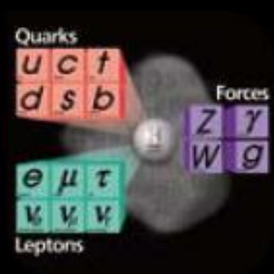
Institute for Basic Science and Rare Isotope Science Project

Sun Kee Kim

ibS 기초과학연구원
Institute for Basic Science

www.ibs.re.kr

Institute for Basic Science



Excellence

Autonomy

Openness

Creativity

Vision & Objective of IBS

Vision

- To be one of the world's leading 10 research institutes in basic science

Objective

- To become a hub of the world's basic science research which will lead the advancement of scientific knowledge
- To train the future leaders of basic science by providing the best possible research environment for young scientists

Refer to the Special Act of ISBB

Goal	To secure creative knowledge and original technology through the world's leading basic science research
Nature	Independent organization
President	President of IBS has been appointed by President of Korea for a five-year term.

Key Functions

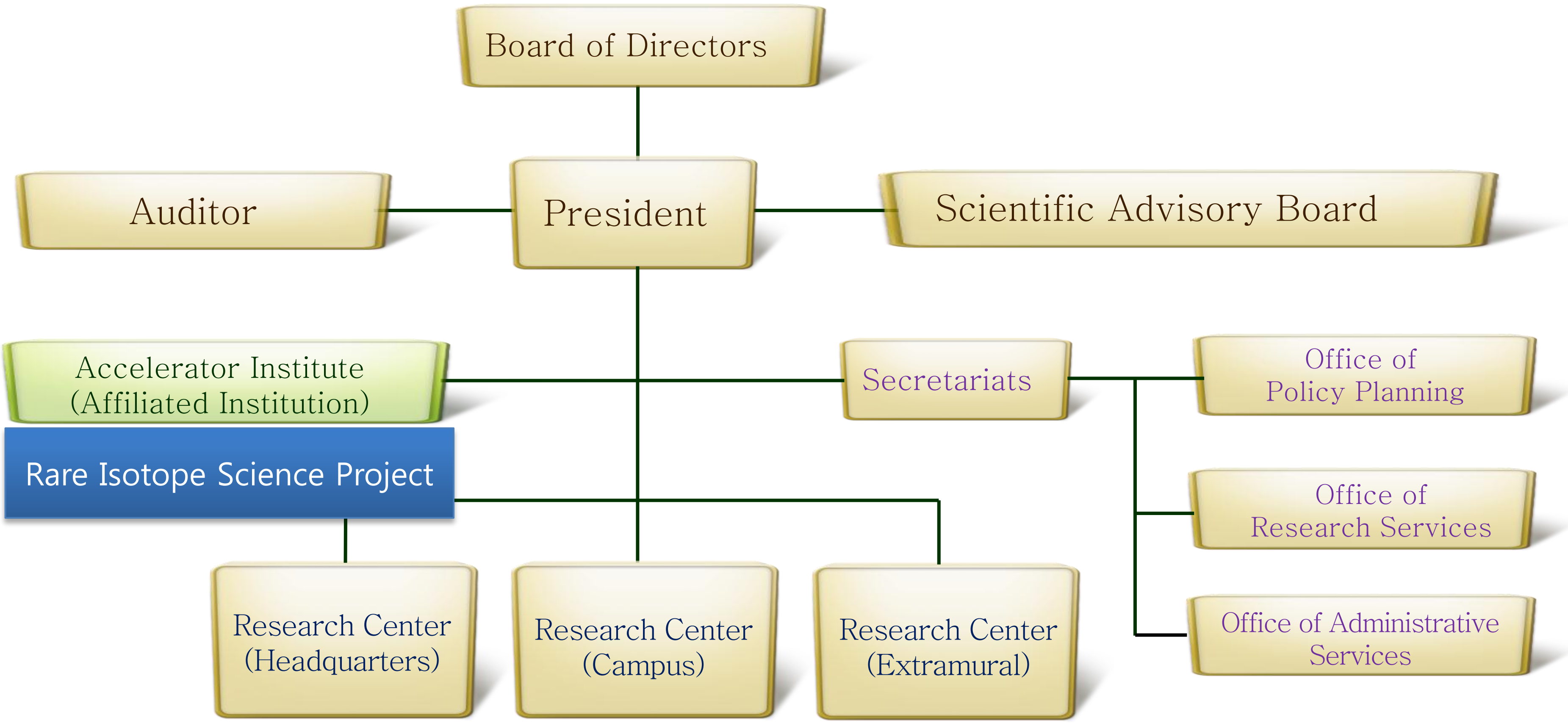
- Conducting the world's top-class research in fields of basic science and pure basic science
- Training the future leaders of basic science
- Building a global network of basic science

Research Themes

Early Stage	Initially Directors are selected without any limit on research themes ⇒ Timetable for the implementation of research fields agreed on the appointment of Directors
Established Stage	Research themes are taken into account in the selection of Directors.


Excellence
Openness
IBS
Autonomy
Creativity

Organization



- The number of staff: 3,000 (2017, including visiting scientists and students)
- Annual Budget: USD 610 million (2017, including operational cost for the Accelerator Institute)

IBS Organization

- IBS consists of 50 research centers, supporting organizations, and affiliated research institutes.
  - The research centers will be separately located at headquarters (15), campuses* (25), and extramural research centers (10).

  ※ When criteria for excellence are not met, the number of research centers for each location may change.

  * Campuses: KAIST Alliance (10), GIST (5), DGIST·UNIST·POSTECH Alliance (10)

Individual Research Center

Function	• Basic unit of IBS conducting research in the same place - Extramural research centers belong to universities or other research institutes.
Staff	• The composition of staff varies depending on research theme and research plan (around 50 staff, USD 9 million for annual budget). - Each center includes a Director, around 5 group leaders, and support staff.
Management	• Director is guaranteed autonomy and independence in operating a research center.

Selection of Directors

Requirements

- Scientists fully committed to managing research centers and conducting research over the long term
- Scientists with world renowned research achievements or the potential to do so
- Scientists capable of carrying out and managing large-scale research projects

Criteria of Selection

- Excellence of candidates will be a top priority while creativity and superiority of research plan will also be considered.

Selection and Evaluation Committee (SEC)

- It evaluates the selection of Directors and their output on a 3 year basis.
- President appoints 15 scholars in various research fields from both at home and abroad.

Step	Invitation	Scouting	By
Planning	Establishing a selection plan of research centers (with consultation from SAB)		President
Recruitment	Year-round recruitment	Candidate scouting through SAB	President
Evaluation	Prior evaluation (SEC) Panel review (Subcommittee) Comprehensive evaluation (SEC)		SEC (Subcommittee)
Consultation	Final review & consultation		SAB
Pre-Selection	Selection of Director		President
Negotiations	Negotiation over research plan* b/w President and Director * Research topics, budget, period, compensation, etc.		President
Confirmation	Confirmation and appointment of Director		President

Staff Management

- Directors have discretion in hiring scientists and staff within the budget of research centers.
- Open-door employment policy with a free flow of renowned scientists and young scientists
  - Dispatched workers from other institutions, post-doc., grad students, and visiting scientists

※ Directors and group leaders should work full time to concentrate on research.

Employment Positions

- Directors and group leaders { Tenured at IBS or Professors / permanent employees at 'partner institutions' **

** Universities · government-invested institutes which signed research center's employment agreement with partner campuses, host institutions, or IBS through MOU

※ As a rule, Directors and group leaders work full time.

Budget Management

- Research budget for each research center is allocated under the three-year plan.

Evaluation of Research Center

- Research output is evaluated on a 3 year basis.

  ※ Output evaluation begins 5 years after the formation of the research centers.
  (preliminary consultation after the first 2 years).

- Results of output evaluation are used in determining research budgets and research topics for the next 3 years.

Buildings

- Temporary headquarters is currently in the Daeduk District with offices for research and administration.
- IBS will construct its own headquarter buildings and 3 campuses (including amenities for overseas scientists).
- Master plan of construction will be established by May, 2012 and the construction is scheduled to be completed by the end of 2015.
- Each campus uses spaces of the universities which host IBS campuses.

Mid of 2012 — Opening of The 1st Research Center

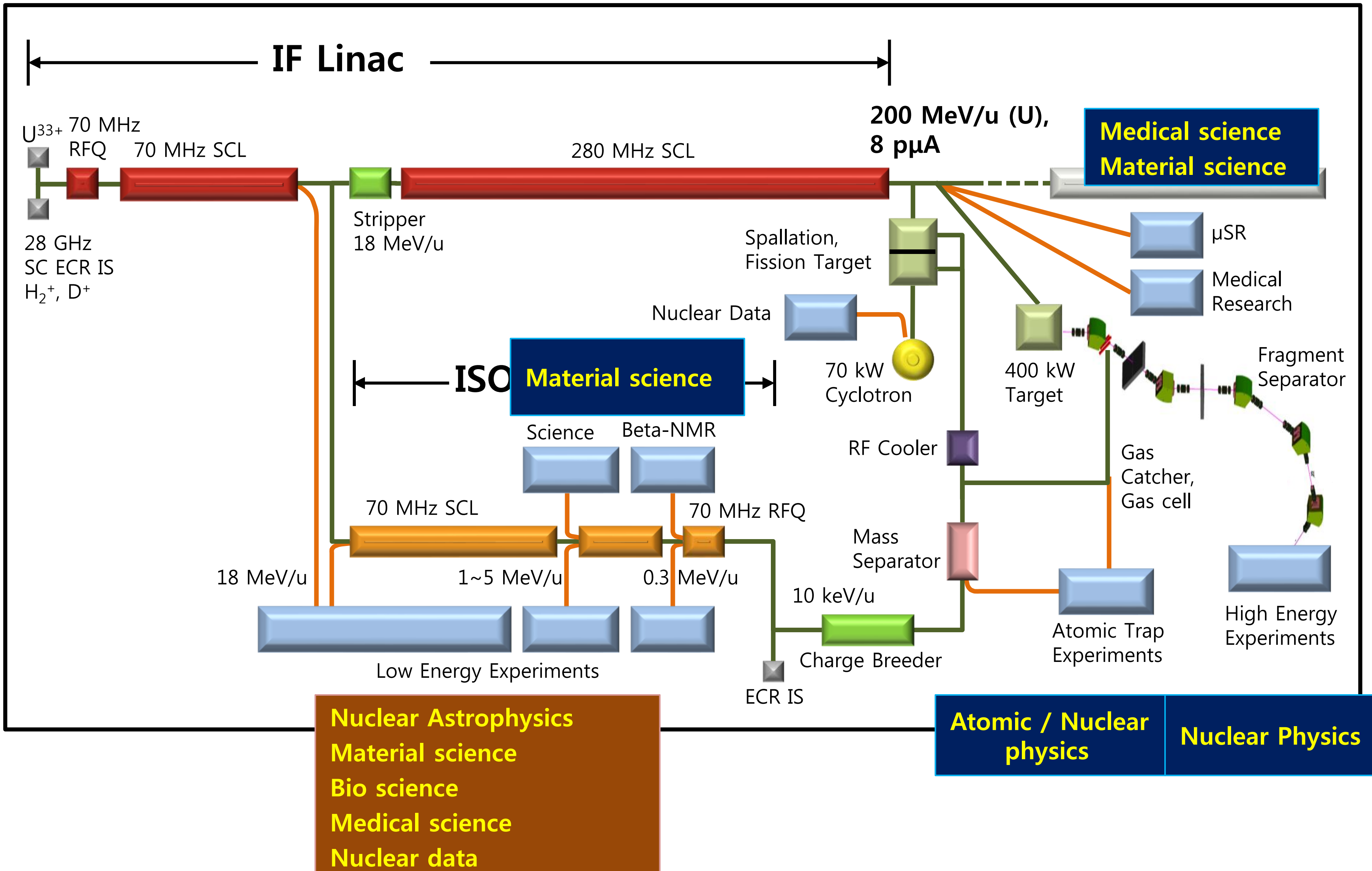
May 2012 — IBS Opening Ceremony & International Symposiums

