Radioactive Beam Facilities for Tomorrow

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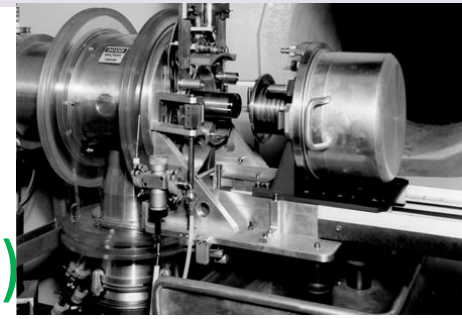
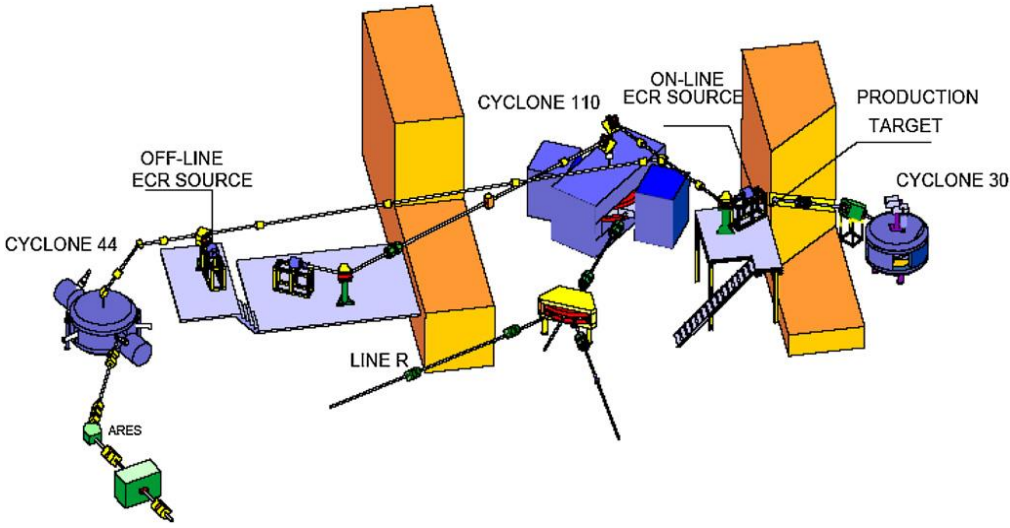
The 20th Century Concept

- Fragmentation
- Bevalac (1984)



- ISOL
- ISOLDE(1967)
- Louvain la Neuve (1989)



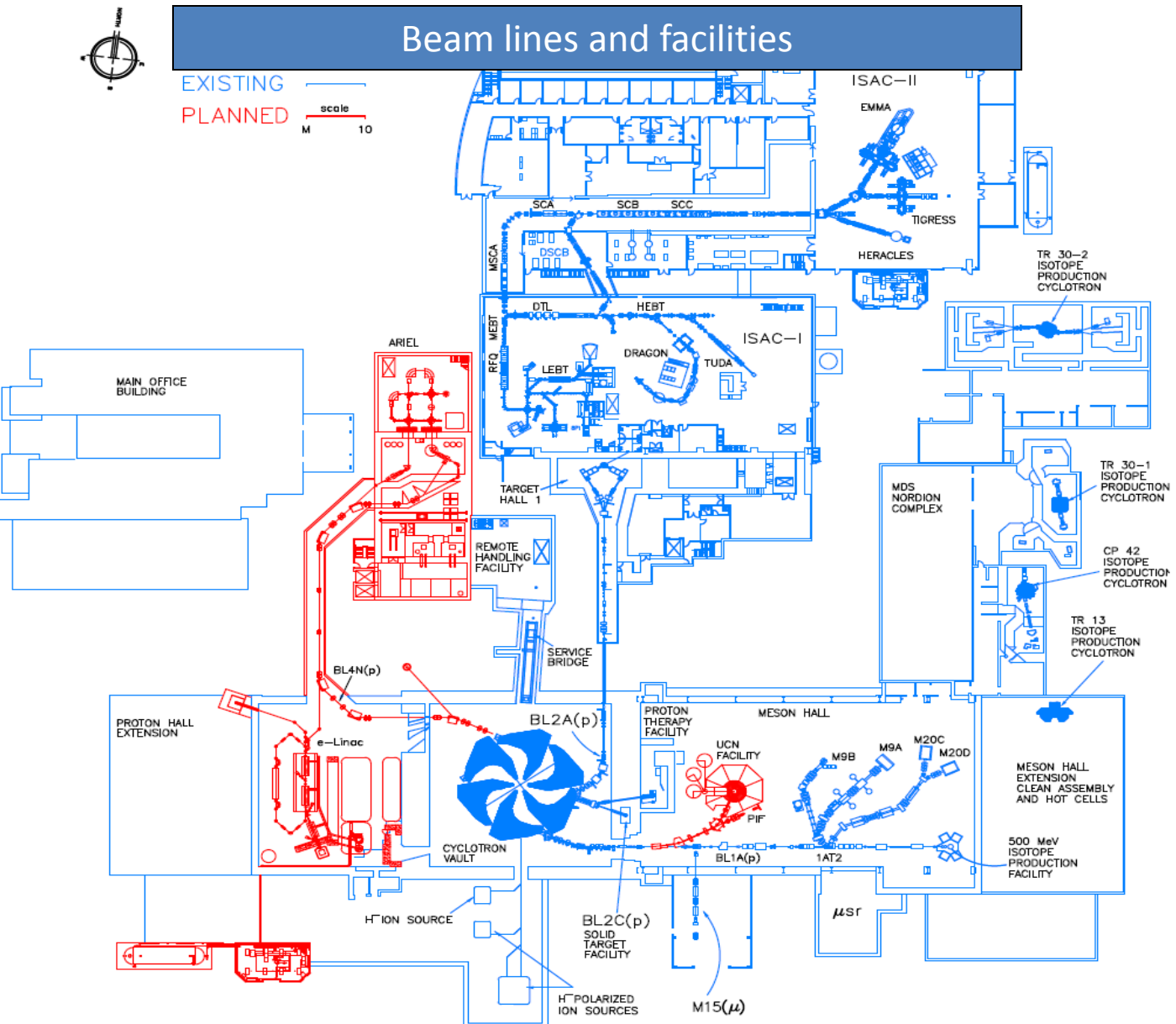
World's First and Strongest
K2600MeV
Superconducting Ring Cyclotron

