"If you work hard for something, then it will turn out the way you want." Sandra Kortner, group leader at the Max Planck Institute for Physics.

The **Particle Hunter**

Some enthusiastically call it the "discovery of the century" when they speak of the discovery of the Higgs boson at Europe's CERN laboratory in the summer of 2012. As a group leader at the **Max Planck Institute for Physics** in Munich, **Sandra Kortner** is closely tied to this research – all the while managing her role as the mother of two small children.

TEXT **FELICITAS MOKLER**

She is blond and rather petite. She just seems a little tired out, like most young mothers. After all, little Adrian, born just a few months ago, presumably demands Sandra Kortner's full attention. But as we sit in her office discussing the quest to discover the Higgs particle, Adrian and his brother David, who is two years older, are at home enjoying the attention of their doting grandparents.

So we are undisturbed during our meeting at the Max Planck Institute for Physics in Munich. That's where the 39-year-old Croatian is hot on the trail of a recently discovered particle: the Higgs boson. She has headed a small research group since 2009 under the Max Planck Society's Minerva Program. She was recently given a permanent position. It's easy to see that she is relieved about this. After all, the path that led her there wasn't always easy.

The specter of uncertainty about what the coming months would bring professionally and financially always lurked in the background. "You often don't know right up until the last second. If you want to stay in science, it's really expected that you relocate frequently – to wherever there happens to be a position open, and then it's normally limited to just a few years," says Sandra Kortner. "That's not easy, especially when you have a family."

FASCINATED BY THE STARRY SKIES AS A CHILD

She herself was close to leaving research and going into industry a couple of times already. But then it always worked out again with another position – albeit one with yet another fixed term. She undoubtedly succeeded at this in part because she believed in herself and never lost sight of the big picture. Her personal recipe for success: concentrate on the research and just don't think about the external circumstances. "If you work hard for something, then it will turn out the way you want, or at least pretty close. You can't lose hope," believes the scientist.

Even as a child, Sandra Kortner found the starry skies fascinating and was interested in astronomy. Later, at school, she was particularly good in subjects like math and physics. It wasn't difficult, then, to choose a major, and she began her physics studies in her home town of Zagreb. She soon came to prefer nuclear and particle physics, so her Croatian mentor, Kreso Kadija, who himself had previously worked at the Max Planck Institute for Physics, sent the then-25-year-old student to Munich for two months.

There, she gained her first practical experience while working on her thesis. The young researcher's enthusiasm for particle physics continued. Later, between 2001 and 2005, she completed her doctoral dissertation in Hubert Kroha's research group at the Max Planck Institute, in cooperation with her alma mater in Zagreb and her dissertation supervisor, Kadija.

Kortner soon came to love the Bavarian capital and she has long since grown to feel at home here. The cultural differences with Croatia aren't all that great, she says. The locals take a very pragmatic approach to day-to-day

Photo: Denise Vernillo

Flashback: As a doctoral student, Sandra Kortner (right) was involved in the construction of so-called muon chambers for the ATLAS experiment. This photo from 2002 shows her with her colleagues Susanne Mohrdieck-Möck and Andreas Manz during a test at CERN.

life, which reminds her of the Croatian mentality. In addition, she really enjoys the fact that Munich offers all the advantages of a big city, such as cinema, theater, museums and shopping, while simultaneously having the homey character of a small town: "The village with a million inhabitants, as they say, with a fascinating variety of personalities," she says.

