Muon Spectroscopy User Meeting:
Future Developments and Site Calculations
Monday, 16th July

Muon experiments using pulsed laser

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Science & Technology Facilities Council
ISIS

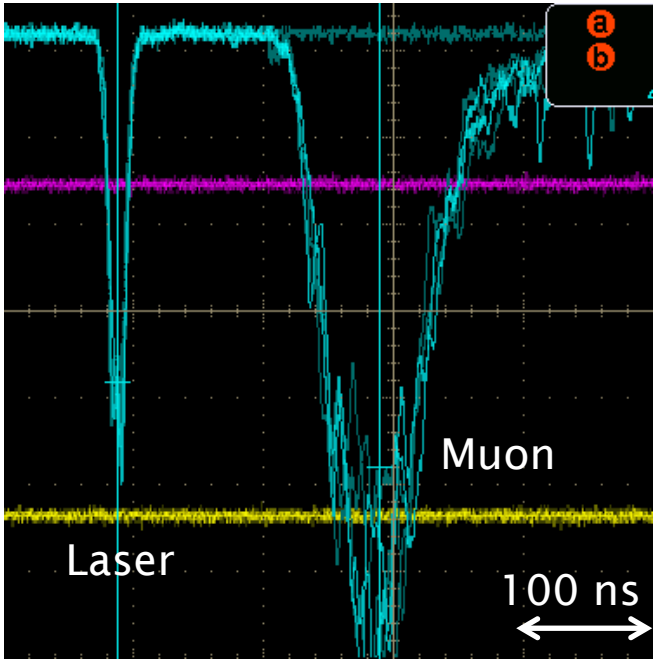
photo-μSR experiments in ISIS

Light-pump muon-probe experiment

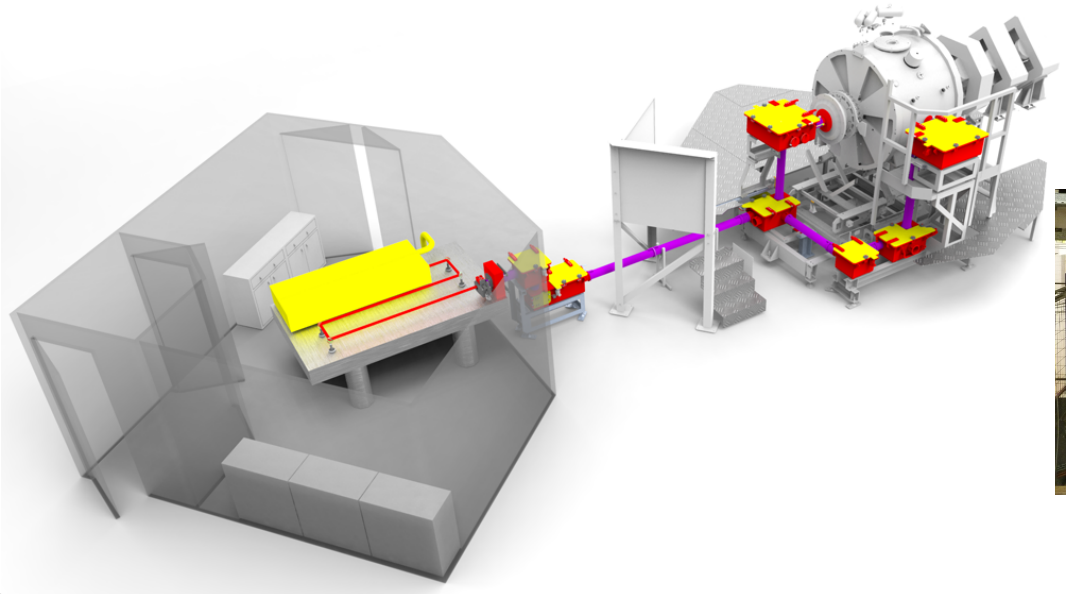
… simple principle

… applicable to many cases

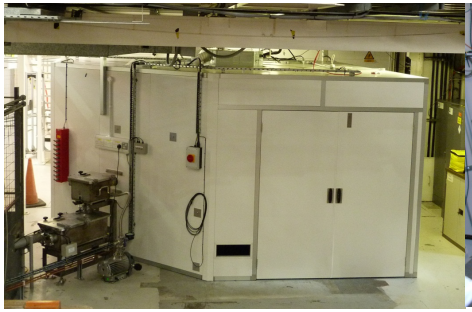
- Time scales are just right:
  Muon 70 ns, Laser 10 ns
- Arbitrary pulse timing
  - wide range of dynamics
- High intensity & large stimulation
  ➔ small disturbance on the system

