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Project Details

INTAS-GSI Collaborative Call for Proposals for Research Projects 2003

Project name: 'Advanced Beam Dynamics for Storage Rings'

Intended starting date and duration: January 2004, 24 month

Scientific Objectives

Future cooler storage rings for ions and antiprotons will require characteristics of beam intensity and beam quality which are far above the limits of the operating facilities. Therefore their realization requires a new level of understanding beam physics and, correspondingly, new tools for the simulation of particle dynamics. As an example the expected luminosity in the proposed High Energy Storage Ring (HESR) at GSI is $2x10^{32}$ $cm^{-2}s^{-1}$ and the energy resolution required for some experiments is 100 keV only [1].

The interaction of the beam particles with the cooling electron beam, through internal Coulomb forces (intrabeam scattering), with the internal target and with the magnetic lattice elements of the ring represents a complex many particle problem with many free machine and beam parameters. The usual starting point is to consider isolated interaction processes, like the electron cooling (EC) force on the beam, intrabeam scattering rates (IBS) and the heating rate due to scattering in the internal target. In a second step the interplay of the processes is studied using rate equation systems or a kinetic describtion (Fokker-Planck or particle simulation). In order to push the beam intensity and quality frontier a much more detailed modeling than presently available will be necessary including also more processes, like the chaotic beam particle orbits due to the nonlinear space charge field of the cooler electrons [2]. A crucial problem for the proposed high luminosity experiments will be the identification of parameter regimes where an equilibrium exists [3].

Because of the required high beam current and qualitiy, the control of collective instabilities induced by ring impedances and by trapped secondary particles will be another major challenge. The interaction of intense, cooled beams with ring impedances can result in beam quality deterioration or beam loss due to microwave instabilities and long-time turbulence [4,5]. Another potential source of beam quality deterioration and loss are two-stream instabilities due to trapped electrons (ion beams) or ions (antiproton beam) are [6,7]. On the other side it shoulbe mentioned that cooler storage rings are a unique tool to observe and study long-time collective phenomena in general.

The goal of this project is the development of analytical models and new simulation tools for the investigation of beam dynamics and beam stability in cooler storage rings for ions and antiprotons. The models and tools will be used in design studies for the future machines NESR and HESR at GSI (Darmstadt, Germany). The joint research will focus on several points related to beam equilibrium and stability:

- Studies of equilibrium, cooled beam distributions in the presence of intrabeam scattering (IBS), internal target scattering, nonlinear space charge fields and confining rf fields. The goal is firstly to exclude parameter regimes where no equilibrium can be reached and secondly to study the equilibrium distribution function in 6-dimensional phase space.
- Simulation studies of collective effects in cooled beams. Strategies for control of collective beam instabilities induced by ring impedances and trapped particles. The goal is to give the ring hardware designers a clear guidance for impedance budgets, required feeback and vacuum quality.

- Development of a beam dynamics software library containing benchmarked physics modules (cooling forces, cross sections,..) for realistic simulations of the interplay of cooling and the various heating processes together with accurate ring lattice tracking.
- Benchmarking of the models and simulation tools with cooler storage ring experiments at low beam energy. Experiments with cooled ion beams interacting with the ring environment (internal targets, impedances, nonlinear fields).

Scientific and Technical Background

The proposed new GSI cooler storage rings [1] promise to give insight into many regions of physics, like high energy hadron physics and the physics of radioactive nuclei. Simultaneously other facilities are designed and (or) constructed worldwide (TWAC, ITEP, Russia; RIKEN, Wako-Shi, Japan), which will operate with similar beam parameters. The proposed HESR high-energy storage ring at GSI is expected to operate with up to 10^{12} antiprotons and with luminosities up to $2x10^{32}$ $cm^{-2}s^{-1}$. As a novel, challenging feature relative momentum spreads in the 10^{-5} range together with high luminosities are demanded by some experiments. In the NESR experiments at medium beam energy with electron cooled radioactive ions are foreseen. Experiments with high energy, laser cooled ion beams are proposed in the SIS 200 synchrotron.

