The ILC energy requirements from constraints on new boson production at the Tevatron

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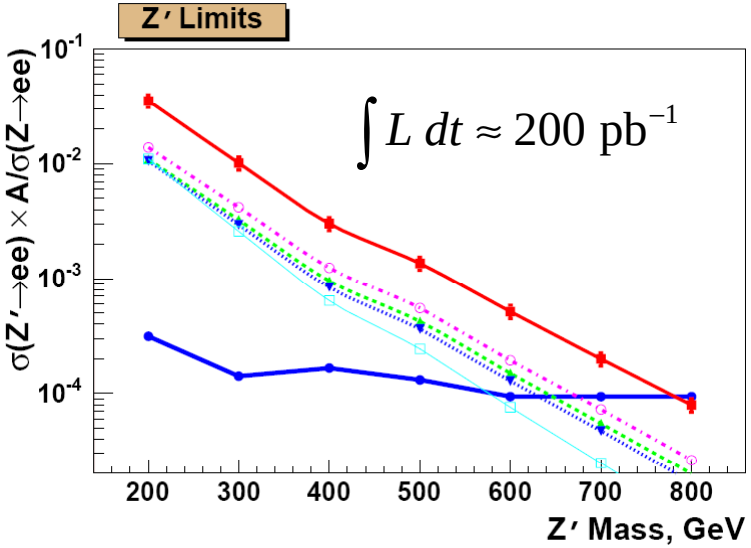
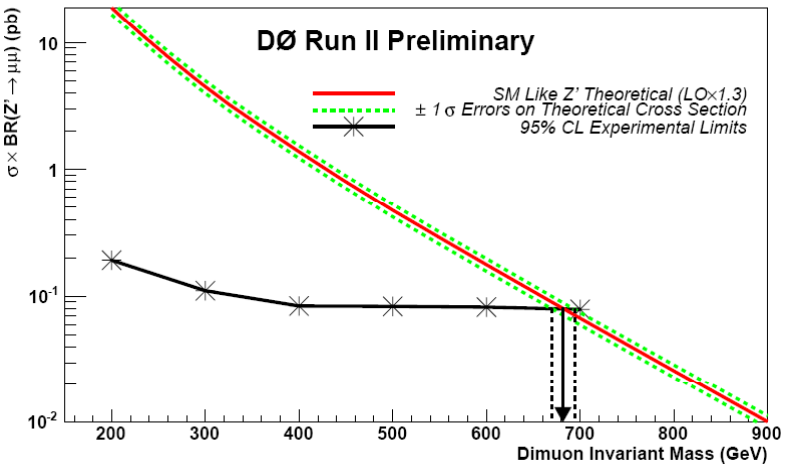
The D0 constraints for high mass di-lepton events



$$M_{Z'_{SM}} < 780\ \mathrm{GeV}$$
$$M_{Z'_{\eta}} < 680\ \mathrm{GeV}$$
$$M_{Z'_{\chi}} < 640\ \mathrm{GeV}$$
$$M_{Z'_{\psi}} < 650\ \mathrm{GeV}$$
$$M_{Z'_{I}} < 575\ \mathrm{GeV}$$

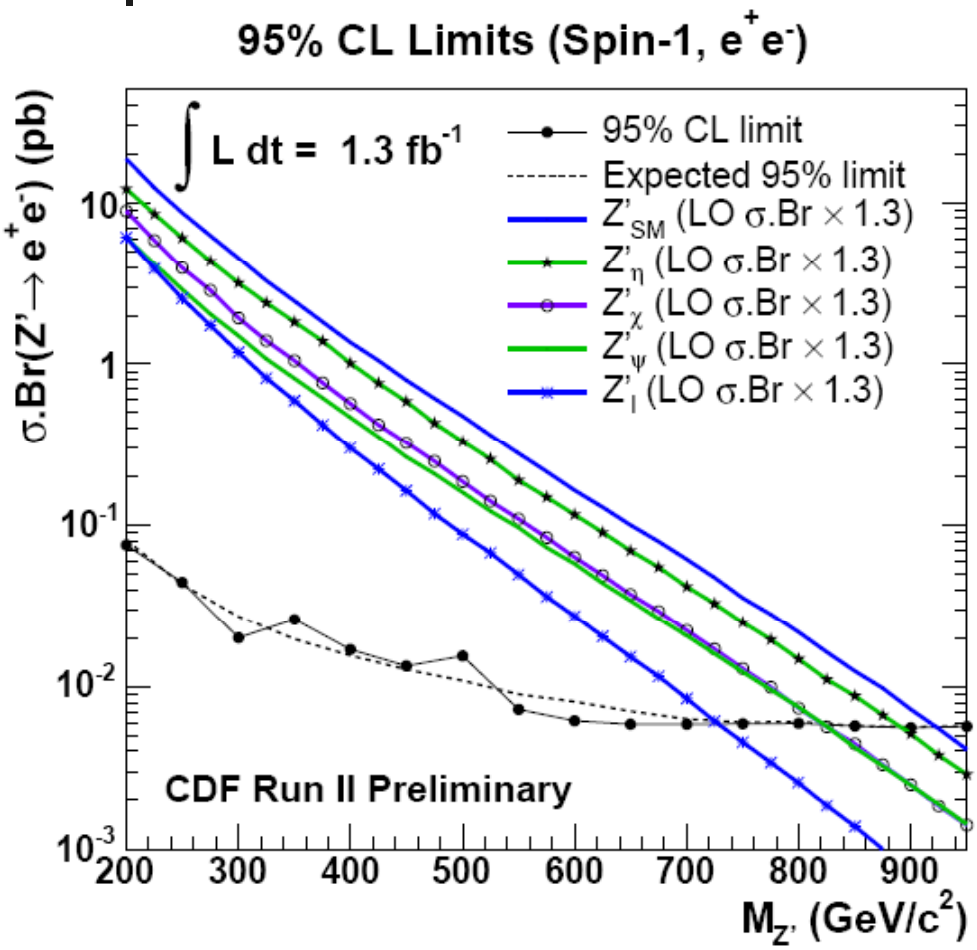
D0 note 4375-CONF



$$\int L\,dt = 250 \pm 16\ \mathrm{pb}^{-1}$$
$$M_{Z'_{SM}} < 680\ \mathrm{GeV}$$

