Research Center for Nuclear Physics Osaka University

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What is RCNP

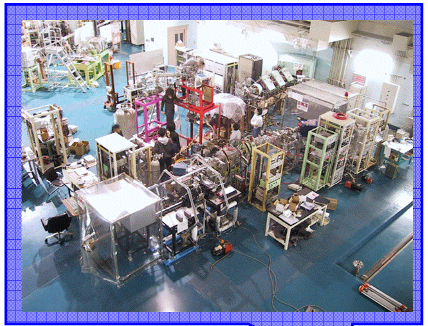
- Founded in 1971
  - User based "Research Center for Nuclear Physics"
- 1973 AVF cyclotron
- 1991 Ring cyclotron
- 1997 Oto Cosmo Observatory
- 2000 LEPS@SPring8
- 2010 Research Center for Subatomic Science (6 years)

- 19 scientific members, 6 technical staffs
- About 10 post doctors
- About 30 graduate students

Osaka University Cyclotron Facility (Suita campus)

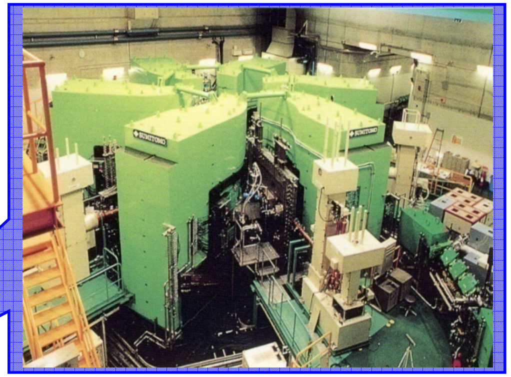
Neutron TOF 100m tunnel

1m × 1m × 10cm × 6
scintillators



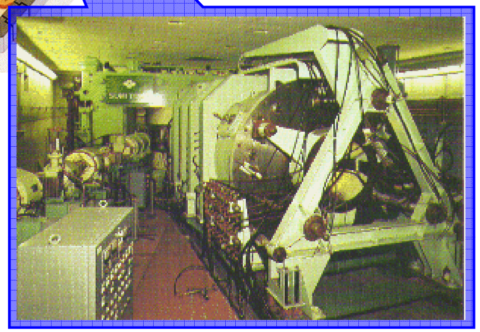
RI beam, UCN

Ring cyclotron K=400 MeV



p to Kr

AVF cyclotron
K=140 MeV

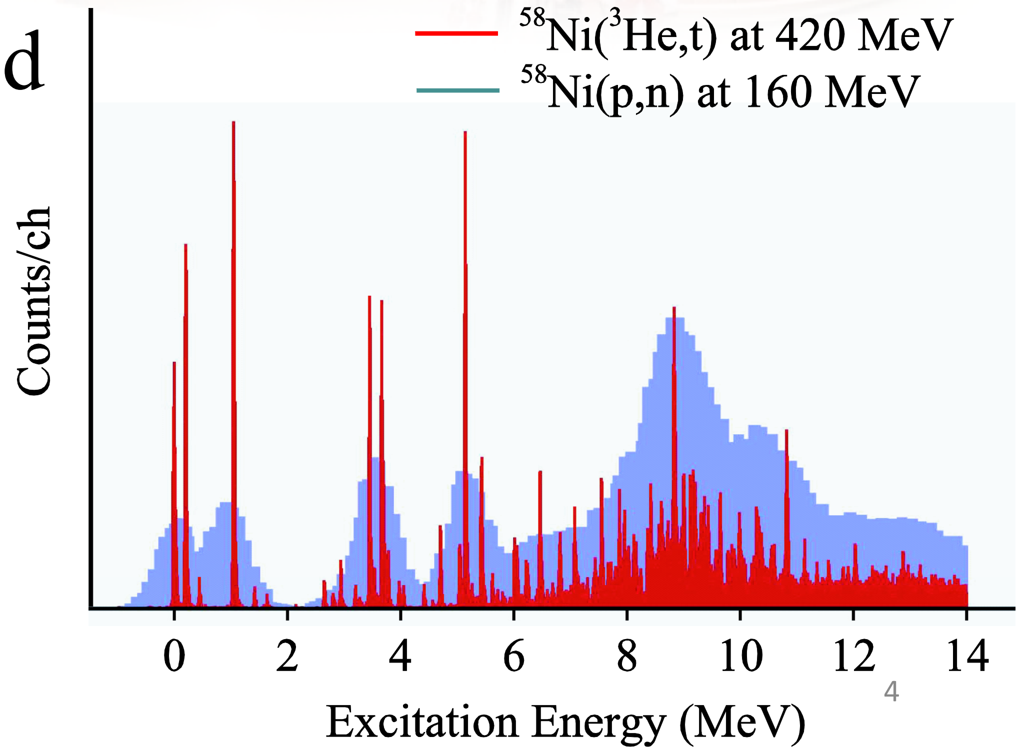


users
~ 300/y
abroad
~ 40/y

