# Control System Upgrade program of the PSI 590 MeV Proton Cyclotron

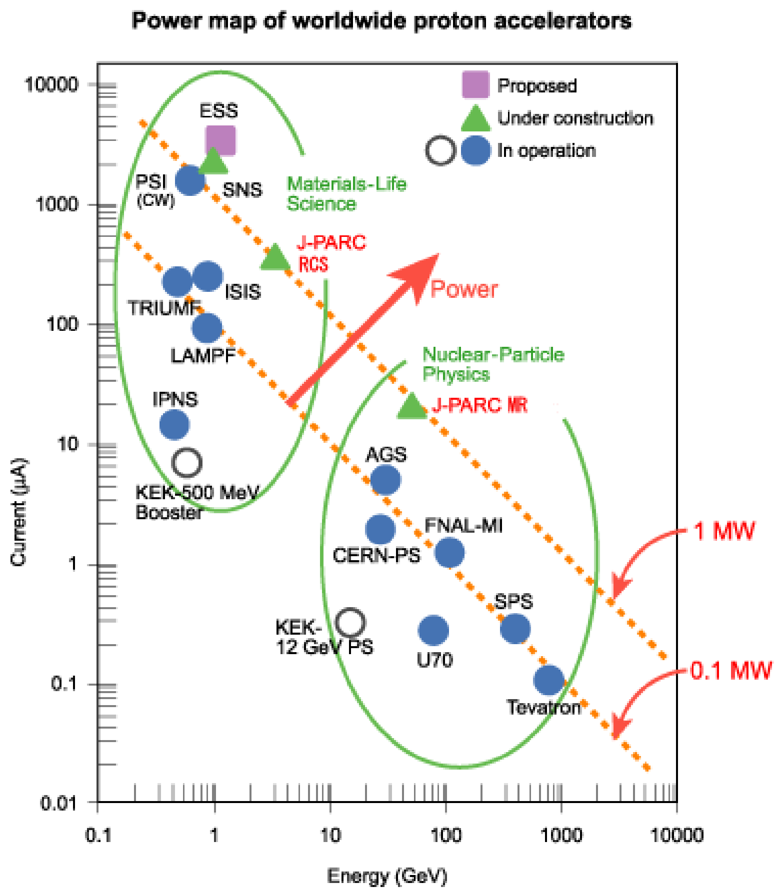
**T.Korhonen, D.Anicic,A.Mezger,D.Vermeulen**

***representing the work of several people of the controls and other sections at PSI***

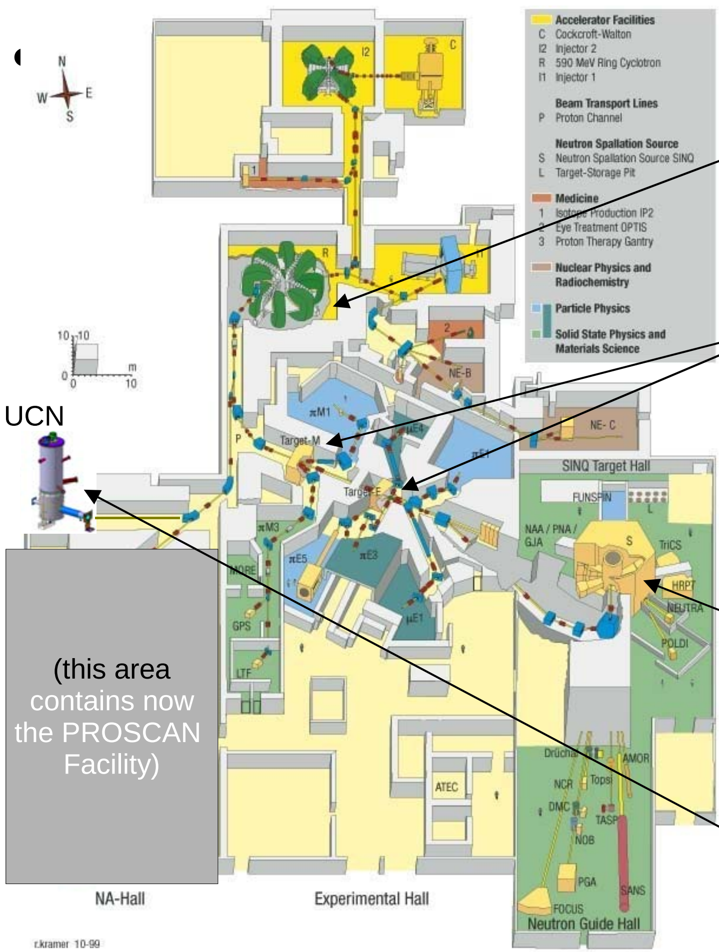
- **Short introduction to the PSI Proton Cyclotron**
- **Motivation, constraints and plan**
- **Some hardware solutions**
- **Software issues we have encountered (so far)**
- **Wins and losses**
- **Summary**

