

R&D STATUS OF THE HIGH-INTENSE MONOCHROMATIC LOW-ENERGY MUON SOURCE : PRISM

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Abstract

PRISM is in the works to build a future intense low-energy muon source, which combines monochromaticity and high purity. In the PRISM project, an FFAG is used as the phase rotator to achieve the monochromatic muon beams. This paper will describe the design status the project.

INTRODUCTION

A high intense, monochromatic low energy muon beam with no pion contamination is desired to search a lepton flavor violating process $\mu - e$ conversion in a muonic atom [1]. The PRISM project was proposed in Japan to build such a future muon source [2]. "PRISM" is the abbreviated name for "Phase Rotated Intense Slow Muon beam." The PRISM beam characteristics are summarized in Table 1. Its aimed intensity is about $10^{11} \sim 10^{12}$ muons per sec, which is almost four orders of magnitude higher than that available at present. The muon beam will have a low kinetic energy of 20MeV so that it would be optimize for the stopped muon experiments such as searching the muon lepton flavor violating processes [1]. Figure fig:prism-layout shows a schematic layout of PRISM, which consists of mainly three sections: a large solid-angle pion capture with a solenoid magnet field of about 6 T, a $\pi - \mu$ decay section consisting of a 10-m long superconducting solenoid magnet, and a phase rotation section to make the beam energy spread narrower. In order to achieve phase rotation, a fixed-field alternating gradient synchrotron (FFAG) is used. We call it PRISM-FFAG. R&D programs are in progress mainly in Japan for the PRISM project. The PRISM-FFAG is under construction in Osaka university, and the other sections are in the design phase. In the following sections, their design and the present status are described focused on PRISM-FFAG.

PRISM-FFAG

A FFAG is suitable for the phase rotator of the muon beam for PRISM, since it has large momentum (longitudinal) acceptance, wide transverse acceptance with strong focusing, and synchrotron oscillation, which is needed to

Table 1: Anticipated PRISM beam characteristics

Parameters	Design goal
Beam Intensity	$10^{11} - 10^{12} \mu^\pm/\text{sec}$
Muon kinetic energy	20 MeV
Kinetic energy spread	$\pm(0.5 - 1.0)$ MeV
Beam Repetition	100 - 1000 Hz
Pion contamination	$< 10^{-18}$

Table 2: Parameters of PRISM-FFAG

No. of sectors	10
Magnet type	Radial sector DFD triplet C-shaped
Field index (k -value)	4.6 (variable 4.4-5.2)
F/D ratio	6.2 (variable 4-8)
Opening angle	F/2 : 2.2deg. D : 1.1deg.
Aperture	H 100cm x V 30cm
Average radius	6.5m for 68MeV/c
Tune	horizontal : 2.71 vertical : 1.52

perform phase rotation. Construction of PRISM-FFAG has started in JFY 2003 as a five-year program. A lattice was designed to obtain a larger acceptance with enough long drift sections where RF cavities are installed to achieve a quick phase rotation [?]. Optics parameters of PRISM-FFAG are listed in Table 2. In order to build the FFAG we have to develop some technically challenging components: large aperture FFAG magnets and ultra-high field gradient RF systems.

Magnet

We adopted a scaling radial sector type FFAG with triplet(DFD) focusing magnets. The detail works on the magnet design is described in Ref. [4]. The magnets have very large aperture of H :100 cm \times V : 30 cm, and small opening angle, so that the ring has enough space to locate RF cavities. Two field clumps are at both end in order to avoid stray fields to the RF cavities. The field gra-

