Summary: Particle Physics with Neutrino Telescopes

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Erlangen Centre for Astroparticle Physics
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VLVnT 2018, Dubna, 04.10.2018

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

Timetable: Tuesday's parallel sessions

14:00

Parallel session 3: Exotics

Investigation of ν properties with the νGEN spectrometer	*Dr. Alexey LUBASHEVSKIY*	
International Conference Center	14:30 - 14:50	
Direct Dark Matter searches: overview	*Dr. Evgeny YAKUSHEV*	15:00
International Conference Center	14:50 - 15:15	
Indirect dark matter searches	*Juan AGUILAR SáNCHEZ*	
International Conference Center	15:15 - 15:40	
Combined dark matter Antares/IceCube	*Sara Rebecca GOZZINI*	
International Conference Center	15:40 - 15:55	
Monopole searches: overview	*Christian SPIERING*	16:00
International Conference Center	15:55 - 16:05	
Search for particles beyond the Standard Model with the proposed SHiP experiment at CERN	*Prof. Roumen TSENOV*	
International Conference Center	16:05 - 16:25	

Parallel session 6: Oscillations

NMO: Status and JUNO plans	*Prof. Alexander OLSHEVSKIY*	17:00
International Conference Center	16:50 - 17:10	
Particle Physics with ORCA (oscill./steriles/DM)	*Ms. Alba DOMI*	
International Conference Center	17:10 - 17:30	
Oscillations with IceCube upgrade	*Dr. Joshua HIGNIGHT*	
International Conference Center	17:30 - 17:50	
Sterile neutrinos: Overview	*Dr. Dmitry NAUMOV*	18:00
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Sterile neutrinos: IceCube results	*Dr. Joshua HIGNIGHT*	
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Sterile neutrinos: Latest results from reactors with focus on DANSS results	*Viacheslav EGOROV*	
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Christian Spiering: please cover these two sessions

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Focused on Very Large Volume Neutrino Telescopes

Touched other talks where possible

Sorry for not touching νGEN & SHiP & direct DM searches

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Slide from Alexander Olshevskiy

Introduction: PMNS today

What We Know

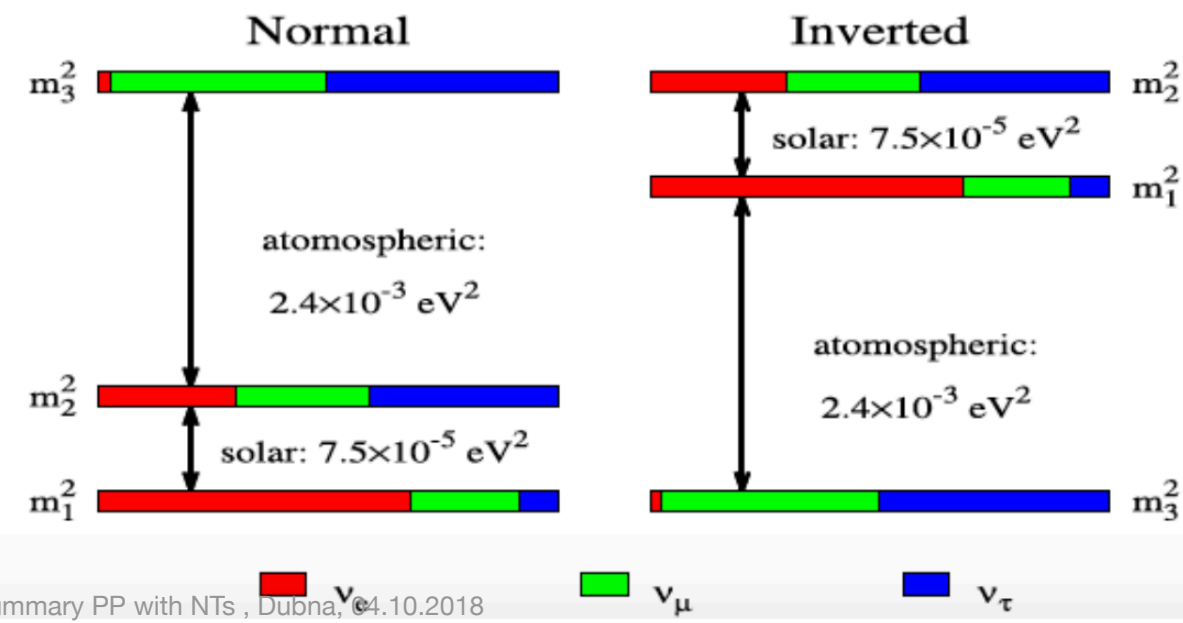
atmospheric accelerator ν_μ | short baseline reactor accelerator ν_e | solar long baseline reactor

Flavor

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

Mass

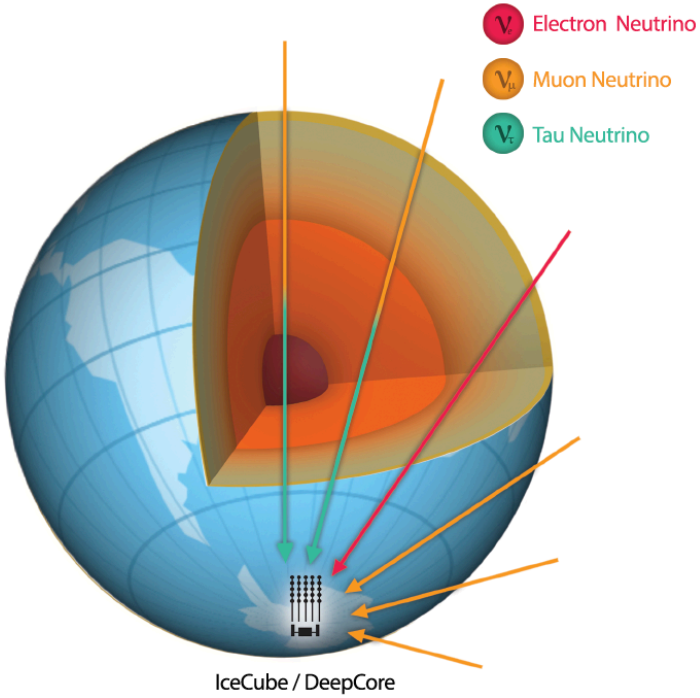
$\theta_{23} \approx 45^\circ$ $\theta_{13} \approx 9^\circ$ $\theta_{12} \approx 34^\circ$



From Joshua Hignight

Particle physics with atmospheric neutrinos

- Atmospheric neutrinos allow for a very broad amount of physics to be done.
  - Wide range of energies from a few GeV to 100's of TeV
  - Many baselines observed up to 12,700 km
- Matter effects for Core-crossing neutrinos
- Can test standard oscillation picture
  - ν_μ disappearance, ν_τ appearance, mass ordering
- Broad spectrum of BSM oscillation physics probed
  - sterile neutrinos, NSI, decoherence, etc.

