News from ANPhA

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 representing Nuclear Physics in Asia Pacific.**
- **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 plays the role of Division of Nuclear Physics of AAPPS.**
  - ANPhA Chair should be the chair of DNP-AAPPS.

ANPhA Board meetings:
Mostly once a year with either symp. or conf.

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

ANPhA/DNP-AAPPS: 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)

ANPhA/DNP-AAPPS: Executive Committee (EXCO)

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

As of August 24, 2017
* To be confirmed

- **Next ANPhA (=DNP-AAPPS) board meeting** will be held at Halong City, Vietnam on Sept. 24th, 2017 and **ISPUN17** will open the days after.
- **Next AAPPS Council meeting** will be held in Kuala Lumpur, Malaysia on December 3rd in 2017 in conjunction with **International Meeting for Frontier of Physics (IMFP2017)** which will be held in December 3-7 at Kuala Lumpur.
- Practically, **ANPhA** is an organization to discuss and pursuit issues in Asian nuclear physics community at present.
- **ANPhA** is organizing **ANPhA awards for young Scientists** for ANPhA supported meetings.
- **ANPhA** White Paper

The first ANPhA awards for young Scientists, at CNSSS, Aug. 29, 2017

Yasuhiro UENO （Tokyo）,
"Precision Test of Bound-State QED via the Spectroscopy of Muonium Hyperfine Structure"

ANPhA White Paper

- Now 29 Accelerator Facilities for Nuclear Physics in Asia Pacific are listed
- 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.

⇒https://kds.kek.jp/indico/category/1706/

⇒Notes for Google Chrome Users,

⇒Please find the username and password at the "click for the password" on the page which you can find after closing the popup window to login.

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	China Initiative ADS	CIADS	The 250 MeV and 10mA (maximum beam current) CW mode superconducting proton LINAC
Munbai, India	Bhabha Atomic Research Centre - Tata Institute of Fundamental Research	BARC-TIFR	14MV heavy ion tandem + superconducting linac (PLF: Pelletron LINAC Facility)
New Delhi, India	Inter-University Accelerator Centre	IUAC	15MV heavy ion tandem + superconducting linac
Kolkata, India	Variable Energy Cyclotron Centre	VECC	VECC 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

News from Major Accelerator Facilities in Asia Pacific

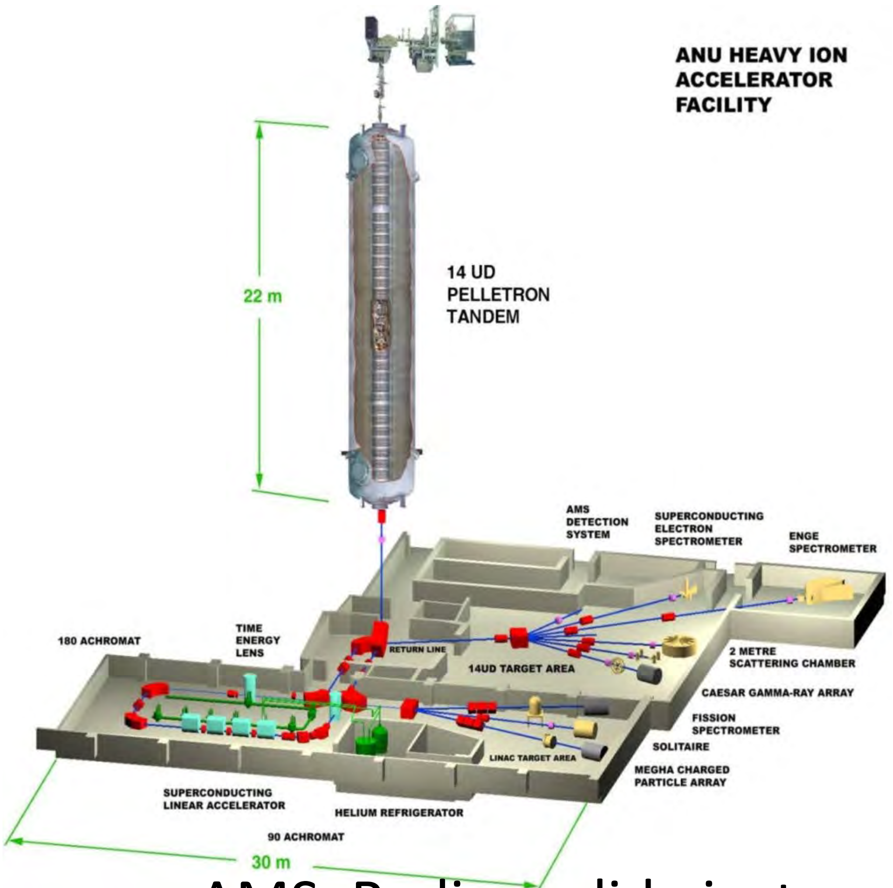
- Australia
  - Australian National University The Heavy Ion Accelerator Facility
- China
  - HIRFL->HIAF (Heavy Ion Research Facility in Lanzhou -> High Intensity Heavy Ion Accelerator Facility)
  - BTANL (Beijing Tandem Accelerator Nuclear Physics National Laboratory) -> Beijing ISOL
- India
  - Mumbai (BARC and TIFR)
    - 14 MV Pelletron coupled to SC Linac (PLF: Pelletron LINAC Facility)
  - Delhi (IUAC: Representing all the university users)
    - 15 MV Pelletron coupled to SC Linac
  - Kolkata (VECC and SINP)
    - K=130 Cyclotron , K=500 SC cyclotron(not fully operational)
- Korea
  - RISP (Rare Isotope Science Project)
- Japan
  - J-PARC->Hd-ex (Japan proton Accelerator Research Complex -> Hadron Hall Extension)
  - RIBF (Radioactive Ion Beam Facility)
  - Spring-8/ELPH (Electromagnetic Probes)
  - Medical Application

Partial 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	**（BES-III）** **（Belle-II）**	**NICA**	**eRHIC** **(eIC)**	1 in the world?
Many body Problem (RI Beam)	PF	**RIBF upgrade** **HIRFL+HIAF**	**GSI/FAIR**	**FRIB**	Good competitions!!
	Both	**RISP**			
	ISOL	**BTANL** **ANURIB**	**SPIRAL2** **SPES** **HIE-ISOLDE**	**ARIEL-II**	
	Super ISOL	**Beijing- ISOL**	**EURISOL**	--	FRIB upgrade?

Australian National University
The Heavy Ion Accelerator Facility

By Anthony Thomas (Univ. of Adelaide, ANPhA Vice Chair)



- Neutron beams to characterise detectors both in terms of their response to background radiation and to determine quenching factors.
- Very low/rare nuclear processes that are background to DM searches.
- Long term plan → **underground accelerator for very rare astrophysical processes.**
- AMS: Radionuclide isotope ratios through atom counting with **atomic mass spectroscopy**

Brief Progress Chinese nuclear physics community in 2017

Weiping Liu

China Institute of Atomic Energy

(ANPhA Vice Chair)

Aug. 13, 2017

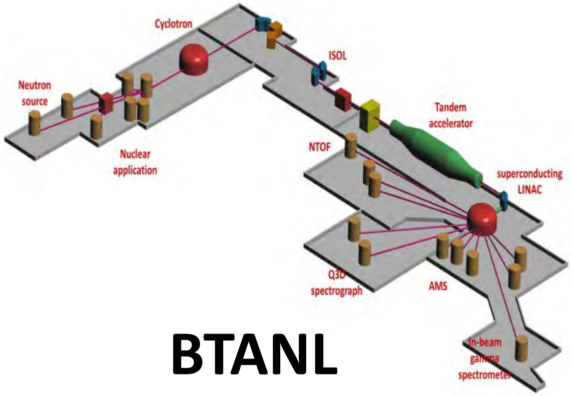
Roadmap of NP facilities

1986
北京串列加速器
HI-13

1988
兰州回旋加速器
SSC

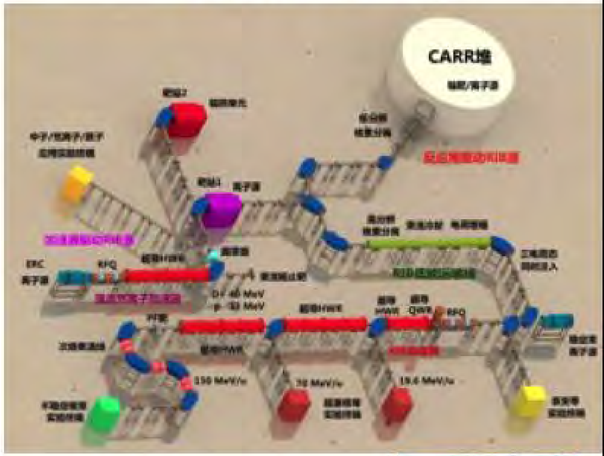
2008
兰州储存环
CSR

2014
北京串列升级工程



2021?
重离子应用装置
HIAF

2028?
北京ISOL装置

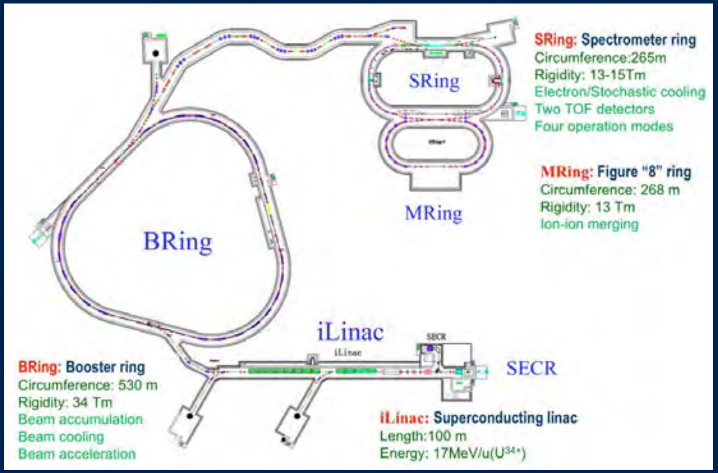


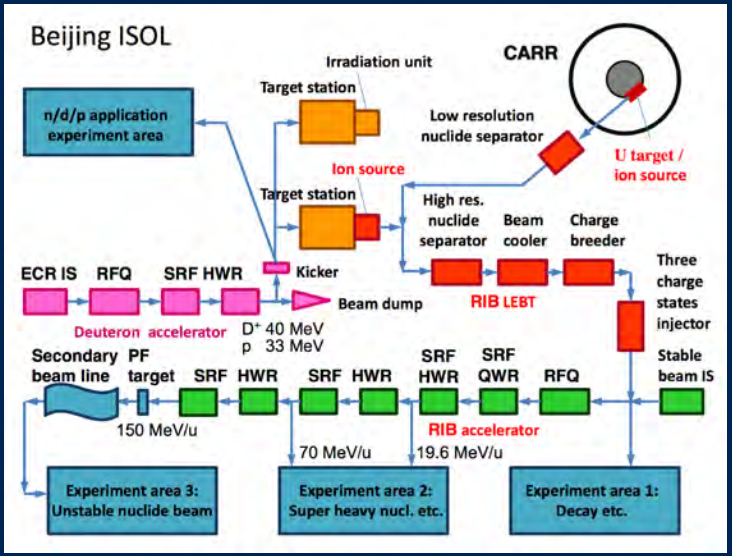
Large scale facility plan

- **Heavy ion facility HIAF granted with feasibility permit by national commission.**

- **ADS transmutation facility CiADS granted with feasibility permit by national commission.**

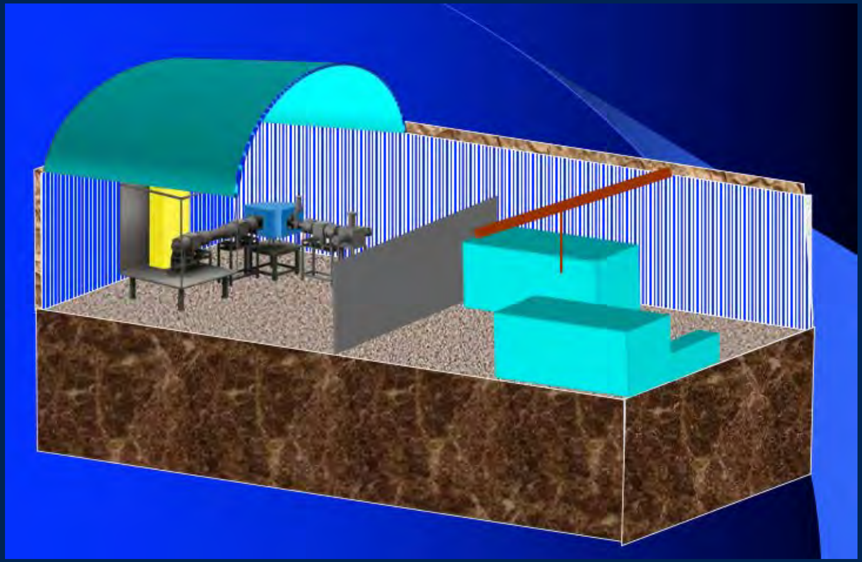
- **Jinping deep underground lab and Beijing ISOL project listed in national 5 years plan, with construction plan submitted.**

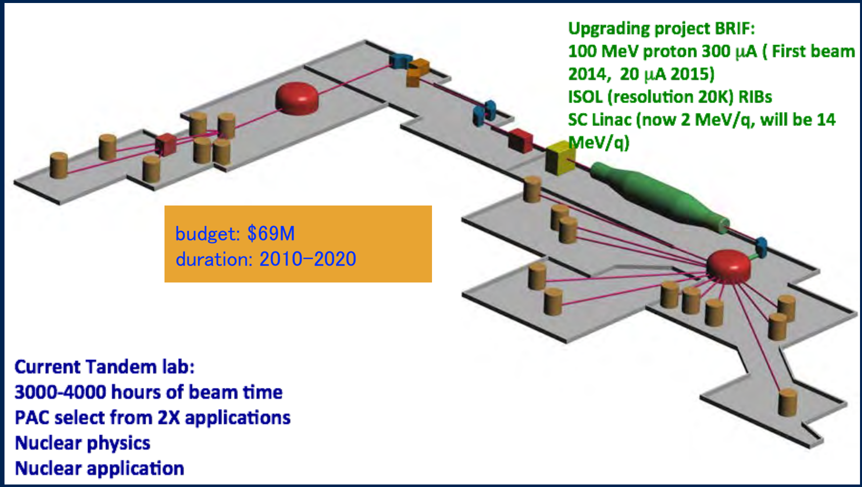




Ongoing project progress

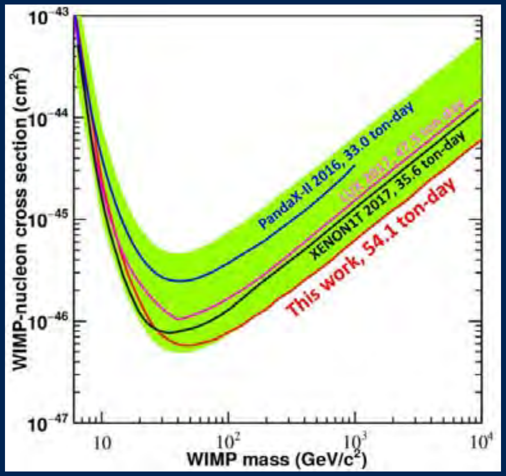
- Jinping nuclear astrophysics experiment JUNA, ground test get proton beam of 260 keV and 3 mA on May 27.
- ADS R&D: get proton beam of 26.1 MeV and 12.4 mA pulsed beam on June 5.
- Beijing Rare Ion Facility BRIF is scheduled to deliver its first Tandem accelerate ISOL beam by Sept. 2017.

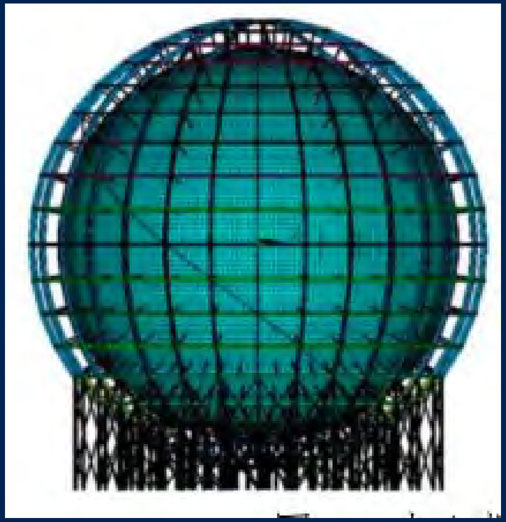




Non-accelerator science project

- **Jinping Xe dark matter project PandaX-II, get 1st round evaluation in NSFC (science foundation), with the world record of current PandaX sensitivity by 54.1 ton-day.**
- **Jinping Ge dark matter project CDEX-II, get another funding support from MOST (science ministry).**
- **Jiangmen reactor neutrino observatory is under construction, with the funding from CAS by amount of 1.1 B RMB.**
- **Large scale cosmic ray observatory LHAASO, is under construction in Daocheng, Sichuan.**



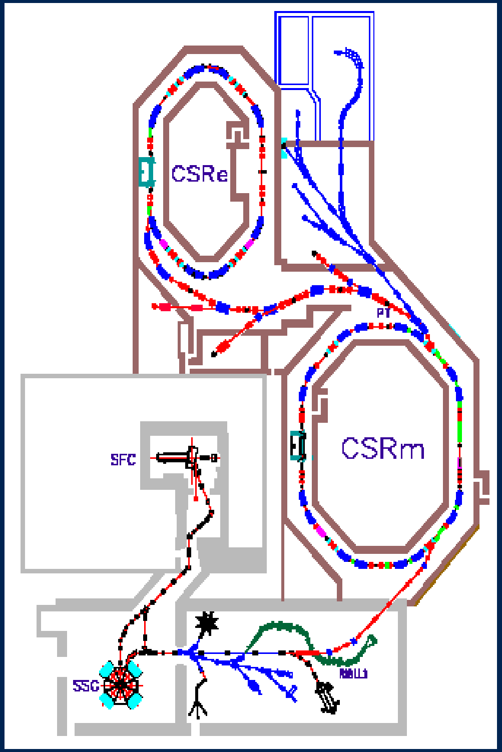


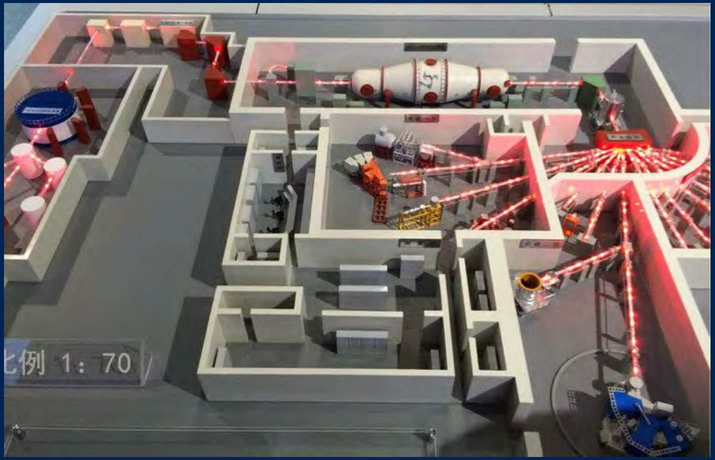
Jiangmen 20 KT tank

Institute anniversary

- **Institute of Modern Physics Lanzhou is celebrating its 60 year anniversary on Aug. 18, 2017.**

- **Beijing Tandem Accelerator is celebrating its 30 year anniversary on July. 2017.**





News from India

- Prepared by
  - Dr. Amitava Roy, **New Director of VECC,** Kolkata**.**
  - Dr. Alok Saxena, **Head of the Nuclear Physics Division at BARC** (Bhabha Atomic Research Centre), Munbai.

Three Major Accelerator Centres in India

Mumbai (BARC and TIFR)

14 MV Pelletron coupled to SC Linac (PLF: Pelletron LINAC Facility)

Delhi (IUAC: Representing all the university users)

15 MV Pelletron coupled to SC Linac

Kolkata (VECC and SINP)

K=130 Cyclotron , K=500 SC cyclotron(not fully operational)

The Thrust Areas :

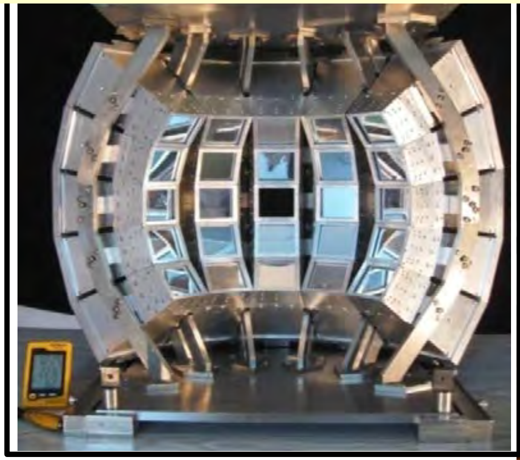
Low and High Energy Nuclear Physics using Accelerator and Reactor; Nuclear Data

Indigenous development of accelerators, detector and instrumentation

Use National Facilities, International Facilities like Legnaro National Laboratory, Ganil, CERN, BNL,FAIR ....

Experimental facilities and
Nuclear Physics Research Activities at VECC

Charge particle detector array

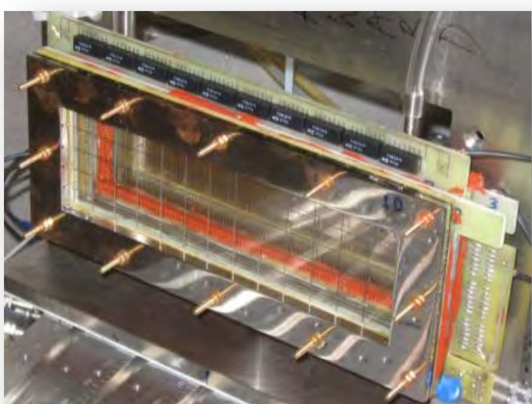


VENUS and VENTURE array

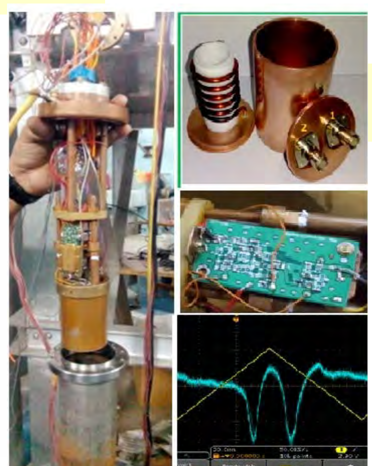
Neutron Detectors

Gamma Multiplicity Filter

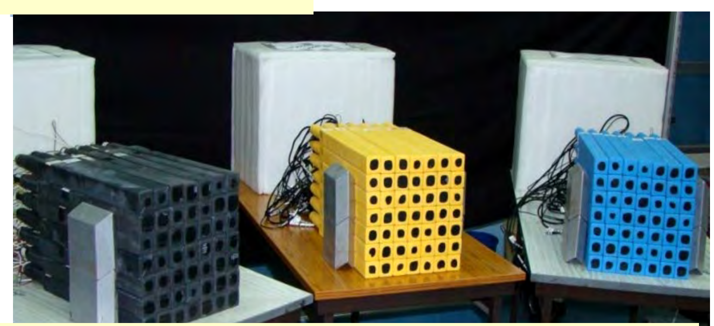
Segmented Clover



MWPC



Penning Ion trap



LAMBDA Detector array

Hall 1

EXPERIMENTAL FACILITIES AT BARC-TIFR PLF (Mumbai)

General purpose scattering chamber

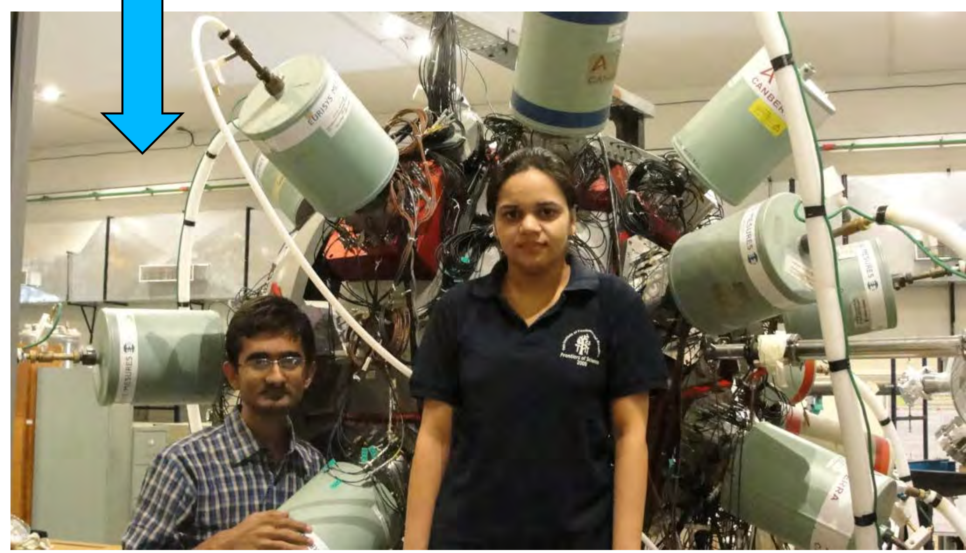
8 CLOVER gamma array is being setup for reactor based work at DHRUVA Reactor

Indian National Gamma Array (INGA) at PLF, Mumbai

Charged Particle Array setup at PLF, Mumbai

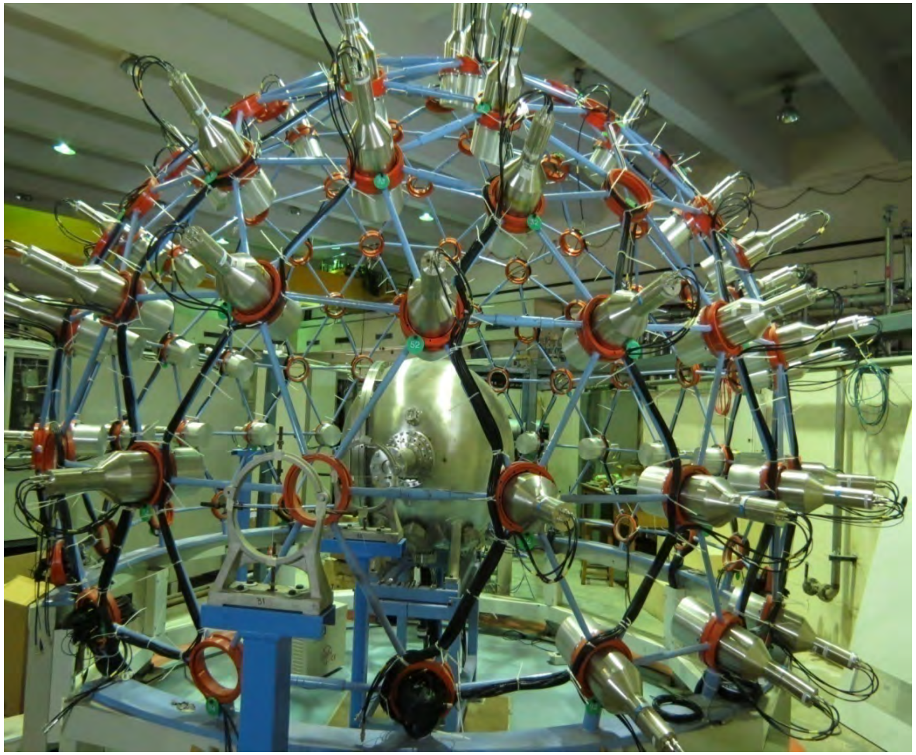
(a) View of the CPDA setup in the LINAC beam hall at TIFR

(b) Experiment using 10 nos of detector telescopes mounted inside the vacuum chamber.



