FE-G (AND A PINCH OF FE) IN SITU THM AND GAS EXPERIMENTS

EURAD GAS+HITEC DOCTORAL SCHOOL, Liège, 31.08.23

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nagra.

KEY TOPICS

- Full Scale Emplacement experiment (FE)
- Some THM data from FE
- FE-G: gases as proxy for chemistry
  - 9 years of monitoring
    - Oxygen
    - Helium
    - Methane
  - Summary of observations for safety
  - Work in progress

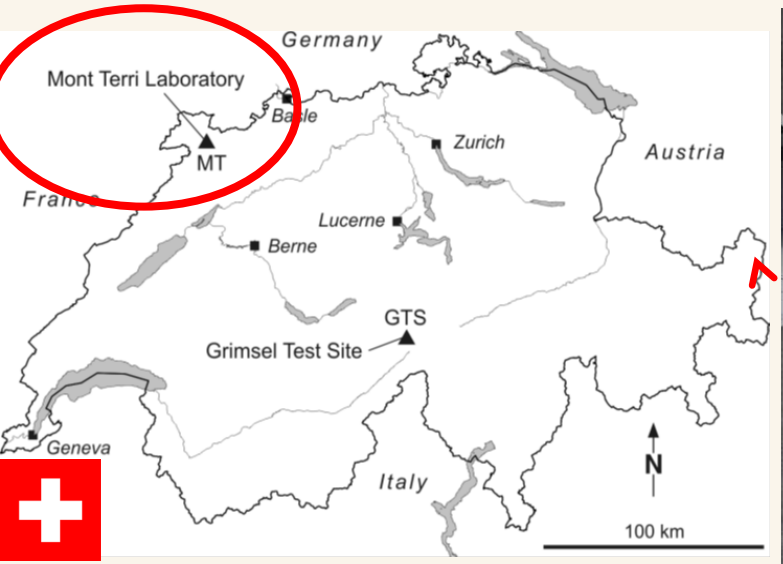
FE- THM

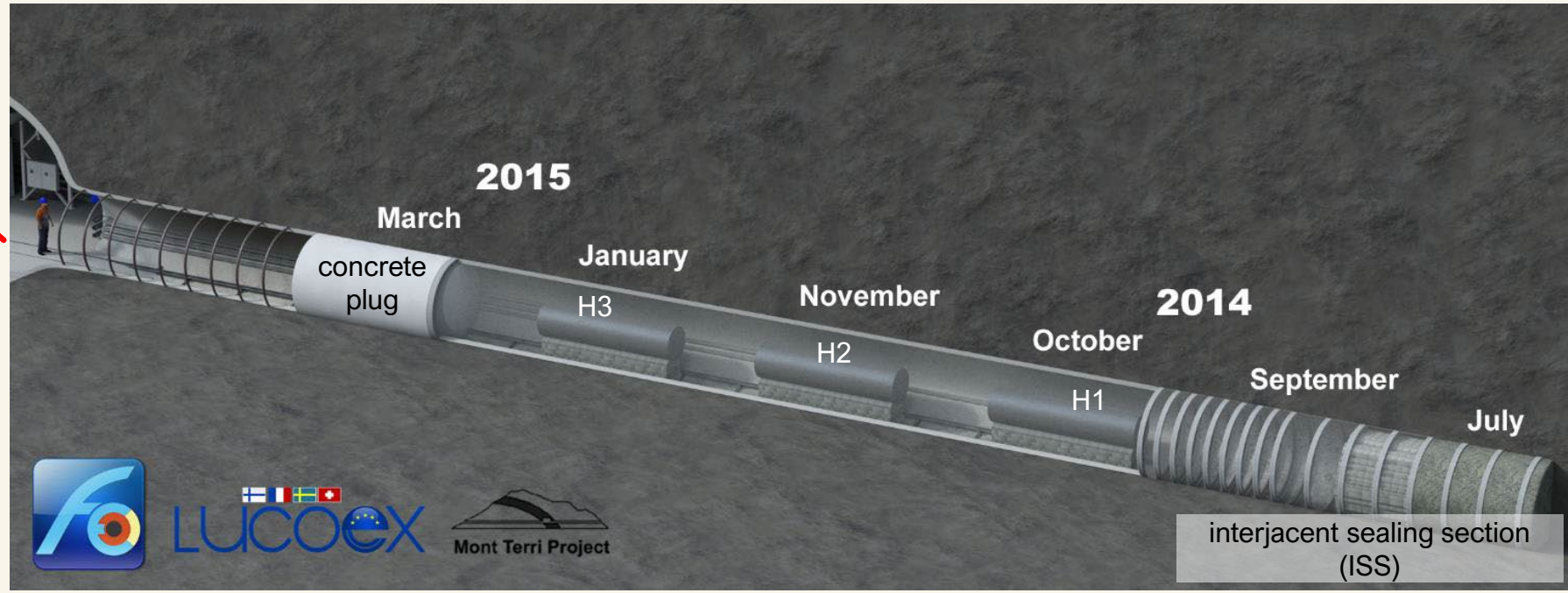
ANDRA BGE BGR FANC federaal agentschap voor nucleaire controle GRS nagra. Nuclear Waste Services nwmo

