



OMA career workshop

RADIOISOTOPE PRODUCTION: **Career opportunities**

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GOBIERNO
DE ESPAÑA

MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES



Seville

3rd September 2019

- **My career path**
- **Radioisotope production with accelerators: a emerging sector**
- **Professional (& personal) point of view**

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My career path



Degree in Physics

- Universidad de Valencia (1996-2001)
- Nuclear Physics specialty



Theoretical Physics PhD

- Universidad Autónoma de Madrid (2002-2006)
- Thesis *"Analysis of the uniformity of the Electromagnetic Endcap Calorimeter of ATLAS"*



Spanish Nuclear Regulatory Body

- 2 years Grant (2001-2002), Temporary employment contract 2006-2007
- *Simulation of linear dynamic systems, applied to the modeling of human actions and integration on the Probabilistic Safety Assessment (PSA)*



CIEMAT

- Since 2007
- Different employment contracts
- Senior Scientist since 2009 (staff member)
- CYCLOMED TECHNOLOGIES S.L (CIEMAT Spin-off): partner and shareholder

CIEMAT (*Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas*) - public research body assigned to the Ministry of Science, Innovation and Universities

- focusing on energy and environment and the technologies related to them.
- It has offices in several different regions of Spain
- its activity is structured around projects which form a bridge between R&D&I and social interest goals.



Energy



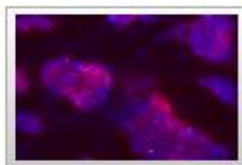
National Fusion
Laboratory



Environment



Technology

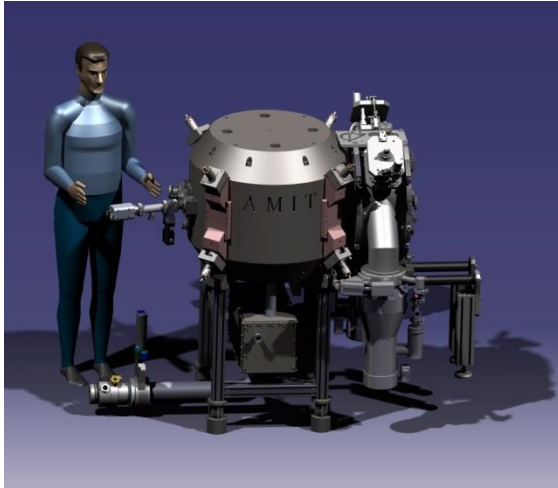


Basic Research

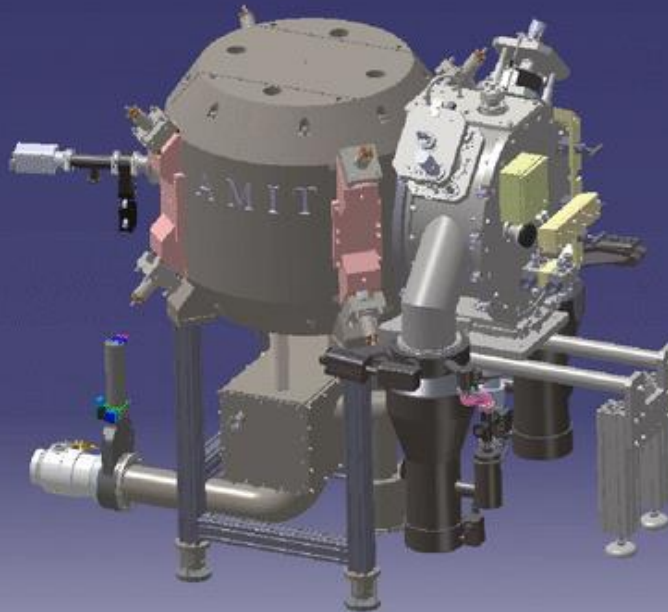
Different R&D areas:

- Particle accelerators
- Elementary particles and astroparticles
- Nuclear fission
- Nuclear fusion
- Renewable energies and energy savings
- Energy conversion of fuel and waste
- Biology and biomedicine
- Environment
- Ionizing radiations
- Scientific instrumentation and medical physics
- Material Analysis and characterization
- Computation and information technology sciences
- Energy and environmental systems studies

AMIT CYCLOTRON



*Production of PET
imaging radioisotopes:
 ^{18}F , ^{11}C*



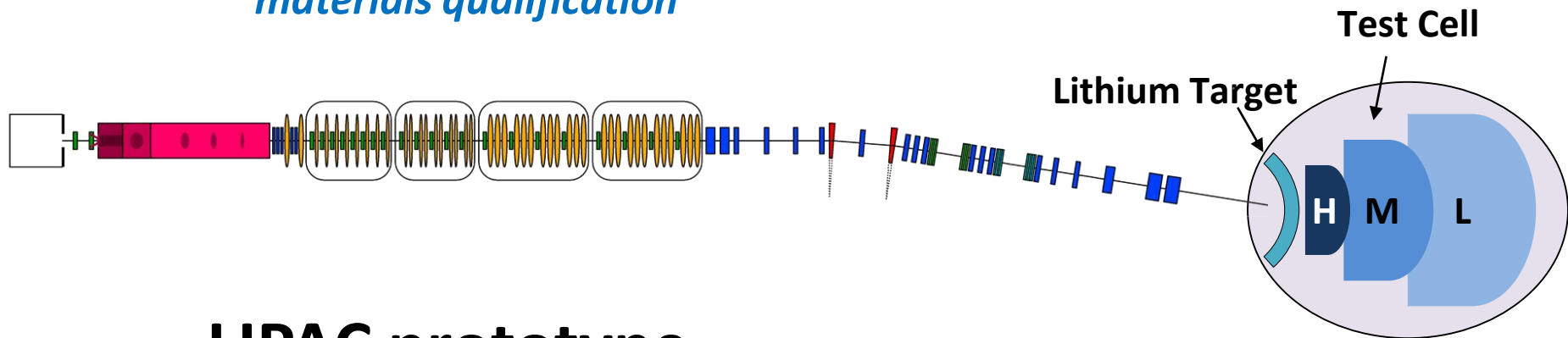
| GENERAL | |
|-----------------|---|
| Cyclotron Type | Classical |
| Energy | >8.5 MeV |
| Current | >10 μA |
| MAGNET | |
| Type | Low To Superconductor |
| Configuration | Warm Iron |
| Superconduct or | NbTi |
| Central Field | 4 T |
| RF SYSTEM | |
| Configuration | One 180° Dee |
| Peak Voltage | 60 kV |
| RF frequency | ~ 60 MHz |
| ION SOURCE | |
| Type | Internal |
| Ions | H^+ |
| EXTRACTION | |
| Extraction | Stripping foil at 110 mm |
| Target | Nitrogen gas (^{11}C) , ^{18}O enriched water (^{18}F) |
| Position | External |

