Single Top Production via Flavour Changing Neutral Currents.

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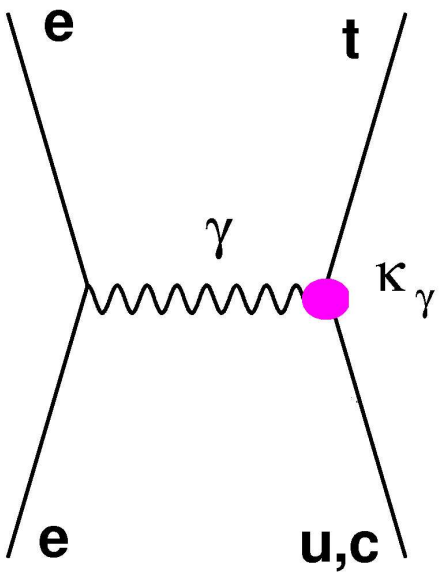
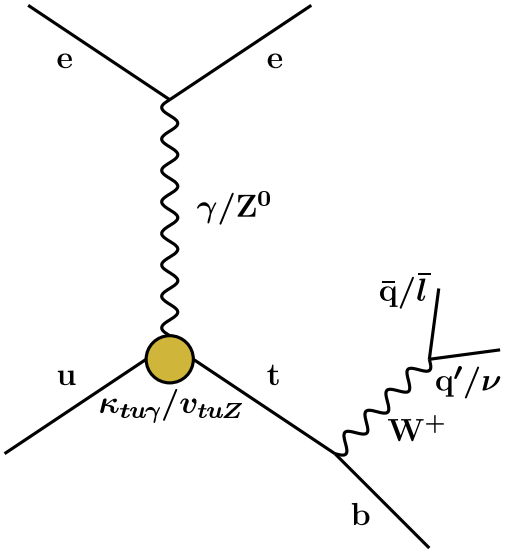
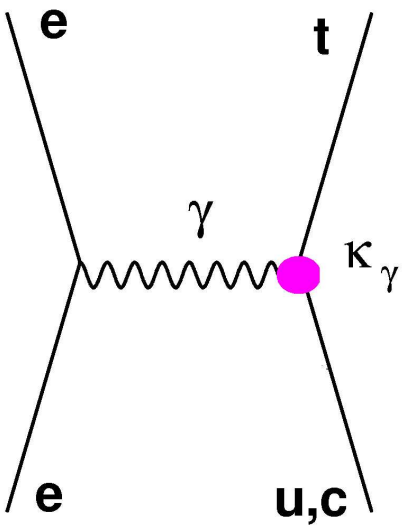
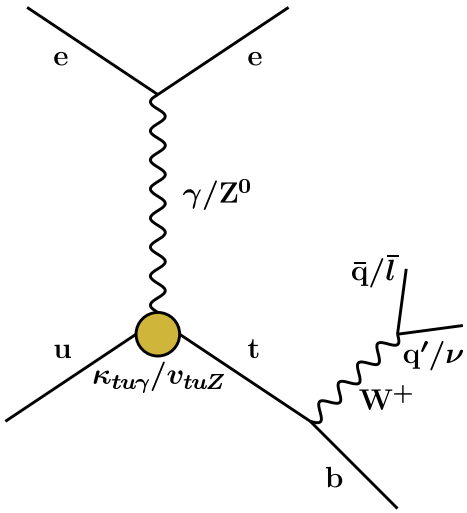
- *STP.*
- *FCNC.*
- *HERA Searches.*
- *LEP Searches.*
- *Exclusion Limits.*
- *Outlook.*





What is Single Top Production?





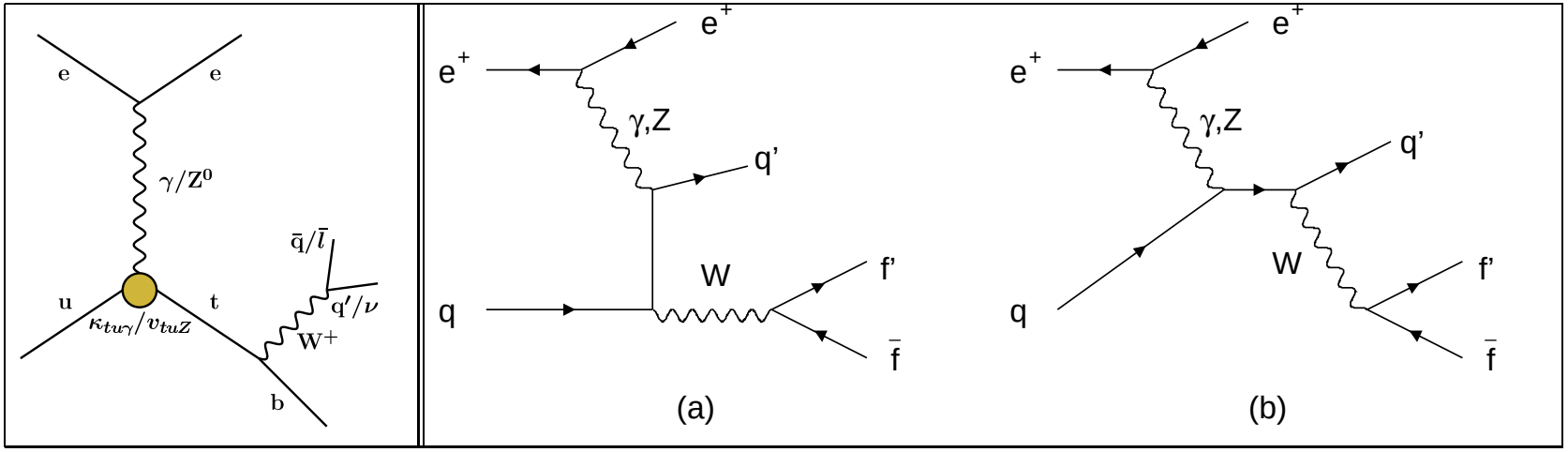
- *Single Top Production (STP) via FCNC as a Standard Model Process:*
  - *Not a tree level SM process.*
  - *Small σ (GIM mechanism): ($\sigma < 1$ fb HERA,$\sigma \approx 10^{-9}$ fb LEP)*
- *Single Top Production via Anomalous FCNC:*
  - $\Delta\mathcal{L}_{\rm eff} = e\, e_t\, \bar{t}\, \frac{i\sigma_{\mu\nu}q^\nu}{\Lambda}$ $\kappa_{tq\gamma}$ $q\, A^\mu + \frac{g}{2\cos\theta_{\rm W}}\, \bar{t}\, \gamma_\mu$ v_{tqZ} $q\, Z^\mu + {\rm h.c.}$
  - *Events at LEP or HERA attributed to STP must be from anomalous couplings.*
  - *Would unambiguously signal new physics.*

