The MEGAPIE Initiative

Executive Outline and Status as per November 1999

M. Salvatores[1] ,G.S. Bauer[2] and G. Heusener[3]

[1] CEA Cadarache, Direction des Réacteurs Nucléaires,
F-13108 Saint-Paul-lez-Durance Cedex France

[2] Paul Scherrer Institut, Spallation Neutron Source Division,
CH-5232 Villigen-PSI, Switzerland

[3] Forschungszentrum Karlsruhe, Projekt Nukleare Sicherheitsforschung,
D-76021 Karlsruhe Germany

1. Background and Goals

MEGAPIE (**MEGA**watt **Pi**lot **E**xperiment) is a joint initiative by Commissariat à l'Energie Atomique (CEA), France, Forschungszentrum Karlsruhe (FZK), Germany, and Paul Scherrer Institut (PSI), Switzerland, to design, build, operate and explore liquid lead-bismuth spallation target for 1MW of beam power, taking advantage of the existing spallation neutron facility SINQ at PSI

A liquid metal spallation target based on the lead-bismuth eutectic mixture with a melting point as low as 125°C and a boiling point as high as 1670°C is the preferred concept in several studies aiming at utilising accelerators to drive subcritical assemblies in order to transmute long lived nuclear waste into shorter lived isotopes in an effort to ease problems of long term storage and final disposal. However, to date, such a target has never been operated. This lends a speculative element to all of these designs, which must be eliminated if serious consideration is given to the implementation of a demonstration facility. Apart from ongoing research into several of the underlying issues, a full demonstration of a working system is highly desirable. For obvious reasons such a feasibility demonstration should be carried out on an existing accelerator with suitable design features.

More specifically, the current orientation in France is a step by step approach towards a possible ADS Demonstration Experiment. In this context the test of a 1 MW liquid metal target is a crucial milestone, even if the final choice of the type of target (solid vs. liquid) has yet to be made. The MEGAPIE experiment will be an important ingredient in defining and initiating the next step, a dedicated ADS-quality accelerator plus target plus (at a later substage) an irradiation oriented, low power, subcritical blanket.

Presently there are only two accelerators available world wide, which have a sufficiently high proton beam power to make the installation of such a target a meaningful experiment: the LANSCE pulsed linear accelerator in the USA with a proton energy of 800 MeV and an average beam current of 1 mA and the ring cyclotron at PSI with 590 MeV proton energy and a continuous current of 1.8 mA.

A test target suitable for installation in the LANSCE beam is currently under construction at the Institute for Physics and Power Engineering (IPPE) in Obninsk, Russia, in the frame of an ISTC-project jointly supported by the European Union, Sweden and the United States. In compliance with the conditions existing at LANSCE, this target is designed for horizontal beam injection and utilises a special diffusor plate to ensure proper cooling of the beam window, a design which cannot be extended to significantly higher power in a straight forward manner. Furthermore, opportunities to instrument the target in a meaningful way are limited. The material used is a ferritic steel made to Russian specifications. Operation of this target will require more or less single purpose running of the LANSCE accelerator and may, therefore, be limited due to financial or other constraints. For these reasons, and also because it seemed unwise to rely on one single test only, the present initiative was started in Europe to carry out an independent pilot experiment at the PSI cyclotron.

2. Opportunities and boundary conditions at PSI

2.1 Accelerator facilities and proton beam line

The Paul Scherrer Institut is operating a large complex of research facilities based on a cascade of three accelerators that deliver a proton beam of 590 MeV in energy at a current up to 1.8 mA. A schematic floor plan of these facilities is shown in Fig. 1. The proton beam is pre-accelerated in a Cockroft-Walton column to an energy of 800 keV and is brought up to an energy of 72 MeV in the 4-sector injector cyclotron. This has replaced the original Phillips injector cyclotron (Inj. 1) also shown in the Figure, which is currently operating for different applications and is intended to be utilised also in the underlying research efforts for MEGAPIE, as discussed below. Final acceleration to 590 MeV occurs in the 8-sector main ring cyclotron, from which the beam is transported through the experimental hall in a shielded tunnel. A small fraction of the beam (20 μA) is split off early to serve a proton irradiation and cancer therapy test facility. (It is intended to provide a separate accelerator for the cancer therapy facility in the near future and thus take off some operational restrictions on the main accelerator system that result from this additional use.) The main beam passes through two pion production targets (M and E), whereby its energy is reduced to 570 MeV. After passing through Target E the beam can either be dumped in a beam stopper or can be recaptured and bent downwards for onward transport to the spallation neutron source SINQ. Target E, a 4 cm long graphite target. After this target 70% of the beam (1.3 mA) can be recaptured and transported to the SINQ target. The beam power available for SINQ thus is roughly 0.75 MW and is expected to be increased to 1 MW by 2004, the period for which the operation of the MEGAPIE target is planned.

2.2 The spallation neutron source SINQ and ancillary equipment

SINQ is designed as a neutron source mainly for research with extracted beams of thermal and cold neutrons, but hosts also facilities for isotope production and neutron activation analysis. Except for its different process of releasing the neutrons from matter, it resembles closely a medium flux research reactor for most of its users, since the neutron beams are extracted from a 2 m diameter heavy water moderator surrounding the target, as shown in Fig. 2. Beam injection into SINQ is from underneath and the target is inserted from the top and is suspended from the upper edge of the target shielding block. Although the beam interaction region in the target is only about 30 cm long, the target unit is a 4 m long structure with 20 cm diameter in its lower 2 m, which widens to 40 cm in the upper half. These dimensions must also be adhered to with the MEGAPIE target. The present target is an array of solid rods cooled in cross flow by heavy water. Since it is essential to minimise neutron absorption in the region of the moderator tank in order to obtain a high neutron flux, the part of the target unit extending into the moderator tank is filled with heavy water, except for the rod bundle, which is about 40 cm long and is located in the centre of the moderator tank. The lower half of the target unit is enclosed in a double walled shell with separate heavy water cooling. This shell is presently made of aluminium alloy. Although it will be necessary to have such a shell surround the liquid metal container also in the case of the MEGAPIE target, it remains to be decided whether aluminium alloys are still suitable or whether a material with higher strength at elevated temperatures needs to be chosen.

