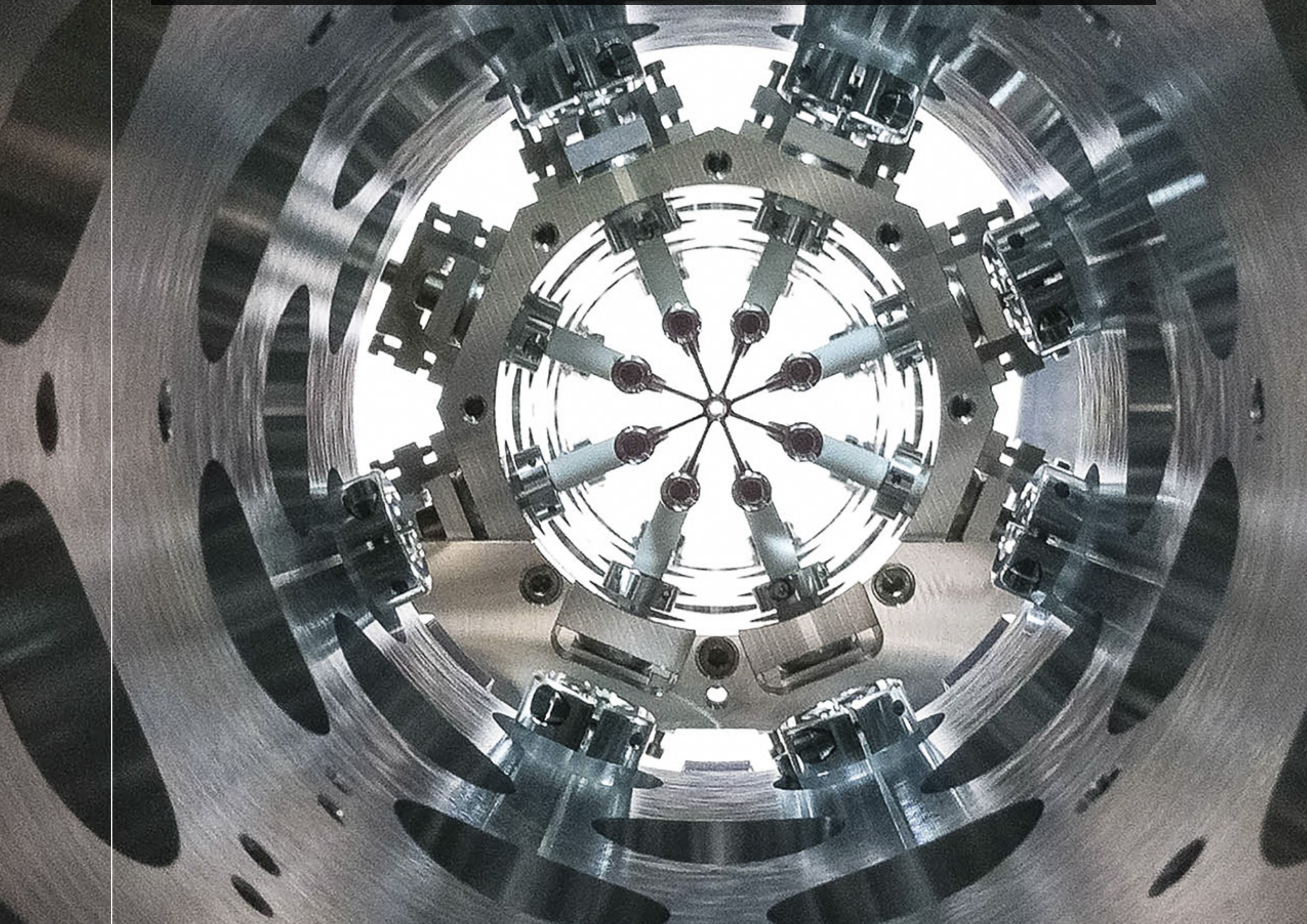
eEDM
Measuring the electric dipole moment of the electron



A view inside the molecule decelerator. A travelling potential is created by a time-varying electric field, applied to over 3000 ring-shaped electrodes that together form a 4 meter long tube. The molecules travel through this tube, and are decelerated in the process. The resulting low velocity allows us to increase the measurement time on the molecules, thereby boosting the sensitivity in the search for the electron's electric dipole moment.