D0 note 4577-CONF

The CDF constraints for high mass di-electron events



$$M_{Z'_{SM}} < 923 \text{ GeV}$$

$$M_{Z'_{\eta}} < 891 \text{ GeV}$$

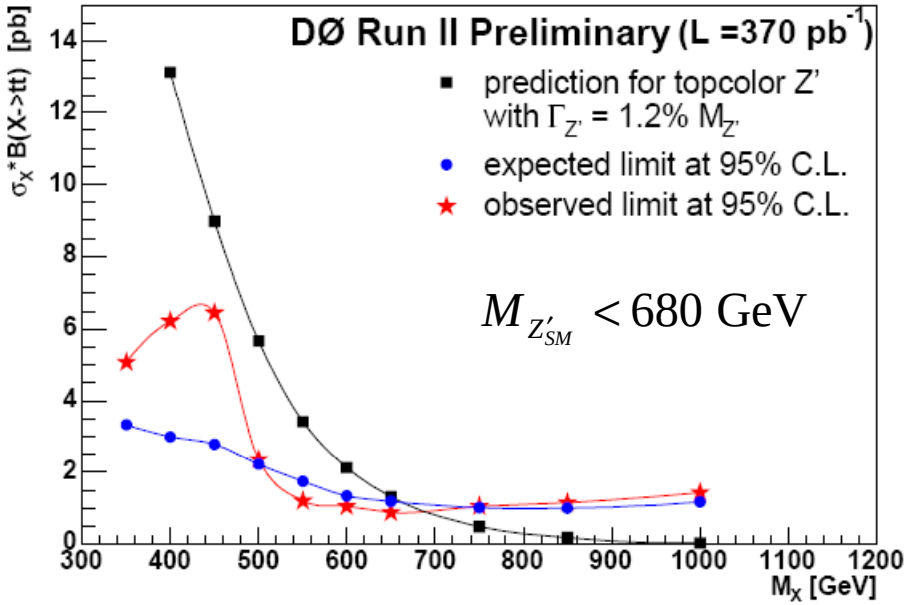
$$M_{Z'_{\chi}} < 822 \text{ GeV}$$

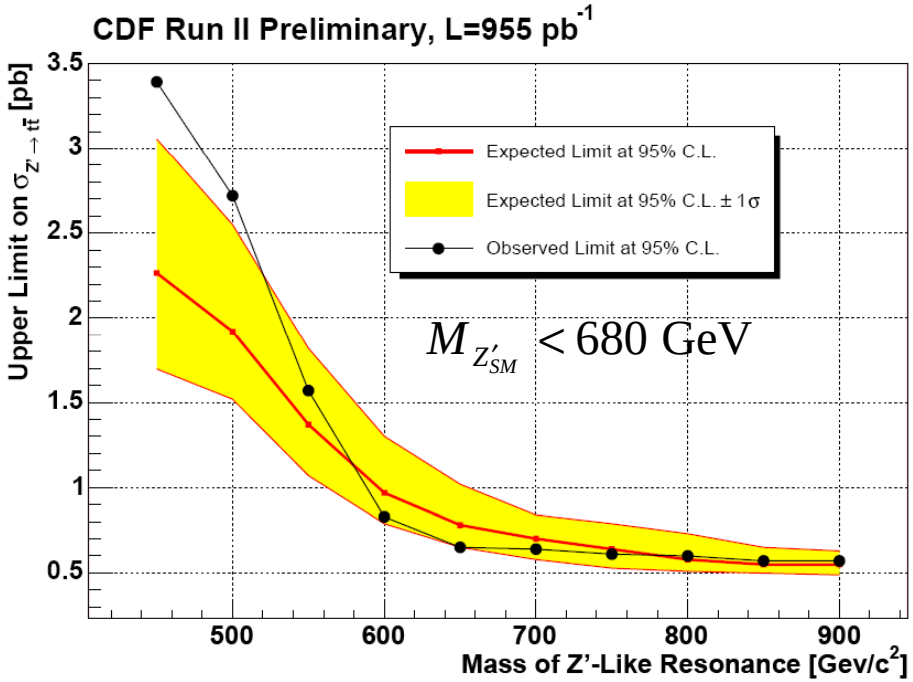
$$M_{Z'_{\psi}} < 822 \text{ GeV}$$

$$M_{Z'_{I}} < 729 \text{ GeV}$$

CDF/PUB/EXOTIC/PUBLIC/8694

Limit on resonant ttbar production

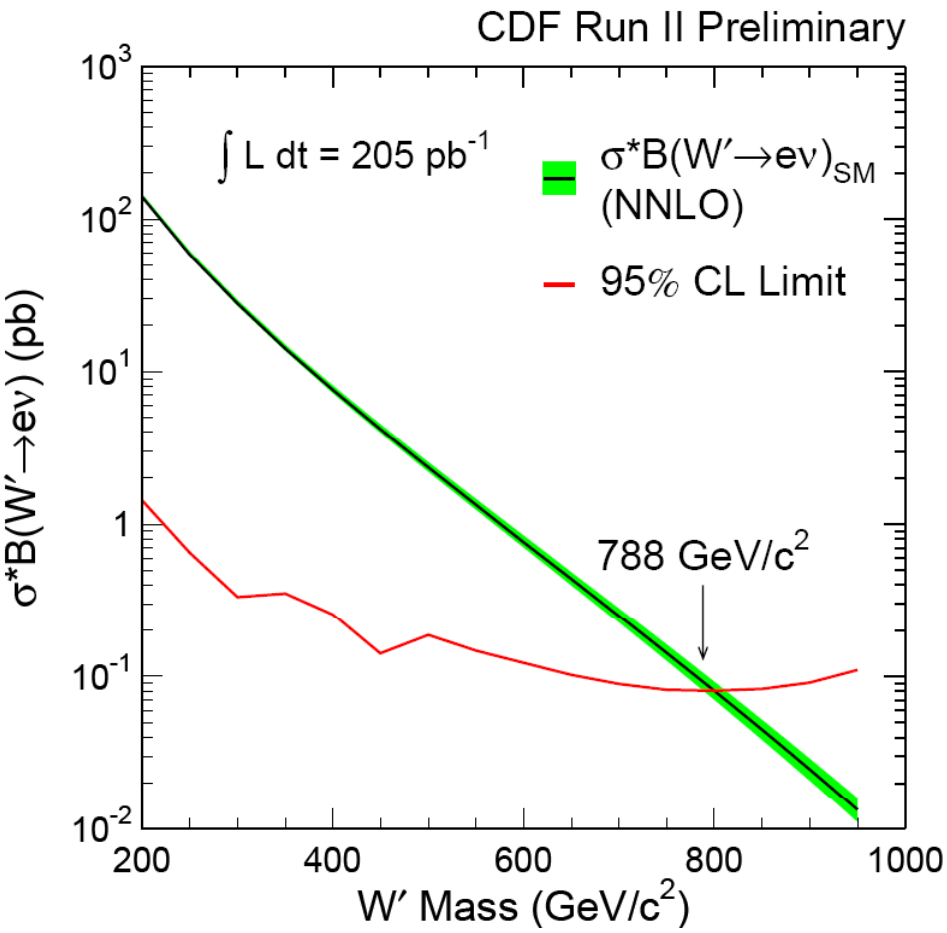


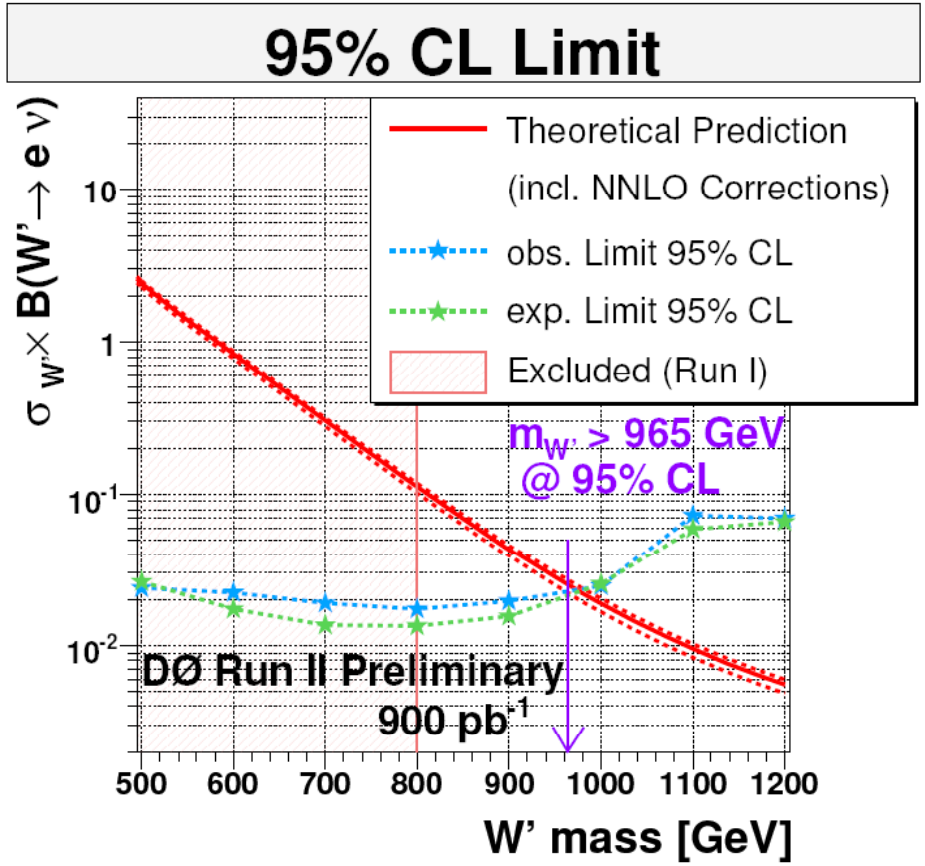


D0 note 4880-CONF

CDF Note 8675

W' Boson decaying to electron-neutrino channel



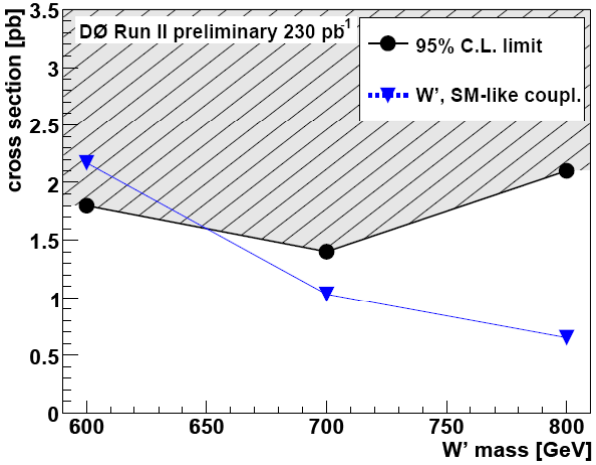


CDF, hep-ex/0611022

D0 Note 5191-CONF

W' Boson Production in the Single Top Quark Channel

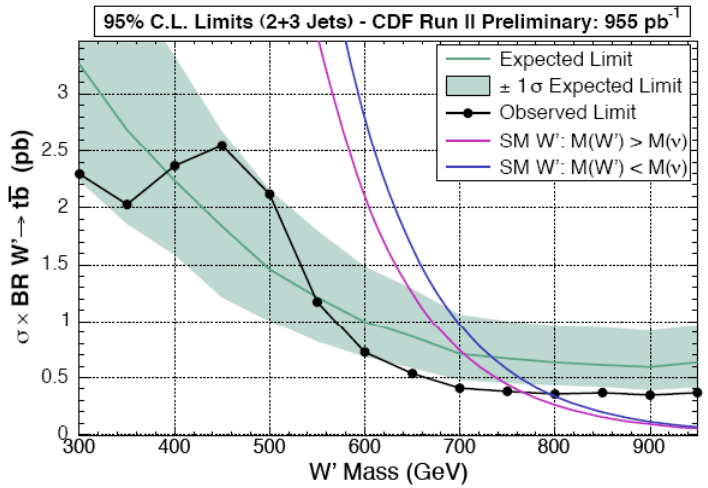
$$200\ \text{GeV} < M_{W'} < 650\ \text{GeV}$$



D0 Note 5024-CONF

$$M_{W'} < 760\ \text{GeV}:\ M_{W'} > M_{\nu R}$$

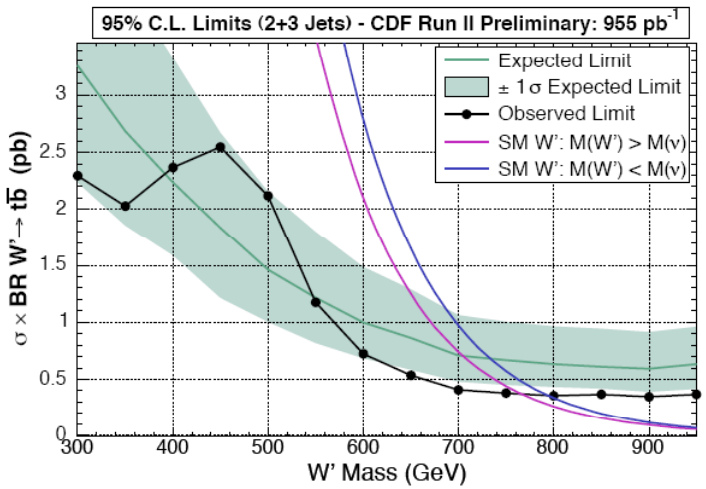
$$M_{W'} < 790\ \text{GeV}:\ M_{W'} < M_{\nu R}$$



CDF Note 8747

Conclusions

In order to produce the heavy charged boson in association with the W boson or the heavy neutral boson one needs a lepton collider with energy above 1 TeV.



