Summary of WG5 sessions
Beyond PMNS

Walter Bonivento, INFN Cagliari, Italy
Sanjib Kumar Agarwalla, Institute of Physics, Bhubaneswar, India
Pedro Machado, FNAL, USA

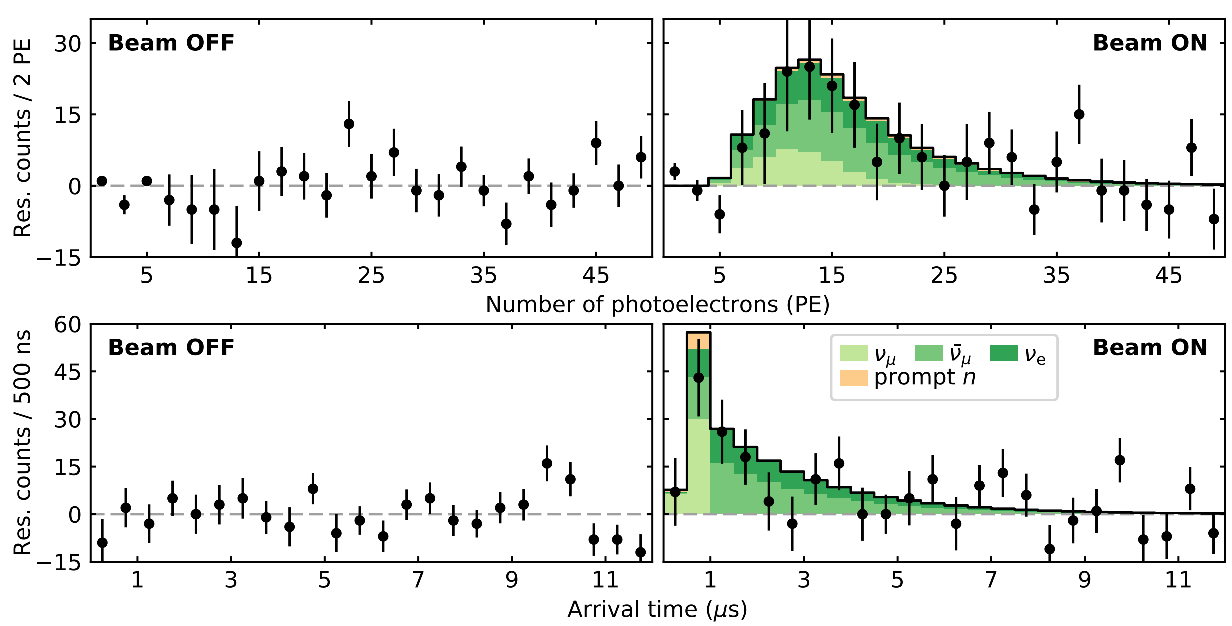
Neutrinos as a stargate to BSM Physics

An experimentalist review of many theory+experimental talks
25 parallel session talks

[+4 (/6)plenaries]

Coherent Elastic Neutrino Nucleus Scattering

The Result D. Akimov et al., Science 10.1126/science.aao0990 (2017).



Observation of coherent elastic neutrino-nucleus scattering

D. Akimov[1,2], J. B. Albert[3], P. An[4], C. Awe[4,5], P. S. Barbeau[4,5], B. Becker[6], V. Belov[1,2], A. Brown[4,7], A. Bolozdy...
+ See all authors and affiliations

Science 03 Aug 2017:
eaao0990
DOI: 10.1126/science.aao0990

Peer Reviewed
← see details

Barbeau-Plenary

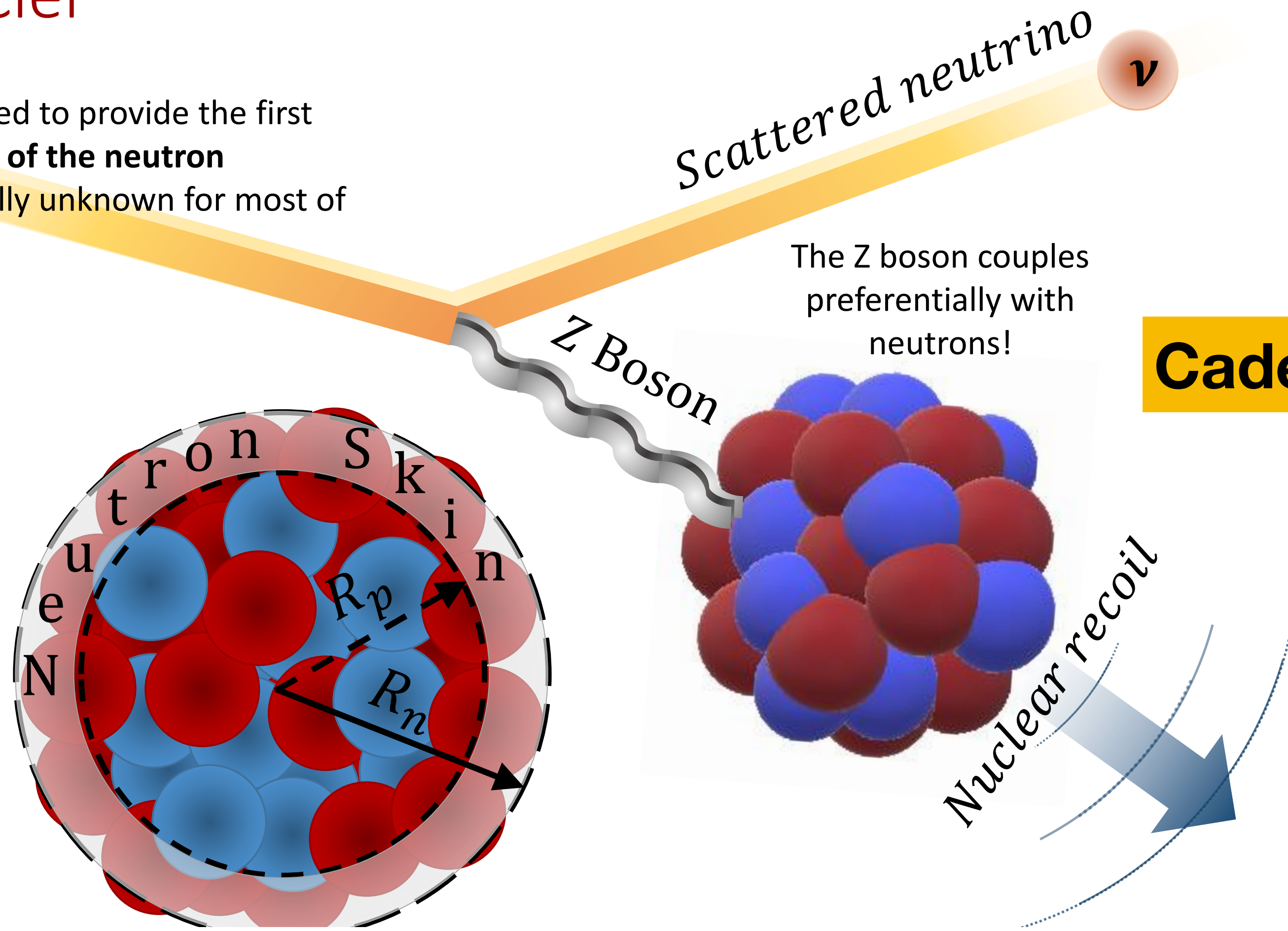
…as a tool to improve our knowledge of the nuclear neutron form factor

The CEnNS process as unique probe of the neutron density distribution of nuclei

The CEnNS process itself can be used to provide the first **model independent measurement of the neutron distribution radius**, which is basically unknown for most of the nuclei.

Even if it sounds strange, spatial distribution of neutrons inside nuclei is basically unknown!

The rms neutron distribution radius Rn and the difference between Rn and the rms radius Rp of the proton distribution (the so-called "**neutron skin**")



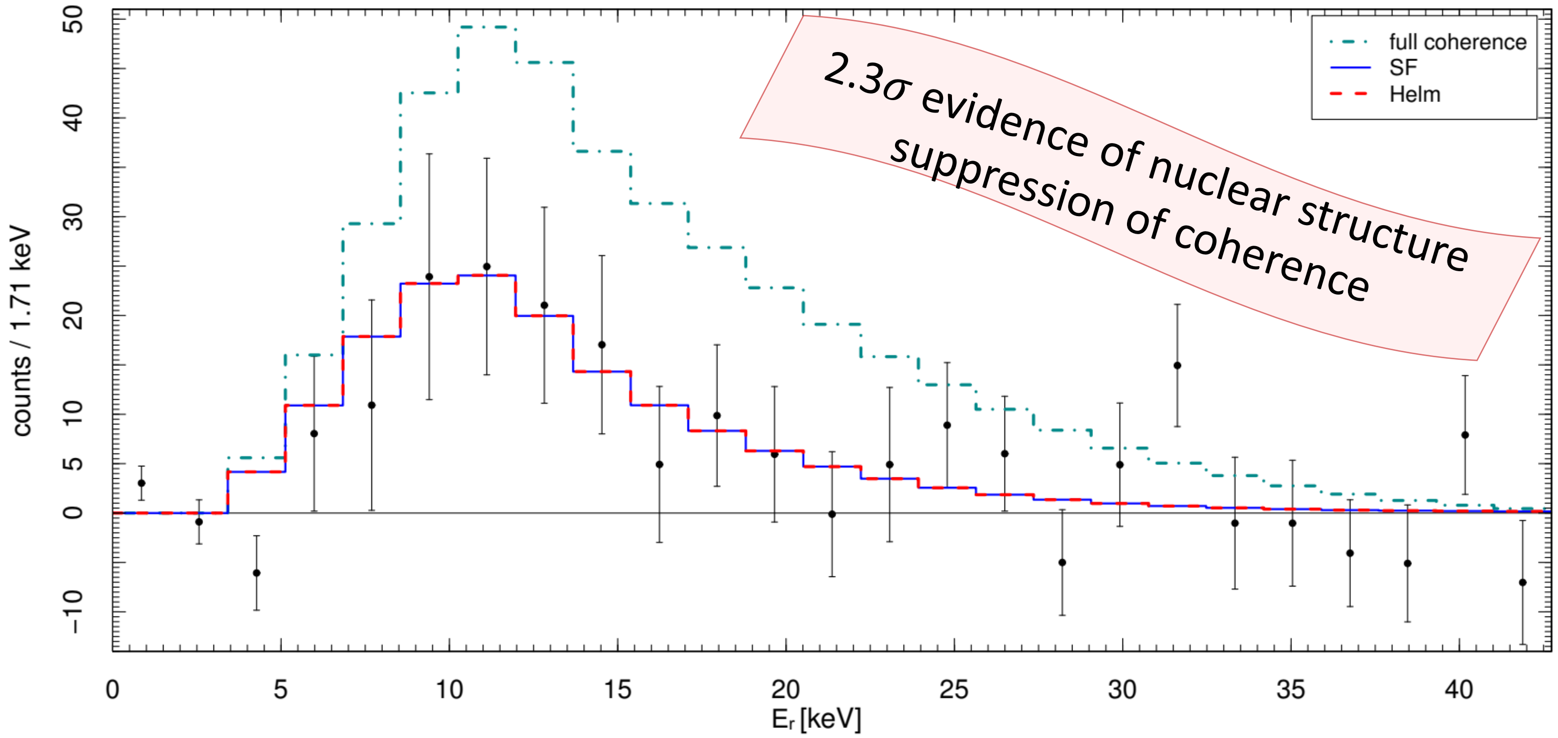
Cadeddu

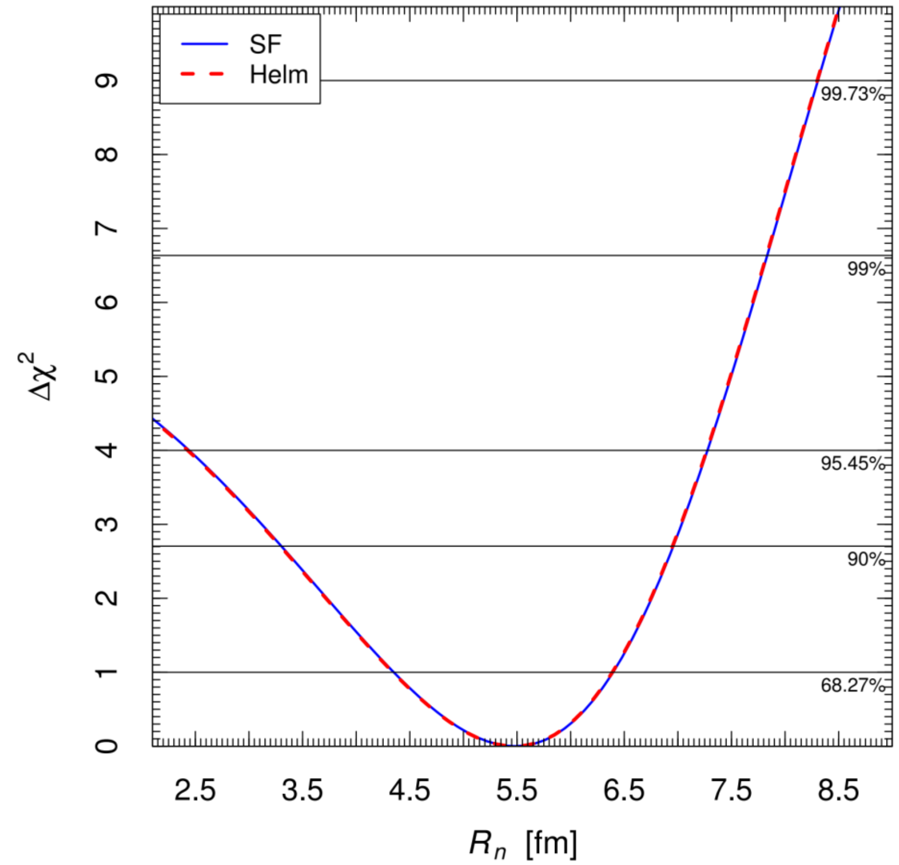
$$\frac{d\sigma_{\nu-CsI}}{dE_r} = \frac{G_F^2\, m_N}{4\pi}\left(1 - \frac{m_N E_r}{2E_\nu^2}\right)\left[N\, F_N(E_r, R_n) - \underbrace{(1 - 4\sin^2\theta_W)}\, Z\, F_Z(E_r, R_p)\right]^2$$

This factor is small ~0.0454 and moreover Z<N so the contribution of the proton form factor is negligible!!

Hence**, measurements of the process give information on the nuclear neutron form factor**, which is more difficult to obtain than the information on the proton one, that can be obtained with elastic electron-nucleus scattering and other electromagnetic processes.

First average CsI neutron density distribution measurement





- We first compared the data with the predictions in the case of full coherence, i.e. all nuclear form factors equal to unity: **the corresponding histogram does not fit the data**.
- We fitted the COHERENT data in order to get information on the value of the neutron rms radius R_n, which is **determined by the minimization of the χ^2** using the **symmetrized Fermi** and **Helm form factors**.

This is the first model independent measurement of the CsI neutron radius

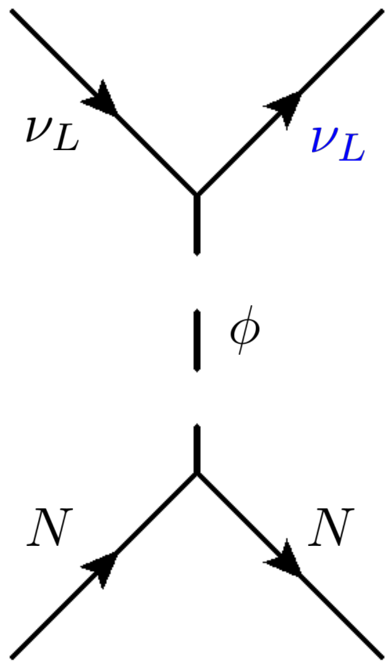
$$R_n^{CsI} = 5.5^{+0.9}_{-1.1}\ \text{fm}$$

17

…and as a new tool for probing BSM physics

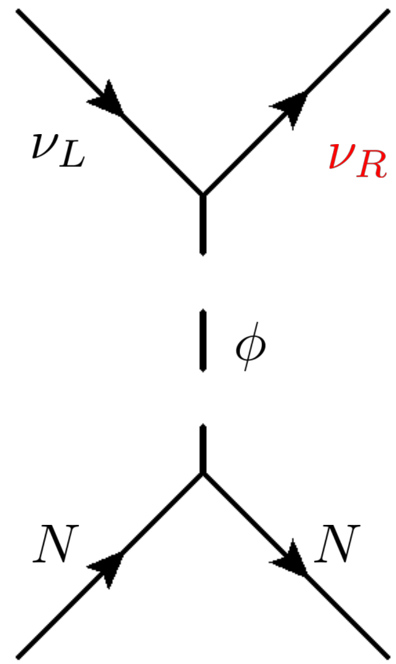
NSI with light mediators (if $M \ll q^2$)

Xu



Lepton number violated

$$\mathcal{L}_{\rm LNV} \equiv \frac{y_\nu}{2}\phi\bar{\nu}_L^c\nu_L + \text{H.c}$$



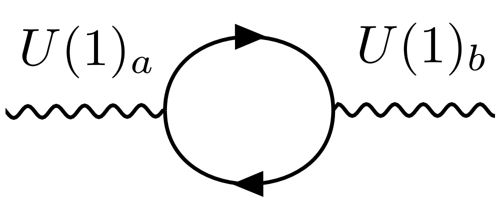
Lepton number conserved

$$\mathcal{L}_{\rm LNC} \equiv y_\nu\phi\bar{\nu}_R\nu_L + \text{H.c.}$$

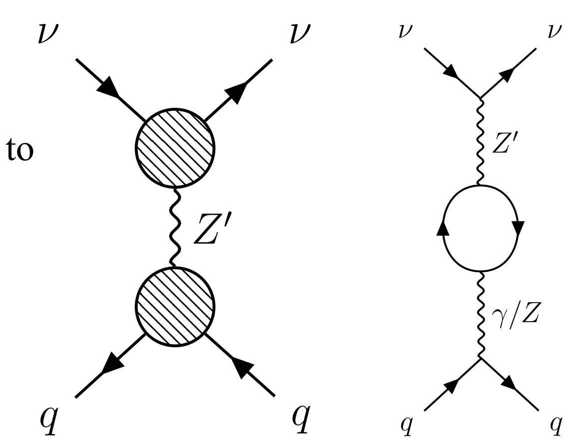
Dent

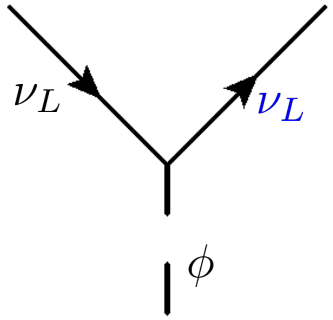
Kinetic Mixing Portal

Extend the SM by an extra $U(1)$ which introduces a new field



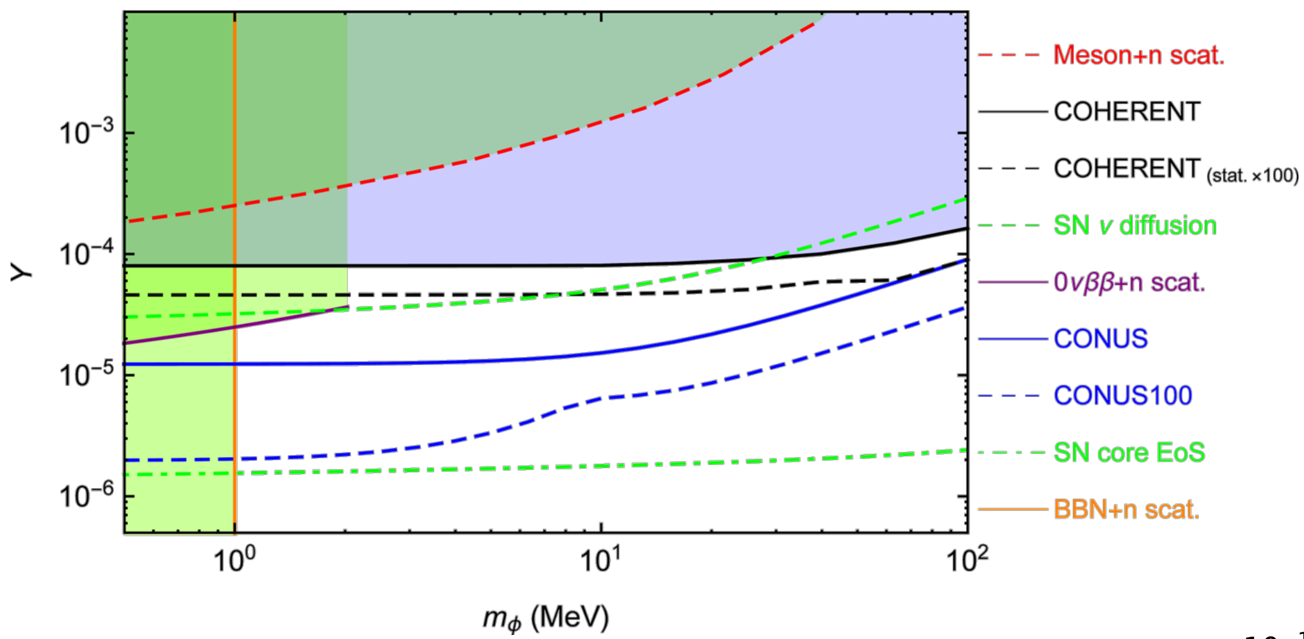
We will examine the cases where the new field has only loop induced couplings to SM fields, as well as tree level couplings with neutrinos.





