# Report on the OEDO project

**This report concerning the Oedo project will discuss the following:**

1) Will this project open new experimental possibilities with secondary beams
2) Is the project answering the aim opening new experimental possibilities
3) Is the project optimized and are the ion optical evaluations complete
4) Conclusion

**1) New experimental possibilities with secondary beams by Oedo**

Different energy domains are most suited for specific reactions. For example, energies below 5MeV/n are necessary for fusion reactions, 5 to 10MeV/n are best for deep inelastic reactions, 10-20MeV/n are best for transfer reactions, higher energies are best for fragmentation, knock-out reactions.

It is quite obvious therefore that for a full coverage of physics domains it is desirable at a facility to offer a large domain of energies, from very low energy to the highest energy. High energy fragmentation of heavy beams provides at the moment highest intensities and highest purity secondary beams. The secondary fragments produced by this method have essentially the same energy/nucleon as the primary beam, this is several hundreds MeV/n at world class fragmentation facilities. To produce intermediate energy beams, two methods are presently developed, slowing down the fragments to the energy desired by degraders, or stop the beams in solid or gas stoppers and re-accelerate them by a re-accelerator. The last method is in competition with thick target production as in Cern-Isolde or Triumf, the Isol technique.

What can be considered as the best method will depend on the beam quality and the beam intensity achieved. In the method of slowing down the secondary fragments by a degrader, the intensity loss will increase and the beam quality decrease with the fraction of energy loss needed due to large increase in the phase space. In the stopped beam method, an important intensity loss originates from the extraction, ionization and re-acceleration process. This qualitative consideration implies that there will be a energy below which the re-acceleration or Isol method is better, and above which the slowing down by degraders will be better. Where this limit is situated, depends on the quantitative results of the two methods. This limit will move to lower or higher energy as relative progress is made in these techniques.

In the proposal Oedo an elegant method is presented that solves the problem that exists in monochromator techniques, in which the emittance of the beam increases dramatically with the thickness of the monochromator. The proposal if realized certainly will lower the limit of energy for optimal slowed down beams significantly and opens a competitive new domain in a fragmentation facility.

Note another advantage of the proposed method as compared to re-accelerated or Isol beams: the time of slowing down by degrader is negligible as compared to even the shortest beta decay lifetimes, whereas the most exotic and therefore the shortest lived isotopes will suffer important losses due to decay during the extraction and re-acceleration.

**2) The technique of deceleration proposed**

**a)** The first part of the device as proposed is a "classical" monochromator (see figure 3). A small focus in a dispersive plane is produced on a degrader with variable thickness, in such a way that the thickness varies with the difference of energy at the different positions. With a matching of dispersion and degrader thickness, the outcoming particles will have the same energy, so this works as monochromator. The first order, resolution is limited by the ratio of the monochromatic beam size and the dispersion, energy straggling in the degrader, and inhomogeneities of the degrader.

The elegance of the proposed method stems, to my feeling, from the simple observation that if you have a point to parallel focussing, the angle in the parallel section is proportional to the x-coordinate, that here is proportional to the energy and hence to the time of flight. With a RF kicker correctly synchronized the angle can be corrected to be zero for all coordinates x of the object, and after this correction the final focus will not depend on of the x object, and a small size monochromatic beam is obtained.

**b)** Higher order aberrations

One can consider charge state changing in the degrader as a higher order effect. This is carefully discussed. It increases the final focus size, however not in a catastrophic manner.

As discussed in the report, higher order optical aberrations play an important role (see figures 9 and 10. They should be minimized in future studies using the existing sextupoles.

"In future discussions, the higher order aberrations at FE8 is most critical for the performance of OEDO beamline. A practical solution for this respect is tuning of sextupole magnets installed with STQs. Presently, we are studying how effective sextupole elements are, including tuning methods and procedures ."
It is too early to know if these existing sextupoles will be sufficient for an effective correction of these aberrations.

**c)** performance

The key figure is figure 16, that shows the transmission of the energy degraded beam at the focus S0. The estimated transmission is quite spectacular: the transmission is greater than 50% for a spotsize of +-20mm, with energy dispersion that should be acceptable in many experiments down to 10MeV/n and even for 5MeV/n the transmission is still in the 10-20% domain. It is clear that in an re-acceleration scheme the total efficiency will be much lower, with of course much better beam quality. For many experiments it will be possible to improve the effective beam quality by measuring event by event the beam particle parameters in the 5-dimensional phase space.

**3) Optimization of the project and the ion optical evaluations**

With respect to the objective of delivering a energy degraded beam the project is clearly optimized in the sense that it proposes a simple, elegant method implying a very low number of optical elements. Taking into account that it will enter in an existent context, it seems difficult to change the parameters chosen, such as the resolution at FE8. The main uncertainty at the moment comes to my opinion from a full evaluation of higher order aberrations and their correction. It would be useful to confirm in this context the results of Cosy Infinity by other ion optical programs.

**4) Conclusion**

The OEDO project presents an elegant and simple method to slow down high energy secondary beams to 5-20MeV/n by a degrader with a very high transmission, of the order of 50%. This will open new possibilities in the domain of fusion, deep inelastic and transfer reactions. The study of corrections of higher order aberrations is necessary to confirm and achieve the very good first order performance.