

# ECFA MidTerm report for **Denmark** July 2010



*Presented by:*

*Ulrik I. Uggerhøj, Department of Physics and Astronomy, Aarhus University, Denmark*

*Frascati, 01.07.2010*

# Basic facts about Denmark

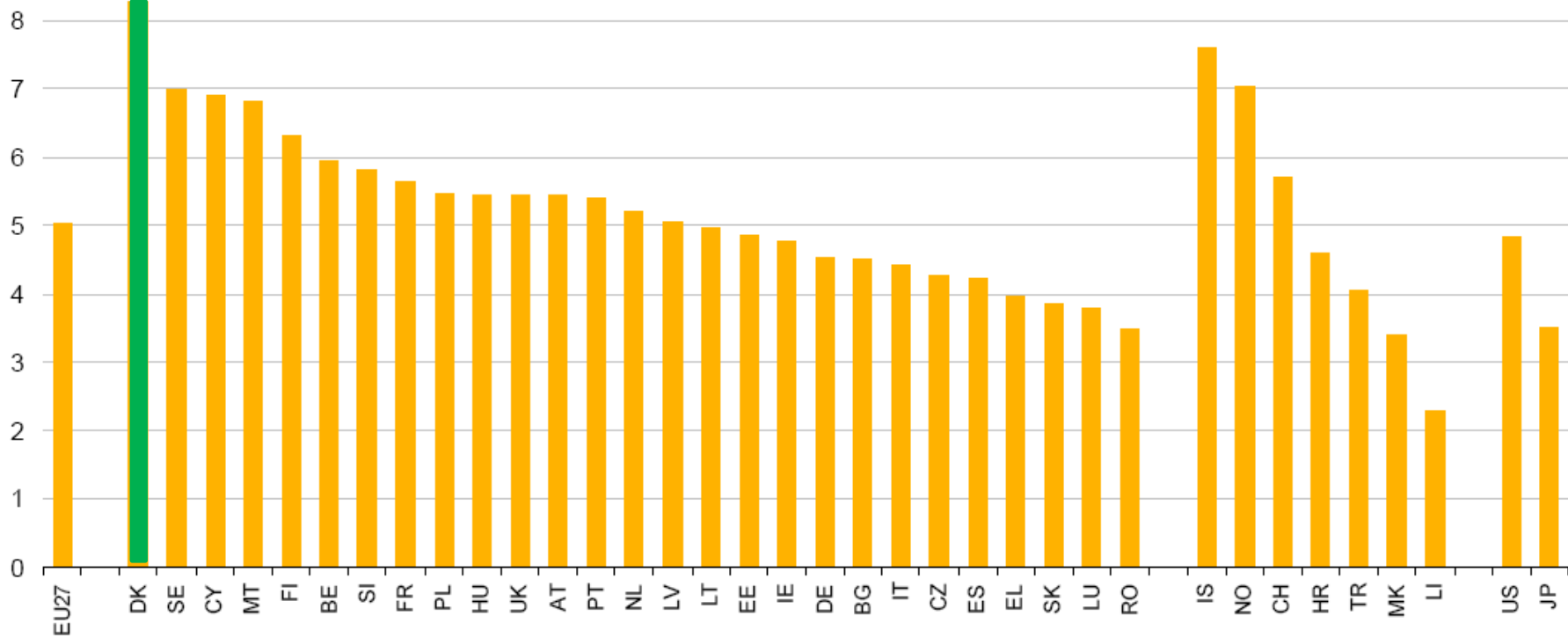


- Population: 5.540.241 (1.1.10)
- The world's highest level of income equality (UN)
- The world's highest minimum wage (IMF)
- 43,094 square kilometres
- No. 17 on the list of countries by GDP (PPP) per capita (IMF): 35,757 Intl. \$
- Denmark frequently ranked as "the happiest place in the world", based on standards of health, welfare, and education.
- Young (20-29 yrs.) tertiary graduates per thousand: 78.7
- R&D expenditure of GDP: 2.43%
- 9.8 researchers for 1000 FTE (2006)
- 6 Universities, 3 with HEP activities

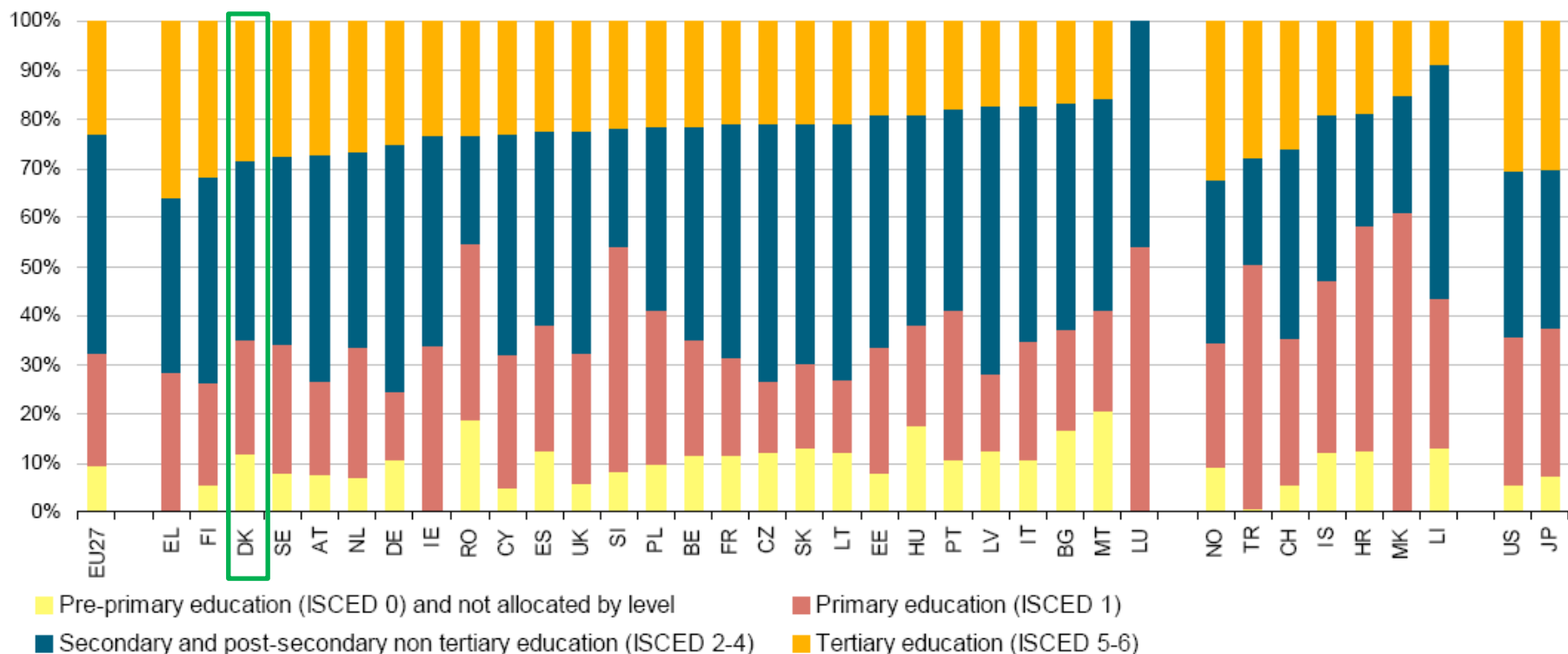
# Education

- 99% of students attend elementary school,
- 86% attend secondary school
- 41% pursue further education.
- All college education in Denmark is free; there are no tuition fees to enroll in courses.
- Students in secondary school or higher may apply for Student Support which provides fixed financial support, disbursed monthly.

Figure 1: Public expenditure on education as a percentage of GDP - 2005



**Figure 3: Breakdown of public expenditure on education by education level - 2005**



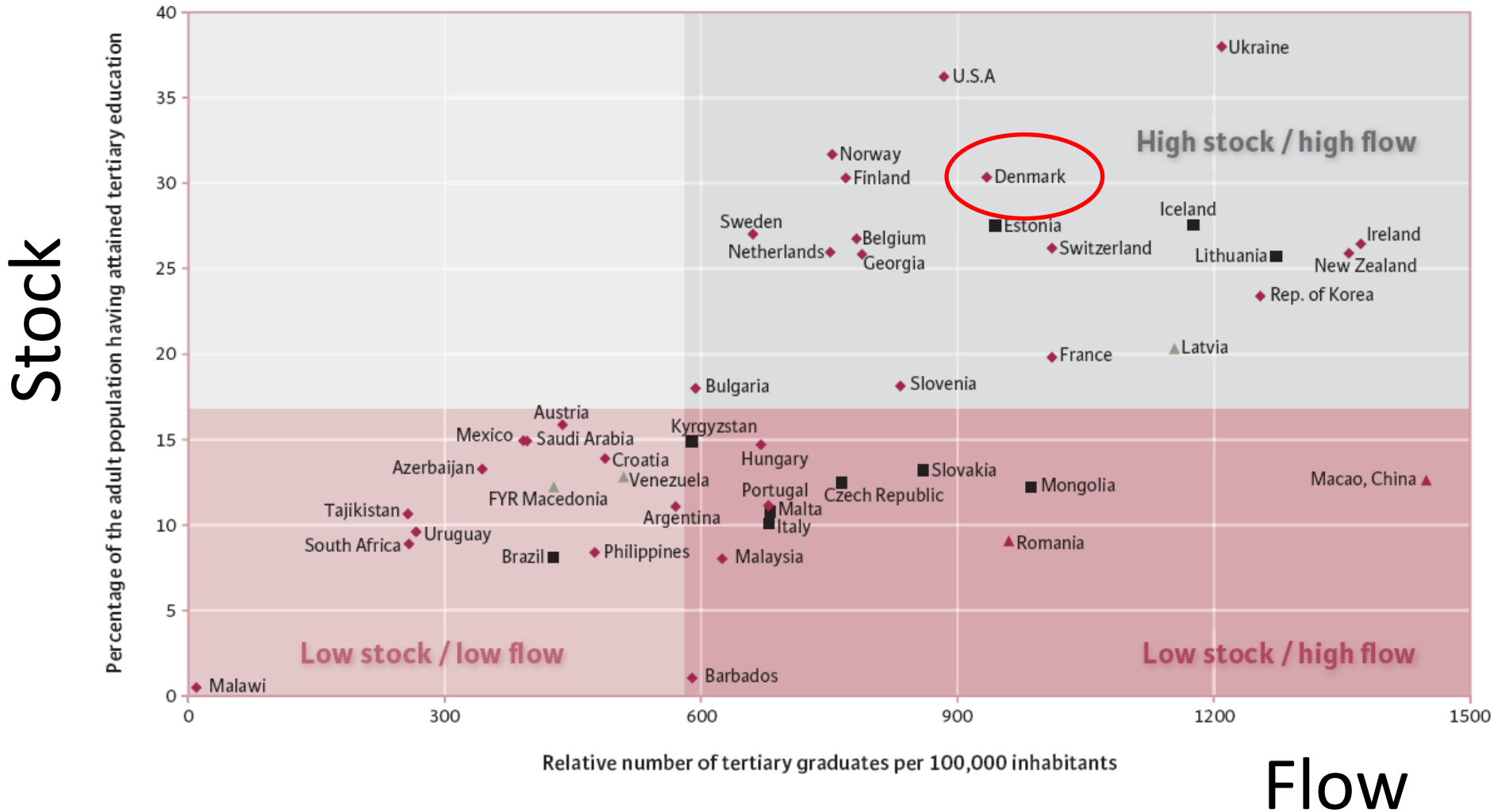
	Public expenditure on education as a % of GDP					Expenditure on educational institutions as a % of GDP	
	All	Primary	Secondary	Tertiary	Pre-primary + not allocated	Public funds	Private funds
EU27 European Union	5.04 <sup>s</sup>	1.15 <sup>s</sup>	2.25 <sup>s</sup>	1.15 <sup>s</sup>	0.48 <sup>s</sup>	4.72 <sup>s</sup>	0.67 <sup>s</sup>
DK Denmark	8.28 <sup>i</sup>	1.93 <sup>i</sup>	3.01	2.38 <sup>i</sup>	0.97	6.83 <sup>i</sup>	0.57