My work at CIEMAT: accelerators

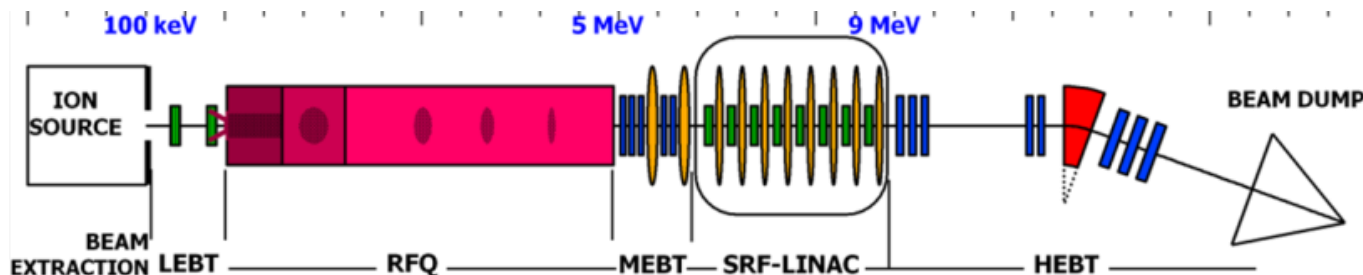
DONES

D-Li neutron source for DEMO materials qualification

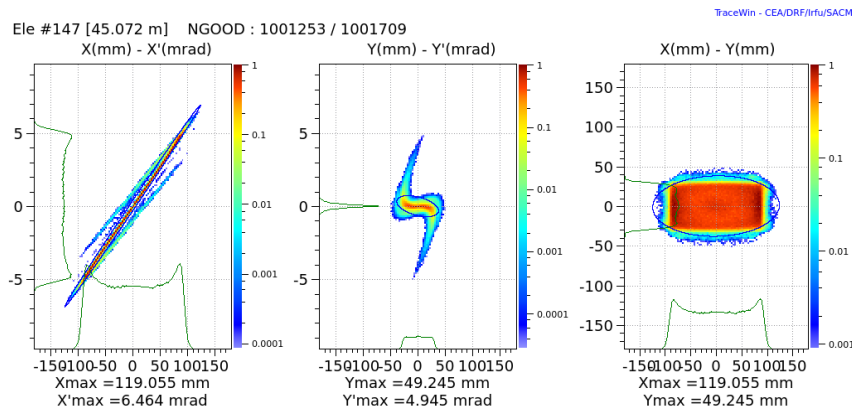
40 MeV
125 mA
5 MW in CW!!



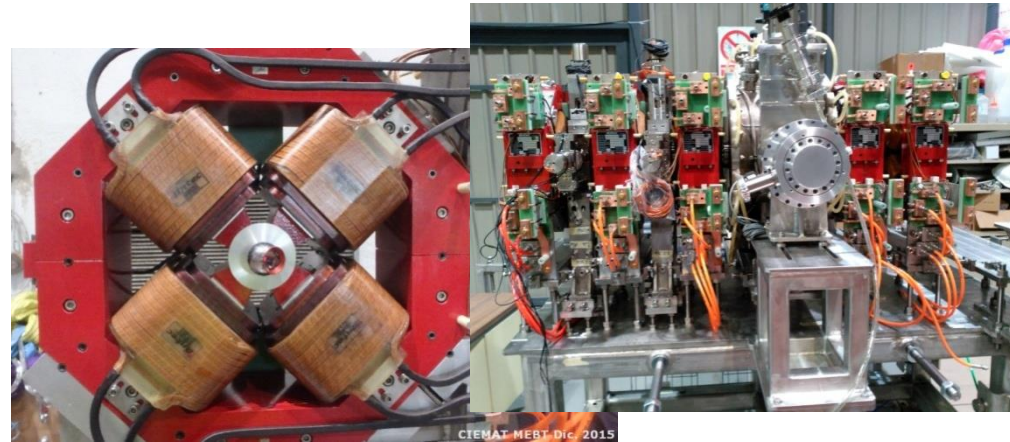
LIPAC prototype



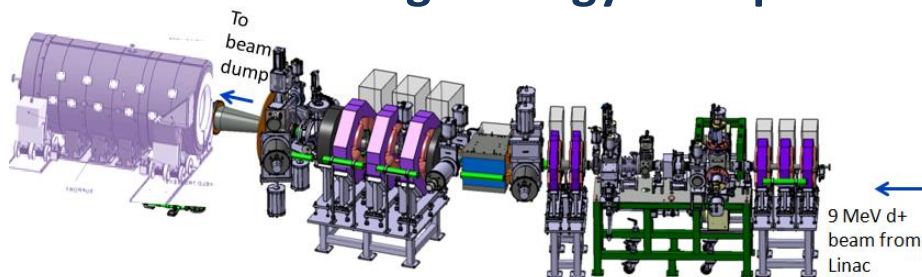
Beam dynamics



Combined magnets



Medium and High Energy Transport lines



Beam diagnostics

(emittance measurement, energy spread)

Characterization of internal ion sources

Not only technical activities (unfortunately!)

- ☐ Funding for research:

- ☐ National funding

- ☐ H2020 calls (**ARIES**)



"I must confess that one reason we have undertaken this biological work is that we thereby have been able to get financial support for all of the work in the laboratory. As you know, it is much easier to get funds for medical research."

—Ernest Orlando Lawrence to Niels Bohr, 1935

- ☐ Coordination of technical activities/groups

- ☐ Supervision of Final Degree Projects, Thesis director

- ☐ Publications

- ☐ Attendance and contributions (poster, oral presentations) to conferences, workshops

- ☐ (Too much) Bureaucracy

- ☐ Procurement follow-up

- ☐ Dissemination activities

- My career path
- **Radioisotope production with accelerators: a emerging sector**
- Professional (& personal) point of view

Key facts in medicine

CVD 1st
Cancer 2nd
leading death cause

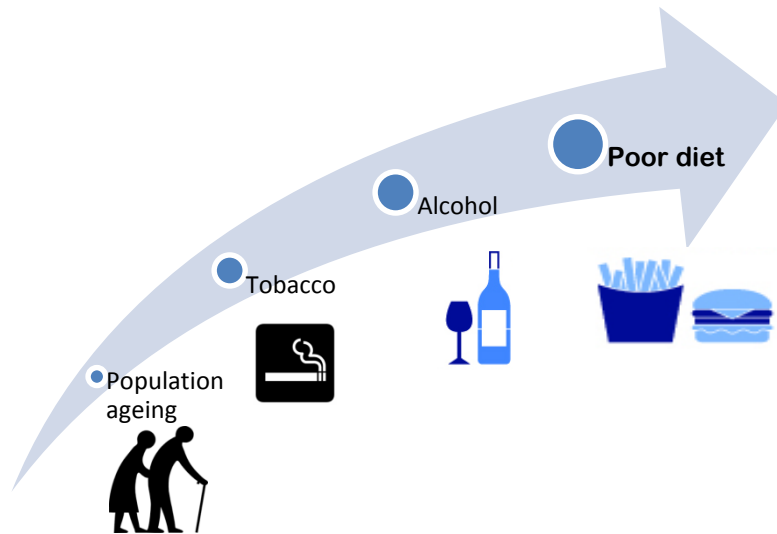
17.9 million deaths
due to CVD (2016)

9.6 million deaths
due to cancer
(2018)

