Overview: Neutrino Experimental Anomalies (NF02)

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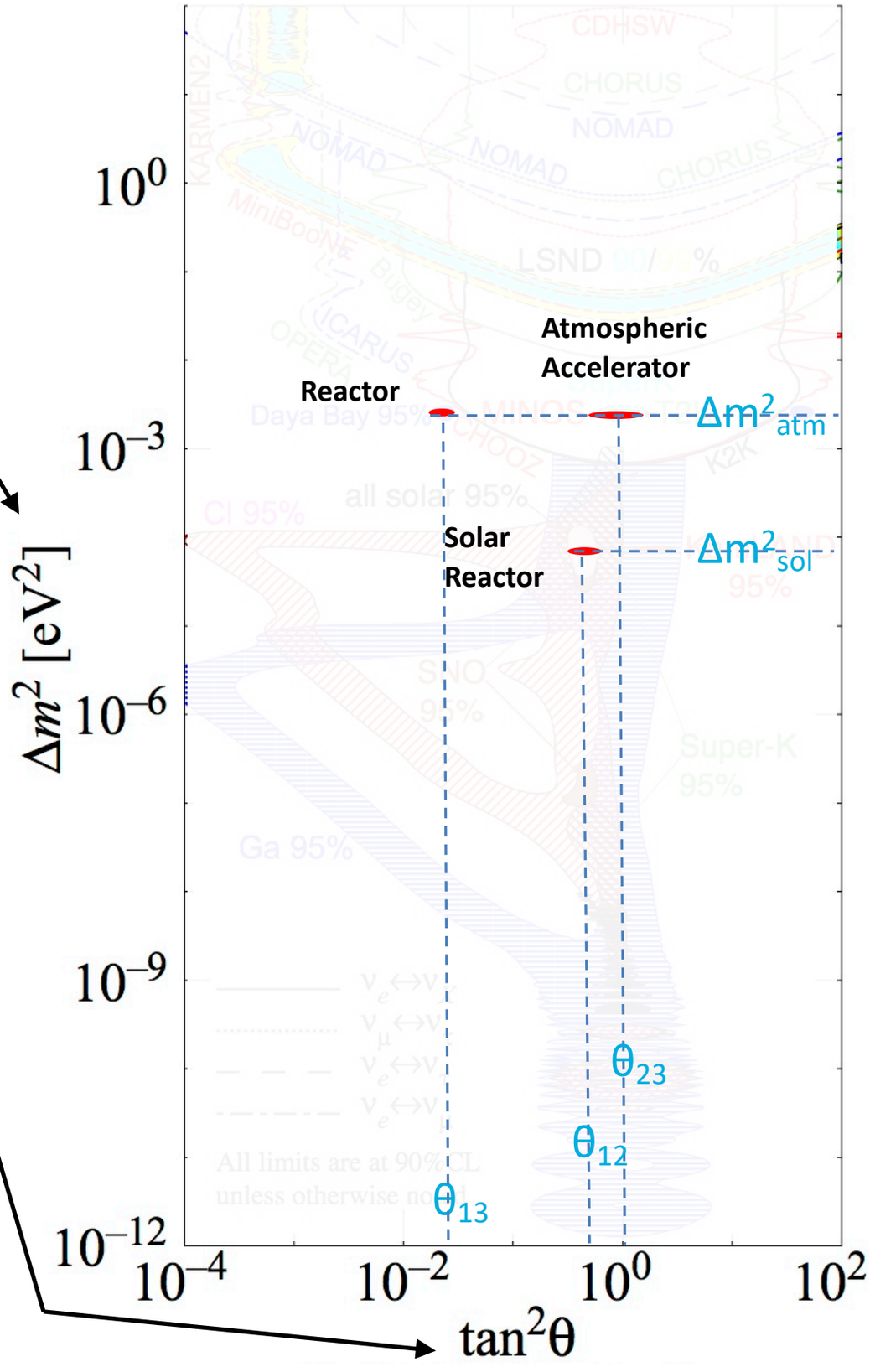
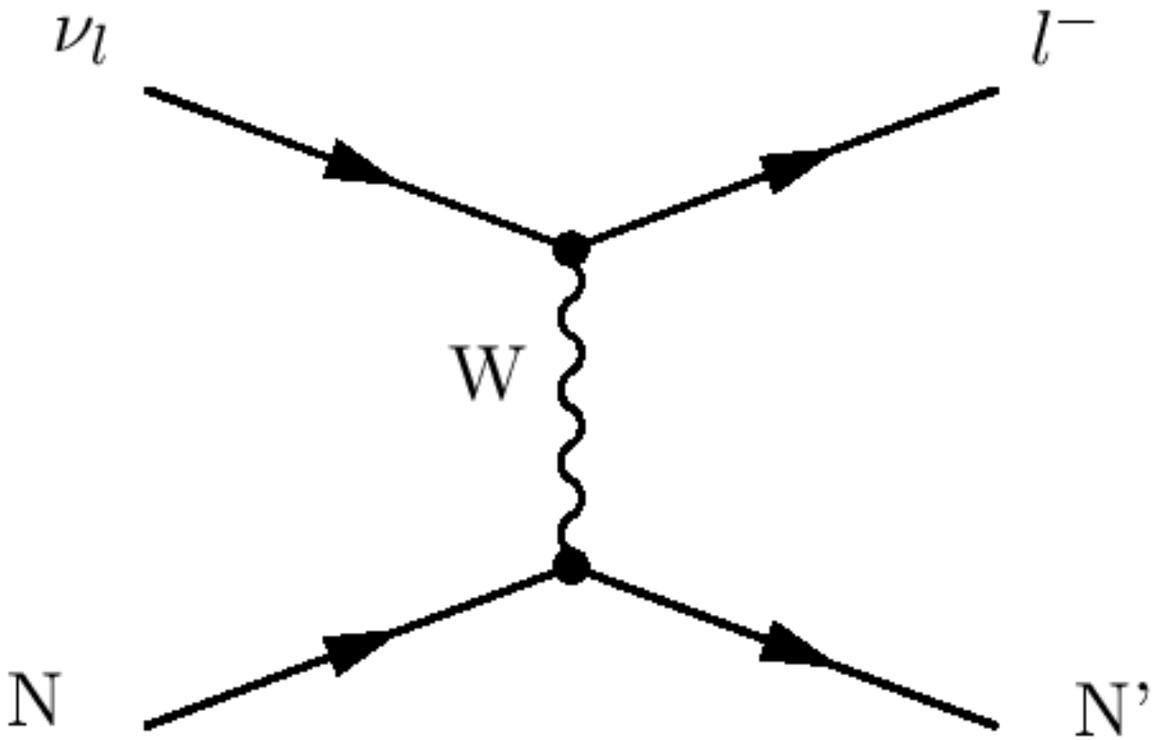
Standard Model Neutrino Oscillations