The water cooling loop for the target has a heat removal capacity well above what is needed for either the solid or liquid metal target. It is, however, limited to operating temperatures below some 80°C and is not suitable for pressurisation to more than about 0.8 MPa. Hence, the water temperature of this loop cannot be raised to more than 125°C in order to prevent freezing of the PbBi. A different solution must be found for this problem.

The target is inserted into and removed from its operating position by means of a specially designed exchange flask which has an internal hoist to lift the target. This flask is transported by means of the overhead crane in the SINQ target hall, whose capacity is limited to 60 tons. The shielding of this flask is currently optimised for the solid target, which has its radioactivity concentrated in the bottom region. Although the specific activity of the liquid metal target will be much lower due to its significantly larger target mass, it remains to be examined whether the shielding in the upper part of the flask is sufficient. Possibilities for back-fitting on the present flask are very limited due to both, its design and the weight limitations on the overhead crane.

2.3 The active handling area ATEC

The area in the PSI Experiment Hall immediately adjacent to the SINQ Neutron Guide Hall (Fig. 1) is designed and equipped to handle large radioactive components and is generally used to service, repair and prepare for disposal all kinds of radioactive parts used in the operation of the facility. Its hot cell is equipped with a power manipulator, master-slave manipulators and a movable heavy duty working table as well as several other items such as radiation monitoring, video cameras etc. Although access to the hot cell is possible through its roof, a specially designed port for horizontal access (blue arrow in Fig 1) is used to insert the SINQ target, because limitations in height prevent vertical insertion with sufficient clearance for the manipulations required. The SINQ target No. 1 was successfully dismantled; samples from the target material were removed and the target was reassembled in this hot cell. In principle this cell and its special equipment prepared for the handling of the SINQ solid target should also be suitable to dismantle the liquid metal target. There are, however, some severe boundary conditions. The most important one is the fact that this hot cell is not equipped and licensed to handle α- activity. Thus, even if a method is developed to drain the liquid metal from the target before opening it, as is desirable for a variety of reasons, one must still be able to guarantee that no α-active isotopes are released into the cell during the foreseen operations. Alternatively, the cell might be retrofit for handling α-active parts, but this would not only mean a significant additional expense, it would also make access much more difficult and would shut down the area for an extended period of time. The latter is a particular problem because the cell is more or less continuously utilised and must be available on short notice in case any of the vital components in the accelerator or beam transport systems fail. It shall, therefore, be an important task in the MEGAPIE design phase to develop a specialised enclosure for use inside the hot cell that guarantees that no α-activity is released into the cell when the target is opened to remove those parts on which post use examinations are foreseen.

2.4 Hot cell facilities and PIE equipment

PSI is operating well equipped hot cells in which post irradiation examinations (PIE) can be carried out wit a large variety of different methods. Definition of the PIE program will be a relevant part of the project activity during the R&D phase.

2.5 Efforts related to the operation of the MEGAPIE target

The MEGAPIE target will, for a period of time of up to one year, replace the neutron production target in SINQ while utilisation of the facility will continue. PSI is therefore willing to cover all efforts related to inserting, running and removing the target in the SINQ facility, on top of the share it agrees to cover in the design, construction and disposal effort within the MEGAPIE collaboration.

2.6 Target development for SINQ in view of the MEGAPIE initiative

The first target (Mark 1) used for commissioning the SINQ facility was made up from simple Zircaloy rods. While this is a relatively well proven material in nuclear applications, its neutron yield is not optimal. It is, therefore, an important goal of the SINQ target development program to improve the neutron flux in the moderator and to maximise the time of reliable operation of the targets. In order to establish a data base for the design and operation of future targets, the first target was removed after half a year of operation (500 mAh total charge delivered). It was replaced by another one (Mark 2) which, while still being essentially a Zircaloy rod bundle, incorporates several test elements designed to provide data for future target concepts. Apart from a large number of test specimens which will allow to examine radiation effects in a mixed proton- fast and thermal neutron spectrum under varying load for the first time (STIP-collaboration, see below), the target also contains elements made from lead filled steel rods. Although results from post irradiation examinations will not be available until at least a year after the end of irradiation, the fact that no problems were encountered up to a total charge of 6 Ah (Nov. 1999) seems to justify the use of a target made up of lead filled steel tubes which, according to calculations, is expected to increase the thermal neutron flux by a factor of 1.5 relative to Zircaloy. This target will, again, be loaded with test specimens. The planning for the future is shown in Fig. 3. Following the investigation of the material from the Mark 2 target it is intended to decide on whether or not Zircaloy can be used as a tube material for the lead rods, in which case another gain factor of 1.3 would be expected for the thermal flux. Currently the projected operating life for each target is 2 calendar years.

A period of 2 years (2000 and 2001) has been allotted to carry out the research and engineering work necessary to decide what the final design of a liquid metal target should be and to prepare the preliminary safety analysis report. At the end of this period a decision will be made whether to go ahead with the detailed design and construction, for which another two years are foreseen, including testing without beam. This sets the beginning of the year 2004 as the goal for putting the MEGAPIE target into SINQ. A standby target will be ready in case some unforeseen difficulty arises in the last minute. This target will be used at the end of the operating period of the MEGAPIE target, unless a follow up liquid metal target will be available. The duration of the irradiation period will be decided upon, based on the results obtained up to that point from supporting research (see below).

3. The basic concept of the MEGAPIE target

Although the conceptual and detailed design for the MEGAPIE target will be worked out within the collaboration, a basic design has been drafted in order to visualise some of the essential features to be incorporated in the target. In some aspects this design takes into account results from preliminary studies carried out by PSI in pursuit of liquid metal targets for the European Spallation Source (ESS) project and for SINQ. A sketch is shown in Fig. 4. In its outer dimensions this target is identical to the one presently in use at SINQ.