Facilities for fusion-fission study at IUAC (Delhi)

Fission fragment mass distribution measurement using MWPC time of flight set-up inside scattering chamber



Neutron detector array for measuring neutron multiplicity in coincidence with fission fragments

Future Plans/ Upcoming facilities

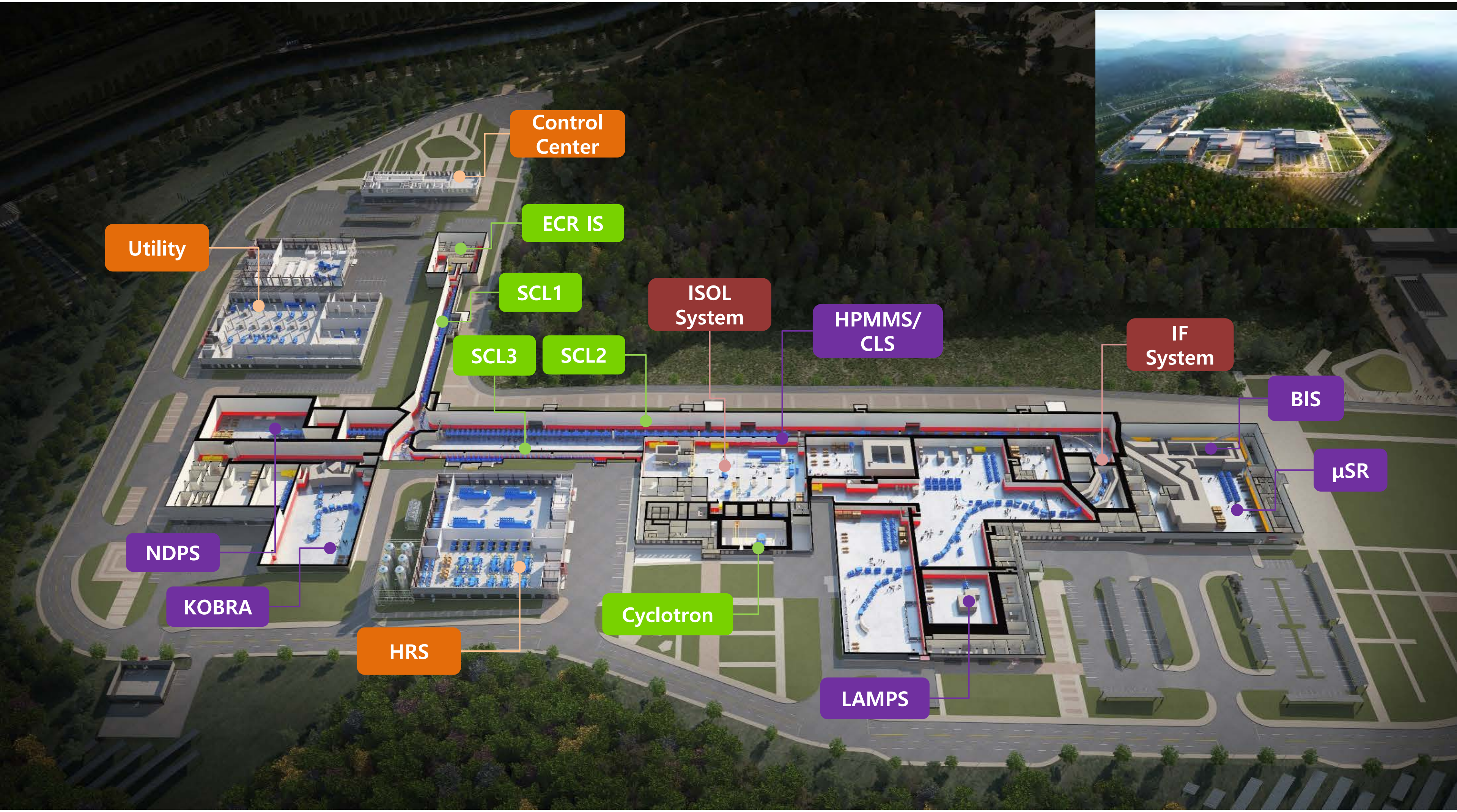
- ECR Injector for the SC Linac (Delhi)(in progress)
- ECR Injector based HI accelerator(Mumbai)(Design and Development)
- Low Energy High Intensity Proton Accelerator(LEHIPA) - 20 MeV Proton Accelerator - (Mumbai)(in progress)
- FRENA - 3 MV Accelerator for Astrophysics (installation in progress Kolkata)
- SC K=500 cyclotron - (Beam trials) (Kolkata)
- ANURIB - National RIB (Design and Development) (Kolkata)
- India Based Neutrino Observatory (INO)
- Antineutrino detection setup at DHRUVA
- GEM subsystem upgrade of CMS detector at CERN

Status of Nuclear Physics Research in Korea

Byungsik Hong

(Korea University)

Layout of RAON



Construction Status of RAON

1. A construction company was selected in September, 2016.
2. The construction and civil engineering for RAON (Rare isotope Accelerator complex for ON-line experiments) has begun.
3. The ground breaking for accelerators and experimental buildings was done on Feb. 13th this year.

SRF Test Facility @ KAIST Munji Campus

- Test facilities for superconducting RF cavities and modules
- Facility List

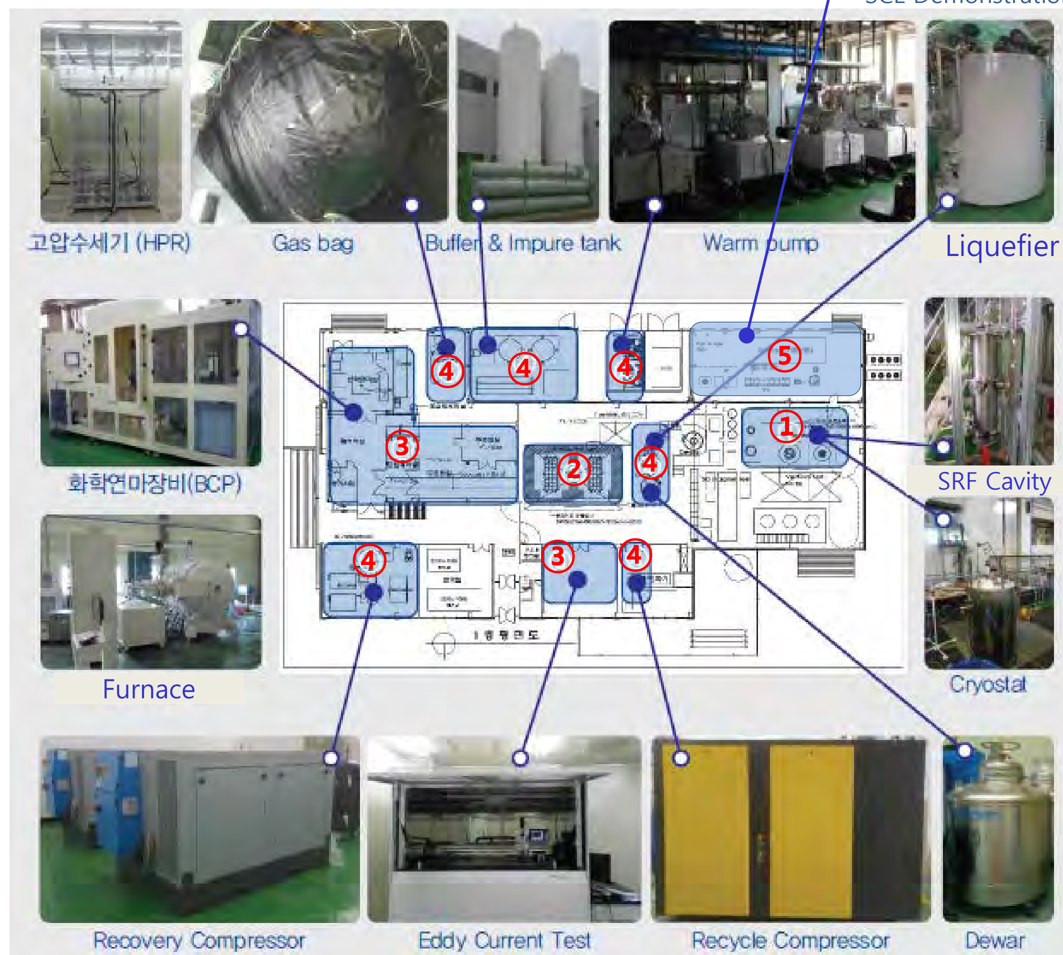
① **Cavity test pit**
(SRF Cavities performance test)

② **Module test bunker***
(SRF Modules performance test)

③ **Clean Room**
(Clean assembly & Inspection)

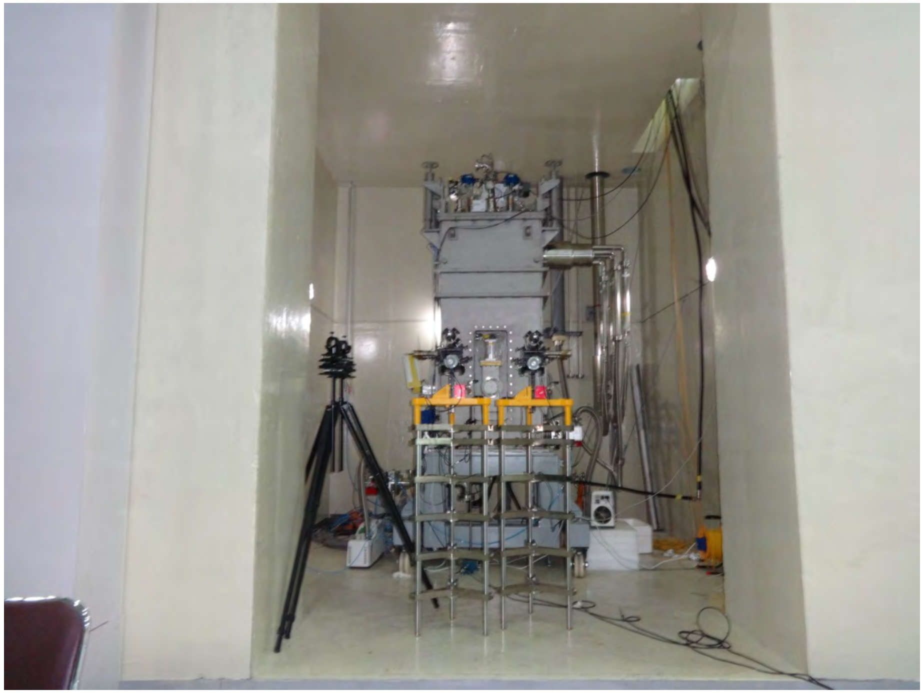
④ **Cryogenic Plant**
(Liquid He, Liquid N_2)

⑤ **SCL Demonstration**
(ECRIS+LEBT+RFQ+MEBT+1 QWR)

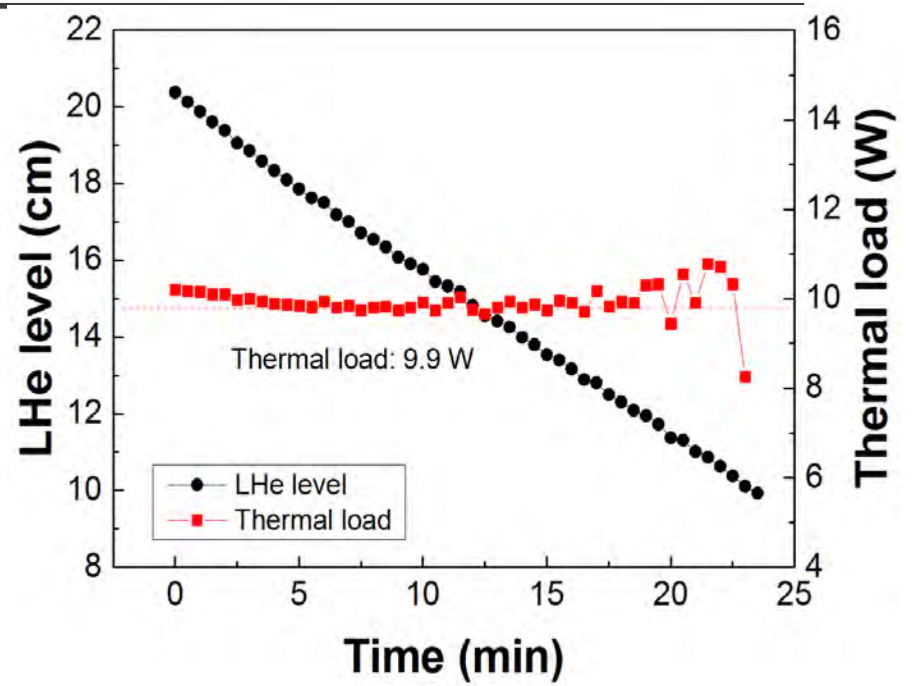


* 1st QWR Module
has been tested successfully in May.

QWR Cryomodule Test Result



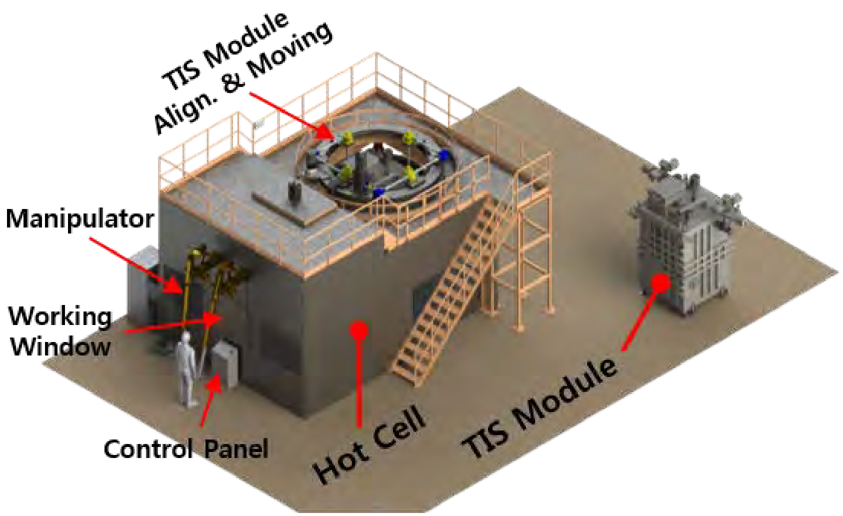
QWR cryomodule test bunker



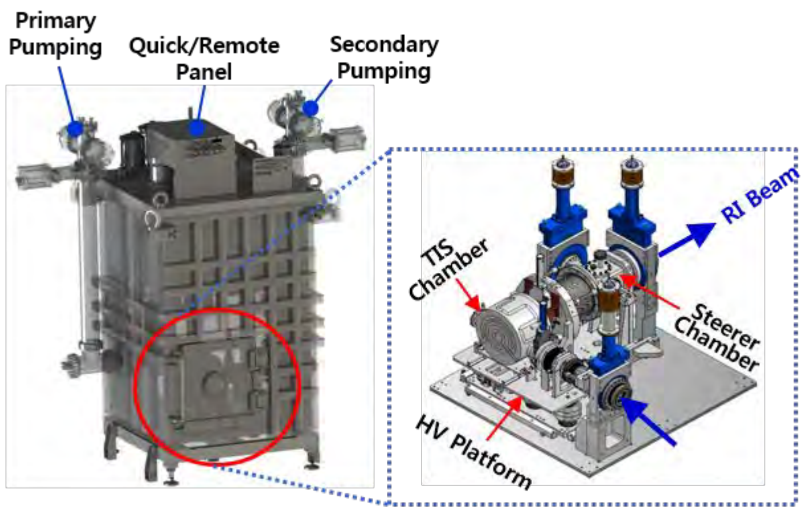
Thermal heat load (9.9 watt @ 6.1 MV/m)

Performance test for QWR cryomodule			
	Reference	**Measurement**	
Thermal heat load	< 25 W @ 4.2 K, 6MV/m	9.9 W @ 4.2 K, 6 MV/m	Pass

ISOL TIS Module & Hot-cell Mock-up



< 4,800mm(W) x 6,852 mm(L) x 4,500 mm(H) >



TIS Module & Vacuum Chamber

TIS & Front-end

Target Module Performance Test

- Primary & Secondary Vacuum Test
- Quick & Remote Connection/Disconnection
- High Voltage Discharge
- Pillow Seal, QDS, Special All Metal Gate Valve

Hot Cell Performance Test

- Coupling & Decoupling of Target Chamber in Target Module
- Target Chamber Exchange
- Target Module Moving System (Rot. & Up/Down)
- Manipulator Jig & Tools

Crane Interface Device Performance Test

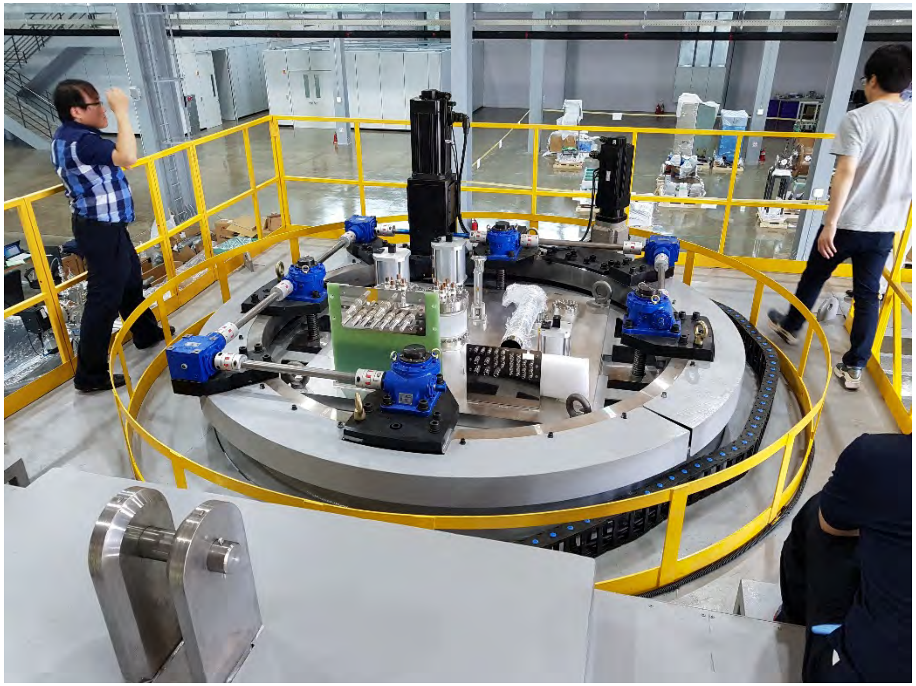
- Alignment / Twist Locking / Interlock

ISOL TIS Module & Hot-cell Mock-up

ISOL TIS Module & Hot-cell Mock-up

* TIS Module is installed in vacuum chamber

ISOL TIS Module & Hot-cell Mock-up



* Load TIS Module to the Hot-cell

ISOL TIS Module & Hot-cell Mock-up

* Inside Hot-cell & Manipulator

Milestone of RAON/RISP in 2017

1. Cryomodule test for QWR and HWR
   → Mass production
2. Cavity test for SSR
   → Cryomodule test planned in early 2018
3. Beam extraction from SCL demo (1 QWR)
4. Test of ISOL Target Ion Source (TIS) Module in Hot-cell Mock-up is going well!

Large

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

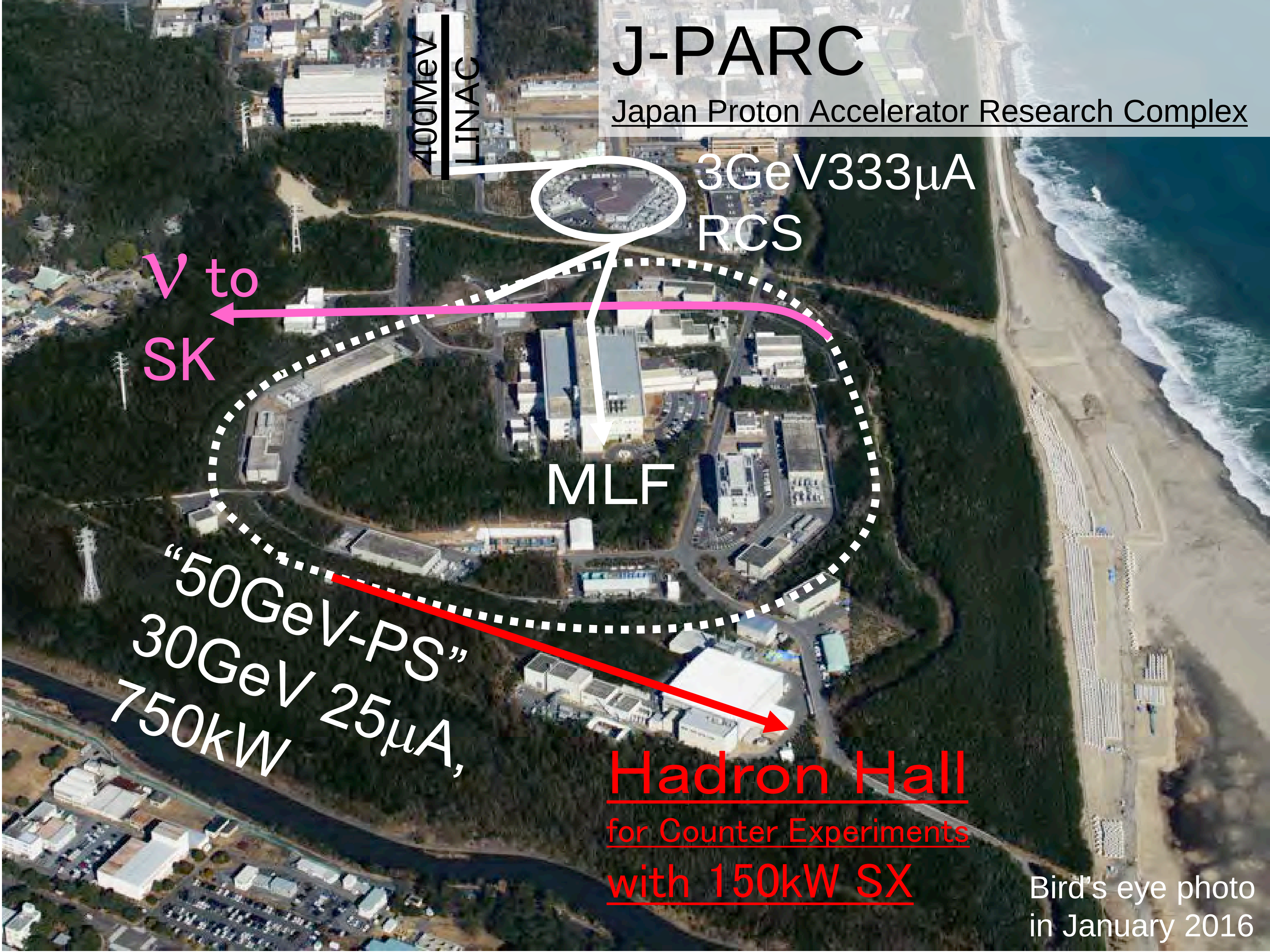
π, K, μ, n, (ν)

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

Endorsed by Japanese Nuclear Physics Executive Committee, 2016

Science Council of Japan selected Major Project

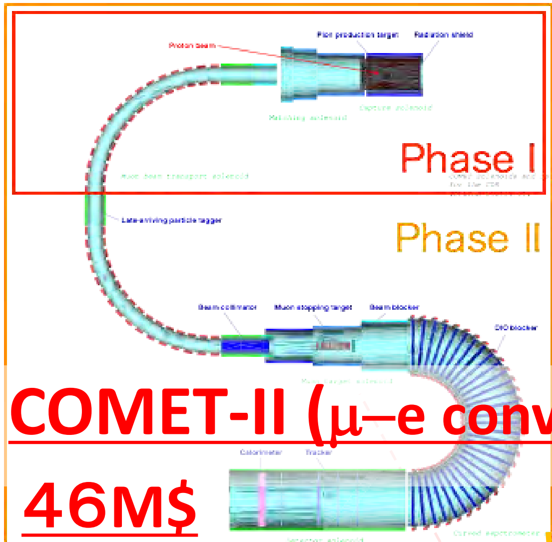
- **J-PARC (KEK)**
  Hadron/nuclear physics w/hadron beams -> Hadron Hall extension
  Fundamental Physics/Particle physics with muons
  -> mu-e conversion (COMET), g-2
- **RIBF (RIKEN)**
  Expand neutron-rich heavy element productions to transuranium
  Production of superheavy Z=119 and beyond
  -> RIBF 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

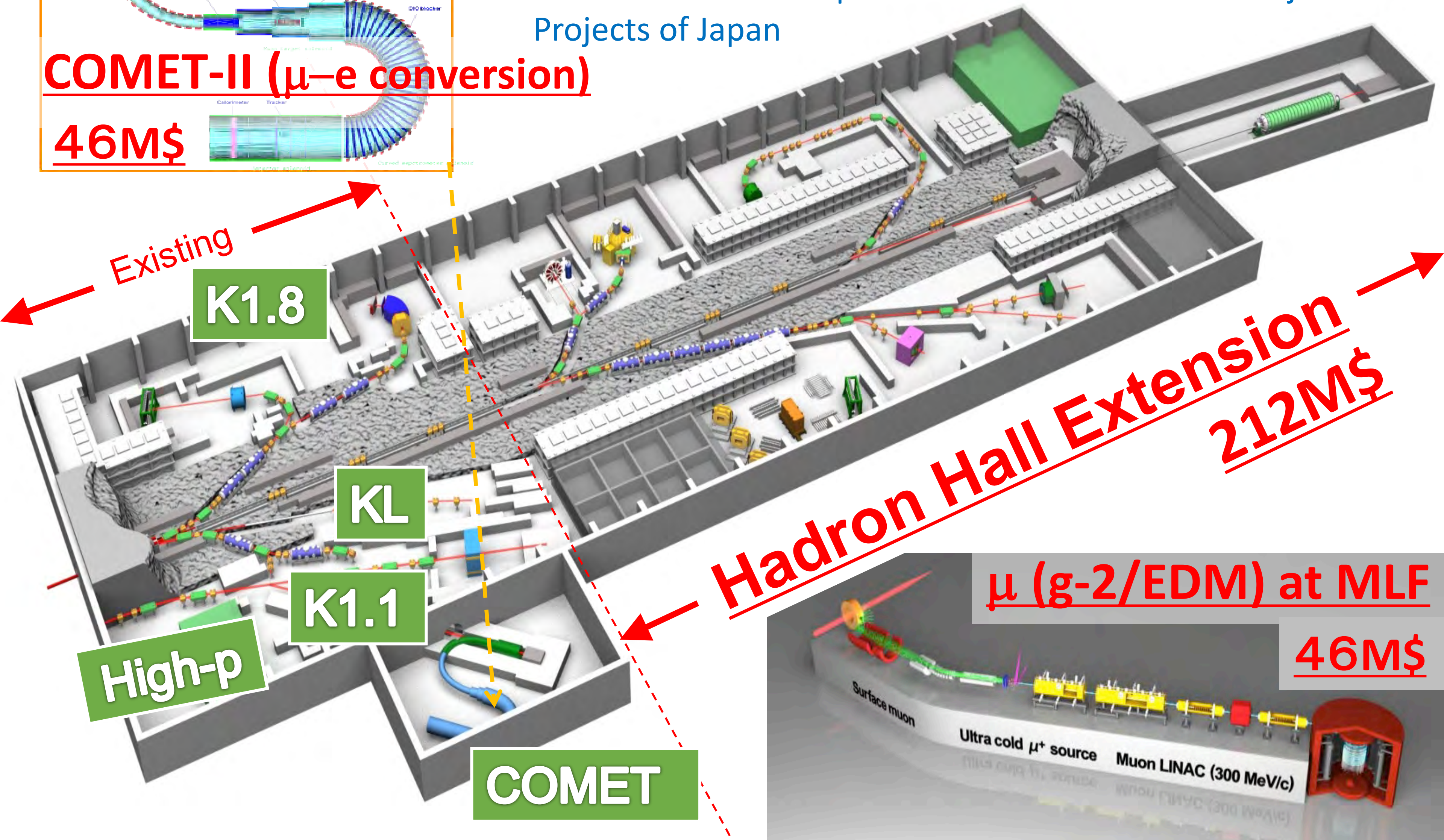


J-PARC
Japan Proton Accelerator Research Complex
400MeV
LINAC
3GeV333μA
RCS
ν to
SK
MLF
"50GeV-PS"
30GeV 25μA,
750kW
Hadron Hall
for Counter Experiments
with 150kW SX
Bird's eye photo
in January 2016

J-PARC Upgrade for Nuclear & Particle Physics

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

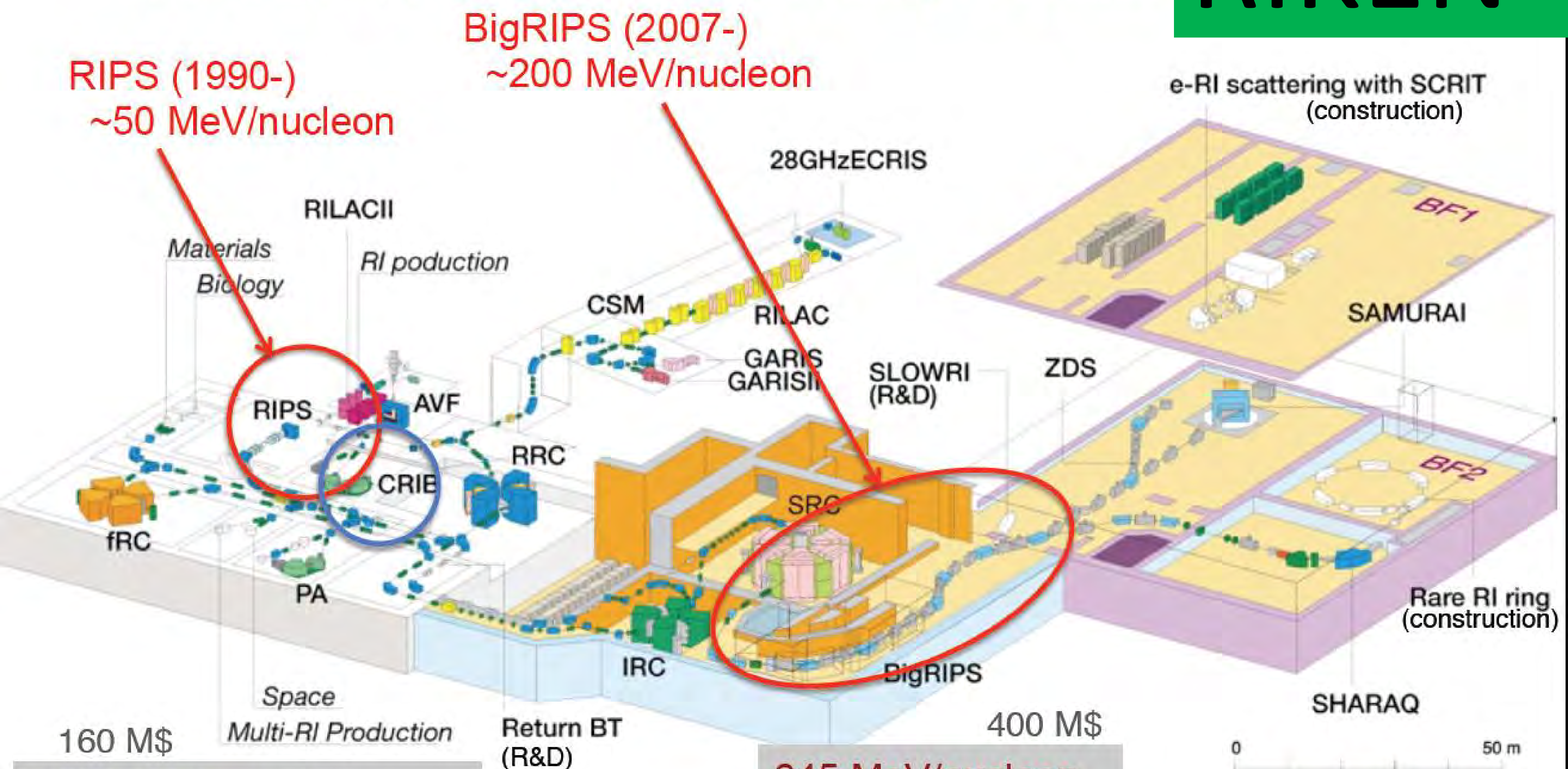




fragmentation-based RI beams (1990- / 2007-)

