Summary of the WG5 parallel sessions

"beyond PMNS"

Walter M. Bonivento - INFN Cagliari, Italy (EX)

Pilar Coloma - FNAL, USA (TH)

Sanjib Kumar Agarwalla - IOP, Bhubaneswar, India (TH)

7 parallel sessions

22 talks

7 posters

All talks and posters were of very good quality

Attendance: always 25-35 people! very many interesting discussions!

Many thanks to all WG5 participants

Special thanks to all the speakers for accepting our invitation to contribute towards the WG5 activity

We would also like to thank the local organisers for their warm hospitality and excellent organisation.

This was the second time this WG has been active

Broad list of topics with very deep connection to plenaries

Search for:
- neutrino decays
- NSI
- sterile neutrinos

and nuisance effects on extraction of standard oscillation parameters in LBL experiments due to the above

Models beyond PMNS
Connections of neutrinos with BAU and quark sector anomalies
Dark sector and matter detection in neutrino experiments
Neutrino Magnetic moment
One whole session dedicated to the newly discovered coherent scattering

Monday 25/9	14:00-16:00	**Neutrinos and New Interactions.** **Chair: Sanjib Kumar Agarwalla**
	14:00-14:30	Invisible and Visible Neutrino Decay and Constraints on them from Oscillation Experiments
	14:30-15:00	Probing the revamped A4 symmetry at long-baseline neutrino experiments
	15:00-15:30	New upper bound for the neutrino magnetic moment from its Dirac/Majorana nature and Borexino data
	15:30-16:00	Fuzzy Dark Matter at neutrino experiments

Invisible and Visible Neutrino Decay and Constraints on them from Oscillation Experiments

O. L. G. Peres[1]

[1] Instituto de Física Gleb Wataghin
UNICAMP, Brazil

NUFACT2017 25 October of 2017

Heavier neutrinos decay to lighter neutrinos (normal hierarchy)

Framework of Neutrino Decay

Possible scenarios:

Initial neutrino states $\longrightarrow$ final neutrino states

final neutrino states $\begin{cases} \text{INVISIBLE} \\ \text{VISIBLE} \end{cases}$

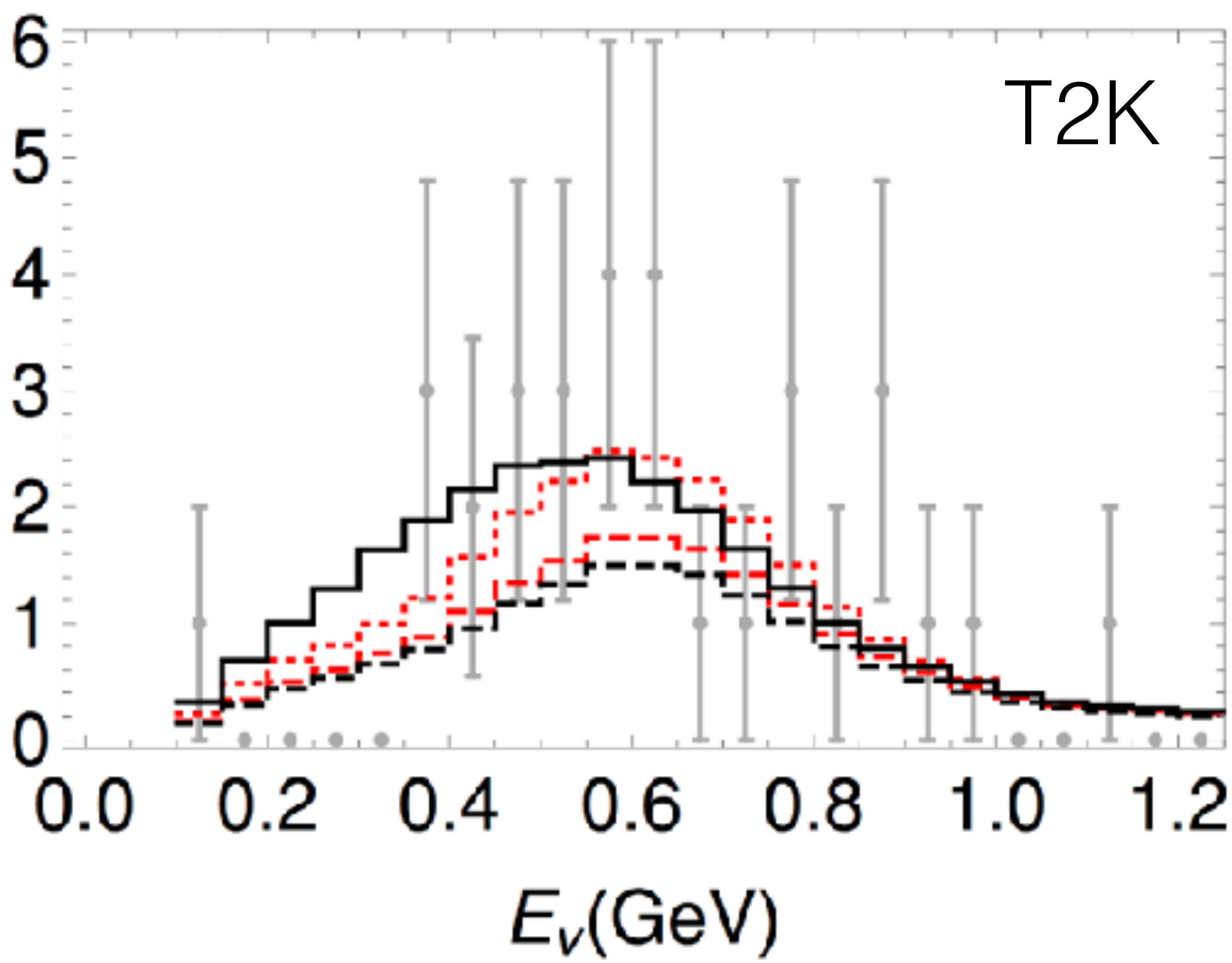
INVISIBLE:
- Sterile states
- Below the threshold of experiment
- Depletion of event rates: even for NC rates

VISIBLE:
- Flavor states
- Increase/Depletion of event rates

Analysis of Visible decay for MINOS and T2K

Work in collaboration with Gago/Gomes[2]/Jones-Pérez/ Peres 2017,

ν_e: invisible decay black dashed , **visible decay: solid black** (both with $\delta_{CP} = \pi/2$) and standard oscillation is in $\delta_{CP} = \pi/2 (\delta_{CP} = -\pi/2)$ for red dotted(dashed) curve



$\nu_3 \to \nu_1 + \phi$ /one non-zero coupling

LBL experiments can give a bound on the ν_3 lifetime

Invisible and visible ν decay have different behaviours: depletion and excess of events.

Conclusions

Analysis	Neutrino	Decay mode	Limit
Solar data	ν_2	Invisible	$\tau_2/m_2 > 7.2 \times 10^{-4}$ s/eV
Solar data	ν_2	Invisible	$\tau_2/m_2 > 7.1 \times 10^{-4}$ s/eV
Atmospheric and LBL data	ν_3	Invisible	$\tau_3/m_3 > 2.9 \times 10^{-10}$ s/eV
MINOS and T2K data	ν_3	Invisible	$\tau_3/m_3 > 2.8 \times 10^{-12}$ s/eV
MINOS and T2K data	ν_3	Visible	$\tau_3/m_3 > 1.5 \times 10^{-11}$ s/eV
JUNO expected sensitivity	ν_3	Invisible	$\tau_3/m_3 > 7.5 \times 10^{-11}$ s/eV
DUNE expected sensitivity	ν_3	Visible	$\tau_3/m_3 > 1.95 - 2.6 \times 10^{-10}$s/eV

Cornering the revamped BMV model with neutrino oscillation data

Mehedi Masud
IFIC-CSIC, U. Valencia
(work done with S.S. Chatterjee, P. Pasquini, J.W.F. Valle: 1708.03290)

NuFact 2017, Uppsala, September 25, 2017

A4 symmetry and BMV model: brief overview

Babu, Ma, Valle: Phys. Lett. B552, 207 (2003)

- Requires the existence of extra heavy fermions and three scalars χ_i, $i = 1, 2, 3$, all of them belonging to A_4 triplets representation and coupled through standard Yukawa interactions.

Revamped A4 symmetry and BMV model: brief overview

Morisi, Forero, Romao, and Valle: PRD88, 016003 (2013)

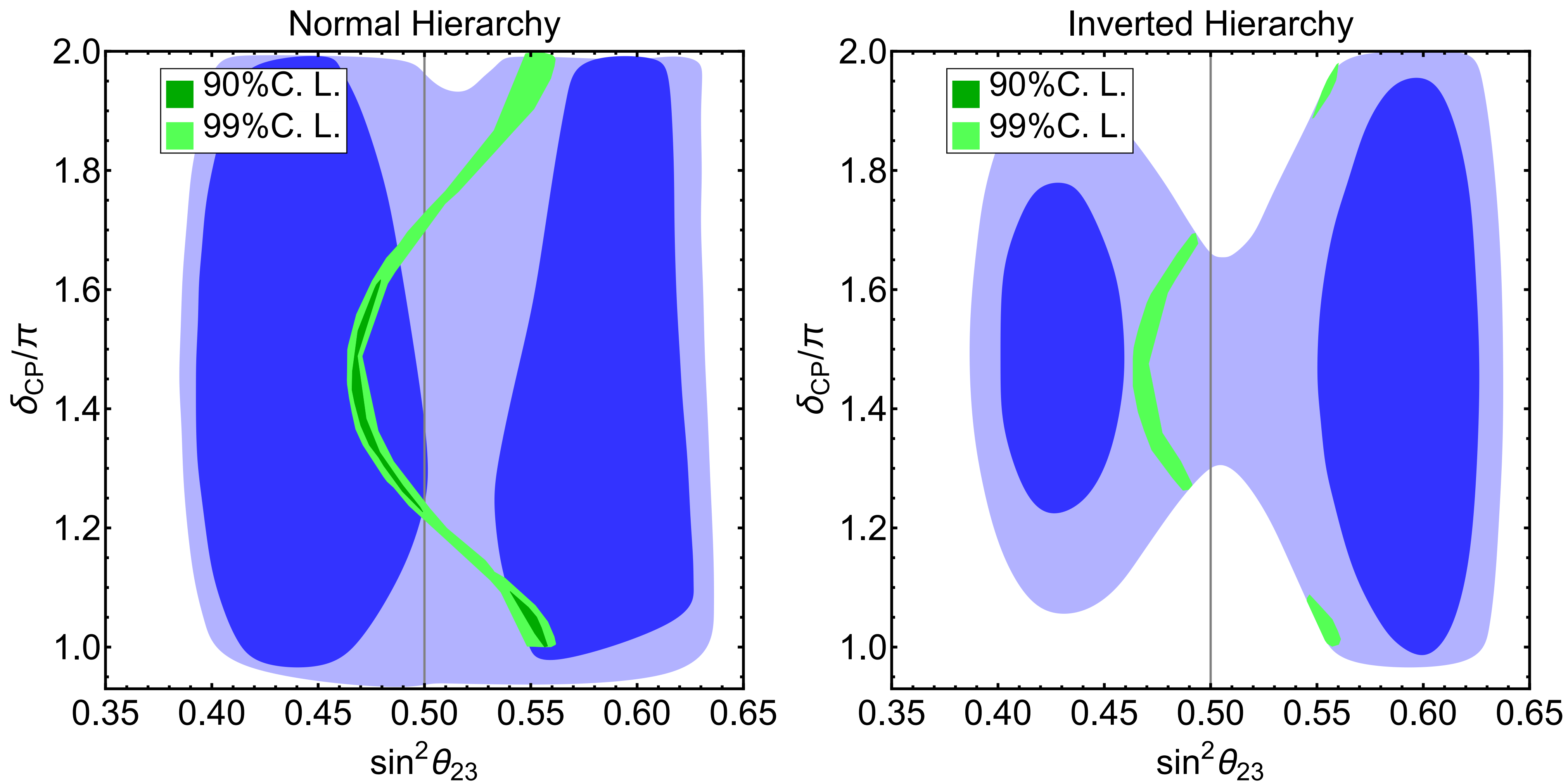
- A single flavon scalar ξ is added to break the remnant symmetry in A4 and the charged fermion mass matrix is changed slightly,

$$M_{eE} M_{eE}^{\dagger} = \begin{pmatrix} (f_e v_1)^2 I & (f_e v_1) Y_D^{\dagger} \\ (f_e v_1) Y_D & U_\omega \mathrm{Diag}[3(h_i^e u)^2] U_\omega^{\dagger} + Y_D Y_D^{\dagger} \end{pmatrix} \tag{1}$$

where $Y_D = M_E(I + \beta \mathrm{Diag}[1, \omega, \omega^2])$, and β is a small complex parameter.

Conclusion

- We have focused on the sharp correlation between θ_{23} and δ_{CP} predicted in the model.
- We showed the allowed regions in this parameter space and compare it with the standard global fits.
- We showed how the ability to reconstruct the CP phase and the atmospheric angle gets significantly affected
- Finally we have also presented the capability of the experiment to exclude the model in a fit independent way.



- Normal ordering is preferred and inverted ordering is only allowed at 99% C.L.
- For normal ordering, preferred solution indicates to the lower octant and maximal CP violation.

New upper bound for the neutrino magnetic moment from its Dirac/Majorana nature and Borexino data

Juan Barranco Monarca
DCI Universidad de Guanajuato

Nufact 2017

Uppsala University, Sweden.

September 25, 2017

Conclusions:

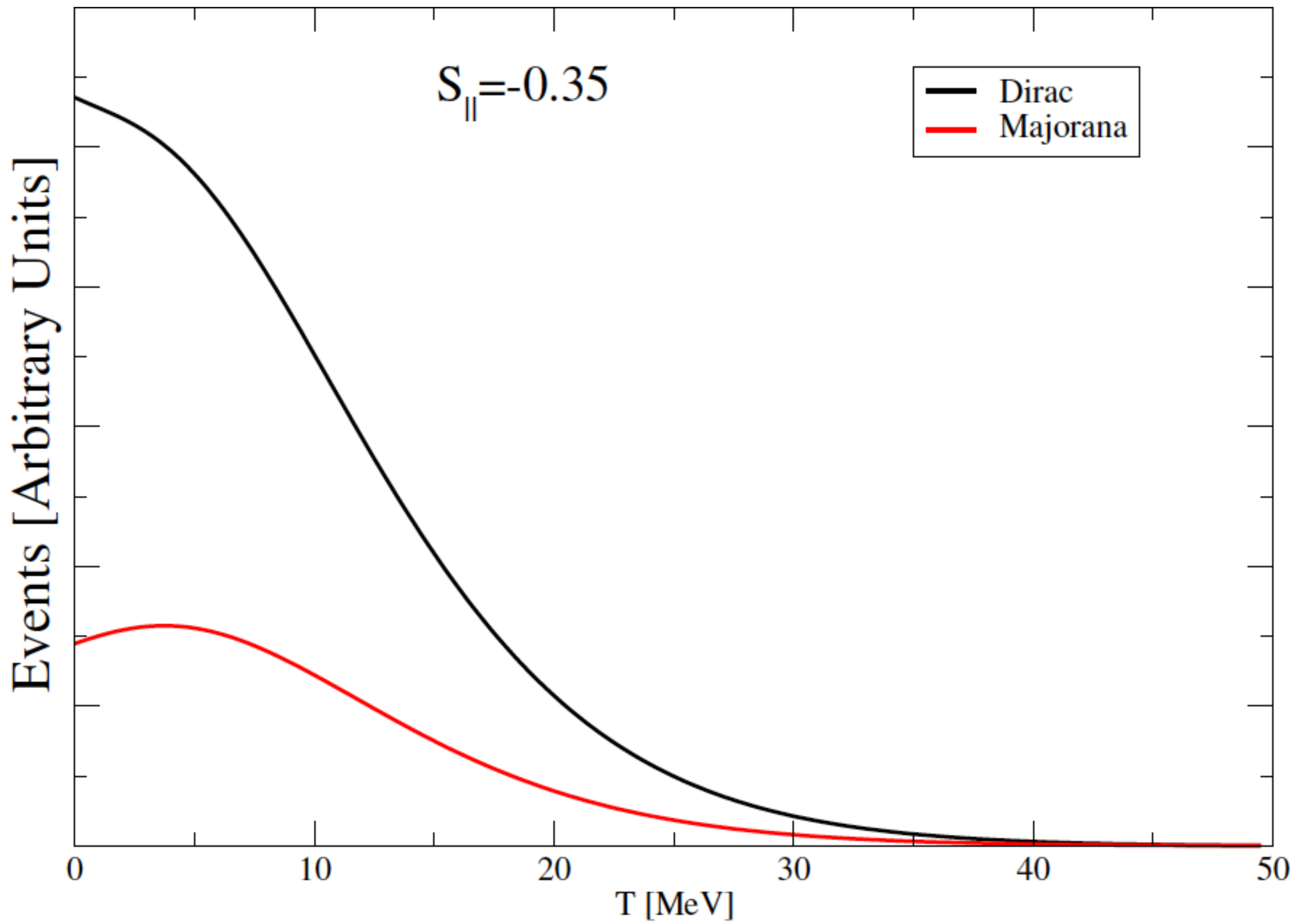
1) We have shows that the neutrino-electron scattering with polarized neutrinos might have different cross sections for the Dirac or the Majorana case

2)We have shown that this fact allows us to constrain the neutrino magnetic moment

3)Future neutrino supernova might tell us the nature of the neutrino

Difference between Majorana and Dirac with SN neutrinos

Even with a neutrino magnetic moment as small as the predicted by the standard model, the Huge magnetic fields In the SN explosions might generate observable differences in both spectra and number of neutrinos.

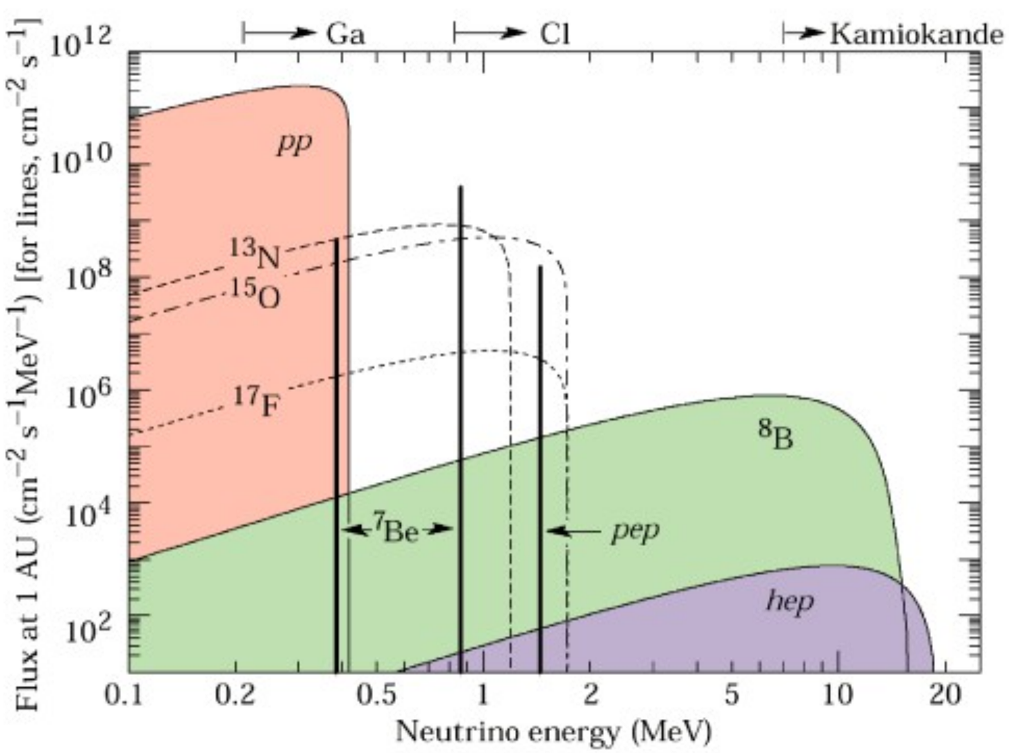


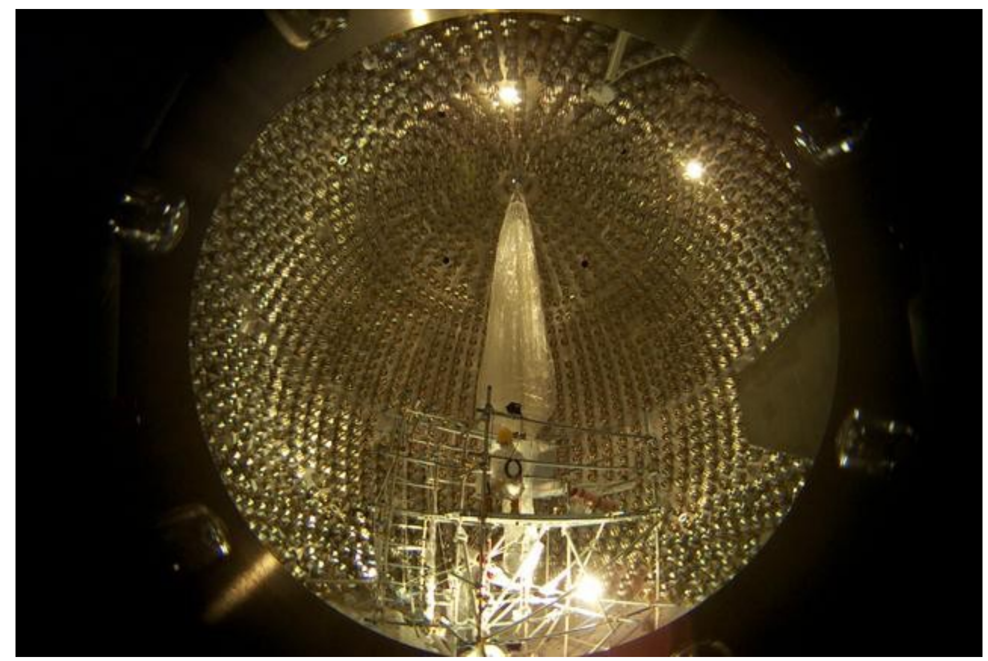
18

Borexino

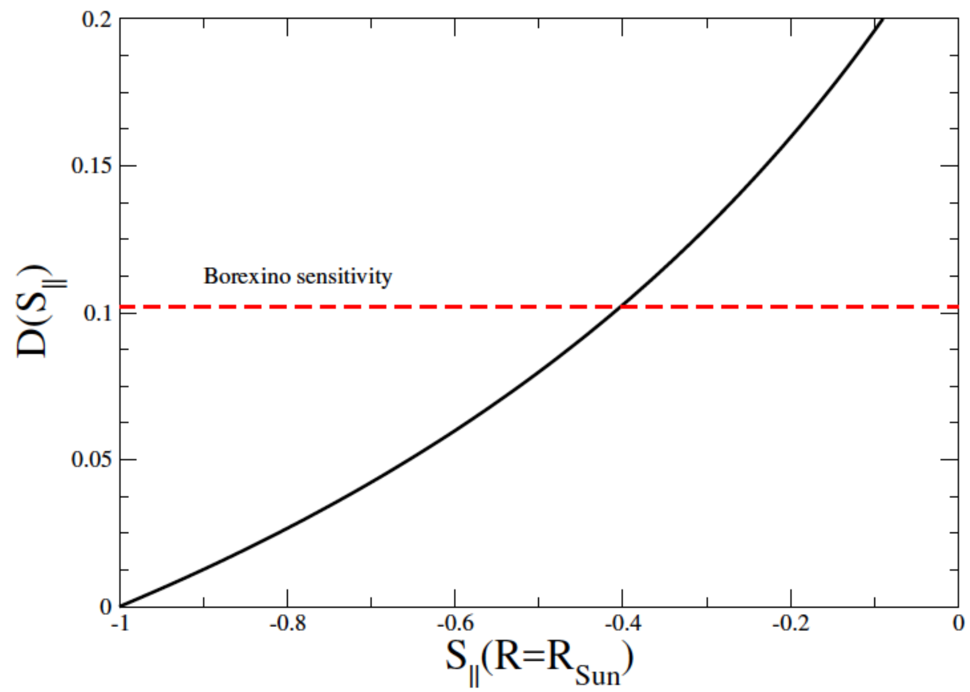
PRL **101,** 091302 (2008) PHYSICAL REVIEW LETTERS week ending 29 AUGUST 2008

Direct Measurement of the ^{7}Be Solar Neutrino Flux with 192 Days of Borexino Data



