Korea RI Accelerator

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On behalf of KoRIA Project Team

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KoRIA in Short

- RI Accelerator in Korea
- ISOL and In-Flight method
- Multi-purpose
  - Not just for nuclear physics
- Proposed budget: 450 M$
- Timeline
  - Design: 2009 - 2012
  - Construction: 2012 - 2016

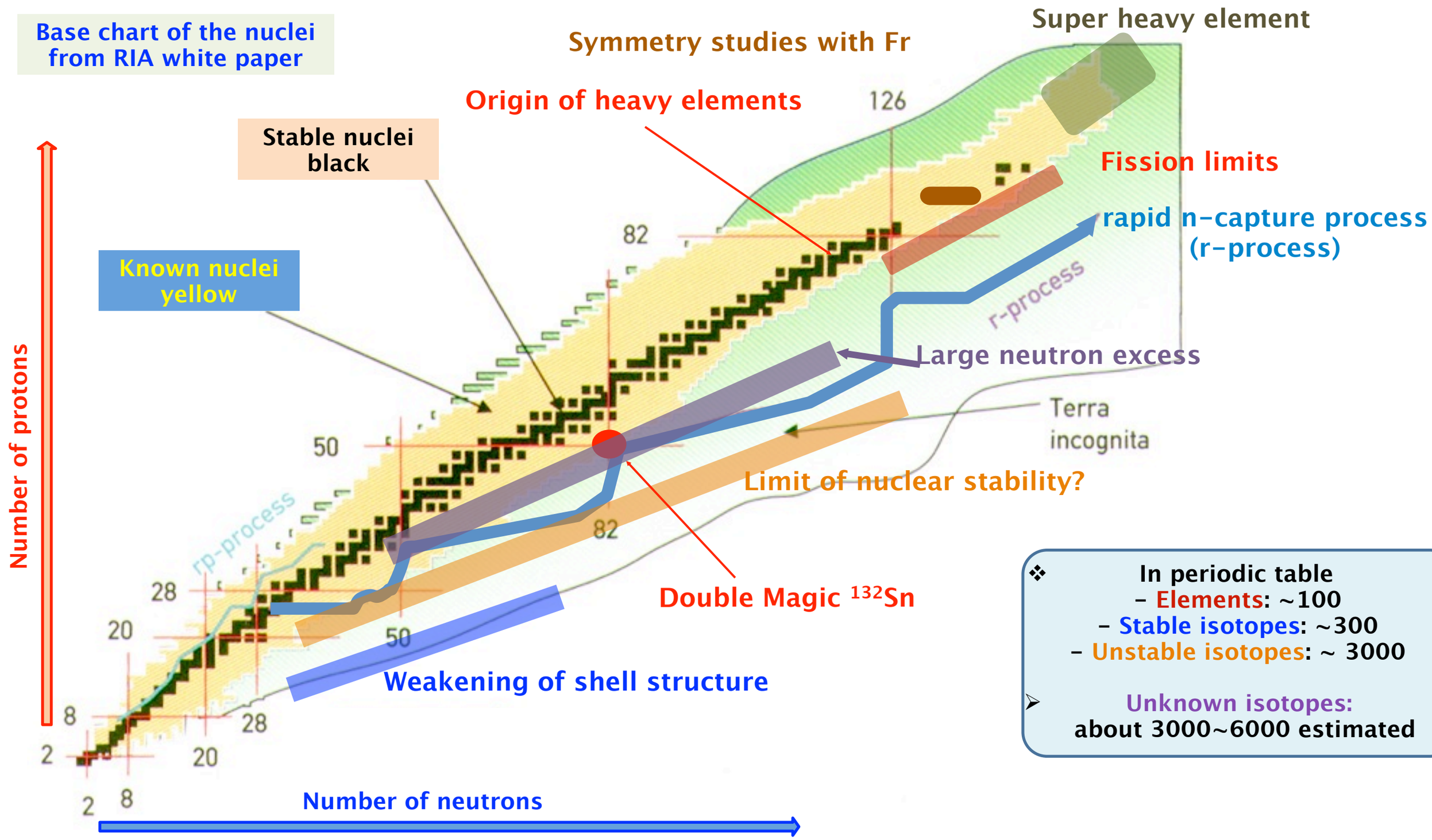
Key Elements

- 200MeV/u, 8pμA Superconducting Linac
- Cyclotron driven ISOL facility
- Particles : H ~ U, Stable Heavy Ion and Unstable Radioactive Isotope
- Both ISOL & In Flight method for production of rare isotope beams

Why RIs?

"Nuclear science is entering a new era of discovery in understanding how nature works at the most basic level and in applying that knowledge in useful ways".

– National Academy 2007 RISAC Report –

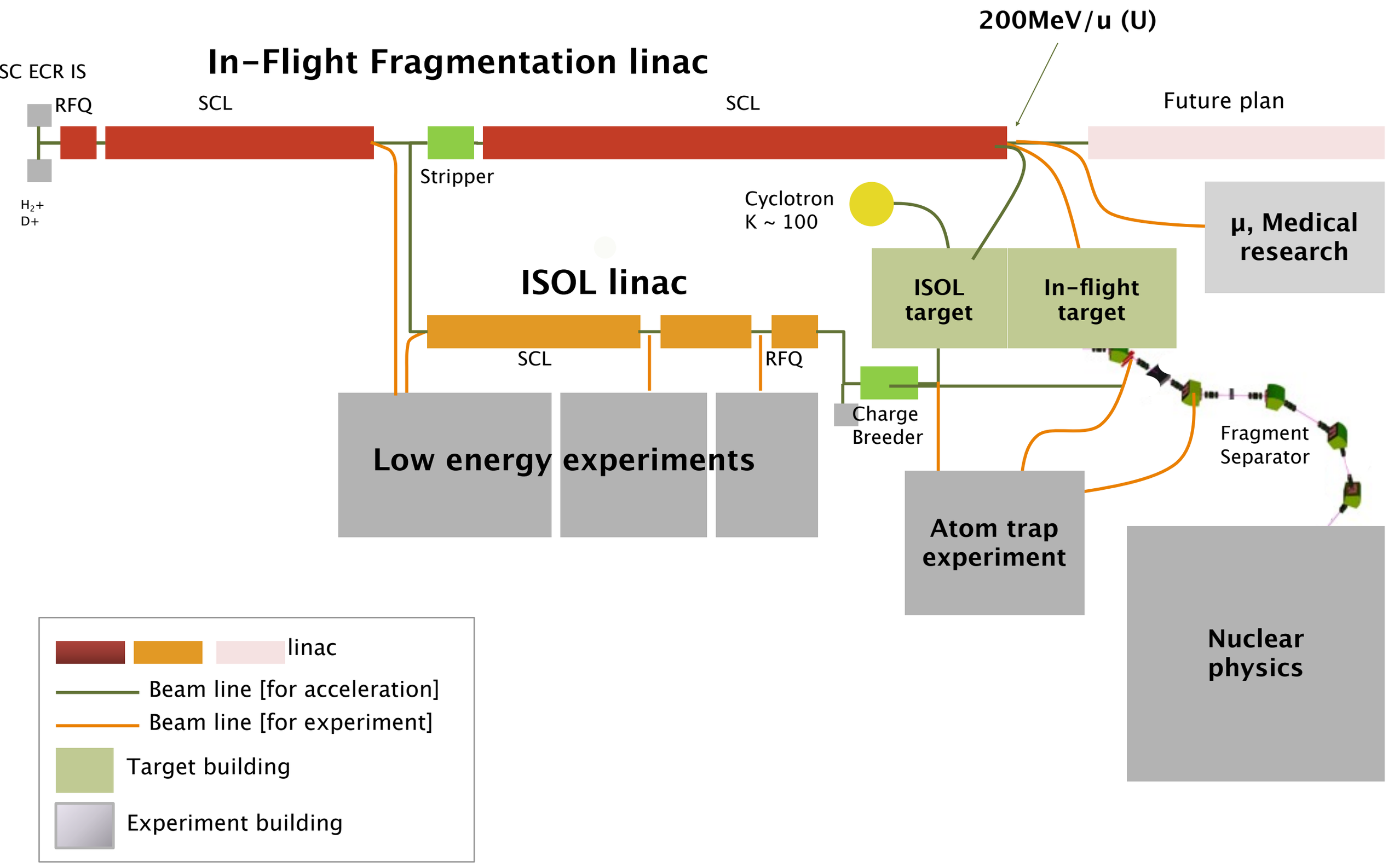


- In periodic table
  - Elements: ~100
  - Stable isotopes: ~300
  - Unstable isotopes: ~ 3000
- Unknown isotopes: about 3000~6000 estimated

Multi-purpose

- Nuclear physics
- Nuclear astrophysics
- Fundamental symmetries
- Material science
- Bio and medical sciences
- Atomic physics
- Nuclear data

