Z-prime physics at colliders

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Anomalies

$$\sum_{\text{left}} \text{Tr}\left(T^a\{T^b, T^c\}\right) - \sum_{\text{right}} \text{Tr}\left(T^a\{T^b, T^c\}\right) = 0 \qquad (1)$$

- $SU(3)_c^2 U(1)_{z'}$ $\qquad SU(2)_w^2 U(1)_{z'}$
- $U(1)_Y^2 U(1)_{z'}$ $\qquad U(1)_Y U(1)_{z'}^2$
- $U(1)_{z'}^3$
- $1^2 U(1)_{z'}$

For SM fermions only $U(1)_{z'}$ is not consistent with anomaly cancellation [Appelquist,Bogdan,Dobrescu and Hopper: 2002]

Z's appear naturally in extension models [Robinett1981,Robinett1982,Langacker1984]

$$SO(10) \longrightarrow SU(5) \times U(1)_\chi, \qquad (2)$$

or

$$E6 \longrightarrow SO(10) \times U(1)_\psi. \qquad (3)$$

In general we consider models of the form [Erler and Langacker: 2002]

$$Z' = \cos\alpha \cos\beta Z_\chi + \sin\alpha \cos\beta Z_Y + \sin\beta Z_\psi \qquad (4)$$

E_6 Allowed breakdown chains [Slansky 1981]

$$E_6 \longrightarrow SO(10) \times U(1)$$
$$E_6 \longrightarrow SU(3) \times SU(3) \times SU(3)$$
$$E_6 \longrightarrow SU(2) \times SU(6)$$
$$E_6 \longrightarrow F4 \rightarrow SO(9)$$

Allowed breakdown chains $E_6 \to U(1) \times SO(10)$

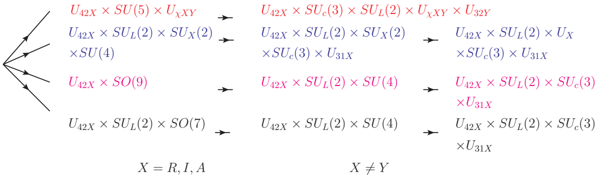


Figure: Jens Erler and E.R Work in progress

$$
\begin{aligned}
E_6 &\to U_{\psi *}(1) \times SO(10) \to U_{\psi *}(1) \times U_N(1) \times SU(5) \\
&\to U_{\psi *}(1) \times U_N(1) \times SU(3)_c \times SU_L(2) \times U_Y(1)
\end{aligned} \tag{5}
$$

E_6 Z' classification
Jens Erler and E.R Work in progress

$$\text{The } Z_N \text{ model is an alternative model for } Z_\chi\text{!!!} \tag{6}$$

Every model in E_6 could have (at most) six alternative models

Low energy constrains: $v_{eff} \sim v_i + (g_1/g_2)\theta_{ZZ'} v'$ $a_{eff} \sim a_i + (g_1/g_2)\theta_{ZZ'} a'$

