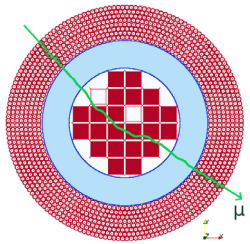
Muography of spent fuel containers for safeguards purposes

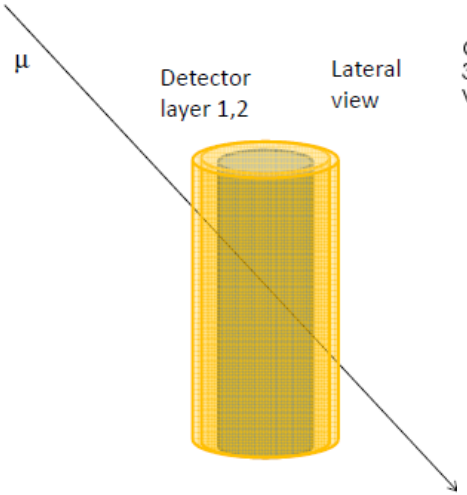
A feasibility test in proximity of a CASTOR® container.

Muon radio/tomography is a technology candidate to verify the content of spent fuel containers without opening them

Detectors positioned around the container ⇒ Absorption, Transmission and multiple Coulomb scattering

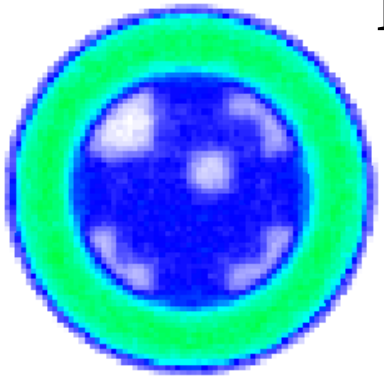
Simulation





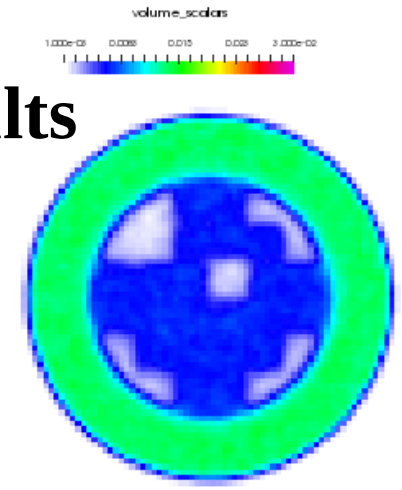
CASTOR@21
3D-muon-CT image
voxel 1 cm side

Horizontal Average



exp. resolution
X,Y: 300 micron
Z: 20 cm

Results

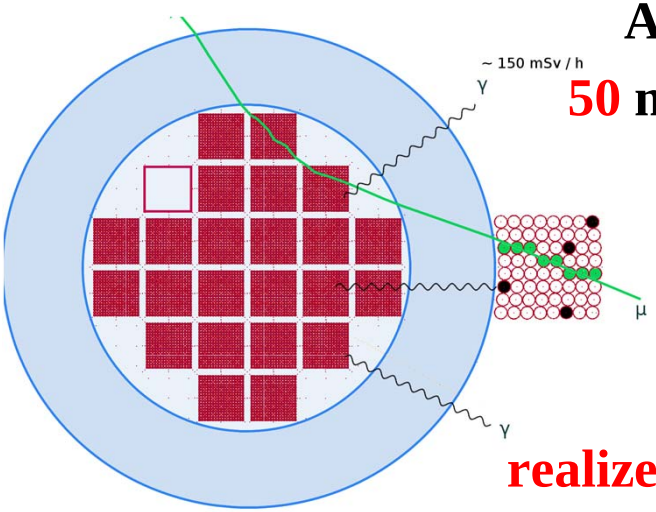


NO experimental error

A radioactive environment

- How much does radioactivity emitted by nuclear material stored inside Canisters interfere with the detector response?
- Is the (low) cosmic-ray intensity (~.1 μSv/h) compatible with the noise induced by radioactivity?

