



Accelerator-Driven System, towards Sustainable Nuclear Energy

Hamid Aït Abderrahim
Myrrha



Symposium to celebrate Carlo Rubbia's 90° birthday, CERN, Geneva (CH), 18 October 2024

- Nuclear energy part of the energy mix for transition towards CO₂ neutral society by 2050 is regularly mentioned in the IPCC, IAEA and IEA reports **but rarely said in the general media.**
- Average lifecycle GHG emissions for electricity production from nuclear energy (**6-10 g CO₂[eq]/kWh**):
 - comparable to the values of hydropower and windmills.
 - about 20 times less than natural gas
 - and 30 to 40 times less than coal.
- End 2023, 418 nuclear reactors are in operation in 32 countries and 59 are under construction. Nuclear electricity represents 10% worldwide, 19,4% for USA and more than 25% for EU, 48% for BE (01.2023)
- In the last COP28 in Dubai, 22 countries declared to commit towards nuclear energy as part of their energy mix for mitigating climate change & Global warming (**x3 installed nuclear by 2050 !**). Confirmed (36 countries) in Brussels on March 2024 @the 1st World Nuclear Energy Summit (IAEA/BE organization)

At the Spring Annual Meeting (April 17-21, 2023) of American Physical Society it was said :

- Make nuclear energy sustainable
- Go SMRs and come with acceptable solutions for nuclear waste
- To achieve industrial deployment, we need:
 - **Establishing an economic viability & competitiveness**
 - **Guaranteeing the safety of the innovative system**
 - Delivering beyond present electricity application (Heat, H₂, fresh H₂O)
 - **Reestablishing capabilities and competences of Large projects Mgt**
 - **Establishing a new regulatory Framework**
 - **Showing societal acceptance**
 - **Meeting security and safeguard regulations & requirements**
 - **Dealing with the nuclear waste in agreement with the citizens**
 - Establishing a world market

Closing Fuel Cycle or Fuel Cycles

$$U_{\text{nat}} = 99,3\% \text{ } ^{238}\text{U} + 0,7\% \text{ } ^{235}\text{U}$$