Jan. ~ Feb. 2012 — Invitation Announcement for Directors

Nov. 2011 — Establishment of IBS
(Prof. Se-jung Oh appointed as Founding President)

Science Business Belt

Concept of the Accelerator Complex

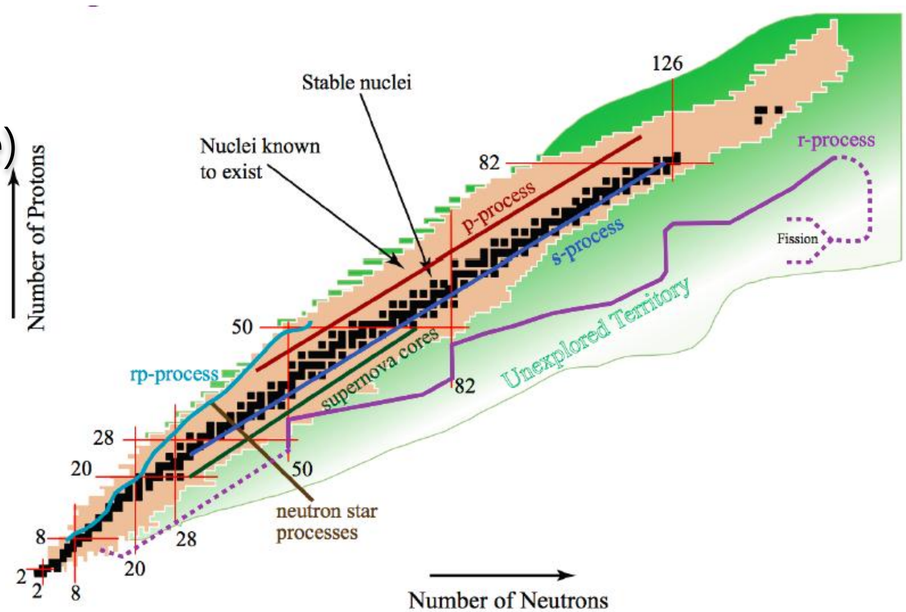


Rare Isotope Factory

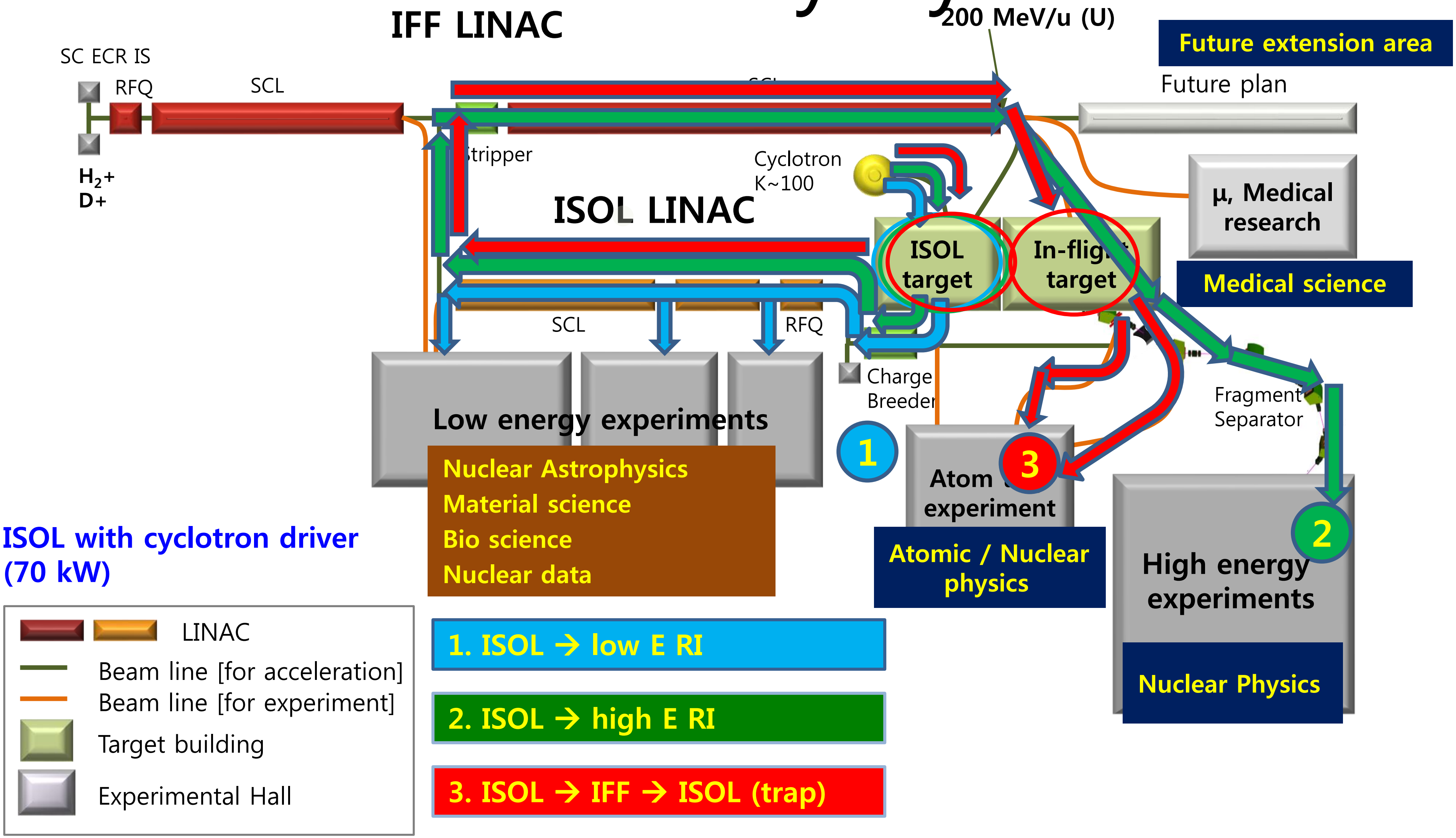
- ❑ High intensity RI beams by ISOL & IFF
  - 70kW ISOL from direct fission of ^{238}U induced by 70MeV, 1mA p
  - 400kW IFF by 200MeV/u, 8pμA ^{238}U
- ❑ High energy, high intensity & high quality neutron-rich RI beams
  - ^{132}Sn with up to ~250MeV/u, up to 9×10^8 pps
- ❑ More exotic RI beams by ISOL+IFF+ISOL(trap)
- ❑ Simultaneous operation modes for the maximum use of the facility

ISOL(Isotope Separator On-Line)
p → thick target (eg. Uranium Carbide)
fission fragments → rare isotopes

