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Osaka Symposium and New Accelerator Projects in Japan

J. Wei

April 1997

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

RHIC/AP/125
RAP seminar
April 25, 1997

Osaka Symposium and New Accelerator Projects in Japan

(A Trip Report)

Jie Wei, Brookhaven National Laboratory

1. The Osaka Symposium

   XVI RCNP Osaka Symposium on Multi-GeV High-Performance Accelerators

2. New/Proposed Accelerator Projects

   Projects in Japan

   Projects in China

3. Coolers and Beam Cooling

   Newly proposed beam cooling methods

DOE Trip No. 9608751
BNL Trip No. 77240

SUMMARY

FOREIGH TRAVEL TRIP REPORT

Jie Wei, Scientist

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RHIC Project
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April 18, 1997

Dates Of Trip: March 1, 1997 to April 5, 1997

Destinations:
Kyoto University, Kyoto, Japan
Research Center for Nuclear Physics, Osaka, Japan
Institute of High Energy Physics, Beijing, China
Tsinghua University, Beijing, China
Shanghai Institute of Nuclear Research, Shanghai, China

Statement of Purpose of trip:
As an invited speaker, present paper "The RHIC Project" in the XVI RCNP Osaka International Symposium, and give seminar at IHEP, Beijing and INR, Shanghai. Collaborate on beam cooling methods and beam crystallization. There is no revisions to the original itinerary.

Abstract:
To participate as an invited speaker to the XVI RCNP Osaka International Symposium on Multi-GeV High-Performance Accelerators and Related Technology, to collaborate with Kyoto University on laser cooling and beam crystallization projects, and to give seminars in Beijing and Shanghai on the Relativistic Heavy Ion Collider.

1. The Osaka Symposium

XVI RCNP Osaka Symposium on Multi-GeV High-Performance Accelerators

Purpose:

- To celebrate the 50th anniversary of RCNP (Research Center for Nuclear Physics)
- To propose a new cooler-synchrotron-collider
- To review the performance and technology development of cooler rings, synchrotrons, and colliders.

March 11 - 14, 1997, Osaka, Japan

3 days, fully packed with talks

16 people from outside of Japan, all expenses paid

Panel review of the proposed RCNP project

Symposium Program:

- Cooler Rings and Cooling Methods

  T. Tanabe (INS): Electron Cooler at TARN II
  J. MacLachlan (FNAL): Electron Cooling
  F. Caspers (CERN): Stochastic Cooling
  B. Franzke (GSI): Diagnosis of Cooled H.I. Beams
  D. Prasuhn (KFA, Juelich): Performance of COSY
  D. Reistad (TSL): Performance of CELSIUS
  L. Tecchio (Legnaro): The CRYSTAL Project
  M. Grieser (MPI): Heavy Ion Storage Ring TSR

- Colliders

  A.M. Sessler (LBL): The Development of Collider
  J. Wei (BNL): The RHIC Project

- Other multi-GeV Machines

  K. Sato (RCNP): Multi-GeV Machine at RCNP
  Y. Yamazaki (KEK): 50-GeV Proton Synchrotron
  W. Gu (IMP): HIRFL - CSR Project in Lanzhou
  A. Goto (RIKEN): RIKEN RI Beam Factory
  T. Katayama (INS/RIKEN): e^- & RI Collision
  T. Tamae (Tohoku): 1.2 GeV Stretcher - Booster
  A. Ando (Himeji): New SUBARU - Isochronous Ring

H. Sato (KEK): KEK 12 GeV-PS and Upgrade

P. Schwandt (IUCF): 20 GeV Synchrotron for Spin

- Theories

B. Autin (CERN): Recent Trends in Lattice Design

S.Y. Lee (IUCF): Nonlinear Dynamics

Y. Batygin (RIKEN): Emittance preservation

A. Garren (LBL): Lattice for μ^+ - μ^- collider

- Technologies

S. Wolff (DESY): Superconducting Magnets

C. Ekstrom (TSL): Internal Targets

M. Kumada (NIRS): Ultimate Power Supply

K. Noda (NIRS): Slow Beam Extraction at HIMAC

Sato

Research and Development for Multi-GeV High-Performance Accelerator at RCNP

Kenji Sato
Research Center for Nuclear Physics(RCNP)
Osaka University

RCNP: Present accelerator facility

High-precision frontier of nuclear physics in the range of intermediate energies up to 420 MeV

AVF-Ring cyclotron cascade

RCNP: Future accelerator project

New high-precision frontier of quark-lepton nuclear physics in the range of multi-GeV energies

protons/light ions/electrons/polarized ions
cooler-synchrotron-collider

Contents

Prof. K. Hatanaka

Sato

Proposal of "figure of 8" configuration synchrotron

Advantage of "figure of 8"

In principle no intrinsic resonances of depolarization during acceleration of polarized ions

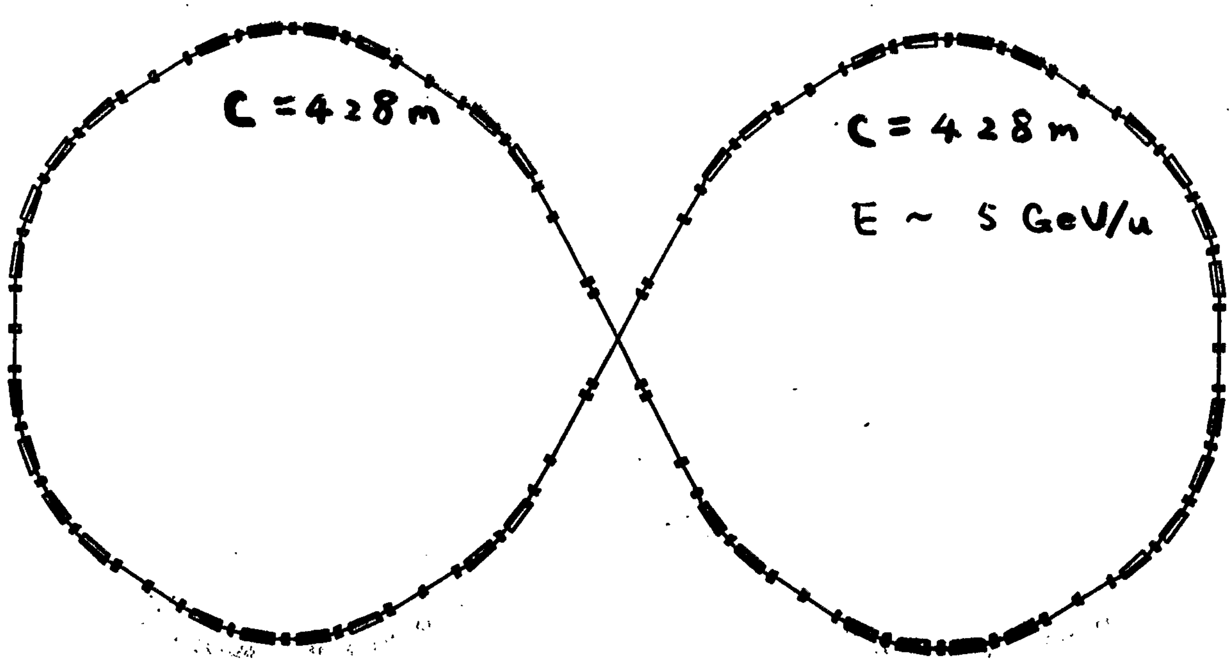
opposite bending directions in both loops

⇩

opposite spin precession motion in both loops

⇩

no intrinsic resonances of depolarization



Request apart from his proposal — only need 5% partial snakes

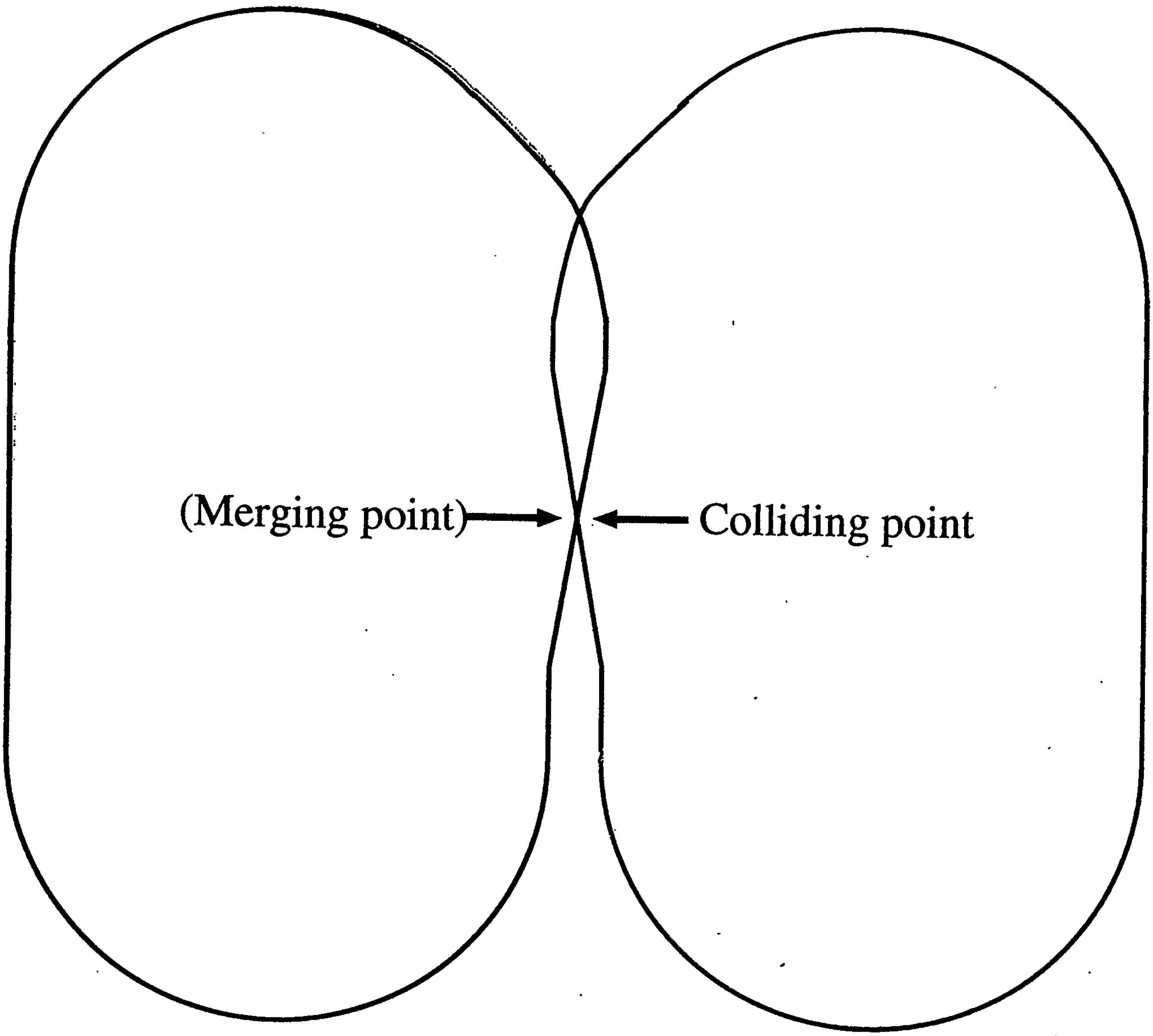
A "figure of 8" configuration based on a combination of two identical rings