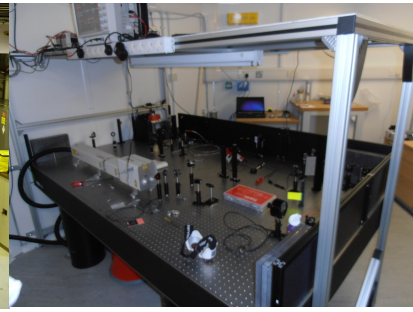


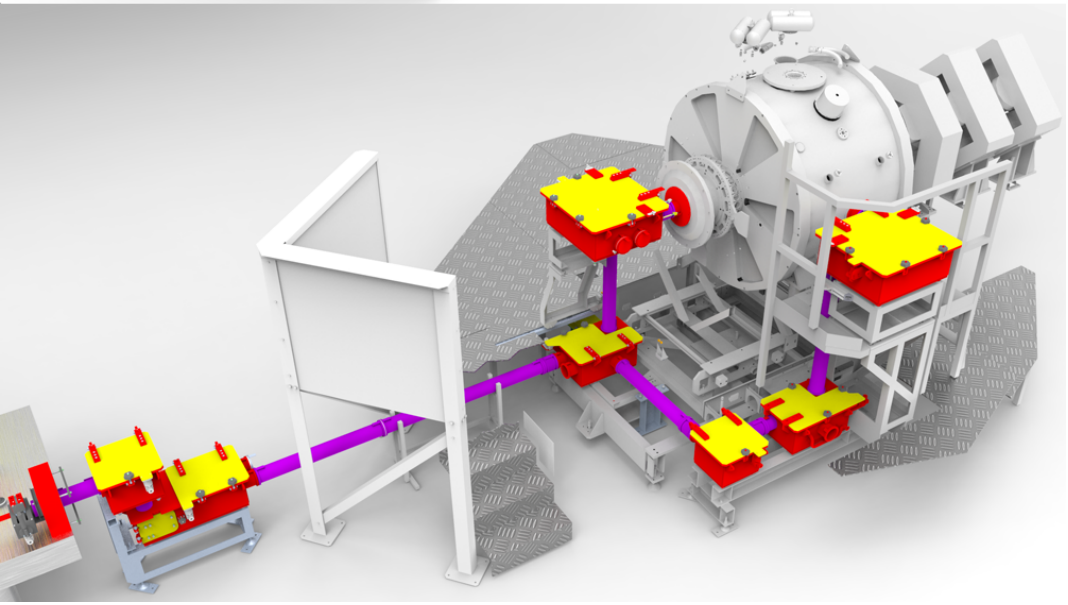
HiFi



- Laser cabin in the down stream of HiFi



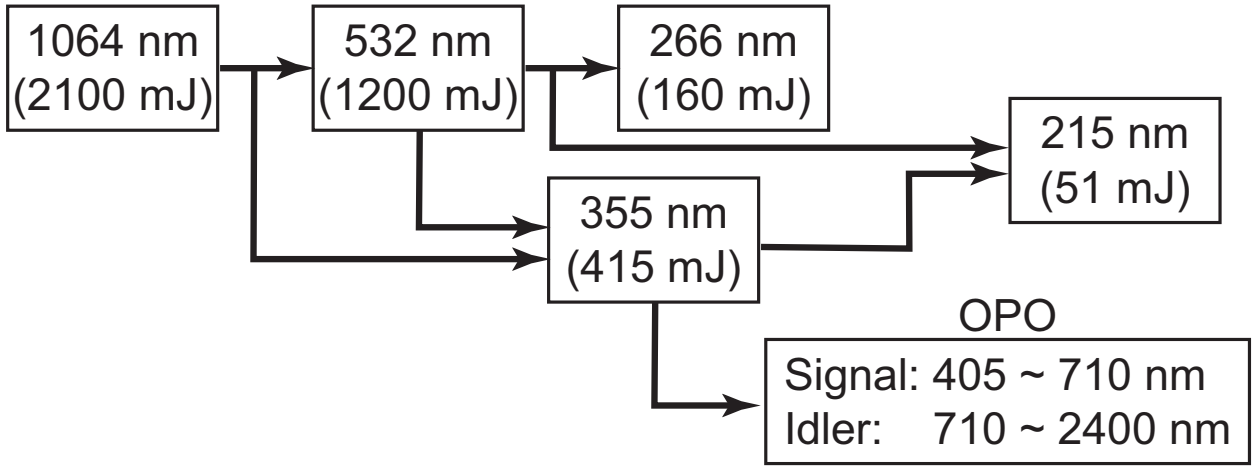


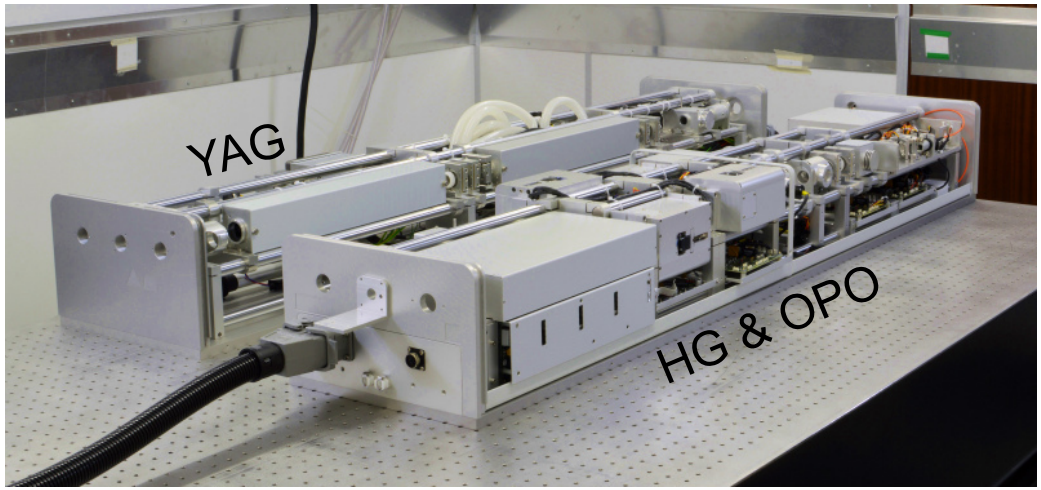


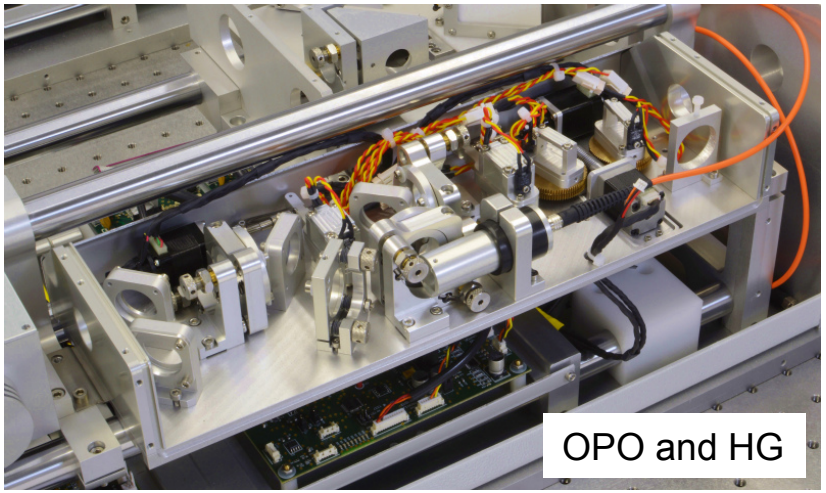
- Laser beam transported through tubes
- “Beam Entry Chamber” is mounted for photo-μSR experiments

HiFi Laser system

- nanosecond Nd:YAG & harmonic generation units
- optical parametric oscillator (OPO)







Project history

- Started in Dec. 2012 for 5 years
- Dr. Alan Drew in QMUL led the ERC funded project
- Main objectives: to probe excited states of molecules with ALC

