

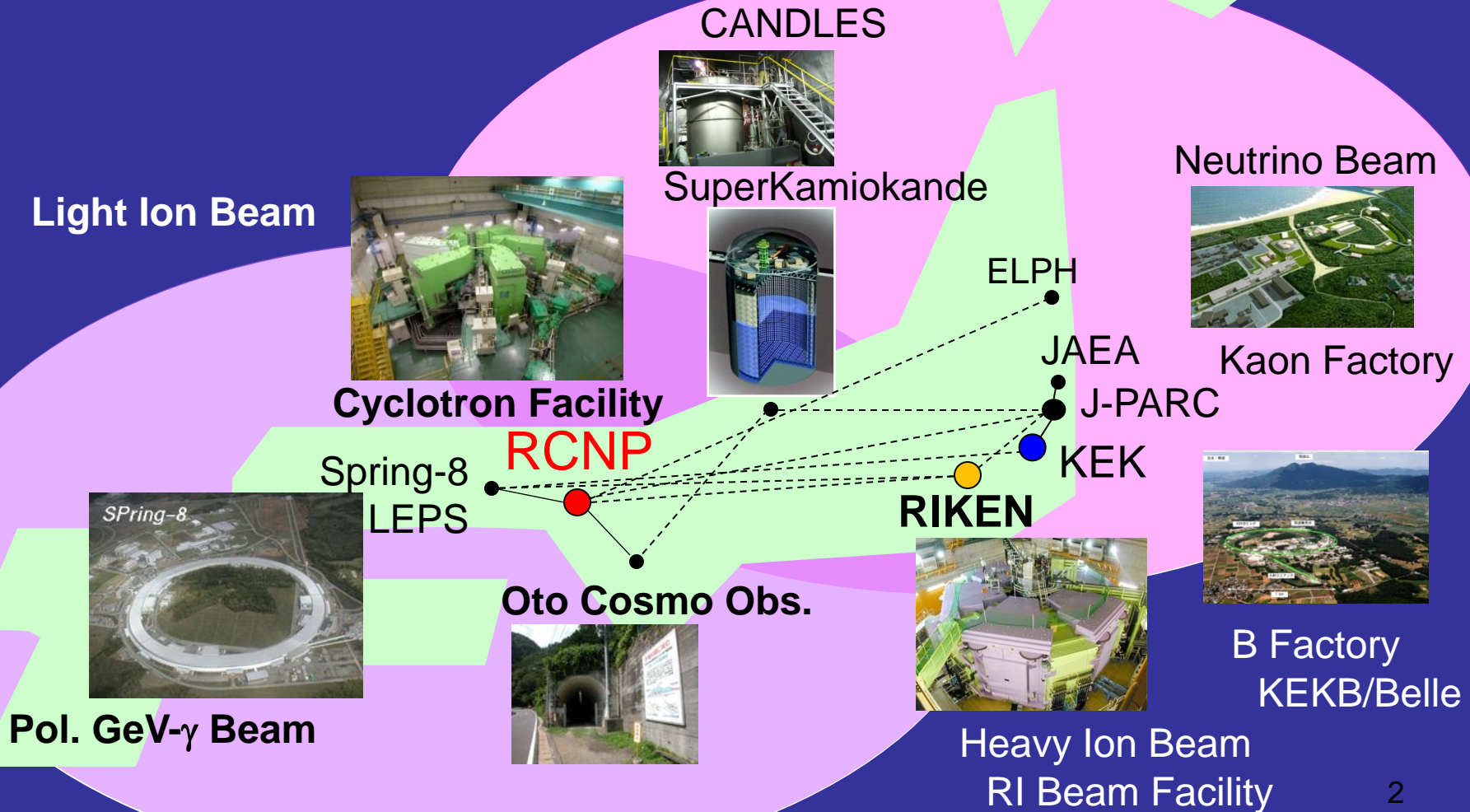
Nuclear Science in Japan

Tadafumi Kishimoto

Physics Department and RCNP

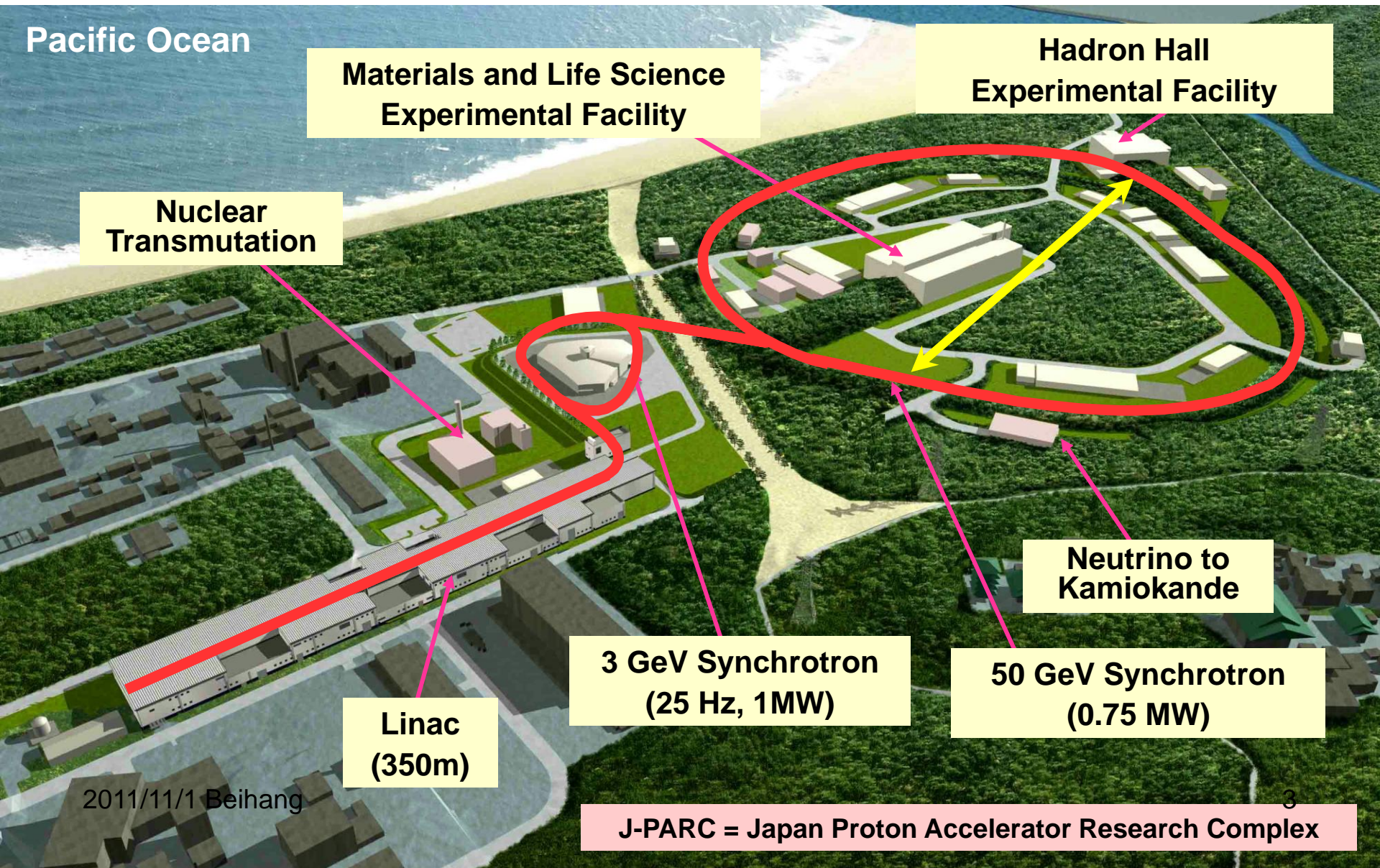
Osaka Univ.

