Major Accelerator Facilities in Asia Pacific

Kazuhiro Tanaka (KEK), Chair of **ANPhA**
(**A**sian **N**uclear **Ph**ysics **A**ssociation)
and the chair of DNP, AAPPS.

ANPhA

- **A**sian **N**uclear **Ph**ysics **A**ssociation
  - Launched in **2009**
  - **Central organization for nuclear physics in Asia**
- **Eight membership countries and regions**
  - **Australia, China, India, Japan, Korea, Mongolia, Taiwan, and Vietnam**
- Objectives
  - To strengthen "**Collaboration**" among Asian nuclear research scientists through the promotion of nuclear physics and its transdisciplinary and applications
  - To promote "**Education**" in Asian nuclear science through mutual exchange and coordination
  - To **coordinate** among Asian nuclear scientists by actively utilizing **existing research facilities**
  - To **discuss future planning** of nuclear science facilities and instrumentation in Asia

ANPhA

- Board meetings
  - Mostly once per year with either symposium or conference
- Most recent one
  - 11th meeting in Tohoku University, Sendai Japan in Nov. 24-25, 2016
  - In conjunction with the ANPhA Symposium
- Practically, ANPhA is an organization to discuss and pursuit issues in Asian nuclear physics community at present.

11th ANPhA Board meeting in Tohoku University, Sendai Japan in Nov. 24-25, 2016 with the ANPhA Symposium

Division of Nuclear Physics of AAPPS

- In the Gyeongju board meeting in Oct. 2015, ANPhA agreed the followings:
  - It is important to strengthen the **cooperation between ANPhA and AAPPS.**
  - ANPhA can play the leading role of **establishing the Division of Nuclear Physics** in AAPPS.
- Submission of the **proposal to AAPPS** in December 14, 2015
- **Proposal approved** in the AAPPS Council meeting in Beijing in January 22-23, 2016
- **Official approval letter** received in January 27, 2016.
- **Now ANPhA plays the role of DNP of AAPPS.**
  - ANPhA Chair should be the chair of DNP of AAPPS.

DNP/ANPhA: Current EXCO Officers

- Chair
  Kazuhiro Tanaka
  (KEK)
- Vice Chair
  Weiping Liu
  (CIAE, China)
  Tohru Motobayashi
  (RIKEN, Japan)
  Anthony Thomas
  (Univ. of Adelaide, Australia)
- Secretary
  Hirokazu Tamura
  (Tohoku Univ. to be confirmed)





DNP: Executive Committee (EXCO)

- **Australia**
  - Anthony Thomas (Univ. of Adelaide)
- **China**
  - Furong Xu (Peking Univ.)
  - Guoqing Xiao (IMP)
  - Weiping Liu (CIAE)
  - Yugang Ma (SINAP)
- **India**
  - Vivek Datar (BARC)
  - Alok Chakrabarti (VECC)
- **Japan**
  - Kazuhiro Tanaka (KEK)
  - Atsushi Hosaka (RCNP, Osaka Univ.)
  - Tohru Motobayashi (RIKEN)
  - Hirokazu Tamura (Tohoku Univ.)
- **Korea**
  - Myeong-Ki Cheoun (Soongsil Univ.)
  - Byungsik Hong (Korea Univ.)
  - Kevin Insik Hahn (Ewha Womans Univ.)
- **Mongolia**
  - TBA
- **Taiwan**
  - Henry Tsz-king Wong (Academia Sinica)
- **Vietnam**
  - Dao Tien Khoa (INST-Hanoi)

As of December 5, 2016

Recent activity of DNP: Preparation of **ANPhA White Paper**

- Table of 26 Accelerator Facilities for Nuclear Physics in Asia
- Data will be updated frequently.
- Critical analysis of the present data will be made for **future facility planning** and for possible **future international collaboration**.
- Data will be open on Web soon, and possibly published in special issue of AAPPS Bulletin.

Town	Institute	Facility	Characteristics
Canberra, Australia	Australian National University (ANU), Heavy Ion Accelerator Facility		15MV Tandem accelerator + superconducting Linear Accelerator
Beijing, China	Beijing Tandem Accelerator Nuclear Physics National Laboratory	BTANL	15 MV tandem accelerator, 100 MeV 20 μA proton cyclotron, ISOL
Shanghai, China	Shanghai Laser Electron Gamma Source	SLEGS	0.4-20 MeV BCS γ-ray source based on Synchrotron Radiation Facility
Jinping, China	China Jinping underground Laboratory (CJPL), JINPING UNDERGROUND NUCLEAR ASTROPHYSICS EXPERIMENT (JUNA)	CJPL / JUNA	400 kV accelerator (Ion species of Stable nuclei: H to He), Max. Energy: 400 kV*q, Beam Intensity: up to 2.5 emA
Lanzhou, China	Heavy Ion Research Facility in Lanzhou	HIRFL	SSC cyclotron: K=450 and full ion acceleration CSRm booster synchrotron 12.2 Tm
Huizhou, China	Heavy Ion Accelerator Facility, Institute of modern Physics	HIAF	Heavy-Ion Linac, Booster-ring ~1GeV/u and Ring spectrometer (Phase 1). Compressor ring ~5GeV/u and Enrgy Recovery Linac.
Huizhou, China	Chinese Initial ADS	CIADS	The 250 MeV and 10mA (maximum beam current) CW mode superconducting proton LINAC
New Delhi, India	Inter-University Accelerator Centre		Heavy ion tandem + superconducting linac
Kolkata, India	Variable Energy Cyclotron Centre	VECC	VEC K130 cyclotron (p,α), K500 Superconducting Cyclotron
Chiba, Japan	Heavy Ion Medical Accelerator, National Institute of Radiological Sciences	HIMAC	High energy heavy ion beams, up to 800 MeV/u, supplied by linear accelerators and two synchrotron rings.
Tokai, Ibaraki, Japan	J-PARC (Nuclear and Particle Physics Facility)	J-PARC	High Intensity Accelarators, 400MeV LINAC, 3GeV RCS, 50GeV MR
Osaka, Japan	Research Center for Nuclear Physics, Osaka University	RCNP/LEPS	Cyclotron complex (K140 AVF + K400 Ring) Laser-electron back-scattered photon facility at SPring-8 site, 2.4 and 2.9 GeV.
SPring-8 site, Hyogo, Japan	Laboratory of Advanced Science and Technology for Industry	NewSUBARU	Laser Compton Scattering Gamma-ray Beam Source (1 - 76 MeV)
Wako, Saitama, Japan	RIKEN Nishina Center for Accelerator-Based Science, RI Beam Factory	RIBF	Heavy Ion Linac and several big Ring Cycrotrons (Max K=2500MeV), Big Rips Projectile Isotope Separator

Town	Institute	Facility	Characteristics
Fukuoka, Japan	Kyushu University, Center for Accelerator and Beam Applied Science		FFAG synchrotron and tandem acceleror
Tokai, Ibaraki, Japan	Japan Atomic Energy Agency (JAEA), Tandem Accelerator Facility		20MV tandem accelerator and superconducting linac booster.
Tsukuba, Ibaraki, Japan	University of Tsukuba, Tandem Accelerator Complex	UTTAC	6 MV tandem accelerator / 1 MV Tandetron accelerator
Sendai, Japan	Tohoku University, Cyclotron and Radioisotope Center	CYRIC	K110 and K12 cycrotrons
Sendai, Japan	Research Center for Electron-Photon Science, Tohoku University	ELPH	60 MeV High Intensity ELECTRON Linac, 1.3 GeV Booster Electron Synchrotron for GeV tagged photon beams
Gyeongsangbuk-do, Korea	Korea Multi-purpose Accelerator Complex	KOMAC	100 MeV and 20 MeV Proton linac
Seoul, Korea	Korea Institute of Science and Technology (KIST), The Accelerator Laboratory		2MeV and 6 MV tandetron accelerators
Seoul, Korea	Korea Heavy Ion Medical Accelerator at Korea Institute of Radiological and Medical Sciences (KIRMAS)	KIRAMS	AVF cyclotron for 50MeV protons
Jeollabuk-do, Korea	Advanced Radiation Technology Institute		15-30 MeV 500microA Proton Cycrotron
Seoul, Korea	National Center for Inter-Universities Research Facilities Electrostatic Ion Accelerator		3.3MV HVEE(High Voltage Engineering Europa) 4130-Tandetron AMS/MPS
Daejeon, Korea	Rare isotope Accelerator complex for ON-line experiments (RAON), Institute for Basic Science (IBS)	RAON	Superconducting Driver Linac (proton: 600MeV, 660 microA, HI: 200MeV/u), Superconducting Post Linac (HI: 18.5 Mev/u), Cyclotron: (proton 70 MeV, 1mA)
Hsinchu, Taiwan	Graduate Institute of Nuclear Science (INS) National Tsing Hua University (NTHU)	INS / NTHU	3MV Van de Graaff (KN) Accelerator, 3MV Tandem accelerator (NEC 9SDH-2), open air 500kV accelerator
Hanoi, Vietnam	Tandem machine at Hanoi University of Natural Science		1.7MV Tandem Pelletron,
Hanoi, Vietnam	Military Central Hospital 108		30 MeV 300 microA proton cyclotron

Major Accelerator Facilities in Asia Pacific

- China
  - HIRFL->HIAF (Heavy Ion Research Facility in Lanzhou -> High Intensity Heavy Ion Accelerator Facility)
  - BTANL (Beijing Tandem Accelerator Nuclear Physics National Laboratory)
  - Beijing ISOL
- Korea
  - RISP (Rare Isotope Science Project)
- Japan
  - Spring-8/ELPH (Electromagnetic Probes)
  - RIBF (Radioactive Ion Beam Facility)
  - J-PARC->Hd-ex (Japan proton Accelerator Research Complex -> Hadron Hall Extension)

Physics promoting projects

	How?	Asia	Europe	America
Quark many body (Hot QCD)	A+A	-	LHC(ALICE) FAIR(SIS300) NICA	RHIC
Quark many body (Cold QCD)	Hd	J-PARC->Hdex	FAIR(SIS100)	
	HI	HIRFL->HIAF		
	EM	Spring-8/ELPH	MAMI	JLAB-12GeV
	Collider	(S-KEKB)	NICA	eRHIC(eIC)
Nucleon many body (RI BEAM)	PF	RIBF	GSI/FAIR	FRIB
	Both	RISP		
	ISOL	HIRFL->HIAF BTANL	SPIRAL2 SPES HIE-ISOLDE Dubna	ARIEL/ISAC2
	Super	Beijing-ISOL	EURISOL	

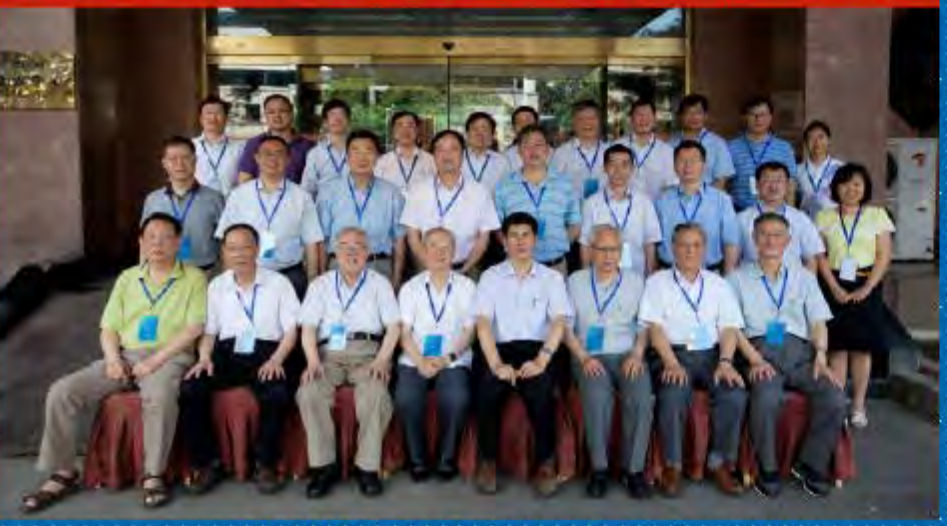
Fundamental Physics / Computation / Applications

2013 China reasarch facility long range plan

- Aiming at basic interaction between basic buliding blaock, search for new physcis beyond standard model, enhance research for nuclear and nuclear astrophsyics
- Particle physics. High energy cosimic ray array, start neutrino and other non accelarator facility and future accelarartor R&D
- Nuclear physics. Advanced heavy ion facilty, to reach to top class in nuclear physics research; start R&D of intense RI beam facility

