Preparing oneself (or one’s students) for visiting National Superconducting Cyclotron Laboratory (NSCL)

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1. Resources one could use before coming for the tour
   a. Look around the Public Education pages of our website
   b. A fabulous article for teachers that really prepares one for learning more about NSCL
   c. A great book about Nuclear Science (most general one I can find): “Introduction to Nuclear Science” by Jeff C. Bryan
   d. Online resources that include some nuclear instruction
   e. A lesson with activities and demonstrations about nuclear science
   f. The NSCL brochure
   g. Some useful YouTube videos
      i. The Rare Isotope Rap (5 min music video about our laboratory)
      ii. The Small Matter of Big Science (45 min documentary about the history of nuclear science, featuring our laboratory starting at 38:43)

2. What students should know coming in
   a. Everything is made of atoms, which are made of Protons, neutrons, electrons
   b. There are many elements in our universe: The periodic table

3. What they will learn about NSCL research
   a. Nucleus is the core of the atom
      i. 10,000 times smaller than the atom itself, contains >99.9% of the mass
      ii. Too small for the most powerful microscopes to see
      iii. Building block of all matter!
   b. We study rare isotopes (unstable nuclei that don’t exist on earth) trying to answer:
      i. Which ones can exist, and for how long?
      ii. How much do they weigh?
      iii. What shapes do they have?
      iv. What are the rules (forces) that govern a nucleus’ existence?
   c. Our job: study nuclei that are too small to see, aren’t found on earth, usually exist for less than a second, and give off radiation. Not an easy task, which is why big laboratories are necessary!

4. Why do we study the nucleus?
   a. What can nuclei do, and what can’t they do? We seek a basic understanding of what we’re made of.
   b. Discover isotopes that have never been observed by humans
   c. Understand the “nuclear force” that binds protons and neutrons together
   d. Rare unstable nuclei don’t exist on earth, but can exist in stars! They can help us learn:
      i. How do stars shine, evolve, and die (explode – a supernova)?
      ii. Where did the elements in our universe come from?
      iii. What is causing some neutron stars to emit tons of x-rays?
5. How do we use what we learn?
   a. Medicine – most medical imaging technologies (x-rays, CAT and PET scans, MRI) were invented to study the nucleus, and later adapted to look inside the human body. Radiation is used as a diagnostic tool and sometimes to treat cancer.
   b. Archaeology/Geophysics – by measuring what kind of isotopes are in objects, you can tell where they are from and when they formed.
   c. Nuclear power – 20% of the electricity in the US is generated from nuclear fission.
   d. Smoke detectors, border security devices, solid-state electronics (smartphones)...

6. How do we study the nucleus?
   a. Accelerate normal (stable, common) nuclei to about half the speed of light.
   b. Smash the “fast beam” of nuclei into a target. Beam nuclei that hit target nuclei will fragment, losing some protons/neutrons and maybe becoming a rare isotope.
   c. We only study one kind of rare isotope at a time, so magnets are used to separate/filter all the other isotopes out of the beam.
   d. Detectors pick up evidence of the nucleus, allow us to measure it.

7. Glossary of terms
   b. Neutron – particle with about the same mass as proton, but no charge.
   c. Nucleus – core of an atom, composed of protons and neutrons.
   d. Element – type of matter as defined by the number of protons in the nucleus (e.g. an “atomic number” of 6 protons = carbon).
   e. Isotope – variety of an element as defined by the number of neutrons in the nucleus (e.g. 6 neutrons in a carbon nucleus = carbon-12, the isotope being 12, the sum of protons and neutrons).
   f. Stable nucleus – a favorable combination of protons and neutrons that will exist forever, barring outside influence.
   g. Unstable/radioactive nucleus – a combination of protons and neutrons that doesn’t last forever. In time, it will “decay” (give off radiation) and often change into a different kind of element/isotope (by altering the number of protons/neutrons, respectively).
   h. Rare isotope – variety of an element that is unstable and thus unlikely to be found on earth. Mostly found where nuclear reactions are currently making new nuclei (e.g. stars).
   i. Half-life – The time it would take for half a sample of unstable nuclei to decay. Effectively a measure of how unstable a particular nucleus is: very unstable nuclei have a short half-life.
   j. Fragmentation – a method of changing a nucleus by smashing it into another one, thus breaking off protons and neutrons. This is a way to make rare isotopes from stable ones.
   k. Cyclotron – a particle accelerator. A large machine that uses magnetic fields to steer nuclei in a circle (hence, “cyclo”) and electric fields (high voltage) to accelerate them. Nuclei must be accelerated to high energies for fragmentation to be successful.
   l. Superconductor – a wire that, when cooled to a low enough temperature, offers no resistance to electricity. Thus, it can carry large amounts of current and waste none of that energy as heat.