KoRIA layout



Scheme of RI beams at KoRIA

ISOL driver: Cyclotron
70 MeV, 1mA proton

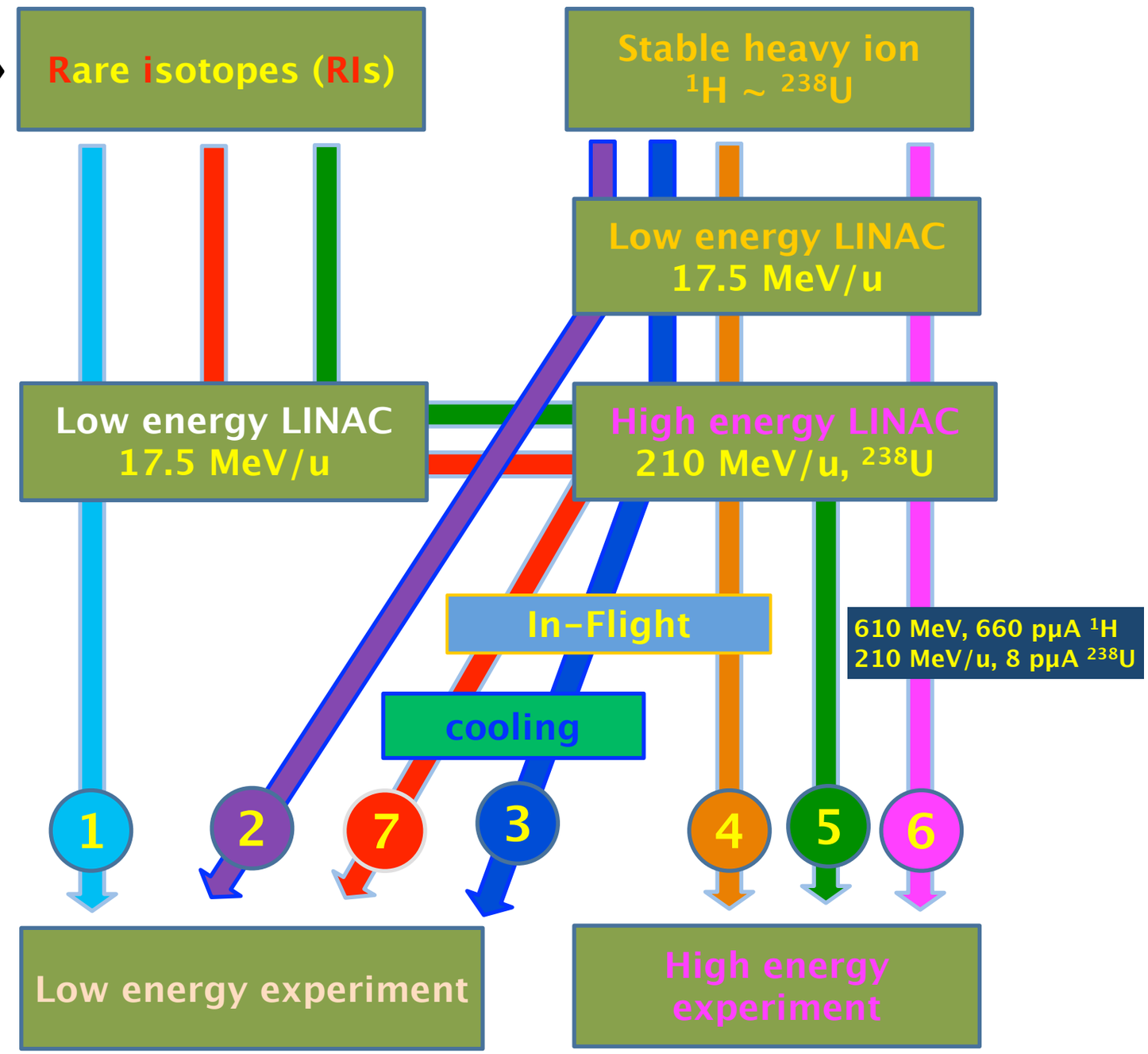
Direct fission target:
Multi-layered UC_x of 70 kW

Beam energy & types

	RI beam	Stable
low E	1, 3, 7	2
high E	4, 5	6

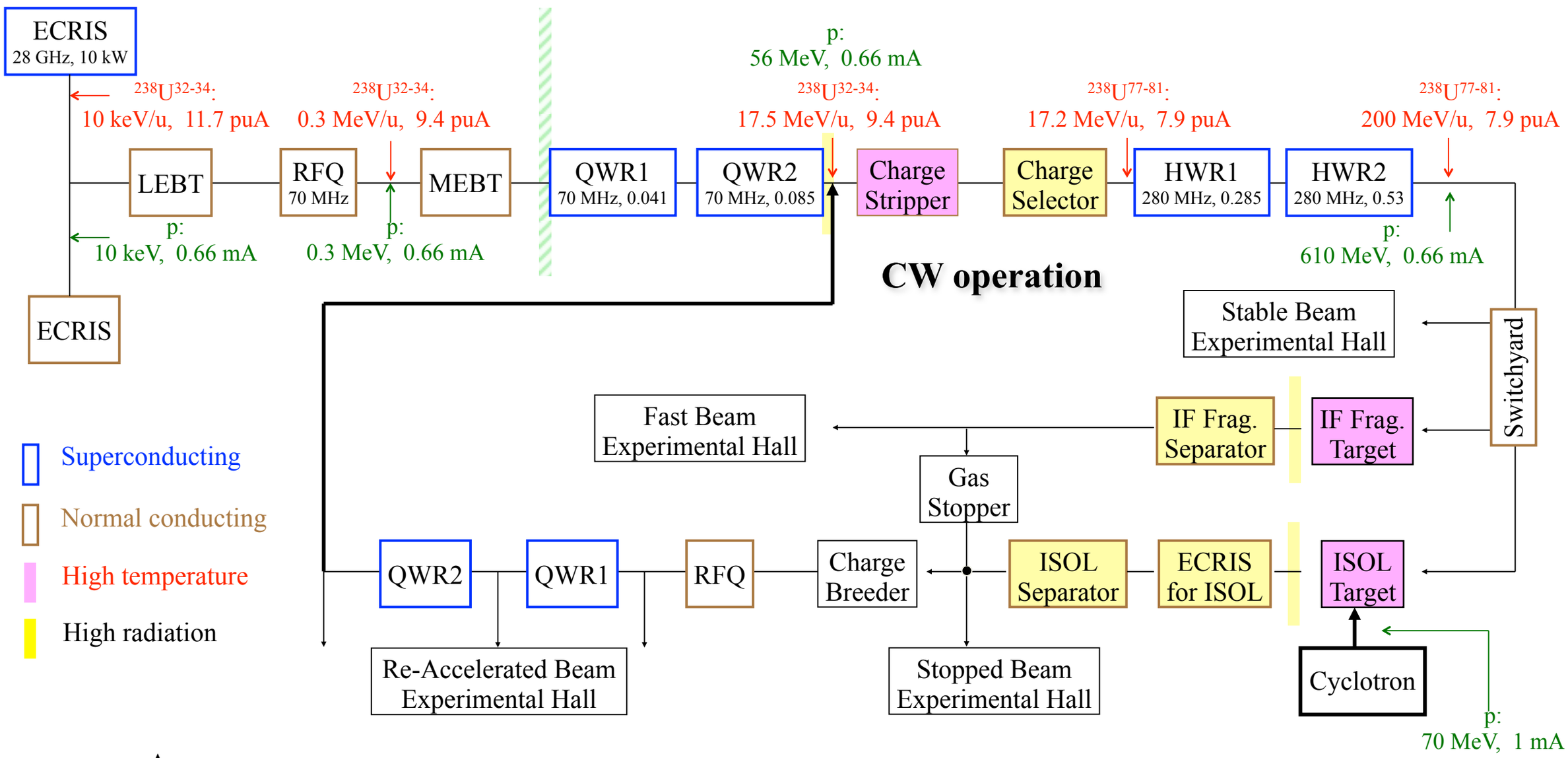
Simultaneous Operation

- 1. ISOL + 4. IFF + high E RI
- 1. ISOL + 6. High E stable HI
- 2. Stable + 5. ISOL+ high E RI
- 2. Stable + 7. ISOL+IFF+ISOL
- 3. IFF → low E RI or ISOL



7 ISOL+IFF+ISOL

Block Diagram of KoRIA



Acronyms

ECRIS: Electron Cyclotron Resonance Ion Source
L(M)EBT: Low (Medium) Energy Beam Transport
RFQ: Radio Frequency Quadrupole
Q(H)WR: Quarter (Half) Wave Resonator
IF Frag.: In-Fight Fragmentation
ISOL: Isotope Seperator On-Line