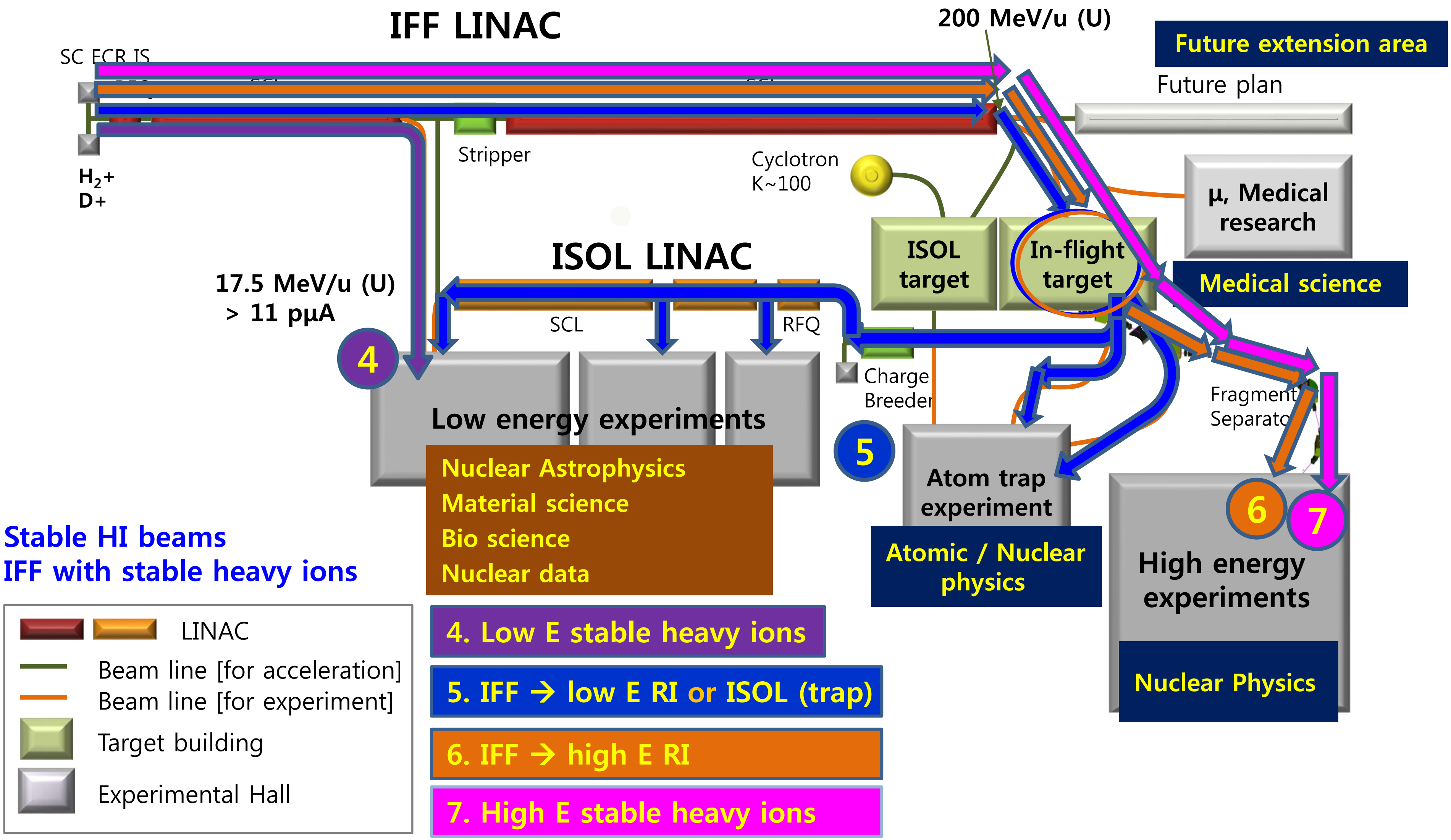
IF(In-Flight Fragmentation)
Heavy ion beam → thin target
projectile fragmentation
→ high energy RI beam or
→ stopping and reacceleration



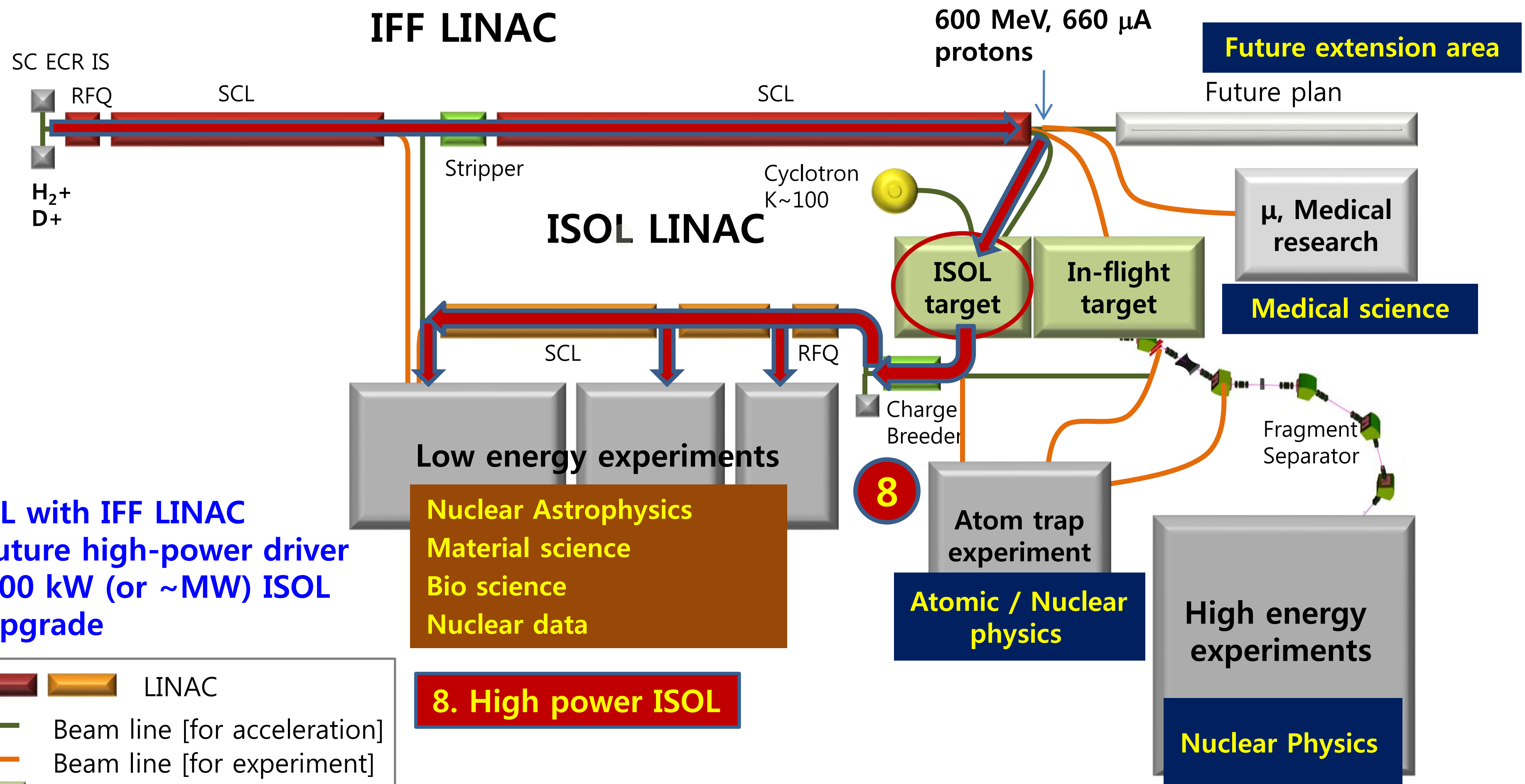
RI from ISOL by Cyclotron



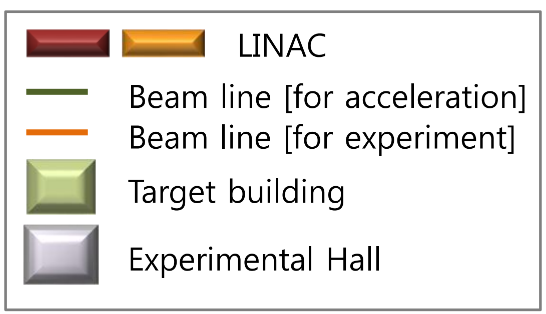
RI from IFF by High-Power SC LINAC and High-Intensity Stable HI beams



RI from ISOL by High-Power SC LINAC (Long term future upgrade option)



ISOL with IFF LINAC
- future high-power driver
- 400 kW (or ~MW) ISOL upgrade



8. High power ISOL

Estimated RIBs based on ISOL

Isotope	Half-life	Yield at target (pps)	Overall eff. (%)	Expected Intensity (pps)
^{78}Zn	1.5 s	2.75×10^{10}	0.0384	1.1×10^{7}
^{94}Kr	0.2 s	7.44×10^{11}	0.512	3.8×10^{9}
^{97}Rb	170 ms	7.00×10^{11}	0.88	6.2×10^{9}
^{124}Cd	1.24 s	1.40×10^{12}	0.02	2.8×10^{8}
^{132}Sn	40 s	4.68×10^{11}	0.192	9.0×10^{8}
^{133}In	180 ms	1.15×10^{10}	0.184	2.1×10^{7}
^{142}Xe	1.22 s	5.11×10^{11}	2.08	1.1×10^{10}

* Calculated by Dr. B. H. Kang (Hanyang Univ.) for proton beams of 70 MeV and 1 mA with 3 cm thick UC_2 target of 2.5 g/cm^3

IFF Linac Beam Specification

Ion Species	Z/ A	Ion source output		SC linac output			
		Charge	Current (pμA)	Charge	Current (pμA)	Energy (MeV/u)	Power (kW)
Proton	1/ 1	1	660	1	660	610	400
Ar	18/ 40	8	42.1	18	33.7	300	400
Kr	36/ 86	14	22.1	34-36	17.5	265	400
Xe	54/ 136	18	18.6	47-51	12.5	235	400
U	92/ 238	33-34	11.7	77-81	8.4	200	400

* Estimated by KAPRA

Comparison to other facilities 1

Facility	Korea	FAIR GSI Germany	FRIB MSU USA	RIBF RIKEN Japan
RI beam production	ISOL+IFF+ISOL(trap)	IFF	IFF+ISOL +	IFF+ISOL*
Beam energy of RI driver	ISOL: 70 MeV p IFF: 600 MeV p 200 MeV/u ^{238}U	2.7 (^{238}U) ~ 30 (^{1}H) GeV/u	~600 MeV p ~200 MeV/u ^{238}U	Heavy ion 440-345 MeV/u
RI beam energy	ISOL: ~250 MeV/u IFF: ~150 MeV/u	0.4 - 1.5 GeV/u of all masses	Catcher-reacceleration: 3, 12 MeV/u IFF: ~150 MeV/u	< 345 MeV/u
Basic science	• Nuclear structure • Nuclear astrophysics and synthesis • Nuclear matter and symmetry energy • Atomic physics using trapping	• Nuclear structure • Antiproton • Nuclear matter • Plasma • Atomic physics	• Nuclear structure • Nuclear astrophysics • Fundamental interaction and symmetry	• Nuclear structure • Nuclear reaction • Nuclear astrophysics • Atomic physics • Molecular physics • Nuclear chemistry
Applied science	• Medical and Bio • Material research • Nuclear data		• Medical application	
Completion	~2017	2016	~2017	~2010

