New Physics in the Neutrino Sector

Joachim Kopp

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Light Sterile Neutrinos

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Anomalies in Short Baseline Oscillations

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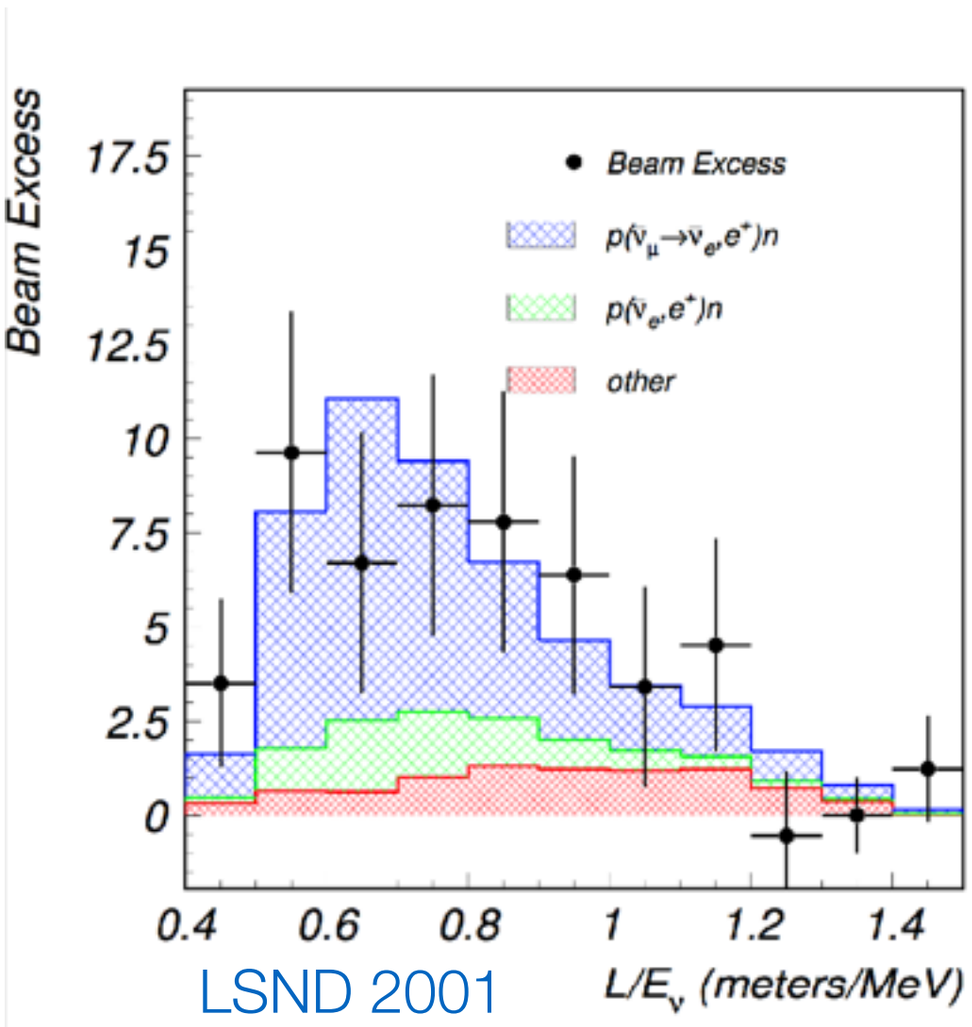
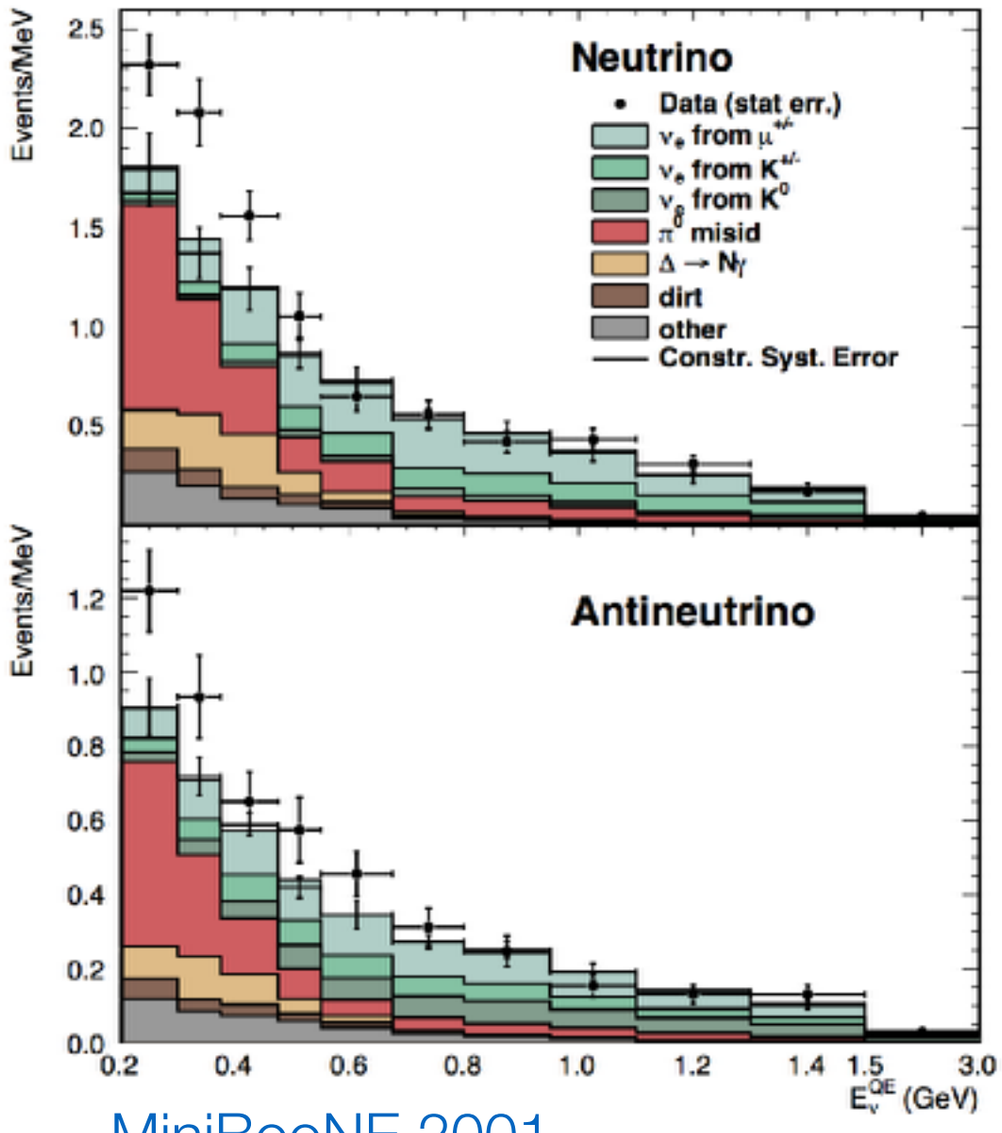
☑ LSND / MiniBooNE: anomalous $\nu_\mu \rightarrow \nu_e$ oscillations