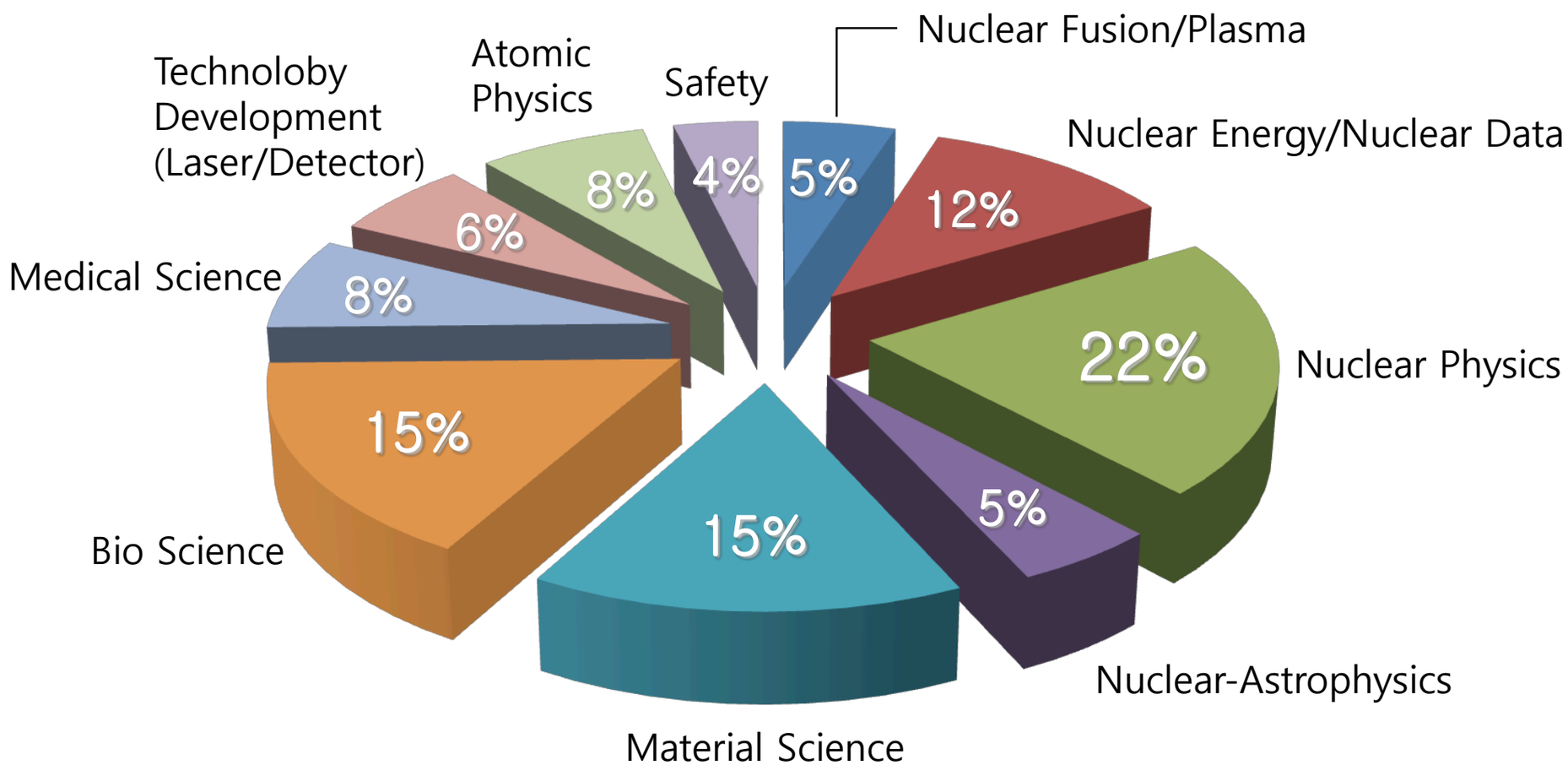
Comparison to foreign facilities

ISOL: Isotope Source On Line
IFF: In-flight fragmentation
* planned

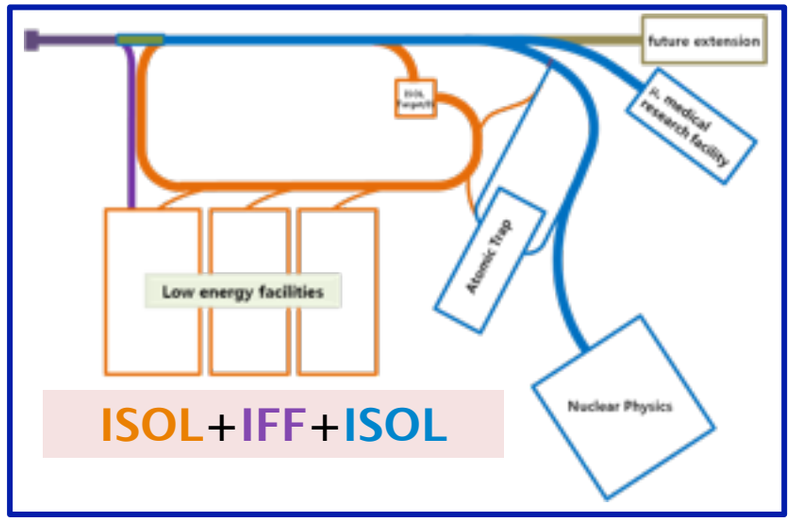
Facility	KoRIA Korea	FRIB MSU	RIBF RIKEN	HIE-ISOLDE CERN	ISAC I, II TRIUMF	SPIRAL2 GANIL	SPES INFN
RI beam production method	ISOL+IFF+ ISOL	IFF+ISOL	IFF+ISOL*	ISOL	ISOL	ISOL	ISOL
Target collision Particle (energy)	ISOL: 70 MeV p IFF: 600 MeV ^{1}H 200 MeV/u ^{238}U	~600 MeV ^{1}H ~200 MeV/u ^{238}U	Heavy ion 440-345 MeV/u	H (~1.4 GeV)	H (~500 MeV/u) E (50 MeV)	H (~33 MeV) D (~40 MeV) 중이온 (~14.5 MeV/u)	H (40-50MeV)
2nd RIB energy	ISOL: 200 MeV/u IFF: 150 MeV/u	Catcher-reacceleration: 3, 12 MeV/u IFF: ~150 MeV/u	< 345 MeV/u	3-10 MeV/u	ISAC I: ~1.8 MeV/u ISAC II: ~16 MeV/u	2-25 MeV/u	10 MeV/u
Accelerator type	Cyclotron RFQ+SC LINAC	RFQ + SC LINAC	RFQ + LINAC + 4 Ring Cyclotron	Synchrotron RFQ + IH structure + SC LINAC	Cyclotron RFQ + SC LINAC e-LINAC	RFQ + SC LINAC Cyclotron	Cyclotron S-RFQ, SC LINAC
Completion	2016	~2017	~2010	2015	~2015	~2012	2012

Letters of Intent

- Call for letters of intent in Korea (2009)
- 83 LoI's received



Research goals at KoRIA

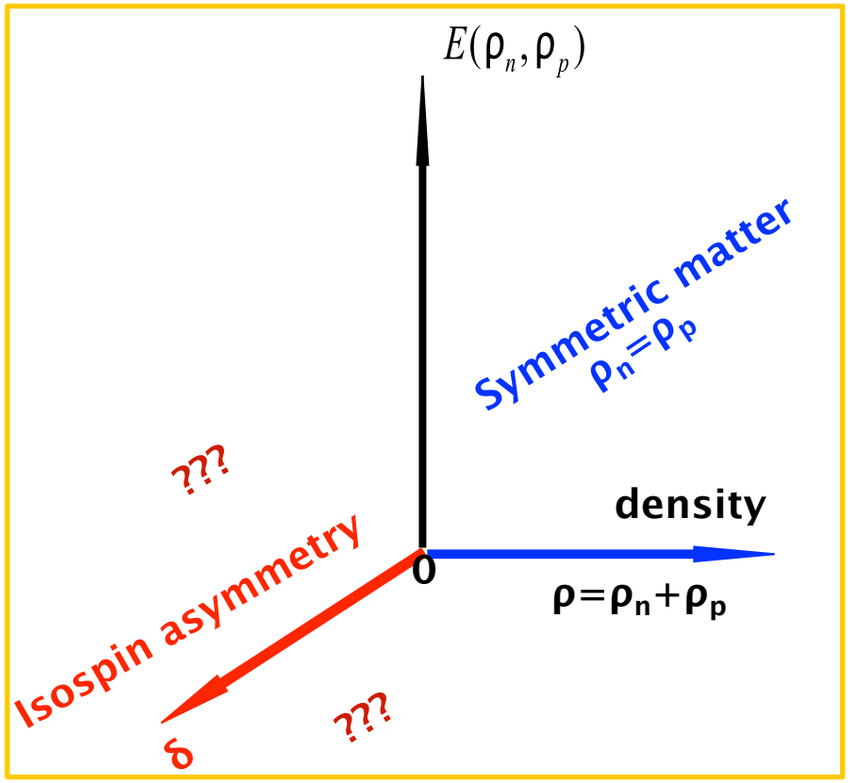


- **Nuclear Physics**
  - exotic nuclei near the neutron drip line
  - Unknown isotopes as super heavy elements (ex: Koreanium)
  - Equation of state (EOS) of nuclear matter
- **Nuclear Astrophysics**
  - Origin of nuclei
  - Paths of nucleosynthesis
  - Neutron stars and supernovae
- **Atomic physics**
  - Limits of nuclear existence
  - Fundamental conservation law
- **Nuclear data** by using fast neutrons
  - Future nuclear energy
  - Radioactive waste transmutation
- **Material science**
  - New materials
  - Properties of materials
  - Dynamic image in nm scale
- **Medical and Bio sciences**
  - Advanced therapy technology
  - Study the mutation of DNA

Nuclear Physics at KoRIA

- Search for drip lines
- Basic properties of n-rich isotopes
- Modification of shell gaps
- Shape deformation
- Neutron halos, skins
- Many more ...