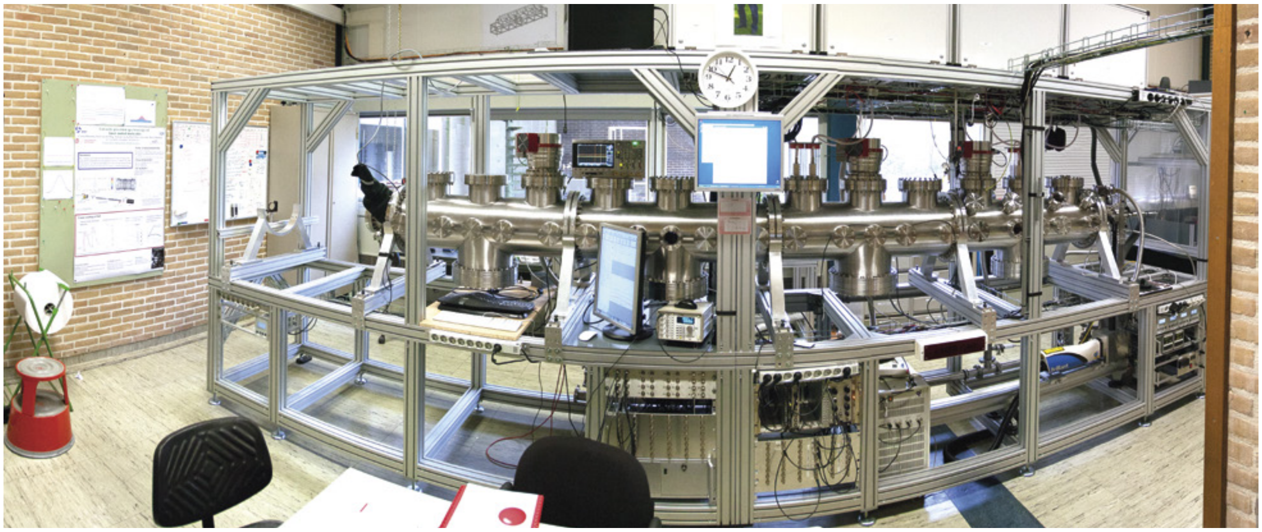


Figure 1. The traveling-wave decelerator in the VSI cold-molecule lab.

Management
prof. dr. S. Hoekstra

Consider the electron. Surely we know all about this fundamental particle? As it turns out, the hunt for the measurement of a basic property – that it so far doesn't seem to have – is motivating a new type of particle physics experiment at a number of research labs worldwide. This elusive property is the electric dipole moment (EDM), which reflects an uneven distribution of the charge. All measurements so far have indicated that if the electron has an EDM (from here on called eEDM), it is smaller than can be measured. This is at first sight not surprising, because the Standard Model of particle physics predicts the electron to be essentially perfectly 'round', and the resulting eEDM is about 10 orders of magnitude smaller than the current measurement sensitivity. So why bother trying to measure this property? It turns out that theoretical models that extend (and thereby try to fix the shortcomings of) the Standard Model all predict an eEDM that is much larger than the Standard Model value! The current best measurement of the eEDM has already put a number of such models under pressure. We have started a new research programmein 2016 to measure the eEDM with unprecedented sensitivity.

Table-top precision experiment

So how to measure the dipole moment of the electron? In the last decade, it has become clear that the most sensitive method is to do the measurement not on a 'bare' electron, but on an electron that is inside a hetero-nuclear diatomic molecule. If such a molecule is placed in an strong electric field, the molecule is polarised. As result, the electron is exposed to a strongly amplified electric field, and this field can be exploited to probe the structure – and thus the EDM – of the electron. The molecule thus effectively amplifies the signal from the EDM. The aim of our experiment is to manipulate, control and probe these molecules in such a way that we can extract the EDM of the electron with optimal sensitivity. This requires extreme measurement precision, since the effects will be small. In contrast to large high-energy collider experiments, in our approach we slow down and cool the molecules in a table-top experiment.