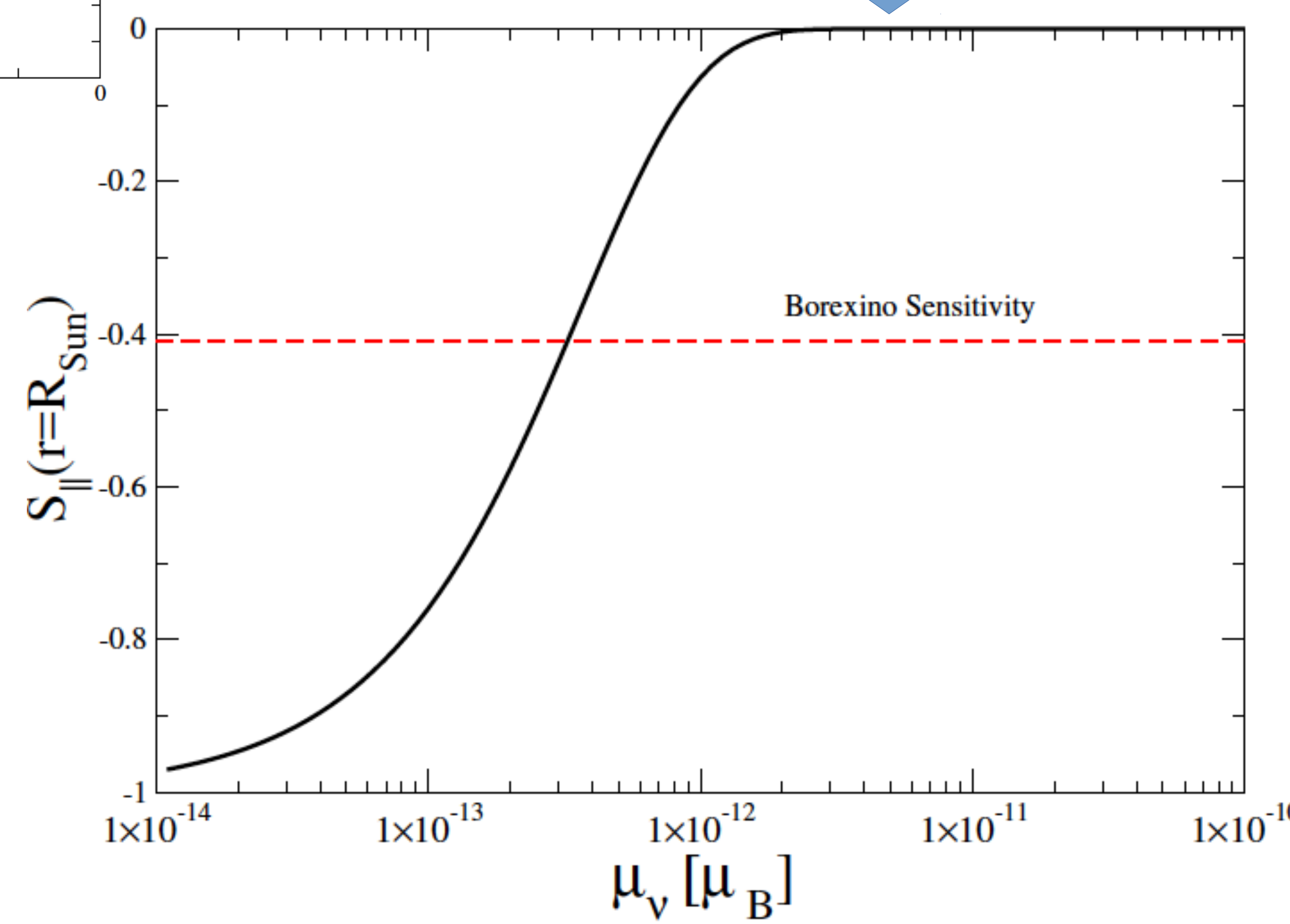


$$\text{Borexino's relative error} = \frac{|\mathrm{N}^{\mathrm{M}} - \mathrm{N}^{\mathrm{D}}|}{\mathrm{N}^{\mathrm{D}}} = \frac{|\sigma^{\mathrm{M}} - \sigma^{\mathrm{D}}|}{\sigma^{\mathrm{D}}} = \mathrm{D}(\mathrm{s}_{||})$$



Borexino relative error = 4%
It implies a maximum value for the Neutrino polarization at the surface of the Sun

Maximum polarization implies an Upper bound on the neutrino magnetic moment



$$\mu_\nu < 3.3 \times 10^{-13} \mu_B.$$

J. Barranco, D. Delepine, M. Napsuciale, A. Yebra arXiv:1704.01549

Fuzzy Dark Matter at neutrino experiments

based on :
VB, J. Kopp, J. Liu, P. Prass, X. Wang arXiv:1705.09455

Vedran Brdar

Johannes Gutenberg Universität Mainz

NUFACT 2017

- in this talk we will focus on the low end of DM spectrum – fuzzy DM with mass $\mathcal{O}(10^{-22})$ eV
- we consider both scalar and vector ultralight DM

Properties of Fuzzy DM candidate

Fuzzy DM can address:

- "core vs. cusp problem"– DM density profile discrepancy between measurements and simulations

$\rightarrow$ DM delocalization
(huge Compton wave length $\lambda = 2\pi/m_\phi \simeq 0.4\,\text{pc} \times (10^{-22}\text{eV}/m_\phi))$

- "missing satellites problem"–lower than expected abundance of dwarf galaxies

$\rightarrow$ higher probability for tidal disruption of DM subhalos and suppression of the matter power spectrum at small scales (Hui et al. 1610.08297)

- "too big to fail problem"– apparent failure of many of the most massive Milky Way subhalos to host visible dwarf galaxies

$\rightarrow$ Fuzzy DM predicts fewer such subhalos (Marsh et al. 1307.1705)

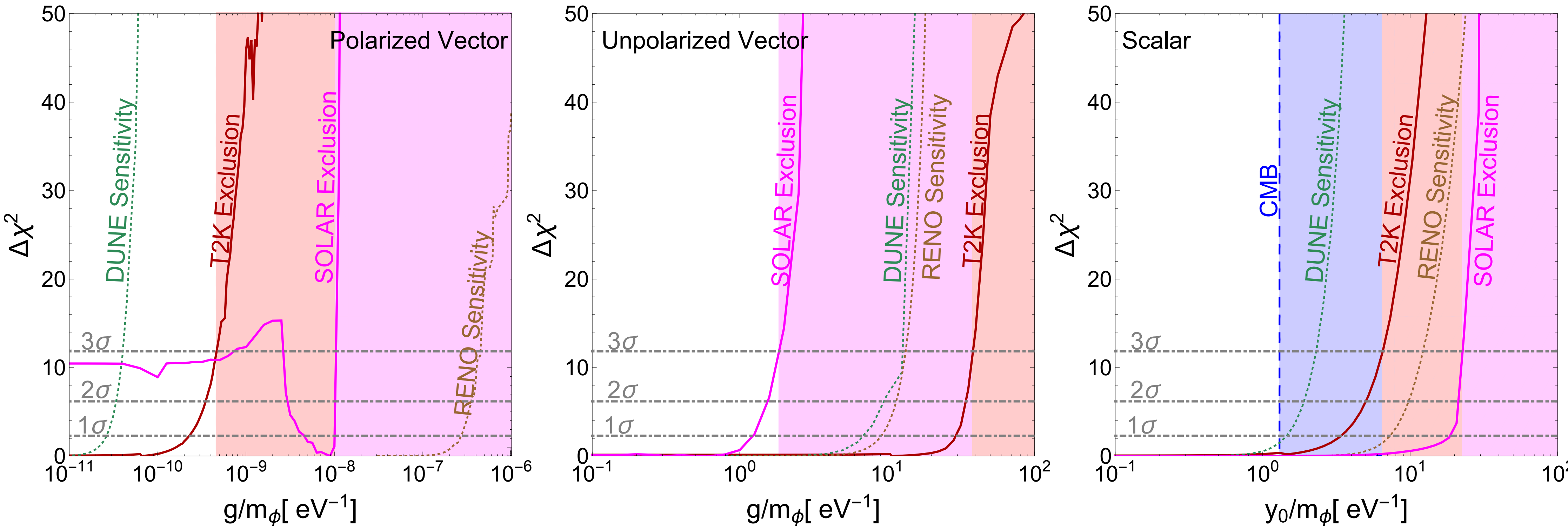
- admittedly, better treatment of baryonic physics in simulations (1602.05957,1202.0554) may solve these puzzles but the possibility that DM physics plays a crucial role is not excluded

Summary

coherent forward scattering of neutrinos on fuzzy dark matter particles can significantly alter neutrino oscillation probabilities.

- fuzzy DM is an interesting alternative to WIMP
- fuzzy neutrinophilic DM has recently received attention (Berlin 1608.01307, Krnjaić et al. 1705.06740)
- we have demonstrated that unique opportunities exist at current and future neutrino oscillation experiments to probe interactions between neutrinos and ultra-light DM particles
- possible connections with LHCb anomalies

Constraints



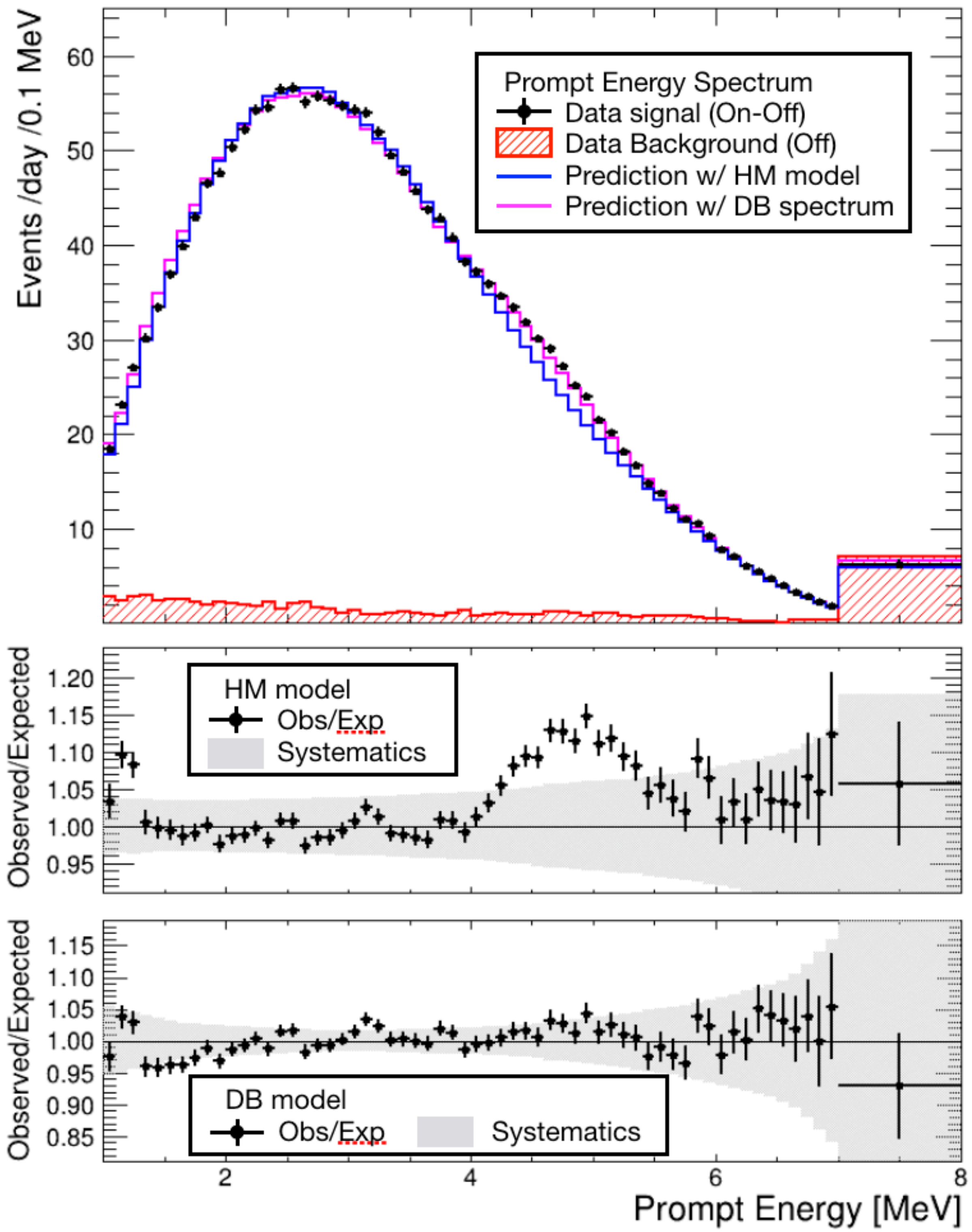
- for vector DM, the sensitivity is more than ten orders of magnitude better in the polarized case
- for scalar and polarized vector DM acceleration-based experiments give stronger limits and sensitivities
- for unpolarized vector DM, experiments at lower energies are better (energy dependence of the potential)

Tuesday 26/9	11:00-12:30	**Recent results on eV-sterile searches (joint session with WG1) Chair: Pilar Hernandez**
	11:00-11:30	Sterile neutrino search at the NEOS experiment
	11:30-12:00	Looking for Sterile Neutrinos via Neutral-Current Disappearance with NOvA
	12:00-12:30	Latest Results from MINOS+ on Sterile Neutrino Search and combined analysis with MINOS, Daya Bay and Bugey-3

Sterile Neutrino Search at the NEOS Experiment

Youngju Ko
Center for Underground Physics at Institute for Basic Science
NEOS Collaboration
September 26, 2017
NUFACT 2017 @ Uppsala University

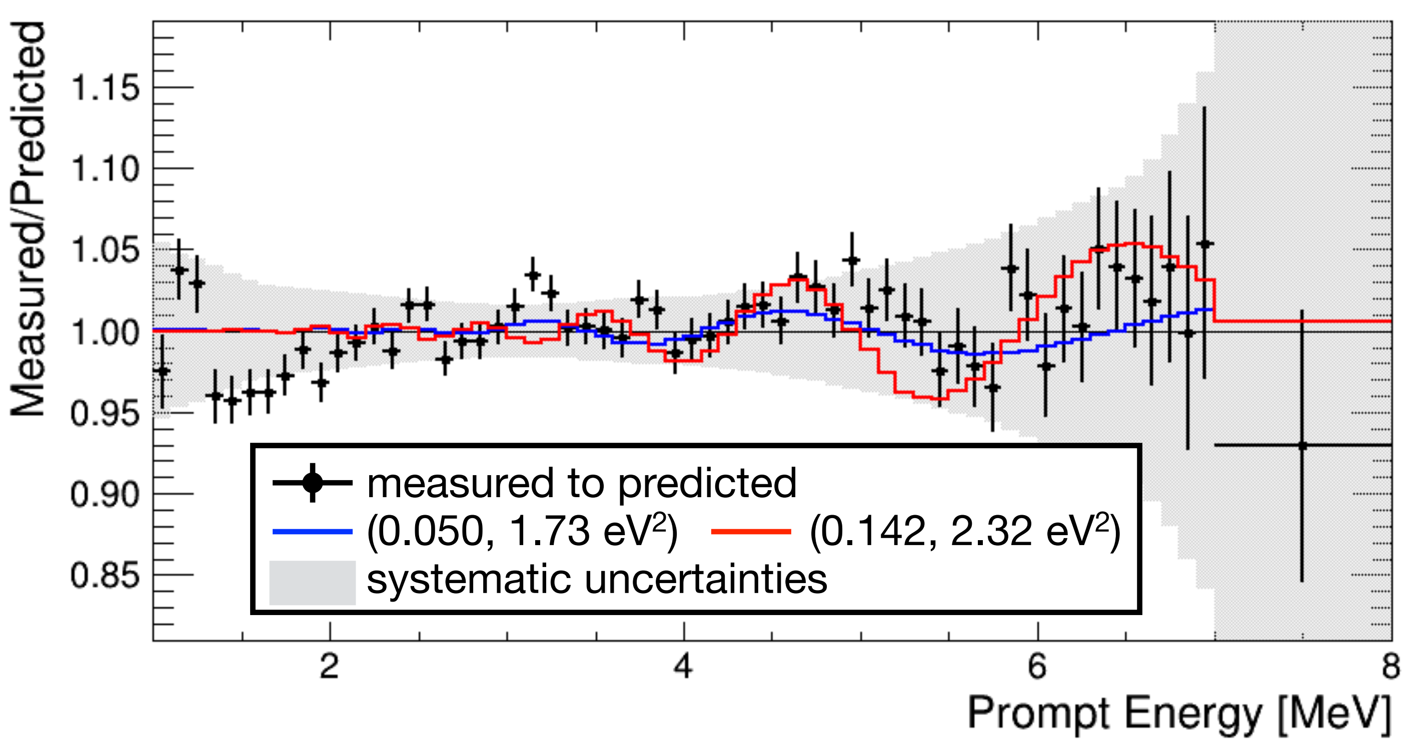
Prompt energy spectrum

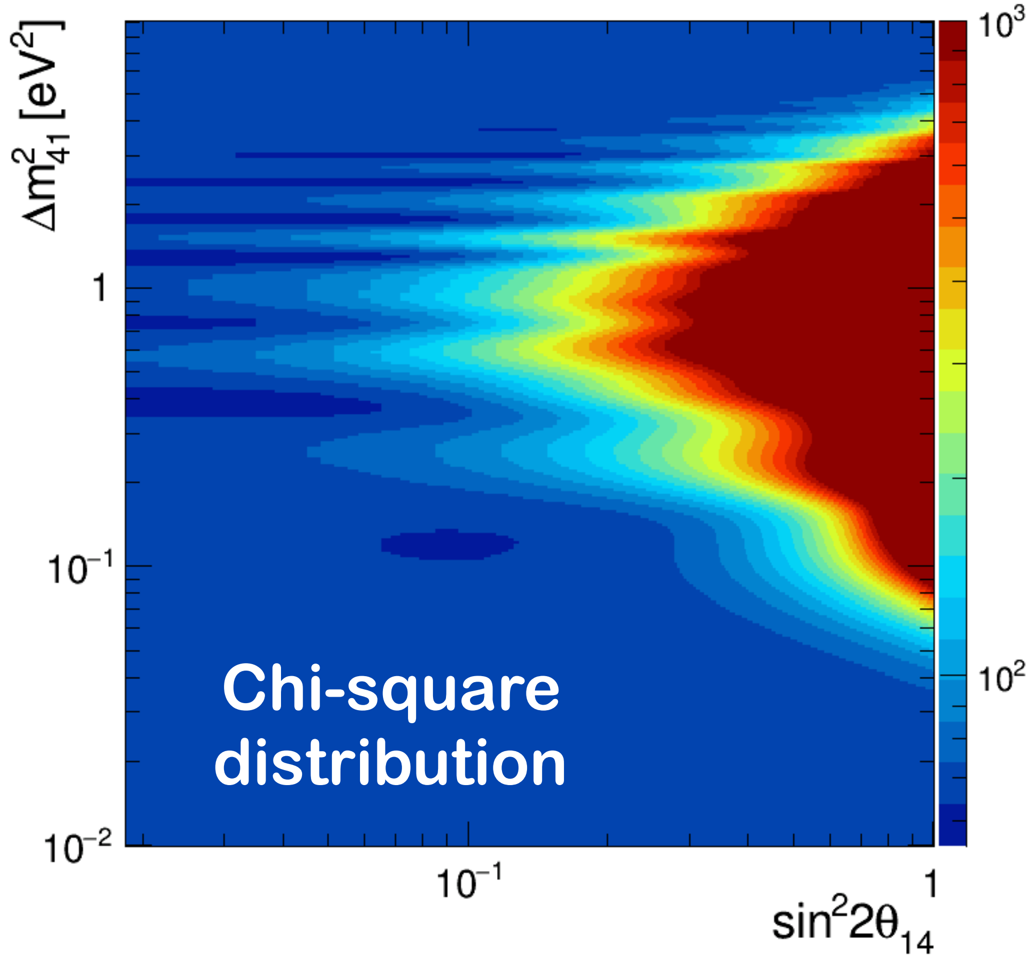


- **S/B ratio ~ 22**
  - **Reactor-on: ~2000 /day**
  - **Reactor-off: ~85 /day**
- **Comparison with HM model**
  - **5-MeV excess**
    - ⇨ **Not suitable for oscillation analysis**
- **Comparison with Daya Bay**
  - **Different fission fraction**
    - ⇨ **Correction with HM**
  - **Generally in an agreement**
  - **Oscillation analysis**
    - **Spectral shape analysis: High dependence on reference spectrum**

Chi-square Distribution

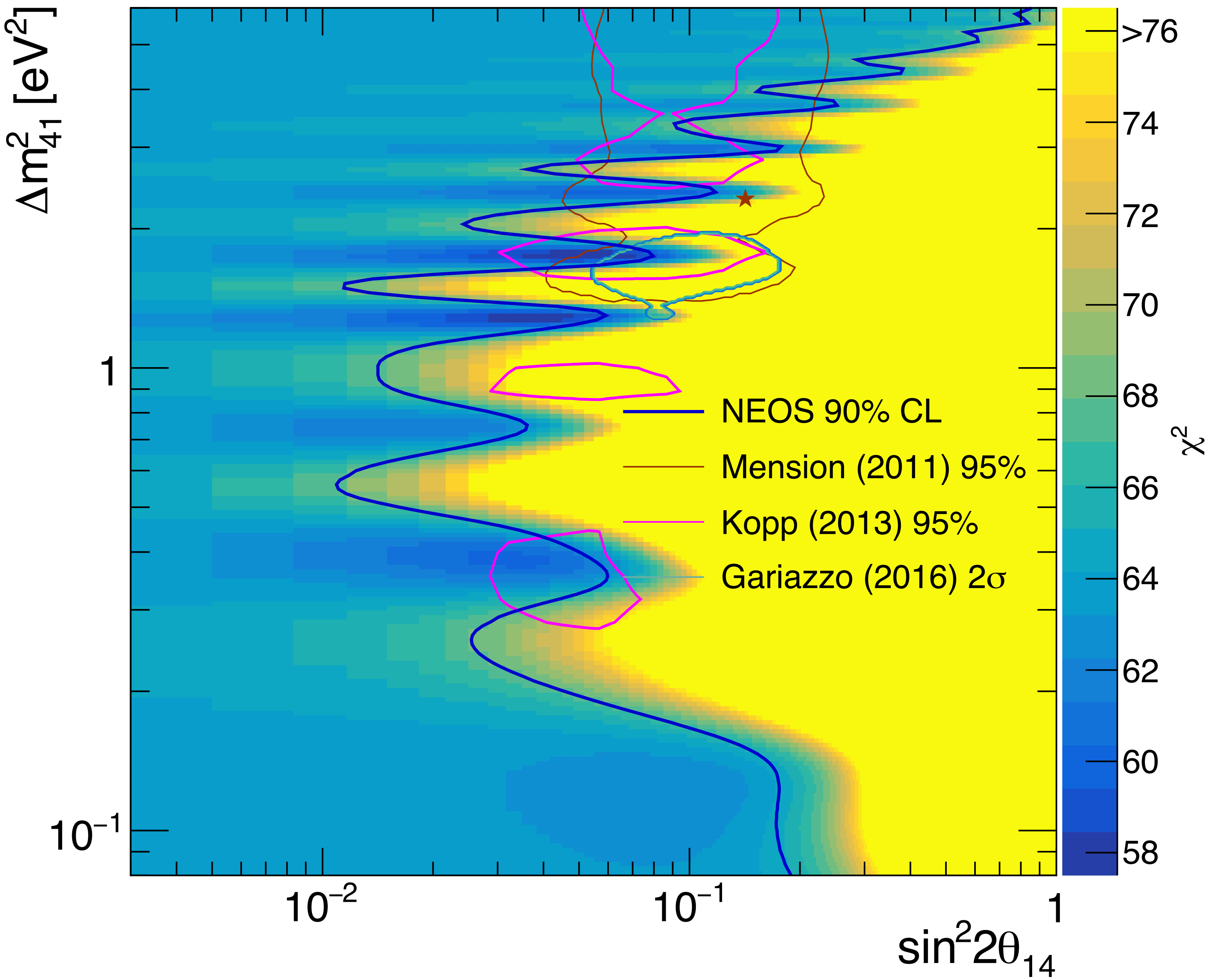
- χ^2 minimum (best fit) with 3+1ν hypothesis
  - $\chi^2_{4\nu}$/NDF = 57.5/59
  - at ($\sin^2 2\theta_{14}$, Δm_{41}^2) = (0.05, 1.73 eV^2)
- χ^2 with 3ν hypothesis
  - $\chi^2_{3\nu}$/NDF = 64.0/61
  - $\Delta\chi^2 = \chi^2_{3\nu} - \chi^2_{4\nu} = 6.5$