Constraints (LNV)

Xu



new Z' mass and coupling bounds

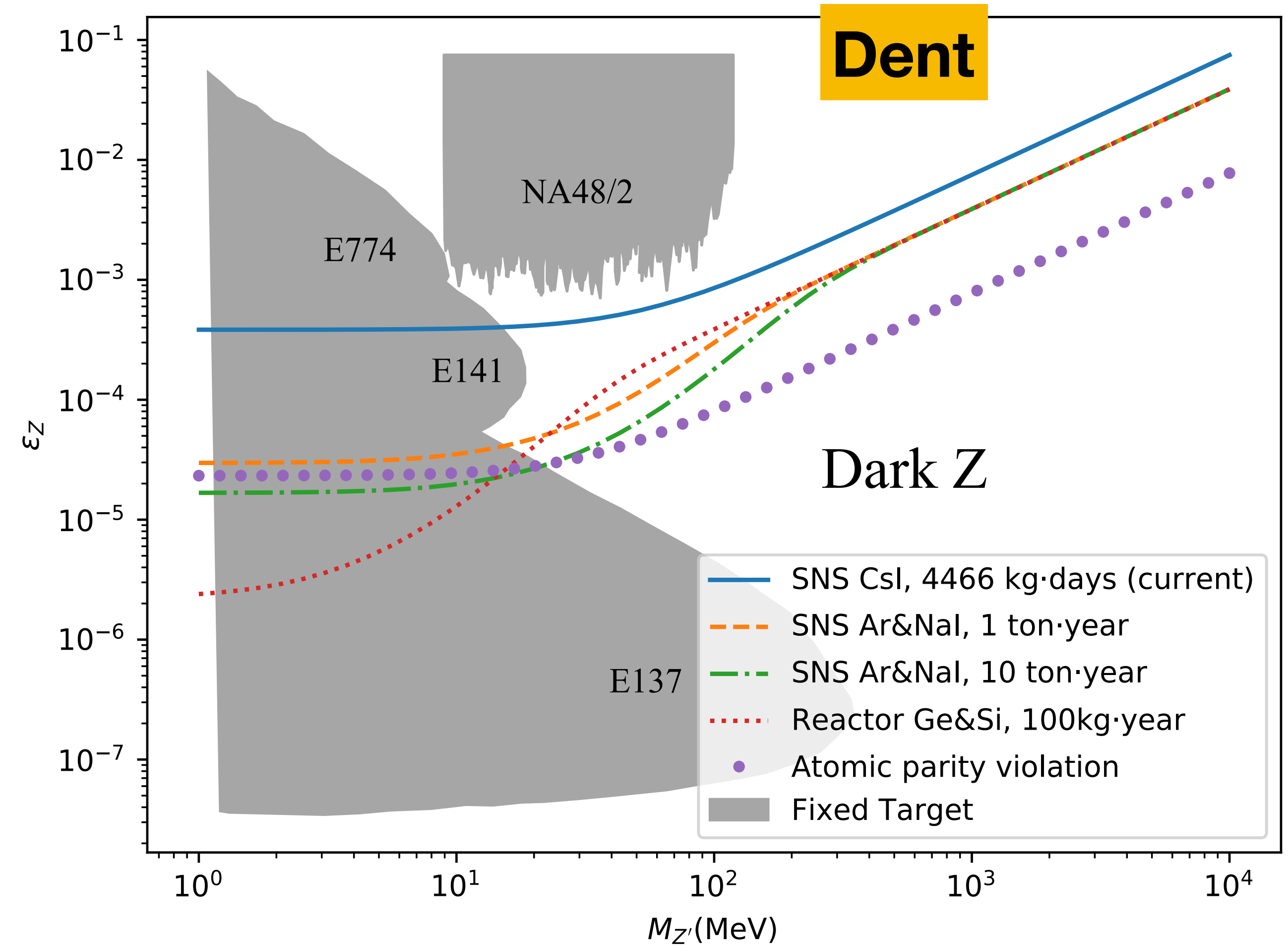
For a Z' coupling as strongly as the SM W,

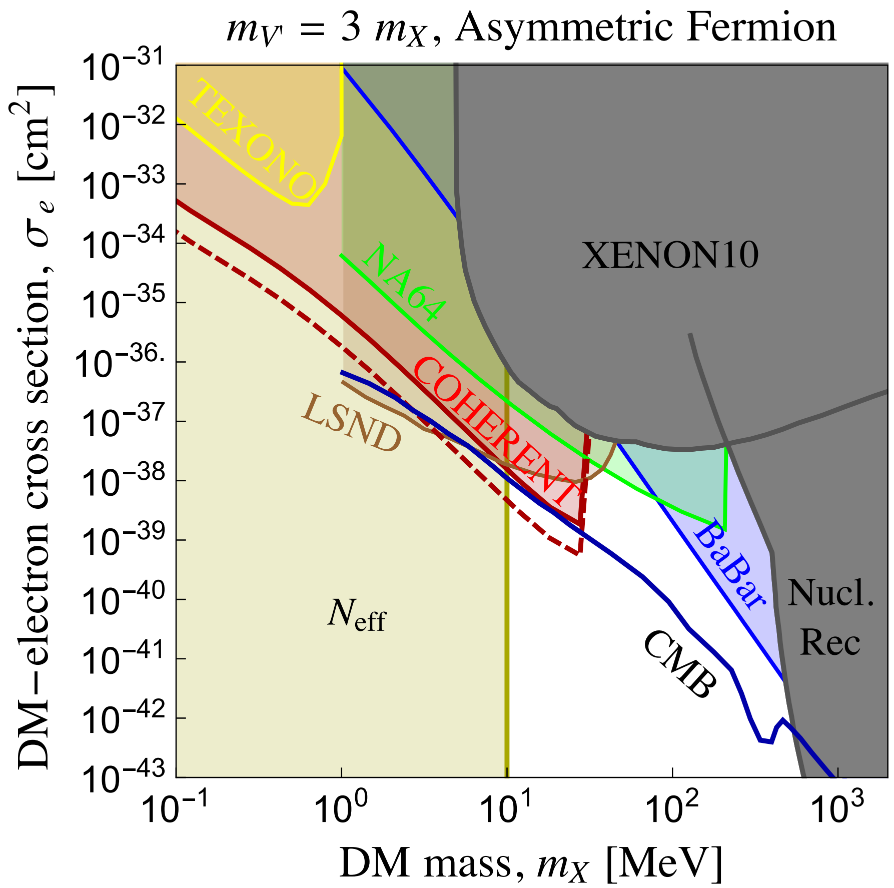
$M_{Z'} \gtrsim 4.5$ TeV, $|\alpha_Z| < 0.001$ at 95% CL.

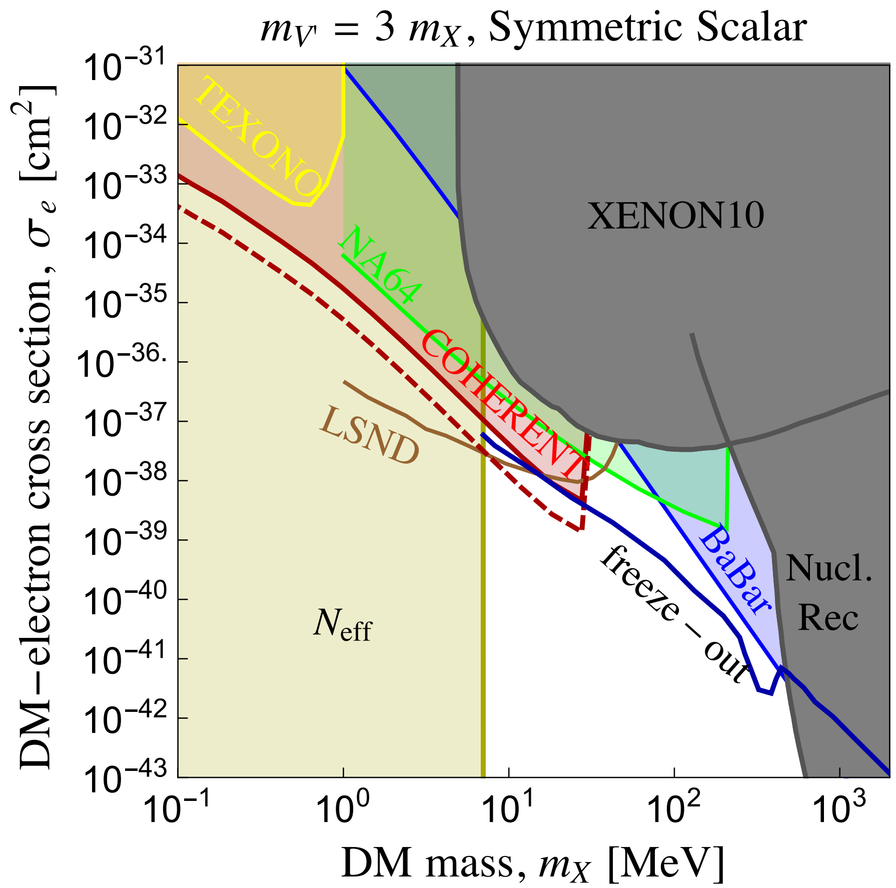
Strongest constraint from DY

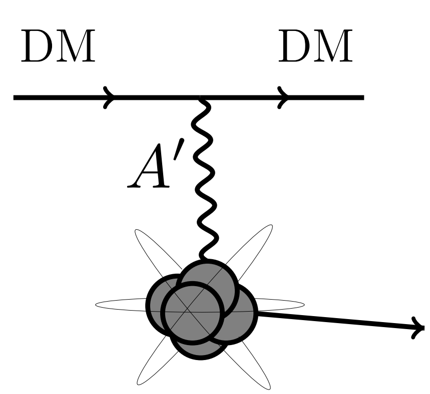
Bandyopadyay

Dent





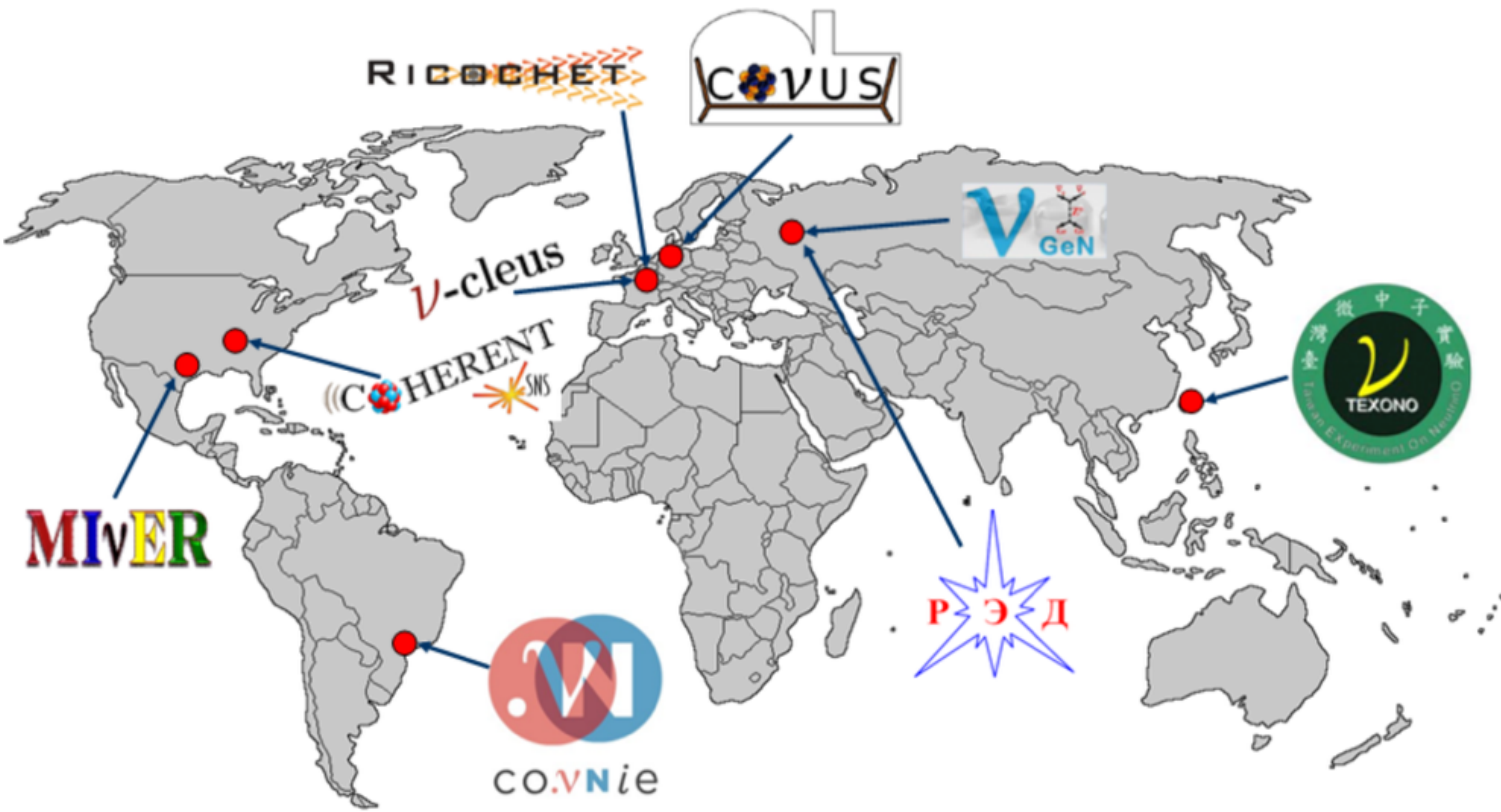




Krnjaic

Shao-Feng Ge, Ian Shoemaker 1710.10889

World-Wide CEvNS Efforts



BSM physics accessible with oscillation experiments

…modifying the oscillation pattern… (most results presented in the context of SBN/DUNE)

A short travel for neutrinos in Large Extra Dimensions

LED can give natural explanation of the smallness of active ν masses

Oscillation Probability

3ν

$$P(\nu_\alpha \to \nu_\beta) = \left| \sum_{i=1}^{3} U_{\alpha i} U^*_{\beta i} \exp\left(-i \frac{m_i^2 L}{2E_\nu}\right) \right|^2$$

Affects Neutrino Oscillation!

LED

$$P(\nu_\alpha \to \nu_\beta) = \left| \sum_{i=1}^{3} \sum_{n=0}^{\infty} U_{\alpha i} U^*_{\beta i} \left(S_i^{0n}\right)^2 \exp\left(-i \frac{\left(\lambda_i^{(n)}\right)^2 L}{2E_\nu R_{\mathrm{ED}}^2}\right) \right|^2$$

KK n-modes of the fermion field

Stenico

$$m_i \to \frac{\lambda_i^{(n)}}{R_{\mathrm{ED}}} \qquad U_{\alpha i} \to U_{\alpha i} S_i^{0n}$$

$$\boxed{\lambda_i^{(n)}\left(m_0, R_{\mathrm{ED}}\right)} \qquad \boxed{S_i^{0n}\left(m_0, R_{\mathrm{ED}}\right)}$$

R_{ED} compactification radius

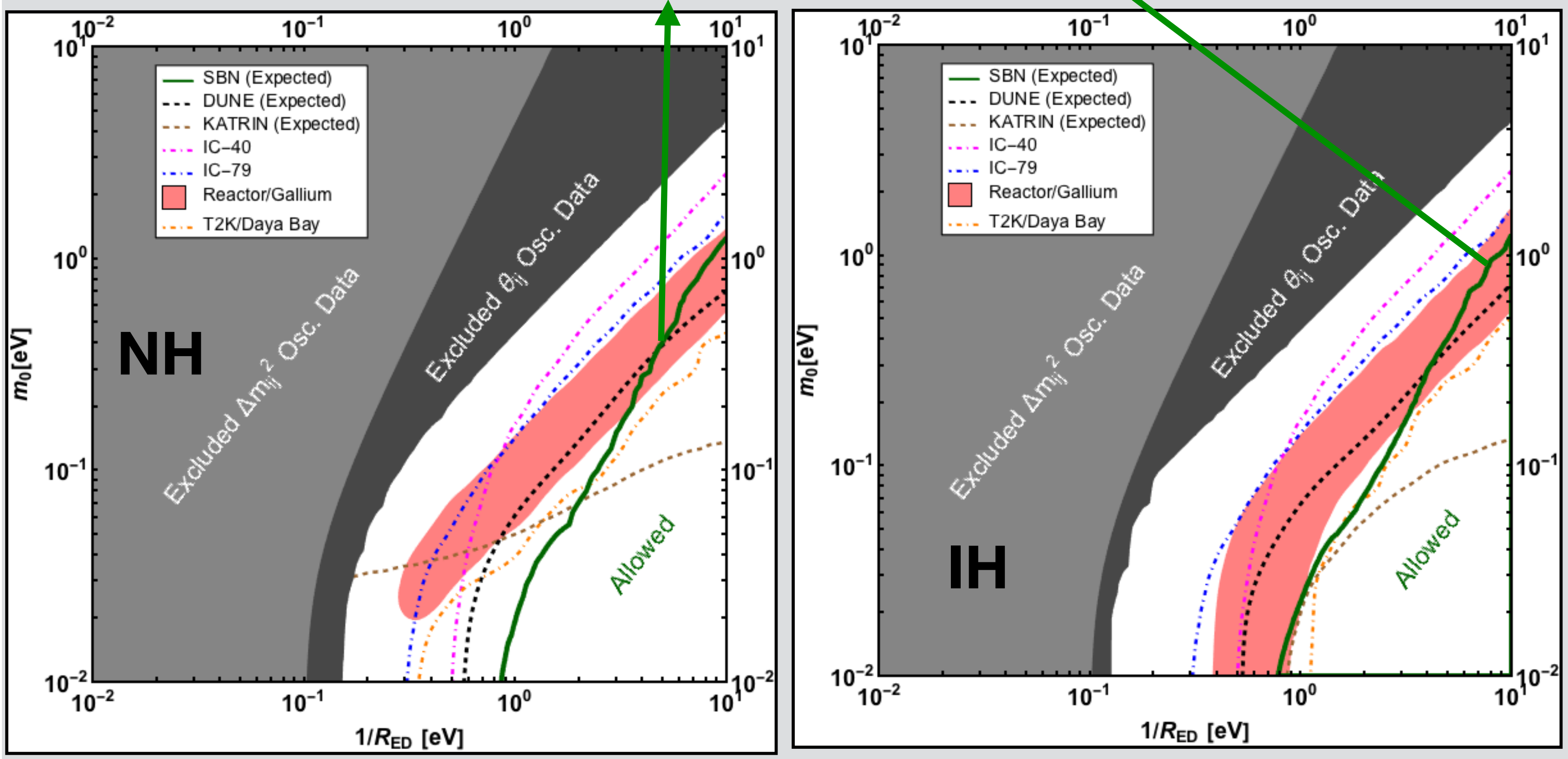
LED model of Phys. Rev. D 65, 105015

Results:

G. V. Stenico, D. V. Forero and O. L. G. Peres

$R_{\text{ED}} < 1.25 \text{ eV}^{-1}$ (90% C.L.)

90% C.L.



New result: sensitivity of SBN and DUNE

- SBN is sensitive to the oscillations predicted in the LED model and have the potential to constrain the LED parameter space better than any other oscillation experiment, for m_1^D < 0.1 eV;
- In case SBN observes a departure from the three active neutrino framework, it also has the power of discriminate between sterile oscillations predicted in the 3+1 framework and the LED ones.

How can a new scalar talk to the SM?

New fields: Lepton-Number-Charged Scalars ($LeNCS$) –

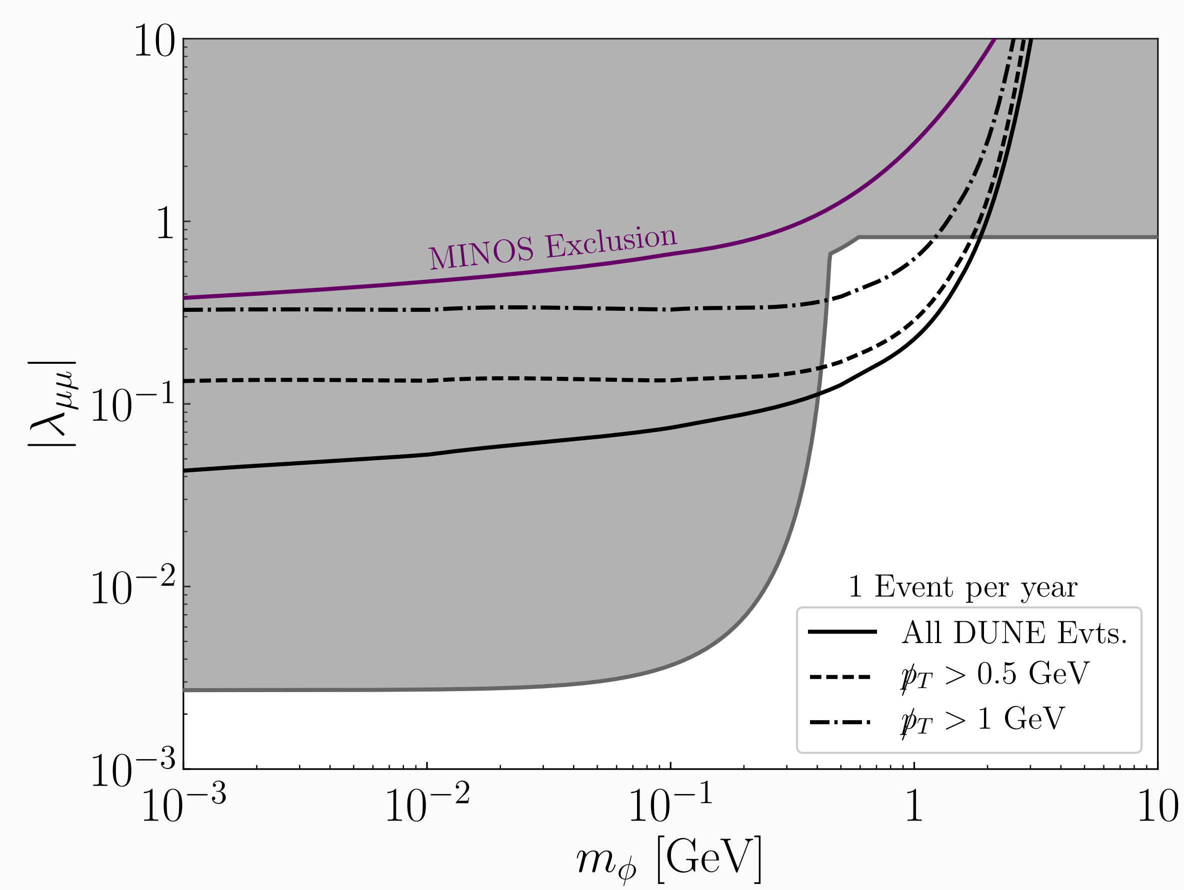
- We explored one new physics extension, in which $(B-L)$ is preserved in nature, and new scalar fields are charged under $(B-L)$.
- The parameter space is already constrained by a number of sources, both related to neutrino beams and not.

Kelly

$$\mathcal{L}_{LeNCS} \to \frac{\lambda_c^{ij}}{2}\nu_i^c\nu_j^c\phi^\star + \frac{\lambda_{\alpha\beta}}{2}\nu_\alpha\nu_\beta\phi + \frac{\lambda_{\alpha\beta}}{v}\nu_\alpha\nu_\beta\phi h + \text{h.c.} + \mathcal{O}(h^2),$$

where $\lambda_{\alpha\beta} \equiv v^2/\Lambda^2_{\alpha\beta}$.

If $\Lambda_{\alpha\beta} \simeq$ electroweak scale, then we can have $\lambda_{\alpha\beta} \simeq 1$ and realiz interactions between ϕ and the active neutrinos ν_α.