Nuclear and Particle Physics in Japan



J-PARC

for High Power Proton Beam of ~Mega Watt



Pacific Ocean

Materials and Life Science
Experimental Facility

Hadron Hall
Experimental Facility

Nuclear
Transmutation

3 GeV Synchrotron
(25 Hz, 1MW)

Neutrino to
Kamiokande

50 GeV Synchrotron
(0.75 MW)

Linac
(350m)

2011/11/1 Beihang

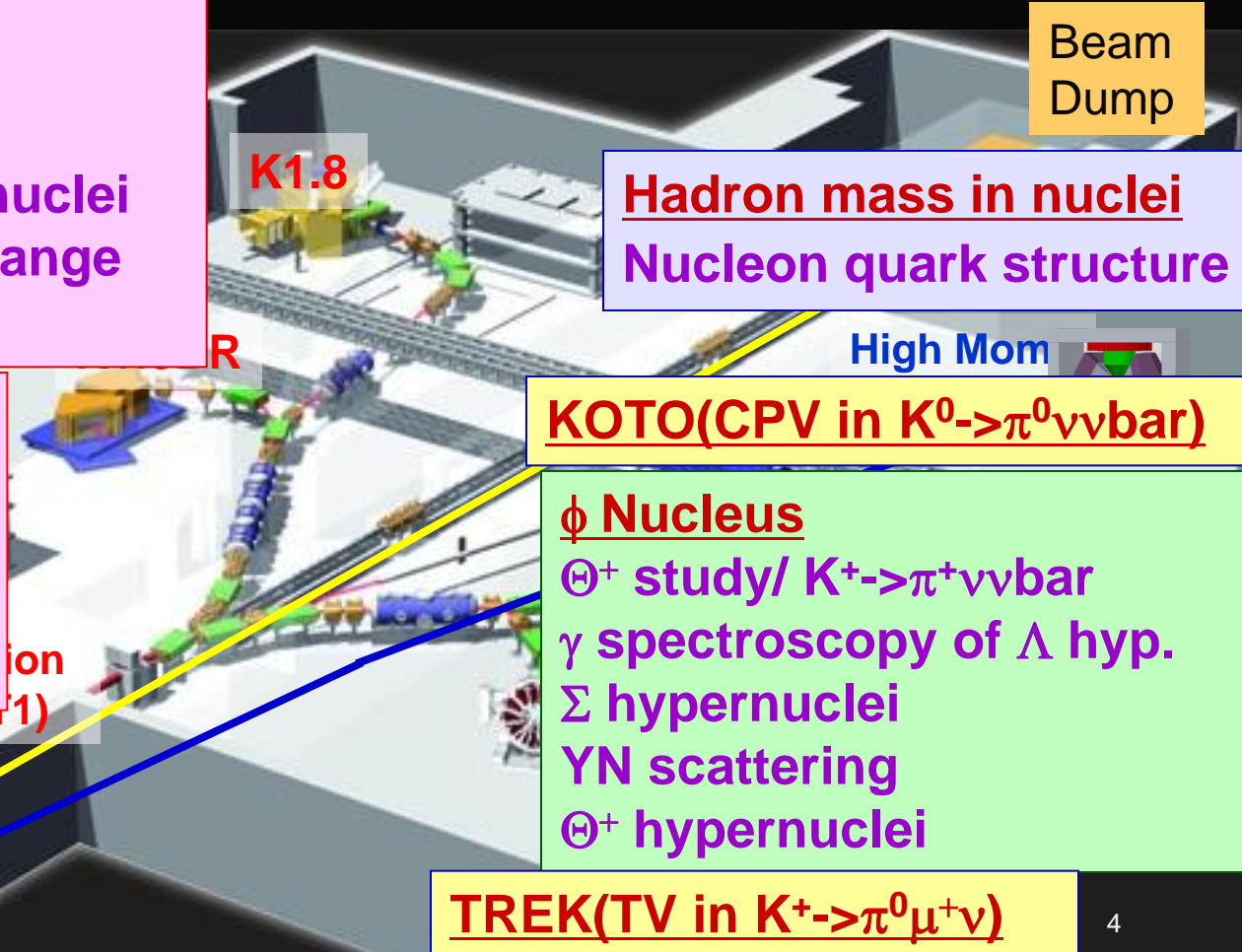
J-PARC = Japan Proton Accelerator Research Complex

J-PARC Hadron Hall

approved / proposed (incl. LOI)

- γ spectroscopy of Λ hypernuclei
- n-rich Λ hypernuclei
- Ξ hypernuclei
- $\Lambda\Lambda$ hypernuclei
- Ξ -atomic X rays
- Θ^+ search
- K^- nucleus via $d(\pi^+, K^+)$
- Σp scattering
- Weak decays of Λ hypernuclei
- Pion double charge exchange
- ω Nucleus

- K^- nucleus bound states
- K^- atomic X rays
- $\Lambda(1405)$
- η nucleus
- Double K nucleus



Beam Dump

Hadron mass in nuclei
Nucleon quark structure

KOTO (CPV in $K^0 \rightarrow \pi^0 \nu \bar{\nu}$)

ϕ Nucleus
 Θ^+ study/ $K^+ \rightarrow \pi^+ \nu \bar{\nu}$
 γ spectroscopy of Λ hyp.
 Σ hypernuclei
YN scattering
 Θ^+ hypernuclei

TREK (TV in $K^+ \rightarrow \pi^0 \mu^+ \nu$)

COMET (LFV in $\mu^- e^-$ conv.)

30~50 GeV
primary beam

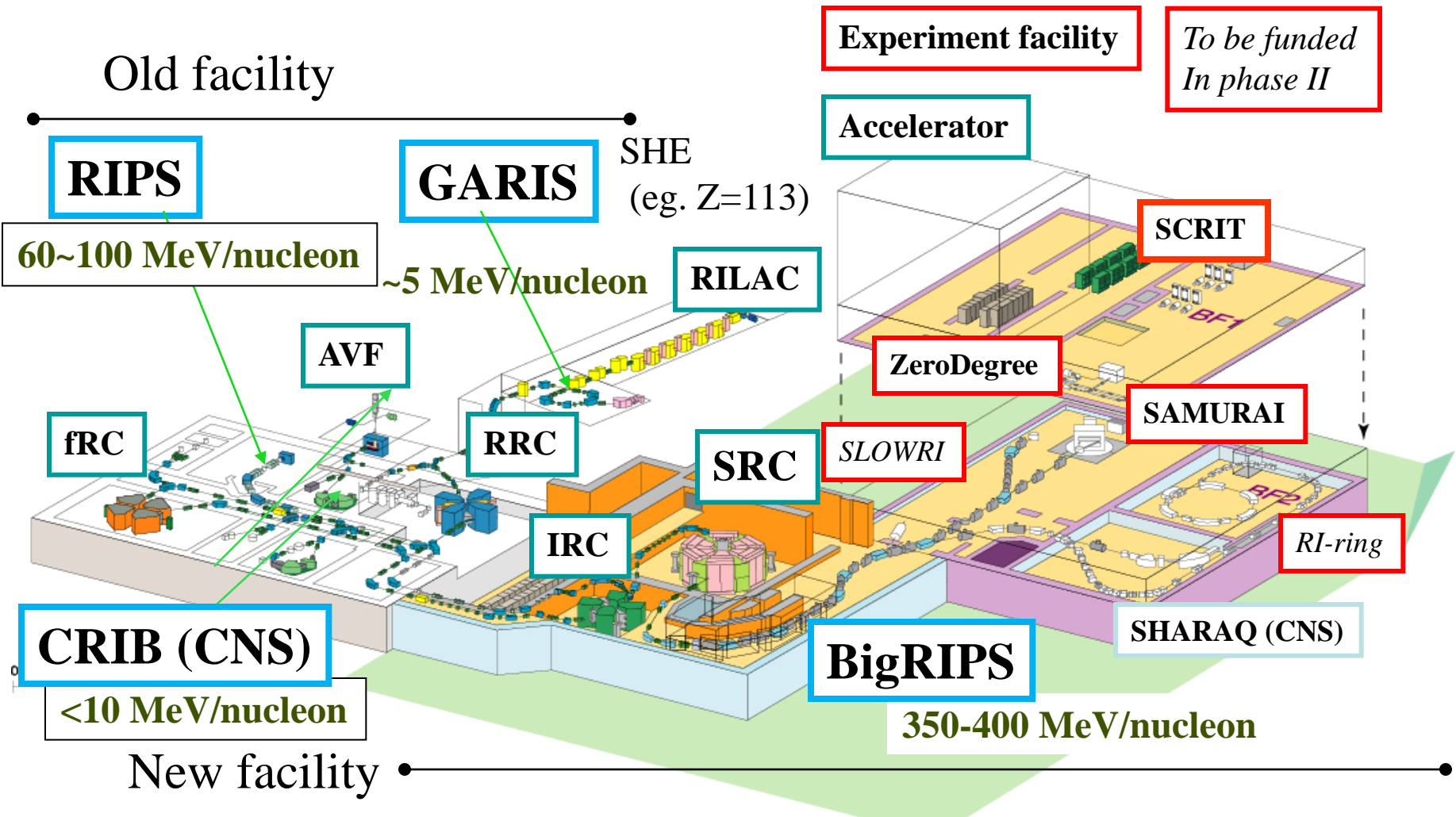
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RI=Radioactive Isotope B=Beam F=Factory

