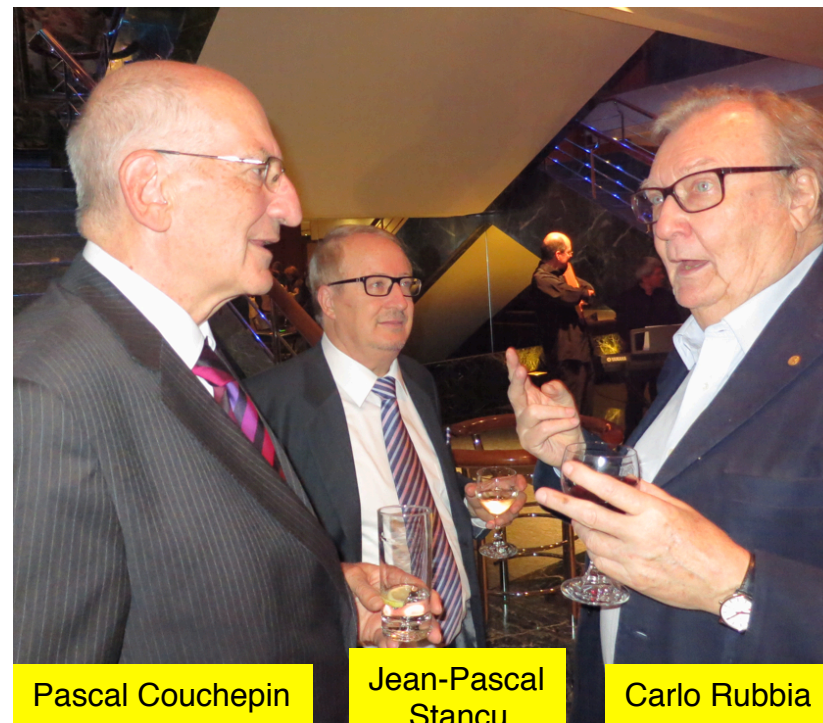
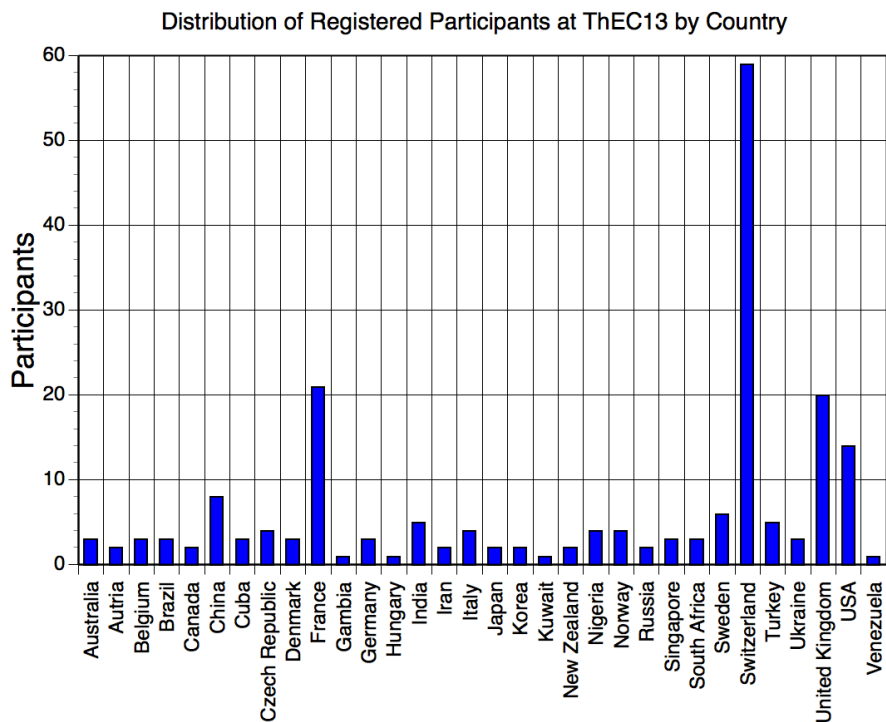


ThEC13 Summary and a look into the future

**ThEC13 – Thorium Energy Conference
Globe of Science and Innovations
CERN, Geneva, Switzerland
October 31, 2013**

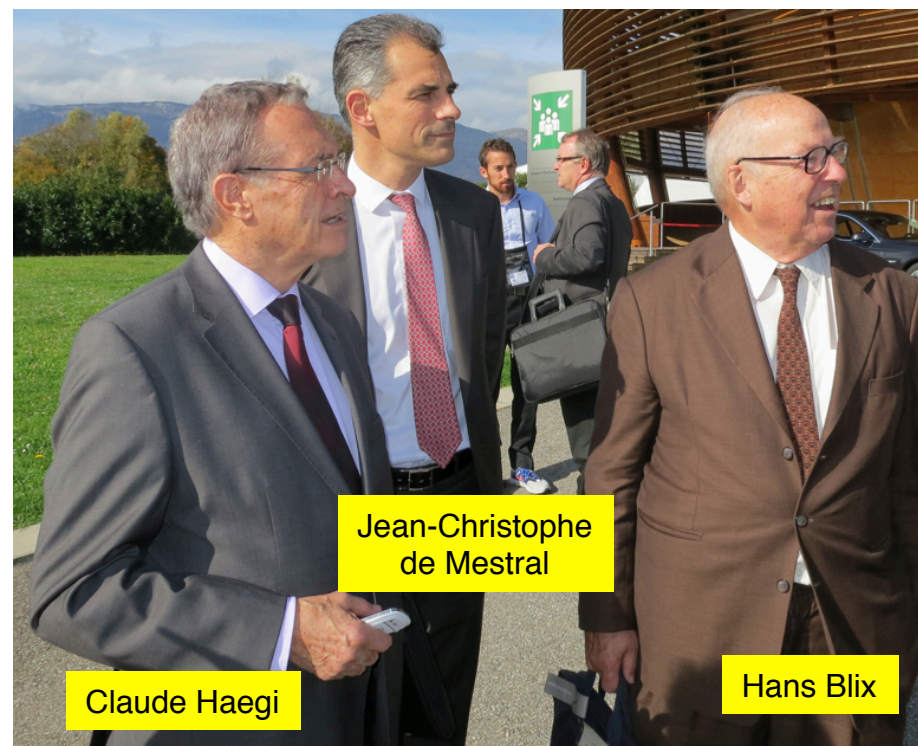
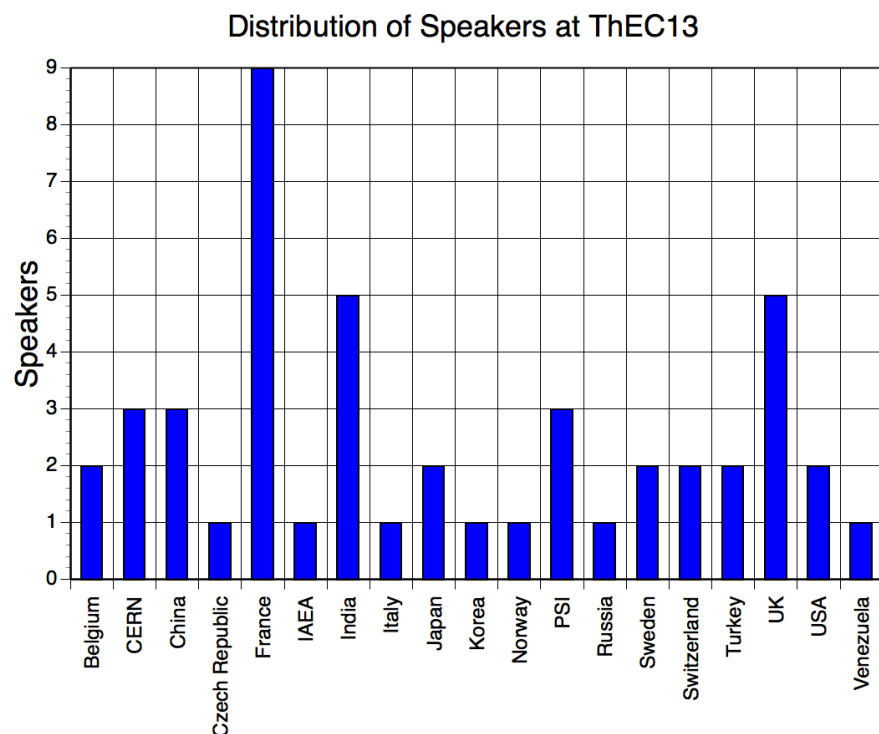
**Jean-Pierre Revol
CERN Physics Department
Geneva, Switzerland**

