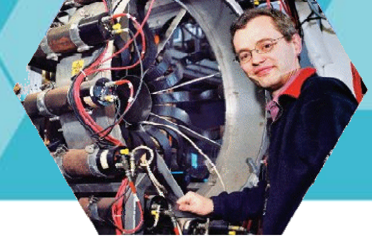
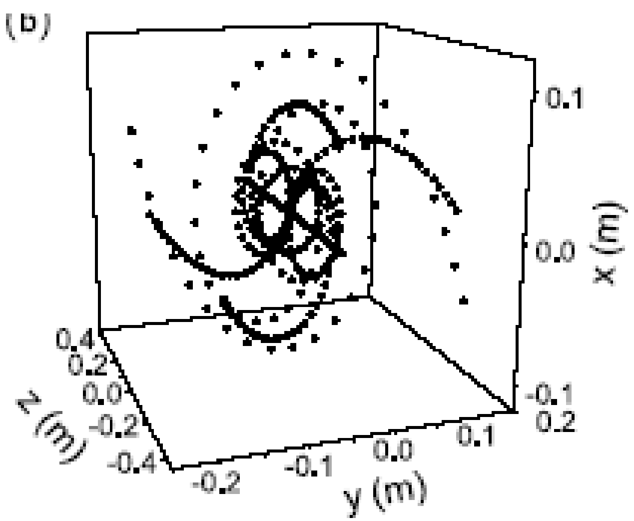
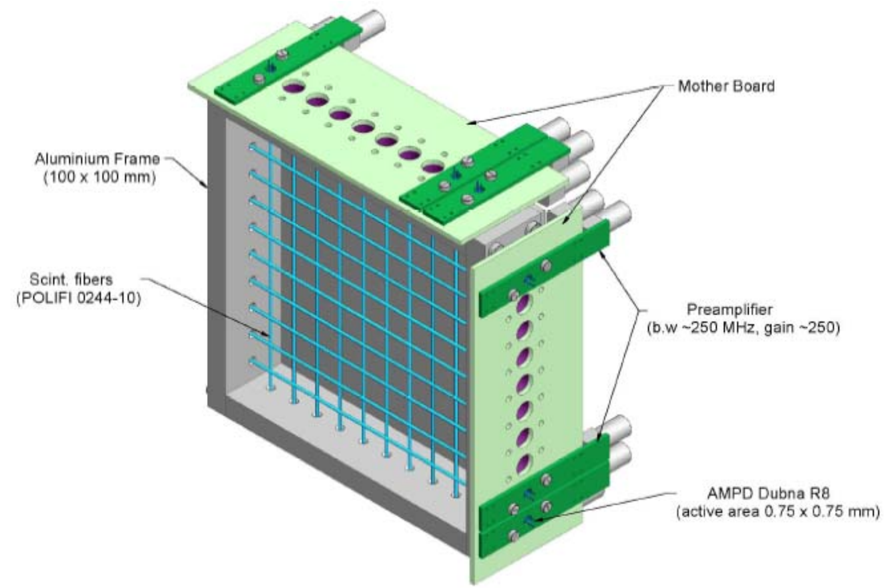


JRA8: Muons

Philip King,
ISIS Muon Facility





Summary of Muon JRA in FP6

- **Partners:**
  - University of Parma, Italy (Co-ordinator)
  - ISIS Pulsed Muon Facility, UK
  - PSI Continuous Muon Facility, Switzerland
  - University of Oxford, UK

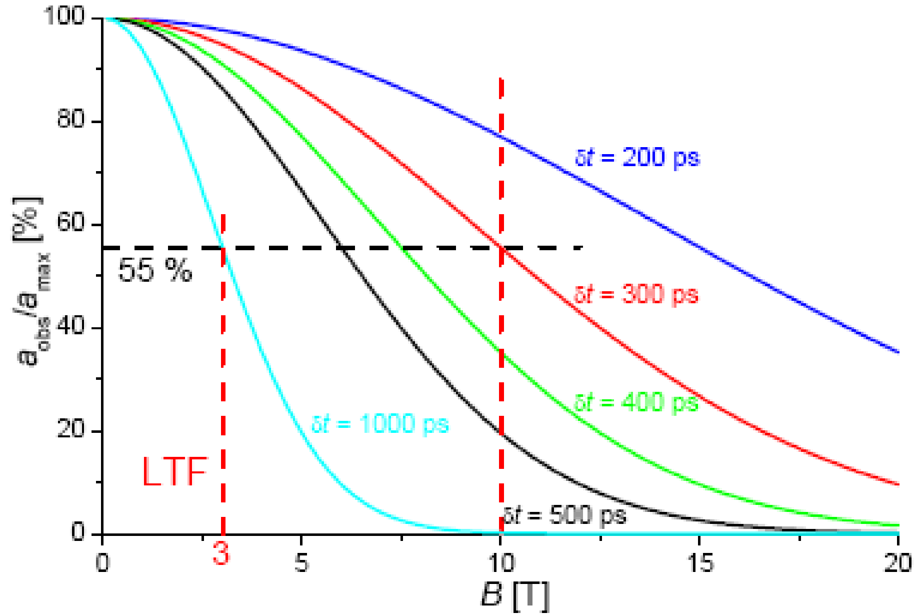
- **Work Packages**
  - WP1: Detector development (PSI responsible)
  - WP2: Development of instrument simulation (Oxford responsible)
  - WP3: Advanced muon technique development (ISIS responsible)
  - WP4: Management and dissemination (Parma responsible)

WP1: Detectors

(post-doctoral worker employed)

For high transverse fields

- Need timing resolution < 300 ps
- Small array, close to sample
- Need to be very field-insensitive
- ➔ Test avalanche photo-diodes



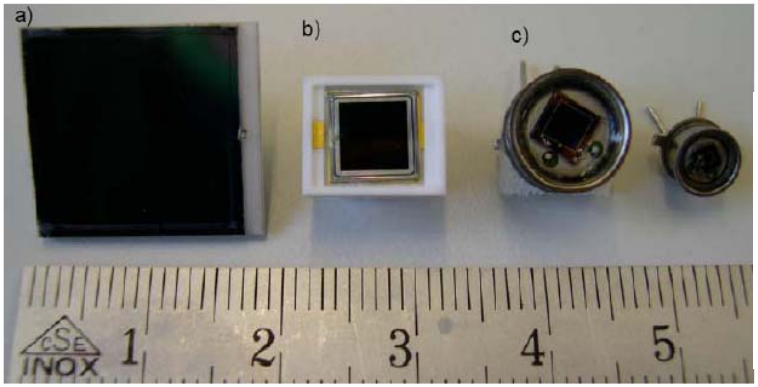
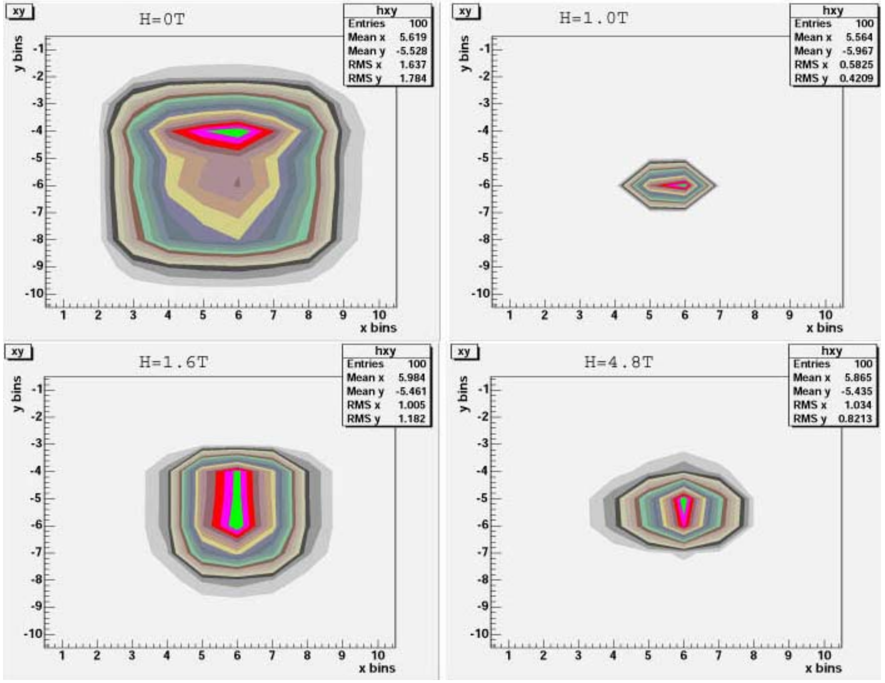


