Oblique Lessons from the *W* Mass Measurement at CDFII

Cari Cesarotti, MIT

IDM 2022, Indirect Searches

July 21, 2022

(2204.05283) w/ P. Asadi, K. Fraser, S. Homiller , A. Parikh

Why are we interested in the W mass?

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Important confirmation of EWSB

$$|D_\mu H|^2 \xrightarrow{\text{SSB}} m_W^2 W^+ W^-$$

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Precision test of SM & possible NP

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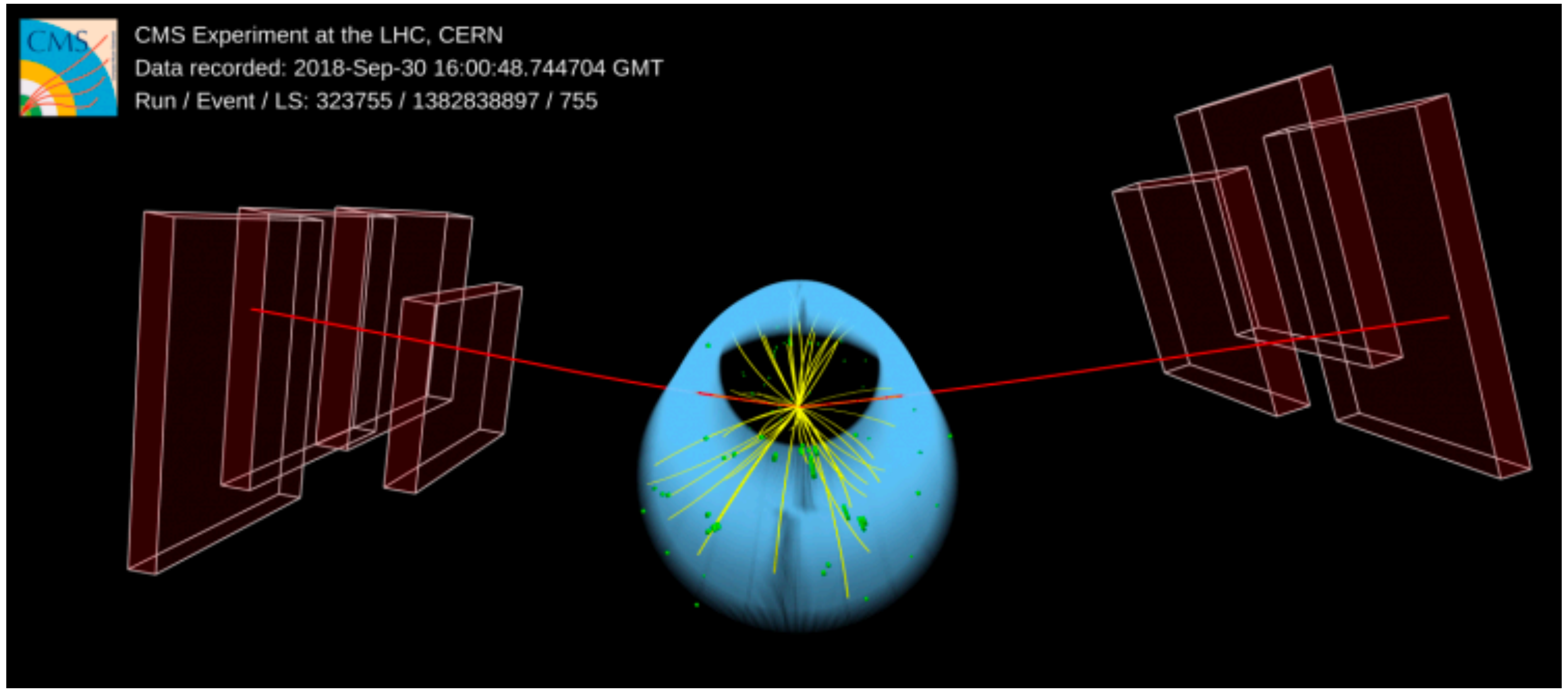

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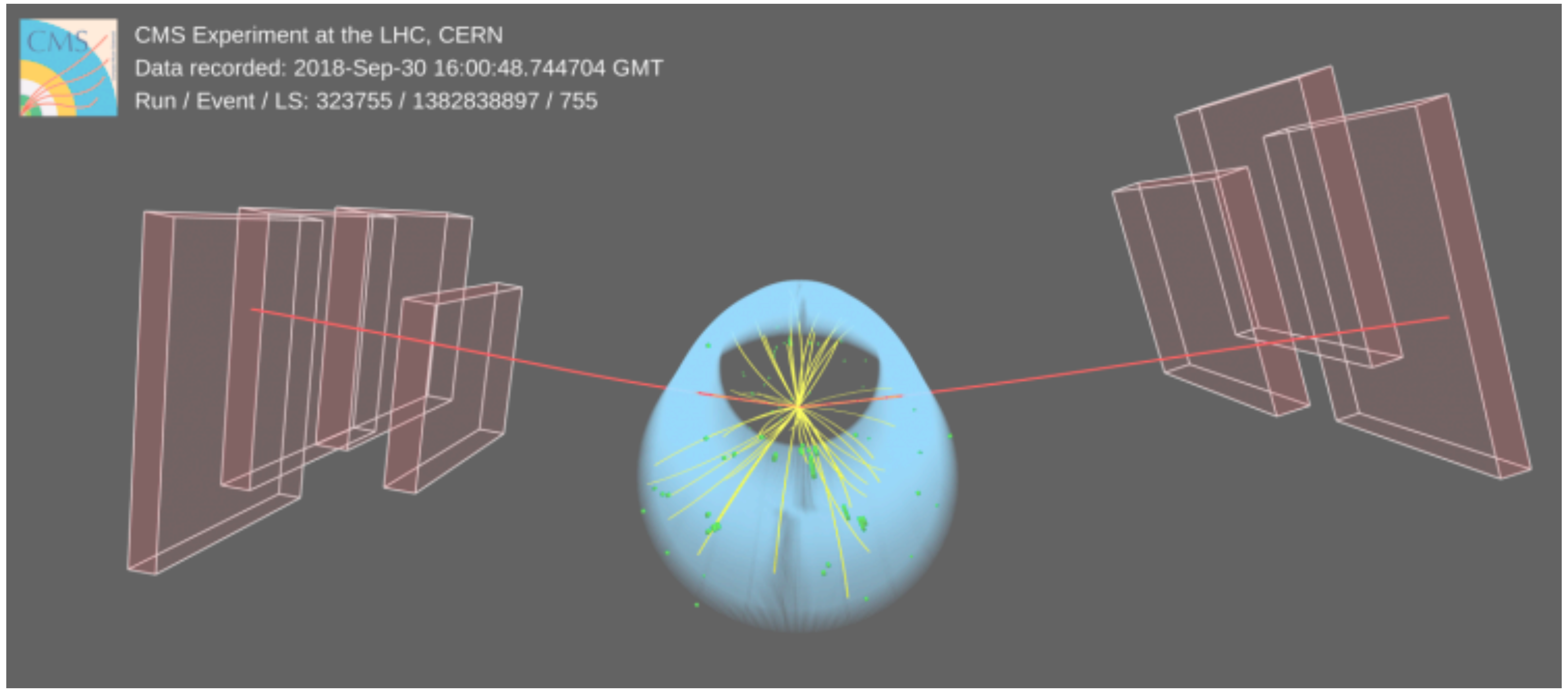

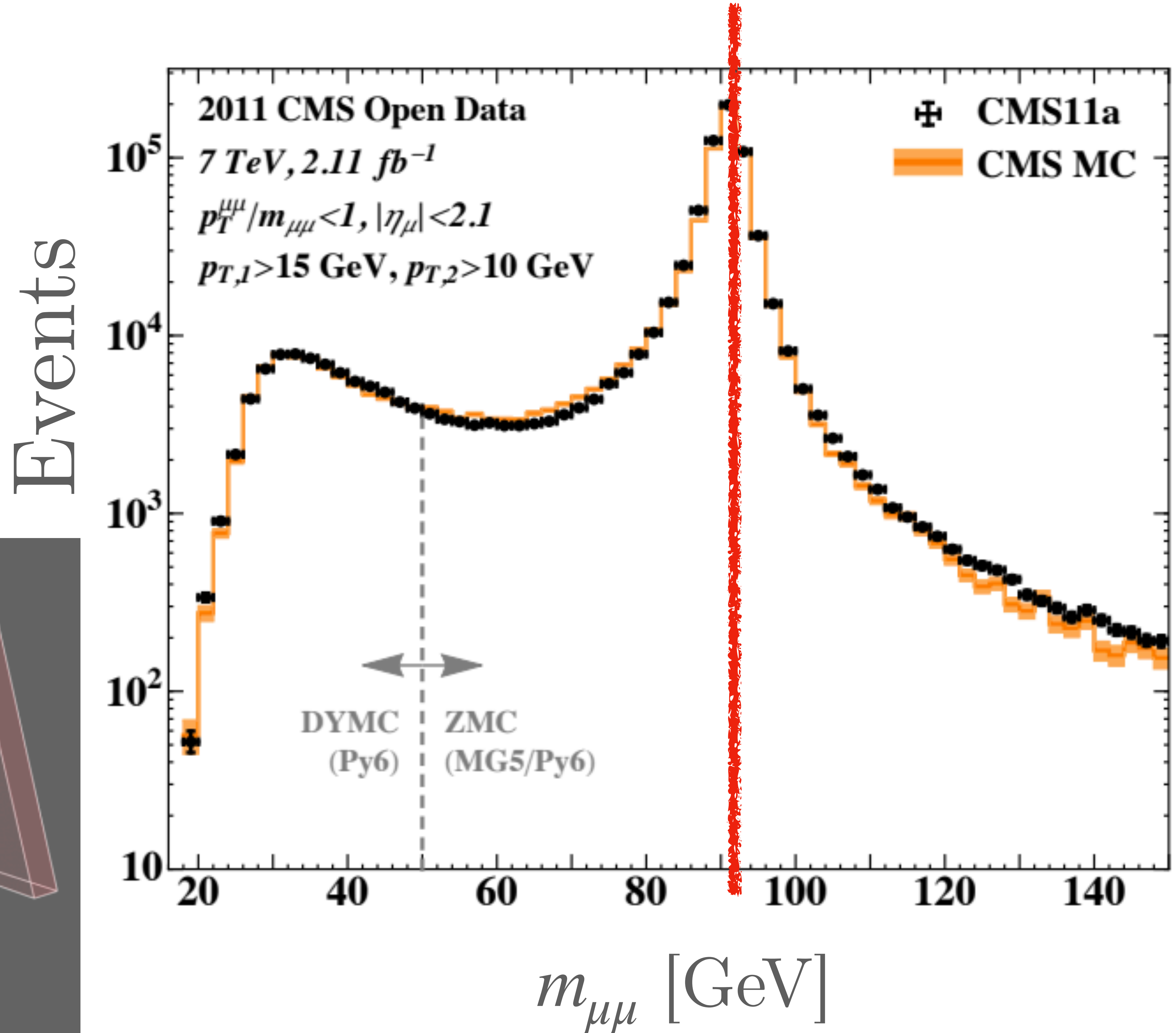

CC w/ Y. Soreq, M. Strassler, J. Thaler, W. Xue

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$W^+ \to l^+ \nu$

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Template fitting of kinematic variables