400 MeV/u Light-ion beam
345 MeV/u Uranium beam

World's Largest Acceptance
9 Tm
Superconducting RI beam Separator

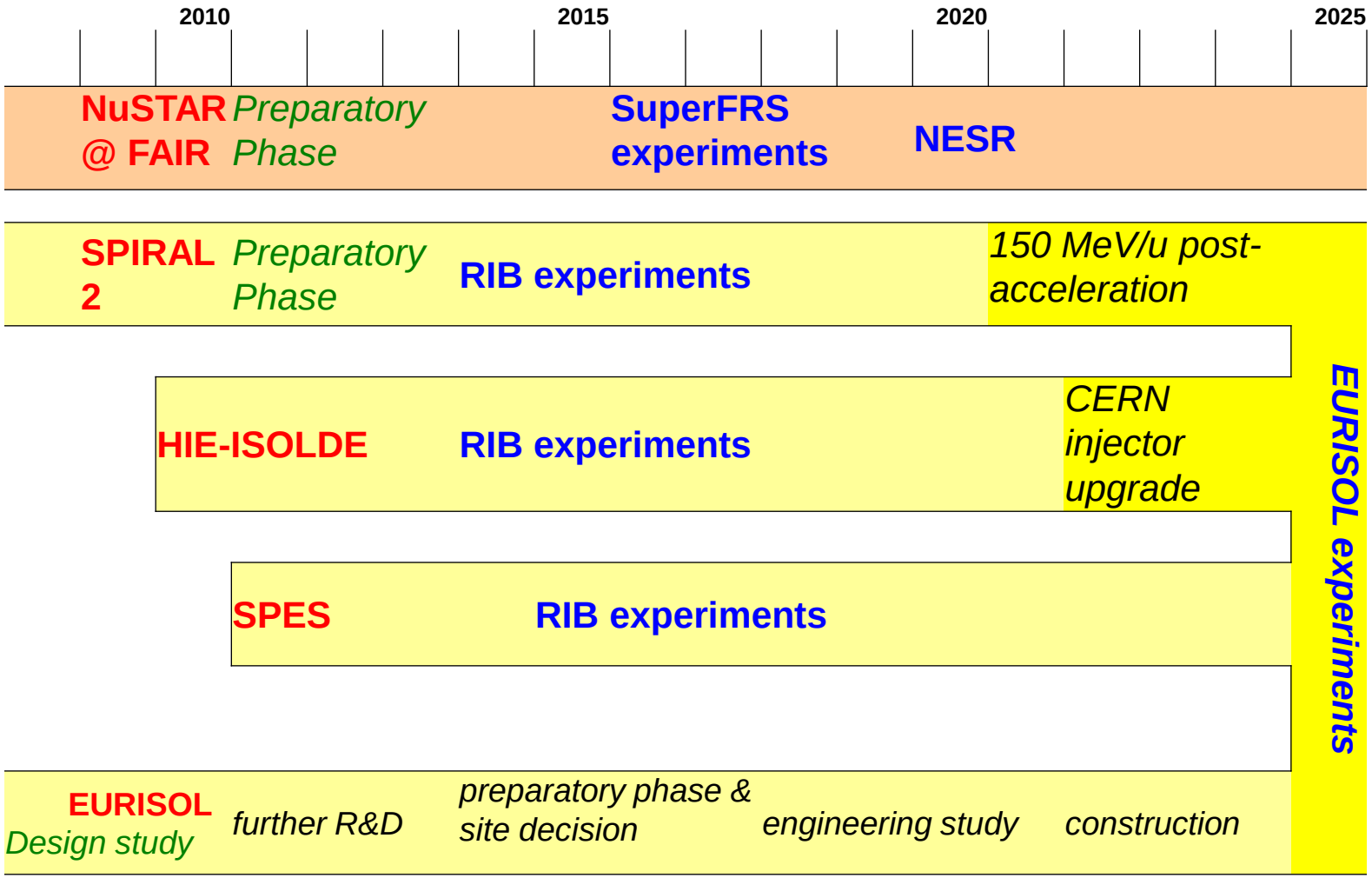
~250-300 MeV/nucleon RIB

ISAC and ARIEL @ TRIUMF

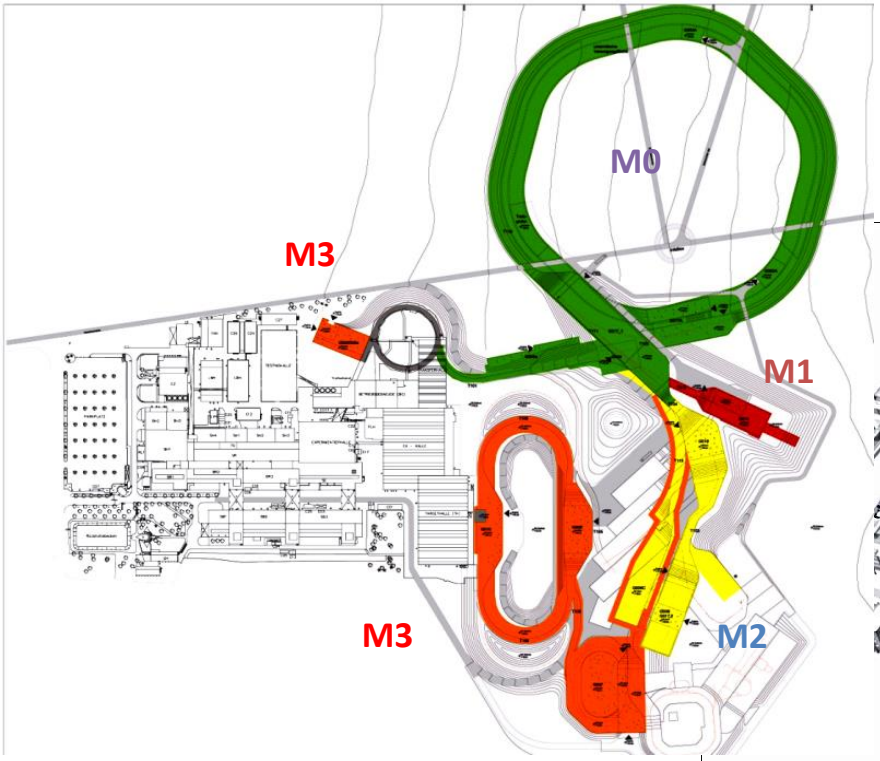


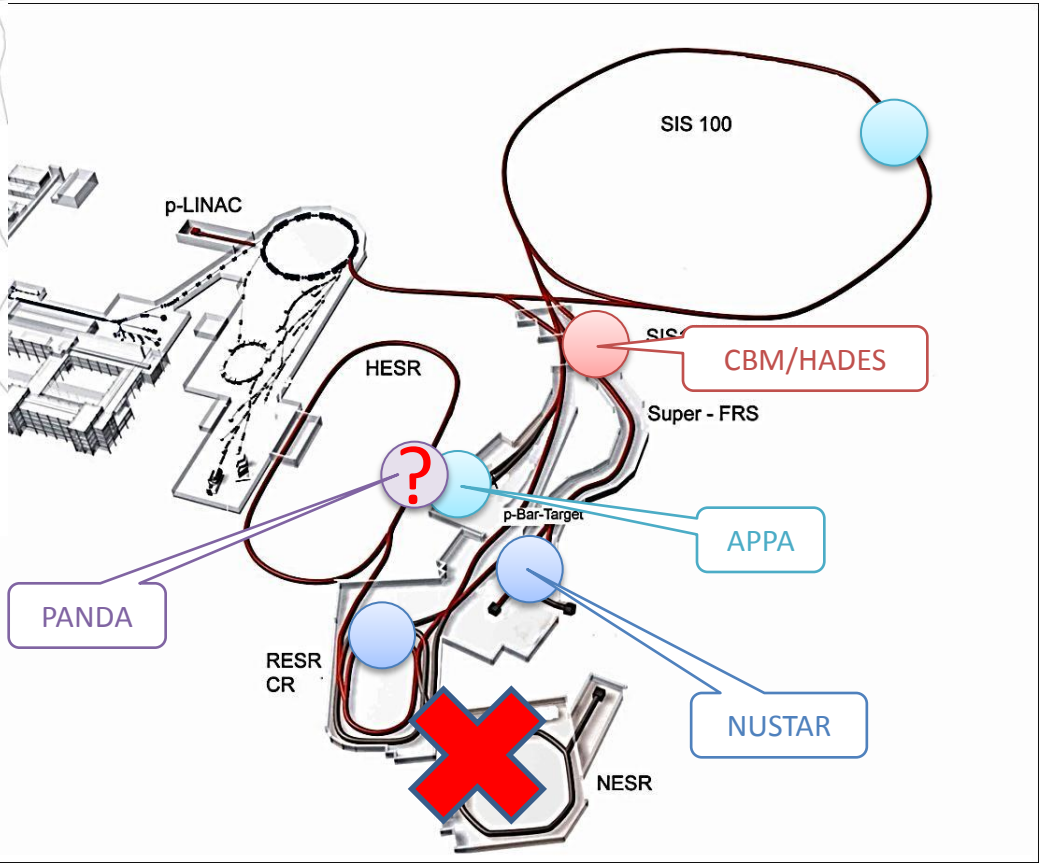
- **BL4N is planned to deliver 500-MeV protons to new actinide target station for beam production**
- **Provide independent production via photo-fission for 'new isotopes' and for ~12 months running (during cyclotron shut-down)**