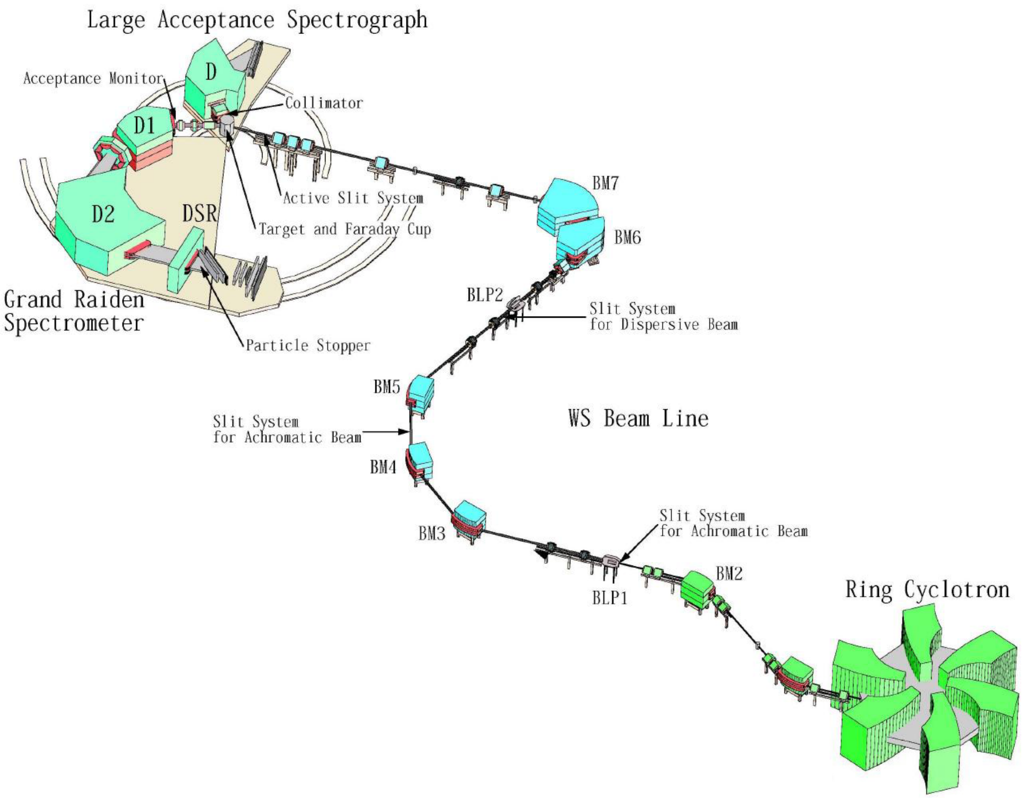
High resolution
Magnetic spectrometers

Research with Ring cyclotron

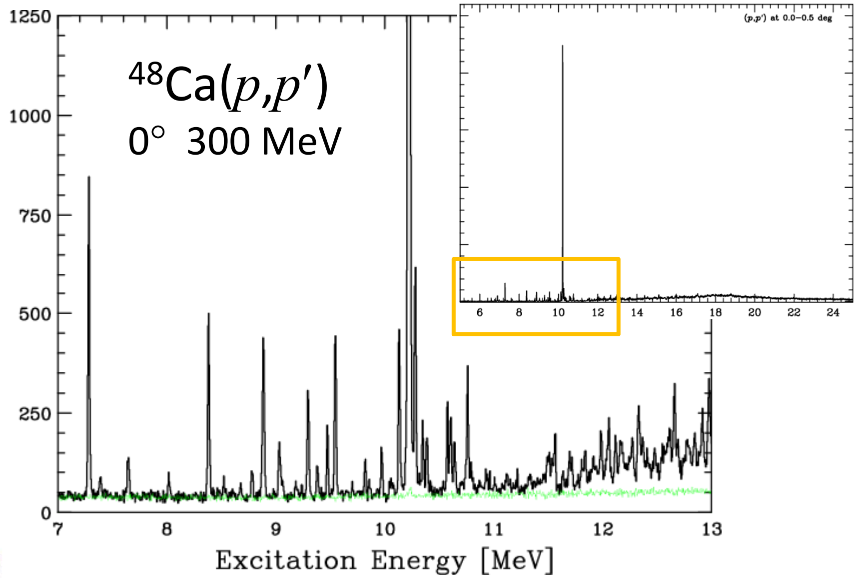
- Nuclear structure and reactions
  - Giant resonance and its decay
  - GT giant resonances and their high resolution study
  - Few body system and three body force
- Weak form factor probed by nuclear reaction
- Ultra cold neutron
- Cosmo-nuclear physics
  - Heavy ion reaction



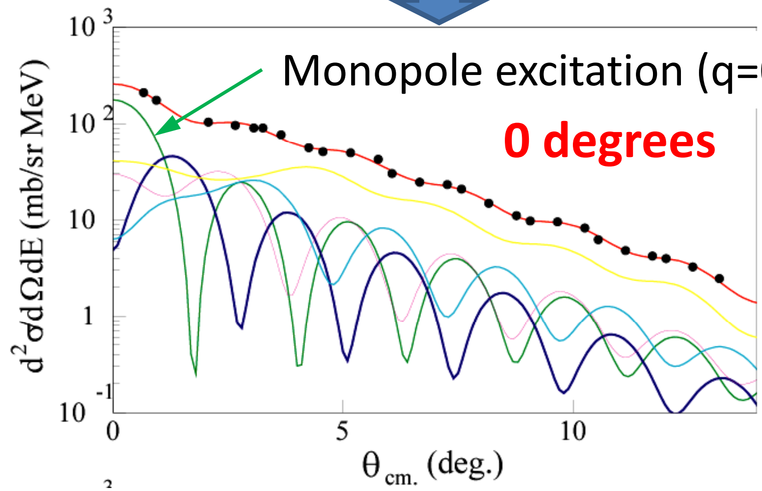
Ring cyclotron + magnetic spectrometer



Inelastic proton scattering at 0 degrees
Ultra Low BG and Ultra high resolution



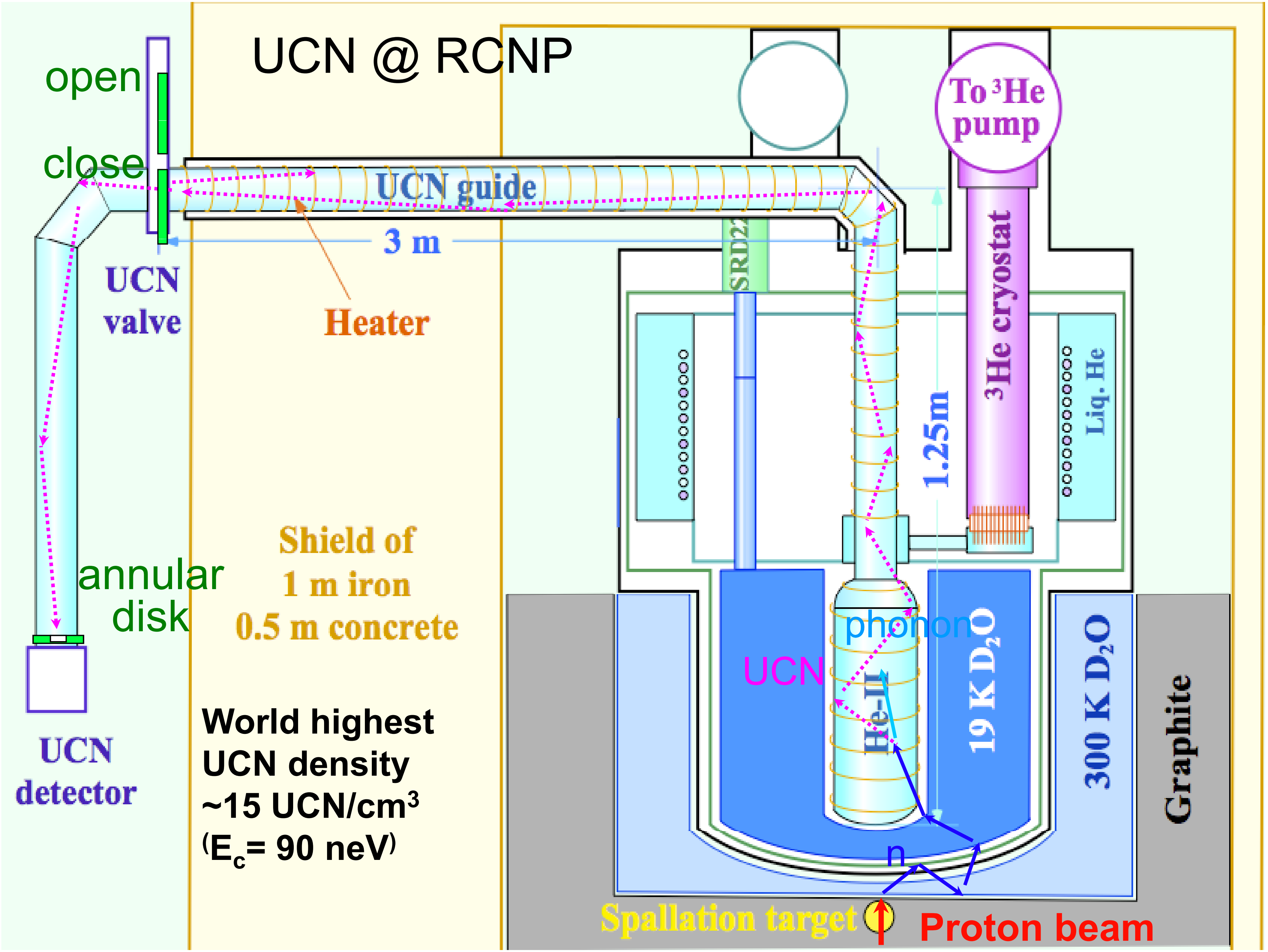
Angular distribution



Monopole excitation ω
⇒ incompressibility

High density nuclear matter
⇒ neutron stars

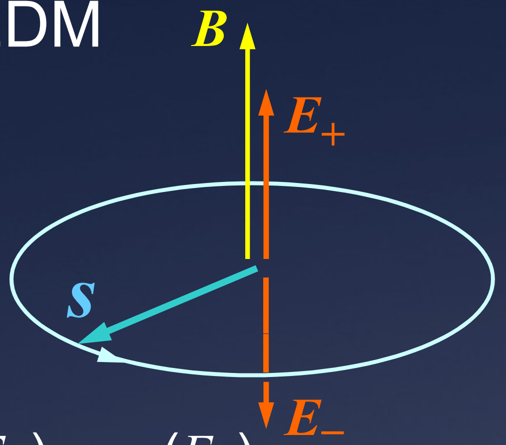
UCN @ RCNP



World highest UCN density ~15 UCN/cm^3 (E_c= 90 neV)