New spin-1 Chiral* Bosons

*The first three letters coincide just accidently with the beginning of my family name.

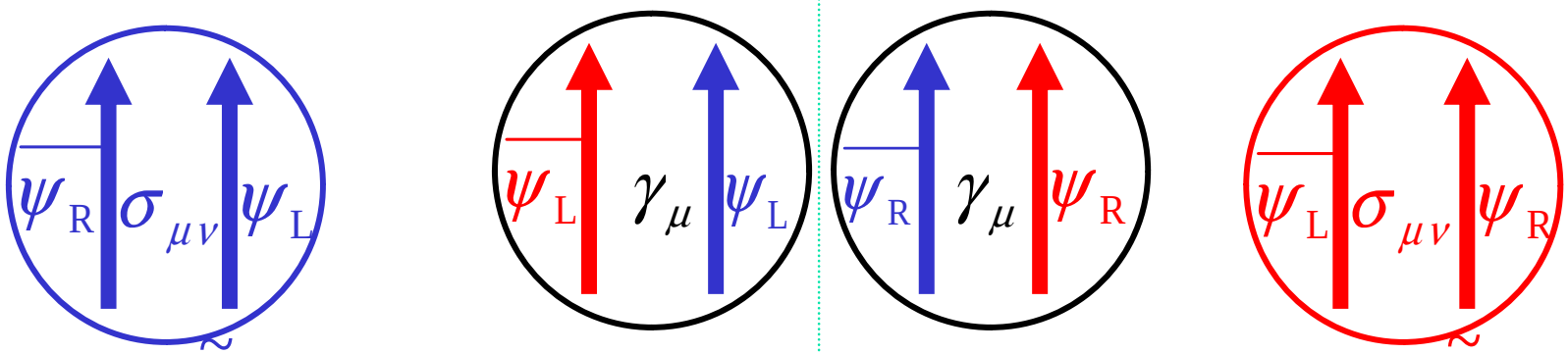
Lorentz group representations

Parity transformation ⟷ Charge conjugation

S=1/2 $(\bar{\psi})_L = \overline{\psi_R}\ \psi_L$ $(\bar{\psi})_R = \overline{\psi_L}\ \psi_R$

(0,1/2) *(1/2,0)*

S=1

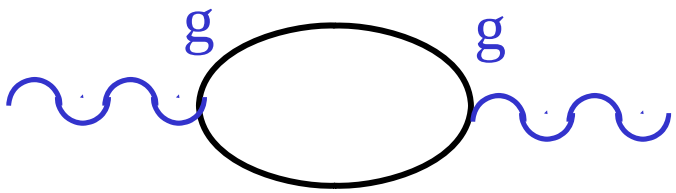


$T_{\mu\nu} - \tilde{T}_{\mu\nu}$ $V_\mu - A_\mu$ $V_\mu + A_\mu$ $T_{\mu\nu} + \tilde{T}_{\mu\nu}$

(0,1) *(1/2,1/2)* *(1/2,1/2)* *(1,0)*

Spin-1 field interactions

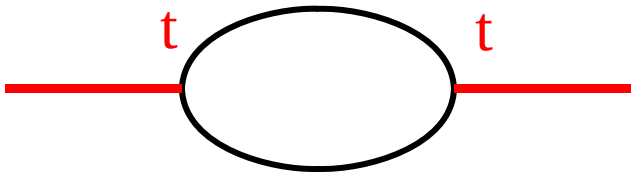
$$g_-\overline{\Psi}\gamma_\mu(1-\gamma_5)\Psi\cdot(V_\mu-A_\mu)+g_+\overline{\Psi}\gamma_\mu(1+\gamma_5)\Psi\cdot(V_\mu+A_\mu)$$



$$\Delta\mathcal{L}_{\text{Maxwell}} \sim -\tfrac{1}{4}F_{\mu\nu}F^{\mu\nu}$$

N. Kemmer, Proc. R. Soc. London, Ser. A166 (1938) 127

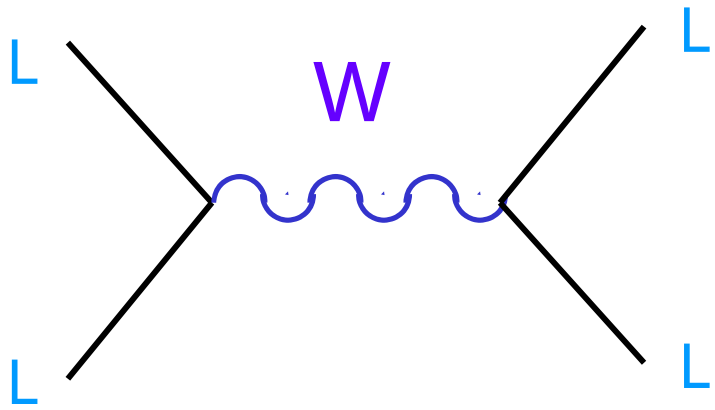
$$t_-\overline{\Psi}\sigma_{\mu\nu}(1-\gamma_5)\Psi\cdot(T_{\mu\nu}-\tilde{T}_{\mu\nu})+t_+\overline{\Psi}\sigma_{\mu\nu}(1+\gamma_5)\Psi\cdot(T_{\mu\nu}+\tilde{T}_{\mu\nu})$$

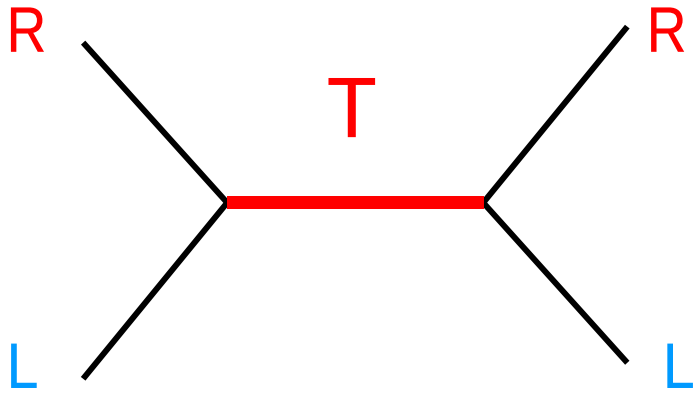


$$\Delta\mathcal{L} \sim \tfrac{1}{4}\partial_\lambda T^{\mu\nu}\partial^\lambda T_{\mu\nu} - \partial_\mu T^{\mu\lambda}\partial^\nu T_{\nu\lambda}$$

V. K. Dobrev, E. H. Christova, V. B. Petkova and D. B. Stamenov, *Conformal covariant OPE of two spin ½ fields*, JINR E2-7456 (1973); see also *U(N)-extended conformal supergravities*

