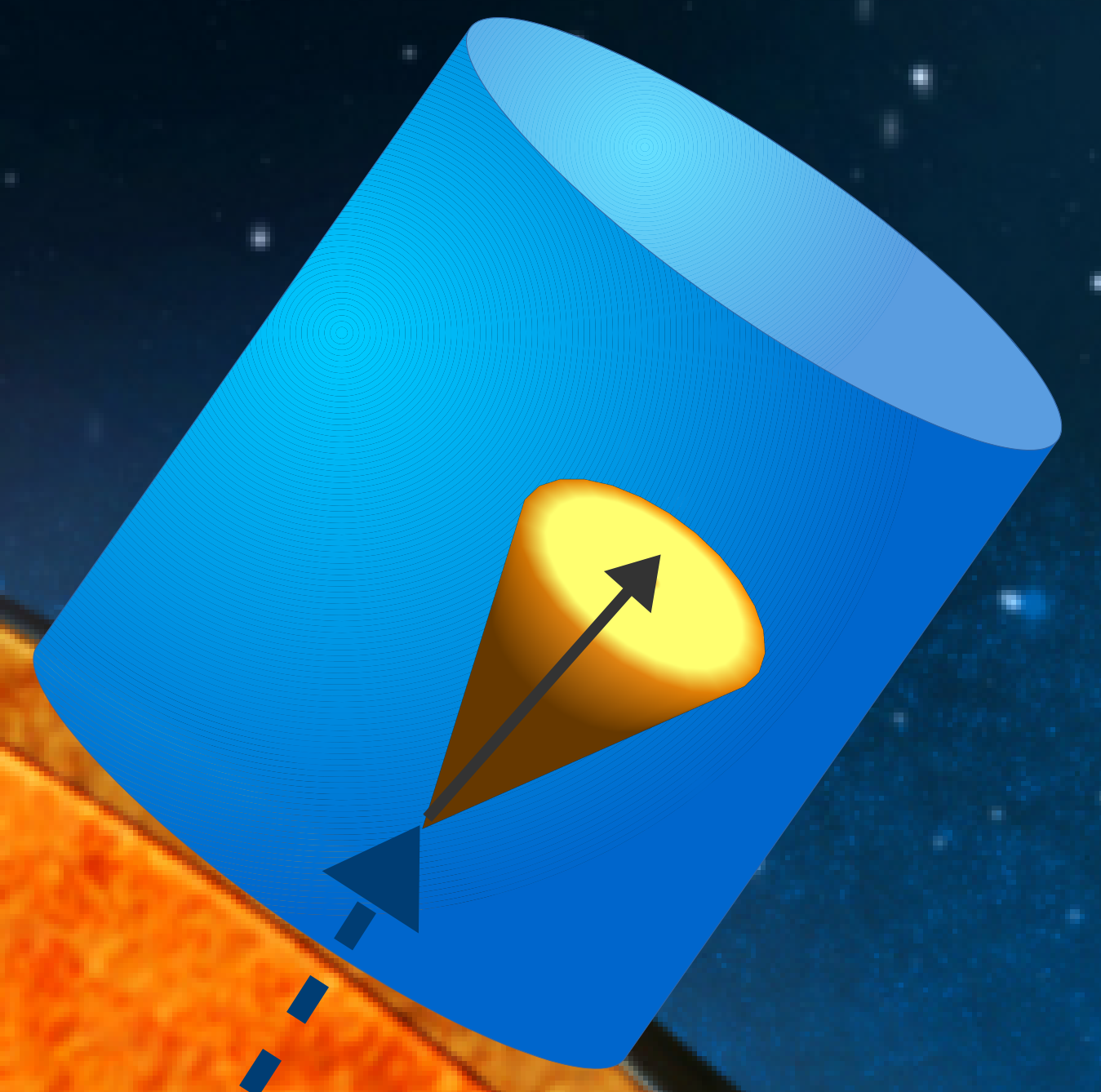
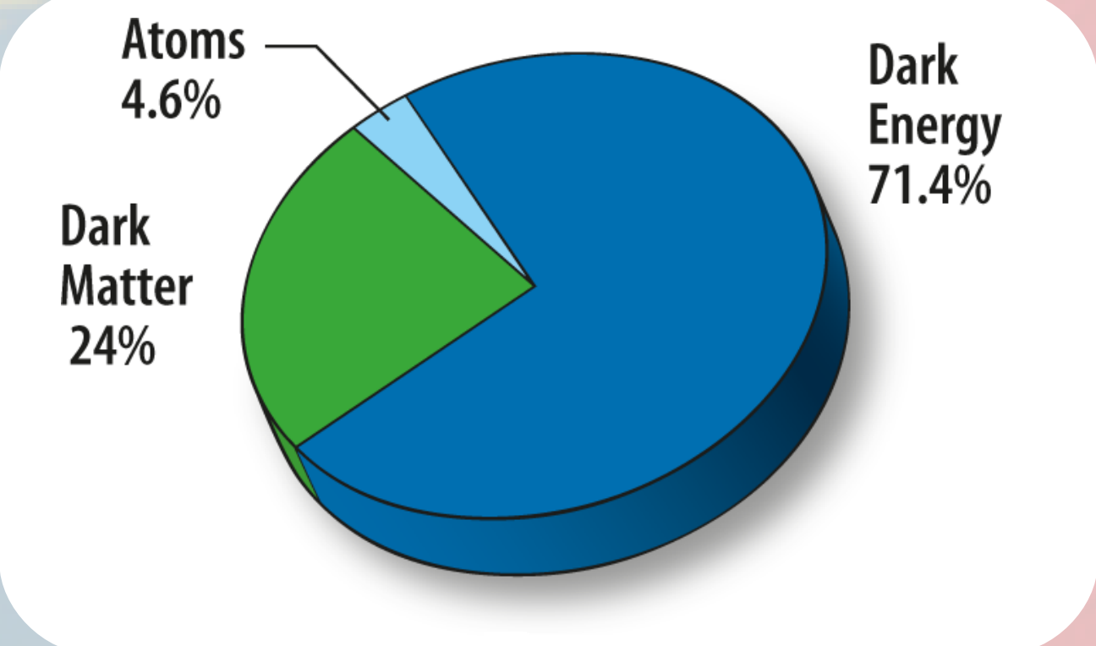
Search for neutrinos from dark matter annihilation in the Earth's core with the Super-Kamiokande detector