Ultralight scalar (Fuzzy) dark matter

Hu, Barkana, Gruzinov
Hui, Ostriker, Tremaine, Witten

- Ultra-light (<< eV) scalar DM has large de Broglie wavelength

$$\lambda = 12 \text{ kpc} \left(\frac{10^{-22} \text{ eV}}{m_\phi}\right) \left(\frac{10 \text{ km/s}^{-1}}{v}\right)$$

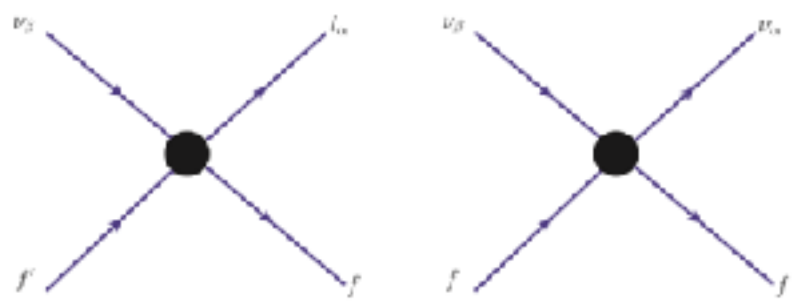
Whisnant

- Fuzzy DM coupling to neutrinos can give a perturbation on the neutrino mass matrix; scalar mass must be large enough to avoid observable time variations
- In models where the unperturbed θ_{13} is zero, Fuzzy DM perturbations can generate nonzero θ_{13}
- In leading order of the perturbation, our model has same effective parameters across all experiments (except for long-baseline)
- High precision experiments (such as JUNO) can probe differences at second order in the perturbation

CC-like NSI with reactors

ffective four-fermion operators

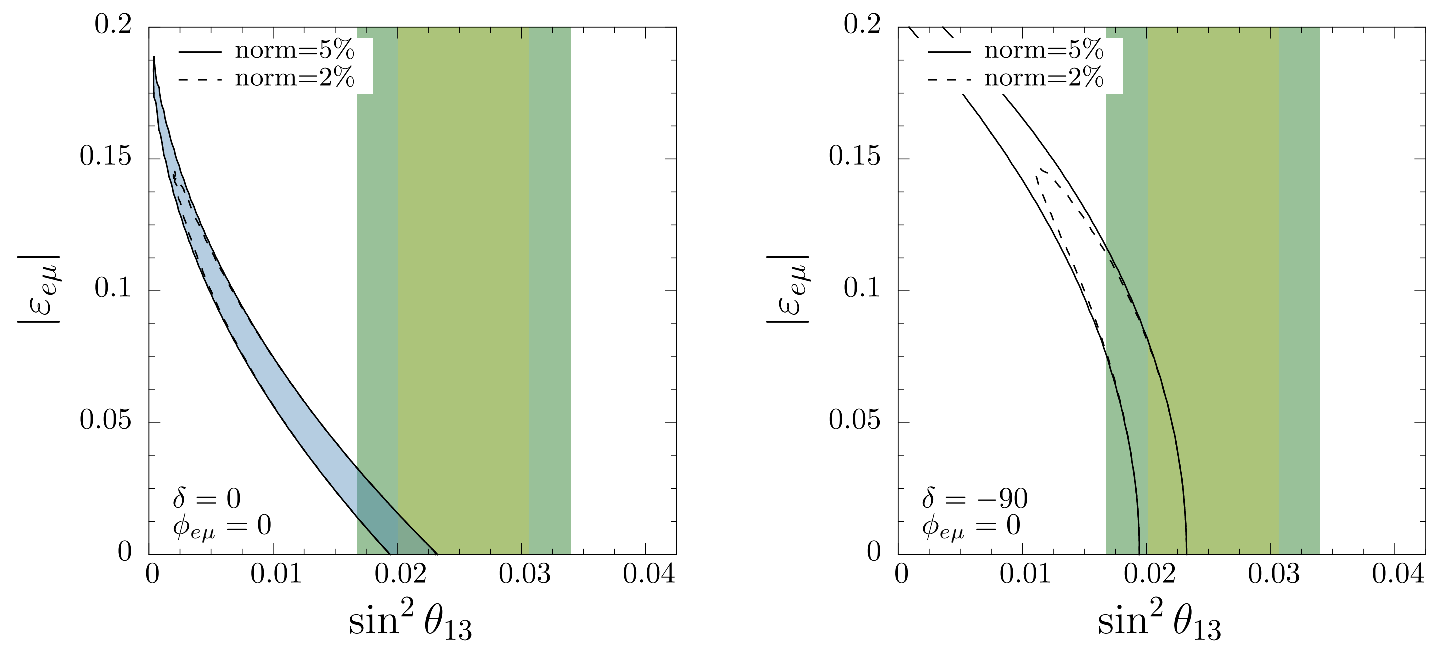
L. Wolfenstein (PRD **17** (1978)), J.W.F Valle (PLB **199** (1987))
M.M Guzzo *et al.* (PLB **260** (1991)), E. Roulet (PRD **44** (1991))



$$\mathcal{L}_{V\pm A} = \frac{G_F}{\sqrt{2}} \sum_{f,f'} \tilde{\varepsilon}^{s(d),f,f',V\pm A}_{\alpha\beta} \left[\bar{\nu}_\beta \gamma^\rho (1-\gamma^5)\ell_\alpha\right]\left[\bar{f}' \gamma_\rho (1\pm\gamma^5) f\right] + \frac{G_F}{\sqrt{2}} \sum_{f} \varepsilon^{m,f,V\pm A}_{\alpha\beta} \left[\bar{\nu}_\alpha \gamma^\rho (1-\gamma^5)\nu_\beta\right]\left[\bar{f} \gamma_\rho (1\pm\gamma^5) f\right] + \mathrm{h.c.},$$

Showing s^2_{13} from LBL-only in vertical bands

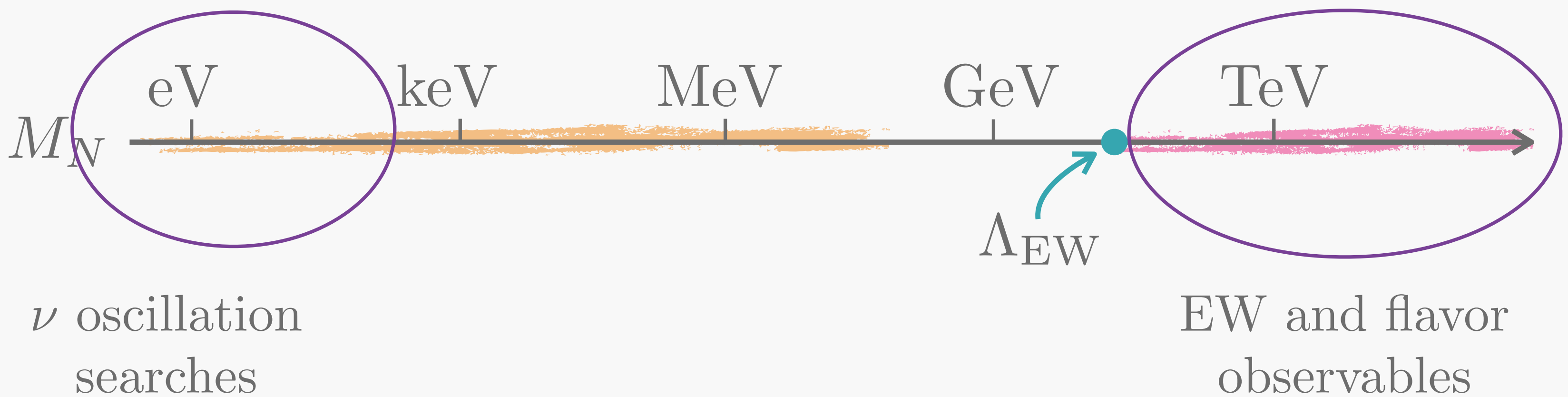
Contours at 90% of C.L for 2 d.o.f. Band: 90% (1σ) of C.L for 1 d.o.f, green(yellow).



Forero

- Multidetector reactor neutrino experiments offer a clean probe of CC-like NSI. The θ_{13} determination is in general NOT robust under CC-like NSI (due to the effect of the phases) while the value of the NSI constrains is limited by our current knowledge of the 'absolute normalization of reactor neutrino fluxes'. New physis might be 'entangled' with syst. errors.
- By using the LBL result for the reactor mixing angle as an input, constrains on the '$\varepsilon_{e(\mu,\tau)}$' and 'FU' couplings substantially improved.

Introduction: SM + Type I Seesaw



Hernandez-Garcia

At some level, both limits

- Very high ($M_N > \Lambda_{\rm EW}$) neutrino $\rightarrow$ Non-Unitarity
- Very light ($M_N <$ keV) neutrino $\rightarrow$ sterile neutrinos

will impact neutrino oscillation searches.

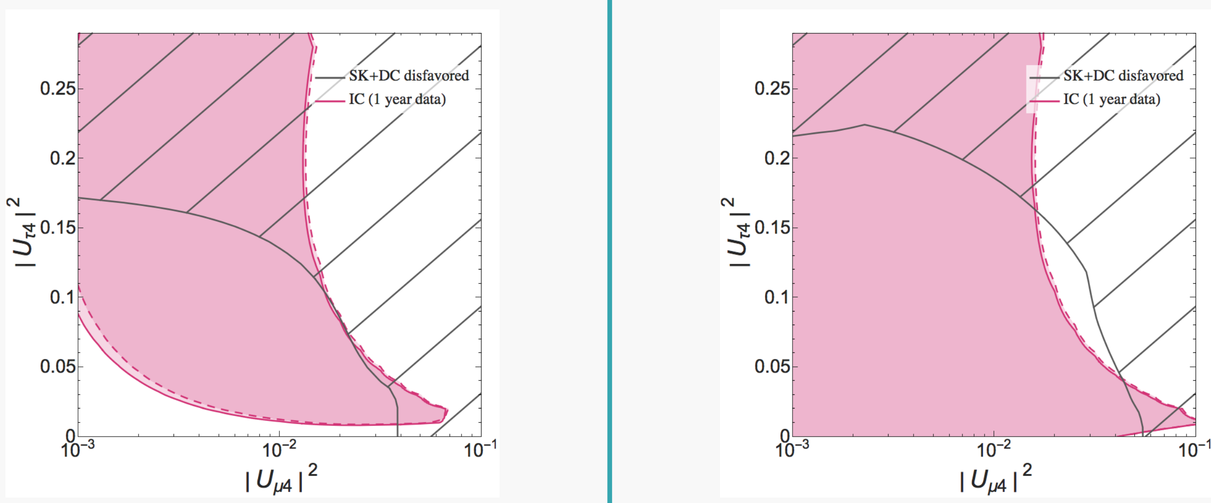
Non-Unitarity induced by heavy neutrinos and oscillations of light sterile neutrinos in the averaged out regime share the same phenomenology at leading order.

Important to consider the role of the Near Detector.

Sterile ν above 10 eV at IceCube

- Constraints obtained for the public 1 year-data

90% | 99%



Mild preference (2.3σ 1 dof) for non-zero mixing

Between 0.75 and 3σ depending on the binning and flux adopted

The results overlap with the favored region for the sterile ν interpretation of the upward shower observed by ANITA.

The preferred mixings are in tension with NOMAD data, and non-standard matter interactions needed to reconcile results.

8 years of IceCube data would be sufficient to confirm or exclude the present preference.

CPT-violating neutrinos

- Most stringent bounds come from the neutral kaon system

$$\frac{|m(K^0) - m(\overline{K}^0)|}{m_K} < 0.6 \times 10^{-18}$$

- But: 1. Kaons are not elementary 2. The kaon mass as scale is arbitrary 3. Kaons are bosons and entering the Lagrangian are the masses squared

Ternes

- Translating the bound gives then

$$|m^2(K^0) - m^2(\overline{K}^0)| < 0.25 \text{ eV}^2$$

- We obtain the current bounds at 3σ C.L.

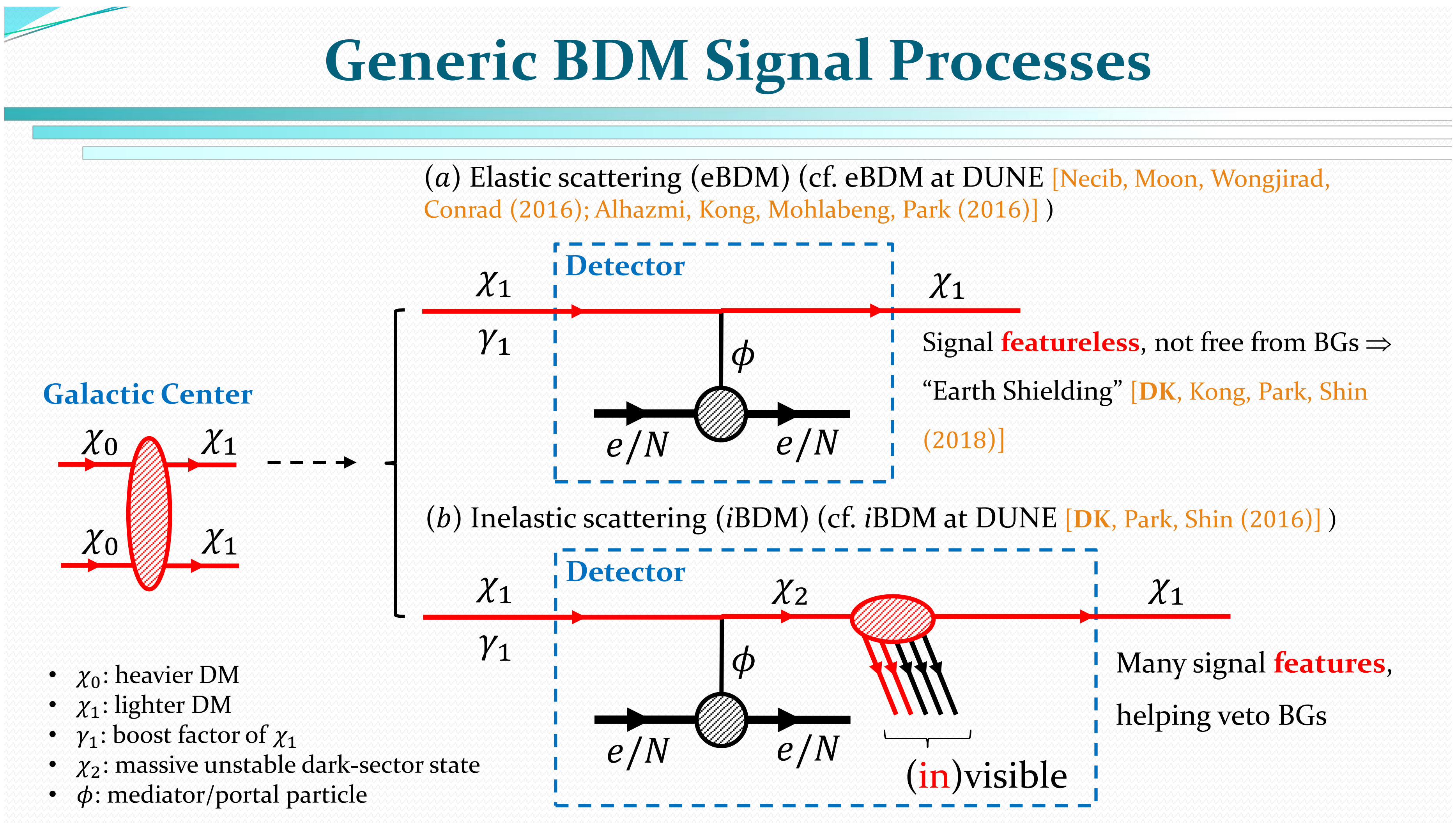
$$|\Delta m^2_{21} - \Delta \overline{m}^2_{21}| \quad < 4.7 \times 10^{-5} \text{eV}^2,$$
$$|\Delta m^2_{31} - \Delta \overline{m}^2_{31}| \quad < 3.7 \times 10^{-4} \text{eV}^2,$$

The bound on both mass splittings is better than the one of the kaons

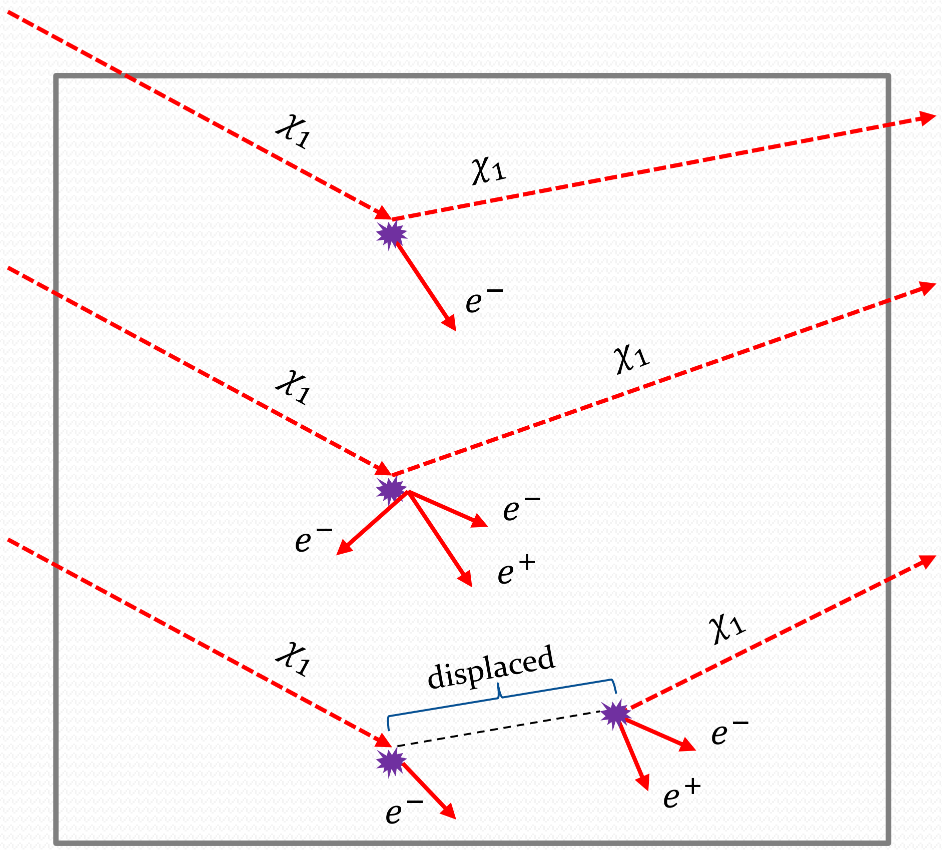
- DUNE could improve the bounds on $|\Delta(\Delta m^2_{31})|$ by one order of magnitude
- If CPT is violated in nature we are committing errors in our analysis by combining neutrino with antineutrino results

…or showing up as unexpected new types of signals…

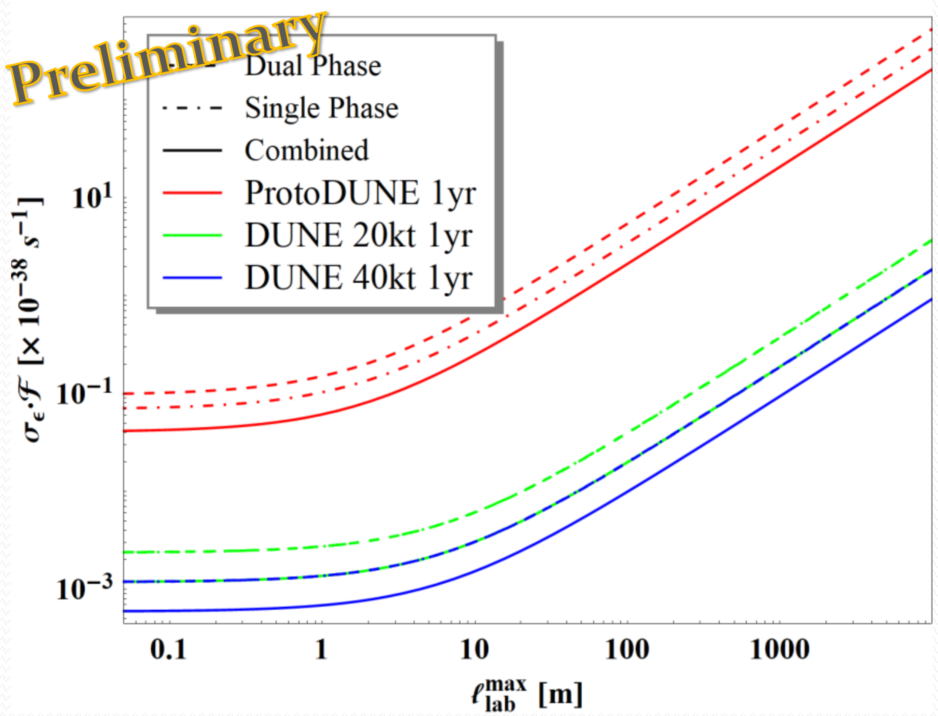
Scattering \ v_{DM}	Non-relativistic ($v_{DM} \ll c$)	Relativistic ($v_{DM} \sim c$)
elastic	Direct detection	**Boosted DM (eBDM)**
*in*elastic	inelastic DM (iDM)	**inelastic BDM (*i*BDM)**

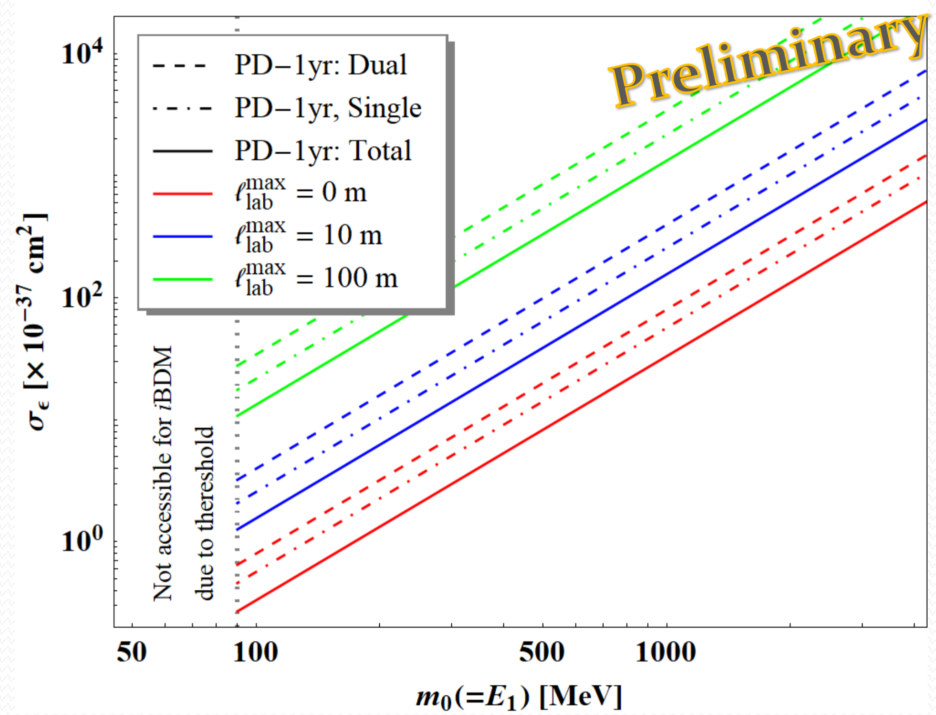


Kim



*i*BDM and eBDM Prospects at DUNE

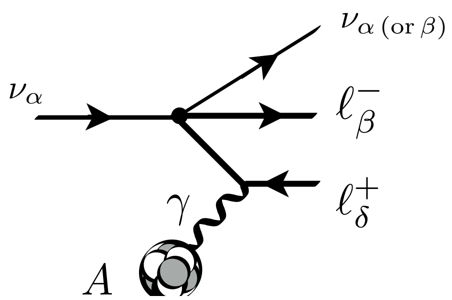




NB: physics possible with protoDUNE!

