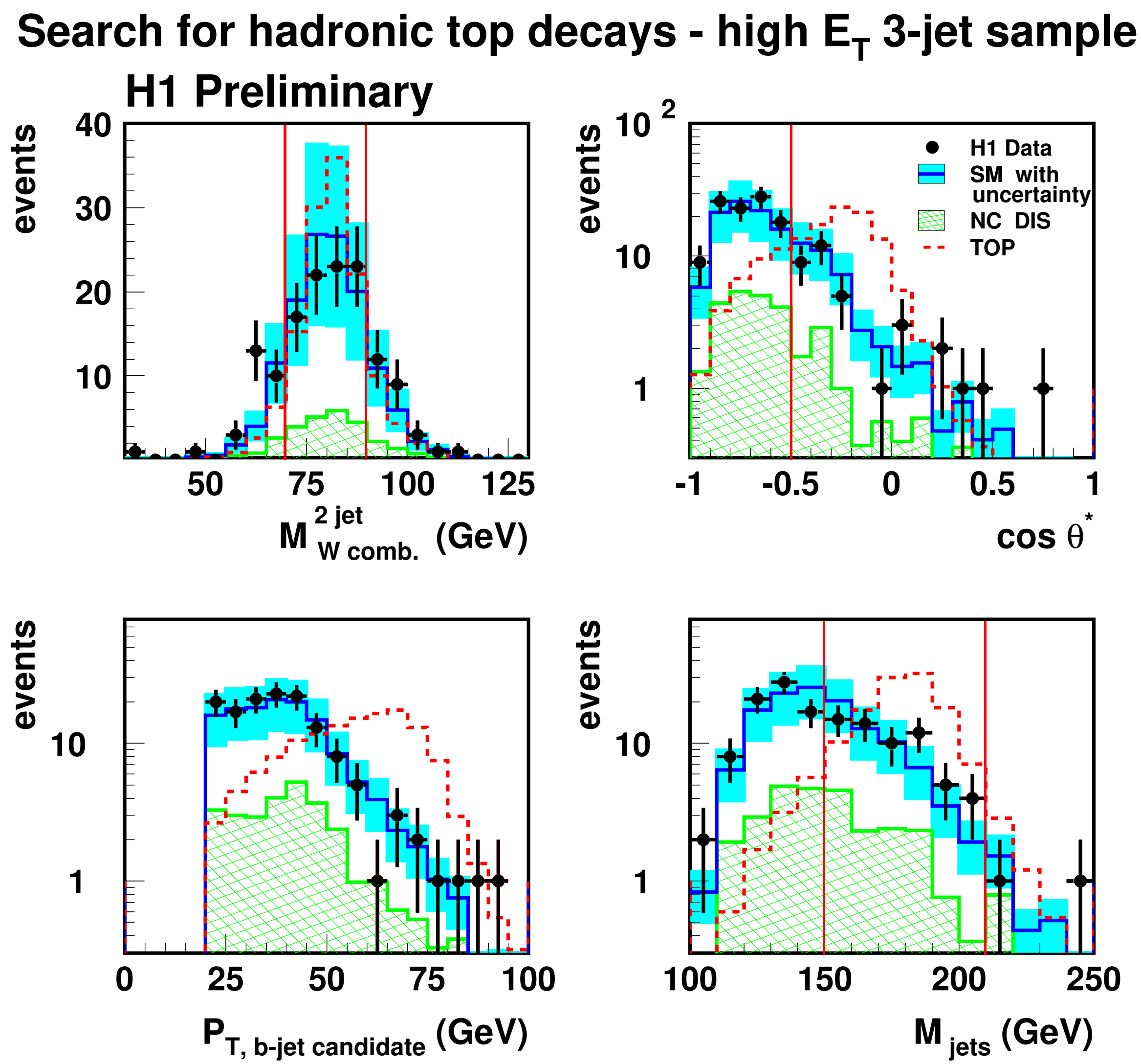
Top selection cuts:

