NIR spectroscopy for the rapid measurement of wood properties

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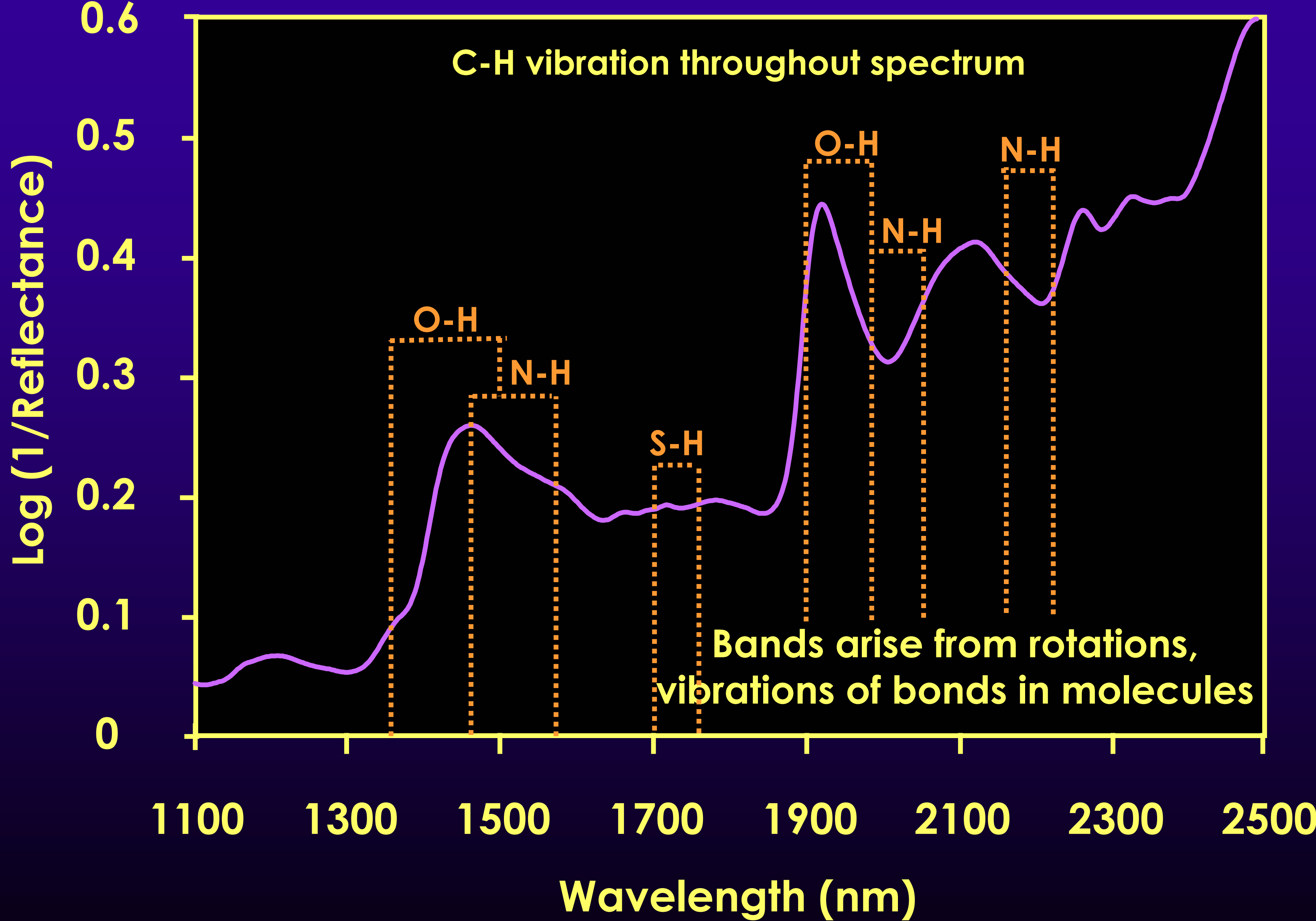
Overview

- Description of NIR spectroscopy
- Application of NIR to whole-trees
- Application of NIR to lumber
- Application of NIR to short clears
- Application of NIR to cores