Simulation challenges for future rings: Beam dynamics studies for future storage rings like the HESR and NESR at GSI, require the numerical simulation of all processes, which occur during beam accumulation and experiments: interaction with the internal target and the residual gas, IBS, electron cooling, stochastic cooling, beam-impedance and beam-trapped particle interactions. The simulations are complicated by the long-time nature (seconds) of the phenomena and, in the case of collective effects, by the high resolution needed to resolve the self-consistent electromagnetic fields.

Existing codes for beam dynamics in cooler rings: The codes presently being used for beam dynamics simulation for HESR (for example, MOCAC [8] and BETACOOL [9] written by the participants of the research project) have a limited application region and sometimes (MOCAC) are not adapted for users. Nevertheless, these codes and the physics models included for electron cooling (EC), IBS and target effects represent the ‚state of the art’. Many important results for the understanding of phenomena in existing storage rings were obtained with these codes. However, the design studies for future cooler rings will require a major extension of these codes. To give an example, the possible heating or loss of the stored beam due to nonlinear space charge fields (‘dynamic aperture’) is an important issue for the HESR and could not be addressed with the existing codes in an adequate manner.

Collective effects induced by impedances: An important aspect not covered by the previously described codes is the electromagnetic interaction of the stored beam with cavity-like objects or other ring components that can be described in terms of an impedance concept. Whereas in the foregoing we were dealing with ‘microfields’ (IBS, EC) or static (nonlinear) external fields this aspect deals with the self-consistent time dependent fields induced by an intense beam. Most of the experience with microwave instabilities was gained in high current proton machines: e.g. in Ref. [10] measurements in the CERN SPS assisted by ESME [11] simulations are presented. The instabilities induced by the impedances are usually much faster than the cooling/heating processes described before. Nevertheless, nonlinear, long-time collective beam phenomena in the longitudinal plane can be observed in storage rings operating close to the intensity limits [5]. Therefore effects like diffusion due to IBS or target effects should be included in estimating beam intensity limits in future storage rings.

Trapped secondary particles: The second source of collective beam instabilities and associated heating in storage rings are electrons or residual gas ions trapped in the beams potential (a review is given in [6]). Recently beam instability induced by ions stored in the cooling electron beam were discovered [7]. This effect needs accurate examination. Presently the analysis is made in the framework of linear theory. Numerical modeling will be necessary to understand the instability and its saturation characteristics.

Accelerator Libraries: The design of modern ring accelerators relies on benchmarked, supported and modular software tools. One example is the Methodical Accelerator Design (MAD) code at CERN [12]. The lattice definition (Standard Input Format 'SIF') used by MAD represents a kind of standard input language. Recently a new modular version, MAD X, was released, that is used for all kinds of beam dynamics studies for the LHC. Behind MAD there are a number of developers that contribute different modules to the code. A different approach is pursued by the developers of the Unified Accelerator Library (UAL) [13] at BNL. UAL represents a platform for existing, mainly tracking/mapping modules. The user accesses the modules through a scripting language (Perl). This approach of reusing existing software has proven to be very powerful. UAL was used for the design and commissioning of RHIC. Presently it is used in the design work for the SNS and all kinds of beam dynamics studies for the AGS/RHIC complex. For the design of future cooler storage rings neither MAD X nor UAL can be used without major additions. It is one of the goals of this project to provide all these additional modules required for effective cooler storage ring.

Research Method

Improving existing tools: For optimal design of the proposed future cooler storage rings it is necessary to improve the existing codes (e.g. MOCAC and BETACOOL) and, if possible, extract the main physical effects, like IBS rates and EC forces, in the form of independent modules from these codes. This will facilitate the benchmarking of separate physical effects as well as the linkage of these code parts to already existing tools, like MAD X or UAL, or to newly developed particle simulation tools. UAL could serve as the software platform for merging the physics modules provided by the different teams and combining them with sophisticated tracking/mapping routines (already included in UAL) in order to arrive at a joint particle simulation tool, including IBS, EC, target effects and nonlinear elements (magnet errors and space charge field of the cooler electrons).