- **Develop new front end to permit three simultaneous RIB beams (two accelerated)**

NuPECC Long Range Plan 2010 Timeline RIB Facilities



FAIR Modularised Start Version





Experiments

M1: APPA

M1: CBM/HADES

M2: NUSTAR

M3: PANDA

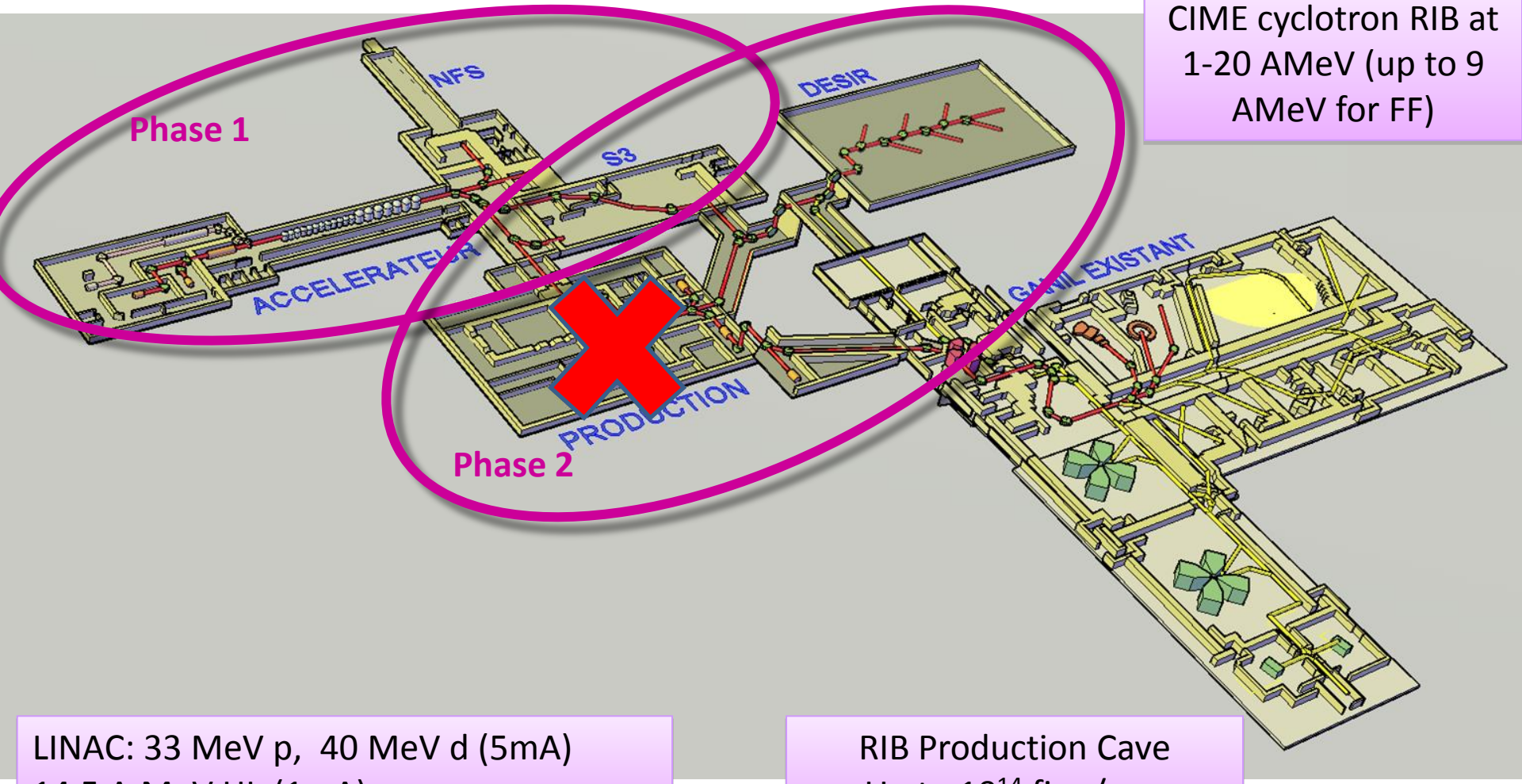
Courtesy Herve Savajols

SPIRAL2 under construction

Phase 1: High intensity stable beams in 2016 + Experimental rooms (S^3 + NFS)

Phase 2: High intensity Radioactive Ion Beams (RIB)

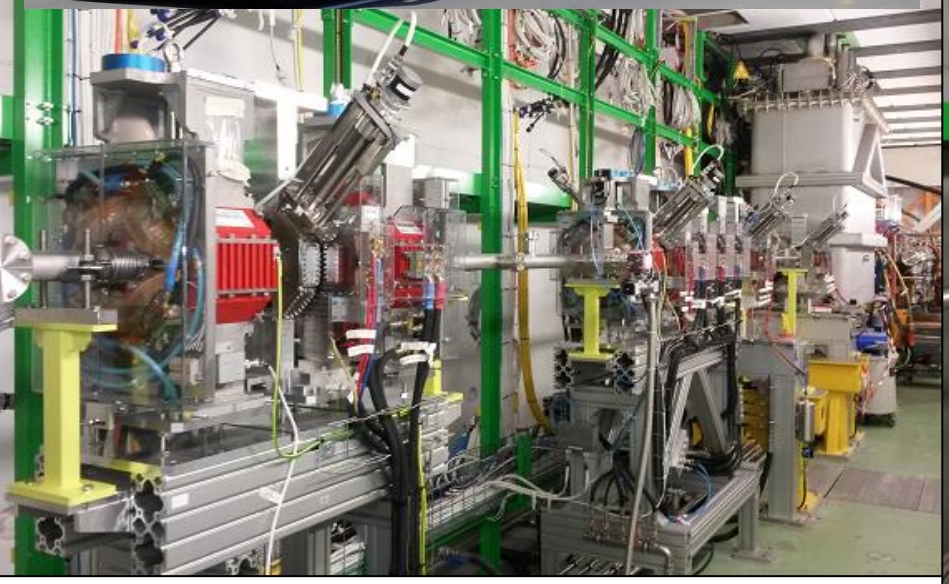
CIME cyclotron RIB at 1-20 AMeV (up to 9 AMeV for FF)