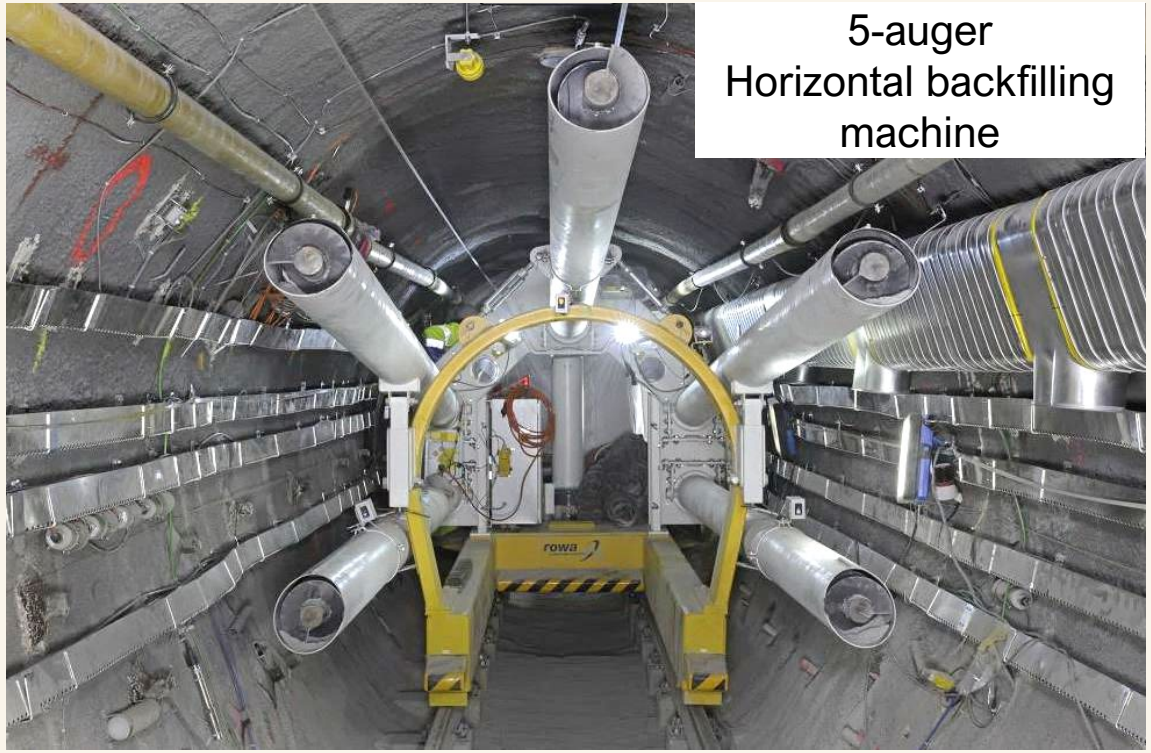
FE OBJECTIVES AND SET UP

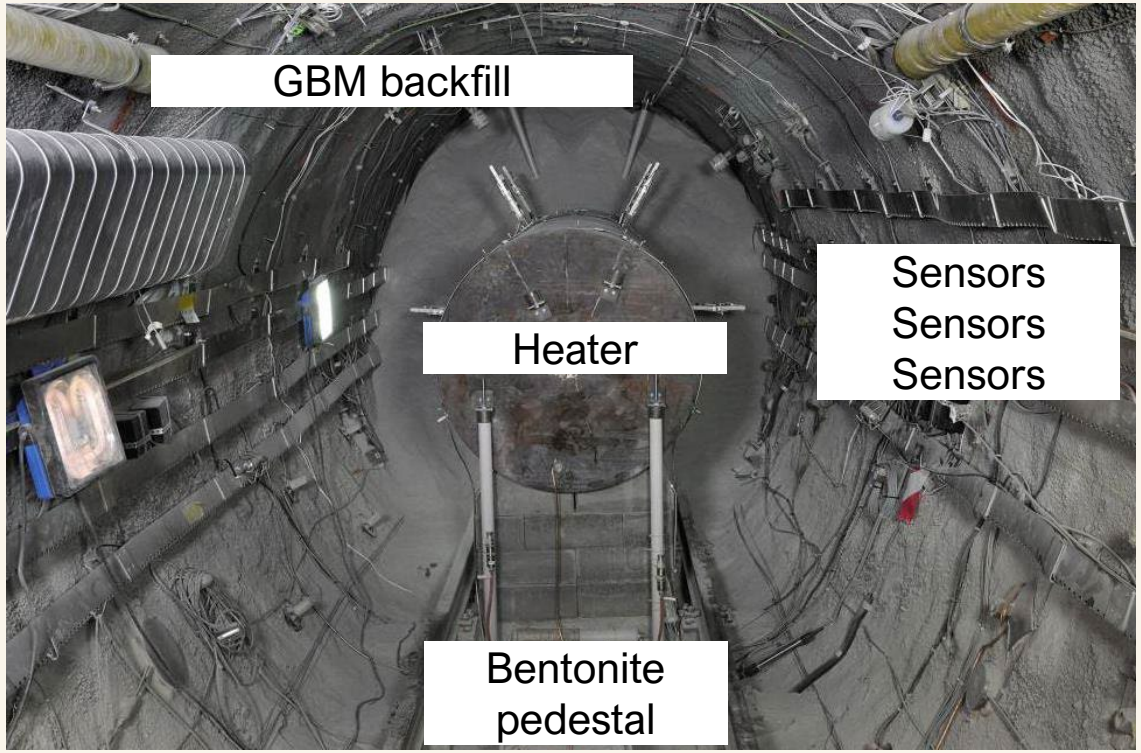
1:1 Full Scale simulation of HLW waste generic Emplacement in Opalinus Clay

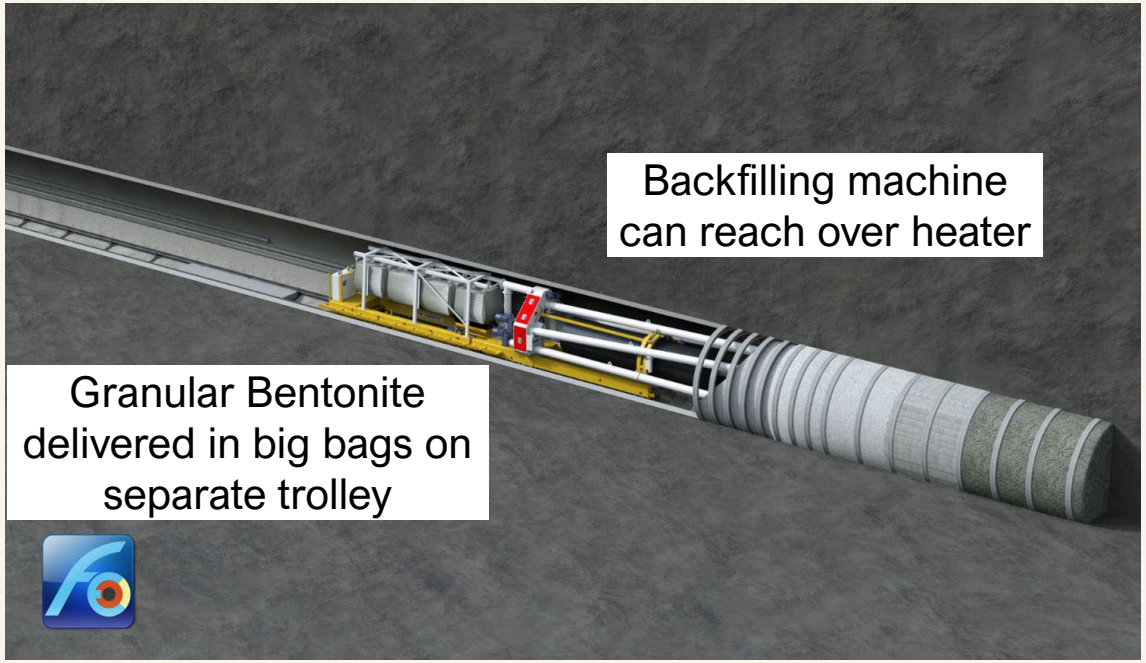
- Simulation of construction and emplacement techniques – feasibility
- Investigation of repository induced thermo-hydro-mechanical (THM) coupled effects on the host rock