- Have a beautiful picture of three oscillating Standard Model neutrinos coming into focus
  - Three mass differences define the relative weights of the different neutrinos
    - Also defines the travel distance required for flavor change to occur
  - Three angles define which flavors are in each mass state
    - Also defines magnitude of flavor changing



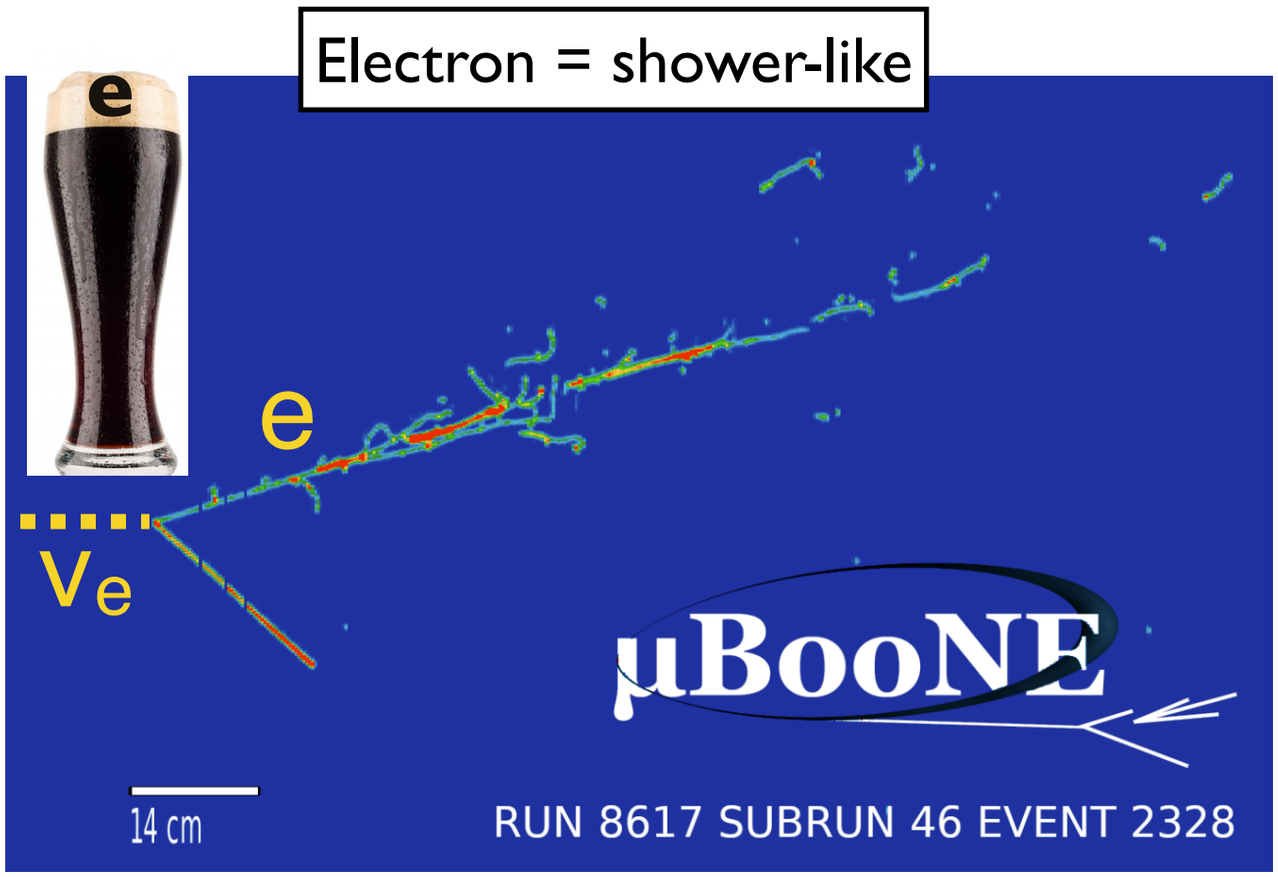
Sampling Neutrino Flavors

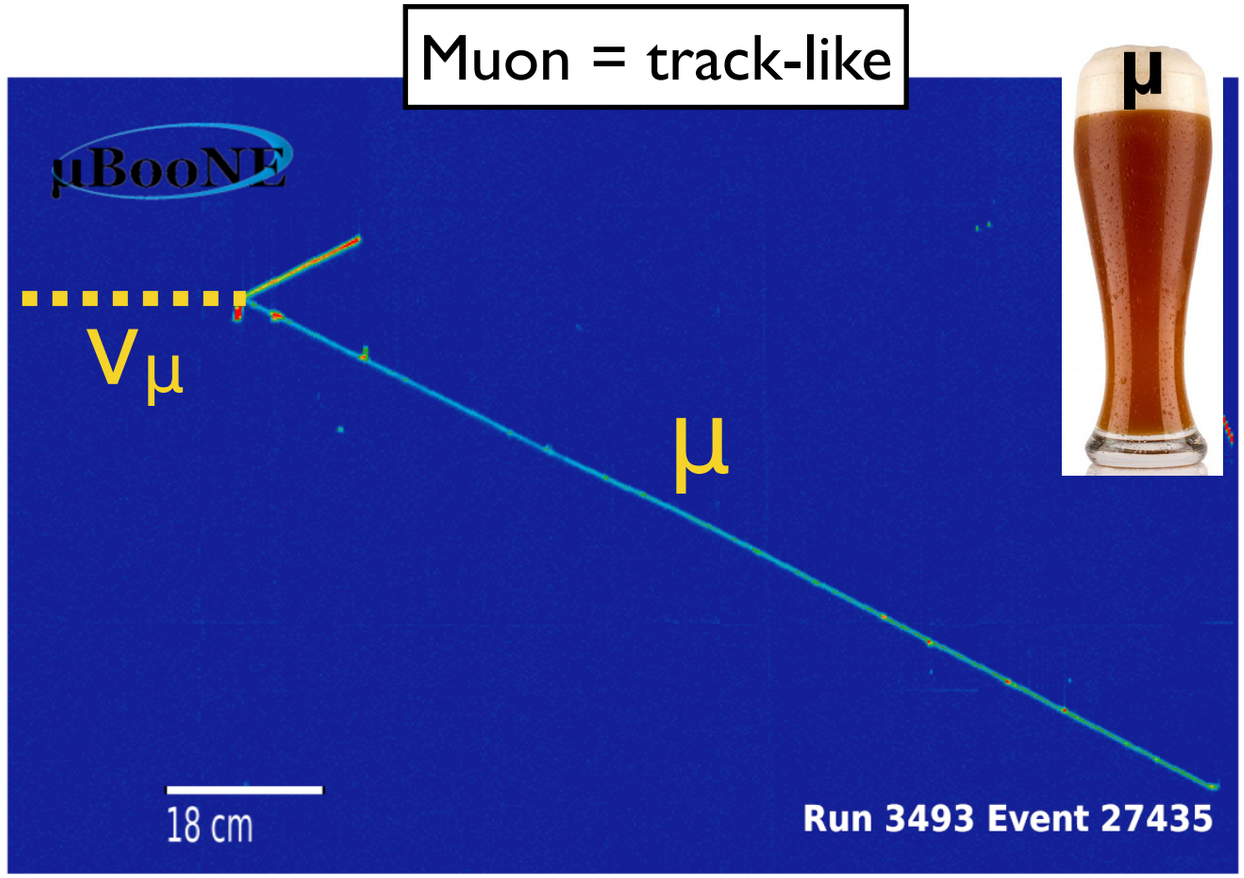
- We got here by sampling neutrino flavors.
  - Want to make sure I <u>taste</u> the flavor that was produced: stout, amber, pilsner?
- For neutrinos, charged current interactions enable this
  - Want to make sure I <u>detect</u> the flavor that was produced: e, μ, or τ ?