$W^+ \to l^+ \nu$ → Missing energy $\not{E}_T$

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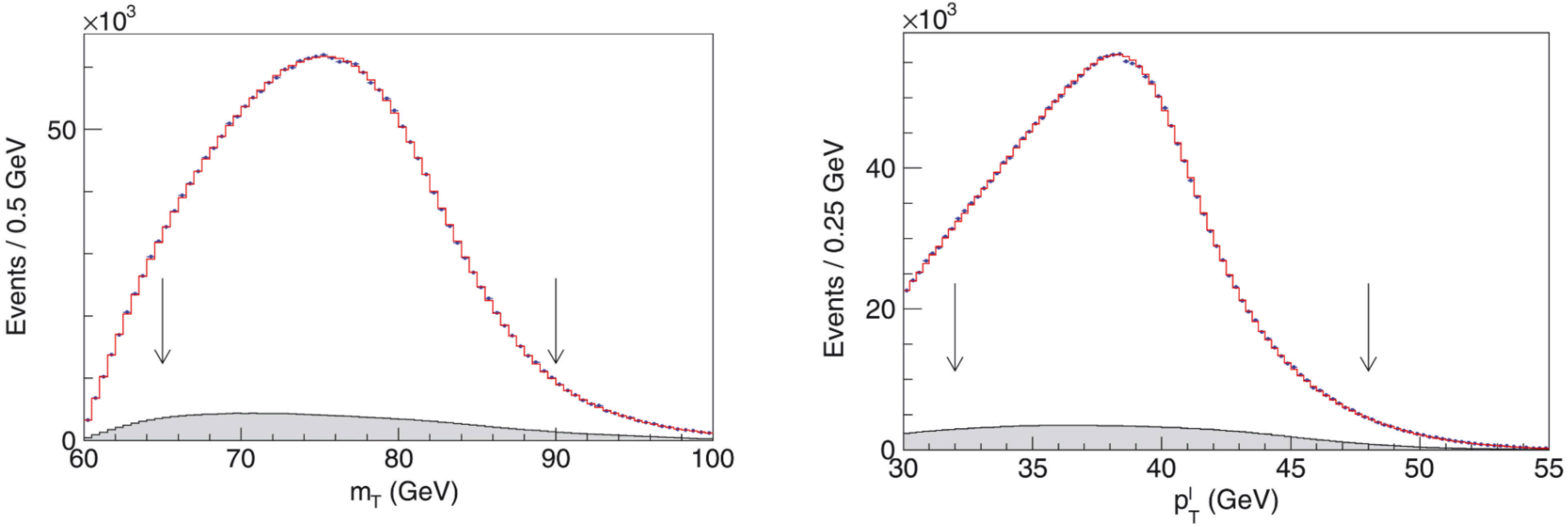
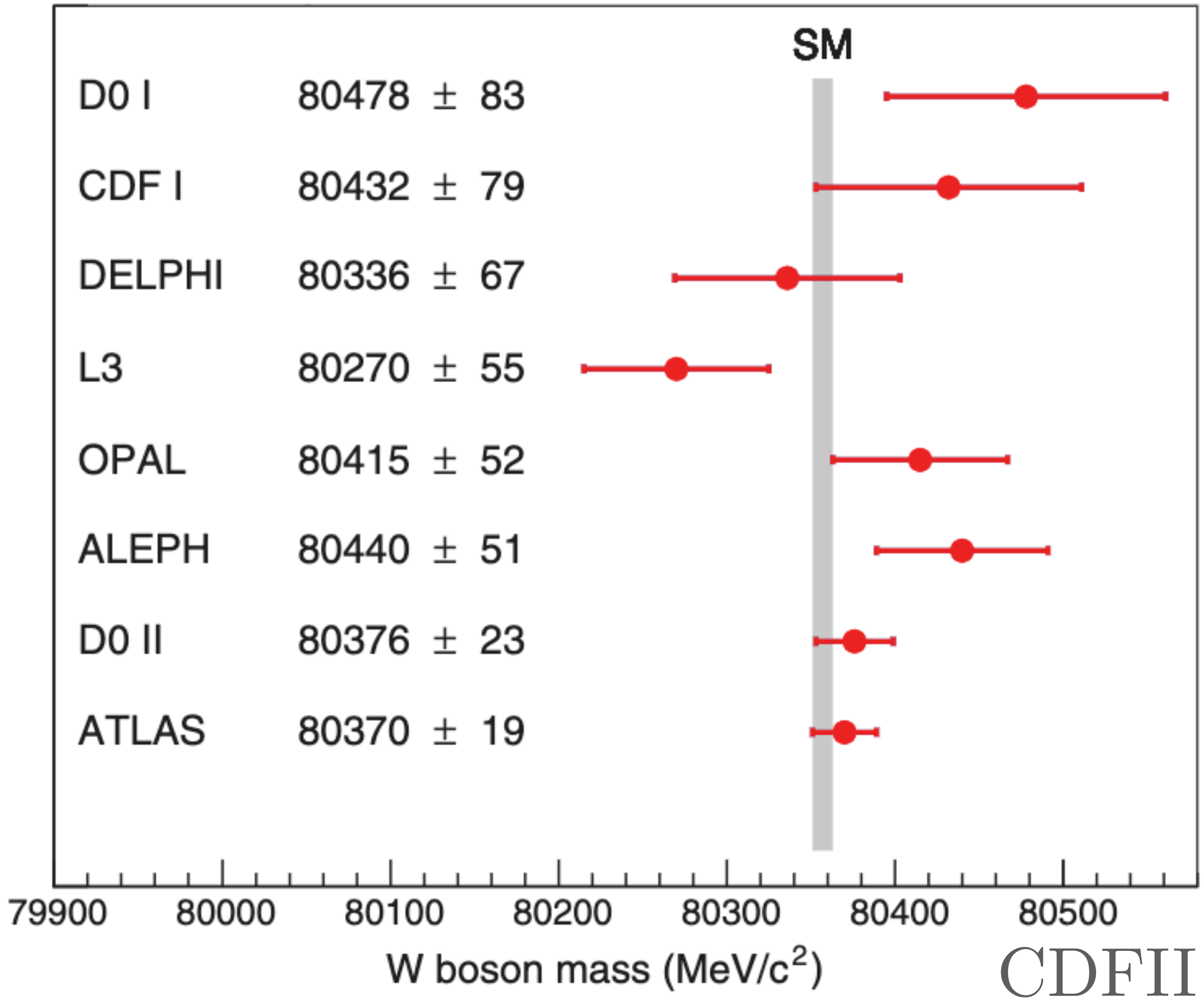
Why is it hard to measure the W mass?

$$W \to \mu\nu$$



CDFII Collaboration, 2022

Current W mass Measurements



PDG Average (2019):
80379 ± 12 MeV

CDFII Collaboration, 2022

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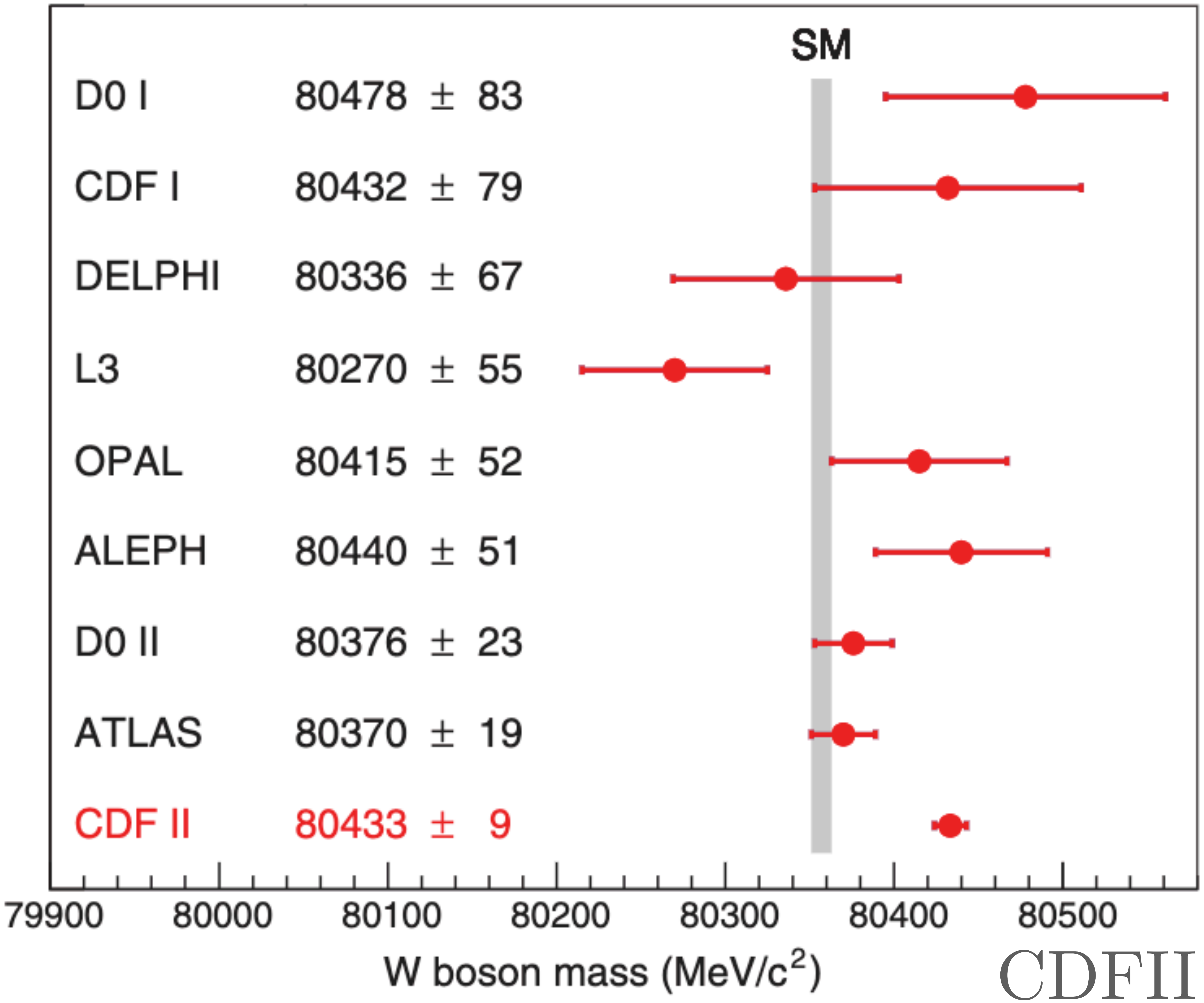

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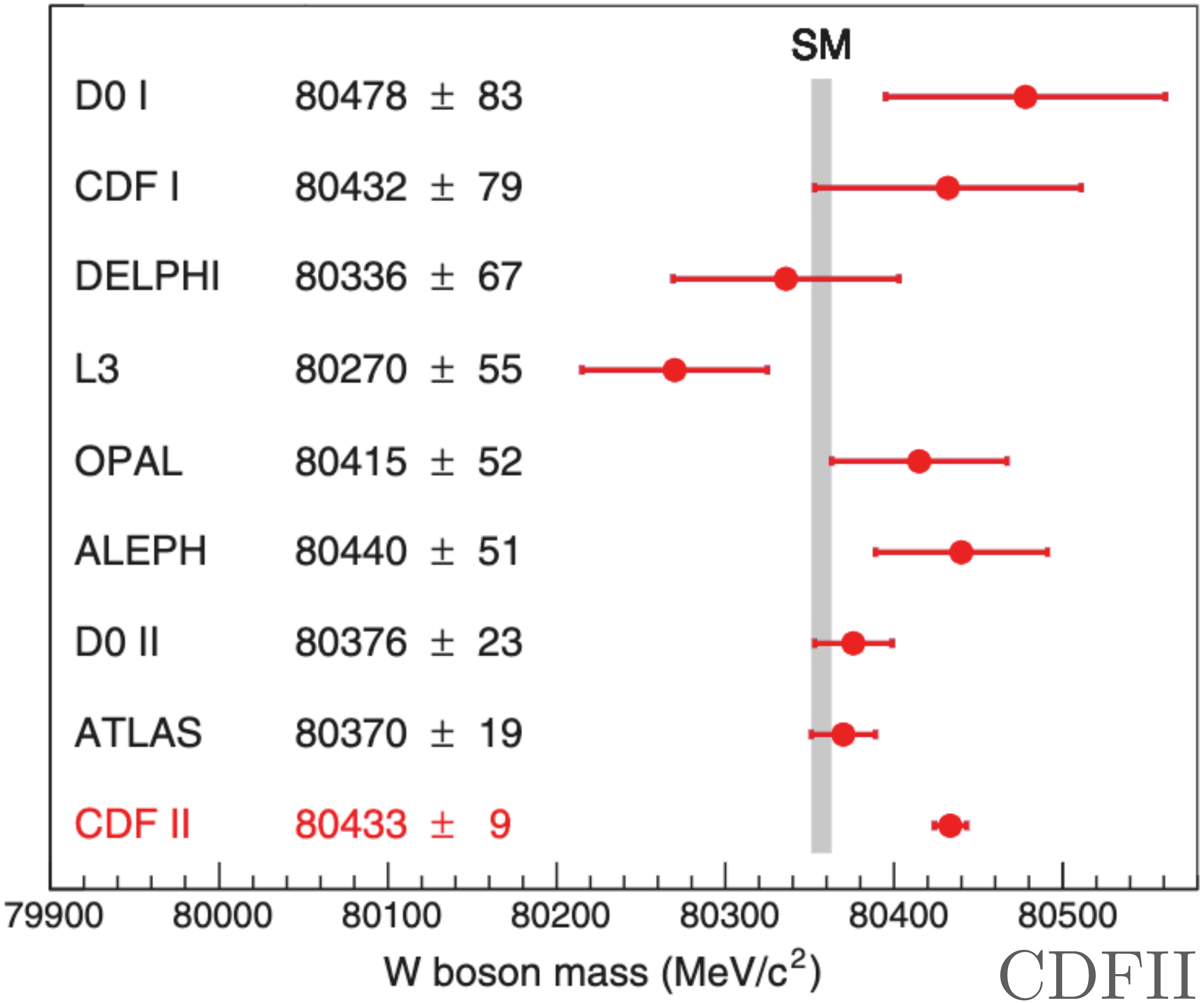

