Proposal for a continuation of the

International Research Training Group
Development and Application of Intelligent Detectors
at the

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Part I

Continuation Proposal

Chapter 1

General Information

1.1 Program Title

Entwicklung und Anwendung von intelligenten Detektoren
Development and application of intelligent detectors

1.2 Applying Universities

Ruprecht-Karls-Universität Heidelberg, Germany
University of Bergen, Norway
University of Oslo, Norway

1.3 Applying Scientists

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1.4 Summary

The International Research Training Group (IRTG) on intelligent detectors aims at developing and applying detection systems for particle, nuclear and space physics that integrate modern information technologies as key features. The design, building and operation of such detectors is the key for advanced nuclear and particle physics experiments. It requires a profound knowledge in a variety of fields that is made available in the interdisciplinary cooperation of physicists working on detector design, signal readout and data analysis, together with departments that focus on information science and work on signal processing, pattern recognition and data management. Some of the technological aspects involved include the design of application-specific integrated circuits (ASIC), design and programming of circuits implementing programmable electronics (FPGAs) and the design and operation of large scale compute facilities (Cluster, GRID) that have to be considered an integral part of next generation detector systems.
The IRTG links the expertise that is available in Heidelberg and Norway (Bergen/Oslo), and has demonstrated that the scientific exchange leads to new contacts and proposals. The expertise available in the different locations is largely complementary, allowing cross fertilisation and for the participating students offering the possibility for a broader education in partially highly specialized fields.
On both sides many major recent experiments in high energy elementary particle and nuclear physics are represented: ALICE, ATLAS, BABAR, CBM, CERES, FOPI, H1, HeraB, LHCb in Heidelberg and ALICE, ATLAS, BRAHMS, NA57 and space physics (INTEGRAL, POLAR) in Bergen/Oslo and by this, a large particle physics background is available to the IRTG. On the technological side there is a nice complementarity: for example ASIC design and cluster computing are centered in Heidelberg, while FPGA-based hardware/software co-design is more centered in Bergen.
A project-oriented collaboration among the participating groups will be strengthened by the IRTG. Common research interests are existing and have been pursued in the past, like the ALICE High Level Trigger (HLT), that is run and operated commonly from KIP/Heidelberg and Bergen. In the next funding period of the IRTG the program will focus on the exploitation of the development effort for the experiments ALICE, ATLAS and CBM and will lead to common projects for the major future international facilities: FAIR at Darmstadt and the ILC.
The continuation of the IRTG will give the unique opportunities to involve students on all levels of high energy particle physics from conceptual design over prototyping to actual running of the experiments. The teaching program

will be held in English and will be open to all participants. The students will be lead to the forefront of experimental nuclear, particle and space physics and will be given the chance to acquire hands-on experience on the most advanced design, simulation and analysis tools available today. The IRTG will be embedded into the larger Heidelberg Graduate School of Fundamental Physics (HGFSP) that will provide additional more generic education, e.g. soft-skill seminars that will cover the aspects of work organization, time planning and presentation techniques.

1.5 Anticipated duration/ starting date

Duration: another 4.5 years
starting: 1. April 2009
ending: 30. September 2013

1.6 Anticipated number of participants

In Germany Heidelberg is applying for 12 PhD. stipends and 1 Bat IIa Post-Doc position. The total number of participating students will be larger by about a factor of two. About 20 additional students funded from other resources will participate in the educational activities of the IRTG [1]. We ask for funding of increased basic scholarships for the students in order to be more competitive in an economical environment, where the best students are being lost very easily. In order to be able to offer an attractive and top-level education program that is tailored to the needs of the participants, a TVL-13 position for a postdoctoral fellows is requested (for details of the tasks and the requested profile see section refsec:3.23.2 below). The number of PostDocs participating in the research activities of the IRTG is estimated to be about 10, providing the necessary intellectual and knowledge-based environment and knowledge from which Ph.D. students will profit. In Norway, a total of eight Ph.D. stipends are being requested in Bergen and Oslo. We note that German Ph.D. stipends are roughly half the size of Norwegian Ph.D. grants. The application includes requests for funding of running costs, e.g. for organizing workshops/schools and to cover travel expenses. The total number of Norwegian students participating in the IRTGs educational program is about 20. The number of Norwegian postdoctoral fellows involved in the projects related to the IRTG is about four. In summary about 30

[1] For reference, see the list of currently active students in the field within the participating groups in Appendix refAppendixC.

Ph.D. students will continue to form the body of the IRTG participating in the regular advanced lectures (see section 3 refsec:3). With such a number of students the investments in terms of manpower in specific education is well justified, and in turn a sizeable number of students will benefit from the specific offers of the IRTG.

Chapter 2

IRTG Profile

The basic Ansatz of the IRTG will not be changed: the focus of the proposed International Research Training Group is Intelligent Detectors and Detector Systems. They are characterized by exploiting the latest developments in sensor technology and merging it with the latest advances in electronics and information science. Such systems emerge from the interdisciplinary interplay of three different building blocks (illustrated below) as set forth below:

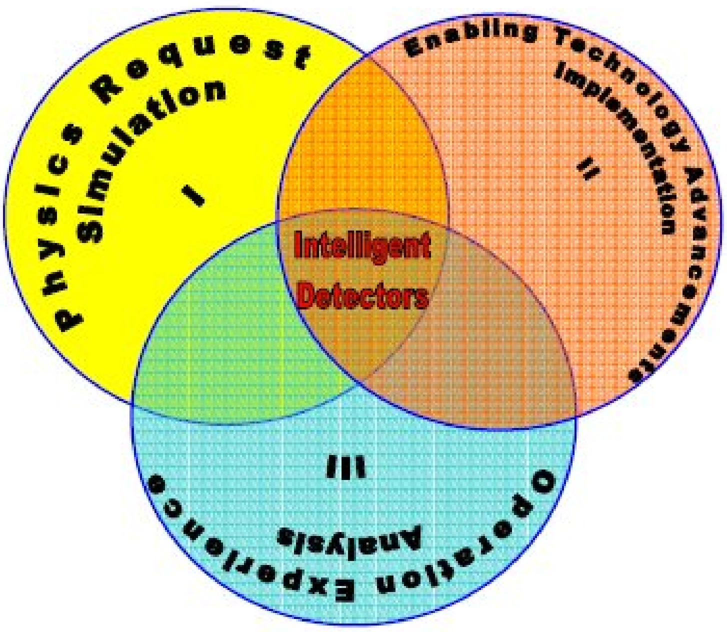

Figure 2.1: irtg

I Fundamental physics like elementary particle, nuclear physics and space physics is one of the major driving forces to advance new detector technology. Experiments that are to be performed in the near future, will present new and challenging problems for data taking and analysis. Very rare signals have to be detected with sufficient accuracy and significance from an extremely large background. The design of modern detection systems is based on the possibility and the knowledge to model the response of the apparatus in detail with respect to the anticipated signal and unavoidable background by means of simulations. The basic task is to derive experimental observables that are linked robustly to the interesting fundamental physics properties of the system. The necessary data rates for many future experiments are so high that the electronics and the data processing has to be considered an integral part of the detector systems. The sensors converting physical observables to electronic signals have to be equipped with on-board intelligence and/or efficient data management in order to form a system capable of fulfilling the physics requirements. The system features must already be incorporated into the design phase of new devices in order to make a realistic assessment of the performance.

II The second cornerstone is the rapid development of modern electronics and information processing technology. Thus, exciting new possibilities for (particle and nuclear) physics detectors are arising. Due to the ever growing integration and better flexible customisation, very complex tasks can nowadays be executed on the detector while simultaneously taking data. The integration of the latest technological possibilities into a new detector design is, however, a very complex task. It requires a profound understanding of all the implications of the choice of a certain technology and should ideally be supported by some experience of its implementation. Acquiring the skills to handle the technologically advanced systems requires special training. The International Research Training Group aims to link in an interdisciplinary fashion basic physics needs with modern cutting-edge electronics and informatics science.

III The concept of using modern information technology in large scale physics experiments is of course not new. Present day examples for Intelligent Detectors are the running experiments at the Relativistic Heavy Ion Collider RHIC at Brookhaven National Laboratory and the planned experiments at the Large Hadron Collider (LHC) at CERN. Several of these experiments (BRAHMS, ALICE, ATLAS and LHCb) are represented by the participants of the IRTG. Local intelligence is implemented for trigger needs in form of ASICs evaluating and compressing the data of specific subsystems and performing the decisive event selection. Special hardware is being installed for organising the data flow and for fast pattern recognition. The experience gained during the development and the operation of those systems is essential for success of the next-gneration development. The evaluation of the performance of the running systems constitutes another important verification step of the whole detector concept. This can only be achieved by running through the full analysis chain and trying to derive those signatures that the detector was designed for. Additional challenges have to be mastered in that area, such as monitoring and controlling a very large number of setup parameters and handling huge amounts of output data. The necessary corresponding techniques are included in the menu of activities of the IRTG.

In particular the International Research Training Group aims at linking these building blocks, namely

- the experience with running state-of-the-art detectors and information
- processing systems to arising future needs,
- physics requirements to possible detection system performance and analysis experience to system specification and verification.

This is clearly an interdisciplinary task that needs expertise from several different research areas and research groups. rewrite: The physics goals have to be well understood. Therefore the underlying physics to be measured with the next generation detection systems is an integral part of the IRTG. The scope of the IRTG is centered around elementary particle physics and high energy nuclear physics. Physics observables have to be modelled by state-of-the-art simulation and reconstruction algorithms in order to define and understand the desired system specifications. Once a system, featuring local intelligence on the detector, is built, its performance and operation will have to be monitored and tuned. The information obtained from the experience of extracting high quality data from running devices is of crucial importance for the design of the next generation systems.
The disciplines required for the research and developments within the framework of the IRTG are:

- Nuclear
- Physics
- High Energy Physics

- Space Physics
- Detector Physics
- Sensoric
- Microelectronics and Electronics
- Computer Engineering
- Computer Science

Chapter 3

Research Program

The research program is building on the existing strong collaboration between Heidelberg and Bergen/Oslo specifically on the ALICE High Level Trigger (HLT), TPC and TRD Detector Control System (DCS), and ALICE physics simulations.
The second major building block for the future interest is ATLAS where strong groups from Germany and Norway are involved in.
The research program is augmented and extended due to new contacts from the past funding period that resulted in two common projects for the future facilities FAIR and ILC.

3.1 ALICE

3.2 ATLAS

3.3 CBM @ FAIR

3.4 HCAL @ ILC

Visions (KIP, HSC,KHM)
The Heidelberg KIP group has identified two scientific areas, which fit well into the concept of the IRTG: ATLAS and ILC detector R&D. Concerning H1, no further hardware activities are planed as data taking has stopped with the HERA shut down in 2007. Instead the KIP involvement in the ATLAS Upgrade and the CALICE project (see below) shall be strengthened during the next 4.5 years.
First, the ATLAS detector will be operated and produce physics output as