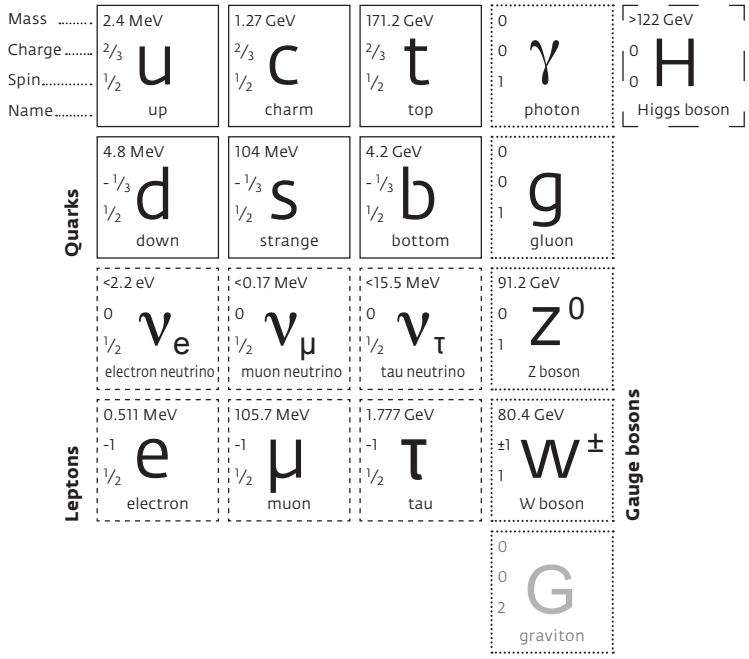
Also, it isn't that far to travel from here to her native country. "That was an ideal combination. I was able to commute between Zagreb and Munich when something had to be discussed at the other place; or if I wanted to visit my family, or if they wanted to visit me."

A CONSTRUCTION KIT OF QUARKS, LEPTONS AND GAUGE BOSONS

As a doctoral student, Sandra Kortner was involved in setting up one of the two experiments that, in 2012, were used to prove the existence of a new particle, the Higgs boson: the ATLAS detector at CERN. This boson is crucial to the Standard Model of particle physics. This model maps out a place for all the known building blocks of matter. The construction kit consists of six quarks, which make up, for instance, protons and neutrons; six leptons, which also include the electron and the associated neutrino; and the mediator particles of the fundamental forces with which the particles interact with one another: the gauge bosons, such as the photon.

"The Standard Model is a theory that has been brilliantly confirmed by all experiments thus far," explains San-

Photo: CERN – Maximilian Brice



Basic building block: The Higgs boson is an important component of the Standard Model, which comprises six quarks, six leptons and a handful of gauge bosons; the latter also include the graviton, which, however, hasn't yet been detected.

dra Kortner. "But one question was long a concern for us researchers, namely: how do the particles get their masses in the first place?" To solve this problem, in 1964, six physicists – Peter Higgs, Robert Brout and François Englert, as well as Gerald Guralnik, Tom Kibble and Carl R. Hagen – suggested, to some extent independently of one another, an addition to the theory: they assumed that the entire universe was permeated by a field that the particles interact with, and that thus gives them their mass.

This field was named after one of the men who posited it, namely Scotsman Peter Higgs. It can't be detected directly. However, it was thought that its mediator particle, the Higgs boson, could be produced at sufficiently high energies in accelerators like the Large Hadron Collider (LHC) at CERN, and leave traces of its existence in the measured data.

According to theory, energies of a few hundred giga-electron volts are needed to excite the Higgs field so strongly that it produces a particle. The physicists created the conditions for this by shooting two proton beams anti-cyclically through the accelerator ring of the LHC until they have reached the necessary energy threshold and, finally, are brought to a collision inside the ATLAS detector. This creates a large number of particles, and with a bit of luck, also the Higgs boson.

But there are two reasons why it isn't possible to detect this particle directly: For one, it can't interact with the detectors because it has no charge. For another, its lifespan is simply much too short. When the Higgs boson decays, the secondarily produced particles can be of a different nature. One path, for instance, is a cascade ranging from the W and Z bosons of weak interaction to certain leptons, such as the longer-lived muons. These can be detected in special muon chambers.