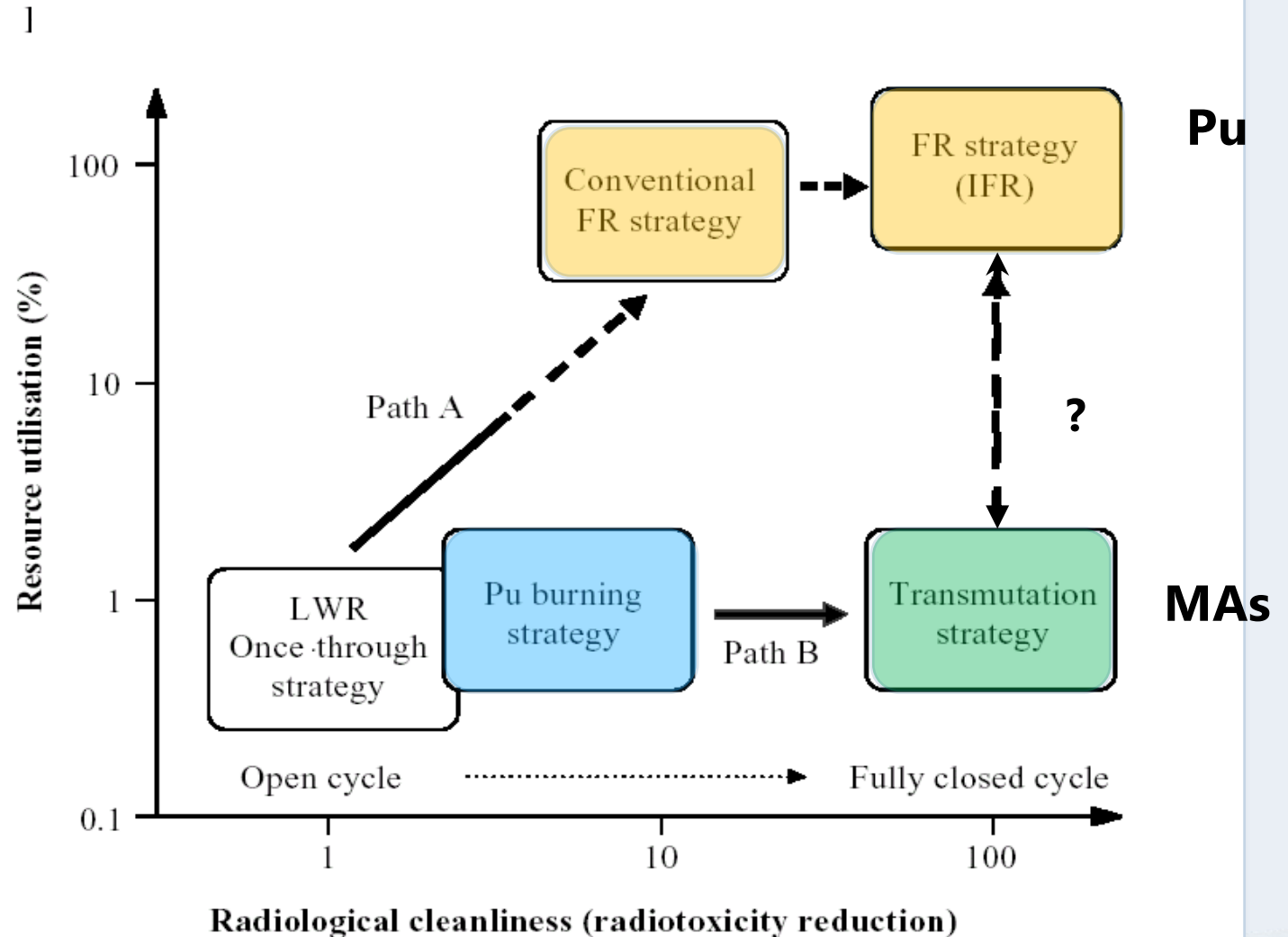
Full Fuel Recycling → 100/0,7

In theory we can retrieve then 145,82 more energy by using Fast Reactors than in Thermal ones (in practice we target 100)

Route towards sustainability

In a later stage why not Th (5X more abundant than U)

20,000 + 100,000 Years !



- Be creative & innovative and question the existing solutions
 - Energy Amplifier → Accelerator Driven System
- Close the nuclear fuel cycle at European level
 - European Technical Working Group for ADS
- Move from uranium cycle to thorium cycle
- Join European Forces and beyond

- “CONCEPTUAL DESIGN OF A FAST NEUTRON OPERATED HIGH POWER ENERGY AMPLIFIER” (CERN/AT/95-44 (ET)) **the reference** paper in any publication on ADS
- FEAT & TARC : very 1st experiments @CERN for confirming feasibility of EA and Transmutation of FPs (MAs)



Pictures courtesy of CERN



The Chairman of ETWG



Explaining, guiding but ...
Giving instructions for reaching the goal

ETWG – ADS → Bringing European actors together

- The members (asked to work hardly and enthusiastically 😊)



MYRRHA ETWG – ADS → After 13 months the result was on the table

- This roadmap is up to now our guidance
- Mobilized a large community from Europe and beyond
- Initiated concrete multilateral projects
- Gave birth to new research facilities to support:
 - ADS development
 - Heavy liquid metal technology → SMR-LFR
 - Closing fuel cycle labs (Advanced fuel fabrication, Advanced reprocessing)
- A European Strategy for preparing industrialization of Closing Fuel Cycle