Sampling Neutrino Flavors

- Many detector technologies can help us taste that flavor:

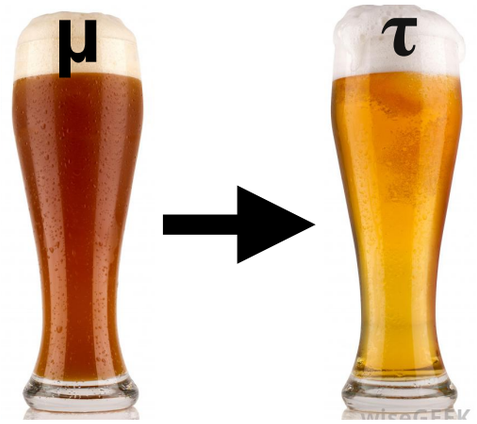




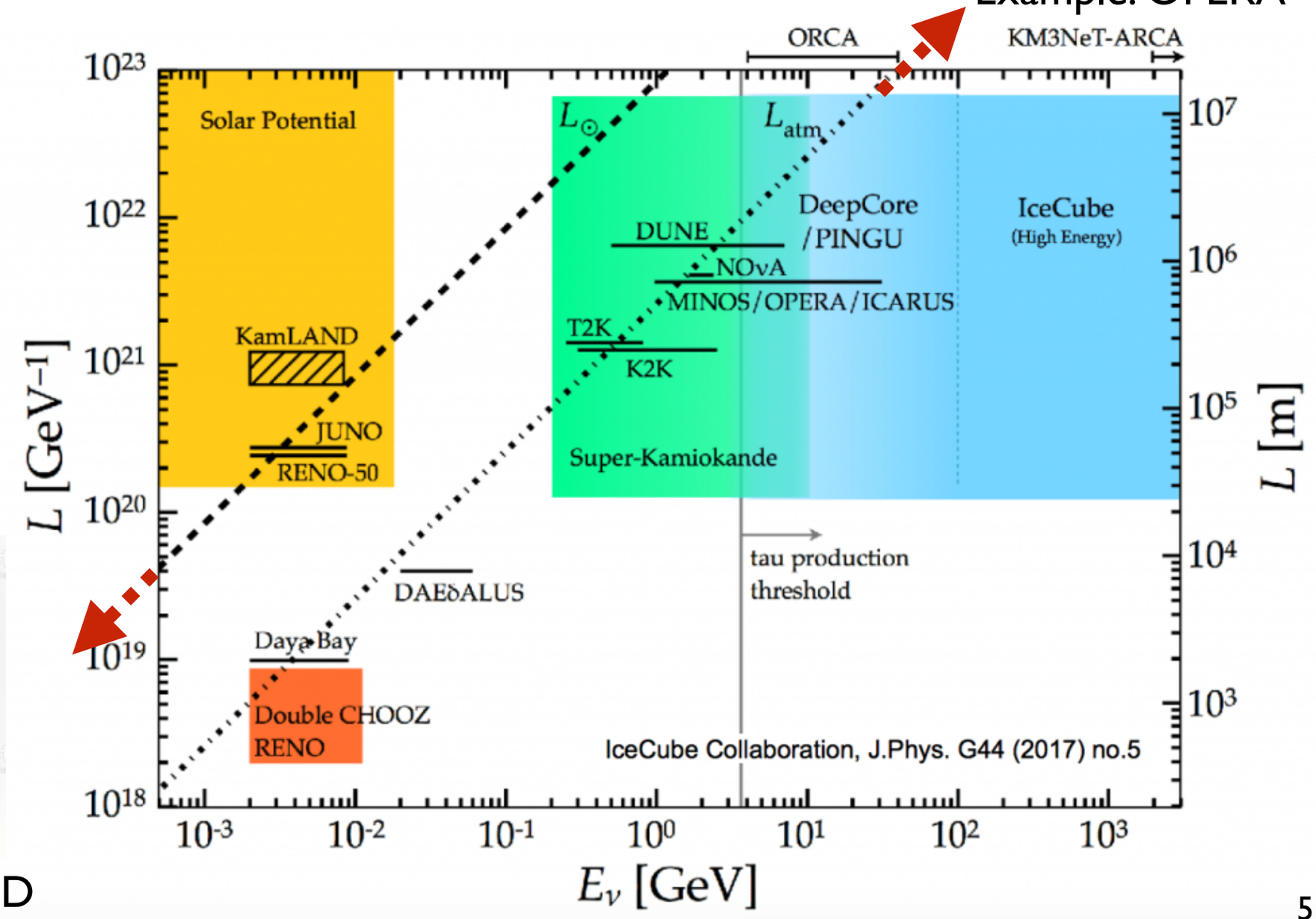
MicroBooNE: a liquid argon TPC in a ν_μ beamline

Neutrino Oscillations: L and E

- Have a beautiful picture of three oscillating Standard Model neutrinos coming into focus
- Took many experiments to get us here!
- Baselines (L): >km-scale
- Energies (E): MeV to GeV++!