Long range plan: Xiangshan forum

“核物理与等离子体物理发展战略研究”第一次会议



2014年9月19-20日

2014年8月28-29日

核物理发展战略研究

核物理发展战略研究编写组

2015 年 7 月 31 日

8章，~320页，~40万字

香山科學會議

第 502 次学术讨论会

我国核物理和核科学装置发展研讨

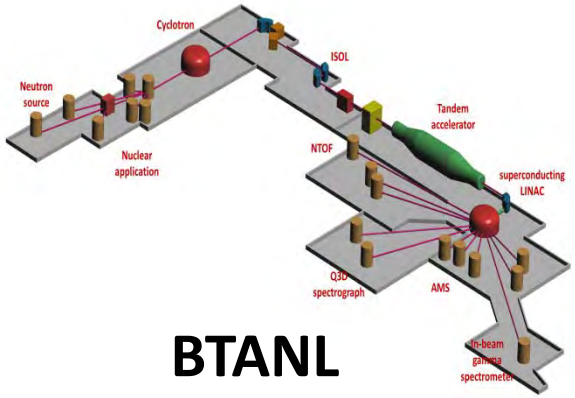
Roadmap of NP facilities

1986
北京串列加速器
HI-13

1988
兰州回旋加速器
SSC

2008
兰州储存环
CSR

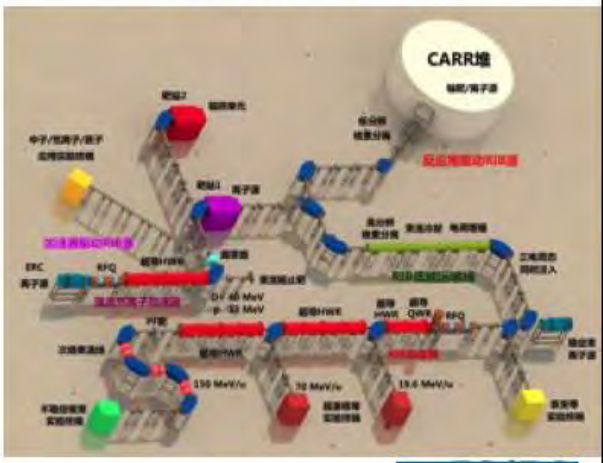
2014
北京串列升级工程



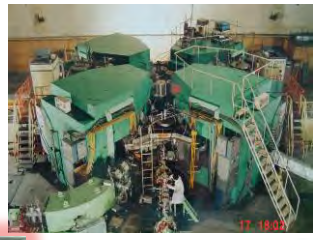
BTANL

2021?
重离子应用装置
HIAF

2028?
北京ISOL装置



Heavy Ion Research Facility in Lanzhou (HIRFL)

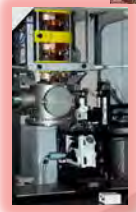


SSC (K=450)

100 AMeV (H.I.), 110 MeV (p)
Operated in 1988

SFC (K=69)

10 AMeV (H.I.), 17~35 MeV (p)
Operated in 1963



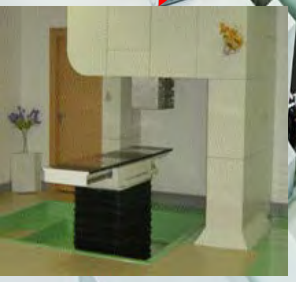
RIBLL1

RIBs at tens of AMeV
Operated in 1997

CSRe

RIBLL2

RIBs at hundreds of AMeV



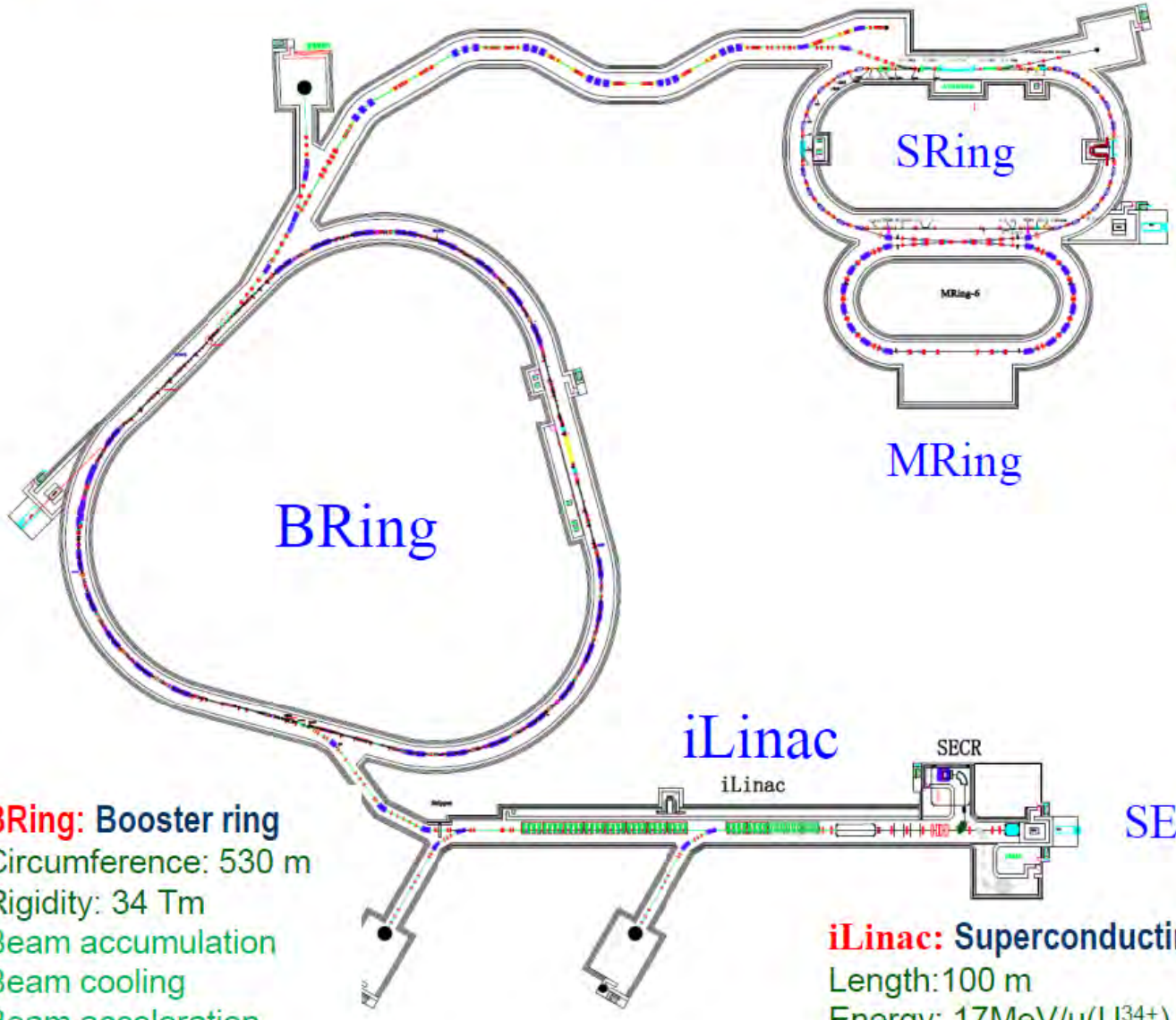
CSR(Cooling Storage Ring)

1000 AMeV (H.I.), ≤ 2.8 GeV (p)
Circumference: 160 m
Operated in 2005

Clinical trial for Skin-tumor therapy started in 2006

Clinical trial for deep-seated tumor therapy started in 2009

HIAF装置组成Layout



SRing: Spectrometer ring
Circumference:265m
Rigidity: 13-15Tm
Electron/Stochastic cooling
Two TOF detectors
Four operation modes

MRing: Figure "8" ring
Circumference: 268 m
Rigidity: 13 Tm
Ion-ion merging

BRing: Booster ring
Circumference: 530 m
Rigidity: 34 Tm
Beam accumulation
Beam cooling
Beam acceleration

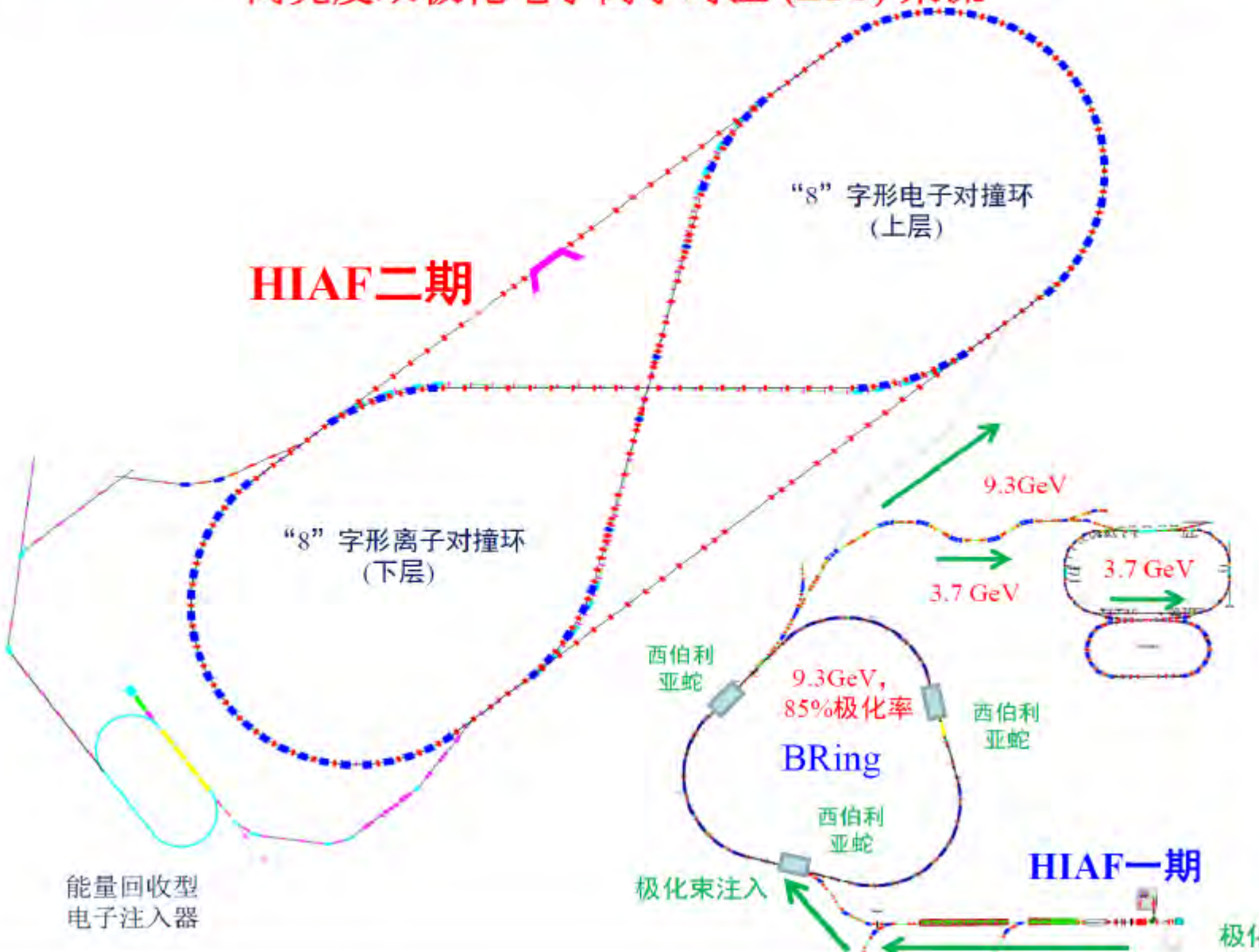
iLinac: Superconducting linac
Length:100 m
Energy: 17MeV/u(U^{34+})

HIAF基本束流参数beam parameter

	Ions	Energy	Intensity
SECR	$^{238}U^{34+}$	14 keV/u	0.05 pmA
iLinac	$^{238}U^{34+}$	17 MeV/u	0.028 pmA
BRing	$^{238}U^{34+}$	0.8 GeV/u	~1.4×10^{11} ppp
SRing	RIBs: 丰质子、丰中子	0.74 GeV/u(A/q=3)	~$10^{9\text{-}10}$ ppp
	全剥离的重离子 类H, 类He的重离子	0.8 GeV/u($^{238}U^{92+}$)	~$10^{11\text{-}12}$ ppp
MRing	$^{238}U^{92+}$	0.8 GeV/u	~1.0×10^{11} ppp

HIAF 升级- 二期Upgrading plan

提供最强的中低能重离子束流；产生最高功率的短脉冲重离子束团；
高亮度双极化电子离子对撞 (EIC) 束流



IMP 及相关中心Relation with IMP

IMP main campus
National Laboratory of Heavy Ion Accelerator in Lanzhou (NLHAL)