# Introduction to the PSI Proton Cyclotron

- **History**
  - **The PSI Ring cyclotron was commissioned in 1974**
  - **During the years, the main use has shifted from particle physics to applications of neutron scattering and uSR (which also motivates to keep the machine going)**
- **Present**
  - **Beam current 2 mA, 1.2 MW beam power. Still a world record in (continuous) beam power**
  - **Successfully operated a liquid metal target (MEGAPIE) in 2006**
  - **Beam current upgrade program is in progress (many parts are already finished), goal is 3 mA**



# Introduction to the PSI Proton Cyclotron




Ring Cyclotron, 590 MeV energy, 2 mA beam intensity (regular operation at >1.9 mA): about 1.2 MW of continuous beam power

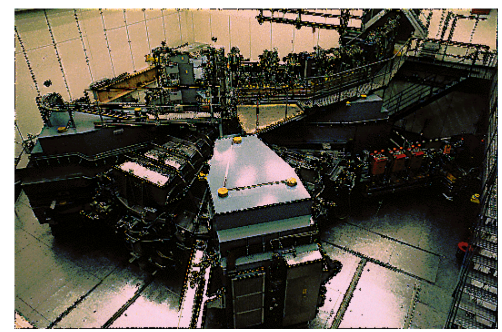
Intermediate targets and secondary (muon and pion) beamlines:
- Muon spin rotation (uSR) experiments (solid state physics)
- Particle physics experiments

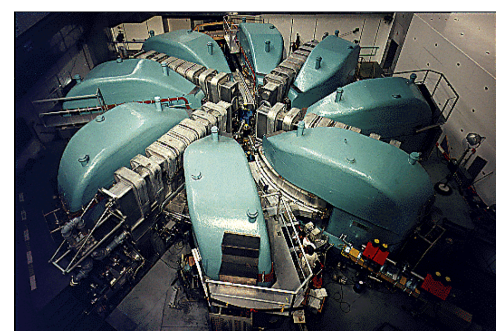
SINQ (Spallation Neutron Source)

UCN (Ultracold Neutron Source), in preparation

# Introduction to the PSI Proton Cyclotron

- The facility
  - Three accelerators
    - Cockroft-Walton, Injector and main cyclotron
- Control system
  - About 100 CAMAC crates
  - Expected to be replaced with ~60 VME64x crates (larger degree of integration)
  - In-house developed software "ACS" (not to be confused with other software packages with the same acronym).





# Main motivations for the upgrade

- **The hardware is aging and needs to be replaced**
  - **Several generations of hardware, developed by people who are not around anymore, sometimes not well known (do not touch)**
  - **Limited number of replacement and spare cards**
  - **Wearing parts need more and more maintenance (CAMAC power supplies, fan units) and special skills**
  - **No new developments done in CAMAC, desire to standardize the hardware**
- **The same controls groups (section) are responsible for all PSI accelerators Cyclotron, PROSCAN, SLS, XFEL (project)**
  - **Use standard tools, hardware and software whenever possible, everywhere**
  - **Make it easier for controls people to work on different projects within PSI**
  - **Make it easier for different groups to work on different projects**
    - **Diagnostics, RF, etc.**
  - **Concentrate efforts on EPICS development**

# Constraints of the upgrade

- **Operation shall not suffer**
  - **Existing functionality should at least be reproduced**
  - **Any major changes shall be done during the yearly shutdown**
  - **Operation safety needs to be guaranteed**
- **New target facility (UCN)**
  - **Will get a macro-pulsed beam(1% duty cycle to UCN, 99% to other targets/SINQ), switched by a kicker magnet**
  - **Need to introduce synchronization hardware**
- **Beam current upgrade**
  - **Need to introduce new (diagnostics) hardware that can cope with the high (and low) currents**
    - **For example, new BPM electronics**
  - **New developments are all in VME**