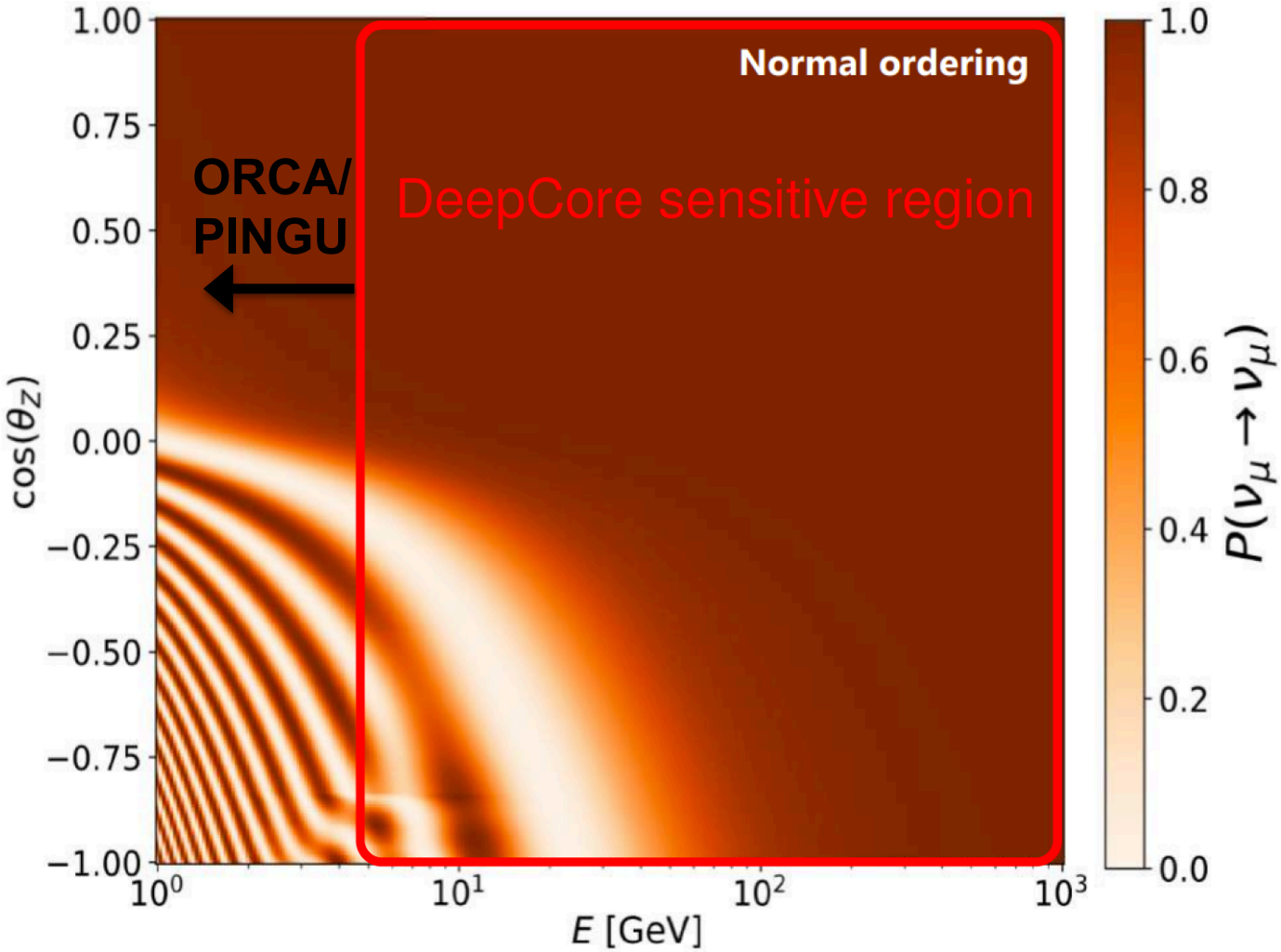


Neutrino telescopes:
IceCube, DeepCore, PINGU, Balkal-GVD, ANTARES, ORCA, ...

From Joshua Hignight

Oscillograms

- Search for 3D distortions of events: [E, $\cos(\theta_{zenith})$, PID]



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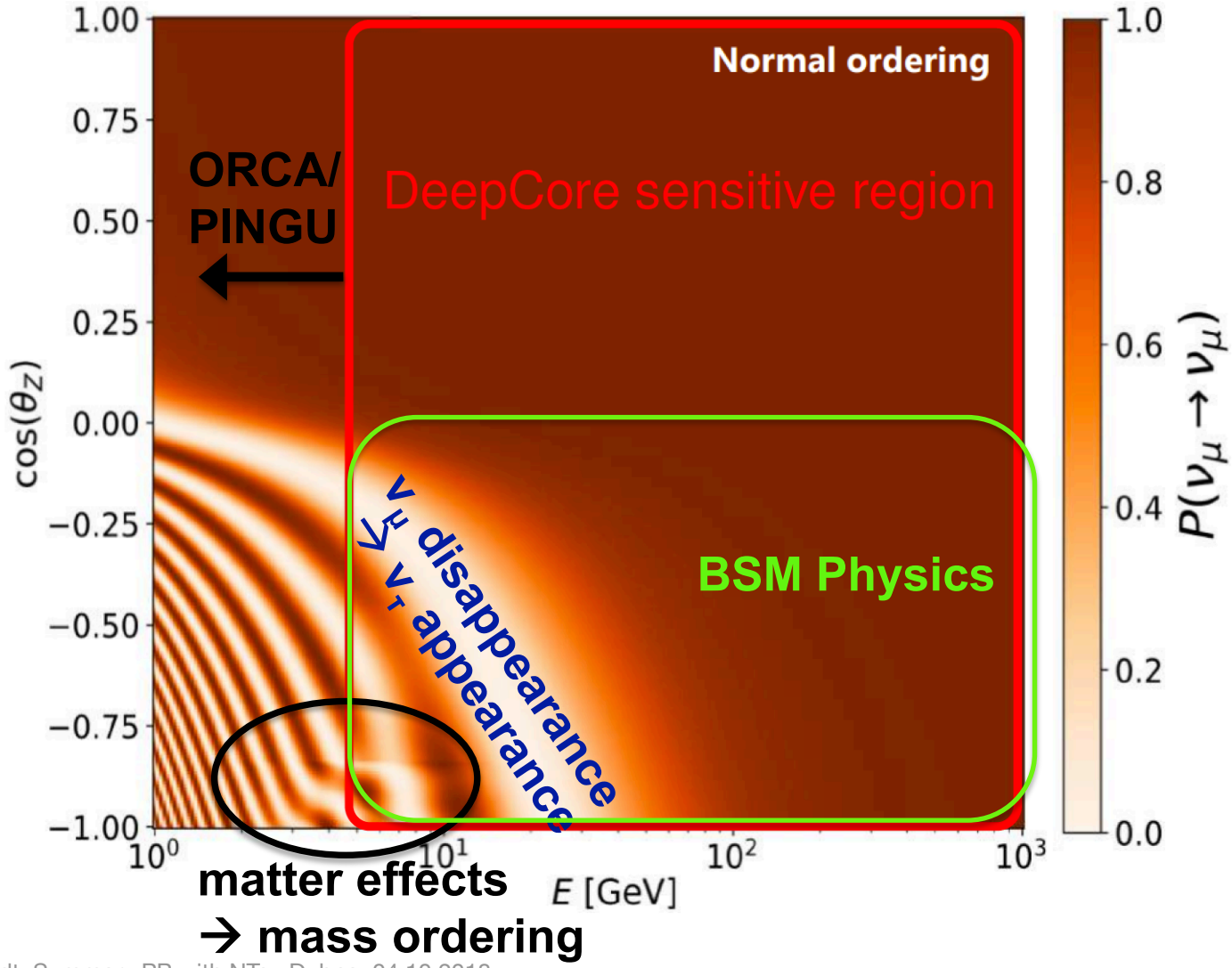
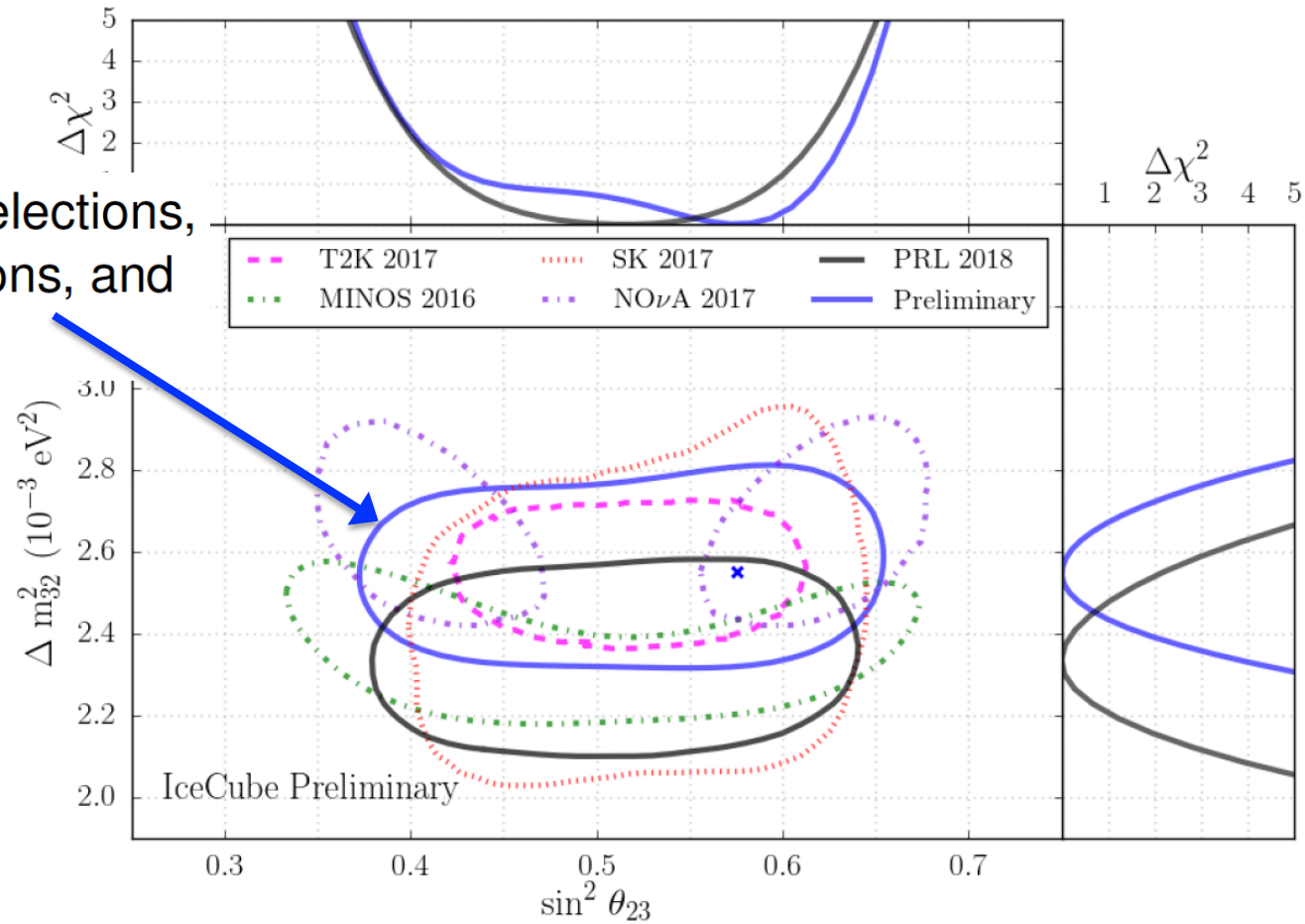