LSND 2001



MiniBooNE 2001

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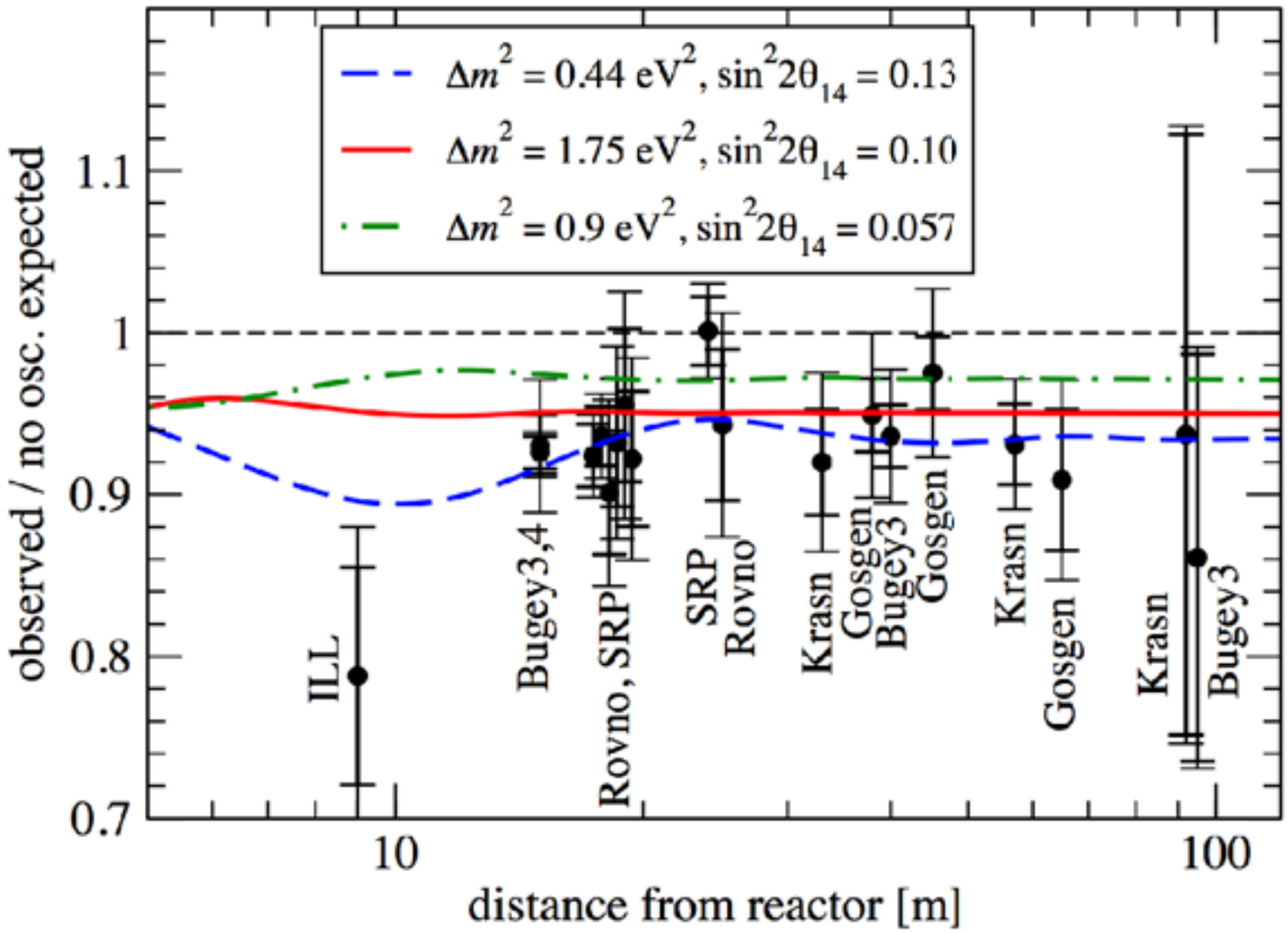

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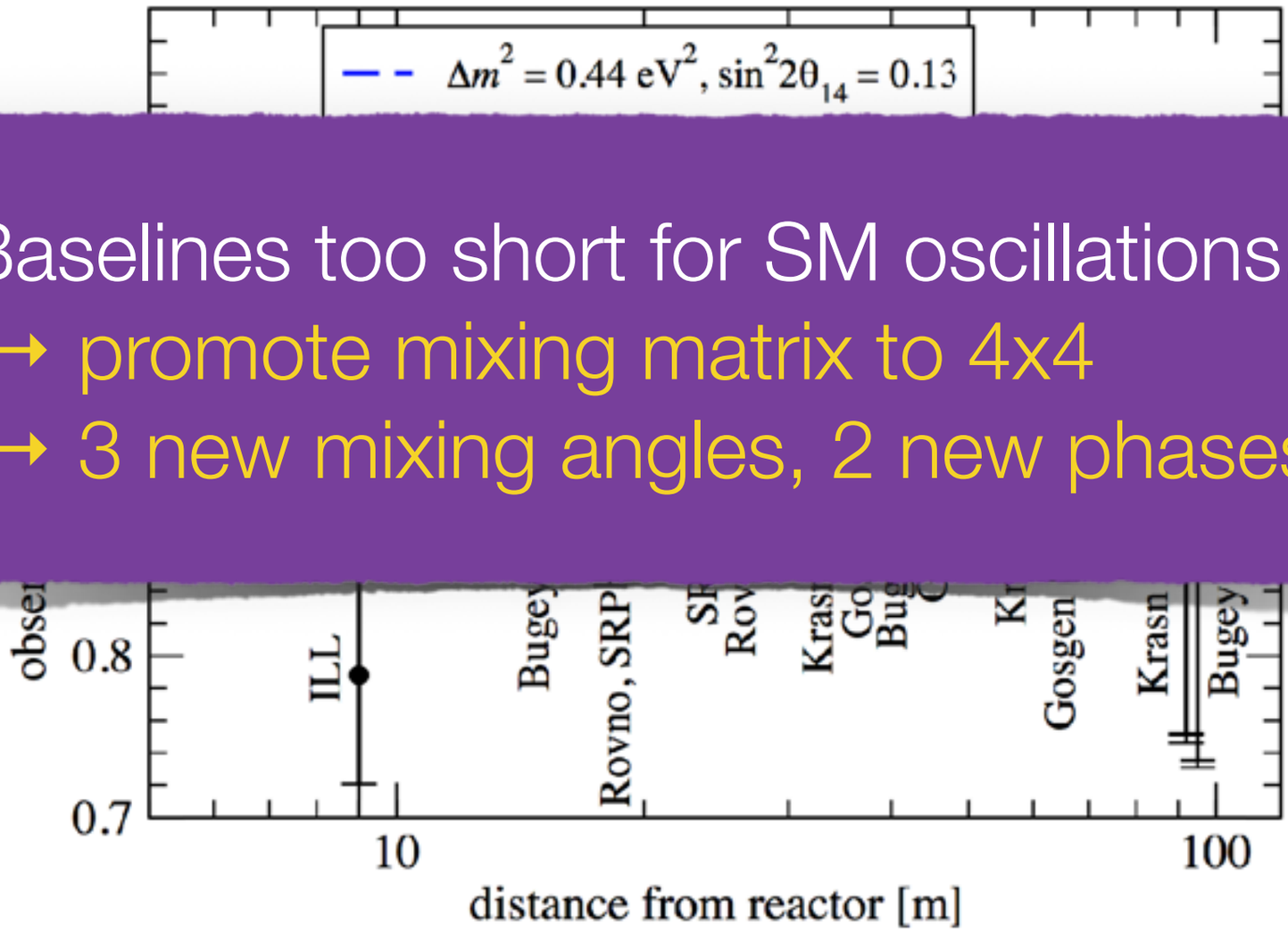
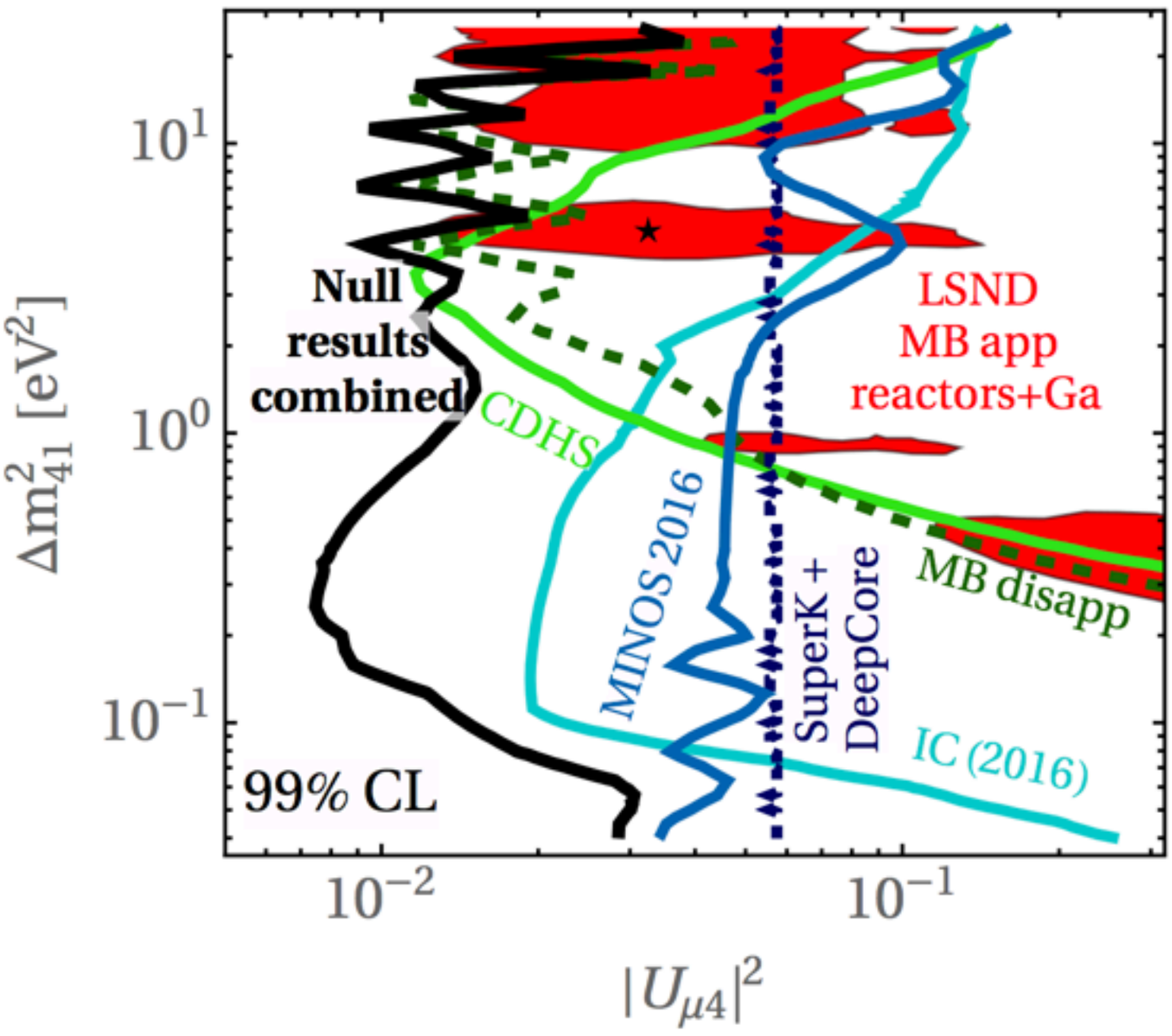


