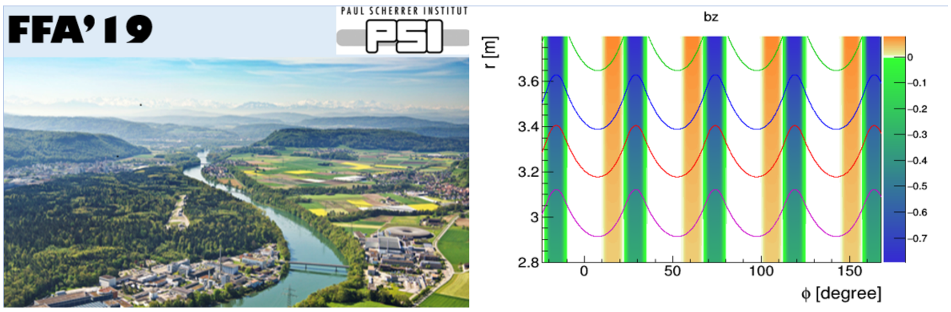
International Workshop on Fixed Field alternating gradient Accelerators (FFA'19)

Tuesday 19 November 2019 - Friday 22 November 2019

TimeOut



Book of Abstracts

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Permanent Magnet VFFA for 18GeV Electron Acceleration

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Fixed-field accelerators with vertical orbit excursion (VFFAs) have the interesting property that the matched beam orbit shape, circumference and optics stay constant with beam momentum. This requires magnets with a vertically exponential field $B_y = B_0 e^{ky}$ on the $x = 0$ midplane. This paper presents prototype measurements of such a magnet, along with a lattice using similar magnets that would allow acceleration of electrons to 18GeV in the RHIC tunnel. The lattice uses a high phase advance cell in order to give better magnetic efficiency while still being essentially a "scaling" FFA.

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Beam optics design and optimization for a superconducting gantry

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The novel superconducting (SC) gantry has become a research hotspot with the tendency of compact proton therapy system. The footprint and weight of the gantry can be significant reduced by using SC magnets, and alternating gradient field of local achromatic bending sectors provides large momentum acceptance which means the magnetic field of SC magnets can remain fixed during tumor treatment. We presented a first order beam optics design of a SC gantry. Considering a large momentum deviation of proton beams, second order aberration and fringe field effect have been studied for optics optimization.

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Muon Accumulator Optics for a Muon Beam produced from positron-electron annihilation

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LEMMA is studying the possibility of a future muon collider where muons are produced from positrons impinging on a target. Unlike conventional muon sources, muons are produced with a very small emittance, however, a small population is produced due to the small cross section of the e+e- annihilation into muons. In order to increase the muon beam population, we are currently designing a muon accumulator ring with small circumference and large energy acceptance.
The current optics has been studied using MAD, and MAD-X PTC, achieving +/-10\% energy acceptance in less than 150˜m of circumference. We are considering the possibility of a FFA lattice design to achieve at least +/-20\% energy acceptance, with smaller circumference and small momentum compaction factor.

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The CBETA project: arXiv:1706.04245

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The CBETA project [1] is the first and unique of its kind electron accelerator which combines two accelerator concepts together. The Energy Recovery Linac (ERL) and the Fixed Field Alternating Gradient (FFA_G) concepts. The CBETA project is currently in the commissioning stage and some of the beam optics of the accelerator has be done using lamp-magnet methods to describe the fields of the FFAG magnets. Recently the zgoubi computer code is used to describe the beam optics of the accelerator during its acceleration and deceleration cycle. In this effort the zgoubi computer code is utilizing field maps of the permanent Halbach type of magnets of the FFA_G section of the accelerator. These field maps have been derived using the OPERA computer code [3] which modeled the Halbach magnets. Two methods of modeling the Halbach magnets using the OPERA code will be described, and some results from the beam optics calculations will be presented.
[1] The CBETA project: arXiv:1706.04245
[2] Zgoubi code: https://www.bnl.gov
[3] The Opera code: https://operafea.com/

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Study of orbit analysis method in an optical design of the Vertical FFA

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The purpose of this study is a basic research for an optical design of the Vertical FFA. This study proposed a New method of an orbit analysis using an approximate transfer matrix and verified. In addition to this, I report current progress of a design electromagnet with Opera3d.

