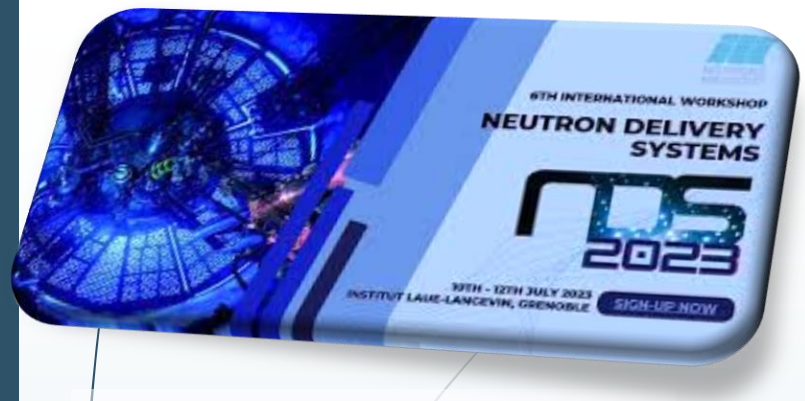


Sophie Bouat , Ph.D & *Engineer*
CEO of Science-SAVED
https://science-saved.com/

6th INTERNATIONAL WORKSHOP

NEUTRON DELIVERY SYSTEMS
NDS 2023

10th – 12th July 2023
Institut Laüé-Langevin
Grenoble – FRANCE

Neutron source: potential industrial application

Detection of hydrate plugs inside submarine pipelines using neutron activation analysis

11/07/2023

Hydrate plugs in deep sub-sea pipelines

Oil & Gas Industry

- Hydrocarbons flow inside deep sub-marine pipelines
- Often solidifies in Hydrate plugs
- Discriminate between those 2 phases in situ & contactless

Hydrate plugs in deep sub-sea pipelines

TechnipFMC

Sophie BOUAT

JÜLICH Forschungszentrum

MLZ Heinz Maier-Leibnitz Zentrum

Neutron Activation Analysis (NAA) at the Neutron Research Reactor FRM II

- **Industrial partner:** TechnipFMC
  - **Ludovic PINIER, Xavier SEBASTIAN**
- **Research Neutron Source FRM II**
  - **Adrian LOSKO, Rudolf SCHÜTZ, Michael SCHULZ, Zsolt REVAY, Zeljko ILIC, Eric MAUERHOFER, Thomas BRÜCKEL, Ralph GILLES**

When large-scale facilities can bring significative breakthroughs

Oil & Gas Industry

Classical techniques limitations

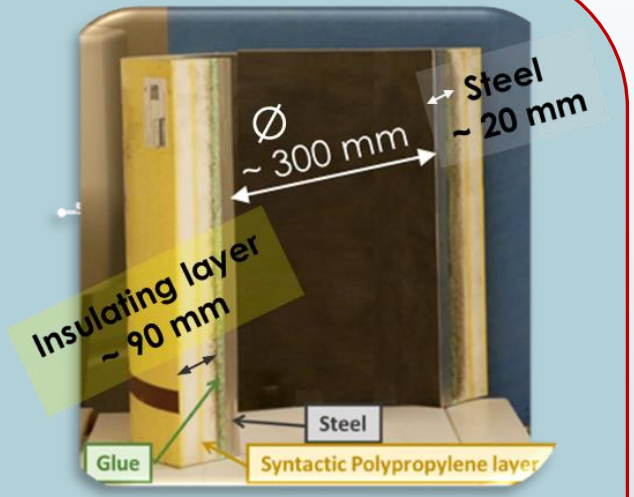
- Hydrate detection

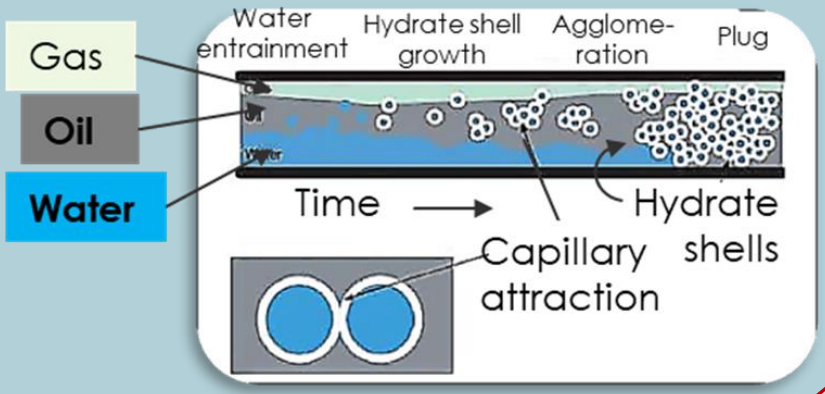
  in the oil and gas industry

  - Thermal imaging & Gamma ray detection
  - **Restricted to observation in the air**