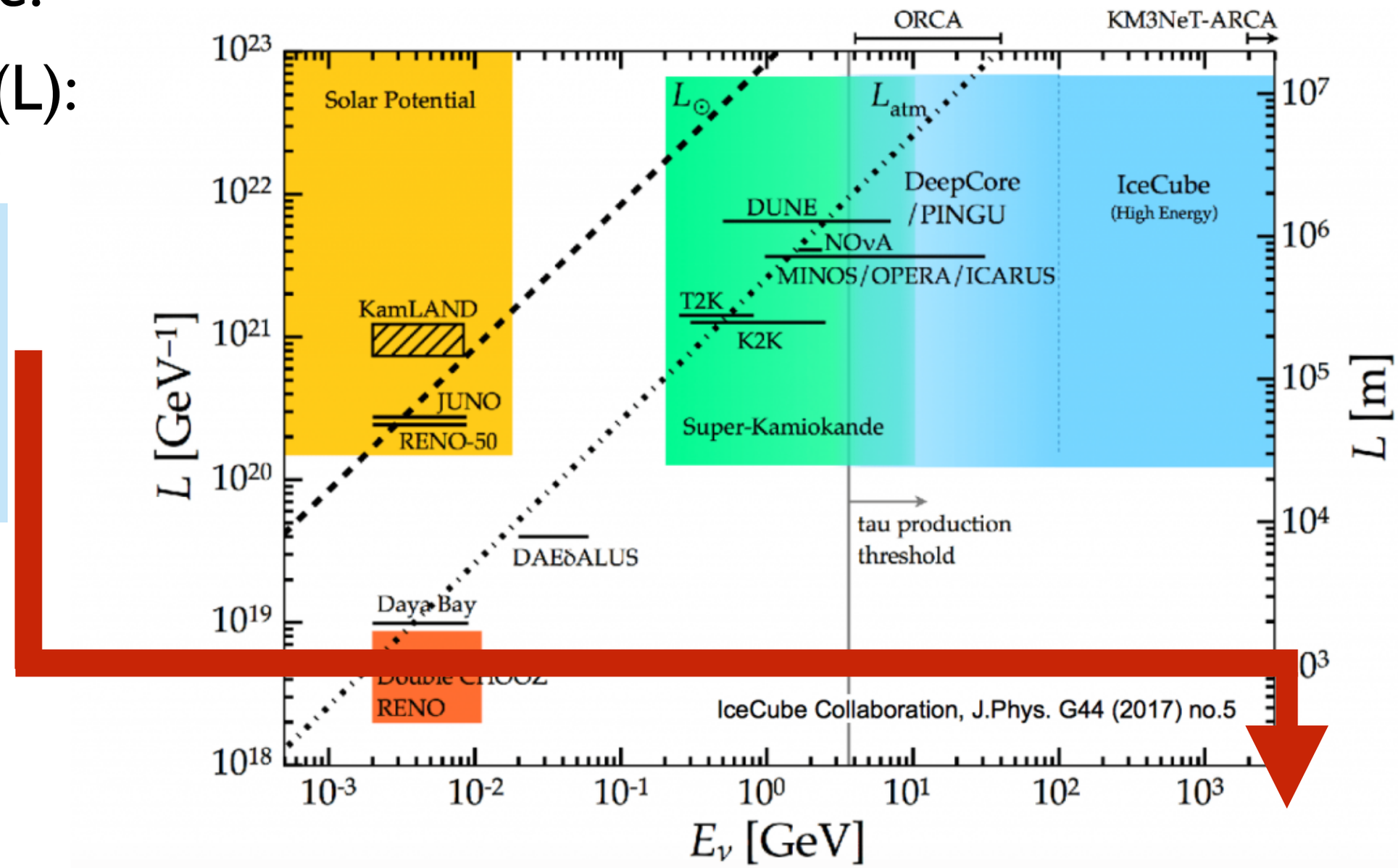
Example: OPERA



Example: KamLAND

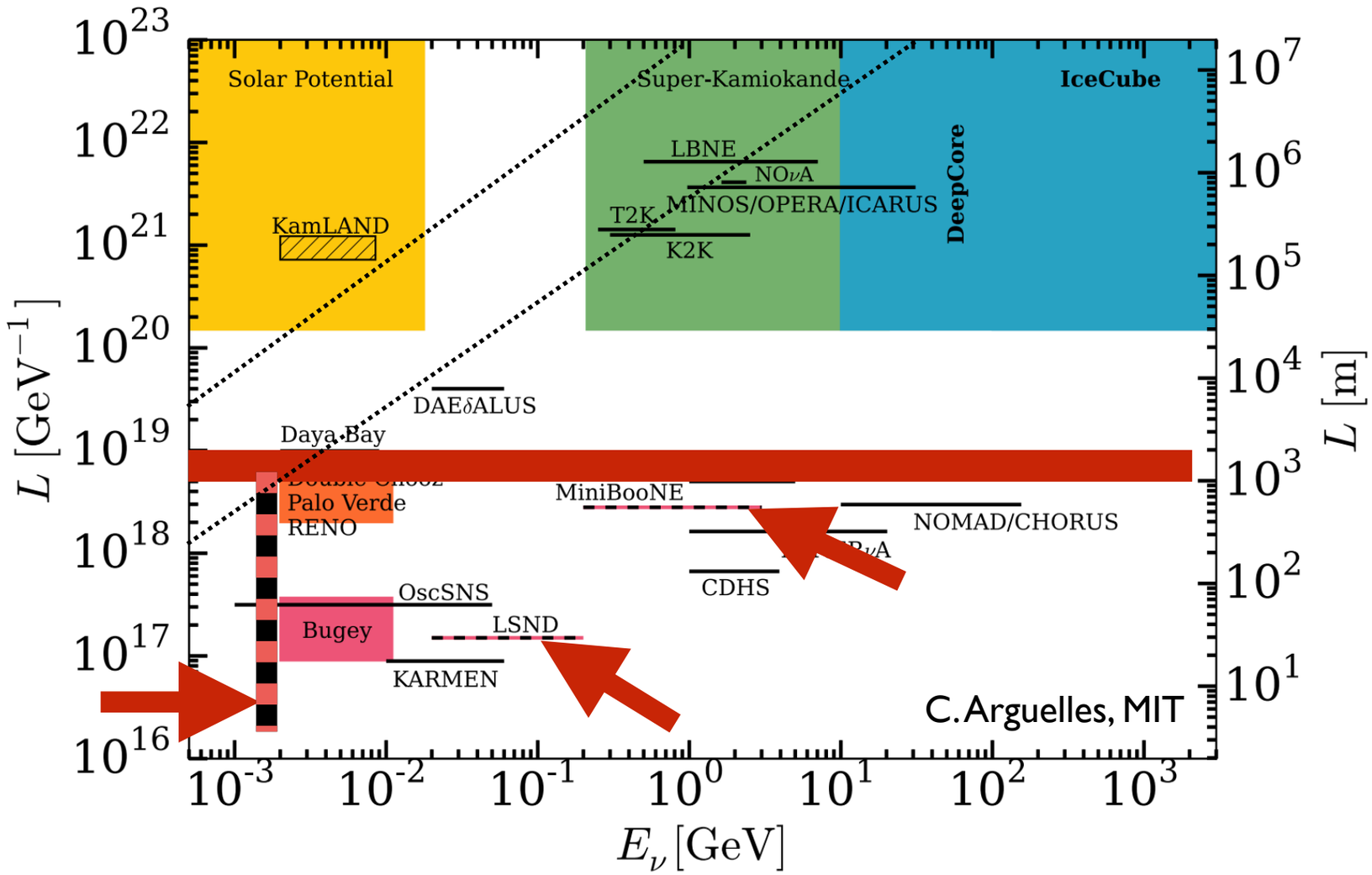
Neutrino Oscillations: L and E

- Have a beautiful picture of three oscillating Standard Model neutrinos coming into focus
- Took many experiments to get us here!
- Baselines (L): >km-scale
- Let's go HERE!
- WHY go here?