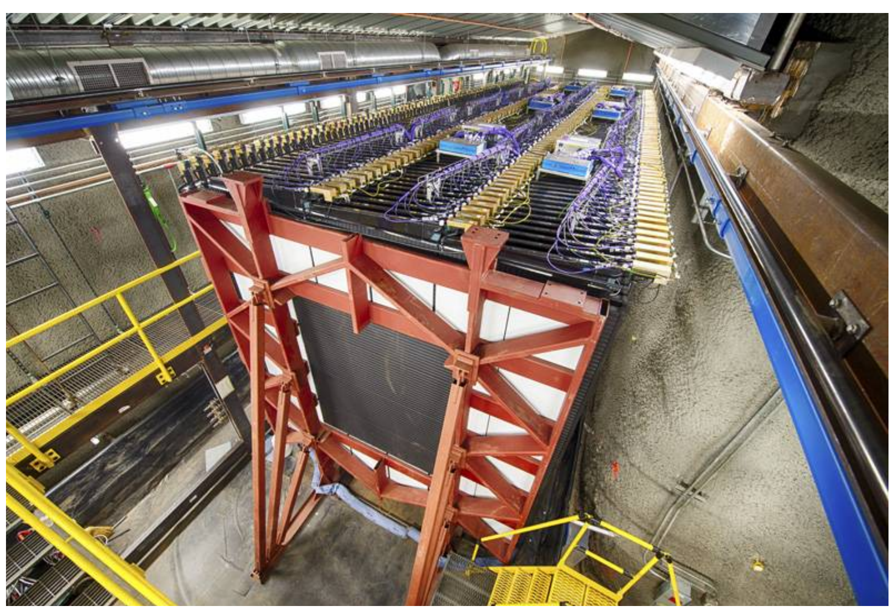
Significance Test and Exclusion Limits

- **Exclusion limits: Raster scan with χ^2 distribution**



arXiv: 1610.05134 / PRL 118, 121802 (2017)

Looking for Sterile Neutrinos via Neutral-Current Disappearance with NOvA



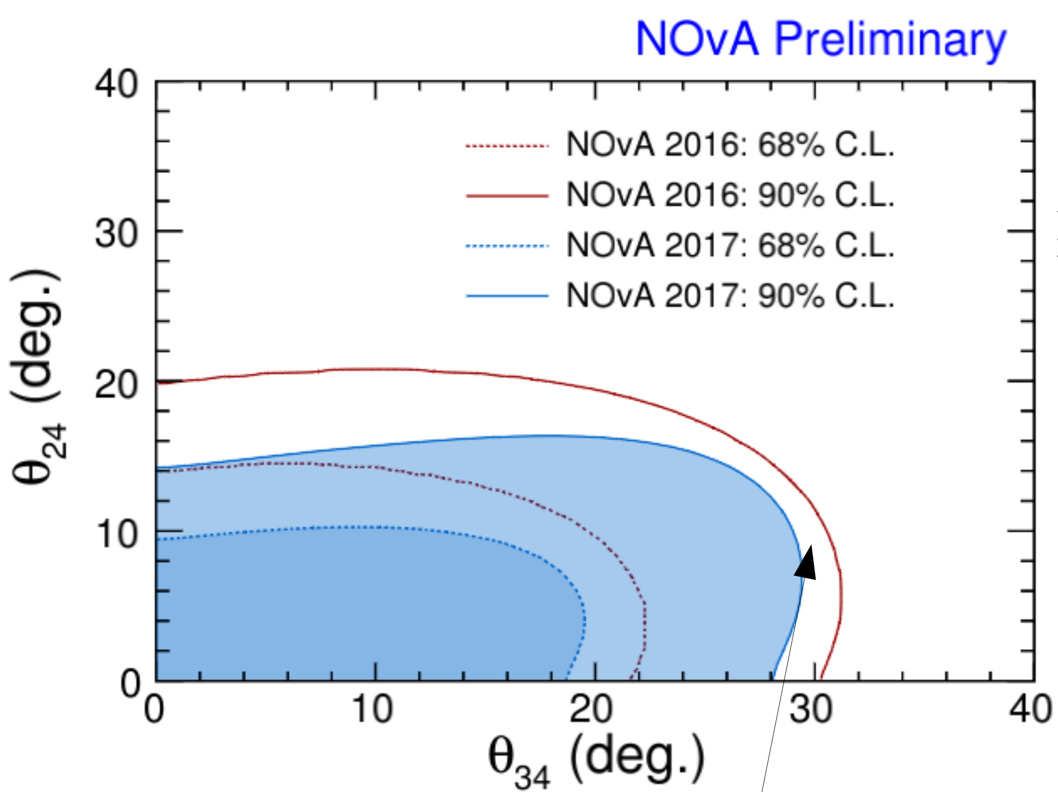
Adam Aurisano
University of Cincinnati

The 19th International Workshop on Neutrinos from Accelerators
26 September 2017

Performed a search for a depletion in the NC rate at the NOvA FD with 8.85×10^{20} POT

- Significant analysis improvements over the 2016 analysis

Shape Fit: 2D 90% C.L. Limits



	θ_{24}	θ_{34}	$\lvert U_{\mu 4}\rvert^2$	$\lvert U_{\tau 4}\rvert^2$
NOvA 2016	20.8°	31.2°	0.126	0.268
NOvA 2017	16.2°	29.8°	0.078	0.228
MINOS	7.3°	26.6°	0.016	0.20
SuperK	11.7°	25.1°	0.041	0.18
IceCube	4.1°	-	0.005	-
IceCube-DeepCore	19.4°	22.8°	0.11	0.15

2016 analysis was a rate only analysis

Fit in the lower octant is the least constraining

NOvA 2017 analysis improves over the NOvA 2016 limit

$\longrightarrow$ θ_{24} by 4.6°

$\longrightarrow$ θ_{34} by 1.4°

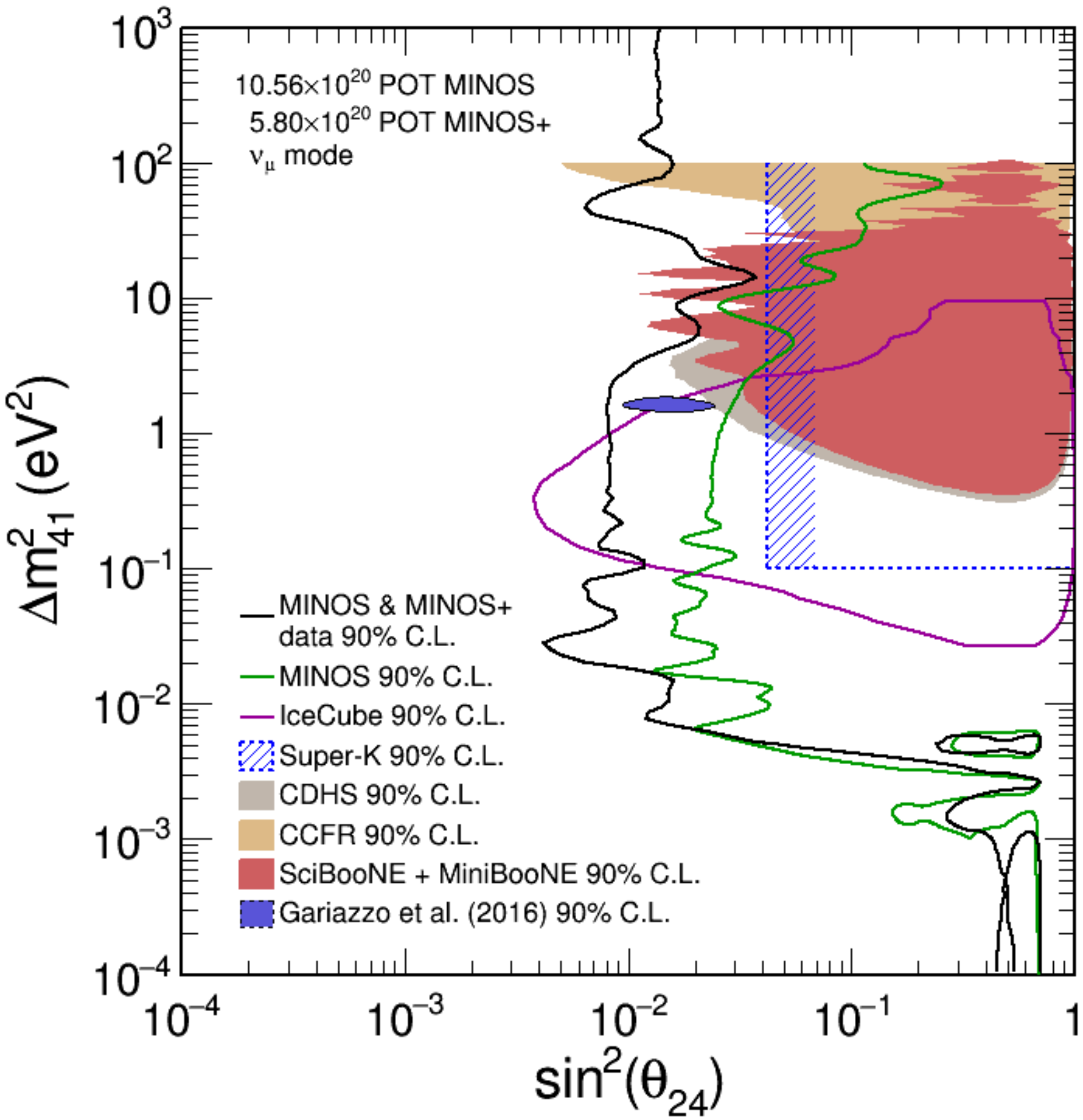
Latest Sterile Neutrino Results from MINOS+
& Combined Analysis with Daya Bay and Bugey-3

Andy Blake, Lancaster University
(for the MINOS+ collaboration)

NuFact Conference, Uppsala University

Tuesday 26th September, 2017

Comparison with Other Experiments



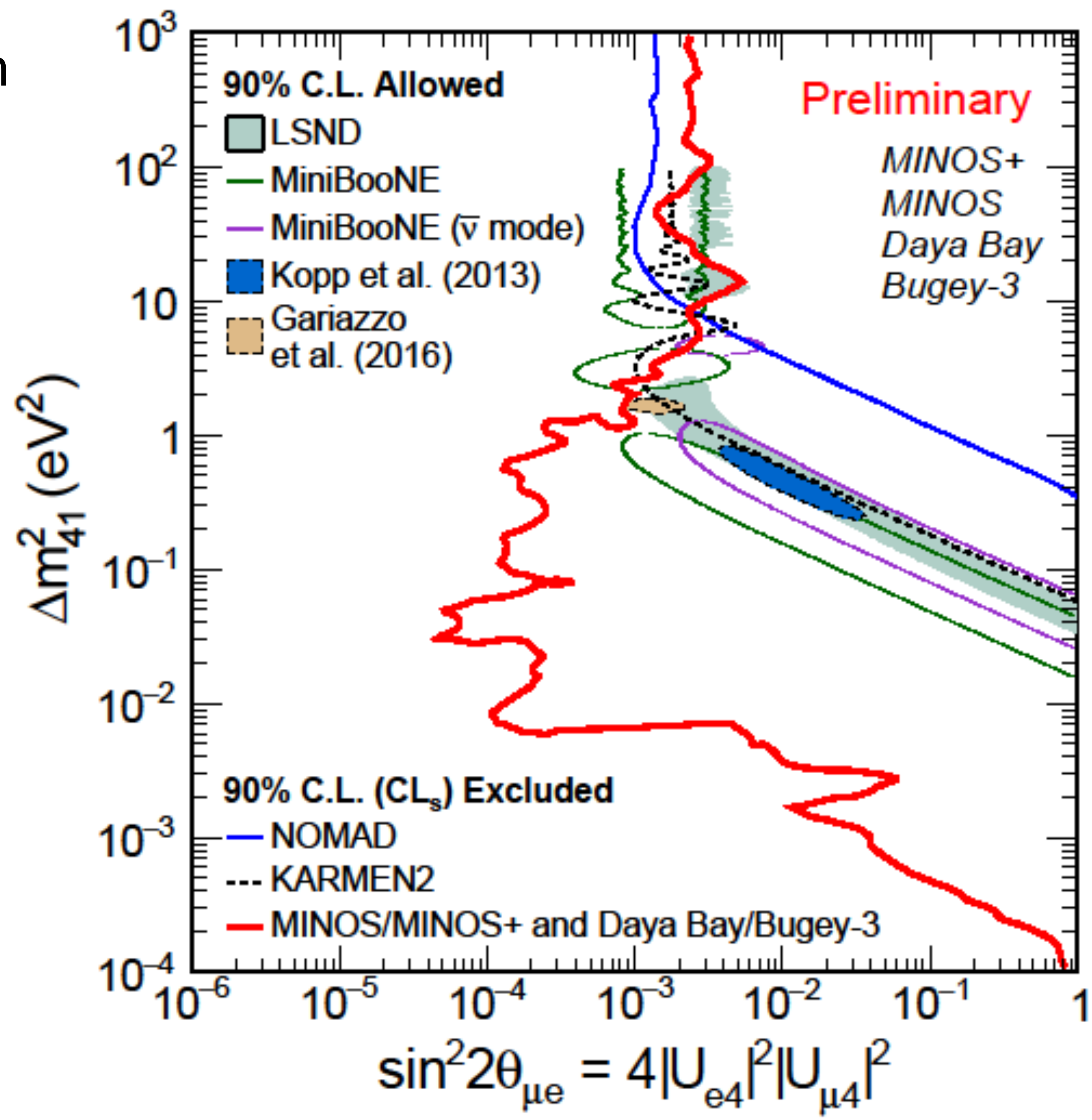
- New MINOS & MINOS+ limit improves upon the previous MINOS analysis.
  - ➢ Limit on θ_{24} is world-leading for much of Δm^2_{41} range.
- Results increase tension with with hints from global fits*.
  - ➢ e.g. fit from Gariazzo et al. is displayed in (Δm^2_{41}, θ_{24}) parameter space by setting $|U_{e4}|^2$=0.023.

(This fit doesn't include data from MINOS or IceCube)

* S. Gariazzo, C. Giunti, M. Laveder, Y.F. Li, E.M. Zavanin, J. Phys. G43, 033001 (2016)

New Combined Result

- New preliminary result from the ongoing collaboration between MINOS/MINOS+ and Daya Bay (with the inclusion of Bugey-3).
- No evidence for 3+1 sterile neutrino oscillations.
- Strong exclusion limits on $\sin^2 2\theta_{\mu e}$ are obtained for a wide range of Δm^2_{41}.



J. Kopp, P. Machado, M. Maltoni, T. Schwetz, JHEP 1305:050 (2013)

S. Gariazzo, C. Giunti, M. Laveder, Y.F. Li, E.M. Zavanin, J.Phys. G43 033001 (2016)

	14:00-15:30	**Non-Standard Interactions in oscillation experiment Chair: Andre De Gouvea**
	14:00-14:30	Study of non-standard charged-current interactions at the MOMENT experiment
	14:30-15:00	The sensitivity of the T2HKK experiment to the flavor-depednent non-standard interactions
	15:00-15:30	Non-Standard Interactions with High-energy Atmospheric Neutrinos at IceCube

Study of CC-NSIs at the MOMENT experiment

Jian Tang

Sun Yat-Sen University, Guangzhou, China

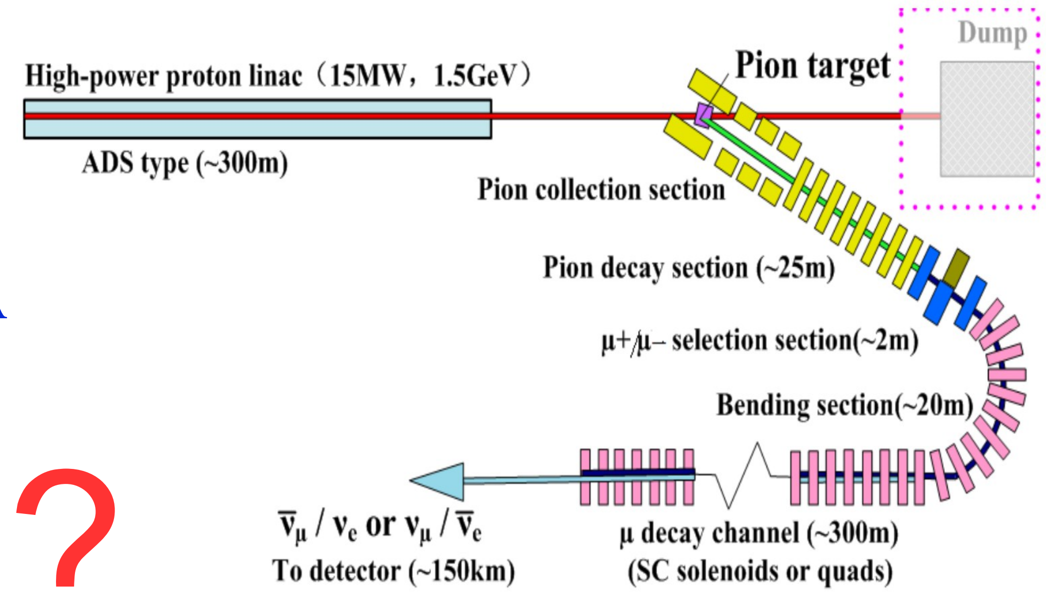
NuFact2017@Uppsala, Sweden

Based on the work with Yibing Zhang
arXiv: 1705.09500

Chinese proposal: MuOn-decay Medium baseline NeuTrino beam experiment (MOMENT)

- **Neutrino flux: 200-300 MeV**
- **Baseline: 150 km**
- **Proton beam: 1.5-2.0 GeV**
- **Intensity of proton beam: 10 mA**
- **POT/y: 1.1*e+24**
- **Neutrino flavors:**

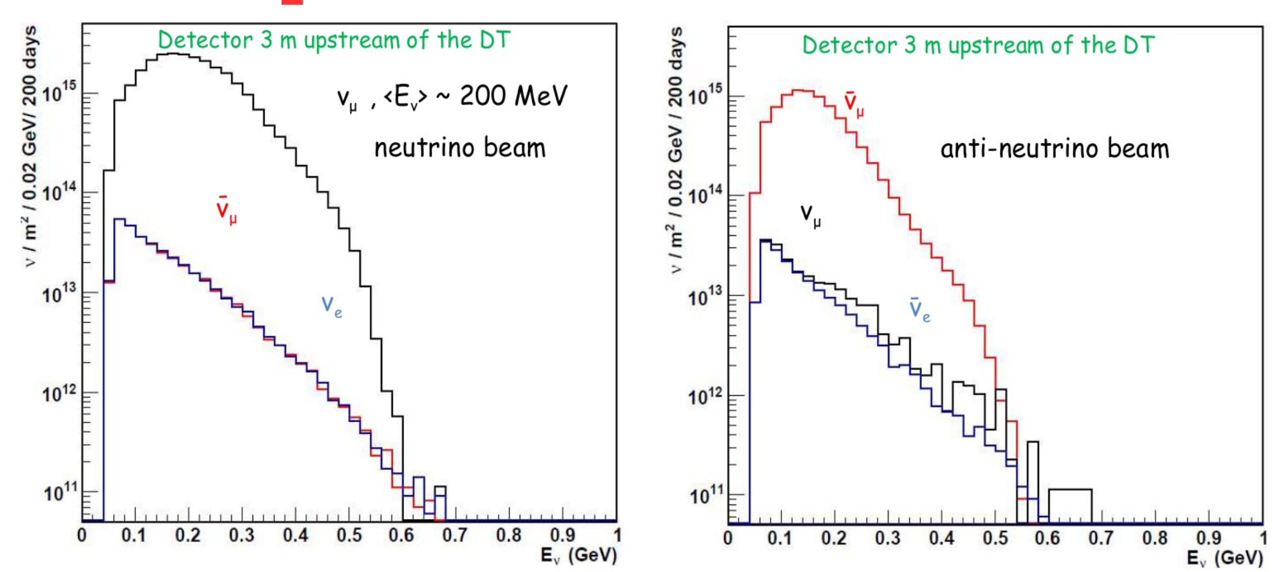
$$+ \;:\; \mu^- \to e^- + \bar{\nu}_e + \nu_\mu$$
$$- \;:\; \mu^+ \to e^+ + \nu_e + \bar{\nu}_\mu$$



?

The proposal sells the design of accelerators with plenty of room for imagination of detectors.

- Which type of detector?
- What kind of physics can we do?



Jian Tang School of Physics 6

Summary

- **We have studied CC-NSI effects with ND+FD at MOMENT.**
- **We have found some improvements of bounds on CC-NSIs at MOMENT.**
- **NSIs destroy the precision measurements of standard mixing parameters.**
- **Degeneracies between NSI and standard mixing parameters deserve further study.**

Parameter	ND constraints	FD constraints	ND+FD constraints	Current bounds
$\lvert\epsilon^s_{ee}\rvert$	0.027	0.028	0.018	0.025
$\lvert\epsilon^s_{e\mu}\rvert$	0.023	0.018	0.014	0.03
$\lvert\epsilon^s_{e\tau}\rvert$	n/a	0.065	0.065	0.03
$\lvert\epsilon^s_{\mu e}\rvert$	0.025	0.021	0.015	0.025
$\lvert\epsilon^s_{\mu\mu}\rvert$	0.028	0.029	0.019	0.03
$\lvert\epsilon^s_{\mu\tau}\rvert$	n/a	0.054	0.054	0.03
$\lvert\epsilon^d_{ee}\rvert$	0.027	0.028	0.027	0.041
$\lvert\epsilon^d_{e\mu}\rvert$	0.023	0.015	0.013	0.026
$\lvert\epsilon^d_{\mu e}\rvert$	0.025	0.022	0.025	0.025
$\lvert\epsilon^d_{\mu\mu}\rvert$	0.028	0.03	0.028	0.078
$\lvert\epsilon^d_{\tau e}\rvert$	n/a	0.065	0.065	0.041
$\lvert\epsilon^d_{\tau\mu}\rvert$	n/a	0.054	0.054	0.013

Thank you for your attention!