DeepCore

From Joshua Hignight

ν_μ Disappearance Result

- Use different event selections, different reconstructions, and different PID metrics
- Samples largely non-overlapping



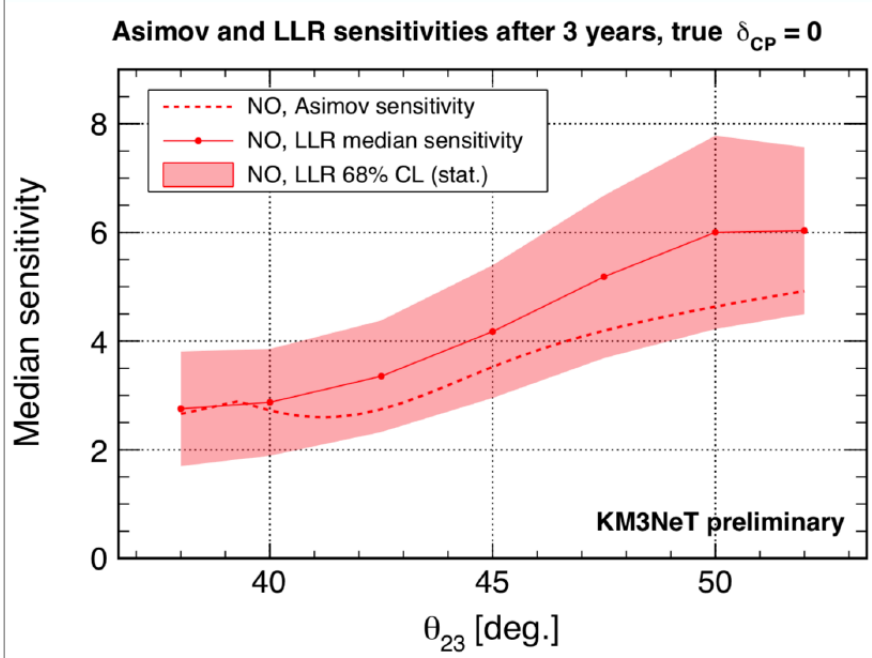
Outlook:

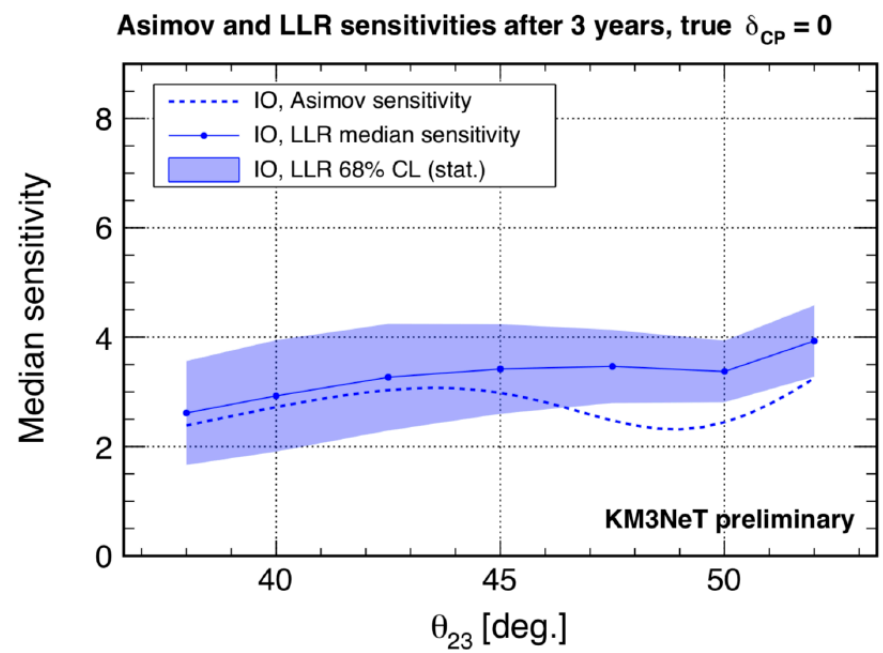
- Updated results with double the statistics currently underway!

From Alba Domi

Sensitivity to NMO

Statistical Methods: LLR tets statistic + χ^2 minimisation





*similar sensitivity for PINGU

** DeepCore not sensitive enough

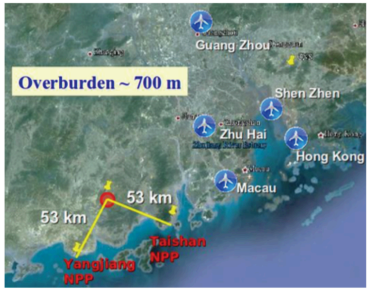
Ref: S. Bourret, L. Quinn: PoS Neutrino 2018