Baselines too short for SM oscillations!

→ promote mixing matrix to 4x4

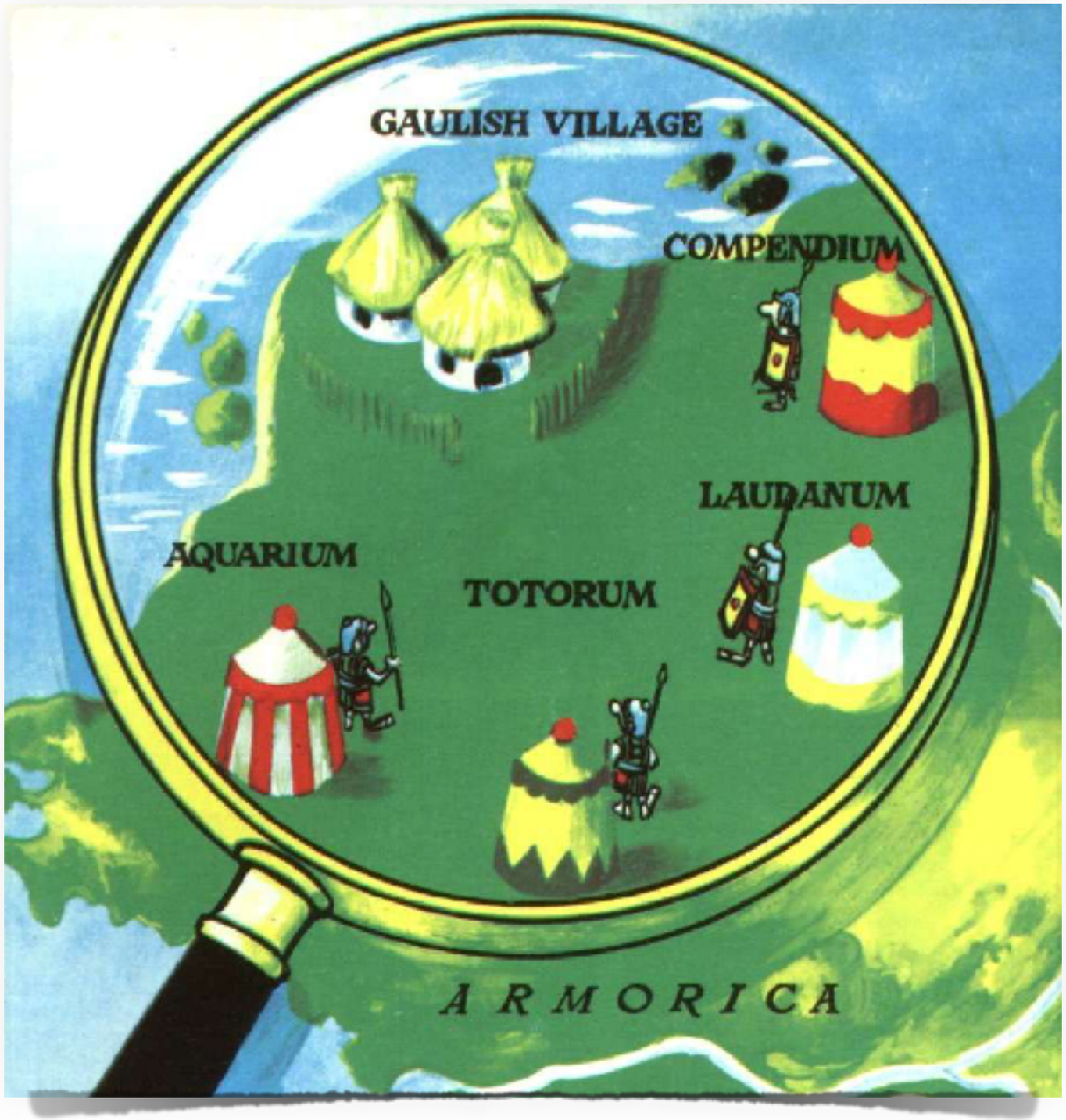
→ 3 new mixing angles, 2 new phases

Global Fit in 3+1 Model



Dentler Hernandez JK Machado Maltoni Martinez Schwetz, in preparation
see also works by Collin Argüelles Conrad Shaevitz, 1607.00011,
Gariazzo Giunti Laveder Li, 1703.00860

