

# Use of NA communications: 2

## EU research project CARbon-14 Source Term

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# NAWG-15



- EU research project Carbon-14 Source Term
  - Short introduction
    - Waste
    - Source Term
  - Group specific dissemination of results
  - Use of NA for dissemination to public
    - Website
    - Newsletters



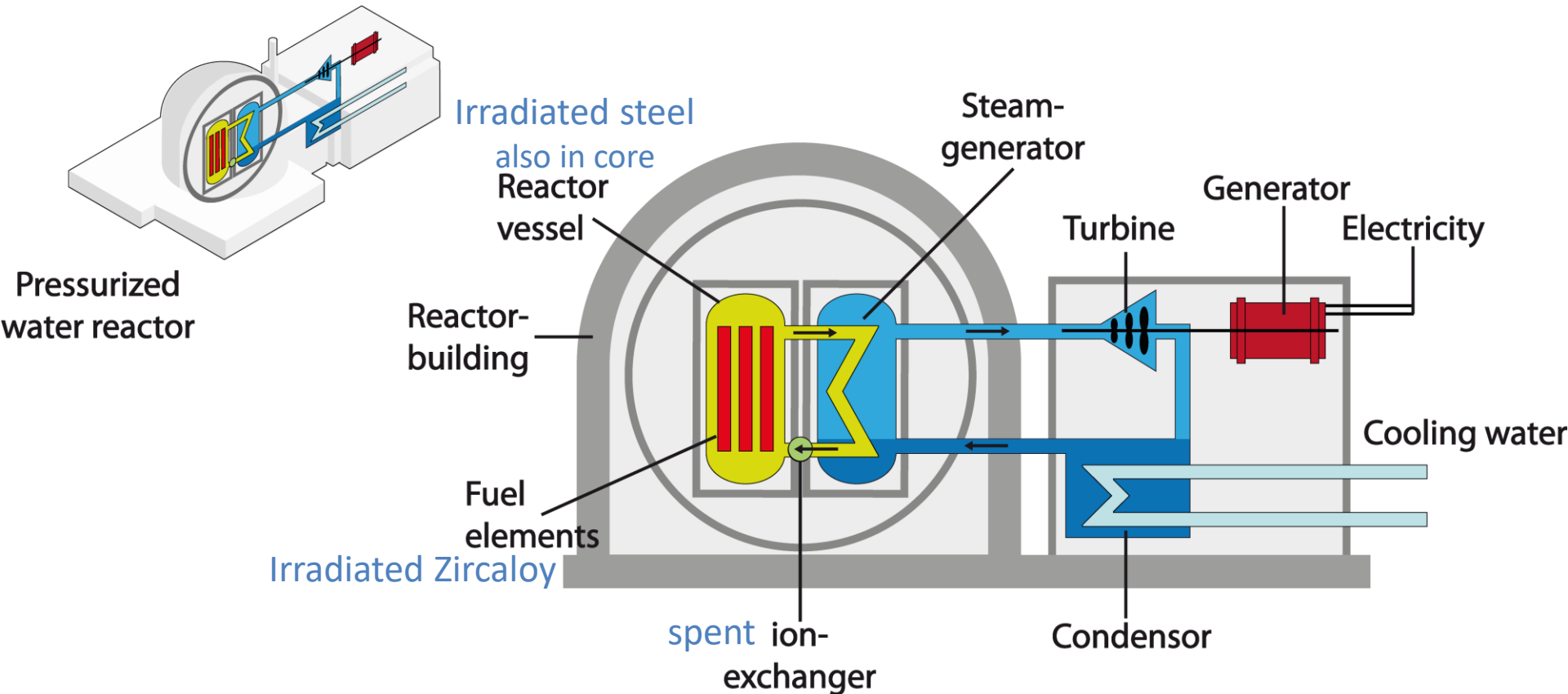
# Short introduction



- Carbon-14
  - During decay only emission of weak betas
    - Difficult To Measure (DTM)  $\Rightarrow$  Radiological characterisation issue
      - Calculations used frequently for the carbon-14 inventory
  - Can be released in a gaseous form during degradation of waste packages  $\Rightarrow$  one of radionuclides that can reach biosphere first



# Short introduction



Irradiated graphite, in CAST mainly LILW: moderator graphite instead of water  
EU research project CarboWaste because HLW engineered barrier →  
expected containment period several decay times of carbon-14 ( $t_{1/2}=5730$  years)



# Short introduction

- Source term: carbon-14 release rate or rates from waste
- Release under conditions relevant for waste packaging and disposal to underground facilities
  - Cementitious matrices, main waste packaging conditions considered in CAST
  - Cement
    - Portland: initially slightly oxidising and largely unbuffered because of lack of electroactive species
      - corrosion of metals may reduce redox potential locally
    - Blast furnace slag: initially reducing due small amount of  $\text{FeS}_2$  – blueish colour when not oxidised –
      - corrosion of metals may locally sustain reducing conditions
  - Underground
    - Near-surface disposal: aerobic exposure conditions
    - Deep geological disposal: anaerobic exposure conditions



# Short introduction



- Release of carbon-14
  - Mainly as dissolved species
    - Further specified as ionic that is dissolution in aqueous media necessary for its transport to biosphere
  - or
  - Mainly as gaseous species
    - Further specified as gas e.g. methane
      - » Dissolved in aqueous media
      - or
      - » Formation of gas phase  $\Rightarrow$  enhanced transport