- 199 persons registered from 32 countries, more than 190 were present at ThEC13, including some prestigious personalities, which is important, as thorium development needs political support



- 5033 connections were made to the live webcast

- A dense programme, during which, we listened to 47 presentations by speakers from 19 countries



- Three and a half days of presentations and discussions



- ❑ There is a clear sign of an increasing worldwide interest in Thorium, reaching nuclear industry
- ❑ AREVA announced official interest in thorium:

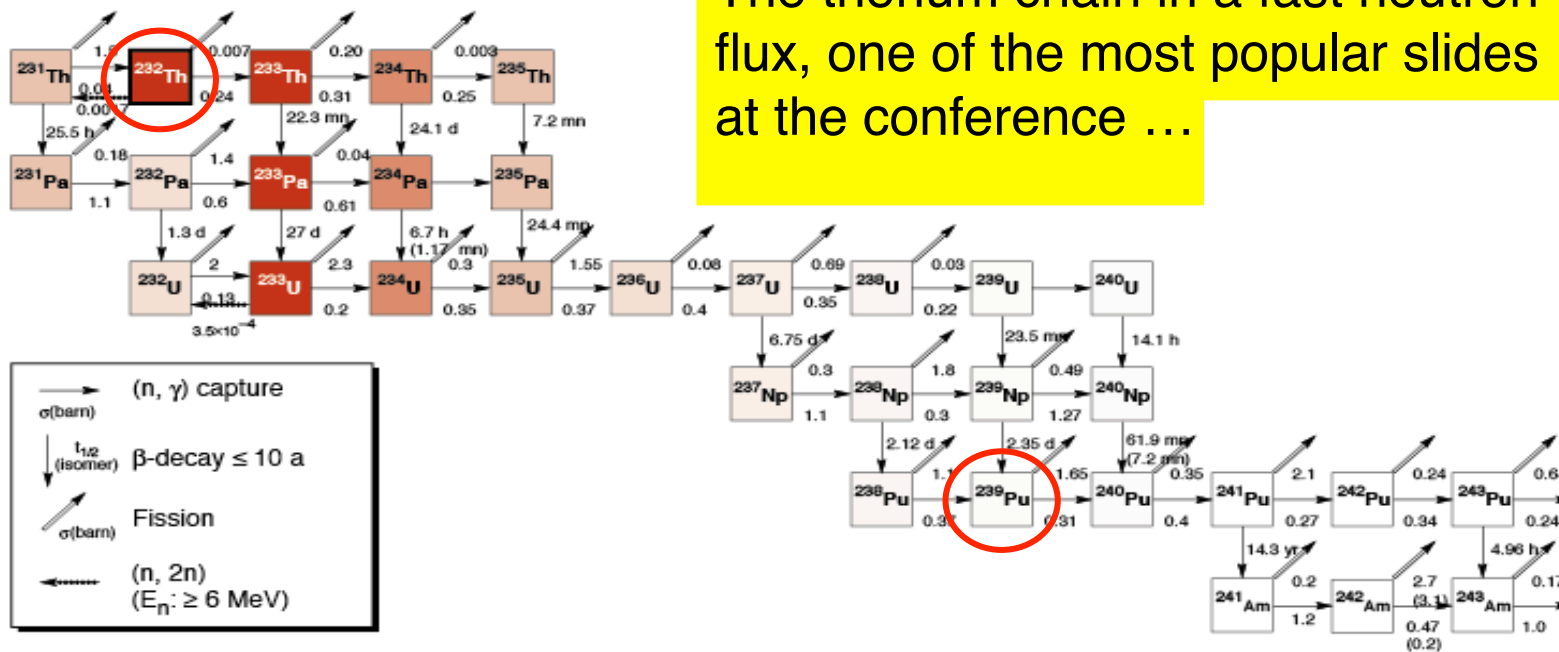
AREVA and SOLVAY join their know-how to add value to thorium's entire life cycle

Luc van den Durpel
Oct. 29, 2013

Why thorium?