well as practical experiences with a highly complex detector system. The detector aspect is of major relevance for the IRTG and the students involved. ATLAS will for the first time give insights into the problems to be encountered during the operation of such a large-scale technology. The experience gained there will be invaluable for the planning and operation of future large-scale facilities in science and industry. It is planned to strongly involve IRTG student in this exciting endeavour. Their work will also form the basis for a possible ATLAS Upgrade programme, which is currently entering an R&D phase. The improvement of the ATLAS data selection capabilities based on the data gathered during the first year will form a major goal of the work performed in the KIP group. As a concrete project the group plans to propose an integrated mixed-signal VLSI solution as an input stage of the ATLAS level-1 trigger. This work will be performed in close cooperation with international project partners but also with a second ATLAS group, which is likely to emerge at the PI in Heidelberg in 2008.
Second, since 2006 the Heidelberg KIP group is involved in the R&D activities for a high-performance hadron calorimeter (HCAL) for the International Linear Collider (ILC). The challenging physics goals of the ILC impose stringent demands on the detector, which by far exceed what is possible with present detector technologies. This is particularly true for the calorimetry, as the anticipated jet-energy resolution necessitates the combination of tracking and calorimeter information and consequently a separation of showers originating from neutral and from charged particles. This is only possible with a highly granular calorimeter, which resolves the complete shape of individual showers. Such a calorimeter is presently developed in the framework of the CALICE collaboration, where the analogue option for the hadronic part (AHCAL) is based on a sampling structure with scintillating tiles individually readout by so-called Silicon-Photomultiplier (SiPM) mounted directly on each tile.
Presently the ILC activities at the KIP comprise the characterization of new Silicon-Photomultipliers, work on test-beam measurements using the first AHCAL prototype and the development of highly integrated electronics for SiPM-readout. Further plans are the development of infrastructure to allow large-scale quality assurance tests of integrated sensor-scintillating systems, which are mandatory when building a calorimeter with millions of channels. The SiPM-studies - also in view of a possible application in medical imaging - are planned in collaboration with the IRTG group at the University of Bergen (G. Eigen et al.); both groups are - among others - partners in a new proposal for the 7th framework program of the EU. Hence, the ILC activities will profit significantly from the scientific exchange fostered by the International Graduate School on Intelligent Detectors, circumstances,

which have already been very helpful when initiating the new involvement. Both activities will also profit from the excellent technical infrastructure in Heidelberg. In particular the new HGF Terascale Alliance will be of strong importance for the ambitious electronics and VLSI development.

(Kebschull)

During the first IRTG funding period from 2005 to 2008, a novel FPGA refresh technology based on partial dynamic reconfiguration was developed. The purpose of this technology was to extend the meantime between failures (MTBF) caused by single event upsets (SEUs). Single event upsets affect the FPGA configuration and lead to malfunction of the active design. SEUs are caused by high energy particles passing through the FPGA chip. The novel refresh technology was successfully used for ALICE TPC readout controller (ROC). Current estimates show, that in CBM the radiation doses will be much higher than for ALICE TPC. Therefore, new and more effective radiation tolerance technologies for FPGAs need to be explored.

Other detector components like the DCS-Boards also require radiation tolerance techniques. However, refresh technology alone is not sufficient since a full set of radiation tolerant and synthesizable IP components like CPU, busses, memory and I/O subsystems are required. Today, these components can fully be integrated into FPGAs at a reasonable performance/cost ratio which is often better than implementing it in radiation hard ASICS.

The refresh technology for FPGAs is not sufficient due to many reasons: blockrams (BRAM) require completely different radiation tolerance techniques, since a reconfiguration would completely destroy their content. Many design tools use look-up tables (LUT) as shift registers or distributed RAMs. A configuration refresh would change their content and therefore destroy the states. The radiation tolerance of FPGA components like PowerPC, multigigabit transceivers, integrated multipliers and others at high energy and flux rate is currently unknown. Other known radiation tolerance technologies like parity checks in data paths, hamming encoding for internal states, or CRC for error correction or even triple redundancy could further improve the robustness of such a device, but most of them have never been analyzed.

The goal of this research is to implement radiation tolerant versions of all digital components used in a complete system. The effectiveness of all radiation tolerance improvement technologies needs to be measured and categorized for FPGAs.

Within this research, we want to investigate the impact of fault tolerance technologies like ECC for RAMs and busses, and we want to design radiation tolerant IP components like CPU, busses, memory controllers and I/O, especially optimized to run on FPGA using the refresh technology.

This work has to be carried out in close cooperation with our Finnish col-

leagues in Bergen and Oslo: The application in ROC and DCS will be implemented together with Bergen (Röhrich) and beam test will be done in Oslo. These beam test will measure the achieved improvement in radiation tolerance.
Therefore the IRTG is a perfect vehicle to enhance these kind of cooperations.

Summary:

Full coverage of all the stages of modern intelligent nuclear/particle detection system design and operation

- physics simulation
- detector simulation
- detector construction, system integration
- readout design, development and operation
- trigger design, development and operation
- data handling and data management
- online data analysis
- offline data analysis
- GRID computing

Development of new, integrated detection techniques for next generation machines (e.g. GSI future, TESLA, astrophysics satellites). Here the demands are very high with respect to the event/data rates and efficient real-time processing required for rare signals.

Techniques developed for existing experiments will be tested for their applicability for future tasks, extended, refined and applied employing the most advanced technologies. Therefore we need to integrate all aspects of the challenge from the basic physics question over the modern implementation to the final analysis of the data into the IRTG.

3.5 Research topics

The following sections give a brief collection of some of the core research topics foreseen for the upcoming funiding period within the framework of the IRTG. They are organized in line with the various stages listed in the workplan set forth in section 3. All subjects cover a rather large field of activities, thus supporting many possible Ph.D. theses.

- Physics analysis (related thesis topics: 1,2,3,4,5,9,10,18) Interesting physics signals for new physics typically have small cross sections. Once identified they are one of the main motivation driving the development of intelligent detectors. Several examples of the search for rare events are represented in the IRTG:

  - particles with large transverse momentum in high multiplicity environment (ALICE) to define JET candidates
  - electron pairs with large transverse momentum of single electrons in high multiplicity environment (ALICE) to define vector meson (J/Ψ, Y) candidates
  - single photons (ATLAS, ALICE)
  - secondary vertices to detect long lived particles (BABAR, CBM, LHCb, ALICE)

- Detector simulation

  New detectors:

  - MMRPC @ CBM
  - HCAL @ ILC

- System integration

  HLT of ALICE

- Subsystem operation

  - TRD @ ALICE
  - Kalorimeter @ ATLAS

- Experiment operation, Slow control
- Electronics design
- Data aqusition / Trigger system development
- GRID computing

