J-PARC Heavy-Ion Project

Study of Heavy Ion Beam Acceleration at J-PARC MR

Kazuhiro Tanaka

for J-PARC-HI Collaboration

IPNS-KEK/ASRC-JAEA

J-PARC HI project

- At present, there is No High Energy Heavy-Ion (E/u>10GeV/u) Accelerator in Japan.
- **Only one realistic solution is to accelerate Heavy-Ions in J-PARC-MR, which can accelerate protons up to 30(50) GeV.**
- J-PARC is a high intensity accelerator. Then **high intensity heavy ion beams (~10^{11}pps)** can be extracted for 11 GeV/u Pb beam.
- I will talk about the overview and the strategic summary for realizing J-PARC-HI **ASAP**, i.e. with reasonably short time and with small budget.

J-PARC

Japan Proton Accelerator Research Complex

High Intensity Facility

30GeV 1MW for FX(ν), 100kW for SX(CE).

J-PARC

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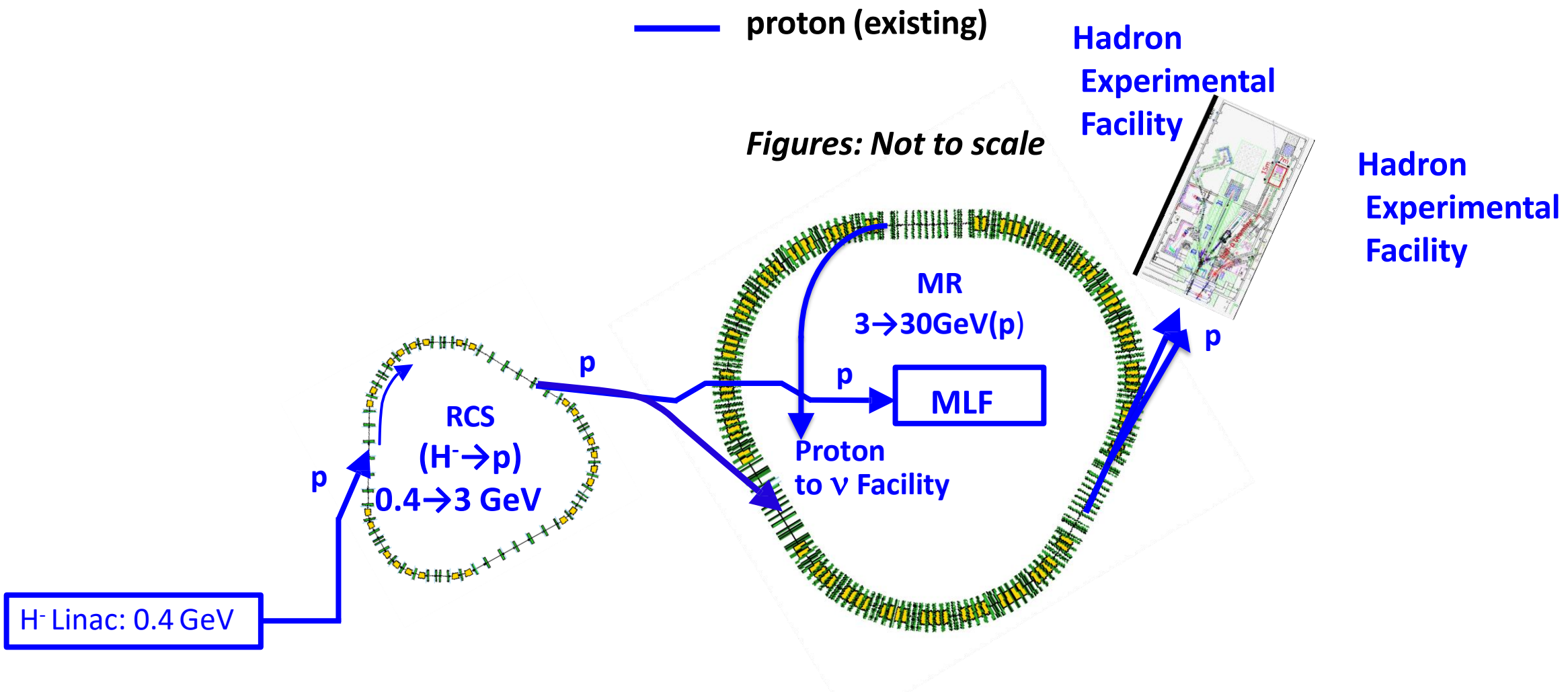
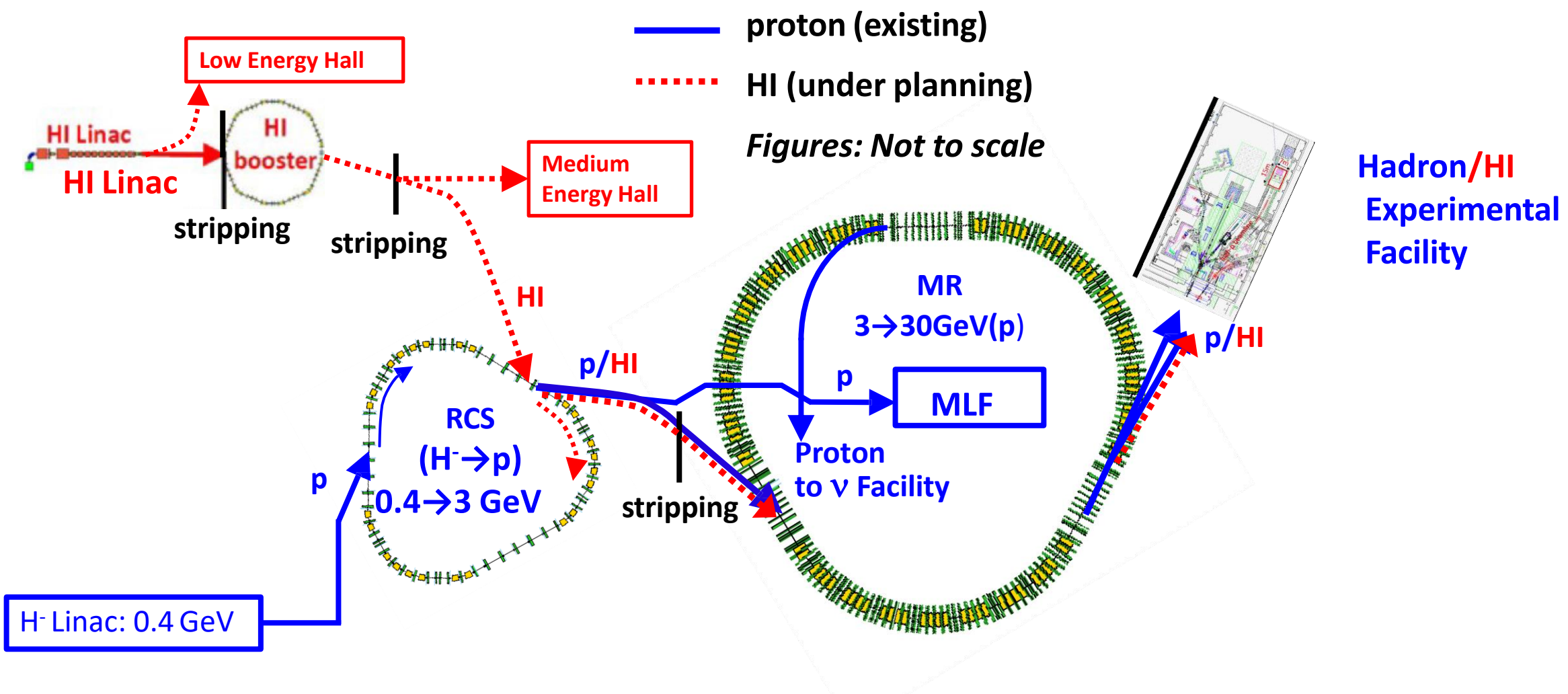
Proton Acceleration at J-PARC



Heavy-ion Acceleration at J-PARC

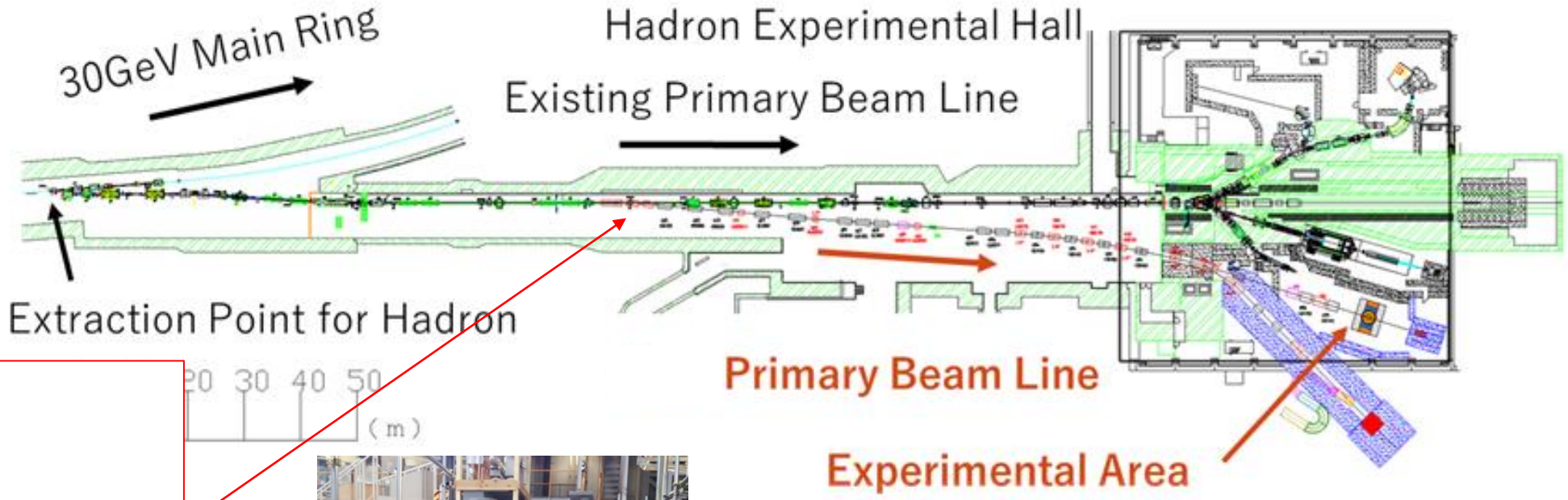


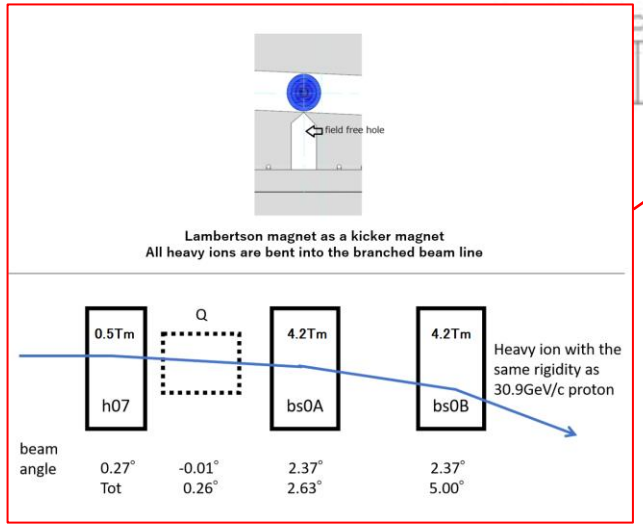
Technical Key point

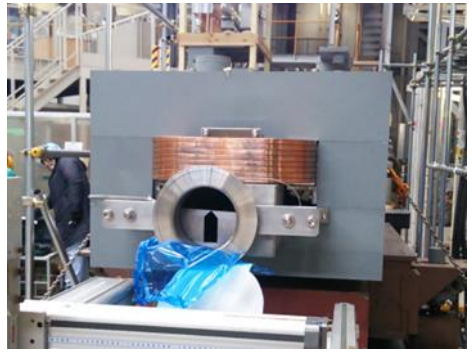
- If heavy ion beams can be accelerated to a momentum equivalent to 400 MeV protons,
- the heavy ions can be accepted by RCS and MR and accelerated to a momentum equivalent to that of 30 GeV protons, i.e. about 11 GeV/u for Pb beam.
- Furthermore, this method enables simultaneous operation of the proton beam and heavy ion beam!

High-p line, HI transport line to the Hall

Heavy Ion beam is transported into the Hadron Experimental Hall with the existing primary beam line (high-p)
Beam rate : 10^8 Au ion / spill equivalent beam power to the proton 10^{10} / spill → No modification necessary in the beamline / beamdump / radiation shield.

