

# European materials R&D activities for GenIV and ADS

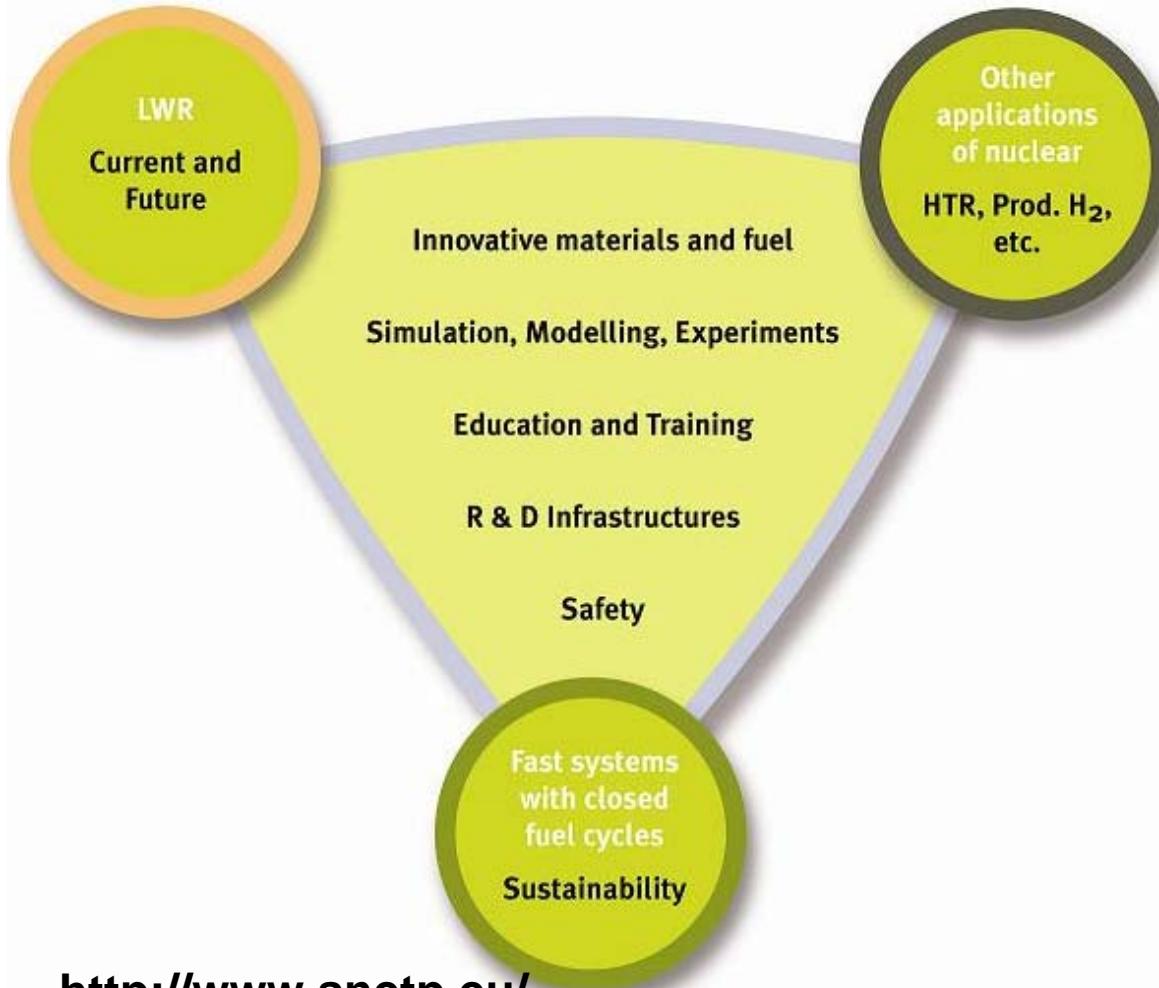
Concetta Fazio



# Outline

- Background: The European Sustainable Nuclear Energy Technology Platform (SNETP)
- Generation IV and ADS in Europe
- LFR and ADS: commonalities and differences
- European initiatives and projects on materials studies
  - EERA Joint Program on Materials for Nuclear
  - EU Project MATTER
  - EU Project GETMAT
- Summary and outlook