CVD



Cancer

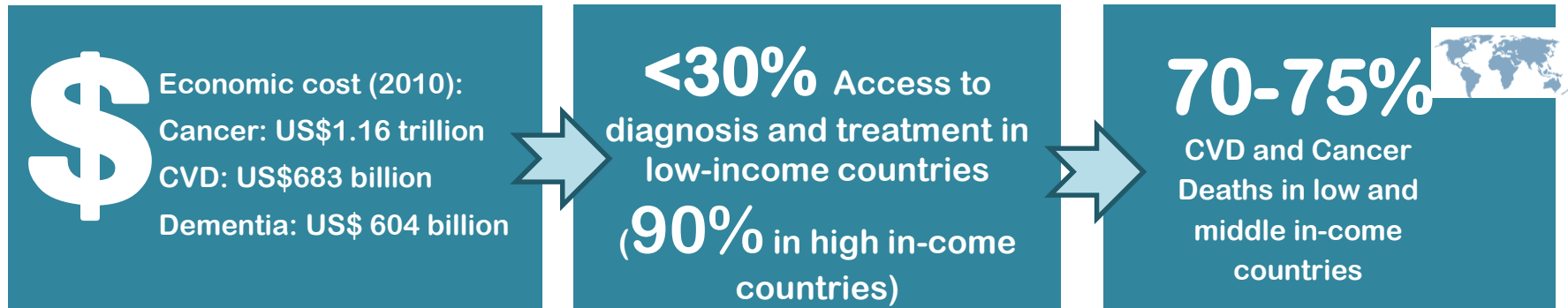
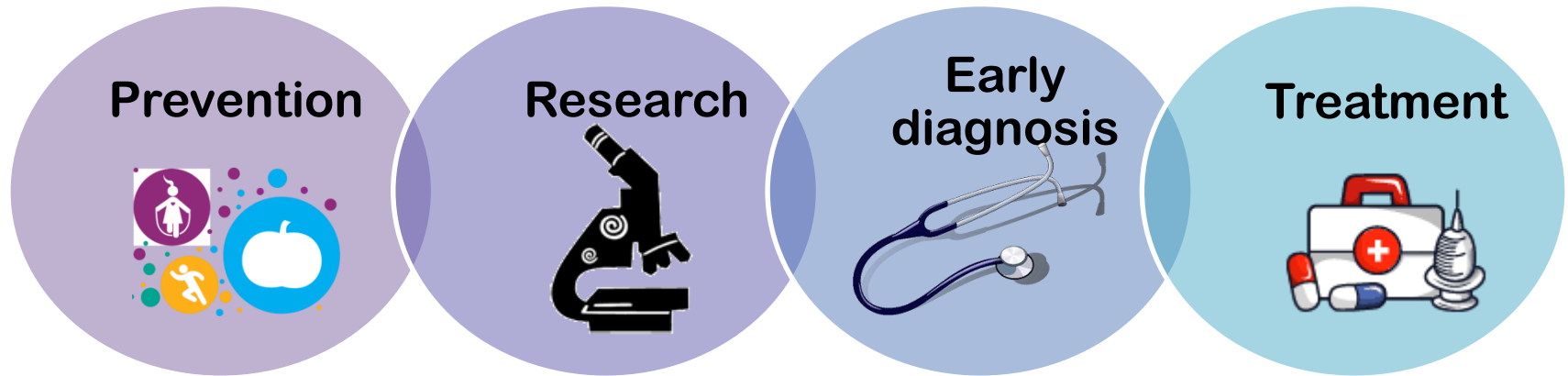


70%

Increase of new CVD & cancers
in next 2 decades

World Health Organization, <http://www.who.int>

What can we do?



World Health Organization, <http://www.who.int>

It is important to expand the use of such techniques (to reduce the cost) to make them more available to the general population ← Radioisotopes

Radioisotopes: A well-known tool

- ❑ Radioisotopes are a key tool in the research, early diagnosis and treatment
- ❑ Nowadays, they have many applications: homeland security, industry, environment, material science, ...
- ❑ ... But where isotopes play a key role is in nuclear medicine
- ❑ Initial application of isotopes as tracers:



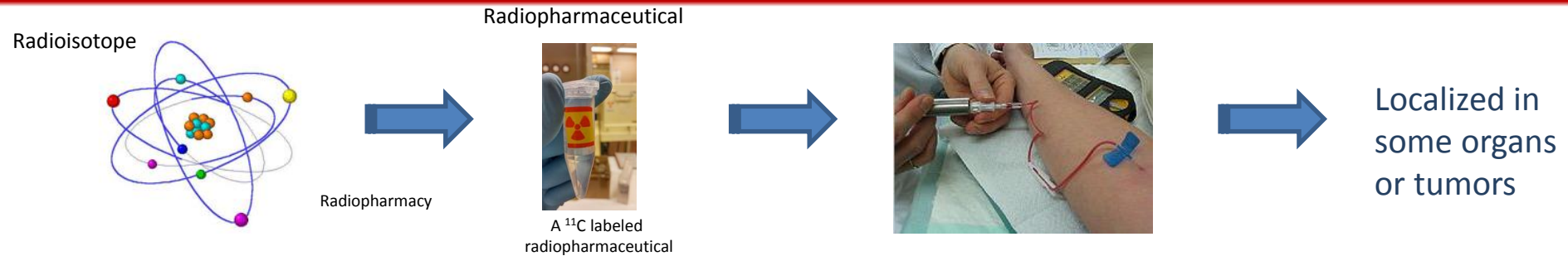
George de Hevesy won the Nobel prize (1943) for his work on the use of isotopes as tracers in the study of chemical tracers



During his trying at Manchester, Hevesy lived in a boarding house. He suspected that the food served by the landlady was made from the previous day leftovers. To test his hypothesis, he placed a small amount of radioisotope in his uneaten food. A few days later, by examining with a detector, he demonstrated that the food was that the same from the previous day leftovers. All the landlady could do was exclaim was "this is magic!"



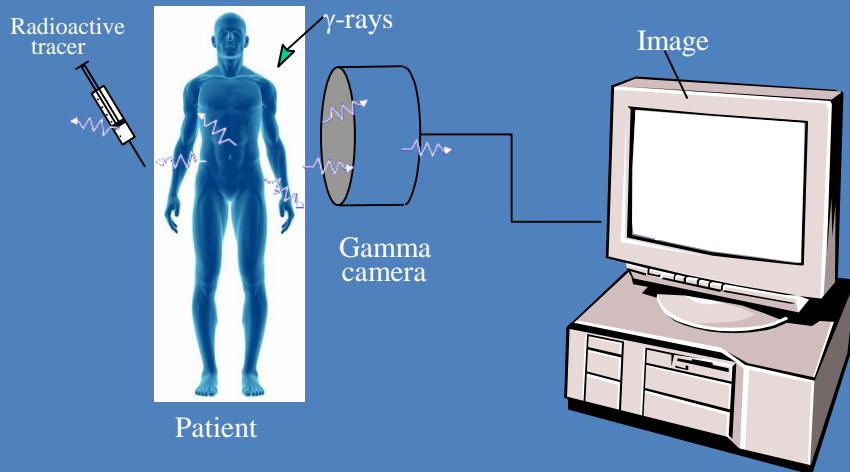
Radioisotopes in Nuclear medicine



Two applications:

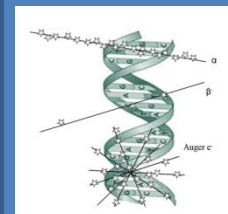
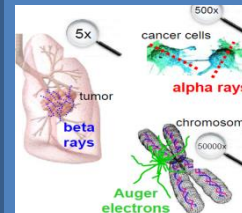
Imaging

- Gamma radiation (Energy 100-300 keV)
- It provides physiological information
- Useful tool for the diagnosis, treatment planning and follow-up of different diseases.
- Short-life process
- Minimum dose to patient

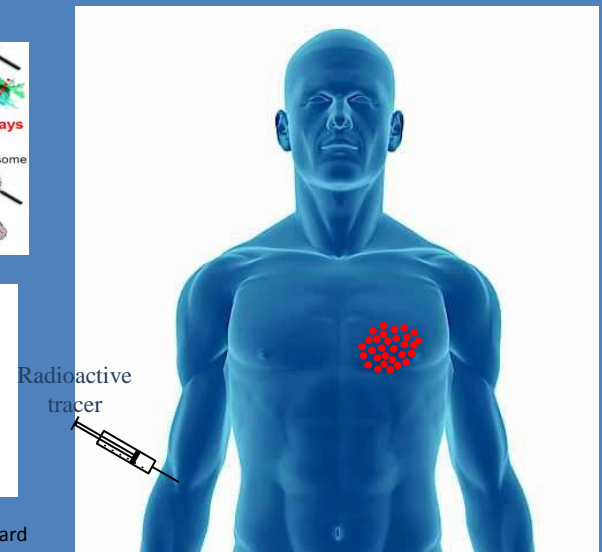


Therapy

- High ionizing particles: alpha, beta, Auger electrons
- High dose

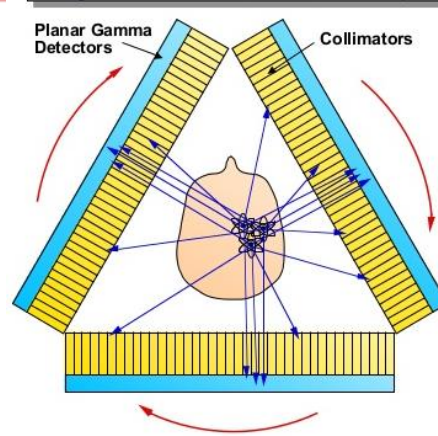
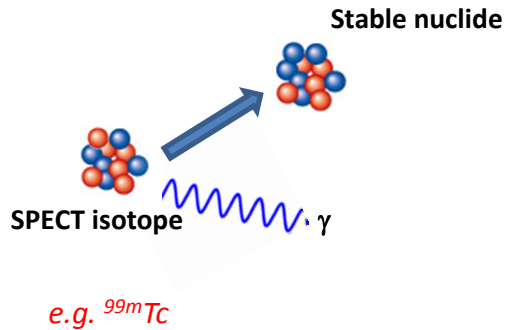