# Stock and flow of tertiary graduates

Percentage of the adult population having attained tertiary education and the current level of tertiary graduate outputs

Average annual growth rate of the relative number of tertiary graduates:

- ◆ < 7%
- ≥ 7% and < 12%
- ▲ ≥ 12% and < 15%
- ▲ ≥ 15%



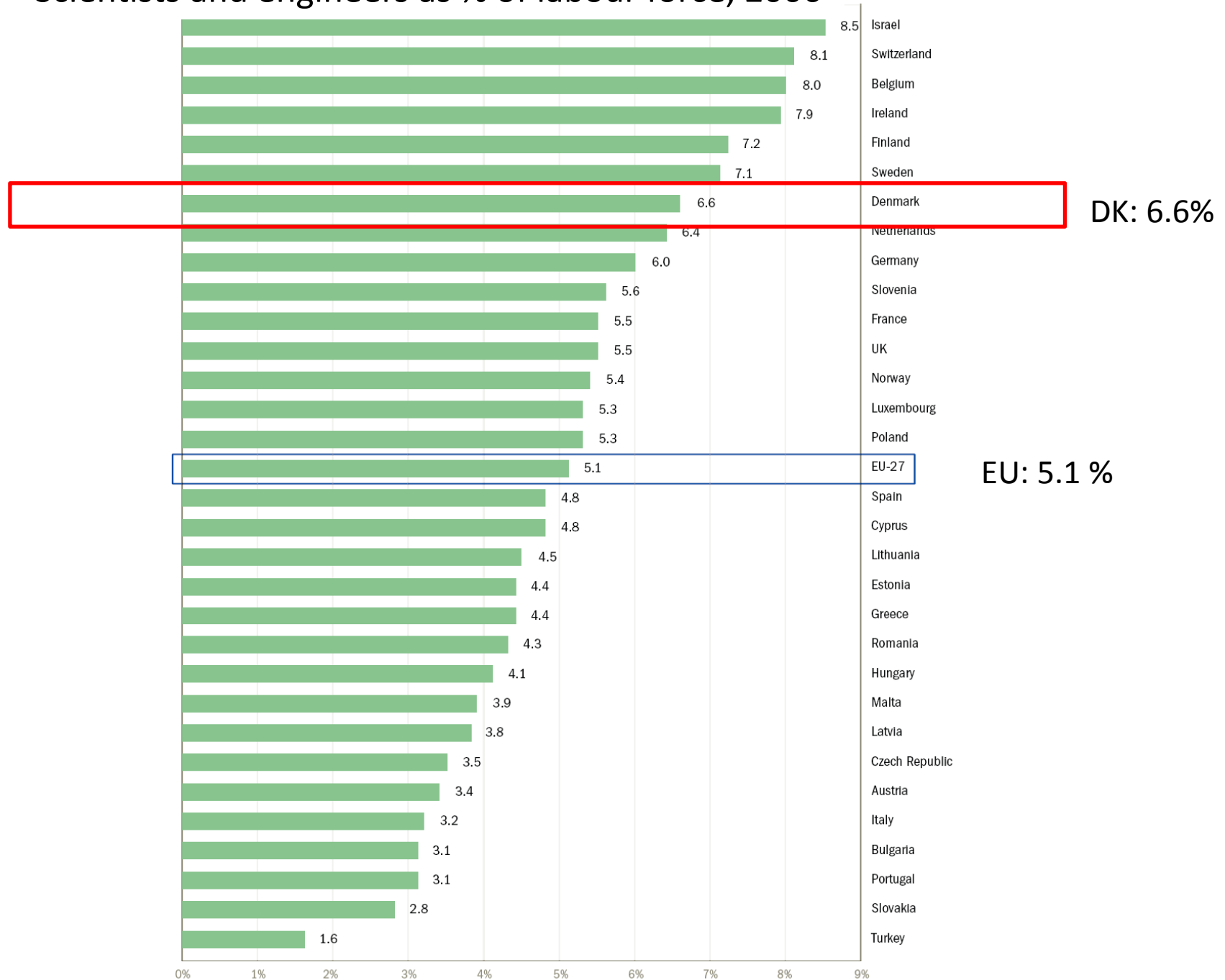
# Young scientists and engineers

TABLE I.2.2 Tertiary graduates per thousand population aged 20-29 by field of education, 2005 and average annual growth, 2000-2005

(Countries are ranked in terms of science and engineering graduates per thousand population, 2005)

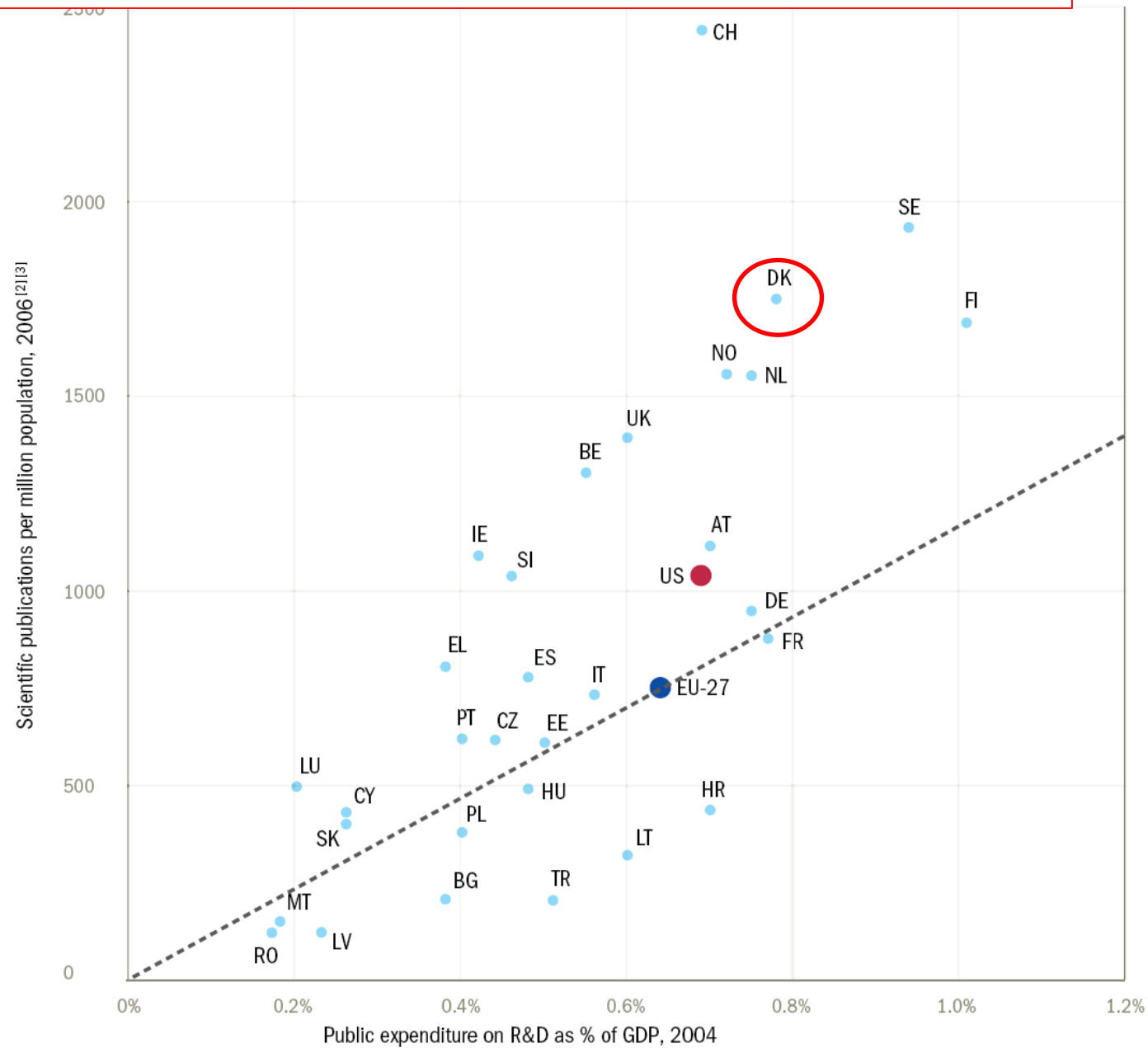
	All fields		Science		Engineering		Science and Engineering	
	2005	Average annual growth 2000-2005	2005	Average annual growth 2000-2005	2005	Average annual growth 2000-2005	2005	Average annual growth 2000-2005
Ireland	85.0	4.1	13.8	-1.7	10.2	2.7	23.9	0.0
France	83.2	5.9	10.2	1.3	12.2	5.2	22.4	3.3
Lithuania	86.2	10.5	4.5	11.9	14.3	5.2	18.8	6.6
UK	82.3	4.3	11.6	0.7	6.6	-2.3	18.2	-0.5
Finland	59.1	0.7	5.2	3.7	12.5	1.5	17.7	2.1
Switzerland	69.8	:	6.5	:	9.5	:	16.1	:
Denmark	78.7	7.7	6.6	8.4	8.3	2.3	14.9	4.7
Sweden	53.9	7.2	4.4	3.4	9.9	4.6	14.3	4.2
<b>EU-27</b>	56.9	6.3	5.7	5.4	7.2	5.0	12.9	5.2