FCNC Search at the Tevatron

- *CDF searched for* $t \to q\gamma$ *and* $t \to qZ$ *with* $\mathcal{L} = 110\ pb^{-1}$.
- *From SM expect* 10^{-10} *branching fraction.*
- *use* $t\bar{t}$ *events, one* $t \to bW$.
- $tq\gamma$
  - *Look for* γj *combination with* $140 < M < 210$ *GeV +*$t \to bW$ *topologies.*
  - *no* b *tagged jet in* γj *combination.*
  - *main background* $W + \gamma + 2$ *or more jet events, Estimated using* $W + \gamma$ *event rate.*
  - *Branching fraction limit:* $3.2\% \to k_\gamma^2 < 0.176$
- tqZ
  - *One* t *quark goes to 3 jets other* $t \to Zq \to l^+l^-q$
  - *Require opposite charge leptons* $75 < M_{ll} < 105$
  - *Branching fraction limit:* $33\% \to k_Z^2 < 0.533$

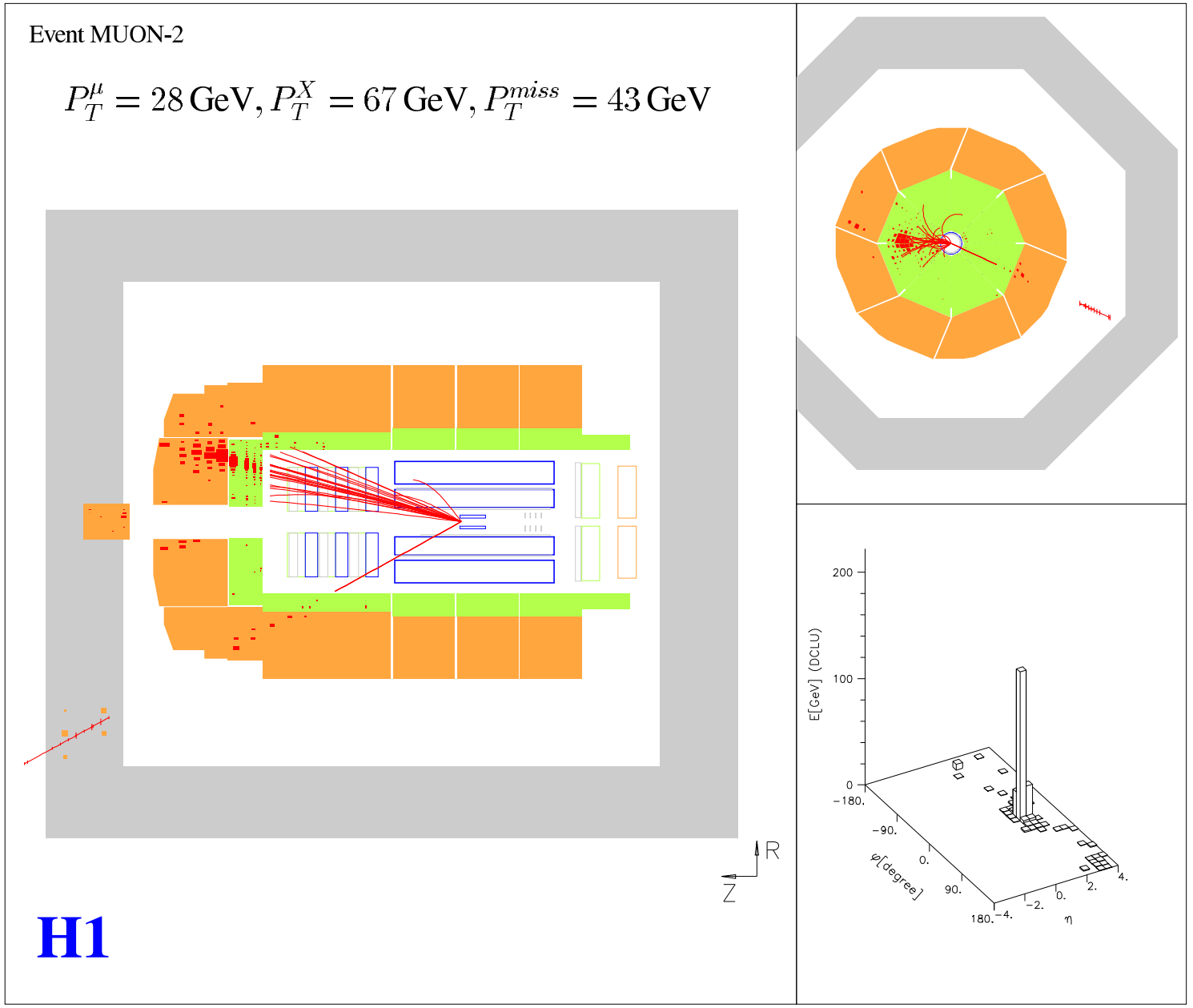
Searches at HERA - I

Signal	*Background (W production)*

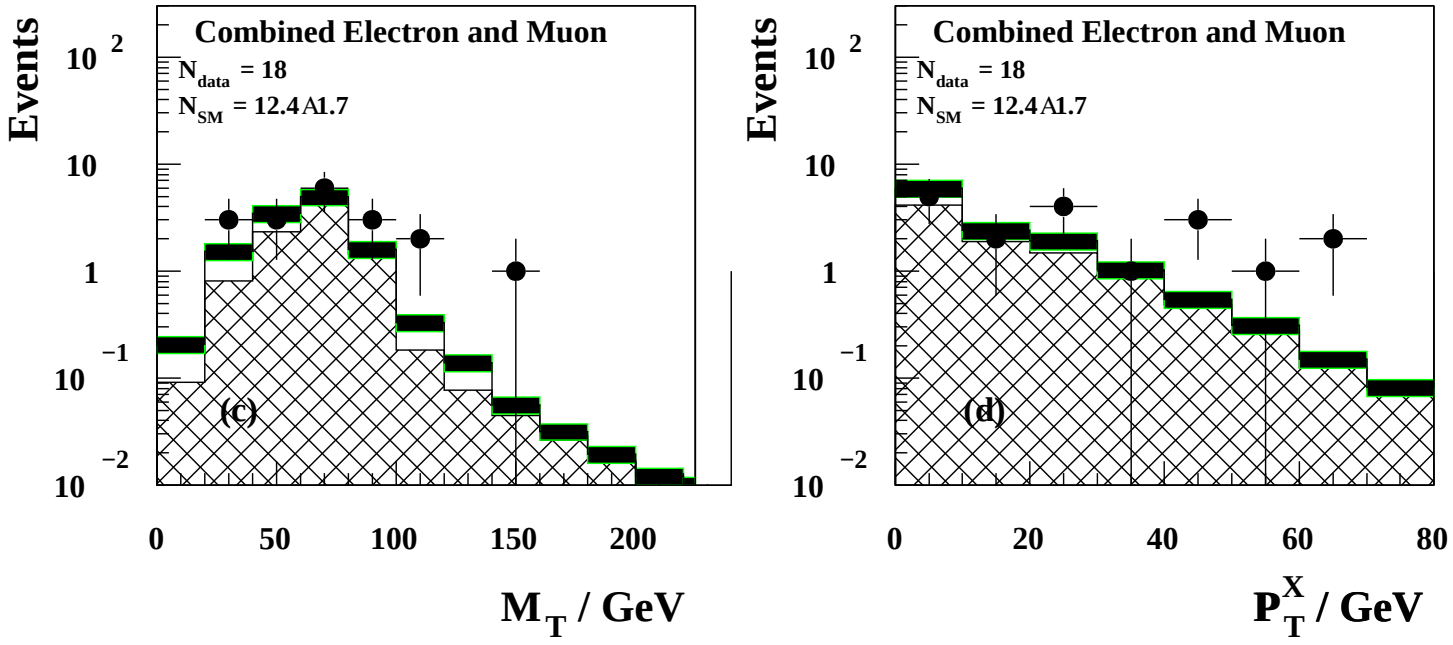


- *Signature of Single Top Production:*
  - *Isolated high p_T lepton in events with large missing transverse momentum)*