'Quick tools': For ring design and ring operation studies it is important not only to have the most realistic tracking or mapping tool, but also to have a fast rate equation tool, that relies on reduced physics models, usually under the assumption of a Gaussian beam distribution function. Therefore the teams working on a particular interaction process, like target effects, should also contribute benchmarked rates to the library.

Collective effects induced by impedances: In addition the joint library for beam cooling/heating processes another library should be developed, summarizing all impedances sources relevant for the NESR/HESR. .Most of the expression can be found in the literature [4,14], but some sources are specific to cooler storage rings, like the impedance of the electron cooler [15]. Feedback systems are another source of artificial impedance which should be included in the library. These models must be examined in detail, before entering in the joint impedance library. For realistic studies of collective intensity limits due to a broadband ring impedance spectrum high-resolution simulation tools will be needed, running on powerful computer systems. At GSI a modular simulation code based in the Vlasov-Fokker-Planck equation was developed [16|. Together with a library for longitudinal cooling forces and diffusion functions the GSI code could be turned into a flexible simulation tool for all kinds of longitudinal studies (impedance scans [16], stacking procedures [17|) for the NESR/HESR. The ESME longitudinal particle tracking code, that is presently used for these kind of studies at FNAL and CERN is not appropriate for these kinds of studies, because of its low resolution and the missing capability to handle collision processes.

Feedback: Means to cure collective beam instabilities by suitable longitudinal (see e.g. [18]) and transverse feedback systems will also be investigated. Moreover, we will develop modules to integrate the feedback in the simulations.

Trapped secondary particles: These studies will require a specialized simulation tool. The presently used code for electron cloud simulations ("ECloud") [19] is written for bunched beams; however, in HESR it is foreseen to use coasting beams. In order to analyze electron trapping in coasting beams it is necessary to account for effects such as intra-beam scattering and heating due to elastic scattering by to beam ions, which are omitted in ECloud.

Benchmarking with beam dynamics experiments: Parts of the new codes will be checked experimentally in in existing storage ring facilities at Jülich, GSI and Uppsala for low energy beams. The three facilities operate internal targets and electron coolers. Important aspects predicted by the computer codes, like the beam equilibrum parameters with EC, IBS and target scattering can be tested in these facilities with low energy ion beams.

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Research program

The major part of the project is devoted to codes for beam dynamics simulation and studies for NESR/HESR using these codes. It includes the analysis of the physical bases of the existing codes, their improvement and adaptation to users.

- Joint examination of the physics base of all existing codes for beam dynamics in storage rings, which special regard to high-energy EC of intense beams, IBS and interaction with dense internal targets.
- The examination will also the include the required lattice tracking/mapping capability as well as possible platforms, like UAL, for the joint library. GSI already has a fruitful collaboration with BNL on adapting UAL for high current beam simulations. This collaboration should be extended towards cooler storage ring modeling.
- Benchmarking of the isolated processes contained in the existing codes. If possible, separation of the most useful routines from the codes and merging into the joint library. Examination of all physics effects or modules missing in the joint library for future beam dynamics studies. Development of the missing models and modules.
- Studies related to NESR/HESR with focus on
  a. Beam intensity effects on the EC forces
  b. Dynamic aperture reduction due to the nonlinear space charge field of the cooler electrons
  c. Heating and beam loss rates due to different types of internal targets
  d. Details of the equilibrium beam distribution function depending on the interplay of all the processes: EC, IBS, Target, and nonlinear fields.
- Review of all impedance sources that are relevant for future storage rings, including cavity-like objects, kickers, feedback systems and the cooling devices.
- Development of a joint simulation tool for studies of collective, longitudinal phenomena in the NESR/HESR, with the main focus on intensity limits due to ring impedances. This tool will then be used for injection studies and for impedance scans. The already existing GSI Vlasov-Fokker-Planck code will be used as a starting point for this development.
- Development of physics models and simulation tools for secondary particle accumulation in stored beams.
- Numerical investigation of the influence of secondary particles on beam stability, including two-stream electron-ion instability (electron cloud + circulating ions) and "three species" (antiproton + cooling electrons + accumulated ions) dipole instability. Application to design optimization and beam stability analysis for HESR and NESR.