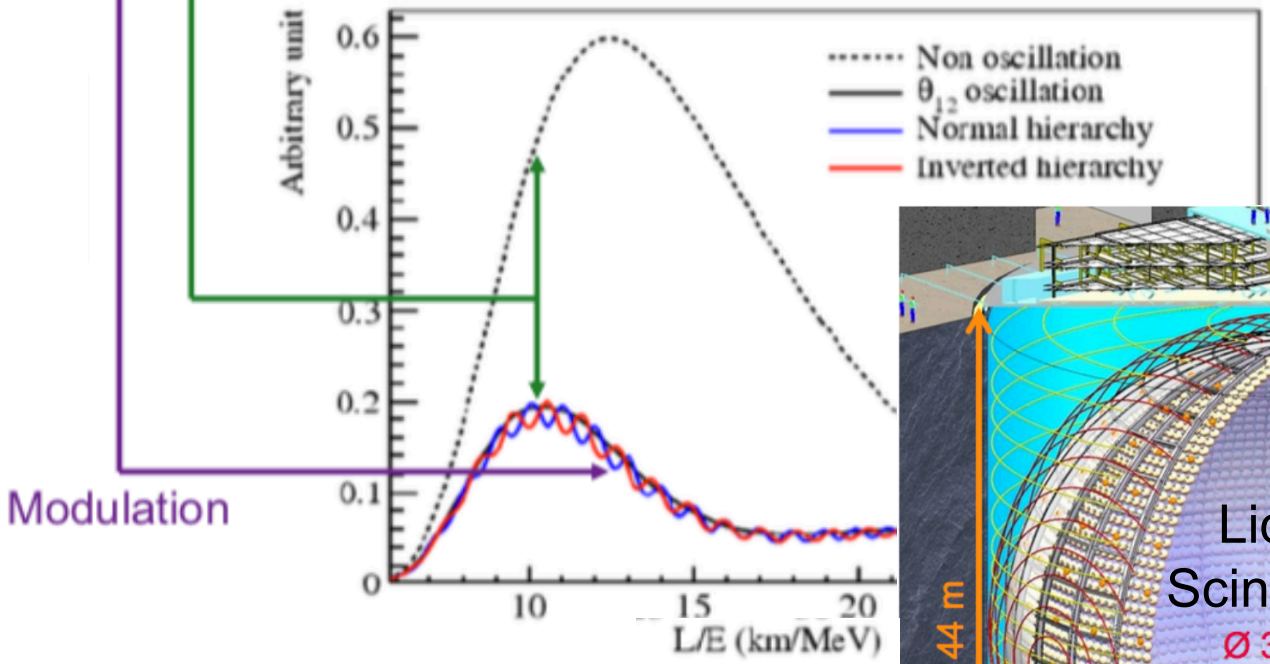
JUNO

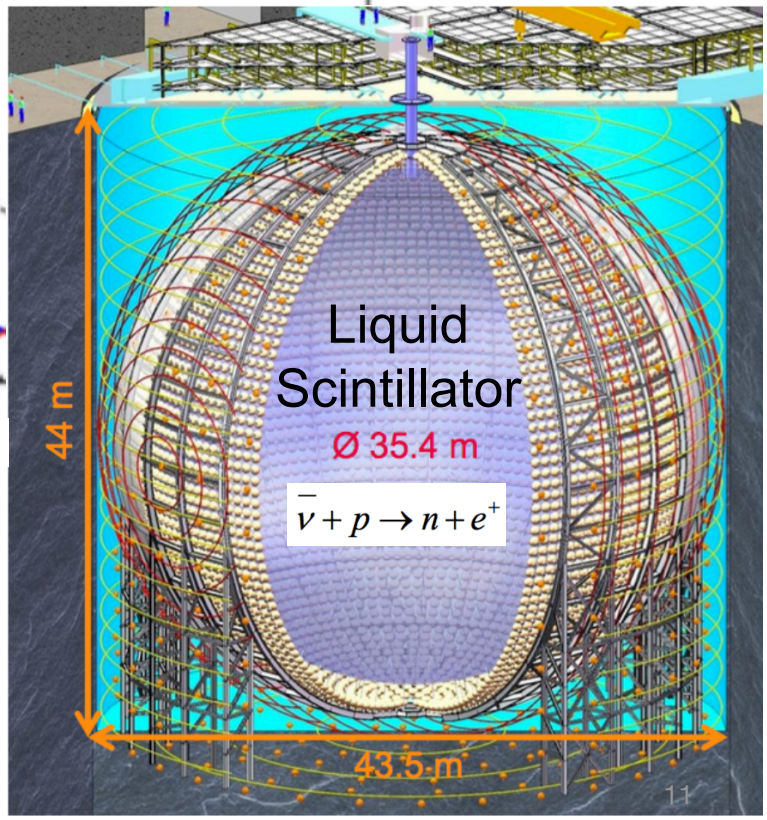
From Alexander Olshevskiy

NMO with JUNO

$$P_{\bar{\nu}_e \to \bar{\nu}_e} = 1 - \sin^2 2\theta_{13} \left(\cos^2\theta_{12}\, \mathbf{\sin^2 \Delta_{31}} + \sin^2\theta_{12}\, \mathbf{\sin^2 \Delta_{32}}\right) - \sin^2 2\theta_{12} \cos^4\theta_{13} \sin^2 \Delta_{21}$$







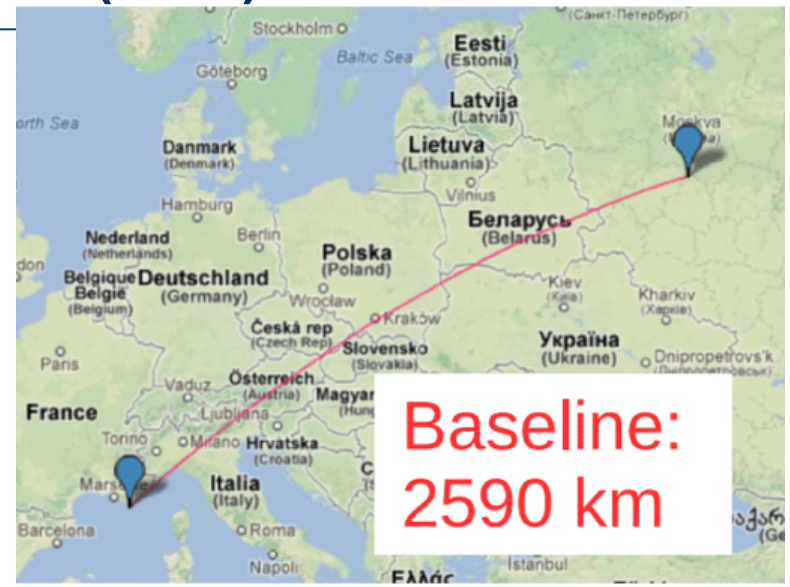
Sensitivity on MH with nominal exposure and energy resolution →6years

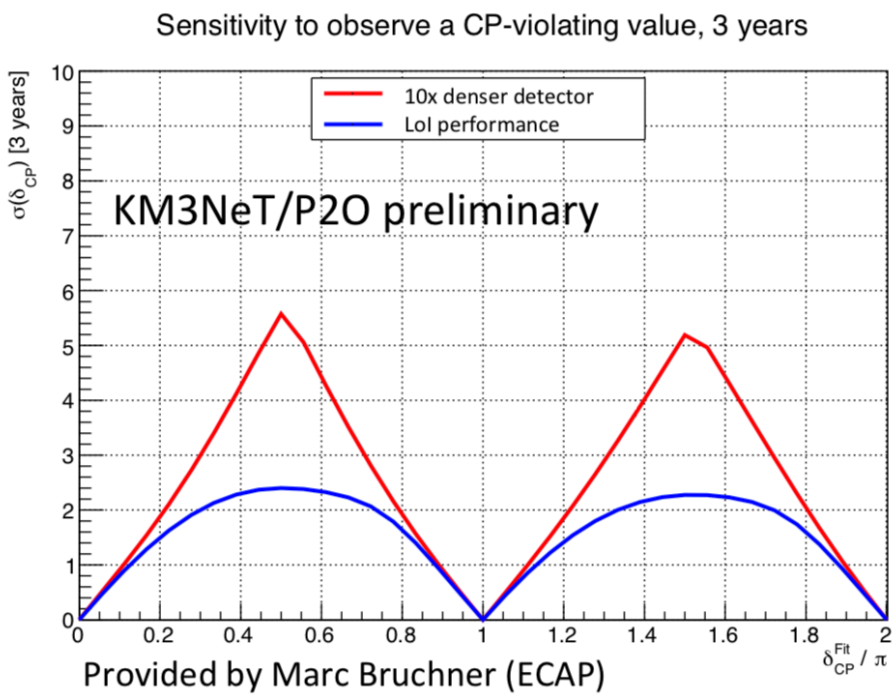
- $\Delta\chi^2 > 9$ with JUNO alone
- $\Delta\chi^2 > 16$ with external input of $\Delta m^2_{\mu\mu} \sim 1\%$

From Juergen Brunner

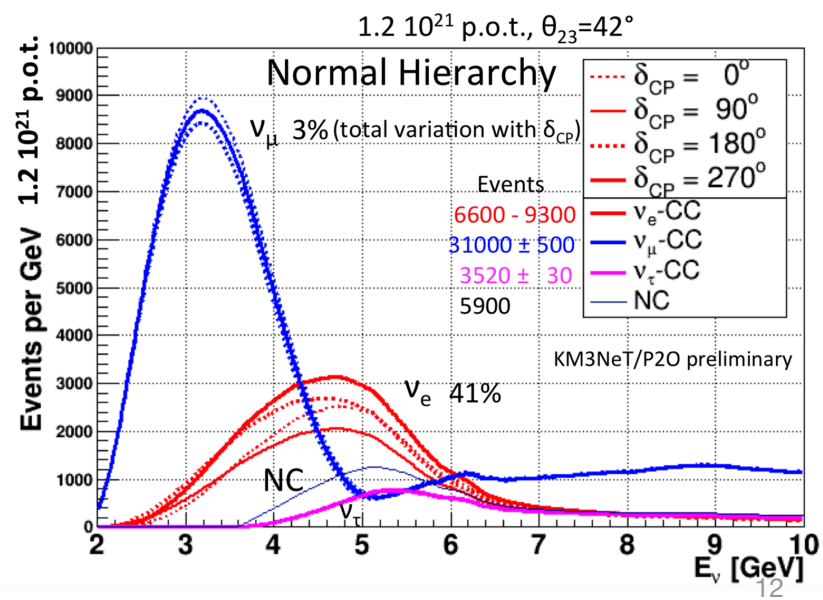
Using a ν-beam: Protvino to ORCA (P2O)

- Optimal baseline for separating NMO from δ_{CP}
- Determine NMO within 1 year, also with low-intensity beam
- Sensitivity to measure δ_{CP}