Neutrino trident production

Pair production in the coulomb field of the **nucleus, nucleons or quarks.**



Hostert

[CHARM II coll., 1990] — First measurement of $\mu^+\mu^-$ trident.

Channel	SBND	μBooNE	ICARUS	DUNE ND	νSTORM ND
Total $e^\pm\mu^\mp$	10	0.7	1	2993 (2307)	191
	2	0.1	0.2	692 (530)	41
Total e^+e^-	6	0.4	0.7	1007 (800)	114
	0.7	0.0	0.1	143 (111)	14
Total $\mu^+\mu^-$	0.4	0.0	0.0	286 (210)	11
	0.4	0.0	0.0	196 (147)	9

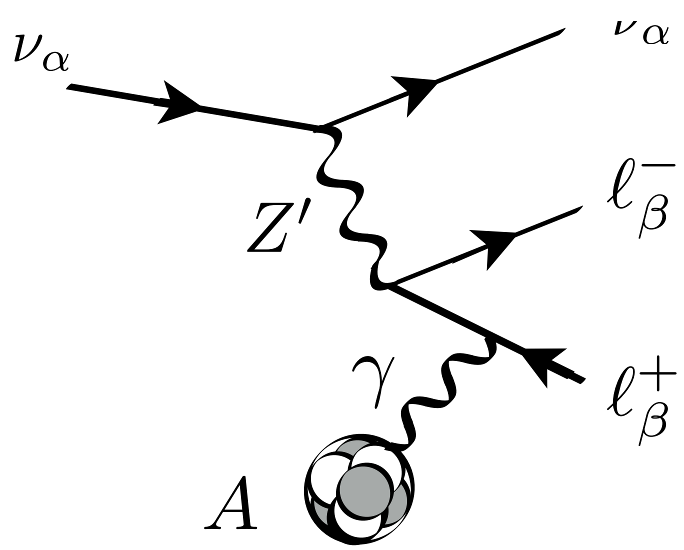
Coherent (upper) and diffractive (lower) trident events for (anti)neutrino mode.

Neutrino trident production measurement is an **attainable goal** of future LAr DUNE ND.

background tough…

Trident events might hide in our current experiments. Can our detectors see them?

Consider first a new gauge boson gauged under the **anomaly free** group $U(1)_{L_\mu - L_\tau}$

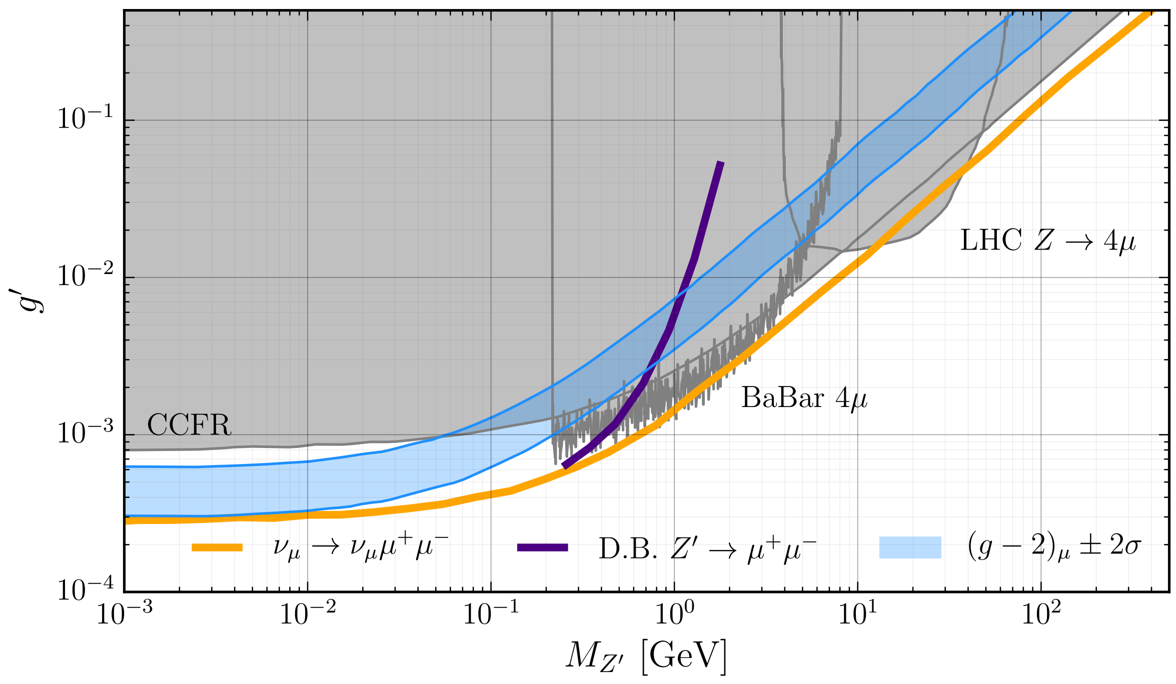


Sensitivity of DUNE ND

$U(1)_{L_\mu - L_\tau}$

Enhancement is largest at **lower energies.**

Log sensitive to the Z' mass below 10 MeV.



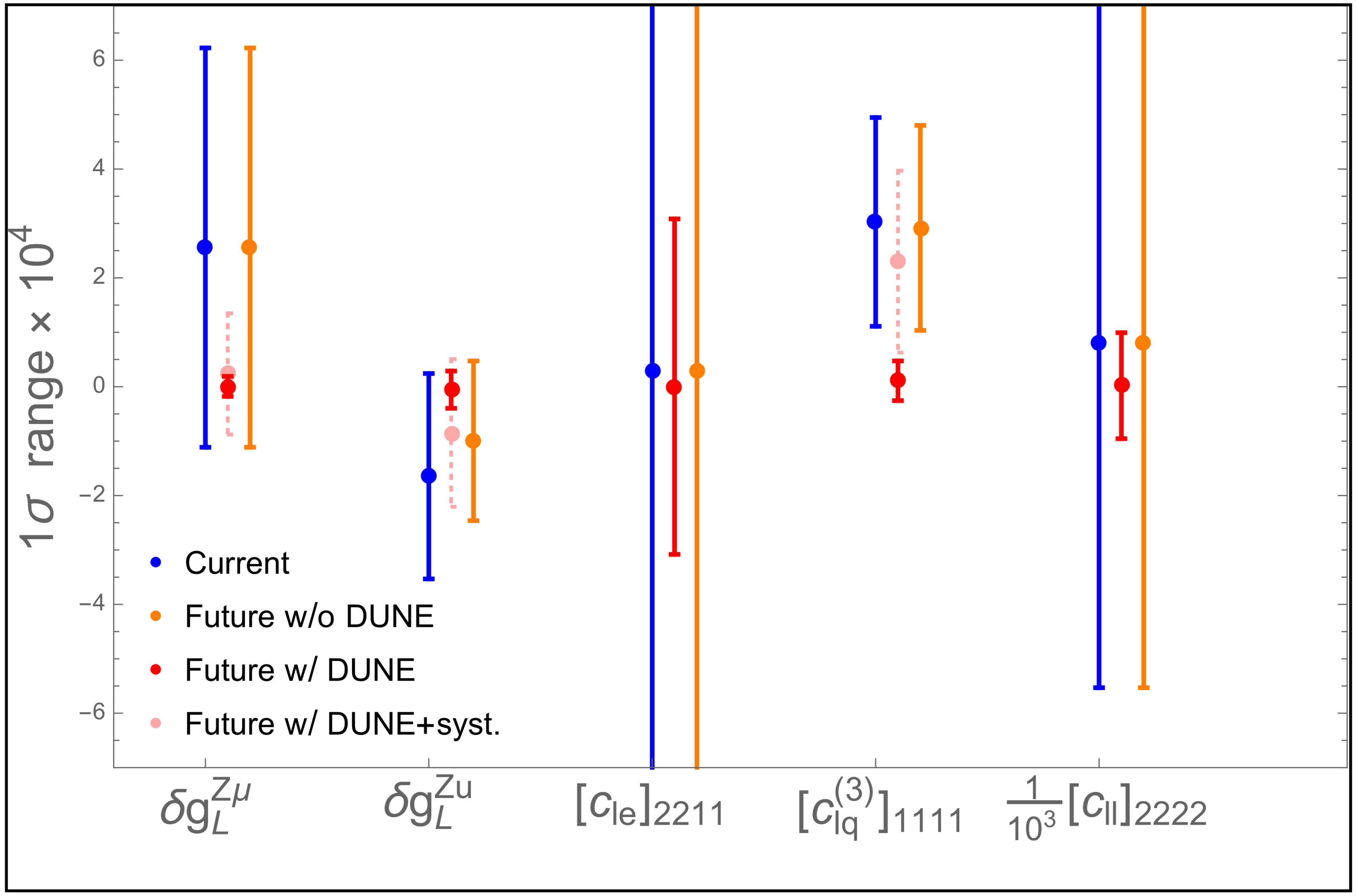
DUNE near detector (**25 t**) at 90 % C.L.

Assume 10% normalisation systematics and no backgrounds.

Future DUNE constraints on EFT

We studied observables related to trident production, neutrino scattering off electrons and neutrino scattering off nuclei at the DUNE Near Detector.

Grilli di Cortona



…or in unitarity tests…

In what circumstance, do we want to test unitarity ?

Minakata

- We don't know what is NP that causes UV
- Yet, we want to test unitarity
- (If we know what is NP, we don't need unitarity test. We can just go to the model of NP to confront it to experiments!)
- The only way we could pursue is to prepare (as much as) model-independent framework for unitarity test

…and how systematics could affect BSM parameter determination…

Non-Unitarity | NSI | Sterile Neutrino

$$P_{\mu e}^{NU} \sim |\alpha_{21}|^2 \quad P_{\mu e}^{NSI} \sim |\epsilon_{e\mu}^d + \epsilon_{e\mu}^s|^2 \quad P_{\mu e}^{3+1} \sim \sin^2 2\theta_{\mu e}$$

Pasquini

Knowing the flux will be challanging!

But we want to measure zero distance effects!

We need to rely on other types of measurements (see hep-ex/arxiv:1201.3025)

(1) Modeling the distribution of π and K produced by the proton beam

(2) Measuring the muon flux in the decay pipeline and relate it to the ν flux

~~(3) Measuring the low energy transfer events (low-ν)~~ May be affected by new physics

→ Need to understand detector very well and is hard to measure E dependency

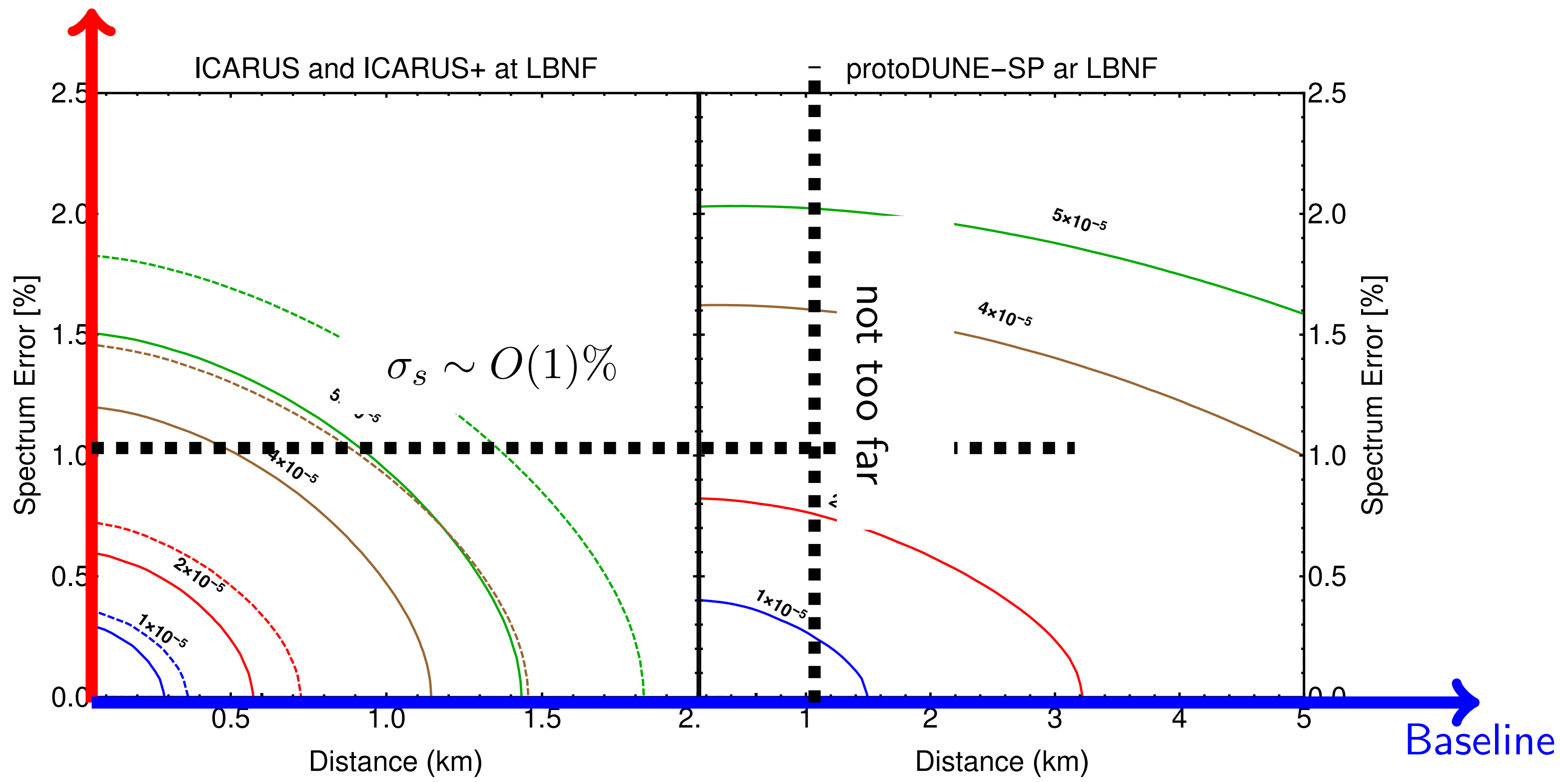
→ Need to know production differential cross section and the horn magnetic field

ND of SBN + DUNE

We need $\sigma_s \sim O(1)\%$

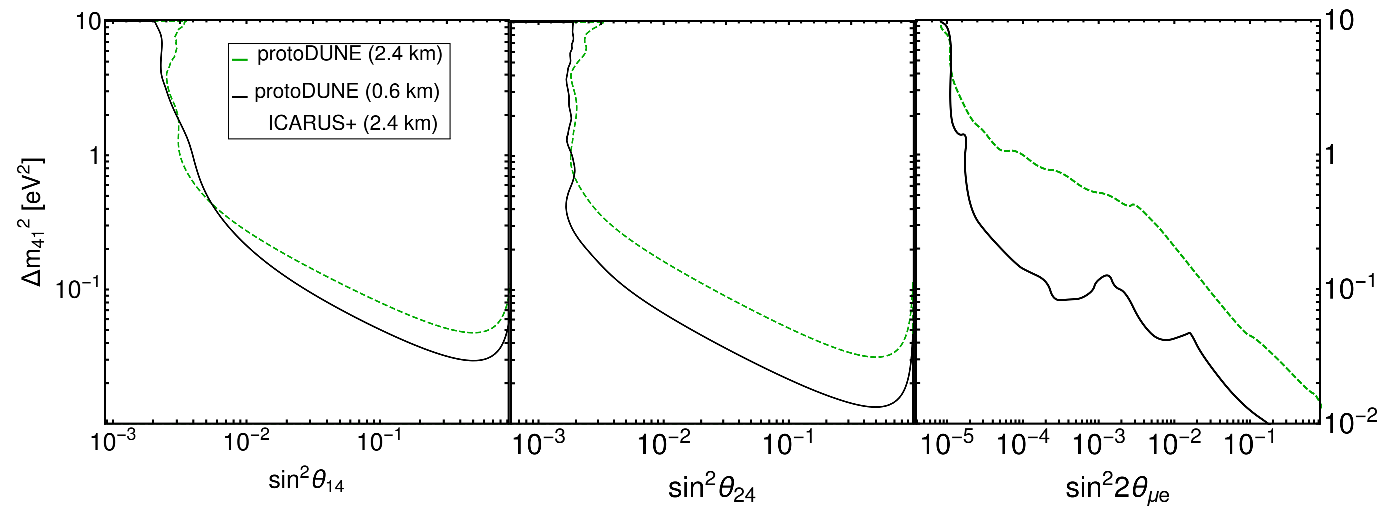
Spectrum error (σ_s)

What we got (for $|\alpha_{21}|^2$):



We can probe sterile neutrinos too!

If it is possible to use two near detectors, we gain a very good improvement!



An alternative/complementary proposal to LBL for δ measurement…

The Dirac CP Phase δ_D @ Accelerator Exp

Accelerator experiment, such as **T2K**, uses off-axis beam to compare ν_e & $\overline{\nu}_e$ appearance @ the oscillation maximum.

- **Disadvantages**:
  - **Efficiency**:
    - Proton accelerators produce ν more efficiently than $\overline{\nu}$ $(\sigma_\nu > \sigma_{\overline{\nu}})$.
    - The $\overline{\nu}$ mode needs more beam time $[\mathbf{T}_{\overline{\nu}} : \mathbf{T}_\nu = \mathbf{2} : \mathbf{1}]$.
    - Undercut statistics $\Rightarrow$ Difficult to reduce the uncertainty.
  - **Degeneracy**:
    - Only $\sin \boldsymbol{\delta}_\mathbf{D}$ appears in $P_{\nu_\mu \to \nu_e}$ & $P_{\overline{\nu}_\mu \to \overline{\nu}_e}$.
    - Cannot distinguish $\boldsymbol{\delta}_\mathbf{D}$ from $\boldsymbol{\pi} - \boldsymbol{\delta}_\mathbf{D}$.
  - **CP Uncertainty** $\frac{\partial P_{\mu e}}{\partial \delta_D} \propto \cos \delta_D \Rightarrow \Delta(\delta_D) \propto \mathbf{1}/\cos \boldsymbol{\delta}_\mathbf{D}$.
- **Solution**:

  Measure $\overline{\nu}$ mode with μ^+ decay @ rest (μDAR)

Ge

New Proposals

1 μDAR source + **2** detectors

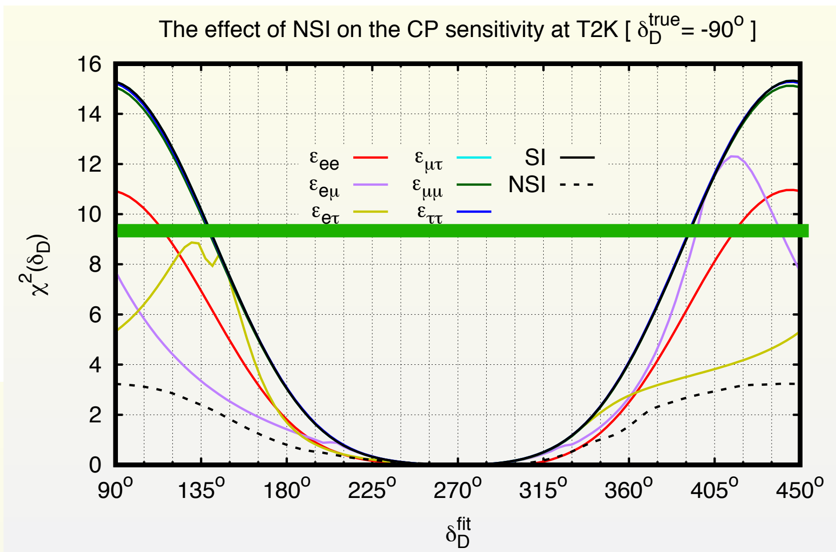
Advantages:

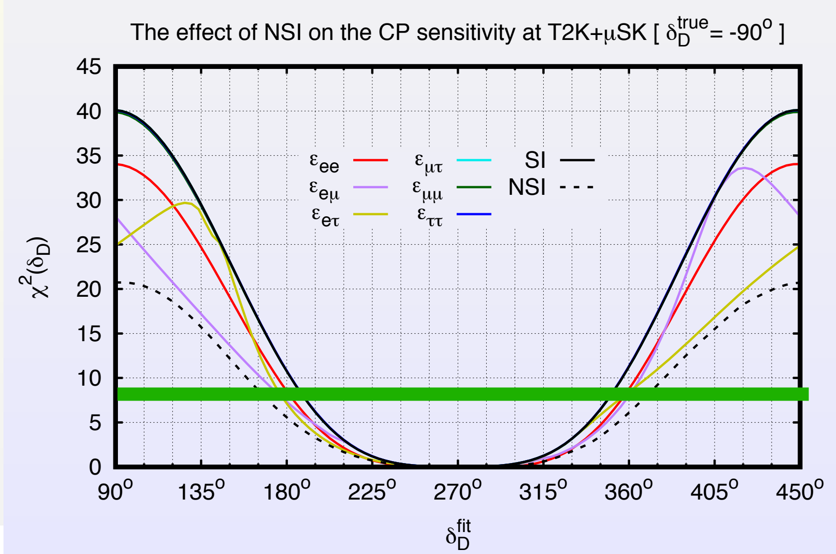
- Full (**100%**) duty factor!
- **Lower** intensity: $\sim$ **9mA** [$\sim$ **4**$\times$ lower than DAEδALUS]
- Not far beyond the current state-of-art technology of cyclotron [**2.2mA** @ Paul Scherrer Institute]
- MUCH **cheaper** & technically **easier**.
  - Only one cyclotron.
  - Lower intensity.

Disadvantage?

