

Ensuring the physics education of the next generation – some lessons from Germany

Johanna Stachel, Physikalisches Institut, Universität Heidelberg
International Seminar

“for a Next Generation of World-Wide Leading Engineers”

～ ドイツに学ぶマイスター & 研究者育成法 ～

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International context

Talk is based on my background and experience in Germany
Studies and activities of German Physical Society (DPG) with 63 000 members

Many of the arguments I will make are valid for any society whose wealth

- is not based on natural resources (gas, oil, coal, precious elements)
- is not based on cheap labor (mass manufacturing of clothing etc.)
- is not based on agriculture, tourism etc.

- but is rather based on inventions and development related to modern technologies, skilled labor in high tech sector or even financial sector (cars, electronics, appliances...)
such as for instance Japan

Why is physics education in school important?

- Society needs physicists

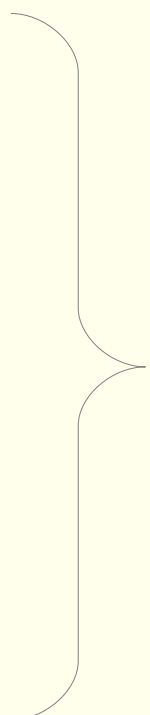
Where do physicists work?

the obvious:

- the academic sector and research institutions
- research and development in industry
- manufacturing in businesses and industry
- public administration
- education in schools and universities

and increasingly as well:

- IT sector
- engineering
- health sector
- consulting
- management
- patents
- financial sector
- media and journalism

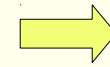


**Physicists
are
everywhere**

Where do physicists work?

the obvious:

- the academic sector and research institutions
- research and development in industry
- manufacturing in businesses and industry



denominated
as “physicist”

- public administration
- education in schools and universities

and increasingly as well:

- IT sector
- engineering } 11%
- health sector
- consulting
- management
- patents
- financial sector
- media and journalism

78%

Physicists are in much
demand in a very broad sector

in Germany, only 22 % of people with physics degrees work as “physicists” as such
in southern Germany, physicists make up 0.37 % of all employed (in the north 0.2%)
14 % have a foreign nationality
only 2.5 % of physicists are out of jobs at any given time
(young people often in between jobs, not unemployed)

Why is physics education in school important?

- Society needs physicists
- Solid physics education needed for future engineers, chemists, biologists, geoscientists, environmental scientists, medical doctors, health professions, ...
'physics is the basis of all natural sciences'
- Knowledge of physics and understanding of the scientific method needed for educated citizens
in context of grand challenges for society:
 - environment
 - climate
 - energy supply
 - natural resources
 - health
 - modern technologies in generalfor informed judgement and decisions
(and this certainly includes all policy makers and people active in the news and media, who are shaping public opinion)

For all 3, high quality physics education in school at all levels is important

How about the future?

A futurologist, asked recently, how the world would look like in 50 years and what skills would be needed, to be prepared, gave this answer:

“the world is getting different faster and in different ways, than we are used to. We do not know how the changes in the next decades will be in detail. The most important skill for a good life will therefore be, to deal successfully with changes.”

In a rapidly changing world, with increasing dominance of technologies and digitization, we need to adapt constantly.

- in some respects, life is getting better and easier,
- on other other hand, climate change and limited resources threaten our societies. people do worry to lose control and feel threatened by changes. many of us worry that our children and grandchildren will have a life worse than ours.
- but we need to be foreward looking and open minded to master the challenges.

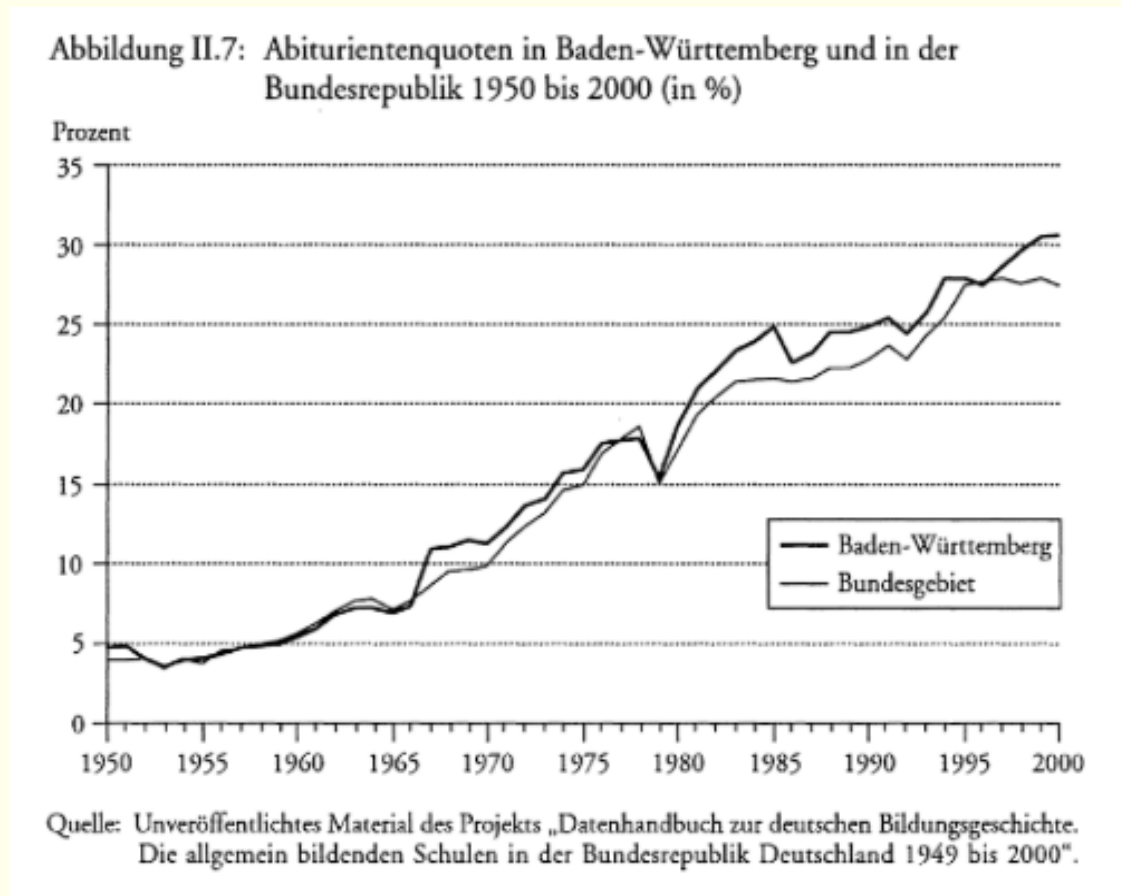
Our children need to be prepared for this*