  - *Or 3 jets with $M_{jj} \approx M_W$, $M_{3j} \approx M_{\text{top}}$*
- *In leptonic channels main backgrounds are 2γ processes (μ), NC DIS and Single W Production.*
- *In hadronic channel, main background is QCD.*
- *Searches have been performed in both hadronic and leptonic channels, $\mathcal{L} \approx 120\, pb^{-1}$.*

$$e^+p \to \mu^+X$$


Event MUON-2
$P_T^{\mu} = 28\,\text{GeV}, P_T^X = 67\,\text{GeV}, P_T^{miss} = 43\,\text{GeV}$
R
Z
H1
E[GeV] (DCLU)
200
100
0
−180.
−90.
0.
90.
180.
φ[degree]
4.
2.
0.
−2.
−4.
η

Searches at HERA - II: H1 Isolated Leptons



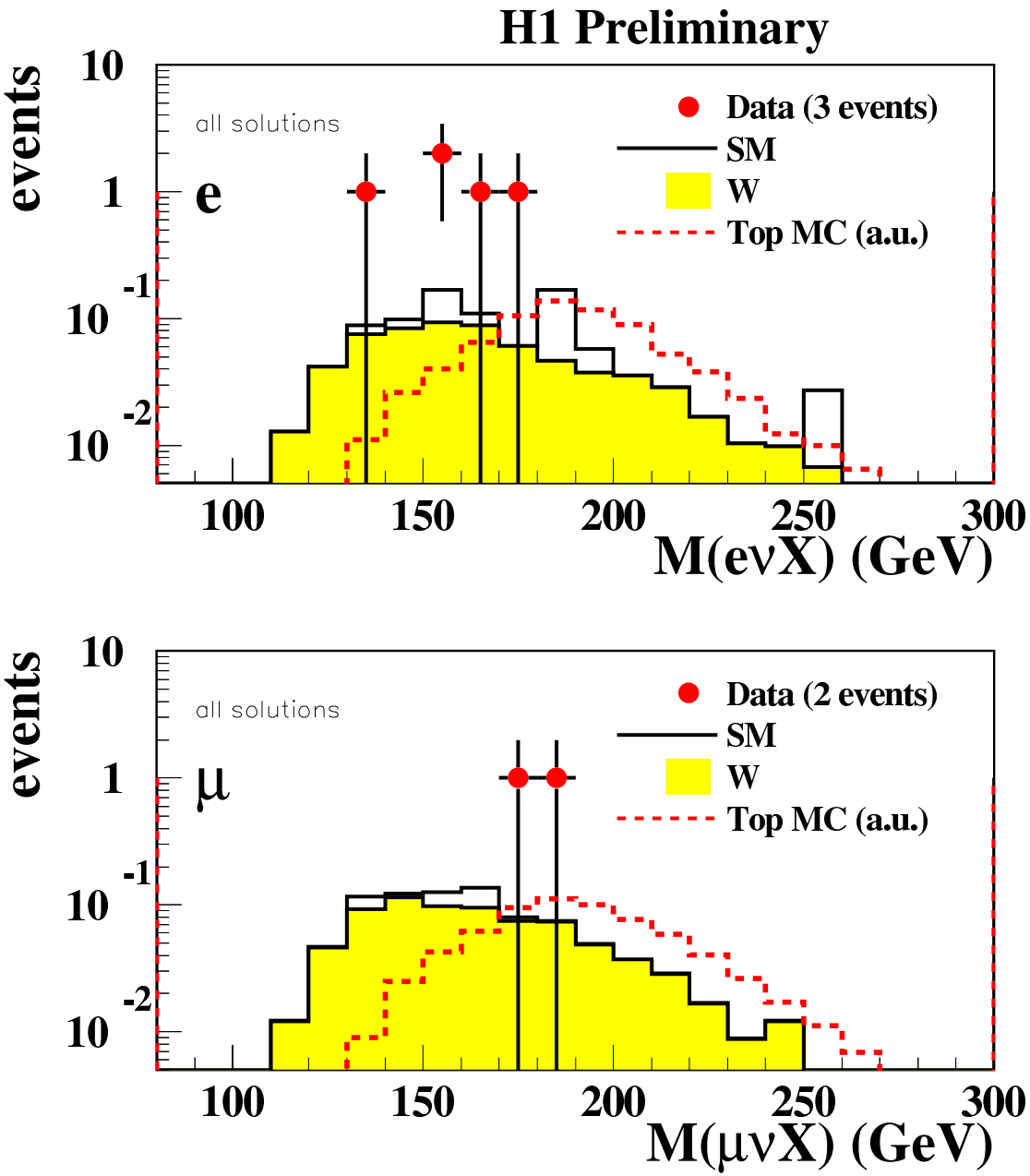
- *18 Events seen,* 12.4 ± 1.7 *expected from SM.*
- *Main excess is at high hadronic* p_T *- from a Heavy particle decay?.*

	e Channel Obs./Exp.	*μ channel Obs./Exp.*
$P_T^{had} > 25$ *GeV*	$4/1.49 \pm 0.18$	$6/1.44 \pm 0.18$
$P_T^{had} > 40$ *GeV*	$3/0.54 \pm 0.11$	$3/0.55 \pm 0.12$