# Scientists and engineers as % of labour force, 2006

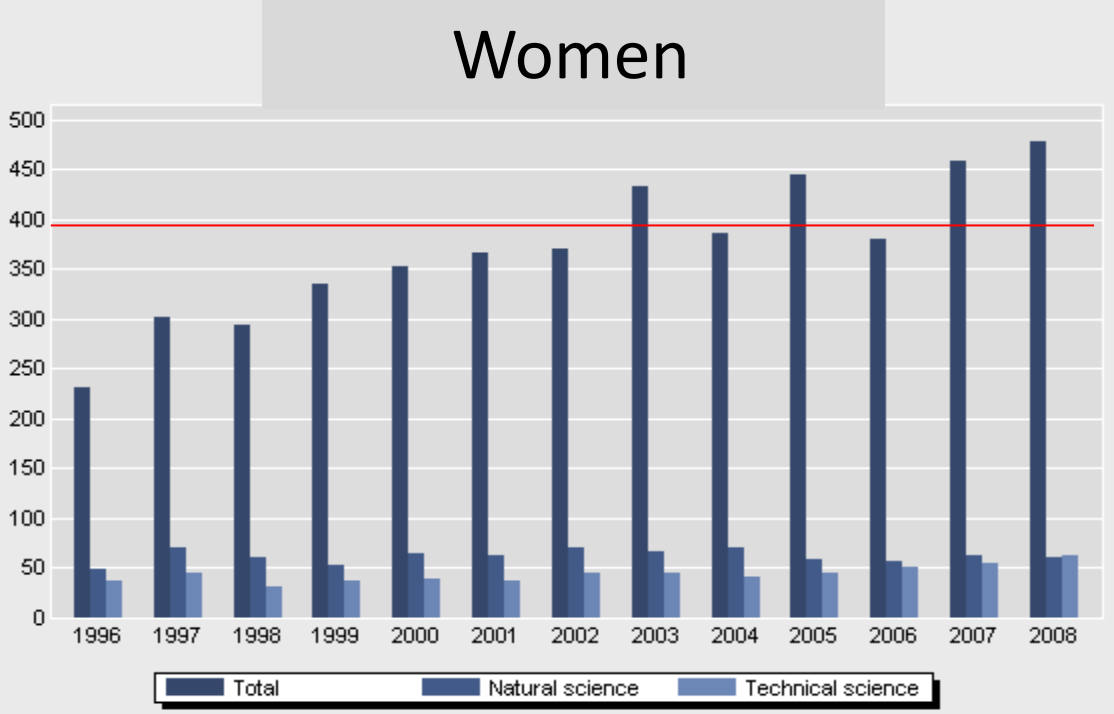
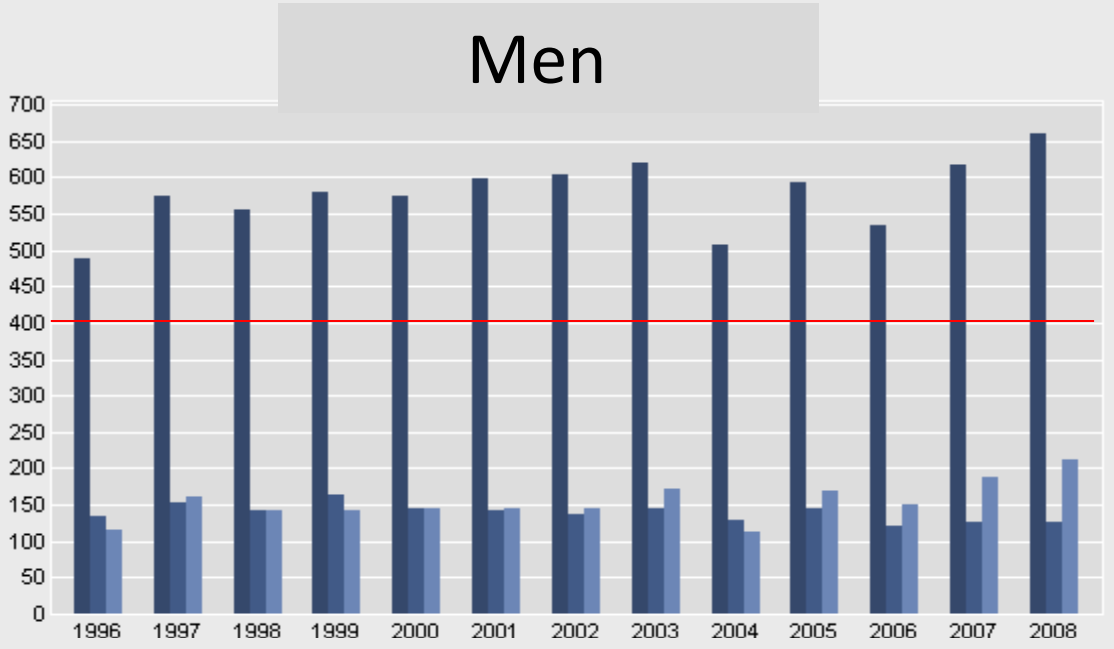




# Scientific publications in relation to public expenditure on R&D



**Doctorate graduates**  
**Total**  
**Natural Science**  
**Technical Science**

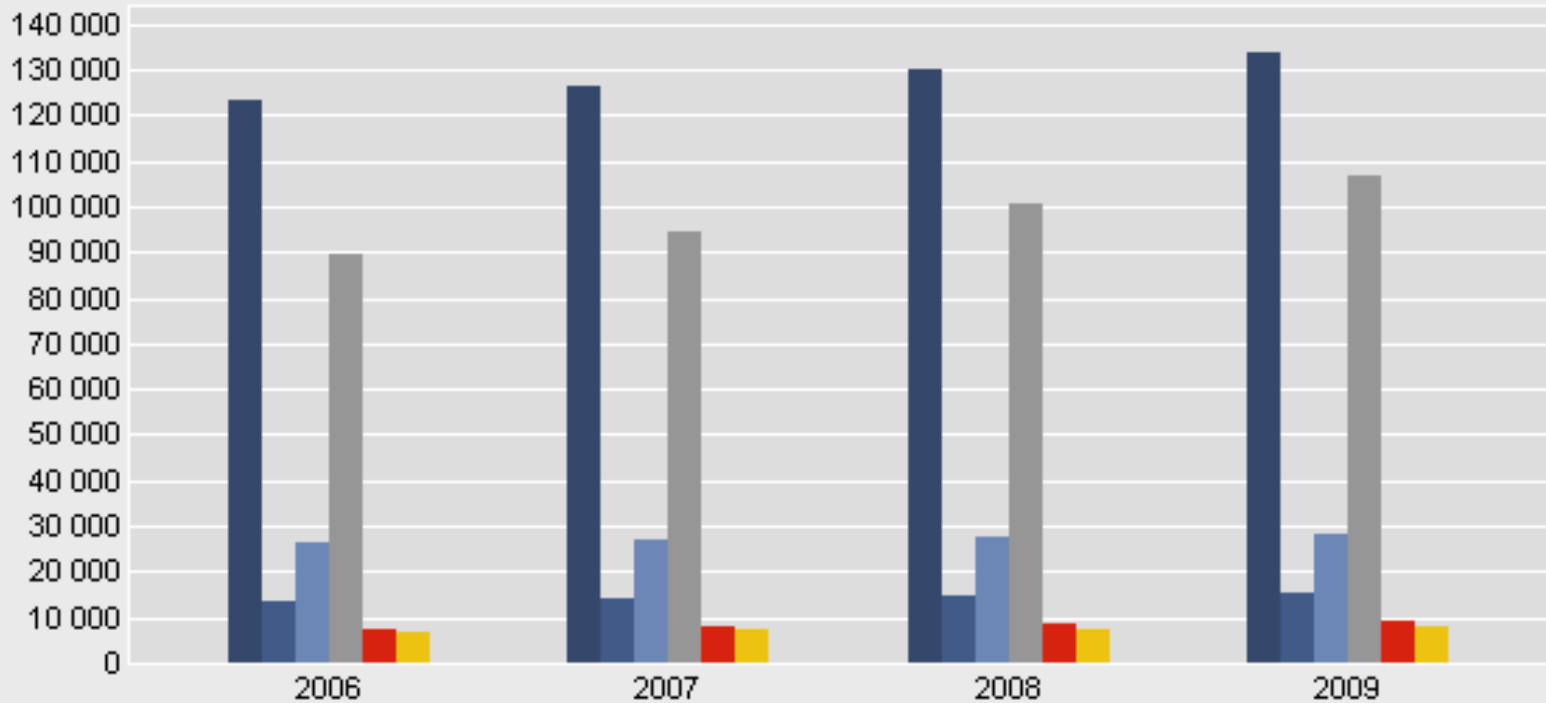


■ Total    ■ Natural science    ■ Technical science

# Educational attainment

Total long-cycle higher education (University MSc degree or above) about 6%

**Educational attainment of the population  
by sex and education and time.  
Age, total, Total, All Denmark. (Number)**



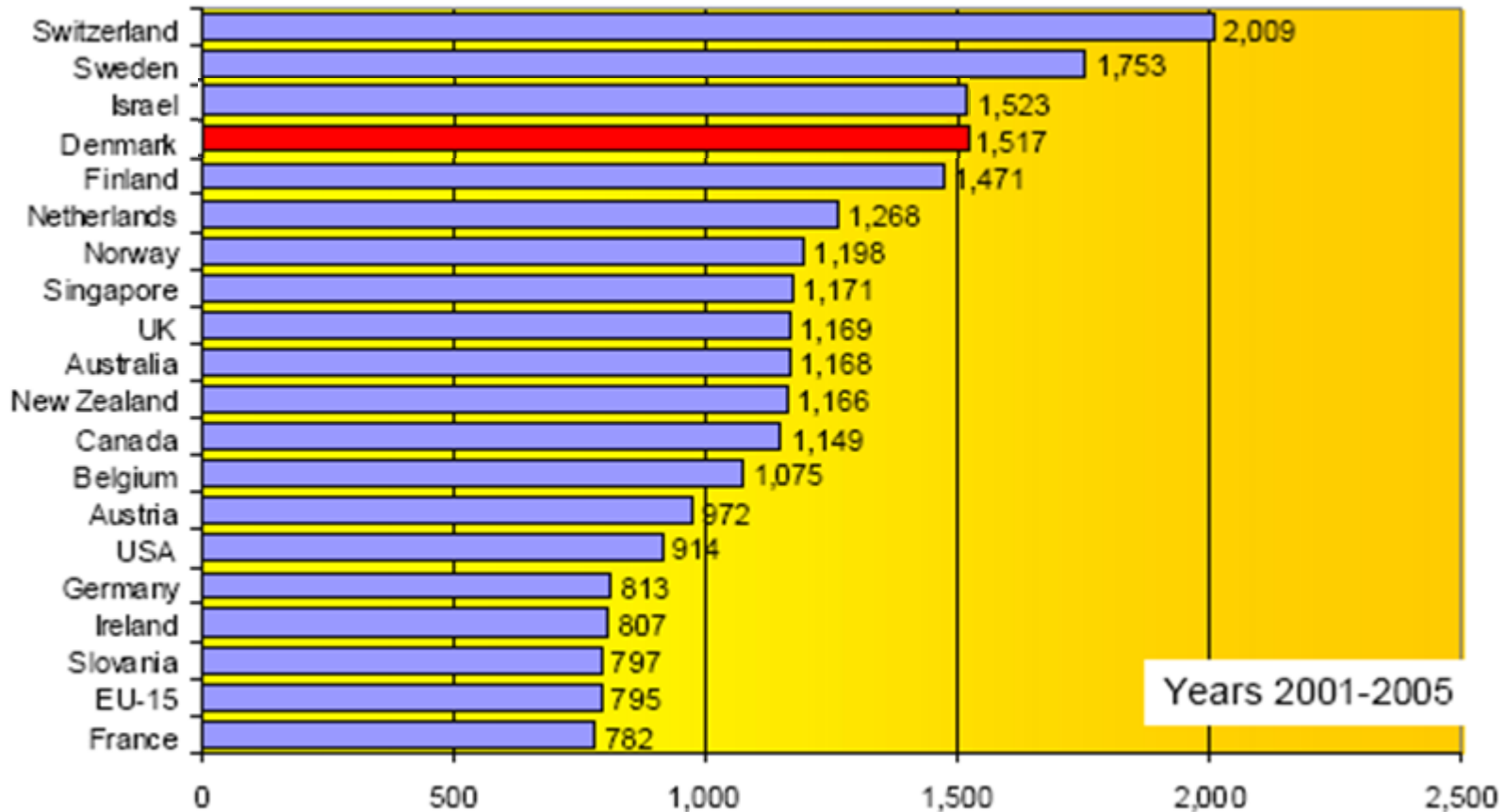
# Research finances in DK

- National research budget, 2009: 2359 Meuro
- CERN contribution 'directly' from the Ministry
- CERN 'utilization budget' applied at research council in principle in competition with other natural sciences
- Other sources: Danish Research Foundation, private funds

	TOTAL NUMBER OF RESEARCHERS (FTE)			RESEARCHERS (FTE) PER THOUSAND LABOUR FORCE		
	2000	2006	Average annual growth 2000-2006 [1]	2000	2006	Average annual growth 2000-2006 [1]
Denmark	19453	28653	8.1	6.8	9.8	7.7