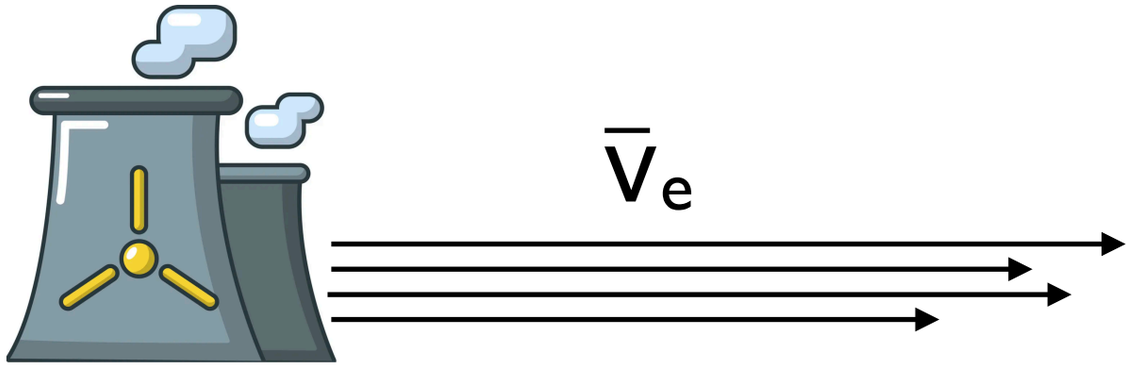
Neutrino Anomalies

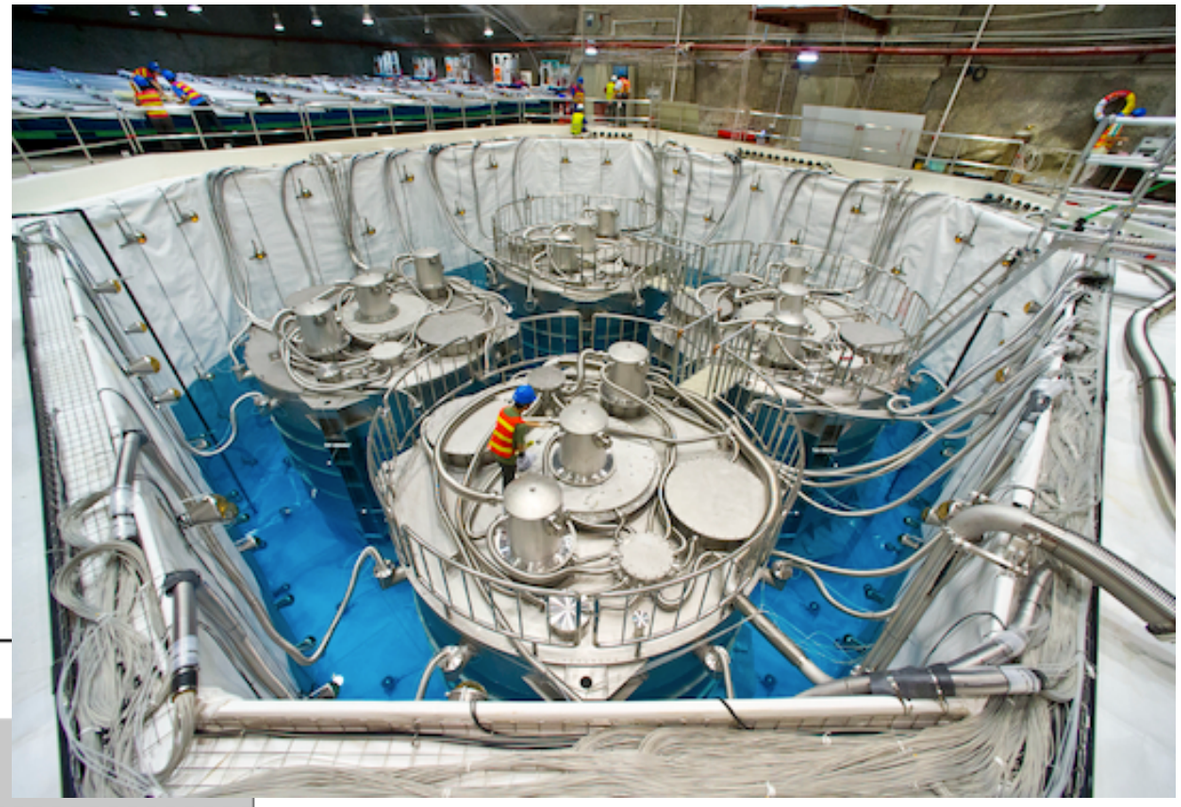
- Neutrino fluxes and energies measured at < km disagree with state-of-the-art neutrino predictions
- Indications of something odd beyond 'SM oscillation'?!

