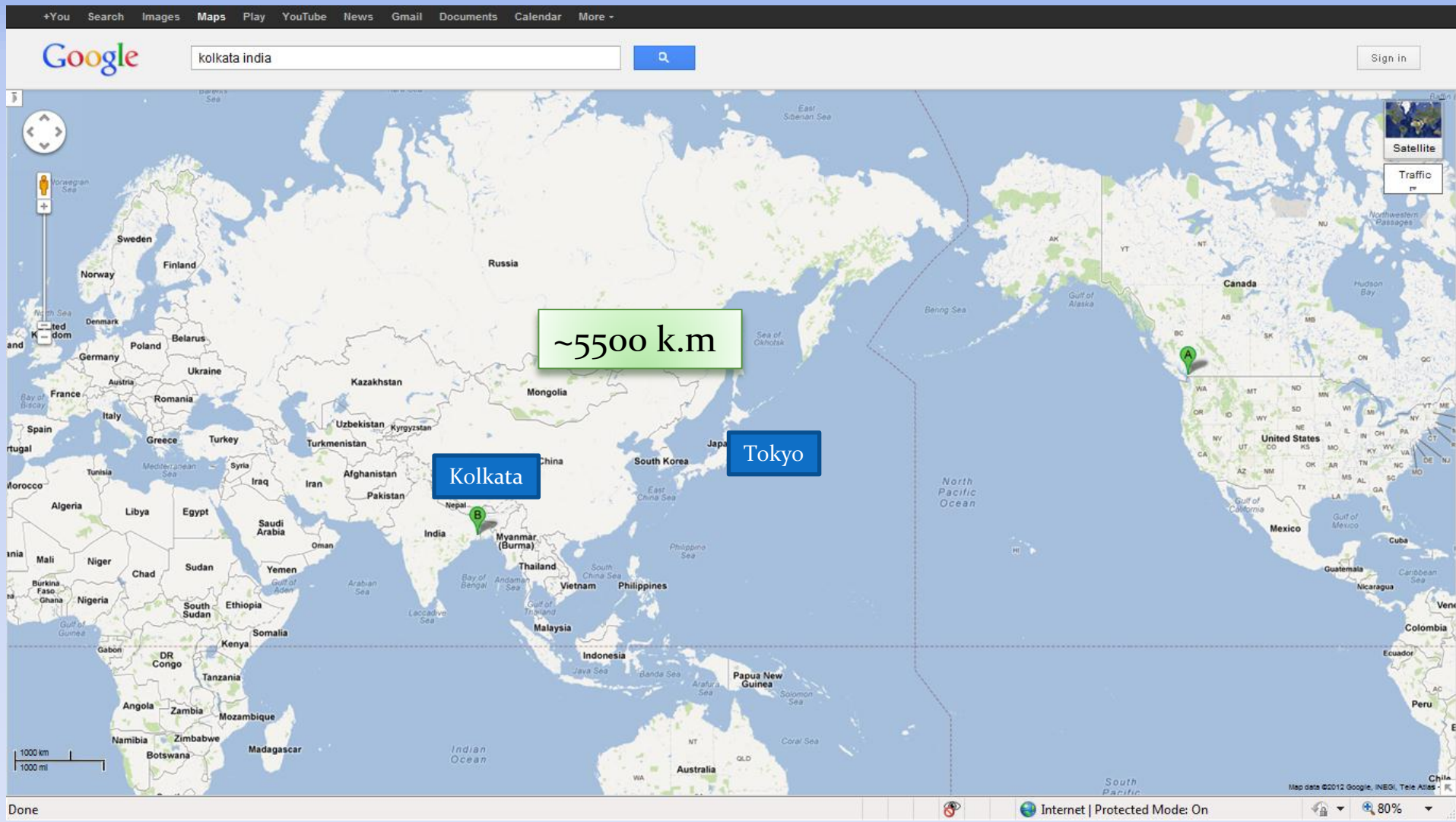
ANURIB project at VECC plans & preparations

Nabhiraj P Y

On behalf of RIB group and staff of VECC

Variable Energy Cyclotron Centre, Kolkata, India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VECC

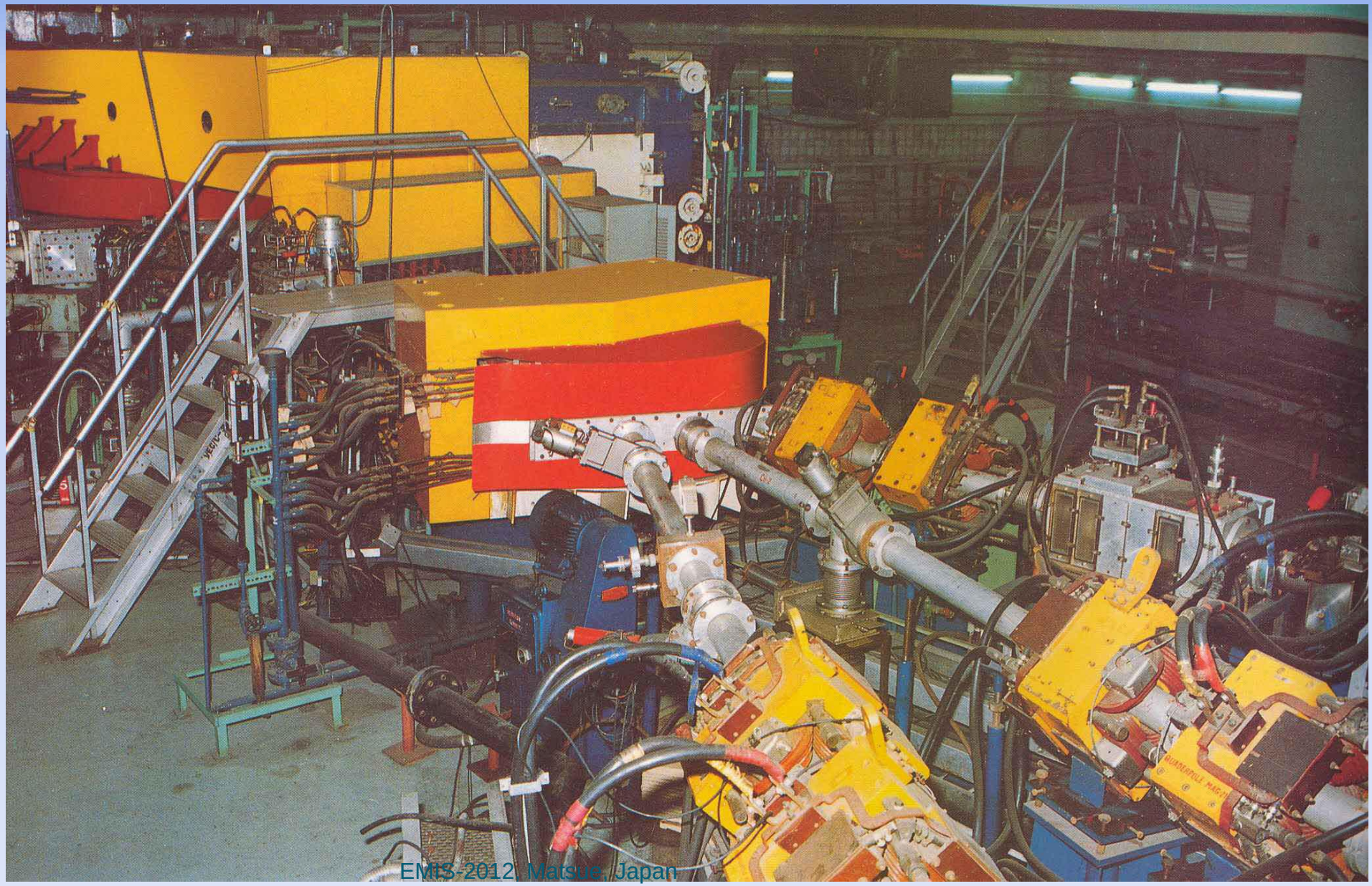
Variable Energy Cyclotron Centre

– main accelerator projects

- K130 cyclotron (since 1977)
- Superconducting cyclotron – internal beam, efforts on to extract external beam
- Last 12 years – design & development of low energy ISOL type RIB facility around the K130 cyclotron

