SHARAQ Overview and Scientific Programs

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Contents

- Overview of SHARAQ
  - Design Concept and Designed Performance
  - Present Status of Focal-plane Detectors
  - Results of SHARAQ Commissioning 2009
- Scientific Programs
  - for access to exotic excitation mode
    - Studies by Charge-exchange reactions
  - for exotic nuclear structure
    - γ-ray spectroscopy with SHARAQ

SHARAQ Overview

Spectrometers at RIBF

RIBF will be equipped with 3 spectrometers:

ZeroDegree spectrometer (Kubo, RIKEN)

multi-purpose

completed in 2007

SAMURAI spectrometer (Kobayashi, Tohoku Univ.)

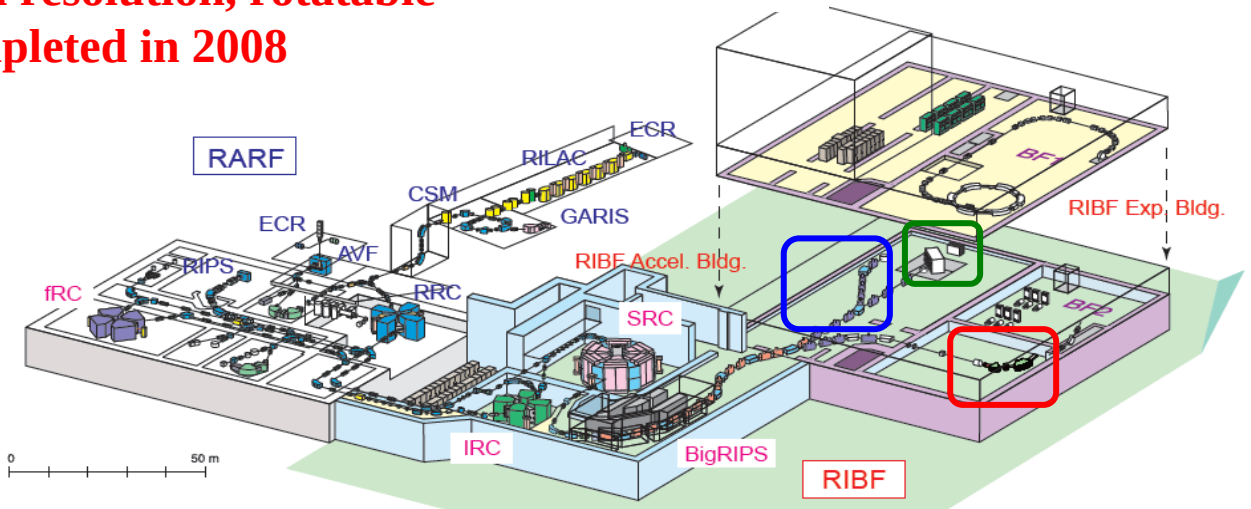
large acceptance, multi-particle

will complete in 2011

SHARAQ spectrometer (Univ. of Tokyo)

high resolution, rotatable

completed in 2008



RIBF RI beam generator
featuring superconducting ring cyclotron (SRC)
and projectile fragment separator (BigRIPS)
will be commissioned late in 2006.

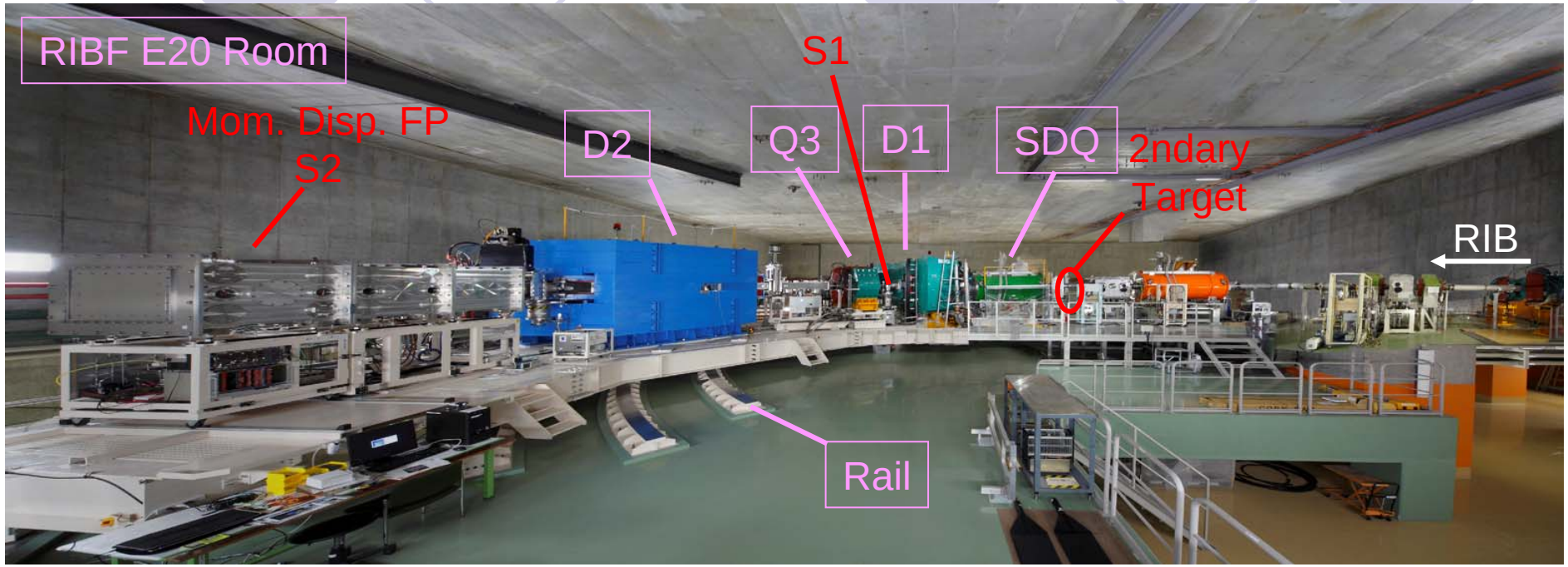
RIBF RI beam experiments
will be started in 2007,
with colored experimental installations.