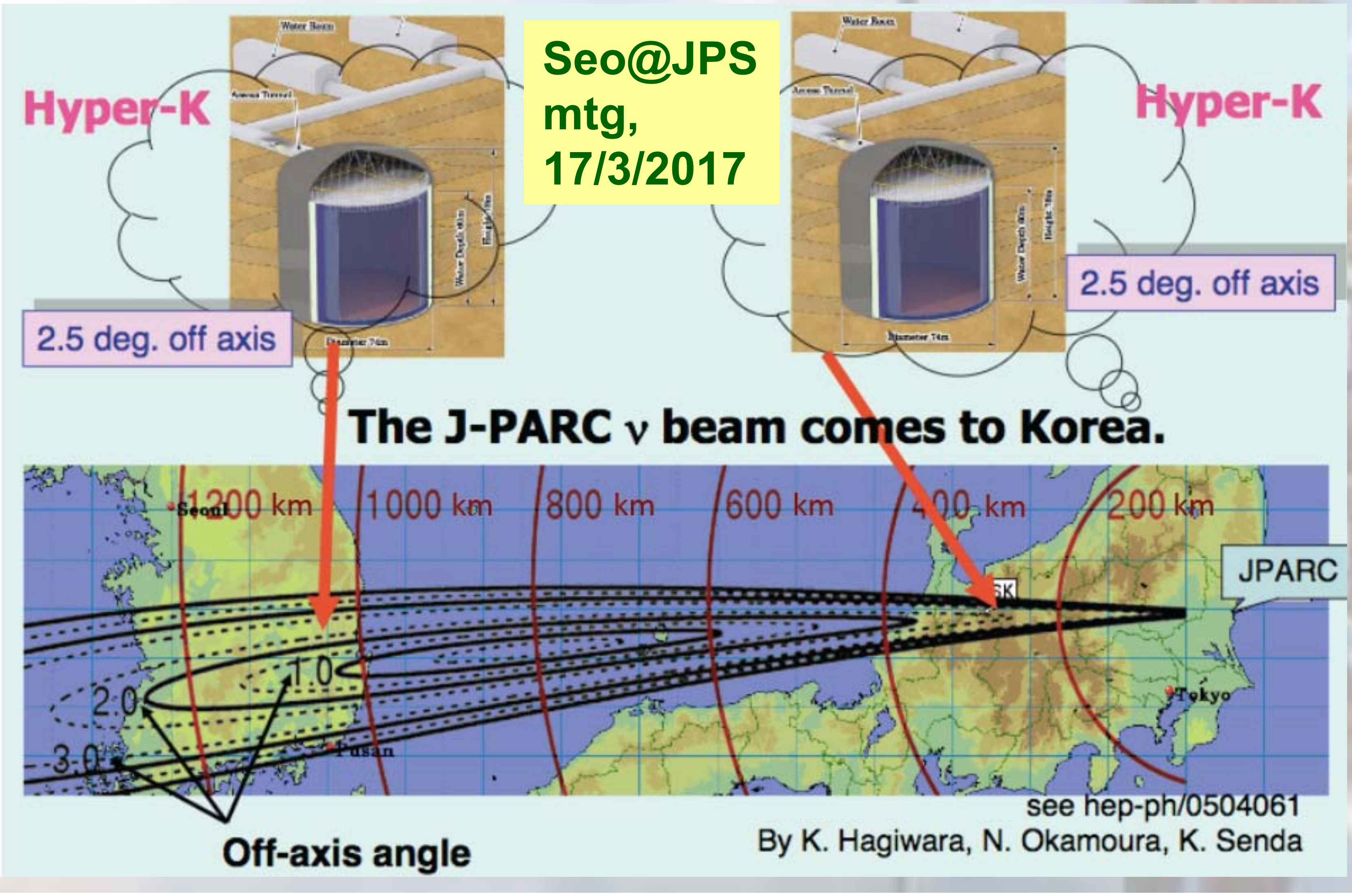
Sensitivity of T2HKK to non-standard flavor-dependent interactions

Osamu Yasuda
Tokyo Metropolitan University

Sep. 26, 2017
WG5, NuFact 2017@ Uppsala, Sweden

Future plan: T2HKK

Recent revival of old T2KK idea in 2005:
T2HKK proposal w/ baselines L=295km, 1100km
→L=1100km is sensitive to the matter effect



Seo@JPS mtg, 17/3/2017

6/31

List of New Physics discussed in ν phenomenology

Scenario beyond SM+m_ν	Experimental indication ?	Phenomenological constraints on the magnitude of the effects
Light sterile ν	Maybe	O(10%)
NSI at production / detection	×	O(1%)
NSI in propagation	Maybe	e-τ: O(100%) Others: O(1%)
Unitarity violation due to heavy particles	×	O(0.1%)

NSI: discussed in this talk

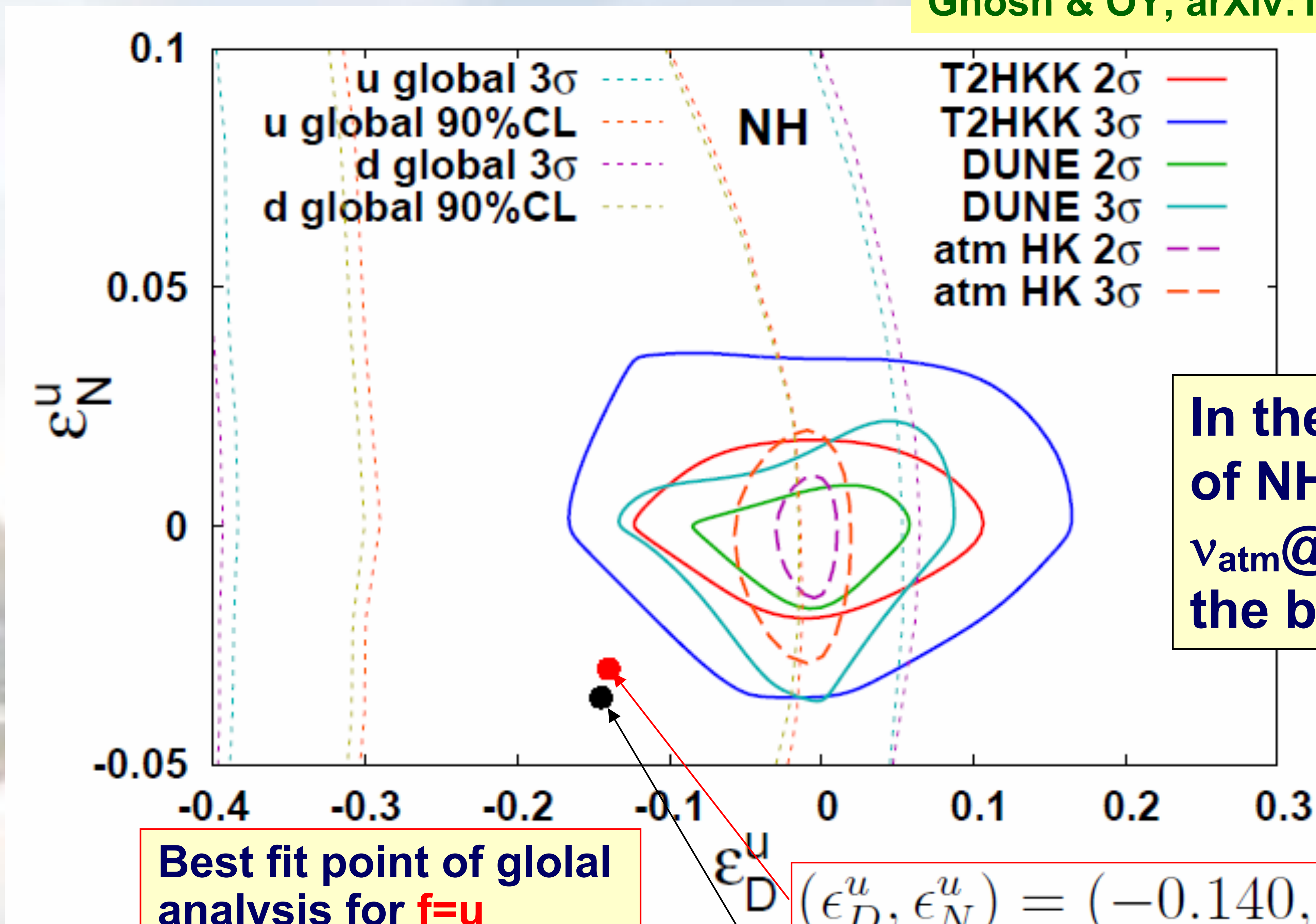
9/31

4. Conclusions

- T2HKK and DUNE have sensitivity to NSI and they cover some of the allowed region in the (ε^f_D, ε^f_N)-plane suggested by the solar ν tension for δ(true) = -90°.
- Sensitivity of DUNE is slightly better than that of T2HKK because DUNE uses information of wide E_ν spectrum.
- Dependence of T2HKK on θ_{23}(true) & δ(true) was found and if δ(true) = 180°, then significance of the best-fit point becomes lower.

●Comparison of sensitivity T2HKK, DUNE, ν_{atm}@HK

Ghosh & OY, arXiv:1709.08264



In the case of NH, ν_{atm}@HK is the best

Best fit point of glolal analysis for f=u

$$(\epsilon^u_D, \epsilon^u_N) = (-0.140, -0.030)$$

Best fit point of glolal analysis for f=d

$$(\epsilon^d_D, \epsilon^d_N) = (-0.145, -0.036)$$

27/31

NSI with High-Energy Atmospheric ν's at IceCube

N. Rius

IFIC, Univ. Valencia - CSIC

With **Jordi Salvado, Olga Mena and Sergio Palomares-Ruiz**, **JHEP 1701(2017) 141**

- Relative size of NSI and standard oscillations depends on neutrino energy:
  - E_ν < 1 GeV ⟹ vacuum oscillations dominate
  - 1 GeV < E_ν < 10 GeV ⟹ intereference NSI – vacuum osc.
  - E_ν > 10 GeV ⟹ NSI may dominate
- NSI affect ν's propagation in a medium
- Atmospheric ν's span a huge range of neutrino energies, 10^{-1} – 10^5 GeV and of neutrino baselines crossing the Earth, 10 – few 10^3 km ⟹ disentangling NSI and standard oscillations

⟹ **ideal tool to test and constrain NSI !!!**

Current bounds:

- SK limit: SK Collab. 2011

$$|\varepsilon_{\mu\tau}| < 1.1 \times 10^{-2} \qquad 90\% \text{ C.L.}$$

- 79-string IceCube configuration + DeepCore data:

$$-6.1 \times 10^{-3} < \varepsilon_{\mu\tau} < 5.6 \times 10^{-3} \,, \qquad 90\% \text{ C.L.}$$

Esmaili, Smirnov 2013

- Analysis of 3-year IceCube-DeepCore data:

$$-6.7 \times 10^{-3} < \varepsilon_{\mu\tau} < 8.1 \times 10^{-3} \qquad 90\% \text{ C.L.} \qquad \varepsilon' = 0$$

IceCube collaboration, arXiv:1709.07079

- Our limit (HG-GH-H3a + QGSJET-II-49):

$$-6.0 \times 10^{-3} < \varepsilon_{\mu\tau} < 5.4 \times 10^{-3} \,, \qquad 90\% \text{ credible interval (C.I.).}$$

Salvado et al. 2016

Wednesday 27/9	11:30-12:30	**Sterile neutrinos in long-baseline experiments** **Chair: Antonio Palazzo**
	11:30-12:00	Parameter degeneracy and hierarchy sensitivity of NOvA in presence of sterile neutrino
	12:00-12:30	DUNE Sensitivities to the mixing between Sterile and Tau Neutrinos

Parameter degeneracy and hierarchy sensitivity of NOνA in presence of sterile neutrino

Monojit Ghosh

Tokyo Metropolitan University
Tokyo, Japan

Nufact 2017
Uppsala University, Uppsala, Sweden
September 25-30, 2017

Based on: MG, S. Gupta, Z. M. Matthews, P. Sharma and A. G. Williams, 1704.04771 (To appear in PRD)

Summary

- We have identified two new degeneracies
- There are unsolved degenerate region in the 3+1 case
- Hierarchy sensitivity get affected depending on the true value of δ_{14}
- If the observed hierarchy sensitivity is less than expected: hint for sterile neutrinos

DUNE sensitivities to the mixing between sterile and tau neutrinos

Based on arXiv:1707.05348

David Vanegas Forero

IFGW - UNICAMP

NUFACT
September 27th, 2017

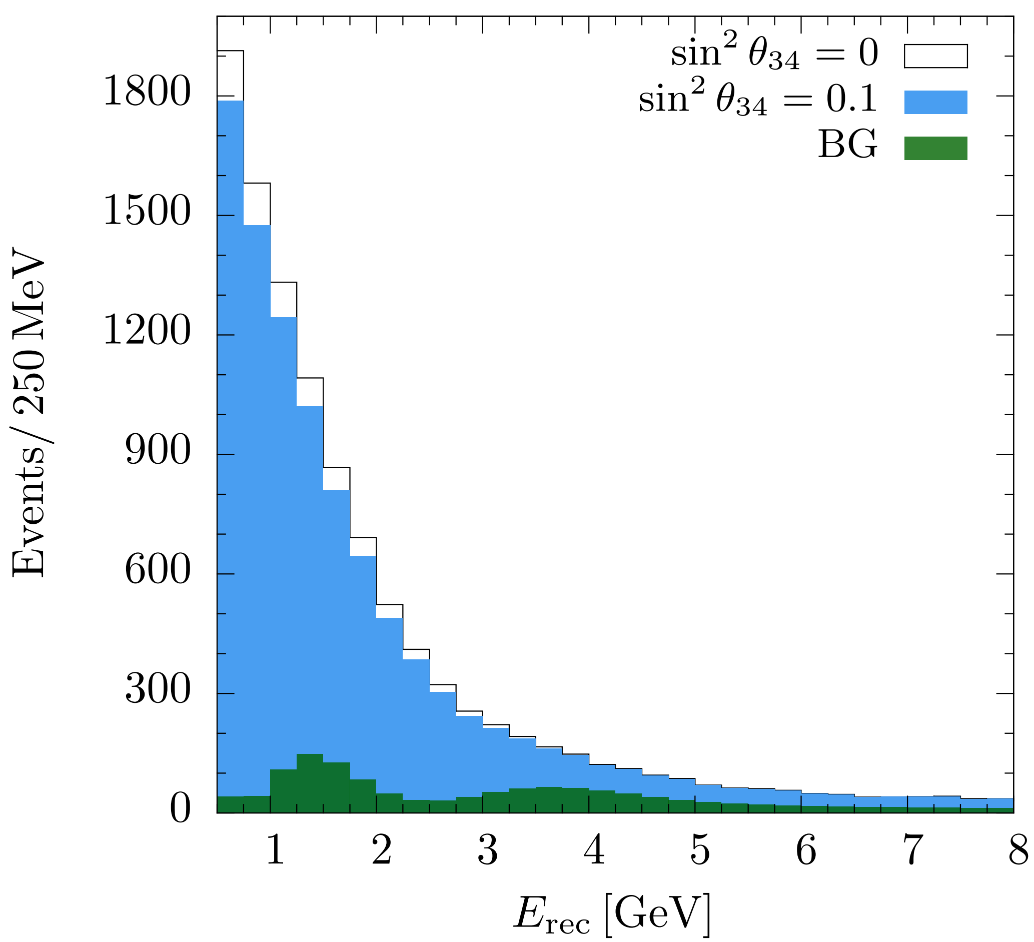
Conclusions

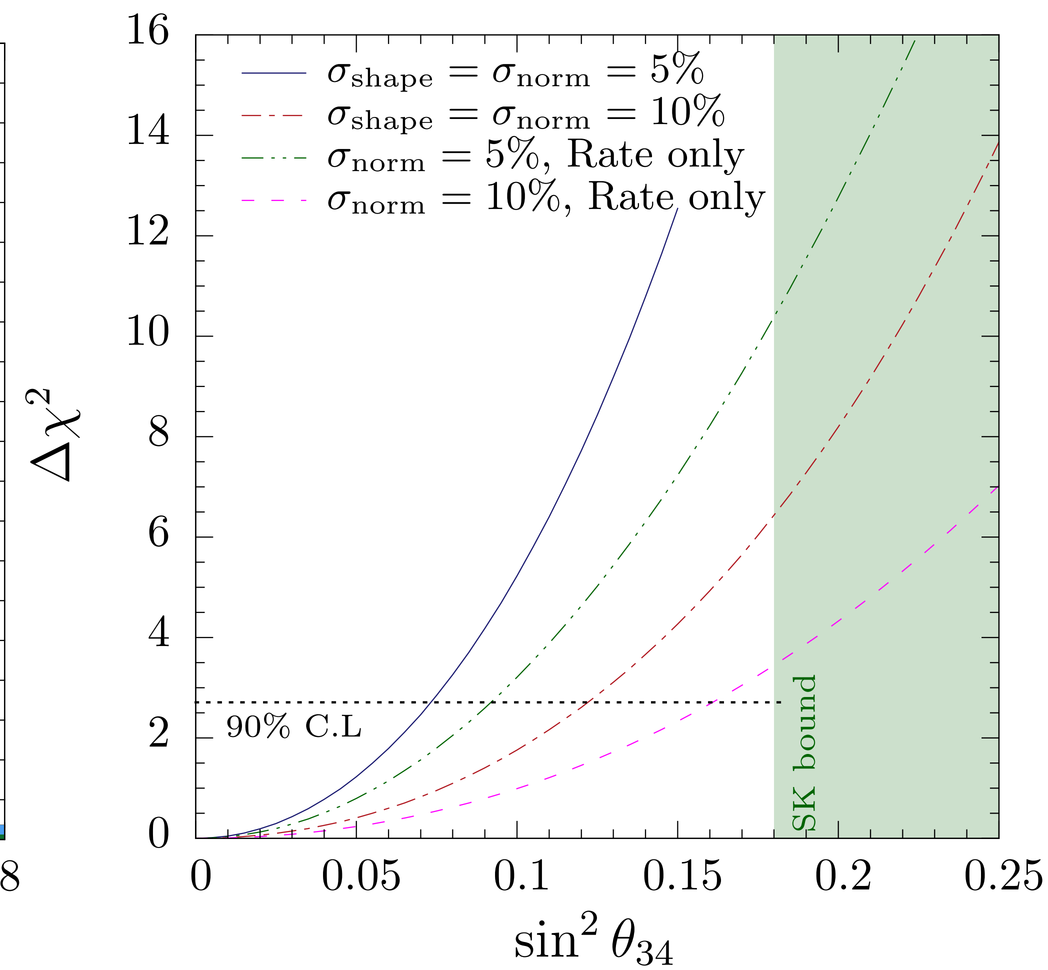
- We have derived the ν_s app. oscillation prob in vacuum and studied it in different regimes focusing in CP-violating effects due to the new phases, and we found that for some of its values, and in a given oscillation regime, cancellations in the osc. amplitude can be produced.
- Taking advantage of the excellent capabilities of liquid Argon to discriminate between CC and NC events, we have perform three different studies considering sterile neutrino oscillations (in the 3+1 scheme) at the DUNE FD by the use NC events.
- Given the current and future limits on the θ_{14}, θ_{24} sterile-active mixing angles, the case $\theta_{24} = \theta_{14} = 0$ becomes relevant by the time DUNE will be running.
  - In this case, the ν_s app. prob. is independent of Δm^2_{41} and δ_{24}, providing a unique sensitivity to the tau-sterile mixing angle.
  - Assuming 10% systematics, DUNE will be sensitive to values of $\sin^2\theta_{34} \sim 0.12$ (at 90% CL) improving the current constraints. If systematic errors could be reduced down to 5%, the experimental sensitivity would reach $\sin^2\theta_{34} \sim 0.07$ (at 90% CL).

First analysis, constraining the tau-sterile mixing

Let us consider the simpler case of having only a non-trivial tau-sterile mixing:

$$P_{\mu s}(\theta_{24} \to 0) = c_{13}^4 \sin^2 2\theta_{23} s_{34}^2 \sin^2 \Delta_{31} .$$





$\theta_{24} \to 0$ case: $P_{\mu s}$ is Δm_{41}^2-independent $\to$ no effect on the ND.

At FD the oscillation is driven by the atmospheric scale. So, a clean constraint on θ_{34} can be obtained!

Thursday 28/9	14:00-16:00	**Dark matter searches at neutrino experiments Chair: Stefan Antusch**
	14:00-14:30	Dark Matter Search in the Miniboone Proton Beam Dump experiment
	14:30-15:00	Mini-review on boosted Dark Matter signatures at neutrino experiments
	15:00-15:30	Indirect searches of Galactic diffuse dark matter in INO-MagICAL detector
	15:30-16:00	Neutrino Lines from Majoron Dark Matter

New Mexico State University
All About Discovery!
nmsu.edu

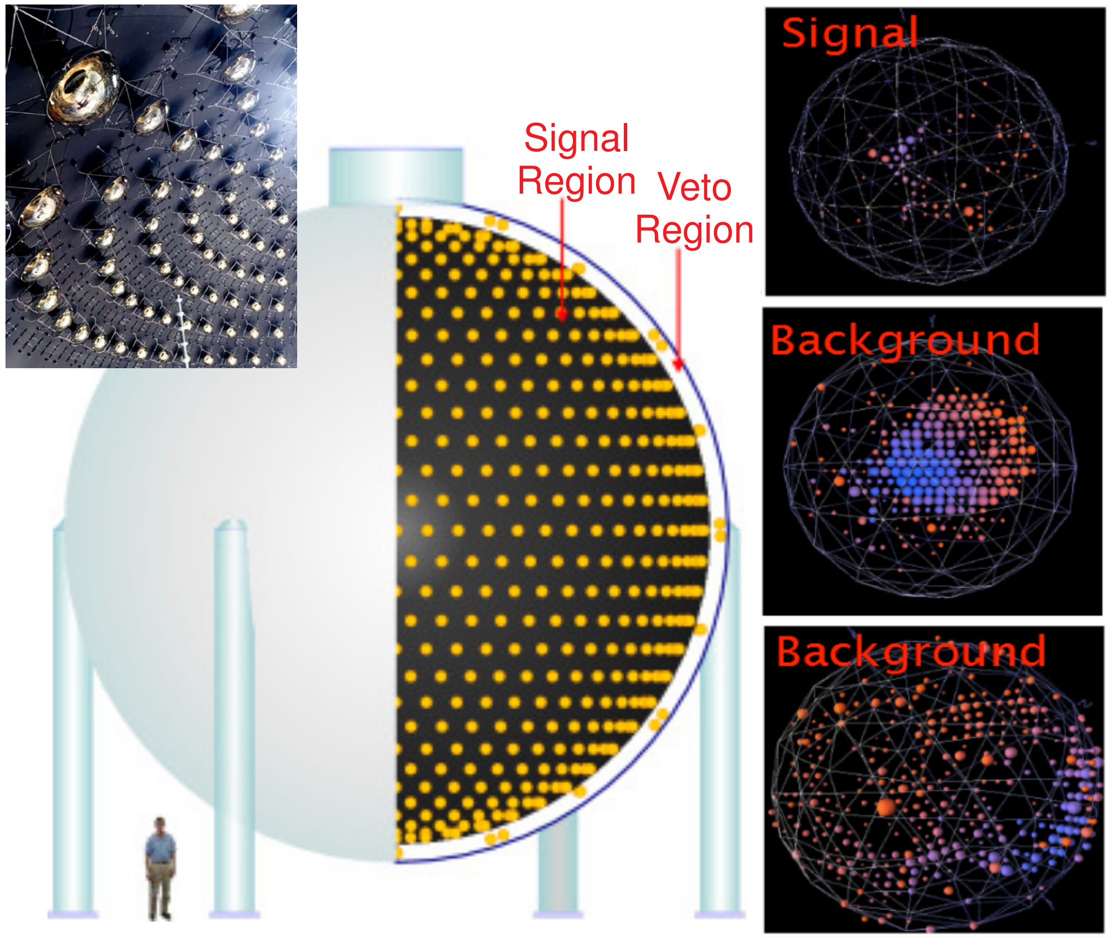
Dark Matter Search in the MiniBooNE Proton Beam Dump Experiment

R.L. Cooper
New Mexico State University / LANL

On behalf of the MiniBooNE-DM Collaboration

The MiniBooNE Detector

- 800 tons pure mineral oil (CH_2) Cherenkov tracker with some scintillation from trace fluors
- Inner region 1280 × 8" PMTs Outer veto region 240 × 8" PMTs (10% photocathode coverage)
- Excellent PID
- **Detector is very well characterized**

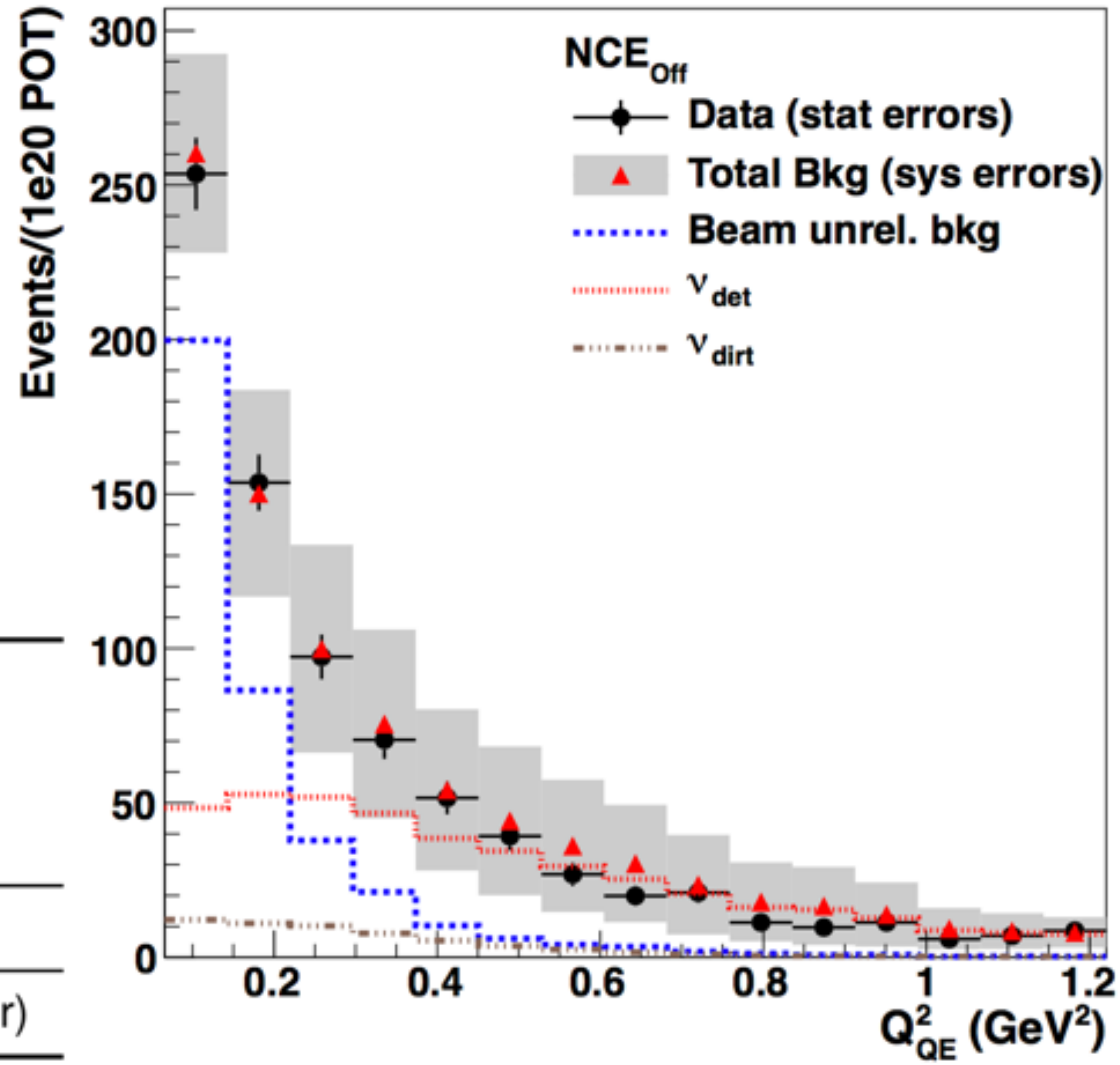


A.A. Aguilar-Arevalo et al., *Nucl. Instrum. Meth.* **A599** (2009) 28. arXiv:0806.4201 [hep-ex].

