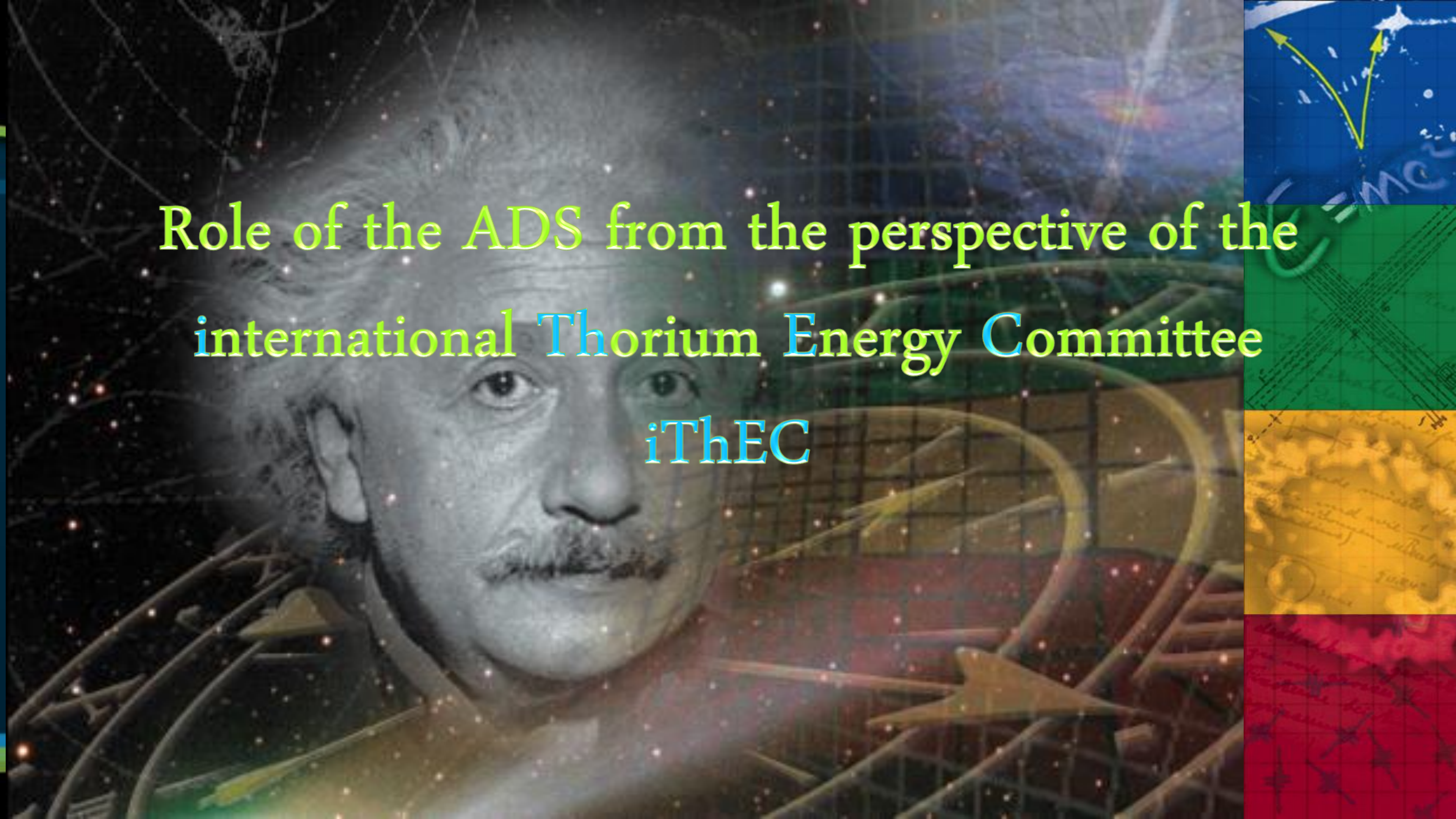


Role of the ADS from the perspective of the international Thorium Energy Committee

iThEC

The energy challenge

international Thorium Energy Committee

- World energy production needs to triple to ensure equal access to all inhabitants of the earth at the same level of consumption as Europeans (50% of American consumption)
- Increased CO2 and climate change make it impossible to fulfil this goal with fossil fuels such as coal
- Having progressed from wind and water power in the distant past, to steam power in the 19th century and to the gas engine in the 20th century, sustainable nuclear power is the energy source of the 21st century.

Concerns on Conventional Nuclear Power Plants Safety

- Accidents & Safety
- Nuclear Proliferation)
- Accumulation of Radioactive Wastes
- Depletion of Uranium Resources

These problems need to be solved before increasing the use of nuclear power.

international Thorium Energy Committee

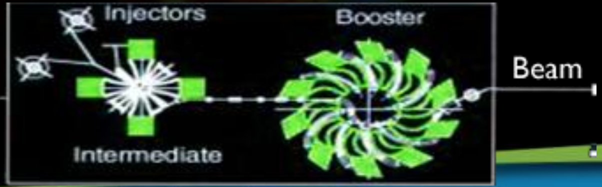
Question 1

Why are sub-critical reactors sometimes called "green nuclear power"?

OR

Could nuclear fission be used in a way that is acceptable to Society?

