Precision Electroweak Tensions and a Wide Dark Photon

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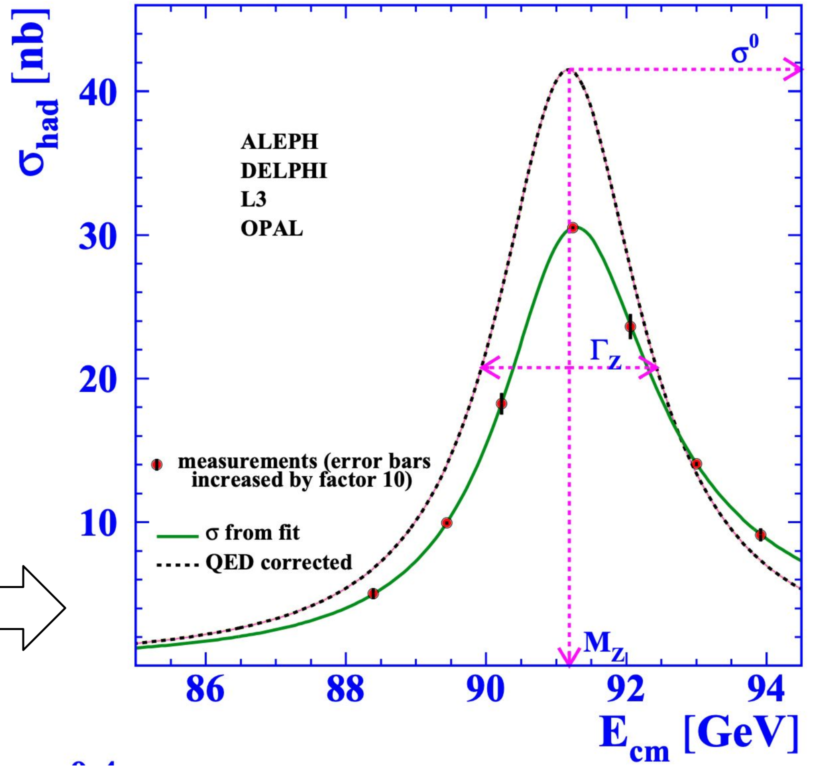
Outline

- Precision Electroweak (PEW) Analysis
  - Oblique Parameters STU
- Kinetic Mixing and the Dark Photon
- Results

The Precision Electroweak Fit

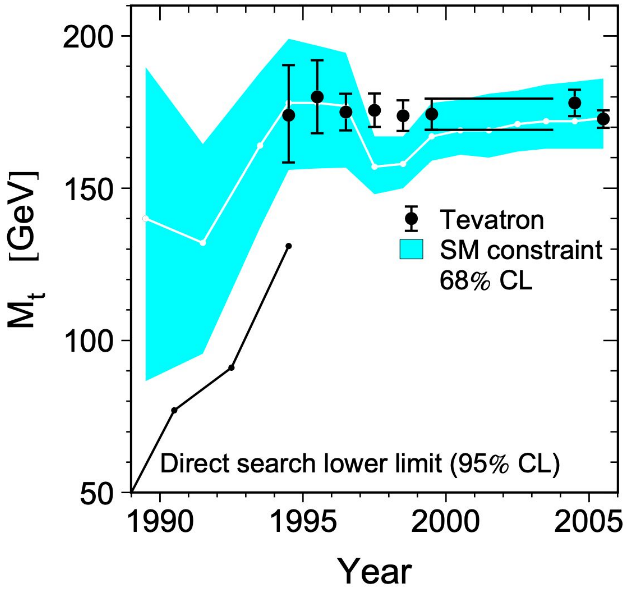
- Precision Measurements
- Computation of observables
- Fit tells us:
  - If the model works
  - Values for parameters

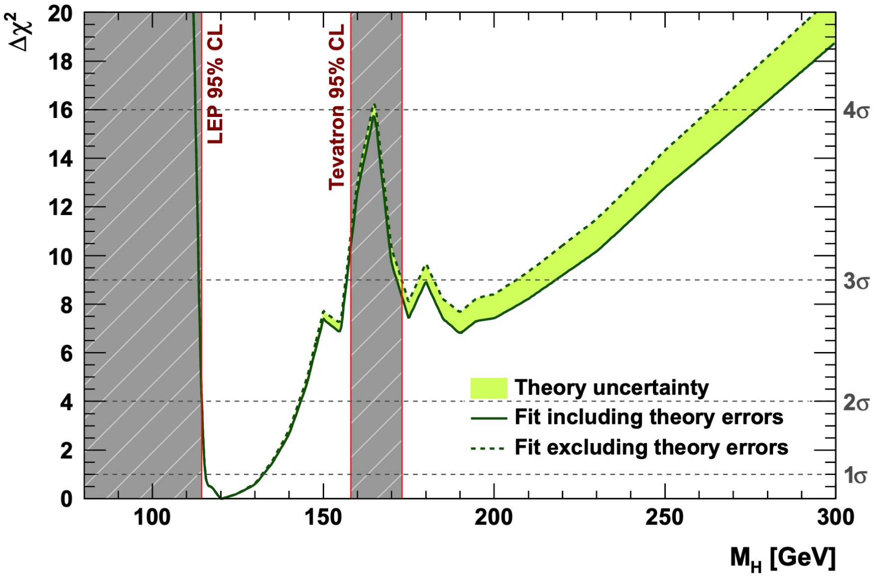
$$\mathcal{O} = \mathcal{O}(M_z, M_h, M_t, \alpha_s, \Delta\alpha_{had}^{(5)})$$



