

How teachers prepare students for visiting National Superconducting Cyclotron Laboratory (NSCL)

By Zach Constan, constan@nscl.msu.edu, 517-333-6363

1. A fabulous article for teachers that really prepares one for learning more about NSCL:
<http://www.phys.utk.edu/news/2010/physics-teacher-09-17-2010.pdf>
2. What students should know coming in
 - a. Everything is made of atoms
 - i. Protons, neutrons, electrons
 - b. There are many elements in our universe
 - i. The periodic table
3. What they will learn about NSCL research
 - a. Nucleus at center 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)
 - 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
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 because of our knowledge of nuclear fission
 - d. Smoke detectors

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
 - a. Proton – positively-charged particle
 - 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. After some 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 in places 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.