The lower (20 cm diameter) part of the target consists essentially of a double walled and separately cooled containment shell, the liquid metal confinement hull with a beam entrance window cooled by the liquid metal, and a central guide tube to separate the downward flow of cooled target material in the outer annulus from the upward flow of heated material in the central region. The concept foresees, subject to computational verification, thermal convection as the main driving force for the flow. Since this is a self-regulating and passive process, it should facilitate the task of adjusting heat removal and auxiliary heating to variations in the power deposited by the beam. Auxiliary heaters are foreseen along the inner guide tube above the region of beam interaction. A hemispherical shape of the windows of the confinement hull and containment shells is proposed in order to minimise stresses from thermal gradients. This requires special care to ensure proper cooling. On the confinement hull this shall be accomplished by a partial stream of the target flow pumped by an auxiliary pump and directed across the beam window by means of a separate flow guiding tube, shown on the right of the central guide tube. For the containment shells the existing cooling concept shall be retained.

Located in the upper (40 cm diameter) part of the target are the bypass flow pump (shown as an electromagnetic pump which can be removed upwards), the heat exchanger (shown as double walled with a suitable medium in the inter-space to optimise the temperature dependent heat transfer) and any components that might be necessary to survey and control the performance of the target and the quality of the liquid metal. A steel shielding block with feed-throughs for the cooling water etc. will prevent excessive activation and dose levels at the target top to make possible hands on uncoupling of the target head from the water pipes for removal.

Preliminary studies have shown that from a thermal hydraulic point of view this target should work at an even higher power level than required for SINQ and that there exists significant margin for optimisation with respect to pump and heat exchanger size as well as the possibility to accommodate the desired instrumentation for temperature and flow control. Details of this instrumentation will have to be specified in the conceptual design phase.

4. The MEGAPIE Collaboration

The MEGAPIE collaboration held its first meeting on May 19, 1999 at PSI with participation from

CEA Cadarache / Saclay
SUBATECH / CNRS
FZK and
PSI.

The purpose of this meeting was to organise the elaboration of a project outline on which a formal decision to launch the project and the budget planning for the participating partners could be based. The contributions to this project outline were subsequently discussed in two further meetings at CEA headquarters in Paris on June 17 and at PSI on Sept. 10, 1999. At the last meeting an informal letter of intent was received from

JAERI, Tokai establishment, Japan,

expressing JAERI's interest to participate actively in the effort.
Similarly, *ENEA* (Italy) has expressed interest in the project and is attending the MEGAPIE meetings as an observer for the time being

A preliminary work breakdown structure for the realisation of the project is reproduced in Fig. 5 and the goals defined for the different phases of the project are shown in Table 1.

Although the collaboration is intended to be limited to members who actively participate in the project and make significant contributions to its funding, it remains open for new members with an active interest in the topic.

Consideration is also given to the possibility of proposing the project for support within the 2nd phase of the 5th Framework Program of the European Union.

Table 1 *Definition of the MEGAPIE project phases*

Phase and approx. duration	**Designation**	**Actions / Deliverables**
Phase 1 Nov 99 - Feb 00	Baselining	Specify goals of the project List boundary conditions Define technical options Identify R&D-needs Outline operational procedures and monitoring Define post irradiation examinations Identify requirements for final disposal Decide on management structure Provide cost and schedule baseline
Phase 2 March 00 - May 00	Feasibility study	Refine technical options Establish design data base Analyse anticipated load levels Identify problem areas Perform scoping calculations Verify cost and schedule plans Identify requirements to ancillary systems
Phase 3 June 00 - Sept. 00	Conceptual design	Select reference technical design Select reference materials Define instrumentation and controls for operation Size individual components Verify compatibility of components' specifications Identify possible sources of failure Analyse consequences of individual components failure Outline design for ancillary systems

Phase 4 Oct. 00 - Sept. 01	Engineering design	Carry out overall safety and life time analysis Carry out detailed calculations to optimise system Verify designs of all individual components Analyse life expectancy and possible failure modes of components and system Design ancillary systems Establish QA plan for manufacturing and testing Produce final design report
Phase 5 Oct 01 - Feb 03	Detailed design and manufacturing	Produce drawings of individual parts for manufacturing Procure and quality control individual parts or subsystems Assemble and factory test subsystems Provide test rigs and equipment
Phase 6 March 03 - Jan 04	System Integration and Testing	Assemble complete system from components Carry out functional tests without beam Demonstrate concepts for remote operations on unirradiated target, in particular draining of PbBi
Phase 7 Feb 04 - (to be decided)	Operation	Insert target in SINQ Run target with beam Continuously record relevant operation parameters Make periodic checks according to monitoring plan Remove target at end of irradiation period
Phase 8 - Dec 2005	PIE and decommissioning	Drain PbBi from target Remove parts to be examined Carry out PIE according to plan Prepare remaining parts for disposal Put conditioned containers in intermediate storage

5. Supporting R&D at the Participating Laboratories

While the MEGAPIE initiative aims directly at designing, building and testing a PbBi liquid metal pilot target in a 1 MW proton beam, it will profit from a variety of different related research activities its members are involved in and which cover most of the questions of more fundamental nature related to this endeavour. The most important ones of these collaborations are listed below:

5.1 The STIP collaboration

As mentioned above, the unique opportunity of investigating the radiation effects from a perfectly realistic spectral mix of the different particles in a spallation environment in the SINQ target is being taken advantage of in an effort to broaden the data base for a variety of materials considered as candidates for target and structural materials in future spallation facilities. A collaboration was formed supported by

CEA Saclay (France)
Forschungszentrum Jülich (Germany),
JAERI Tokai Establishment (Japan)
Los Alamos National Laboratory, (USA)
Oak Ridge National Laboratory (USA)
Paul Scherrer Institut (Switzerland)

different types and materials were assembled in 10 of the SINQ target rods and embedded in the Zircaloy target that went into operation in the beginning of the year 1998. At the end of the target's service life (end of 1999), the peak radiation damage from protons alone will be of the order of 10 dpa in steel, with a similar contribution resulting from the fast neutron flux. The specimens will be removed from the spent target during the summer of 2000 and will be shipped to the participating laboratories for examination by different methods such as tensile testing, tear testing, bend bar and Charpy testing as well as electron microscopy. Due to the rather large range of radiation damage levels and irradiation temperatures which the specimens experienced in different positions of the SINQ target, a large parameter space will be covered by the data obtained.