- **Same densities so ultrasonic techniques are underperforming**





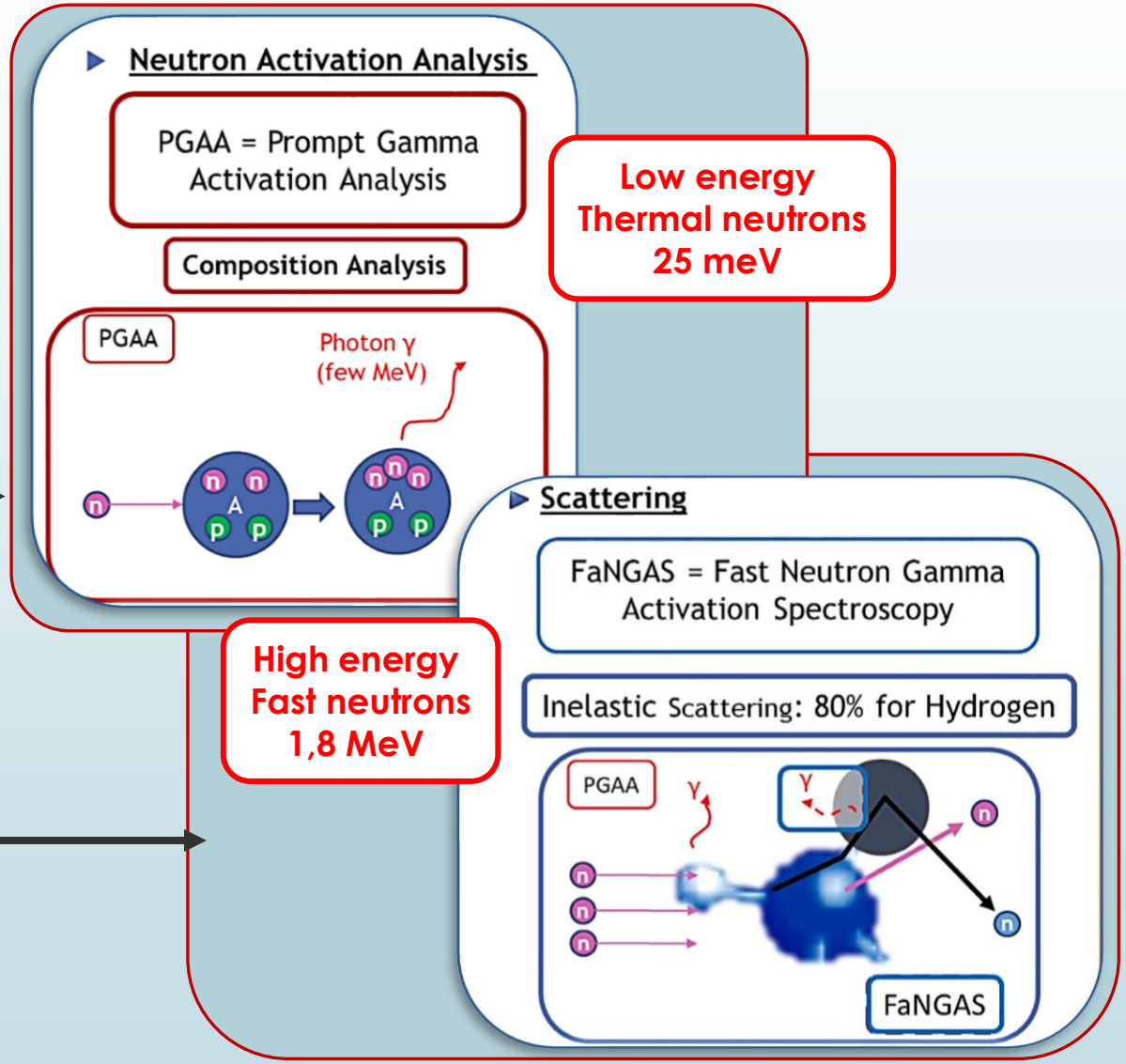
FRM II: neutrons as a probe

NDT

Oil & Gas Industry

Neutron-based techniques

- **At the FRM II neutron source in Garching near Munich**
- **PGAA technique: P**rompt neutron-induced **G**amma **A**ctivation **A**nalysis
- **FaNGaS instrument: Fa**st **N**eutron-induced **G**amma **S**pectroscopy



FRM II: neutrons as a probe

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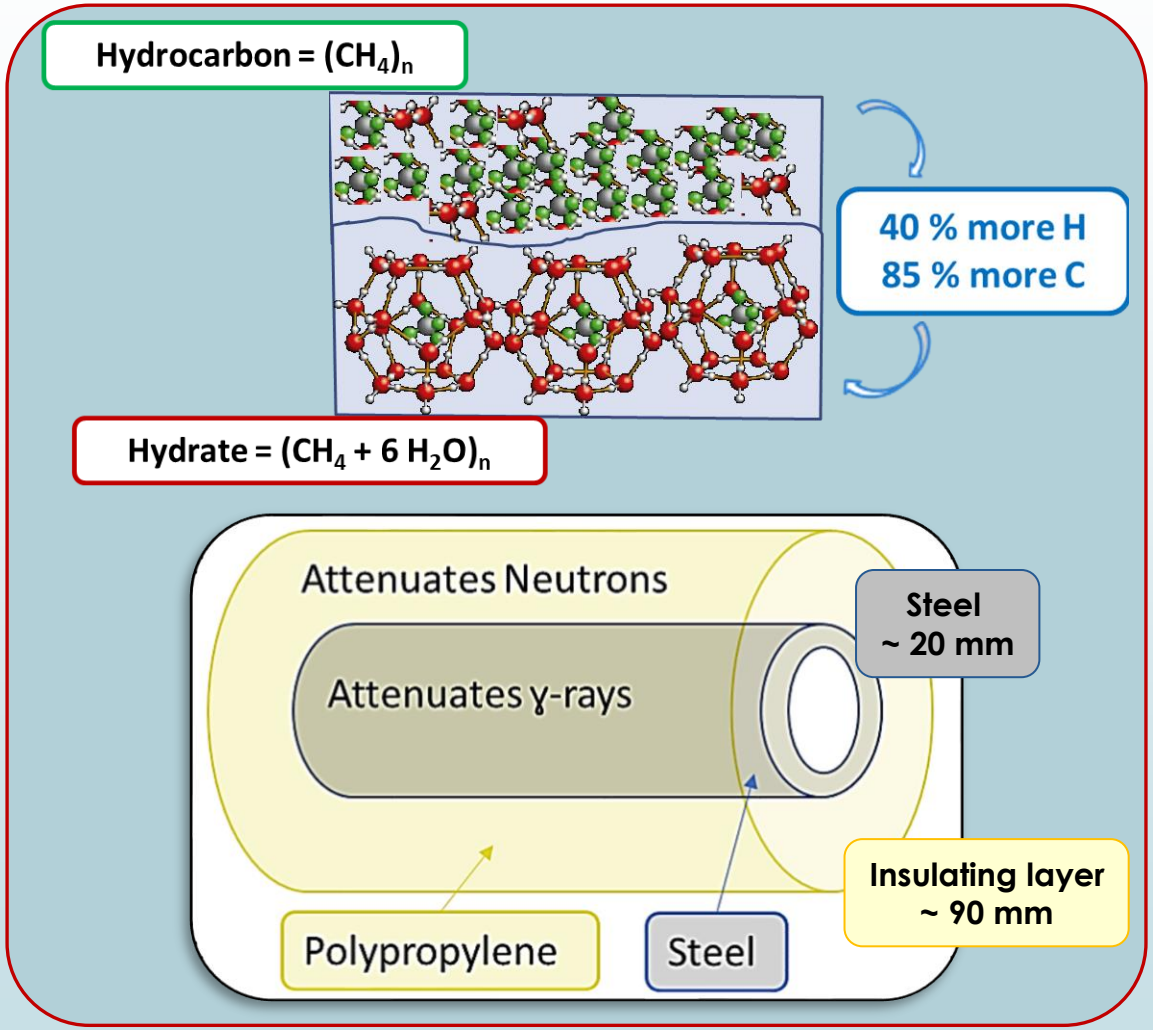
Neutron-based techniques

