Nuclear properties

(automated transcription)

And I said we will be avoiding mathematics to some extent, we will think in concepts and cartoons, and that's one of our first concepts that we have to deal with, a cartoon of the atom with the nucleus in the center. This course will deal with properties of the nucleus, and usually in these cartoons people just put a dot there, that's the nucleus. But that dot has quite some properties, do you know some? If I would give you a particular isotope and you have to describe the nucleus of that isotope, which properties could you mention? Number of protons and neutrons, for sure, that's a very defining property of the nucleus. The mass, that is more or less connected to the number of protons and neutrons, but not completely. The deformation parameter, the beta probably, we will see that quantity, so whether the nucleus is elongated or squeezed or rather spherical. I didn't tell it should be a stable nucleus, the lifetime of the nucleus. So let's go through the list, we had the Z and the A, charge and mass, spin wasn't mentioned, so the spin of the nucleus is a quite defining property. The parity, its lifetime, if it is an excited nucleus, what is the energy of that nucleus compared to the ground state of the isotope? So how large the nucleus is, even if you don't speak about deformation, but just about size, if you represent the nucleus not by a point, but by a sphere, what is the radius of that sphere? That's a property of the nucleus. The deformation, is it elongated or squeezed, that is contained in the electric quadrupole moment. And then a nucleus has also magnetic properties, it can have a magnetic dipole moment, that also is one property of the list. So this cartoon-like dot is in reality an object with this list of properties and many more. Some of these quantities are the ones that will interest us here. Just for the record, I give you two examples there for the iron-57 nucleus, where you see for every quantity in this list, the corresponding number in the ground state of the iron-57 nucleus, and in one particular excited state, that is 14.4 keV above the ground state. That will turn out to be a very important nucleus in one of the methods that we will see. Just to have a feeling for the numbers, let's look at the spread of all these quantities. So nuclear physicists, they list their nuclei on what they call the chart of nuclides, with on the vertical axis the Z-number, on the horizontal axis the number of neutrons. And so there you see in one glance what are all the possible isotopes that have already been produced, and then you can start exciting these. So the excitation, that's what you see on these nuclear energy diagrams. So the lower line here is for one of these nuclei, the ground state, and then all the energies of all the possible excited states. And so the range of numbers, charge obviously can go from 1 to about 100, the mass 1 to about 300, spin from 0, often something around 10, order of magnitude 10, but there is no upper limit, spin can be as high as you want, parity plus or minus, only two possible values. The lifetime can range from a few femtoseconds to something that is longer than the lifetime of the universe, and perhaps up to infinity, although nobody is really sure whether even the proton is really infinitely stable. So maybe the entire universe will decay sooner or later. These excitation energies typically between 0 for the ground state and up to about 1000 mega electron volts, the radius 1 to 6 femtometers, the dipole moment, either 0 or something that can go up to 10 nuclear magnetons, and an electric quadrupole moment that will be expressed in a unit that is bar, a measure for a surface area, so between 0 for a spherical nucleus and up to 5 bar for something that is very strongly deformed.