Dzhelepov Laboratory of Nuclear Problems. Neutrino

Nikolay V. Anfimov

Structure of DLNP

- Particle Physics
- Accelerator Technologies
- Neutrino Physics & Astrophysics
- Radiation Medicine, Genetics, Molecular Genetics
- Radiochemistry & Nuclear Spectroscopy
- IT, design office, workshop, services, etc
- Education & Outreach
- about 650 employees
- among them about 500 scientific staff

SCEINCE & TECHNOLOGIES

Particle Physics

- ATLAS
- Mu2e, g-2
- COMET
- BES-III
- PANDA

Neutrino Physics & Astrophysics

- BAIKAL GVD
- Daya Bay/JUNO
- NOVA
- BOREXINO
- GERDA
- GEMMA/vGEN
- SuperNEMO
- TUS/Nucleon/TAIGA
- EDELWEISS

Technologies

- Precise Laser Metrology
- New semiconductor detectors
- Ultra cold temperatures

SCEINCE & TECHNOLOGIES

Medicine & Molecular Genetics

- Proton Therapy
- Medical-biological studies
- Radiation genetics

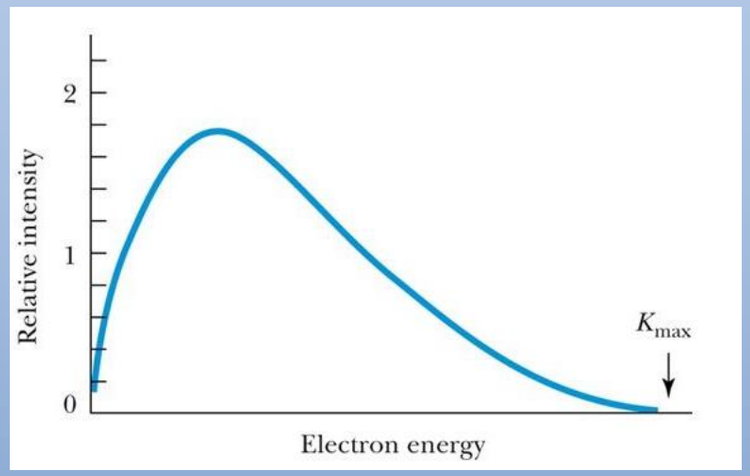
Education & Outreach

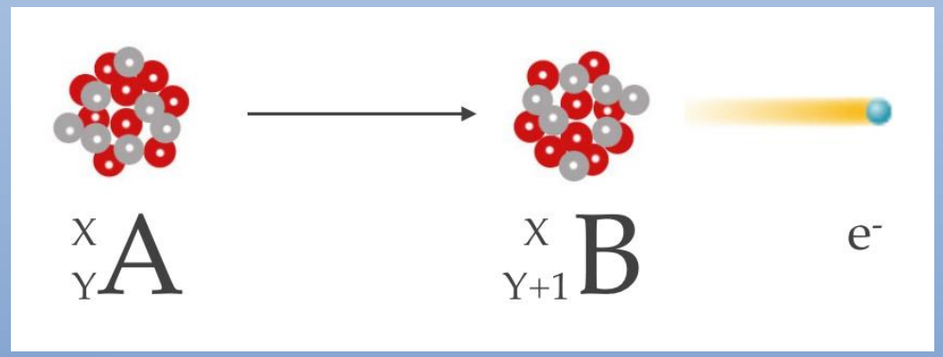
- Schools, conference, seminars
- Web-site of DLNP, social networks
- Lecturing at MSU, MIPT, «Dubna» University and others

Neutrino Physics

What is neutrino?

What with the Energy Conservation Law?



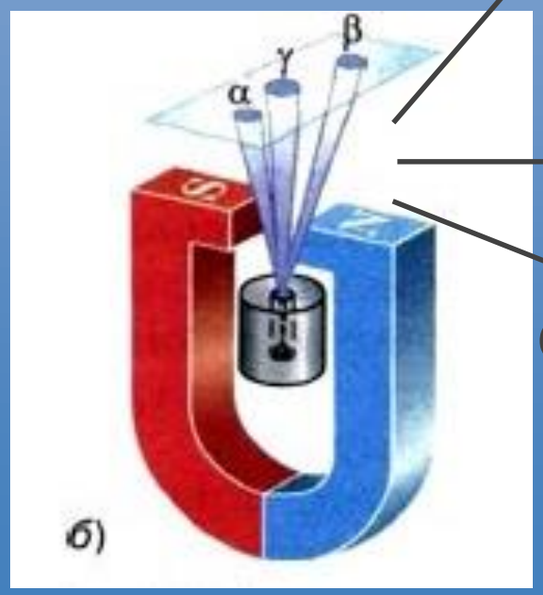


β

$$p = mv$$

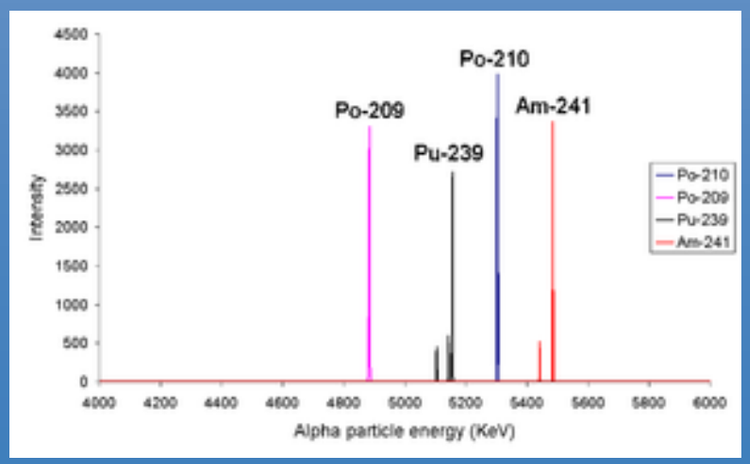
$$E = \frac{mv^2}{2}$$

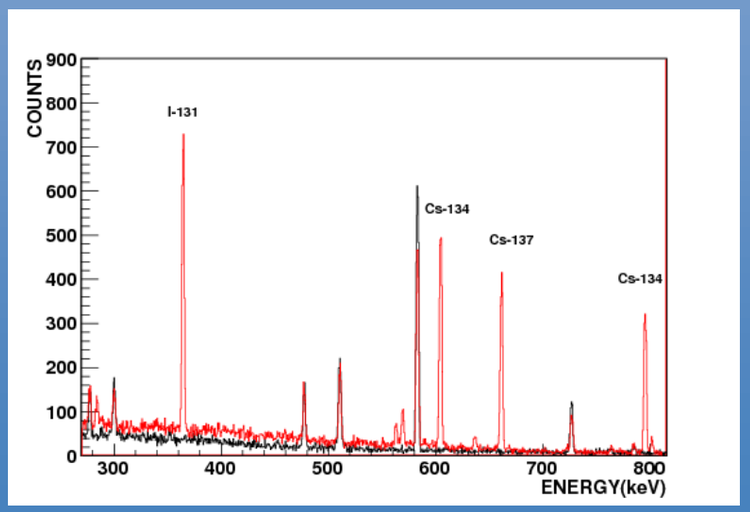
Almost full Energy is taken out by a particle !
Energy levels are strictly certain!



α

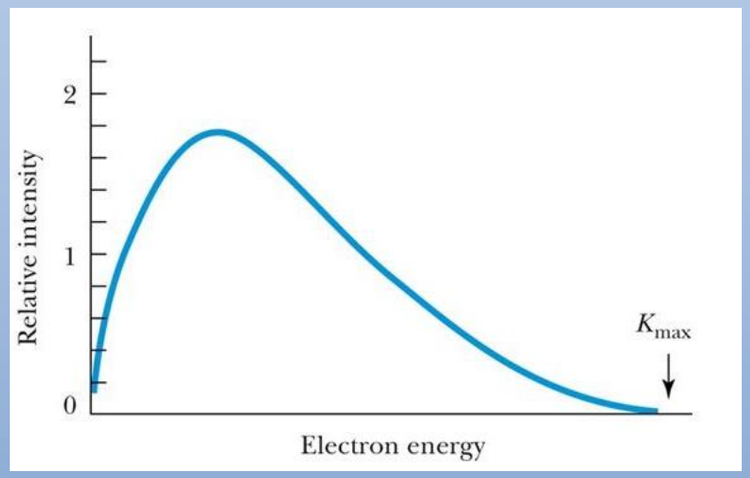
γ

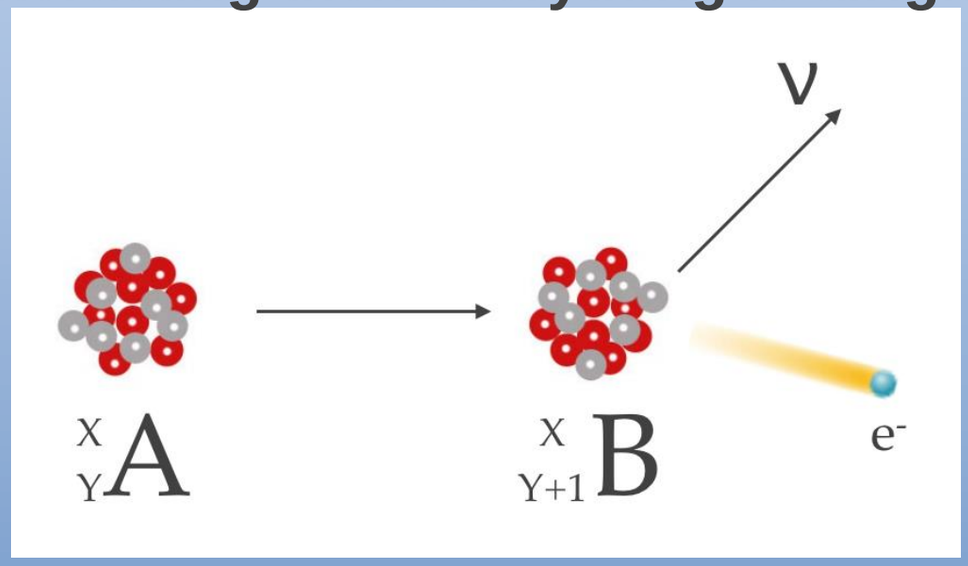




What is neutrino?

If there is something neutral and weakly interacting then everything is alright!





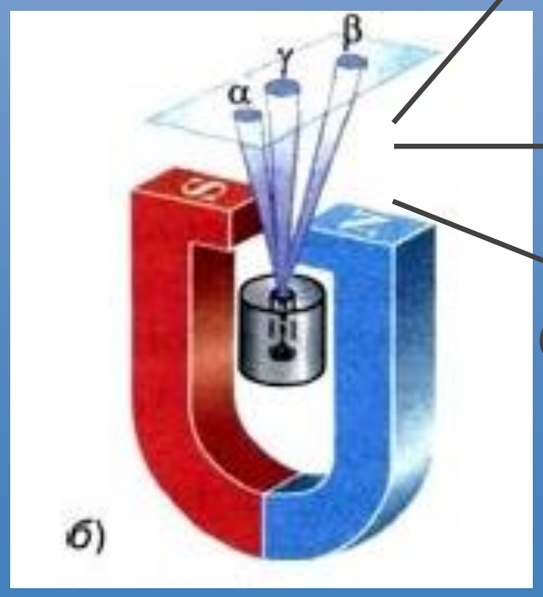
W. Pauli

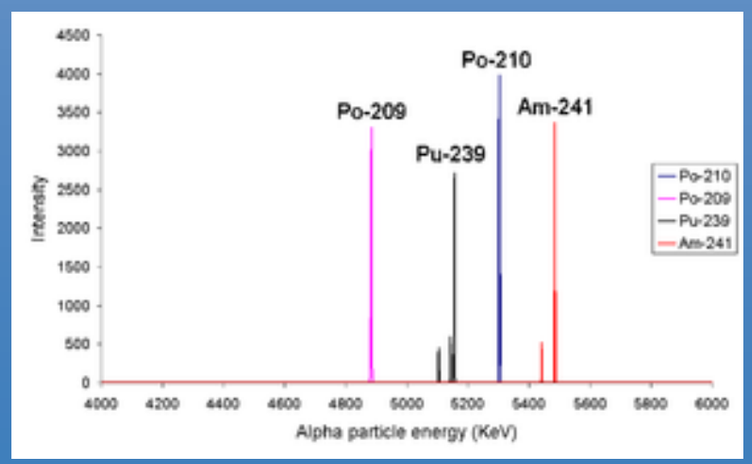
Neutrino - tiny neutron (italian)