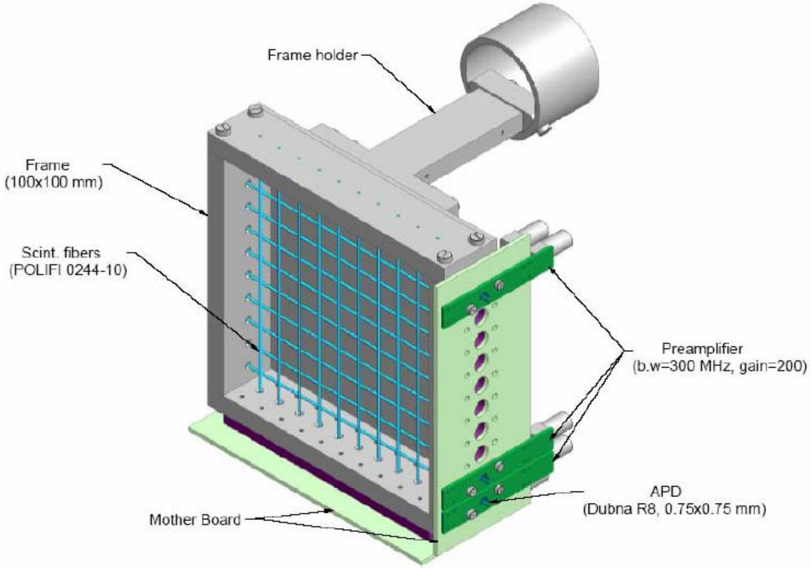
Figure 2. Examples of some state-of-the-art APDs:

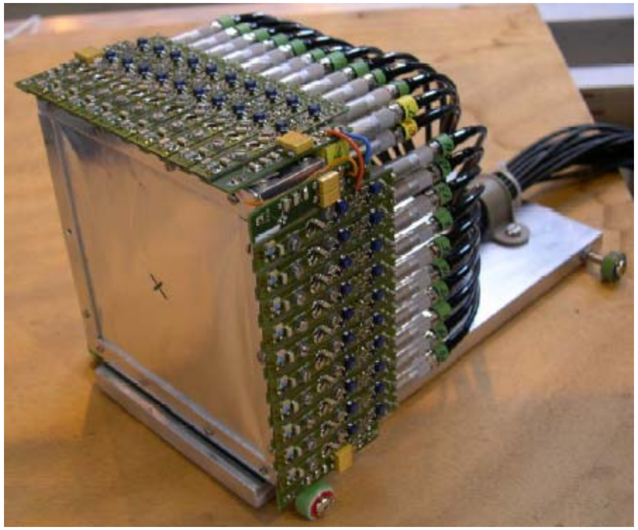
a) RMD S1315 (13 x 13 mm^2); b) Hamamatsu S8148 (5 x 5 mm^2);

c) Dubna R8 AMPDs (2.75 x 2.75 mm^2 and 0.75 x 0.75 mm^2).

- Development of position-sensitive beam profile monitor
  - **Importance:** beam tuning in high fields
  - **Importance:** demonstration of field insensitivity of APDs