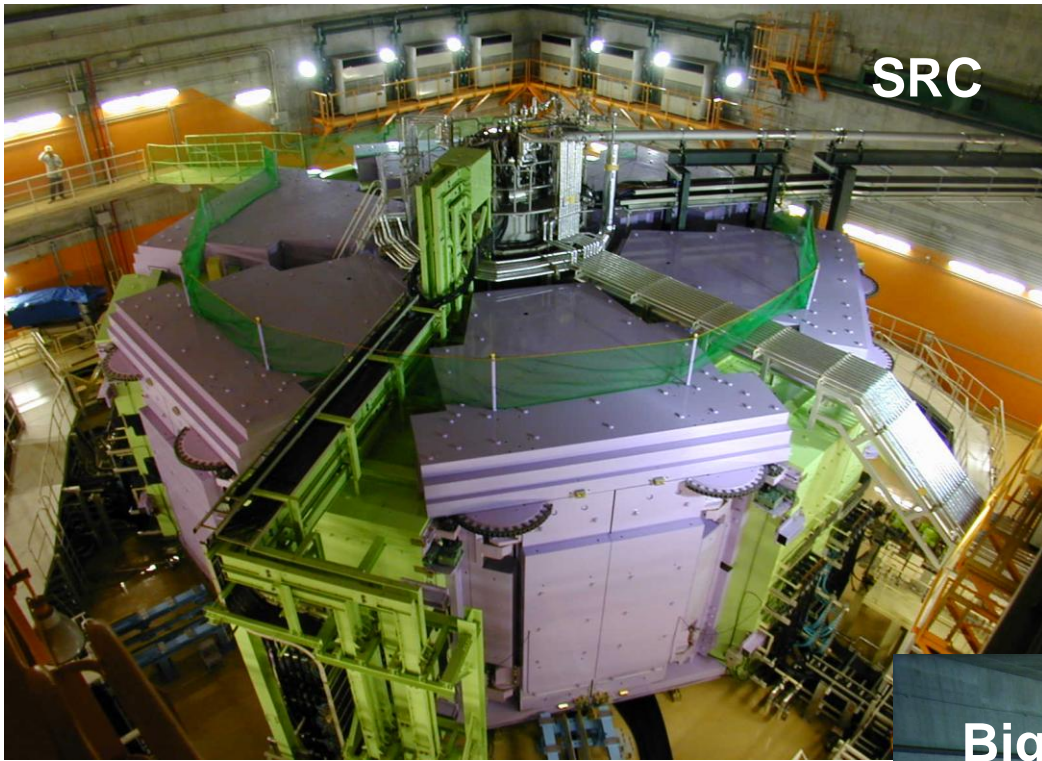
Mass production of radioactive isotopes as secondary beams



RIKEN RI Beam Factory (RIBF)



Intense (80 kW max.) H.I. beams (up to U) of 345A MeV at SRC
Fast RI beams by projectile fragmentation and U-fission at BigRIPS
Operation since 2007



SRC

Superconducting Ring Cyclotron

**World's First and Strongest
K2600MeV**

400 MeV/u Light-ion beam

345 MeV/u Uranium beam

BigRIPS In-flight Separator

World's Largest Acceptance

9 Tm

Superconducting RI beam Separator

~250-300 MeV/nucleon RIB

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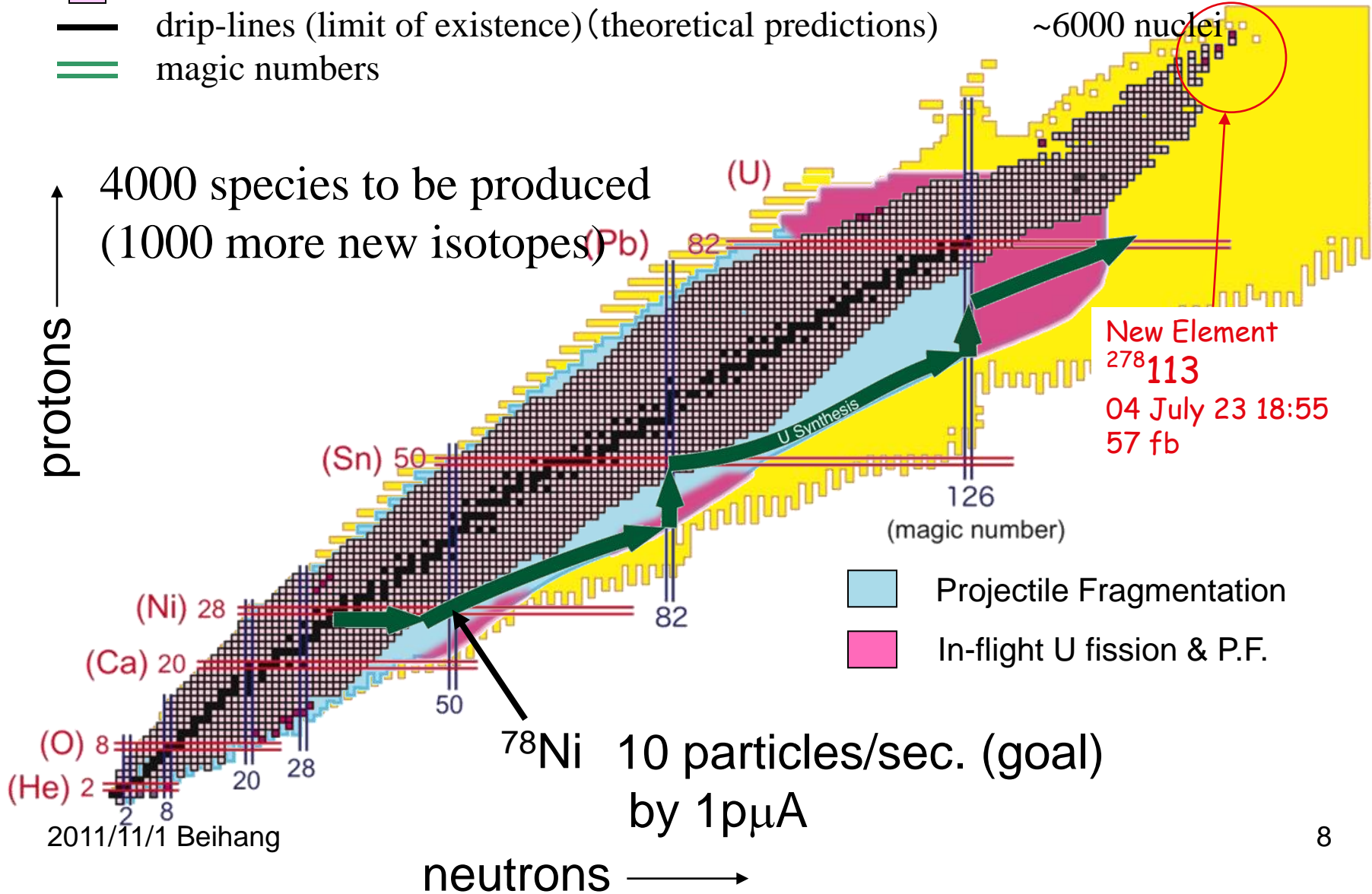


BigRIPS

Exploration of the Limit of Existence

- stable nuclei
- unstable nuclei observed so far
- drip-lines (limit of existence) (theoretical predictions)
- magic numbers

~300 nuclei
 ~2700 nuclei
 ~6000 nuclei



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RCNP : User Based Research Center for Nuclear Physics

Founded in 1971

Laser Electron Photon at SPring-8 (LEPS)

Cyclotron Facility (AVF, RING-G-RAIDEN)

Oto Cosmo Observatory (Science under the ground)

Kamioka

Light Ion Beam



Cyclotron Facility



CANDLES
Kamioka

Spring-8
LEPS



Pol. GeV- γ Beam

Oto Cosmo Obs.