EW physics



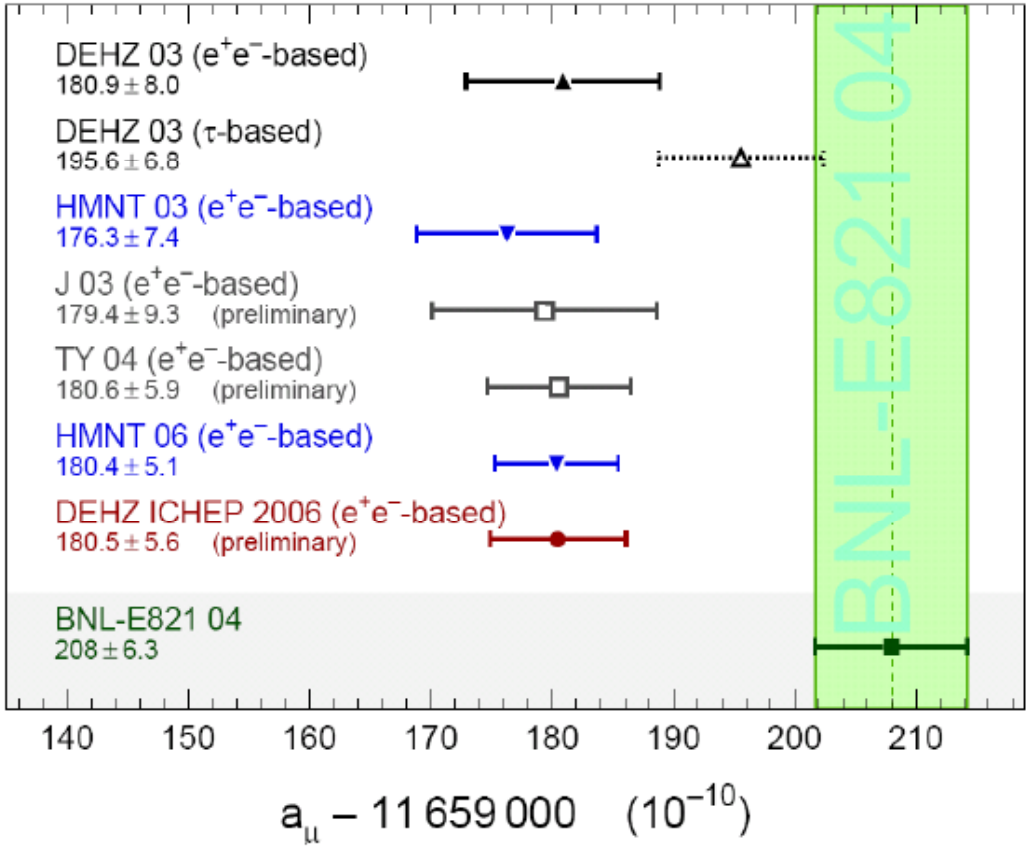


$G_F \sim (g/M_W)^2$ $\qquad$ $G_T \sim (t/M_T)^2 \sim 10^{-2}\, G_F$

M.C., Phys. Part. Nucl. Lett. 2 (2005) 193

if $t \sim g$: $\qquad$ $M_T \sim 10\, M_W$

Status of g_μ-2

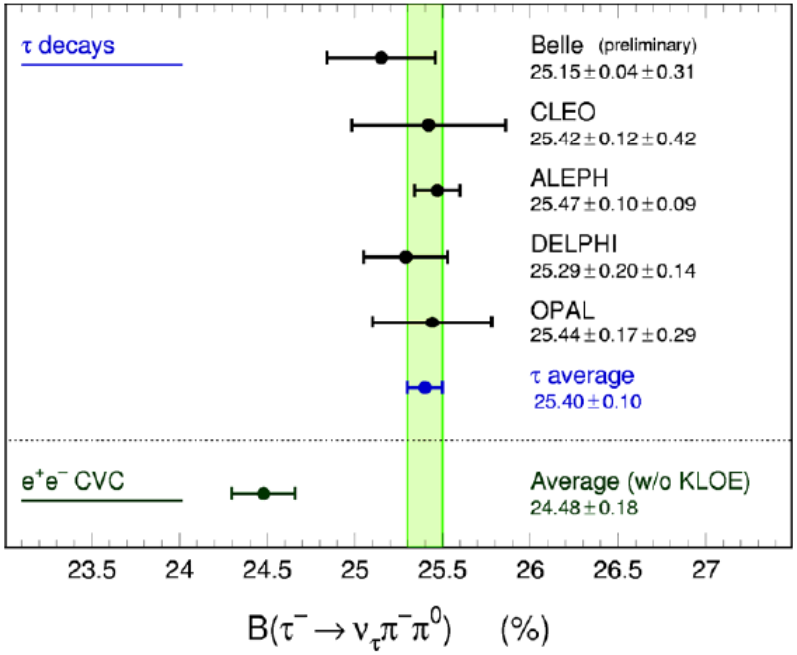


Whereas τ based prediction agrees with the measurement within 1σ
all recent e+e- based predictions have a deviation with data at over 3σ

$\tau^- \to \nu\, \rho^- \to \nu\, \pi^-\, \pi^0$

The additional tensor contribution leads to excess of ρ meson production with respect to CVC predictions:

$(Br^{exp} - Br^{CVC})/Br^{CVC} = 5.5\%$ M.C. hep-ph/0311360



This value is in good agreement with $6.2 \pm 1.4\%$ derived from the older e^+e^- data and does not contradict $3.8 \pm 1.4\%$ when the new CMD-2 data are used.

Difference: BR[τ] - BR[e^+e^- (CVC)]:

Mode	$\Delta(\tau - e^+e^-)$	Sigma
$\tau^- \to \pi^- \pi^0 \nu_\tau$	+ 0.92 ± 0.21	4.5

From M.Davier, hep-ph/0701163

Extension of the SM

M.C., Mod. Phys. Lett. A **8** (1993) 2753

$$\begin{pmatrix} H_1^+ \\ H_1^0 \end{pmatrix} \quad \begin{pmatrix} H_1^- \\ \bar{H}_1^0 \end{pmatrix} \qquad \begin{pmatrix} H_2^+ \\ H_2^0 \end{pmatrix} \quad \begin{pmatrix} H_2^- \\ \bar{H}_2^0 \end{pmatrix}$$

$$\boxed{\begin{pmatrix} U^+ \\ U^0 \end{pmatrix} \quad \begin{pmatrix} U^- \\ \bar{U}^0 \end{pmatrix} \qquad \begin{pmatrix} T^+ \\ T^0 \end{pmatrix} \quad \begin{pmatrix} T^- \\ \bar{T}^0 \end{pmatrix}}$$

M.C., hep-ph/0609141

$$M_{U^\pm} \approx 509\ \text{GeV}, \quad M_{U^0} \approx 719\ \text{GeV}, \quad M_{T^0} \approx 1017\ \text{GeV}, \quad M_{T^\pm} \approx 1137\ \text{GeV}$$

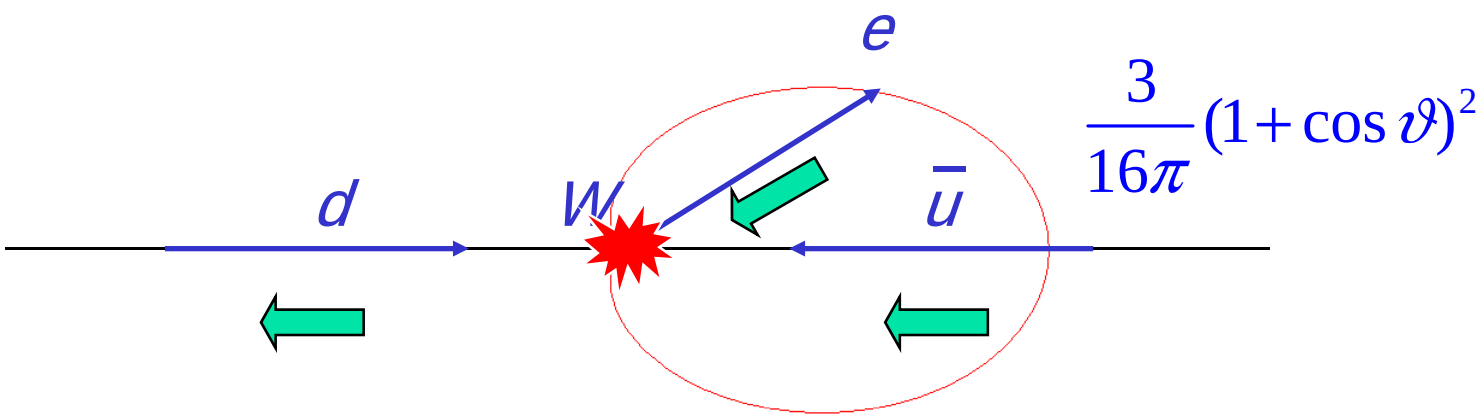
$$1 \quad : \quad \sqrt{2} \quad : \quad 2 \quad : \quad \sqrt{5}$$

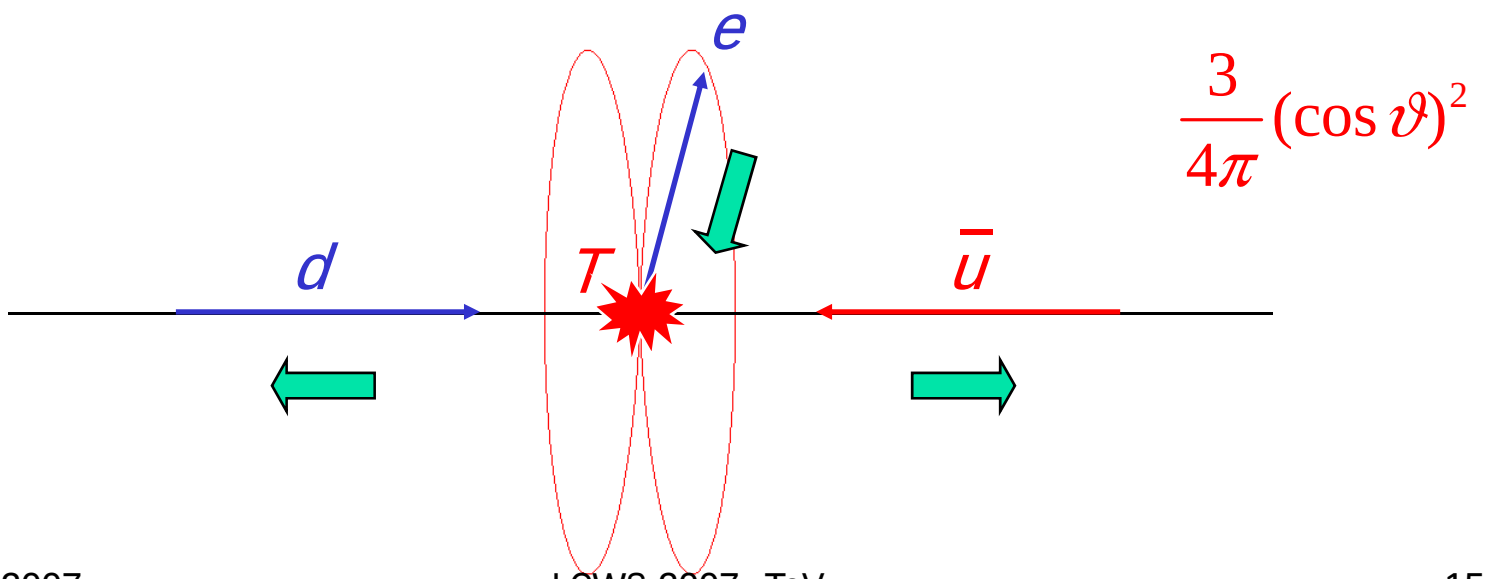
$$\Gamma(U^\pm \to \ell\nu) \approx 360\ \text{MeV}, \quad \Gamma(U^0 \to \ell^+\ell^-) = 0, \quad \Gamma(T^0 \to \ell^+\ell^-) \approx 2.9\ \text{GeV}$$