THE DRIFT CHAMBERS MUST BE ABSOLUTELY DUST-FREE

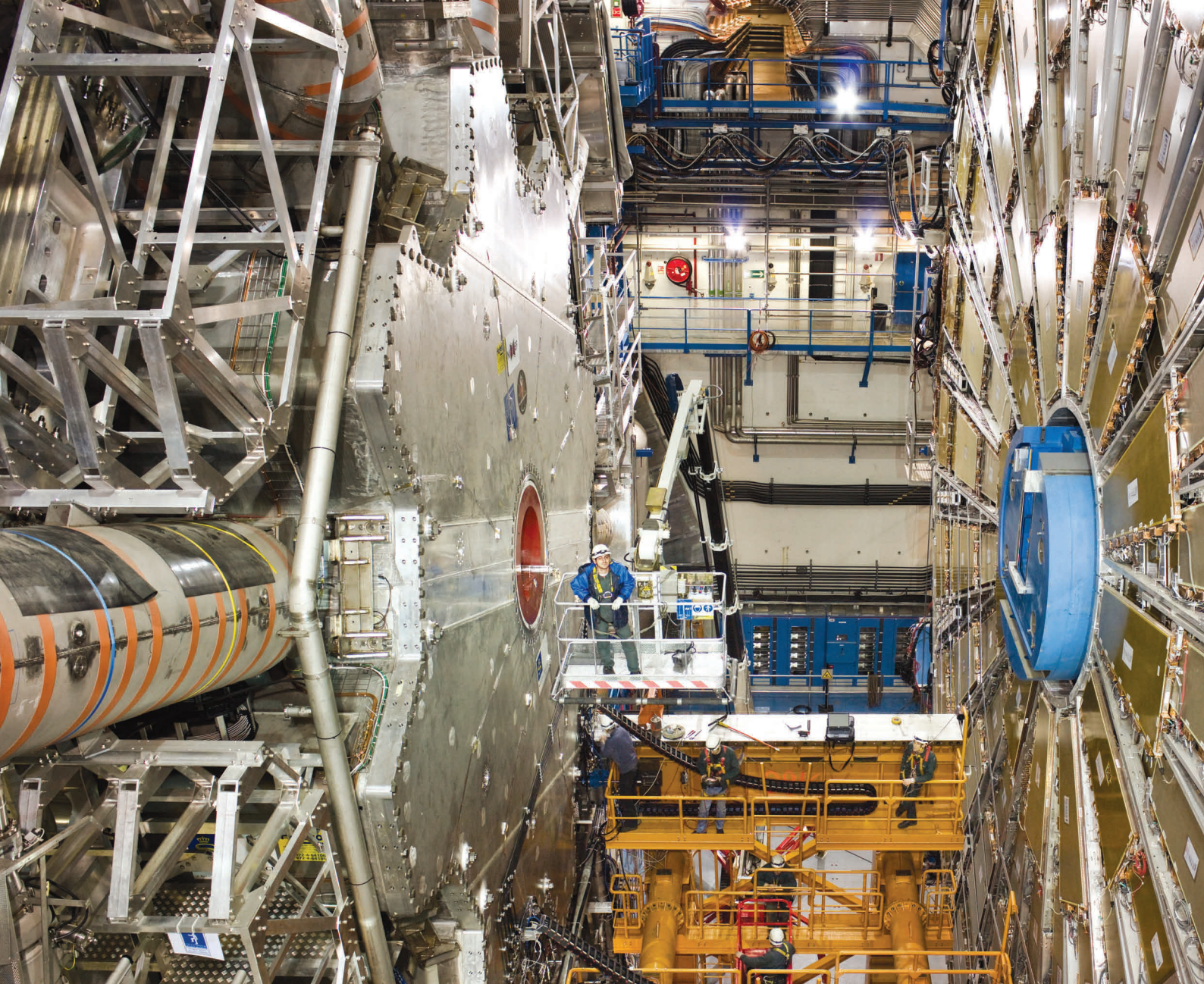
On the way from her office to the institute's clean rooms, where muon chambers are designed and built for the ATLAS experiment, Sandra Kortner uses a model to explain what such a detector looks like and how it works. Not one speck of dust can be allowed to contaminate the aluminum drift chambers that will later be traversed by charged particles. The wires in the aluminum tubes, to which a voltage will eventually be applied in order to deflect the particles, must be positioned with a precision of 10 to 20 micrometers (thousandths of a millimeter). All of the components are specially designed and constructed for this experiment – nothing is industrially manufactured in serial production.