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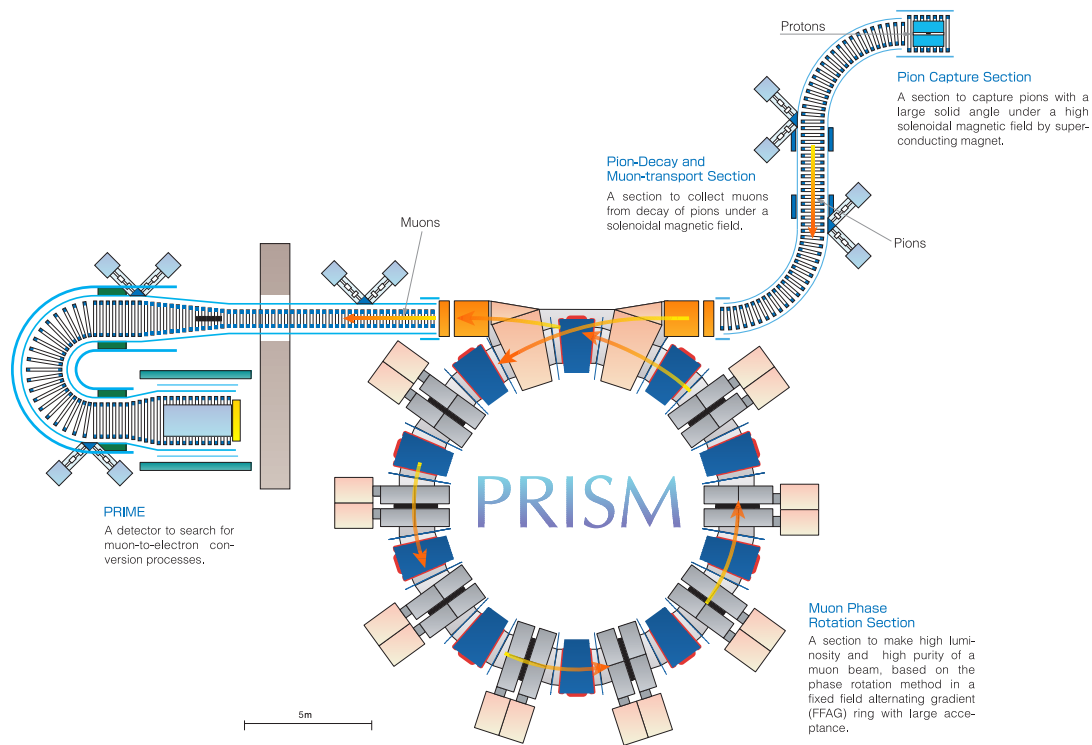


Figure 1: Schematic layout of PRISM

dent is generated by the pole shapes. Its shape was decided so as to satisfy the scaling conditions. The three-dimensional magnetic field was calculated by using a 3D field calculation code, TOSCA. According to the tracking simulations using this TOSCA field, the PRISM-FFAG has a zero-chromatismity and a large transverse acceptance more than about $40,000 \pi \text{mm}\cdot\text{mrad}$ in horizontal and about $6,500 \pi \text{mm}\cdot\text{mrad}$ in vertical for the all aimed energy region.

Three magnets for the PRISM-FFAG have already been built. Figure 2 shows the first magnet. A magnetic field measurement of the magnets is underway in KEK. The other magnets would be coming and waiting for forming a ring.

RF SYSTEM

Since the muon is an unstable particle (lifetime $\sim 2.2 \mu\text{s}$), it is crucial to complete phase rotation as quickly as possible in order to increase a number of surviving muons. In present design, PRISM requires very high field gradient of 200kV/m at the low frequency ($4\sim 5 \text{ MHz}$). As compared with usual cavities, PRISM has to operate its cavities at a remarkably outstanding condition. Such an operation can be achieved by a low duty factor and ultra-thin magnetic alloy (MA) cavities [5]. The MA core has stable impedance at a required magnetic field for PRISM (320 Gauss). The thickness of MA cores is 35 mm . The racetrack-shaped core is adopted. Cores are all air-cooled since the RF power loss into the core is very small owing to the small duty factor (about 0.1%).