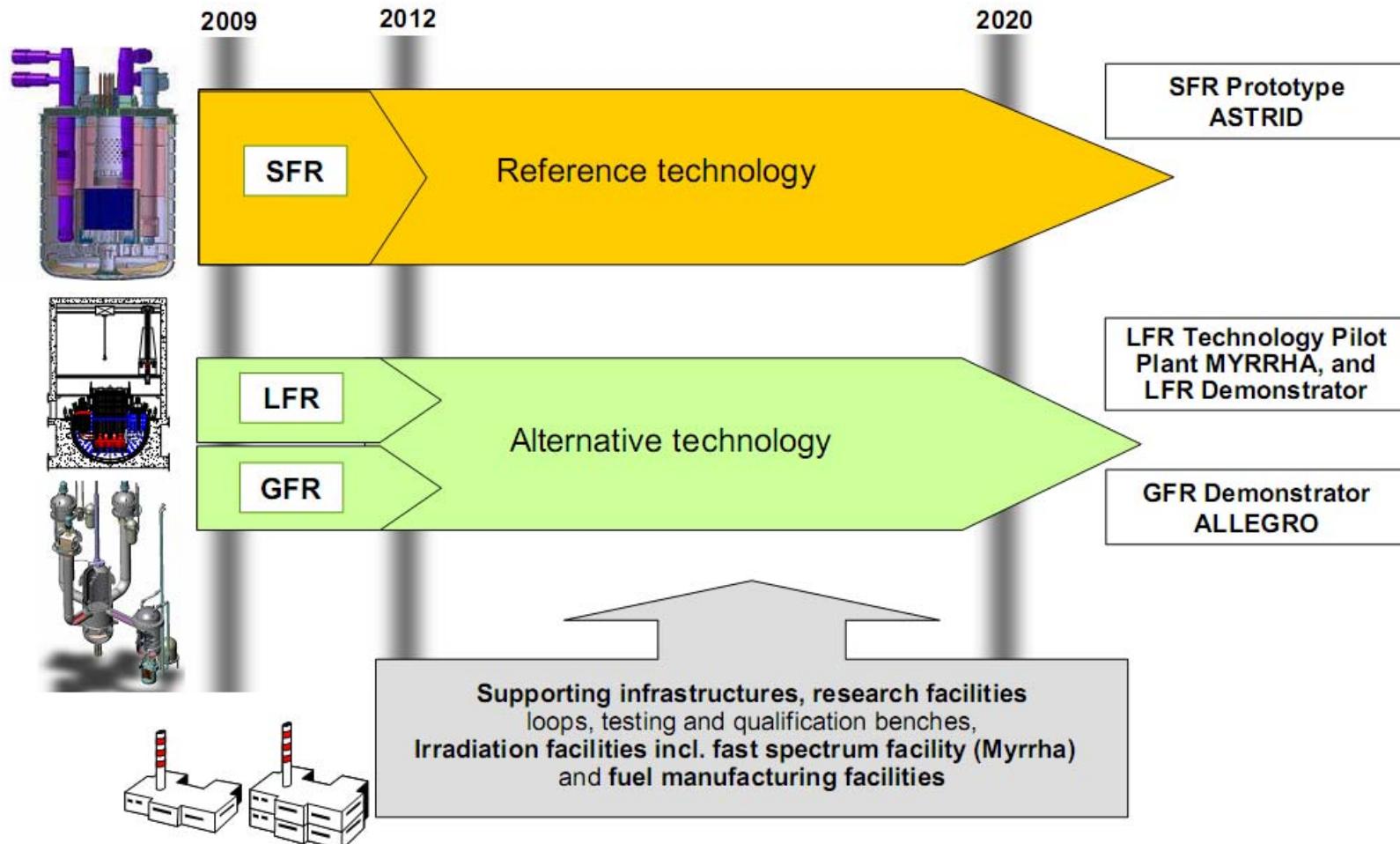
# Background: SNETP



<http://www.snetp.eu/>



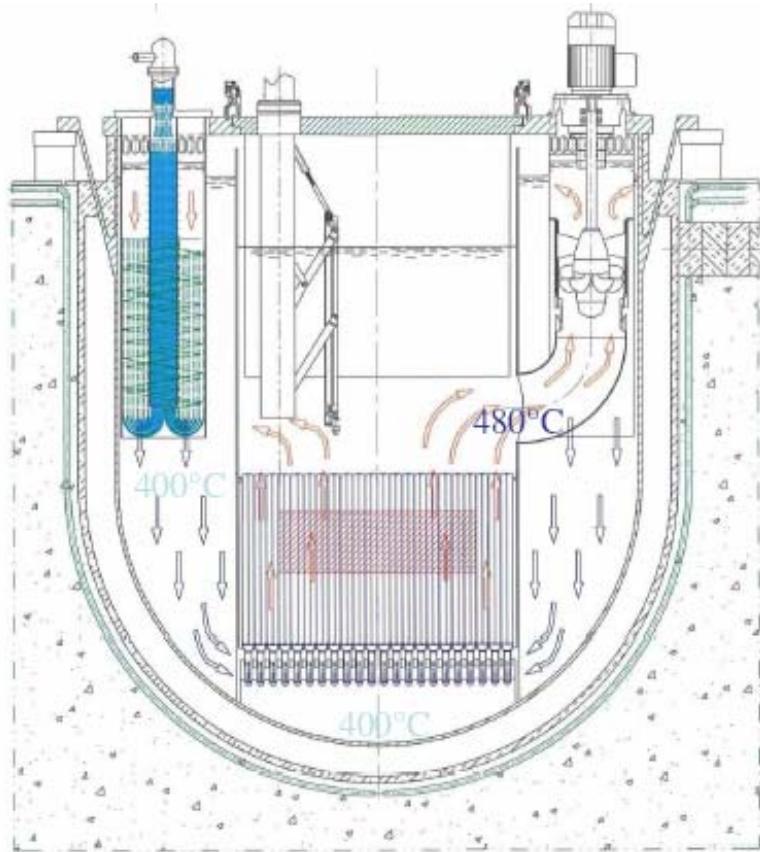
# Generation IV and ADS: EU development



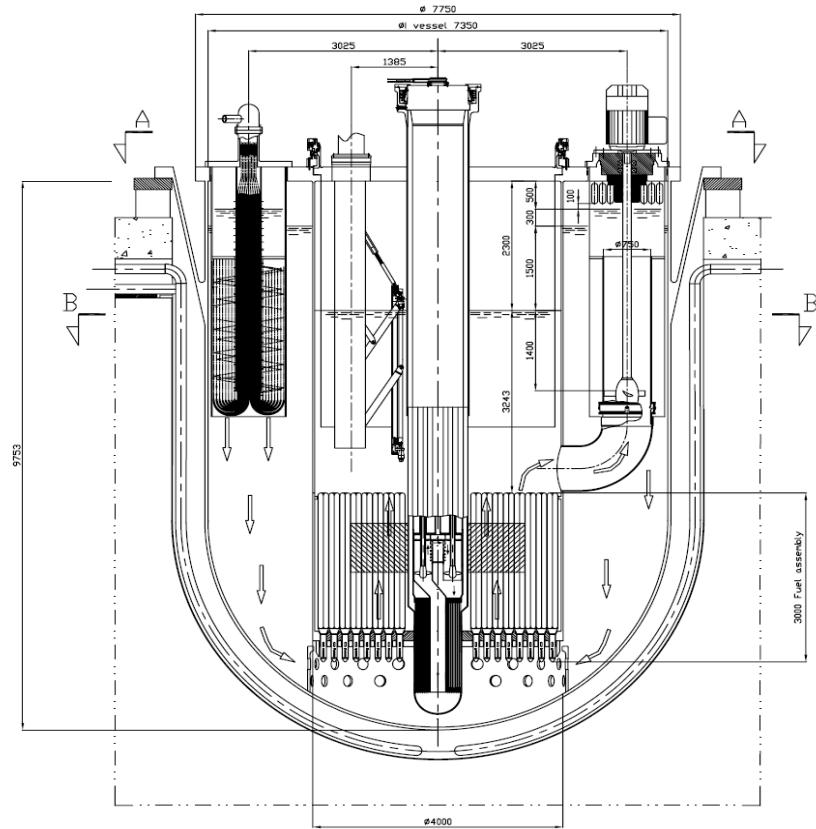
# Generation IV and ADS

Components	GFR	SFR	LFR (Pb)	ADS (LBE)
Fuel Claddings	ODS SiC <sub>fiber</sub> /SiC	ODS 15-15Ti	ODS T91coated 15-15Ti	T91 15-15Ti
Clad peak T and irradiation dose	1200 ° C / ~90 dpa	750 ° C / ~ 200 dpa	550 ° C / ~100 dpa	480 ° C / ~100 dpa
In core Components	9Cr F/M SS316L(N) TiC, NbC	T91 SS316LN 15-15Ti ODS	T91 SS316L	T91 <b>Spallation Target</b> T91
In vessel components	9Cr F/M SS316 Ni Fe/Cr/Ni bases alloys	SS316LN	SS316L	T91
Reactor Vessel	T91	SS316LN	SS316L	SS316L
Steam Generator, heat exchanger systems	SS316L(N) Ni-base alloys	SS316LN T91	T91	T91

# The LFR and ADS: differences and commonalities



LFR: ELSY



ADS: EFIT

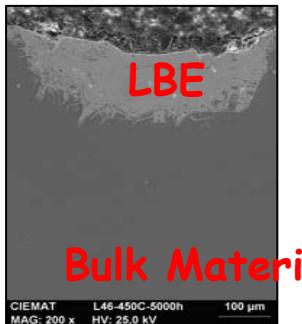
# The LFR and ADS: differences and commonalities

		ADS cooled with LBE	ELSY - Pb
Core components: mechanical stresses: e.g. Hoop stress on cladding	T	300 – 500 ° C	400 – 530 ° C
