POLITECNICO DI MILANO

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ATOMEXPO 2015

Round Table:

«Methods and mechanisms of international cooperation to support education&research for sustainable nuclear power development»

ROSATOM





International cooperation towards development of SMR technology
The experience of Politecnico di Milano

prof. Marco E. Ricotti
Politecnico di Milano, Rector's Delegate for Research, Department of Energy Deputy Head
CeSNEF-Nuclear Engineering Division, Nuclear Reactors Group

Moscow, 2015 June 1st

Key questions on the table

1. Why we need (international) cooperation on R&D and E&T?

2. Which mechanisms of cooperation are suitable?

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- **effective** nuclear R&D and innovation are complex and expensive: we need to **share ideas** and share **costs**
- development of new solutions and **time-to-market** constraint: we need to **share facilities** and **expertise** (e.g. to support licensing and training)
- nuclear sector in the wake of a generational change process: we need (soon) a **new generation** of nuclear experts
- nuclear sector in the development phase: we need a new workforce (at industrial and institutional level, esp. in "**newcomer**" countries)
- nuclear is becoming a real **international** market: we need to prepare experts on different nuclear technologies (international E&T)

2. Which mechanisms of cooperation are suitable?

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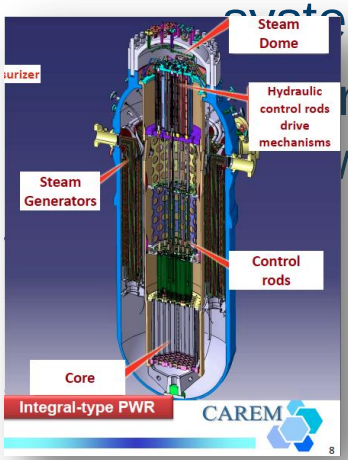
2. Which mechanisms of cooperation are suitable?

- objectve of this presentation: to share some **ideas**

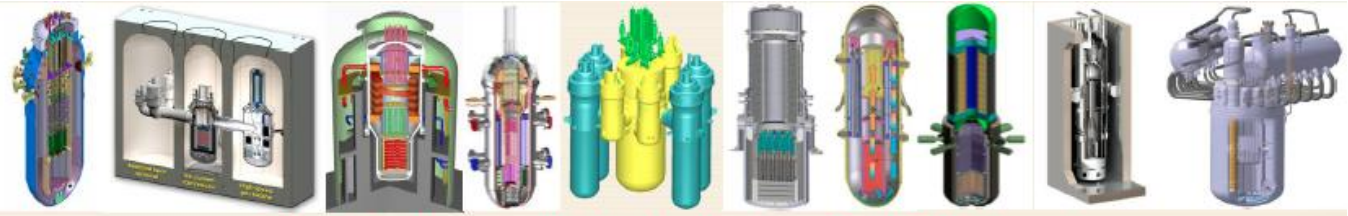
International R&D cooperation on new nuclear technology deployment: the SMR case

- **Why Small Modular Reactors (SMRs, 30 - 300 MWe)?**
  - **reduced:** size, costs, complexity, construction time
  - **less financial risk** (investment affordability, cost increase due to delays)
  - modularity, shop construction: demand , **quality** control
  - technology innovation: enhanced safety (e.g. **passive safety** systems)
  - **markets**: district heating, desa… plir… wa…



- Since 2005, several actions at **IAEA** level, to support SMR understanding & knowledge sha… and to foste… collaboration

International R&D cooperation on new nuclear technology deployment: the SMR case

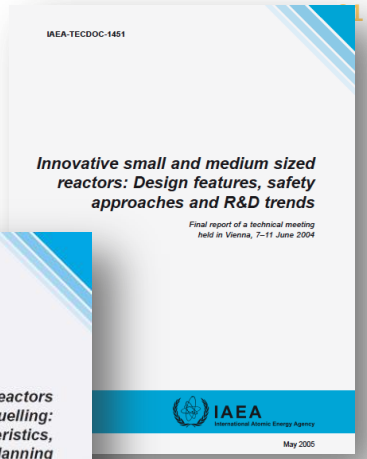


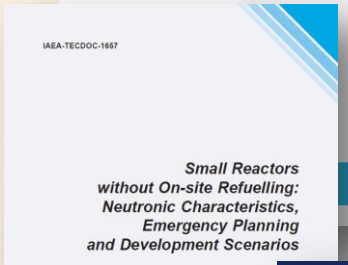
CM on Development of Technology Roadmap for SMR Deployments,
Politecnico di Milano, ITALY, 14 – 16 April 2015

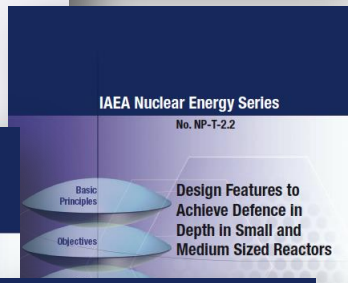
Status of IAEA Programme on SMRs
&
Update on Global SMR Design and Technology Development for Near-Term Deployments

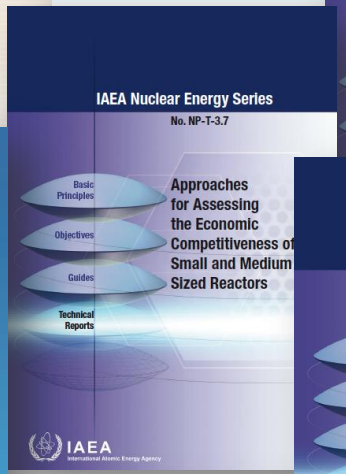
M. Hadid Subki
Nuclear Power Technology Development Section (NPTDS)
Division of Nuclear Power, Department of Nuclear Energy