$$\Gamma_{\text{tot}}(U^\pm) \approx 17.2\ \text{GeV}, \qquad \Gamma_{\text{tot}}(T^0) \approx 34\ \text{GeV}$$

$$\Gamma(U^\pm \to \ell\nu)/\Gamma_{\text{tot}}(U^\pm) \approx 2\%, \qquad \Gamma(T^0 \to \ell^+\ell^-)/\Gamma_{\text{tot}}(T^0) \approx 8\%$$

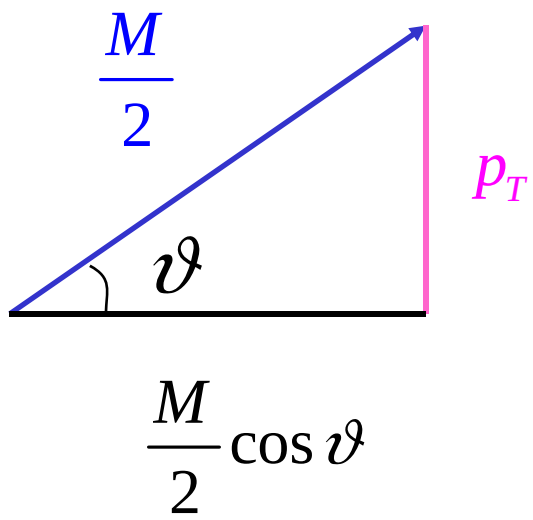
Angular distributions

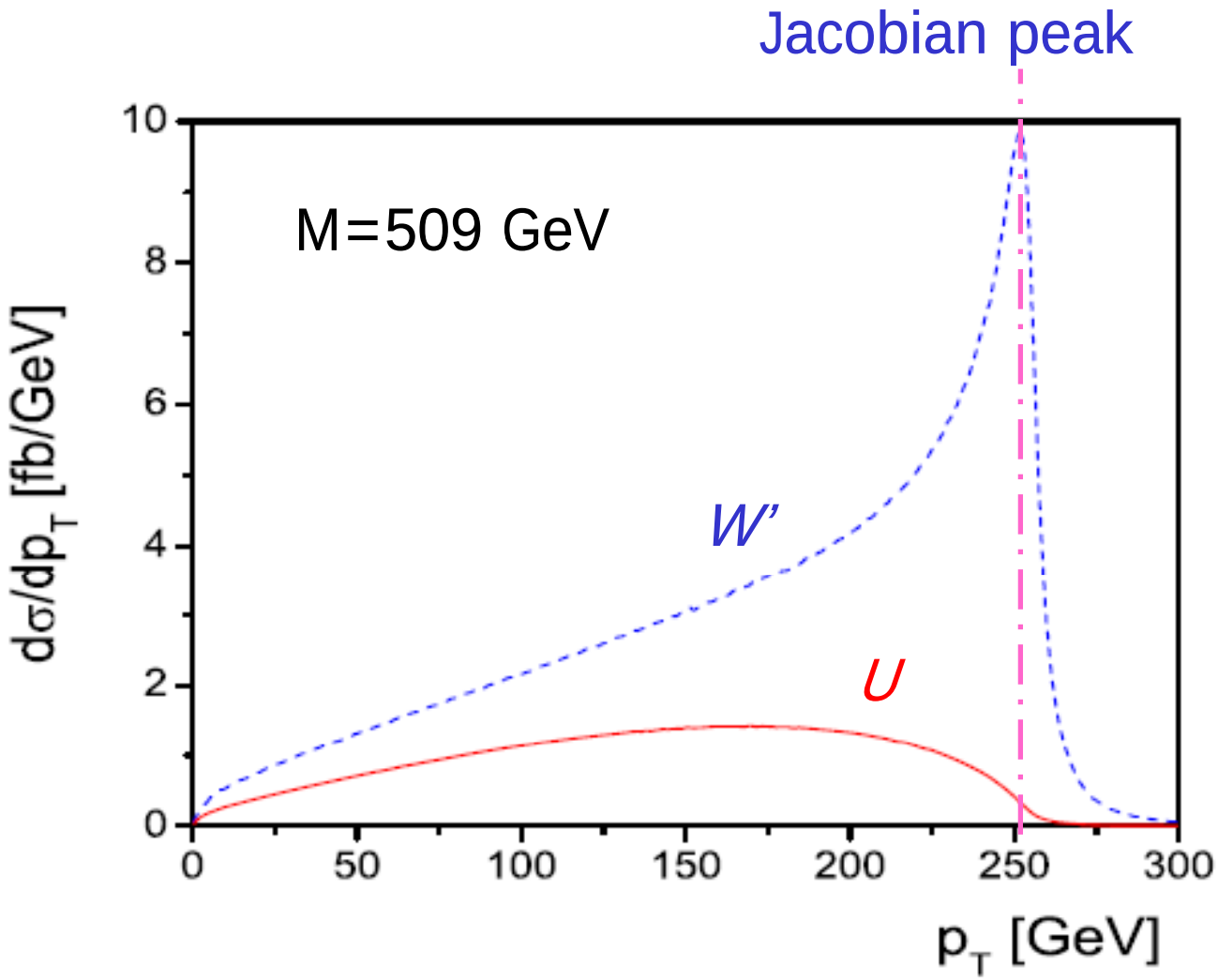




$$\frac{d\sigma}{dp_T^2} = \left|\frac{d\cos\vartheta}{dp_T^2}\right| \cdot \frac{d\sigma}{d\cos\vartheta} = \frac{2}{M^2\cos\vartheta} \cdot \frac{d\sigma}{d\cos\vartheta}$$