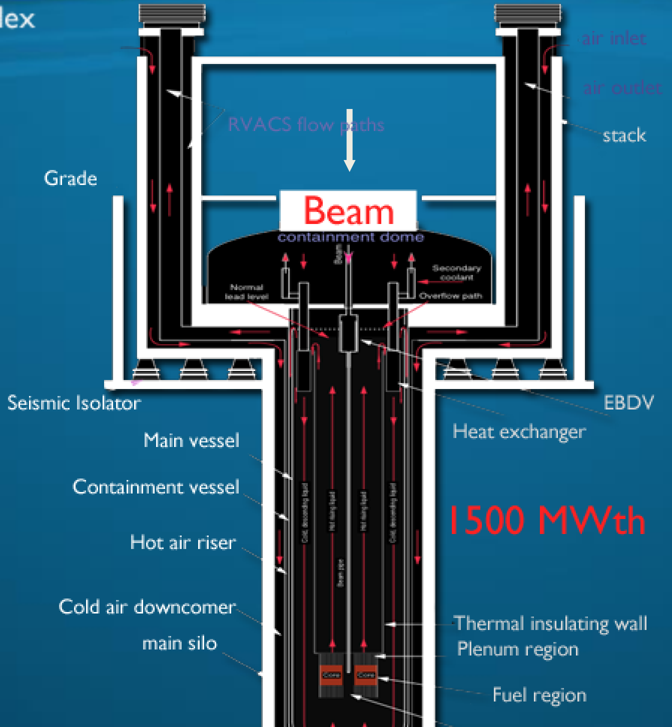
international Thorium Energy Committee



Accelerator Complex

Carlo Rubbia’s Energy Amplifier based on nuclear fission:

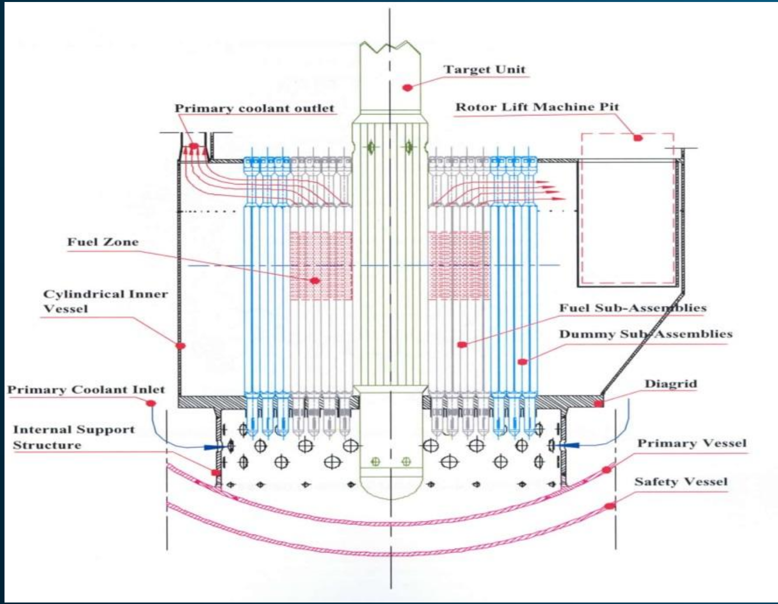
- Is a **sub-critical** system (no Chernobyl-type accident possible) **driven by a proton accelerator**;
- Is a **fast neutron** system (use of lead as moderator/coolant);
- equipped with **passive safety features** (no core meltdown);
- uses **thorium based fuel** rather than uranium used in PWRs (minimize waste, proliferation resistant)