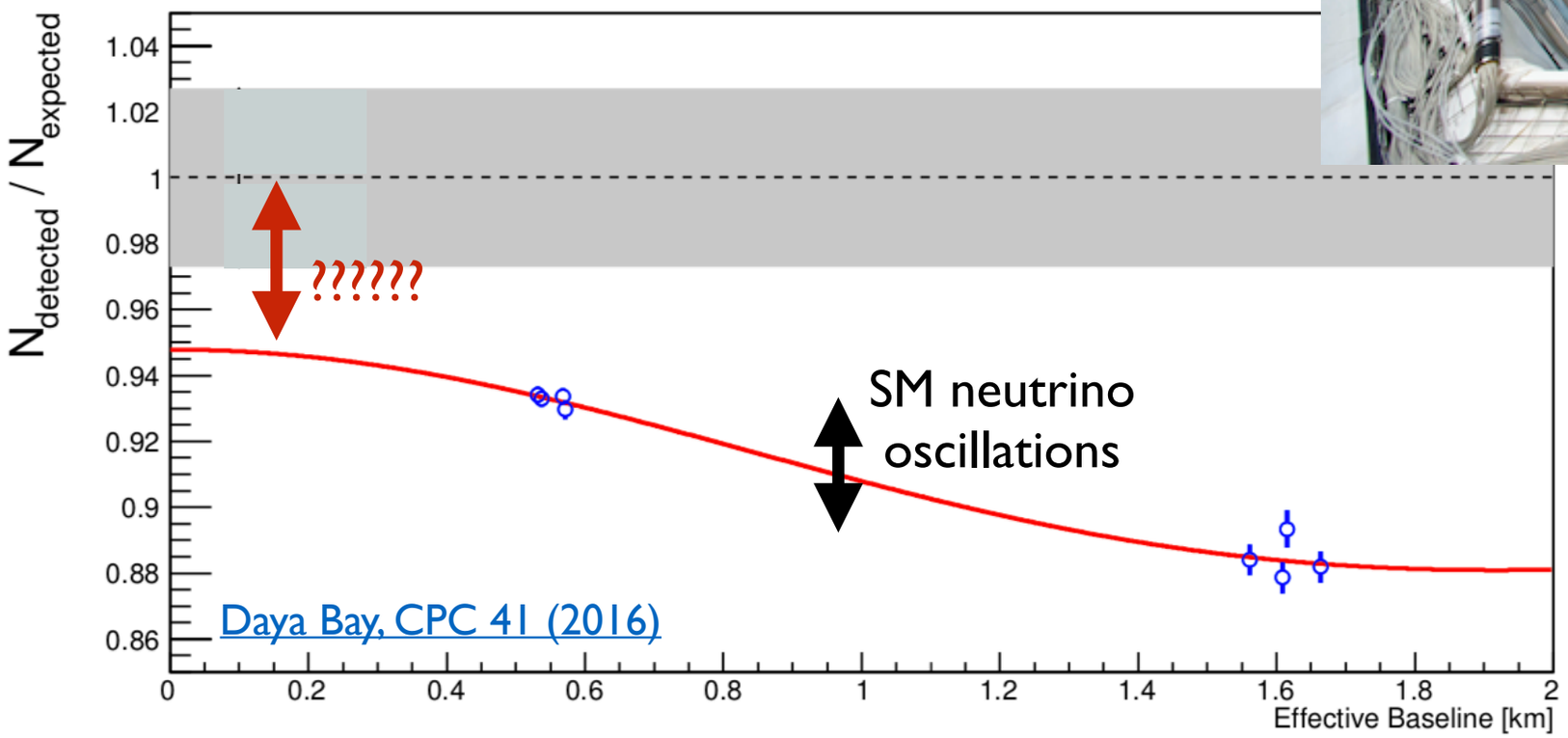


Reactor and Gallium Anomalies

- Deficits in neutrino detection rates at electron-flavor sources
- Sources host only lower (MeV-scale) energy scale processes