- $p_t^j > 40, 25, 20$ GeV
- $E_{T,tot} > 110$ GeV



$W \rightarrow q\bar{q}'$ decay

in top rest frame



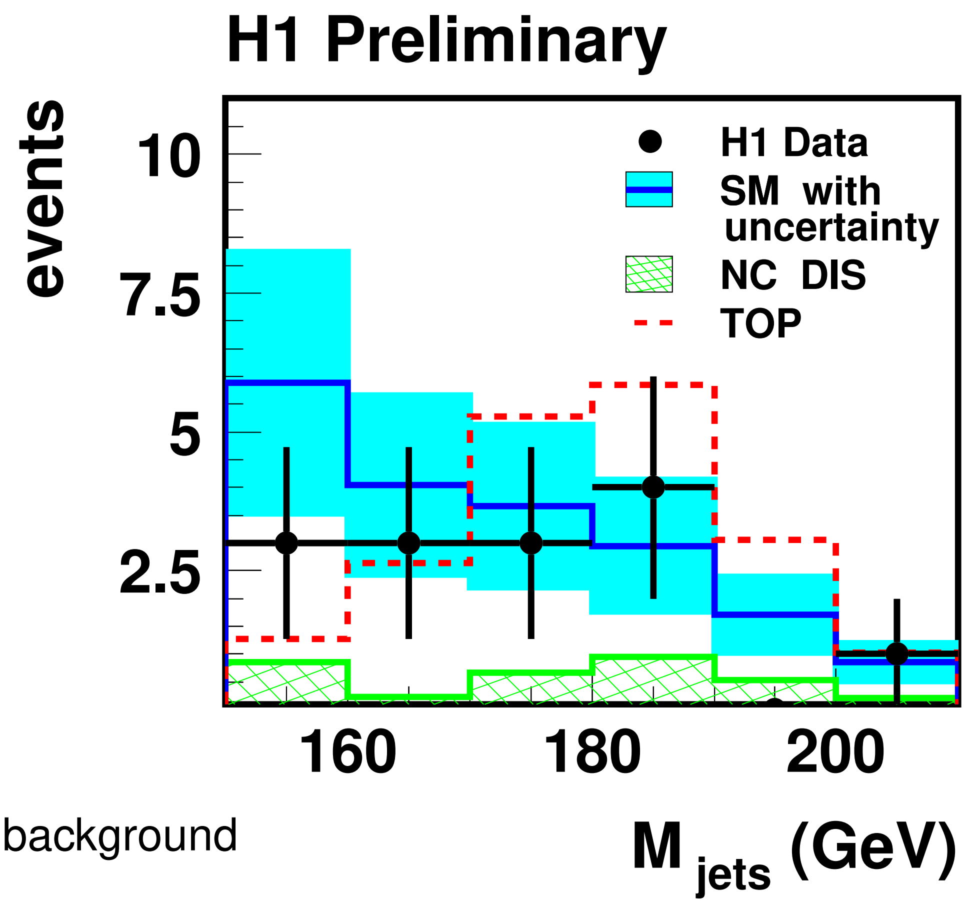
Final Selection of the Hadronic Top Decay

final selection:

- $70 < M_W^{2\text{jet}} < 90$ (GeV)
- $150 < M_{\text{jets}} < 210$ (GeV)
- $\cos\Theta^\star > -0.5$

$\Rightarrow$ 14 candidates

- SM expectation: 19.6 ± 7.8 events
- efficiency for $t \rightarrow 3$ jets: 27%
- systematic error: $\approx 40\%$
  - mainly from 30% SM uncertainty on 3-jet background



After all top cuts

Results

- no signal found $\Rightarrow$ calculate cross section limits
  - assume $t \to bW$ be 100%
  - combine: e^+p at $\sqrt{s} = 300$ GeV
    e^-p at $\sqrt{s} = 320$ GeV
    e^+p at $\sqrt{s} = 320$ GeV

- result from search for hadronic top decay:
  $\sigma_{320}(ep \to etX) < 0.40$ pb at 95% CL

  $\Rightarrow$ # events from semileptonic top decay < 5.4 (5 observed)

- result from search for semileptonic and hadronic decay combined:

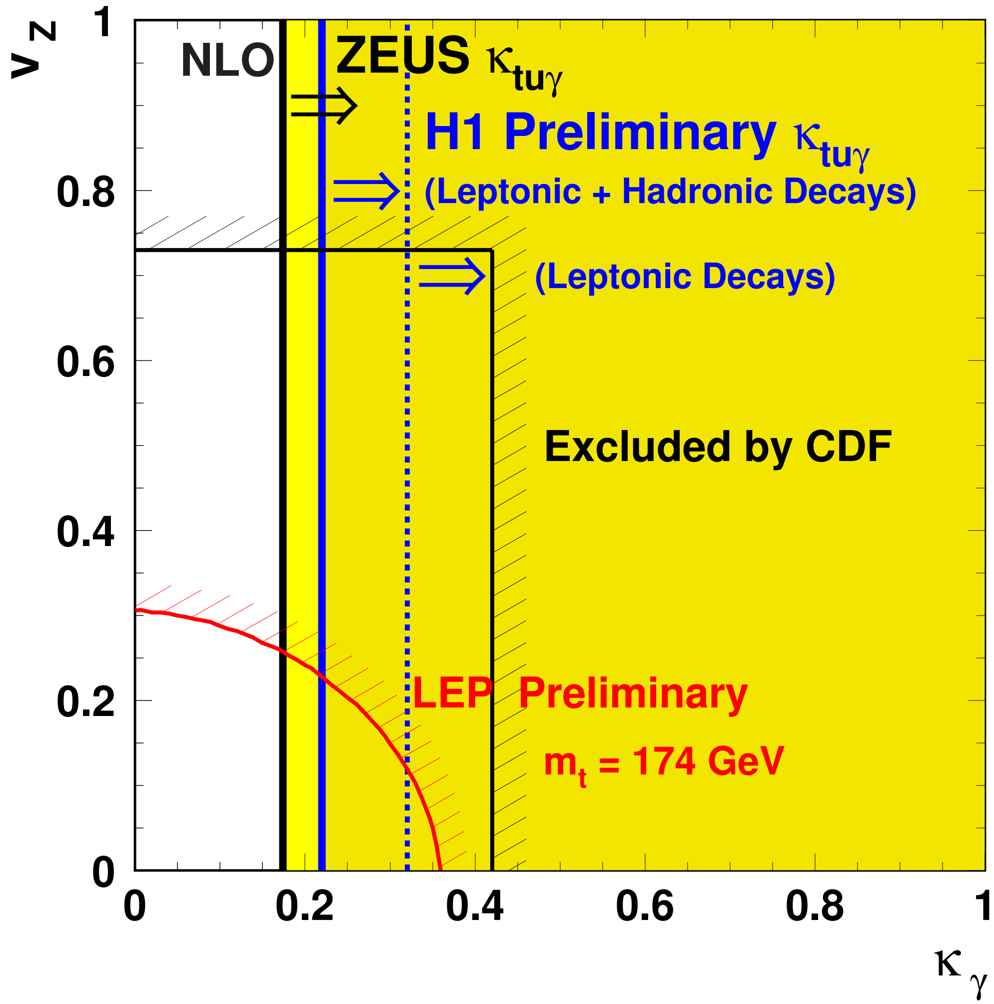
  $\sigma_{320}(ep \to etX) < 0.43$ pb at 95% CL

Limit on Anomalous Top Quark Production

- limit on anomalous magnetic coupling:

$$\kappa_{\gamma,u} < 0.22 \quad \text{at 95\% CL}$$

- limit includes:
  - all decay channels investigated
  - 20% NLO correction on top signal
  - statistical and systematic errors



Summary

- Search for single production of top quarks presented using HERA I data.
- Search for top quarks yields 5 (1.77$\pm$0.46) candidates in semileptonic and 14 (19.6$\pm$7.8) candidates in hadronic channel (theor. uncertainty large).
- Comparison between semileptonic and hadronic channel shows consistency.
- Derived limit by H1 on anomalous $tu\gamma$ magn. coupling is competitive (ZEUS) or even better than results from other experiments (LEP, Tevatron).

- The improved luminosity of HERA II (1 fb^{-1}) will substantially increase. the sensitivity to rare process such as single top production.