The Precision Electroweak Fit - Successes

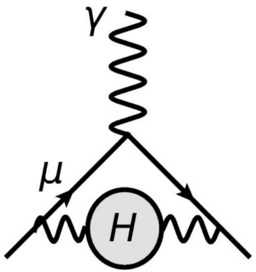
- Successful predictions of the top and higgs masses



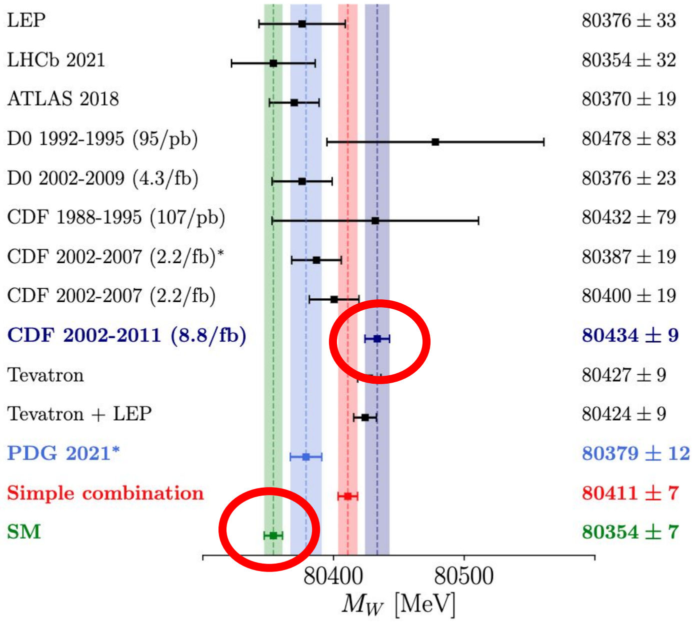


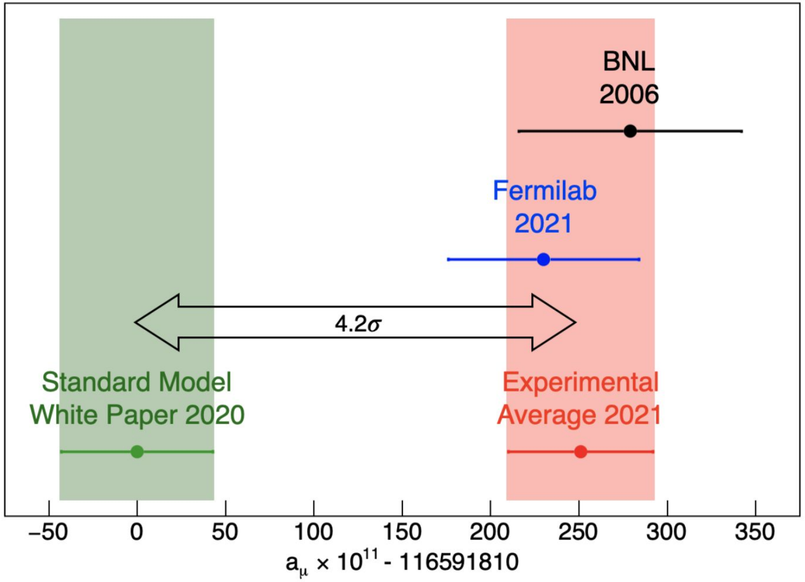
[0509008; 1107.0975]

