Determining Properties of a Z' Using Third Generation Fermions at the LHC

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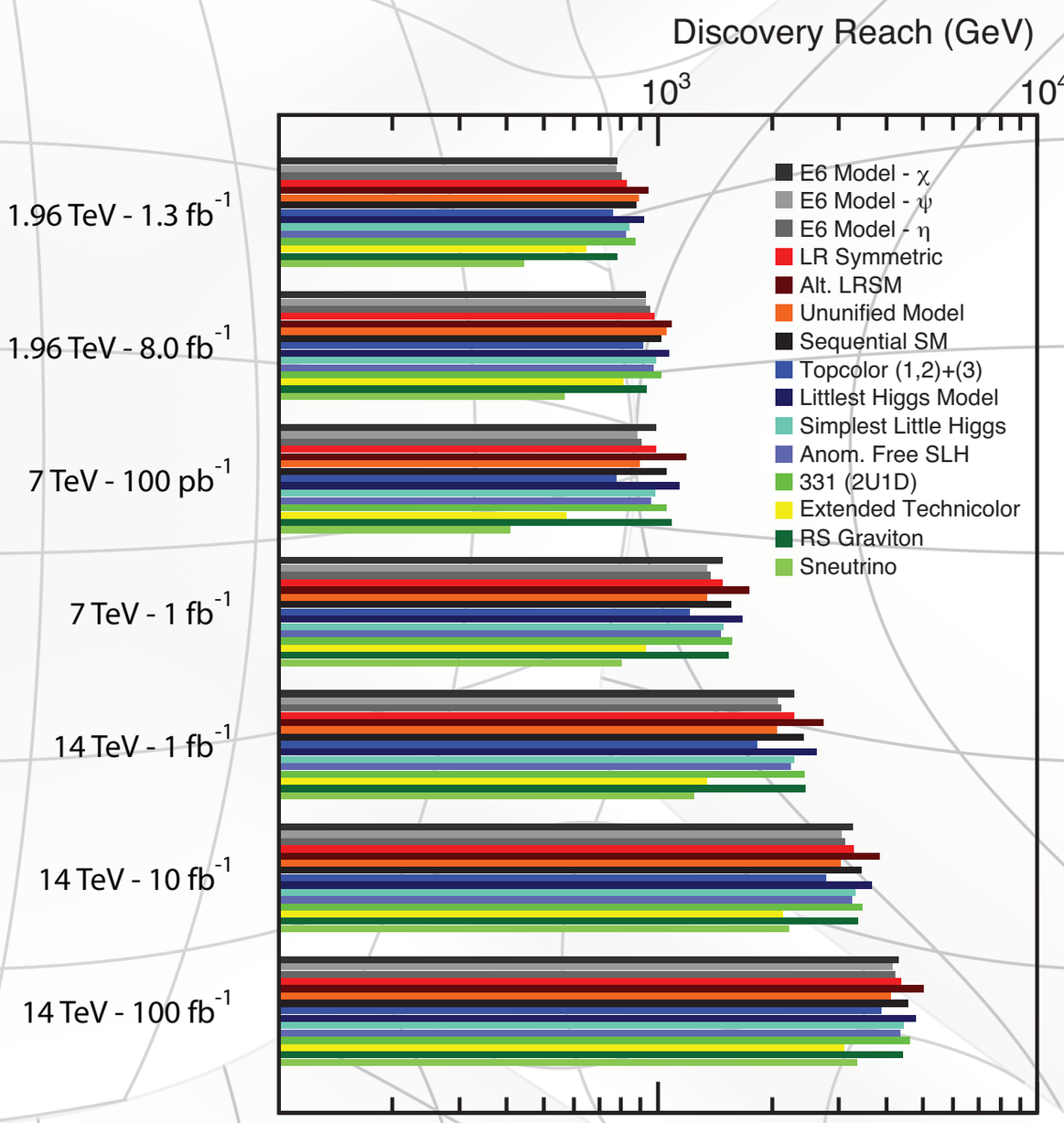
Overview

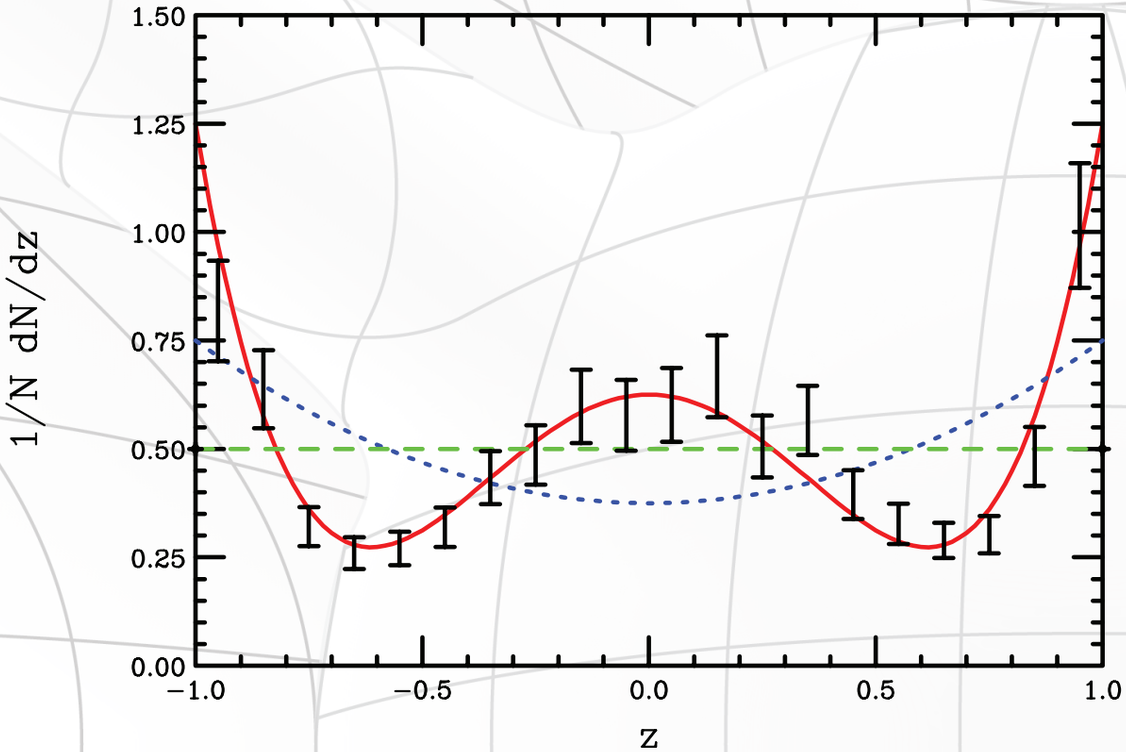
- Z', models, discovery
- Top and Bottom Final States
- Tau Final States
- Closing comments

Models and Discovery

- E6 - χ, ψ, η
- Left-Right Symmetric (Alt.)
- Sequential SM
- Little Higgs (LH, SLH, AFSLH)
- 3-3-1 Model
- Topcolor Assisted Technicolor (1,2)+(3)
- Extended Technicolor
- Ununified Model