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

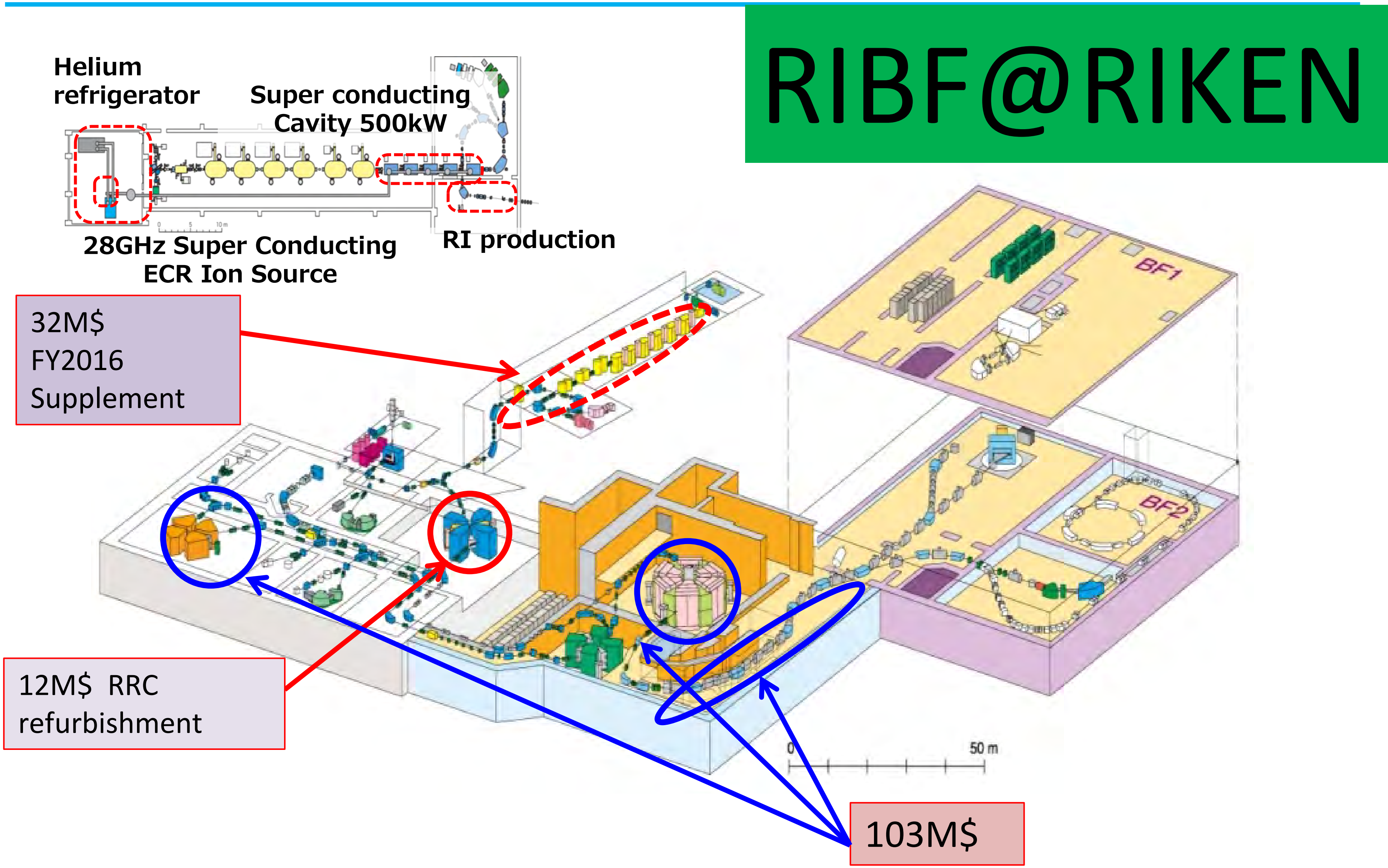
Nov. 2016

On November 30th 2016, IUPAC Announced formally

Elements **113,** 115, 117, and 118 are named **nihonium (Nh),** moscovium (Mc), tennessine (Ts), and oganesson (Og)

Naming Celemony, March 14, 2017 on the presence of Crown Prince of Japan

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



Hadron Hall Extension Project: chosen as one of the top 28 big projects

- **The Science Council of Japan** selected the hadron hall extension project of J-PARC as one of the top 28 major projects selected this year. The selection was made in every three years.
  - From these 28 big projects, 10~15 big projects will be selected by **Council for Science & Technology （CST) in MEXT** (Funding agency in Japan) and will appear in **MEXT's "Road Map".** The budget approval will be made only on these "Road Map“ projects.

“Big projects” in NP, HE and Space

- **4 New projects were selected by SCJ + 1 (added by CST)**
  - **Hadron Hall Extension + μe conversion exp. + g-2/μEDM**
  - HyperKAMIOKANDE + Neutrino Beam Power Upgrade
  - HL-LHC
  - LiteBIRD (Light satellite for the studies of B-mode polarization and Inflation from cosmic background Radiation Detection)
  - SPICA (Space Infrared Telescope for Cosmology and Astrophysics)

- **4 On-Going projects (financed!)**
  - High Intensity J-PARC (750kW for ν, 100kW for SX)
  - Super KEK-B
  - KAGRA (Kamioka Gravitational wave detector, Large-scale Cryogenic Gravitational wave Telescope)
  - 30m Telescope (TMT)

ROADMAP Project selected by CST

- **4 New projects were selected by SCJ + 1 (added by CST)**
  - HyperKAMIOKANDE + Neutrino Beam Power Upgrade
  - HL-LHC
  - LiteBIRD (Light satellite for the studies of B-mode polarization and Inflation from cosmic background Radiation Detection)
  - SPICA (Space Infrared Telescope for Cosmology and Astrophysics)

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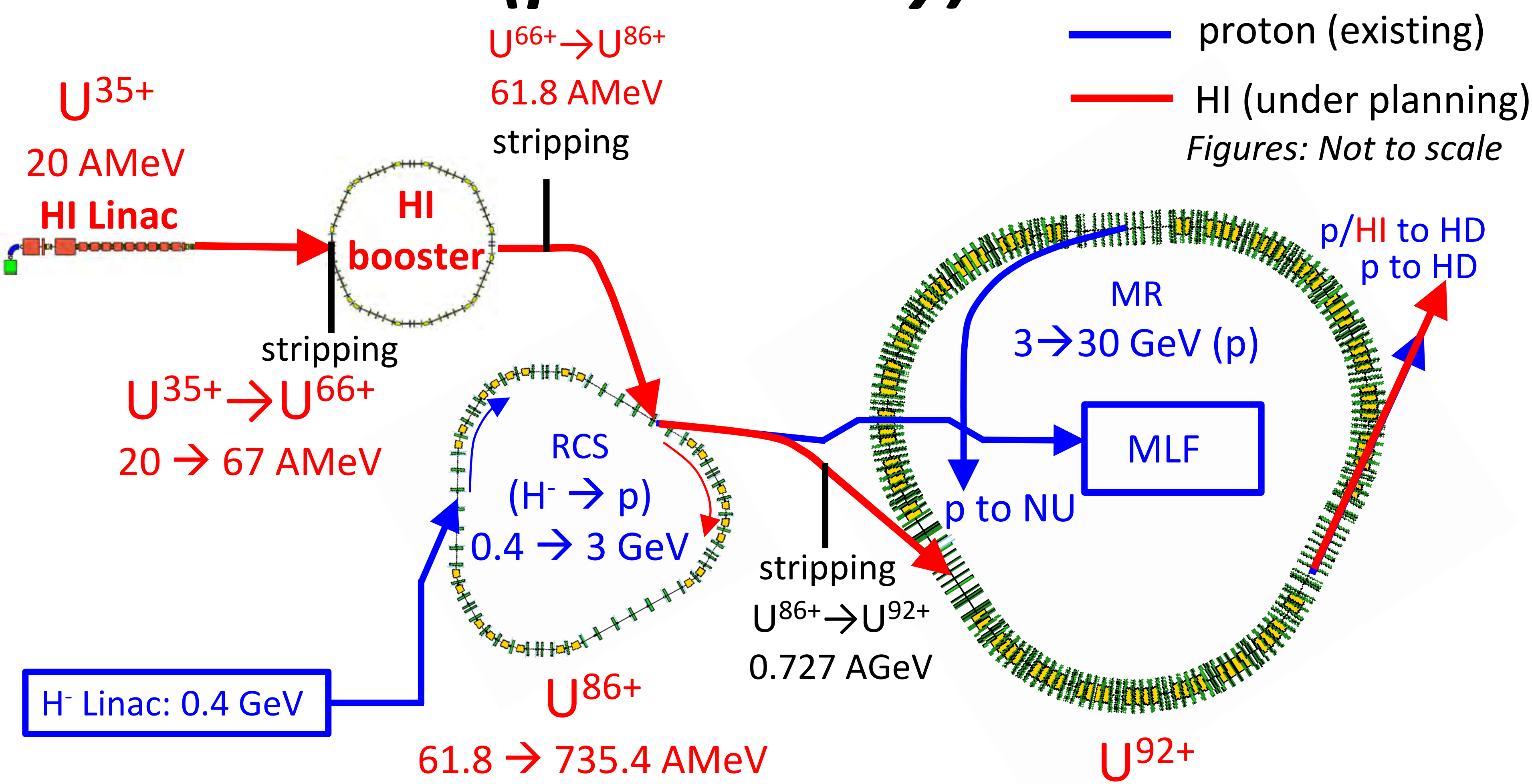
  - Super KEK-B
  - KAGRA (Kamioka Gravitational wave detector, Large-scale Cryogenic Gravitational wave Telescope)
  - 30m Telescope (TMT)

Hadron Hall Extension Project:

捲土重来！

- Gather strength for a renewed attack！

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

Partial 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	**（BES-III）** **（Belle-II）**	**NICA**	**eRHIC** **(eIC)**	1 in the world?
Many body Problem (RI Beam)	PF	**RIBF upgrade** **HIRFL+HIAF**	**GSI/FAIR**	**FRIB**	Good competitions!!
	Both	**RISP**			
	ISOL	**BTANL** **ANURIB**	**SPIRAL2** **SPES** **HIE-ISOLDE**	**ARIEL-II**	
	Super ISOL	**Beijing- ISOL**	**EURISOL**	--	FRIB upgrade?

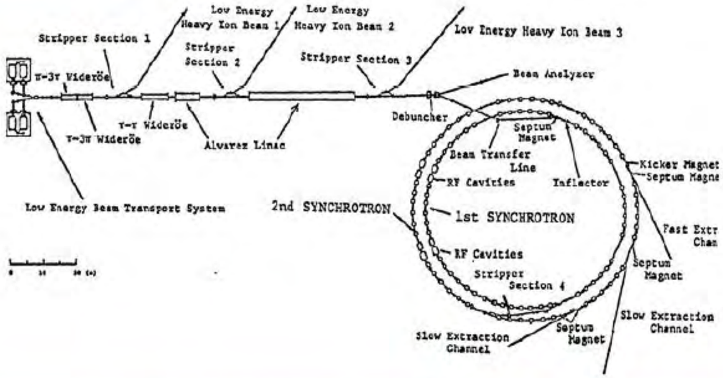
Summary

- Major accelerator facilities in Asia Pacific 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. Final goal is “Super ISOL”.
- We have only one facility for electromagnetic probes (LEPS) in AP.
- J-PARC is becoming the KAON factory in the world? SIS100 will catch us up soon.
- How about baryon rich nuclear matter physics in AP, i.e. J-PARC-HI?

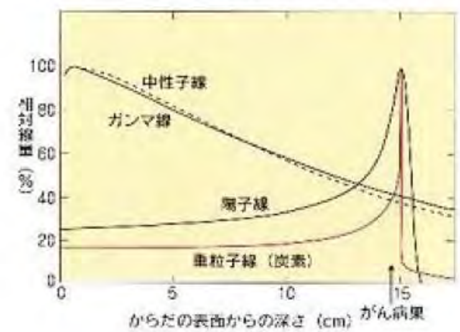
Cancer Treatment by Heavy-Ion/Proton Accelerators in Japan

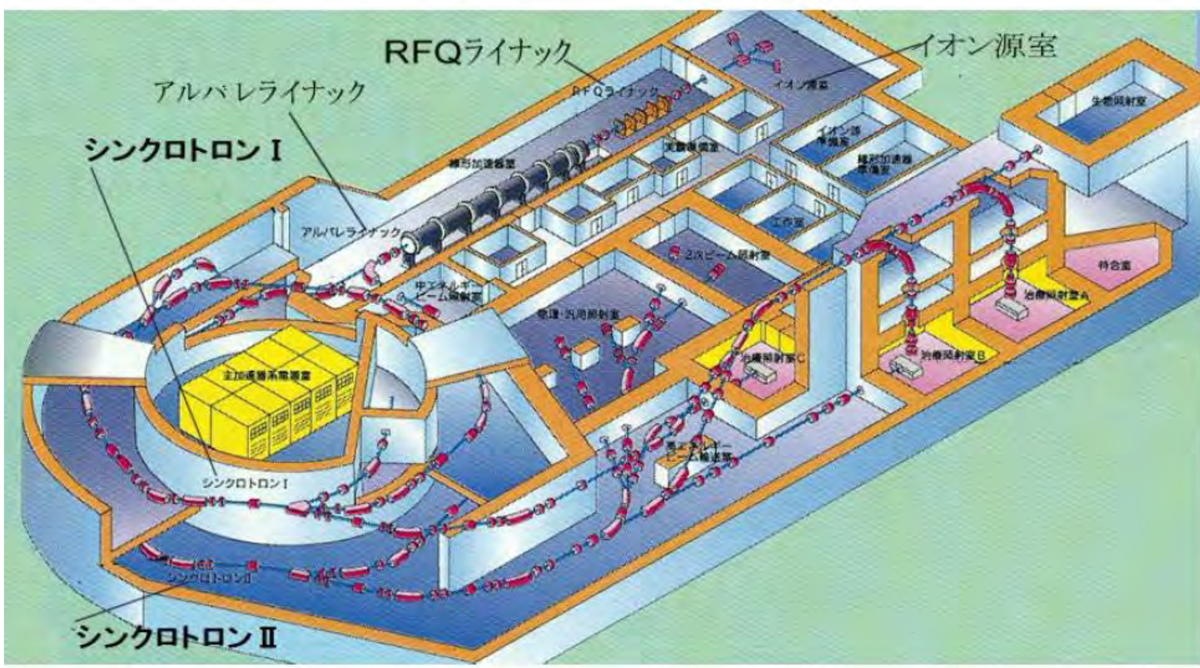
One of big issues from NUMATRON

Heavy-Ion Medicine



各種放射線の生体内における線量分布





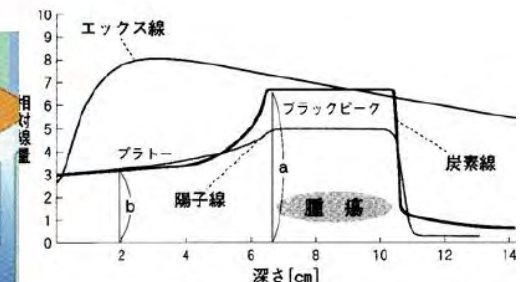
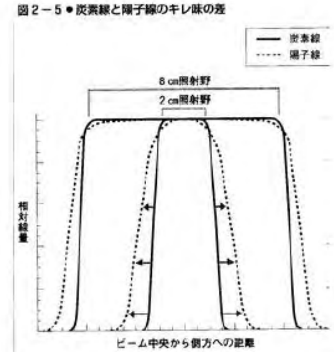


図2－5●炭素線と陽子線のキレ味の差



Particle Beam Cancer Treatment Center in Japan

http://www.antm.or.jp/05_treatment/04.html

Heavy-Ion	Proton	Prefectire	Facility Name	Accelerator
	●	Hokkaido	Hokkaido Univ. Hospital	Synchrotron
	●	Hokkaido	Teisinkai Hospital	Cyclotron
	●	Fukushima	Southern Tohoku Cancer Treatment Center	Synchrotron
●		Gunma	Gunma Univ. Hospital	Synchrotron
	●	Ibaraki	Tsukuba Univ. Hospital	Synchrotron
	●	Chiba	National Cancer Research Center Hospital	Cyclotron
●		Chiba	NIRS-HIMAC	Synchrotron
●		Kanagawa	Kanagawa Cancer Research Center Hospital	Synchrotron
	●	Nagano	Aizawa Hospital (Ai-PROTON)	Cyclotron
	●	Shizuoka	Shizuoka Cancer Research Center Hospital	Synchrotron
	●	Aichi	Nagoya Proton Beam Cancer Treatment Center Hospital	Synchrotron
	●	Fukui	Fukui Proton Beam Cancer Treatment Center Hospital	Synchrotron
●	●	Hyogo	Hyogo Particle Beam Medical Center Hospital	Synchrotron
	●	Okayama	Okayama Univ. + Tsuyama Central Hospital	Synchrotron
●		Saga	Kyushu International Heavy-Ion Cancer Treatment Center	Synchrotron
	●	Kagoshima	Medi-Police Interntional Cancer Treatment Center	Synchrotron

Proton Beam Cancer Treatment Center Teishinkai Hospital, Sapporo.

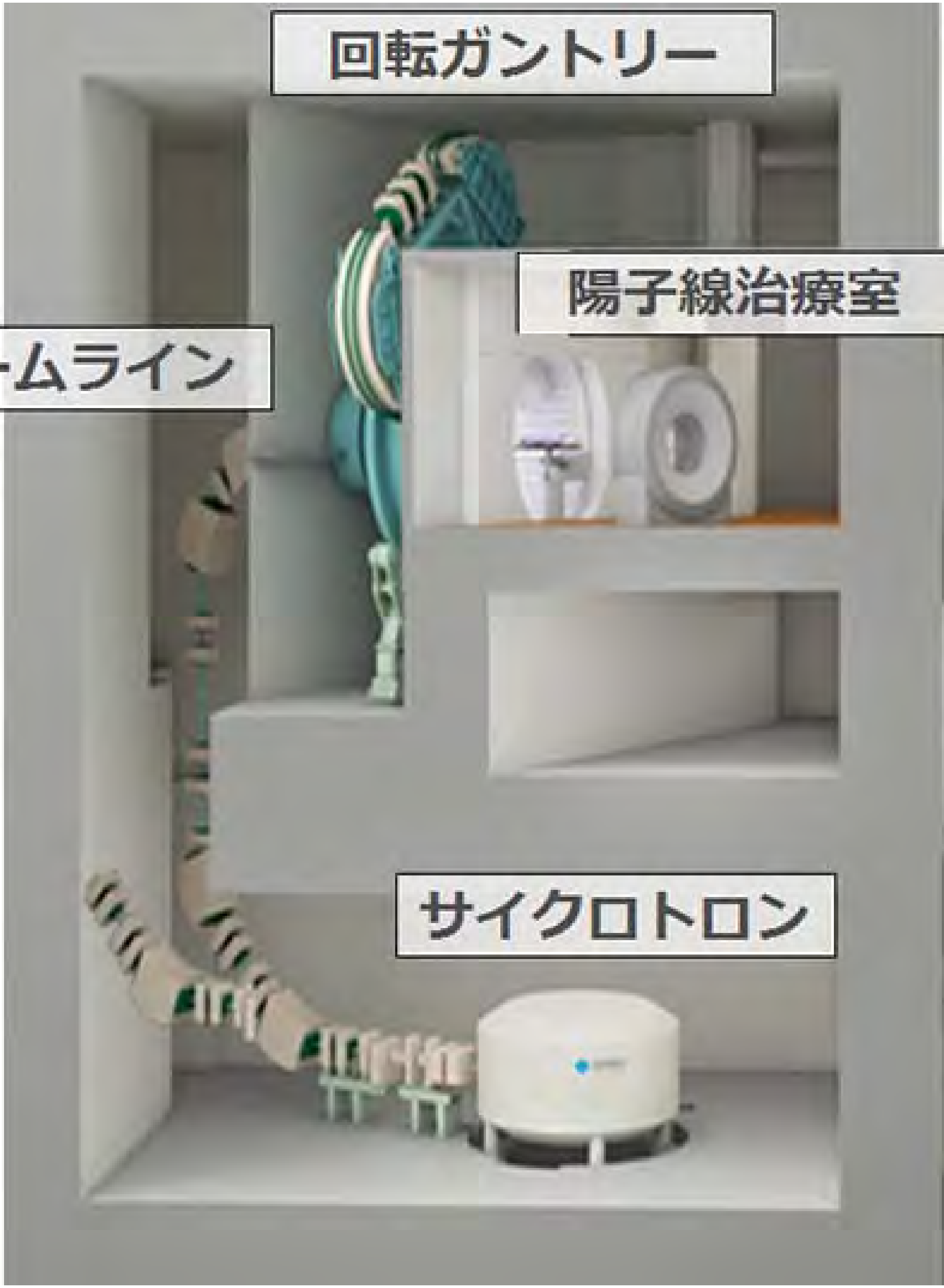
Proton Beam Cancer Treatment Center
Teishinkai Hospital, Sapporo.

235MeV proton Cyclotron
(Diameter: 5m, Weight: 220t)

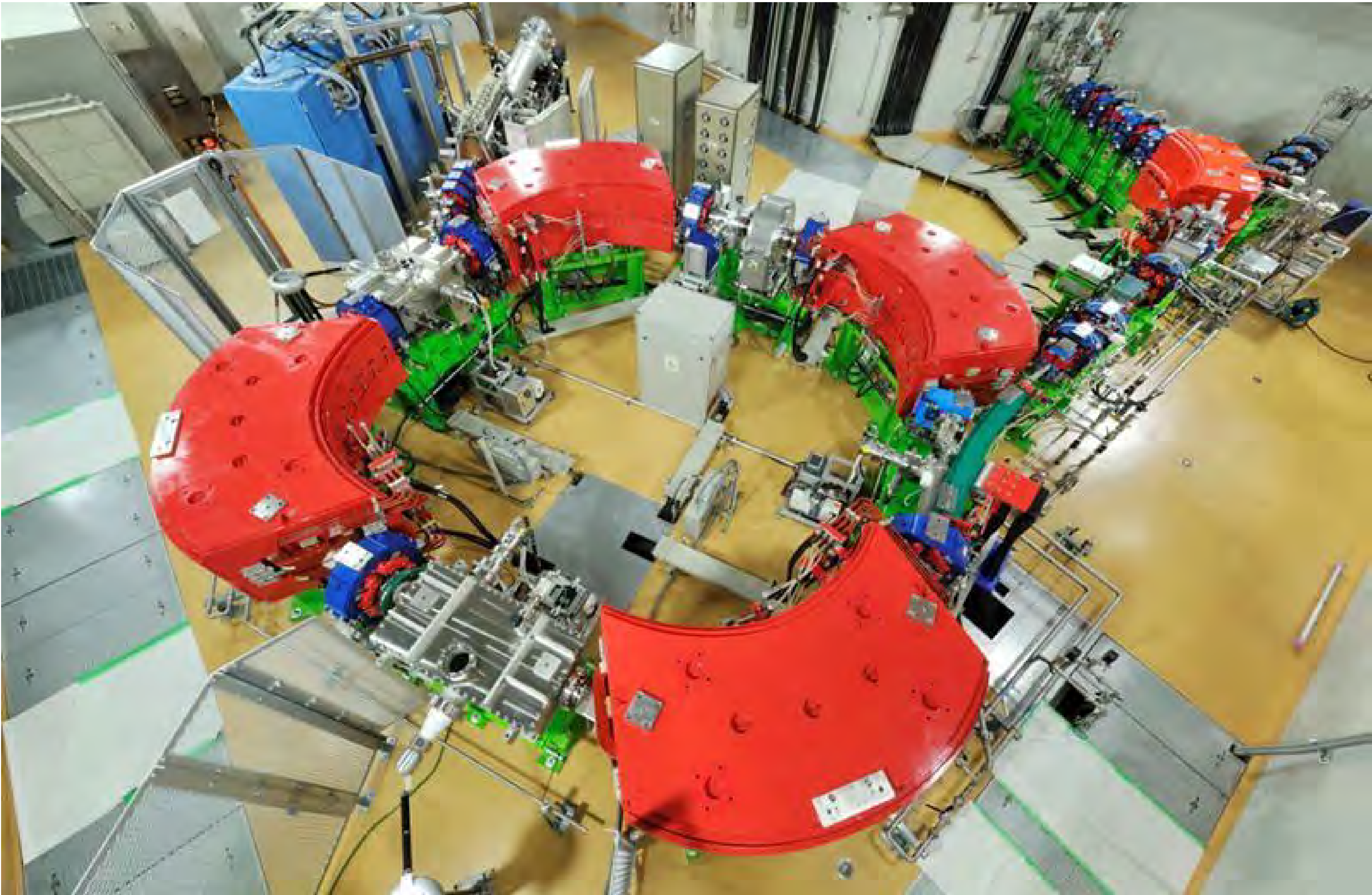
Cancer Treatment System with 235 MeV Proton Cyclotron

Sapporo Teishinkai Hospital

- Succeeded in reducing the installation area by arranging the accelerator, beam line, and rotating gantry vertically.
- 3km from Sapporo JR station and 5min walk from subway station.