Precision Electroweak Fit - Tensions

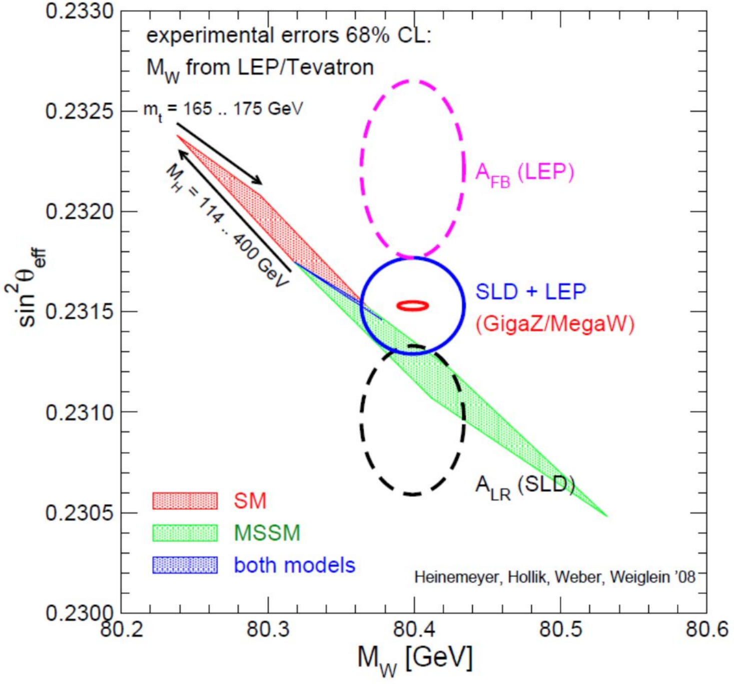


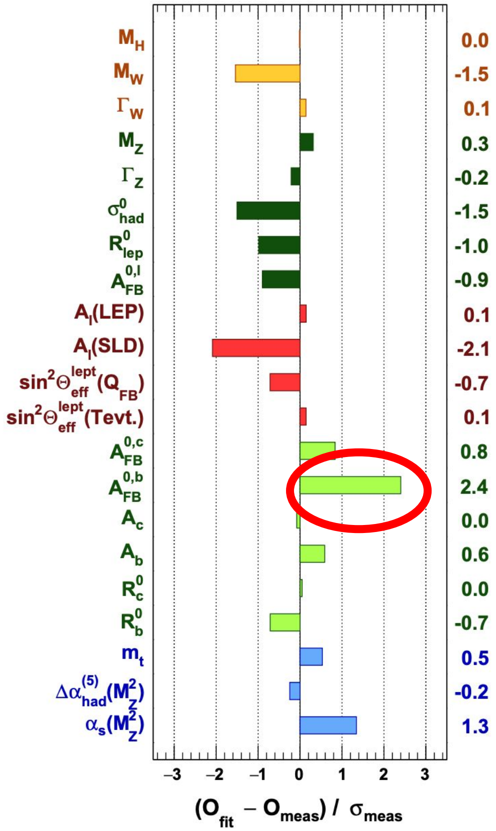
- Things look pretty good, but a few tensions remain





Precision Electroweak Fit - Tensions (2)





[1504.01726;1803.01853]

Precision Electroweak Analysis + BSM Physics

- One Option: Modify SM and recompute all observables
  - Problem: Not very efficient
- Better Option: Find a generic way to parameterize BSM effects
  - Oblique Parameters - Capture modifications to gauge boson propagators
    - S, T, U