- Discovery $\longrightarrow$ 5 $\mu^+\mu^-$ events within 2 invariant mass bins

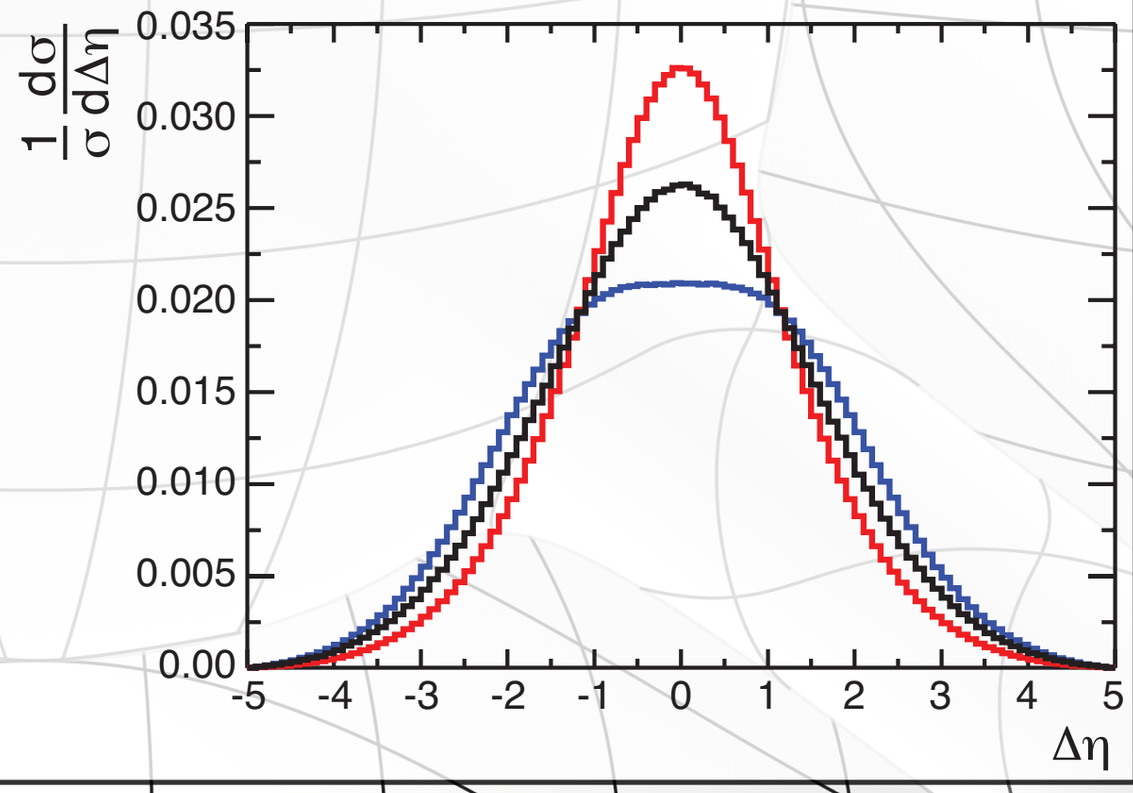




Rizzo, Thomas G., *Z' Phenomenology and the LHC*, **hep-ph/0610104**

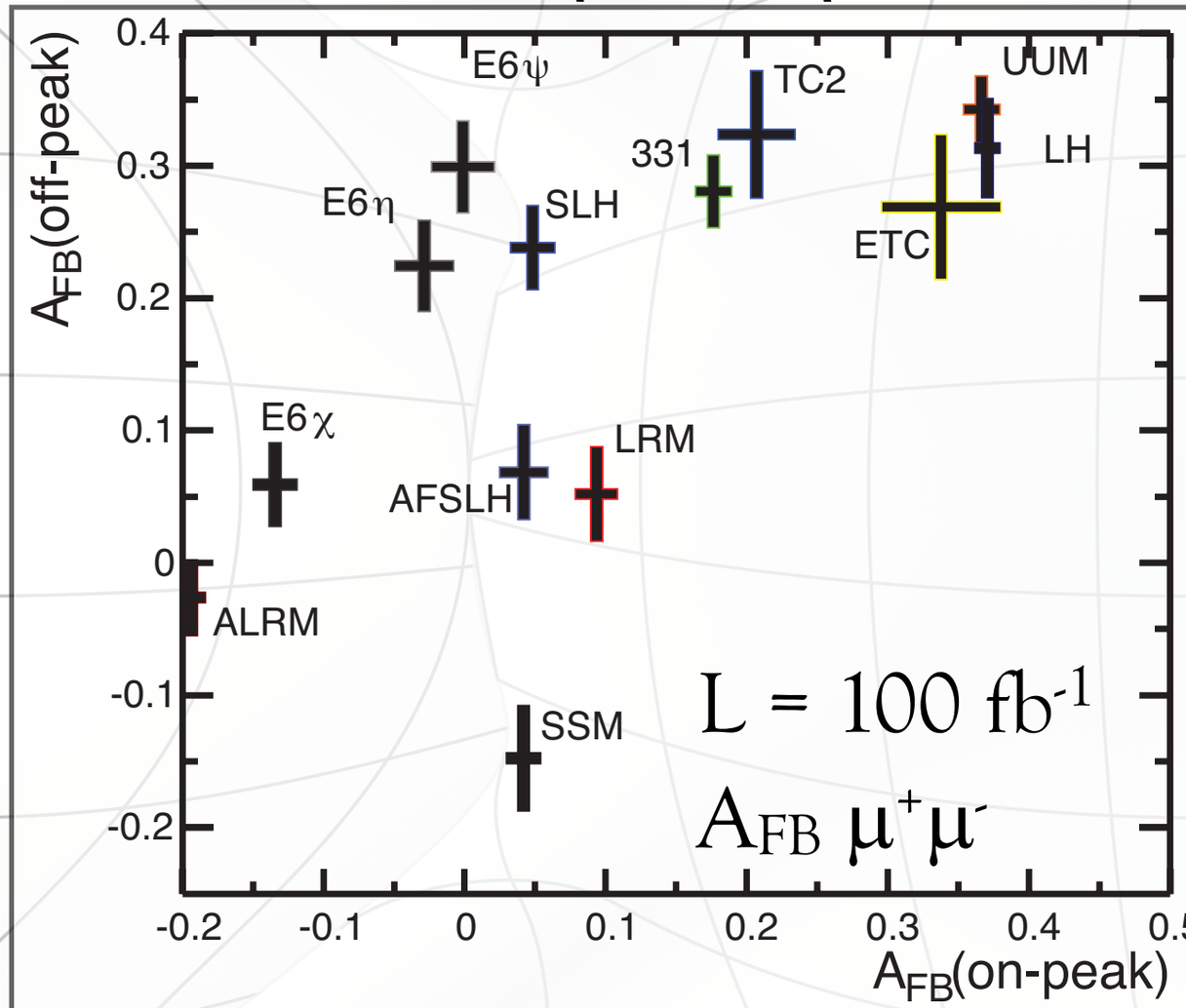
$$\tilde{A}_{CE} = \frac{\left(\int_{-\Pi}^{\Pi} - \int_{-\infty}^{-\Pi} - \int_{\Pi}^{\infty}\right) \frac{d\sigma}{d\Delta\eta} d\Delta\eta}{\int_{-\infty}^{\infty} \frac{d\sigma}{d\Delta\eta} d\Delta\eta}$$

Diener, R., Godfrey, S. and Martin, T.,
Using Final State Pseudorapidities to Improve s-channel Resonance Observables at the LHC,
PhysRevD.80.075014

