Study of Neutrino Oscillations in NOvA experiment
(JINR Participation)
Project extension for the period 2018-2020

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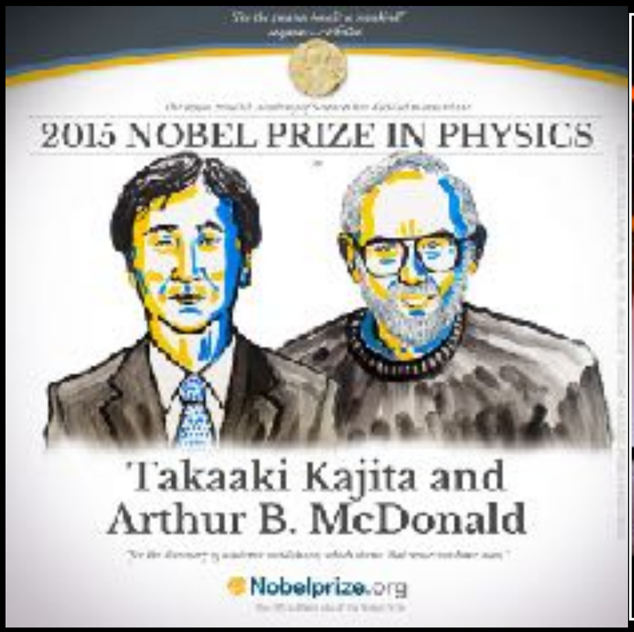
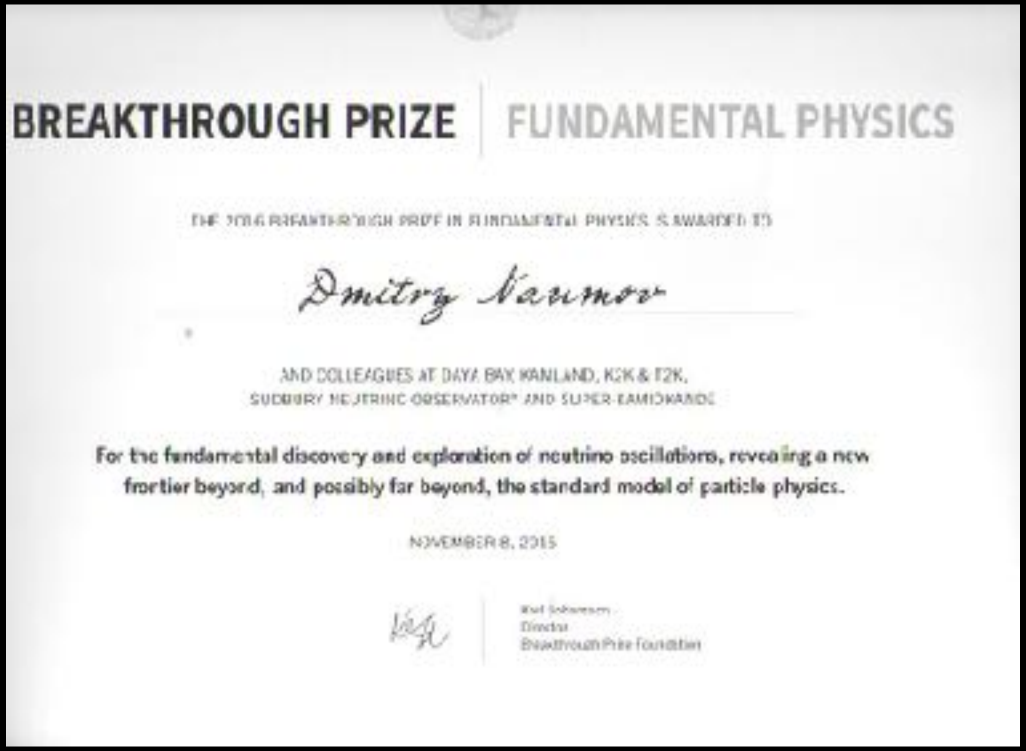
O.Samoylov PAC PP 26 June 2017

Neutrino. The big picture

Nobel Prize 2015 and Breakthrough 2016





BREAKTHROUGH PRIZE | FUNDAMENTAL PHYSICS

THE 2016 BREAKTHROUGH PRIZE IN FUNDAMENTAL PHYSICS IS AWARDED TO

Dmitry Naumov

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.

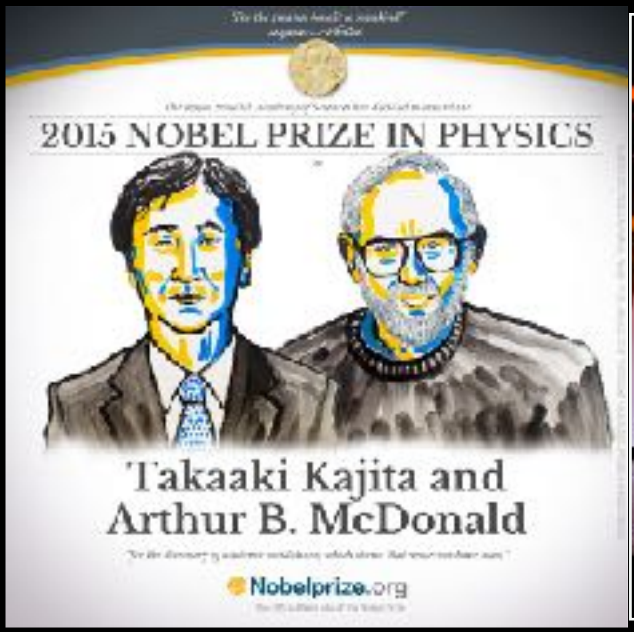
NOVEMBER 8, 2015

Director
Breakthrough Prize Foundation

«The 2016 Breakthrough Prize in Fundamental Physics Awarded to 7 Leaders and 1370 Members of 5 Experiments Investigating Neutrino Oscillation: Daya Bay (China); KamLAND (Japan); K2K / T2K (Japan); Sudbury Neutrino Observatory (Canada); and Super-Kamiokande (Japan)».

Neutrino. The big picture

Nobel Prize 2015 and Breakthrough 2016



- **NOBELS**
- **1988**, Leon Lederman, Melvin Schwartz, Jack Steinberger — for the neutrino beam method and the demonstration of the doublet structure of the leptons through the discovery of the muon neutrino
- **1995**, Frederick Reines — for the detection of the neutrino
- **2002**, Raymond Davis and Masatoshi Koshiba — for pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos
- **2015**, Takaaki Kajita and Arthur B. McDonald — for the discovery of neutrino oscillations, which shows that neutrinos have mass

- **SHORT NEUTRINO HISTORY**
- **1914**, James Chadwick discovered continuous β-spectrum
- **1930**, Wolfgang Pauli proposed a light neutral particle of spin 1/2 emitted alongside the electron.
- **1934**, Enrico Fermi published his theory of β-decay.
- **1956**, Fred Reines and Clyde L. Cowan detected reactor (anti)neutrino.
- **1957**, Bruno Pontecorvo proposed neutrino-antineutrino oscillations.
- **1958**, Maurice Goldhaber, Lee Grodzins and Andrew Sunyar found that neutrinos are left handed.
- **1962**, Leon Lederman, Melvin Schwartz, Jack Steinberger discovered muon nu.
- **1962**, Ziro Maki, Masami Nakagawa and Shoichi Sakata introduce neutrino flavor mixing and flavor oscillations.
- **1968**, Raymond Davis got first radiochemical solar neutrino.
- **1987**, Kamiokande, IMB and Baksan detectors detect burst of antineutrinos from SN1987A in Large Magellanic Cloud (51.474 kpc).
- **1989**, LEP experiments determine only 3 light neutrinos (via Z-decay).
- **1998**, Super-Kamiokande found muon neutrino oscillations in atmospheric neutrinos.
- **2000**, DONUT observed ν_τ.
- **2001**, SNO announced observation of neutral currents from solar neutrinos.
- **2002**, KamLAND announces detection of a deficit of electron antineutrinos from reactors at a mean distance of 175 km.
- **2005**, KamLAND announced first detection of neutrino flux from the Earth.
- **2010**, OPERA announced observation of the first ν_τ from ν_μ beam.
- **2011**, Borexino presented a high precision measurement of solar neutrino (Be).
- **2011**, T2K announces first evidence for a nonzero mixing between the 1st and 3rd neutrino generations.
- **2012**, Daya Bay announced a precision results on measuring $\theta 13$ with significance 5.2σ.

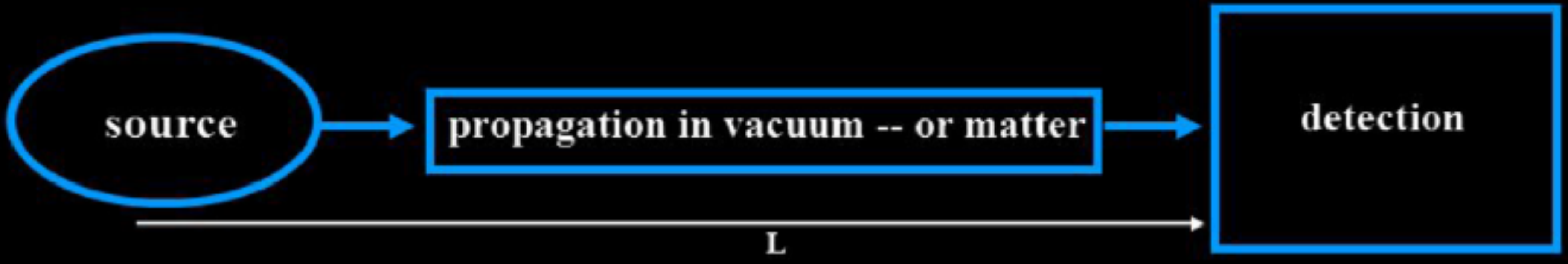
Neutrino oscillations

$\theta_{23} \sim 45^\circ$ $\theta_{13} \sim 8.5^\circ$ $\theta_{12} \sim 30^\circ$

$$\begin{vmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{matrix}\right\rangle = \begin{pmatrix} 1 & & \\ & c_{23} & s_{23} \\ & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & & s_{13}e^{-i\delta} \\ & 1 & \\ -s_{13}e^{i\delta} & & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & \\ -s_{12} & c_{12} & \\ & & 1 \end{pmatrix} \left| \begin{matrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{matrix}\right\rangle$$

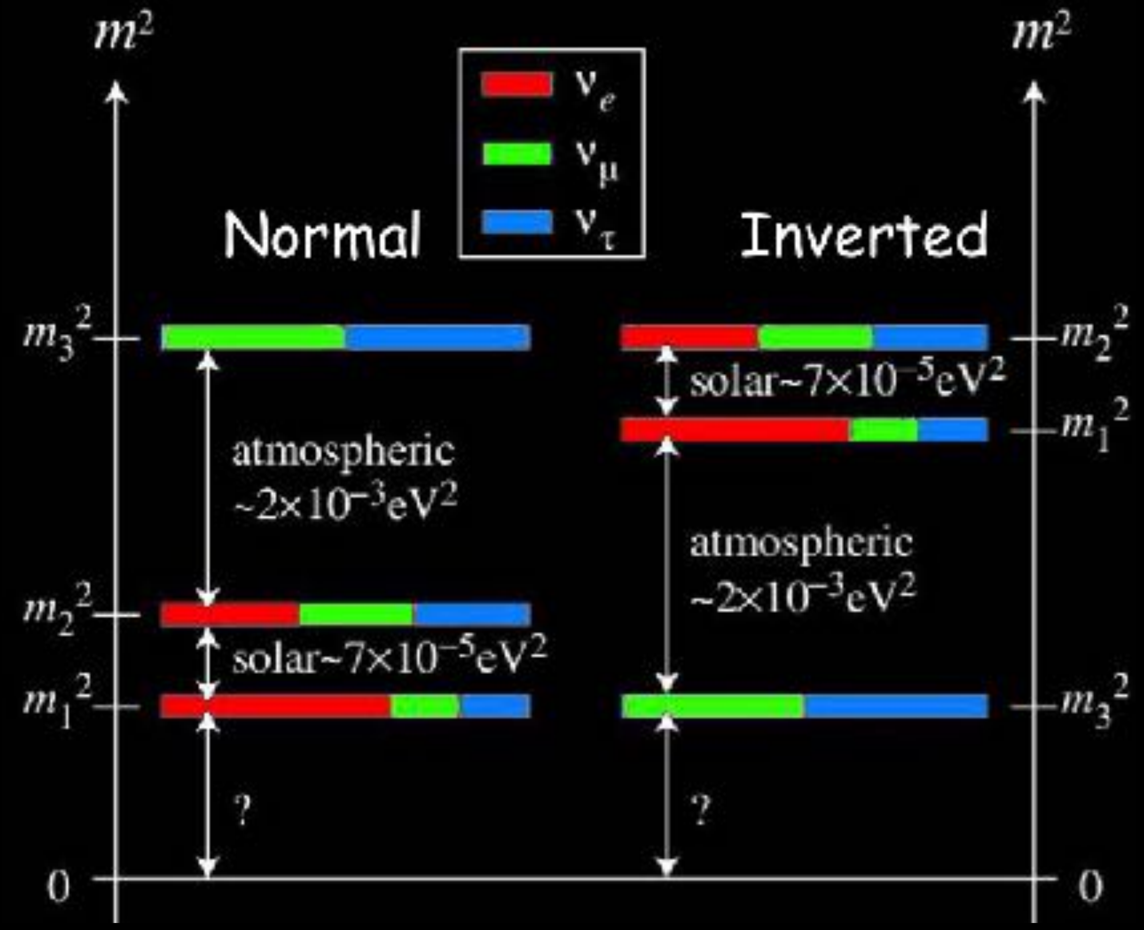
$\lvert\Delta m^2_{32}\rvert = \lvert m^2_3 - m^2_2\rvert$ $\simeq 2.5 \times 10^{-3}\ \mathrm{eV}^2$	$\Delta m^2_{31} \simeq \Delta m^2_{32}$	$\Delta m^2_{21} = \lvert m^2_2 - m^2_1\rvert$ $\simeq 7.5 \times 10^{-5}\ \mathrm{eV}^2$
$\nu_\mu \to \nu_\mu$	$\nu_e \to \nu_e$	$\nu_e \to \nu_e$
$\nu_\mu \to \nu_\tau$	$\nu_\mu \to \nu_e$	$\nu_e \to \nu_\mu, \nu_\tau$
atmospheric and long baseline	reactor and long baseline	solar and reactor

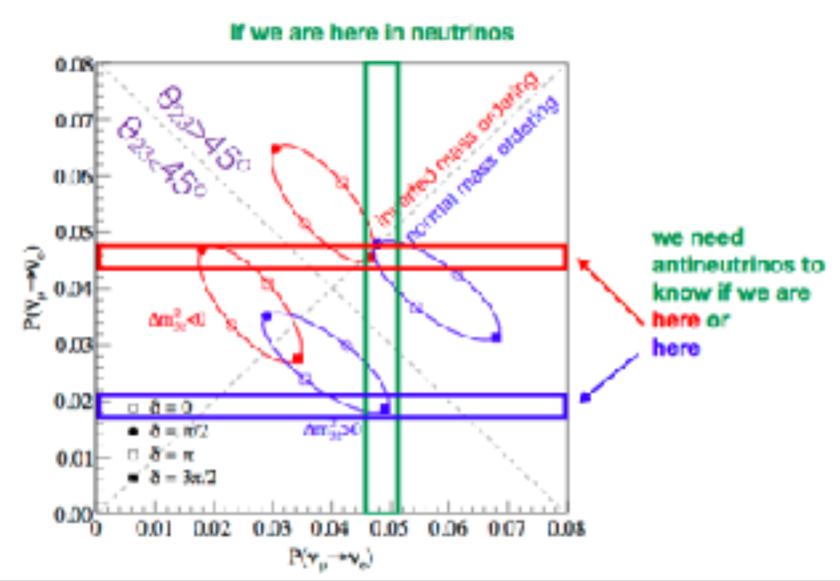
Oscillation parameters: $\theta_{12}, \theta_{23}, \theta_{13}$, CP phase δ, $|\Delta m^2_{13}|$, Δm^2_{12}