Mode 1: "figure of 8" synchrotron

Requests for additional colliding mode

Sato

Design study for cooler-synchrotron-collider



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Single ring characteristics

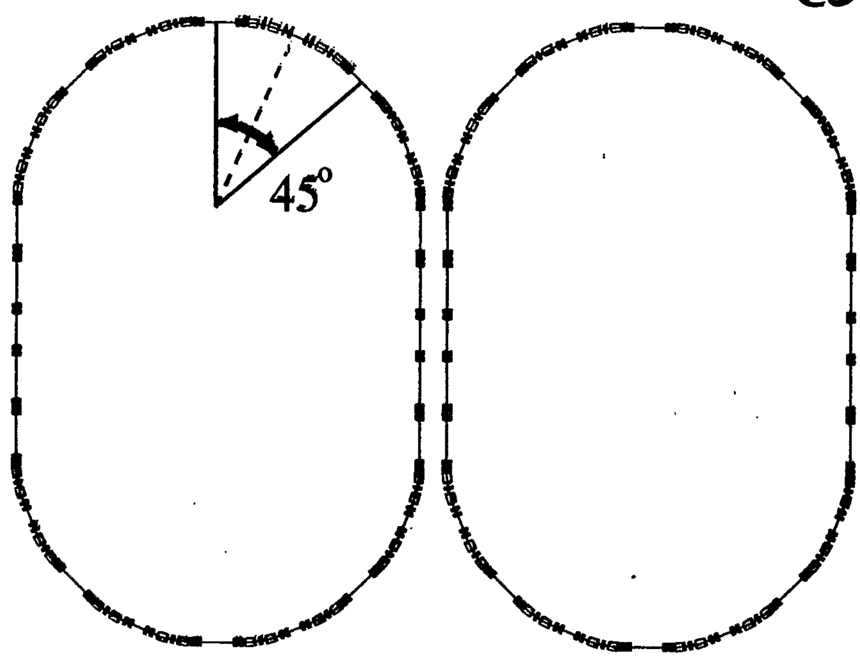
Unit cells of 45 degree arc

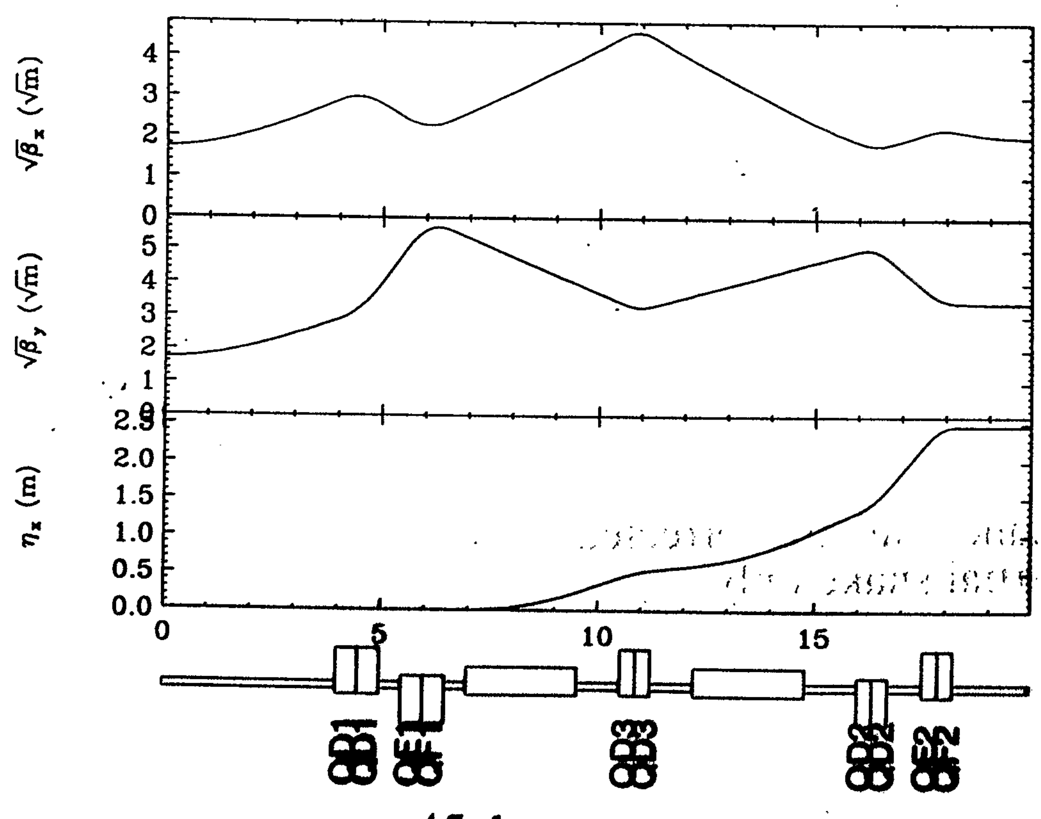
- mirror symmetry of doublet lattice OFDBFBDFO
- double achromat

Straight sections

- double achromat
- betatron phase advance of 2π

Mode 2: two separated rings, ⇒ collider





45 degree arc

The Proposed RCNP Cooler Collider:

- Store/collide protons, light ions, electrons, polarized ions

  allow collision between different species

- Collision energy at multi-GeV range

  adjustable, around 5 GeV/u

- Various kinds of beam cooling for emittance preservation

  intrabeam scattering is strong for low energy ions

- Two independent rings, flexible modes for storage and collision

- "Figure of 8" configuration for depolarization minimization

Accelerator Functions

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Injection
- Multi-Turn Injection
- Slow Resonant Injection
- Charge Stripping/Charge Exchange Injection
- RF Stacking Injection
- Cooling Injection
- Single-Turn Injection with Fast Kicker
- Bunch to Bucket Injection

Acceleration

Extraction
- Slow Resonant Extraction
- Slow Resonant Extraction with RF Knock-Out
- Slow Stochastic Extraction
- Fast Extraction with Fast Kickers
- Fast Resonant Extraction
- Carbon Fiber Scattering Extraction
- Charge Stripping/Charge Exchange Extraction

Storage

Accumulation

Colliding

Merging

Cooling
- Electron Cooling
- Stochastic Cooling
- Laser Cooling
- Ionization Cooling
- Radiative Cooling

Other functions
- Insertions: Low Beta, Dispersion-Free
- Adjustments and Corrections: Tune, Chromaticity, COD, Non-Linearities
- Focusing Mode Change: e.g. between Q-Triplet and Q-Doublet

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High Performance in HIMAC Synchrotron during both Acceleration and Slow Extraction

M. Kumada et al.,
"Towards an Ultimate Synchrotron Power Supply"

K. Noda et al.,
"Slow Beam Extraction at HIMAC Synchrotron"

Essentials of high-performance HIMAC synchrotrons

Very low ripple synchrotron magnet field

Very low ripple synchrotron power supply

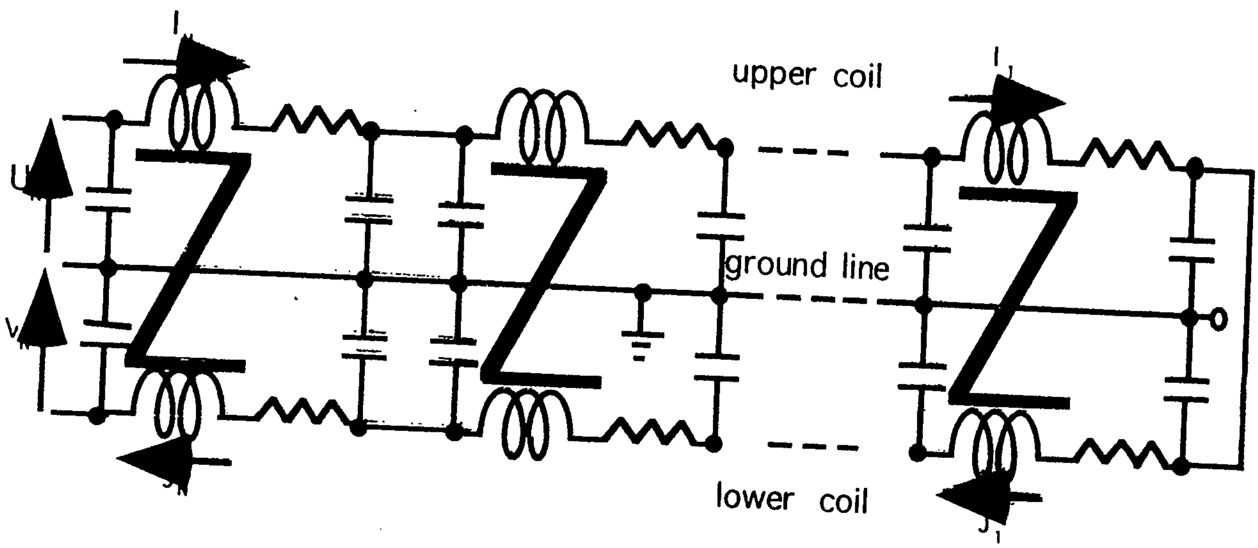
Performance of HIMAC Q-magnet power supply with normal mode active filter

Frequency spectrum of normal mode output between positive and negative terminals

Frequency (Hz)	Voltage (dB: measured)	Current ripple (relative: reduced)
50	-95	1.4×10^{-7}
100	-76	5.1×10^{-7}
150	-88	0.9×10^{-7}
200	-81	1.4×10^{-7}
300	-89	0.4×10^{-7}
600	-77	0.9×10^{-7}
1200	-85	0.1×10^{-7}

Kumada

3. Ripple suppression



The potential develops at the neutral point of the power supply.

Normal mode current: Anti-Parallel current, I+J
Common mode current: Parallel current, I-J

Normal mode voltage: U+V
Common mode voltage: U-V

Normal mode impedance: $Z_n = \frac{U+V}{I+J}$

Common mode impedance: $Z_c = \frac{U-V}{I-J}$

cancellation of "common mode" field

⇒ ripple suppression

Autin

RECENT TRENDS IN LATTICE DESIGN

B. AUTIN

CERN, PS Division, 1211 Genève 23, Switzerland

Introduction

Lattice periods

FODO cell and scaling variables

Triplet cell, foci and principal planes

Quasi-isochronous period and orbit length

Betatron matching modules

Single lens

Doublet

$\lambda/4$ transformer

Afocal telescope

Inversor

BeamOptics

Conclusion

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The program *BeamOptics*

FODO cell	**FODO**[f, ϕ] or **FODO**[Sin[μ/2], ϕ]
Triplet cell	**Triplet**[f, d, ϕ]
Isochronous period	**IsoPeriod**[n, MissingMagnet -> m, Resonance -> h]
Matching lens	**MatchingLens**[β_x,β_y]
Matching doublet	**MatchingDoublet**[β, d]
λ/4 Transformer	**Transformer**[σ_1,σ_2]
Afocal telescope	**Telescope**[f_1, f_3]
Inversor	**Inversor**[m]

Franzke

COOLED HEAVY ION BEAMS IN THE ESR

DIAGNOSIS AND APPLICATIONS

B. FRANZKE, K. BECKERT, F. NOLDEN, H. REICH,
A. SCHWINN, M. STECK , T. WINKLER

1. Heavy Ion Facilities at GSI

1.1 Accelerators UNILAC/SIS
1.2 Experimental Storage Ring ESR

2. Diagnostics for Cooled Ion Beams

2.1 Overview
2.2 Schottky diagnosis system

3. Results of Electron Cooling

3.1 Overview
3.2 Extremely low beam temperature

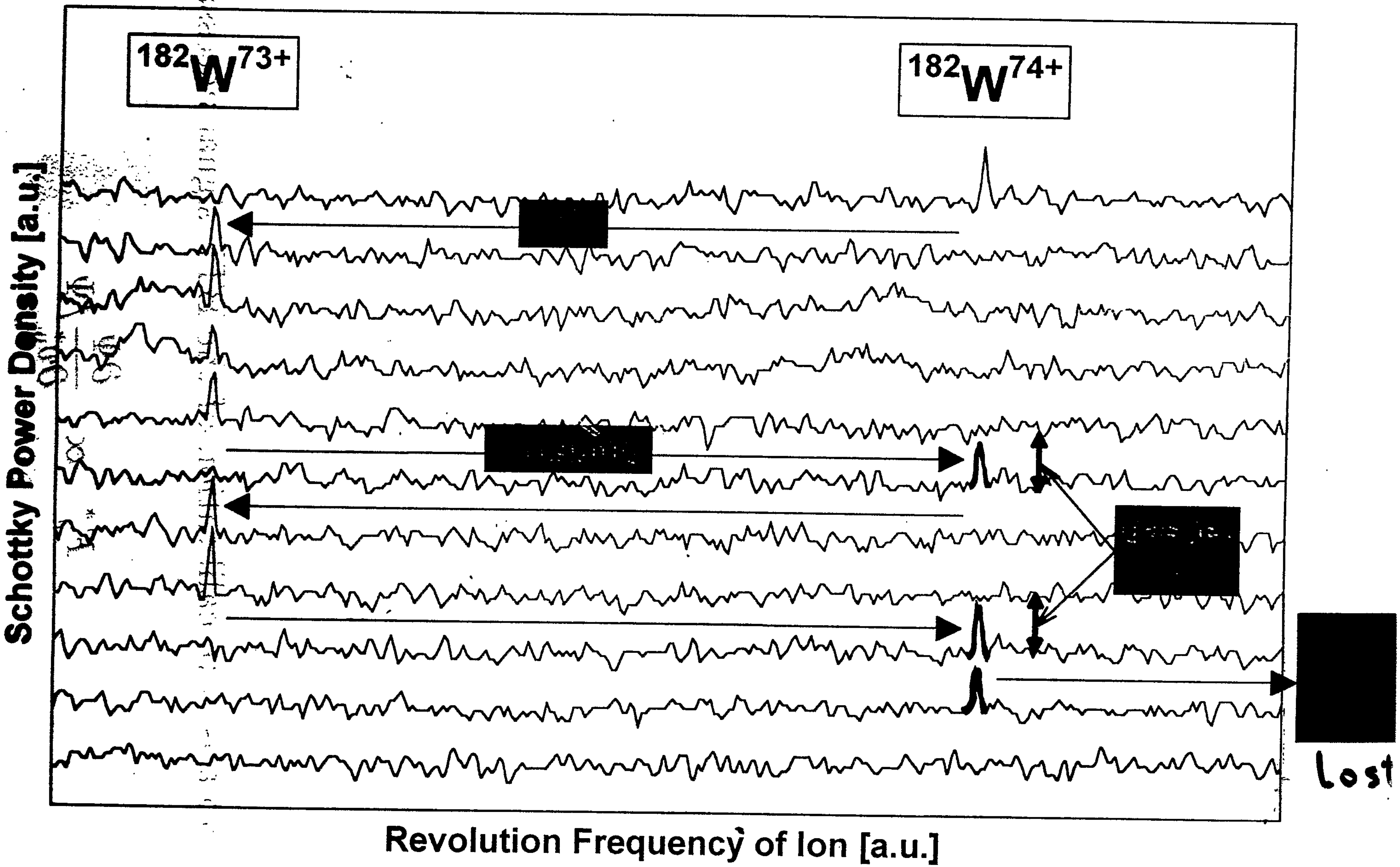
4. Applications

4.1 Schottky Mass Spectrometry
4.2 Bound-beta-decay
4.3 Di-electronic Recombination (DR)

5. Conclusion and Outlook

Franzke

Consecutive Stripping and Electron Capture of a Single Stored Ion



4. Applications

Franzke

Novel experimental methods because of:
- High resolving power of the Schottky diagnosis
- High sensivity with highly charged ions
- Electron cooled beams
- Relatively high stability of ring components