Nuclear symmetry energy at KoRIA



❖ **Nuclear equation of state in the extended isospin space?**

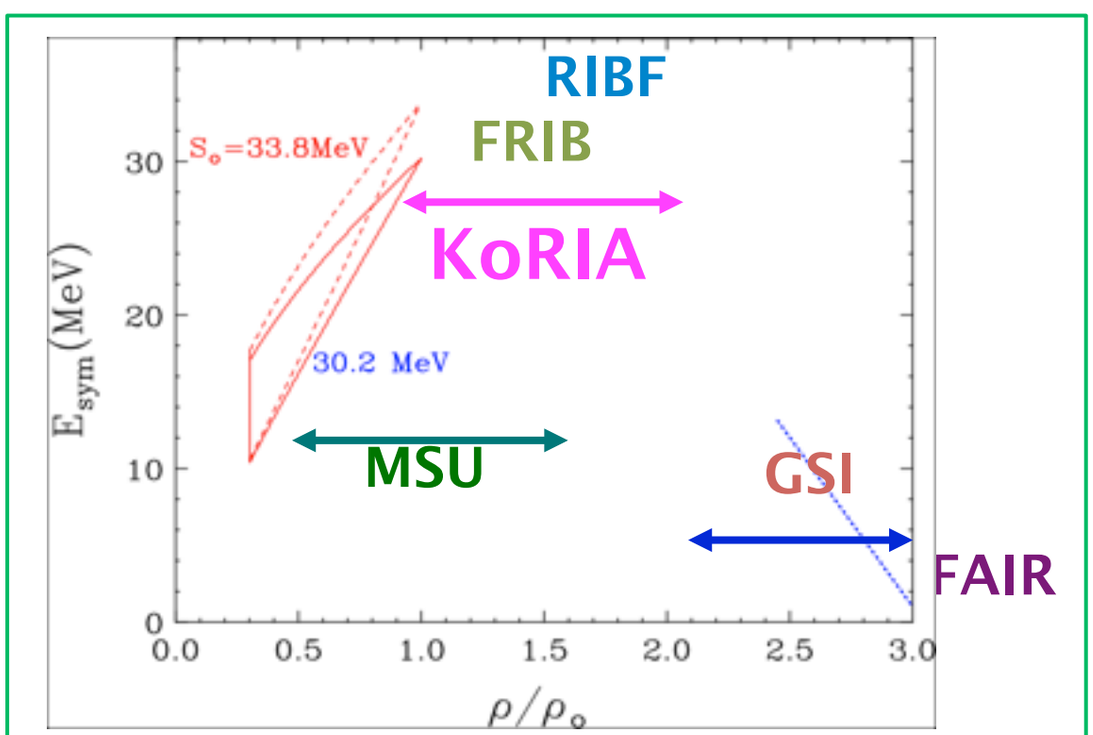
Energy per nucleon in asymmetric matter

$$E(\rho_n,\rho_p) = E_0(\rho_n = \rho_p) + E_{sym}(\rho)\left(\frac{\rho_n-\rho_p}{\rho}\right)^2 + o(\delta^4)$$

Energy per nucleon in symmetric matter — symmetry energy — Isospin asymmetry

ρ (nucleon density)=$\rho_n+\rho_p$

ρ_n : neutron density
ρ_p : proton density



❖ **Exploring a wide range of N/Z asymmetry**

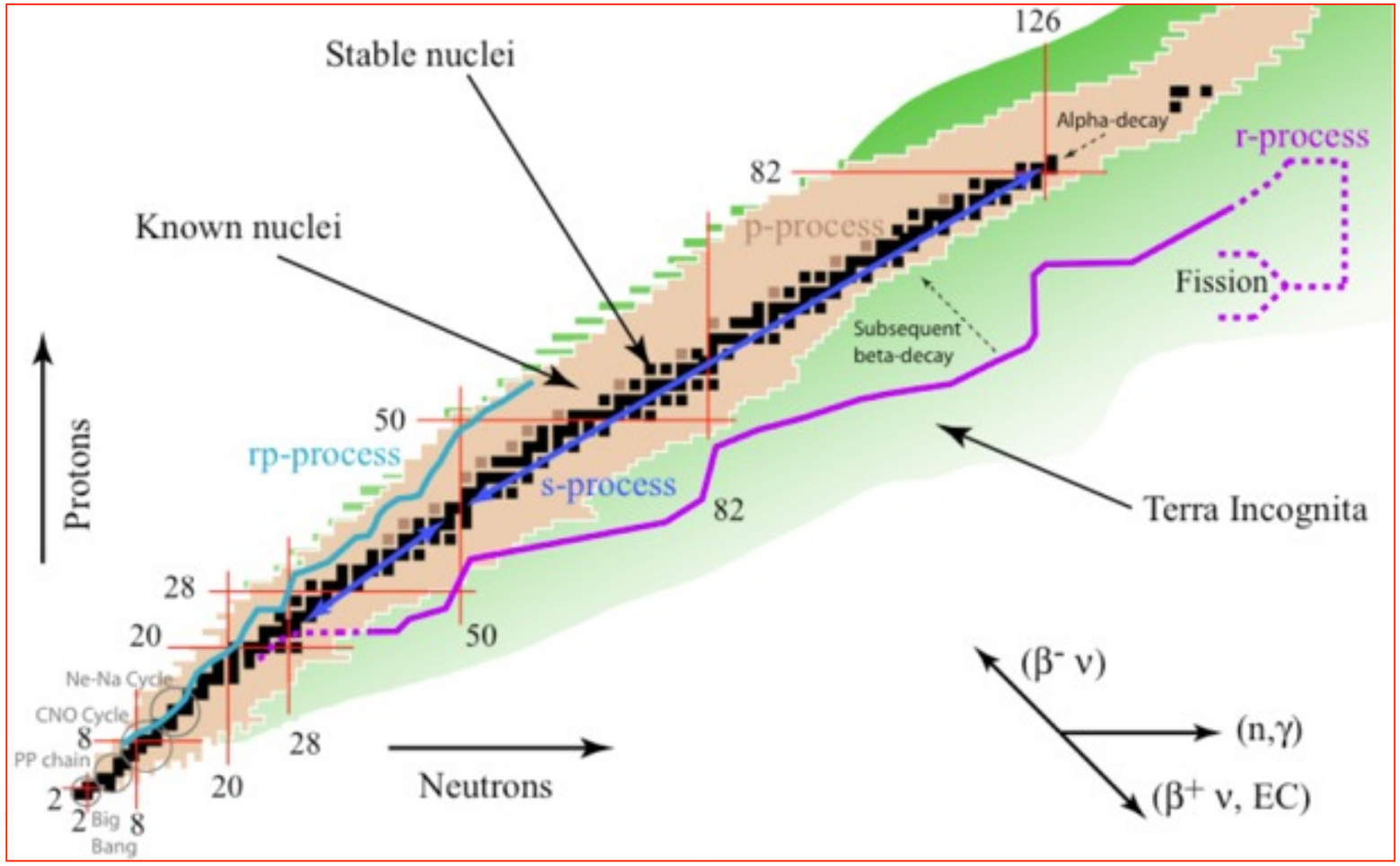
Density dependence of the asymmetric energy of the nuclear EoS

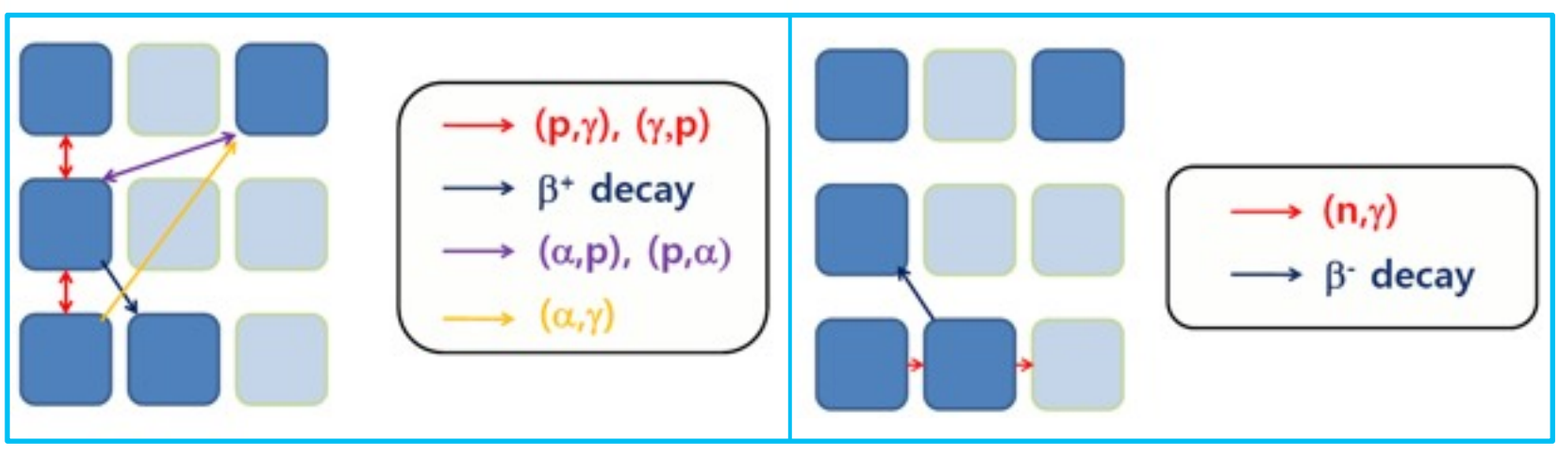
❖ **Experimental observables for EOS**

- Size of nuclei
- π^-/π^+, n/p, or $^3H/^3He$ ratio
- Isospin effect
- Collective flow