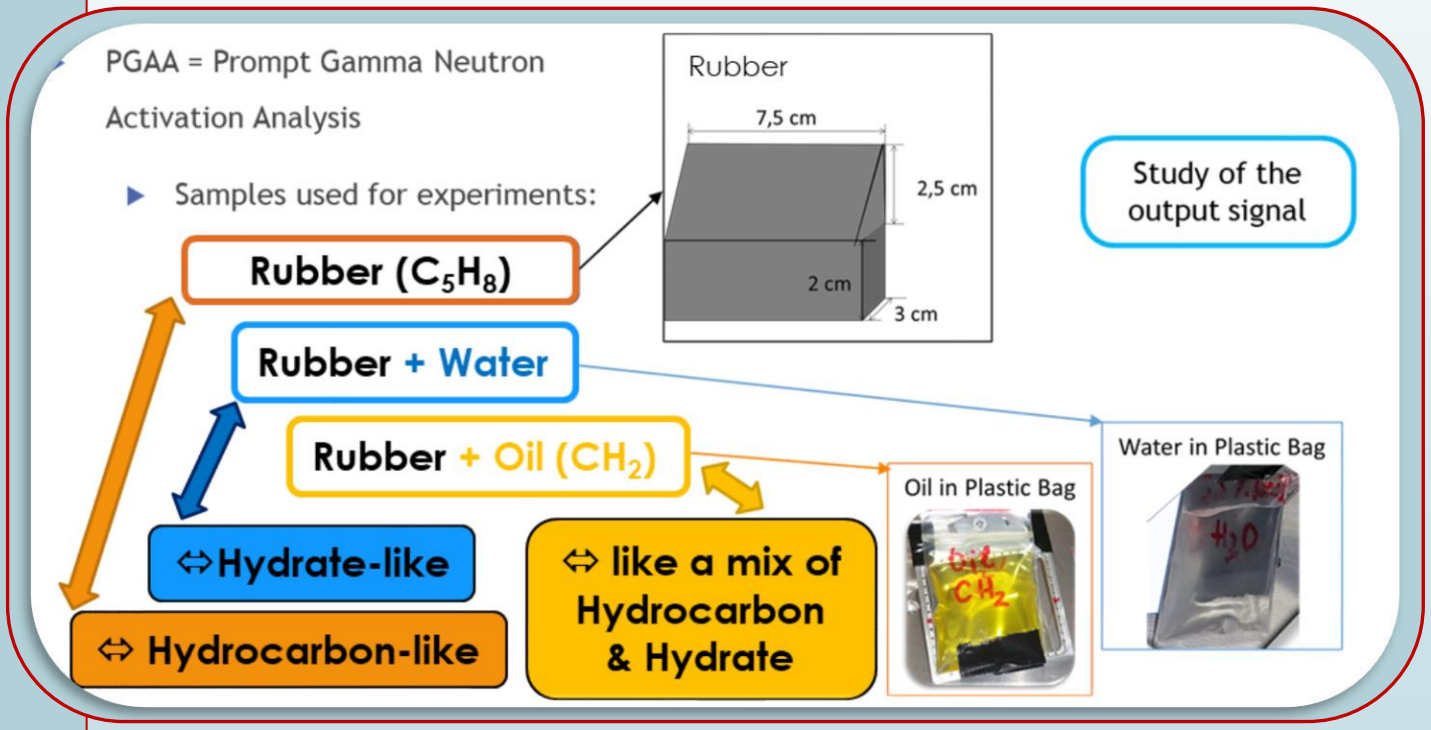
- **At the FRM II neutron source in Garching near Munich**
- **PGAA**
- **FaNGaS**
- **Hydrocarbons & hydrates**
  - Atomic concentrations differ
- **Detection through pipe structures?**



FRM II: less dangeraous samples

Hydrocarbon-like and hydrate-like samples used at the FRM II

- Less dangerous materials than hydrocarbons and hydrates
- With similar content in hydrogen and carbon
- Polyethylene (C_2H_4) for FaNGaS experiments



FRM II: significative breakthrough 1/2

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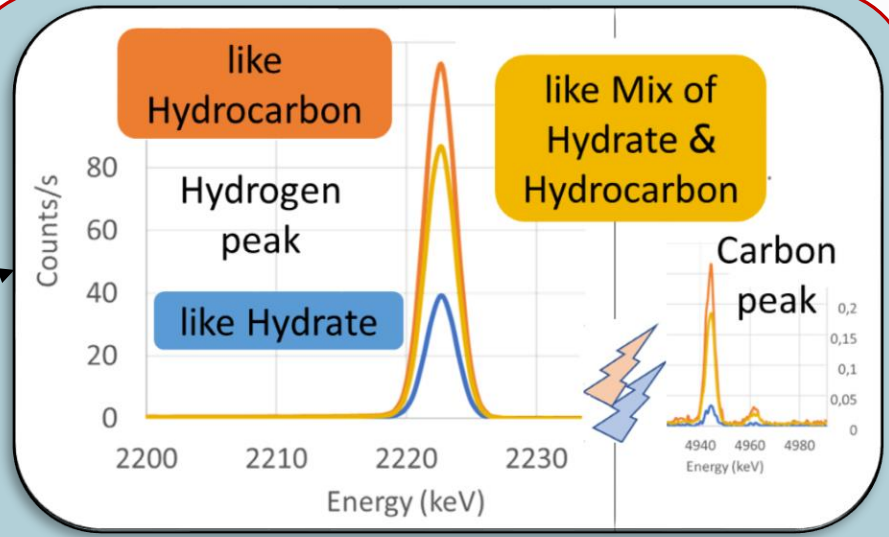
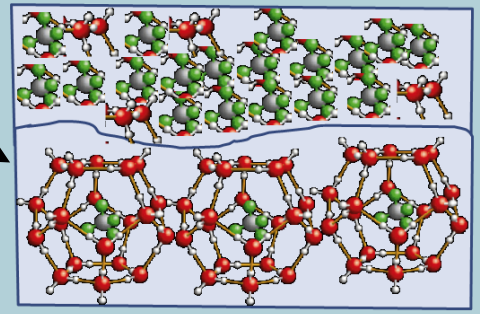
Neutrons: Discrimination capacities