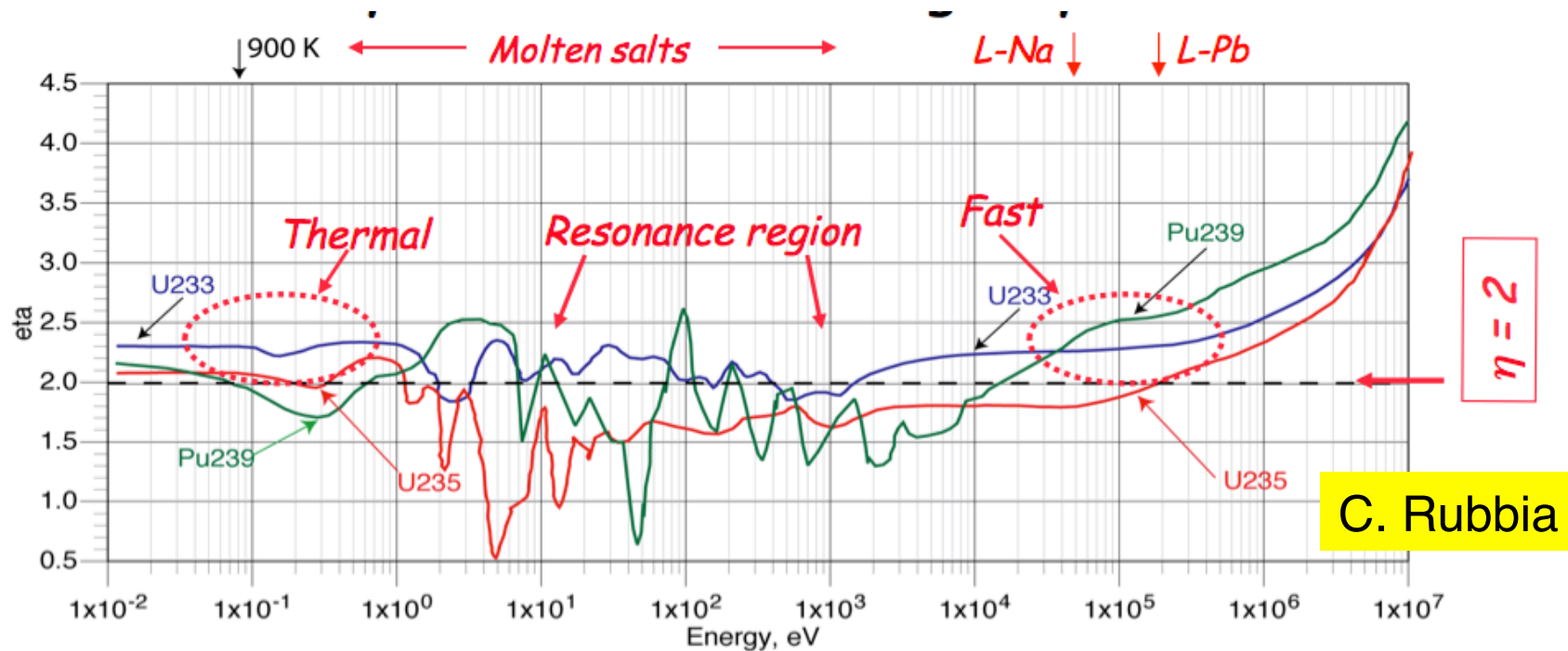
- Because it is 7 neutron captures away from plutonium-239
- It is more abundant than uranium, and in breeding mode, there is a potential factor 140 gained compared to uranium in PWR
- Unique potential for nuclear waste elimination and nuclear weapon proliferation resistance

The thorium chain in a fast neutron flux, one of the most popular slides at the conference ...



Why is it challenging to use thorium?

- Even though ^{233}U is generally better than ^{235}U and Pu (except above a few tens of keV), it cannot be used simply in a standard critical reactor because of neutron inventory issues.
- If one wants to work with a fast neutron flux, to optimize TRU destruction, the issue is even more severe.



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□ What are the options?

- ☛ Use **thorium blankets** around reactors, to breed uranium-233
- ☛ **Continuously moving the fuel out**, such as to always have fresh fuel
 - Pebble bed reactors (once through)
 - Molten salt reactors (reprocessing on-line)
(we heard a lot about molten salt reactors)
- ☛ **Accelerator Driven Systems** (ADS), this is in particular the solution proposed by C. Rubbia, and promoted by iThEC
(we also heard a lot about various aspects of ADS)



Thorium blankets challenges

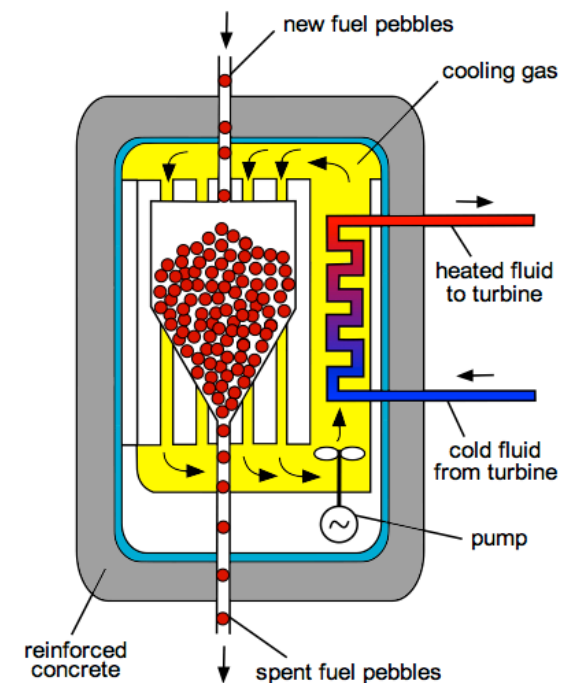
- ❑ **Example of India** with little uranium resources, but a lot of thorium:
 - Use heavy water reactors (CANDU) or LWR to produce plutonium from their small uranium supply
 - Use sodium cooled U-Pu fast reactor with a thorium blanket to breed ^{233}U
 - Reprocess blanket and manufacture ^{233}U -Th fuel for advanced fast or thermal water reactors

- ❑ This is the most advanced scheme on the use of thorium, including front end and back end of the fuel cycle. India improving knowledge of thorium properties.

