

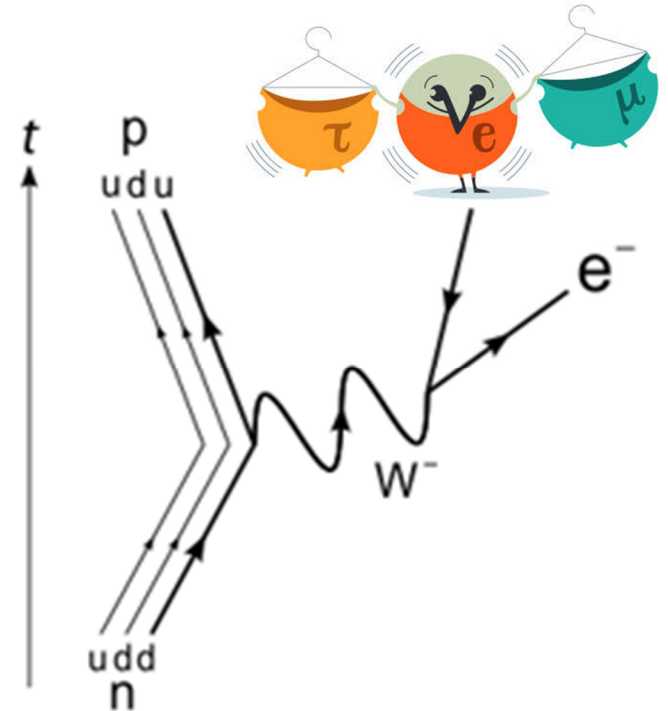


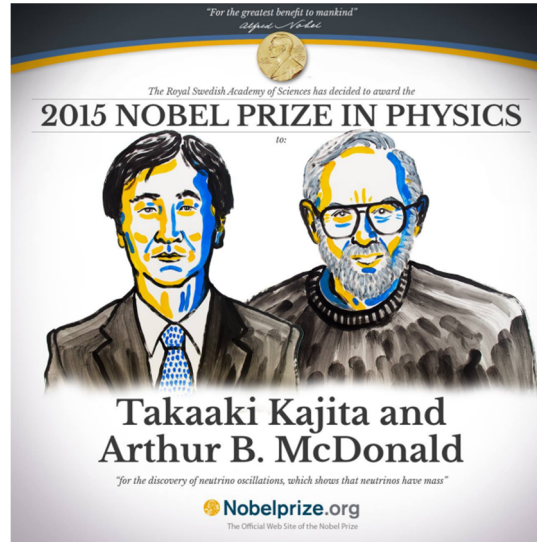
The IsoDAR Experiment and Applications of a High Power Cyclotron

Loyd Waites
on Behalf of the IsoDAR Collaboration
(lwaites@mit.edu)

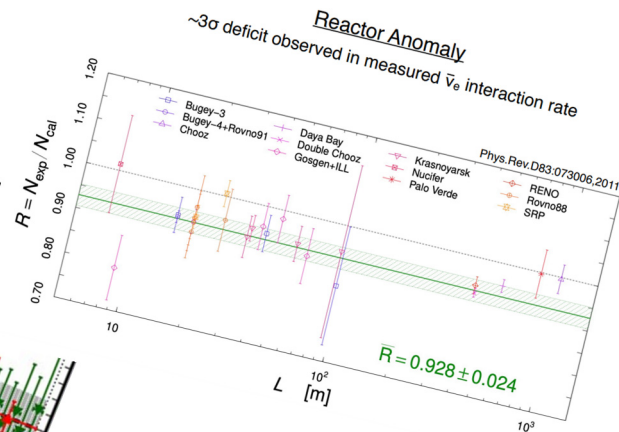
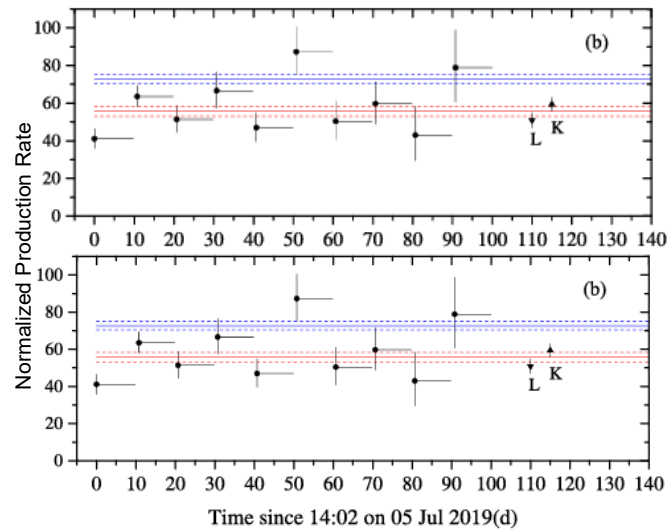
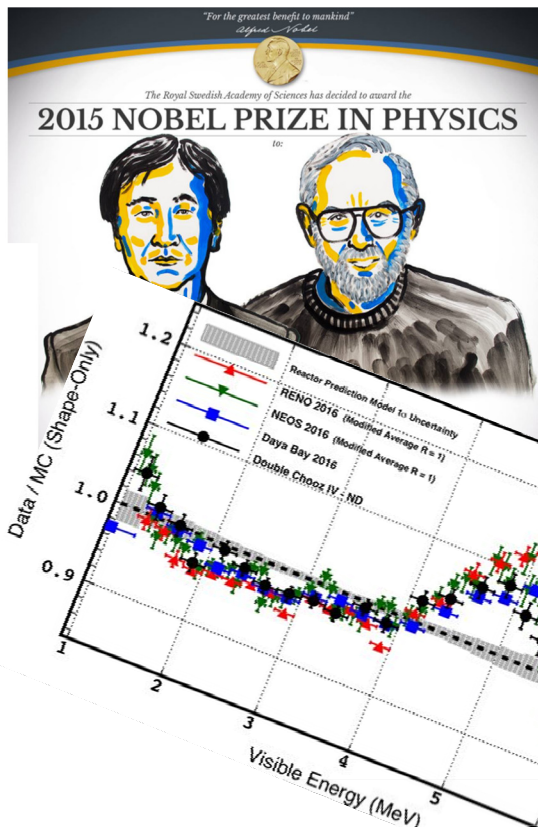
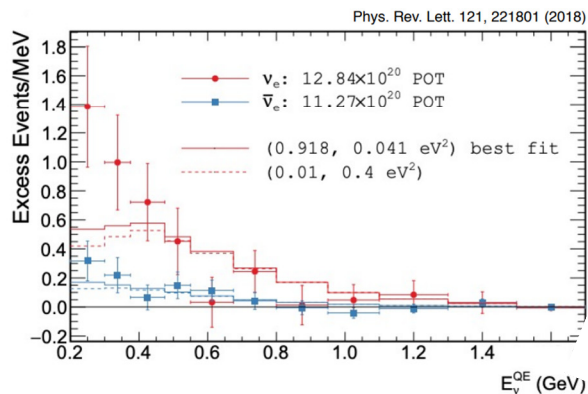
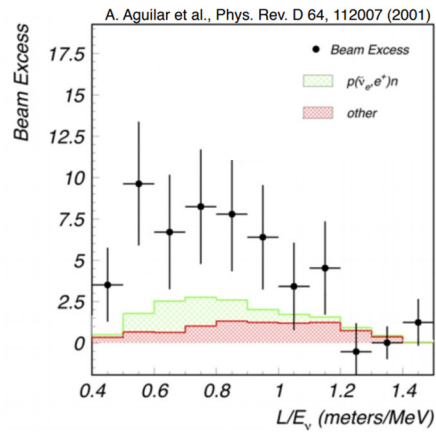
Introduction to Neutrino Physics