- So far experiments done mainly in semiconductors
- Making steady progress:

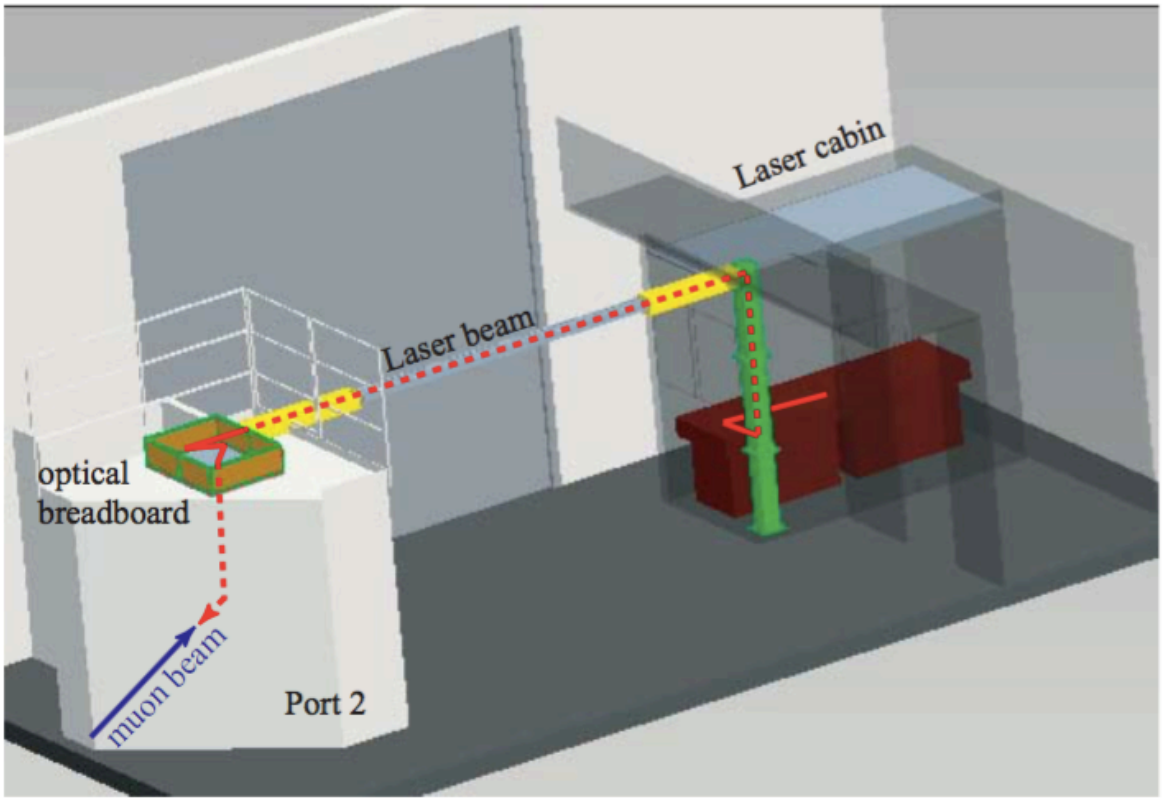
K. Yokoyama, J. S. Lord, P. Murahari, K. Wang, D. J. Dunstan, S. P. Waller, D. J. McPhail, A. D. Hillier, J. Henson, M. R. Harper, P. Heathcote, and A. J. Drew, Review of Scientific Instruments **87**, 125111 (2016).

