Title
A Storage Ring for Radioactive Beams

Author
Moltz, D.M.

Publication Date
1994-05-01

LBL-36064
UC-413

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

Presented at the ISAC Workshop, Lake Louise, Alberta, Canada, February 1994, and to be published in the Proceedings

A Storage Ring for Radioactive Beams

D.M. Moltz

May 1994

NUCLEAR SCIENCE DIVISION

Prepared for the U.S. Department of Energy under Contract Number DE-AC03-76SF00098

DISCLAIMER

LBL - 36064

A Storage Ring for Radioactive Beams

Contribution for the ISAC Workshop, Lake Louise
Alberta, CANADA
February 1994

D.M. Moltz
Lawrence Berkeley Laboratory, Berkeley, California 94720, USA

May 1994

This work was supported in part by the Director, Office of Energy Research, Division of Nuclear Physics of the Office of High Energy and Nuclear Physics of the U.S. Department of Energy under Contract DE-AC03-76SF00098.

Contribution for the ISAC Workshop, Lake Louise, Alberta, February 1994

A STORAGE RING FOR RADIOACTIVE BEAMS

D.M. Moltz
Nuclear Science Division, Lawrence Berkeley Laboratory, Berkeley, CA 94720

ABSTRACT:

Preliminary ideas are presented for the scientific justification of a storage ring for radioactive beams. This storage ring would be suitable for many nuclear and atomic physics experiments. Ideally, it would be constructed and tested at an existing low-energy heavy-ion facility before relocation to a major radioactive beam facility.

There have been significant discussions regarding the scientific justification for a major North American radioactive beam facility. These discussions led to the Isospin Laboratory (ISL) conceptualization put forth in a rather extensive document [1]. Because there exists several facilities which either have, or will have, radioactive beams available produced via projectile fragmentation, it has long been assumed that ISL would be an ISOL (isotope separator on-line) based facility. This assumption leads to many technical problems associated with high radiation fields, large target power densities, and the post-acceleration of very low-energy beams with large m/q ratios. Although these problems all deserve significant efforts, final beam intensities vary drastically over the entire nuclidic chart, necessitating the development of detector techniques which can be useful even at the lowest intensities. The low beam intensities would therefore require detectors which approach the 4π theoretical solid angle limit with large granularity. Detector arrays composed of germanium, silicon, phoswich, or hybrid systems are generally quite expensive yet necessary for radioactive beam experiments. For example, it would be difficult to justify measuring even something as simple as elastic scattering by moving a single detector from angle to angle to obtain an angular distribution. With a 4π detector array, one could obtain the entire angular distribution concurrently assuming the granularity is sufficient to yield a suitable number of data points in the relevant angular range.

There exists a second important problem with radioactive beams incident upon stable targets, namely the intense background in the detector systems from the radioactive beam itself. Even if the post-accelerated beam was transported with 99.9% efficiency through collimators, targets, etc., there would still be count rates in the detector array vicinity of up to 10^{10}/second; this decay rate would be unacceptable for all detector arrays. In this paper I present some preliminary ideas for a detection system which could increase the available beam intensities for more weakly produced radioactive species, eliminate most of the *in situ* background due to the beam decay, and possibly provide a technique to accurately measure all ground state atomic masses; this system is a storage ring.