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



DARK MATTER neither emits or absorbs light, nor does it interact electromagnetically and cannot be observed directly with telescopes. It is expected to account for a large part of the Universe.



Dark matter particles can scatter off a nucleus inside a massive celestial bodies, lose energy, and be gravitationally trapped. Once captured, they eventually sink to the core and then annihilate, producing **neutrinos** in the subsequent decays.

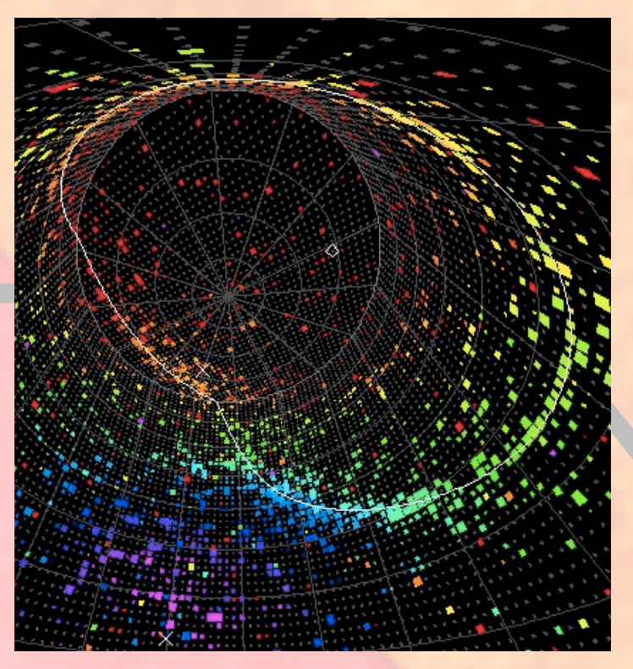
INDIRECT DETECTION EXPERIMENTS focus on search for the products of dark matter annihilation, e.g. **neutrinos**, among the cosmic rays. Produced neutrinos provide very good information about:

- **source position**
- **generated energy spectra.**

$$\chi\chi \rightarrow \begin{array}{c} q\bar{q}(c\bar{c}, b\bar{b}, t\bar{t}, \ldots) \\ l\bar{l} \\ W^{\pm}, Z^{0}, H \end{array} \rightarrow \ldots\ldots \rightarrow \nu\ , \gamma, \bar{e}, \bar{p}, \bar{H}_2,$$