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An overview of Zgoubi Workshop 2019, Boulder, CO, Aug. 26-30, 2019

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A zgoubi workshop - actually, more of a "zgoubi tutorial" - was organized in Boulder, CO, last August (https://zgoubi-workshop.com/), latest one in a long series which started in the early 2000s with the re-birth of FFAG science and happened to cover EMMA at Daresbury, FFAG schools, CBETA prototyping today, etc. The Boulder workshop gathered 20 attendees, who bent and sweat during four days on a number of computer simulation exercises which covered proton and electron beam and spin dynamics in rings including large electron-ion collider challenges in the matter, FFAG and ERL simulations, time-of-flight spectrometer and other magneto-electrostatic optics. This presentation gives an overview of these "ACCELERATOR" computer games held in Boulder.

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Study and beam experiment on MERIT scheme

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Intense negative muon is useful for reduction and recycling the radioactive wastes from nuclear plants. As an intense negative muon source, MERIT(Multiplex Energy Recovery Internal Target) scheme was proposed. To prove the principle of the MERIT scheme, FFA ring (MERIT-PoP ring) has been developed and the beam experiment was carried out. In this presentation, the detail of this study will be reported.

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Current status and plans of FFA at KURNS

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Current status and future plans of the FFA main ring at KURNS will be presented.

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ISIS upgrade and feasibility study

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As a future upgrade option of the ISIS neutron and muon source, we consider FFA as a proton driver. Vertical excursion FFA (vFFA) was chosen because of compact and less complex structure of the main lattice magnets although the maximum field is relatively high. As a proof of principle of the vFFA concept, a prototype machine to accelerate from 3 to 12 MeV is being designed. We will discuss the design principle, code benchmarking, beam dynamics of the strong transversely coupled optics and the current status of hardware R&D.

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FFA for muon accumulation and acceleration

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Vertical excursion FFA's (vFFA) momentum compaction factor is zero like linac. That makes the machine isochronous for ultra-relativistic particles. Applications of vFFA for muon accumulation and acceleration were considered. It would be ideal as a muon accumulator of the LEMMA scheme and a muon accelerator of collider complex. We will discuss the design and issues.

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Proposal of FFA 2-way collider for muon catalyzed fusion

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Triton FFA 2-way collider for efficient muon production for muon catalyzed fusion has been designed. Characteristics and expected performance of the ring are presented.

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CBETA: a 4-pass superconducting ERL with permanent FFA magnet return arc

Author: Stephen Brooks[1]

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Beam commissioning is currently in progress for the CBETA ERL recently built at Cornell University in collaboration with BNL. This machine has a 6MeV injector and 36MeV main superconducting RF module at ˜1.3GHz frequency. The beam is designed to pass through the main RF up to four times accelerating and four times decelerating, before being dumped at 6MeV. These four energies (42, 78, 114, 150MeV) are returned to the RF by a racetrack FFA return loop of permanent magnets. These magnets have been designed so that all four energies are stably transported through the same R=25mm good field aperture. Between the RF and return loop on either side, the four energies are split apart for adjustment to tune energy recovery and optics performance. At the date of writing, beam has made one turn energy recovery through the permanent magnet loop at 42MeV including orbit correction to <1mm.

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Surrogate Models for Particle Accelerators

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Precise accelerator simulations are powerful tools in the design and optimization of exiting and new charged particle accelerators. We all know from experience, the computational burden of precise simulations often limits their use in practice. This becomes a real hurdle when requiring real time computation. I will demonstrate two techniques, based on Polynomial Chaos Expansion [1] and Deep Neural Networks [2] that hints a path forward, towards precise real time computing. The examples will be based on linear accelerators and cyclotrons.

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An Update on OPAL

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After a general introduction of OPAL, I will introduce a set of new features available with version 2.0 [1]. All new features will be presented together with examples of ongoing research projects. In the OPAL-cyc flavour, a robust way of generating matched distributions with linear space charge is introduced. A new method for describing fixed field accelerators (FFAs) in a very general way will be shown. A new element TRIMCOIL can be used to correct for field-errors in cyclotrons and FFAs [2]. The OPAL was extended to allow the specification of multi objective optimisation problems, which are then solved with a built in NGSA-II genetic algorithm. A new feature SAMPLER allows you to setup and run random or sequential parameter studies and seamless utilisation of a vast number of computing cores. Future plans such as the new AMR-Solver for preceise neighbouring bunch simulations will presented.