Furthermore, 13 rods are made up either of different types of steel as bulk material or of steel tubes filled with lead. In addition to 5 Zircaloy rods designed for easy removal from the target, these will be available for non-destructive and destructive testing using, among others, neutron small angle scattering, neutron radiography and internal strain measurements with neutrons at SINQ.

Preparations are under ways to equip the follow-up target, which will go in operation in early 2000, in a similar way but predominantly with materials and materials combinations in which interest has arisen more recently.

5.2 The LiSoR experiment

One of the major unknowns in liquid metal target development is related to the question, whether **li**quid metal-**so**lid metal **r**eactions are enhanced under irradiation in the presence of (static or cyclic) stress. Since this is a problem that must be solved before a liquid metal target can be irradiated in a proton beam for an extended period of time, an experiment has been initiated to use PSI's 72 MeV Phillips cyclotron to irradiate stressed steel specimens in contact with flowing liquid metal. Scoping calculations showed that, while much less radioactivity is produced, the damage levels and gas production in thin specimens by 72 MeV protons are, within reasonable limits, comparable to those on the inside of the proton beam window at 600 MeV. Also, the beam parameters can be adjusted in such a way that relevant heating rates at the solid-liquid interface are obtained. A proposal to carry out such an experiment has been received positively by the Experiment Review Committee and irradiation time has been set aside for the operating period of the year 2000. Currently the rig is being designed by SUBATECH with support from CNRS and CEA, France. LiSoR was originally planned as a stand alone investigation. Due to its immediate relevance for MEGAPIE it is intended to be incorporated into the initiative, but, for the time being it is still pursued on an independent basis. This is mainly due to temporal restrictions which result from PSI's intention to discontinue operation of the Phillips cyclotron in 2001 and from the time, when results are needed to affect the MEGAPIE design. Support for LiSoR is being sought under the first phase of the EU 5th Framework Program.

5.3 The TERM experiments

In a quest to study some of the unresolved problems related to the design of liquid metal targets in the context of the ESS project and in preparation of a data base for thermal hydraulic studies for a possible later SINQ liquid metal target, a ***T****est* ***E****xperiment at the* ***R****iga Mercury* ***L****oop* (TERM) was set up. The main goal was to study experimentally questions of heat transfer between the window and the fluid and related flow distributions in various geometrical configurations. The first phase, which used the geometry of the SINQ target has been finished. Methods developed and used include **U**ltrasonic **V**elocity **P**robes (UVP), based on a though the wall measurement of the Doppler effect in the fluid, **H**eat **E**mitting **T**emperature **S**ensitive **S**urfaces (HETSS) and Surface Thermography. Data from this phase of the experiment are still being evaluated. Ongoing experimental work now concentrates on the geometry of the ESS target and the effect of gas in the fluid on the coolability of the beam window. The full scale SINQ target model is also still available for further investigations.

5.4 The PSI Lead -Bismuth loop

In order to be able to carry out experiments even more realistic for SINQ than were possible at the Riga Mercury Loop, a PbBi-loop has been constructed and is being commissioned at PSI. Without a test section attached, the loop contains 0.12 m^3 of PbBi and has a total height of 5.1 m. Operating temperatures are rated at 250°C and below. It is equipped with an EM-pump (32-58 kVA) with a head of 1.5 m LBE and a capacity up to 200 l/min. The pressure rating of the loop is -1 to 2 bar. Test sections can be added to the loop depending on the problem under investigation. The loop is intended for both, testing of individual components as well as studies of flow configuration and heat transfer problems.

5.5 The Karlsruhe Lead Laboratory KALLA

Within the German HGF-Strategy Fund Project 99/16 entitled „Reduction of Radiotoxicity“, the ***KA****rlsruhe* ***L****ead* ***LA****boratory* ***KALLA*** is being planned and constructed at the Forschungszentrum Karlsruhe. KALLA comprises three different experimental loops, each emphasising on different specific objectives, briefly summarised in Tab. 2, together with the main data.

The Technology Loop concentrates on the establishment of an oxygen measurement and control technique, an important prerequisite to safely operate a Pb or Pb-Bi loop, over extended periods of time. Measurement techniques are adapted to or specially developed for Pb and Pb-Bi. In addition, basic heat transfer experiments and experiments on turbulence quantities will be performed.

The Thermalhydraulic Loop is, in the first place designed for single-effect investigations of the thermally highly loaded beam window and the heat removal from a complete, closed target module. Further on, detailed experiments can be done for a windowless target, a fuel element and a steam generator. Secondly, integral real-height investigations into the core heat removal and the decay heat removal from the pool of an ADS or a closed target module can be performed.

The Corrosion Loop allows fundamental investigations of corrosion mechanisms, the formation and the stability of protection layers and the performance of mechanical tests. The final aim is the continuing development of available low-activation steels and structural materials.

Table 2: *Investigations and capabilities at KALLA:.*

Technology Loop	**Thermal-hydraulic Loop**	**Corrosion Loop**
	Single-effect investigations:	
Oxygen measurement	Solid beam window	Corrosion mechanisms
	Windowless design	
Oxygen control	Closed Target module	Protection layers
Measurement techniques	Fuel element	Mechanical tests
Heat transfer and turbulence	Steam generator	
High-performance heaters	Heat exchanger	
	Integral investigations:	
	Core heat removal	
	Decay heat removal	
Fluid volume: 0.1 m³	Fluid volume: 0.5 - 4.0 m³	Fluid volume: 0.03 m³
Temperature: max 550°C	Temperature: max 550°C	Temperature: max 550°C
	Power: 0.3 - 4.0 MW	
Flow rate: max 5 m³/h	Flow rate: max 100 m³/h	Flow rate: max 3.5 m³/h

5.6 The SPIRE Programme

As part of the SPIRE programme proposed to be funded under the first phase of the EU 5th Framework Programme irradiation effects in structural materials under a proton neutron mixed spectrum will be investigated The participants to SPIRE are :

CEA (France)	*FZ Jülich (Germany)*	*PSI (Switzerland)*
CIEMAT (Spain)	*FZ Karlsruhe (Germany)*	*SCK-CEN (Belgium)*
CNRS (France)	*KTH - RIT (Sweden)*	
ENEA (Italy)	*NRG (The Netherlands)*	