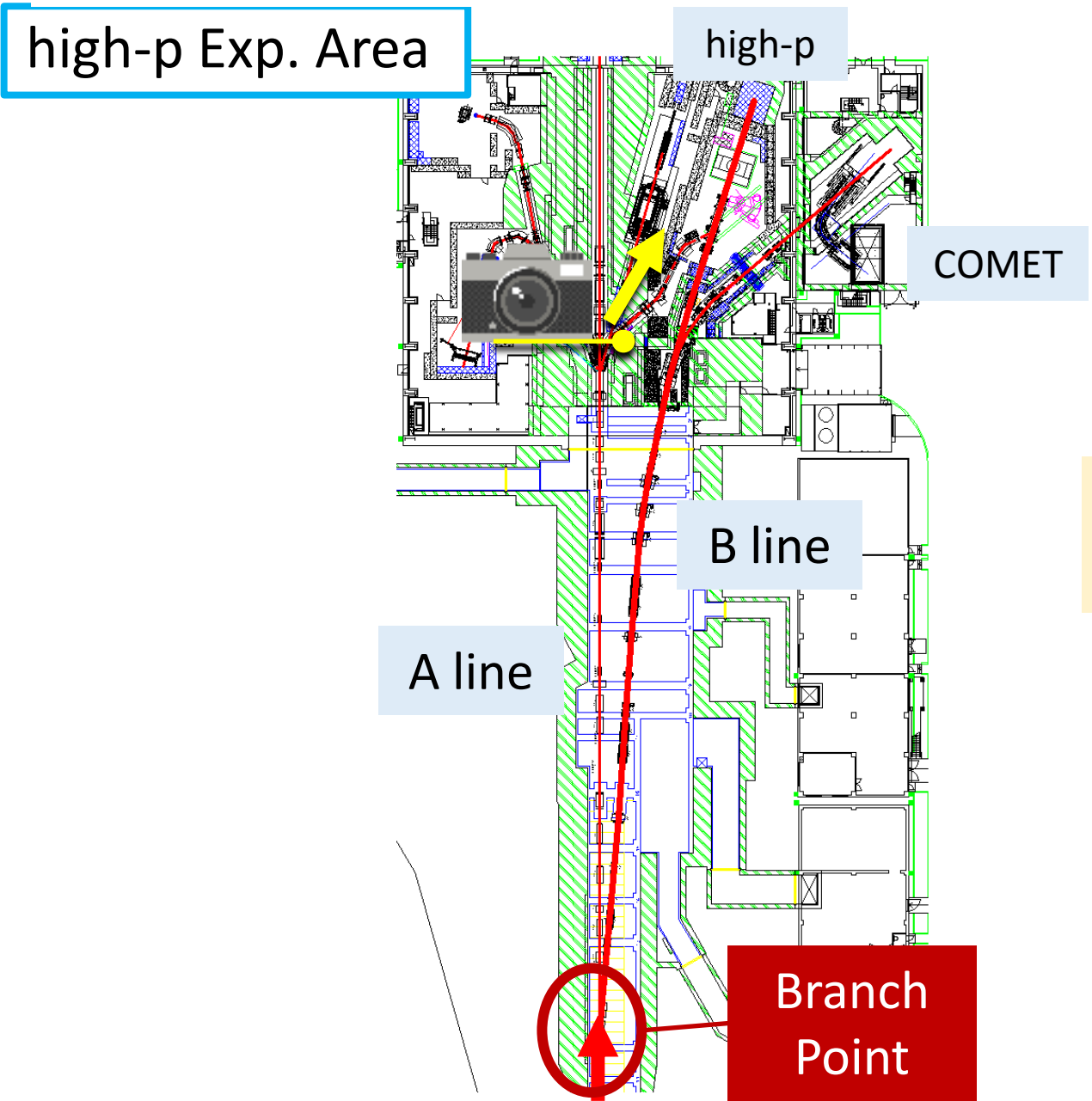


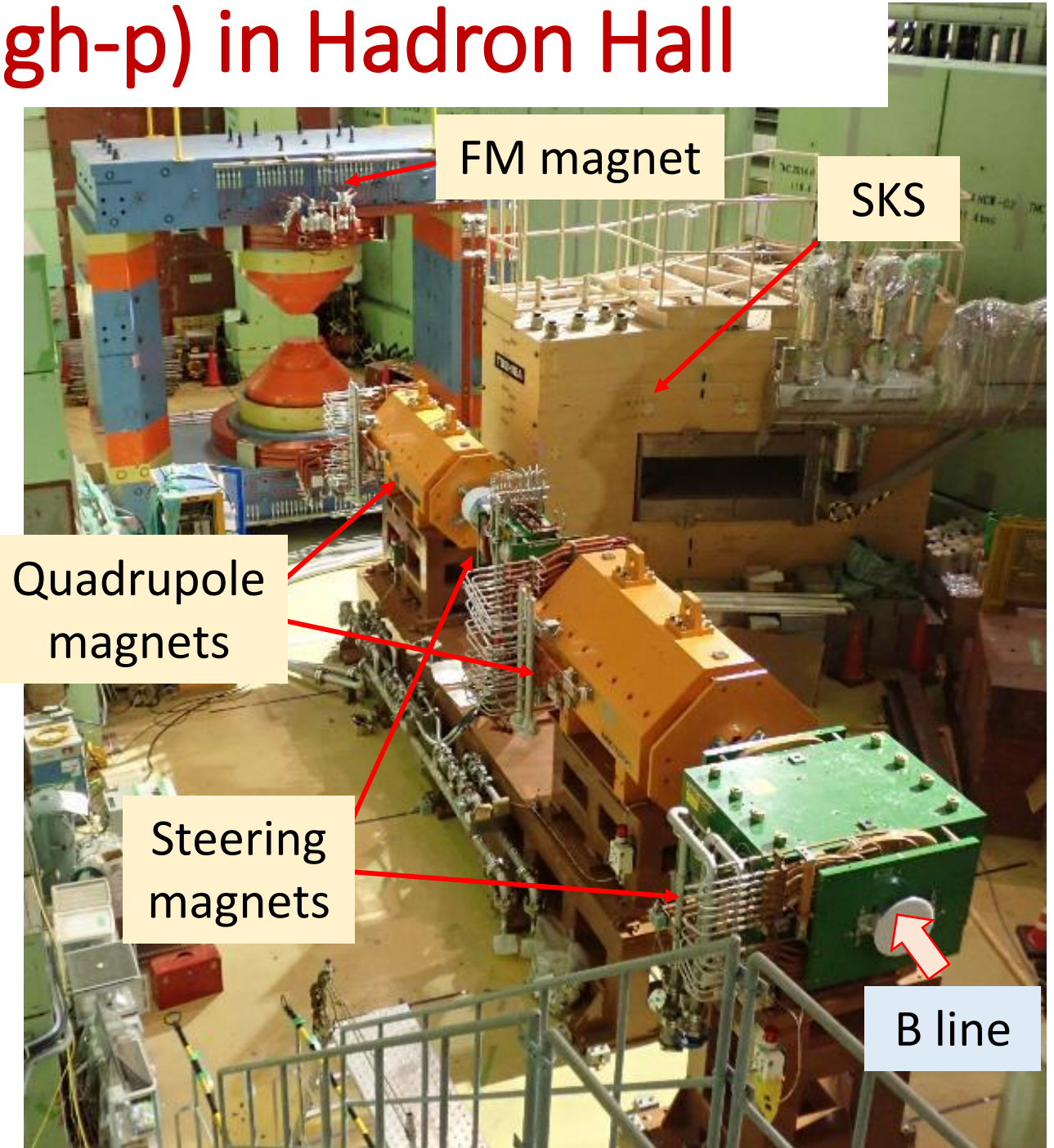




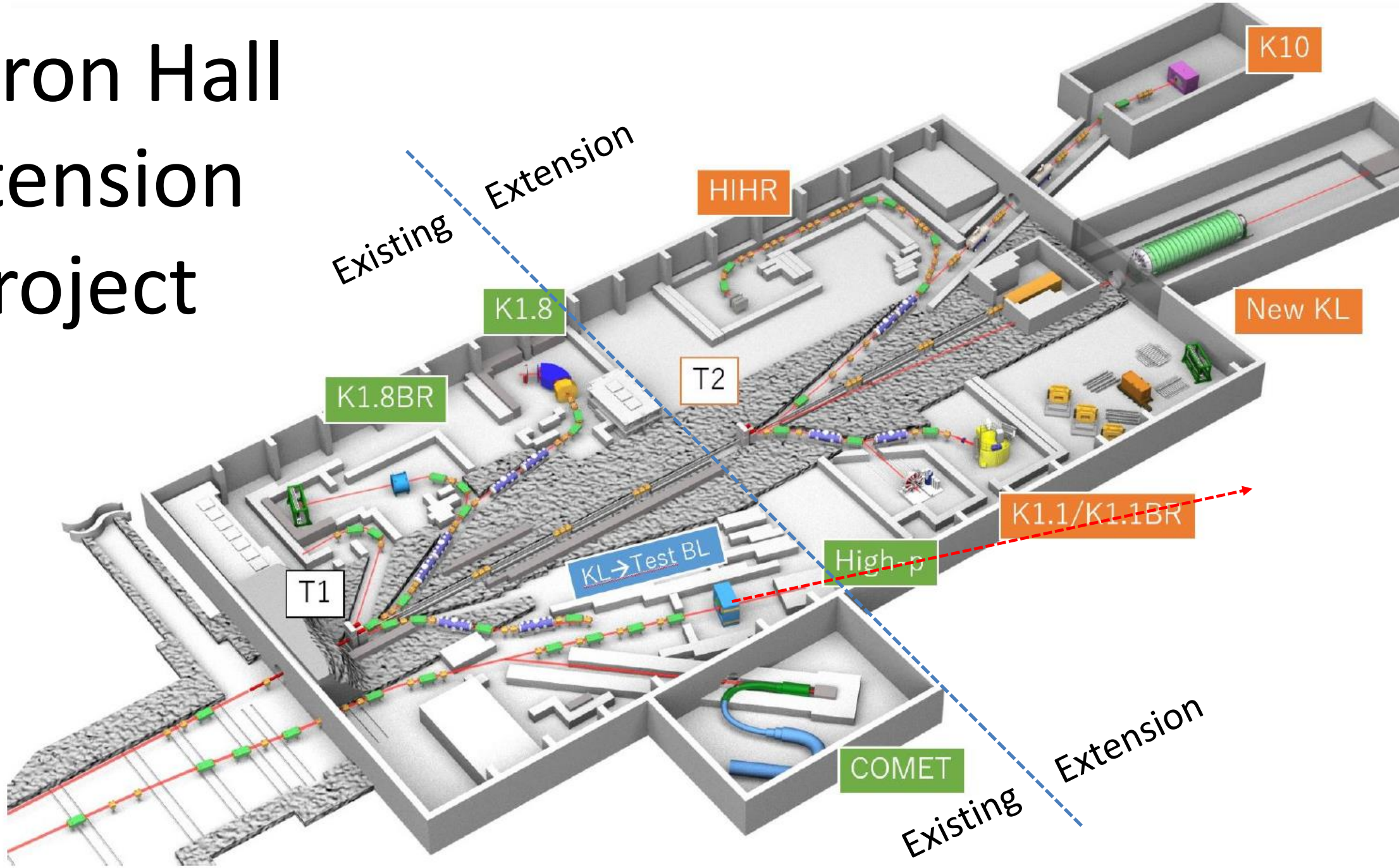
Branching Point and Magnet

New Primary Beam Line (high-p) in Hadron Hall

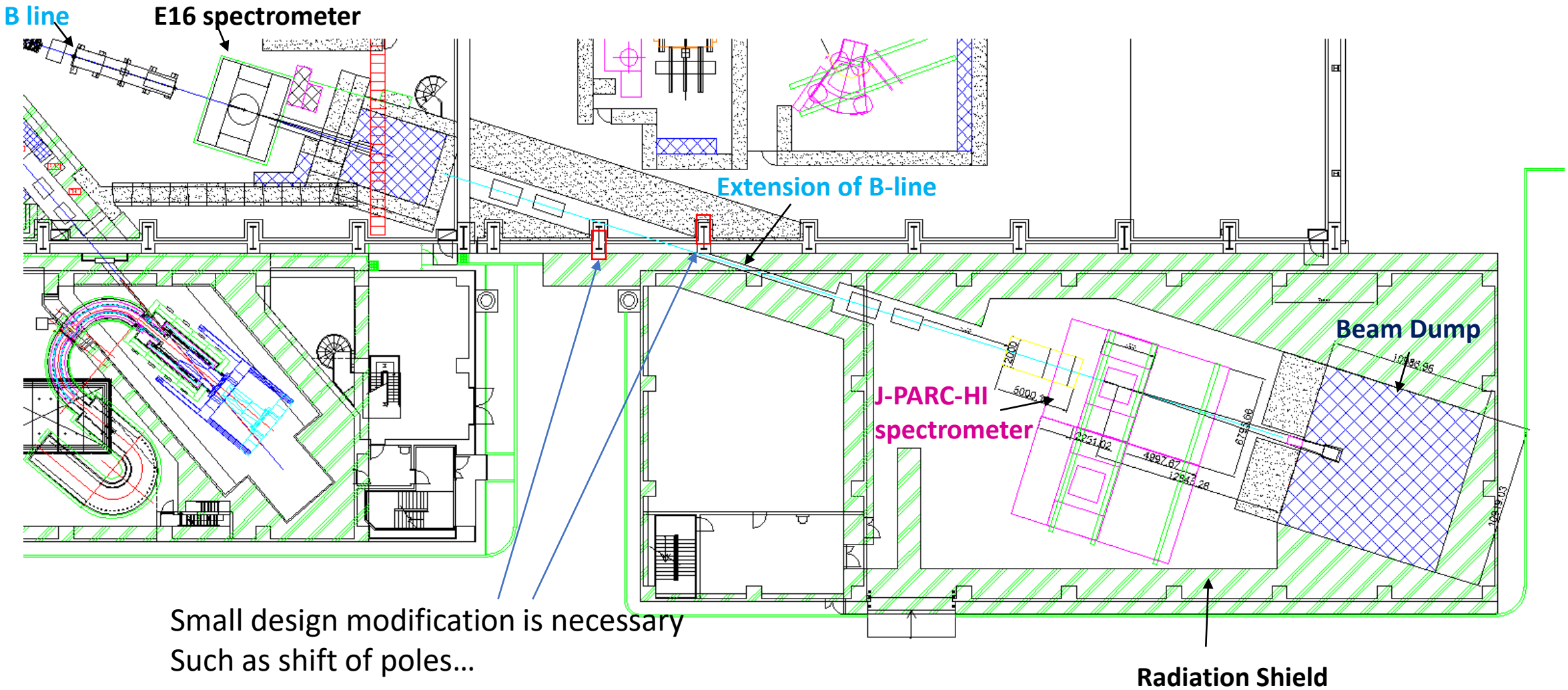




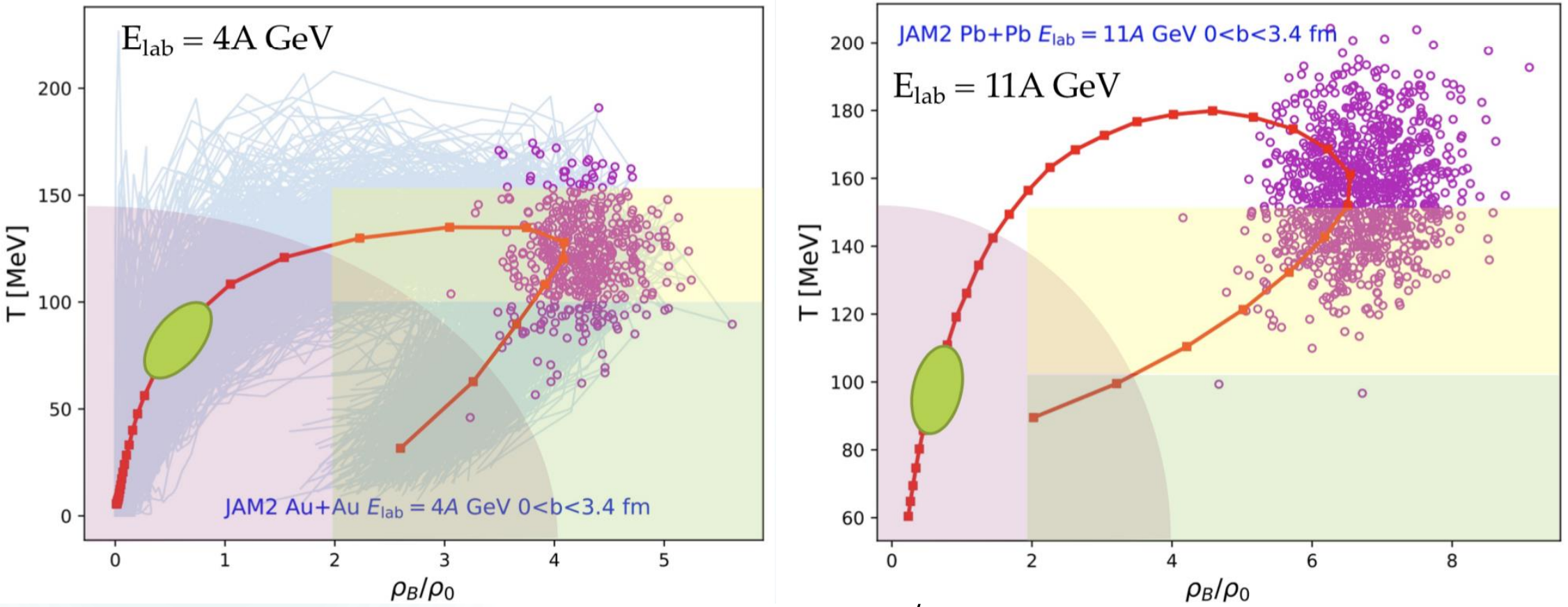
Hadron Hall Extension project



J-PARC New Heavy-Ion Annex



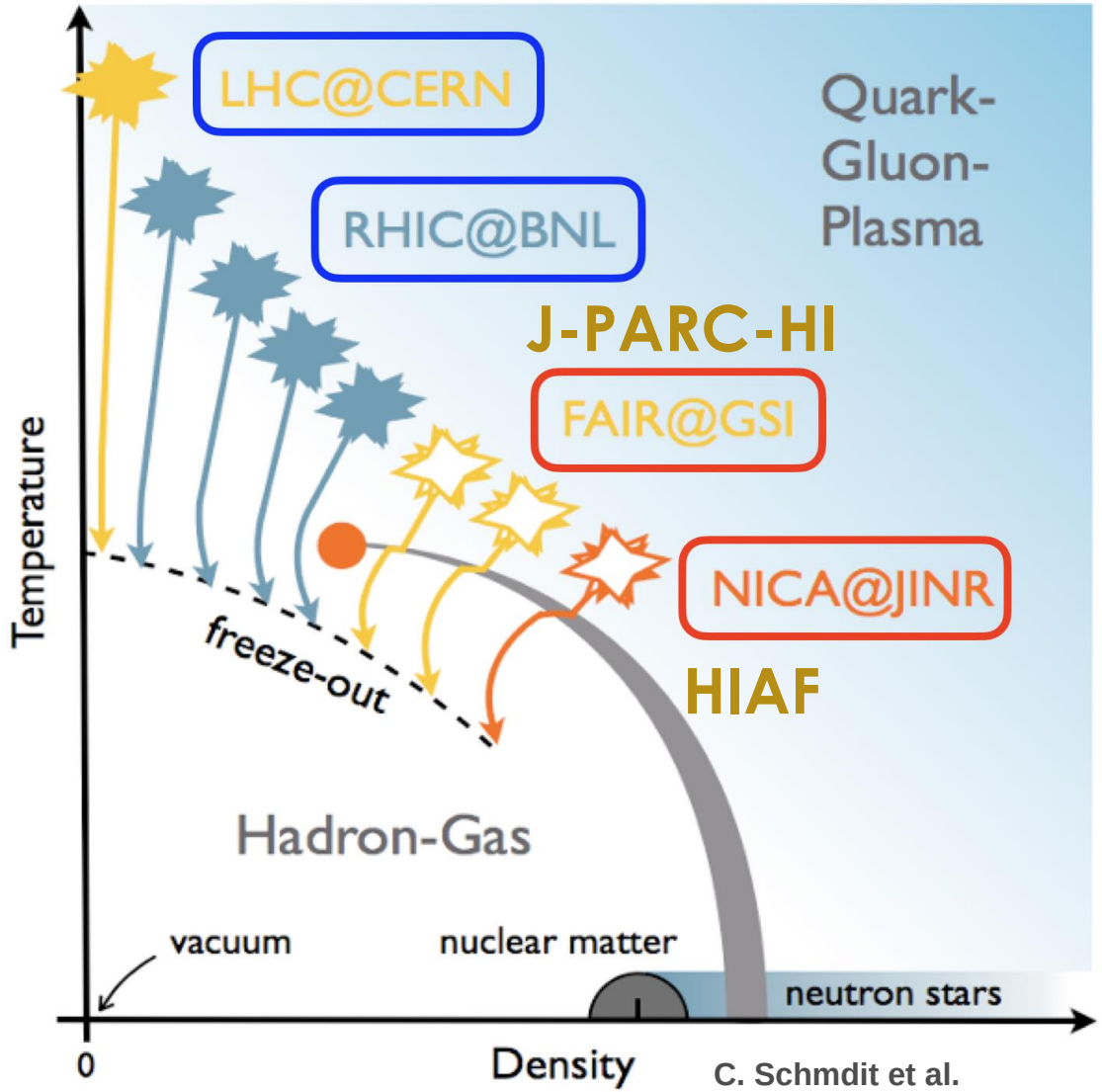
Maximum achievable density @J-PARC-HI



Maximum achievable density = 4-8ρ_0 @$\sqrt{s_{NN}}$ ~ 2-5 GeV
Rare event study with high intensity Beam (High density event, Lepton Pair Productions, Heavy Quark Production…)