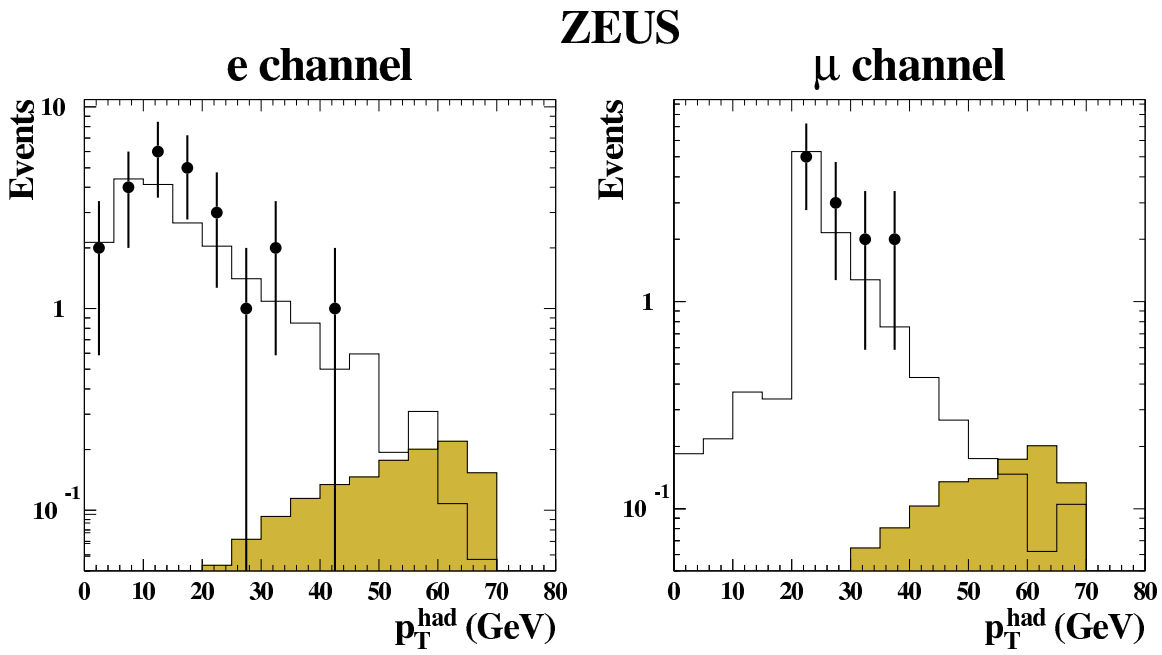
Searches at HERA - III: H1 Single Top

Top mass is reconstructed from invariant mass of $l\nu j$ combinations.

- *Final Selection*
  - *Isolated l^+.*
  - *$p_T^X > 25(35)$ GeV.*
  - *$M_T^{l\nu} > 10$ GeV*
- *Results*
  - *3 e, 2 μ events compatible with STP.*
  - *expect 1.77 ± 0.46 from W production.*



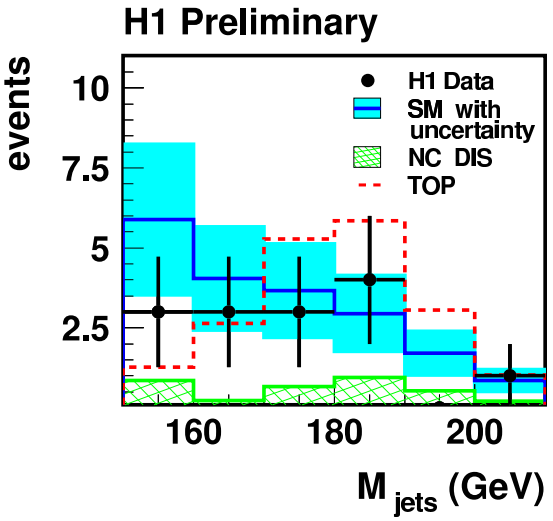
Searches at HERA - IV: ZEUS Isolated Leptons + Single Top



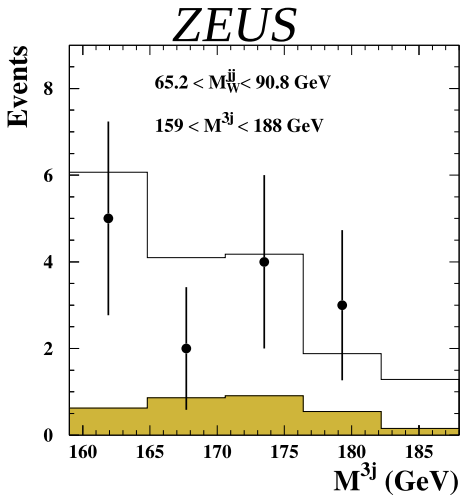
- *Kinematic distributions compatible with SM ,no excess over SM observed*

	e Channel Obs./Exp.	*μ Channel Obs./Exp.*
preselection	$24/20.6^{+1.7}_{-4.6}$	$12/11.9^{+0.6}_{-0.7}$
$p_T^{\rm had} > 25$ *GeV*	$2/2.90^{+0.59}_{-0.32}$	$5/2.75^{+0.21}_{-0.21}$
$p_T^{\rm had} > 40$ *GeV*	$0/0.94^{+0.11}_{-0.10}$	$0/0.95^{+0.14}_{-0.10}$

Searches at HERA - V: Hadronic Channel



After all top cuts

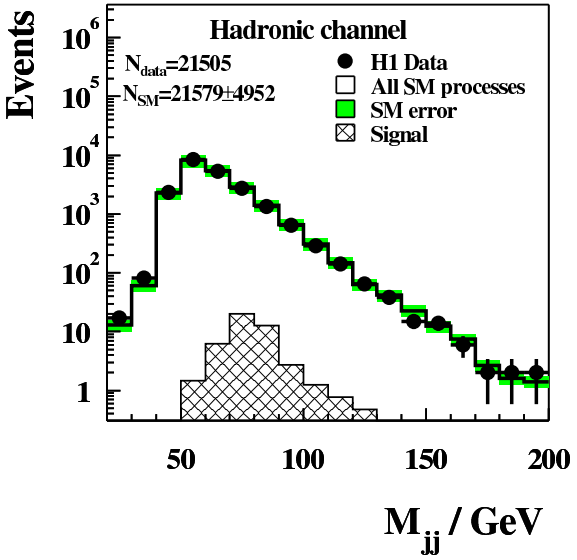


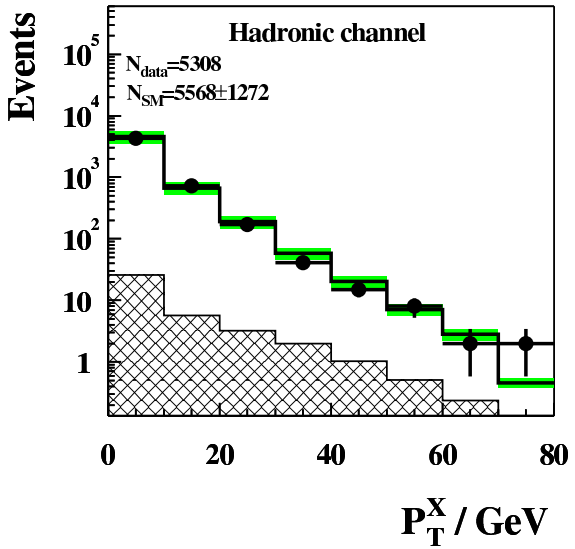
- *Search for* $eu \to et \to ebW \to ebqq$.
- *look for* $M_{jj} \approx M_W$, *make 3j Mass spectrum.*
- *After final cuts:*