Within this framework, CEA has implemented a programme the objectives of which are to (i) determine the in service properties of the selected structural steels: tensile properties, fracture toughness, irradiation creep and swelling, (ii) provide the basic understanding and modelling of the observed phenomena induced by atomic displacements and production of spallation elements, and (iii) contribute to a validated data base. The CEA programme includes studies aiming at the understanding of the effects of spallation elements production (He, H, Ca, P, S, Ti) on the physical metallurgy, microstructure and mechanical properties of the selected steels, neutron irradiation in Phénix (Antarès up to 40dpa) and Bor60 (Altaïr up to 30 dpa) to complement the existing data base, post irradiation examination (PIE) of conventional martensitic steels included in SITP, and basic studies to predict the hardness and the cohesion energy of segregated boundaries.

5.7 The TECLA Programme

Corrosion, quality control in Pb-Bi and associated technology will be investigated as part of the programme "Technologies, Materials, Thermal-Hydraulics for Lead Alloys" (TECLA) proposed to be funded under the first phase of the EU 5th Framework Programme. The participants to this programme are:

CEA (France)	*ENEA (Italy)*	*KTH - RIT (Sweden)*
CIEMAT (Spain)	*FZ Karlsruhe (Germany)*	*SCK-CEN Belgium)*
CNR (Italy)	*FZ Rossendorf (Germany)*	*PSI (Switzerland)*
CNRS (France)	*JRC-Ispra (Italy)*	

The objectives of this corrosion programme are to provide a validation of the envisaged structural materials under varied experimental conditions: (i) quantify the corrosion kinetics under different chemical (oxygen and spallation elements contents) and hydraulic (Pb-Bi velocity) conditions and (ii) identify and assess structural materials protection methods against corrosion. Corrosion kinetics versus oxygen potential of the various selected materials will evaluated within a co-operation with IPPE Obninsk. This experimental effort will result in a data base that will allow the comparison between the selected materials and offer a reference baseline to anticipate the behaviour of the MEGAPIE window. Different devices, static and rotating probes, will be used in CEA to asses the effect on corrosion of flow velocity and of spallation elements introduced as chemical impurities. This includes initial impurities before start-up, corrosion products, spallation products, impurities, such as air, introduced during operation, etc. . After identifying sources and nature of impurities and establishing functional specifications of purification systems, selected processes (cold traps, getters, filters, EM traps, ...) have to be qualified. A benchmark is being organised to provide a standard for the laboratories involved in physico-chemical studies in order to be able to compare results from various laboratories. CEA is working on a chemical specification for lead bismuth in collaboration with its European partners. Research activities are also foreseen to validate a strategy to maintain a constant oxygen concentration: The Collaboration intends to evaluate various processes to maintain the oxygen concentration at a constant value, in order to protect the structures against corrosion. The oxygen value will be defined from corrosion studies. The processes of gas control cold trapping, equilibration method, 'electrochemical pump' will be investigated and compared. The most promising processes will be tested on the available experimental facility.
Thermal hydraulic investigations will be performed at FZK (within KALLA), ENEA (within CIRCE) and FZR.

5.8 The GEDEON Network (Groupement de Recherche)

The GEGEON "Groupement de Recherche" is a joint initiative of CEA, CNRS, EdF and FRAMATOME, which co-ordinates the R&D activities on ADS in France as a contribution to the research on innovative options for waste management. GEDEON has launched a number of research projects in the fields of materials for targets and beam windows (radiation effects, physico-chemical properties and behaviour), neutronics of subcritical systems, spallation physics, nuclear data, accelerator requirements and system studies. The CEA/CNRS participation in the MEGAPIE project will be co-ordinated through GEDEON.

6. Conclusions

The MEGAPIE initiative will be an essential step towards demonstrating the feasibility of the coupling of a high power accelerator, a spallation target and a subcritical assembly. It will specifically address one of the most critical issues, namely the behaviour of a liquid metal target under realistic operating conditions. As an intensely instrumented pilot experiment it will provide valuable data for benchmarking of frequently used computer codes and will allow to gain important experience in the safe handling of components that have been irradiated in contact with PbBi.

The parallel R&D activities will provide opportunities to focus on-going research and to streamline efforts in several European laboratories.

MEGAPIE will also be a valuable contribution to potential collaborations with partners outside Europe, and can help to establish an effective sharing of work.

The envisaged target date (irradiation in 2004) is consistent with development plans in the Accelerator Driven System domain and with the milestones of the 5th and 6th European Union Framework Programs, as well as with upgrade plans in the SINQ facility.

The results obtained in this pilot experiment will also help PSI to decide whether or not it wants to go ahead with the development of a liquid metal target for routine use in its spallation neutron source. If the answer is positive, this will be a continuous source of experience and information which will benefit the ADS activities of all participating parties.