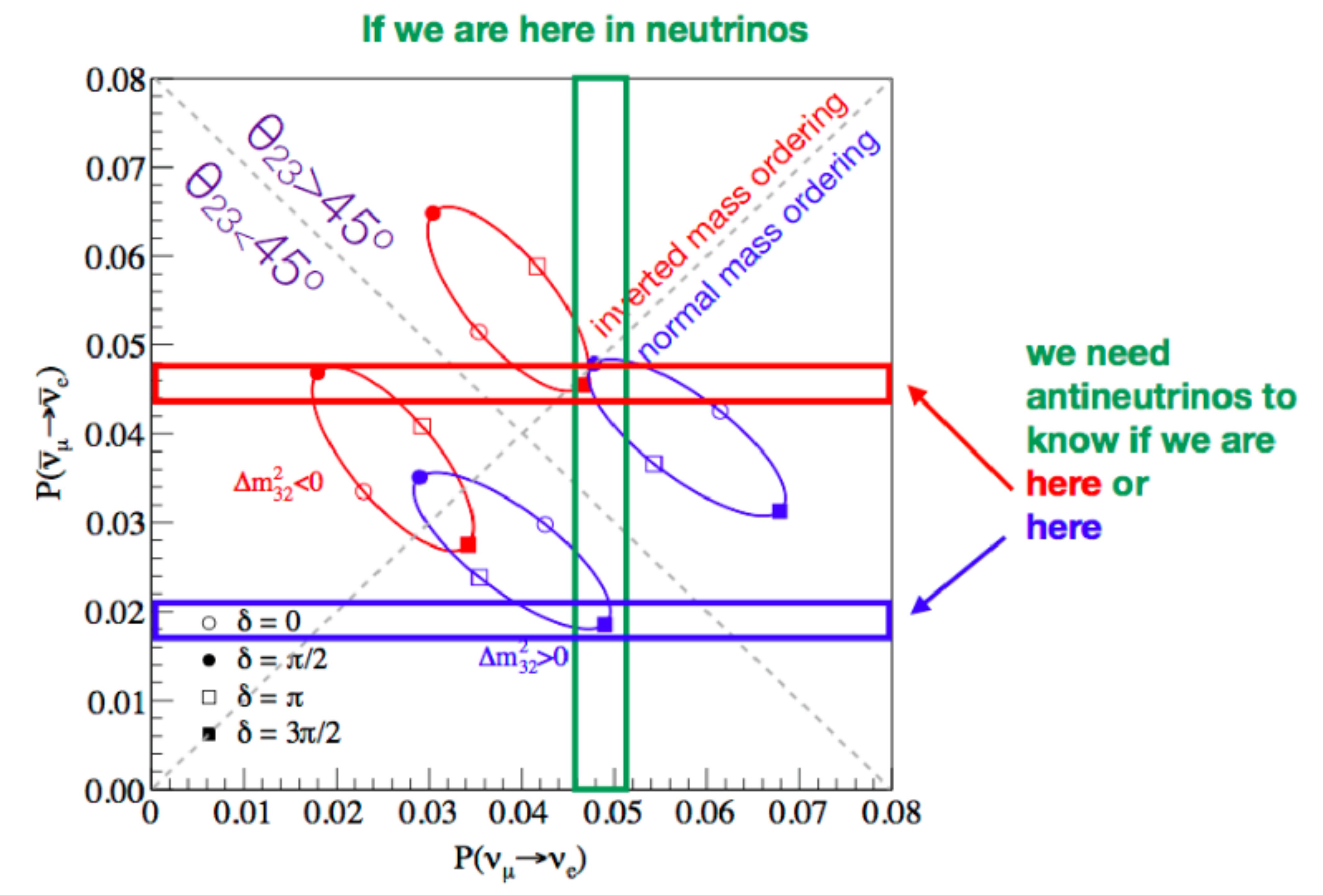
Neutrino. The big picture and NOvA

- Neutrino mass hierarchy (**NOvA** is about 2020, JUNO/DUNE >2025, PINGU)
- CP violating phase (T2K and **NOvA** 2020, DUNE > 2025)
- Precise measurements of oscillation parameters (**NOvA** for θ_{23} 2020)
- Dirac or Majorana (0νββ experiments)
- Absolute mass (KATRIN)
- Sterile neutrinos (reactor or radioactive source short baseline experiments, long baseline accelerator neutrino experiments looking for NC including **NOvA**)
- Supernova neutrinos (large volume detectors as **NOvA**, SNEWS)
- High energy cosmic neutrinos (IceCube, Baikal, KM3NET)
- Detection of the Cosmic Neutrino Background / CNB (no idea for the moment)



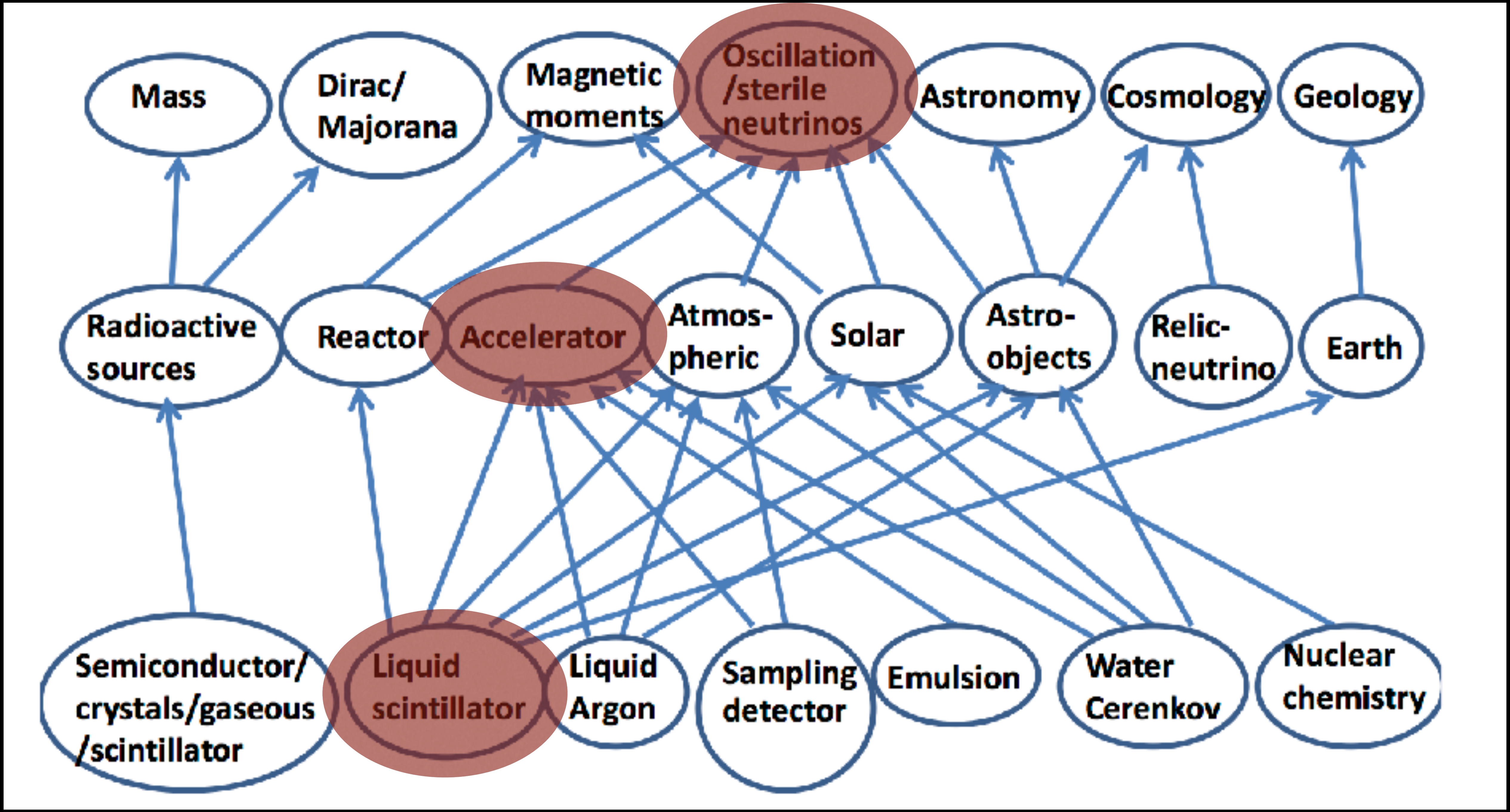


Neutrino. The big picture and NOvA

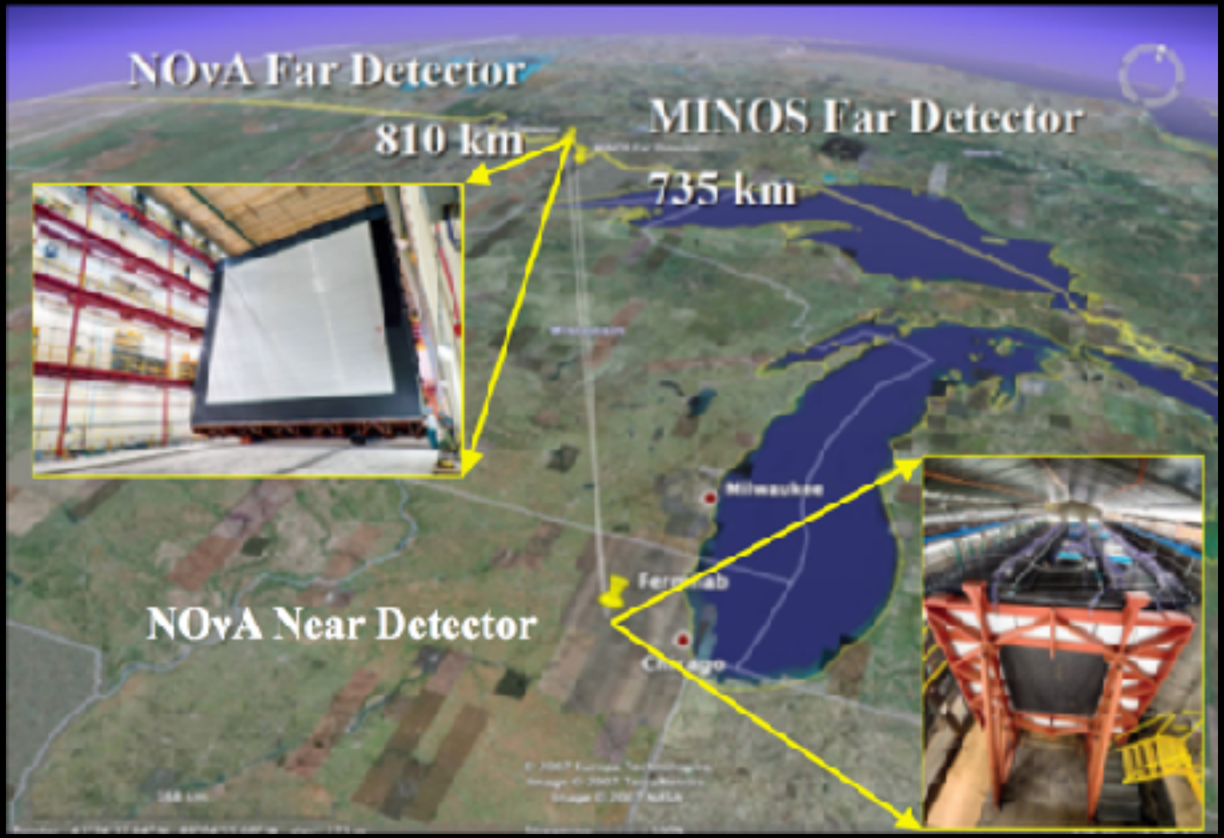


- Neutrino mass hierarchy • CP violating phase
- Precise measurements of θ_{23}

Neutrino. The big picture and NOvA



Detectors, Beam and Data taking

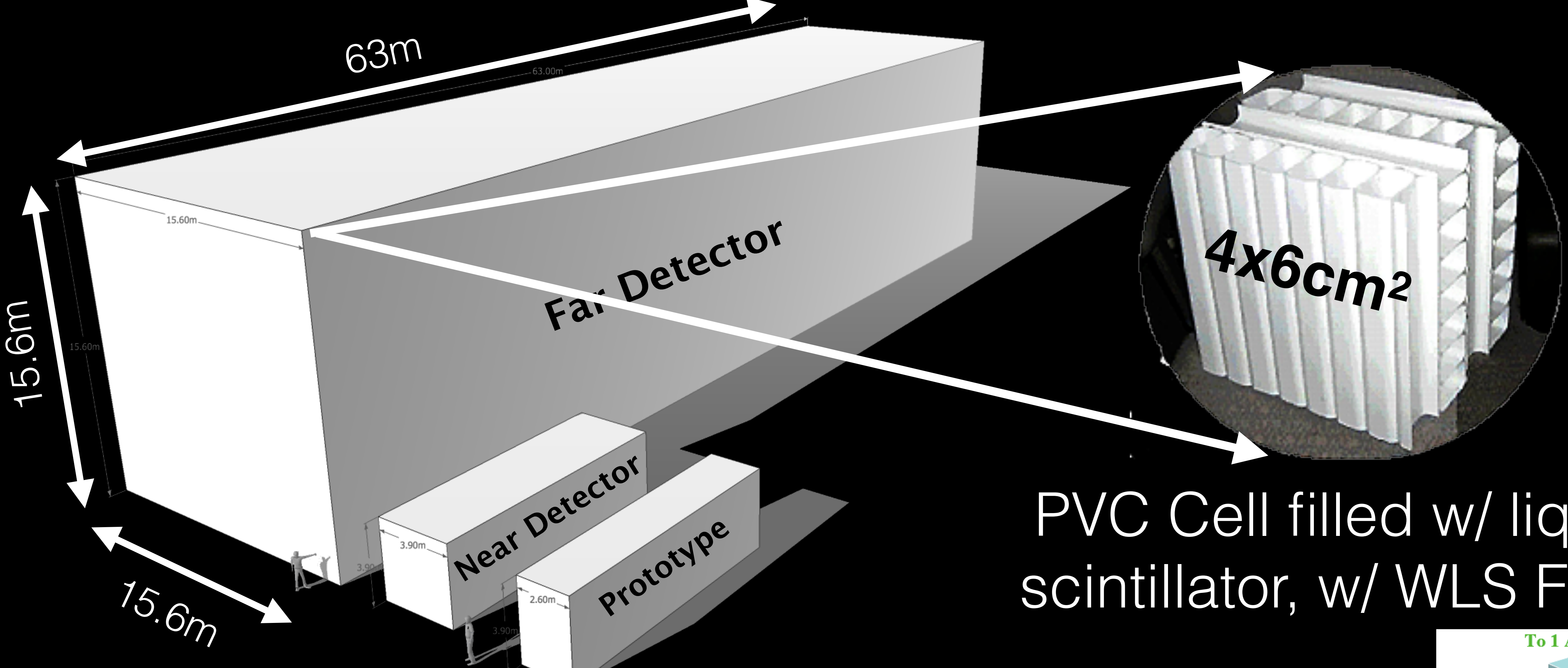


- Precision is achieved by placing a detector close to the source (Near Detector) and one at or close to the oscillation maximum (Far Detector)

$$
\begin{aligned}
ND(\nu_\mu) &= \boxed{\Phi(E_\nu) \times \sigma(E_\nu, A)} \times \epsilon_{ND} \\
FD(\nu_\mu) &= \boxed{\Phi(E_\nu) \times \sigma(E_\nu, A)} \times \epsilon_{FD} \times P_{osc}
\end{aligned}
$$

- 14 mrad off the NuMI beam axis, yields a narrow 2-GeV spectrum at the NOvA detectors
- A distance of 810 km provides covering the first oscillation maximum
- Far Detector: 14-kton, fine-grained, low-Z, highly-active tracking calorimeter (344,064 channels)
- Near Detector: 0.3-kton version of the same
- Collected up to now 9e20 POT in neutrino mode (6e20 for the current published analysis), running in anti-neutrino mode since 20 February 2017

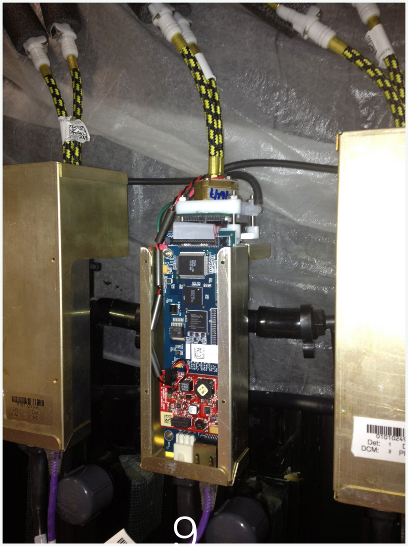
NOvA Detectors



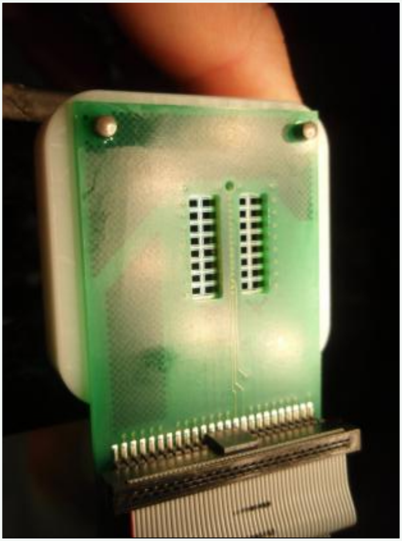
PVC Cell filled w/ liquid scintillator, w/ WLS Fiber