3.6 Proposed thesis topics

The following table presents a list of possible thesis topics that would fit into the research program of the IRTG. Common interest in between the various groups can be clearly identified and will serve as starting point for joint developments. We expect to adjust and/or change priorities during the course of the IRTG depending on the scientific results, achieved.
This list clearly exceeds the funding possibility of the IRTG and may also be filled by some of the contributed Ph.D. students. Candidates will be admitted to the IRTG optimising the exchange in between the German and Norwegian groups. The long list demonstrates the research topics that will be worked on in the participating groups and thus represent the environment into which the IRTG is embedded. Clearly, all the students working on the listed subjects will benefit from the educational program of the IRTG.
Many of the proposed theses relate to the development of complex subsystems of large-scale experiments carried out by international collaborations. These subsystems will be designed, implemented, and run by larger groups of researchers. Many of them have comparable goals and use comparable, up-to-date technology, so that the PhD students assigned to a certain task will benefit hugely from a cooperation. Below closely related theses are compiled. We plan that the German and Norway PhD students will do part of their work at their home institution and at a guest institution. This will stimulate an intensive cooperation between the involved research groups.

	Title
1	Performance of a High pt Global Tracking Trigger for ALICE
2	Development of an open charm trigger for ALICE
3	Reconstruction of open charm and bottom yields with ALICE from displaced vertices
5	Development of a L0/L1 trigger for the PHOS detector in ALICE
6	Full scale slice test of ATLAS calorimeter trigger and its integration into the data acq
7	Full scale slice test of ATLAS Readout Buffer and its integration into the data acquisi
8	Experimental investigation of ATLAS level-1 trigger performance based on signals for
9	Heavy quark production at LHC
10	Search for isolated electrons and photons at the LHC with special emphasis on level-1
11	2nd Level Trigger Algorithms for ATLAS
12	GRID based analysis of B decays, BABAR
13	Intelligent Monitoring of ALICE TRD subsystem
14	FPGA Coprocessor based High Level Trigger for ALICE
15	Fast tracking algorithms for the ALICE HLT
16	LHCb track trigger: Data link and implementation
17	Readout and data reduction for the LCHb tracking chambers
18	Development of an open charm trigger for CBM
19	High resolution intelligent TOF system for CBM
20	Electron ID with high rate TRD (CBM)
21	CBM: High rate online data processing
22	CBM: High rate online data readout & processing
23	GRID Data Management for Physics simulation
24	Reconfigurable computing networks based on integrated specialized processors
25	GRID Cluster operating system
26	Programming, monitoring, and control of systems consisting of FPGAs, DSPs, and em
27	FPGA/Coprocessors: Integration of VHDL and C++ description
28	FPGA/Coprocessors: Hardware/software co-design
29	FPGA-Coprocessors: Programming in High Level Languages
30	Load sharing between FPGAs, DSPs, and embedded CPUs
31	Kalman filter for FPGA co-processors
32	Mixed mode electronics: ADC + Processor Time
33	discretising switched preamps
34	High speed readout systems
35	Radiation tolerant designs with commercial grade technology
36	Low noise digital logic
37	High resolution, low power DLL circuits
38	Analysis of data from the INTEGRAL and POLAR satellites
39	Development of the next generation satellite based gamma and X-ray imaging systems
40	Reliable readout electronic and online data processing
41	Si detectors for harsh environments (to be confirmed)
42	New integration methods for semi-conductor sensors and electronics
43	New sensor materials for particle detection

Table 3.2: Table of thesis projects

Chapter 4

Study Program

Participants of the graduate school are expected to actively participate in the study program. This program should allow students to:

- Deepen their knowledge in their area of research concerning the basic physics questions and instrumentation, and to bridge the gap to actual research work
- Gain expert knowledge in key technologies, while making best use of the expertise available at the German and Norwegian institutions.
- Present their results and exchange their knowledge with other students in seminars and study weeks
- Make contact with the best experts from all over the world and learn from them in topical workshops organised by the graduate school.
- Get the opportunity to participate in research work at other places in the framework of the exchange program.

Based on the experience obtained so far the study program will have the following components which are discussed in more detail below:

An advanced regular lecture program (in english) covering basic courses in particle physics and astrophysics. These courses will be organised independently at Heidelberg and in Bergen/Oslo. If, however, a subject is only offered at one location, exchange lecturers will present such courses in a condensed format at the other location.

An exchange program between the institutions with two components:

(a) The offer of compact (lab) courses (1-2 weeks) allowing students to get special training which they cannot get at their home institute.

(b) Extended stays (3-6) months to visit research groups and participate in their research program working on a well defined mini project. Such a visit has of course to fit into the main thesis work and will in most cases be realised in the framework of common research projects

A lecture week every spring alternating between Heidelberg and Bergen/Oslo for members of the school. The lecture program will cover special advanced subjects in physics and instrumentation covered by both local and external lecturers. The week will also give students a platform to present and discuss their work.

A yearly international school on intelligent detectors combined with a 1 day topical conference in fall also alternating between Heidelberg and Norway. This program will be offered also to outside participants.

A bi-weekly graduate school seminar will be organised at every place by the students to have a regular meeting place. The program will comprise both internal reports and seminars by invited guests.

4.1 Regular advanced lectures

The members of the IRTG will participate for a minimum of two semesters in general advanced lectures offered in Heidelberg and Bergen, which will cover Basic Physics, Experimental Techniques and the Informatics Aspects. The following advanced lectures are planned to be offered regularly:

- Experimental probes of fundamental interactions
- Standard model of particle physics
- Observing the big bang
- Cosmology
- Particle detectors
- Relativistic heavy ion physics
- (Micro) Electronics

Most of these subjects are already offered regularly. In Heidelberg this is partly organised inside the graduate school of particle physics astrophysics and cosmology or it is part of the course program for advanced students.
In addition lectures will be offered on an irregular basis depending on demand in the areas:

- CP violation
- Hadron physics
- Space physics
- Digital signal processing
- Computer architectures
- Pattern recognition
- Data management
- Software engineering / modelling and simulation

These lectures are fully integrated into the teaching activities of the faculties and the time spent is fully accountable as part of the teaching duties (Lehrdeputat). In order to profit maximally from the available expertise and preparation, we also plan to offer these courses in Norway if they are scheduled for Heidelberg and vice versa. Accordingly, the lecturers of the desired courses will be invited to give a compact course at the partner institutions.