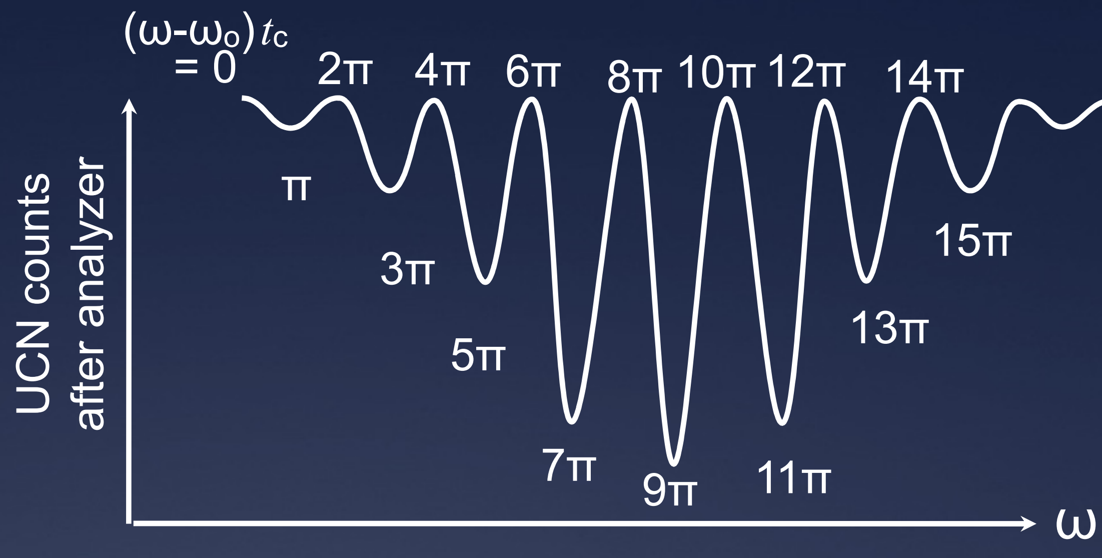
E334 (UCN)