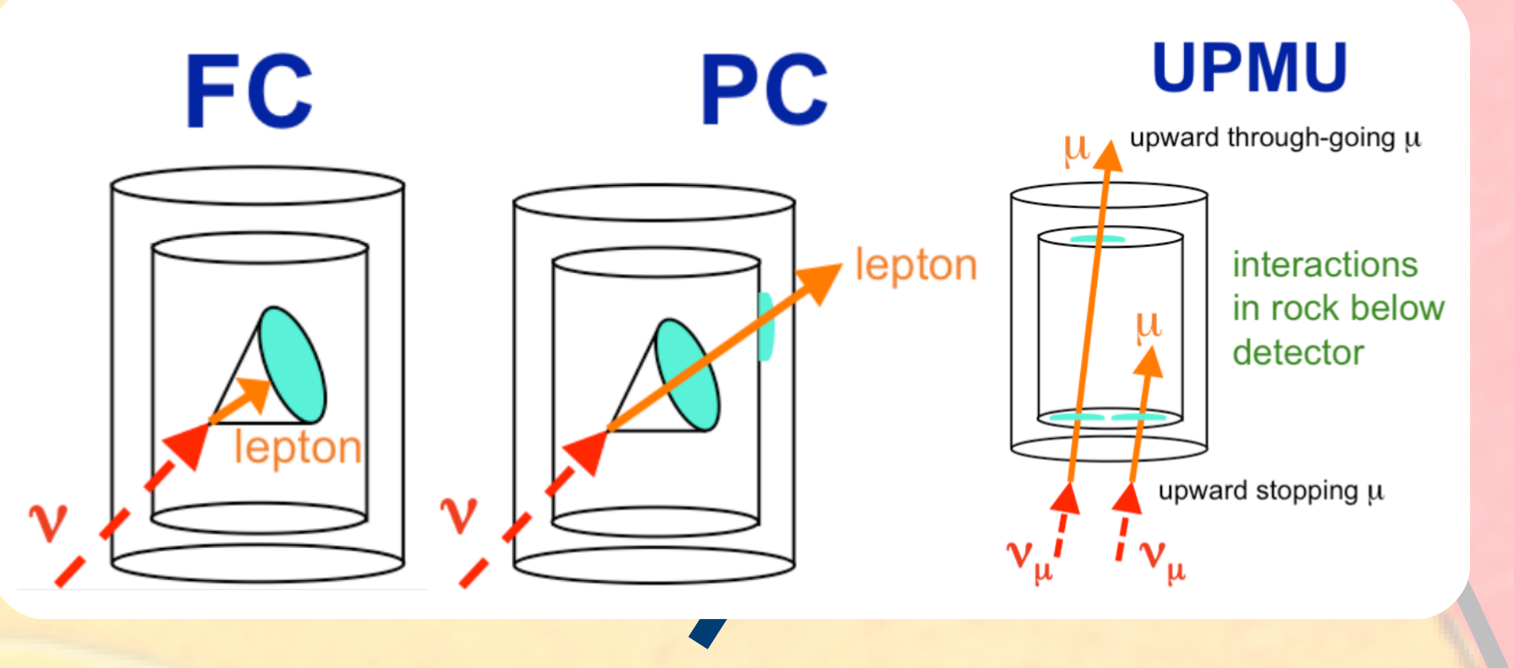
SUPER-KAMIOKANDE is a **water Cherenkov detector**, which measures **solar**, **atmospheric**, **cosmic** and **accelerator** neutrinos.

- 50 000 tons of water (22.5 kt FV)
- located in Japan, 1 km underground
- ID ~12 000 PMTs, OD ~2 000 PMTs
- far detector for T2K experiment