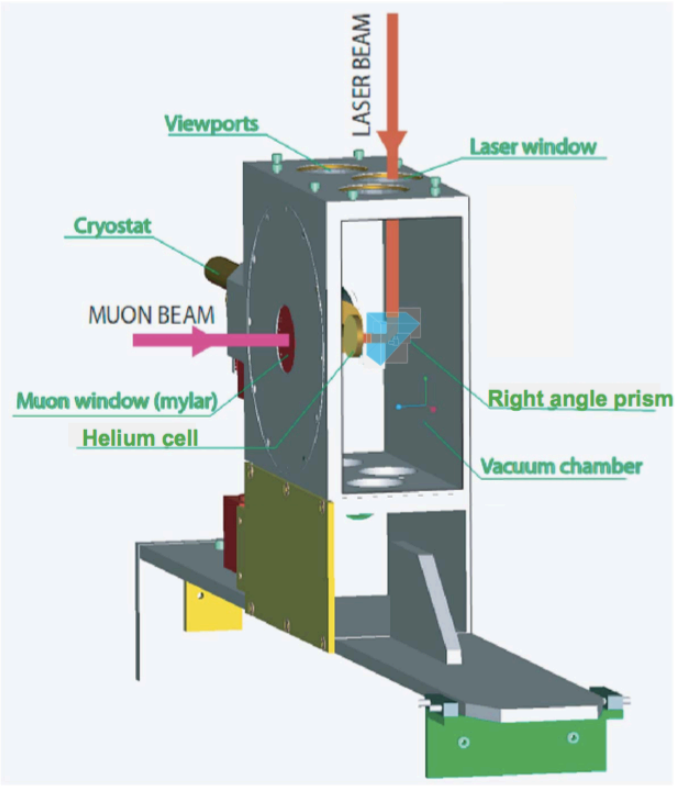
K. Wang, P. Murahari, K. Yokoyama, J. S. Lord, F. L. Pratt, J. He, L. Schulz, M. Willis, J. E. Anthony, N. A. Morley, L. Nuccio, A. Misquitta, D. J. Dunstan, K. Shimomura, I. Watanabe, S. Zhang, P. Heathcote, and A. J. Drew, Nature Materials **16**, 467 (2017).

K. Yokoyama, J. S. Lord, J. Miao, P. Murahari, and A. J. Drew, Phys. Rev. Lett. **119**, 226601 (2017).

… and more improvements/developments …

ARGUS





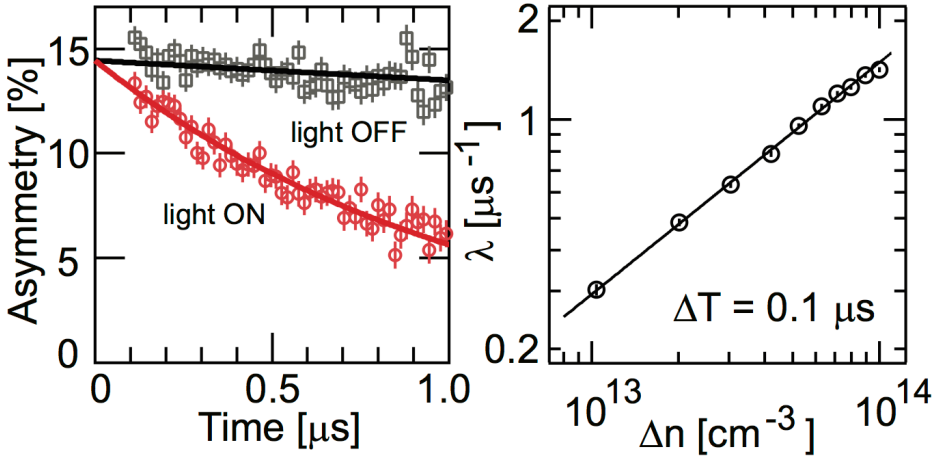
- Installed in 2008
- Similar laser setup (YAG + OPO)
- Excellent field homogeneity
- Ideal for experiments in gas

P. Bakule et al. J. Phys. Chem. Lett. 3, 2755 (2012).
P. Bakule et al. J. Phys. B: At. Mol. Opt. Phys. 48, 045204 (2015).

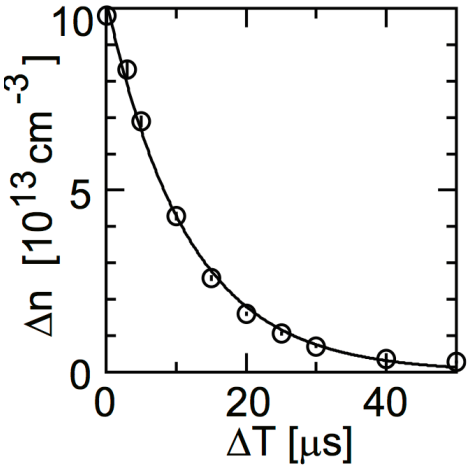
PRL 119, 226601 (2017) PHYSICAL REVIEW LETTERS week ending 1 DECEMBER 2017