- **PGAA at the FRM II neutron source in Garching near Munich**
- **Easy discrimination between hydrocarbon and hydrate with the PGAA technique**
- **Hydrocarbons & hydrates**
  - Atomic concentrations differ

Low energy Thermal neutrons 25 meV



Hydrocarbon = $(CH_4)_n$



Hydrate = $(CH_4 + 6\ H_2O)_n$

40 % more H
85 % more C

In hydrocarbon than in hydrate

& (H/C) 4 x higher for Hydrate

FRM II: significative breakthrough 1/2

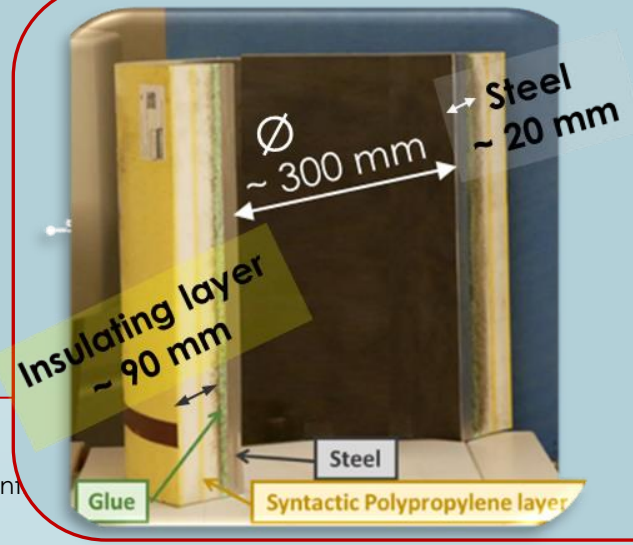
NDT

Oil & Gas Industry

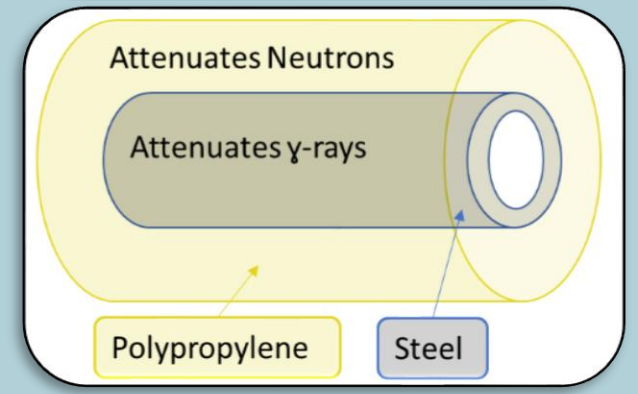
Neutrons: Discrimination capacities

- **PGAA at the FRM II neutron source in Garching near Munich**
- **Easy discrimination between hydrocarbon and hydrate with the PGAA technique**
- Two 60 kg half pipes handled at the FRM II

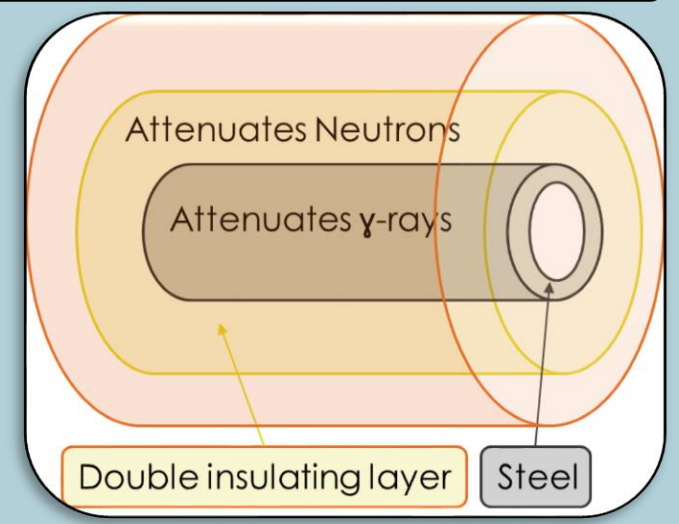
Low energy Thermal neutrons 25 meV



Single pipe (base case)



Double pipe (worst case scenario)



