HESR-project in FAIR at GSI

High Energy Storage Ring for antiprotons in the Facility for Antiproton and Ion Research at GSI, Darmstadt, Germany
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  – Properties of HESR, ...
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• Future extension: Polarization
• Staging of FAIR, EU funding, synergy with current accelerator activities at COSY
Symbiosis (1)

Experimentalists cannot live without accelerator physicists and accelerator physicists cannot live without experimentalists.

You need accelerators, but no accelerator will be built without constant visible demand for the experiments. In the case of HESR we are talking about a phase of 5 – 8 years in which this demand should increase steadily (~3 generations of thesis !)
Experiments and accelerator layout are intimately connected for state-of-the-art experiments. Seek discussion during the early planning phase of the accelerator. Some requirements might exclude each other.

Example: Idea for polarized antiprotons nearly missed the deadline for being included. Now the HESR can be planned to allow this extension.
Mission of HESR

- Provide a door to the physics with antiprotons in the low GeV region
- Make precision antiproton beams available for state-of-the-art experiments

Presently the following experiments are planned
- PANDA
- PAX, ASSIA

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R. Tölle, FZJ, HESR-project in FAIR at GSI
FAIR: The Facility

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HESR Parameters and Layout

• HESR is a storage ring with cooling and ONE place for experiments
• Momentum range is 1.5 GeV/c to 15 GeV/c (0.831 GeV/c$^2$ to 14 GeV/c$^2$)
• At the target place a beam diameter < 1 mm will be provided
• Betafunctions at the target ~ 1 m
Lattice Parameters

(designed by Y. Senichev)

- Large $\beta$-functions at the Electron Cooler
- Small $\beta$-functions at the target position
- Large (or imaginary) $\gamma_{\text{transition}}$ for beam stability
HESR Modes (aims!)

- The users would like to get:

<table>
<thead>
<tr>
<th>High luminosity mode</th>
<th>High resolution mode</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>0.85 GeV</strong></td>
<td><strong>6 GeV</strong></td>
</tr>
<tr>
<td>beam intensity : $5 \times 10^{10}$</td>
<td>beam intensity : $5 \times 10^{10}$</td>
</tr>
<tr>
<td>effective target thickness : $3 \times 10^{15}$ cm$^{-2}$</td>
<td>effective target thickness : $3 \times 10^{15}$ cm$^{-2}$</td>
</tr>
<tr>
<td>$\Rightarrow$ luminosity of $10^{32}$ cm$^{-2}$ sec$^{-1}$</td>
<td>$\Rightarrow$ luminosity of $10^{30}$ cm$^{-2}$ sec$^{-1}$</td>
</tr>
<tr>
<td>radius $\sigma_T$ : 0.78 mm $\Rightarrow$ 0.2 mm</td>
<td>radius $\sigma_T$ : 0.78 mm $\Rightarrow$ 0.1 mm (#)</td>
</tr>
<tr>
<td>momentum spread $\sigma_p/p : 7.2 \times 10^{-4}$ $\Rightarrow$ $1 \times 10^{-4}$</td>
<td>momentum spread $\sigma_p/p : 7.2 \times 10^{-4}$ $\Rightarrow$ $0.15 \times 10^{-4}$ (*)</td>
</tr>
<tr>
<td>$\sigma_T$ is the rms beam radius at target ($\beta_T = 1$ m at target) : (#) is 0.1 tune spread</td>
<td></td>
</tr>
<tr>
<td>numbers marked by (*) are the limiting values for 100 $\Omega$ impedance and pulse width $\sigma_b = 0.11$ µsec</td>
<td></td>
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</tbody>
</table>

- the HESR ring with dedicated cooling systems can deliver:

<table>
<thead>
<tr>
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<tr>
<td><strong>15 GeV</strong></td>
<td></td>
</tr>
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<td>$\Rightarrow$ luminosity of $10^{31}$ cm$^{-2}$ sec$^{-1}$</td>
</tr>
<tr>
<td>radius $\sigma_T$ : 0.22 mm $\Rightarrow$ 0.6 mm</td>
<td>radius $\sigma_T$ : 0.22 mm $\Rightarrow$ 0.1 mm</td>
</tr>
<tr>
<td>momentum spread $\sigma_p/p : 0.6 \times 10^{-4}$ $\Rightarrow$ $2 \times 10^{-4}$</td>
<td>momentum spread $\sigma_p/p : 0.6 \times 10^{-4}$ $\Rightarrow$ $0.2 \times 10^{-4}$ (*)</td>
</tr>
</tbody>
</table>
HESR Electron Cooler

High voltage (8 MV) tank

12 m

Charger: H⁻ Cyclotron

HESR beam

1 A electron beam

30 m Solenoid
Cooling

• Electron cooling links transverse and longitudinal cooling. 8 MV not done before. 8 MV corresponds to 15 GeV/c.

• Stochastic cooling can be used separately for longitudinal, horizontal and vertical particle motion.

• Sophisticated combination of electron and stochastic cooling under investigation. Modelling (beam-target interaction, intrabeam scattering)!

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Relation of IKP / FZJ to HESR

- FZ Jülich (IKP-COSY Group) takes over the responsibility for building the HESR
- Formal commitment / agreement pending, first draft of MoU is circulating
- Successful application for EU money (Design Study) together with other subprojects of FAIR
  - Contract negotiations with EU in progress. 90% of the applied money will be granted. For HESR ~ 1.3 M€ can be expected for 2005-2007. HESR consortium between FZJ, TSL and GSI.
Extension: Polarization

To polarize antiprotons two ideas have been proposed:

The first, called Spin Filter (see talk by Frank Rathmann), is based on the fact that absorption of antiprotons in a polarized proton target is different when the two spins are parallel or antiparallel. If the spin-dependent cross-sections $\sigma_L$ or $\sigma_T$ are not negligible, the transmitted beam can be (slightly) polarized.

The effect is enhanced in the case where a polarized hydrogen target based on the storage cell technique is installed in a storage ring. Preferred!

The second idea is the Spin Splitter which based on the separation of particles with opposite spins by Stern-Gerlach effect in the inhomogeneous field of a quadrupole.
Polarization: HESR add-ons

Additional equipment in the HESR
Acceleration from 1.5 GeV/c to 15 GeV/c (830 MeV to 14 GeV)
- Synchrotron Magnets
- Dynamic Power supplies
- Control
- Polarisation conservation
- Polarimeter
- Full and helical snakes
- RF Dipole
- Pulsed quadrupoles
- Proton Injection

Larger Circumference: 1 M€ per 10 m

Estimated Costs and Manpower: 45M€+25 M€ & (350 MY for HESR)
The Antiproton Polarizer

Ring itself
  Acceleration from 240 MeV/c to 1.5 GeV/c (30 MeV to 830 MeV)

  Electron Cooler
    Full snake at low energy
    Polarisation conservation ( Fast Quads, RF Dipole )
  Polarimeter
  2 Injections
  2 Extractions
  Targetstation
  Polarized H^+ - source

30 MeV injector

Estimated Costs and Manpower: 30 M€ & 150 MY without infrastructure costs
Synergy with future COSY activities

• Experience with the planned 2 MV cooler for a COSY upgrade will influence the proposed 8 MV cooler for HESR
COSY 2 MV cooler

Basic concept proposed by V.V. Parkhomchuk et al.  
(Budker Institute, Novosibirsk, RUS)

Main Parameters

HV terminal:
- 0.25-2 MV, 3 A
- cascade charger
- 10 bar SF₆

Cooling section:
- length 3 m
- magnetic field 0.05-0.2 T
- beam diameter 14-29 mm