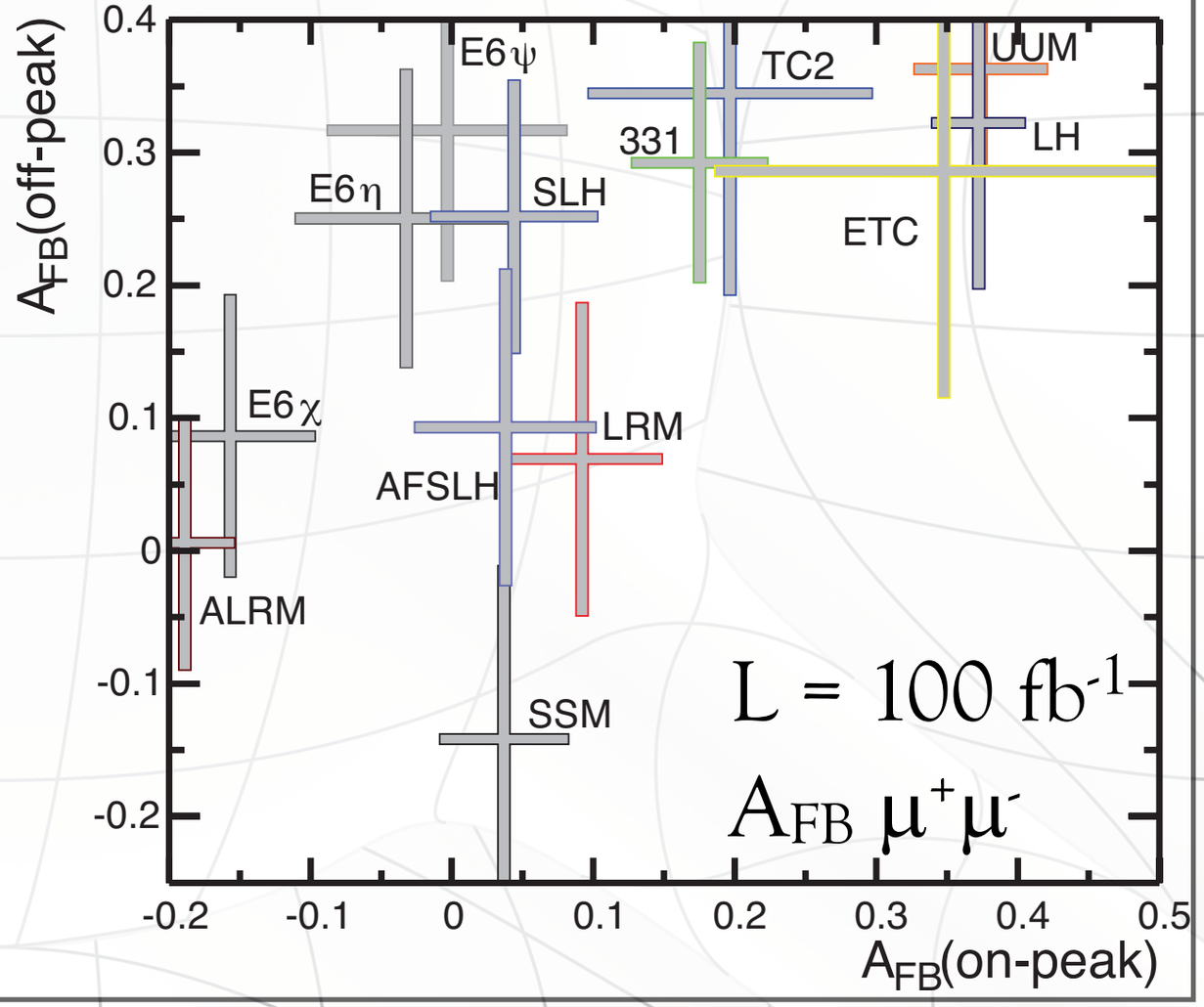


Forward-Backward Asymmetry

- Forward: $|\eta_f| > |\eta_{\bar{f}}|$



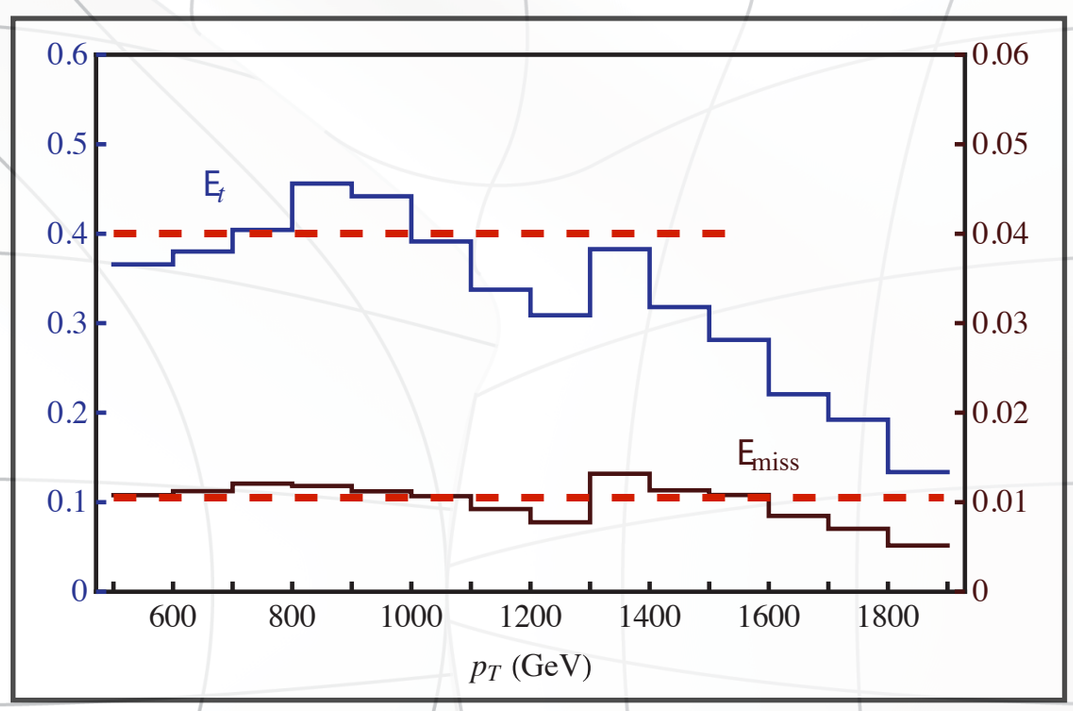
$M_{Z'}$ = 1500 GeV

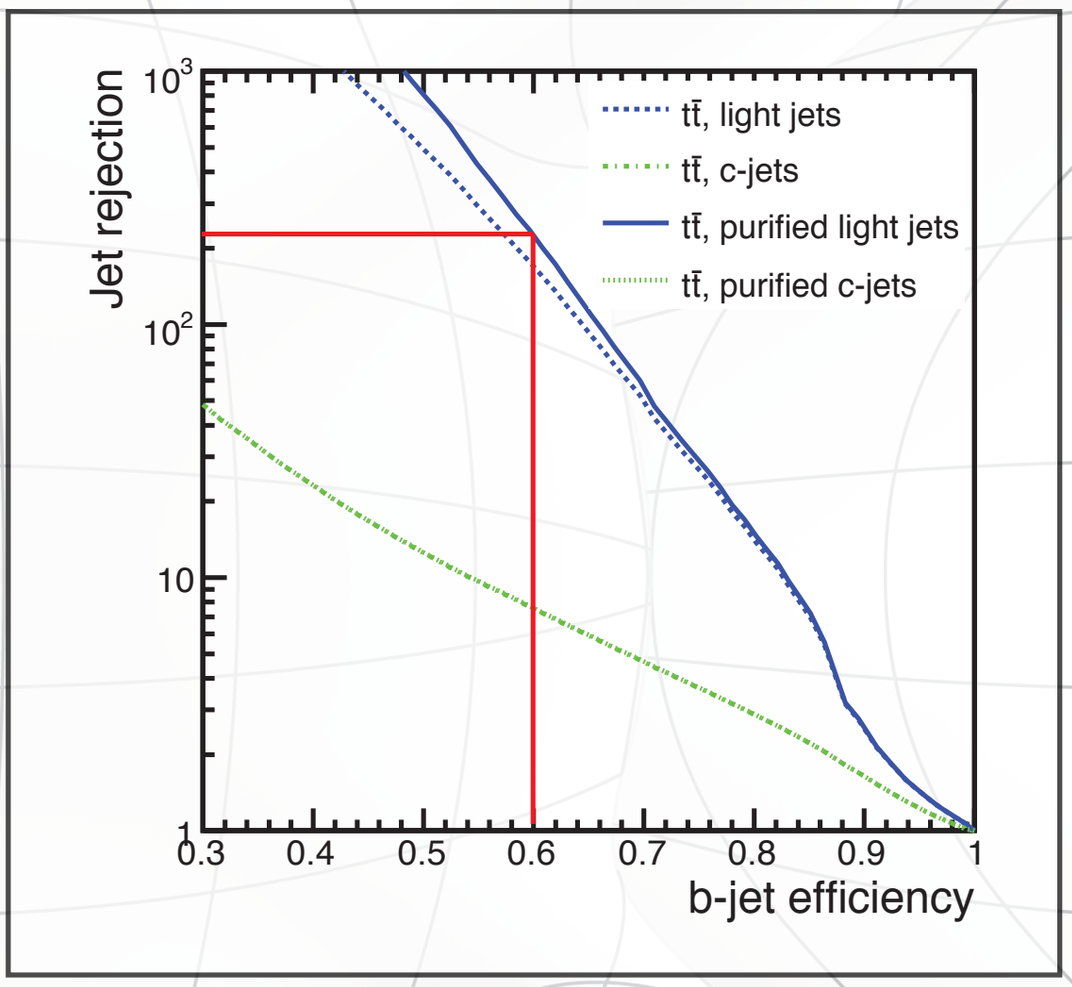


$M_{Z'}$ = 2500 GeV

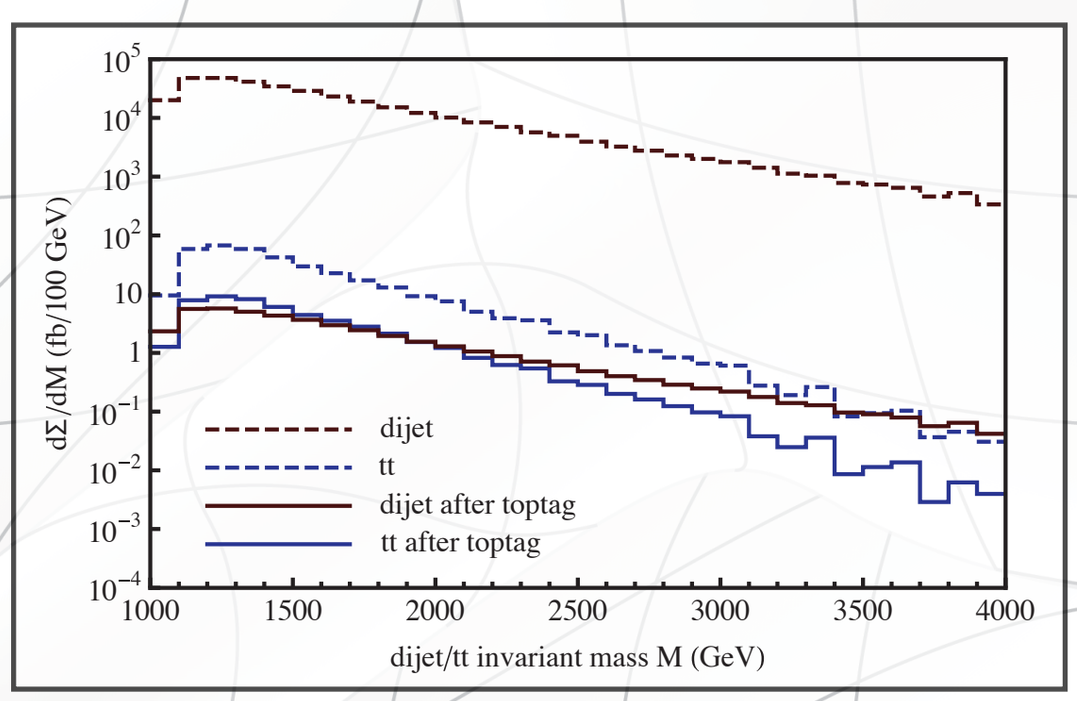
- Using FCAL? 50% ε_e Diener, R., Godfrey, S. and Martin, T., PhysRevD.80.075014

Tops & Bottoms





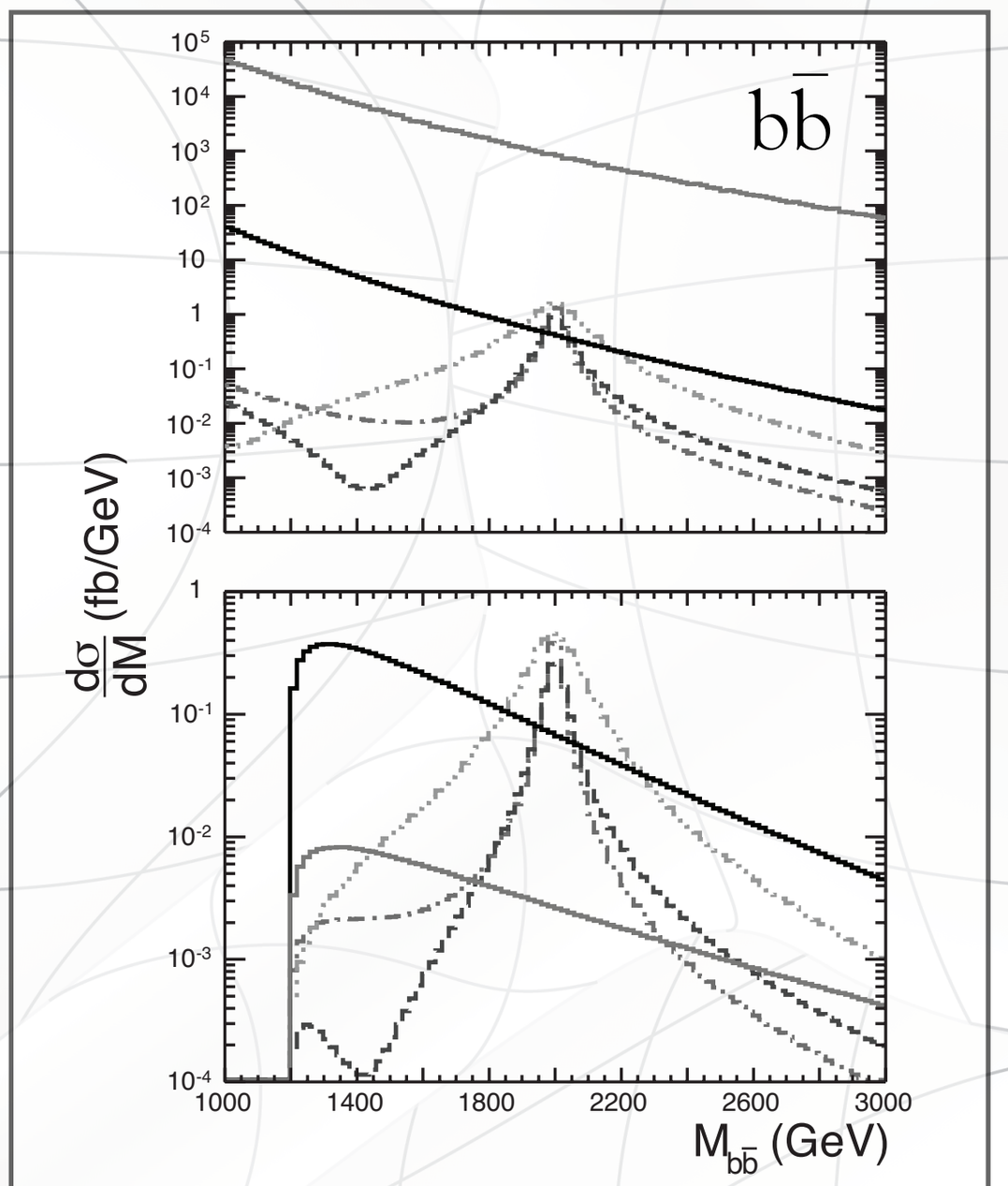
The ATLAS Collaboration, G. Aad et al, 2008 JINST 3 S08003