K-500 Superconducting Cyclotron

K-130 Room Temperature Cyclotron



Outline of talk

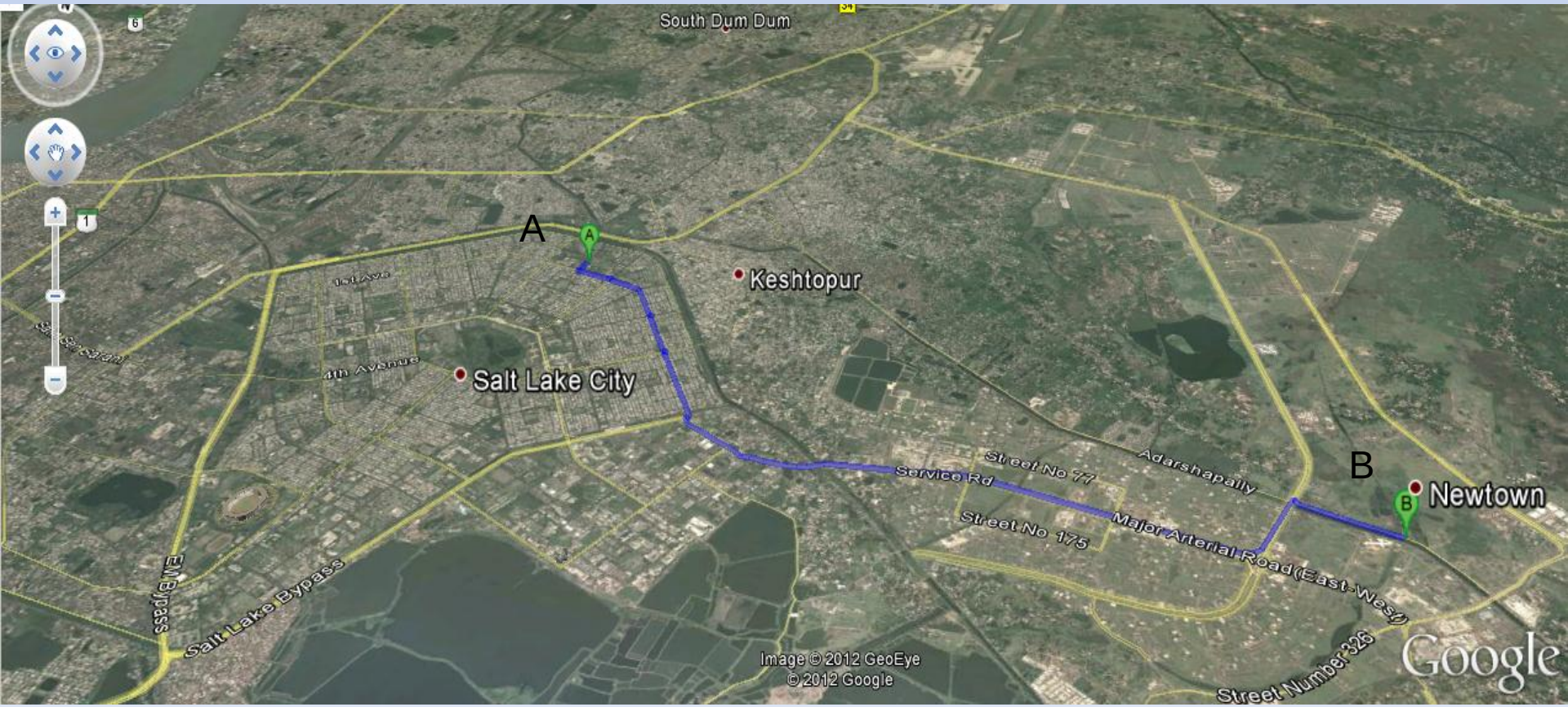
- ANURIB project – scheme
- Activities at VECC in preparation for ANURIB
  - Low energy RIB facility around K130 cyclotron ✓
  - First production of RIB ✓
  - 10 MeV SC injector for electron linac
- Gap areas to be filled in coming 2-3 years
  - Superconducting heavy-ion linac
  - Target module design & R&D on uranium targets
- Summary

ANURIB

A National facility for Unstable and Rare Ion Beams

- To be built around super-conducting electron linac photo-fission driver for production of neutron-rich RIB
- Will accelerate both RIB and stable isotope beams
- Ring cyclotron for acceleration to high energy
- Combines features of ISOL & PFS type facilities. Possibility for fragmentation of RI beams.

A: VECC Salt lake campus B: New Campus; around 10 km away



Project implementation strategy

ANURIB

Phase-2 : 2017-2024

INR. 705 crore
$130M

Phase-1 : 2012-2017

*ANURIB ph-1
(12th plan project)

INR. 165 crore
~ $30M

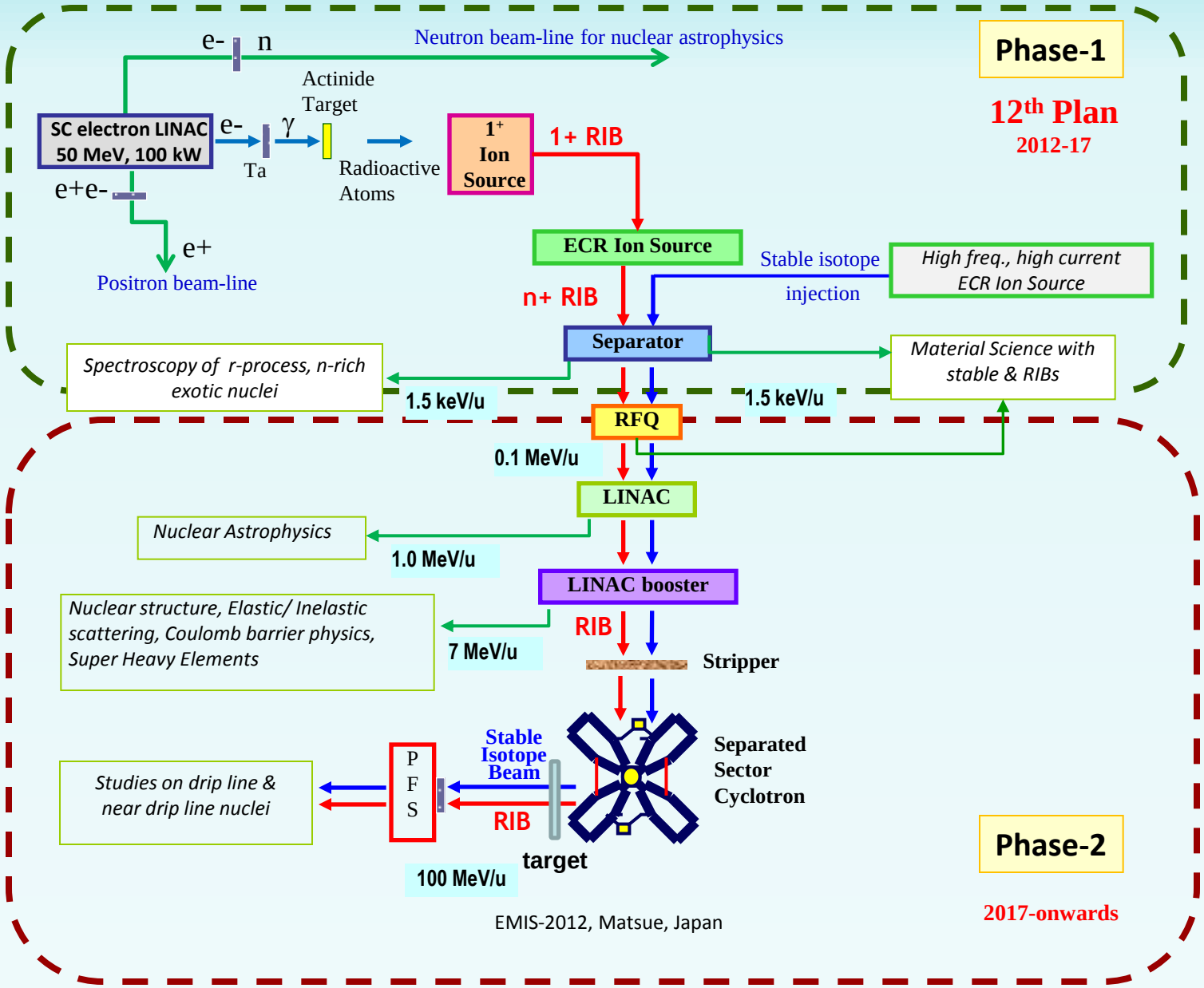
*Superconducting linac s for electron & heavy-ions :Advance RIB phase-2
(12th plan project)

INR. 85 crore
~$15M

*Two different projects with well defined deliverables and minimal inter-dependence

ANURIB facility

A National Facility for Unstable and Rare Isotope Beams



EMIS-2012, Matsue, Japan

12th plan ANURIB Phase-1 Activities

1. Physics & Engineering Design of entire ANURIB facility (both phases)

2. Construction of high power actinide target modules, Accelerator Cryo-Module (ACM) for electron-linac, ECR ion-source, low energy beam line (Isotope Separator)