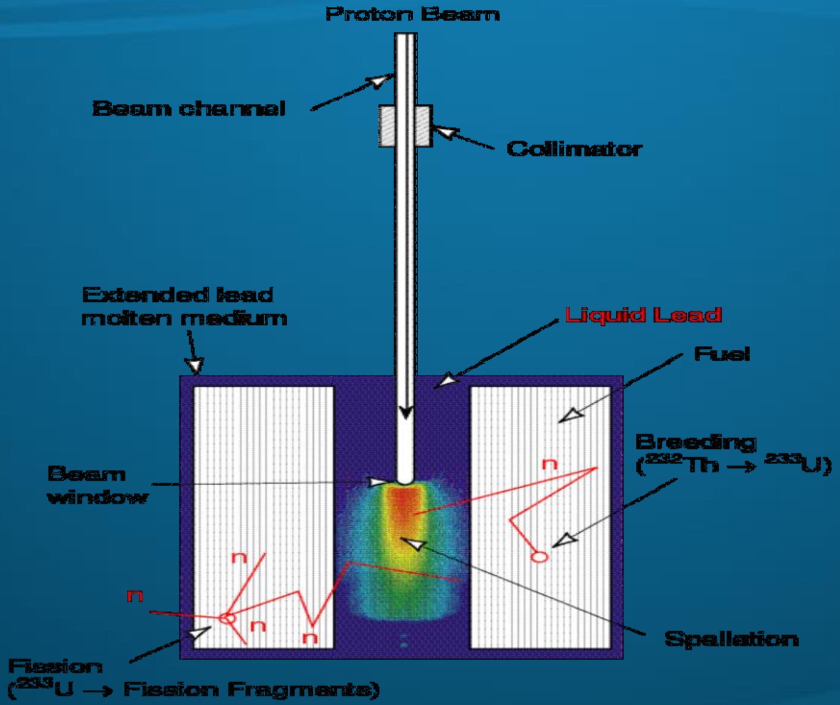


C. Rubbia et al.
CERN/AT/95-44(ET)

iThEC international Thorium Energy Committee

General features of an ADS

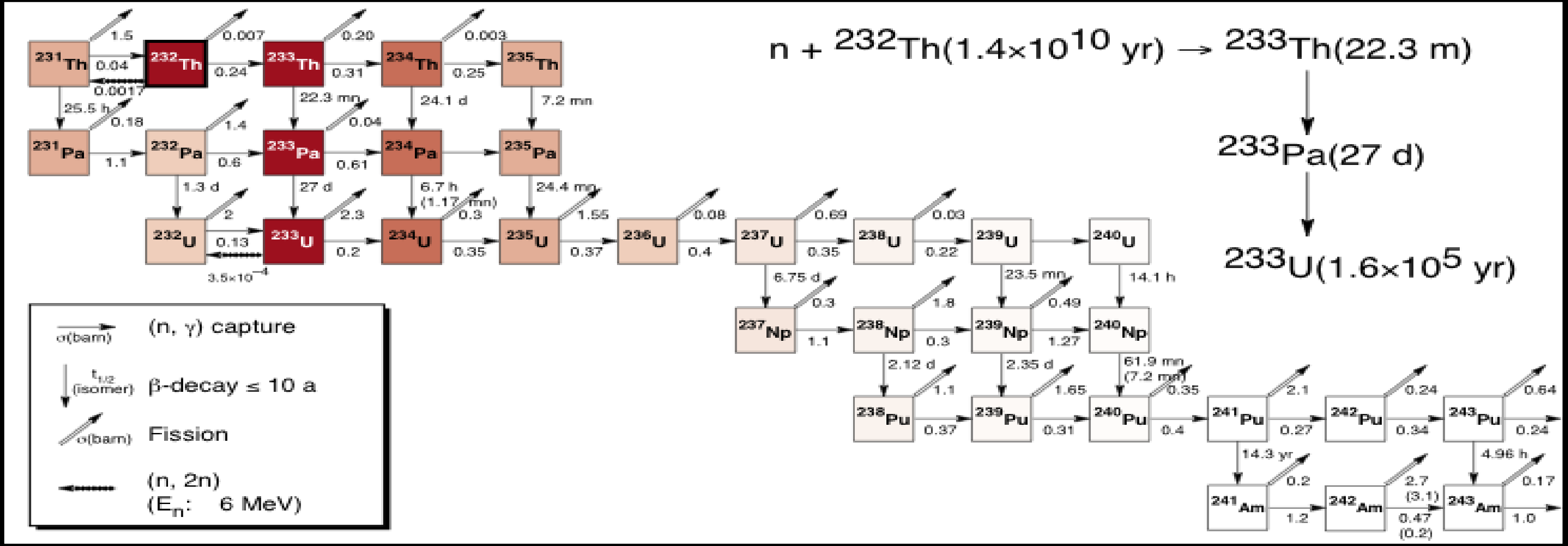




Question 2

Is nuclear energy feasible without uranium or plutonium?

Thorium as fuel in a system breeding ^{233}U



It is the presence of the accelerator which makes it possible to choose the optimum fuel. Low equilibrium concentration of TRU makes the system favourable for their elimination: Pu 10^{-4} in Th vs 12% in U.

Thorium, a Sustainable Nuclear Energy Source

1. **Abundance of Resources**
   - large reserves to sustain requirement for generations
2. **Resource consumption is matched by resource production**
   - Neither breeding nor burning – self-sustaining
3. **Environmentally friendly**
   - Low-level long-lived radiotoxicity/transmutation nuclide
4. **Waste Safety**
   - Fuel itself is a stable matrix for actinide and fission products, better than vitrified glass
5. **Proliferation resistance**
   - U^{232} presence in U^{233} ⇨ difficulty for military use