Kaplan, Rehermann, Schwartz and Tweedie, *Top-Tagging: A Method for Identifying Boosted Hadronic Tops*, Phys. Rev. Lett.101:142001 (2008)

Calculations

- Monte Carlo, Weighted Events
- $|M_{ff} - M_{Z'}| < 2.5\Gamma_{Z'}$



Cuts: $|\eta_f| < 2.5 \quad p_T > 0.3\ M_{Z'}$

$L = 100\ fb^{-1}$

$S/\sqrt{S+B}$
1500 GeV (2000 GeV)

Model	t-quark	b-quark
E6 Model - χ	3.8 (2.1)	42.9 (22.4)
E6 Model - ψ	11.4 (6.3)	30.7 (16.3)
E6 Model - η	17.6 (9.6)	32.6 (17.3)
LR Symmetric	19.9 (10.8)	81.0 (41.9)
Alt. LR Symmetric	21.8 (12.0)	10.9 (6.2)
Ununified Model	57.9 (30.8)	147.8 (77.0)
Sequential SM	19.9 (10.9)	66.5 (35.1)
Topcolor (1,2)+(3)	14.8 (8.1)	13.4 (7.6)
Littlest Higgs Model	26.4 (14.3)	69.5 (36.8)
Simplest Little Higgs	22.9 (12.3)	54.2 (28.6)
Anomaly Free SLH	21.2 (11.4)	50.0 (26.4)
3-3-1 (2U 1D)	14.4 (7.9)	34.8 (18.8)
Extended Technicolor	16.3 (8.8)	44.4 (23.8)

$$R_{b/\mu} = \frac{\sigma(pp \to Z' \to b\bar{b})}{\sigma(pp \to Z' \to \mu^+\mu^-)} \qquad R_{t/\mu} = \frac{\sigma(pp \to Z' \to t\bar{t})}{\sigma(pp \to Z' \to \mu^+\mu^-)}$$

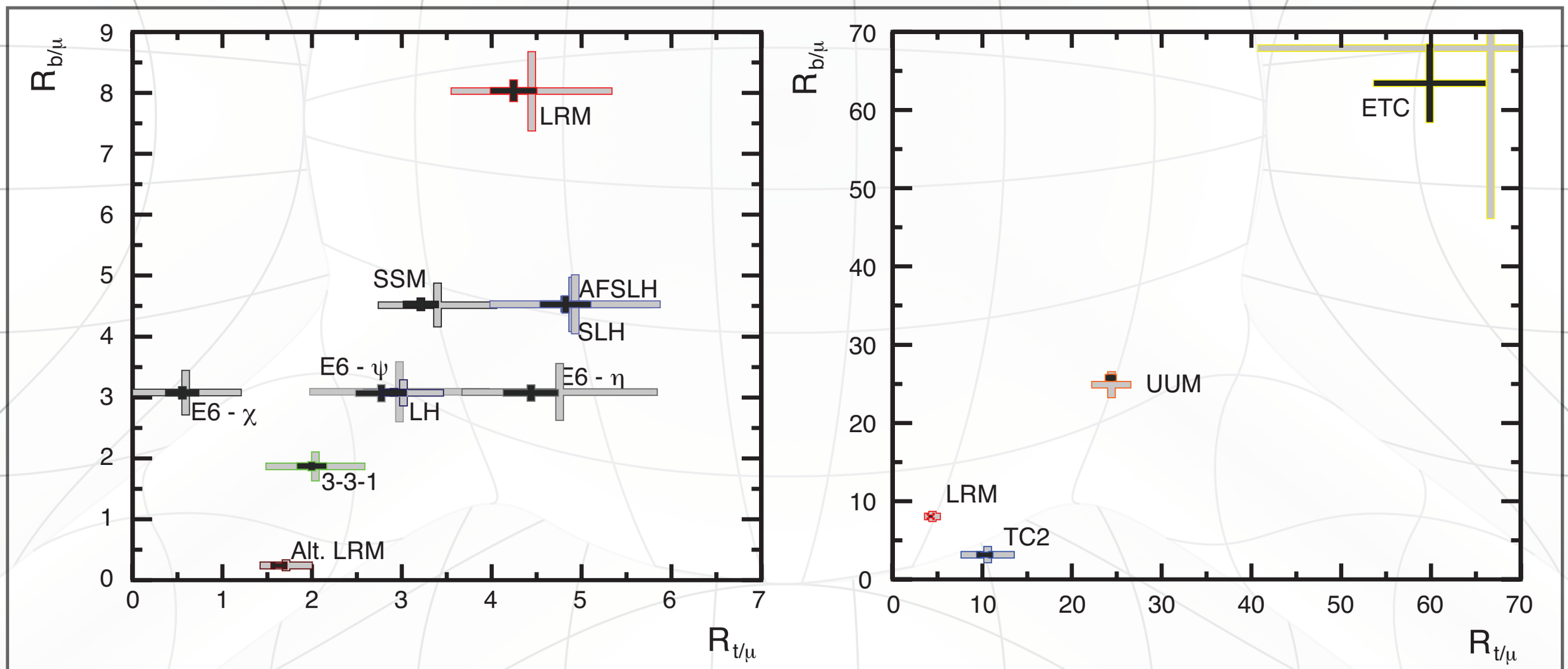
$M_{Z'}$ = 1500 GeV (dark), 2500 GeV (light)