n-EDM

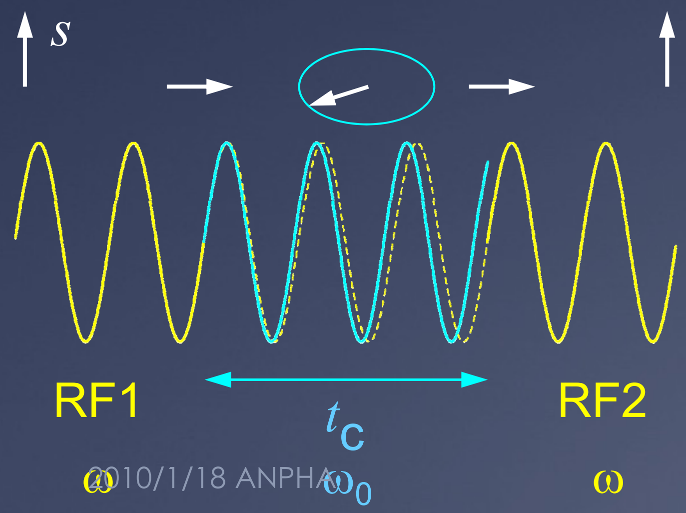


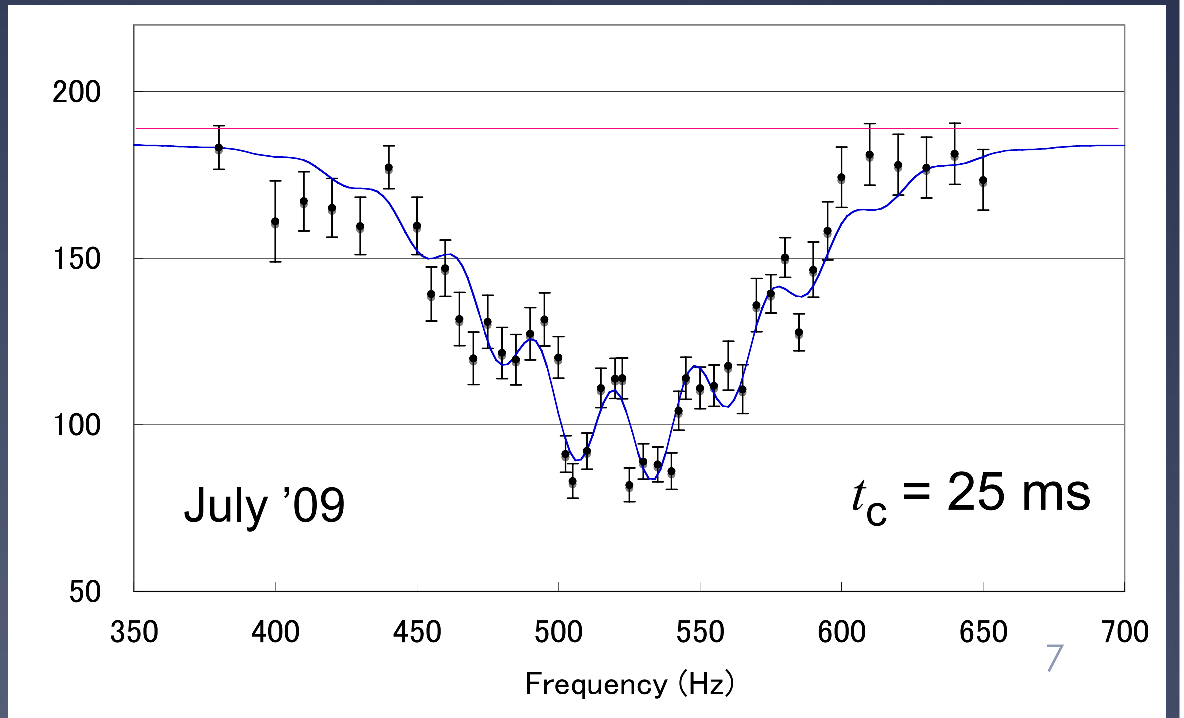
$\omega_0(E_+) - \omega_0(E_-)$

Ramsey resonance $P_n \cos(\omega-\omega_0)\, t_c$



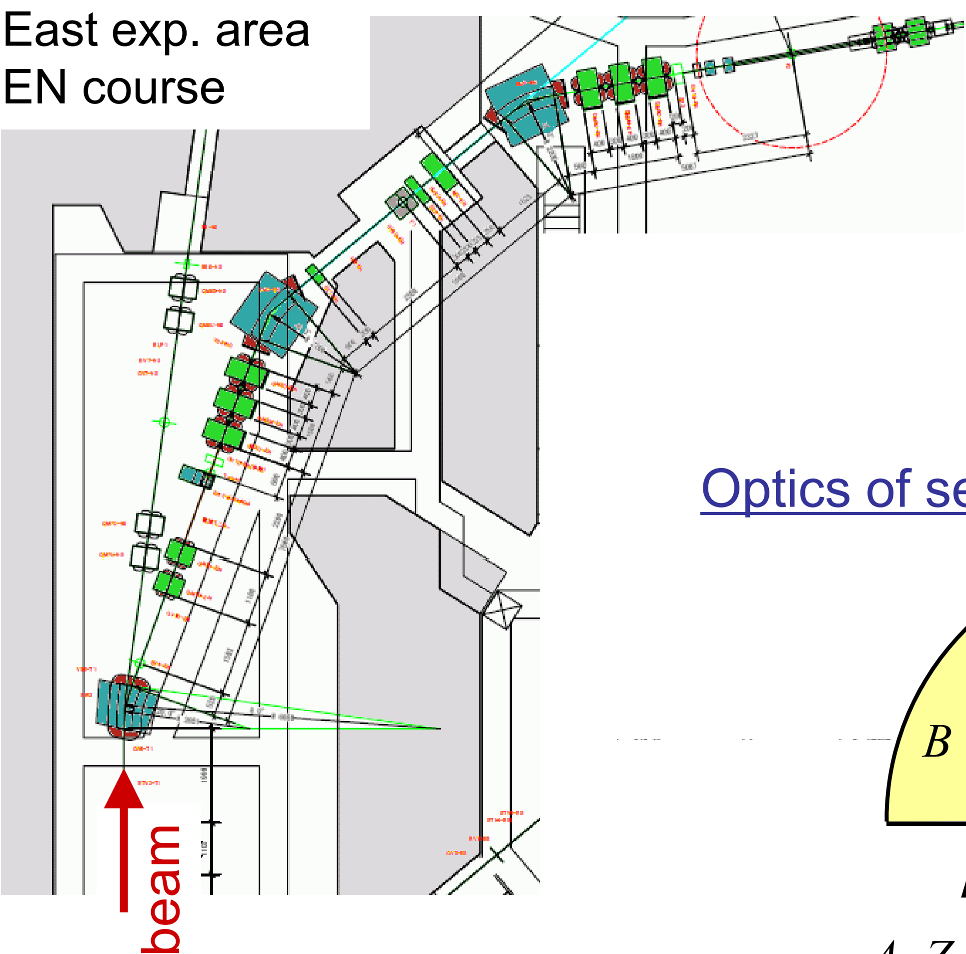
Ramsey fringe





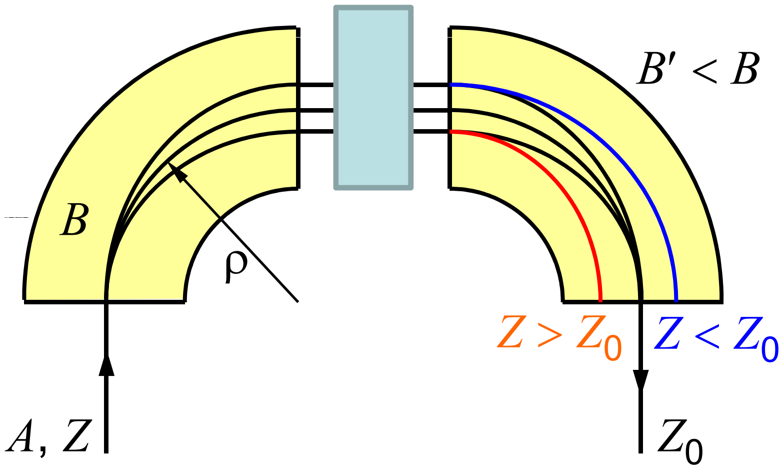
RCNP unstable nuclei project

2005 AVF renewal（superconducting ECR IS・bypath line）
2007.10 cosmo-nuclear physics division started
2008.08 project "RI beam at RCNP"



- wide energy range
  AVF（K=140）+ Ring（K=400 MeV）
- flat degrader
  small beam size @ low energy
- low background
  γ ray measurement