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- 4x Data Set
- PDF Uncertainty improvement
- Track reconstruction (p_T)

CDFII Collaboration, 2022

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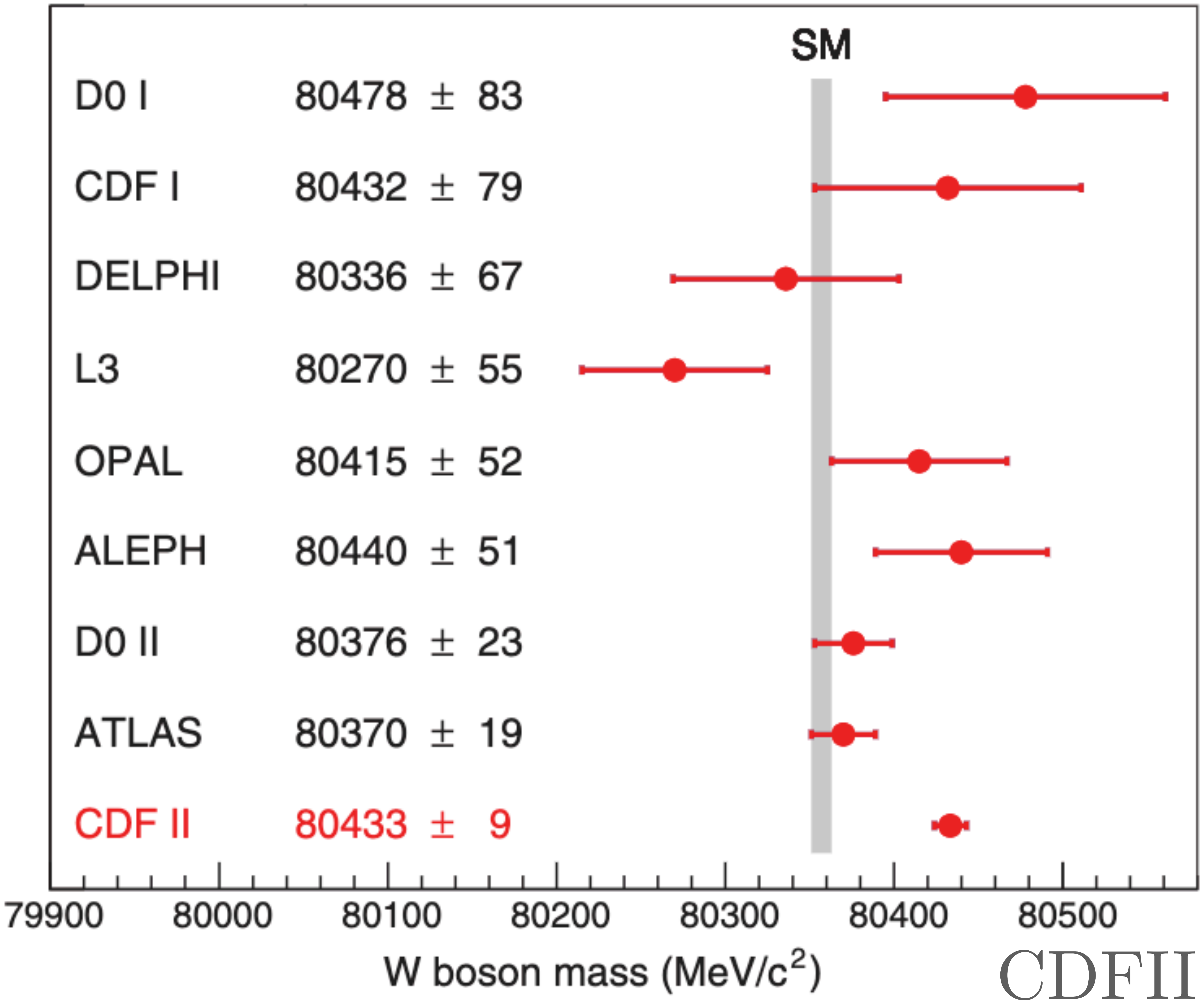

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SM Prediction:
80357 ± 6 MeV

CDFII Collaboration, 2022

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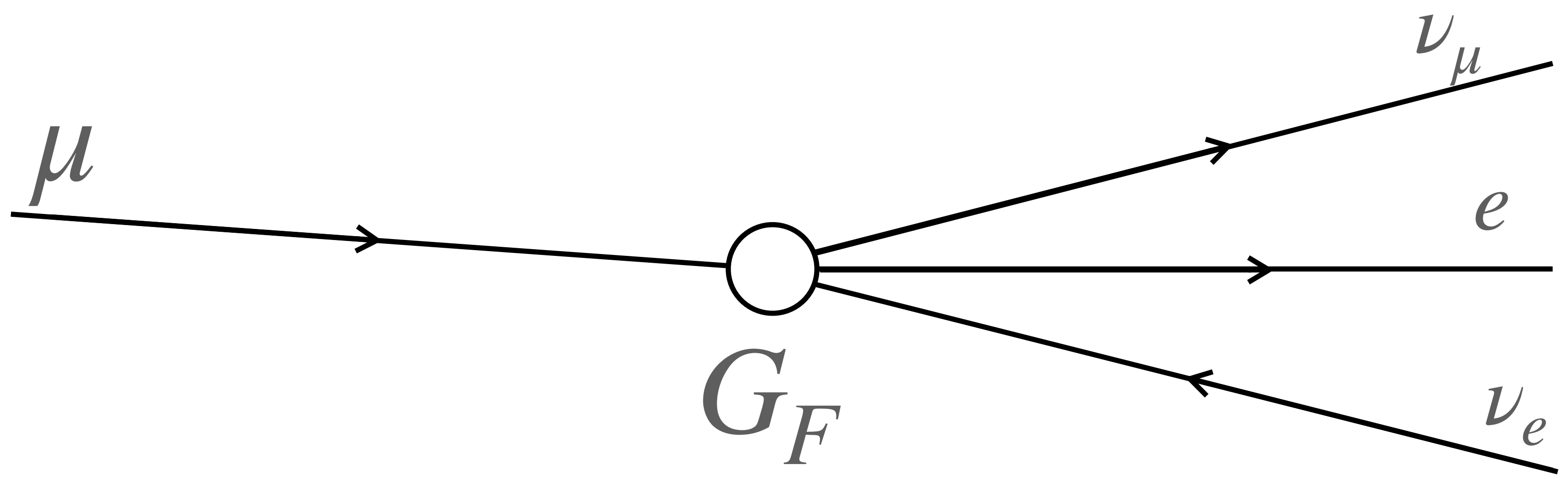
Basis of Free Parameters

$G_F, \alpha(q^2 = 0)$



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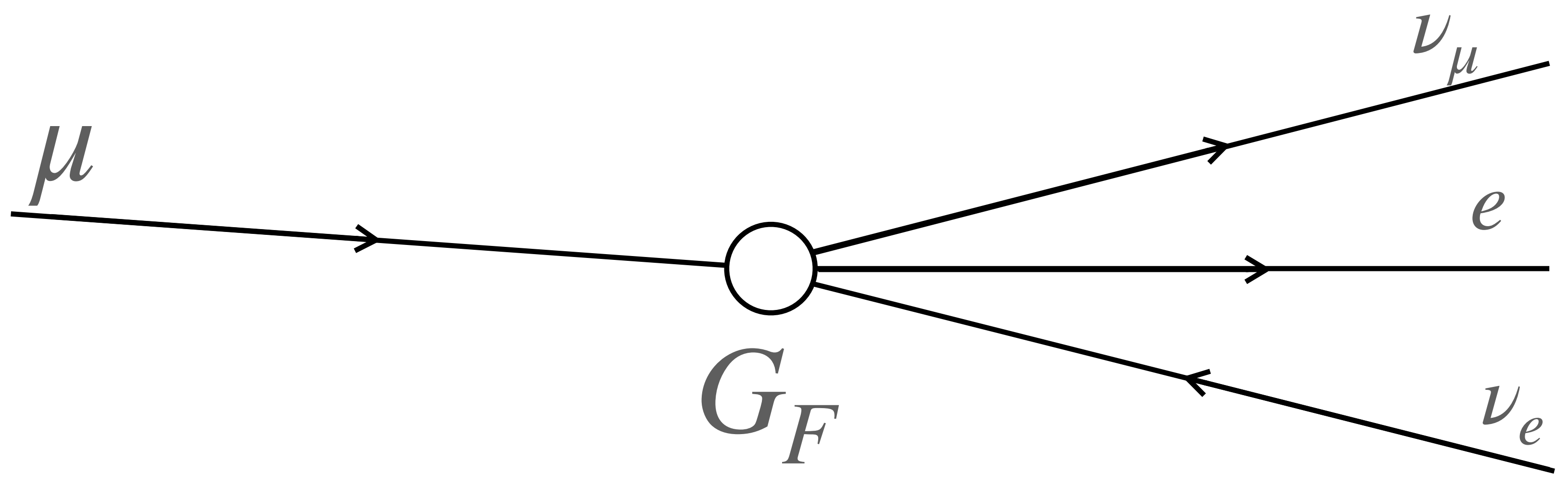

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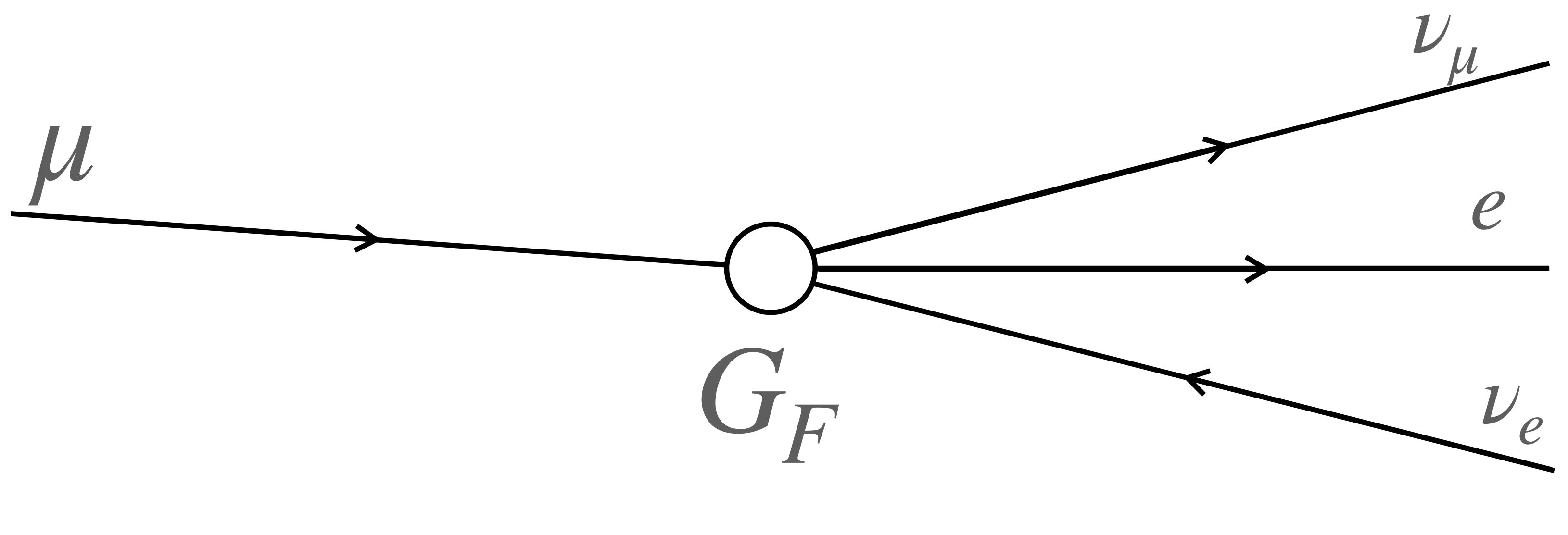