Nucleon NC-Like Events – No Excess

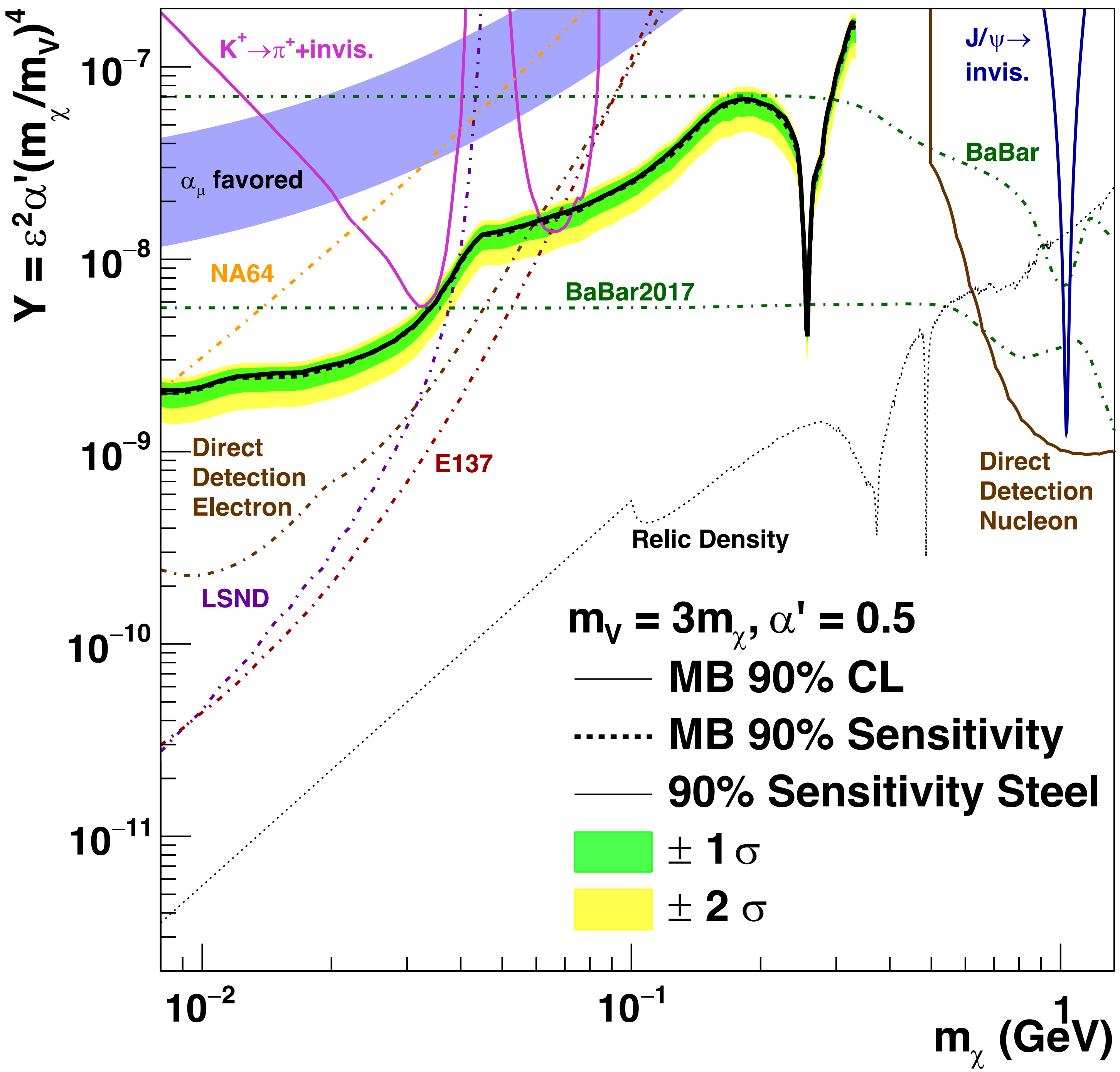
- A significant excess found with simple search
- Large uncertainties → must improve!
- Use auxiliary channels with correlated errors

	#events	uncertainty
BUB	697	
ν_{det} bkg	775	
ν_{dirt} bkg	107	
Total Bkg	1579	33.5% (pred. sys.)
Data	1465	2.6% (stat.)
Fit Results	1548	12.8% (fit effective error)



Confidence Limit Results

- Many ways to "slice" parameter space
- This parameter choice is rejected as solution for *g-2* anomaly (Vector Portal)



Boosted Dark Matter Signatures at Neutrino Experiments

Yue Zhao

TDLI & SJTU
MCTP, University of Michigan

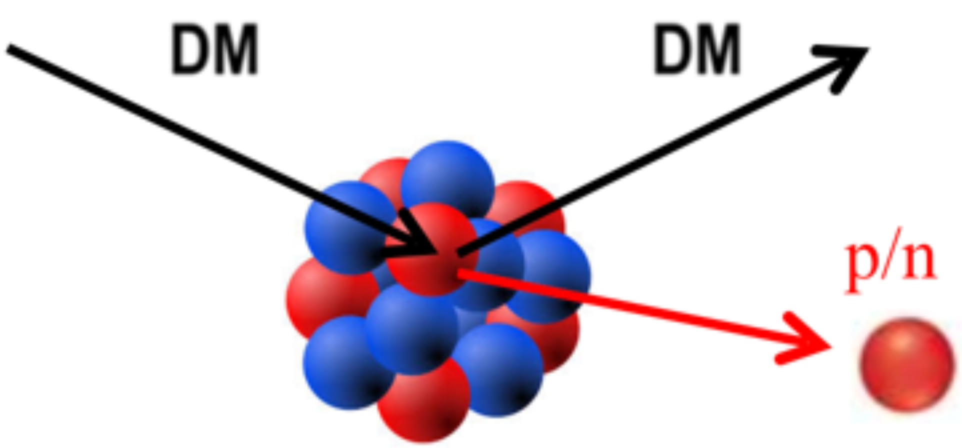
NuFact2017, WG5

Boosted DM detection Channels:

Boosted DM detection:

⇨ DM particle is energetic enough to knock a nucleon out!

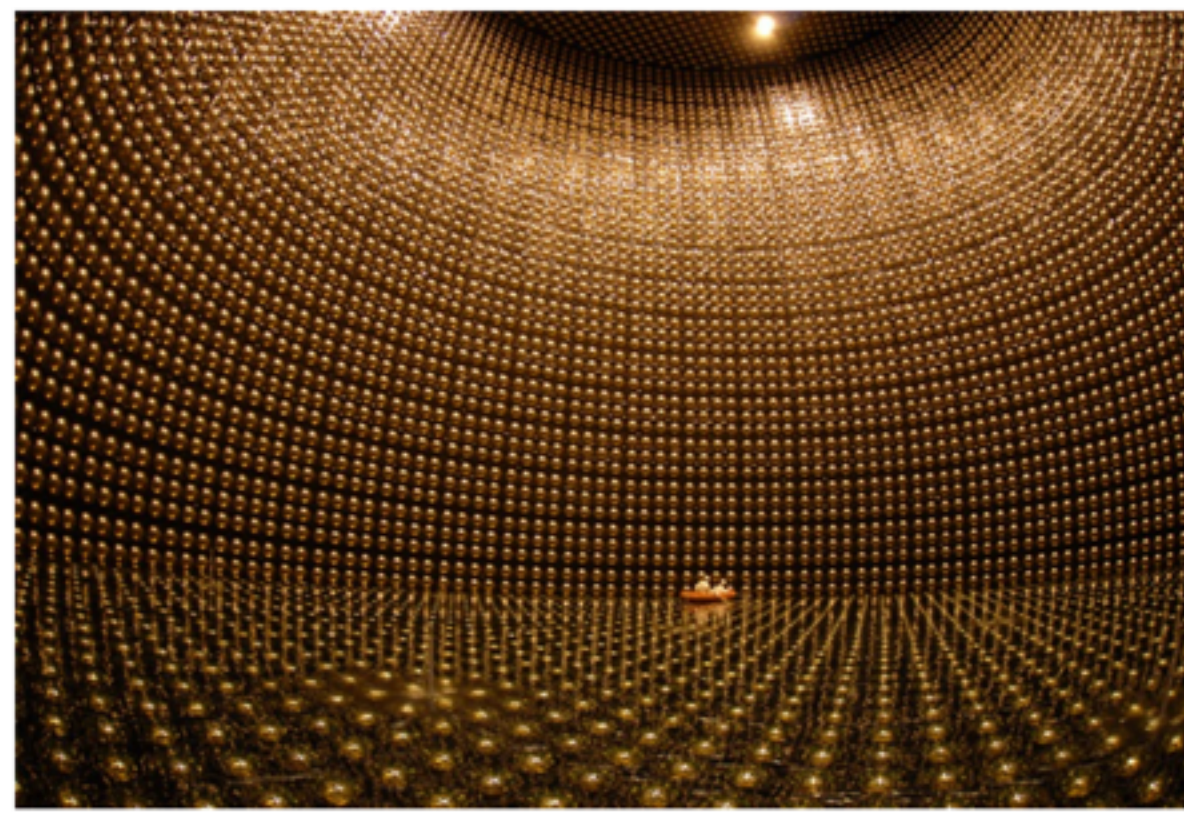
v ~ O(1) c



Looking for proton/neutron knocked out of a nucleus.
Similar to neutrino neutral current interaction!

$$\sigma_{\nu p \to \nu p}(E) \simeq 6 \times 10^{-46} \mathrm{cm}^2 \left(\frac{E_\nu}{\mathrm{MeV}}\right)^2$$

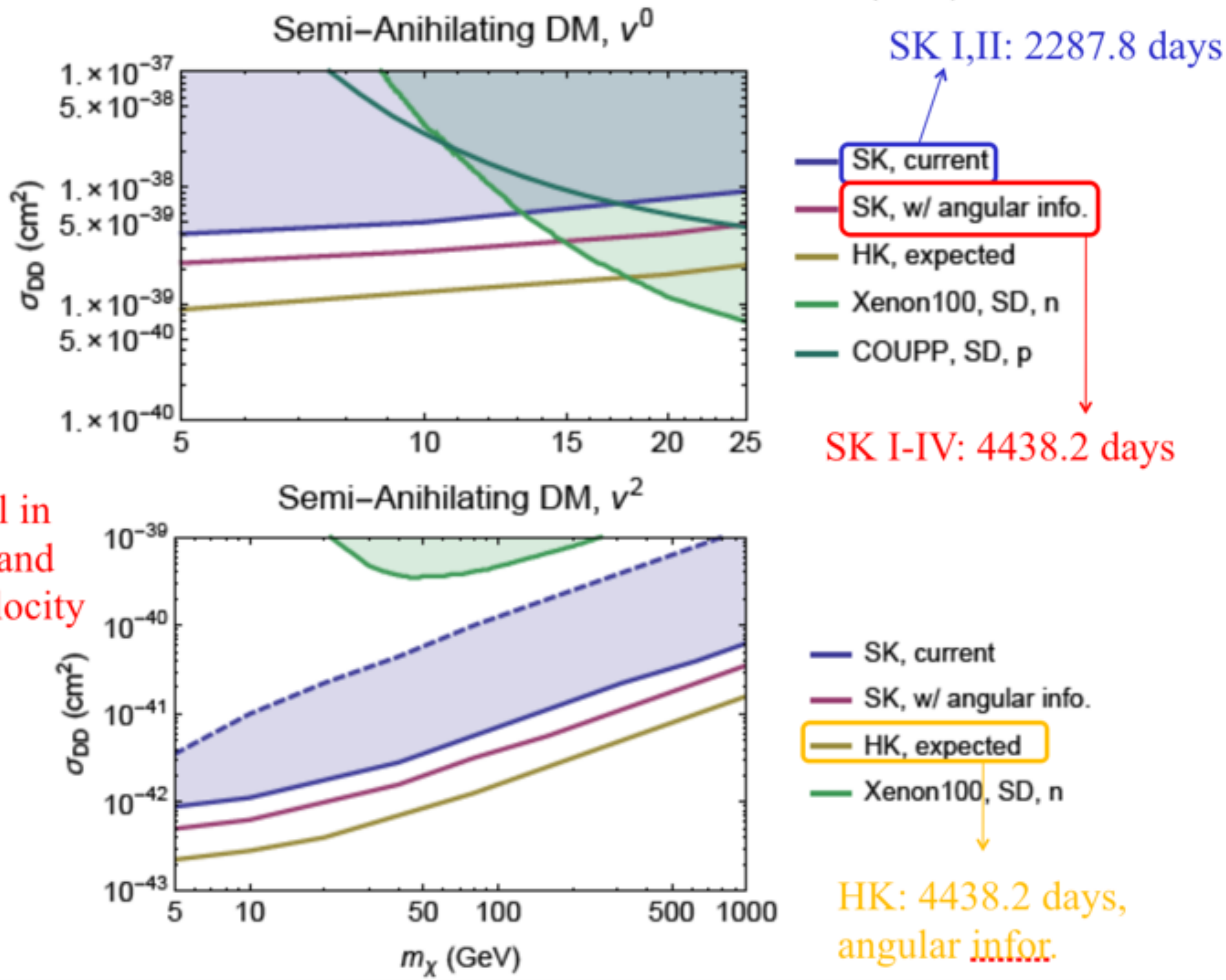
DM-nucleon scattering cross section can be less constrained!



Large Volume Neutrino Experiments
Super-K ~ 50K ton! DUNE ~ 68K ton!

Nucleon Channel: Super/Hyper-K

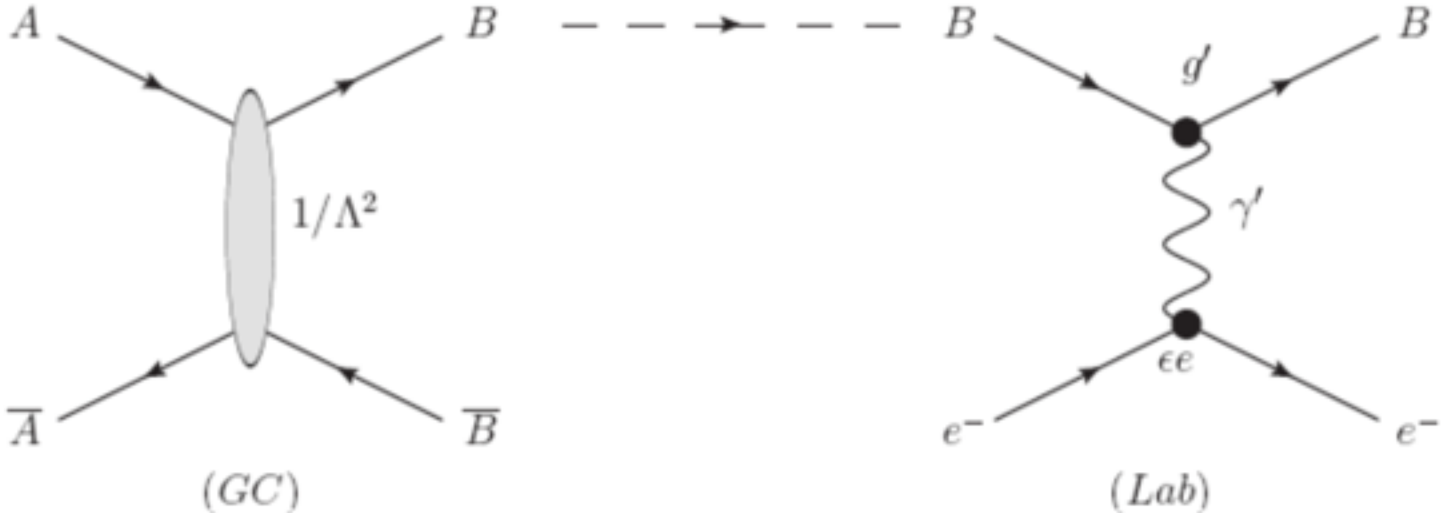
Joshua Berger, Yanou Cui , Y.Z.
JCAP (2015)



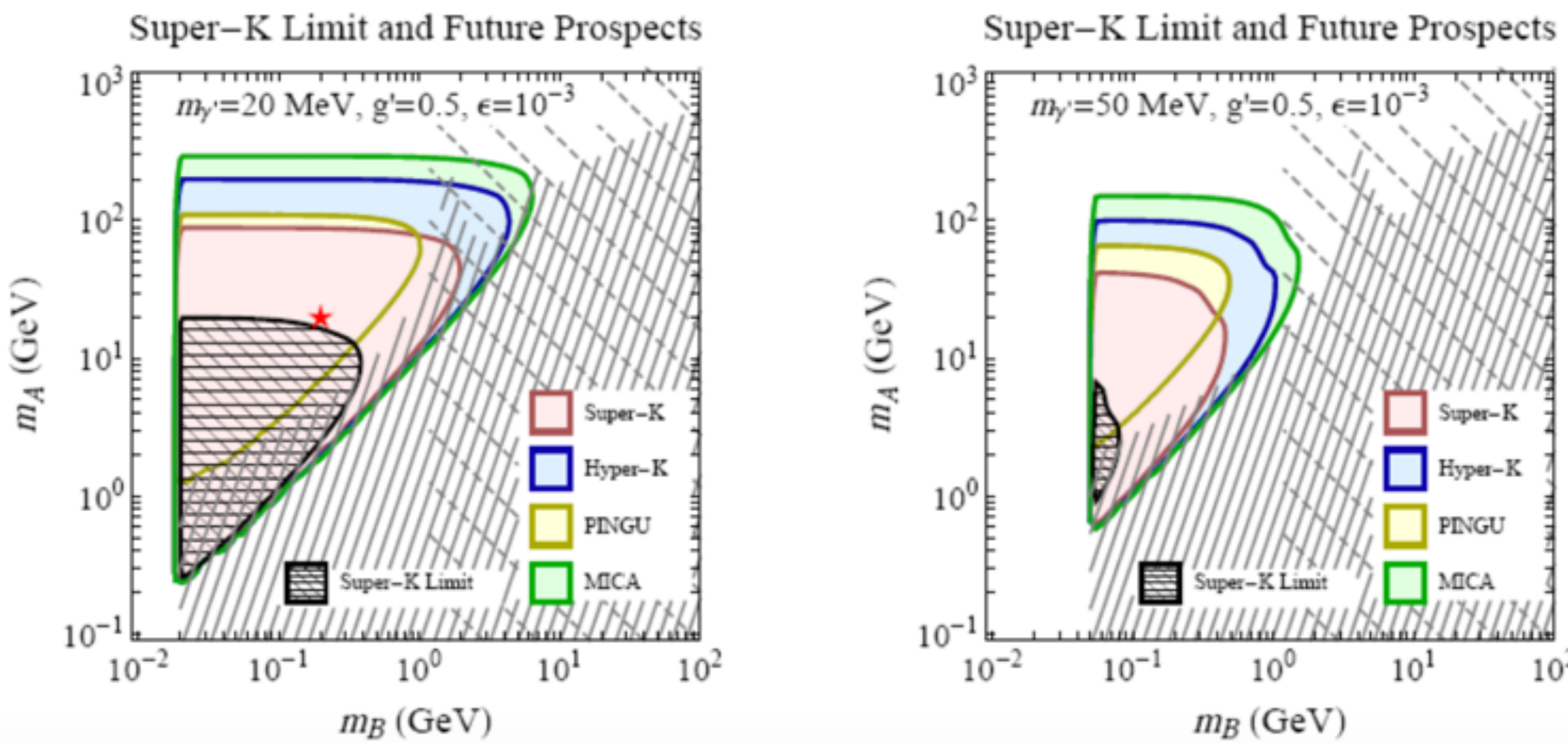
Already exceed the limits from DM DD!

Particularly useful in low mass regime and operators with velocity suppression!

Electron Channel: Super/Hyper-K (PINGU/MICA)



Kaustubh Agashe, Yanou Cui, Lina Necib, Jesse Thaler
JCAP 1410 (2014) no.10, 062



Indirect Searches of Galactic Diffuse Dark Matter in INO-MagICAL Detector

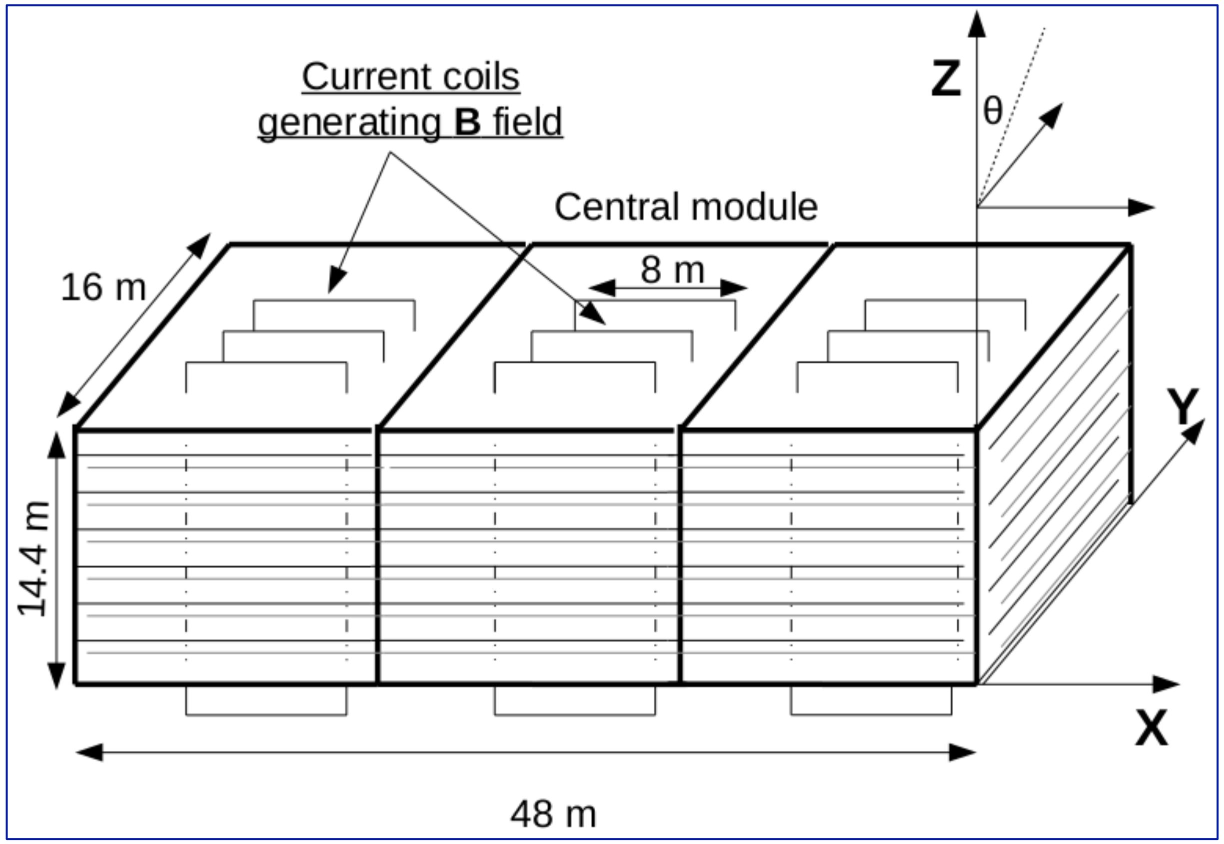
Sanjib Kumar Agarwalla

sanjib@iopb.res.in

Institute of Physics, Bhubaneswar, India

S. K. Agarwalla, NUFACT 2017, Uppsala University, Sweden, 28st September, 2017

Magnetized Iron CALorimeter (MagICAL) @ INO



3 modules each of size 16m × 16m × 14.4m, sampling detector with 151 layers

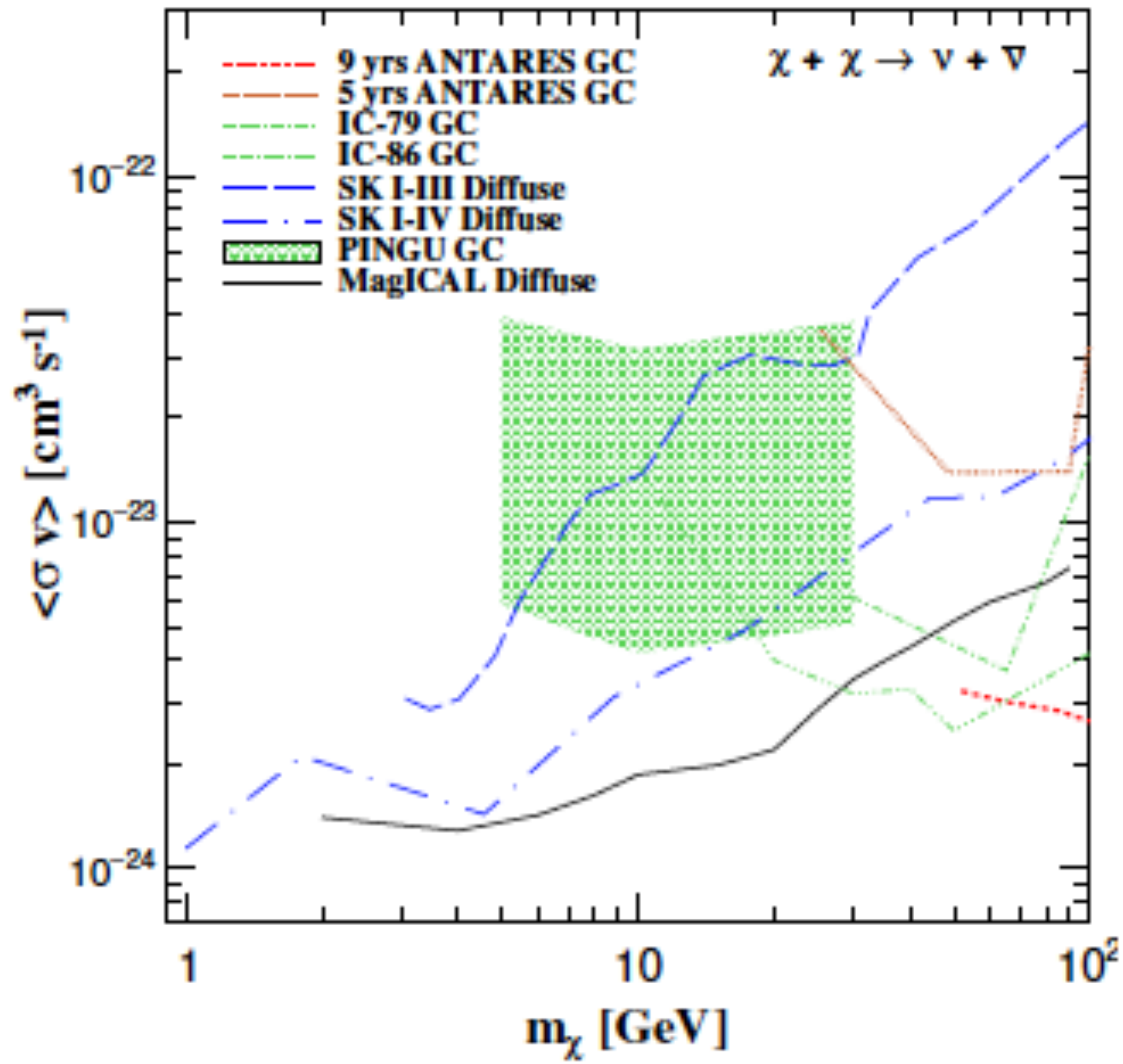
Each layer: Resistive Plate Chamber (RPC) as active detector& a 5.6 cm thick Iron Slab as target