Nuclear astrophysics at KoRIA

➢ **Understand the role of unstable nuclei in the nucleosynthesis**





❖ **Nuclear reactions related to important cosmic gamma-ray observations**

❖ **Crucial reactions in the CNO and HCNO cycles**

❖ **Nucleosynthesis**

1. **Rapid proton capture process (rp-process)**
2. **Slow neutron capture process (s-process)**
3. **Rapid neutron capture (r-process)**

Atomic and nuclear physics at KoRIA

Precision Mass Measurements

High-accuracy mass measurements and mass comparisons of stable or radioactive nuclides on the level of 10^{-8}

Key questions

Fundamental property
Test of nuclear models and formulas

Limits and Islands
Drip lines and Superheavies

Nuclear Structure
Shell closures, pairing, deformation Halos

Nuclear Astrophysics
r- and rp-process

Reaction and decays
Q-values, Boundaries on exotic decays

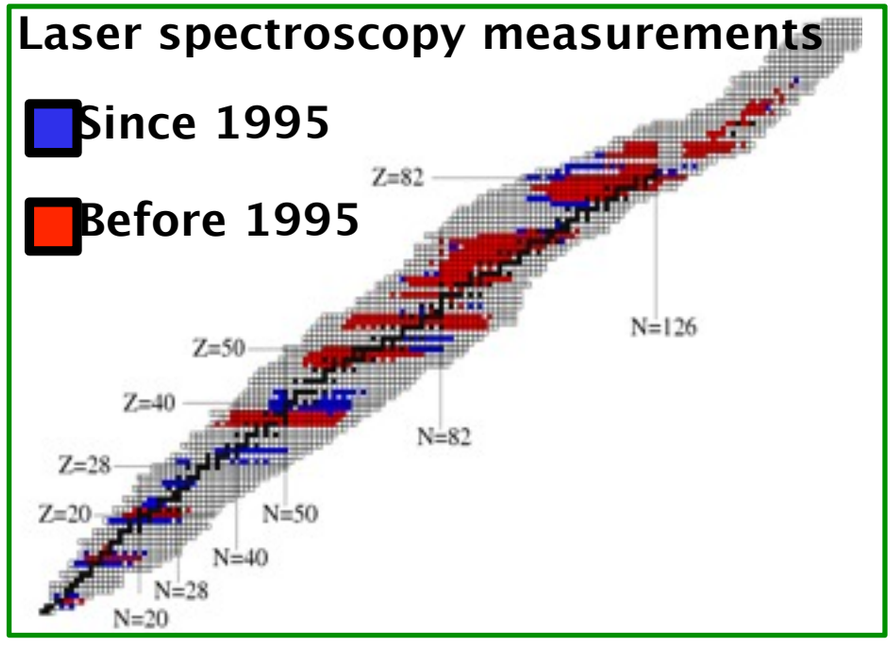
Fundamental tests
Symmetries
Weak interaction: CVC hypothesis, search for scalar and tensor currents

Precision Laser Spectroscopy

Magnetic & electrostatic hyperfine structure
spin, magnetic moment, and quadrupole moment

Key questions

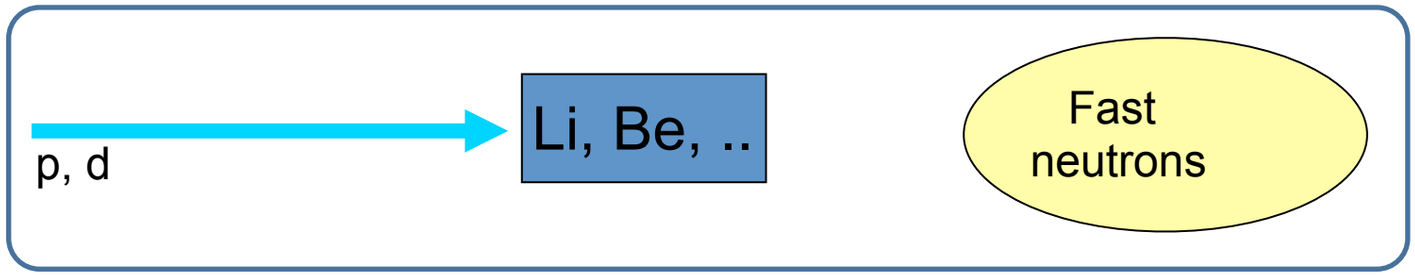
Limits of nuclear existence
New formation type of nuclear matter
New collective motion
Change of the ordering of quantum states