SM Predictions of Observables

$\Gamma_Z, \Gamma_W, \sigma_{\text{had}}, \cdots$

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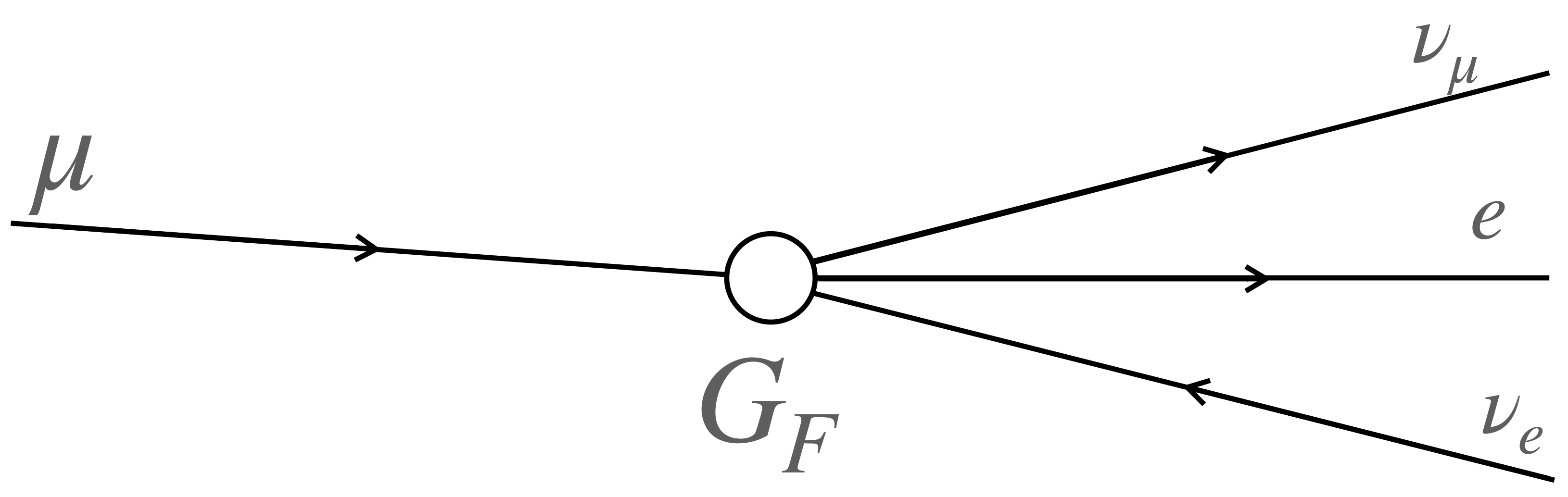

SM Predictions of Observables

$$\Gamma_Z, \Gamma_W, \sigma_{\text{had}}, \cdots$$

$$M_W^2\left(1 - M_W^2/M_Z^2\right) = \frac{\pi\alpha}{\sqrt{2}G_F}(1+\Delta r)$$

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Calculate χ^2 of fit

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Find values that minimize χ^2

Could new physics be hiding?

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Test with oblique parameters

Peskin & Takeuchi '91
Barbieri, Pomerol, Rattazzi, et al '04

$$S,\ T$$

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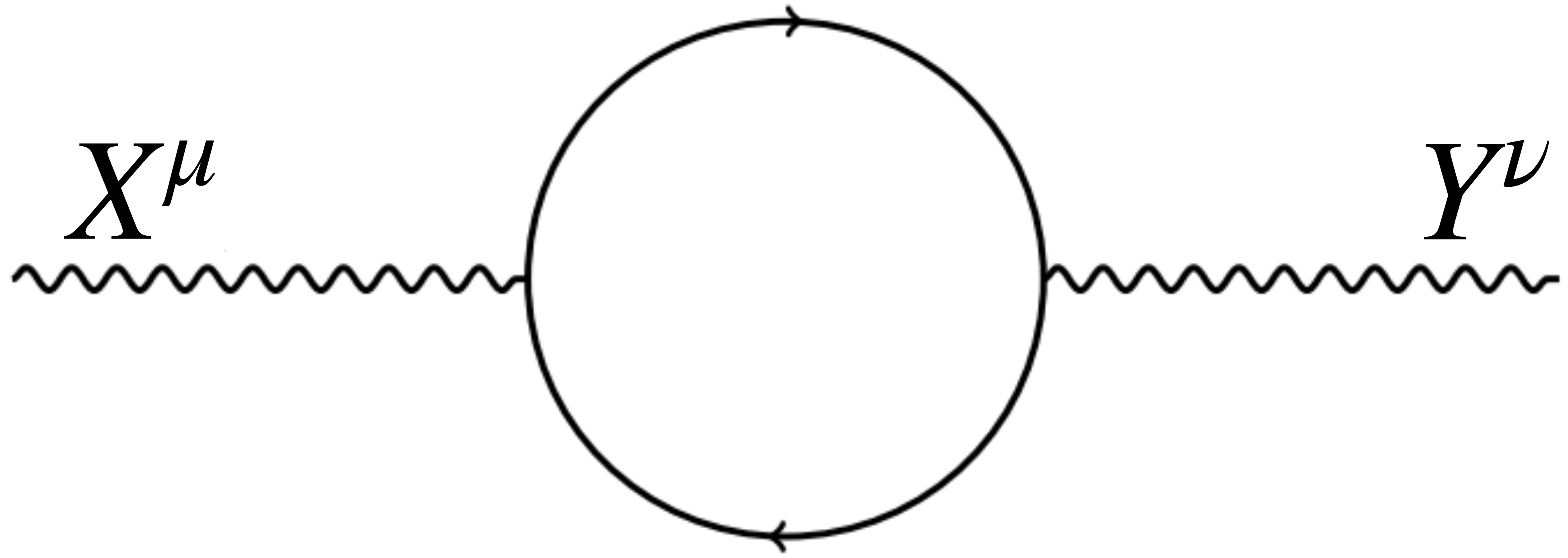
Radiative corrections to vacuum polarizations



$$= i\Pi_{XY}(p^2)g^{\mu\nu}$$

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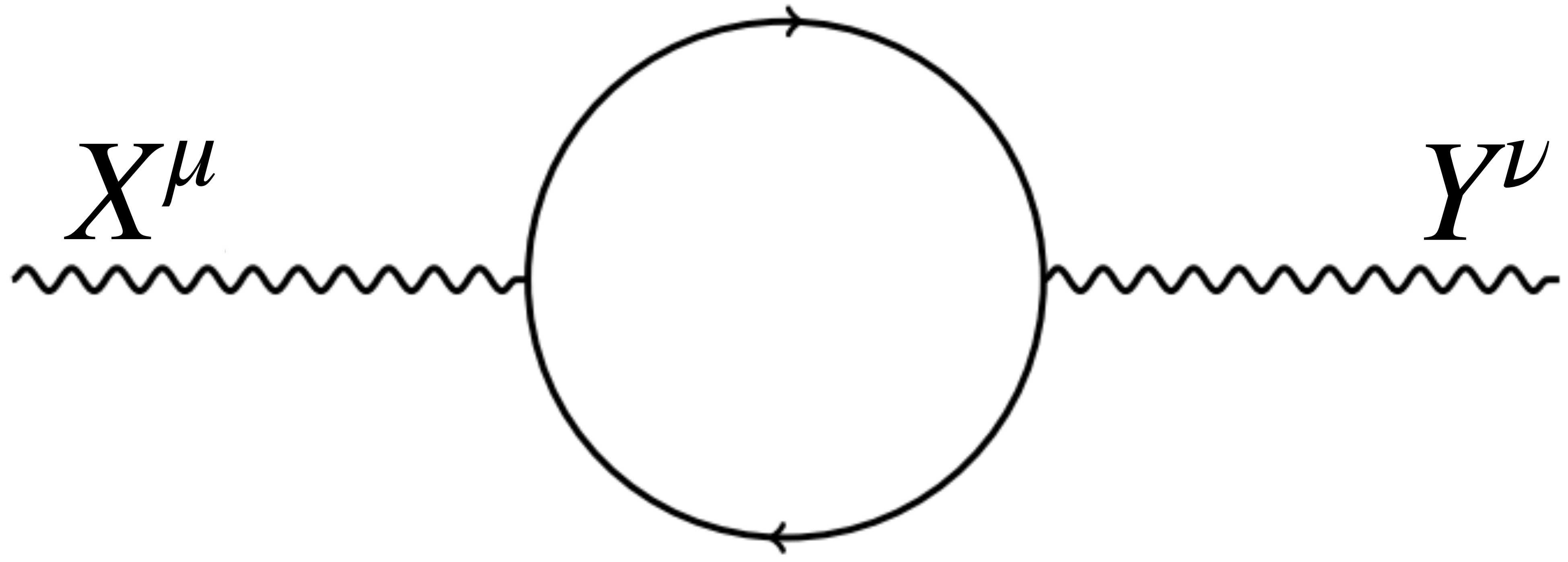

$= i\Pi_{XY}(p^2)g^{\mu\nu}$

$$S \equiv \frac{4c_W^2 s_W^2}{\alpha}\left[\Pi'_{ZZ}(0) - \frac{c_W^2 - s_W^2}{c_W s_W}\Pi'_{Z\gamma}(0) - \Pi'_{\gamma\gamma}(0)\right],$$

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

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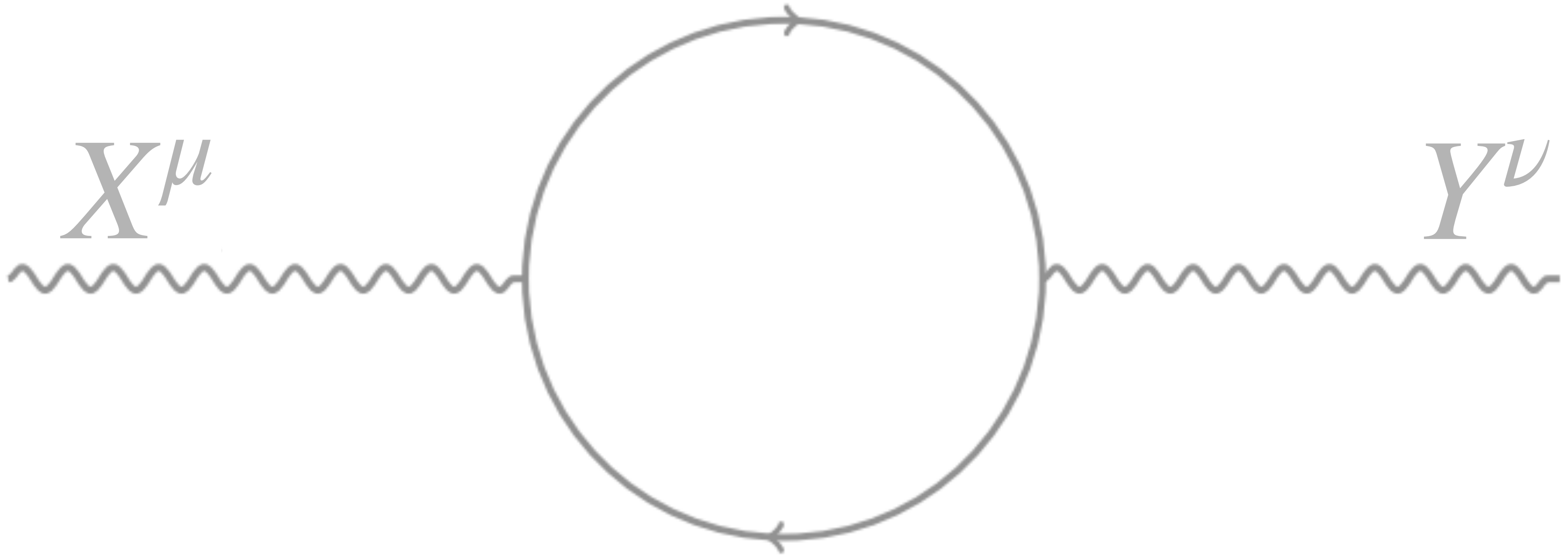