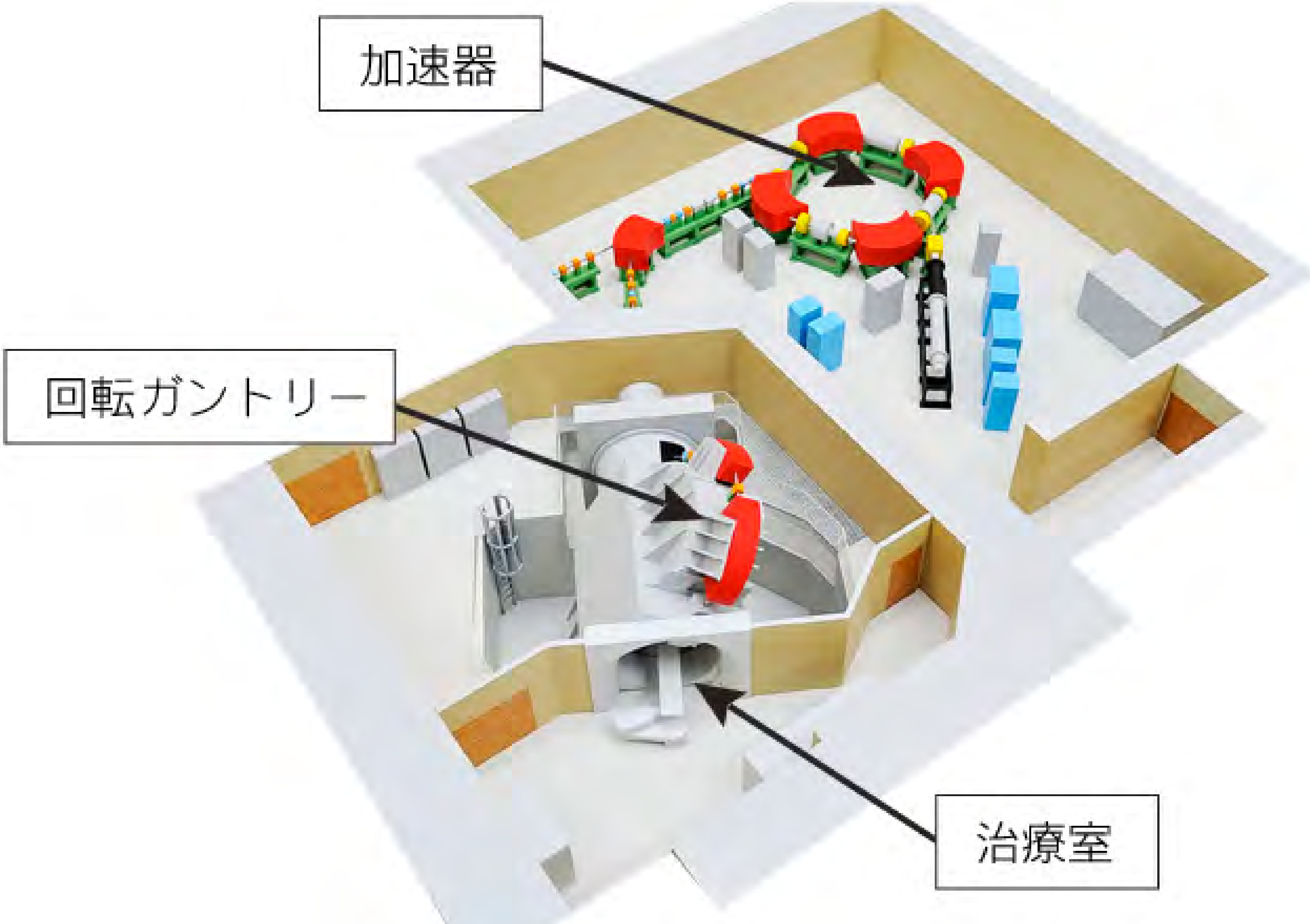


Simple Proton Synchrotron (250MeV)



Gantry at Tsukuba University Hospital

Typical Layout with Synchrotron



Medical Heavy-Ion Accelerator System (Gunma Univ. Hospital)

backup

中国核物理学会 (CNPS)

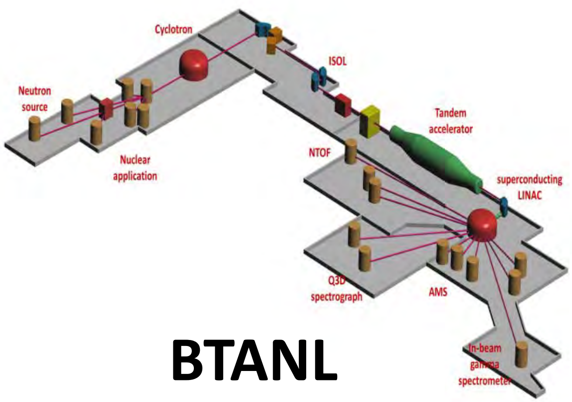
Roadmap of NP facilities

1986
北京串列加速器
HI-13

1988
兰州回旋加速器
SSC

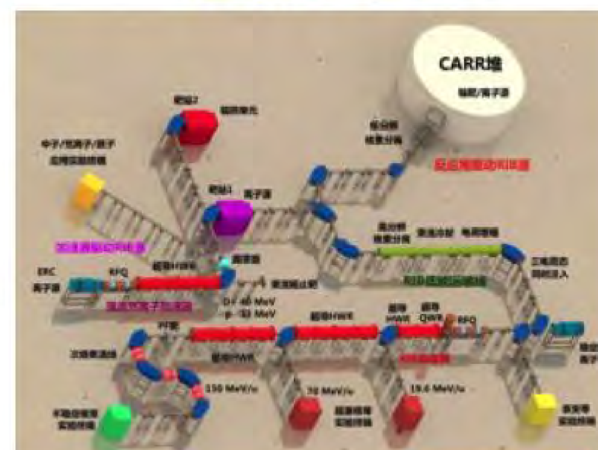
2008
兰州储存环
CSR

2014
北京串列升级工程

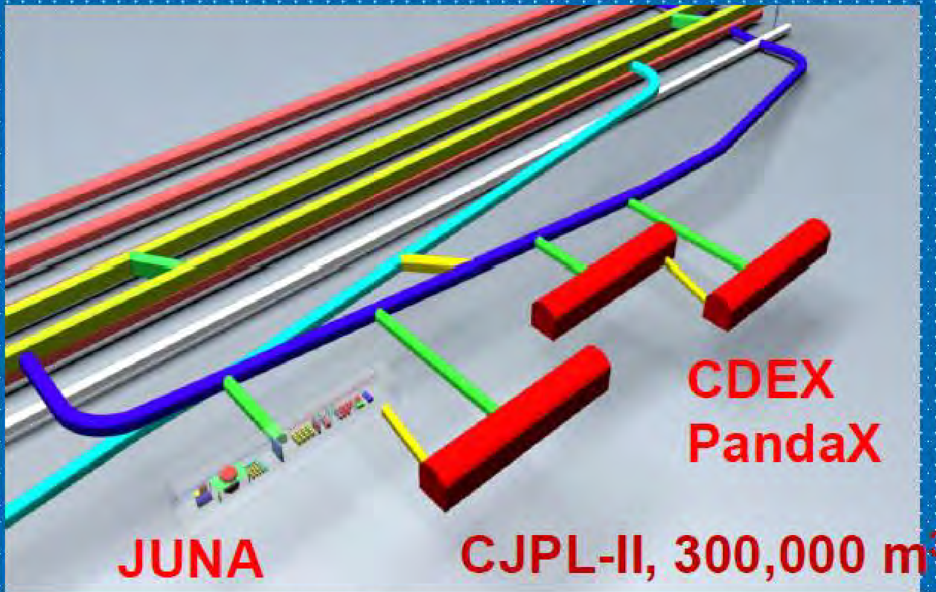


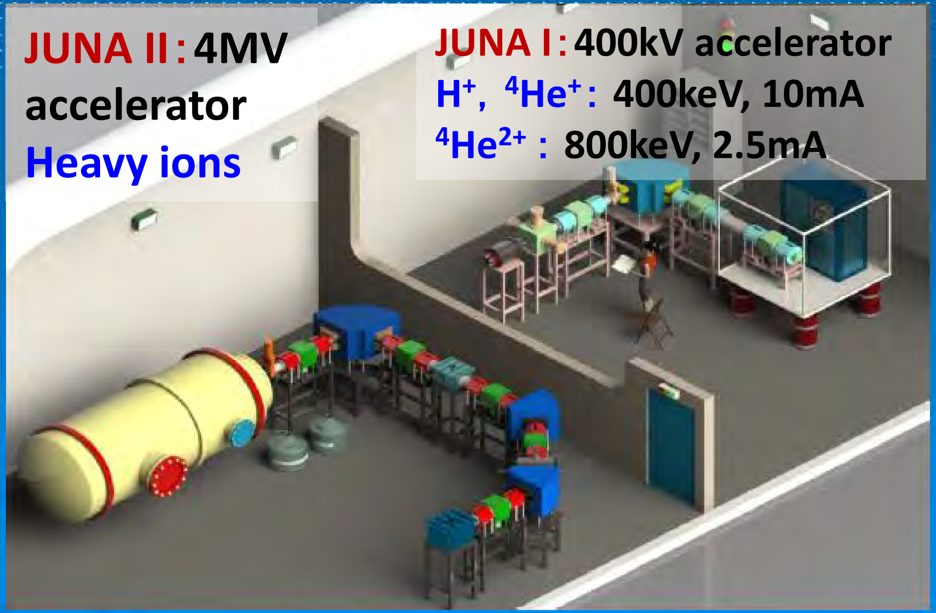
2021?
重离子应用装置
HIAF

2028?
北京ISOL装置



JUNA : Jinping underground nuclear astrophysics





China JinPing Underground Laboratory（CJPL）

Big Bang 関係は、左側の列の上の2つ。類似の施設は、Gran Sasso にある LUNA

愿望清单 wish list

JUNA

氢燃烧

$^{3}He(\alpha,\gamma)^{7}Be$

$^{2}H(\alpha,\gamma)^{6}Li$

$^{3}He(^{3}He,2p)^{4}He$

$^{7}Be(p,\gamma)^{8}B$

$^{12}C(p,\gamma)^{13}N$

$^{14}N(p,\gamma)^{15}O$

$^{15}N(p,\gamma),(p,\alpha)^{16}O,^{12}C$

$^{17}O(p,\gamma),(p,\alpha)^{18}F,^{14}N$

$^{18}O(p,\gamma),(p,\alpha)^{19}F,^{15}N$

$^{19}F(p,\gamma),(p,\alpha)^{20}Ne,^{16}O$

氦燃烧

$^{12}C(\alpha,\gamma)^{16}O$

$^{16}O(\alpha,\gamma)^{20}Ne$

$^{20}Ne(\alpha,\gamma)^{24}Mg$

$^{18}O(\alpha,\gamma)^{22}Ne$

$^{22}Ne(\alpha,\gamma)^{26}Mg$

$^{24}Mg(\alpha,\gamma)^{28}Si$

中子源

$^{13}C(\alpha,n)^{16}O$

$^{22}Ne(\alpha,n)^{25}Mg$

$^{25}Mg(\alpha,n)^{28}Si$

$^{26}Mg(\alpha,n)^{29}Si$

碳氧燃烧

$^{12}C+^{12}C$

$^{12}C+^{16}O$

$^{16}O+^{16}O$

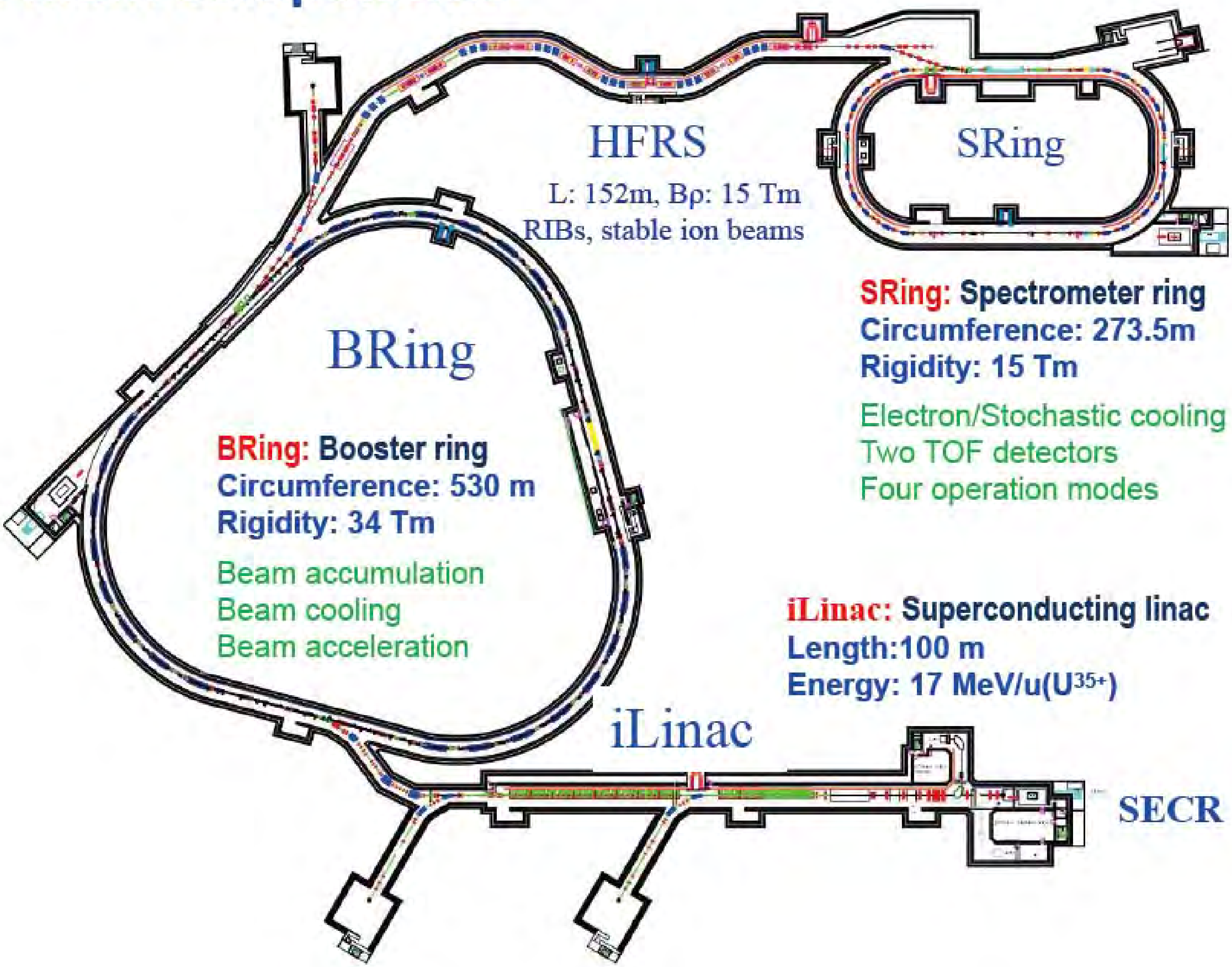
γ天文学

$^{25}Mg(p,\gamma)^{26}Al$ ：

本项目计划测量

Layout and beam specification

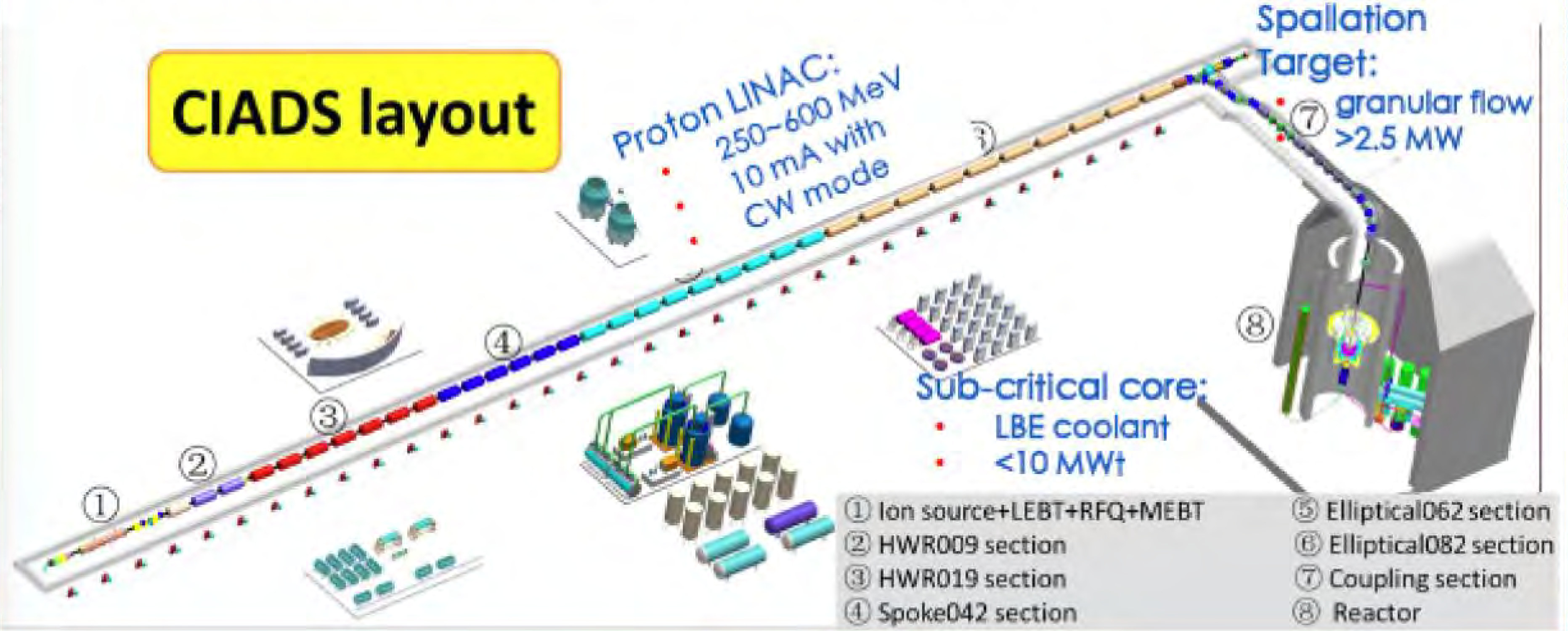
The main components



CIADS Project (2016-2023)

China Initiative Accelerator Driven System (CIADS)

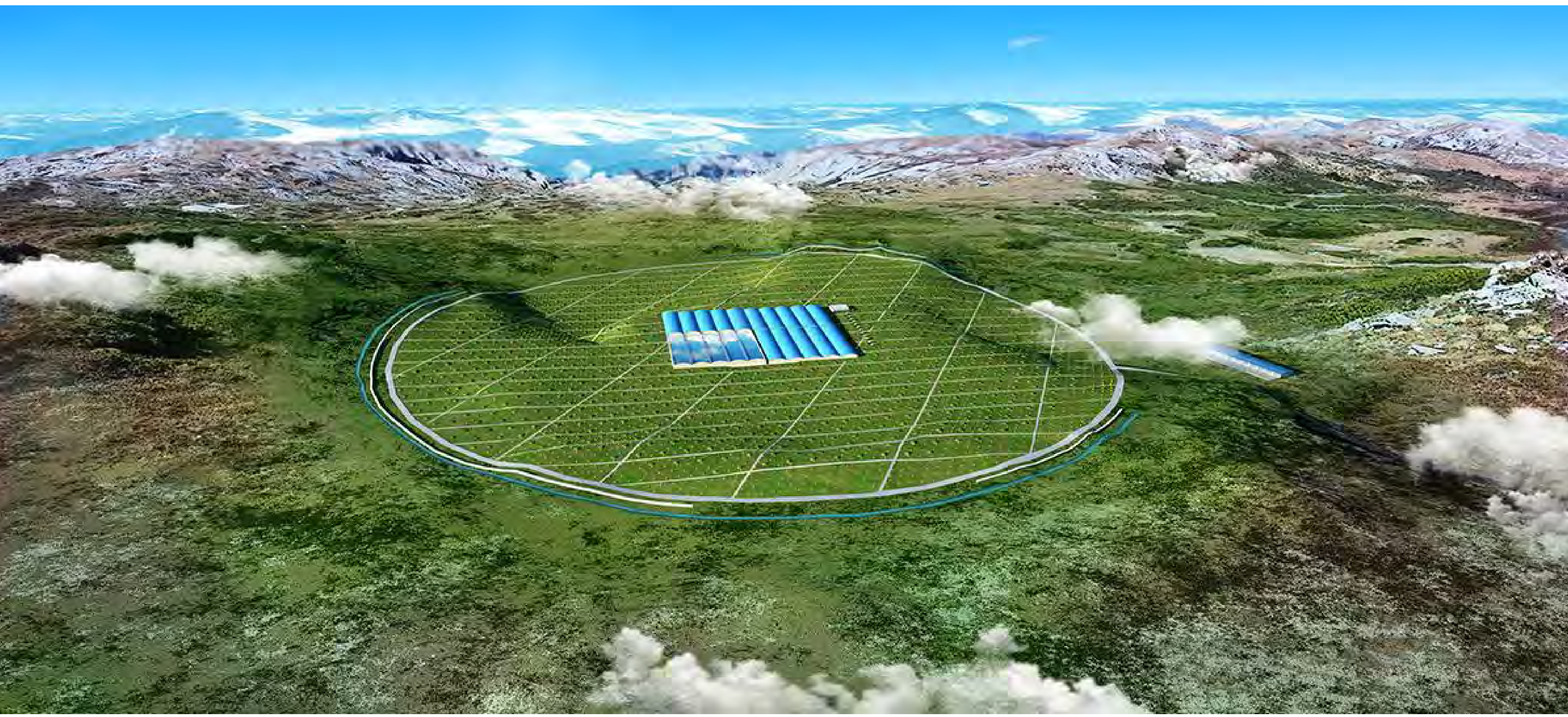
- 2015年12月建议书获国家发改委批准
- 经费: ~(18+12)亿元 (中央财政+地方政府)
- 建设地点: 广东省惠州市
- 建设及合作单位: 广州分院、近物所、高能所、合肥物质院、401、中广核等



IMP 及相关中心Relation with IMP

Large High Altitude Air Shower Observatory
四川省甘孜州稲城県海子山

LHAASO is expected to be the most sensitive project to face the open problems in Galactic cosmic ray physics through a combined study of photon- and charged particle-induced extensive air showers in the energy range 10^{11} - 10^{17} eV.



News from India

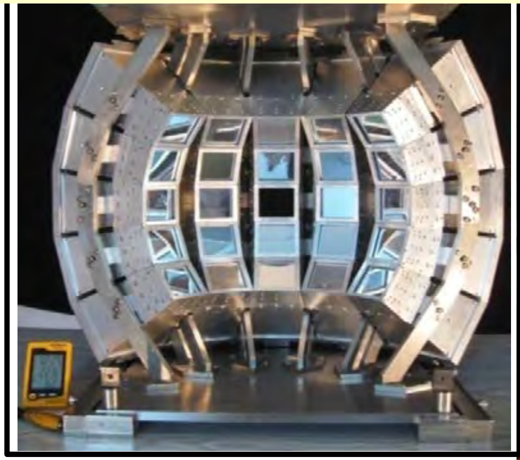
- Prepared by Dr. Amitava Roy, **New Director of VECC,** Kolkata and Dr. Alok Saxena, **Head of the Nuclear Physics Division at BARC** (Bhabha Atomic Research Centre), Munbai.

Three Major Accelerator Centres in India

Mumbai (BARC and TIFR)
14 MV Pelletron coupled to Pb based SC Linac facility (PLF)
Delhi (Representing all the university users)
15 MV Pelletron coupled to Nb SC Linac
Kolkatta (VECC and SINP)
K=130 Cyclotron , K=500 SC cyclotron(not fully operational)
The Thrust Areas :
Low and High Energy Nuclear Physics using Accelerator and Reactor; Nuclear Data
Indigenous development of accelerators, detector and instrumentation
Use National Facilities, International Facilities like Legnaro National Laboratory, Ganil, CERN, BNL,FAIR ….

Experimental facilities and
Nuclear Physics Research Activities at VECC

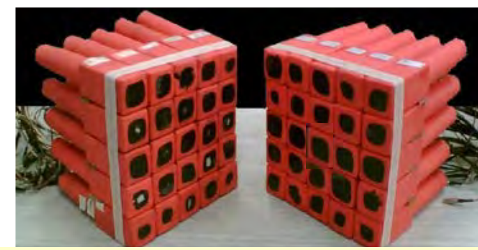
Charge particle detector array



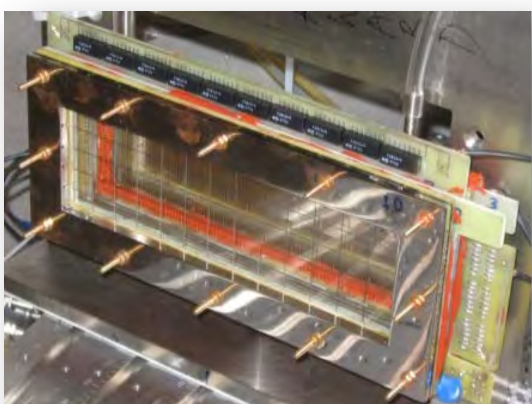
VENUS and VENTURE array

Neutron Detectors

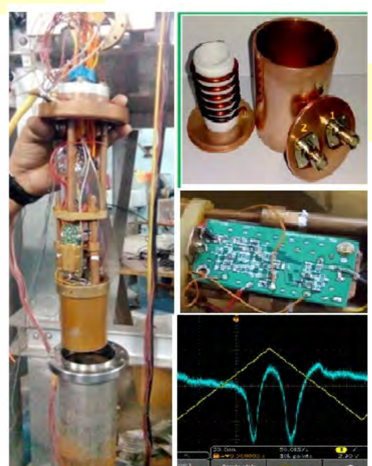
Segmented Clover



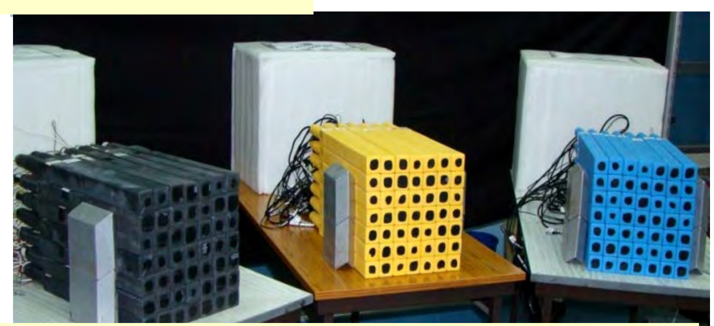
Gamma Multiplicity Filter



MWPC



Penning Ion trap



LAMBDA Detector array

Recent studies:

Studies on GDR using LAMDA array

- Study of dependence of GDR width at high temperatures
- Probing clustering phenomena in atomic nuclei using GDR as a tool
- Jacobi shape transition
- Systematic study of isospin mixing

Studies on nuclear level density using neutron detector

- effect of angular momenta
- effect of collectivity
- shell effect and its damping

Fission studies using MWPCs

- Fission dynamics
- Fusion- fission vs. Quasi fission
- Physics related to Super Heavy Elements(SHE)

International Collaborations:

- FAIR NUSTAR (GSI,Germany)
- DST-RFBR project , JINR, DUBNA
- AGATA Expt., GANIL, FRANCE
- PARIS collaboration (FAIR)

Studies using Charged Particle detector

- Fragments emission mechanisms
  - Fusion-fission, DIO, DI, QE etc.
- Deformation of nuclei using LCP as probe
- Cluster structure studies
  - Hoyle state,
  - Other cluster states of ^{12}C
  - Hoyle analogue sates and excited states of Hoyle analogue states in other nuclei
  - Effects of clustering in fragments emissions

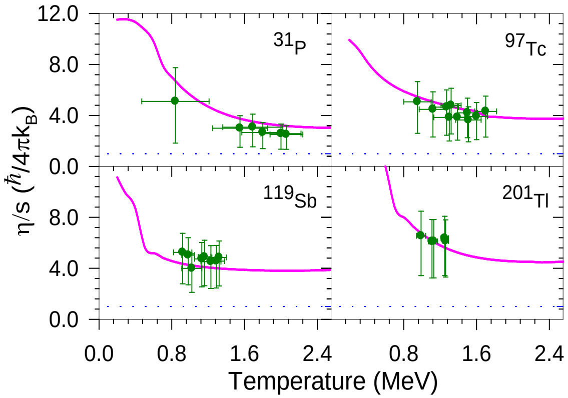
Gamma ray spectroscopic studies using VENUS, INGA and other setup :

- spectroscopy of heavy nuclei
- Complete spectroscopy of nuclei using lifetime and quadrupole moment measurement
  - a. In beam prompt spectroscopy to study nuclei in A ~ 130 region
  - b. Decay spectroscopy of radio-chemically separated fission fragments around ^{132}Sn

Study of long lived beta decaying isomers using beta-gamma coincidence measurement

High spin states, evolution of deformation, new modes of excitations

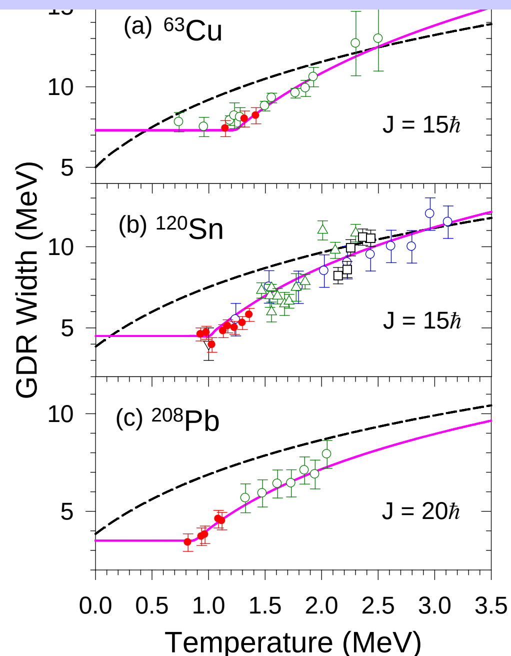
η/s for finite nuclear matter : Experiment at VECC



η/s remains within (2.5-6.5) ℏ/4πk$_B$ for finite nuclear matter

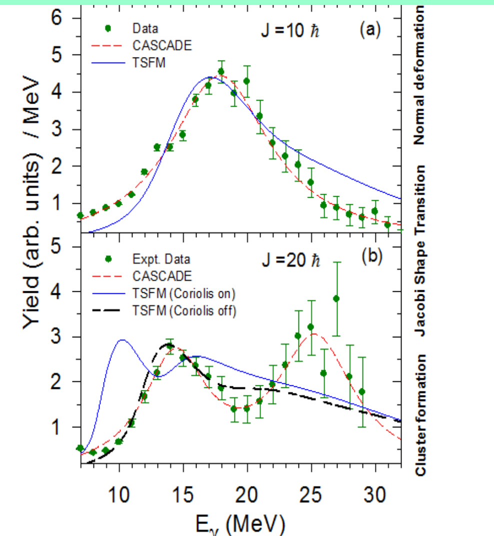
Debasish Mondal et al., Phys. Rev. Lett. 118 (2017) 192501

Critical behavior in the evolution of GDR with at low T



Phys. Lett. B 713 (2012) 434

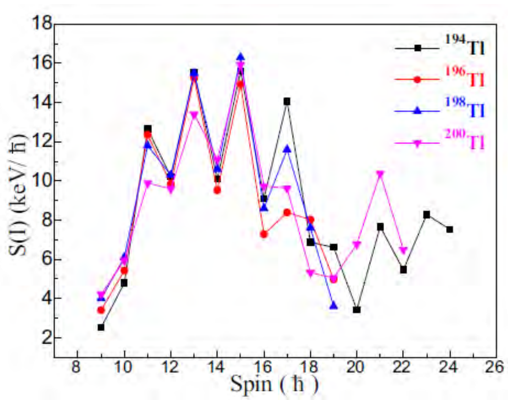
Study of cluster formation in atomic nuclei via GDR decay:



Phys. Rev. C 95 034301 (2017)

Experiments with INGA

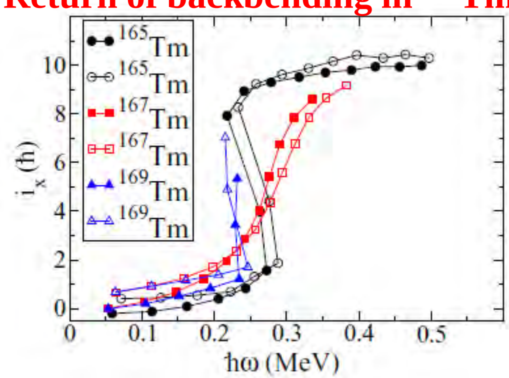
^{198}Pt(^{7}Li, 5n)^{200}Tl



Soumik Bhattacharya et al, PRC 95, 014301 (2017)

