Evolution of underground biology in LSM

Laboratoire Souterrain de Modane

2nd Dulia-bio meeting

November 4-5 2019

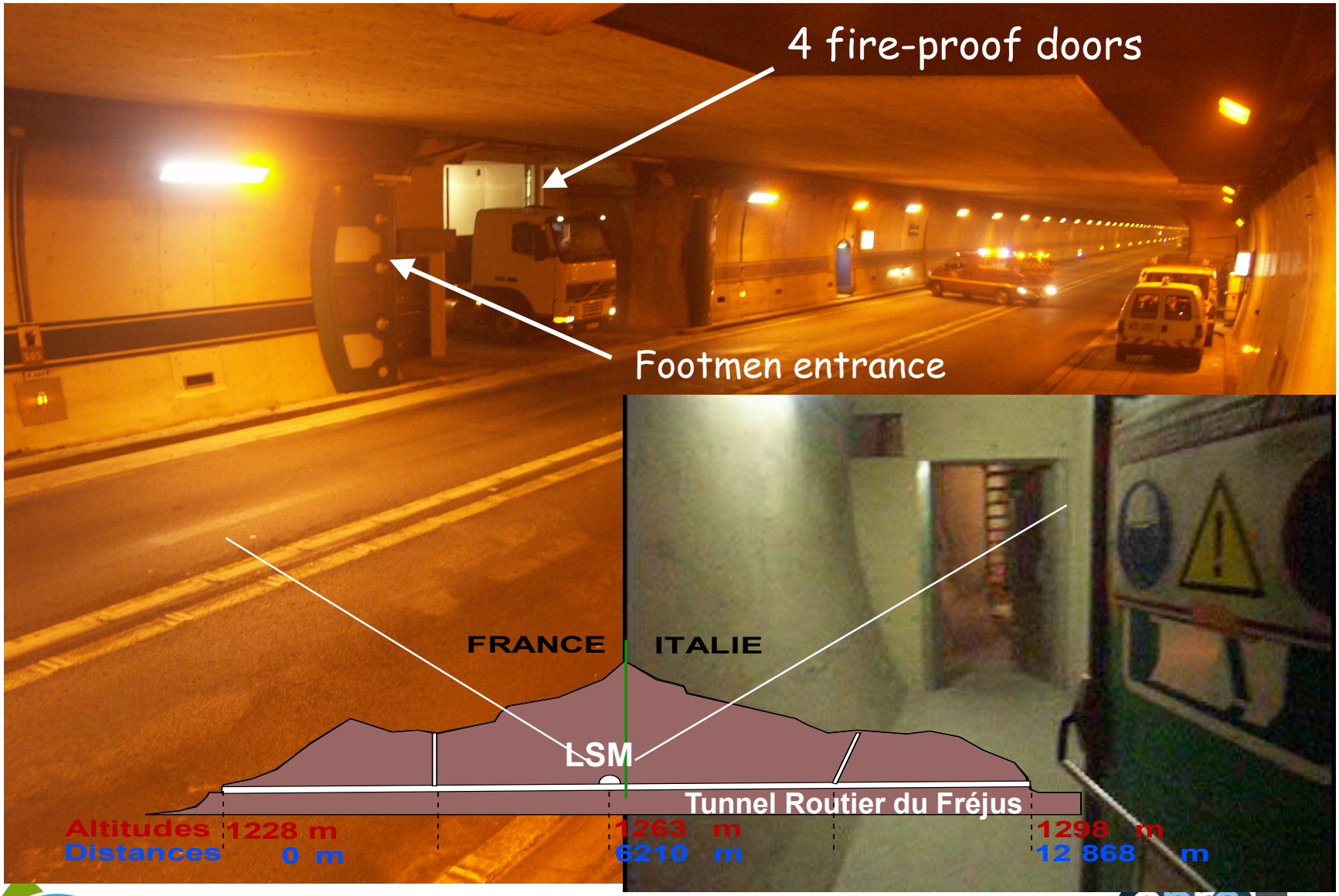
Laboratoire Souterrain de Modane

- Located in Modane,France
- Middle of Fréjus tunnel
- 12 permanents
- 1000 visitors days per year
- Wide range of interdisciplinary topics
- Astroparticles, nuclear physic, environment, electronics, radioactivity measurement, biology