From Thesis H- Thisgaard



Two imaging modalities:

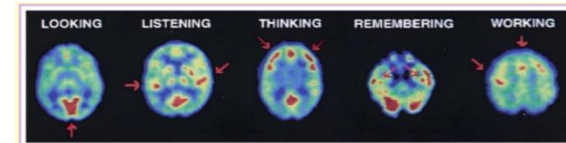
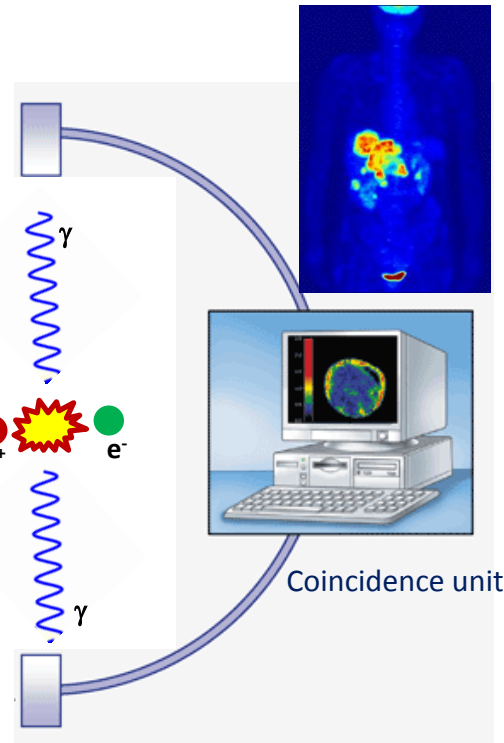
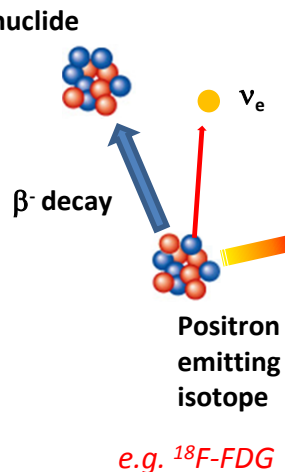
SPECT: Single Photon Emission Computed Tomography



Discovery NM630 GE SPECT camera

PET: Positron Emission Tomography

Higher resolution but
expensive technique



Phelps, PNAS, 2000, 97, 9226



Siemens PET-CT camera

Which radioisotopes are needed?

| | | | |
|---------|-------|------------|---|
| Imaging | SPECT | | ^{67}Ga , $^{81\text{m}}\text{Kr}$, $^{99\text{m}}\text{Tc}$, ^{111}In , ^{123}I , ^{133}Xe , ^{201}Tl , ^{131}I , ^{177}Lu |
| | PET | Short-life | ^{11}C , ^{13}N , ^{15}O , ^{18}F , ^{68}Ga , ^{82}Rb |
| | | Long-lived | ^{44}Sc , ^{64}Cu , ^{76}Br , ^{86}Y , ^{89}Zr , ^{124}I |
| Therapy | | Beta | ^{32}P , ^{89}Sr , ^{90}Y , ^{131}I , ^{153}Sm , ^{166}Ho , ^{177}Lu , ^{169}Er , ^{186}Re , ^{188}Re |
| | | Alpha | ^{212}Pb , ^{213}Bi , ^{211}At , ^{224}Ra , ^{225}Ac , ^{227}Th , ^{230}U |
| | | Auger | ^{51}Cr , ^{75}Sr , ^{77}Sr , ^{125}I |

Choice of a radioisotope:

- Half-life
- Low dose (gammas and beta+ emitter)
- High production yield (reaction cross section)
- High specific activity, purity
- Radioisotope chemistry
- Biological pathway
- Image quality (positron and gamma energy)
- **Cost and complexity**

Available at low cost

Production

Artificially produced by research reactors or accelerators

- Sometimes the parent isotope is produced and by the generator concept, the daughter is extracted with an efficient separation technique (e.g.

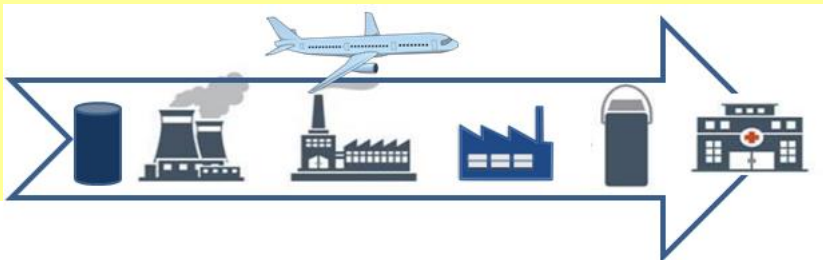
$^{99}\text{Mo}/^{99\text{m}}\text{Tc}$)



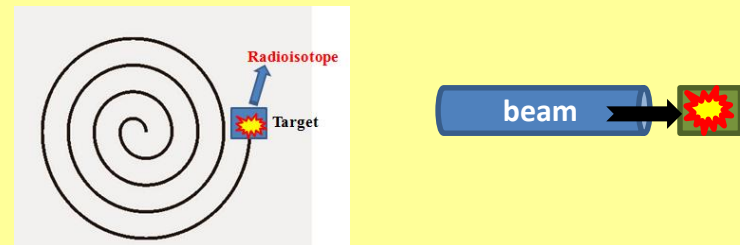
Research reactors



- n-fission or n-capture of HEU targets
- Neutron-rich radioisotopes ($^{99\text{m}}\text{Tc}$, ^{131}I , ^{166}Ho , ^{177}Lu)
- High production yield but low specific activity
- Non-proliferation issues: from HEU to LEU targets



Accelerators



- Target irradiation by accelerated particles in accelerators
- Proton-rich radioisotopes (^{18}F , ^{201}Tl , ^{123}I , ^{67}Ga , ...)
- High specific activity products but low production yield
- Smaller amount of radioactive waste
- Less capital, operating and decommissioning costs
- Easier access than to reactors

Current issues on isotope supply market

Emerging market

- Over 10.000 hospitals worldwide use radioisotopes in medicine
- Tc^{99m} : 80% of all nuclear medicine procedures
- Over 40 million nuclear medicine procedures each year
- Nuclear medicine/radiopharmaceuticals market: USD 7.27 billion by 2021 (USD 4.67 billion in 2016)

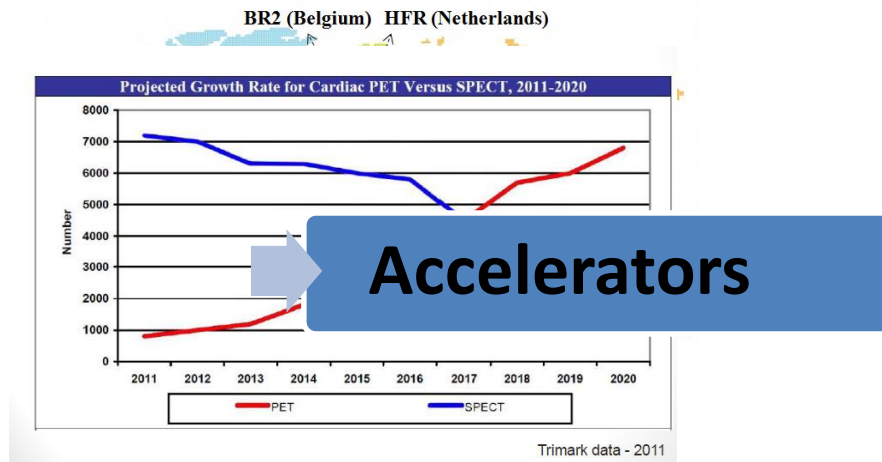
(World Nuclear Association, <http://www.world-nuclear.org> updated September 2016)