To optimize phase rotation, not only a high field gradient but also the shape of RF voltage is important. According to our simulations, a saw-tooth RF voltage makes a final energy spread narrower than that by a sinusoidal one. Therefore, adding higher frequency harmonics to form a saw-tooth pulse shape is being considered. By using the cut core configuration, a wide band RF system with μQf



Figure 2: The first magnet of PRISM-FFAG

Number of gap per cavity	5
Length	33cm/gap
Number of core per gap	6
Core material	Magnetic Alloy
Core shape	Racetrack
Core size	1.7m × 1.0m × 3.5cm
Inner aperture	1.0m × 0.3m
Shunt impedance	~900Ω/gap
RF frequency	4~5MHz
Field gradient	150 ~ 200kV/m
Flux density in core	320 Gauss
Power tube	tetrode : 4CW100,000E plate voltage : DC33-37kV
Maximum current	60A/gap
Maximum RF power	1.5MW
Core cooling	Air cooling
Duty	<0.1%

Table 3: Parameters of PRISM-FFAG RF system.

@ 5MHz = 5.5×10^9 can be designed. The first and second harmonics could be applied on RF simultaneously with sufficient efficiency. A cavity, which consists of 5 gaps, is installed in one straight section. In the current design, each gap has 6 MA cores and has a length of 35 cm along the beam direction. One gap generates the RF voltage of 25-38 kV and is driven by two bus bars which are connected to an RF amplifier. Each gap will be driven by push-pull amplifiers using tetrode tubes, 4CW100,000E. The plate voltage of 33-37 kV will be applied and RF current of 60 A per gap maximum is possible to generate. Tetrode amplifiers are installed either on-the-top-of or underneath the cavity. A low duty factor enables the tubes to generate the maximum RF power of 1.5 MW. Parameters of the RF system are summarized in Table 3.

An RF system, which consists of an amplifier and an anode power supply and an auxiliary power supply, has been build. RF tests are underway. RF voltage of ± 43 kV/gap has already achieved with a test cavity, which has a shunt impedance of 735 Ω at 5MHz. It promises a field gradient with a PRISM cavity, which would have a shunt impedance of 900 Ω , to be 165kV/m. A simulation result of phase rotation in the PRISM-FFAG ring is shown in Fig.3. The initial momentum spread of $68\text{MeV}/c \pm 20\%$ is reduced to $\pm 2\%$ in 6 turns ($=1.5\mu\text{s}$). A muon surviving rate is 56%.

DIAGNOSTICS

In order to carry out experiments of PRISM-FFAG using the magnets and RF systems described above sections, we develop a novel method to study the beam dynamics of accelerators using an alpha particle source. The method enable the performance study of the accelerators even in construction phase, and can execute without a costly injection system. We will study the closed orbit distortion, beta-tron tune, and acceptance using this method. The detail is described in the another paper in this conference [6].

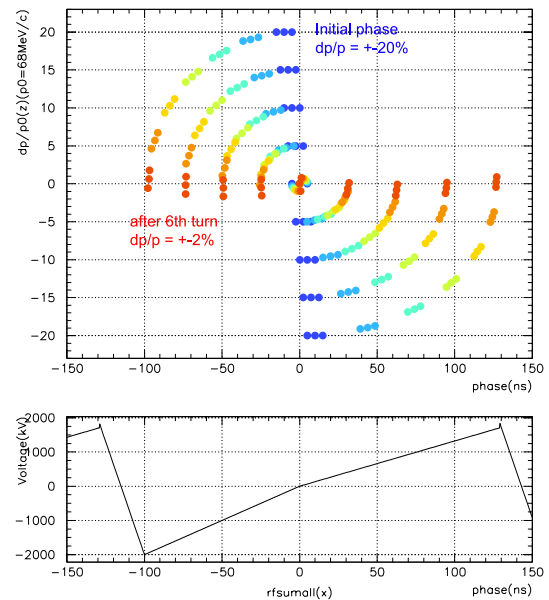


Figure 3: A result of simulation of phase rotation in the PRISM-FFAG ring. 6 turns in the ring is enough for finishing the phase rotation. Initial momentum spread of $68\text{MeV}/c \pm 20\%$ is reduced to $\pm 2\%$. An RF voltage based on the RF tests is applied as shown in the bottom figure.

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