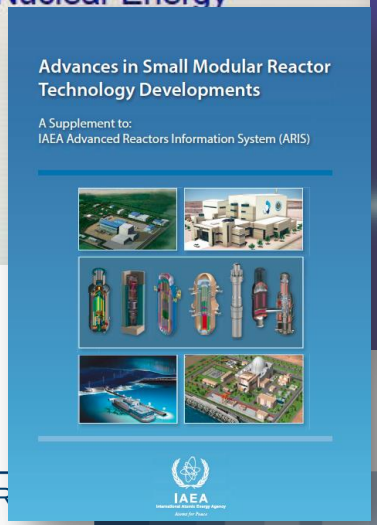
IAEA
International Atomic Energy Agency

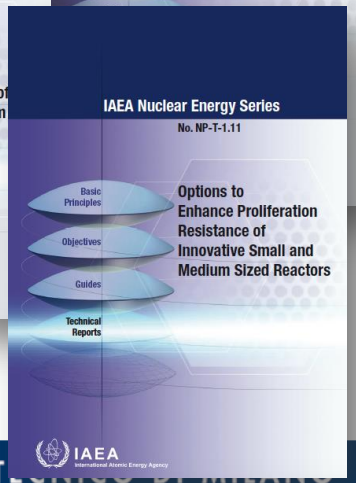




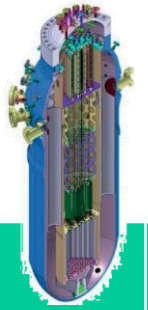


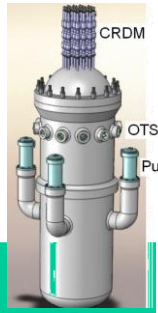


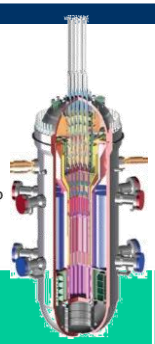


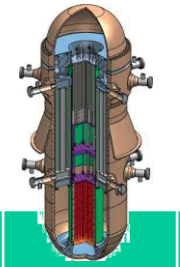
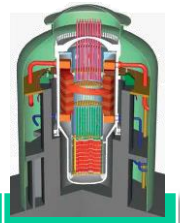


Innovative SMR technology: iPWR (almost) full integration





Integration of components	ABV-6M	CAREM	NuScale	ACP 100	SMART	mPower	WEC	IRIS	IMR
Pressurizer	X	X	X	X	X	X	X	X	X
Steam Generators	X	X	X	X	X	X	almost	X	X
Pumps	NC	NC	NC					X	NC
CRDMs	X	X				X	X	X	
SIZE MWth **MWe**	38 **6**	100 **25**	160 **45**	310 **100**	330 **100**	530 **180**	800 **225**	1000 **335**	1000 **350**

SMR – iPWRs
R&D needs – testing

- **Fuel, Integrated components**: pumps, steam generators, CRDMs, pressurizer
- **Safety systems**: (usually) passive, natural circulation, two-phase flow systems

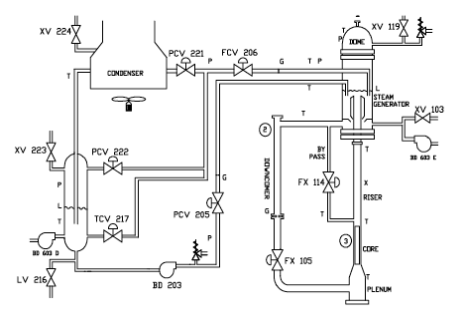
Separate Effect Test (SET)

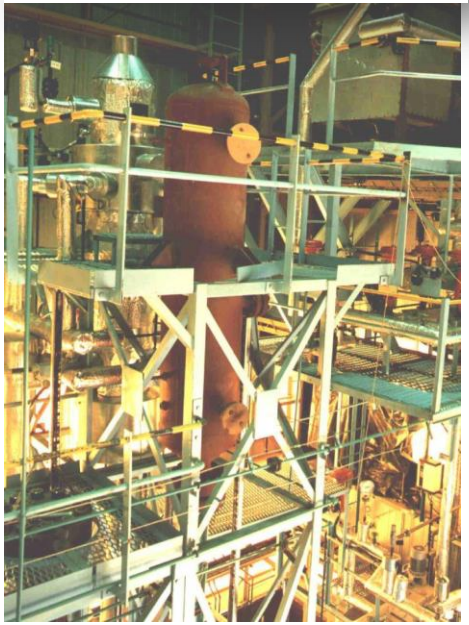
- **Integral layout**: integration of components, safety systems, (containment)

Integral Effect Test (IET)

Main goals: i) to test safety effectiveness, performance
ii) **to validate codes & models**

SMR – iPWRs: Integral Effect Tests (IET) facilities





CAREM25: CAPCN, TH dynamics in conditions similar to CAREM-25 operational states

(1:1 in height and P, T; 1:335 in power)

NuScale: NuScale Integral System Test (NIST) facility

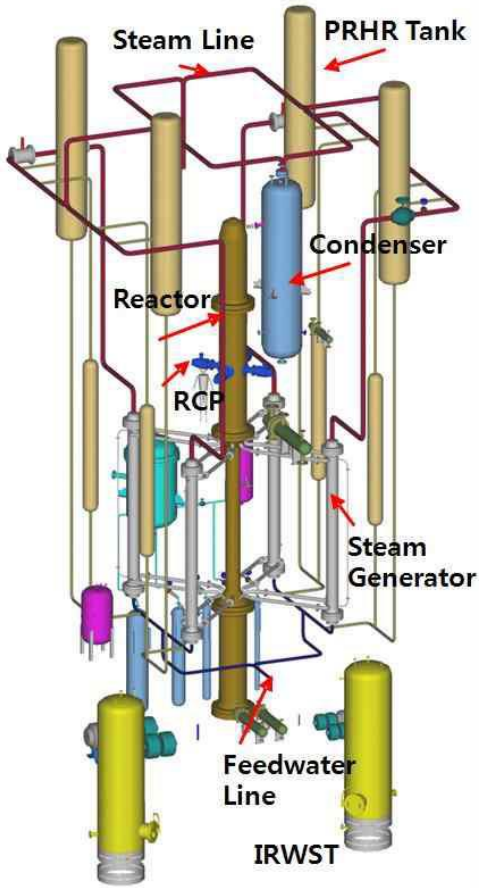
(1:1 in P, T; 1:3 in height, 1:253 in volume, 1:1 in time)

mPower: Integrated Systems Test (IST) facility

(1:1 in height and P, T; 1:375 in power)