Center of Heavy Ion Therapy at Wuwei city

R&D Center of Heavy Ion Applications, New Campus in Lanzhou

Center of Heavy Ion Therapy at Lanzhou

WuWei

288km

BaiYin

76km

LanZhou

2420km

NingDe

HuiZhou

Industrialization Pilot Base at Baiyin city

Lab of Superconducting Technology at Baiyin city

Lab of Spallation Target at Baiyin city

Center of Nuclear Energy For ADANES

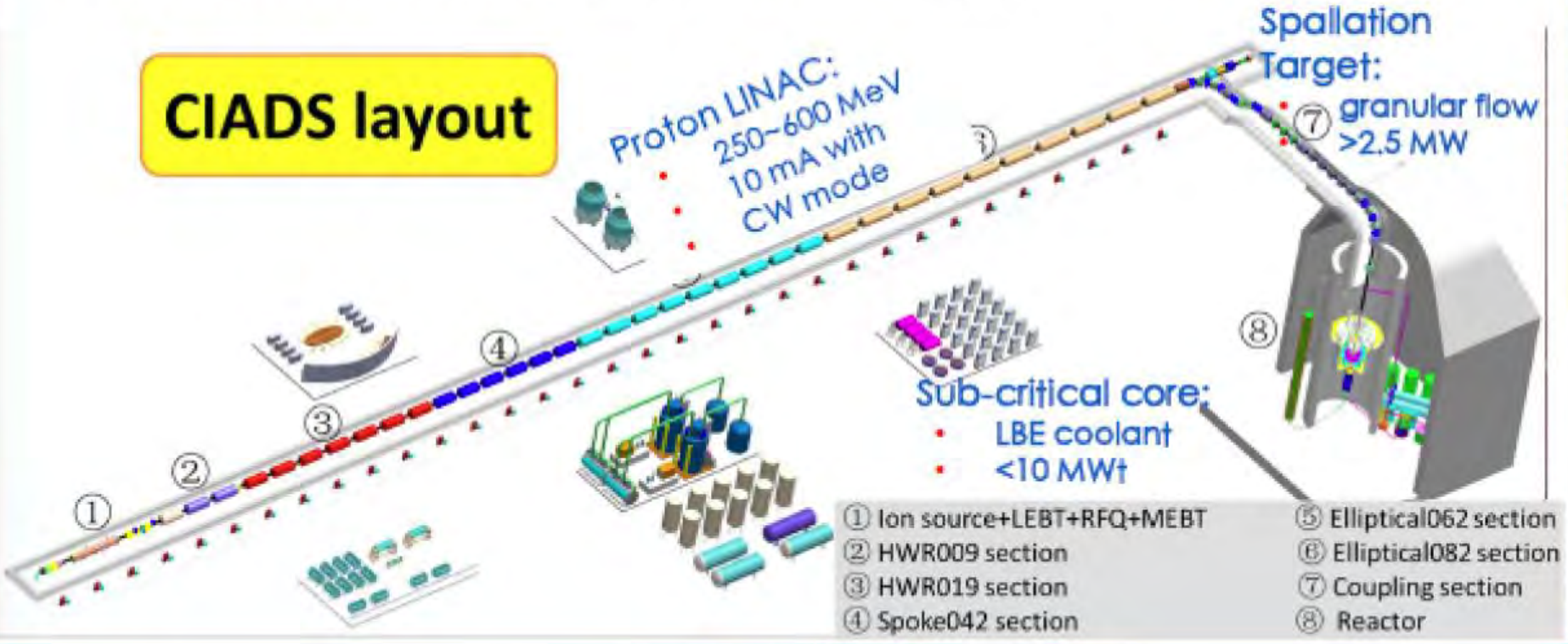
Center of Heavy Ion Science Branch of IMP at Huizhou

Research Center of Advanced Energy and materials at Huizhou

CIADS Project (2016-2023)

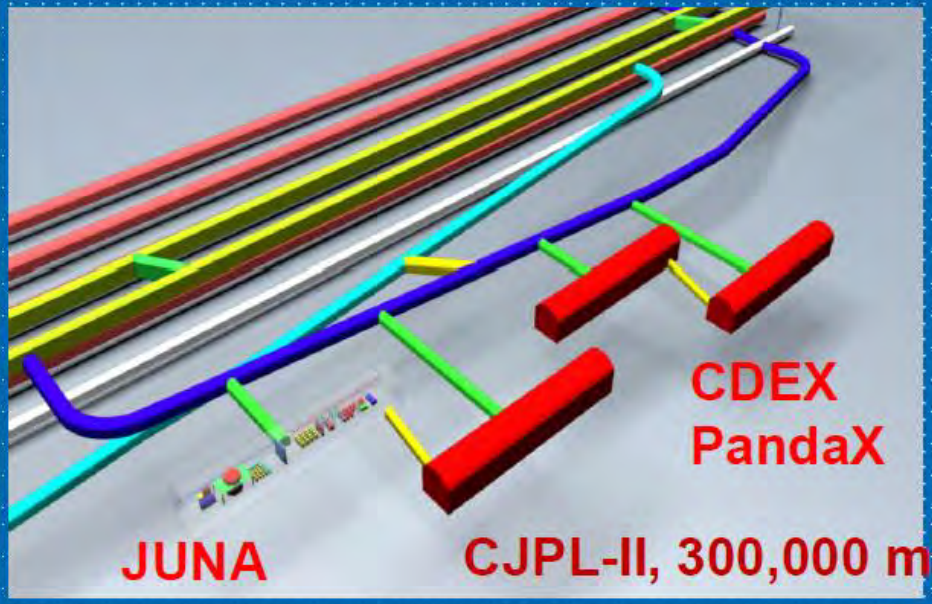
China Initiative Accelerator Driven System (CIADS)

- 2015年12月建议书获国家发改委批准
- 经费: ~(18+12)亿元 (中央财政+地方政府)
- 建设地点: 广东省惠州市
- 建设及合作单位: 广州分院、近物所、高能所、合肥物质院、401、中广核等



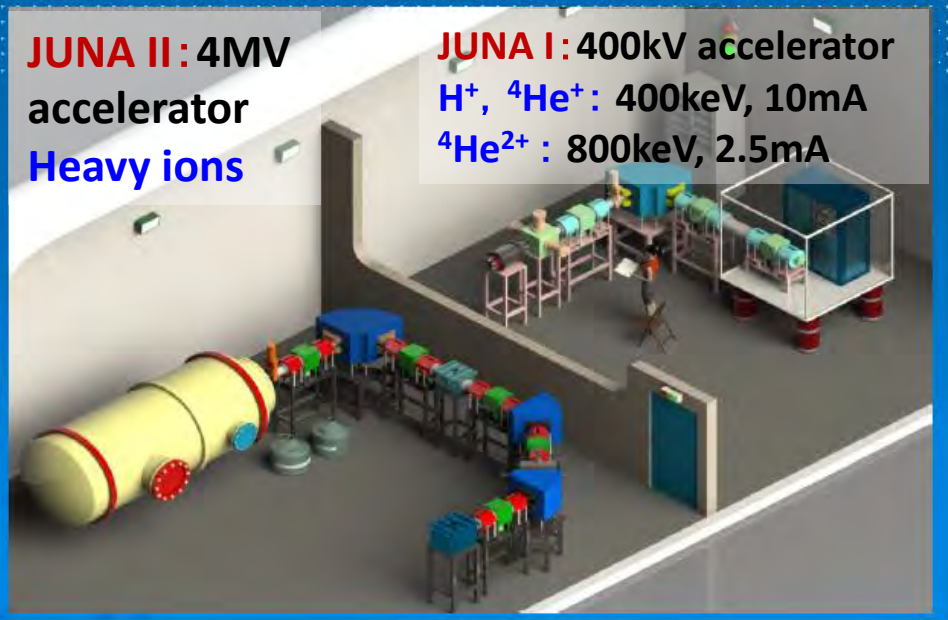
China JinPing Underground Laboratory (CJPL)

JUNA : Jinping underground nuclear astrophysics



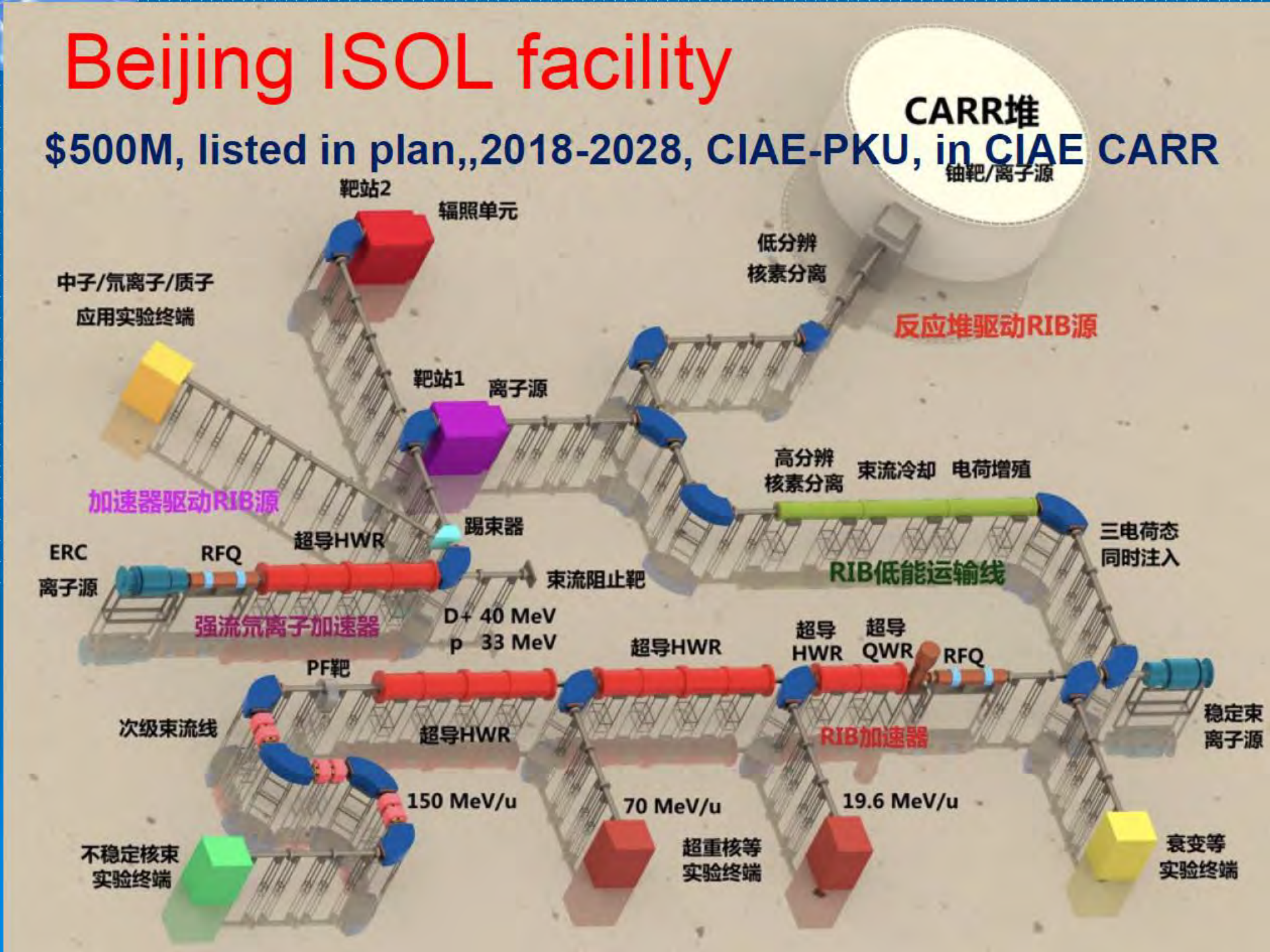
JUNA II : 4MV accelerator
Heavy ions

JUNA I : 400kV accelerator
H^+, $^4He^+$: 400keV, 10mA
$^4He^{2+}$: 800keV, 2.5mA



Beijing ISOL facility

$500M, listed in plan,,2018-2028, CIAE-PKU, in CIAE CARR



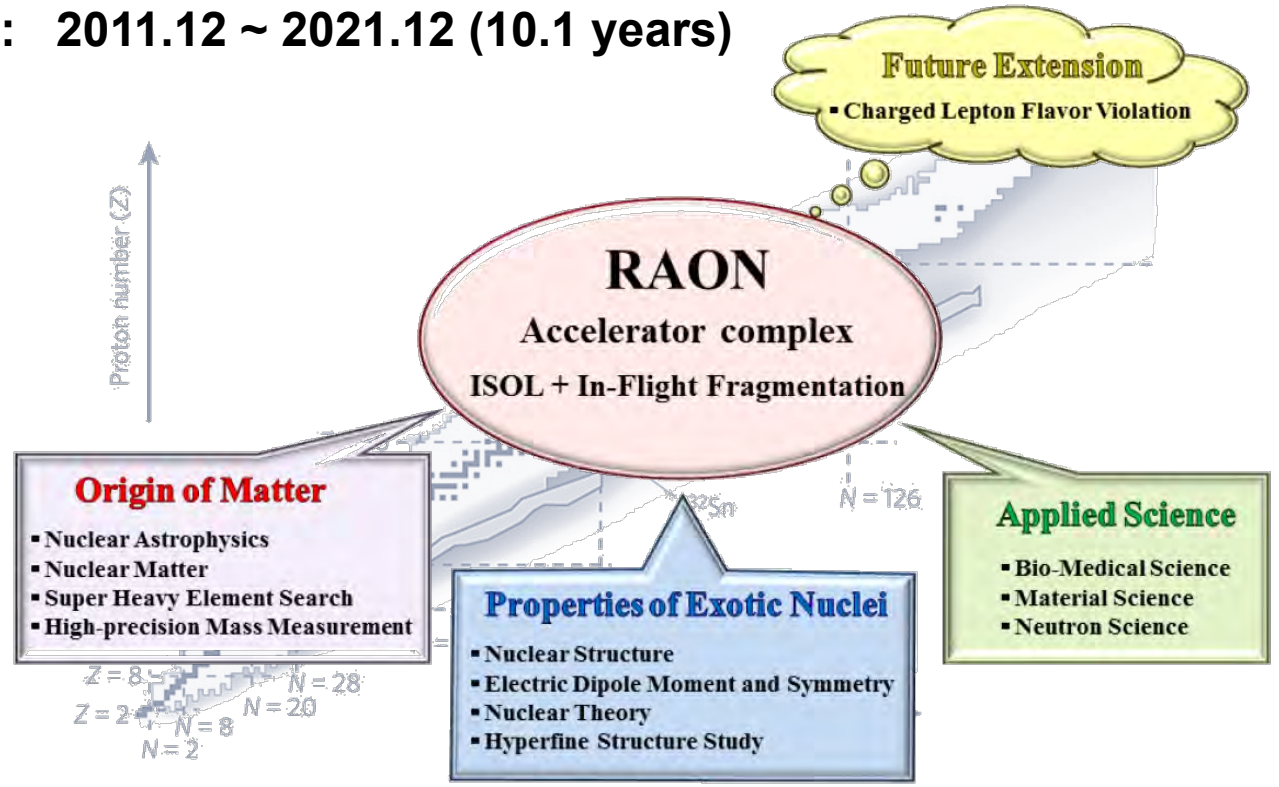
Rare Isotope Science Project (RISP)

- **Goal:** To build **a heavy ion accelerator complex RAON,** for **rare isotope science** research in Korea.