Study of QCD-Phase Structure with High Statistics

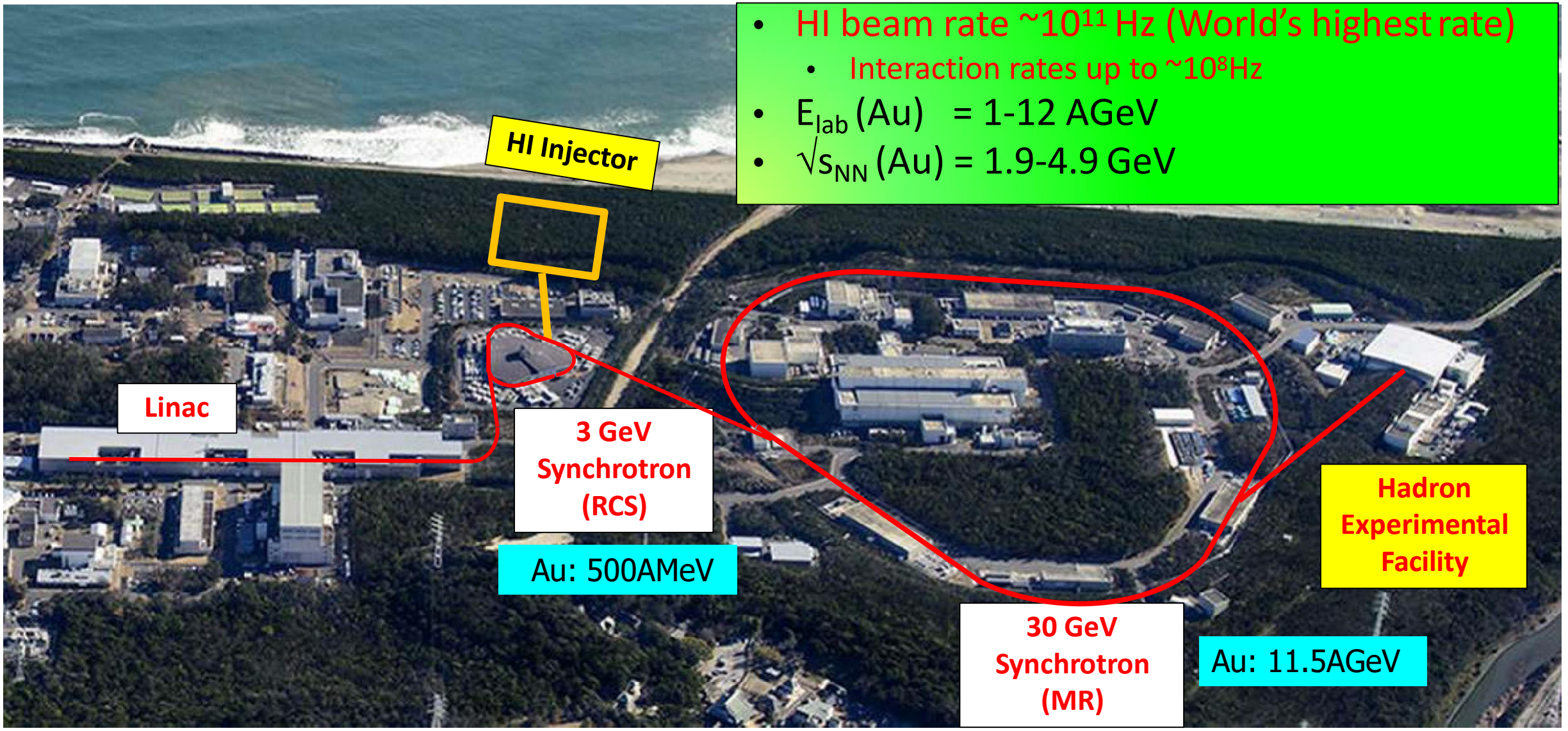
High Energy Heavy-Ion Accelerators

- **In Oparation**
  - RHIC@BNL (>2000, $\sqrt{s_{NN}}$=3 - 200 GeV)
  - LHC@CERN (>2009, $\sqrt{s_{NN}}$=2.76, 5.02 TeV)
  - SPS@CERN(固定標的, $\sqrt{s_{NN}}$ ~ 20 GeV)
  - SIS18@GSI(固定標的, $\sqrt{s_{NN}}$ ~ 2 GeV)
- **Under Construction**
  - FAIR-SIS 100 (固定標的, $\sqrt{s_{NN}}$ ~ 2-5 GeV)
  - NICA (衝突型, $\sqrt{s_{NN}}$ ~ 4-15 GeV)
  - HIAF
- **In Proposal**
  - FAIR-SIS300 ($\sqrt{s_{NN}}$ ~ 6-8-10 GeV)
  - FCC@CERN ($\sqrt{s_{NN}}$ ~ 39 TeV)
  - J-PARC-HI ($\sqrt{s_{NN}}$ ~ 2-5 GeV)