	dpa	Up to 160	Up to 100
	flow	~ 2m/s	~ 2m/s
Reactor Vessel	T	300 – 400 ° C	400 – 430 ° C
	dpa	< 0.02	< 0.003
	flow	~ 1 m/s	~ 0.1 m/s
	stress	50-150 MPa	80-150 MPa
Heat exchanger	T	300 – 400 ° C	400 – 480 ° C
	dpa	< 0.02	< 0.03
	flow	~ 1 m/s	~ 1 m/s
	stress	~100 MPa	125-190 MPa
Spallation target	T	240 - 340 ° C	-
	dpa/yr	Up to 40	-
	flow	~ 3 m/s	-
	stress	~100 MPa + 40 fatigue cycles/yr	-

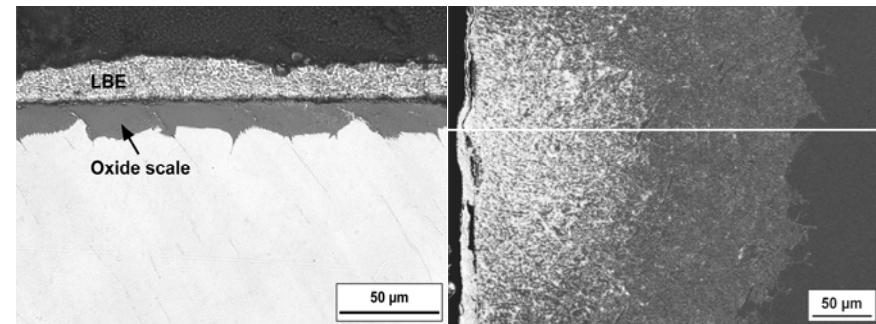
# The LFR and ADS: key materials issues

- Compatibility with Pb and LBE
  - Corrosion / oxidation resistance
  - Environmental assisted degradation of mechanical properties
- Irradiation in a fast neutron and for ADS in a proton/neutron field
  - High dpa (cladding)
  - High H and He (spallation target)
  - coolant / irradiation synergetic effects

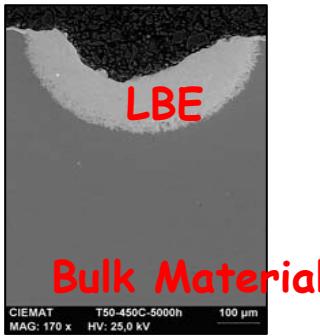
# Corrosion / oxidation resistance



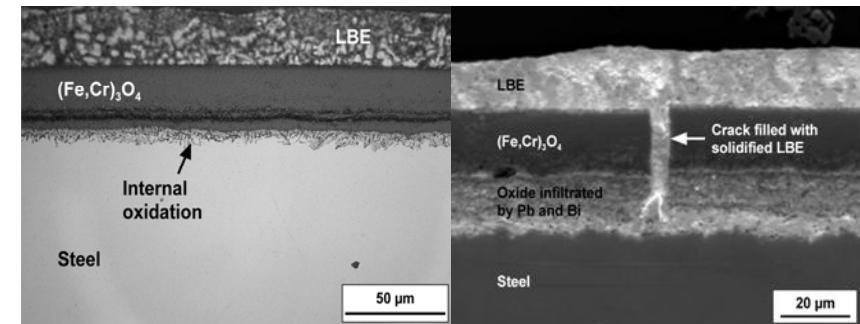
AISI 316L at 450 °C and low oxygen  
Courtesy CIEMAT



AISI 316L at 550 °C and 10-6 wt.% oxygen (left low exposure time; right high exposure time)  
Courtesy KIT