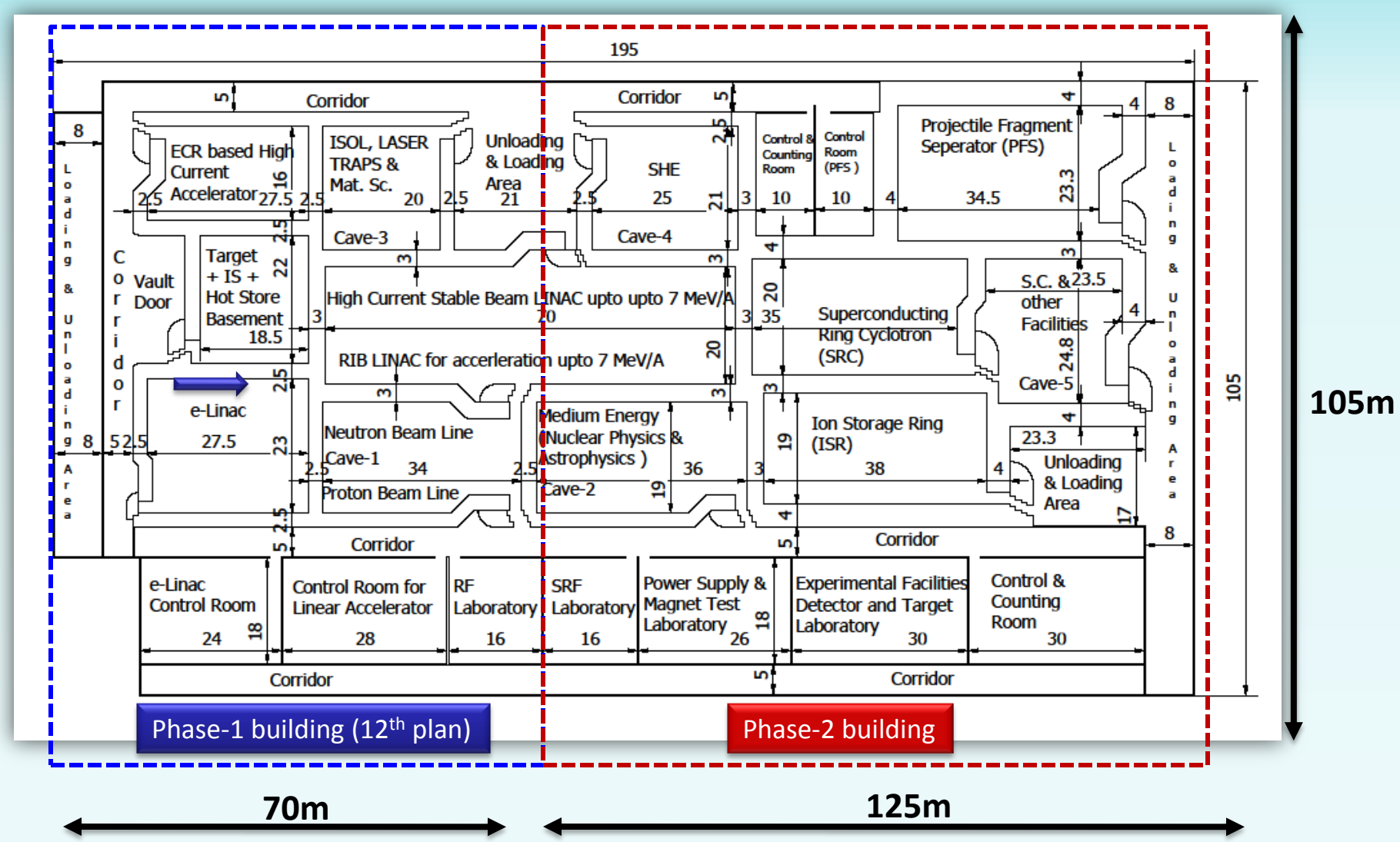
3. Experimental facility for 1.5 keV/u beams – nuclear spectroscopy of r-process nucleo-synthesis nuclei, laser spectroscopy, ion-beam based material science

4. Design of phase-1 building & AERB clearance

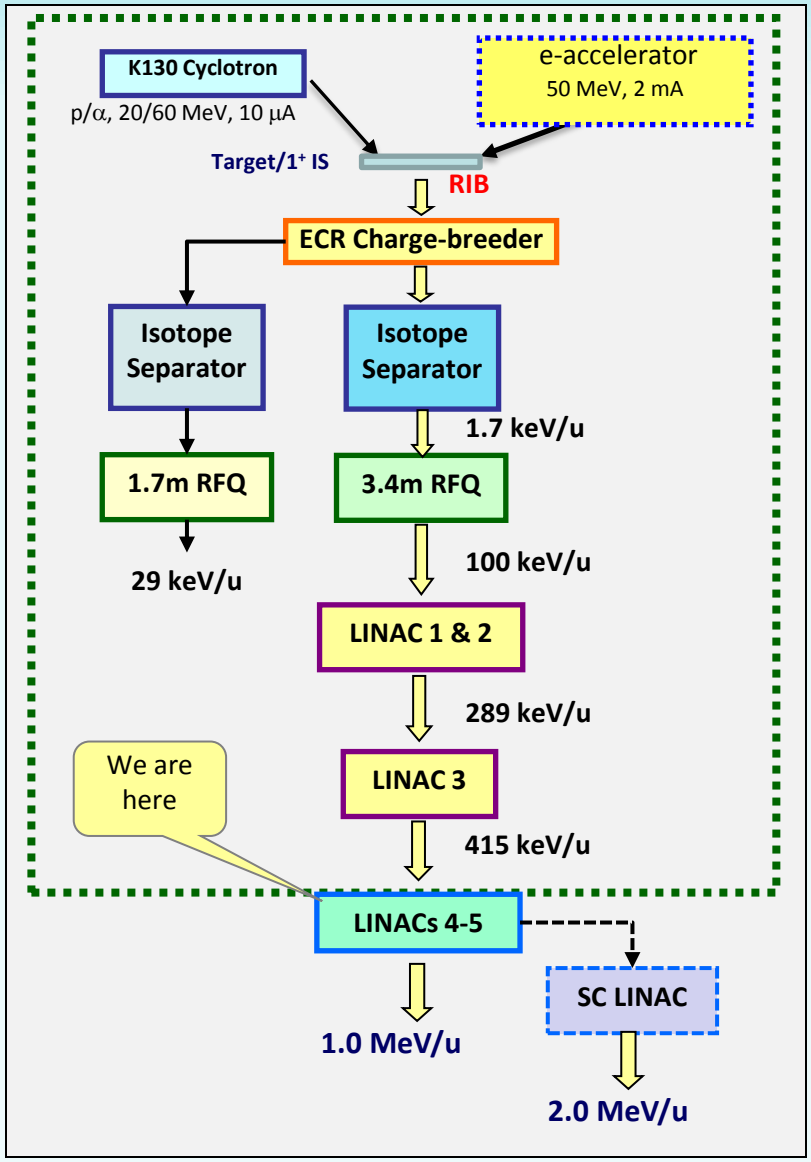
5. R&D on high current injector, prototype development

6. Construction of Phase-1 building that will house the following:
(i) Electron linac (ii) Target stations (iii) ECR ion-source (iv) Isotope separator (v) Neutron facility cave (vi) Misc. expt. cave (vii) positron cave

ANURIB – tentative layout plan

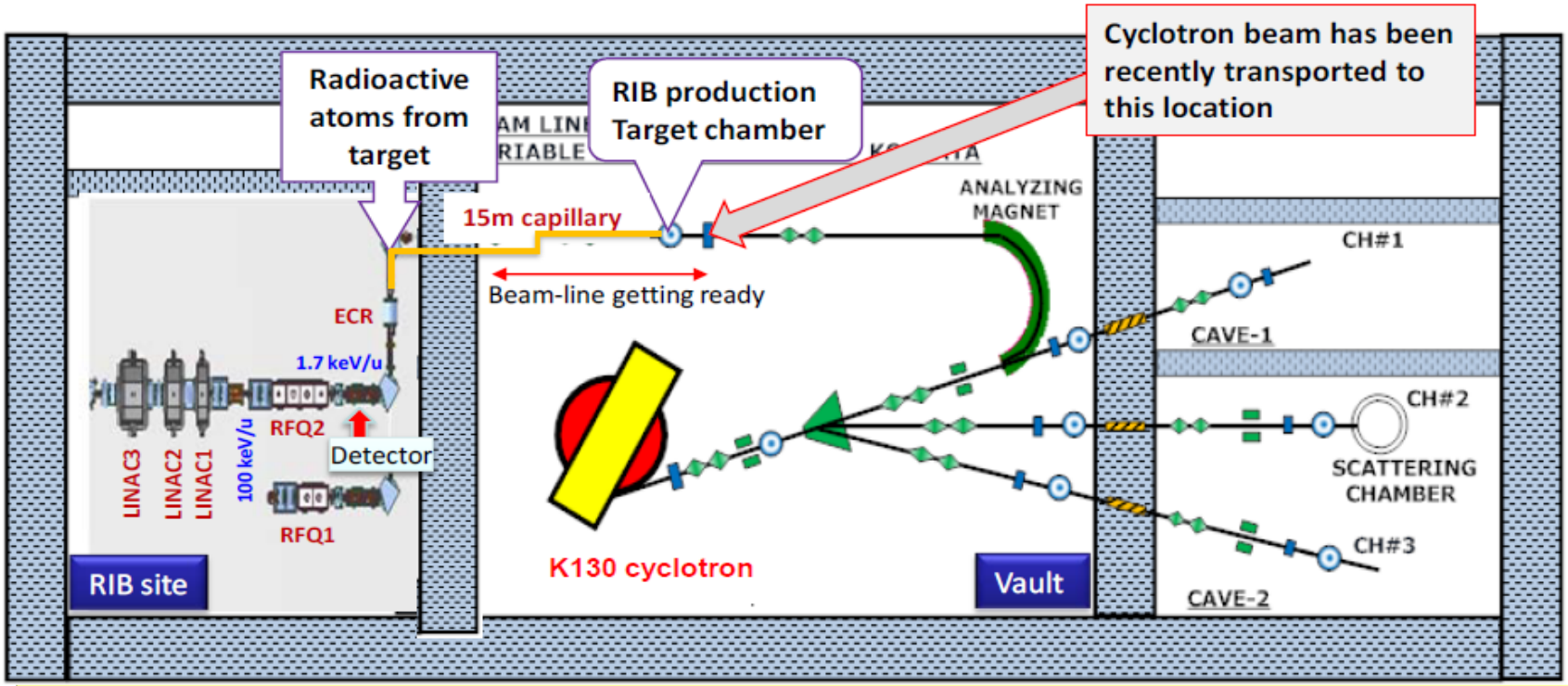

195
105
105m
Corridor
ECR based High Current Accelerator
ISOL, LASER TRAPS & Mat. Sc.
Unloading & Loading Area
SHE
Control & Counting Room
Control Room (PFS)
Projectile Fragment Seperator (PFS)
Loading & Unloading Area
Vault Door
Target + IS + Hot Store Basement
Cave-3
Cave-4
High Current Stable Beam LINAC upto upto 7 MeV/A
RIB LINAC for accerleration upto 7 MeV/A
Superconducting Ring Cyclotron (SRC)
S.C. & other Facilities
Cave-5
e-Linac
Neutron Beam Line
Cave-1
Medium Energy (Nuclear Physics & Astrophysics)
Cave-2
Proton Beam Line
Ion Storage Ring (ISR)
Unloading & Loading Area
e-Linac Control Room
Control Room for Linear Accelerator
RF Laboratory
SRF Laboratory
Power Supply & Magnet Test Laboratory
Experimental Facilities Detector and Target Laboratory
Control & Counting Room
Phase-1 building (12th plan)
Phase-2 building
70m
125m

Towards our aim..