$$S \leftrightarrow (h^\dagger \sigma^a h) W^a_{\mu\nu} B^{\mu\nu}$$

$$T \leftrightarrow (h^\dagger D^\mu h)(D_\mu h^\dagger h)$$

$$U \leftrightarrow (h^\dagger W^{a\mu\nu} h)(h^\dagger W^a_{\mu\nu} h)$$

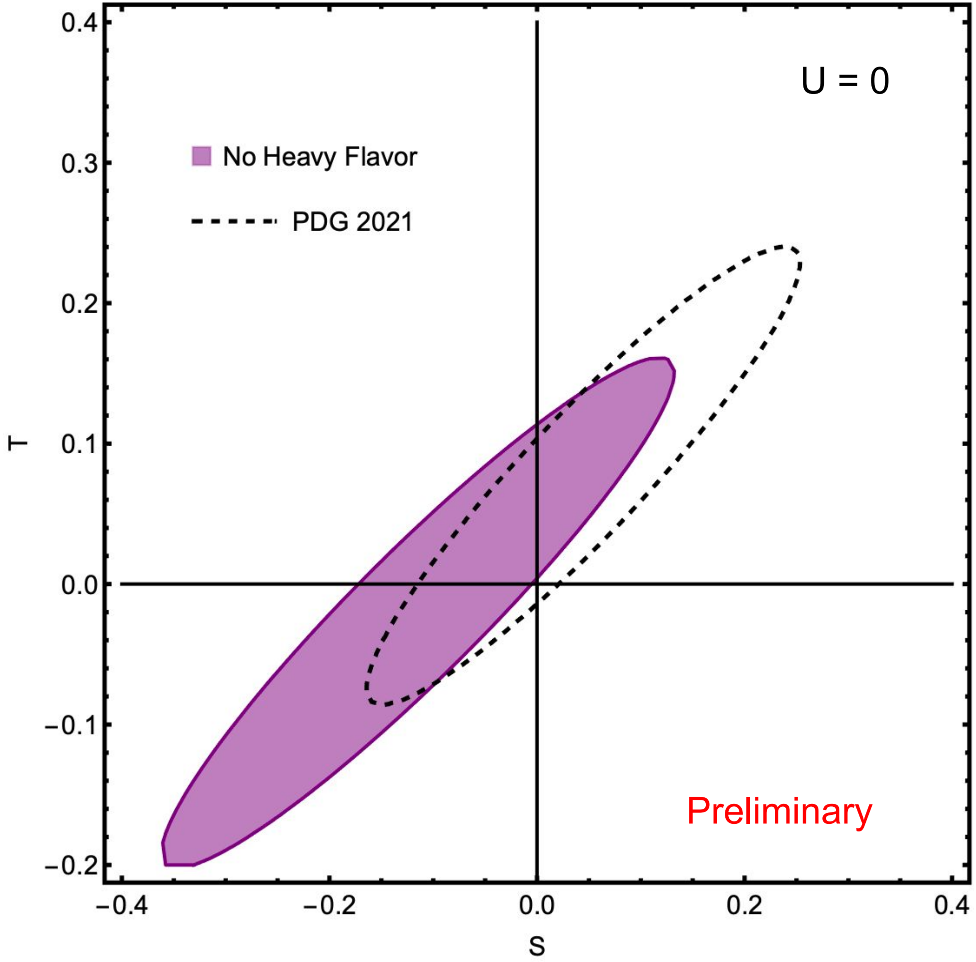
⇐ Dim 8

[PRL. 65, 964; PRD 46, 381]

Oblique Fits

$$\chi^2(\theta = M_z, M_h, M_t, \alpha_s, \Delta\alpha^{(5)}_{had}, S, T)$$

$$= (\mathbf{y} - \boldsymbol{\mu}(\theta))^T V^{-1} (\mathbf{y} - \boldsymbol{\mu}(\theta))$$



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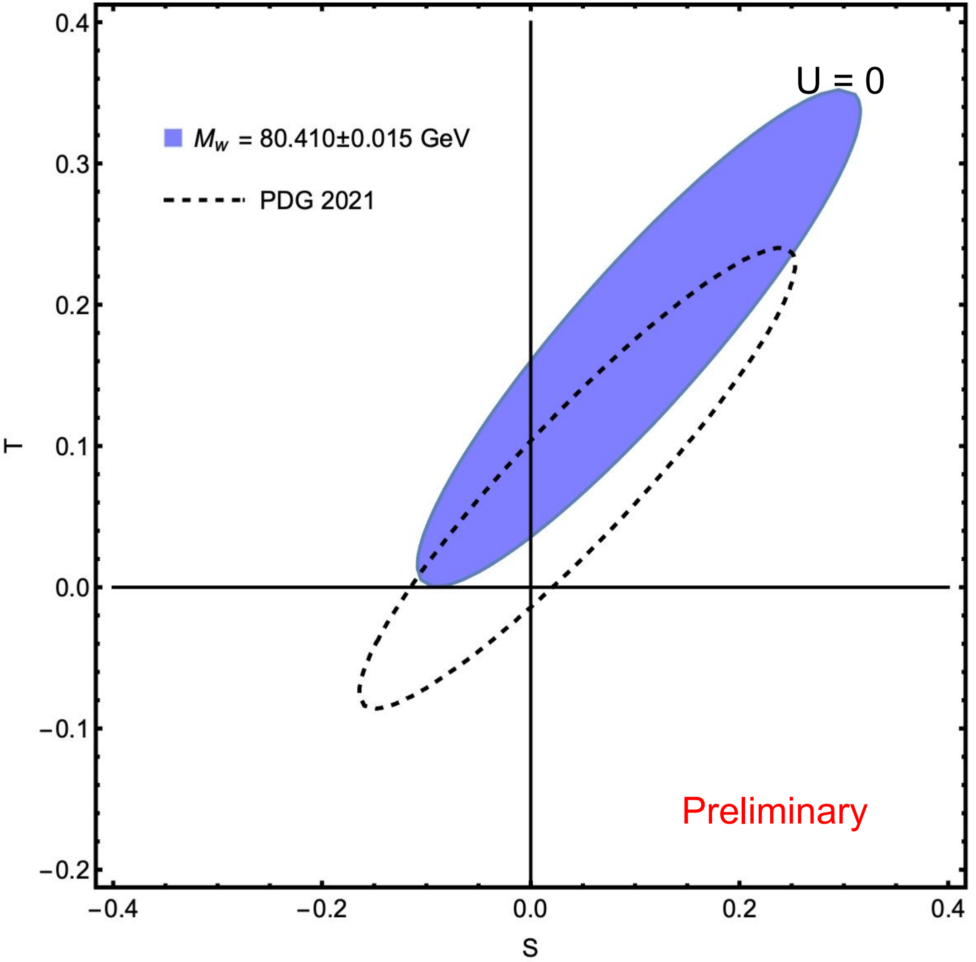