4.2 Exchange program

An integral part of the study program is an exchange program for students between the partner institutions. A strong motivation for this is of course the stimulation of international exchange and of common projects. It must be stressed however that such a program can only be successful if the visits to the partner institutions are strongly coupled to the thesis work of the students. This is naturally the case if they work in common research projects. Students, adtmitted to the IRTG will be admitted with topics that help to extend the international collaboration between the participating groups. The existing and future projects such as preparation work for a linear collider project (TESLA) or for the future GSI accelerators are ideal candidates here, as their timelines extend more than a decade into the future.
The exchange program will be based on two concepts:

The institutions will offer compact (lab)courses over periods of 2 to 3 weeks which are open also to foreign students to provide education and training which are important for their thesis work and career and which are not available at their home institutions. Typical examples for such courses are:

- High speed ASIC design (with lab work)
- High speed digital design
- Si detectors and nano/microtechnology
- Introduction to RHIC data analysis and rare signal simulation
- Cluster and Grid computing (Heidelberg) (Bergen) (Oslo) (Bergen) (Heidelberg)

Specifically, in Heidelberg we will offer the introduction to two classes of problems

(a) Hardware design

(b) Software modelling (C++)

For both activities, we request the support of a PostDoc position each within the framework of the IRTG. The candidates for those positions are supposed to be actively involved in the research programs specified above, but to devote about 50% of their time to the definition and monitoring of the course activities. This includes startup help, installation of test benches.

The institutions will offer longer term stays for students to participate in their research program. Special expertise is available in Bergen and Heidelberg, for which a technology transfer is foreseen by extended exchange visits (periods of 3 to 6 month) of the participants. The second motivation for participating in the exchange visit program is the extension of the general knowledge of the problem class that the students are involved in, e.g. software oriented people will get the chance to understand the hardware level, designers will be given the opportunity to understand the basic physics motivation that drives the effort, physics analysis can be complemented by a working knowledge of some design tools. It is this broad interdisciplinary education that helps physicists to successfully perform on the job market. Such an exchange will broaden the expertise and knowledge of the students. It will however normally also be done inside common research projects and only if the student and his mentor can expect at least a strong longer term benefit for the project.

Typical examples of projects would be:

- participation at beam tests of subdetectors and data evaluation
- testing of common readout chains together with detectors where several institutions have delivered components.
- getting familiar with Grid-Computing for simulation or analysis

We expect that in first years at least 50% of the students will participate in the exchange program and that this fraction will increase with time as we expect more common projects to start.

4.3 Lecture weeks

We plan to organise one lecture weeks per year in spring which are mandatory for all participants and where they live together at one place. One motivation for this is to strengthen the contacts and the coherence within the graduate school. The other one is to guarantee some minimal impact of the study program for every participant. The lectures are held by internal and external lecturers on commonly interested subjects. All participating faculty member will represent their field of expertise (see appendix B) in regular intervals (typically once per 3-4 years). During this week also a good fraction of time will be dedicated to reports of students on their own work giving them a chance to express them selves and to get critical feedback to their work. This week is for participants only. The lecture week will be organized alternatingly by the Heidelberg/Mannheim and Bergen/Oslo groups, one of the two weeks will happen every year in Germany and one in Norway, starting in Heidelberg, organized by V. Lindenstruth and followed by Bergen, organized by D. Rhrich.

4.4 Workshops, schools

Each year (in fall) a school will be organized as part of the outreach program of the IRTG. The school will combine lectures with a topical conference. The school will be open to the public, it will be advertised and we hope that at least 50% of the participants will come from outside. The program will consist of a series of lectures on advanced subjects by invited speakers and at the end by a one day topical conference on instrumentation covering recent results in

Year	Type / Place	Topic
2004 Fall	School / Heidelberg	Programmable hardware/hardware programmin
2005 Spring	Lecture Week / Oslo	Introduction to Relativistic Heavy Ion Physics
2005 Fall	School / Bergen	Fast pattern recognition
2006 Spring	Lecture Week / Mannheim	Pixel Detectors
2006 Fall	School / Heidelberg	Frontieres of Particle Identification
2007 Spring	Lecture Week / Bergen	Introduction to Physics of and Beyond the Star
2007 Fall	School / Oslo	On-detector electronics and signal processing

Table 4.1: schools

the area. One important aspect of the school and topical conference is the outreach to the field in the local area. So far a corresponding program is not yet available neither in Heidelberg nor in Norway. However, the discussed program is an international extension of the Heidelberg Graduiertenkurse, which have proven to be very effective and successful. Here a school is held for an entire week where students have the option to attend two classes one in the morning and on ein the afternoon during the week. At this point more than 150 students participate in each school, where more than 50% are from outside Heidelberg.
The table below gives an overview of both the planned lecture weeks and schools for the first four years of the IRTG. The tentative organisers are listed as well:
The program for the following years will be adjusted to the latest developments.

4.5 Biweekly Seminars

In order to train students presentation skills, biweekly seminars are organized locally. It is mandatory for all students to present their work either in case of an accepted presentation at a conference, or when he or she approaches the end of the thesis. Further at least one status report is expected from each student per year. The attendance of the seminar is mandatory. The seminars are complimented by external speakers. The external speakers are selected according to the demands or suggestions of the students.

4.6 Soft skill seminars

Offered by the HGFSP now! Soft skill seminars covering basic techniques like work organisation, team management, presentations and rhetoric will be offered on an irregular basis according to the need expressed by the students. The seminars will be given by external professional lecturers that specialize in the field and readily available at the participating universities.

4.7 Procedural details

The IRTG fits without any special effort into the graduate programs of the German and Norwegian universities. The standard rules for acceptance criteria are valid.