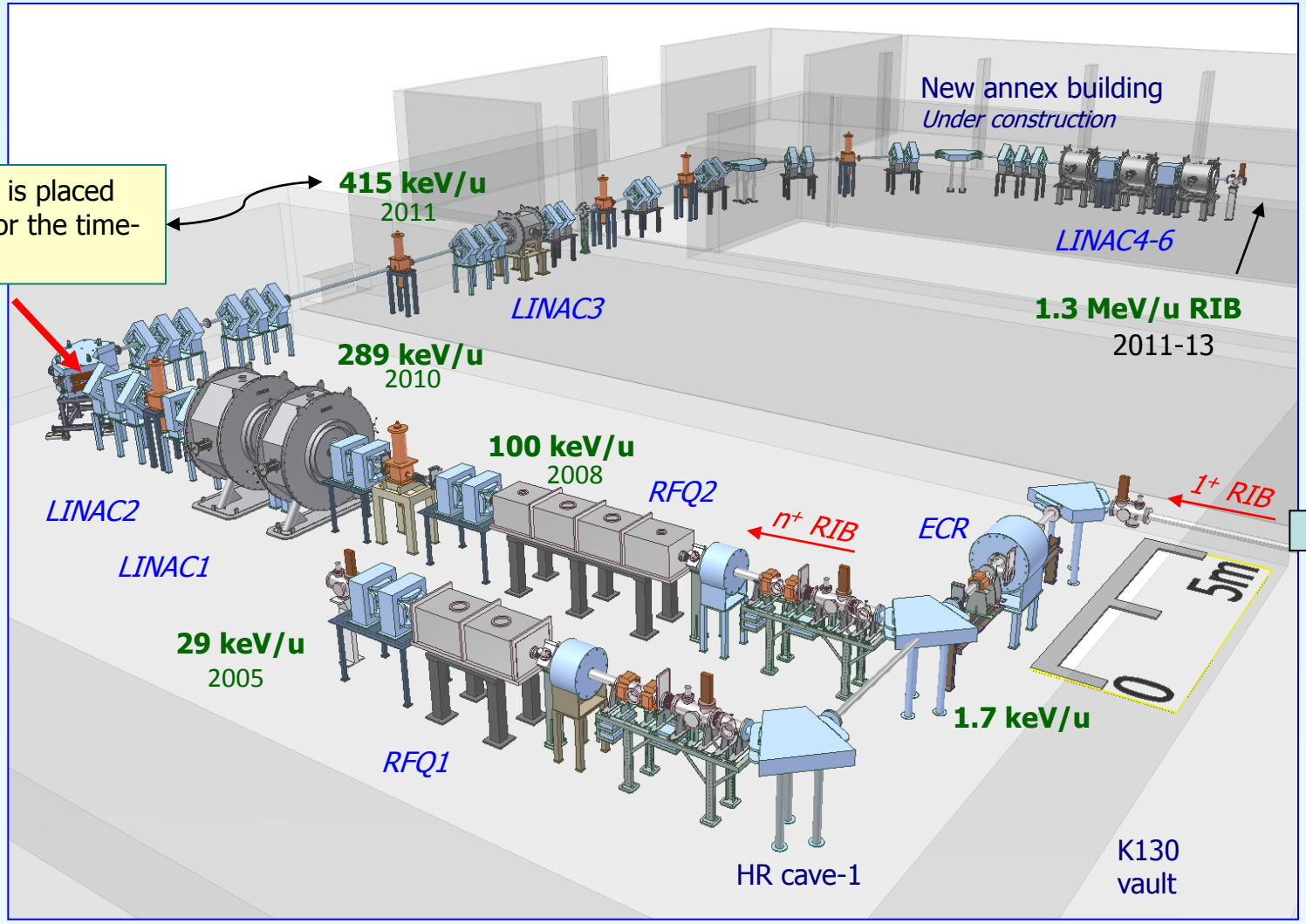
- Developed 1st RFQ in the country (29 keV/u; 2005). Second RFQ commissioned in 2008 (100 keV/u). Fully indigenous development.
- Developed 1st IH-Linac in the country. Linac-1 & 2 & 3 are already commissioned; Linac 4 tested; Linac 5 being ordered. Both to be installed in new annex building by 2013
- May 12, 2012 – First RIB : ^{14}O (71 sec) accelerated to 1.4 MeV through RFQ. Intensity after RFQ ~ 3300 pps;
- Also produced RI beams of $^{42,43}K$ and ^{41}Ar .
- Accelerated beams of $^{16}O^{4+}$ and $^{14}N^{4+}$ to 415 keV/u through Linac-3.
- Target R&D , on-line experiments ongoing.
- Superconducting Electron Linac development started, in collaboration with TRIUMF .
- Ion-beams from the facility being used for material science experiments.
- Fragment Separator based experiment & PFS design (collaboration with RIKEN)

We have successfully produced first Radioactive Ion Beams at VECC using a novel technique based on helium jet transport and combination of two skimmers. Beams of ^{14}O (half-life 71 sec), ^{41}Ar (109 min), ^{42}K (12.4 hrs) and ^{43}K (22 hrs) were produced



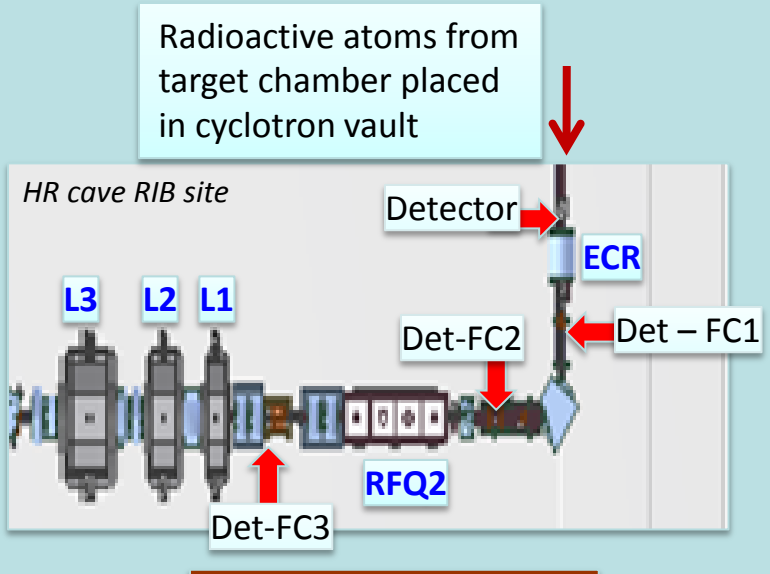
- Target chamber placed in cyclotron vault.
- Reaction products transported to RIB site using gas-jet recoil transport method
- Reaction products stopped on a porous RVCF catcher placed inside ECR ion-source.
- A skimmer and roots pump used to discard carrier gas

Schematic layout of RIB beam-line at VECC

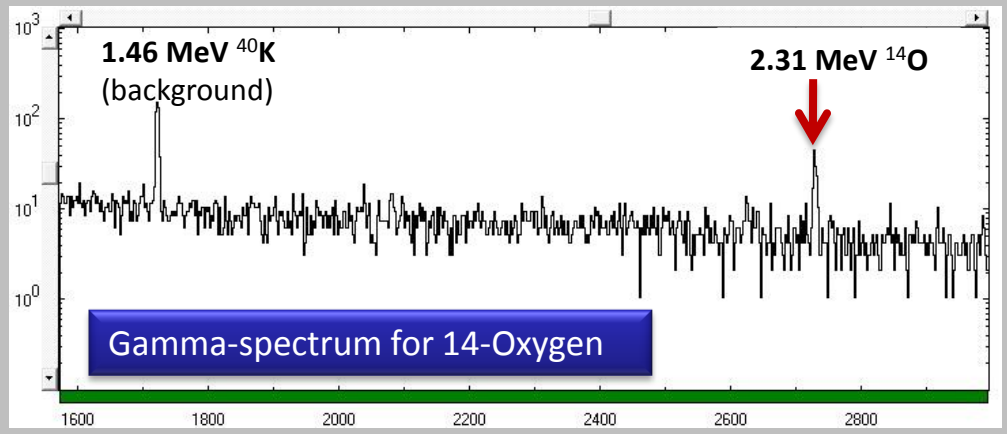


List of RIBs produced

RIB	Prod. route	T1/2	pps @ ECR exit (FC1)	pps @ before RFQ (FC2)	pps @ after RFQ (FC3)
^{14}O	$^{14}N(p, n)$	71 s	6.7×10^4	5.0×10^3	3.2×10^3
^{42}K	$^{40}Ar(\alpha,pn)$	12.36 hr	3.1×10^4	2.7×10^3	-
^{43}K	$^{40}Ar(\alpha,p)$	22.3 hr	2.0×10^4	1.2×10^3	-
^{41}Ar	$^{40}Ar(\alpha,2pn)$	109 min	4.6×10^3	1.3×10^3	-