C. Schmdit et al.
J. Phys. G 44, (2017), 10, 104002

HI acceleration scheme for J-PARC-HI

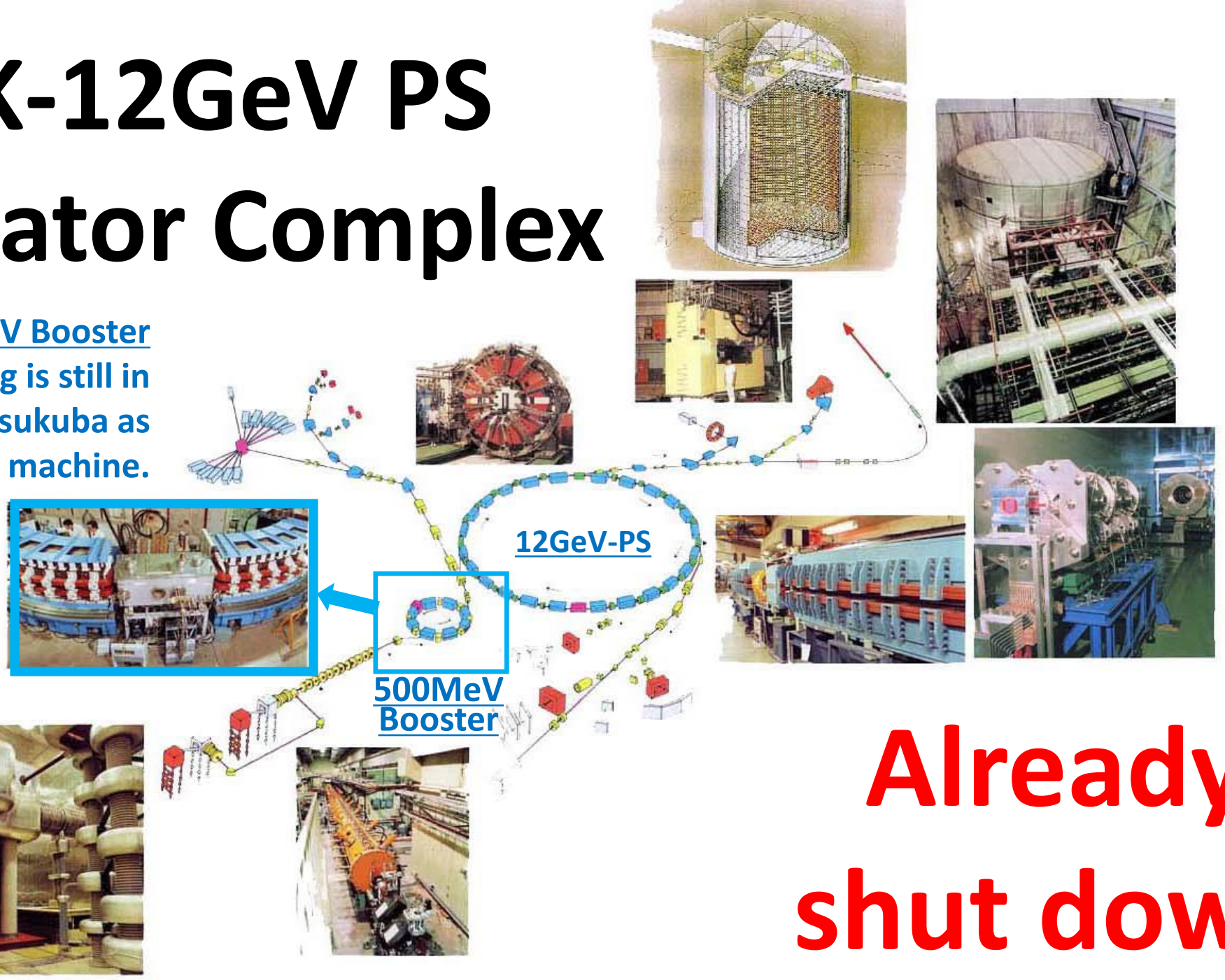


- HI beam rate ~10^{11} Hz (World's highest rate)
  - Interaction rates up to ~10^{8}Hz
- E_{lab} (Au) = 1-12 AGeV
- $\sqrt{s_{NN}}$ (Au) = 1.9-4.9 GeV

Time/Money Saving (Staging Plans)

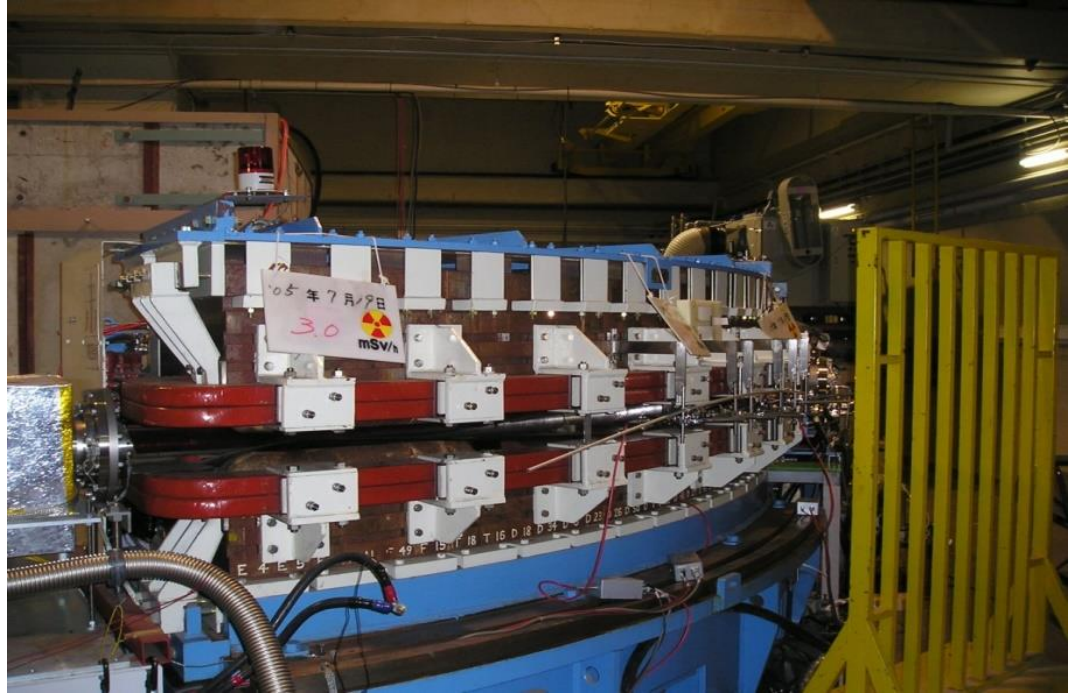
Old KEK-12GeV PS Accelerator Complex

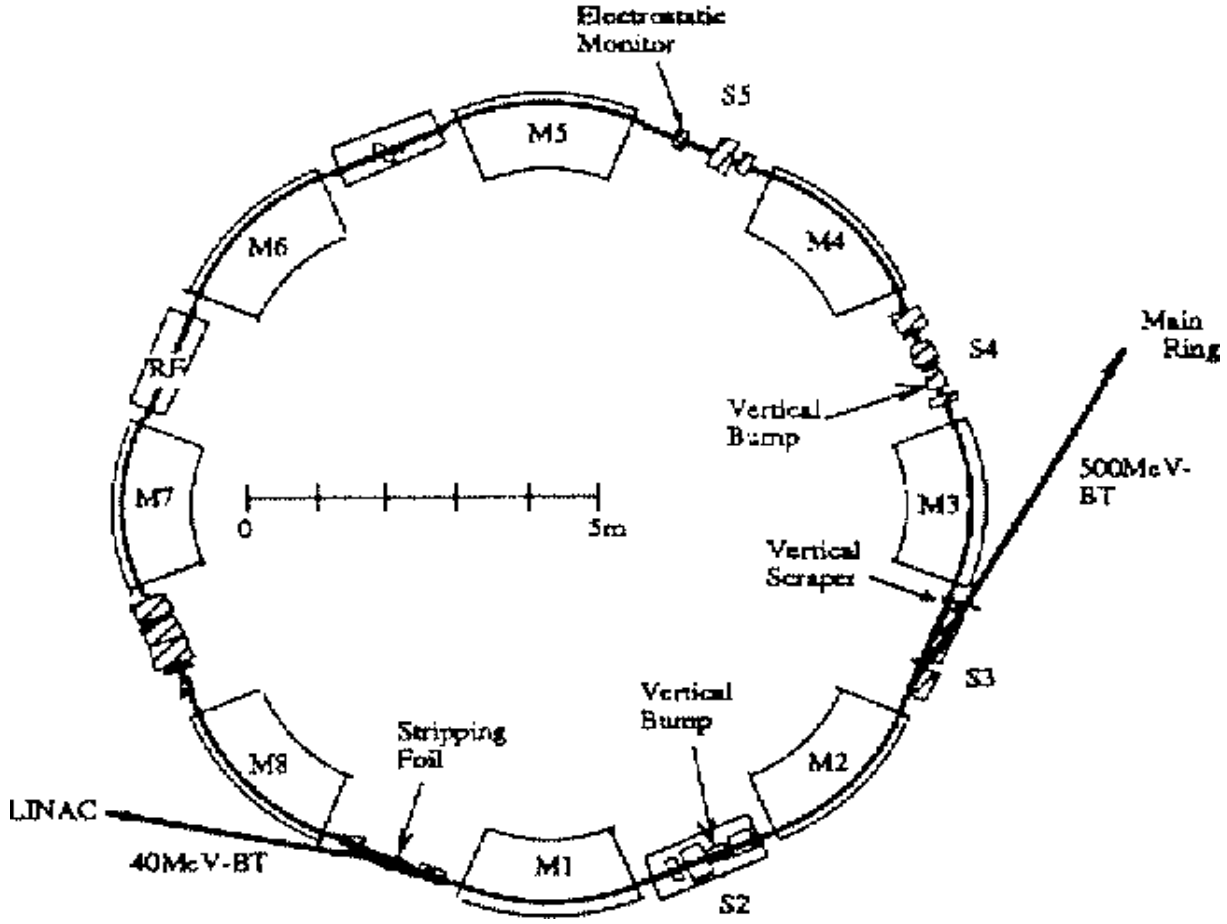
500MeV Booster
Synchrotron Ring is still in operational in Tsukuba as a R&D machine.



Already shut down

KEK-PS 500MeV Booster, kept in working condition in KEK-Tsukuba campus!