* see also keynote article in Physik Journal 12/2016

Preparing our children for the future

- Children are curious to explore and understand their environment, they are born with the spirit to discover and investigate.
- Our most important task in their education is to not destroy this curiosity!
- This challenge needs to be mastered by educators and teachers – they need to be prepared to bring across the joy of understanding math and science
And we need to prepare the teachers and educators

An explosion in access to higher education



by 2016, in the state of Baden-Württemberg, 40% of all children go to high school
in Heidelberg 69.5% (top runner)

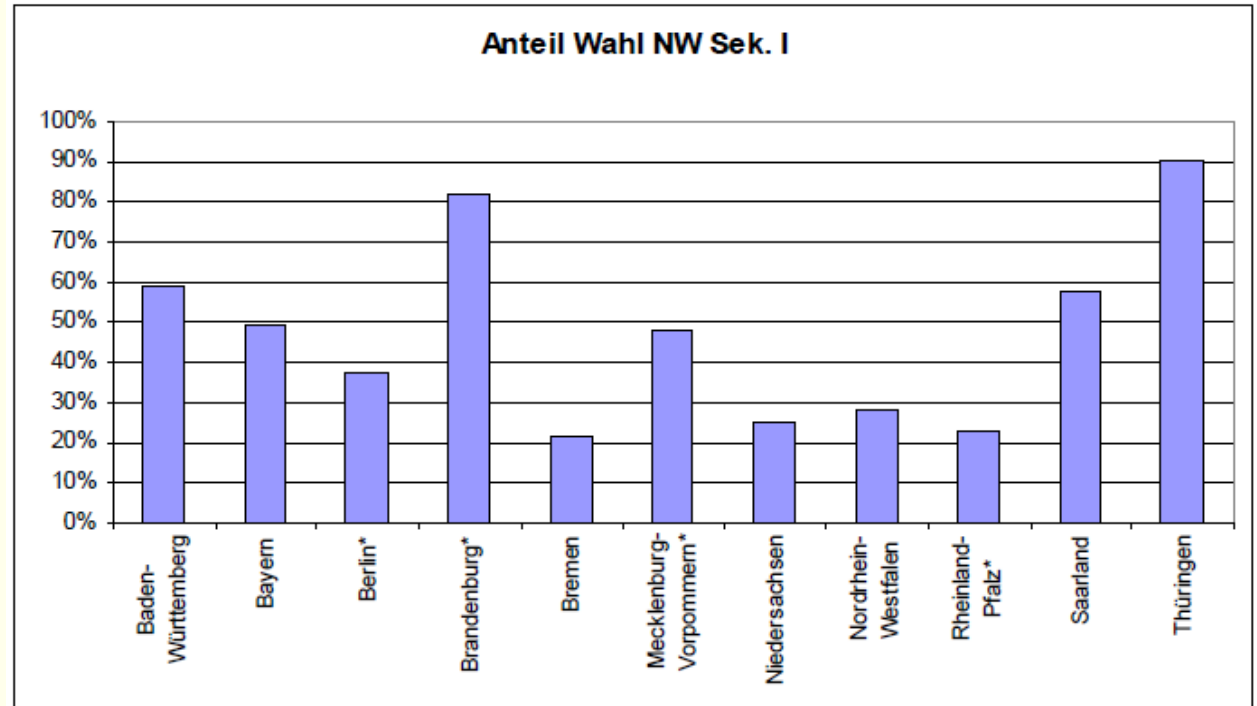
but do the children succeed?

And what choices in subjects of education to they make?

Do school children chose science courses?

in states, where there is a choice in grades 8-10 for a STEM centered education, 44% chose science, but only 33% of of female students

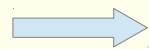
fraction varies a lot between states



connected to education of teachers?

there is difference between cities (more) and rural areas (less)

the bad news: fraction drops in the last 2 years in school, particularly among girls: 40% chose some form of physics course, but only 24% of female students and: only 11% chose physics as topic for Abitur (final high school exam) – considered difficult to get good grades