Laboratoire Souterrain de Modane

- Merged with Laboratoire de Physique Subatomique & Cosmologie (LPSC-IN2P3) in Grenoble
  - 70 researchers, 90 Engineers & technicians
  - Covering fields in particle & nuclear physics, astroparticle and cosmology
- LSM now becomes a « national facility » as labelled by the CNRS
  - National facility for IN2P3 / CNRS
- LSM as a national experimental facility for :
  - Fundamental Physics
    - Neutrino property determination
    - Direct Dark matter search
  - Gamma spectrometry measurement
    - 14 detectors measuring continuously
    - Open to geosciences, materials, biology and medecine
      - Actually 1000 samples measured per year
    - PARTAGe project to automatize measurments
      - Increase significantly the scope of the LSM

Location and access



History of LSM

1979 - 1981 | **1982- 1990** | **1990- 2000** | **2000 - ….**

Digging | **Proton decay** | **Prototypes** → **Experiments**

- 2.10^{-6} n/cm2.S
- 4 µ/m2.d
- 3500m3
- 400m2

- 15Bq/m3 Rn in air
- Radonless air 125m3/h 15mBq/m3

Evolution of biology

- First test in 2011
- Culture of E.coli in underground condition

Guillaume Warot

LSM
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Biology at LSM

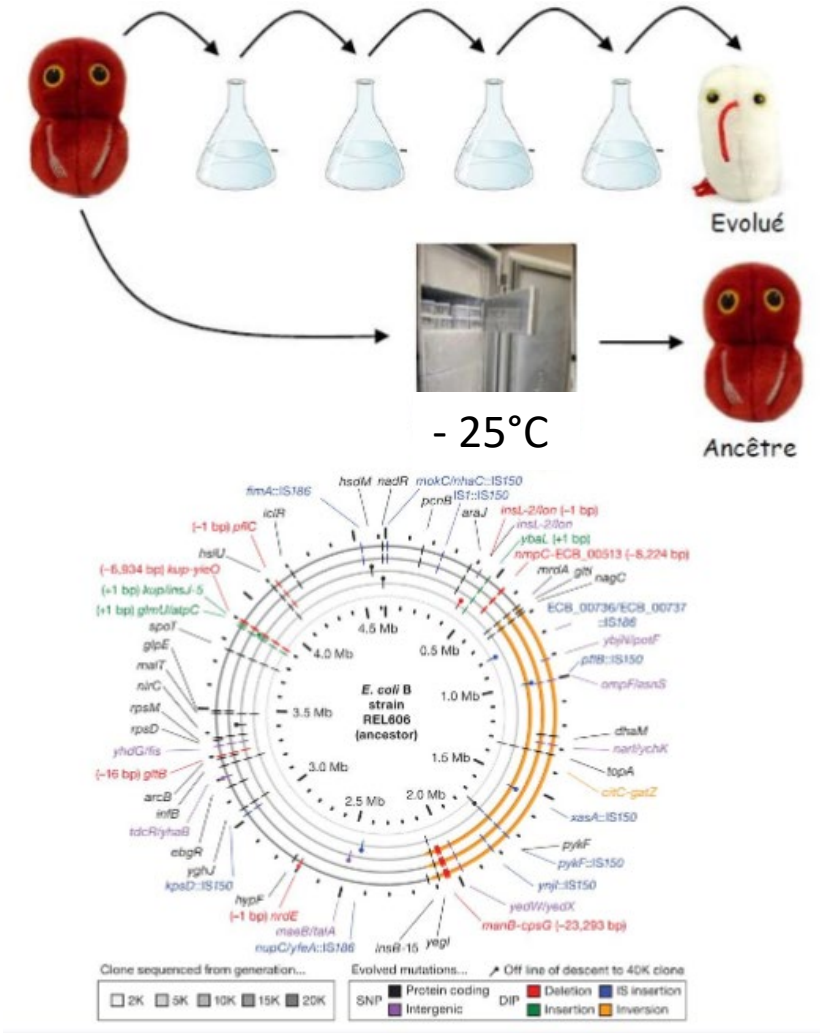
- Biology laboratory created in 2014
- Cleaner condition with PSV,incbator and more space for experiments
- Shielded fridge are running to alllow save of culture during experiment