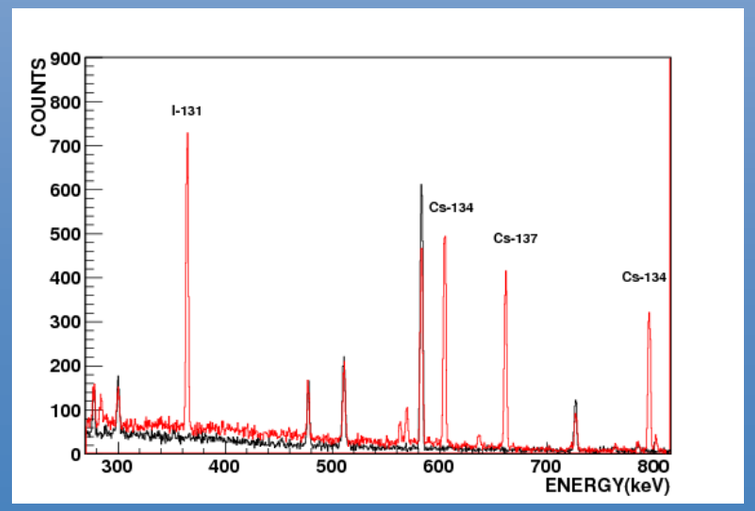
β

γ

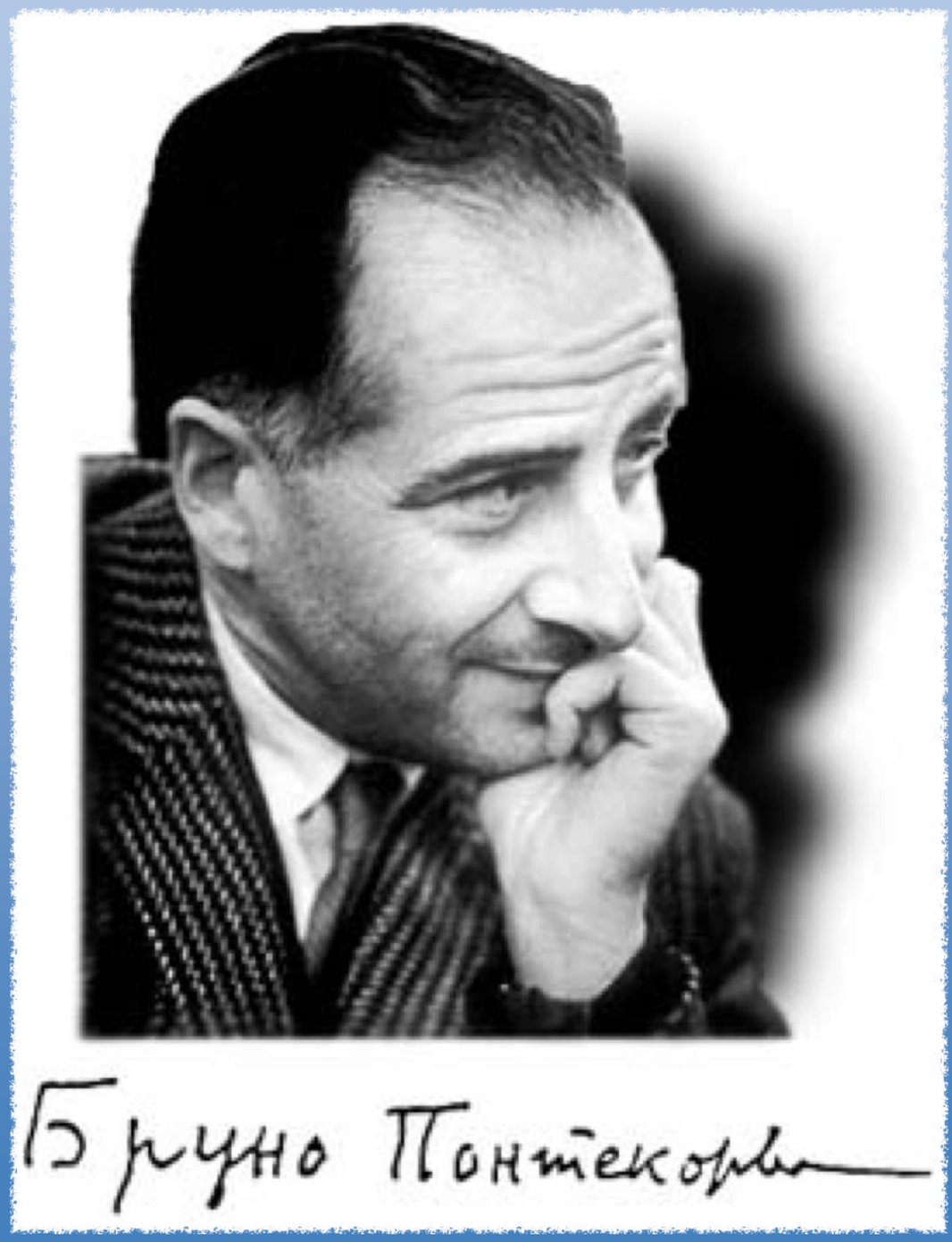
α







Bruno Pontecorvo worked in JINR (1950-1993) establishing a School of Neutrino Physics



Nobel Prizes for Neutrino Physics

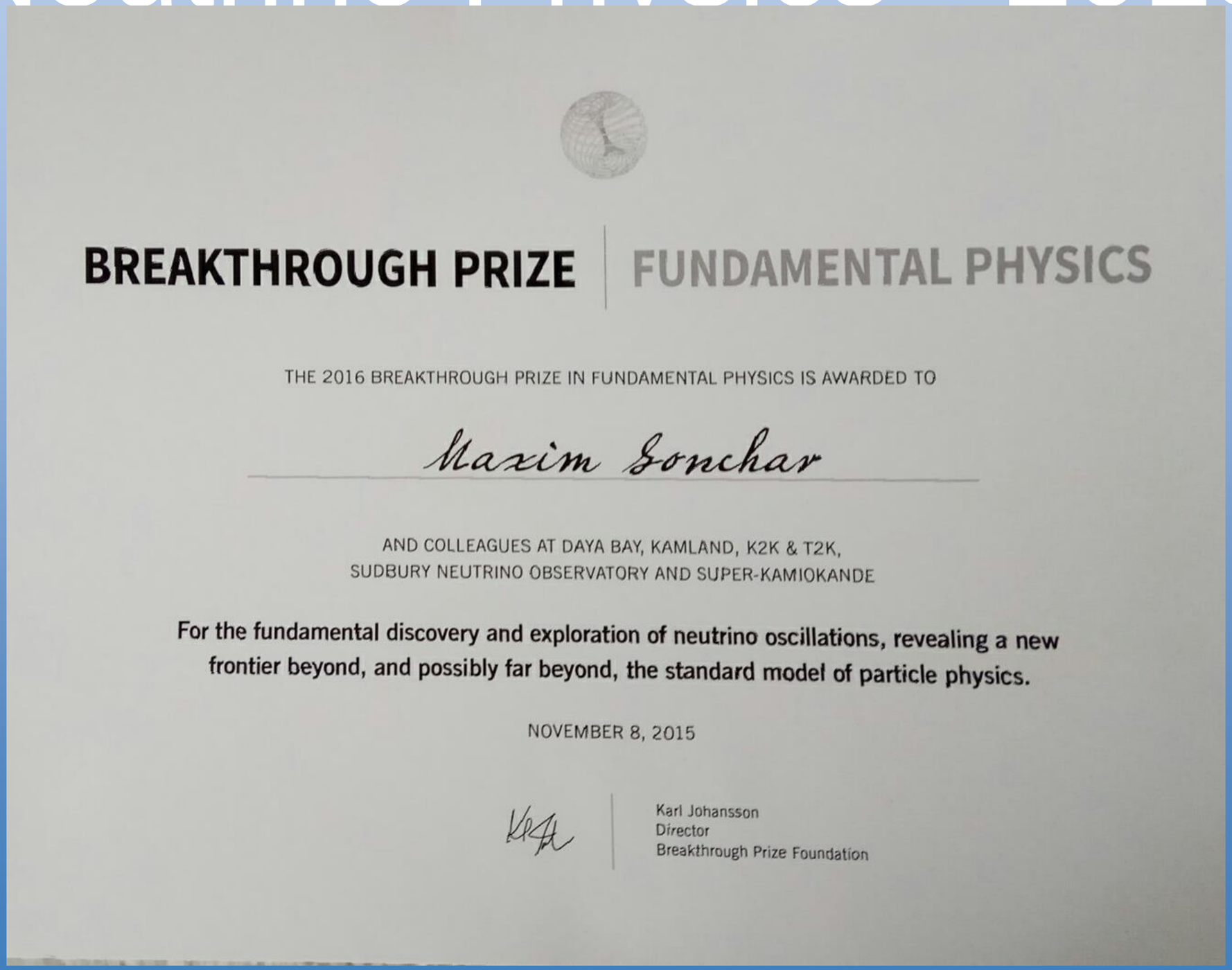
- 1988 (Leon M. Lederman, Melvin Schwartz and Jack Steinberger). Discovery of muon neutrino.

- 1995 (Frederick Reines). Discovery of electron antineutrino

- 2002 (Raymond Davis, Jr. и Masatoshi Koshiba). SN 1987A.

- 2015 (Takaaki Kajita and Arthur B. McDonald). Discovery of neutrino oscillations.

Breakthrough Prize for Neutrino Physics - 2015



BREAKTHROUGH PRIZE | FUNDAMENTAL PHYSICS

THE 2016 BREAKTHROUGH PRIZE IN FUNDAMENTAL PHYSICS IS AWARDED TO

Maxim Gonchar

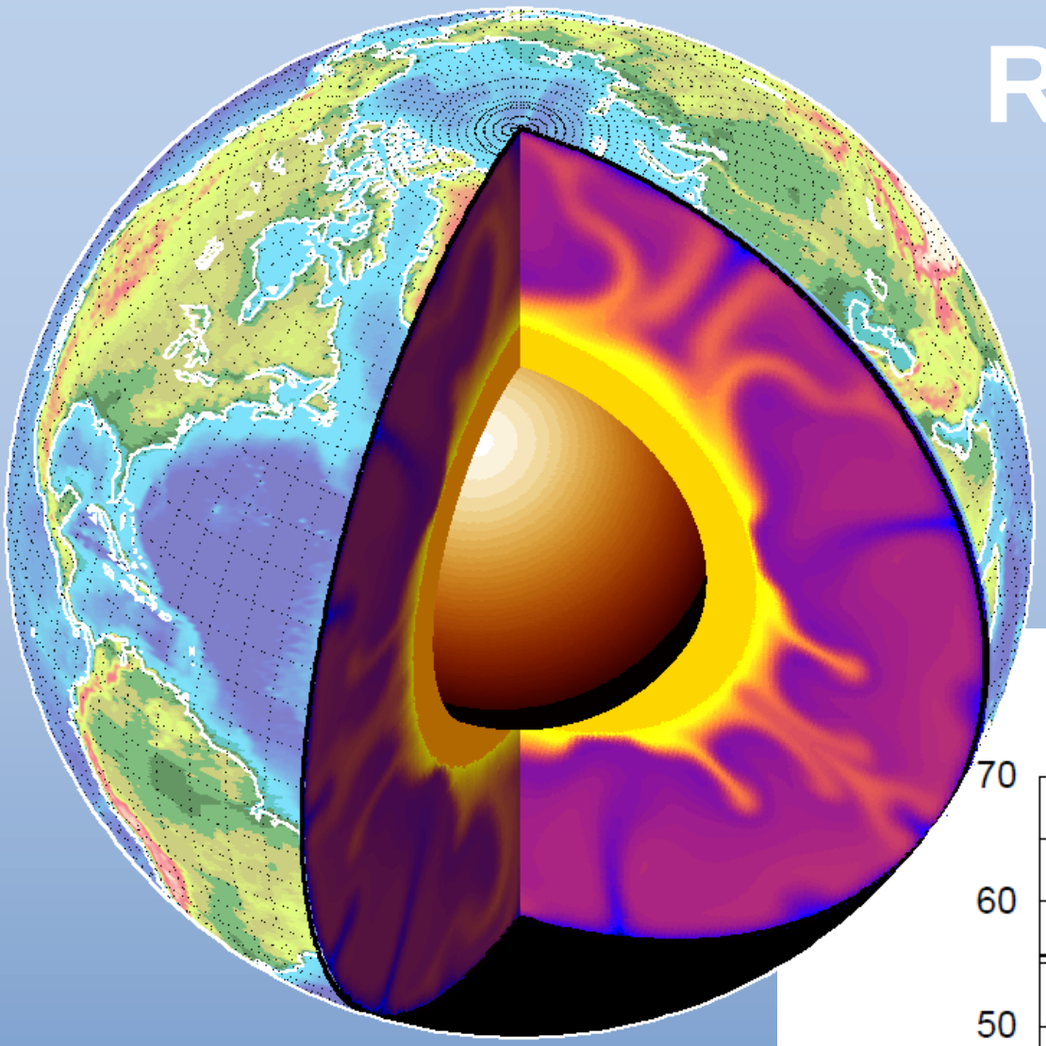
AND COLLEAGUES AT DAYA BAY, KAMLAND, K2K & T2K,
SUDBURY NEUTRINO OBSERVATORY AND SUPER-KAMIOKANDE