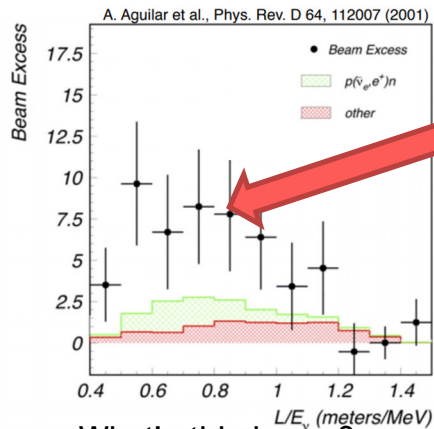
- Neutrinos outnumber e^- , p^+ , and n by 10 orders of magnitude
- Three “known” neutrinos in Standard Model
- Example: $\bar{\nu}_e$ produced in beta decay
- Oscillate between neutrino flavors



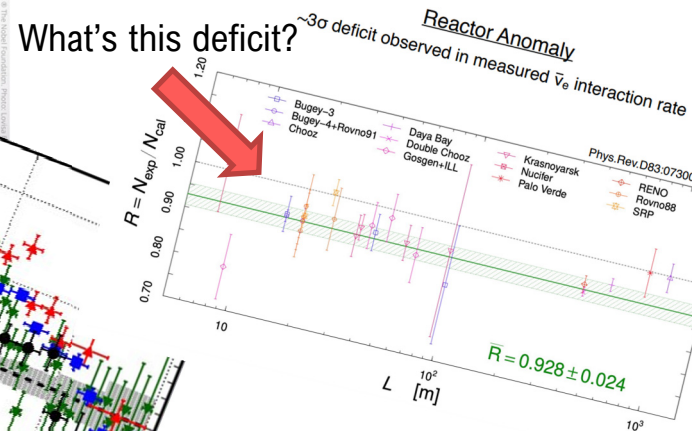
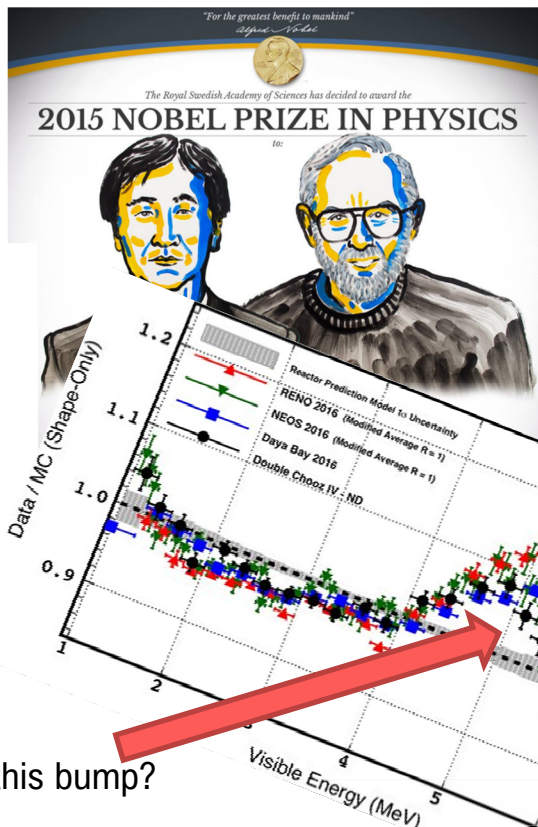
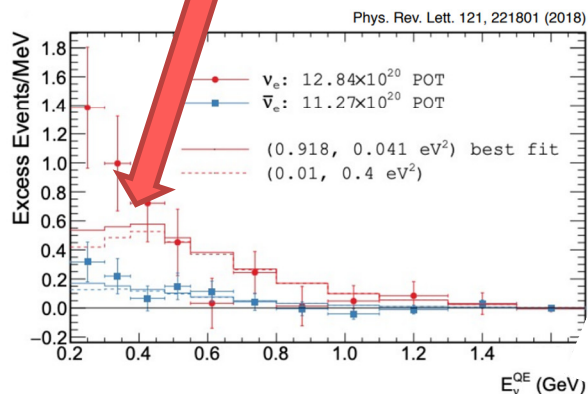
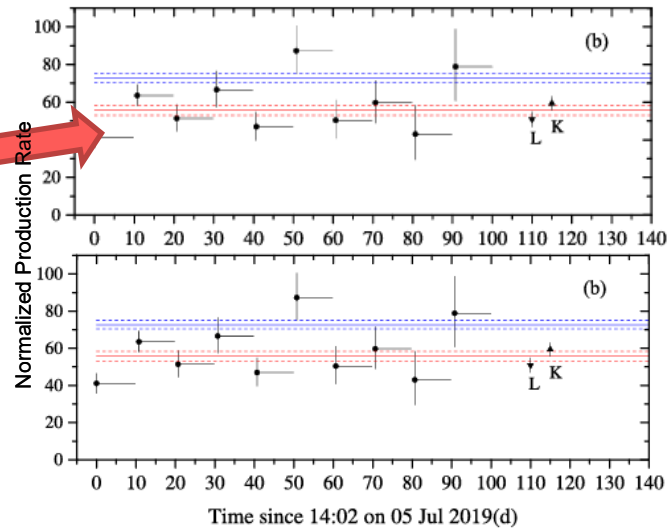


$$|\nu_{\mu}\rangle \longrightarrow |\nu_{1,2,3}\rangle \longrightarrow |\nu_e\rangle$$