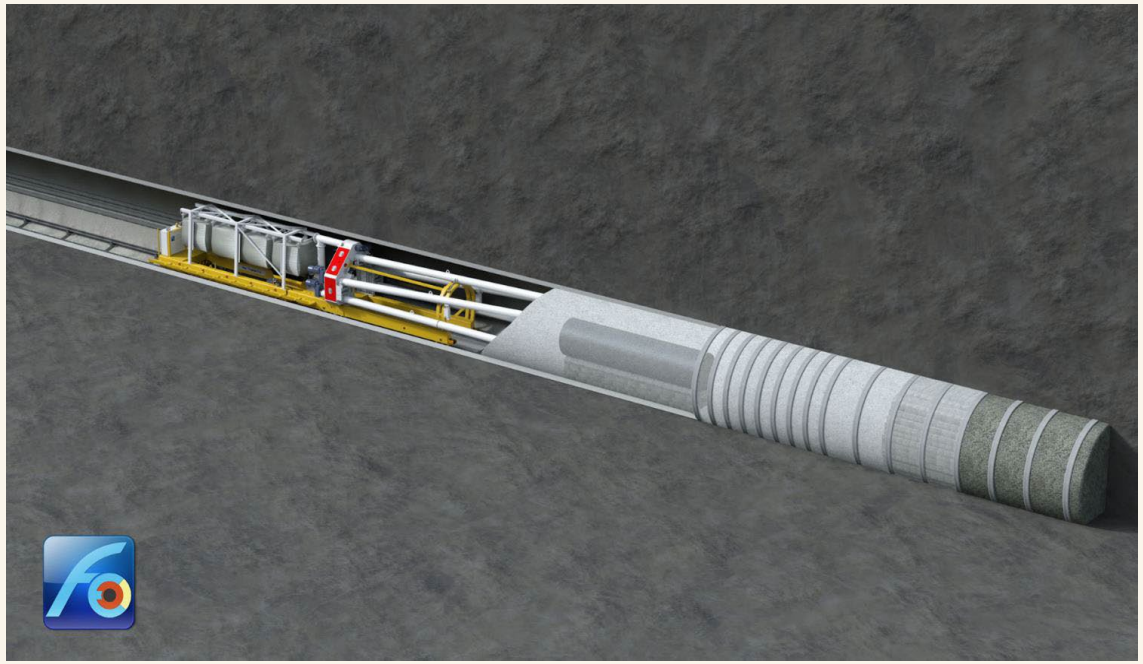




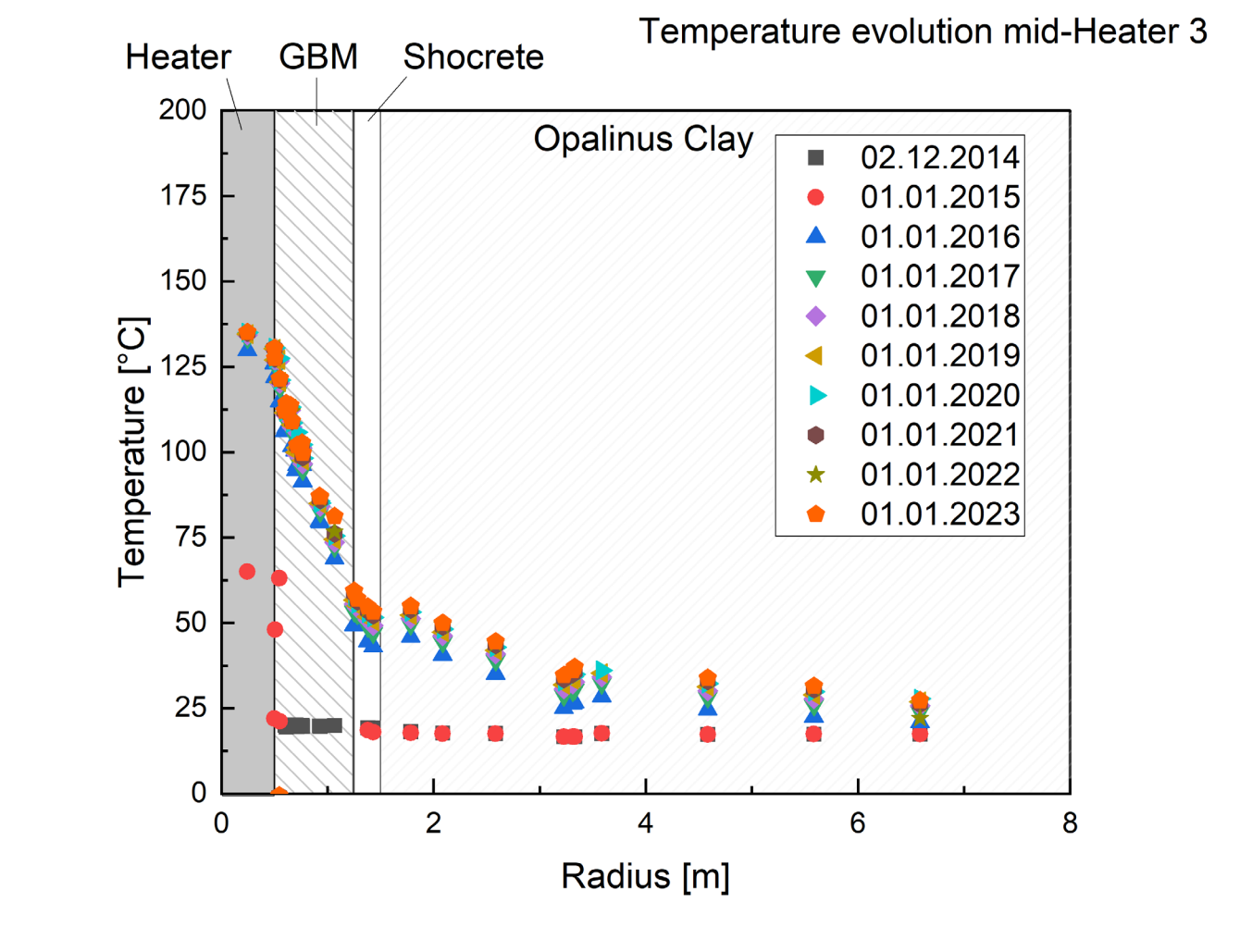

5-auger
Horizontal backfilling
machine


GBM backfill
Heater
Sensors
Sensors
Sensors
Bentonite
pedestal


Backfilling machine
can reach over heater
Granular Bentonite
delivered in big bags on
separate trolley