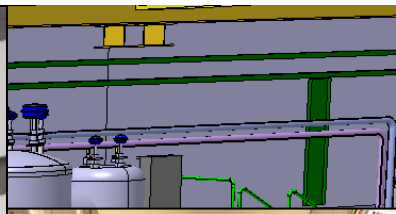


LINAC: 33 MeV p, 40 MeV d (5mA)
14.5 A.MeV HI (1mA)

RIB Production Cave
Up to 10^{14} fiss./sec.

HIE LINAC elements

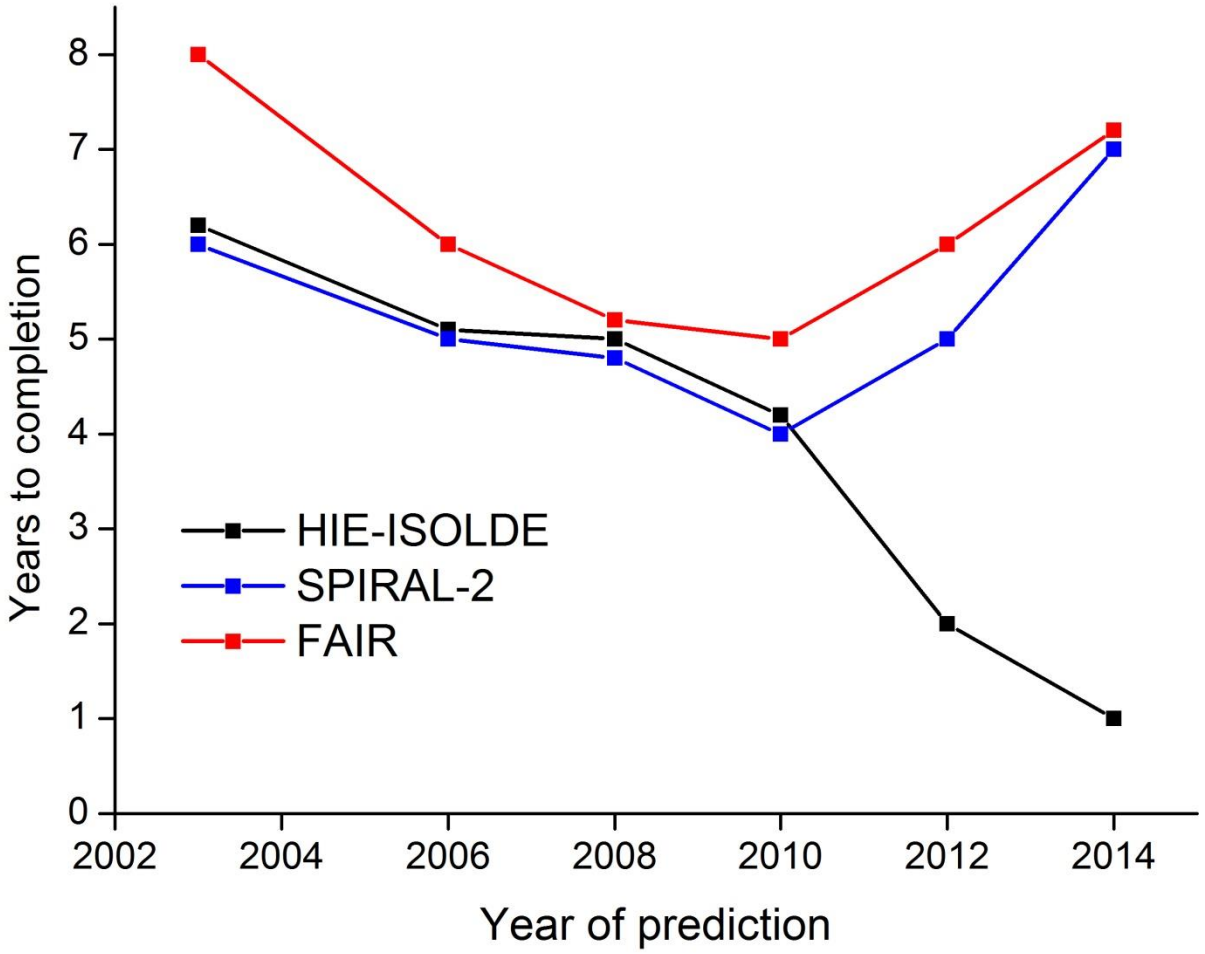




Cryo Module 1 arrived Saturday 2nd May.
XT00 HW commissioning for the elements and vacuum system done.
All infrastructure was ready by 2nd June to start CM1 HW commissioning.
Scenario: Physics at ~4MeV/u with 1 CM as of mid October 2015

