seminarium sprawozdawcze za rok 2018, Świerk, 10/XII/2018

Astrofizyka neutrin i ciemna materia

Piotr Mijakowski

SUPER K

KM3NeT

NARODOWE CENTRUM BADAŃ JĄDROWYCH ŚWIERK

GROUP IN 2018

Part of Warsaw Neutrino group led by prof. Ewa Rondio.
Two main projects:

- Super-Kamiokande (2 pers.)
  - Piotr Mijakowski (coordinator+research), Katarzyna Frankiewicz (phd student until Sep/2018, now: researcher@NCBJ, next: post-doc at Boston University)
  - Topics: *dark matter*

- KM3NeT (5 pers.: 1 + 2 post-docs + 1 PhD + 1 MSc)
  - Piotr Mijakowski (coordinator, Conference and Outreach Committee, Insitute Board, Review & Resources Board, CORSIKA sim. group coordinator), Piotr Kalaczyński (PhD since Dec/2017), Meghna K.K. (post-doc since May/2018), Rafał Wojaczyński (post-doc since Dec/2018), Jerzy Mańczak (MSc in 2018)
  - Topics: *dark matter* (Meghna), *cosmic ray shower simulations & MC in general* (Piotr K.), *neutrino interactions & Glashow Resonance search* (Jerzy)

FINANCING

KM3NeT + Super-Kamiokande

1. NCN: SONATA-BIS, coordinator: P.Mijakowski, May/2016-2020, 1.13 mln PLN

Super-Kamiokande

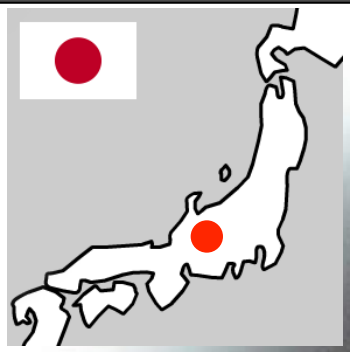
2. NCN: Preludium, coordinator: K. Frankiewicz, March/2016-/2018, 100k PLN

3. EU: Horizon-2020, MSCA-RISE-2014 “SKPLUS”, Dec/2014-/2018, 58.5k EUR for NCBJ, consortium: NCBJ-PW-UAM (Madrid), coordinator@NCBJ: P.M.

4. MNiSW: Premia na Horyzont related to SKPLUS, ~50k PLN

5. MNiSW: projekt współfinansowany, related to SKPLUS, ~30k PLN

SUPER-KAMIOKANDE



Super-Kamiokande

@ Kamioka Observatory (ICRR, University of Tokyo), Japan

photomultipliers (PMTs) detect Cherenkov light

located 1km underground

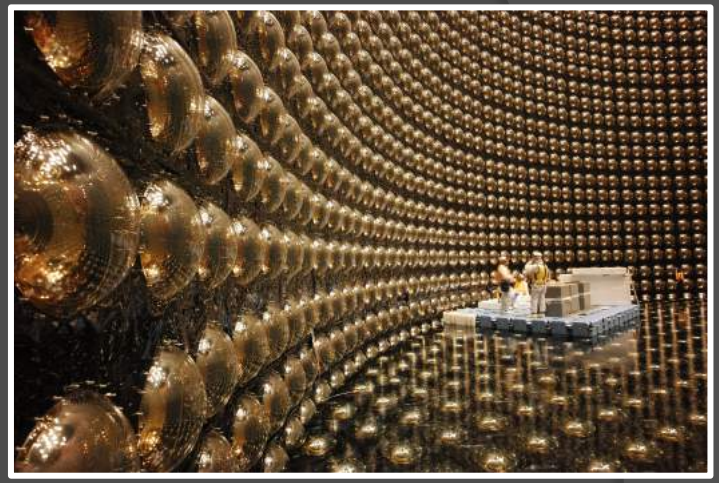
40m

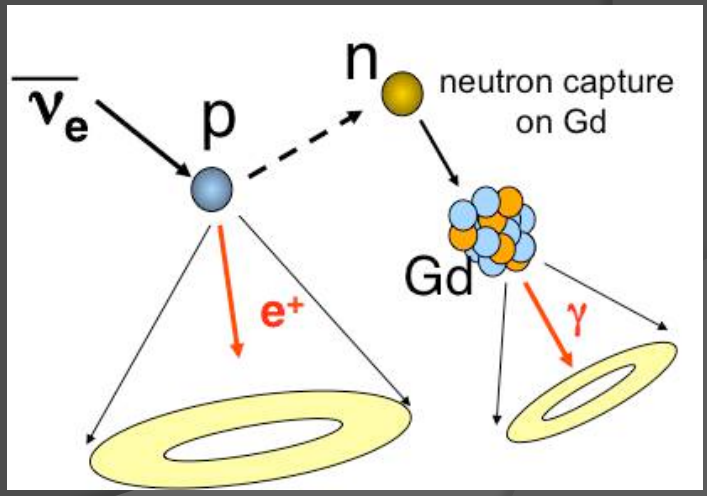
40m

- 50 kton of pure water (22.5 kton FV)
- inner (ID) & outer/veto (OD) detection regions
- SK runs from 1996
- measures solar, atmospheric, cosmic & accelerator neutrinos
- T.Kajita → Nobel Prize 2015

Super-Kamiokande: TANK WORK

- Physical work at the SK detector upgrade, summer 2018
- 5 people from NCBJ participated, thanks to EU, SKPLUS grant: K.Frankiewicz, P.Kalaczyński, K.Kowalik, P.Mijakowski, G.Żarnecki (3 pers•months in total)
- PMT checks & calibration, rust removal, tyvek installation, surface cleaning → detector will have to be water sealed, before we loose ~1.5 ton of water/day
- GOAL: SK-Gd phase, ~8 tons of gadolinium sulfate dissolved in water (0.2% concentration) increase sensitivity to SN anti-ν which is limited currently by backgrounds
- Possibility to discover diffuse SN background neutrinos by coincidence reaction with n capture (up to ~5 events/year at Super-K & ~800 evts at Hyper-K)
- WORK IS DONE, DETECTOR IS BEING FILLED WITH WATER