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

* Planned
\+ Option

Comparison to other facilities 2

Facility	Korea	HIE-ISOLDE CERN Swiss (EU)	ISAC I,II TRIUMF Canada	SPIRAL2 GANIL France	SPES INFN Itly
RI beam production	ISOL+IFF+ISOL(trap)	ISOL	ISOL	ISOL	ISOL
Beam energy of RI driver	ISOL: 70 MeV p IFF: 600 MeV ^{1}H 200 MeV/u ^{238}U	H (~1.4 GeV)	H (~500 MeV/u) E (50 MeV)	H (~33 MeV) D (~40 MeV) HI (~14.5 MeV/u)	H (40-50MeV)
RI beam energy	ISOL: ~250 MeV/u IFF: ~150 MeV/u	3-10 MeV/u	ISAC I: ~1.8 MeV/u ISAC II: ~16 MeV/u	2-25 MeV/u	10 MeV/u
Basic science	• Nuclear structure • Nuclear astrophysics and synthesis • Nuclear matter and symmetry energy • Atomic physics using trapping	• Nuclear structure • Atomic physics • Nuclear astrophysics • Fundamental interaction • Solid state physics	• Nuclear structure • Nuclear astrophysics • Fundamental interaction and symmetry	• Nuclear physics • Condensed matter physics • Chemical effects of radiation	• Nuclear structure • Low energy nuclear reaction • Nuclear astrophysics • High T nuclear matter • Atom trap for Nuclear physics
Applied science	• Medical and Bio • Material research • Nuclear data	• Bio science		• Radiation biology	
Completion	~2017	2015	~2015	~2013	2012

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

Research Topics

Origin of Elements

Stellar Evolution

Nuclear Physics

- Exotic nuclei near the neutron drip line
- Superheavy Elements (SHE)
- Equation-of-state (EoS) of nuclear matter

Nuclear Astrophysics

- Origin of nuclei
- Paths of nucleosynthesis
- Neutron stars and supernovae

Nuclear data with fast neutrons

- Basic nuclear reaction data for future nuclear energy
- Nuclear waste transmutation

Atomic physics

- Atomic trap
- Fundamental symmetries

Material science

- Production & Characterization of new materials
- β-NMR / μSR

Medical and Bio sciences

- Advanced therapy technology
- Mutation of DNA
- New isotopes for medical imaging

Application of Rare Isotopes

Facilities for the scientific researches

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

Nuclear Structure → Multi-Purpose Spectrometer

Nuclear Matter → Large Acceptance Multi-Purpose Spectrometer (LAMPS)

Nuclear Astrophysics → KoRIA Recoil Spectrometer (KRS)

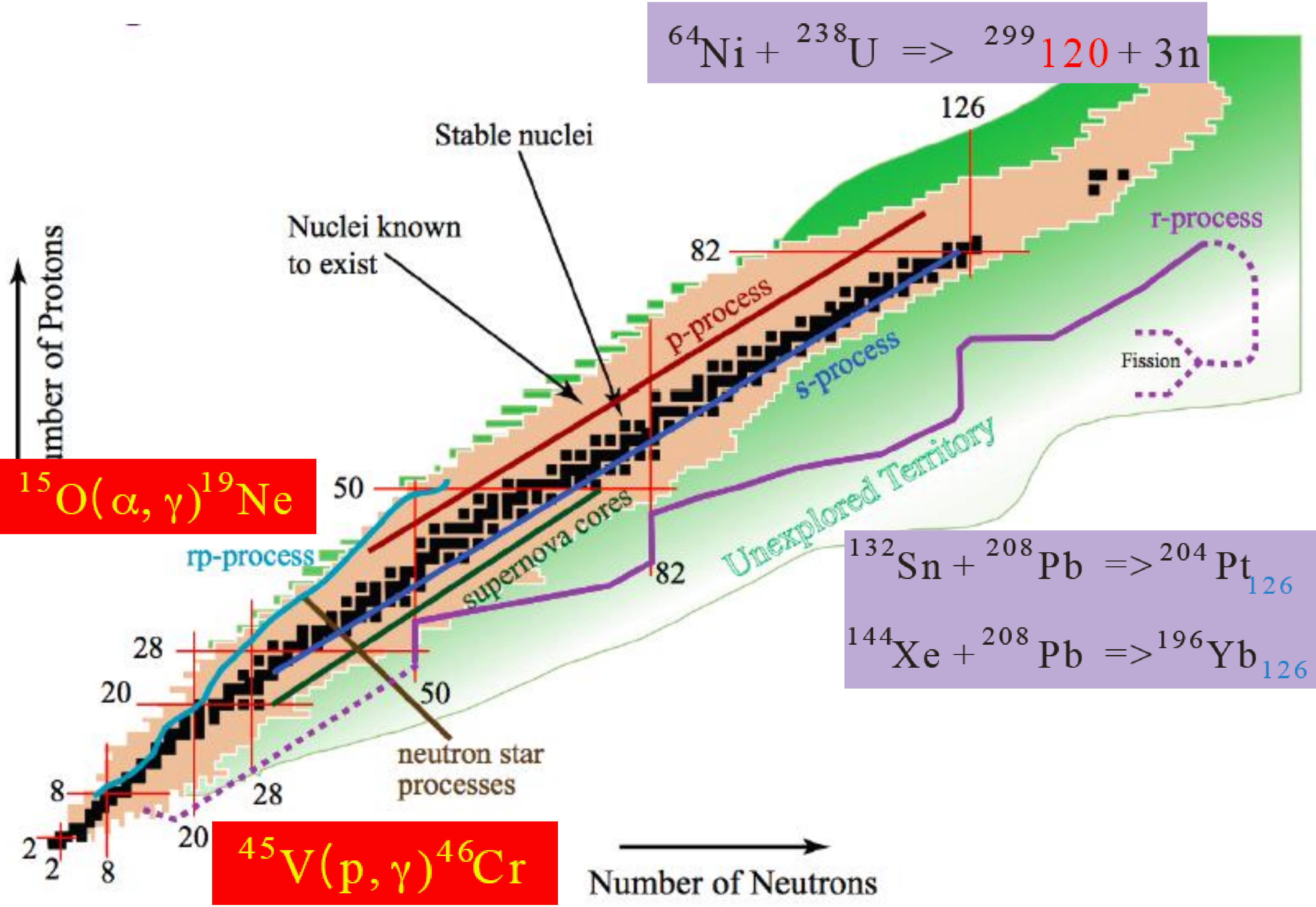
Atomic physics → Atom & Ion Trap System

Nuclear data by fast neutrons → neutron Time-of-Flight (n-ToF)

Material science → B-NMR/NQR; Elastic Recoil Detection (ERD); Laser Selective Ionizer

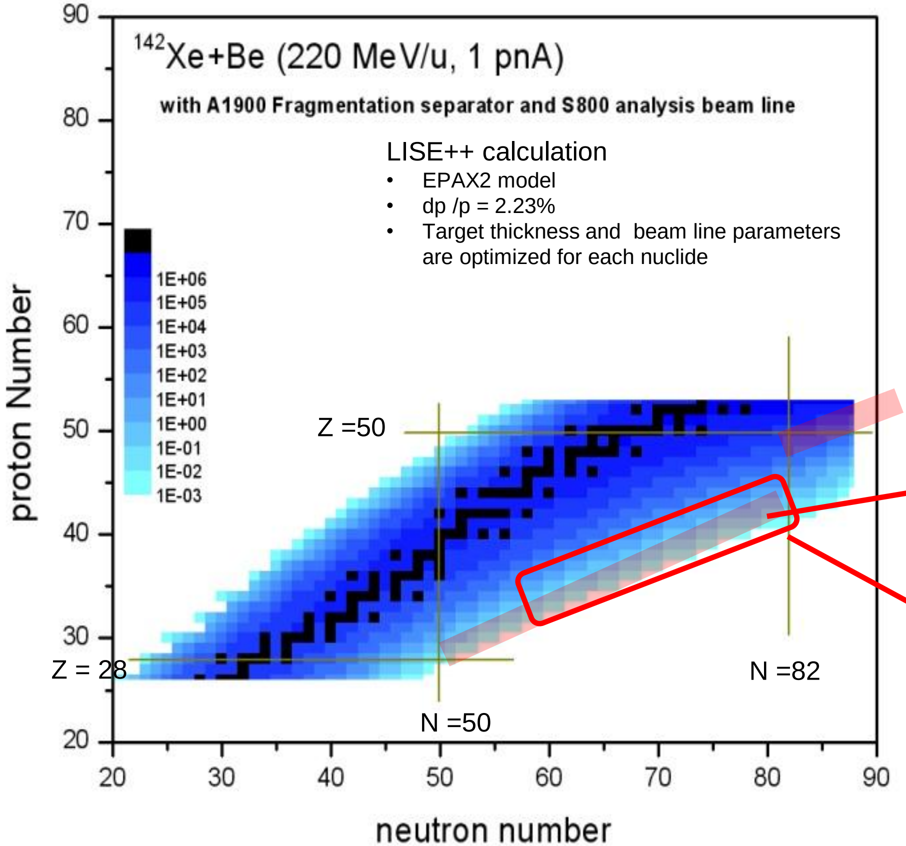
Medical and Bio sciences → Heavy Ion Therapy; Irradiation Facility