$\varepsilon_{tt} = 0.075$, $r_{jj} = 100^2$

$\varepsilon_{bb} = 0.36$, $r_{jj} = 200^2$

$L = 100\ fb^{-1}$

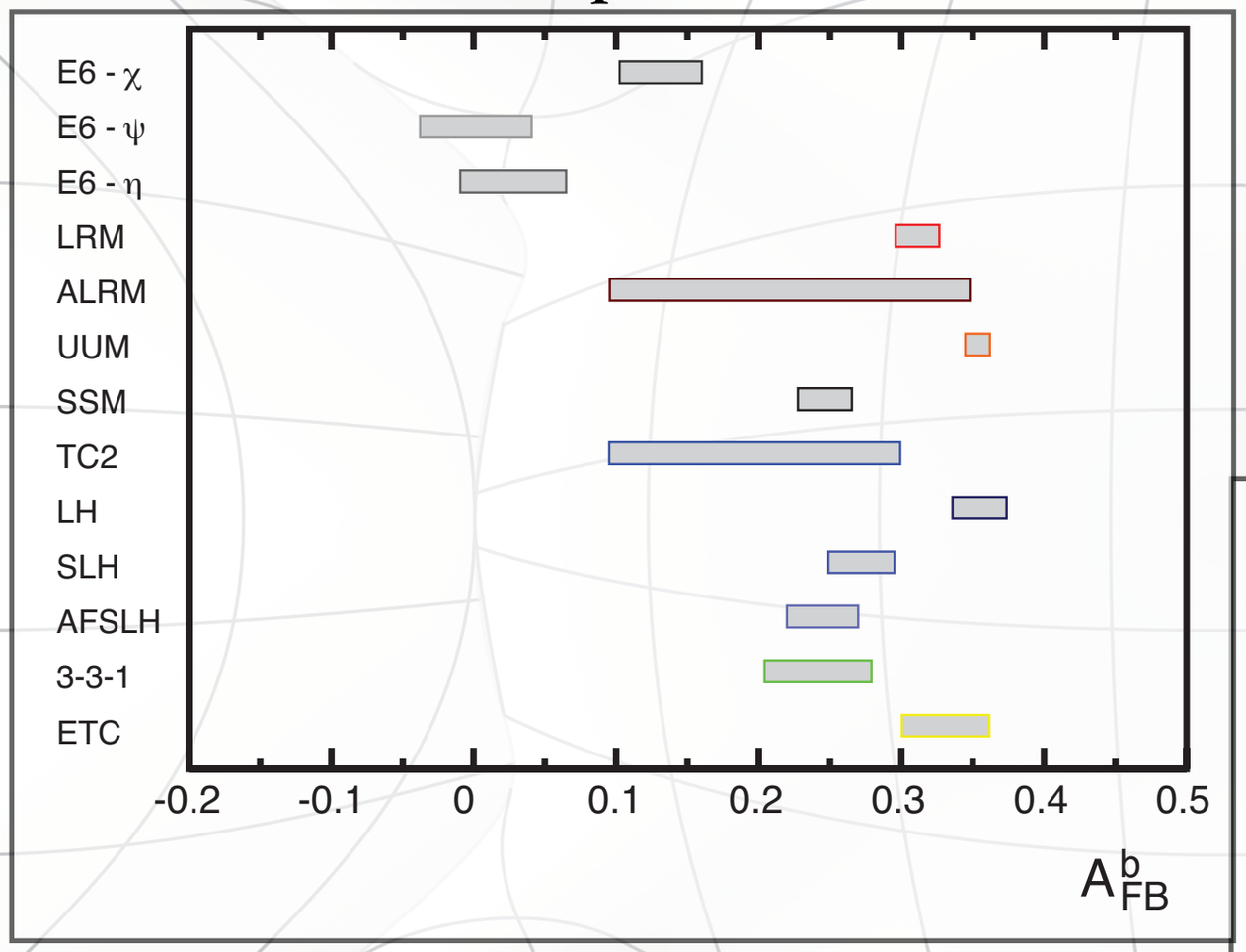
$\varepsilon_{\mu\mu} = 0.92$



Diener, R., Godfrey, S. and Martin, T., Phys.Rev.Lett.101:151803,2008

Top & Bottom A_{FB}

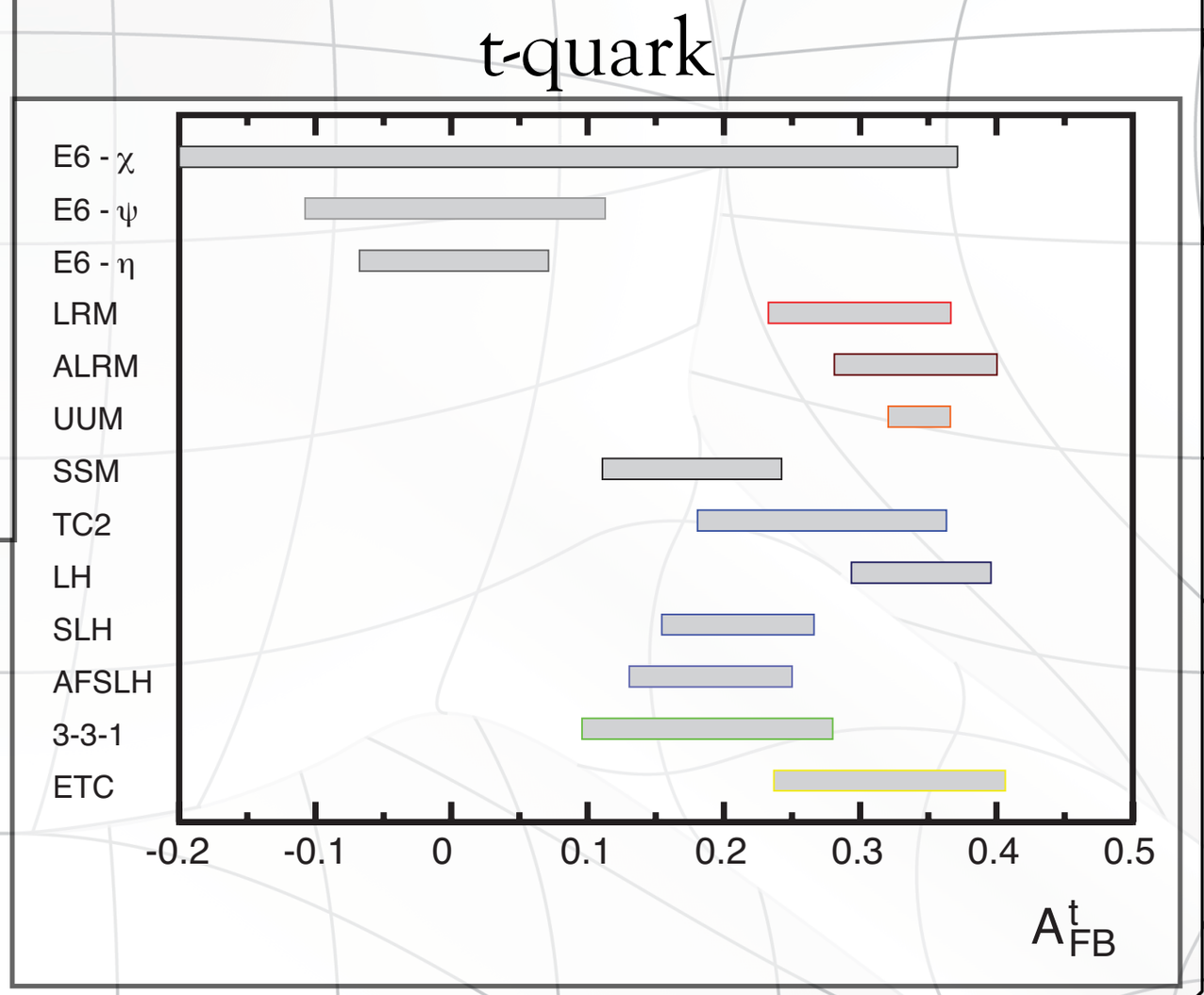
b-quark



$\varepsilon_{tt} = 0.075,\ r_{jj} = 100^2$

$\varepsilon_{bb} = 0.36,\ \ r_{jj} = 200^2$

t-quark



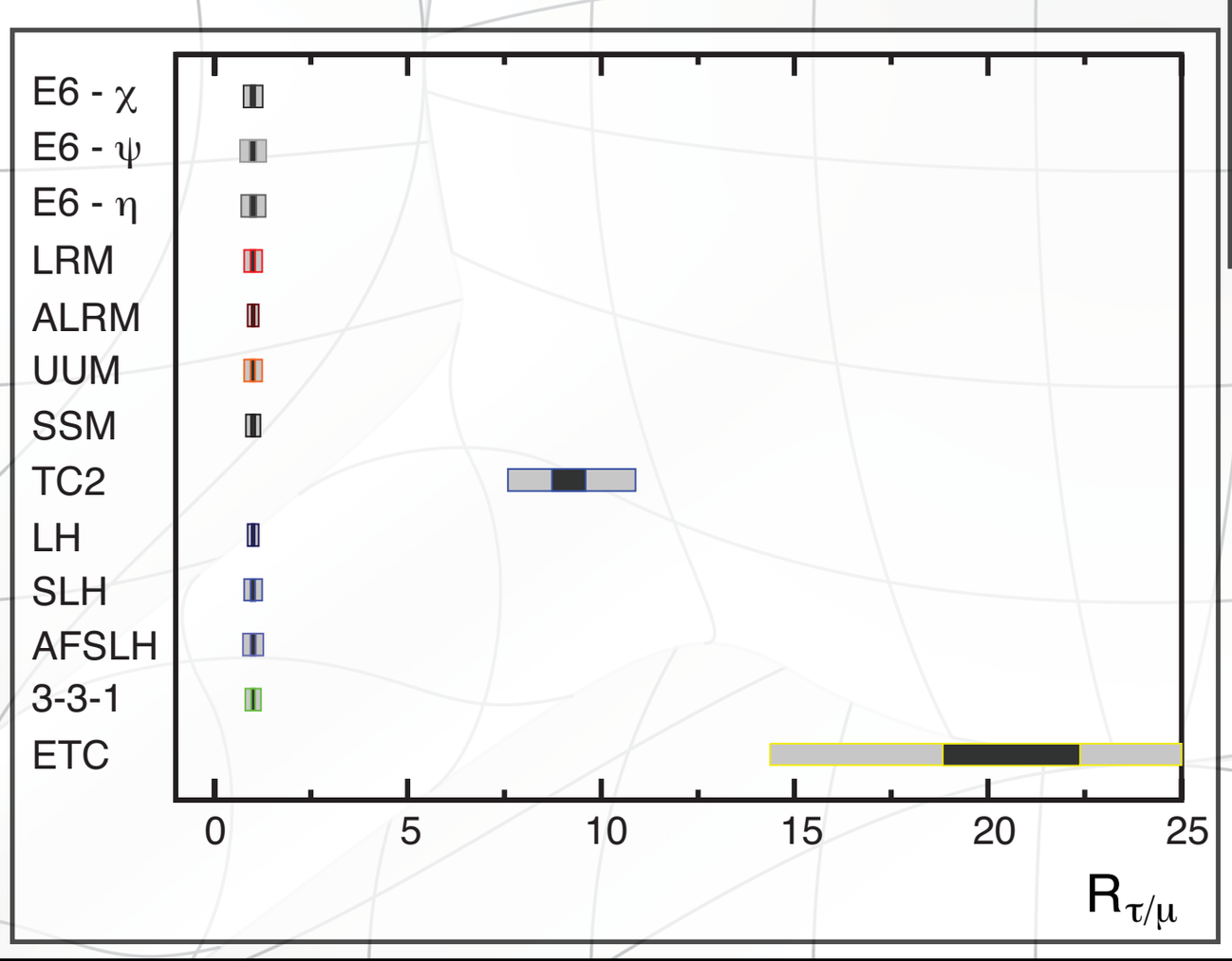
$M_{Z'} = 1500$ GeV

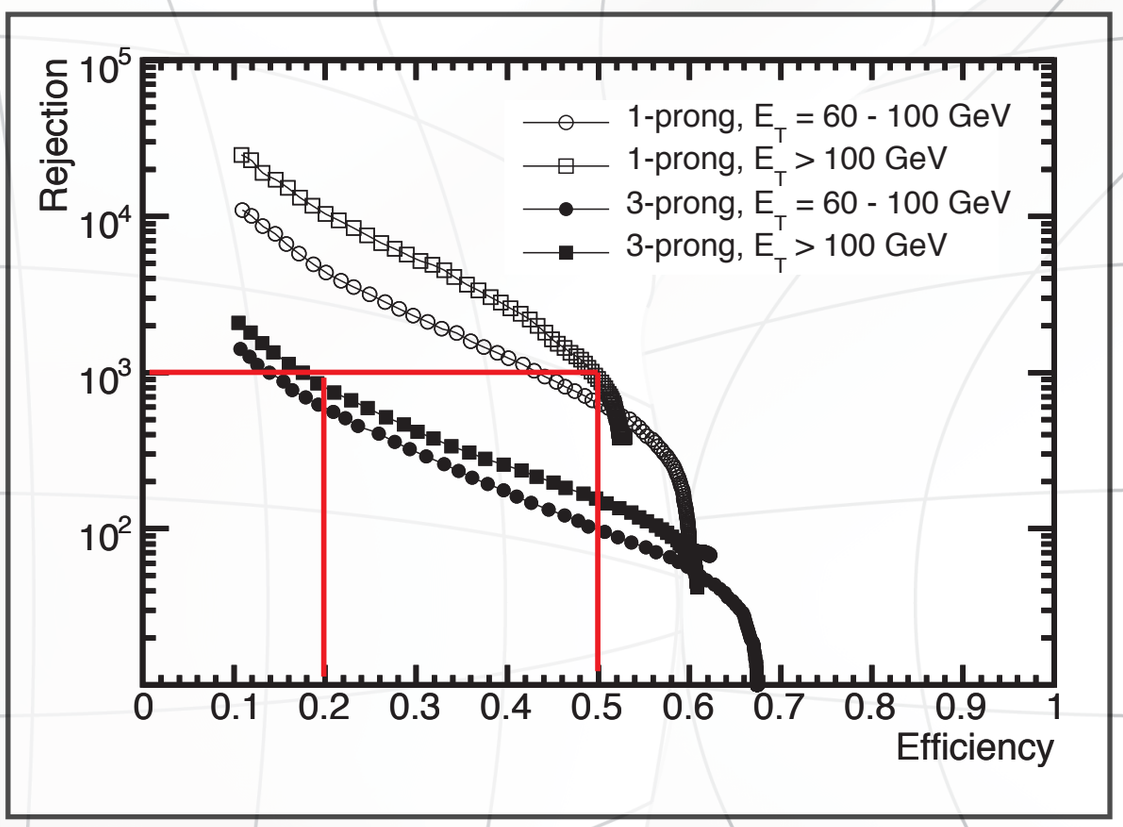
$L = 100\ fb^{-1}$

Tau/Muon Ratio

$M_{Z'}$ = 1500 GeV (dark),
2500 GeV (light)