TANK WORK


top of inner
detector


gondola access


outer/veto
detector work

Super-Kamiokande: DARK MATTER

2 independent analyses (PM and KF are preforming these works solo)

- Search for DM-induced neutrinos using a fit method

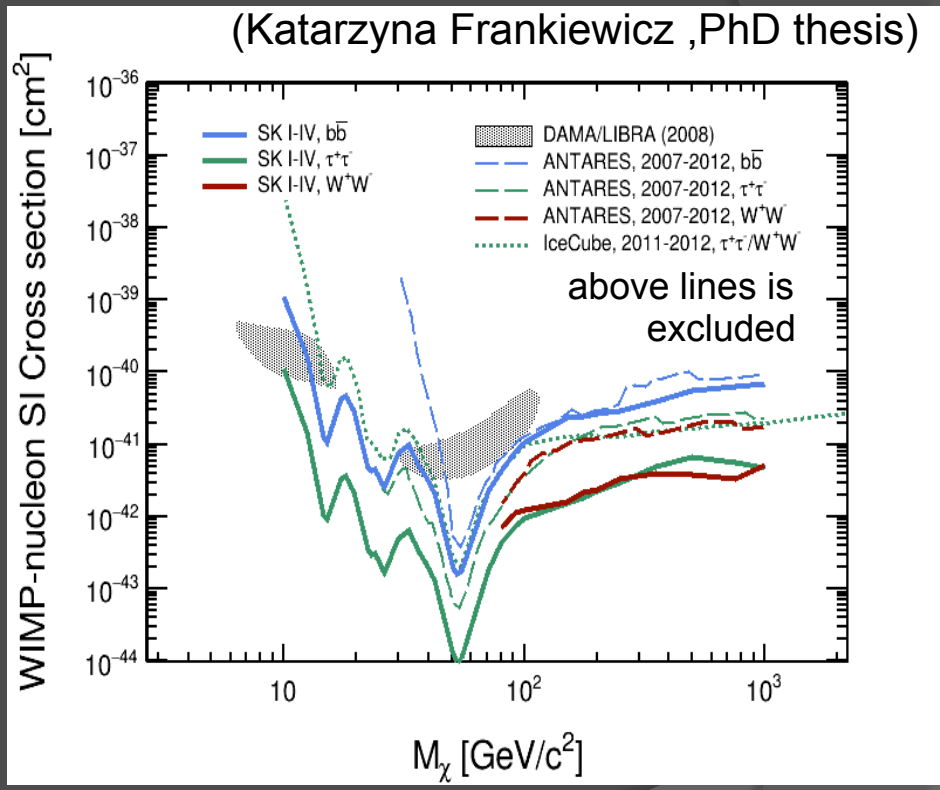
$$\chi\chi \rightarrow \nu\bar{\nu}, W^+W^-, b\bar{b}, \mu^+\mu^- \rightarrow ... \nu_{e/\mu/\tau}$$

$$\text{DATA} \overset{?}{=} \underbrace{\text{DM} + \nu \text{ ATM}}_{\text{Monte Carlo}}$$

- Galactic Center (by PM): finished in 2017, paper to Physical Rev. D under internal revision in 2018

- Earth WIMPS (by K.Frankiewicz): finished in 2018, paper to PRL under internal revision
  - Result was published in the **PhD thesis** of KF, defended in Sep/2018 → **nominated for distinction by 2 referees**

EARTH WIMP search, SK limits 2018
(Katarzyna Frankiewicz ,PhD thesis)

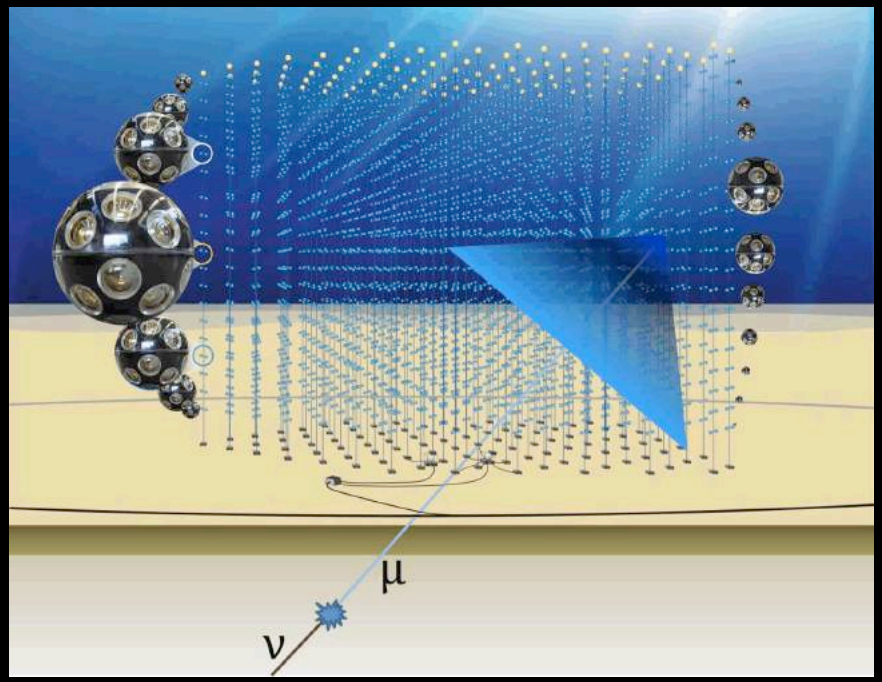


The strongest limits among all neutrino experiments!