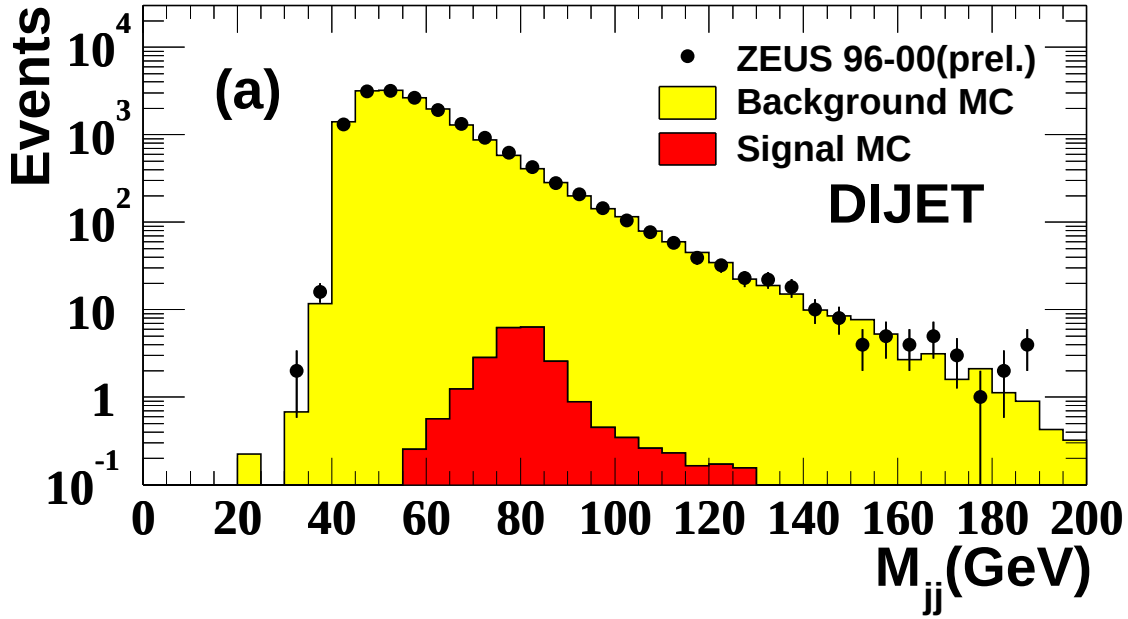
	H1(94-00)
Data	*14*
SM	19.6 ± 7.8
	ZEUS(95-00)
Data	*14*
SM	$17.6^{+1.8}_{-1.2}$

- *No excess in either experiment.*

Searches at HERA - VI: $W \rightarrow$ Jets



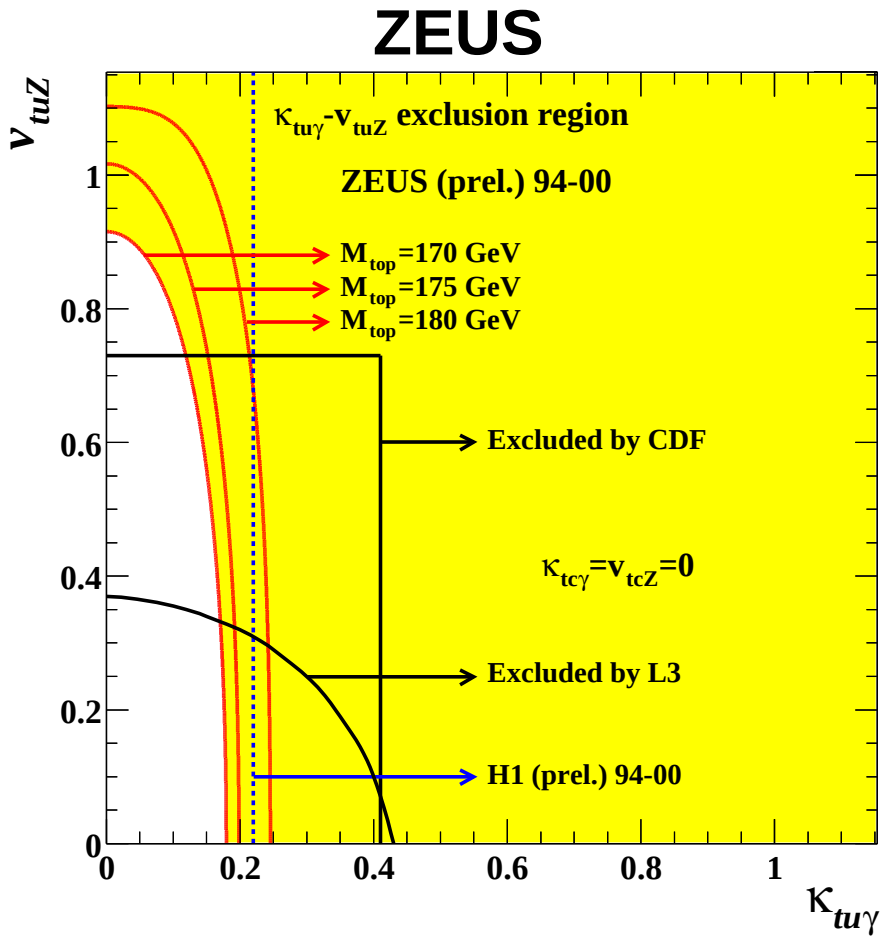




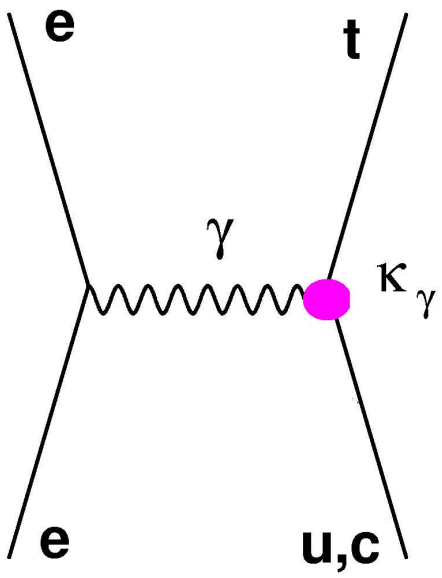
- *Leptonic excess from anomalous W production? ($\sigma_{SM} = 1\text{pb}$)*
- *Check in hadronic channel.*
- *Select Events with 2+ High E_T jets.*
- *Reconstruct invariant mass spectrum.*
- *No excess over SM seen.*
- *Limit (ZEUS):* $\sigma < 8.3$ pb, *does not eliminate possibility of anomalous W production.*