Purpose of the test is to prove that it is possible to record muon tracks and to measure the effects induced by radioactivity



A small prototype: 8 layers of 8 Al tubes:

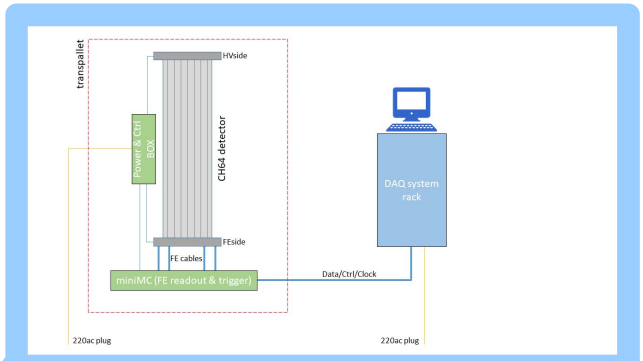
50 mm diameter, 1.5 mm thickness, 2 m length,
central 100 μm anode wire (+3000 V),
Ar-CO_2 (85%-15%) gas mixture

realized by INFN Padova group

Field test in nuclear power station at Neckarwestheim

Two positions for data taking

Far (~no radioactivity)

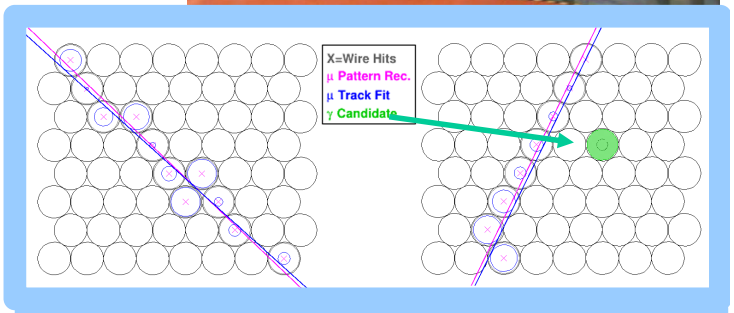


Layout of the apparatus.

Near CASTOR®
~14μSv/h γ

Main result: it is possible to reconstruct muon tracks with very little additional background:

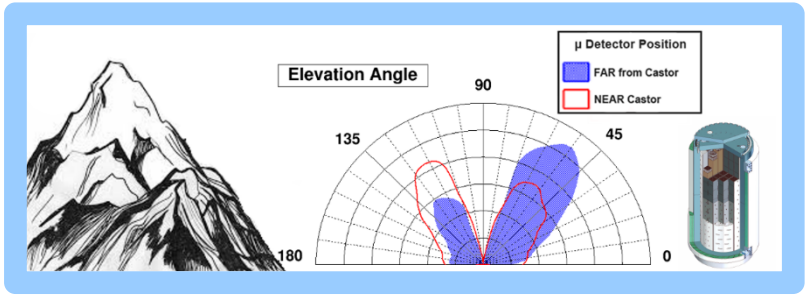
Probability for a tube to have a hit in coincidence with a muon <1%