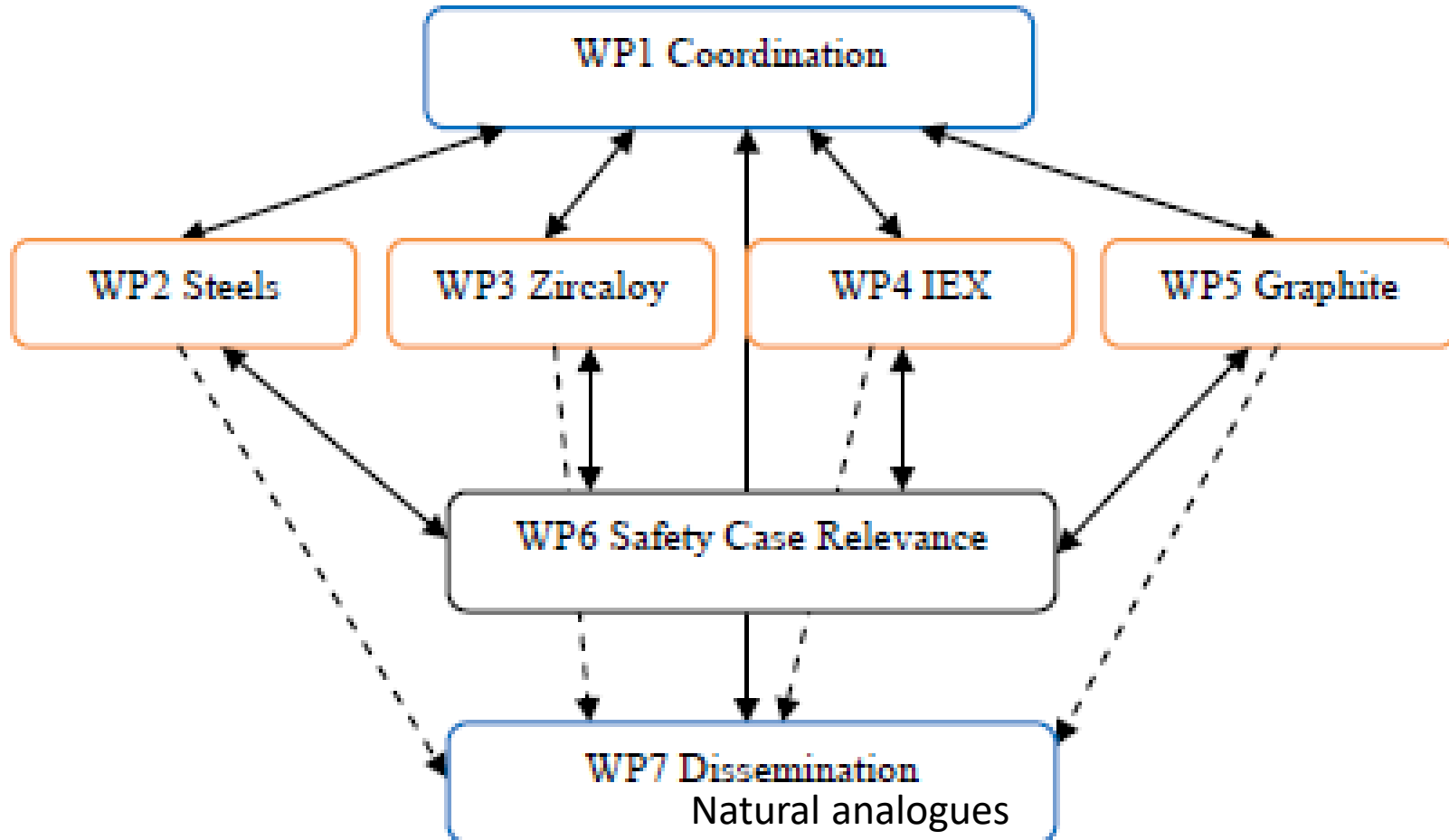


# Short introduction

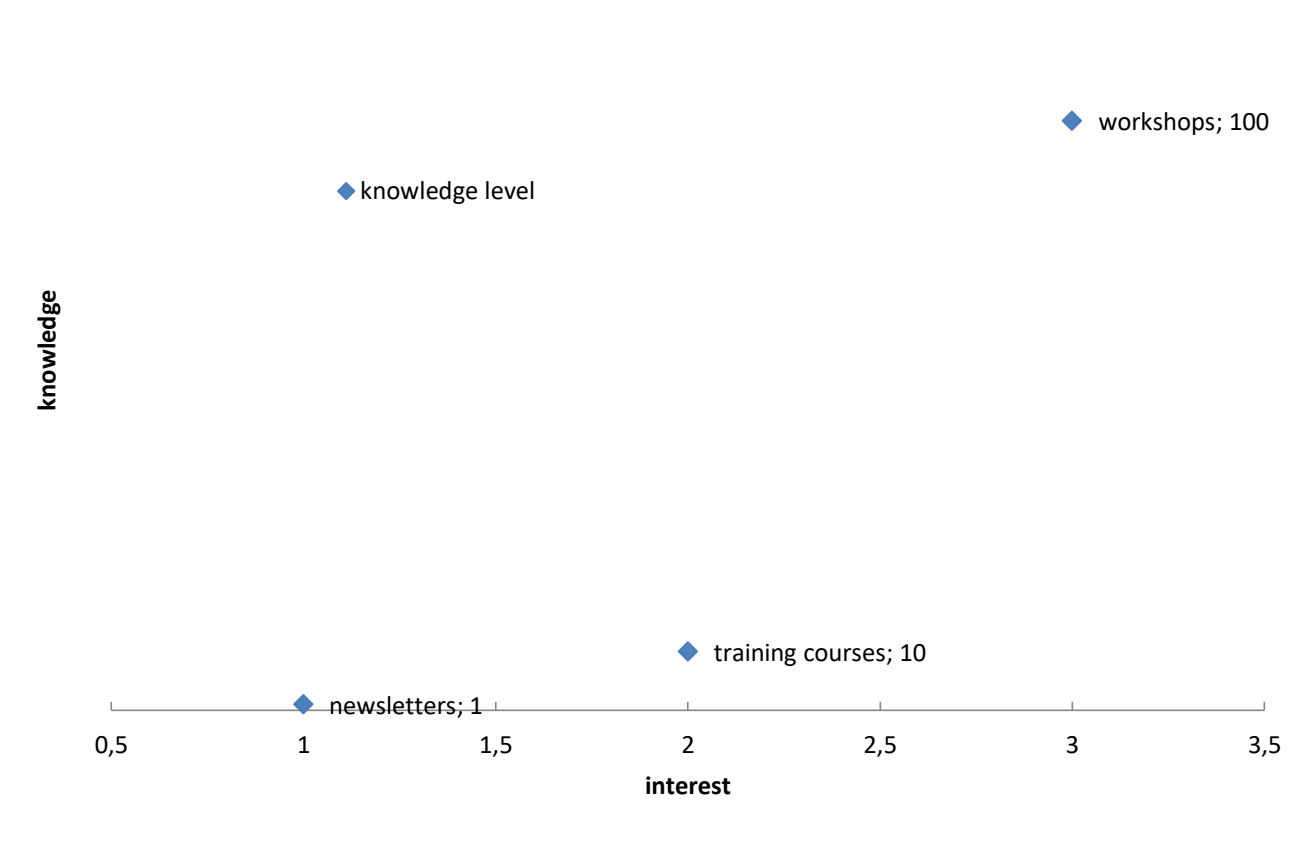


- Release of carbon-14, based on thermodynamics:
  - Oxidizing environment, aerobic : a bounded fraction of gaseous carbon dioxide. Main component:
    - $\text{pH} > 10$ : carbonate
    - $6 < \text{pH} < 10$ : bicarbonate
  - Reducing environment, anaerobic: gaseous e.g. methane, ethylene