ACP100: Core Cooling and REsidual heat removal System Test facility (CREST)

(1:1 in height and P, T; 1:37 in volume; 1:100 in power)

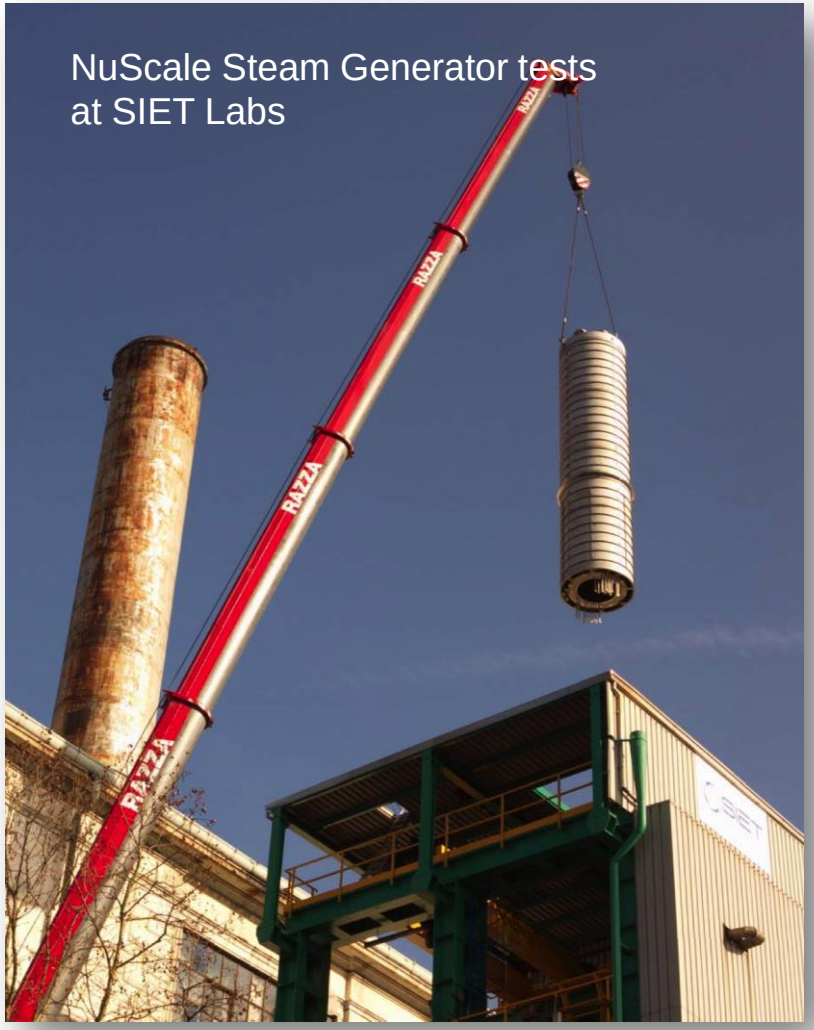


SMART: SMART-ITL large scale integral test facility (1:1 in height, 1:1 in P, T; 1:49 in power)

International collaboration for an "Open" iPWR facility?

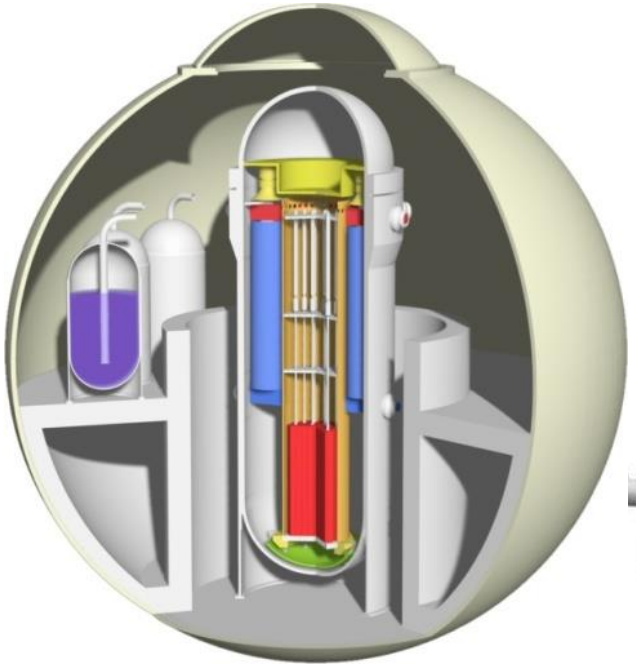
- Sensible level of **similarities** among SMR-iPWR concepts
- IET facilities usually adopted for licensing purposes (**proprietary**, not accessible now)
- "**Open**" IET facility for iPWRs at SIET labs: SPES3

(SIET labs are performing SG tests for NuScale licensing)