Nuclear data at KoRIA

Topic 1

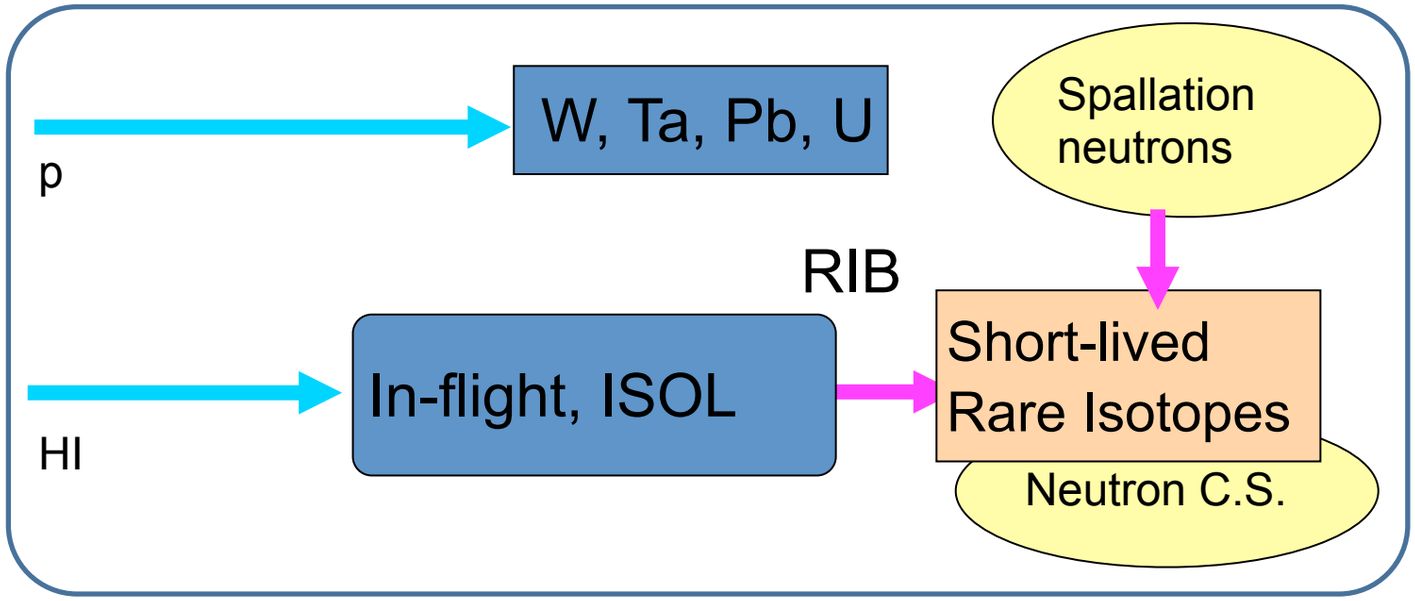
Fast neutron data & fusion applications



Topic 2

Nuclear data for GEN-VI & future system

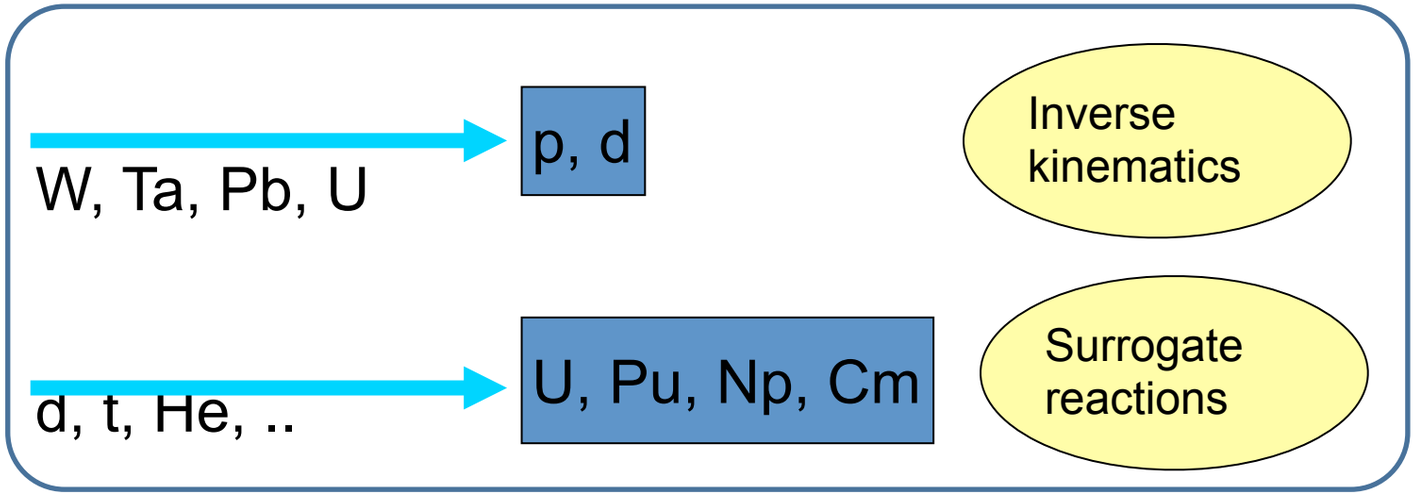
Nuclear data for waste transmutation



Topic 3

Improve nuclear reaction models

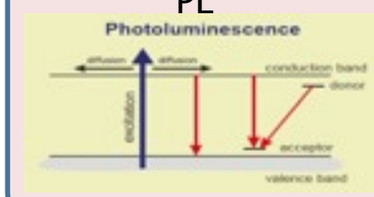
Nuclear data for ultra short-lived isotopes



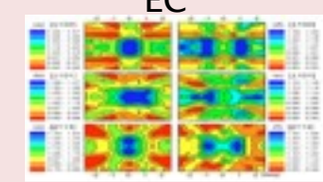
Material science at KoRIA

❖ **Semiconductor**
- Electric and magnetic configuration
- Lattice location of dopant
- Band structure
- Diffusion properties

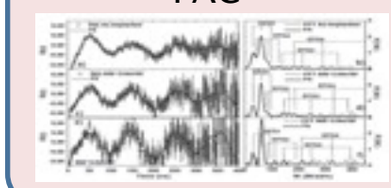
PL

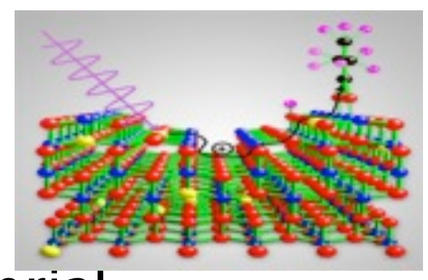


EC

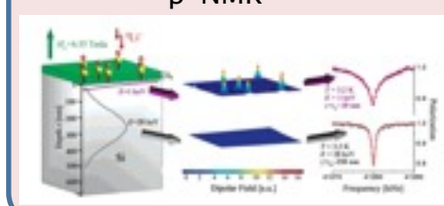


PAC

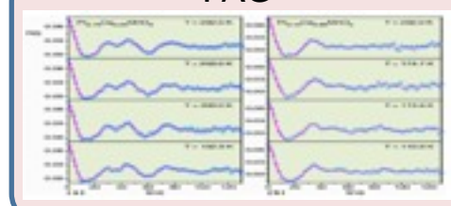




β-NMR

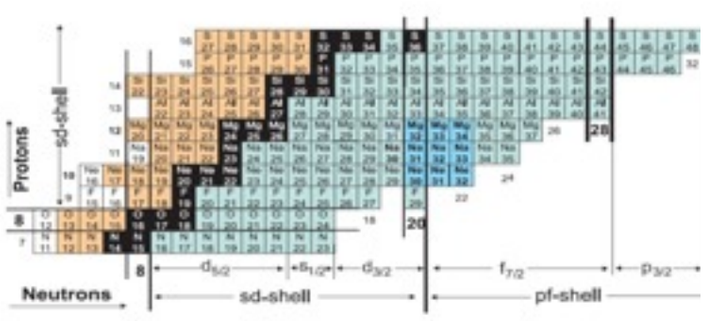


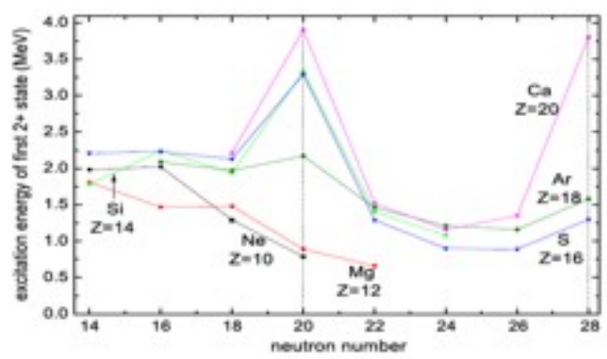
PAC



❖ **Magnetism & Superconductor**
- Spin-lattice relaxation
- Resonance shift in the magnetic material
- Nano-scopic analysis on the phase transition of the transition metal oxide materials.

❖ **Nuclear Moments:** Unique tool to investigate the nuclear wave function
- Magnetic Moment : Island of Inversion, Mirror Symmetry (β-NMR)
- Electric Quadrupole : Core polarization (β-NQR)





Medical and Bio science at KoRIA

Medical Science

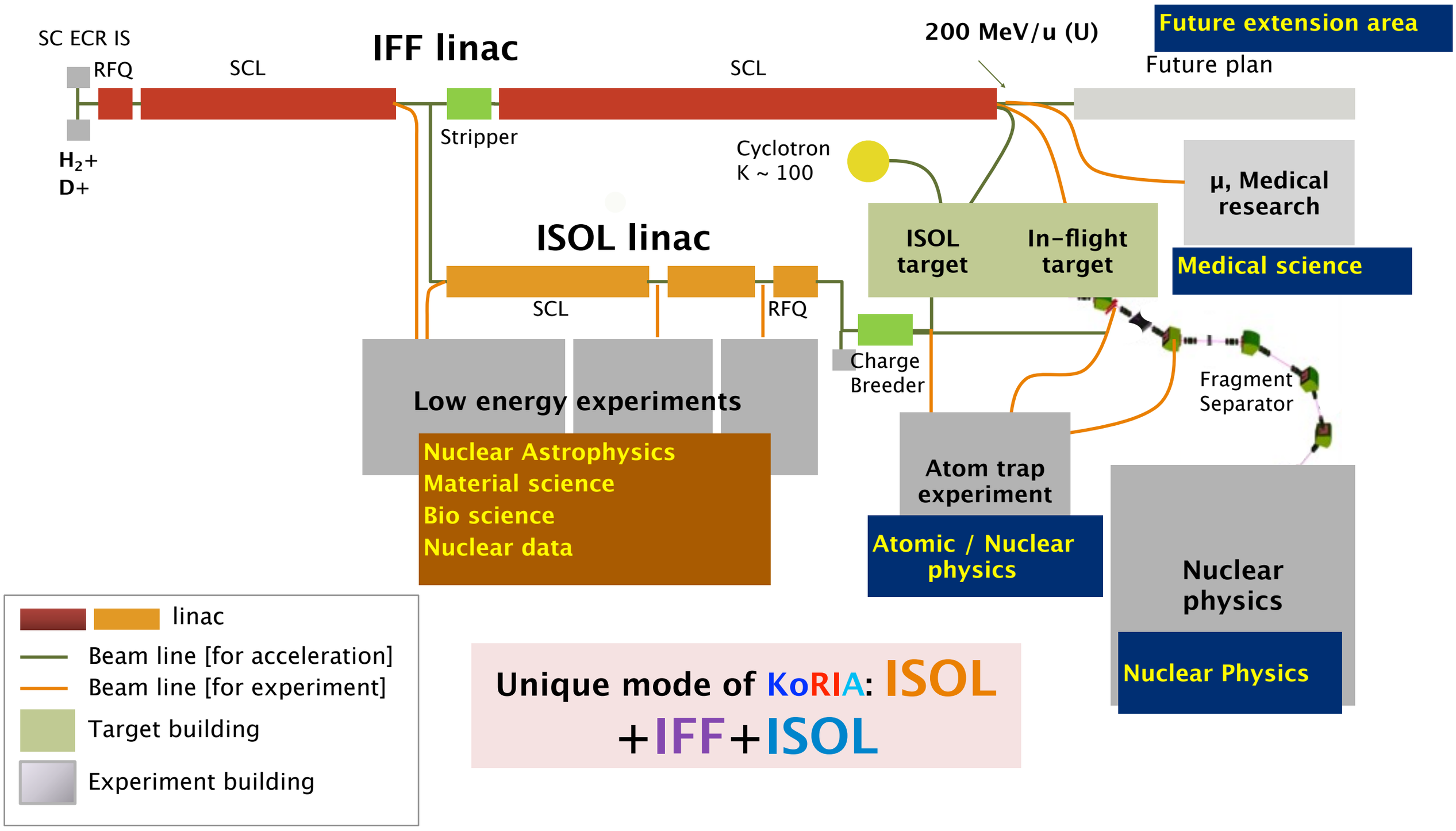
- Radioresistance of cancer cells to RI beams.
- Damage of normal tissues to RI beams.
- Radiation dose distribution using ^{11}C.
- New genes and proteins from microorganisms for human application.
- Particle beam therapy using π^-, He, O, Ne, Si, and Ar.