SPES @ Legnaro

European RIB



Made by Peter Butler

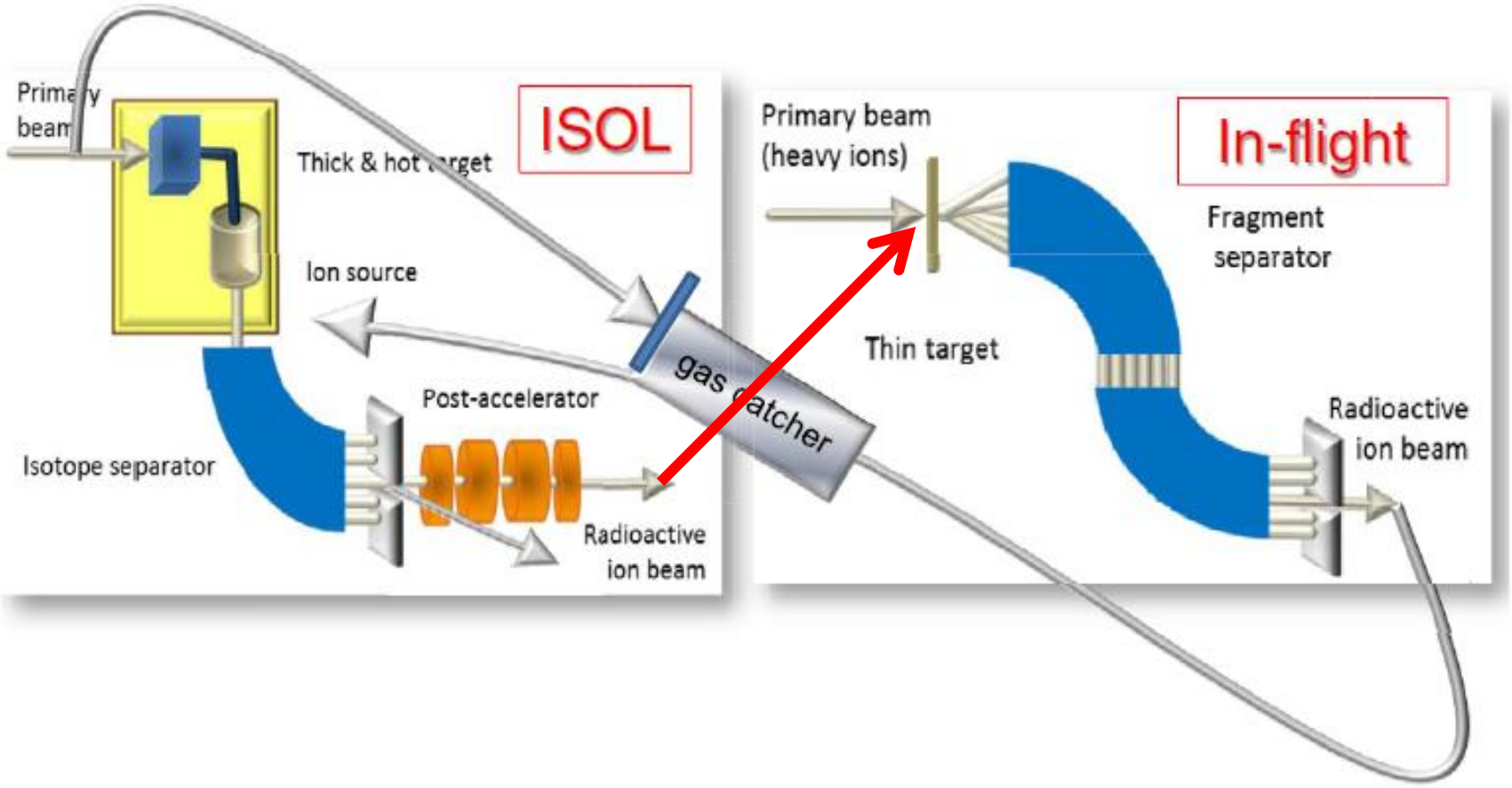
Europe can build large scientific facilities

Accelerator tunnel at ESS, Lund, Sweden

Some reflections on the difficulties encountered

- Too many projects; lack of European coordination?
- Shrinkage of the community?
- Difficulties of coordination of multiple funding sources?
- Unreasonable safety requirements?
- Lack of emphasis on societal applications?
- Lack of scientific focus?
- ….