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A 15-20 MeV/nucleon iso-FFA for Radioisotope Production*

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A compact, isochronous fixed-field, gradient ion accelerator, ˜1.5 meters in radius, is under design utilizing high-gradient cavities in order to accelerate multi-ion species up to 15-20 MeV/u with large turn-to turn, centimeter-level separation for low-loss extraction without the need for lossy foil stripping. A strong-focusing radial field profile is optimized in a separated-sector format establishing control over machine tune simultaneously imposing isochronous orbit requirements to promote high-current (˜0.5 milliamp) operation. Innovation in injection will be introduced to replace the high-loss central region; either an ion RFQ or a solid-state tandem. Designing for a charge to mass of ½ is proposed to allow either protons in the form of H2+ and light ions (up to Ca) to be accelerated and delivered using the same system. The high-current machine under design is ideal for producing radioisotopes with numerous applications in medicine, biology, physics, chemistry, agriculture, include national security and environmental and materials science. Further, the use of separated sectors allows extraction or insertion of targets at optimal energies for isotope production. With multi-ion capability (H2+ and He2+) both 211At and 225Ac can be mass produced. Additionally, an intense neutron beam can be generated using a high current of protons on a Be target for production of Moly-99; a reaction which requires less energy per secondary neutron than a current approach using a DT source.

- Work supported by U.S. Department of Energy, Office of Defense Nuclear Nonproliferation under SBIR grant DE-SC0020009 †johnstone29w@gmail.com

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A 2-8 GeV Fixed-field, Transition-less, Transition-less Synchrotron*

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Rapid cycling synchrotrons are limited in duty cycle from ramped magnetic fields, with 50-60Hz the current or practical technical state of the art. To achieve a higher cycling rate requires fixed magnetic fields. A strong-focusing proton synchrotron with fixed magnetic fields and swept-frequency RF (53 MHz at extraction) has been proposed to replace the present 8 GeV Fermilab Booster synchrotron to accommodate the high current and increased energy in the PIP II era and plan for the PIP III phase at Fermilab. A conceptual fixed-field synchrotron design is presented using a nonlinear gradient, nonscaling FFA approach. The radial field profile will be optimized to provide strong-focusing, constant synchrotron tunes over the acceleration range from 2-8 GeV in a 24-sector machine with 24 10-meter straight sections to accommodate injection and ferrite RF cavities. The extraction radius is constrained to 513 meters in circumference to match to the Fermilab Main Injector which accelerates 8 GeV protons to 120 GeV.

*Work supported by Fermi Research Alliance, LLC under contract no. DE-AC02-07CH11359

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The Vortex Effect in High-Intensity Cyclotrons and Isochronous FFA's

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We discuss the main factors that influence the space charge induced vortex
motion of particles within high intensity bunches (Gordon 1969)
in isochronous circular machines.
Firstly a phase slip due to deviations from strict isochronism determines
if the bunches of a specific turn are above, below or at "transition",
and hence whether stable vortex motion of the bunches is possible at all.
Secondly, at low energy, there are possible longitudinal and transverse
effects of rf electric fields, the former depending on the bunch phase
("bunching" or "debunching"), the latter depending on the gradient of the
accelerating voltage. Very high accelerating voltages in the first turns
call the validity of adiabatic approximations and analytic methods into question.
While the influence of the rf acceleration is significant only at low beam
energy, the phase slip has influences the stability of vortex motion up to
beam extraction.

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Adaptive mesh refinement Poisson solver for neighbouring bunch simulations

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In this talk the new adaptive mesh refinement capability of OPAL including the implementation of the hardware architecture independent Poisson solver is presented. This new feature enables to study neighbouring bunch effects in circular machines more precisely with the benefit of lower computational costs compared to standard Particle-In-Cell simulations of same resolution.The numerical model of neighbouring bunches is explained and first results of the PSI Ring cyclotron are shown.