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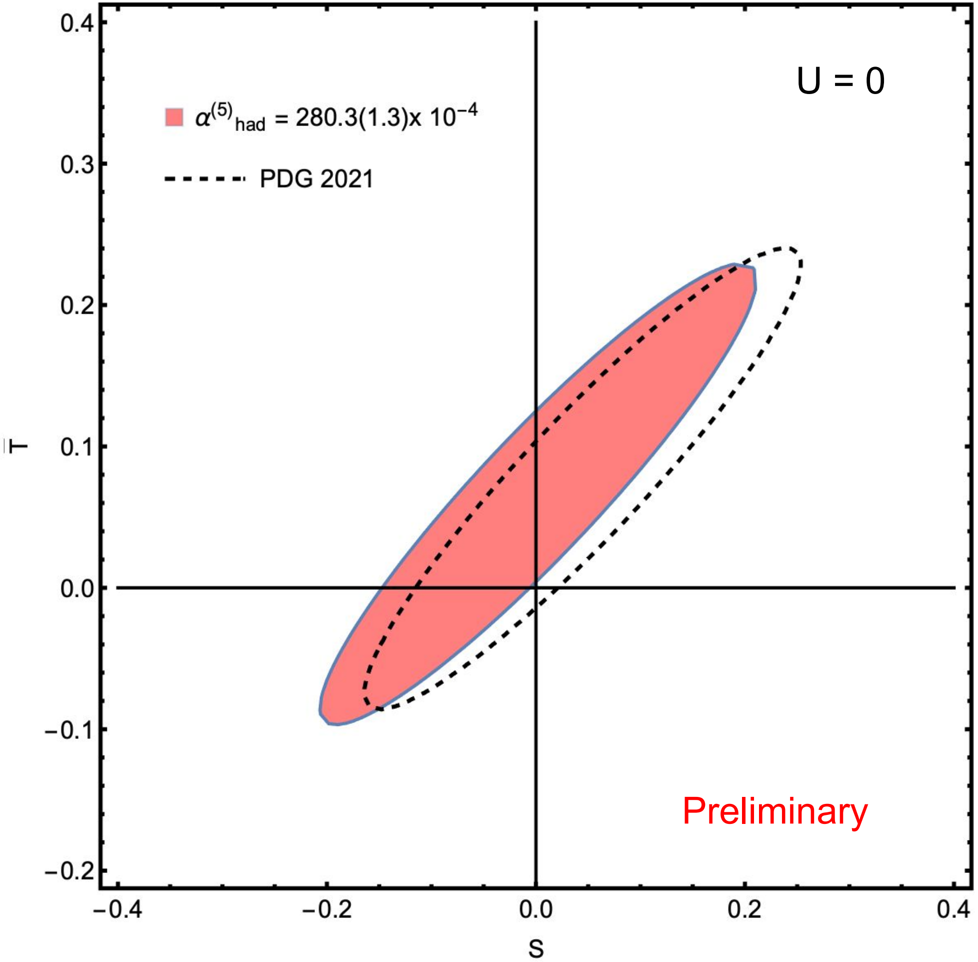
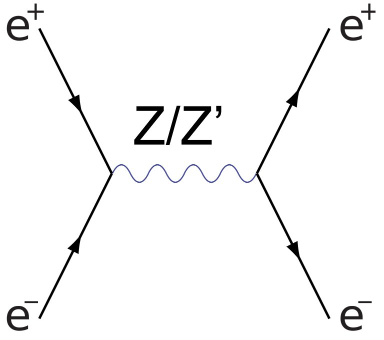


Kinetic Mixing



- Add a new spontaneously broken U(1) symmetry
  - "Dark Photon", "Dark Z", "Z'"
- Simple and well-motivated extension to the SM
- Renormalizable coupling between new field strength and hypercharge

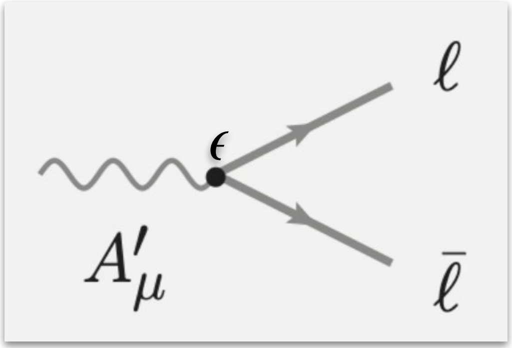
$$\mathcal{L} \supset -\frac{1}{4}\hat{B}_{\mu\nu}\hat{B}^{\mu\nu} - \frac{1}{4}\hat{Z}_{D\mu\nu}\hat{Z}_D^{\mu\nu} + \frac{\epsilon}{2\cos\theta_w}\hat{Z}_{D\mu\nu}\hat{B}^{\mu\nu} + \frac{1}{2}M_{D,0}^2\hat{Z}_{D\mu}\hat{Z}_D^{\mu}$$