  * RAON - Rare isotope Accelerator complex for ON-line experiments

- **Budget: US$ 1.44 B** (1 B$~1T Won)
  - accelerators and experimental apparatus : 0.46 B$
  - civil engineering & conventional facilities : 0.98 B$ (incl. construction site purchase)
    (recently approved in June 2014)

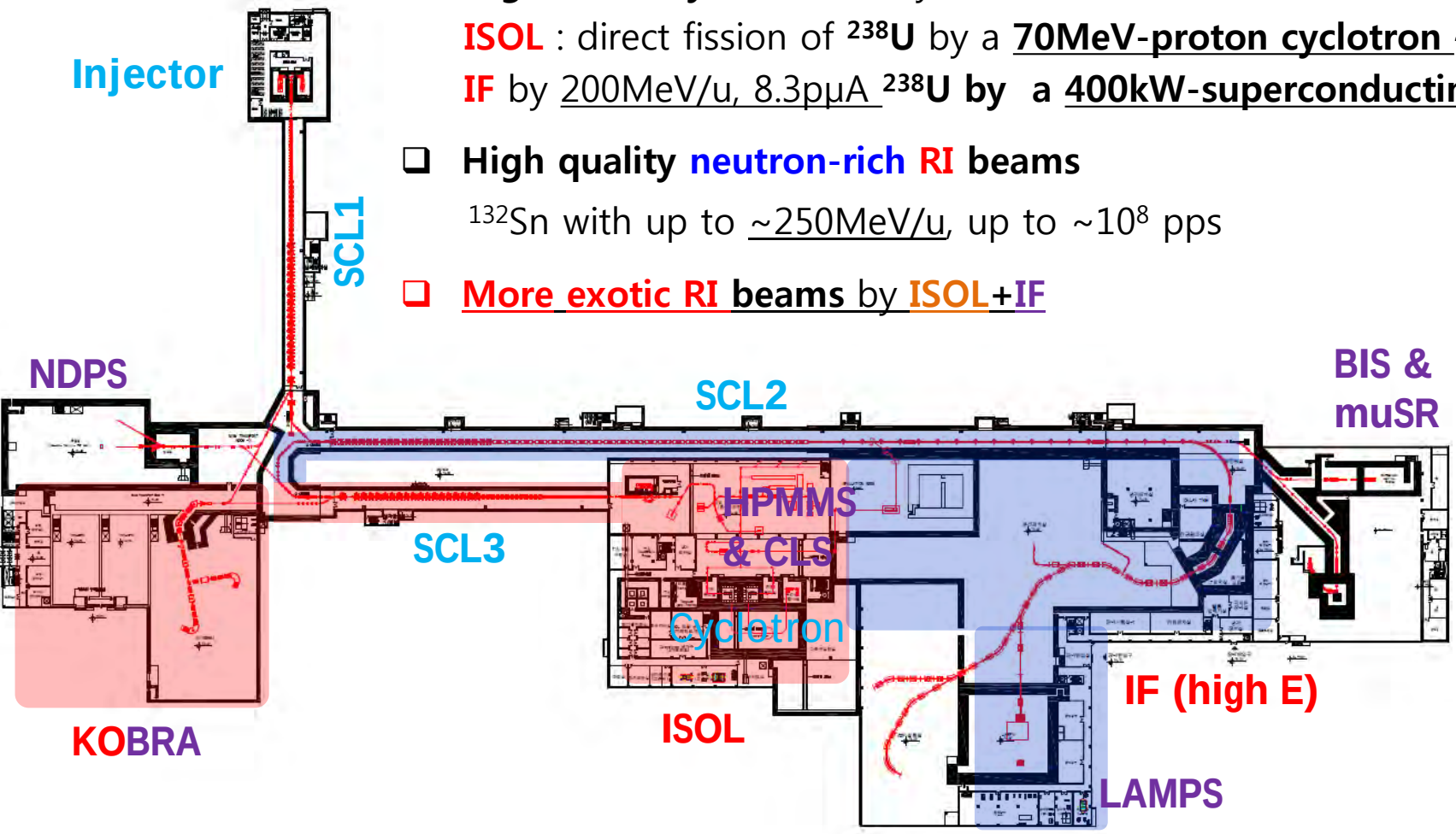
- **Period: 2011.12 ~ 2021.12 (10.1 years)**



RAON Concept

: Accelerator complex for producing rare isotope beams

- **High intensity RI beams** by **ISOL & IF**
  ISOL : direct fission of **^{238}U** by a **70MeV-proton cyclotron** ~ 10^{14} f/s
  IF by 200MeV/u, 8.3pμA **^{238}U by a 400kW-superconducting LINAC**
- **High quality neutron-rich RI beams**
  ^{132}Sn with up to ~250MeV/u, up to ~10^{8} pps
- **More exotic RI beams** by **ISOL+IF**



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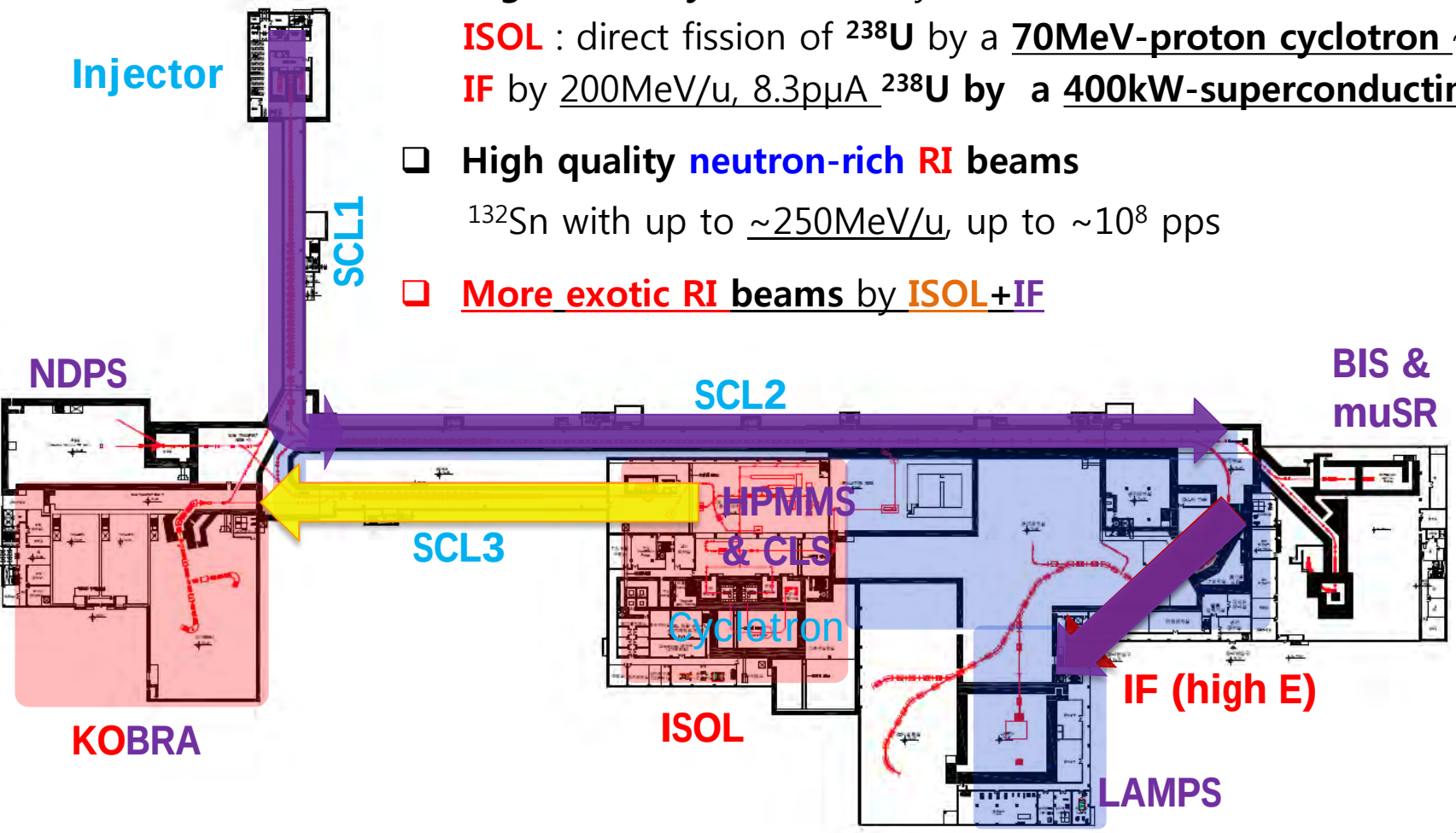

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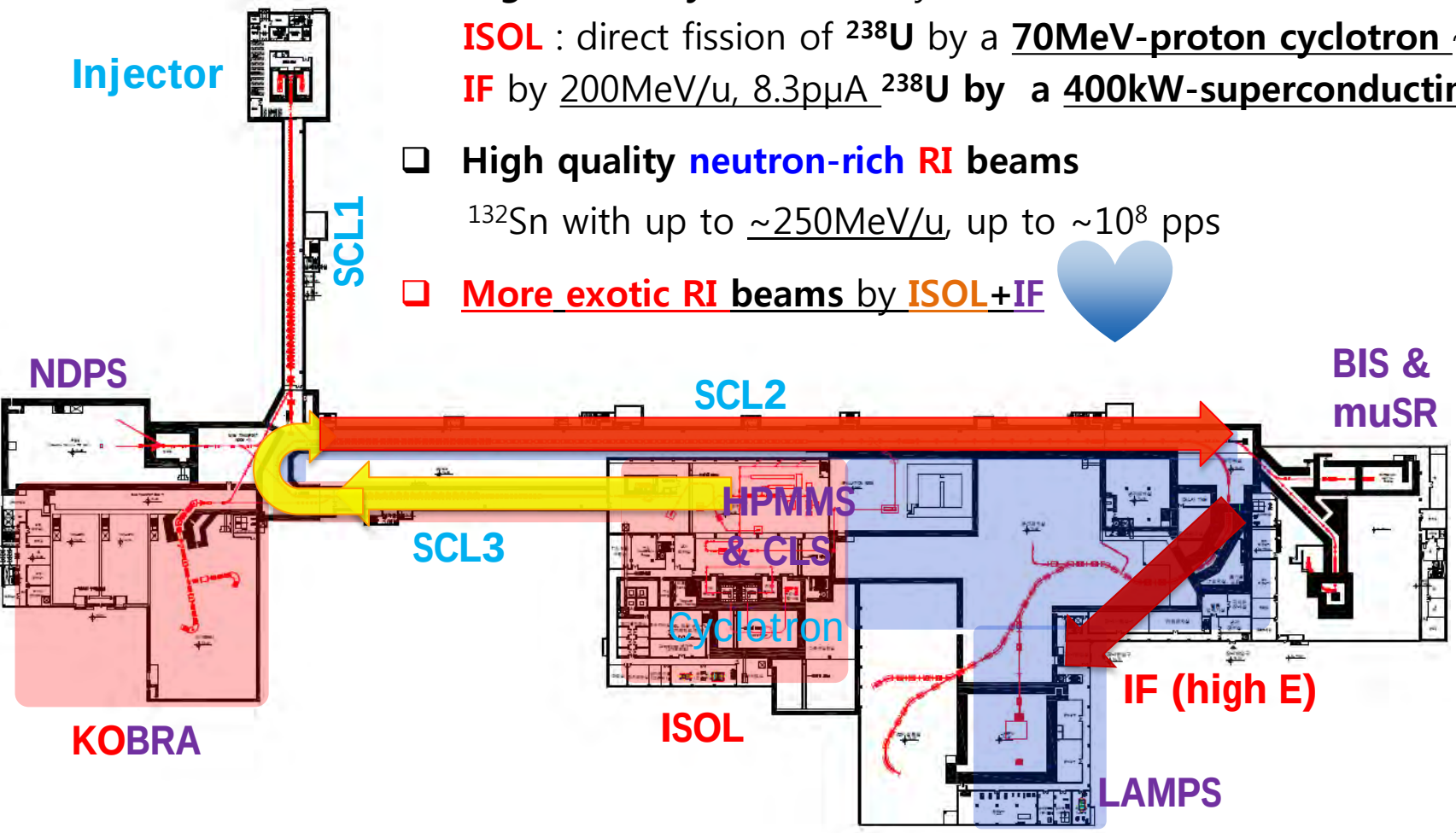
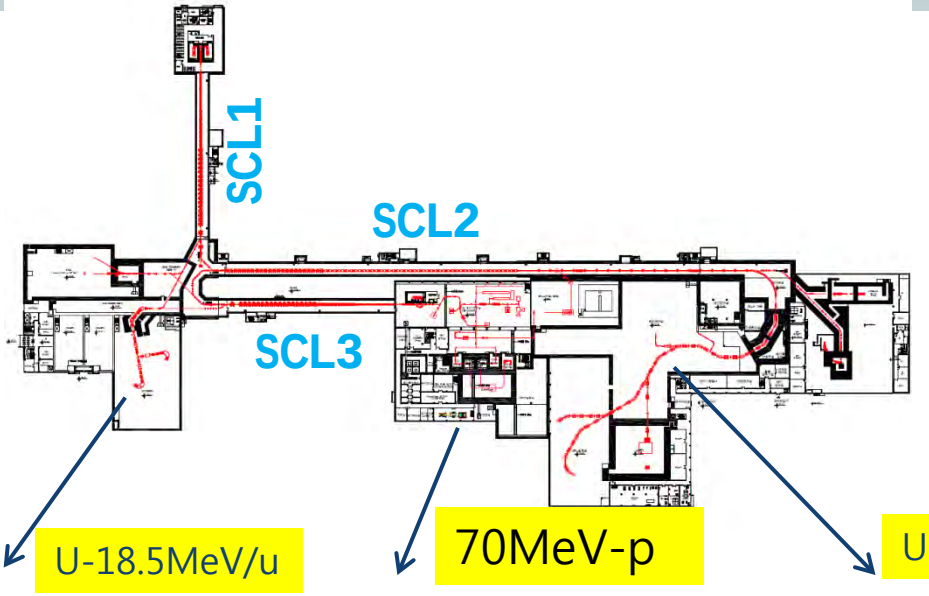