# Research output

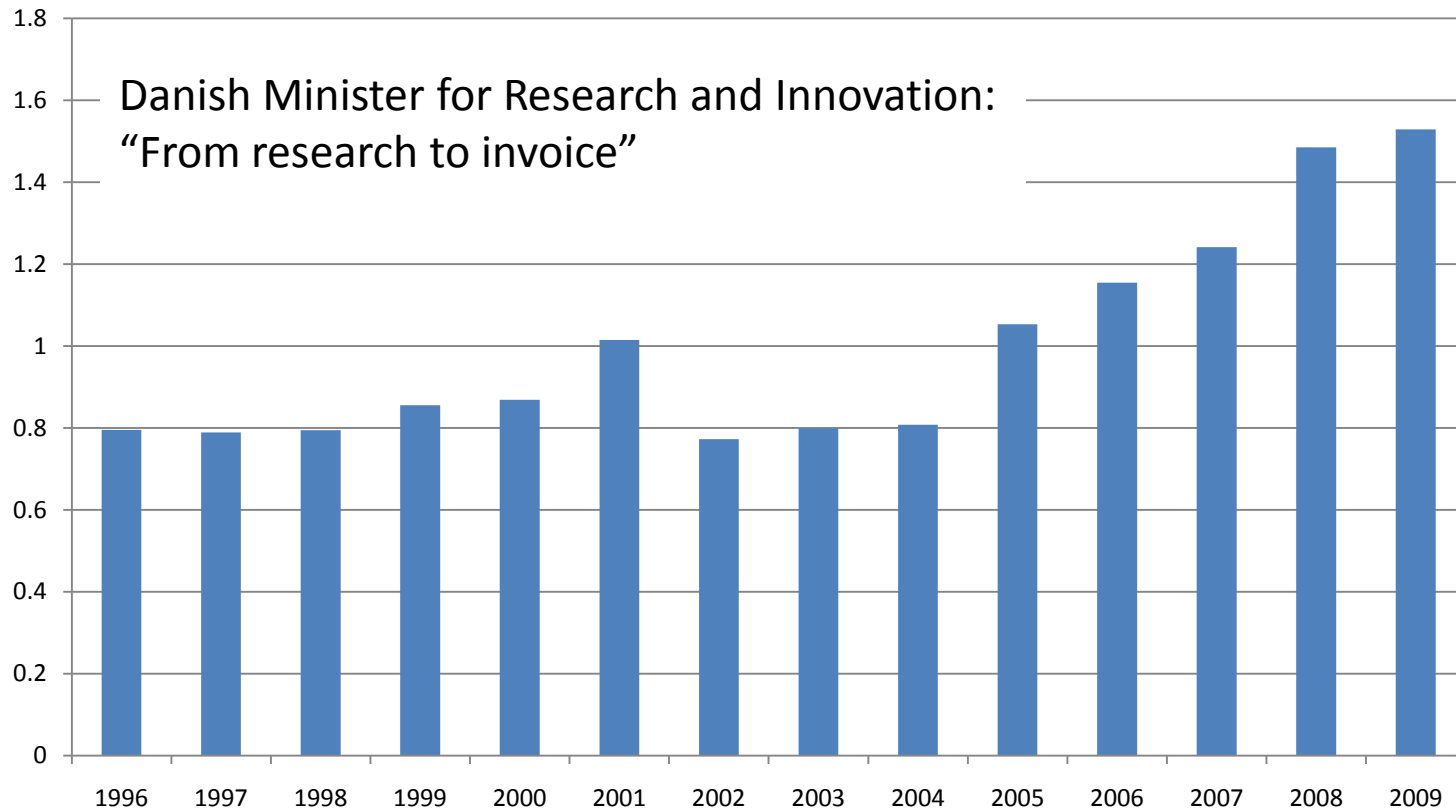
Papers per 1 million population **World Top 20**



Years 2001-2005

# Basic research and R & D

Basic research and R & D general public services in percent of government expenditures



‘University Acts 2003, 2006, 2007’ – reallocation of finances for the Universities:  
The Minister subsidises study programmes, research and dissemination  
based on ‘completed courses of study’.  
Universities have at ‘free disposal’ subsidies, income and capital.

# Relations with CERN

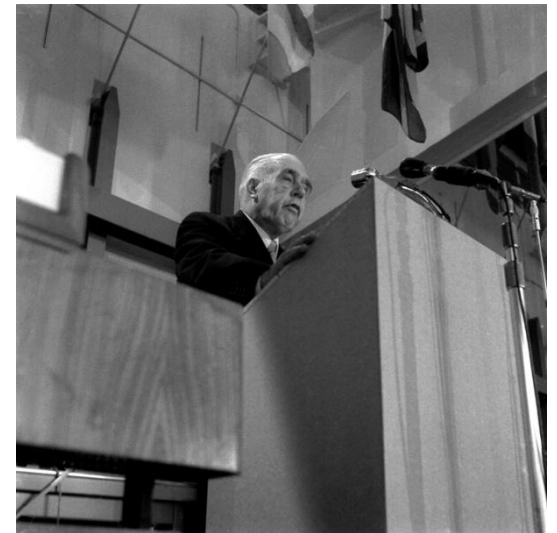
- Contribution to CERN budget 1.76% in 2009
- Total 106 persons in HEP in DK
- CERN member state since 1954

Numbers (dec. '09) of:

users 64

fellows 3

staff 19

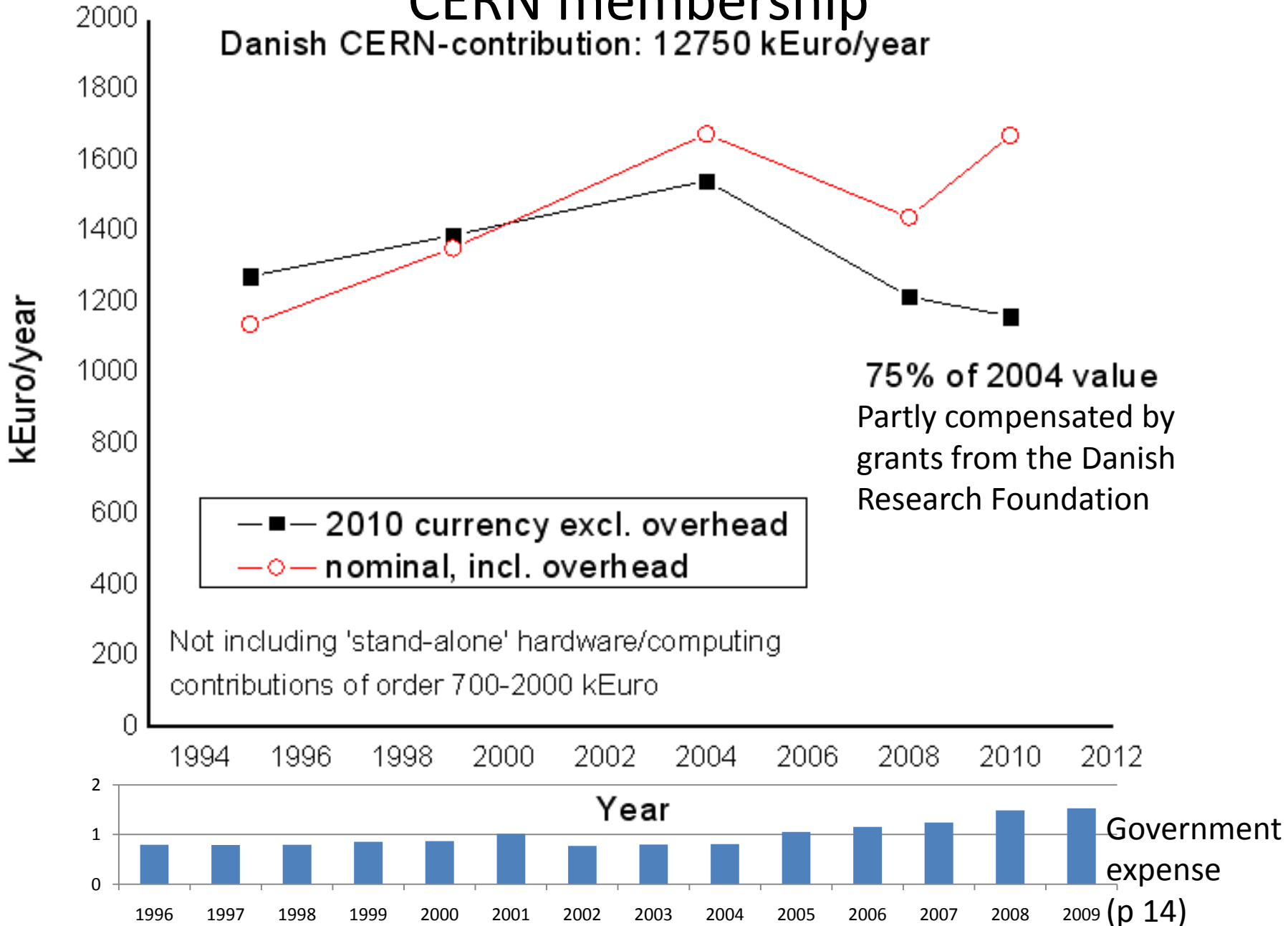


Niels Bohr,  
PS inauguration, 5.2.1960

# Money spent by research council to utilize DKs

## CERN membership

Danish CERN-contribution: 12750 kEuro/year





# HEP/CERN-related physics in Denmark

‘Traditionally divided’ among:

- Niels Bohr Institute, Copenhagen (HEP theory and exp., large experiments)
- Aarhus University (Atomic and nuclear, small ‘niche’ experiments, CMB Planck)
- ... and recently University of Southern Denmark (HEP theory)

This ‘division’ means that the recent trend of CERN policy to also encourage non-LHC experiments is popular in DK (new FT exp. effectively under embargo 2000-2006)

# COPENHAGEN ATLAS WEEK overview



UNIVERSITY OF COPENHAGEN

## RF FOR ACCELERATORS

CERN Accelerator School and Aarhus University will organise a course on RF for Accelerators



This course will mainly be of interest to staff in accelerator laboratories, university departments and companies involved in producing RF equipment for accelerators.

The course will present a review of the RF technology presently used in the field of particle accelerators. As well as a review of the theoretical fundamentals, the different pieces of equipment will be discussed along with their practical applications in terms of RF diagnostics, measurements and RF gymnastics.

Dedicated hands-on exercises and seminars will complete the programme.



8-17 June 2010

Hotel Ebeltoft Strand,  
Ebeltoft, Denmark

Contact: CERN Accelerator School  
CH-1211 Geneva 23 - Switzerland  
Fax: +41 22 767 5466 - [www.cern.ch/schools/CAS](http://www.cern.ch/schools/CAS)



Information: [atlas2010.dk](http://atlas2010.dk)

June 28th - July 2nd 2010

University of Copenhagen

Dines Hansen (chair), Peter H. Hansen,  
Troels C. Petersen, Stefania Xella.



CERN  
School of Computing  
Denmark, 2011

# HEP/CERN-related physics in Denmark

- ATLAS (KU)
  - ALICE (KU)
  - ISOLDE (AU)
  - AD-3 (AU)
  - AD-4 (AU)
  - AD-5 (AU)
  - NA63 (AU)
  - Theory (KU, AU, SDU)
- Particle Physics / Nuclear Physics
- (Relativistic) Atomic Physics

# Denmark in ATLAS

- University of Copenhagen in ATLAS from the beginning of the collaboration.
- 6 permanent staff (3 FTE), 6 postdoc, 5 PhD students, 1 engineer.
- Contribution to construction: 4MCHF
- Yearly M&O: 150kCHF
- Main hardware contribution: Transition Radiation Tracker back-end electronics and front-end test-facilities.