$$\cos\vartheta = \sqrt{1 - 4p_T^2 / M^2}$$



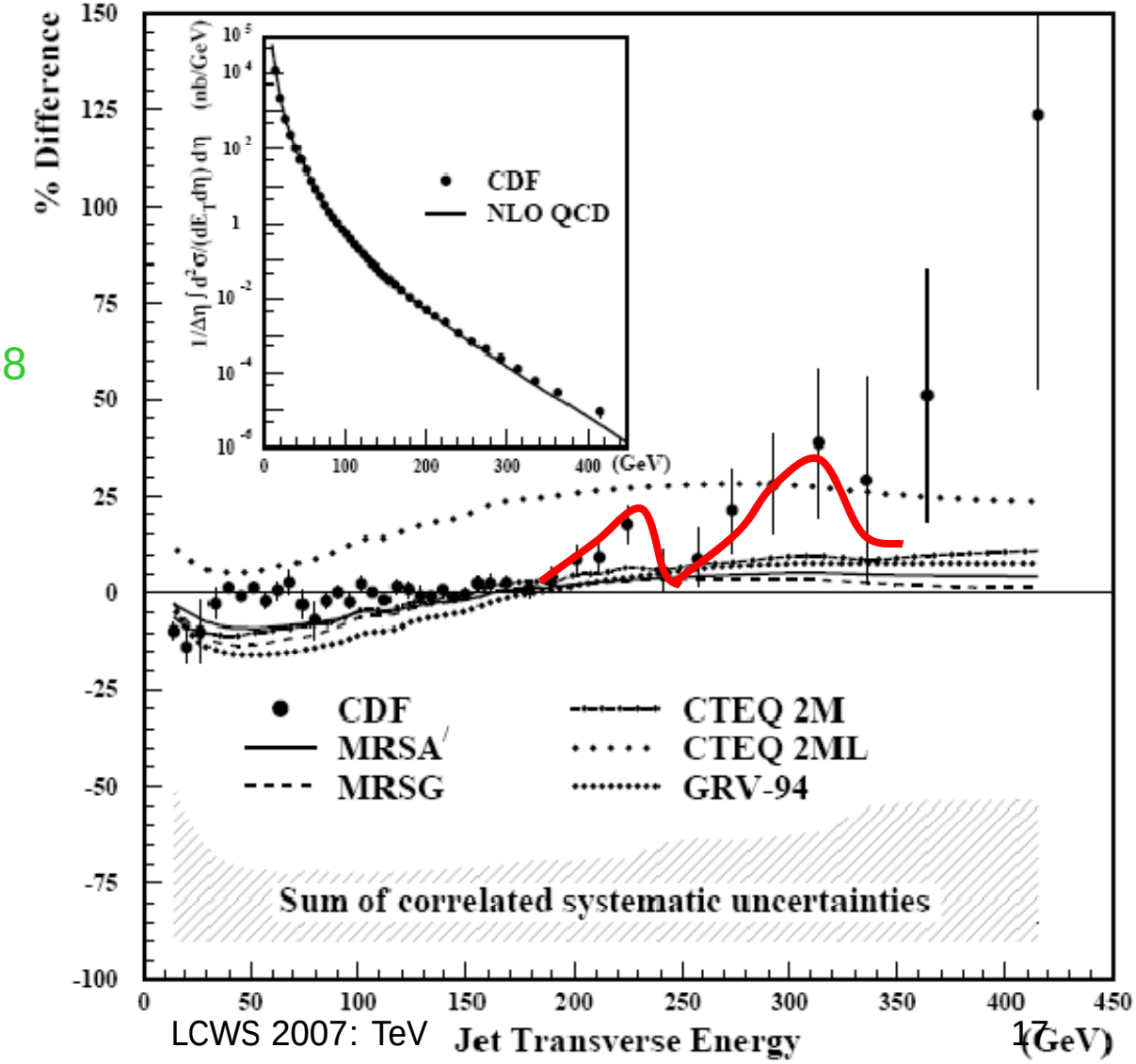


Tevatron

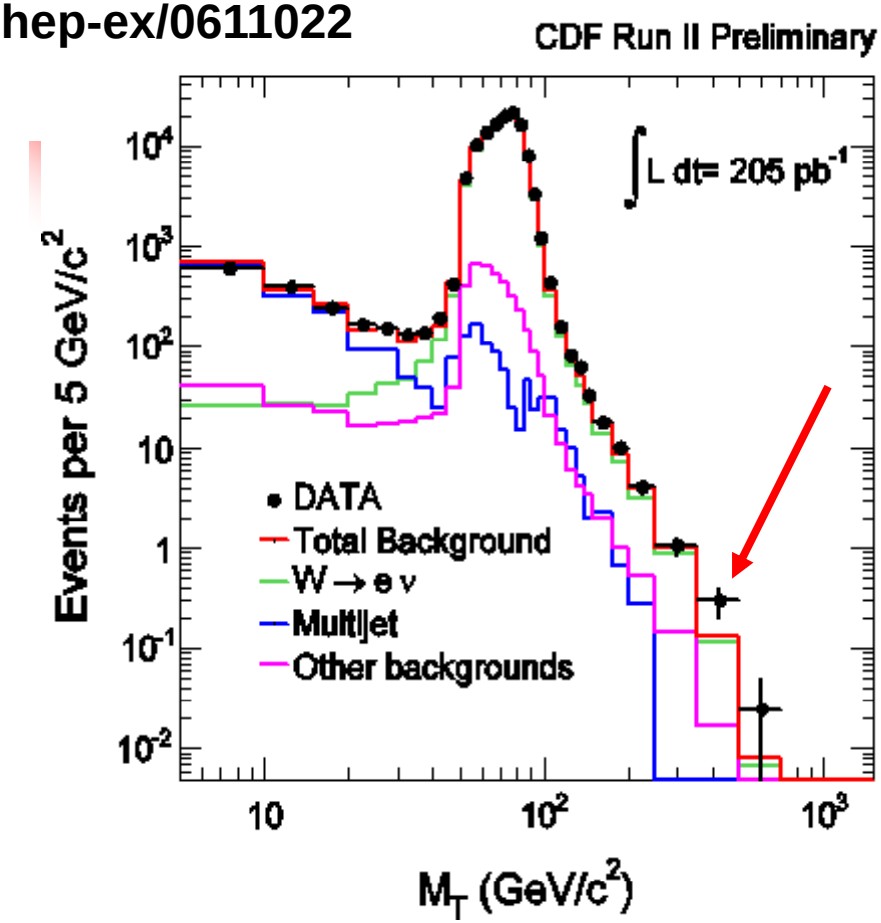
F. Abe *et al.*,
Phys. Rev. Lett. **77** (1996) 438