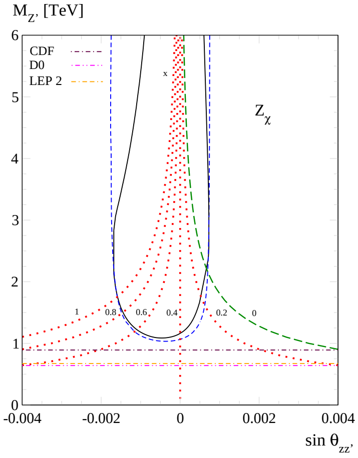


Figure: Jens Erler, Paul Langacker, Shoaib Munir and E.R, 2009

constrains coming from LR asymmetries

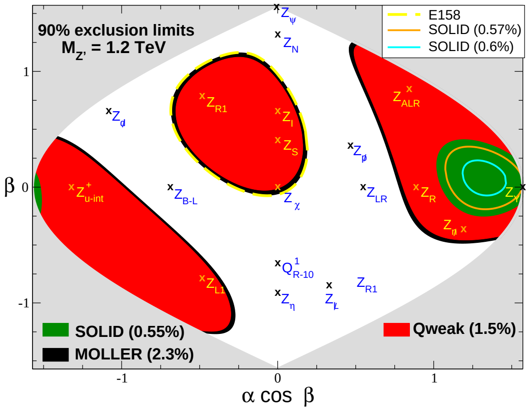


Figure: Jens Erler and E.R, work in progress

CDF experiment Search of high-mass resonances Decaying to dimuons at CDF

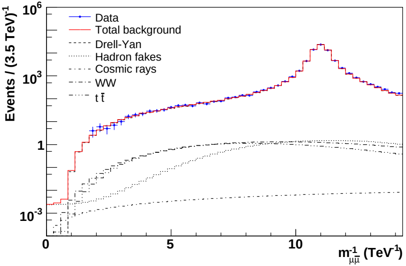
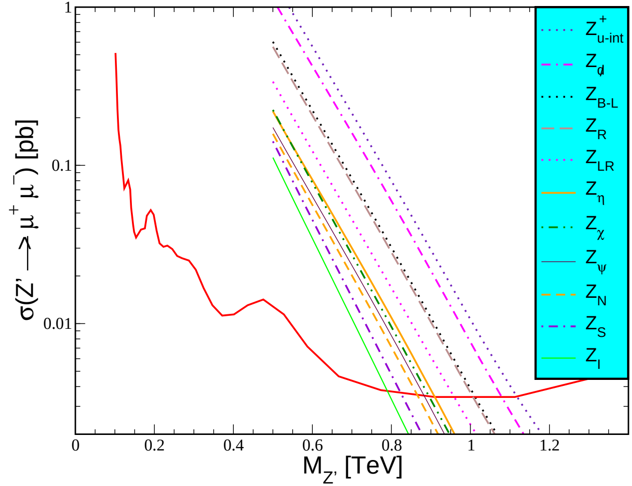


Figure: The distrubution of $m^{-1}_{\mu\bar{\mu}}(\mathrm{TeV}^{-1})$ for the observed data [cdf: 2009]

95% C.L. limits on the signal cross section [CDF: 2009]



CDF bounds mass limits

Model	$m_{Z'}^{lim}$ (GeV)	$m_{Z'}^{m_t}$	$m_{Z'}^{CDF}$	$m_{Z'}^{EW}$ [1]
Z'	this work	CDF	electroweak	projection
Z_χ	895	892	1141	1062
Z_ψ	883	878	147	1040
Z_η	910	904	427	1064
Z_I	789	789	1204	945
Z_N	865	861	623	1024
Z_S	823	821	1257	985
Z_R	1006		442	1190
Z_{B-L}	1012		546	1192
Z_{LR}	959		998	1149
$Z_{\not d}$	1079		472	1250
Z_{u-int}^{+}	1117		762	1298
Z_{SM}	1030	1030	1403	1278

Table: Jens Erler, Paul Langacker, Shoaib Munir and E.R, arXiv:1103.2659 [hep-ph]

[1] J.Erler,P.Langacker,S.Munir and ER (2009)

CDF bounds

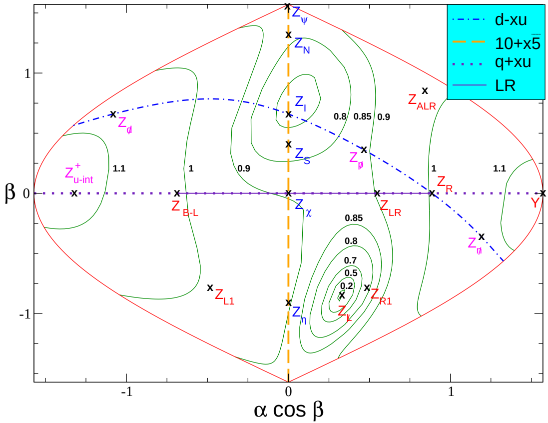


Figure: Jens Erler, Paul Langacker, Shoaib Munir and E.R, arXiv:1103.2659 [hep-ph]