Event numbers – Neutrino Beam



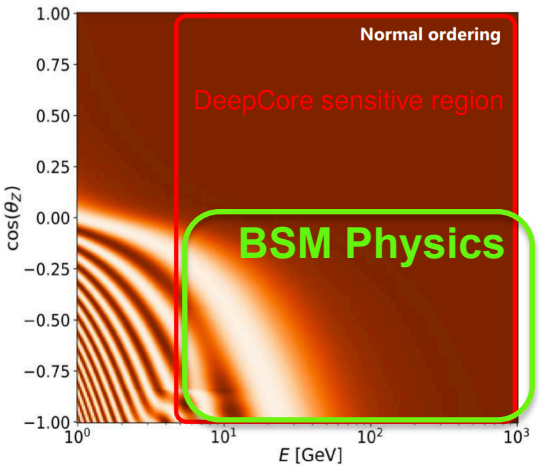
From Joshua Hignight

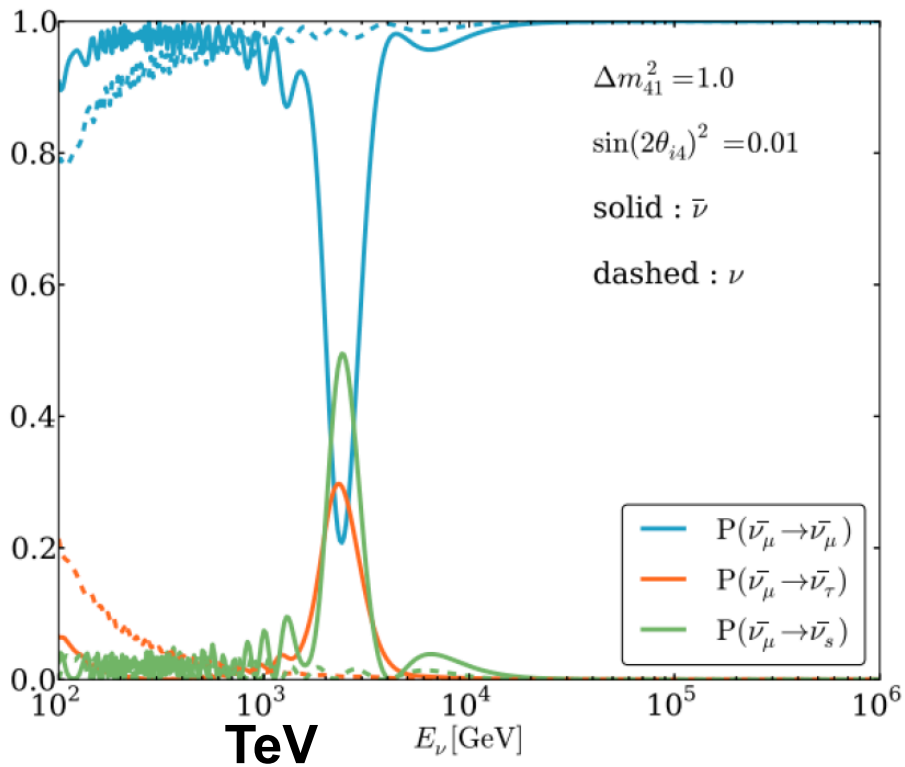
Sterile neutrino search with atm. ν

Resonance Effects

- In the Earth, for sterile neutrinos of $\Delta m^2 = \mathcal{O}(1\,eV^2)$ there is a matter-induced (parametric) resonant effect when:

$$E_\nu^{res} = \frac{\Delta m^2 \cos 2\theta}{2\sqrt{2} G_F N} \sim \mathcal{O}(TeV)$$

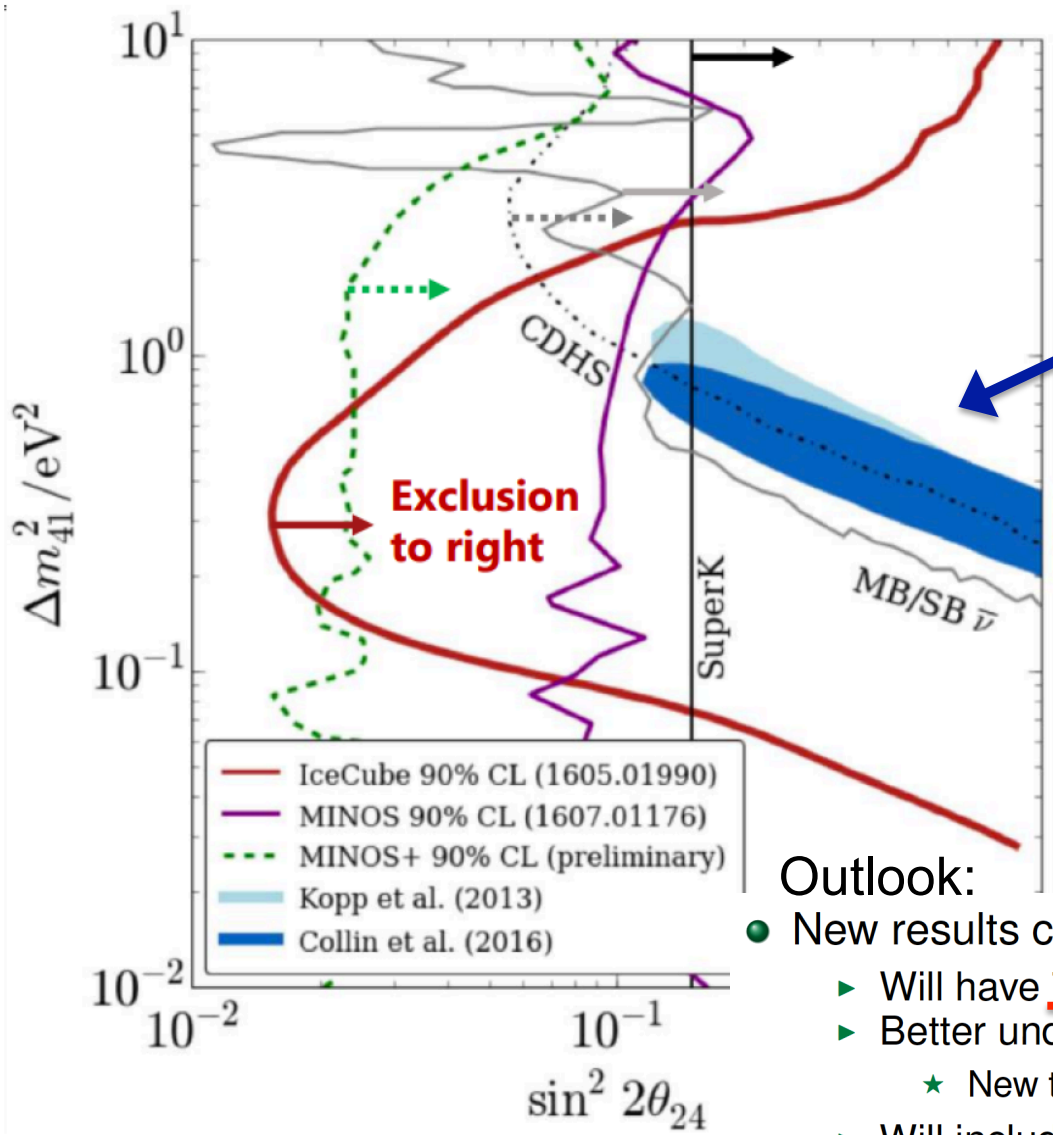




IceCube

From Joshua Hignight

Sterile neutrino search



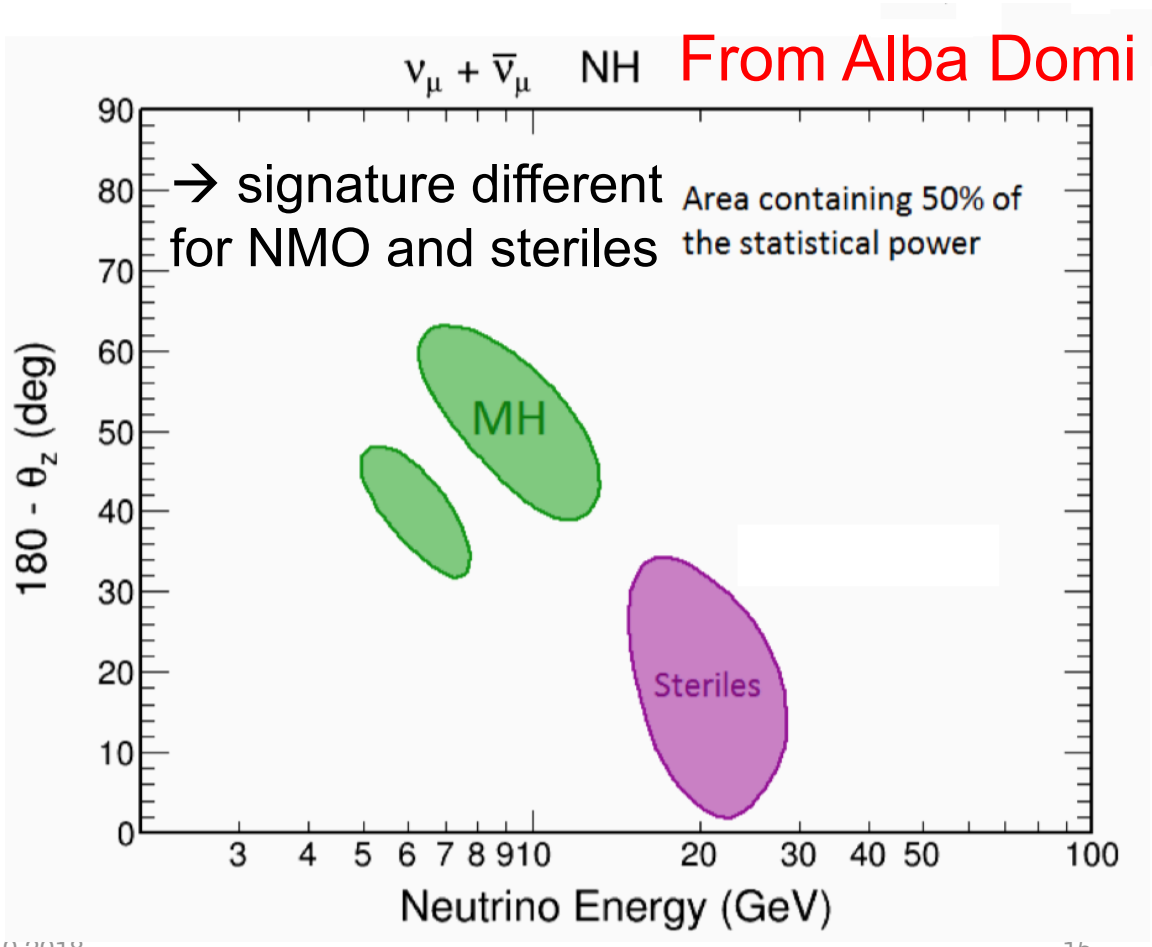
Allowed region from global fits (ν_e excess in LSND & MiniBooNE; deficit reactor $\bar{\nu}_e$)

