FFAG'17 Abstract Submissions

Tune Compensation and Dynamic Acceptance Studies in imperfect Scaling FFAG

Malek Haj Tahar

The experimental results from the KURRI 150 MeV FFAG revealed some major losses that need to be understood and eventually overcome. By developing analytical models that account for the field defects, one identified major sources of imperfection in the design of scaling FFAG that explain the important tune variations resulting in the crossing of several betatron resonances. A new formula is derived to compute the tunes and properties established that characterize the effect of the field imperfections on the transverse beam dynamics. The results obtained allow to develop a correction scheme to minimize the tune variations of the FFAG and maintain a large dynamic acceptance. This is the cornerstone of a new fixed tune non-scaling FFAG that represents a potential candidate for high power applications.

S. Machida

FFAG design for next generation short pulse neutron and muon source

Abstract: As a future of the ISIS facility, we are considering a FFAG based short pulse neutron and muon source facility. We will present lattice design, single particle tracking study and (hopefully) multi-particle tracking study with high intensity effects. Parameters of a prototype model as a proof of principle of some key issues such as adjustment of orbit and optics control will be proposed. Some area of essential hardware R&D will be discussed.

Peter McIntyre

Programmable octupole in a strong-focusing cyclotron: a possible pathway to integrable optics

Peter McIntyre, Akhdiyor Sattarov, and James Gerity

Integrable optics offers a method to remove the impact of unstable fixed points in the dynamics of an accelerator and thereby enhance the potential to accelerate high-current beams that produce large space charge tune shift. We are investigating the possibility to integrate a spatially modulated octupole field along the beam transport channels of a strong-focusing cyclotron as a way to accomplish that objective.

Francois Meot

Over the past 3 years, the CBETA cell Halbach design has been assessed, and eventually validated, based on stepwise ray-tracing methods, using 3D OPERA field maps of the cell magnets. Validation includes zero (orbit), first (focusing) and second order (chromaticity) parameters, as well as the dynamical admittance and resonance structure of the cell, over the useful energy range. This contribution describes the methods, their outcomes including sample alignment and field defect studies, and concludes with the detailed properties of the final CBETA arc cell design.

Y. Mori

" Intense Muon Source with MERIT_FFAG"

Y.Mori. H.Okita, Y.Ishi, T.Uesugi, Y.Kuriyama, M. Muot, Y.Ono, A.Sato, M.Kisho, M.Yoshimoto, K.Okabe and Y.Miyake; Kyoto U. , Osaka U. JPARC

An intense muon source for muon nuclear transformation, in particular, to mitigate the long lived fission products of nuclear reactor wastes is presented. The scheme is based on ERIT(energy recovery internal target) ring with acceleration/ storage FFAG ring. Negative muon production of more than 1016μ-/s seems to be possible with this scheme.

"Harmonictron as intensity frontier"

Y.Mori; Kyoto U.

A new proposal of "Harmonictron" for intense particle accelerator is presented.

"Energy effective negative muon production with FFAG for energy production"

Y. Mori, Kyoto U.

A new scheme of highly efficient μ- production for energy production with μCF using FFAG concept is presented.

Mitsutaka Ueda, Kyushu University

Correction of focusing force with pole surface coils for the radial sector type FFAG accelerator

Abstract

In the radial sector type FFAG accelerator, the method which corrects horizontal focusing force with pole surface coils will make it possible to control horizontal betatron tune during beam acceleration. The prototypes of the coils have been developed. In this presentation, details of the design of the coils and results of measurement of the magnetic field will be reported.

Dejan, Trbojevic, BNL

NS-FFAG matched to the long linac straight section,

This is an attempt to allow NS-FFAG to be used together with the long linac with adiabatic matched curved arc. Applications are of multiple kinds: Energy Recovery Linacs (ERL's), Recirculating Linacs Accelerators (RLA's), and other fast acceleration applications. The transition from the NS-FFAG arc to the straight section NS-FFAG has already been solved where multiple orbits and betatron functions are adiabatically matched. This attempt is of a similar kind but the betatron functions in the NS-FFAG of small values will grow adiabatically along the matching arc to the values corresponding to the linac.