4.7.1 Admission to the IRTG

In order to maintain the high standard that the current activities in the field have reached in the various participating groups, the positions available from the IRTG will be announced worldwide. Candidates will be selected by an admission commission on the basis of the achievements of the diploma exams the originality and quality of the diploma project an oral presentation of the candidate about the diploma project (or equivalent). The basic idea is to find candidates that show the necessary skills for the anticipated interdisciplinary work between experimental physics, engineering and informatics. This is not necessarily always coinciding with the best grades in the often theoretically oriented diploma exams. Therefore interesting candidates that can demonstrate from some project work innovative and creative ideas will be given the chance to present themselves in front of the admission commission.

4.7.2 Supervision and Performance evaluation

All the graduate students participating in the IRTG have their thesis advisors at their home institutes. Thus a day-by-day interaction is guaranteed providing the most efficient monitoring of the progress of the thesis project. For long-term visits at the partner institution a specific mentor (faculty member of the host institution) will be assigned for each student serving as contact for any problem that might arise during those stays. This mentor will keep track of the project work that the student is pursuing and will help to integrate the foreign students into the social activities of the hosting group. The students will report regularly on the progress of their work in the bi-weekly seminar that is part of the IRTG (see section 4.5). Due to the interdisciplinary character of the IRTG, special efforts will be made so that all the students can follow the presentations and that the subjects are discussed in depth. Besides the internal IRTG seminar, all projects are embedded into large international collaborations, providing numerous opportunities for status reports at workgroup and collaboration meetings. At the later stage of their work the participants will present their achievements at international conferences by poster presentations or talks. For the students the interaction with the full international community is of special importance to acquire visibility to the outside world and to get into contact with other projects that might be of importance for their future careers. The IRTG will support the participation of each participating student in at least one major conference in the last 2 years of her/his thesis work.

4.7.3 Doctoral degree

The final performance control will be the acceptance of the doctoral thesis and the successful oral defense of the thesis according to the local rules of the participating institutions. The doctoral degrees will be issued by the parent institution in which the student is enrolled, according to the local rules. The IRTG will though help to support the mobility of the students, should they decide to continue their work at the partner institution, e.g. due to some interesting development during the project work phase. Joint thesis projects will be realized by admitting the mentor of the student into the examination commission at the university that is awarding the degree.

Chapter 5

Visiting scientist program

Experts on various fields of physics, detector design, readout electronics and compute infrastructure will be invited to the different activities of the IRTG, as described above, according to the needs of the participants of the IRTG.

Chapter 6

Organizational Structure

The IRTG organization, sketched below, emphasizes the binational nature. The body of the IRTG is the IRTG board, which includes all participating faculty members and two students from each country, which are elected by the participating students by simple majority. The IRTG board meets at least once a year during a lecture week or school.

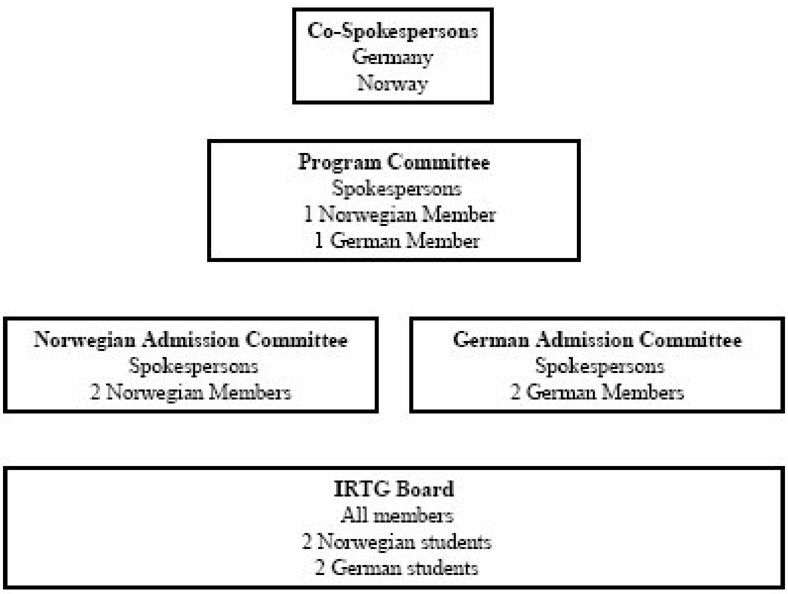

Figure 6.1: Organizational Structure

The term of a spokesperson is two years. The initial spokespersons are Prof. Dr. Norbert Herrmann for Germany and Prof. Dr. Dieter Rhrich for Norway. The two national spokespersons are elected by all members the IRTG board.

The schools and lecture weeks (see section 4) are organized by the IRTG program committee with the membership of the spoke spersons (ex officio) plus one elected national member.
Admission to the IRTG is performed nationally by the two national admission committees. In order to ensure coherence within the IRTG both spokespersons are ex officio members of both admission committees.
The responsibility for the proper organization of the biweekly local seminars is rotating on a semester basis amoung the local professors. It is the responsibility of the national spokesperson to ensure proper execution of the program.

Chapter 7

Infrastructure

7.1 Affiliation with (inter)national research projects

The research to be performed as part of the IRTG is closely related to the major current and new activities in experimental elementary particle and nuclear physics in Europe and USA. The participating groups are involved into running experiments at RHIC (BNL), SPS (CERN), BABAR (SLAC) and SIS (GSI). They contribute major parts to the preparation of upcoming LHC experiments at CERN, ALICE, ATLAS and LHCb.
Significant contributions to the future FAIR facility at GSI and especially to the design of the Compressed Baryonic Matter experiment (CBM) are planned. This is manifested in the participation to several Joint Research Activities as part of the I3HP initiative that has recently been awarded by the EU. Similar intentions exist for the preparation of the TESLA facility.