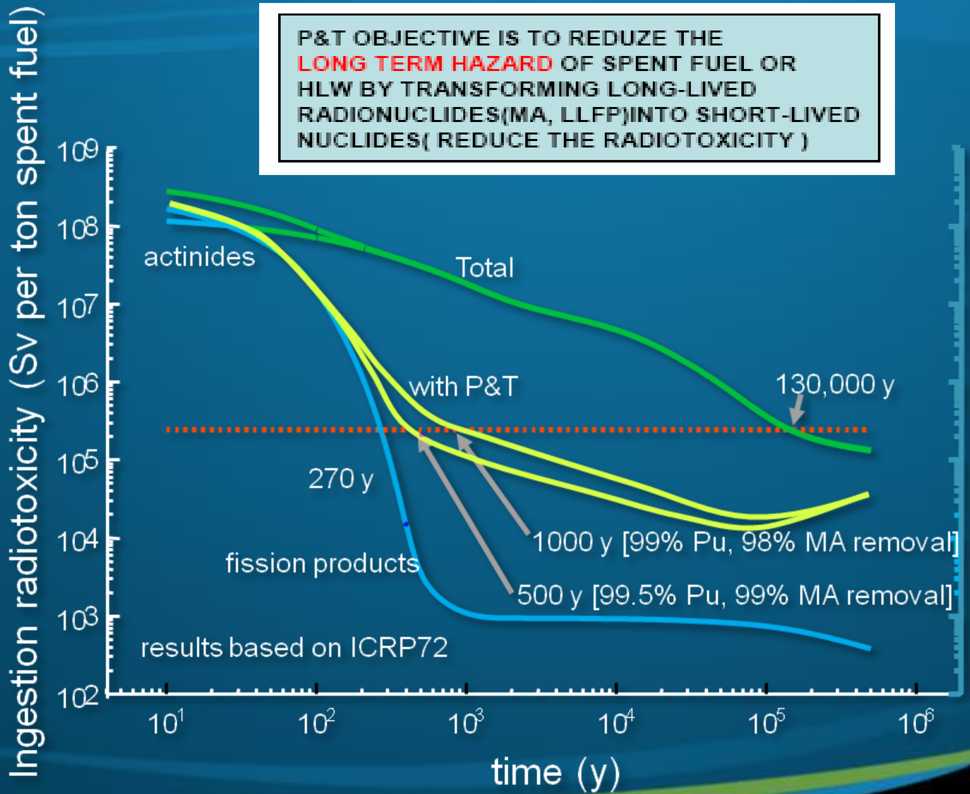
Thorium-based fuel cycle fits the bill

Question 3

Is it possible to burn the existing nuclear waste stockpile so as to generate electricity?

Partitioning &Transmutation

- P/T applies to **TRU** (**Pu** and **M**inor **A**ctinides) and **L**ong **L**ived **F**ission **P**roducts.
- It should be kept in mind that Plutonium is a special case: it can be considered as a valuable resource or part of the wastes.
- However, P/T technologies apply to the most general case.



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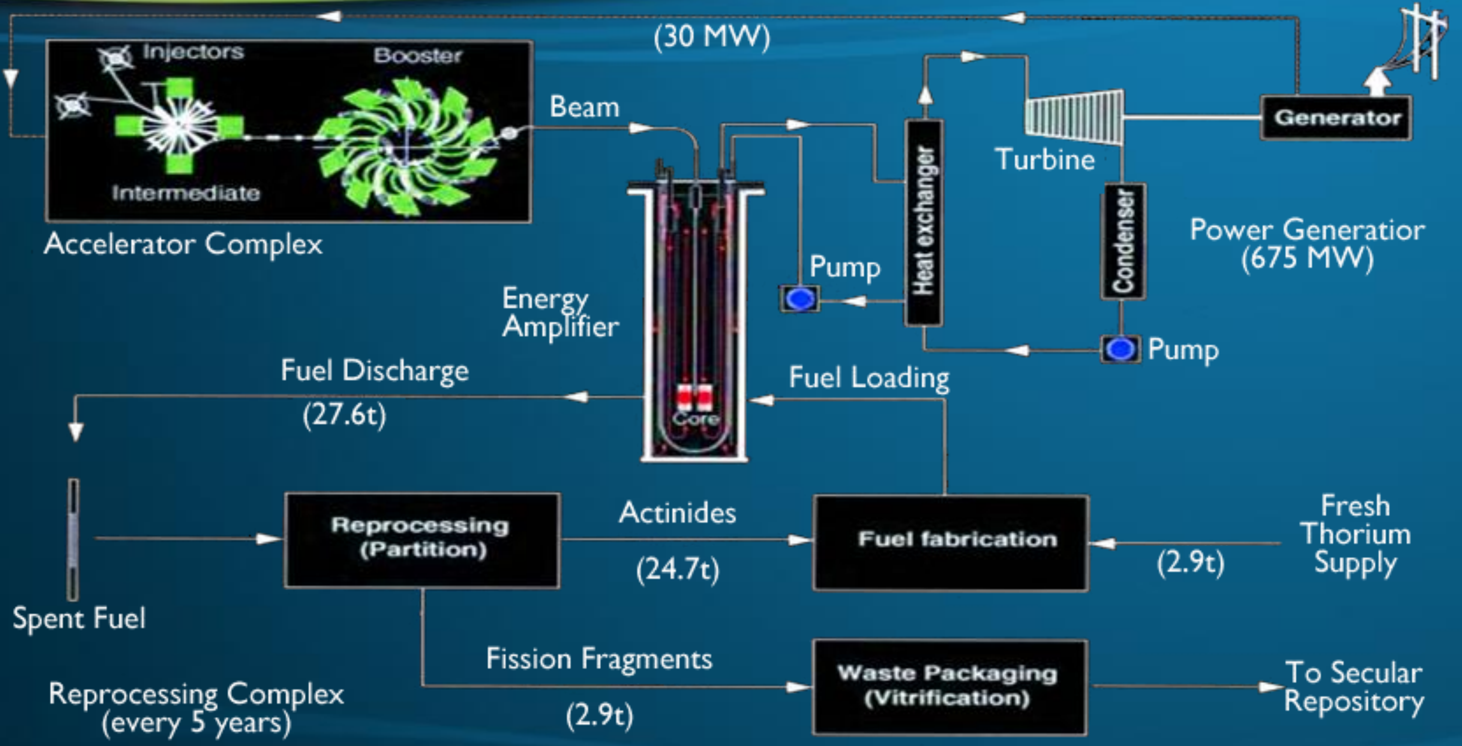
Question 4