1.5 T Mag. field: Excellent Charge-Id, can probe the DM properties in ν and $\bar{\nu}$ modes separately

Timing information will be used to distinguish between upward and downward going events

S. K. Agarwalla, NUFACT 2017, Uppsala University, Sweden, 28st September, 2017 7/20

A Comparison



S. K. Agarwalla, NUFACT 2017, Uppsala University, Sweden, 28st September, 2017

15/20

Neutrino Lines from Majoron Dark Matter

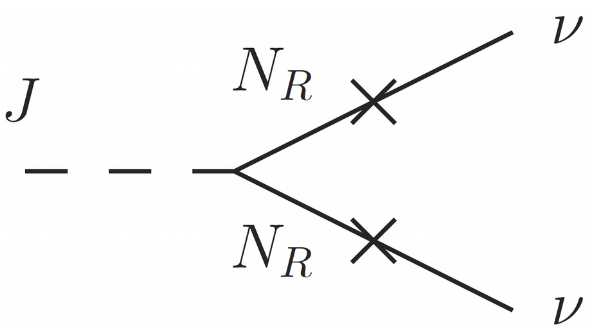
Julian Heeck

based on: JH, Camilo Garcia-Cely, JHEP 1705 (2017) 102 [1701.07209].

NUFACT2017

28.9.2017

Tree-level couplings



- $\mathrm{L} = iJ \sum_k \left(\frac{m_k}{2f}\right) \overline{\nu}_k \gamma_5 \nu_k + \ldots$

Tiny coupling: neutrino mass over B-L breaking scale!

- Long lifetime → majoron dark matter!

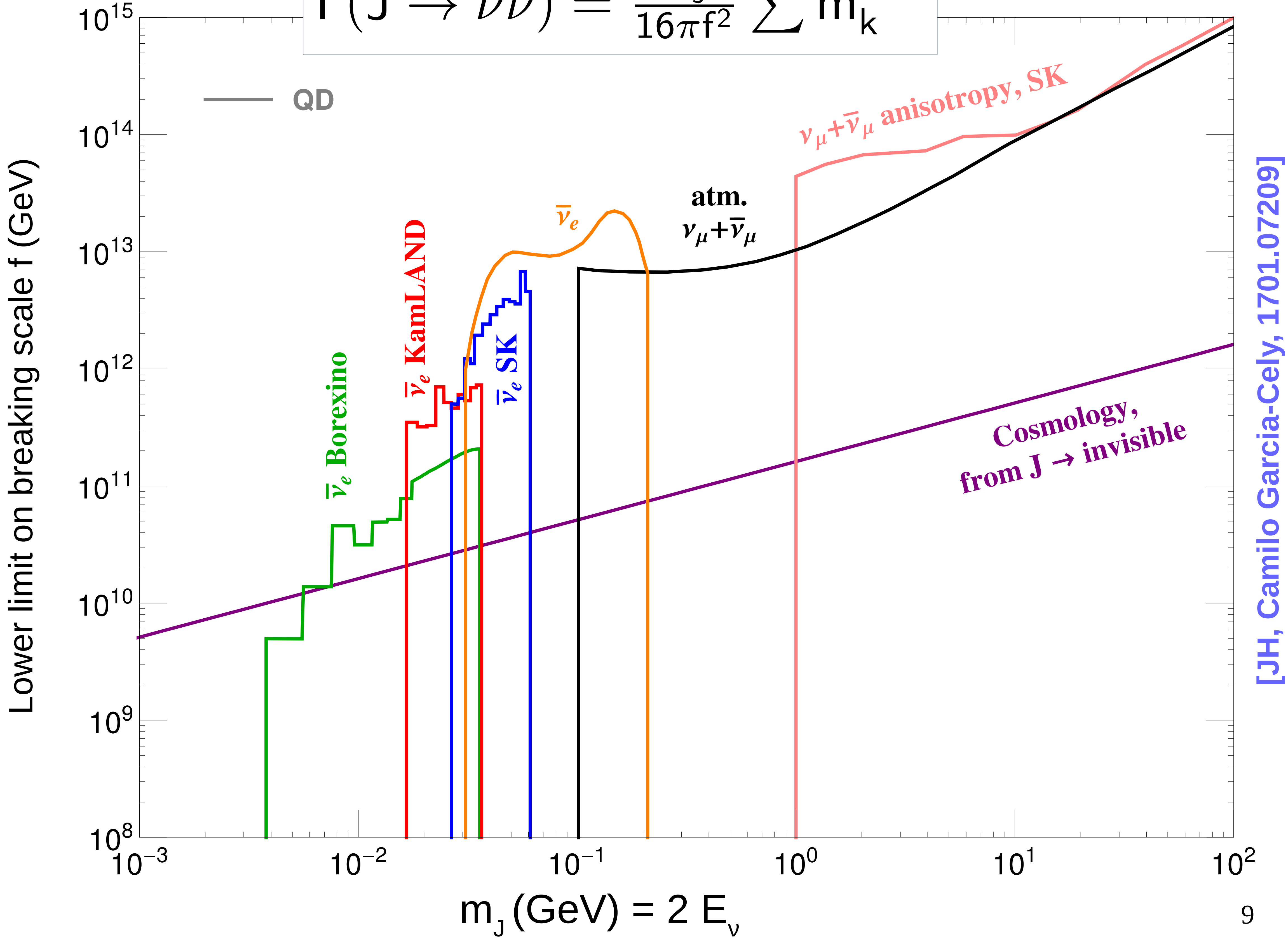
[Berezinsky, Valle '93; Lattanzi, Valle '07; Queiroz, Sinha, '14]

$$\Gamma(J \to \nu\nu) \simeq \frac{1}{3\times 10^{19}\mathrm{s}} \left(\frac{m_J}{\mathrm{MeV}}\right) \left(\frac{10^9\,\mathrm{GeV}}{f}\right)^2 \left(\frac{\sum_k m_k^2}{10^{-3}\mathrm{eV}^2}\right)$$

- DM abundance e.g. via freeze-in.

[McDonald, '02; Hall, Jedamzik, March-Russell, West '10; Frigerio, Hambye, Masso, '11]

$$\Gamma(J \to \nu\nu) = \frac{m_J}{16\pi f^2} \sum m_k^2$$

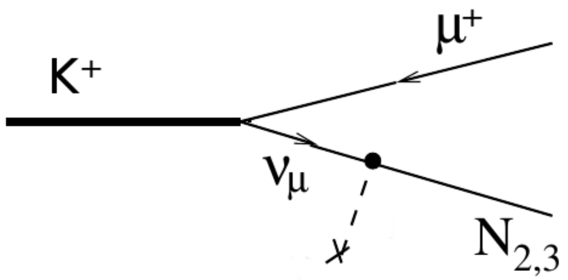


9

Friday 29/9	11:00-12:30	**Neutrinos and collider physics** **Chair: Walter Marcello Bonivento**
	11:00-11:30	Prospects of the SHiP and NA62 experiments at CERN for hidden sector searches
	11:30-12:00	A connection between neutrino mass and the recent B physics anomalies
	12:00-12:30	Connections between low-energy CP violation, lepton number violating collider signals and genesis mechanisms


Hidden sector searches at NA62 and SHiP
Philippe Mermod, on behalf of the SHiP Collaboration
NUFACT, Uppsala, 29 September 2017

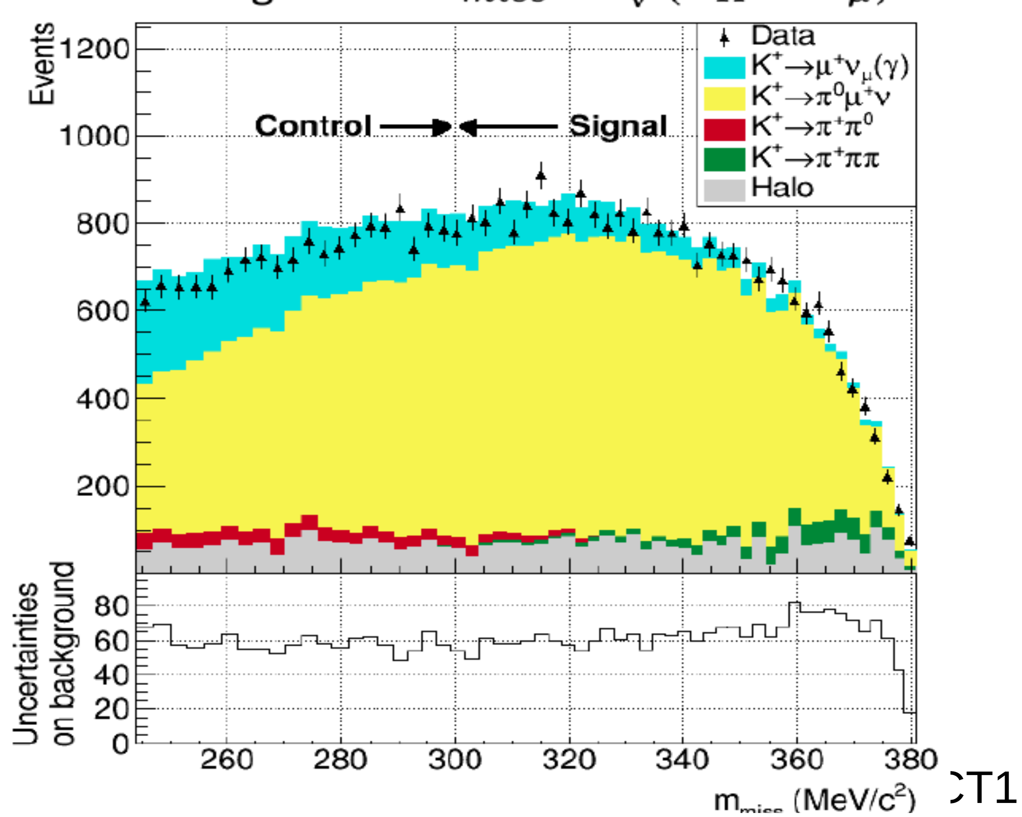
N search at NA62 in beam mode

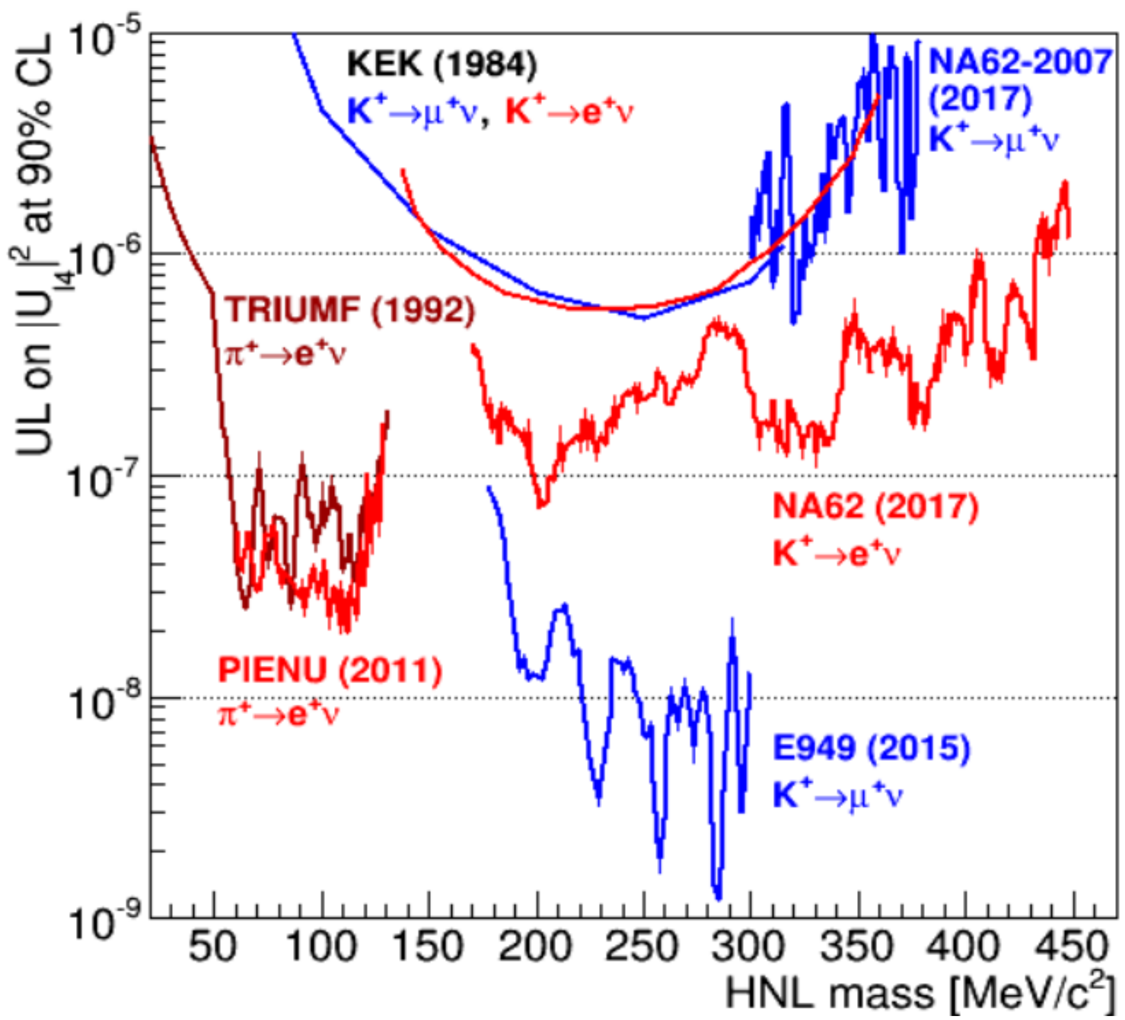


- Analysed datasets
  - 2007: 60 millions K^+, muon channel
  - 2015: 300 millions K^+, electron channel
- Look for excess in missing mass spectrum
- Probe couplings $U^2 \sim 10^{-7}$ for $m_N \sim 0.2 – 0.45$ GeV

$K^+ \rightarrow \mu^+ N$ arxiv:1705.07510

Missing mass: $m_{miss} = \sqrt{(P_K - P_\mu)^2}$



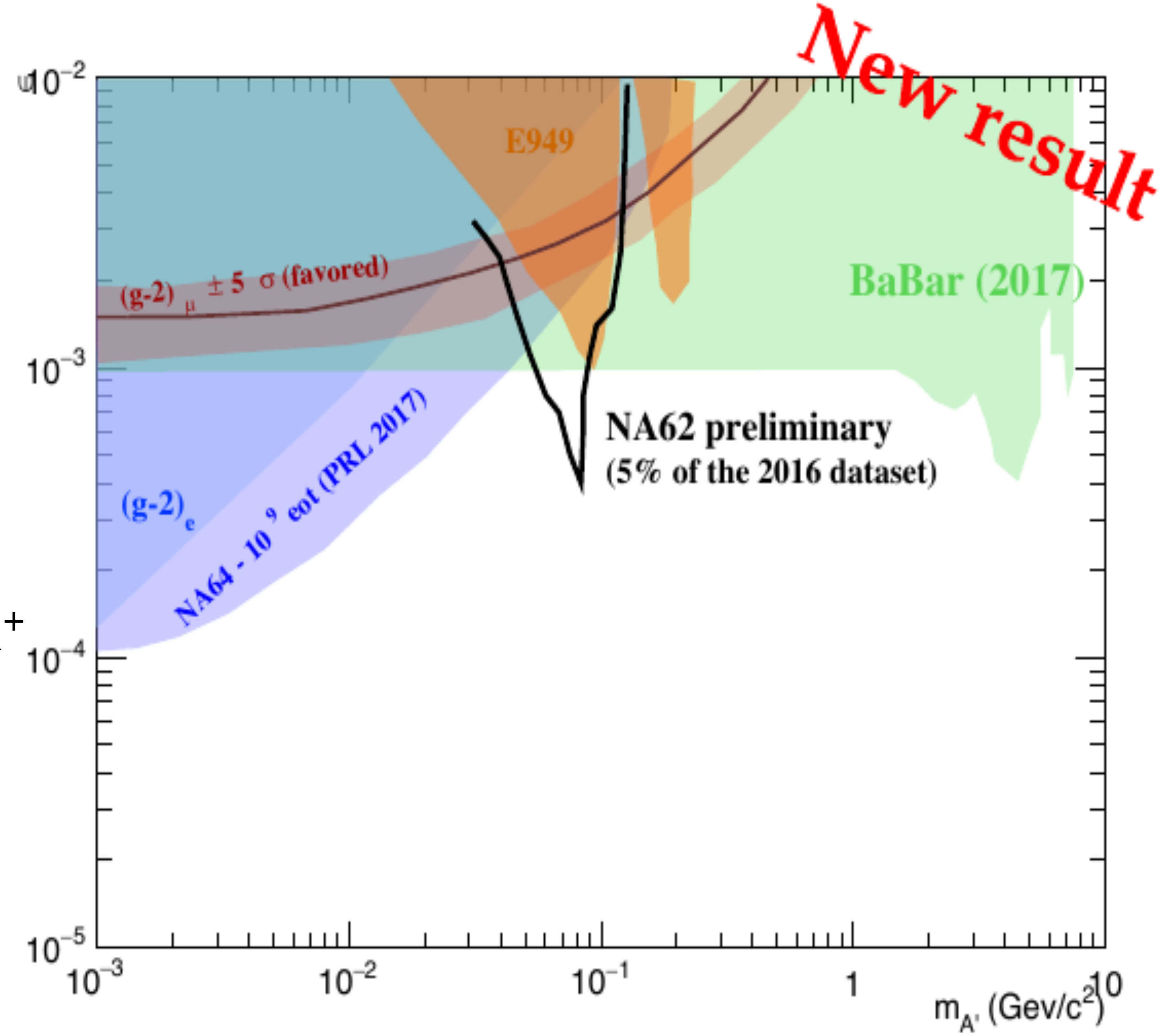


Dark photons at NA62 in beam mode

Use the decay $K^+ \rightarrow \pi^+ \pi^0$

(BR ~21%)

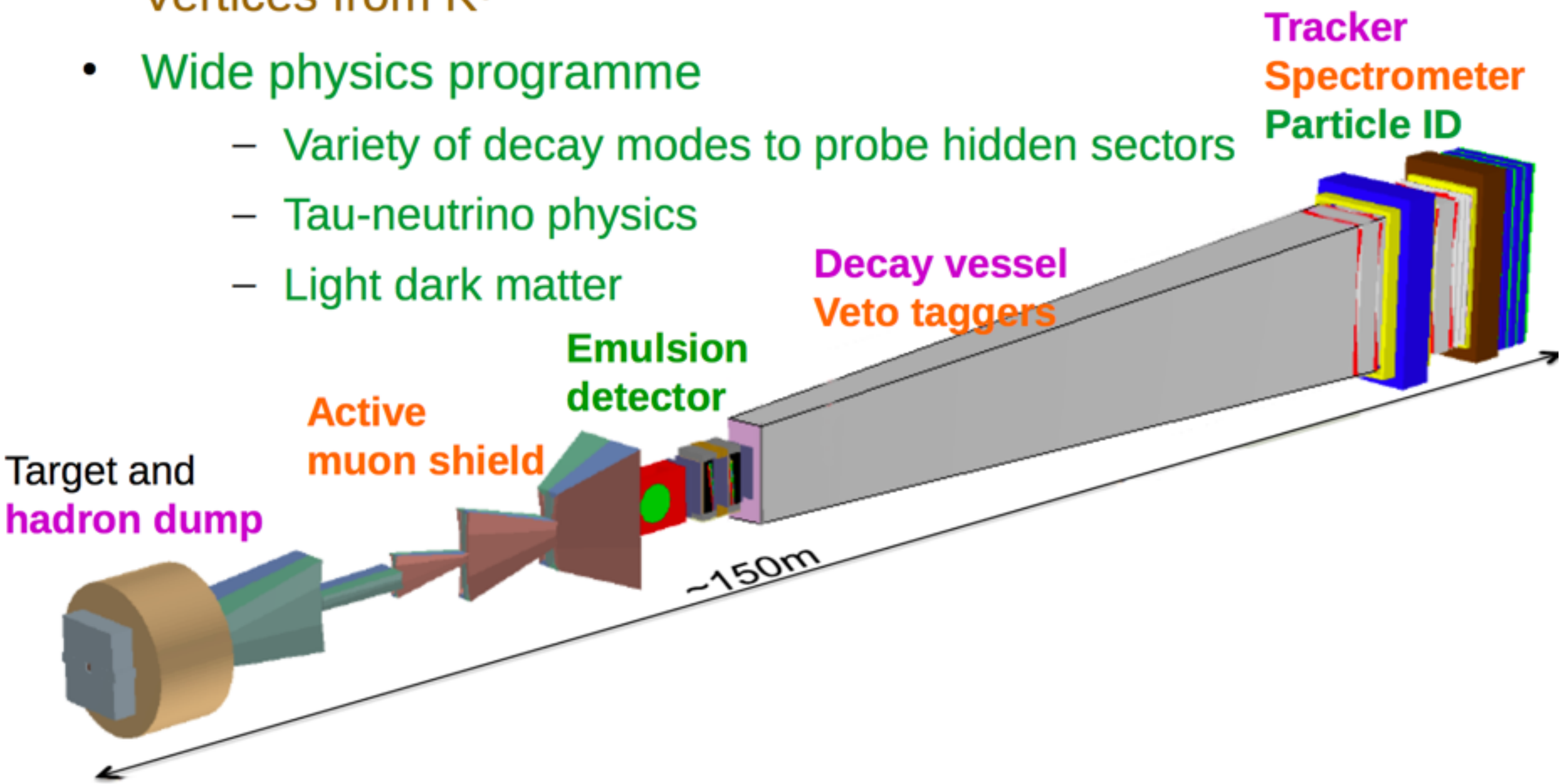
- $\pi^0 \rightarrow \gamma A'$
- Reconstruct K^+, π^+, γ
- Constrain A' using π^0 mass
- Sensitivity improves linearly with number of K^+