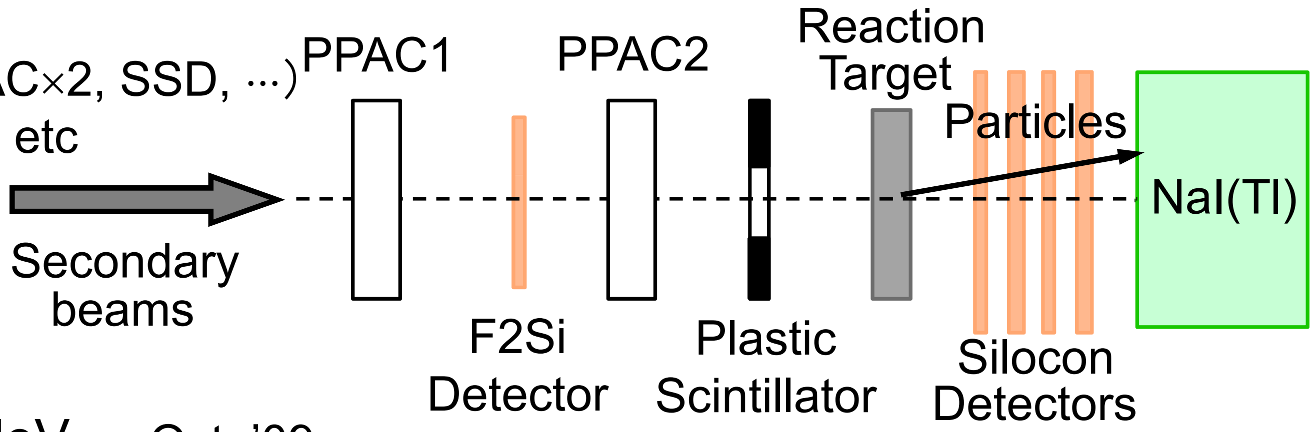
Optics of separator



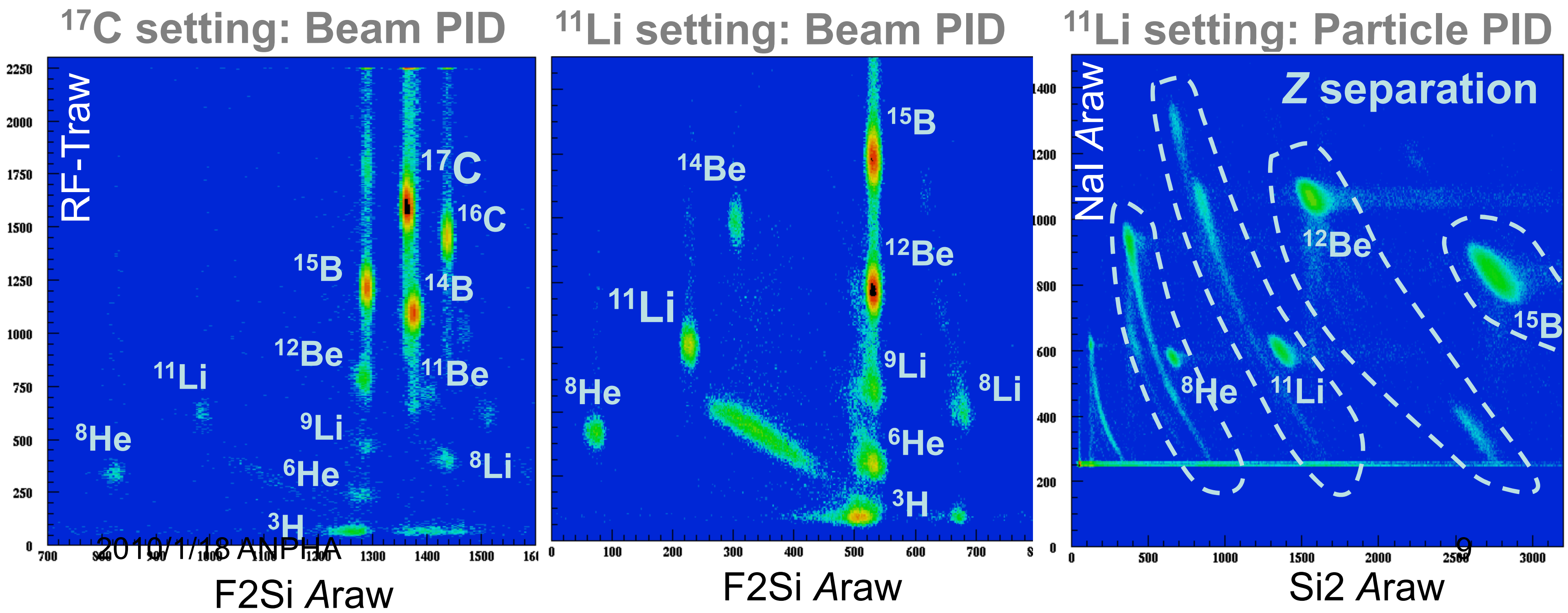
→ wedge degrader is not a sole solution

RI beam at RCNP

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



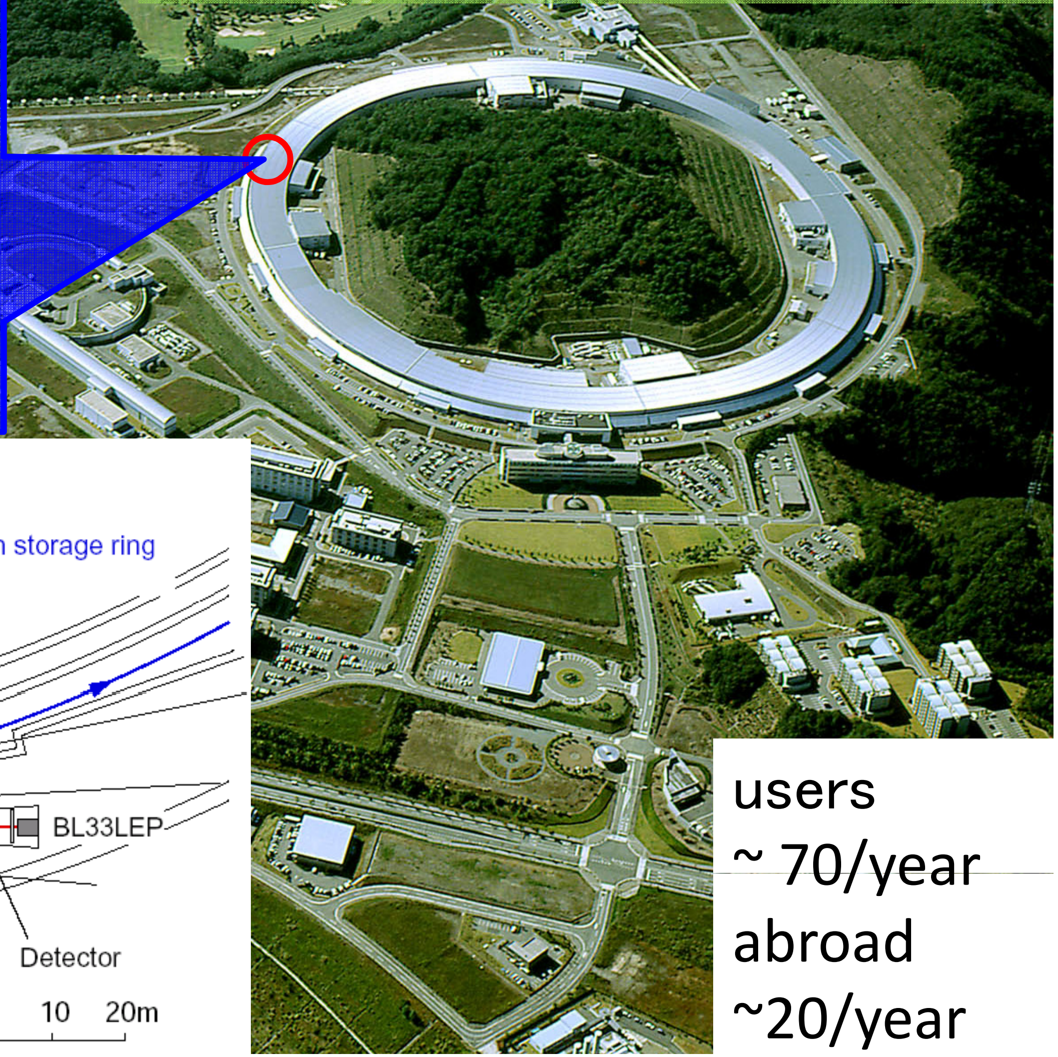
80 A MeV ^{18}O → 30 A MeV   Oct. '09

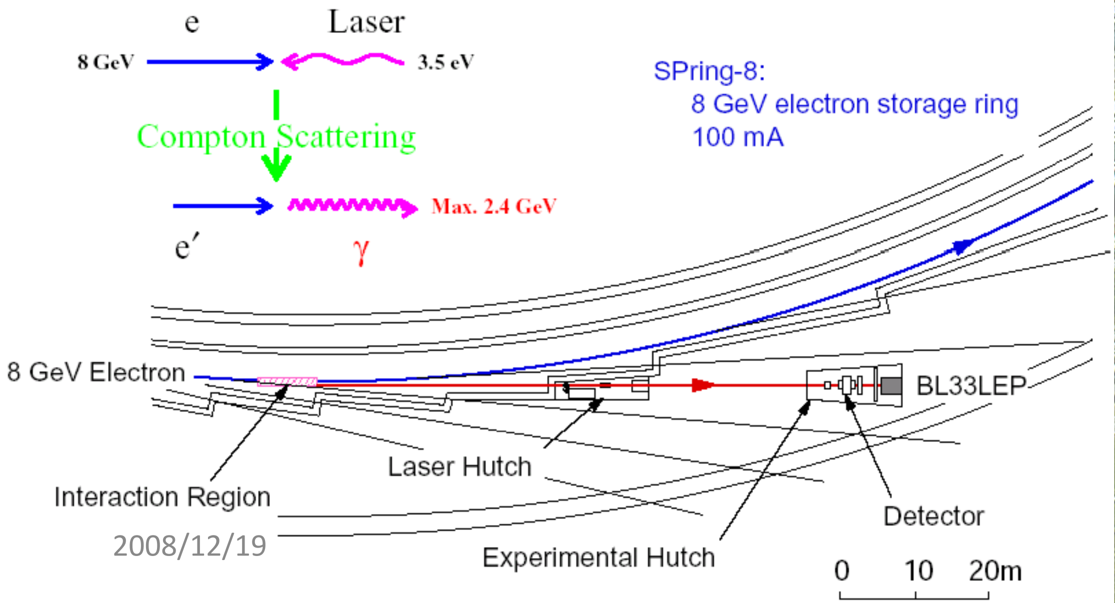


LEPS@SPring-8

Super Photon ring-8 GeV

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

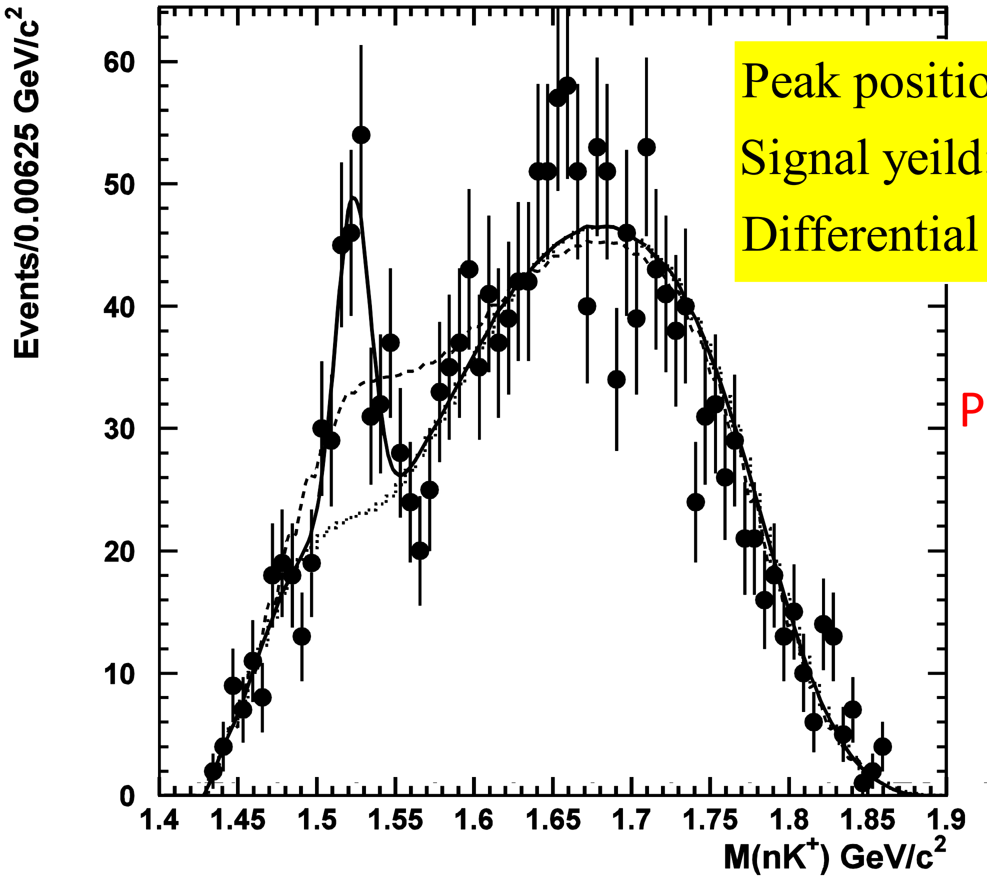




users
~ 70/year
abroad
~20/year

Results of Θ^+ analysis

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



Peak position: 1.527 ± 0.002 GeV/c^2

Signal yeild: 116 ± 21 events

Differential cross-section: 12 ± 2 nb/sr

PRC **79,** 025210 (2009)

