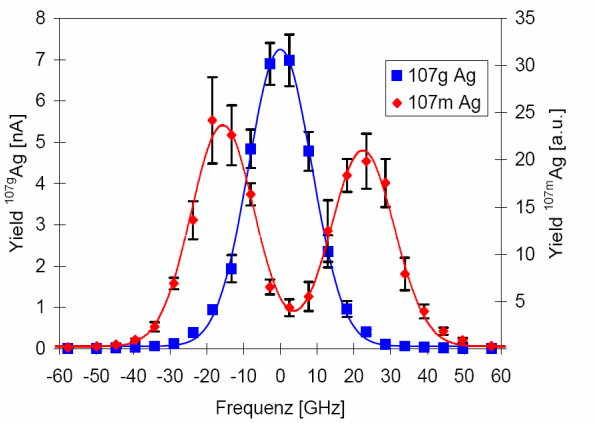
Exploiting the potential of the laser ion source at Eurisol for nuclear physics:
In-source laser spectroscopy & production of isomeric beams

A laser ion source can be used not only as a tool to produce isol beams but as a instrument for spectroscopy in its own right. Indeed, charge radii and nuclear moments can be determined by scanning one of the laser wavelengths in a multi-step resonant ionisation scheme over the range of the atomic hyperfine splitting. Since the technique is exploited at the ion source itself, the gain in sensitivity is considerable. Its ability for reaching high accuracy in isotopes with half-lives as short as fifty milliseconds and at production rates of one atom per second was demonstrated in a successful programme on neutron-deficient lead, bismuth and polonium carried out at Isolde [1].

The prospects to push charge radii and moment measurements to shorter lifetimes is dependent on the release profiles from the primary isol target that can be met, in turn contingent on the ion source design. Synergy with ion source development is hence essential, as rapid diffusion and effusion should be aimed at. At Eurisol, the millisecond polonium isotopes at the neutron mid-shell N=104 could then be targeted for in-source laser spectroscopy.

Future implementation of Doppler-free two-photon spectroscopy, in which resonant ionisation is achieved by two oppositely traveling photons of half the full wavelength such that the first order Doppler shift cancels, would open up the technique to lighter elements with smaller electronic F factors [2]. Proton emitters at the drip-line in particular could come under investigation, as particle detection can provide a clear and background-free signature for identification.

Once the hyperfine pattern is known for an isotope and its isomeric states, selection of a resonance line by a narrow bandwidth laser allows to extract isomeric beams. Starting out with beta-decay of silver isotopes at Isolde [3], isomeric copper beams with a purity of 85% were notably obtained for post-acceleration and Coulomb excitation, probing single-particle configurations [4].



Isomer separation of Ag-107 with the Isolde laser ion source [3]

By way of example, dedicated beam development in synergy with beam preparation would bring post-accelerated beams of high-spin polonium isomers within reach for reaction studies. It would become possible to shed new light on how neutrons in specific orbitals would stimulate the internal formation of an alpha particle, as the neutrons couple to the two protons outside the lead core.

Interest for isomeric beams also arises from the nuclear astrophysics community, for instance in determining the destruction rate of Al-26m in stellar environments. The relevance of this resides in our understanding of the nucleosynthesis of Al-26, the gamma-ray emission of which has been mapped in great detail throughout the Milky Way [5].

[1] H. De Witte et al., submitted to Physical Review Letters
[2] F. Biraben, B. Cagnac and G. Grynberg, Physical Review Letters 32, 643 (1974) & G. Huber, Letter of Intent, Tandem-Alto Programme Advisory Committee (2006)
[3] V. Fedoseyev et al., Hyperfine Interactions 127, 409 (2000)
[4] I. Stefanescu et al., submitted to Physical Review Letters
[5] C. Angulo and N. de Séréville, private communication