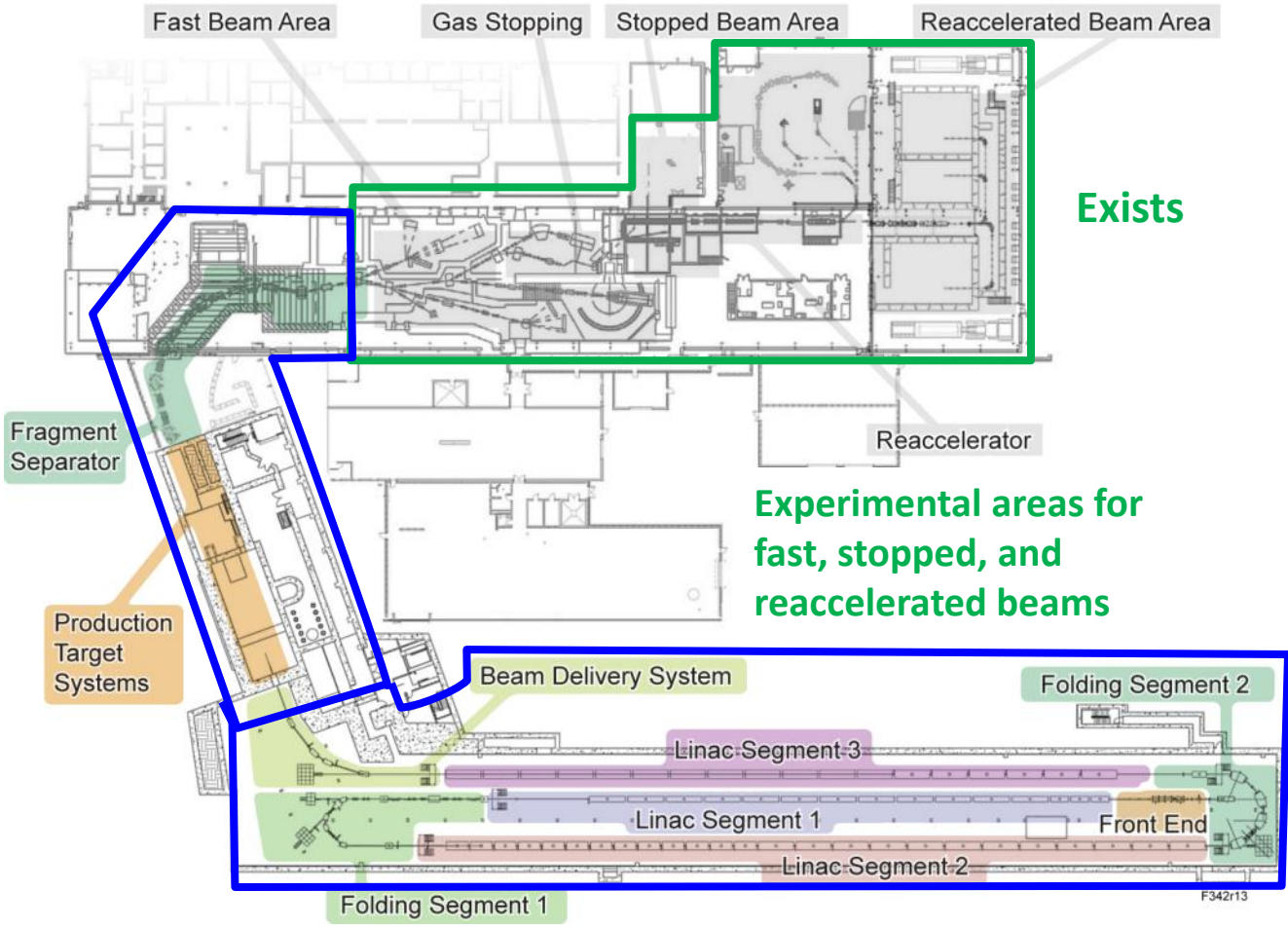
21st Century: The Best of Both Worlds

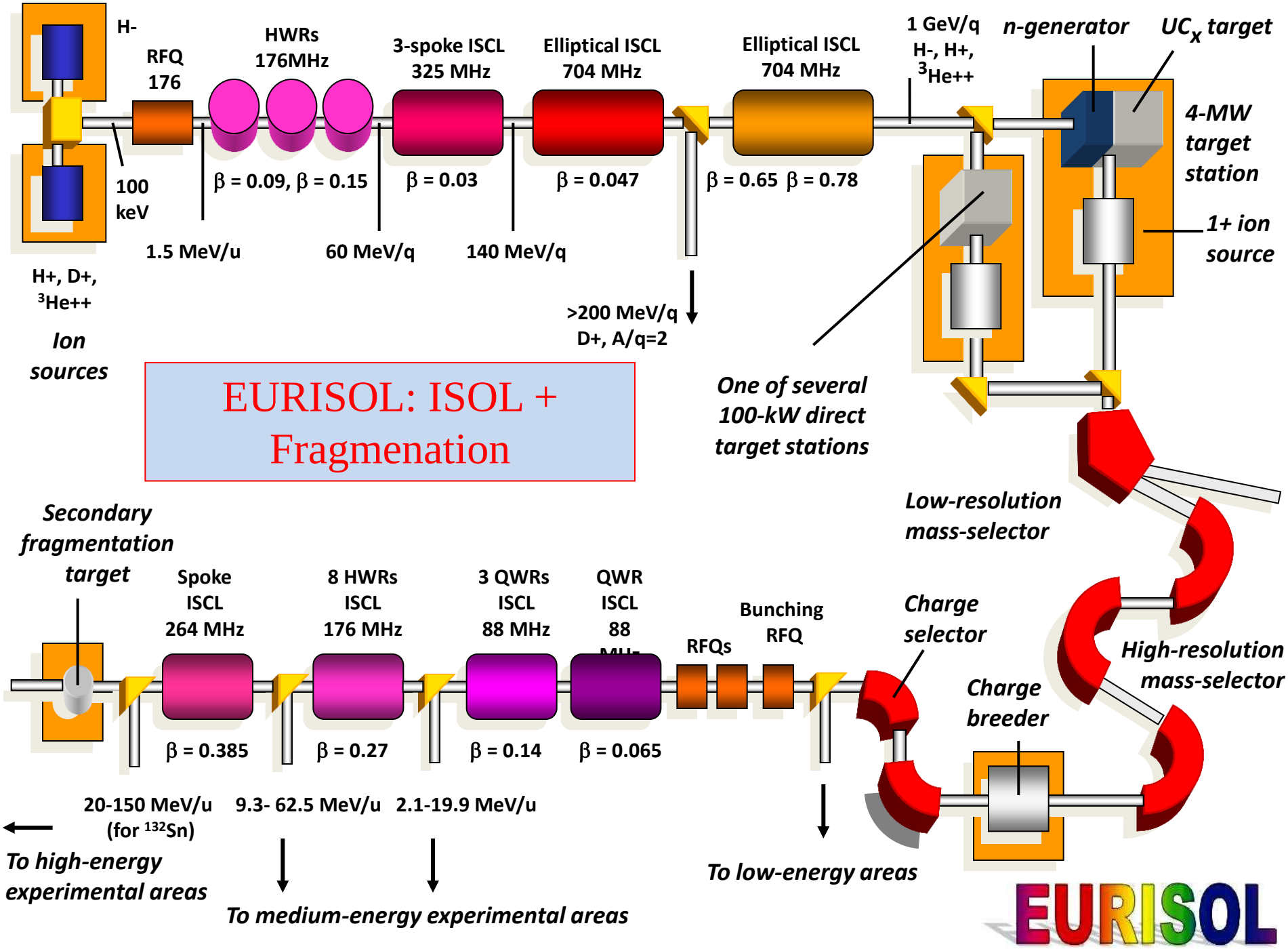


Facility for Rare Isotope Beams:

In-Flight+ Post-acceleration

- Conventional Facilities
  - Linac tunnel and service building
  - Target building
- Accelerator Systems
  - Frontend
  - Linear Accelerator
  - Central Systems
- Experimental Systems
  - Production target facility and fragment separator
  - Beam stopping systems, reaccelerator, experimental areas, experimental equipment

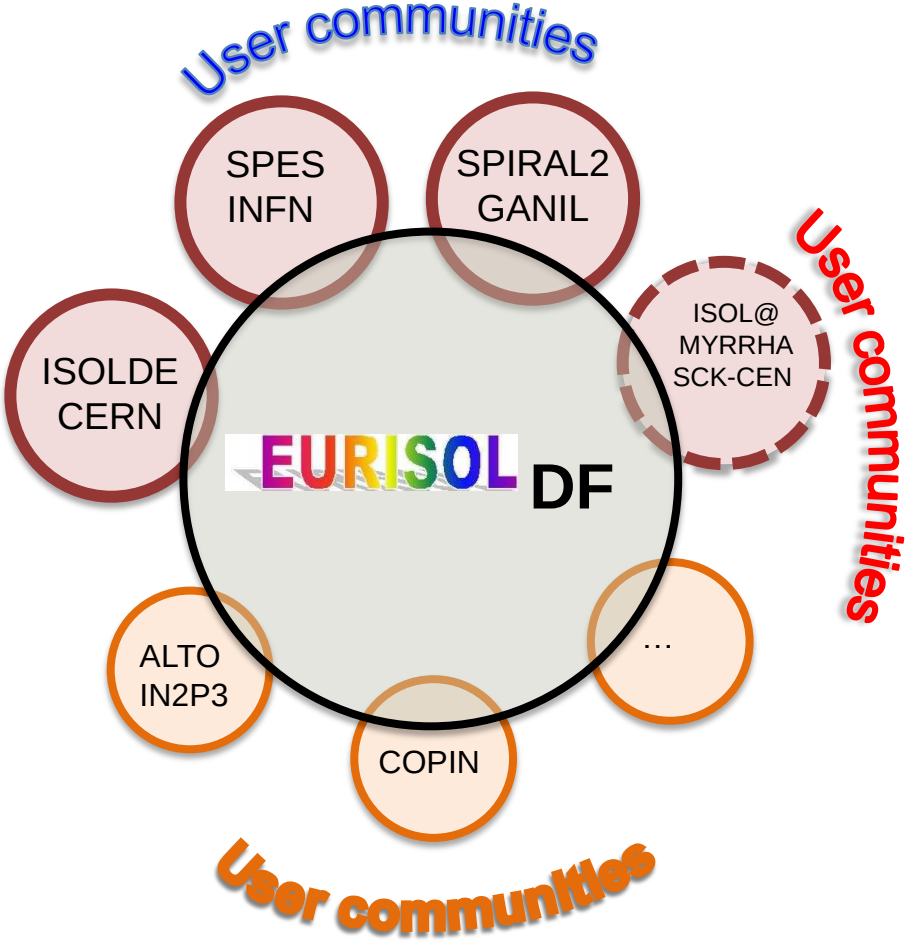



H-
RFQ
176
HWRs
176MHz
3-spoke ISCL
325 MHz
Elliptical ISCL
704 MHz
Elliptical ISCL
704 MHz
1 GeV/q
H-, H+,
3He++
n-generator
UCx target
4-MW
target
station
1+ ion
source
100
keV
β = 0.09, β = 0.15
β = 0.03
β = 0.047
β = 0.65 β = 0.78
1.5 MeV/u
60 MeV/q
140 MeV/q
H+, D+,
3He++
Ion
sources
>200 MeV/q
D+, A/q=2
One of several
100-kW direct
target stations
EURISOL: ISOL +
Fragmenation
Low-resolution
mass-selector
Secondary
fragmentation
target
Spoke
ISCL
264 MHz
8 HWRs
ISCL
176 MHz
3 QWRs
ISCL
88 MHz
QWR
ISCL
88
RFQs
Bunching
RFQ
Charge
selector
High-resolution
mass-selector
Charge
breeder
β = 0.385
β = 0.27
β = 0.14
β = 0.065
20-150 MeV/u
(for 132Sn)
9.3- 62.5 MeV/u
2.1-19.9 MeV/u
To high-energy
experimental areas
To low-energy areas
To medium-energy experimental areas
EURISOL