- **Main Challenge: stable and economically sustainable radioisotope supply**

Last decade crisis in reactor-production

Demand for very short half-life PET isotopes

Need of therapeutic isotope availability



Radioisotope production

Production route

- Direct production with ions (p,d) : cyclotrons, linacs, DC, FFAG, ...
- γ -induced reactions (electron machines)
- n- induced reactions (CANS, spallation sources, ...)
- particle-induced U fission

Goal:

- High specific activity \rightarrow ~E choice
- Maximum production yield \rightarrow linear with I



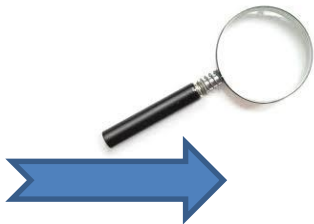
In a medical environment

Localized production:

- Compact machines (footprint, weight, shielding, few infrastructure needs)
- Low acquisition and operation cost
- High reliability operation

On-site production at hospitals:

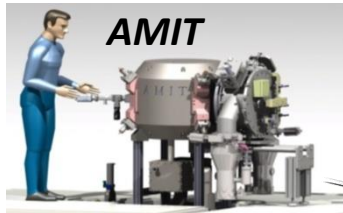
- Automatic operation, maintenance-free, low radiation to personnel



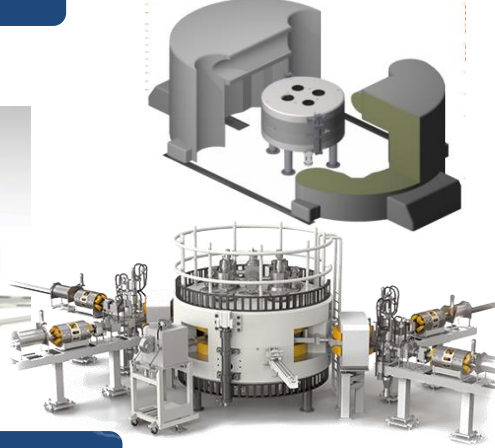
- Development on compact, low cost accelerator technology but also
- Targetry development
- Target processing to get a radiopharmaceutical fulfilling standard requirements
- Target recycling for a cost-effective production

Many options

CYCLOTRONS



CYCLONE11

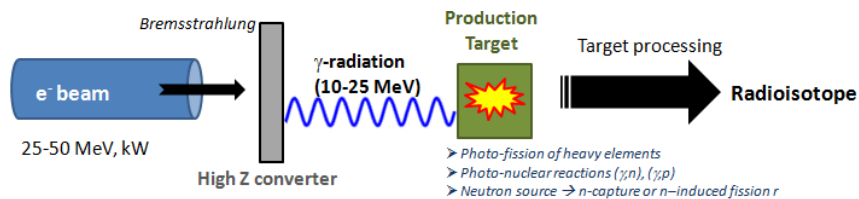


ION LINACS

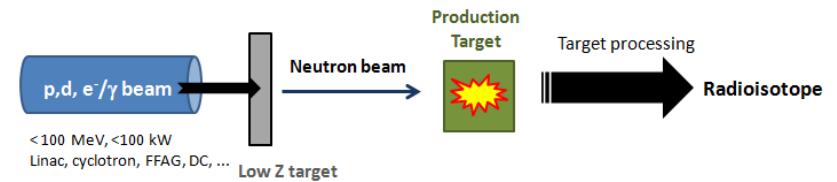
HF-RFQ, by CERN



ELECTRON LINACS



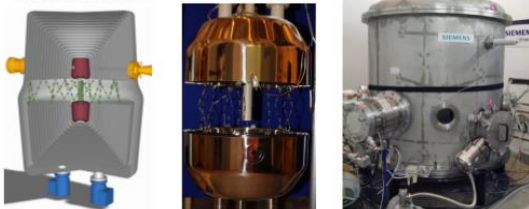
NEUTRON SOURCES



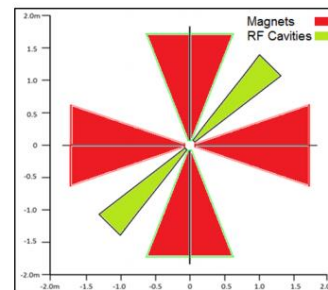
ELECTROSTATIC ACC.

ONIAC (Siemens)

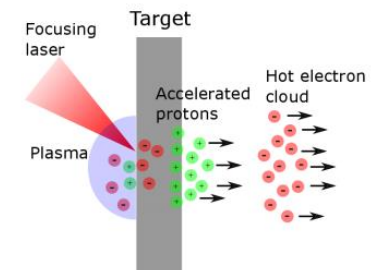
- Spatial foot print of $< 2 \text{ m}^2$
- Multiple beam lines



FFAG

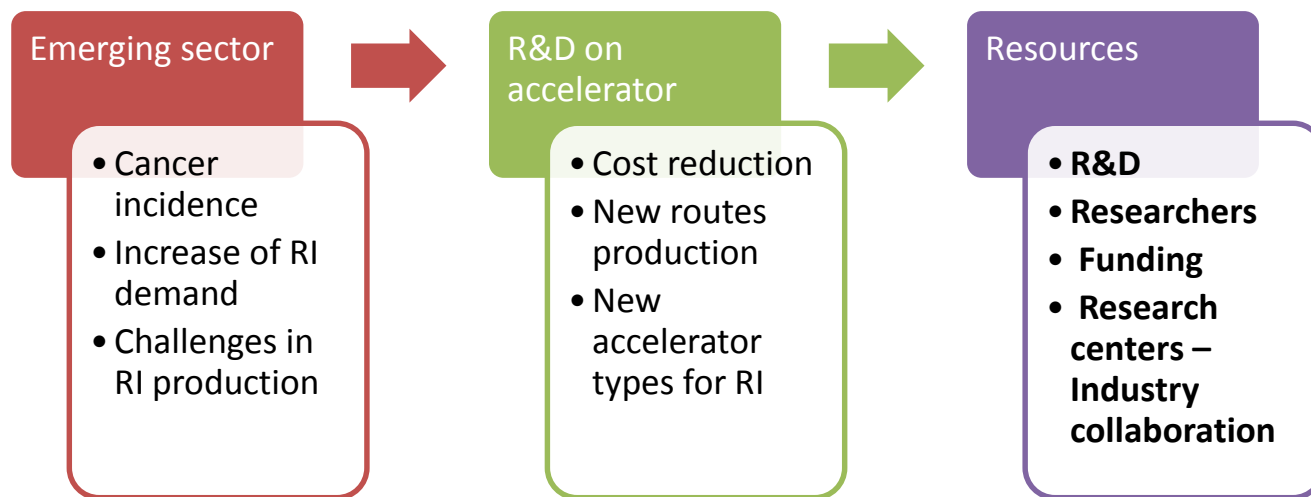


LASER



- My career path
- Radioisotope production with accelerators: a emerging sector
- Professional (& personal) point of view

Career opportunities in RI production market



| Career opportunities as: | R&D area: | Where: | Degree: |
|--|---|--|--|
| <ul style="list-style-type: none">• Accelerator researcher• Target development• Operator and maintenance staff | <ul style="list-style-type: none">• Beam dynamics• RF design• Beam diagnostics• Magnet technology• Target design• Ion source | <ul style="list-style-type: none">• Research centres• Academia• Industry• User facilities• Hospital• Start-up companies | <ul style="list-style-type: none">• Physics• Mathematics• Engineering• Chemistry• Pharmacy• Multidisciplinary field |

After PhD?