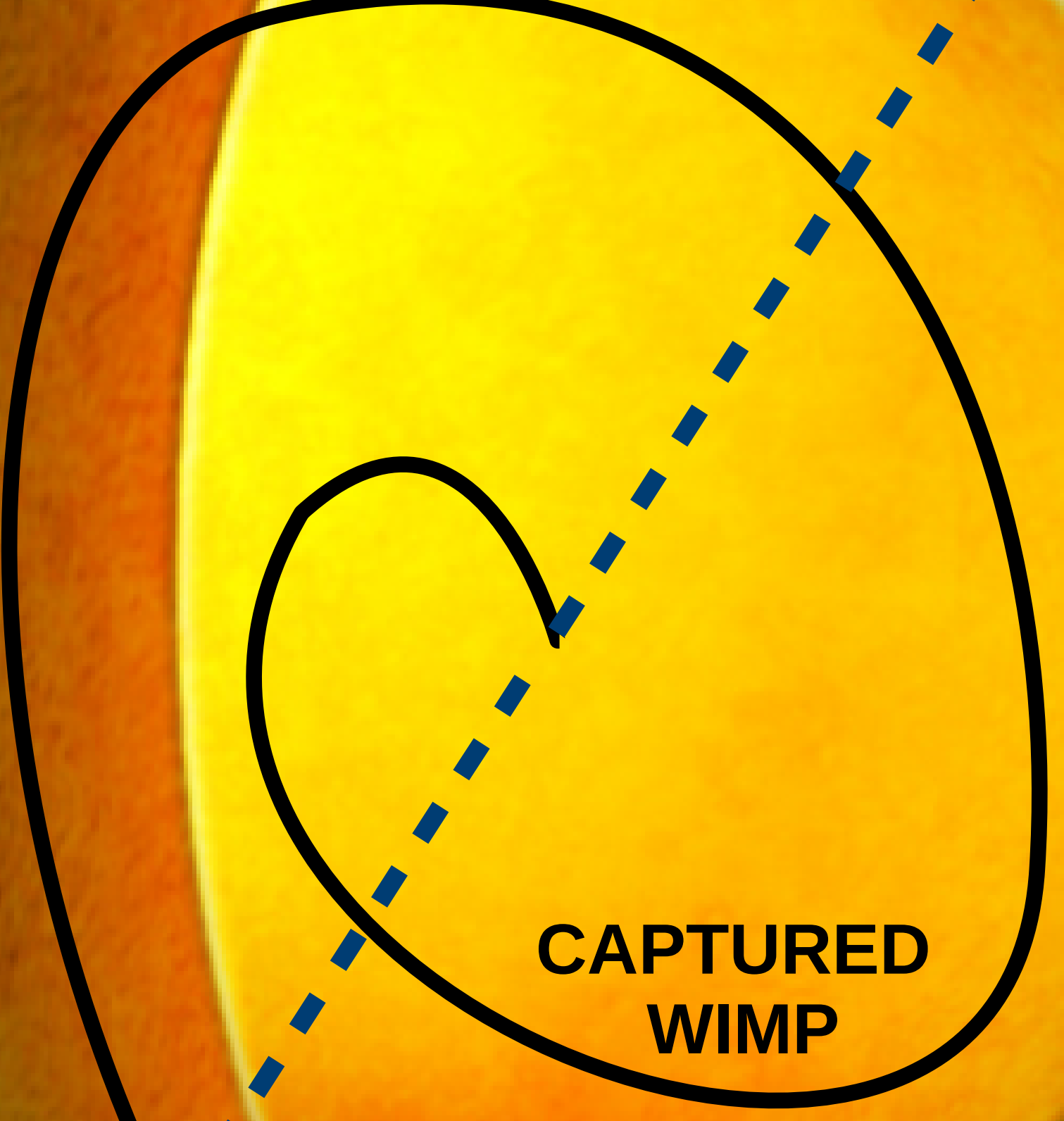


Detected light allows for reconstruction of the **energy**, **direction** and **flavor** of the produced lepton.