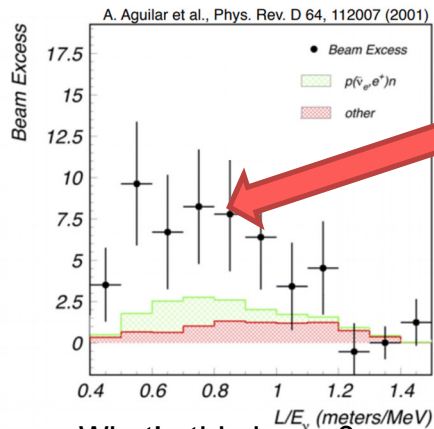




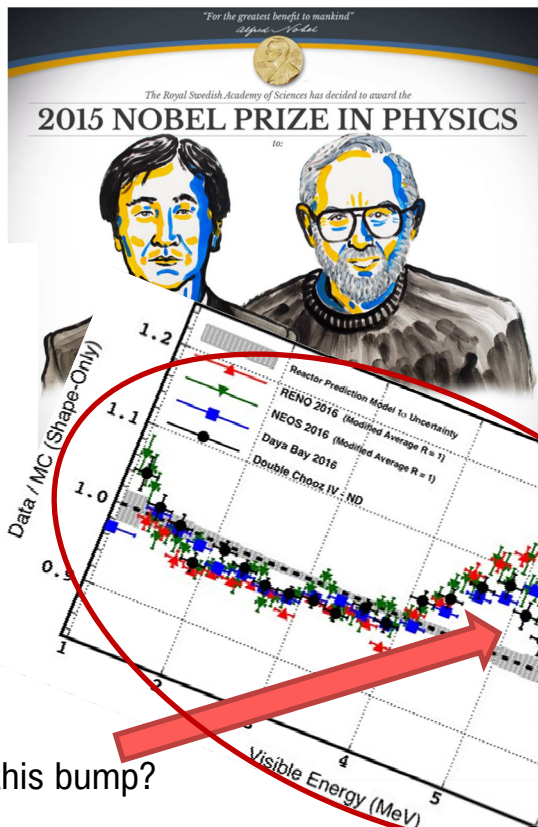
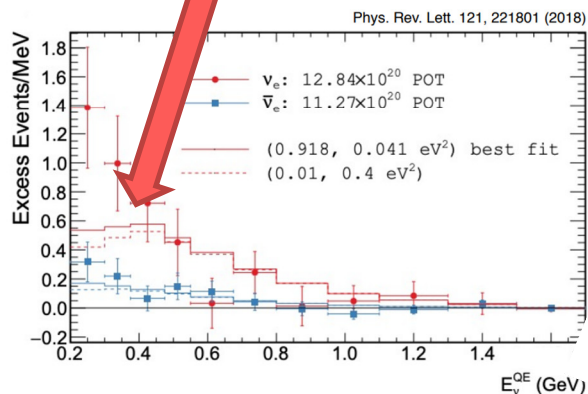
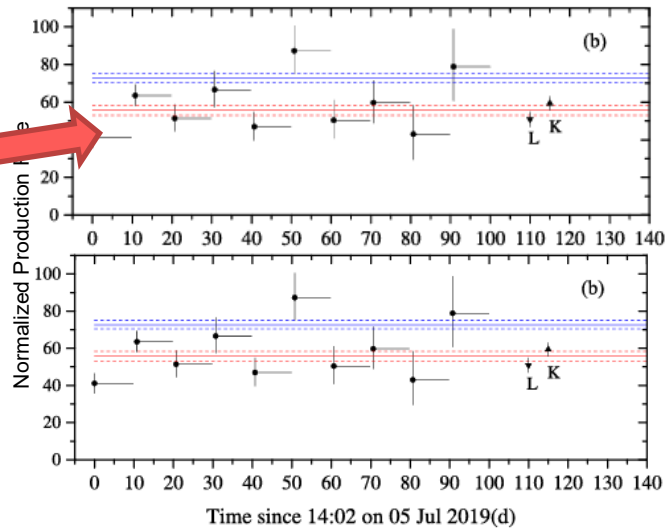
What's this bump? What's this deficit?



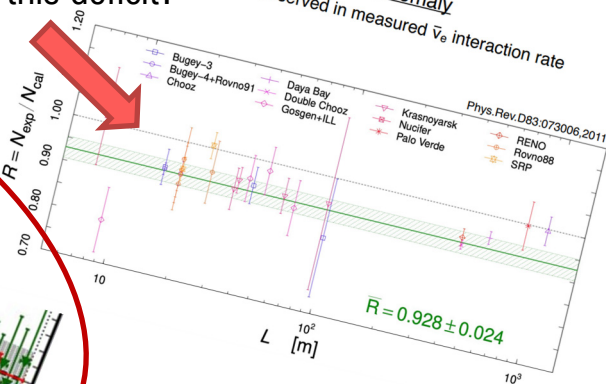
What's this bump?



What's this bump? What's this deficit?

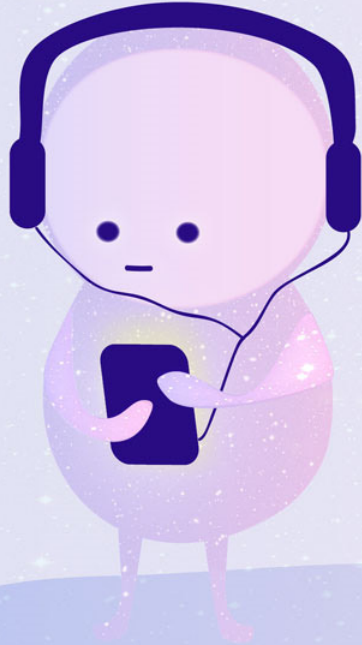


What's this deficit? ~3 σ deficit observed in measured $\bar{\nu}_e$ interaction rate

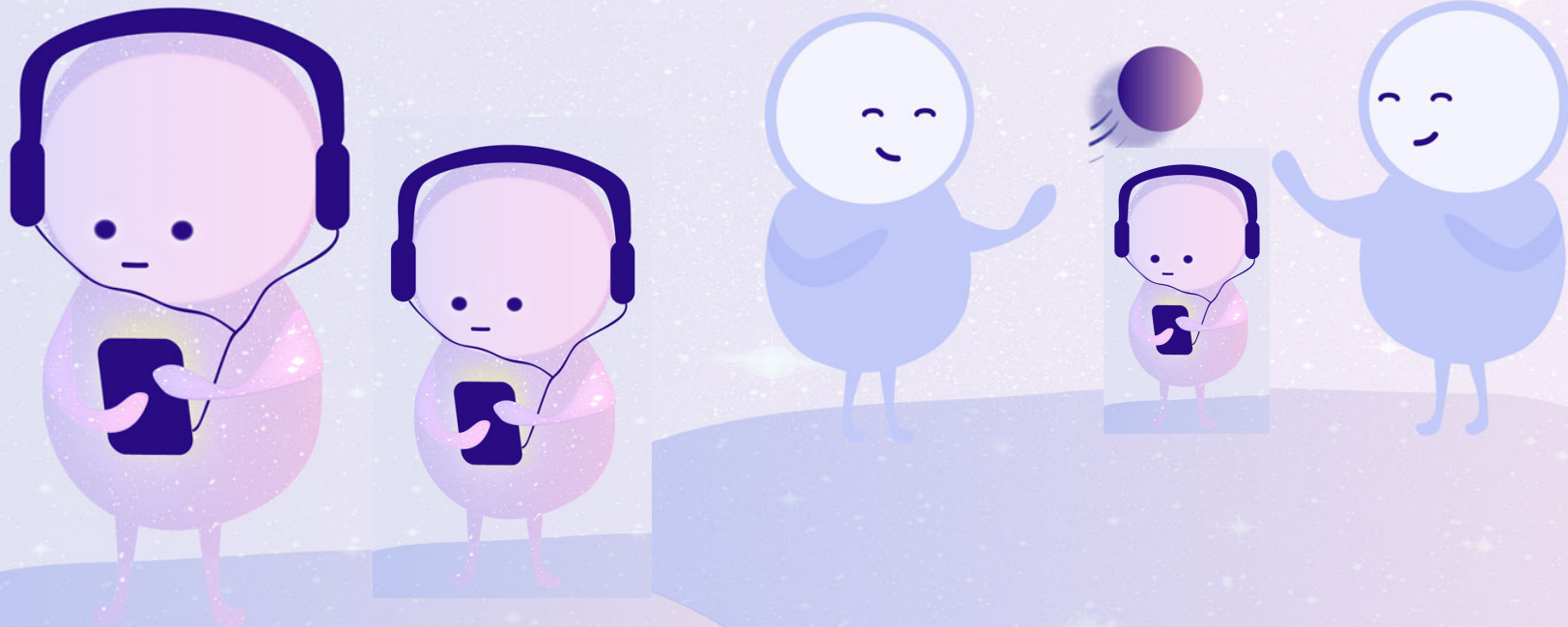


What's this bump?