What is SHARAQ

- **SHARAQ**
  = **S**pectroscopy with **H**igh-resolution **A**nalyzer
  of **R**adio**A**ctive **Q**uamtum beams

- BigRIPS × High-resolution Beamline × SHARAQ spectrometer
  - BigRIPS
    provides High intense RI beam
  - High-Resolution beamline
    realizes dispersion-matching transport
    against large momentum spread of RI Beam
  - SHARAQ spectrometer
    analyzes momentum of reaction products with high resolution

SHARAQ spectrometer



- Detectors can be arranged at:
  - **Secondary target**
  - S1 (Just after D1, optionally)
  - **S2 (final momentum dispersive focus)**

Design Concepts

- **QQDQD configuration**
  - good angular resolution and momentum resolution
- **Normal conducting magnets except for Q-doublet**
  - Minimization of higher-order aberration by pole-edge curving
    - Easier tuning to dispersion matching conditions
    - Easier data analysis
- **Superconducting doublet Q**
  - Higher resolution & Larger acceptance
  - Minor modification of triplet Q (STQ) magnet in BigRIPS
- **Rotatable (–2deg to +15deg)**
  - Measurement of angular distribution
  - Unique character in RIBF
- **Full use of existing resources**

Basic Performance

Maximum rigidity	**6.8 Tm**
Dispersion (D)	**5.86m**
Horizontal magnification (M_x)	**0.40**
D/M_x	**14.7m**
Momentum resolution	**1/14700**
Vertical magnification (M_y)	**0.0**
Angular resolution	**< 1mrad**
Vertical acceptance	**± 3 deg**
Dispersion matching	**p & θ_x**

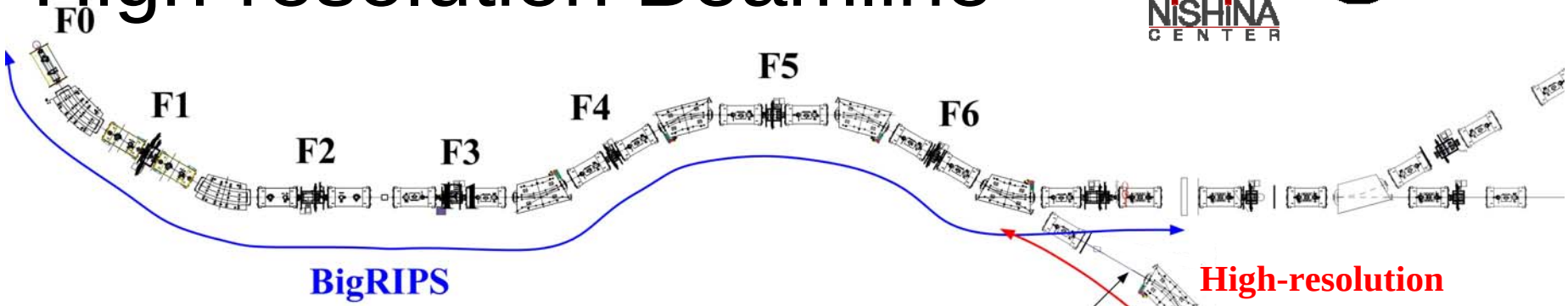
In Dispersion matching operation

Typical spot size	60mm(H) × 10mm(V)
Horizontal acceptance	± 1 deg
Solid angle	2.7 msr

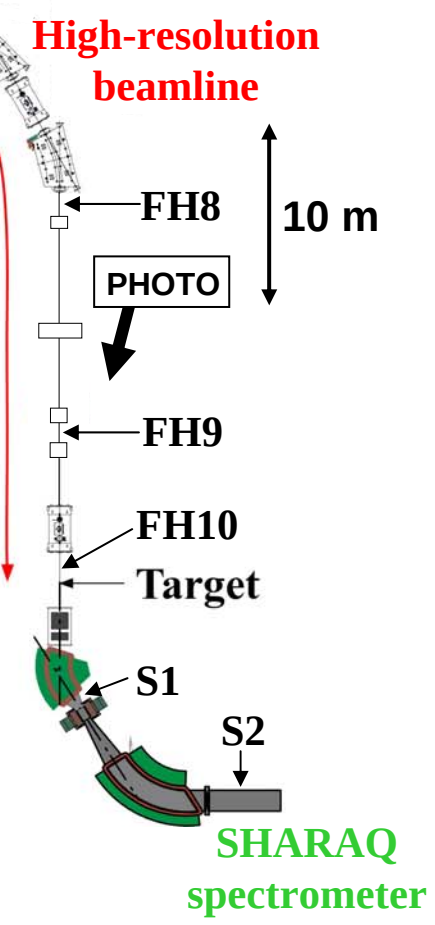
In Achromatic focus operation

Typical spot size	10mm(H) × 10mm(V)
Solid angle	4.8 msr

High-resolution Beamline



- designed to satisfy dispersion-matching condition against Large momentum spread of RI Beams
  - ^{12}N at 200A MeV $\Delta p/p = \pm 0.3\% \rightarrow \Delta E_{RIB} \sim 30$ MeV
  - Dispersion matching condition is fulfilled between BigRIPS-F3 and S2



Beam Transport Mode of HRBL

Mode	Dispersion	High-resolution Achromatic	Large-Acceptance Achromatic
Acceptance			
$\Delta p/p$ (%)	± 0.3	± 0.3	± 2
$\Delta\theta_x$ (mrad)	± 10	± 10	± 20
$\Delta\theta_y$ (mrad)	± 30	± 30	± 20
Maximum Dispersion	Target	F6	F5
Typical Spot size at target (mm)	100×10	$20\text{–}30 \times 10$	$20\text{–}30 \times 10$
Resolution $\Delta p/p$	1/15000	1/7500	1/1500

You can select beam transportation for your experiment.