Location of detectors



Gamma-spectrum for 14-Oxygen

Optimized parameter	value
beam	$^{14}O^{2+}$
ECR ext. vol.	12.3 kV
RFQ power	10 kW cw
RFQ vane vol.	27 kV

RFQ parameters for 14-Oxygen

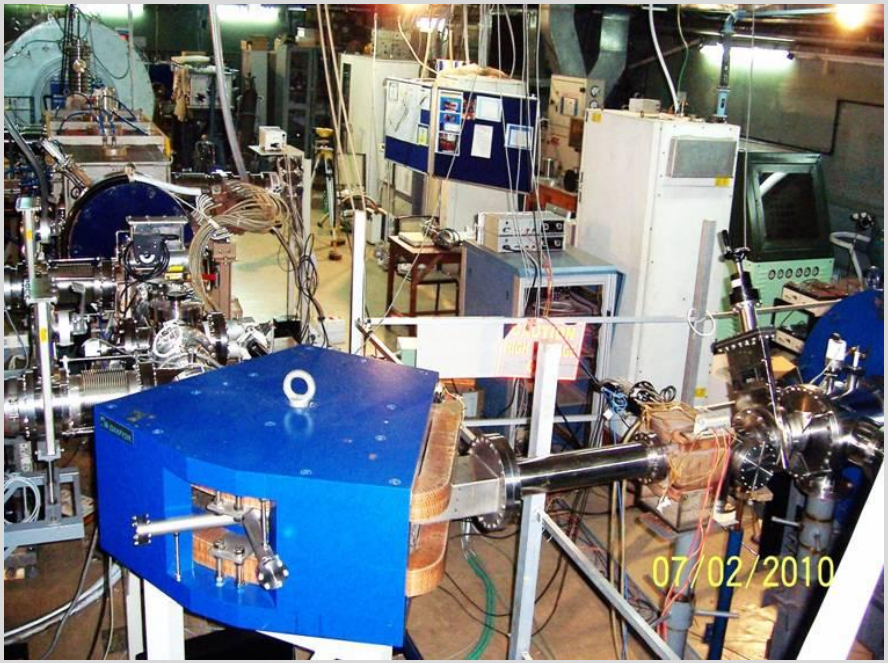
What have we achieved so far…

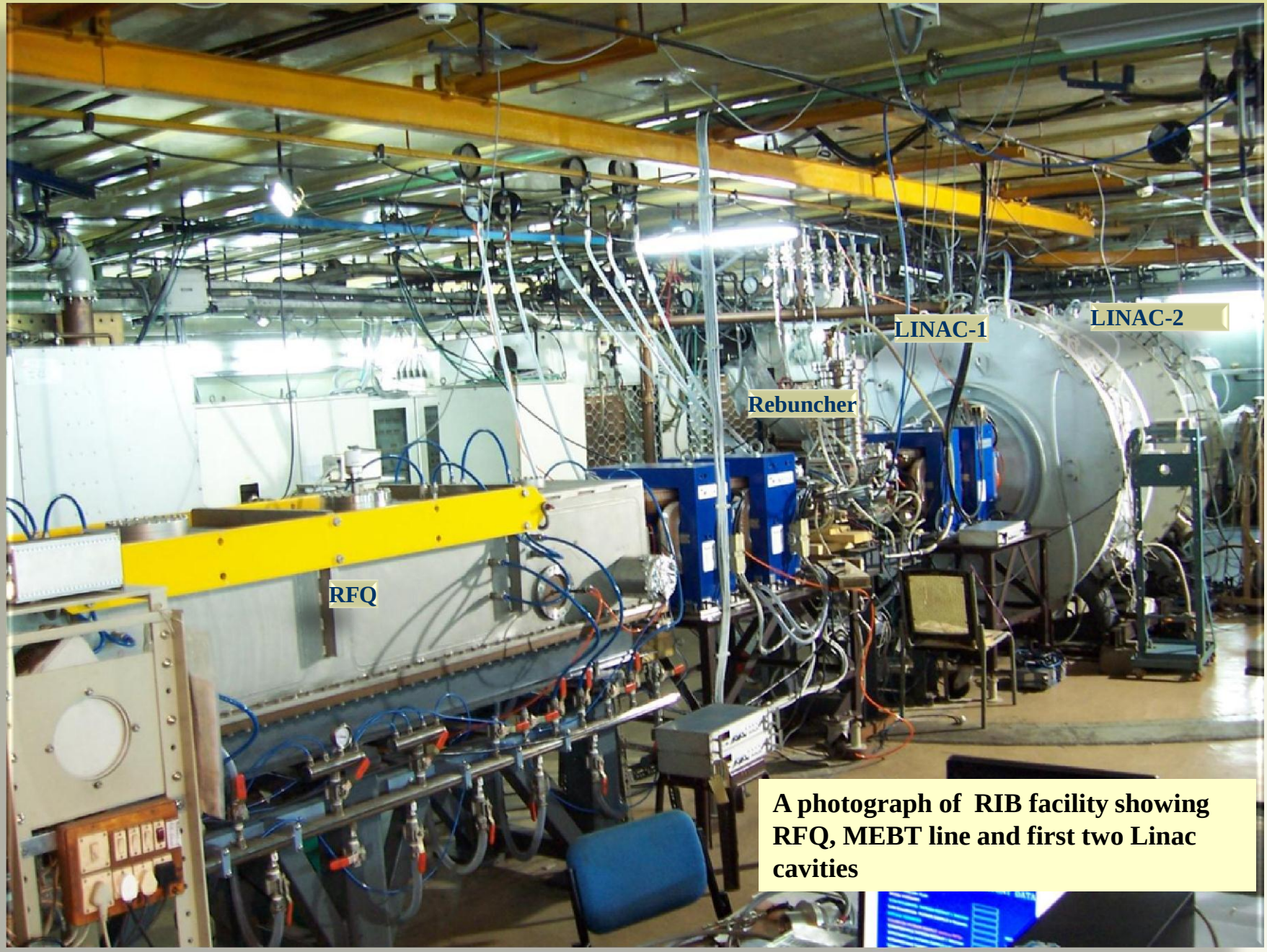
ECR ion source

Nucl. Instrum. & Meth. A 447 (2000) 345 ;
Nucl. Instrum. & Meth. A547 (2005)270.

Separator (ECR-RFQ beam-line)

Nucl. Instrum. & Meth. A562 (2006)41



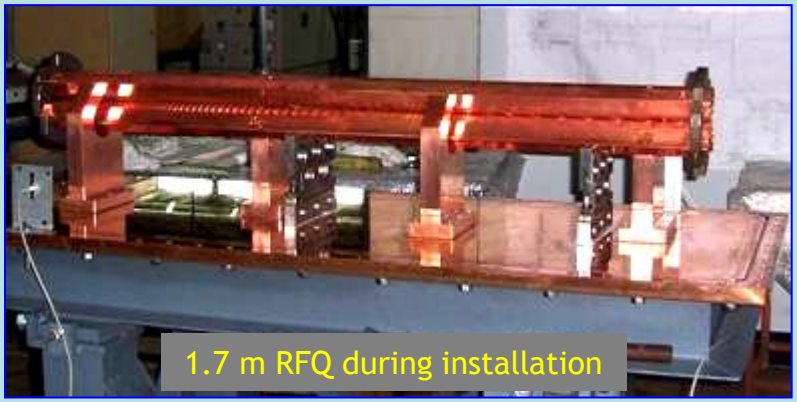


A photograph of RIB facility showing RFQ, MEBT line and first two Linac cavities

Milestones …

RFQ1: Sept 2005
Output energy = 29 keV/u

Rev Sci Instrum. 78 (2007) 043303 ;
Rev. Sci. Instrum. 80, (2009) 103303



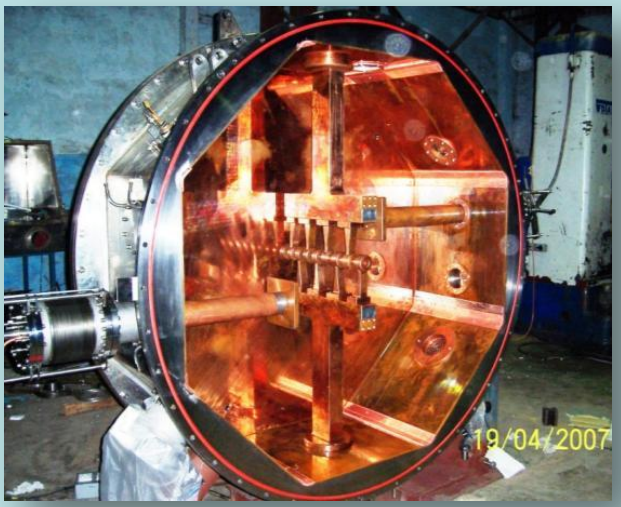
First RFQ in the country

RFQ2: July 2008
Output energy = 99 keV/u

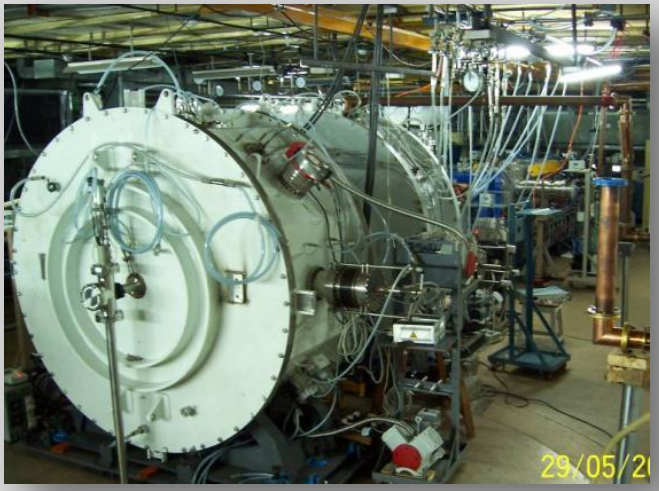
Rev Sci Instrum. 81 (2010) 023301
Rev. Sci. Instrum. 80, (2009) 103303