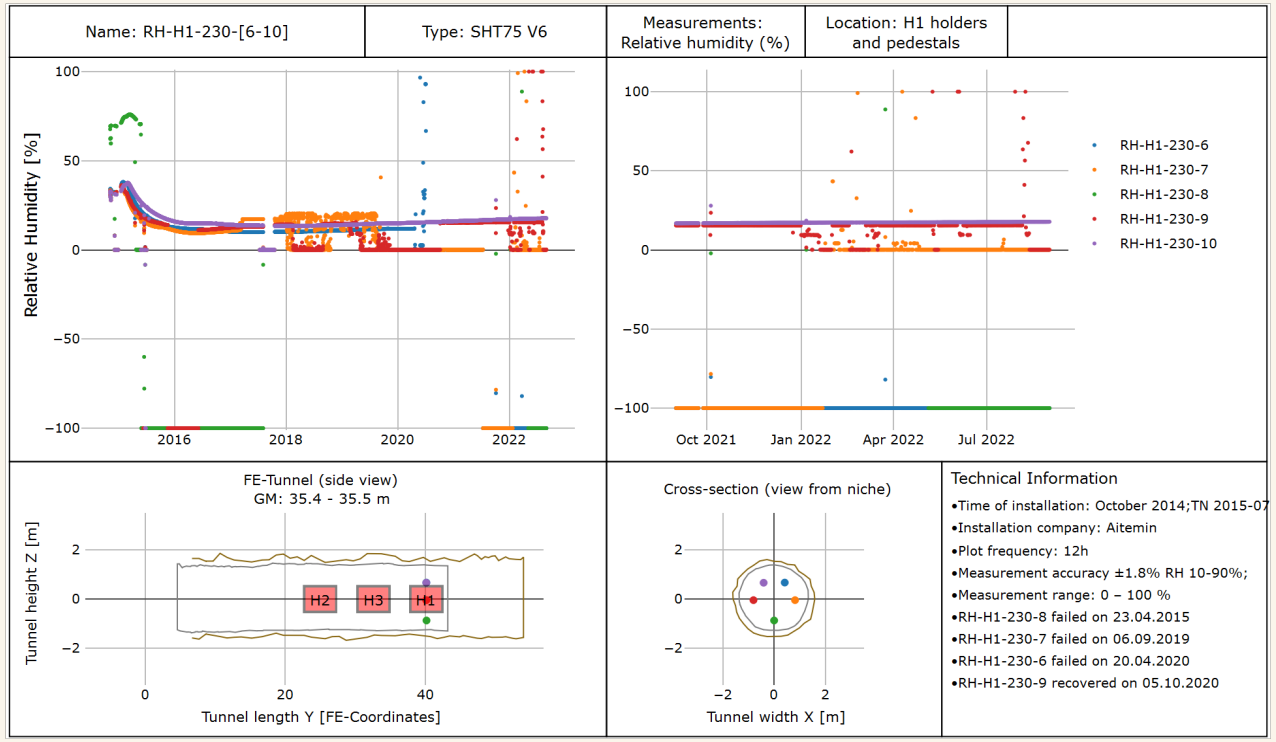


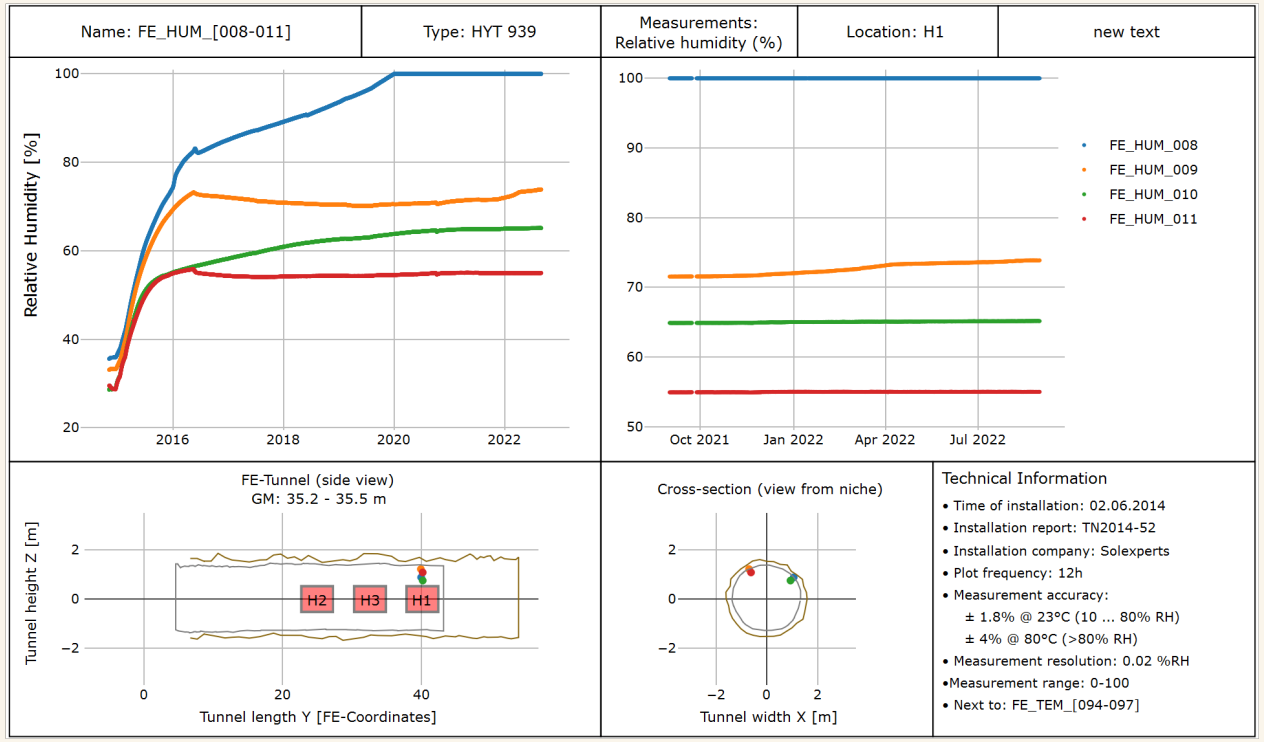
FE DATA - TEMPERATURE



- Heater
  - Top: ~135°C
  - Centre: ~133-135°C
  - Bottom: ~126°C
- Gap: ~55-60°C
- GBM from 125 to ~50°C
- Tunnel wall
  - SC: ~50°C
- Near field from 50 to ~25°C

FE DATA – RELATIVE HUMIDITY





- 65% sensors in operation
- RH close to Heaters shows increase of RH in 2015, drying, then slight increase in RH
- RH at tunnel wall shows increase, mostly in 2015 (initial 20-30%, current 60-90%, wet spots 100%)

FE MODELLING TASK FORCE

Mission:

- Elaborate models of the FE with THM codes, capable to mimic the complete history of the experiment
- Elaborate workflows for predictive modelling of temperature, pore pressure evolution and stress-strain behavior in the bentonite buffer and the host rock

Tasks:

1. Code-to-code comparison / Code & Calculation Verification – C&CV (CodeBright / CodeAster / OpenGeoSys)
2. Back-analyses of FE monitoring data
3. Prediction evaluation exercise

FE-G THE GASES

eawag
aquatic research

ANDRA

Mont Terri Project

Nuclear Waste Services

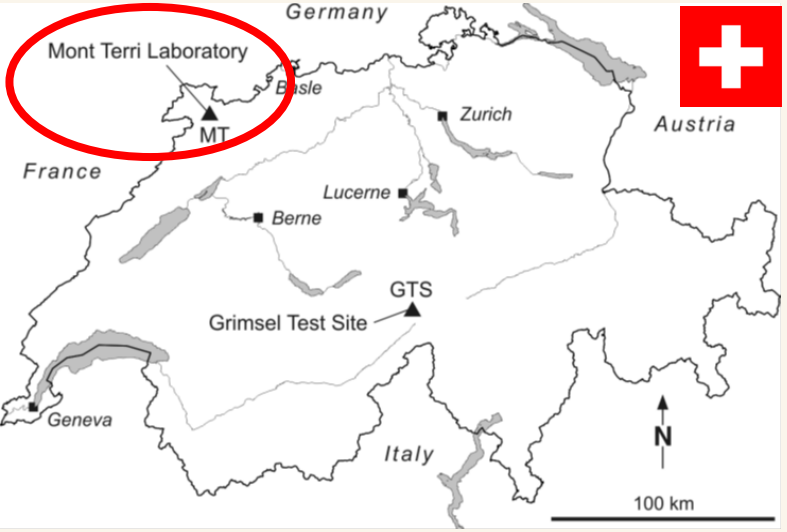
nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION

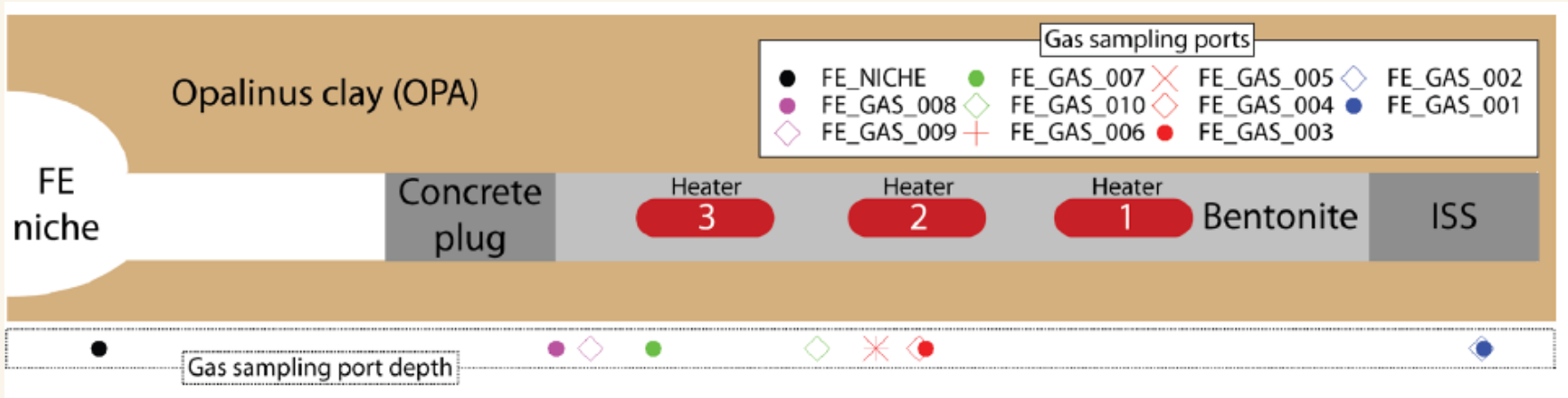
nagra.

FE-G OBJECTIVES AND SET UP

Processes controlling gas phase evolution in an emplacement tunnel for HLW/SF (FE)

Monitoring and modelling gas evolution for long term safety (pressure build up, reactions)





- Measurements
  - 6 in-situ O_2 sensors emplaced within the tunnel
  - Twice per year gas sampling of 10 port lines for off-site analyses – gases, isotopes
  - On-site mass spectrometer miniRUEDI for monitoring

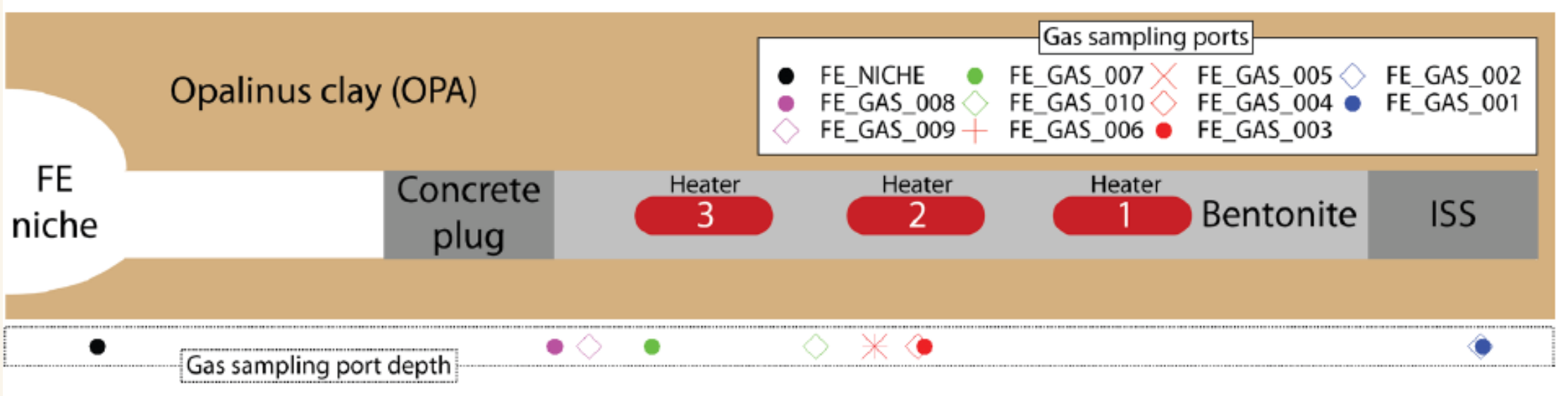
FE-G CAVEATS

Concrete plug is not gas tight

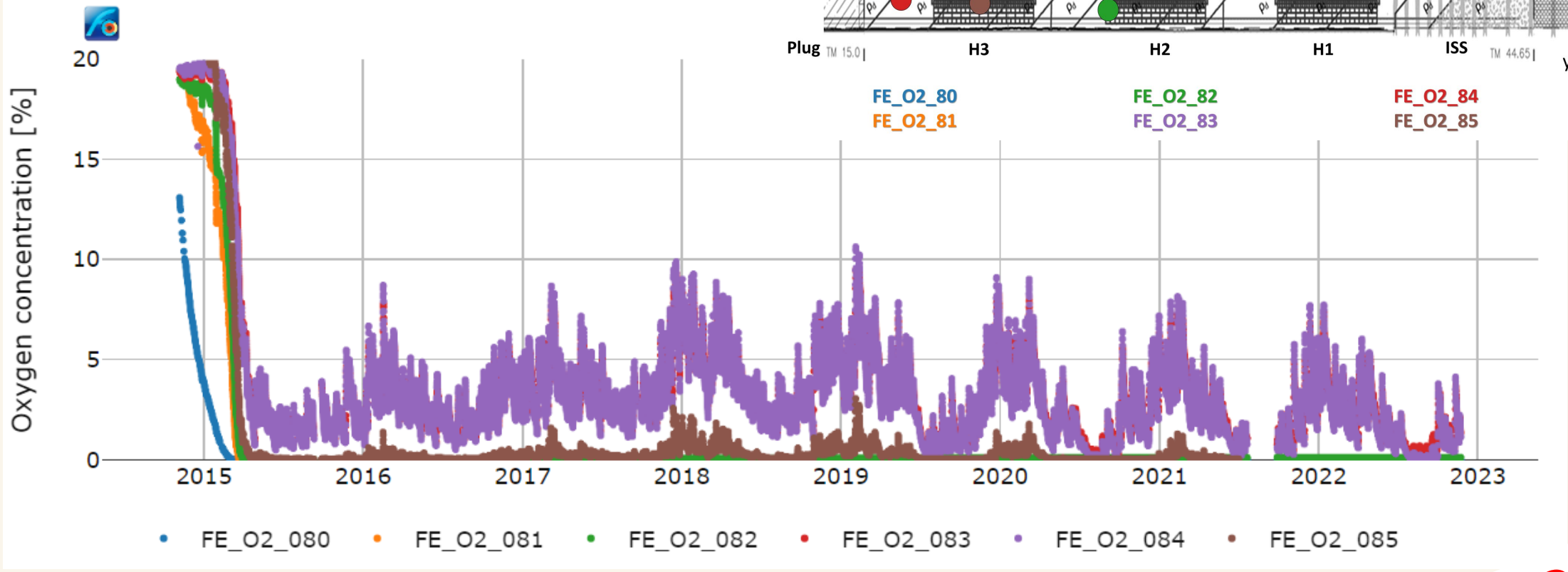
Excavation Damaged Zone (EDZ) in contact with air - resaturation