Bio Science

- RBE of heavy ion beam and oxygen dependence
- Genomic and proteomic research responsible to heavy ion beam
  - Neoplastic cell transformation of heavy ions
  - γ-radiation is carcinogen in normal animal?
- Epigenetic change by heavy ion beam
  - Embryonic development

Korea Rare Isotope Accelerator (KoRIA)

Researches of basic and applied science with stable and unstable isotopes



Unique mode of KoRIA: ISOL

+IFF+ISOL

Facilities for the scientific researches

- Design the experimental facilities in conceptual level
- User training program with the international collaboration

Nuclear Physics	Large Acceptance Multi-Purpose Spectrometer (LAMPS)
Nuclear Astrophysics	KoRIA Recoil Spectrometer (KRS)
Atomic physics	Atom & Ion Trap System
Nuclear data by fast neutrons	neutron Time-of-Flight (n-ToF)
Material science	B-NMR/NQR Elastic Recoil Detection (ERD) Laser Selective Ionizer
Medical and Bio sciences	Heavy Ion Therapy Irradiation Facility

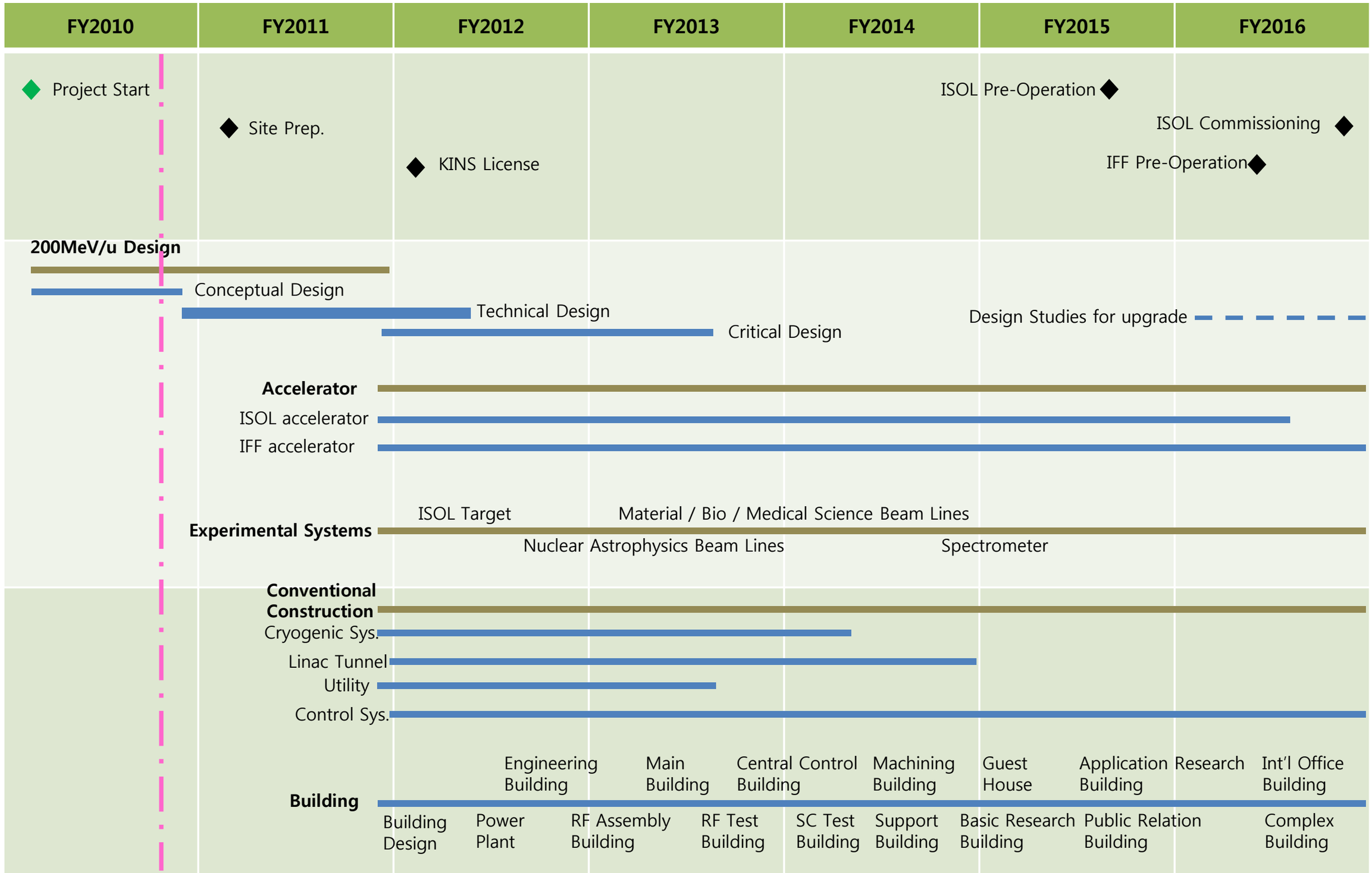
KoRIA User Community

67 Ph.D.s and 43 students in 8 working groups

Principal Investigator	Y. K. Kim	B. G. Cheoun, B. H. Kang, M. S. Ryu, S. M. Kang, D. Y. Jang, B. H. Park, T. Schaarschmidt, S. K. Lee, J. S. Kang, K. H. Jo, B. K. Shin, S. H. Kim, I. S. Lee (4/10)