Stable isotope beams accelerated in RFQ used for material science experiments

Linac1: 2008, energy = 187 keV/u

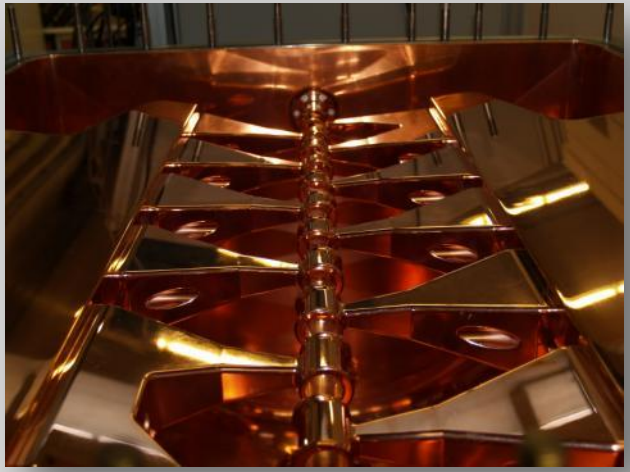


Linac2: 2010, energy = 289 keV/u



Linac3: 2011, energy = 415 keV/u

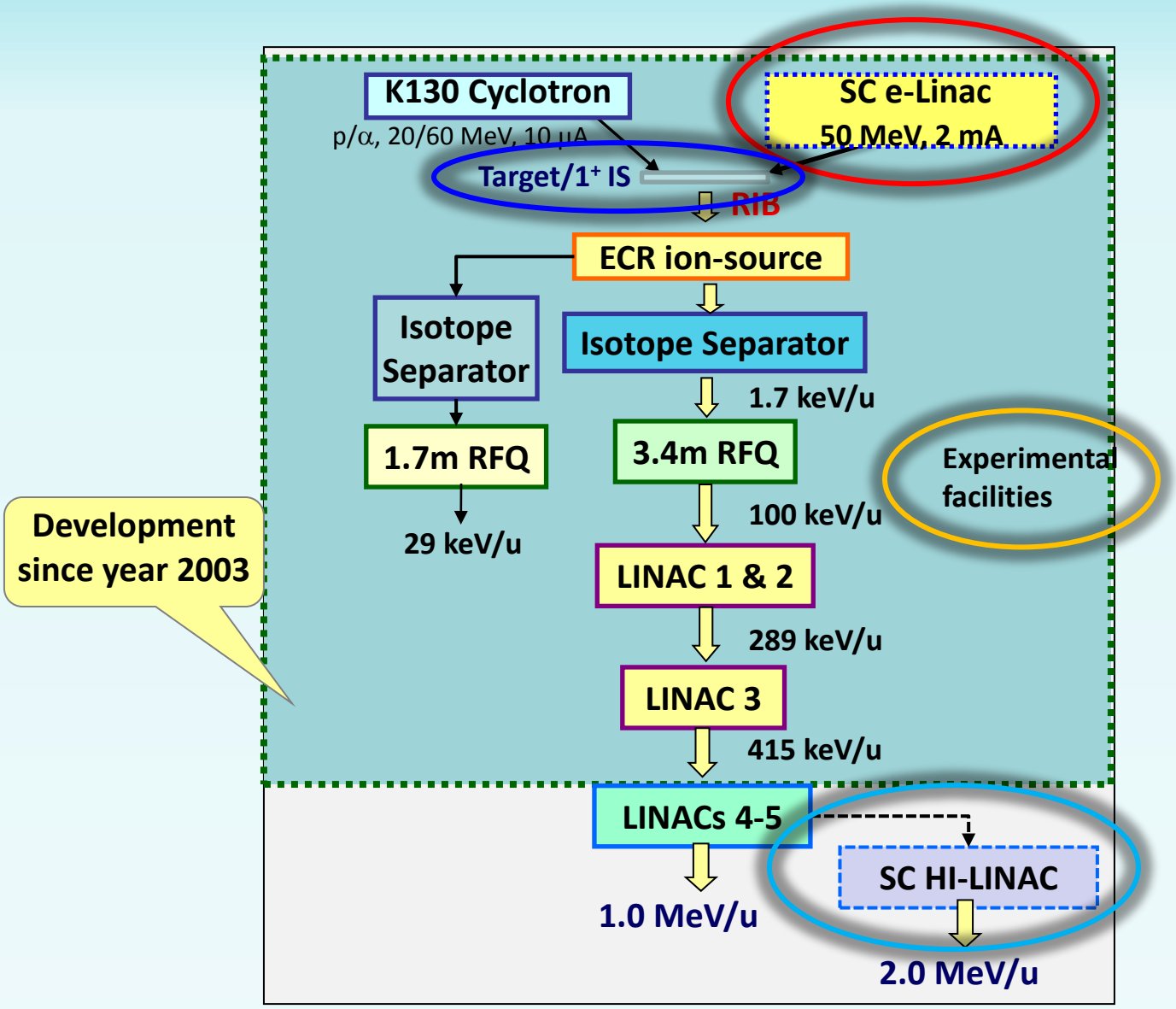
Linac4: 2012, energy = 718 keV/u



Nucl. Instrum. & Meth. A560 (2006)182
Pramana 75 (2010) 485.
Nucl. Instrum. & Meth. A 631 (2011)