4.1 Schottky Mass Spectrometry

Procedure: exotic beams produced and pre-selected FRS
fragmentation,
electro-magnetic dissociation
fission of fast projectiles.
injected to the ESR, electron cooled
Schottky diagnosis applied

Result: High accuracy : $\Delta m/m \leq 2\times10^{-7}$ attained
High redundancy by multi-component spectra
Nearly 150 new or essentially improved mass values

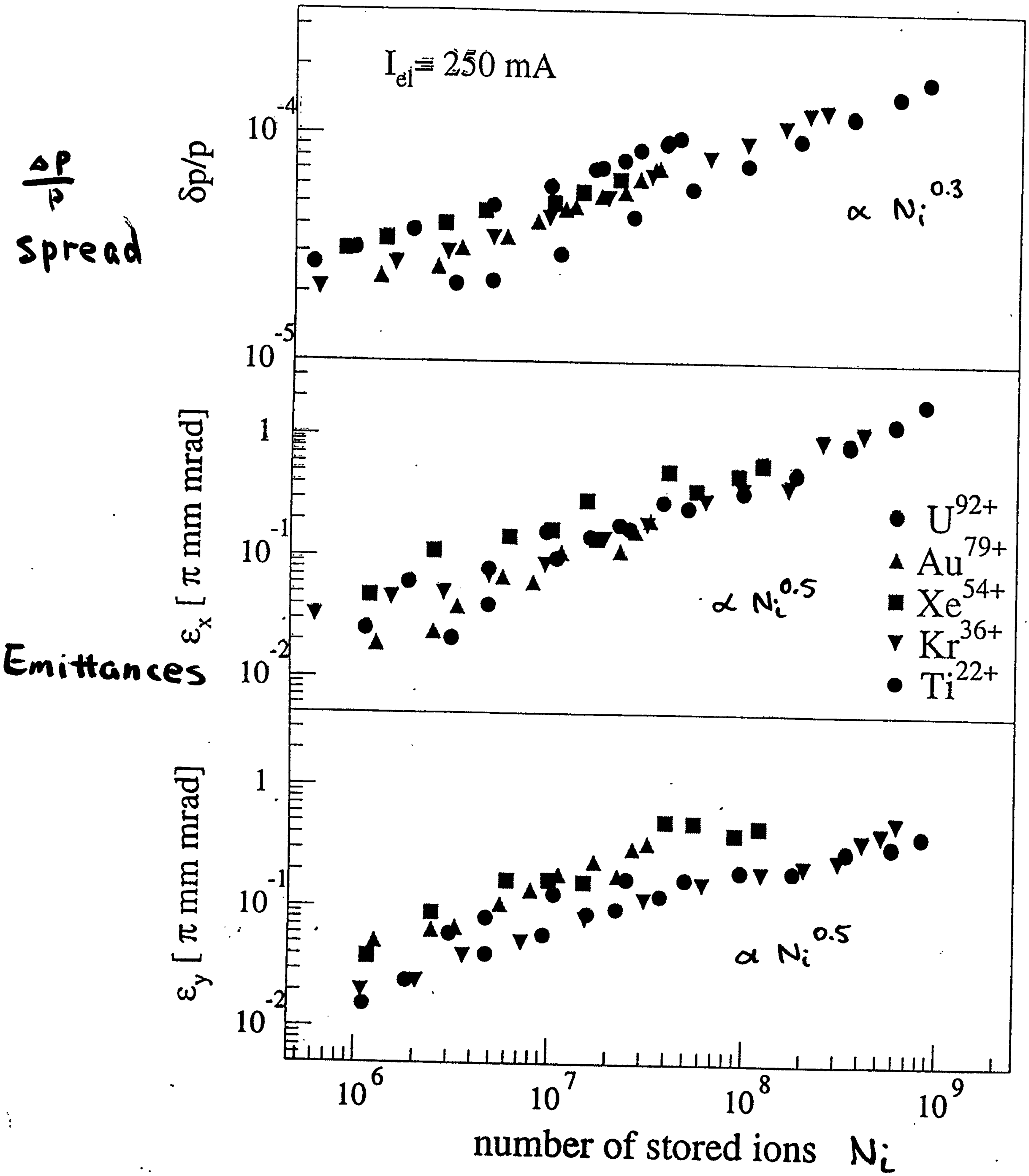
Limitation:Limited stability of ESR-components

4.2 Bound-beta decay of nuclei (BBD)

Komplex strategy for the measurement
BBD life time of nearly 33y for $^{187}Re^{75+} \rightarrow ^{187}Os^{75+}$

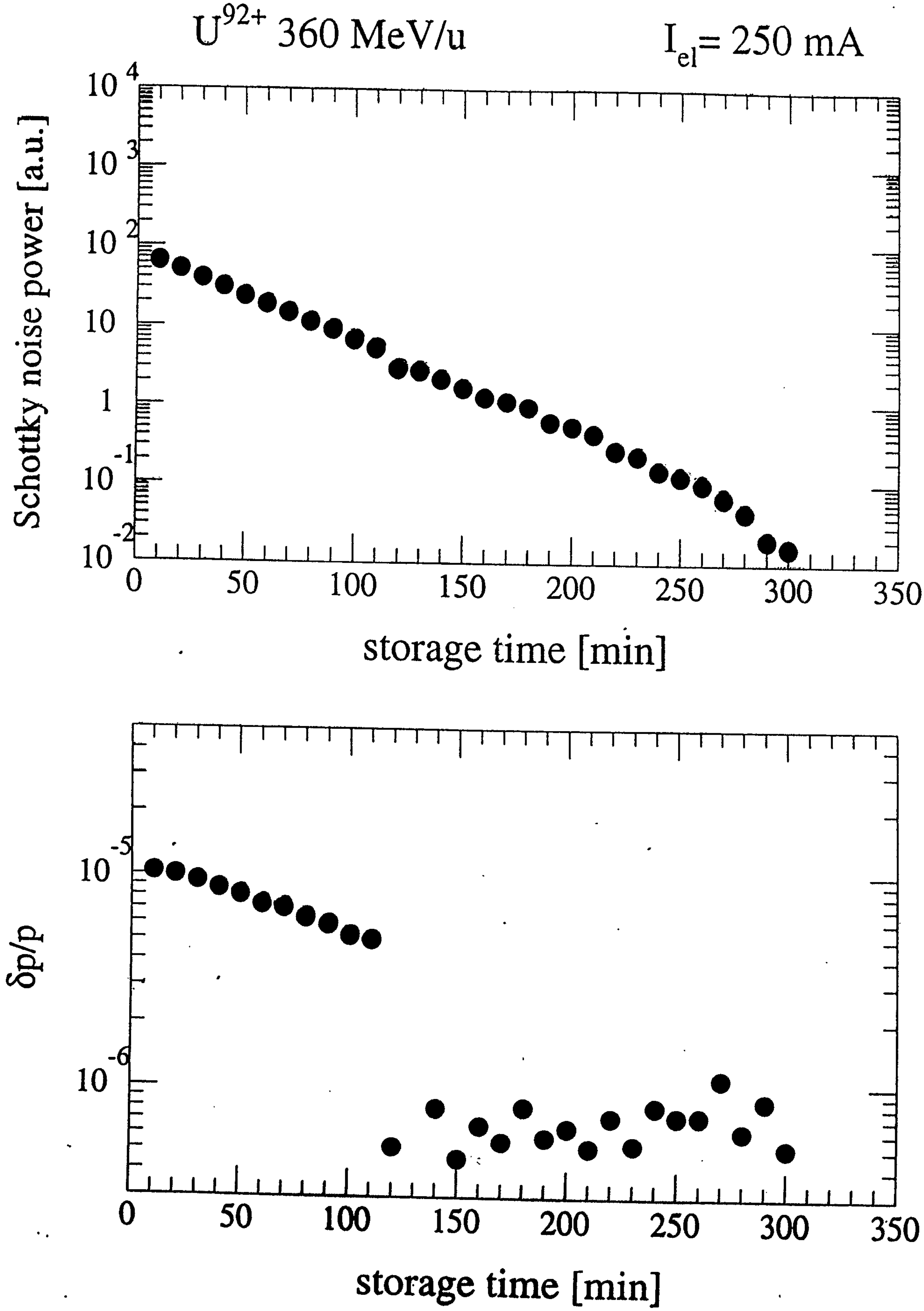
4.3 Di-electronic recombination (DR)

Energy resolution better tha 0.01 eV!
$2s_{1/2}$ - $2p_{1/2}$ -splitting precisely measured
Relevant for higher oder QED



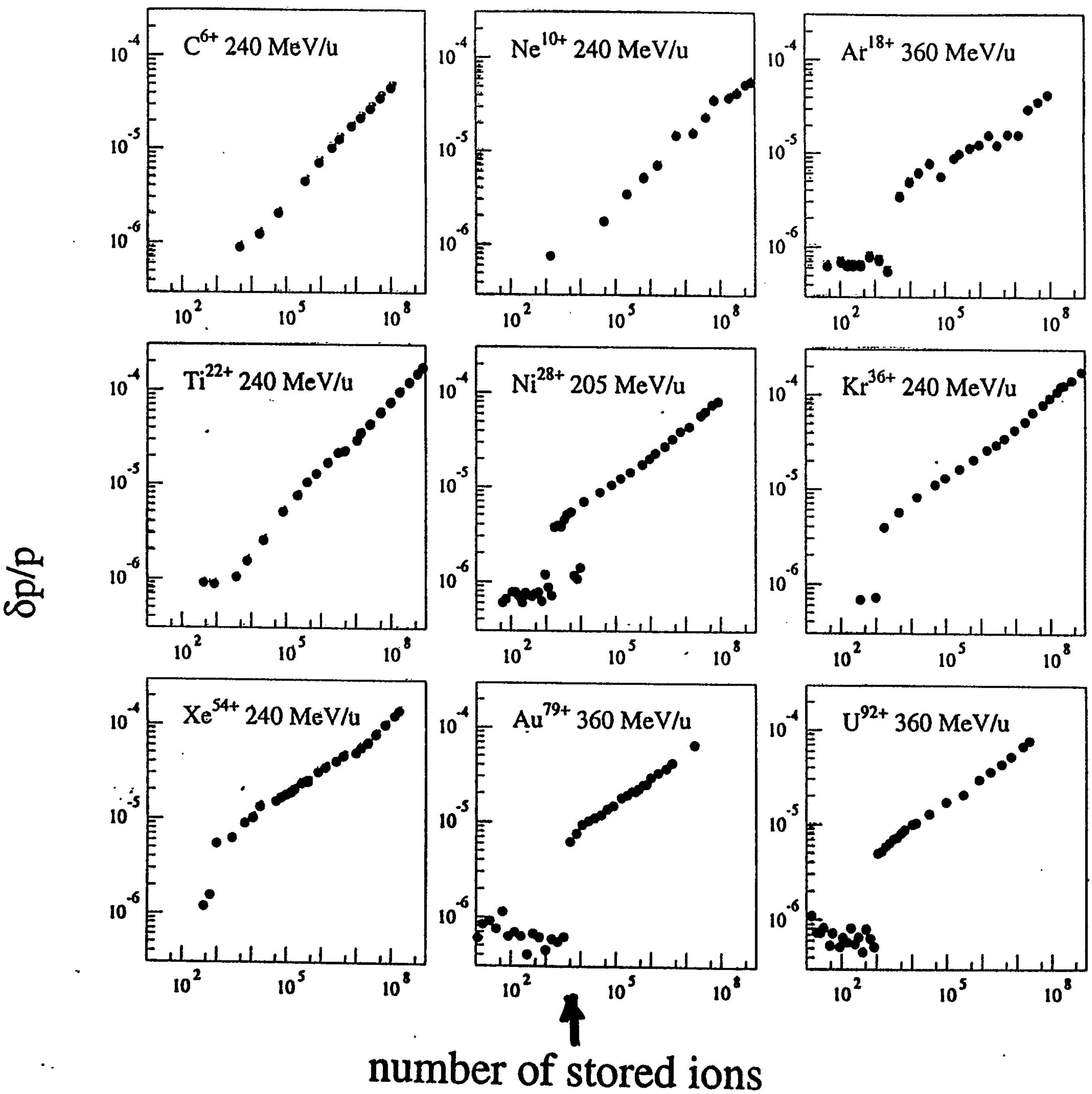
$\frac{\Delta p}{p}$ Spread
Emittances
$I_{el} = 250$ mA
$\delta p/p$
ε_x [π mm mrad]
ε_y [π mm mrad]
∝ $N_i^{0.3}$
∝ $N_i^{0.5}$
∝ $N_i^{0.5}$
U^{92+}
Au^{79+}
Xe^{54+}
Kr^{36+}
Ti^{22+}
10^{-4}
10^{-5}
1
10^{-1}
10^{-2}
10^6
10^7
10^8
10^9
number of stored ions N_i