$$M_{U^{\pm}} \approx 509 \text{ GeV}$$

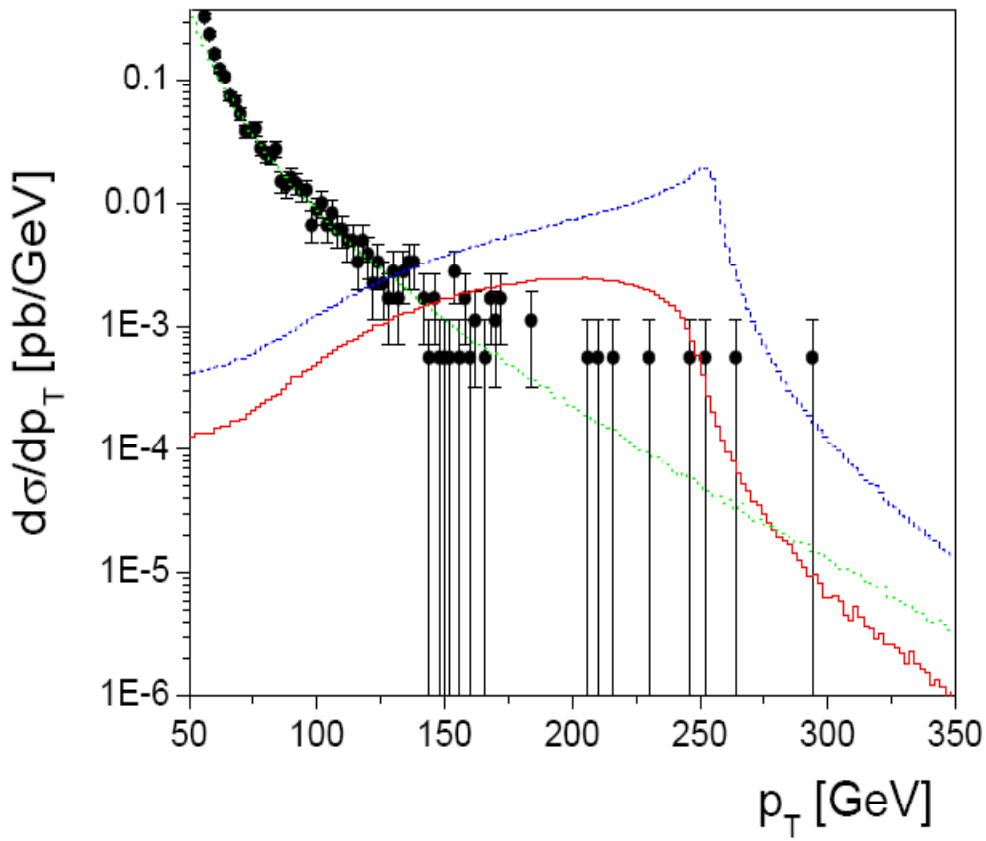
$$M_{U^{0}} \approx 719 \text{ GeV}$$



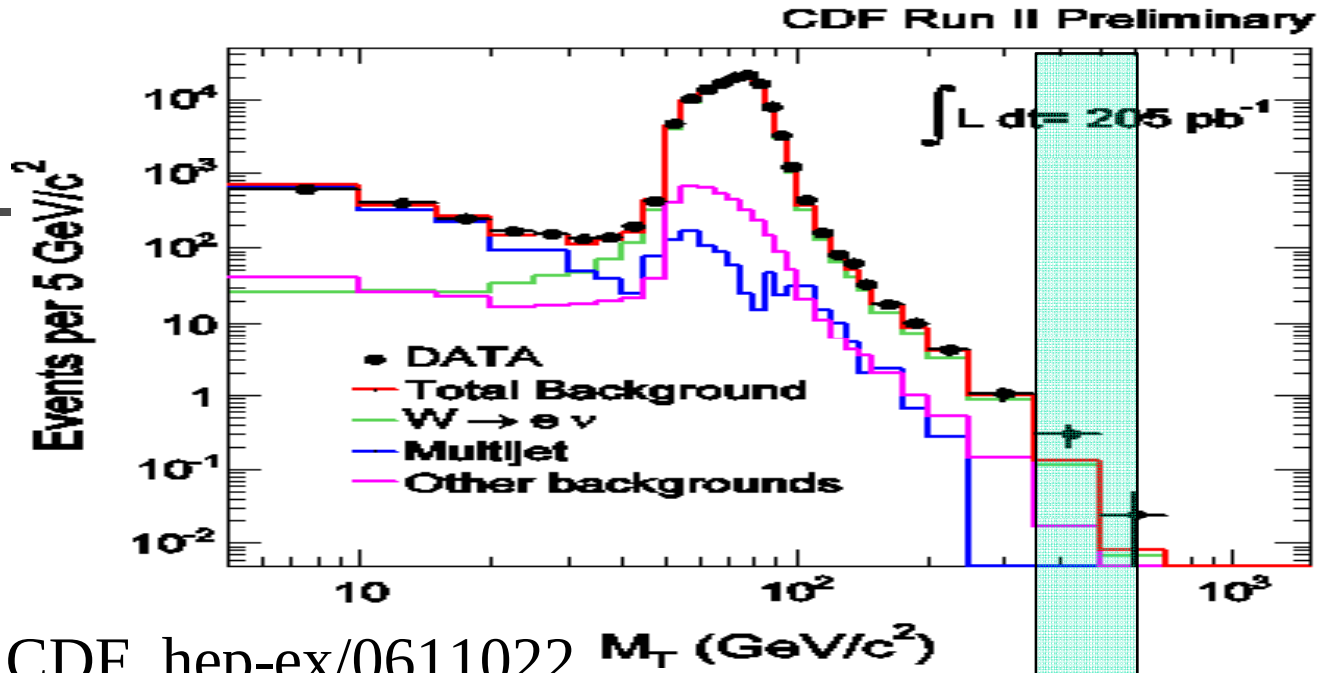
hep-ex/0611022



D0 note 5191-CONF 900 pb^{-1}

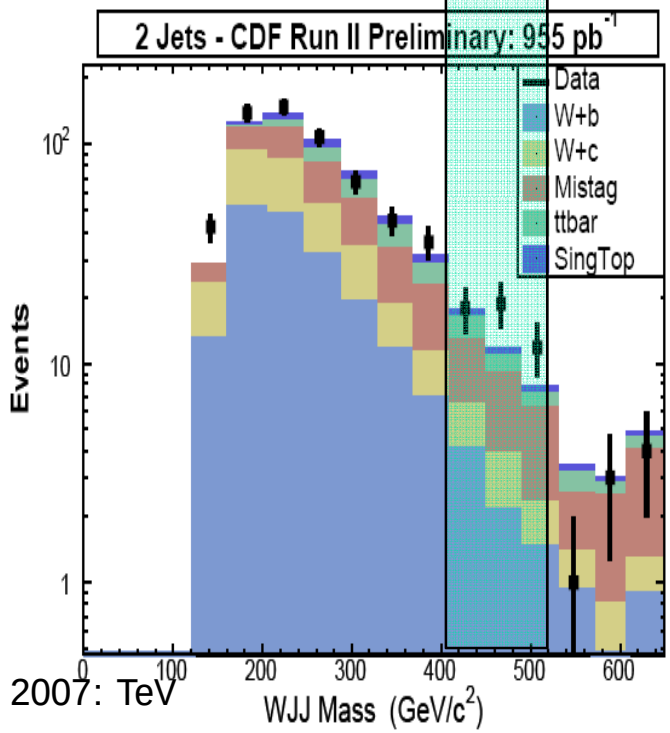


	Events in Each M_T Bin (GeV/c^2)				
	200 - 250	250 - 350	350 - 500	500 - 700	700 - 1000
$W \to e\nu$	30.8 ± 5.7	17.0 ± 4.0	3.52 ± 1.70	0.27 ± 0.45	0.00 ± 0.00
Multijet	2.7 ± 6.1	0.0 ± 3.3	0.00 ± 0.29	0.00 ± 0.01	0.00 ± 0.00
Other Backgrounds	5.2 ± 1.0	3.0 ± 0.9	0.51 ± 0.22	0.06 ± 0.08	0.00 ± 0.03
Total Background	38.7 ± 8.9	20.0 ± 5.9	4.03 ± 1.97	0.33 ± 0.53	0.01 ± 0.03
Data	41	21	9	1	0



CDF, hep-ex/0611022

$p\bar{p} \rightarrow X + V \rightarrow e\nu$



CDF note 8747

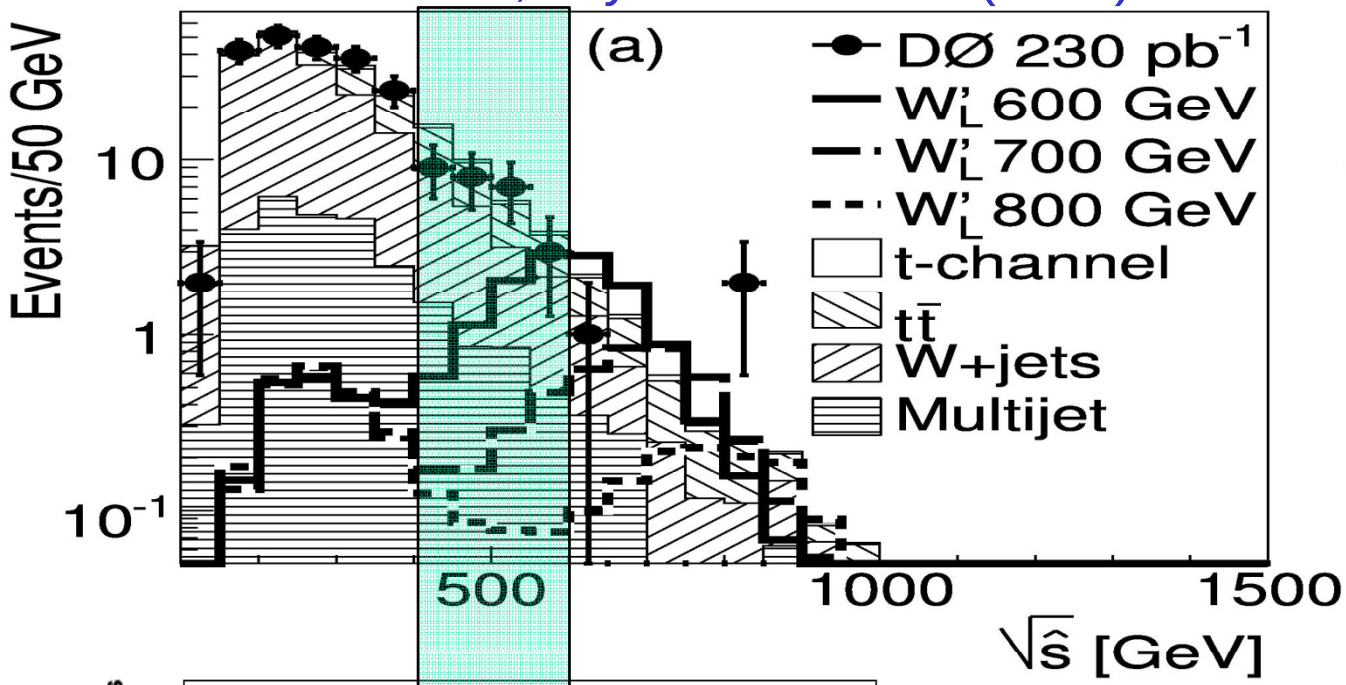
$p\bar{p} \rightarrow X + V \rightarrow t\bar{b}$

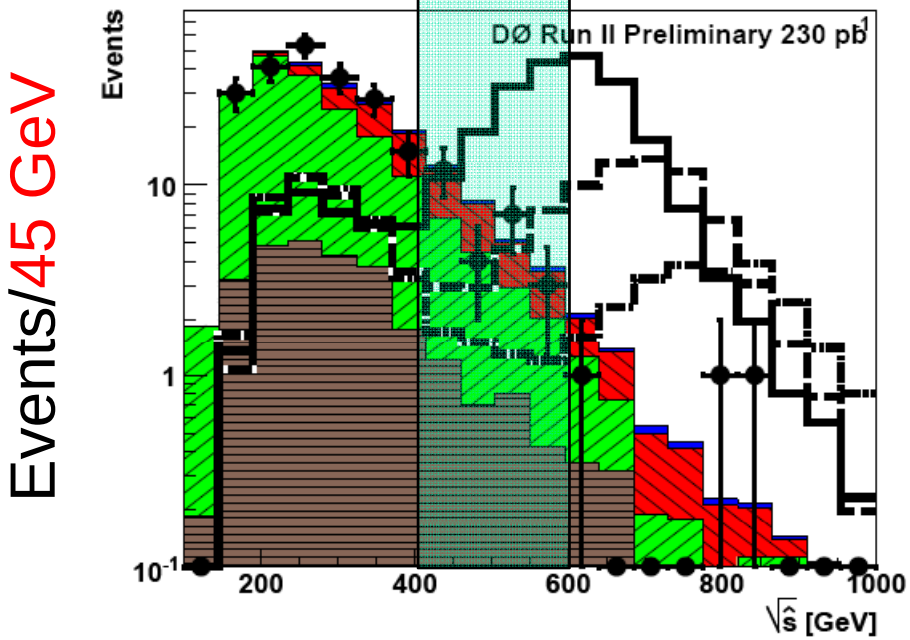
Conclusions

"A small excess of events with a significance 1.8 standard deviations above the background expectation is observed in the 350–500 GeV/c^2 M_T bin." [hep-ex/0611022]

"There is a slight excess over expectation observed in the region near 450-500 GeV/c^2.
The 2-jet bin at approximately 475 GeV/c^2 shows an excess.
Since the predictions in the neighboring bins agree with the observation, and since the three jet bin does not show a similar excess, we anticipate that the excess in this region is a statistical fluctuation." [CDF note 8747]