Bayesian Analysis
bin-to-bin event migration effects

$$\Delta\chi_i^2 = \mathrm{LLR}_i = 2\left(\nu_i' - \nu_i + n_i \ln \frac{\nu_i}{\nu_i'}\right),$$

The number of events for bin is:

$$\nu_i = \epsilon\left[\mathcal{L}\int_{\mathrm{bin}} dm_{\mu\mu}^{-1}\, A(m_{\mu\mu}) \int_0^\infty dM_{\mu\mu}^{-1}\, p(m_{\mu\mu}^{-1}|M_{\mu\mu}^{-1})\, K^{2/1} K_\gamma \frac{d\sigma^{\mathrm{NLO}}}{dM_{\mu\mu}^{-1}} + \nu_{n\mathrm{DY}}\right],$$

where $\mathcal{L} = 2.3\ \mathrm{fb}^{-1}$ is the integrated luminosity, ϵ is the detector efficiency, $\nu_{n\mathrm{DY}}$ refers to the non-DY background, $A(m_{\mu\mu})$ is the total acceptance of the CDF detector, and fsr are the final state radiation effects.

NLO cross-section

The NLO differential cross-section at a $p\bar{p}$ collider for the Drell-Yann process with a neutral gauge boson γ, Z, Z' as mediator, is given as

$$\frac{d\sigma}{dM^2}(p\bar{p} \to (\gamma, Z, Z')X \to l^+l^-X) \tag{7}$$

$$= \frac{1}{N_c s}\int dz dx_1 \frac{1}{x_1 z}\theta\left(1 - \frac{1}{x_1 z r_z^2}\right)\sum_q \hat{\sigma}(q\bar{q} \longrightarrow l\bar{l})(M^2)$$

$$\times\left[\left\{f_q^A(x_1, M^2) f_{\bar{q}}^B(x_2, M^2) + f_{\bar{q}}^A(x_1, M^2) f_q^B(x_2, M^2)\right\}\right.$$

$$\left.\times\left(\delta(1-z) + \frac{\alpha_s(M^2)}{2\pi}D_q(z)\right) + \cdots\right],$$

log-likelihood ratio (LLR) confidence levels

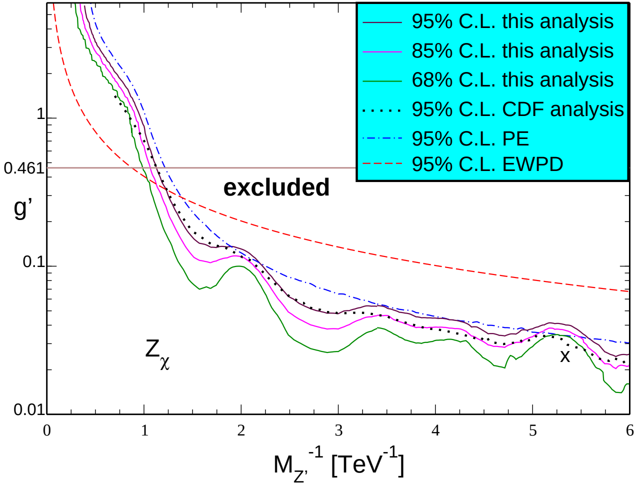


Figure: Jens Erler, Paul Langacker, Shoaib Munir and E.R Work, arXiv:1103.2659 [hep-ph]

log-likelihood ratio (LLR) confidence levels Interference Effects

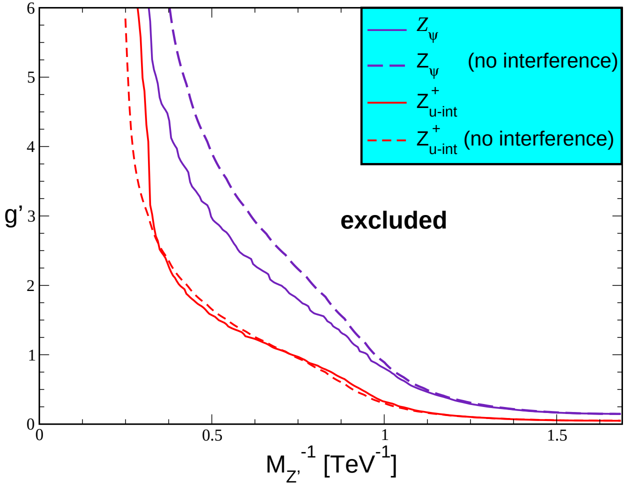


Figure: Jens Erler, Paul Langacker, Shoaib Munir and E.R, arXiv:1103.2659 [hep-ph]