- Software activities:
  - TRT simulation and reconstruction (co-coordinator)
  - Electron identification (TRT coordinator)
  - Tau-trigger software (release coordinator)
  - Offline tau reconstruction
  - Test-beam and cosmics analysis
- Physics analysis
  - Searches for exotic long-lived particles
  - Higgs- $\rightarrow$ tau searches, Exotics- $\rightarrow$ tau searches.
  - Boson couplings and masses
  - Combined analysis of di-lepton final states
  - Hadron production in pp and AA collisions

# Denmark in ATLAS

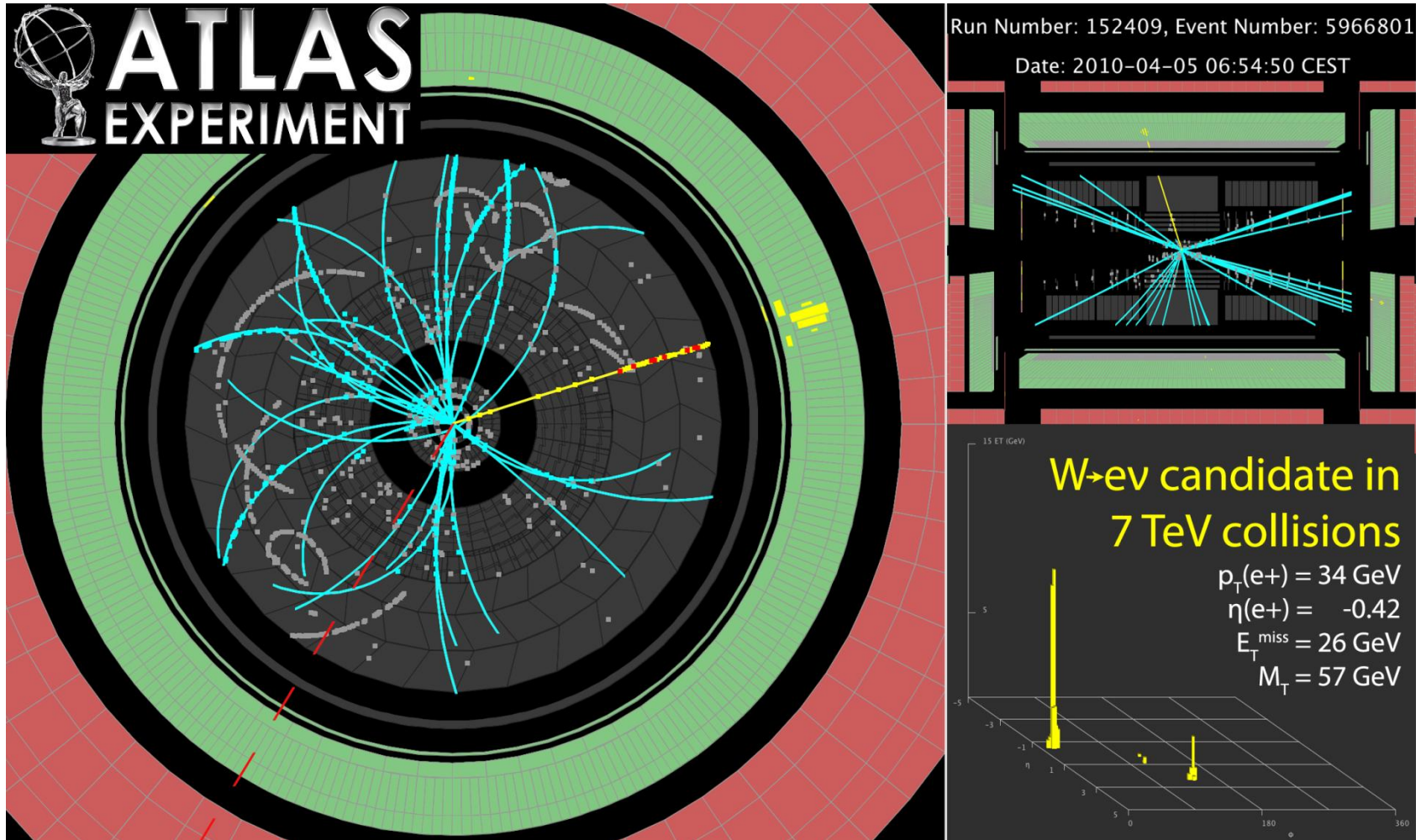


Illustration of the capabilities of the TRT:  
Continuous tracking at  $0.5 < R < 1 \text{ m}$   
Electron identification (red TR hits)

# Danish ALICE group

- 4 staff (1 prof + 3 assoc. prof).
- 2 post docs.
- 3 Ph. D students
- 3-4 undergraduates
- 1-2 eng/tech.
- (1-2 positions to be filled in 2011).

Part of the NBI FMD (Forward multiplicity detector) after installation in the central part of ALICE. The detector augments the rapidity coverage of ALICE to  $1.7 < \eta < 5.1$ .

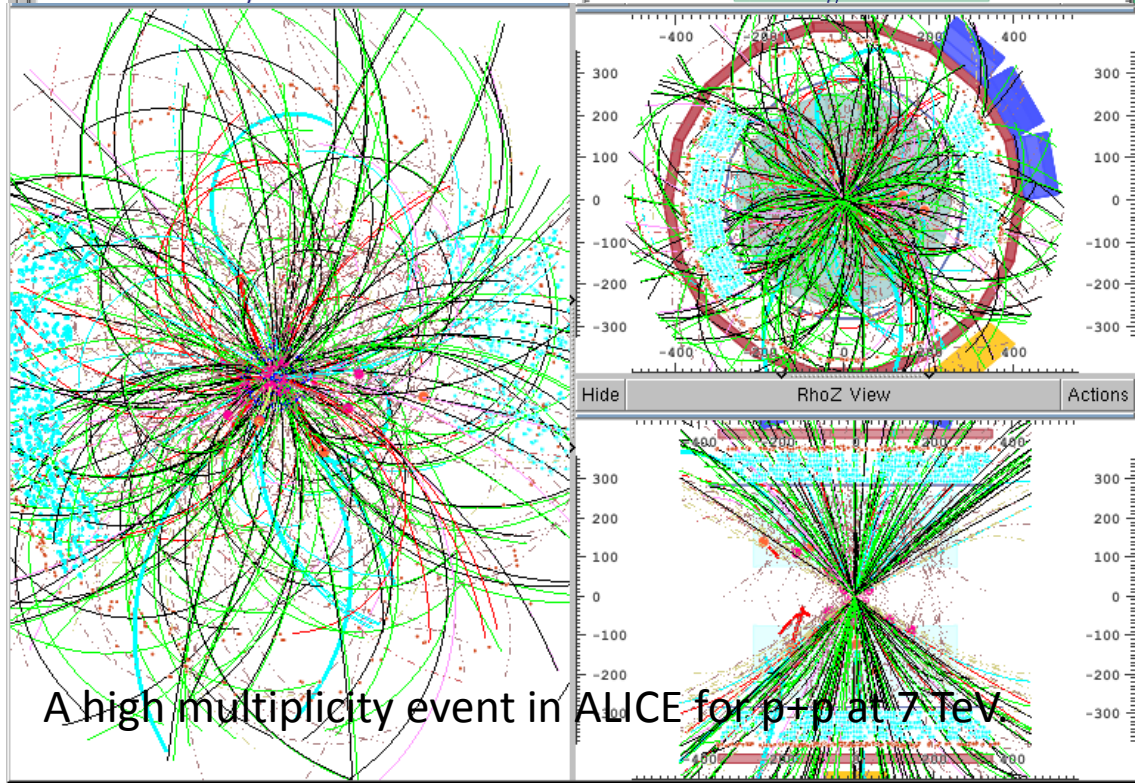
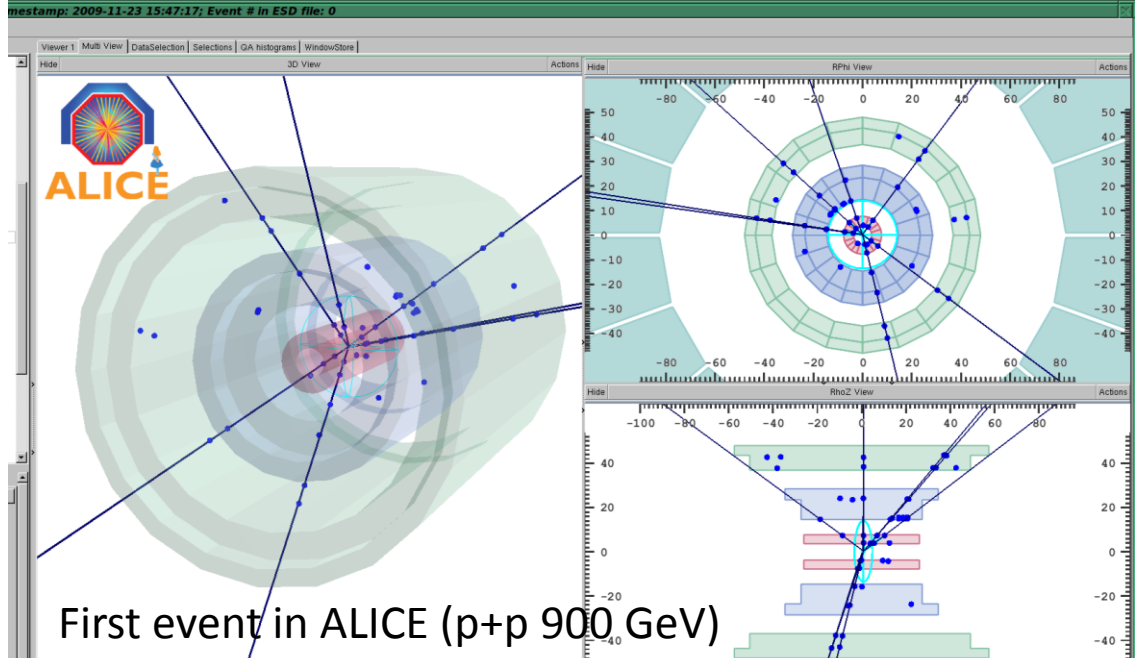
# DK role in ALICE instrumentation

- Full NBI responsibility for designing, constructing and maintaining the FMD (Forward Multiplicity Detector) – a 51000 channel si-strip detector extending the ALICE kinematical coverage into the region  $5.1 < \eta < 1.7$ .
- Full NBI responsibility for designing, constructing and maintaining the laser system for the ALICE TPC. This is the main device for calibrating the TPC. (High power laser that distributes approx. 350 (UV-266nm) light beams to the interior of the TPC simulating straight tracks.