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FFA injection systems using pulsed magnets

Author: Rogers Chris[None]

Existing FFAs use fixed field injection systems, possibly using charge exchange foils. In synchrotrons it is more conventional to use pulsed magnets to bring beam into the ring in addition to the charge exchange injection. In this presentation the use of a pulsed magnet system is considered for injection into horizontal and vertical FFAs proposed for ISIS upgrades. Simulation of the lattices in OPAL is discussed. The necessary magnet parameters are studied, together with effects such as dynamic aperture reduction that may occur due to the bump magnets.

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Next generation Hadron therapy, FFA beamlines and plans at the University of Melbourne

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In this talk I will give an overview of activities in the new Medical Accelerator Physics group particularly in the area of FFA accelerators. Australia is rapidly moving toward realisation of their first proton therapy facilities and a national working group has been convened to plan for a heavy ion (p, He, C, etc) treatment and research facility. Together with CERN and other European partners who are embarking on a new design study 'Next Ion Medical Machine Study', there is great interest in FFA optics for large acceptance gantries. In Melbourne, we will work on designs for these gantries and are in the process of planning a test-beamline which is scaled down to suit a 1-4 MeV proton accelerator already in operation in Melbourne, in collaboration with industry. This flexible test beamline can be used to test FFA concepts and research questions, as well as potentially providing a unique platform for radiobiology studies.

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Muon production and acceleration with FFA

Author: Yoshiharu Mori[1]

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A new scheme for muon production and acceleration with FFAG is presented.

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nuSTORM decay ring

Author: Jean-Baptiste Lagrange[None]

Precise neutrino cross section measurements and search for sterile neutrinos can be done with neutrino beams produced from muons decaying in a storage ring due to its precisely known flavour content and spectrum. In the proposed nuSTORM facility pions would be directly injected into a racetrack storage ring, where circulating muon beam would be captured. The storage ring has three options: a FODO solution with large aperture quadrupoles, a racetrack FFA (Fixed Field Alternating gradient) using the recent developments in scaling FFAs and a hybrid solution of the two previous options. Machine parameters, linear optics design and beam dynamics are discussed in this talk.

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Longitudinal tomography in a scaling FFA

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Abstract: Longitudinal tomography, already well established in synchrotrons, involves reconstructing the phase space using bunch monitor data obtained for a sufficient number of turns in a synchrotron oscillation. In this presentation it is shown how this technique can be adapted for the FFA case. The resulting tomography code is used to reconstruct the longitudinal phase space using data from the 150MeV scaling FFA at KURNS, Osaka, Japan. In the broadband RF cavity used at KURNS, multi-harmonic components can be significant. Using tomography, it is possible to establish the effect of these components on the longitudinal distribution.

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Design of LhARA facility

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LhARA (Laser hybrid Accelerator for Radiobiological Applications) aims to provide multi-ion beams for in-vitro and in-vivo radiobiological studies to inform the next generation radiotherapy. As the source of ion beams a thin target irradiated by high power laser will be used followed by a capture and transport system based on Gabor Lenses. In the next stage of the project FFA accelerator is planned to allow further acceleration of the ion beams. The design of the beam transport and the FFA ring is presented. The options for the FFA ring are also discussed.

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Precise Modelling and Large Scale Multiobjective Optimisation of Cyclotrons

Author: Jochem Snuverink[None]

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The usage of numerical models to study the evolution of particle beams is an essential step in the design process of particle accelerators. However, uncertainties of input quantities such as beam energy and magnetic field lead to simulation results that do not fully agree with measurements, hence the final machine will behave differently compared to the simulations. In case of cyclotrons such discrepancies affect the overall turn pattern or alter the number of turns. Inaccuracies at the PSI Ring cyclotron that may harm the isochronicity are compensated by 18 trim coils. These are often absent from simulations or their implementation is simplistic. A realistic trim coil model within the simulation framework OPAL is presented that was used to match the turn pattern of the PSI Ring. Due to the high-dimensional search space consisting of 48 simulation input parameters and 182 objectives (i.e. turns) simulation and measurement cannot be matched in a straightforward manner. Instead, an evolutionary multi-objective optimisation with more than 8000 individuals per generation together with a local search approach was applied that reduced the maximum error to 4.5 mm over all 182 turns.

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vFFA optics, dynamics, codes and magnets

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RF Voltage in KURNS FFA

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