20 years of data taking
1996-2016

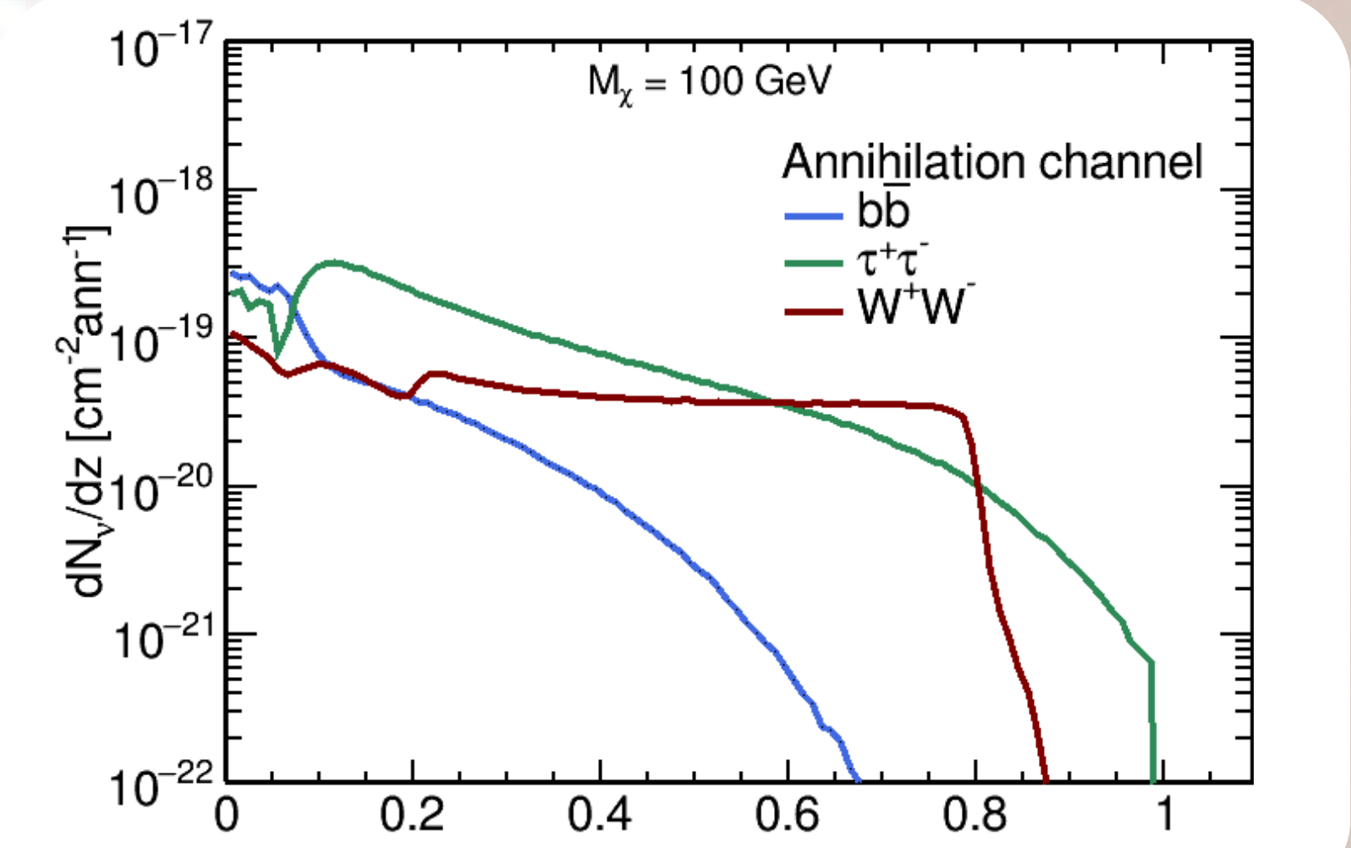


ATMOSPHERIC NEUTRINOS cover wide energy range (from hundreds of MeV up to tens of TeV), where dark matter induced neutrinos are expected.



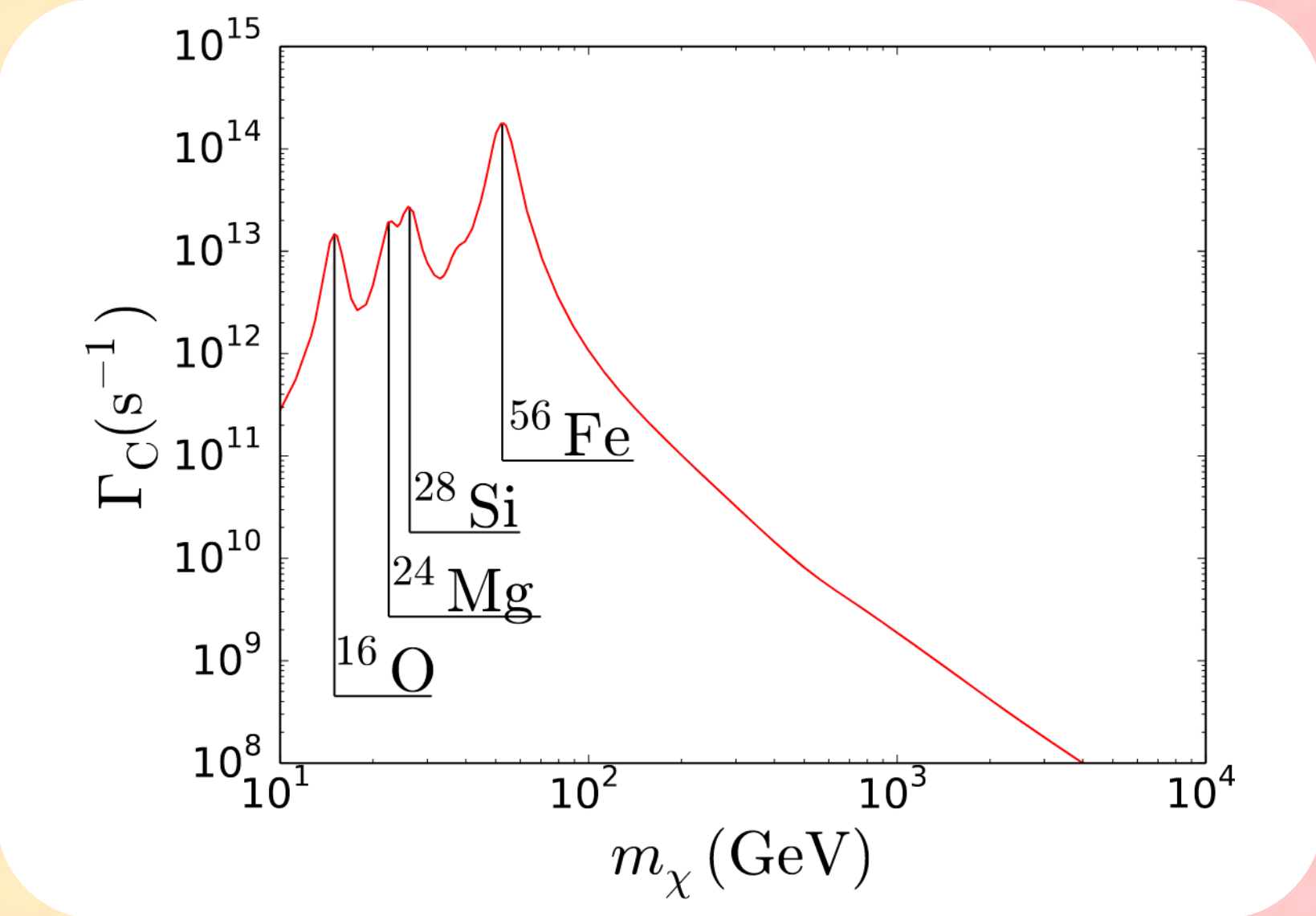
ANALYSIS: Search for an **excess of neutrinos** from the **Earth's core direction** as compared to **atmospheric neutrino background**.