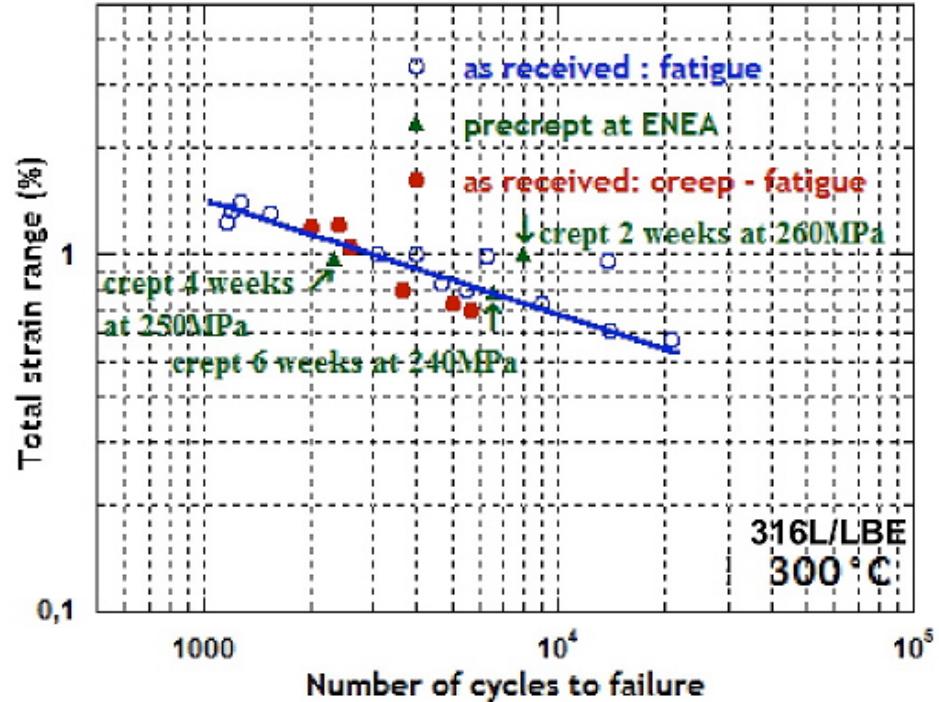
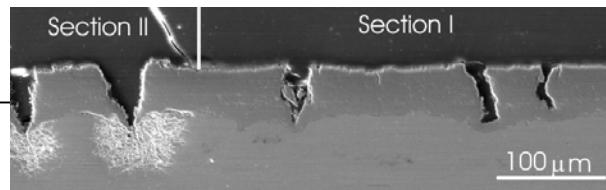


T91 at 450 °C and low oxygen  
Courtesy CIEMAT



T91 at 550 °C and 10-6 wt.% oxygen (left low exposure time; right high exposure time)  
Courtesy KIT

# Mechanical behaviour in HLM



Creep-rupture test T91. Impact on LCF, fracture toughness and tensile have been observed as well

LCF test AISI316L. Tensile and fracture toughness test have shown as well no effect

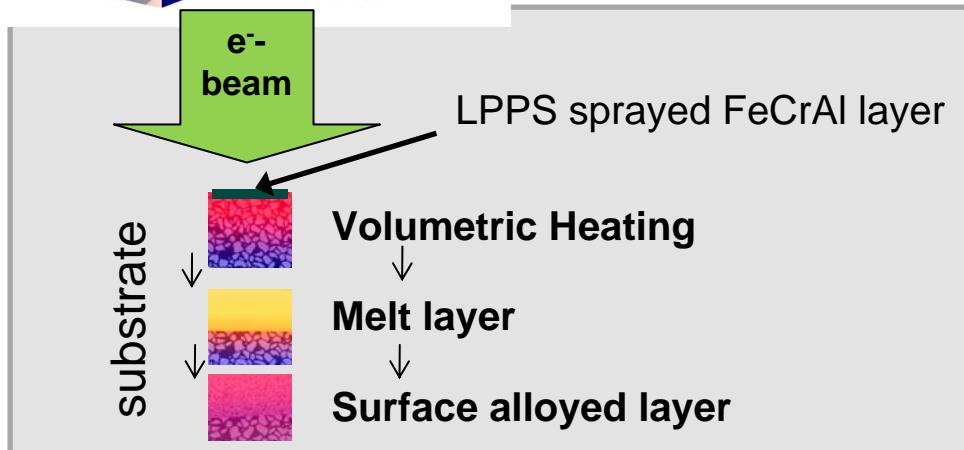
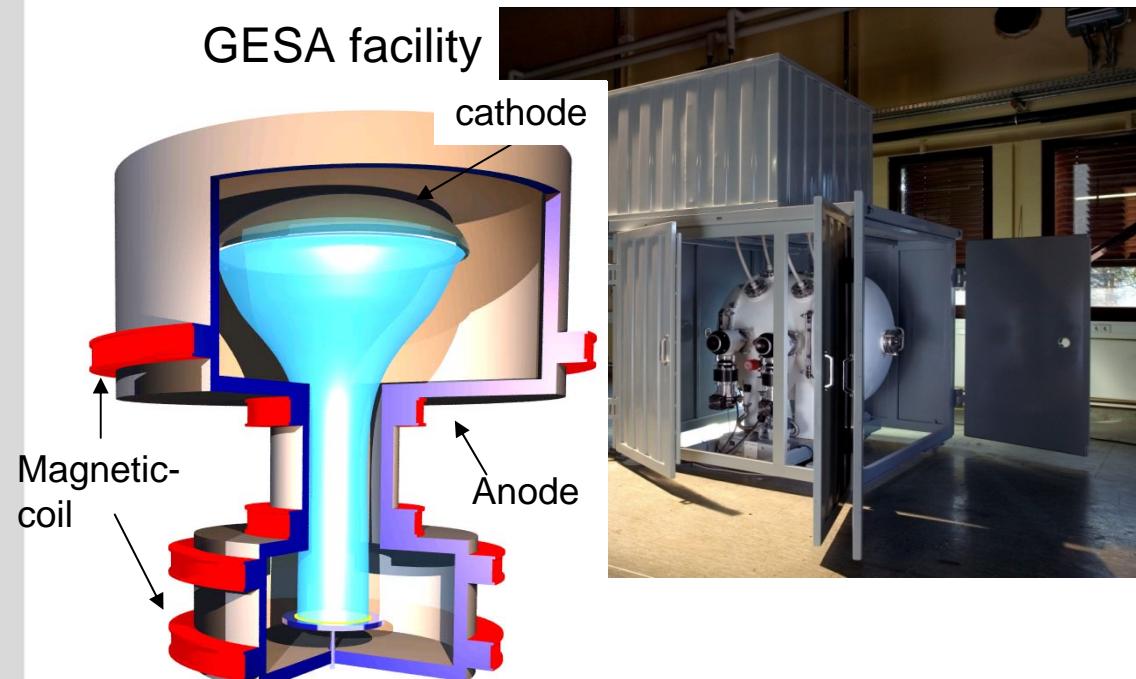
# Summary T91 and AISI316L