- ❑ **It works. However, there remain some issues on the complexity of the present scheme (three technologies), sustainability and nuclear waste.**

- ❑ First proposed by Farrington Daniels at Oakridge, in the 1940s. Initial developments in Germany (AVR Jülich), followed by THTR-300. New developments in South Africa and the United-States, and also in Turkey:
 - 👉 No account given on Pebble Bed Reactor technology in this conference

Pebble Bed Reactor scheme

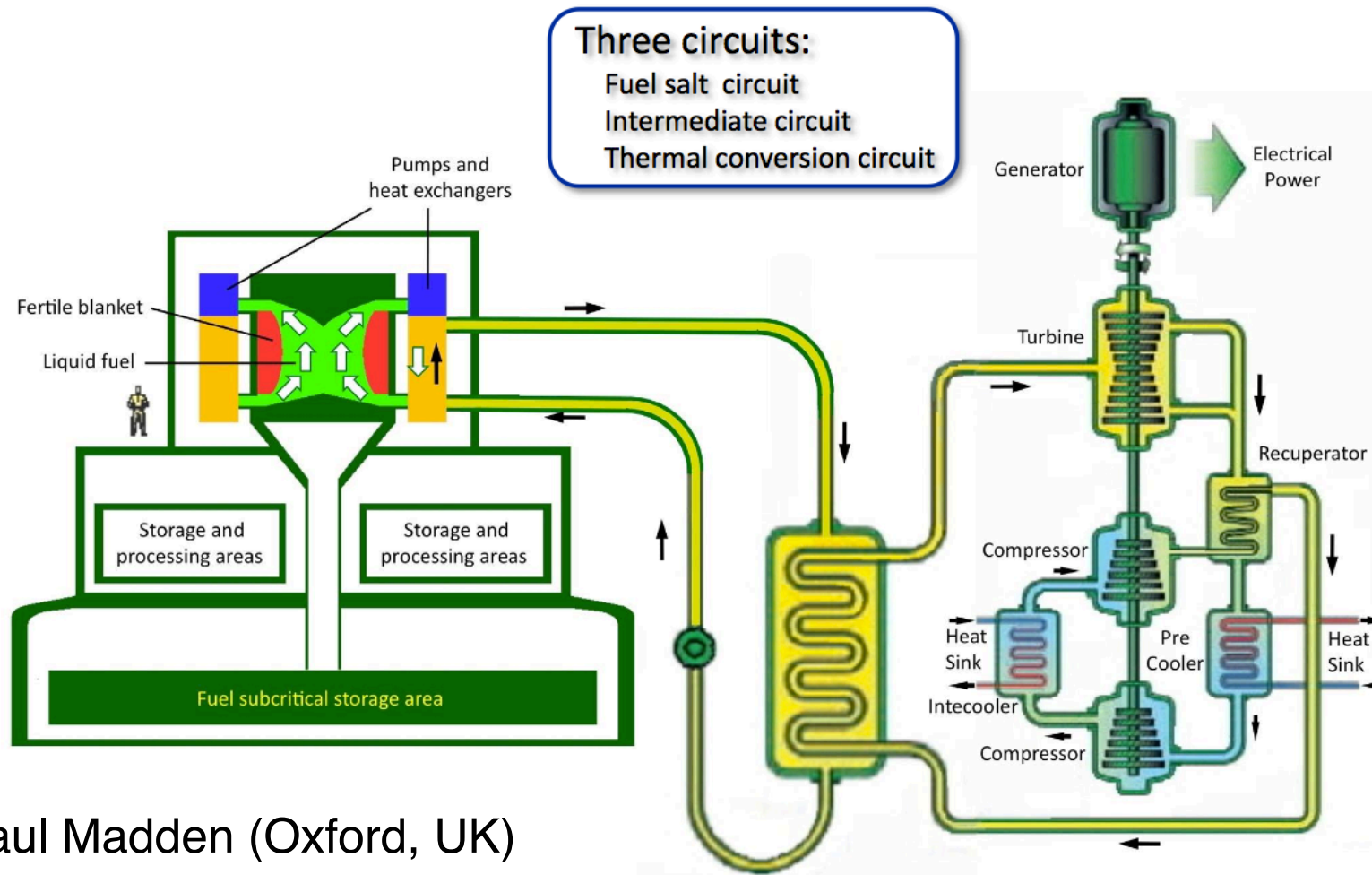




Molten salt critical reactors

- ❑ This is clearly a technology concentrating interest if one can judge by the number of talks related to the subject at this conference (10 talks)
- ❑ This is clearly a line of research where synergy should be improved, as there are a lot of developments to be made to demonstrate the practicality of the scheme.
- ❑ There is a particularly focussed effort in China on MSR (see talk by Xu Hongjie)

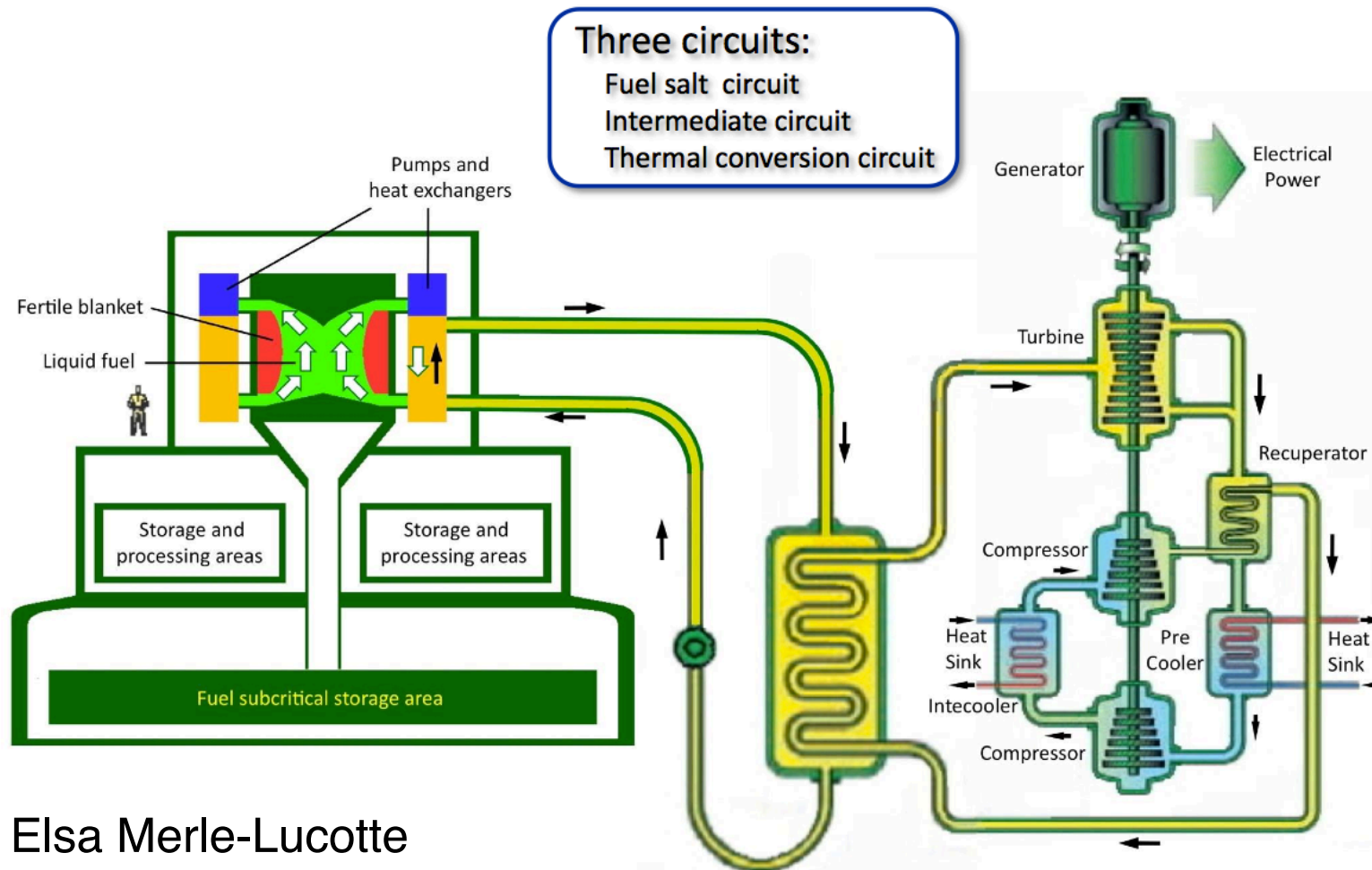
Molten Salt Fast Reactor (MSFR)