Biology at LSM

- 2017 a clean room class 1000 was built
- CO flushed incubator are now available
- Radonless air inlet for additionnal radiopurity
- Ongoing debate on the dryness of such clean room

Evolution in vitro

- Comparison of E.Coli evolution between surface and underground
- Fitness tests against ancestor
- Most studied bacteria, easy to cultivate, cryosaved every 100 generation
- Comparison with R.Lenski et al depuis 1988



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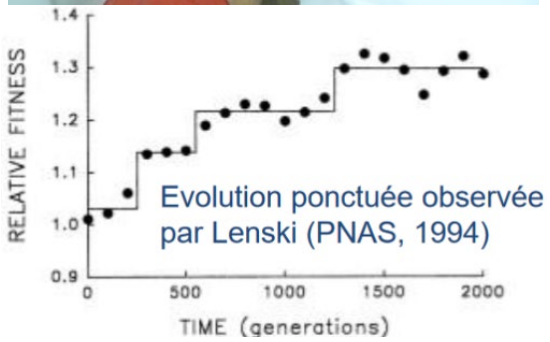
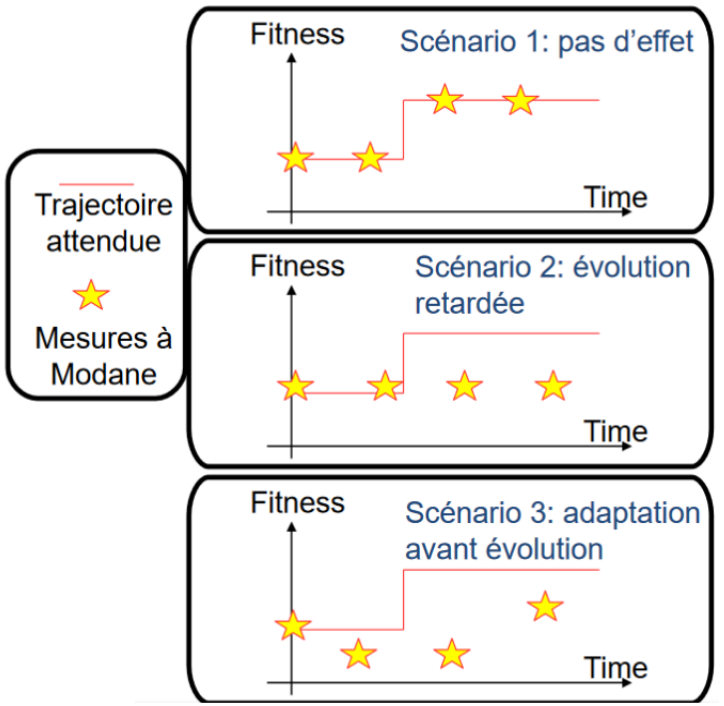
Evolution in vitro

- Radioactivity induces DNA modification
- driving force for evolution
- Suppression of IR leads to a measurable difference





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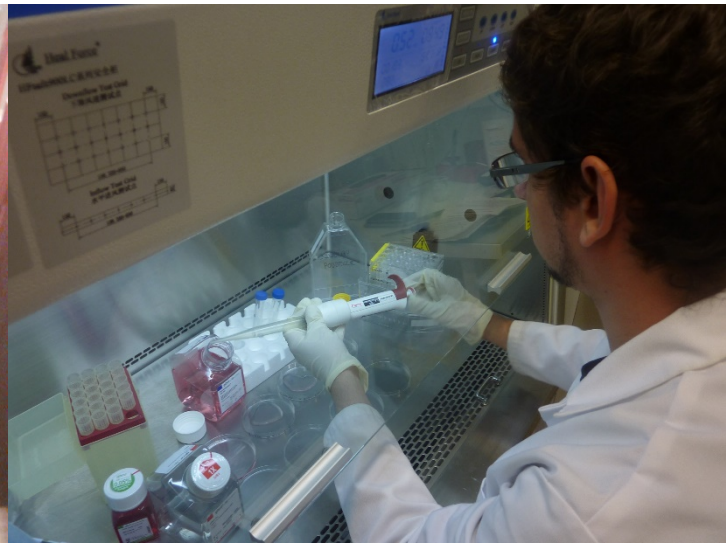
Evolution in vitro