NuScale Steam Generator tests at SIET Labs

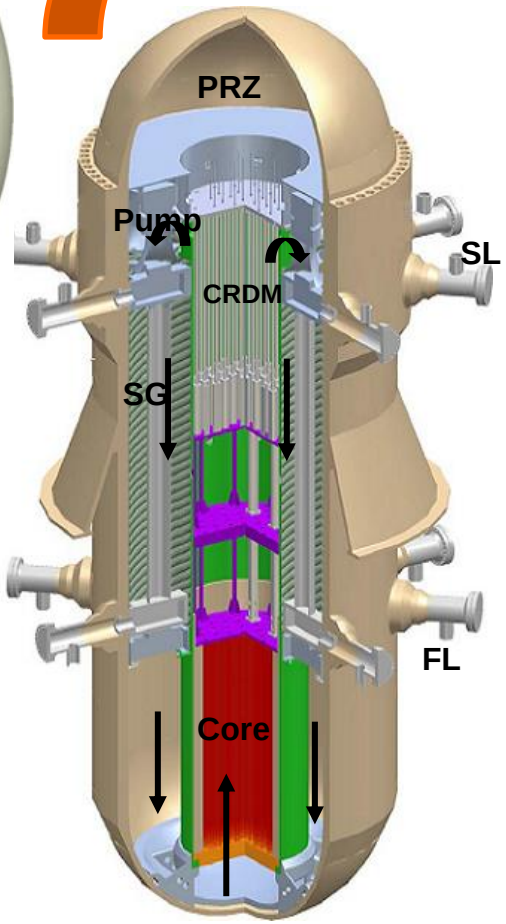
IRIS – SPES3: a possible IET case



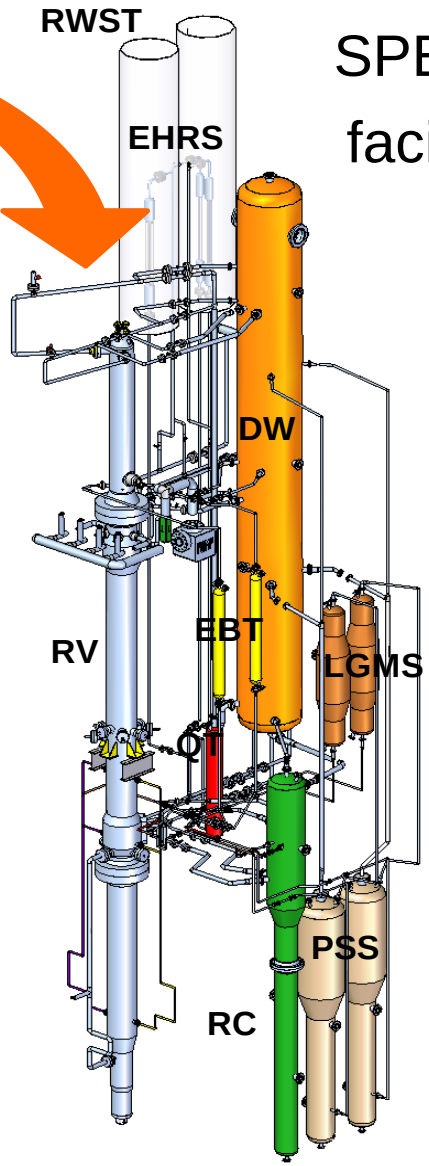
IRIS spherical Containment

+

IRIS integral RPV



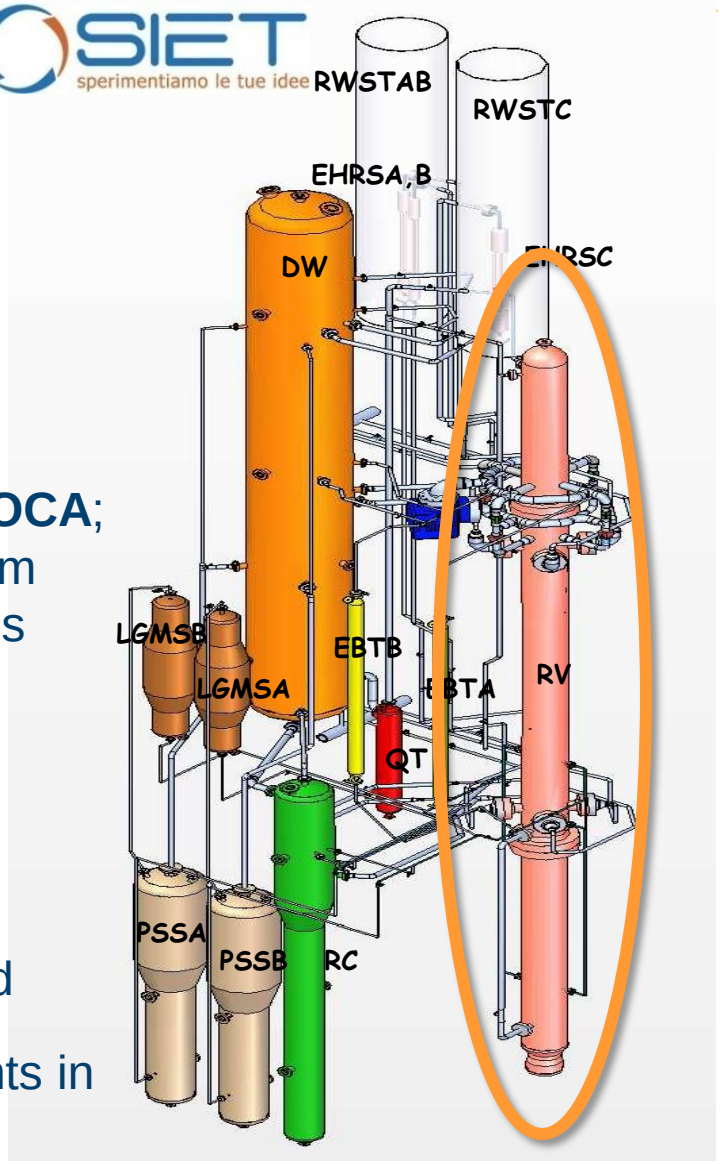
SPES3 facility



SPES3: large scale integral test facility for iPWRs

iPWR (IRIS-based) Integral, Large Scale Test Facility

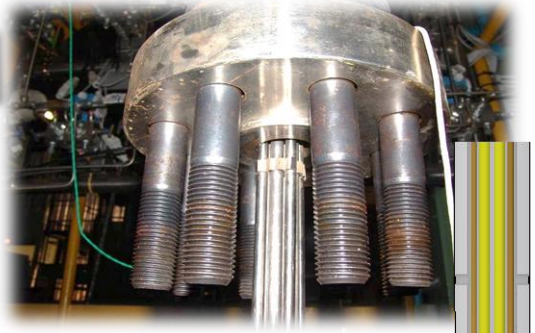
- **Full scale** (1:1) in height, temperature, pressure
- Scaled **1:100 in power** and volume
- > **700 measurement points**, new instrumentation developed
- thermal-hydraulic phenomena during **SBLOCA**; **dynamic coupling** between primary system and containment system; EHRS capabilities

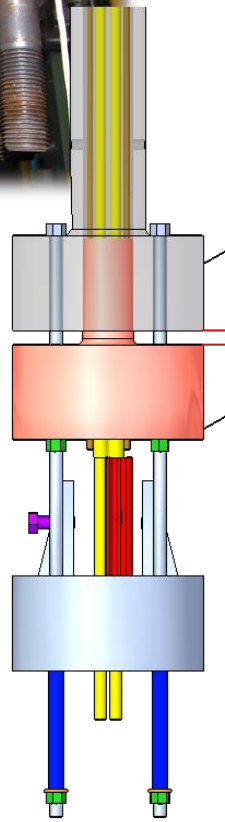


- ✓ scaling phase and design phase completed
- ✓ site preparation and control room completed