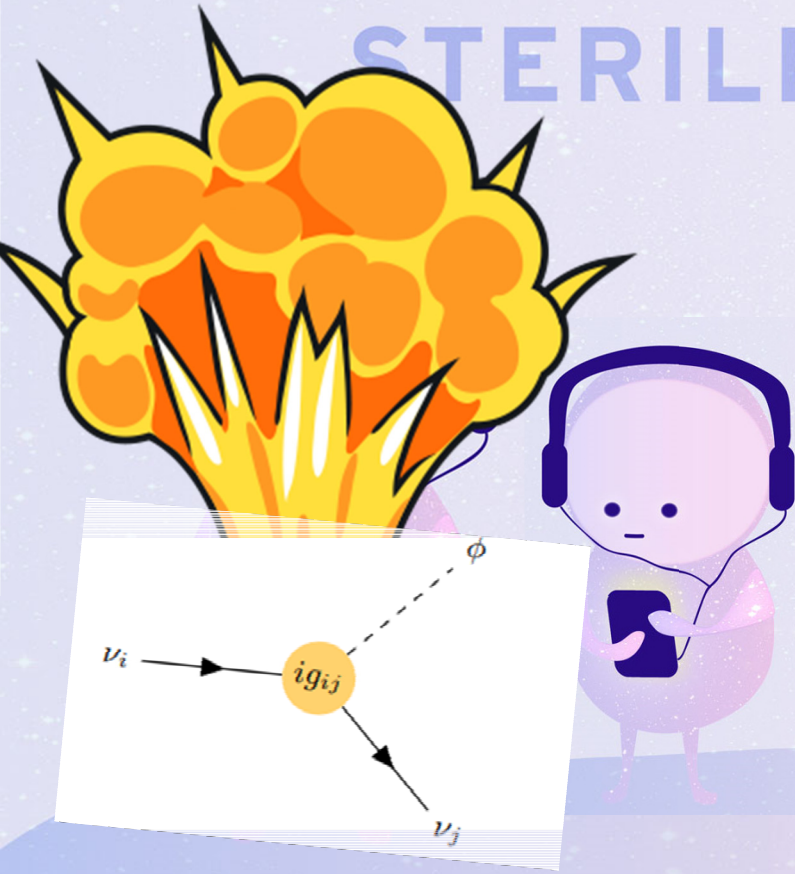
STERILE NEUTRINO

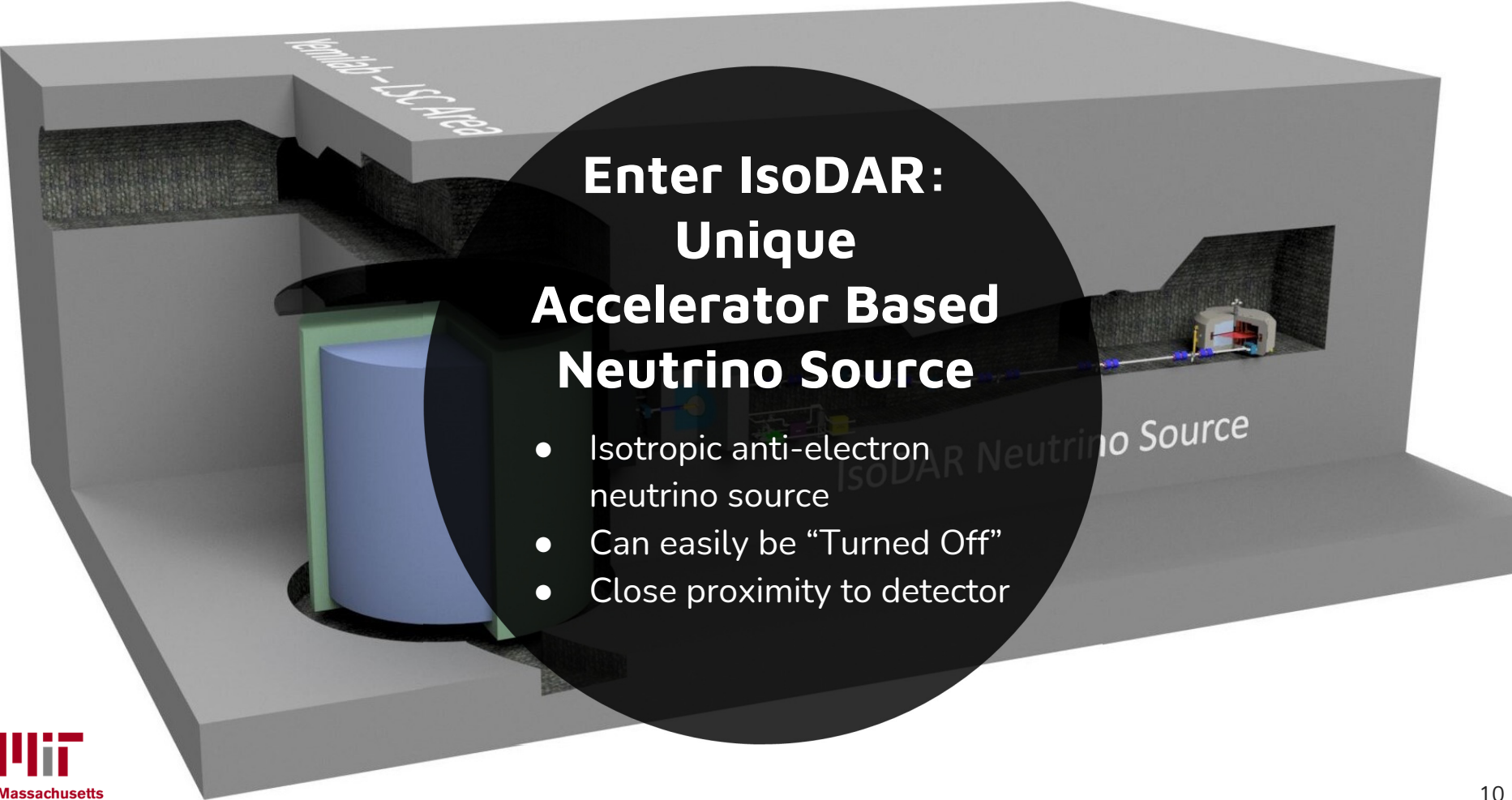


STERILE NEUTRINOS



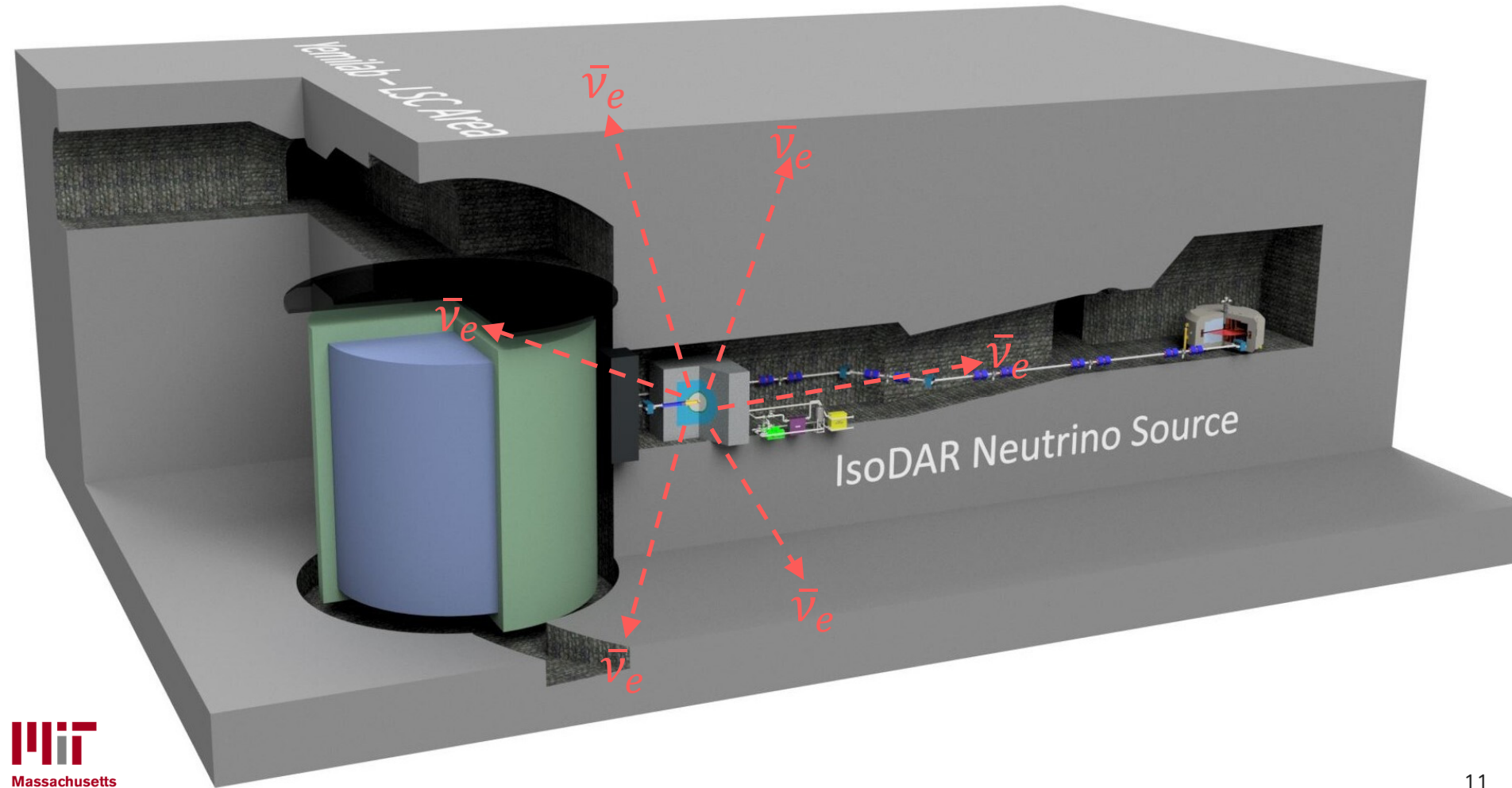
STERILE NEUTRINOS

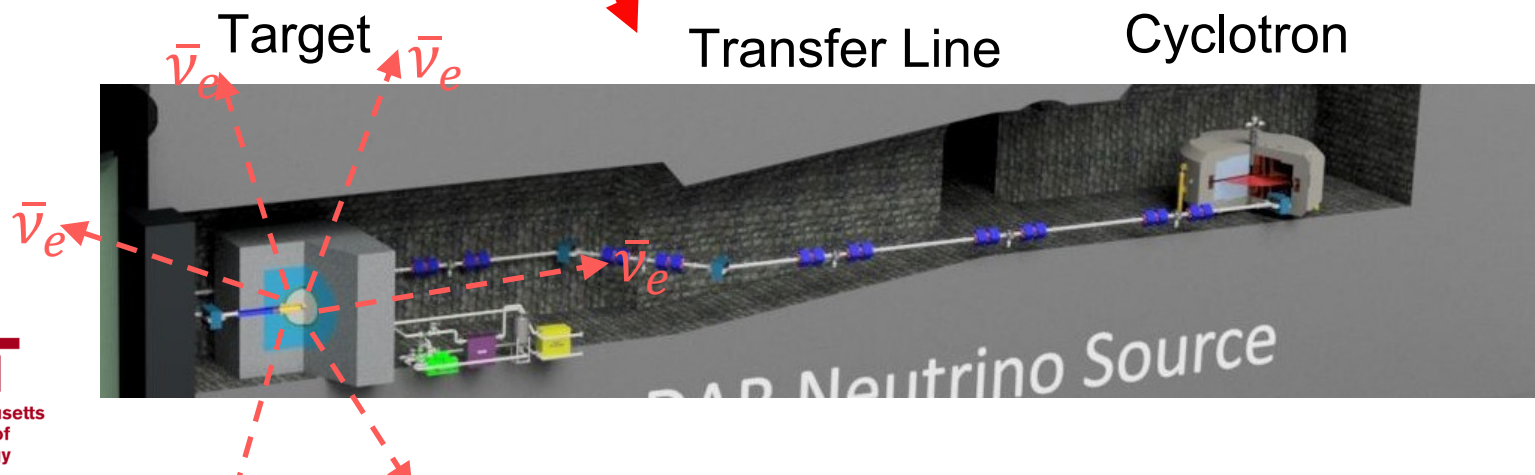
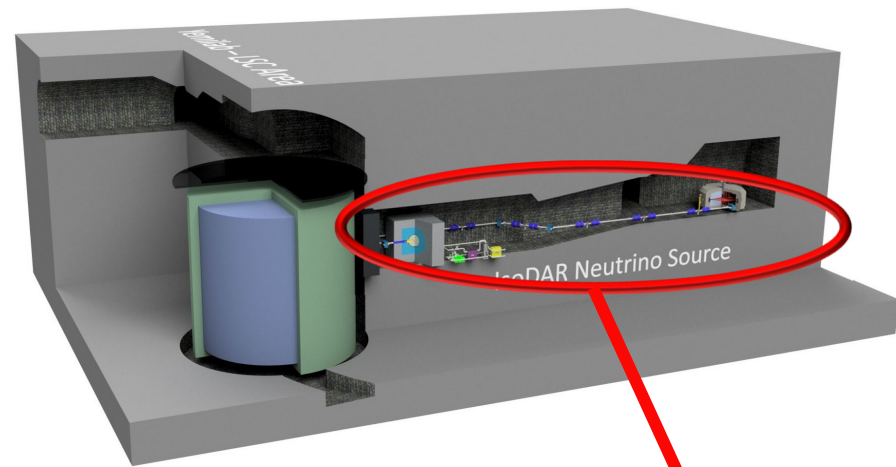


A 3D cutaway diagram of the IsoDAR facility. The diagram shows a large concrete structure with a central blue cylindrical component, likely a target or detector, and a smaller component on the right. A black circular overlay is centered over the diagram, containing text and a bulleted list. The text 'Enter IsoDAR: Unique Accelerator Based Neutrino Source' is prominently displayed. Below it, a bulleted list highlights three key features: 'Isotropic anti-electron neutrino source', 'Can easily be "Turned Off"', and 'Close proximity to detector'. The background of the diagram shows the internal structure of the facility, including various pipes and components.