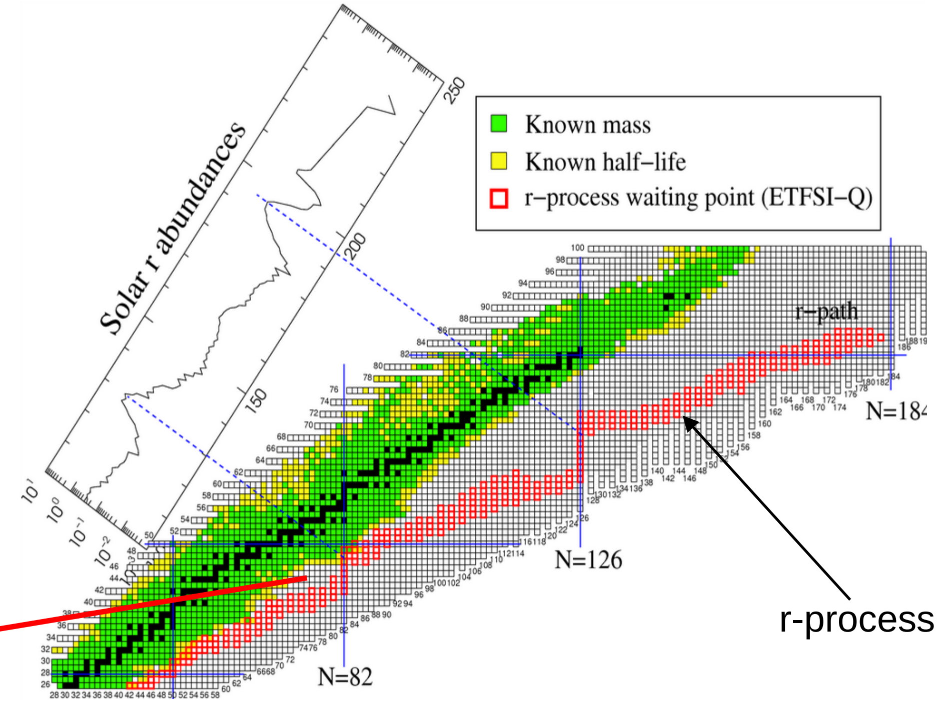
KoRIA user community



$^{64}Ni + ^{238}U \Rightarrow ^{299}120 + 3n$
$^{15}O(\alpha,\gamma)^{19}Ne$
$^{45}V(p,\gamma)^{46}Cr$
$^{132}Sn + ^{208}Pb \Rightarrow ^{204}Pt_{126}$
$^{144}Xe + ^{208}Pb \Rightarrow ^{196}Yb_{126}$
Stable nuclei
Nuclei known to exist
Number of Protons
Number of Neutrons
p-process
s-process
r-process
rp-process
supernova cores
neutron star processes
Unexplored Territory
Fission
126
82
50
28
20
8
2

Production of more-exotic medium mass n-rich RI





Korea RI Accelerator could reach new n-rich isotope with rates of 10^{-3}-10 pps.

nuclide	Estimated Intensity (pps)
^{110}Y	1.8
^{110}Zr	1.8
^{114}Nb	1.1
^{116}Mo	3.8
^{118}Tc	1.4

^{142}Xe (ISOL) → post-accelerator → re-accelerator → → In-flight target → Fragmentation separator → experiments

Note that ~10^3 times higher than ^{136}Xe (350 MeV/u, 10 pnA)+Be.

Nuclear astrophysics

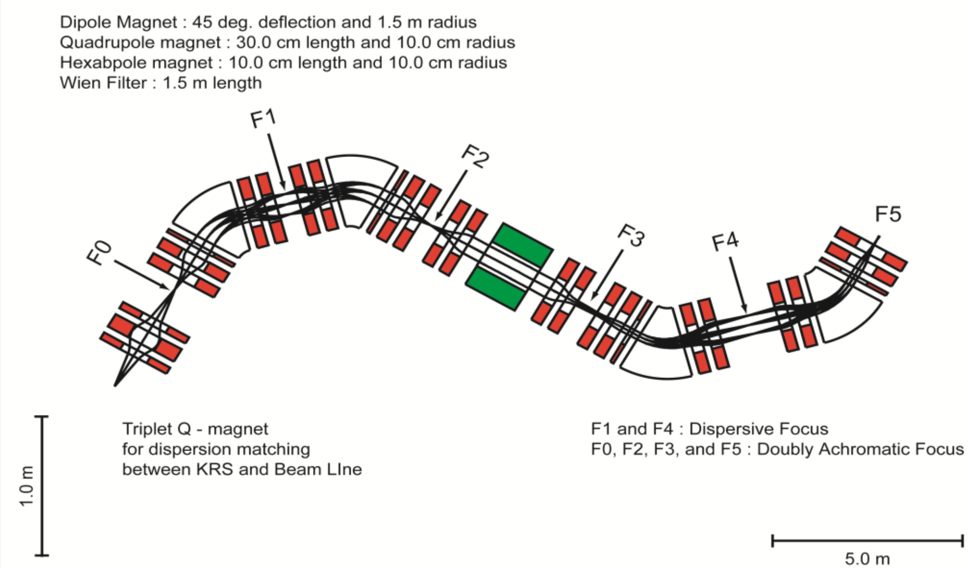
KoRIA Recoil Spectrometer (KRS)

Beam transport system
with performance of high efficient, high selective and high resolution spectrometer

Configuration
Length: ~25 m
Space : 20 X 5 m^2

1) 4 dipole magnets
2) 20 quadruple magnets
3) 4 hexapole magnets
4) velocity filter (Wien filter)

Schematic representation of the KRS



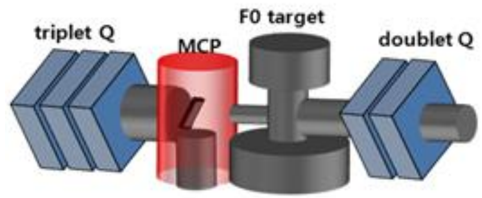
	RMS mode (recoil mass separator)	IRIS mode (In-flight RI separator)	BT mode (beam transport)
Main purpose	• **direct measurements of capture reaction (p,γ) and (α,γ)**	• in-flight RI beam separation using stable or RI beam from KoRIA + spectrometer • **production of more exotic beams**	• **beam transport from KoRIA to the focal plane of KRS**
Requirements	• background reduction • high mass resolution (M/ΔM) • large angular acceptance • highly efficient detection system	• large angular acceptance • high-density production target system • high-quality beam (high purity, low emittance, high intensity)	• 100% transport efficiency

Nuclear astrophysics

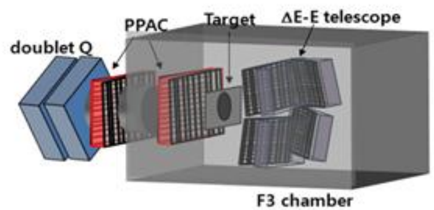
Target System

Supersonic jet gas target developed in GSI

Beam Tracking at F0 & F3

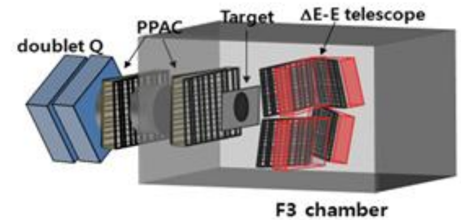


	MCP	PPAC & MWPC
Multiple scattering	~0.1 mrad	~0.05 mrad
Counting rate	> 1 MHz	> 2MHz

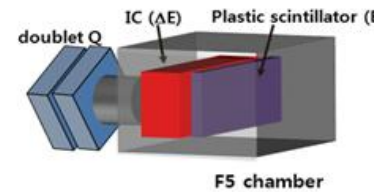


Energy loss: < 1 MeV

Particle Detection at F3 & F5



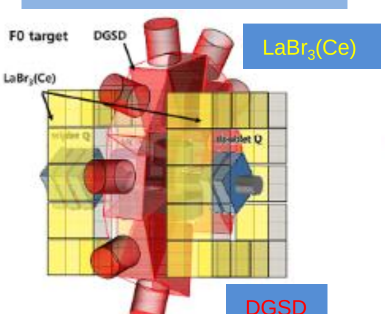
50 keV (FWHM) @ 5 MeV α-particle

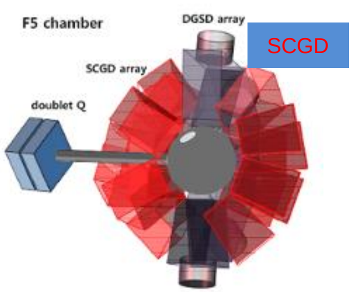


PID for low-energy recoil particle

Gamma-ray Detection at F0 & F5

ε~ 20 % @ 2 MeV γ-ray

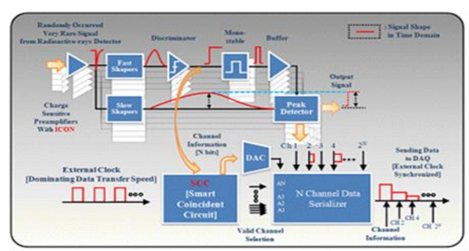




Position resolution : < 1 mm

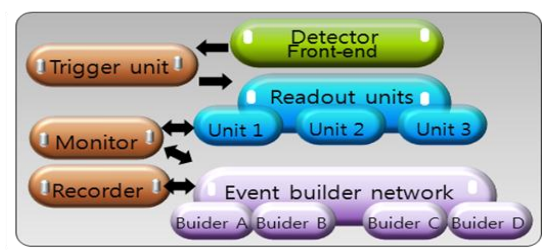
Front-end electronics

10^5 Channels



DAQ

> 2 GHz high frequency



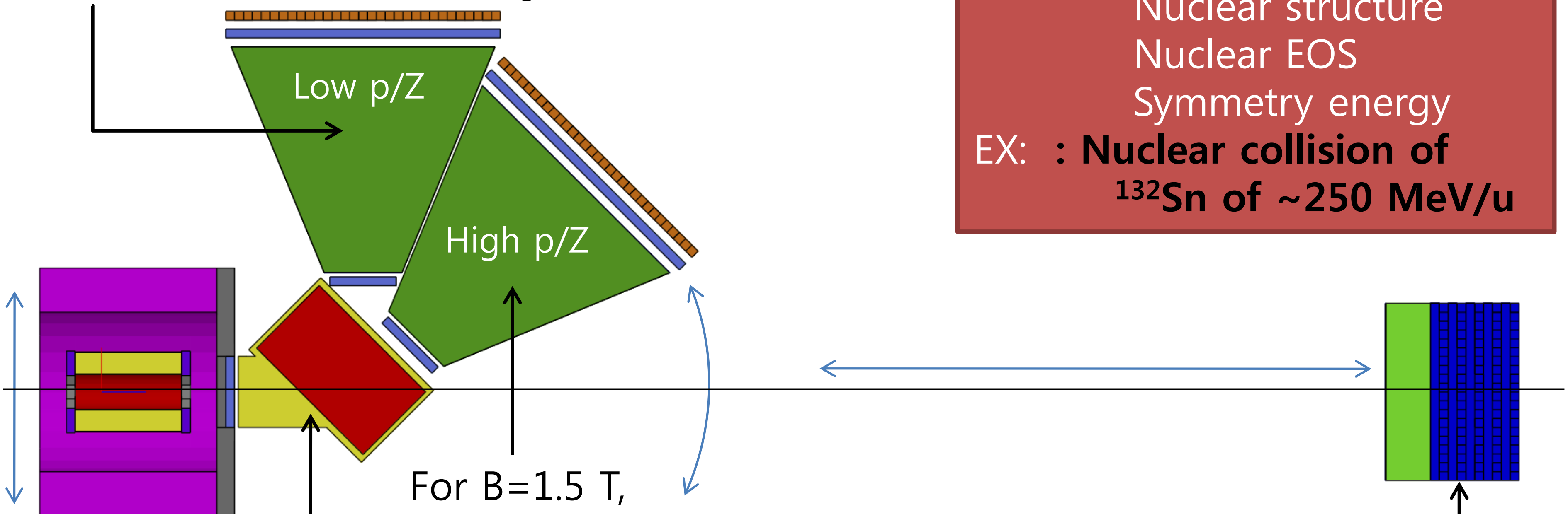
Conceptual Design of LAMPS (high energy)