- 2018: all SK DM results presented by PM at 3 international conferences (Moriond, TMEX, Dark Ghosts) & 2 seminars

KM3NET

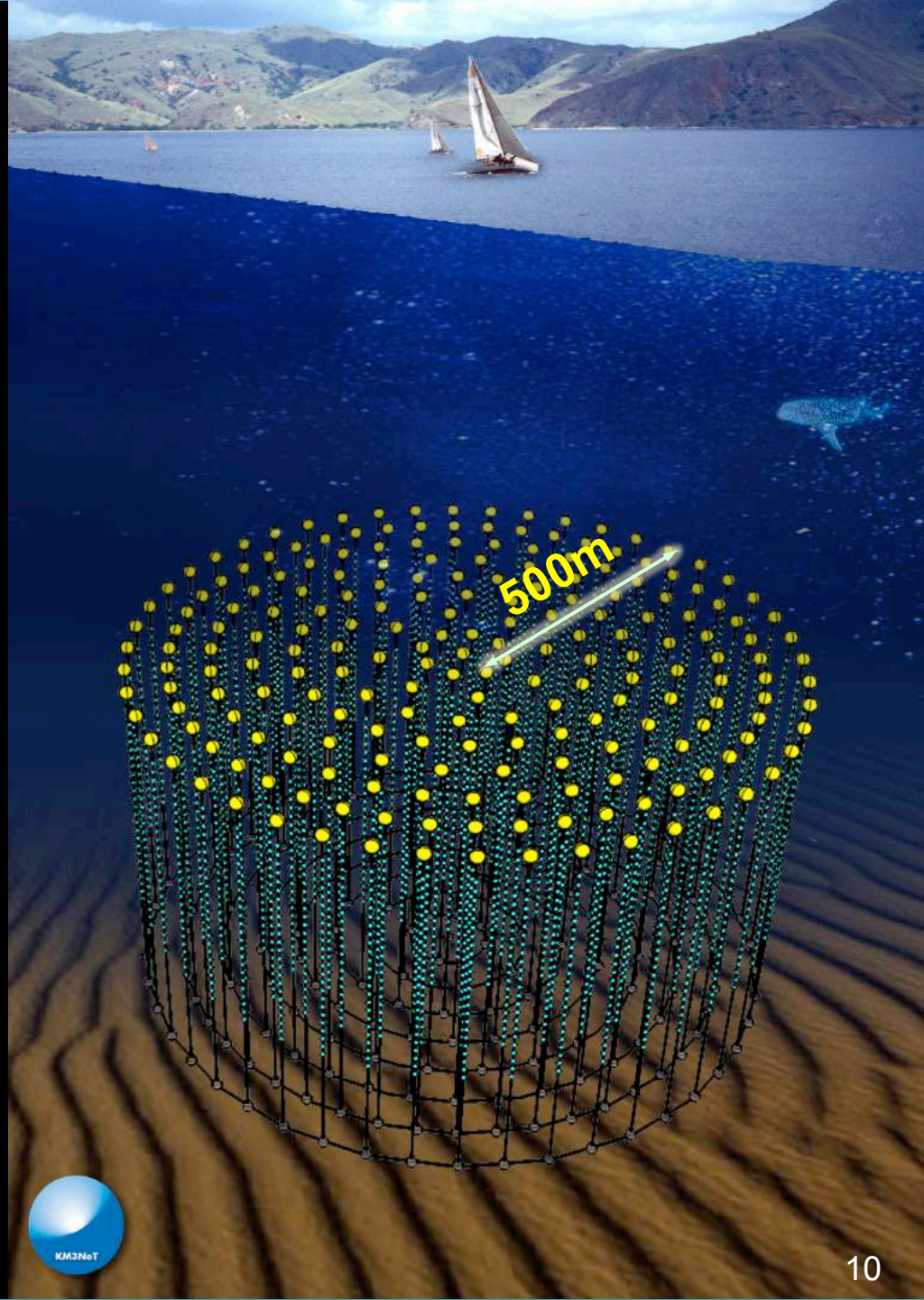
KM3NeT



- Modular neutrino research infrastructure in the Mediterranean Sea (aim for ~1km^3)

2 DETECTORS:

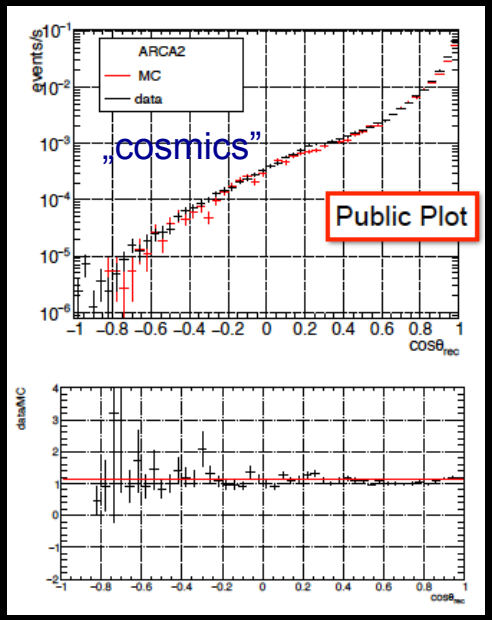
- ORCA Toulon (FR) ~2.4km depth
- ARCA Capo Pasero (IT) ~1km^3, ~3.4km depth

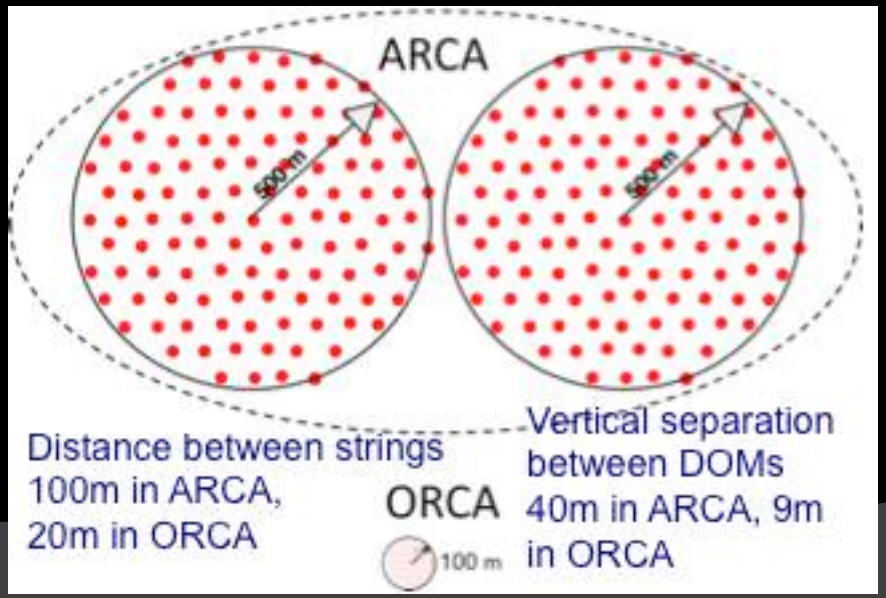


ARCA / ORCA

ARCA (Astroparticle Research with Cosmics in the Abyss)