Tasks

T1. Physics models for the equilibrium beam distribution
Definition of appropriate models for a joint library in terms of accuracy and computing time.
T2. Joint simulation tool for the equilibrium distribution
Develope a joint simulation library for cooler storage ring studies.

T3. Beam-impedance interaction in storage rings
Study of beam intensity limits in cooler storage rings due to coherent instabilities induced by ring impedances.
T4. Trapped particle studies
Study of the role of trapped secondary particles in cooler storage rings for intense ion and antiprotons beams.
T5. Beam physics experiments at existing storage ring facilities
Experiments with low energy, cooled beams in order to benchmark simulation codes and physics models.
T6. Full design simulation studies for NESR/HESR
Full design studies using the developed tools for NESR/HESR.

Teams Information

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A. **Bogdanov**
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Beam dynamics calculations
Calculation of the equilibrium cooling - heating
Collective beam instabilities

Design, construction, commissioning and operation of the cooler synchrotron and storage ring COSY.
Participation in beam dynamic calculations of AGS and RHIC and commissioning of RHIC
Beam dynamics calculations for synchrotrons, storage rings and linacs.
Calculation of the equilibrium cooling - heating in storage rings.

Access to machine experiments with cooled beams and target interaction at COSY
Super computer center including user support at the CENTRAL INSTITUTE FOR APPLIED MATHEMATICS (ZAM) at FZJ
Linux Workstations

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- **A. Lehrach**, R. Gebel, **R. Maier**, D. Prasuhn, H. Stockhorst, *Matching Intrinsic Spin Harmonics at COSY*, Nucl. Instr. and Methods in Physics Research A 439, 26-30(2000).
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- I.N. Mechkov (JINR), A.O. Sidorin (JINR), A.V. Smirnov (JINR), G.V. Trubnikov (JINR), K. Fan (FZJ), **R. Maier** (FZJ), D.Prasuhn (FZJ), H.J. Stein (FZJ), H. Stockhorst (FZJ), *Electron cooling applications for luminosity preservation in an experiment with internal targets at COSY*, Report des Forschungszentrums Jülich, Jül-4031.
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A2. Gesellschaft für Schwerionenforschung mbH (GSI), Darmstadt, Germany

Participation in T1, T2, T3, T4, T5

Dr. Oliver Boine-Frankenheim (project co-ordinator and teamleader, 1968, 35)
Dr. Alexei Dolinsky (1963)
Dr. Rainer Hasse (1943)
Dr. Markus Kirk (under 35)

GSI operates the ESR heavy ion cooler storage ring and the SIS sysnchrotron, including a electron cooler. The GSI ESR and high-current beam physics (HSSP) groups have made many contributions to the field of beam dynamics modeling and experiments. One of the highlights are the measurements of chain-like heavy ions beams in the ESR and SIS and their theoretical explanation [2,5]. Experience exists in *computer simulation modeling* using both, the particle-in-cell method (PIC) [3] and direct integration of Vlasov's equation [5] . The groups have carried out a variety of experiments with space-charge-dominated beams in storage rings (see e.g. [1]). The theoretical modeling and interpretation have resulted in new insight into *nonlinear phenomena* like overshoot and long-term saturation of resistive instabilities, in the presence of electron cooling and IBS. Recently studies of general scaling laws for equilibrium beam parameters in the ESR and HESR were started [6]. The groups disposes of a 16-node 'beowulf' parallel computer dedicated for beam dynamics studies to cope with the needs of 3D simulation.

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A3. Russian Federation State Scientific Center "Institute for Theoretical and Experimental Physics" (ITEP)

Participation in T1, T2, T5

Dr. Pavel R. Zenkevich (teamleader)
Dr. Alexander Y. Bolshakov
Petr N. Alexeev (under 35).