SHiP – detector

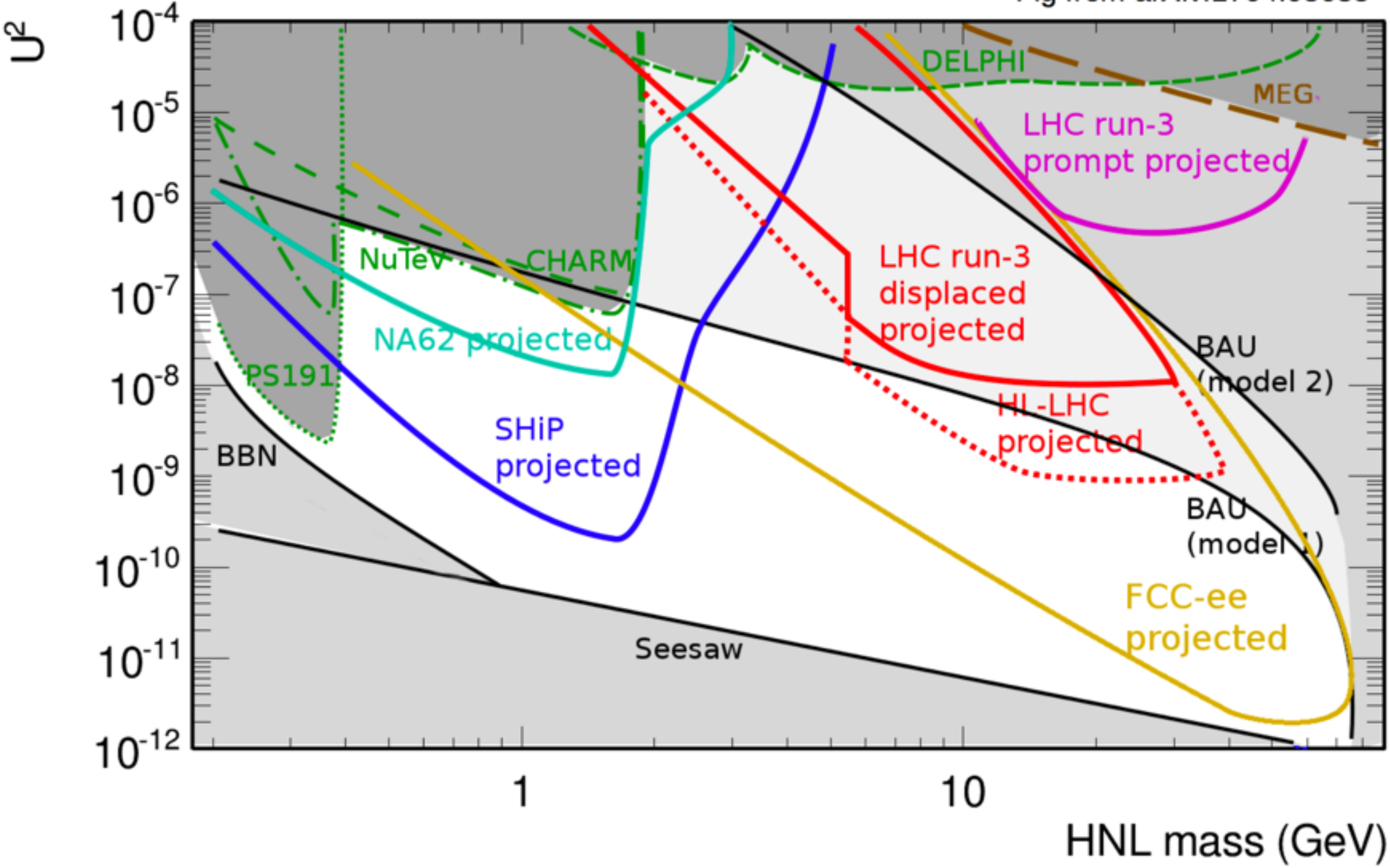
Designed for **large acceptance** and **zero backgrounds**

- Vertices from neutrinos
- Muon crossings
- Vertices from K^0
- Wide physics programme
  - Variety of decay modes to probe hidden sectors
  - Tau-neutrino physics
  - Light dark matter



N at CERN in a 10-year timesecale ... and beyond

Fig from arXiv:1704.08635



NUFACT17, Philippe Mermod 23

A connection between neutrino mass and the recent B physics anomalies

Michael A. Schmidt

29 September 2017

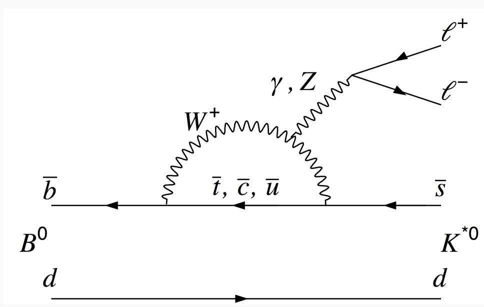
NuFact 2017

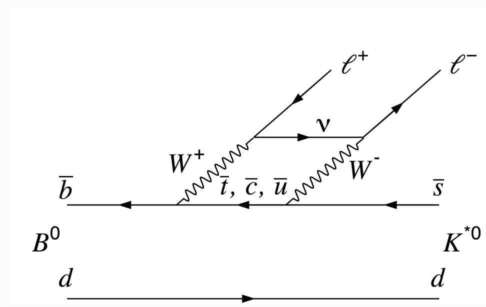
based on
Y. Cai, J. Gargalionis, MS, R. Volkas [JHEP accepted 1704.05849]
Y. Cai, J. Herrero-Garcia, MS, A. Vicente, R. Volkas [1706.08524]
P. Angel, Y. Cai, MS, R. Volkas [JHEP 1310 (2013) 118]
Y. Cai, J. Clarke, MS, R. Volkas [JHEP 1502 (2015) 161]

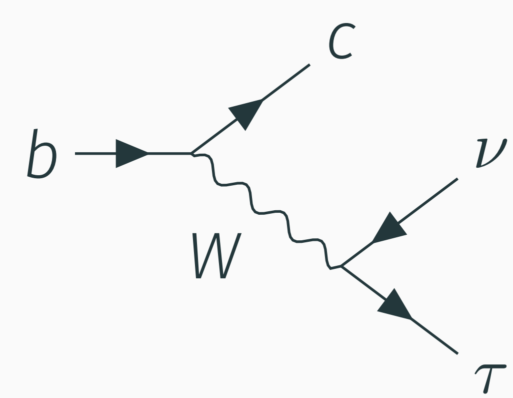
B physics anomalies

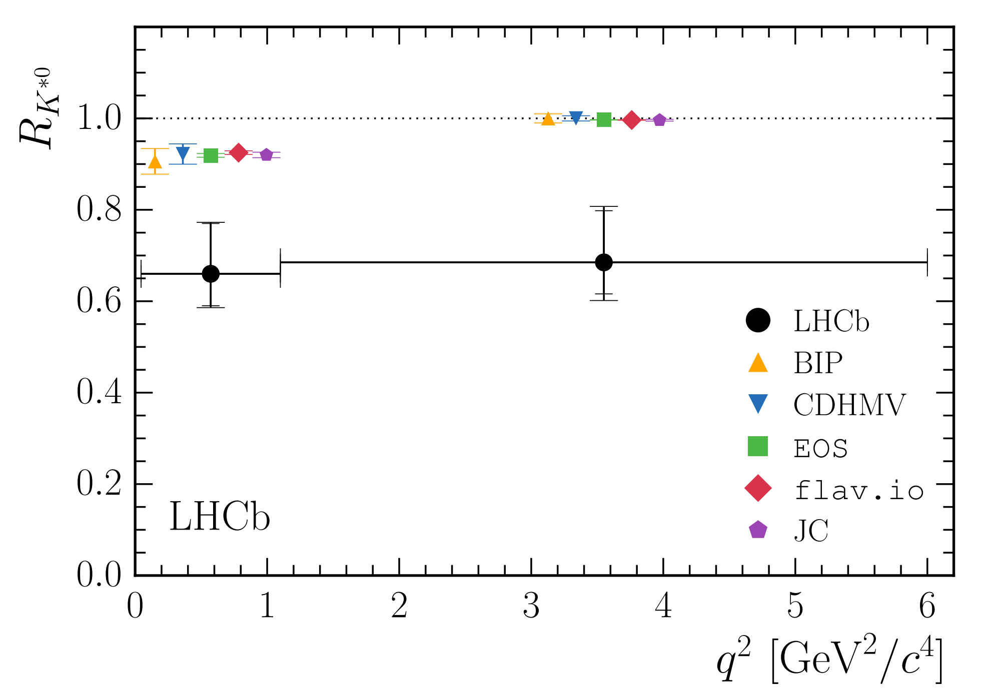
Hints for violations of LFU in $R_{K^{(*)}}$ and $R_{D^{(*)}}$

$$R_{K^{(*)}} = \frac{\Gamma(\bar{B} \to \bar{K}^{(*)}\mu^+\mu^-)}{\Gamma(\bar{B} \to \bar{K}^{(*)}e^+e^-)} \qquad R_{D^{(*)}} = \frac{\Gamma(\bar{B} \to D^{(*)}\tau\bar{\nu})}{\Gamma(\bar{B} \to D^{(*)}\ell\bar{\nu})}$$

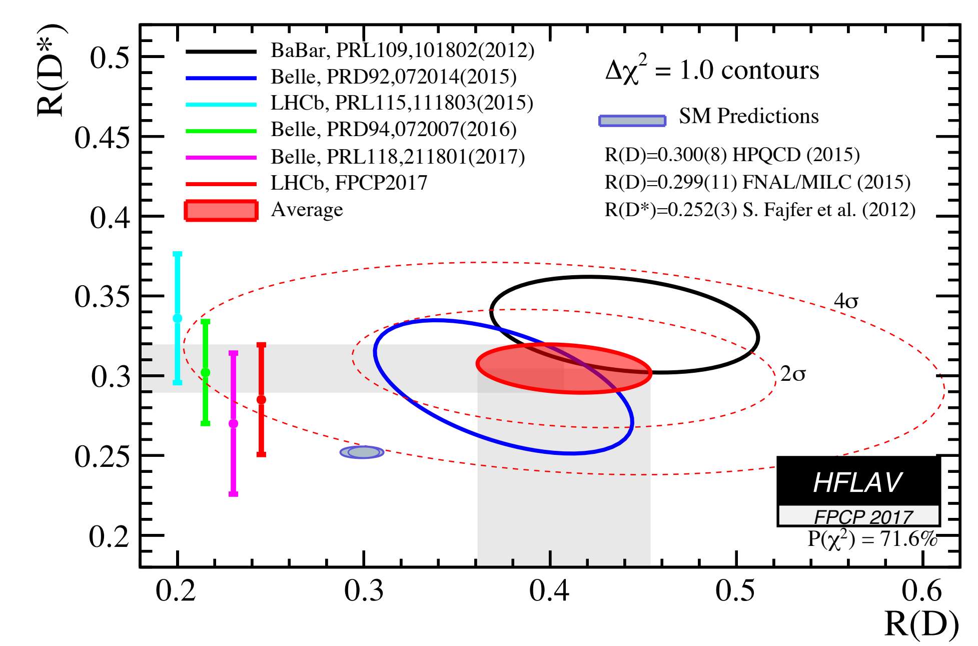








1705.05902



9

Summary and conclusions

One leptoquark solution with S_1 leptoquark $(3, 1, -\frac{1}{3})$

- can seperately explain $R_{K^{(*)}}$ or $R_{D^{(*)}}$ to 1σ along with $(g-2)_\mu$
- provides fit to $R_{D^{(*)}}$ inconsistent with vanishing RH coupling y_{32}
- $R_{K^{(*)}}$ requires large $b - \mu$ coupling x_{23} and LQ mass ~ 3 TeV
- S_1 can accommodate $R_{K^{(*)}}$ and $R_{D^{(*)}}$ together to 2σ

Radiative neutrino mass generation interesting possibility, particularly in connection to other new physics

- S_1 leptoquark naturally part of radiative neutrino mass models
- two-loop scenario considered can explain $R_{D^{(*)}}$ and $(g-2)_\mu$ well

Connections between low-energy CP violation, lepton number violating collider signals and genesis mechanisms

C. Hagedorn

CP^3-Origins, University of Southern Denmark, Odense, Denmark

The 19th International Workshop on Neutrinos
from Accelerators (NuFact2017),
25.09-30.09.2017, Uppsala, Sweden

Conclusions

- flavor and CP symmetry can constrain low-energy CP phases δ, α, β
- in scenarios with RH neutrinos we can correlate δ, α, β with the sign of the baryon asymmetry Y_B of the Universe
- connection to lepton number violating signals at LHC exists

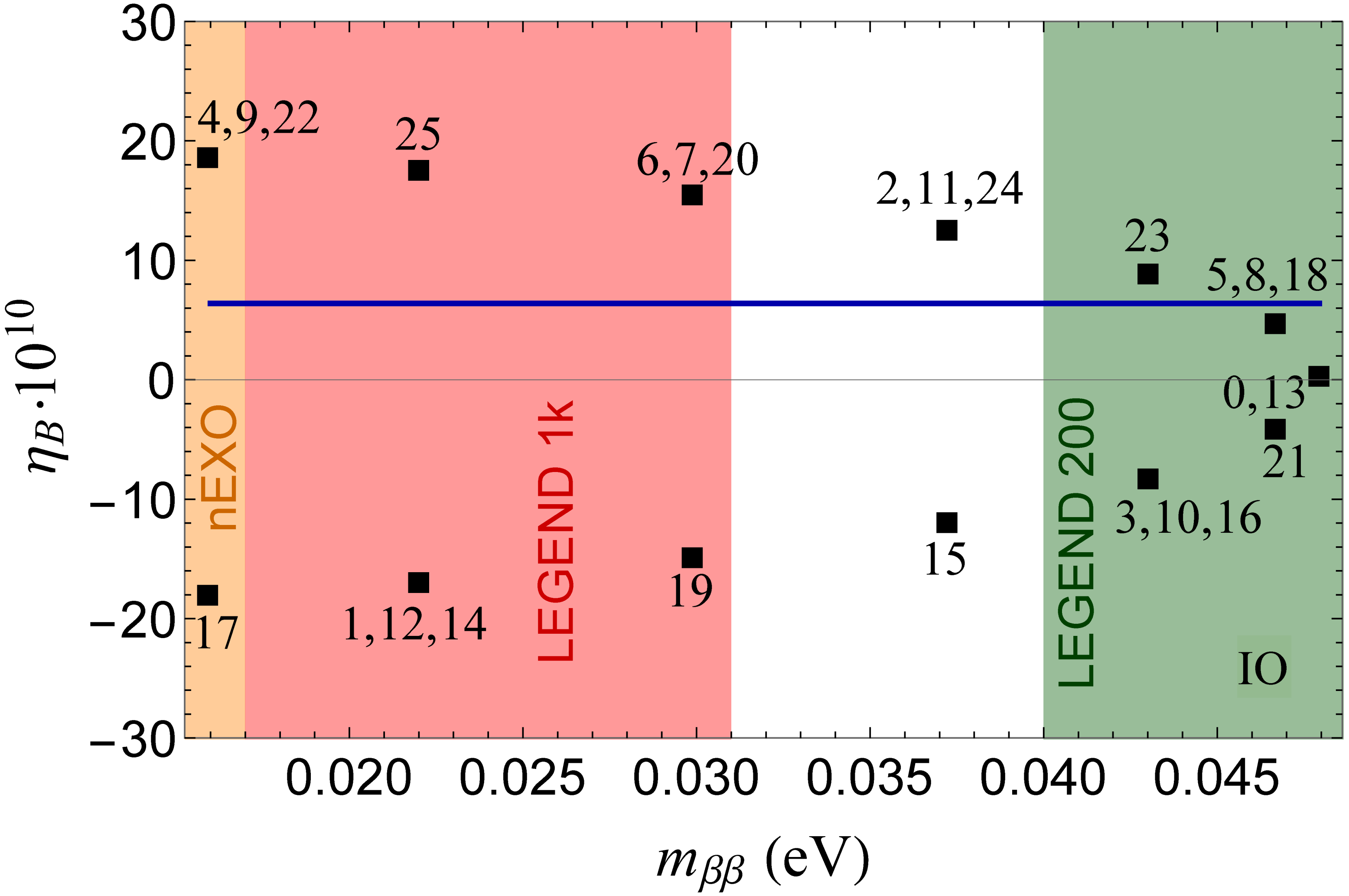
Prediction of CP phases with a flavor and a CP symmetry

- framework: 3 copies of charged leptons & Majorana neutrinos
- impose flavor symmetry G_f on space of 3 lepton generations
- G_f is non-abelian, finite and discrete
- impose also CP symmetry

Example

Case 1) and $n = 26$

(Dev/H/Molinaro (in preparation))



for light neutrinos with inverted ordering and $m_0 = m_3 = 0$

	14:00-15:30	**New physics searches with coherent neutrino-nucleus scattering** **Chair: Kate Scholberg**
	14:00-14:30	COHERENT constraints on non-standard neutrino interactions
	14:30-15:00	COHERENT and the LMA-dark solution
	15:00-15:30	New light mediators using coherent neutrino nucleus scattering experiments

COHERENT constraints on Non-Standard neutrino Interactions

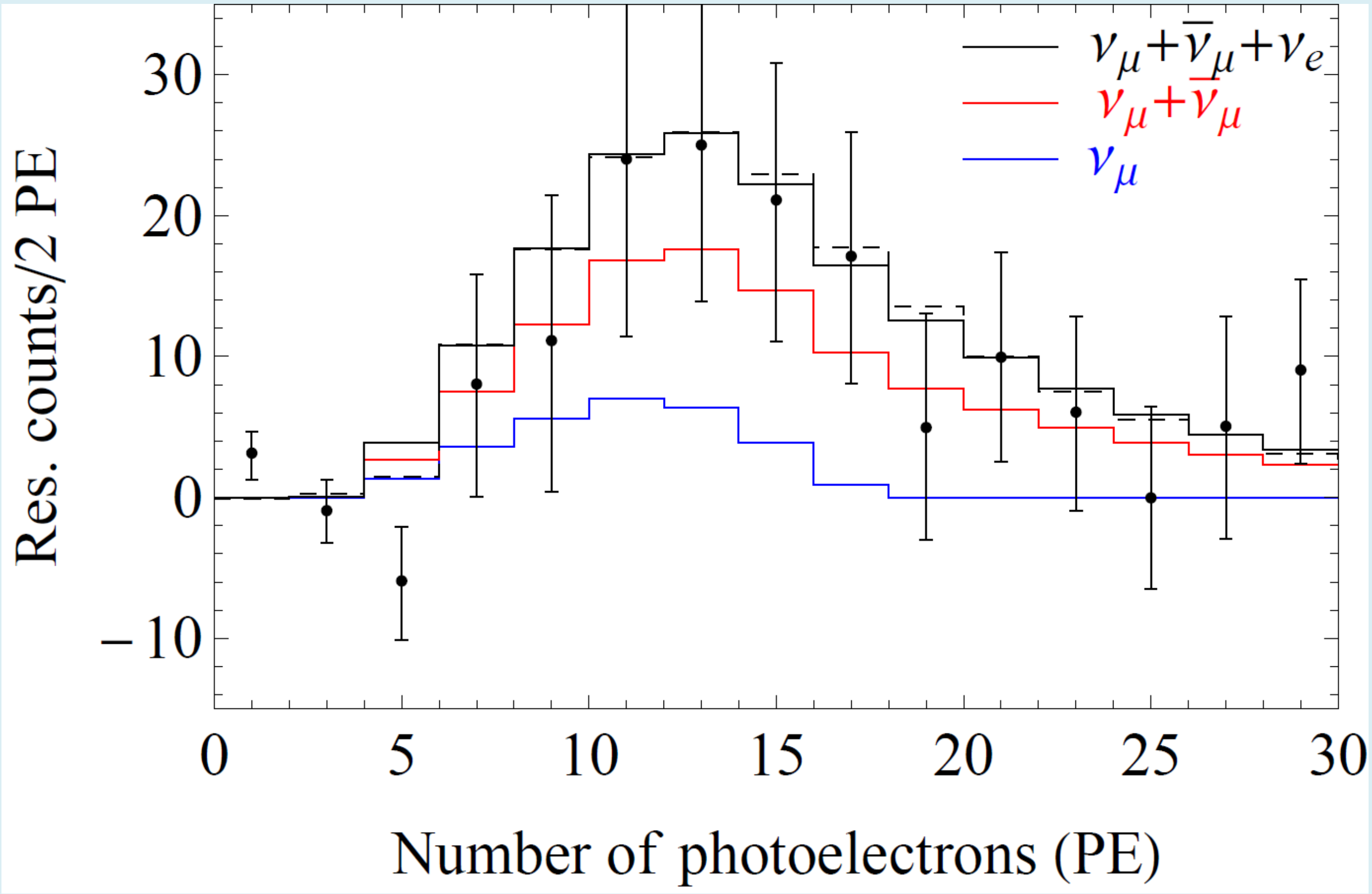
Jiajun Liao

University of Hawaii

with Danny Marfatia, based on work in [arXiv:1708.04255]

NUFACT 2017, Uppsala, Sweden, 09/30/2017

SM spectrum



Sterile neutrinos: Anderson et al. 2012; Dutta et al. 2015; Kosmas et al. 2017

Neutrinos magnetic moment: Dodd et al. 1991; Scholberg 2005; Kosmas et al. 2015

Light dark matter: deNiverville et al. 2015

Nonstandard neutrino interactions: Barranco et al. 2005, 2007; Scholberg 2005; Dutta et al. 2015; Lindner et al. 2016; Dent et al. 2016; Coloma et al. 2017; Shoemaker 2017

see also COHERENT Collaboration, Science (2017), Coloma et al. 1708.02899

8

Summary

We analyzed the COHERENT spectrum to constrain NSI.

- For a lighter mediator, COHERENT data only constrain the mediator coupling, and it does not apply to matter NSI induced by a very light mediator.
- For a heavier mediator, the COHERENT constraints are weakened by degeneracies between different combinations of NSI parameters. However, the data can still place meaningful constraints on the effective NSI parameters in Earth matter since they depend on the sum of the up-type and down-type NSI parameters.

Thank you!