# Short introduction



# Group specific dissemination



## Group

- 1) Definition of audience in terms of interest and knowledge
- 2) Methodology: mass media or interpersonal tools
- 3) Evaluation with pre-defined performance indicators



# Use of NA to public



- Definition of public in CaST
  - laymen
- Mass media in CaST
  - Website
  - Newsletter
- No predefined performance indicators

# Use of NA

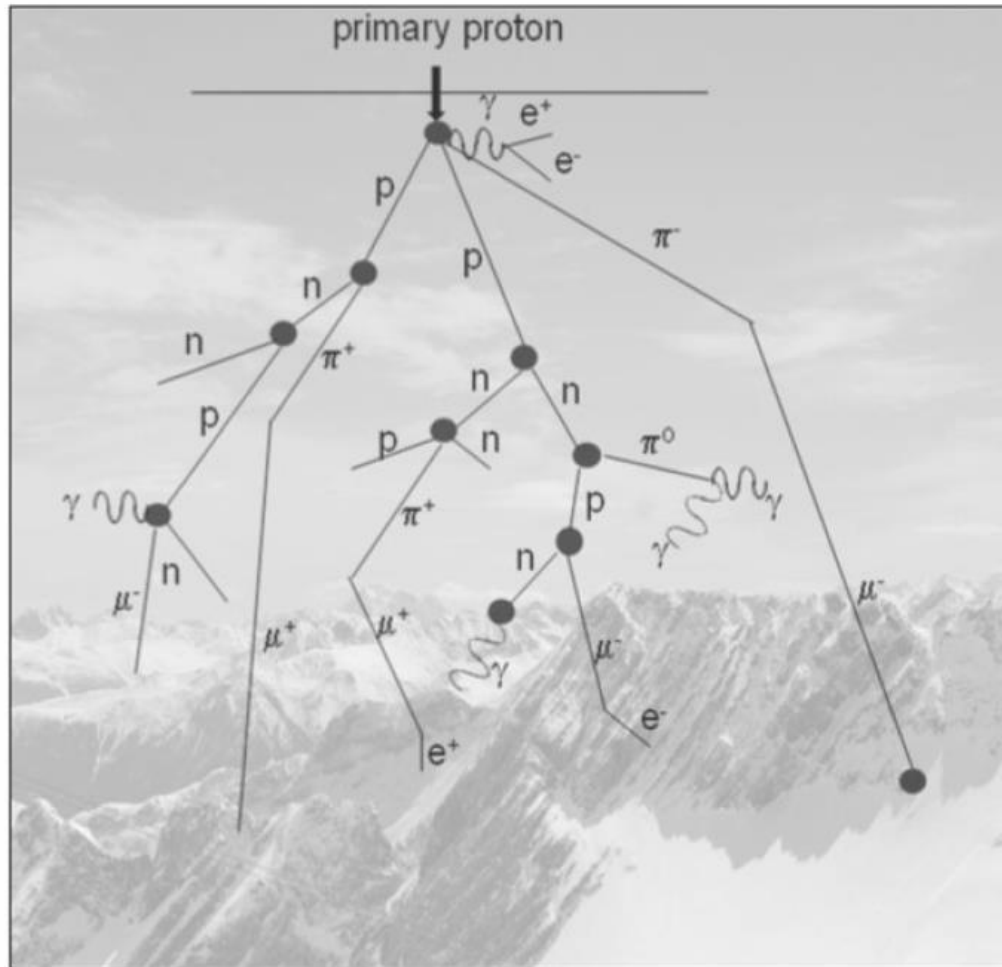
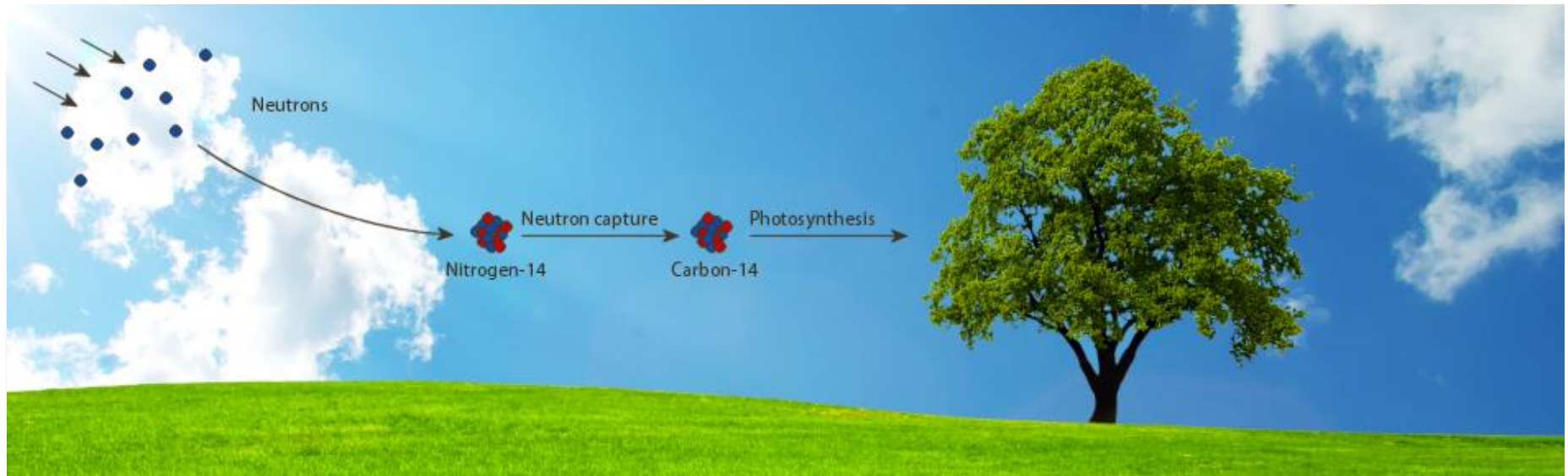


Image: ICRP 132 (2016)

Fig. 2.1. Sketch of cascade of secondary cosmic radiation:  $\mu$ , muon;  $e^-$ , electron;  $e^+$ , positron;  $\gamma$ , gamma rays;  $n$ , neutron;  $p$ , proton;  $\pi$ , pion (picture from W. Rühm).