Lot of opportunities:



Academia

**Research
center**

Industry

**Start-up
founder**

**Regulatory
bodies,
Consulting,
...**

**Alternative
career
path**

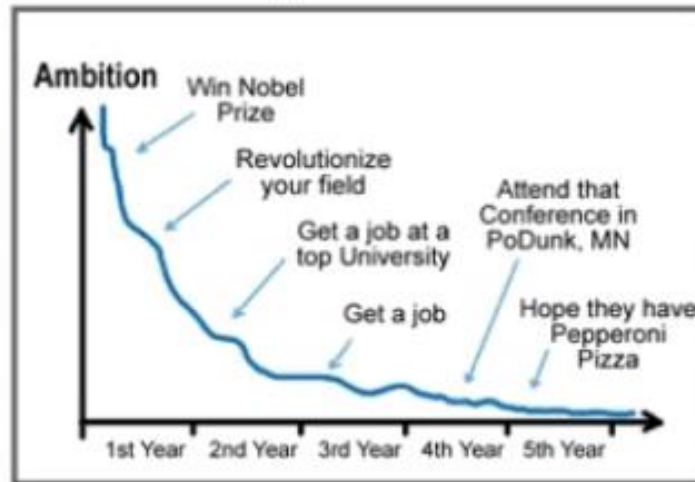
But also a lot of uncertainties ...



What is needed?

- ✓ Strong technical abilities and theoretical abilities
- ✓ Scientific discipline and capacity for analysis
- ✓ Ability to learn quickly
- ✓ Communication skills
- ✓ Mobility
- ✓ Ambition... (but don't forget coming back down to the earth)

Most acquired
during your
PhD



Working as a researcher

Benefits



- ☺ At forefront of science
- ☺ Earn recognition
- ☺ Flexibility
- ☺ Multidisciplinary environment
- ☺ International collaborations
- ☺ Travelling
- ☺ Strong collaboration with industry

Difficulties



- ☹ Endless workdays
- ☹ Temporary contracts/grants
- ☹ Looking for funding continuously
- ☹ Low salary (at least in Spain)
- ☹ Patience
- ☹ Mobility
- ☹ Work/family balance

**You don't choose to
be a scientist
because of money,
do you??**



50 kilo



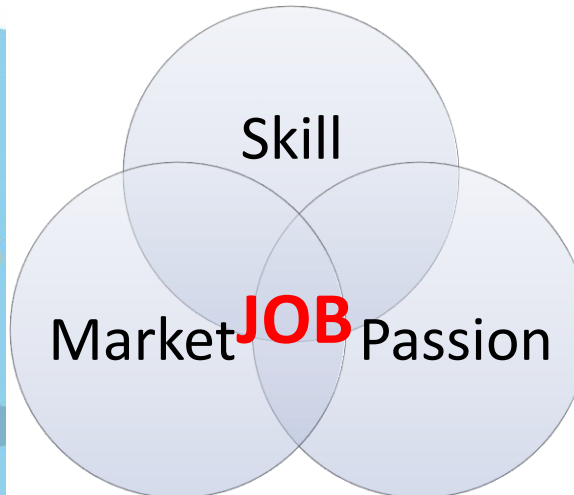
40 Million



Average salary at CIEMAT

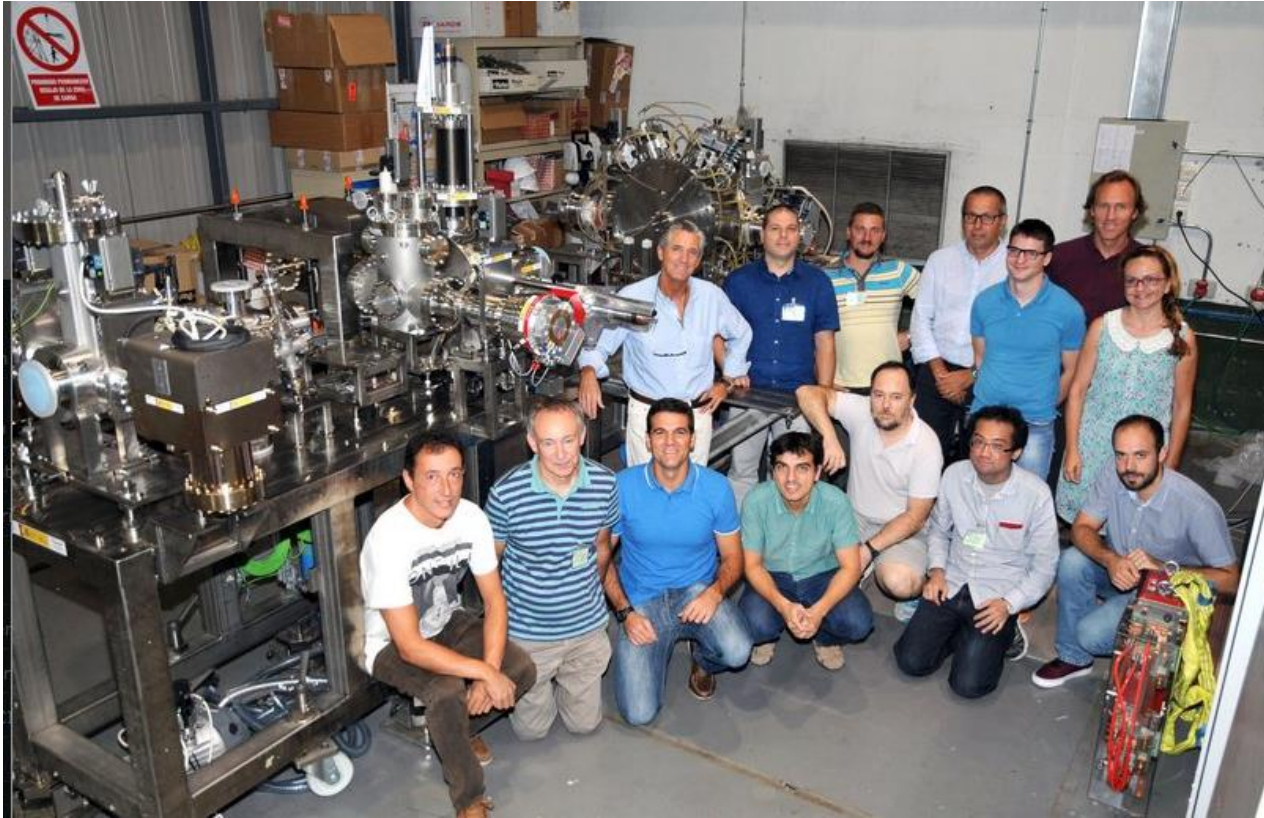
Personal recommendations:

- Reach out to the real world
 - make yourself exposed to good opportunities
 - visit events and talk to people
- Be ready for opportunities
- Identify important trends and grand challenges that you can contribute to them
- No forget about personal life!



Coming back to my career path

A woman in a world of men...