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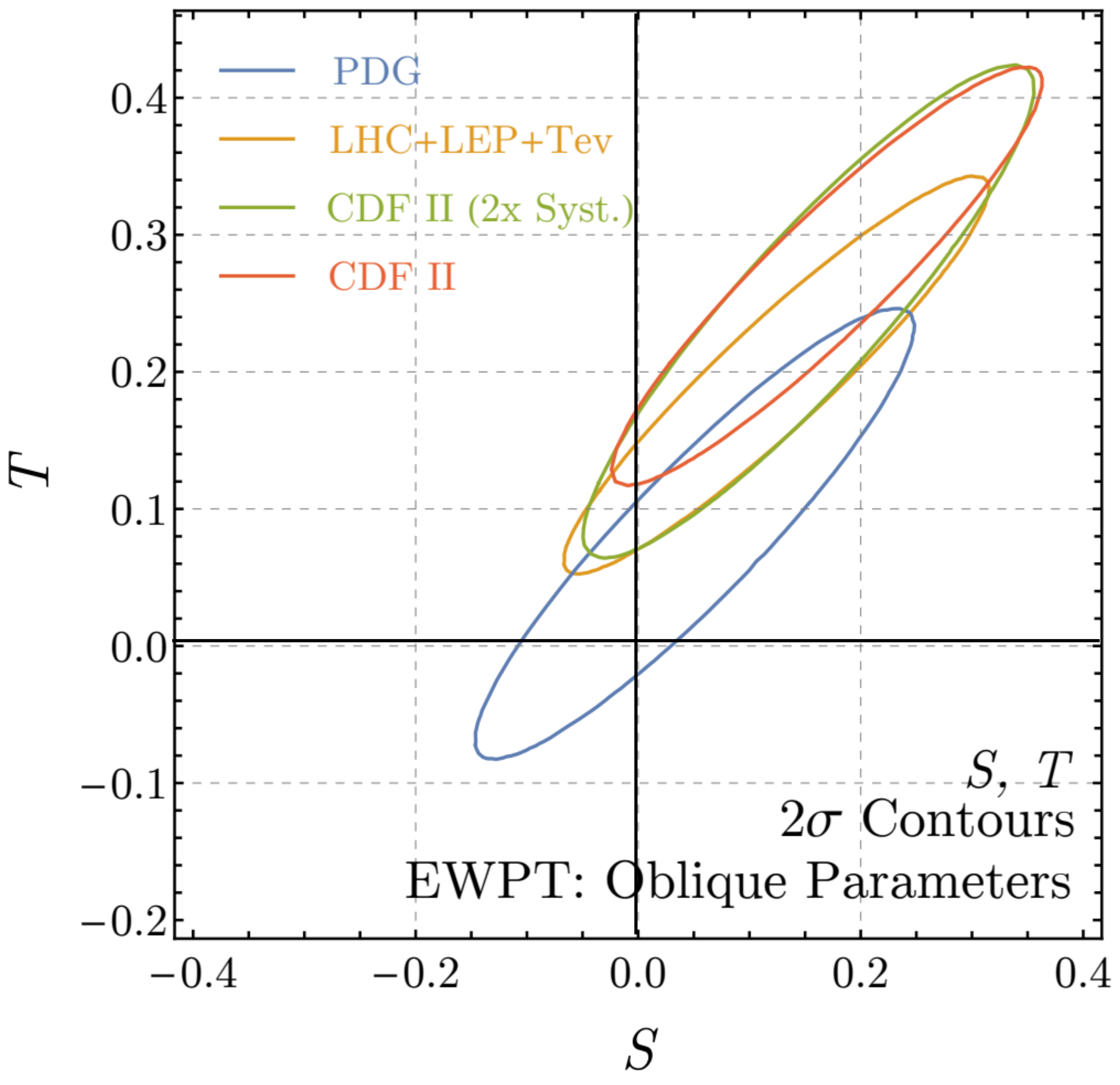
Include in EWPT

EWPT with S, T

$$f(\text{SM free parameters}, S, T) \Longrightarrow \text{calculable observables}$$

EWPT with $S,\ T$

$$f(\text{SM free parameters}, S, T) \implies \text{calculable observables}$$



SM Prediction:

$S,\ T \sim 0$

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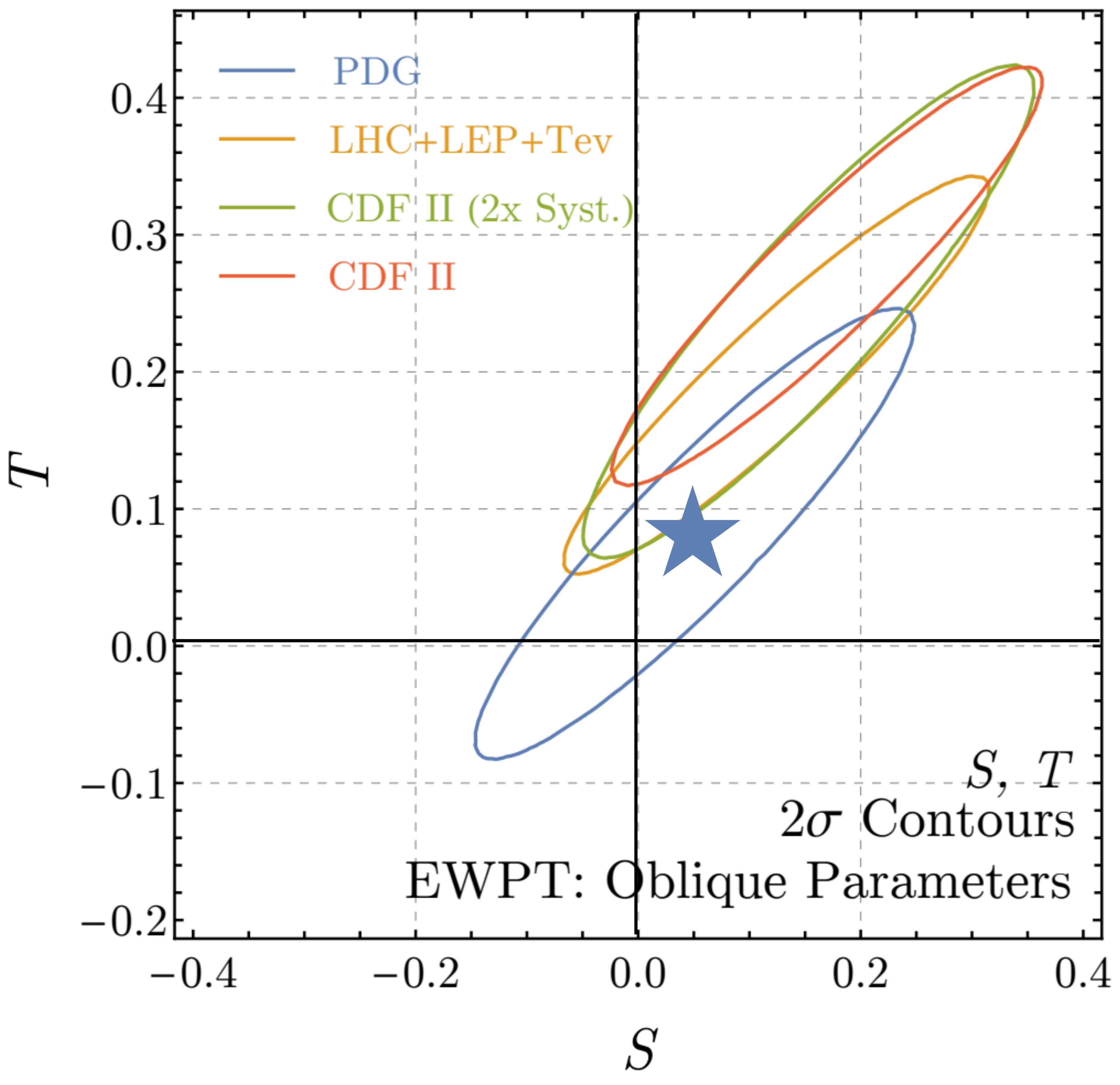

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PDG (2020)

$S \sim 0.05,\ T \sim 0.08$

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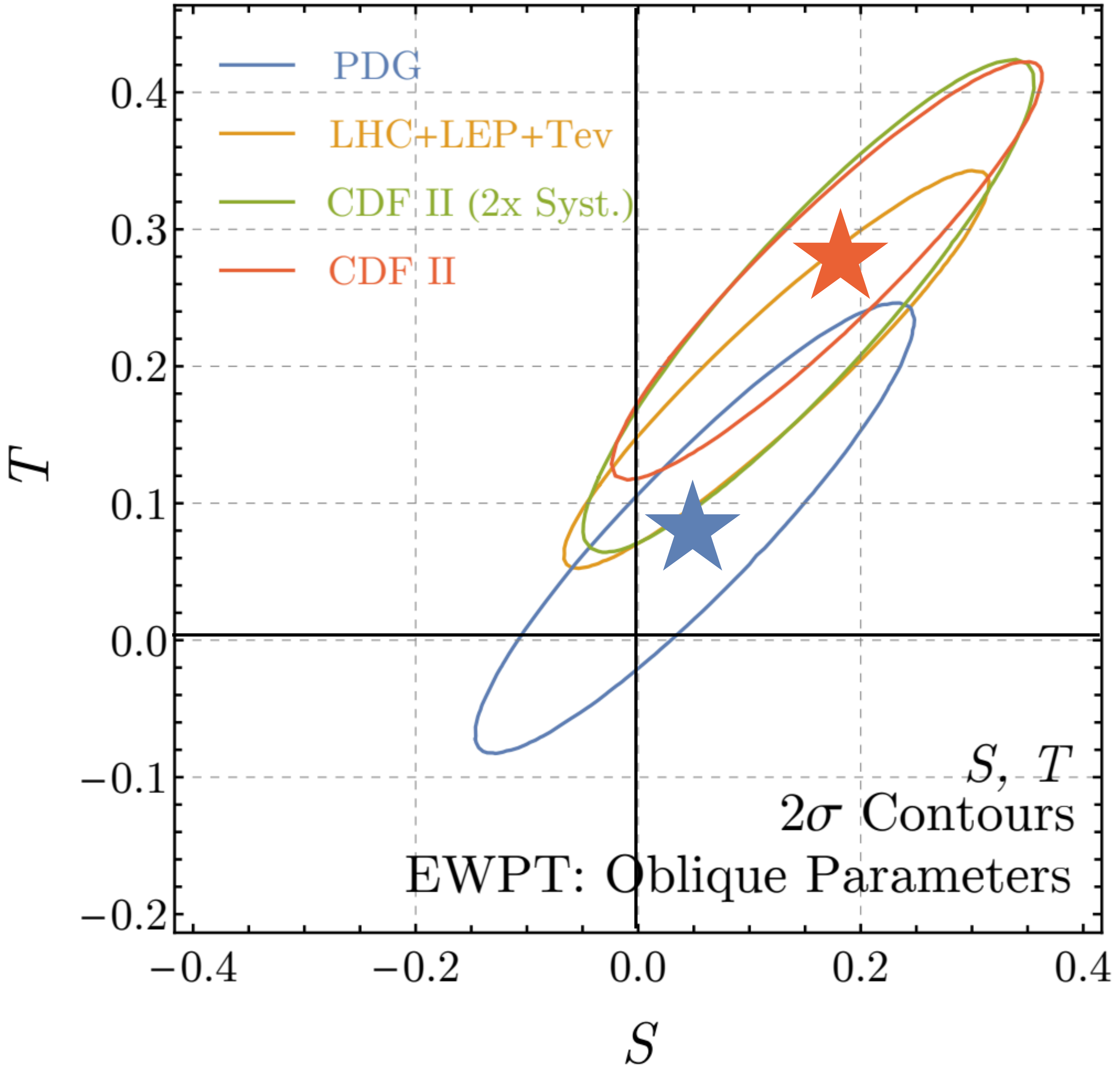

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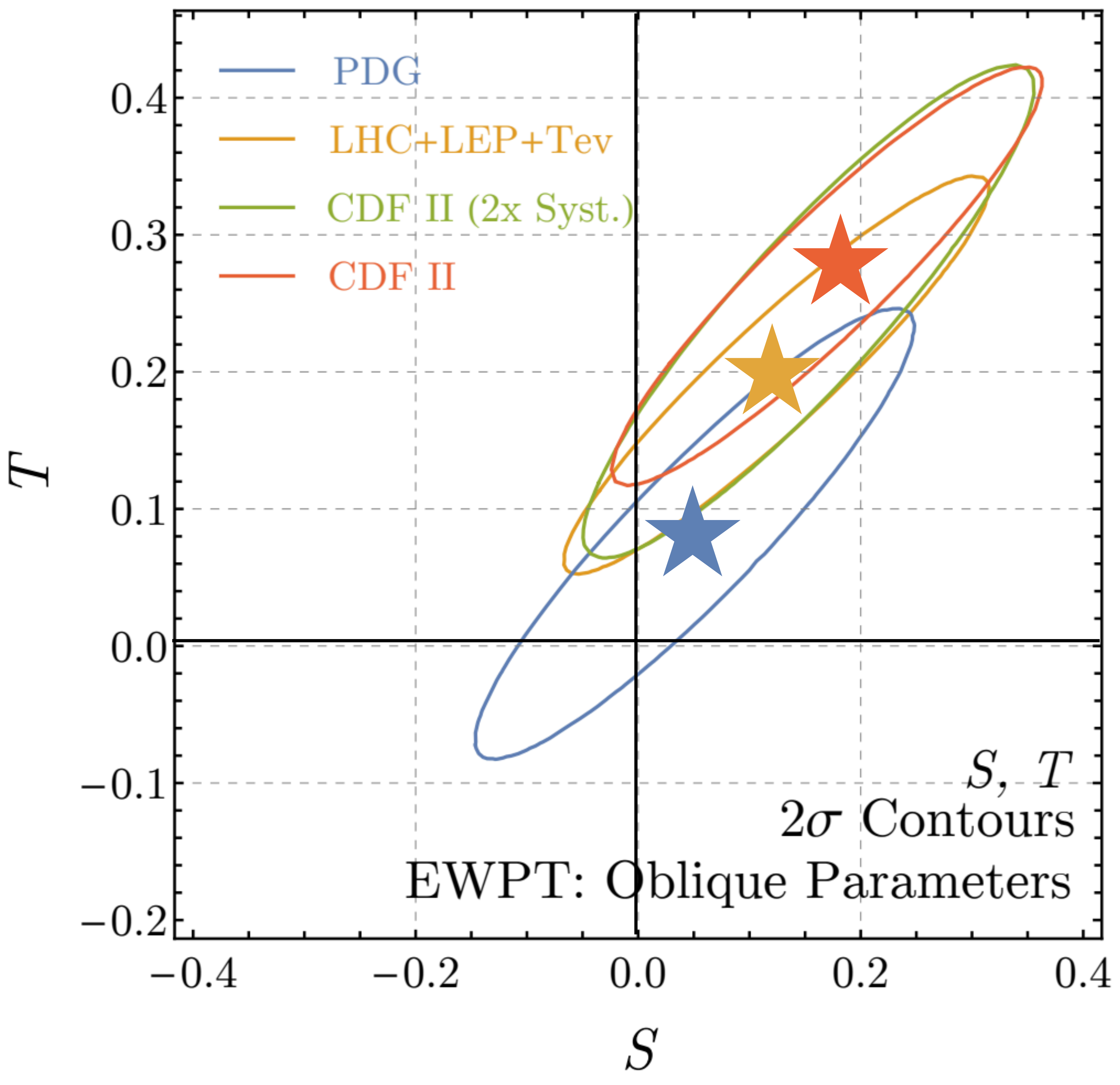