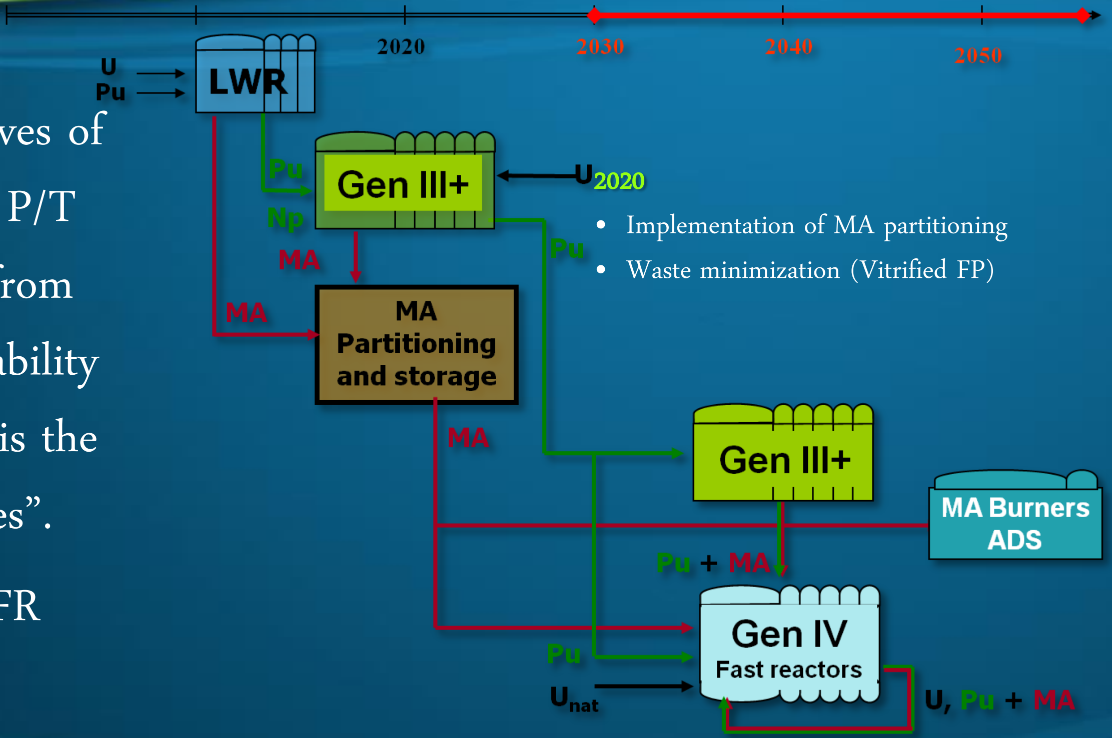
Can Accelerator-Driven Systems meet a 10 GW implementation scale within the next 20 years?

Layout of a 1500 MWth thorium-fuelled ADS



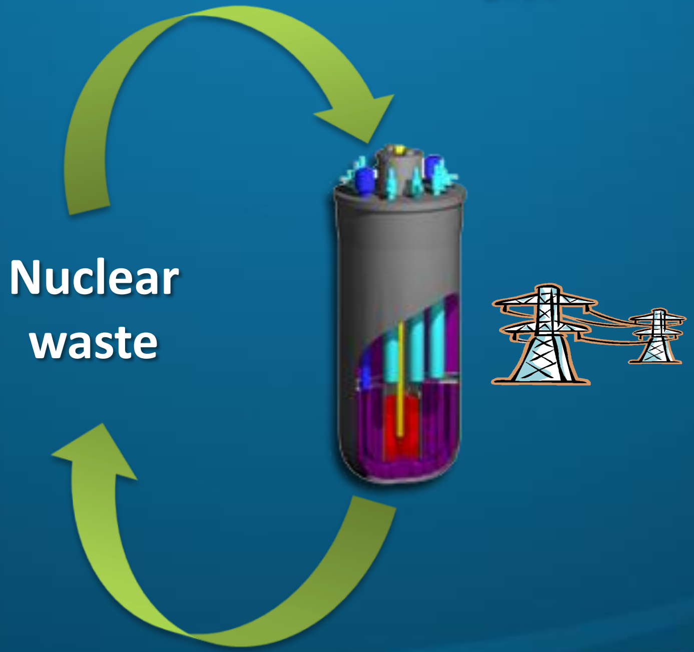
Deployment Scenario

- A turning point ~2000 : the objectives of GENERATION-IV start to include P/T (waste minimization). P/T is seen from then on, as consistent with sustainability and non-proliferation objectives: it is the path towards "Advanced Fuel Cycles".
- Implementation: closely related to FR deployment decision.



The path towards sustainability

- 400 – 800 GWe
  - ➢ Business as usual
  - ➢ Open fuel cycle
- 1200 GWe by 2030 / 7000 GWe by 2050
  - ➢ Accelerated alternative scenario
  - ➢ Only made possible by closing fuel cycle
- Commercial demos
  - ➢ Th-ADS by 2030
  - ➢ Multilateral initiatives ⇨ **iThEC**