7.2 Available infrastructure at German institutes

7.2.1 Scientific personal

The following table gives a summary of the scientific personal that is available to the groups participating in the IRTG:

	Physikalisches Institut Heidelberg	Kirchho
C4	2	2
C3	2	2
C1	2	1
BAT	6	6

7.2.2 Technical Personal

Technical personnel is available to the different groups on a project basis from centralized and commonly used workshops. The following table gives the approximate number of people available to the groups participating in the

		Physikalisches Institut Heidelberg	Kirchhoff Institut, Heidelberg
IRTG:	Electronics	8	12
	Mechanics	20	8

7.2.3 Office and laboratory space

The participating groups are equipped with sufficient office and laboratory space to host the graduate students and their activities. The offices are equipped with workstations with appropriate compute power and network links. The chair for circuit simulation is presently being set up. The infrastructure for chip design is fully available, and test environments will be available soon. These will include a fully automated wafer prober, environmental chamber and high speed digital and analog test equipment. The faculty in Heidelberg hosts several CIP pools for student use and a Hardware Praktikum for lab courses and hands-on exercises. The figure left shows a picture of one of the available 12 seats. Each workbench features a PC with a PCI bus extender, a logic analyser, a DSO and an AWG signal source. For design courses the available CIP pools have all necessary software installed, including the complete Mentor and Cadence tool suite.

7.2.4 ASIC Laboratory at Heidelberg University

Microelectronics is one essential building block for the development and integration of intelligent detectors. The only way to combine low noise, low power, possibly radiation hard, low cost and intelligent signal processing and acquisition systems is by virtue of developing highly advanced integrated microelectronic devices. Therefore, foreseeing this trend, the ASIC Laboratory Heidelberg was founded in 1994 as a joint facility of the Institute for High Energy Physics and the Physics Institute of Heidelberg University together with the MaxPlanck-Institute for Nuclear Physics. Later the Institute for Applied Physics of Heidelberg University joined the lab and subsequently merged with the Institute for High Energy Physics into the present Kirchhoff-Institute for Physics (KIP), which hosts the ASIC lab on its site [1].

The positive evolution of the Lab is also well represented by the personnel employed: Starting with 6 people in 1994, the head-count has grown to more

[1] For details refer to http://wwwasic.kip.uni-heidelberg.de

than 30 scientists 2008.

7.3 Available infrastructure at Norwegian institutes

7.3.1 Scientific personal

The following table gives a summary of the scientific personal that is available to the groups participating in the IRTG:

	UiB	UiO	HiB
Professor	3	4	1
Assoc. Professor	4	-	-

7.3.2 Technical Personal

Technical personnel are available to the different groups on a project basis from centralized and commonly used workshops. The following table gives the approximate number of people available to the groups participating in the IRTG:

	UiB	UiO	HiB
Electronics	4	2	-
Mechanics	2	2	-

7.3.3 Office and laboratory space

The participating groups are equipped with sufficient office and laboratory space to host the graduate students and their activities. The offices are equipped with workstations with appropriate compute power and network links.

7.3.4 Laboratories at UiB

The cleanroom Class 10000 cleanroom equipped with a semi-automatic probe station for inspecting and probing microstrip detectors. This includes GPIB operated stepper motors, powersupplies, current and capacitance meters, switching unit. Furthermore, a VME based data-aquisition system for powering and reading out signals from the front-end electronics of silicon detector modules.

The detector laboratories Subatomic Physics Group: Laboratory for detector development: HV-power supplies, CAMAC-, VME- and PCI-based

data acquisition systems, measurement equipment, electronics design tools, electronics prototype production facility.
Space Physics Group: The INTEGRAL laboratory was established in connection with the development, prototyping, manufacturing and testing and delivery of flight quality subunits to the INTGRAL IBIS (Imager on Board Integral Satellite) Veto subsystem. It mainly consists of general equipment for detector prototyping and testing, miscellaneous gamma-ray sources, equipment for thermal cycling, equipment for development of electronics and PCB design, access to clean room, access to mechanical workshop.
The Space Physics group at Department of Physics, UiB, is establishing a laboratory with electron and ion beams of energies less than about 200 keV/unit charge. Detectors can be mounted inside the UHV vacuum chamber on a pedestal with 4 degrees of freedom. Most of the equipment is already acquired and partly assembled. A modest funding and some work still remains. The aim is to have the laboratory operational by end of 2004.

The microelectronics laboratory The microelectronics lab was established in 1988 in as a result of the increasing demand for advanced electronics in space physics instrumentation. Its main purpose is to serve as an environment for education and research in microelectronics related to experimental physics. The activity is focused on embedded sensor electronics, ranging from analogue amplifier and shaper design to digital control and support circuits. Both full custom ASIC design and high level language design of FPGAs is supported. The microelectronics laboratory is a member of Europractice, which makes available a wide range of leading edge IC, FPGA, Electronics Systems, and Microsystems design tools, plus Intellectual Property Blocks (IP). It is equipped with HP and Sun workstations and PCs running Windows and Linux. A number of instruments are available in the lab, and at the Department of Physics, including a Vanguard Networked PCI-X/PCI Bus Analyzer and Exerciser and mixed signal oscilloscopes.

7.3.5 Laboratories at UiO

The Oslo Cyclotron Laboratory (OCL) The Oslo Cyclotron Laboratory (OCL) was established in 1978, and is based on a Scanditronix MC35 cyclotron. This multi-purpose machine can produce beams of protons, deuterons, 3He and alpha, with energies ranging from 5 to 45 MeV, and intensities from around 10 pA to 100 A.The accelerator is thus far more versatile than many specialized ones found elsewhere.
Current projects at the OCL include, but are not limited to:

- Study of the structure of thermally excited nuclei at low spin.
- Production of radionuclides (18F, 211At) for medical purposes.
- Radiation hardness tests of electronic components being evaluated for possible use with the ALICE detector.

Apart from the cyclotron itself, power-supplies and beam-lines, the laboratory infrastructure comprises specialized detectors, advanced data-acquisition electronics and computer equipment. VME based front-end processors plus Sun workstations and PC's running Linux are used. Many of the technical solutions, mechanics, electronics and software, have been developed locally.