The idea for using a storage ring as a detector is not unique. They have been used as accumulators, accelerating structures, and decelerating structures; they have been used at low and high energies, with electrons, protons, antiprotons and heavy ions; they have been used for solid state, atomic, nuclear and particle physics experiments; they form the basic entity for light sources from ultraviolet to hard x-ray frequencies. The idea of using a storage ring as part of a detection system has arisen primarily in nuclear and atomic physics. A proposal for building a storage ring primarily for atomic physics was developed at Oak Ridge [2]. One particularly interesting proposal for the use of a storage ring was that developed for the GSI ESR ring [3]. The basic idea of this proposal is to operate the ring at the transition point which is inherently a dispersive solution. Although the solution is dispersive, the flight path length is independent of the exact momentum, thereby making the system essentially isochronous for all atoms of the same isotope. Thus if one can achieve a large number of orbits before losing the circulating particle, one obtains an equivalently long flight path. The possibility thus exists to measure the atomic mass of very exotic nuclei one atom at a time. There exists no fundamental reason why, however, that this use of a storage ring need be confined to energies on the order of 10 Tesla-m. Several years ago I proposed to build a storage ring primarily to measure masses at ~ 10 MeV/nucleon. Such a storage ring would have been moderately costly. In recent years, however, the nuclear science one could envision performing with a storage ring has been increased dramatically by the advent of several new radioactive beam facilities in North America.

Radioactive beams present a myriad of new possibilities and have been covered extensively in many conferences and publications. A subset of these experiments such as elastic scattering, reaction dynamics, in-beam gamma rays, giant resonances, inverse kinematic reactions, low-energy fusion cross sections, and nucleus-nucleus Bremstrahlung would be particularly suited for study with a storage ring. There also exists many atomic physics experiments coming under the general headings of low-energy electron-ion interactions, ion-atom collisions, and atomic spectroscopy, which could be enhanced with the use of a storage ring. It is important to note that although it has been shown [4] that one can never achieve the thick target yields in a nuclear process with a circulating beam and thin target, all of the experiments suggested above cannot tolerate these thick targets because they can stop significant amounts of the radioactive beams, thereby creating an intolerable background. There has been no attempt to fully justify the use of a storage ring as part of a detection system. Instead I have attempted to give a brief overview of the general utility of such a device.

It is also worthwhile to give some operating parameters for a storage ring envisioned for use with a radioactive beam facility. One design possibility is shown in Fig. 1. The operating characteristics given in Table 1 were conservatively chosen based upon the design energy goals for the ISL post-accelerator structure. The design pressure should give sufficiently long coast times for most experiments.

Table 1: Design parameters for a storage ring suitable for use with post-accelerator radioactive beams.

6 dipoles - 1.6T
8-12 quadrupoles
2 kicker magnets (2-100 μs)
Bρ ~2.0 Tm
P_{ring} = 10^{-11} - 10^{-12} Torr
Electron beam cooling, ~60 kV, 5A
Circumference - 35.5 m

q/A	Max Energy/nucleon
0.5	46.3
0.4	30.0
0.25	11.8

Of course it is important to build such a complicated system in parallel with any major radioactive beam facility (such as ISL, but not limited to ISL). This development should occur not only where significant accelerator expertise resides, but also where an accelerator exists which could provide stable heavy ion beams in the relevant energy range. Such conditions exist at Lawrence Berkeley Laboratory because of the wide range of available beams at the 88-Inch Cyclotron. Geographically, such a storage ring could easily be placed at the rear of the existing experimental hall. This is depicted in Fig. 2.

It would be imperative to not only test such a device, but also perform some significant physics measurements. These could include some atomic physics, many proton-rich mass measurements very far from stability, and some simple radioactive beam measurements such as mirror elastic scattering. Based upon the cost estimate put together for the Oak Ridge proposal [2], it is estimated that a storage ring as outlined here would cost in the $15-20M range, but this investment would be very worthwhile considering the scientific potential.

This work was supported by Director, Office of Energy Research, Office of High Energy and Nuclear Physics, Division of Nuclear Physics, U.S. Department of Energy under Contract DE-AC03-76SF00098.

REFERENCES

[1] Proceedings of the Workshop on the Science of Intense Radioactive Ion Beams, April 10-12, 1990, Los Alamos, NM, Report LA-11964-C.

[2] HISTRAP, proposal for "A Heavy Ion Storage Ring for Atomic Physics", Oak Ridge National Laboratory, November, 1988.

[3] H. Wollnik, private communication.

[4] L. Buchmann, J.S. Vincent, J.M. D'Auria, J. King and R.E. Azuma, in proceeding of Radioactive Nuclear Beams: The First International Conference, 16-18 October 1989, Berkeley, CA, (World Scientific), p.46.