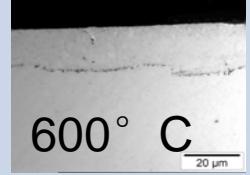
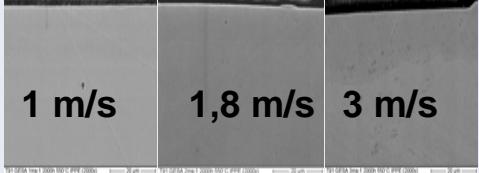
T	T91	AISI 316L
Low (< ~ 400 ° C)	<ul style="list-style-type: none"><li>Irradiation H &amp; E</li><li>Corrosion low</li><li>Impact on mechanical properties if wetting and stress above certain values</li></ul>	<ul style="list-style-type: none"><li>Irradiation H</li><li>Corrosion low</li><li>No Impact on mechanical properties</li></ul>
Medium (≤ ~ 450 ° C)	<ul style="list-style-type: none"><li>Slight Irradiation H &amp; E</li><li>Oxygen control stringent</li><li>Impact on mechanical properties (see low T)</li></ul>	<ul style="list-style-type: none"><li>No Irradiation H &amp; E</li><li>Oxygen control stringent</li><li>No Impact on mechanical properties</li></ul>
High (> 450 ° C)	<ul style="list-style-type: none"><li>No irradiation H &amp; E</li><li>Oxygen control very stringent (oxide layer thickness)</li><li>Impact on mechanical prop if oxide layer fails</li></ul>	<ul style="list-style-type: none"><li>No irradiation H &amp; E (high dose swelling)</li><li>Dissolution attack T&gt; 500°C</li><li>No impact on mechanical properties</li></ul>

In the high temperature range for both material corrosion protection would be mandatory

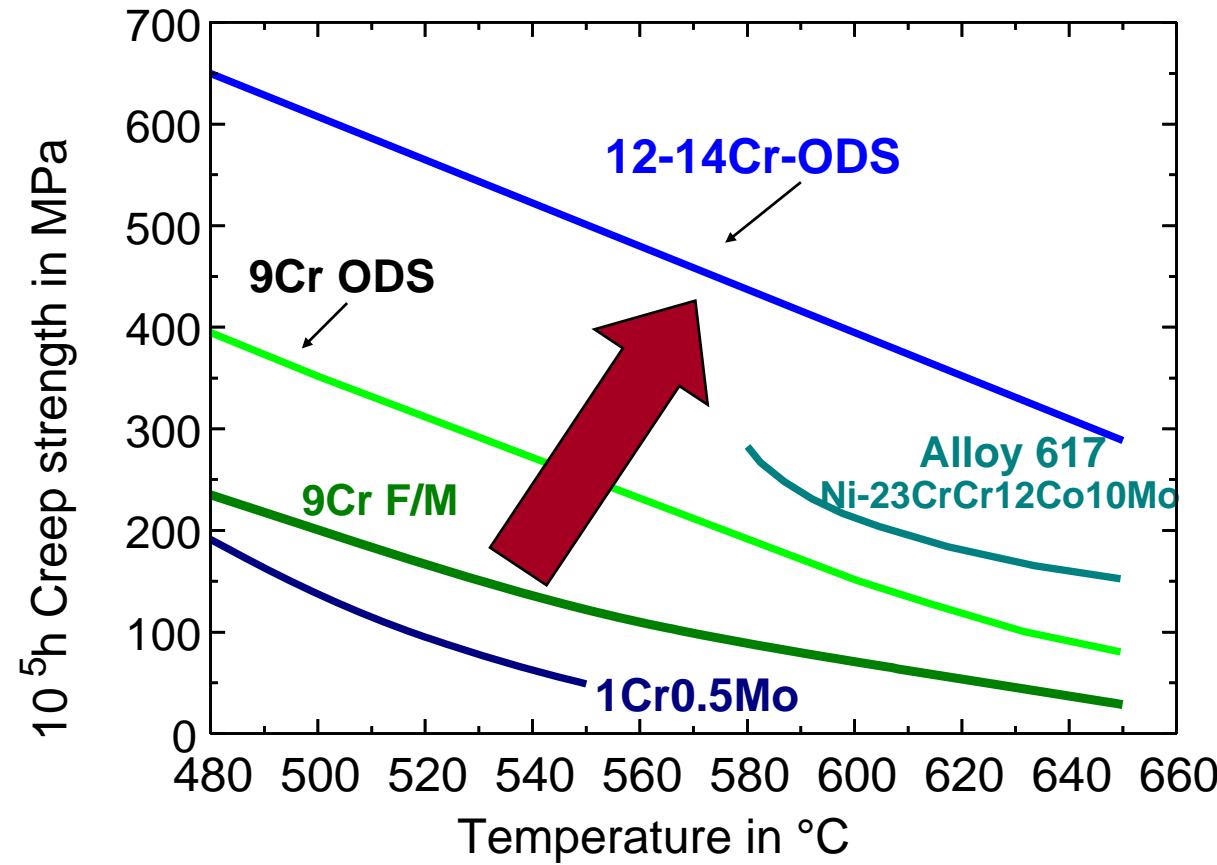
# GESA for corrosion protection

GESA facility



Tests on GESA	Results		
Corrosion resistance	 600 ° C 20 µm		
Erosion resistance	 1 m/s    1,8 m/s    3 m/s		
LCF	No reduction		
Creep-to-rupture	No reduction		
LISOR	No corrosion Hardening		

