2° Workshop COST E55 “Modelling of performance of Timber Structures”
4-5 October 2007 – Eindhoven, The Netherlands

# *The application of FT-IR spectroscopy to monitor biodegradation of wood during decay tests*

## *Short Term Scientific Mission - Italy/The Netherlands*

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- Strength loss prediction due to decay
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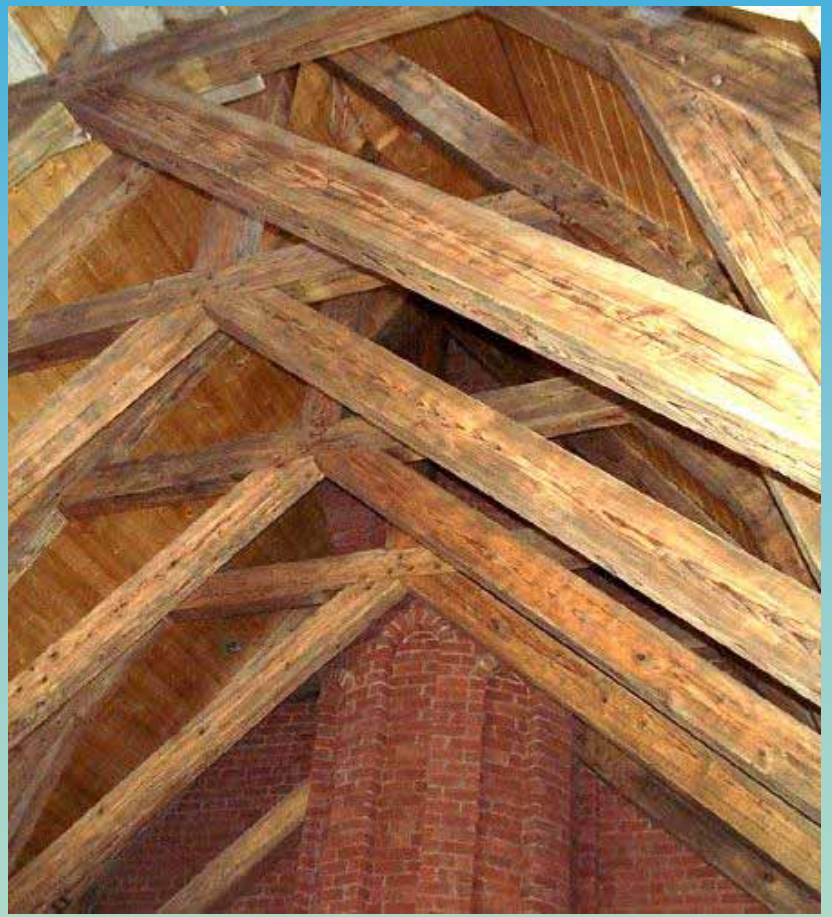
- Conclusions and future work

Service life of timber structures depends on many parameters.

Probabilistic models have been developed to describe time dependent changes in residual strength of a structure taking into account the **mechanical loads**.

Environment affects buildings, so it is necessary to consider also the degradation of structures caused by **physical** and **biological** factors.



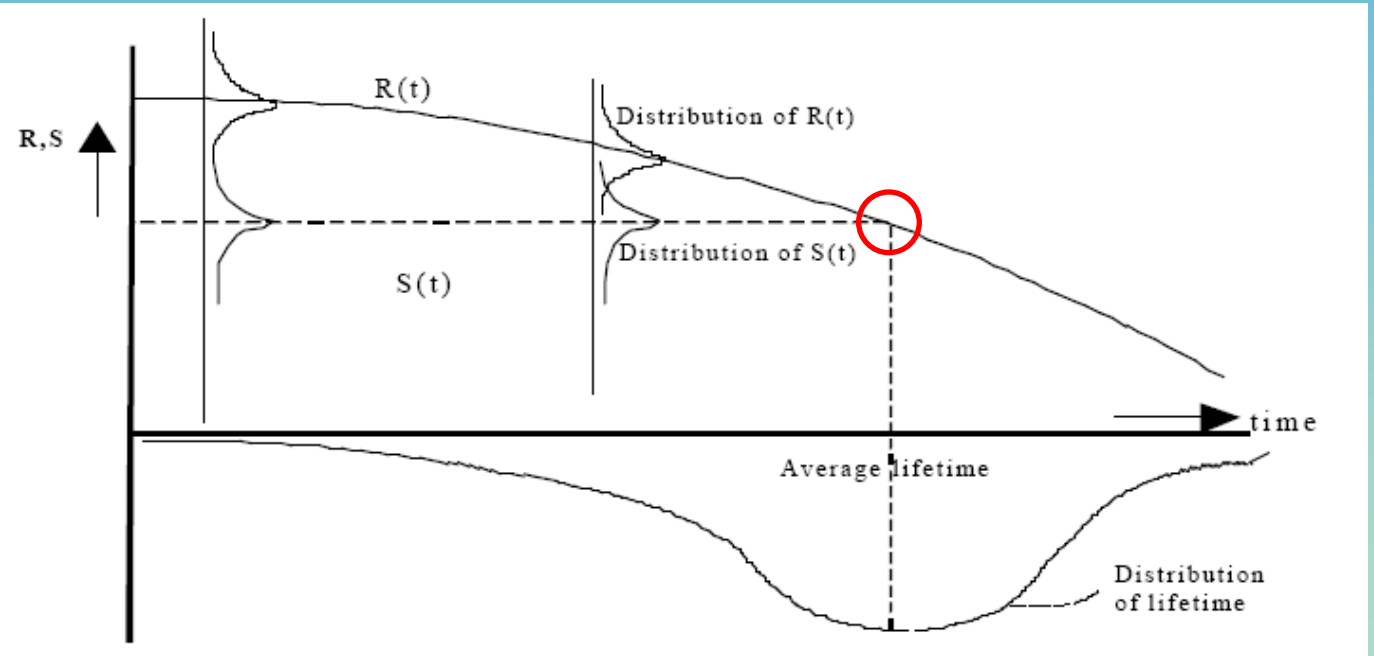
# Reliability model

Limit state function:

$Z(t)=R(t)-S(t)$ $Z<0 \rightarrow$ failure

R: resistance (strength)

S: load



# Reliability model

For timber:

$Z(t) = R(s(t),t)-S(t)$

Exponential damage function [Gerhards and Link]:

$$\frac{d\alpha}{dt} = \exp(-a + b\frac{\sigma(t)}{\sigma_s(t)})$$

Now:

$\sigma_s(t)= f\ (t,\omega,T,\sigma_{decay})$

$\sigma(t)= f\ (t, \sigma_{mech},\sigma_w)$

$\sigma_s$= strength

σ = stress function

ω=moisture content (varying with t and R.H.)