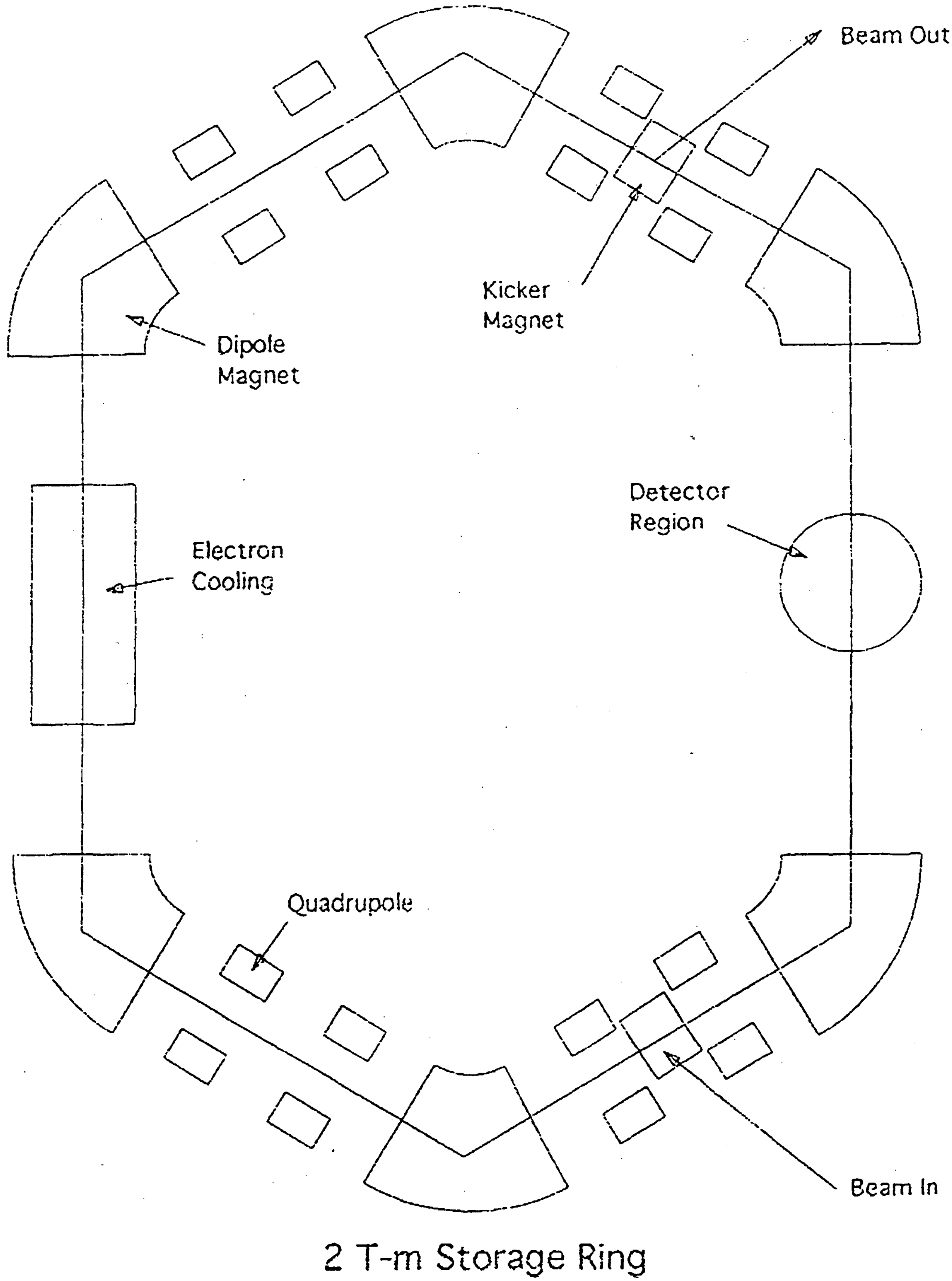

Fig. 1 One design possibility for a storage ring suitable for use at a radioactive beam facility.