Photoexcited Muon Spin Spectroscopy: A New Method for Measuring Excess Carrier Lifetime in Bulk Silicon

photo-μSR can characterise carrier recombination dynamics in semiconductors (Silicon)



Muon spin relaxation rate can be a measure of Δn because muonium interacts with the carriers



Traditional lifetime spectroscopy measures:

$$\frac{1}{\tau_{eff}} = \frac{1}{\tau_{bulk}} + \frac{1}{\tau_{surf}}$$

carries information
e.g., impurity density

- Muon is a bulk probe
- Can directly measure τ_{bulk}

- Applied to other semiconductors? e.g. new solar cell materials

nature materials

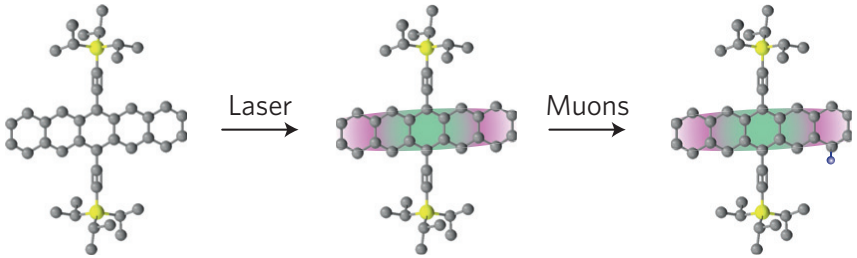
ARTICLES

PUBLISHED ONLINE: 12 DECEMBER 2016 | DOI: 10.1038/NMAT4816

Temporal mapping of photochemical reactions and molecular excited states with carbon specificity

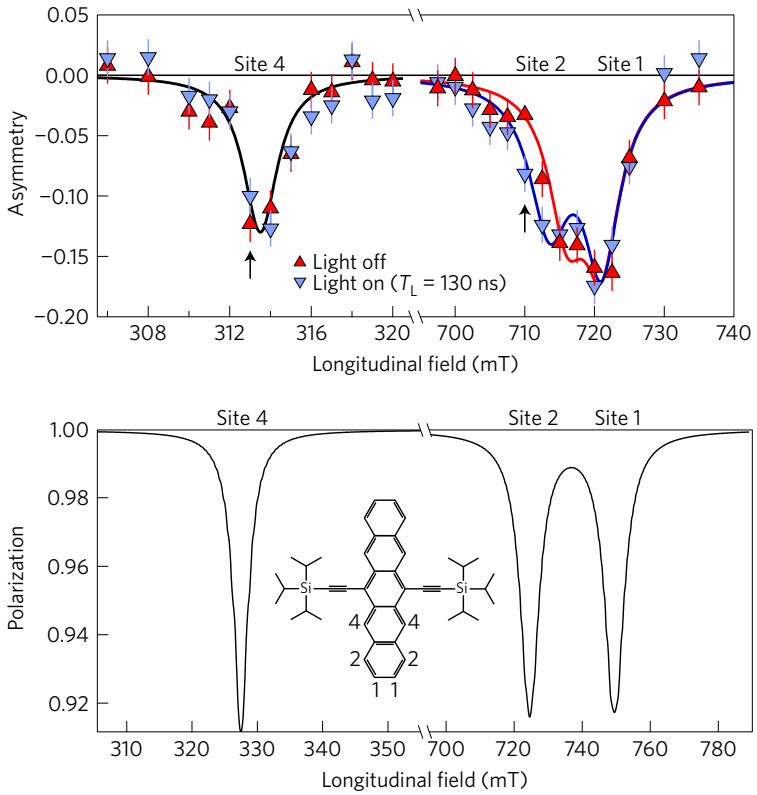
K. Wang[1,2†], P. Murahari[2†], K. Yokoyama[2,3], J. S. Lord[3], F. L. Pratt[3], J. He[1], L. Schulz[1], M. Willis[1], J. E. Anthony[4], N. A. Morley[5], L. Nuccio[6], A. Misquitta[2], D. J. Dunstan[2], K. Shimomura[7], I. Watanabe[8], S. Zhang[1], P. Heathcote[9*] and A. J. Drew[1,2,3*]

