Antiprotons at the Future GSI Facility

Walter Henning
GSI
Planckstr. 1, 64291 Darmstadt, Germany

1 Introduction

The GSI laboratory is considering a major extension of its accelerator facilities. The concept includes the capability for energetic antiprotons ($E \leq 15$ GeV/c) [1]. This is the aspect of primary interest to this workshop. But to gauge the prospects and constraints of the facility, and presumably also the chances of its realization, it might be useful to first describe the overall project and its research goals, and then to provide some details on the proposed antiproton capabilities.

GSI is a national research laboratory in Germany with the original – and still primary – mission to perform fundamental research in nuclear physics and related areas. These latter include – due to the capability of the GSI accelerators to provide heavy-ion beams over a fairly wide energy range and for all beam species from protons to uranium – the areas of atomic physics, plasma physics, biomedical physics (including now heavy-ion therapy) and material sciences.

2 Future Facility Concept

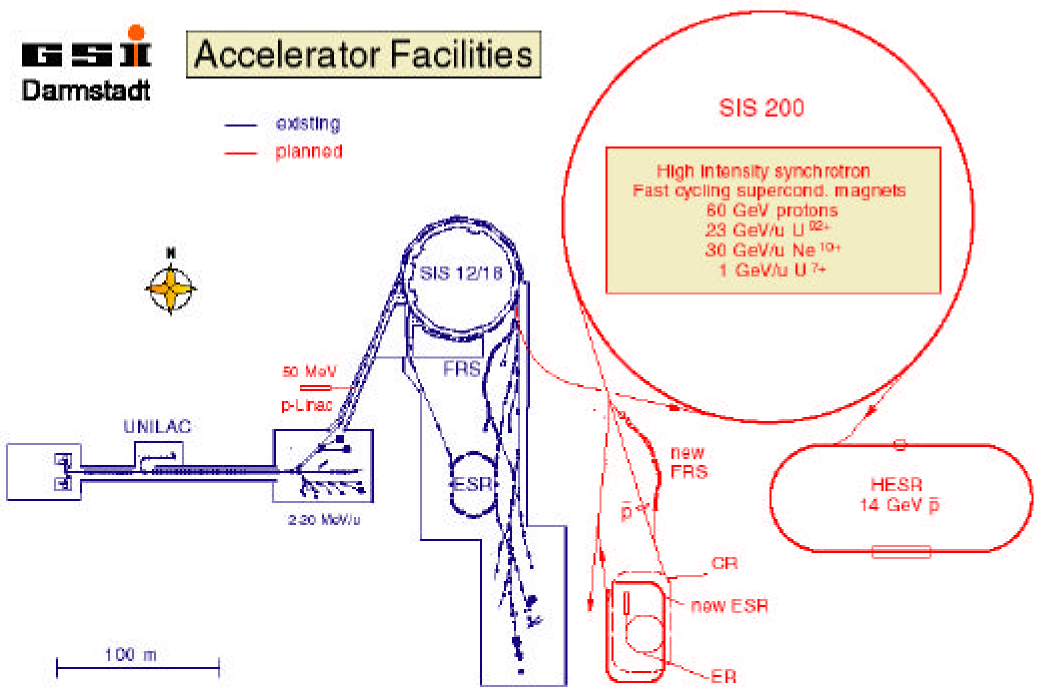

Figure 1: Overall layout of the present (left) and future (right) GSI accelerator facilities.

Figure 1 shows the present facility and the planned upgrade. On the left the current accelerator system is shown, with a heavy-ion linac as injector (UNILAC, $E \leq 10 - 20$ MeV/nucleon), a synchrotron to boost energies into the relativistic regime (SIS18, $E \leq 1 - 2$ GeV/nucleon) and an experimental ion storage ring with electron cooling (ESR, $E \leq 750$ MeV/nucleon). Current key programs, if we focus for the purpose of the present discussion on the primary research area, *i.e.* nuclear physics, are in nuclear structure research, in studies of hadrons in the nuclear medium, and of nuclear matter at high densities.

