Poster Prize Competition: Wednesday Finals

2’40” each

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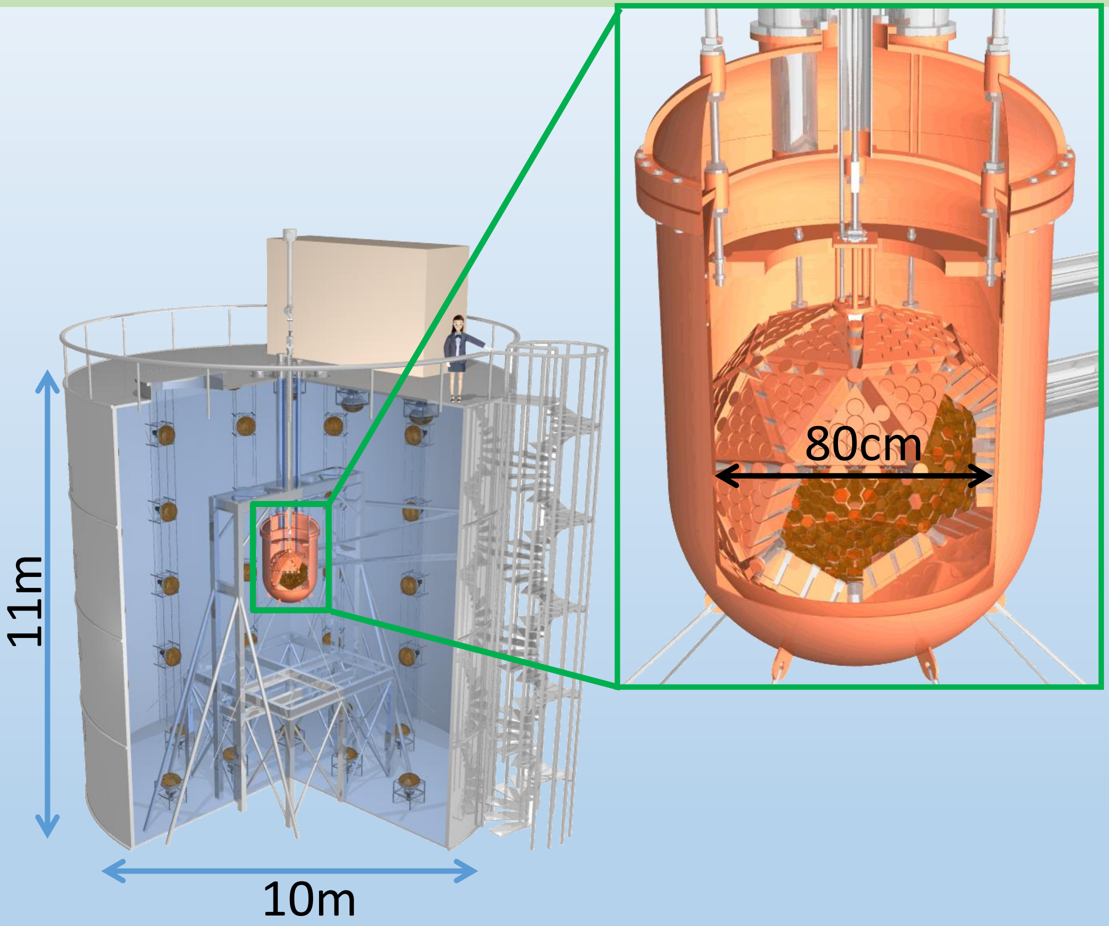
Poster Wall #1

Neutrino physics with the XMASS liquid xenon detector

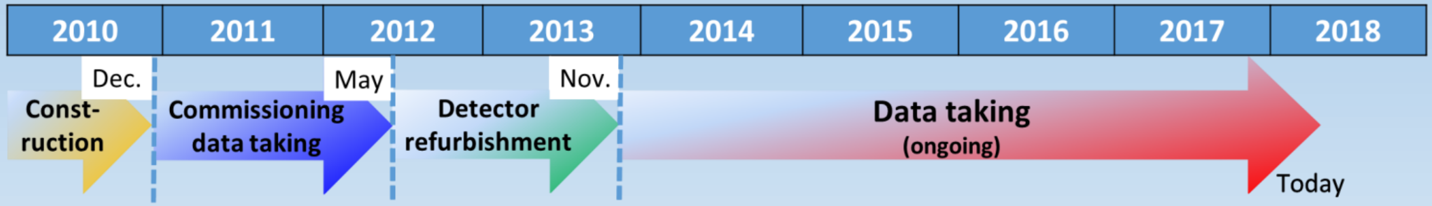
K. Hiraide (ICRR, the University of Tokyo)
for the XMASS Collaboration

XMASS project

- **A multi-purpose experiment using liquid xenon at the Kamioka Observatory in Japan**
  - Direct detection of **dark matter**
  - Observation of low energy **solar neutrinos (*pp*/^{7}Be)**
  - Search for **neutrino-less double beta decay**
- **XMASS-I detector**
  - **832 kg of liquid xenon**
  - **Low energy threshold, low background, large mass**
  - Sensitive to ***e*/γ events** as well as **nuclear recoil events**
  - Stably taking data for **more than 4 years**



XMASS has challenged a variety of topics in neutrino physics



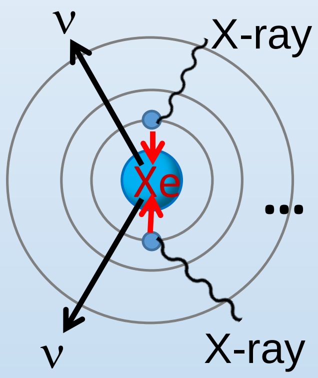
Poster Wall #1

Neutrino physics with the XMASS liquid xenon detector

K. Hiraide (ICRR, the University of Tokyo)
for the XMASS Collaboration

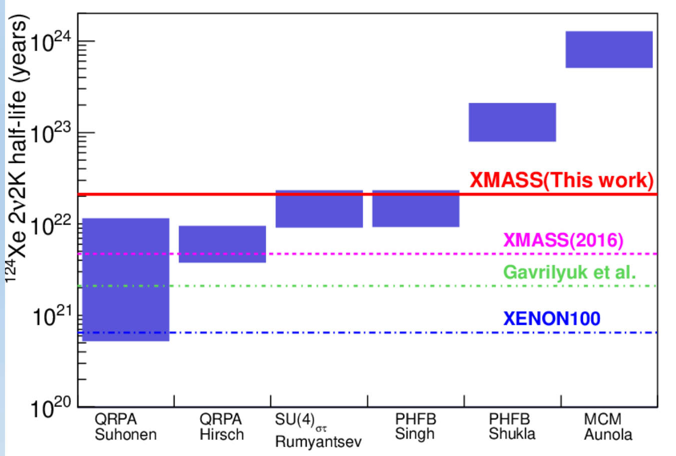
Two-neutrino double electron capture (ECEC)

- **Analogue to double beta decay**
  - 2ν mode: allowed but observed **only for ^{78}Kr and ^{130}Ba**
  - 0ν mode: **Majorana if observed**



- **Signature of ^{124}Xe 2ν ECEC**
  - $^{124}Xe + 2e^- \rightarrow {}^{124}Te + 2\nu_e$
  - A peak at **63.6 keV** by X-rays/Auger electrons

- **Results**
  - Improved analysis w/ particle ID
  - No significant signal observed.
  - **$T_{1/2} > 2.1 \times 10^{22}$ yrs (90% CL)**



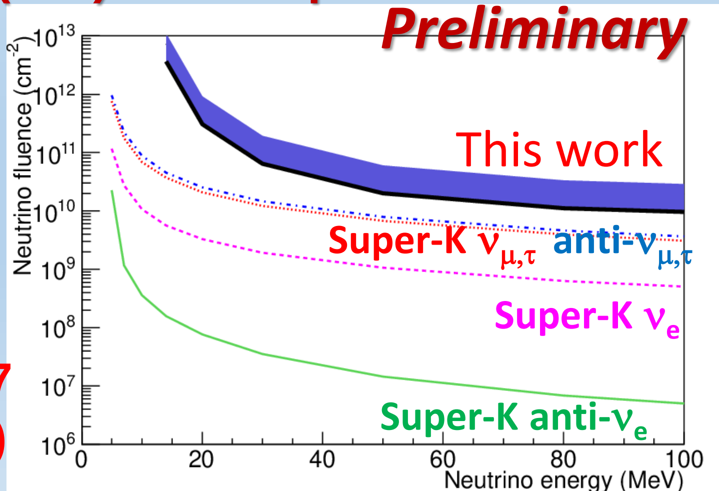
Supernova (SN) neutrinos and GW follow-up

- **Coherent elastic ν-nucleus scattering (CEνNS)**
  - Neutral current → **sensitive to all ν flavors**
  - **Large cross section**
  - **Recoil energy ~O(10 keV)**

$$\nu + A \rightarrow \nu + A$$

- **New way to detect galactic SN neutrinos**
  - Expect **3~21 evts** (10 kpc), **O(10^4) evts** (196pc)