- GOAL: 2x115 strings, ~1km3
- Phase I: 24 strings, 0.1 km3
- So far: 3 strings





ORCA (Oscillation Research with Cosmics in the Abyss)

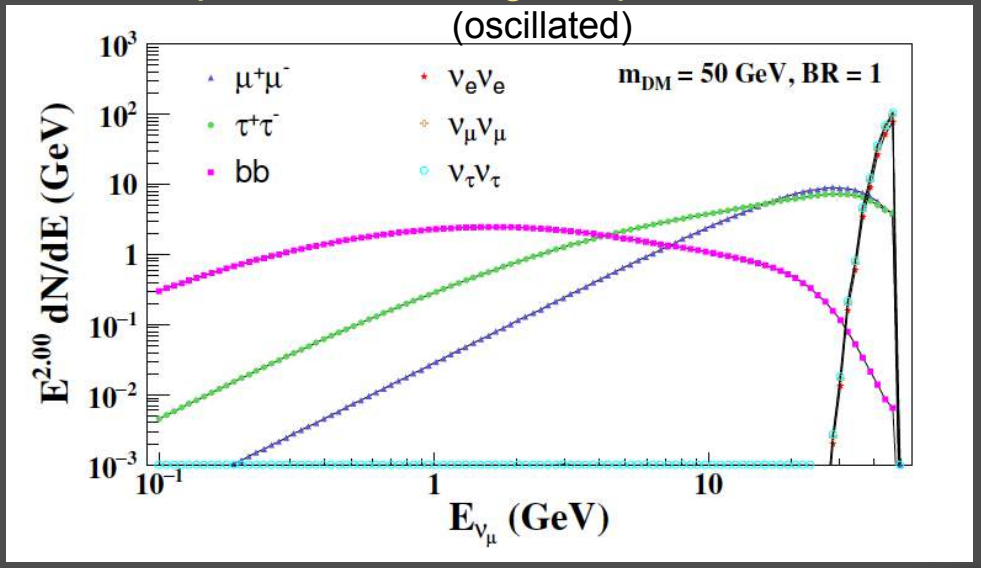
- study of atmospheric ν
- 1st stage: 6 strings in KM3NeT-FR (Toulon) already funded, 3 already deployed
- next phase: 115 strings, 3.7Mton (x20 bigger than Hyper-K)

KM3NeT: our activities in 2018

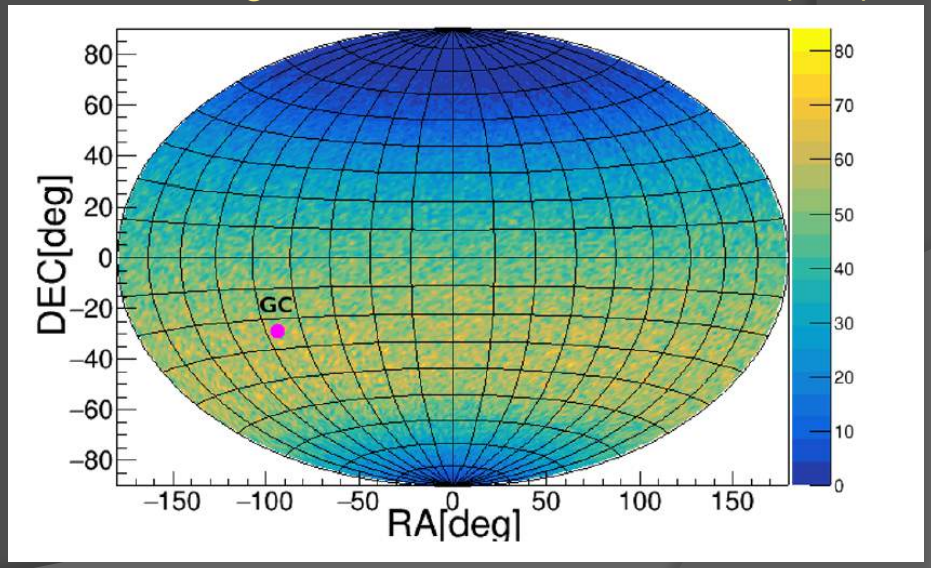
1. Dark Matter: sensitivity search for DM-induced νs from Galactic Center and halo using ORCA detector, *Meghna K. K.*

- in 1 year ORCA is expected to reach 3-10x better sensitivity than Super-K in 20 yrs
- post-doc started in May/2018, work in progress …

example: simulated signal spectra from GC (oscillated)



atm. νs bkg seen in ORCA in RA/DEC (MC)