- 800 generations were produced and stored
- So far no statistical deviation from Lensky
- Simulation were run to model the number of mutation under GEANT4-DNA
- Lampe et al Radioprotection 2015
- Lampe Dulia-bio 2015

Source	Measurement Method	LPC Clermont (nGy/day)	Modane (nGy/day)	Modane (shielded) (nGy/day)
γ background	Dosimeter measurement (rate varied by 10%)	2400	480	15
Muon flux	From theory	460	0	0
Potassium-40 (γ)	Simulations based on concentration	0.4	0.4	0.4
Potassium-40 (β)	Simulations based on concentration	74.4	74.4	74.4
Carbon-14 (β)	Simulations based on concentration	0.02	0.02	0.02
Total		2935	555	90

Muscle stem cells

- Culture of muscle stem cells
- Comparison between sea level and inside the lab
- Hard time to compare even with the material
- First 10% more cells at sea level, second run 20%more in the lab



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RaCS experiment LSM-Pasteur

- DNA is exposed to agression (chemical, biological, radioactivity…) but constantly repaired
- Stemcells have a wide potential of application
- By 2050 66% of diseases are expected to be tackled by stem cells application.
- 5516 clinical trials ongoing on 2016
- Harvest and cryostored for further application
- Cryostorage stops DNA reparation and chemical biological agression
- Radiations remain
- *L. J. Fernyhough, VA Buchan, LT McArthur and BD Hock ; Relative recovery of haematopoietic stem cell products after cryogenic storage of up to 19 years ; Bone Marrow Transplantation (2013) 48,32–35*

RaCS experiment

- Measurement of radiation impact
- Preparation of 4 cryostats with different exposures
- Measure of DNA DSB through foci counting
- Measurement of gene activities
- Engraftment potential measures

RaCS experiment

- Comparison to yearly dose
- integration of radon at the level cell is ambiguous but it will just scale the result

Condition	Depth (meter of water equivalent)	Cosmic ray dose (mSv/year)	Total dose (mSv/year)	Neutron flux (neutron/cm^2.s)
Reference I	10	0,04	0.52 – 1.77 (calculated)	3.10^{-3}
Altitude II	0	1.17	1,65 – 2,91 (calculated)	10^{-2}
Increased III	0	1.17	76.65 (measured)	10^{-2}
Deep underground IV	4800	$<2.7\ 10^{-6}$	$<2.7\ 10^{-6}$ (calculated)	3.10^{-6}

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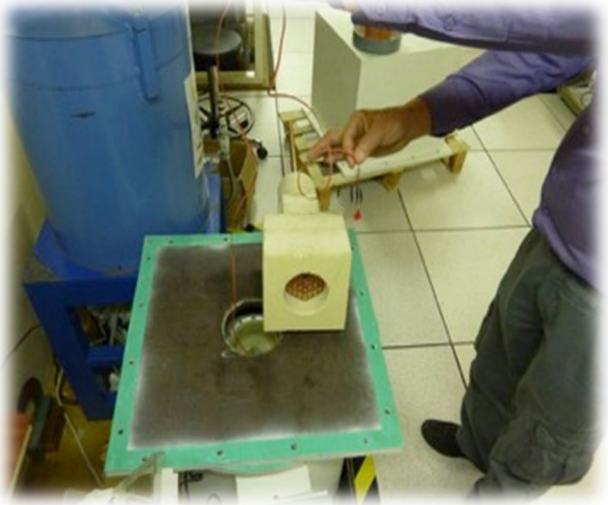
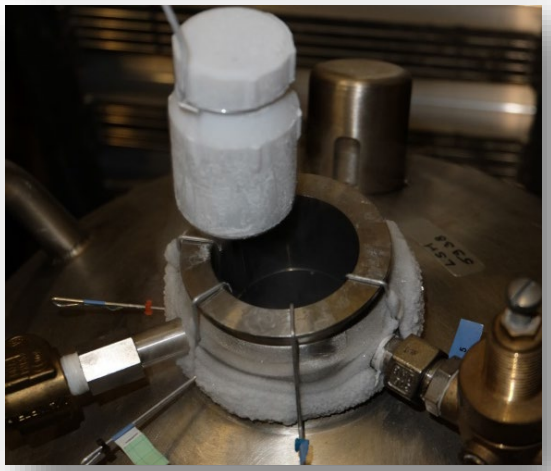
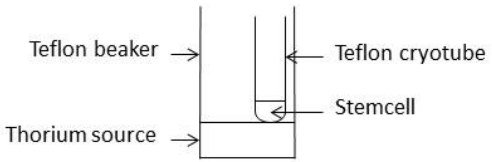
RaCS experiment