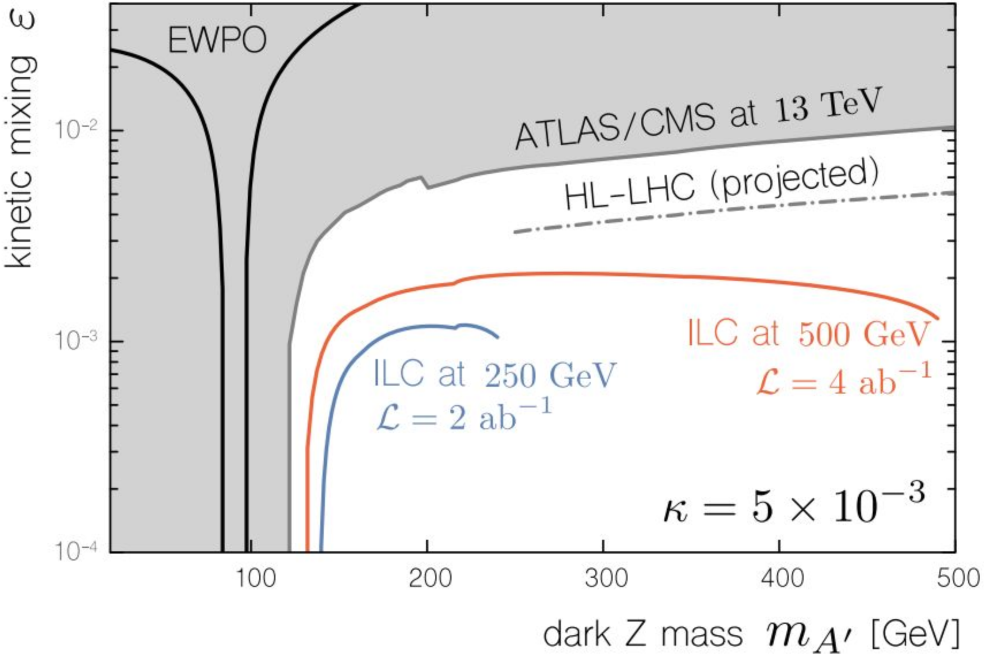
$$\alpha S = 4\xi c_W^2 s_W \tan\chi \qquad \alpha T = \xi^2\left(\frac{M_{Z_2}^2}{M_{Z_1}^2} - 1\right) + 2\xi s_W \tan\chi$$

Kinetic Mixing - Collider Bounds and Width Effects

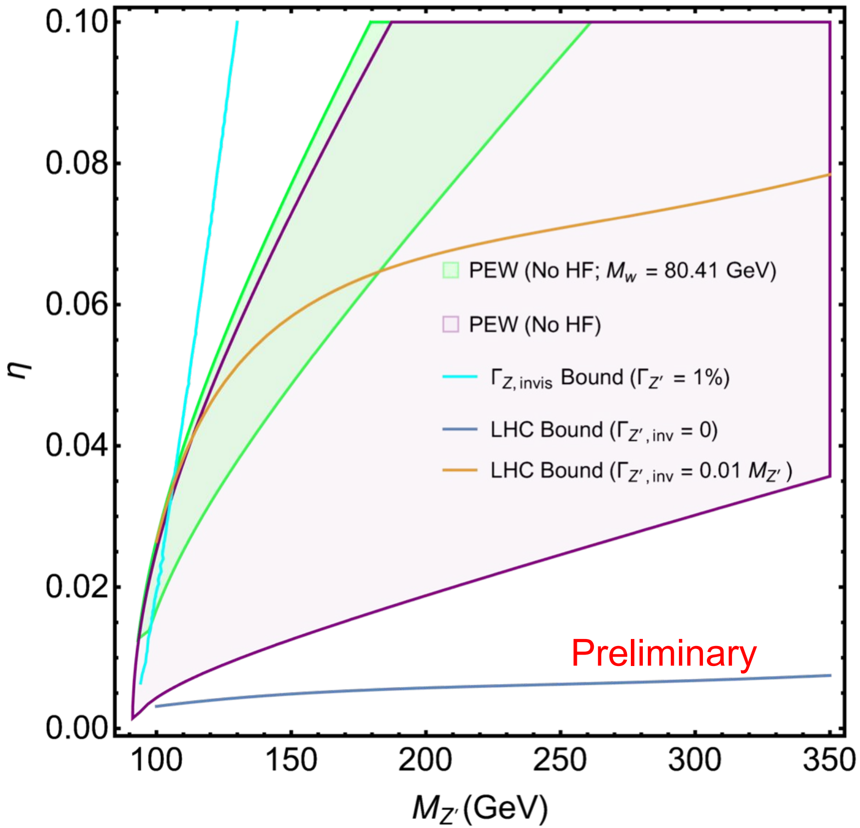
$$\sigma(q\bar{q} \to l^+ l^-) \sim \epsilon^2$$