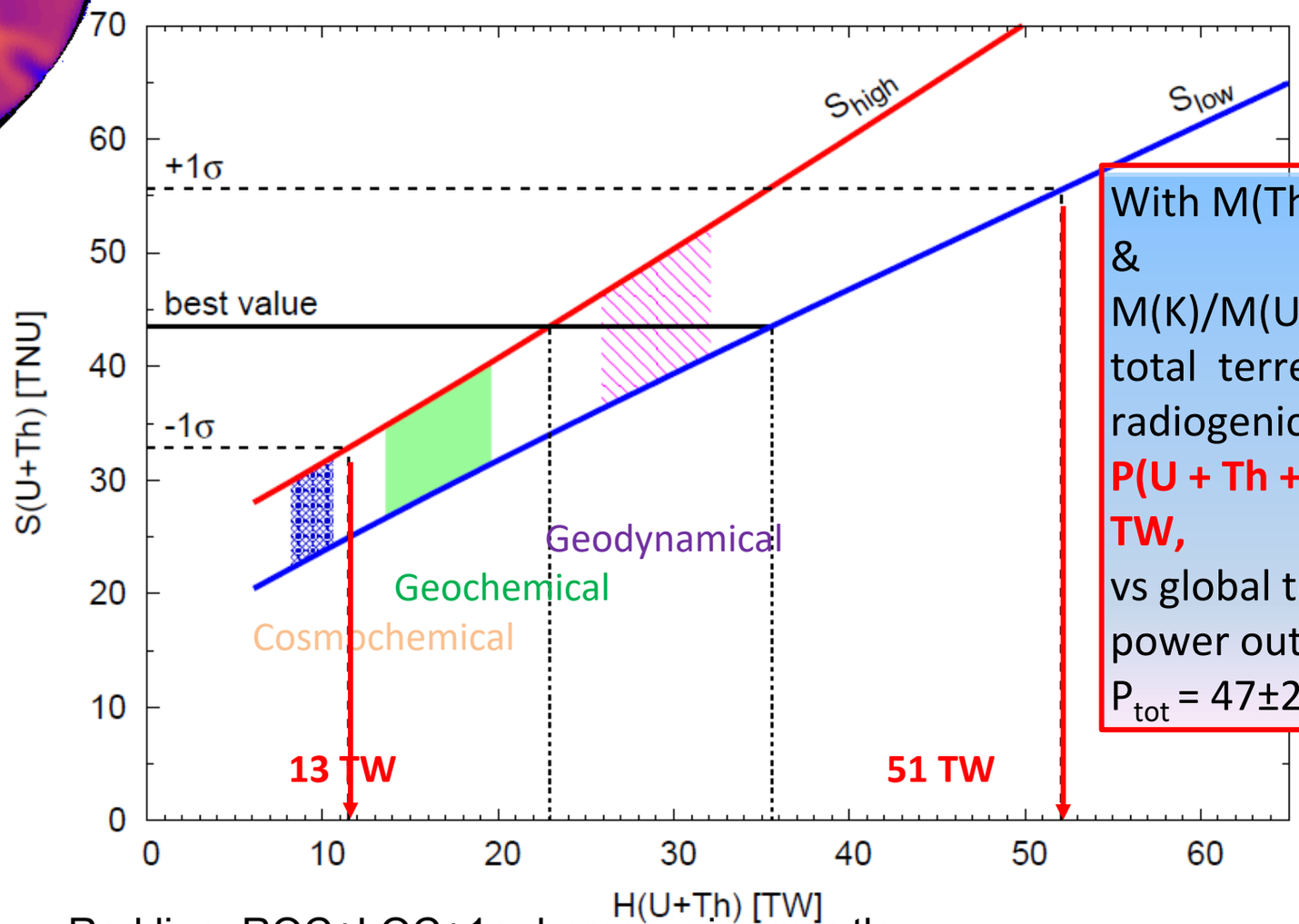
For the fundamental discovery and exploration of neutrino oscillations, revealing a new frontier beyond, and possibly far beyond, the standard model of particle physics.

NOVEMBER 8, 2015

Karl Johansson
Director
Breakthrough Prize Foundation

Radiogenic heat: Borexino





With M(Th)/M(U)=3.9
&
M(K)/M(U) = 10^4 the total terrestrial radiogenic power :
$P(U + Th + K) = 33^{+28}_{-20}$ TW,
vs global terrestrial power output
P_{tot} = 47±2 TW

Red line: ROC+LOC+1σ, homogenios mantle
Blue line: ROC+LOC-1σ, radiogenic material on the mantle/core interface

Neutrino experiments at the Kalinin NPP

- **Pressurised Water Reactor (ВВЭР-1000)**
- **Thermal Power: 3 100 MW**
- **Core: ∅ 3.20 m × *h* 3.70 m**
- **Fuel (70 ton): ^{238}U + ^{235}U** (3.3-5.5%)
- **Neutrino Flux: $\sim 6\times10^{20}\ \overline{\nu_e}$ / 4π / day**
- **Campaign: 18 months + recharge (50 days)**
- **1100 kg of ^{235}U is burned out**
- **200 kg of ^{239}Pu is produced**
- **which changes neutrino flux and spectrum**

(Tver region, 285 km NW from Dubna)

GEMMA
(Neutrino Magnetic Moment)

νGeN
(Coherent ν-Ge scattering)

DANSS
(reactor monitoring and search for sterile neutrino oscillations)

2

3

4

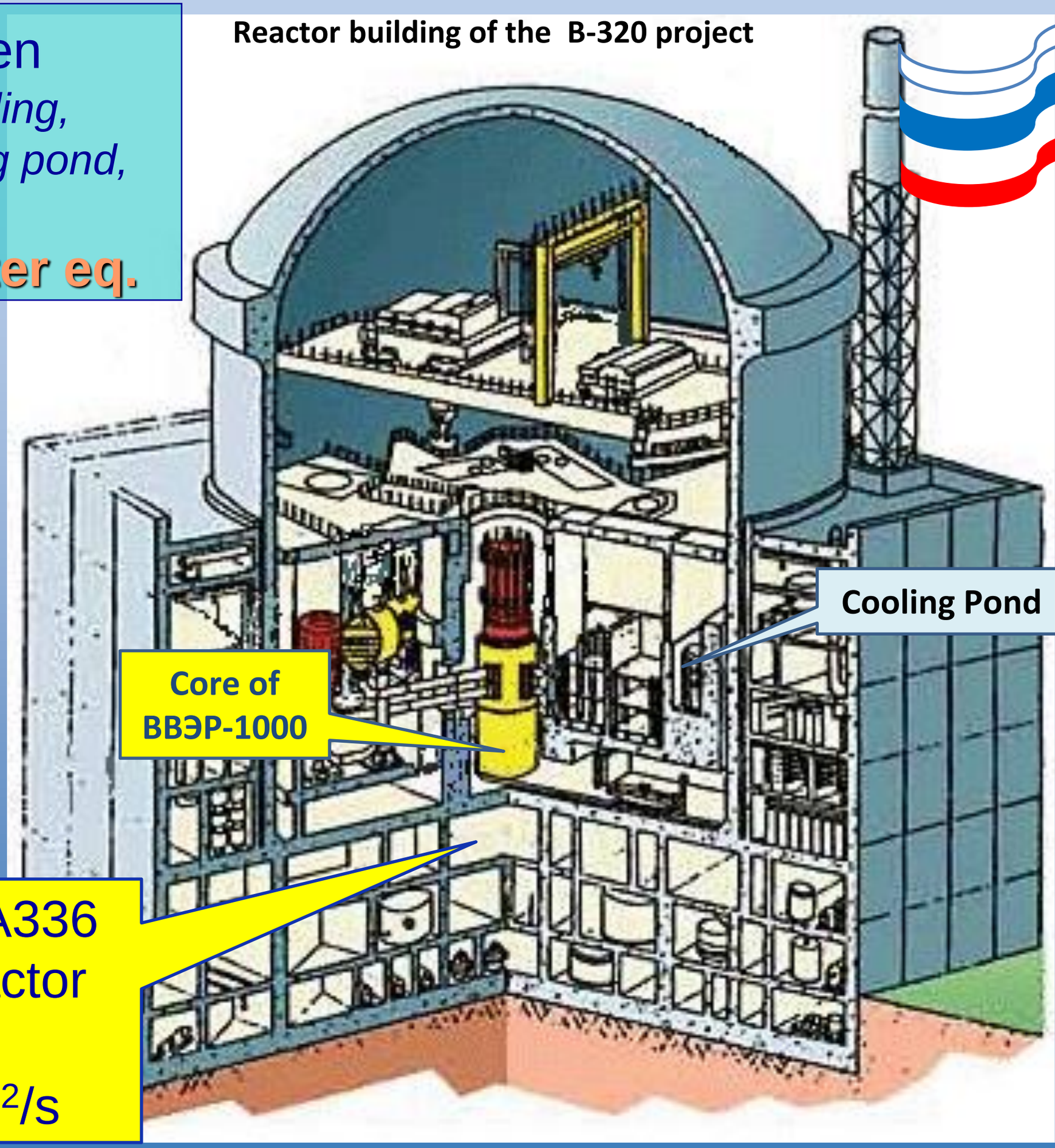
ourtesy of V.Egorov

Overburden

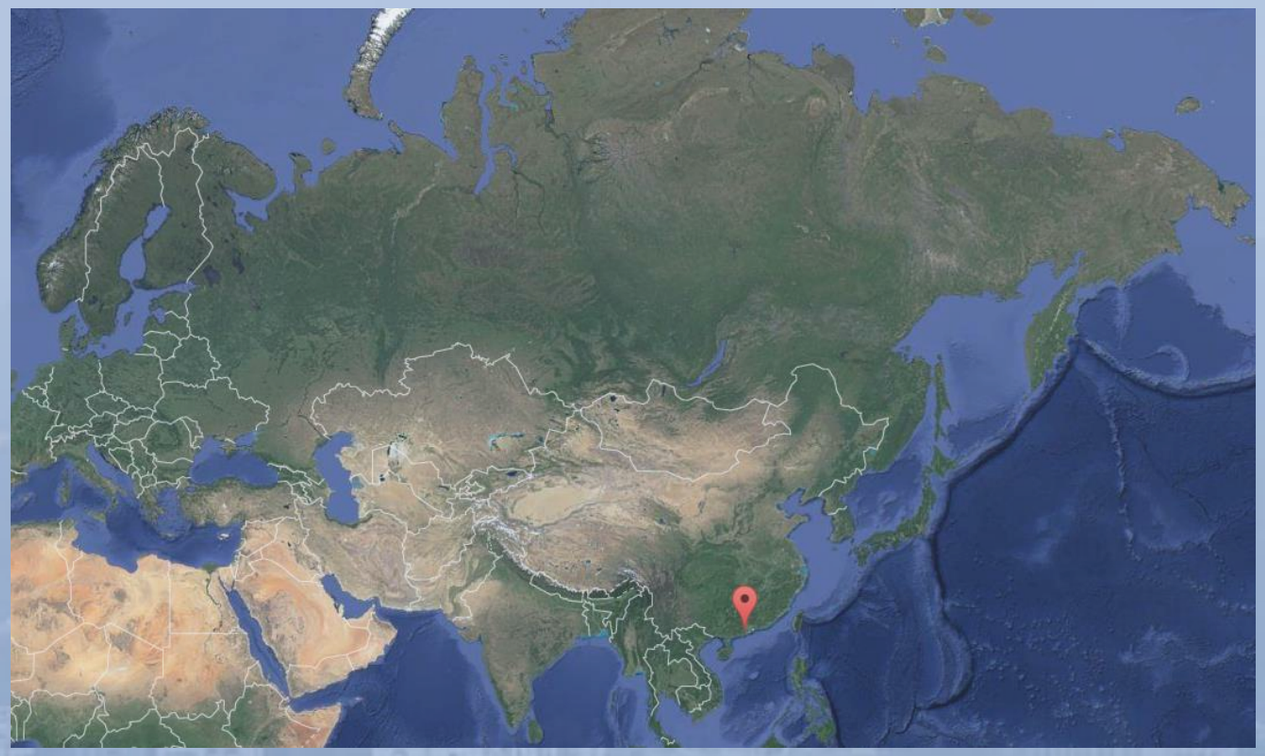
(reactor, building, shielding, cooling pond, etc.):

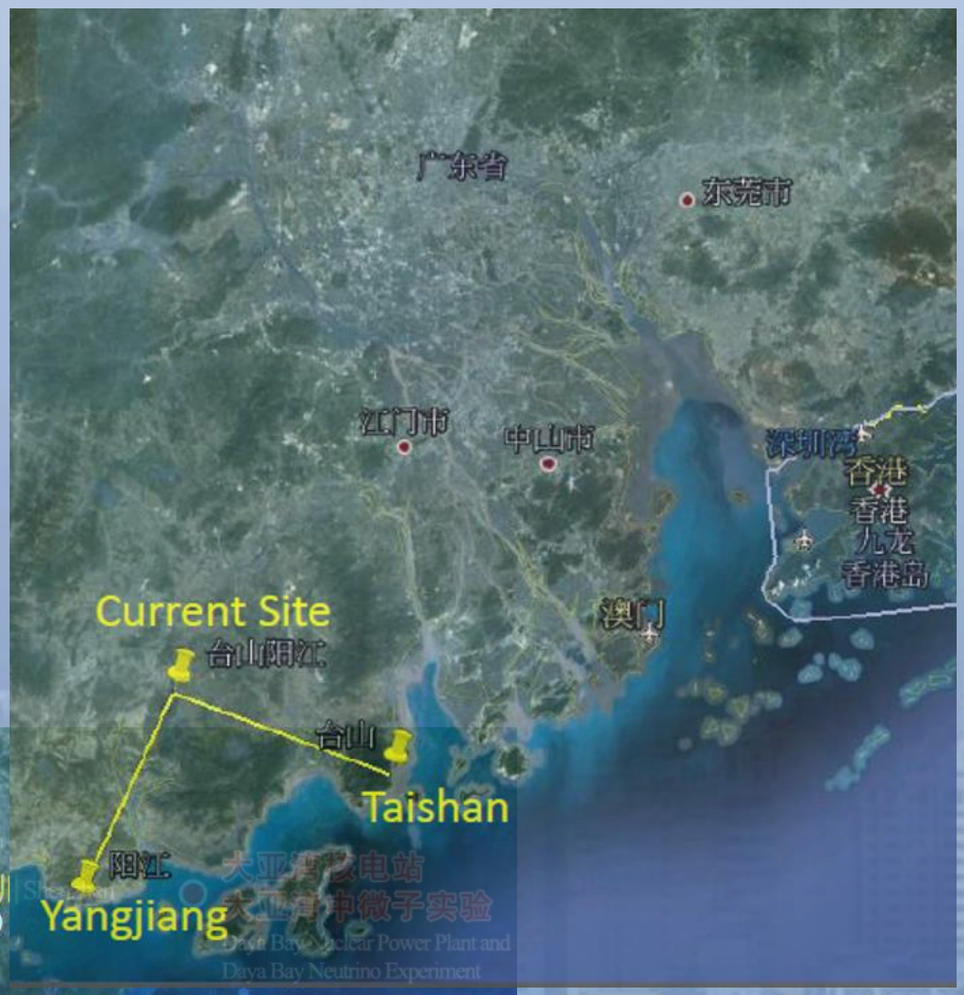
~50 m of water eq.