Paul Madden (Oxford, UK)

Molten Salt Fast Reactor (MSFR)

It is clear that collaboration has already started, at least at the level of figure sharing ...



Elsa Merle-Lucotte
 (CNRS/IN2P3/LPSC, France)



- ❑ R&D should be extended to other salts in view of transmutation (to work with a fast neutron spectrum).
- ❑ Licensing issues should be addressed from the beginning, as it implies new safety considerations (confinement barriers, chemistry, neutron irradiation, corrosion, etc.).
- ❑ Industry shows interest in MSR.

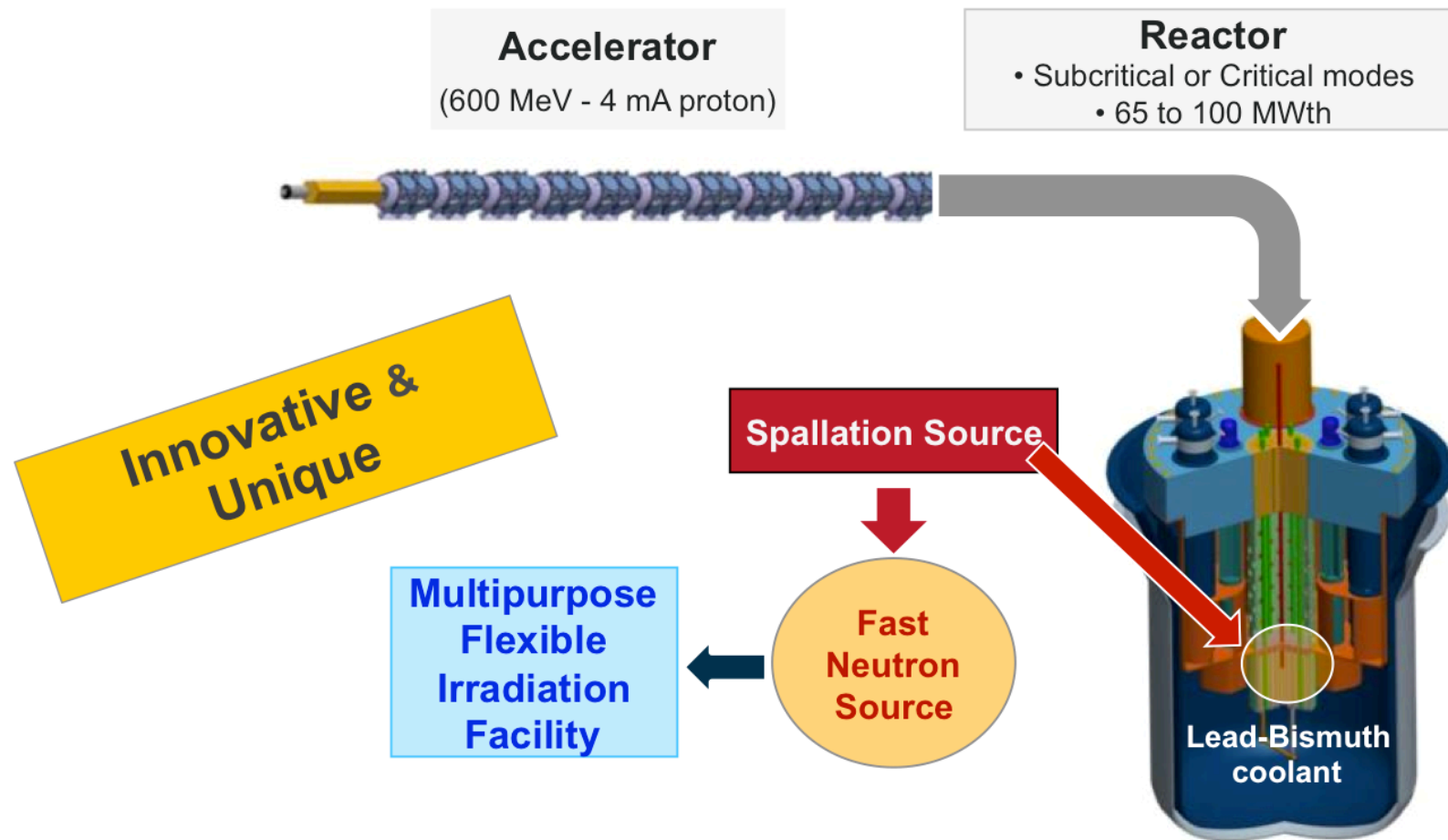


Accelerator Driven Systems

- ❑ Also a lot of interest (16 talks), very advanced conceptual studies (Carlo Rubbia), physics is well understood
- ❑ Status of readiness of technologies
 - Accelerator(s) (cyclotrons, linacs, FFAG)
 - Spallation Targets
 - Core designs
- ❑ Presentation of systems
 - MYRRHA,
 - Troitsk (Russia) & CADS (China) for burning minor actinides, and a discussion in India to use ADS to simplify the present thorium utilization scheme
- ❑ Concrete tests
 - PSI beam
 - MW Spallation target (MEGAPIE, SINQ (Swiss Spallation Neutron Source), SNS (US Spallation Neutron Source), etc.)
 - Reactivity measurement by beam pulses (Cheol Ho Pyeon)
 - Corrosion, material compatibility
- ❑ Several types of ADS concepts were presented