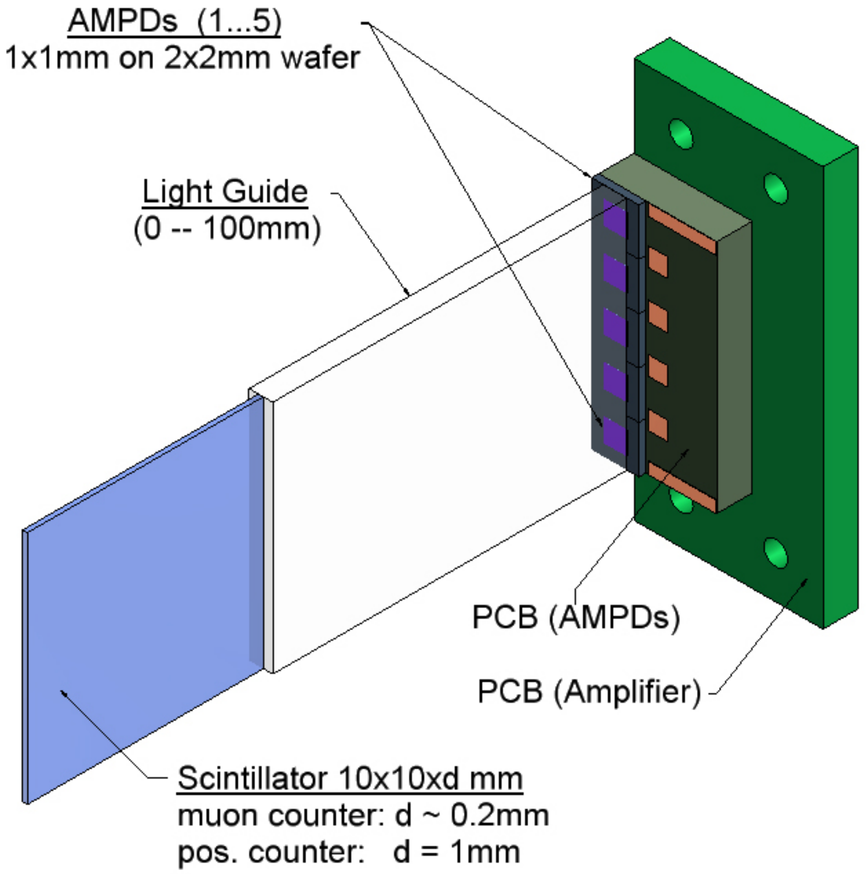




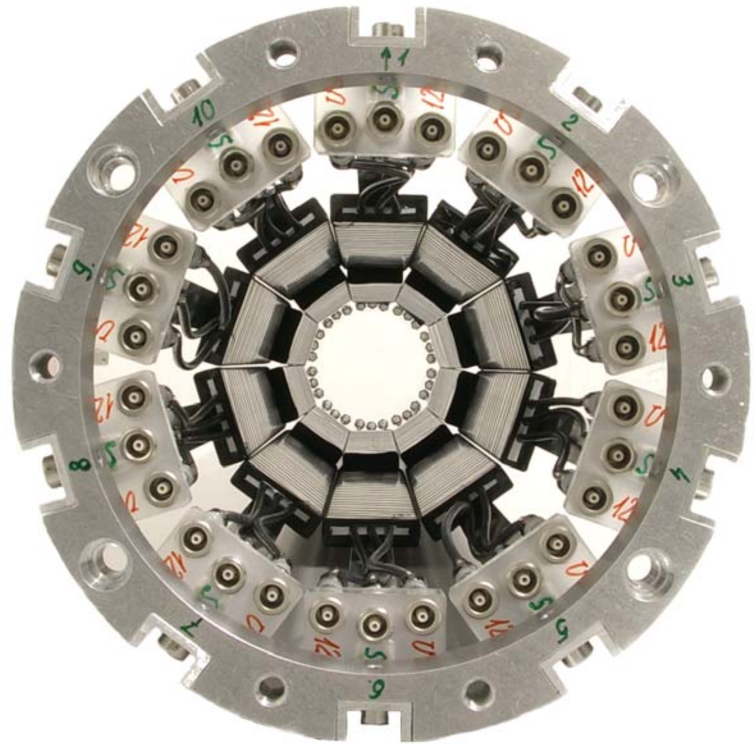


- An AMPD scintillation detector
  - Use of an array of AMPDs
  - Field-insensitive
  - Compact, robust
  - Fast-timing

Importance: demonstration of technology feasibility for detector array

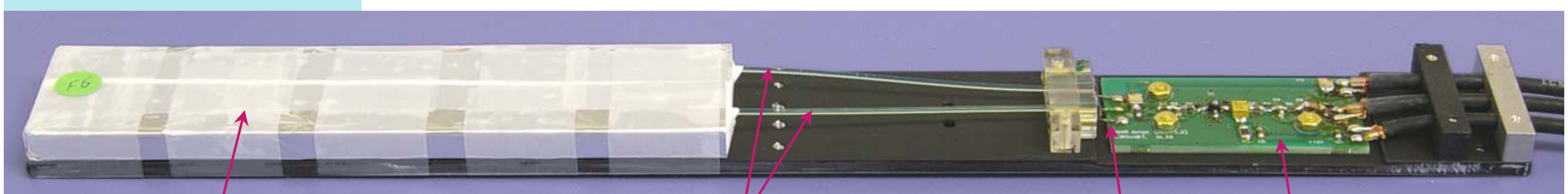


- PSI instrument detector array being replaced by one based on APDs!
- 1m long construction to be inserted into the warm bore of a 5 Tesla superconducting solenoid.



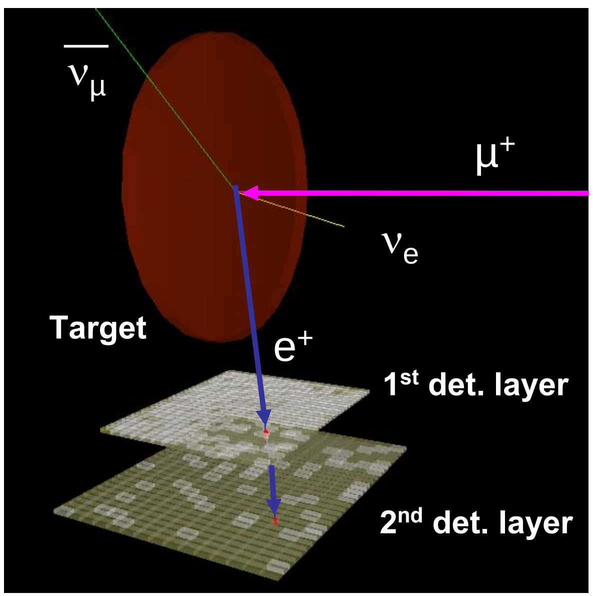
Importance: First muon instrument ever to not use photomultiplier tubes.

Positron counter

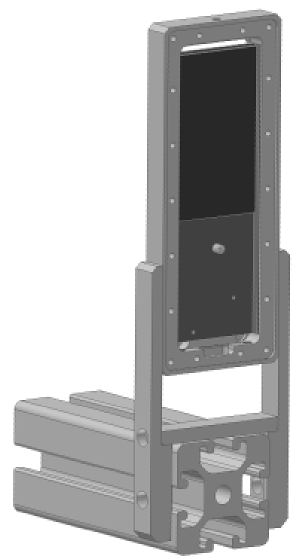


- R&D on e^+ position-sensitive detectors (silicon and/or scintillating fibres):
  - Particle origin reconstruction
    Importance: improved S/N ratio
  - Fine detector segmentation
    Importance: avoid pile-up effects

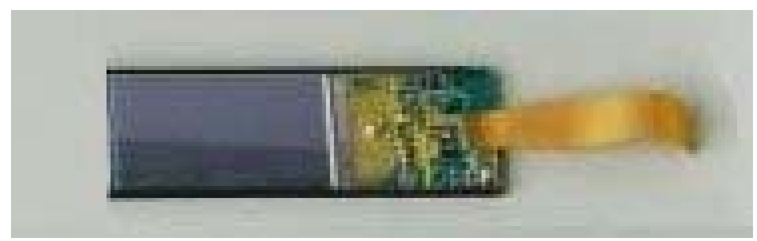
PSD performance testing



PS detector holder (light-tight & cooled)

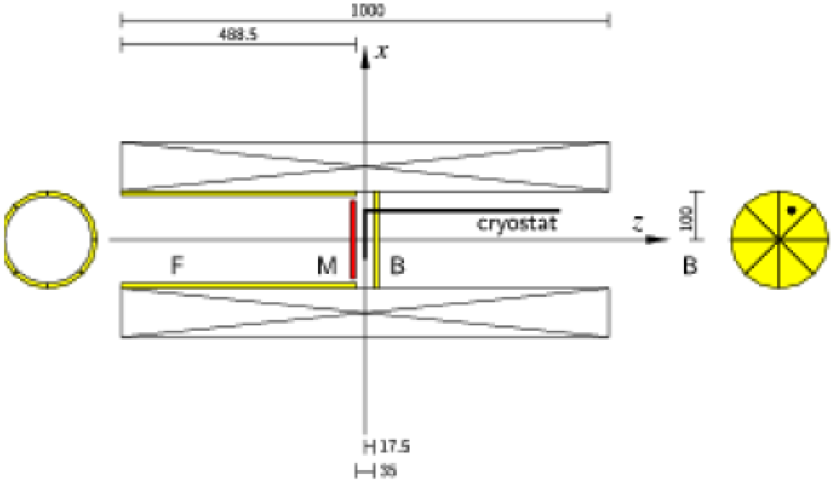


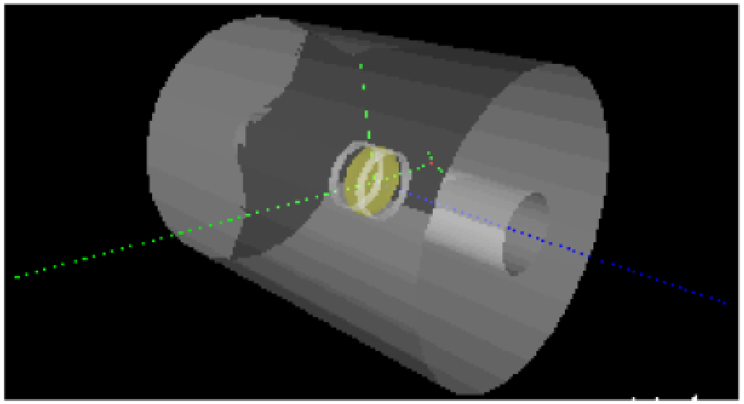
New data acquisition control system (Etrax – Altera Cyclone FPGA)