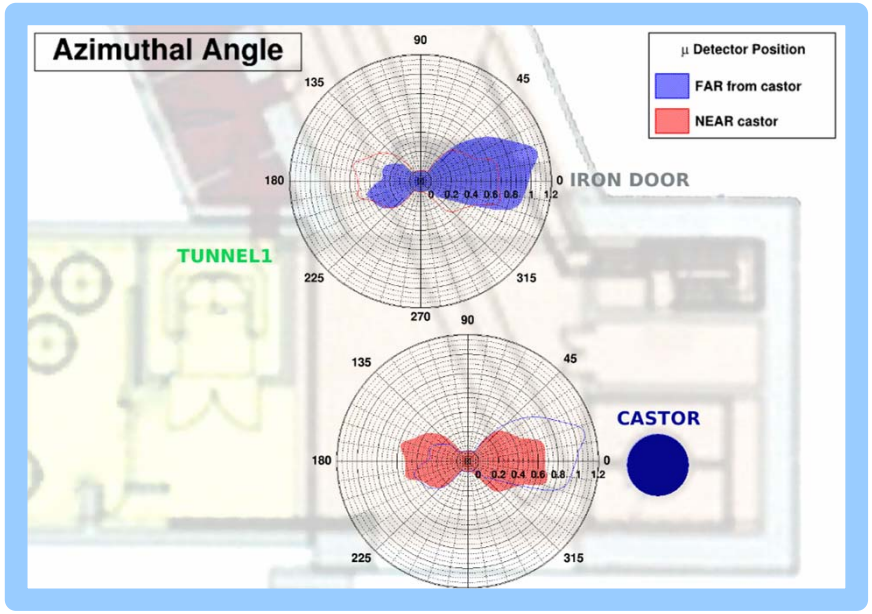
Display of reconstructed muon tracks.

Field test in nuclear power station at Neckarwestheim

The test was not conceived to study the CASTOR® content but we can show the influence of the container to modify the muon flux



Elevation angle distribution: effects of the geological environment and of CASTOR® presence. The blue area and the red curve are normalized to the total number of entries of the corresponding data-taking.

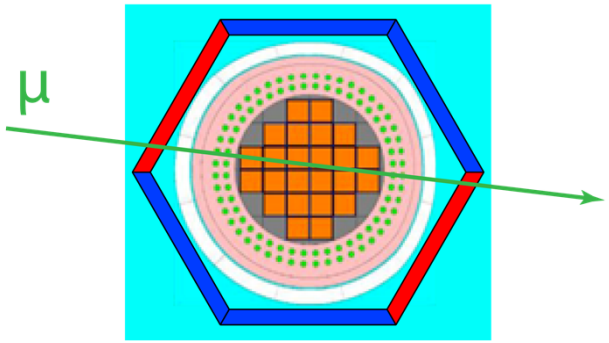


Azimuthal angle distribution, superimposed to the hall map sketch, for the far (blue) and near (red) data. The flux reduction in correspondence of CASTOR® is evident.

Conclusions and future perspective

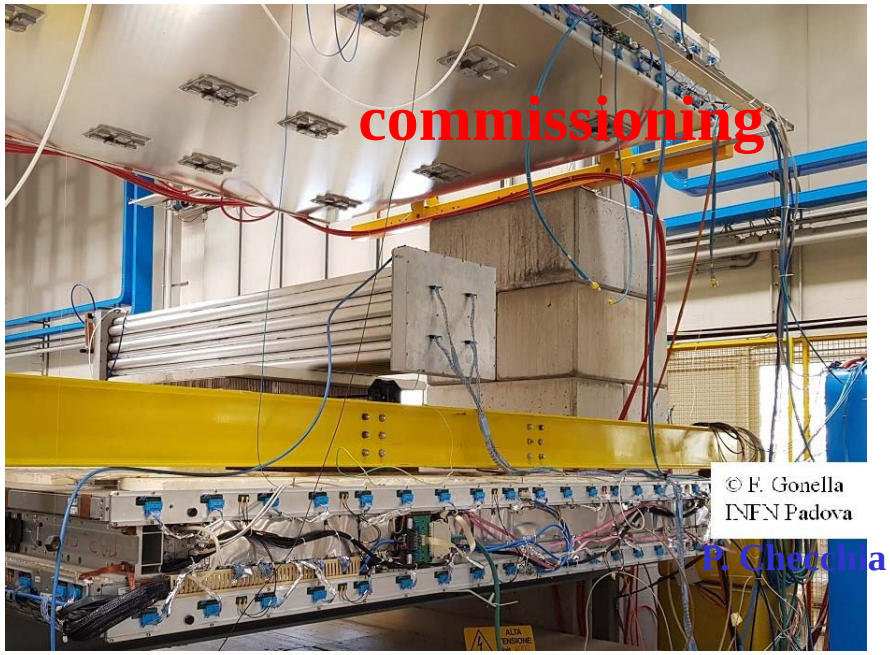
The technique works: it is possible to study CASTOR content using cosmic muons measured with a gas drift detector