# Physics interests (High density QCD)

- **Global observables:**  
pseudorapidity distributions of charged particles over  $5 < \eta < 1.7$ , supplementing central region covered by ITS, TPC etc.
- **Elliptic flow** ( major signal identified at RHIC for partonic thermalization)
- **Hadronic physics** with the ALICE-TPC
- **Jet physics** with EMCAL. (jet suppression- QGP tomography)



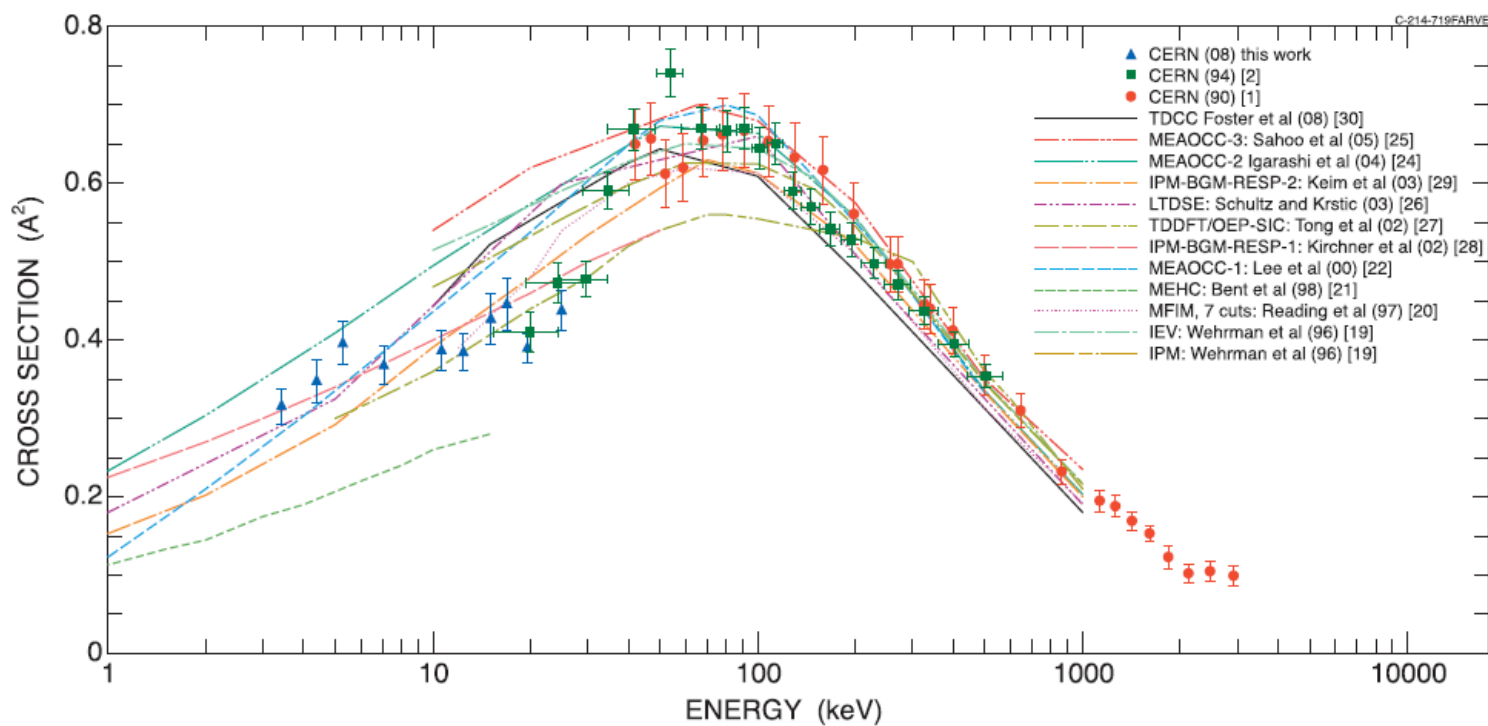
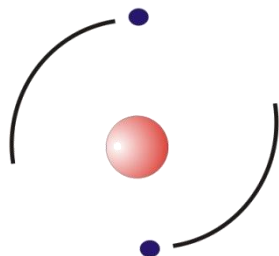


# The future: ALICE upgrades and e-A physics

- Near term: Upgrade of ALICE with a forward tracking calorimeter for forward physics (low  $x$ , e.g. gluon saturation physics).
- Long term: Low  $x$  physics e.g. with e-ion collider (LHeC).



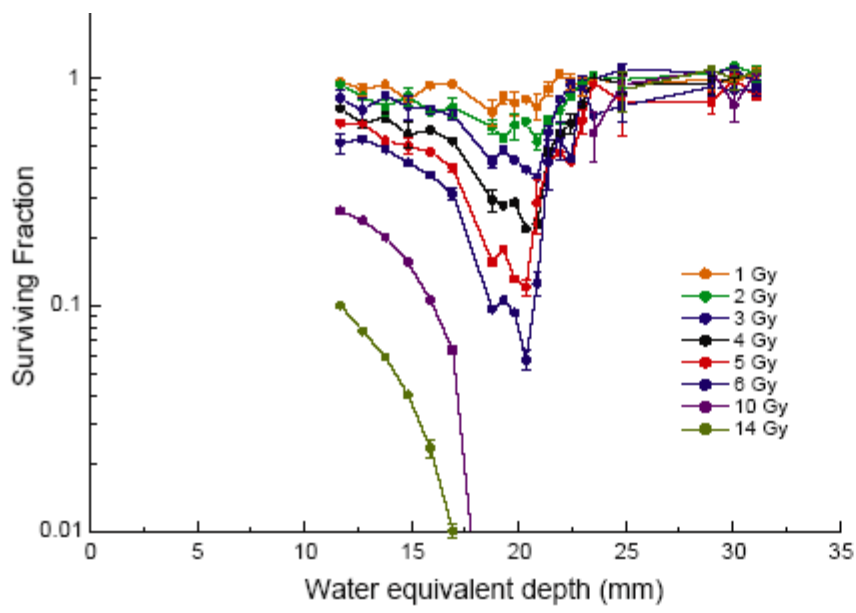
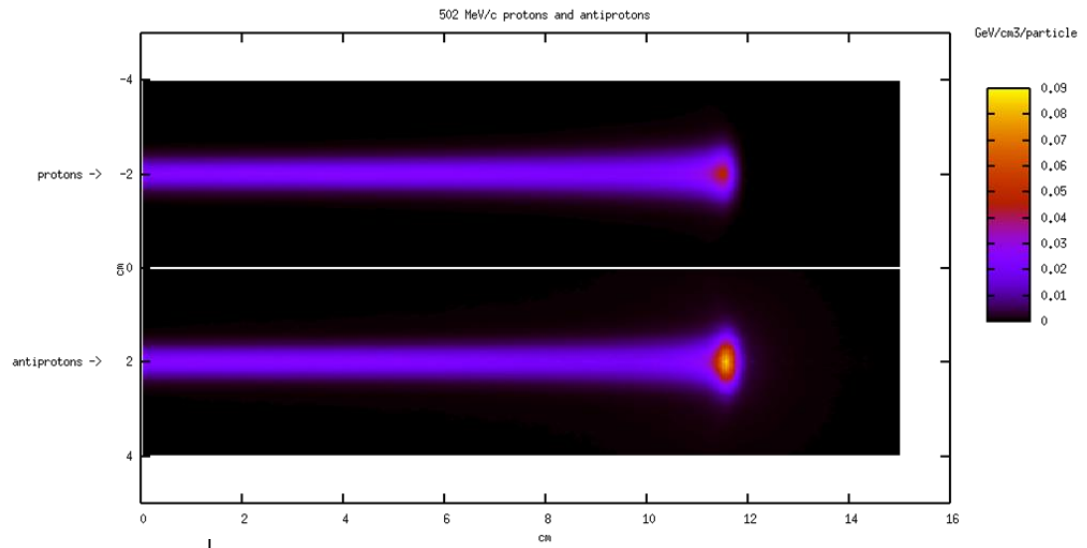
# ASACUSA (AD3)



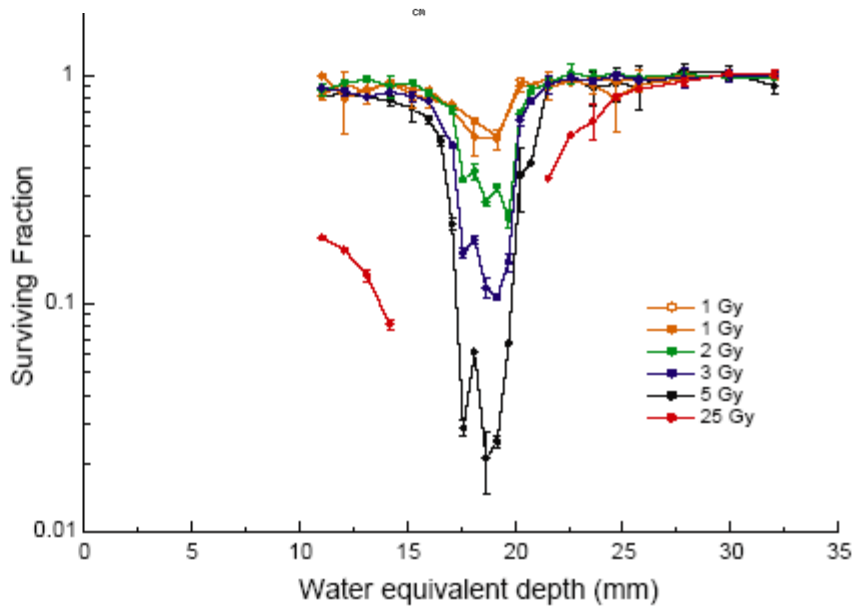
# ACE (AD4)

Are antiprotons an advantage for cancer-therapy?

'Relative Biological Efficiency'



protons

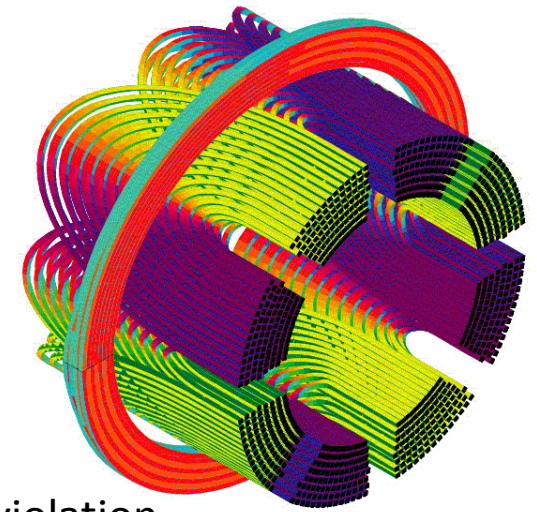


antiprotons

**Yes. Antiprotons are a factor of four better than protons (but costly)**



ALPHA  $\alpha$  (AD-5)



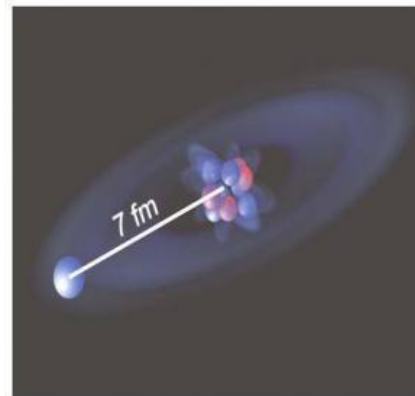
Possible CPT- and Lorentz-invariance violation

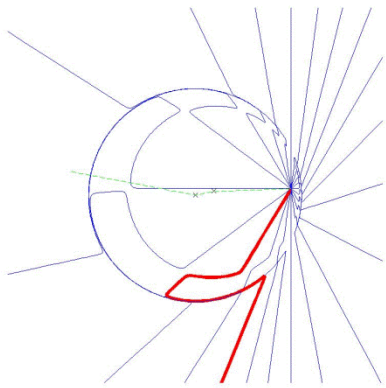
1S-2S transition in Hydrogen/Antihydrogen,  $10^{-15}$  relative prec.