Solid-state Si pixel detector (adapted from HERA H1 CST)

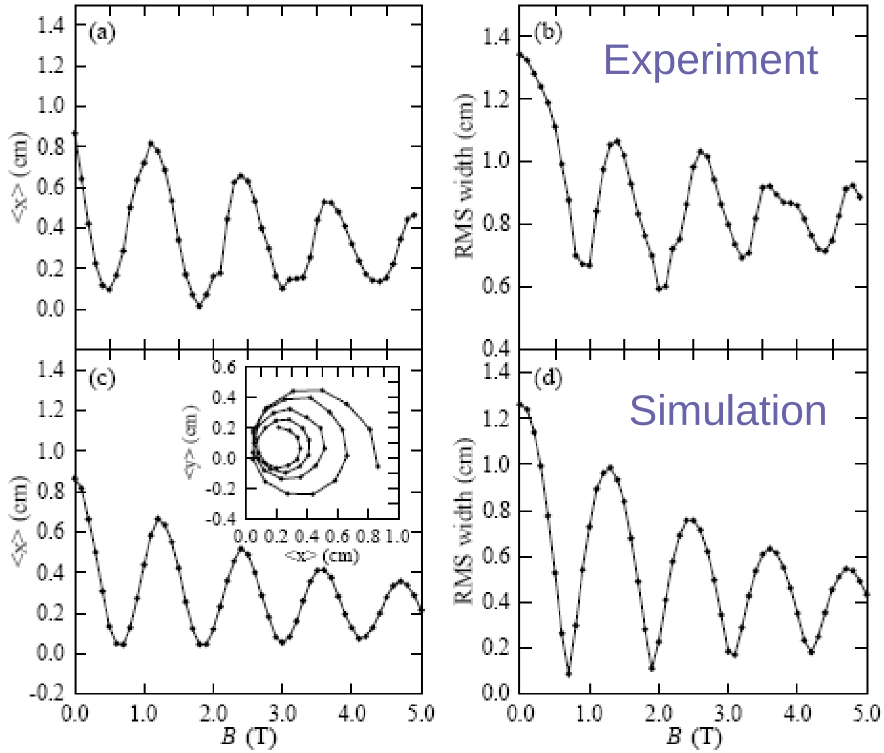
- **WP2: Instrument simulation**
  (Post-doctoral worker employed)
  - Assessment of simulation platforms (GEANT4 chosen)
  - Incoming muon beam and outgoing positrons simulated
  - Variable detector and applied field geometries
  - Experimental code testing
  - Existing spectrometers simulated
  - Extremely important for designs of new instruments

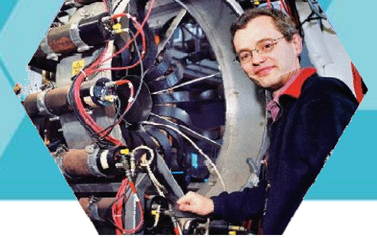


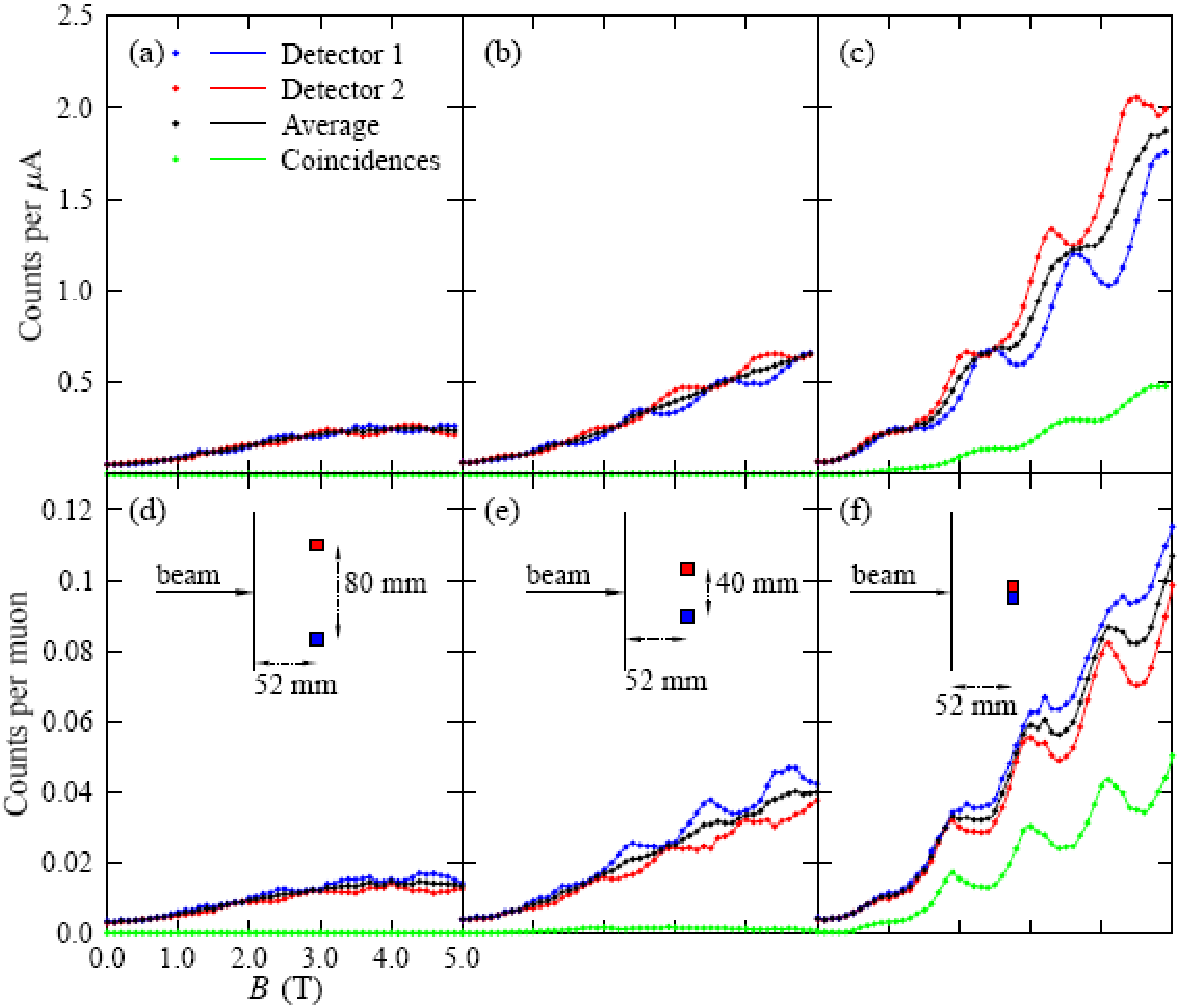


- **Code testing**
  - Beamtime at PSI
  - Effects on incoming muons (using beam profile monitor!)
  - Effects on outgoing positrons (using 2-element movable array)
  - Allowed testing of principles for a real high-field detector array

Importance: code can model incoming muons and outgoing positrons ➔ real instrument design