# Evolution: rough sketch

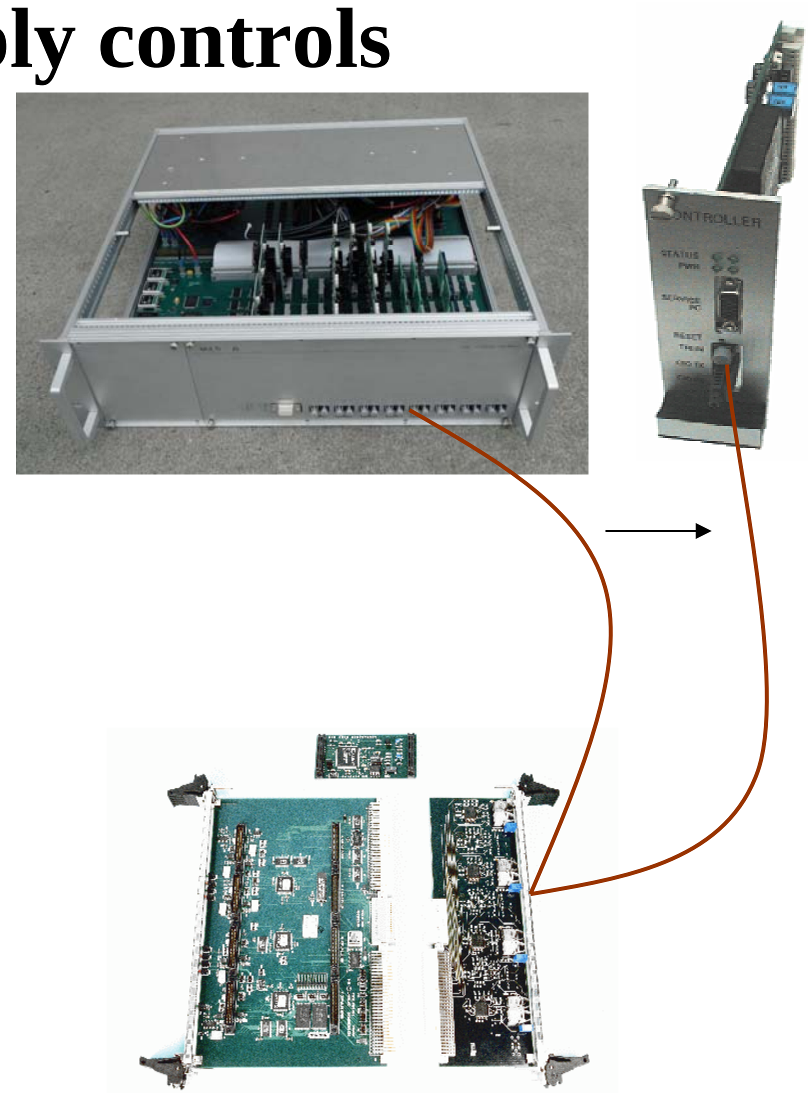
- **First: replacement of the controls hardware**
  - **Will be done gradually, as soon as the replacements become available**
    - **Timescale is ~4 years from now**
- **Then, migrate to EPICS on the low (IOC) level**
  - **There would be little benefit writing drivers for hardware that we are going to replace soon anyway**
- **Port as much as possible the good features of the "ACS" software to EPICS**
  - **Extensive configuration database, all IO and applications configured from a single source**
  - **Device discovery using the configuration data**
  - **Several smaller features that are used in application development and people are familiar with**
- **Finally, convert all the applications, and modify them to best utilize EPICS facilities**
  - **Develop some new record types to reproduce features of the existing system**

# Hardware issues

- **New generation of electronics**
  - Use the same hardware that is and will be used for other projects and facilities, as far as possible
  - Not everything can be covered with standard hardware
  - Many solutions are already developed and even deployed, some are under development (some examples in the next slides)
  - The beam switching operation of the new UCN source requires a new method to synchronize the operation of several components (beam kicker, diagnostics, interlock systems.)