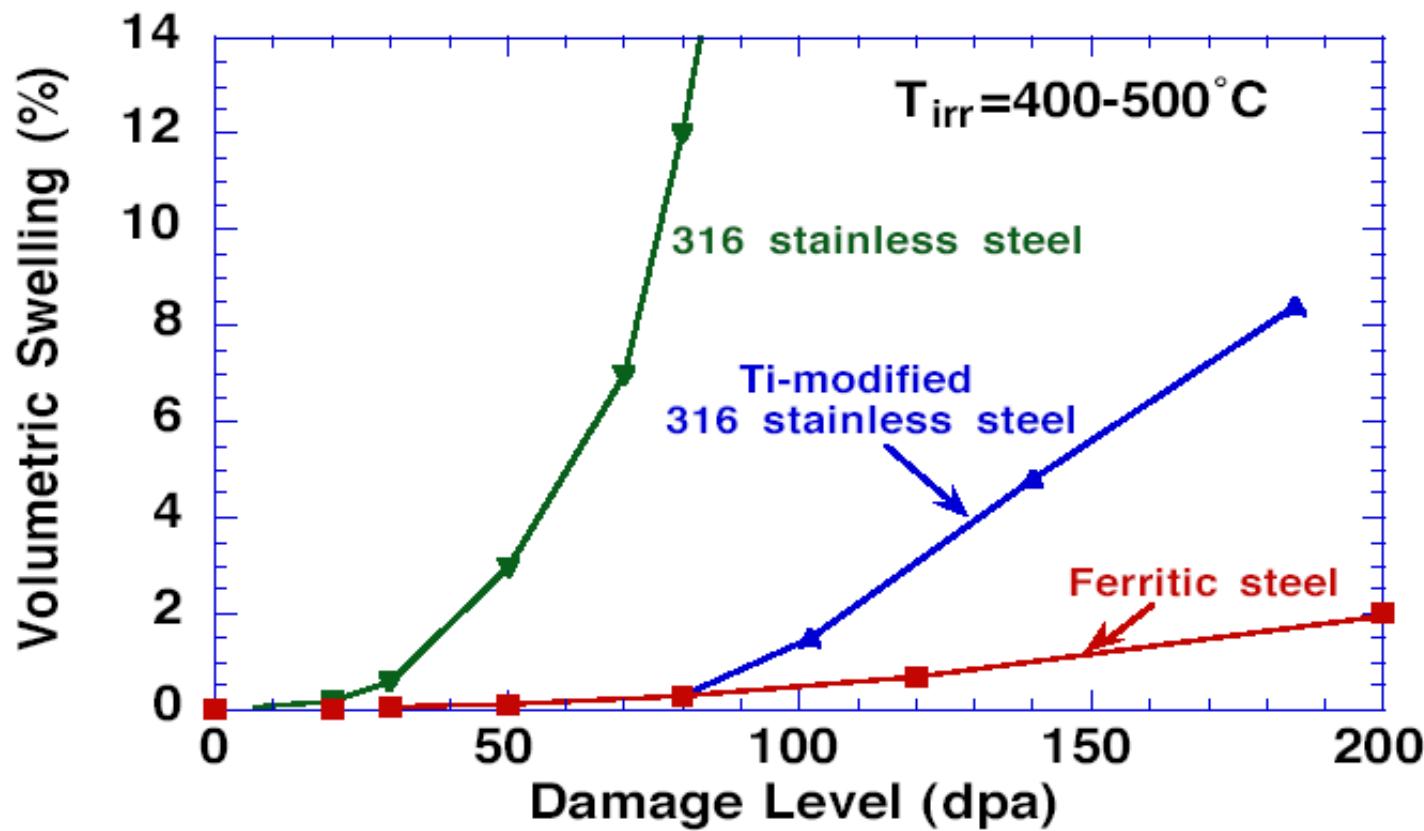
# Thermal and irradiation limits of 9Cr F/M and austenitic steels



Courtesy KIT

Improvement of thermal creep strength (important parameter for clad material)

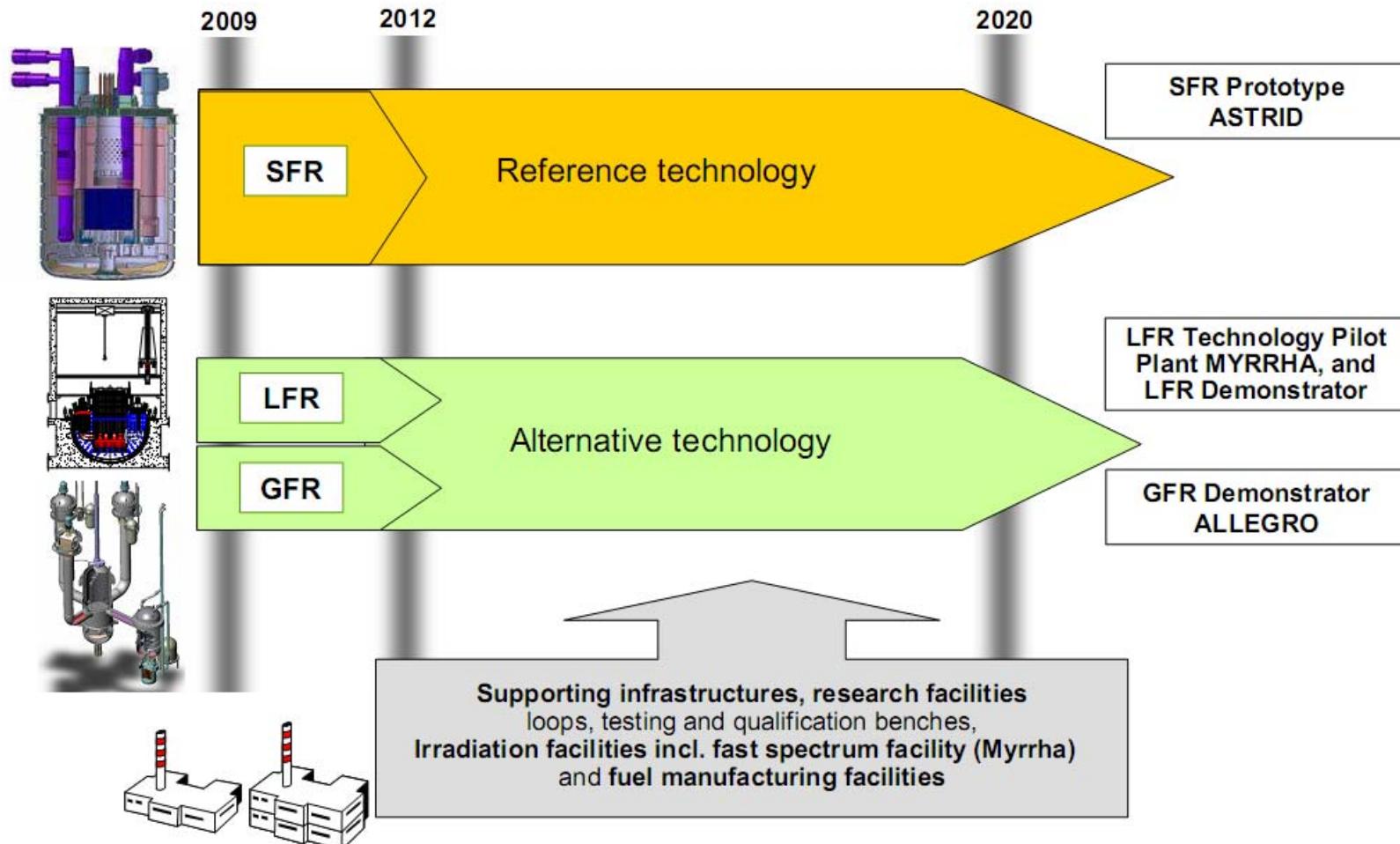
# Thermal and irradiation limits of 9Cr F/M and austenitic steels