- **Gravitational-wave (GW) follow-up**
  - Searched for **event bursts** associated with GW events
  - Upper limits on **ν fluence from GW170817 (NS-NS merger)**



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Prospects for Exploring New Physics in Coherent Elastic Neutrino-Nucleus Scattering

Julien Billard, Joseph Johnston, and Bradley J. Kavanagh

Poster #23

CEvNS is a Standard Model process:

$$\frac{d\sigma}{d(\cos\theta)} = \frac{G_F}{8\pi} {Q_W}^2 E^2 (1 + \cos\theta)$$

$$Q_W = Z(4\sin^2\theta_W - 1) + N$$

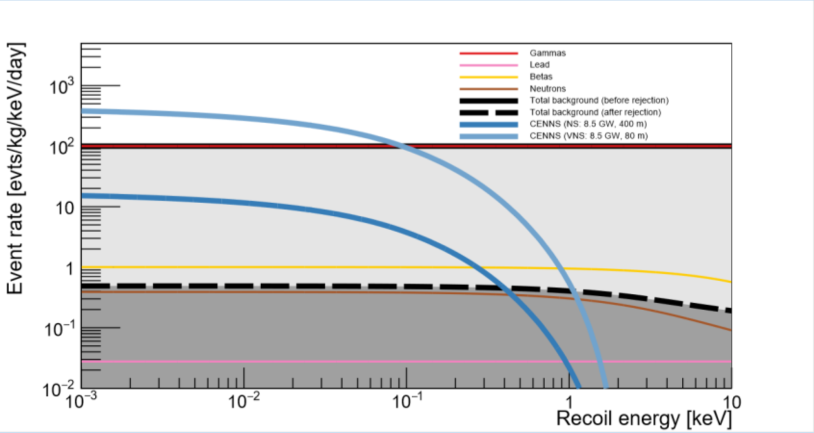
Target Nucleus	T_{Max} $E_\nu = 3$ MeV	T_{Max} $E_\nu = 30$ MeV
Ar	484 eV	48.3 keV
Zn	296 eV	29.5 keV
Ge	266 eV	26.6 keV
	(Reactor)	(Spallation)

- Bolometers at a reactor probe lower energies
- Consider a bolometer at the 8.5 GW Chooz reactor complex, placed at the 400m near site or 80 m very near site

Current and planned CEvNS Projects:

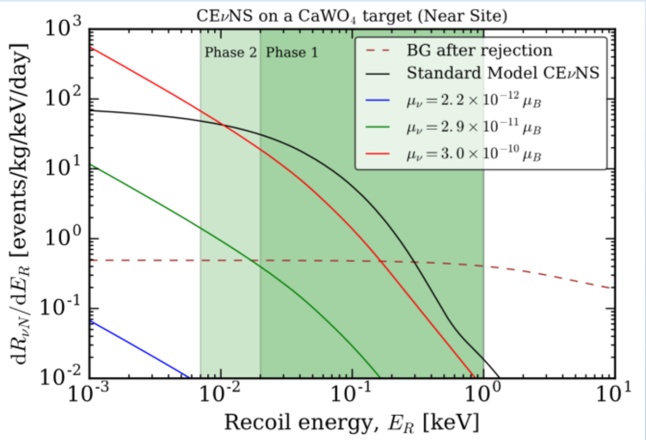
- MINER: 10 kg Si+Ge at a 1 MW, 200 eV threshold
- NUCLEUS: Several grams CaWO4 + Al2O3, 10 eV energy threshold
- Ricochet: Several kg of Zn, Ge, Si, or Os, 50 eV threshold

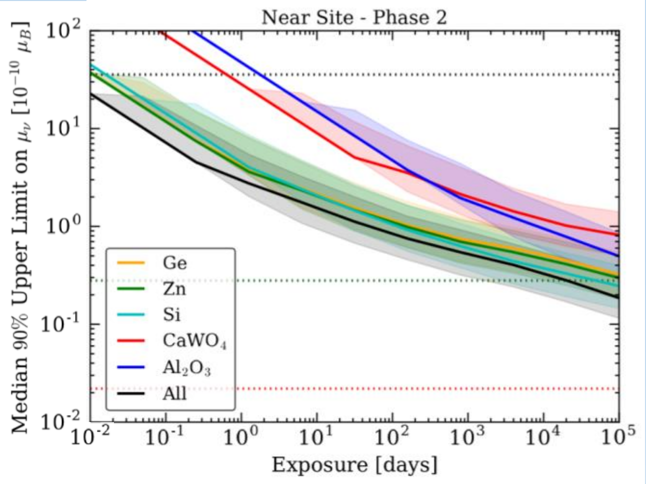
Target	Phase 1 E_{th} [eV]	Phase 1 Mass [g]	Phase 2 E_{th} [eV]	Phase 2 Mass [g]	Background reduction gamma	Background reduction neutron
Zn	50	500	10	5000	1000	1
Ge	50	500	10	5000	1000	1
Si	50	500	10	5000	1000	1
$CaWO_4$	20	6.84	7	68.4	1000	10
Al_2O_3	20	4.41	4	44.1	1000	10



Neutrino Magnetic Moment: Adds a term to CEvNS

$$\frac{d\sigma^{mag.}_{\nu-N}}{d(E_R)} = \frac{\pi\alpha^2\mu_\nu^2 Z^2}{m_e^2}\left(\frac{1}{E_R} - \frac{1}{E_\nu} + \frac{E_R}{4E_\nu^2}\right)F^2(E_R)$$





Neutrino Coupling to Quarks

Massive Scalar Mediator:
Adds a term to CEvNS

$$\frac{d\sigma_\phi}{d(E_R)} = \frac{g_\nu^2 Q_\phi^2}{4\pi}\frac{E_R m_N^2}{E_\nu^2 (q^2 + m_\phi^2)^2} F^2(E_R)$$

$$Q_\phi = (15.1\, Z + 14\, N) g_q$$

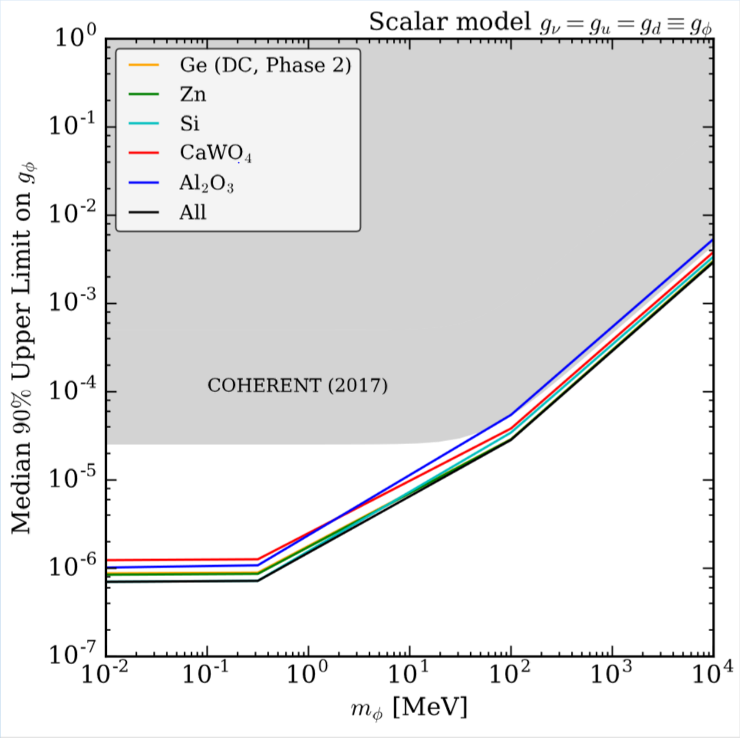
Massive Vector Mediator:
Interferes with CEvNS