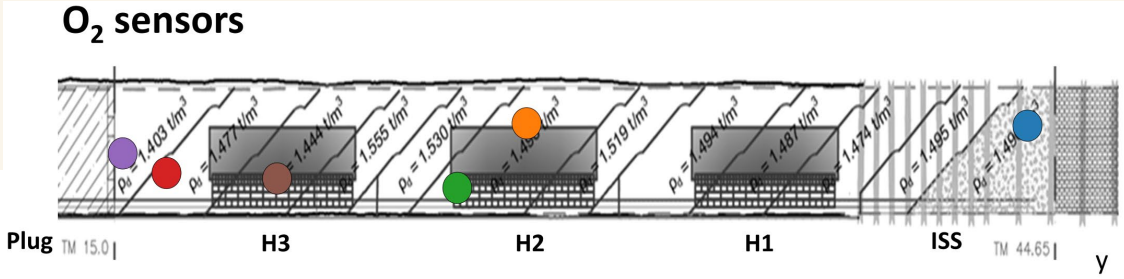
Material set up:

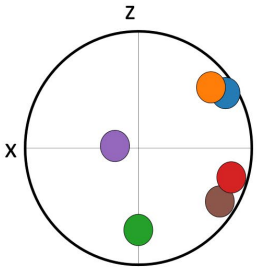
- Metallic components – corrosion
- H_2S not collectable



FE-G - OXYGEN







- Rapid O_2 loss at early stages of emplacement
- O_2 exchange with niche - ongoing
- O_2 decrease between concrete plug and heater 3 - ongoing

Any ideas???

FE-G - OXYGEN MODELLING

Extended 3D COMSOL model for early evolution of O_2

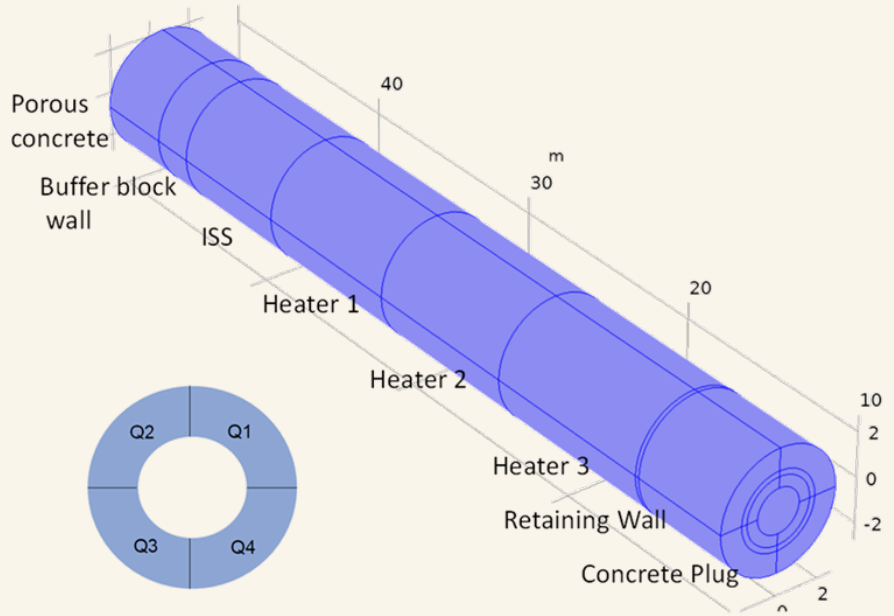
- First O_2 budgeting in model

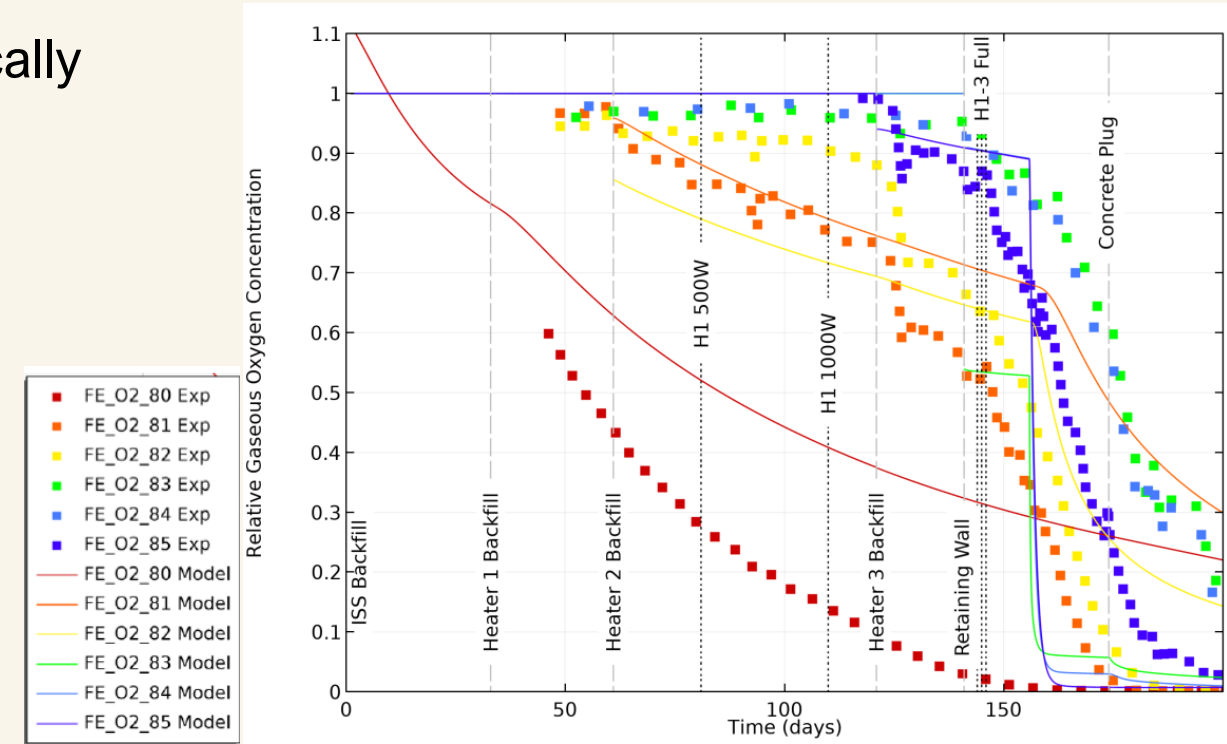
Narrowed down the processes impacting early O_2 budget

- O_2 reversible sorption onto dry bentonite
- O_2 reactions where RH is high enough – also only locally

Current work:

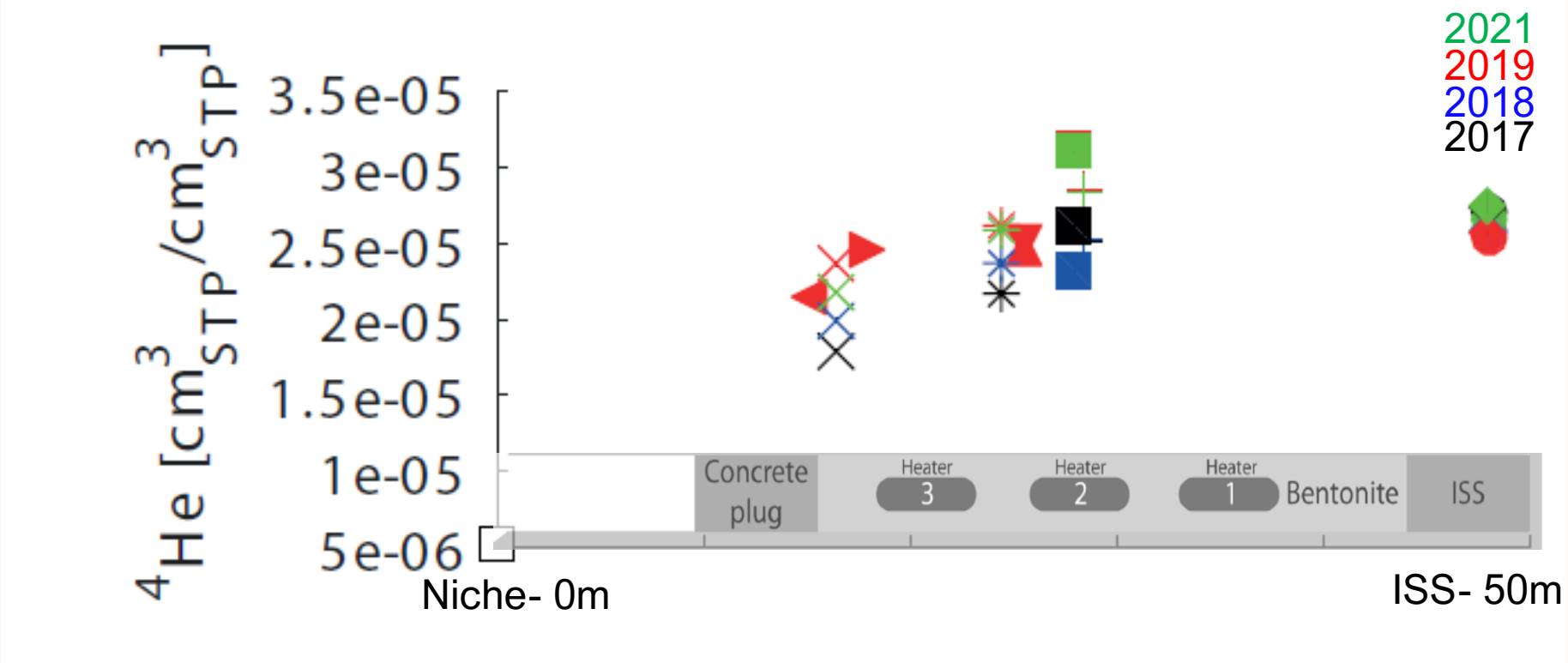
Polynomial fit, canisters, mesh refinement, EDZ



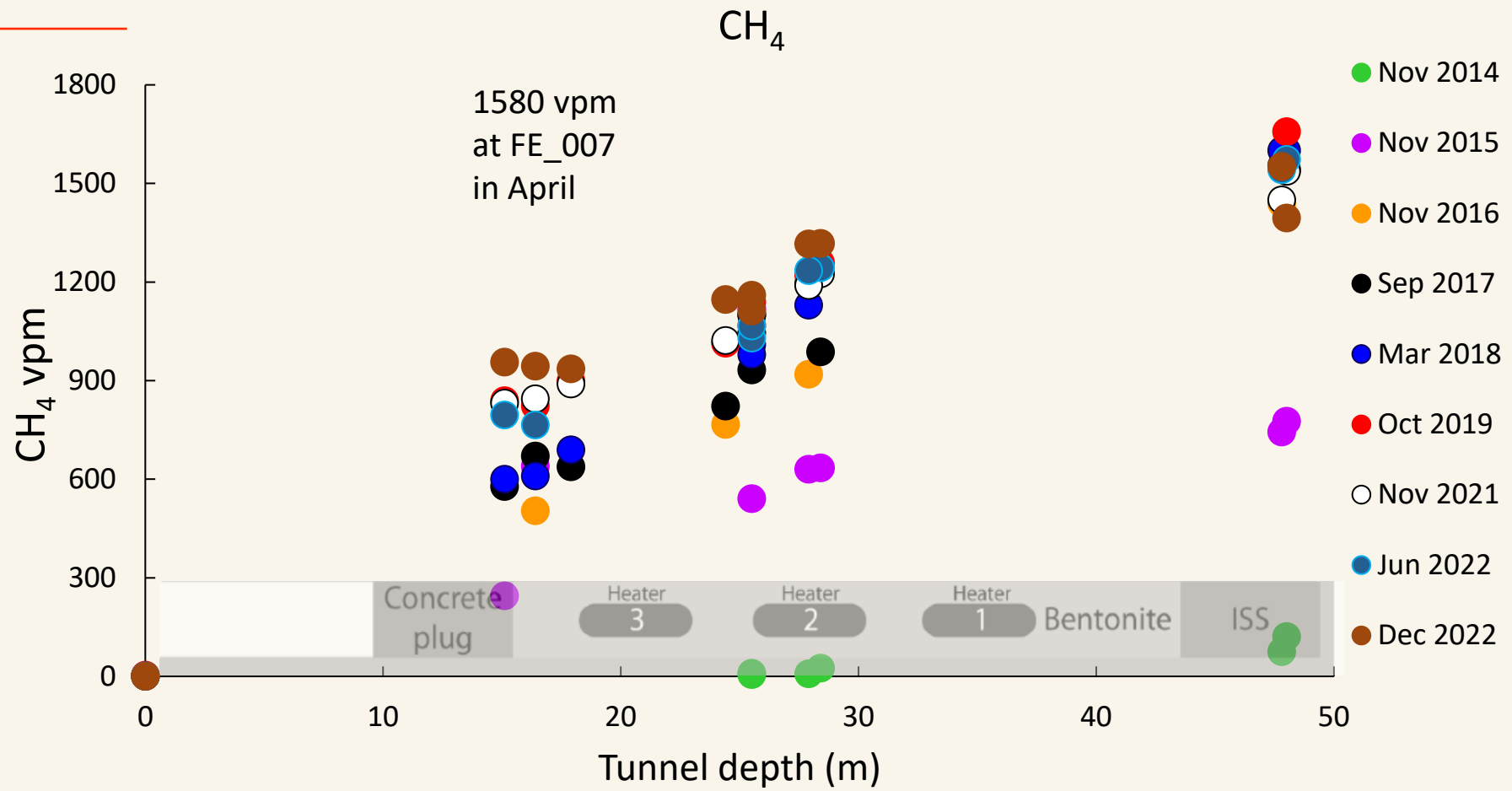


FE-G - HELIUM

- Indicates terrigenic ^4He gas exchange with OPA pore water
- Slight temporal accumulation
- Some decrease of concentrations towards the plug – air mixing