NIR spectrum of a typical wood sample



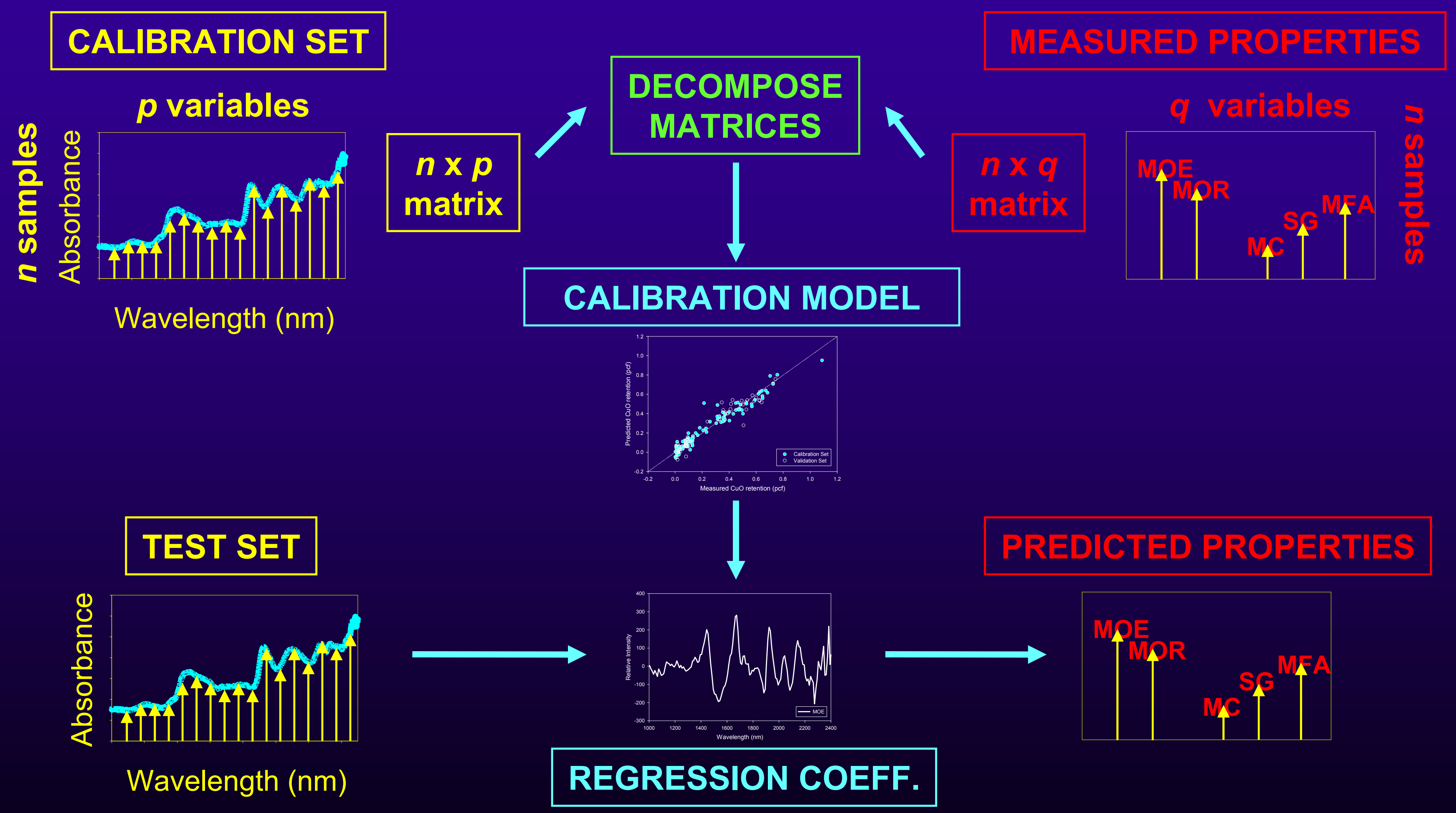
Methodology

- Estimation of a parameter involves the following steps:
- Collect spectra of calibration samples
- Develop a calibration (regression)