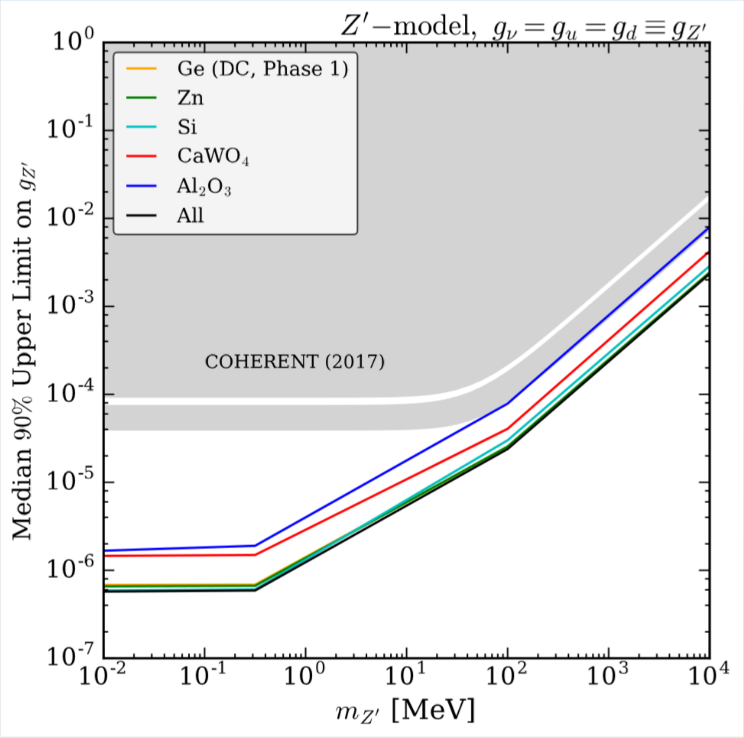
$$Q_W \to Q_{SM+NP} = Q_W - \frac{\sqrt{2}}{G_F}\frac{Q_{Z'}}{q^2 + m_{Z'}^2}$$

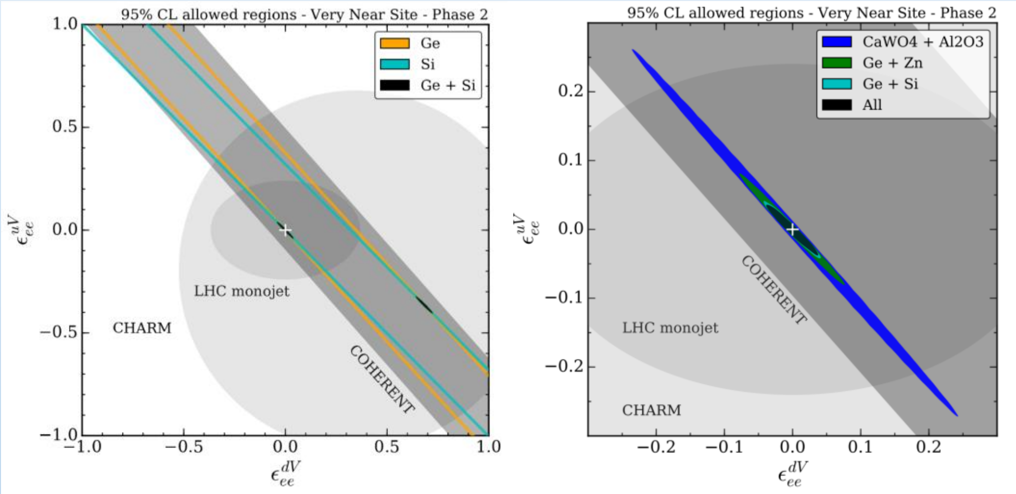
General Non-Standard Interactions:

$$Q_W = \left[4N\left(-\frac{1}{2} + \epsilon_{ee}^{uV} + 2\epsilon_{ee}^{dV}\right) + Z\left(\frac{1}{2} - 2\sin^2\theta_W + 2\epsilon_{ee}^{uV} + \epsilon_{ee}^{dV}\right)\right]^2$$

$$+4\left[N\left(\epsilon_{e\tau}^{uV} + 2\epsilon_{e\tau}^{dV}\right) + Z\left(2\epsilon_{e\tau}^{uV} + \epsilon_{e\tau}^{dV}\right)\right]^2$$







- Breaking the $\epsilon_{\alpha\beta}^{uV}$ *and* $\epsilon_{\alpha\beta}^{dV}$ degeneracy is important for determining the mass hierarchy with DUNE (P. Coloma and T. Schwetz, Phys. Rev. D 95, 079903 (2017))
- Probing low energies places strong bounds at light mediator masses below ~ 10 MeV
- Combining multiple targets places strong NSI bounds

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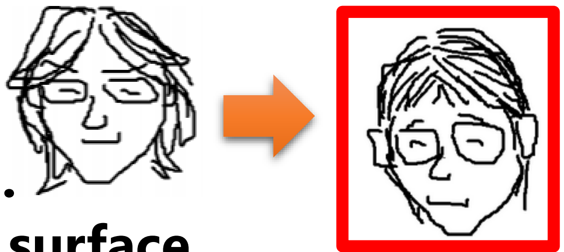
Study for g-mode oscillations in the Sun using solar neutrino with Super-Kamiokande

@Neutrino 2018, 6th June 2018.

Yuuki Nakano (Kamioka observatory, ICRR, Univ. of Tokyo)

for the Super-Kamiokande collaboration



■ Introduction and motivation

- There are several periodic variations in the Sun.
  (1) 11-years periodic change of sunspot at the surface.
  (2) Solar oscillations around its equilibrium due to restoring force.

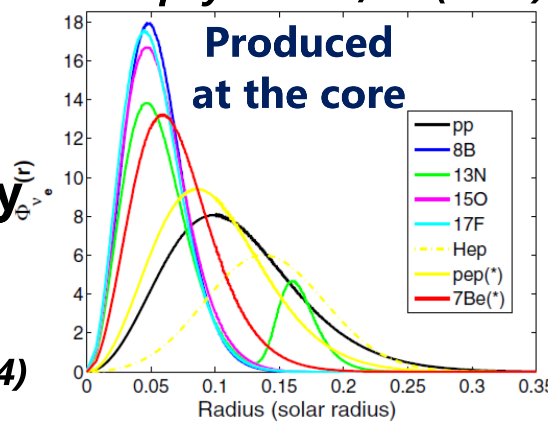
Oscillation	Restoring force	Region	Frequency
p-mode	Pressure	Surface convection	A few mHz (~ 5 minutes)
g-mode (Never detected)	Gravity (Buoyancy)	Core	100-300 μHz (a few hours)

- These variations may affect the solar neutrino production.
 → Search for periodic variation using solar neutrino in Super-Kamiokande.

■ ^{8}B neutrino production and g-mode oscillation

- Production rate of ^{8}B ν is depends on temperature.
  → $T^{24\text{-}25}$ (T_{core}~$10^{6\text{-}7}$ K) at the core of the Sun.

Astrophys. J. 765, 14 (2013)



- Due to g-mode, temperature (electron density) may fluctuate at the core of the Sun.

→ **Flux of ^{8}B ν may be amplified by a factor of 170.**

Astrophys. J. Lett. 792, L53 (2014)

■ Method to search for g-mode oscillation

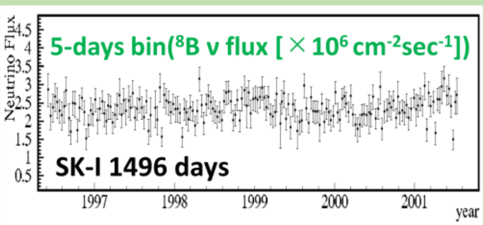
- Super-Kamiokande has accumulated **~100k neutrino events** so far.
- There are **two methods** to search for g-mode oscillations in Super-K.

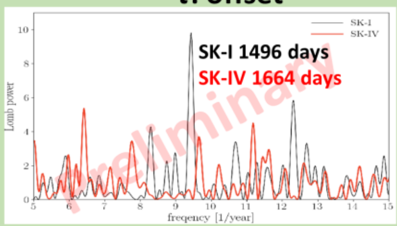
Generalized Lomb-Scargle method (Binned analysis)

Search for periodic signals in uncontinuous data set

$$\hat{p}(\omega) = \frac{1}{\sum_i y_i^2}\left\{\frac{[\sum_i y_i \cos\omega(t_i-\hat{\tau})]^2}{\sum_i \cos^2\omega(t_i-\hat{\tau})} + \frac{[\sum_i y_i \sin\omega(t_i-\hat{\tau})]^2}{\sum_i \sin^2\omega(t_i-\hat{\tau})}\right\}$$

y_i: flux of i-th bin
t_i: time of i-th bin
ω: angular frequency
τ: offset



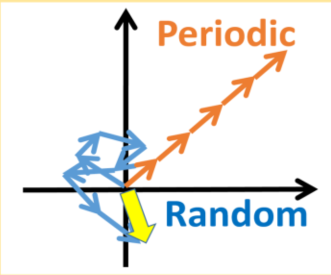


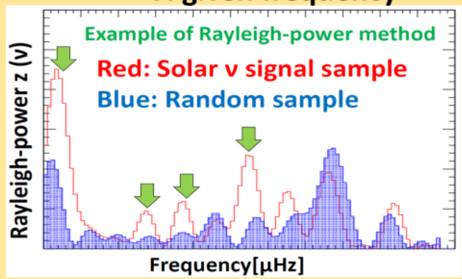
Rayleigh power method (Unbinned analysis)

Power spectrum considering timing of observed events

$$z(\nu) = \frac{1}{N} \times \left[\left(\sum_i^N \sin 2\pi\nu t_i\right)^2 + \left(\sum_i^N \cos 2\pi\nu t_i\right)^2\right]$$

N: number of total event
t_i: time of i-th event
ν: given frequency





- For more detail: come to my poster. I'm happy to discuss this study with you.