Reactor building of the B-320 project



Techn. room A336
just under reactor
9 m only!
5×10^{13} ν/cm²/s





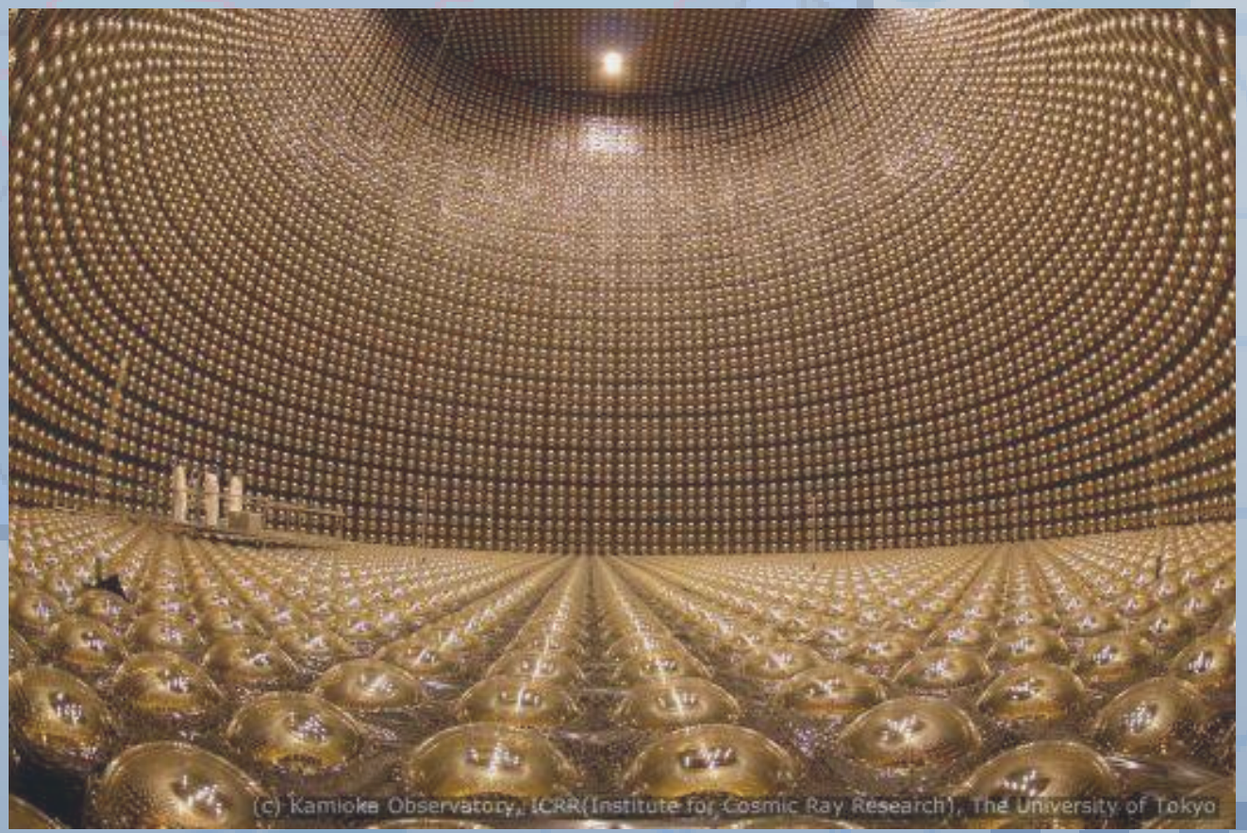
JUNO

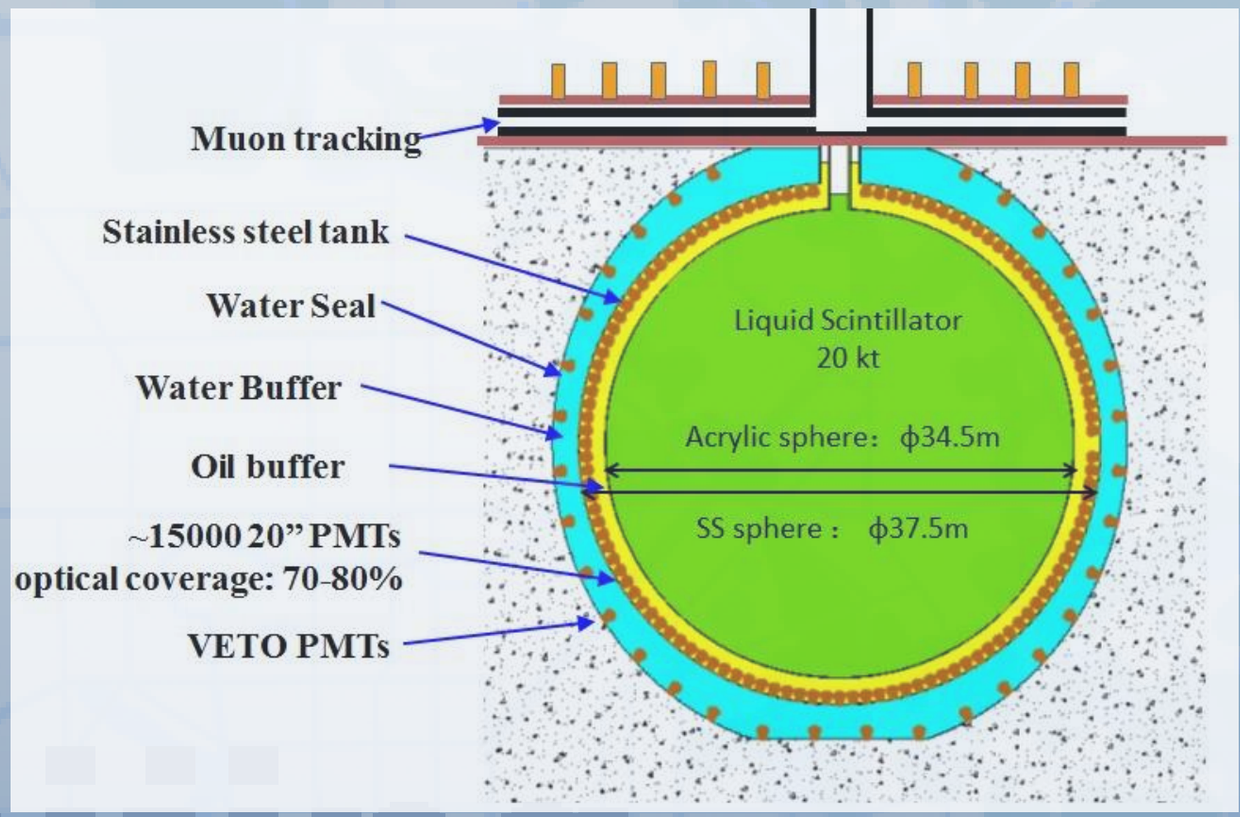
IHEP, China

IHEP

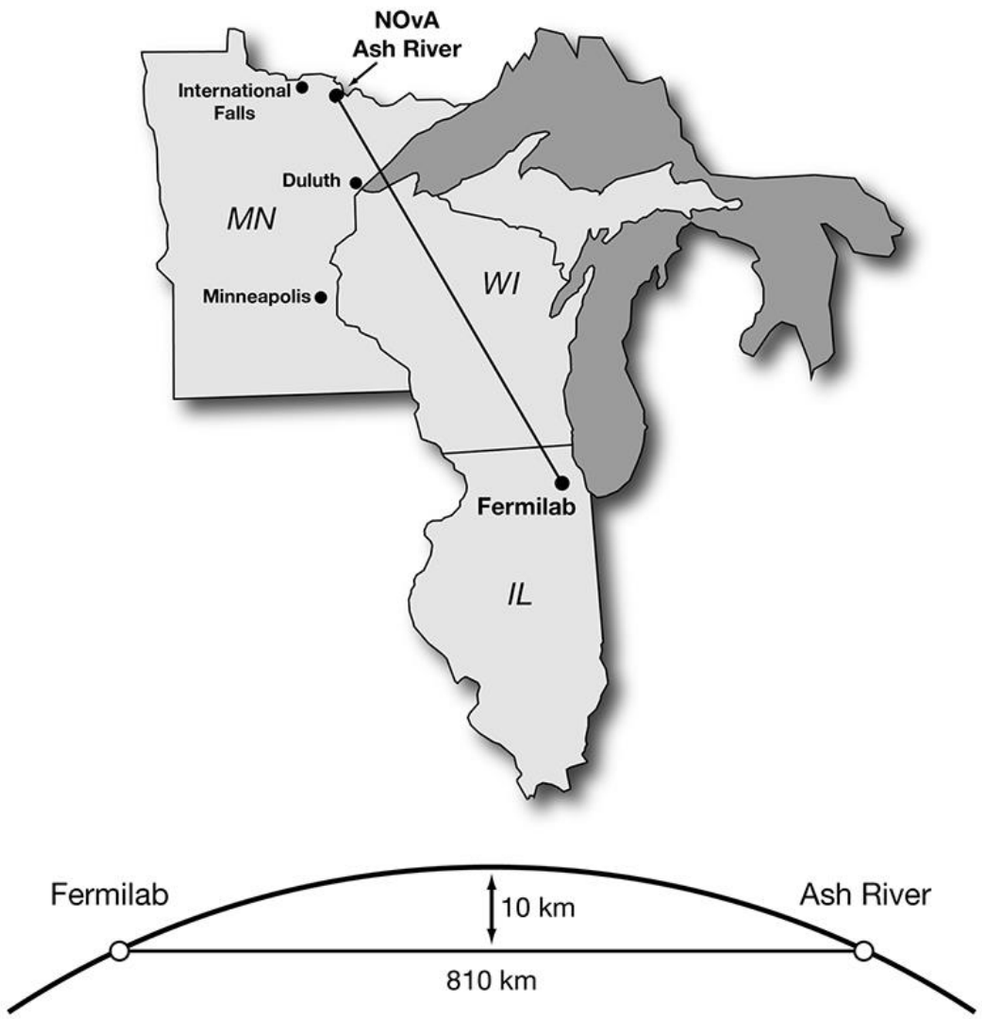
JUNO DETECTO

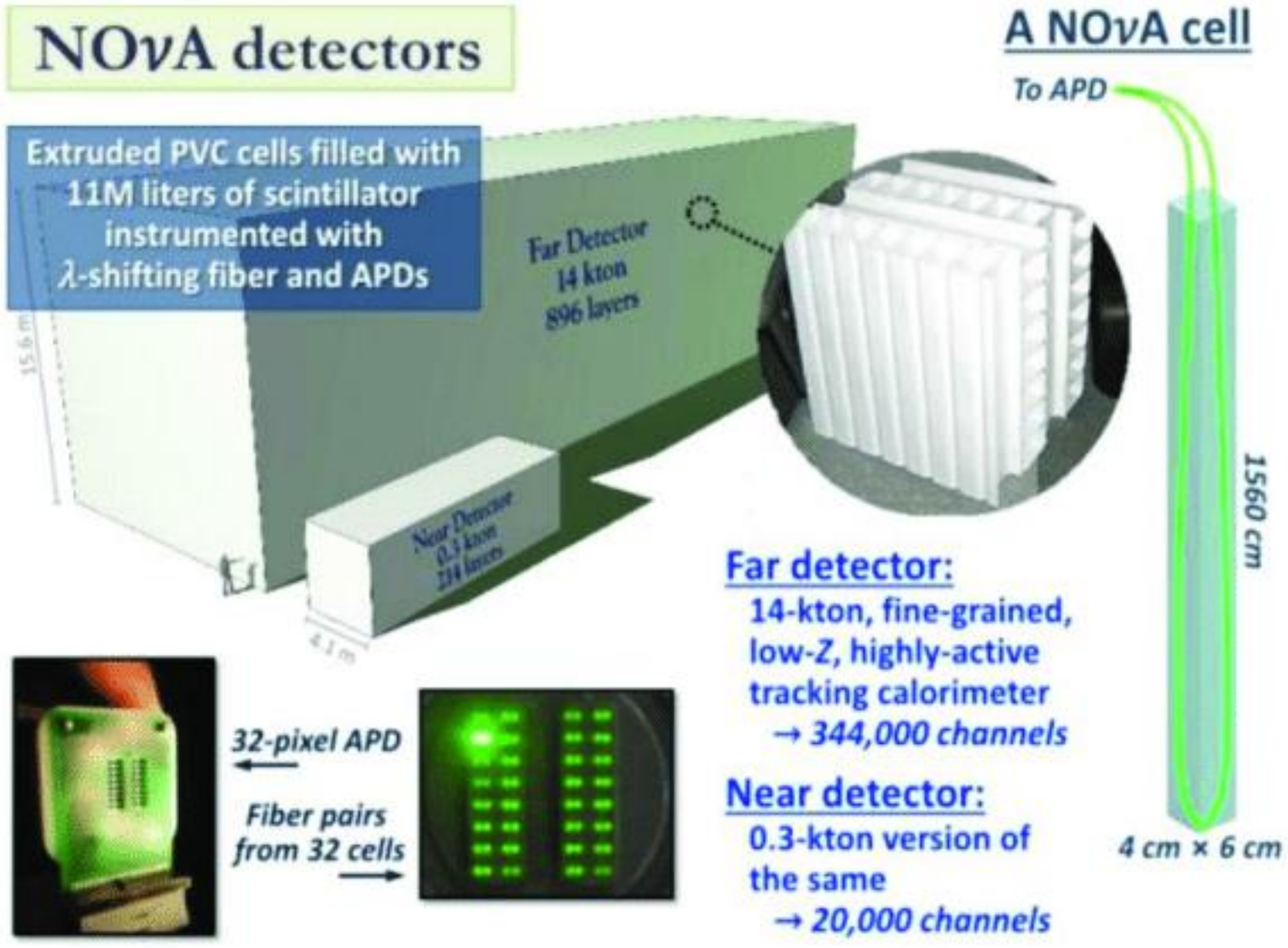
project, readout electronics



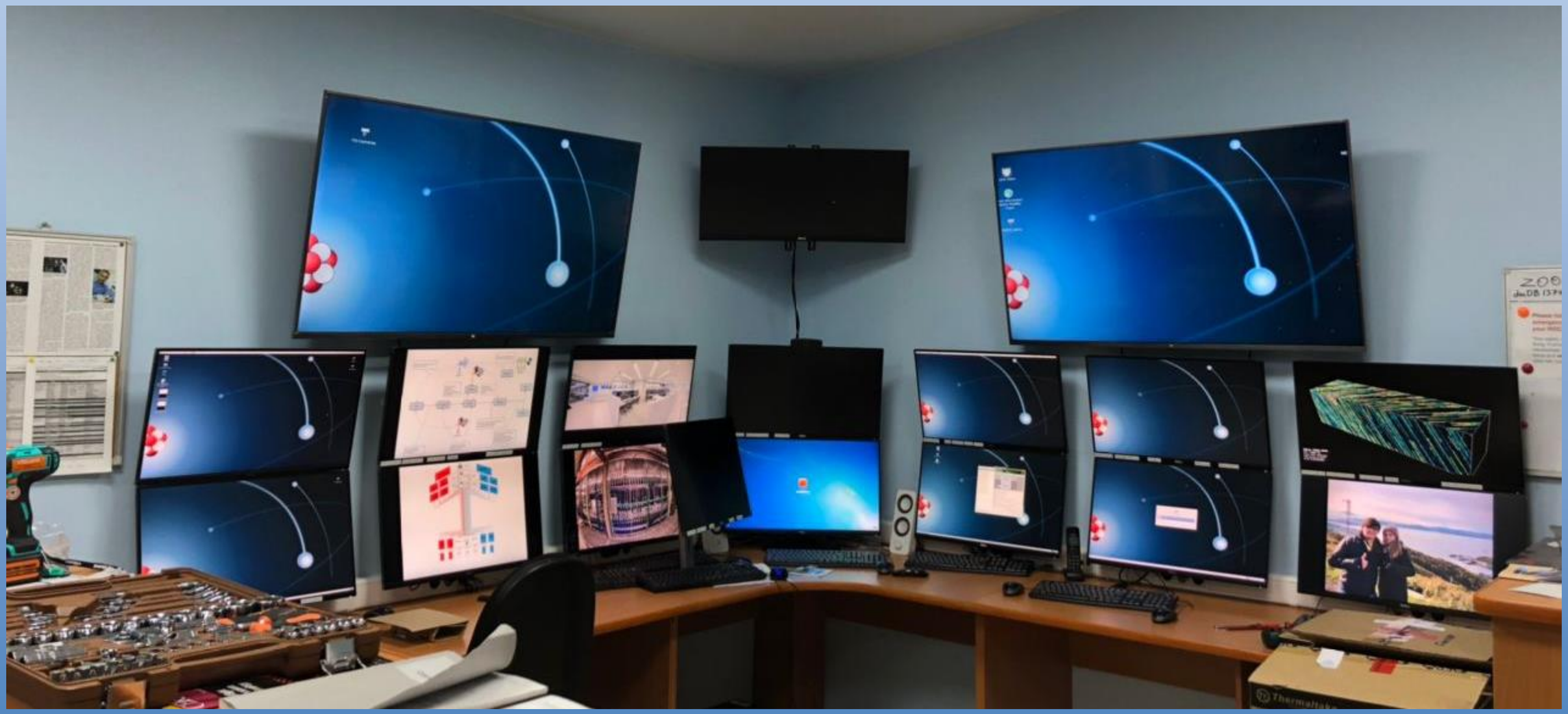


The NOvA experiment

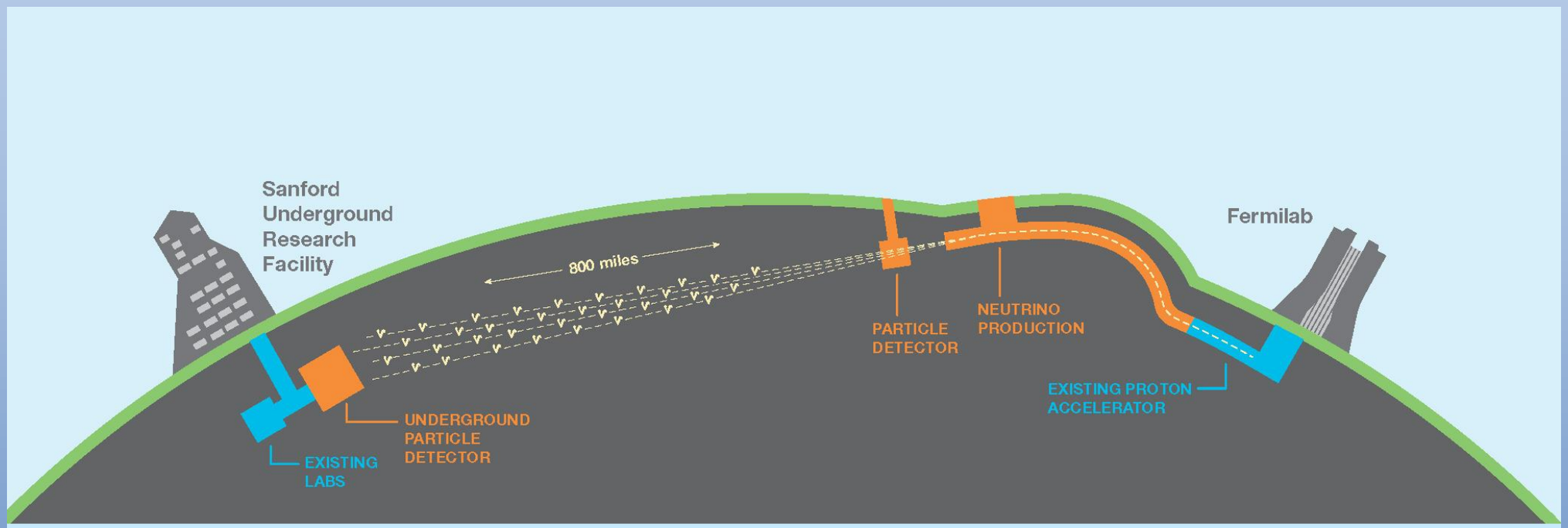


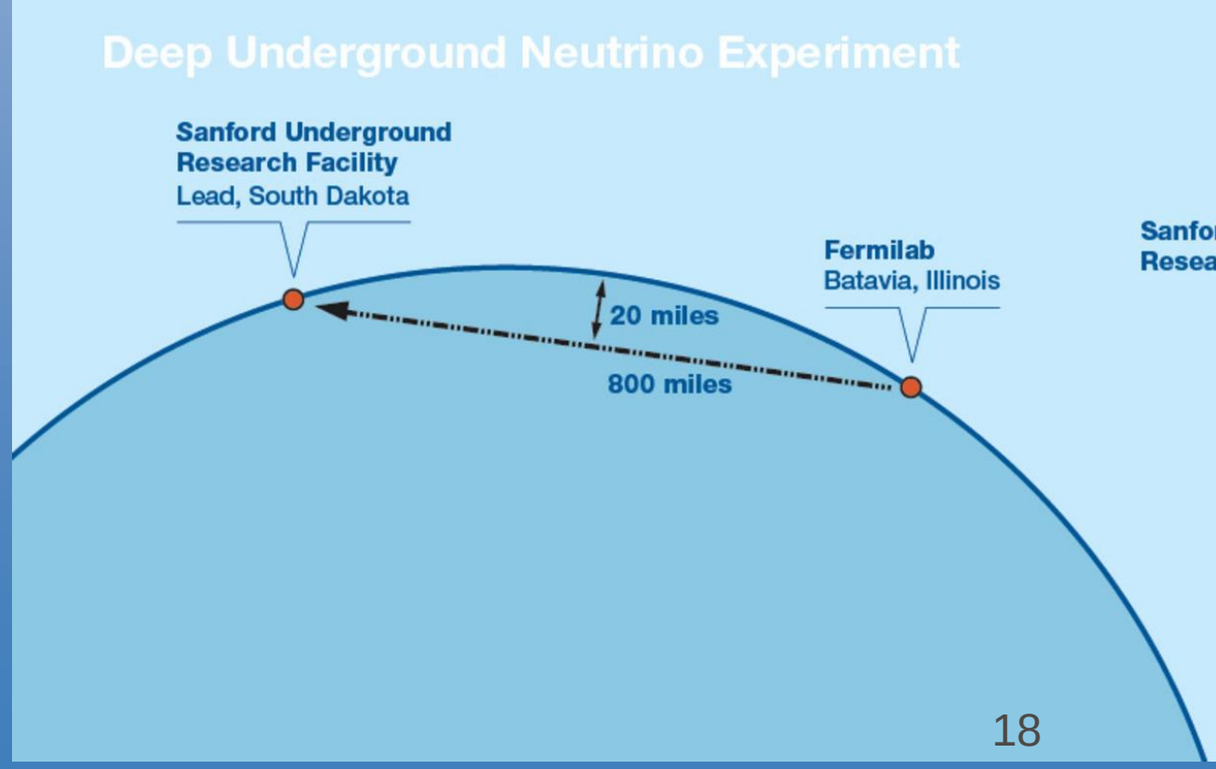


NOvA ROC