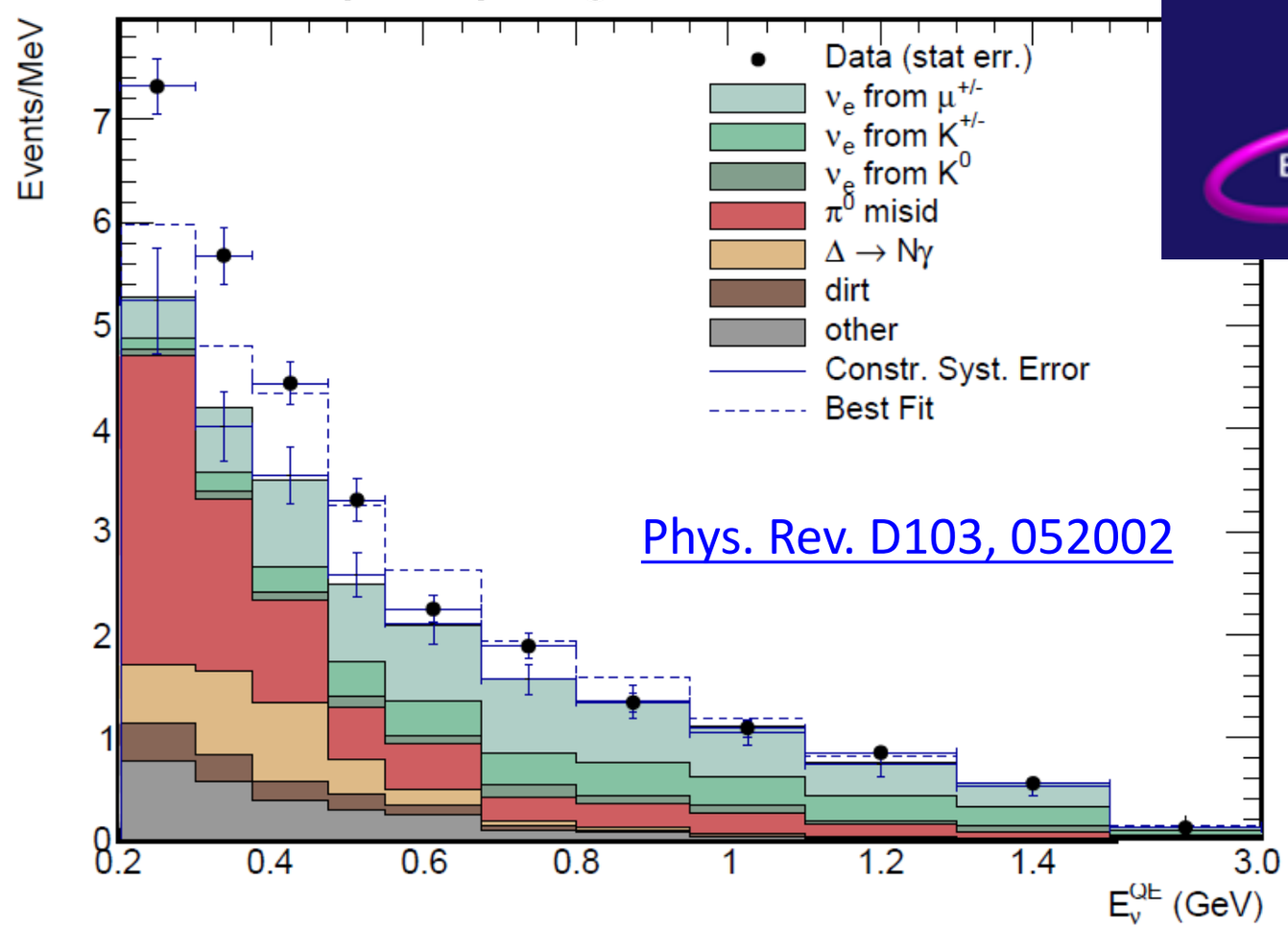


Daya Bay: liquid scintillator inverse beta decay detectors

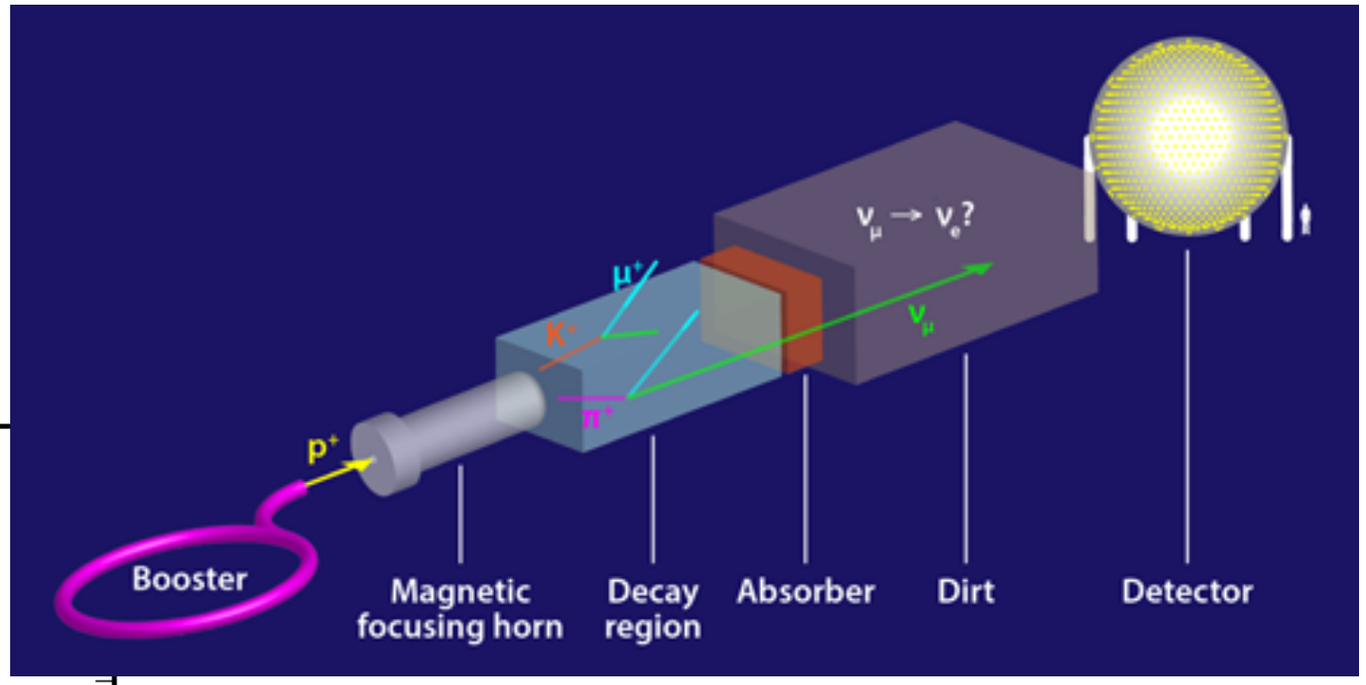
MiniBooNE and LSND Anomalies

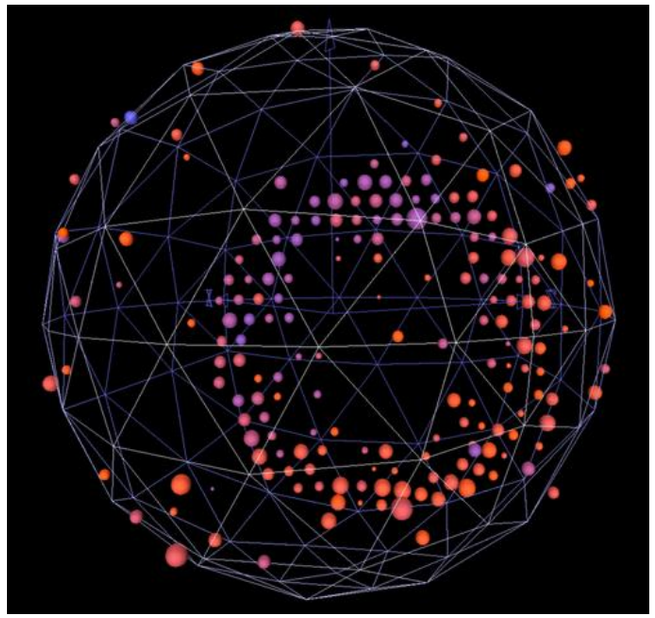
- Excesses of electron-like events in ~muon-flavor sources
- Sources host some higher (GeV-scale) energy scale processes

Too many fuzzy rings in MiniBooNE!



Phys. Rev. D103, 052002





Electron Cherenkov ring event in MiniBooNE

MiniBooNE: an oil Cherenkov detector

New Neutrino Mass States?

- Neutrino fluxes and energies measured at < km disagree with state-of-the-art neutrino predictions
- Indications of new physics beyond 'SM oscillations'?(!)
  - New flavor transformations (like sterile osc)? New dark sector interactions?