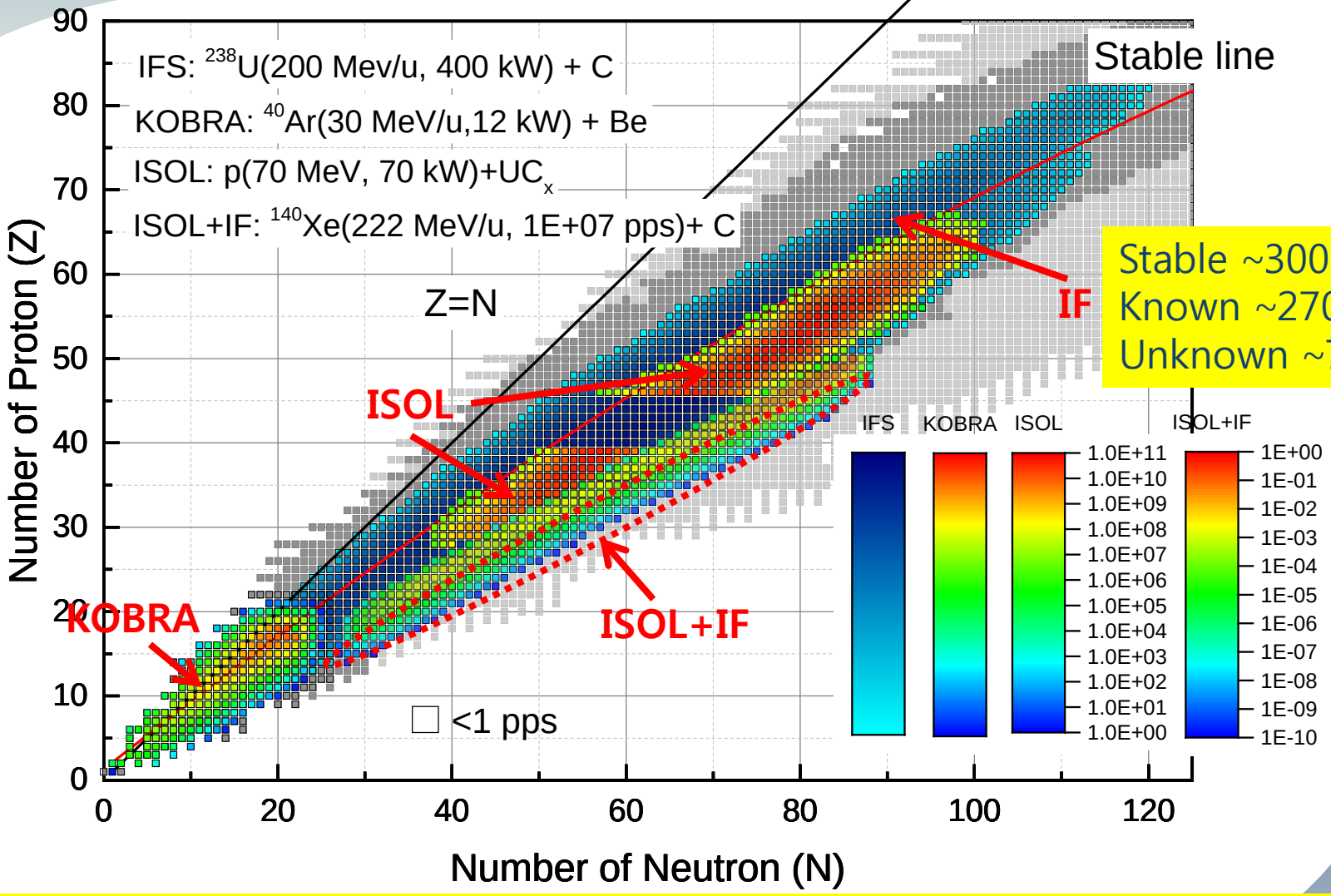
Lineup of RIB production & separation

- ISOL→IF
  - : ISOL→SCL3→SCL2→IF
  - : ISOL→SCL3→KOBRA
- IF→Re-Acc (future upgrade)
  - : IF→stopped beam→SCL



	KOBRA (low E IF)	ISOL	IF (high E)
Driver	SCL3 or SCL1	Cyclotron	SCL3→2 or SCL1→2
Post Acc		SCL3 or SCL3→2	
Production mechanism	Direct reactions - (p,d), (^{3}He,n) etc , MNT	p induced U fission	PF, U fission
Available RIB energy	< a tens of MeV/u	> a few of keV/u	< a hundreds of MeV/u

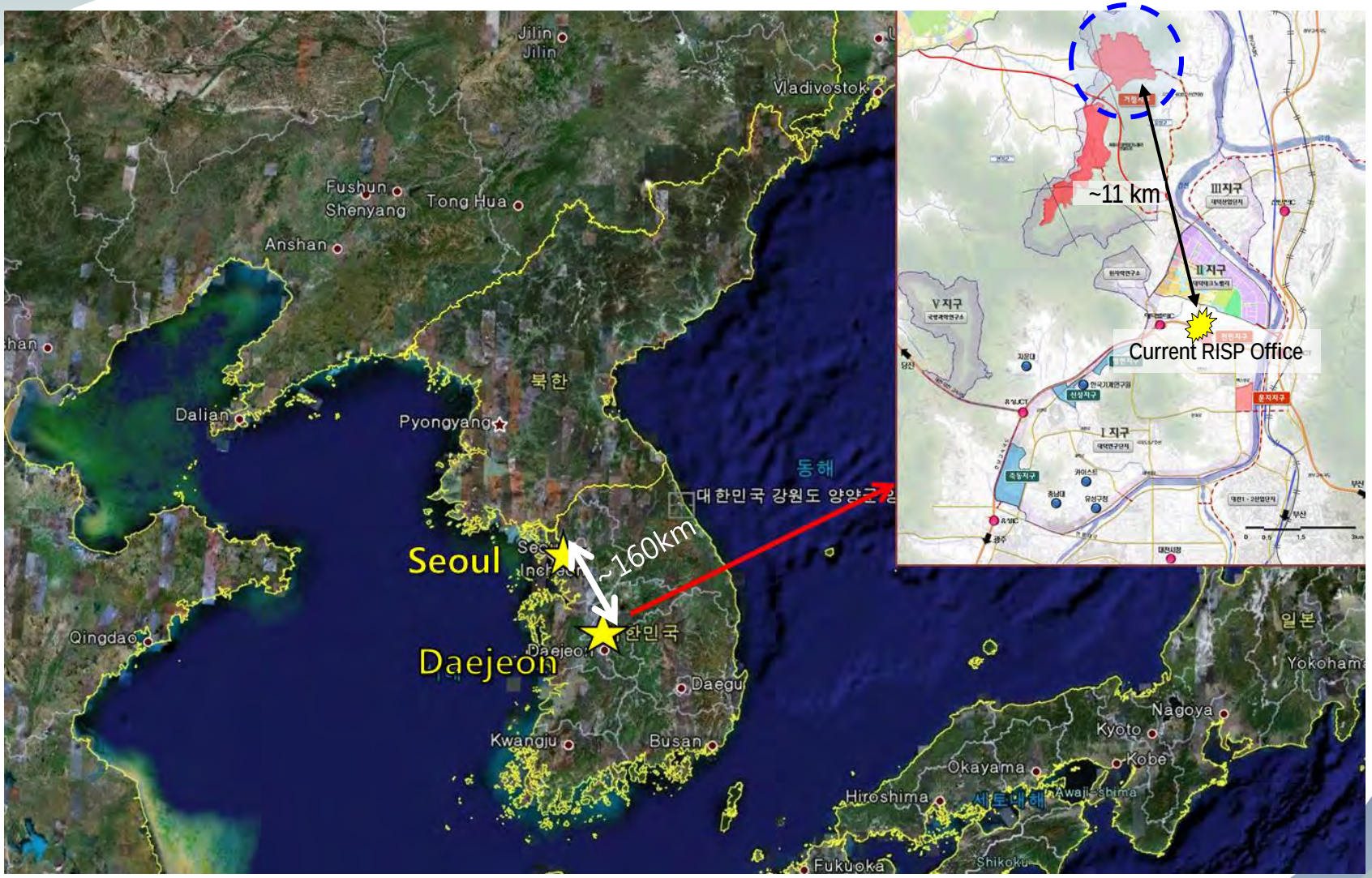
Expected RIBs at RAON in nuclear landscape



- **RAON will provide access to unexplored regions of the nuclear chart !**
- **RAON will be a powerful RIBs' supplier to users globally**

→ **More exotic, More intense, and More various RIBs**

RAON Site : Sindong in Daejeon



Future Plans (~5 years) of Nuclear Physics in Japan

Endorsed by Japanese Nuclear Physics Executive Committee, 2016

- **J-PARC (KEK)** — Science Council of Japan selected Major Project
  Hadron/nuclear physics w/hadron beams -> Hadron Hall extension
  Fundamental Physics/Particle physics with muons
  -> mu-e conversion (COMET), g-2
- **RIBF (RIKEN)**
  Expand neutron-rich heavy element productions to transuranium
  Production of superheavy Z=119 and beyond
  -> RIBF upgrade for intensity x30
- **ELPH (Tohoku) and LEPS@SPring-8 (RCNP Osaka)**
  Hadron Physics with electron beams -> Detector/Beam upgrades
- **High Energy Heavy Ion Collision (LHC, RHIC, J-PARC)**
  QGP properties, QCD phase diagram, High density matter
  -> ALICE upgrade, s-PHENIX/STAR upgrade, J-PARC-HI R&D
- **Nuclear Theory**
  Hadrons via Lattice QCD, Nuclear structure via Monte Carlo Shell Model, etc. -> 9 projects with K computer and beyond

Accelerator facilities for nuclear physics in Japan - 1

Nishina Center, RIKEN

K2600 **RIBF**

Heavy ion (RIB)

Research Center for Electron Photon Science, Tohoku University (**ELPH**)

1.2GeV electron Stretcher

e^-

SPring-8 (RIKEN/JASRI)

8GeV e - Synchrotron

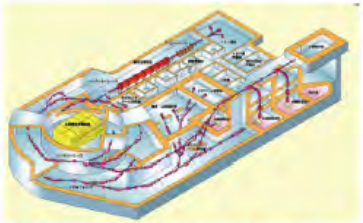
photon

RCNP, Research Center for Nuclear Physics, Osaka University

K400 Cyclotron

light ion / light heavy ion

HIMAC at National Institute of Radiological Sciences



800MeV/A Synchrotron

heavy ion (therapy)

J-PARC, KEK/JAEA)

30GeV Proton Synchrotron

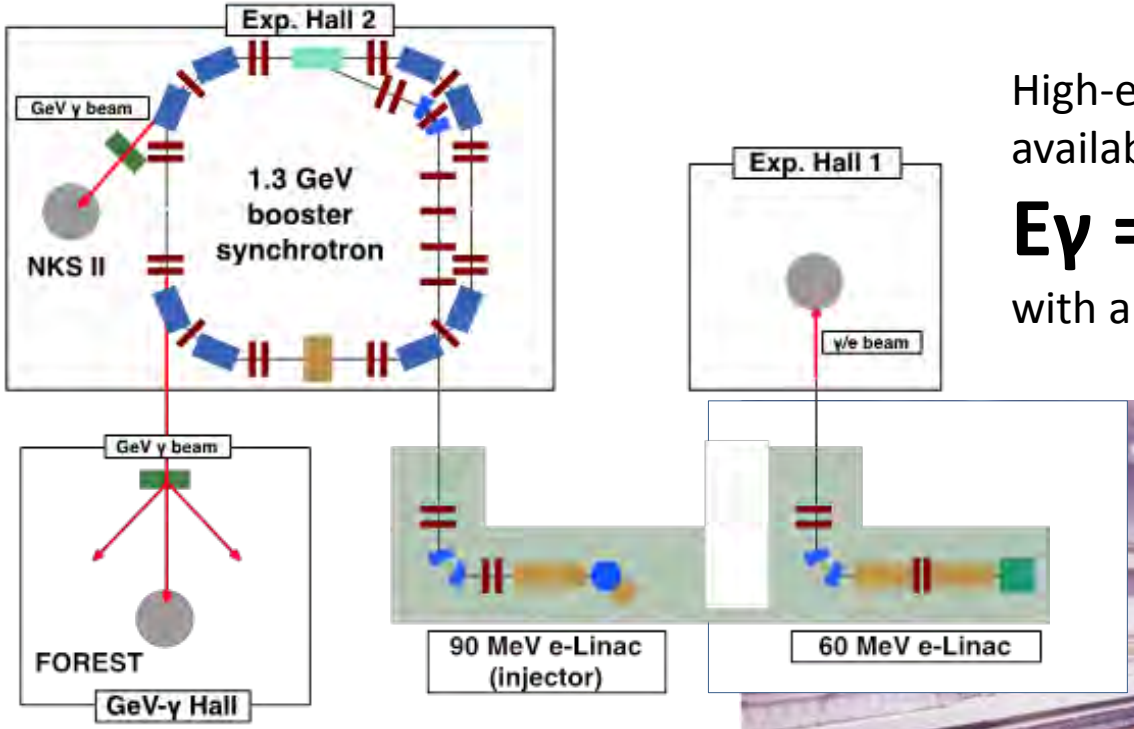
π, K, μ, n, (ν)