# Use of NA to public



Use of NA to show that processes are understood  
e.g. possibility to use same data (parameters and parameter values)



# Use of NA to public



- Five newsletters for Five topics based on scheduled publications in WP2 /3 /4 /5 and 6
  - 1) Origin of carbon-14 in waste
  - 2) Radiological characterisation of waste
  - 3) Experimental approach for determination of release of Carbon-14
  - 4) Analysis and chemical forms of Carbon-14
  - 5) Quantification of source term for safety assessment



# Origin of carbon-14



- Carbon-14
  - Neutron activation precursors
    - Carbon-13
    - Oxygen-17
    - Nitrogen-14
  - Ternary fission product
  - Decay of actinides (e.g. radium, actinium)



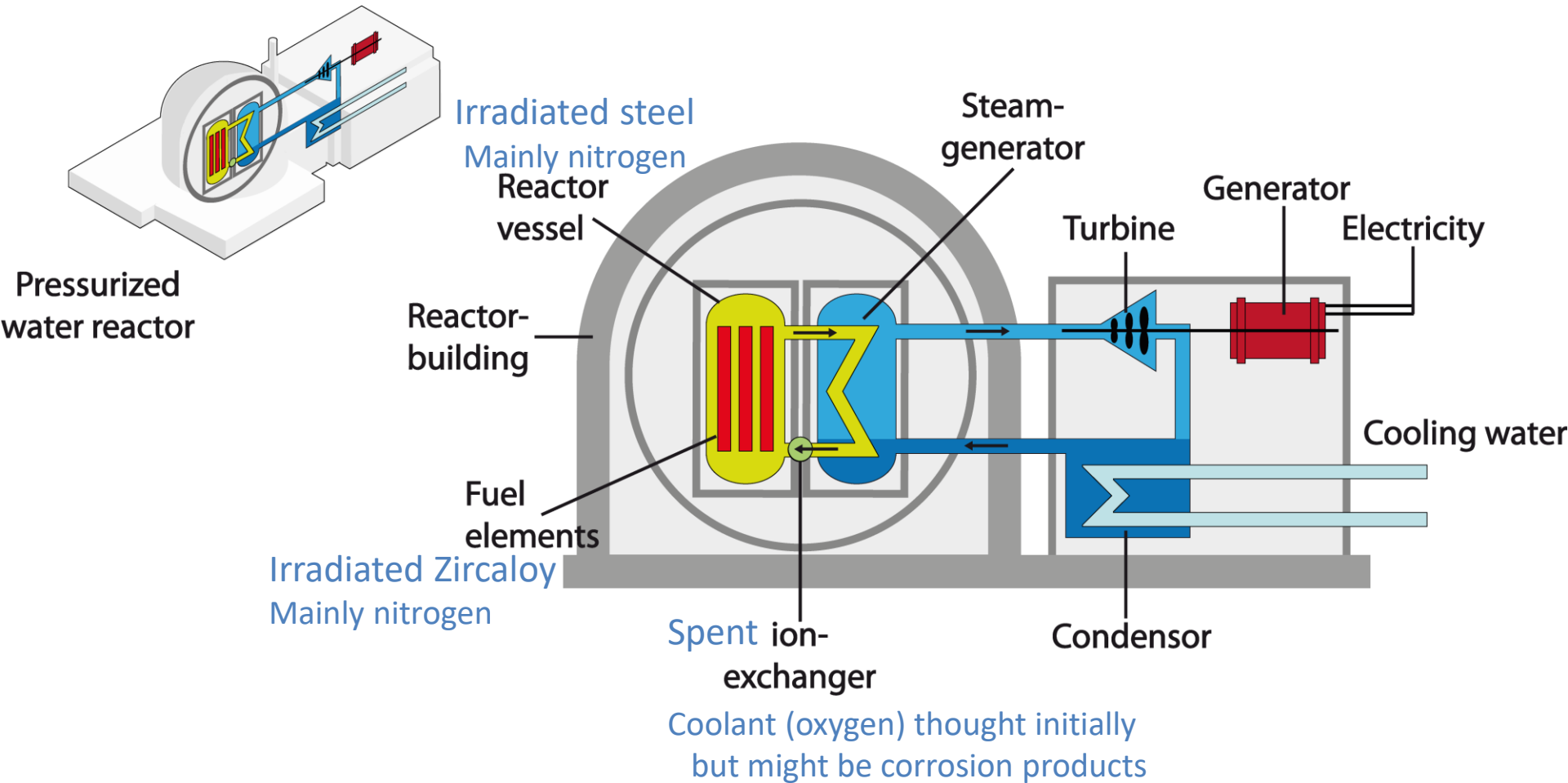
# Origin of carbon-14



- Cosmogenic carbon-14
  - NASA (1979) only considered nitrogen-14 as a contributor to carbon-14