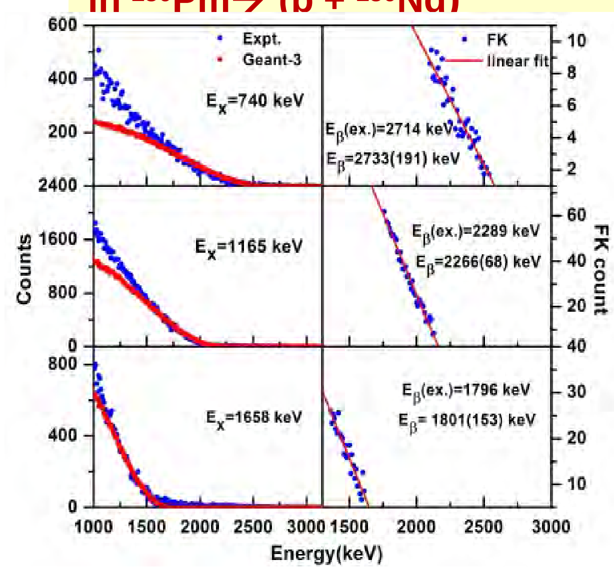
^{169}Tm(^{32}S, ^{32}S′)^{169}Tm*

Return of backbending in ^{169}Tm



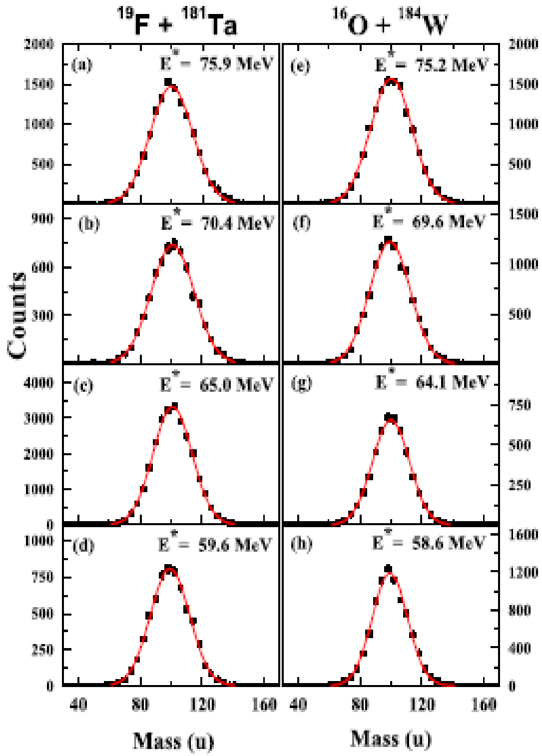
Md. A. Asgar et al., PRC 95,031304(R) (2017)

Long lived beta decaying isomer in ^{150}Pm→ (p + ^{150}Nd)



T. Bhattacharee et al. NIM A 767, 10(2014).

Exploring fission valleys of pre-actinides

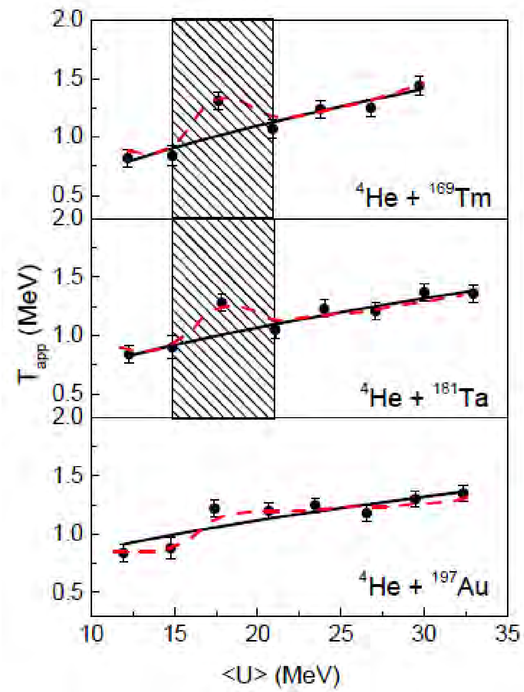


A. Chaudhuri et al; PRC 94, 024617 (2016)

A. Chaudhuri et al; PRC 92, 041601 (2015) (R)

A. Chaudhuri et al; PRC 91, 044620 (2015*)*

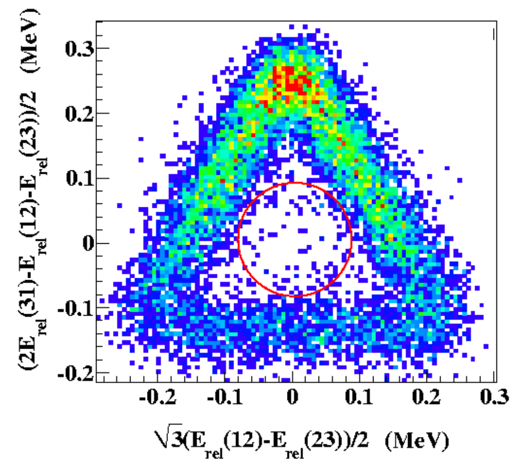
Evidence of fadeout of collective enhancement in nuclear level density



K. Banerjee*et al.* PLB 772, 105 (2017)

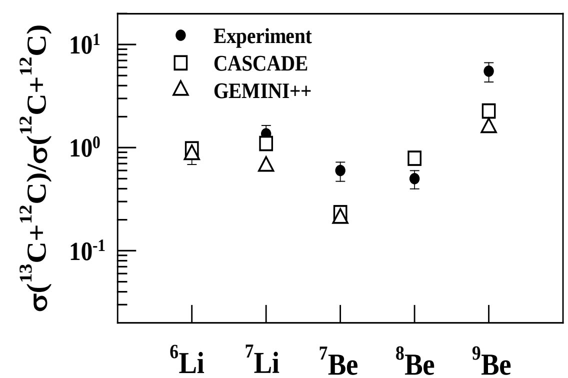
P. Roy et al., PRC 88, 031601 (2013) (R)

Direct vs. Sequential decay of the Hoyle state



T. K. Rana *et al*., PRC 88, 021601(R) (2013)

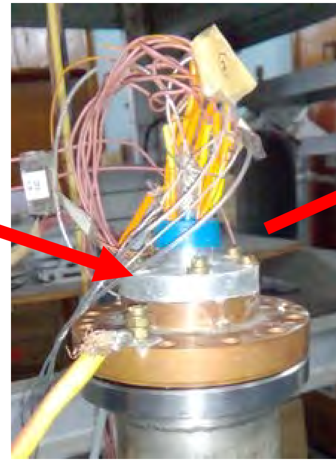
Survival of cluster structure at high excitation



S Manna et. al., PRC 94, 051601((2016)(R)

Electron cloud trapped in VECC Penning Ion Trap and observed using indigenously developed resonant detection electronics setup

Penning Ion trap assembly

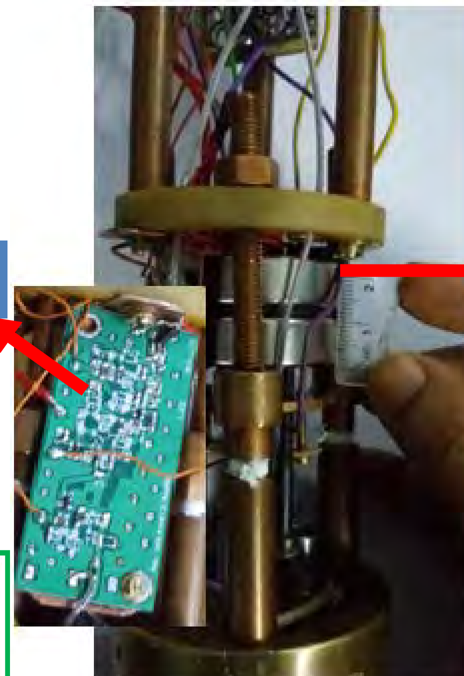


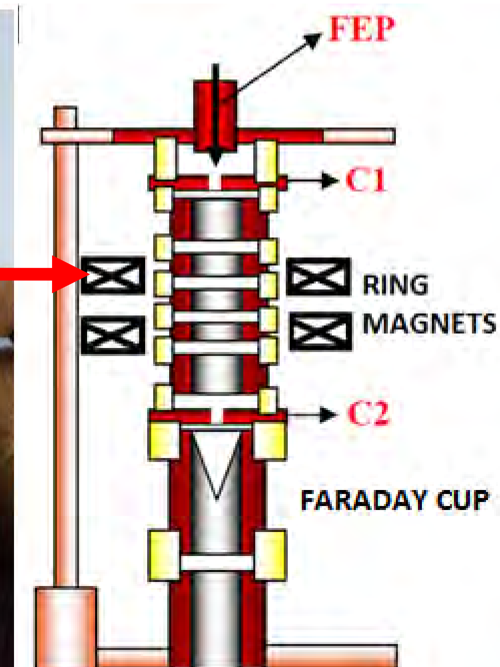
Indigenously developed 19 pin cryogenic feedthrough

Low noise amplifier

Helical resonator

Designed and developed at VECC



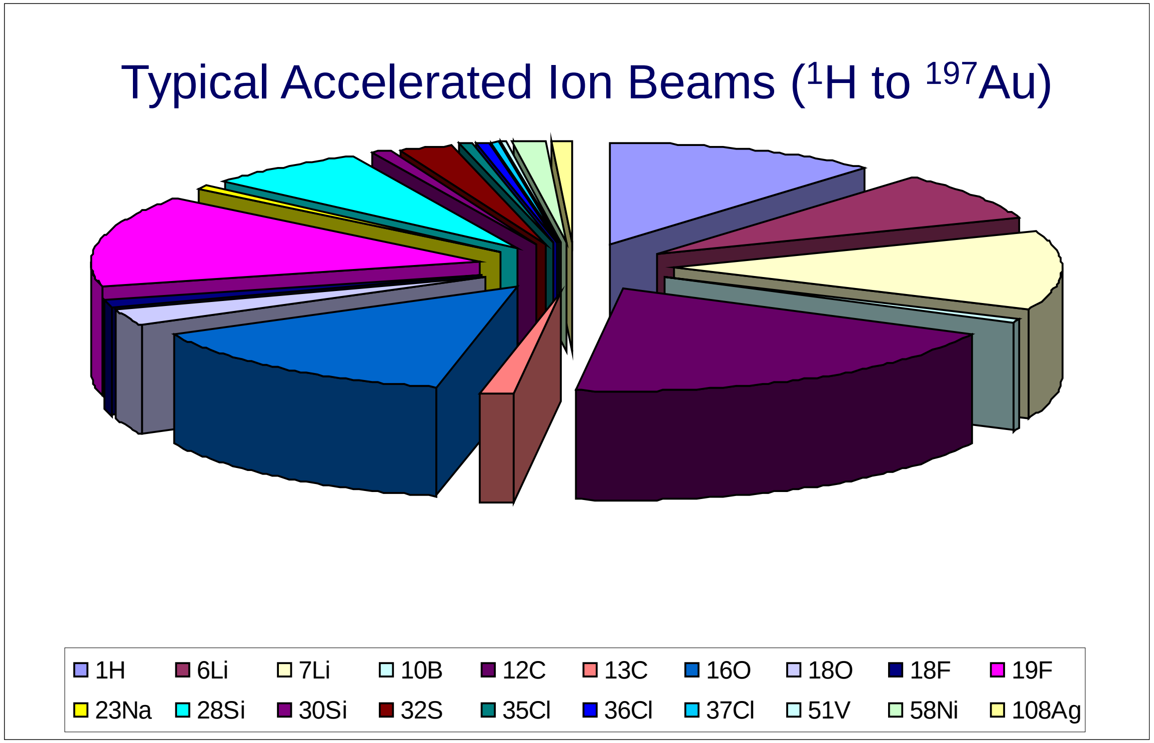


TWO RING MAGNETS ENCLOSING FIVE ELECTRODE TRAP ASSEMBLY

FEP: Field Emission Point for electron generation

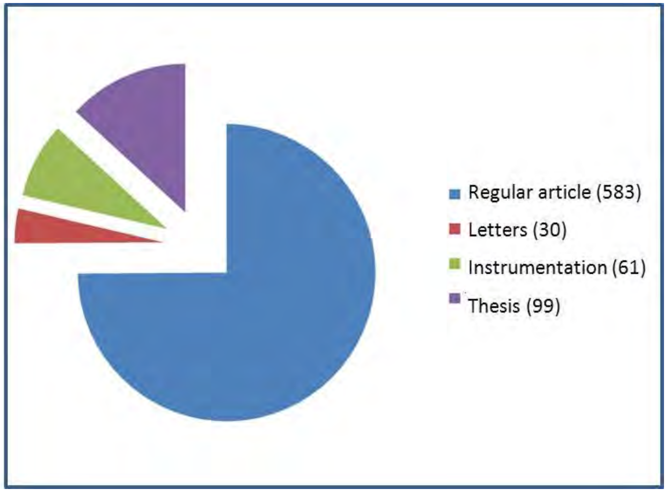
BARC-TIFR Pelletron-LINAC Facility

- **Experimental Facilities for**
  - Nuclear physics
  - Atomic physics
  - Condensed matter physics and material science
  - Radioisotopes production
  - Production of track-etch membranes
  - Low flux Protons irradiation damage studies
  - Secondary neutron production
  - Accelerator Mass Spectrometry



- **Users**
  - BARC
  - TIFR
  - SINP & VECC, DRDO, ISRO and other research & educational institutions.

Publications



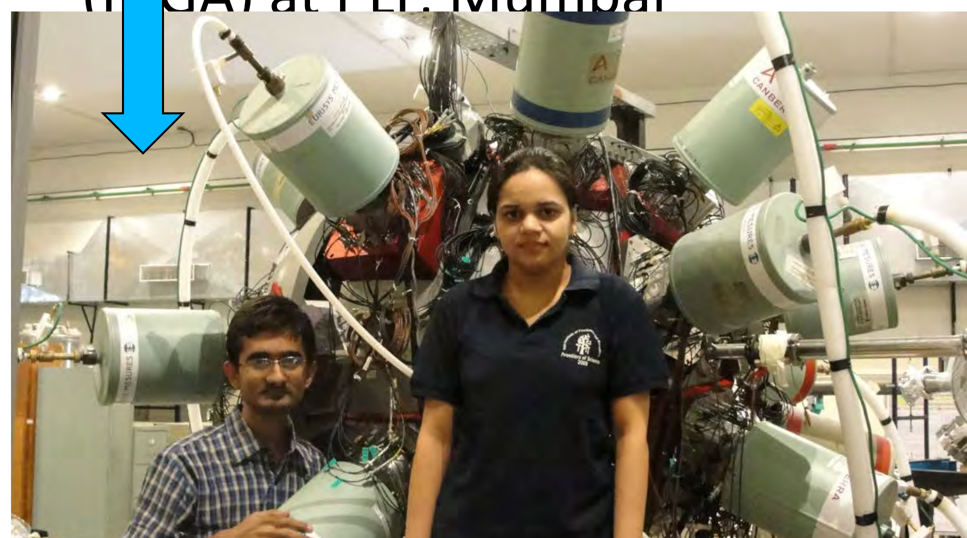
Hall 1

EXPERIMENTAL FACILITIES AT BARC-TIFR PLF

General purpose scattering chamber

8 CLOVER gamma array is being setup for reactor based work at DHRUVA Reactor

Indian National Gamma Array (INGA) at PLF, Mumbai



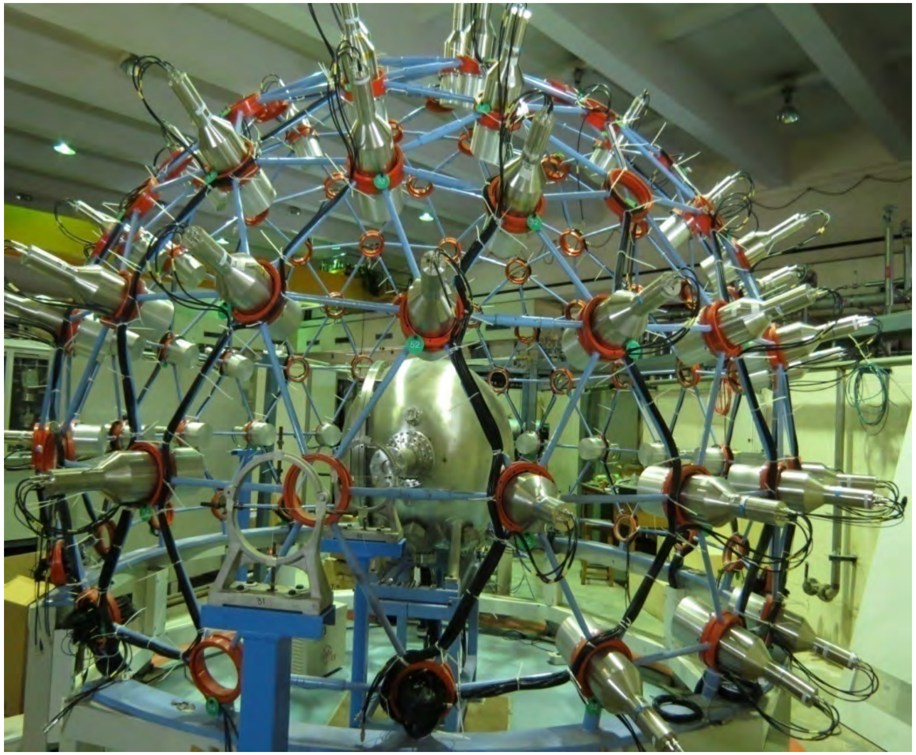
Charged Particle Array setup at PLF, Mumbai

(a) View of the CPDA setup in the LINAC beam hall at TIFR

(b) Experiment using 10 nos of detector telescopes mounted inside the vacuum chamber.

Facilities for fusion-fission study at IUAC

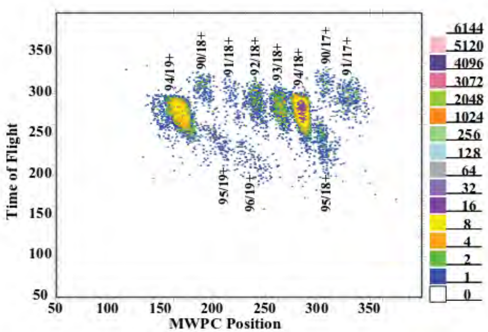
Fission fragment mass distribution measurement using MWPC time of flight set-up inside scattering chamber



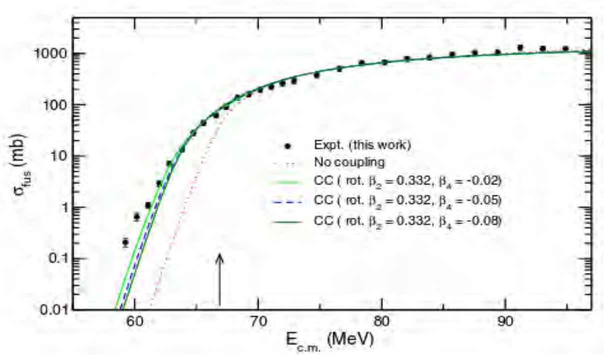
Neutron detector array for measuring neutron multiplicity in coincidence with fission fragments

Heavy Ion Reaction Analyzer (HIRA) at IUAC, New Delhi

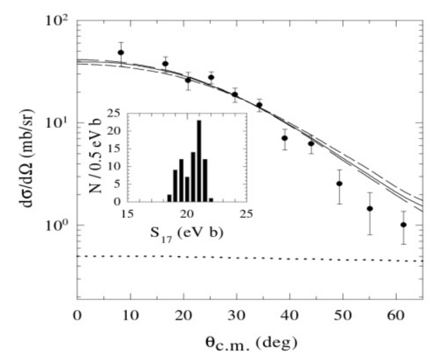
Fusion reactions around Coulomb barrier
Multi-nucleon transfer reactions around Coulomb barrier
ER-gated spin distributions and high spin spectroscopy
Microsecond isomer search
Production and use of secondary RIB, ^{7}Be, using direct reactions in inverse kinematics



Multi-nucleon transfer mass spectrum for ^{28}Si + ^{94}Zr entrance channel



Sub-barrier fusion cross-section explained using Coupled Channels approach for ^{16}O + ^{174}Yb system



$S_{17}(0)$ factor extracted using ^{7}Be secondary RIB in inverse kinematics

- ➢ 50 Bakelite RPCs and 200 Cu cooling sets supplied to CMS experiment at CERN for RE4 upgrade (improve trigger efficiency)
- ➢ RPCs played a crucial role in Higg's Discovery
- o Collaborators : NPD-BARC, MD&PDD-BARC & Panjab University, Chandigarh

Benefits :

- ❑ RPC experience directly benefits the INO programme
- ❑ Large Area detectors for Cargo Scanning via Muon Tomography

- ➢ Single Mask GEM foil development in India (RD51 Collaboration)
- o Collaborators : NPD-BARC, CERN, M/s Micropack Bangalore

Benefits

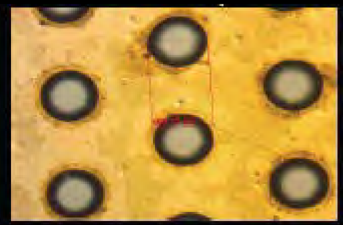
- ❑ Free transfer of patented technology from CERN
- ❑ GEMs have excellent position & timing resolution
  Ideal for Medical Imaging with high granularity

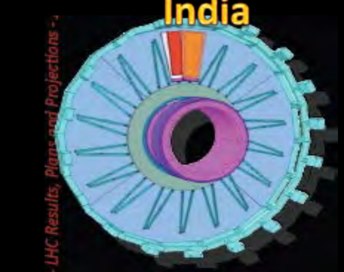
- ➢ Heavy Ion Studies with CMS data from LHC and PHENIX data from RHIC
- o 10 Leading Int. Publications in last 2 years from NPD-BARC

Benefits

- ❑ Development of Analysis Software & Computational Techniques

Single Mask GEM Foil Development in India





Typical Research Activities

- Fusion dynamics
  - Fusion around Coulomb barrier with stable. weakly bound and exotic projectile **Phys. Lett. B, 755, 332 (2016).**
- Fission dynamics (neutron and charged particles emission, fragment angular, mass and total kinetic energy distributions)
  - Dynamical hindrance, Nuclear level density ***Phys. Rev. Lett. 110, 062501 (2013)***
  - Studies in super heavy mass region , **Phys. Rev. C 94 (2016) 044618**
- Fission fragment spectroscopy using reactors and accelerators, INGA experiments, **Phys. Rev. C 96, 014315 (2017)**
- Elastic, inelastic scattering, breakup, multi-nucleon transfer, threshold anomaly studies, cluster states - electromagnetic transitions, **Phys. Rev. C 94 061602(R) (2016)**
- Nuclear Data with direct and surrogate method, **Phys. Rev. C 93, 021602(R) (2016)** Nuclear Data Physics Centre of India **(About 350 entries to EXFOR database), N_TOF studies at CERN**
- Development of Monte Carlo nucleon transport codes, **GEANTV, MONC**
- Theoretical studies of geometrical phases of anti-neutrino propagation ***Phys. Lett. B754, 135 (2016)***
- Nuclear Collisions at high energy, **Phys. Lett. B770, 357 (2017).**

Typical studies from INGA

- Shape evolution in 66Ga – *PRC 96, 054330 (2017)*
- High spin γ-ray spectroscopy in 41Ca – *PRC 94, 054312 (2016)*
- *Candidates for twin chiral bands in 102Rh -PRL 112, 052501 (2014)*
- Negative-parity high-spin states and a possible magnetic rotation band in 135Pr – *PRC 92, 054325 (2015)*
- High spin spectroscopy and shape evolution in 105Cd – *PRC 91, 024319 (2015)*
- Evidence for octupole correlation and chiral symmetry breaking in 124Cs – *PRC 92, 064307 (2015)*
- Band structures in 99Rh – *JPG 41, 105110 (2014)*
- A new high spin isomer in 195Bi – *EPJA 51, 153 (2015)*

Studies in Nuclear Astrophysics at SINP: experimental and theoretical efforts

Experimental

•. Indirect methods in Nuclear Astrophysics-

- *•Cluster transfer, breakup and ANC technique.*
- *•Coulomb breakup*

Theoretical

•Nuclear reaction modelling- Continuum Discretized Coupled Channel (CDCC) and Asymptotic Normalisation Constant method

- *R-matrix theory analysis of capture reaction*
- *Shell model studies of neutron – rich exotic nuclei on the r-process path: new shell closure predicted*

- **Facility for experimental Nuclear Astrophysics (FRENA) : 3MV Tandetron**

  Civil work for installation of the machine in full swing

Developmental work for utilization of FRENA

•Detector testing: background suppression

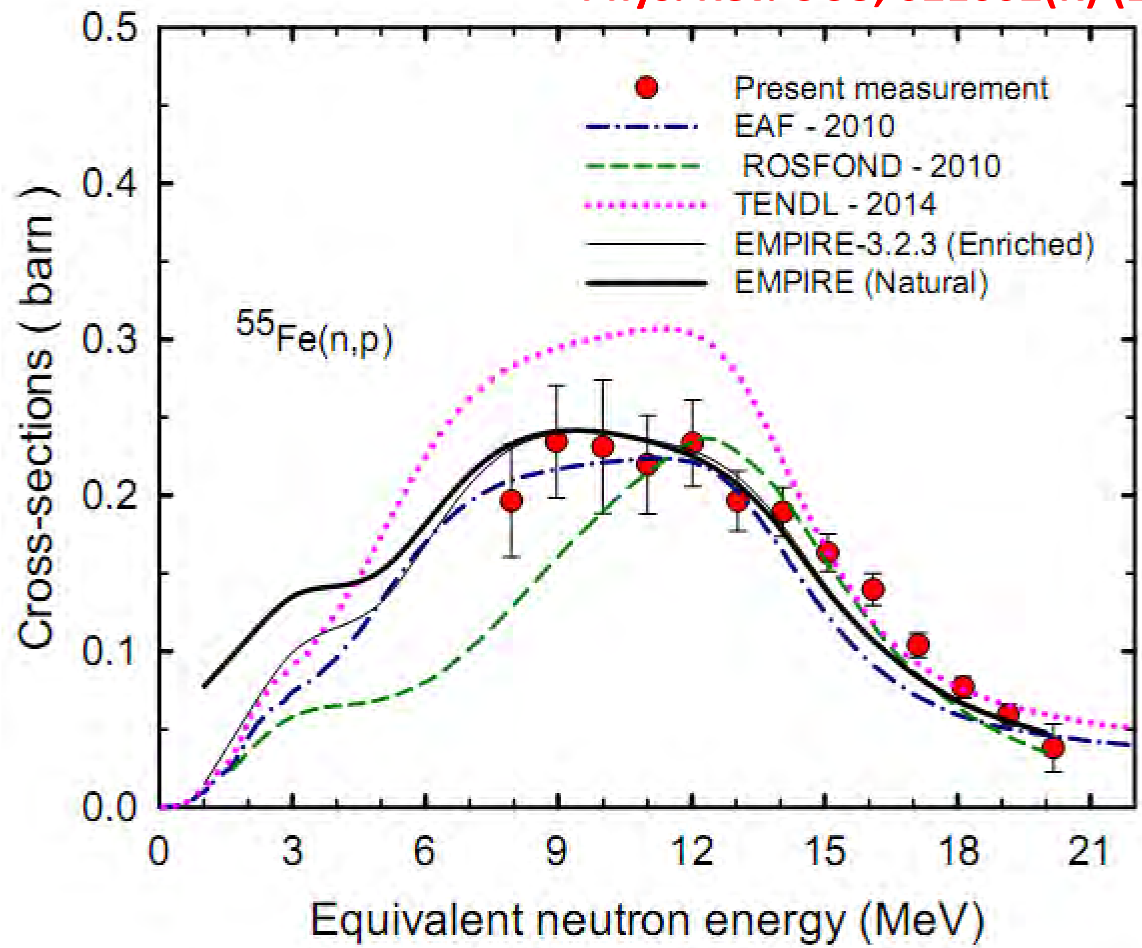
• Implanted Target preparation, development and characterization

•Gas detector development

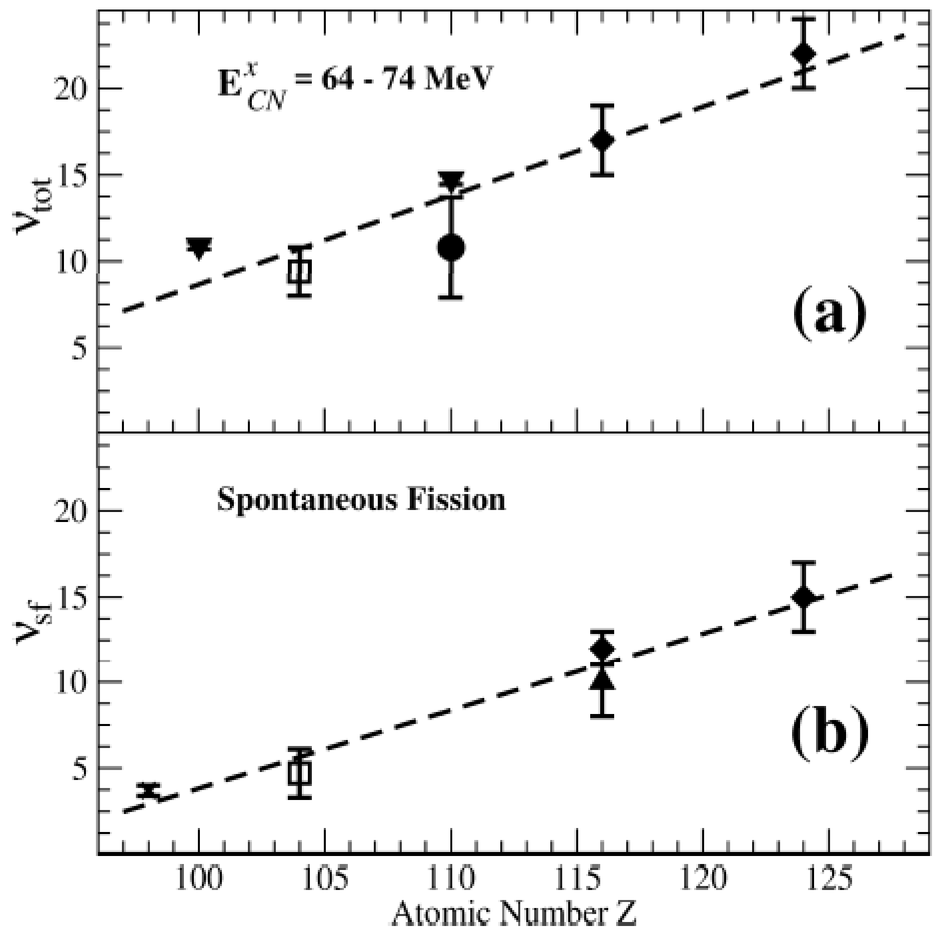
•Offline gamma array installation – digital data acquisition testing

$^{55}Fe(n,p)$ excitation function

Phys. Rev. C 93, 021602(R) (2016))



The $^{55}Fe(n,p)$ cross-section as a function of equivalent neutron energy along with various evaluation results and EMPIRE-3.2.3 calculations.