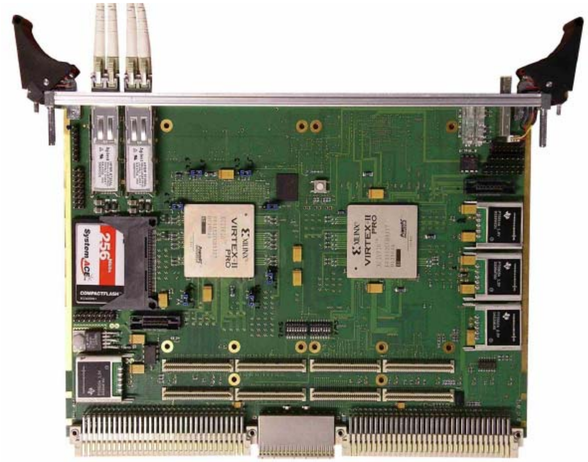
# Power supply controls

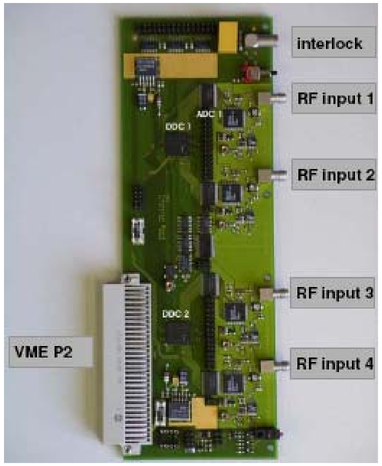
- Most power supplies are old, analogue controlled. Gradually being replaced by new, digitally controlled ones. Problem: this process will be slow! (> 10 years)
- Each PS has a local controller, connected by a fieldbus (“Road-C”, or CAN)
  - Uncomfortable mixture, difficult to troubleshoot
- Solution: MultiIO (FPGA-based controller, with AD/DA, DI/O)
  - Control interface is compatible to the “PSI” digital power supply
  - Can be simply “dropped in” to the existing controls. Changing to digital PS a matter of replacing a control cable (optical fiber)
- Makes us independent of the PS replacement schedule



# Beam diagnostics

- The diagnostic electronics needs to be rebuilt as well
- The solutions are based on a FPGA-based board and signal conditioning boards for each application
- The same base board with different firmware is used for several applications
- The “VPC”-board was developed at PSI but is commercially available from a company





# Synchronization

– For the UCN operation, the beam kicker, diagnostic devices and the interlock system need to be synchronized
  - We will be sweeping a >1 MW beam with a kicker! (reliability is essential)
  - Diagnostics need to be warned of a coming (or disappearing) beam
  - Experiments want to know about the (regular) beam interruptions
  - Interlock system needs to know when the kick happens

– Here we can utilize the timing system developed for SLS (but use the newer evolution versions of the board)
  - Overkill in terms of precision (not needed for injection, for example) but is a well-known system for us (easy to integrate)
  - Several useful recent enhancements: real-time, deterministic data distribution, configurable I/O blocks (like interlock input)

# Software migration to EPICS

- **There is a functioning software solution that has to be replaced**
  – Lots of applications with their look and (especially) feel
- **In many ways, the architecture is not that far from EPICS**
  – But, there are a number of differences

# Encountered software issues (#1)

- **Differences in how things work in ACS vs. EPICS**
  - Different paths of evolution, different philosophies: Buffered I/O and direct network I/O (reading/writing of values)
  - Consequently, the applications have been written with different assumptions (do/how do/I know that my value went to the hardware? When was this value read?)
  - The behavior has to be learnt and understood

# Encountered software issues (#2)

- **Thick vs. thin clients**
  - **Where to put the application intelligence?**
    - **ACS: In the workstation layer**
    - **EPICS: both client and server (IOC) layer possible, but many functions fit best to the IOC level**
      - **For example, operation sequencing following a fixed schedule**
  - **This has implications on how to best proceed**
    - **In EPICS, abstraction starts at device support level (mapping to record types)**
    - **Old applications have not been written with the same abstractions. Will probably need intermediate steps**

# Merits of evolution

- **What will we benefit from this?**
  - **Maintenance**
    - **One set of hard- and software to be looked after**
  - **New features and possibilities**
    - **Low-level intelligence (instead of client level apps)**
      - **Alarms, pushing alarms**
    - **IOC-level communication, synchronous actions, time correlation**
  - **Co-operation, sharing of knowledge**
  - **Opportunity to improve application interface(s)**
    - **Introduce a middle layer? (depends on progress with other projects)**

# Merits of evolution

- **What we do not want to lose?**
  - **Database-driven configuration**
    - **Consistency of the system, everything from a single source**
    - **Lots of know-how, but mapping to EPICS structure is not a simple task**
      - **Implementation rules not very strict for device connections (I/O parameters)**
  - **Device & property discovery in application layer**
    - **By-product of the database**
    - **Can be resolved if we manage to (re)implement the configuration database**
    - **Need support from channel naming**

# Merits of evolution

- **What will we lose?**
  - **Diversity**
    - **Danger of feeling (too) happy with what we have**
    - **Taking things for granted**
  - **Some features**
    - **Try to minimize the loss by design**
  - **Full database configuration will be a tough goal**
    - **We may have to compromise between flexibility and full consistency**

# Conclusions

- **Difficulties**
  - **Lots of constraints to solve**
  - **Readjusting the style of work**
- **Challenges**
  - **Try to provide the best possible systems for the future**
- **Opportunities**
  - **The new(er) generation has a chance to re-discover the machine**
- **Fun**
  - **We hope to learn a few new things along the way**

**Thanks to people in and outside of PSI who have participated in discussions and contributed ideas (in various areas)**