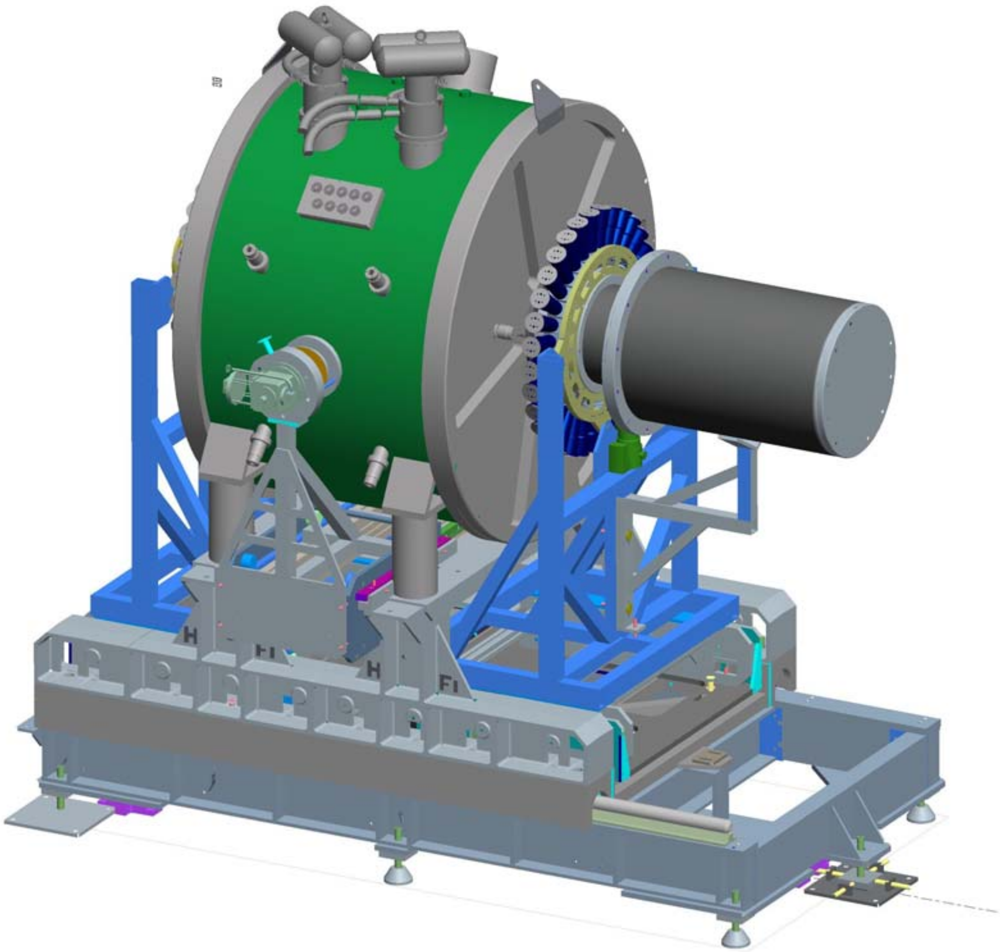


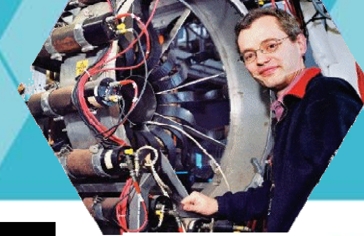
Experiment

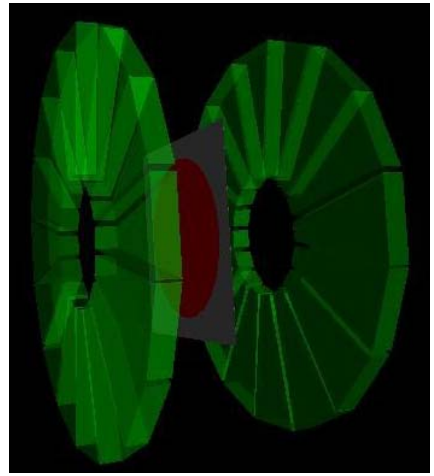
Simulation

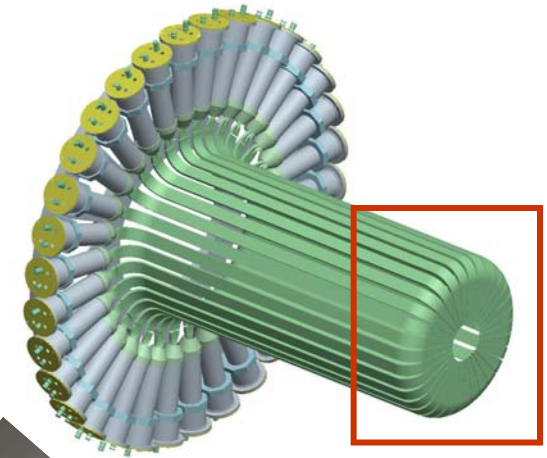
- **Building a real instrument!**
  - High field instrument at ISIS
  - Fields up to 5T
  - Being built at present
  - Due for operation late 2008