T=temperature (varying with t)

# Strength loss due to decay

Decay: change in chemical and/or physical properties of wood caused primarily by the enzymatic activities of microorganisms (soft-rot fungi and wood-rotting basidiomycetes)

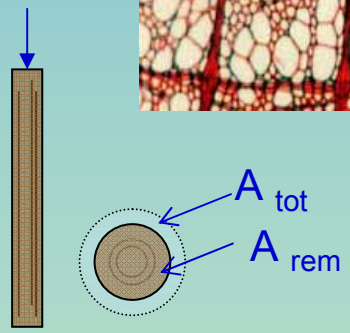
Mechanisms of strength loss in timber:

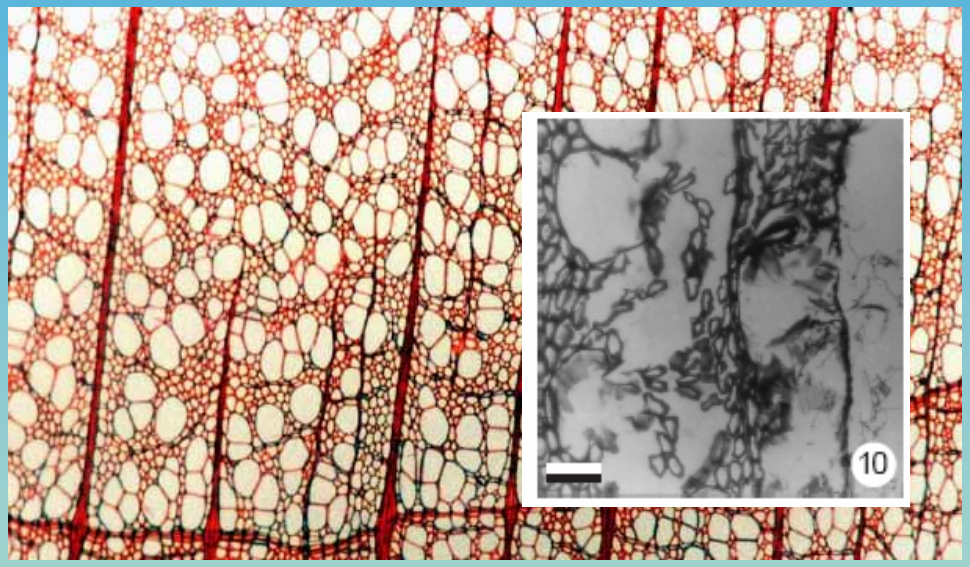
- break down of the complex polymers of wood

$$f_{c,0,dec} < f_{c,0}$$

- Reduction of cross section in case of (superficial) deterioration of timber

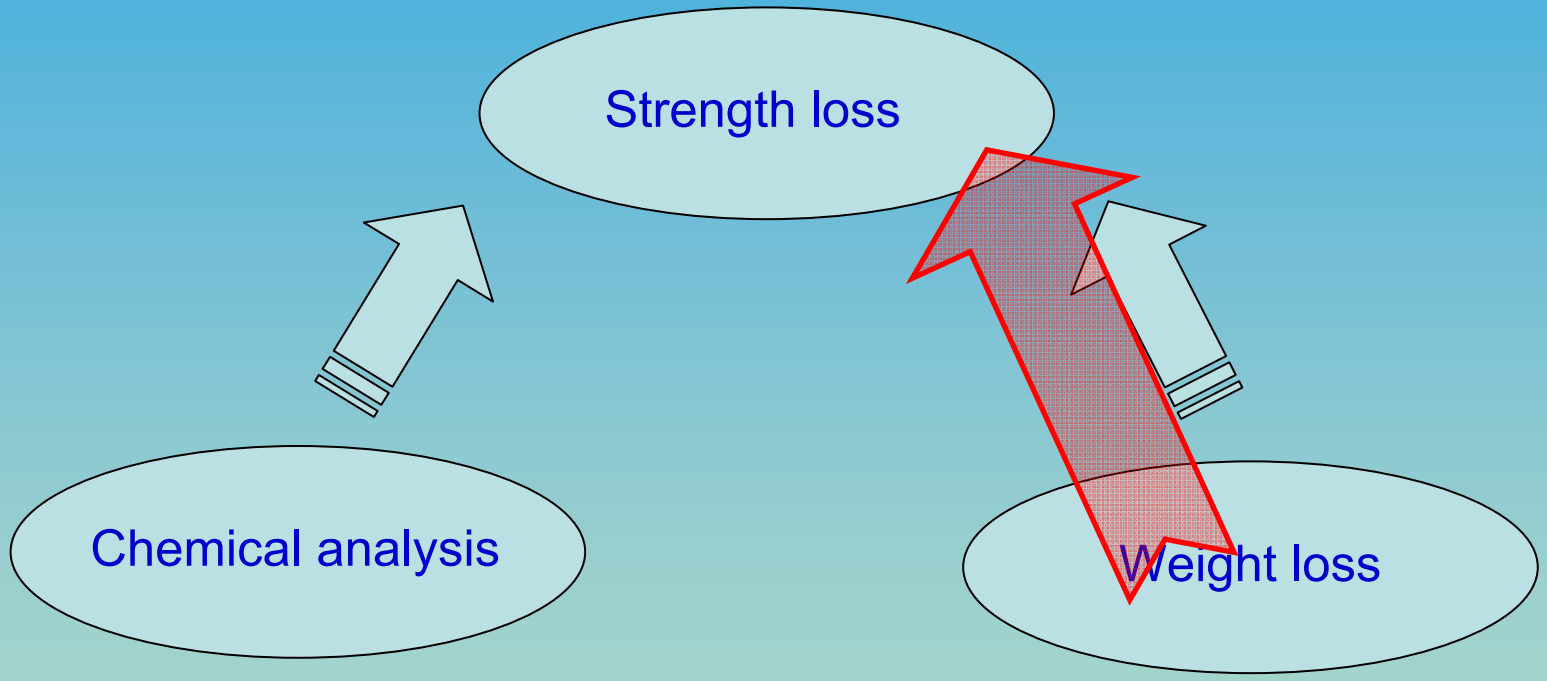
$$F_u = f_{c,0} * A_{tot} \rightarrow F_u = f_{c,o} * A_{rem} + f_{c,0,dec} * A_{dec}$$



