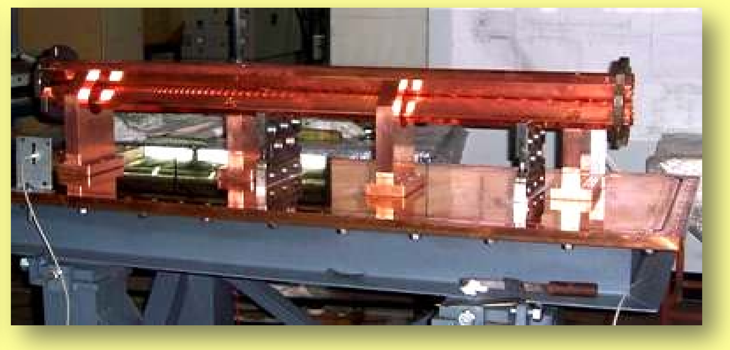
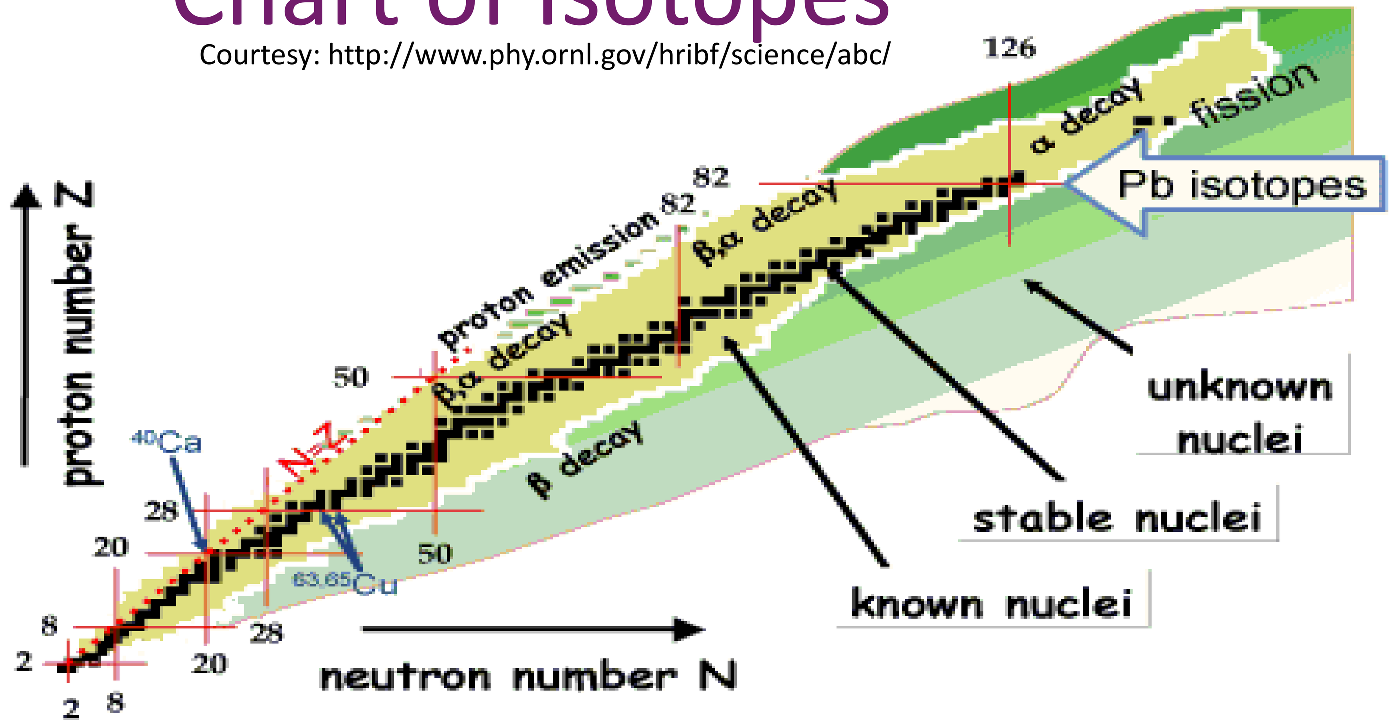



An invitation to the world of Radioactive Ion Beams

What are Radioactive Ion Beams and why we need them?