FRM II: significative breakthrough 2/2

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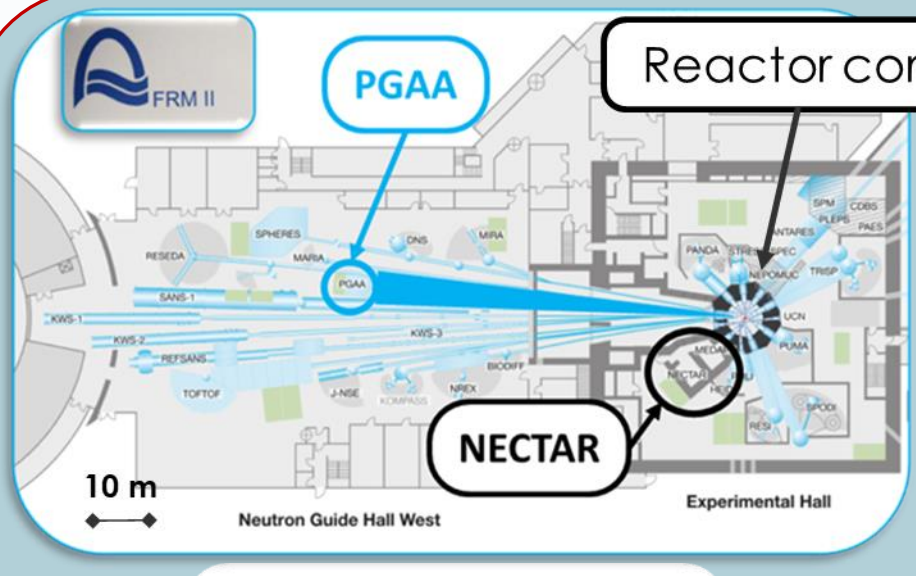
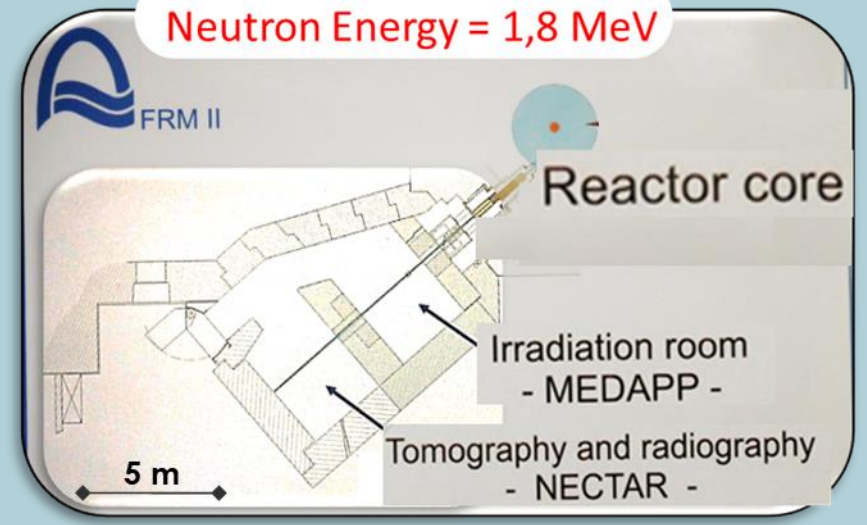
Oil & Gas Industry

Penetration capacities

- Penetration through the thick pipeline structures
- NECTAR hall: Neutron Tomography & Radiography
- MEDAPP: Medical Applications
- FaNGaS instrument in the MEDAPP experimental hall

High energy Fast neutrons 1,8 MeV





FRM II: significative breakthrough 2/2

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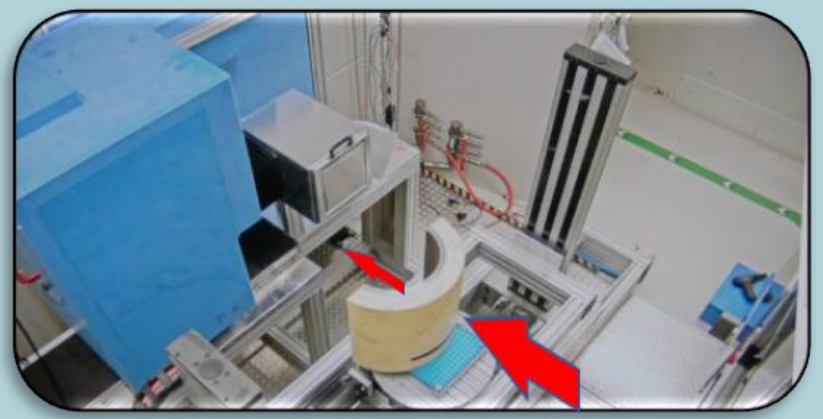
Neutrons: Penetration capacities

- **Neutron radiography through the pipe structures in the NECTAR hall at the FRM II**
- **Base case: single pipe**

High energy
Fast neutrons
1,8 MeV

Experiment disposition in case of the single pipe



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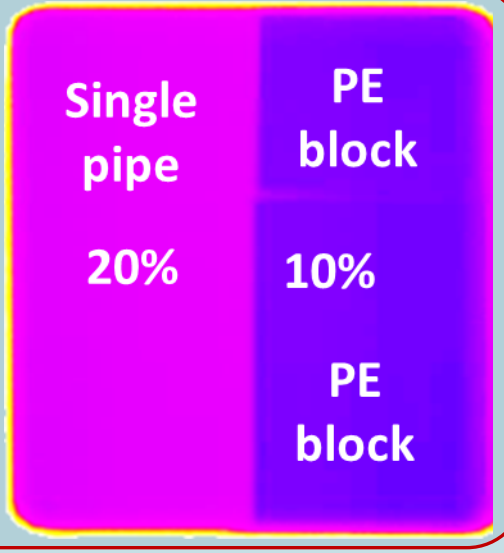
PE blocks observed through the single half-pipe



FRM II: significative breakthrough 2/2

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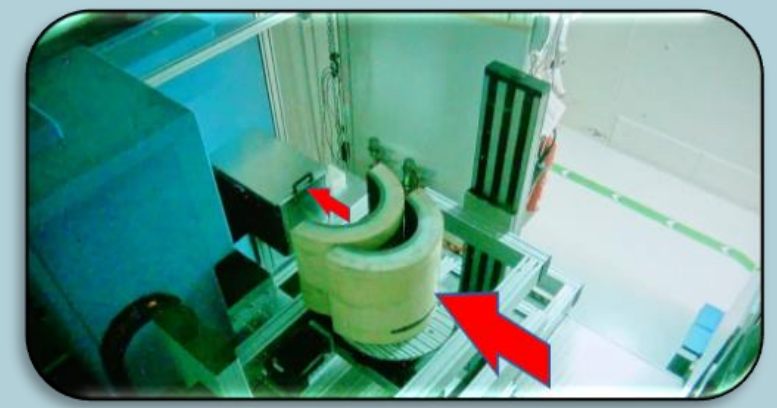
Neutrons: Penetration capacities

- **Neutron radiography through the pipe structures in the NECTAR hall at the FRM II**
- **Worst case scenario: double pipe**