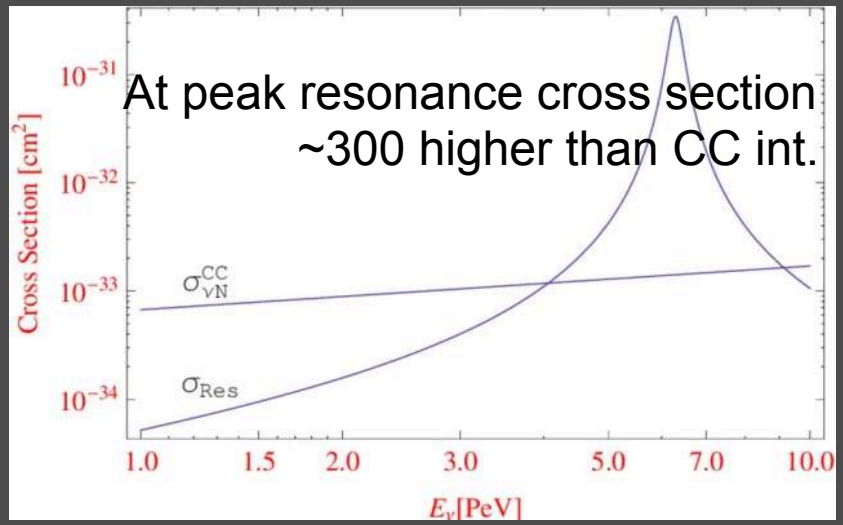
KM3NeT: our activities in 2018

2. MSc thesis:

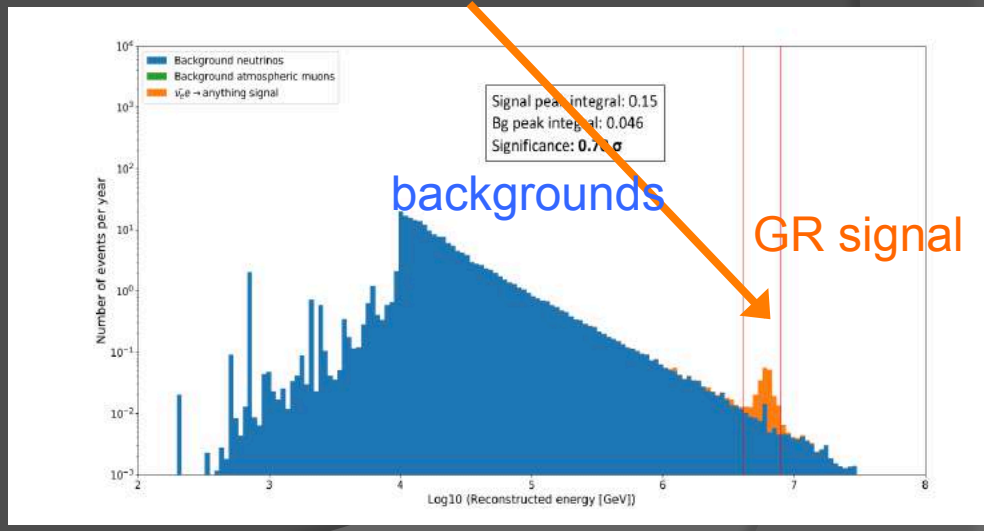
"Sensitivity study for the Glashow Resonance detection at KM3NeT", *Jerzy Mańczak*

- thesis graded with 5 (supervised by PM and M.Posiadała-Zezula UW),
- Jerzy currently PhD @ fellow KM3NeT group in Valencia

electron anti-n interactions@6.3 PeV



expected signal after reconstruction



reconstructed ν energy

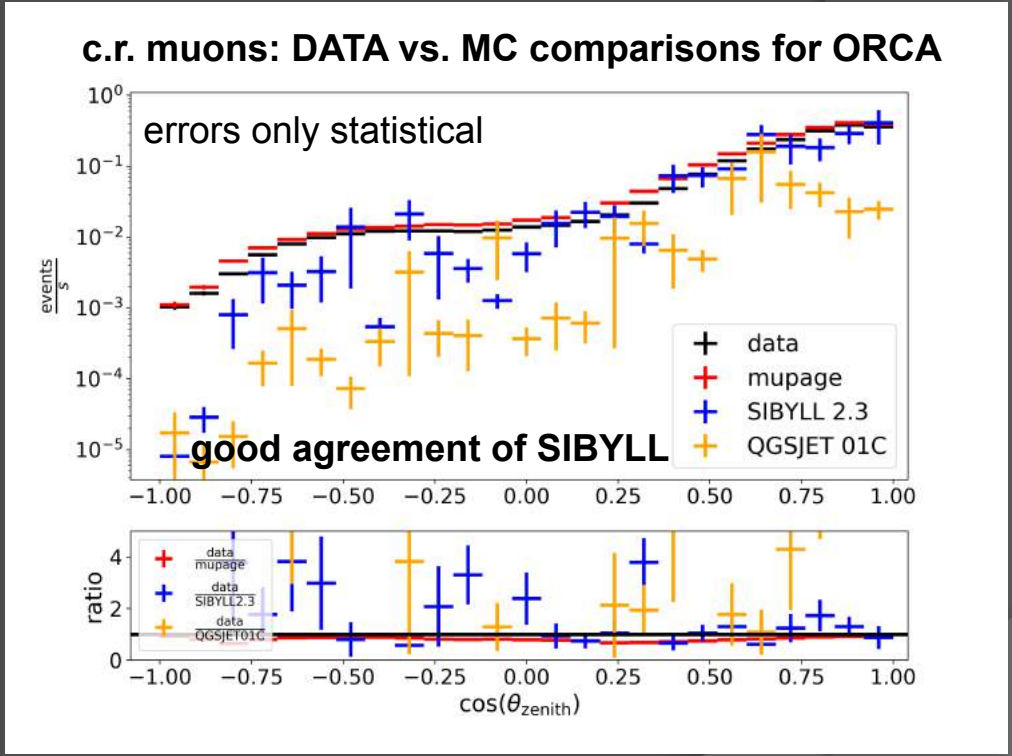
Full ARCA detector: **0.7σ in 1 year, 3σ in 9.2 yrs**

KM3NeT: our activities in 2018

3. ARCA/ORCA Monte Carlo work: CORSIKA based cosmic ray shower simulations, *Piotr Kalaczyński (PhD student)*

- atm. ν and muons are main bkg in search for astrophysical neutrinos
- full detector simulation chain: CORSIKA products @ sea level, propagation in water, interactions in detectors, light prod. simulation, trigger, detector reconstruction etc.
- *GOALS:* ***compare with cosmic ray muon data from phase-1 ARCA & ORCA detectors****, self-veto study, search for charm component of the cosmic rays*
- *CIŚ is being used for some of these simulations*

Reaching agreement of MC with DATA
→ important milestone for the ARCA/ ORCA prototypes due to Piotr's work



So far, no one has measured cosmic rays at the depth of 3.4 km of water

OUTREACH: COSMIC WATCH

CosmicWatch

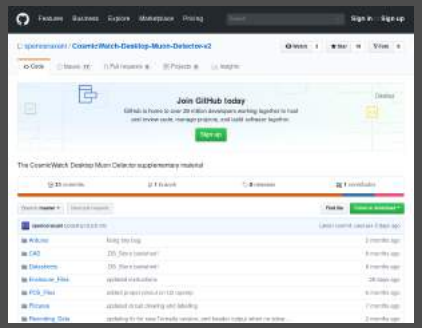
a particle detector you can build yourself