RCNP

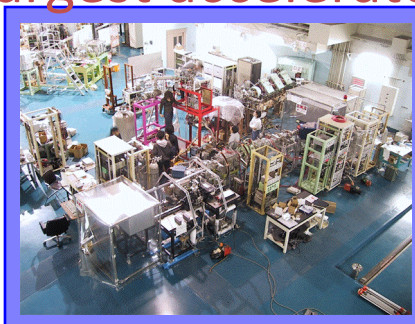
Osaka University Cyclotron Facility (Suita campus)

Largest accelerator complex belonging to universities

Neutron TOF 100m tunnel



1m × 1m × 10cm × 6
scintillators

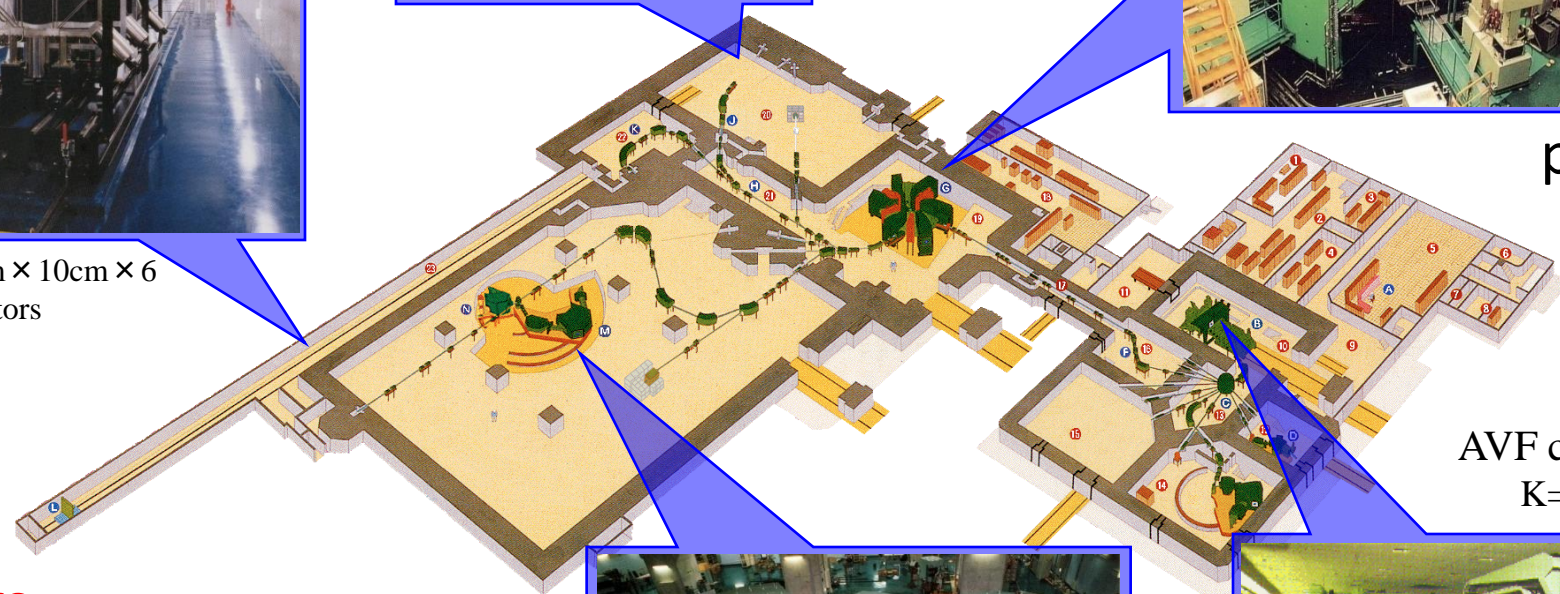


RI beam, UCN

Ring cyclotron K=400 MeV



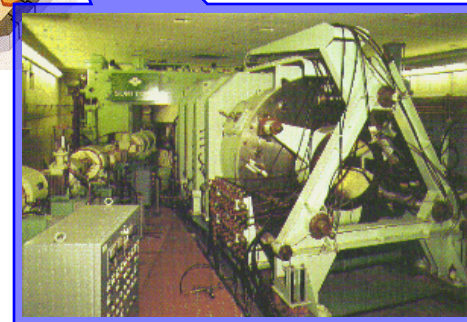
p to Kr



AVF cyclotron
K=140 MeV

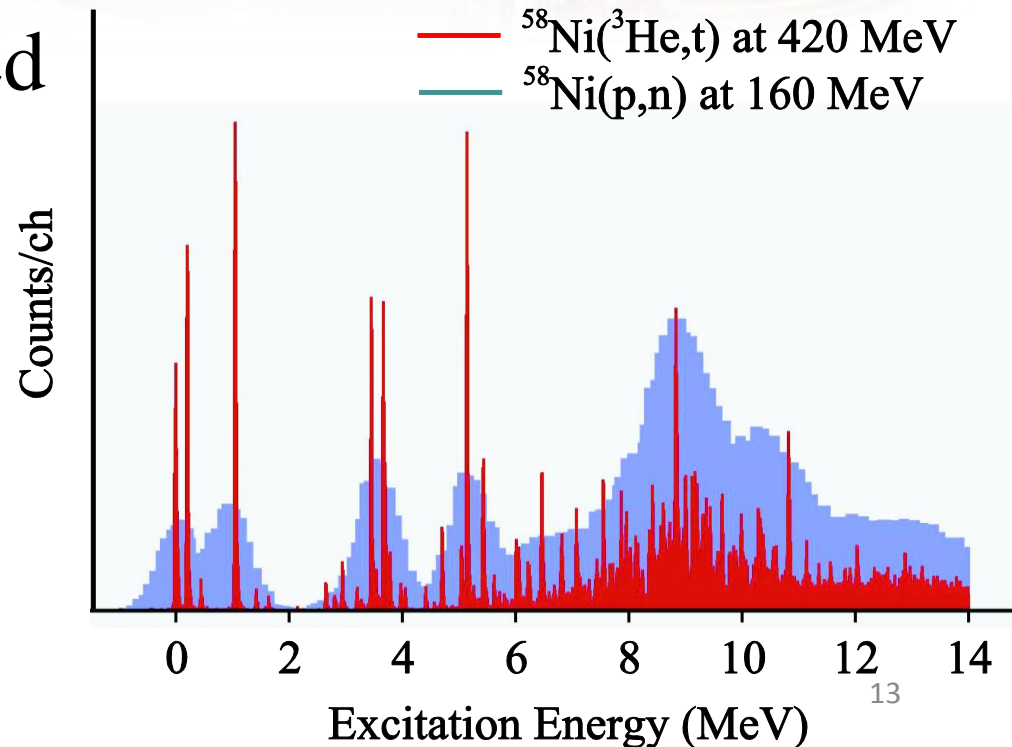
users
~ 400/y
abroad
~ 50/y

High resolution
Magnetic spectrometers