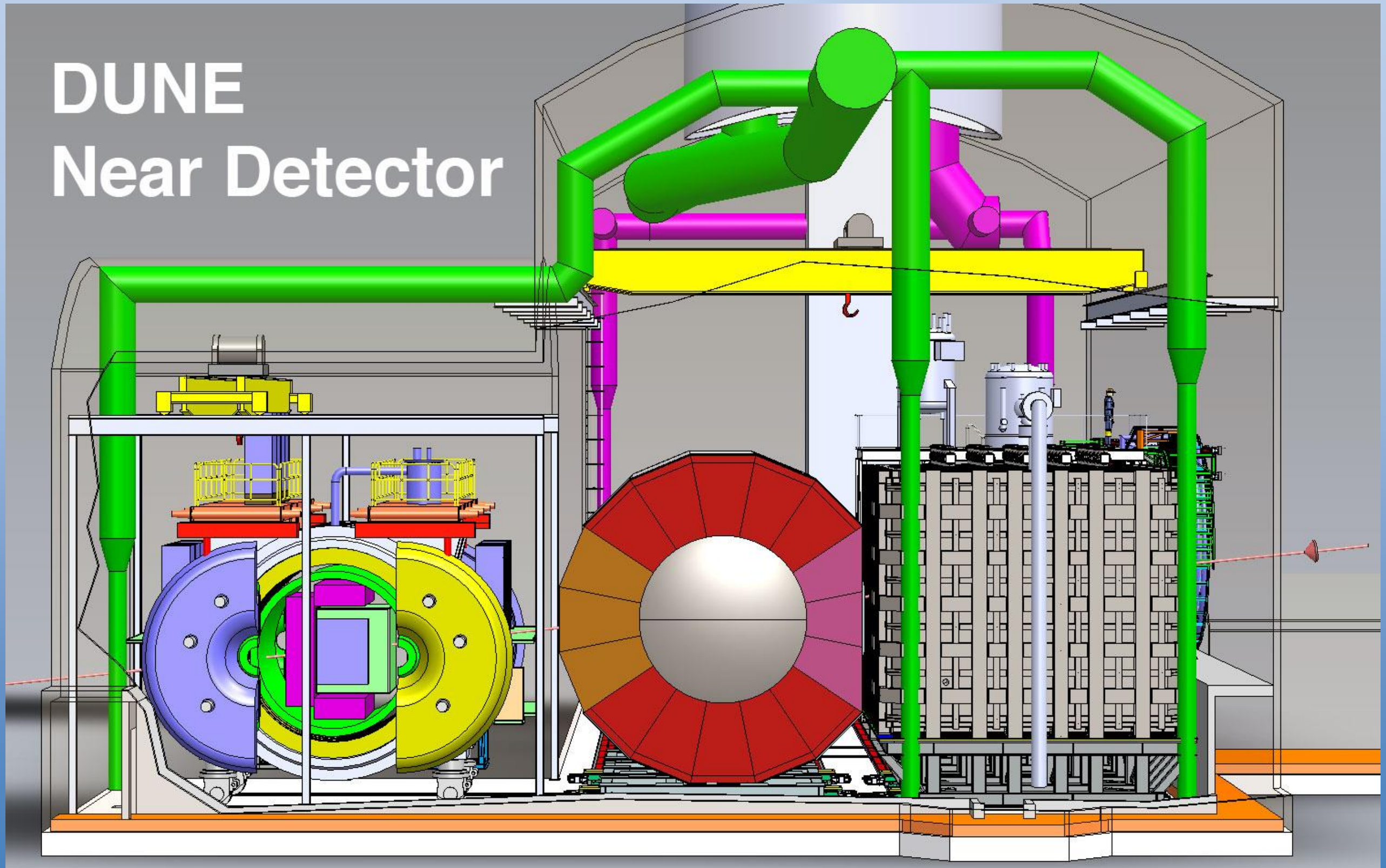


The DUNE experiment





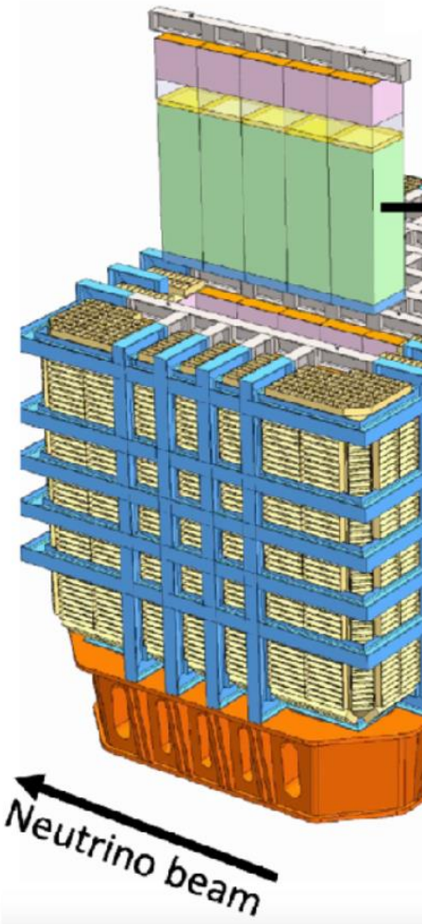
DUNE
Near Detector

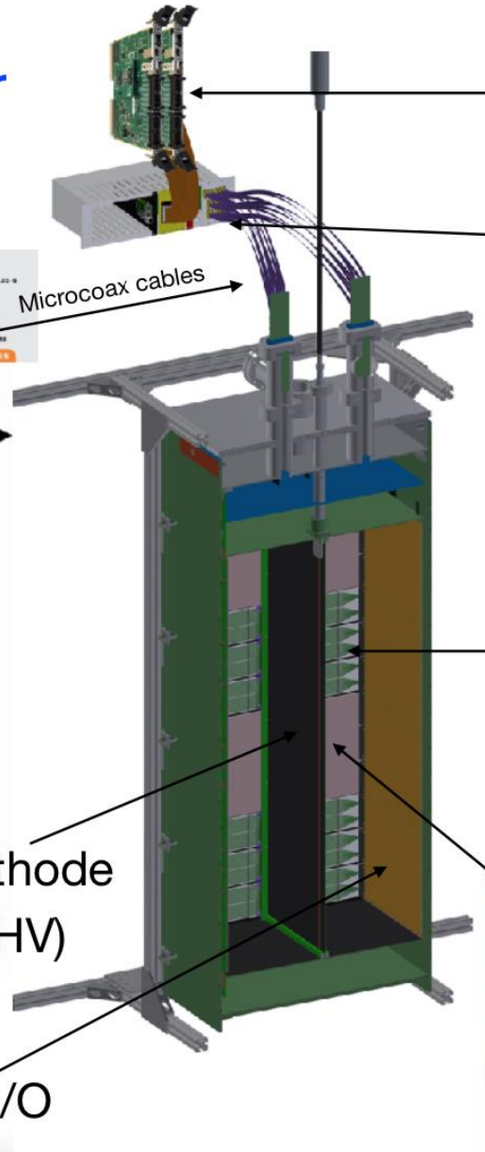


Full readout chain

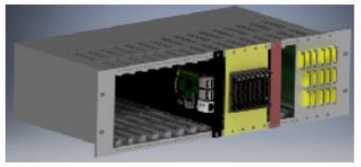
Light R/O for LArTPC of the DUNE ND

JINR Group is responsible for whole Light R/O Chain





AFI JINR ADC

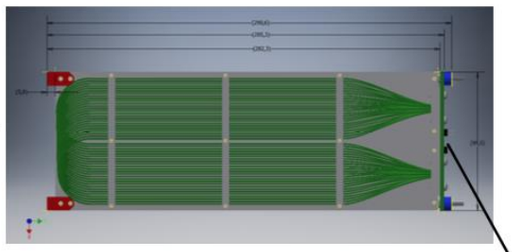


Crate with JINR
Custom electronics
SiPM power/ PGA

Slow Control
Software

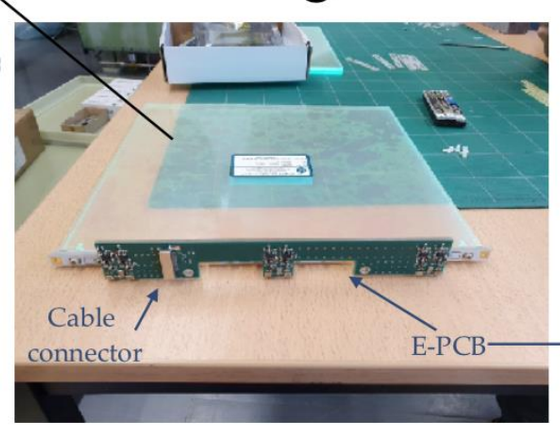
Light collection modules

LCM