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$S \sim 0.12,\ T \sim 0.2$

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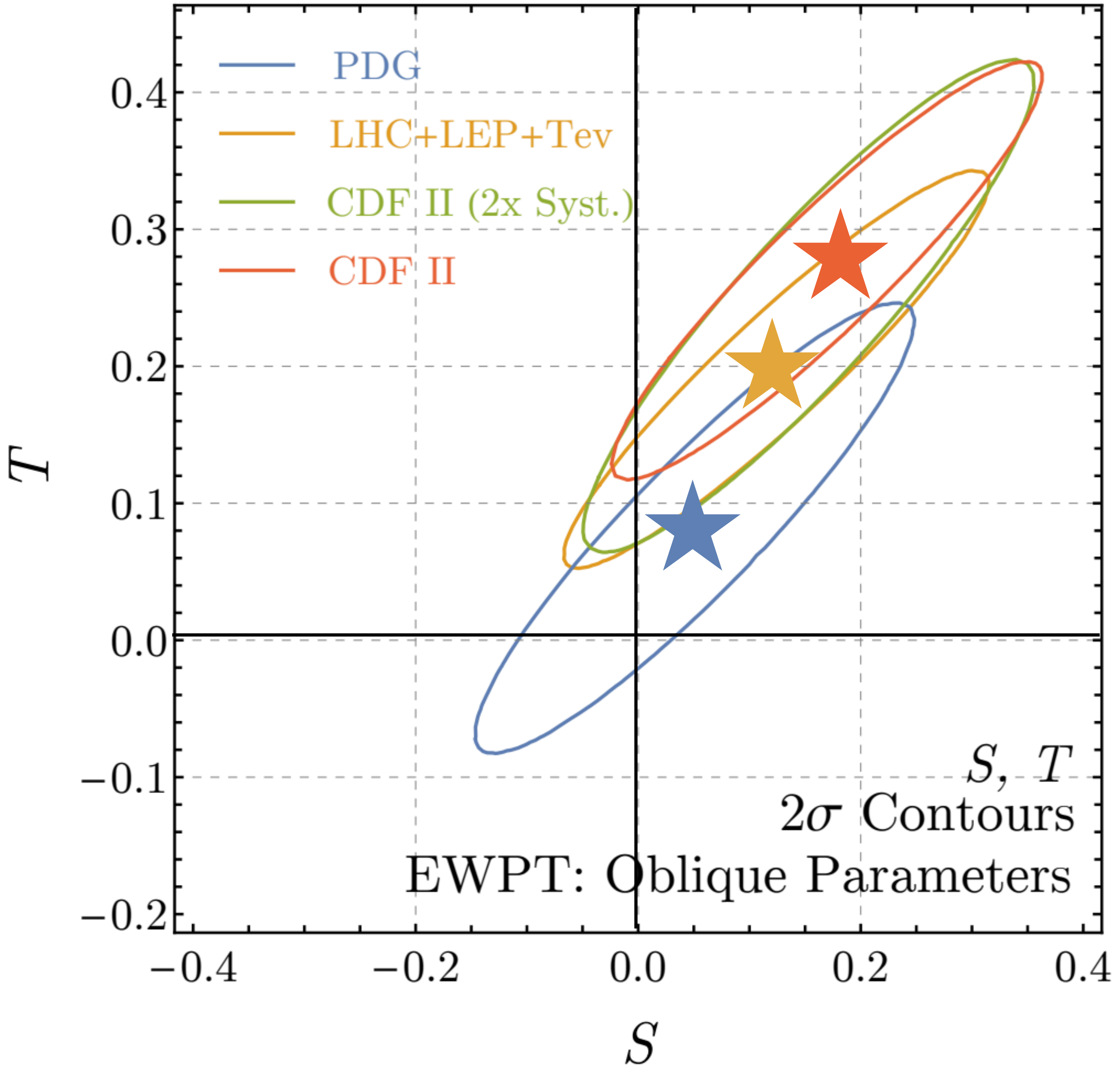

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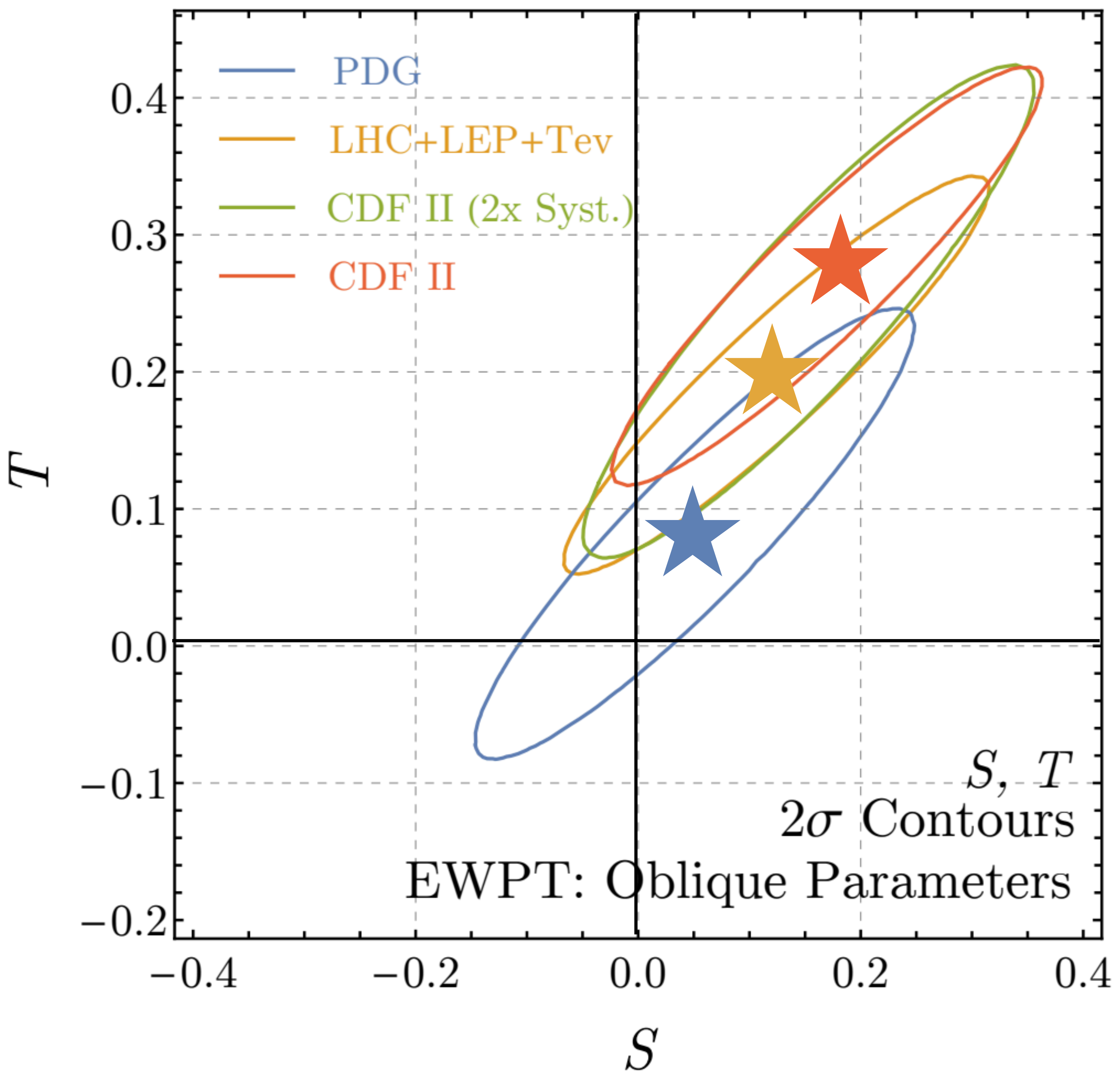

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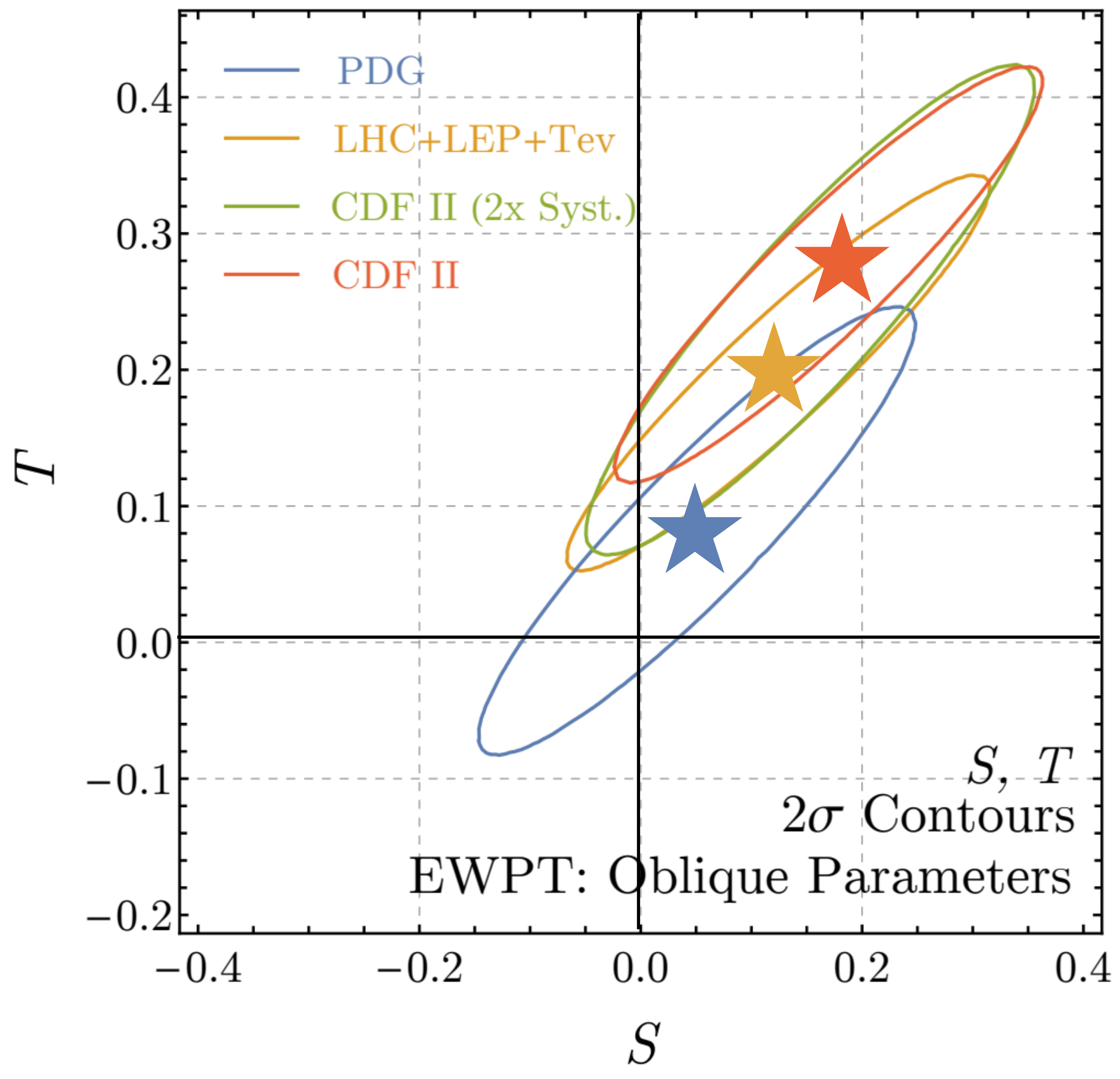