STEP 1. Simulate neutrinos produced in dark matter annihilation in the Earth, including produced **energy spectra** and **angular distribution** ➡ WimpSim [1].



Example: differential $\nu_\mu\bar{\nu}_\mu$ energy spectra per dark matter annihilation in the Earth for M_χ= 100 GeV.

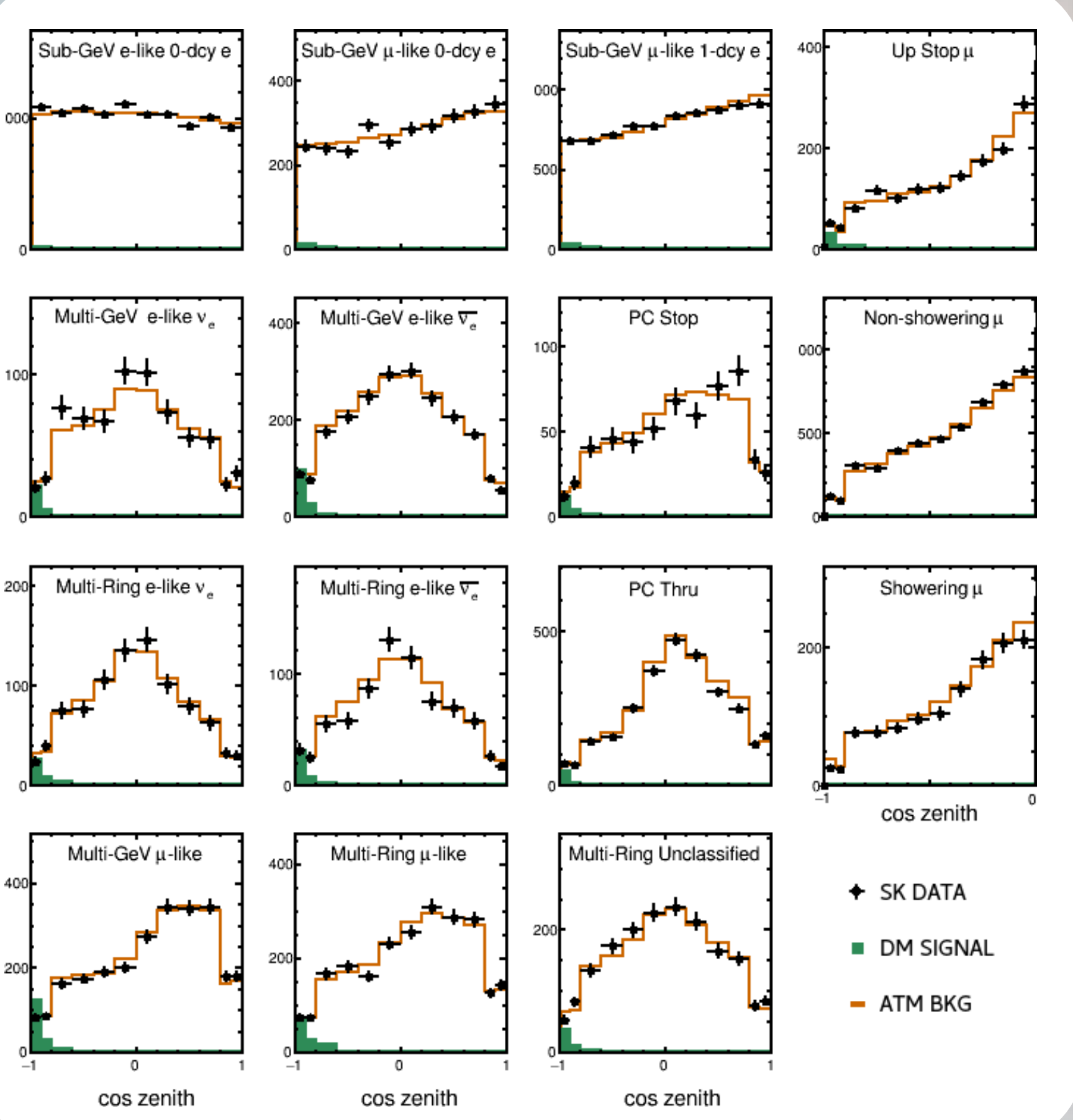
CAPTURE RATE OF WIMPS IN THE EARTH



When the **WIMP mass** matches the mass of an element present in the Earth, the Earth can **efficiently capture** relic particles directly from the galactic halo. The **peaks** correspond to **resonant capture** on the most abundant elements and their isotopes [2].