FEB / DCMs / Buffer Nodes

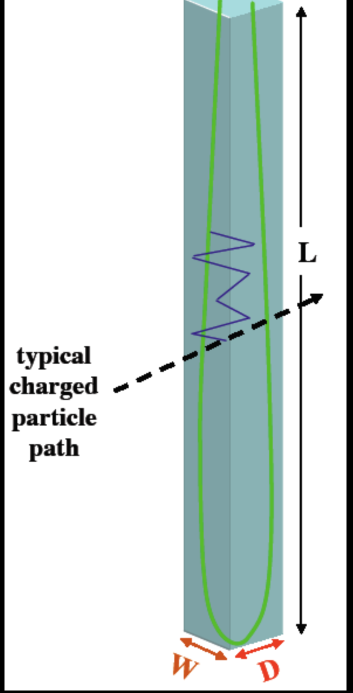
FEB



APD

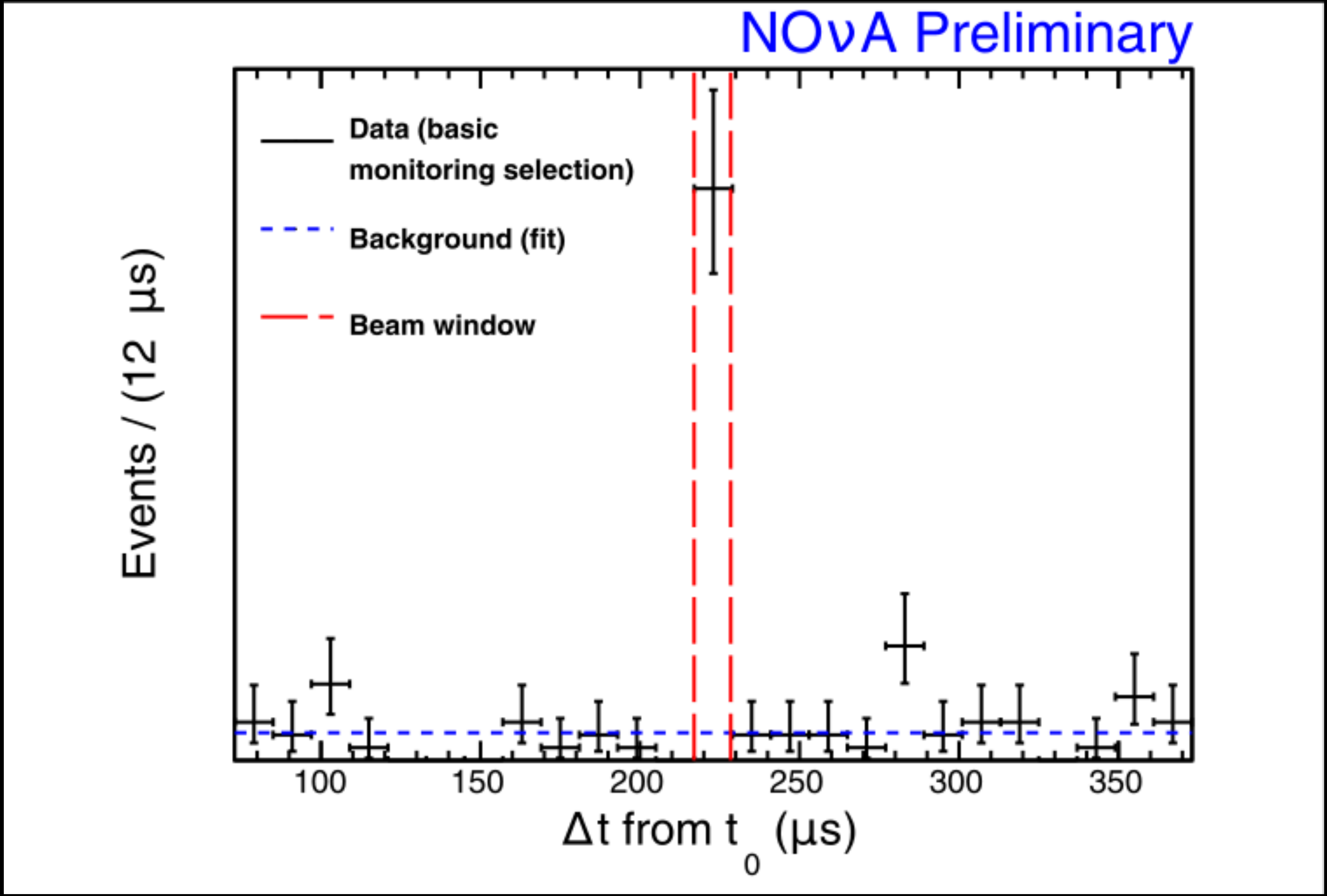


Fiber end



FD Beam Peak

- Trigger structure: 550 μs window, NuMI neutrinos arrive for 10 μs starting at 218 μs



NOvA Goals

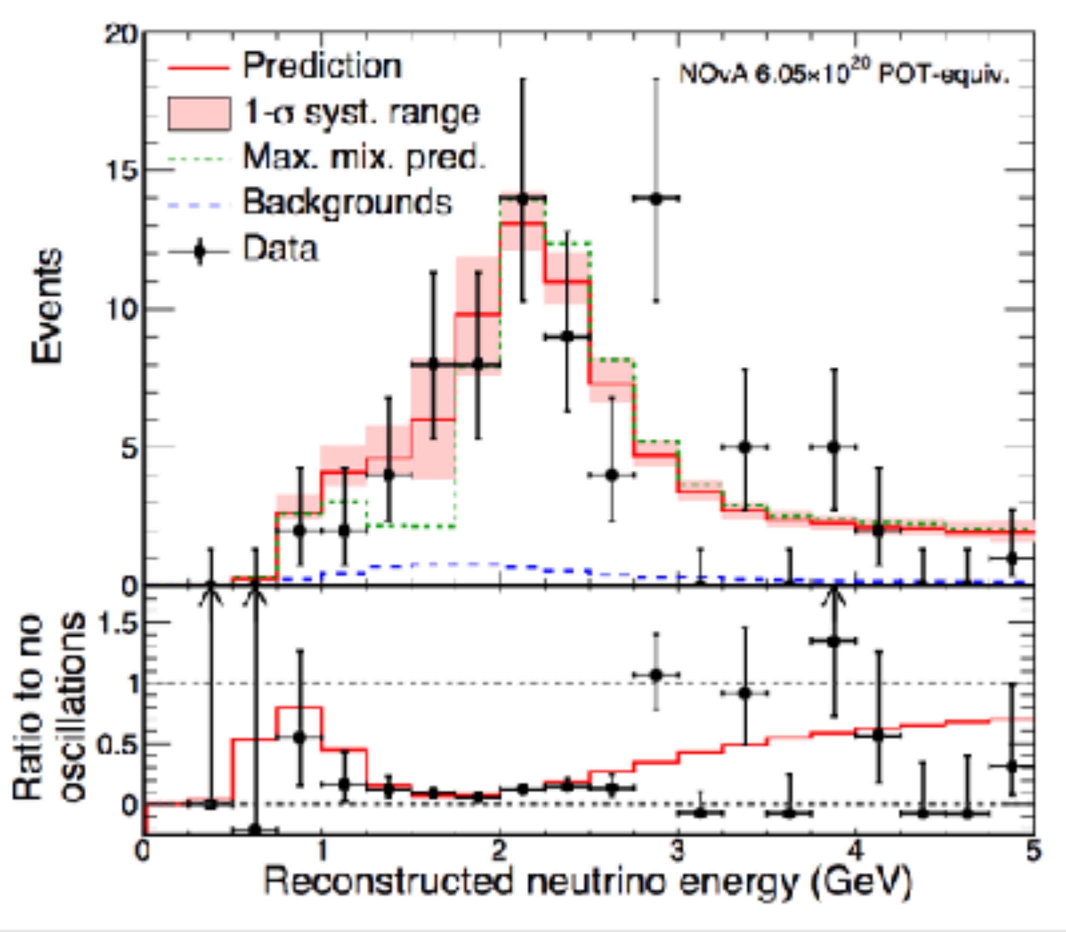
- Within electron neutrino appearance NOvA catchs Mass hierarchy and CP-violation phase
- Within muon neutrino disappearance NOvA precisely measures θ_{23} octant
- Search beyond the Standard Model
  - Sterile neutrino(s)
  - Dark Matter
  - Magnetic monopoles
- Look into the Universe
  - Cosmic rays
  - Supernova neutrinos
  - Gravitational waves coincidence
- Within high intensity neutrino beam NOvA Near Detector measures neutrino cross-sections

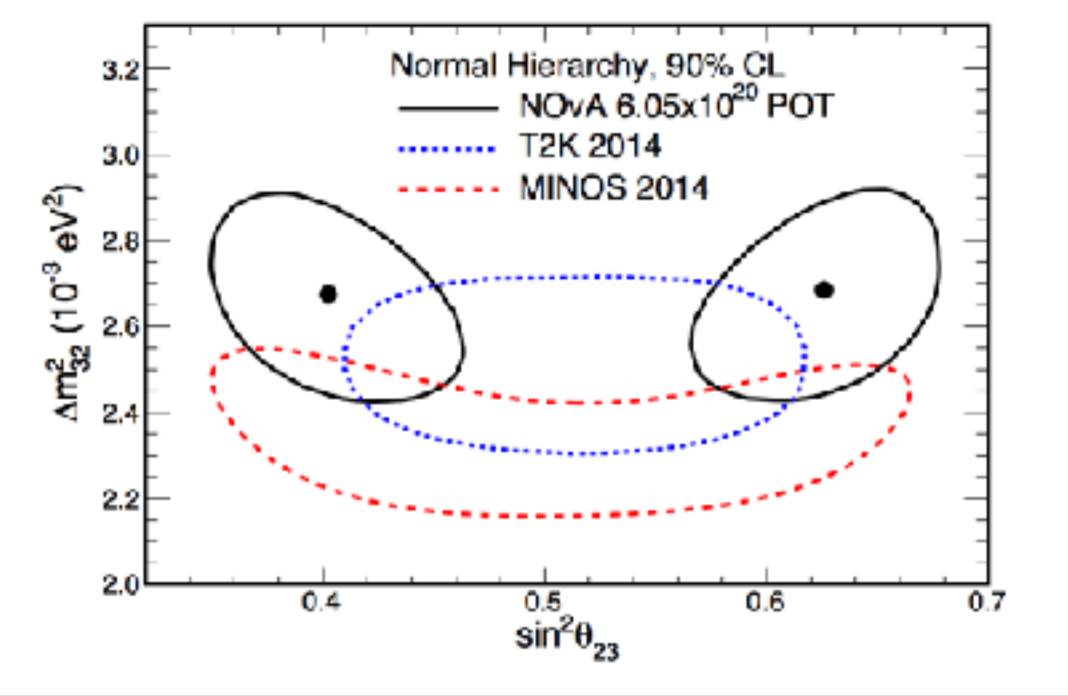
Muon neutrino disappearance results 2016

- A 3 flavour fit to the ν_μ selected spectrum provides the allowed parameter space.
- Dominant systematics: normalisation, NC bkg, flux, muon and hadronic energy scales, cross section, detector response and noise.
- Expect 473±30 events before oscillations.
- Observe 78 events (expect 82 at the best fit oscillated prediction).
- Parameter measurements (NH):

$$\Delta m^2_{32} = (+2.67 \pm 0.11) \times 10^{-3}\,\mathrm{eV}^2$$
$$\sin^2(\theta_{23}) = 0.404\,^{+0.030}_{-0.022} \text{ and } 0.624\,^{+0.022}_{-0.030}$$

- Maximal mixing excluded at 2.6σ



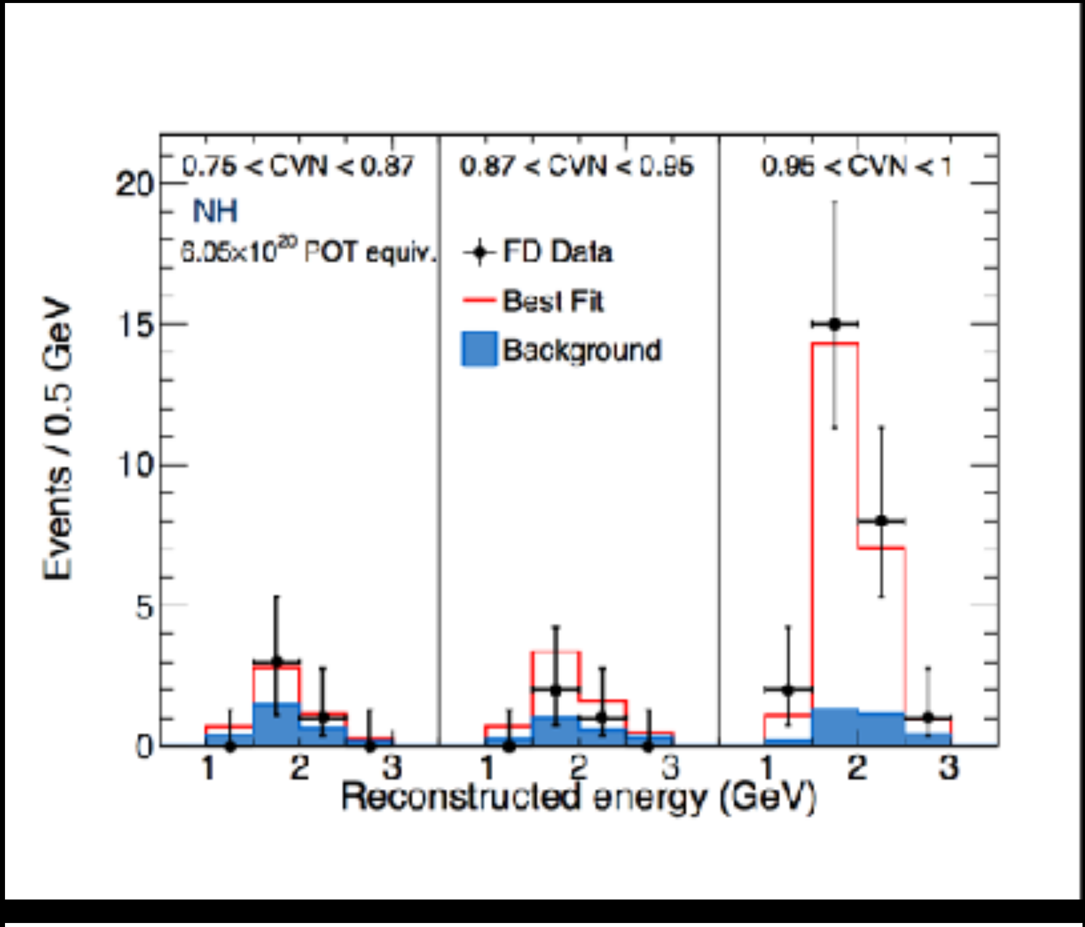


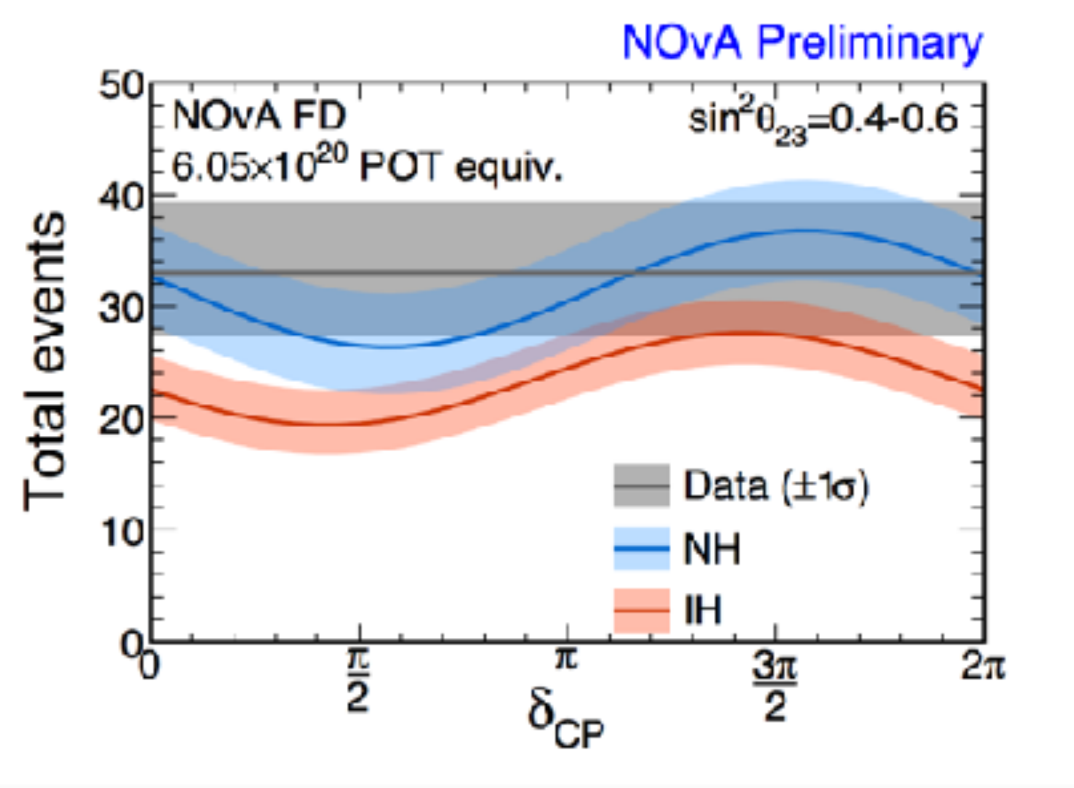
Electron neutrino appearance results 2016

- Observe 33 events for 8.2 expected background events.
- Using 3 bins for our selector CVN
- Range of expectation (for maximal mixing):