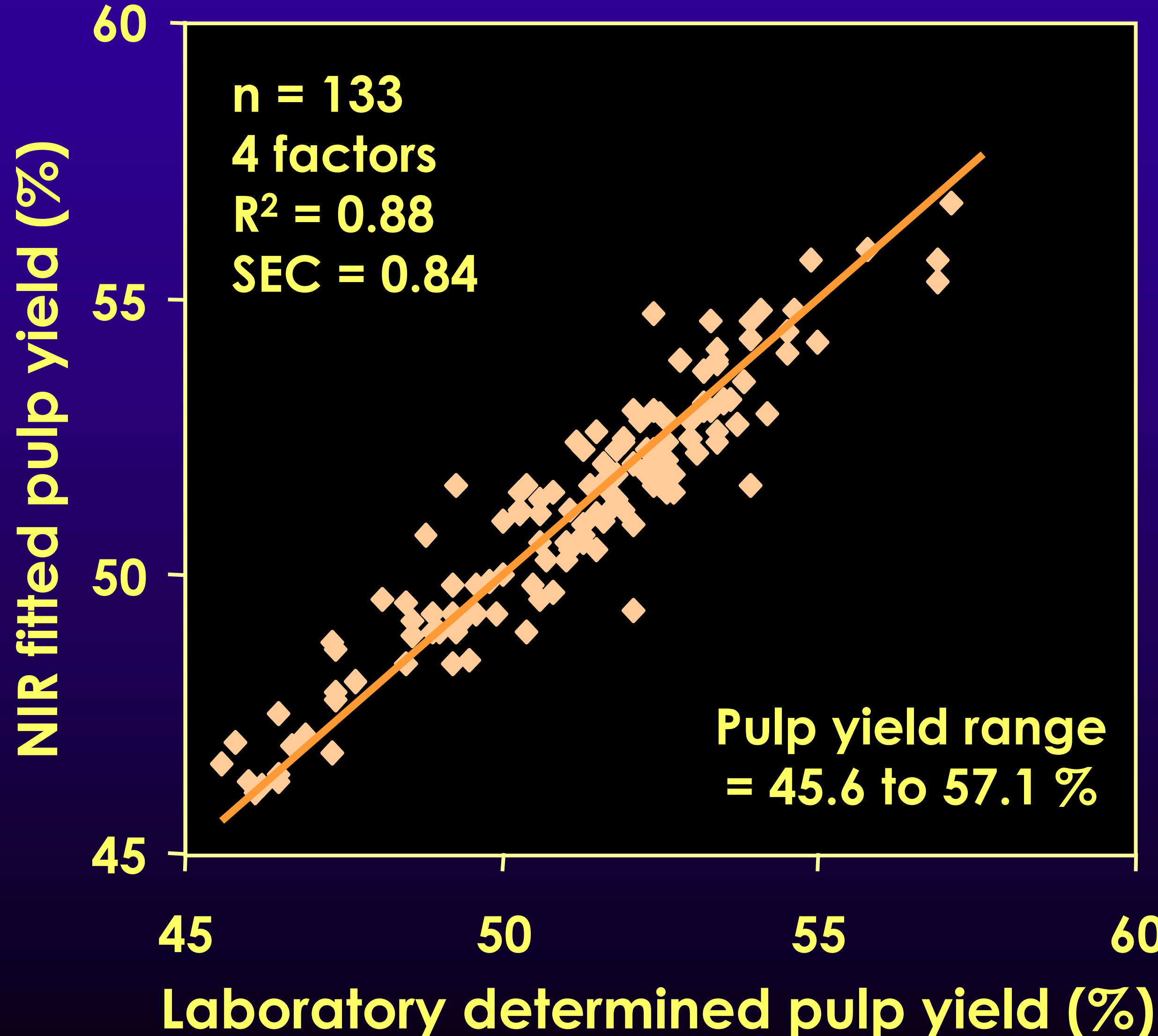
$(y = B_0 + X_1{*}B_1 + X_2{*}B_2 + \ldots\ldots\ldots\ldots + X_N{*}B_N)$

- Collect NIR spectra of test (or unknown) samples
- Estimate parameter of interest for test set samples using the calibration