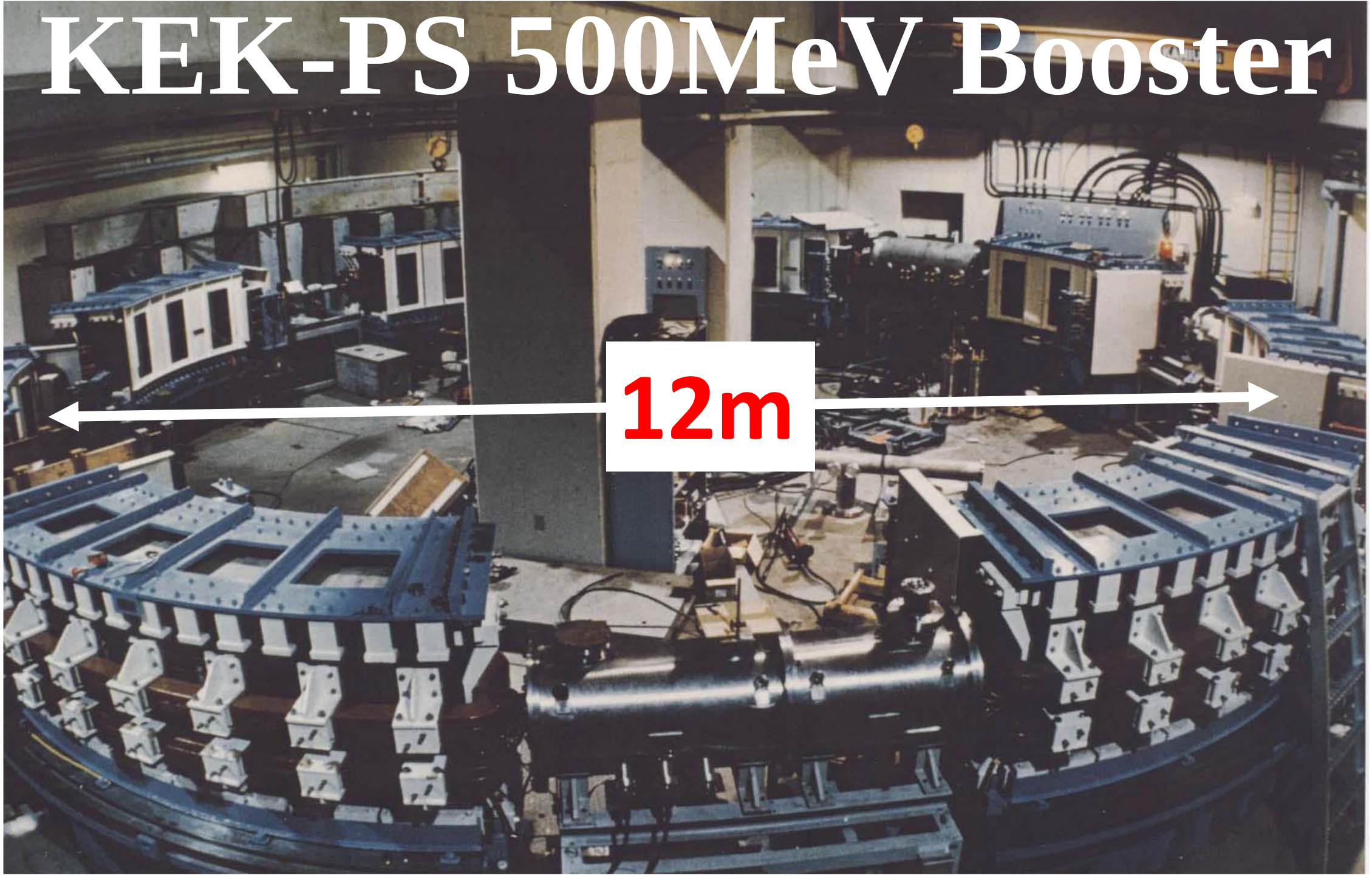




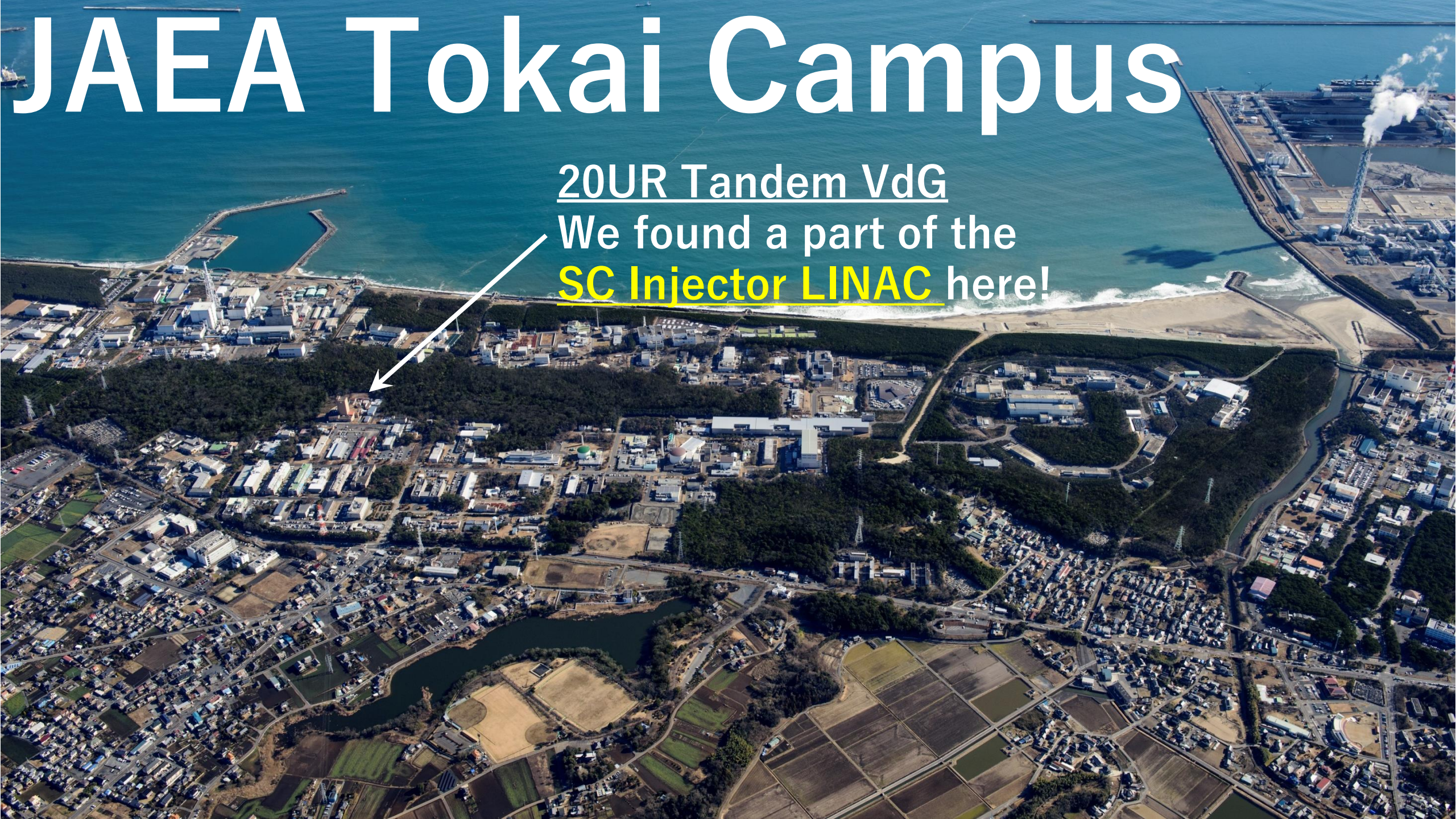
- Real Radius ~6m.
- Circumstance 37.7m.
- Max. B 0.84T.
- Repetition Rate 10Hz.
- Betatron Frequency is $2.17_H/2.30_V$
- Max energy (proton) is 500 MeV.

d and α were successfully accelerated by this 12 GeV-PS

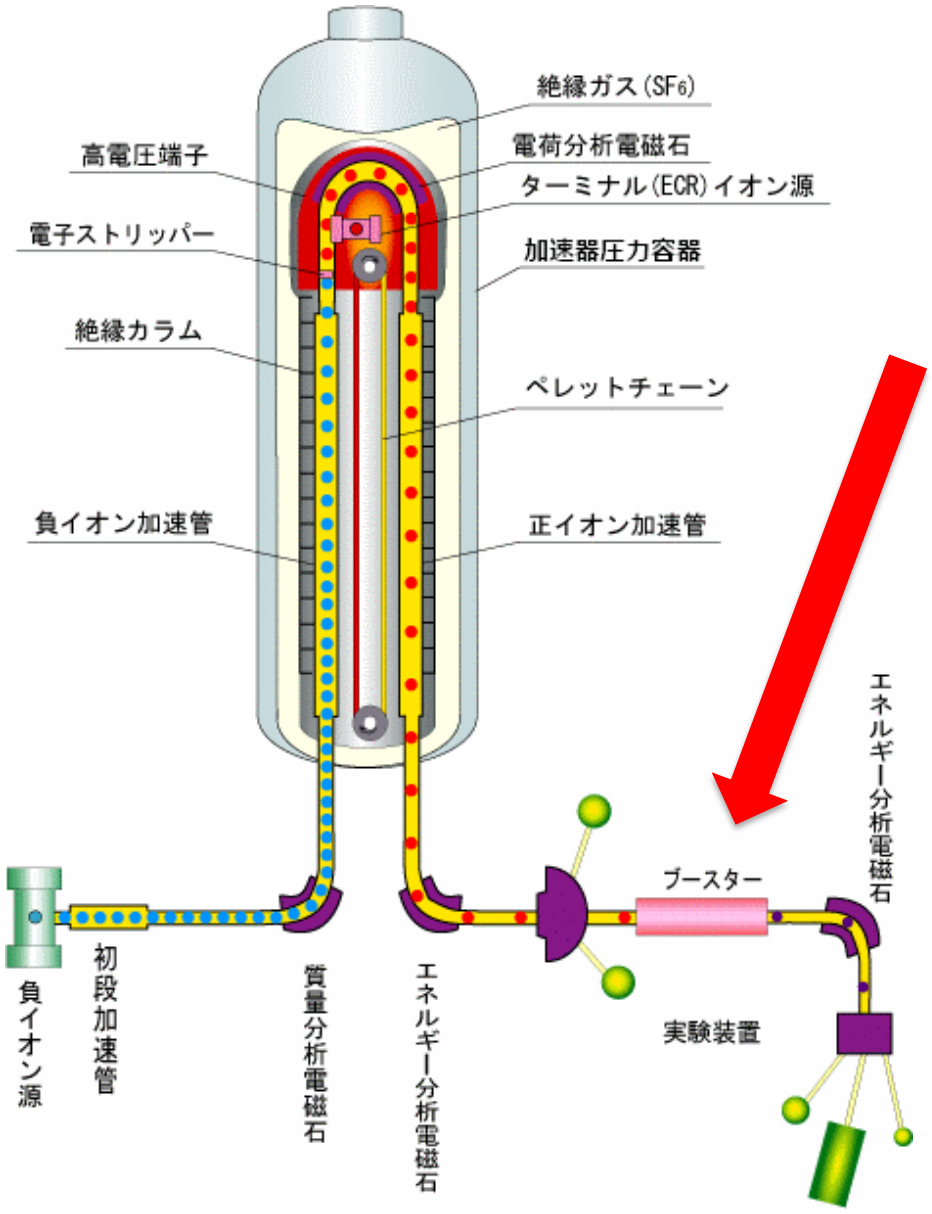
KEK-PS 500MeV Booster



JAEA Tokai Campus

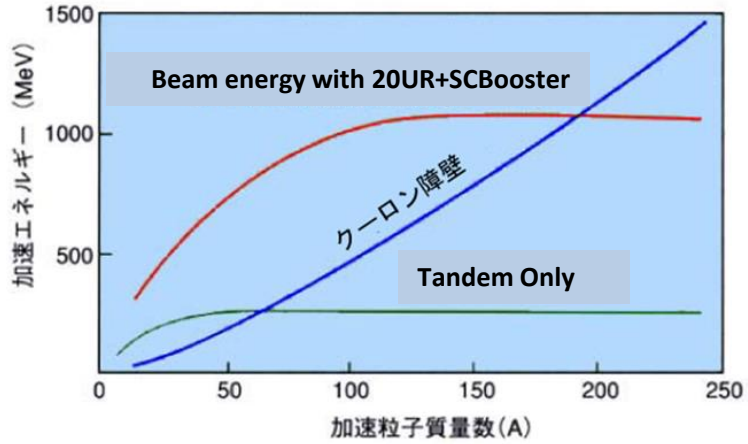


Existing SC Cavity at old 20UR Tandem VdG



Superconducting Booster LINAC for 20UR Tandem VdG is kept in vacuum!