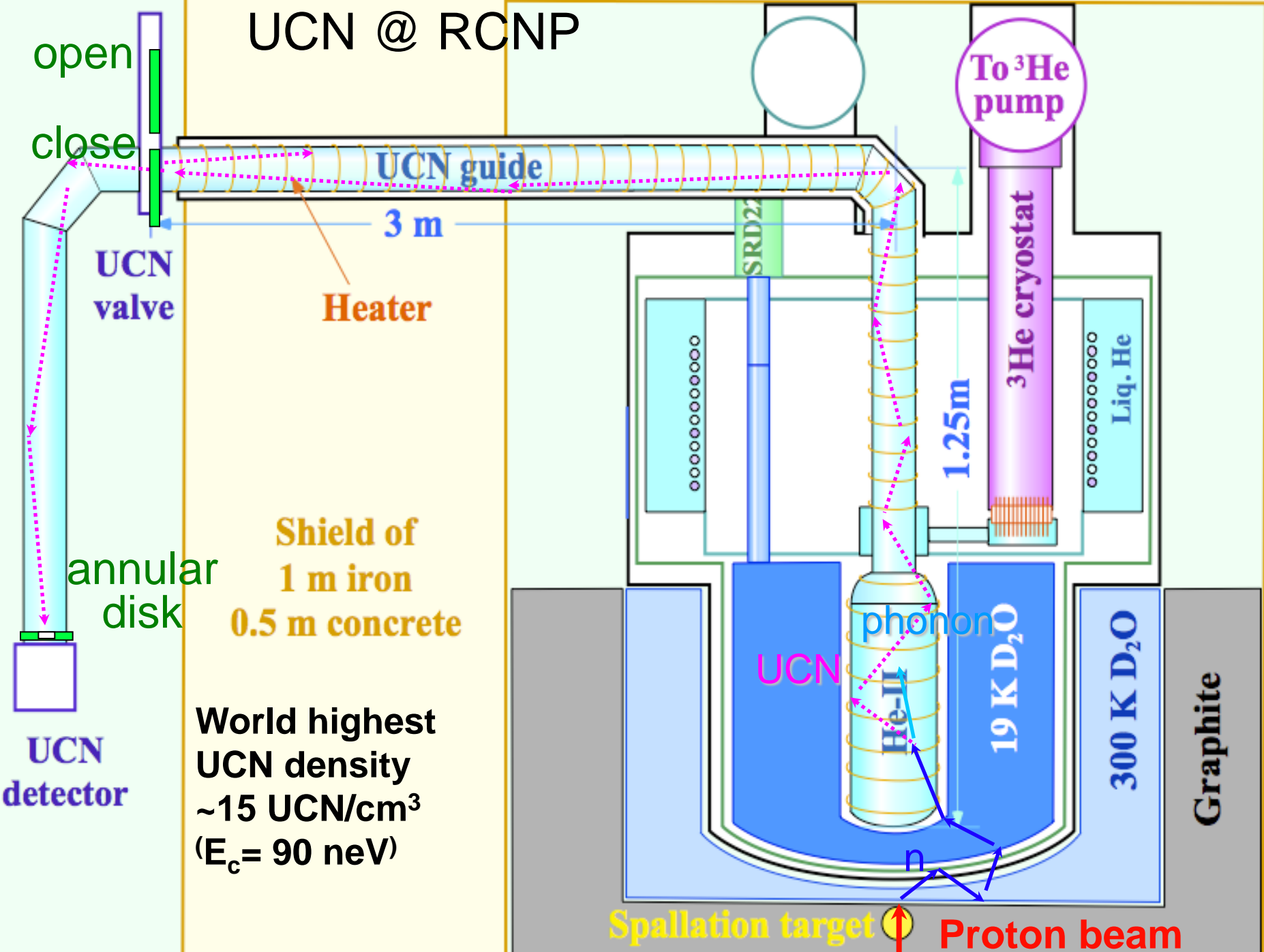


Research with Ring cyclotron

- Nuclear structure and reactions
 - Giant resonance and its decay
 - GT giant resonances and their high resolution study
 - Few body system and three body force
- Weak form factor probed by nuclear reaction
- Ultra cold neutron
- Cosmo-nuclear physics
 - Heavy ion reaction

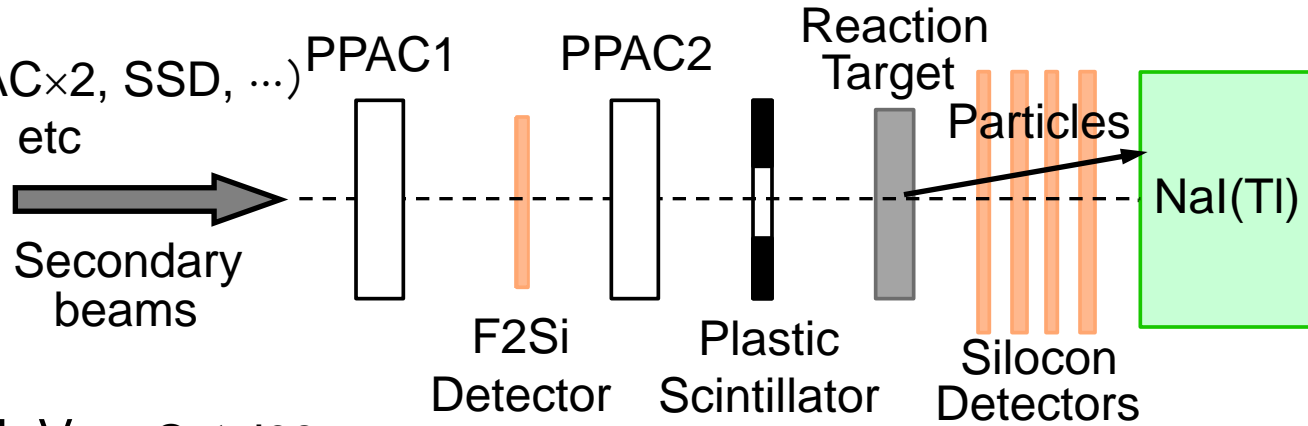


UCN @ RCNP



RI beam at RCNP

- ✓ Improvements
- ✓ Beam diagnostics (PPAC×2, SSD, ...)
- ✓ Vacuum TMP, chamber, etc