Given the test positive results: next step is to realize a prototype covering a large fraction of a spent fuel container



Backup slides

The detector for a test

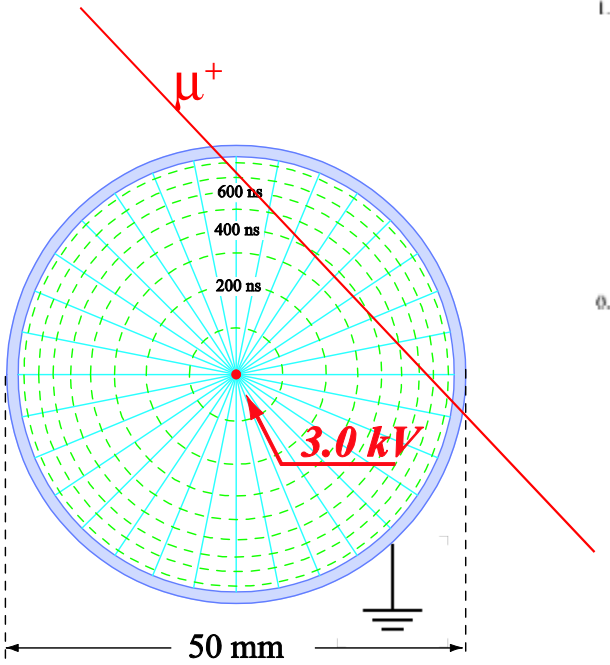


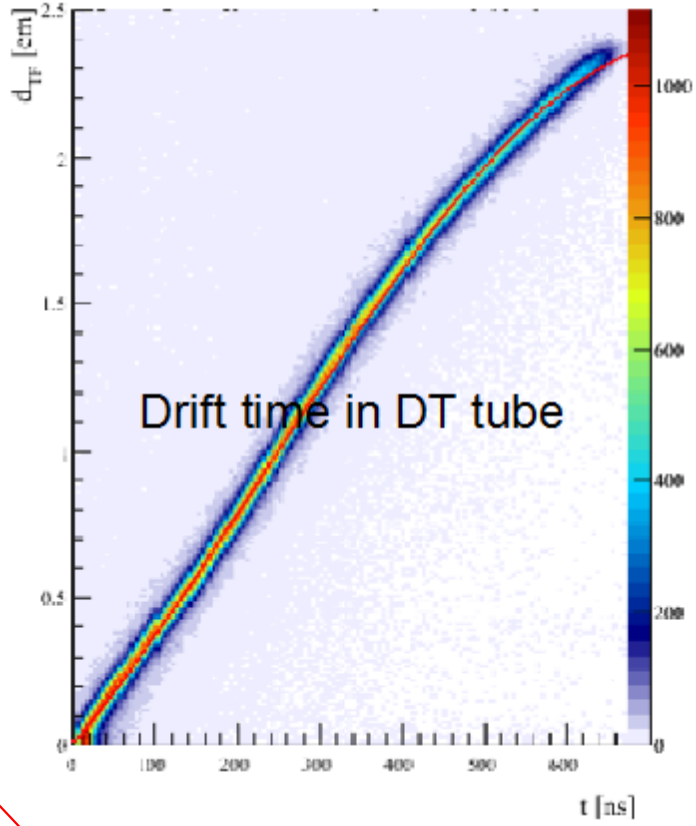
A possible detector

- **Drift tubes technique is adequate for industrial production**

- **A charged particle crossing the tube ionizes the gas**

  (e.g. Ar 85% CO_2 15%)
- **Electrons drift in presence of the electric field and in proximity of the wire (E~1/r) an avalanche process starts allowing signal detection**





Typical drift time: ~1 μs for 2.5 cm