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Search for heavy neutrinos with the T2K experiment

Poster # 43, Wednesday session — *Presenter:* M. Lamoureux

How to explain neutrino masses (and consequently oscillations)?

A natural extension is one with 3 new right-handed neutrinos (**sterile**):

$$-\frac{1}{2}\begin{pmatrix} \overline{\nu_L} & \overline{\nu_R^c} \end{pmatrix} \underbrace{\begin{pmatrix} 0 & m_D \\ m_D^T & m_R \end{pmatrix}}_{\mathcal{M}} \begin{pmatrix} \nu_L^c \\ \nu_R \end{pmatrix}$$

light neutrinos

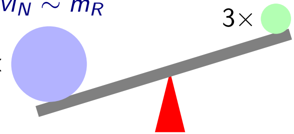
$m_\nu \sim \frac{m_D^2}{m_R} \lesssim 0.1\,\mathrm{eV}$

heavy neutrinos

$M_N \sim m_R$

3×

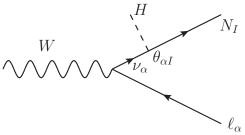
3×



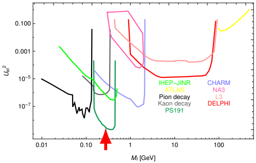
Three new heavy neutrinos at an unknown scale (eV → GUT)!

How to detect heavy neutrinos?

- N_I couple to W and Z with a strength $U^2_{\alpha I} \equiv |\Theta_{\alpha I}|^2 \sim \mathcal{O}\left(\frac{m_\nu}{M_N}\right)$



- Can be produced e.g. in colliders or in **meson decays** (arXiv:1502.00477).
- For $0.1 < M_N < 100$ GeV/c^2, we have $\boxed{U^2_\alpha \sim 10^{-10} - 10^{-8}}$.



90% limits from current experiments on the mixing of heavy neutrinos to electron and muon.

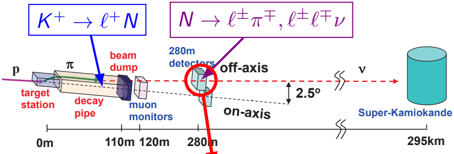
Search for heavy neutrinos with the T2K experiment

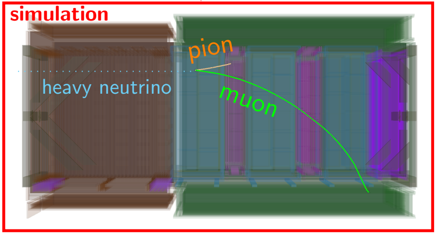
Poster # 43, Wednesday session *Presenter:* M. Lamoureux

Detection in T2K:

Heavy neutrinos are produced alongside standard neutrino beam.

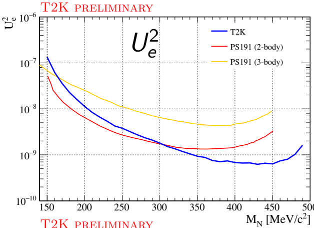
They propagate and can decay in T2K near detector **ND280** → detection of 2 particles with opposite charges.



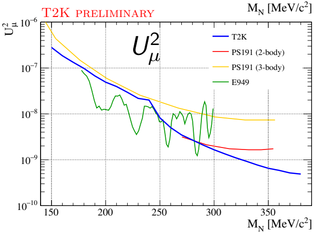


Analysis and results:

- *Remaining background after selection:* less than 2 evts (from active ν int.)
- Bayesian approach, marginalization with a **Markov Chain Monte Carlo**.



90% C.L.



T2K put the most stringent limits in the high mass region.

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Poster #48

Studying the impact of neutrino cross-section mismodelling on the T2K oscillation analysis

T2K Oscillation Analysis

T2K oscillation analysis aims to extract oscillation probability from a rate of event in the Super-K detector.

Need to modelize neutrino flux and interaction.

Cross-section Osc. Probability

$$N^{FD}_{\nu_\beta}(E_\nu) = \Phi^{FD}_{\nu_\beta}(E_\nu) \times \sigma^{FD}_{\nu_\beta}(E_\nu) \times \varepsilon^{FD}(E_\nu) \times P_{\nu_\alpha \to \nu_\beta}(E_\nu)$$

Flux Det. Efficiency

External data

Build some flux and cross-section models with external data sets (NA61/SHINE, MINERvA, MiniBooNE...)

ND280 data

Constrain those models with un-oscillated neutrino data at the near detector

Super-K data

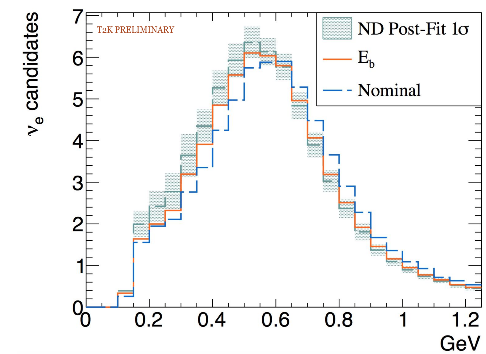
Fit those models to the Super-K data to extract the oscillation parameters of interest : θ_{23} Δm^2_{32} θ_{13} δ_{CP}

How to evaluate ?

Cross-section mismodelling could introduce biases on the final values of oscillation parameters.

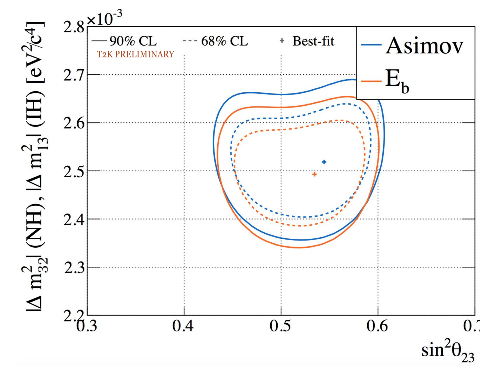
➤ **Need to evaluate this**

1) Build simulated data at ND280 and SK with alternative models.



2) Fit at ND280 with nominal model.

3) Propagate at SK and fit SK simulated data.



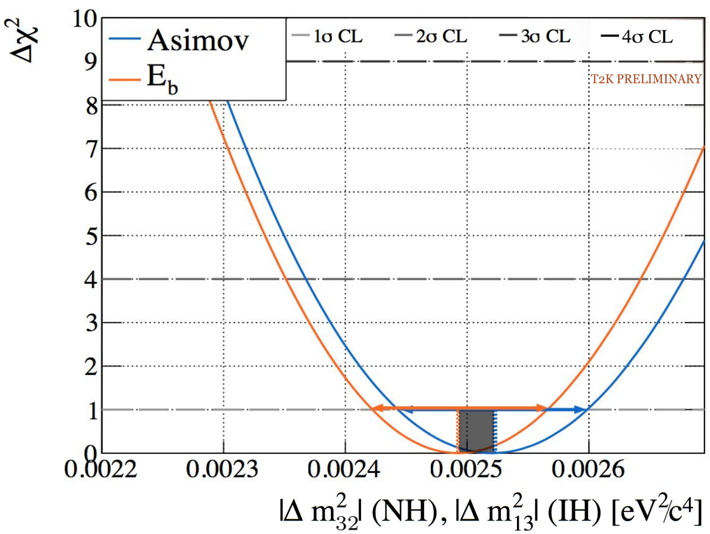
4) Compare the result with a fit to the nominal MC.

Studying the impact of neutrino cross-section mismodelling on the T2K oscillation analysis

Poster #48

What's the impact on the analysis ?

We can quantify this effect by comparing 1D oscillation parameters likelihood curves.



$$\text{bias} = \frac{\text{mean}_{\text{SD}} - \text{mean}_{\text{MC}}}{\sigma_{\text{MC}}}$$

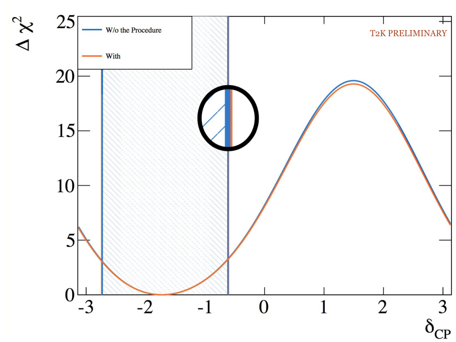
We get bias for all the alternative models and oscillation parameters.

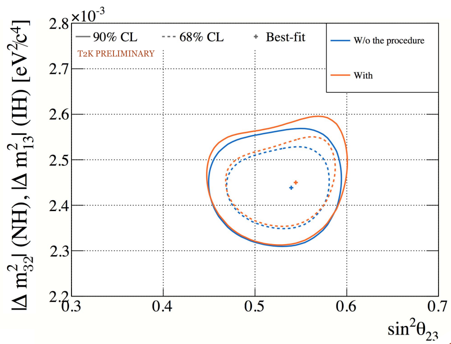
We can define if biases are acceptable.