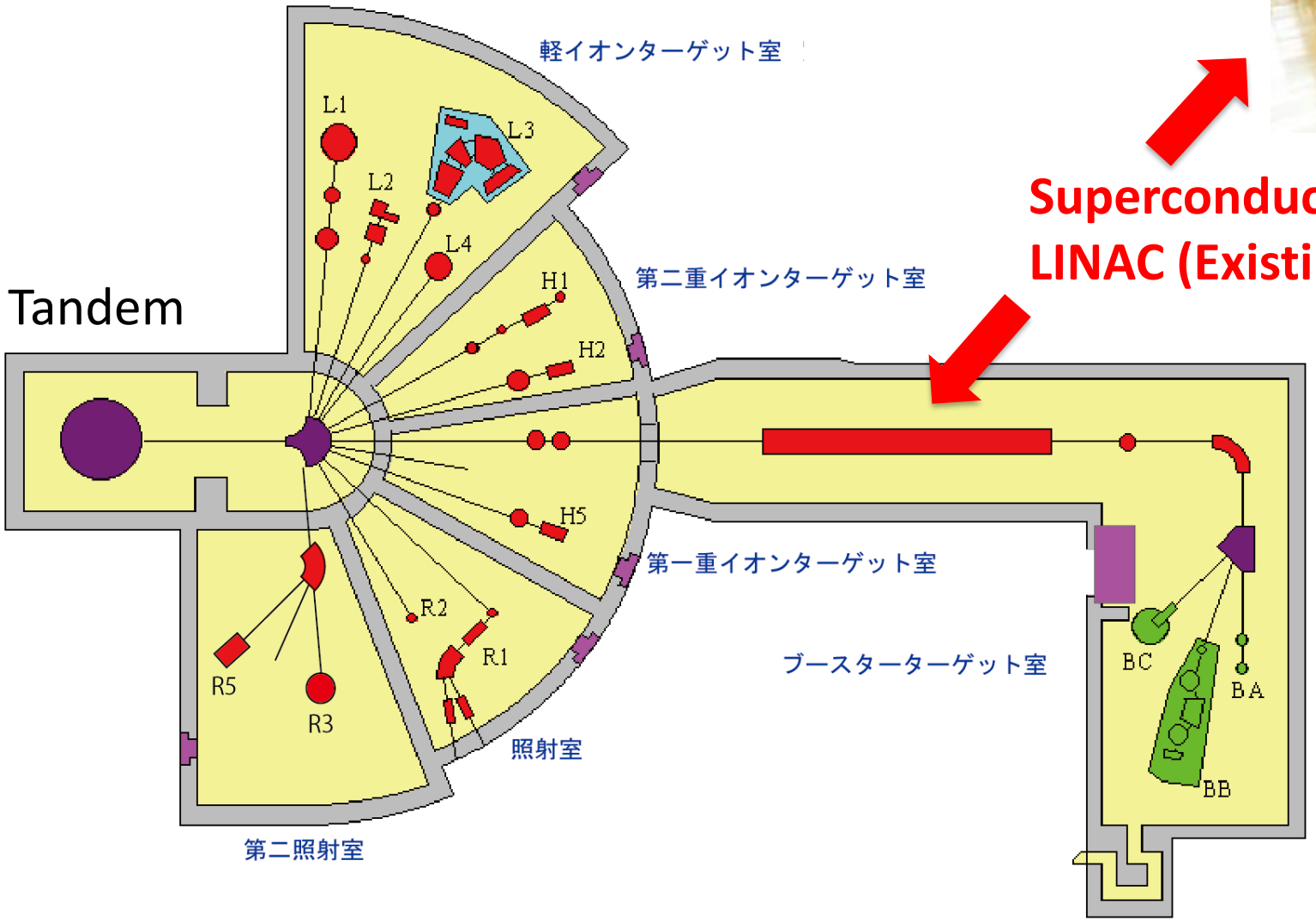
Beam energy with 20UR+SCBooster

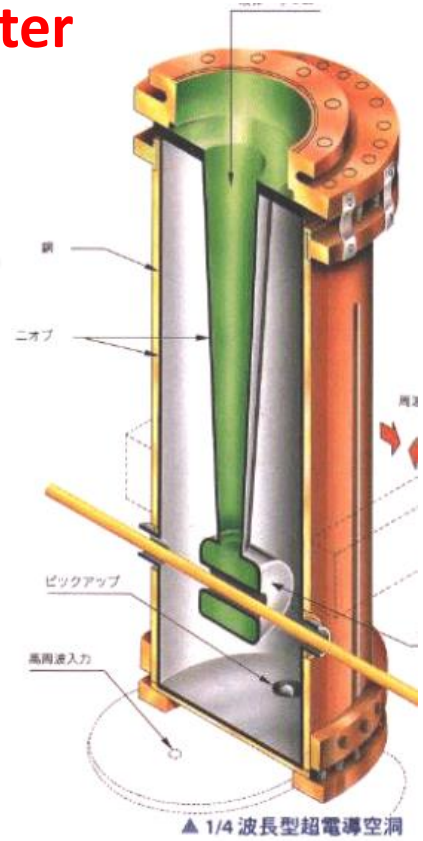


Typical Acceleration Enegy
A ～100 region: 10 MeV/u
A ～50 region: 20 MeV/u

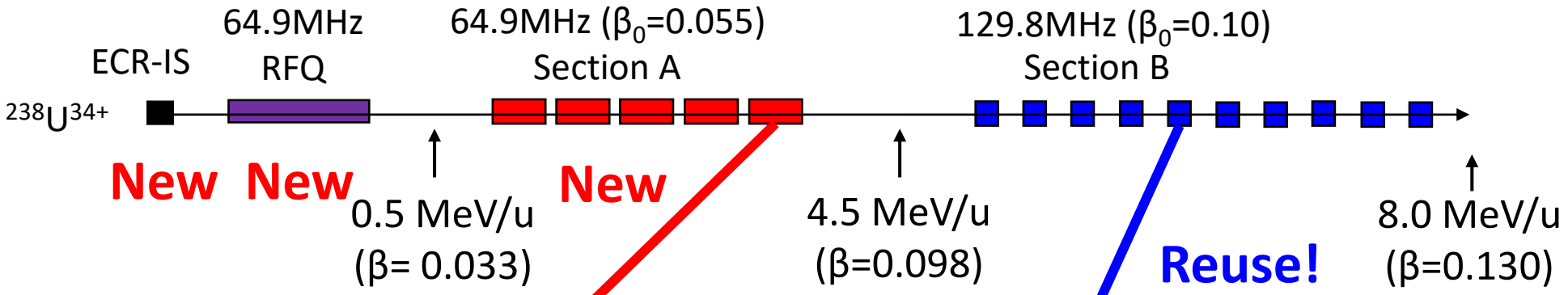
Superconducting Tandem Booster Linac

Superconducting Booster LINAC (Existing)

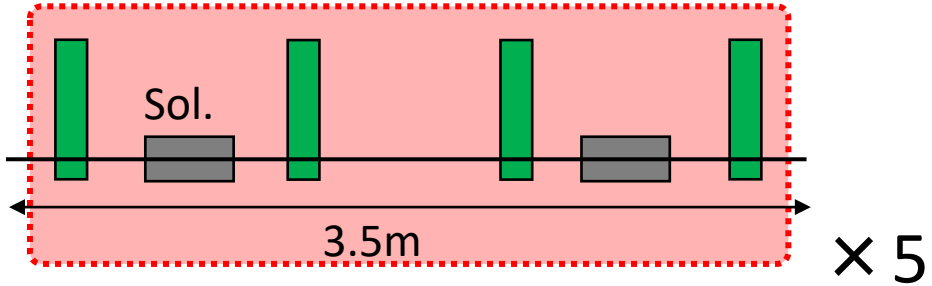




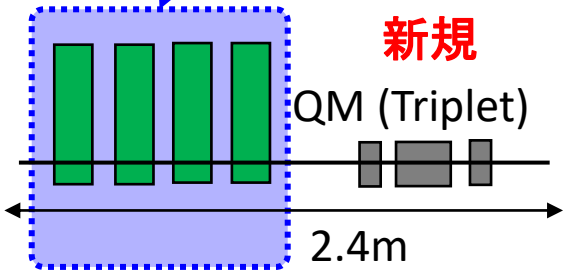
New H-I Linac Construction using Old SC Cavity



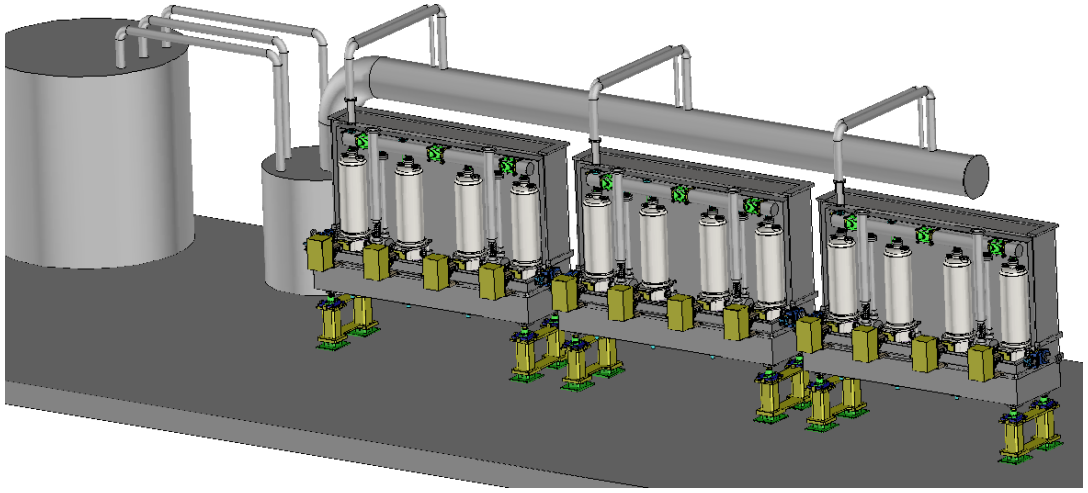
SC Cavity New System! Design Completed！



× 5

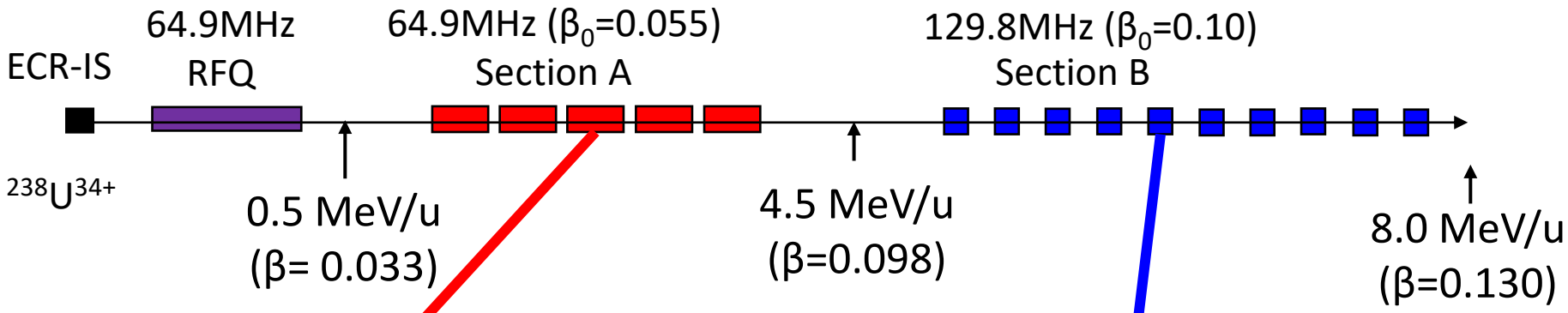


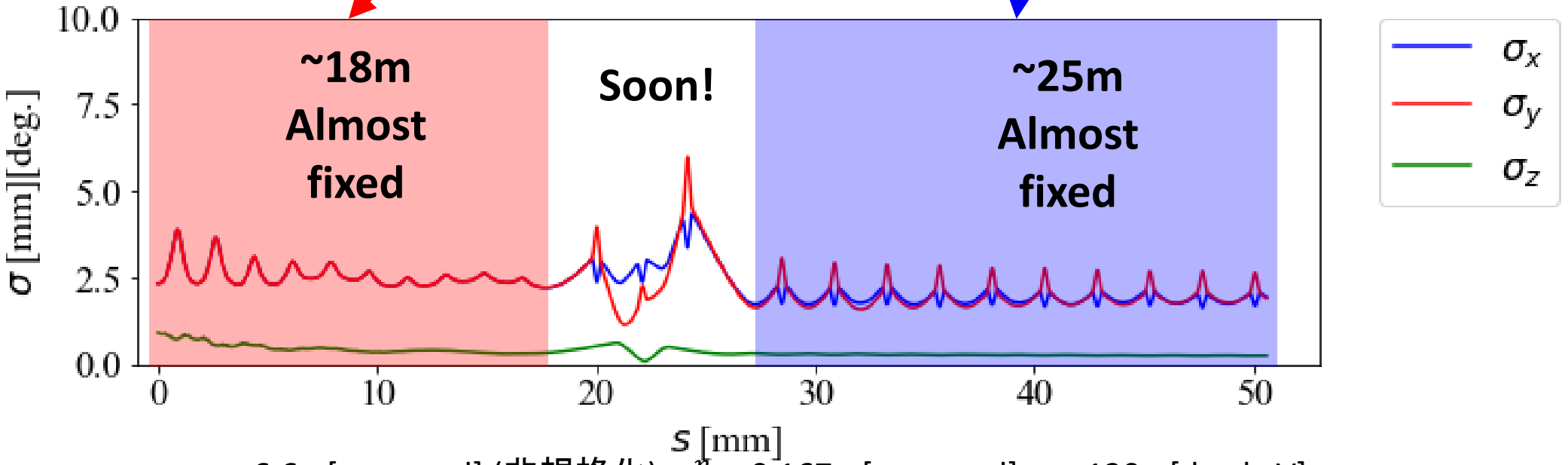
× 10



40 Existing SC Cavity

Optics etc.