Partial least squares regression

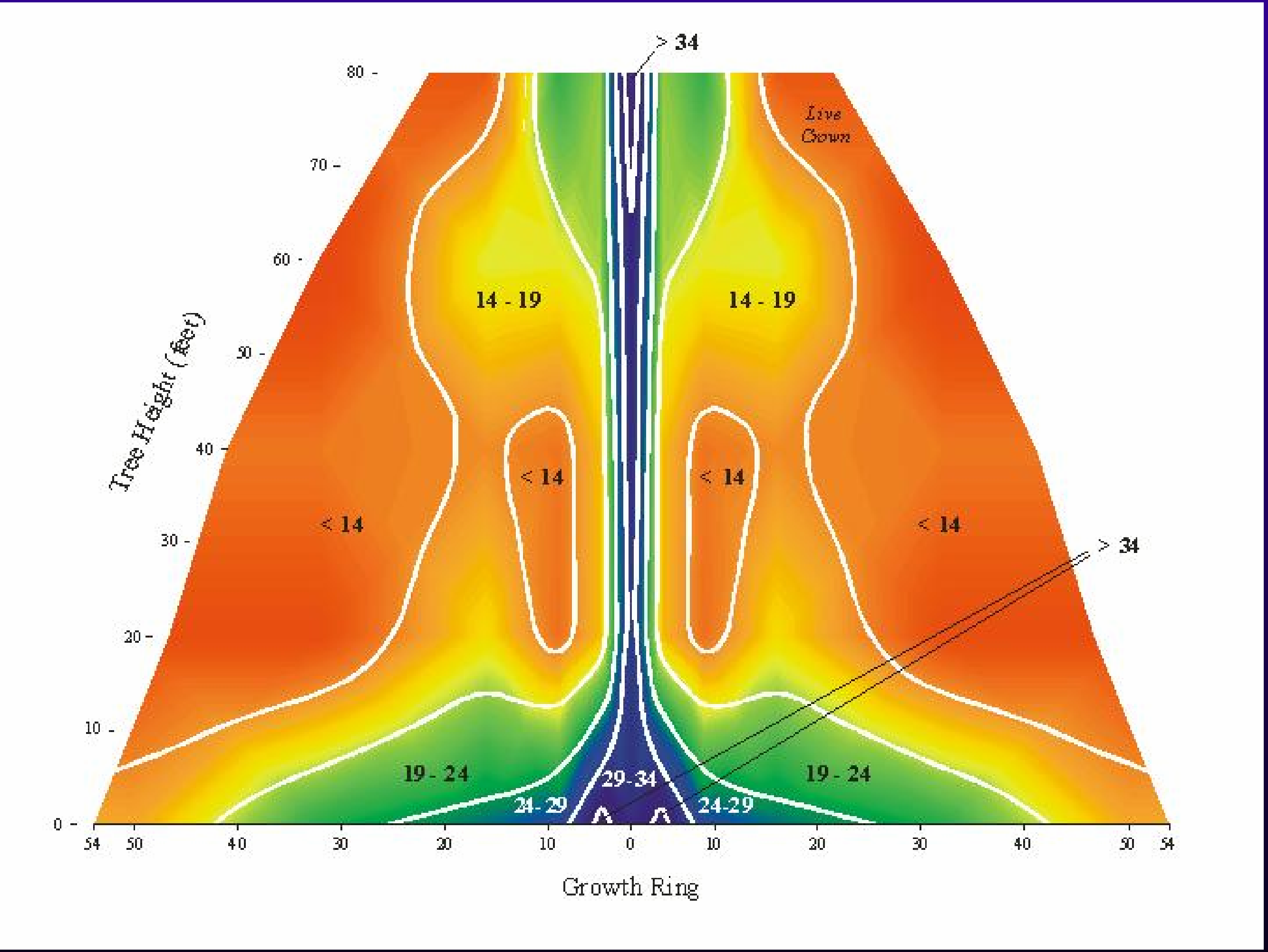


Pulp yield calibration for Tasmania



Within-tree property variation

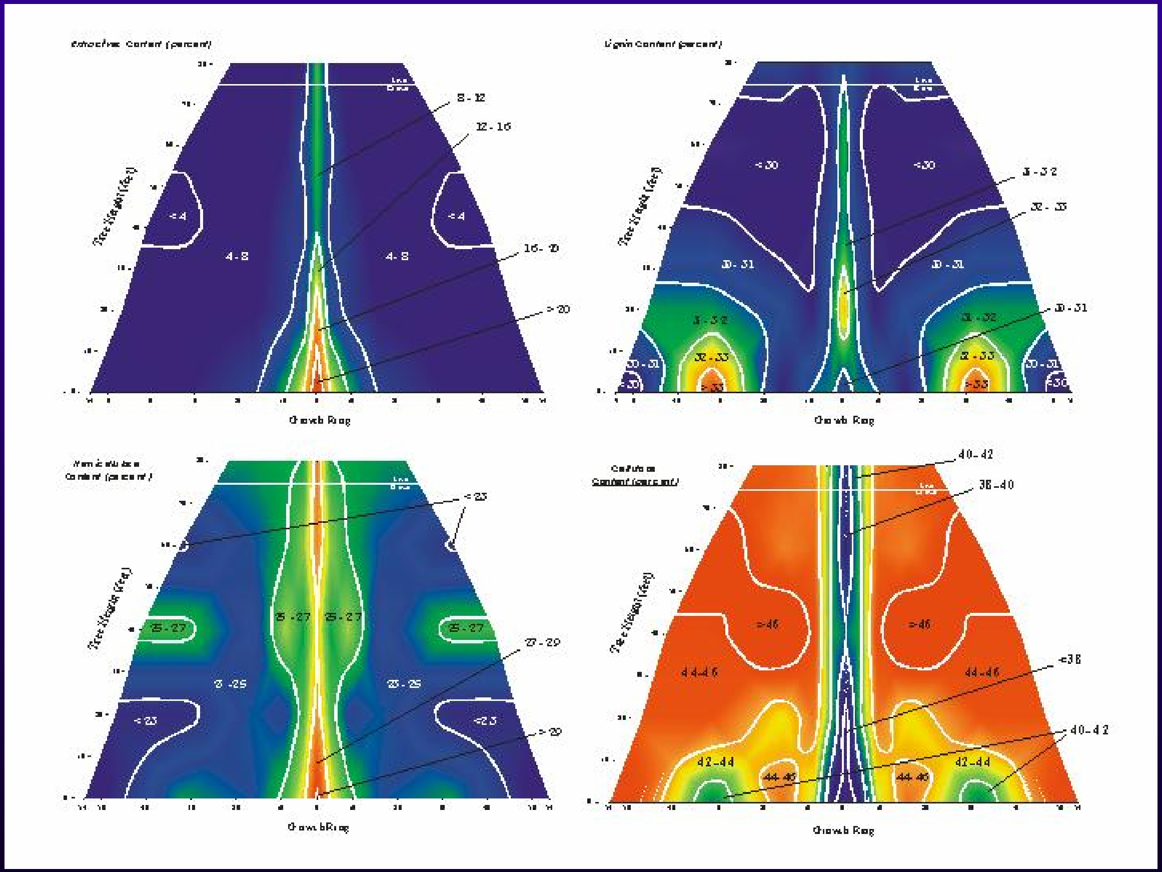