STEP 2. Simulate the **detector response** in outgoing lepton **momentum/visible energy** and $\mathbf{cos\theta_{ZENITH}}$.

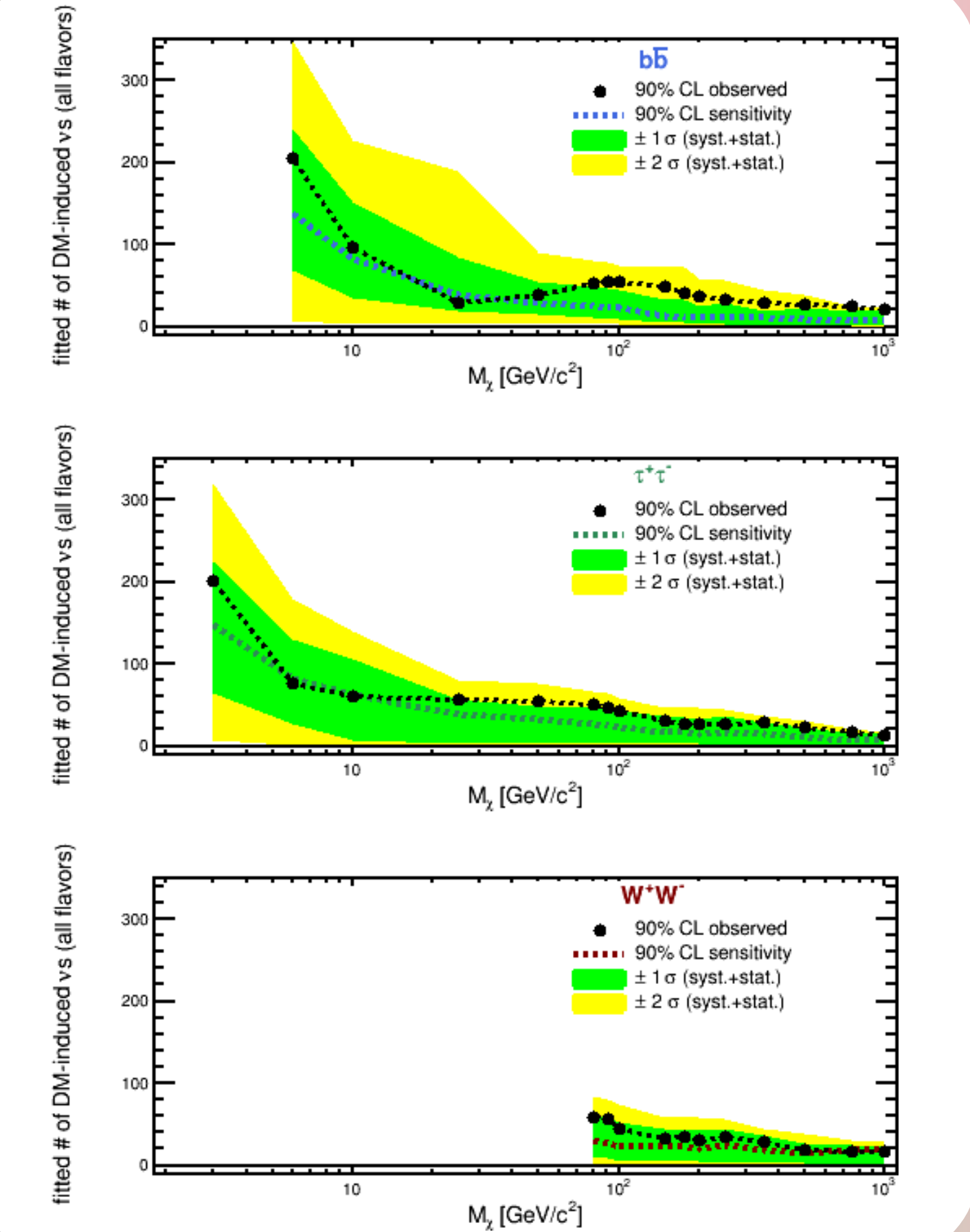
Example: signal illustration for M_χ= 6 GeV WIMPs annihilating into $\tau^+\tau^-$ leptons in the Earth's core.