# Origin of carbon-14



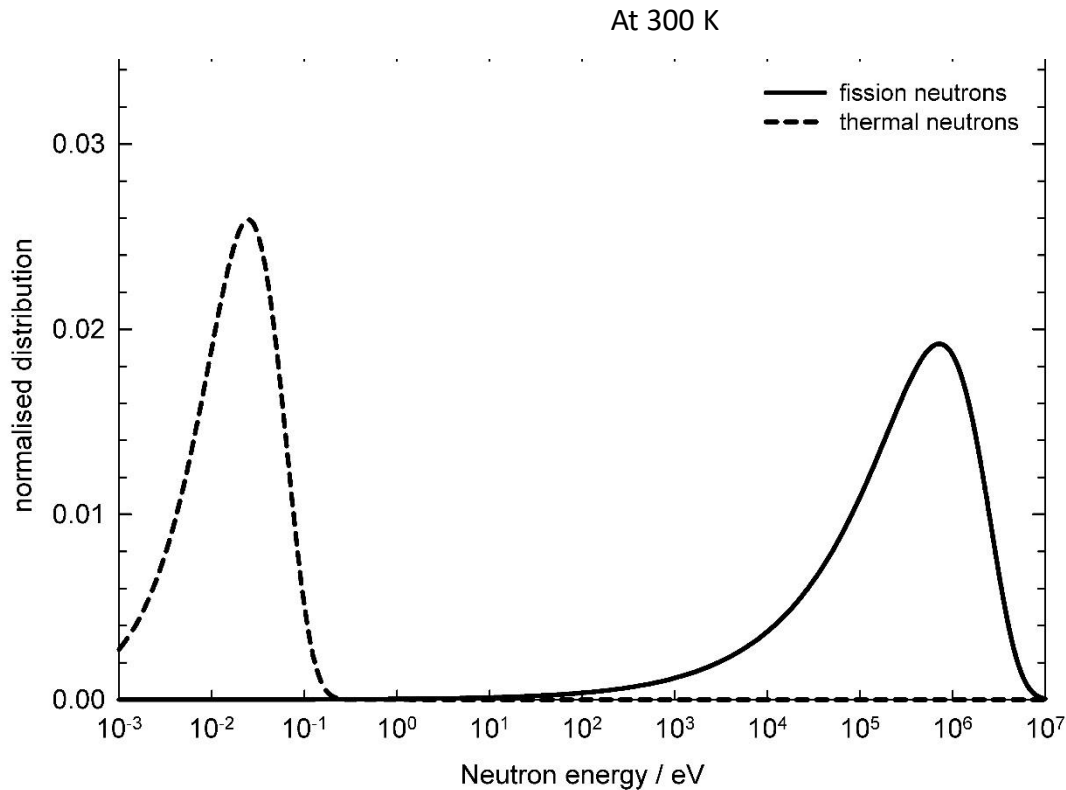
Irradiated graphite (in CaST mainly LILW): nitrogen and carbon