ELPH

TOHOKU UNIVERSITY

東北大学 電子光理学研究センター

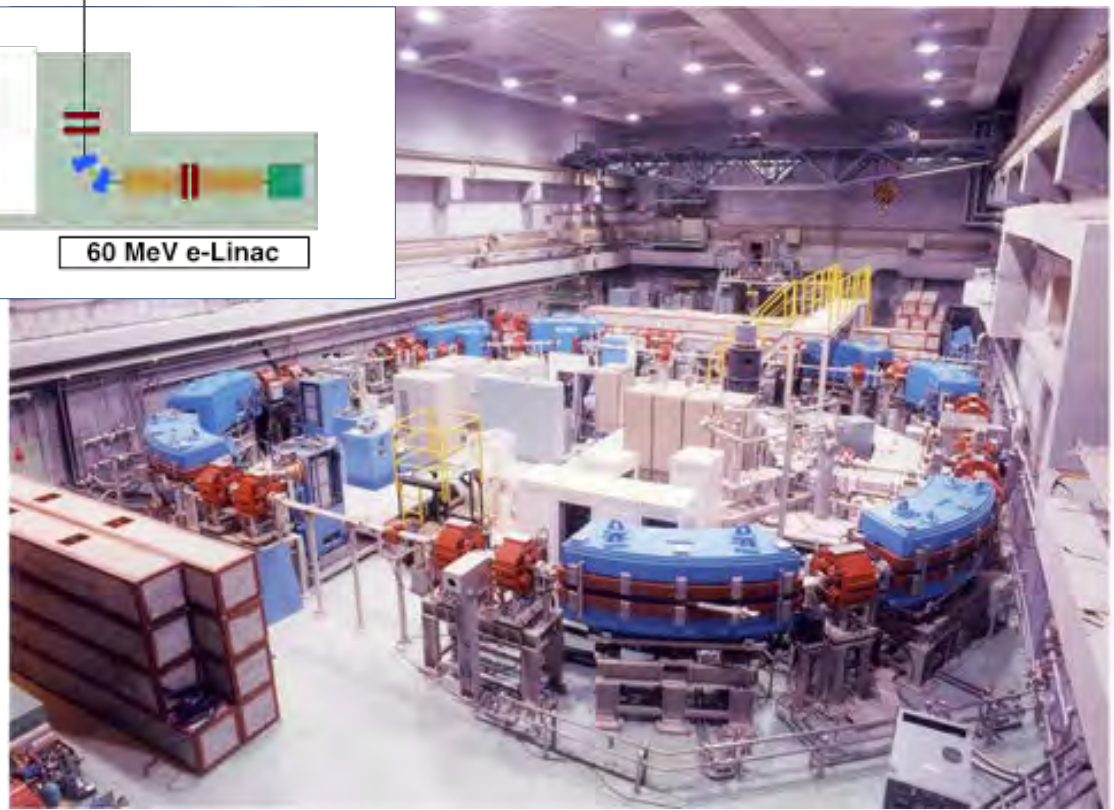
RESEARCH CENTER FOR ELECTRON PHOTON SCIENCE (ELPH), TOHOKU UNIVERSITY



High-energy tagged photons are available in the energy range of

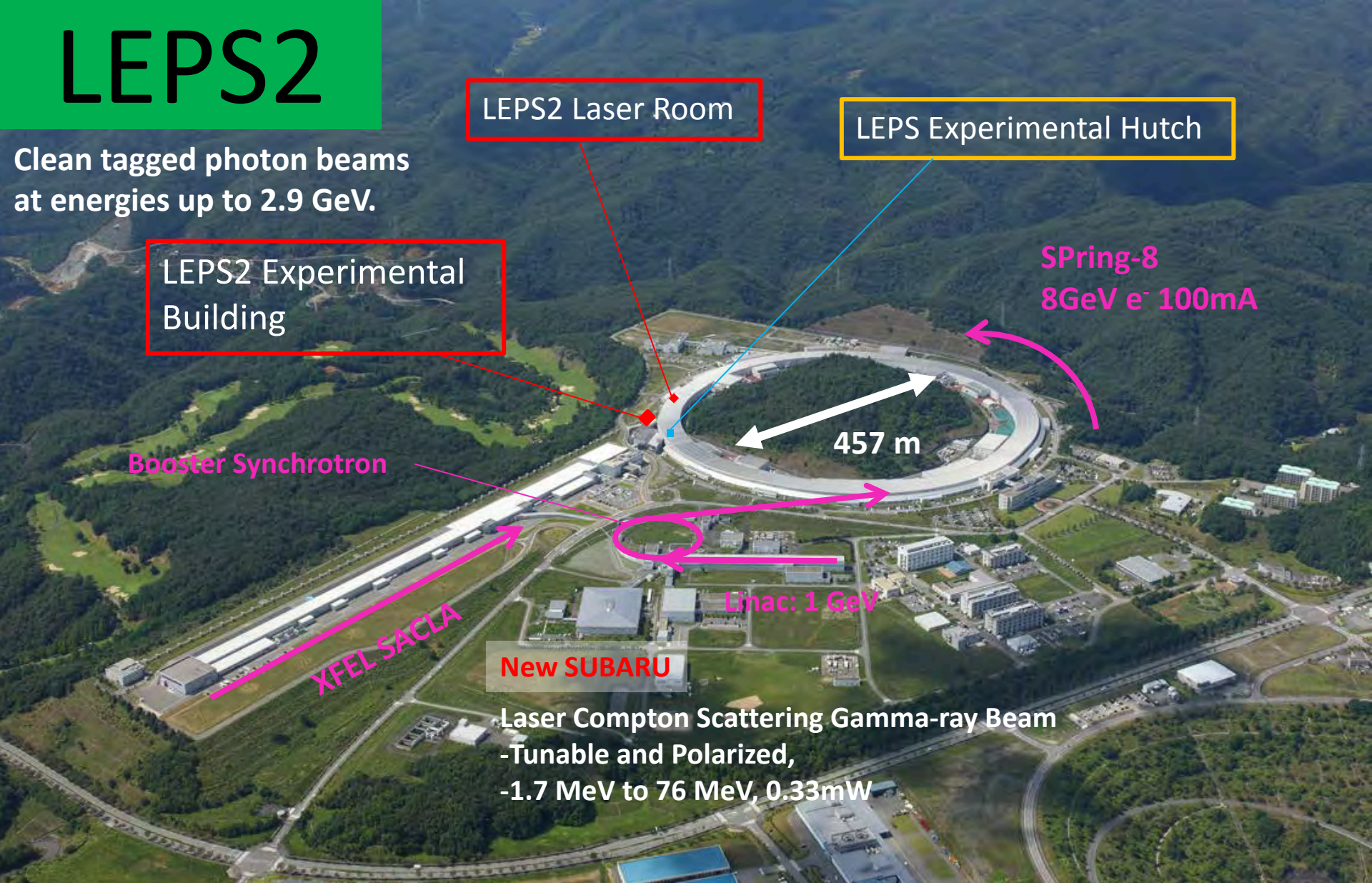
Eγ = 0.6 - 1.2 GeV

with a typical intensity of Nγ ~ 10^7 Hz.



LEPS2

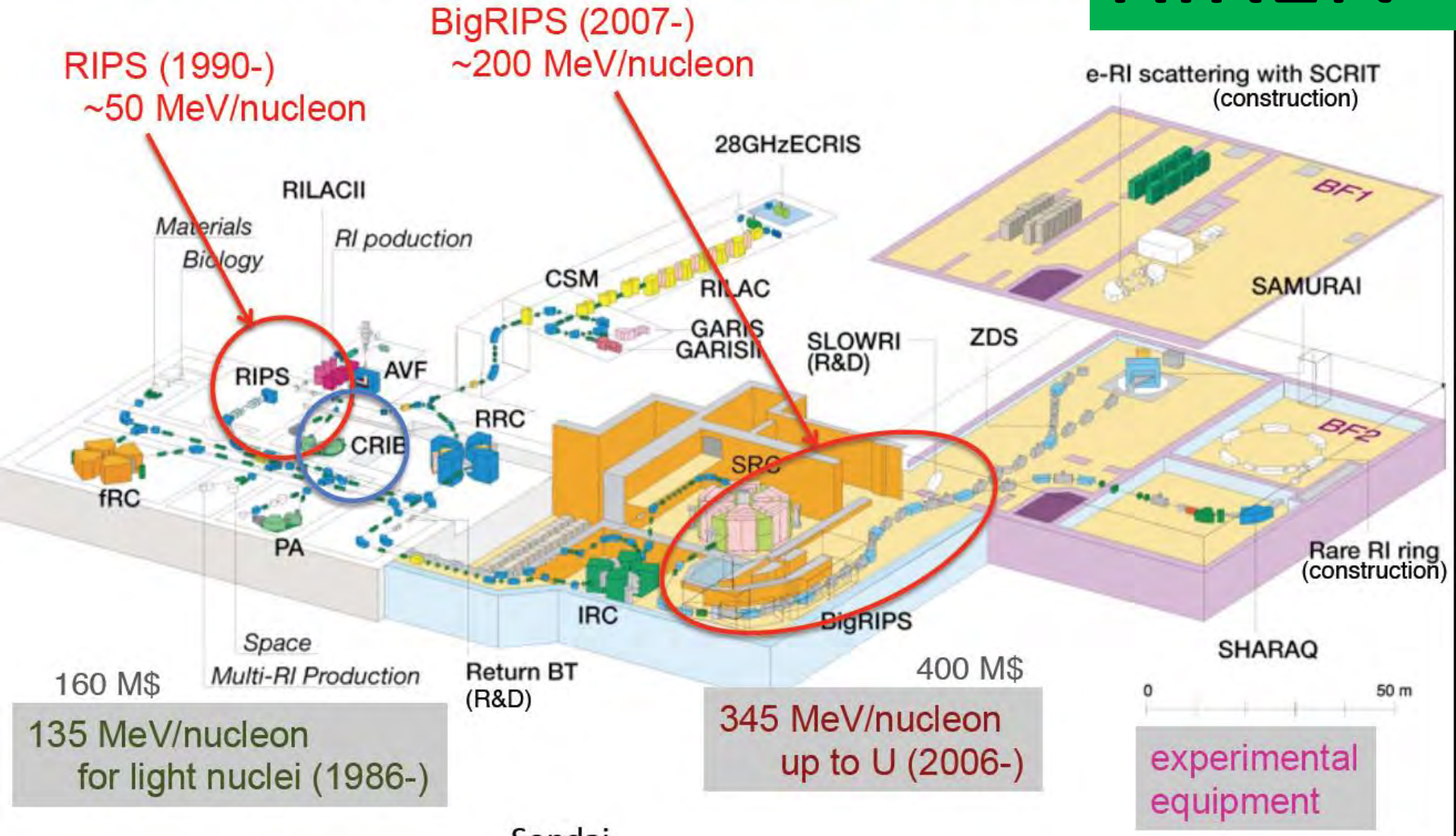
Clean tagged photon beams at energies up to 2.9 GeV.