projected limits on $M_{Z'}$ in the Z_χ model from the LHC.

	$M_{Z'}$ [TeV]							
$\sqrt{s}$[TeV]→		2		7		14		28
$\mathcal{L}$ [fb^{-1}]	pp	$p\bar{p}$	pp	$p\bar{p}$	pp	$p\bar{p}$	pp	$p\bar{p}$
3	0.6522	0.8806	1.604	2.115	2.458	3.261	3.765	4.524
10	0.7389	0.9841	1.857	2.501	3.068	4.055	4.584	5.866
30	0.8159	1.079	2.141	2.851	3.559	4.520	5.364	7.153
100	0.8991	1.161	2.431	3.223	4.101	5.291	6.232	8.591
300	0.9699	1.251	2.693	3.550	4.598	5.974	7.853	9.893
1000	1.051	1.325	2.979	3.889	5.140	6.698	8.981	11.25
3000	1.117	1.381	3.240	4.183	5.630	7.332	9.998	12.52

Table: Projected 95% exclusion limits [in TeV] on $M_{Z'}$ for the Z_χ model at the typical LHC CM energies and integrated luminosities $\int \mathcal{L}$ for pp and $p\bar{p}$ colliders. We get these limits using the bayesian method

conclusions and goals!

- we have been able to extend cdf lower limits bounds on the Z' mass to one of the most general and better motivated class of models, i.e E6 with kinetic mixing
- we were able to construct a χ^2 function which allows us to analyze the strong coupling constant and the interference effects
- We use the Bayesian method to project 95% lower limits on the Z mass for Tevatron and for various reference CM energies and luminosities at the LHC.
- We have remarked the importance of a systematic classification for the Z' in E_6 that allow us to identify the alternative models of a given Z' in E_6.

GRACIAS

Allowed breakdown chains [Robinett and Rosner: 1982]

$SU_X(2) \times SU(5) \times U_{51X} \to SU_X(2) \times SU_c(3) \times SU_L(2) \times U_{51X} \times U_{32X} \to SU_c(3) \times SU_L(2) \times U_X \times U_{51X} \times U_{32X}$

$SU_X(2) \times SU(4) \times SU_L(2) \times U_{42X} \to SU_X(2) \times SU(3)_c \times SU_L(2) \times U_{42X} \times U_{31X} \to SU(3)_c \times SU_L(2) \times U_{42X} \times U_{31X} \times U_X$

$SU_X(2) \times SU(3) \times SU_c(3) \times U_{21\overline{X}} \to SU_X(2) \times SU(3)_c \times SU_L(2) \times U_{21\overline{X}} \times U_{33} \to SU(3)_c \times SU_L(2) \times U_{21\overline{X}} \times U_{33} \times U_X$

$X = R, I, A$

Figure: Jens Erler and E.R Work in progress

Allowed breakdown chains [Robinett and Rosner: 1982]

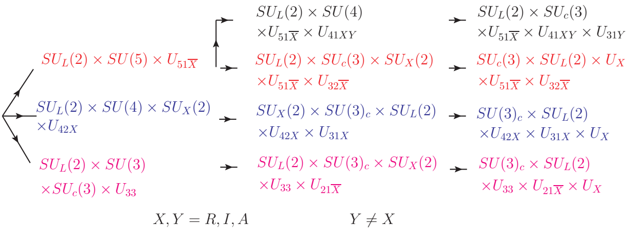


Figure: Jens Erler and E.R Work in progress

Bibliography I