"Since muons lose very little energy in the detector, they can traverse it completely. That is why the muon chambers are built at the very edge of the detector. Further inward are devices for detecting other particles, such as photons, electrons and protons," explains Sandra Kortner. From the values measured in various detector sections, the researchers can then conclude which type of particles they are and at which location and with what energy the particles were produced.

Kortner was personally involved in the construction of the first muon chambers for ATLAS during her doctoral studies, and conducted the test measurements on it at CERN. Today, in contrast, she simulates particle paths on the computer and compares her results with the measurement data. Which type of work does she prefer? "Both, actually. I always dedicate myself wholeheartedly to everything I do. I believe there's no point in doing something if you're not fully focused on it," she replies.

Already head of a research group, she and a colleague co-coordinated the Higgs physics collaboration between

Graphic: OH



CERN and the Max Planck Institute in Munich, which involved a total staff of around 300, from October 2010 to October 2012. That undertaking required a good deal of assertiveness, tenacity and organizational talent.

A YOUNG MOTHER – YET DOING RESEARCH AROUND THE CLOCK

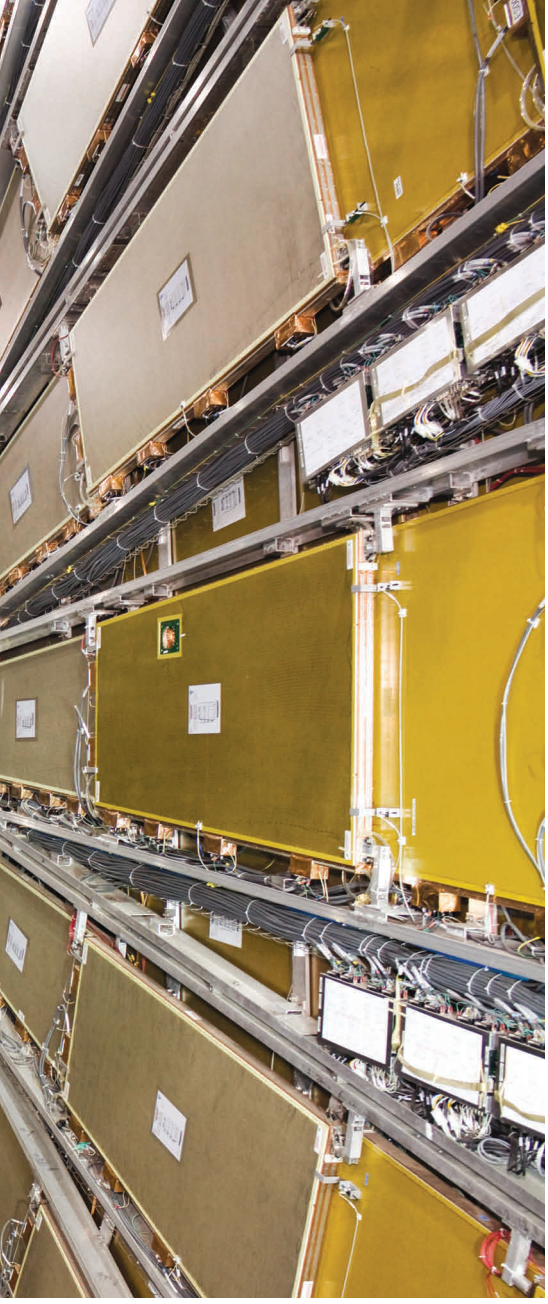
The scientist initially spent about half of her working time at CERN, near Geneva, and the other half in Munich. When the search for the Higgs boson really kicked off in July 2011, her son David was born. She then cut back on her travels. Nevertheless, not a day passed without her reading her e-mails, and many days were filled with team meetings about the findings. Sandra Kortner was doing research around the clock.