The facility extension aims primarily at increasing intensities of the primary – and thus the secondary – beam species. For a ring accelerator, whose space charge limit is reached, this can be only achieved by faster cycling and by reducing the charge, which is possible for heavy ions (not for protons, unfortunately!). However, reduced ionic charge state leads to higher magnetic rigidity of the beam particles and thus to the need for more bending power and a larger ring. The proposed 200 Tm rapidly cycling, superconducting synchrotron ring achieves this goal. It will be filled at 5 Hz from SIS18 and with a charge state reduced by a factor of ~ 3 over present (*i.e.* about an order of magnitude higher space charge limit due to its quadratic dependence on charge state). At reduced intensity, high charge states (*e.g.* Ne^{10+} or U^{92+} ions) can be accelerated to energies of about 23 and 30 GeV/nucleon, respectively. The new ring also provides for 60 GeV protons. To maximize production, collection and storage of secondary beams and to optimize their beam phase-space, additional rings (with lower rigidity) are planned, as shown in Figure 1. They include a collector and a storage ring for radioactive beams, which will also be used for antiprotons, and a high-energy electron-cooler and storage ring for the antiprotons.

3 Research Programs

The future research program focuses on 4 key areas: i) nuclear physics with beams of short-lived nuclei ("radioactive beams" or "rare isotope beams"), ii) studies of QCD structure and dynamics in the charmed sector with antiprotons, iii) studies of the QCD phase diagram and of nuclear matter at highest densities through nucleus-nucleus collisions, and iv) studies of bulk matter under extreme conditions, *i.e.* plasma physics.

Figures 2-6 illustrate the research programs envisioned with these capabilities. Figure 2 shows the three principal areas to be addressed with intense radioactive beams: i) studies of the nuclear many body systems at the limits of stability and delineation of the relevant degrees of freedom and of the physical phenomena resulting from that; ii) questions of nuclear astrophysics, in particular for explosive nucleosynthesis, *i.e.* X-ray bursters, novae and supernovae; and iii) precision studies of fundamental symmetries in nuclear decays, capitalizing on the high intensities of rare unstable nuclei that will become available with the new facility.

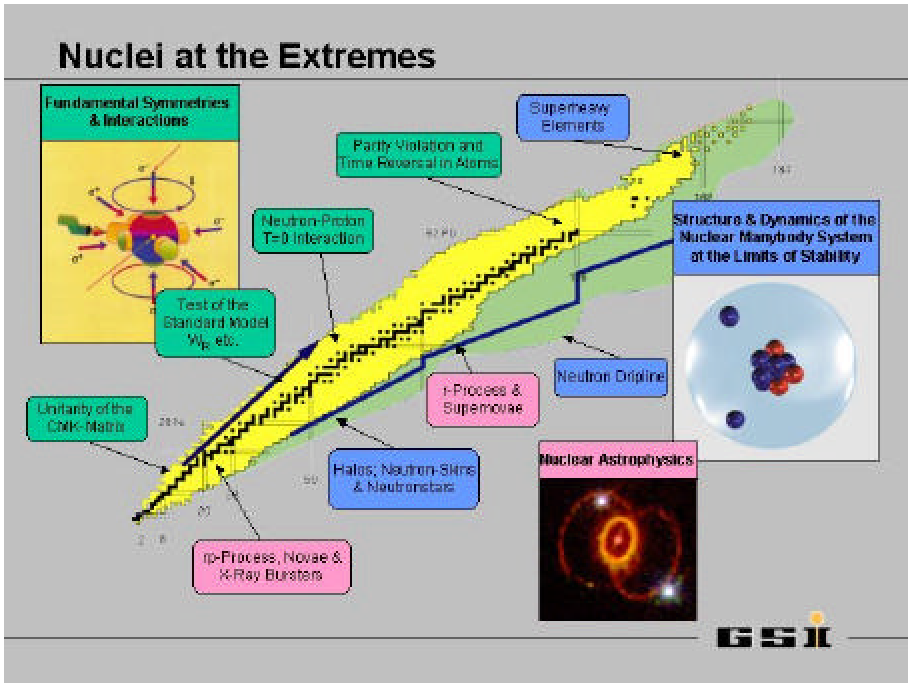

Figure 2: The physics withbeams of short lived nuclei ("radioactive beams" or "rare isotope beams").