  - High field instrument at PSI
  - Presently being designed







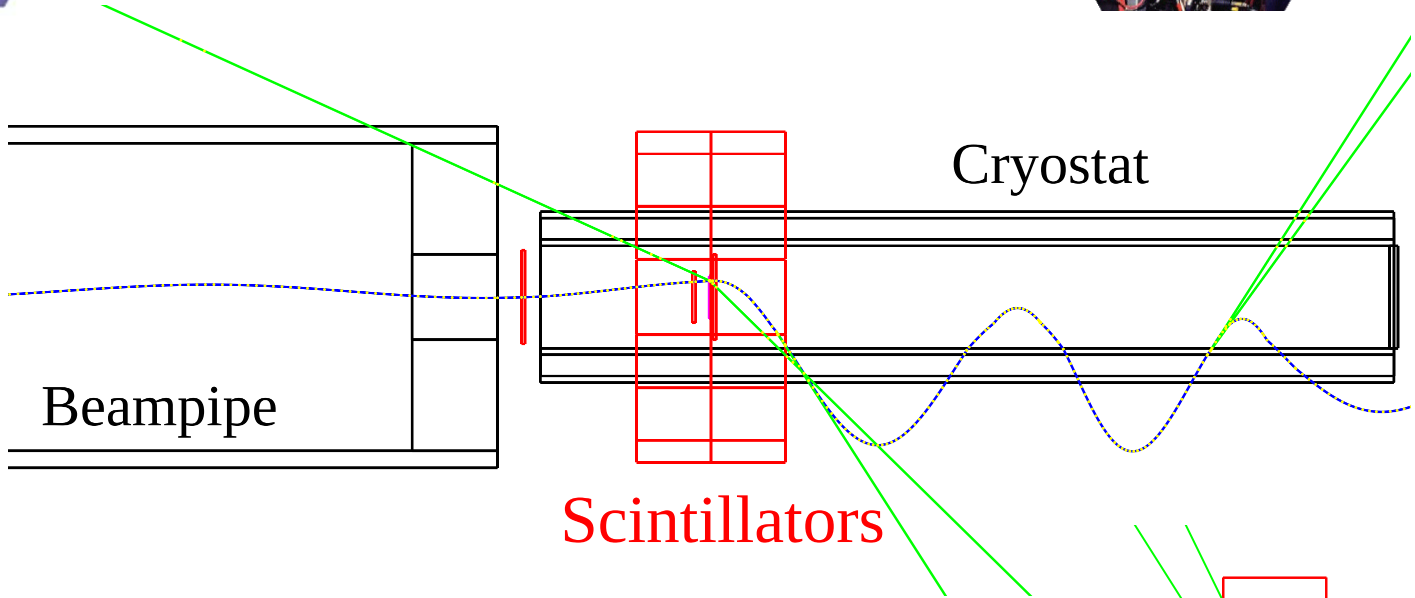


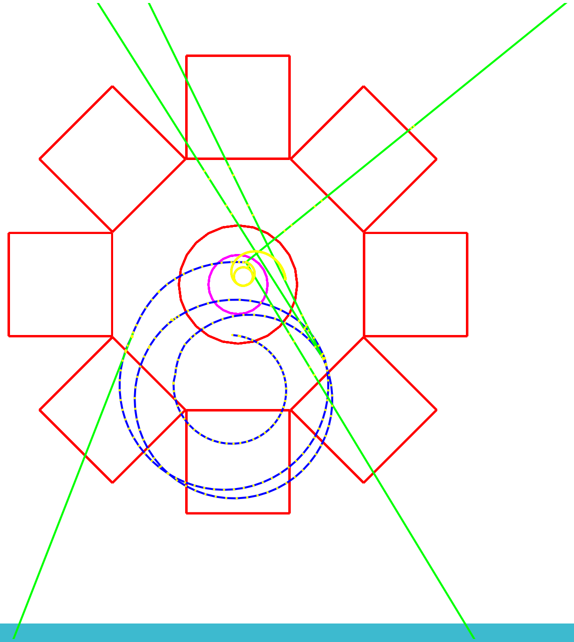
- Code used for
  - Modelling a variety of detector geometries
  - Calculations of solid angle, counts per segment, double counts
  - Detector positions, angles, no. segments, etc. varied
  - Performance as a function of field
  - Also – modelling of incoming beam, effects of field on quadrupole performance

From GEANT . . .

. . . to design drawings . . .

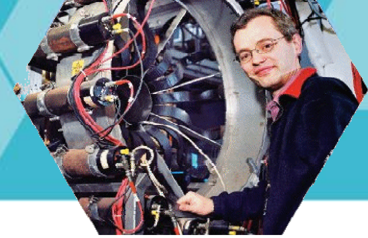
. . . to construction



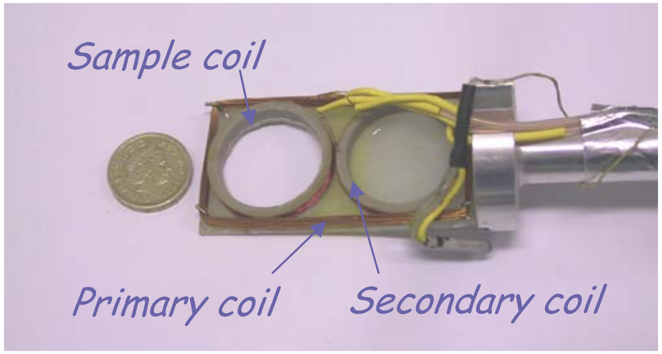


- Similar studies at PSI for a 10T transverse field instrument

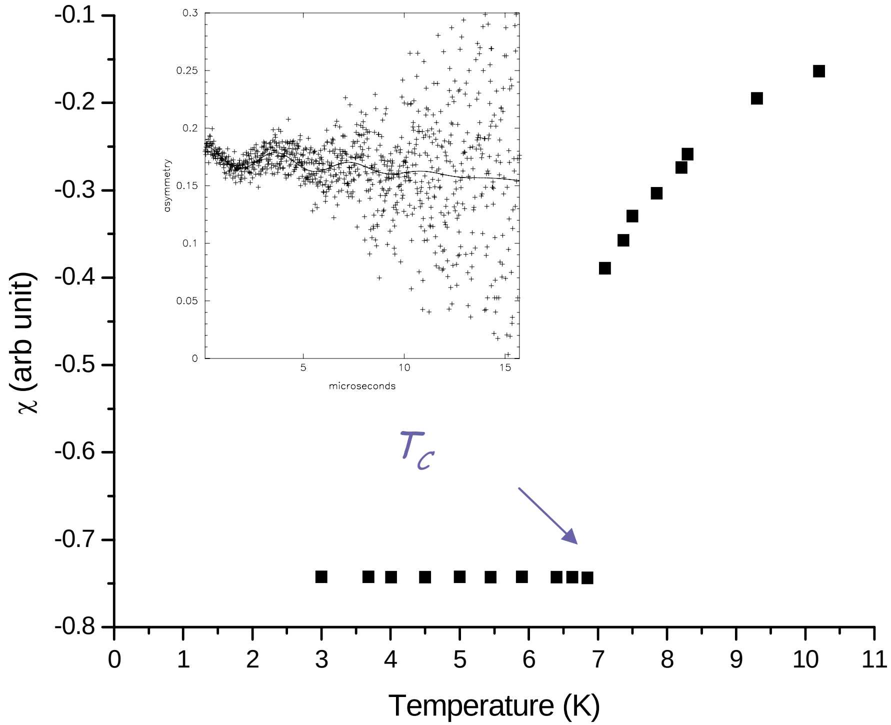
Importance: We are building instruments based on simulations.