Hamid Aït Abderrahim

MYRRHA - Accelerator Driven System

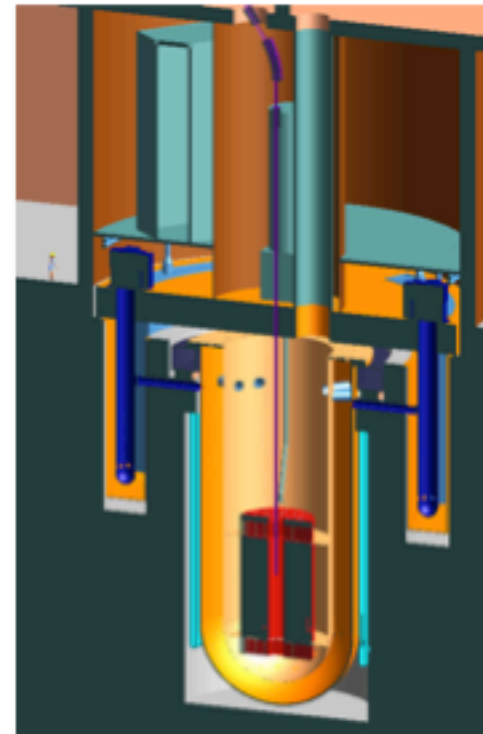


EA Feasibility Study: Aker ASA and Aker Solutions ASA (2010)

- 1500MW_{Th}/600MW_e
- Sub-critical core
- Thorium oxide fuel
- Accelerator driven via central beam tube
- Molten lead coolant
- Coolant temp 400-540°C
- 2 Axial flow pumps
- 4 Annular heat exchangers
- Direct lead/water heat exchange
- *It may be modified to a Minor Actinide burner (ADS)*