Operated by Research Center for Nuclear Physics (RCNP), Osaka University at SPring-8 site

RIBF@RIKEN

RIBF – a new generation RIB facility in operation with world highest capability of **providing RI beams**



160 M$

135 MeV/nucleon
for light nuclei (1986-)

400 M$

345 MeV/nucleon
up to U (2006-)

experimental equipment

Sendai

Nov. 2016

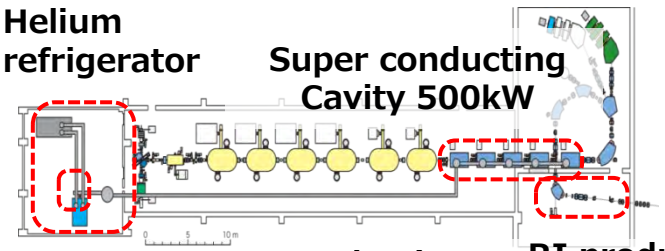
On November 30th 2016, IUPAC Announced formally

Elements **113,** 115, 117, and 118 are named **nihonium (Nh),**

moscovium (Mc), tennessine (Ts), and oganesson (Og)

RIBF upgrade plan submitted to Science Council of Japan (146M$)

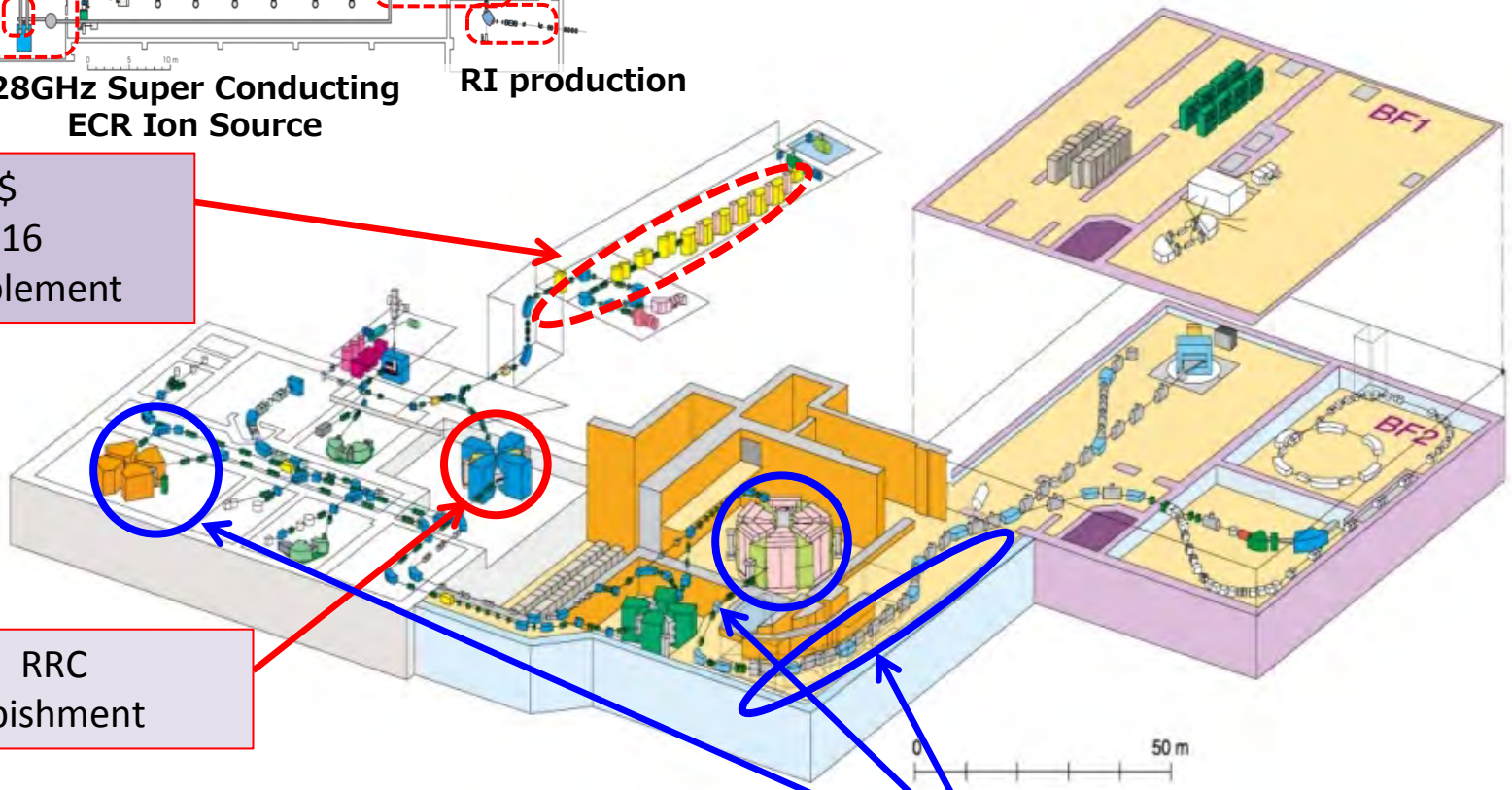
RIBF@RIKEN



32M$ FY2016 Supplement

12M$ RRC refurbishment

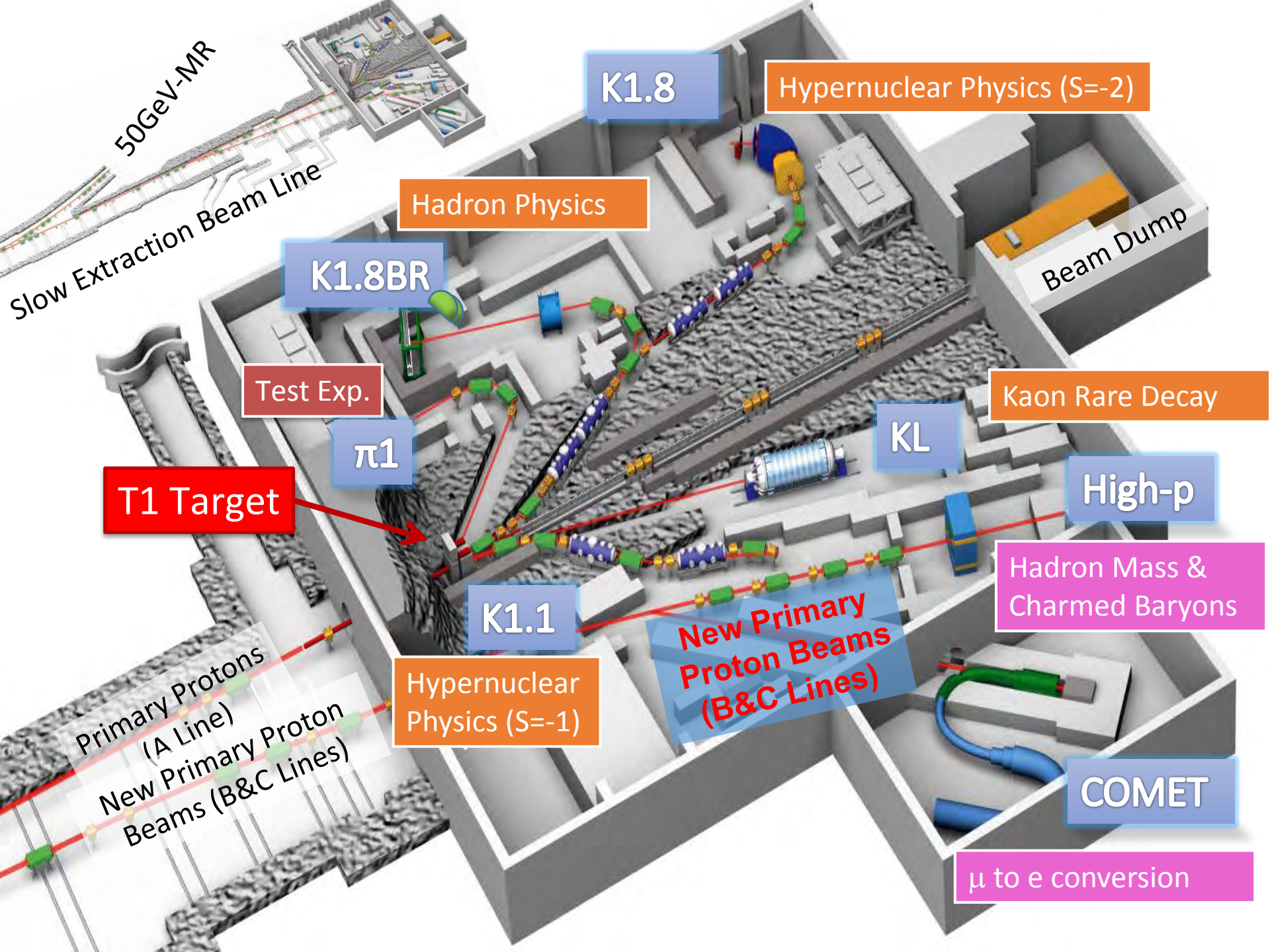
103M$



J-PARC Japan Proton Accelerator Research Complex

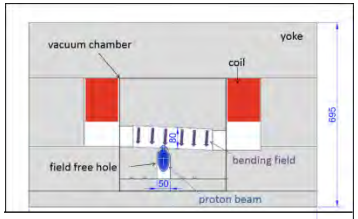
J-PARC at Tokai-mura, Ibaraki-ken


J-PARC
Japan Proton Accelerator Research Complex
400MeV
LINAC
3GeV333μA
RCS
ν to
SK
MLF
"50GeV-PS"
30GeV 25μA,
750kW
Hadron Hall
for Counter Experiments
with 150kW SX
Bird's eye photo
in January 2016


50GeV-MR
Slow Extraction Beam Line
K1.8
Hypernuclear Physics (S=-2)
Hadron Physics
K1.8BR
Beam Dump
Test Exp.
Kaon Rare Decay
π1
KL
T1 Target
High-p
Hadron Mass &
Charmed Baryons
K1.1
New Primary
Proton Beams
(B&C Lines)
Primary Protons
(A Line)
New Primary Proton
Beams (B&C Lines)
Hypernuclear
Physics (S=-1)
COMET
μ to e conversion

Construction Status of the beam lines at J-PARC Hadron Hall


Lambertson Magnet



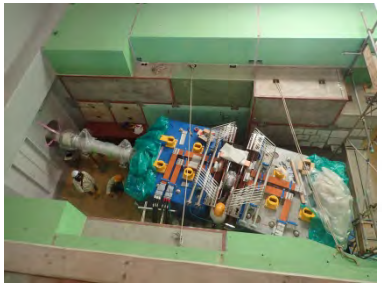
Lambertson (Design)

Branching point

Beamline magnets

In SY-HD Wall

Spectrometer Magnet



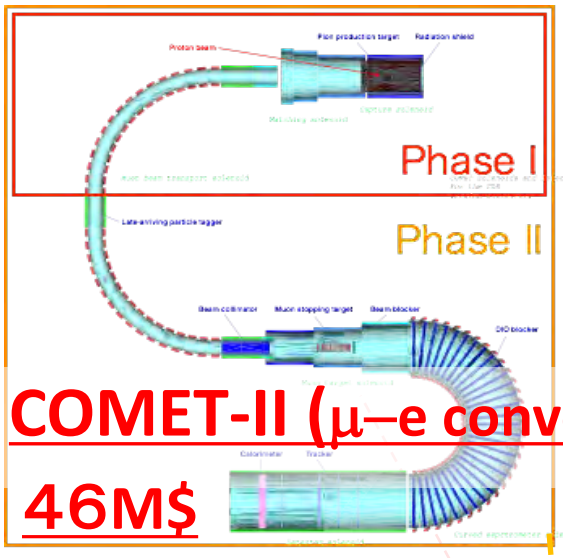
New Line

Existing A-Line

COMET & Control room

J-PARC Upgrade for Nuclear & Particle Physics

Science Council of Japan selected this one of 27 Major Projects of Japan



COMET-II (μ–e conversion)

46M$

Existing

K1.8

KL

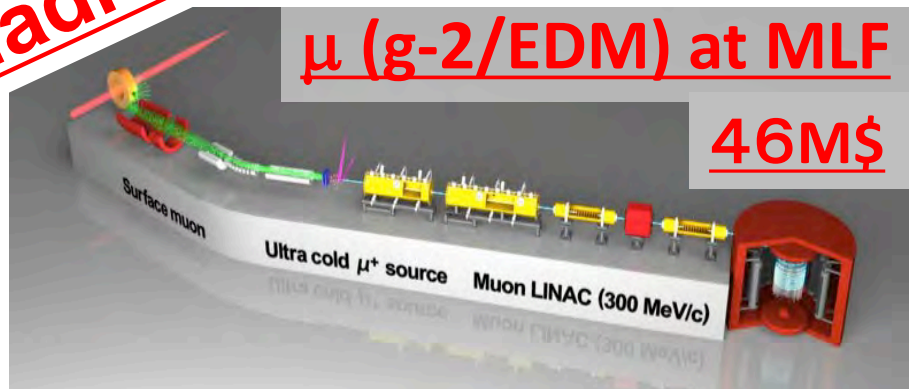
K1.1

High-p

COMET

Hadron Hall Extension

212M$



μ (g-2/EDM) at MLF

46M$

Hadron Hall Extension

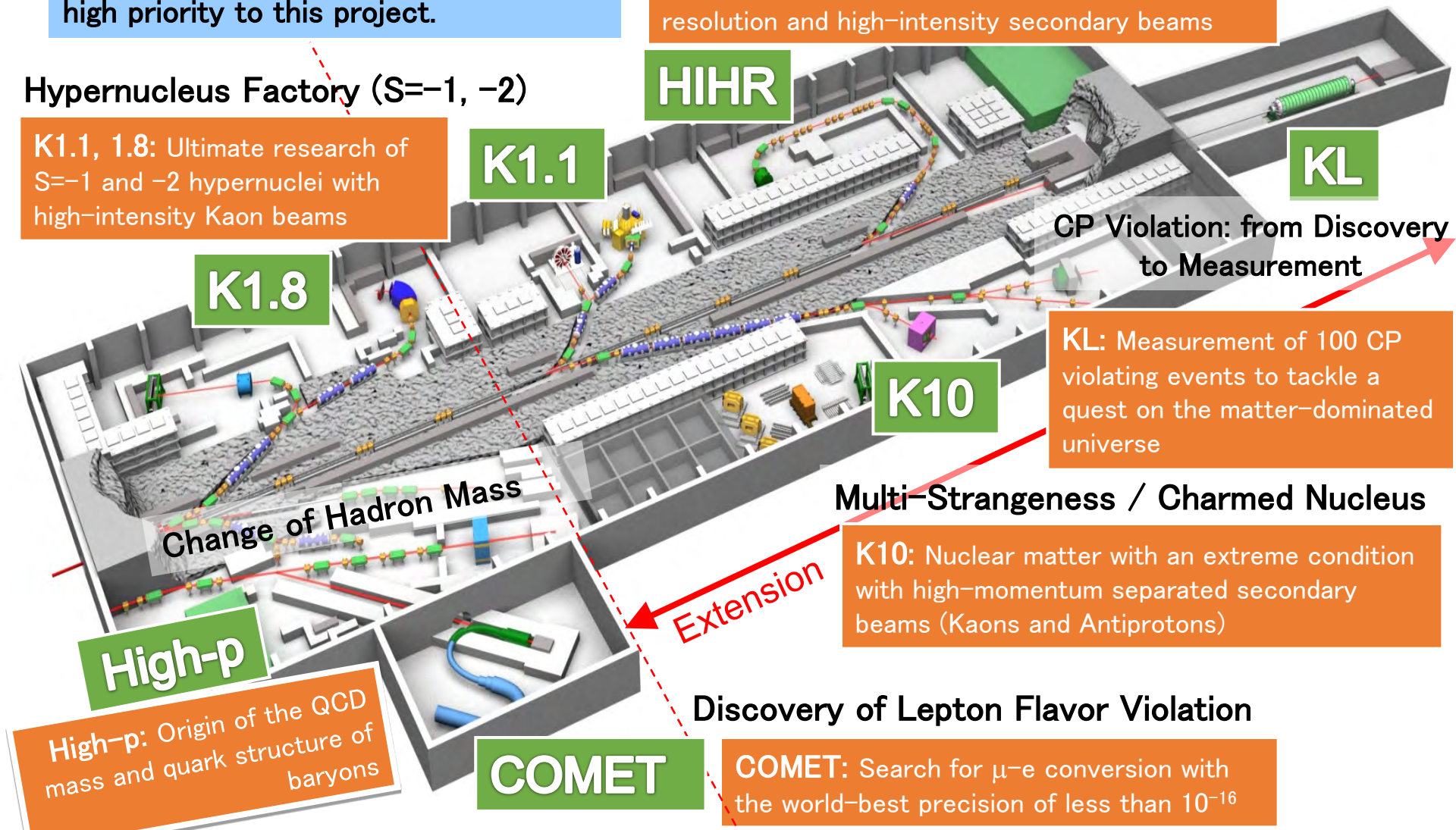
Both Nuclear Physics community and High Energy Physics community gave high priority to this project.