## ISOLDE

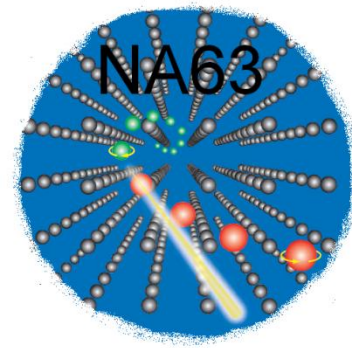
'Halo'-nuclei, Li-11, Be-14

Neutron-rich light elements  
( $N/Z$  about as for Pb)

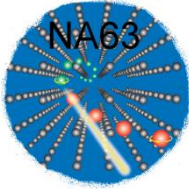




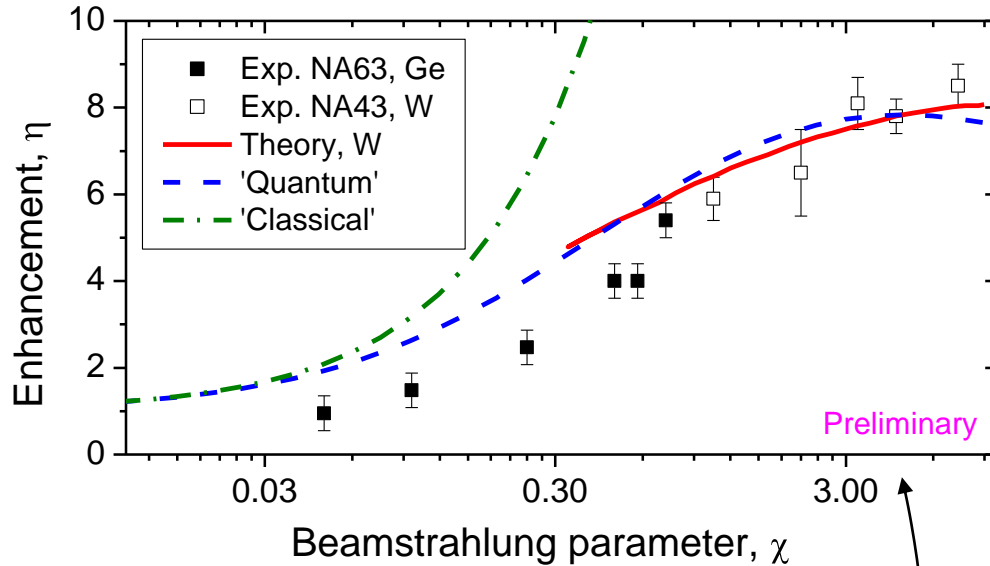
# NA63 (SPS)



- Studies of QED, radiation emission processes in amorphous media and crystals
  - Formation time effects
  - strong (critical) fields
- Relevant for:
  - Beamstrahlung in next generation linear colliders
  - Radiation from magnetars
  - Ultra-high energy cosmic rays



# Quantum suppression of radiation emission



$$\Upsilon = \frac{2\hbar\omega_c}{3E_0}$$

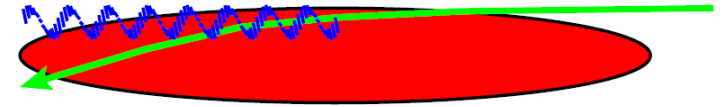
$$\Upsilon \propto \frac{N\gamma}{(\sigma_x + \sigma_y)\sigma_z}$$

$\Upsilon \ll 1$ : classical regime

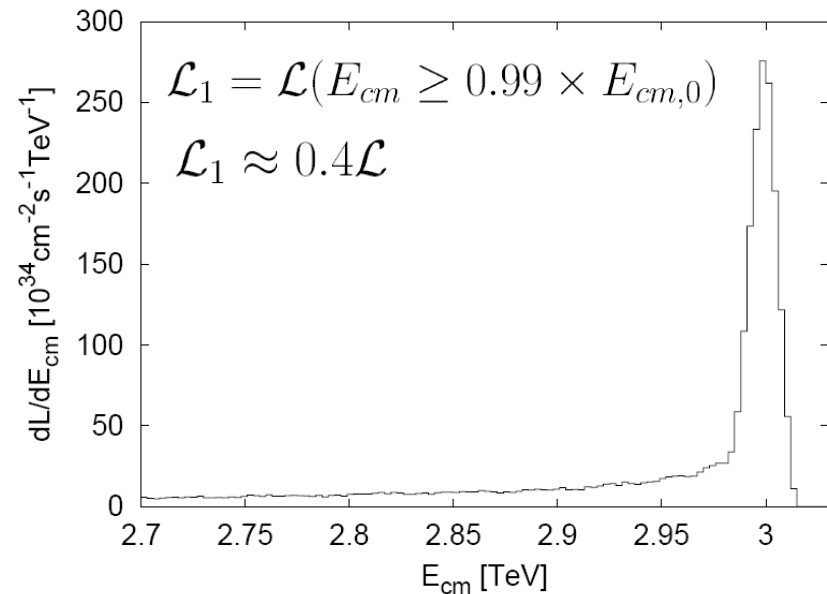
$\Upsilon \gg 1$ : quantum regime

in CLIC  $\langle \Upsilon \rangle \approx 4$

## Beam-Beam Interaction



● beamstrahlung  $\Rightarrow$  luminosity spectrum



From: CLIC: Beam Dynamics and Limitations on Main Parameters

# Theory in Denmark

- University of Copenhagen: 7 permanent, 5 postdocs, 5 PhD students.
- University of Aarhus: 2 permanent, 4 PhD students
- University of Southern Denmark:
- 5 permanent, 4 postdocs, 3 PhD students



# Theory in Denmark: subjects

- String theory: 10 persons
- Field theory: 3 (multi-leg amplitudes)
- Particle physics phenomenology: 16 (4 KU+10 SDU+2AU) (mostly models for dynamical symmetry breaking).
- Astro-particle physics
  - phenomenology: 2 KU
  - Neutrino cosmology, dark matter: 4 AU
- Cosmology: 6 (analysis of Planck data, theories of inflation)

# HEP/CERN-related physics in Denmark - manpower

	Profs.	Assist. Prof.	PhD-stud.	Engineers
ATLAS	5	4	5	0.5
ALICE	4	2	3	0.5
ISOLDE	2	0	2	0.5
AD-3	2	0	2	0.5
AD-4	2	1	0	0
AD-5	2	1	1	0.5
NA63	1	0	2	0.5
CLIC/IceCube	0.5	0	1	0
Phenomen.	4+3	4+4	2+3	-
String	4+2	2+0	2+0	-
CMB, cosm.	3+2	3	1+3	-
Astropart.	2	1	1	-

# GRID, NorduGrid (Nordic Tier 1 collaboration)

site capacity (CPUs)

- 1-10
- ◻ 10-50
- ◼ 50-100
- 100+
- planned



## • Status

- 2728948 succesful jobs in 2009 (2/3 that of UK or F)
- World record efficiency 92.1%
- 2 hour per data set transfer (first collisions)
- 6% of the global resources for the LHC
- DK: 880 cores, 400 TByte disk storage and 800 TByte tape capacity (ATLAS and ALICE)

## • Ambitions for the future

- Maintain the share of 6% of the global resources, estimated to be:
  - 10-15 PetaByte storage per year and 10 times more for simulations
  - Enough CPU to process 0.1-1 GigaByte of new data each second
- For NorduGrid this translates into:
  - 4.7 PetaByte Tape
  - 4.3 PetaByte Disk
  - 6.9 MSI2k CPU

and out of these Denmark contributes 20% (DK/N/SF/S=1/1/1/2).

# Outreach

- Big CERN exhibit during fall 2010, Copenhagen
- “Colliderscope” on Niels Bohr Institute façade (LEDs showing ATLAS tracks online - hit the world press).
- Cosmic ray for schools setup in Aarhus and Copenhagen
- “Hands-on-CERN” both as international and national events.
- Many popular books, talks and presentations

## **NBI Colliderscope**



<http://colliderscope.nbi.ku.dk/english/video1/>

# R&D intensity, Gross Domestic Expenditure as % of GDP, 2006

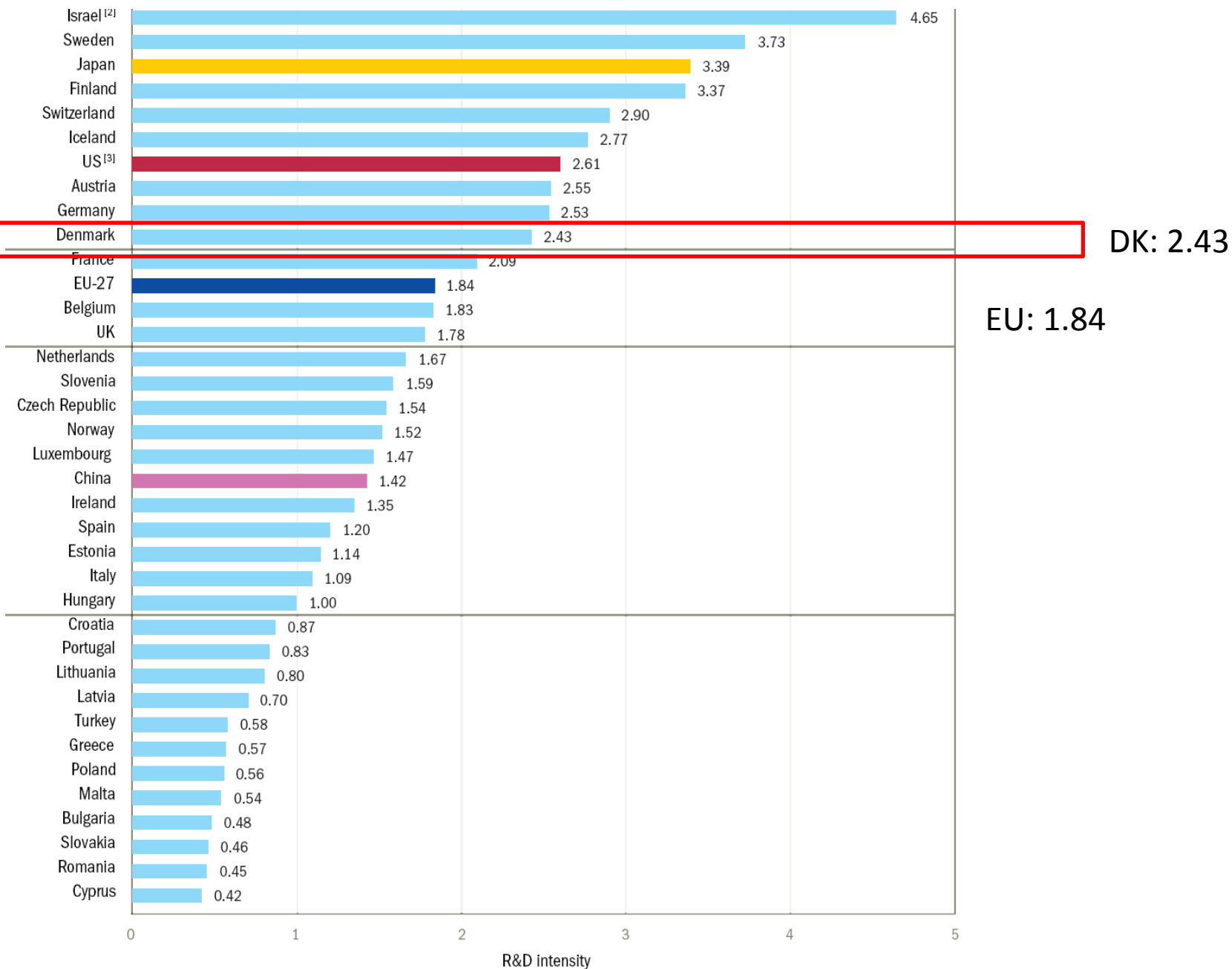


Figure 8: R&D intensity (GERD as % of GDP), 2003  
 Gross domestic expenditure on R&D (GERD)