An additional uncertainty

The biases being too large, defined a procedure based on the results of the study to have an additional uncertainty.

- ➤ Additional parameter being able to absorb shape effects.
- ➤ Smearing of the oscillation parameters likelihood.





This additional uncertainty impacts mainly the disappearance parameters θ_{23} Δm^2_{32}

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2’40” each

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NOvA joint $\nu_e + \nu_\mu$ oscillation results in neutrino and antineutrino modes

Ashley Back (ISU), Liudmila Kolupaeva (JINR)

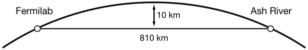
on behalf of the NOvA Collaboration

Poster №82

June 2018
NEUTRINO 2018

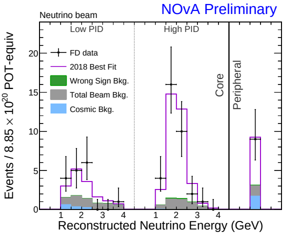
Neutrino oscillation physics goals:

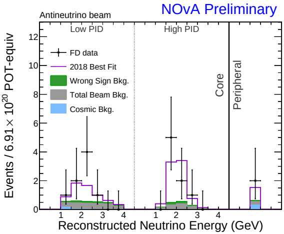
- ν Mass Hierarchy
- δ_{CP}
- octant of θ_{23} and Δm^2_{32}



With 8.85 $\times 10^{20}$ POT in ν mode
and 6.91 $\times 10^{20}$ POT in $\bar{\nu}$ mode we found:

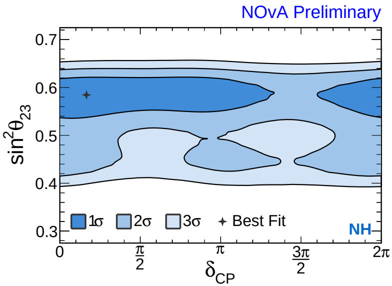
- 58 ν_e event with background expectation 15.1
- 18 $\bar{\nu}$ events with background expectation 5.3

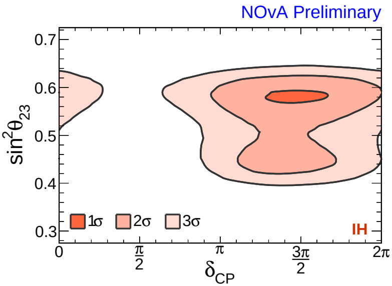


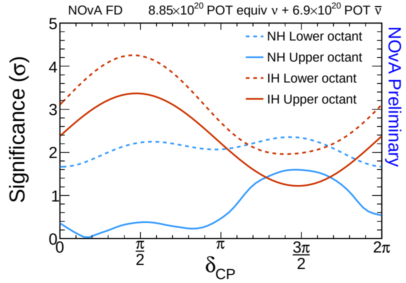


Fitting the ν_e and ν_μ spectra we get the following results.

Joint $\nu_e + \nu_\mu$ fit 2018 analysis results







Joint fit results:

- Best fit:
  NH, $\delta_{CP} = 0.17\pi$,
  $\sin^2\theta_{23} = 0.58 \pm 0.03$ (UO),
  $\Delta m^2_{32} = 2.51^{+0.12}_{-0.08} \times 10^{-3}$ eV^2
- Reject the IH, $\delta_{CP} = \pi/2$ at $>3\sigma$,
  reject IH, all values of δ_{CP} at 1.8σ.

See the poster №82 for details

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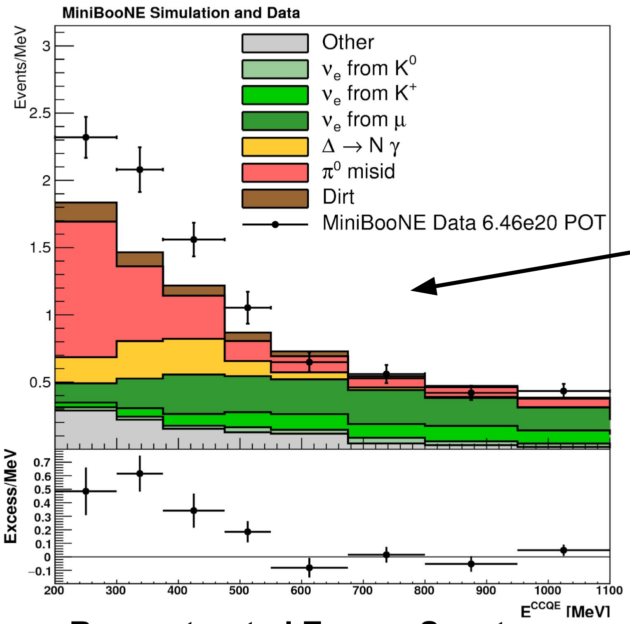
MicroBooNE Low-Energy Excess Signal Predictions through Unfolding MiniBooNE Monte-Carlo and Data

Mark Ross-Lonergan

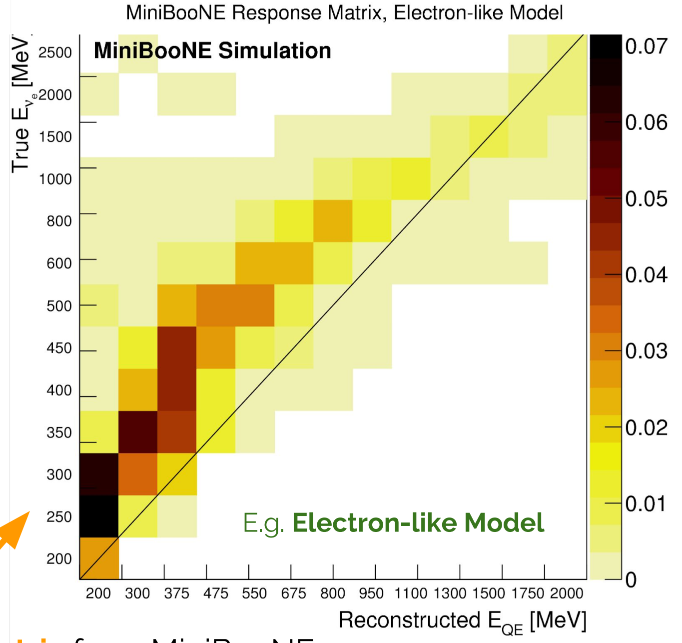
on behalf of the MicroBooNE Collaboration



Reconstructed Energy Spectrum

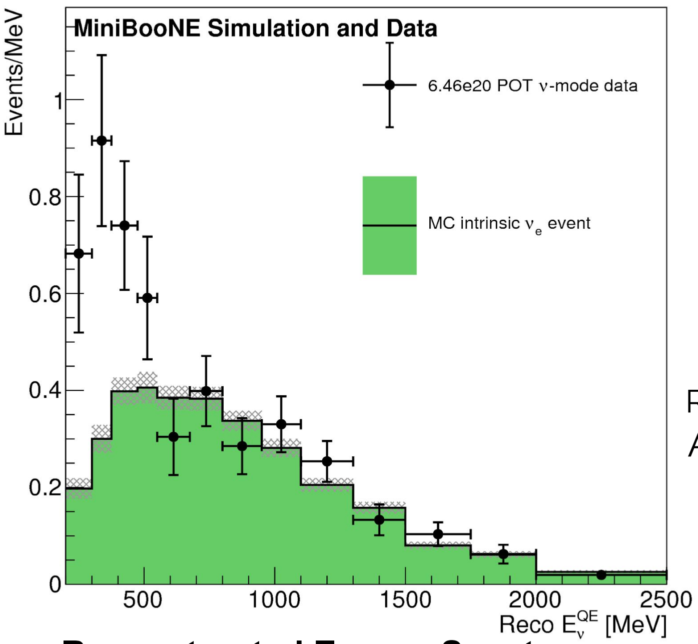
In order for MicroBooNE to weigh in on the origin of the LEE, **we need concrete models to test**.

For this we need to move from the **observed excess** in MiniBooNE data to a predicted **true underlying excess.**



First step, construct a **response matrix** from MiniBooNE Monte Carlo Simulations which, ***for a given hypothesis***, contains all the detector, reconstruction and selection effects.