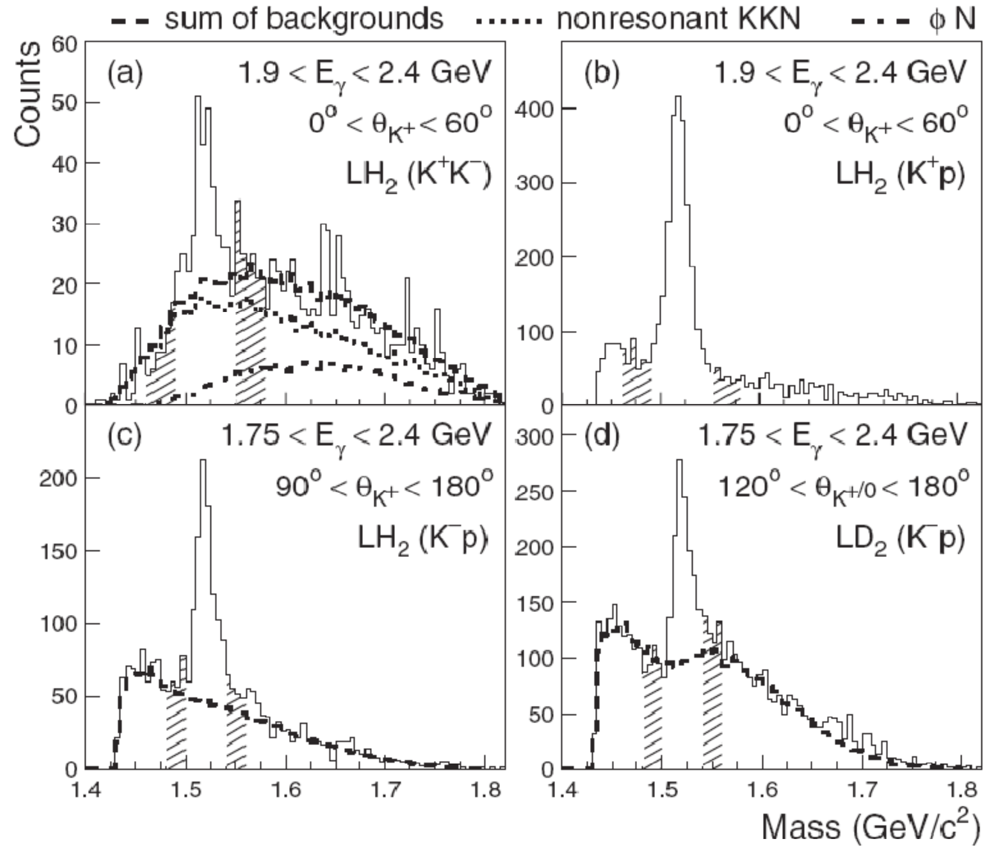
"The narrow peak appears only after Fermi motion correction."

$\Delta(-2\ln L)$ =31.1 for Δndf=2 $\longrightarrow$ 5.2σ $\quad \mathrm{Prob}(5.2\sigma) = 2\times 10^{-7}$

Photoproduction of Λ(1520) from p/d

$$\gamma + p \rightarrow K^{+} + \Lambda(1520) \rightarrow K^{+} + p + K^{-}$$

$$\gamma + n \rightarrow K^{0} + \Lambda(1520) \rightarrow \pi^{+} + \pi^{-} + p + K^{-}$$



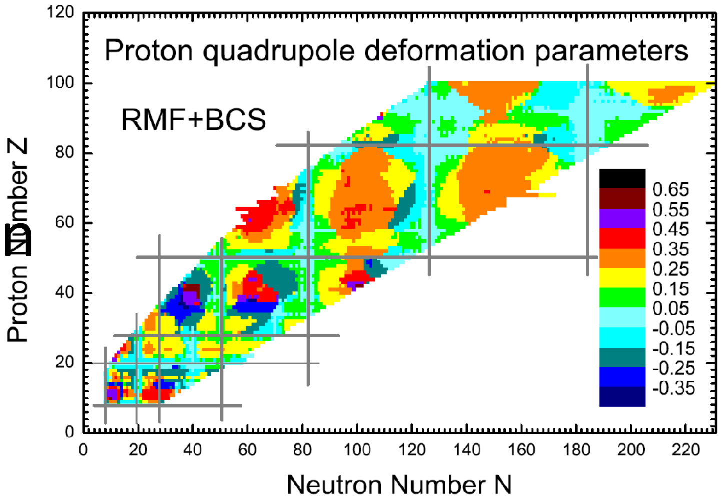
$\sigma(d) \square \sigma(p)$

$\sigma(n) \square \sigma(p)$

N. Muramatsu et al. (LEPS Collaboration), PRL 103, 012001 (2009)

Theoretical nuclear Physics division

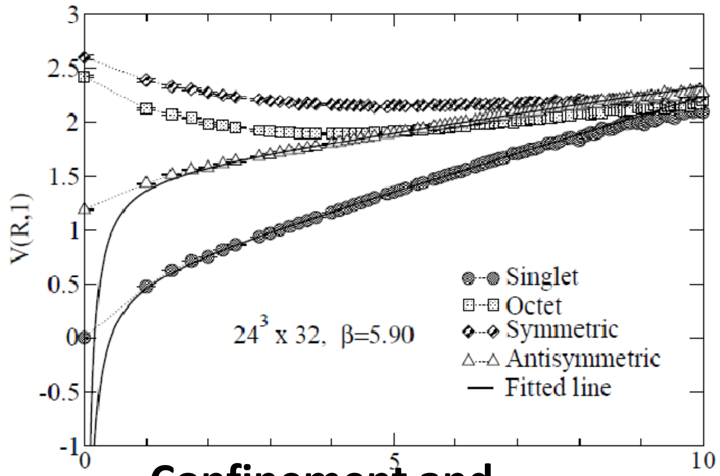
- Nuclear physics
  - Chiral RMF model for finite nuclei
  - Renormalization of chiral Lagrangian
  - ^{4}He+n phase shift for tensor force
  - RMF for all nuclei



Quadrpole deformation

- Hadron physics
  - Pentaquark structure and formation
  - Λ(1405) structure and formation
  - Lattice QCD in Coulomb gauge

- Supercomputers



Confinement and long range force

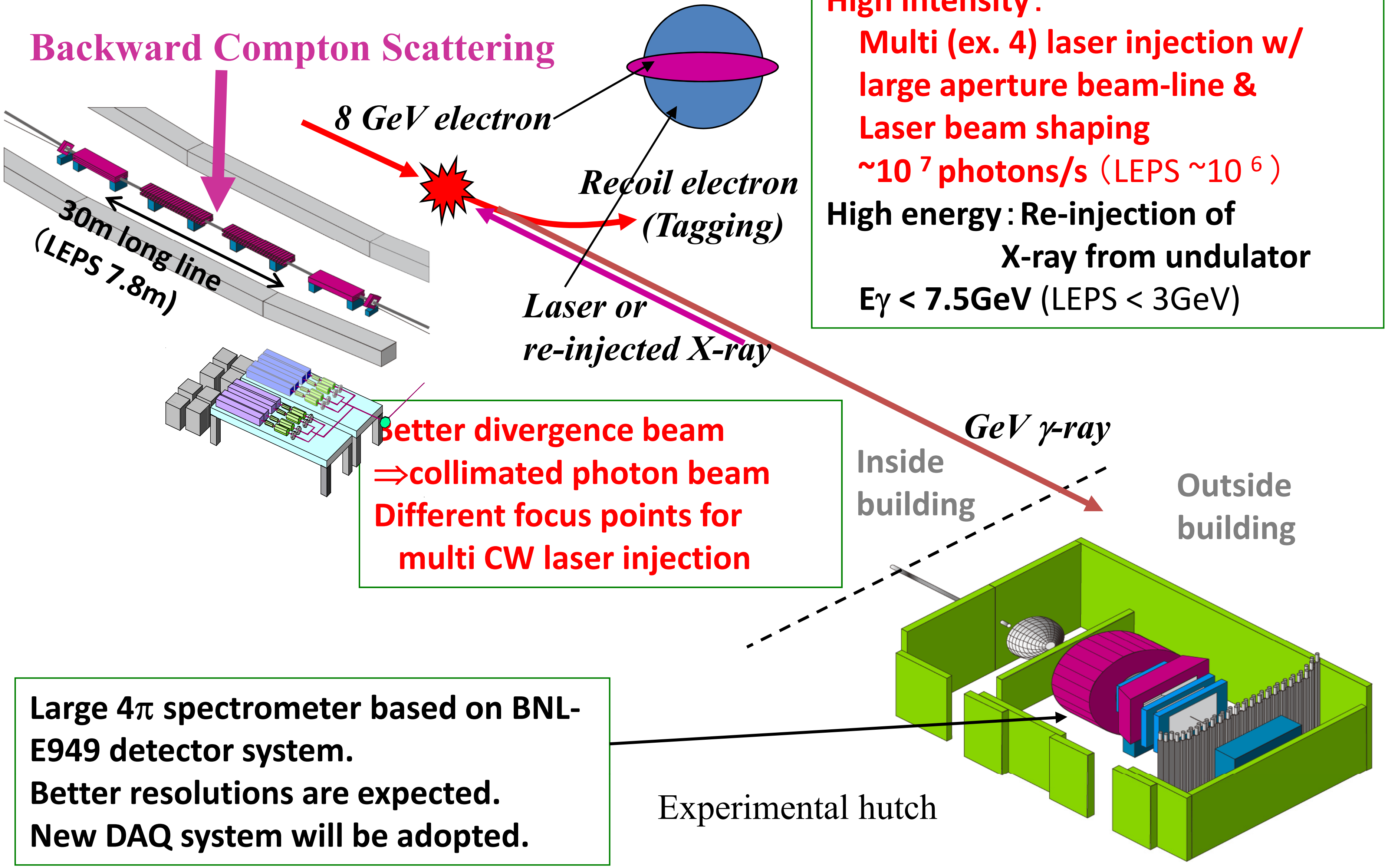
Present to near future

- 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



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

High energy: Re-injection of X-ray from undulator
- **E_γ < 7.5GeV** (LEPS < 3GeV)