Stable isotope beams accelerated to 415 keV/u

Radioactive Ion Beam – Activities in coming years

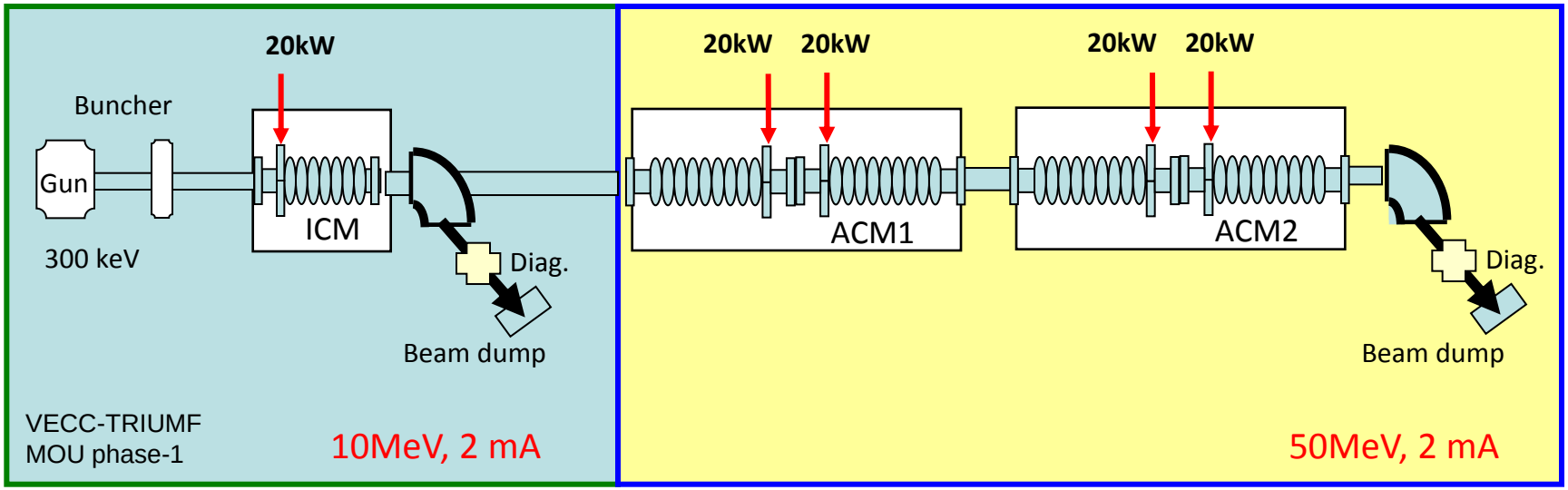


Scheme for RIB production & acceleration

50 MeV Superconducting Electron Linac – VECC-TRIUMF collaboration

Injector
300 keV to 10 MeV

Accelerator
10 MeV to 50 MeV



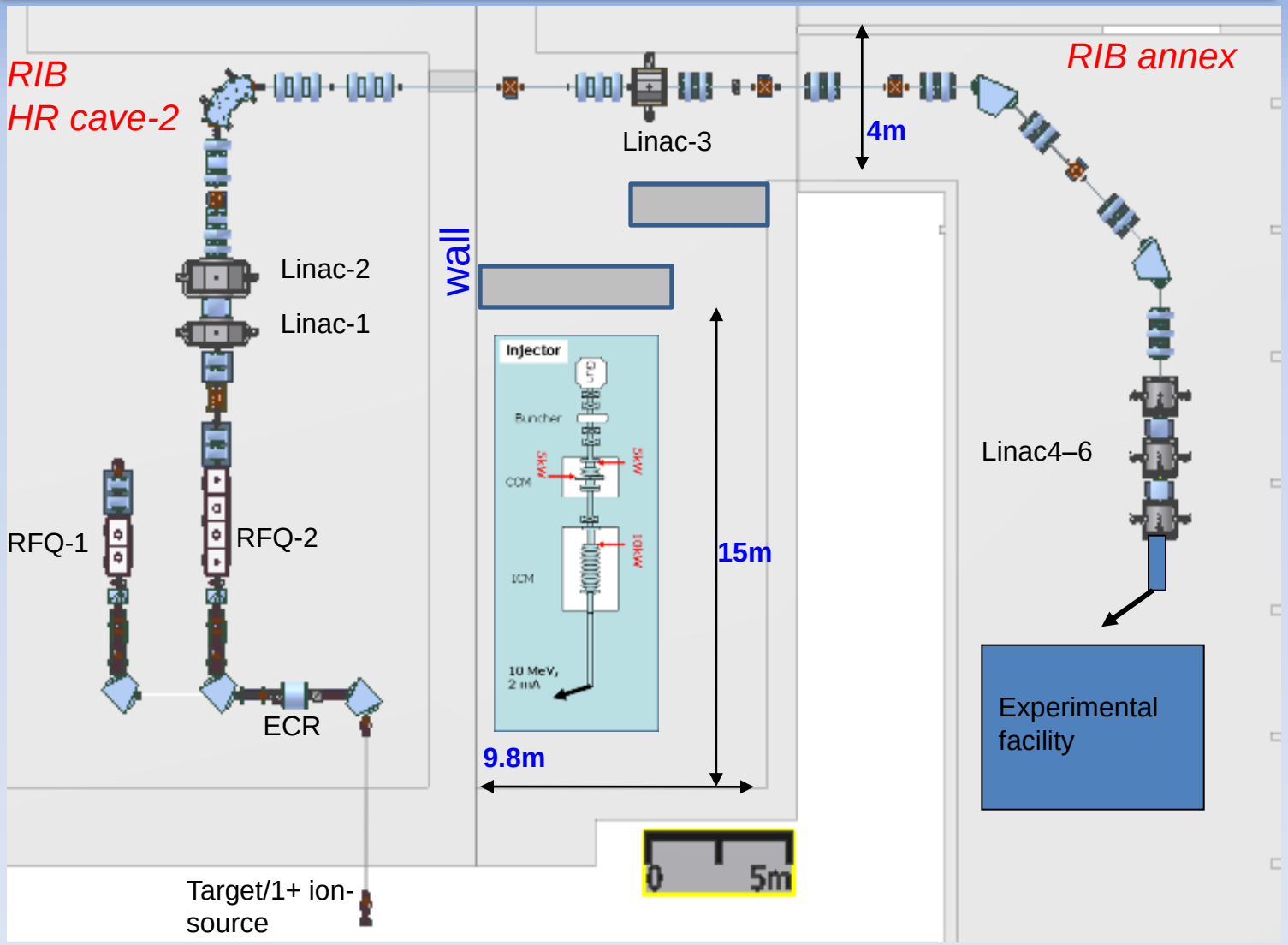
Phase-1 : 2009 – 2013

Phase-2 : 2013 – 2017

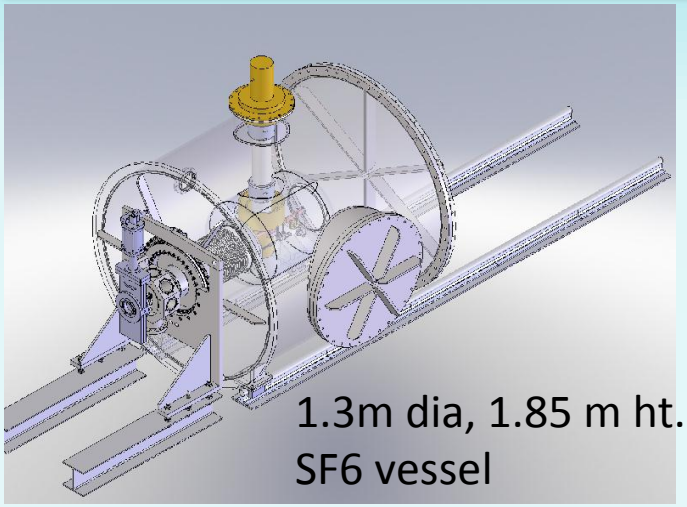
- 50 MeV, 2 mA; 100 kW CW, 1.3 GHz, 2 deg K; Being developed in collaboration with TRIUMF
- Production of neutron rich nuclei through photo-fission of Uranium
- based on 1.3 GHz, 2K SRF technology. High current CW acceleration – heavy beam loading, high cryogenic loads