High energy Fast neutrons 1,8 MeV

Experiment disposition in case of the double pipe



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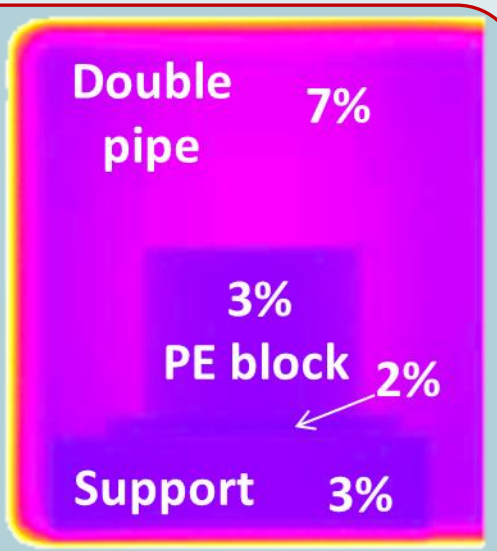
PE blocks observed through the two half-pipe superimposed



FRM II: significative breakthrough 2/2

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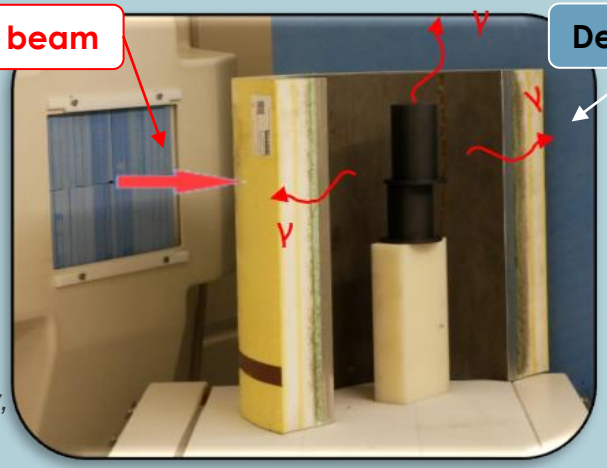
Gamma rays: Penetration capacities

- Identification of the content of the pipeline with the FaNGAS instrument in the MEDAPP hall at the FRM II

High energy
Fast neutrons
1,8 MeV



Experiment disposition in case of the single pipe

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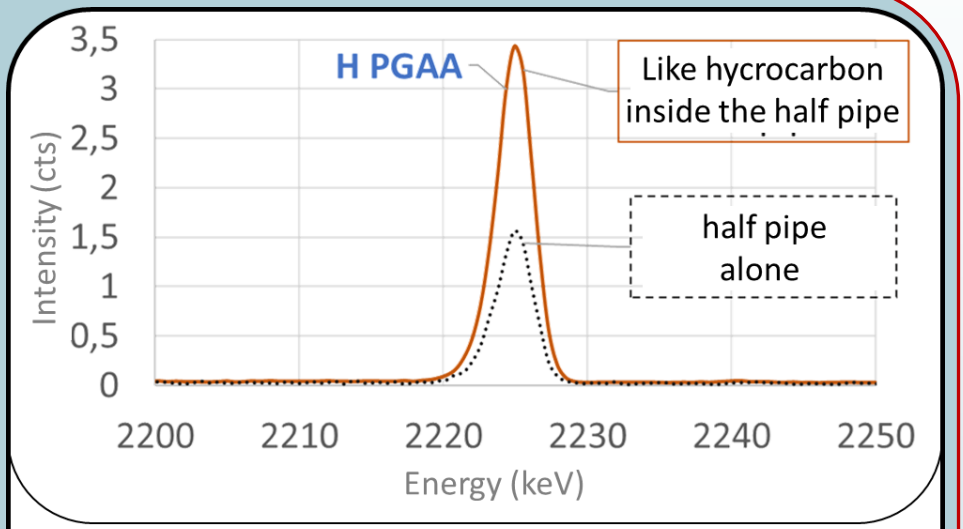