- A second detector!
  - **μDAR** with **T**wo **S**cintillators (**μDARTS**) [Ciuffoli, Evslin & Zhang, 1401.3977]
  - **T**okai 'N **T**oyama to(**2**) **K**amioka (**TNT2K**) [Evslin, Ge & Hagiwara, 1506.05023]

- **Better CP measurement than T2K**
  - Much larger event numbers
  - Much better CP sensitivity around maximal CP
  - Solve degeneracy between δ_D & $\pi - \delta_D$
  - Guarantee CP sensitivity against NUM
  - Guarantee CP sensitivity against NSI

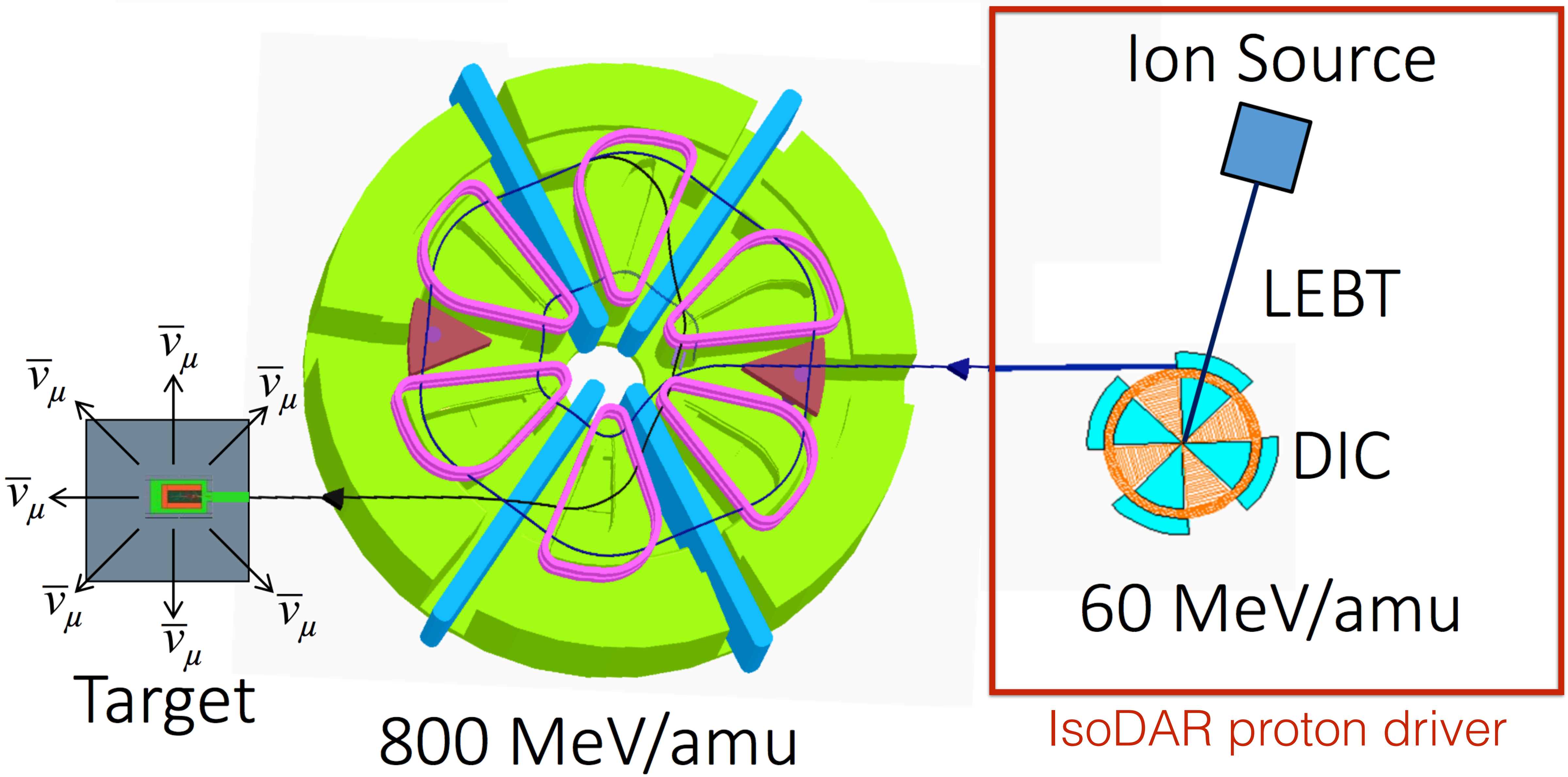




The Daeδalus experiment

Axani

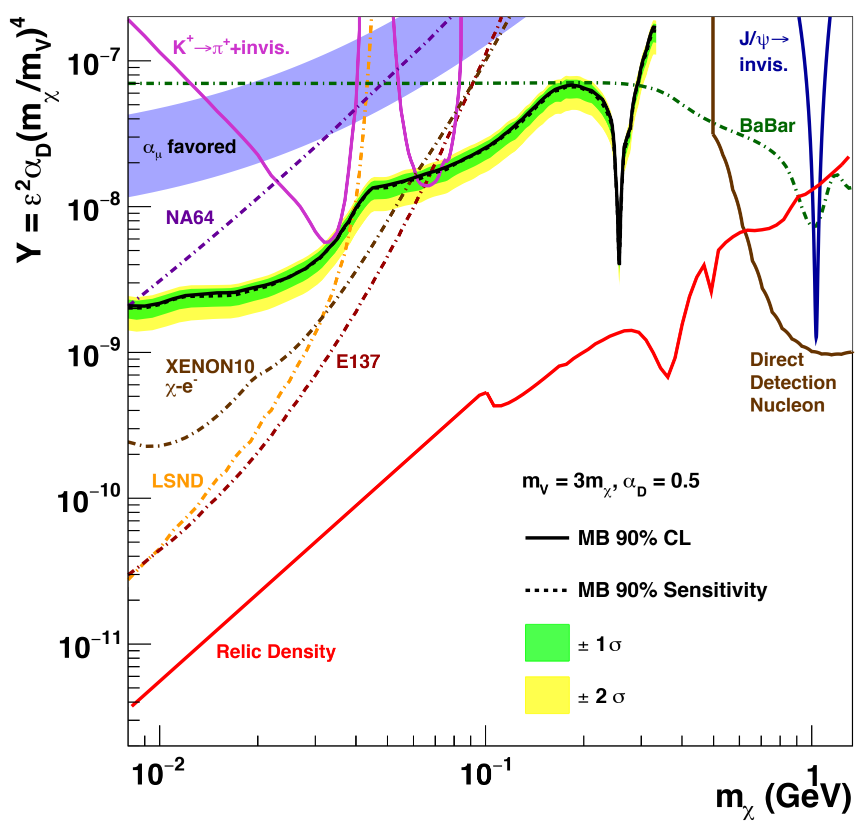
(Decay At rest Experiment for δ_{CP} At Laboratory for Underground Science)



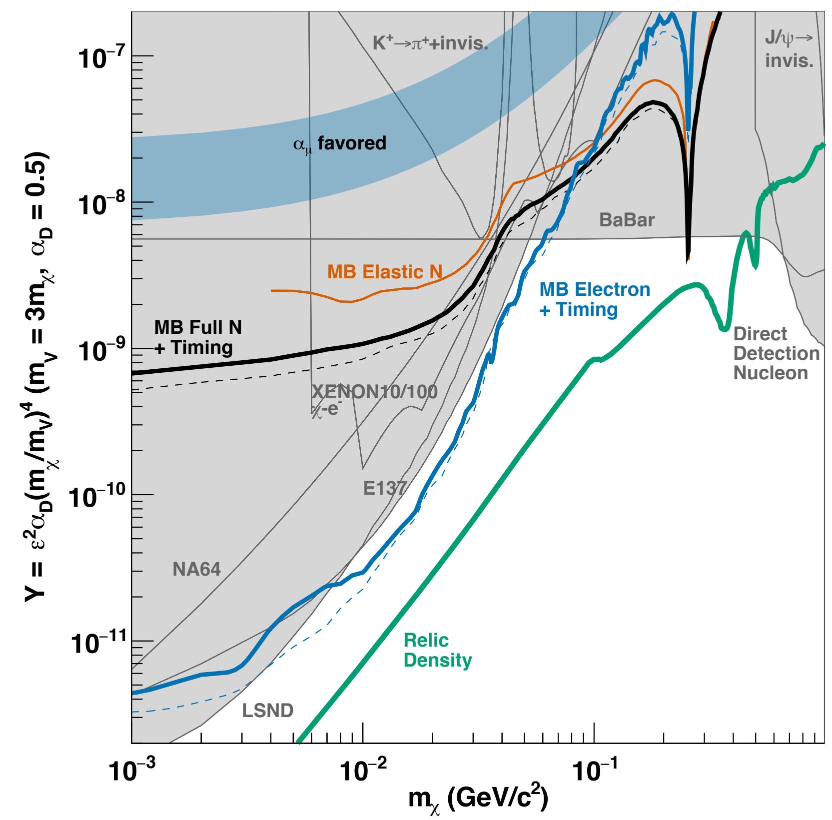
IsoDAR proton driver

Dark matter can show up in neutrino experiments when run in dump mode…

The experimental era has arrived: MiniBooNE-DM



nucleon recoils (PRL 2017)



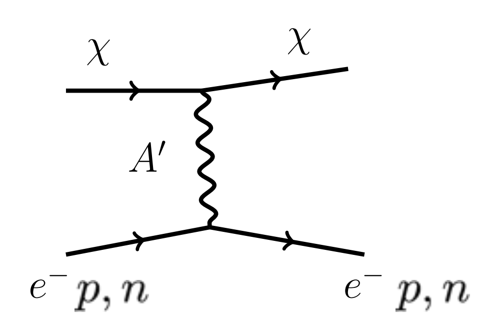
electron recoils (2018)

Krnjaic

First ever dedicated search for light < GeV DM

DM beam from pi0/eta decays

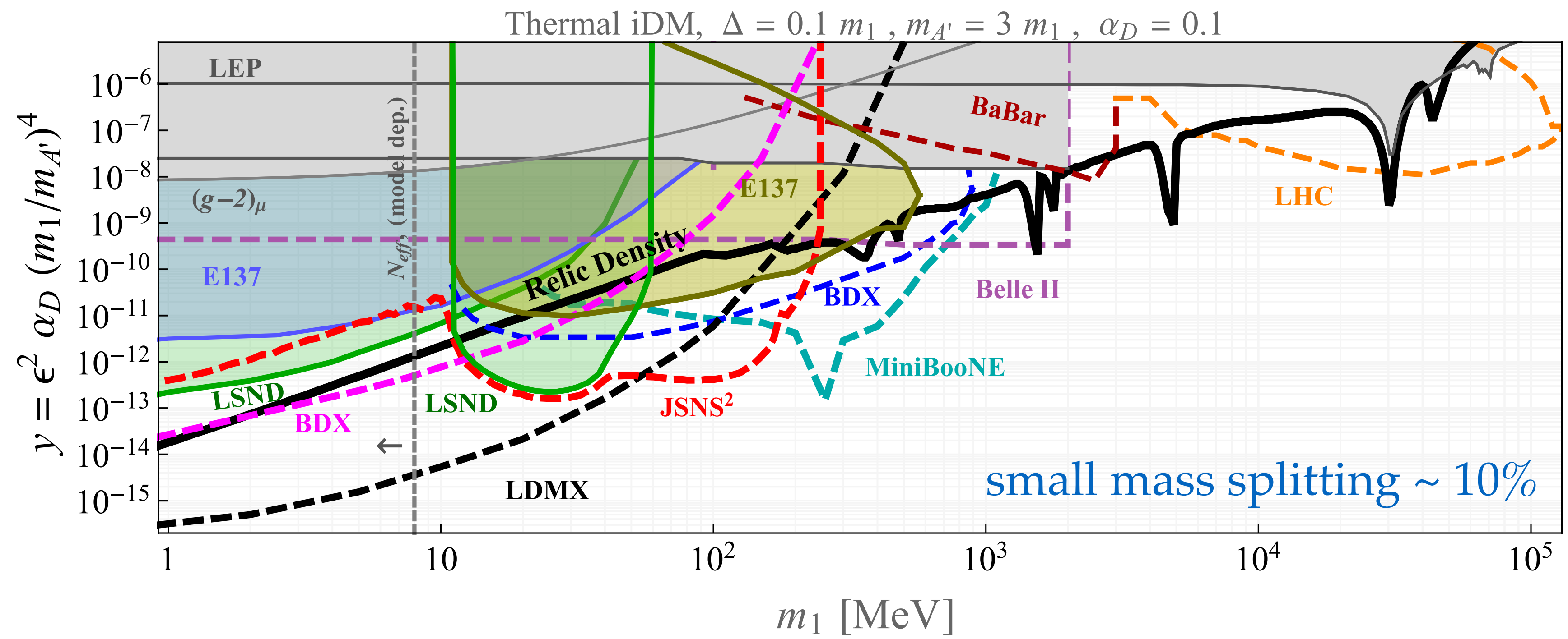
$E_p \sim 8$ GeV , 2×10^{20} POT

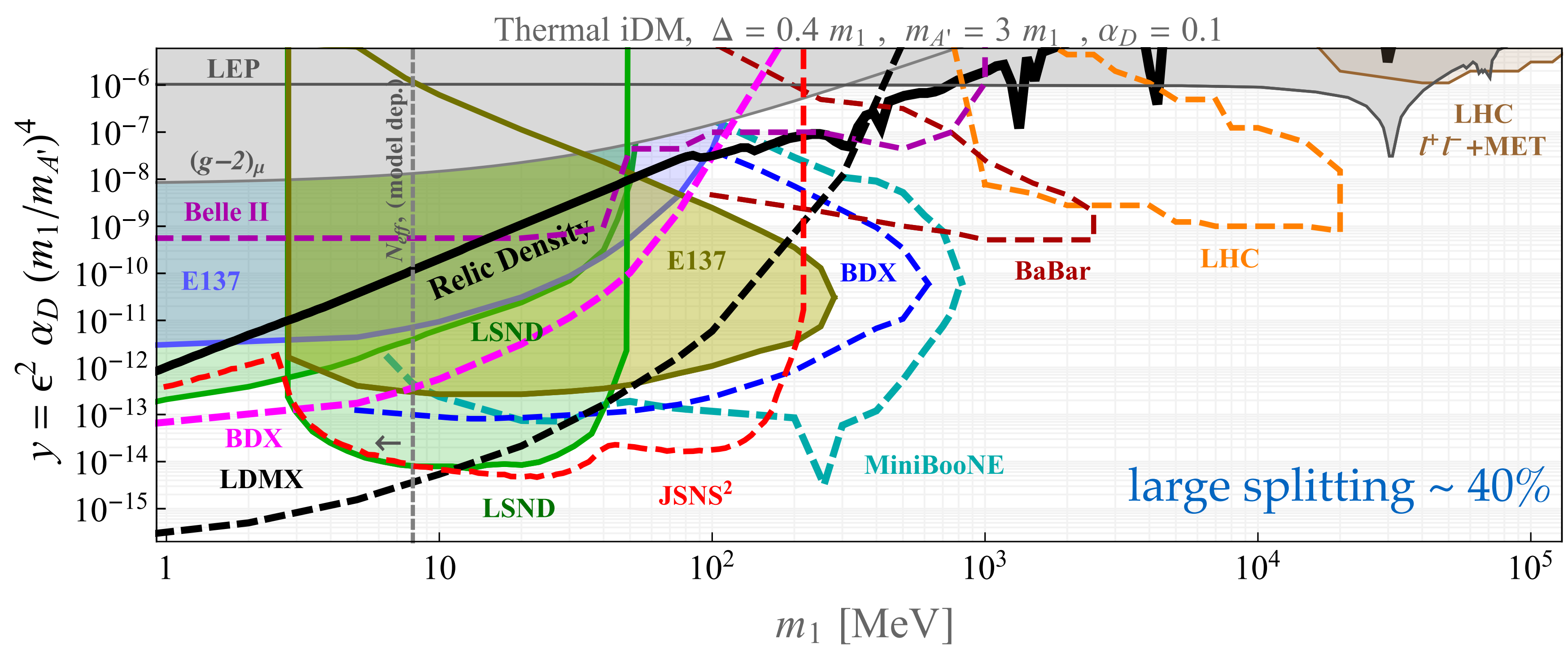


MiniBooNE-DM Collaboration arXiv:1807.06137

MiniBooNE-DM Collaboration Phys. Rev. Lett. 118 (2017)

Neutrino experiments + electron fixed targets + B-factories + LHC



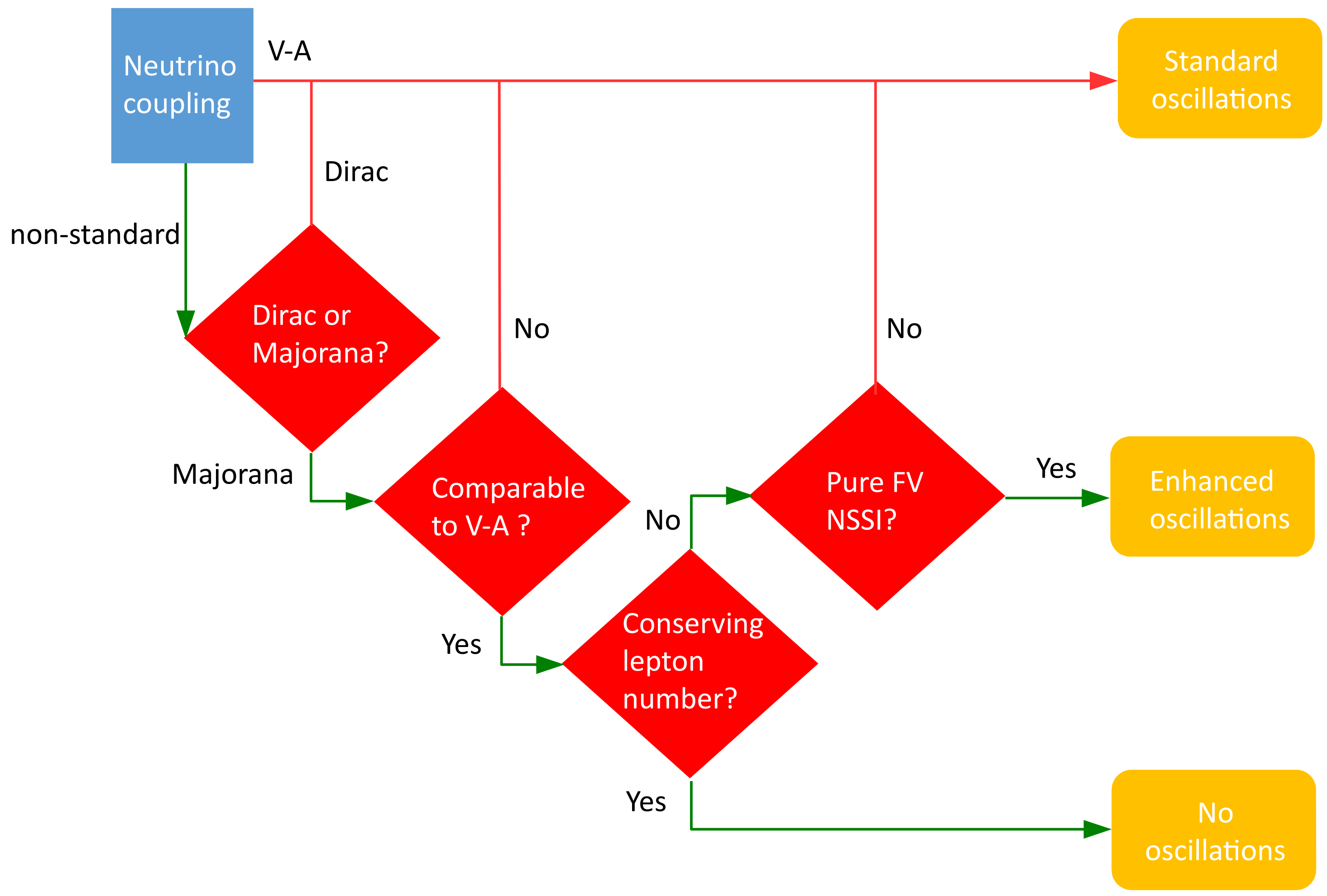


again inelastic DM!

BSM physics with supernova neutrinos

- Over the years many have considered new, Non-Standard Interactions (NSI), of neutrinos with matter in supernovae.

- We can also consider new non-standard interactions of neutrinos with other neutrinos – Non-Standard Self Interactions (NSSI).



Kneller

- Future work:
  - the signatures of NSSI in detectors need to be computed.
  - we need an understanding of why NSSI has the effects it does.

Cosmic eV-scale sterile neutrino background and supernova neutrinos

Diffuse SN background

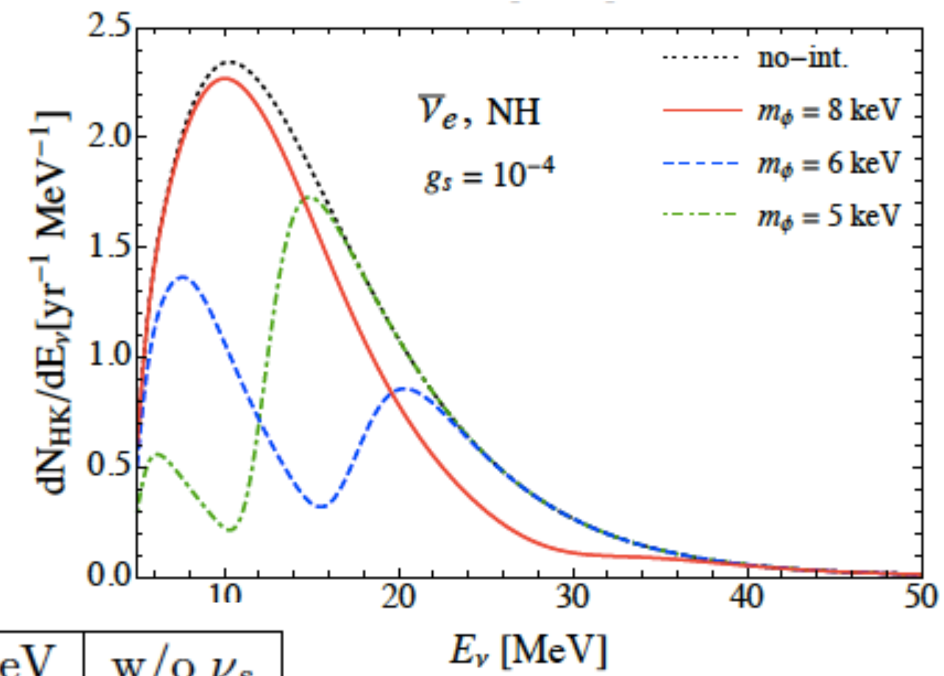
supernova neutrinos →

sterile neutrino background →

$$s = 2E_{\nu_s} m_s = m_\phi^2$$

$$E_{\nu_s} = 10 \text{ MeV}, \; m_s = 1 \text{ eV} \implies m_\phi \simeq 5 \text{ keV}$$

It is possible to probe keV-scale gauge boson mediators with supernova neutrinos, through absorption dips.