16

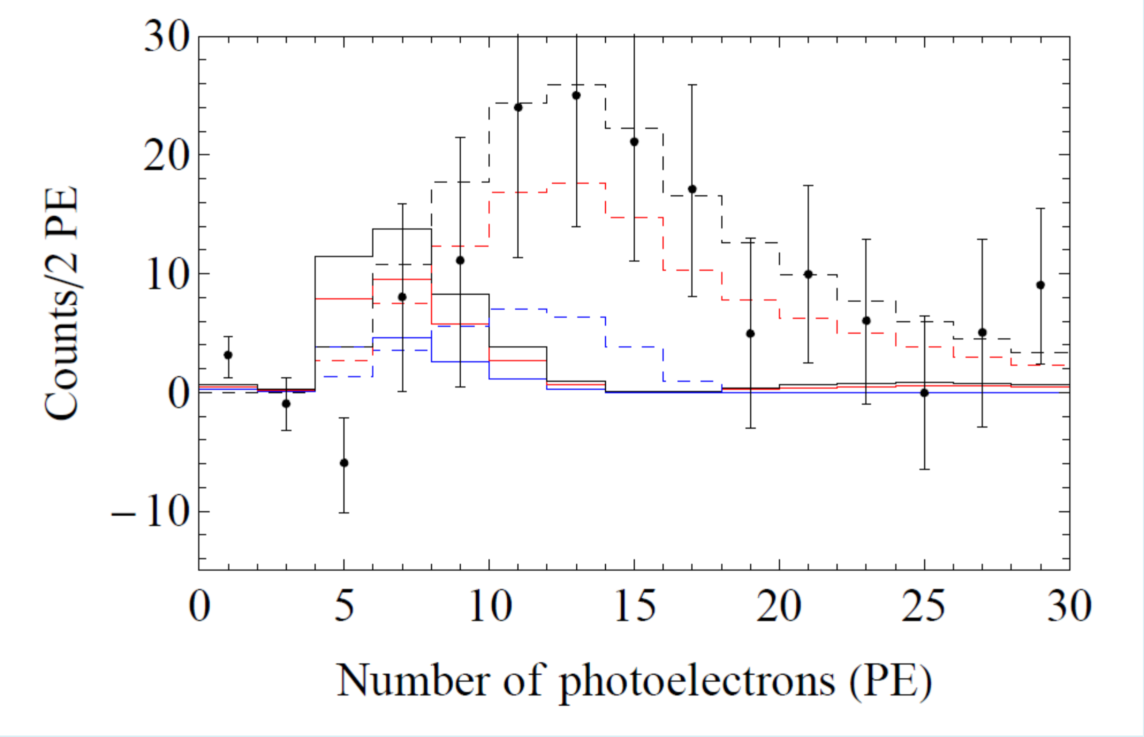
Light mediator

A purely vector mediator

$$\mathcal{L}_{\rm NSI} = -g\left(\bar{\nu}\gamma^\rho\nu + \bar{\mu}\gamma^\rho\mu + \bar{u}\gamma^\rho u + \bar{d}\gamma^\rho d\right) Z'_\rho$$

Modified effective charge

$$Q^2_{\alpha,\rm NSI} = \left[Z\left(g_p^V + \frac{3g^2}{2\sqrt{2}G_F(Q^2+M^2_{Z'})}\right) + N\left(g_n^V + \frac{3g^2}{2\sqrt{2}G_F(Q^2+M^2_{Z'})}\right)\right]^2$$



Moment transfer

$$Q^2 = 2ME_r$$

$$M_{Z'} = 10 \text{ MeV and } g = 10^{-4}$$

10

COHERENT and the LMA-Dark NSI Solution

Peter B. Denton

NUFACT 2017 Uppsala

September 29, 2017

1701.04828 JHEP

with P. Coloma, M. C. Gonzalez-Garcia, M. Maltoni, T. Schwetz

The Niels Bohr International Academy

VILLUM FONDEN

Wrap-up

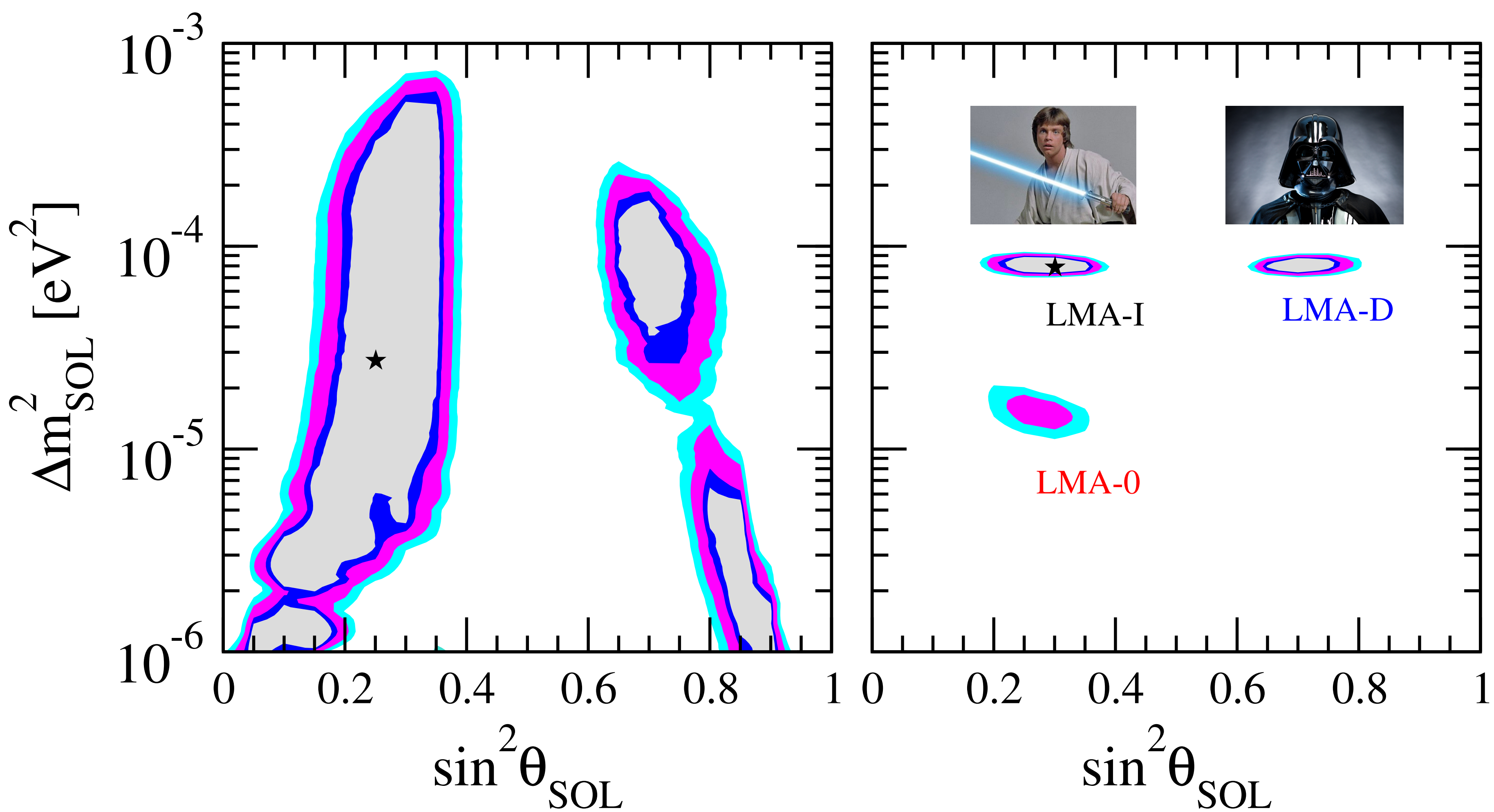
- NSI parameterizes generic BSM phenomenology in the neutrino sector.
- Large NSI $\mathcal{O}$(electroweak) consistent with oscillation data.
- Scattering experiments are crucial to measure diagonal NSI.
- For heavy mediators $M'_Z \gtrsim 1$ GeV,
  - CHARM and NuTeV apply.
  - LMA-D is ruled out for d quarks.
  - With COHERENT LMA-D is completely ruled out.
- For light mediators $M'_Z \gtrsim 10$ MeV,
  - CHARM and NuTeV are suppressed, but COHERENT applies.
  - With COHERENT LMA-D is completely ruled out.
- Anticipate future COHERENT results.
- Making progress on constraining BSM ν physics.

Are solar neutrino oscillations robust?

O. G. Miranda, M. A. Tortola, J. W. F. Valle

(Submitted on 24 Jun 2004 (v1), last revised 7 Sep 2006 (this version, v3))

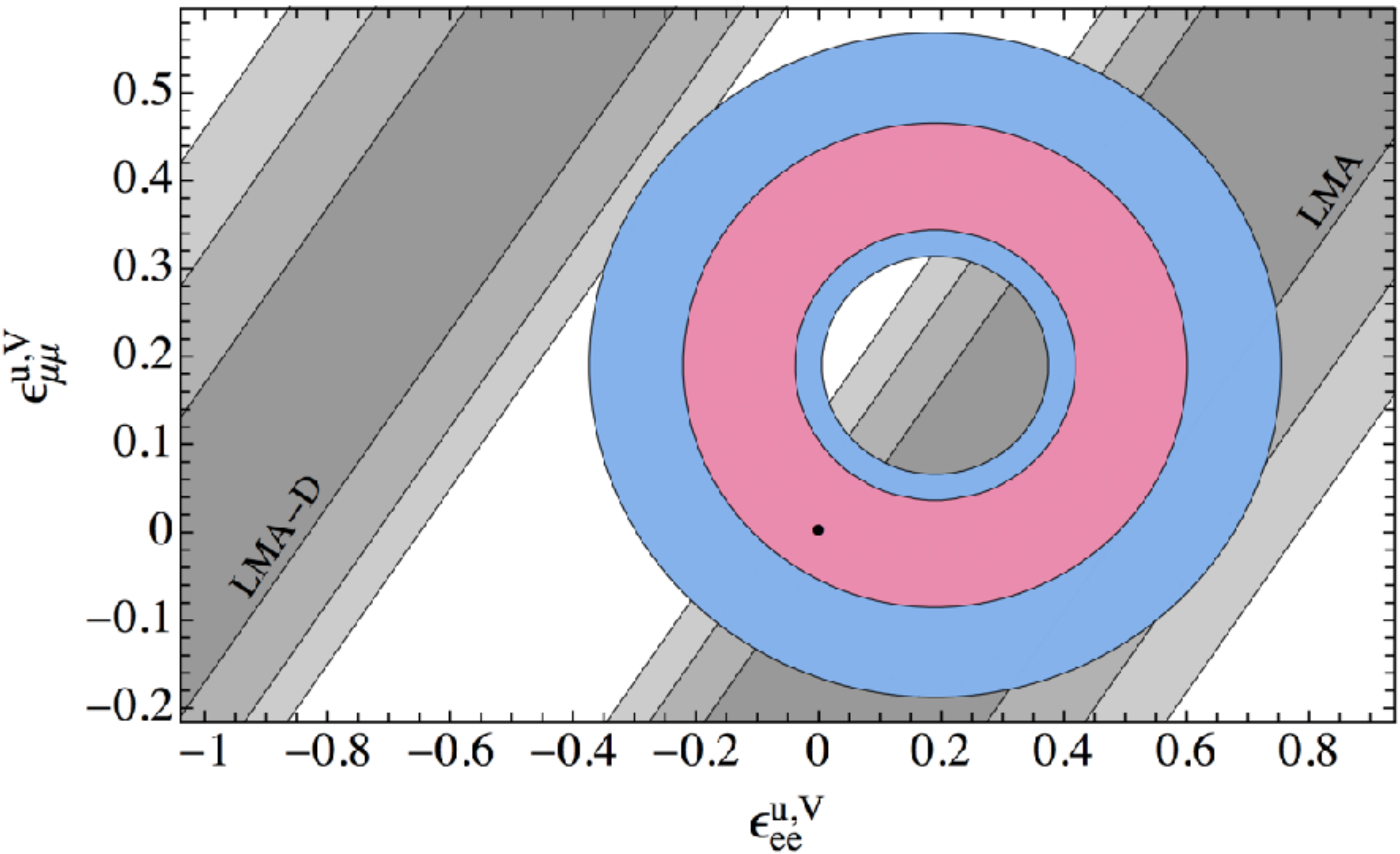
Allowing For New Neutrino Interactions



O. Miranda, M. Tórtola, J. Valle, hep-ph/0406280

Solar (left), solar + KamLAND (right), $\Delta\chi^2 = 80.2 - 79.7$.

Latest Light NSI Constraints



P. Coloma, M. C. Gonzalez-Garcia, M. Maltoni, T. Schwetz, 1708.02899

NUFACT - Uppsala - September 2017

Probing light dark sectors with coherent neutrino-nucleus scattering

Adam Ritz
University of Victoria

P. deNiverville, M. Pospelov & AR, 2015

[related work with B. Batell, C.-Y. Chen, P. deNiverville, D. McKeen, M. Pospelov & members of MiniBooNE, T2K & SHiP]

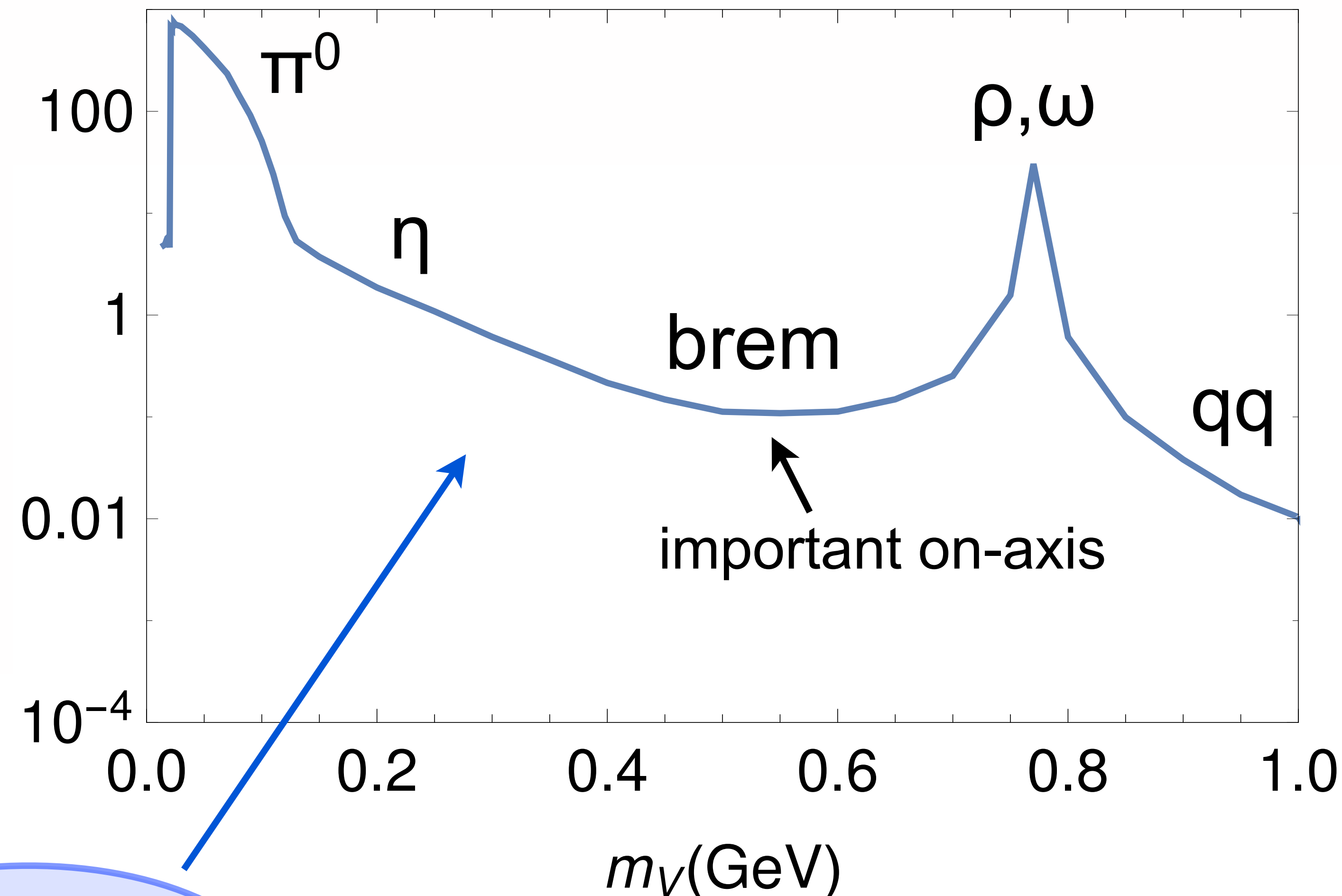
1

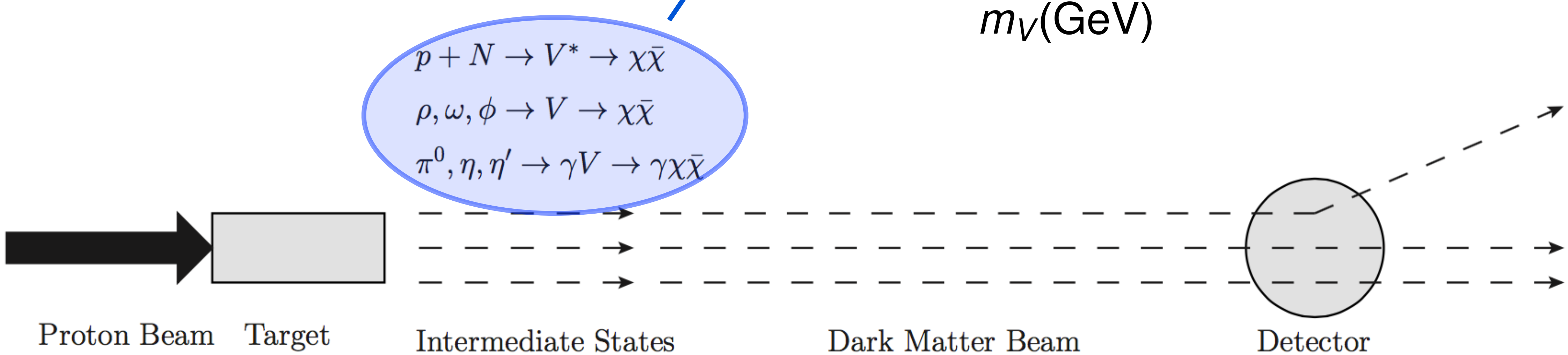
Fixed target - DM production

[deNiverville et al '16]

Unnormalized production rate at e.g. MiniBooNE (vector mediator)

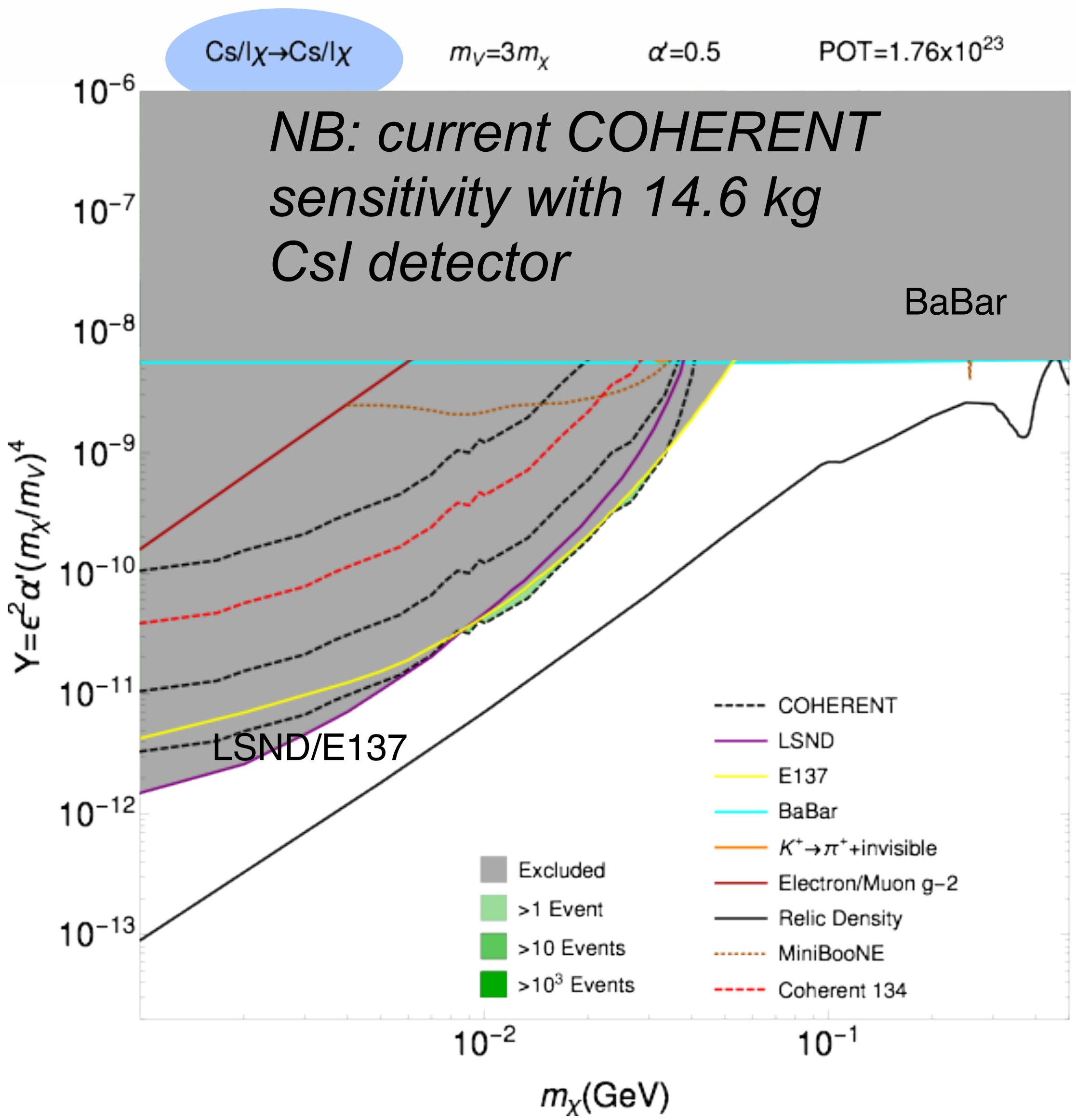
- NB: some components of production model can be validated with data, but not all...



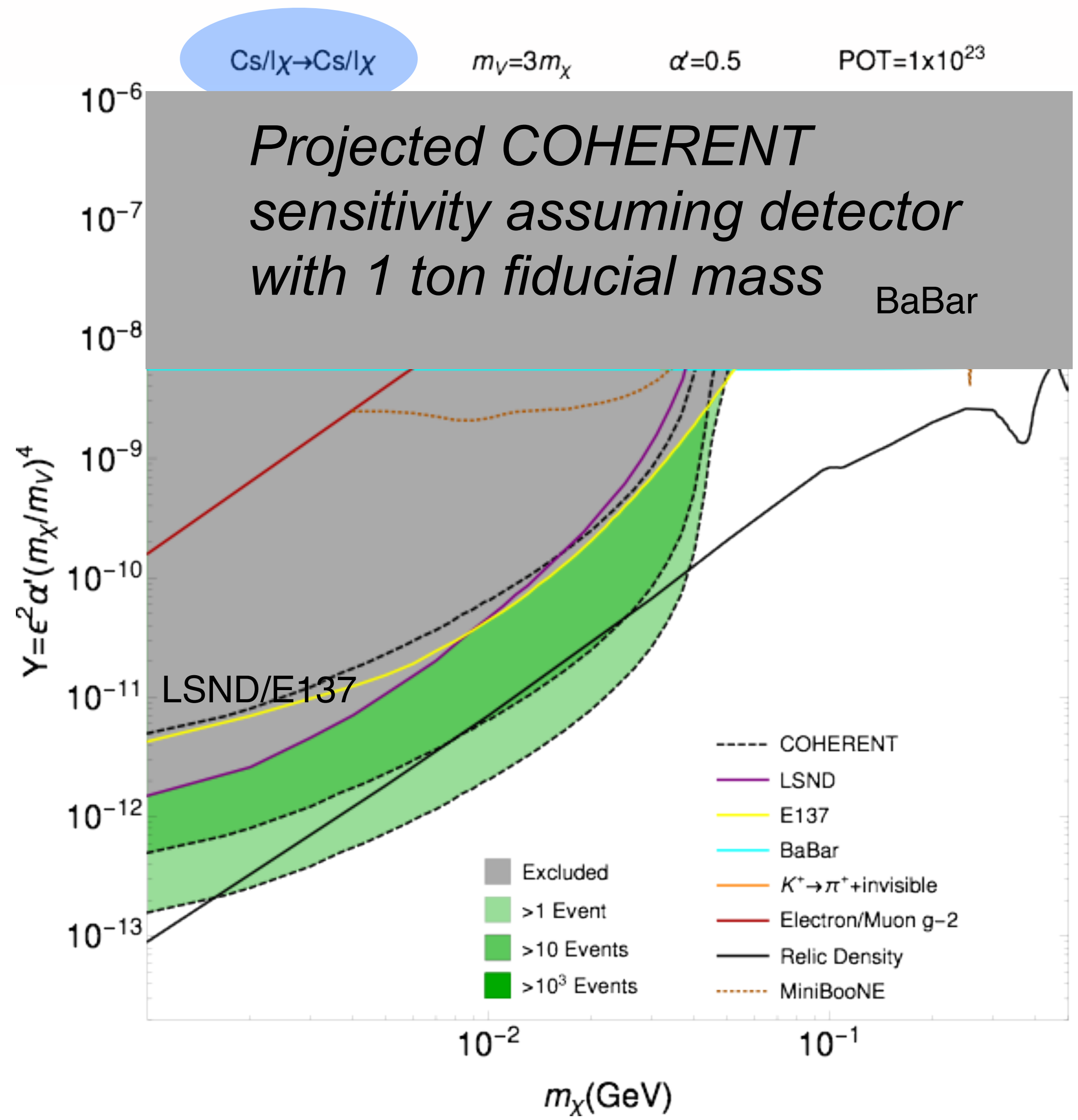


COHERENT (SNS)

[deNiverville et al ’15; update courtesy P. deNiverville]



[deNiverville et al ’15]



Currently weaker than LSND and E137, but distinct as COHERENT does not rely on the electron coupling. Sensitivity will improve with more detector mass

23

Questions

First we have one answer: 7's observed!
We have another tool to test BSM physics!

Main future issues:

- sensitivity of present and future scattering and oscillation experiments to BSM physics (NSI, steriles,others)
- need of disentangling BSM and true SM effects (Dirac CP phase, mass hyerarchy,octant) in LBL experiments? will this be possibile for DUNE/HK?
- when the sterile neutrino issue at eV scale will be settled experimentally? what about MINOS+ ? will SOX be decisive?
- do we need to continue searching for it even if the anomaly will be ruled out? (Alain) e.g ISODAR/nuSTORM?
- how can we test the existence of massive sterile neutrinos in the GeV range and with coupling relevant to leptogenesis with new experiments? which fraction of HEP funding can be dedicated to it? SHiP, FCCee
- how can we settle the issue of the 3.5keV sterile neutrino as DM candidate? we have see some new evidences at this conference (Boyarsky)!

This was my second and last NUFACT convenership

These have been exciting times for me and allowed me to get in touch with very competent people

Thank you all for sharing this with me and I wish my successor great success!