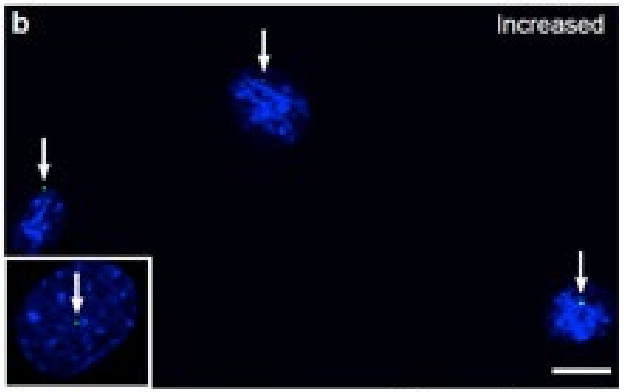
Irradiated tubes

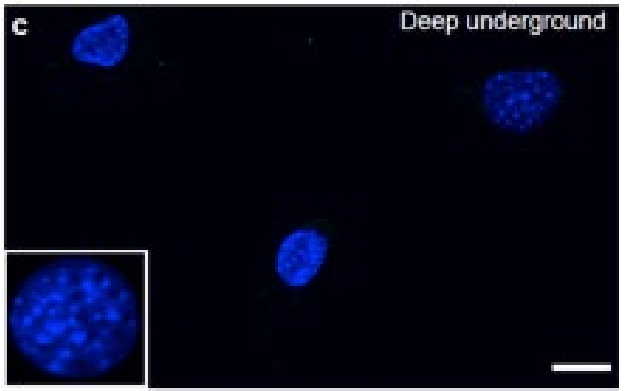
Side view



RaCS results

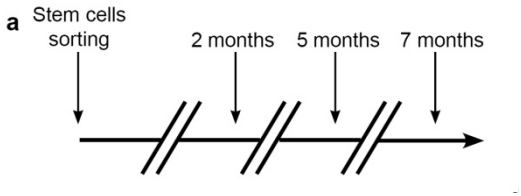
- Radioactivity impact is measured by Double Strand Break
- Cell are thawed in LSM and projected on glassplate
- Measurment of foci on microscope

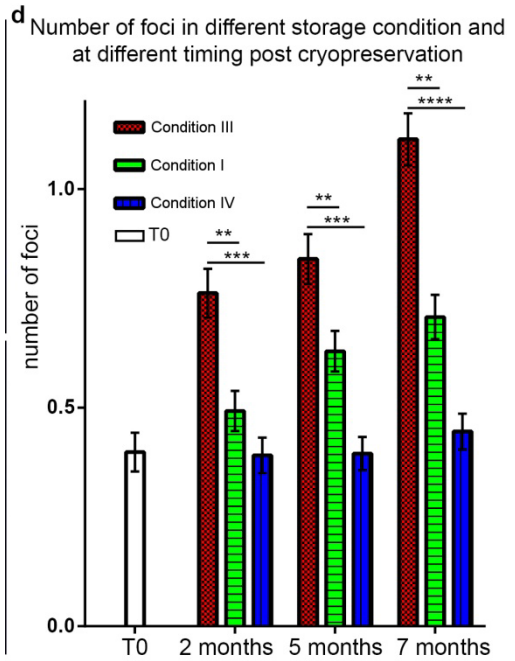




Racs result

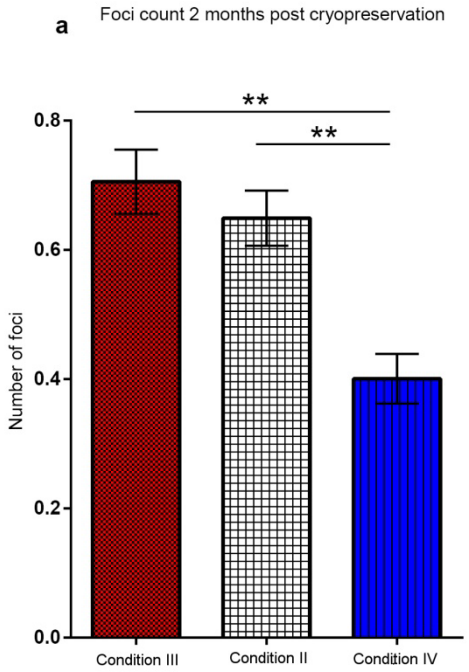
- Counting of foci
- First comparison between samples
- Ordered by dosis
- Also ordered by time
- In LSM condition the number doesnt stasticaly evolve