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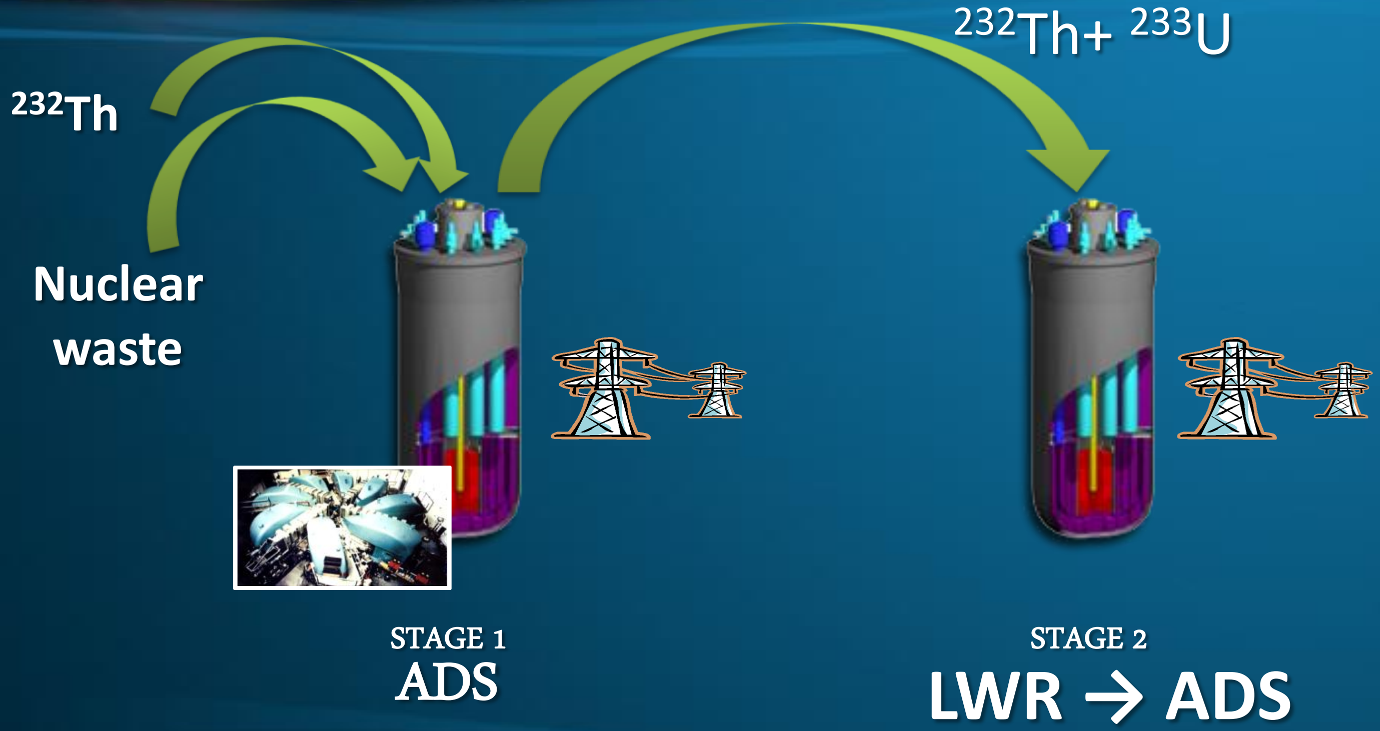
Deployment Scenario



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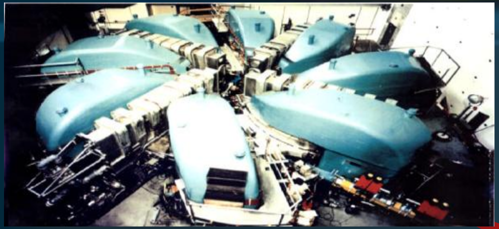
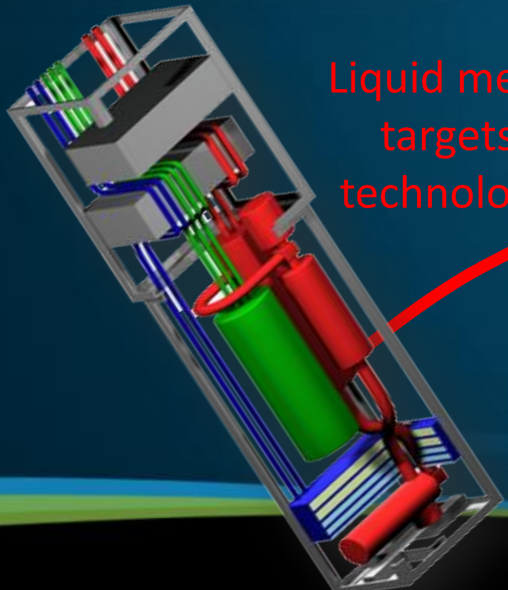
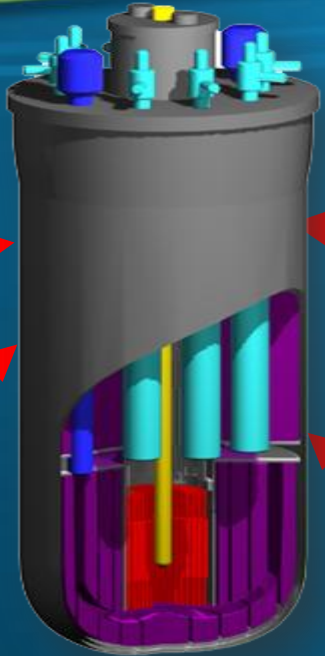
Integration of consolidated technologies in an innovative engineering design



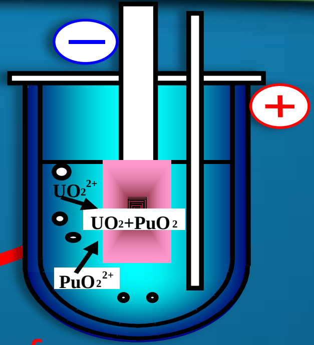
High power accelerators technology



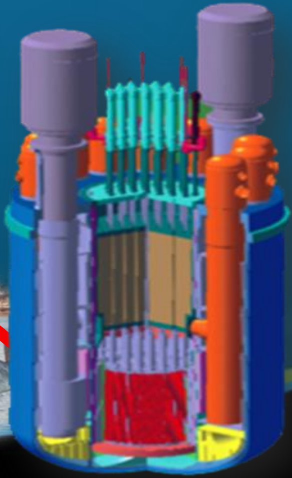
Liquid metal targets technology



Technology of pyrochemical reprocessing of fuel



Technologies of fast reactors with lead-bismuth coolant



Question 5

Has anyone built sub-critical Thorium reactors?