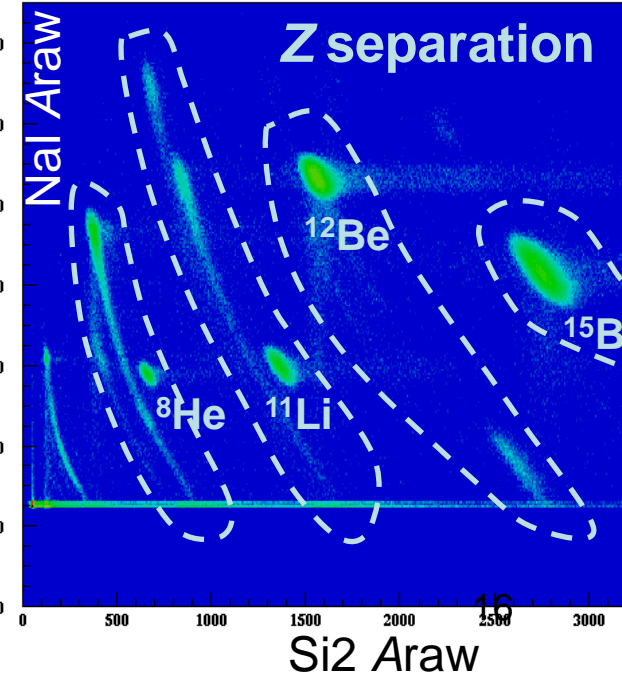
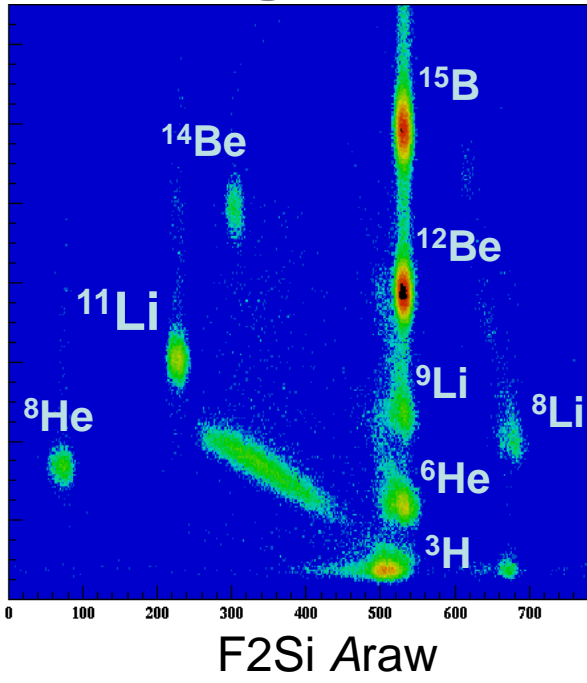
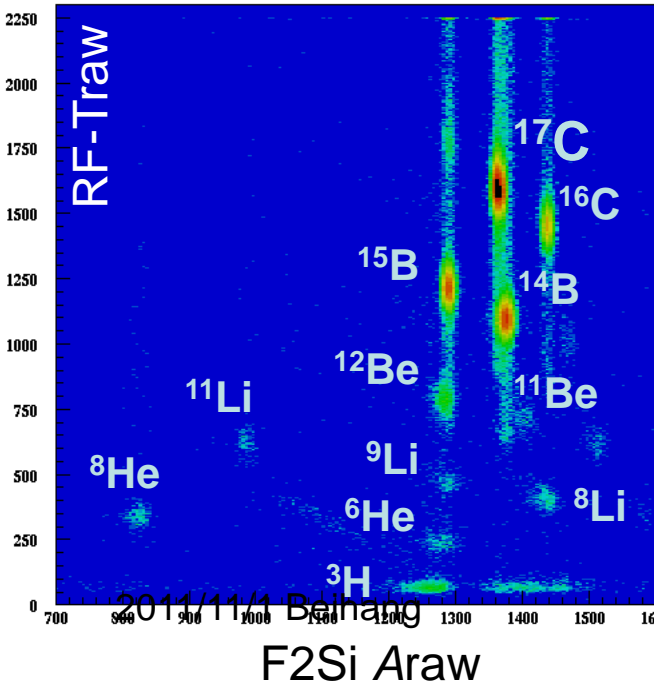


80A MeV $^{18}\text{O} \rightarrow 30\text{A MeV}$ Oct. '09

^{17}C setting: Beam PID

^{11}Li setting: Beam PID

^{11}Li setting: Particle PID



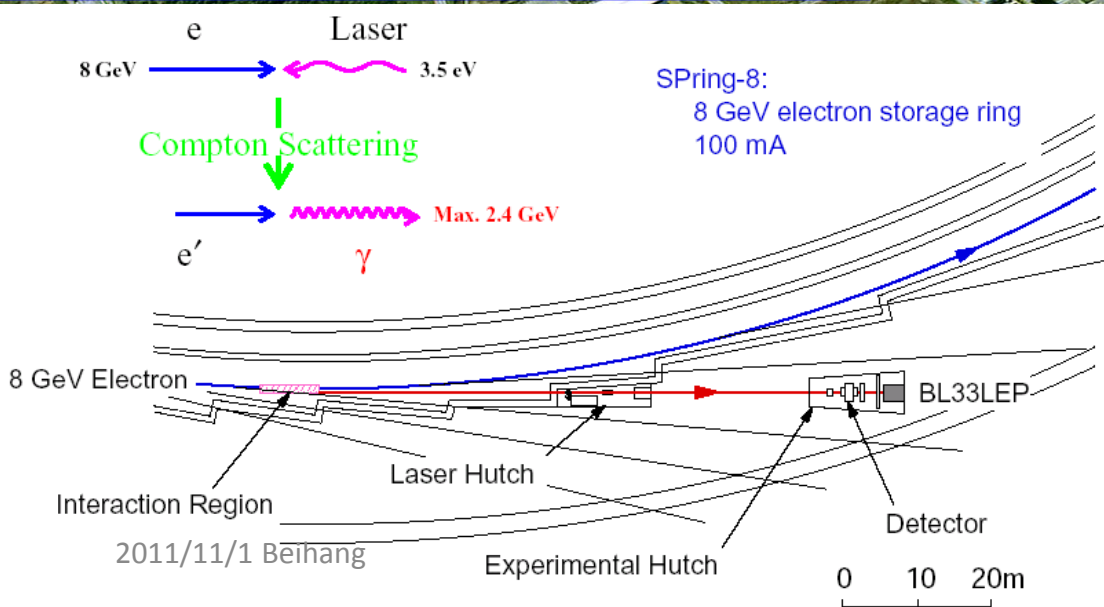
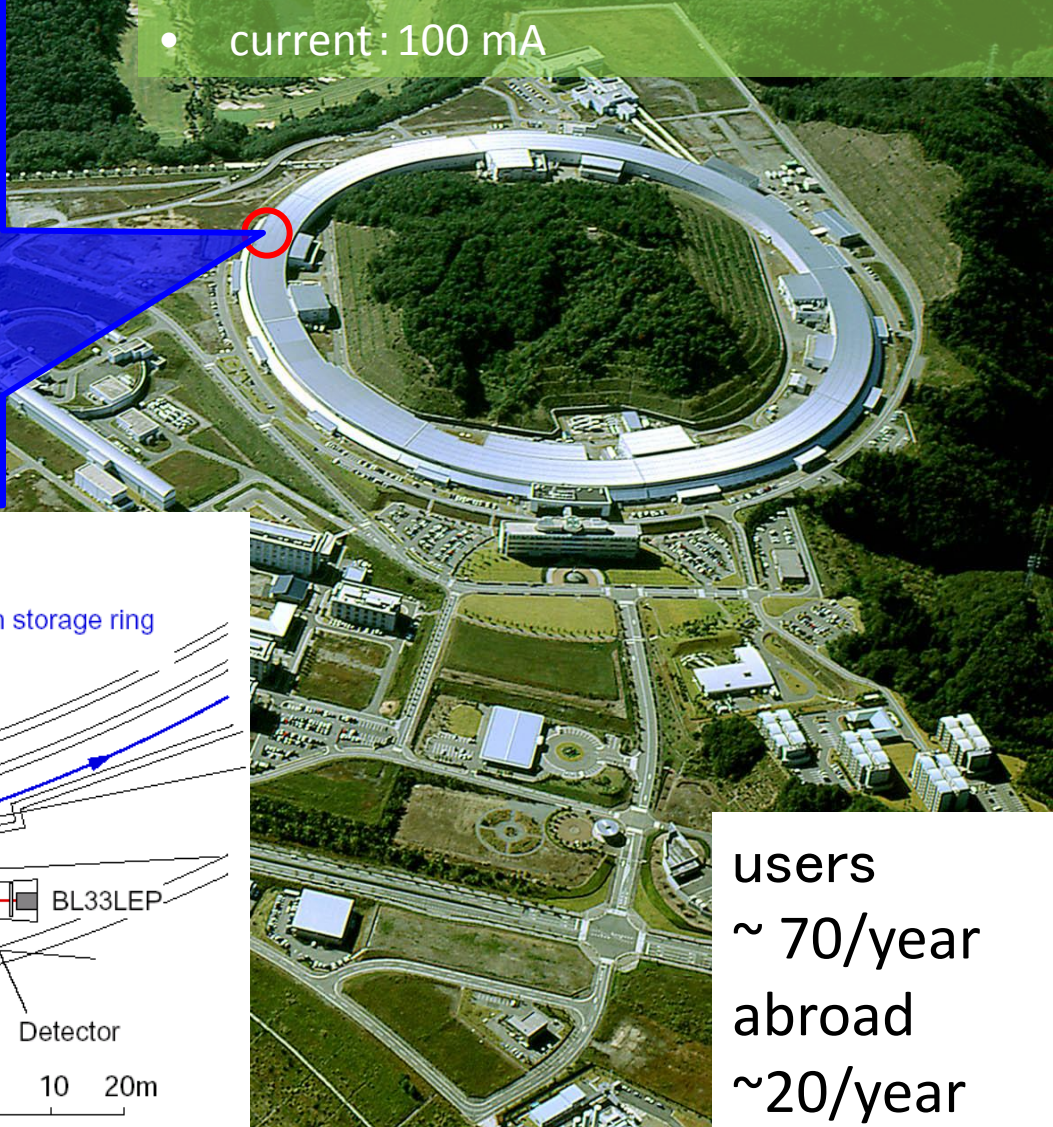
LEPS@SPring-8