Status of Light Sterile Neutrinos



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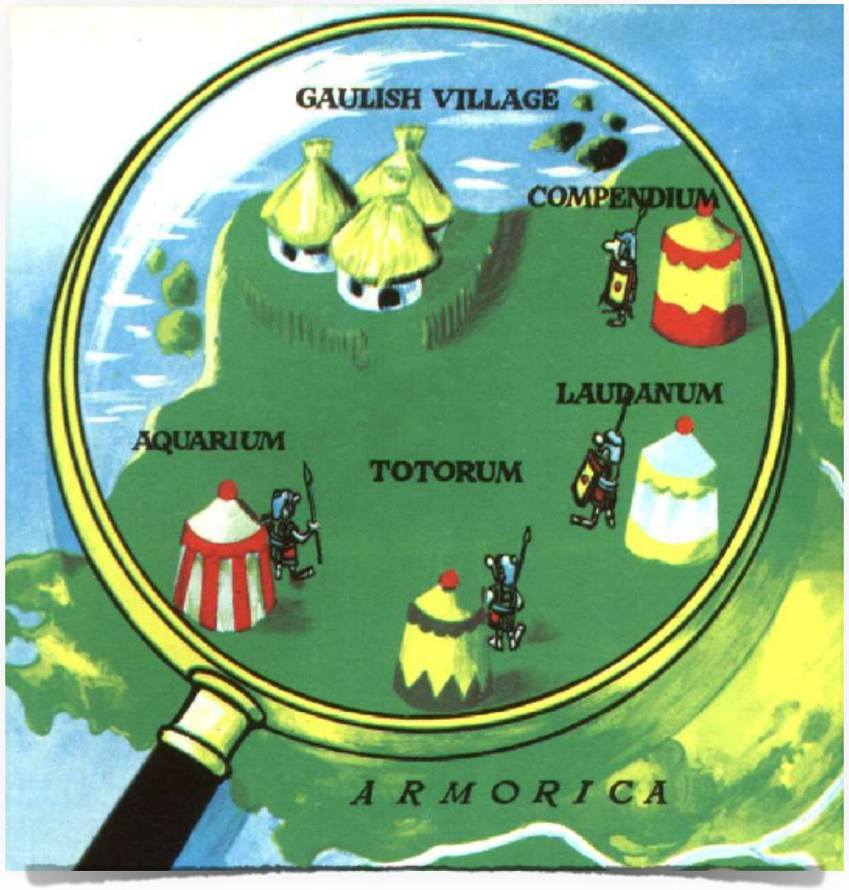

severe tension ($p < 10^{-4}$)

★ scrutinize anomalies for unknown systematics (need 4 independent effects!)

★ scrutinize also null results!

Flux Measurement by Daya Bay

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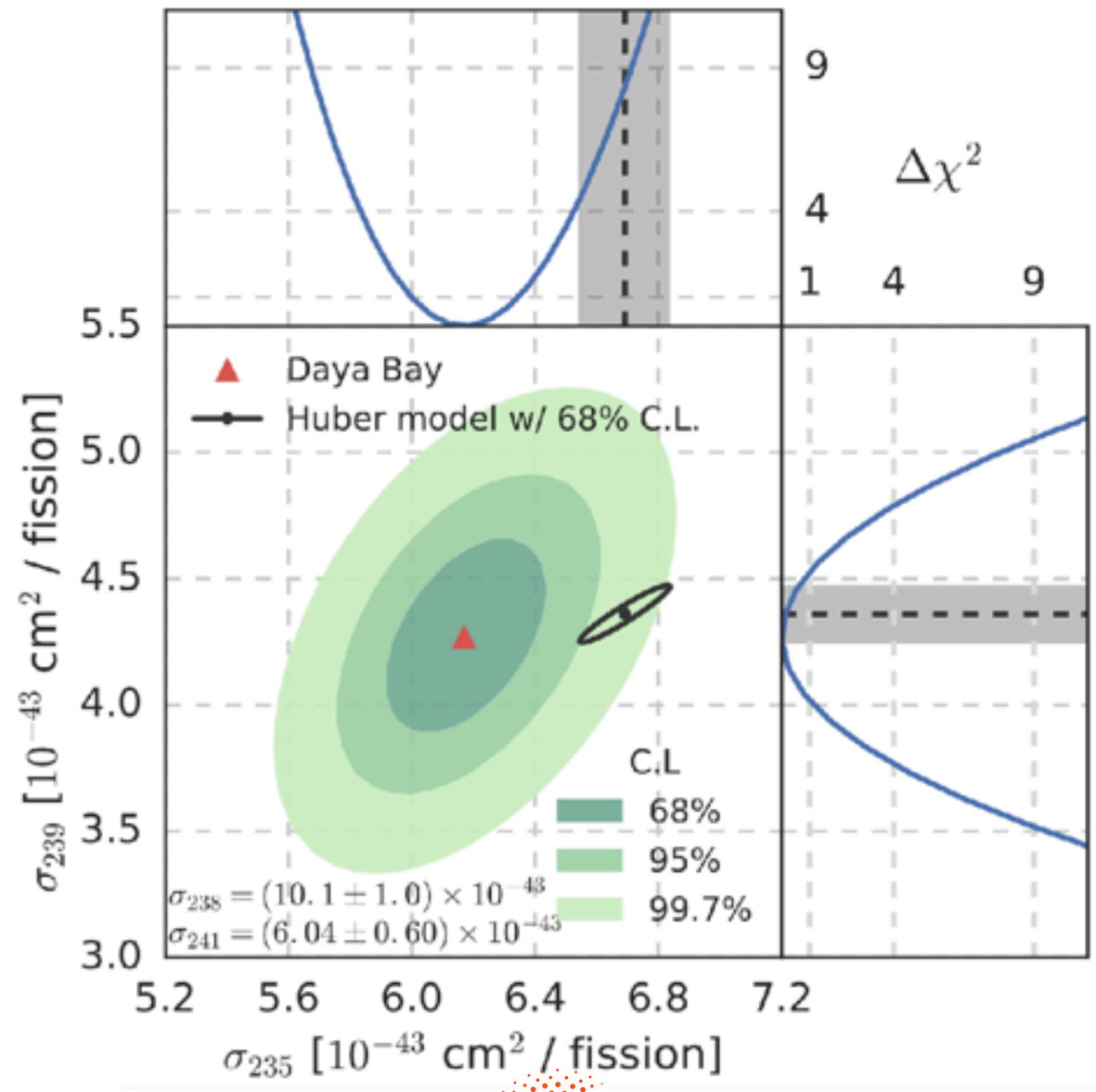