7. Acknowledgements

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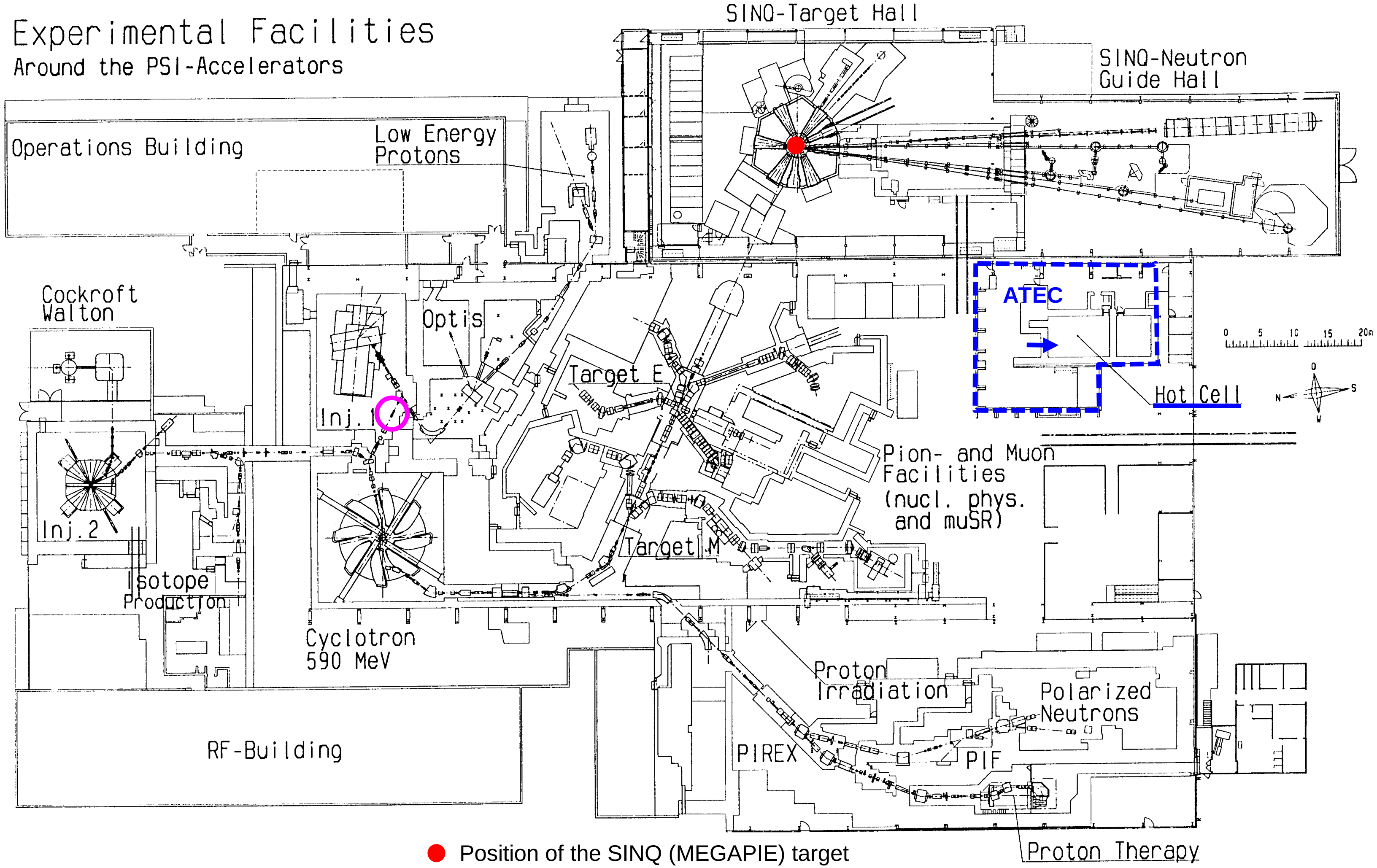

Position of the SINQ (MEGAPIE) target

Location of the LiSoR experiment

Horizontal access port to hot cell

Figure 1: *Schematic floor plan of the PSI accelerator complex and associated research facilities*

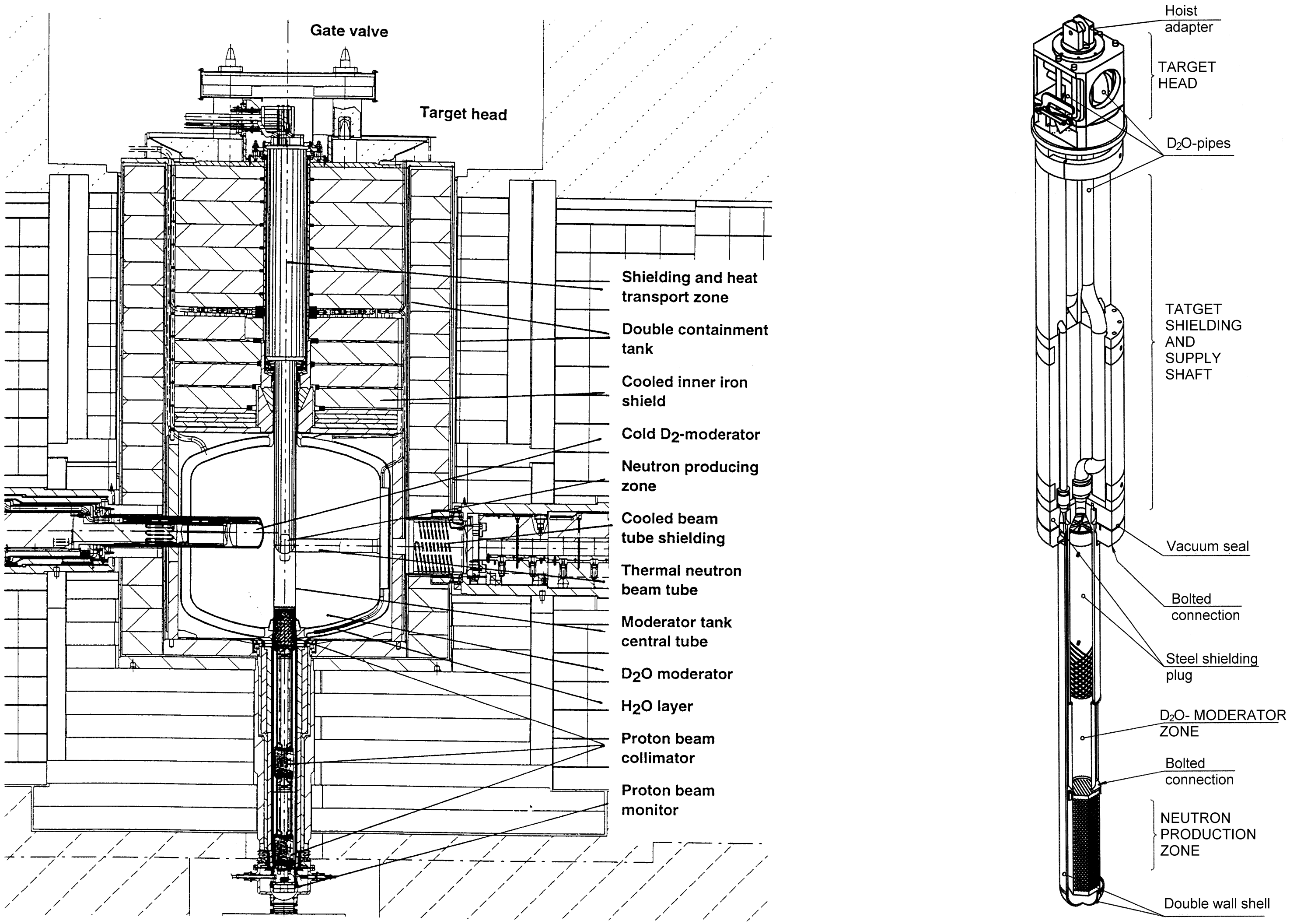

Figure 2: *Vertical section through the SINQ target block and the present water cooled solid rod target*