That was no mean feat for a young mother. And still: "Modern telecommunications options are a great help. For instance, we can hold telephone and video conferences. For one thing, that saves a lot of time that would otherwise be spent on traveling. For another, I had the opportunity to work from home a lot. That let me spend some time with my son in between meetings."

A daycare center was, and still is, out of the question. They are in very high demand in Munich, and there aren't enough of them to meet this demand. But she and her husband, Oliver, who likewise works as a physicist at the Max Planck Institute, split their parental leave. And then there are the in-laws, who live nearby and were also already helping out back then. In this way, Kortner was able to fully attend to her responsibilities as coordinator of the ATLAS Higgs Group despite her young family.

The effort paid off: Since 2010, there have been new research findings to discuss every three months. Around Christmas 2011, the first signs appeared in the jumble of data showing that the events became more frequent at the appropriate energy of 125 giga-electron volts. In March 2012, the signal was initially somewhat weaker again, and then, in late June, somewhat stronger than expected. The data analysis showed

Photo: CERN



left | One section of the world machine: The ATLAS detector in the Large Hadron Collider of the European research center CERN is, like the CMS experiment, used in the search for the Higgs boson. ATLAS is enormous: it measures 45 meters in length, 25 meters in height, and weighs 7,000 tons – as much as the Eiffel Tower.

below | Traces in the quantum world: In accelerators like the LHC, high-energy proton beams are made to collide. This creates a cascade of particles that, with a bit of luck, include Higgs particles.

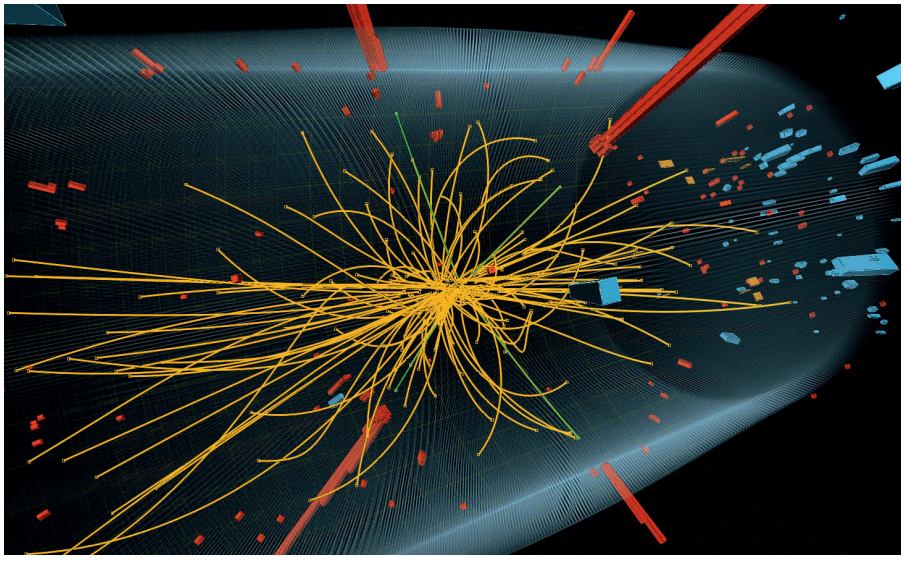


Photo: CERN

relatively reliably that there must be a previously unknown particle cavorting about at the energy mark predicted for the Higgs boson. On July 4, 2012, the findings were to be officially announced at a press conference.