SHARAQ Commissioning Run

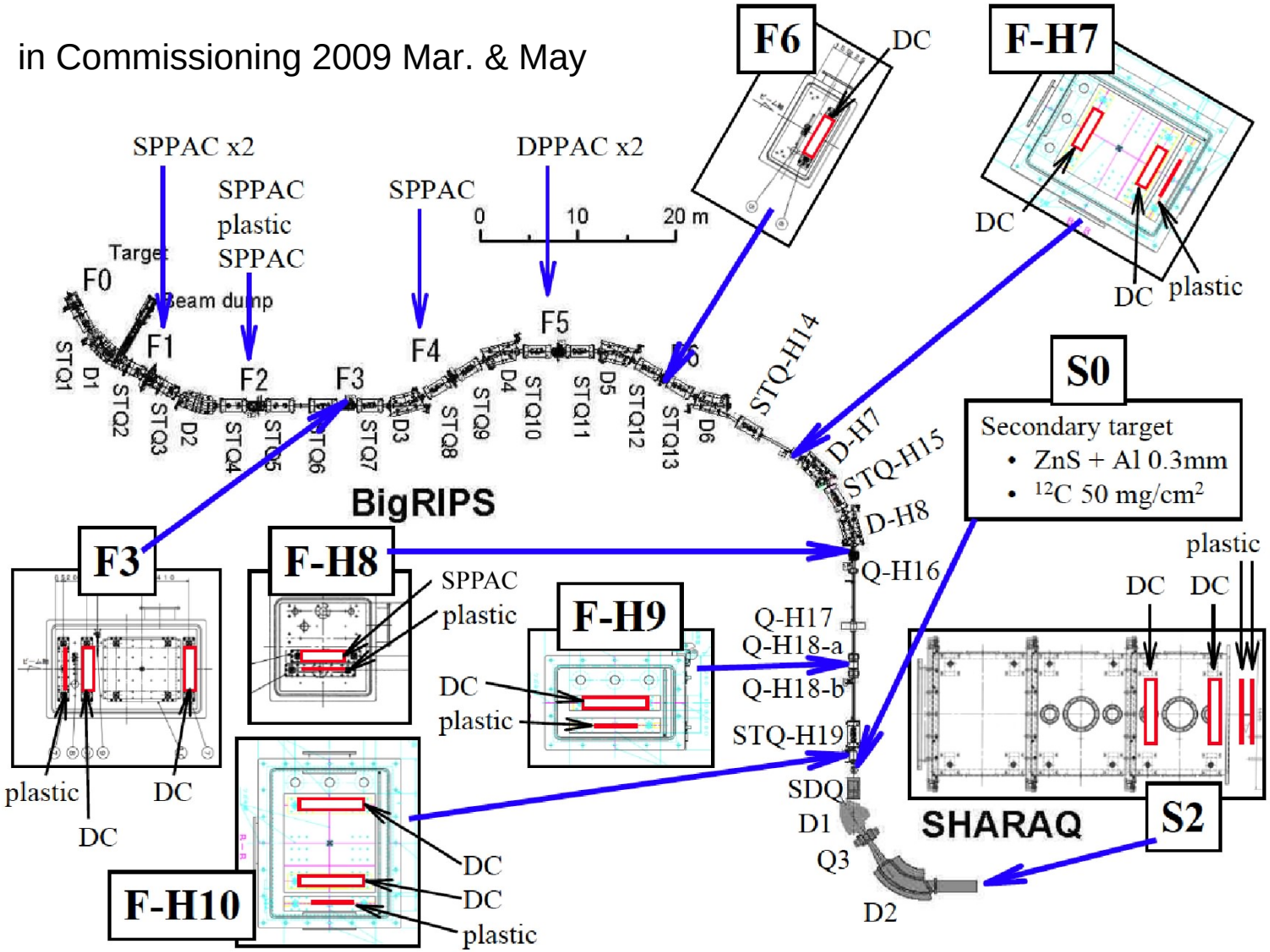
- Date
  - 1st run　23－30/March/2009 (8 days)
  - 2nd run　1－ 8/May /2009 (8 days)

- Primary and Secondary Beams
  - Primary beam　^{14}N @ 250*A* MeV
  - Secondary beam ^{12}B, ^{12}N, ^{6}He, t @ ~200*A* MeV

- Contents
  - Studies of detector responses to light ions
    - Estimations of Detection efficiency, Tracking efficiency
    - Position resolution
  - Basic data of ion-optical properties of SHARAQ and High-resolution beamline

Detector Setup in Beamline to SHARAQ

in Commissioning 2009 Mar. & May



Requirement of Tracking Detectors

- **for dispersion matching**
  - Little disturbing of the beam
  - Low Multiple Scattering: ~1 mrad (s)
    - Low Energy Straggling: thickness/L_R < 10^{-3}
  - Precise measurement of the beam trajectory
    - High Position Resolution: ~300 μm (FWHM)
      [30 cm*1 mrad ~ 300 mm]