Phys. Rev. C 94 044618(2016)

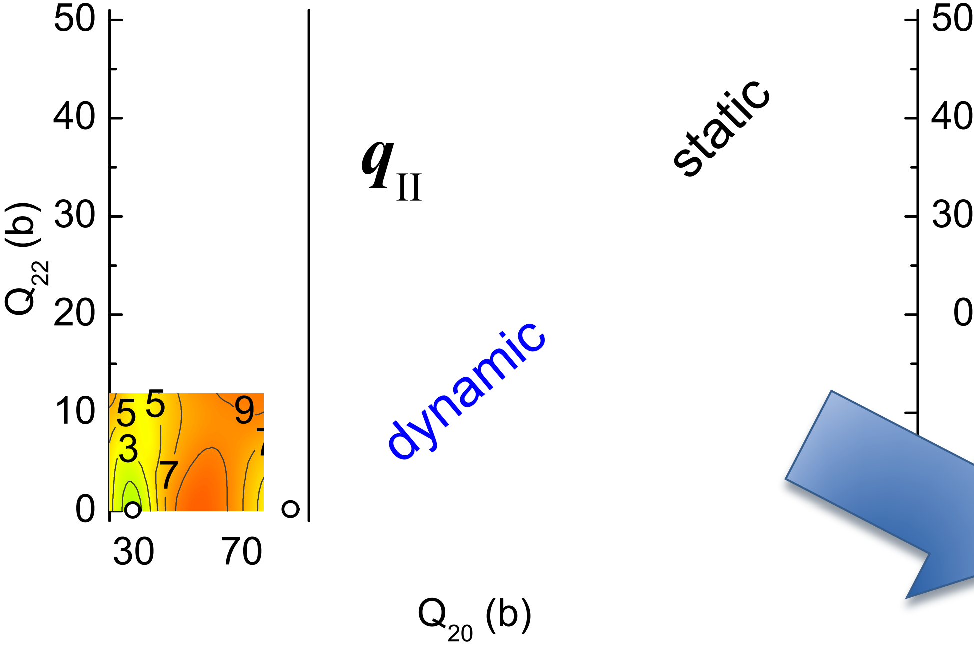
Future Plans/ Upcoming facilities

- ECR Injector for the SC Linac (Delhi)(in progress)
- ECR Injector based HI accelerator(Mumbai)(Design and Development)
- Low Energy High Intensity Proton Accelerator(LEHIPA) – 20 MeV Proton Accelerator-(Mumbai)(in progress)
- FRENA – 3 MV Accelerator for Astrophysics (installation in progress Kolkatta)
- SC K=500 cyclotron- (Beam trials) (Kolkatta)
- ANURIB–National RIB (Design and Development) (Kolkatta)
- India Based Neutrino Observatory (INO)
- Antineutrino detection setup at DHRUVA
- GEM subsystem upgrade of CMS detector at CERN

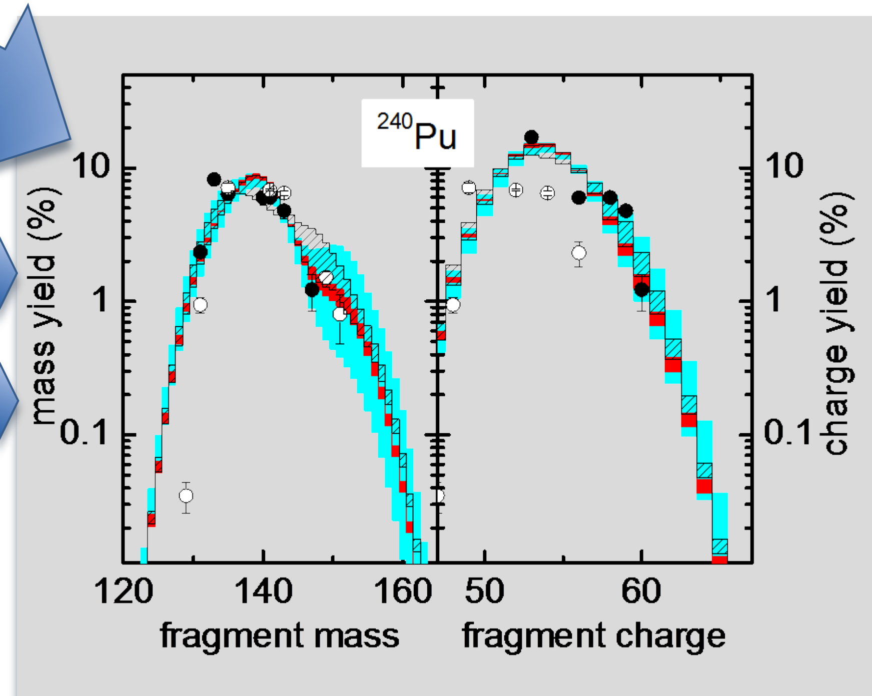
Recent works on Nuclear Theory
at
Variable Energy Cyclotron Centre,
Kolkata

Microscopic Calculations of Fission Fragment Yield Distribution in Spontaneous Fission

Multidimensional Potential energy surface calculated at T=0 using Density Functional Theory



Calculation took ~14M CPU hours in High Performance Computers



Mass (left) and charge (right) distributions of the heavier fission-fragment of ^{240}Pu

Shaded regions indicate model-dependent error

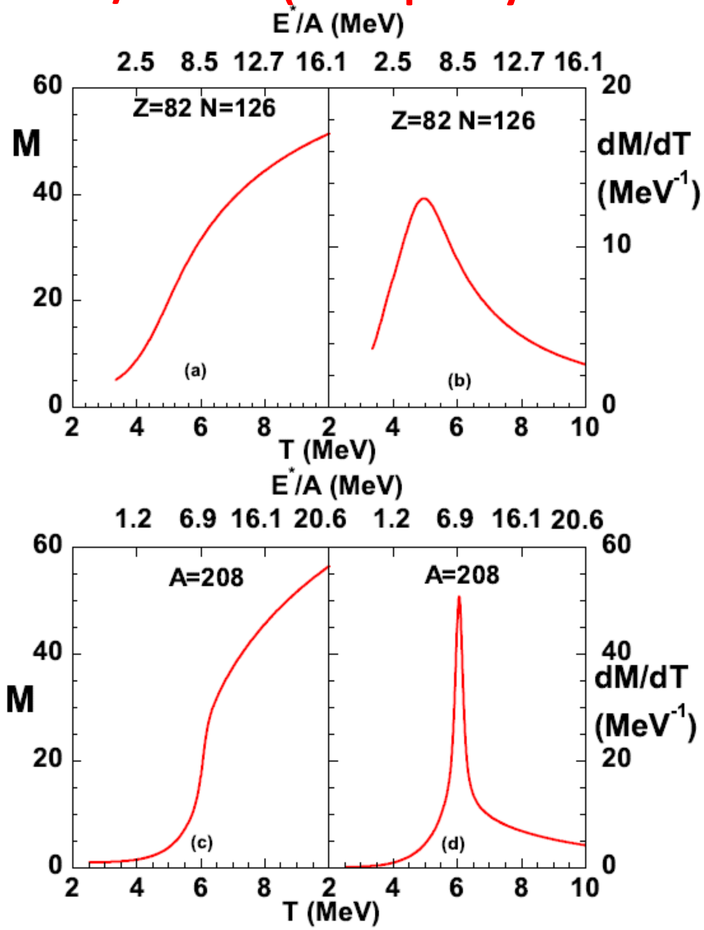
a predictive framework to describe spontaneous fission yields of a heavy nucleus

J Sadhukhan, W Nazarewicz & N Schunck, Phys. Rev. C 93, 011304(R) (2016).

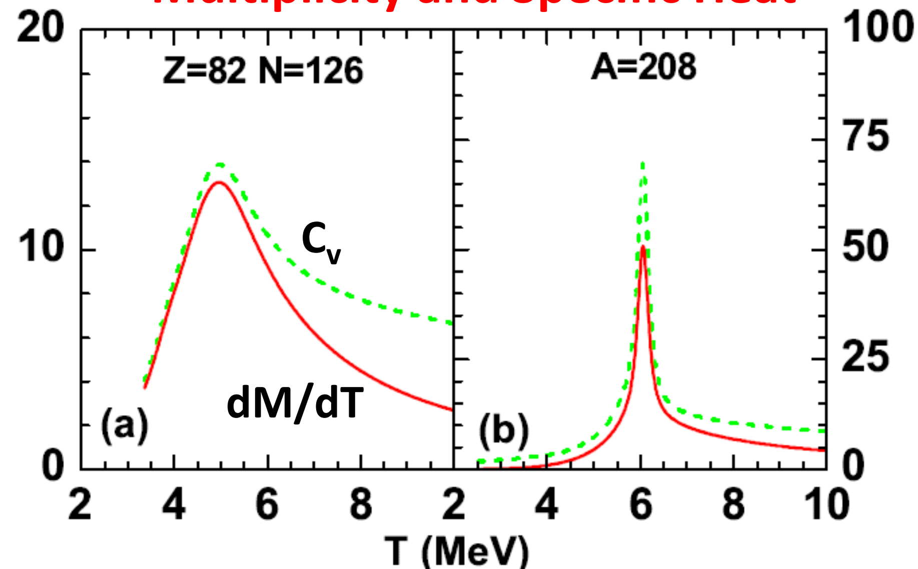
❑ *Nuclear Liquid gas phase transition: A new proposed signature:-*

Canonical Thermodynamical Model

dM/dT vs T (Multiplicity Derivative)



Multiplicity and Specific Heat



C_v & **dM/dT** peaks at same **T**

dM / dT much more accessible **experimentally**

To be continued in other models..........

M: **total multiplicity** from nuclear fragmentation at intermediate energies

T: **temperature**

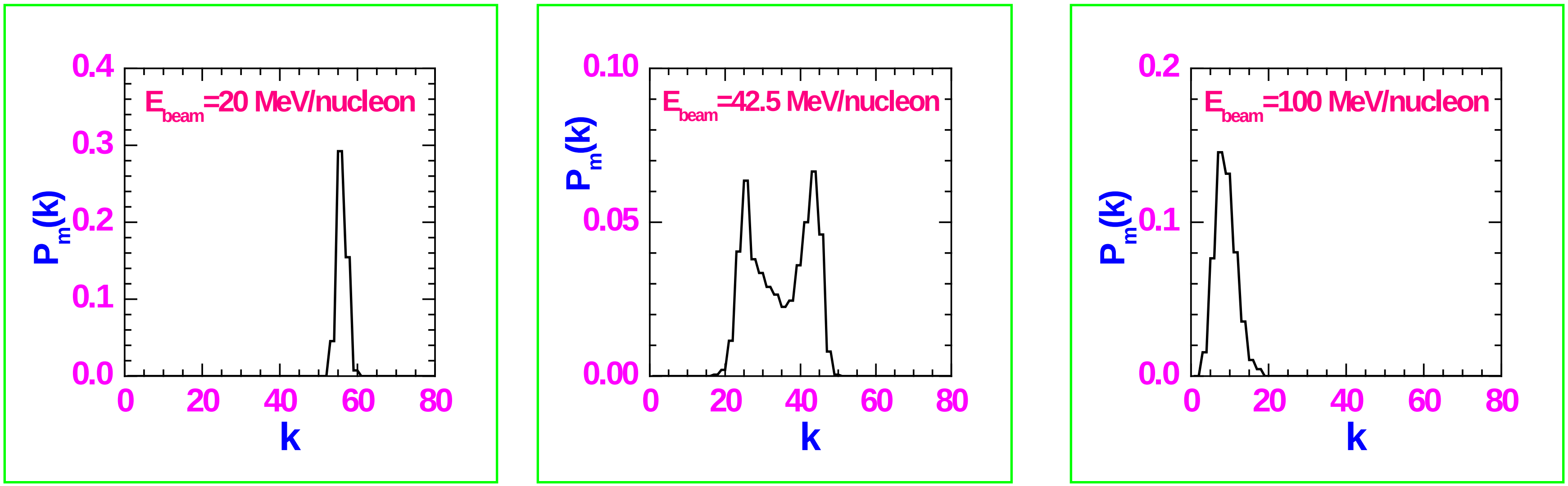
Ref: S. Mallik, G. Chaudhuri, P. Das and S. Das Gupta , Phys. Rev. C. 95, 061601 (2017)

(Rapid communication and Editor's suggestion)

❑ *Bimodality in largest cluster probability distribution from transport model calculation :-*

- Most important signature for nuclear liquid gas phase transition.
- Studied by Boltzmann-Uehling-Uhlenbeck (BUU) model.
- Bimodal behavior obtained for the **first time** from any transport calculation for central collision.

Studied Reaction A_P=40 on A_T=40 **No. of Events-500 , Time= 300 fm/c**



Nuclear Liquid *Nuclear (Liquid+Gas)* *Nuclear Gas*

(Bimodality)

Status: Work is completed.

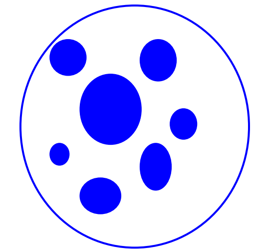
Ref: S. Mallik, S. Das Gupta and G. Chaudhuri , Phys. Rev. C. 93, 041603 (2016) (Rapid)

❑ *Formulation of a transformation relation between grand canonical and canonical ensembles in two component thermodynamical model :-*

Statistical models @ Clusterization from phase space calculation

⇓

Very accurate and successful for explaining multifragmentation reactions



Canonical model is physically more acceptable for intermediate energy heavy ion reaction.

Grand canonical model calculation is much simpler.

Requirement of ensemble transformation relation for finite nuclei and its successful application important observables

$$
\begin{aligned}
R_c(\langle N_0\rangle_{f_n,f_z},\langle Z_0\rangle_{f_n,f_z}) \approx\; & R_{gc}(f_n,f_z)-\frac{1}{2}\sigma_n^2\frac{\partial^2 R_{gc}}{\partial\langle N_0\rangle^2}\bigg|_{\langle N_0\rangle_{f_n,f_z},\langle Z_0\rangle_{f_n,f_z}} - \frac{1}{2}\sigma_z^2\frac{\partial^2 R_{gc}}{\partial\langle Z_0\rangle^2}\bigg|_{\langle N_0\rangle_{f_n,f_z},\langle Z_0\rangle_{f_n,f_z}} \\
& - \sigma_{nz}\frac{\partial^2 R_{gc}}{\partial\langle N_0\rangle\partial\langle Z_0\rangle}\bigg|_{\langle N_0\rangle_{f_n,f_z},\langle Z_0\rangle_{f_n,f_z}}
\end{aligned}
$$

Status: Work is completed.

Ref. P. Das, S. Mallik and G. Chaudhuri, Phys. Rev. C (Article in Press)

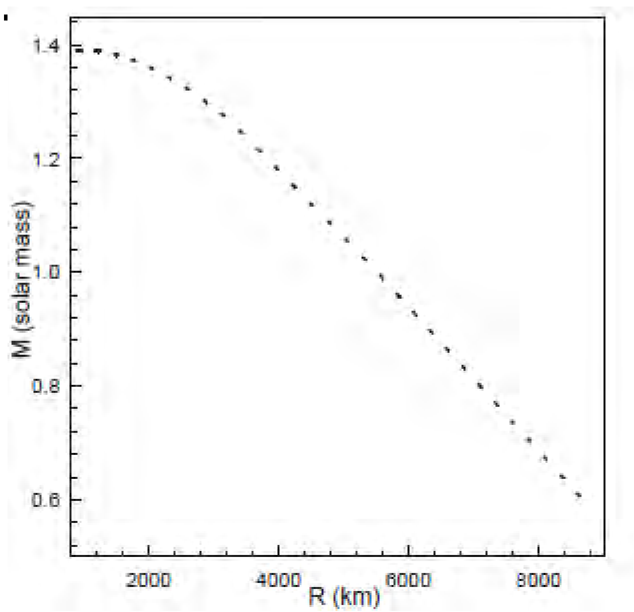
Landau quantization and mass-radius relation of magnetized White Dwarfs

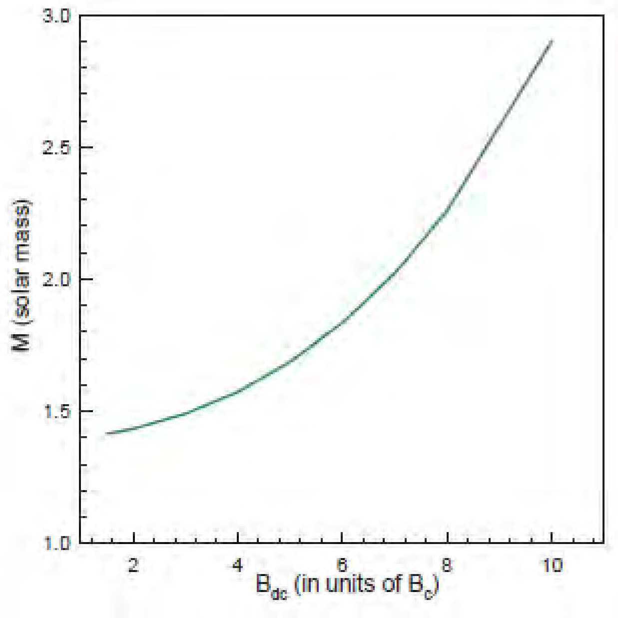
- For EoS of White Dwarfs, the pressure is provided by the relativistic degenerate electrons only while the for energy density both electrons (with its kinetic energy) and atomic nuclei contribute.

- For magnetized White Dwarfs, electrons, being charged particles, occupy Landau quantizedstates. This changes the EoS, which, in turn, changes the pressure and energy density.

- The mass-radius relations for non-magnetized & magnetized White Dwarfs are obtained by solving the Tolman-Oppenheimer-Volkoff equations. Surface magnetic field is kept at 10^9 Gauss estimated by observations while central magnetic field goes up to maximum $10B_c = 4.414\times10^{14}$ Gauss (theoretical limit).

- The masses of non-magnetic White Dwarfs remain within Chandrasekhar's limit of 1.4 $M_\odot$ but for magnetized White Dwarfs it increases with central magnetic field and goes far beyond Chandrasekhar's limit .





Ref: Somnath Mukhopadhyay, Debasis Atta, D.N. Basu, Romanian Reports in Physics 69, 101 (2017)

Mass, Radius, Core-crust transition & crustal fraction of moment of inertia of neutron stars

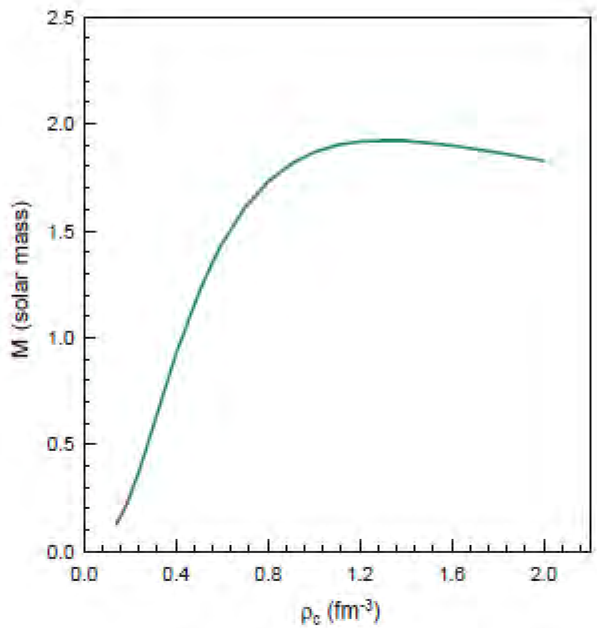
• The high-density behavior of neutron star matter obtained from DDM3Y interaction satisfies constraints from the observed flow data of heavy-ion collisions.

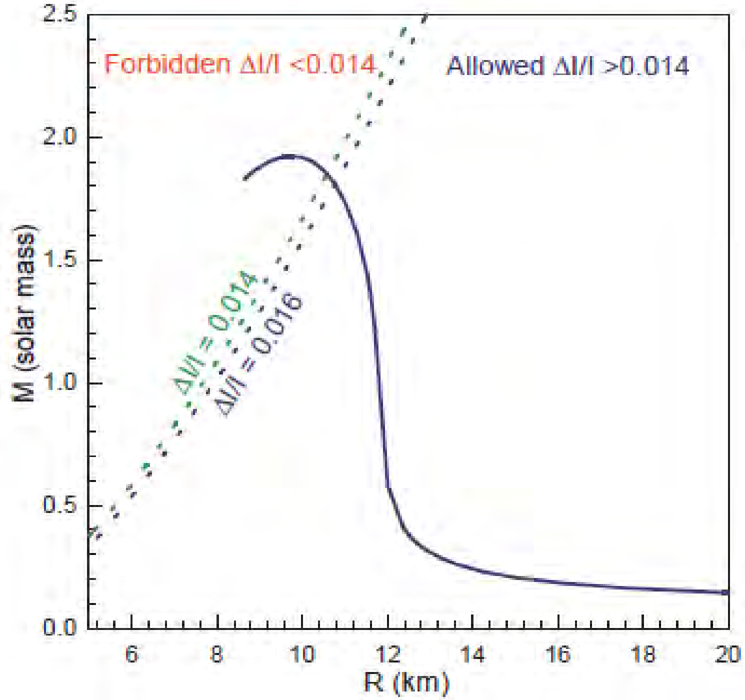
• The neutron star properties agree with the recent observations of the massive compact stars.

• The density, pressure and proton fraction at the inner edge separating the liquid core from the solid crust of neutron stars are determined thermodynamic stability conditions:

$$\rho_t = 0.0938\ \text{fm}^{-3},\quad P_t = 0.5006\ \text{MeV fm}^{-3}\quad \text{and } x_{p(t)} = 0.0308, \text{ respectively}$$

These results for pressure and density at core-crust transition together with the observed minimum crustal fraction (1.4% -1.6%) of the total moment of inertia provide a new limit for the radius of the Vela pulsar: R > 4.10 + 3.36M/M⊙ kms. Present calculations suggest that this fraction can be at most 3.6% due to crustal entrainment because of Bragg reflection of unbound neutrons by lattice ions

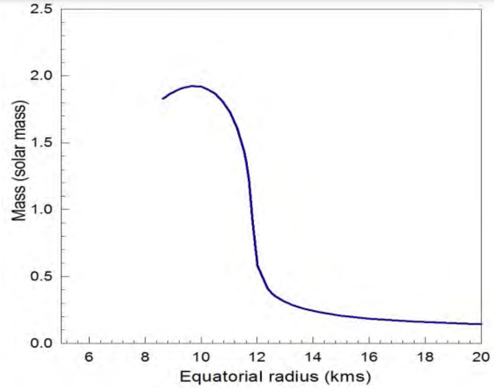




(1) D. Atta, D.N. Basu, Phys.Rev.C90,035802 (2014)

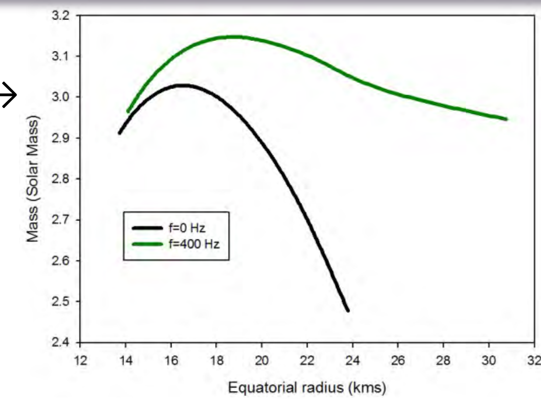
(2) D. Atta, S. Mukhopadhyay, D.N. Basu, Ind.J.Phys 91, 235 (2017)

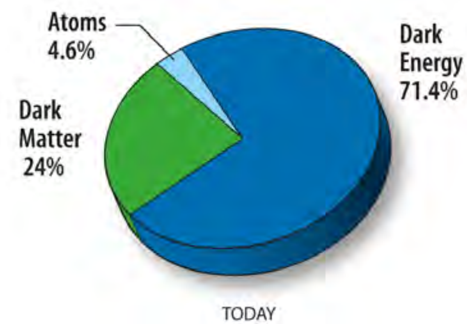
Compact bi-fluid stars : Hadronic Matter mixed with self-interacting Asymmetric Dark Matter

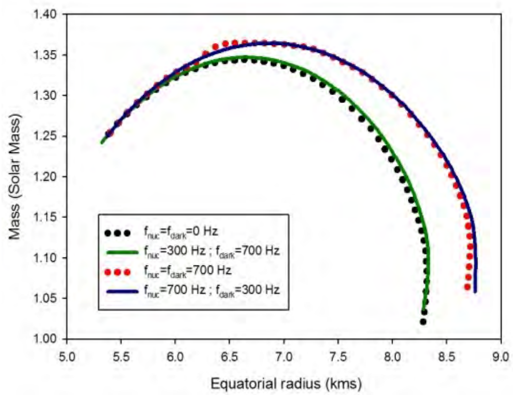


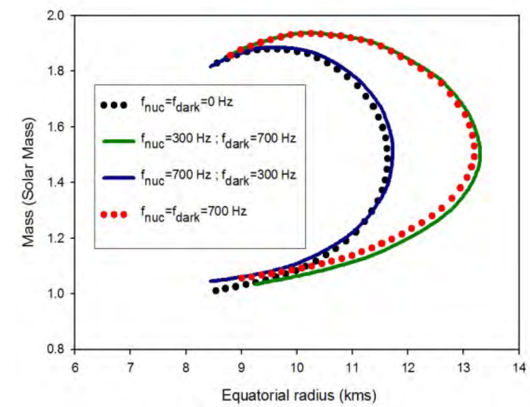
←Neutron Star

Dark Star→









Constant dark matter central density = 0.14 fm^{-3}
$M_{max(rot)}$=1.3640 M_{sun} ; R_{rot}=6.7523 kms
when f_{nuc}=700 Hz and f_{dark}=300 Hz

Constant nuclear matter central density = 0.38 fm^{-3}
$M_{max(rot)}$=1.9355 M_{sun} ; R_{rot}=10.3717 kms
when f_{nuc}=300 Hz and f_{dark}=700 Hz

The masses and radii of non-rotating and rotating configurations of pure hadronic stars mixed with self interacting fermionic Asymmetric Dark Matter are calculated within the two-fluid formalism of stellar structure equations in general relativity. The Equation of State (EoS) of nuclear matter is obtained from the density dependent M3Y effective nucleon-nucleon interaction. We consider dark matter particle mass of 1 GeV. The EoS of self-interacting dark matter is taken from two-body repulsive interactions of the scale of strong interactions. We explore the conditions of equal and different rotational frequencies of nuclear matter and dark matter and find that the maximum mass of differentially rotating stars with self-interacting dark matter to be 1.94M⊙ with radius 10.4 kms.