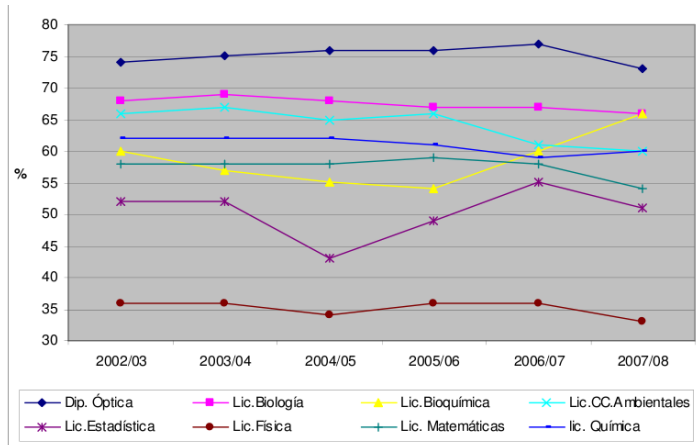


Personal
point of view

The gender problem in STEM

The gender problem in STEM: my experience

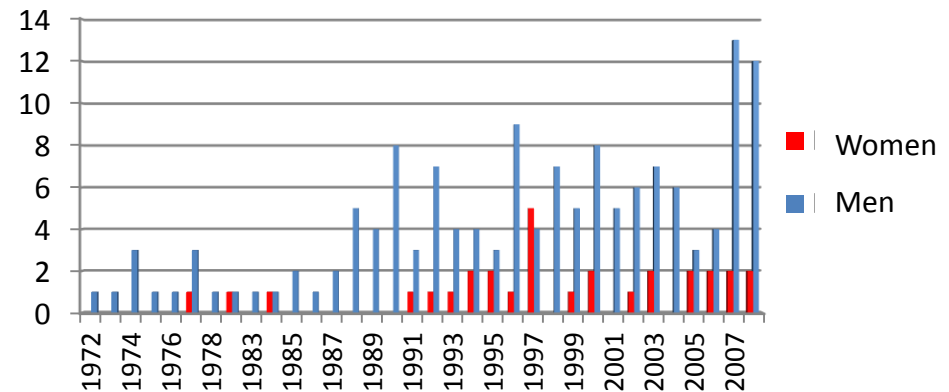
Degree



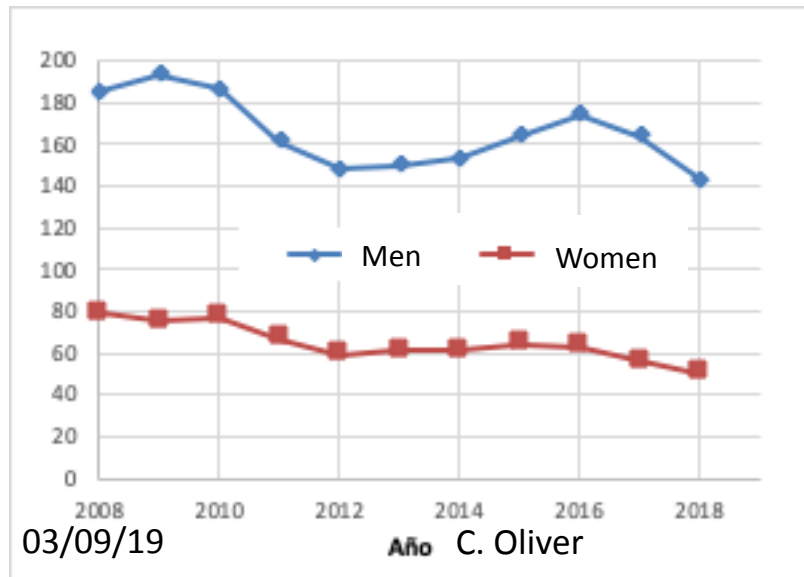
Fuente: Servei d'Anàlisi i Planificació. Universitat de València. Elaboración propia.

PhD

Thesis
Theoretical Physics UAM

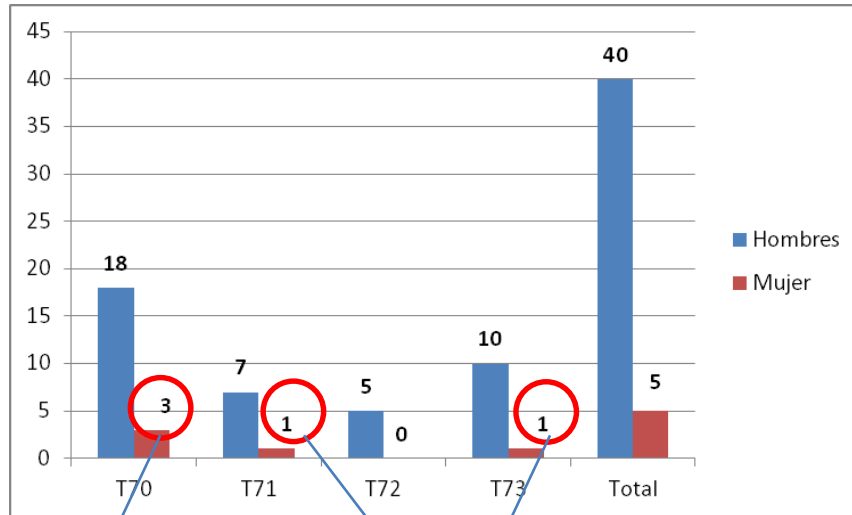


**CIEMAT,
TECHNOLOGY
DEPARTMENT**



The gender problem in STEM: my experience

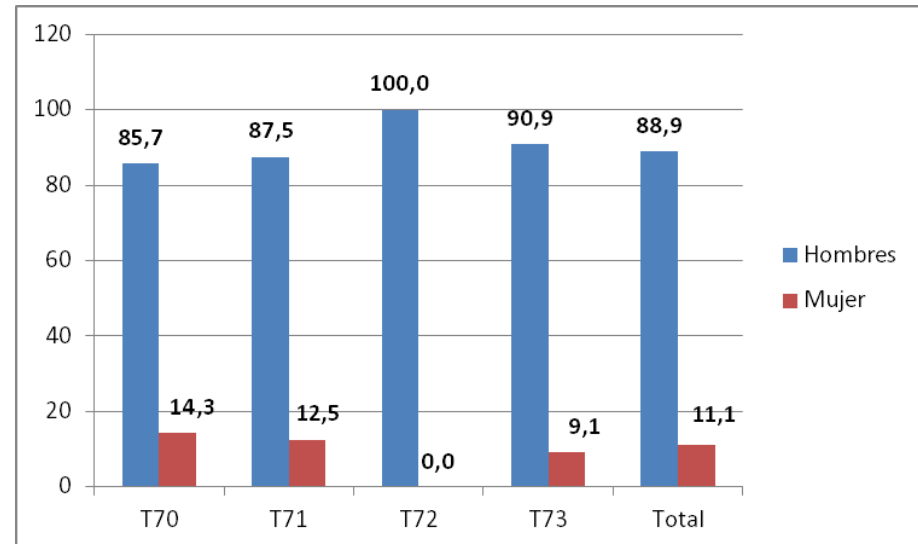
Electric Engineering Department



At CERN

Only 2 at CIEMAT

T70. Electric Engineering Department
T71. Electric Technology Unit
T72. Power Electric Systems Unit
T73. Particle Accelerators Unit



The gender problem in STEM: Today

**15 OMA fellows
7 women**



The gender problem in STEM: Today

But if you look at the wall ...

**8 dean of Physics Faculty
Only 1 woman!**



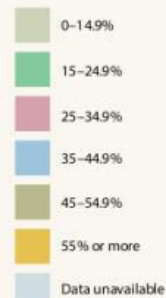
The gender problem in STEM

Regional shares of female researchers, 2013 (%)



Note: Data are unavailable for North America. The regional averages are based on available data and are derived by using the nearest year's data, whenever data are missing for 2013.