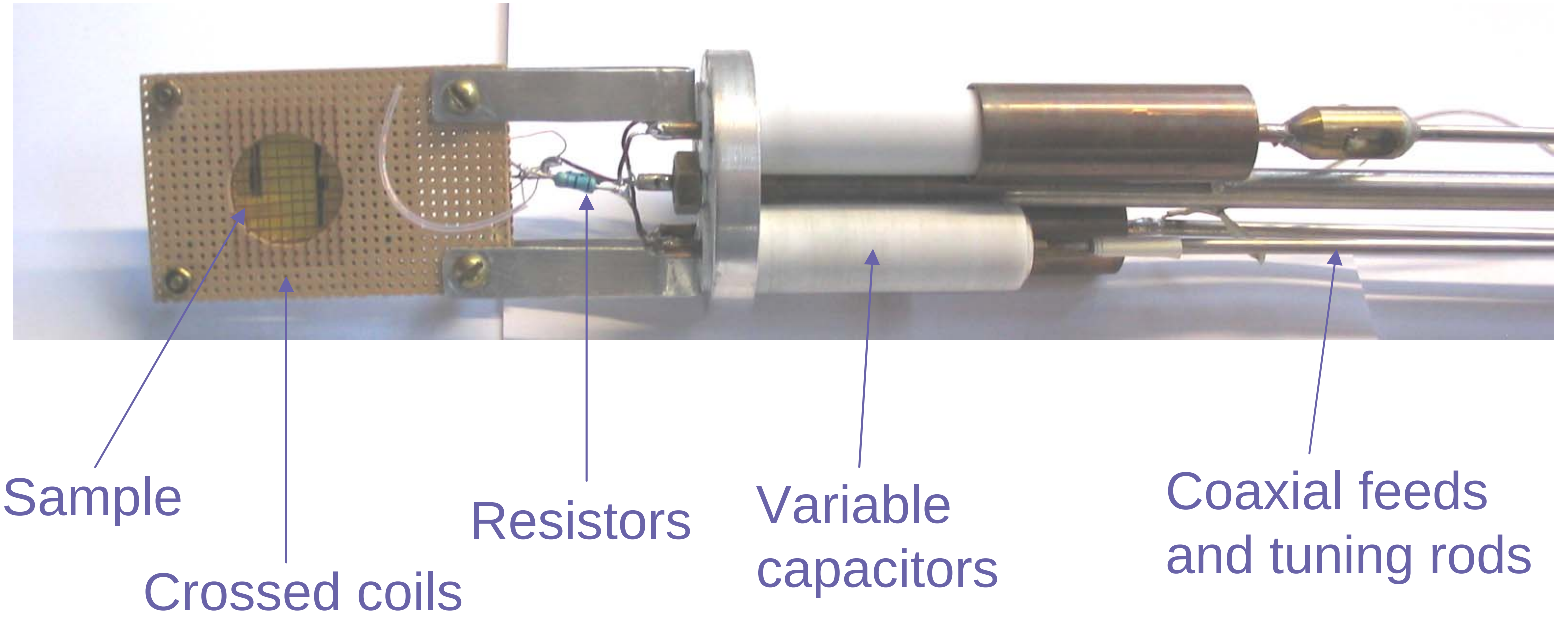


- WP3: Advanced Techniques
  - Simultaneous AC-susceptibility measurements
  - RF-μSR development:
  - Microwave μSR demonstration

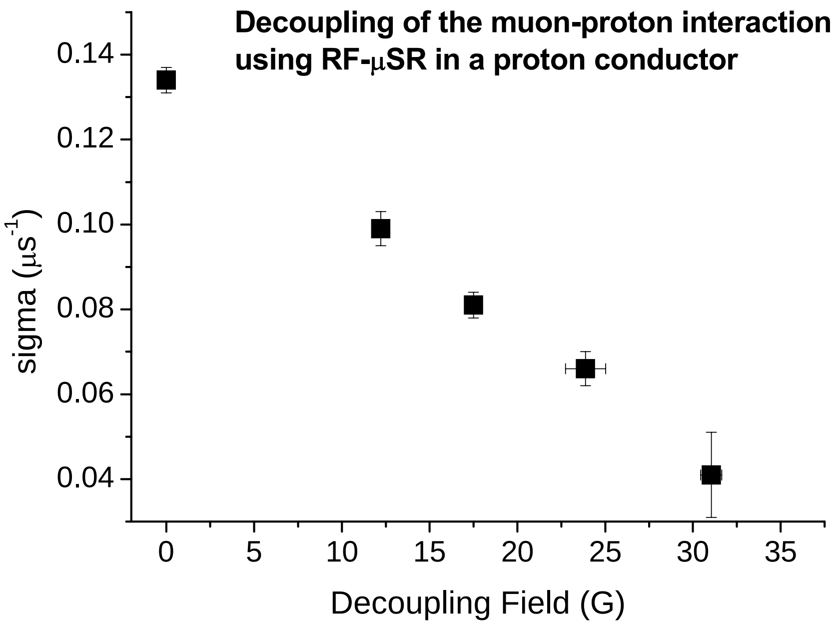


- **AC susceptibility**
  - Simultaneous measurements now possible
  - Figures show initial results – superconducting transition in lead
  - **Importance:** Apparatus now available to user community





- **RF μSR development**
  - Multi-pulse excitation
  - Decoupling
  - Circularly polarised RF



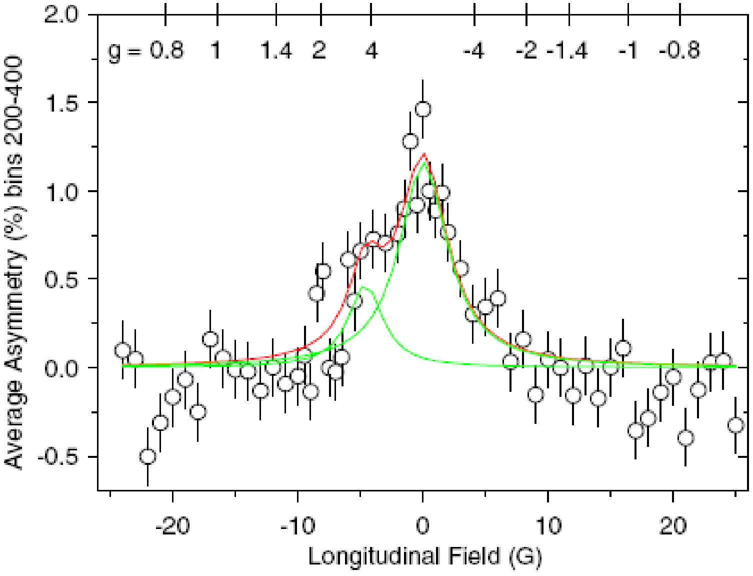
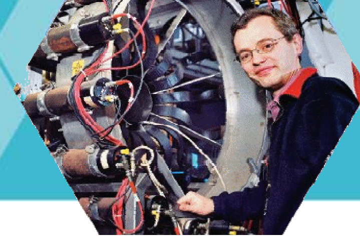
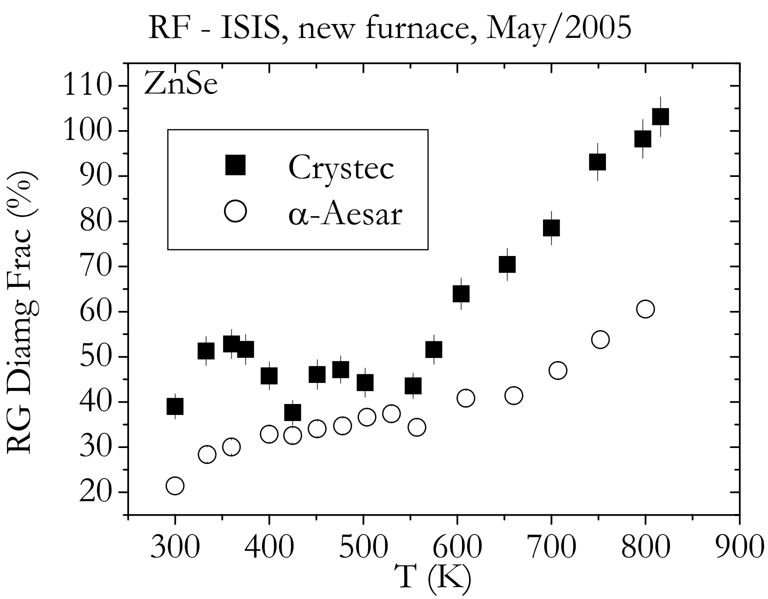


Fig. 4. Resonant repolarisation of the shallow donor state in CdS.