At the last years P. R. Zenkevich and A. E. Bolshakov (in collaboration with I. Hofmann) have developed new codes for simulation of particle accumulation in storage rings ("MOCAC") and code for calculation of dynamical aperture with account of space charge. The code MOCAC allows us to investigate the evolution of non-Gaussian beams and to find the particle losses; this code has been already applied to simulation of beam dynamics in GSI (HESR) and ITEP storage rings. The team leader Zenkevich P.R. is one of pioneers in investigation of two-stream effects (1971). At the last years he returned to the problem investigating such effects as the drift instability due to interaction of the circulating beam with the electron cooler beam (with A. E. Bolshakov), "three beam" dipole instability (this instability appears because of interaction of the circulating beam with the electron cooler beam and "ion cloud" stored in potential well of the electron beam) and the dipole instability of coasting and bunched ion beams with electron cloud (the last paper with O. Boine-Frenkenheim and.N. Mustafin). Bolshakov A. E. is a very qualified specialist in accelerator physics (he has long experience of practical work on ITEP accelerator complex) and numerical modeling. P. N. Alexeev is working in ITEP as accelerator engineer. He is coauthor in 14 published papers in accelerator physics and particle dynamics. He has advanced experience in programming (C, C++, Fortran, PERL). The team has access to operating ITEP storage ring, which can be used for the relevant experiments.

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The JINR team has a long extensive experience in the design and development of electron cooling devices. Created devices (electron gun and collector) were used successfully at LEAR (CERN). BETACOOL code for the simulation of ion beam parameters in storage ring have been elaborating more than 6 years. This code is used in a few scientific centres: GSI, COSY (Germany), BNL (USA), RIKEN (Japan), ITEP (Russia).
Each team person has the personal computer with 400 MHz – 2 GHz processor and Microsoft Windows operation system. Team has access to super computer of JINR. Team is familiar with C++ Builder and MS Visual Studio compilators.

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Dipl.-Phys. Robert Hampel, geb.: 29.06.1977

Expertiese:
Relevant beam dynamcis experise: CST MicrowaveStudio, CST EM Studio, CST DesignStudio, CST MAFIA customisation for electromagnetic field and impedance calculations. Impedance of accelerator structures, also with rough surface. Study of collective effects and simulations of beam instabilities. Further developments and application of such simulation codes will be used to characterise the impedance, and to study intensity limitations and ultimate performance of future High-Energy/High-Intensity Electron and Proton Accelerators, such as TESLA, LHC and its injectors.

Infrastuktur:

Parallelrechner und Rechencluster

Relevante Publikationen:
T. Weiland, M. Bartsch, U. Becker, M. Bihn, U. Blell, M. Clemens, M. Dehler, M. Dohlus, M. Drevlak, X. Du, R. Ehmann, A. Eufinger, S. Gutschling, P. Hahne, R. Klatt, B. Krietenstein, A. Langstrof, P. Pinder, O. Podebrad, T. Pröpper, U. v. Rienen, et al.: MAFIA Version 4. Proceedings of the Computational Accelerator Physics Conference (CAP), 1996, Williamsburg, Virginia, pp. 65-70.

M. Krassilnkov, A. Novokhatski, T. Weiland, W. Koch, P. Castro: V-Code Beam Dynamics Simulation. Online Proceedings of the 6th International Computational Accelerator Physics Conference (ICAP 2000), Darmstadt, Sept.2000, www.ICAP2000.de.

R. Wanzenberg, T. Weiland: Wakefields and Impedances. CCAS- CAT-CERN Accelerator School, Vol. 1, Proceedings , Indore, India, 7-16 November 1993, pp. 140-180.

A. Novokhatski, T. Weiland: The Model of Ensembles for the Beam Dynamics Simulation. Proceedings of the 1999 Particle Accelerator Conference (PAC 99), New York City, USA, Vol. 4, pp. 2743-2745.