Searches at HERA - VII: Summary

- *Searches for Single Top Production performed by H1 , ZEUS.*
- *In Leptonic channel H1 sees an excess of isolated lepton events compatible with STP:*
  - *H1 : 5 seen , expect 1.8.*
  - *ZEUS: 0 seen, expect 1.0.*
- *No excess in hadronic channel.*
- *ZEUS sets strongest limit on photon coupling (0.2).*
- *ZEUS latest results add sensitivity to v_{tuZ}*
- *No sensitivity at HERA to tcZ/γ couplings.*
- *Waiting for HERA II:*
  - *10x more luminosity.*
  - *Improved detectors.*



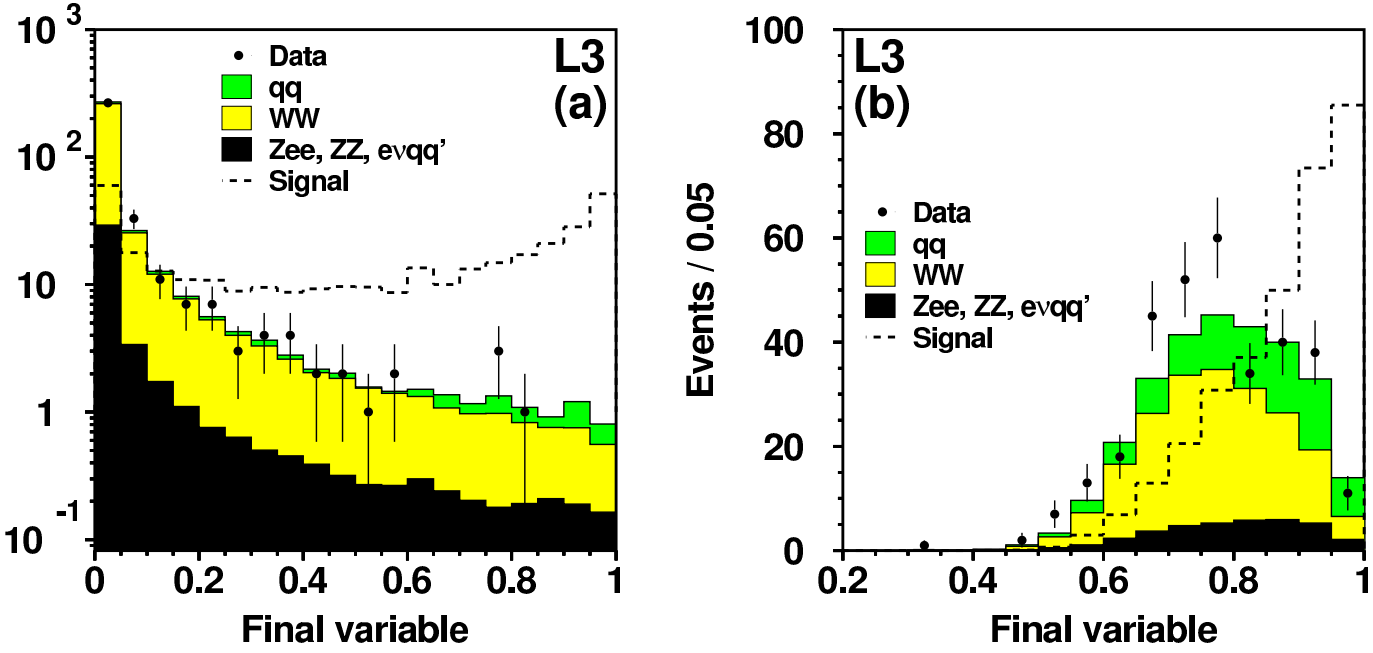
Searches at LEP - I



- *Searches for* $e^+e^- \to tq \to Wbq$
- *LEP has sensitivity to* $q = u, c$*, assume equal.*
- *Good sensitivity to* k_Z*.*
- $\mathcal{L} \approx 600\,\mathrm{pb}^{-1}$*.*
- *Small difference between* m_t *and* $\sqrt{s} \to$ *clear kinematic signature.*
- t *is produced almost at rest.*

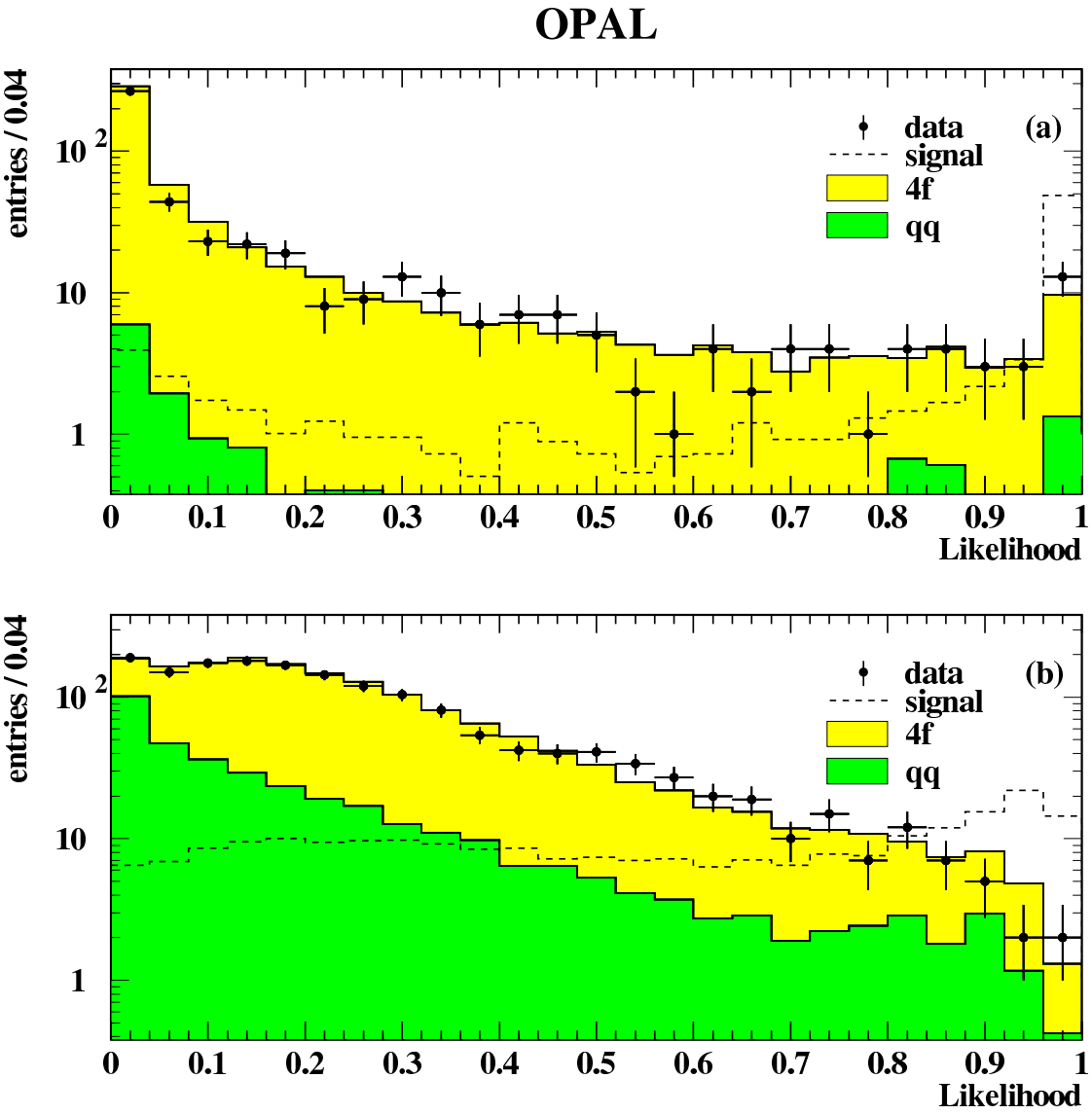
- $E_W \approx (m_t^2 + m_W^2 - m_b^2)/(2m_t) \to E_b \approx (m_t^2 - m_W^2 + m_b^2)/(2m_t)$.
- *One jet from* t *must be* b *tagged.*
- *Signal is diluted as* $\sqrt{s}$ *increases.*
- *Variety of sophisticated techniques used.*
- *Change in Lagrangian means limits for HERA in LEP convention:* $k_\gamma^{LEP} = \sqrt{2}k_\gamma^{ZEUS}$ *and* $k_Z^{LEP} = \sqrt{2}v_Z^{ZEUS}$