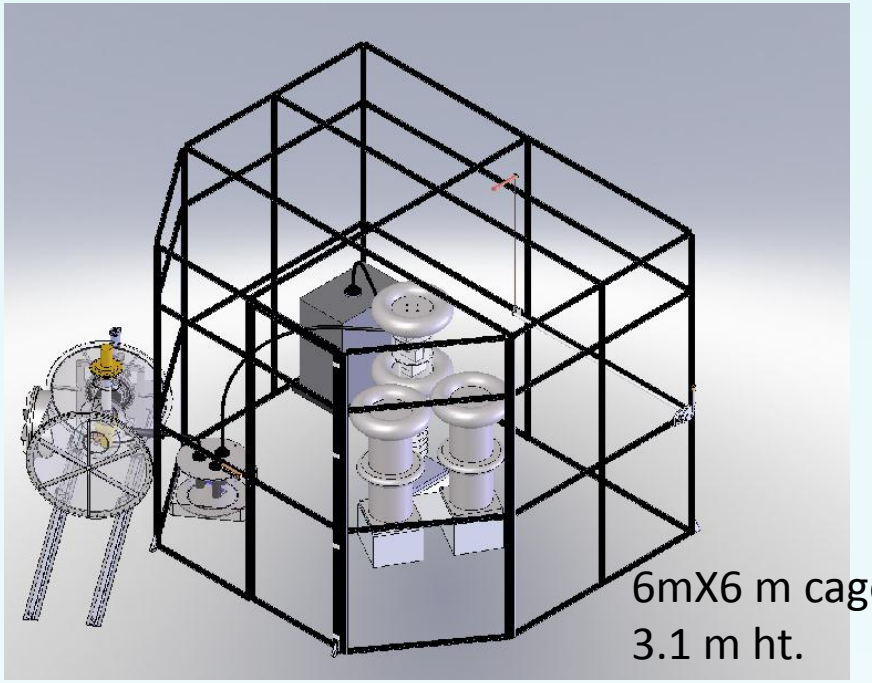
EMIS-2012, Matsue, Japan

Location of 10 MeV Electron Linac Injector at HR Cave 1



Site limitation in testing 10 MeV Injector at HR Cave 1

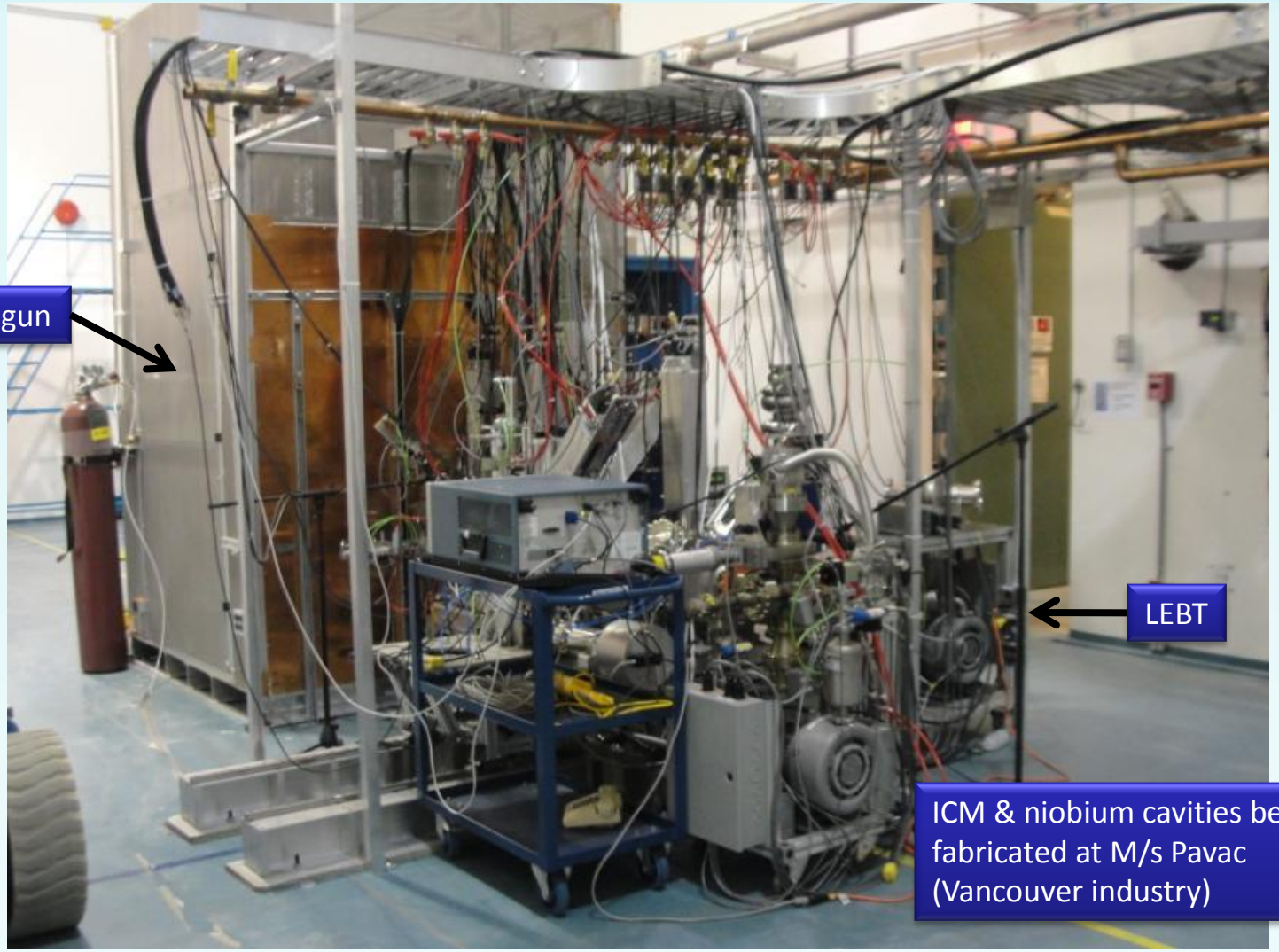




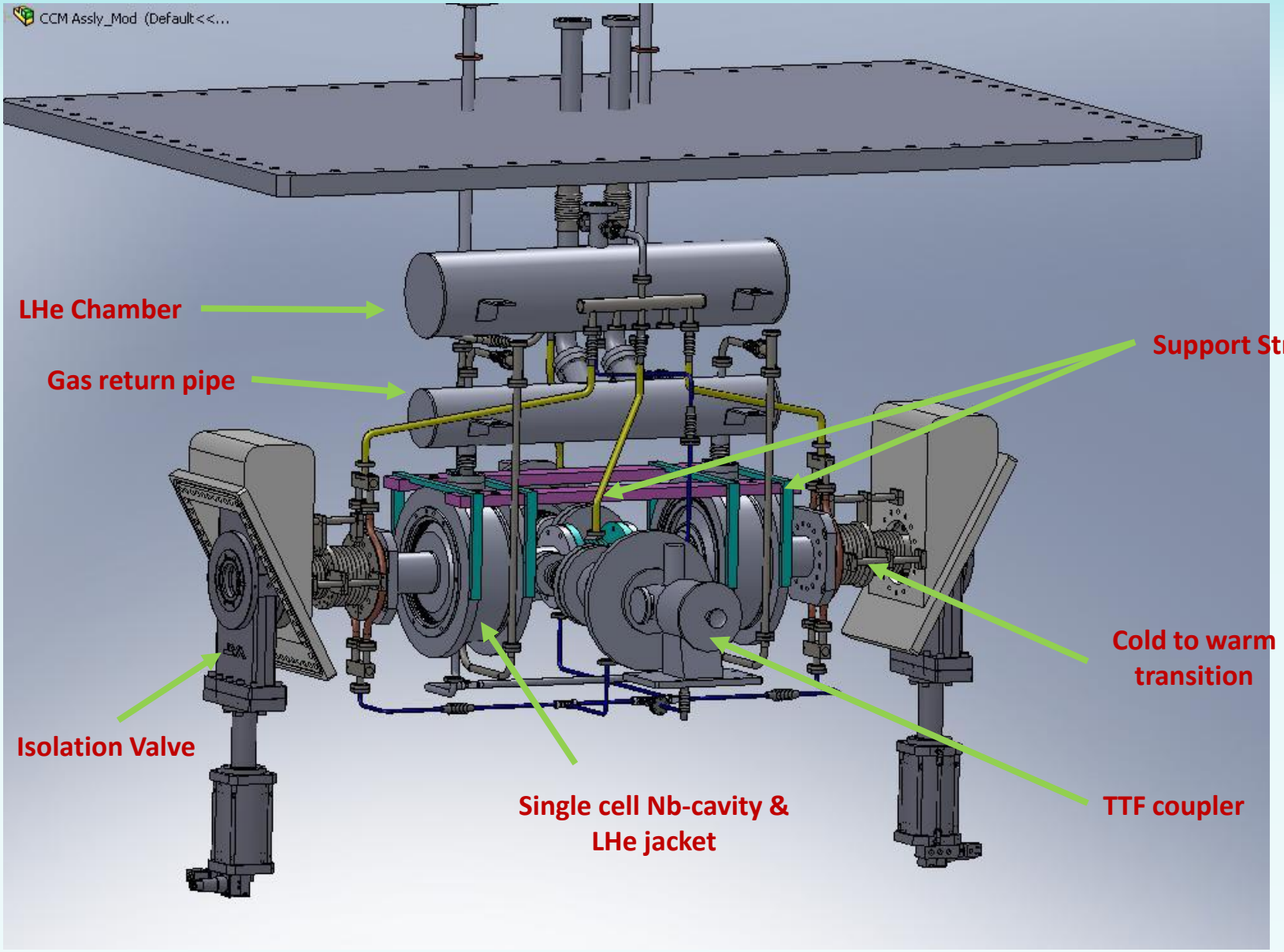
- e-Linac injector test area at VECC Kolkata has site limitations – will not allow 300 keV gun installation
  - 10 m x 15m available
  - ceiling is 3 m high
  - no experience in SF6 handling

- 10 MeV Injector at VECC campus to be tested with 100kV gun

VECC e-Linac test area set-up at TRIUMF for beam tests of ICM

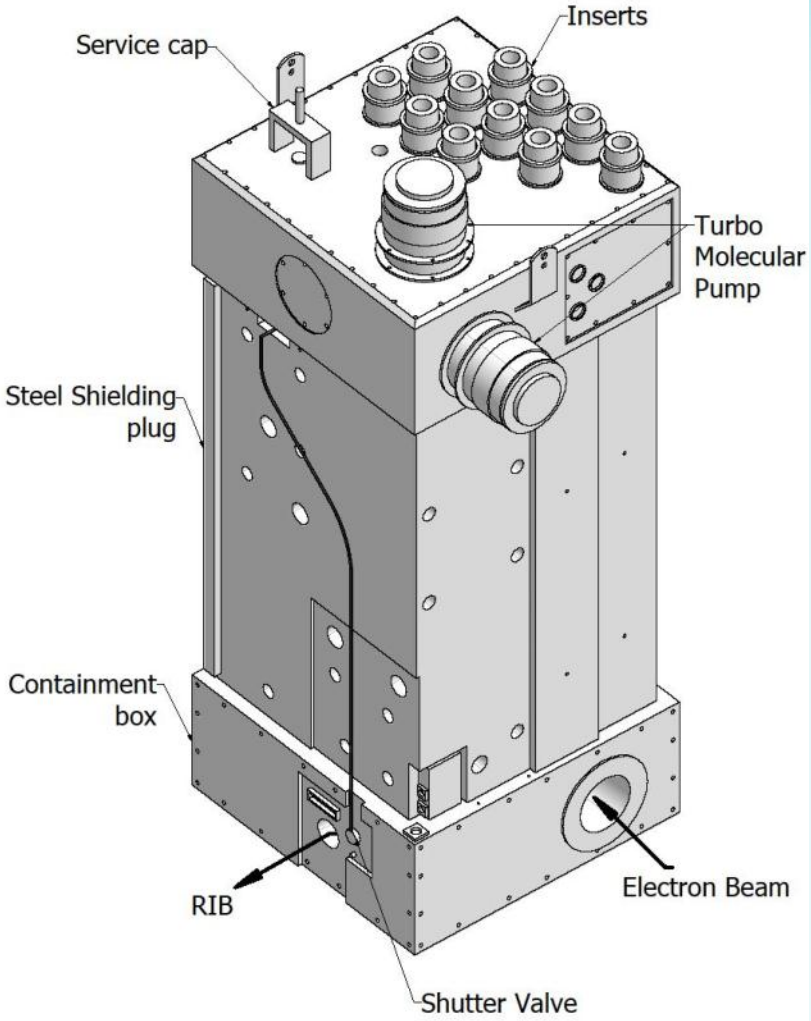


Capture Cryo-Module (CCM) for 10 MeV Injector



Manas Mondal, A. Sampath, A. Bose, Bob Laxdal

RIB Target/Ion-source (TIS) Module



Three Dimensional view of target/ion source module

Based on TRIUMF design

Main features

- Target /IS module can be lifted & transferred directly to hot-cell facility for maintenance.

- ANURIB beam-line will have 2 target stations. 3 target modules needed –
two placed in RIB beam-line and third kept ready for use when TIS module 1 or 2 is Removed for maintenance.

- high voltage inserts, o-rings etc. away from radiation zone.

collaborations …

RIKEN Japan – Physics design of accelerators, exotic nuclei physics

SAMEER Mumbai – RF transmitters

CMERI Durgapur – RFQ vanes, posts

TRIUMF Canada – SC electron linac

Summary

- VECC is planning to build a facility for rare isotope beams – the ANURIB facility
- It is to be built around a superconducting electron linac photo-fission driver as primary accelerator
- Much development has been done at VECC in preparation for the ANURIB facility for past decade or so.
- 10 MeV superconducting electron linac Injector is being developed in collaboration with TRIUMF for the e-Linac
- New areas of collaboration namely design & development of target module and SC-QWR cavities

Thank you