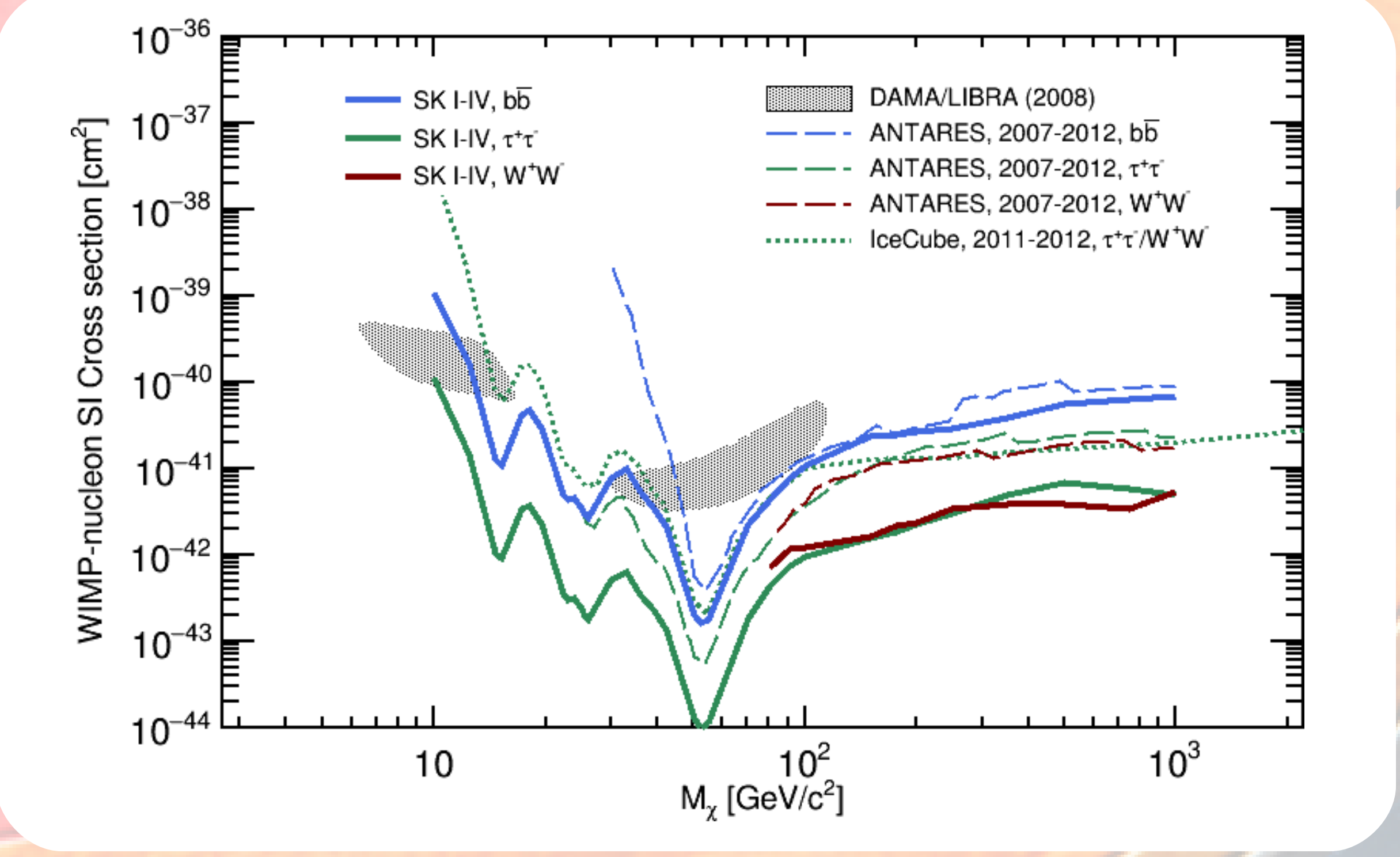
All neutrino flavors (ν_e, $\bar{\nu}_e$, ν_μ, $\bar{\nu}_\mu$ and ν_τ, $\bar{\nu}_\tau$) are used in the signal and background simulation.

STEP 3. Fit **SIGNAL** + **BKG** to **DATA** with the constrains from systematic uncertainties.

NO EXCESS HAS BEEN OBSERVED



RESULTS: For the **Earth**, the **spin independent** (SI) interactions, where the WIMPs couple to the nucleus as a whole, dominate in the capturing process. The **cross section** for SI scattering **∝A²**, where A is an atomic mass number.



The limits from the **Super-K** experiment are **the strongest** among **all neutrino experiments** [2][3], due to high sensitivity of the detector. Moreover, the Super-K limits **rule out** a majority of the WIMP parameter space favored by the DAMA/LIBRA [4], using very different, independent technique.

CONTACT: katarzyna.frankiewicz@ncbj.gov.pl

REFERENCES:

[1] M. Blennow et al., arXiv: 0709.3898, 2008.
[2] M.G. Aartsen et al., Europ.Phys.J. C, 77(2):82, 2017.
[3] A. Albert et al., Physics of the dark universe, 16:41–48, 2017.
[4] R. Bernabei et al., Europ.Phys.J. C, 73(12):2648, 2013.