"Of course we suspected and hoped there was something there – after all, our measurements showed a clear signal. But we also didn't know that until a week before the scheduled press conference, and we didn't yet know the results of the CMS experiment. It was a terribly exciting moment," says Sandra Kortner, and a bit of the excitement from that time can still be heard in her voice.

The CMS detector is likewise used for the search for the Higgs particle, and is designed similarly to ATLAS. But the two research groups involved in these experiments work entirely independently of one another. No member of one group knows what data the other has just measured. In this way, the scientists can preclude systematic errors in their analyses.

EVERYONE WAS SO BUSY THEY FORGOT TO CELEBRATE

Kortner and her colleagues were thus overjoyed when it turned out that the data sets from the two experiments delivered exactly the same result. "More than anything, that was an incredible feeling of fulfillment. After ten years of data analysis and model calculations, it was simply incredible. Everyone on the CERN premises was beaming," recalls Sandra Kortner. Right up to the last minute, the scientists were so absorbed in their work that no one had really given any thought to celebrating. So they improvised. Whoever had a bottle of champagne or sparkling wine to spare brought it out.

But the next day was business as usual. The research had to go on. A lengthy vacation, for instance in her native Croatia, wasn't possible. As yet, the newly discovered particle hadn't been definitively characterized. For example, no one knew its spin properties – an important parameter in particle physics in order to be able to classify a particle. The researchers have since

Today, team meetings can be held via telephone or video conference. But don't underestimate the occasional spontaneous exchange of ideas in person. Sandra Kortner brainstorms with her colleague Daniele Zanzi.

proven that the particle has a spin of zero, as predicted for the Higgs boson.

In October 2013, Peter Higgs and François Englert were awarded the Nobel Prize in Physics. Sandra Kortner was pleased about this, of course. She finds it very satisfying to know "that your own long years of work contributed to finally confirming a theory." And she is certain that all the other 6,000 or so staff involved in the ATLAS and CMS collaborations share this feeling.

Nevertheless, the analyses of the Higgs particle are far from complete. To get to know the boson better, the scientists are currently working on an expansion of the experiment. The LHC is expected to run about another ten years at nearly twice the energy. After that, it's due to receive an upgrade to allow it to take measurements at even higher collision rates.

For Sandra Kortner's day-to-day research, this means, above all, continuing to simulate the decay of the Higgs boson. Such calculations are necessary in order to be able to interpret the measured data correctly. After all, such high-energy collisions in the accelerator create all kinds of particles, and in much greater numbers than the Higgs particles being sought. These other particles, in turn, also quickly decay into secondary particles, and all of their traces show up in the measured data.

"It's like the proverbial search for a needle in a haystack – or even more drastic: imagine an Olympic swimming pool filled with sand. The number of grains of sand corresponds to the number of particles created when a collision occurs. Only ten to a hundred of those are Higgs bosons," explains Kortner.

IT'S ONLY NATURAL THAT HER PARTNER SUPPORTS HER

After a couple of months of caring solely for Adrian, she is now working again, initially on a part-time basis. After all, while her family is what's most important to her, she is a full-blooded physicist, and completely foregoing research wouldn't work for her at all. In a couple of months, her husband will start working part-time for six months so that she can be completely available for the research. She greatly appreciates the fact that her partner so naturally supports her in this way.

Reconciling career and family requires effort. It means continually replenishing the reserves. "The best way for me to do that is on vacation at my family home in a small village near Zagreb, with all the relatives," she says. And when the children are a bit older, she dreams of driving to the Croatian coast again with them and her husband, as she loves the sea – and also because it holds a bit of nostalgia from her own childhood.

"For a quick getaway from everyday life at home, I like to go for a walk with the family. I just really like to be out in nature," says Sandra Kortner. And even then, she is on a journey of discovery – albeit with the roles reversed. Now it is her two-year-old son who heads up the research. "This is the age at which children begin exploring their surroundings on their own and asking questions. We then learn to discover the world anew through their eyes." ◀

Photo: Denise Vernillo

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