Industrial Experience of Thorium Critical Reactors

Country	Name	Type	Power	Operation
Germany	AVR	HTGR	15 MW_e	1967 - 1988
Germany	THTR	HTGR	300 MW_e	1985 - 1989
UK, OECD-EURATOM also Norway, Sweden & Switzerland	Dragon	HTGR	20 MW_{th}	1966 -1973
USA	Fort St Vrain	HTGR	330 MW_e	1976 – 1989
USA, ORNL	MSRE	MSBR	7.5 MW_{th}	1964 – 1969
USA	Shippingport & Indian Point	LWBR PWR	100 MW_e 285 MW_e	1977 – 1982 1962 – 1980
India	KAMINI, CIRUS & DHRUVA	MTR	30 kW_{th} 40 MW_{th} 100 MW_{th}	In operation

Most Project Using Thorium were Terminated by the 1980s

Main Reasons:

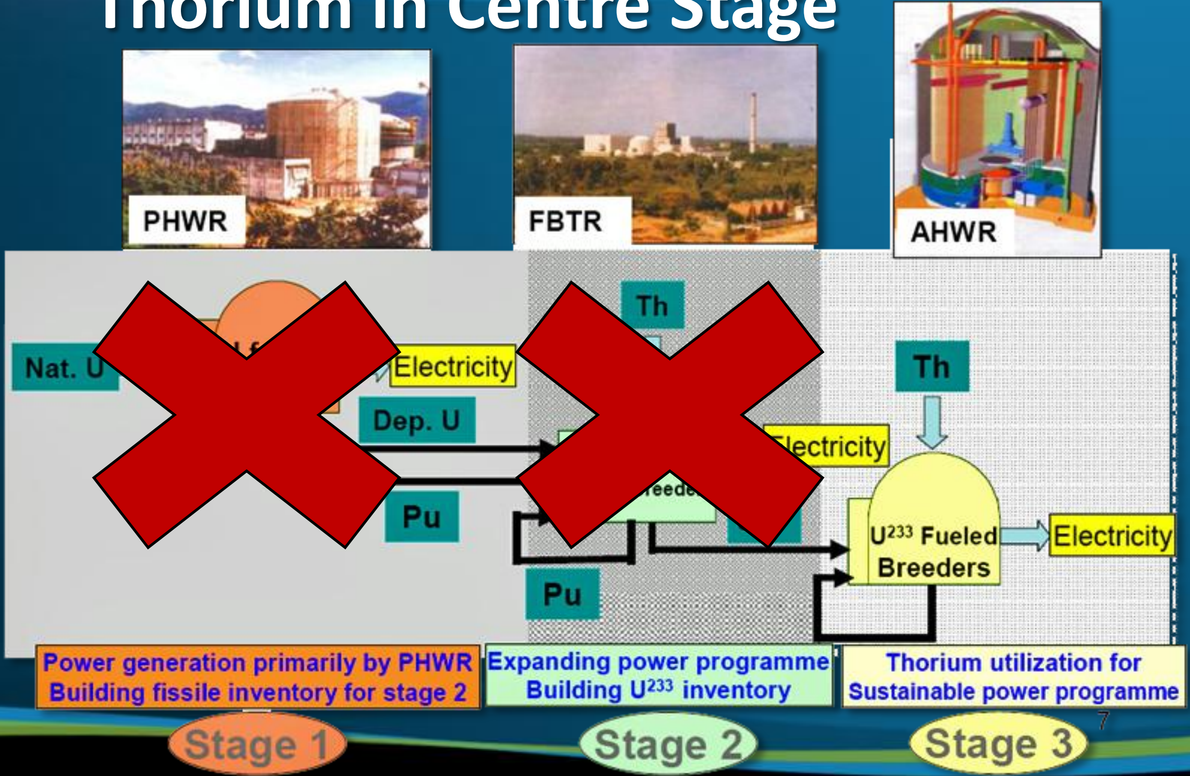
- The thorium fuel cycle could not compete economically with the well-known uranium cycle
- Lack of political support for the development of nuclear technology after the Chernobyl accident
- Increased worldwide concern regarding the proliferation risk associated with reprocessing of spent fuel

Except for India:

- That utilizes thorium for its long term energy security

Except for… three Stage Program in India

Thorium in Centre Stage



ADS Experience: the FEAT Experiment at CERN

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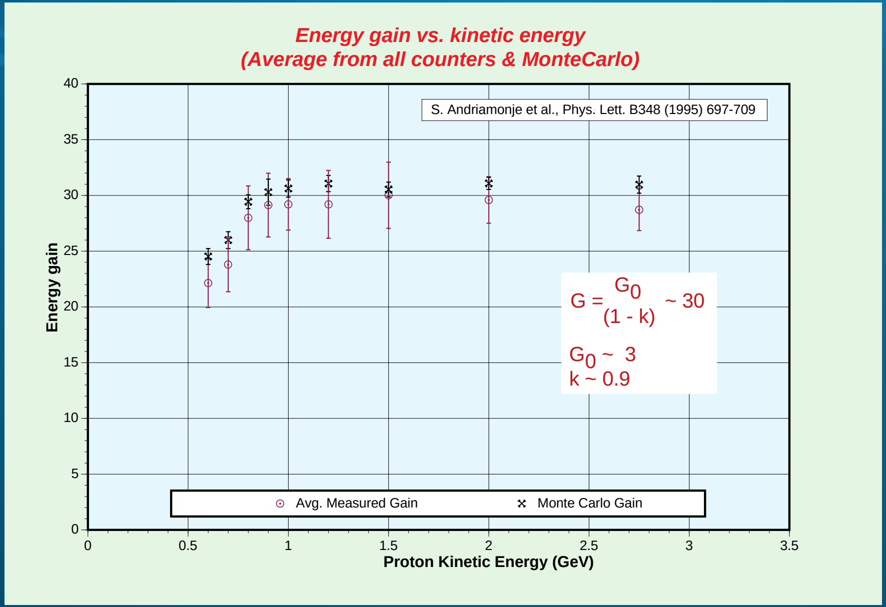

- Consistent measurement of the energy gain.
- Validation of innovative MC simulation tool.
- Energy gain increases with particle beam energy □ constant above 900 MeV □ modest requirement for Energy Amplifier.
- The first Energy Amplifier (with a power rating ≈ watt) was operated at CERN in 1994.

ADS Expertience: the MEGAPIE Experiment at PSI

- World’s first Megawatt class neutron spallation source
- 80% increase in the neutron flux.
- The liquid metal neutron spallation source was operated at PSI in 2006 over 4 months.

Concluding remarks: can nuclear power be green?

Physics suggests : yes Thorium can!

- Accelerator-driven systems have additional safety margins, which give operational flexibility to future systems for safe and clean energy production and/or waste transmutation (including nuclear weapons)

- Present accelerator technology offers the possibility for applying a closed thorium cycle, but also for an open once-through 'cycle' using thorium oxide with some topping fuel and a very high fuel burn up. The Energy Amplifier is one of the examples with high potential

iThEC aims to encourage these goals

The role of iThEC

- **Key objective is to encourage**

1. Transmutation of nuclear waste
2. Thorium power generation

- **Actions :**
  - Organising conferences, adressing political circles, the media and the public
  - Fostering links between academia and private investor
- **Concrete steps :**
  - September 2012: iThEC founded as a non-profit organisation in Geneva.
  - December 2012: Decision to host the next Thorium conference THEC13 in October 2013

Thorium Energy Conference ThEC13

October 27 - 31, 2013, Globe of Science and Innovation, CERN, Geneva, Switzerland

Scientific Advisory Committee

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Hans Blix, Ex director IAEA
Robert Cywinski, Univ. of Huddersfield, UK
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Conference Secretaries

Carnita Hervet, CERN
Ulla Tihinen, CERN

Conference Web Page: http://indico.cern.ch/event/thec13
Enquiries and Correspondence: Ulla.Tihinen@cern.ch
Organized by iThEC, www.ithec.org, in collaboration with iThEO, www.itheo.org

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Thank You

Yacine Kadi

iThEC

Additional Slides

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Development is Time-Consuming

Generation I
Early Prototype Reactors

- Shippingport
- Dresden, Fermi I
- Magnox

Generation II
Commercial Power Reactors

- LWR-PWR, BWR
- CANDU
- AGR

Generation III
Advanced LWRs

- ABWR
- System 80+
- AP600
- EPR

Generation III +
Evolutionary Designs Offering Improved Economics for Near-Term Employment

Generation IV
- Highly Economical
- Enhanced Safety
- Minimal Waste
- Proliferation Resistant

Gen III | Gen III+ | Gen IV

1950 1960 1970 1980 1990 2000 2010 2020 2030

Worldwide Programs

Project	Neutron Source	Core	Purpose
FEAT (CERN)	Proton (0.6 to 2.75 GeV) (~10^{10}p/s)	Thermal (≈ 1 W)	Reactor physics of thermal subcritical system (k≈0.9) with spallation source - **done**
TARC (CERN)	Proton (0.6 to 2.75 GeV) (~10^{10}p/s)	Fast (≈ 1 W)	Lead slowing down spectrometry and transmutation of LLFP - **done**
MUSE (France)	DT (~10^{10}n/s)	Fast (< 1 kW)	Reactor physics of fast subcritical system - **done**
YALINA (Belorus)	DT (~10^{10}n/s)	Fast (< 1 kW)	Reactor physics of thermal & fast subcritical system - **done**
MEGAPIE (Switzerland)	Proton (600 Me) + Pb-Bi (1MW)	-----	Demonstration of 1MW target for short period - **done**
TRADE (Italy)	Proton (140 MeV) + Ta (40 kW)	Thermal (200 kW)	Demonstration of ADS with thermal feedback - **cancelled**
TEF-P (Japan)	Proton (600 MeV) + Pb-Bi (10W, ~10^{12}n/s)	Fast (< 1 kW)	Coupling of fast subcritical system with spallation source including MA fuelled configuration - **postponed**
SAD (Russia)	Proton (660 MeV) + Pb-Bi (1 kW)	Fast (20 kW)	Coupling of fast subcritical system with spallation source - **cancelled**
TEF-T (Japan)	Proton (600 MeV) + Pb-Bi (200 kW)	-----	Dedicated facility for demonstration and accumulation of material data base for long term - **postponed**
MYRRHA (Belgium)	Proton (350 MeV) + Pb-Bi (1.5 MW)	Fast (60 MW)	Experimental ADS - **under study FP6/FP7 EUROTRANS**