Franzke



U92+ 360 MeV/u
Iel= 250 mA
Schottky noise power [a.u.]
10 4
10 3
10 2
10
1
10 -1
10 -2
0
50
100
150
200
250
300
350
storage time [min]
δp/p
10 -5
10 -6
0
50
100
150
200
250
300
350
storage time [min]

Franzke



C6+ 240 MeV/u
Ne10+ 240 MeV/u
Ar18+ 360 MeV/u
Ti22+ 240 MeV/u
Ni28+ 205 MeV/u
Kr36+ 240 MeV/u
Xe54+ 240 MeV/u
Au79+ 360 MeV/u
U92+ 360 MeV/u
δp/p
10-4
10-5
10-6
10 2
10 5
10 8
number of stored ions

F. Caspers (CERN)
Osaka, March 1997

EXPERIENCE WITH STOCHASTIC COOLING OF PARTICLE BEAMS

1. Introduction

2. Review of existing systems
   - 2.1 AAC
   - 2.2 LEAR
   - 2.3 FNAL
   - 2.4 TARN 1

3. Review of stochastic cooling systems under construction
   - 3.1 GSI Darmstadt (ESR)
   - 3.2 FZJ Jülich (COSY)

4. Bunched beam stochastic cooling (BBSC)
   - 4.1 SPS
   - 4.2 FNAL
   - 4.3 Experiments at AAC and LEAR

5. Some comments on theoretical aspects

6. A list of practical hints for design, setting up and trouble shooting

7. Conclusion

4.2 BBSC TEST IN THE TEVATRON

- A 4-8 GHz betatron BBSC system has been installed in the Tevatron (aim: reduction of emittance blow-up to increase luminosity lifetime).

- PU-kicker separation is about 60 m (= $\lambda_\beta/4$). PU and kicker have movable plates with 16 co-planar loops each.

- The system uses fiber-optic delay lines for ps-timing level stability and as a high Q notch filter (photon storage ring).

- For BTF measurements "bucket gating" technique was used.

- The decrease in revolution harmonics power is much slower than predicted form a smooth Gaussian bunch shape.

- So far, observation of signal suppression when loop closed.

- As an important obstacle dynamic range limitation was identified (front end amplifier). To overcome this problem, presently a phase dispersive pulse stretcher (like a waveguide) is under construction in order to "smear out" the high peak signals without loss in bandwidth. After the last power amplifier a low loss pulse compressor cancels the phase distortion.

2. New/Proposed Accelerator Projects

New projects in Japan:

- SPRING-8
- Japanese B-Factory
- 50-GeV Proton Synchrotron
- New SUBARU - Isochronous Ring
- RIKEN RI Beam Factory
- Japanese Linear Collider
- RCNP (Osaka) Cooler Collider
- ...

Spring-8 Hara

Table 1.
Storage Ring Synchrotron Radiation Sources (March 1994)

LOCATION	Inst	Electron Energy (GeV)	Notes
BRAZIL			
Campinas	LNLS-1	1.15	Ded*
	LNLS-2	2	Design/Ded
CHINA (PRC)			
Beijing	BEPC	1.5-2.8	Partly Ded
Hefei	HESYRL	0.8	Ded
ROC-TAIWAN			
Hsinchu	SRRC	1.3	Ded
DENMARK			
Aarhus	ASTRID	0.6	Partly Ded
ENGLAND			
Daresbury	SRS	2	Ded
	DIAMOND	3	Design/Ded
	SINBAD	0.6	Design/Ded
FRANCE			
Grenoble	ESRF	6	Ded
Orsay	DCI	1.8	Ded
	SuperACO	0.8	Ded
Discussed	SOLEIL	2.15	Design/Ded
GERMANY			
Bonn	ELSA	1.5-3.5	Partly Ded
Dortmund	DELTA	1.5	Ded/FEL*
Dresden	ROSY	3	Plan/Ded
Hamburg	DORIS III	4.5-5.3	Ded
	PETRA II	7-14	Partly Ded*
Berlin	BESSY I	0.8	Ded
	BESSY II	1.7	Ded*
INDIA			
Indore	INDUS-I	0.45	Ded*
	INDUS-II	2	Design/Ded
ITALY			
Frascati	ADONE	1.5	Shut down
	DAFNE	0.51	Parasitic*
Trieste	ELETTRA	1.5-2	Ded
JAPAN			
Hiroshima	HISOR	0.4-1.0	Design/Ded
Kyushu	SOR	0.7	Design/Ded
Nishi Harima	Spring-8	8	Ded*
Okasaki	UVSOR	0.75	Ded
Osaka	Kansai SR	1.8	Design/Ded
Sendai	TSSR	1.5	Design/Ded
Tokyo	SOR-ring	0.38	Ded
	HBLS	1.5-2	Design/Ded
Tsukuba	TERAS	0.8	Ded
	NIJI IV	0.5	Ded/FEL
	Photon Factory	2.5	Ded
	Acc Ring	6	Partly Ded
	Tristan	8-32	Plan/Ded
KOREA			
Pohang	P L S	2	Ded*
NETHERLANDS			
Eindhoven	EUTERPE	0.4	Plan*
RUSSIA			
Moscow	Siberia I	0.45	Ded
	Siberia II	2.5	Ded*
Novosibirsk	VEPP-2M	0.7	Partly Ded
	VEPP-3	2.2	Partly Ded
	VEPP-4	5-7	Partly Ded
	Siberia-SM	0.8	Ded*
Zelenograd	TNK	1.2-1.6	Ded*
SPAIN			
Barcelona	Catalonia SR Lab	2.5	Authorised
SWEDEN			
Lund	MAX I	0.55	Ded
	MAX II	1.5	Ded*
SWITZERLAND			
Villigen	SLS	1.5-2.1	Design/Ded
USA			
Argonne, IL	APS	7	Ded*
Baton Rouge, LA	CAMD	1.2	Ded
Berkeley, CA	ALS	1.5	Ded
Durham, NC	FELL	1-1.3	Ded/FEL
Gaithenburg, MD	SURF II	0.28	Ded
Ithaca, NY	CESR	5.5	Partly Ded
Raleigh, NC	NC Star	2.5	Design/Ded
Stanford, CA	SPEAR	3-3.5	Ded
Stoughton, WI	ALADDIN	0.8-1	Ded
Upton, NY	NSLS I	0.75	Ded
	NSLS II	2.5	Ded

* In construction

Status Report on the SPring-8

SPring-8 Accelerator Group, presented by M. Hara
JAERI-RIKEN SPring-8 Project Team
Kmigori-cho, Hyogo
678-12 Japan

Abstract

The SPring-8 is a high energy third generation synchrotron radiation source designed to deliver X-ray beam with a brilliance more than 10^{19} photons/sec/mm^2/mrad^2/0.1%b.w. The facility consists of a 1 GeV linac, an 8 GeV booster synchrotron and an 8 GeV low emittance storage ring. The construction was started in 1990. Accumulated budget to date amounted to about a half of the total budget. Commissioning of the storage ring is expected in Feb. 1997.

1. INTRODUCTION

The SPring-8 is designed and constructed by Japan Atomic Energy Research Institute (JAERI) and The Institute of Physical and Chemical Research (RIKEN). After construction, Japan Synchrotron Radiation Research Institute (JASRI), which was established in 1990 as a nonprofit research institute, will be responsible for the management and operation in collaboration with JAERI and RIKEN. This is a user facility for SR researchers from universities, national laboratories, and industries not only in Japan but also from abroad. In Phase I, from '91 to '98, construction and commissioning of the accelerators and 10 beamlines are included. In Phase II, construction of beamlines will continue.

2. INJECTORS

2.1. Injector Linac

The SPring-8 linac has 26 accelerating columns. Each column is 2.835 m long and operated at the gradient of 16 MeV/m. The linac has space for electron/positron converter at 250 MeV, and can accelerate electron or positron up to 1.15 or 0.9 GeV. Main parameters of the linac is listed in Table 1.

Table 1 Parameters of linac

Output Energy	1 GeV
Operation Rate	60 Hz
Radio Frequency	2856 MHz
Type of Acc. Column	Travel. Wave
Length of Acc. Column	2.835 m
Number of Columns	26
Total Length	140 m
Klystron Max. Power	80 MW
Emittance (1 GeV)	< 1.0 πmm•mrad
Energy spread	± 1.0 %

The construction of the injector linac was started in 1991. The preinjector part of the linac has been operational in Tokai campus and the beam performance has already been evaluated. Measured emittance was about 5 πmm•mrad(9 MeV), and the pulse width for short pulse mode was less than 1 nsec. All the accelerating columns have already been delivered in the site. The performance test for the first fabricated one was good enough to satisfy the specification. Construction of linac building will be completed in September '94. Detailed description is in reference [1].

2.2 Booster Synchrotron

The booster synchrotron has 2-fold symmetric 40 FODO cells. Two straight sections are used for injection, extraction and RF acceleration. Eight 5-cell cavities with inductive coupling slots are adopted and the RF power of 508.58 MHz is provided by Two 1.2-MW klystrons. Maximum RF voltage is 18.2 MV/turn with 10 sec of quantum lifetime. The construction of the synchrotron was started in March 1993. All the components have been ordered to manufacturers and each preceding component (dipole, quadrupole, sextupole, cavity etc.) has manufactured and now under testing. Construction of the synchrotron building will be completed in March 1995.

Table 2 Parameters of synchrotron

Injection Energy	1 GeV
Max. Energy	8 GeV
Circumference	396.12 m
Repetition Rate	1 sec
Natural Emittance	230 n m•rad.
Momentum Spread	0.00126
Number of Cells	40
Nominal Tune (ν_x/ν_y)	11.73/8.78
Radio Frequency	508.58 MHz
Radiation Loss(8 GeV)	12.27 MeV/turn

3. STORAGE RING

3.1. Lattice and fundamental features

Design principles of the SPring-8 storage ring are as follows;

1) insertion device oriented ring,

2) the first harmonic undulator radiation from 10-20 keV with more than 10^{19} photons/sec/mm^2/mrad^2/0.1%b.w.,

3) several very long straight sections for special insertion devices,

4) low emittance lower than 10 n m•rad.,

5) good photon beam stability,

6) good time structure.

To satisfy above requirements, energy of 8 GeV and Chasman-Green lattice structure was adopted. The ring has a 4-fold symmetric structure with 44 normal cells and 4 straight cells, and total circumference is 1436 m. A normal cell has 2 dipole, 10 quadrupole, 7 sextupole magnets, and a 6.65 m long straight section, while a straight cell has no dipole magnets and can be changed to 30 m long straight section by rearranging Q and S magnets at a matured phase. This long straight section is one of the special merits of SPring-8[2,3]. Table 3 summarizes major parameters of the storage ring.

Table 3 Major parameters of the SPring-8 storage ring

Electron Energy	8 GeV
Current (multi-bunch)	100 mA
(single-bunch)	5 mA
Circumference	1435.95 m
Synchrotron Radiation	
Energy Loss per Turn	9.23 MeV/turn arc
	12.4 MeV/turn with ID
Critical Photon Energy	28.9 keV
Length of Straight Section	6.65 m normal
	~30 m long
Bending Radius	39.272 m
Natural Emittance	5.55 nm•rad.
Synchrotron Frequency	0.01005
Momentum Compaction	1.46×10^{-4}
Type of Lattice	Chasman-Green
Number of Cells	44 Normal cell
	4 Straight cell
Energy Spread	0.001094
Harmonic Number	2436
Radio Frequency	508.58 MHz
RF Voltage	17 MV
Bunch Length σ	3.63 mm

About a half of the main magnets (dipole, quadrupole, sextupole ones) have already been delivered in the site and the remainings are under fabrication. A part of power supplies for these magnets have been completed. Magnetic field measurement for bending magnet is underway. The measurement for 72 dipole magnets has been completed and the deviation of performance has been proved to be low. The measurement for QM and SM is to start. Field measuring instrument is being improved to get the field center within 10 μm. Magnet alignment will be performed in two stages. QMs, and SMs in a common girder are aligned within 50 μm, and girders are within 200 μm. Prototype girder has been made and under testing. Injection system of the storage ring has 5 bump magnets and DC and pulse septum magnets. One extra bump magnet will be used for on-axis injection only at commissioning phase.