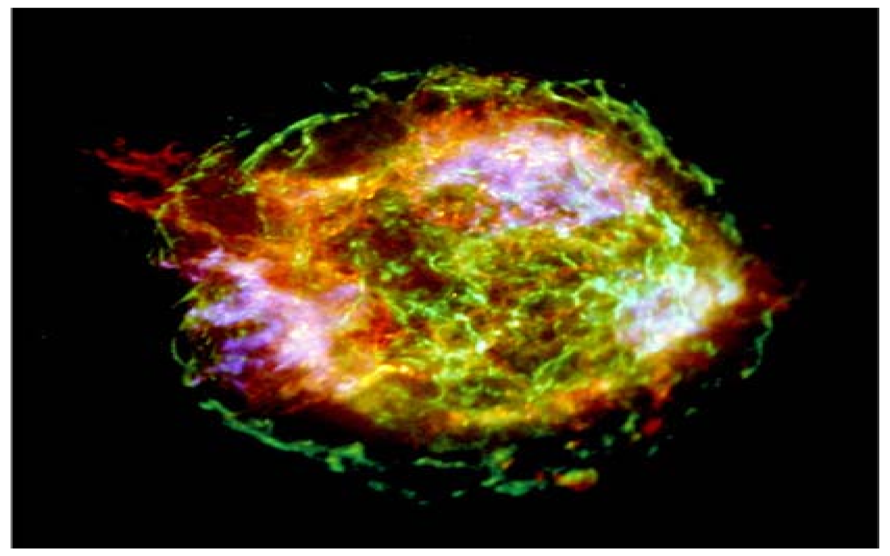
Radioactive Ion Beams are ion-beams of radioactive isotopes that have been artificially created using particle accelerators. Radioactive Ion Beams (RIB) are needed for producing radioactive nuclei that have not yet been identified in the nuclear chart. Also, nuclei that are already identified but not studied in detail can be produced in much larger quantities and studied using RIB. Nuclear reactions between radioactive nuclei play an important role in understanding element synthesis in the universe and explaining the abundance of chemical elements. Nuclear reactions going on in the interiors of stars can be recreated the in the laboratory using RIB. Apart from nuclear physics and astrophysics, RIB has important applications in materials science, atomic physics, nuclear medicine and biology.

Chart of Isotopes



Practical uses of Radioactive Isotopes

Nuclear Medicine (Tc-99m, Tl-201, I-123); Positron Emission Tomography (PET) ; Brachytherapy (Cs-137, Ir-192, Ra-226) ; Teletherapy (Co-60) ; Radiopharmaceuticals (I-131, Sr-89, Sm-153) ; Archeology -Carbon dating (C-14) ; Food preservation (Co-60) are some examples of practical uses of radio-isotopes. Traditionally radio-isotopes have been chemically doped in samples to be used as tracers but with the advent of radioactive ion beams, these can be ion-implanted in required samples. Advantage is that one can choose the implantation depth by tuning energy of the ion beam and can also implant in a chemically in-compatible lattice thus opening up several new kinds of study.



Chandra Telescope image of Supernova remnant Cassiopeia-A (NASA) showing remains of an exploded star. Red & blue regions indicate emission from silicon and iron in the ejecta. These and other elements are created via nuclear reactions in the core of the star and during the explosive event.

List of RIBs produced so far at VECC facility

RIB	Production route	Half-life	Intensity (particles per sec)	Potential Applications
^{14}O	$^{14}N(p, n)$	71 sec	5.0×10^3	Beta-decay & nuclear-astrophysics studies
^{42}K	$^{40}Ar(\alpha,pn)$	12.36 hr	2.7×10^3	bio-medical tracer
^{43}K	$^{40}Ar(\alpha,p)$	22.3 hr	1.2×10^3	bio-medical tracer
^{41}Ar	$^{40}Ar(\alpha,2pn)$	109 min	1.3×10^3	tracer for wear studies
^{111}In	$^{nat}Ag(\alpha,xn)$	2.8 days	1.6×10^4	Perturbed angular correlation spectroscopy, medical radio-tracer