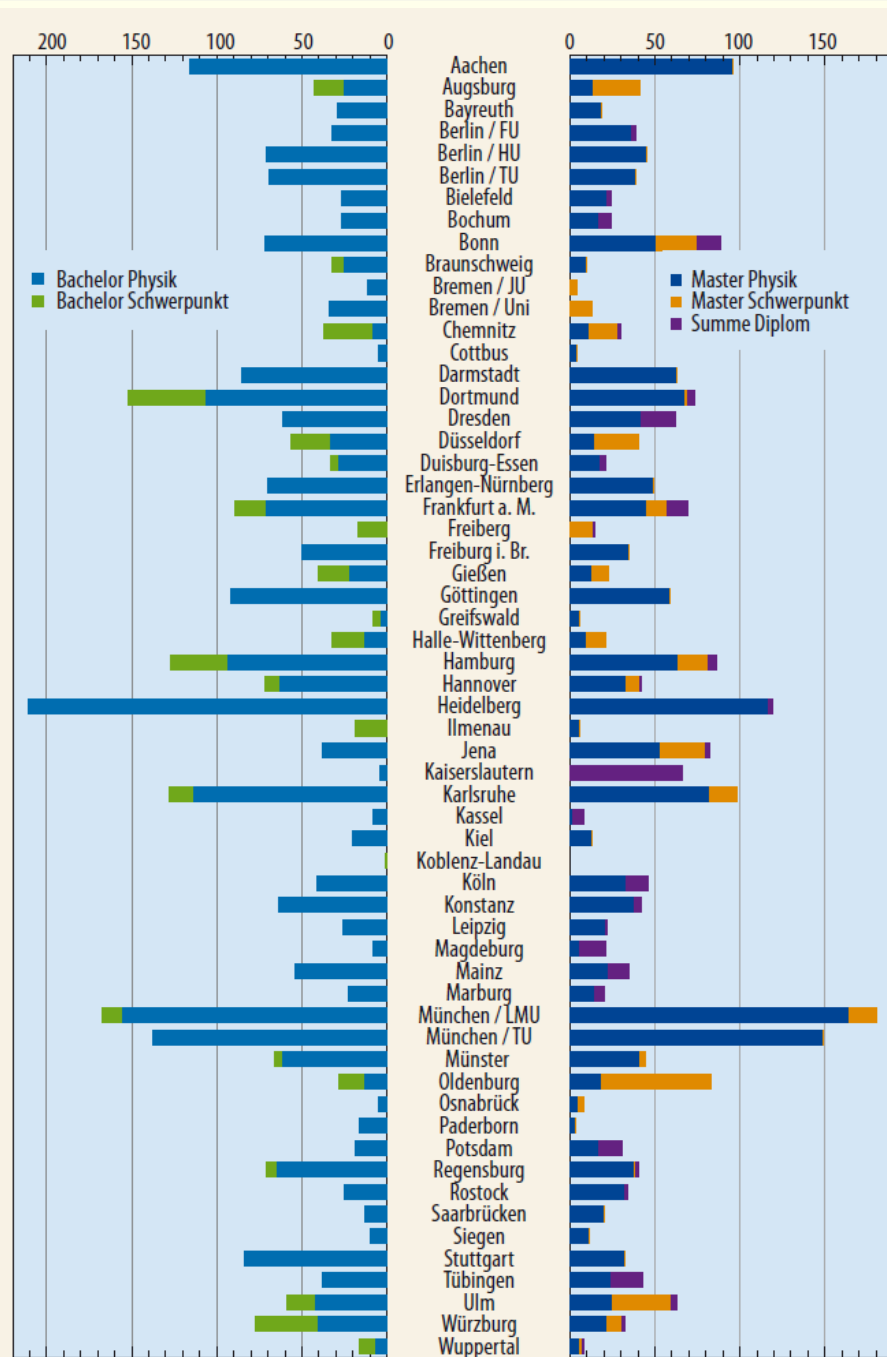


room for improvement



Are we supplying the physicists, society needs?

Annual number of physics degrees in Germany



59 universities awarded between 10/2015 and 9/2016:
 3066 bachelor degrees – 15% female
 2500 master or equivalent degrees – 17% female
 new master enrolements: 3238

Doctoral degrees in physics

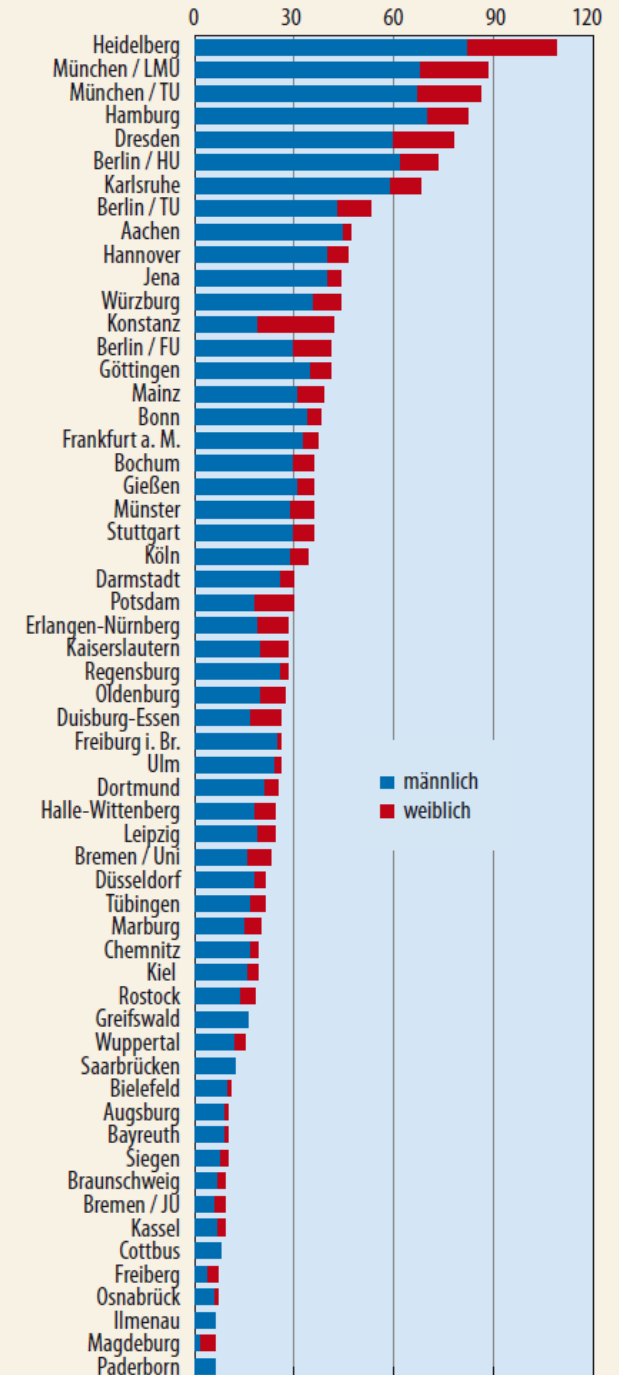
currently about 1848 doctoral degrees in physics per year in German universities – a 25% increase over the past 20 years

19 % female

22 % from abroad

The job situation for physicists is very good, nearly full employment
the demand in the future is rather growing*
We must make sure the supply is not dropping