Figure 3 illustrates the potential of intense heavy-ion beams at "low" energies (200 MeV $\leq E \leq 1$ GeV/nucleon) for studies of bulk matter in the plasma state at very high temperatures, densities and pressures.

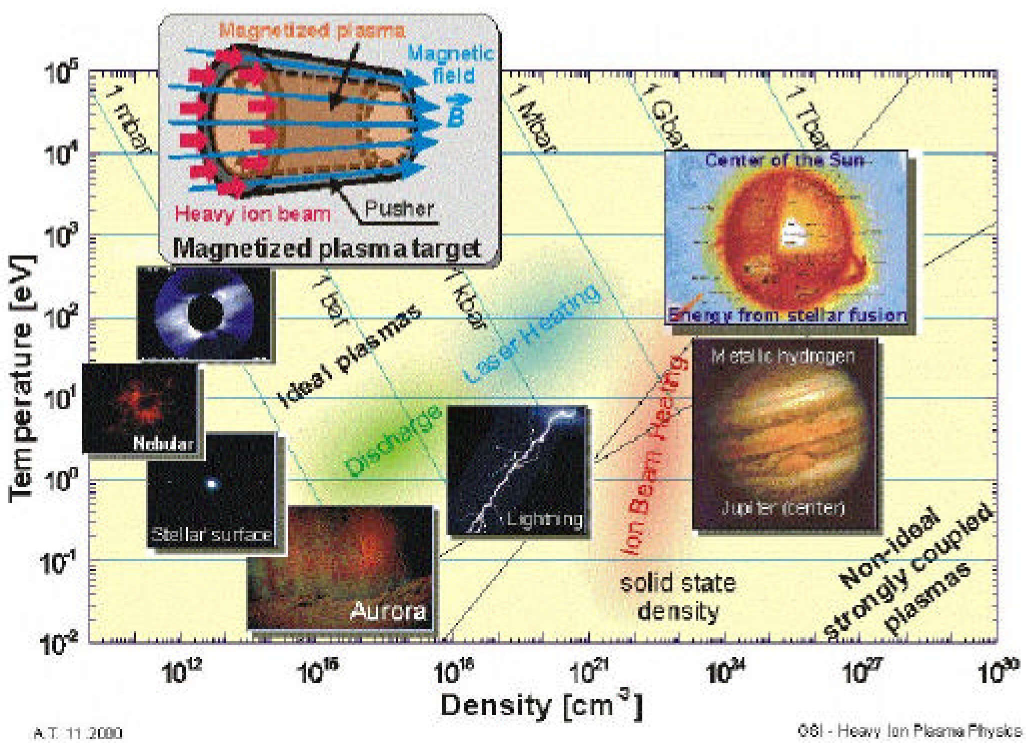

Figure 3: The physics of hot and compressed bulk matter in the plasma state

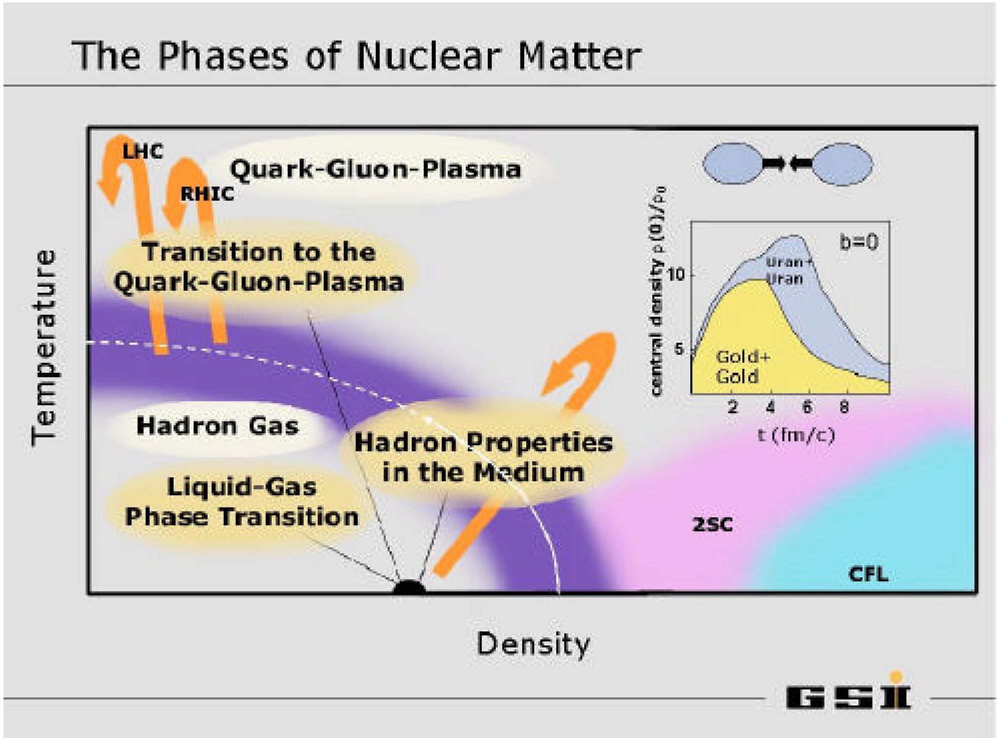

Figure 4: The phase diagram of nuclear matter.

The QCD phase diagram of nuclear matter with emphasis on the high-density region, where studies of phase transitions to deconfined matter and/or color superconductivity are envisioned, is shown in Figure 4. It indicates that for the new facility, new approaches in probing nucleus-nucleus collisions with specialized detectors and, possibly, speculative schemes to achieve a high and long-lasting density phase in tip-on-tip collisions of deformed nuclei, are being considered. Finally, in Figures 5 and 6 the studies envisioned with antiprotons are summarized.

4 Antiprotons

The physics goals for antiprotons are spectroscopy in the charmed sector aiming at QCD dynamics and the confinement potential, the study of properties of hadrons in dense nuclear matter and the restoration of chiral symmetry; and possibly studies of CP symmetry violation in the charmed sector, although the latter needs further detailed studies to see whether the required luminosity can be reached with the facility.