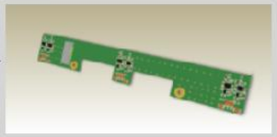
Is in production…

ArcLight



R/O Chain

SiPM Boards

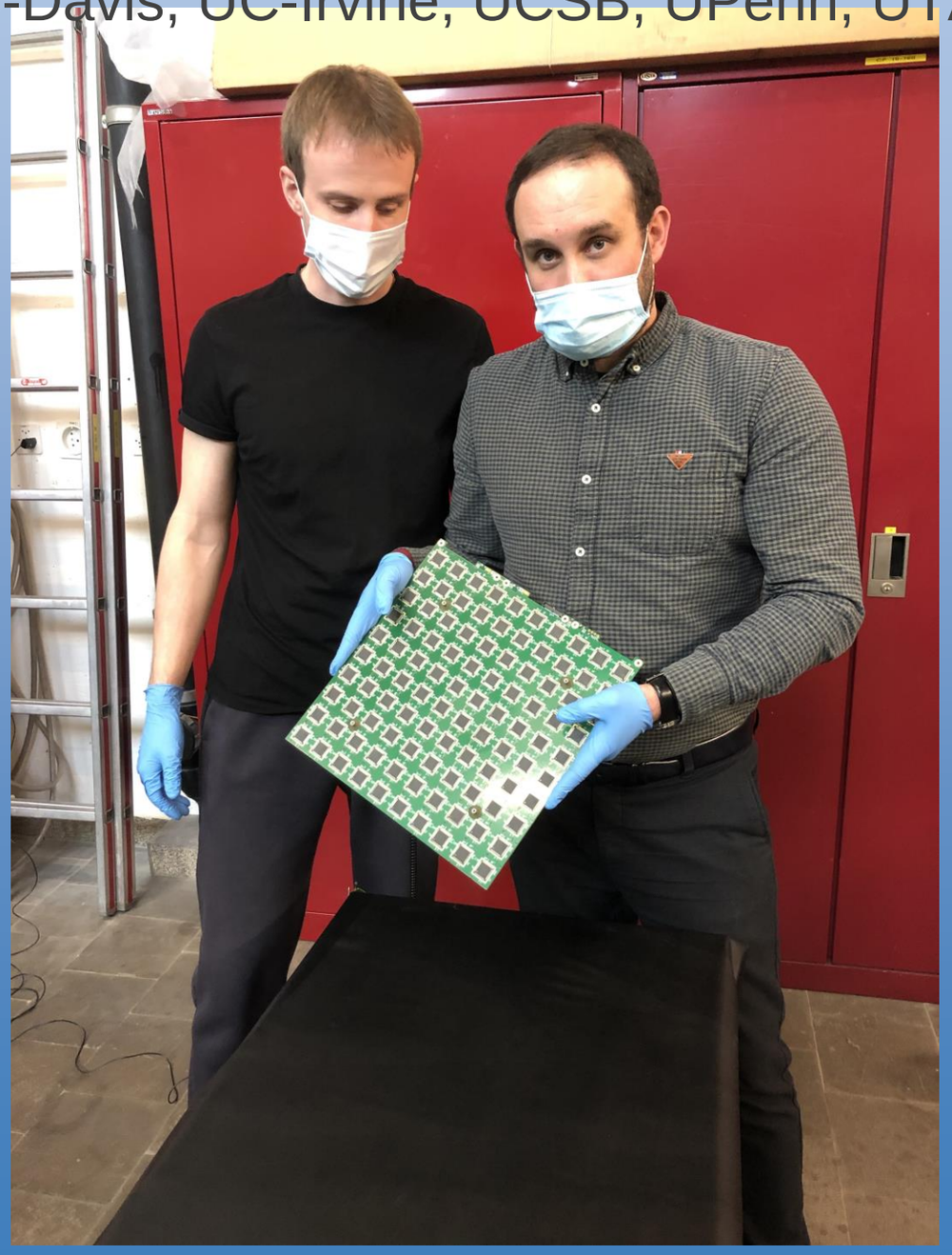


E-PCB/Cold
PreAmps

Including: Detectors, electronics, Front-End, DAQ, Slow Control, Calibration system

Charge detection system - CDS

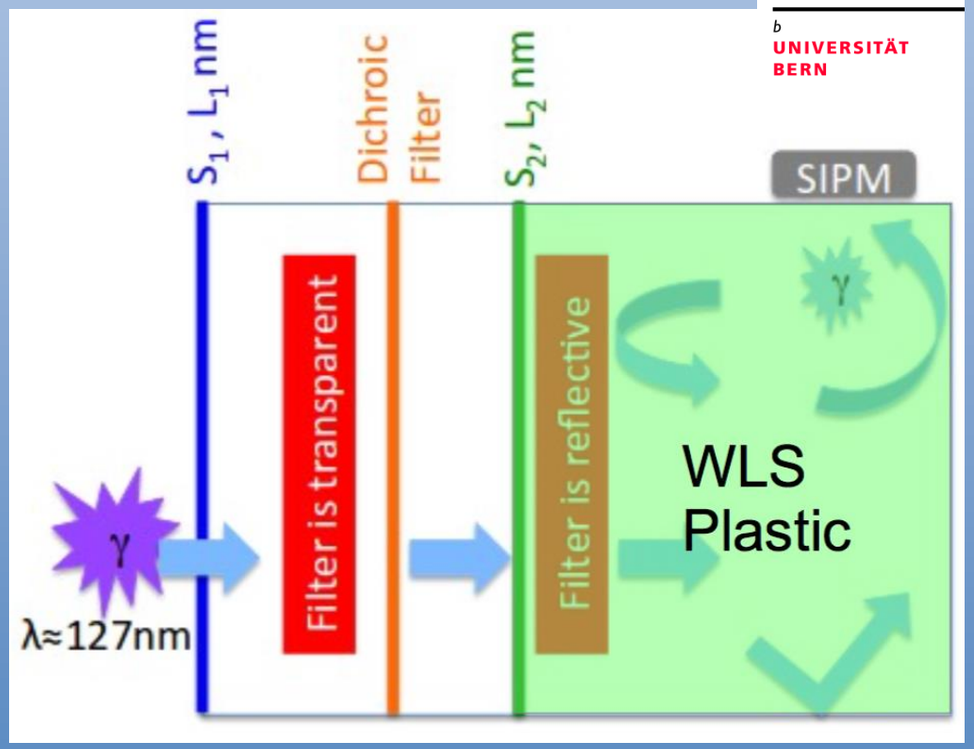
Institutions: LBNL, Caltech, CSU, Rutgers, UC-Davis, UC-Irvine, UCSB, UPenn, UTA



Light readout. LCM & ArCLight

Both approaches are based on shifting UV light (128 nm) into visible (425 nm) by TPB