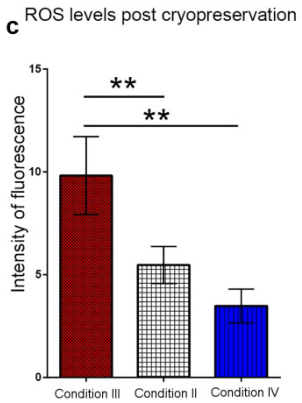




RaCS results

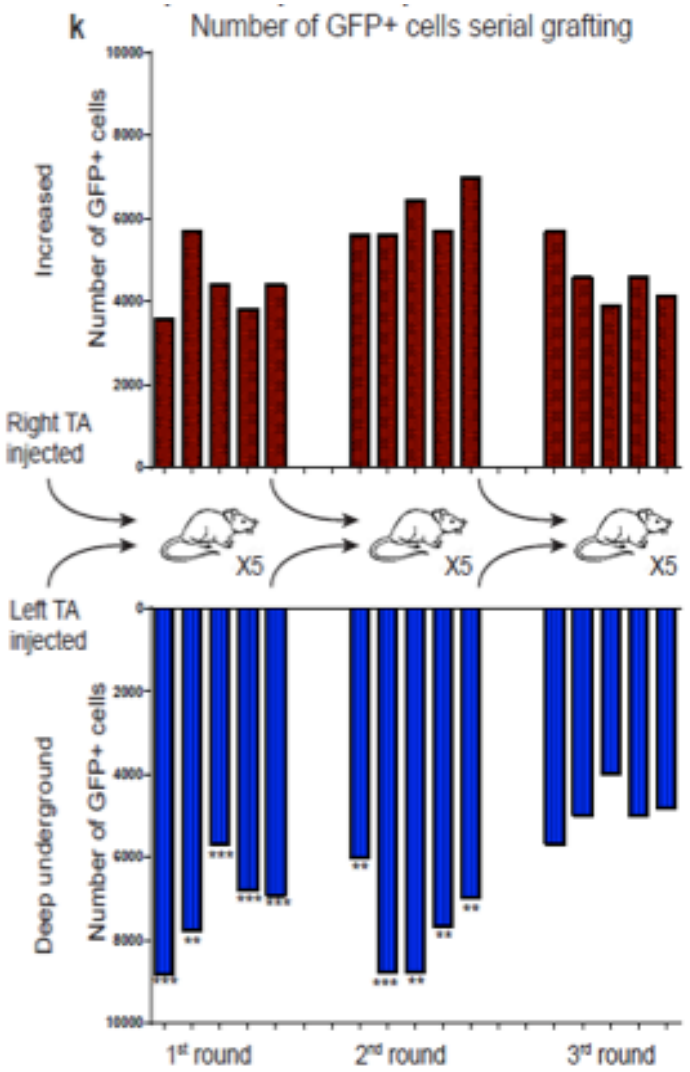
- Cosmic rays alone produce foci as radioactivity enhanced
- Radioactivity produce an increase of ROS
- Importance on the nature of particule
- Difficult to work with integral dosis





