AD-4
Antiproton Cell Experiment
Future Plans

During the 2003 run period AD-4 has successfully demonstrated an enhancement in the Biological Effective Dose Ratio between Peak and Plateau of antiprotons stopping in a target containing live cells compared to a proton beam of similar energy and spatial structure. This enhancement is significant and opens up the opportunity to develop further the technology of using antiproton beams in cancer treatment.

In 2004 we will continue our experiments at the AD, with the main emphasis being placed upon:

- Studying the peripheral damage due to medium range annihilation products
- Assessing the applicability of different dosimeters to antiproton annihilation
- Improving our modeling capabilities through enhancing the GEANT4 package
- Developing and testing proposed technical solutions for real time imaging

Assuming that these tests will support our current assessment of the possible use of antiprotons in cancer therapy we plan to prepare a full proposal to the SPSC to continue the fundamental scientific studies and technological developments needed to validate the use of antiprotons in cancer therapy as soon as the AD becomes available again.

Future work will concentrate on several areas:

1. The physical properties of the antiproton annihilation event:

A detailed understanding of the annihilation event and the exact physical properties of the secondary particles generated in the annihilation event would allow to use theoretical models to predict the biological effects in human tissue with a high level of confidence. Such studies will require the study antiproton annihilations on an event-by-event level and have been done neither experimentally nor theoretically at the required level of detail. Access to low energy antiprotons would provide experimental benchmarks against which Monte Carlo calculations can be tested for their validity.

2. Detailed studies of the spatial distribution of the energy deposited as well as the effective biological effect of the deposited energy:

While the stopping distribution of antiprotons in matter itself can be modeled precisely and is nearly identical to that of protons, the energy deposited by antiprotons varies from that deposited by protons due the annihilation. Some of this additional energy is deposited through heavy ions with a very short range, but also through medium range neutrons and minimum ionizing particles like pions and high-energy gamma's. A detailed study of the energy deposited by the various particles as well as the biological effect of the individual portions of the deposited energy is necessary to assess the precision with which energy can be delivered to a target area in human tissue. Up to now the experiments were averaging over a relative large volume (cylinders of 0.5 mm thickness and 6 mm

diameter). We are currently studying different assays and higher cell densities (up to actual tissue densities) that would yield a higher spatial resolution and would allow us to compare Monte Carlo simulations on the localization of the energy deposition with actual experimental data.

3. Technology Research & Developments:

The minimum ionizing particles resulting from the annihilation event can in principle be used to image in real time with high precision where the antiprotons are stopping. This offers an immediate feedback opportunity to the clinical staff and would allow for automatic feedback to keep the antiproton beam precisely on a prescribed target volume. Possible detector technology is available from high-energy physics experiment at CERN and we hope to test a variety of ideas for their applicability and cost effectiveness in a medical environment.

4. Initial biological tests on real tumor situations.

Combining the knowledge gained in the previously described areas controlled experiments on tumors induced in living tissues can be used to validate the overall approach and are needed before a final development effort can be launched.

While points 1 and 2 can be studied at the level of intensity and the pulsed beam structure currently available at the AD it is of high interest to us that eventually the beam is delivered as a semi slow extracted beam (bunch length of approx. 1 sec) and possibly at a higher intensity. Developing multi-bunch stacking into the AD ring as well as slow (or multi-bunch) extraction would enhance our ability to carry the research forward towards our goal of utilizing antiprotons for cancer therapy. We would be interested to work with the CERN/AD team and the other experiments in providing such capabilities.

Additional work using protons and heavy ion beams will be performed in parallel at different laboratories to allow direct comparison between different beams for hadron therapy. This work can be used also to perform initial tests on new experimental set-ups where applicable, thus minimizing our need for antiproton usage.