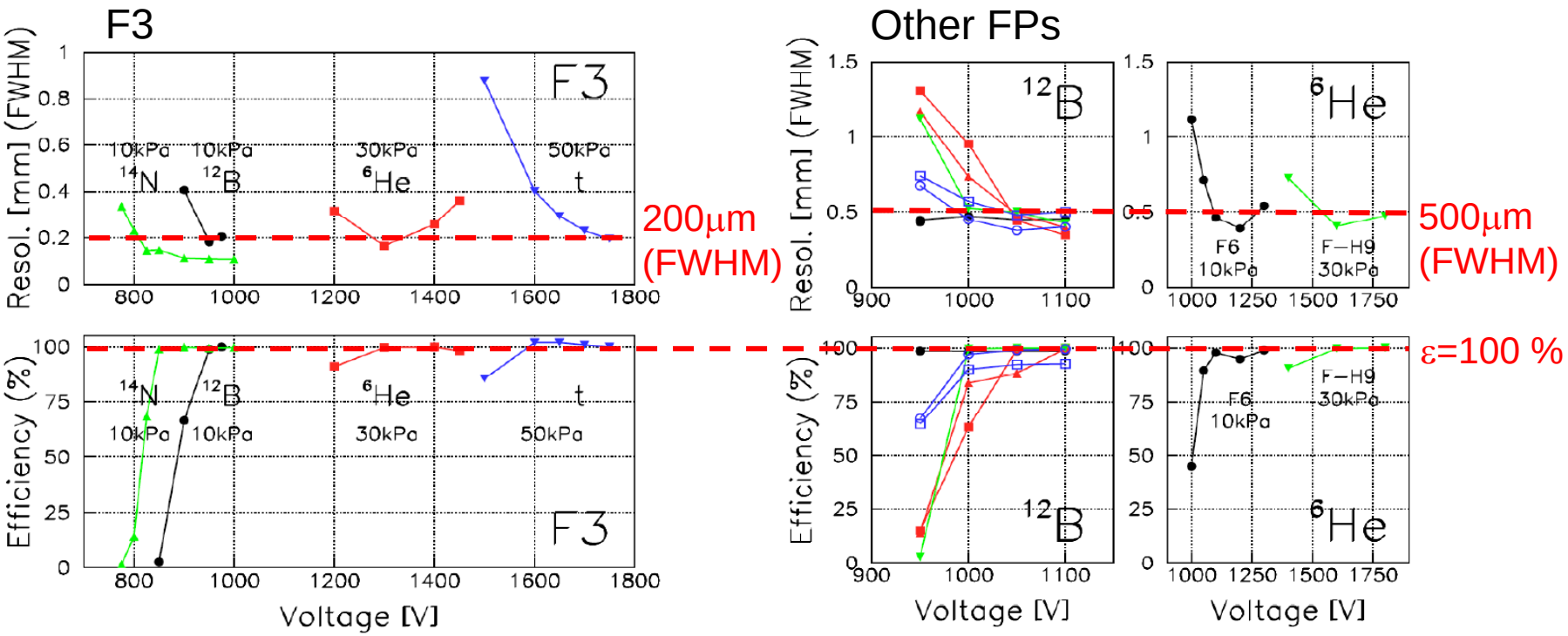
- **for using RI Beam**
  - Overcoming of Low intensity
    - 100% Detection Efficiency for light particles

- **in Beam-line detectors, especially**
  - Operate under High Counting Rates
    - Goal : Over 1 MHz

Performance of Beamline Detectors

A.Saito, K.Miki, H.Miya et al.

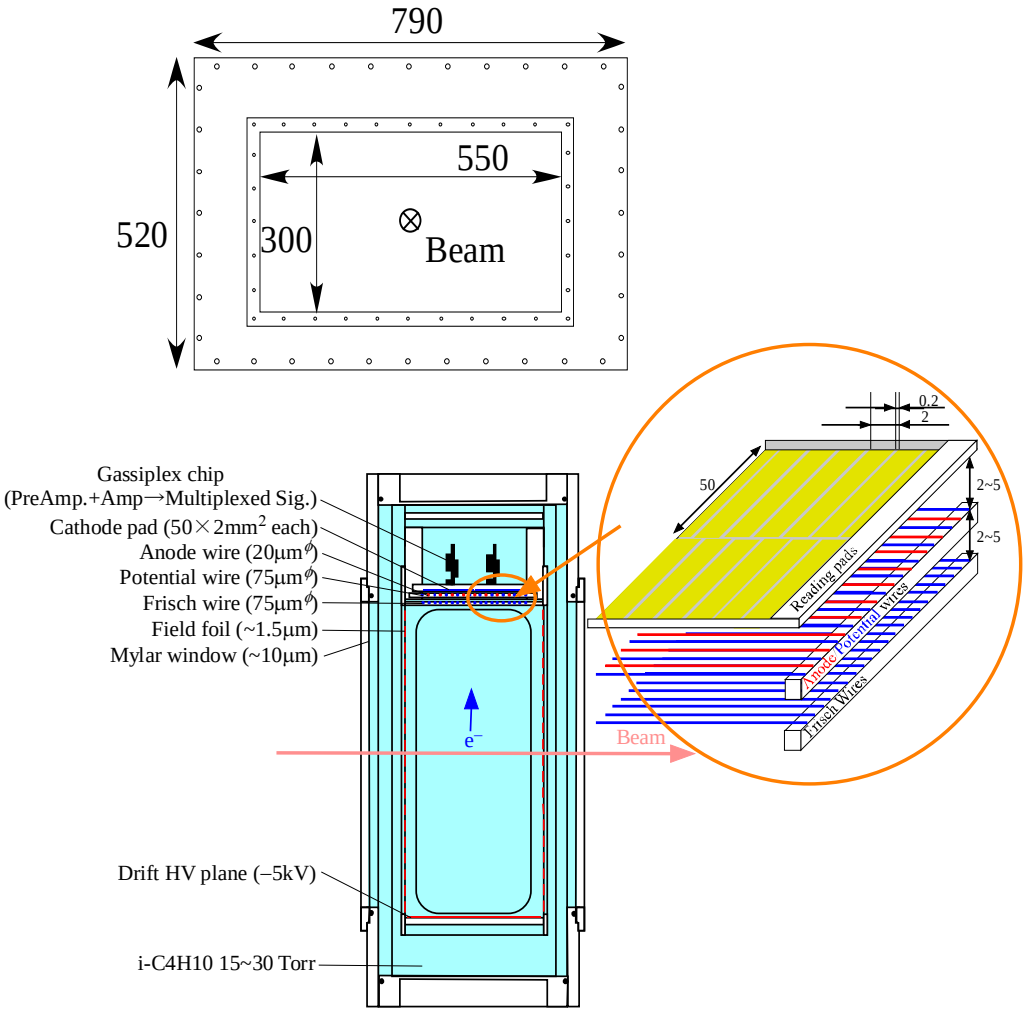
- Low-pressure MWDC
  - Thin thickness: $t/L_R < 10^{-4}$
  - Isobuthane (iso-C_4H_{10}) gas at p=10,30,50 kPa
  - Configuration: xx'yy'xx'yy' (@F3) and xuy (@F6,FH7,FH9,FH10)



Focal Plane Detector of SHARAQ Spectrometer

S.Michimasa, H.Tokieda et al.