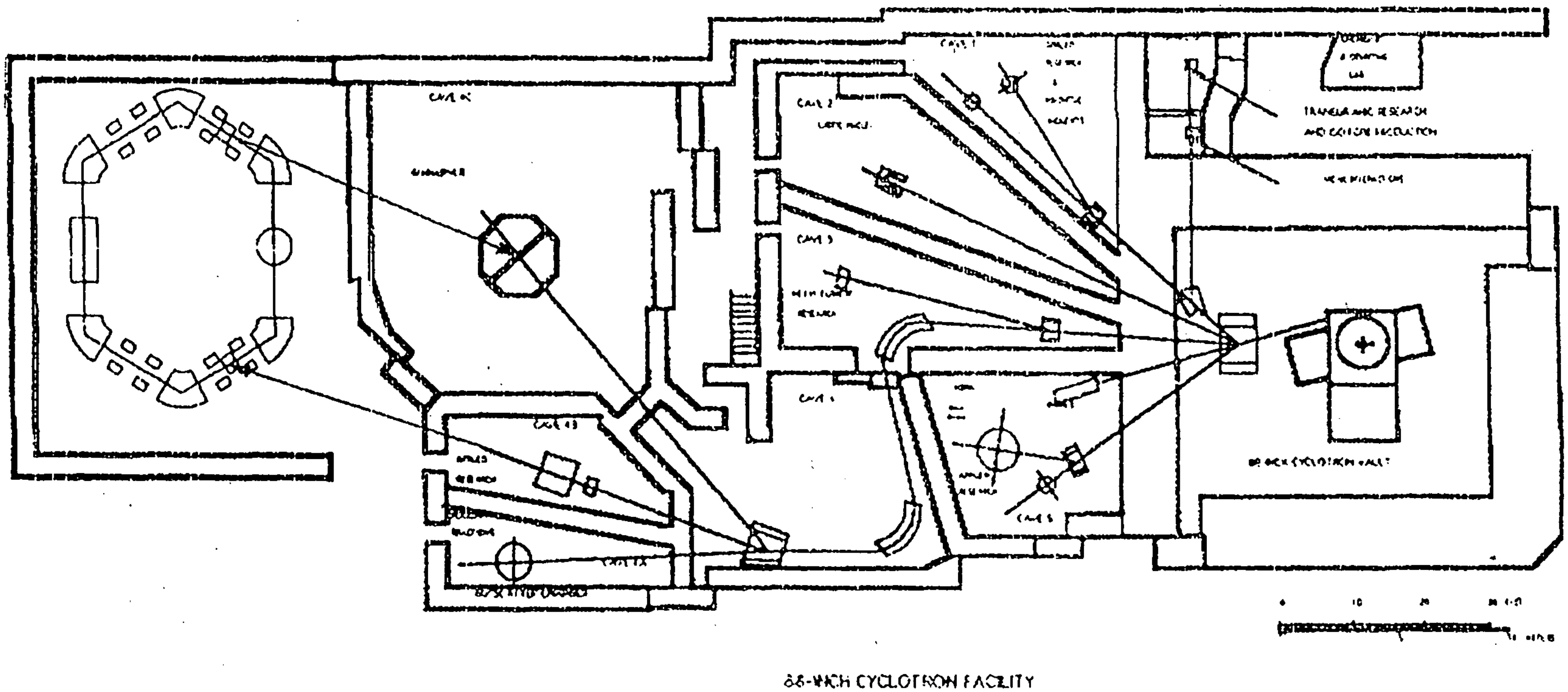

Fig. 2 Potential location for the storage ring depicted in Fig. 1 at the LBL 88-Inch Cyclotron.

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
TECHNICAL INFORMATION DEPARTMENT
BERKELEY, CALIFORNIA 94720