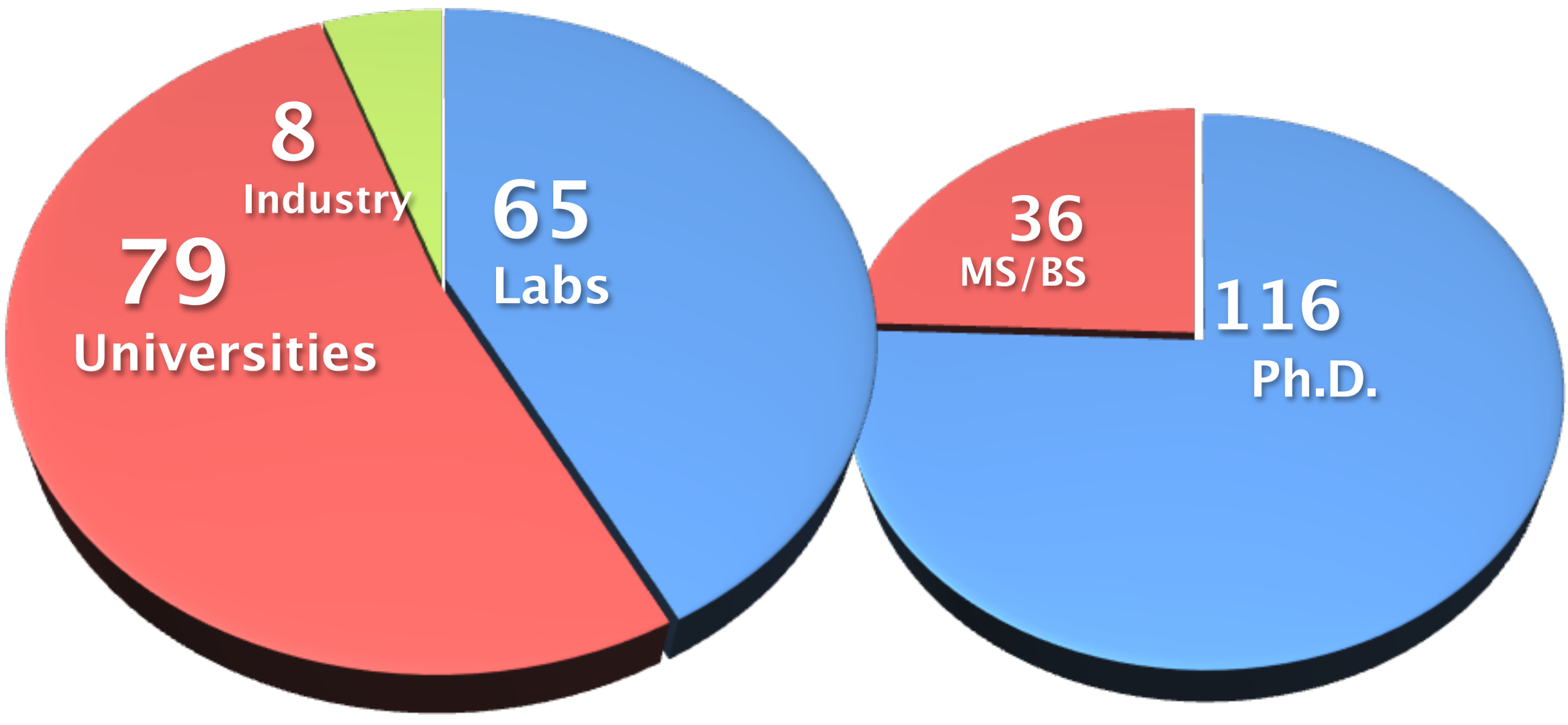
Working Group	Nuclear structure	Nuclear astrophysics & synthesis	Symmetry energy	Theory for Supernova & Astrophysics	Medical & Bio Application	RI Material Research	Nuclear Data	Atom traps for RI research
Leader (Institution)	S. Choi (Seoul National Univ.)	C. B. Moon (Hoseo Univ.)	C. H. Hyun (Daegu Univ.)	M. K. Cheoun, (Soongsil Univ.)	W. Y. Park (Chungbuk National Univ.)	S. H. Park KAERI	Y.O. Lee KAERI	D. H. Yu KRISS
Group member	I. K. Yoo S. Stepanian Sato H. S. Lee #K. S. Lee #E. J. Ha M. Evgeniy H. S. Do J. K. Lee C. W. Son K. S. Oh K. E. Choi J. H. Song H. K. Kim J. S. Song (5+2/9)	I. S. Hahn J. H. Lee Y. K. Kwon J. Y. Moon C. C. Yun J. S. Yoo A. Kim E. H. Kim J. S. Park (8/2)	S. H. Lee H. C. Kim E. J. Kim J. K. Ahn Y. S. Oh K. S. Lee C. H. Lee H. J. Lee B. Hong #K. S. Lee H. J. Jeong, J. H. Jeong K. B. Kim, S. H. Kim J. Y. Park, J. H. Jeong S. Y. Yu, H. S. Jo S. J. Kim, K. H. Lee M. E. Baek, B. H. Choi E. A. Joo, K. Y. Baek J. H. Jang, S. H. Hwang H. H. Shim, J. K. Lee Y. M. Kim (11/19)	C. Ryu #E. J. Ha (3/0)	Y. C. Ahn I. G. Kim K. C. Kim I. L. Jeong H. J. Song J. R. No J. C. Ahn *J. W. Gwak *D. H. Shin *S. J. Ye *Join research not project member (5+3/3)	J. K. Kim W. Hong B. Y. Han S. K. Ahn H. S. Shin N. Y. Kim H. S. Kim B. J. Seo #Y. J. Rhee #J. M. Han #H. M. Park #K. H. Ko #G. Lim (14/0) # Joining 2 working groups	G. D. Kim J. G. Yoo H. J. Woo T. Y. Song H. I. Kim C. W. Lee #Y. J. Rhee #J. M. Han #H. M. Park #K. H. Ko #G. Lim (7+5/0)	Y. K. Lee C. Y. Park J. C. Moon T. Y. Kwon S. E. Park S. B. Lee H. S. Kang M. K. Oh Y. H. Park (10/0)

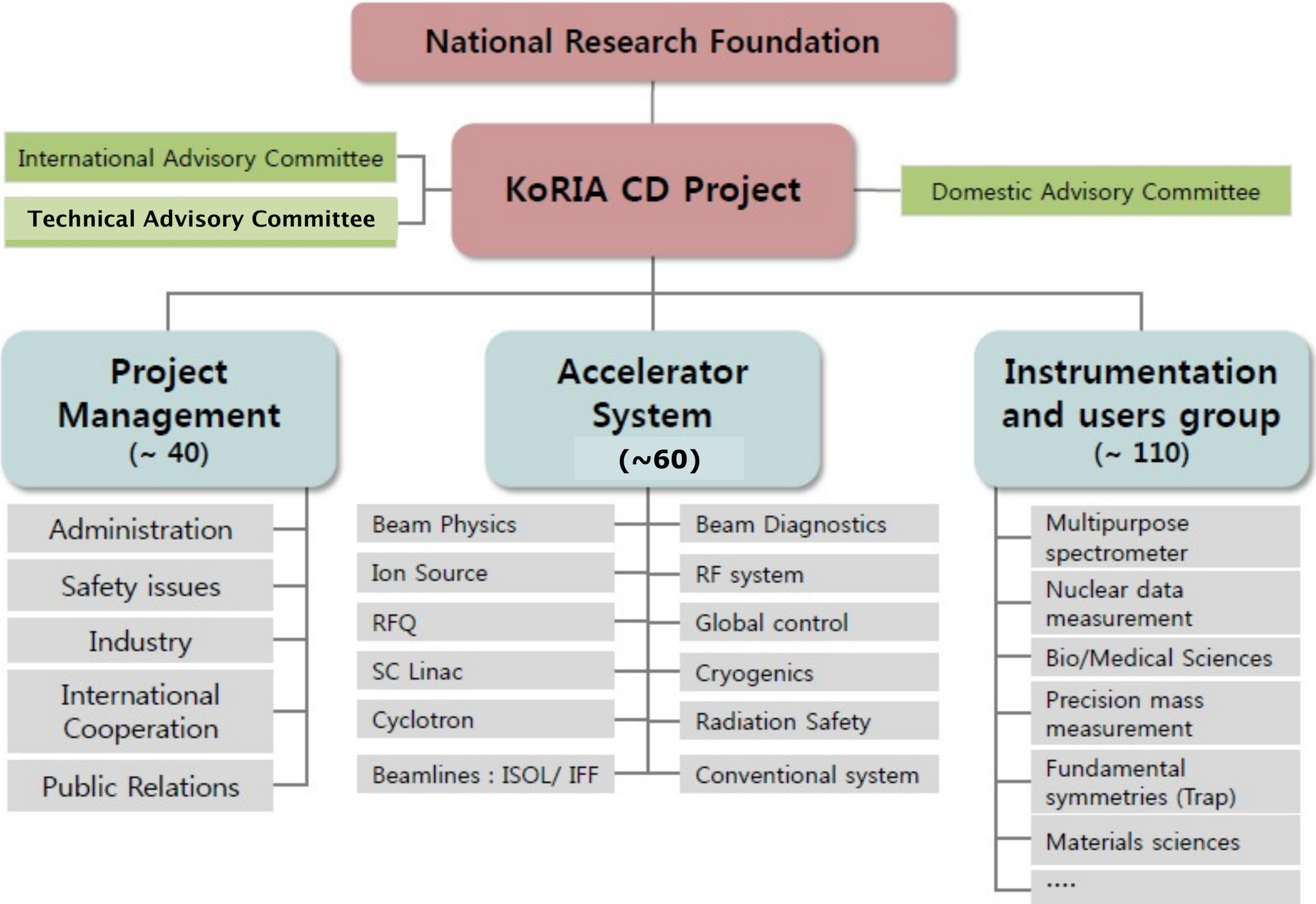
Timeline


FY2010
FY2011
FY2012
FY2013
FY2014
FY2015
FY2016
Project Start
Site Prep.
KINS License
ISOL Pre-Operation
ISOL Commissioning
IFF Pre-Operation
200MeV/u Design
Conceptual Design
Technical Design
Critical Design
Design Studies for upgrade
Accelerator
ISOL accelerator
IFF accelerator
Experimental Systems
ISOL Target
Material / Bio / Medical Science Beam Lines
Nuclear Astrophysics Beam Lines
Spectrometer
Conventional Construction
Cryogenic Sys.
Linac Tunnel
Utility
Control Sys.
Building
Engineering Building
Main Building
Central Control Building
Machining Building
Guest House
Application Building
Research
Int'l Office Building
Building Design
Power Plant
RF Assembly Building
RF Test Building
SC Test Building
Support Building
Basic Research Building
Public Relation Building
Complex Building

Conceptual Design Project

1. Budget : ~ 2M $
2. Period : March 10 ~ January 9, 2011
3. Manpower : ~ 200 persons




National Research Foundation
KoRIA CD Project
International Advisory Committee
Technical Advisory Committee
Domestic Advisory Committee
Project Management
(~ 40)
Administration
Safety issues
Industry
International Cooperation
Public Relations
Accelerator System
(~60)
Beam Physics
Ion Source
RFQ
SC Linac
Cyclotron
Beamlines : ISOL/ IFF
Beam Diagnostics
RF system
Global control
Cryogenics
Radiation Safety
Conventional system
Instrumentation and users group
(~ 110)
Multipurpose spectrometer
Nuclear data measurement
Bio/Medical Sciences
Precision mass measurement
Fundamental symmetries (Trap)
Materials sciences
....

KoRIA for Nuclear Physics in Asia

- One of new major construction project in the world
- One more facility for nuclear physics community in the world
- Great opportunities for young scientists
- Collaborations are welcome from all over the world, especially from Asia!

Stay hungry. Stay foolish.

Steve Jobs, CEO, Apple Inc.

All dreams come true.

Your job is dreaming dreams.

A hungry, foolish nuclear physicist


Thank you