Ref: S. Mukhopadhyay, D. Atta, K. Imam, D.N. Basu, C. Samanta **arXiv: 1612.07093 Communicated**

Status of Nuclear Physics Research in Korea

Byungsik Hong

(Korea University)

Division of Nuclear Physics in the Korean Physical Society

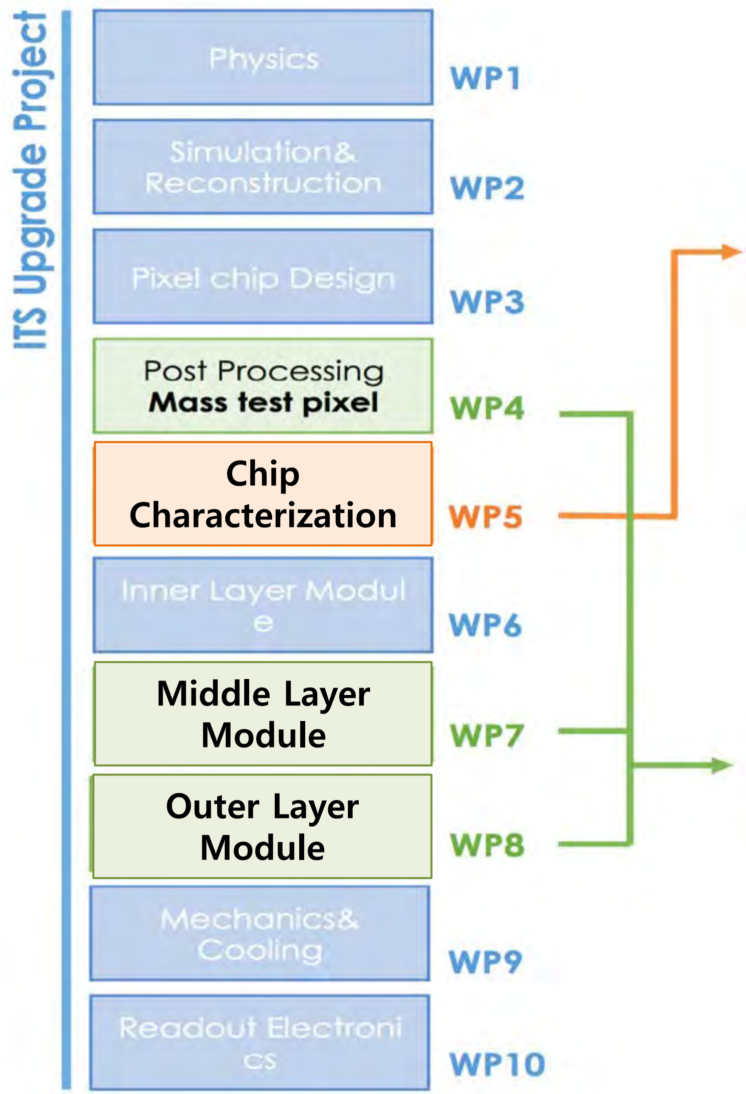
- HIM : Relativistic Heavy-Ion Collisions
  ▷ ALICE, CMS, PHENIX, STAR
- LENS : Low-Energy Nuclear Science
  ▷ RAON, RIBF, NSCL
- HaPhy : Hadron Physics
  ▷ J-PARC, CEBAF

- **Chair**: B. Hong
  - **Secretary**: H. J. Lee
  - **ANPhA Committee**: M. K. Cheoun , K. I. Hahn, B. Hong,
  - **Executive Committee**
    - **HIM**: K. S. Jeong, K. J. Kwak, M. J. Kweon
    - **HaPhy**: S. H. Choi, S. I. Nam, Y. Oh
    - **LENS**: K. Chae, Y. Kim
    - **Applications**: K. Cho, K. B. Lee
    - **International Relations**: Y. K. Kwon, H. J. Lee

Korea in ALICE

- Analysis topics
  - Multiplicity ($dN/d\eta$) distribution in pp
  - Path-length dependence of R_{AA}
  - Flow using two-particle correlations
  - Anisotropy of Λs
  - Heavy-flavor production and R_{AA} of $c, b \rightarrow e + X$ and $b \rightarrow e + X$
  - Hyperon (Σ, Ξ) production from pp to PbPb
  - Pomeron reactions in $pp \rightarrow 4\pi$
  - Lattice calculation for Υs at finite T
- Hardware contributions
  - Inner Tracking System (ITS) upgrade
- Some highlights on hardware in the next slides

Inner Tracking System Upgrade

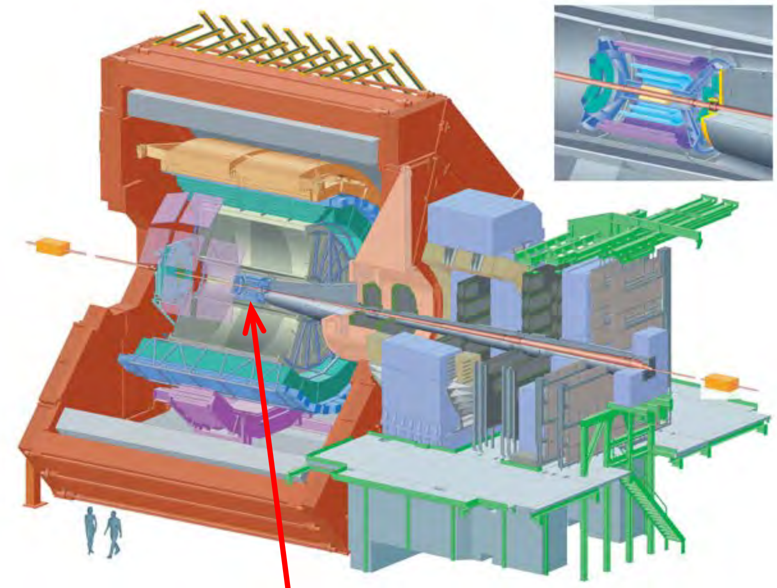


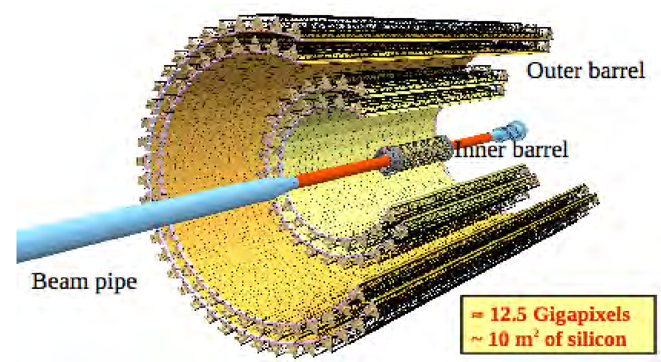
- **Characterization of pixel chip (Inha and PNU)**
  - Lab. & beam tests at PAL and KOMAC

- **Mass chip test (Inha, PNU and Yonsei)**
  - Test 60k pixel chips ('17.01 ~ '18.01)
- **Module assembly (Inha & PNU)**
  - Assemble ~400 modules ('17.05 ~ '18.04)

Inner Tracking System Upgrade

- Goals of new ITS design
  - Improve the vertex resolution (x3)
  - High efficiency and p_T resolution (x10)
  - Fast readout: 50 kHz (PbPb), 400 kHz (pp)
  - Fast insertion/removal





- Features of new ITS

	Current ITS	New ITS
# of layers	6	7
Inner radius	3.9 cm	2.3 cm
Pipe radius	2.9 cm	1.9 cm
Innermost layer thickness	1.14% X_0	0.3% X_0
Innermost layer pixel size	50x425 μm^2	28x28 μm^2
Max. PbPb readout	1 kHz	100 kHz

MAPS: Monolithic Active Pixel Sensor Technology

Korea in CMS

- Analysis topics
  - Quarkonium production in pPb and PbPb
  - Azimuthal anisotropy of quarkonium in PbPb
  - Upsilon production in PbPb
  - B production in pPb
  - Isolated photons in PbPb
  - Jet-photon correlation in PbPb
  - Pomerons in ultraperipheral collisions
- Hardware contribution
  - Forward RPC upgrade
  - High-rate muon trigger with GEM
- Some highlights on hardware in the next slides

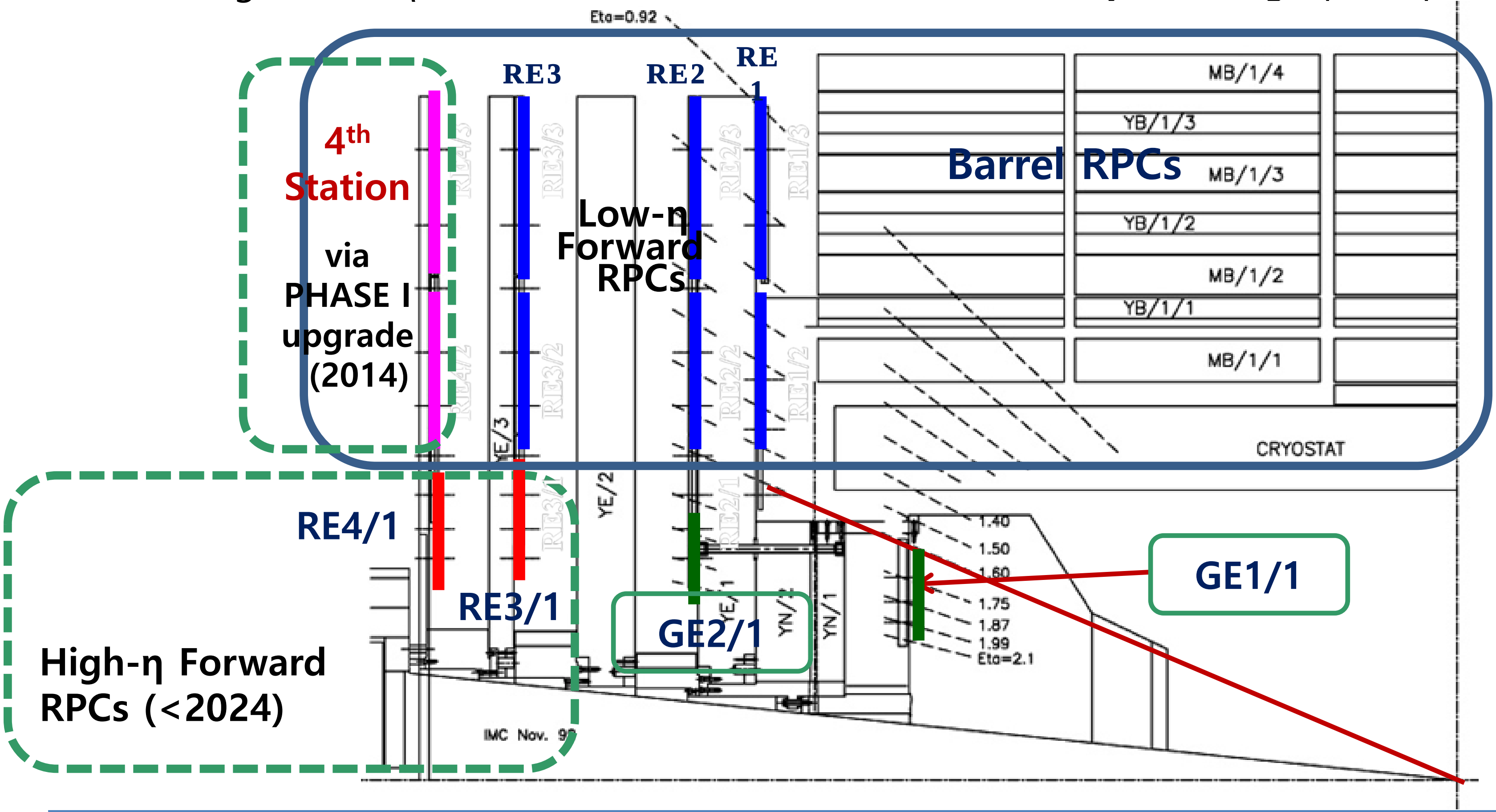
Current RPC System in CMS

Endcap RPCs

- 2 wings (RE+, RE-)
- 4 stations (RE1, RE2, RE3, RE4) in each wing
- Covering $0.92 < \eta < 2.1$

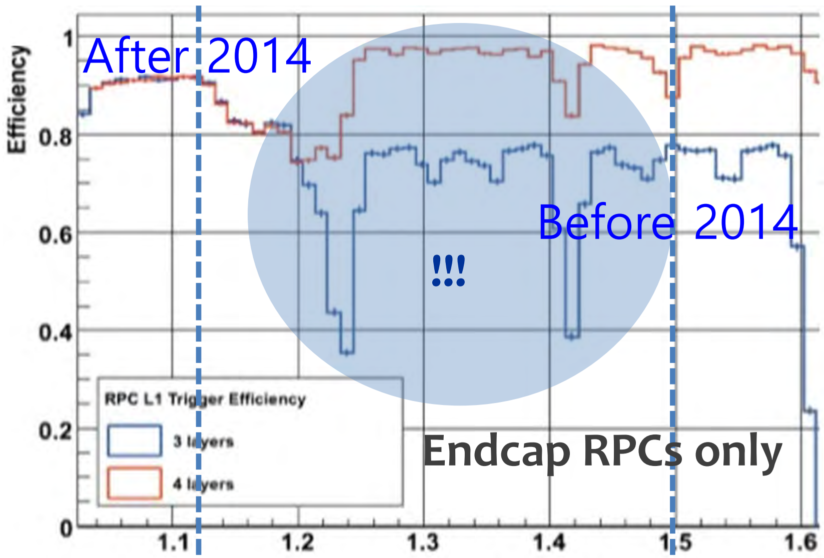
Barrel RPCs

- 6 stations (layers)
- Fully covering up to $\eta = 0.8$
- Partially covering up to $\eta \sim 1.2$



Phase II: Upgrade of CMS RPC

- Current ENDCAP composed of 4 RPC stations covering 1.1 $<\eta<$ 1.6
  - Trigger efficiency of the muon system is still low due to absence of the RPC in 1.6 $< \eta <$ 2.4 range.



RPC Trigger Efficiencies

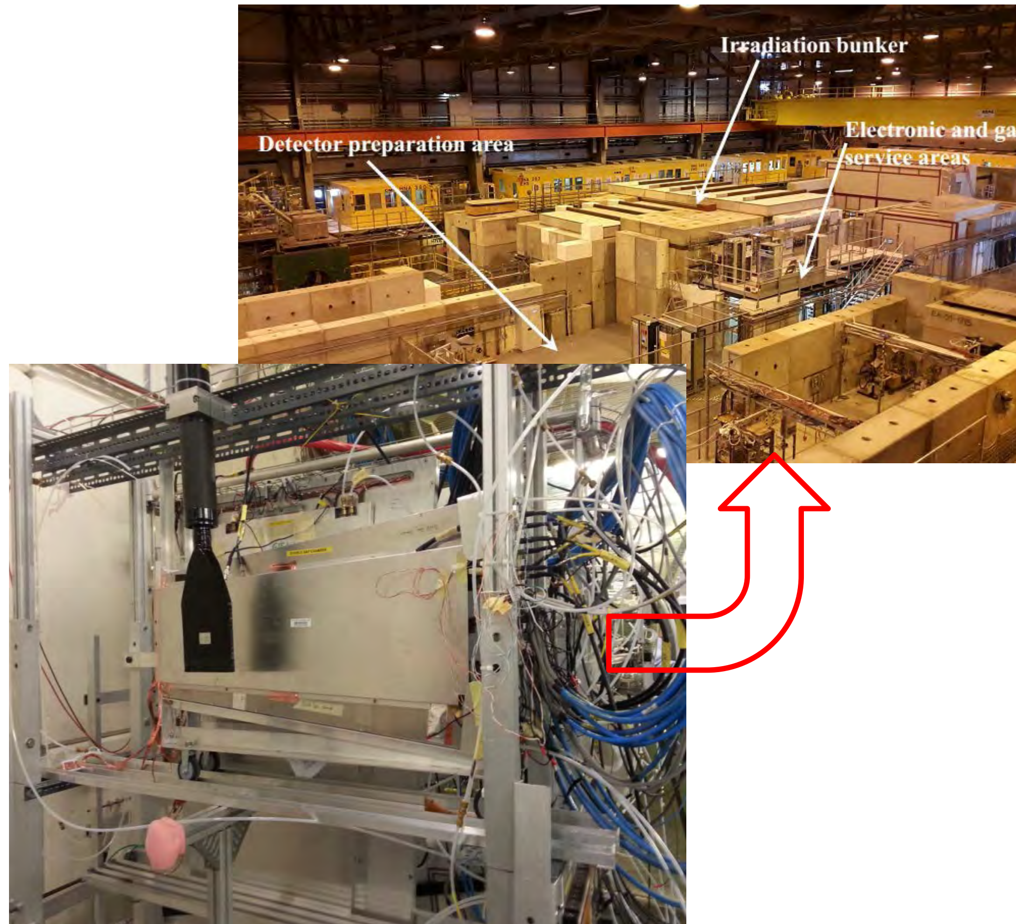
RED: requiring 3/4 with a new 4th station
BLUE: requiring 3/3 with initial 3 stations

- Completion of 36 RE3/1 and 36 RE4/1 RPCs together with GE0, GE1/1, and GE2/1, before LS3 (2024).
  - 2015 – 2017: Confirmation of detector technology
  - 2017 – 2018: Pre-productions
  - 2019 – 2023: Detector productions, installation, and integrations

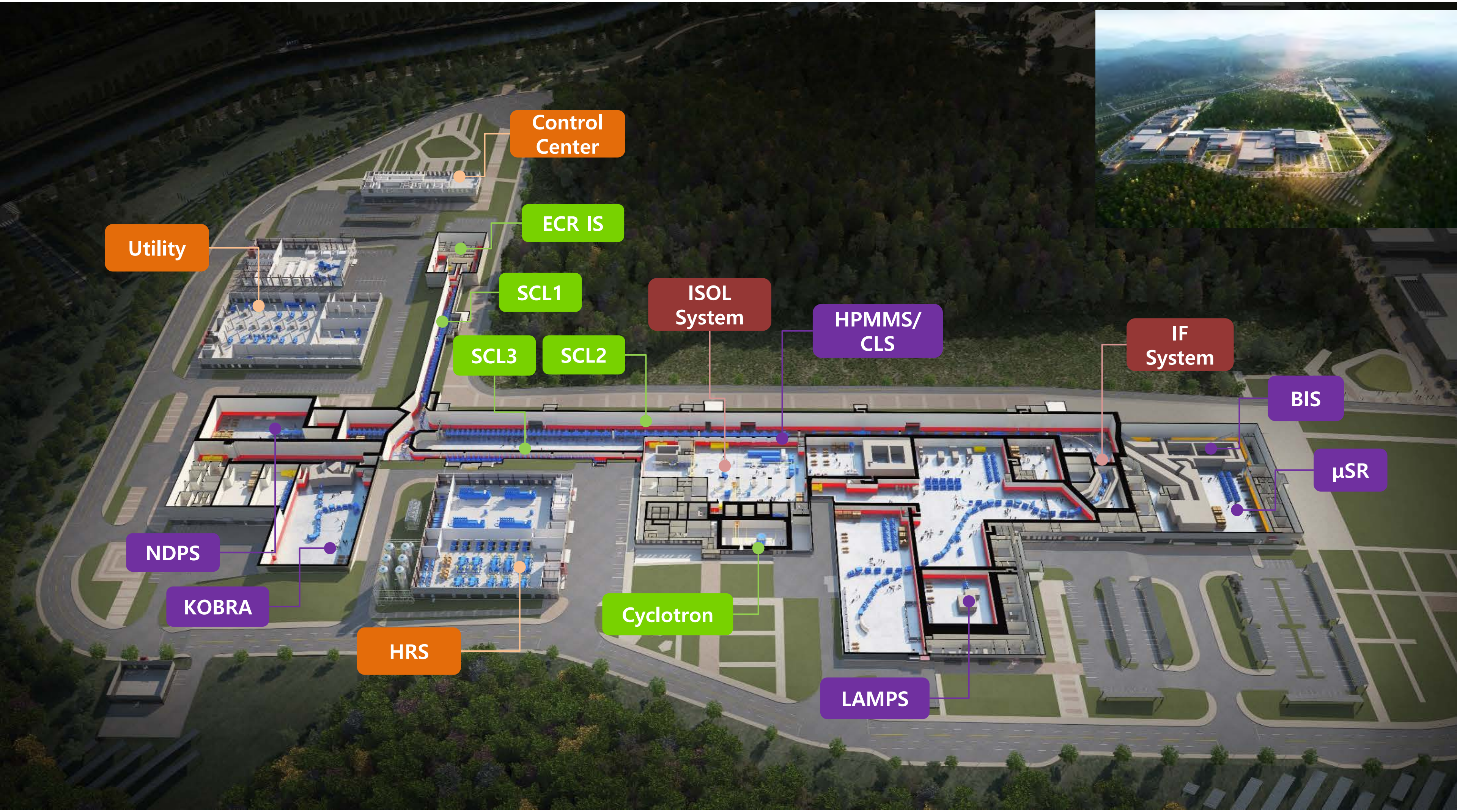
R&D for high-η CMS RPCs

200-mCi ^{137}Cs at Korea University
Current activity = 5.55 GBq
Maximum γ rate at 37 cm~1.4 kHz cm^{-2}

H4 beam line at GIF++
Activity = 1.4 TBq (^{137}Cs)
Maximum γ rate at the test position~1.5 kHz cm^{-2}



Layout of RAON



Construction Status of RAON

1. A construction company was selected in September, 2016.
2. The construction and civil engineering for RAON (Rare isotope Accelerator complex for ON-line experiments) has begun.
3. The ground breaking for accelerators and experimental buildings was done on Feb. 13th this year.

SRF Test Facility @ KAIST Munji Campus

- Test facilities for superconducting RF cavities and modules
- Facility List

① **Cavity test pit**
(SRF Cavities performance test)

② **Module test bunker***
(SRF Modules performance test)

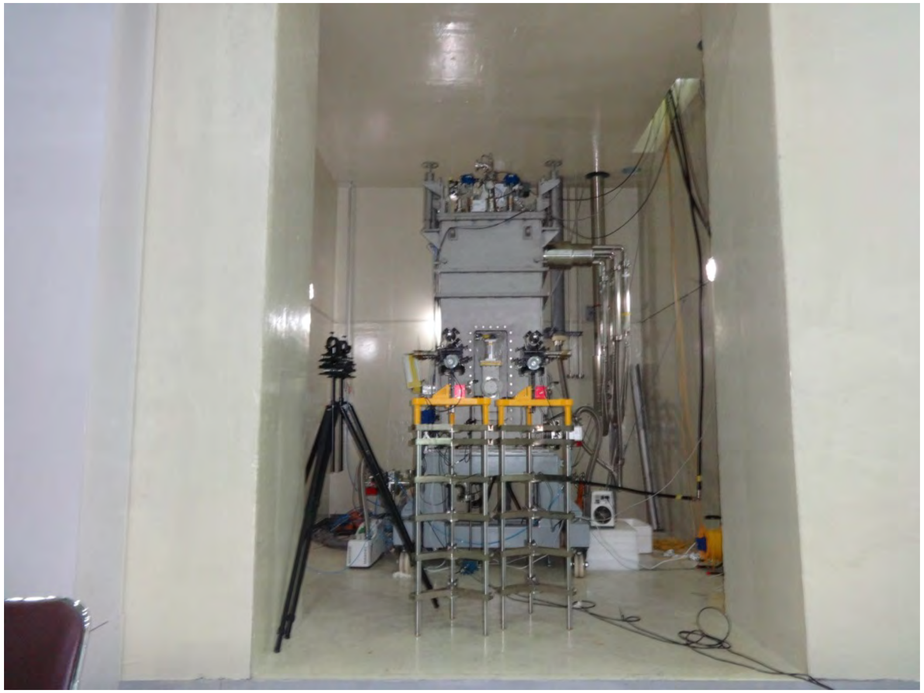
③ **Clean Room**
(Clean assembly & Inspection)

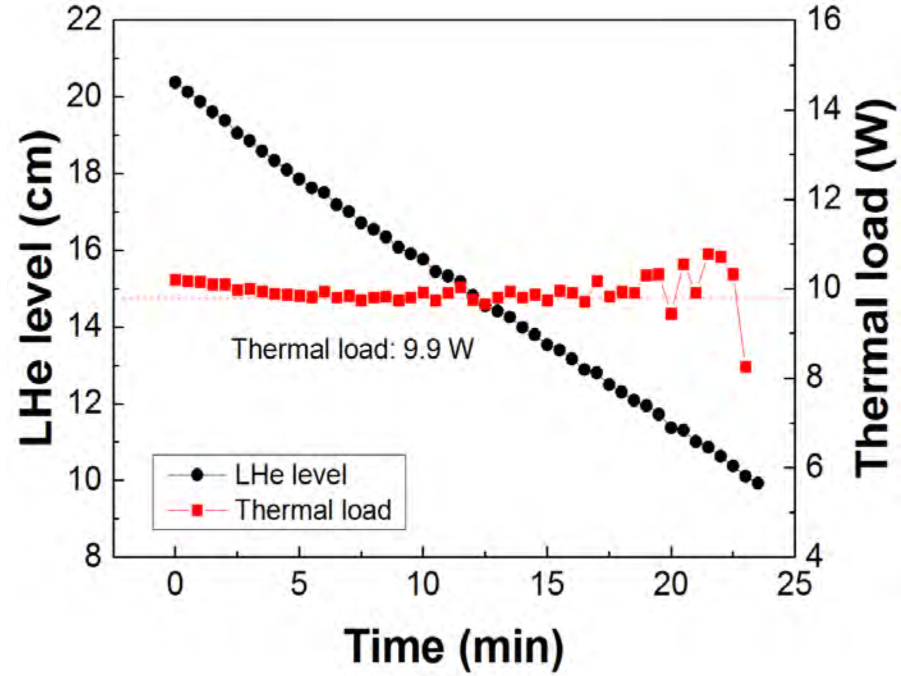
④ **Cryogenic Plant**
(Liquid He, Liquid N_2)

⑤ **SCL Demonstration**
(ECRIS+LEBT+RFQ+MEBT+1 QWR)

* 1st QWR Module
has been tested successfully in May.

QWR Cryomodule Test Result


QWR cryomodule test bunker



Thermal heat load (9.9 watt @ 6.1 MV/m)

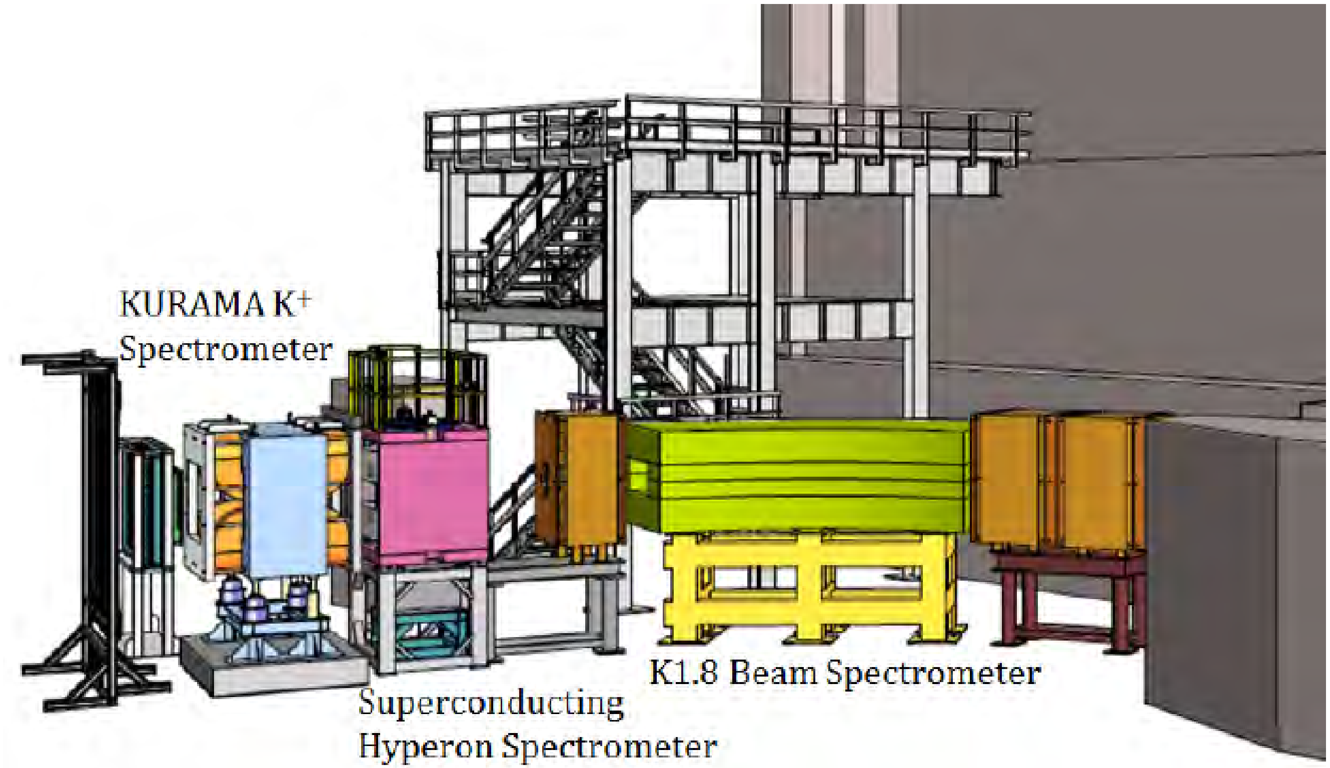
Performance test for QWR cryomodule			
	Reference	**Measurement**	
Thermal heat load	< 25 W @ 4.2 K, 6MV/m	9.9 W @ 4.2 K, 6 MV/m	Pass

Milestone of RAON in 2017

1. Cryomodule test for QWR and HWR
   → Mass production
2. Cavity test for SSR
   → Cryomodule test planned in early 2018
3. Beam extraction from SCL demo (1 QWR)