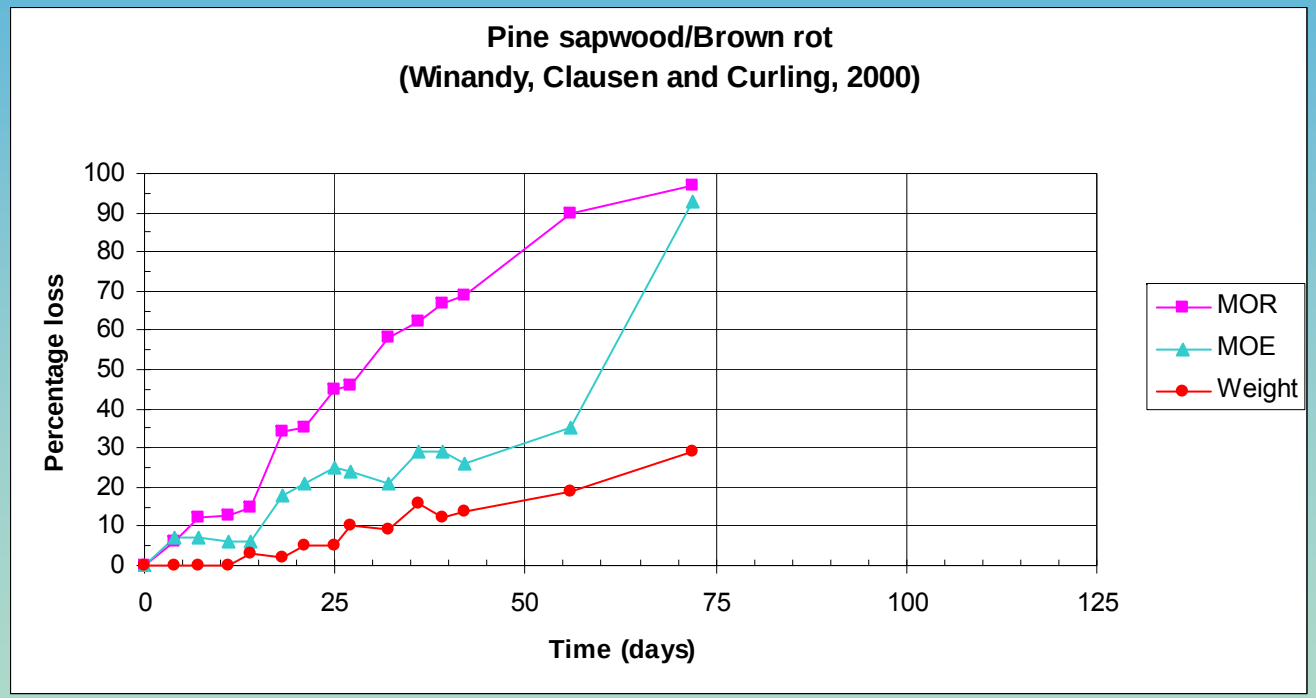

*Resistance decreases with decay!*

# Strength loss prediction



# Strength loss prediction

## Relationship strength – weight loss



# Weight loss - Strength loss relationship

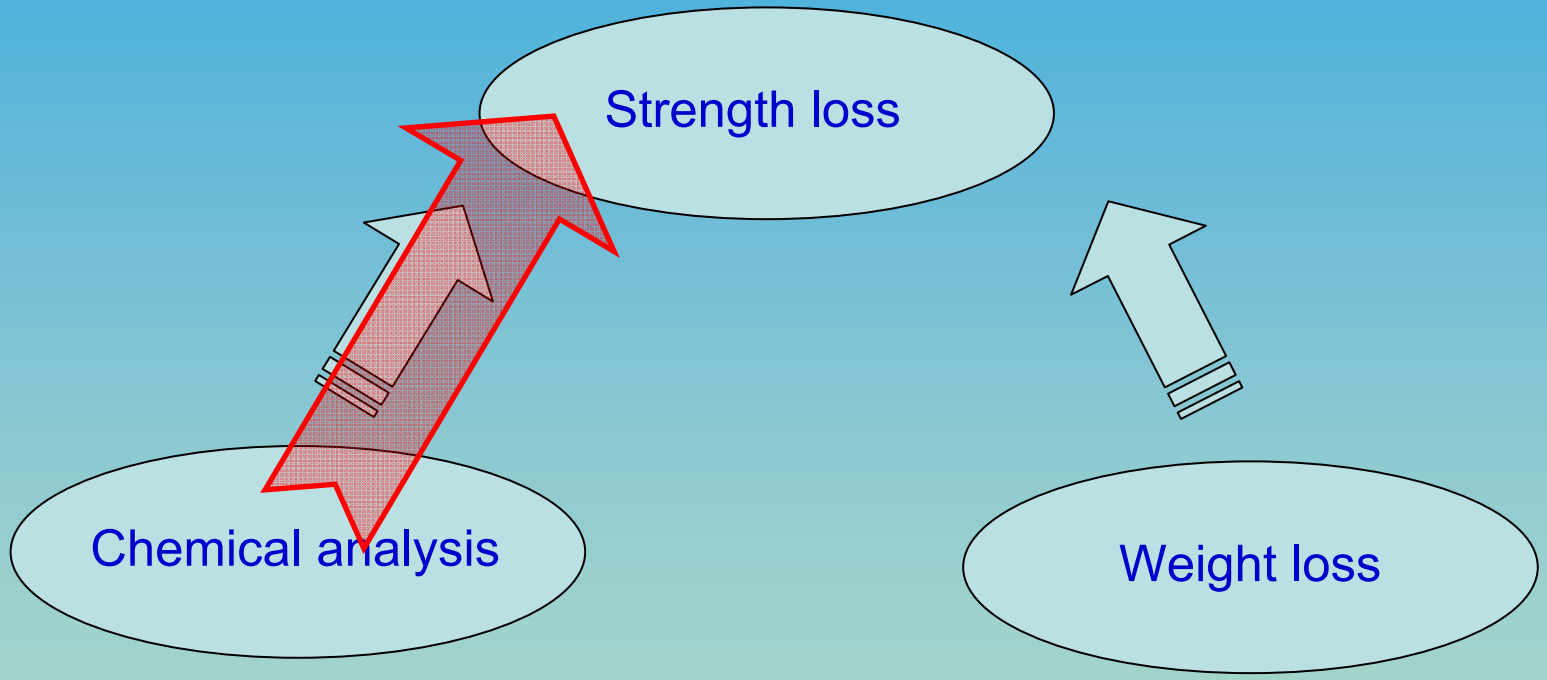
Literature study:

- Literature not extensive
- The greatest part of it concerns tests on wood treated with preservatives
- Decay tests standardized (EN 113, ENV 807 or ASTM D2017) evaluate the durability of treated wood mainly via **weight loss measurement**
- In some works mechanical properties are investigated with standards such as EN 408 (standard bending strength test)