MiniBooNE excess, Electron-Like Model

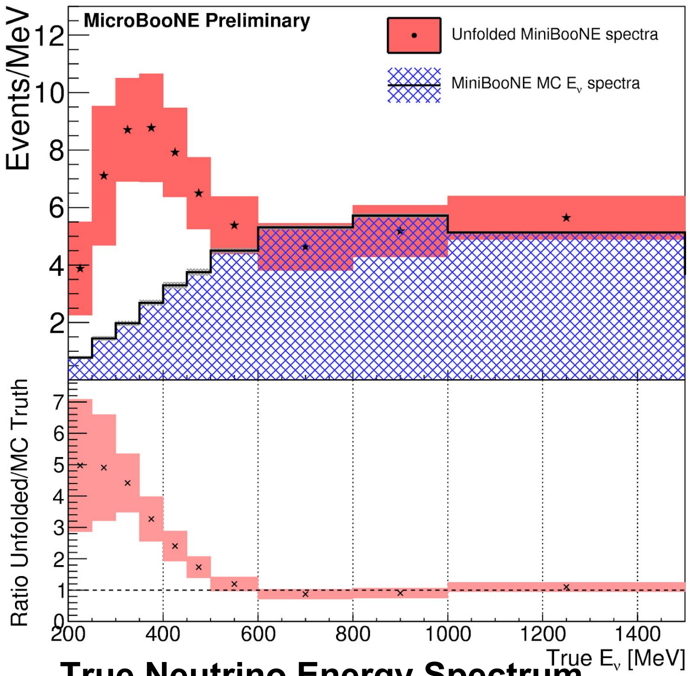


Reconstructed Energy Spectrum

Unfold!

Removes
Detector Smearing,
Reconstruction Effects,
Analysis Selections,
..etc..

Unfolded Result in MiniBooNE, Electron-like Model



True Neutrino Energy Spectrum

Given an underlying hypothesis, the constructed response matrix is used to "***unfold***" and remove all analysis specific and detector effects, recovering the **true underlying excess**

In this **electron-like example** we assume the excess is solely due to an energy dependent **increase in the intrinsic ν_e CC event rate**

For an example **photon-like model** & more, Come see my **Poster #114**

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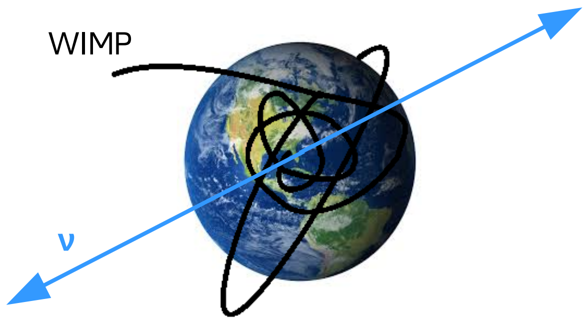
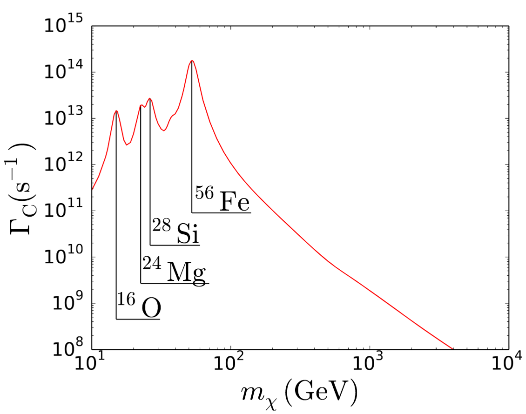
Search for neutrinos from dark matter annihilation in the Earth's core with the Super-Kamiokande detector

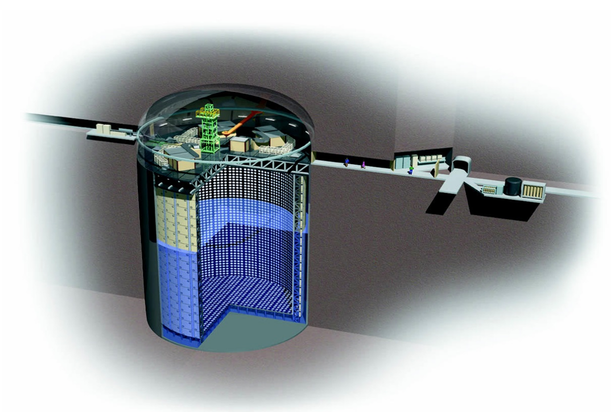
Katarzyna Frankiewicz
on behalf of the **Super-Kamiokande Collaboration**



In the Earth's core, the **spin-independent (SI)** interactions dominate in the capture process.

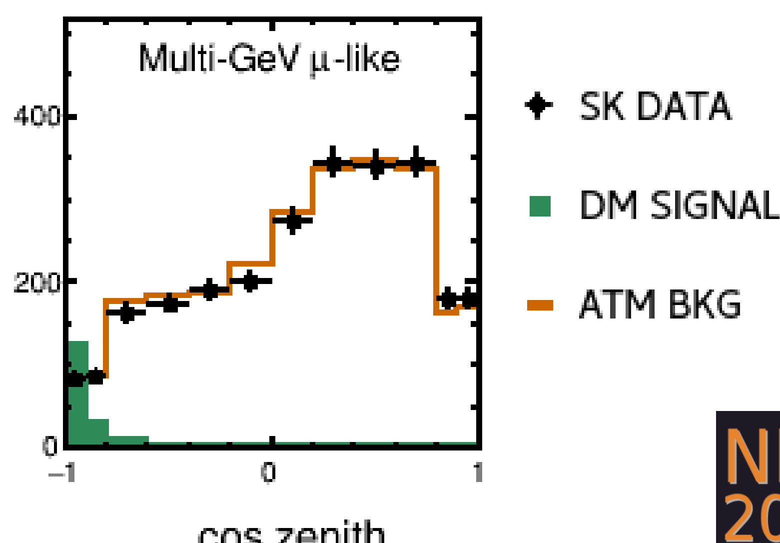


If the **WIMP mass** matches the mass of a **heavy element** in the Earth, the **capture rate** will **increase** considerably.



20 years of atmospheric neutrino data collected with the Super-K is used ~50 000 events

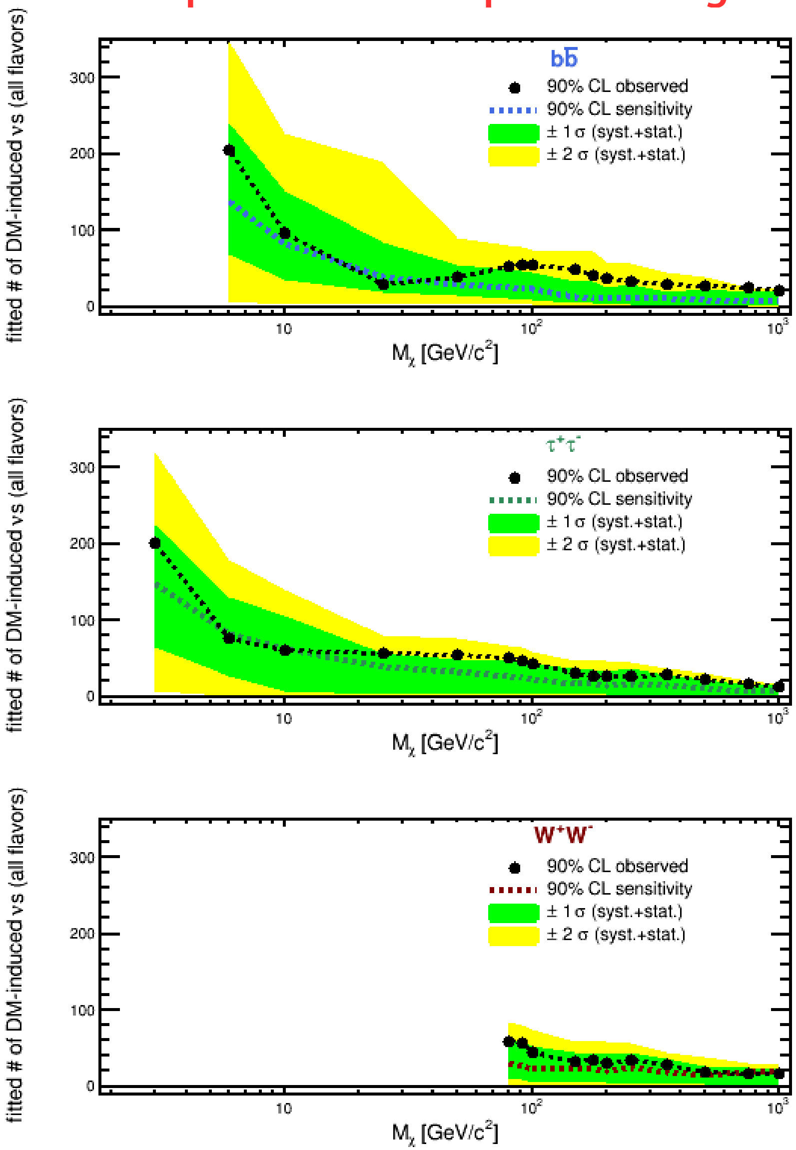
For each tested WIMP mass and annihilation channel, we find the configuration of **ATM BKG** + **DM SIGNAL** that would match **DATA** the best.