* according to a 2016 study commissioned by the DPG, O. Koppel, Physikerinnen und Physiker im Beruf, and U. Weigelt and A. Metzethin, Physik Journal 12/2016



The crucial role of physics teachers

In the DPG, we have a long-term study of students graduating from high school (1000 winners of book prize by DPG for excellent performance in physics)

one of the outcomes: “the better prepared and excited about physics and STEM topics in general teachers are, the more they can excite their students and the more likely those will decide to study physics (or another STEM area) at university”

this was the key motivation to study physics for 58% of female and 42% of male physics students*

*DPG 2010

Even great minds need to be nurtured

Maryam Mirzakhani, Fields Medal 2014

„when I was 12 years old, I thought,
I didn't have talent for math”

None of my peers said “math is
uncool”

and

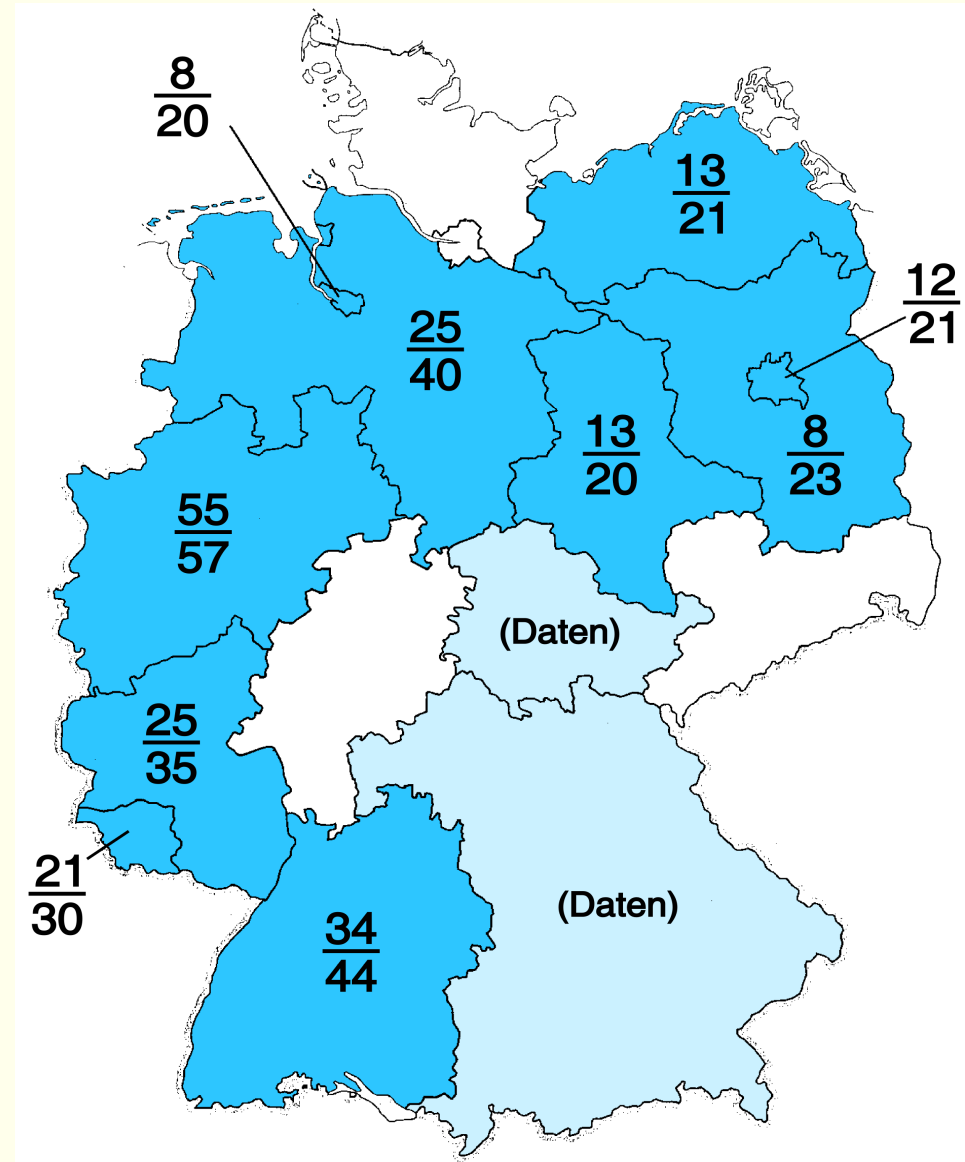
“I always had teachers who
motivated me”