Schematic view of CRDC



Designed specification

Thickness: < 1 mrad of multiple scattering
Gas: isobutane < 5 kPa
Read-out information
T,Q from Sensing wires
Q from 512 Cathode pads
Ch. Number: total 4 ch.
2 ch Anode
2 ch Cathode (256-ch multiplexed)
Position-measurement:
x: induced charge distribution
y: drift time
Resolution:
x: 300μm(FWHM)
y: 600μm(FWHM)
Counting Rate:
up to 10^4 Hz

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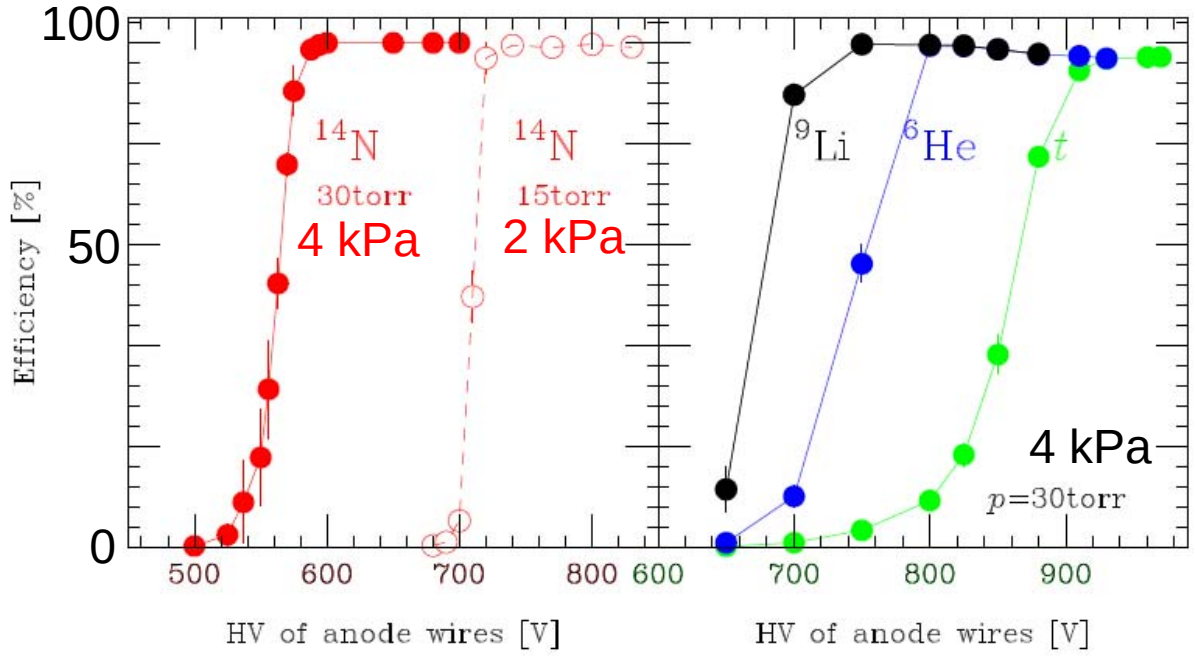
Performances of CRDC



Evaluation of Position resolution for ^{6}He particles.

Horizontal (x; Pad)	~ 0.5 mm (FWHM)
Vertical (y; Drift)	~ 1 mm (FWHM)

Tracking detectors work well even for light ions of Z=1-7

Ion-optical study of SHARAQ and Beamline

Y.Sasamoto, T.Kawabata et al.

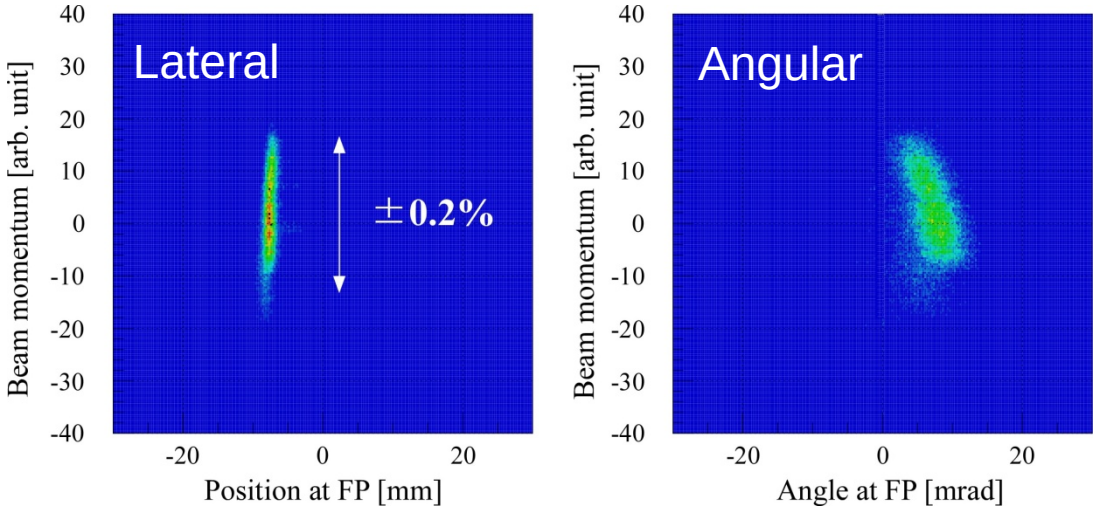
- **Dispersive focal plane on the beamline**
  - F6 D = 7.8 m
  - FH7 D = 7.5 m
- **Ion-optical property of SHARAQ spectrometer**
  - D/Mx = 14.7 m (measured)
    - We tuned magnet settings to obtain a good condition:
      (x|d) = 6.8 m, (a|d) = 0.63 rad, (x|x) = 0.46, (y|y) ~ 0