- ✓ construction phase started: main components in place (except RPV simulator)

SPES3: area preparation for components installation + heating rods testing (fuel)

SPES3 side view





SPES3: drywell and EHRS pools

SPES3: iPWR Integral Open Facility

>10M€ investment (Italian Min.Econ.Dev.), >60% completed

Main goals:

- Access to experimental data by different international stakeholders (safety authorities, technology developers, newcomer countries, R&D organisations)
  - Computer codes & models validation (safety), e.g. ISP, database
  - Integrated system performance
  - Safety features demonstration
  - Control and protection systems verification
- iPWR **knowledge development & share**
- **Educational & Training purposes**

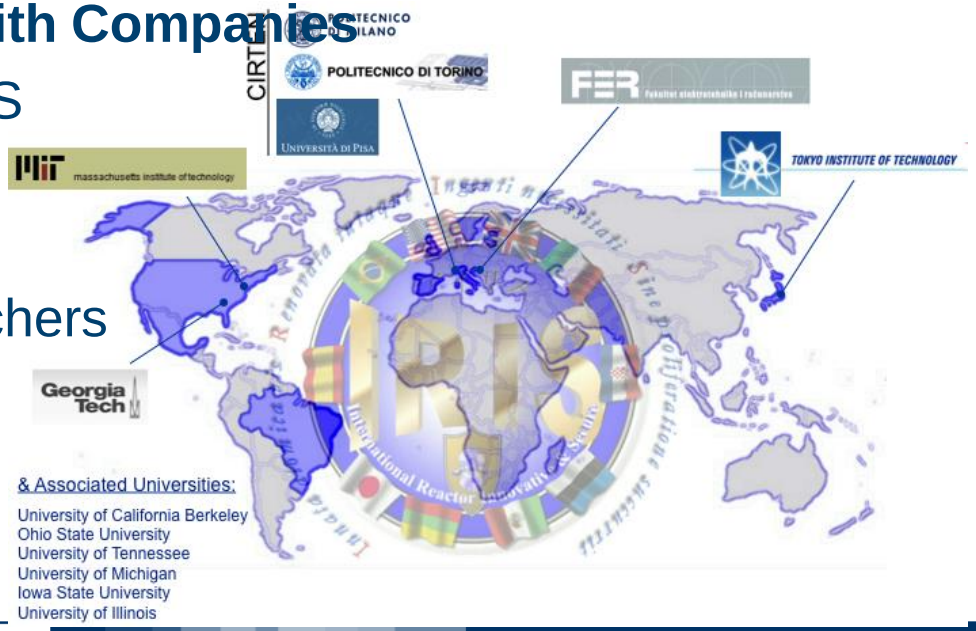
How to proceed?

- Expression of Interest from potential partners
- International Advisory Board
- Cost-sharing