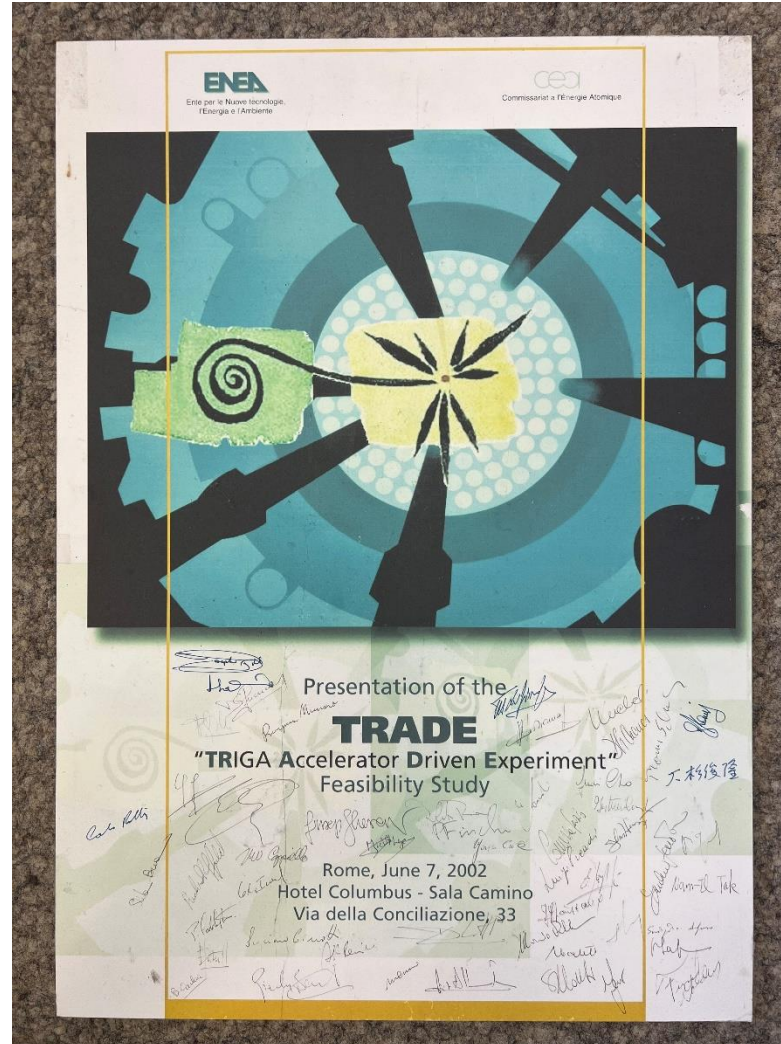


A European Roadmap for Developing
Accelerator Driven Systems (ADS)
for Nuclear Waste Incineration

April 2001

The European Technical Working Group on ADS

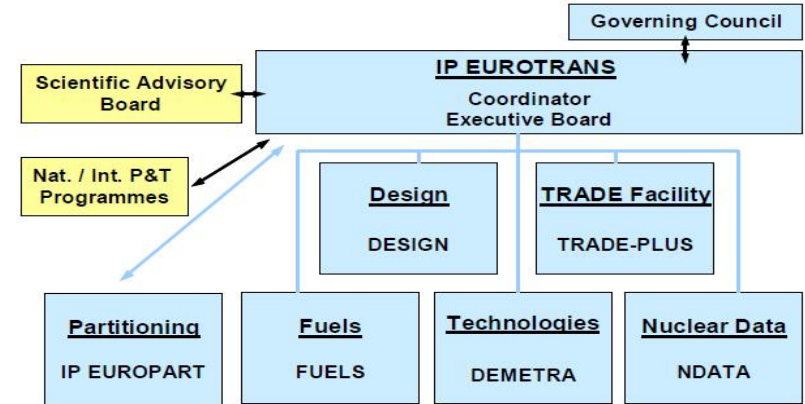
ETWG – ADS → TRADE



ETWG – ADS → IP EUROTRANS (FP6 : 43 M€ !)

Largest ever funded EURATOM FP project

Outline and Objectives of
An Integrated Project on Transmutation (IP EUROTRANS)
 to be proposed
 within EURATOM 6th Framework Programme
 proposed by
Carlo Rubbia ENEA, Jacques Bouchard CEA,
Peter Fritz FZK, and Paul Govaerts SCK-CEN



Organisation of the IP EUROTRANS.

Status

Within the member countries of the European Union the importance of finding a permanent solution for the disposal of radioactive waste is universally recognised, independent of the future development of nuclear energy production.

The Enlarged Technical Working Group (ETWG), which is chaired by Professor Carlo Rubbia, has the objective to identify critical issues of nuclear waste transmutation using an Accelerator Driven System (ADS) and to prepare a European Roadmap for a demonstration programme to be performed within 12 years. The result is a comprehensive report delivered to the parliaments of the respective countries in 2001.

Within the EURATOM 5th Framework Programme in the area of waste management a large number of RTD Projects are funded which deal with the various aspects of partitioning & transmutation (P&T). The projects are integrated in four clusters, being