$L = 100\ fb^{-1}$



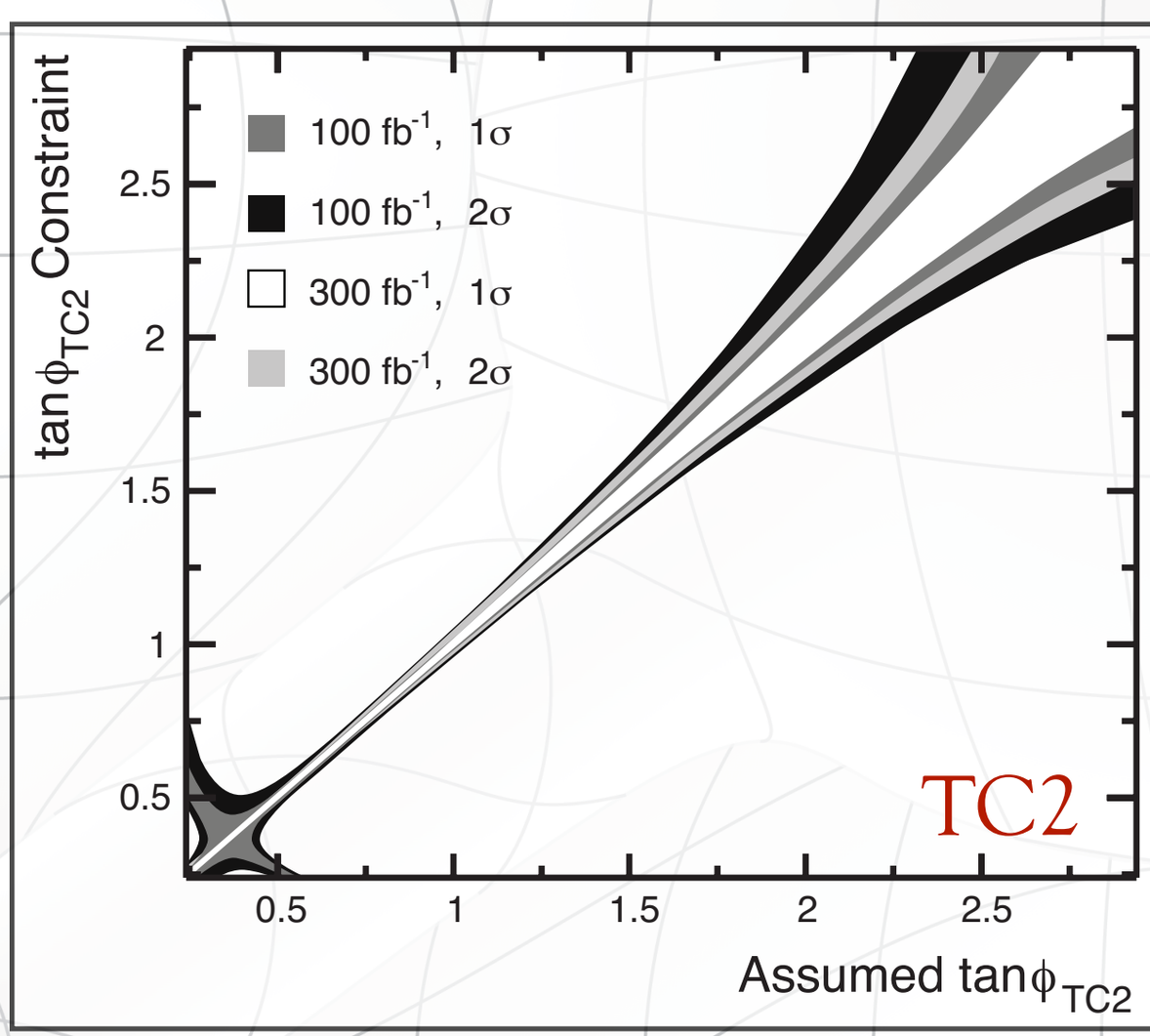


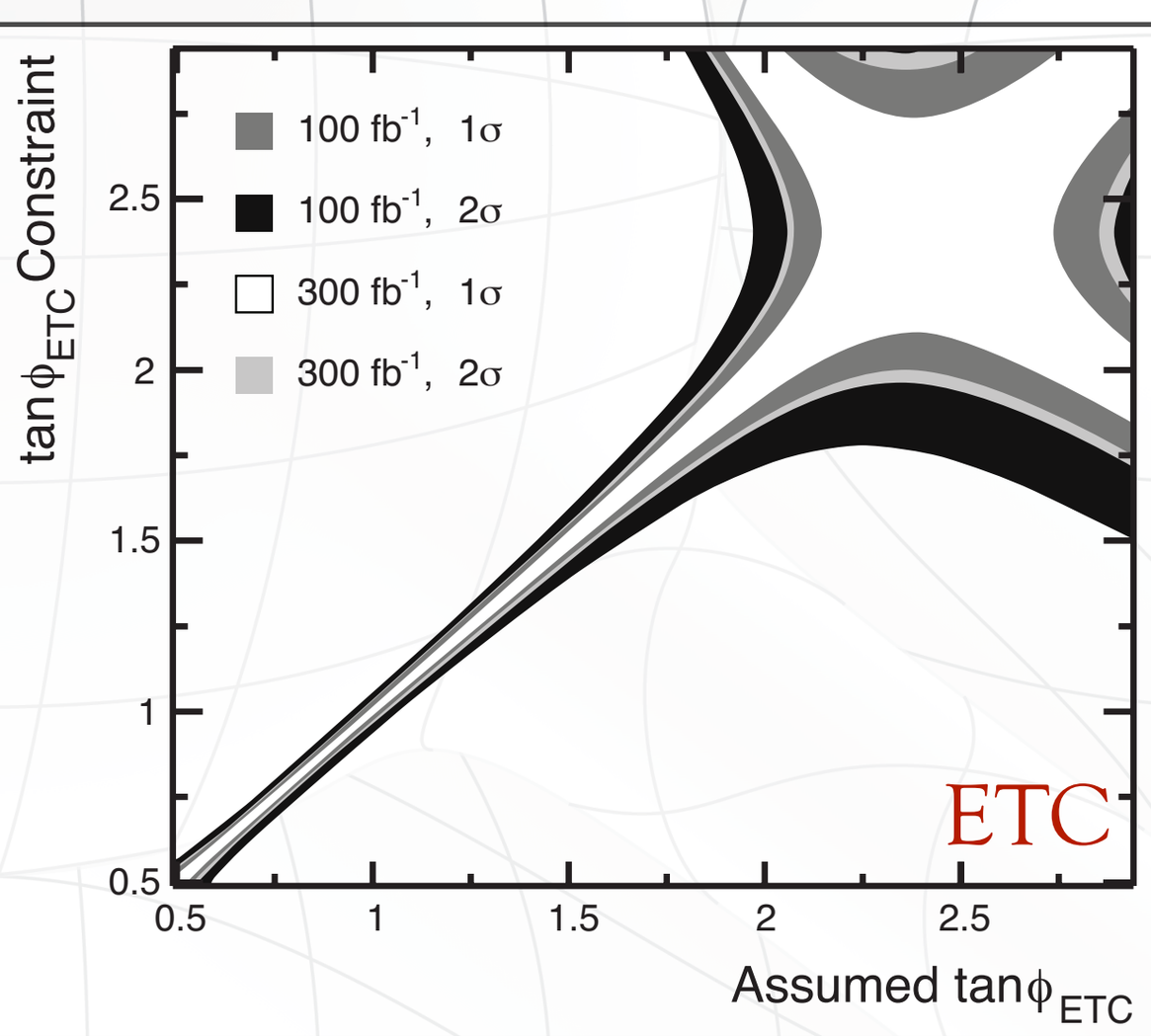
The ATLAS Collaboration, G. Aad et al,
2008 JINST 3 S08003