Impact of Universities involvement in R&D in international environment

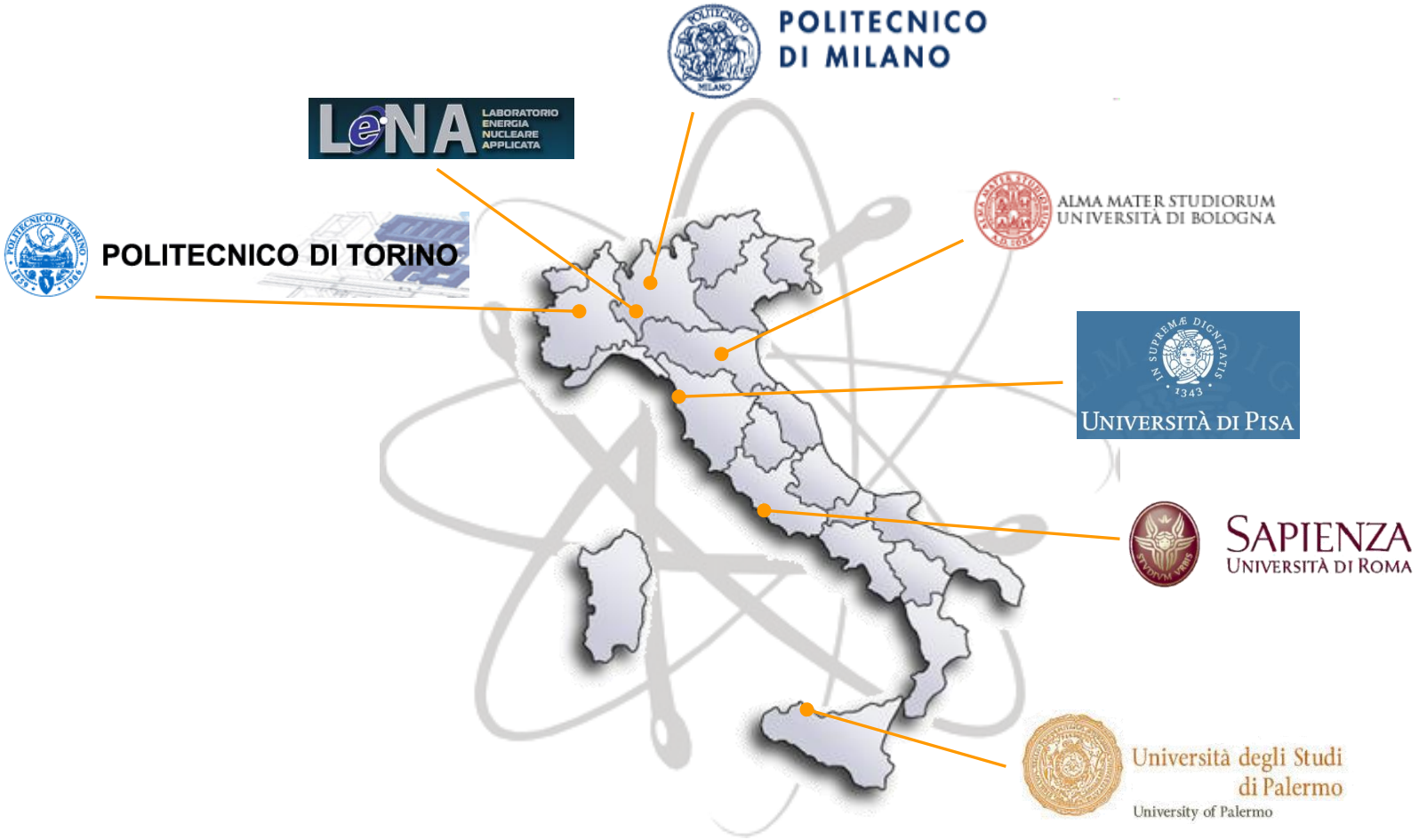
The IRIS case (2002-2007):

- **Students' collaboration**
  - within University labs and/or through Company internships
  - thesis work (3-to-12 months)
  - PhD program (6 months-3 years)
  - post-graduation period (6 month-1 year)
- Formal agreements (students exchange) among U-IRIS; formal/informal agreements **with Companies**
- **>130 students** worked on IRIS
- **400 papers** co-authored by students, professors, experts
- Professors/permanent researchers involved: >30



Nuclear Education & Training: open to international collaboration

The italian Nuclear Universities case: since 1994, **CIRTEN** consortium (ENEN partner)



Nuclear Education & Training: open to international collaboration

Politecnico di Milano (Engineering, Architecture, Design, since 1863):

- the leading technology university in Italy, among top 5 in EU (QS Employer ranking), 31st in the World in Engineering & Technology (QS ranking 2014)
- Nuclear Engineering education since 1956 (first MSc in NE and first nuclear research reactor in Italy)

Today:

- Still first MSc in NE in Italy, one of the largest in EU

How to be prepared for international collaboration?

- fully **English taught MSc + PhD + professional** edu programmes in Nuclear Engineering
- Brand-**new experimental labs**
- Access to **external facilities**
- **Partnership** with selected Universities and Companies

New experimental labs, opening ceremony March 6, 2015

- New, advanced experimental labs for research, training & education
- Chemical-energetic and Nuclear engineering labs
- 3 stories building, more than 6 000 m^2, more than 15M€ investment (POLIMI)

POLIMI new Nuclear Engineering experimental labs

- Radiochemistry
- Radioprotection
- Nuclear instrum. & measurements
- Nuclear electronics
- Calibration and testing
- Health physics
- Contaminants migrati
- Nuclear safeguards
- Material science & nanotechnology

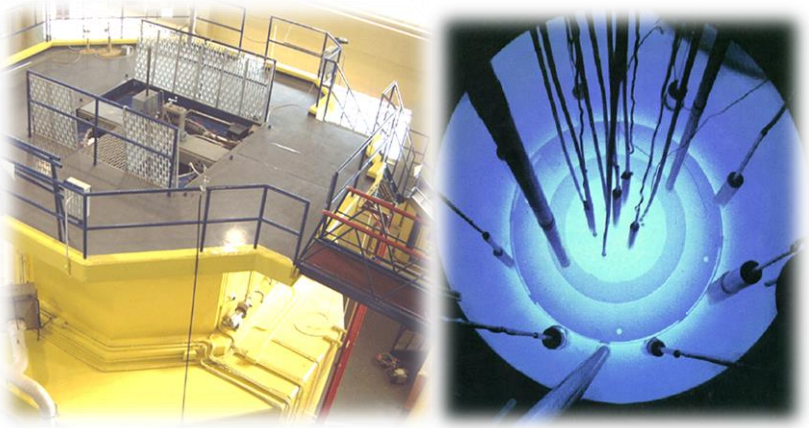
- The facility includes also a **bunker for irradiation**

Open access for companies, universities and research centers, for E&T and R&D

Full access to external laboratories and facilities

- **TRIGA research reactor (at Pavia)**

Training and R&D activities



TRIGA MarkII (250 kW)