For B=1.5 T,
p/Z ≈ 0.35 GeV/c at 110°

- Dipole acceptance ≥ 50mSr
- Dipole length =1.0 m
- TOF length ~8.0 m

Science Goal:
using isototpes with high N/Z at high energy for
Nuclear structure
Nuclear EOS
Symmetry energy

EX: **: Nuclear collision of ^{132}Sn of ~250 MeV/u**



For B=1.5 T,
p/Z ≈ 1.5 GeV/c at 30°

Solenoid magnet

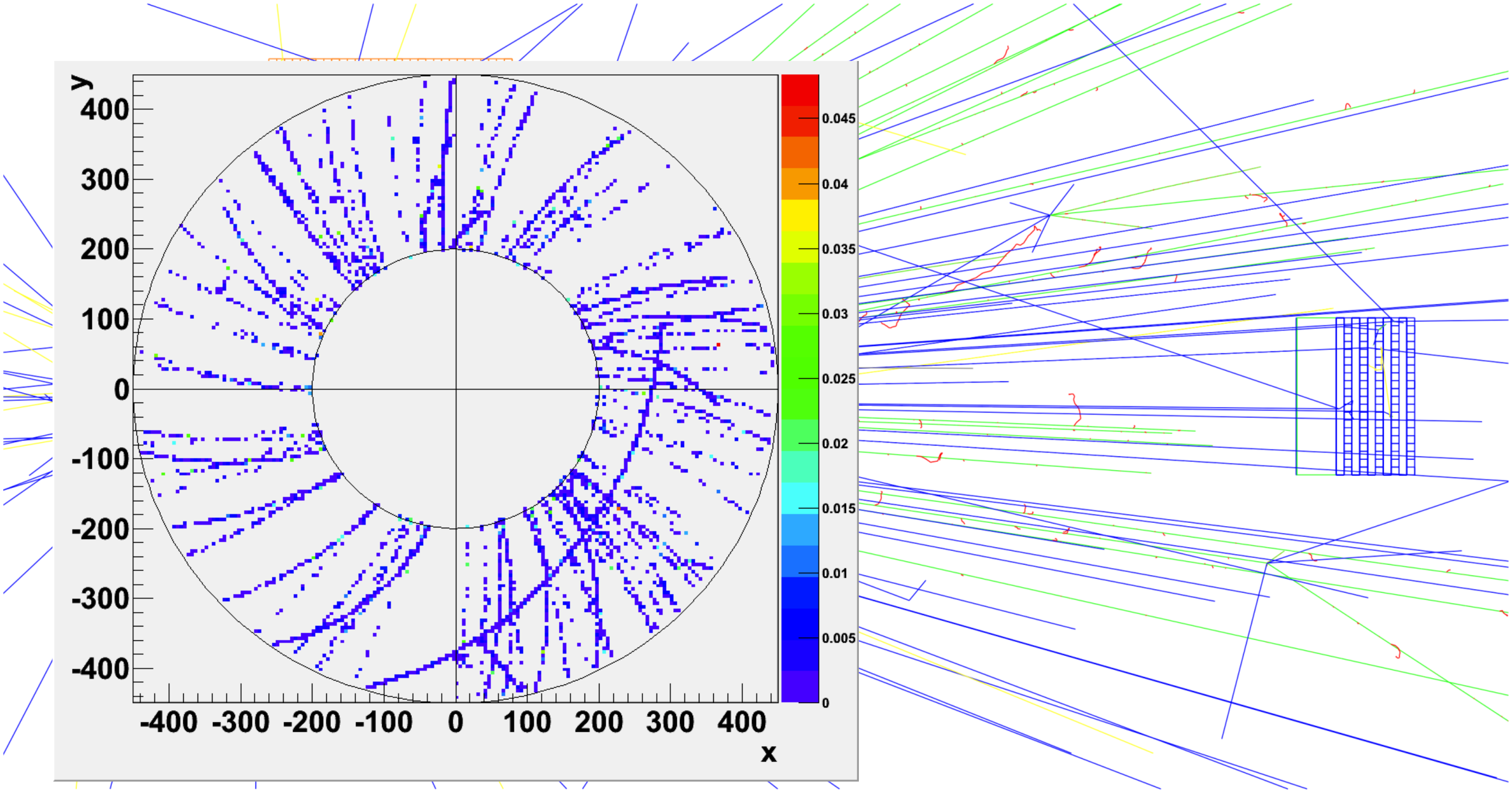
Dipole magnet: We can also consider the large aperture superconducting dipole magnet (SAMURAI type).

Neutron-detector array

: Nuclear collision experiment with ^{132}Sn of ~250 MeV per nucleon

Simulated Event Display

IQMD for Au+Au at 250A MeV

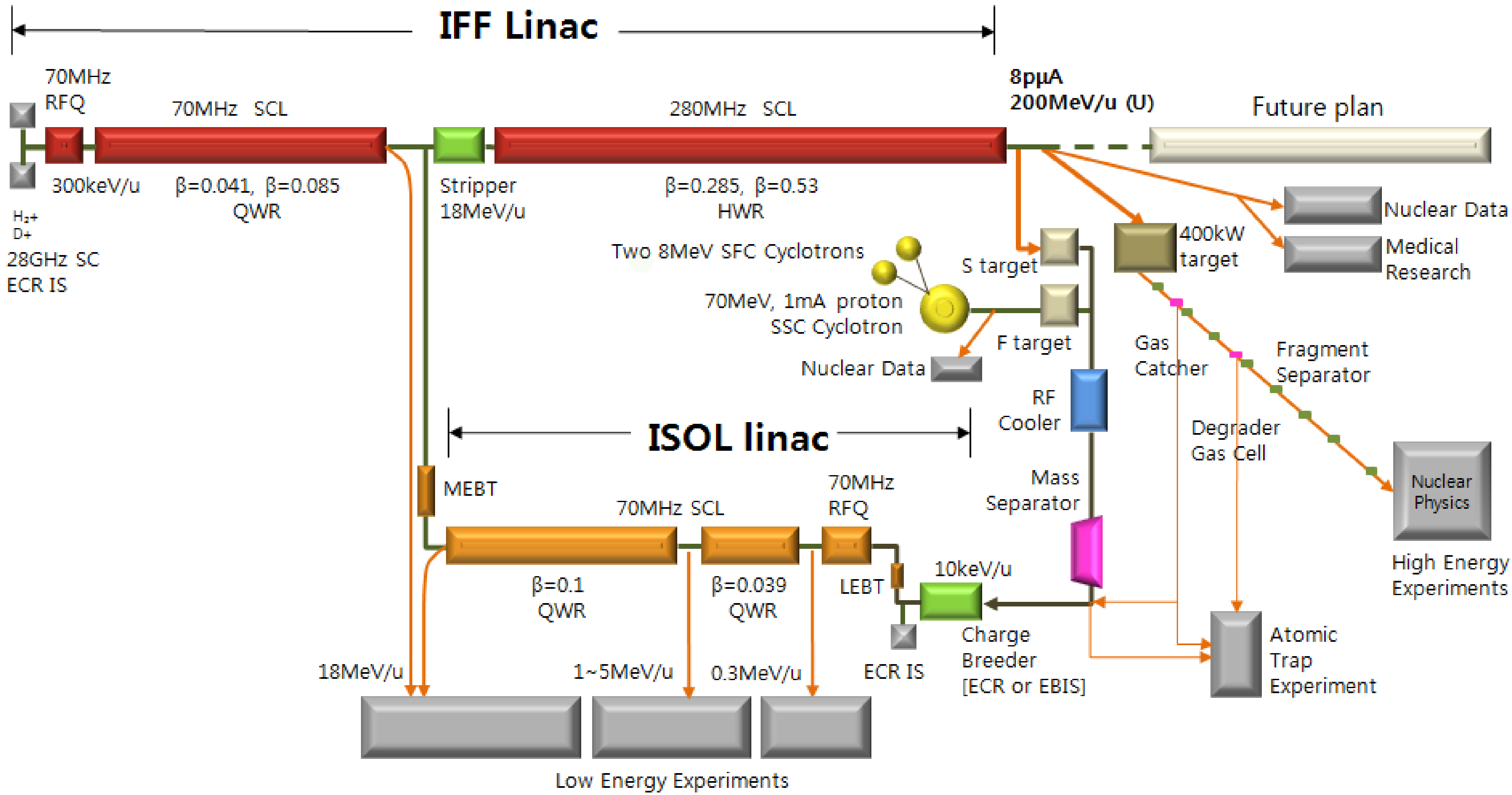


Status and Plan

- Conceptual Design report (Mar. 2010 - Feb. 2011)
- IAC review (Jul. 2011 – Oct. 2011)
- Rare Isotope Science Project started in IBS (Dec. 2011)
- Technical Design Report (by Jun. 2013)