3.2. Vacuum System

Vacuum system consists of two types of vacuum chamber, crotches, absorbers, and various components such as bellows, flanges and valves. One cell components (2 bending chambers, 3 straight chambers, crotches, absorbers, pumps and so on) have been assembled in a test bench with girders and magnets. In this test bench, various test such as girder alignment, magnets set up and alignment, installing chambers and vacuum components (taking off the upper part of magnet), vacuum test, and baking, and so on, have already been performed. After the performance confirmation, construction of the rest 47 cells of chambers are to start.

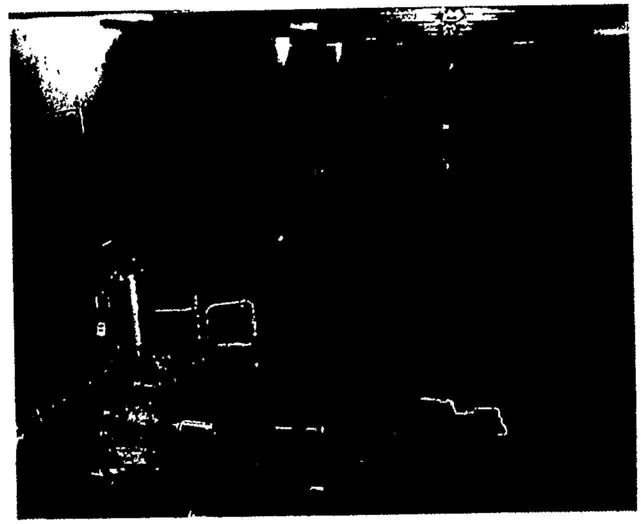


Figure 1. String test set up in one cell test bench.

3.3. RF system

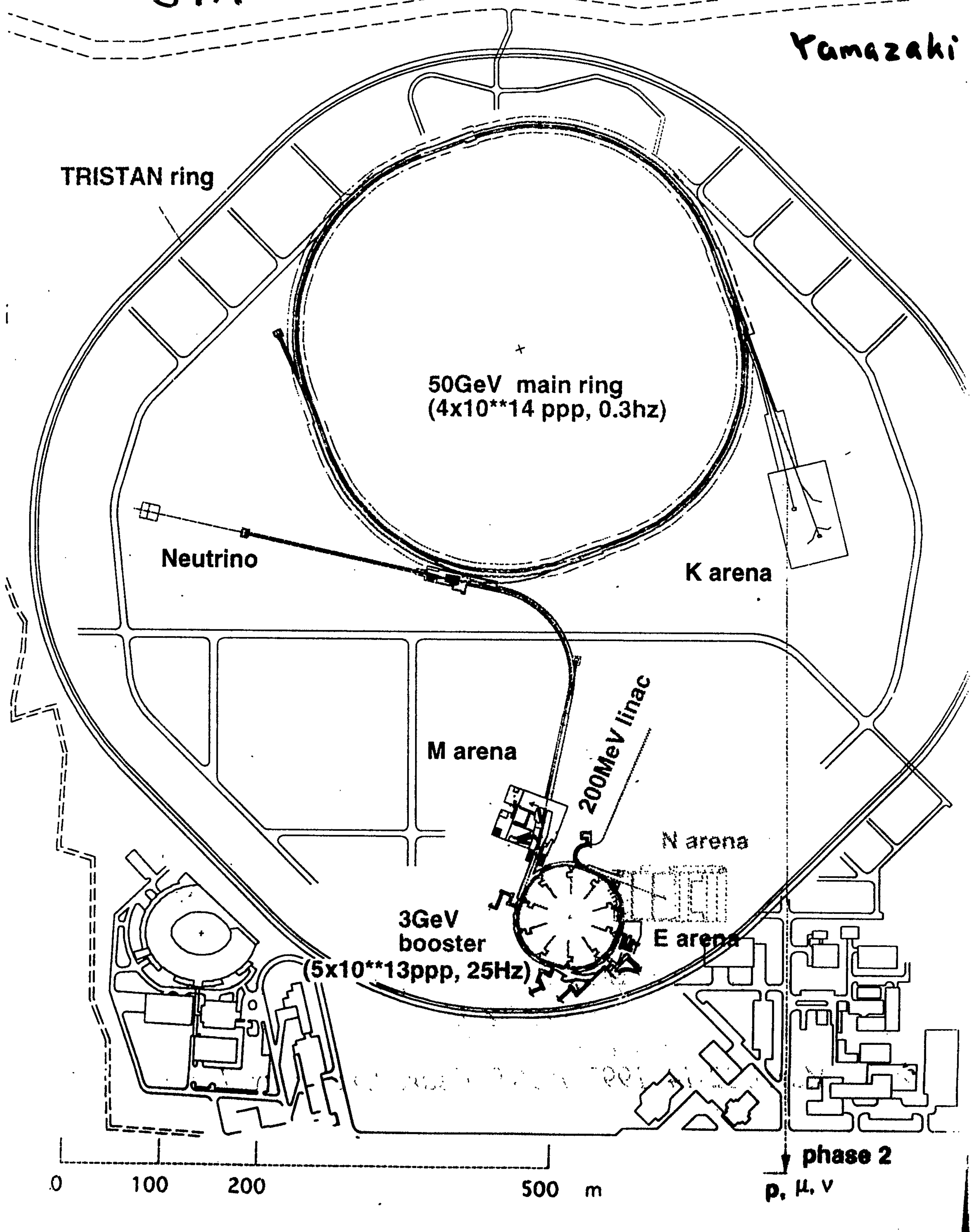
The storage ring has 4 RF stations and each station has 8 single cell cavities which are powered by 1.2 MW klystron at 508.58 MHz. A klystron and a new type of high voltage power supply for one of the four RF stations was installed in Dec. 1993, and the test of the power supply is in progress. Some of the RF components were tested with high power[4]. HOM property of the prototype cavity has been completed and 8 cavities for one RF station have been ordered and will be fabricated in 1995.

Figure 2. Klystron, waveguides, circulator, and dummy loads in D-RF station.

3.4. Control system

JAP - 50 GeV

Yamazaki



Yamazaki

Original JHP was as follows:

1-GeV H^- Linac

(20 mA peak, 400 μs, 50 Hz, 400 μA average)

1-GeV Compressor, Stretcher Ring

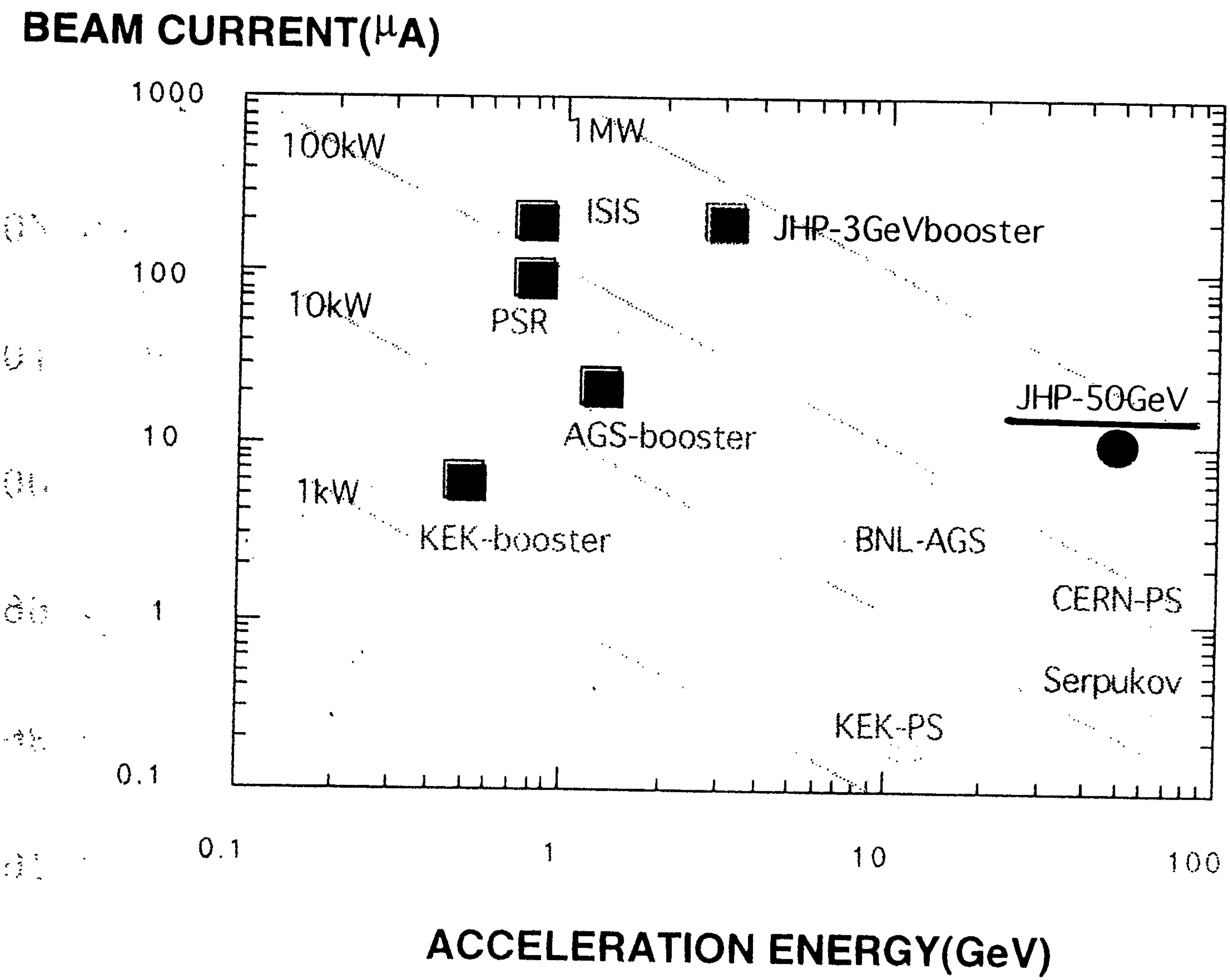
The accelerator R&D group was organized in May, 1987.
During the course of eight years,

1. The KAON project at TRIUMF was canceled.
2. It was widely realized that the spallation neutron yield increases as the proton energy increases.(At first we believed that the optimum proton energy is around 1 GeV regarding the neutron yield.)
3. MW-class spallation neutron sources were strongly requested.

1. A few 10-GeV proton synchrotron was strongly requested by nuclear physicist community.
2. The cost should be optimized regarding the product of the current and the energy.
3. Upgradability.

The 3-GeV-class rapid cycle synchrotron can be an injector to a few 10-GeV synchrotron.
The proton linac should be able to cope with the future increase in the peak current at the ion source. For this the electromagnets have to be used in DTL. Then, the frequency should be lowered in order to contain the electromagnaets in the drift tubes.

Yamazaki



BEAM CURRENT(μA)
1000
100
10
1
0.1
100kW
1MW
10kW
1kW
ISIS
JHP-3GeVbooster
PSR
AGS-booster
KEK-booster
JHP-50GeV
BNL-AGS
CERN-PS
Serpukov
KEK-PS
0.1
1
10
100
ACCELERATION ENERGY(GeV)

Yamazaki

Proposed Time Profile of JHP

1997 New Organization

1998 Construction Start

1999 Neutrino Oscillation Experiment at 12-GeV PS

2000

2001 3-GeV Ring Installation into the 12-GeV PS Tunnel

2002 50-GeV Ring completion, First Beam

Yamazaki

Accelerator Complex

• 200-MeV linac — high brightness

accelerated particle	H^- ion
peak beam current	>30(50) mA (25Hz, 400μs
structures	RFQ + DTL + ACS

• 3-GeV booster — rapid cycling

intensity	5×10^{13} ppp
repetition rate	25Hz
beam power	0.6 MW
RF frequency	1.99-3.43MHz
RF voltage	389kV
circumference	339.4m (KEK-PS tunnel)

• 50-GeV main ring — transition free(negative α

intensity	2×10^{14} ppp
acceleration cycle	0.3Hz
RF frequency	3.43-3.51MHz
RF voltage	270kV
momentum compaction	$\sim -10^{-3}$
circumference	1442m (north site of KE

Japan B-factory Toge

t on the present status
ational Laboratory for

ON

:essfully operating the
1986. It consists of a
8 GeV Accumulation
; (MR). Concurrently
ommendations by the
nittee, survey studies
: facilities at KEK. We
nely, the asymmetric
TRISTAN-II) and the
ose of this paper is to
present an update on

actory)

is to allow studies of
ays of b-mesons. The
serve this purpose by
4S) resonance with
3.5 GeV (e^+) [1, 2].
e ring parameters, our
ged to build two new
nnel. Best efforts will
nd facilities.
neters of TRISTAN-II
n energy ring (HER).
operation where every
ver a peak luminosity
nase-II operation, by
g the same particle
minosity may reach
ate during the Phase-I
[goal.