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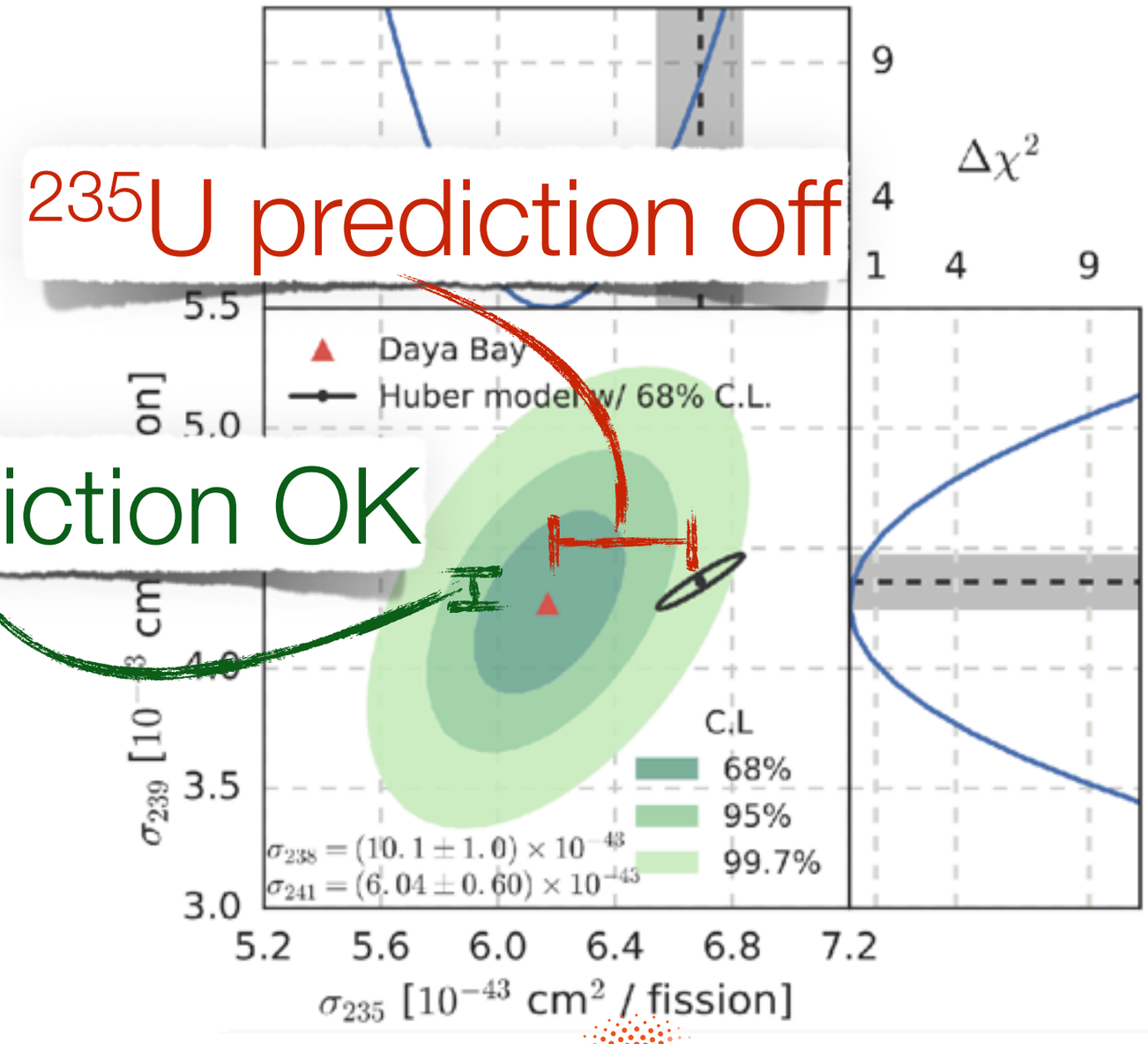

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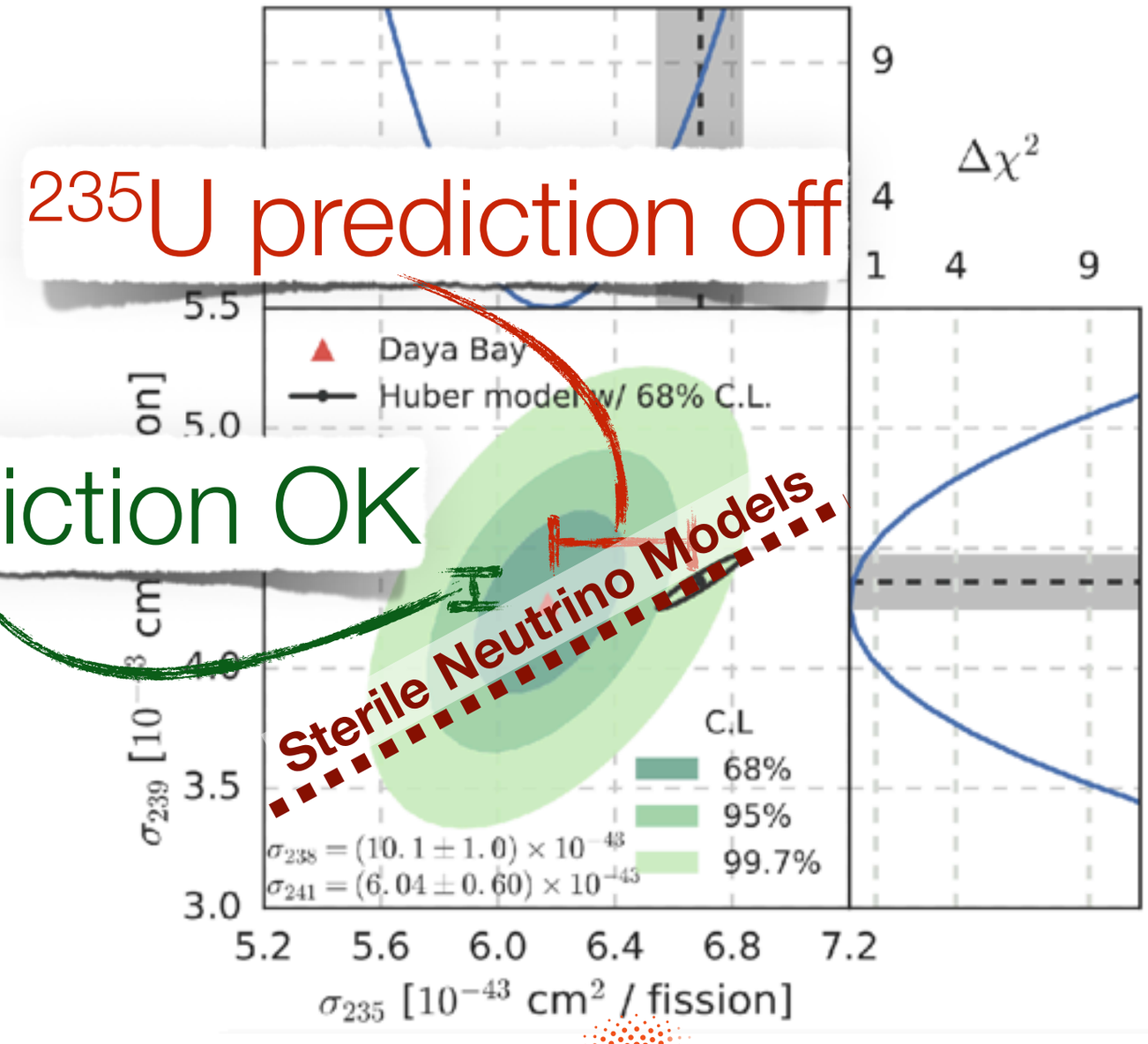