LIMITS 

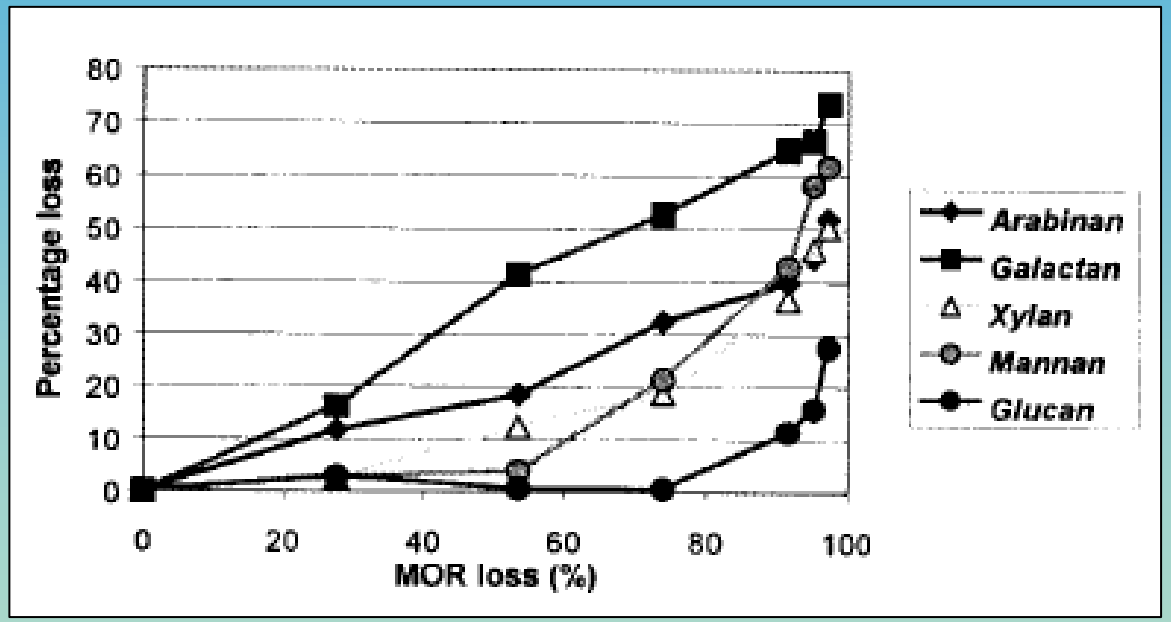
- Small wooden samples tested (max 10x25x250 mm3)
- Mainly weight loss measurements, few data on strength loss
- No data on growth rate of fungi depending on volume
- Short term period analyzed

# Strength loss prediction



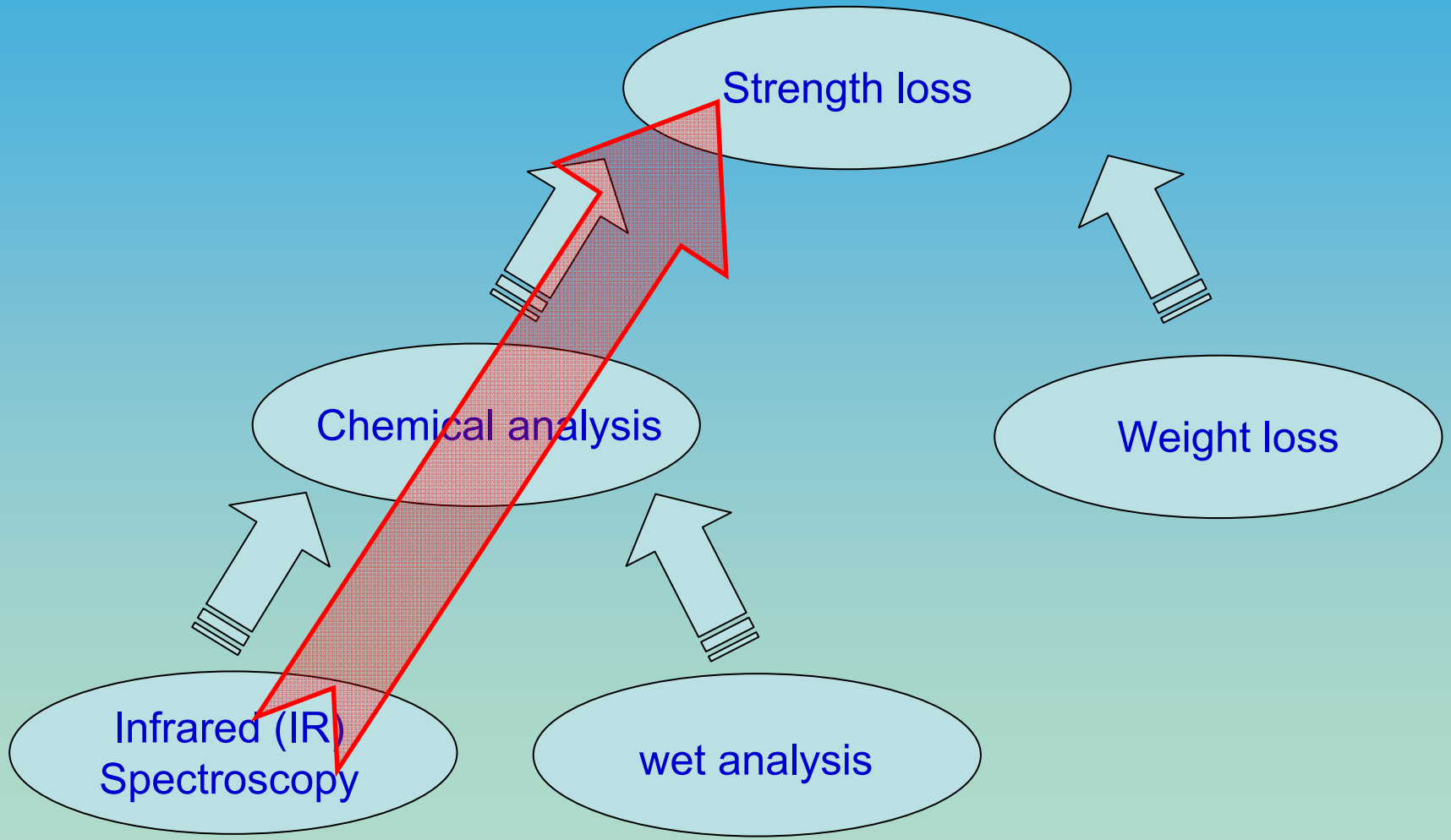
# Strength loss prediction

## Relationship strength – chemical degradation




Winandy, Clausen, Curling (2000)

# Strength loss – Chemical analysis



# FT-NIR spectroscopy

- Promising technique to analyze physical state and chemical composition of wood
- Nondestructive technique, with future applications for online monitoring during manufacturing processes or in-situ inspection
- Fast acquisition of spectral data and almost no sample preparation required