Supply and education of physics teachers in Germany

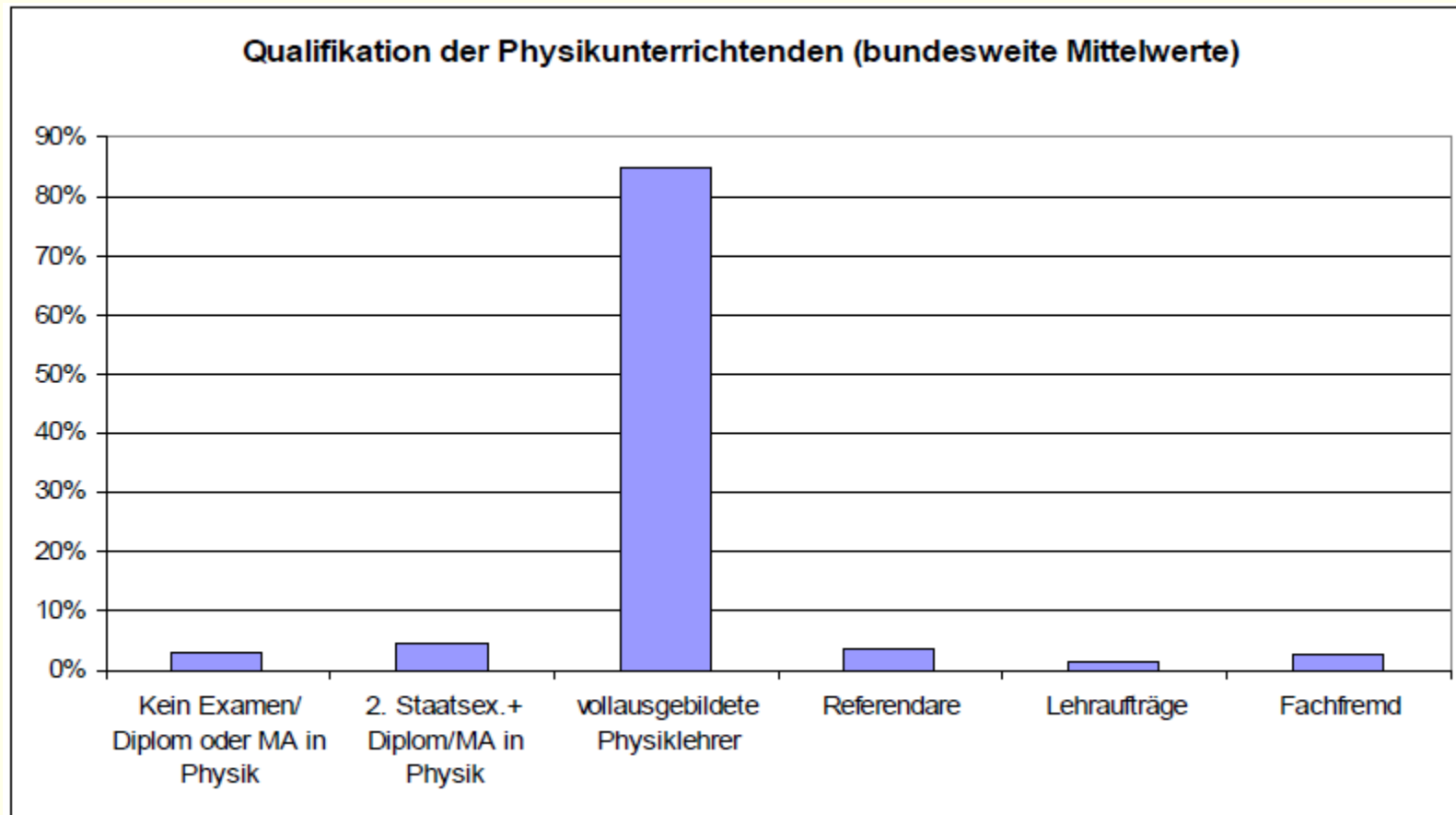
based on a 2014 study by the DPG



Questionnaires to 204 schools in 10 German states (7% of high schools)

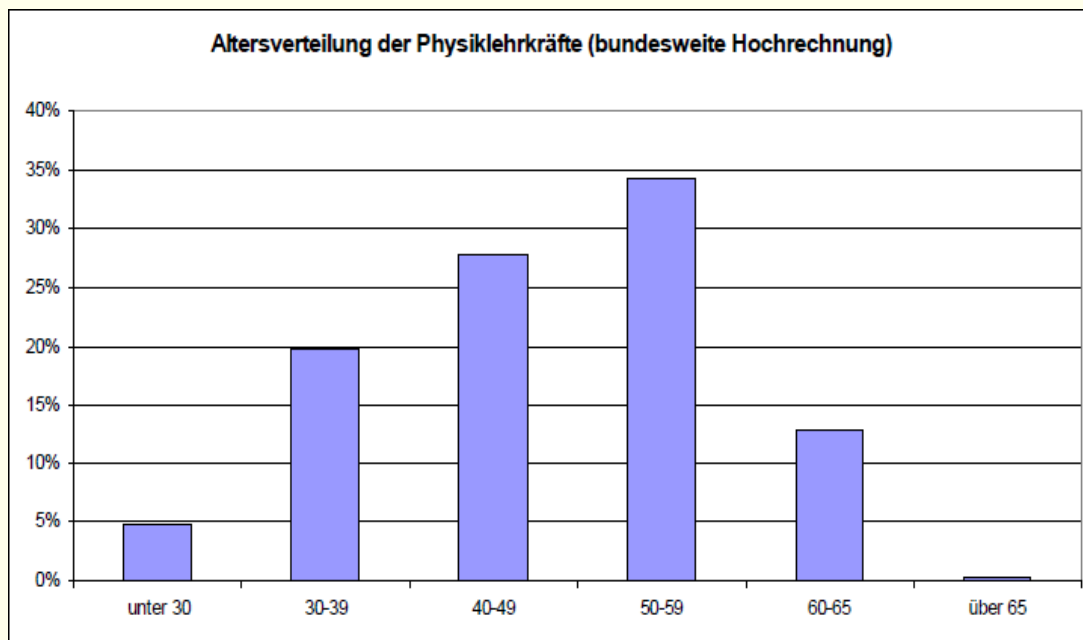


Are the physics instructors educated as physics teachers?



- already now 1/7 teachers instructing physics is not a fully educated physics teacher
- huge variations from state to state; in Bremen, 12% of physics classes are taught by teachers, who's subject area is not physics
- in grades 11/12/13 only physics teachers teach physics