# Radiological characterisation



## calculating carbon-14 concentration.

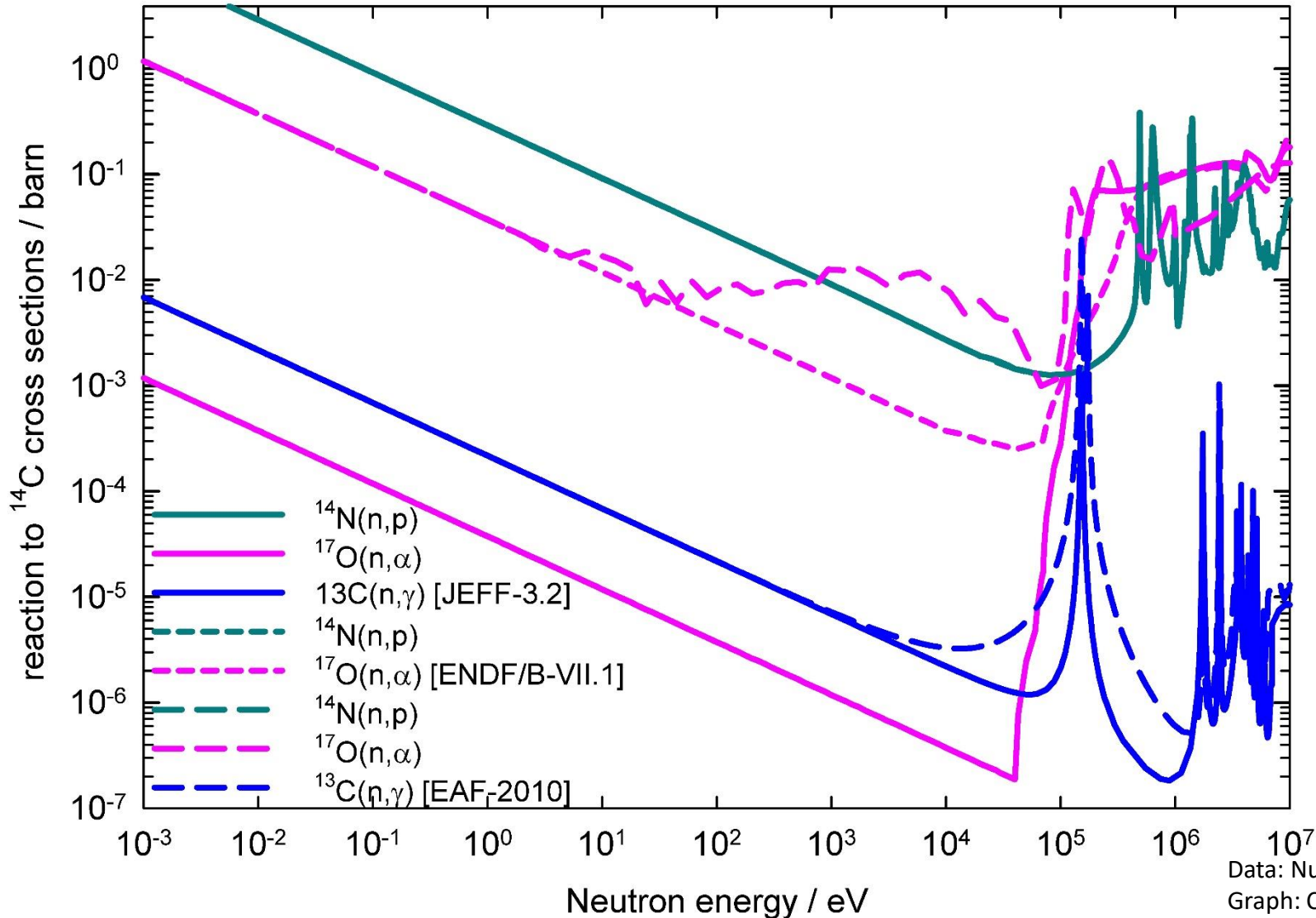


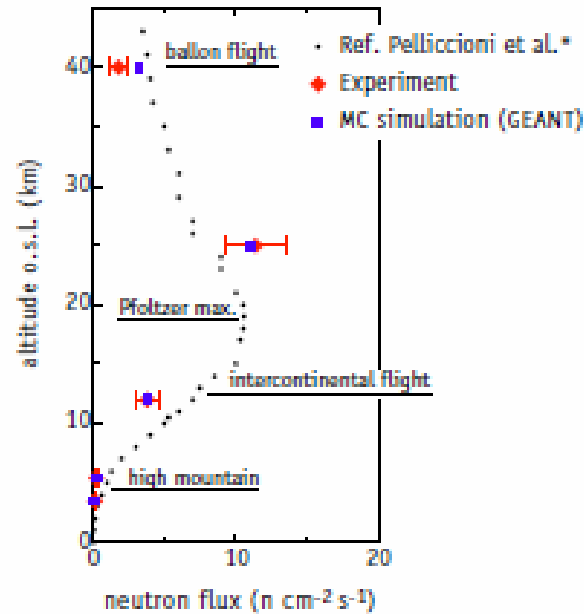
Info: any educational nuclear book  
for light-water-moderated reactors  
Graph: CAST Newsletter 2



Secondary cosmic  