A. Novokhatski, T. Weiland: Self-Consistent Model for the Beams in Accelerators. Proceedings of the 1998 International Accelerator Physics Conference, ICAP'98, Monterey, USA, Sept. 14-18, 1998, pp.69-73.

A5. The Svedberg Laboratory (TSL), Uppsala University, Sweden

Dr. Bjorn Galnander (35 years old)
Dr. Dag Reistad
Dr. Tor Lofnes
Dr. Volker Ziemann (team leader)

Expertise:
Experience of operating ion beams interacting with pellet and gas jet targets in CELSIUS.
Expertise of simulating ion beams in computer models.
Analyzing the beam-pellet interaction.
Diagnostics of cooled beams.
Non-linear beam dynamics.
Tools for vacuum calculations.

Infastructure:
Ion storage ring CELSIUS (Brho = 7 Tm).
Electron cooler (300 keV).
Cluster gas jet target.
Hydrogen pellet target.
Fast narrow band spectrum analyzer for Schottky diagnostics.

Publications:

1. D. Reistad, et.al. "Experiences of operating CELSIUS with a Pellet Target", invited talk at

ECOOL03.
2. V. Ziemann, "Design Considerations for a Digital Feedback System to control Self-Bunching in Ion Storage Rings," Phys. Rev. ST Accel. Beams 4, 042801 (2001).
3. V. Ziemann, "Electron Cooler driven Transverse Resonances," contributed to the 1998 European Particle Accelerator Conference, Stockholm, Sweden.
4. D. Reistad, et. al., "Machine Studies related to internal hydrogen pellet target and to electron cooling/heating at CELSIUS," contributed to the 2000 European Particle Accelerator Conference, Vienna, Austria
4. T. Lofnes, V. Ziemann, "Fast Cooling Time Measurements in CELSIUS using a Third Generation Mobile Phone Signal Processing Device,"contributed to the 2002 European Particle Accelerator Conference, Paris, France.
5. V. Ziemann, Analytic Expressions for Longitudinal Schottky Spectra from Beams with Gaussian Energy Distribution, contributed to the1997 Particle Accelerator Conference, Vancouver, Canada, May 1997.
6. V. Ziemann, Measuring Hamiltonian Coefficients with a Wobbling Method, Part. Acc. 55, 419, 1996.
7. V. Ziemann, "Vacuum Tracking," proceedings of the Particle Accelerator Conf., Washington, D.C., May 17-20, 1993; expanded version available as SLAC-PUB-5962, October 1992.

A6. University of Kiev (UoK), Ukraine

Dr. Igor KADENKO (team leader, 1962)
Dr. Volodymyr KONDDRATYEV (1961)
Oleg BEZSHYYKO (1964)
Ruslan YERMOLENKO (1977, under 35)
Konstantin BEZSHYYKO (1976, under 35)

The team has the following experience:

1. Modeling the nuclear reactions for the projectile energy region up to 200 MeV (EMPIRE-II statistical model code for nuclear reaction calculations, written on Fortran 77). We modified and extended EMPIRE-II code to include the photonuclear channel and fission processes.

2. Windows/Linux coding in various fields – nuclear spectrometry and spectroscopy, Monte Carlo methods for ionizing particle transport, databases, SCADA (Supervisor Control And Data Acquisition) systems, dosimetry, dose planning for radiotherapy, development of 3D model for Eddy-current examination method [see paper 12].

3. Collisions of Ions and Particles with Atoms, Atomic Clusters and Solids:
   Polarization processes in ion and particle beam interactions with gases, atomic clusters and solids.
   Stopping power.
   Transport phenomena in gases and solids.
   Phase transitions and phase behavior in condensed system.

4. Nuclear Structure, Reactions, and Nuclear Astrophysics:
   Indirect methods in nuclear astrophysics.
   Supernova and Neutron stars.
   The many-body correlations and response properties of nuclei.
   Quantum effects in many-body transport theory.

5. Atomic-Nuclear Phenomena and Nuclear Spectroscopy:
   The excitations in condensed matter at nuclear processes (gamma, beta- and internal conversion radioactivity, nuclear reactions).
   The influence of external fields and chemical properties of matter in nuclear phenomena.