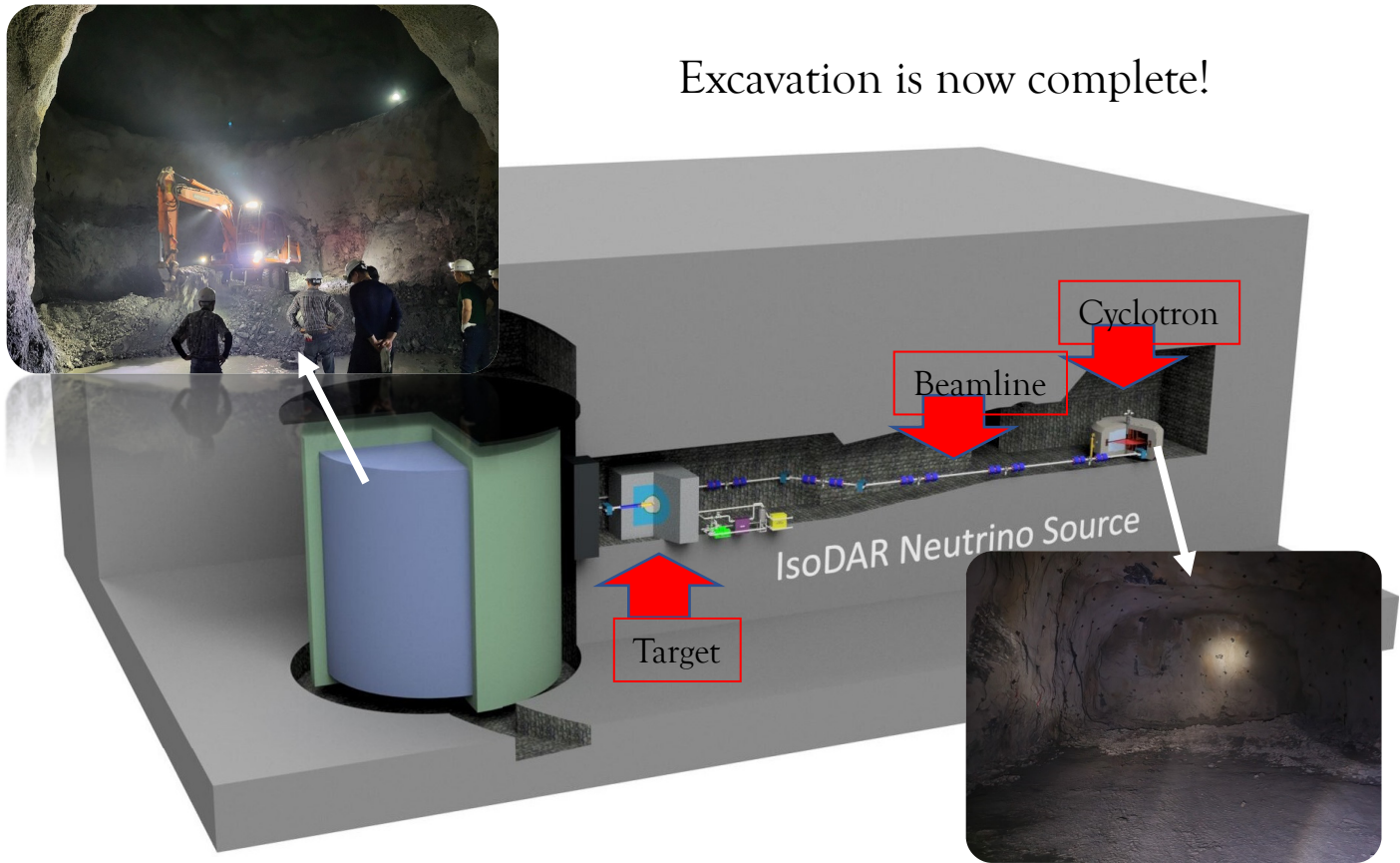
Enter IsoDAR: Unique Accelerator Based Neutrino Source

- Isotropic anti-electron neutrino source
- Can easily be “Turned Off”
- Close proximity to detector



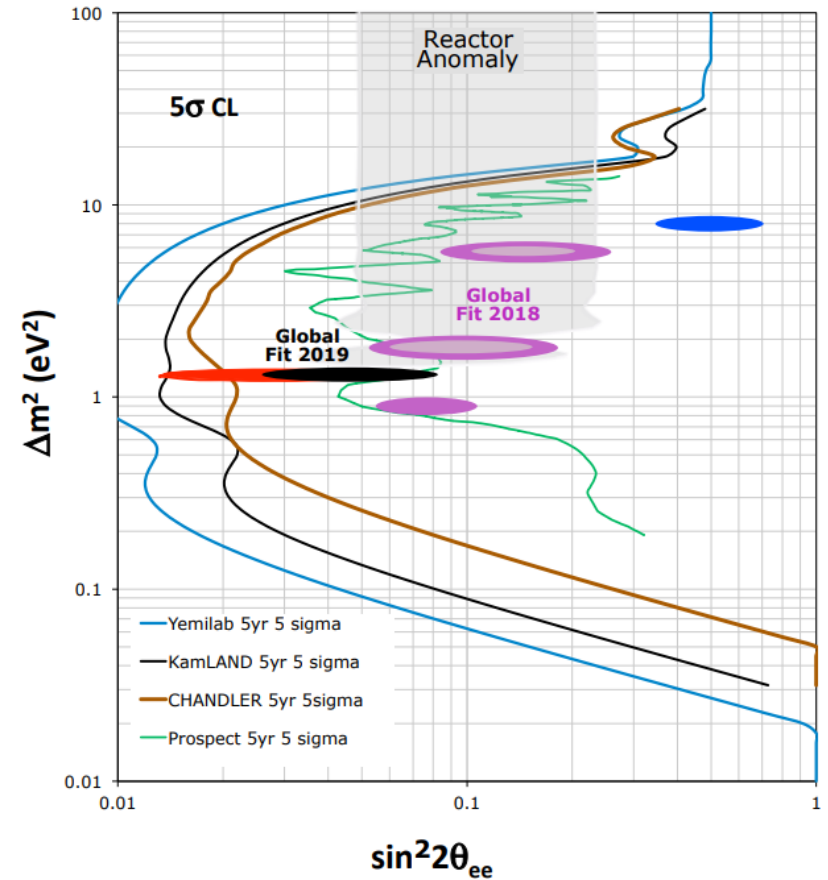


Excavation is now complete!

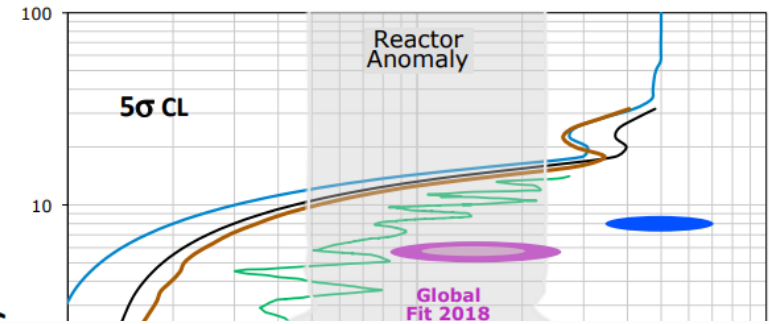


Excavation is now complete!

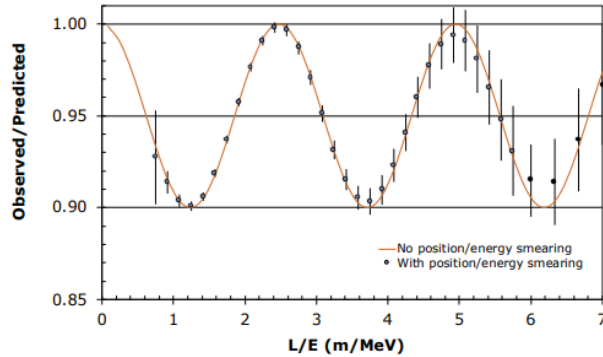
- 2.0 million IBD events in 5 years at Yemilab
- Can exclude massive parameter space to 5 sigma confidence over 5 years
- Including the global fits of several anomalies