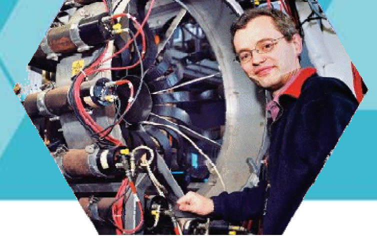
- RF decoupling
- **Importance:** Proton site information in proton conductor $Zr(H_2PO_4)(PO_4).2H_2O$

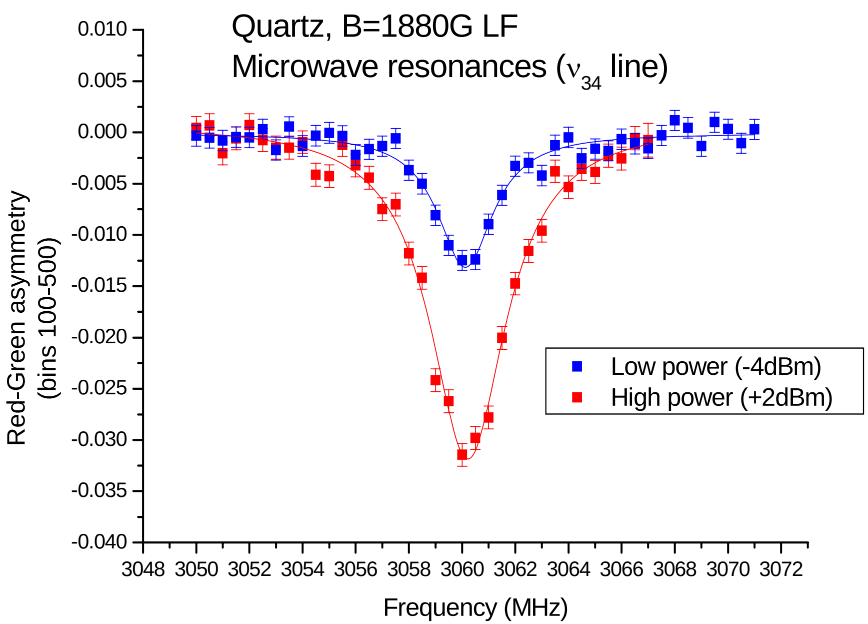
- Circularly polarised RF
- **Importance:** Used for measurement of shallow donor H states in semiconductors

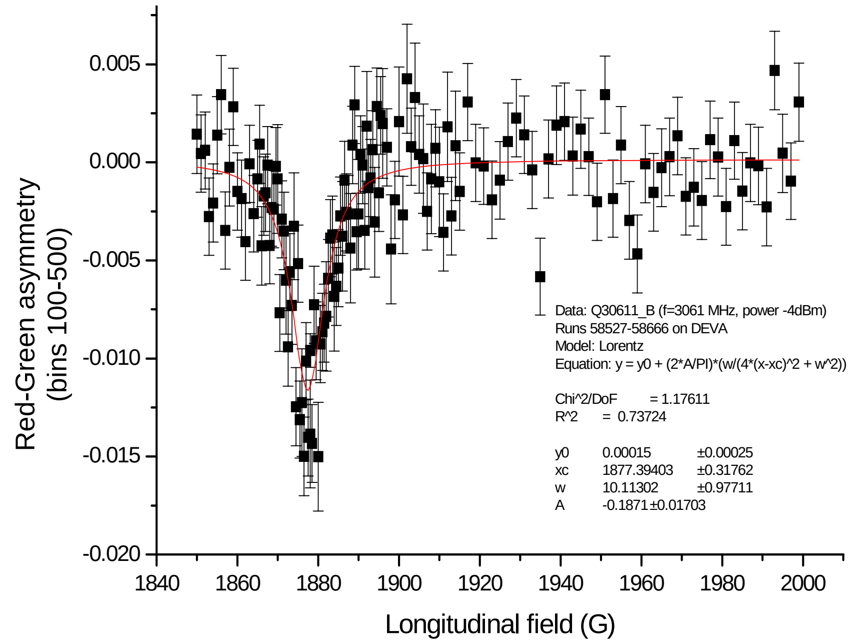




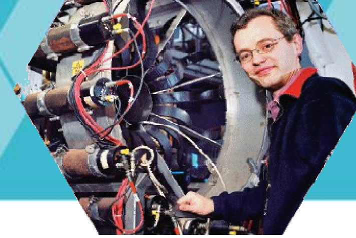
- **RF μSR development**
  - Development of 1500K reflector furnace for RF
  - RF on small samples
  - RF on liquid and gaseous samples
  - **Importance:** techniques in demand by user community





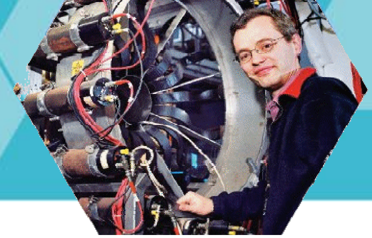


- **Microwave μSR development**
  - Extending frequencies into GHz region
  - Applications in muonium studies including semiconductors
  - Successful demonstration experiment
  - **Importance:** extends pulsed technique range for semiconductors, etc



Publications from the Muon JRA (19 + reports)

- **A scintillating fiber detector for muon beam profile measurements in high magnetic fields** A Stoykov et al., Nucl. Inst. Meth. A 550 (2006) 212
- **Study of avalanche microchannel photodiodes for use in a scintillating fiber muon beam profile monitor** A Stoykov et al., Nucl. Inst. Meth. A (2006)
- **Study of avalanche microchannel photodiodes for use in scintillation detectors** I Britvitch et al., IOP - Journal of Instrumentation 1 (2006) P08002
- **Position-sensitive detectors for muon spectroscopy: design goals, constraints and perspectives** T Shiroka et al., Physica B 374 (2006) 494
- **Simulations of the μSR experiment** T Lancaster et al., Physica B 374 (2006) 480
- **Magnetic field effects on particle trajectories in the μSR experiment: towards a high-field spectrometer** T Lancaster et al., Nucl. Inst. Meth. A 580 (2007) 1578
- **Thin window cell for gas-phase studies by radio-frequency muon spin resonance** C Johnson et al., J. Phys. B **38** (2005) 119-134
- **Muon spin relaxation study of $Zr(H_2PO_4)(PO_4)_2H_2O$** NJ Clayden et al., Phys. Chem. Chem. Phys., 8 (2006) 3094
- **Muonium g-sign determination with circularly polarised RF fields** JS Lord et al., Physica B 374 (2006) 475
- **Exploring the performance of μSR position-sensitive detectors through numerical simulations** T Shiroka et al, Nucl. Inst. Meth. A 591 (2008) 306
- **Development of scintillation detectors based on avalanche microchannel photodiodes** I Britvitch et al, Nucl. Inst. Meth. A 571 (2007) 317
- **Scintillation detectors for operation in high magnetic fields: Recent developments based on arrays of avalanche microchannel photodiodes** R Scheuermann et al., Nucl. Inst. Meth. A 581 (2007) 443
- **Development of microwave resonance at ISIS** JS Lord, to be published in Physica B
- **HiFi – a new high-field muon spectrometer at ISIS** Z Salman et al., to be published in Physica B
- **Scintillating fibres for future μSR spectrometers** T Shiroka et al., to be published in Physica B
- **Simulation of the upgraded ALC spectrometer** K Sedlak et al, to be published in Physica B
- **A new detector system for the ALC spectrometer – first experience with G-APDs in μSR instrumentation** A Stoykov et al, to be published in Physica B
- **GEANT4 as a simulation framework in μSR** T Shiroka et al, to be published in Physica B
- **Fast timing detectors for the high field μSR spectrometers** A Stoykov et al, to be published in Physica B
- + a wide variety of reports (see www.neutron-eu.net/jra8)



Conclusions

- Successful and productive Muon JRA in FP6
- JRA funding:
  - enables development of new technologies for muon spectroscopy
  - fosters collaboration between ISIS and PSI, and with university partners
  - improves facilities for users at ISIS and PSI
- A Muon JRA is proposed for FP7 with four work packages
  - Technologies for high field instruments
  - Developing muon experimental methods: pressure, RF/NMR techniques
  - Muon beamline control and modelling
- Further collaborative and developmental benefits would be expected from this JRA in FP7