- **SIET labs (at Piacenza)**

world-class, large scale exp. labs for safety systems and thermalhydraulic tests, for nuclear reactor components and systems

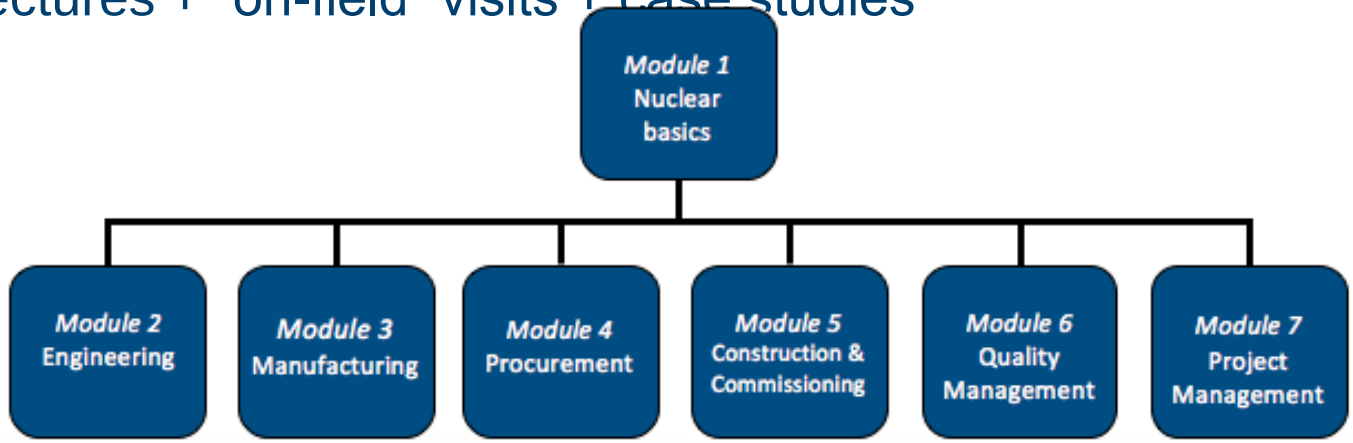
- **CNAO (at Pavia)**

Sincrotron for adrontherapy, for medical applications of radiation (few in the world)

Edu & Training for non-nuclear executives and professionals

"**Executive Master in Nuclear Plant Construction Management**"

- Specialisation course, 1 year
- designed with companies (ENEL, AREVA, EPCs, etc.) for companies
- lectures + "on-field" visits + case studies



Thank you for your attention

MILANO 2015

SPES3 simulation capabilities of advanced SMR

Common set of design principles with iPWRs:

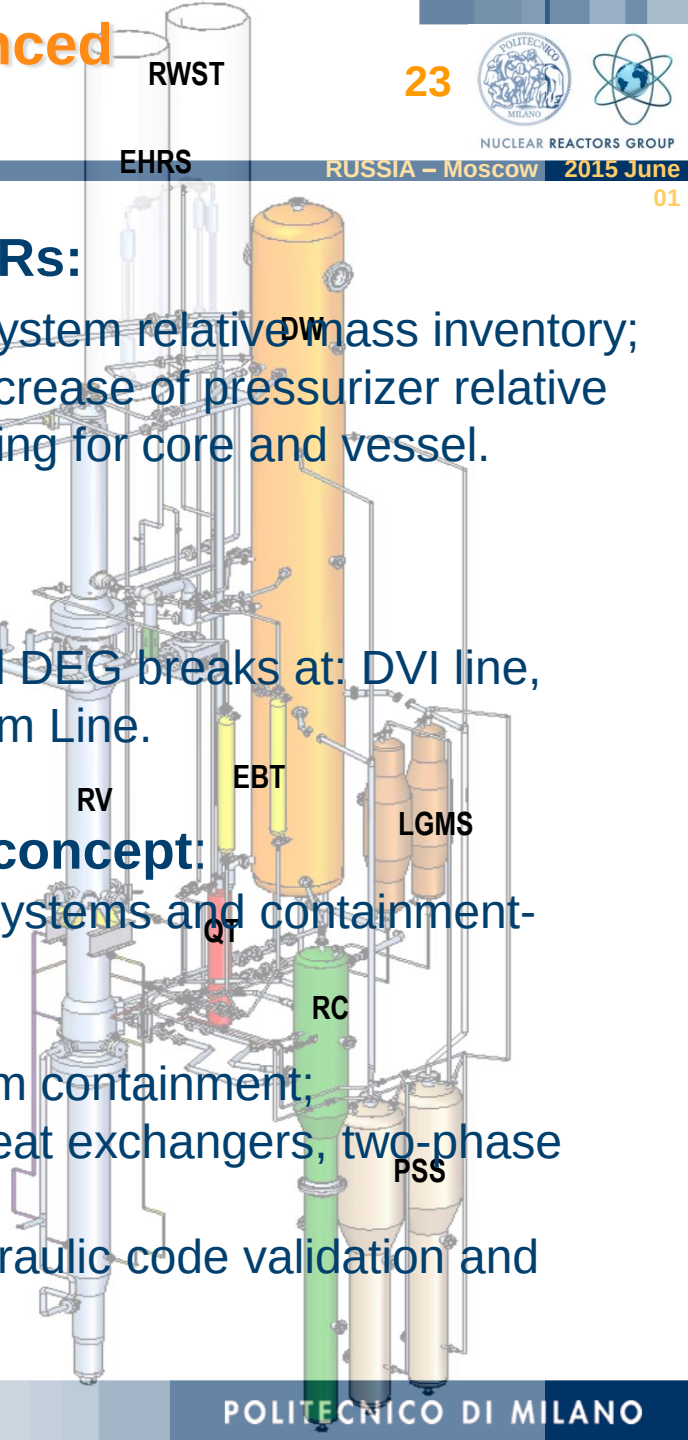
- integral vessel layout; increase of primary system relative mass inventory; passive safety systems for heat removal; increase of pressurizer relative volume; increase of natural convection cooling for core and vessel.