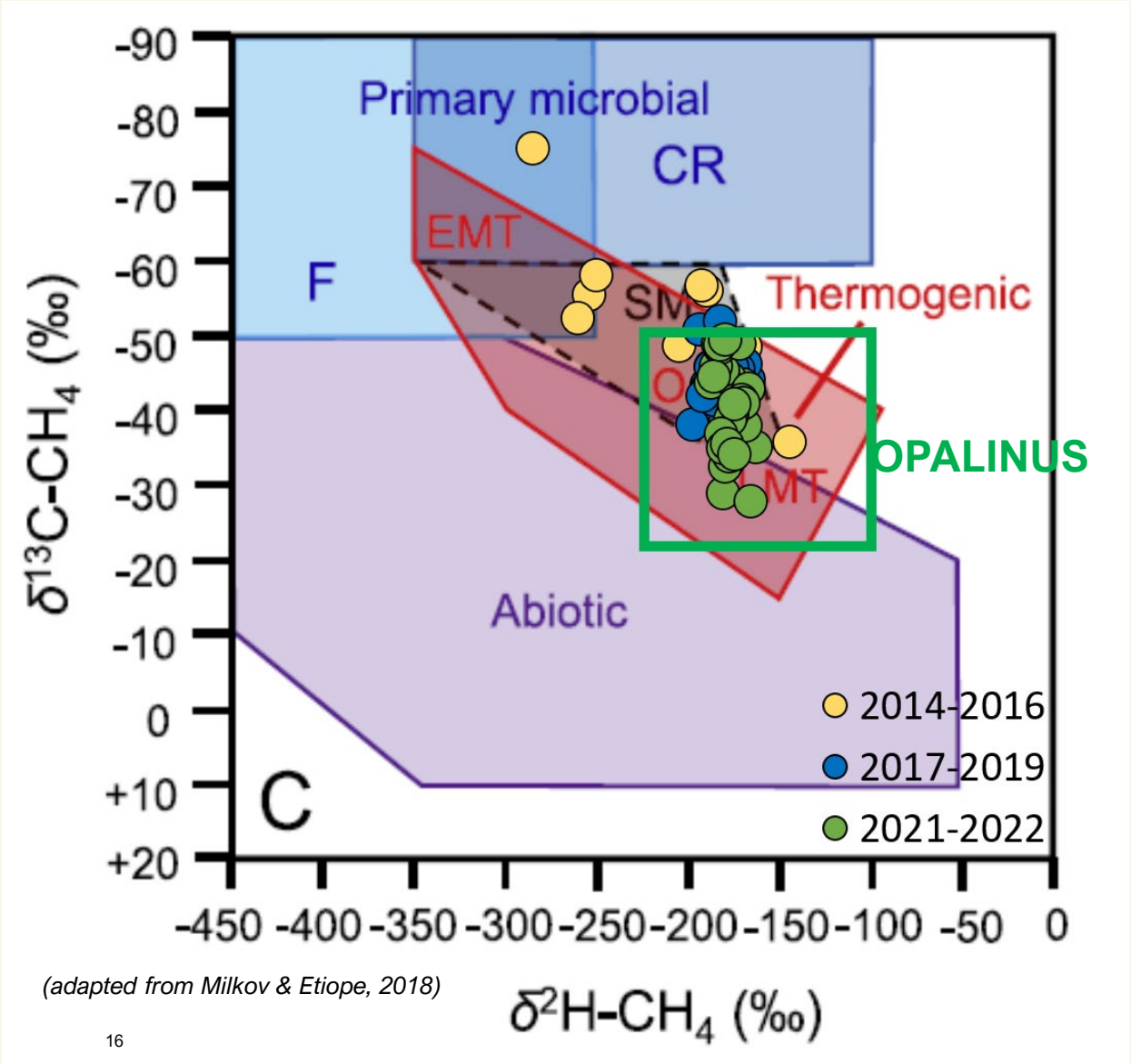


FE-G - METHANE



- CH_4 accumulation from OPA pore water
  - Concentrations compatible with OPA pore water (Vinsot et al., 2017)
  - More marked decrease across the tunnel compared to ^4He – lower atmospheric abundance + air dilution

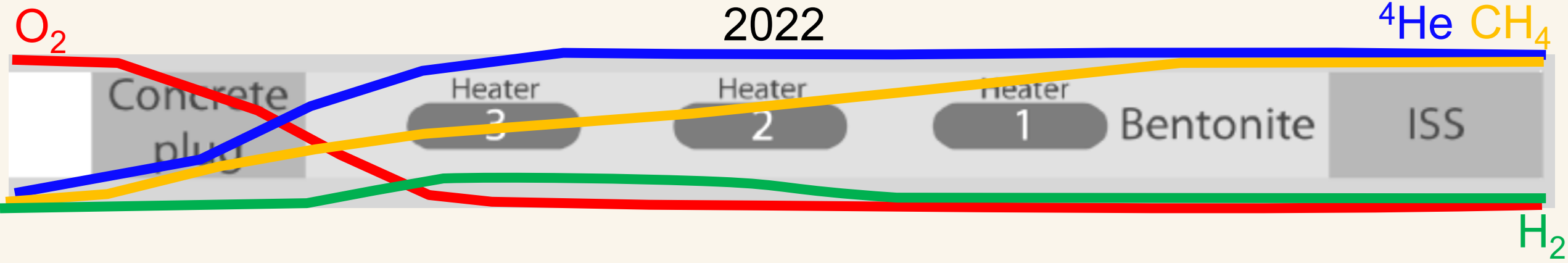
FE-G - METHANE ISOTOPES



(adapted from Milkov & Etiope, 2018)

After variability at the beginning of the emplacement, when methane concentrations were low, values stabilised towards a range typical of OPA pore water

FE-G - SUMMARY FOR SAFETY



- No gas pressure build up or anomalous gas observed (plug and EDZ!!)
- Ongoing temporal gas changes and dynamic system during heating phase
  - O_2 budget at early emplacement phase for corrosion, ongoing O_2 diffusion/advection
  - He accumulation from OPA
  - CH_4 later emplacement phase from OPA

FE-G: INTERPRETATION STRATEGIES AND WORK IN PROGRESS

- O_2 at early emplacement for budget
  - Implementation of COMSOL model #4 (fits, canisters, RH of pedestal sensors, refined mesh)

- Gas fluxes – conservative steady state conditions
  - Noble gases data and P sensors
  - Diffusion/advection (air) model based on ^4He and P
  - Role of EDZ

- CH_4 and hydrocarbons investigations

- Comparison with similar emplacement studies (i.e. HotBENT experiment)

FE-G recent reports

TN 2022-13 – model COMSOL #3
TN 2022-11 - lab results offsite analyses
TN 2022-09 – noble gases offsite analyses
NAB 19-36
Giroud et al., App. Geochem., 2018
Tomonaga et al., App. Geochem., 2019

Thanks

FE and FE-G Project Partners
FE and FE-G Contractors
You for your attention

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