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$$\text{Tree Level: } T \sim \left(\frac{v^2}{2\alpha}\right)\frac{1}{\Lambda^2} \to \Lambda_{\text{NP}} \sim \mathcal{O}(\text{TeV})$$

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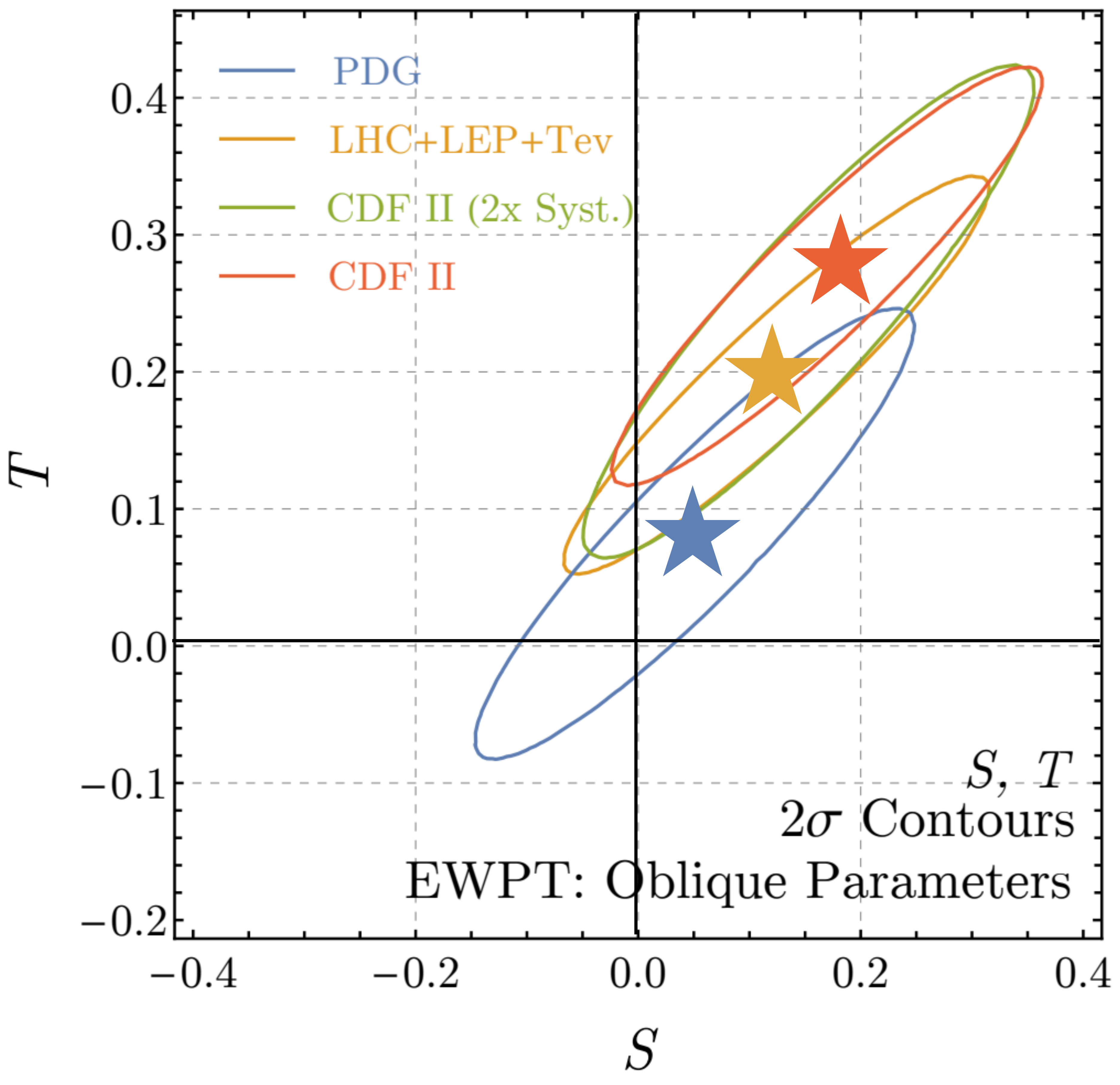

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Loop Level: $T \sim \left(\frac{v^2}{2\alpha}\right)\frac{1}{\Lambda^2}\frac{1}{16\pi^2} \to \Lambda_{\text{NP}} \sim \mathcal{O}(100\text{ GeV})$

New Physics Model: Fermion Singlet-Doublet

$$\mathcal{L} = \mathcal{L}_{SM} + \mathcal{L}_{\text{kinetic}} - m_2 \psi_2 \cdot \tilde{\psi}_2 - \frac{m_1}{2} \psi_1 \psi_1$$
$$+ y\, \mathrm{e}^{i\delta_{\text{CP}}/2} \psi_1 H^\dagger \psi_2 - \tilde{y}\, \mathrm{e}^{i\delta_{\text{CP}}/2} \psi_1 H \cdot \tilde{\psi}_2 + \text{h.c.}$$

Singlet Fermion ψ_1

Dirac Fermion $(\psi_2, \tilde{\psi}_2)$

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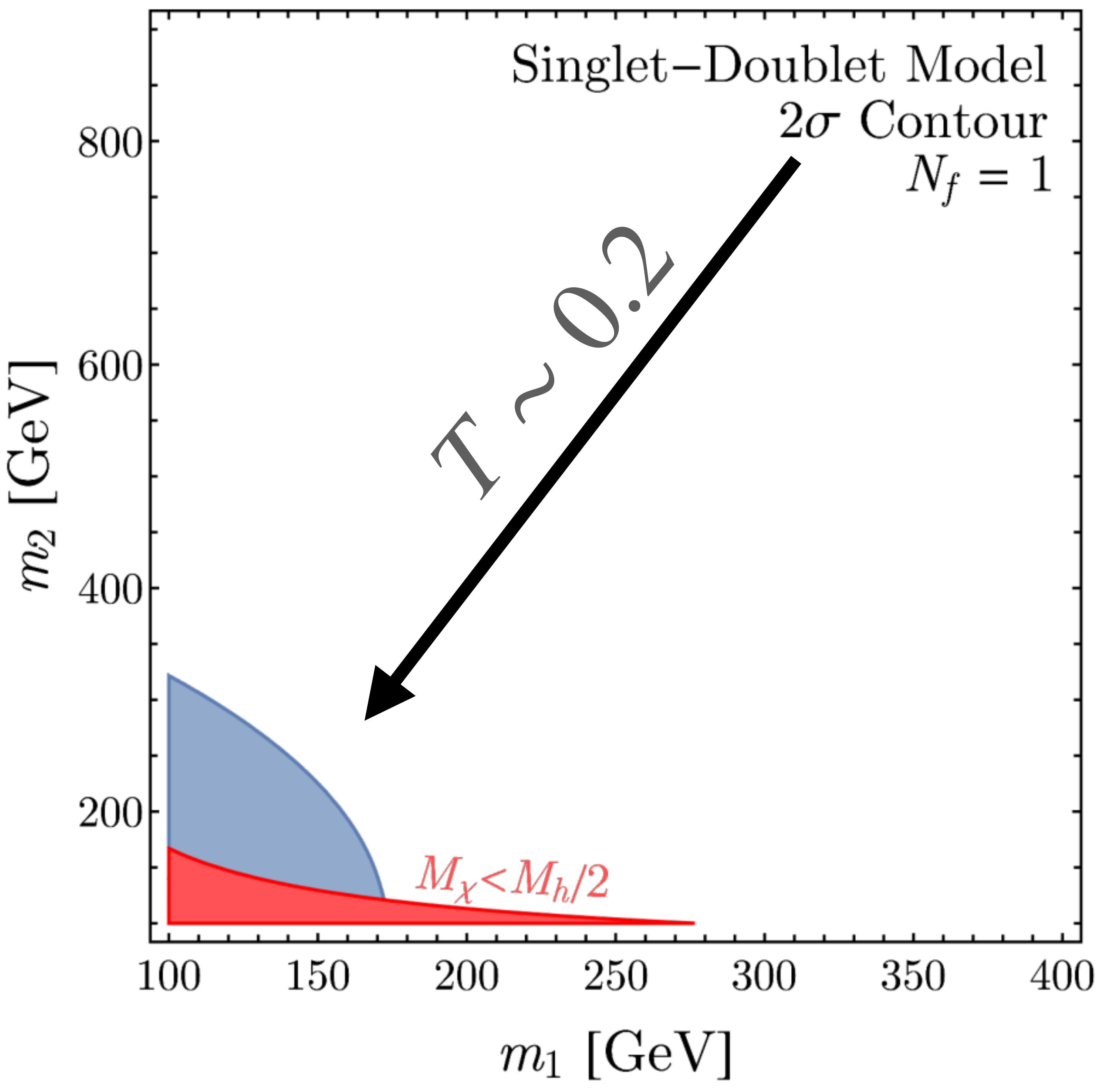

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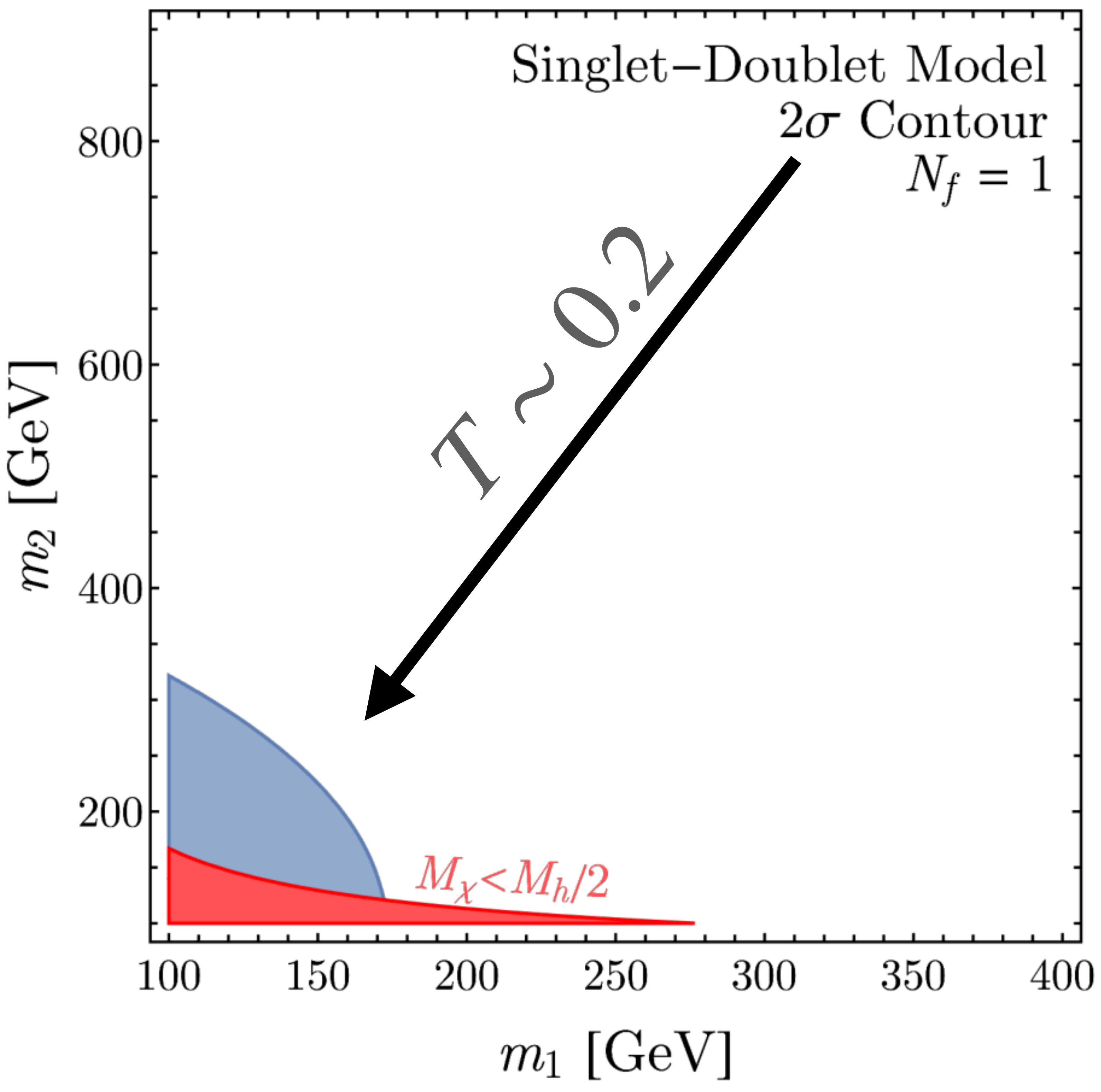