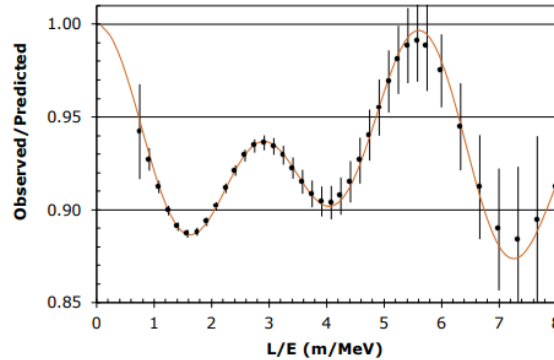
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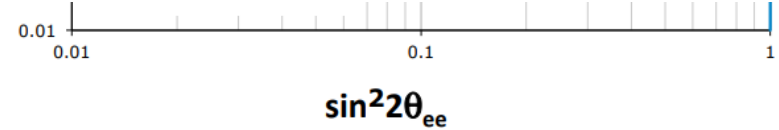
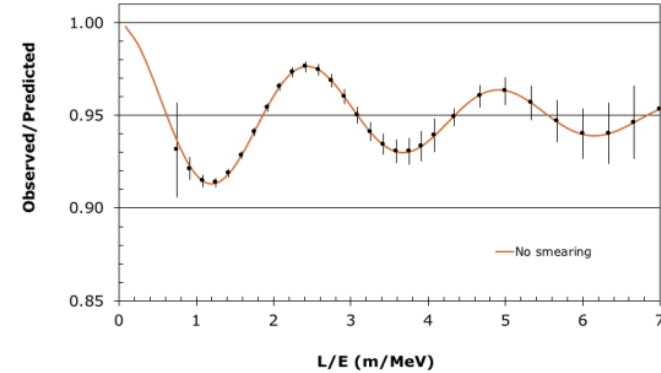
IsoDAR@ Yemilab: $\Delta m^2 = 1 \text{ eV}^2$ and $\sin^2 2\theta = 0.1$



IsoDAR@Yemilab: (3+2) Model with Kopp/Maltoni/Schwetz Parameters



IsoDAR@Yemilab: (3+1) plus Decay Model
 $\Delta m^2 = 1.35 \text{ eV}^2$, $\sin^2 2\theta = 0.214$ and $\tau = 4.5 \text{ eV}^{-1}$



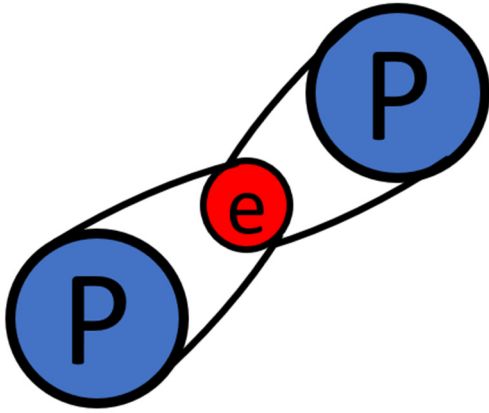
Innovation

- Intense neutrino source requires intense proton source
- Built underground, at a reasonable cost
- 10 mA beam current
 - 10X higher than commercial

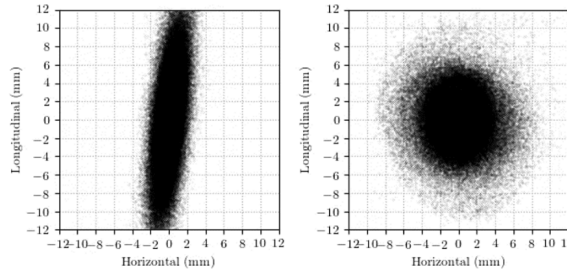




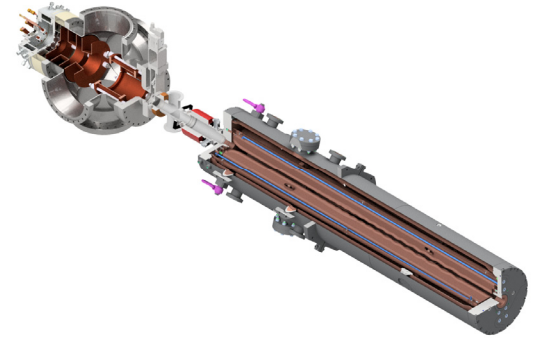
Use of H_2^+



Vortex Motion



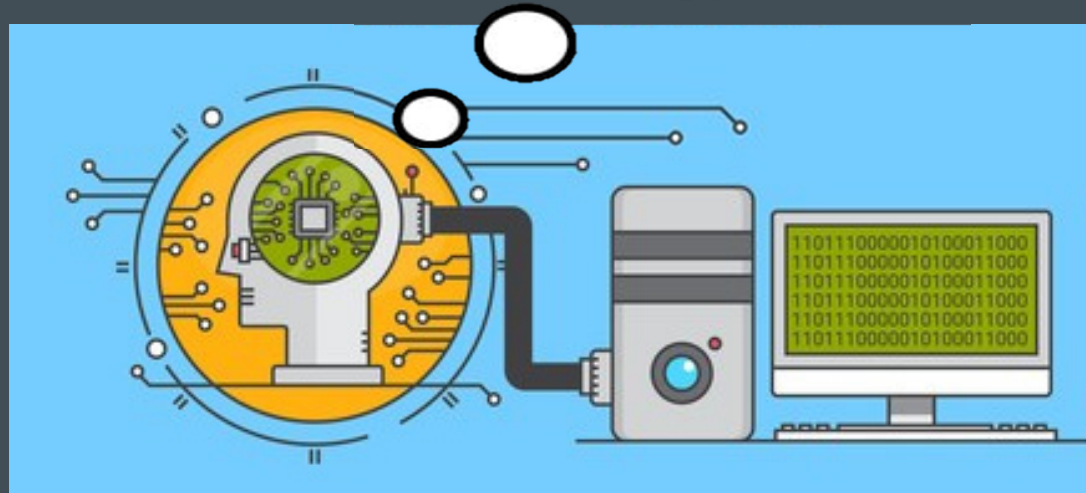
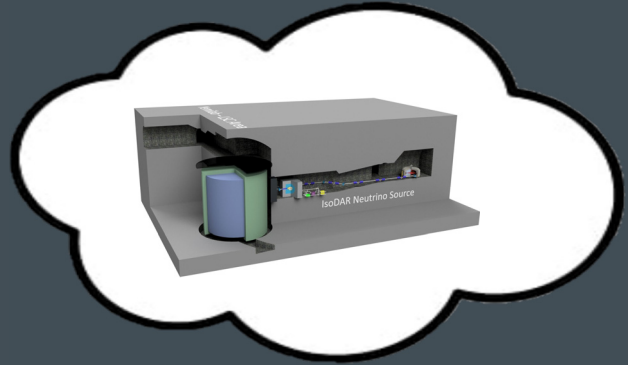
RFQ Direct Injection



Three Breakthroughs to Higher Currents

Use of Machine Learning

- Machine learning techniques to Model Accelerator System
 - Neural Networks
 - Polynomial Chaos Expansion
- Computational Speed Up
 - Sensitivity studies
 - Design Optimization





New Technology

- Ground-breaking current and power
- Capable of applications beyond the scope of particle physics

Parameter	IsoDAR	IBA C-30	IBA C-70
Maximum energy (MeV/amu)	60	30	70
Beam current (milliamps)	10	1.2	0.75
Pole radius (meters)	1.99	0.91	1.24
Outer diameter (meters)	6.2	3	4
Iron weight (tons)	450	50	140
Elect. Power reqd. (megawatts)	3.5	0.15	0.5