- Self-contained, pocket size detector
- Based on plastic scintillator and silicon PMT
- USB powered, open-source software available
- Easy to build and inexpensive (~100 USD)
- Broad educational applications

Web page: **www.cosmicwatch.lns.mit.edu**

Facebook:
www.facebook.com/cosmicwatch.mit

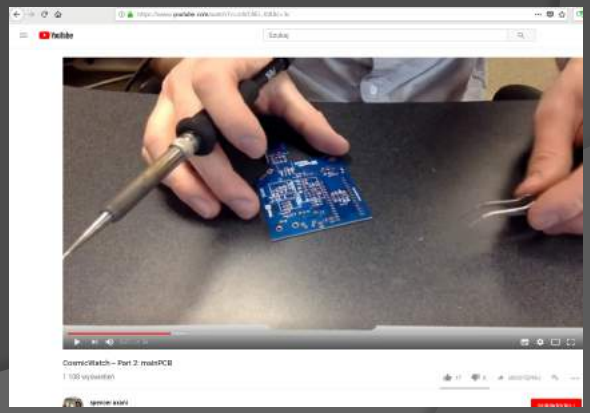
GitHub repository:
→ all necessary information



github.com/spenceraxani/
CosmicWatch-Desktop-Muon-Detector-v2

Recent Paper:
S. N. Axani, K. Frankiewicz, J. M. Conrad,
"*The CosmicWatch Desktop Muon Detector: a self-contained, pocket sized particle detector*"
JINST 13 (2018) no.03, P03019

YouTube: step-by-step instructions



www.youtube.com/watch?v=e4lXzNiNxgU&

NCBJ, Education and Training Division

Program: **“Detectors for schools”**
→ Schools can borrow particle detectors to perform various measurements and discuss the results. We provide some ideas, instructions and software.
https://www.ncbj.gov.pl/edukacja/detektory-szkol

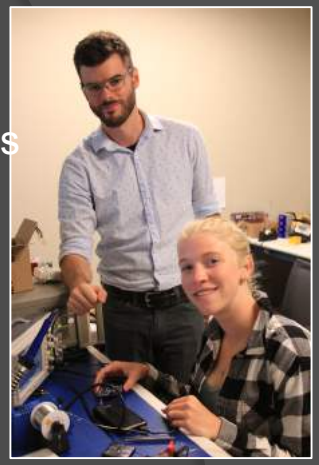
30 Detectors

Workshop for teachers, Olsztyn

Wisconsin IceCube Particle Astrophysics Center

50 Detectors

Madison, USA
Program for high school and undergraduate students



ALPhA’s Laboratory Immersions

Learn a new advanced laboratory experiment well enough to teach it with confidence! 3 day intensive program

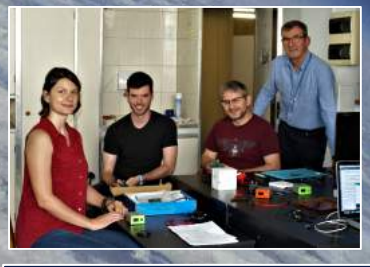
Adler Planetarium Chicago, USA

Program “**Far Horizons”:** Design an experiment and launch it into space!

CREDO project

Cosmic-Ray Extremely Distributed Observatory
Konrad Kopański, Wojciech Noga

Near Space Conference Touruń, 22/09/2018

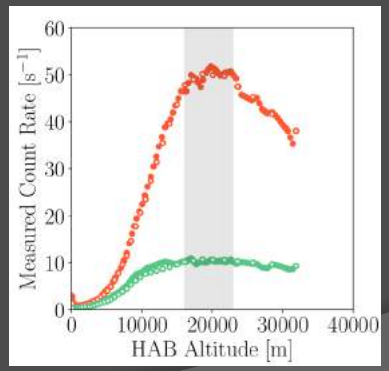


Katarzyna Frankiewicz
Bartosz Maksiak
Armand Budzianowski
Andrzej Bigos
Spencer Axani (MIT)

Two CosmicWatch detectors sent for high attitude balloon flight ~ 32 km

Detector presentation

Interesting data: count rate vs altitude



Regener-Pfotzer maximum visible ~ 19 km

Article in Świat Nauki 11/18

OTHER ACTIVITIES

TMEX 2018 CONFERENCE

- As a whole neutrino group@NCBJ we organized TMEX 2018 WCP conference, Sep/2018 in Warsaw
- SKPLUS grant context
- 3 days, ~50 participants, 35 invited talks
- Distinguished guests: director of J-PARC lab (Japan): T.Kobayashi; director of Canfranc lab. (Spain): C. Peña-Garay; T2K spokesman: T.Nakaya …

http://neutrino.ncbj.gov.pl/tmex2018wcp/

LoI WITH KOŹMIŃSKI UNIVERSITY

- Letter of Intent between NCBJ and Koźmiński University, Oct/2018
- Intended collaboration in the field of applied machine learning (ML) and artificial intelligence (AI)
  - Cross science-industry grant applications
  - Working group formed between NCBJ, Koźmiński Univ. and DZP law company (one of the largest in PL) → ML/AI in legal industry, aim for NCBiR, *PM* coordinator from NCBJ
  - Koźmiński Univ. started new MSc. course "Big Data Analysis" → NCBJ has expertise, possible educational support