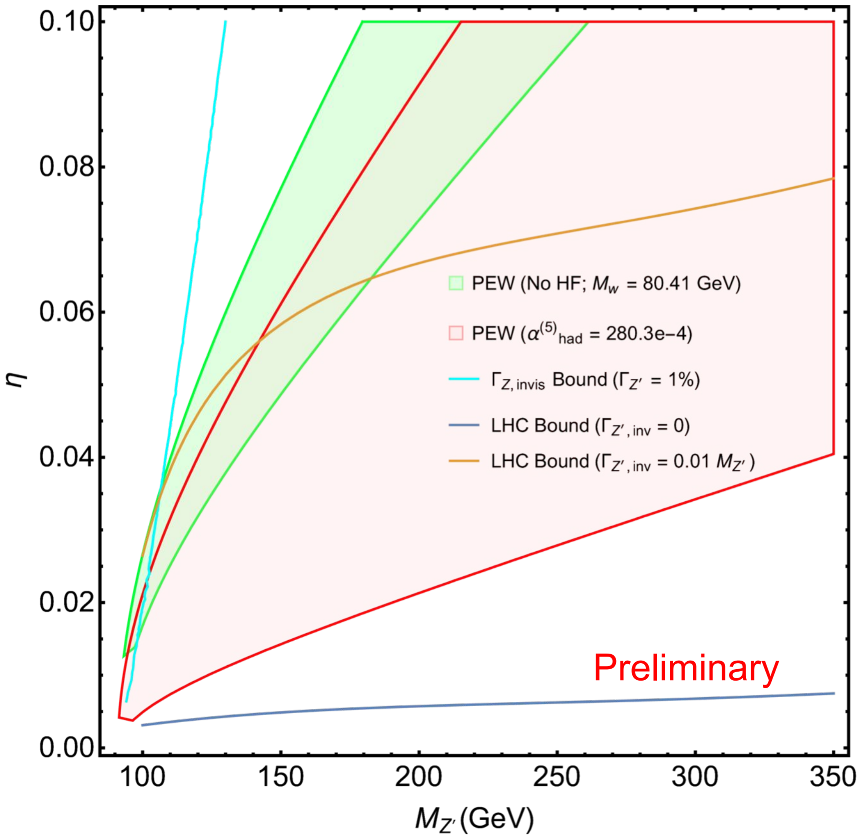
$$\Gamma(Z' \to \text{SM}) \sim \epsilon^2$$





Dark Photon Parameter Space





Summary

- Existing tensions motivate the exploration of different data combinations in the PEW fit
- S-T preferred region for different data combinations
  - Connection to kinetic mixing
- Complementarity between PEW and collider bounds
- Interesting target for future LHC searches

Thank You!

Backup Slides

Oblique Parameters

$$T \equiv \frac{1}{\alpha(m_Z)}\left(\frac{\Pi_{WW}(0)}{m_W^2} - \frac{\Pi_{ZZ}(0)}{m_Z^2}\right) = \frac{\rho - 1}{\alpha(m_Z)}$$

$$S \equiv \frac{4c^2s^2}{\alpha(m_Z)}\left(\frac{\Pi_{ZZ}(m_Z^2) - \Pi_{ZZ}(0)}{m_Z^2} - \frac{c^2 - s^2}{cs}\frac{\Pi_{Z\gamma}(m_Z^2)}{m_Z^2} - \frac{\Pi_{\gamma\gamma}(m_Z^2)}{m_Z^2}\right)$$

$$U \equiv \frac{4s^2}{\alpha(m_Z)}\left(\frac{\Pi_{WW}(m_W^2) - \Pi_{WW}(0)}{m_W^2} - \frac{c}{s}\frac{\Pi_{Z\gamma}(m_Z^2)}{m_Z^2} - \frac{\Pi_{\gamma\gamma}(m_Z^2)}{m_Z^2}\right) - S$$

$$\mathcal{L}_{\text{eff}} = \mathcal{L}_{SM}(\tilde{e}_i) + \hat{\mathcal{L}}_{\text{new}},$$