Better divergence beam
⇒collimated photon beam
Different focus points for multi CW laser injection

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

MUSIC

Why three families for quarks and leptons.

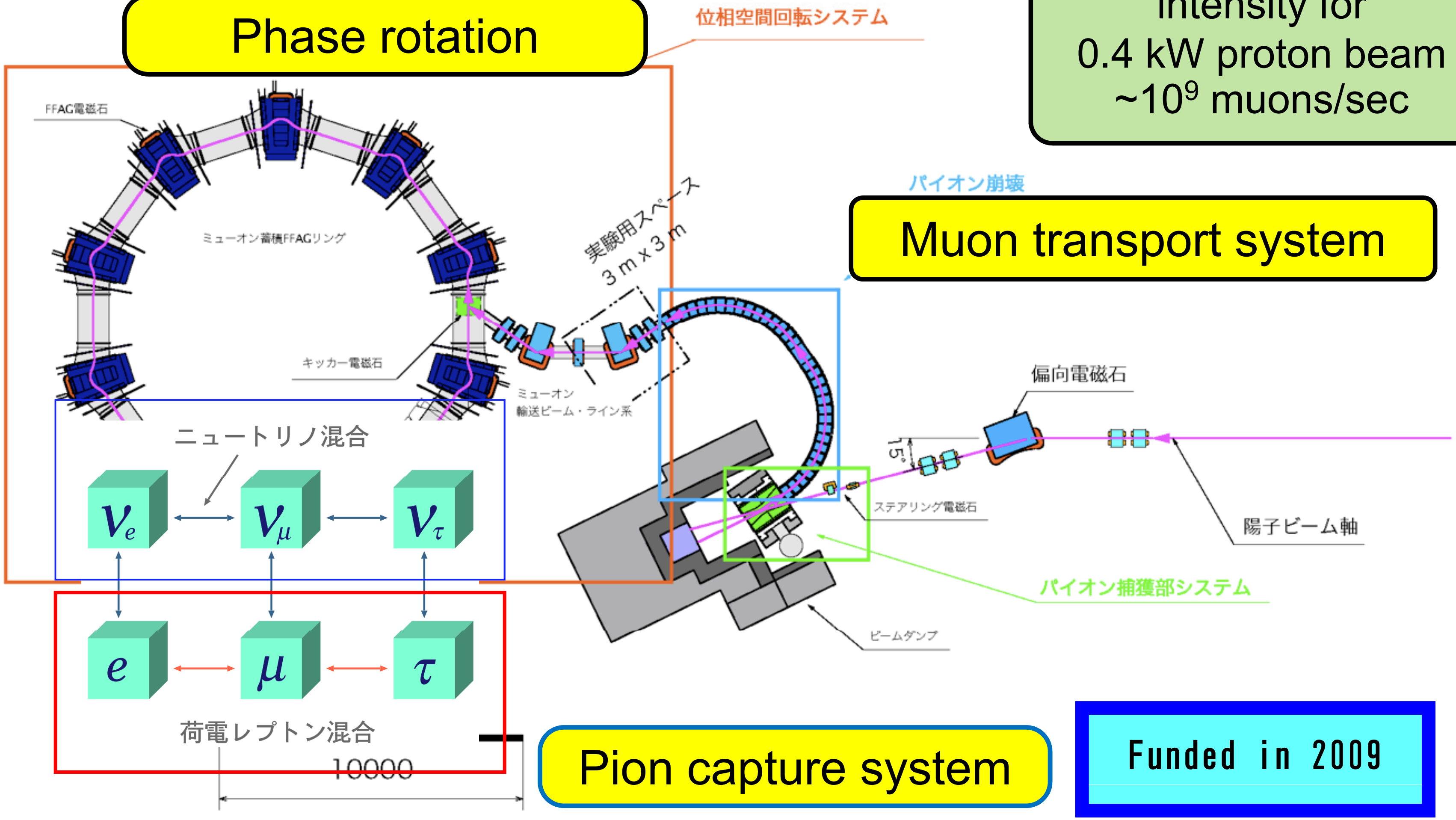
$$\mu^- + {}^AZ \rightarrow e^- + {}^AZ$$