Super Photon ring-8 GeV

- 3rd generation SOR
- Circumference: 1436 m
- Electron energy : 8 GeV
- current : 100 mA



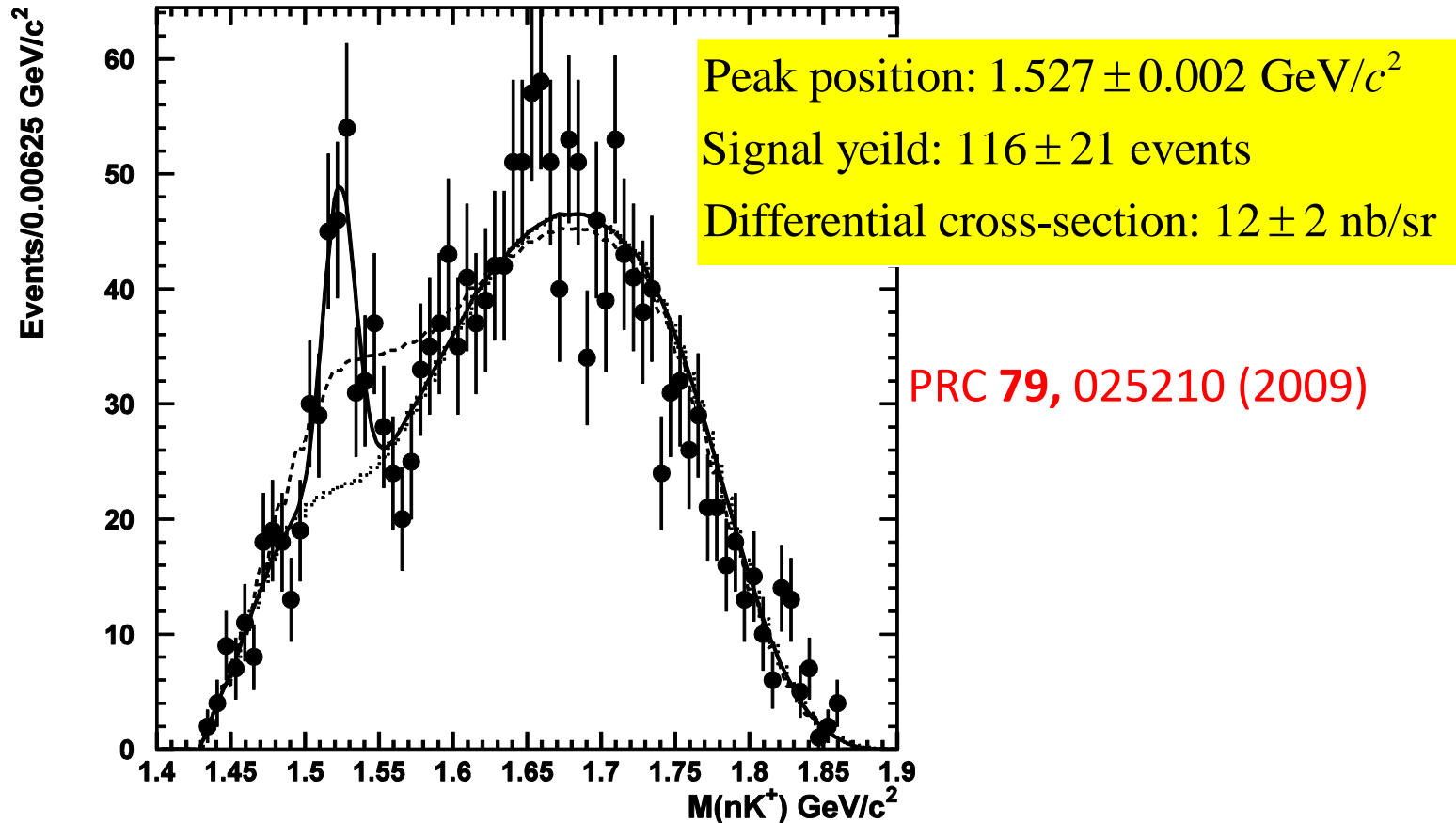
BL33LEP beam line



users
~ 70/year
abroad
~20/year

Results of Θ^+ analysis

nK^+ invariant mass with MMSA: Fermi motion effect corrected.



“The narrow peak appears only after Fermi motion correction.”

$$\Delta(-2\ln L) = 31.1 \text{ for } \Delta ndf = 2$$

$$\longrightarrow 5.2\sigma$$

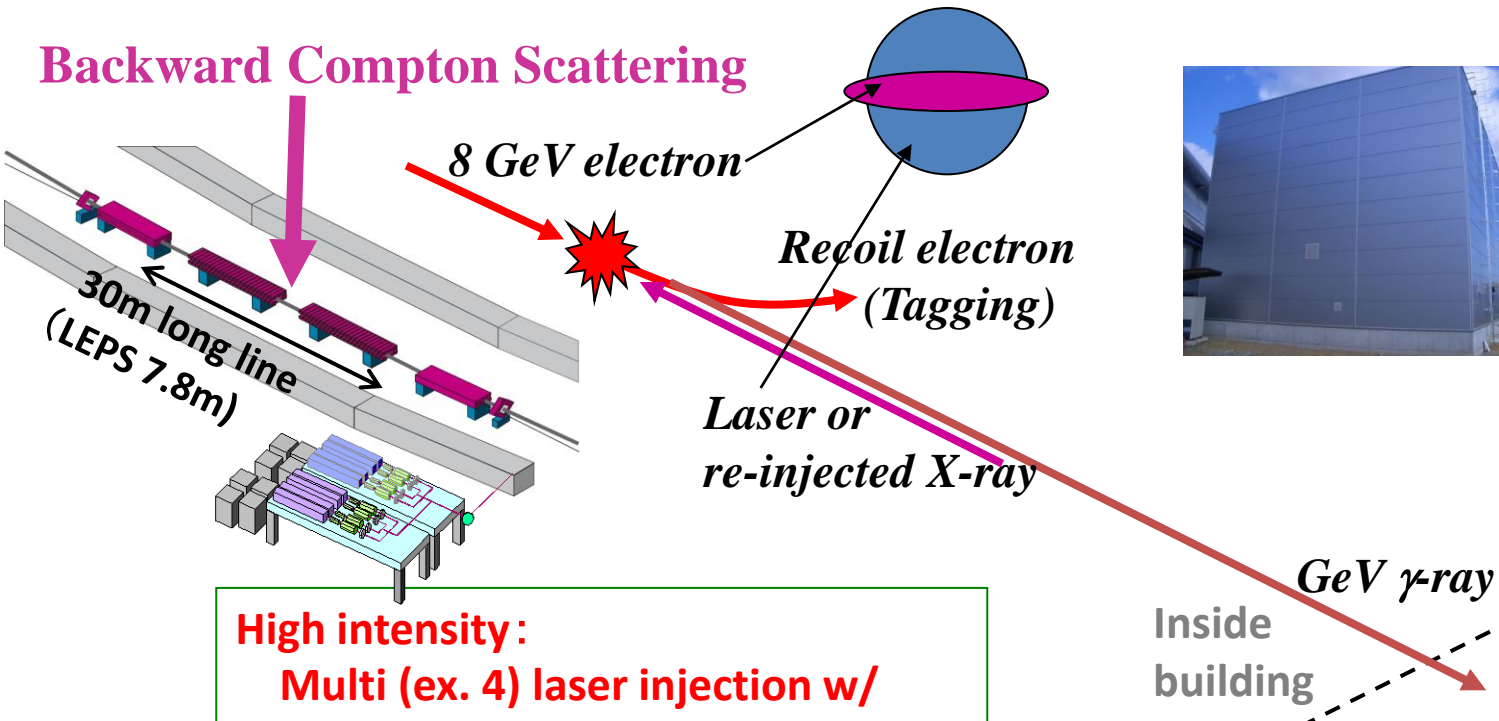
$$\text{Prob}(5.2\sigma) = 2 \times 10^{-7}$$