Cancer Therapy Proton Gantry made of Halbach type Permanent Magnets

An isocentric proton therapy gantry with permanent magnet design is presented. It is made of two parts: an achromatic Non-Scaling FFAG (NS-FFAG) arc bending upwards and an opposite NS-FFAG bending arc returning the proton beam to the patient. The transverse scanning system is placed above the patient after the second arc. There are multiple advantages of this proposal with respect to the all other existing and proposed proton gantries:

a. The large momentum acceptance range between $-32 < Dp/p < 35\%$, or proton kinetic energy between 65-250 MeV, allows fast patient treatment as the three dimensional scanning is possible. A fast energy change (obtained by either the fast cycling synchrotron, fast pulsing linac, 1 kHz FFAG, etc.) allows longitudinal movement of the Bragg peak through the tumor. For each longitudinal scan the transverse scanning magnets are fixed.

b. The transverse scanning is significantly slower then all present scanners.

c. The patient treatment and operation is simplified as the magnetic field is fixed during the whole treatment time.

d. Significant reduction of the electric bill.

e. The cost of the gantry is estimated to be one order of magnitude lower with respect to the existing gantries

f. The weight of the magnets is significantly reduced allowing simpler and lighter rotating structure.

g. The magnet size and weight is significantly smaller as the outside radius of the Halbach type permanent magnets are ~ 6 cm.

Yujiro Yonemura, Kyushu University

Status of 150-MeV FFAG accelerator of Kyushu University, Machine Status

The construction of a new accelerator facility has been completed at Center for Accelerator and Beam Science of Kyushu University in 2016. The facility consists of the 8-MV tandem accelerator and the 150-MeV FFAG accelerator. In this presentation, the present status of the FFAG accelerator are reported.

David Kelliher, ISIS-RAL-STFC

Dynamic aperture studies in scaling FFAGs

Scaling FFAGs require a nonlinear field to ensure the bare tune for zero amplitude particles remains fixed over the momentum range. Magnet apertures can be reduced by increasing the field index k and the machine can be made more compact by introducing a spiral angle. However, both measures may result in an increase in the variation of tune with amplitude and so a reduction in dynamic aperture. Here the mechanisms behind the dependence of tune with amplitude are studied in detail. Results are applied to the case of ISIS-II - a high power proton FFAG for spallation neutrons.

The study of scaling FFAGs in a multipole ion trap

Beam dynamics have been studied in quadrupole ion traps for almost two decades. These compact devices, physically equivalent to a quadrupole channel, allow collective effects to be studied in detail. A multipole ion trap would allow controllable higher order components to be introduced, greatly extending the accelerator physics topics that can be investigated. Here it is determined how the multipole content of the field (up to octupole) in a scaling FFAG can be replicated in such a device. Topics that could be addressed in such a multipole ion trap, particularly those relevant to high power scaling FFAGs, are discussed.

Stephen Brooks, BNL

Test of a Linear-Field Non-Scaling FFAG Arc with a Wide Energy Range

A linear-field non-scaling FFAG arc was installed at the original Accelerator Test Facility (ATF-1) at BNL. It has a 6-cell approximately FODO lattice and bends through a total angle of 40 degrees. It is designed for a kinetic energy range from 18 to 72MeV and has transmitted beam through most of this range already, demonstrating a ratio of 2.9x in energy. Scans of the input beam position allow study of the transfer function from the beginning to the end of the FFAG arc. This arc also uses a novel Halbach permanent magnet design similar to CBETA, so requires no power supplies to operate.

Malek Haj Tahar, Columbia University Medical Center

Novel concept of a Non-Scaling Fixed Field Alternating Gradient accelerator

One major issue in the design of a fixed field accelerator for medical applications is to extract the beam at various energies. In order to remediate this problem, one has developed a novel concept of a racetrack fixed field alternating gradient accelerator. In this talk, one describes the design approach and reports on the outcomes of the beam dynamics studies. In particular, one shows that this concept yields a large dynamic acceptance of the beam as well as an easy correction scheme of the optics that makes it suitable for high power applications

Dr. Sugahara and Yasutomi Ritsuki, Kindai University

1) and 2) Title: Measurement of magnetic hysteresis effects of the bending magnet for beam transport

TOSCA is one of the de facto standard software for magnetic analysis and it has been used for accelerator magnet design until now, however, hysteresis effects is one of the biggest challenge which has not be taken into account at the designing stage.

In recent years, “play model” was proposed which can be incorporated into finite element magnetic field analysis with ease and the hysteresis effects can be qualitatively evaluated, thus, there is a possibility that design accuracy of the accelerator magnets will be significantly improved. The “play model” is based on the idea of the” direct current hysteresis”, therefore, to apply the “play model” to the accelerator magnets, quantitative discussions on the coupling between the hysteresis effects, and time-dependent effects such as magnetic after effects, and eddy current effects are required.

The objective of this work is to quantitatively evaluate the influence of current excitation pattern of accelerator electromagnet and to judge applicability of direct current hysteresis model for magnetic field design of electromagnets for accelerator. We are now constructing a measurement system of the magnetic fields of the bending magnet for beam transport

By the development of this technique, it may be possible to design and control the magnetic field of the FFAG accelerators, taking hysteresis effects into account, and tunes of FFAG accelerator would be adjusted to improve the beam intensity.