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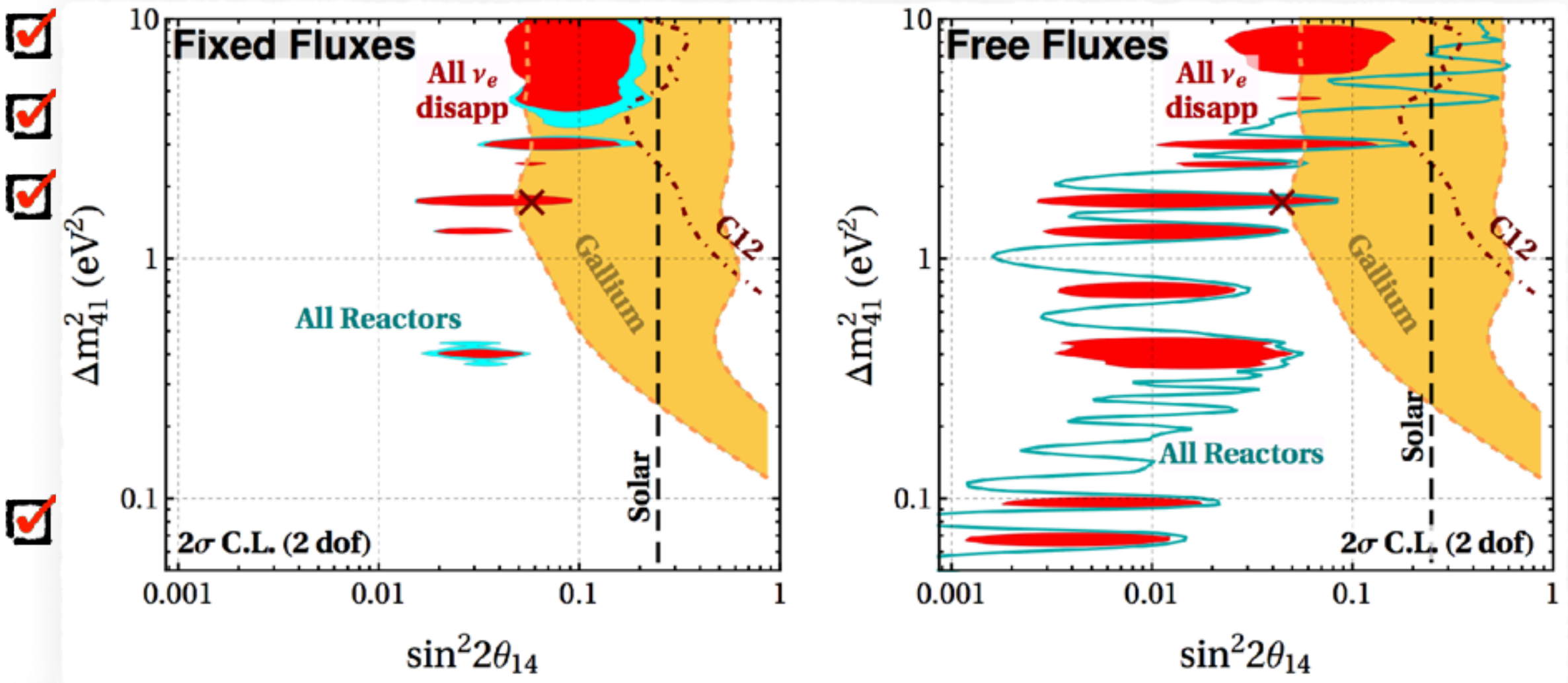

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  - minimal scenario now disfavored — Cherry Friedland Shoemaker 1605.06506; Chu Dasgupta Dentler JK Saviano, in preparation
- ☑ ν_s properties change in late phase transition — Bezrukov Chudaykin Gorbunov, 1705.02184

Neutrinos and Dark Matter

Recent Developments

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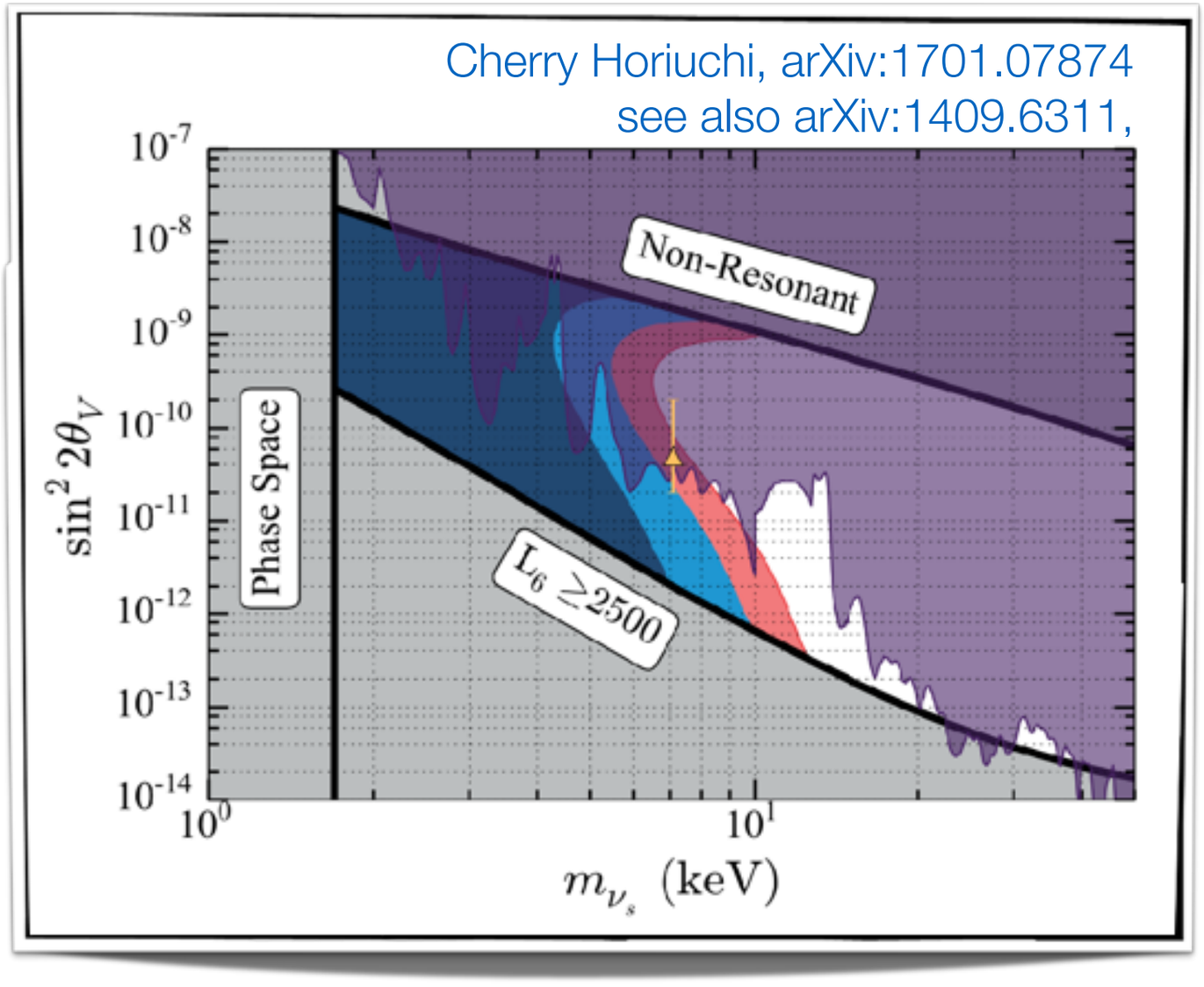
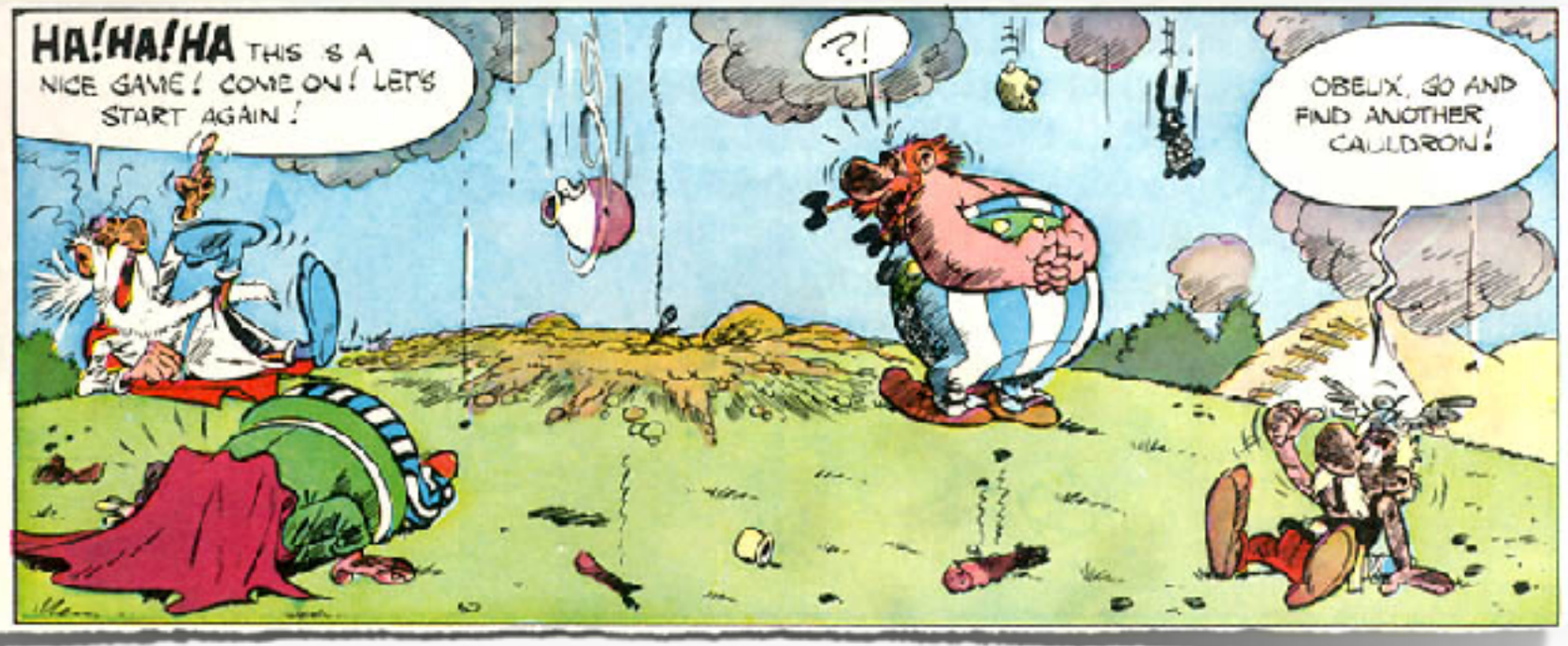
Sterile Neutrinos as Dark Matter