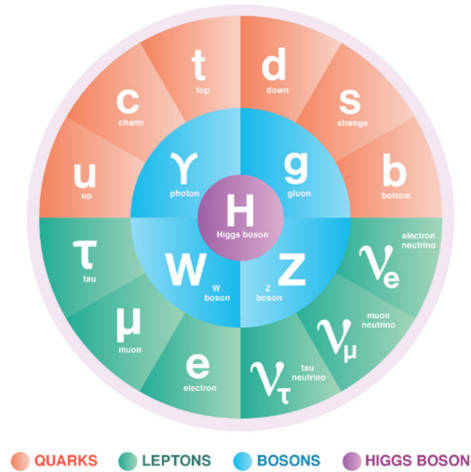


New Technology

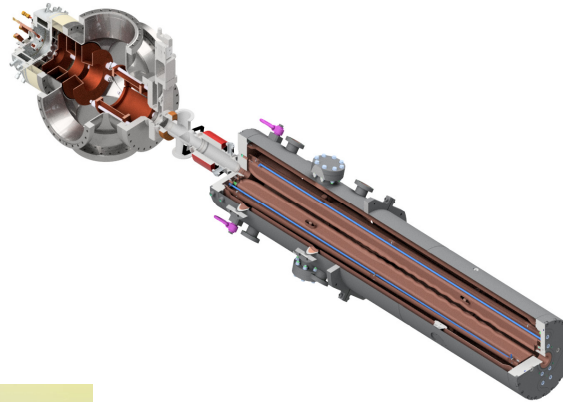
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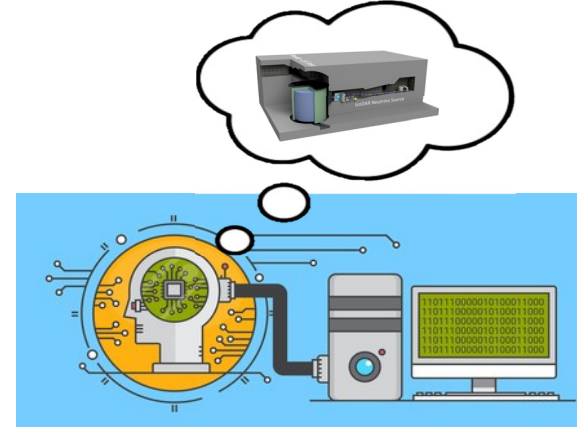
1. Neutrino Physics



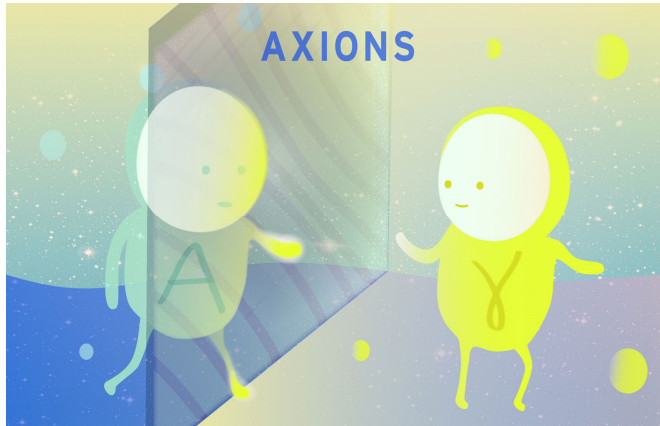
2. Accelerator Physics



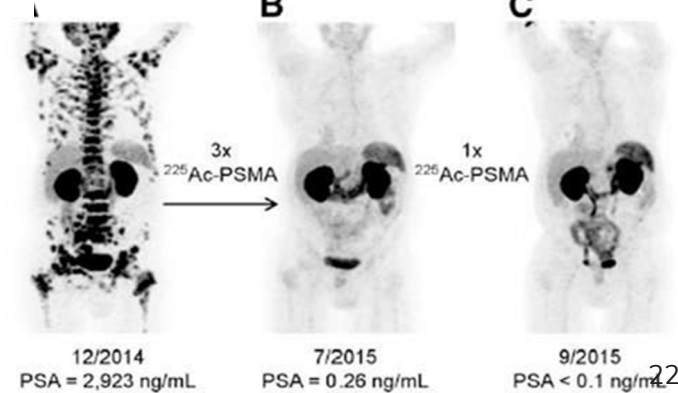
3. Machine Learning for Accelerators

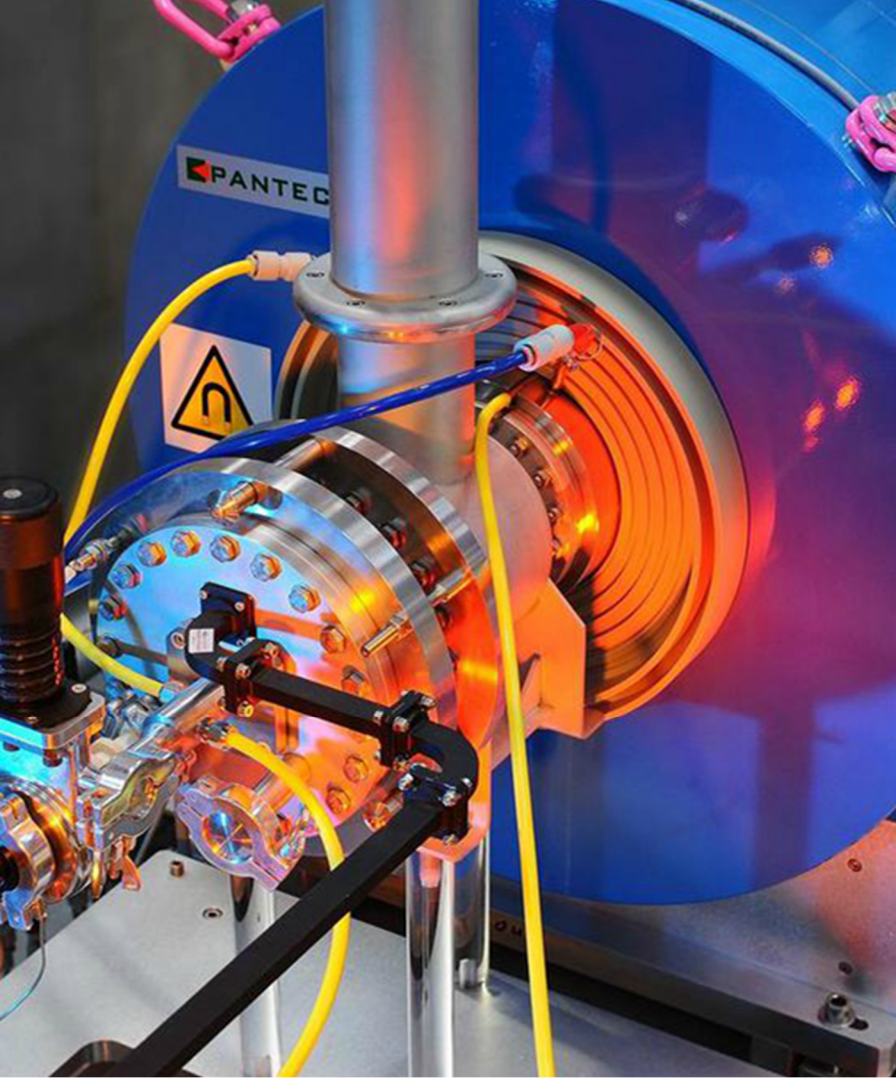


4. Axions with IsoDAR



5. Medical Isotopes with IsoDAR





Accelerating New Ions

- With minor tuning changes, can accelerate particles with the same charge/mass ratio
 - He^{++} , C^{6+} ,
 - There are commercially available ion sources for this (2.4 mA of alphas and 100 μA of C^{6+})
 - New Reactions



Conclusions

The requirements of an ambitious particle physics experiment have driven the development of new cyclotron technology. This development can grow beyond the scope of neutrino physics, and shift paradigms in the medical isotope community.

IsoDAR not only has the opportunity to change physics, but also has the opportunity to change lives.

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