World highest muon intensity for
0.4 kW proton beam
~10^9 muons/sec

Phase rotation

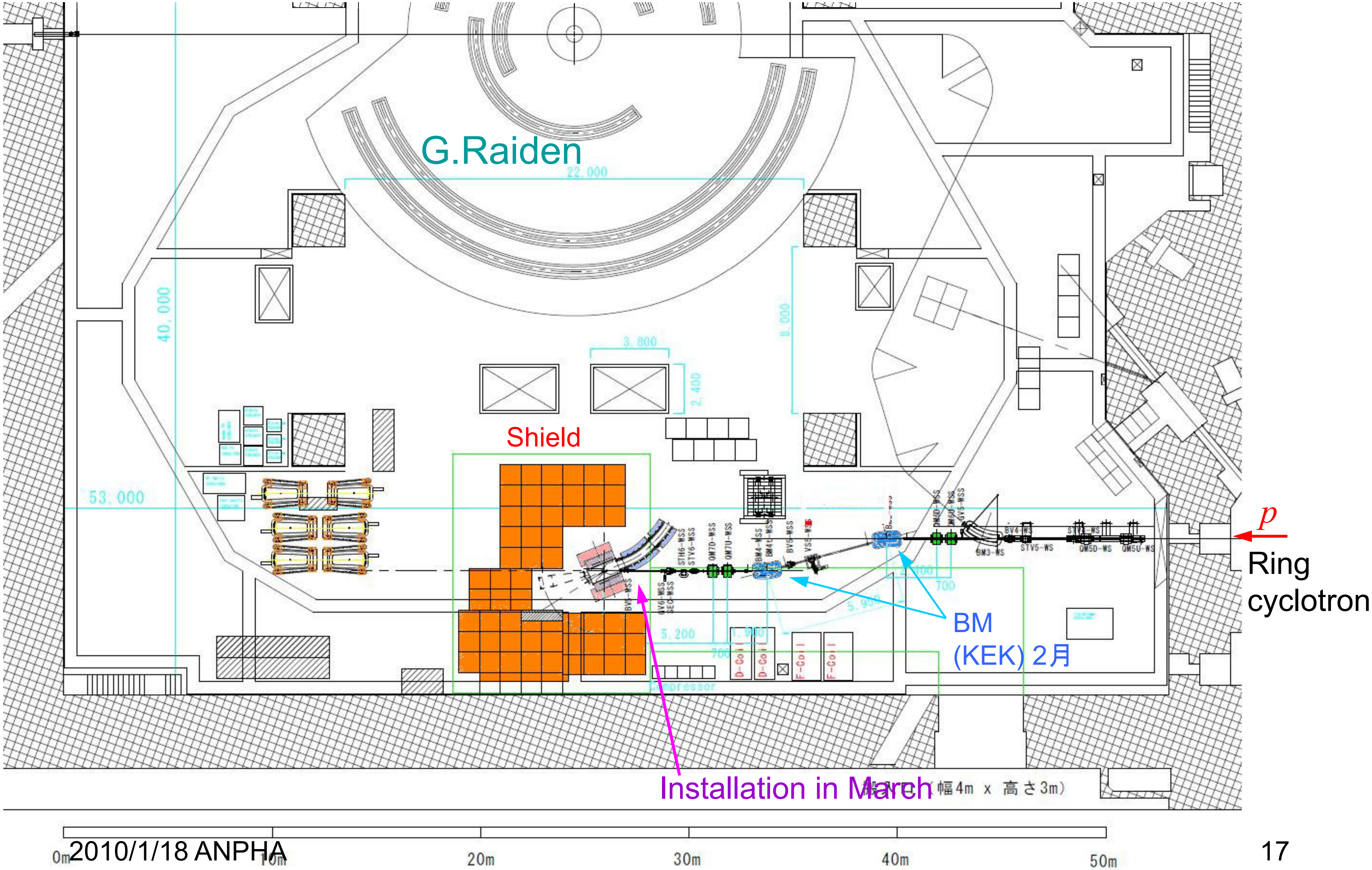
Muon transport system

Pion capture system



Funded in 2009

Muon（MUSIC）in west experimental area



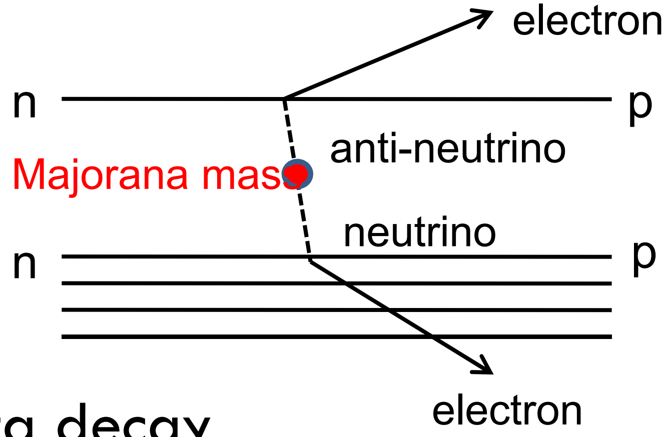
CANDLES

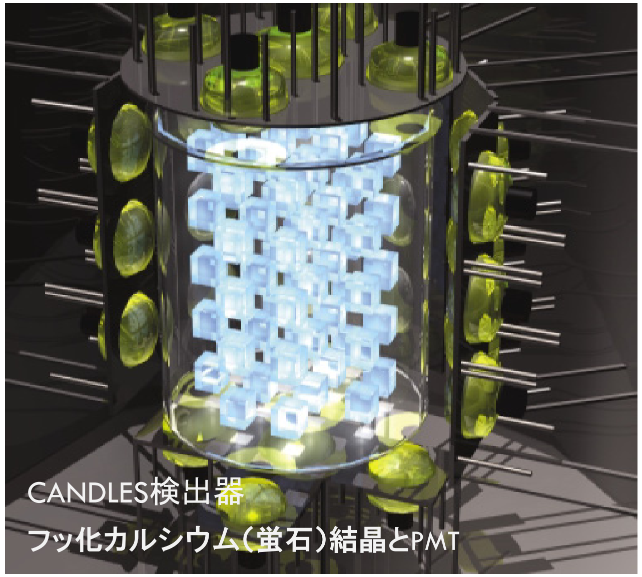
Why matter is dominant over anti-matter?
Leptogenesys

- Our universe is matter dominated (no anti matter)
  - Lepton number is not conserved
  - CP violated(matter and anti-matter world is not the same)

Neutrinoless double beta decay

Ultra low background

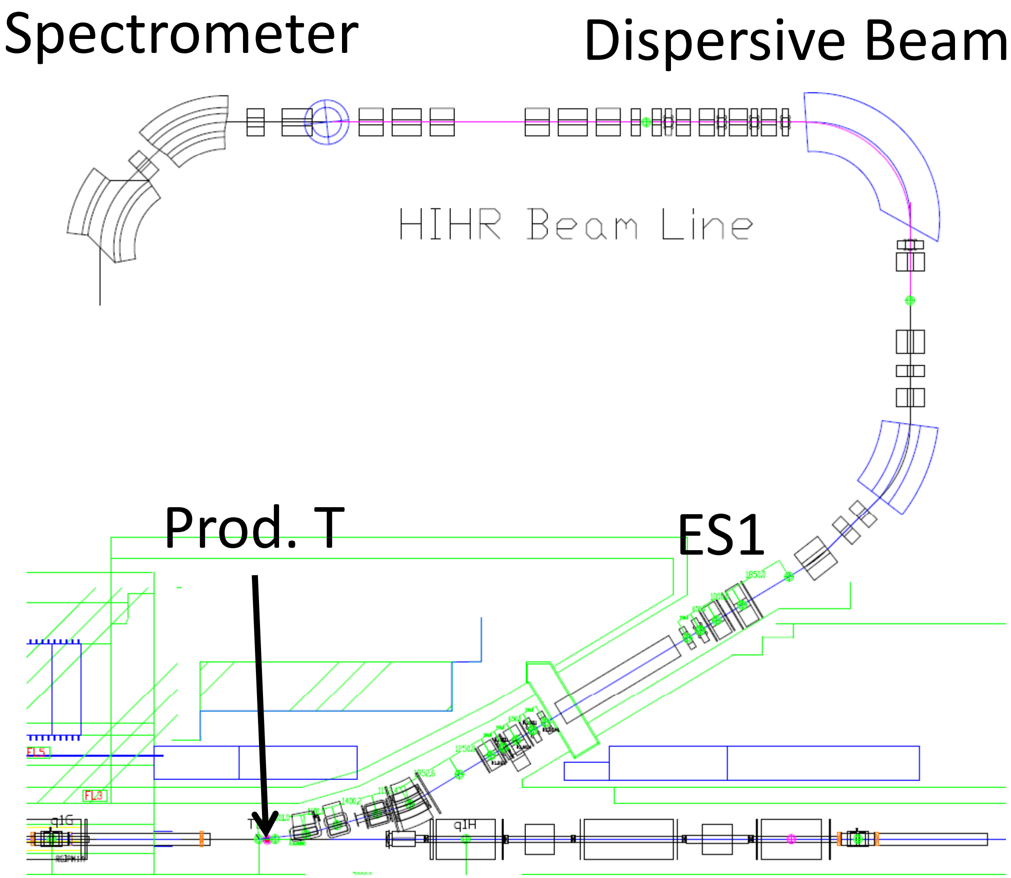




- ^{48}Ca double beta decay
- Oto cosomo observatory →

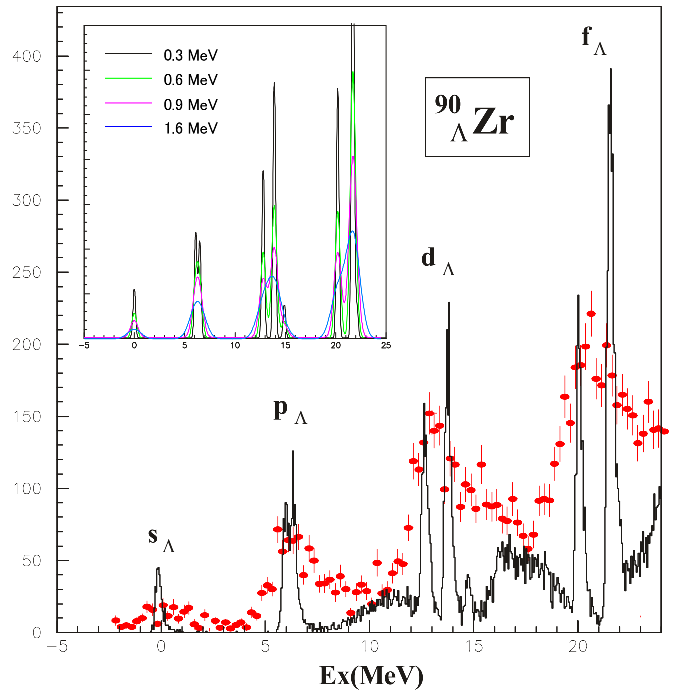
CANDLES III installed at Kamioka

High intensity and high resolution pion beam @J-PARC



pion: 10^8~10^9 Hz

pbar: 10^7 Hz



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- Higher Intensity for cyclotron facility (near future)
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- International collaboration