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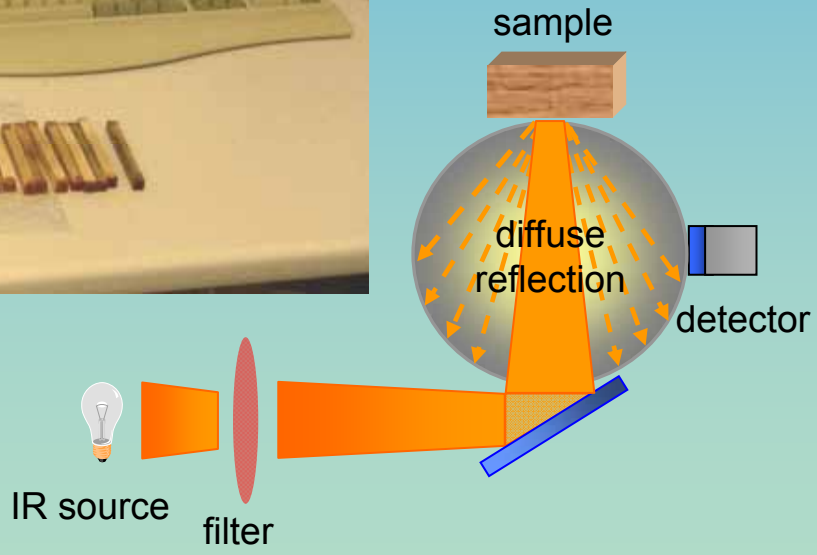
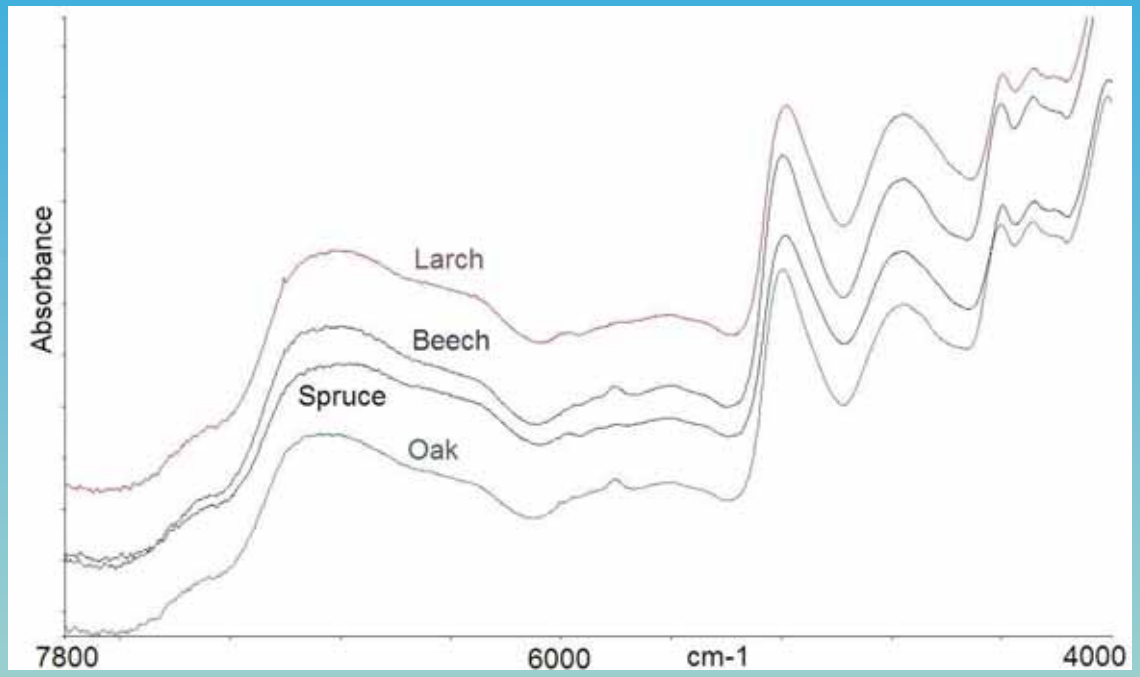
# Near InfraRed (NIR) analysis



# NIR spectral data




- Absorption bands in NIR spectra arise from overtone and combinations of C-O, O-H, C-N and N-H bonds
- The problem of multiple overlapping bands can be handled with the multivariate analysis (MVA)

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# Aims of this study

- New protocol for laboratory decay test on 2 set of samples differing in *volume* sizes
- Relationship between the rate of decay (in terms of weight loss in time) and the volume of samples

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- Compression tests on the bigger samples after different incubation time intervals (ongoing at TUDelft)
- Application of a new non-destructive technique to identify decay, the InfraRed (IR) Spectroscopy
- Use InfraRed (IR) Spectroscopy to study the advancement of decay in large samples

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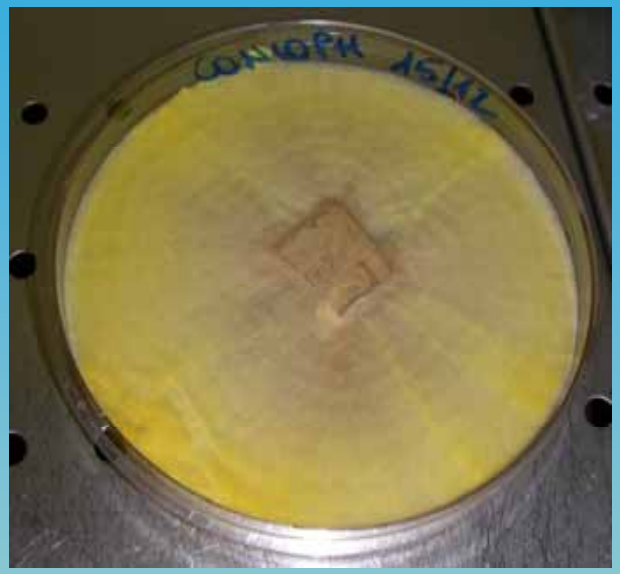
# Decay test

- 20 ministakes (10x10x100 $mm^3$) and 20 stakes (45x45x200 $mm^3$) of *Picea abies and Larix kaempferi*
- Brown rot *Coniophora Puteana* (Schumacher ex Fries) Karsten
- Laboratory decay based on standard EN 113, with some modifications
- Exposure time intervals for the ministakes: 2, 4, 8, 12, 16 weeks
- Exposure time intervals for the stakes: 1, 3, 6 months (up to now!)