NH, $3\pi/2$	IH, $\pi/2$
36	19

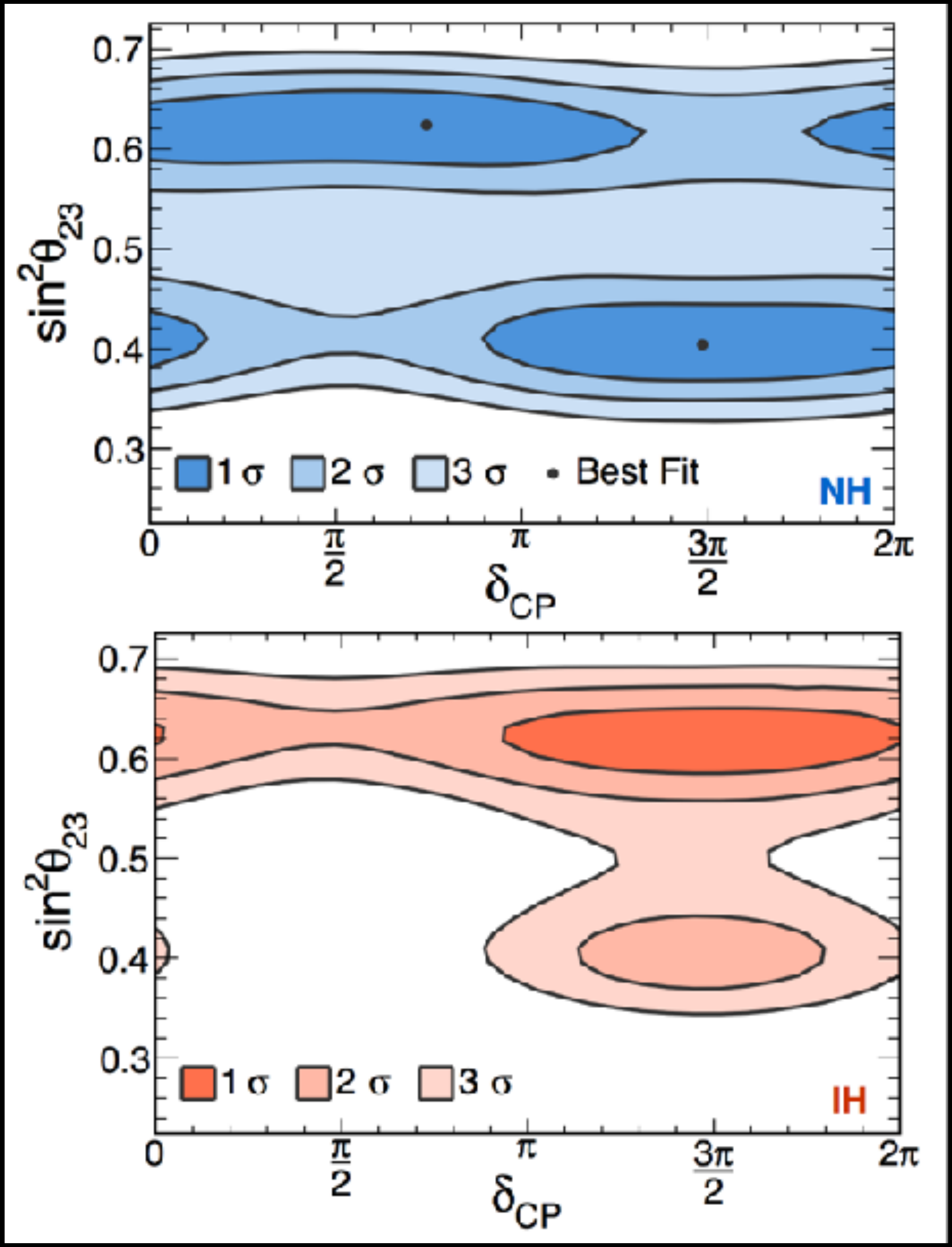
- Electron neutrino appearance observed at $> 8\sigma$





Electron neutrino appearance results 2016

- Fitting the electron neutrino appearance spectrum with muon neutrino disappearance data which for NOvA hints at a non maximal mixing angle.
- Both octants and hierarchies are allowed at 1σ.
- Very small χ^2 difference (0.47) between NH and IH.
- NOvA sees a 3σ exclusion at IH, lower octant around δCP $= \pi/2$.



Results 2016 published now

Constraints on Oscillation Parameters from ν_e Appearance and ν_μ Disappearance in NOvA

P. Adamson *et al.* (NOvA Collaboration)
Phys. Rev. Lett. **118**, 231801 – Published 5 June 2017

Measurement of the Neutrino Mixing Angle θ_{23} in NOvA

P. Adamson *et al.* (NOvA Collaboration)
Phys. Rev. Lett. **118**, 151802 – Published 10 April 2017

Oscillation publications by NOvA

Constraints on Oscillation Parameters from ν_e Appearance and ν_μ Disappearance in NOvA

P. Adamson *et al.* (NOvA Collaboration)
Phys. Rev. Lett. **118**, 231801 – Published 5 June 2017

Measurement of the Neutrino Mixing Angle θ_{23} in NOvA

P. Adamson *et al.* (NOvA Collaboration)
Phys. Rev. Lett. **118**, 151802 – Published 10 April 2017

First Measurement of Electron Neutrino Appearance in NOvA

P. Adamson *et al.* (NOvA Collaboration)
Phys. Rev. Lett. **116**, 151806 – Published 13 April 2016

First measurement of muon-neutrino disappearance in NOvA

P. Adamson *et al.* (NOvA Collaboration)
Phys. Rev. D **93**, 051104(R) – Published 25 March 2016

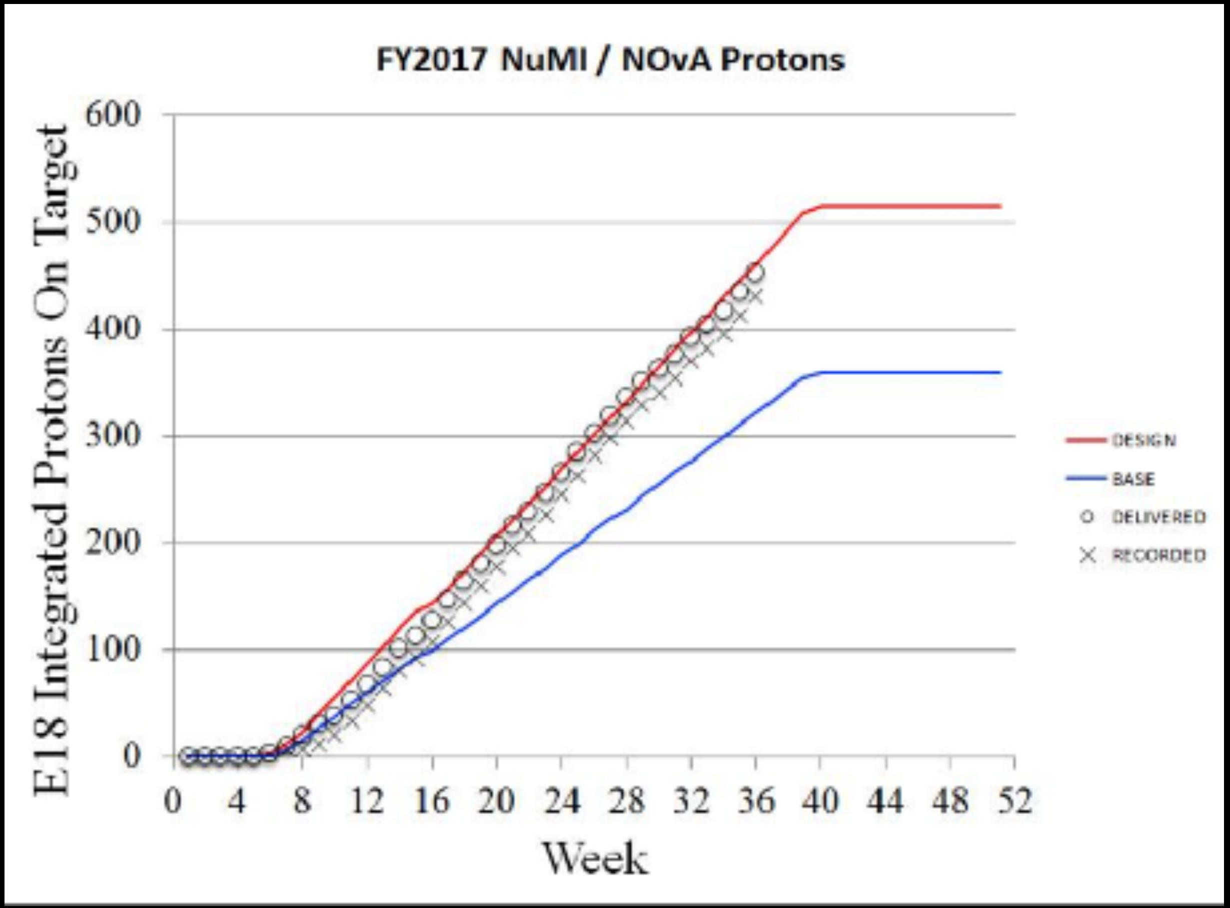
arXiv.org > hep-ex > arXiv:1706.04592

High Energy Physics – Experiment

Search for active-sterile neutrino mixing using neutral-current interactions in NOvA NOvA Collaboration; *(Submitted on 14 Jun 2017)*

Milestones of 2017

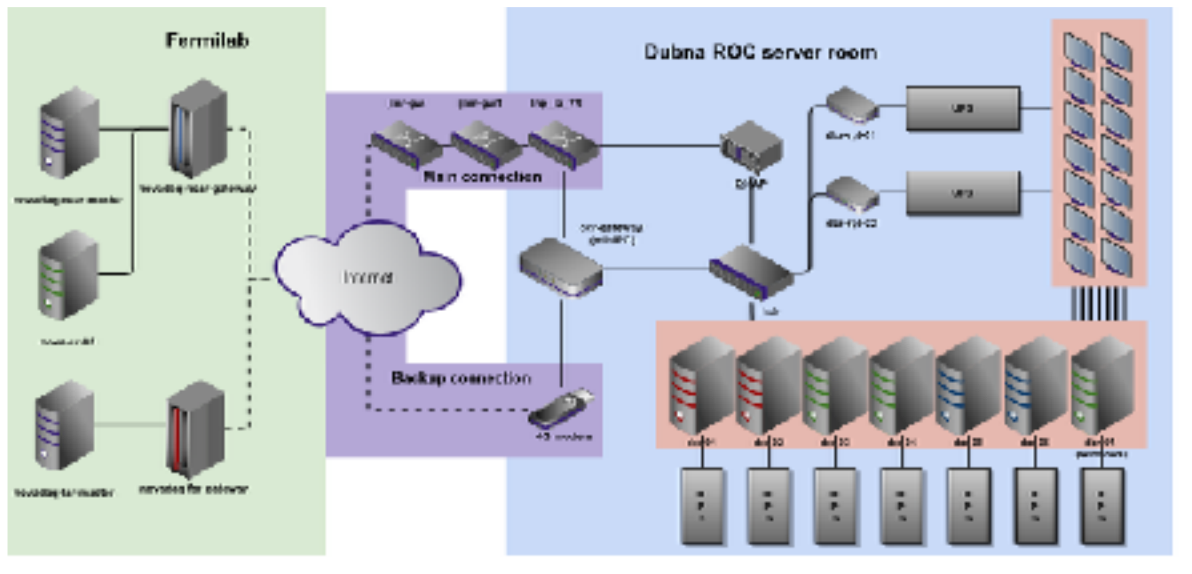
- Beam Delivery
  - NuMI routinely running at design intensity of 650 kW (715 kW w/o switchyard)
  - Set record of 770 kW for a short time this year
- Operations
  - 98,8% protons recording during FY 2017
  - 13 active Remote operation centers monitor the NOvA Detectors
- New oscillation results expected in late summer/fall 2017



NOvA at JINR

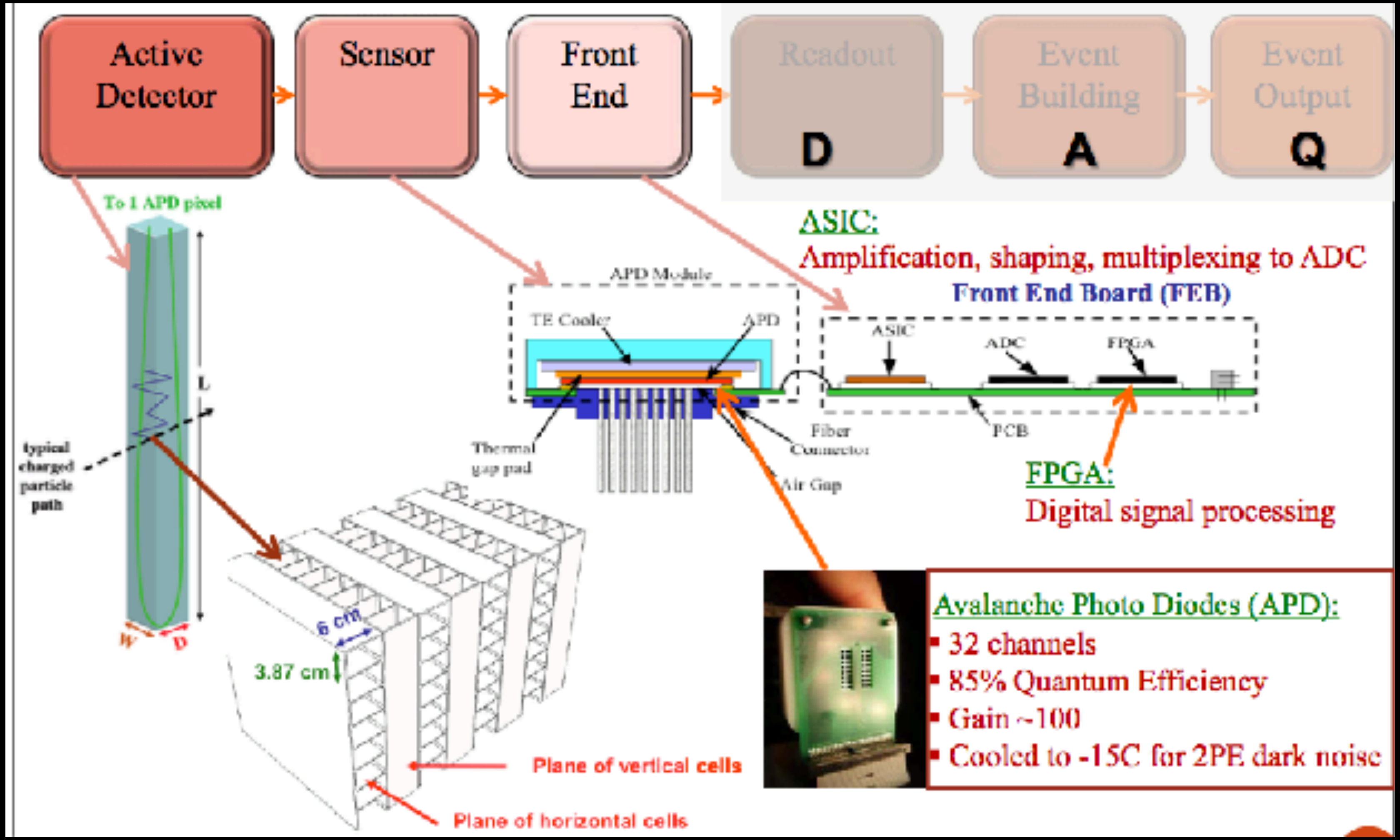
- Remote Operation Center at Dubna (ROC-Dubna)
- NOvA test Bench at JINR
- Computing Infrastructure including LIT resources
- MC Simulation and Theory effort from BLTP
- ν_e Analysis optimization
- Neutrino signal from Supernova
- Study of the Cosmic Ray (Muons)
- Search for Slow Monopole
- Near Detector Measurements

Remote Operation Center at Dubna

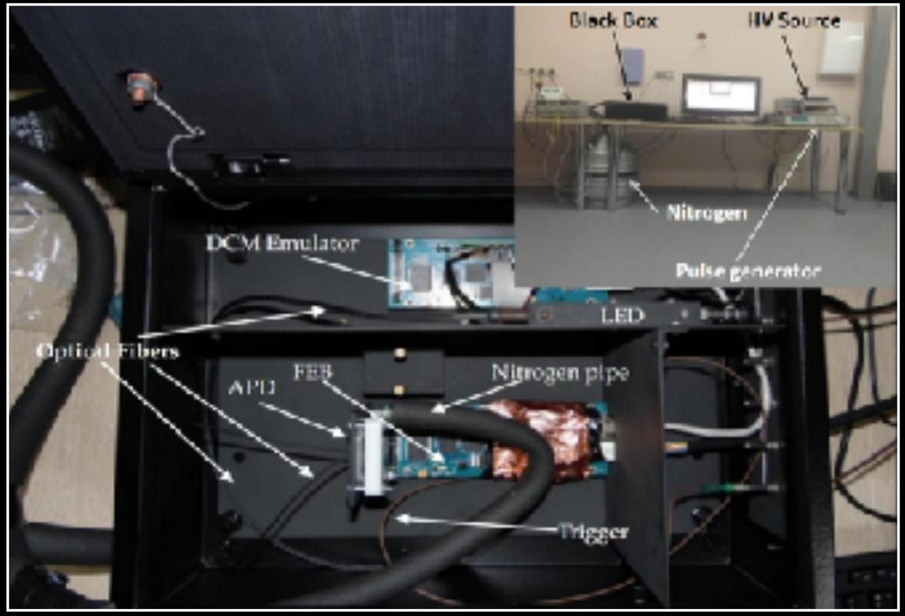


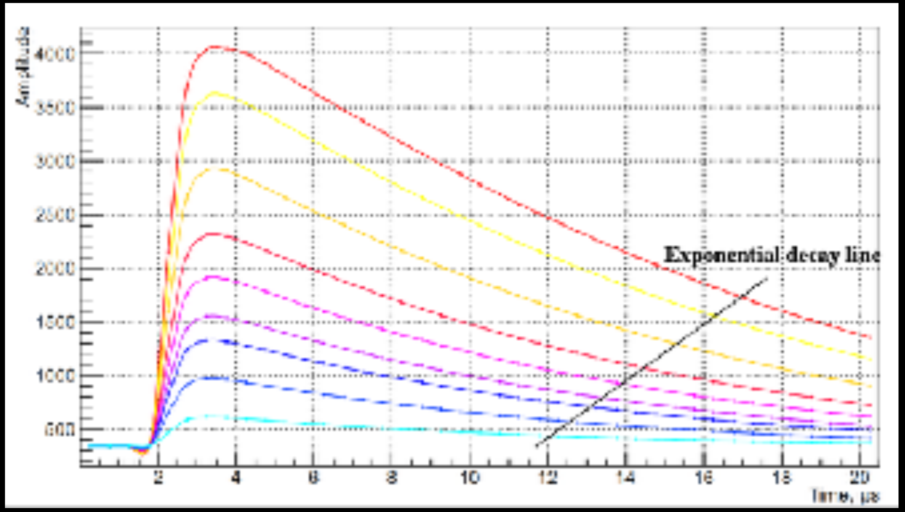
- Developed infrastructure of the ROC-Dubna allows for non-interruptible continuous work
- Includes: stable and backed up internet connection, communication tools including international land-line, kitchen, etc.
- A computing monitoring system, based on Nagios, controls ROC-Dubna equipment and notifies JINR experts in case of trouble.