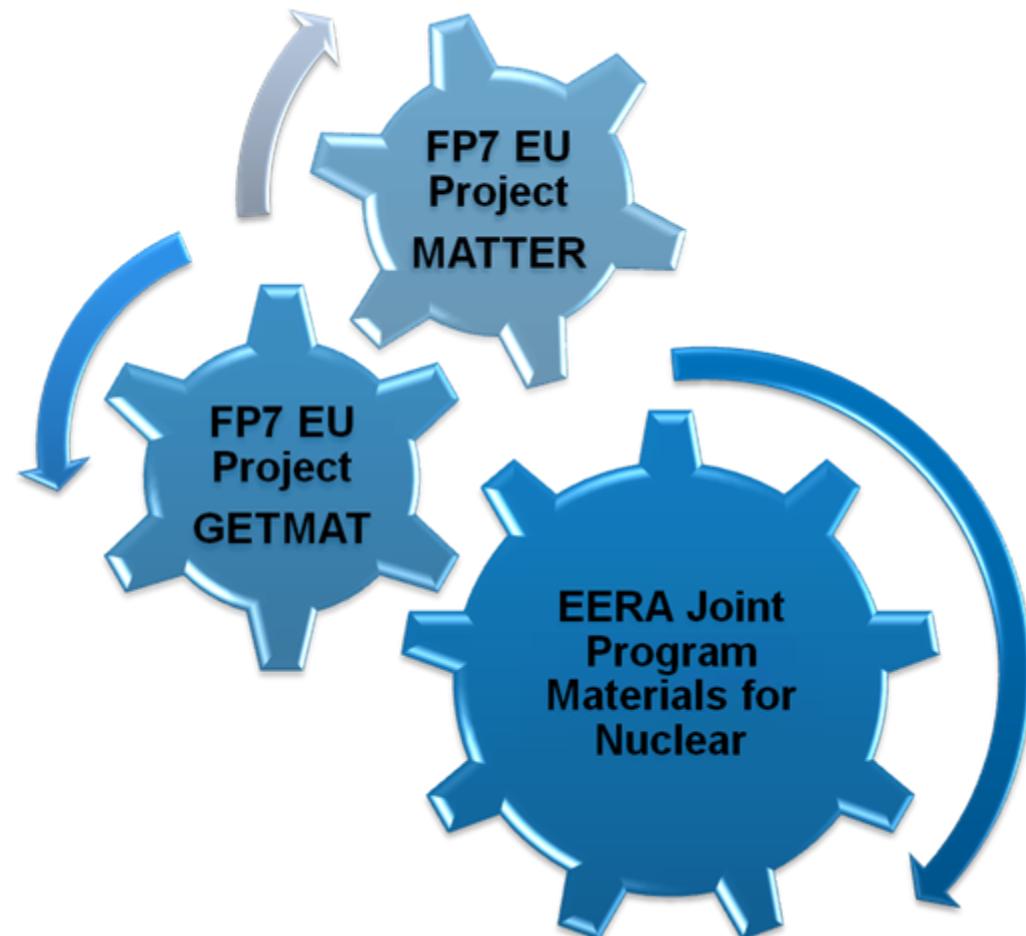
Improvement of swelling resistance

Courtesy CEA

# Generation IV and ADS: EU development



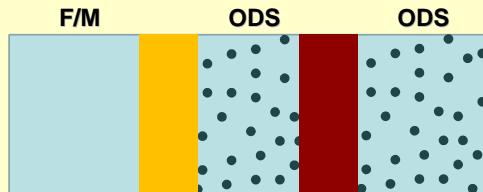
# European initiatives and projects on materials to support SNETP development



## WP1: Metallurgical and mechanical behaviour



ODS steel



**Fusion Welding**  
 • TIG (filler wire)  
 • EB (without filler)

**Solid State Welding**  
 • Diffusion  
 • Explosive  
 • EMP  
 • Friction Stir

## WP2: Materials compatibility with coolant



Oxidation  
in He



Oxidation  
in LBE



Oxidation  
in SCW

## WP3: Irradiation behaviour of Structure materials PIE Program

### Experiment

Matrix/Phénix  
 Lexur/BOR 60  
 ASTIR/BR2  
 IBIS, SUMO/HFR  
 STIP/SINQ  
 MEGAPIE