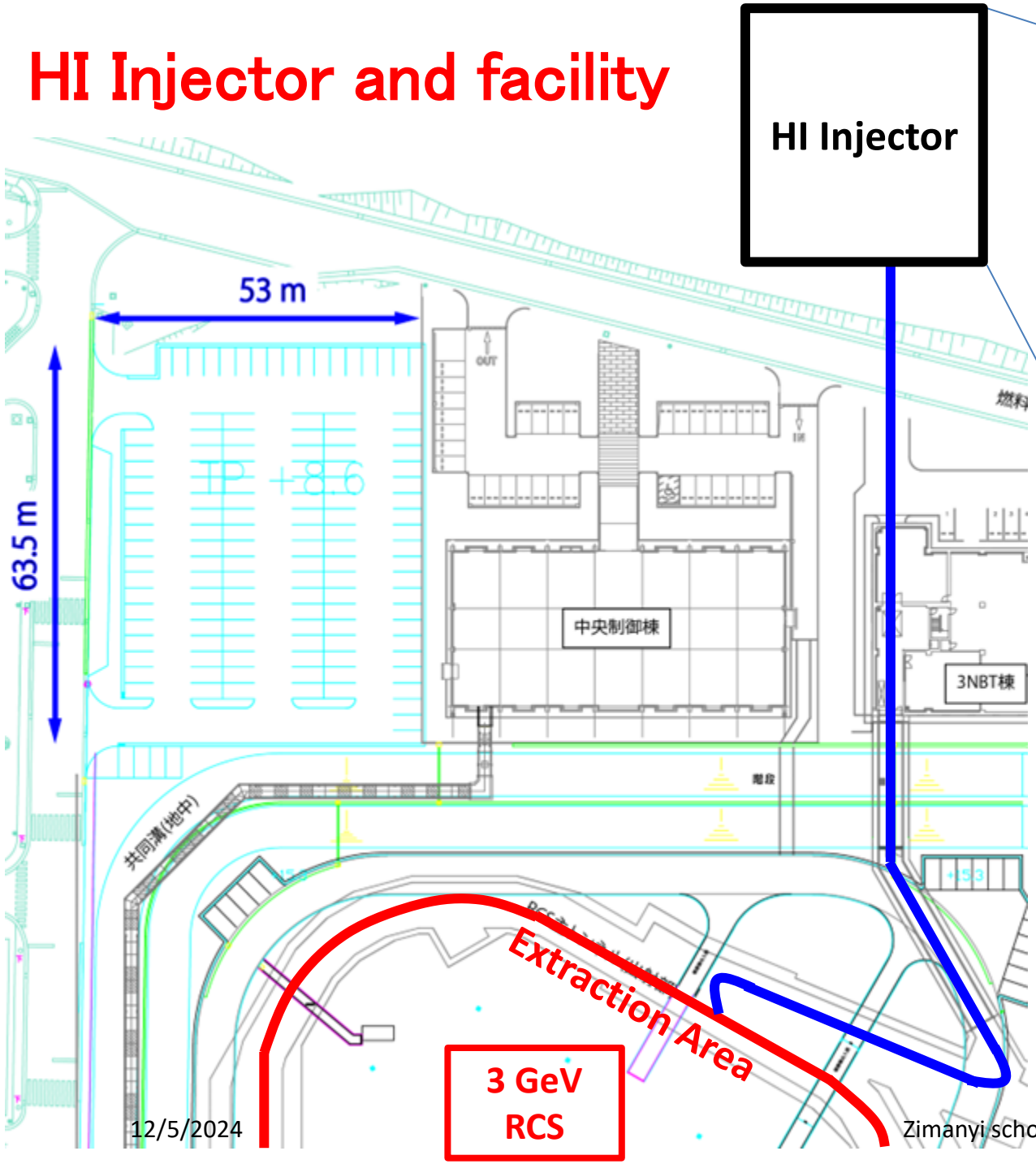


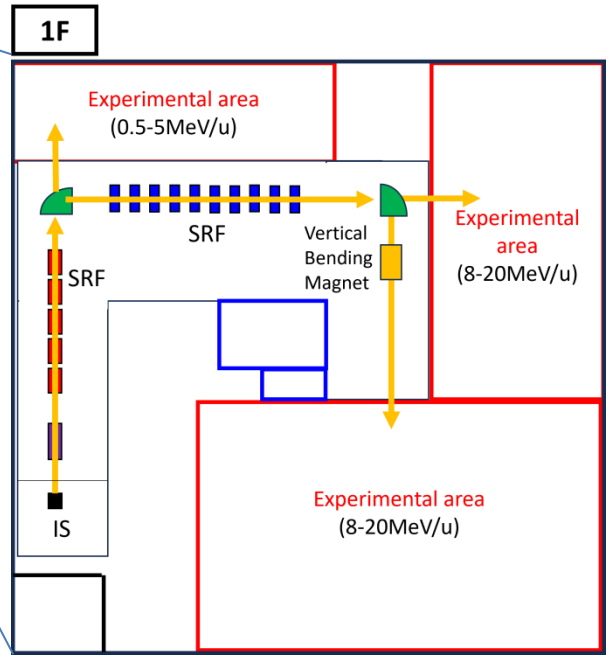


$\varepsilon_{x,y}$=6.6π [mmmrad] (非規格化), $\varepsilon^n_{x,y}$=0.167π [mmmrad], ε_z=120π [deg keV]

New plan in 2024

HI Injector and facility

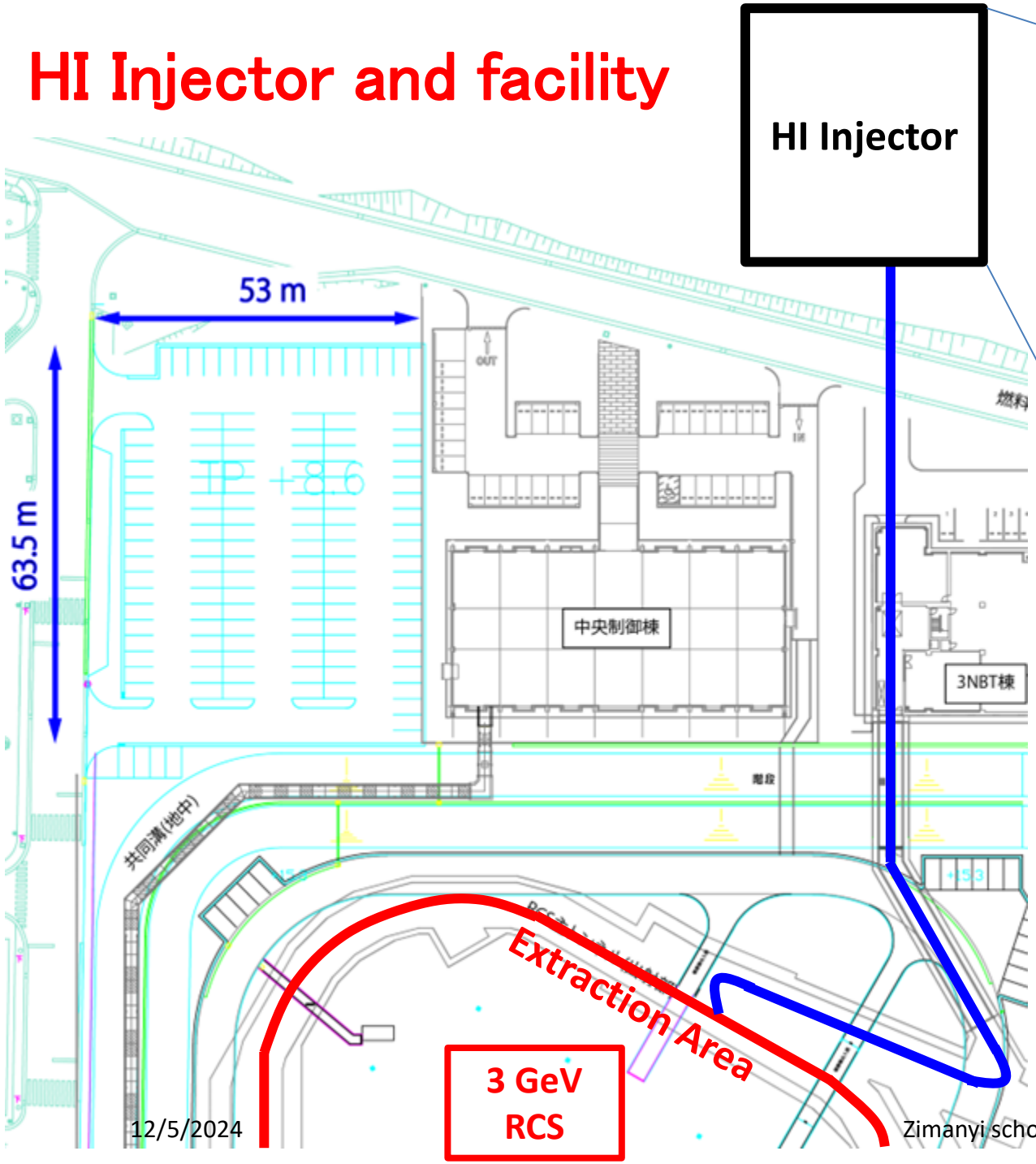


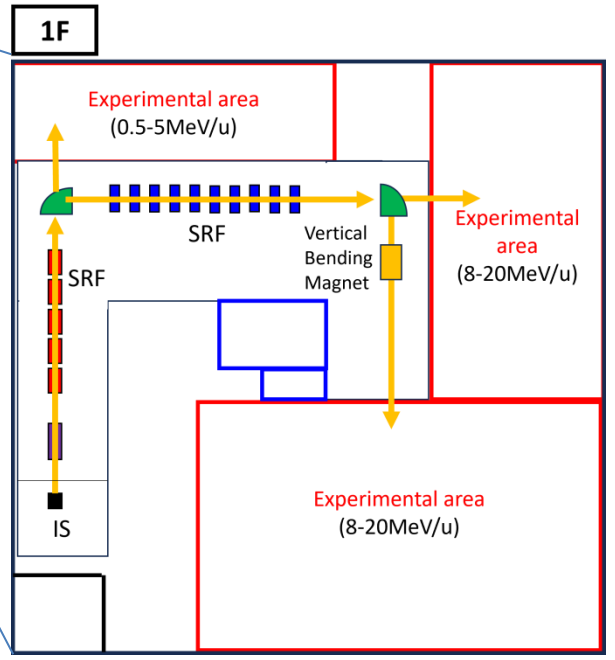


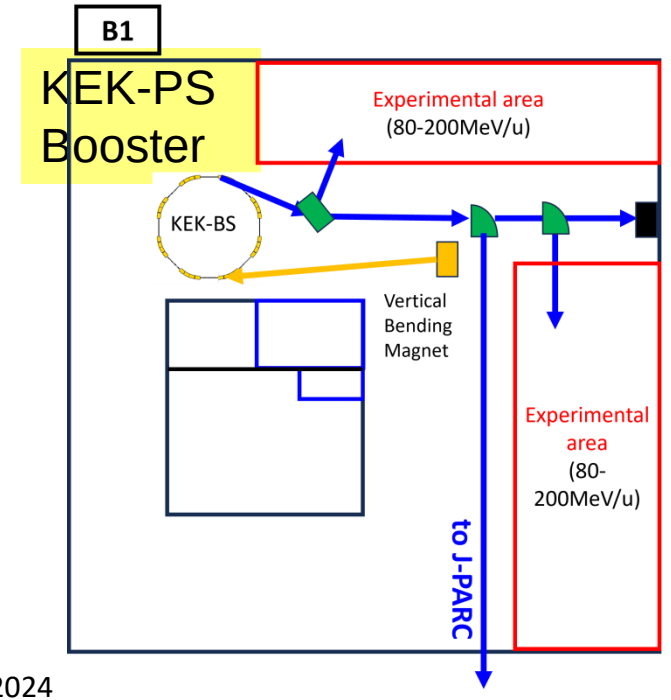
Conceptual design
by H. Harada (J-PARC)

"Tokai HI Frontier Project" at JAEA
Super-heavy nuclear physics
Nuclear chemistry
Reactor fuels and materials
J-PARC-HI Injector