- ☑ keV-scale sterile neutrinos are leading candidate for Warm Dark Matter
  - Improved small scale structure
  - x-ray line signature
- ☑ Production through oscillations challenged by e.g. Lyman-α data



Dark Matter Model Building Flowchart



Production via Scalar Decays

☑ Decay of heavy scalars

$$\mathcal{L} \supset i\overline{N_\alpha}\partial\!\!\!/ N_\alpha + \frac{1}{2}(\partial_\mu S)(\partial^\mu S) - \frac{y_\alpha}{2} S\overline{N_\alpha^c} N_\alpha + 2\lambda(H^\dagger H)S^2$$

☑ S freezes in via $hh \leftrightarrow SS$, decays via $S \to NN$

☑ N produced with relatively cold spectrum

Shaposhnikov Tkachev hep-ph/0604236
Kusenko hep-ph/0609081
Merle Niro Schmidt 1306.3996
Merle Totzauer 1502.01011
König Merle Totzauer 1609.01289

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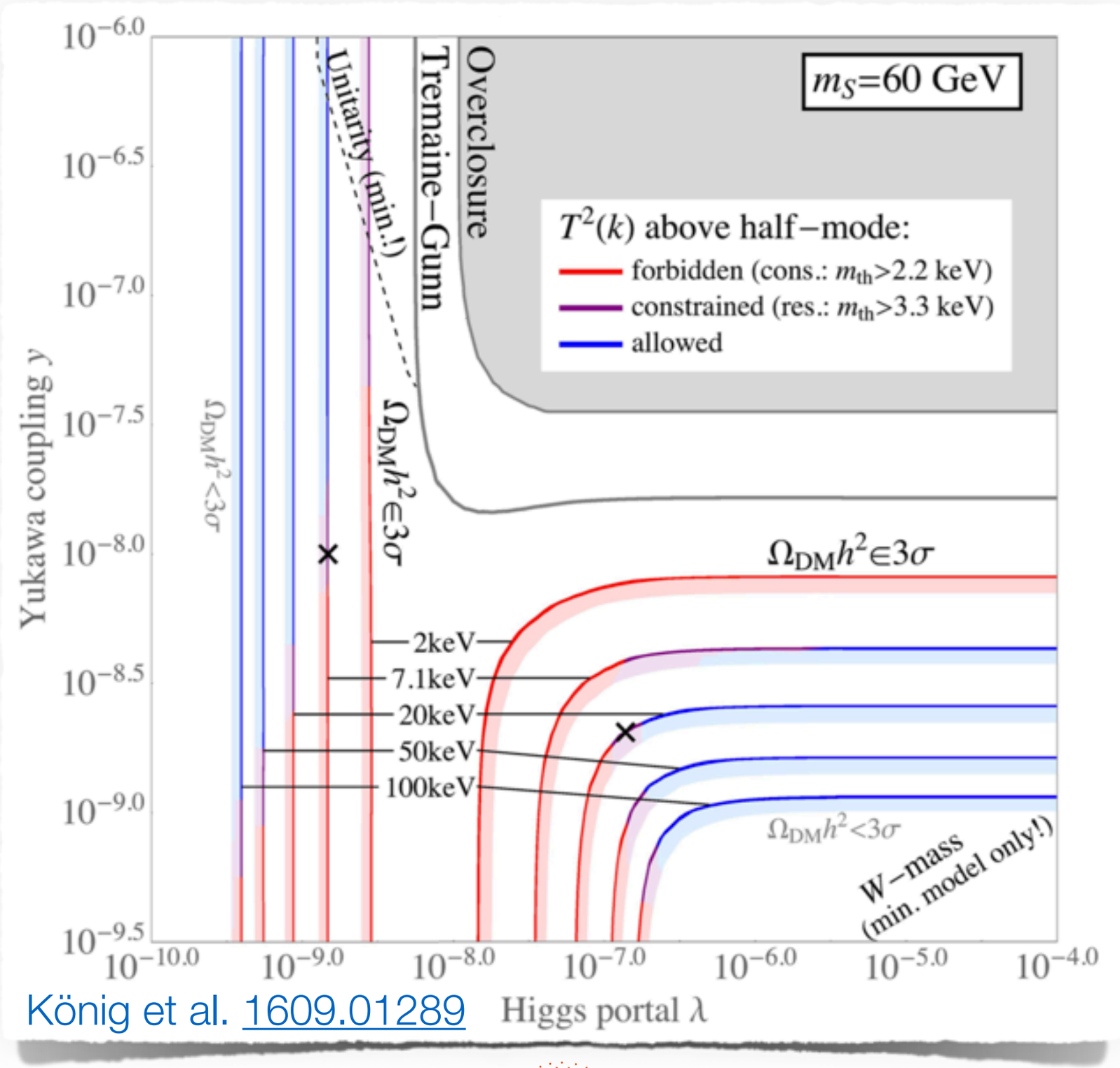