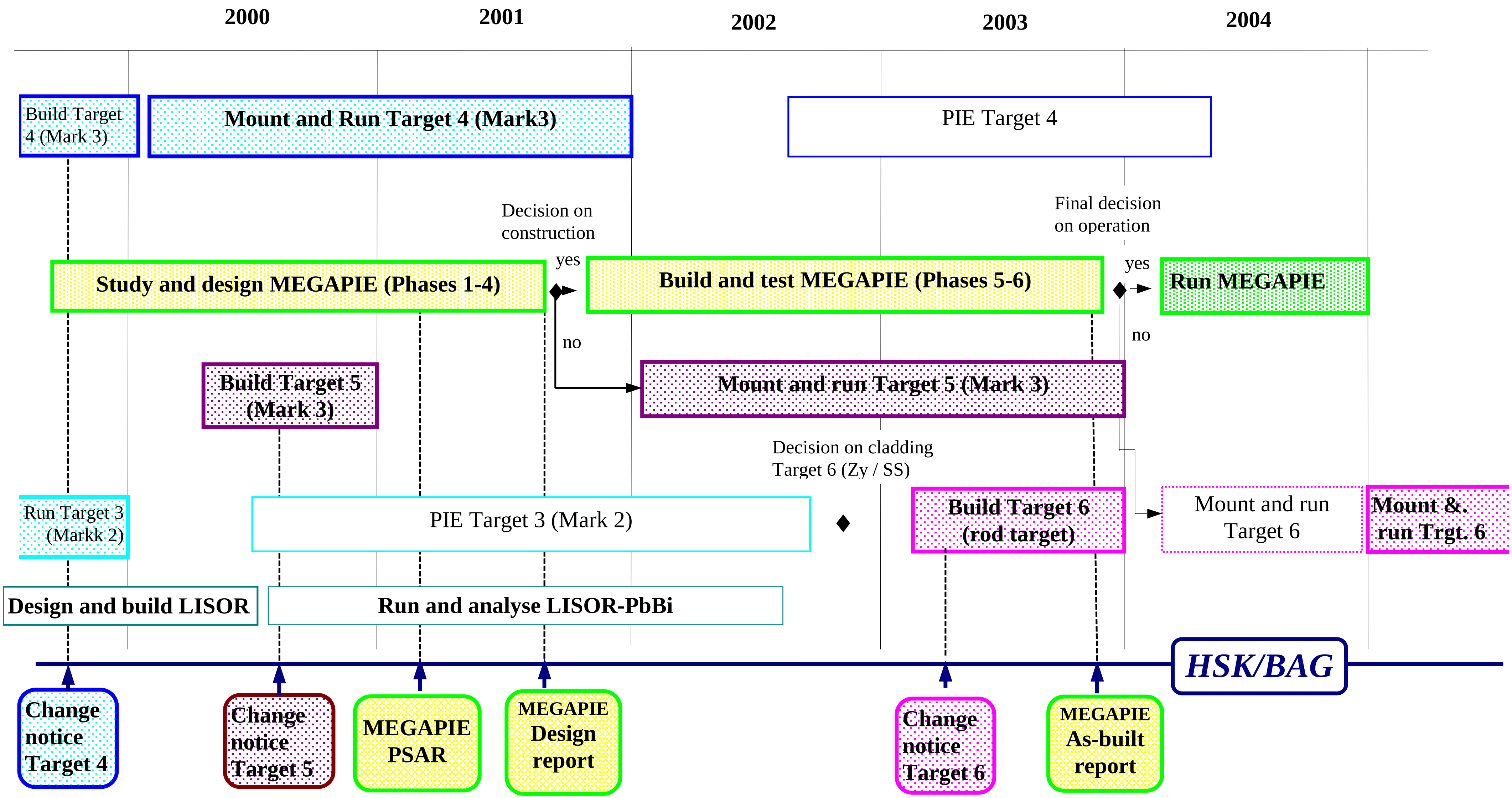

Figure 3 : *Target Development SINQ - Master Plan. Information from the analysis of used targets and the LiSoR experiment will be essential to decide on the duration of the of the service time of the MEGAPIE target.*