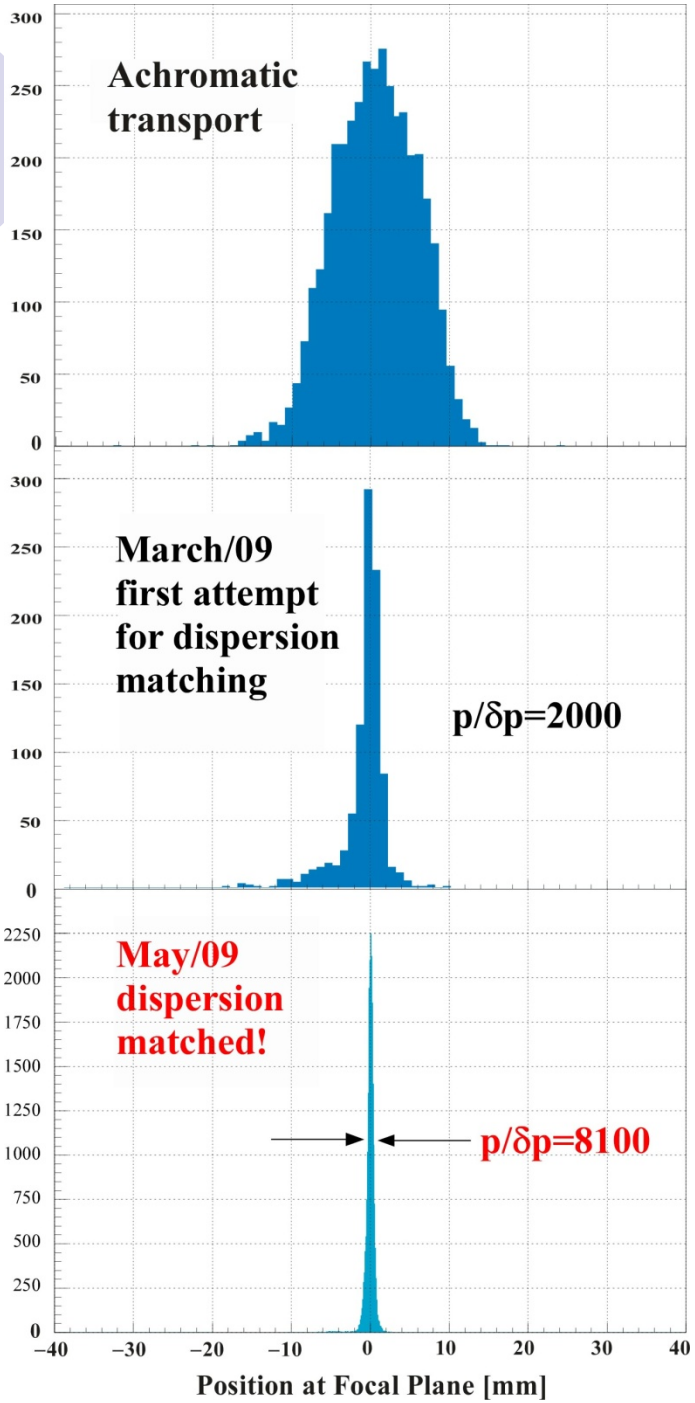
High-resolution Beamline and SHARAQ spectrometer are constructed as per the design specification

Dispersion Matching

- For a primary beam (^{14}N)

  Lateral and angular dispersion matching are simultaneously fulfilled!





Scientific Programs with SHARAQ

Scientific opportunity with SHARAQ

- **Missing mass spectroscopy with RI probes**
  - spin-isospin excitation by RI-beam induced reaction
    - highly excited states of stable nuclei with extremely small momentum transfer
      eg. IVSMR, DGTR, tetra neutron spectroscopy
    - IV Spin-non-flip MR search by using Super-allowed Fermi-type reaction
  - elastic scattering experiments

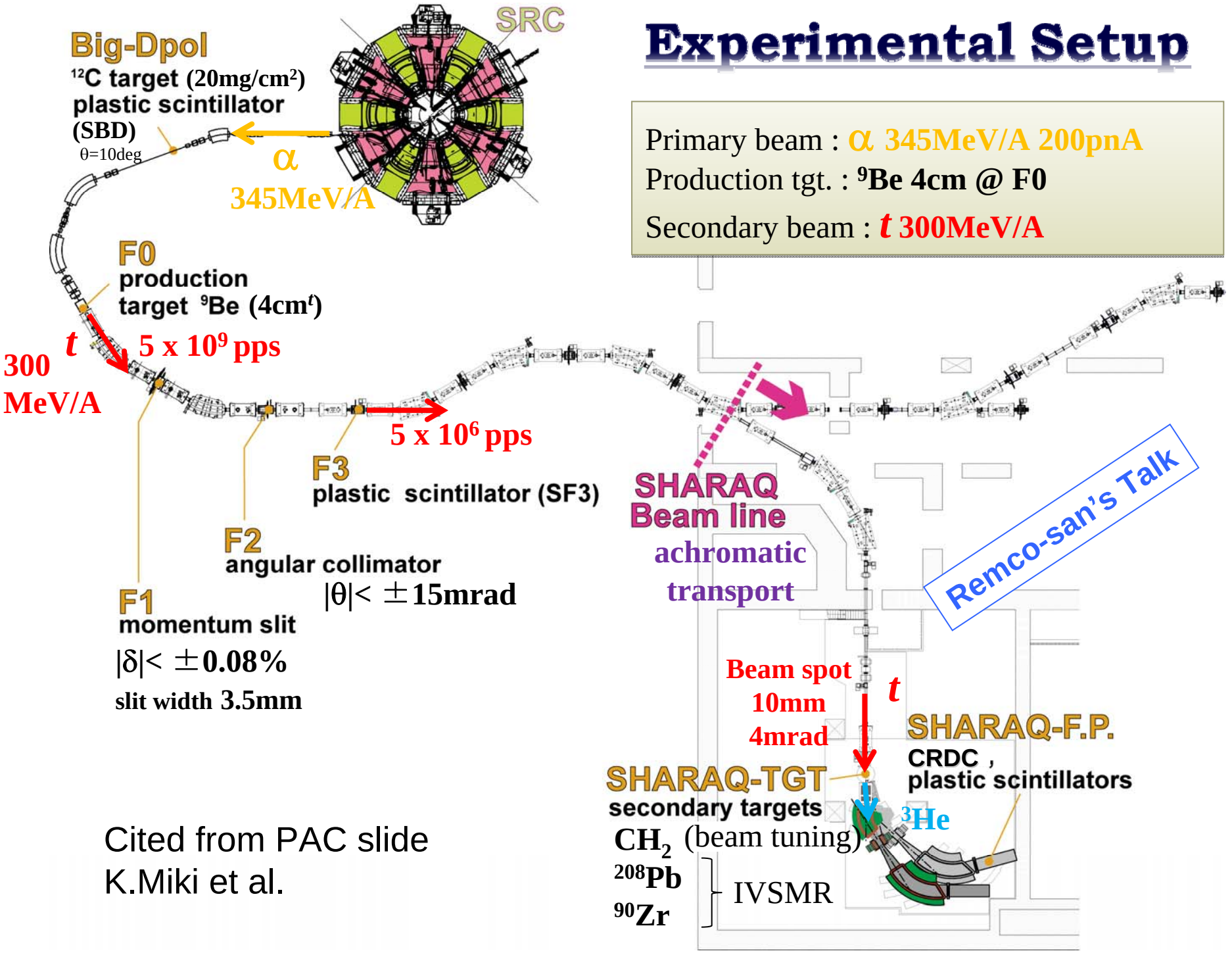
- **High resolution analysis of reaction products**
  - Inelastic, Breakup, Knockout reactions induced at SHARAQ target (S0)
    - Combination with γ-ray and/or decay-particles measurements
    - Particle identification for heavy isotopes
    - Q value measurement
    - Momentum distribution measurement
    - Selectivity of unique targets: Liq.H_2, Liq. He, Pol. proton target, and Pol. ^{3}He target
  - Fragments produced at BigRIPS production target (F0)
    - Mass measurement
- and more . . . . *model case: S800@NSCL*