Add More Species

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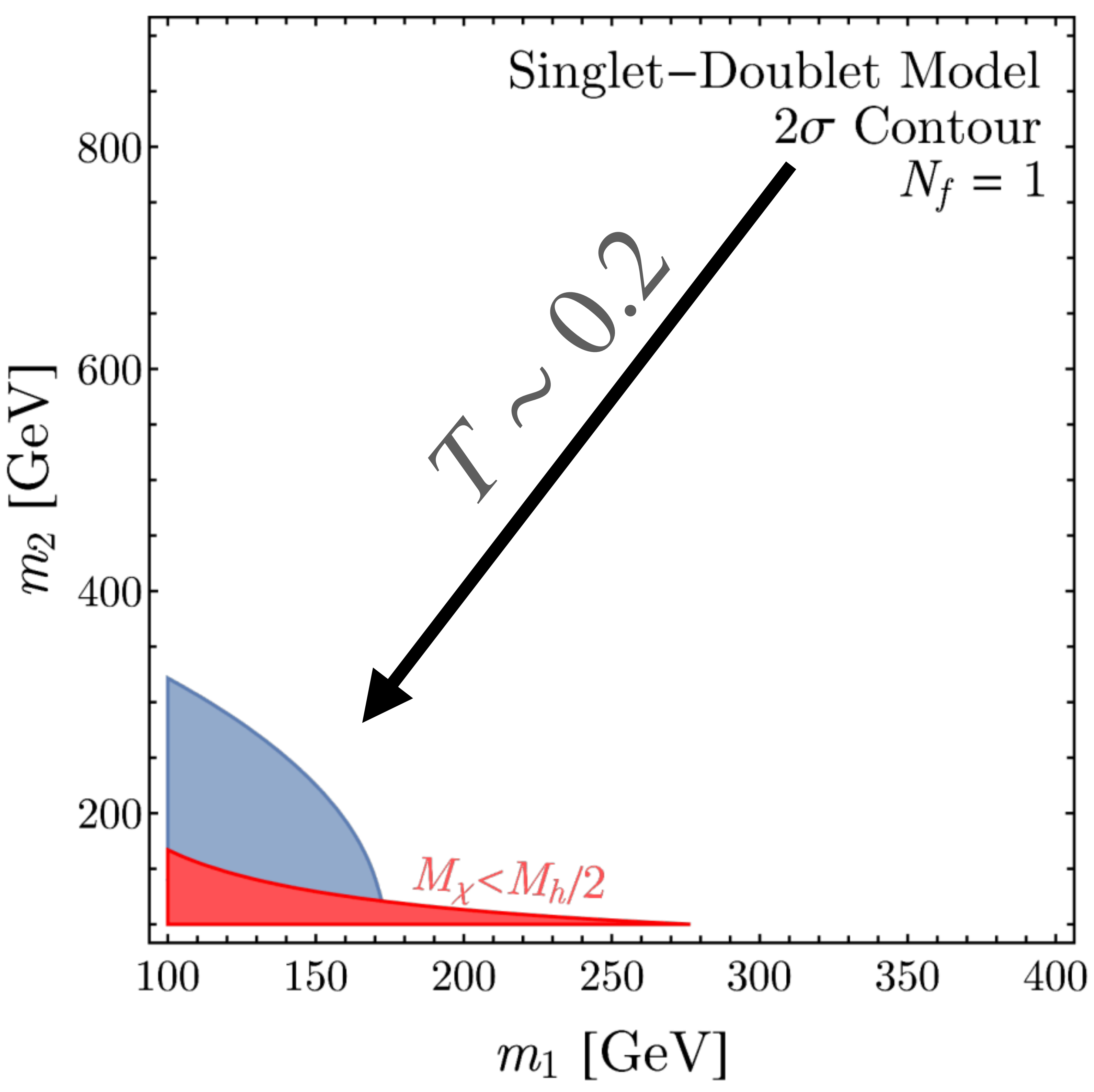

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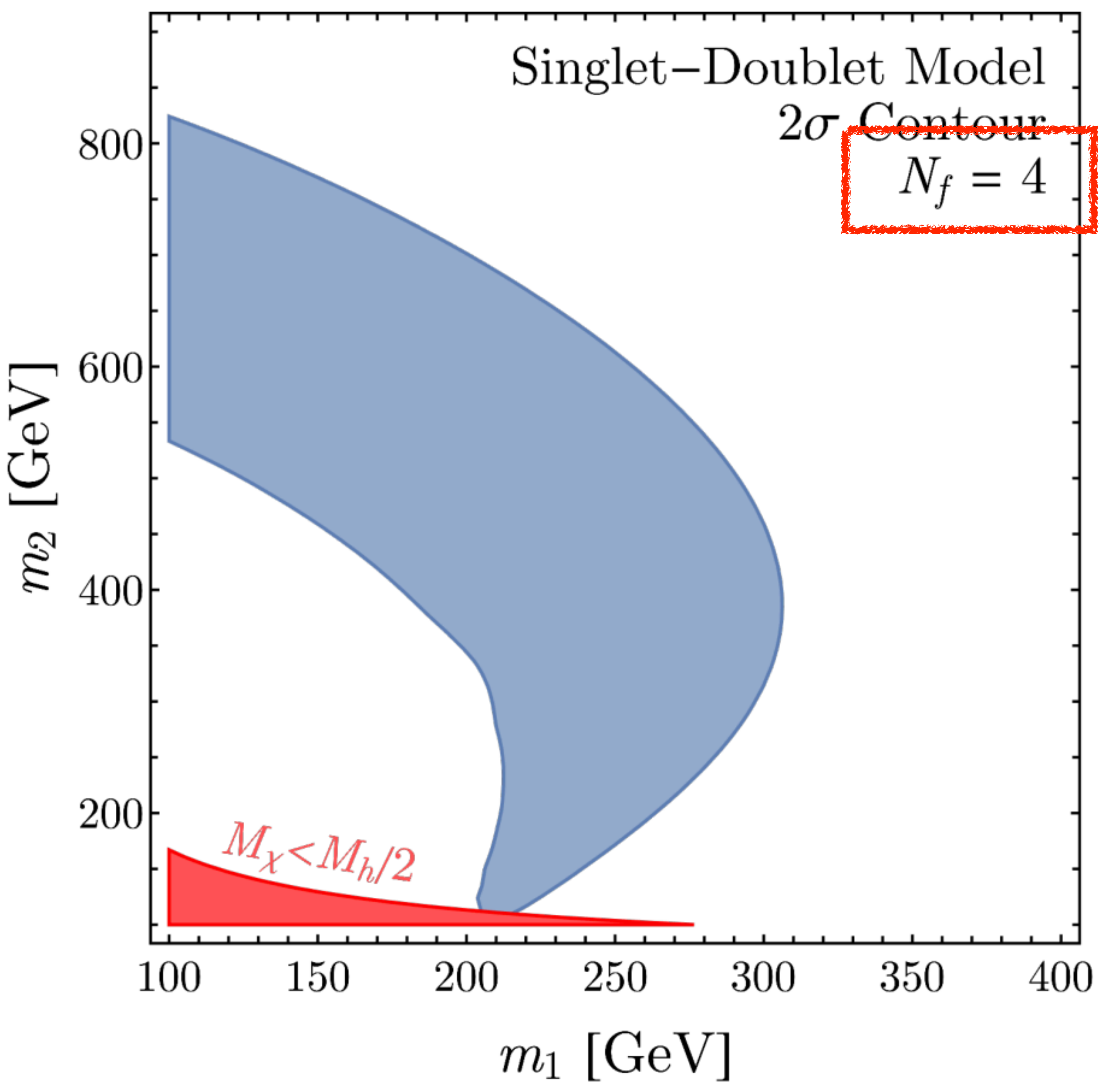

New Physics Model: Fermion Singlet-Doublet *for the GCE*

$$\mathcal{L} = \mathcal{L}_{SM} + \mathcal{L}_{\text{kinetic}} - m_2 \psi_2 \cdot \tilde{\psi}_2 - \frac{m_1}{2}\psi_1\psi_1$$
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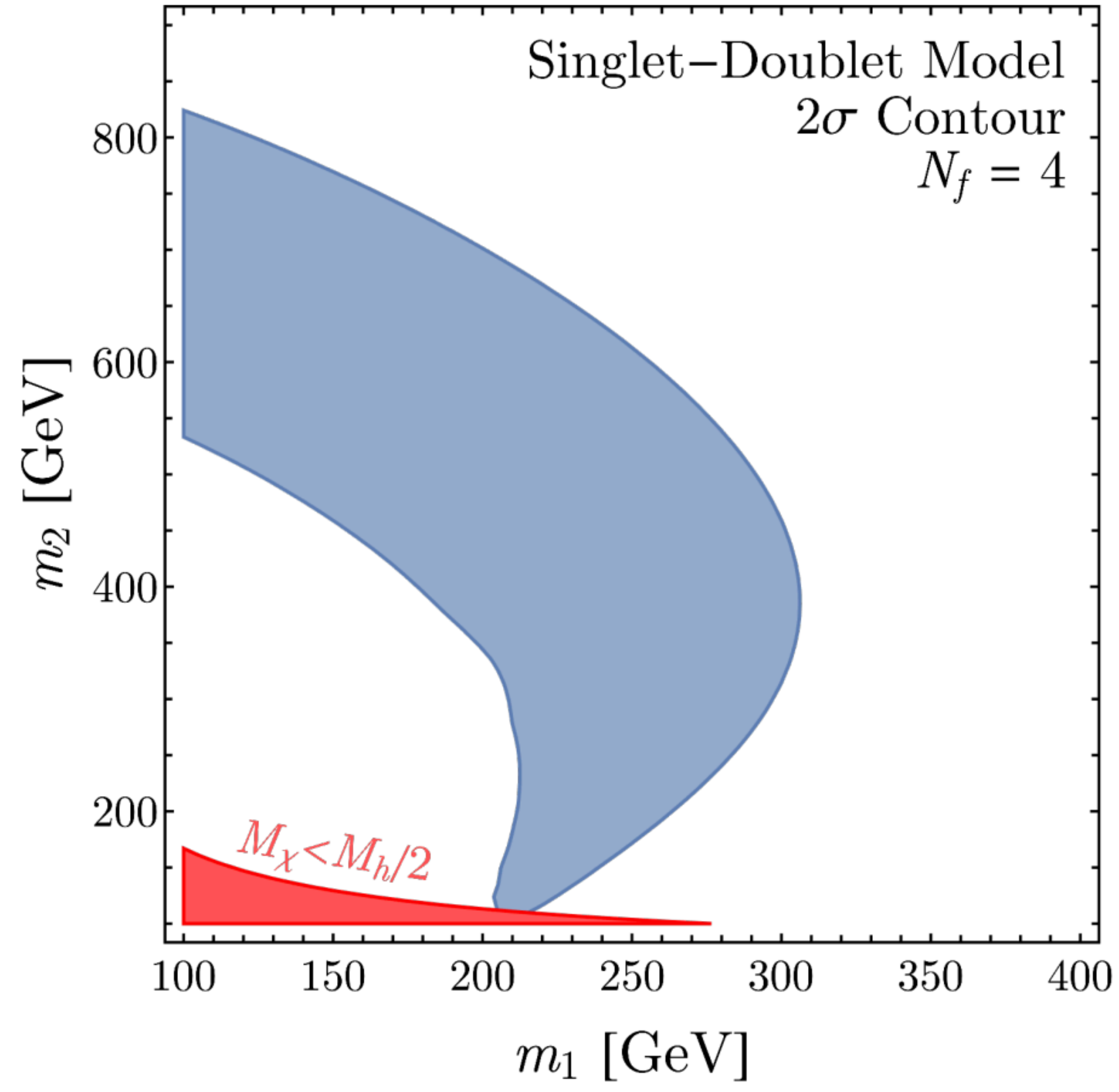
A Closer Look at CP-Violating Higgs Portal Dark Matter as a Candidate for the GCE

Katherine Fraser, Aditya Parikh, and Weishuang Linda Xu

Department of Physics, Harvard University, Cambridge, MA 02138, USA



Discussion

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Potential signs of TeV-scale NP

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Could be dark matter

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Thanks!

Oblique parameters as dim-6 operators*

$$\mathcal{O}_s \sim g g' H^\dagger \sigma^a H W^a_{\mu\nu} B^{\mu\nu} + \frac{1}{4}\left(\frac{ig}{2}(H^\dagger \sigma^a \overleftrightarrow{D}_\mu H) D^\nu W^a_{\mu\nu}) + \frac{ig'}{2}(H^\dagger \sigma^a \overleftrightarrow{D}_\mu H)\partial^\nu B_{\mu\nu}\right)$$

$$\mathcal{O}_T \sim \frac{1}{2}(H^\dagger \overleftrightarrow{D}_\mu H)^2$$

$$T, S \sim \frac{v^2}{\Lambda^2}$$

*Basis dependent operators

Wells & Zhang '15