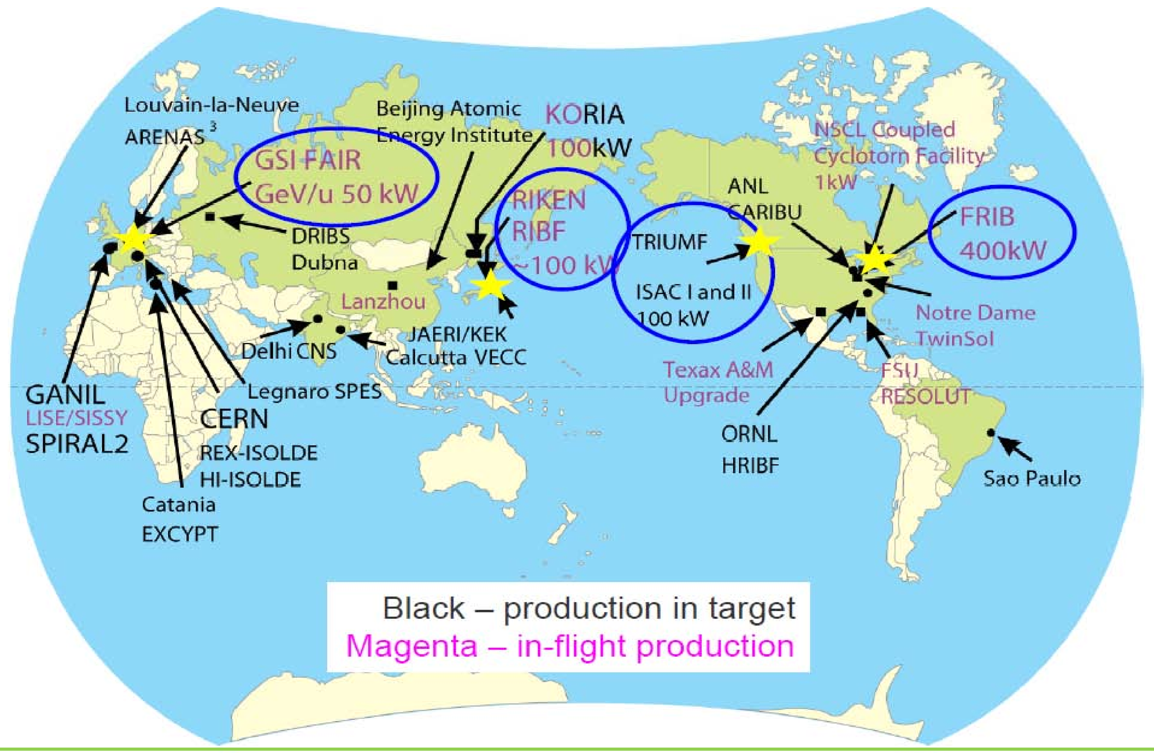
How to produce Radioactive Ion Beams?

Isotopes are first created in a target by bombarding it with energetic beams of protons or alpha-particles/ heavy-ions from a primary accelerator – such as a cyclotron. Nuclear reaction products created in the target are transported in atomic form to an ion-source where they get ionized by stripping of electrons. The low energy radioactive ion beam selected after a downstream isotope separator is finally accelerated to the desired energy, needed for experiments, using linear accelerators (linac) such as radio frequency quadrupole (RFQ) linac and heavy-ion Linacs.

How many radioactive isotopes are expected to exist?

According to present estimates, more than 6000 radioactive isotopes may exist. Much like the periodic table of chemical elements, isotopes are represented in a nuclear chart as shown in the figure on the top-right. Here number of protons is plotted versus number of neutrons and each row represents isotopes of a certain element. Black dots represent stable isotopes which are around 300 in number and their locus is called line of beta stability. Less than 3000 isotopes have been experimentally studied and almost an equal number is yet to be identified.

Radioactive Ion Beam facilities worldwide



Radioactive Ion Beam facility project at VECC

Construction of a RIB facility involves development of state-of-art particle accelerators and intense R&D on targets and ion-sources. Development of various species of beams is done through on-line experiments aimed at optimizing target release efficiency and ionization efficiency of the ion-source. Blue-prints for RIB facility are not available but have to be created via the route of physics & engineering design followed by prototype development and there-after construction and testing of the actual accelerator components. For this reason world-wide enormous effort has been put-in by accelerator physicists and technologists in developing RIB facilities suited to the available primary accelerators while exploiting the technological base in-house and in local industry. The effort at VECC is no different. In preparation for the construction of a full-fledged RIB facility, a low energy R&D facility has been built that uses beams from VECC K130 cyclotron to produce RIB via the isotope separator on-line route. Radioactive isotopes produced in the target are transported to a 6.4 GHz ECR ion-source, ionized and after separation in a magnetic separator are accelerated in a RFQ and three heavy-ion linacs. Respective output energy after RFQ and the three linac modules is around 100, 186, 289 and 415 keV/A. The accelerator components have been designed at VECC and fabricated indigenously in collaboration with industry and institutional partners such as CSIR-CMERI Durgapur and SAMEER Mumbai. Apart from RIBs listed in the table, beams of stable isotopes of boron, carbon, oxygen, nitrogen, argon, potassium, iron, nickel and zinc are accelerated and are being used for surface science, nano-science and material science studies.

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