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 AkerSolutions

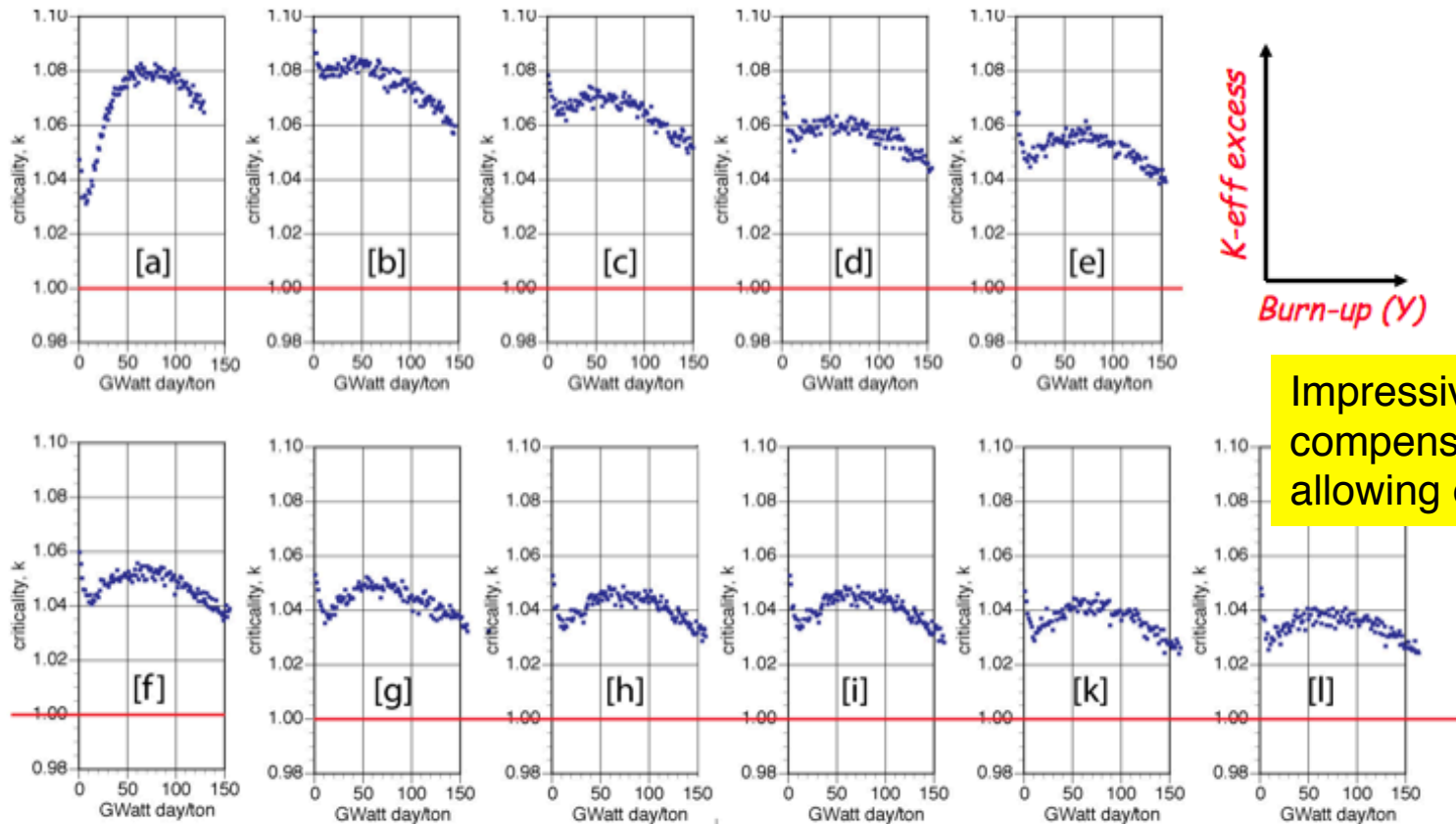


A Thorium fuelled reactor for power generation

Carlo Rubbia

Slide# : 23

From Pu to asymptotic Th-U mixture

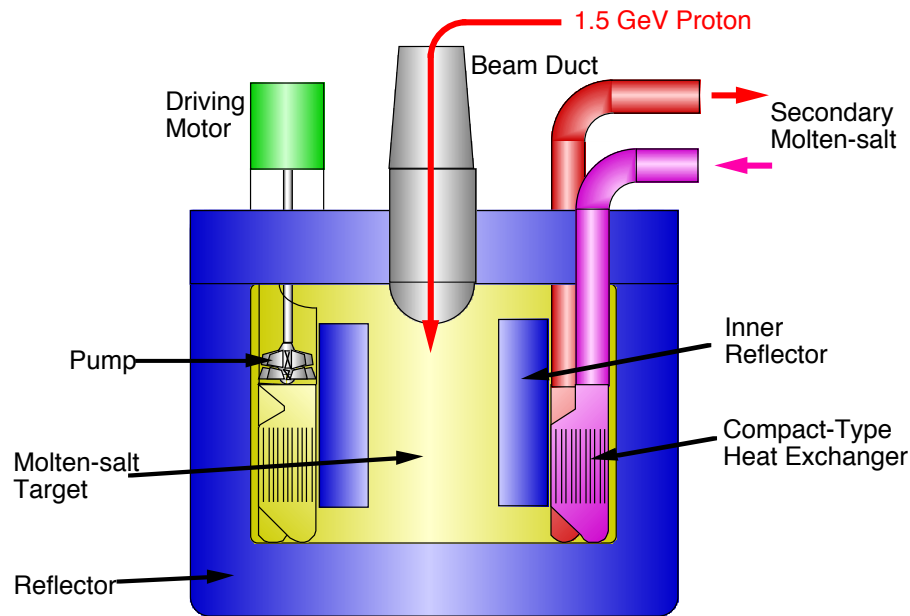


Impressive demonstration of compensation mechanism allowing extended burnup

The appropriate $k < 1$ value is adjusted with the help of control bars
 CERN_Oct_2013 Slide# : 31

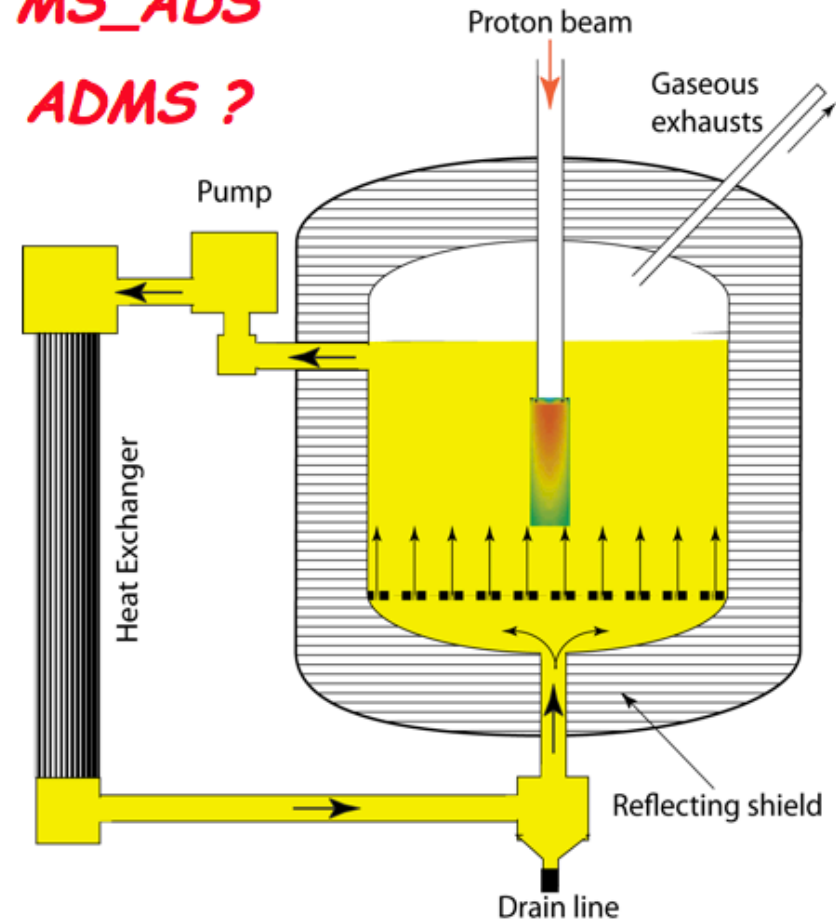
Carlo Rubbia

- Several Molten Salt ADS were discussed: Carlo Rubbia, Toshinobu Sasa and Laszlo Sajo-Bohus.



Toshinobu Sasa

MS_ADS
ADMS ?



Carlo Rubbia




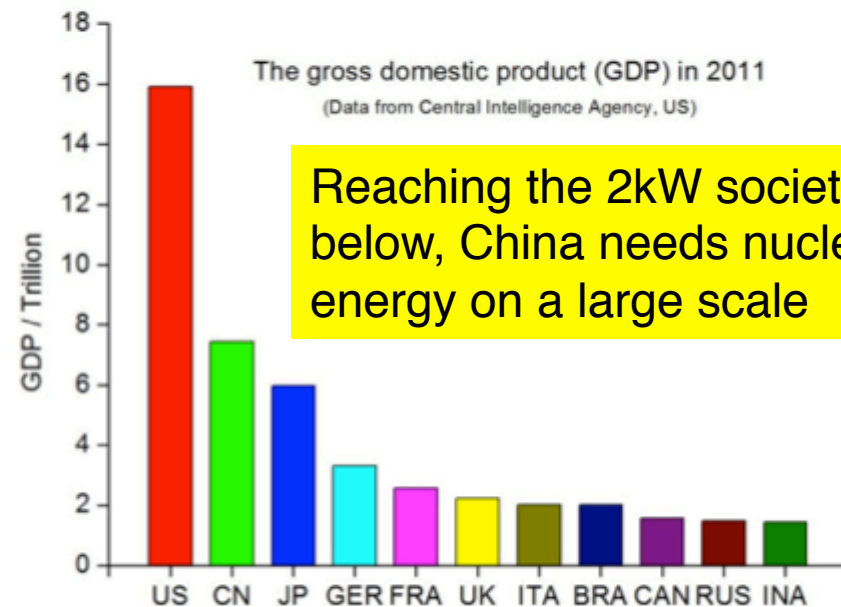
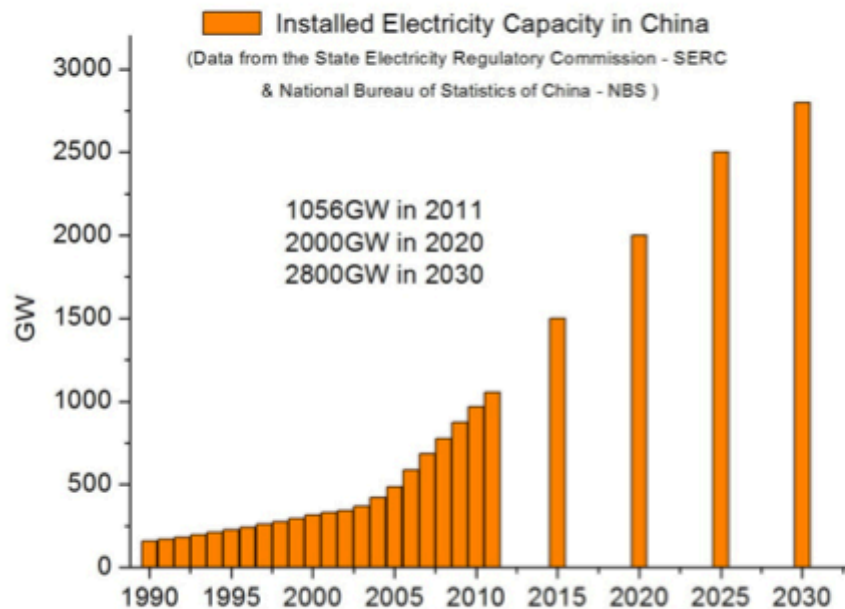
- ❑ As for MSR developments, the need for a coordinated effort on ADS is clearly needed, in order to go from physics to technological solutions.
- ❑ The main issue for ADS today is the absence of a demonstrator. This is more a political issue (funding) than a scientific one.
- ❑ **The technology for a demonstrator is ready.**