König et al. 1609.01289

-ph/0604236
-ph/0609081
dt 1306.3996
r 1502.01011
r 1609.01289

Neutrino—DM Interactions

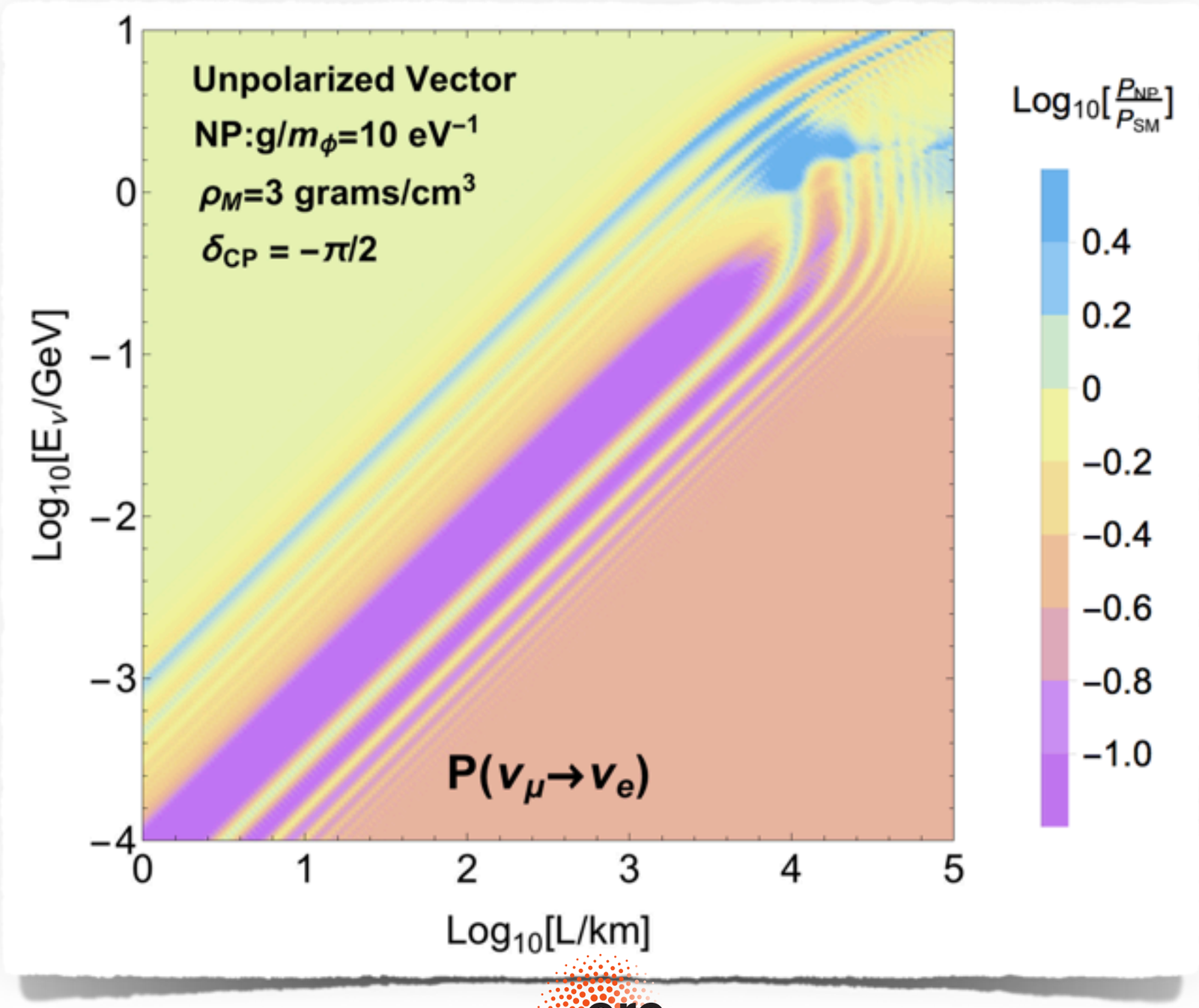
- ☑ Coherent forward scattering of neutrinos on DM
  - analogous to SM matter effects (“MSW effect”)
  - Observability requires huge DM number density
- ☑ Fuzzy Dark Matter
  - scalar or vector, $m < 10^{-20}\,\mathrm{eV}$
  - Compton wave length $\sim \mathrm{pc}$
  - Interesting for small scale structure

Krnjaic Machado Necib, 1705.06740
Brdar JK Liu Prass Wang, 1705.09455

Neutrino—DM Interactions

Modified Oscillation Probabilities

- ☑ Coherent
  - anal
  - Obs
- ☑ Fuzzy
  - scal
  - Com
  - Inte



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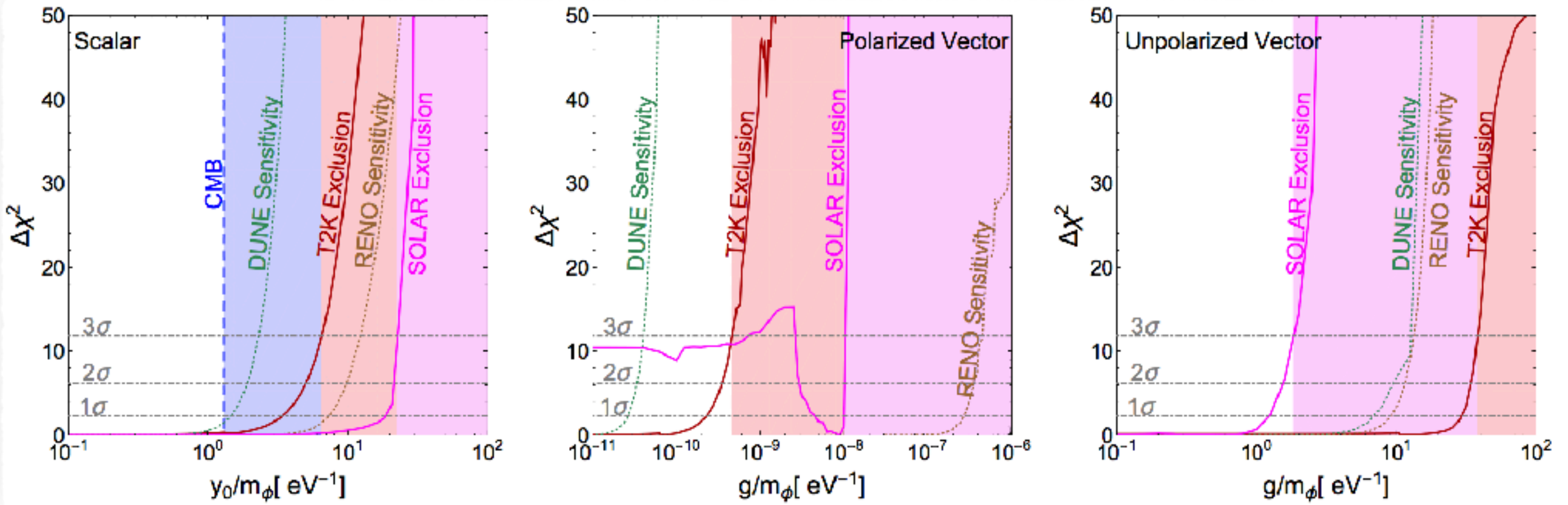
Limits from Long-Baseline Experiments



Questions?

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