In this presentation, Dr. Sugahara will talk about the theory and the background of the “play model” for about 20 minutes and Yasutomi Ritsuki (M1 student of the Graduate School of Kindai University) will report the current implementation of the measurement system and the measured data for 20 minutes.

Dr Yoshihiro Ishi, KURRI

"Status report of KURRI FFAG facility"

Dr Carol Johnstone

Progress on Ion Therapy in the US

Cancer is the second-largest cause of death in the U.S. With more than one million new cases currently diagnosed in the U.S. every year and decreasing death rates from cardiovascular disease and increasing life expectancy is rapidly becoming the largest health problem in the 21st century. About half of all cancer patients receive definitive radiation therapy either as their primary treatment or in combination with chemotherapy or surgery; overall approximately two-thirds of all cancer patients will receive radiation therapy at some point during their course of disease. Radiation therapy has become a very dynamic research- and technology-driven field. The majority of external radiation treatments are still performed with linacs that generate energetic electron and x-ray beams. However, in recent decades, particle beam therapy using primarily proton and carbon ion and, in the near future, helium and oxygen ion beams has rapidly evolved into a new frontier in cancer therapy concurrent with significant advances in radiation biology and immunotherapy. Treatment facilities using carbon ions are currently in operation in Germany, Italy, Austria, China, and Japan. In the US initiatives are underway and progressing towards realizing both research and clinical ion beam therapy facilities. A number of institutions including UT Southwestern, Stanford Medical Center in collaboration with the Veteran's Administration, and the North American Particle Therapy Alliance (a consortium) are actively pursuing ion therapy research and/or clinical programs. This presentation reviews the status of these programs and present innovative developments of compact technologies impacting the future of ion therapy in the U.S. and worldwide.

Huddersfield

HEATHER - HElium ion Accelerator for radioTHERapy

A compact variable energy non-scaling fixed field alternating gradient (nsFFAG) accelerator is being designed for helium ion therapy. This facility will consist of 2 superconducting stages, and accelerate particles with charge to mass of 1/2. The design allows treatment with helium ions (He^{2+}) and the ability to image with hydrogen ions ($H + 2$). Currently only carbon ions are used to treat cancer, yet there is an increasing interest in the use of lighter ions for therapy as they hold advantages both physically and clinically over carbon ions. Physically the beam rigidity is approximately half for helium ions allowing for a more compact accelerator and clinically there is a reduced dose tail of low z fragments beyond the tumour site. An FFAG approach for helium therapy has never been previously considered, and having demonstrated the survival of a realistic beam, we discuss beam extraction from the first stage.

PIP - Dual Proton - Helium accelerator for radioisotope production

A design of a compact accelerator has been made for the production of radioisotopes, in particular 99mTc and 211At. As well as fixed magnetic fields, this machine is isochronous up to 28 MeV and able to operate in continuous wave (CW) mode for both protons and He2+. Detailed tracking studies with the OPAL (Object Oriented Parallel Accelerator Library) code, including the effects of space charge, have demonstrated the ability to accelerate a proton beam with a current of up to 20mA, significantly larger than achievable with any current cyclotrons. The accelerator is able to deliver beams of both protons and He2+ particles through careful optimisation of the field, which would allow production of a wider range of isotopes including 211At which is of interest for therapy. As well conventional target configurations the use of a thin internal target and recycled beam is being considered. The large acceptance of the accelerator allows the beam to be recirculated many times despite scattering through the target, the lost energy being restored on each cycle. In this way, the production of 99mTc for example, can take place at the optimum energy increasing yields and purity.

Dr Akira Sato, Osaka

"FFAG applications for muon science"

Dr Yasuhiro Fuwa, KURRI

Conceptual Design of Proton Drivers for Accelerator Driven System

Dr Jaroslaw Pasternak

Towards nuSTORM facility - overview of accelerator designs

The neutrino beam originating from muons decaying in a storage ring is an ideal tool for precise neutrino cross section measurements due to its exactly known flavour content, including both muon and electron ones, and spectrum. The proposed nuSTORM facility would use pions directly injected into a racetrack storage ring, where circulating muon beam would be formed. The sketch of the nuSTORM facility is discussed. The alternative storage ring designs including a FODO and FFAG (Fixed Field Alternating Gradient) based ones are presented in details including their estimated physics potentials.

Additional suggestions by Mori-san:

Okita-san

1) Development of MERIT

Kuriyama-san:

1) Control of KURRI FFAG