Outlook:

- New results currently in progress
  - Will have 7 times the statistics of previous results
  - Better understanding and handling of many systematics
    - New treatment of holeice, bulkice, and flux
  - Will include limits on $|U_{\tau 4}|^2$

Sterile neutrino search at low energies

- Sterile neutrinos also modify oscillation pattern below ~100GeV → limits from:
- → IceCube
  Phys. Rev. D 95, 112002
- → ANTARES
  paper in preparation
- → promising sensitivities for ORCA & PINGU



From Dmitry Naumov

Sterile neutrino theory

15 minutes review of sterile neutrino

How sterile state can be observed

In neutrino oscillation as a

- Deficit of the rate
- E/L oscillation pattern

} Both in charged and neutral currents

- Loss of coherence could be important for eV scale neutrino

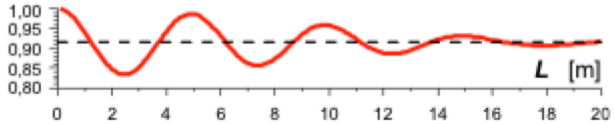
DANSS

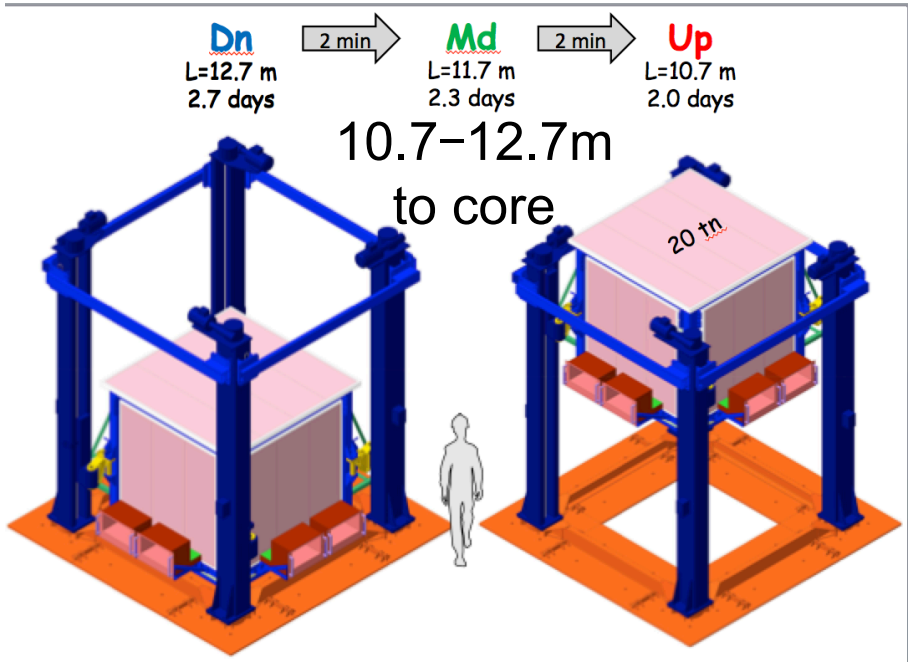
From Viacheslav Egorov

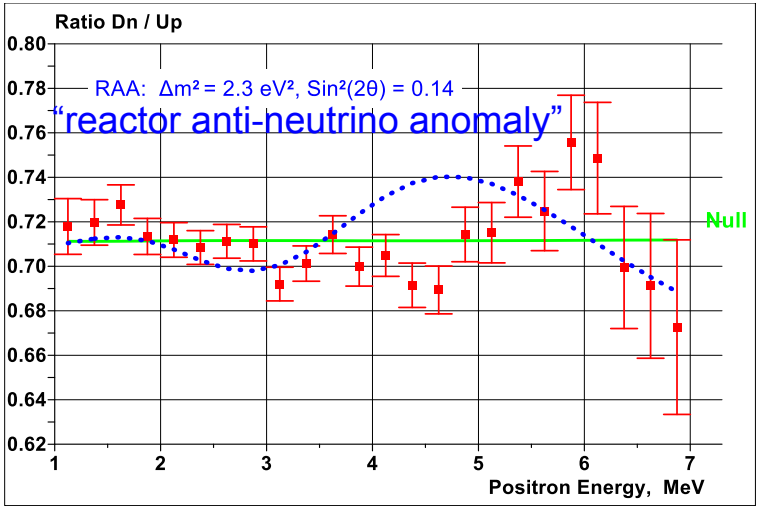
Sterile neutrino search @ reactors

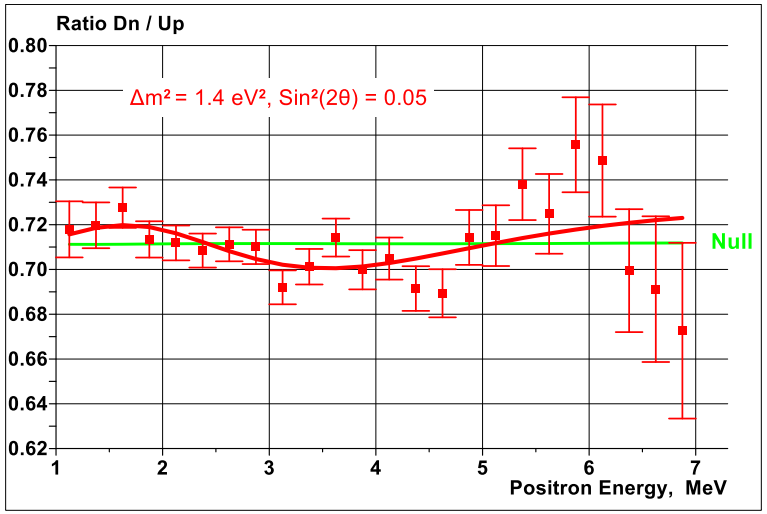
- Observe evolution of the neutrino flux with distance

(model-independent, free of main systematic errors and therefore is the most reliable)









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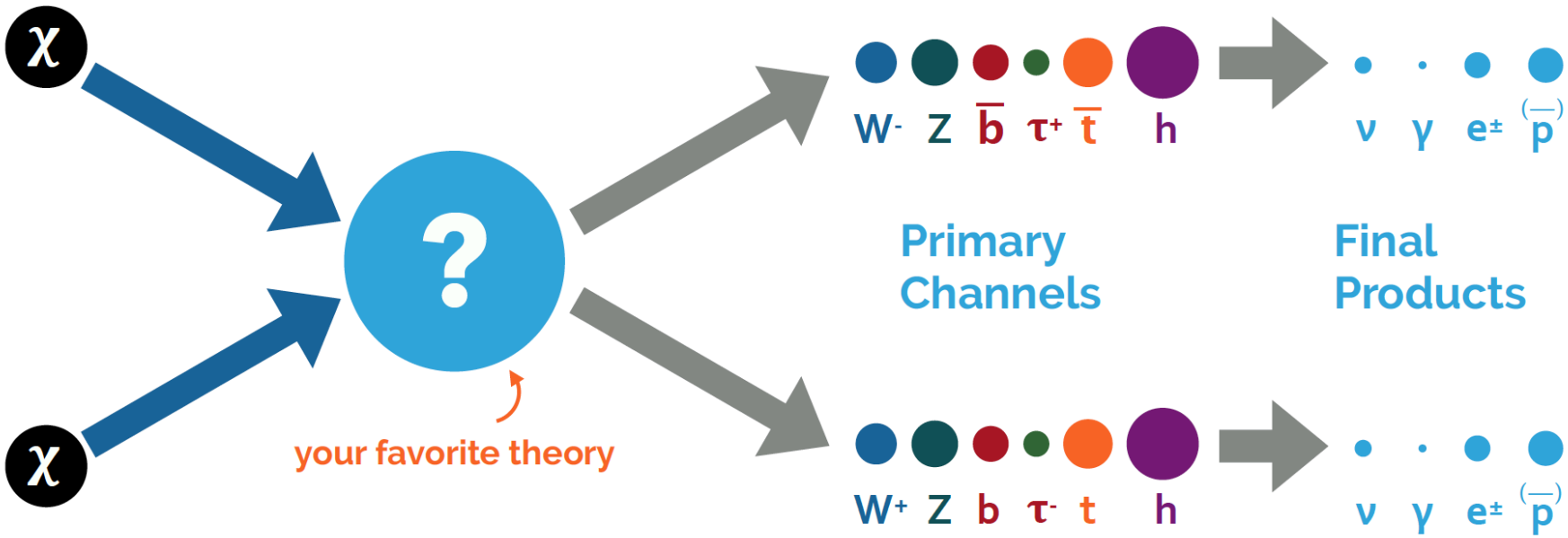
Indirect Detection of Dark Matter