- ❑ Two sessions were devoted to the thorium fuel cycle, including:
 - ☛ Commercial development of thorium fuel, licensing (Norway)
 - ☛ Complexity of chemistry, but well advanced
 - ☛ Back end of the fuel cycle (Pyro and aqueous reprocessing) was also discussed

Xu Hongjie **China's Energy Challenge**

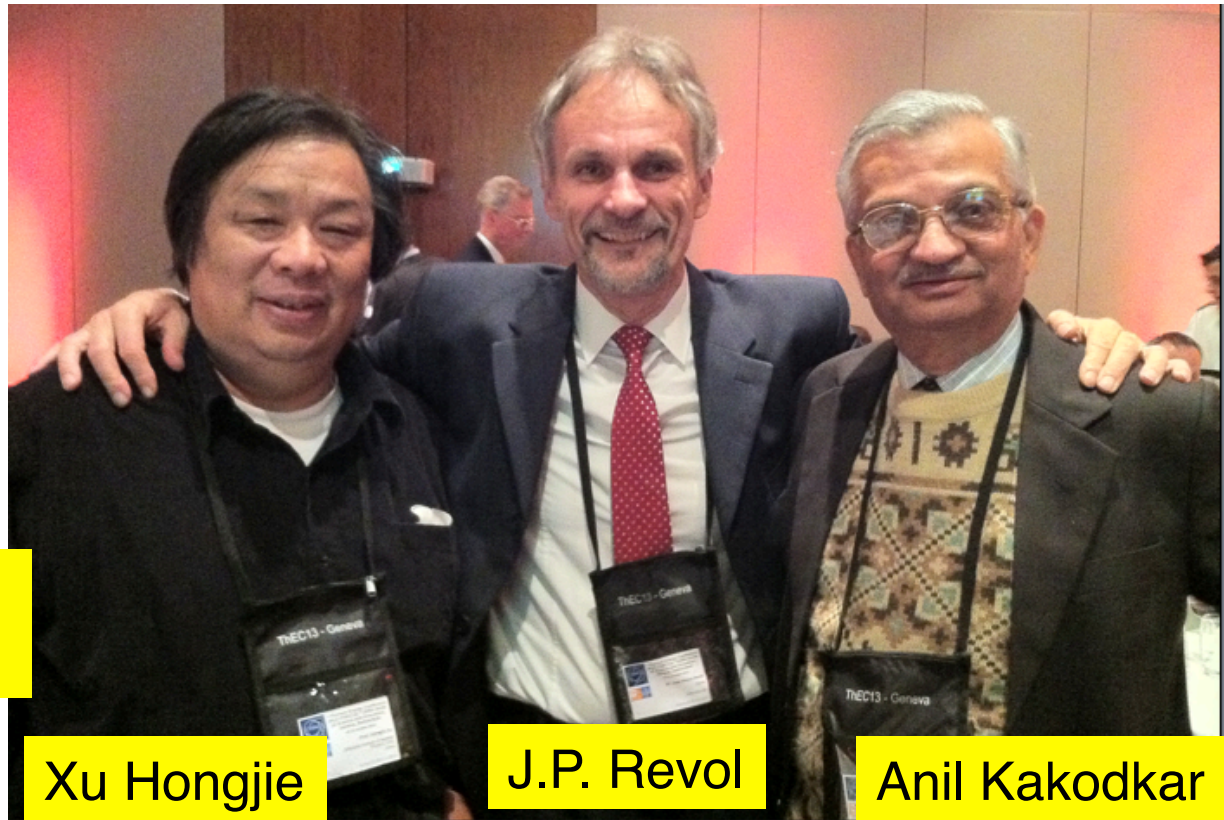
 Analysis and forecast on national electric power in China: In 2030, the electricity demand of per person will be about 2KW, total generation capacity will reach about 3000GW, the MW - level power stations will need 3000.





- ❑ Impressive amount of work presented on many aspects of thorium technologies
- ❑ A lot of activities worldwide happening in parallel, **international cooperation is a necessity** – energy is a global issue
- ❑ Is it possible to converge on concrete projects, involving partnership within international collaborations? The CERN model should work for:
 - An MSR demonstrator
 - An ADS demonstrator (iThEC as a catalyst)
 - Specific common developments (fuel cycle for MSR and ADS?).
See round table discussion comments by Anil Kakodkar
- ❑ One cannot predict the future, therefore, **all R&D on thorium are important and should be encouraged**

- ❑ On behalf of iThEC and ThEC13 Organization Committee, I would like to thank you all for having contributed in such a professional way to this conference, either by making presentations, or by participating in discussions, or simply by your presence here.
- ❑ **iThEC will organize another conference on thorium in Geneva in 2015**
- ❑ The goal of iThEC is to promote international cooperation on thorium R&D



Thank You!

Xu Hongjie

J.P. Revol

Anil Kakodkar