$\varepsilon_{\tau\tau} = 0.08,\ r_{jj} = 5x10^5$

Determining ϕ

- Using only $R_{\tau/\mu}$
- Can include other observables





Closing Comments

Backup Slides

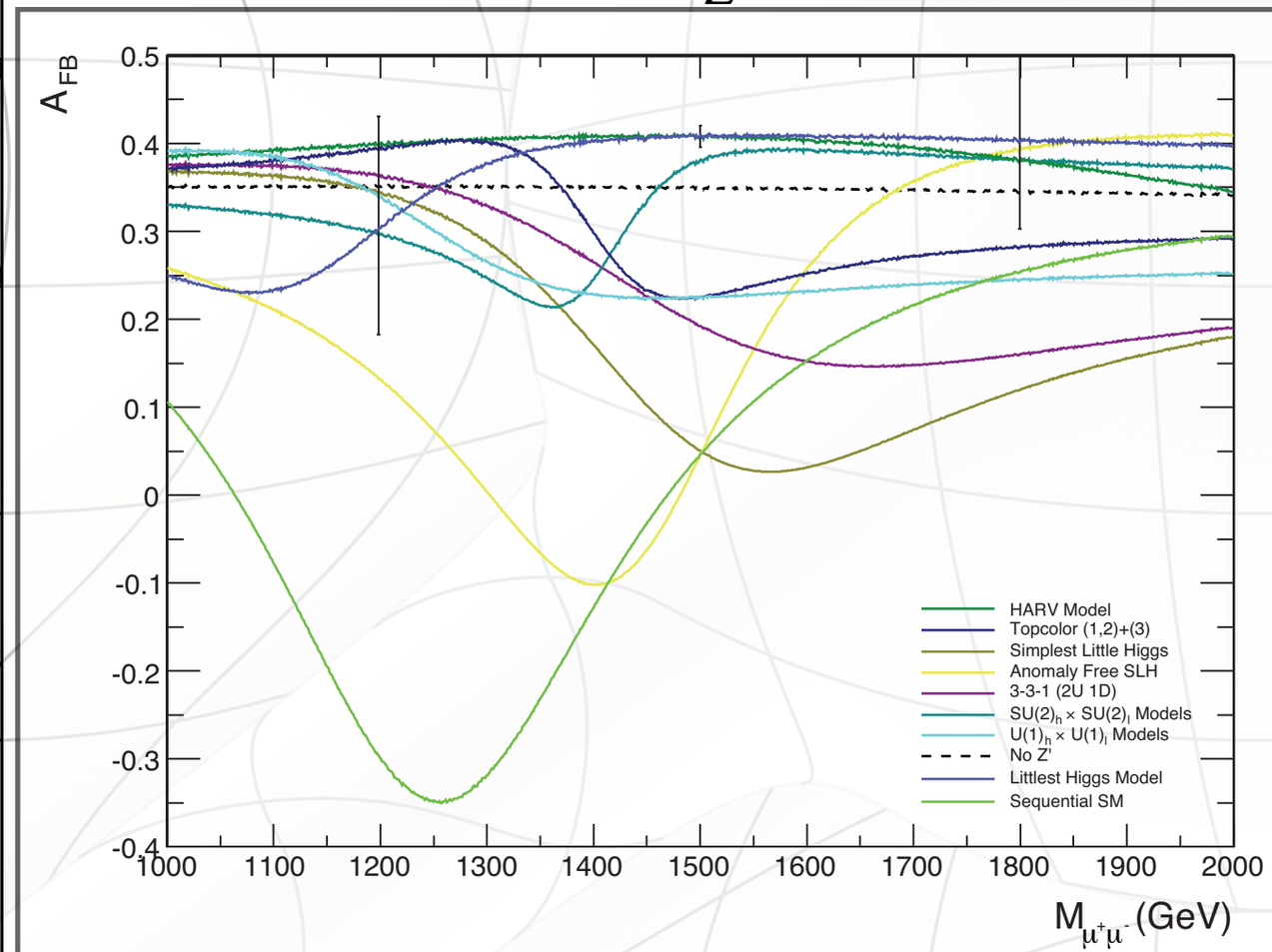
Muon Measurements

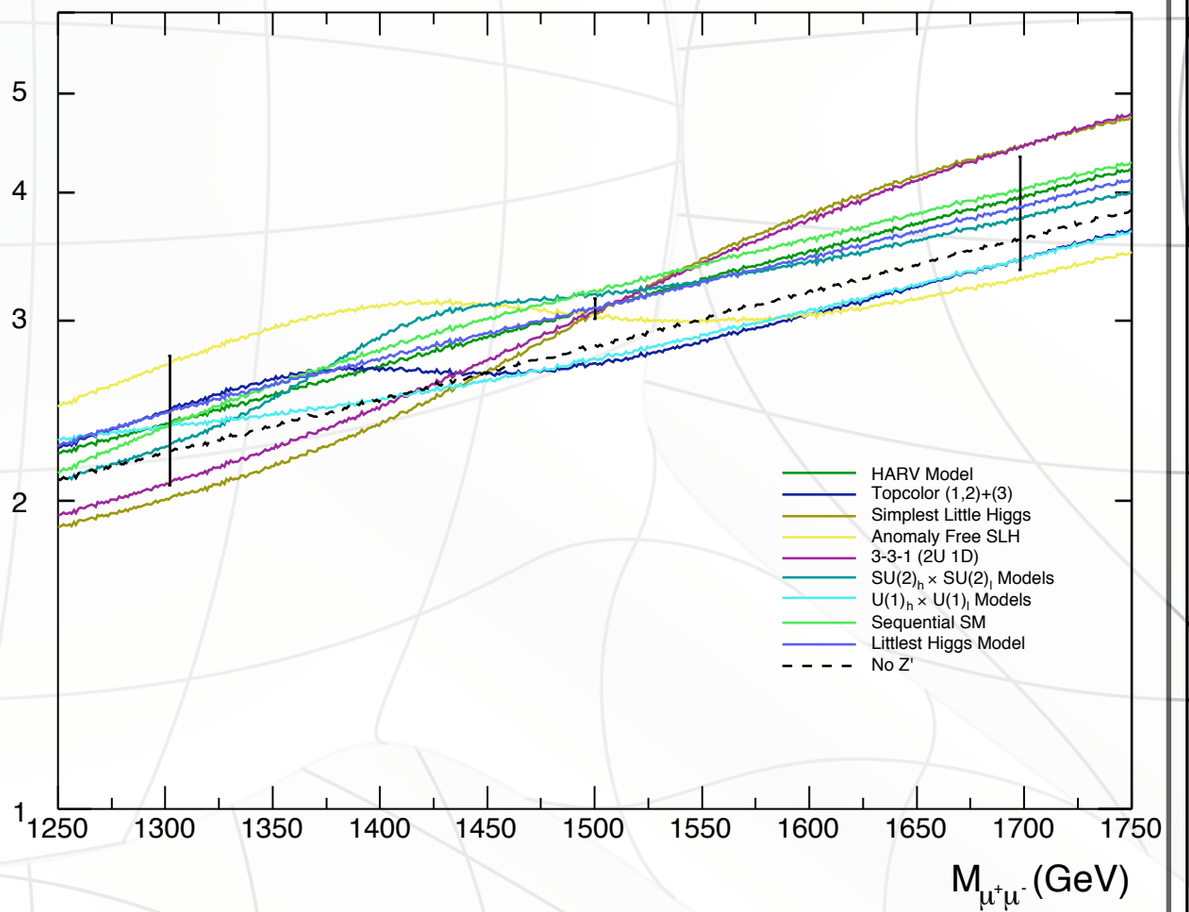
$$A_{FB} = \frac{\sigma(F) - \sigma(B)}{\sigma(F) + \sigma(B)}$$

$$R_y = \frac{\int_y^{y} \frac{d\sigma}{dy}\, dy}{\int_{-Y}^{-y} \frac{d\sigma}{dy}\, dy + \int_y^{Y} \frac{d\sigma}{dy}\, dy}$$

$M_{Z'}$ = 1500 GeV

L = 100 fb^{-1}



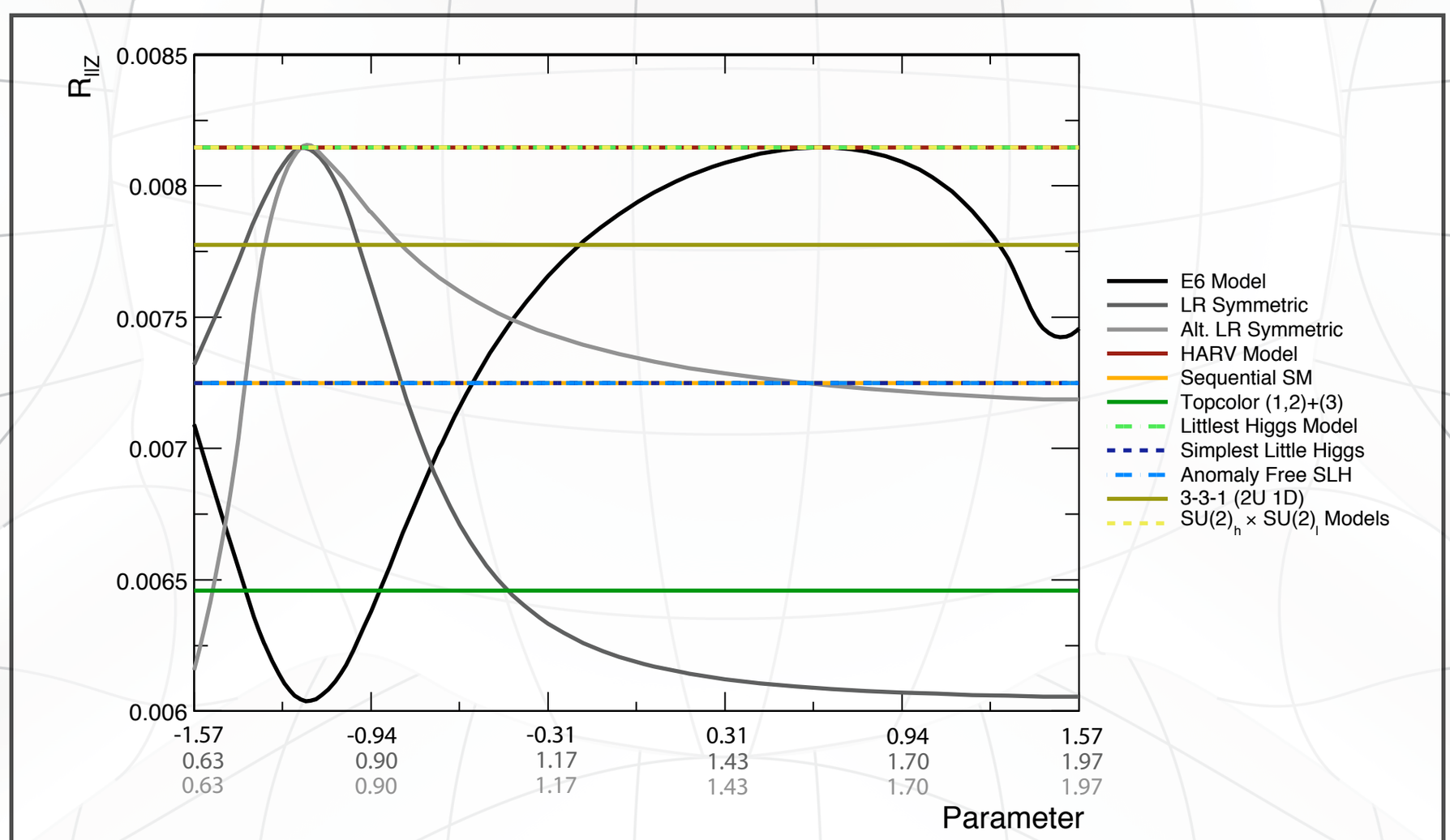


Uncertainties: Statistical, 100 GeV bin

Rare Decays

$$R_{llZ} = \frac{Br(Z' \rightarrow llZ)}{Br(Z' \rightarrow ll)} \qquad R_{l\nu W} = \frac{Br(Z' \rightarrow l\nu W)}{Br(Z' \rightarrow ll)} \qquad R_{\nu\nu Z} = \frac{Br(Z' \rightarrow \nu\nu Z)}{Br(Z' \rightarrow ll)}$$