NOvA test Bench at JINR

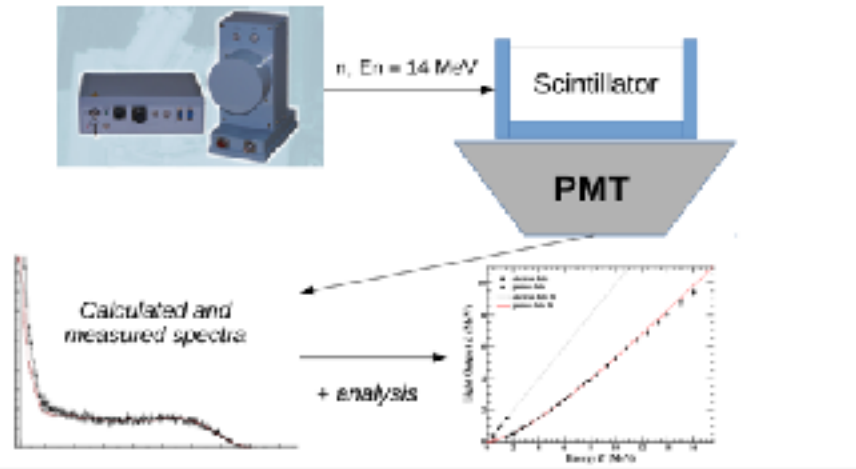


Avalanche Photo Diodes (APD):
- 32 channels
- 85% Quantum Efficiency
- Gain ~100
- Cooled to -15C for 2PE dark noise





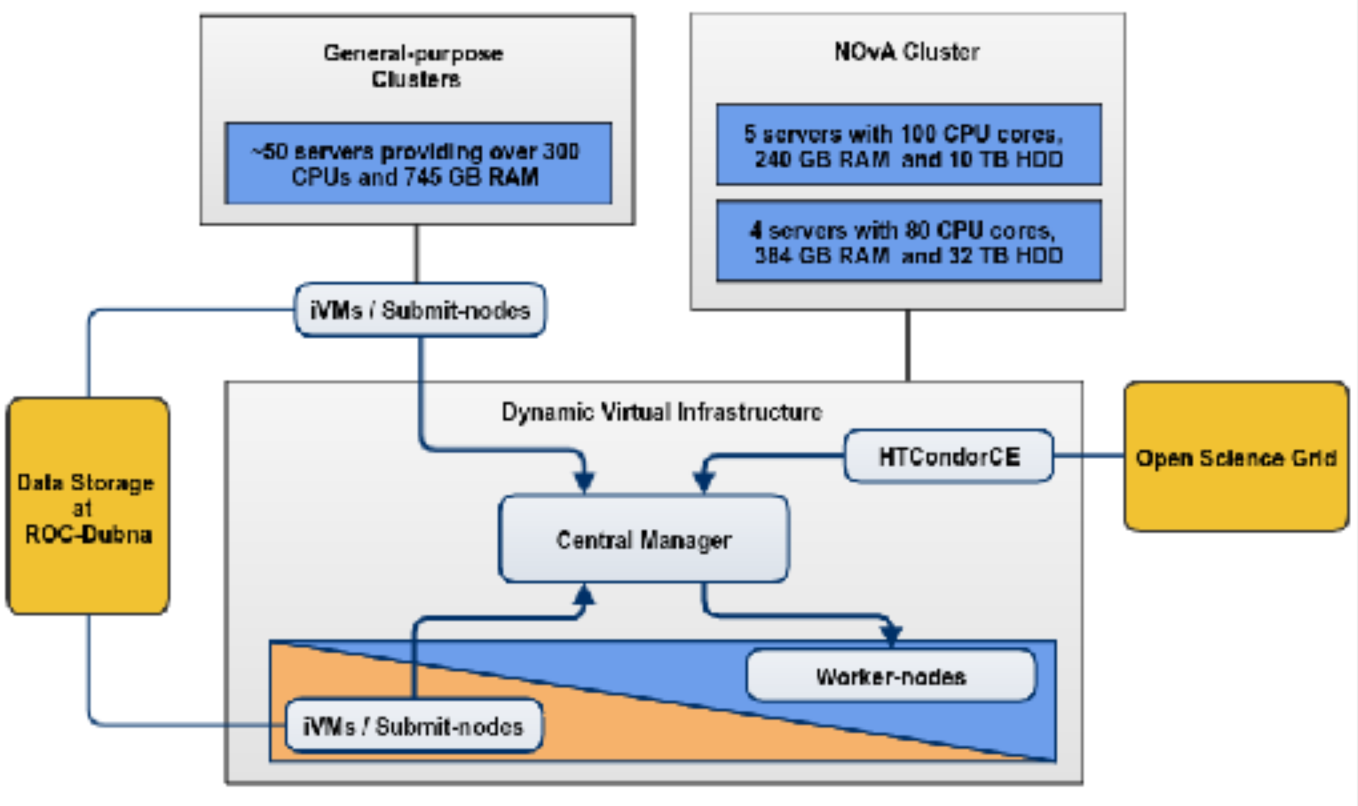
Measurement with neutron source ING-27



- Several important measurements were performed at the JINR NOvA electronics test bench, and more are planned.
- We performed precise measurements of signal shaping parameters for both FD/ND by a request from NOvA collaboration.
- We also study special responses from very high signals and long signals.
- We are going to make a study of the quenching factor for the NOvA scintillator.

Computing Infrastructure

- We prepared universal virtual machine (VM) images containing all the necessary NOvA software.
- We integrated our Cloud into OSG to support NOvA production.
- JINR Tier-2 infrastructure was also integrated into OSG in opportunistic mode.
- We are going to extend the infrastructure.
- Setting up storage and data-cache.


General-purpose Clusters

~50 servers providing over 300 CPUs and 745 GB RAM

NOvA Cluster

5 servers with 100 CPU cores, 240 GB RAM and 10 TB HDD

4 servers with 80 CPU cores, 384 GB RAM and 32 TB HDD

iVMs / Submit-nodes

Data Storage at ROC-Dubna

Dynamic Virtual Infrastructure

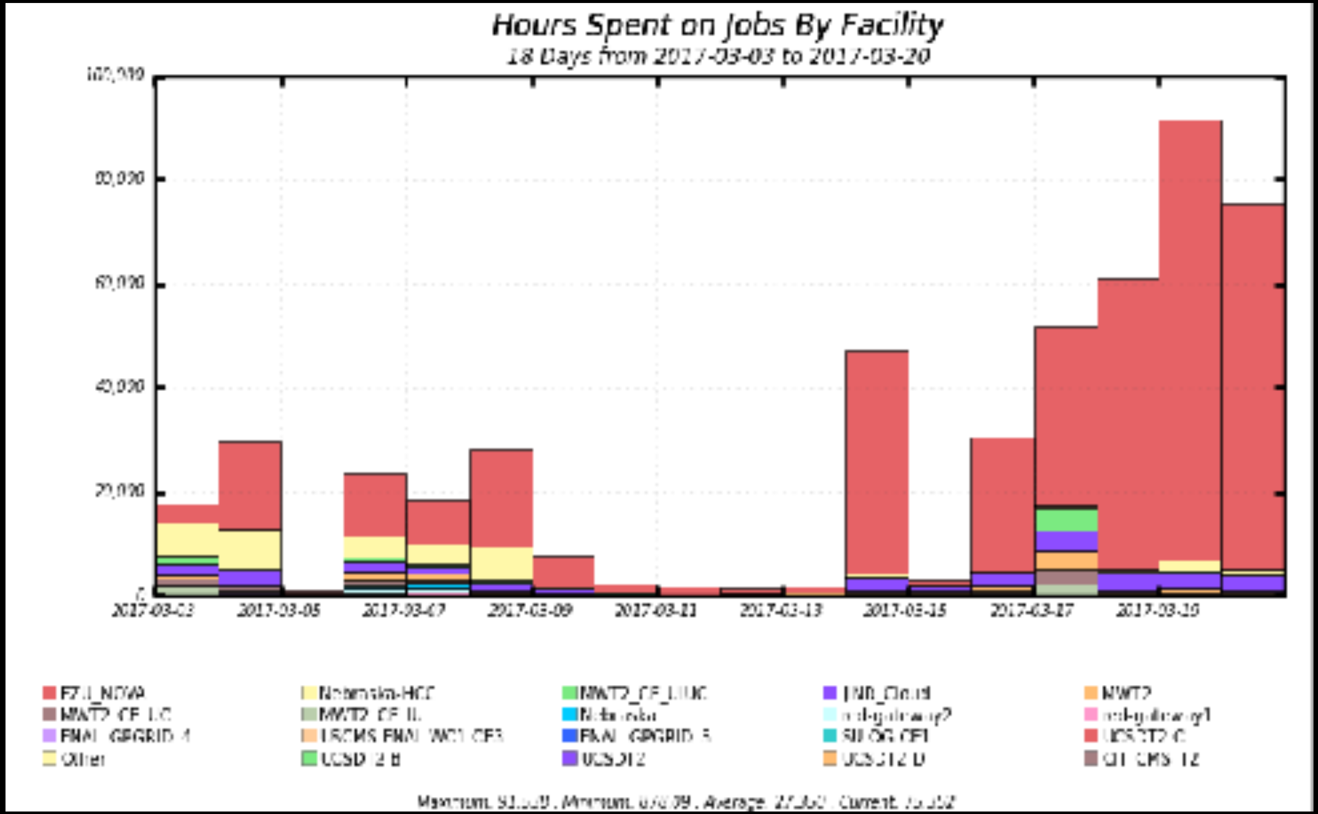
HTCondorCE

Open Science Grid

Central Manager

Worker-nodes

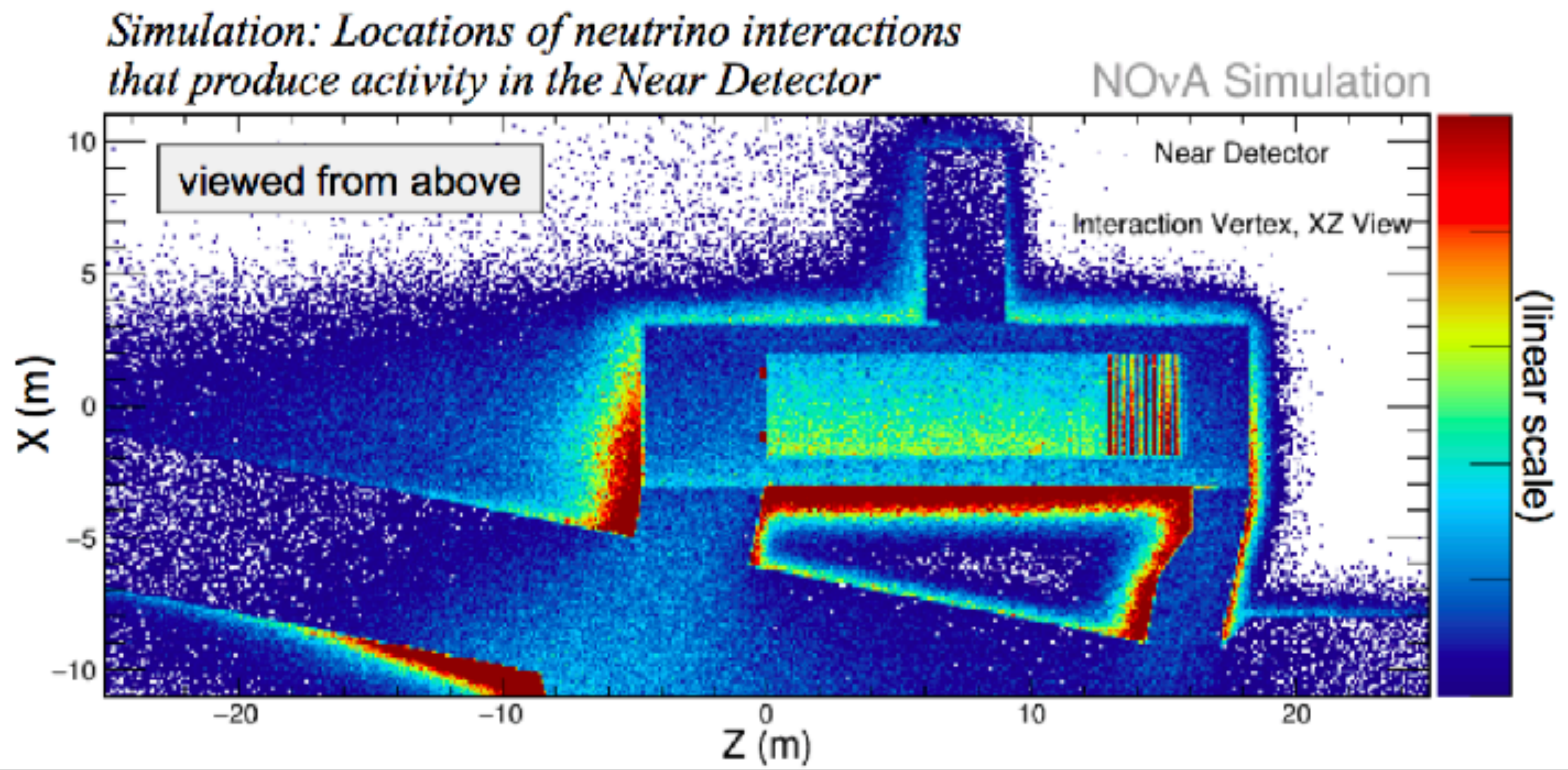
iVMs / Submit-nodes


Hours Spent on Jobs By Facility

18 Days from 2017-03-03 to 2017-03-20

Simulation

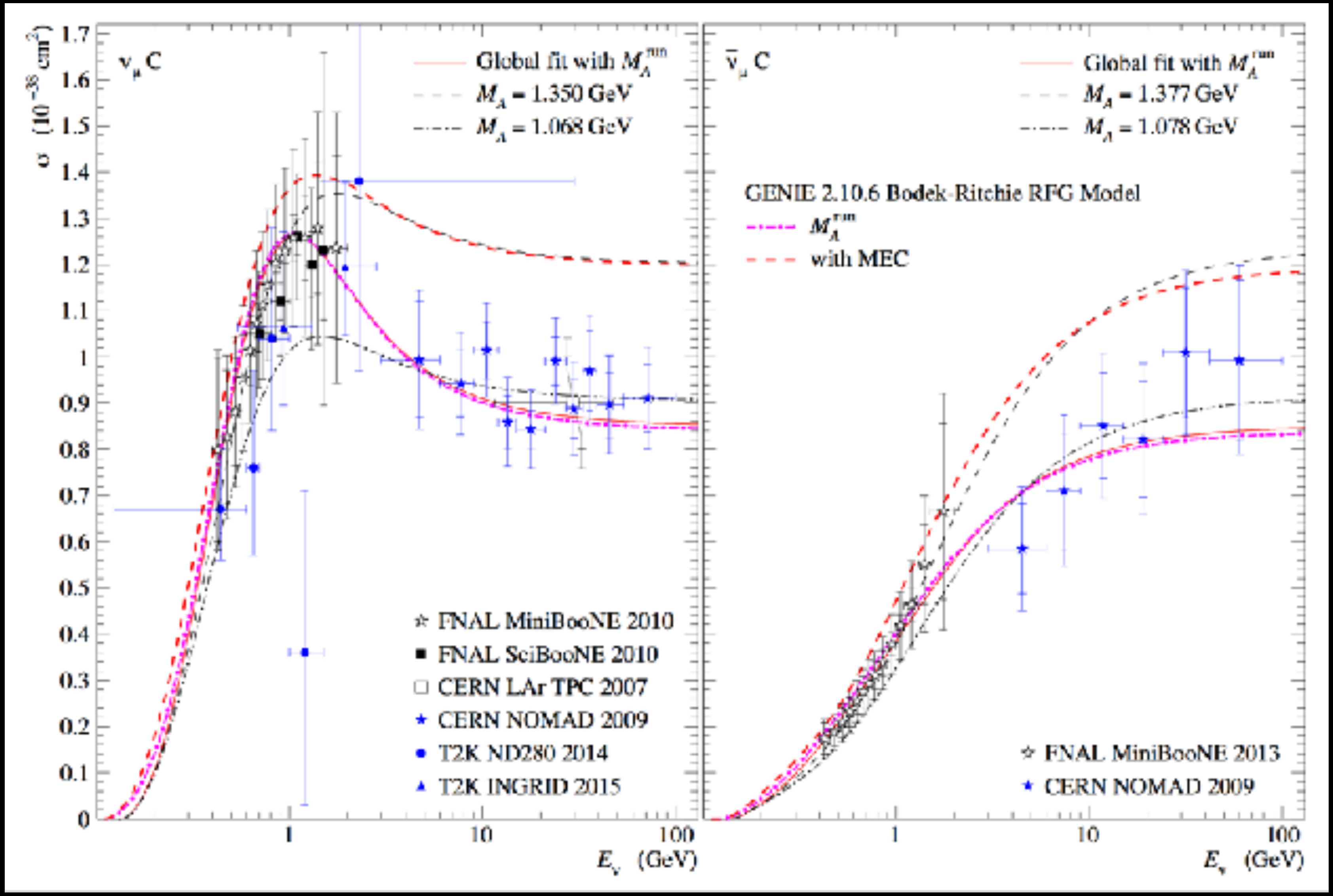
- Beam hadron production, propagation; neutrino flux: FLUKA / FLUGG
- Cosmic ray flux: CRY
- Neutrino interactions and FSI modeling: GENIE
- Detector simulation: GEANT4
- Readout electronics and DAQ: Custom simulation routines



- The JINR group is working on several parts of the simulation in the NOvA experiment: neutrino-nucleon cross sections, electronics readout, supernova fluxes and cosmic ray muons.