Research group laboratories The research groups for electronics, space physics, particle physics and nuclear physics operate laboratories for the design and construction of experimental specific detector and data processing electronics. A wide range of CAD tools for electronic design is available. The groups can also acquire development tools distributed through the membership of the University of Oslo in the Europractice organization. The laboratories feature a wide range of test and measurement equipment, software packages, and Real-Time development systems.
A common electronics laboratory offers central facilities for surface mounted circuit technology etc. For ASIC development there is collaboration with SINTEF and the Institute of Informatics.

The cleanroom A cleanroom for silicon module assembly is equipped with high precision assembly tables, including test facilities for silicon modules.

Computational physics An advanced programme in Computational physics has been under construction the last year at the Department of Physics. Currently 10 courses are given, mainly for Master studies, but more advanced courses are being planned. The scientific programme is a collaboration between the Department and other university institutes and external institutions, like the Simula Research Laboratory which was established in 2001.

Norwegian Microtechnology Centre The new Norwegian Microtechnology Centre (NMC) is part of a national programme on micro-technology. NMC is a joint laboratory operated by the research organization SINTEF, the University of Oslo, and industry. The construction has been partly financed by the Norwegian Research Council. The Centre is located on the

Oslo University campus. The inauguration will take place end September 2003.
NMCs core competence is the development of micro-components and complete instrumentation systems based on microcomponents. The laboratory is equipped with a processing line for 6 wafers. The research will include ASICs, micro-system manufacturing, MEMS, packaging technology, photonics and radiation detector systems. Scientists from SINTEF will collaborate with professors and students of the University of Oslo in order to design and prototype new micro-systems.
The NMC will focus on research in joint projects with staff at the Department of Physics, University of Oslo. The research program is currently under definition. A project in Advanced Sensors for Micro-Systems has been proposed to the Norwegian Research Council, with project members from the University of Oslo and SINTEF. This project is a Strategic University Program (SUP) for the period 2003-2006 at the Department of Physics,University of Oslo. Two groups at the Department of Physics have been working on Si sensors for more than two decades; the Electronics groups and the Experimental Particle physics (EPP) group. In the Electronics group MSc and PhD students have been studying fundamental issues related to the detection of ionizing radiation using semiconductors, most of them in collaboration with the Department of Microsystems at SINTEF Electronics and Cybernetics. The EPP group has been working on applications of Si detectors for high energy physics experiments since the mid 1980s. The SUP addresses issues regarding the requirements and fabrication of novel sensors for operating in harsh environments. Two types of sensors are considered; (i) silicon detectors for ionizing radiation and (ii) high temperature silicon carbide gas sensors.

Chapter 8

Funding

8.1 Funding (German share)

8.1.1 Scholarships for PhD students

We ask for the support of 18 students for the German groups participating in the IRTG. In order to be able to attract the most active and capable students we have to offer an increased salary for the interdisciplinary work profile. It should be noted that PhD student in informatics and electrical engineering typically enjoy full BatIIa positions. We intend to maximize the number of students participating to the projects and ask for each student the increased stipends.
Subtotal for 4.5 years:

Base amount $4,5x12x18x1.365$	$= 1.326.780$
Family support (estimated 20% of all students) $4,5x12x4x205$	$= 44.280$
Sum	1.371.060

8.2 Postdoc positions

The postdoc positions are necessary to implement the unique and specific educational program of the IRTG, namely the installation of courses and project work making use of the most advanced design and analysis tools available today. The duties connected to the postdoc positions are detailed in section 3.2.
Postdocs in all the participating groups are payed according to BatIIa. In order not to discriminate among people on the same level of experience and education, and to be able to motivate people to join into the educational

activities of the IRTG, we ask for 2 postdoc positions according to the BatIIa tariff.
Subtotal for 4.5 years: Estimate 4,5 x 2 x 50.000 = 450.000

8.3 Qualifizierungsstipendium

8.4 Mittel für Gastwissenschaftler

8.5 Mittel für Forschungsstudenten

8.6 Sonstige Kosten

8.6.1 Joint activities

Two joint lecture weeks/schools will be organized each year, one being internal to the IRTG participants the other one being a school that is open to the public. The location will alter in between Germany and Norway.

> Internal workshop We base our funding estimate on the assumption that all the participants of the IRTG will participate in the mandatory internal 5day lecture week.
>
> 4.5 x (18 students + 12 faculty) x (350 + 5x100) = 114.750
>
> A flight from Frankfurt to Bergen costs 350 (note all flights to Norway are included here), the estimate for housing and food is 100/day (120 for Norway)
>
> Participation to the school activities:
>
> 4.5 x (18 students + 6 faculty) x (5x100) = 54.000
>
> External lectures The cost for the invitation of an external lectures is estimated to 2000 per 4day course.
>
> We therefore ask for
>
> 4.5 x 3 x 2000 =
>
> Invited speakers at the topical workshops
>
> 4.5 x 5 x 1000 =

8.6.2 Mobility costs

The cost for long term exchanges of students is divided among the participating institution in the following way: The travel expenses are supplied by the home institute of the student while the local expenses are covered by the host institutes.

Travel money for German students to Norway Typically half of the participating students will visit the partner university once per year.

We therefore ask for

4.5 x 9 x 350 = 14.145 22.500 27.000

We expect visits of Norwegian students to the advanced courses and project work in Heidelberg. The cost is estimated to 400/month/person. On average about 10 Norwegian students will spent about 3 month in Germany.

Therefore we ask:

4.5 x 10 x 3 x 400 = 54.000

8.7 Forschungssemester

Chapter 9

Erklärungen

9.1 Beziehung

Besteht eine thematische Beziehung zwischen dem Grako und einem a, Ort befindlichen Sonderforschungsbereich

9.2

Chapter 10

Verpflichtungen

does not apply

Chapter 11

Publications

Chapter 12

Signatures

	Sprecher	Hochschulleitung
C		

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