Searches at LEP - II L3



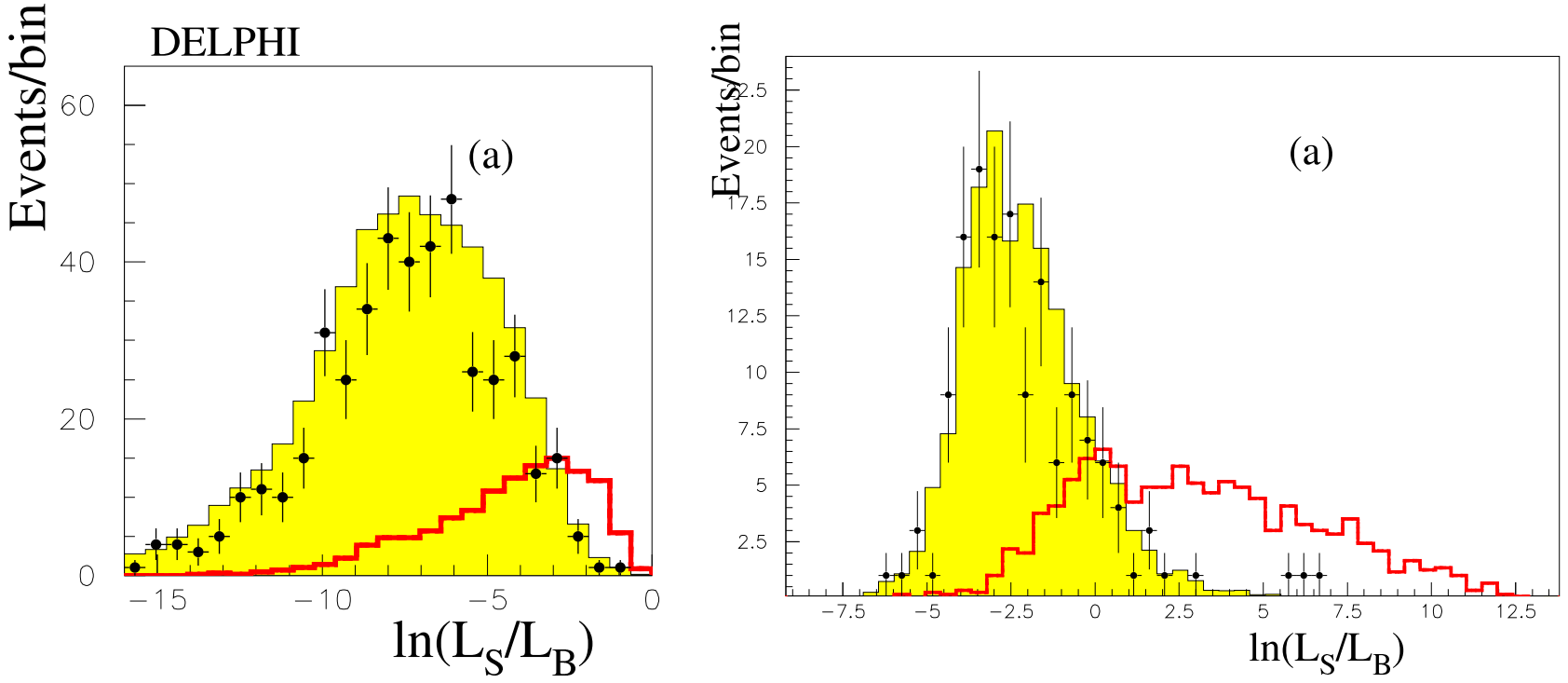
- *A neural network technique is used.*
- *variables include:*
  - *b-tag.*
  - E_l , $\vec{p}_{\mathrm{miss}}$, M_{jj},$M_{l\nu}$ *(leptonic)*
  - *jet charactersitics, event shapes (hadronic).*
- *Limits set in k_γ, k_Z plane.*