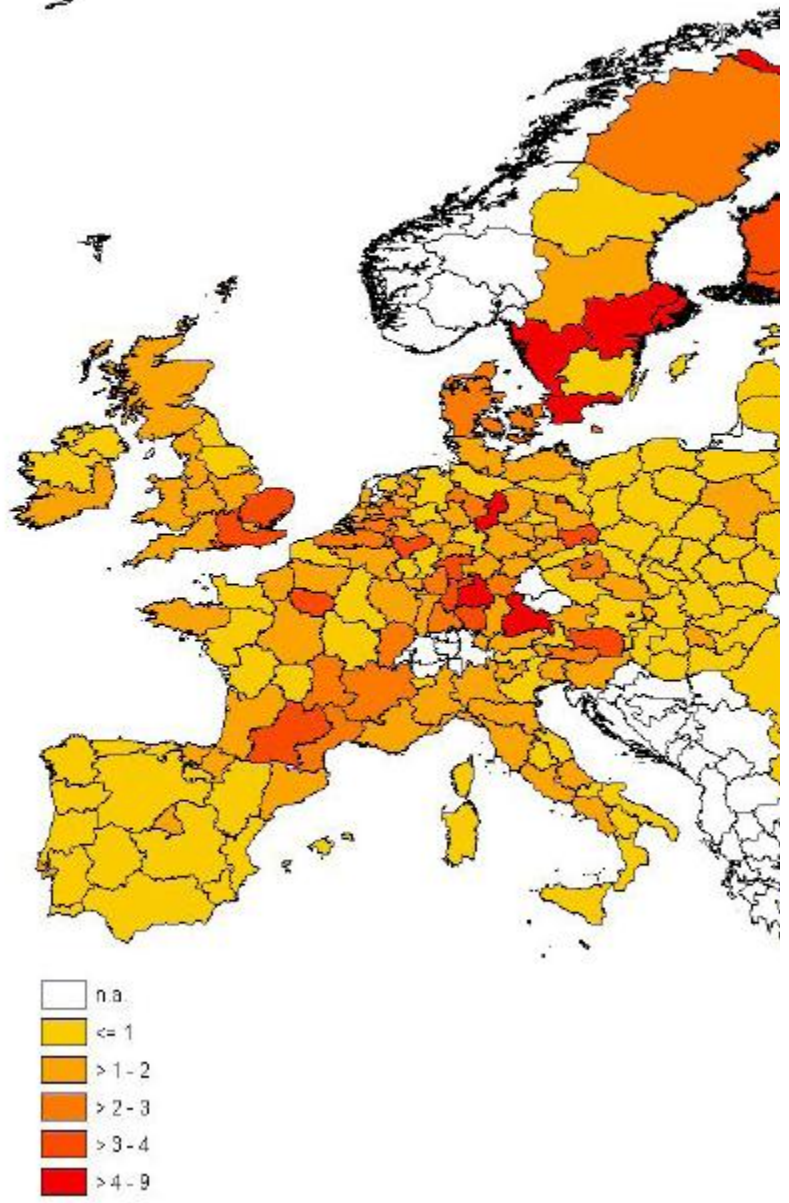
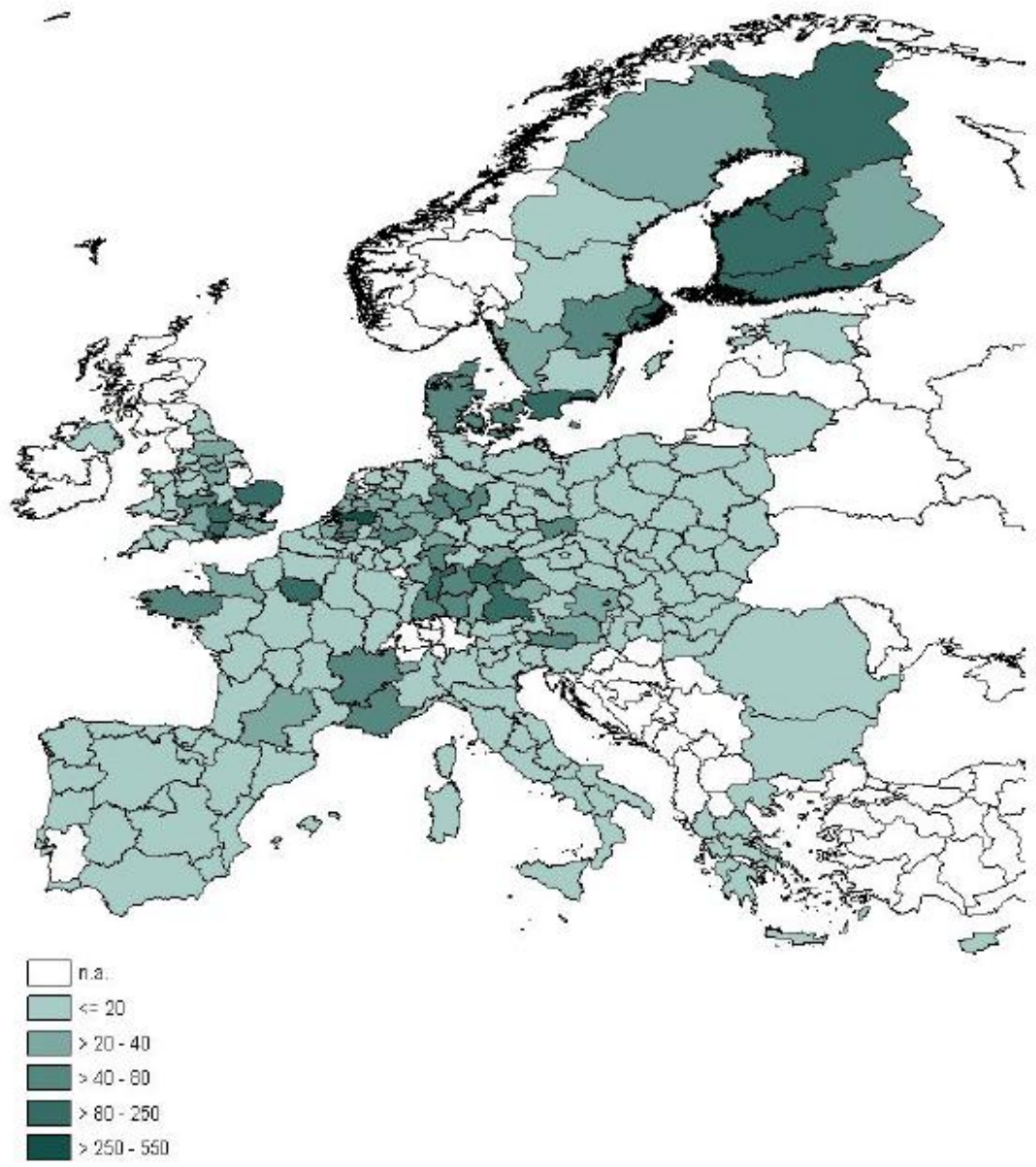
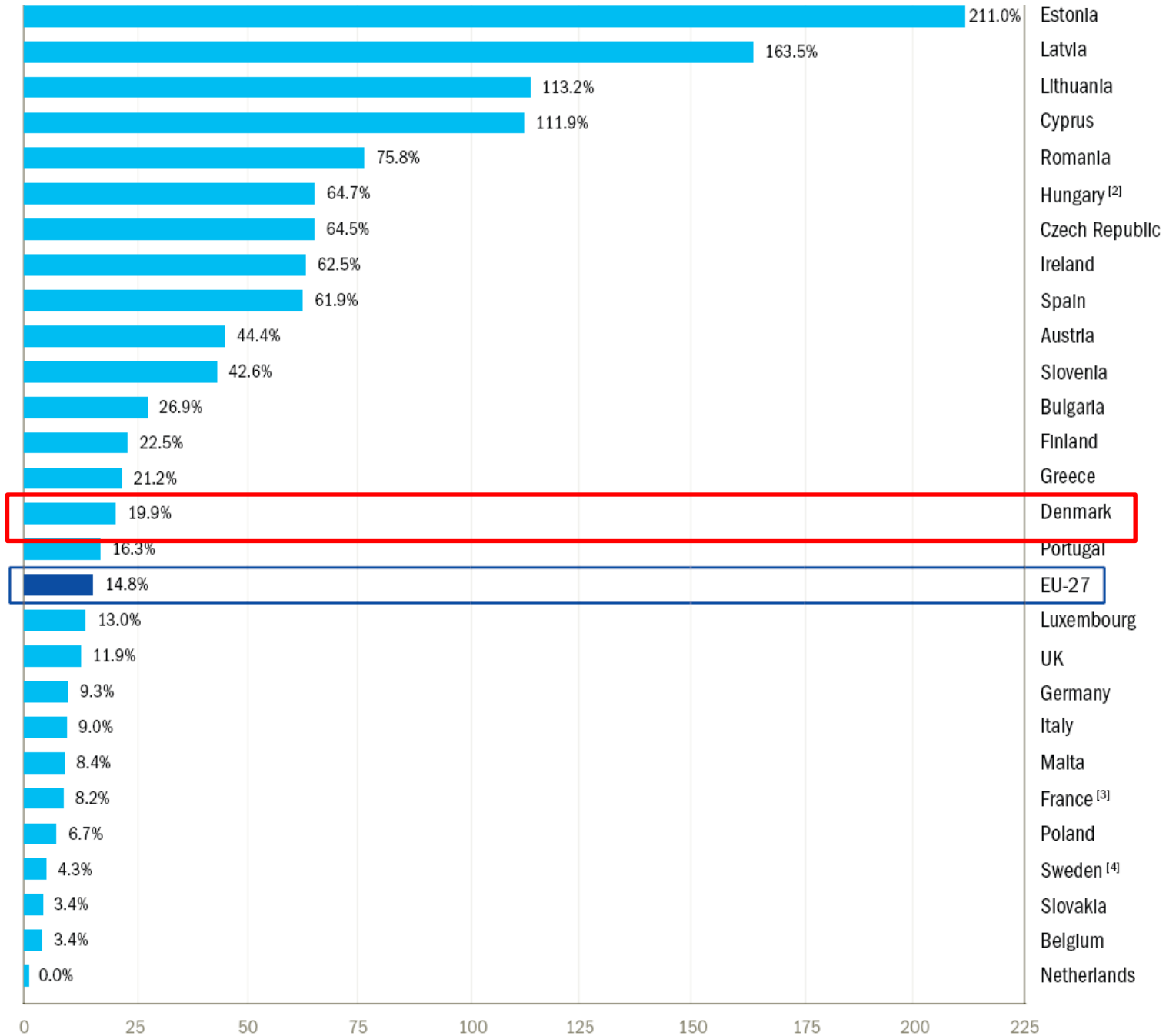


Figure 25 High-tech patent intensity (EPO filings by high technology fields per million inhabitants) 2001



Note: NUTS 2 data do not include BG, IE, RO; NUTS 0 data used for BG, RO.  
 Source: Regional Key Figures database, own compilation; 235 regions included

# R&D intensity **growth** in %, 2006



# Technology transfer



“Danfysik accelerator systems and accelerator components are in service at most particle accelerator facilities worldwide”

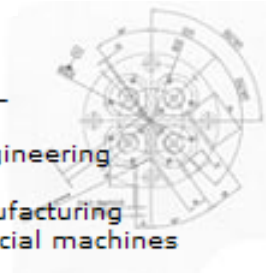


- medium voltage switchboards
- transformers
- low-voltage distribution boards and motor control centres
- computerized and PLC-based control systems
- SCADA systems
- power and control installations



**MARK & WEDELL**

High-technology engineering and development  
Workshop and manufacturing  
Development of special machines



“... a specialist in advanced printed circuit boards”



**ASTRID Aarhus STORAGE RING in Denmark.**

Built with substantial help –  
equipment/expertise - from CERN

**Return coefficient: 0.9 (2005-2008)**