19 samples, binned in **lepton momentum** & **cosθ_z → 595 bins**

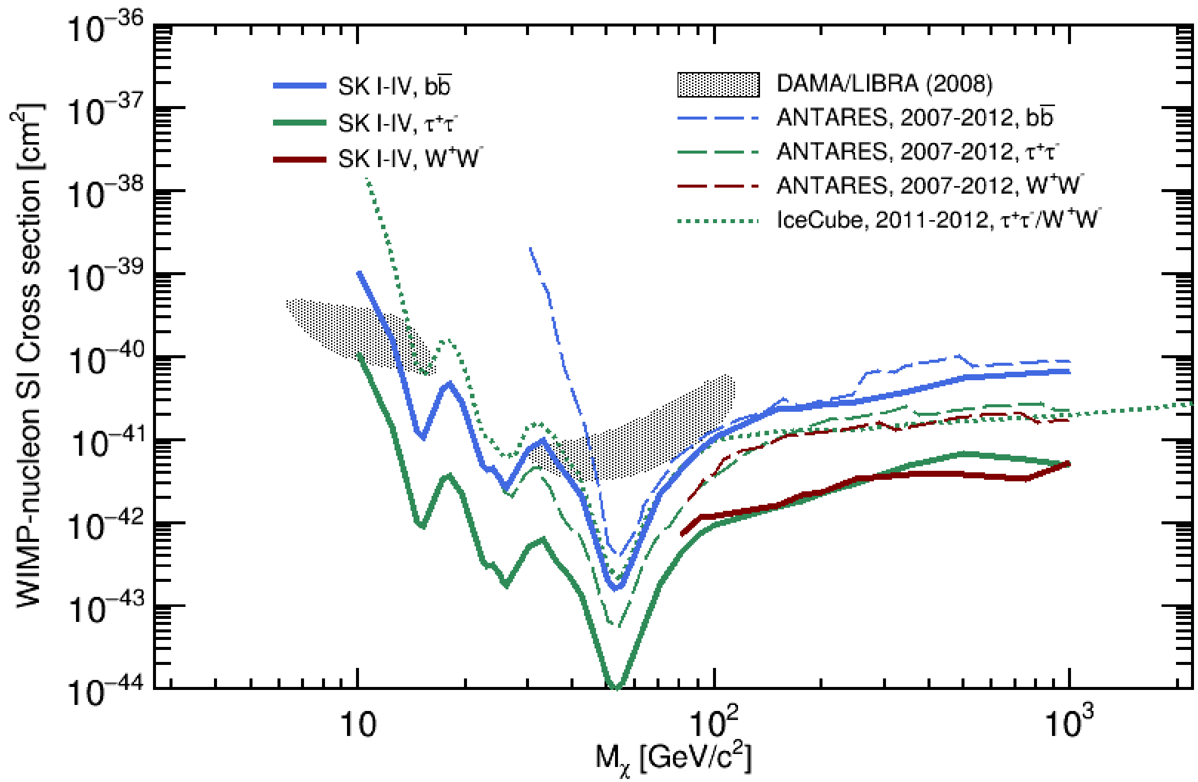
NEVTRINO 2018 Heidelberg 4–9 June

No excess of dark matter induced neutrinos has been observed as compared to atmospheric ν bkg



- wide range of tested WIMP masses
- three dark matter annihilation channels considered
- unique sensitivity for low energies

90% CL limits on WIMP-nucleon SI scattering x-section



The peaks correspond to **resonant capture** on the most abundant elements: **^{16}O, ^{24}Mg, ^{28}Si** and **^{56}Fe,** and their isotopes.

- The **strongest limits** among all neutrino experiments up to date.
- Majority of the WIMP parameter space favored by the DAMA/LIBRA results is ruled out.

→ poster #134

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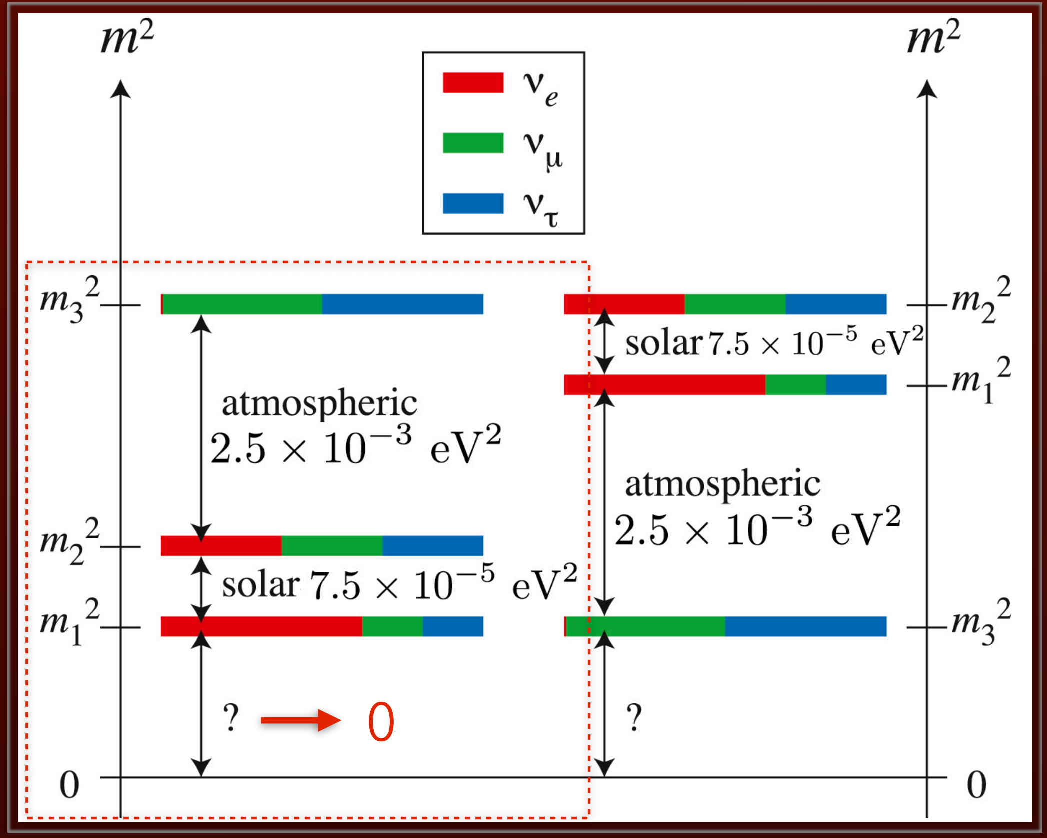
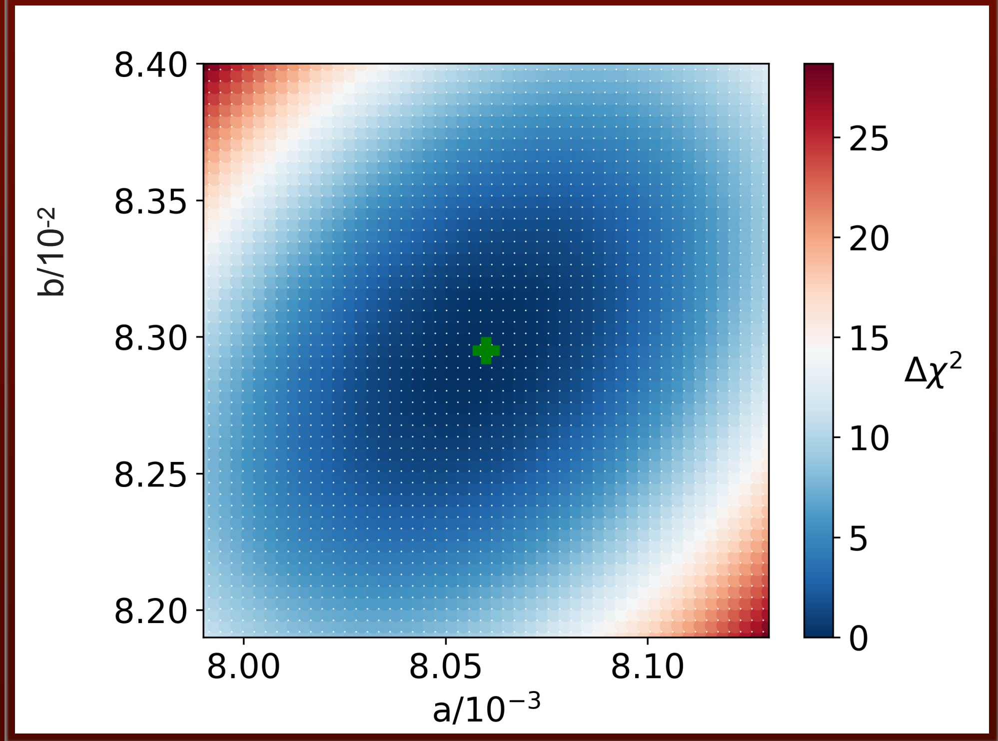
Determining the masses of Right-Handed Neutrinos in the Littlest Seesaw