Simulation and Theory

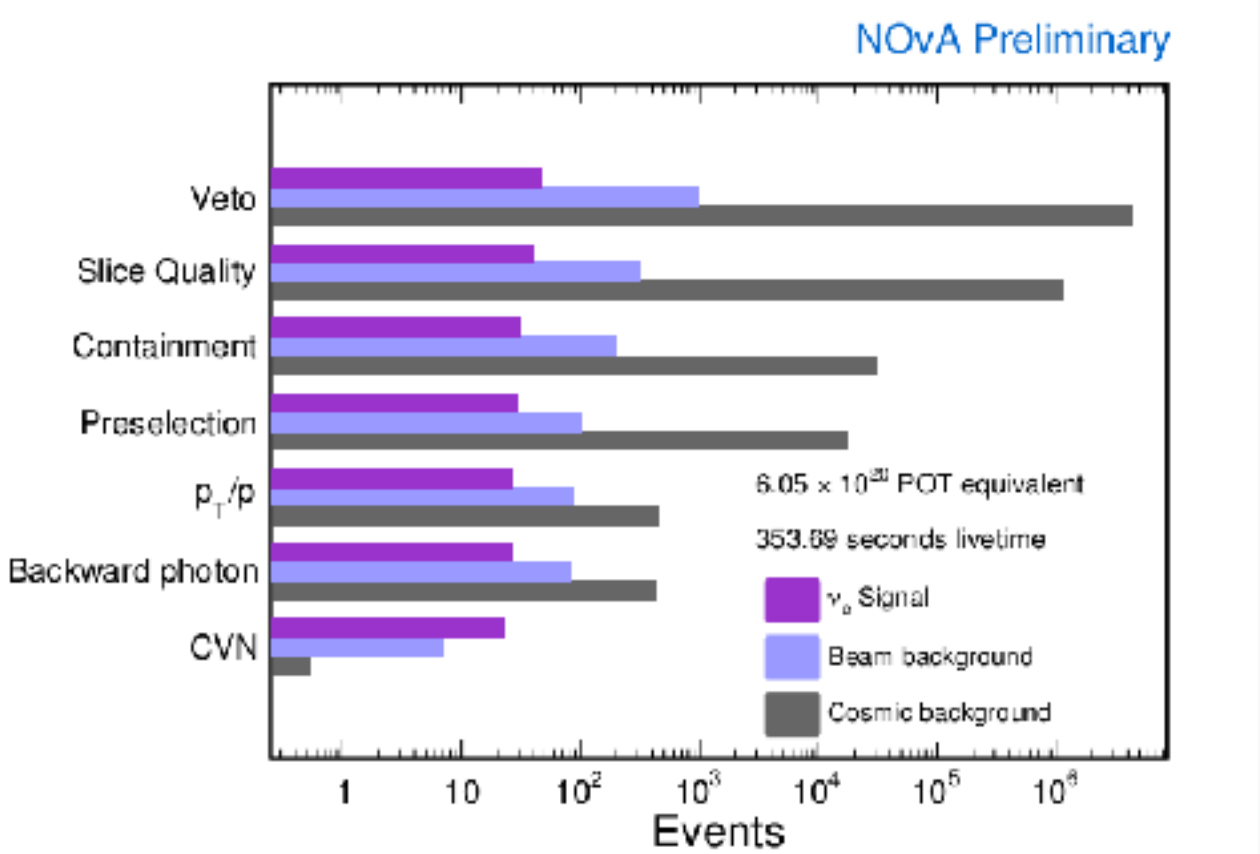
- Neutrino-nucleus cross sections are important for neutrino oscillation experiments to calculate event rates and energy distributions in both near and far detectors.
- Cross section measurements, which are used to develop and tune neutrino-nucleus interaction models, currently have 10-50% uncertainties depending on the process.



- The BLTP neutrino group developed a phenomenological method based on the notion of the so-called “running axial mass”, which permits a high-accuracy calculation of the total and differential QE cross sections for all nuclear targets, and at all energies of interest, by utilizing the conventional RFG model.
- This model was developed and implemented into the latest version of GENIE.

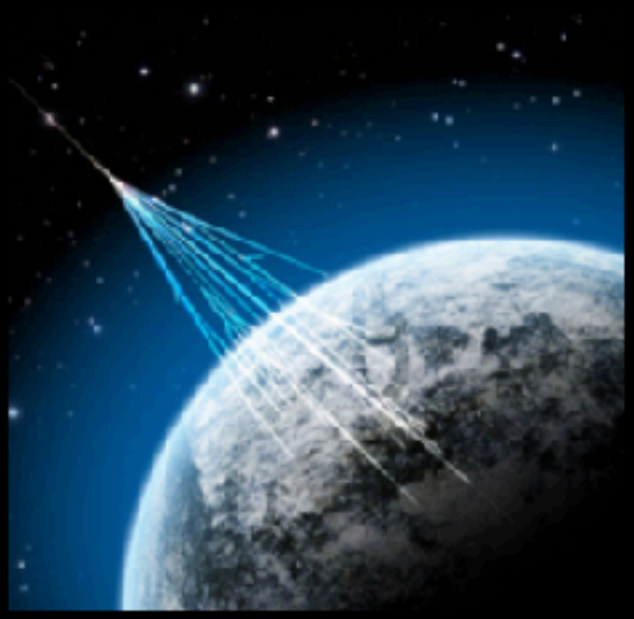
ν_e Analysis Optimization

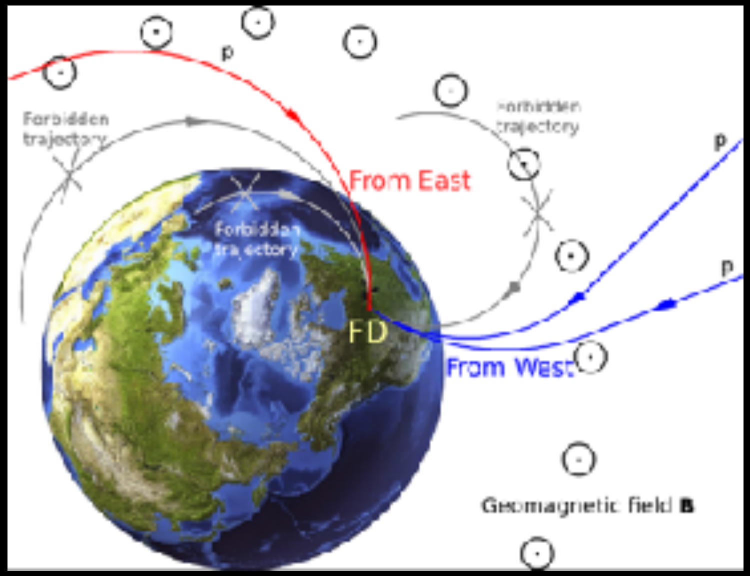
- NOvA analysis currently uses Convolutional Visual Network (CVN) algorithm, gives +30% to experiment exposure.
- Improvements of upcoming analyses will be in retuning cuts for neutrino.
- Antineutrino for the first time!
- For the Future: an application of the BDT algorithm from numu analysis to nue.



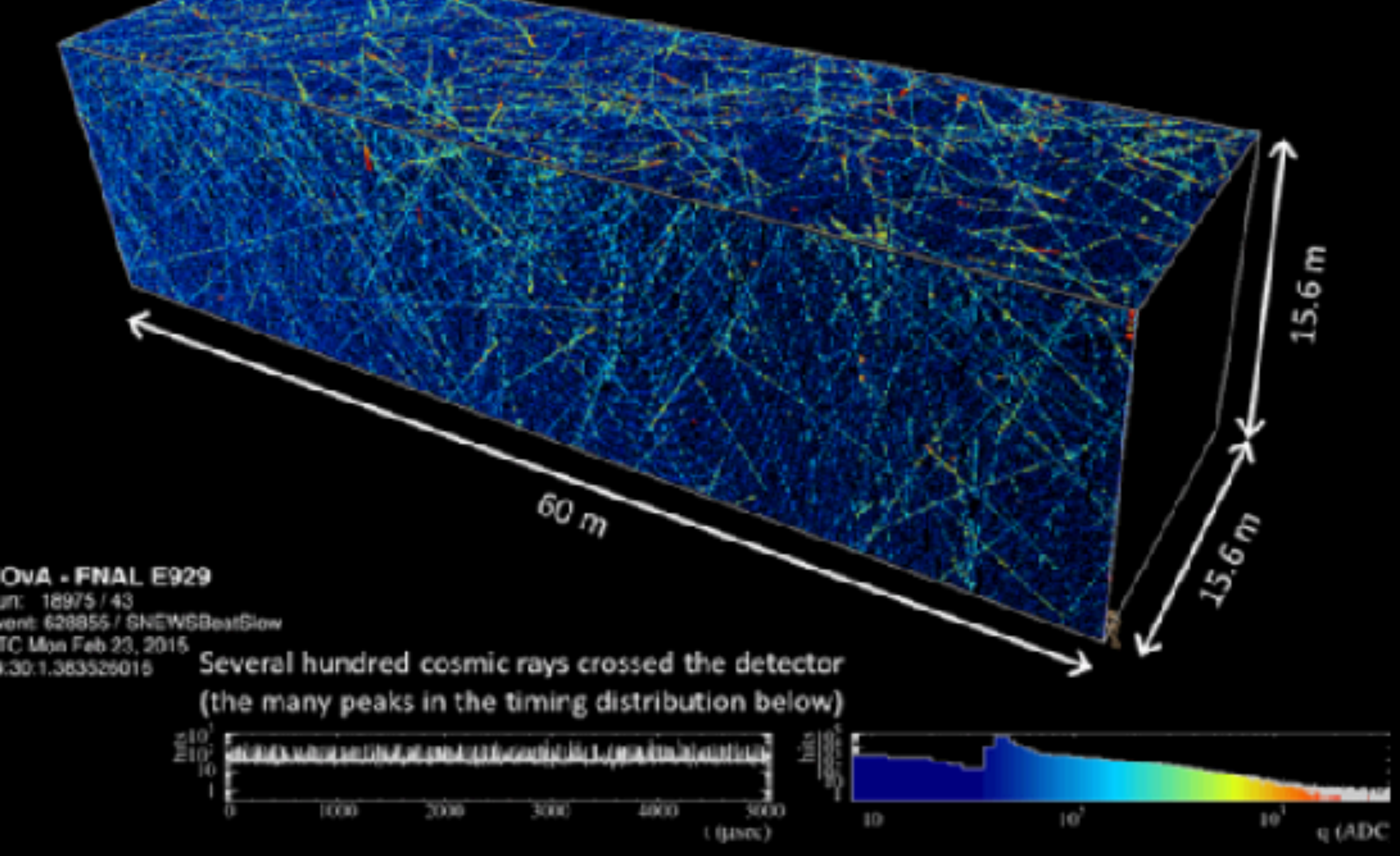
Near future improvements	
Data Quality	+2%
Containment	+13.4%
Preselection	+1.6%
p_T / p	+2.8%
Backward photon	+5%
CVN	+3%
TOTAL	> +25%

NOvA as a Cosmic-Ray Telescope

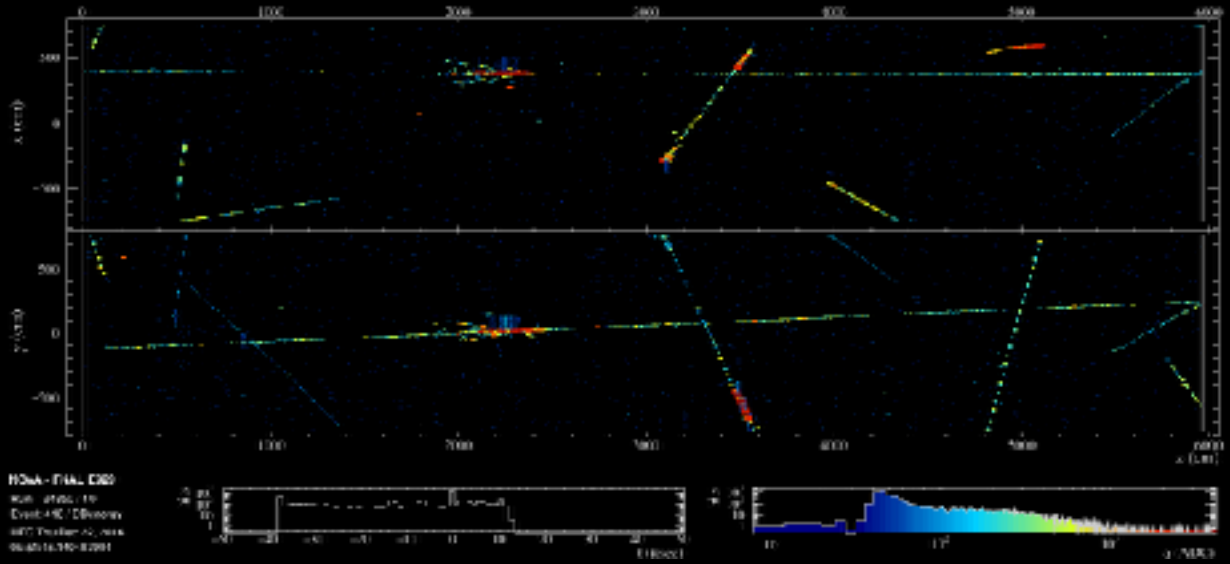




5ms of data at the NOvA Far Detector
Each pixel is one hit cell
Color shows charge digitized from the light

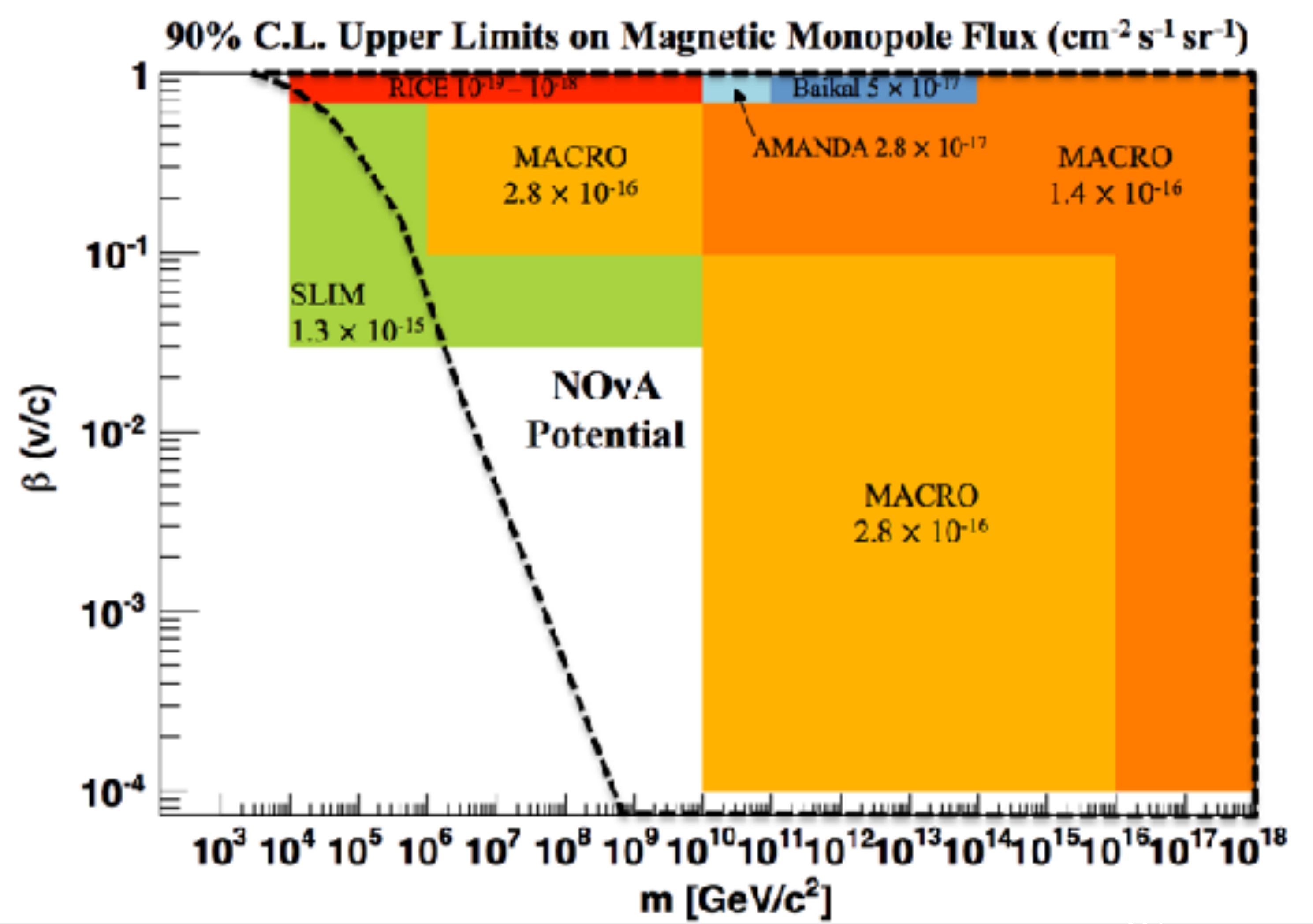


- The NOvA detectors have unique potential beyond oscillation physics.
- The far detector, in particular, is large, finely segmented and located close to the surface.
- We have 100k muons passing our Far Detector every second.
- A huge influx of cosmic ray events allows us to study the east-west asymmetry of cosmic ray muons, caused by geomagnetic field.
- We just started to study High Energy CR Muons and we can utilise our Far Detector with "Parmetr" method.