DUNE (ν_e)	w/o interaction	$M_\phi = 5$ keV	$M_\phi = 6$ keV	$M_\phi = 8$ keV	w/o ν_s
NH	32	29	21	17	32
IH	23	21	15	12	27

HK ($\bar{\nu}_e$)	w/o interaction	$M_\phi = 5$ keV	$M_\phi = 6$ keV	$M_\phi = 8$ keV	w/o ν_s
NH	337	252	164	273	528
IH	209	170	111	133	642

Reno

solar neutrinos an issue at lower energies

4 flavors, φ not in interesting range for absorption dips

$$10 \text{ MeV} \leq E_\nu \leq 30 \text{ MeV}$$
$$g_s = 10^{-4}$$

3 flavors

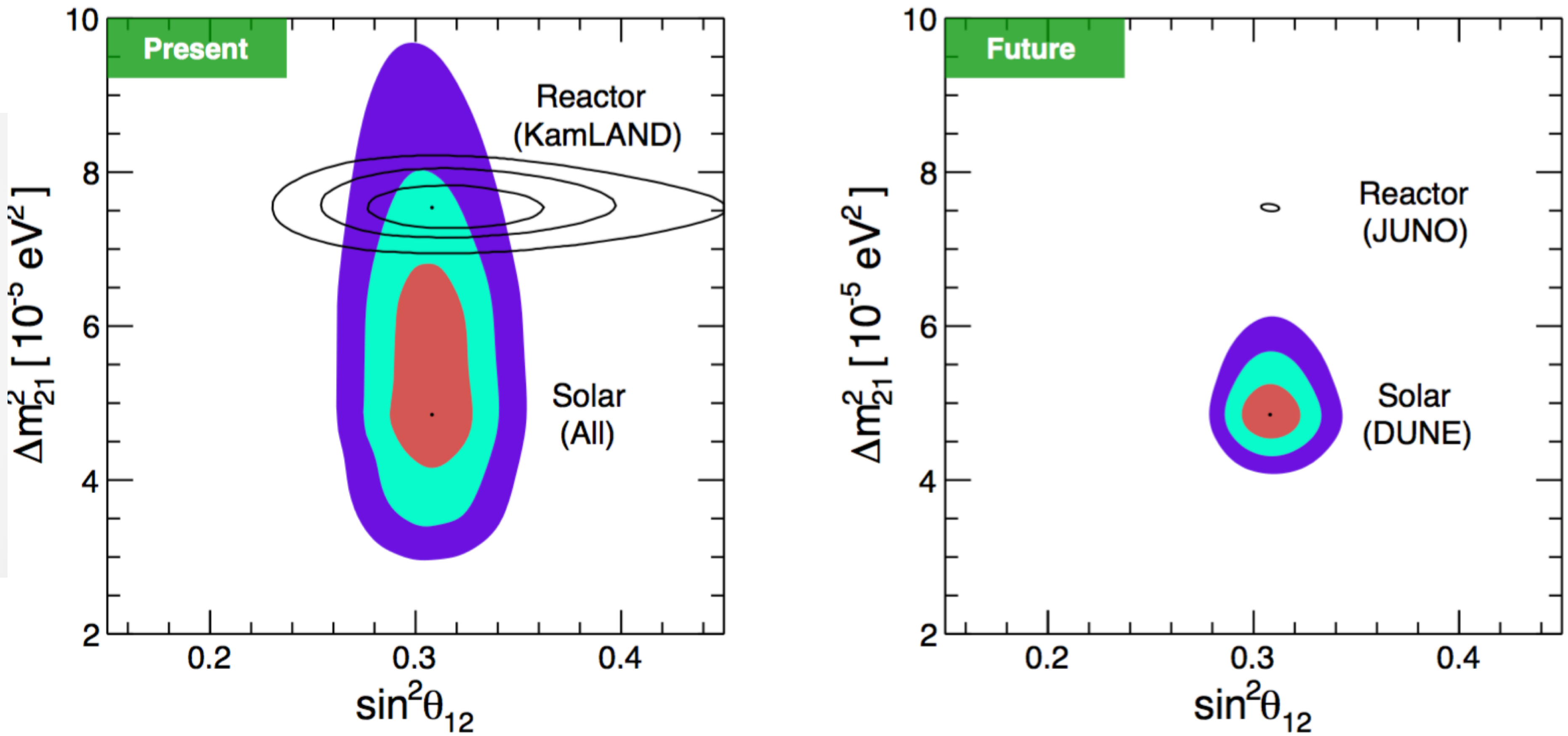
Solar neutrinos to probe a tension that could be related to BSM…

Li

CC channel: $\nu_e + \text{Ar} \rightarrow e + \text{K}^*$

Reactor: vacuum oscillation

Solar: matter effect



proposal to reduce the threshold from 10MeV to 5MeV in DUNE
AND
add neutron shielding all around

and dedicated searches for light steriles…

Finished phase I | Taking data | Planned

Apologize if I missed any

Experiment	Reactor	Baseline (m)	Overburden (m.w.e)	Mass (ton)	Segmentation	Energy res. (@ 1 MeV)
NEOS (South Korea)	LEU 2.8 GW	23.7	~20	1.0	none	5%
Nucifer (France)	HEU 70 MW	7.2	~12	0.6	none	10%
NEUTRINO4 (Russia)	HEU 100 MW	6 - 12	~10	0.3	2D	
DANSS (Russia)	LEU 3.1 GW	10.7 - 12.7	~50	1.1	2D	17%
STEREO (France)	HEU 58 MW	9 – 11	~15	1.6	1D 25 cm	8%
PROSPECT (USA)	HEU 85 MW	7 - 12	< 1	1.5	2D 15cm	4.5%
SoLid (UK Fr Bel US)	HEU 70 MW	6 - 9	~10	1.6	3D 5cm	14%
CHANDLER (USA)	HEU 75 MW	5.5 - 10	~10	1.0	3D 5cm	6%
NuLAT (USA)	HEU 20 MW	4	few	1	3D 5cm	4%

Zhang-Plenary

First Results from the PROSPECT Short Baseline Reactor Experiment

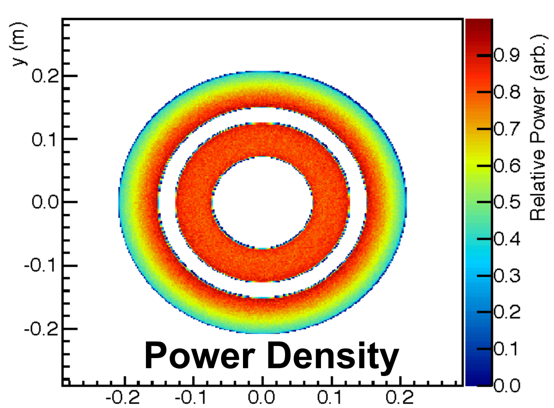
Experimental site: High Flux Isotope Reactor @ORNL

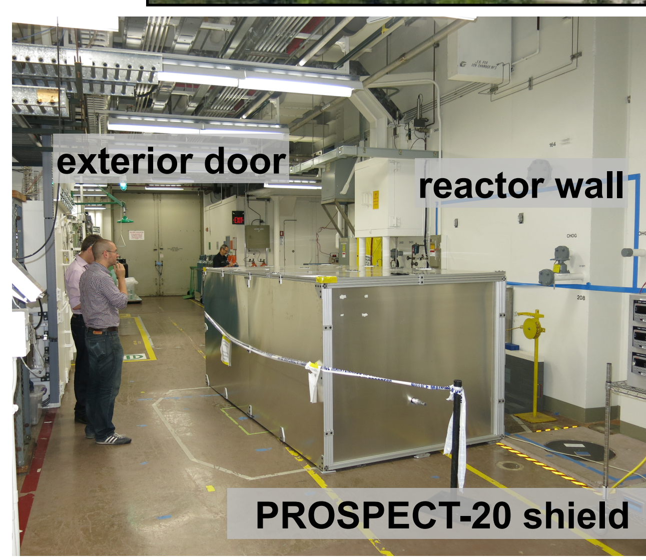
Compact Reactor Core

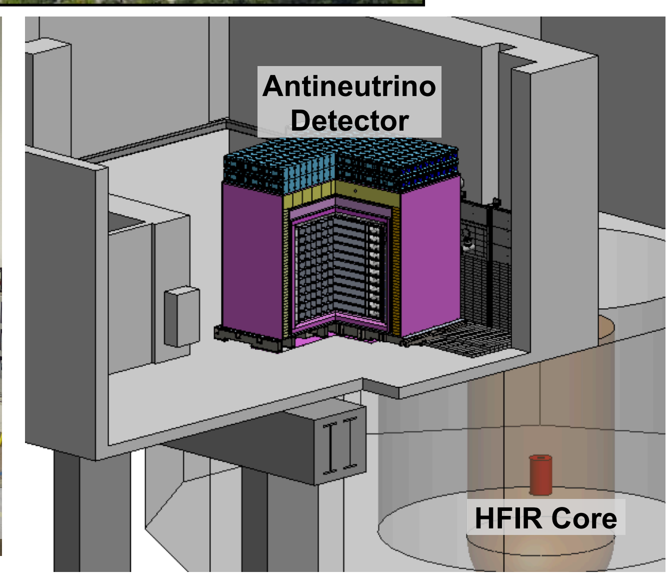
44cm

Bowden

Power: 85 MW
^{235}U Fission Frac.: >99%
Size: h=51cm d=44cm
Duty-cycle: 46%

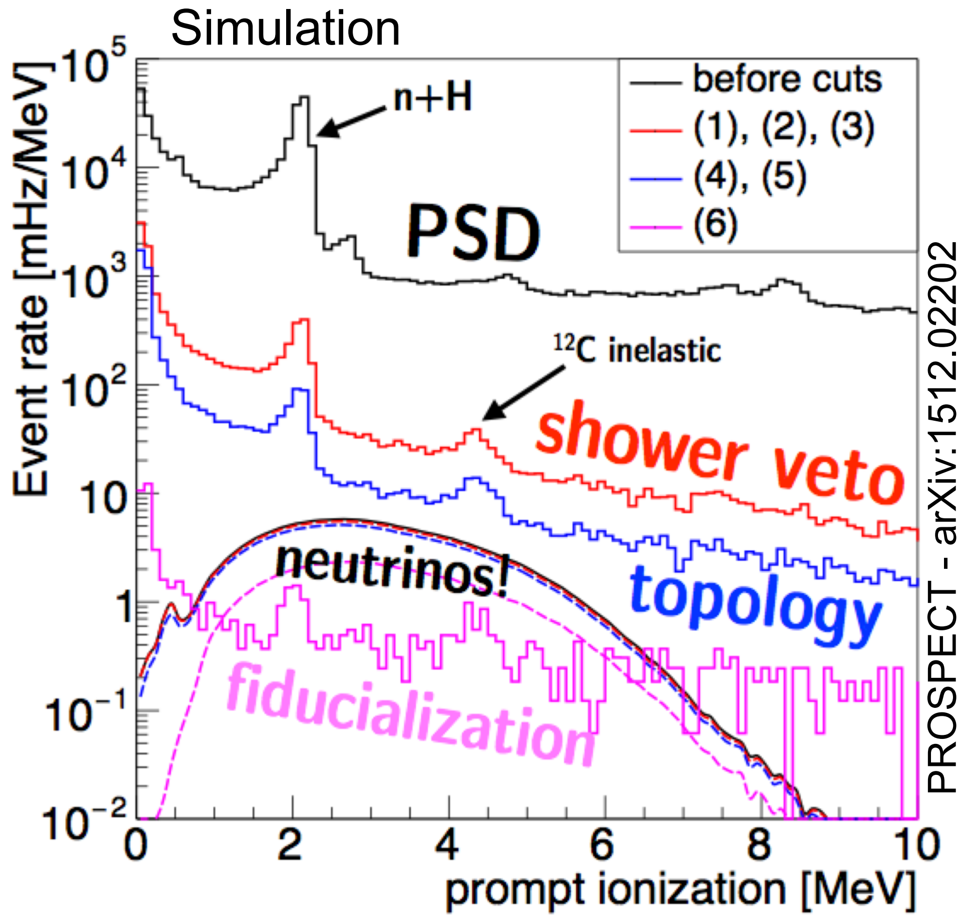




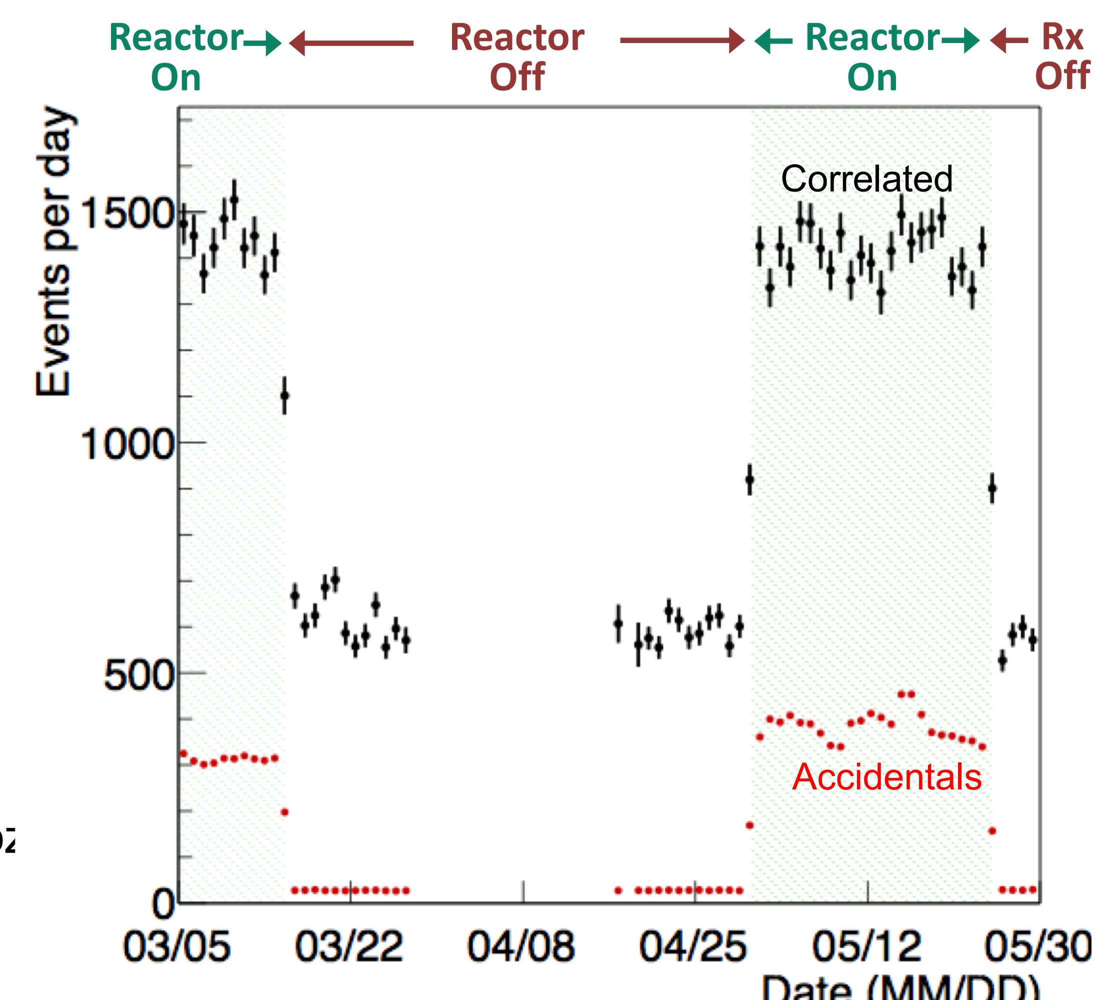


User facility with 24/7 access; Exterior access at grade

^{6}Li-doped liquid scintillator (LiLS)

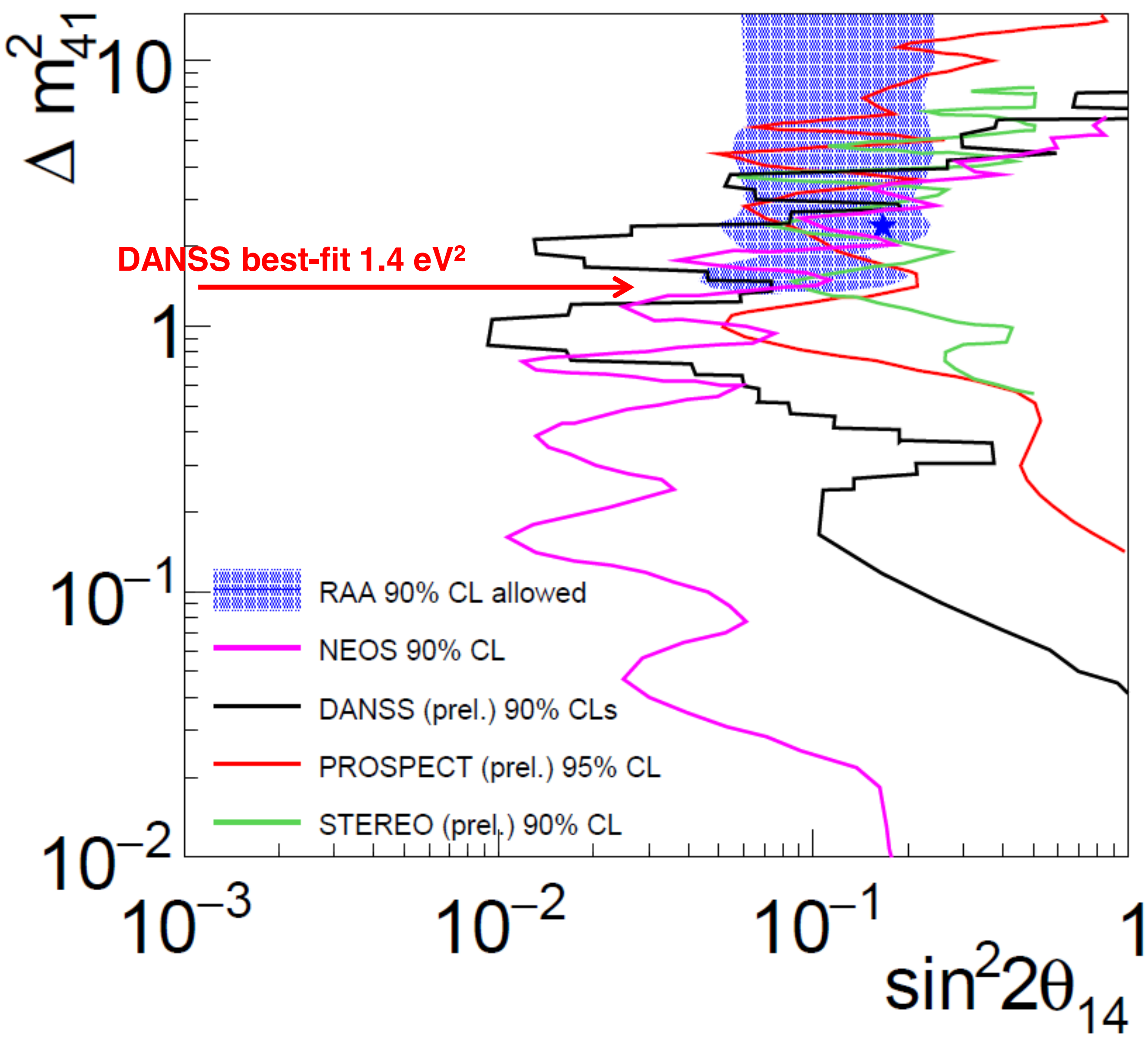


rejection of neutron background not underground!