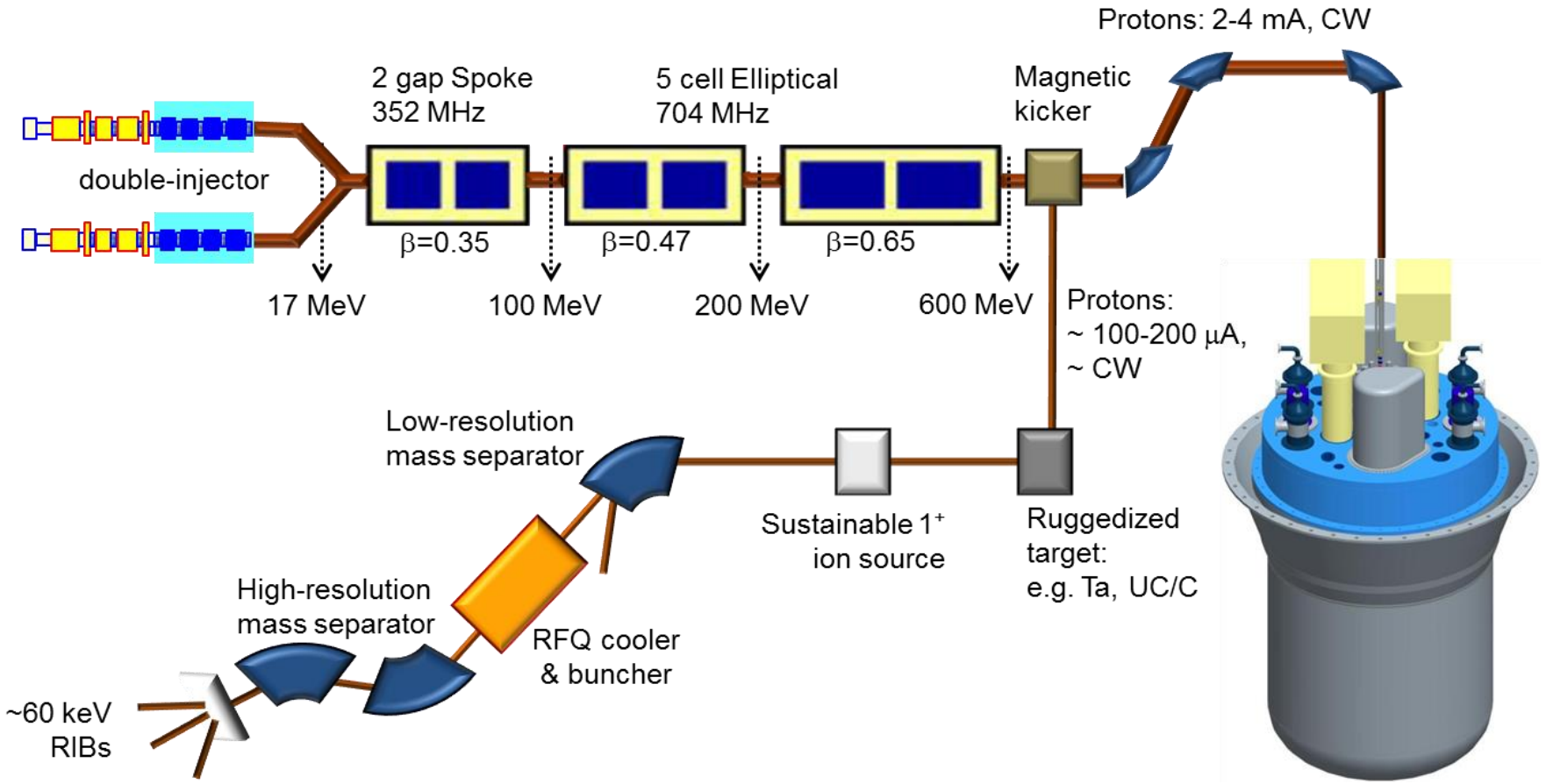
EURISOL – Distributed Facility (DF) Initiative

Goals:

- Prepare strong scientific case for RIB science and applications
- Support, upgrade, optimize and coordinate ISOL-based European facilities and projects (HIE-ISOLDE, SPES, SPIRAL2, ISOL@MYRRHA) as a necessary step towards EURISOL
- Foster R&D on RIB production and Instrumentation towards EURISOL
- Get EURISOL-DF on the ESFRI list as a candidate project by 2018
- EURISOL as a single site facility as a long term goal



ISOL@MYRRHA


Protons: 2-4 mA, CW
2 gap Spoke
352 MHz
5 cell Elliptical
704 MHz
Magnetic
kicker
double-injector
β=0.35
β=0.47
β=0.65
17 MeV
100 MeV
200 MeV
600 MeV
Protons:
~ 100-200 μA,
~ CW
Low-resolution
mass separator
Sustainable 1⁺
ion source
Ruggedized
target:
e.g. Ta, UC/C
High-resolution
mass separator
RFQ cooler
& buncher
~60 keV
RIBs

A bright novel idea: SCRIT Electron Scattering Facility

RIKEN NiSHiNA CENTER

Wakasugi et al.

2009 Facility constructions
2010 Tuning of accelerators
Installation of SCRIT
2011 SCRIT performance test
ISOL commissioning
2012 Test of RI production
Tuning of ISOL
2013 Upgrade RTM
Construction e-Spectromete
Full-scale RI production
Start Experiments for RI's

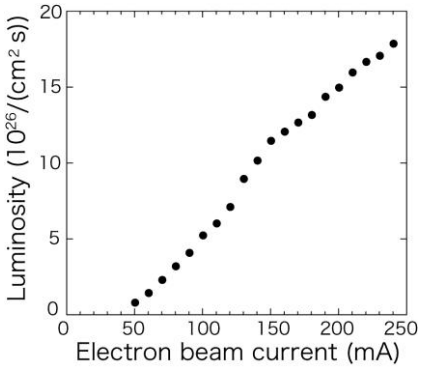
Commissioning of ISOL and preparation of UCx target

Training of target production $^{238}UO_2$+C (disk) → UCx (^{238}U 30g)

Test with stable Xe isotopes
Mass resolution M/ΔM 1660
Overall efficiency 21 %

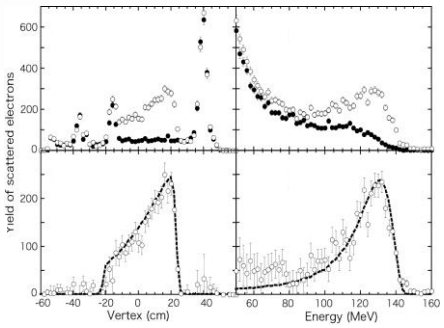
Test Experiments using Stable ^{133}Cs

Achieved luminosity 1.8×10^{27} /(cm^{2}s)
Ion trapping efficiency 85 %
at 240 mA