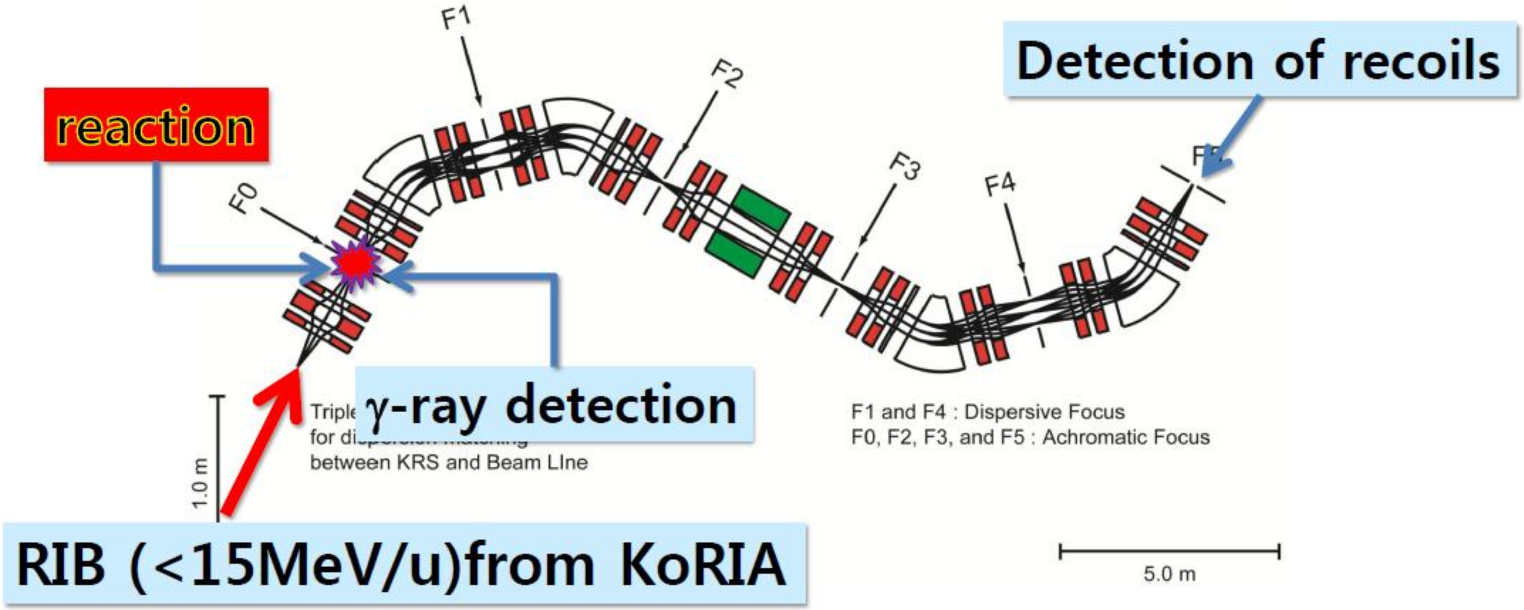
Institute for Basic Science
463-1 Jeonmin-dong, Yusung-gu, Daejeon, Korea, 305-811
Tel +82-42-878-8114 | **Fax** +82-42-878-8079
www.ibs.re.kr

기본계획(안) 파일의 그림

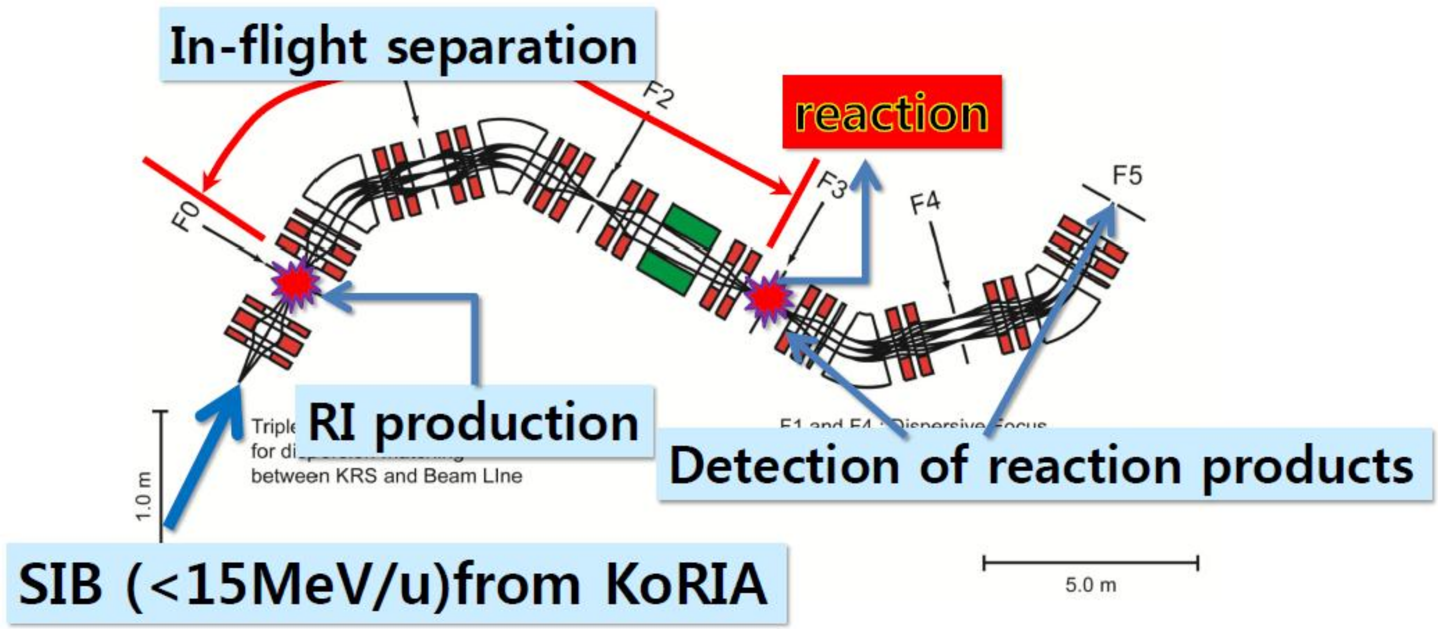


IFF Linac
70MHz
RFQ
70MHz SCL
280MHz SCL
8pμA
200MeV/u (U)
Future plan
300keV/u
β=0.041, β=0.085
QWR
Stripper
18MeV/u
β=0.285, β=0.53
HWR
H₂+
D+
28GHz SC
ECR IS
Two 8MeV SFC Cyclotrons
70MeV, 1mA proton
SSC Cyclotron
Nuclear Data
S target
F target
400kW
target
Nuclear Data
Medical
Research
Gas
Catcher
Fragment
Separator
Degrader
Gas Cell
RF
Cooler
ISOL linac
MEBT
70MHz SCL
70MHz
RFQ
Mass
Separator
Nuclear
Physics
High Energy
Experiments
10keV/u
β=0.1
QWR
β=0.039
QWR
LEBT
Charge
Breeder
[ECR or EBIS]
Atomic
Trap
Experiment
18MeV/u
1~5MeV/u
0.3MeV/u
ECR IS
Low Energy Experiments

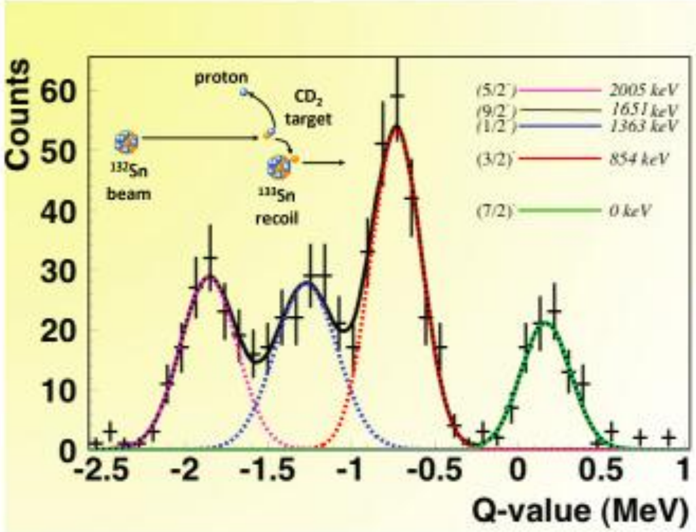
- principle of RMS mode



- principle of IRIS mode



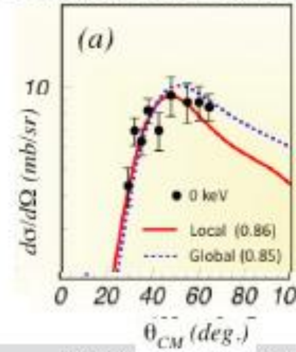
research highlight: $^{132}Sn(d,p)^{133}Sn$ measurement

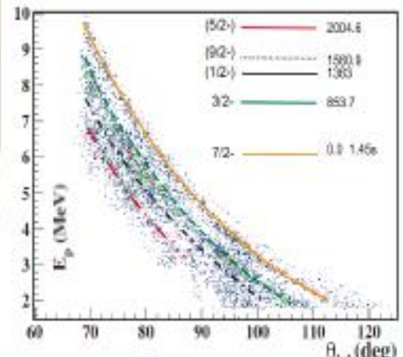


Kate Jones et al. 2010

E_x (keV)	nℓj	Spectroscopic Factor DWBA	ADWA-BG	ADWA-CH
0	2f7/2	0.86 ± 0.07	1.2 ± 0.1	**1.00 ± 0.08**
854	3p3/2	0.92 ± 0.07	1.0 ± 0.1	**0.92 ± 0.07**
1363±31	(3p1/2)	1.1 ± 0.2	1.2 ± 0.3	**1.2 ± 0.2**
2005	(2f5/2)	1.1 ± 0.2	1.3 ± 0.3	**1.2 ± 0.3**