From Juan A. Aguilar



Many results

Galactic Center ANTARES & IceCube 8

Celestial Bodies Results from the Sun 11

Celestial Bodies Results from the Earth 12

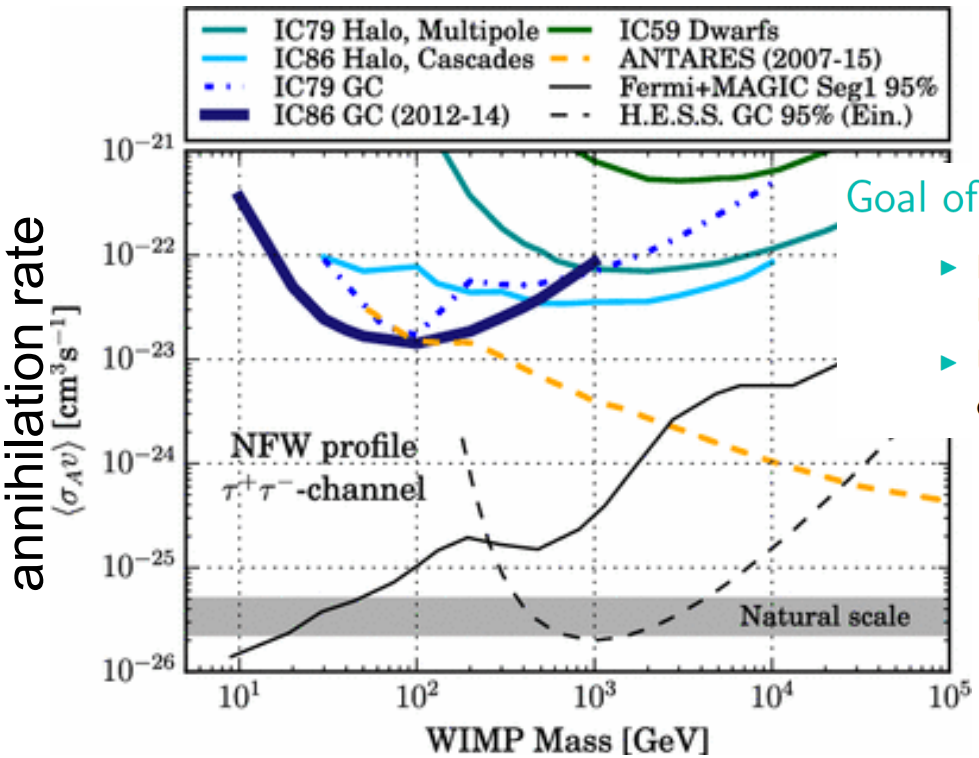
Decaying Dark Matter Lifetime 14

Neutrino Dark Matter Scattering 15

ANTARES & IceCube

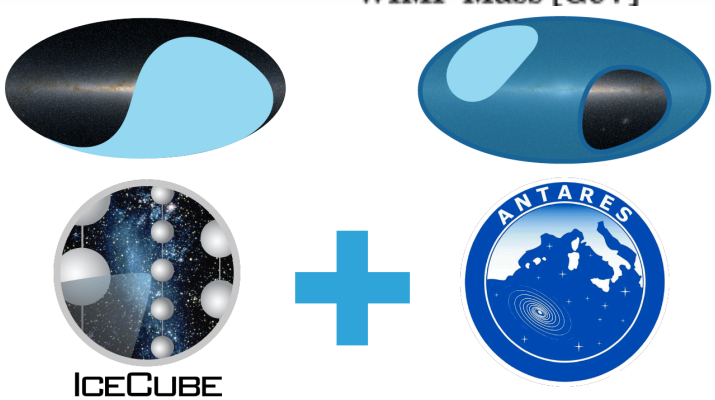
From Rebecca Gozzini

Dark Matter from Galactic Center



Goal of combined analysis

- Improve the limit on $\langle \sigma v \rangle$ in the region where ANTARES and IceCube are comparable: between 50 GeV and 1 TeV
- Understand and unify the analysis method of the two collaborations



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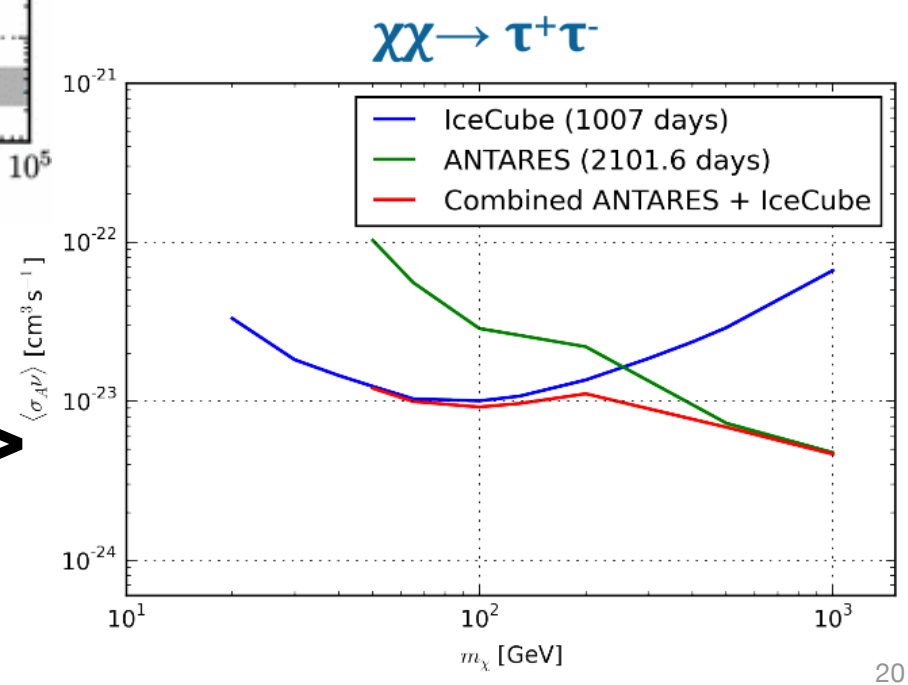
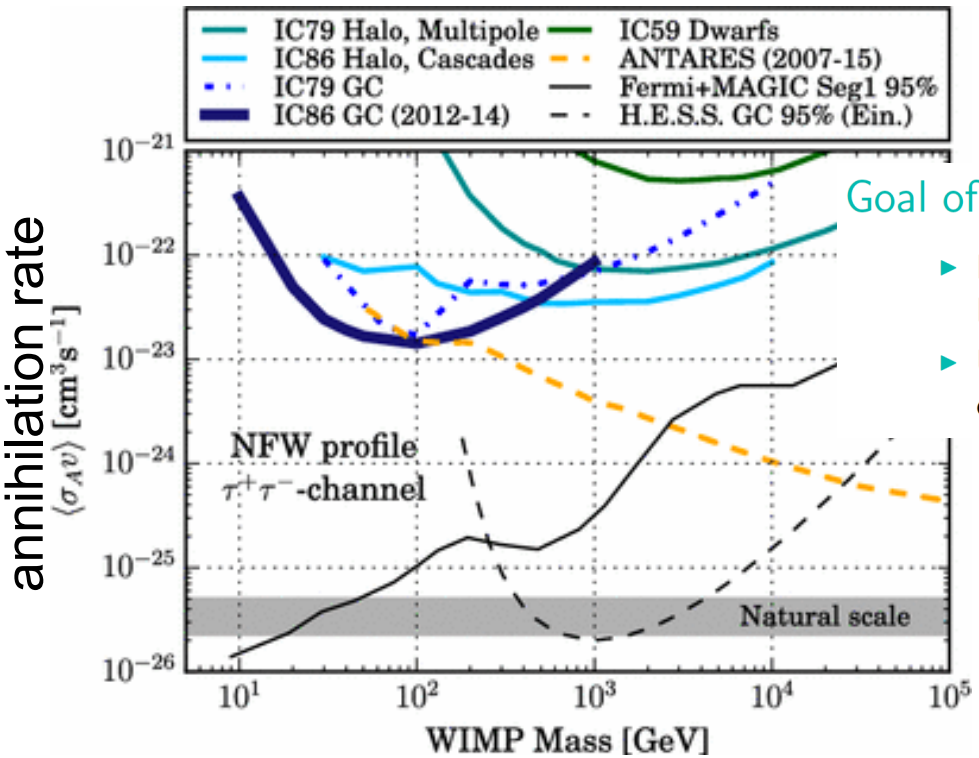