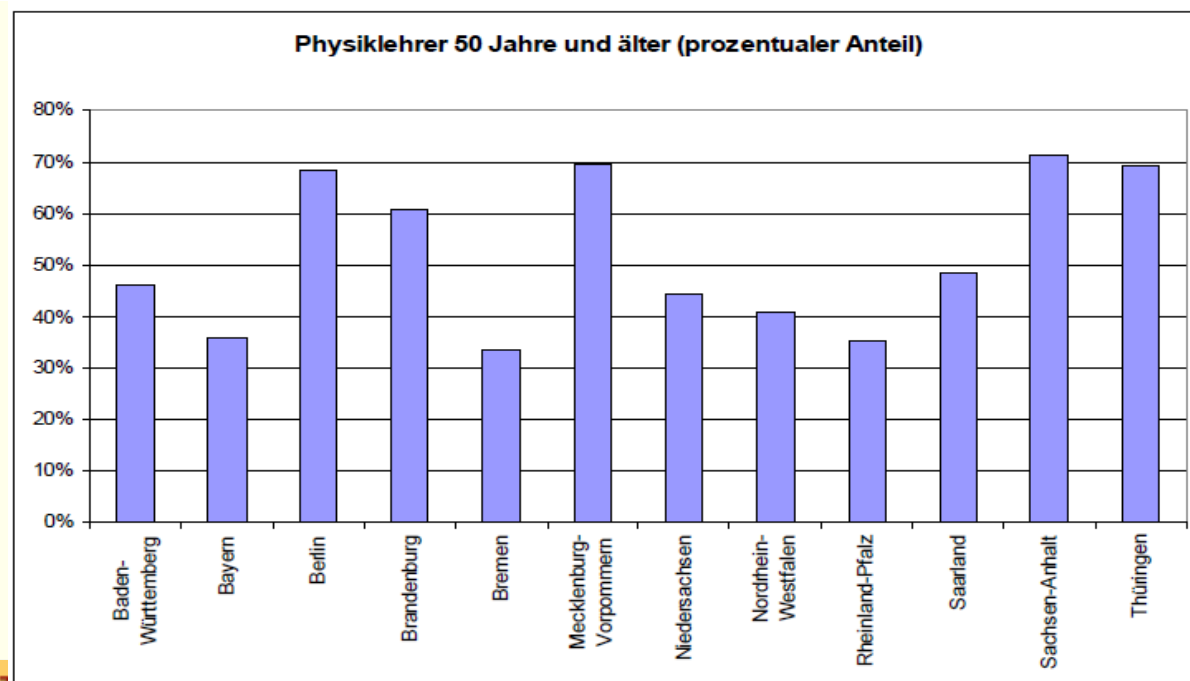
Age structure of physics teachers



- about 1/2 of the physics teachers are more than age 50
- large regional variation
- in east Germany, 60% of the (well educated) physics teachers will retire in the next 13 years

What is the demand?

90% of school principals estimate the need in physics teachers in the future unchanged or increasing



How is the supply?

in 2016, 667 students finished education as physics teachers
of these 456 at the high school level
less than 20% of degrees at this level

not clear, that this is enough to replace physics teachers who retire
at high school level 500 – 700 per year in the coming years

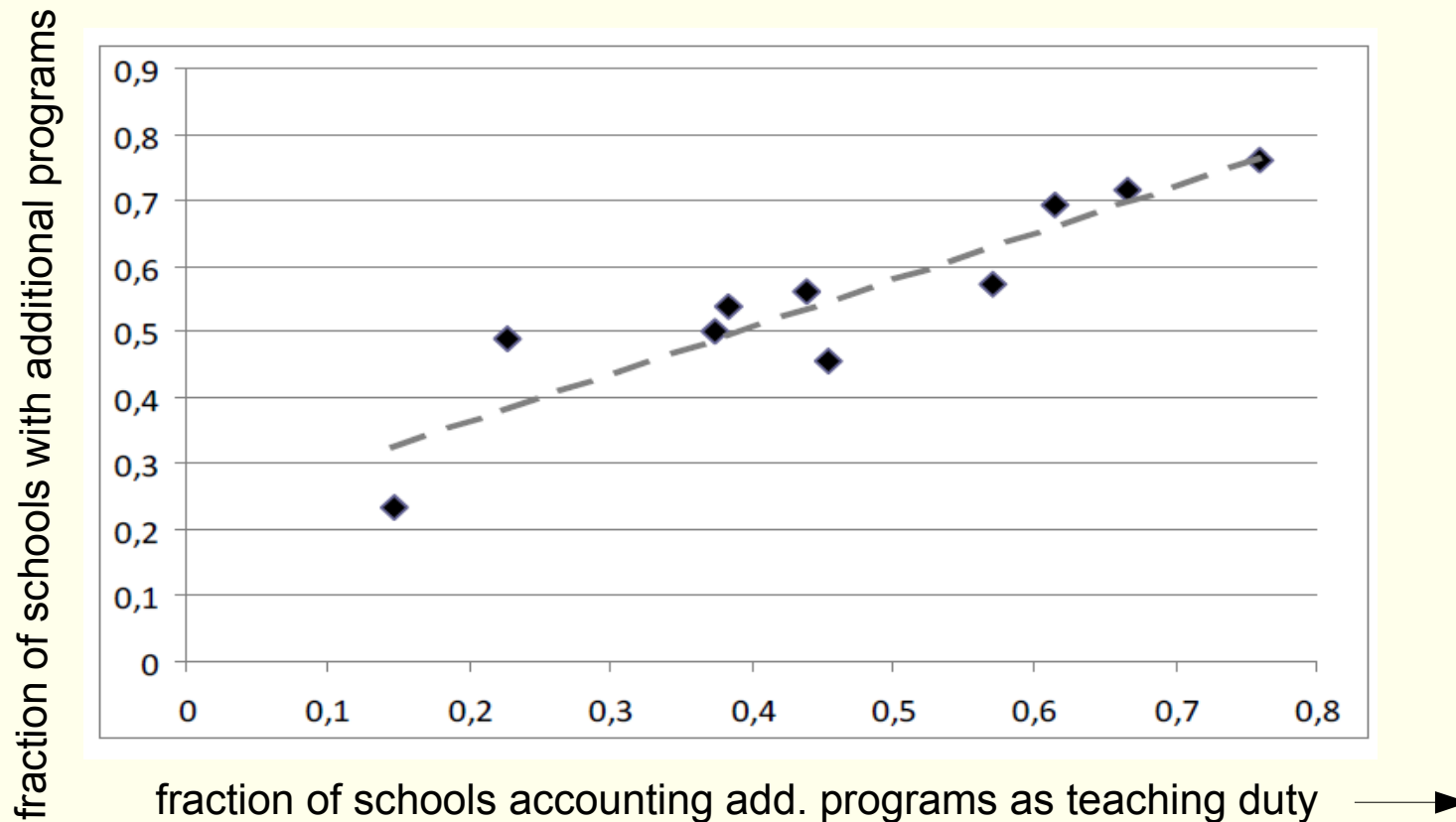
One way out: teach physics combined with other topics