6. We have also a good experience in the design and development of the computer codes. The group carries out the development of the Friendly User Interfaces for new programs and adaptation of earlier written codes, optimisation of Monte Carlo algorithms and using various methods for speed-up of calculations, interconnection of C++, Fortran and Perl modules, porting programs between Windows and Linux OS, composing library modules.

Infrastructure:
1. The cascade accelerator of ions with energy up to 500 KeV;
2. 4 neutron generators (D-D, D-T reactions, intensities 10^7 – 10^{10} n/s);
3. Access to cyclotron U-120 and Van der Graaf accelerator (tandem).

Computational facilities:
20 cluster nodes connected in local network and may be used within Condor system (one of the realizations of GRID system for parallel computations [see paper 11].
Access to the University of Kyiv computational cluster (http://www.unicc.kiev.ua/eng/) containing 24 processors – Xeon 2.4GHz and PIII 1GHz.

Publications:

1. **I.N.Kadenko**, A.N.Galushka, **R.V.Yermolenko**, B.I.Krupskii, Yu.B.Storonskii. *A Combination □-□-Radiometer and Dose-Rate Meter with an Extended Dynamic Range*, Instruments and Experimental Techniques. – V44. – No.3 – 2001. – P. 398 – 401.
2. S.V.Begun, **I.M.Kadenko**, V.K.Maidanyuk, V.M.Neplyuev, V.A.Plujko, G.I.Primenko, V.K.Tarakanov. Determination of the Cross Sections of (n, x) Nuclear Reactions on Y, La, Ta, Pb and Bi at the Energy of Neutrons About 14 MeV // Journal of Nuclear Science and Technology, Supplement 2, p. 425 – 428 (August 2002).
3. L.L. Balashova, N.M. Kabachnik and **V.N. Kondratyev**,
   The Impact Parameter Dependence of Antiproton Energy Loss. -
   Nucl. Instr. and Meth. B 48 (1), 18 (1990).
4. **V.N. Kondratyev** and M. Di Toro,
   Higher Order Long Range Correlations in Nuclear Structure and Dynamics.-
   Phys. Rev. C 53 (5), 2176 (1996).
5. **V.N. Kondratyev** and A. Iwamoto,
   Nonlocality and Polarizability in the Fusion of Fermi Droplets.-
   Phys. Lett. B 423 (1), 1 (1998).
6. **V.N. Kondratyev**, Ph. Blanchard and H.O. Lutz,
   Critical Dynamics in Clusters of Noble Gas Atoms.-
   Eur. Phys. J. D 8, 241 -- 244 (2000).
7. **V.N. Kondratyev**
   Statistics of Magnetic Noise in Neutron Star Crusts. -
   Phys. Rev. Lett. 88, 221101 (2002).
8. Frolov O.S., Shevchenko V.A., Sadovnichiy A.A., **Kadenko I.N.**, Frolov D.O., Fabrikov S.P., Podvijanuk R.B., Silicon diode arrays as coordinate-sensing detectors for nuclear physics., Compressed Barionic Matter, CBM-2002, 13-16 May 2002, GSI, Darmstadt,www.gsi.de/cbm2002/transperansis, 12 _.
9. **O. A. Bezshyyko, R.V. Yermolenko, I.M. Kadenko**, V.A. Plujko,

V.A. Zheltonozhskiy, Using of Empire II code in photonuclear reaction calculation, Bulletin of the University of Kiev, S.:Physics & Mathematics, _1, 2003

10. V.A. Plujko, S.N. Ezhov, M.O. Kavatsyuk, A.A. Grebenuyk, **R.V. Yermolenko**. Testing and improvements of gamma-ray strength functions for nuclear model calculations// Journal Nucl. Sci. Technol., Suppl.2 (2002) 811-814.
11. **_.A.Bezshyyko,O.A.Bezshyyko**, L.O.Golinka-Bezshyyko, **I.M.Kadenko**, A.V.Chizh, Using the Condor system for the parallel computing in physical process modelling, Bulletin of the University of Kiev, S.:Physics & Mathematics, _1, 2003
12. **I.Kadenko, R. Yermolenko**, V. Kubitsky, N. Sakhno, A. Zakusilo. Application of 3-D Eddy Current Testing Model for Evaluation of Reliability of ISI Results for VVER Steam Generator Tubing. // Proceedings of the Joint EC-IAEA Technical Meeting on Improvements in ISI Effectiveness, Petten, The Netherlands, 19-21 November 2002 – 6 p.