$$\hat{\mathcal{L}}_{\text{new}} = -\frac{A}{4}\hat{F}_{\mu\nu}\hat{F}^{\mu\nu} - \frac{B}{2}\hat{W}^{\dagger}_{\mu\nu}\hat{W}^{\mu\nu} - \frac{C}{4}\hat{Z}_{\mu\nu}\hat{Z}^{\mu\nu} + \frac{G}{2}\hat{F}_{\mu\nu}\hat{Z}^{\mu\nu},$$
$$- w\,\tilde{m}_W^2\,\hat{W}^{\dagger}_{\mu}\hat{W}^{\mu} - \frac{z}{2}\tilde{m}_Z^2\,\hat{Z}_{\mu}\hat{Z}^{\mu}.$$

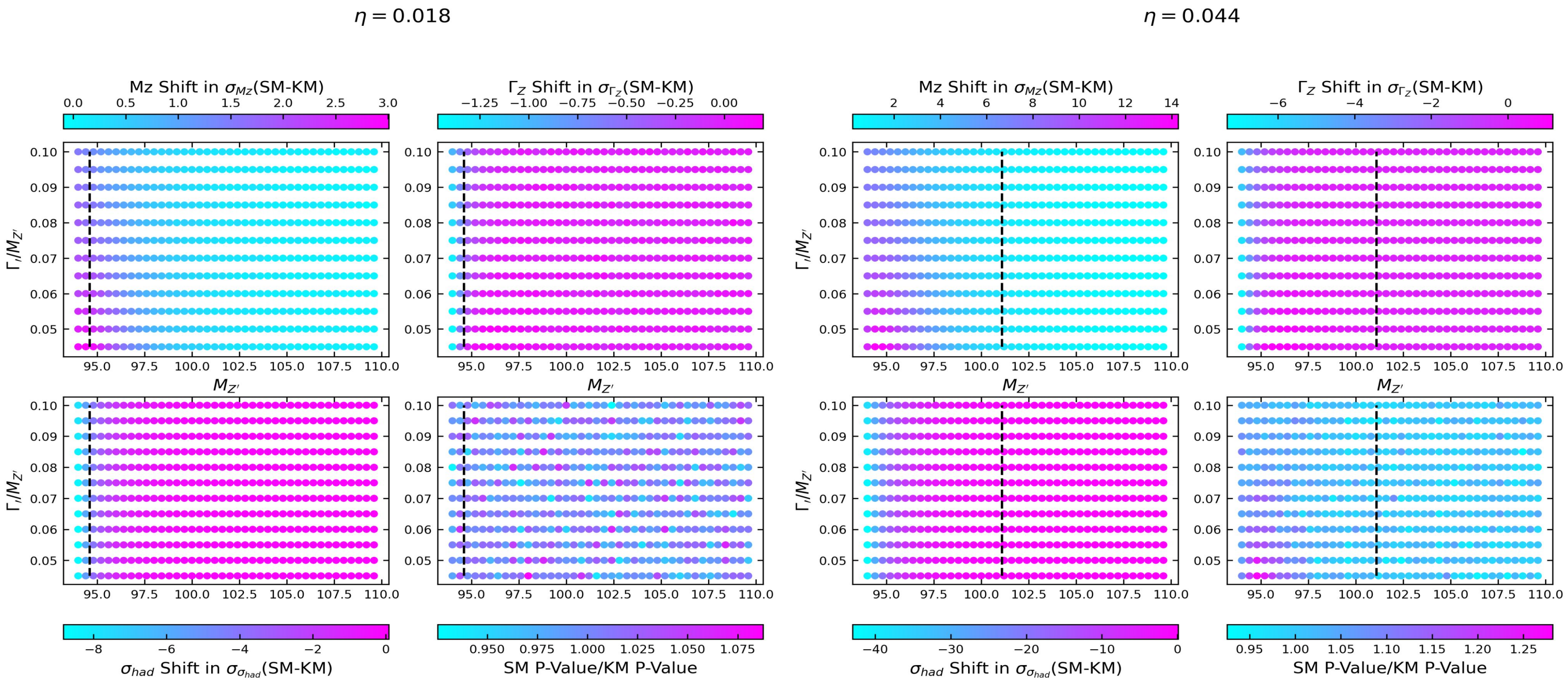
$$\alpha S = 4s_w^2c_w^2\left(A - C - \frac{c_w^2 - s_w^2}{c_w s_w}G\right),$$

$$\alpha T = w - z,$$

$$\alpha U = 4s_w^4\left(A - \frac{1}{s_w^2}B + \frac{c_w^2}{s_w^2}C - 2\frac{c_w}{s_w}G\right).$$

[9312291; PRL. 65, 964; PRD 46, 381]

What about interference or effects on Z-pole fit?



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