- 1/3 of the schools questioned practice this model, but dominantly in grades 5 and 6, few in grade 8, very few later teaching 'nature, science and technology'
- in this case, the teacher doesn't have to be a physics teacher
- huge local variation, 100% in Bremen, 0% in Sachsen-Anhalt
- need to watch this, what are trends?
potentially dangerous - do we want the biology teacher to teach physics?
a way to hide lack of physics teachers

Extracurricular programs outside of class room

a key component of physics and STEM education!

about half the schools in Germany make offers beyond the normal class room instruction - broad spectrum, some examples to follow
the states can influence this



schools offering programs would see the need to offer more, if personell available; schools which don't, don't see urgent need

Schülerforschungszentren



Research centers for school kids

- to further talent and technology
- access for children of all ages from elementary school to high school
- first SFZ founded in 1999 in Bad Saulgau in the south west of Germany by Dr. Rudolf Lehn



DPG executive committee member
2012 - 2016



SFZ – now a Germany wide network

8 centers in Baden-Württemberg and more all over Germany



What is happening at a SFZ?
preparation for competitions
workshops
research projects (also commissioned)
seminars
continuing education for teachers

Who is working with the children?
teachers
university professors
experts from industry
retired teachers and experts
students

Who is financing a SFZ?
support is local to state or region – **grass roots**
states by reducing teaching load in school
communities, regional governments,
companies, chambers of commerce, donations,
sponsorships, partnerships, a lot of volunteer work



Example research project for high school students



In 2015,
53 projects for
'Jugend forscht'
supported,
18 winners
23 medals

Marcel Mohn and Marvin Motzet – smart refrigerator, regional winners of 'Jugend forscht' 2015 in area 'technology', applied for german patent jointly with company Liebherr

And for the youngest

Team 'elementary school': arouse STEM curiosity, develops teaching material for elementary school teachers (who are not university educated)



Physics for children in elementary school



2012 Georg Kerschensteiner Preis of the DPG for Christian Heilshorn, Raabeschule, Braunschweig project **“Physics for Bright Minds”**

Highschool students from grades 9 and 10 go into elementary school to teach basic and fun concepts of physics, largely with experiments and demonstrations
e.g. optics: light, color, spectrum, mirrors, refraction

in the mean time, program is open to schools all over the state of Niedersachsen



PiA Physics in Advent



- 24 experiments to do at home with easily available tools and components for kids in grades 5-10
- Explained by youtube movie every day
- Solution by youtube movie the next day
- Many prizes and fun animation
- now also in English!



Grand prize 2015

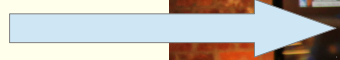


PiA Physics in Advent



23 400 registered participants from 20 countries
more than 1 million visitors
more than 50% of the participants and facebook friends female!

and this is the guy who
created it with his team
Prof. Arnulf Quadt
DPG executive
committee member
2014-2018



IYPT International Young Physicist Tournament

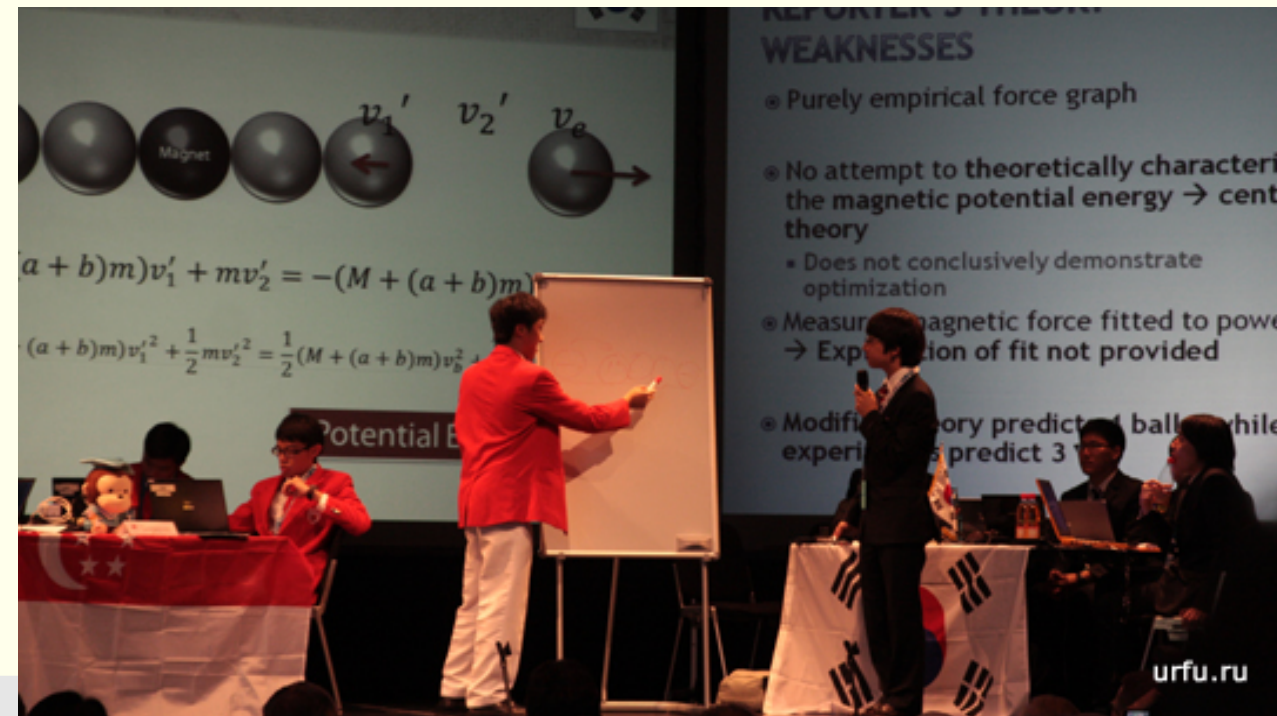
conceived by Yevgeny Yunosov in 1979, first tournament in 1988 in Moscow, since then every year in another city and continent

- 5-member teams solve 17 problems with unknown solutions, all ways to solve are fine, often experiments, consultation with experts, theory, ,...
- Solutions are presented in a tournament, other teams challenge a team that presents it's solution
- Teams from 45 countries participating not from Japan so far ;-(

Problem 17 from 2016

tournament: 'Crazy Suitcase'

- When one pulls along a two wheeled suitcase, it can under certain circumstances wobble so strongly from side to side that it can turn over.
- Investigate this phenomenon. -
- Can one suppress or intensify the effect by varied packing of the luggage?