00 m long) produces
25 Hz (maximum 50

	LER	HER	unit
Energy	3.5	8.0	GeV
Circumference	3018	3018	m
Tune shifts (x/y)	0.05 / 0.05	0.05 / 0.05	
Beta at IP (x/y)	1.0 / 0.01	1.0 / 0.01	m
Beam current	0.52	0.22	A
Energy spread	0.078	0.073	%
Bunch length (1σ)	5	5	mm
Bunch spacing	3.0	3.0	m
Bunch population	3.3	1.4	10^{10}
Emittance (x/y)	19 / 0.19	19 / 0.19	nm.rad
Synchrotron tune	0.014	0.070	
Betatron tune	~ 43	~ 39	
Energy loss / turn	0.84	4.1	MeV
Momentum compaction	2.0×10^{-4}	1.0×10^{-3}	
RF voltage	4.4	47	MV
RF frequency	508	508	MHz
Energy damping decrement	2.4×10^{-4}	5.1×10^{-4}	
Bending radius	16.2	91.3	m
Length of bend magnet	0.85	2.56	m

L $2\times10^{33} \sim 10^{34}$ $cm^{-2}s^{-1}$

Table 1. Parameters of TRISTAN-II B factory

1994 .

The upgrade involves replacement of existing 30 MW klystrons with 60 MW types and installation of SLAC-style pulse compression systems (SLED) which will amplify the accelerating power. It will increase the accelerating gradient from 9 MeV/m to 25 MeV/m. With a modest extension of accelerating structures, the total energy of 8 GeV for electrons will be achieved. The positron target will be relocated so that the positrons will be produced by 4 GeV electrons, resulting in a factor 20 increase of positron intensity to 3.2×10^9 / pulse.

To provide beams to the TRISTAN-II with improved stability and good optical matching, enhanced beam diagnostic tools and improved timing control systems will be built and implemented.

C. Ring Lattice

An important consideration in the lattice design is to maintain a sufficiently large dynamic aperture. This is to eliminate the need to alter the optics during injection, and to obtain a long beam lifetime during collisions. The very small β^* would create a large chromaticity which needs to be compensated without much compromising the operability of

Japan Linear Collider

Table 1.1

Linear Colliders: Overall and Final Focus Parameters – 500 GeV (c.m.)

	TESLA*	SBLC	JLC (S)	JLC (C)	JLC (X)	NLC	VLEPP	CLIC
Initial energy (c.of .m.) (GeV)	500	500	500	500	500	500	500	500
RF frequency of main linac (GHz)	1.3	3	2.8	5.7	11.4	11.4	14	30
Nominal Luminosity (10^{33} cm^{-2}s^{-2})†	2.6	2.2	5.2	7.3	5.1	5.3	12.3	0.7-3.4
Actual luminosity (10^{33} cm^{-2}s^{-2})†	6.1	3.75	4.3	6.1	5.2	7.1	9.3	1.07-4.8
Linac repetition rate (Hz)	10	50	50	100	150	180	300	2530-1210
No. of particles/bunch at IP (10^{10})	5.15	2.9	1.44	1.0	.63	.65	20	.8
No. of bunches/pulse	800	125	50	72	85	90	1	1-10
Bunch separation (nsec)	1000	16.0	5.6	2.8	1.4	1.4	–	.67
Beam power/beam (MW)	16.5	7.26	1.3	2.9	3.2	4.2	2.4	.8-3.9
Damping ring energy (GeV)	4.0	3.15	2.0	2.0	2.0	2.0	3.0	2.15
Main linac gradient, unloaded/loaded††(MV/m)	25/25	21/17	31/–	40/32	73/58	50/37	100/91	80/78
Total two-linac length (km)	29	33	22.1	18.8	10.4	15.6	7	8.8
Total beam delivery length (km)	3	3	3.6	3.6	3.6	4.4	3	2.4
$\gamma\epsilon_x/\gamma\epsilon_y$ (m-$rad \times 10^{-8}$)	2000/100	1000/50	330/4.8	330/4.8	330/4.8	500/5	2000/7.5	300/15
β_x^*/β_y^* (mm)	25/2	22/0.8	10/0.1	10/0.1	10/0.1	10/0.1	100/0.1	10/0.18
σ_x^*/σ_y^* (nm) before pinch	1000/64	670/28	260/3.0	260/3.0	260/3.0	320/3.2	2000/4	247/7.4
σ_z^* (μm)	1000	500	120	120	90	100	750	200
Crossing Angle at IP (mrad)	0	3	6.4	6.0	6.1	20	6	1
Disruptions D_x/D_y	0.56/8.7	.36/8.5	.29/25	.20/18	.096/8.3	.07/7.3	.4/215	0.29/9.8
H_D	2.3	1.8	1.6	1.4	1.4	1.34	2.0	1.42
Upsilon sub-zero	.02	.037	.20	.14	.12	.089	.059	0.07
Upsilon effective	.03	.042	.22	.144	.12	.090	.074	.075
δ_B (%)	3.3	3.2	12.7	6.5	3.5	2.4	13.3	3.6
n_γ (no. of γ's per e)	2.7	1.9	2.2	1.5	.94	.8	5.0	1.35
N_{pairs}(p_T^{min}=20 MeV/c,θ_{min}=0.15)	19.0	8.8	31.6	10.3	2.9	2.0	1700	3.0
$N_{hadrons}$/crossing	0.17	0.10	0.98	0.23	0.05	0.03	45.9	0.05
$N_{jets} \times 10^{-2}$ (p_T^{min}=3.2 GeV/c)	0.16	0.14	3.4	0.66	0.14	0.08	56.4	0.10

* Refer to Section 1.1 regarding possible TESLA parameter changes.

† For the sake of uniformity, the nominal luminosity is simply defined as $N^2/4\pi\,\sigma_x^*\,\sigma_y^*$ times the number of crossings per second, and in all cases assumes head-on collisions, no hour-glass effect and no pinch. The actual luminosity incorporates all these effects, including crossing angle where applicable. NLC calculations assume crab-crossing.

†† The loaded gradient includes the effect of single-bunch (all modes) and multibunch beam loading, assuming that the bunches ride on crest. Beam loading is based on bunch charges in the linacs, which are slightly higher than at the IP.

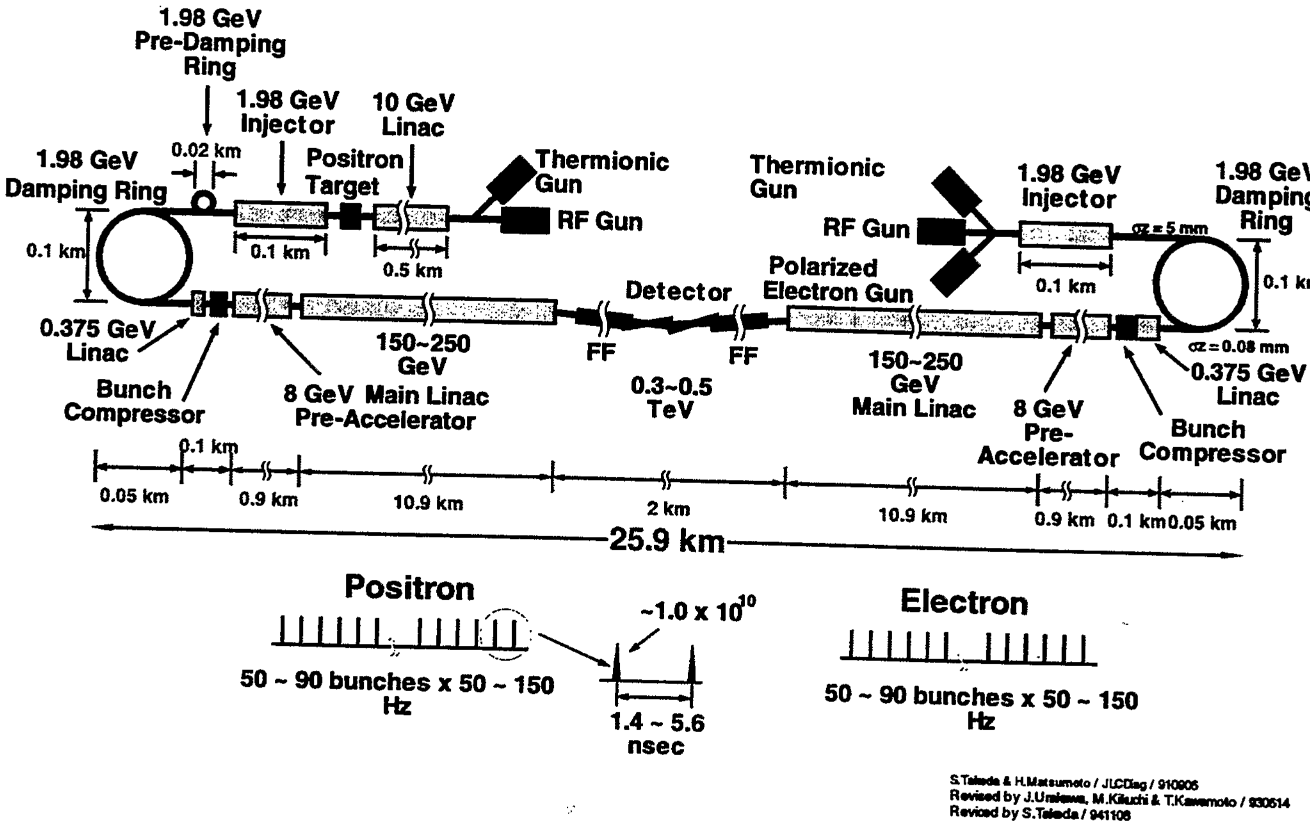


Fig.1.6 JLC schematic layout.

Ando

new SUBARU project

1. Promote Industrial Activities in Hyogo Prefecture

① Micromachining; Extreme Ultraviolet Projection Lithography
LIGA

② New Material

③ Development in Bio-technology

2. New Light Source; Coherent , Short pulse

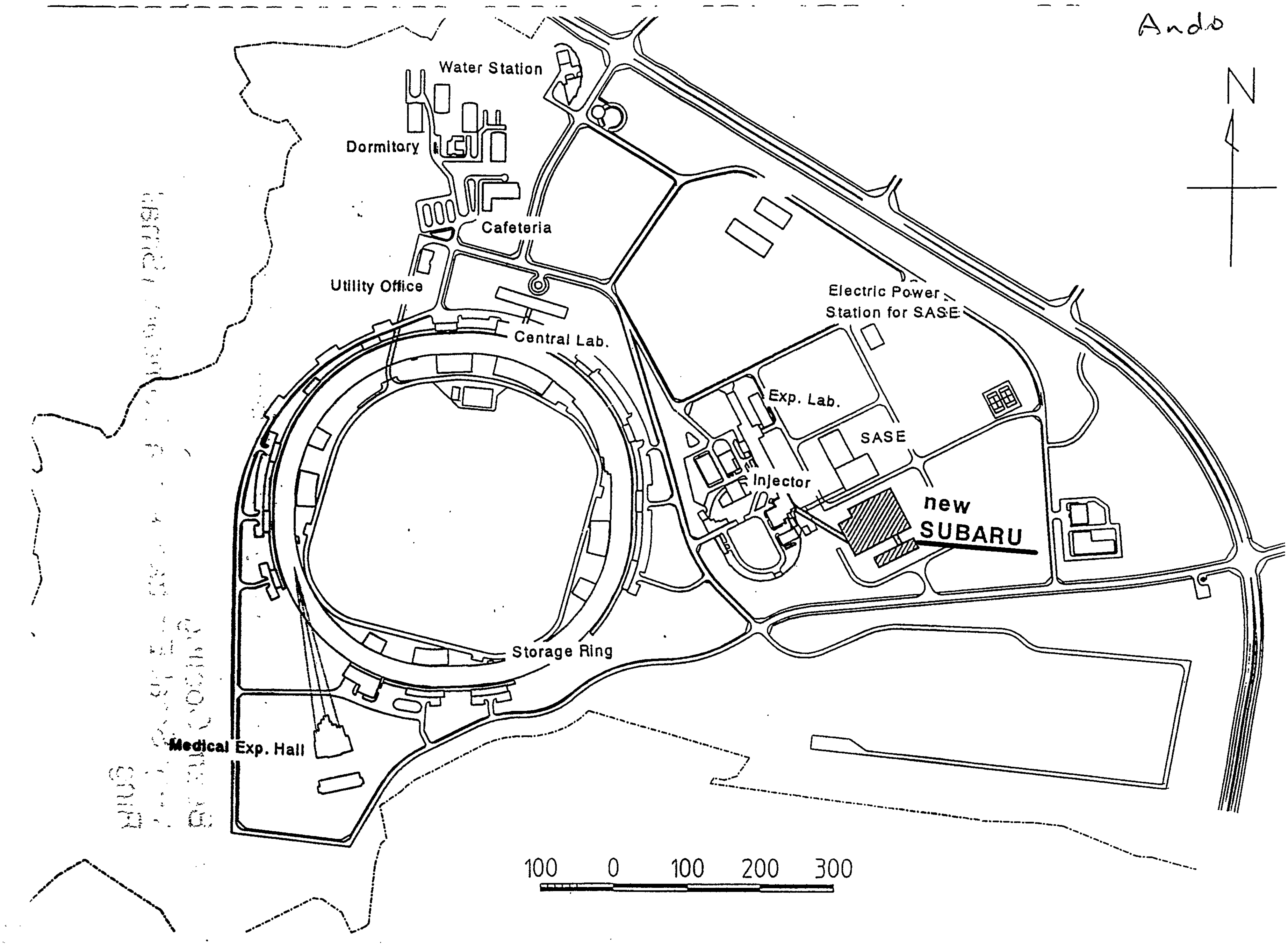
14m Long Straight Sections
FEL
Very Long Undulator
Laser / External Beam & e-Beam Interaction