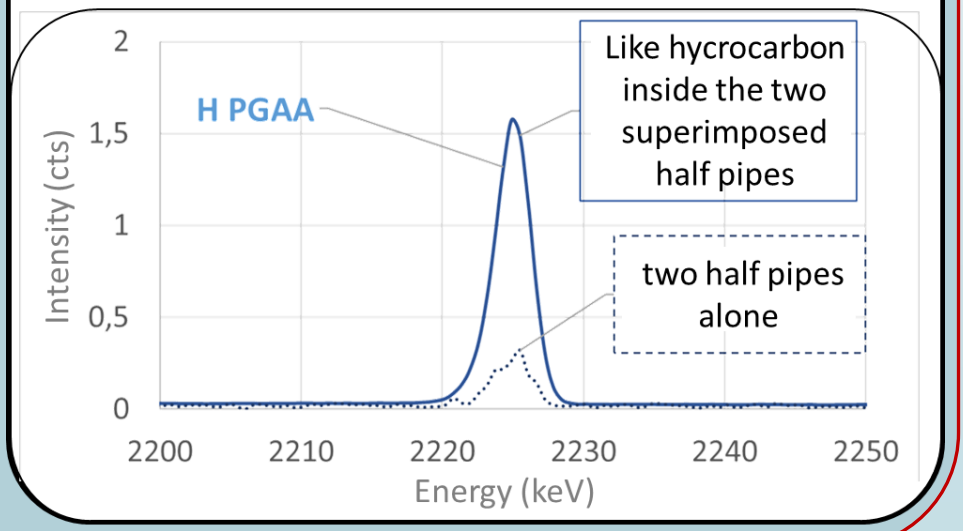

FRM II: significative breakthrough 2/2

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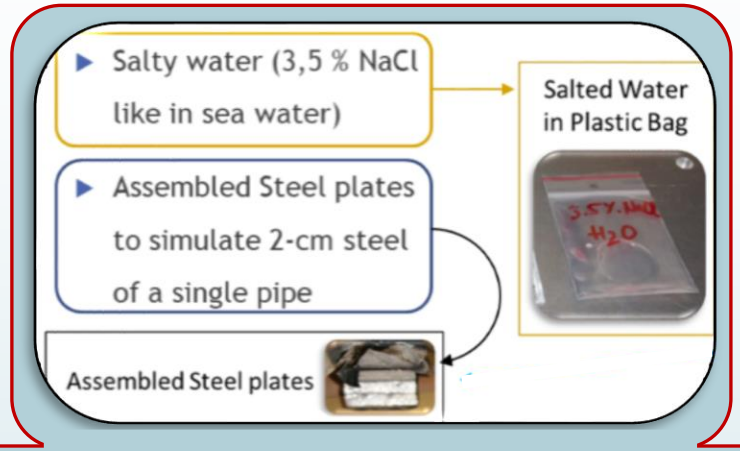
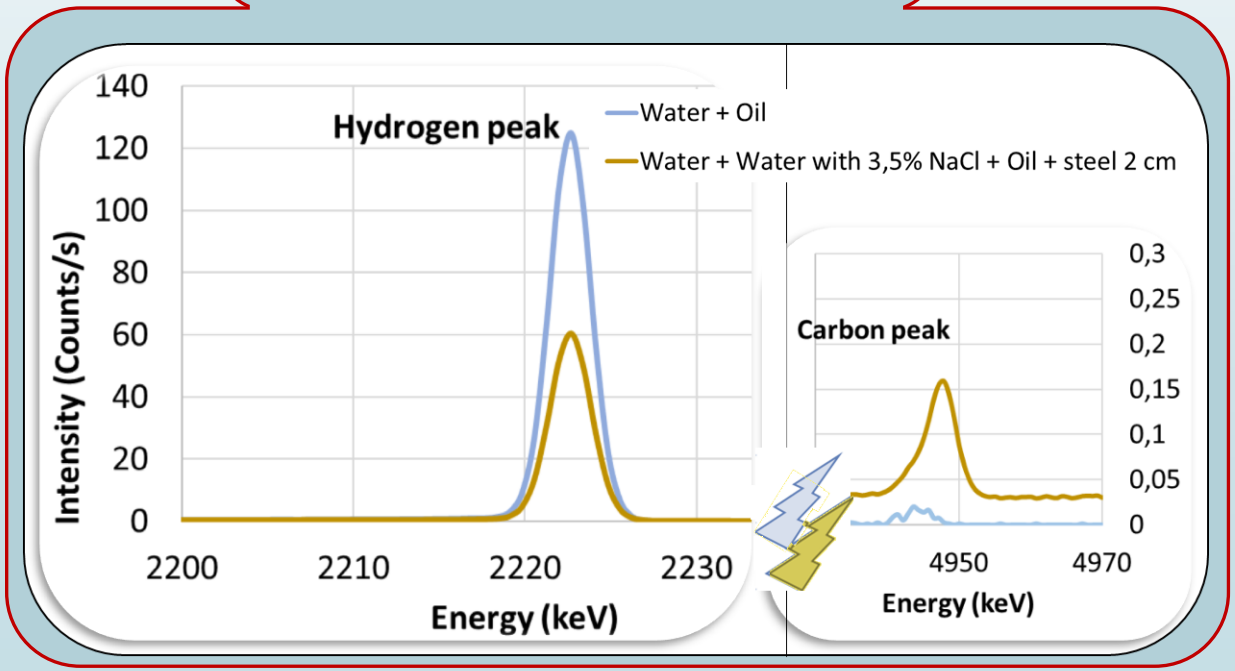
Oil & Gas Industry

Real deep sea environment

- Conditions simulating real deep sea environment
- Detection of hydrogen and carbon peaks variations still possible





Conclusion : significative breakthroughs

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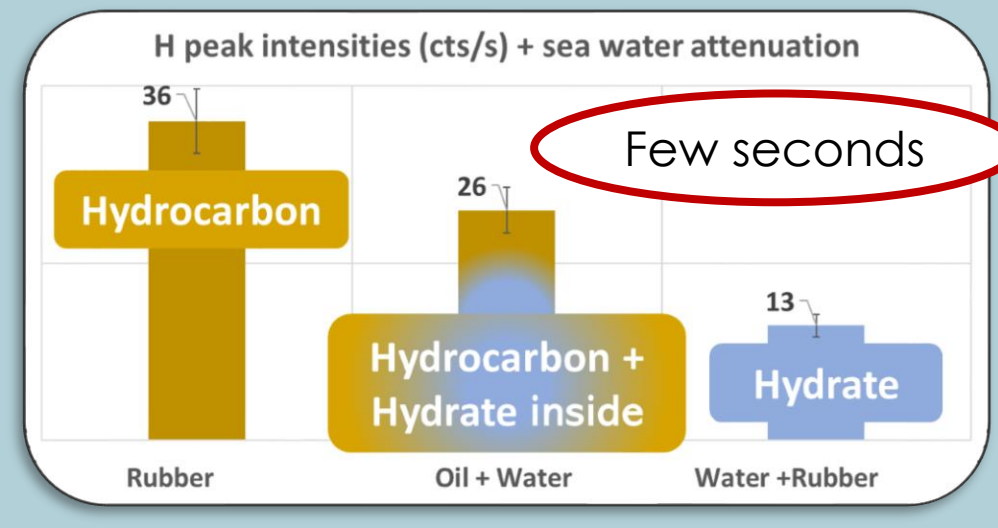
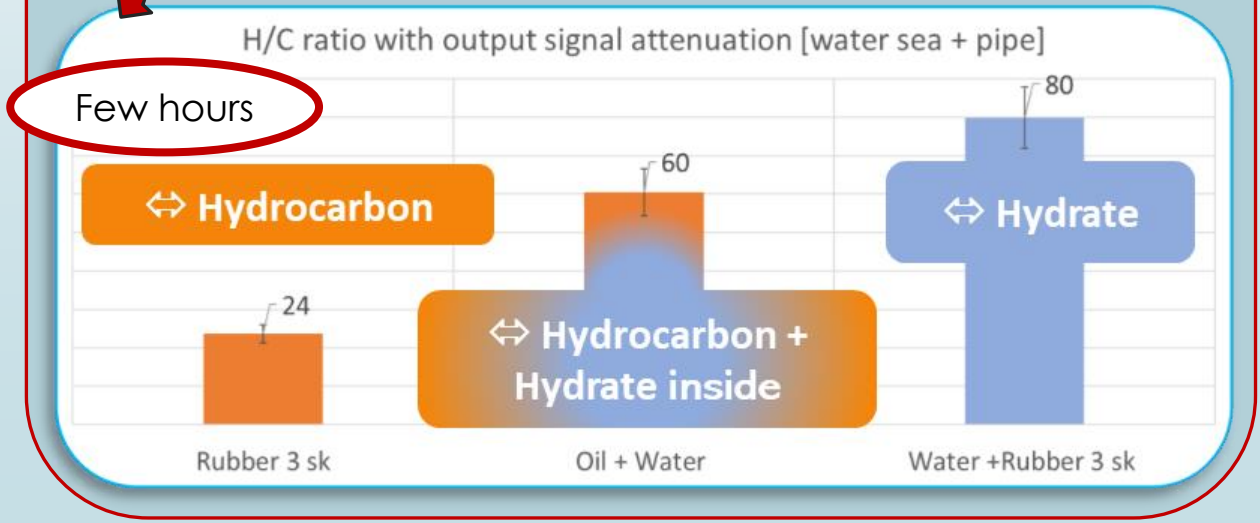
Discrimination possible