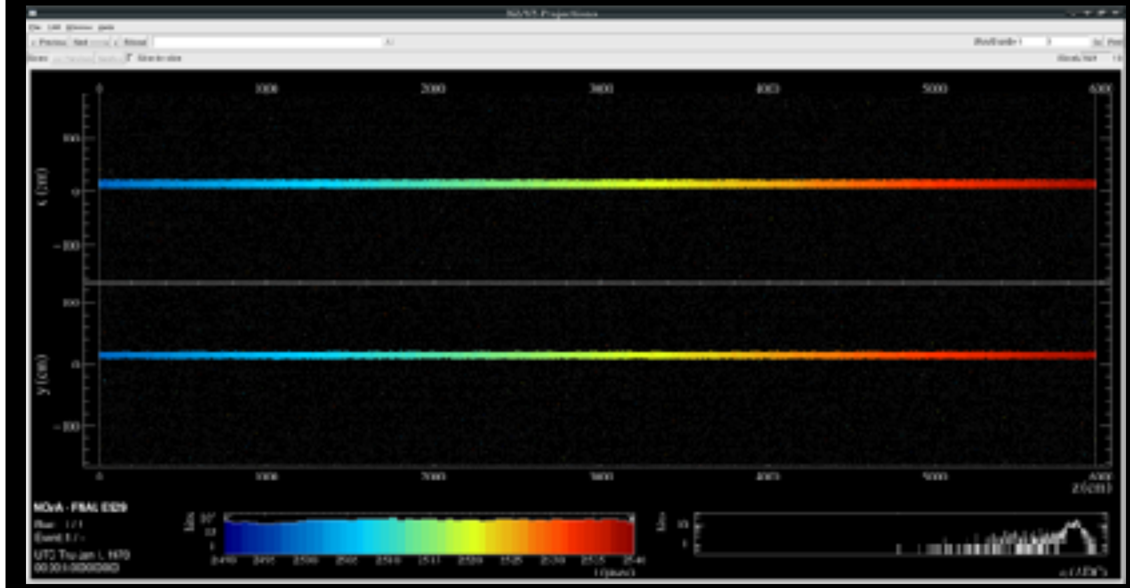


Search for Slow Monopole

- Their existence would explain the quantization of electric charge, restore symmetry between electricity and magnetism. They naturally appear in many grand unified theories.
- The large surface area of the NOvA Far Detector is comparable to MACRO.
- NOvA is near to surface and more sensitive to lighter monopoles which do not penetrate far into the earth.

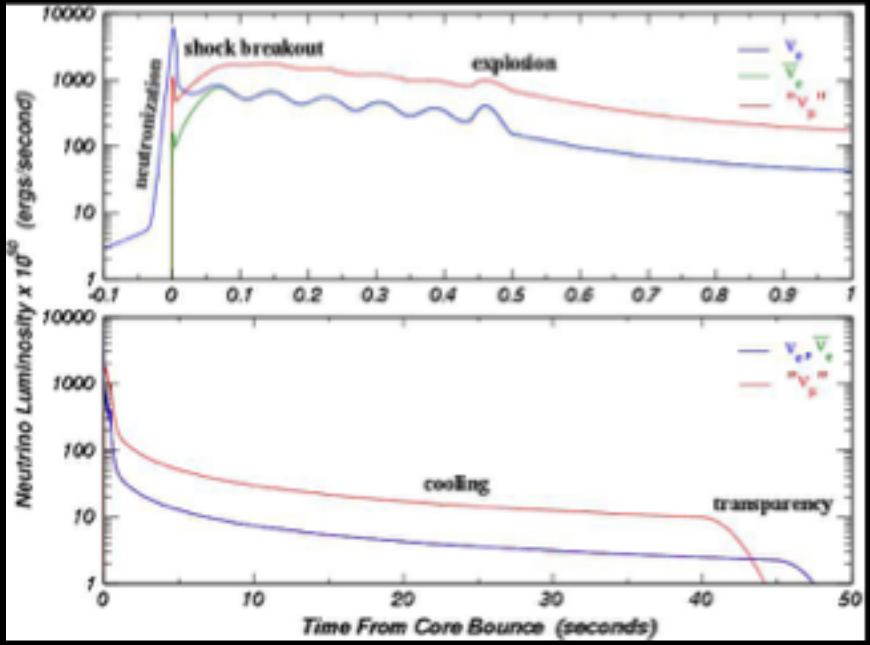


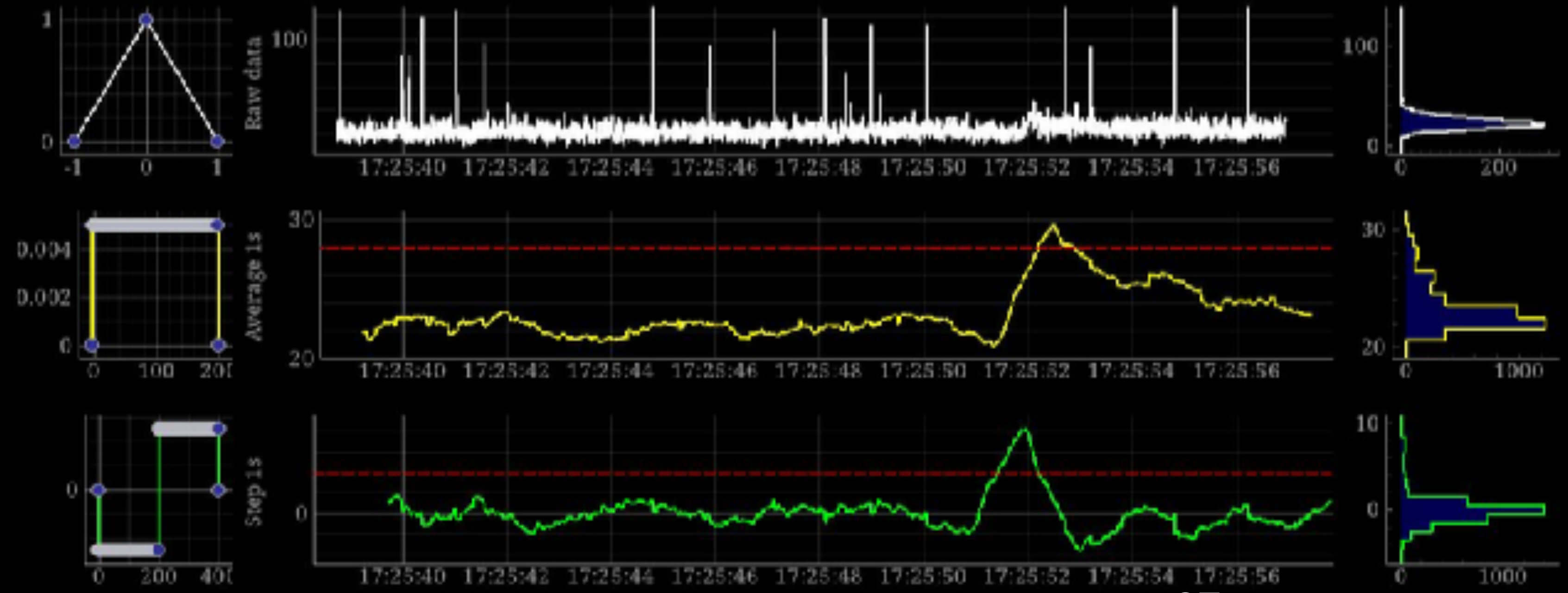
Surface area comparison	
SLIM	427 м^2
OHYA	2,000 м^2
MACRO	3,482 м^2
NOvA	4,168 м^2

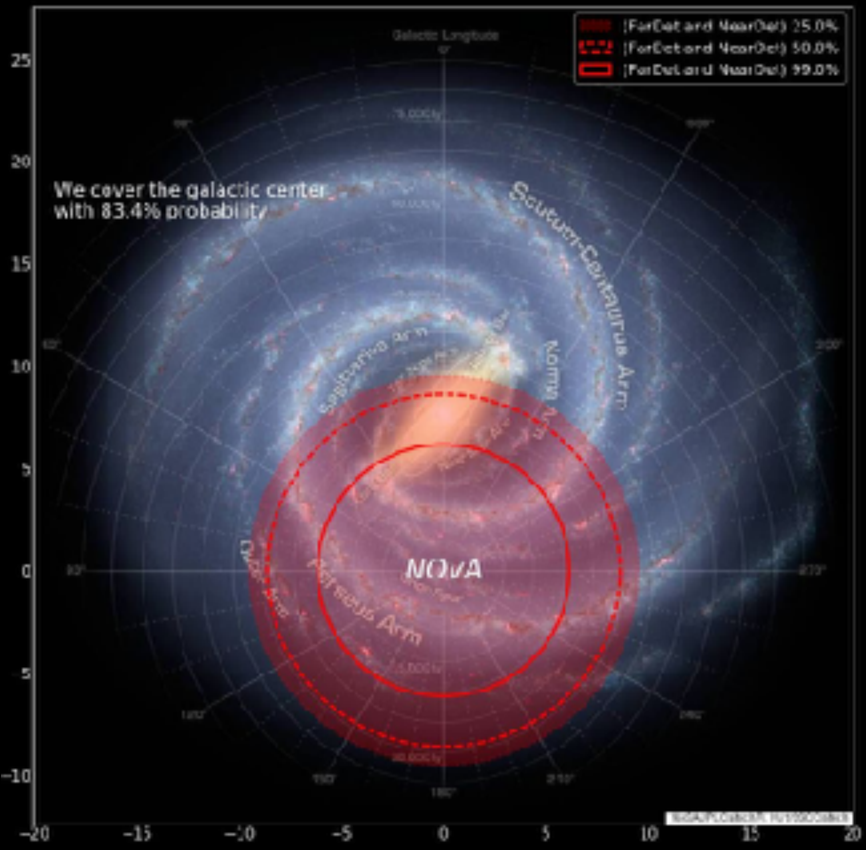


Detection of Supernova neutrino signal

- A dedicated software package was developed to simulate interactions of supernova neutrinos inside the NOvA detectors (GenieSNova).
- Supernova trigger infrastructure was developed and deployed on both Far and Near Detectors
- Selection criteria optimize statistical significance
- Detection efficiency of IBD positrons was evaluated
- NOvA sensitivity region covers Galactic Center
- Plan to integrate with SNEWS
- Stay tuned for improvements of current algorithms

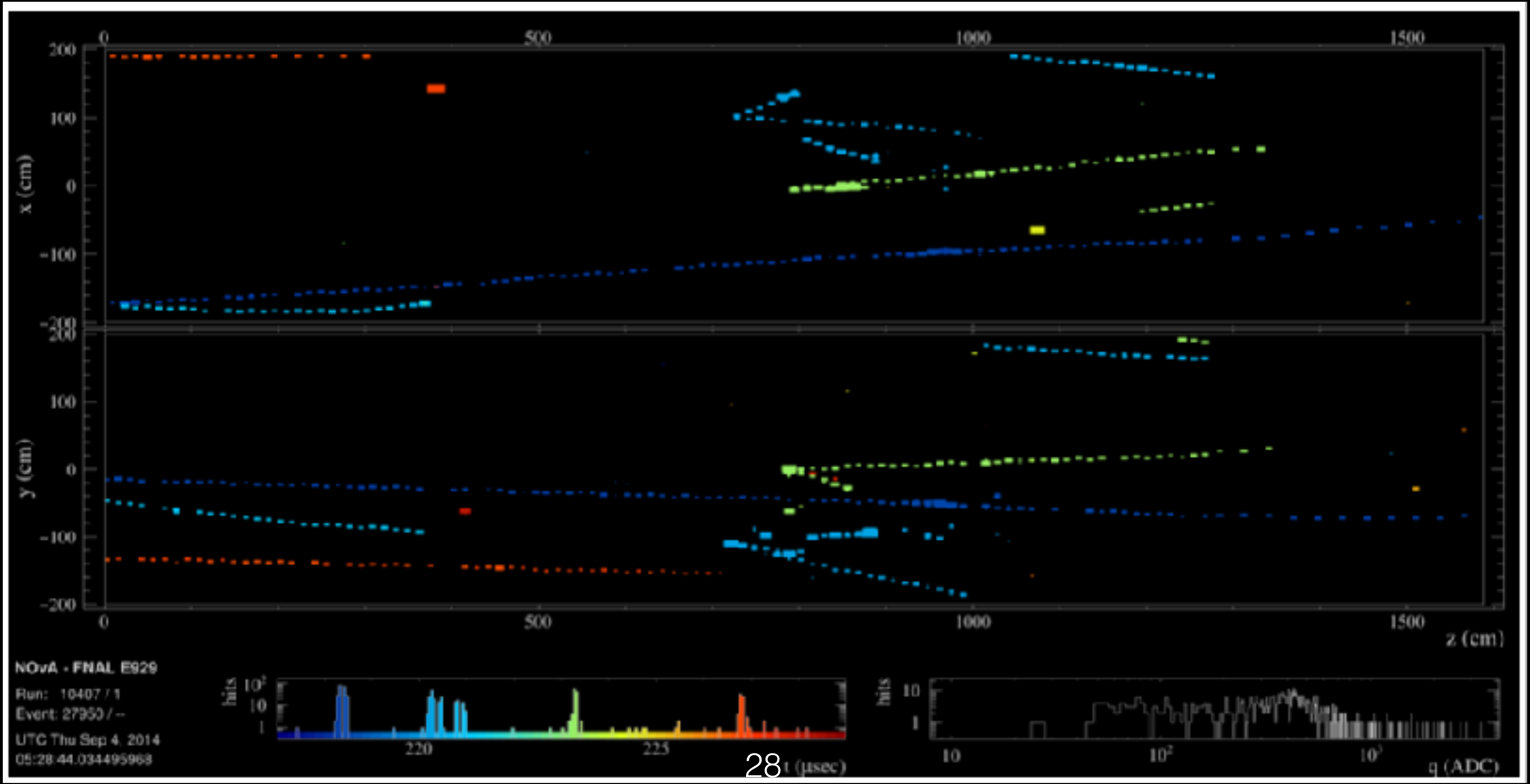






Near Detector Measurements

- The intensity of neutrinos in the Near Detector is such that multiple neutrino interactions occur in a typical beam spill.
- The NOvA ND group has a large-scale program of different physics measurements. In particular, NOvA is working to characterize the muon/electron neutrino charged current interactions on the detectors nuclear materials.
- The JINR group covers the following activities: single proton production channel, coherent interactions with charged pions, and s-quark production including exotics channel.
- Most of these tasks are motivated by the experience gained by the JINR team members from the analysis of the NOMAD data.