Present to near future

- Cyclotron accelerator facility
 - Study of nuclear physics
 - Applications: radiochemistry, medical, solid state physics
- Research center for subatomic science (present)
 - LEPS2: Hadron physics (GeV photon)
 - MUSIC: Lepton Flavor mixing (muon)
 - CANDLES: Double beta decay (Lepton number violation)
 - Collaboration with J-PARC, RIKEN, Tohoku,...
- Higher Intensity for cyclotron facility (near future)
 - Neutron EDM, Muon, BNCT

LEPS2 Project at SPring-8

Backward Compton Scattering



LEPS2 experimental hall
RIKEN-NISHINA

E949 BNL



High intensity:
Multi (ex. 4) laser injection w/
large aperture beam-line &
Laser beam shaping
 $\sim 10^7$ photons/s (LEPS $\sim 10^6$)

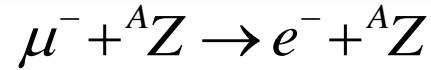
Large 4π spectrometer based on BNL-E949 detector system.
Better resolutions are expected.
New DAQ system will be adopted.

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Experimental hutch

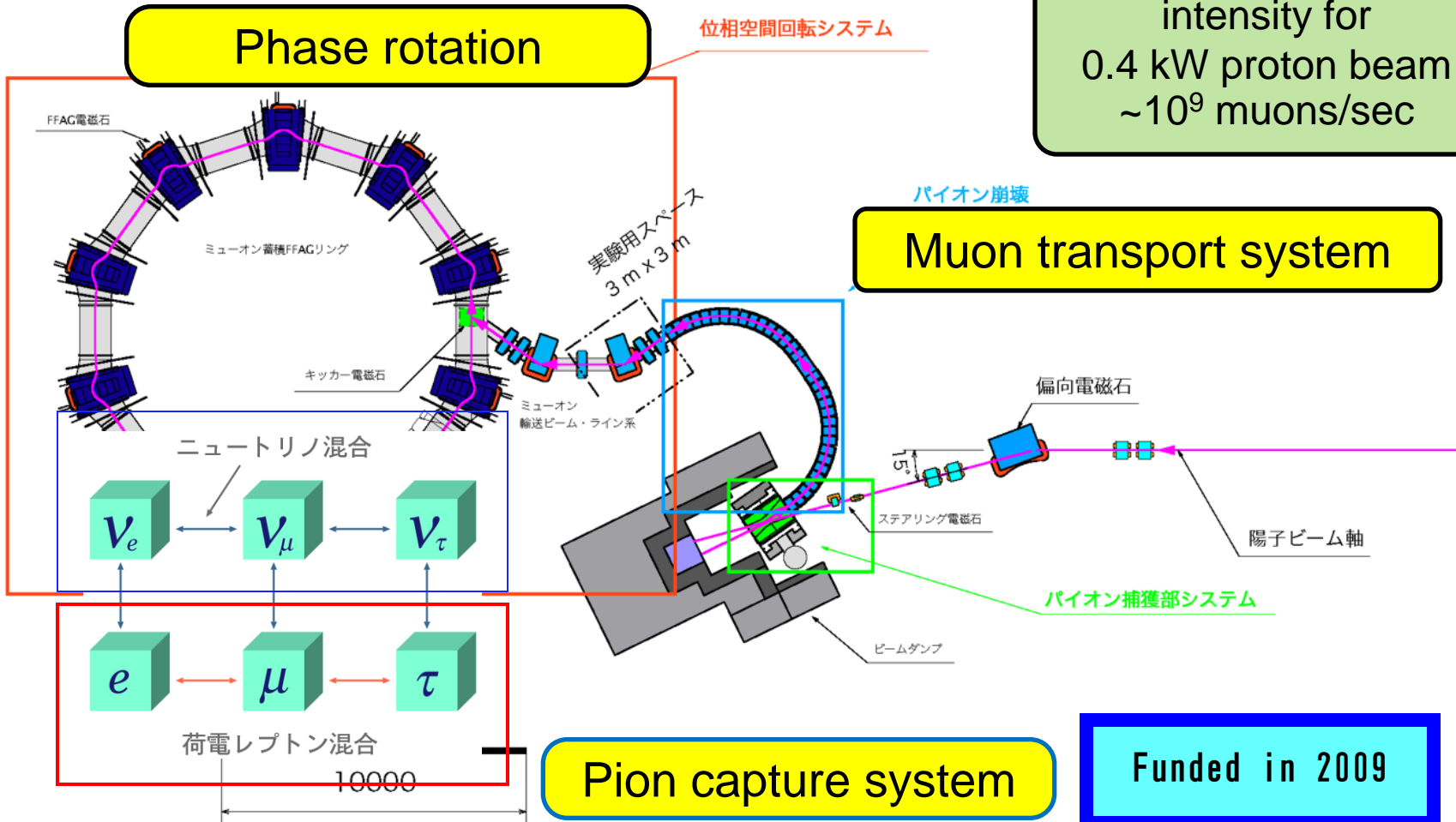
MUSIC

Why three families for quarks and leptons.



21

World highest muon intensity for 0.4 kW proton beam
 $\sim 10^9$ muons/sec



CANDLES

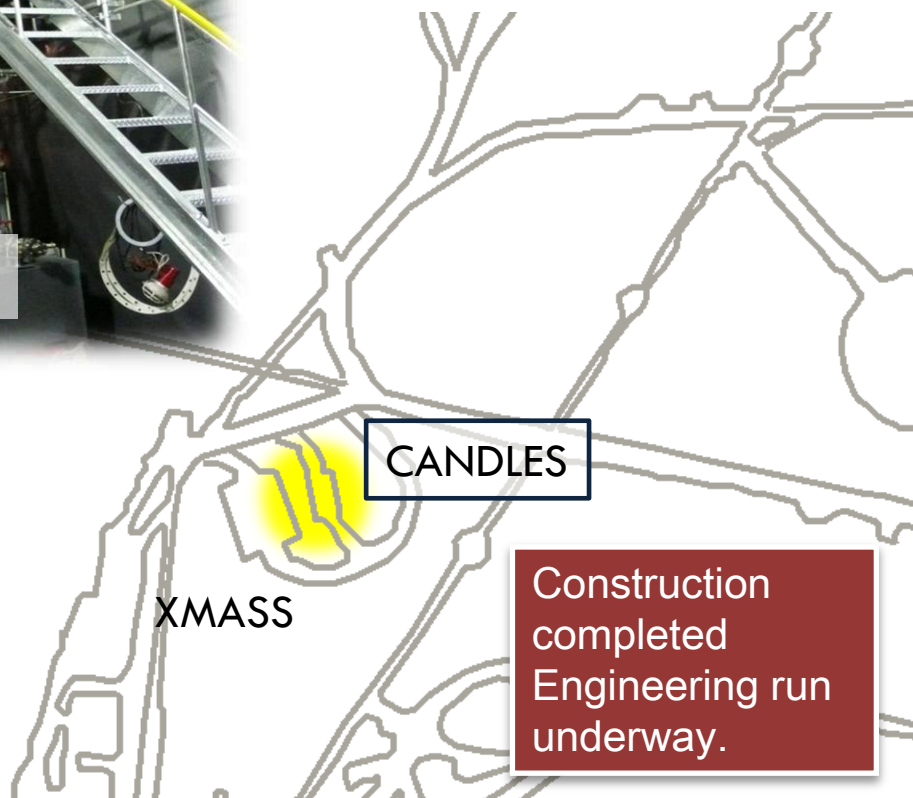
Study of ^{48}Ca double beta decay
by CaF_2 scintillator

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Kamioka underground
Laboratory

KamLAND



SK

CaF_2 crystals