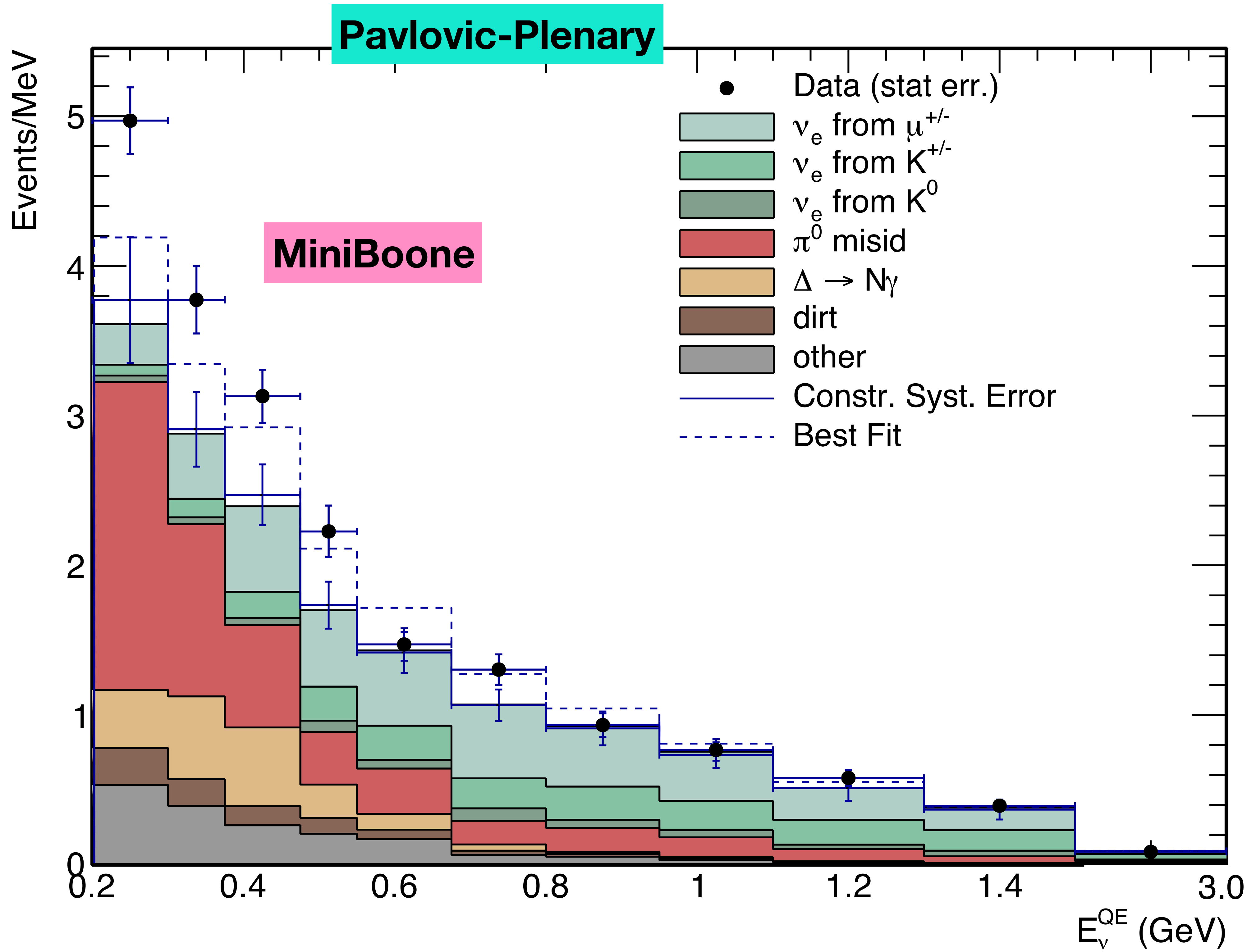
PROSPECT - arXiv:1806.02784

X. Qian and J-C Peng, arXiv:1801.05386

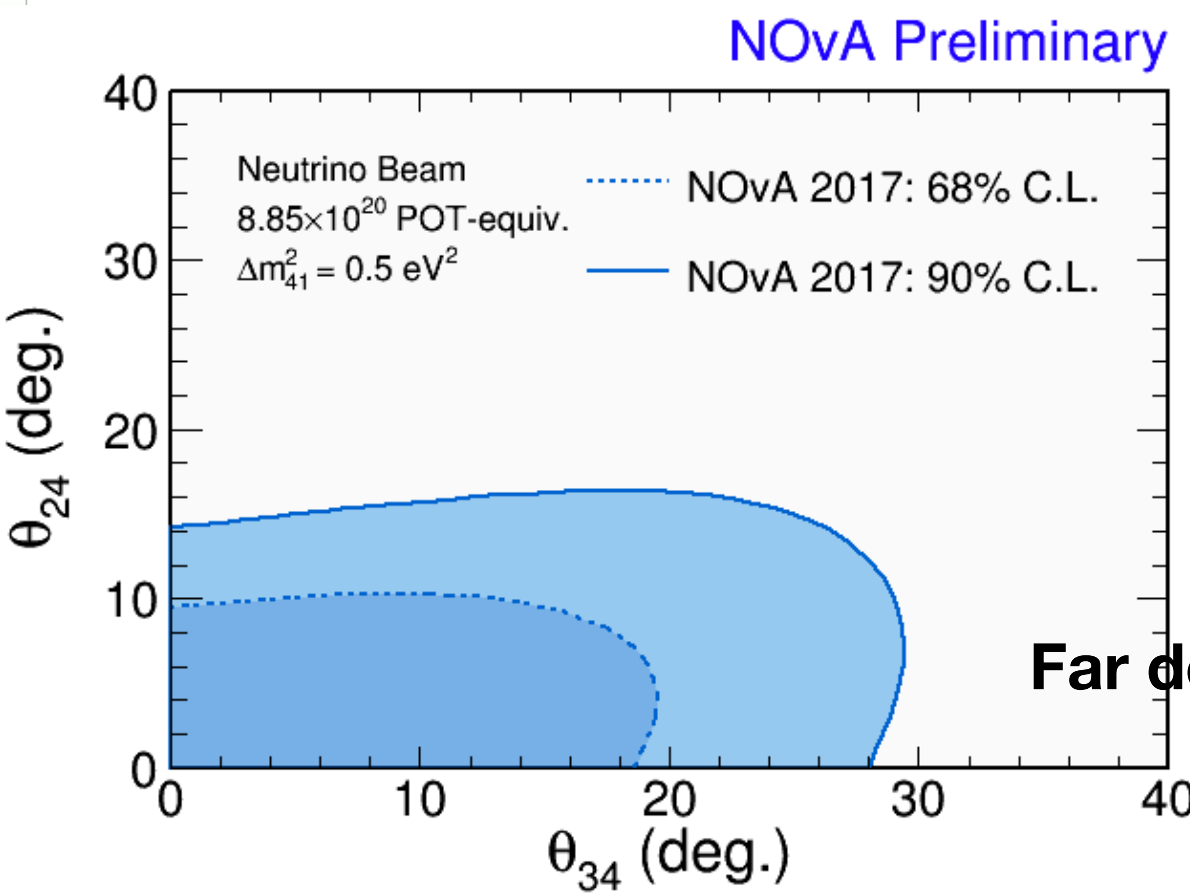


ν_e disappearance

and of course the great star of the week…

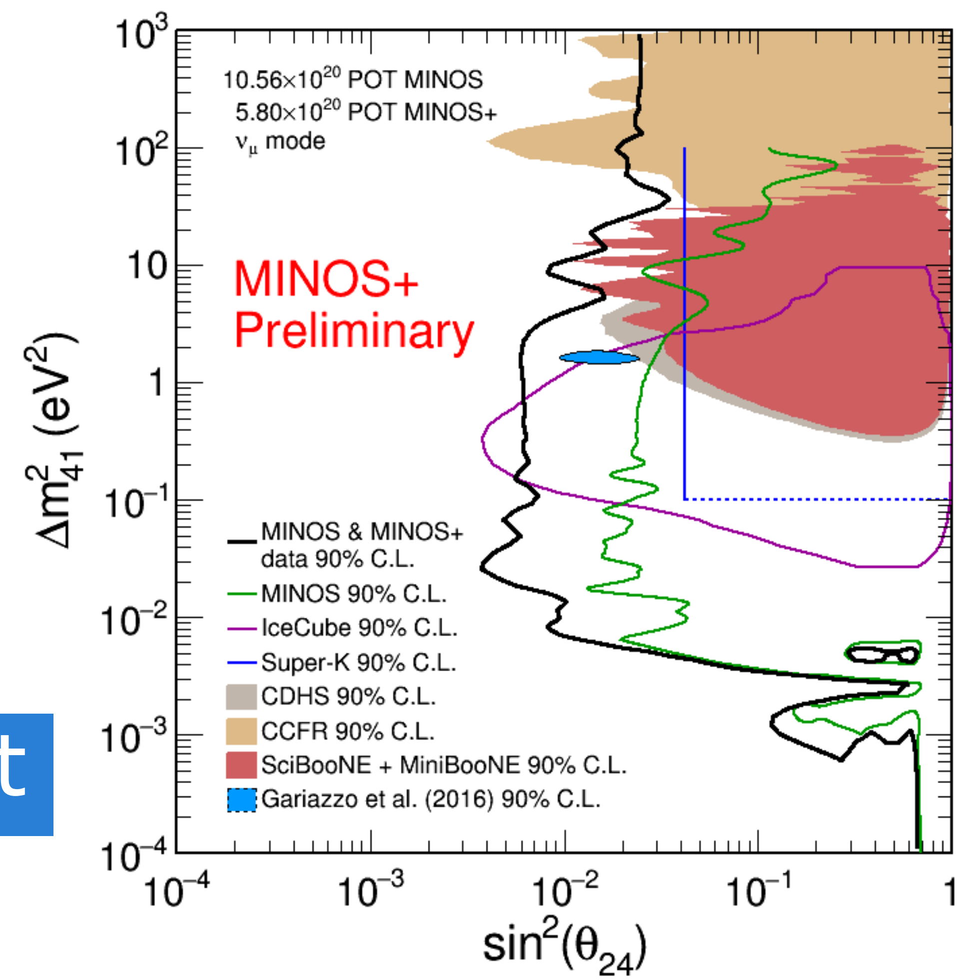

Pavlovic-Plenary
MiniBoone
Events/MeV
Data (stat err.)
ν_e from $\mu^{+/-}$
ν_e from $K^{+/-}$
ν_e from K^0
π^0 misid
$\Delta \rightarrow N\gamma$
dirt
other
Constr. Syst. Error
Best Fit
0
1
2
3
4
5
0.2
0.4
0.6
0.8
1
1.2
1.4
3.0
E_ν^{QE} (GeV)

Neutral-Current Disappearance with NOvA



Wallbank

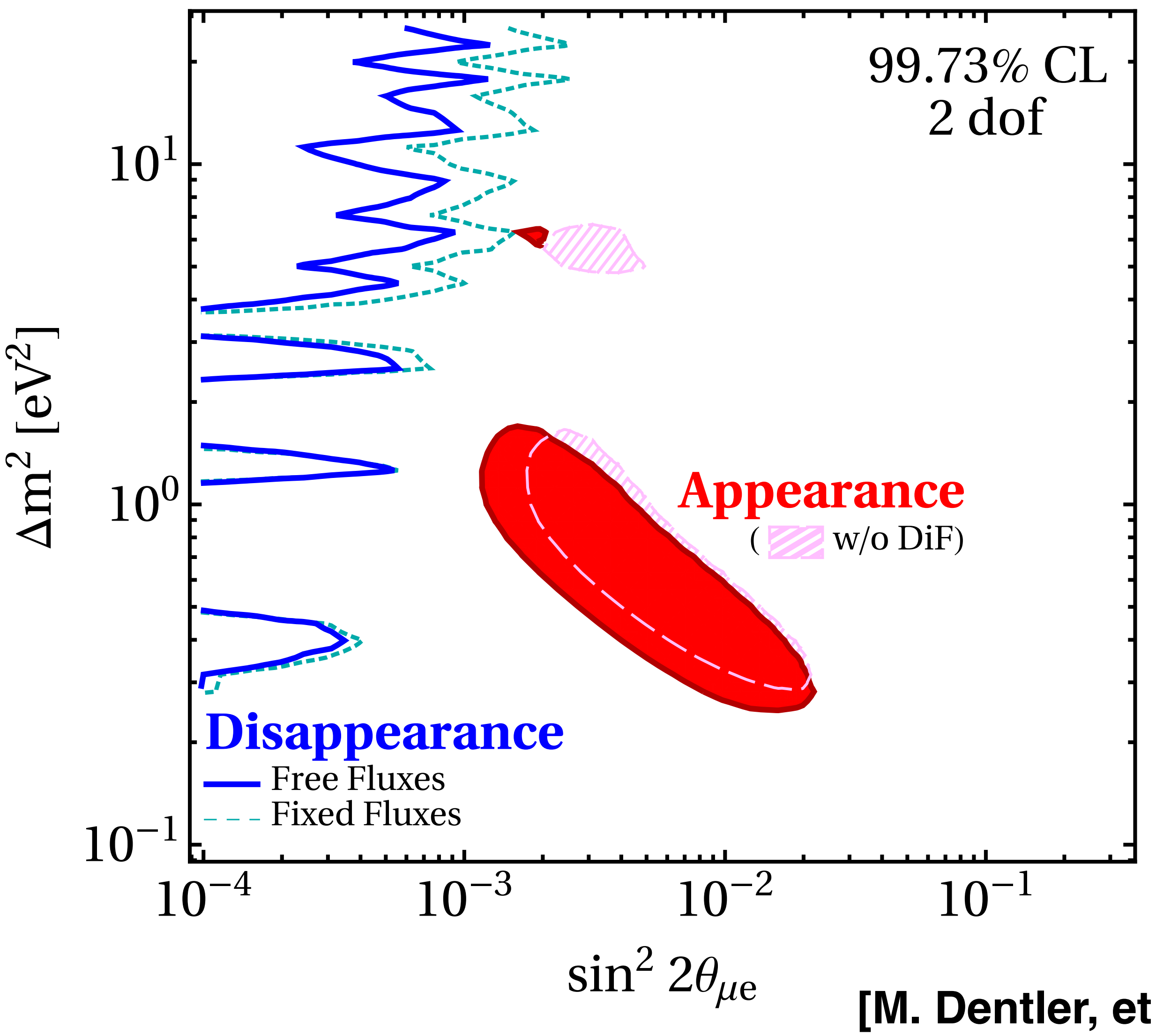
Far detector only



Todd

Simultaneous Two-Detector Fit

…therefore, also with ν_μ…



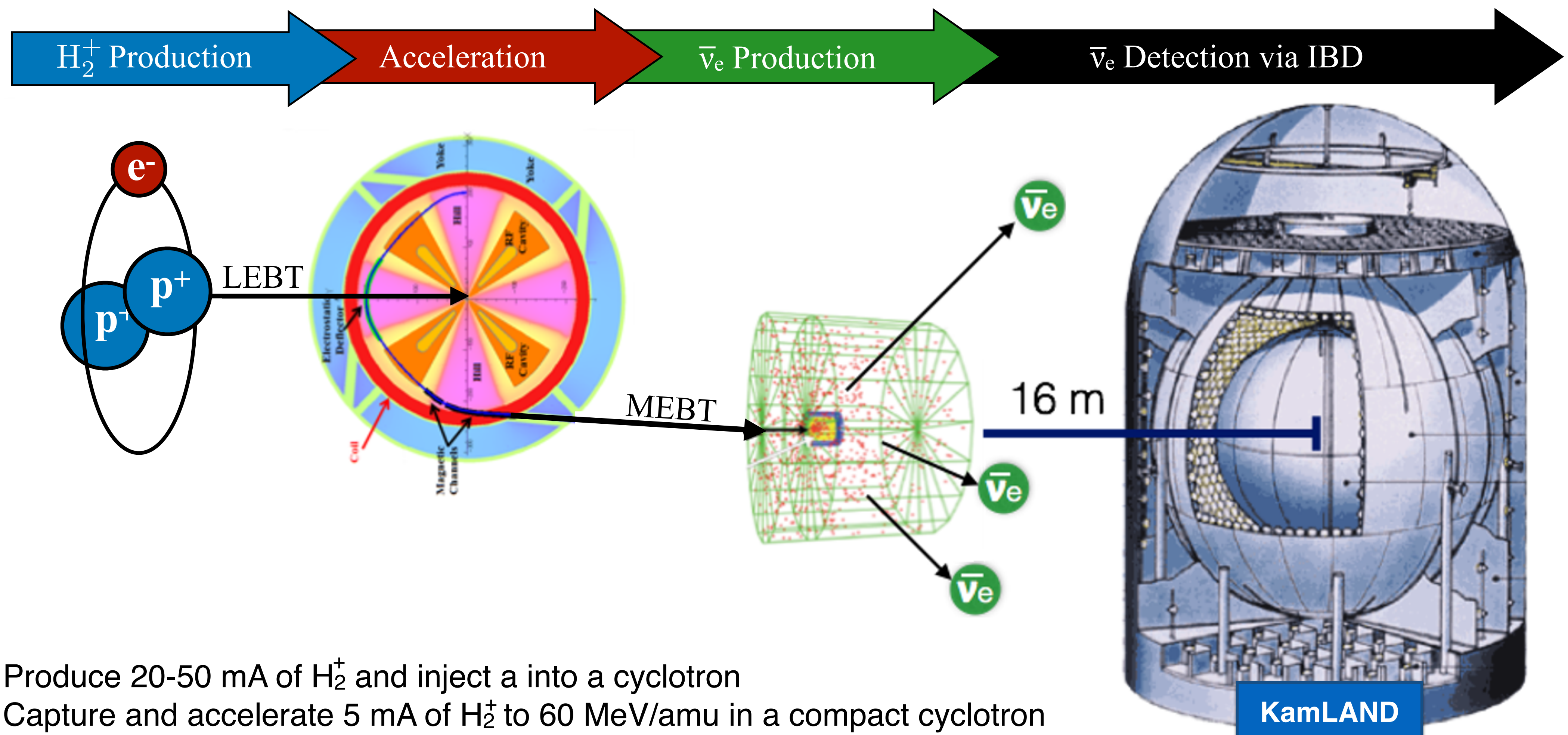
[M. Dentler, et al., JHEP 1808 (2018) 010]

Therefore, an explanation of the LSND anomaly in terms of sterile neutrino oscillations in the $3+1$ scenario is excluded at the 4.7σ level. This result is robust with

new experiments with great sensitivity on the way…

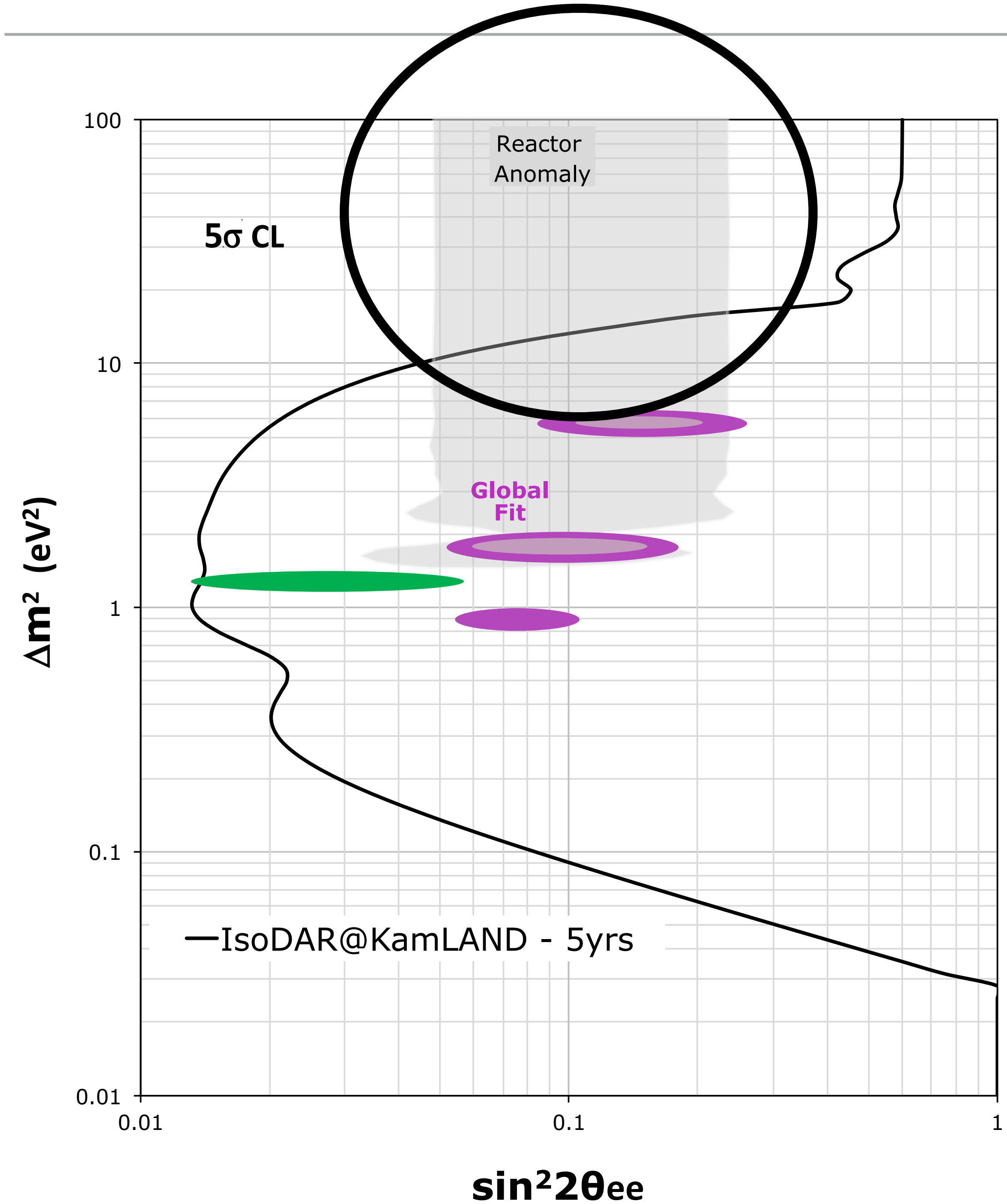
IsoDAR overview

Axani



1. Produce 20-50 mA of H_2^+ and inject a into a cyclotron
2. Capture and accelerate 5 mA of H_2^+ to 60 MeV/amu in a compact cyclotron
3. Impinge on a ^{9}Be target to induce a beta-decay. $^7\text{Li}+n \longrightarrow {}^8\text{Li} \longrightarrow {}^8\text{Be} + e^- + \bar{\nu}_e$
4. Map out oscillation in anti-electron neutrino disappearance within a kiloton scale detector like KamLAND

3+1 sterile neutrinos sensitivity



Anomalous oscillation measurements drive the global allowed regions.

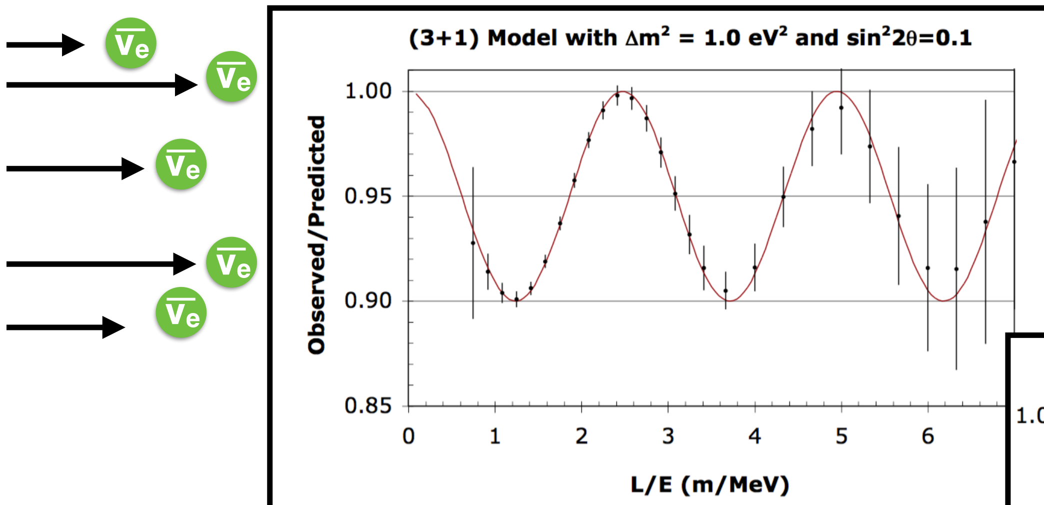
- LSND
- MiniBooNE
- Global reactor deficit
- GALLEX/SAGE anomaly

Including NEOS and DANSS, an updated global allowed favors $\Delta m^2 \sim 1.3 eV^2$

IsoDAR@KamLAND, will be able to make a definitive statement about the existence of light sterile neutrinos.