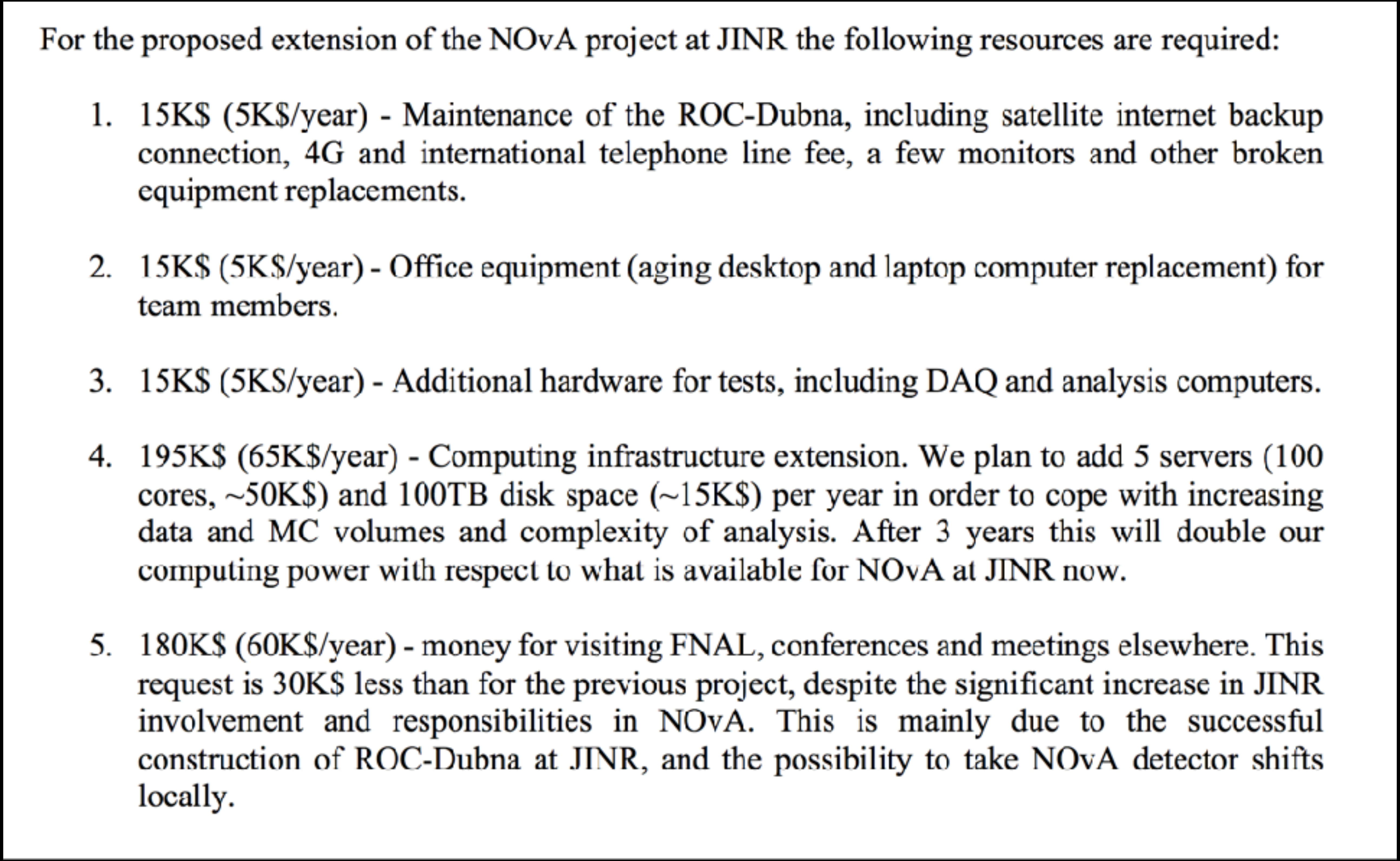


People and Tasks

Name	Labor	Tasks	FTE	Name	Labor	Tasks	FTE
Allakhverdian, V.	DLNP	ND Physics, s-quark prop	0.4	Kuznetsov, E.	LIT	Computing, hardware	0.1
Amvrosov, V,	DLNP	Numu oscillation analysis	0.1	Matveev, V.	BLTP	Theory, Coll management	0.1
Anfimov, N.	DLNP	Det operations, test stand	0.3	Morozova, A.	DLNP	Exotics, CR muons	0.3
Antoshkin, A.	DLNP	Det operations, test stand	0.3	Naumov, V.	BLTP	Osc and cross sec theory	0.3
		Exotics, slow monopoles	0.3	Olshevskiy, A.	DLNP	Coll and JINR manag,	0.5
		Det control, ROC-liaison	0.1	Petrova, O.	DLNP	Exotics, CR muons	0.7
Balashov, N.	LIT	Computing	0.3			Det sim, cross sec calc	0.3
Baranov, A.	LIT	Computing, Cloud	0.1	Samoylov, O.	DLNP	Det sim, co-convener	0.5
Bolshakova, A.	DLNP	Reco, Proton ID	0.5			Det control, ROC-manag	0.3
		Det sim, ADC thresholds	0.5			JINR ana coordinations	0.1
Bilenky, S.	BLTP	Oscillation theory	0.1			Coll manag, deputy at JINR	0.1
Dolbilov, A.	LIT	Computing, network	0.1	Sheshukov, A.	DLNP	DAQ, software dev/support	0.3
Kakorin, I.	VLHE	Det sim, GENIE	0.5			DDT, supernova trigger dev	0.3
Klimov, O.	DLNP	Reco, Proton ID	0.6			Exotics, supernova detect	0.3
Kolupaeva, L.	DLNP	Nue oscillation analysis	0.8			Det control, ROC software	0.1
		Software, release manag	0.2	Sotnikov, A.	DLNP	Det operations, test stand	0.1
Kullenberg, K.	DLNP	ND Physics, con pion	0.6	Velikanova, D.	DLNP	Det operations, test stand	0.1
Kuzmin, K.	BLTP	Det sim, cross sec theory	0.1	**TOTAL 24**			**10.3**

- The average age of the JINR NOvA team is ~35 years. There are 5 bachelor and master students, 8 young scientists preparing PhD, 4 engineers, 4 staff members with PhD degree and 3 professors.

Requested Resources



For the proposed extension of the NOvA project at JINR the following resources are required:

1. 15K$ (5K$/year) - Maintenance of the ROC-Dubna, including satellite internet backup connection, 4G and international telephone line fee, a few monitors and other broken equipment replacements.

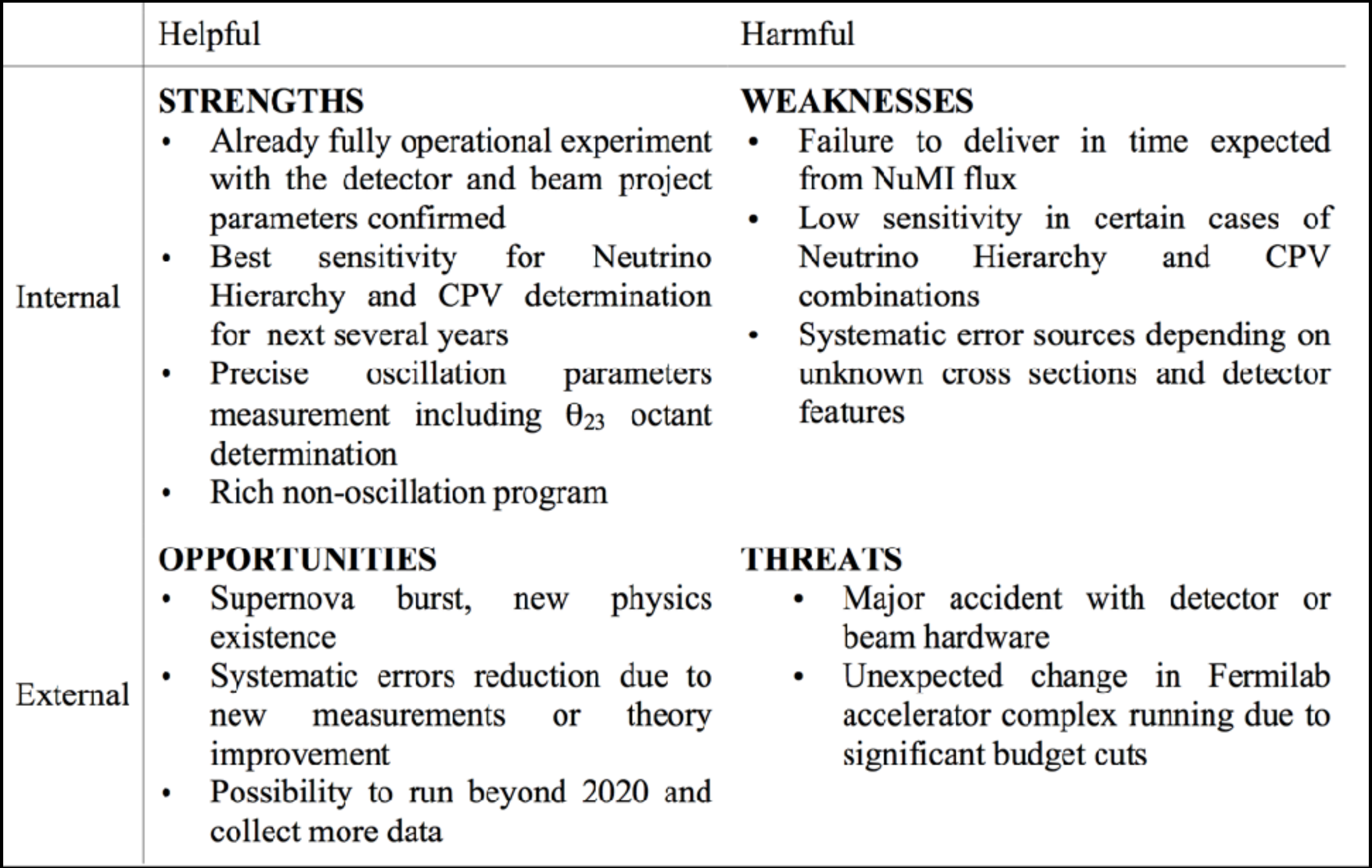
2. 15K$ (5K$/year) - Office equipment (aging desktop and laptop computer replacement) for team members.

3. 15K$ (5KS/year) - Additional hardware for tests, including DAQ and analysis computers.

4. 195K$ (65K$/year) - Computing infrastructure extension. We plan to add 5 servers (100 cores, ~50K$) and 100TB disk space (~15K$) per year in order to cope with increasing data and MC volumes and complexity of analysis. After 3 years this will double our computing power with respect to what is available for NOvA at JINR now.

5. 180K$ (60K$/year) - money for visiting FNAL, conferences and meetings elsewhere. This request is 30K$ less than for the previous project, despite the significant increase in JINR involvement and responsibilities in NOvA. This is mainly due to the successful construction of ROC-Dubna at JINR, and the possibility to take NOvA detector shifts locally.

SWOT analysis



	Helpful	Harmful
Internal	**STRENGTHS** • Already fully operational experiment with the detector and beam project parameters confirmed • Best sensitivity for Neutrino Hierarchy and CPV determination for next several years • Precise oscillation parameters measurement including θ_{23} octant determination • Rich non-oscillation program	**WEAKNESSES** • Failure to deliver in time expected from NuMI flux • Low sensitivity in certain cases of Neutrino Hierarchy and CPV combinations • Systematic error sources depending on unknown cross sections and detector features
External	**OPPORTUNITIES** • Supernova burst, new physics existence • Systematic errors reduction due to new measurements or theory improvement • Possibility to run beyond 2020 and collect more data	**THREATS** • Major accident with detector or beam hardware • Unexpected change in Fermilab accelerator complex running due to significant budget cuts

Future plans

- NOvA
  - ➡ FY17: 3e20 POT additional neutrino data to clarify the ν_μ situation. We can push the significance beyond 3σ if θ_{23} really non-maximal.
  - ➡ FY18: 9e20 neutrino + 9e20 antineutrino provide $>2\sigma$ to mass hierarchy determination
  - ➡ FY20: 30e20 POT in total has possibility to have 2σ octant determination, $>2.5\sigma$ to mass hierarchy, about 1.5σ to CPV
  - ➡ Extension 2023/24 has an opportunity for breakthroughs on all its major physics goals: 54 POT in total, 5σ exclusion of maximal and 3σ octant determination, $>3\sigma$ to mass hierarchy, $>2\sigma$ to CPV
- JINR
  - ➡ The JINR team is planning to continue and extend its involvement in the NOvA data taking and analyses. As a part of this work we are planning maintenance of ROC-Dubna and the hardware test bench facility, as well as a further increase of the NOvA computing power at JINR to cope with the large amount of data, and the continuation of the aforementioned analyses.

Backup slides

Publications

- First Analysis Epoch (2014/15 statistics)
  - ➡ P. Adamson et al. (NOvA Collaboration), Phys.Rev. D93 (2016) no.5, 051104, arXiv:1601.05037 [hep-ex]
  - ➡ P. Adamson et al. (NOvA Collaboration), Phys.Rev.Lett. 116 (2016) no.15, 151806, arXiv:1601.05022 [hep-ex]
- Second Analysis Epoch (2014/16 statistics)
  - ➡ P. Adamson et al. (NOvA Collaboration), arXiv:1701.05891 [hep-ex]
  - ➡ P. Adamson et al. (NOvA Collaboration), arXiv:1703.03328 [hep-ex]
  - ➡ NC Sterile analysis paper will be published soon
- Our journal papers
  - ➡ L.Kolupaeva, K.Kuzmin, O.Petrova, I.Shandrov, Mod.Phys.Lett. A31 (2016) no.12, 1650077
  - ➡ K.Kuzmin, V.Naumov, O.Petrova, Acta Phys.Polon.Supp. 9 (2016) 795-796.

Conference presentations and seminars

1. L.Kolupaeva, Measurements for neutrino mass hierarchy and delta CP from the NOvA experiment, DLNP neutrino seminar, 17 March 2017.
2. O.Samoylov, Measurement for theta23 in the NOvA experiment, DLNP neutrino seminar, 03 March 2017.
3. O.Samoylov, SA results from the NOvA experiment, DLNP neutrino seminar, 21 December 2016.
4. A.Sheshukov Supernova neutrino detection in NOvA experiment, Poster on Neutrino-2016, London, 4-9 July 2016.
5. I.Kakorin et al., Running axial mass for quasielastic neutrino-nucleus scattering, NuTune2016, Liverpool, Great Britain, July, 2016.
6. L.Kolupaeva, Current results of the NOvA experiment, plenary talk on 19th International Seminar on High Energy Physics QUARKS-2016, 29 May - 04 June 2016.
7. O.Samoylov et al., Remote operation center at Dubna for the NOvA experiment, AYSS-2016, Dubna 14-18 March 2016 and GRID-2016, Dubna, 5 July 2016.
8. N.Balashov et al., JINR LIT resources for NOvA experiment, AYSS-2016, Dubna 14-18 March 2016 and Poster on The 2016 European School of High-Energy Physics, Skeikampen, Norway, 15-28 June 2016.
9. A.Antoshkin et al., NOvA test bench at JINR, AYSS-2016, Dubna 14-18 March 2016.
10. L.Kolupaeva, Matter effect in neutrino oscillations for NOvA experiment, AYSS-2016, Dubna 14-18 March 2016 and young scientist talk on 120th JINR Scientific Council, 23 September 2016.
11. L.Kolupaeva, NOvA sensitivities after first year of running, Lomonosov-2016, 11-15 April 2016.
12. O.Samoylov, Current results of the NOvA experiment, ICSSNP, Neutrino Physics, Dubna, 12-15 April 2016.
13. O.Petrova et al., Quasielastic neutrino-nuclei interactions and the approach of running nucleon axial mass, ICSSNP, Neutrino Physics, Dubna, 12-15 April 2016.
14. O.Samoylov, First results from the NOvA experiment, DLNP neutrino seminar, 18 September 2015.
15. L.Kolupaeva et al., Some uncertainties of neutrino oscillation effect in the NOvA experiment, 6th summer Pontecorvo school on neutrino physics, 27 August - 04 September 2015.
16. O.Petrova et al., Neutrino-nuclear interactions for neutrino oscillation in NOvA, Alushta-2105, June 2015.
17. O.Samoylov, Neutrino oscillation in accelerator experiments (NOvA/T2K) and in reactor experiments (JUNO), ISU seminar, Irkutks, September 2014.
18. O.Petrova et al., The effective nucleon axial mass approach and quasielastic neutrino event rates in NOvA and Super-Kamiokande, Flavour Physics Conference (Xth Rencontres du Vietnam), International Center of Interdisciplinary Science Education (ICISE), Quy Nhon, Vietnam, 2014.
19. O.Petrova et al., The effective nucleon axial mass approach and quasielastic neutrino event rates in the Near Detector of NOvA, 18th International Seminar on High Energy Physics (QUARKS-2014), INR RAS Moscow, JINR Dubna, Suzdal, Russia, 2014.
20. O.Petrova et al., The effective nucleon axial mass approach and quasielastic neutrino event rates 1) in the Super-Kamiokande, AYSS-2014, February 2014 and ESHEP2014.
21. O.Samoylov, Status of the NOvA experiment, Prospects of Particle Physics: Neutrino Physics and Astrophysics, Valdai, January 2014.
22. O.Petrova et al. Impact of the nucleon axial mass uncertainty on evaluation of the quasielastic neutrino event rate in the Super-Kamiokande detector, 16th International Moscow School of Physics (41th ITEP Winter School of Physics), 2013.
23. O.Samoylov, Neutrino oscillation in the NOvA experiment, DLNP neutrino seminar, November 2013.