Searches at LEP - III OPAL



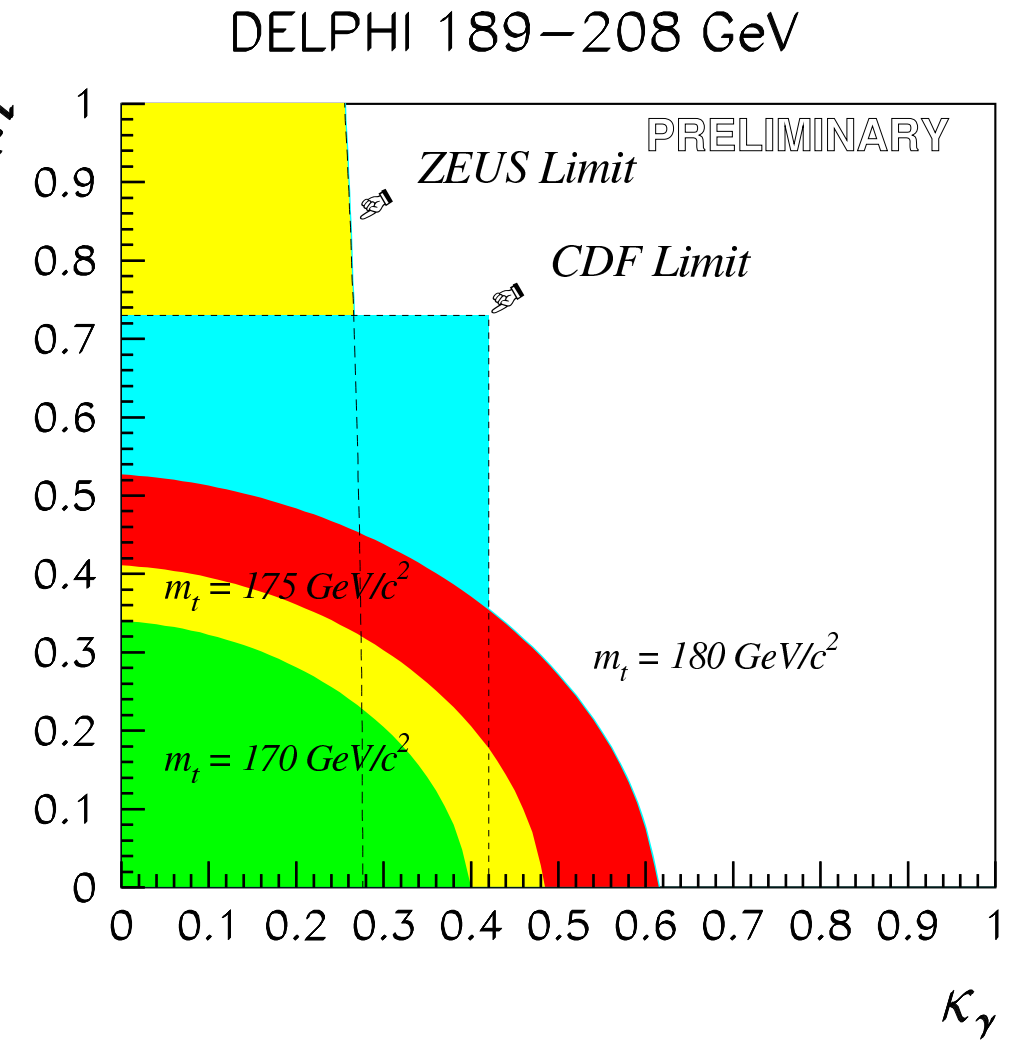
- *Separation with conventional likelihood function.*
- $\mathcal{L} = \frac{\mathcal{P}_{\text{signal}}}{\mathcal{P}_{\text{signal}}+\mathcal{P}_{\text{background}}}$
- *variables :*
  - *kinematic fits, b tag,*$E_{c(u)}$.
  - *Thrust(hadronic),* $M_{l\nu}$ *after kinematic fit (leptonic).*
- *Limits consistent with previous ALEPH result.*

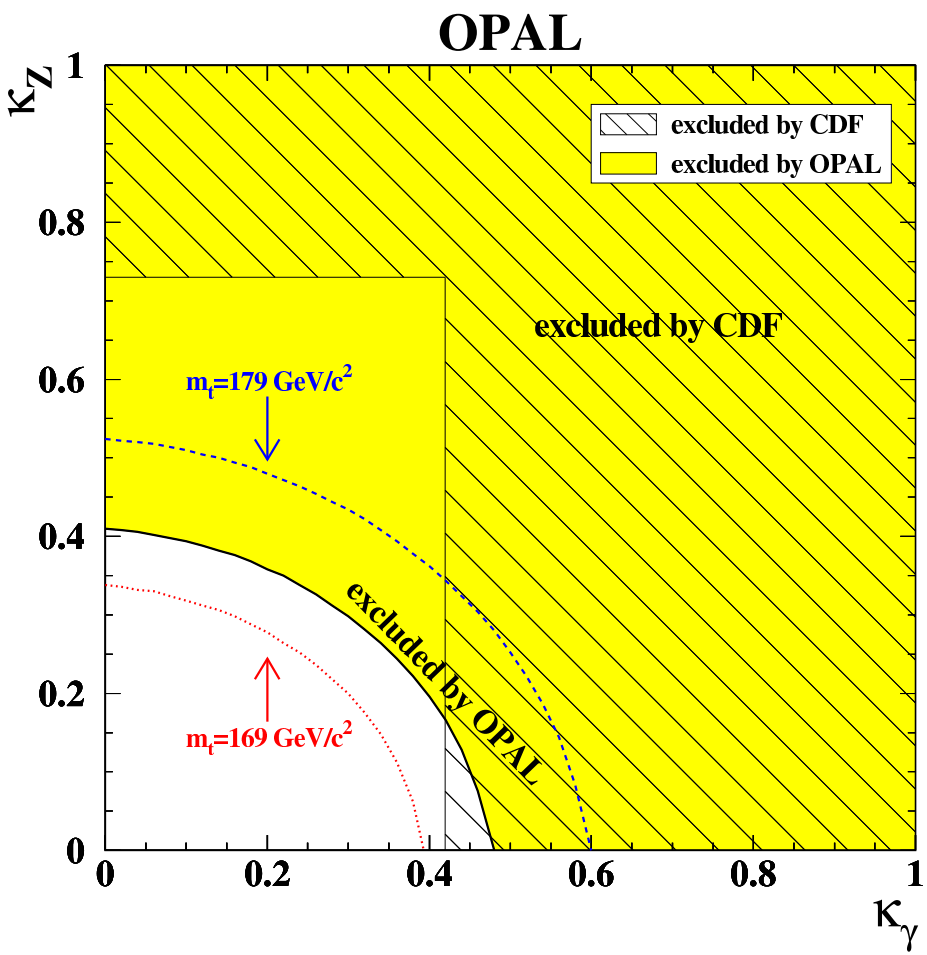
Searches at LEP - IV DELPHI



- *Separation with* $\ln(L_S/L_B)$
- $L_S = \Pi_i \mathcal{P}_i^{\text{signal}}$,$L_B = \Pi_i \mathcal{P}_i^{\text{background}}$
- *Similar variables to OPAL, likelihood function used.*
- *No evidence for STP seen.*

Searches at LEP V: Exclusion Limits





Searches at LEP - V: Summary

- *Searches have performed with LEP data in hadronic and leptonic channels.*
- *Unlike HERA LEP has sensitivity to* $tc\gamma/Z$
- *No evidence for FCNC observed*
- *Good agreement between all 4 LEP experiments.*

Overall Summary and Outlook

- *Searches at Tevatron (Run 1), HERA I, and LEP.*
- *No evidence seen at LEP for STP via FCNC.*
- *events compatible with STP via FCNC seen at H1, unconfirmed by ZEUS.*
- *HERA and LEP set strongest limits on FCNC.*
- *HERA II and Tevatron Run 2 will lower limits further.*
- *HERA II data needed to clarify isolated lepton excess seen by H1.*