# Inoculation with brown rot





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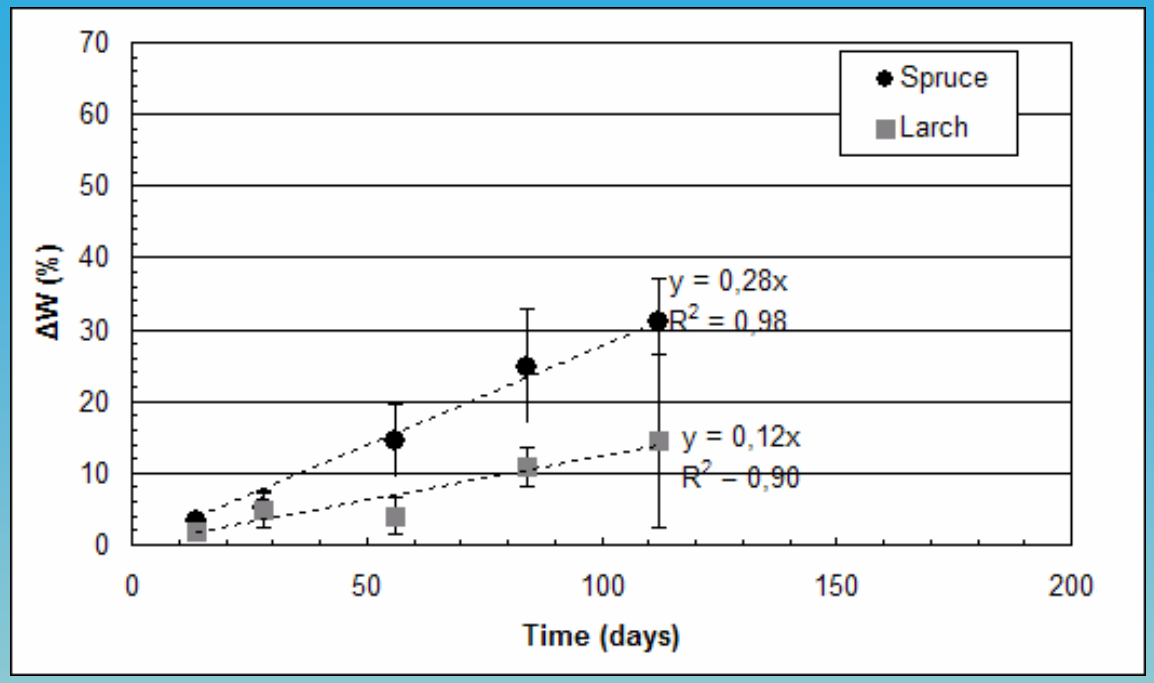
# Biodegradation

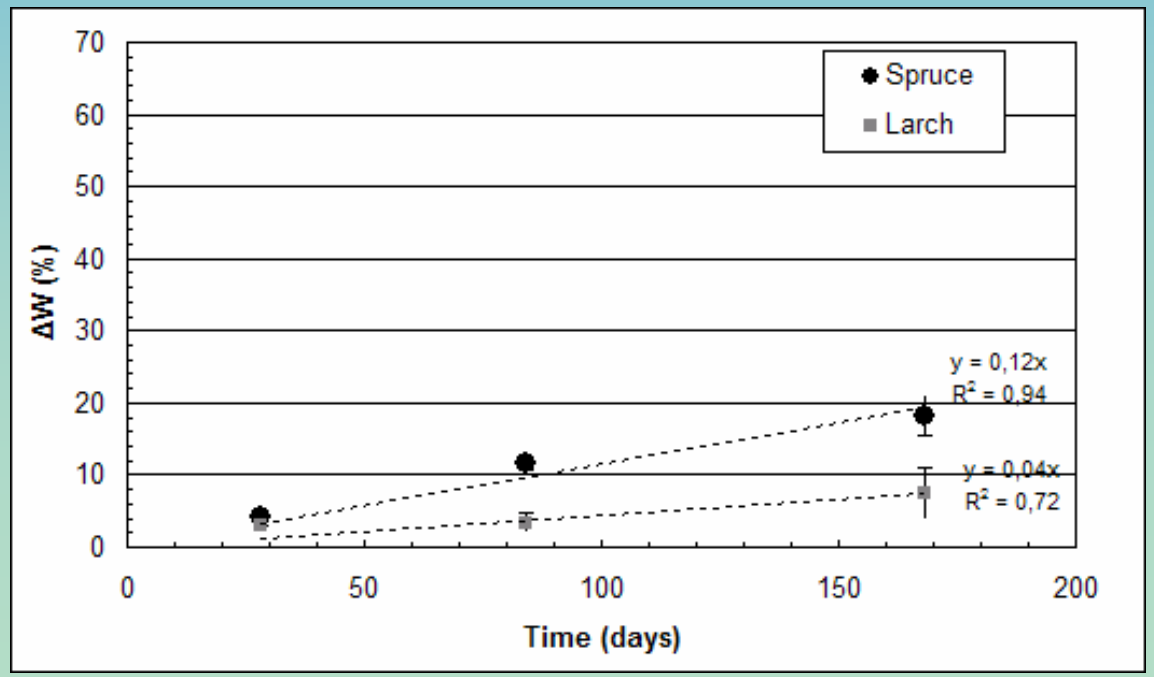
1 week

16 weeks

# Weight losses vs. Time




Ministakes
(V=10x10x100 mm³)




Stakes
(V=45x45x200 mm³)