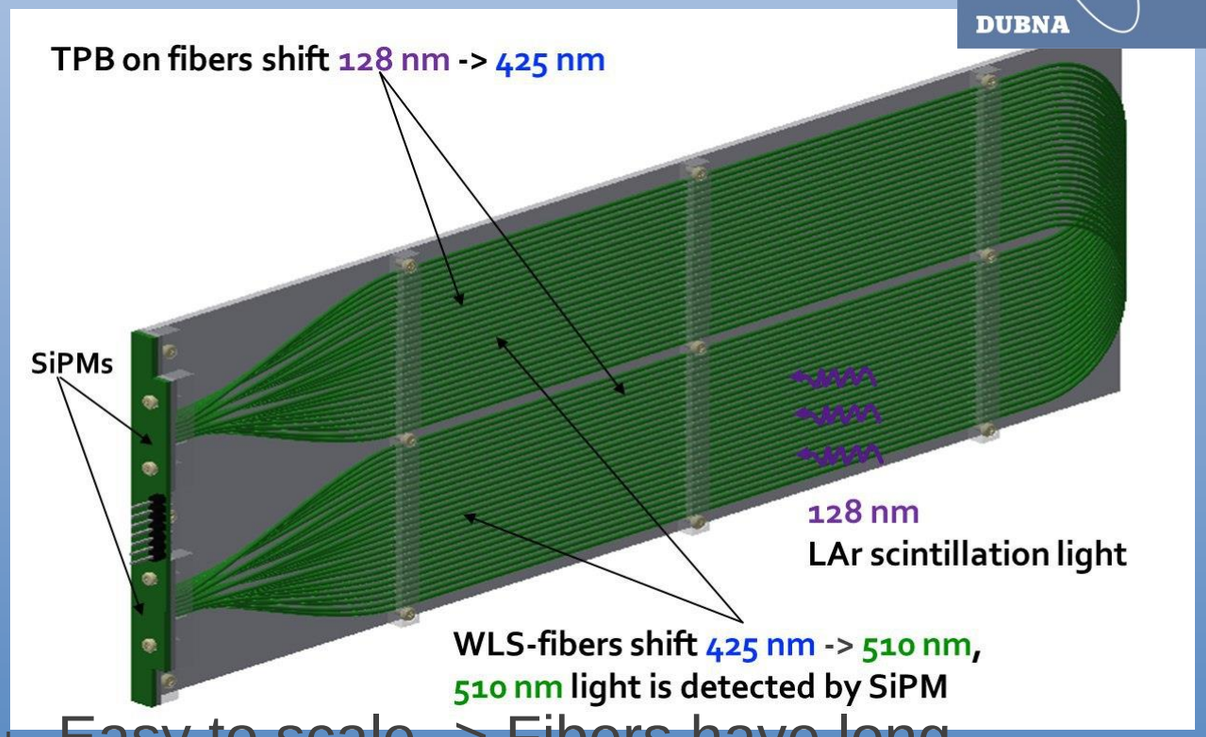
ArCLight Concept



+ Provides more rigid construction
+ Better spatial resolution

- PDE ~ 0.1% (Currently)
- Can lose PDE for scaling up.

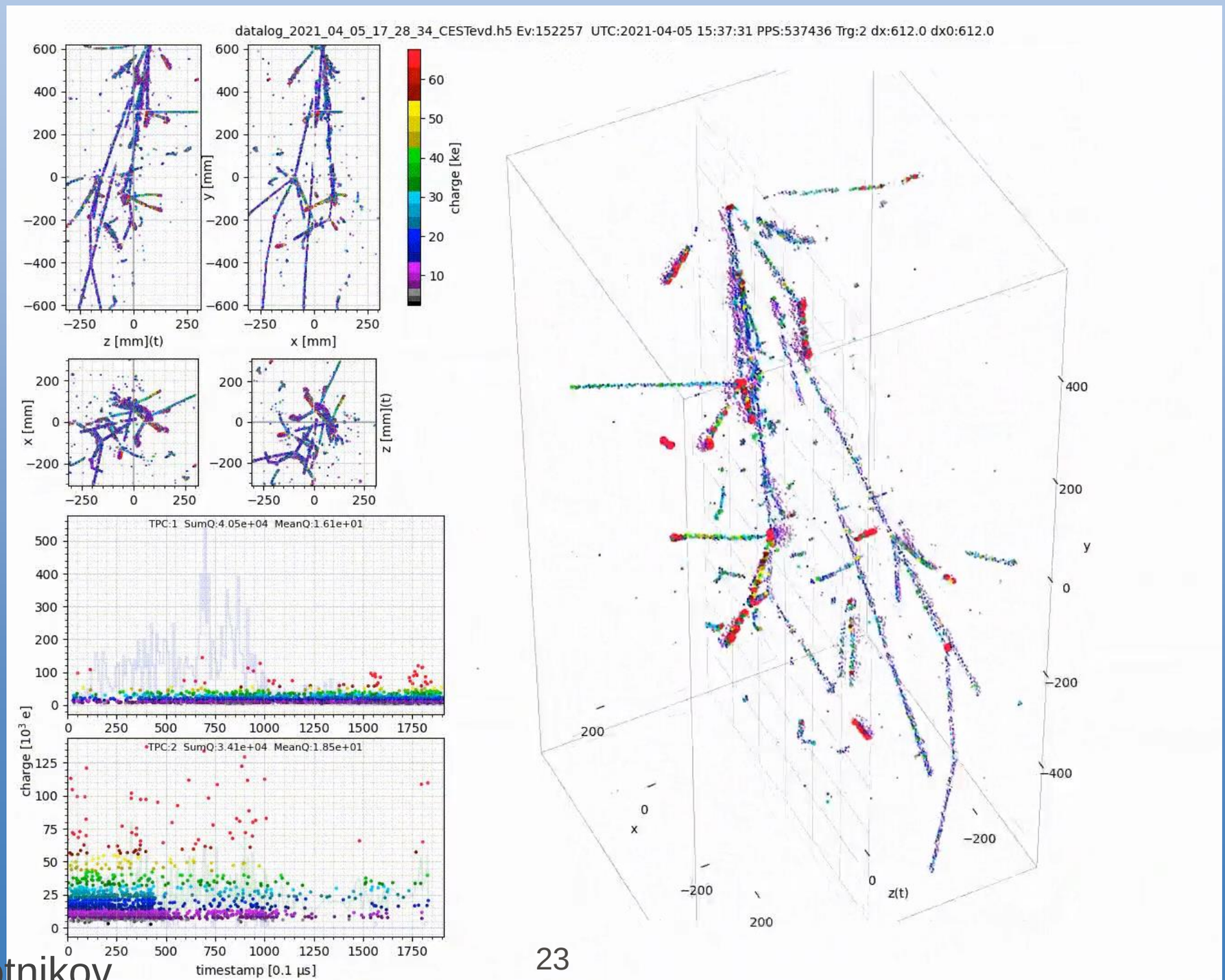
LCM Concept



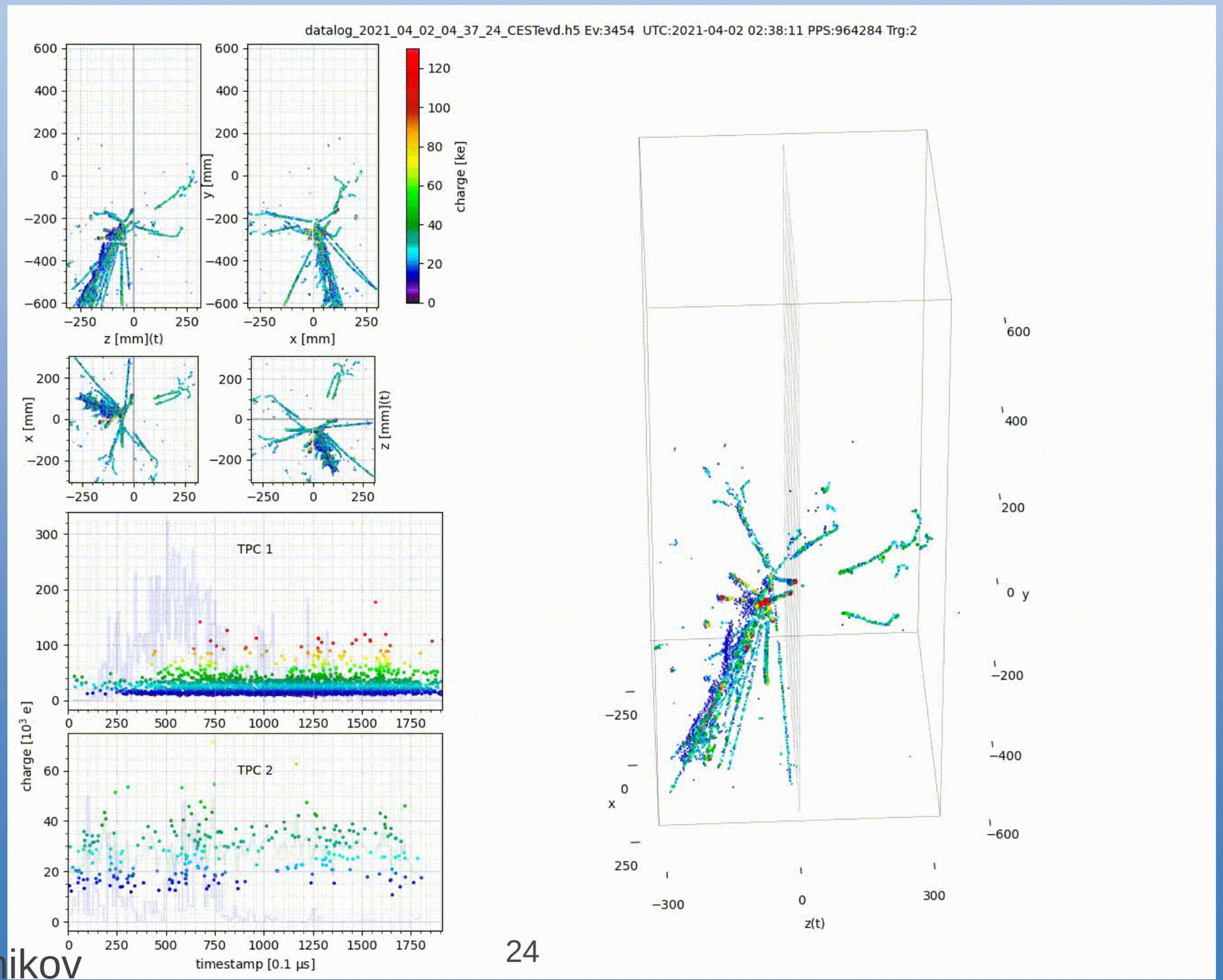
+ Easy to scale -> Fibers have long attenuation
+ Doesn't loose efficiency (PDE) with scaling up. PDE ~ 1 - 2 %
+ Can be used as 1 DAQ channel

- Complex and flexible

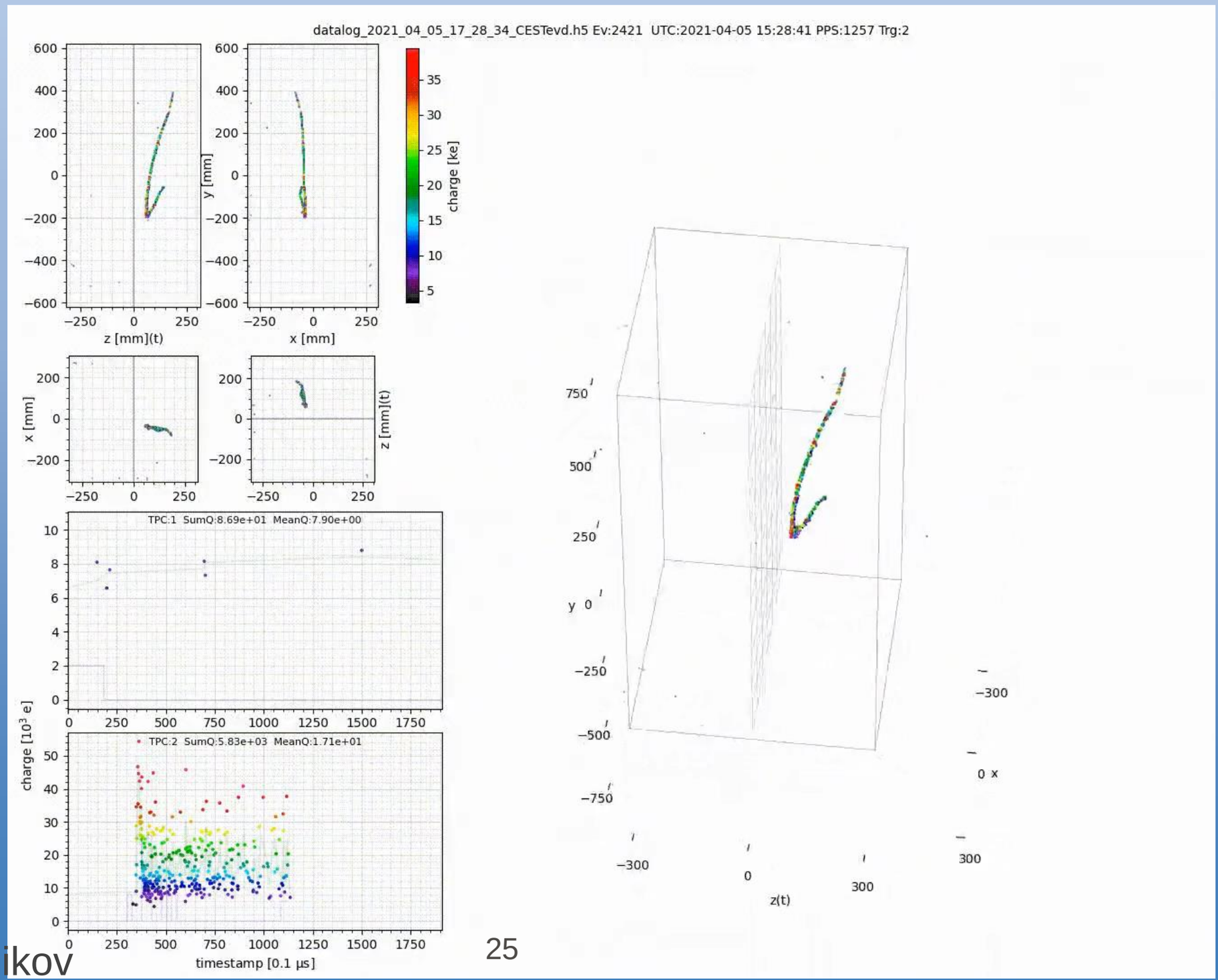
Events reconstruction



Events reconstruction



Events reconstruction (Michel)