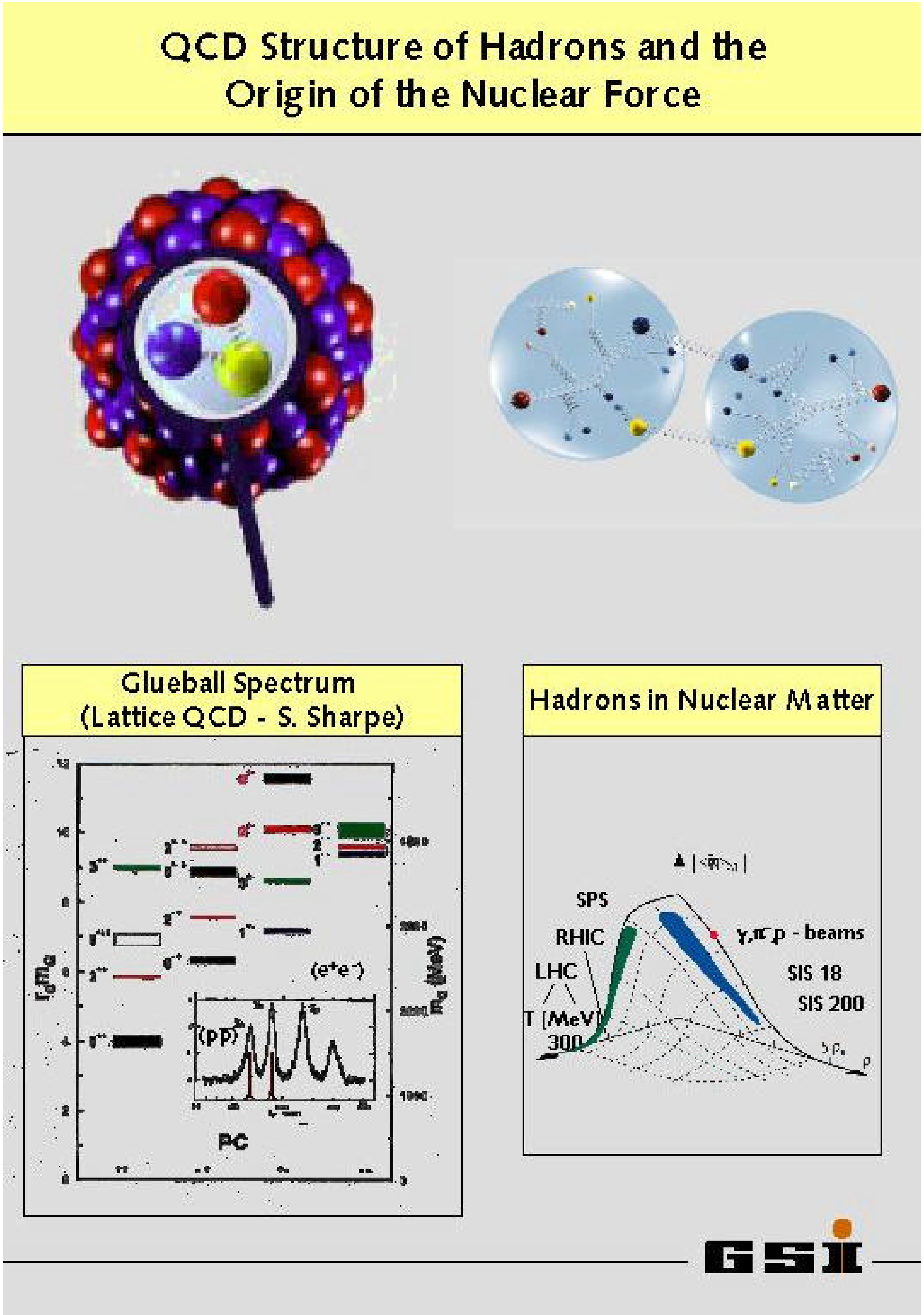

Figure 5: Physics with antiprotons.