- Littlest Seesaw:
  SM extension with 2 new RHν singlets
- Renormalisation Group Evolution:
  Evolve observables to low scales using RG running (REAP)
- Leptogenesis:
  Lepton asymmetry generated through decay of lightest RHν



$$Y_{\Delta\alpha} = \eta_\alpha \epsilon_\alpha Y_{N1}^{eq} \quad \Rightarrow \quad Y_B = \frac{12}{37} \sum_{\alpha=e,\mu,\tau} Y_{\Delta\alpha}$$

Method: Fit high scale parameters to low scale neutrino data and BAU from Leptogenesis (χ^2 analysis)



Scan over neutrino masses:

$$1.0 \times 10^9 \leq M_1 \leq 5.0 \times 10^{12} \quad \text{[GeV]}$$
$$5M_1 \leq M_2 \leq 1.0 \times 10^{16} \quad \text{[GeV]}$$

and *a*, *b* : free parameters in Yukawa matrices

⟹ 4-dimensional gridding

	Case A	Case D
M_{atm} / GeV	5.051 x 10^{10}	1.357 x 10^{13}
M_{sol} / GeV	5.067 x 10^{13}	1.056 x 10^{10}
a	0.00805868	0.13484
b	**0.082948**	**0.00115694**
χ^2 / d.o.f.	3.17 / 3	4.65 / 3

> LS highly predictive: 7 observables from 4 parameters

> Excellent fit; suggests $\delta \simeq -90°$; allows indirect prediction of RHν masses

Learn about high energies ⇄ Testable at low energies

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Blazars as high-energy neutrino emitters

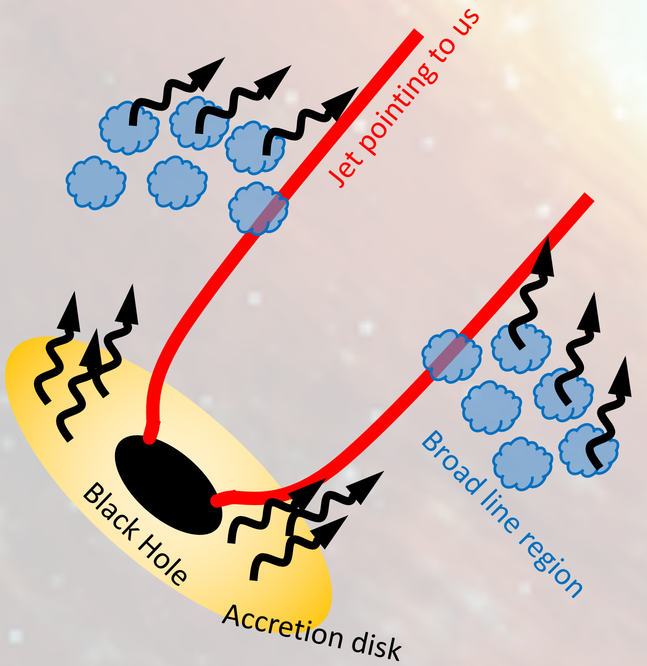
The source ofthe astrophysical neutrino source is still unknown. Blazars are considered as possible astrophysical ν emitters.

Blazars

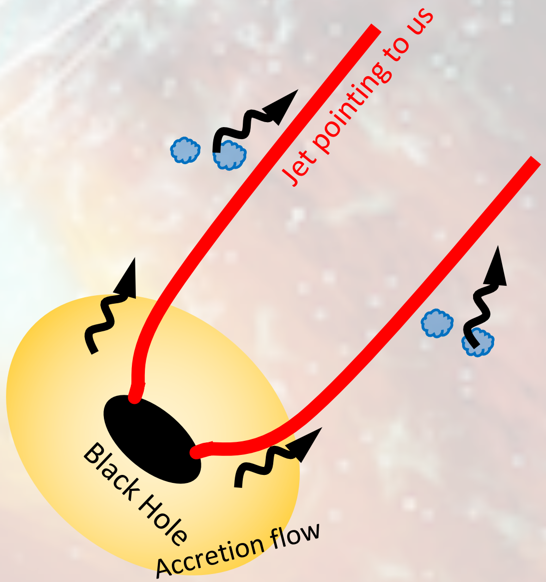
Flat Spectrum Radio Quasars:

✓ The rich radiative environment boost the $p\gamma$ reation.

✗ But they are too rare in the Universe to produce the entire neutrino flux observed by IceCube. (No multiplets detection)



BL Lacs:



✓ They are abundant in the nearby Universe.

✗ Their photon density is not enough to trigger $p\gamma$ reation. (low accretion rate)

BUT

✓ structured jet could potentially boost the BL Lac emission up to the level required by the ν detected by IceCube!

✓ TXS0506+056 is a BL Lac object!!

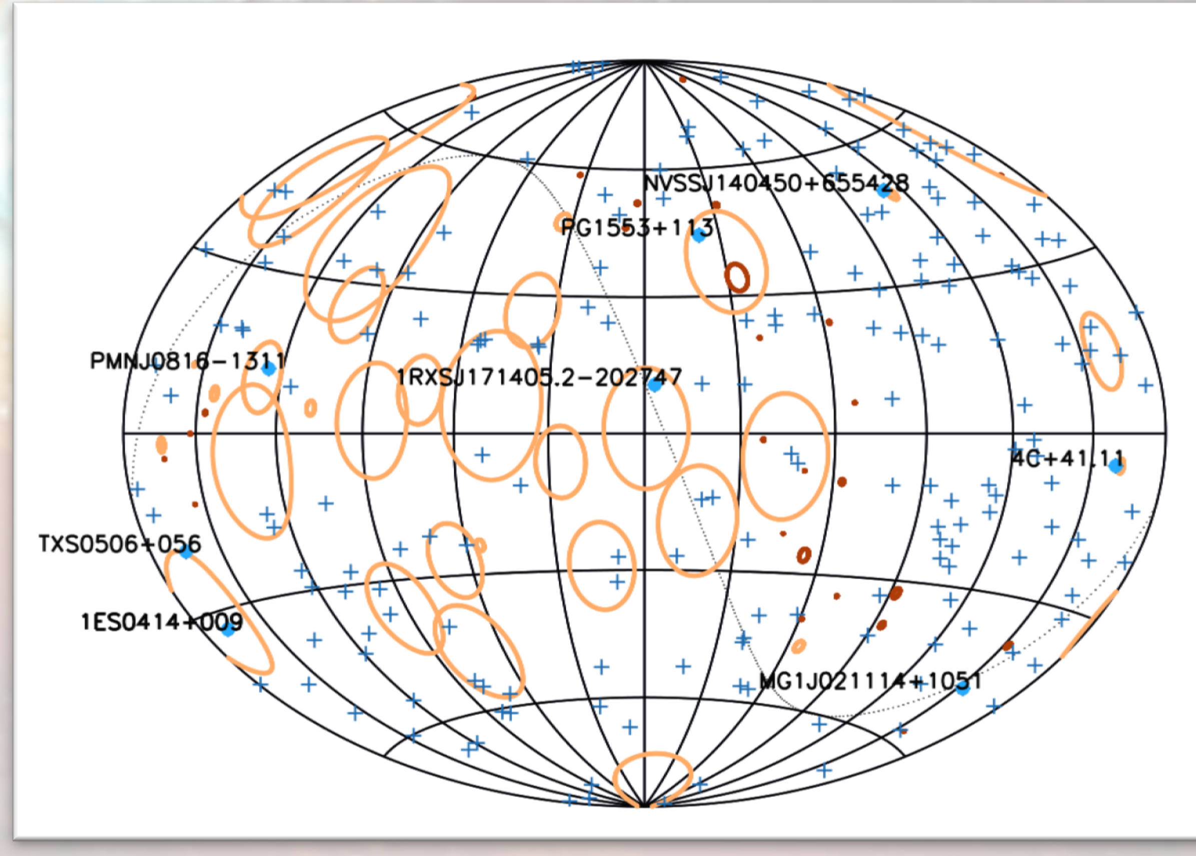
Righi C. Tavecchio F.

BL Lac as neutrino emitters

TXS0506+056 is a BL Lac of 2FHL catalogue (Fermi detection above 50GeV).

Assuming BL Lacs objects of 2FHL as the only emitters of IceCube neutrino flux:

- We assume a simple linear relation between γ-ray and neutrino fluxes, F_γ and F_ν to obtain a neutrino flux for each source and the expected count rate observed by IceCube and Km3NeT.*[Righi et al. 2017]*
- We started an observational campaign to a better characterization of 7 others BL Lacs of 2FHL in spatial correlation with a neutrino event.*[Righi et al. submitted]*



A NEW PROBLEM:

Mkn421 is the brightest BL Lac object in the sky.
Why we we do not have clear detection of neutrino events from this source?*[Righi et al. in prep.]*

For more details have a look to my poster

Righi C. Tavecchio F.

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