radiation  
GeV

at 300 K





\*min. solar activity, max. latitude

**Fig. 2.** Neutron vertical profiles: experimental neutron fluence.

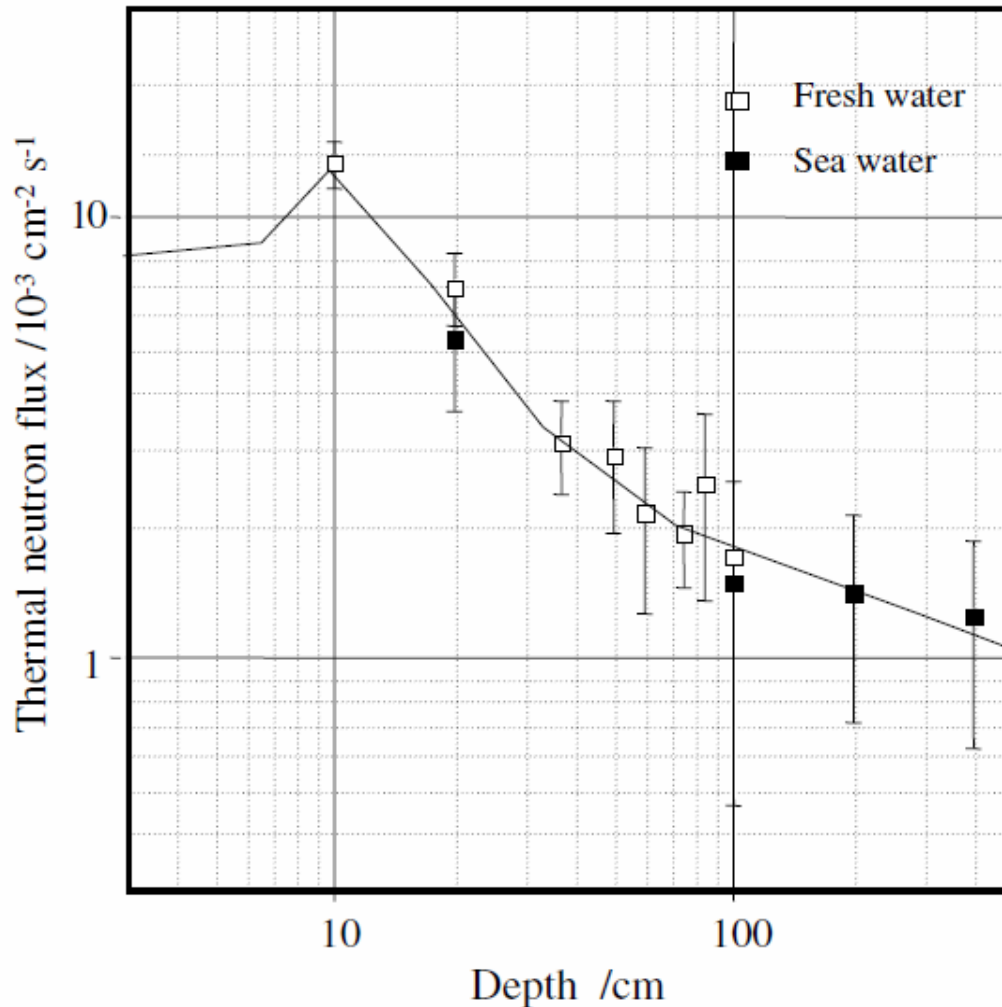
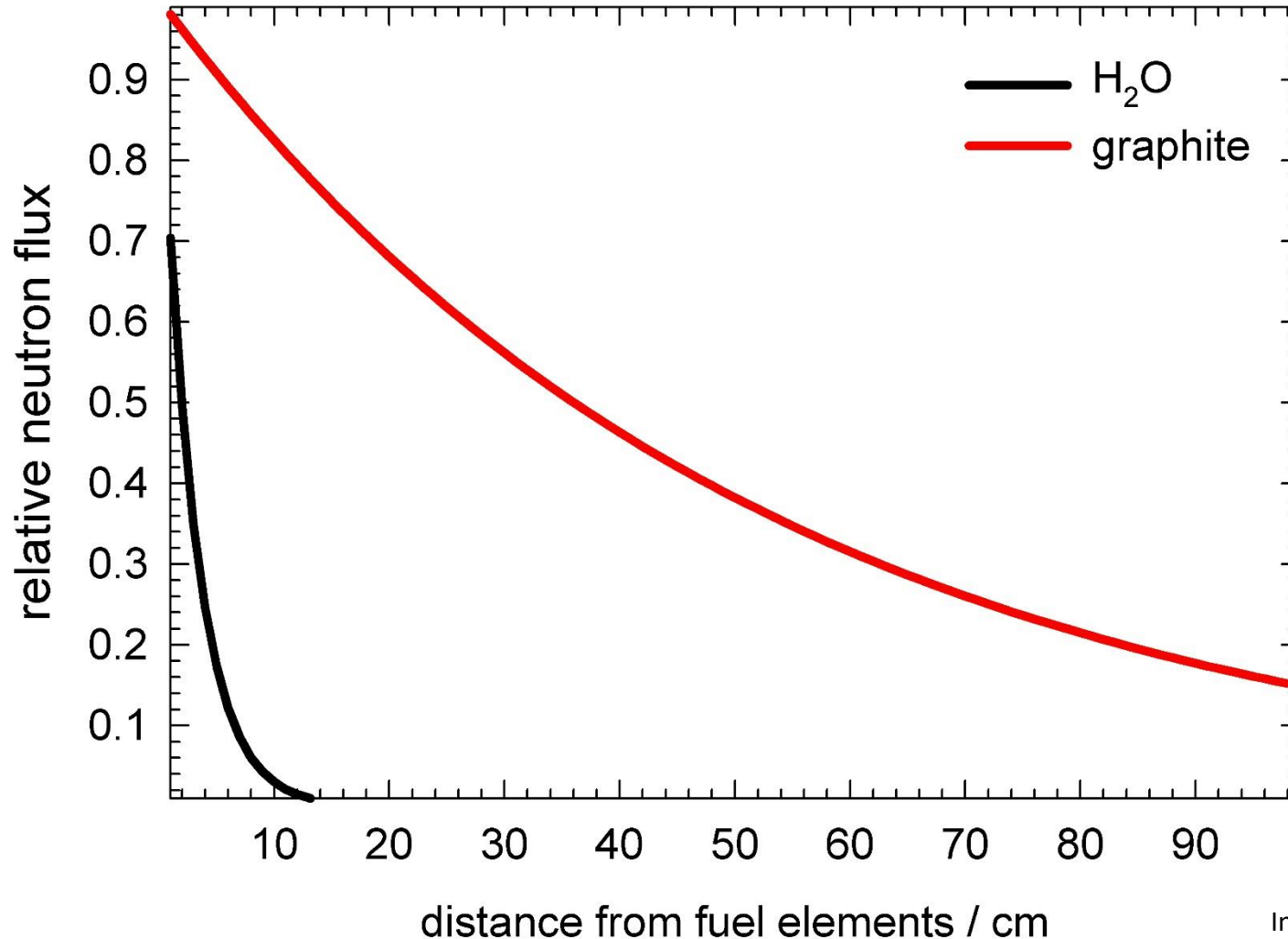
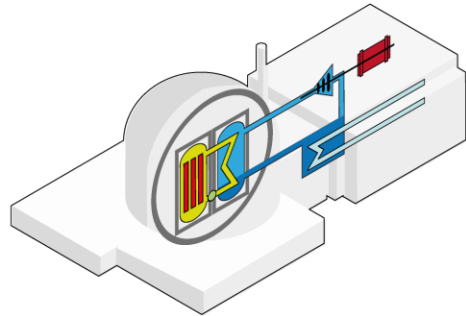