GYPT German Young Physicist Tournament

In 2012, IYPT took place in Germany and we (DPG) realized: only 1 team prepares in Germany but 100 in South Korea!

- the one year preparation process is the key event, not winning!
- the people who prepare come out as different people
- an idea was born: a preparatory competition, the GYPT
- the goal: to have at least 10 German teams preparing
- first GYPT in 2014
- the outcome: in 2017, 32 teams from 13 preparation centers were competing to be selected to the German national team

initiated by Prof. Metin Tolan and Dr. Rudolf Lehn, funded by the Wilhelm & Else Heraeus Foundation and die DPG



Extracurricular programs attract girls in particular



German national team for the IYPT 2015 in Thailand

Highlights of Physics

A one week festival of physics, taking place every year in a different mid-size German town
Attracts typically 35 000+ visitors, mostly from schools
Hands-on exhibit with experts present, shows on open-air stages, live experiments, Einstein Slam, talks by prominent physicists, a competition for school teams, a huge evening show



Ulm Hbf



**Mikro
kosmos**
27.9.-1.10.2016

2016
highlights der physik

2016 in the birth place of Albert Einstein

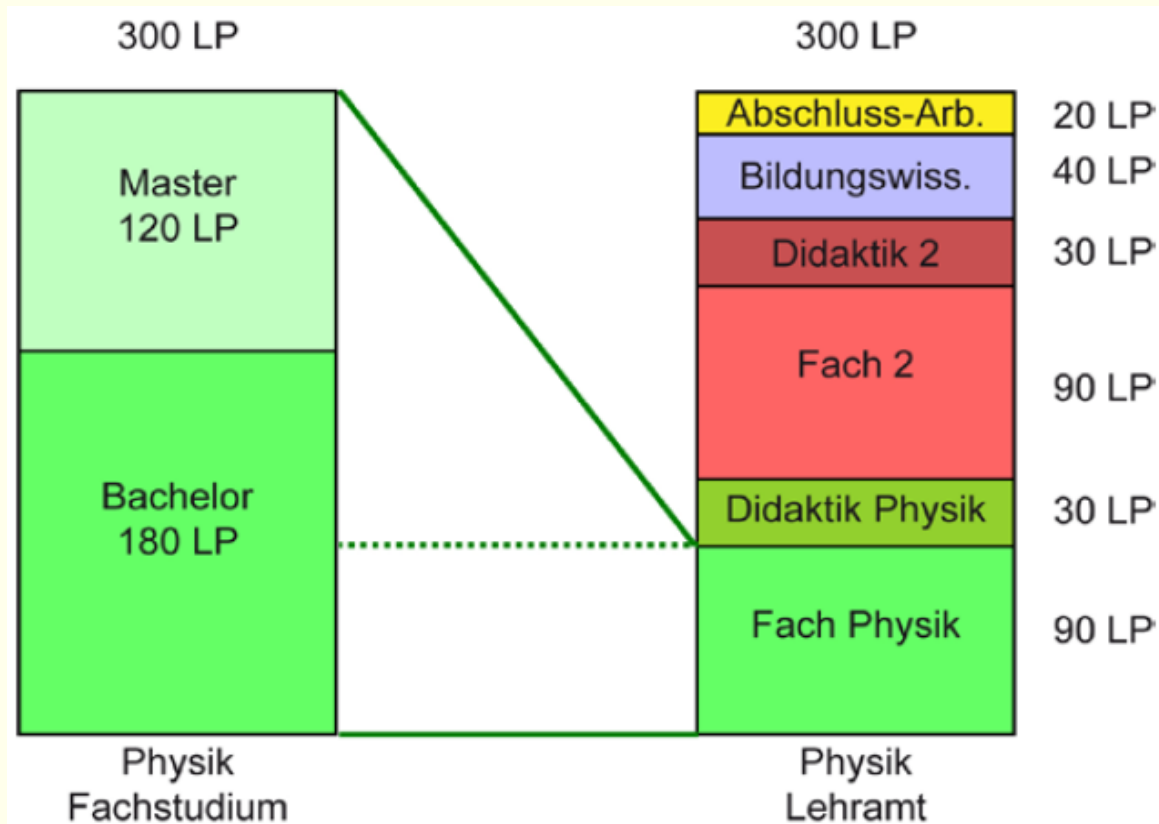


All of this needs great physics teachers

How can we get the most gifted young people to become physics teachers again?

Some thoughts on education of physics teachers

- Physics teachers need very good physics background in their education
 - on the other hand, we need to be judicious about the amount and the formal mathematical training
- Physics teachers study 2 subjects
 - if the second subject is not mathematics, this will be tough
 - even if it is, the number of credit points for physics is only 90, equivalent to 3 semesters full-time (out of 10)



Some thoughts on education of physics teachers

- Need to custom tailor the curriculum and (at least part of) the courses specifically for future teachers
- High quality education in didactics of physics and aspects of pedagogics
- At what stage in their education should a student have to decide for the teaching profession?
Maybe right after high school is too early?
- We need a transparent system that allows transitions towards the teaching profession at various stages
and vice-versa
additional education in didactics could come via a special (stipend) program to avert crisis in supply of teachers

Thank you for your attention

Additional material