$$M_{Z'} = 1500 \text{ GeV}$$



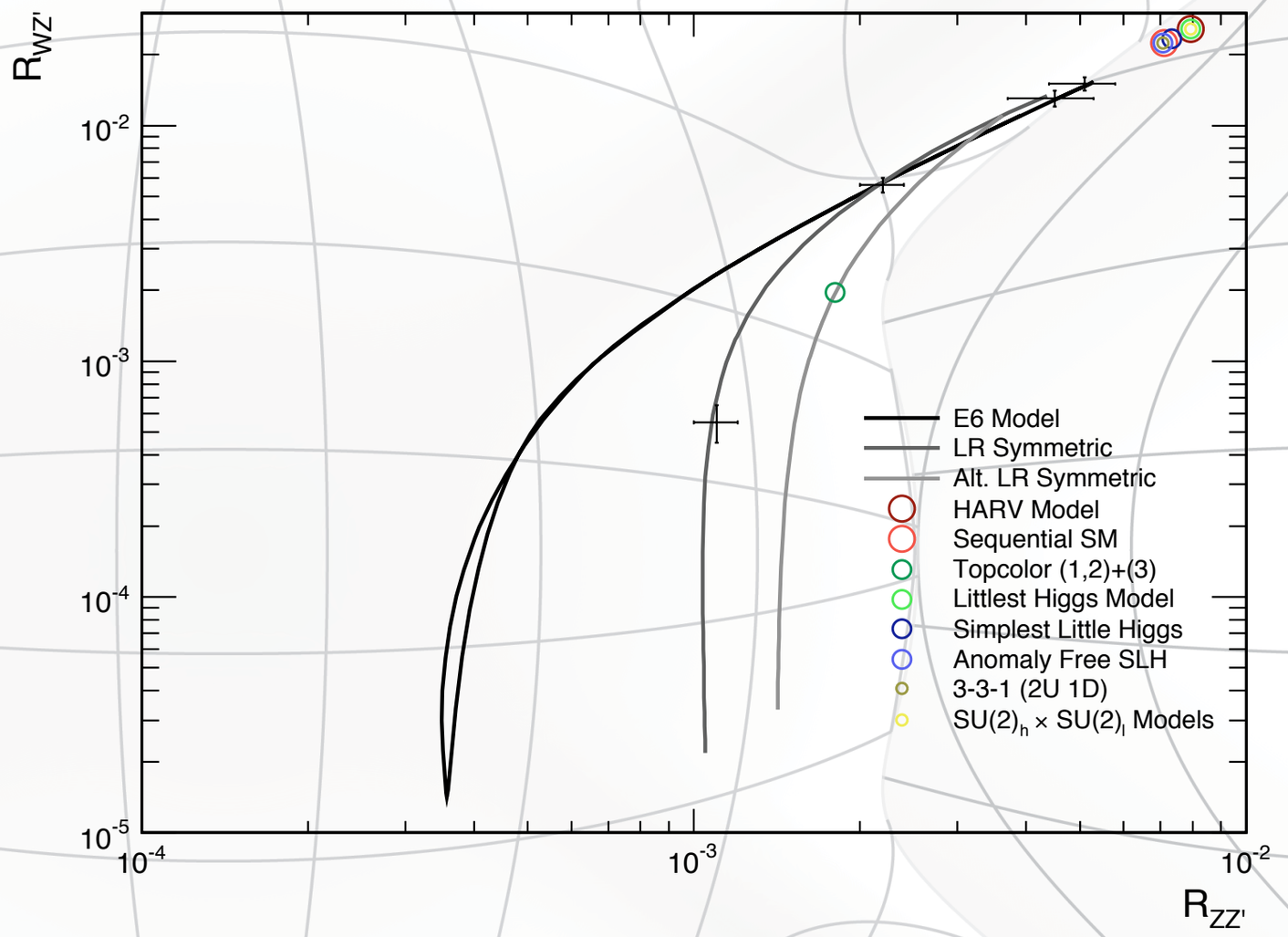
Adapted from Cvetic and Langacker, Phys. Rev. D46:14-18 (1992)

Associated Production

$$R_{Z'V} = \frac{\sigma(pp \to Z'V \to llV)}{\sigma(pp \to Z' \to ll)}$$

$M_{Z'} = 1000$ GeV

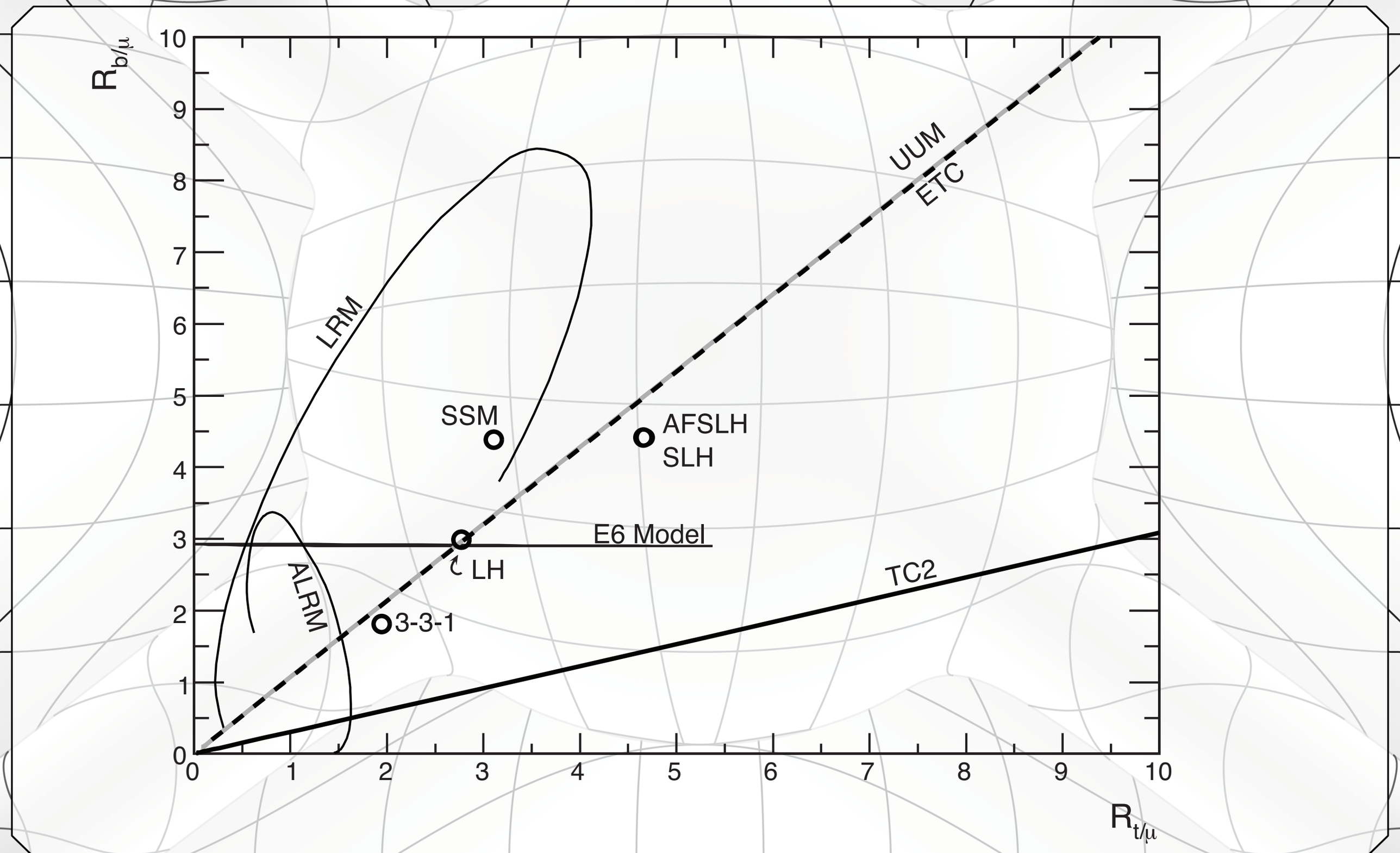
$(L = 10^{34}\ cm^{-2}s^{-1})$



$\tilde{U} = (g_R^u/g_L^u)^2 \quad \tilde{D} = (g_R^d/g_L^d)^2$	χ	ψ	η	LR
$R_{Z'Z} = 10^{-3}\frac{7.94+0.96\tilde{U}+0.11\tilde{D}}{1+0.68\tilde{U}+0.32\tilde{D}}$	0.0022 ± 0.0002	0.0045 ± 0.0008	0.0051 ± 0.0007	0.0011 ± 0.0001
$R_{Z'W} = 10^{-3}\frac{25.7}{1+0.68\tilde{U}+0.32\tilde{D}}$	0.0056 ± 0.0004	0.013 ± 0.001	0.015 ± 0.001	0.00055 ± 0.00010
$R_{Z'\gamma} = 10^{-3}5.62\frac{1+0.89\tilde{U}+0.11\tilde{D}}{1+0.68\tilde{U}+0.32\tilde{D}}$	0.0035 ± 0.0003	0.0056 ± 0.0009	0.0061 ± 0.0008	0.0049 ± 0.0003

Adapted from del Aguila, Cvetic and Langacker, Phys.Rev.D48:969-973 (1993)

Evolution of b/μ and t/μ Ratios



Defining "forward" with η

- Assuming massless fermions

$$\beta = \frac{x_a - x_b}{x_a + x_b}$$

$$\eta_f = \frac{1}{2}\ln\frac{1+\beta}{1-\beta} + \frac{1}{2}\ln\frac{1+z}{1-z} \qquad Y = \frac{1}{2}\ln\frac{1+\beta}{1-\beta}$$

$$\eta_f^- = \frac{1}{2}\ln\frac{1+\beta}{1-\beta} - \frac{1}{2}\ln\frac{1+z}{1-z} \qquad Z = \frac{1}{2}\ln\frac{1+z}{1-z}$$

$$\eta_f = Y + Z \qquad \eta_f^- = Y - Z$$

$|Y + Z| > |Y - Z|$ when both Y and Z are like signed. ("Forward")
$|Y + Z| < |Y - Z|$ when Y and Z are opposite signed. ("Backward")
recalling that Y and Z are signed the same as $y_{Z'}$ and z.

- Proof for massive fermions similar, but messy