Management

Dr. Oliver Boine-Frankenheim from GSI, Darmstadt will carry out the coordination of the proposed research project. The coordinator will be assisted by the team leaders and the task leaders. A project home page for easy access of all relevant material during the proposal phase has already be set up (please visit http://www-linux.gsi.de/~boine/intas/intas.html). During the project phase the home page will be extended towards a forum for the project members with the possiblity to upload/download reports, to monitor the status of the joint work and to work on the joint software library. Following the approval of the proposal, the coordinator will invite all participants to a coordination meeting at Darmstadt. It is planned to hold the next meeting end of 2004 in a differnt place. Short visits between the groups will be encouraged by the coordinator. In particular to give the young researchers in the project a broader picture of their field of work. The coordinator will contact in regular intervalls all partners in the project to discuss the exchange and balance of work, and to help the teams in carrying out their tasks.Together with the final report, giving account of the scientific achievements of the project, a final workshop will be organized. The coordinator will make special efforts to encourage the participants to publish their work in refereed journals, like Phys. Rev. ST Accel. Beams or Nucl. Inst. Meth. A. The joint software libraries will be documented with easy access over the web.

Workplan

	T1	**T2**	**T3**	**T4**	**T5**	**T6**
Team	year	year	year	year	year	year
	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3
FZJ						
GSI	———					
ITEP						
JINR						
TSL						
UoK						

Cost information

Total costs (over 24 month)

Team	Labor (TEUR)	Travel (TEUR)	Overheads (TEUR)	Total (TEUR)
FZJ	0	2	0	2
GSI	0	3	1	4
ITEP	24	4.5	2	30.5
JINR	31.2	5	2	38.2
TEMF	0	2	0	2
TSL	0	2	2	2
UoK	15.36	2.5	1	18.86
Totals	**70.56**	**12**	**8**	**97.56**

NIS Labor cost summary

Team	Individual grants	Number of people	Cost per month	Number of month	Total cost (TEUR)
ITEP	Team leader	1	400	24	9.6
	Scientist	1	300	24	7.2
	Engineer	1	300	24	7.2
JINR	Team leader	1	400	24	9.6
	Scientist	2	400	24	9.6
	Engineer	3	300	24	7.2
	Other	1	200	24	4.8
UoK	Team leader	1	200	24	4.8
	Scientist	1	220	24	5.28
	Engineer	1	220	24	5.28
Totals		**13**			**70.56**

Innovation Information

The library including benchmarked modules for the relevant beam interaction processes in storage rings will have a large potential for application in the design of future ring accelerators for ions and antiprotons. The scope of potential users extends to many accelerator laboratories worldwide, including e.g. Brookhaven National Laboratory (BNL) with plans to install electron cooling in RHIC.

Summary

The design of future cooler storage rings for ions and antiprotons at GSI and worldwide, operating far above the beam intensity levels of existing machines, requires a much more detailed understanding of long-time collective phenomena in cooled beams. In cooler storage rings the complex interplay of many processes determines the final equilibrium distribution of the beam particles. The aim of this project is to develop analytical models and simulation tools for the study of the beam distribution function, accounting for all relevant beam cooling and heating processes. The study will include also collective instabilities induced by ring impedances or trapped secondary particles. The physics models will be cast into a modular software library for beam dynamics simulations. Experiments with cooled, low energy ion beams are foreseen at

serval storage ring facilities in or to benchmark the physics models and simulation codes that will be developed.