Spotlight on Europe



33.1%

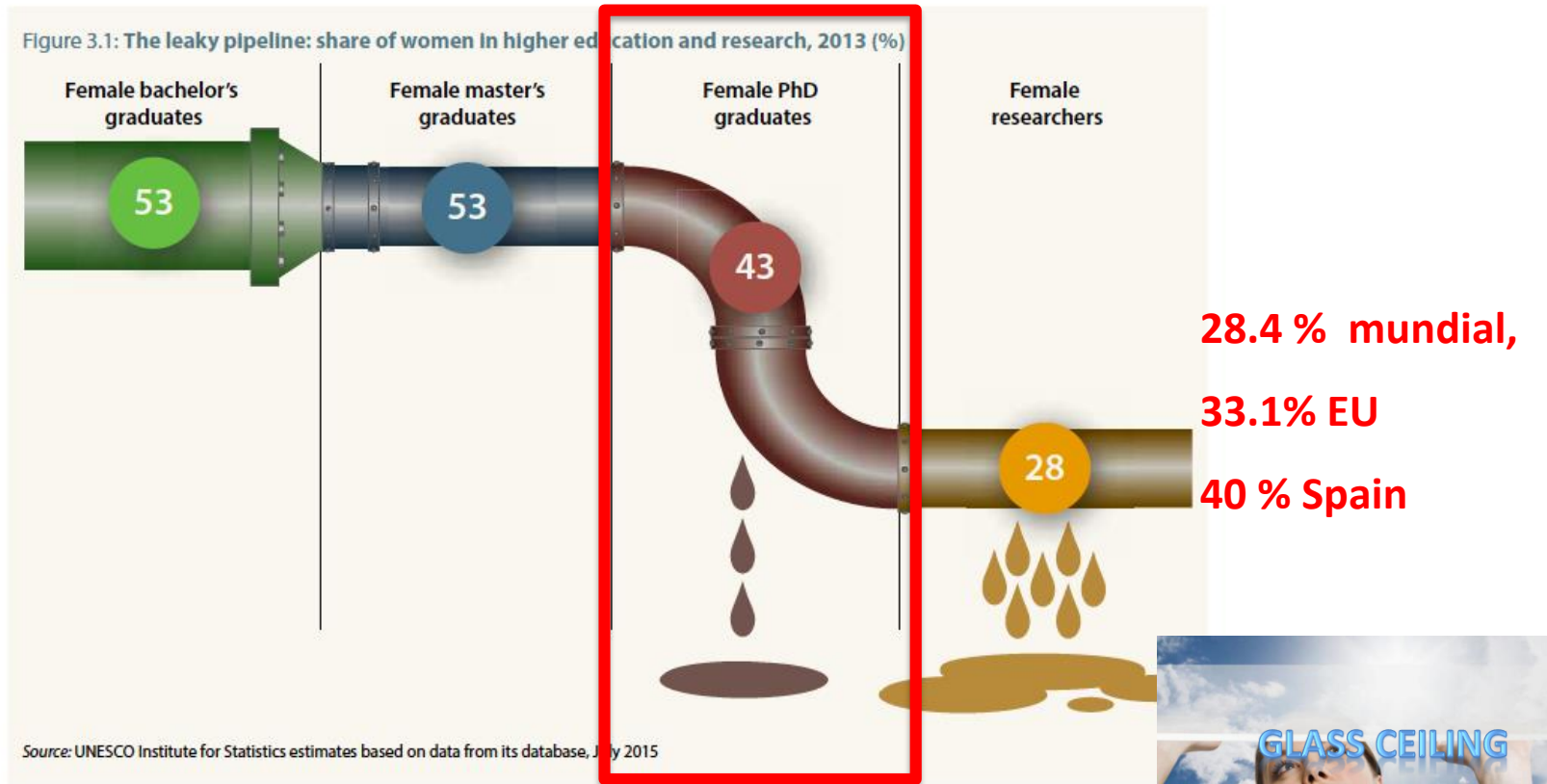
Share of women researchers in the European Union

Note: Data for the most recent year available since 2007. For China, data cover R&D personnel rather than researchers. For Congo, India and Israel, data are based on full-time equivalents rather than head counts.

Source: UNESCO Institute for Statistics estimates based on data from its database, July 2015



“Leaky pipeline”



Maybe the Time to start a family



But, are we equal?

Although we have the same opportunities (at least at Spain) ...

... we also have important differences ...



But, are we equal?

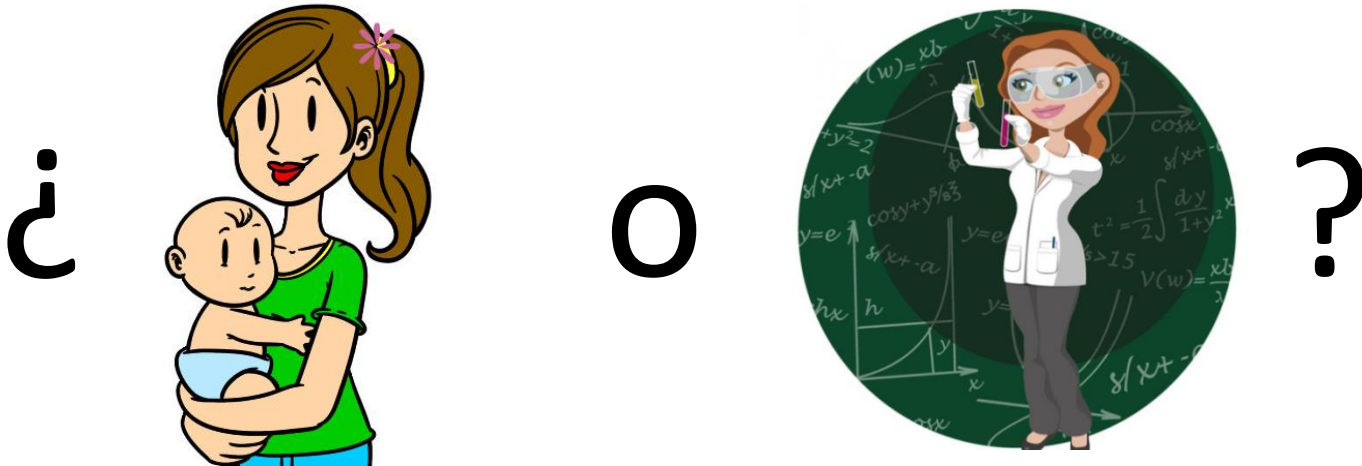
“Little things” that make a world of difference



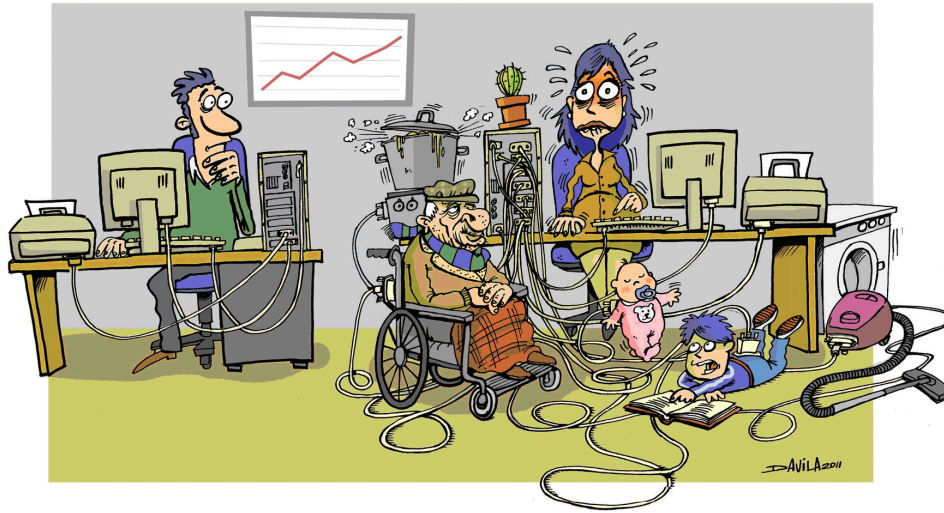
- ❖ 9 months pregnancy
- ❖ Maternity leave (only 16 weeks at Spain + 2 breastfeeding weeks!!)
- ❖ Breastfeeding period

But, are we equal?

But the worst is yet to come ...



The gender problem in STEM



Not only women!!

Real life!

The gender problem in STEM

Challenges for an academic career and family

- Working hours → flexibility, teleworking, kindergartens, day cares
- Low salary
- Following their partners (mobility)
- Travelling (important in breastfeeding period) → videoconferences, support from the research centers
- Career break (maternity leave) → government support
- Work/family balance skills



TAKE AWAY MESSAGE



THANK YOU!!