Transient simulation:

- Integral tests of DBA, BDBA, SBO; split and DEG breaks at: DVI line, EBT top line, ADS line, Feed Line and Steam Line.

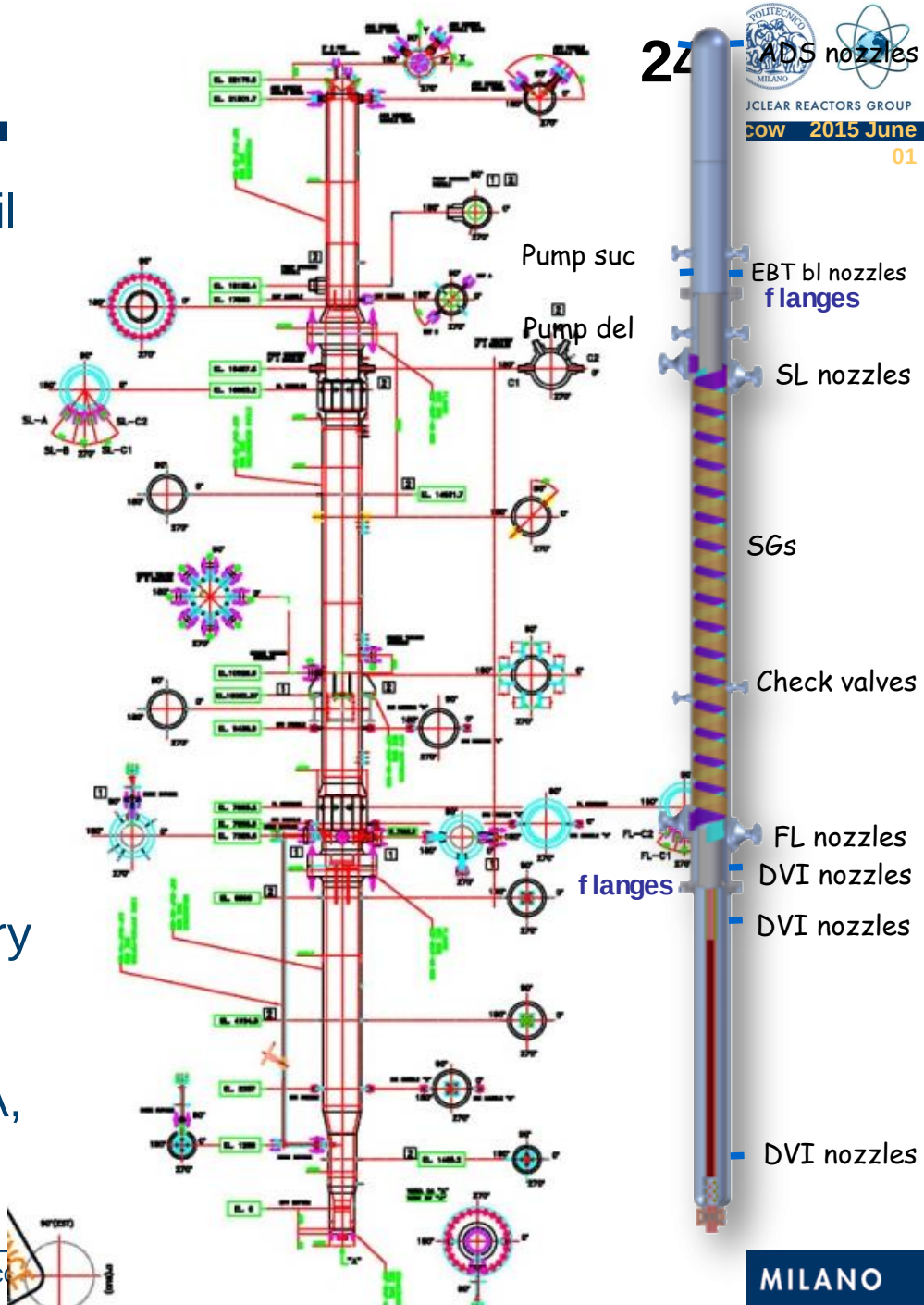
SPES-3 may offer critical insight on iPWR concept:

- investigation of behavior of passive safety systems and containment-vessel coupling;
- safety systems intervention sequence;
- heat removal capabilities from RPV and from containment;
- SETs on SGs and EHRS, pumps, in pool-heat exchangers, two-phase flow instrumentation;
- qualified data for best-estimate thermal-hydraulic code validation and benchmark.



SPES-3: integral reactor simulator

- 3 forged pieces + 4 helical coil SG simulators
- Detailed design provided by italian manufacturing enterprises
- Co-funding (50%) by italian companies
- Estimated cost: 5 M€
- Co-funding: discussions with Regional Government, Ministry of Economic Development
- Partnership: Industries, ENEA, SIET labs, POLIMI



How to proceed?

- Secure funding to conclude construction phase

  ➔Declaration / Expression of Interest letters about the use of the Open Facility (e.g. from international org., gov.ntl org., R&D centers, EU-Euratom, etc.)

- **Set up of an International Advisory Panel, to support/advice the Open Facility operational management (SIET)**

  ➔Experts/representatives from countries interested in SMR technology (e.g. IAEA, safety authorities/TSO, R&D centres, etc.)

  ➔Select experimental campaigns of main interest, propose ISP, organise blind benchmarks, iPWR-SMR workshops, etc.

- **Cost-sharing**

  ➔Typical cost of an experimental campaign (order of magnitude): 500K€