3. Isochronouse & $\alpha_p < 0$
Very Short Bunch $\sigma_z \Rightarrow 1mm$

⇒ Deep Investigation of Beam Dynamics

⇒ Beam Cooling
Very Small Emittance in a Compact (Small) Ring

Ando



Water Station
Dormitory
Cafeteria
Utility Office
Central Lab.
Electric Power
Station for SASE
Exp. Lab.
SASE
Injector
new
SUBARU
Storage Ring
Medical Exp. Hall
N
100 0 100 200 300

$$\left.\frac{\Delta T}{T}\right]_{rev} = \sum \alpha_k \delta^k$$

$$\alpha_p \Rightarrow 0$$

Ando

1. Higher Order Synchrotron Oscillation
Stable Area of "

Second Islands at ($\delta = \Delta E/E$)

$$\delta_{\pm} = [-\alpha_2 \pm (\alpha_2^2 - 4\alpha_1 \alpha_3)^{1/2}] /(2\alpha_3)$$
$$\Rightarrow -\alpha_2/\alpha_3 \quad (\alpha_1 \rightarrow 0)$$
$$\Rightarrow -\alpha_1/\alpha_2 \quad (\alpha_3 \rightarrow 0)$$

Overall control not only ordinary chromaticity but also α_k's
keeping enough dynamic aperture.

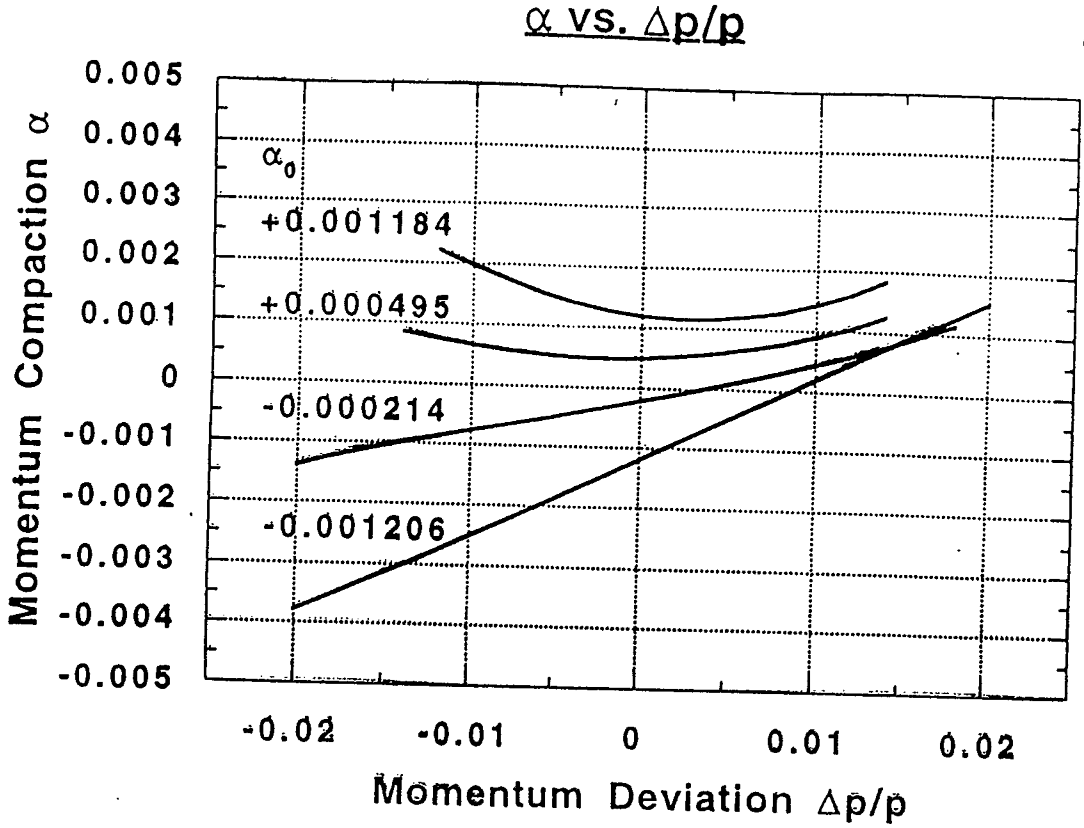
2. (Micrwave) Instability
Growth time $\propto 1/|\alpha_p|$
Experimental Study

3. Tousheck Effects ----- How to overcome ?

4. Technical Improvement
Presice & Stable Control of power supplies, etc.

* T(sychrotron osci.) > T (radiation damping) ?

Ando



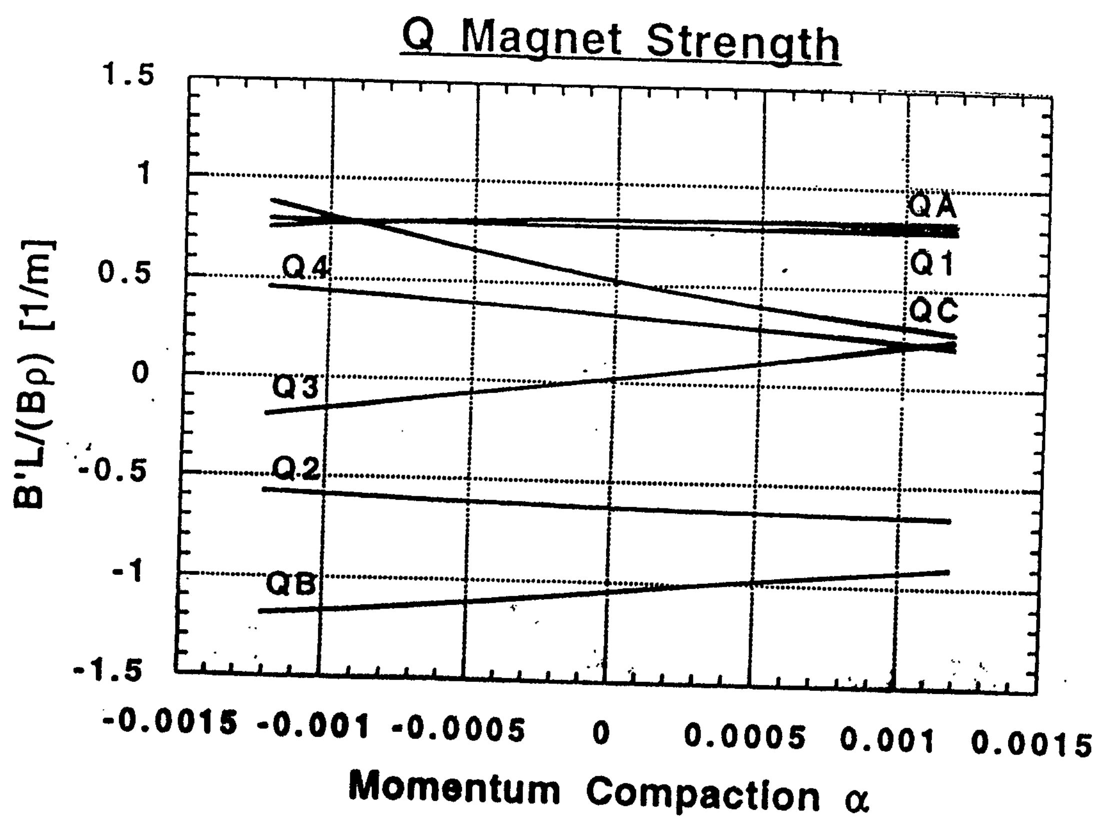


図2－5．チューンを固定しα_pを変えたときの他パラメーターの変化（その5）

Ando

Table 1: Main parameters of new SUBARU storage ring.

Fundamentals		
Injection energy	1	GeV
Operation energy	1.5	GeV
Stored current	<500	mA
Circumference	118.716	m
Revolution period	0.396	μ sec
Revolution freq.	2.525	MHz
Harmonic No.	198	
RF frequency	500	MHz
Betatron Tunes	6.21/2.17	
Chromaticity	-19/-7.5	
α_p	0.001	
Straiht sections	4m	×4
	14m	×2

Operation parameters	1. 5	GeV
Natural emittance	67	nm
Coupling	10	%
Bending field	1.55	T
Critical photon	0.53	nm
	2.33	keV
Radiation / Turn	176	keV
Damping time		
Longitudinal	3.42	msec
X	6.56	msec
Y	6.73	msec
Energy spread	0.072	%
RF voltage	> 250	kV
Bucket height	> 0.83	%
Synchrotron tune	0.0021	
Bunch length	7.76	mm
Toushck life	> 10	hrs

RIKEN RI Beam Factory

Katayama

MUSES

-Multi USe Experimental Storage rings-

Scentific Research Objectives

Double Storage Rings(DSR)

1) RI + Electron Collisions
2) RI + X-ray Collisions
3) RI + RI Merging
4) Ion + Ion Collisions

Accumulator Cooler Ring (ACR)

1) RI + Internal Target Collisions
2) Ions + Cooler Electron Merging
3) Molecules + Cooler Electron Merging
4) Micro RI beams production

MUSES PROJECT AT RIKEN

T. KATAYAMA
(INS, UNIV. OF TOKYO / RIKEN)

RIKEN
(INSTITUTE OF PHYSICAL AND CHEMICAL RESEARCH, BELONGS TO THE SCIENCE AND TECHNOLOGY AGENCY OF THE GOVERNMENT)

STARTED THE CONSTRUCTION OF HEAVY ION ACCELERATOR FROM 1997.

NAME OF THE PROJECT IS RI BEAM FACTORY

TOTAL BUDGET FOR CONSTRUCTION
~600 M$ FOR 10 YEARS

ACCELERATOR SYSTEM
INJECTOR
SUPERCONDUCTING RING CYCLOTRON

MUSES
(MULTIUSE EXPERIMENTAL STORAGE RINGS)
ACCUMULATOR COOLER RING(ACR)
BOOSTER SYNCHROTRON(BSR)
DOUBLE STORAGE RINGS(DSR)

OPTIONALLY HIGH CURRENT INJECTOR LINAC

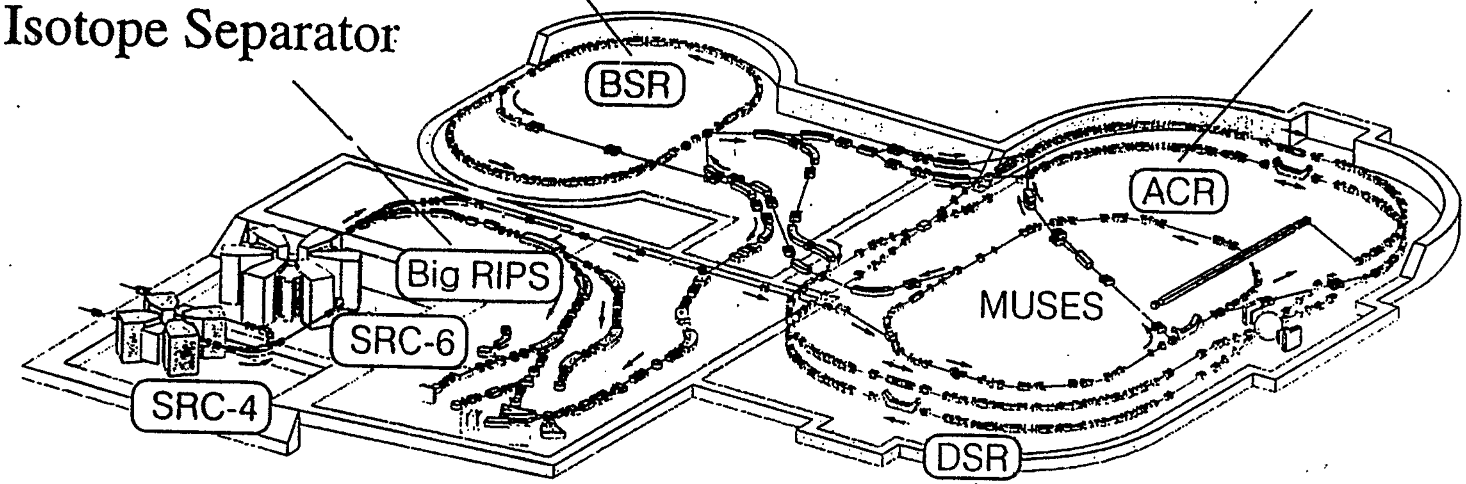
Katayama

MUSES (Multi USe Experimental Storage rings)