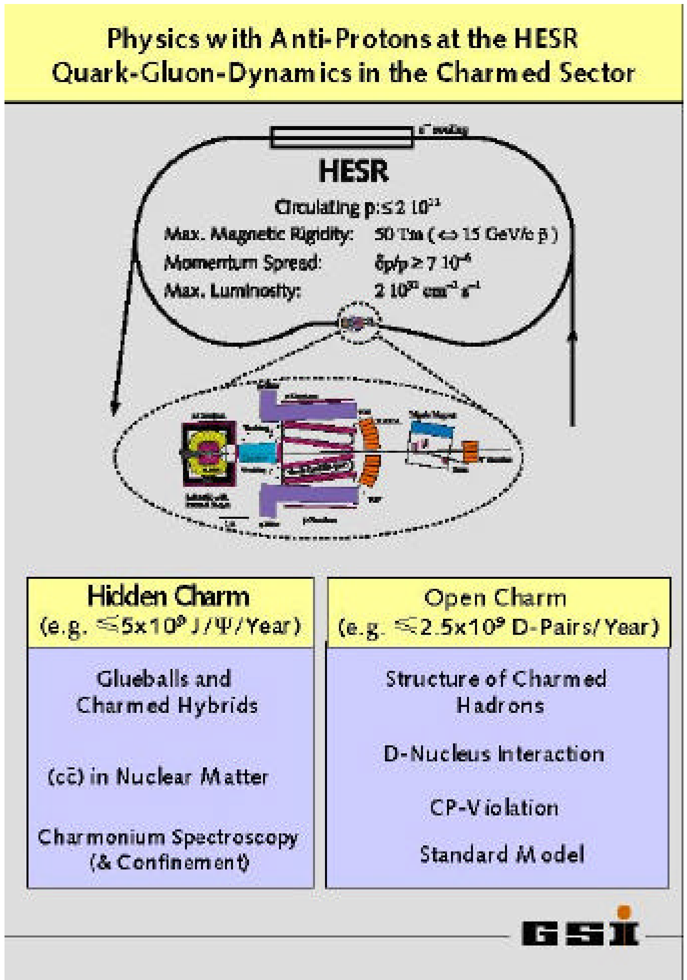

Figure 6: Schematic of the antiproton storage ring, internal target and detector system to address the physics issues summarized in the lower half of the figure.

The experimental setup for the antiproton experiments (Figure 6) involves a high-energy, electron-cooled antiproton storage ring, internal targets and a sophisticated detector system. Some design parameters are listed in Figure 6.

5 Summary and Outlook

Figure 7 summarizes in a pictorial way the parameters aimed for with the technical concept for the proposed facility and the research goals to be addressed.

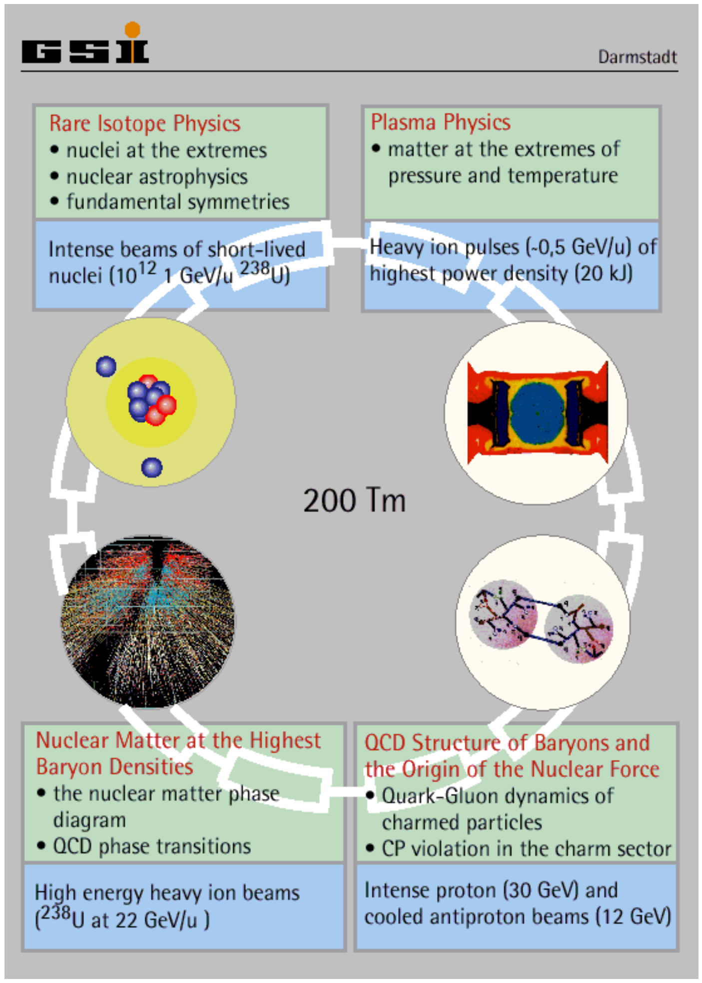

Figure 7: Summary illustration of the future GSI facility: research goals and general performance characteristics.

Presently, details of the concept are being worked out and supporting R & D and prototyping is being initiated. About 2 – 3 years of design effort and R & D is needed before construction could begin.

References:

[1] B. Franzke (GSI Darmstadt), P. Kienle (Techn. Univ. of Munich), H. Koch (editor; Univ. of Bochum), W. Kühn (Univ. of Giessen), V. Metag (Univ. of Giessen), U. Wiedner (CERN & Univ. of Uppsala), Letter-of-Intent "Construction of a GLUE/CHARM Factory at GSI," Informal report (1999).