- Both neutrons and gamma rays can go through the thick pipeline structures
- Discrimination possible even in conditions simulating real deep sea environment





Conclusion: neutrons, the ideal probe

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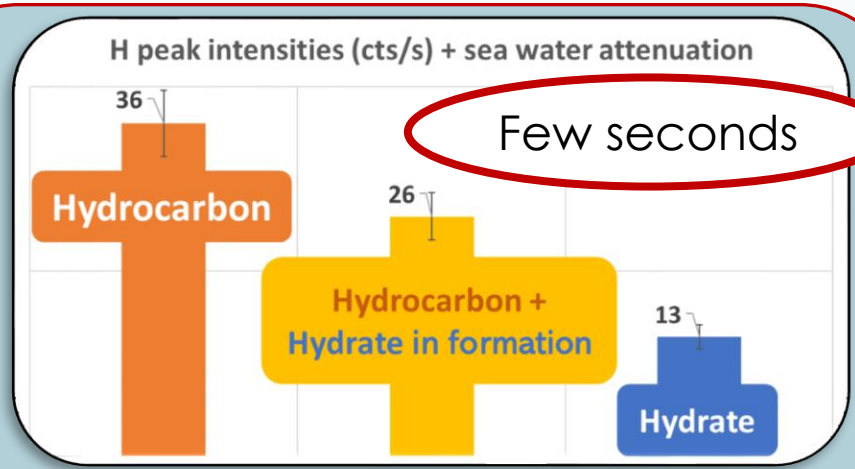
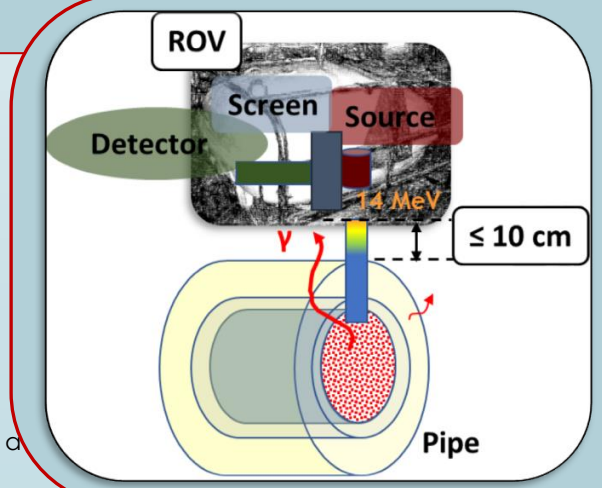
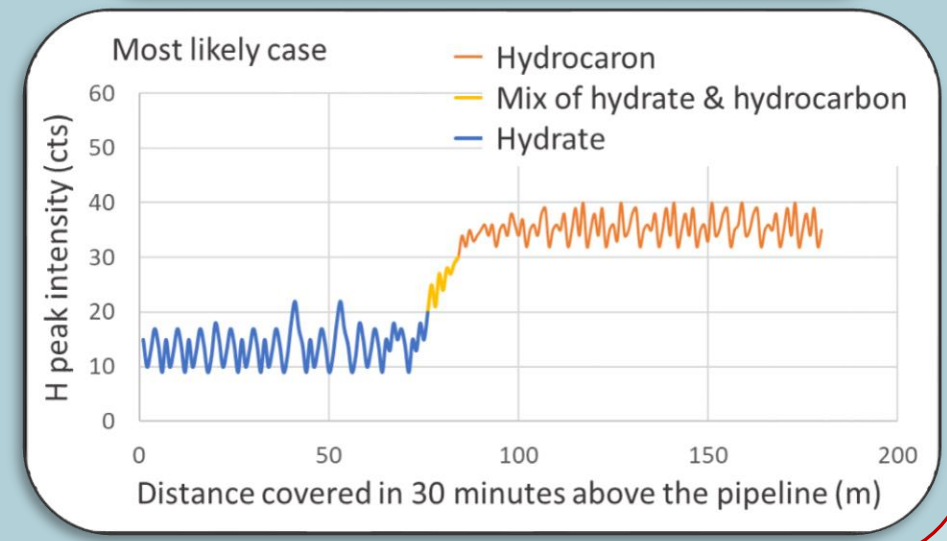
Following hydrogen peak intensity variations

- **Contactless & in situ analysis of sub-marine pipeline content in deep sea water with neutrons as a probe: easy discrimination between hydrate & hydrocarbon**







S. Bouat, L. Pinier, X. Sebastian, A. Losko, R. Schütz, M. Schulz, Z. Revay, Z. Ilic, E. Mauerhofer, T. Brückel and R. Gilles, "*Detection of hydrate plugs inside submarine pipelines using neutrons*", Nondestructive Testing and Evaluation (2022), Vol. 37 (3), p. 245-257.

Thank you for your attention

- **Questions?**

Member of the MIXN network - https://mixn.org/

Mediators connecting Industry to X-rays and Neutrons

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11/07/2023