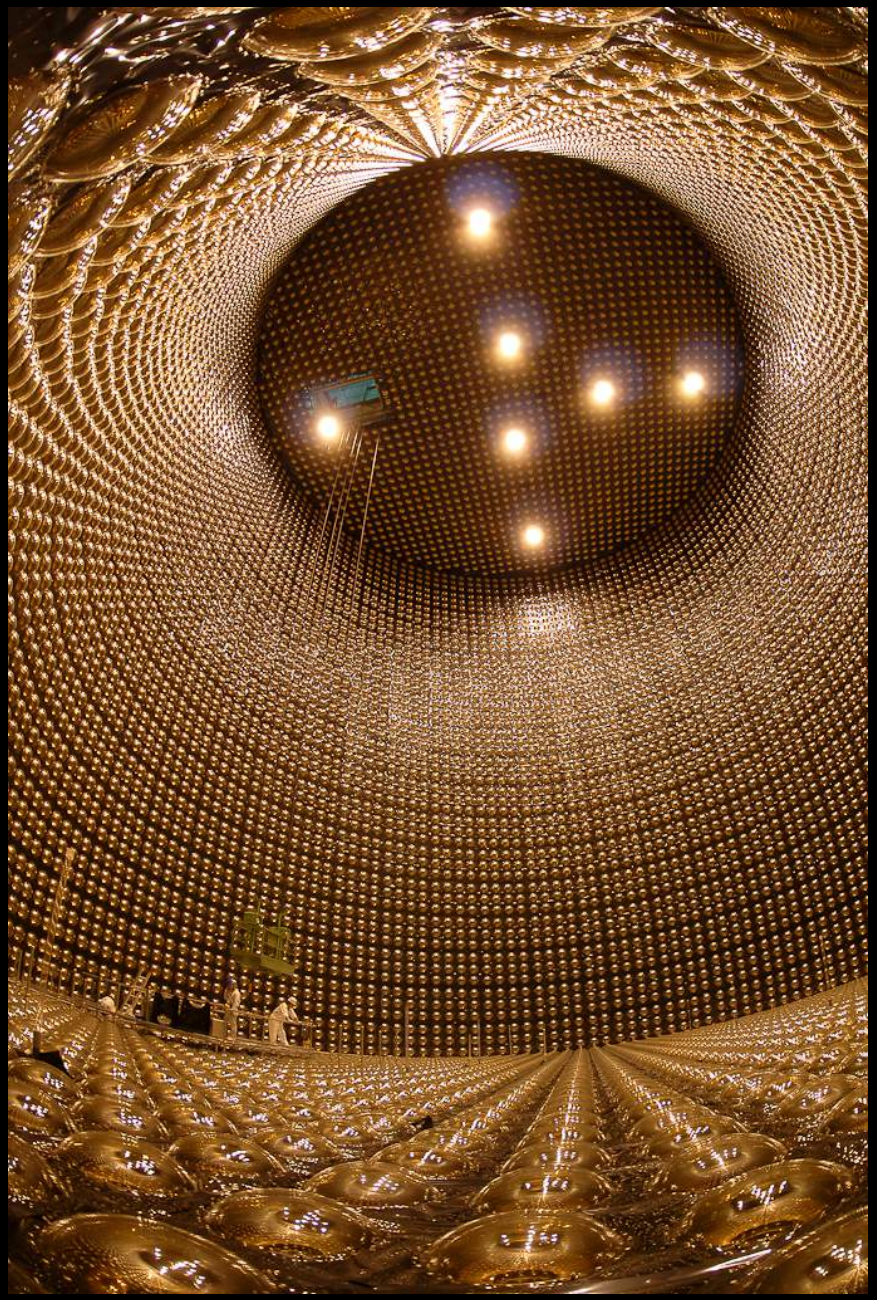
NARODOWE CENTRUM BADAŃ JĄDROWYCH ŚWIERK

KOZMINSKI UNIVERSITY

SUMMARY FOR 2018

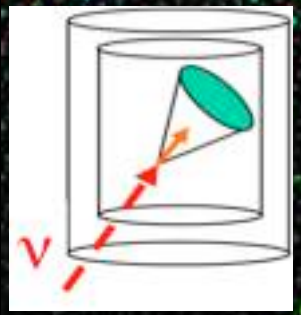
- Super-Kamiokande
  - Detector upgrade work
  - DM analysis: Earth WIMP search & ON-/OFF-source Galactic WIMP search in PhD thesis of Katarzyna Frankiewicz: defended in Sep/2018, distinction
  - 2 collaboration papers in preparation (one by P.Mijakowski, one by K. Frankiewicz)
- KM3NeT
  - MSc. thesis by J. Mańczak (Glashow Resonance & neutrino interactions) → defended in Sep/2018
  - Progress in Monte Carlo simulations of cosmic rays → getting agreement with ORCA and ARCA data, Piotr Kalaczyński
- TMEX conference
- Cosmic Watch in progress by K. Frankiewicz

BACKUP



Detected Cherenkov light allows for reconstruction of:

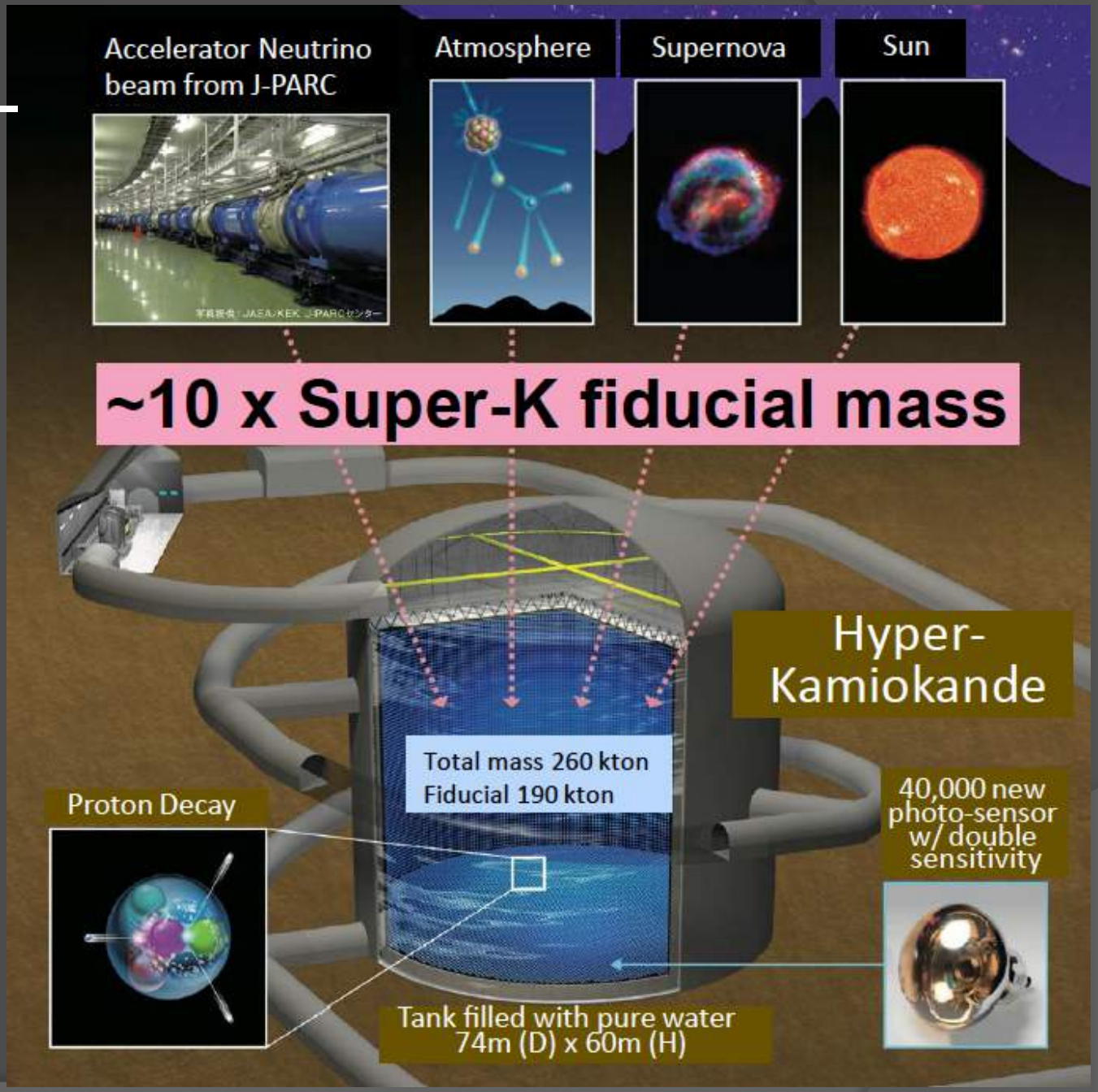
- lepton momentum (neutrino energy)
- lepton direction
- lepton flavor (e-like vs. μ-like, good separation possible)



$\nu_e + N \rightarrow e^- + N'$

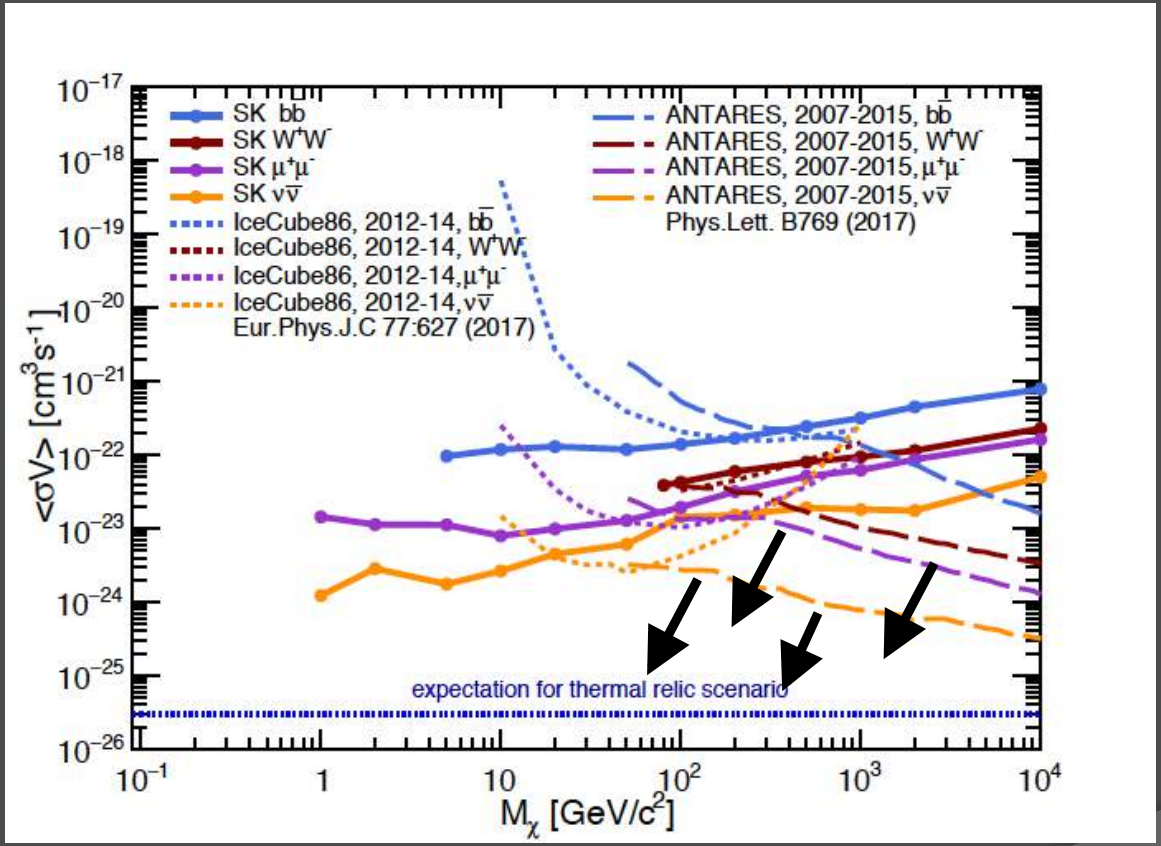
Future: Hyper-Kamiokande

- start 2026 (after 7 years construction)
- main goal: neutrino mass hierarchy and δCP
- some astro potential: SN, DSNB (~2evts per day), WIMPs, cosmic neutrinos



DM: Prospects at KM3NeT

Strong limits from Antares (0.01km^3, 12 strings) → great potential of KM3NeT (0.1 → ~1km^3, 230 strings)



Super-K: 0.45 Mton•yrs (current limit)
Hyper-K: 3-10x improvement in 20 yrs
ORCA: 3-10x imprv. in ~ 1 yr (wrt. SK)
ARCA-2 blocks: 30-10^{2}x imprv. in ~ 1yr