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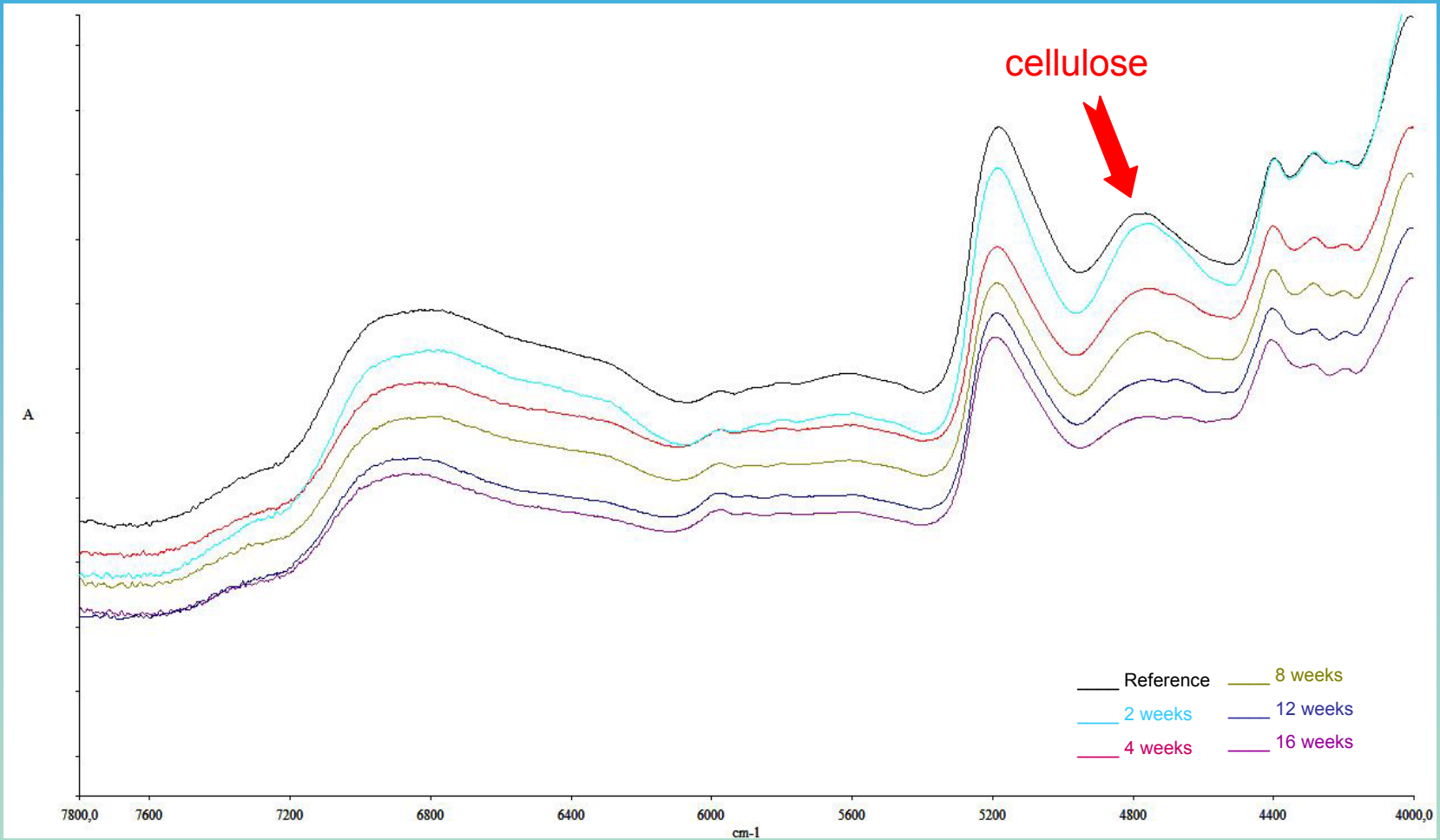
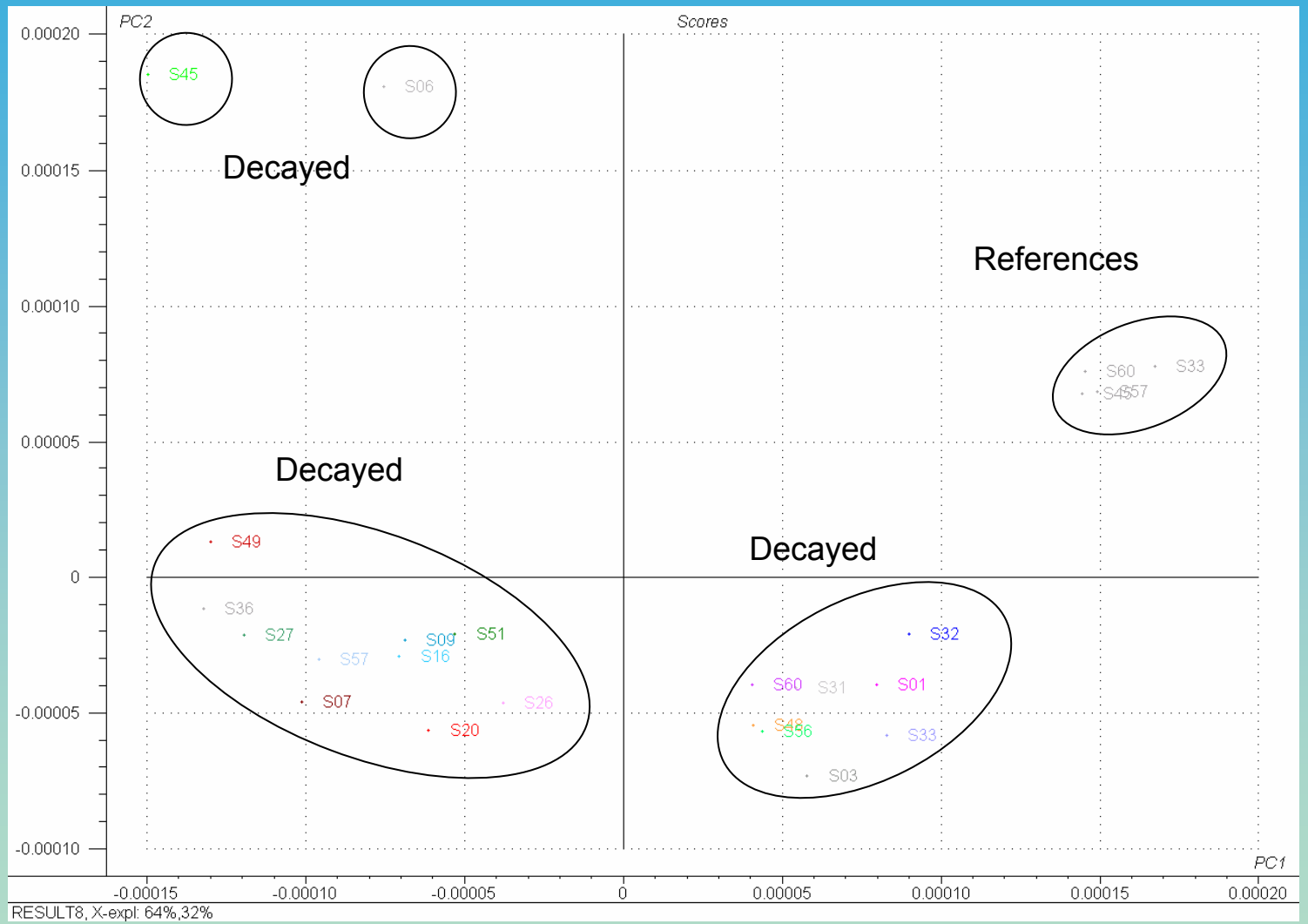
# NIR spectra at different incubation time