Approved Proposals with SHARAQ

- K.Miki et al.: (t,^{3}He) experiment at 300A MeV
  - β^{+}-type IVSMR search
  - Reaction target : 90Zr and 208Pb
  - Scheduled in Nov./2009
- S.Noji et al.: Exothermic (^{12}N,^{12}C) experiment
  - β^{-}-type IVSMR search
  - Reaction target : 90Zr
- Y.Sasamoto et al.: (^{10}C,^{10}B*(IAS)) experiment
  - Super-allowed Fermi-type charge exchange reaction
  - Reaction target : 90Zr

- Use of RI beams as new probes
  to attack exotic excitation modes

Experimental Setup



Cited from PAC slide
K.Miki et al.

Scientific opportunity with SHARAQ

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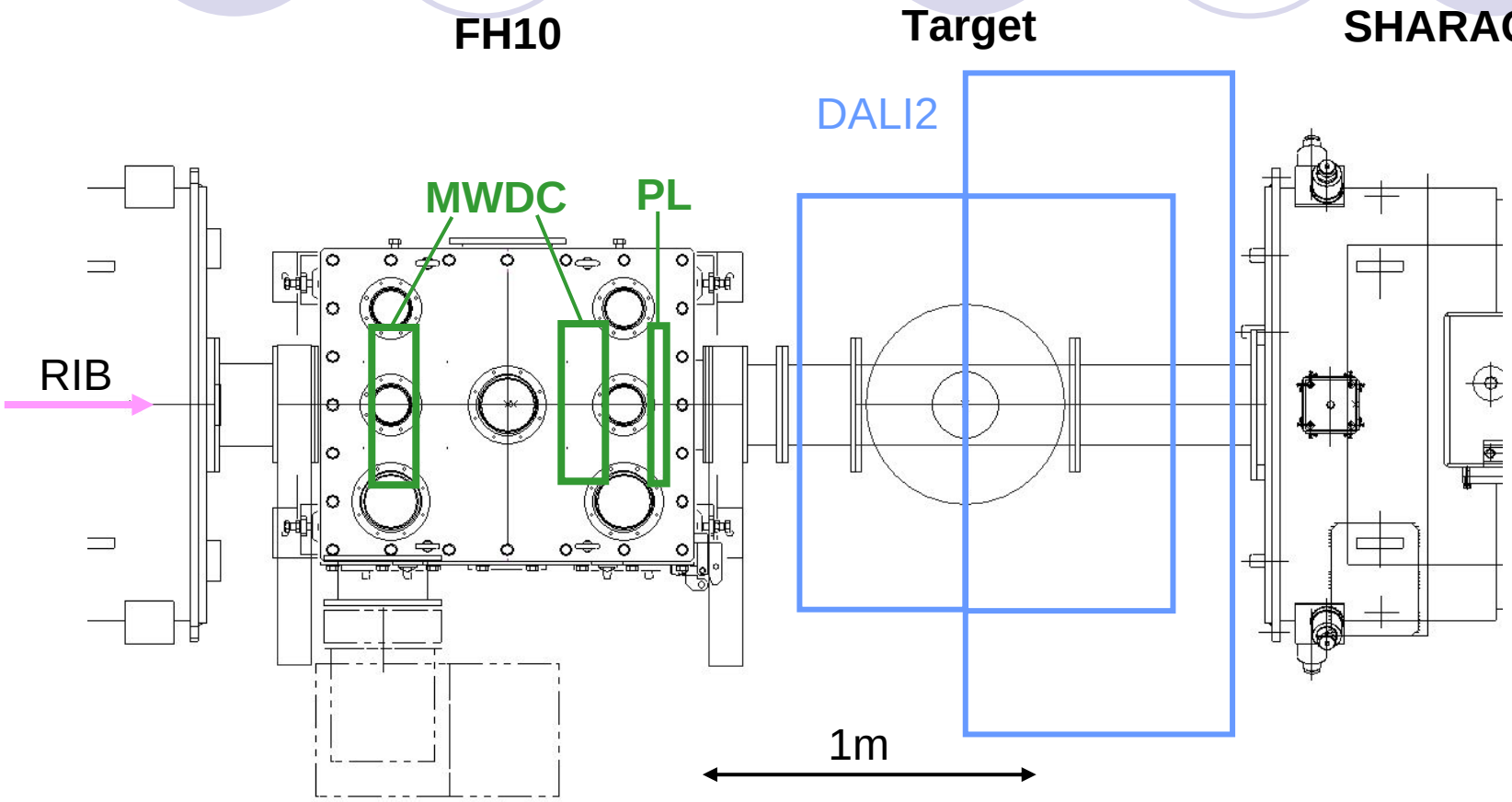
- and more . . . . *model case: S800@NSCL*