MEGAPIE Liquid Metal Target for SINQ

conceptual draft

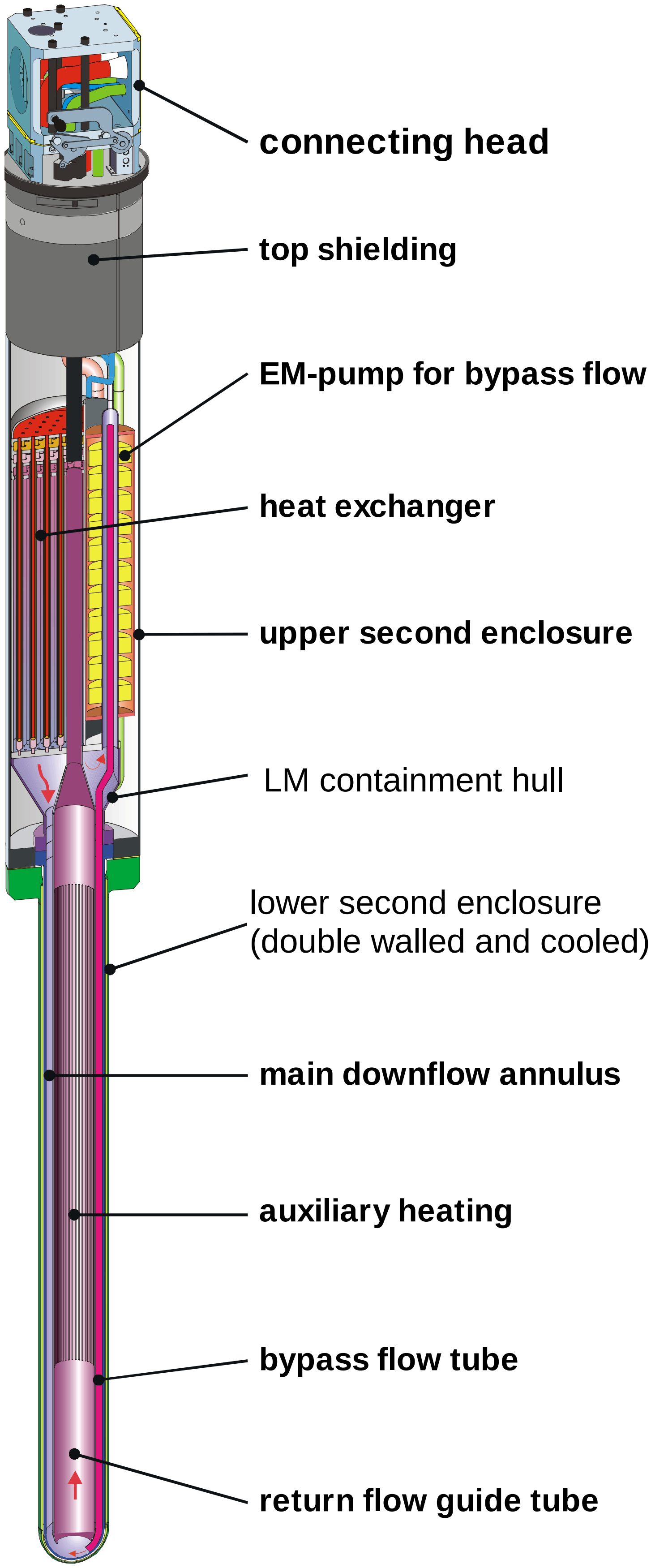

Figure 4: *Conceptual draft of the MEGAPIE Target for SINQ*

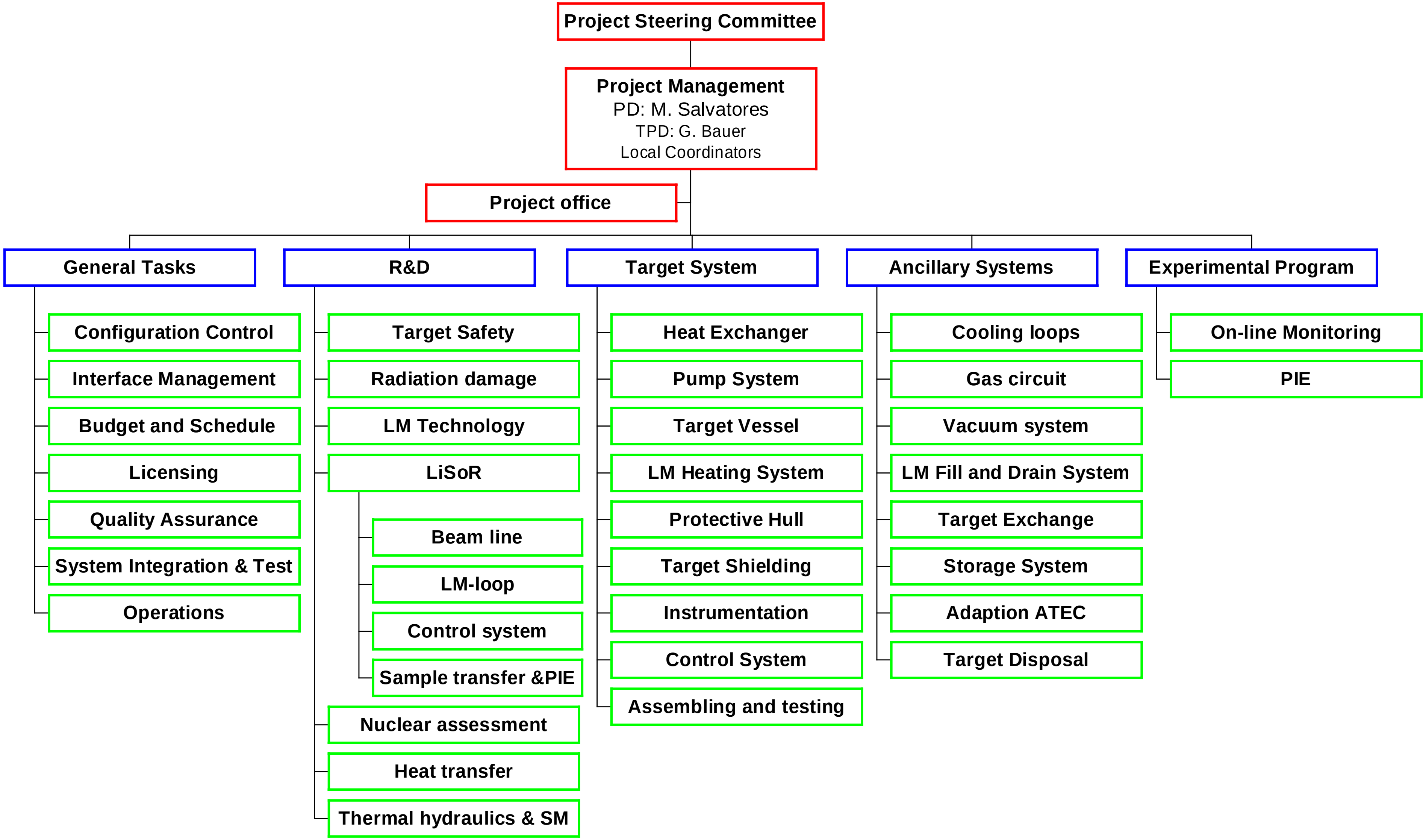

Fig. 5: *Proposed Work Breakdown Structure (WBS) for the Realisation of MEGAPIE*