Figure 1. Depth profile of thermal neutron flux in the freshwater and seawater.

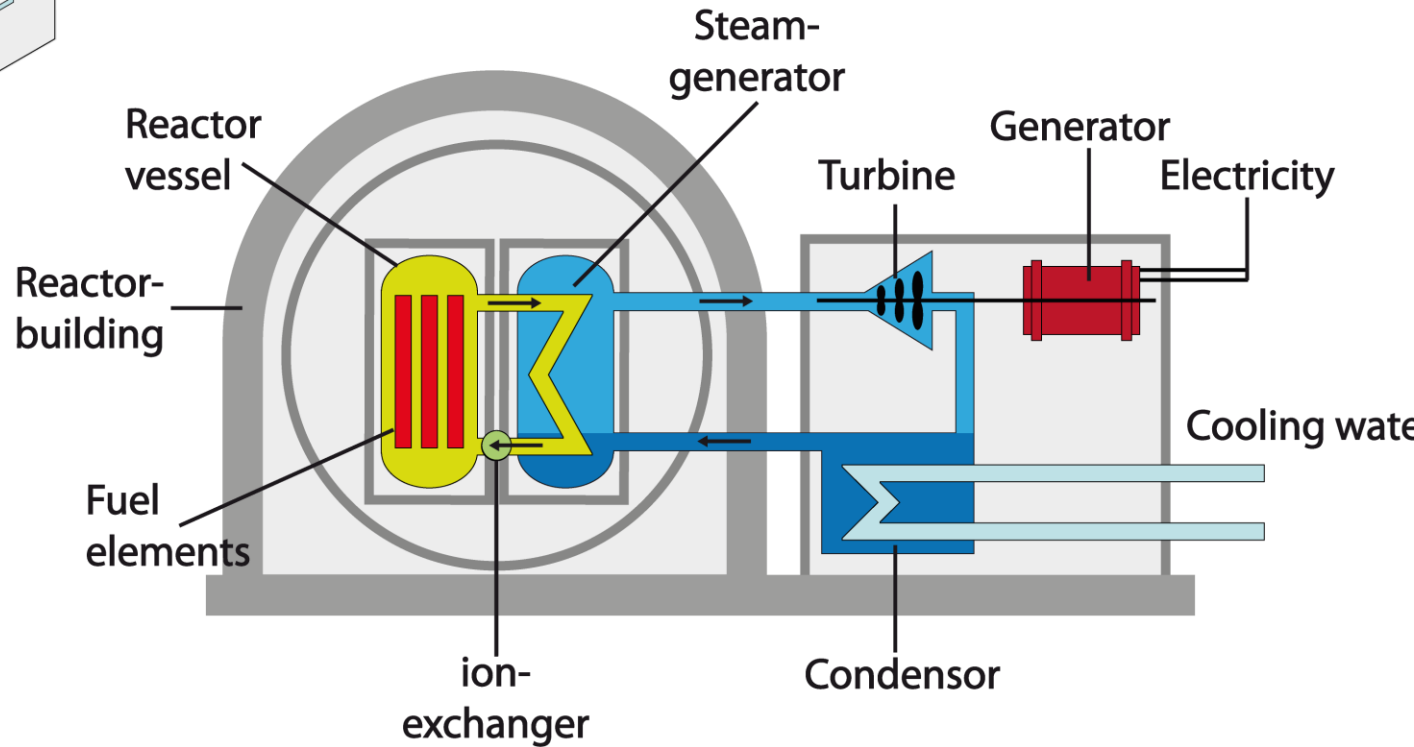




# Radiological characterisation

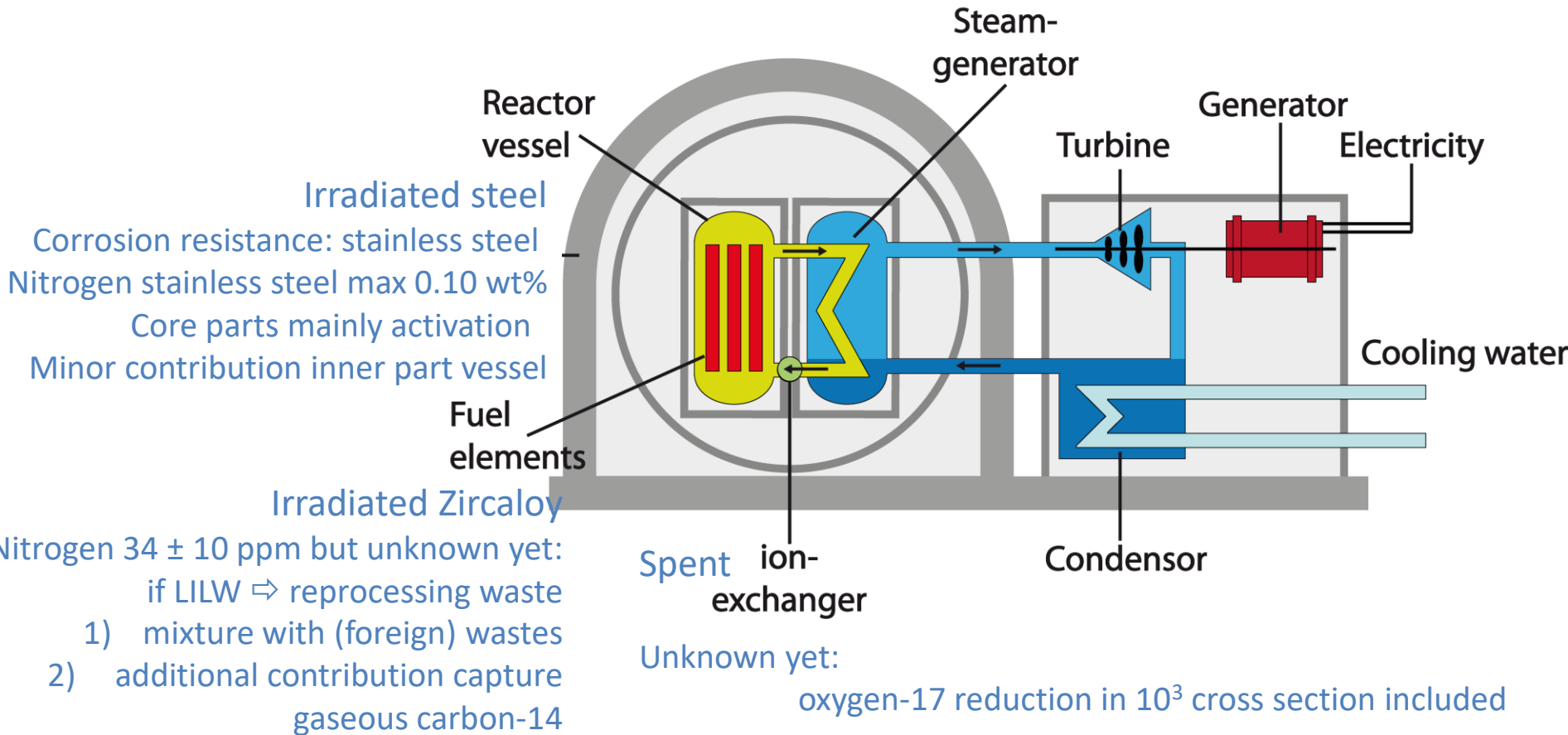


Pressurized water reactor





- Same parameters and parameter values for cosmogenic and artificial carbon-14
  - Natural abundances
    - Nitrogen-14 : 99.636%
    - Oxygen-17 : 0.038%
    - Carbon-13 : 1.07%
  - Natural abundance + thermal cross sections for the same carbon-14 contribution:
    - Chemical content carbon  $\gg 10^5$  chemical nitrogen content
    - Chemical content oxygen  $\gg 10^7$  chemical nitrogen content
- Same parameters but parameter values are different, orders in magnitude:
  - Thermal neutron flux
    - Environmental flux
      - altitude intercontinental flight: about  $10 \text{ n cm}^{-2} \text{ s}^{-1}$  [Zanini et al, 2003]
      - at Earth's surface due to shielding (i.e. deflection magnetic field and collisions with atomic particles in our atmosphere) about  $10^{-3} \text{ n cm}^{-2} \text{ s}^{-1}$  [Komura et al, 2008]
    - Artificial thermal flux
      - Close to core due to moderator properties e.g. 1500 MW graphite moderated reactor : about  $10^{14} \text{ n cm}^{-2} \text{ s}^{-1}$  [Ancius et al, 2005]
  - Presence of nitrogen
    - Environmental: 80% atmosphere
    - Artificial: impurity level



**Irradiated graphite (in CAST mainly LILW):**

if nitrogen content larger than 15 ppm  $\Rightarrow$  main contribution to carbon-14



# Conclusion / outlook



- Use of NA
  - Check whether processes are sufficiently understood
    - E.g. can it be answered when the same data be used to determine the impact of processes taking place in nature and for the investigated artificial ones?
      - For Carbon-14 Source Term answered generation of carbon-14 in nuclear plant for radiological characterisation of dismantling waste: steel and graphite
  - Discriminate the negligible impacts from the significant impacts
    - E.g. main origin carbon-14 in waste: neutron activation or fission of actinides or decay of actinides
      - What message to give to public (laymen)?
    - E.g. measurements : which chemical data will contribute to a more reliable calculated carbon-14 inventory, carbon or nitrogen content?
- If NA are not used
  - Are processes sufficiently understood for a safety case?
  - What 'metadata' is available for their input / measurements / calculated results?
    - For Carbon-14 Source term: a calculated activity concentration of carbon-14 (DTM) without the nitrogen content may not be considered reliable, opinion expressed by some regulators in EU
      - Substantiation of input for safety assessment in order to be able to evaluate calculated outcomes
  - Are the suggestions for further research worthwhile?
    - Collecting which data
      - E.g. Corrosion rates for stainless steel or carbon steel?
    - Which measurements / experimental investigations
      - E.g. Carbon content of steel usually known but not always nitrogen content



# Further information



[www.projectcast.eu](http://www.projectcast.eu)