D0 Coll., Phys. Lett. B **641** (2006) 423



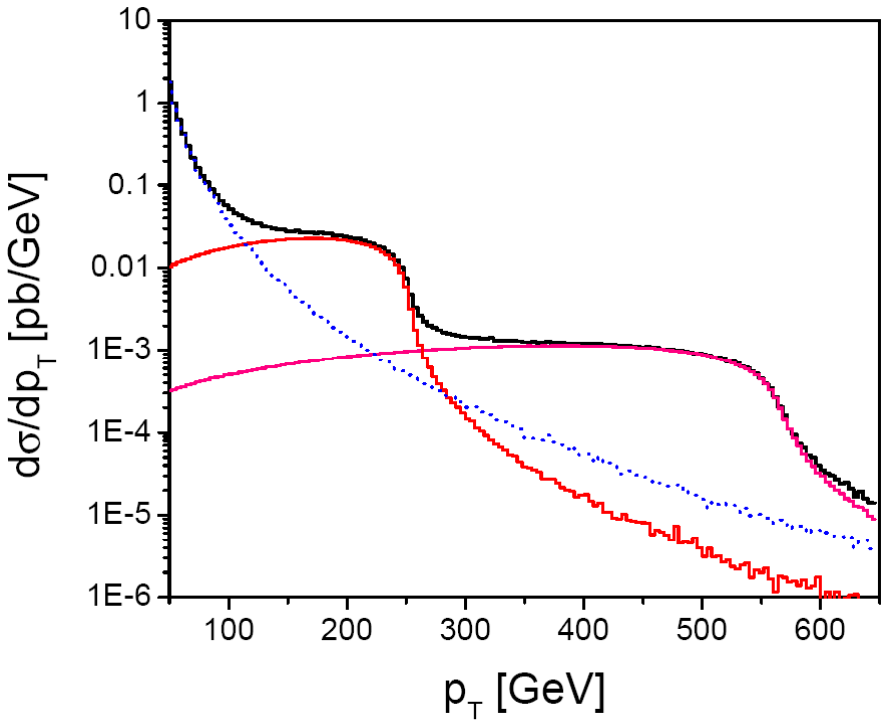


$t\bar{b}$ channel

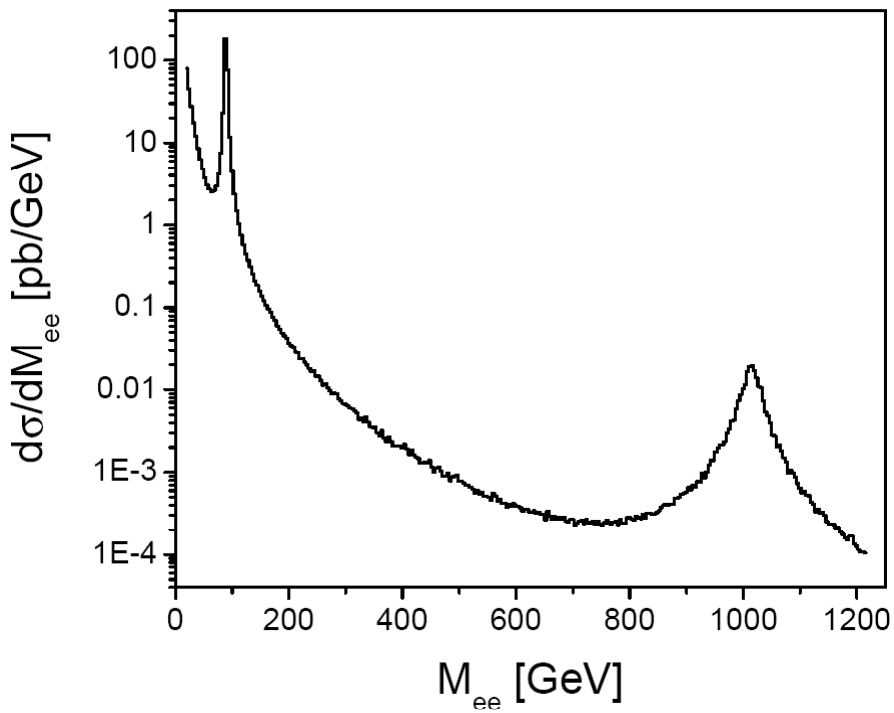
D0 note 5024-CONF

Large Hadron Collider

$$pp \to e\not{E}_T$$



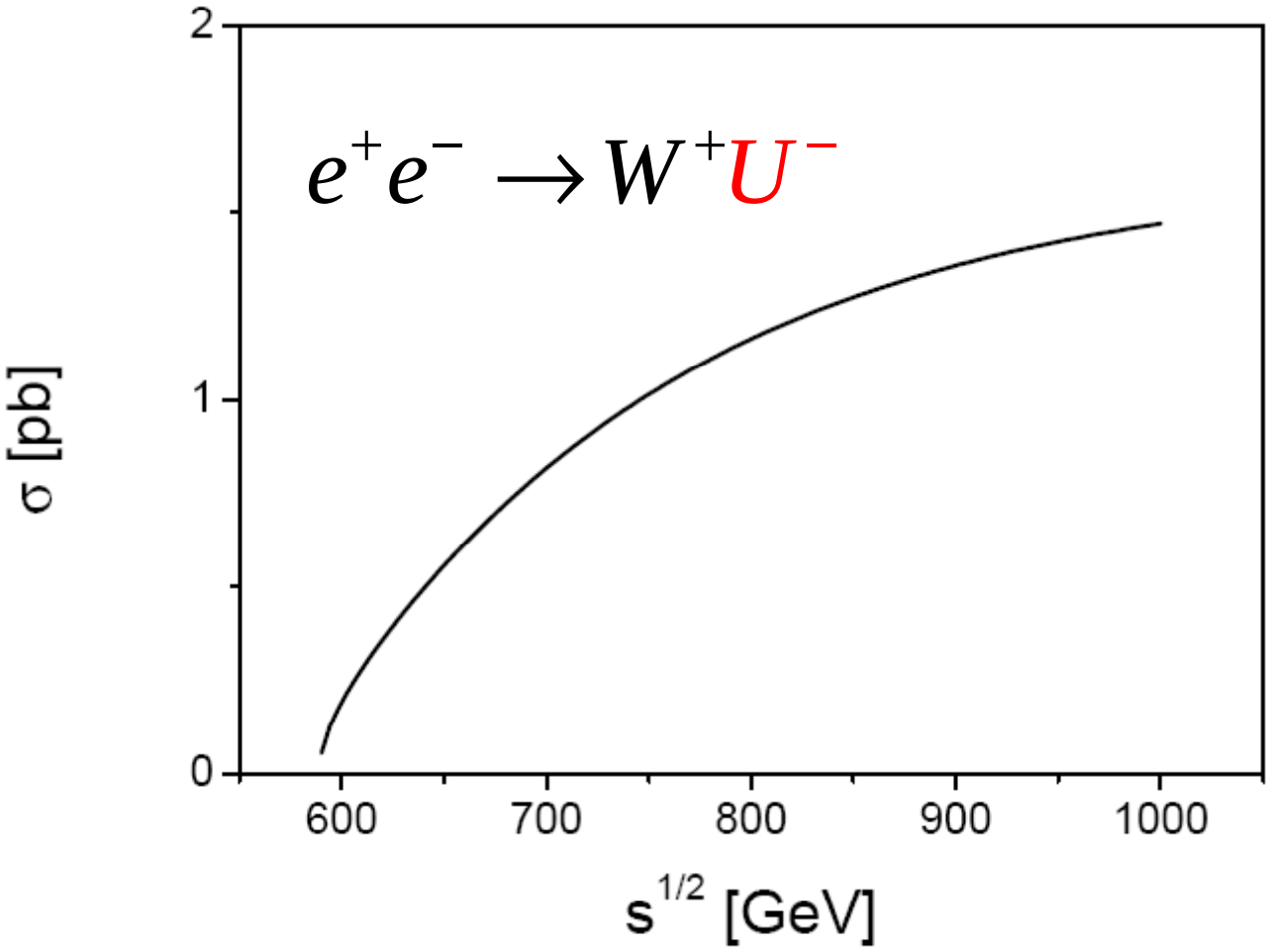
$$pp \to e^+e^-$$



Conclusions

- There are some hints of the existence of the lightest charged chiral boson with a mass around 500 GeV in the Tevatron data.
- In the positive case the LHC would be able to discover all predicted charged and neutral chiral bosons spanning in mass up 1 TeV.
- The ILC with such energy would be an ideal place to produce and to study these particles.

Chiral boson production at ILC



Production cross-sections

$\sigma_{U^{\pm}}^{\mathrm{Tev}} \approx 11.7\ \mathrm{pb};$ $\sigma_{U^{+}}^{\mathrm{LHC}} \approx 360\ \mathrm{pb},\quad \sigma_{U^{-}}^{\mathrm{LHC}} \approx 190\ \mathrm{pb}$

$L^{\mathrm{Tev}} = 1/\mathrm{fb}:\quad 24\ \mathrm{Kevents}$

$\sigma_{e^{\pm}}^{\mathrm{Tev}} \approx 0.24\ \mathrm{pb};$ $\sigma_{e^{+}}^{\mathrm{LHC}} \approx 7.5\ \mathrm{pb},\quad \sigma_{e^{-}}^{\mathrm{LHC}} \approx 4\ \mathrm{pb}$

$L^{\mathrm{Tev}} = 1/\mathrm{fb}:\quad 480\ \mathrm{events};$ 1 event every 10 seconds

$$\sigma_{e^{+}e^{-}}^{\mathrm{LHC}} = \sigma_{T^{0}}^{\mathrm{LHC}} B(T^{0} \to e^{+}e^{-}) \approx 1\ \mathrm{pb}$$

1 event every 50 seconds