July 9, 2003

Carlo Rubbia

Carlo Rubbia ENEA

Jacques Bouchard

Jacques Bouchard CEA

Peter Fritz

Peter Fritz FZK

Paul Govaerts

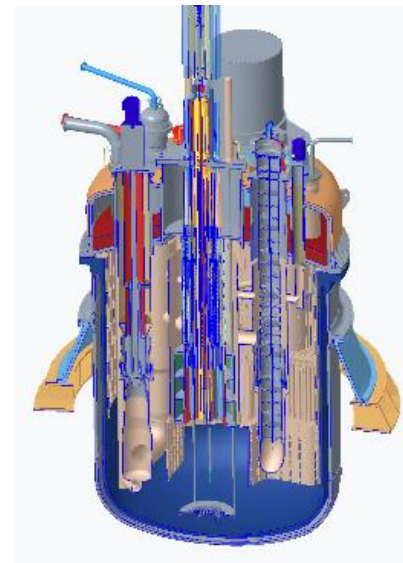
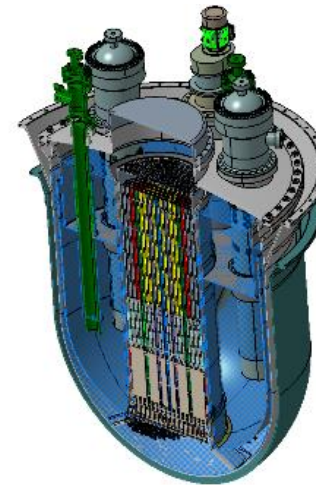
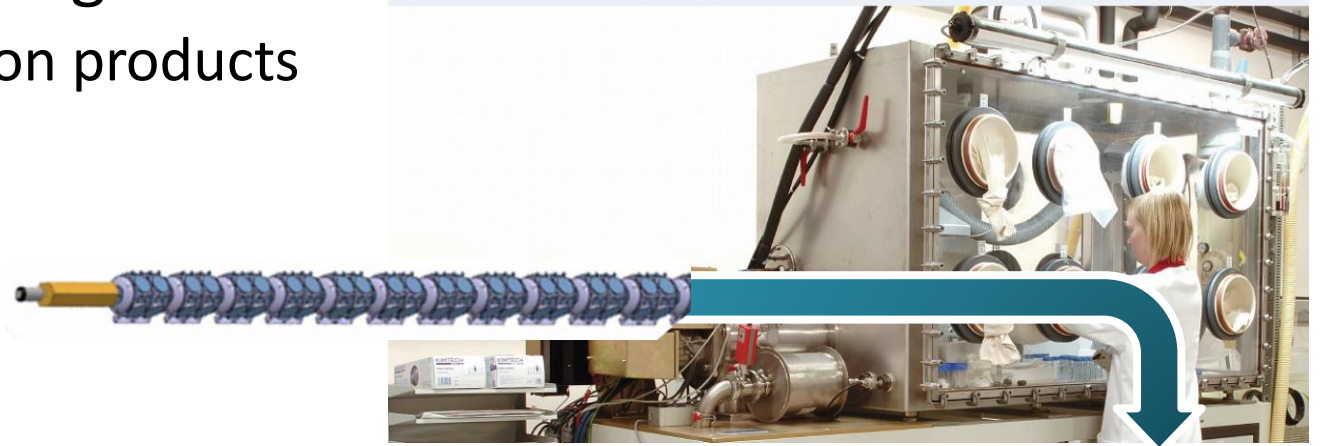
Paul Govaerts SCK-CEN

*as far as the programme will be
 reviewed considering the outcome
 of FP-5 - PDS-ADS project.*