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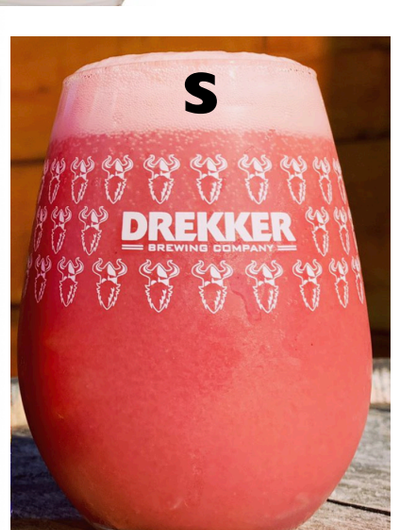
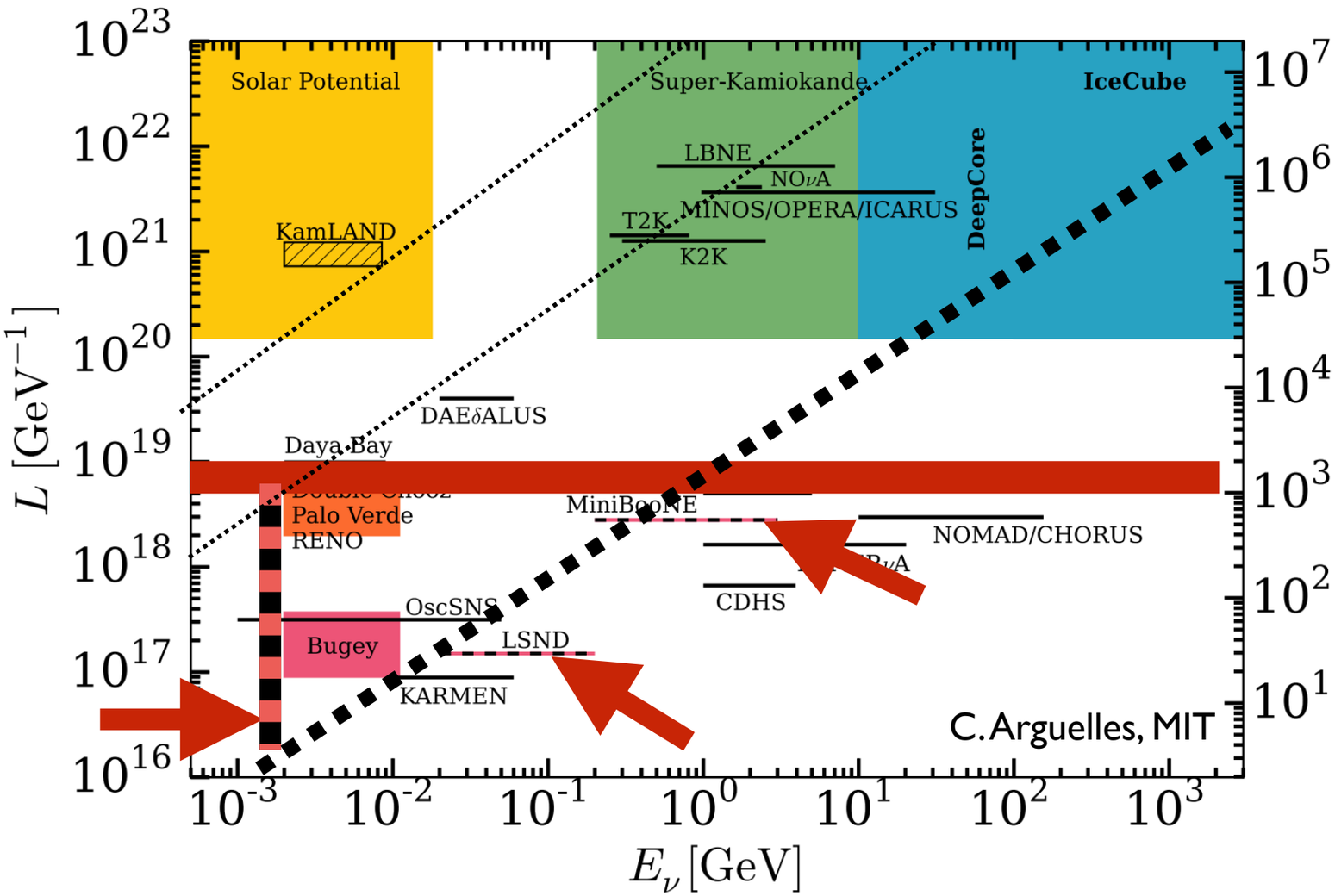
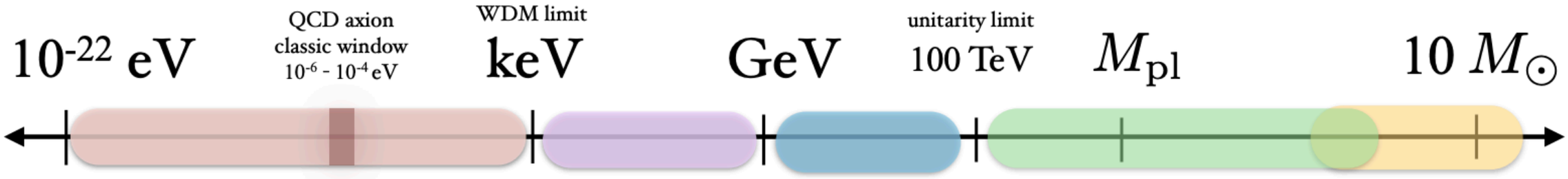




New Neutrino Mass States?

- Other good reasons to look for new mass states, too
  - Dark matter: could heavy neutral leptons be a viable candidate?
  - See-saw mechanism: heavier neutral leptons help explain why SM neutrinos are so light?



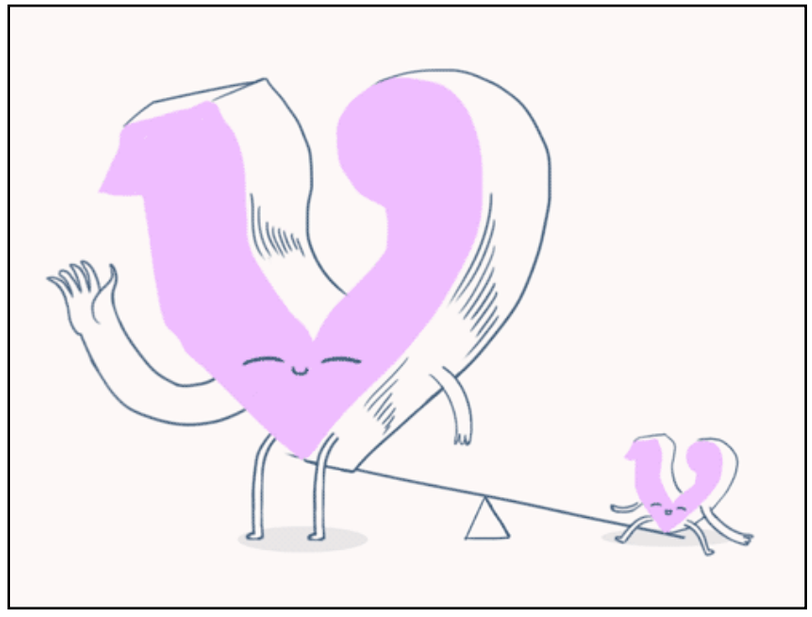
``Ultralight" DM
non-thermal
bosonic fields

``Light" DM
dark sectors
sterile ν
can be thermal

WIMP

Composite DM
(Q-balls, nuggets, etc)

Primordial
black holes



Outline For This Session

- In the Neutrino Frontier, we are excited about these anomalies!
- Our plan for this session:
  - 2 talks summarizing what we've learned about anomalies in the last P5 period
  - 1 talk recent describing developments in theory/pheno views of the anomalies
  - A panel discussion aimed at what the next P5 period holds for the sub-field

10:15 AM	**Experimental Status: Atmospheric/Accelerator DIF and DAR** ¶ **Speaker**: Mark Ross-Lonergan	15m
10:30 AM	**Experimental Status: Radioactive Sources and Reactors over the Past 10 Years** **Speaker**: Pranava Teja Surukuchi (Yale University)	15m
10:45 AM	**Recent Theory Progress and Interpretation(s)** **Speaker**: Matheus Hostert (Perimeter Institute)	20m
11:05 AM	**Panel: Path to Resolution through Neutrino Experiments and Beyond**	55m