Booster Synchrotron Ring
Acceleration of ion and electron beams

Accumulator Cooler Ring
Accumulation and cooling of RI beams

Isotope Separator



0 50 m

Double Storage Rings
Various unique types of experiments

Katayama

Key Issues of Accelerator Aspect of MUSES

1) RI beams production
   Peak Intensity, Emittance, Momentum/Phase spread

2) Accumulation of RI beams
   Multiturn injection, RF stacking

3) Fast beam cooling
   Electron cooling, Stochastic cooling

4) Acceleration/Decelaration of RI beams in ACR/BSR
   Ultra slow extraction

5) High current electron beam accumulation in DSR
   Low emittance electron beams for X-ray production

6) Beam-beam effects due to collisions/merging
   High Luminosity

Proposed projects in China:

- Synchrotron Light Source at Shanghai

  √ 200 M $ equivalent

  3rd generation

- Tau-Charm Factory at Beijing

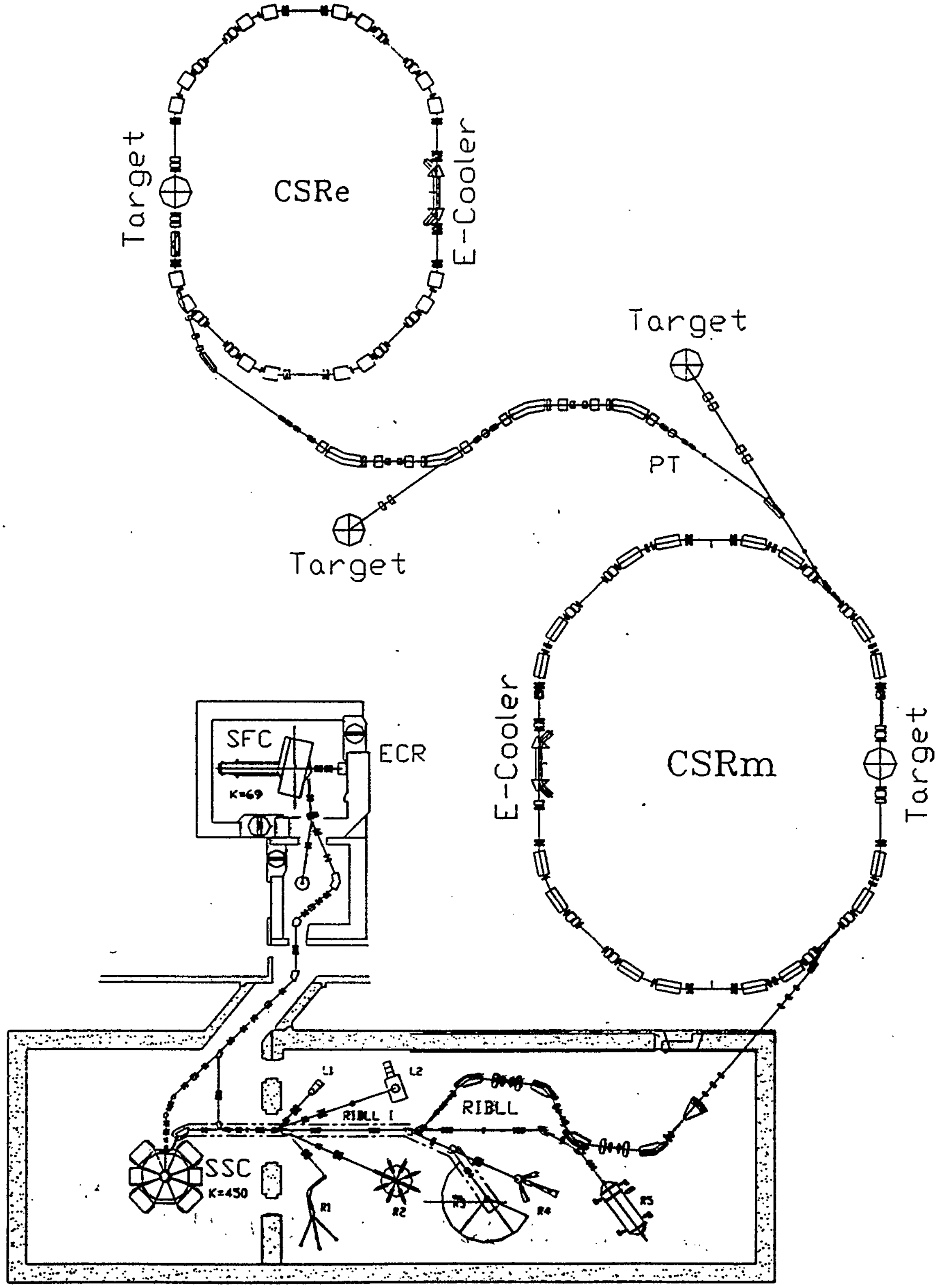
  ? ?

- Heavy Ion Cooling Storage Ring at Lanzhou

  ?

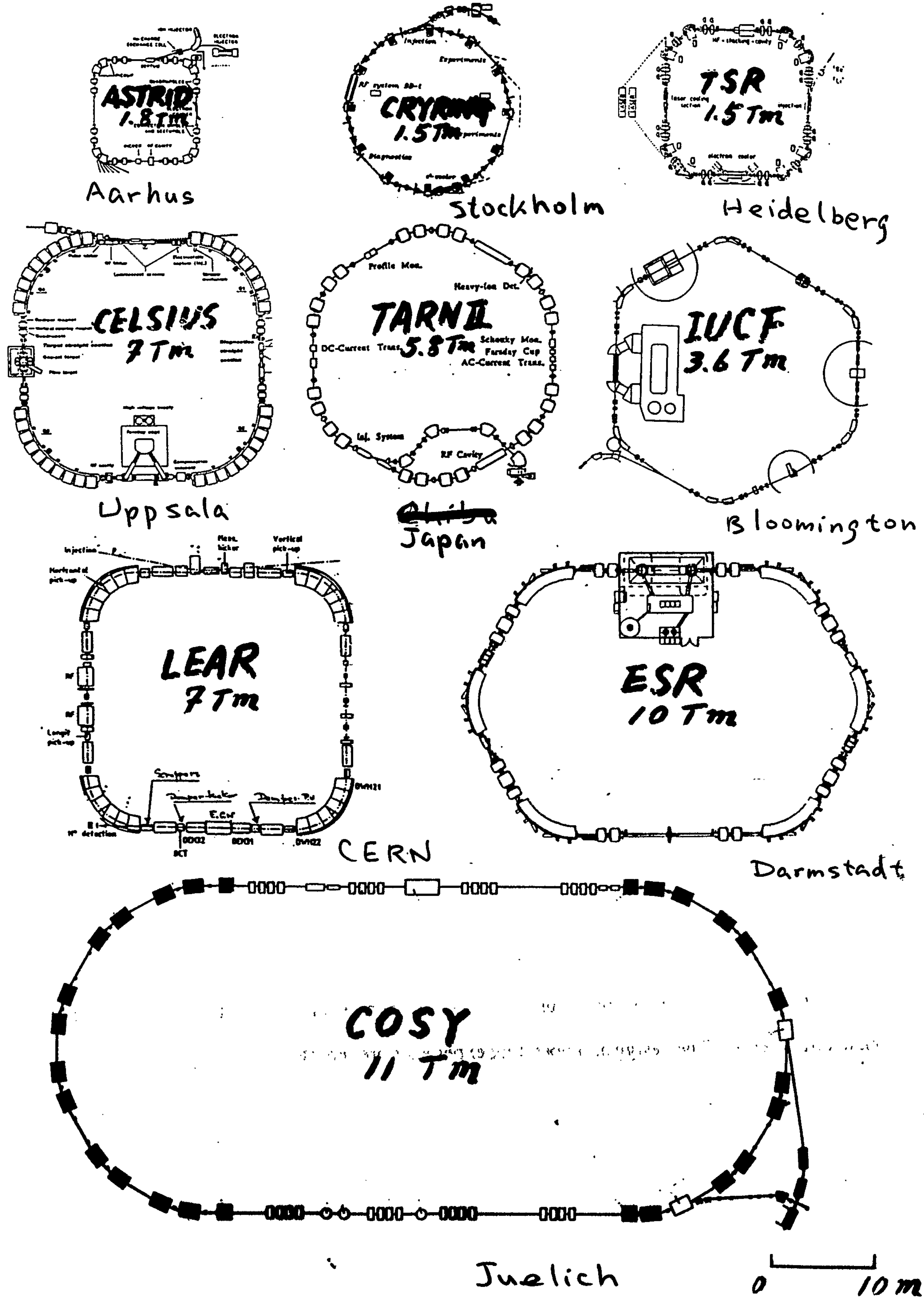
- Hefei Synchrotron Light Source Upgrade

  √



The overall layout of HIRFL-CSR

3. Coolers and Beam Cooling



ASTRID
1.8 Tm
Aarhus
CRYRING
1.5 Tm
Stockholm
TSR
1.5 Tm
Heidelberg
CELSIUS
7 Tm
Uppsala
TARN II
5.8 Tm
Profile Mon.
Heavy-ion Det.
DC-Current Trans.
Schottky Mon.
Faraday Cup
AC-Current Trans.
Inf. System
RF Cavity
Japan
IUCF
3.6 Tm
Bloomington
LEAR
7 Tm
CERN
ESR
10 Tm
Darmstadt
COSY
11 Tm
Juelich
0
10 m

Methods of Beam Cooling:

- Radiative Cooling

  1956, Kolomenski and Lebedev

  natural in circular machines; 3D

  for electrons and other radiative particles; high energy

- Electron Cooling

  1967, Budker

  using cold electron beams; 3D

  for protons and ions; low to medium energy

- Stochastic Cooling

  1968, van der Meer

  using GHz pick-ups, amplifiers, and kickers; 3D

  for charged particles; any energy

- Laser Cooling

  1975, Wineland, Dehmelt, Hanchand, Schawlow

  based on velocity-selective transfer of photon momentum

  for partially stripped ions; longitudinal

  applied to ion beams by MPI Heidelberg group and Aarhus group; achieved 1 mK ($\Delta p/p \approx 4 \times 10^{-7}$)

- Ionization Cooling

  1980, Skrinsky

  based on energy loss by particles passing through a material medium

  for muons

- Optical Stochastic Cooling

  1993, Mikhailichenko, Zolotorev, Zholent,

  using wigglers for pick-ups and kickers, and wide-band lasers as amplifiers; $\sim$ 90 GHz

- Stimulated Radiation Cooling

  1996, Bessonov and Kim

  using wide band lasers as a wiggler for damping

  for non-fully-ionized ions

- Laser Cooling in 3D

  1994, Okamoto, Sessler, Moehl

  using coupling cavities or dispersive location rf cavities on synchro-betatron resonance

  for laser cooling of ions in all 3 dimension

- Tapered Cooling for Beam Crystallization

  1995, Wei, Li, Sessler, et. al.

  forcing particles of different momenta to circulate at the same angular frequency

ITINERARY

Itinerary:

March 1, 1997	Depart New York
March 2	Arrive Kyoto, Japan
March 3 – 11	Collaboration, Kyoto, Japan
March 12 – 15	Attend Osaka Symposium, Osaka, Japan
March 16 – 21	Collaboration, Kyoto, Japan
March 22	Depart Kyoto, Arrive Beijing
March 23	Visit Tsinghua University, Beijing, China
March 24	Visit IHEP and give seminar, Beijing, China
March 25	Depart Beijing, Arrive Shanghai
March 26	Visit INP and give seminar, Shanghai, China
March 27 – April 3	Weekend time and vacation, Shenzhen, China
April 4, 5	Depart Shenzhen, China, Arrive New York

Persons contacted:

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I. Hoffman, GSI
M. Tigner, Y. Z. Wu, T. J. Deng, et. al., IHEP, Beijing
Y. P. Kuang, Y. P. Yi, Tsinghua University, Beijing
W. Q. Shen, X. F. Zhao, W. Q. Lai, et. al., INP, Shanghai
Participants at the Osaka Synposium including:
A. Ando, SUBARU
F. Caspers, B. Autin, CERN
B. Franzke, GSI
T. Katayama, INS/RIKEN
K. Sato, K. Hatanaka, RCNP
S. Y. Lee, IUCF
D. Reistad, TSL
W. Gu, Jin, Lanzhou, China

Literature acquired:

Copies of transperancies of the invited talks of Osaka Symposium
Papers by H. Okamoto, et. al., on laser beam cooling
Papers on proposed IHEP Tau-Charm Factory and INP synchrotron light source

Conclusion: A trip well worth the effort!