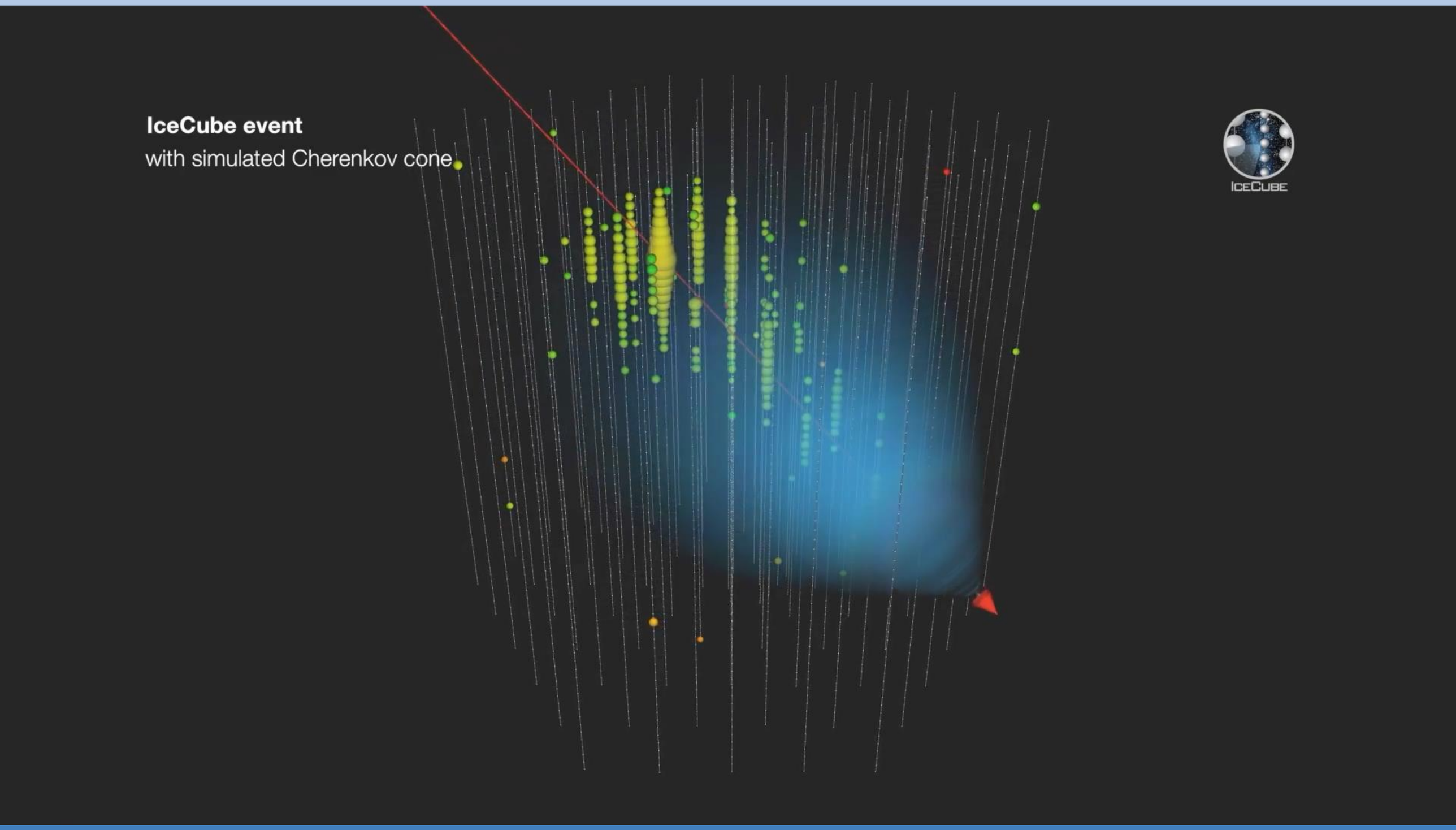


BAIKAL GVD

Neutrino Telescope

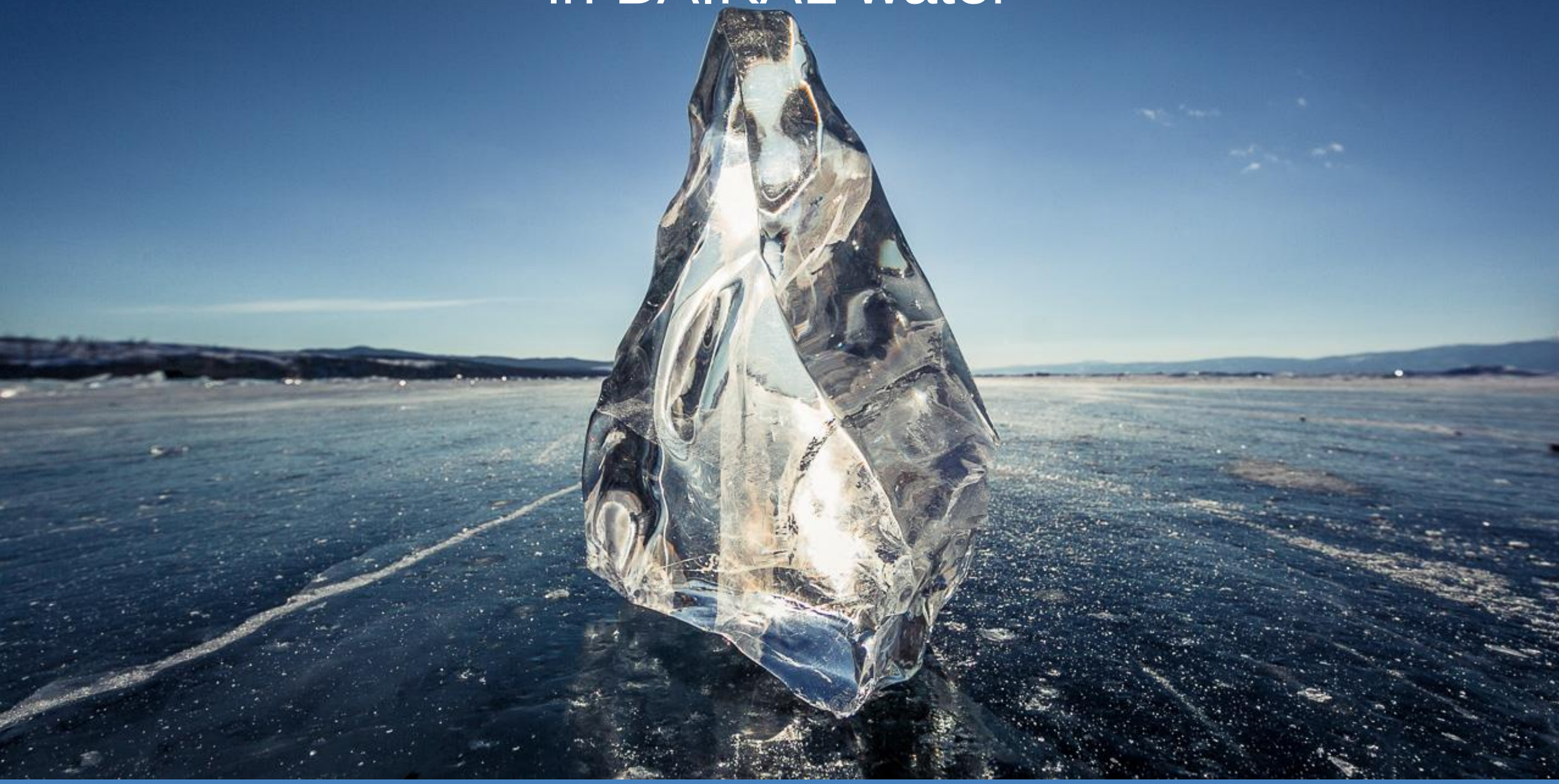
GVD = Gigaton-volume-detector

A new boost in BAIKAL Neutrino Telescope history:
Discovery of UltraHigh energy Neutrinos by IceCube (2014)
JINR major contribution to construction of cubic-km BAIKAL GVD



Why BAIKAL?

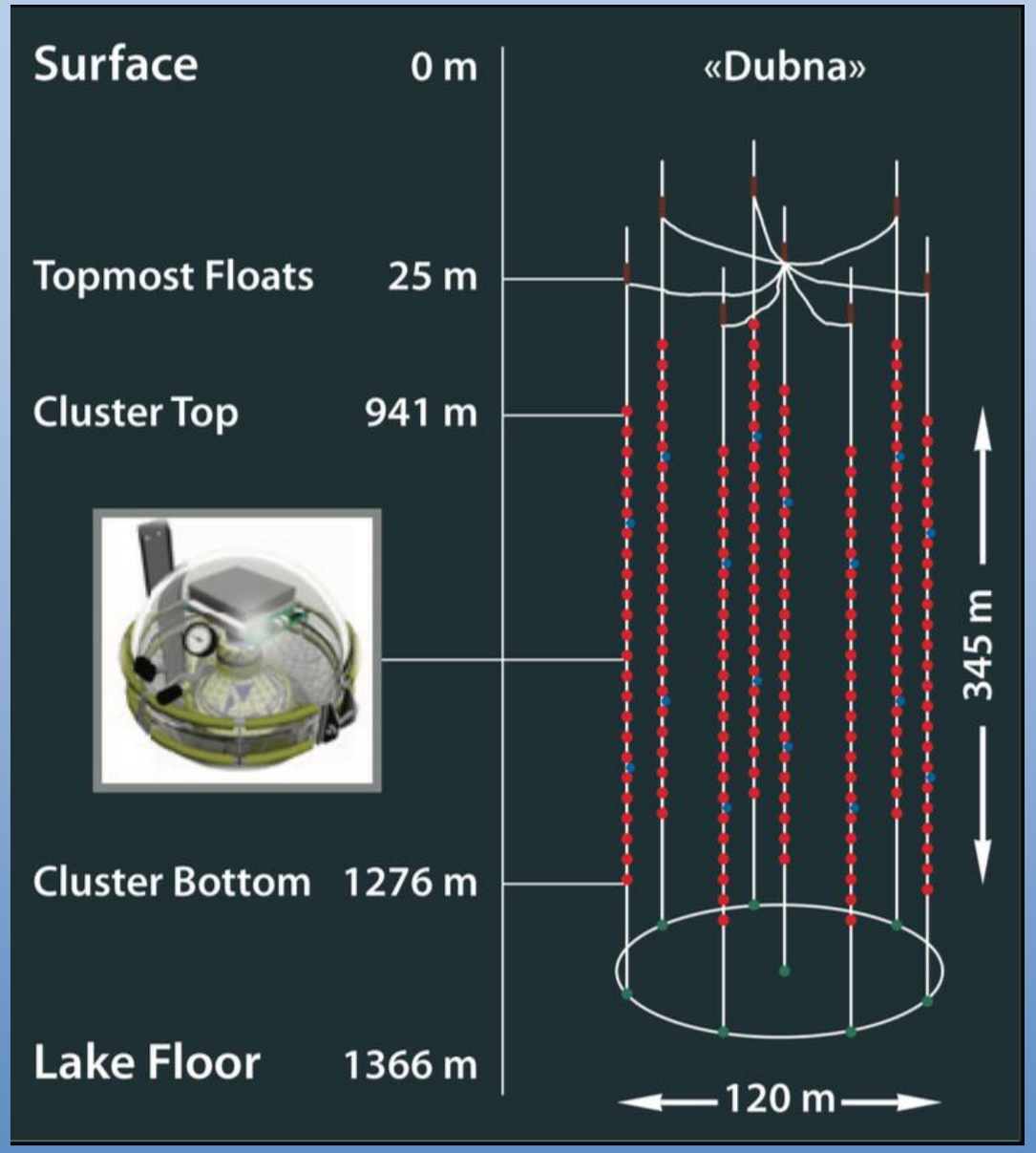
Accurate determination of arrival direction in BAIKAL water



Light re-scattering in ice is large

The Plan

- Main Goal
  - Point sources of UHE neutrino
- 3D Array of photo-sensors
  - Phase I: 0.4 km3 (by 2021)
  - Phase II: 1.5 km3 (by 2027)
- Installation site
  - South Baikal
  - Depth 1.4 km
  - Distance from shore 3.5 km
- Requirements
  - Adjustable structure



BAIKAL Collaboration in 2019

65 physicist & Engeneers

1. Institute for Nuclear Research, Moscow, Russia
2. Joint Institute for Nuclear Research, Dubna, Russia
3. Irkutsk State University, Irkutsk, Russia
4. Skobeltsyn Institute of Nuclear Physics MSU, Moscow, Russia
5. Nizhny Novgorod State Technical University, Russia
6. Saint Petersburg State Marine University, Russia
7. Institute of Experimental and Applied Physics, Czech Technical University, Prague, Czech Republic
8. Comenius University, Bratislava, Slovakia
9. EvoLogics GmbH, Berlin, Germany
10. Krakow Institute of Nuclear Physics PAN, Poland

OM assembling hall @DLNP JINR

12 OM/day