Hypernucleus Microscope

HIHR: Very Precise spectroscopy with high-resolution and high-intensity secondary beams

Hypernucleus Factory (S=−1, −2)

K1.1, 1.8: Ultimate research of S=−1 and −2 hypernuclei with high-intensity Kaon beams



CP Violation: from Discovery to Measurement

KL: Measurement of 100 CP violating events to tackle a quest on the matter-dominated universe

Multi-Strangeness / Charmed Nucleus

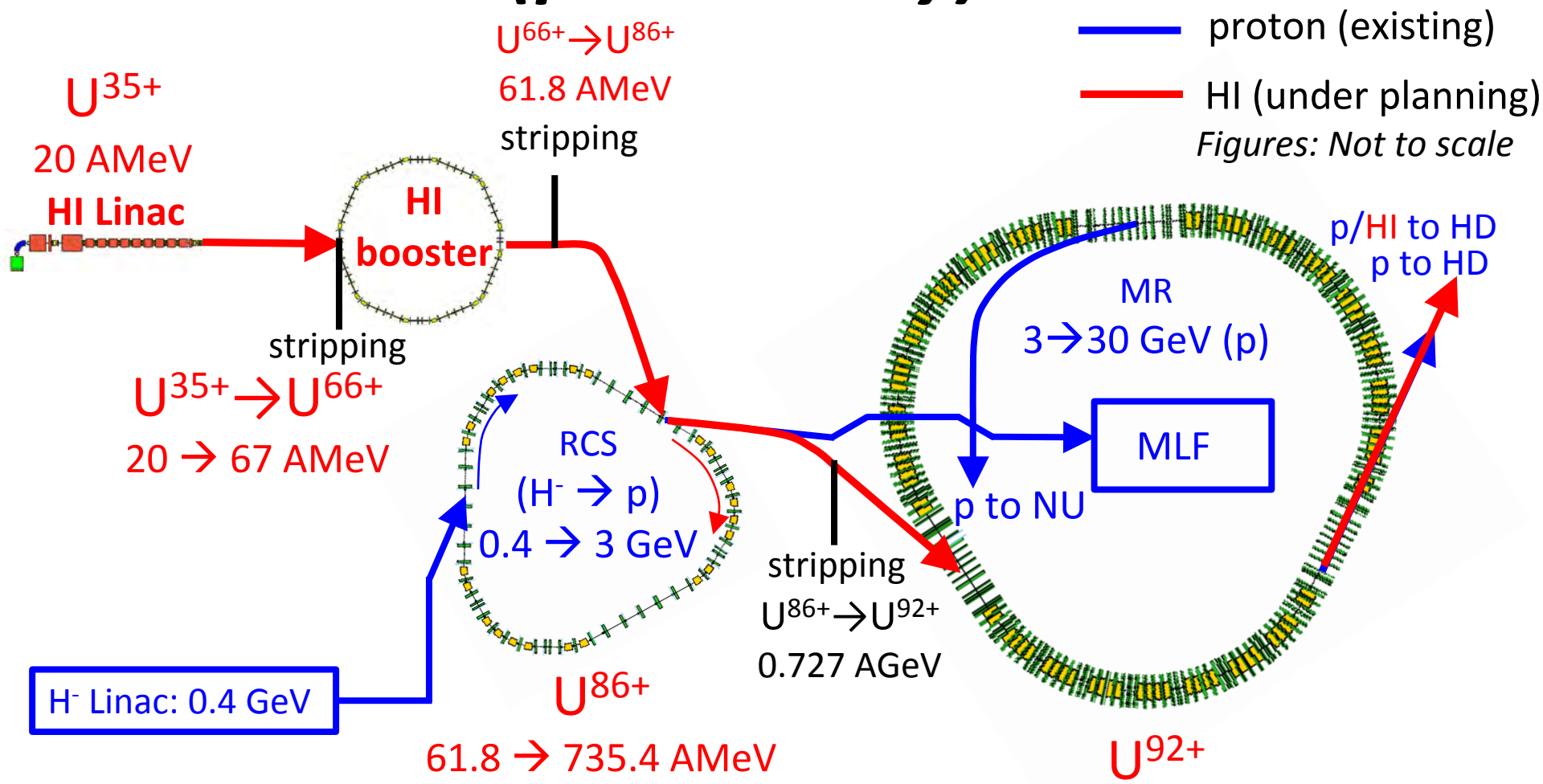
K10: Nuclear matter with an extreme condition with high-momentum separated secondary beams (Kaons and Antiprotons)

High-p: Origin of the QCD mass and quark structure of baryons

Discovery of Lepton Flavor Violation

COMET: Search for μ-e conversion with the world-best precision of less than 10^{-16}

HI Accelerator scheme in J-PARC (preliminary)



In the RCS, more than 10^{11} U^{86+} ions can be achieved without any significant beam losses.


J-PARC
(JAEA & KEK)
400 MeV H⁻ Linac
HI linac
&
Booster
3 GeV RCS
NU
50 GeV MR
MLF
HD

Summary

- Major accelerator facilities in Asia Pacific region were briefly reviewed.
- We gave up to construct high energy heavy-ion colliders in Asia Pacific.
- We have big medium energy heavy-ion (RI beam) facilities in AP and their future extension projects.
- Now RI beam facility is changing/expanding from projectile fragmentation facility to the target ion source (ISOL type) facility.
- We have only one facility for electromagnetic probes (LEPS).
- J-PARC is becoming the KAON factory in the world.
- How about baryon rich nuclear matter physics in Japan, i.e. J-PARC-HI?

Summary in Table

	Beams	Asia	Europe	America	
Hot QCD	A+A	--	**LHC(ALICE)** **FAIR(SIS300)** **NICA**	**RHIC**	Missing Asian? J-PARC-HI for dense matter?
Cold QCD	hadron	**J-PARC** **+Hdex** **HIRFL+HIAF**	**FAIR(SIS100)**	--	Missing American?
	e-	**Spring-8** **/ELPH**	**MAMI**	**JLAB-12GeV**	1+many
	collider	**(Belle-II)**	**NICA**	**eRHIC** **(eIC)**	1 in the world?
Many body Problem (RI Beam)	PF	**RIBF**	**GSI/FAIR**	**FRIB**	Good competitions!!
	Both	**RISP**			
	ISOL	**HIRFL+HIAF** **BATANL**	**SPIRAL2** **SPES** **HIE-ISOLDE**	**ARIEL**	
	Super ISOL	**Beijing- ISOL**	**EURISOL**	--	FRIB upgrade?

Backup

2. Shanghai Laser-Electron Gamma Source @SINAP

Shanghai Synchrotron Radiation Facility (SSRF)-II (2017-2021)

16 beamlines, SLEGS is 1 of them:

E_gamma 0.4-20.MeV; Delta_E: ~5%;

D_theta: 0.5mrad; Flux: 10^5 -10^7 phs/s

T2K (Tokai-to-Kamioka) Experiment

Purpose of the T2K experiment ;
Generate intense neutrino beam at J-PARC and shoot Super-Kamiokande detector, measure neutrino properties at SK to explore neutrino oscillation parameters, and eventually detect CP violation in the neutrino sector.

Hyper-Kamiokande

「素粒子」と「宇宙」を地下から見上げる

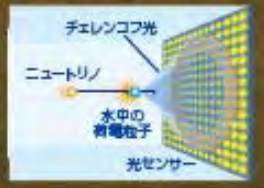
ハイパーカミオカンデは、地下に設置される100万トン級の巨大水タンクとそのタンクの中に並べる超高感度光センサーからなります。この実験装置は、素粒子を観察する「顕微鏡」であると同時に、飛来するニュートリノを用いて太陽や超新星爆発を見る「望遠鏡」でもあります。陽子崩壊の発見やニュートリノのCP対称性の破れ（ニュートリノ・反ニュートリノの性質の違い）の発見、超新星爆発ニュートリノの観測などを通して、素粒子の統一理論や宇宙の進化史の解明を目指します。国際研究プロジェクトとして世界の研究者が協力し、2025年の実験開始を目指しています。

超高感度光センサー

スーパーカミオカンデのものより50％感度の高い、世界最大の高感度光センサーの開発を行っています。写真左は、半導体電子増幅素子を内蔵したハイブリッド型光センサーであり、右は高性能電子増幅電極構造を持つ光センサー。下の2つの写真はそれぞれの電子増幅部のもの。

実験原理

ハイパーカミオカンデでは、検出器に入ってきたニュートリノと水が衝突した時にはじき出される荷電粒子が放つ光（チェレンコフ光とよびます）を、壁に取り付けられた光センサーで捉えます。得られる光の量やリングの形から、ニュートリノのエネルギー、方向、種類などを決定します。

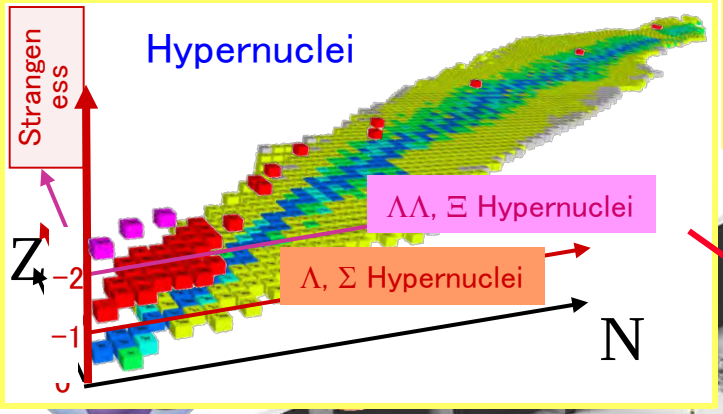


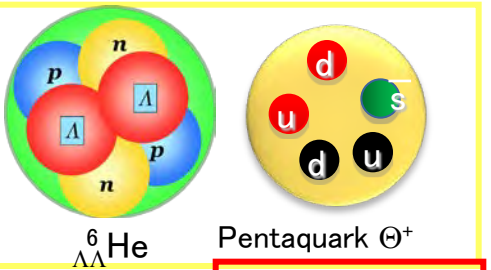
100万トンの超大型タンク

スーパーカミオカンデの100年分のデータがハイパーカミオカンデでは5年で得られることになります。そのため、これまで見えなかった素粒子のまれな現象や、対称性のわずかな破れの測定が可能になります。

Nuclear, Hadron, & Particle Physics at Hadron Hall

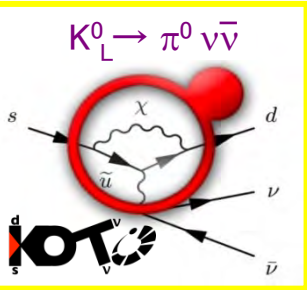
High Density Nuclear Matter, Nucelar Force



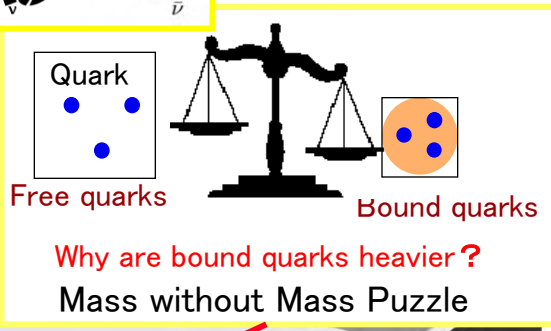


$^{6}_{\Lambda\Lambda}$He Pentaquark Θ+

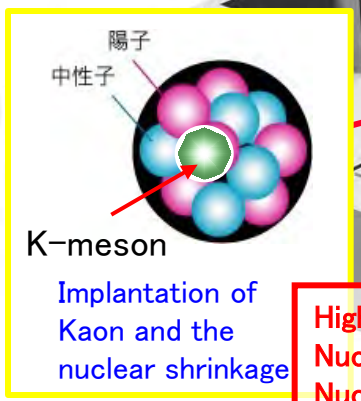
CP−Violation



Origin of Mass



Confinement



High Density Nuclear Matter, Nucelar Force

Kaonic atom

Kaonic nucleus

T−Violation