# Multivariate analysis (PCA)



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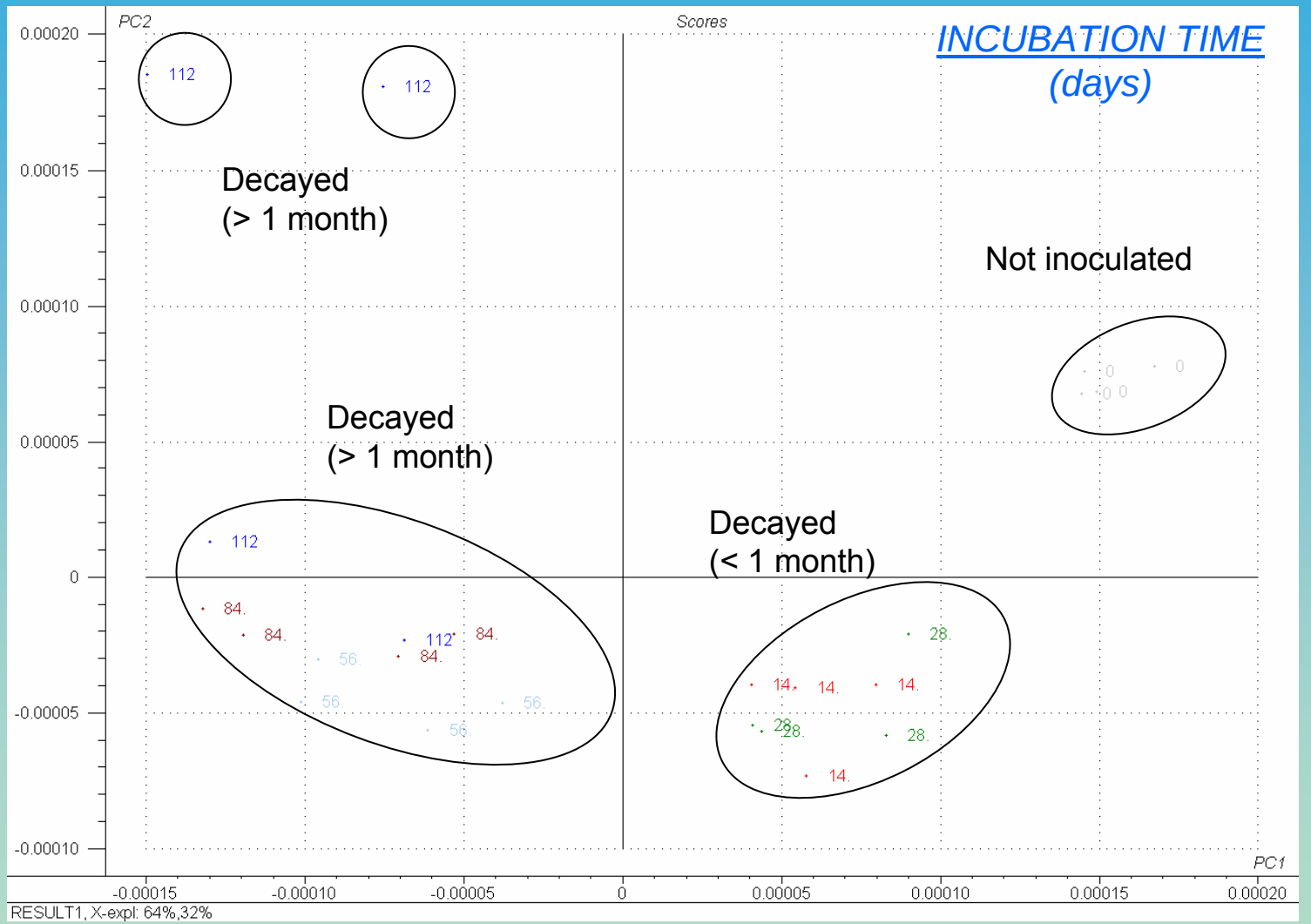

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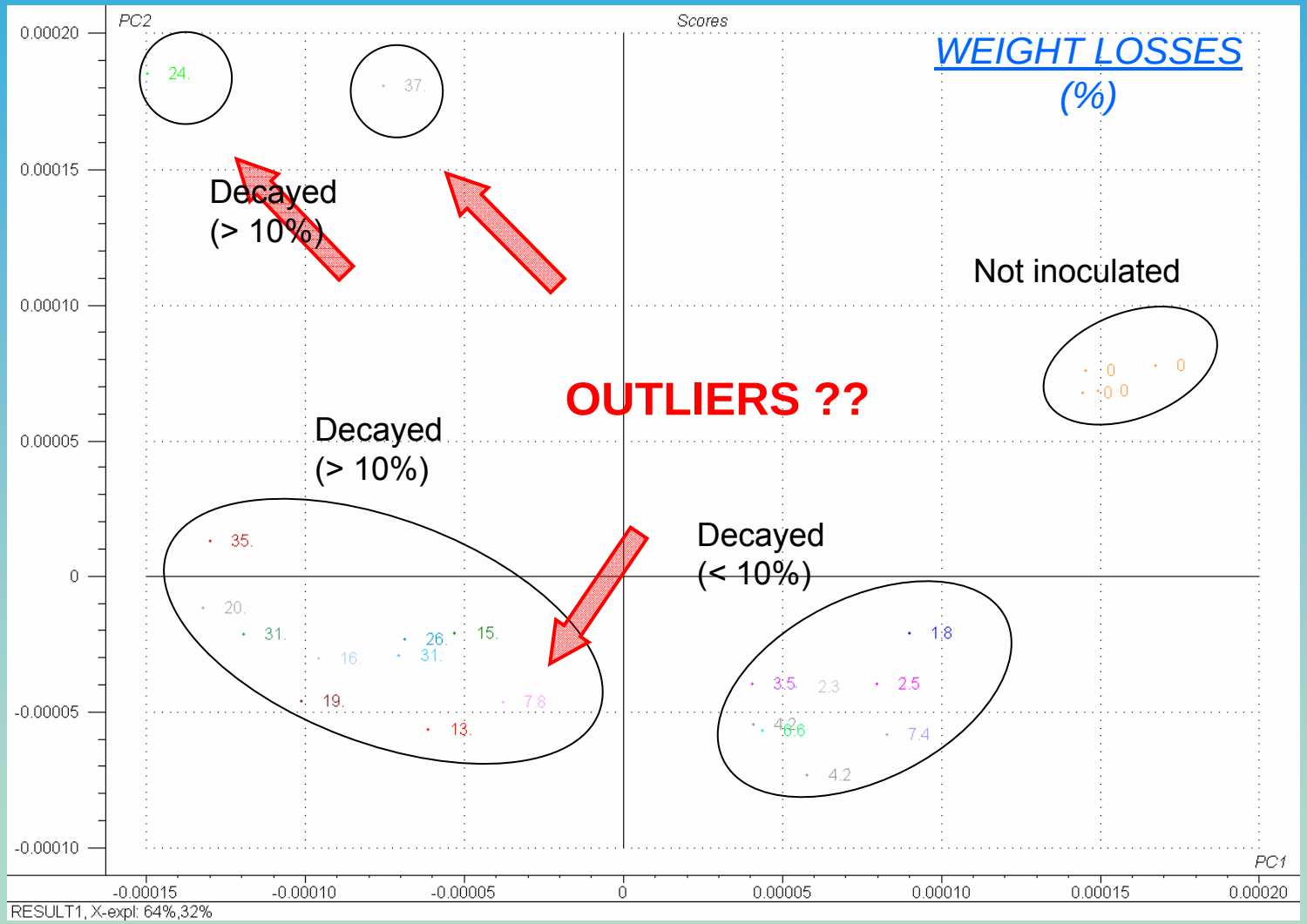

# Conclusions and future work

- The new test set-up to study decay in different size specimens was successful using a special protocol for incubation
- It was proven that the rate of weight loss is strongly influenced by the volume of the samples, decreasing up to one third when increasing specimen's volume from $10^4$ $mm^3$ to 40 times bigger for larch samples: therefore, weight loss itself is not a good indicator for decrease in structural reliability.
- The chemical approach via IR spectroscopy has good potentials for studying the effect of decay in wood
- Future compression tests have to be performed to correlate FT-IR spectra with strength

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# References

Tsuchikawa, S. (2007). "A review of recent near infrared research for wood and paper." Applied Spectroscopy Reviews **42**: 43-71.

Curling, S., C. A. Clausen, et al. (2002). “Experimental method to quantify progressive stages of decay of wood by basidiomycete fungi.” International Biodeterioratian & Biodegradation **49**: 13-19.

Thank you for your attention