Cold molecules and lasers

We have designed a low-energy precision experiment, based on a pulsed beam of neutral BaF molecules that is being cooled and decelerated using a combination of recently-developed techniques. These techniques are cryogenic buffer-gas cooling, traveling-wave Stark deceleration, and molecular laser cooling. The eEDM is read out using optical, microwave and RF fields in a Ramsey-type spin-interferometer in a carefully shielded and controlled interaction zone. Since we are just starting this research program, a large part of the experiment will be designed, constructed and taken into operation in the coming years. This new Nikhef research programma is carried out in a collaboration of the Van Swinderen Institute (VSI) in Groningen, where the experiment is located, and the VU Amsterdam. One central part however, the traveling-wave decelerator, has already been constructed and is operating routinely in the cold-molecule labs at the VSI in Groningen. Also a large part of the laser infrastructure that is needed to cool, control and readout the molecules is already available, based on a range of low-energy precision experiments that have been operated at the VSI.

An exciting outlook

In the coming year a number of new PhD students will join the current students and staff in our common task to design, simulate and construct the eEDM experiment. We look forward to an exciting eEDM search!

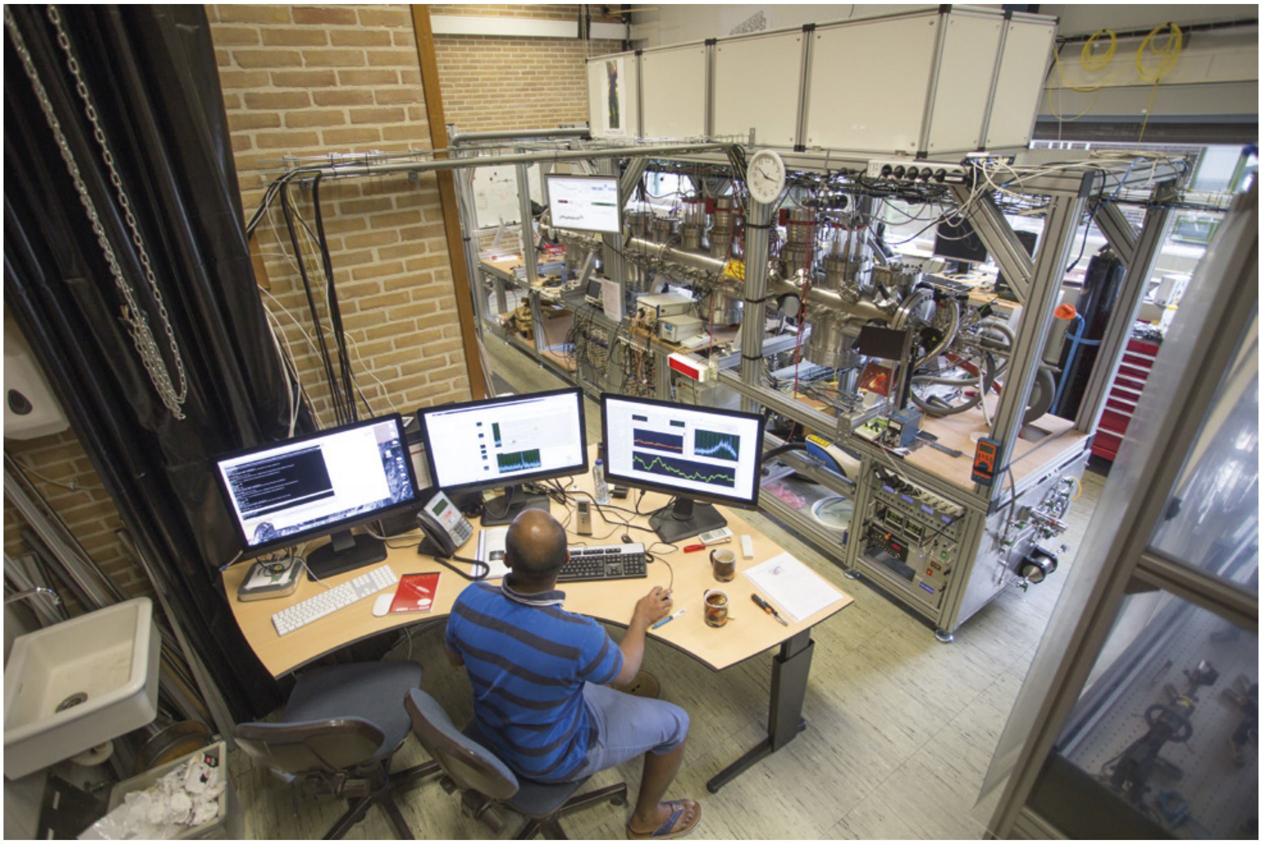


Figure 2. The control room of the traveling-wave decelerator..