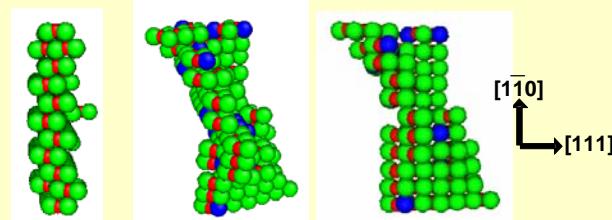
### Environment

Na  
 Pb, gas  
 LBE, gas  
 LBE, Na  
 gas  
 LBE

### Spectra

fast neutron  
 fast neutron  
 mixed neutron  
 mixed neutron  
 proton/neutron  
 proton/neutron

## WP4: Multiscale modelling and model experiments



Pure Fe      Fe-7%Cr      Fe-12% Cr  
 Cluster of self-interstitials in Fe and FeCr alloys.  
 Green = Fe, blue = Cr, red = lattice site

- **Objectives**
  - Coordination action related to the JP operation
  - Best practice guidelines for testing and evaluation aimed at screen and characterization (part of SP1)
  - Pre-normative research activities, to answer some short term needs of ASTRID and MYRRHA (part of SP1)
  - Support research activities for understanding and optimisation of ODS fabrication (part of SP2)

# EERA Joint Program Materials for Nuclear

**SP1 (ESNII) Short term program**  
activities on already existing materials. Focus is on **pre-normative research**

**SP4 (Modelling) Cross-cutting program**

Focus is on definition of **models and codes** for materials prediction

**JP Materials for Nuclear**

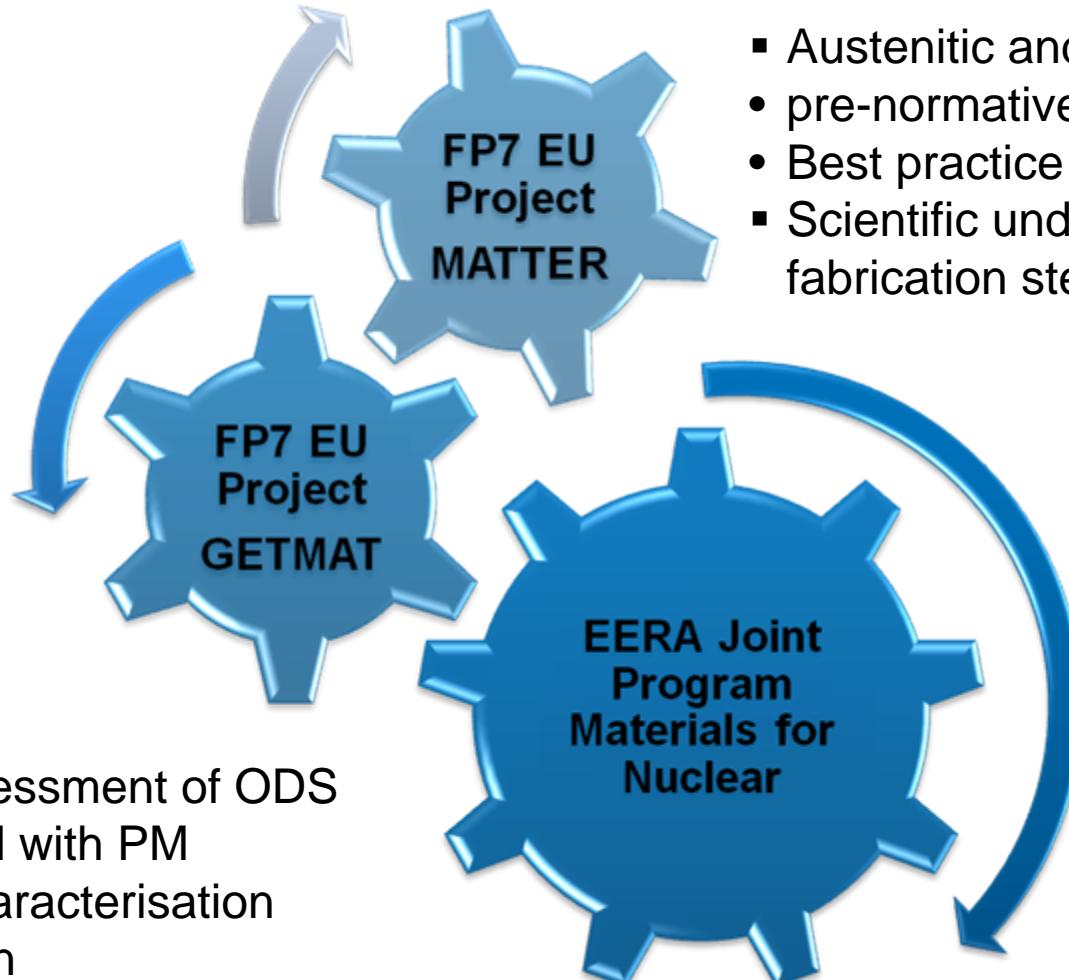
**SP2 (ODS material) Long-term program**

Focus is on materials for high fuel burn-up core of **LMFR**

**SP3 (Comp/Refr) Long-term program**

Focus is on high temperature materials for **GFR core** (e.g. SiCSiC)

# EERA JP, GETMAT and MATTER



- First assessment of ODS produced with PM
  - Basic characterisation
  - Weld/Join
  - Corrosion
  - Modelling

- Austenitic and martensitic steels:
  - pre-normative research
  - Best practice guidelines
  - Scientific understanding of ODS fabrication steps
- Support to ESNII
- ODS for LMFR
- Composites for GFR
- Modelling

# Summary and outlook

- Experiments performed on T91 and AISI316L steel for HLM systems have produced an important set of results and better understanding of phenomena
- In Europe the EERA Joint Program is a unique opportunity to create synergies and to possibly align national research activities on materials priority topics to support Generation IV system development
- The European Commission is funding relevant project supporting pre-normative research, best practice guidelines for materials testing and development and qualification of high temperature and high burn-up resistant materials as ODS and Multiscale modelling