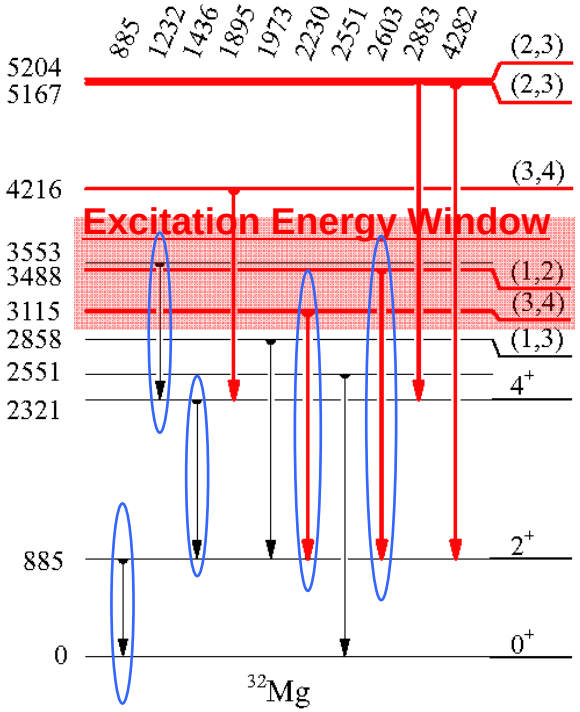
Setup with SHARAQ + γ detectors



- SHARAQ has enough space around the target for γ-ray detectors arrays, DALI and GRAPE.

γ-ray spectroscopy with SHARAQ

Excitation energy window by SHARAQ



S. Takeuchi et al. Phys.Rev. C, 79:054319, 2009.

In γ-ray spectroscopy with high statistics
→ a lot of γ-decay paths are observed,
sometimes in similar energies
→ We need to identify cascade g-ray events
→ It make more difficult to
identify excited states by γ-energies
in such a case.

If SHARAQ may make
some excitation energy limitation,

It is helpful for clear identification of population distribution.

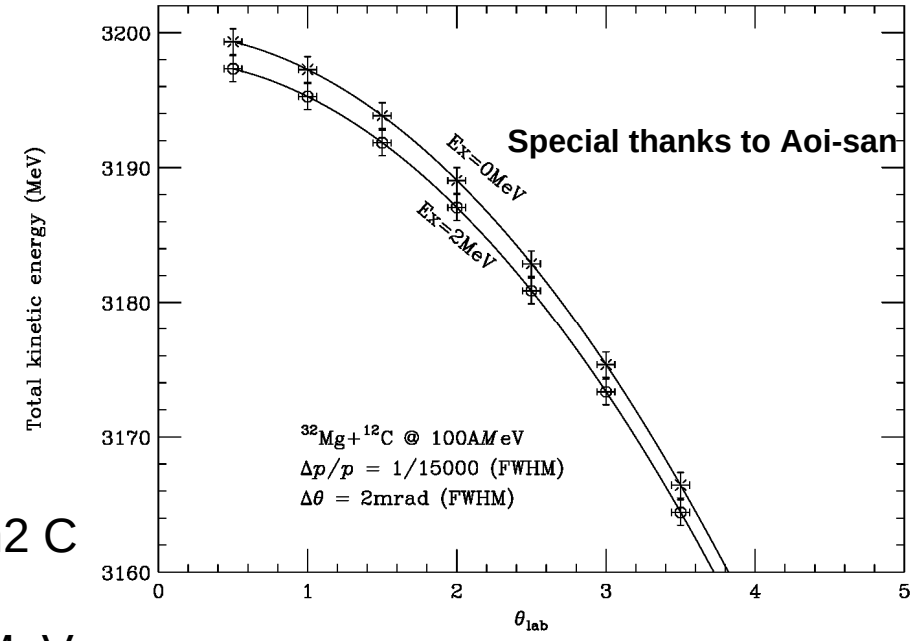
γ-ray spectroscopy with SHARAQ

- **Momentum Resolution of SHARAQ:**
  p/Δp ~ 15000 → Energy Resolution: E/ΔE ~ 7500
- **Angular resolution ~ 1 mrad**

A Case :
^{32}Mg+^{12}C, E/A = 100 MeV
→ We deduce excitation energy from energy of outgoing ^{32}Mg.

Resolution is determined by
DE Resolution = 430 keV
dE/dq$_{proj}$ = 500 keV/mrad at q$_{proj}$=2 deg
Energy starggling ~ 800 keV in 50 mg/cm2 C

→ We may limit exitation energy around 1 MeV



It seems to be helpful for clear identification of population distribution.

When you come up with ideas about experiments at SHARAQ…

- Contact to
  - Prof. Susumu Shimoura
    Email: *shimoura@cns.s.u-tokyo.ac.jp*
  - Prof. Tomohiro Uesaka
    Email: *uesaka@cns.s.u-tokyo.ac.jp*
  - *or me (Shin'ichiro Michimasa)*
    Email: *mitimasa@cns.s.u-tokyo.ac.jp*

Summary

- Present status of SHARAQ
  - A major part of the spectrometer and the high-resolution beamline is completed in FY2008.
  - In two commissioning runs, we achieved fruitful results:
    - All the detectors work well even for light ions of Z=1-7.
    - Dispersion-matching and High-resolution achromatic Ion-optical properties were studied.
    - Lateral and angular dispersion matching conditions were simultaneously achieved, and Resulting resolving power of the whole system is found to be p/dp=8100 at present.

Summary

- Future plan
  - We will perform 3 approved experiments:
    - K.Miki et al., (t,^{3}He) Nov./2009
    - S.Noji et al., (^{12}N,^{12}C) next year (not fixed)
    - Y.Sasamoto et al., (^{10}C,^{10}B[IAS]) next year (not fixed)
  - Development
    - Control system of vacuum, magnets etc..
    - Continue of data analysis on ion optics, and tracking detectors
    - Detector development
      - At F3 Diamond detectors for better position and timing resolutions
      - At SHARAQ target, We start active target system for better resolution and higher statistics.


Collaborators
CNS, UT, RIKEN, Kyoto,Niigata, Notre Dame, GANIL, NSCL
We welcome you to come and join SHARAQ.
Thank you for your attention.
First Beam on 23/March/2009
SHARAQ has launched.