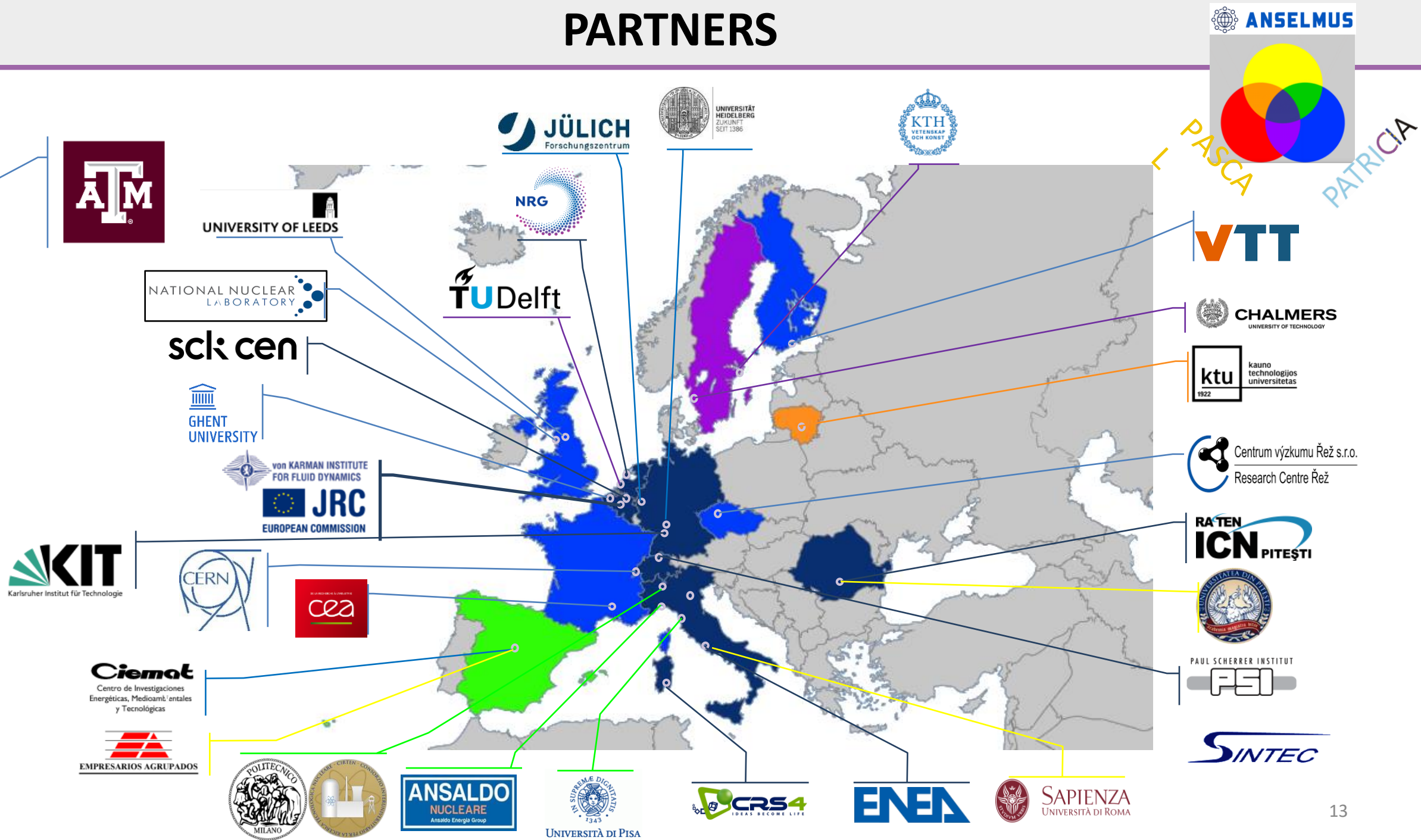
[Signature]

EURATOM FP : Partitioning and Transmutation building blocks

1. Advanced (multiple) reprocessing
 - Separate U, Pu, Am, Np, Cm, fission products
2. Transmuter fuel
 - Create MA bearing fuel
 - Understand behaviour
3. Transmuter
 - Build safe machine that can burn MA
 - Fast neutrons needed
 - Accelerator driven system
 - Fast critical reactor
4. Transmuter fuel reprocessing
5. Ad. Fuels transportation, cooling, and handling