HI Injector and facility







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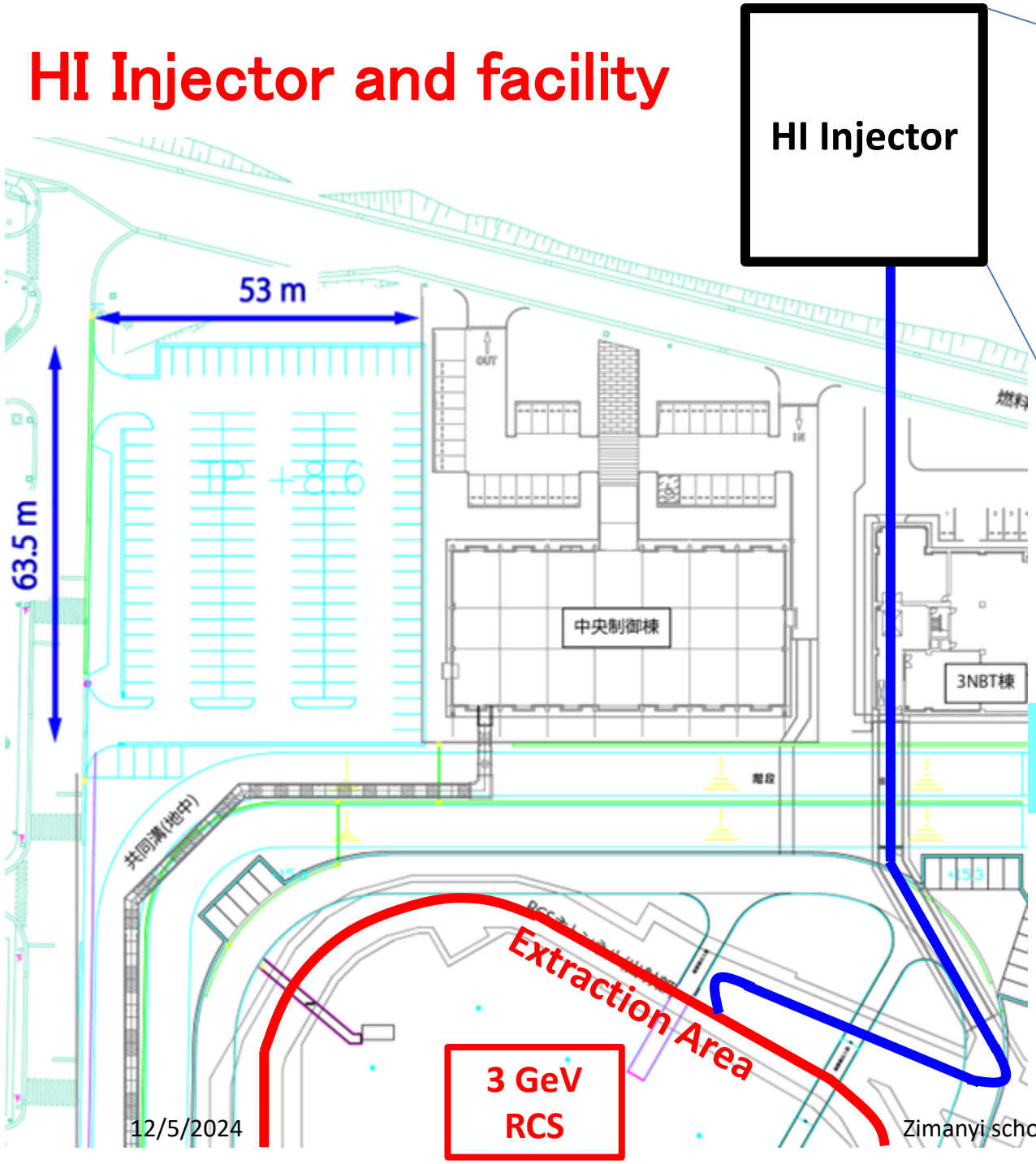
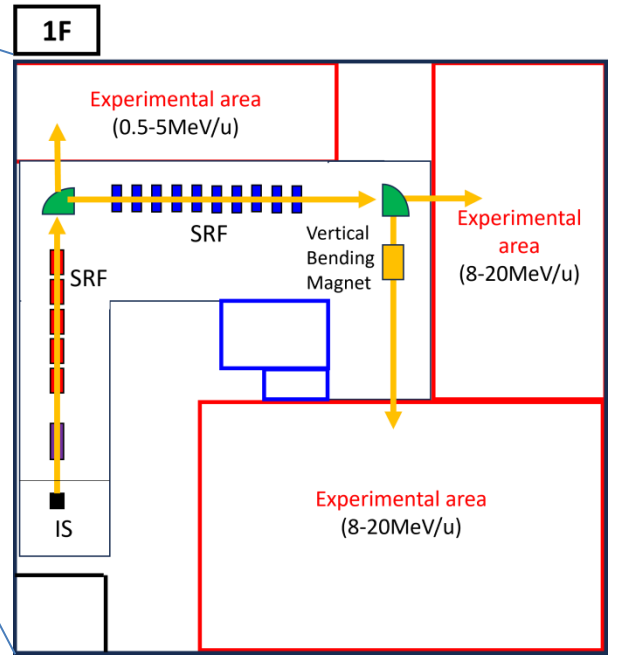
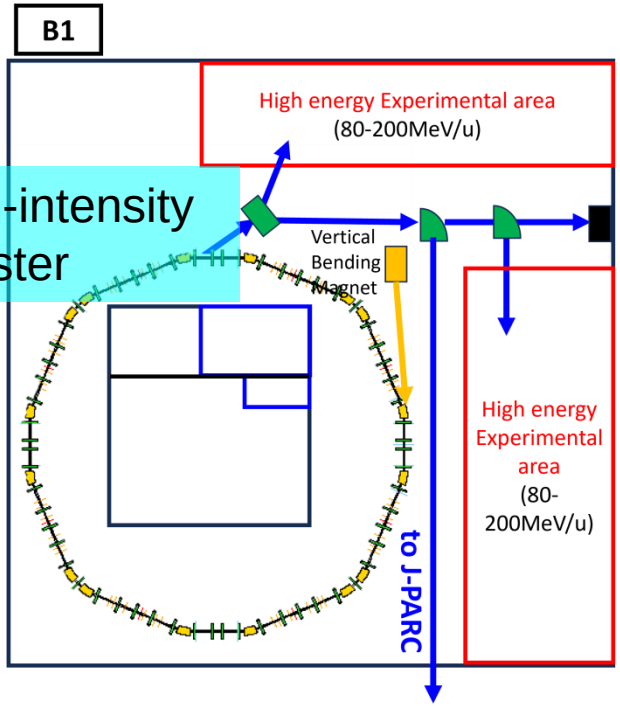
Phase I
10^8 / spill

HI Injector and facility







High-intensity Booster

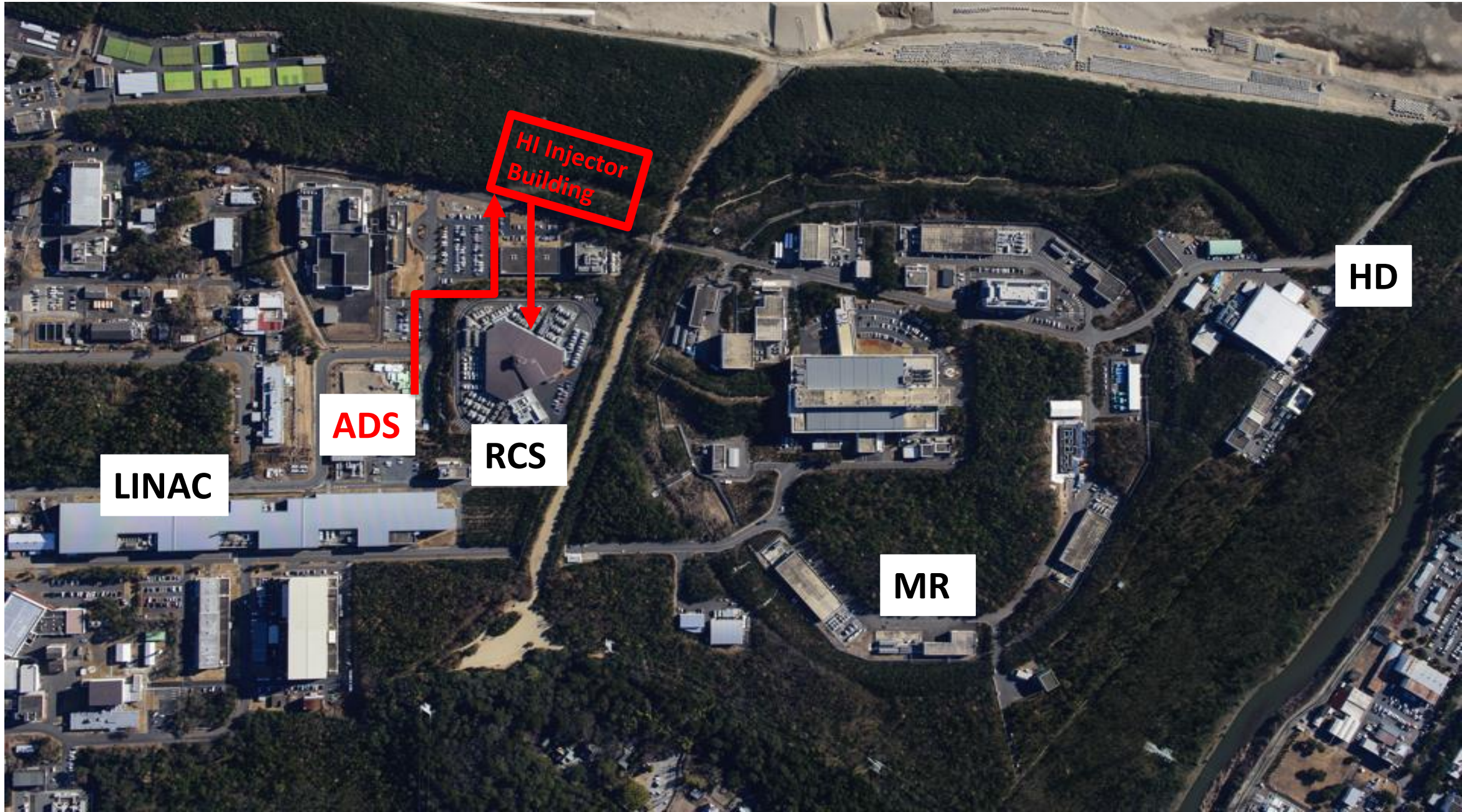
Conceptual design by H. Harada (J-PARC)

"Tokai HI Frontier Project" at JAEA
Super-heavy nuclear physics
Nuclear chemistry
Reactor fuels and materials
J-PARC-HI Injector

Phase II
10^{11}/ spill

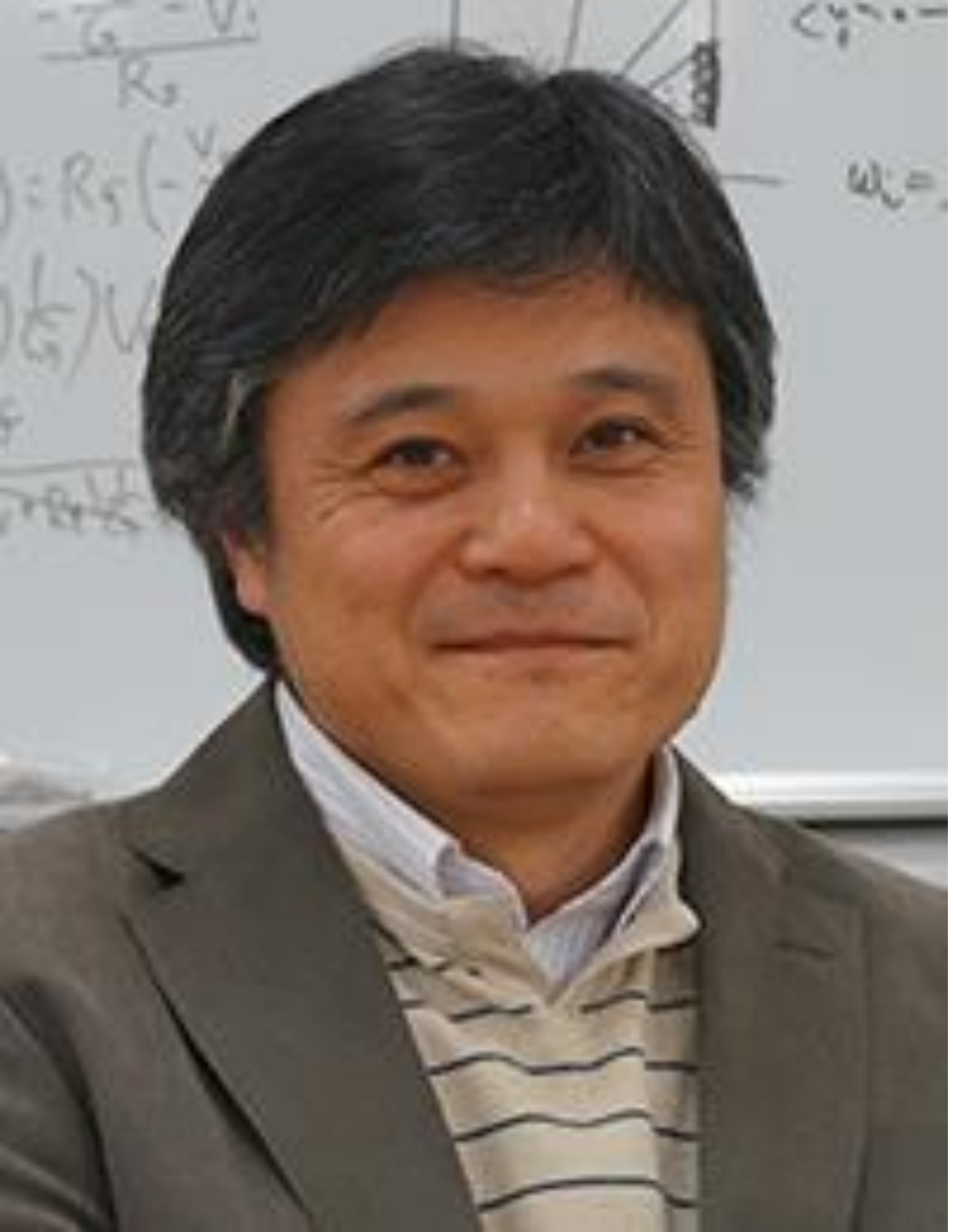
RI Beam Acceleration

Future Future-Plans : Unstable Ion beams from ADS



Summary

- We have briefly introduced the possible scheme to accelerate heavy-ions by J-PARC MR.
- Using old but existing **KEK-PS 500-MeV Booster** and **JAEA Tandem VdG SC Booster Linac**, we can drastically shorten the construction time & money (~200 M$) of Heavy-Ion injector to the present J-PARC!
- Low and intermediate energy HI laboratory will be prepared for Tandem VdG users. Injector accelerators will be used solely for low energy experiments during proton run period of J-PARC.
- + Two more NEWS



Prof. Shimizu-Izumi

Institute of Pure and Applied Sciences, The University of Tsukuba.
(New ANPhA Board member from Japan as a successor to KHT)