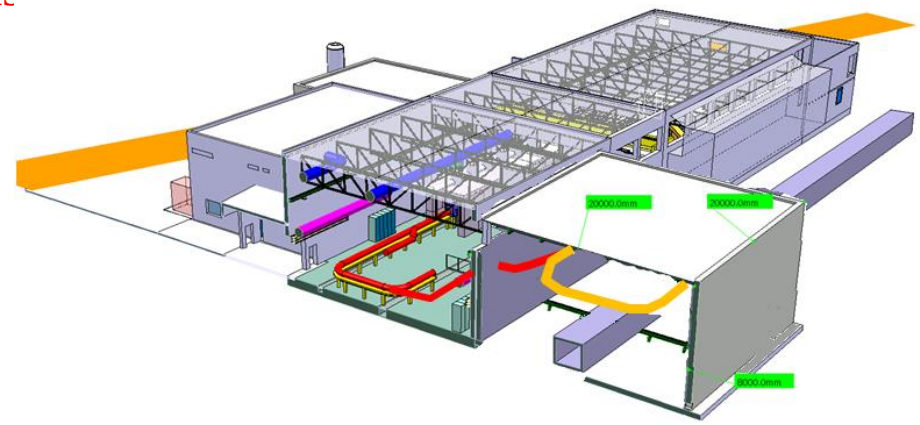
Measurements of Electrons elastically scattered from trapped Cs ions in SCRIT

○ with Cs
● without Cs



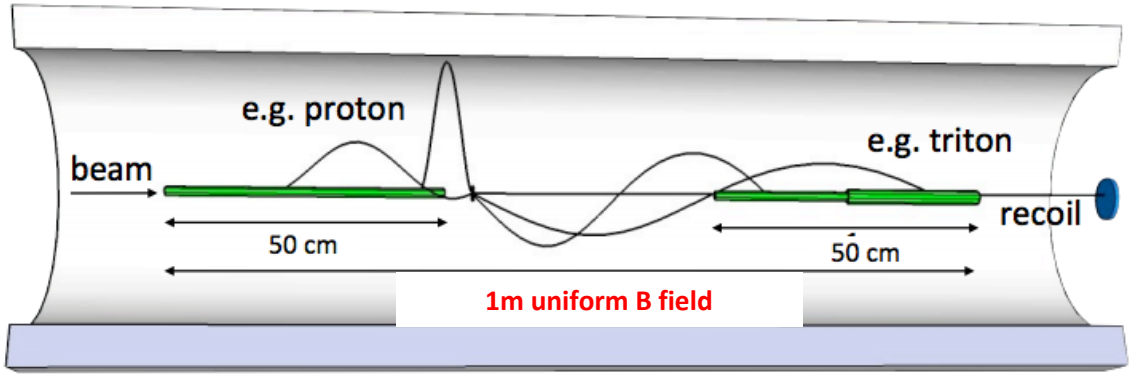
Physics cases for the TSR@ISOLDE

1. Half-life measurements of ^{7}Be in different atomic charge states
2. Capture reactions for astrophysical p-process
3. Nuclear astrophysics through transfer reactions
4. Nuclear structure through transfer reactions
5. Long-lived isomeric states
6. Atomic effects on nuclear half-lives
7. Di-electronic recombination on exotic nuclei
8. Atomic physics experiments
9. Neutrino physics
10. Laser spectroscopy experiments in the storage ring



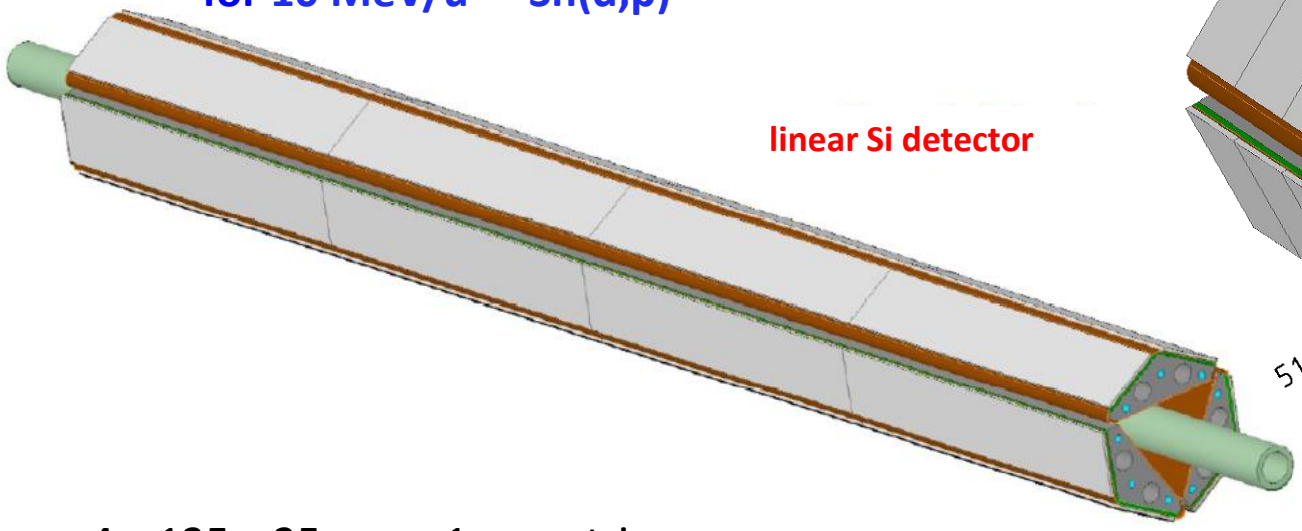
External target: HELIOS

Funded by UK

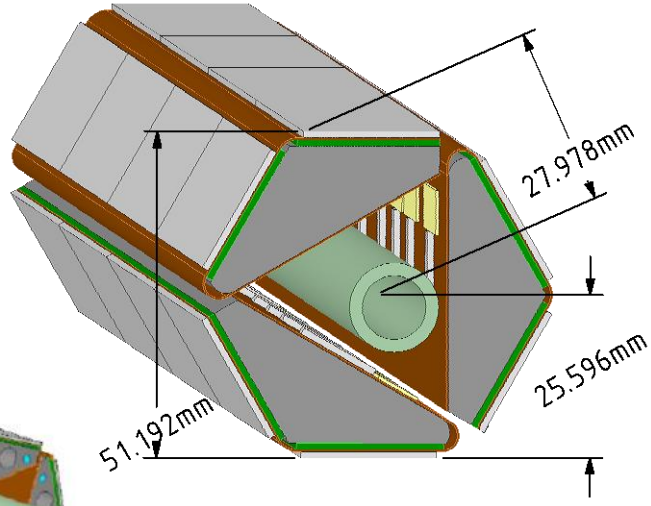


detector

e.g. Q-value = 1.01 E_{lab} (MeV) - 9.92 - 0.21 z (cm)
for 10 MeV/u ^{132}Sn(d,p)



linear Si detector



4 x 125 x 25 mm; 1 mm strips
R^3B-type ASIC readout