PARTNERS



Move from uranium cycle to thorium cycle



Because $\eta > 2$ at low as well as at high energy

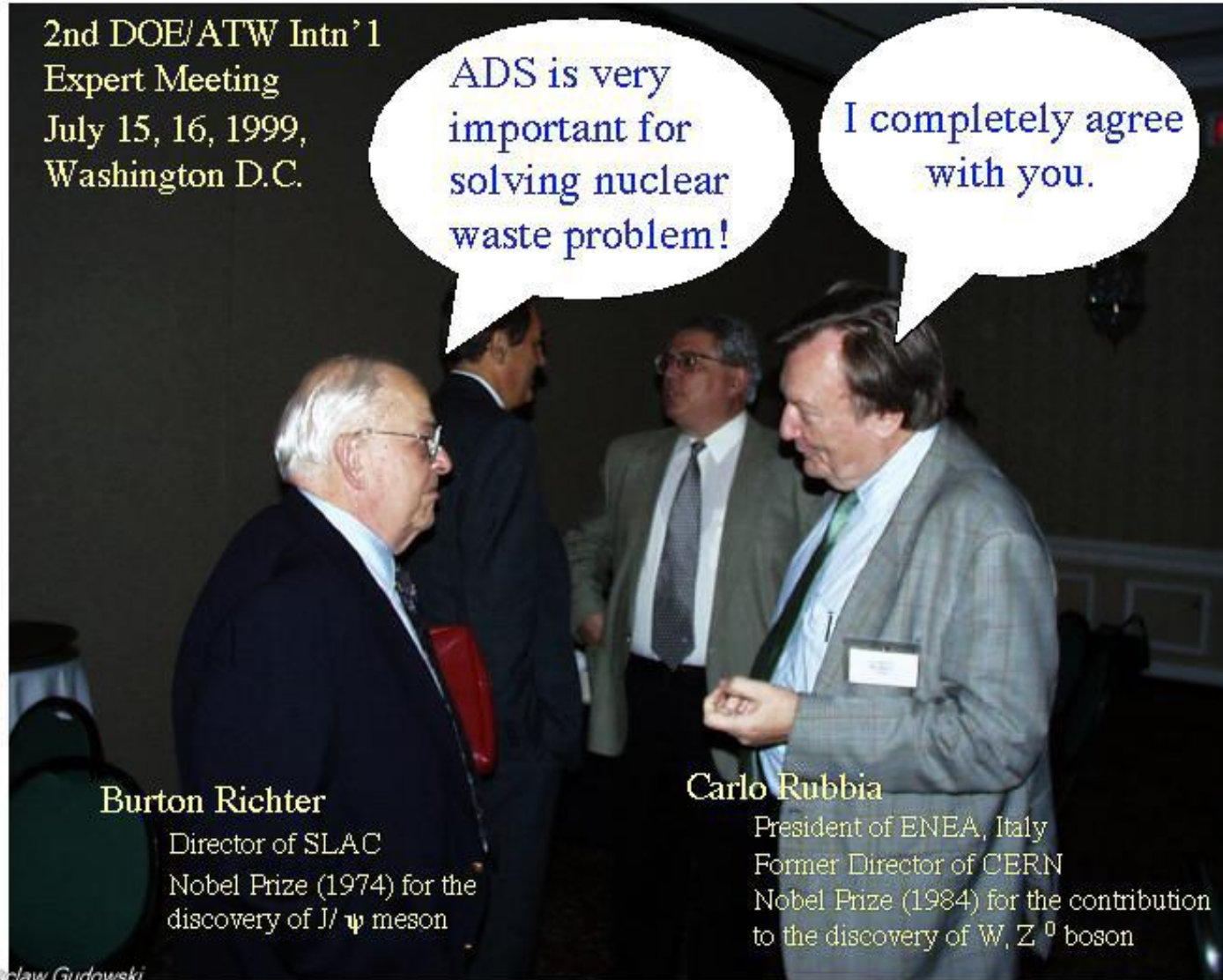


Join European forces and beyond

2nd DOE/ATW Intn'l
Expert Meeting
July 15, 16, 1999,
Washington D.C.

ADS is very
important for
solving nuclear
waste problem!

I completely agree
with you.



Burton Richter

Director of SLAC
Nobel Prize (1974) for the
discovery of J/ψ meson

Carlo Rubbia

President of ENEA, Italy
Former Director of CERN
Nobel Prize (1984) for the contribution
to the discovery of W, Z^0 boson

© Wacław Gudowski

Carlo's collaboration with Commissioner Antonio RUBERTI.

- Professor Ruberti held a high view of research. He was also a fervent, committed European with a challenging vision of European research. Although he was a commissioner for only two years, this short time was enough for him to make his mark on European research policy. He was one of the great builders of the European research community.
- Together with a small group of advisors, amongst which Carlo played an important role,
- Created European Science and Technology Assembly (ESTA) in 1994
- As advisory body for science and technology to EC for the implementation of the EU's research and technological development policy
- Assist EC to promote scientific and technical culture in Europe and to stimulate debate on science and technology at European level.
- The Assembly consisted of 100 senior scientist – amongst which several Nobel Laureates - and managers from industry, chosen from European organizations representing "exact and natural sciences, industry, economics, social sciences and humanities.

The most noteworthy achievement of the ESTA creation in 2007 of **EUROPEAN RESEARCH COUNCIL (ERC)**

Thank Carlo for all what you did and do

- For promoting Science at European level
- For supporting & stimulating young generation of talents
- For bringing people from different horizons and cultures to realize great projects for the benefit of all humans and their environment
- For contributing to making nuclear energy sustainable, enabling abundant energy for all, and reducing the struggle for a better quality of life





Thank you for helping MYRRHA

We don't make projects because they are easy but because they are desired & needed by and for the society