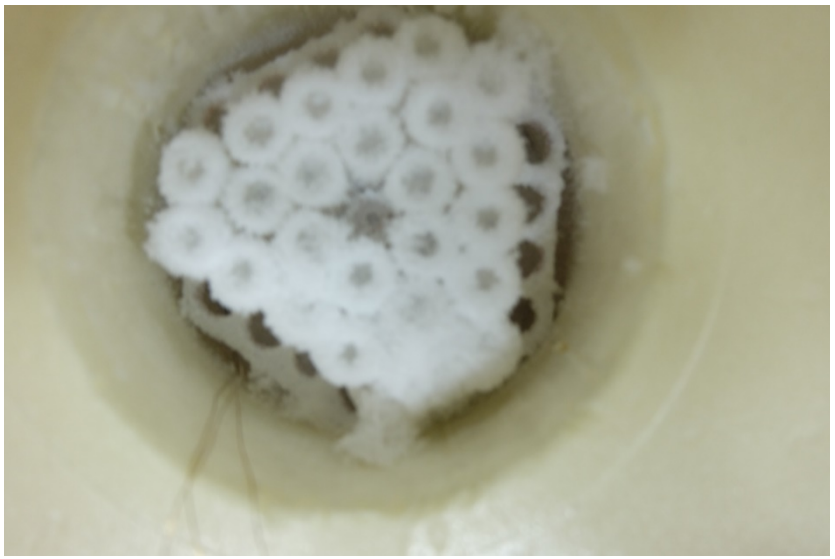
RaCS result

- Shielded cells are more potent
- Compared with 7 months storage
-



Stem cell storage

- LSM-pasteur institute collaboration
- Funded by interdisciplanary mission from CNRS
- Allowed to test a stem cell storage shielded from natural radioactivity and terrestrial cosmic rays
- Patented cryostat
- Publication in progress