F. Nunes





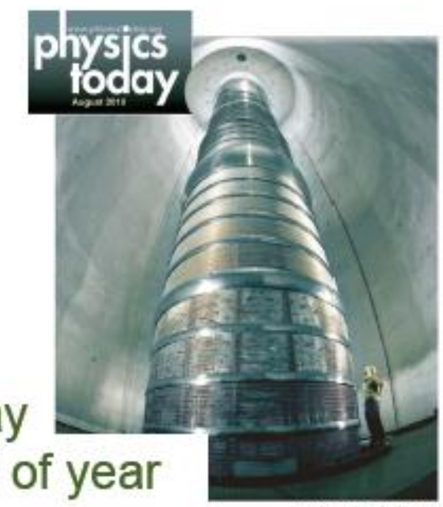

nature

LETTERS

The magic nature of ^{132}Sn explored through the single-particle states of ^{133}Sn

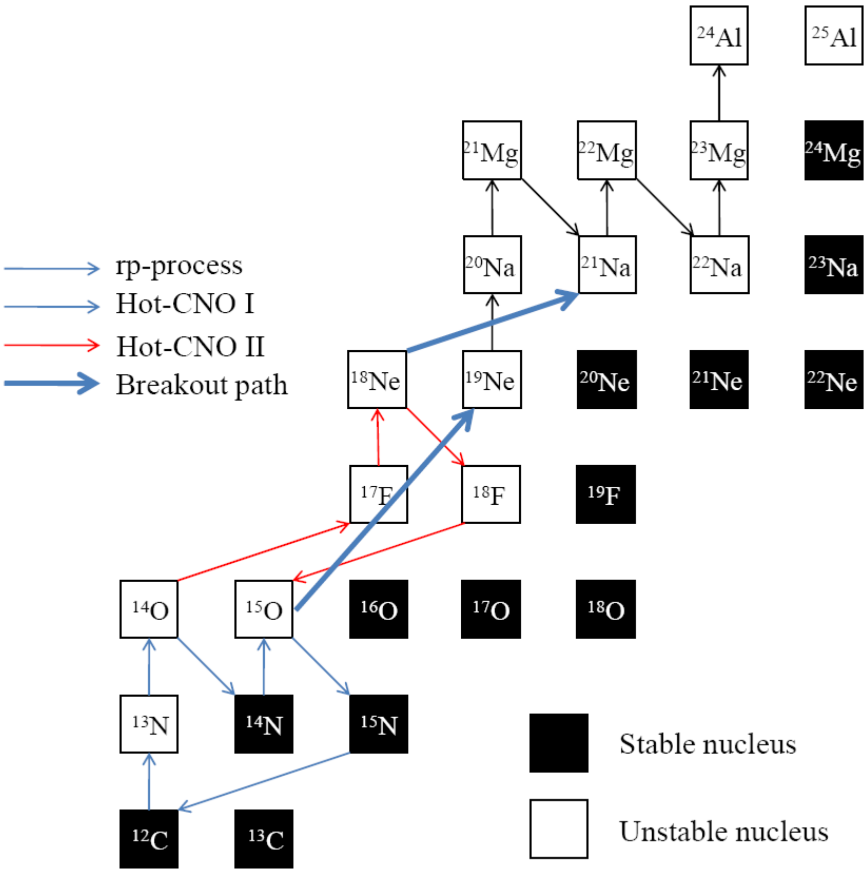
K. L. Jones, A. S. Adekola, D. W. Bardayan, J. C. Blackmon, K. Y. Chae, K. A. Chipps, J. A. Cizewski, L. Erikson, C. Harlin, R. Hatarik, R. Kapler, R. L. Kozub, J. F. Liang, R. Livesay, Z. Ma, B. H. Moazen, C. D. Nesaraja, F. M. Nunes, S. D. Pain, N. P. Patterson, D. Shapira, J. F. Shriner Jr, M. S. Smith, T. P. Swan & J. S. Thomas

- four single particle states seen w/ large spect factors ~ 1.0
- p1/2 state observed for the first time
- Ex, J^{π}, spectroscopic factors determined
- confirmation of doubly magic nature of ^{132}Sn
- new touchstone for extrapolations of nuclear models & shell structure off stability
- accolades: published in **Nature**, highlighted on Physics Today cover, over 25 popular news articles, ORNL Research paper of year

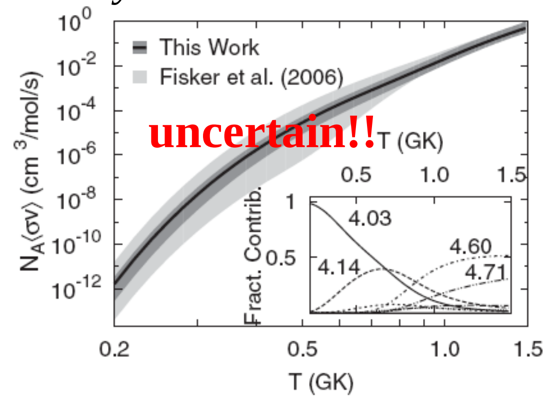


$^{15}O(\alpha,\gamma)^{19}Ne$

- **Breakout reaction from hot-CNO to rp-process** in stellar explosion such as in binary system (novae and X-ray bursts)



Reaction rate of $^{15}O(\alpha,\gamma)^{19}Ne$ by indirect methods



PRL **98**, 242503 (2007)

- **No direct measurement has been made before!!**
- **Challenges**

  - for direct measurement we need beam intensity > 10^{11} pps, target density > 10^{18} atoms/cm^2, recoil detection efficiency > 40% → then **~1counts/hr**

$^{45}V(p, \gamma)^{46}Cr$

Very important constraint on building up Core-collapse supernova model

✓ One of key Reactions related to ^{44}Ti (Cosmic gamma-ray source) issue, but still very uncertain.

Key reactions :
3α process , $^{40}Ca(\alpha, \gamma)^{44}Ti$, $^{44}Ti(\alpha, p)^{47}V$, **$^{45}V(p, \gamma)^{46}Cr$**

✓ ^{44}Ti is the first unstable nucleus on the a-line and feeds one of minor Ca isotopes , ^{44}Ca by beta-decays, i.e. $^{44}Ti\ (\beta^+)^{44}Sc(\beta^+)^{44}Ca$ (1.157MeV –g ray).

✓ Based on the model, more plausible source of ^{44}Ti is the core collapse supernova, especially the mass cut region near core, but no observations have been presented so far.

Question :
our knowledge on the condition of C-C supernova is certain?

✓ Reduction of uncertainty of nuclear physical measurements on several key reactions related to ^{44}Ti production under C-C supernova condition should be needed to confirm our model.

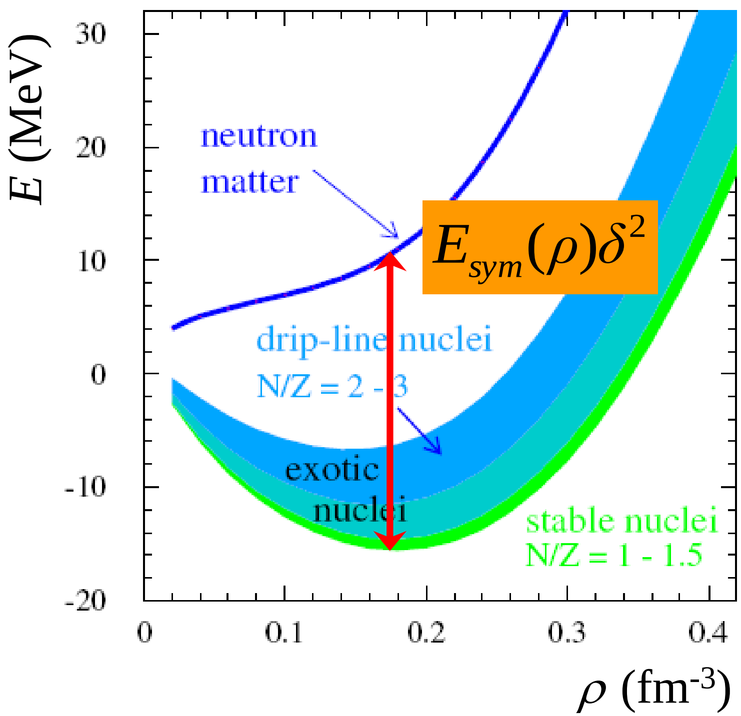
Nuclear Equation of State

$$E(\rho_n,\rho_p) = E(\rho_n=\rho_p) + E_{sym}(\rho)\delta^2 + O(\delta^4)$$

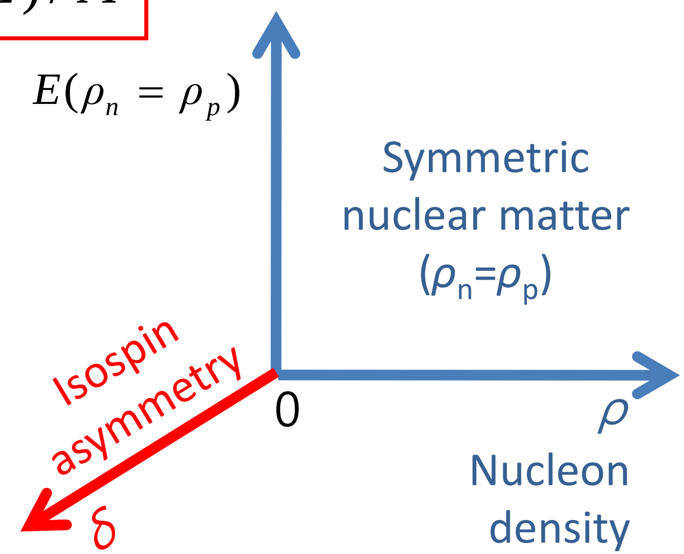
$$E_{sym}(\rho) = \frac{1}{2}\frac{\partial^2 E}{\partial \delta^2} \approx E(\rho)_{\substack{\text{pure}\\ \text{neutron matter}}} - E(\rho)_{\substack{\text{symmetric}\\ \text{nuclear matter}}}$$

$$\text{with } \rho = \rho_n + \rho_p,\ \delta = (\rho_n - \rho_p)/\rho = (N-Z)/A$$

B.-A. Li, L.-W. Chen & C.M. Ko
Physics Report, **464,** 113 (2008)



CDR, FAIR (2001)



F. de Jong & H. Lenske, RPC 57, 3099 (1998)
F. Hofman, C.M. Keil & H. Lenske, PRC 64, 034314 (2001)