- Organic semiconductor molecule (TIPS-Pentacene) in photoexcited state
- Excited molecule has a different electron wave function
- Should change the ALC signal



Ground state (before light and muons) | Excited state (after light pulse) | Muoniated state (after muon pulse)

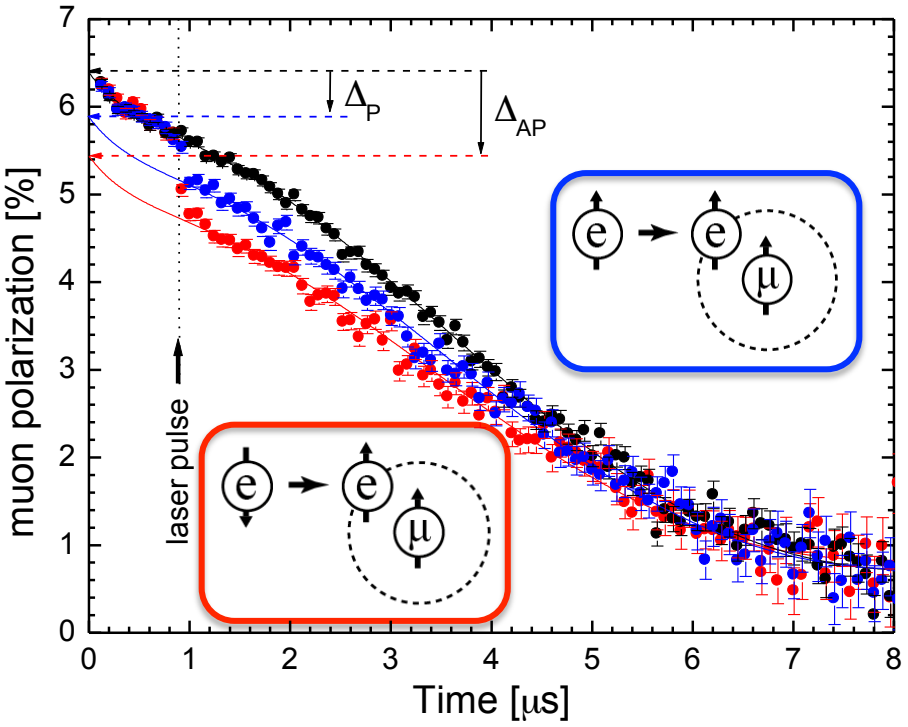
Illumination effect in the ALC spectrum

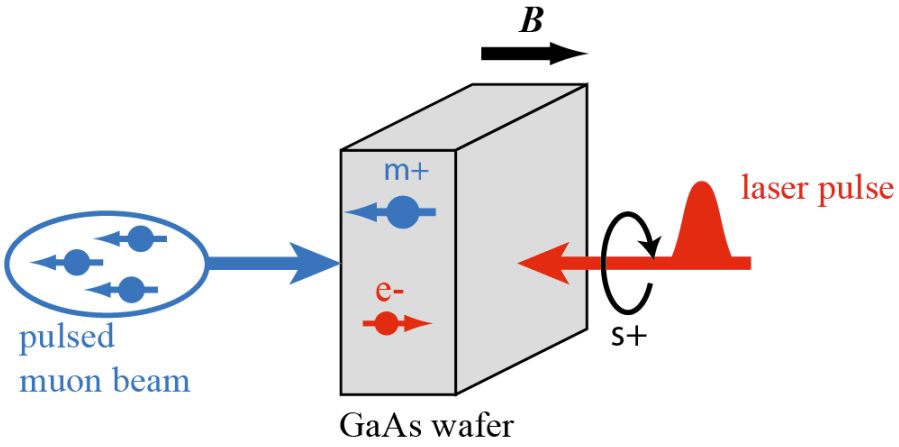


DFT calculation supports the observation: more electron density in its ends

Optical pumping also available

- Electronic spin can be injected with optical spin orientation
- Uses circularly polarised light





Parallel: less depolarisation

Anti-parallel: more depolarisation

- Originally developed in ARGUS
- This setup is also available in HiFi

Experimental support

- ISIS is now maintaining/developing the setup
- KY supports laser experiments
- Two proposals per Round
- Normally one experiment per Cycle

*** Open to new ideas & welcoming proposals ***