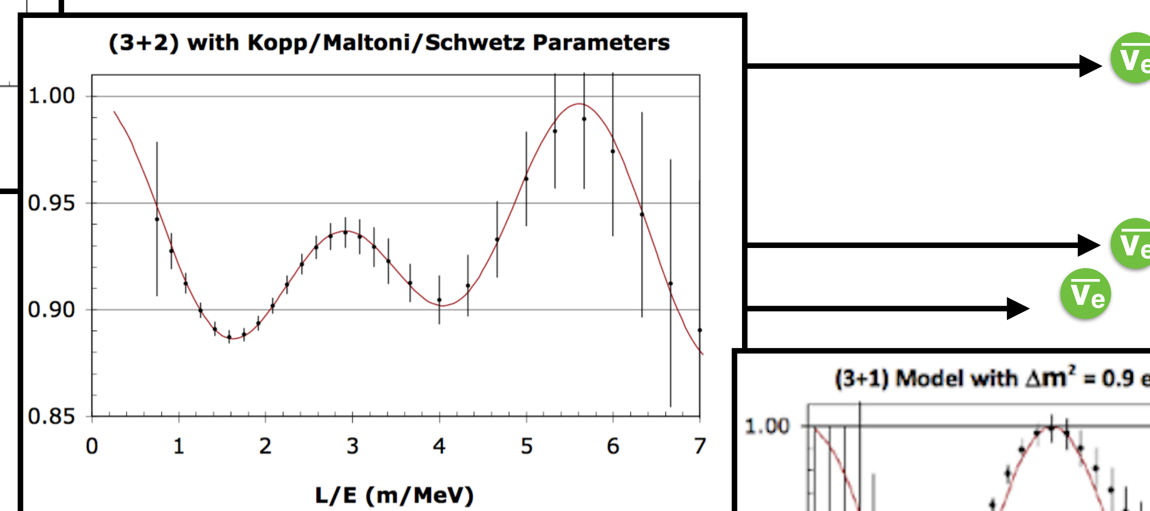
- Rule out 3+1 global fit region:
  - 20σ in 5 years
  - 5σ in 4 months

Sterile neutrino search (IBD sample)

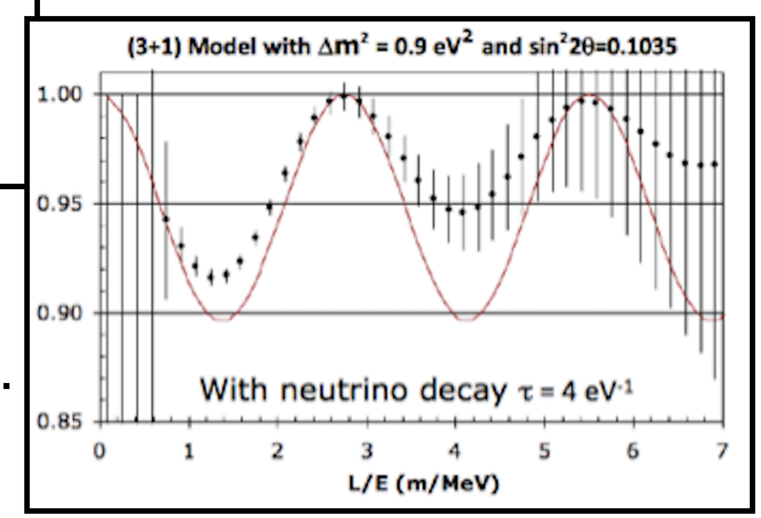


By accurately mapping out the short baseline oscillations through a single detector, over an L/E of 0.6 to 7.0 m/MeV, IsoDAR can test 3+1 sterile model.

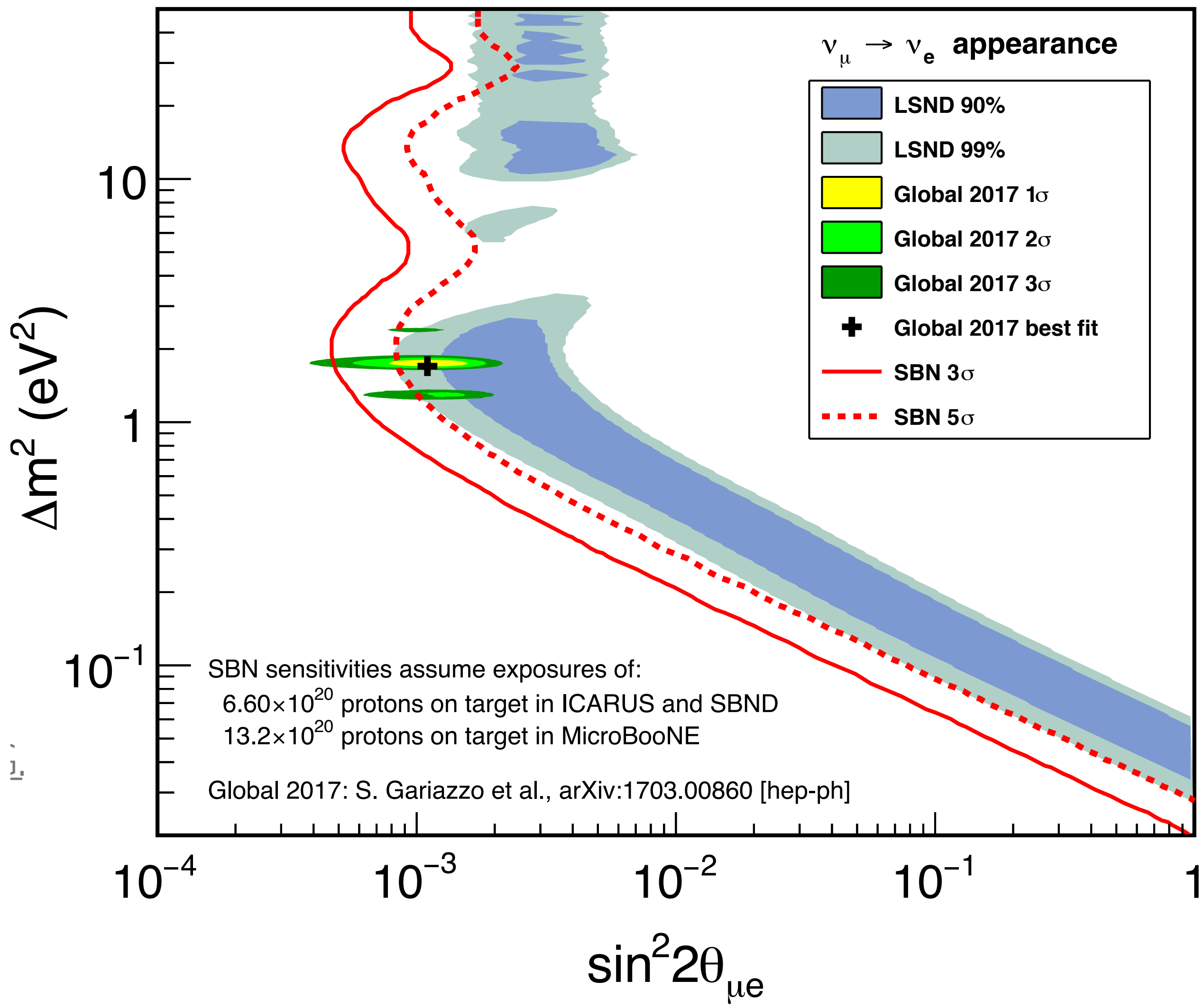
...or 3+N sterile models.



...or sterile decay models.

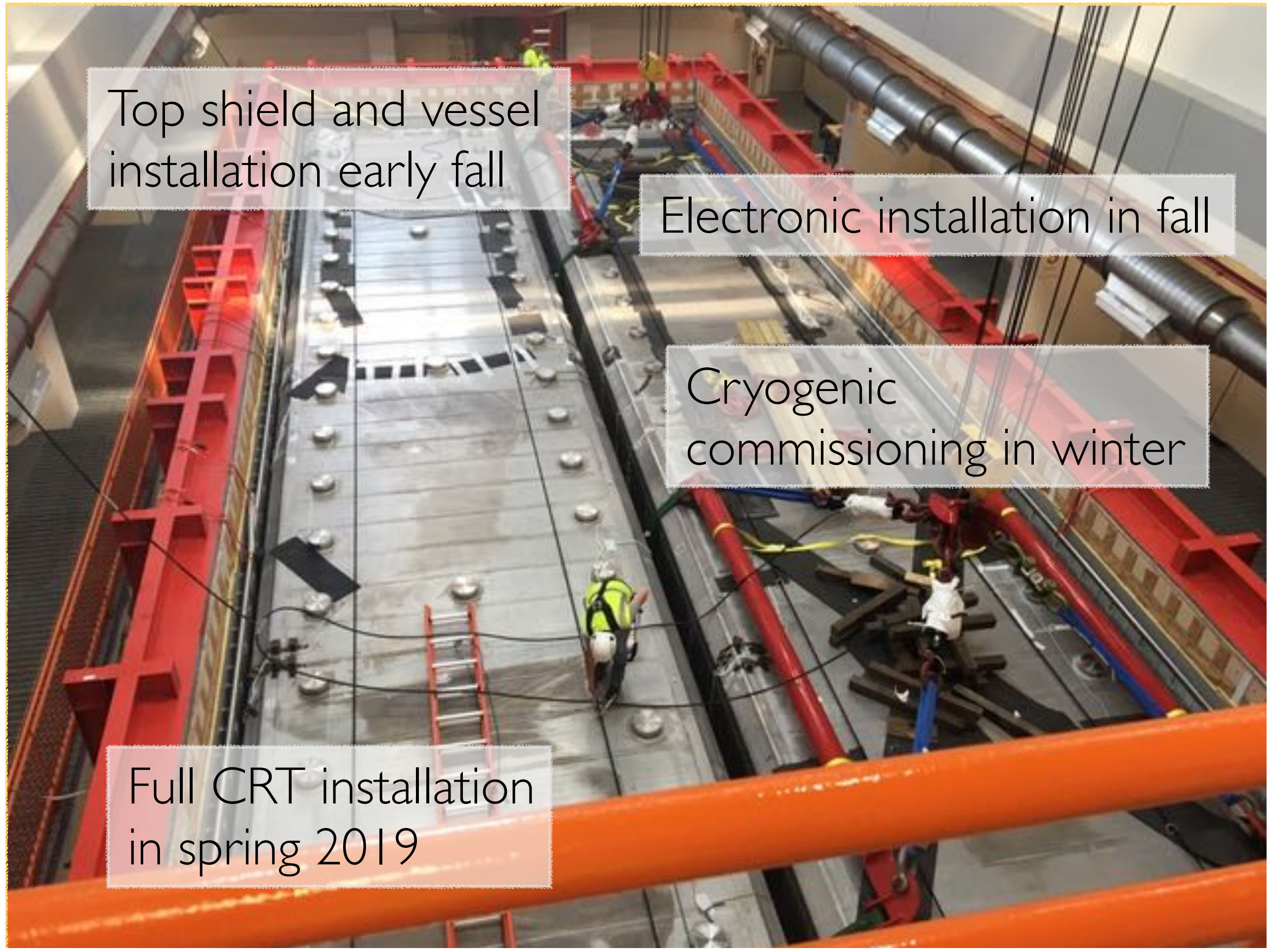


SBN Sensitivity



Tsai

ICARUS



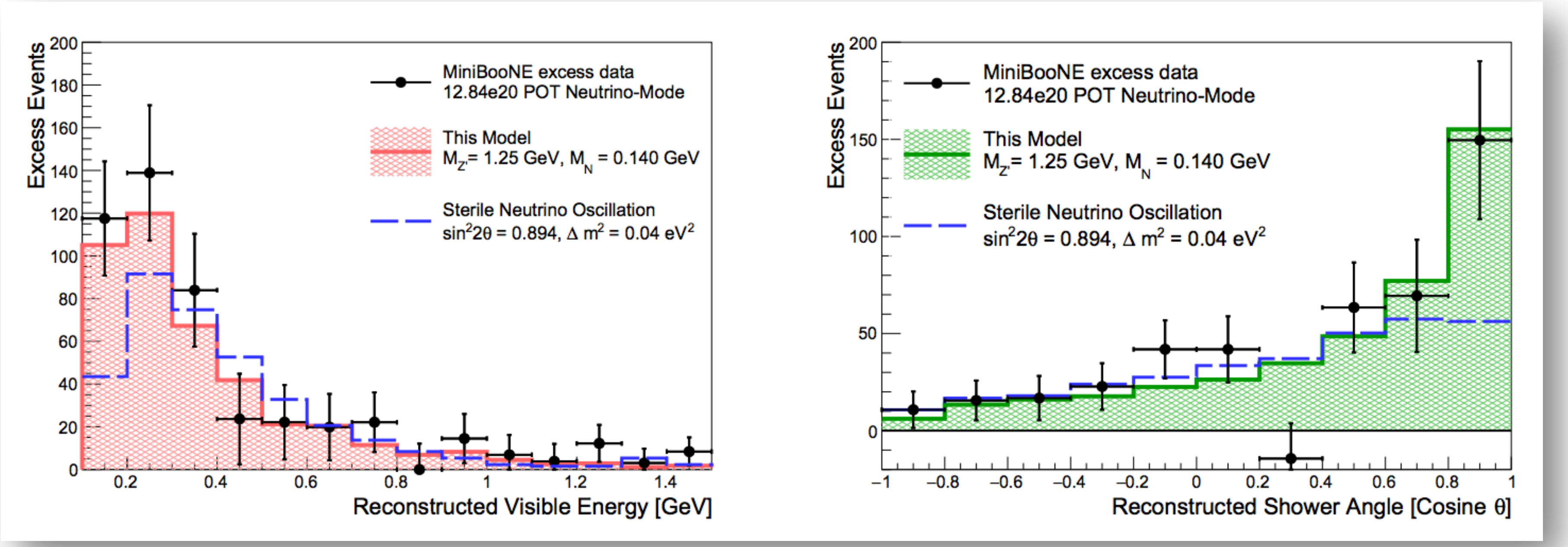
and, if the anomalous pattern will hold, please theorists squeeze your mind…

A shift in focus?

The inability of 3+N global fits to provide a satisfactory, coherent explanation to all SBL anomalies has prompted the **exploration of new (physics) ideas**:

2. **Sterile neutrino + decay through Z'** [P. Ballet, et al., arXiv:1808.02915]

$$\nu_\mu + \mathcal{N} \to \nu_4 + \mathcal{N} \qquad \nu_4 \to \nu_\alpha \, e^+ \, e^-$$



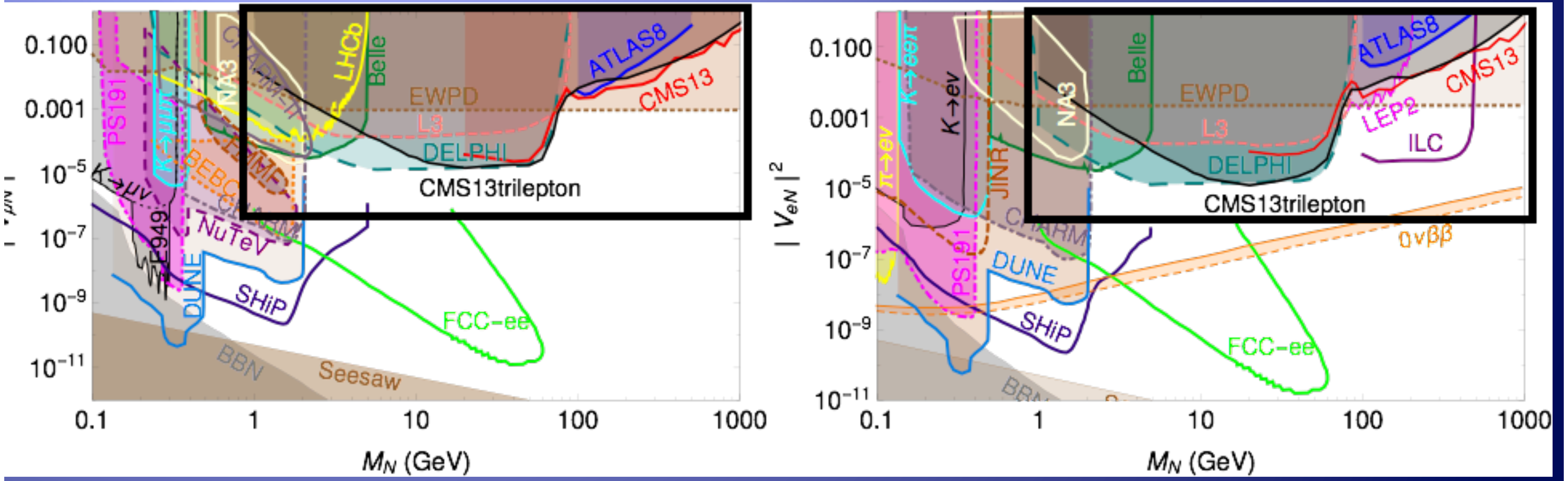
Best fit: m_4 = 0.14 GeV, $|U_{\mu 4}|$ = 1.5E-6, $m_{Z'}$ = 1.25 GeV, $|U_{\tau 4}|$ = 7.8E-4, χ^2 = 5E-6

Karagiorgi - Plenary

Also dedicated searches for heavy steriles were discussed… (they have also cosmological interest)

Summary on the type I

- LHC experiments probed heavy N in mass range: 1~1.6TeV with $10^{-5} < |V_{lN}|^2 < 1$



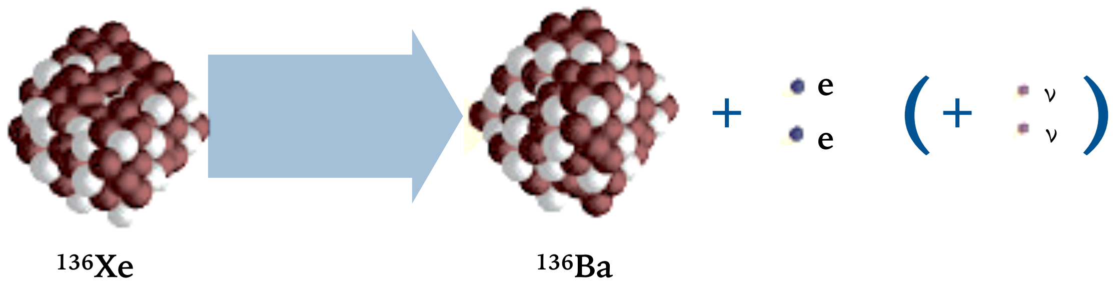
Yang - Plenary

Watch out - 2019 ESPP!

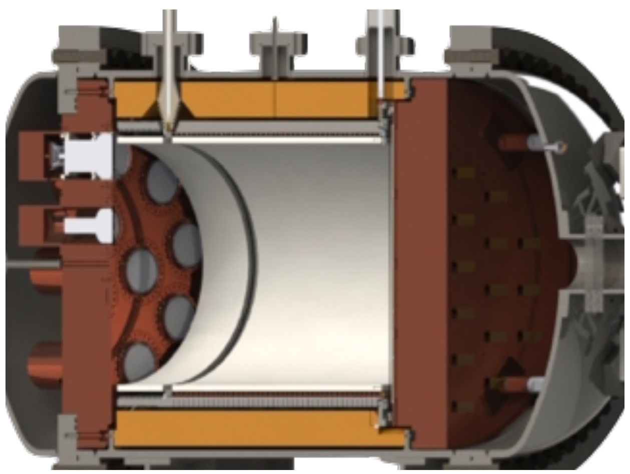
…and a new idea for the search for $0\nu2\beta$…

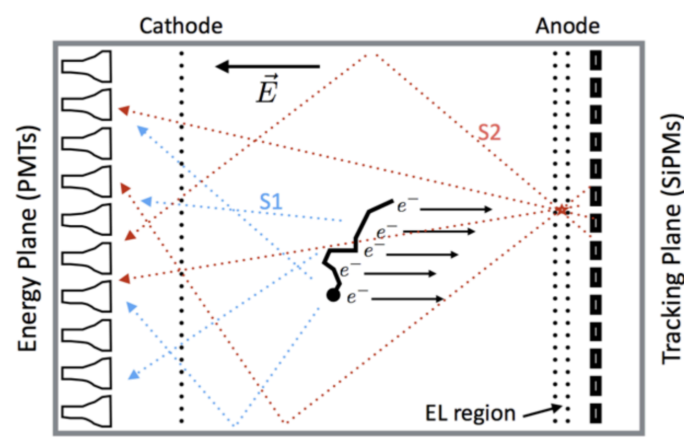
Single Ion Ba^{++} Tagging for $0\nu\beta\beta$

NEXT program - Searching for $0\nu\beta\beta$



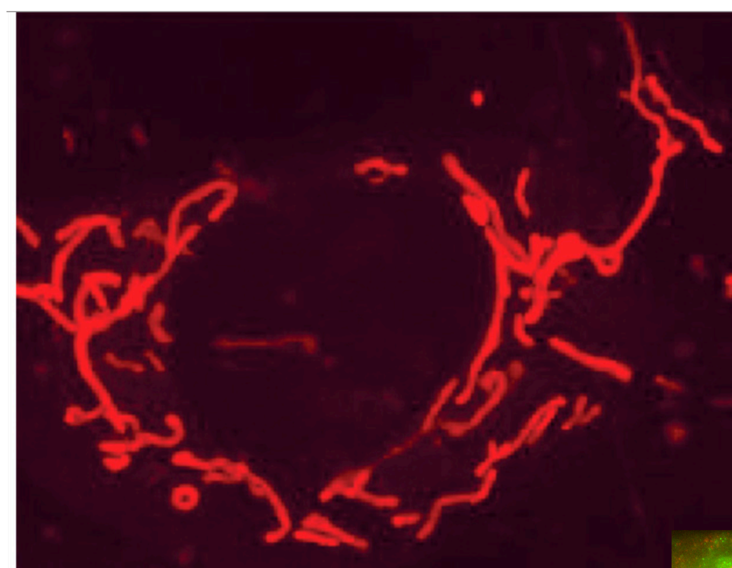
Psihas



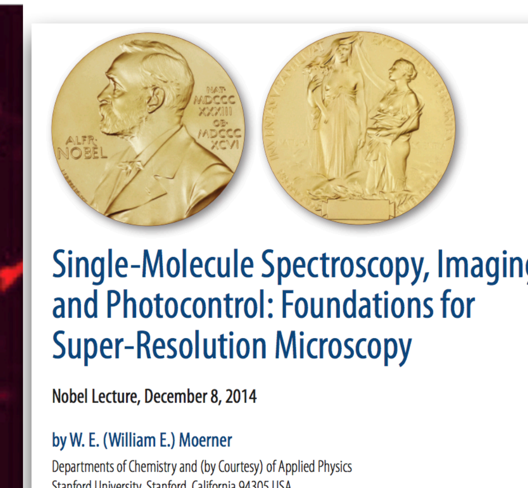


High pressure ^{136}Xe gas Electro-luminescence TPC

Single Molecule Fluorescence Imaging



J Cell Biol 145, 795 (1999).



Single-Molecule Spectroscopy, Imaging, and Photocontrol: Foundations for Super-Resolution Microscopy

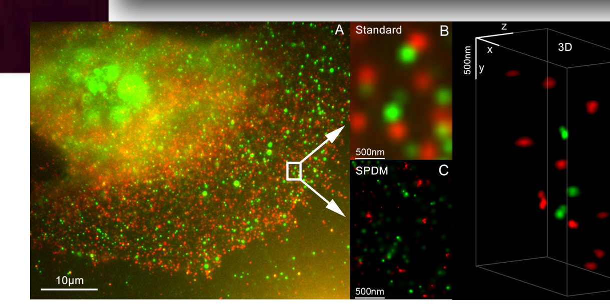
Nobel Lecture, December 8, 2014

by W. E. (William E.) Moerner

Departments of Chemistry and (by Courtesy) of Applied Physics
Stanford University, Stanford, California 94305 USA.

Calcium production tracked in rat cells.

Single molecule tracking using SMFI is the basis of super-resolution microscopy



J Microsc. 2011 Apr;242(1):46-54

Scientific summary

A very exciting field with many open questions and ongoing projects!
Thanks a lot to all the speakers and session conveners!

Personal conclusion

this has been my 3rd year serving as WG convener and I have to say I had a great time with this conference!