ANTARES & IceCube

From Rebecca Gozzini

Dark Matter from Galactic Center



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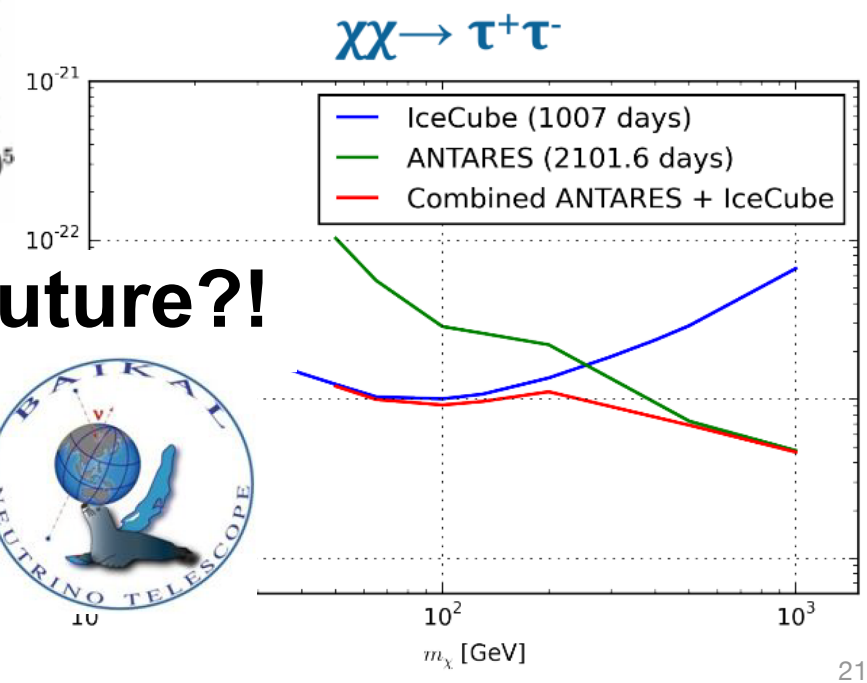
Future?!

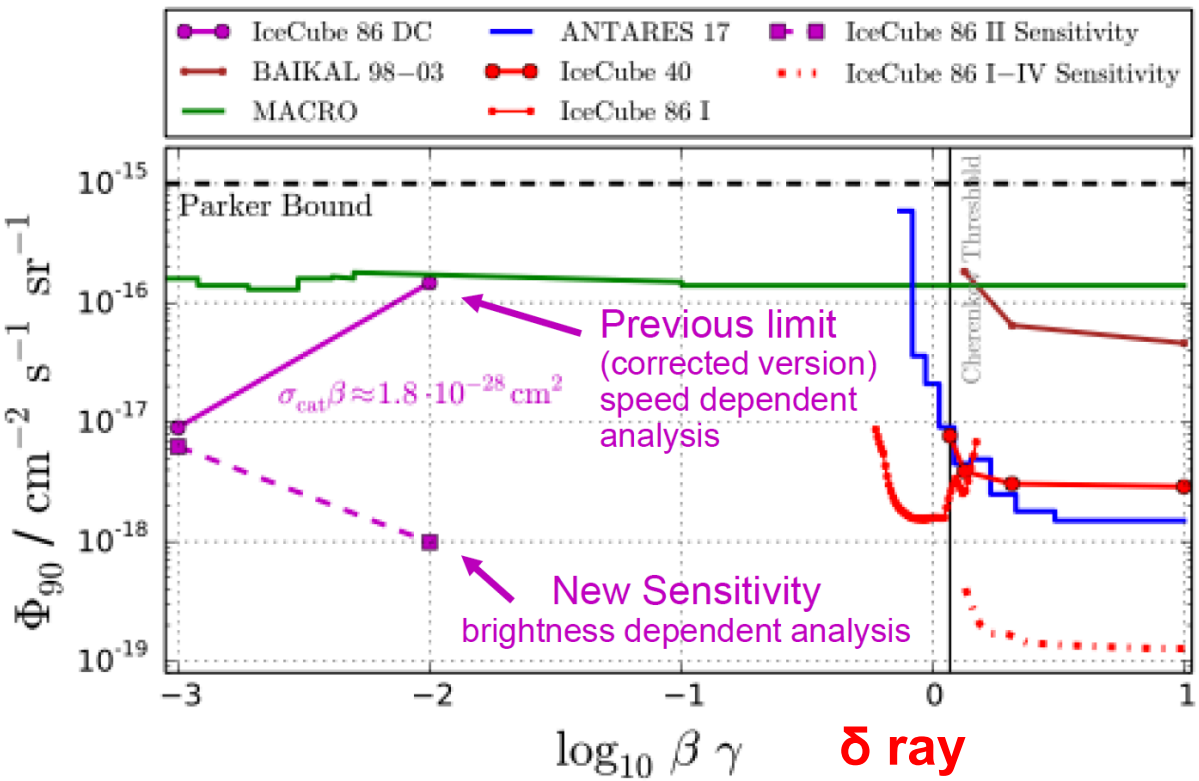


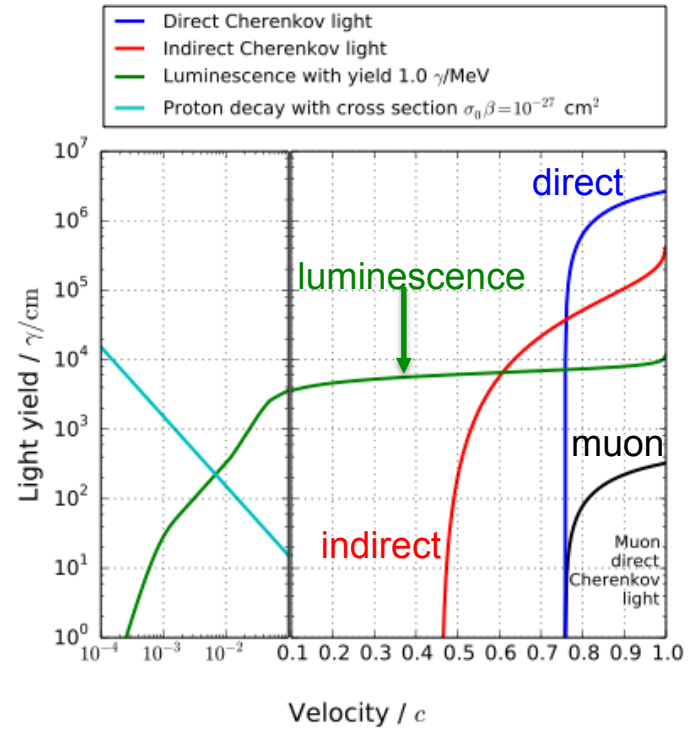
IceCube
Magnetic Monopoles

From Christian Spiering
(using material of Anna Pollmann)

Signature:

- ***High*** **energy deposition**
- ***Smooth*** **energy deposition along the track**
- ***Lower*** **velocity**





Estimated
new density
- unblinding (results) expected soon

δ ray

Catalysis of proton decay
"Rubakov-Callen effect"

Luminescence

Indirect Cherenkov radiation

Direct Cherenkov radiation

… summary of Exotics & Oscillation sessions in hopefully 15min….

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International Conference Center		15:15 - 15:40
Combined dark matter Antares/IceCube	*Sara Rebecca GOZZINI*	
International Conference Center		15:40 - 15:55
Monopole searches: overview	*Christian SPIERING*	
International Conference Center		15:55 - 16:05
Search for particles beyond the Standard Model with the proposed SHiP experiment at CERN	*Prof. Roumen TSENOV*	
International Conference Center		16:05 - 16:25

15:00

16:00

Parallel session 6: Oscillations

NMO: Status and JUNO plans	*Prof. Alexander OLSHEVSKIY*	
International Conference Center		16:50 - 17:10
Particle Physics with ORCA (oscill./steriles/DM)	*Ms. Alba DOMI*	
International Conference Center		17:10 - 17:30
Oscillations with IceCube upgrade	*Dr. Joshua HIGNIGHT*	
International Conference Center		17:30 - 17:50
Sterile neutrinos: Overview	*Dr. Dmitry NAUMOV*	
International Conference Center		17:50 - 18:10
Sterile neutrinos: IceCube results	*Dr. Joshua HIGNIGHT*	
International Conference Center		18:10 - 18:20
Sterile neutrinos: Latest results from reactors with focus on DANSS results	*Viacheslav EGOROV*	
International Conference Center		18:20 - 18:40

17:00

18:00