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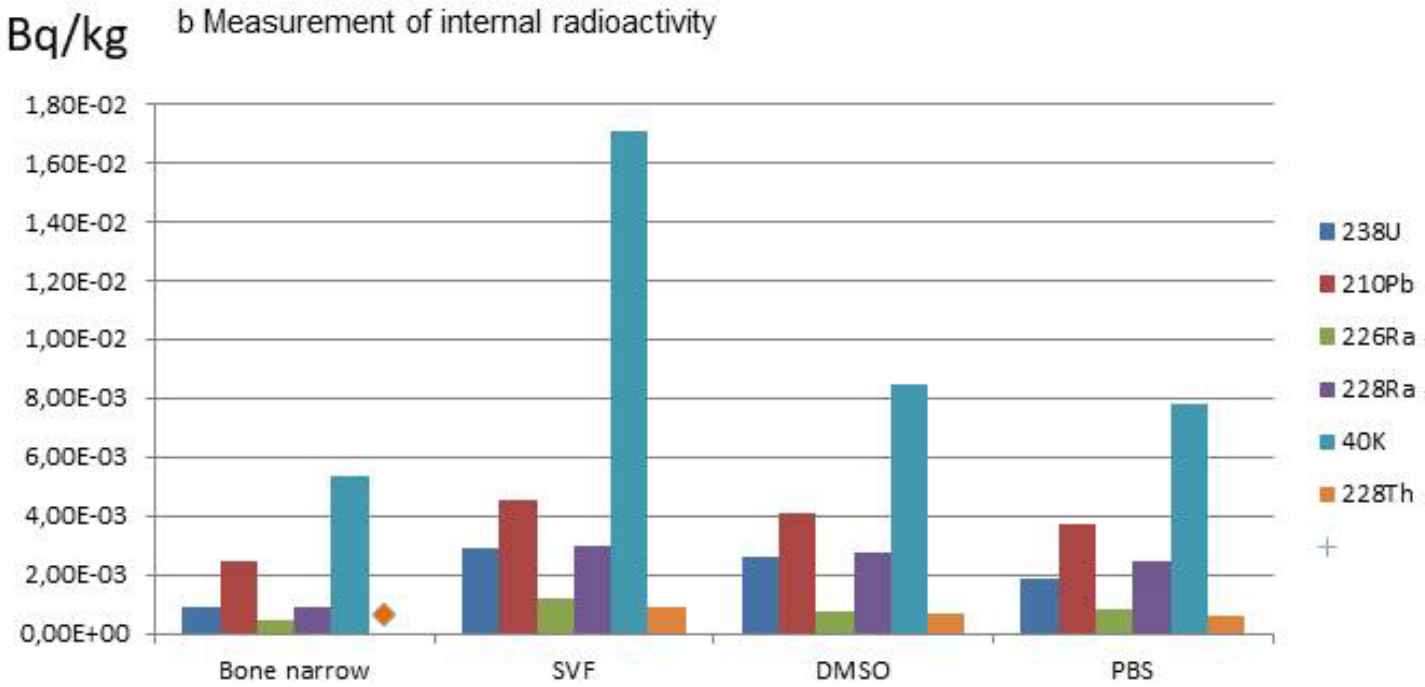
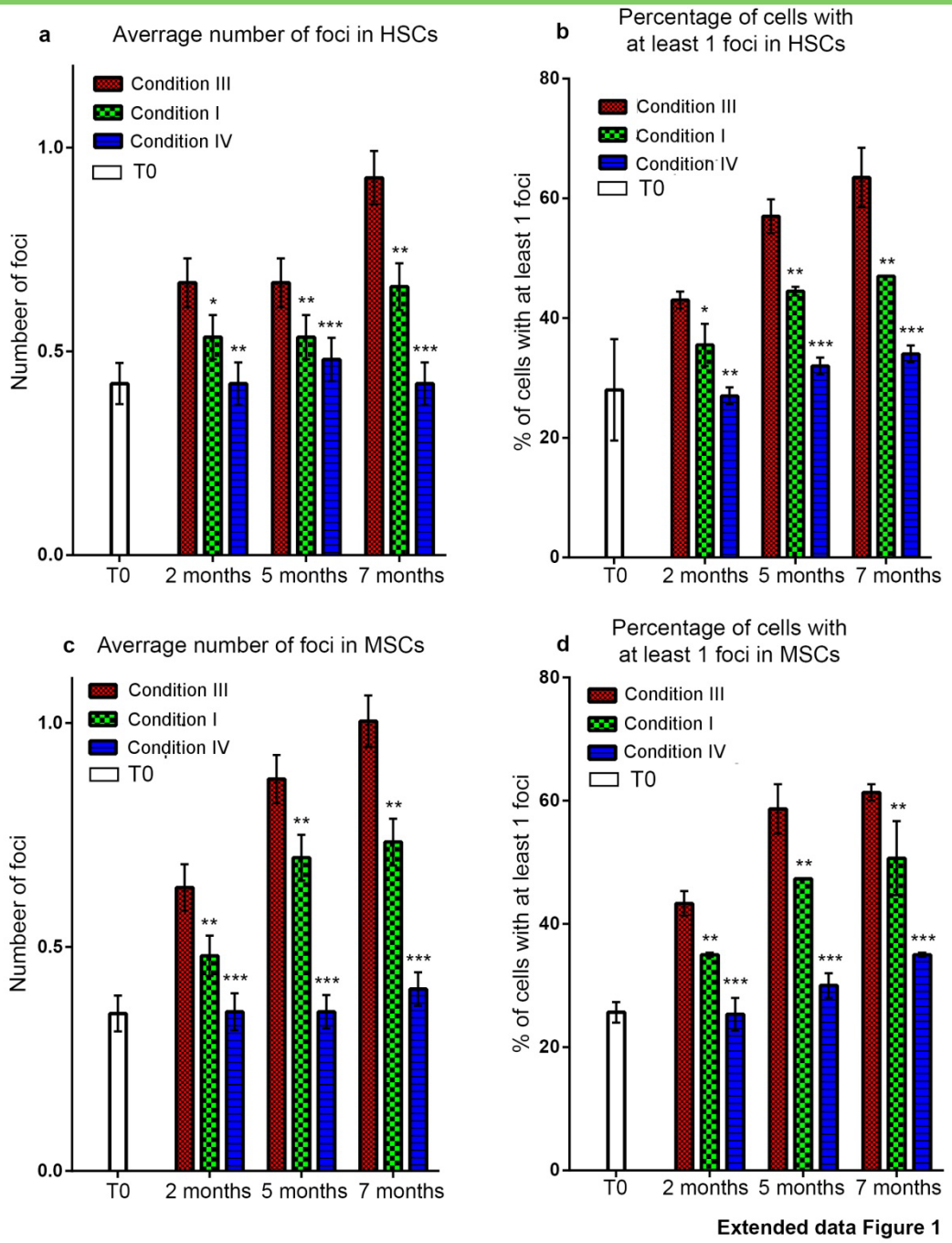
Institut Pasteur

Conclusion

- Underground labs are designed for large scale fundamental physics
- Unique environment find always a use sometimes unforeseen at digging
- Leaves room for interdisciplinary program at moderate cost
- Biology underground needs biologists undeground

- Measurement gives mainly limits





Extended data Figure 1

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