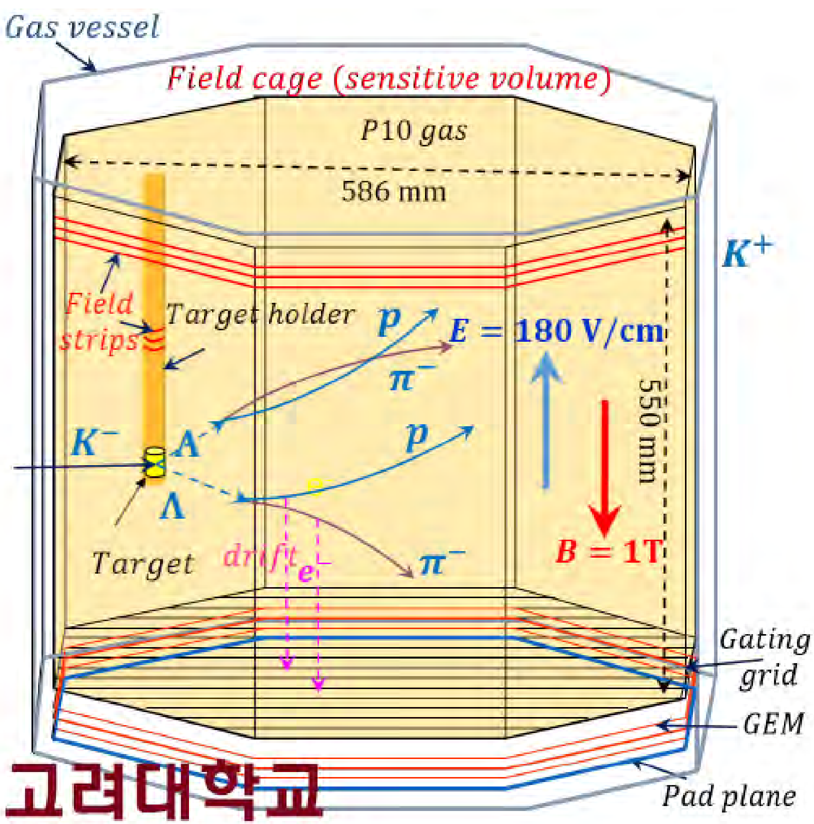
J-PARC E42 Experiment

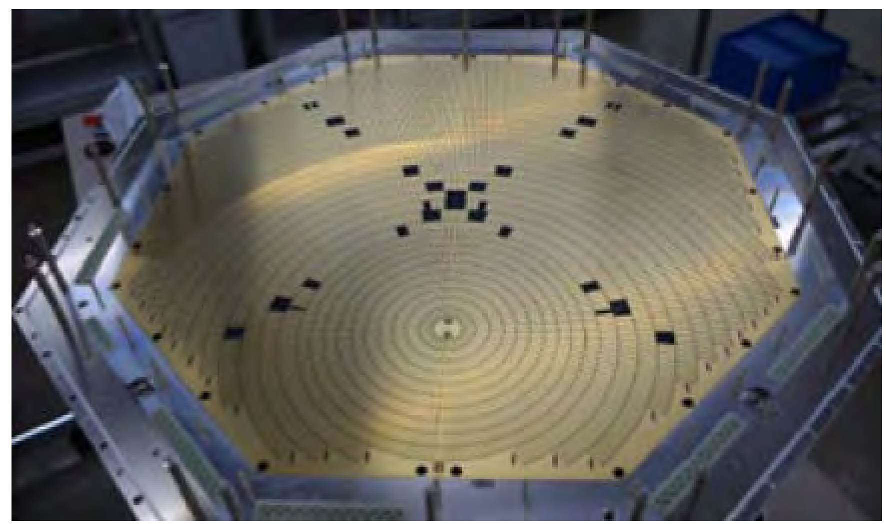
- Search for H-dibaryon on proton pair via (K^-, K^+) reaction
- K^- beams on the diamond target at 1.7 GeV
- Hyperon spectrometer at K1.8 beamline
  - HypTPC and superconducting Helmholtz Coil



HypTPC

- Some features
  - Gating grid
  - Concentric pad plane (5768 pads)
  - Position resolution: < 300 μm
  - Triple GEM layers
  - Gain ~10^4
  - $\Delta p/p = 1\sim3\%$ for π and p



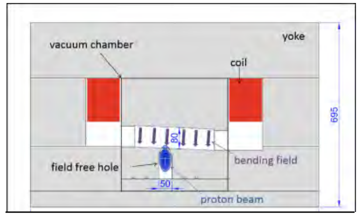


Summary

1. Nuclear Physics Community in Korea
   - Relatively small, but active
   - Still growing, especially, with the RAON project
2. Experimental efforts
   - Active contribution to the data analysis
   - Significant contribution to the detector constructions for the last 10-15 years
     - ▷ RPC and GEM for CMS @ LHC
     - ▷ ITS for ALICE @ LHC
     - ▷ Various detector components for KOBRA & LAMPS @ RAON
     - ▷ TPC and SC magnet for E42 @ J-PARC

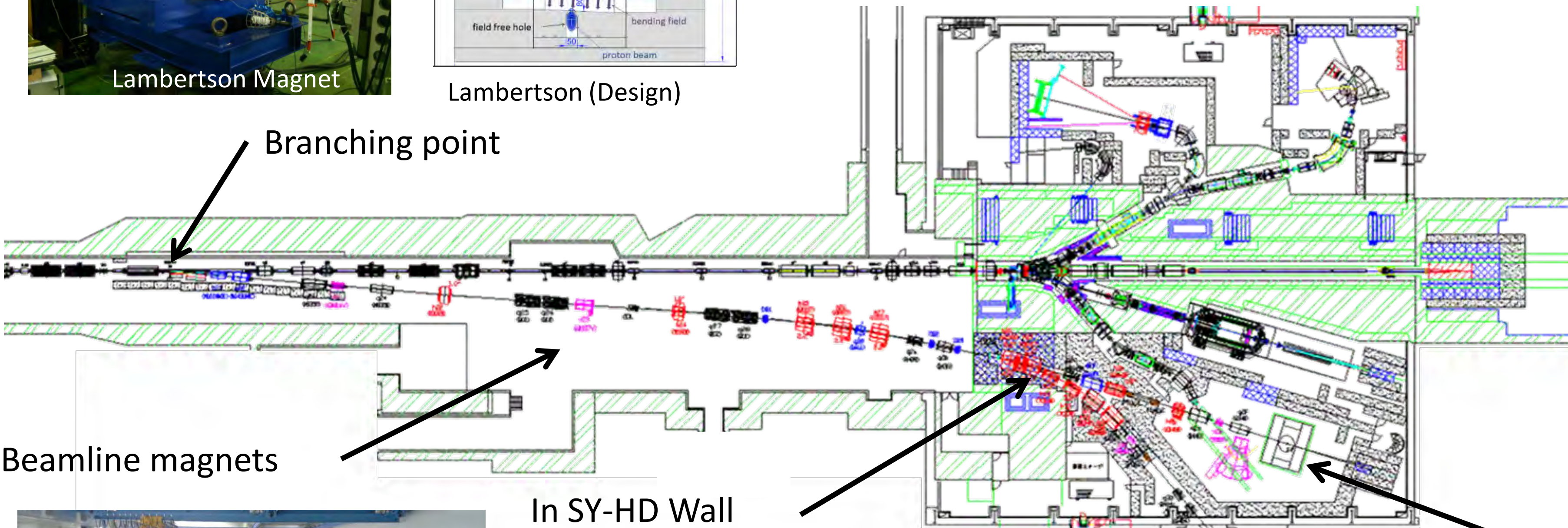
Construction Status of High-p Beam Line at J-PARC HADRON

Lambertson Magnet



Lambertson (Design)

Branching point



Beamline magnets

In SY-HD Wall

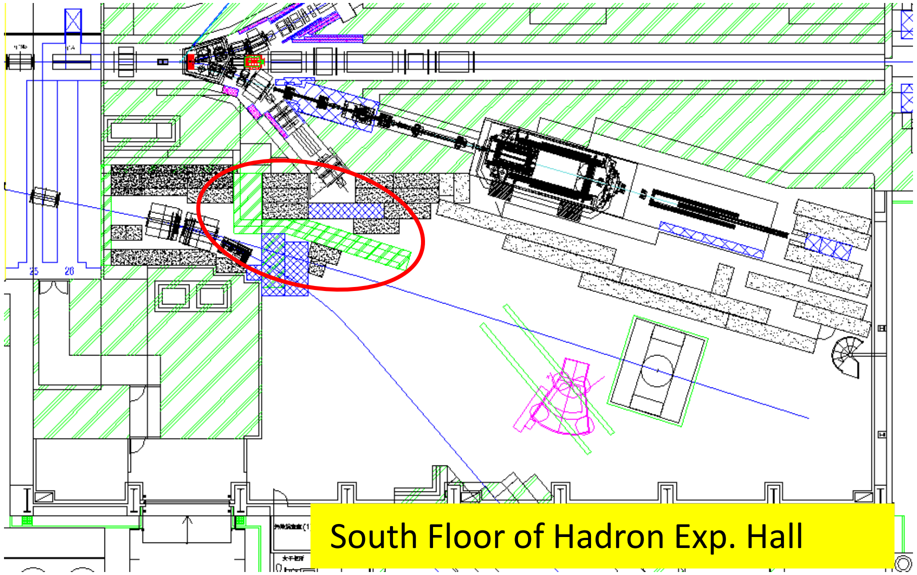
Spectrometer Magnet

New Line

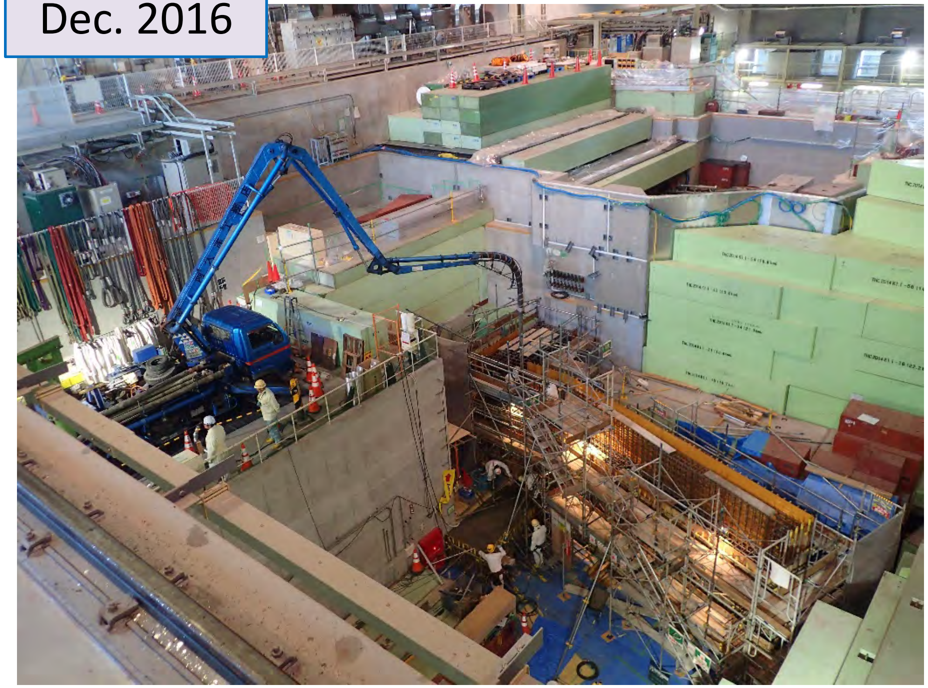
Existing A-Line

COMET & Control room

Construction of Radiation Shield in the Hall

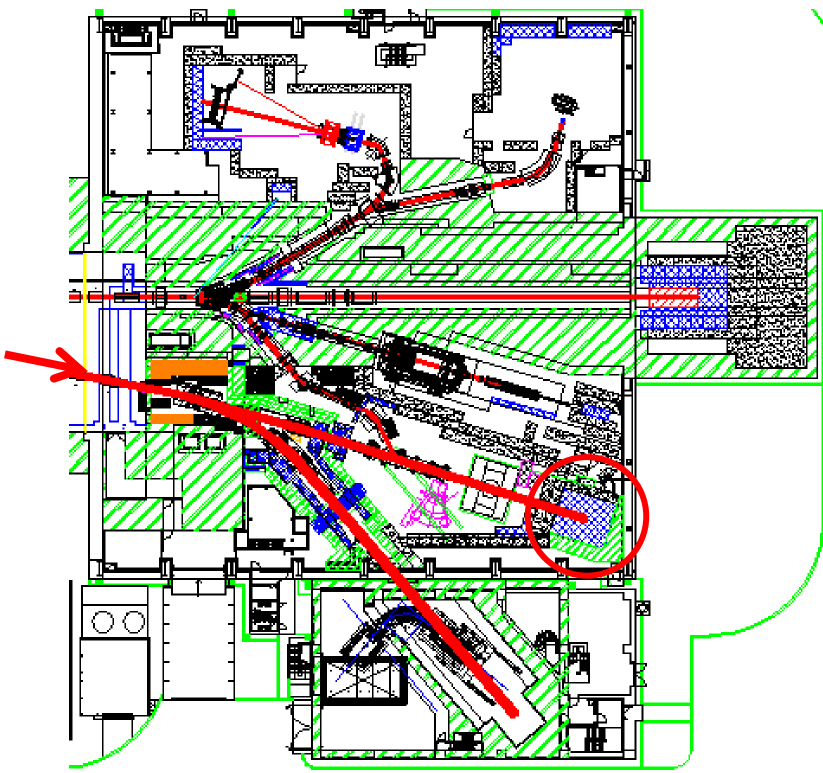


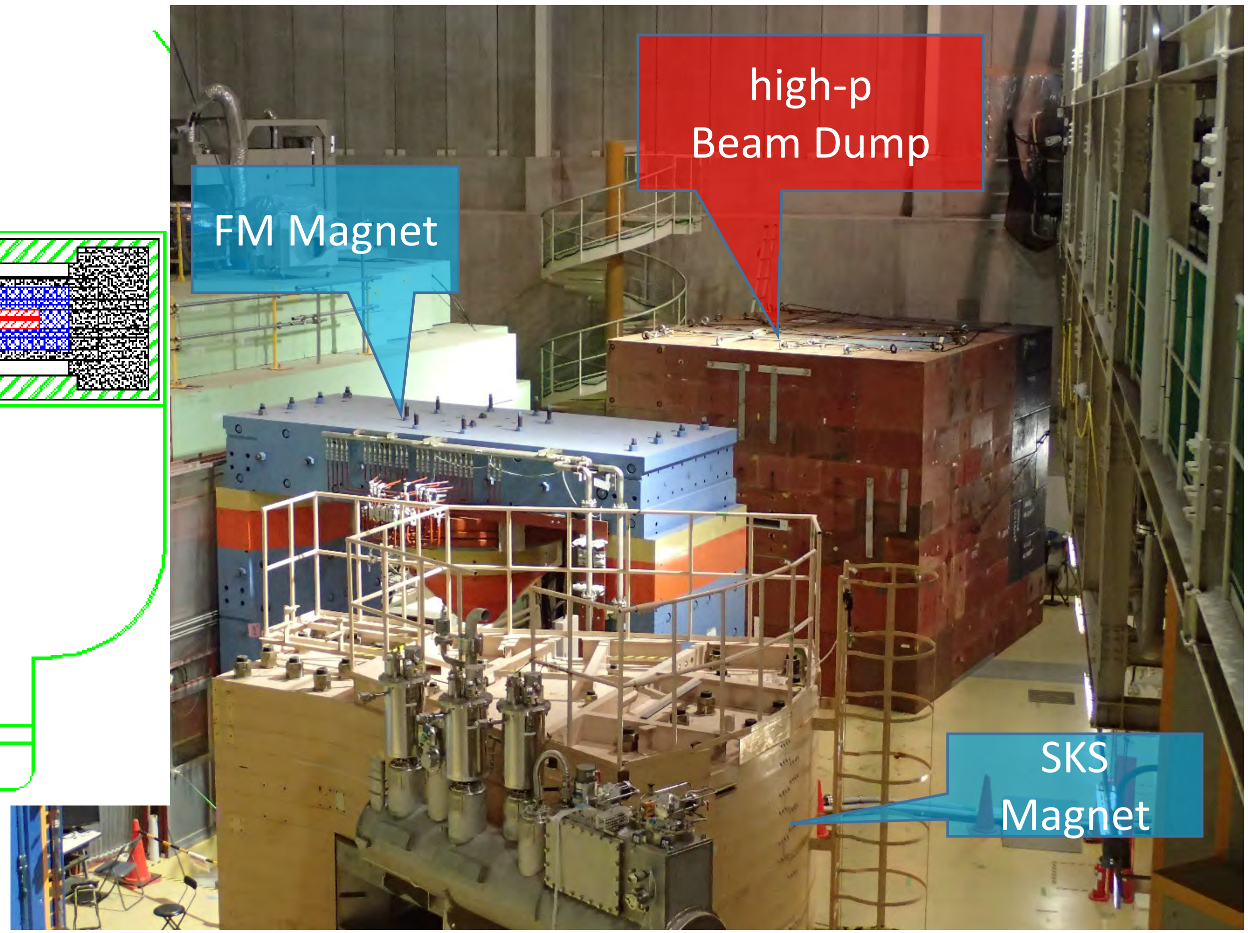
Dec. 2016



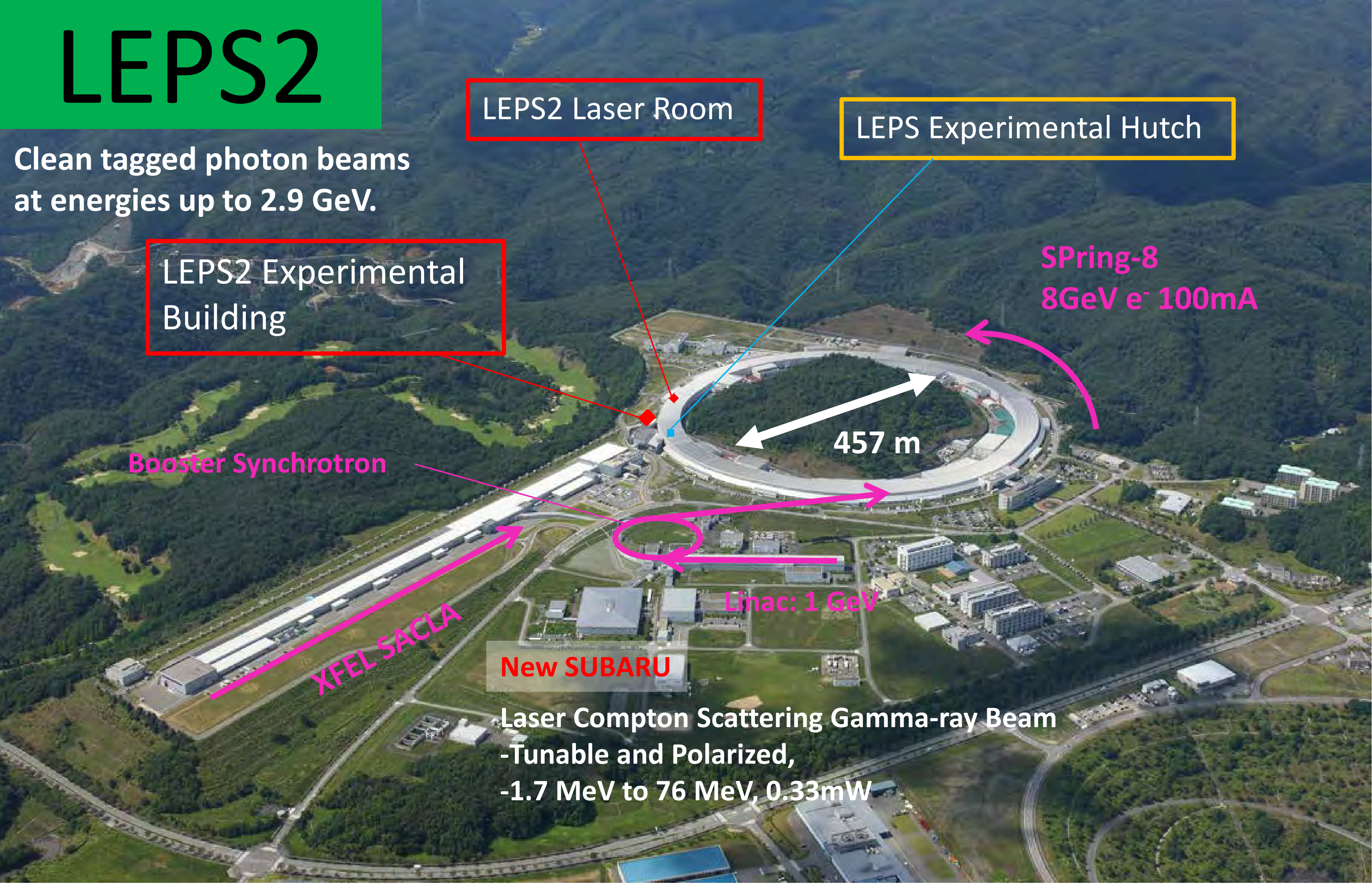
Jan. 2017

May 2017, Beam Dump (Iron Part) Completed





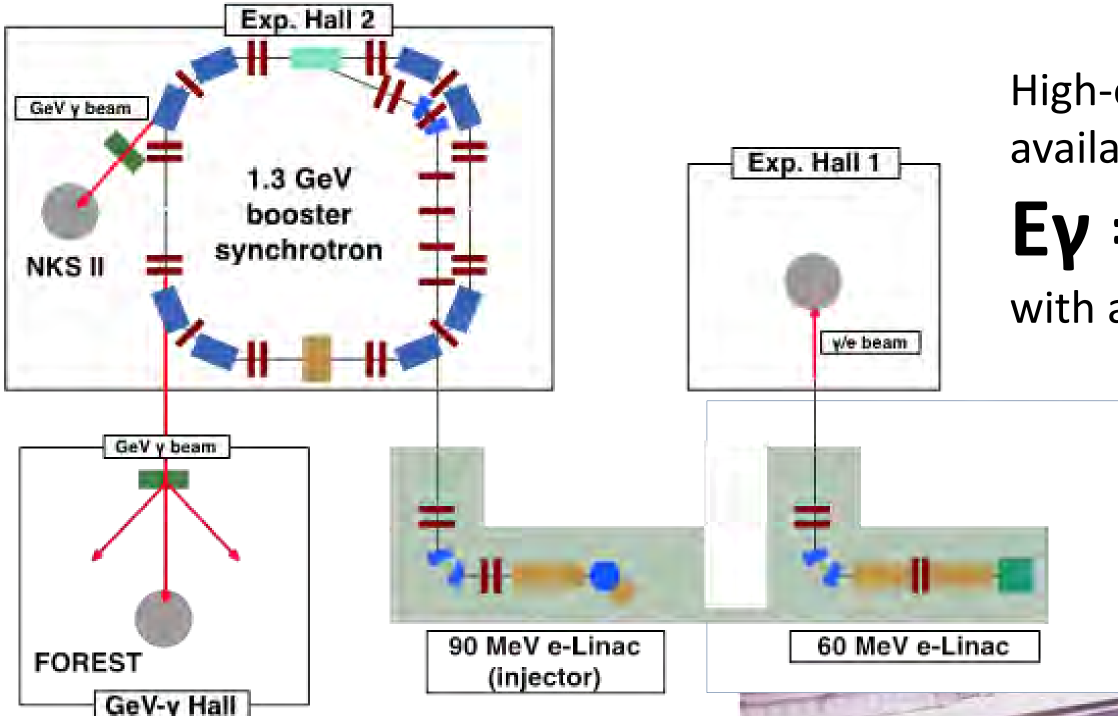
LEPS2



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

ELPH

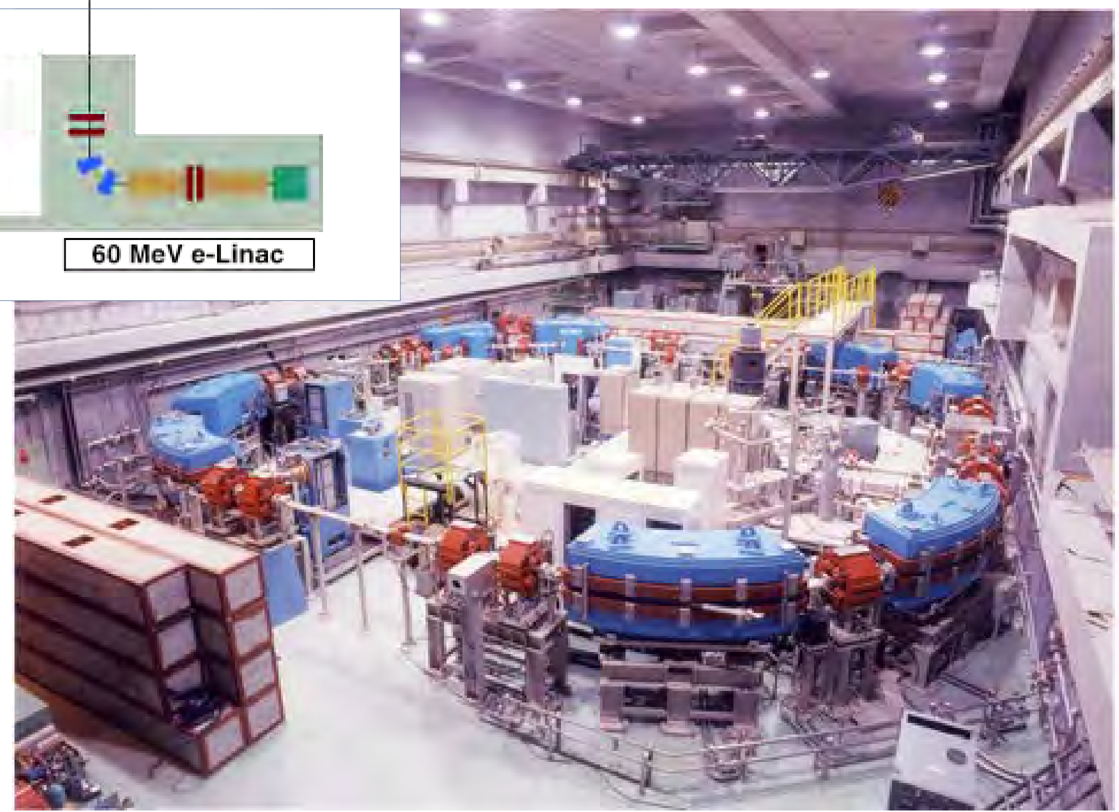
東北大学 電子光理学研究センター
RESEARCH CENTER FOR ELECTRON PHOTON SCIENCE (ELPH), TOHOKU UNIVERSITY



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

Eγ = 0.6 - 1.2 GeV

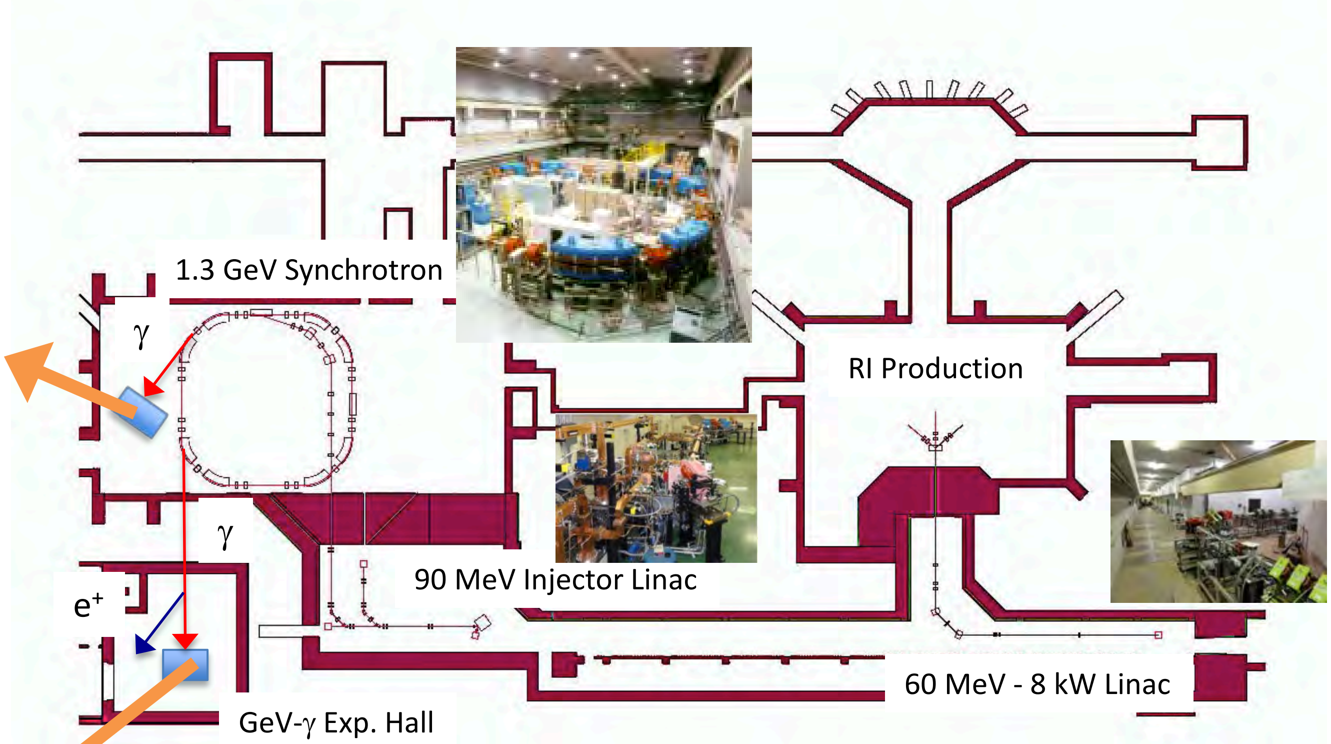
with a typical intensity of Nγ ~ 10^7 Hz.

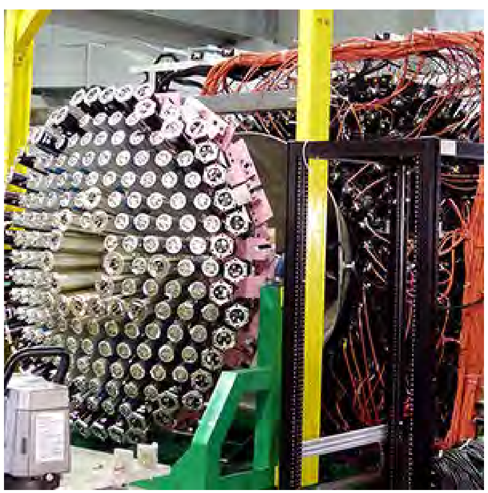


Research Center for Electron Photon Science

Tohoku University

NKS2 detector





FOREST

1.3 GeV Booster Storage Ring, " Source of γ rays"

- Tagged bremsstrahlung γ-rays from internal target wires.
- Two γ-ray beam lines available.
- Maximum stored beam current ~ 40 mA.

[What's new]

A spectrometer for "forwardscattered" charged particle was installed in the GeV-γ experimental hall.