Microfibril Angle



Within-tree property variation

Extractives

Lignin



Hemicellulose

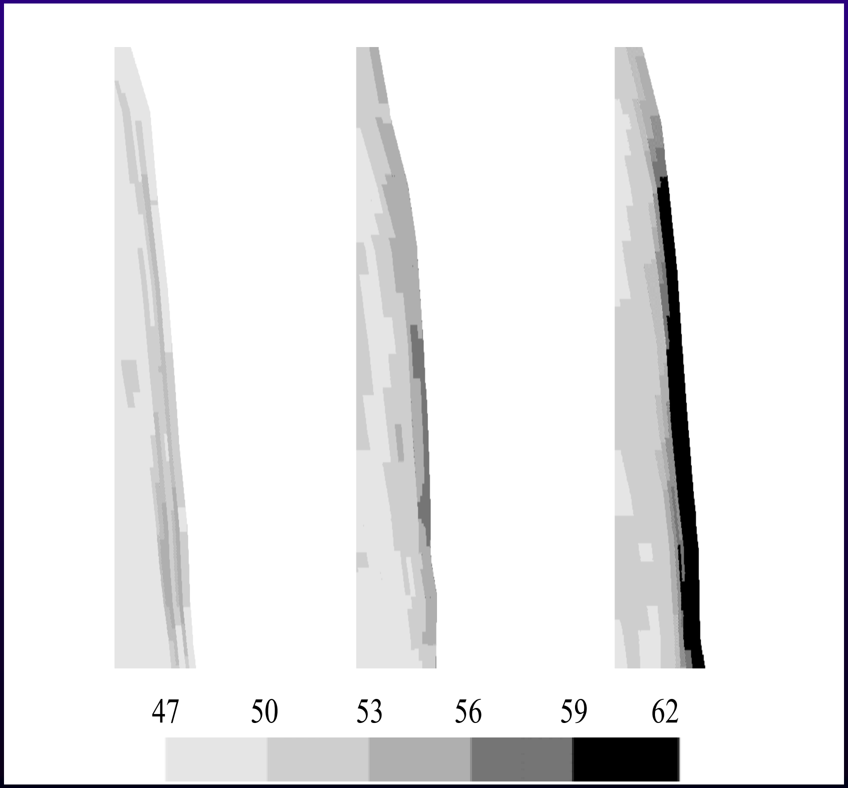
Cellulose

Application of NIR to whole-trees

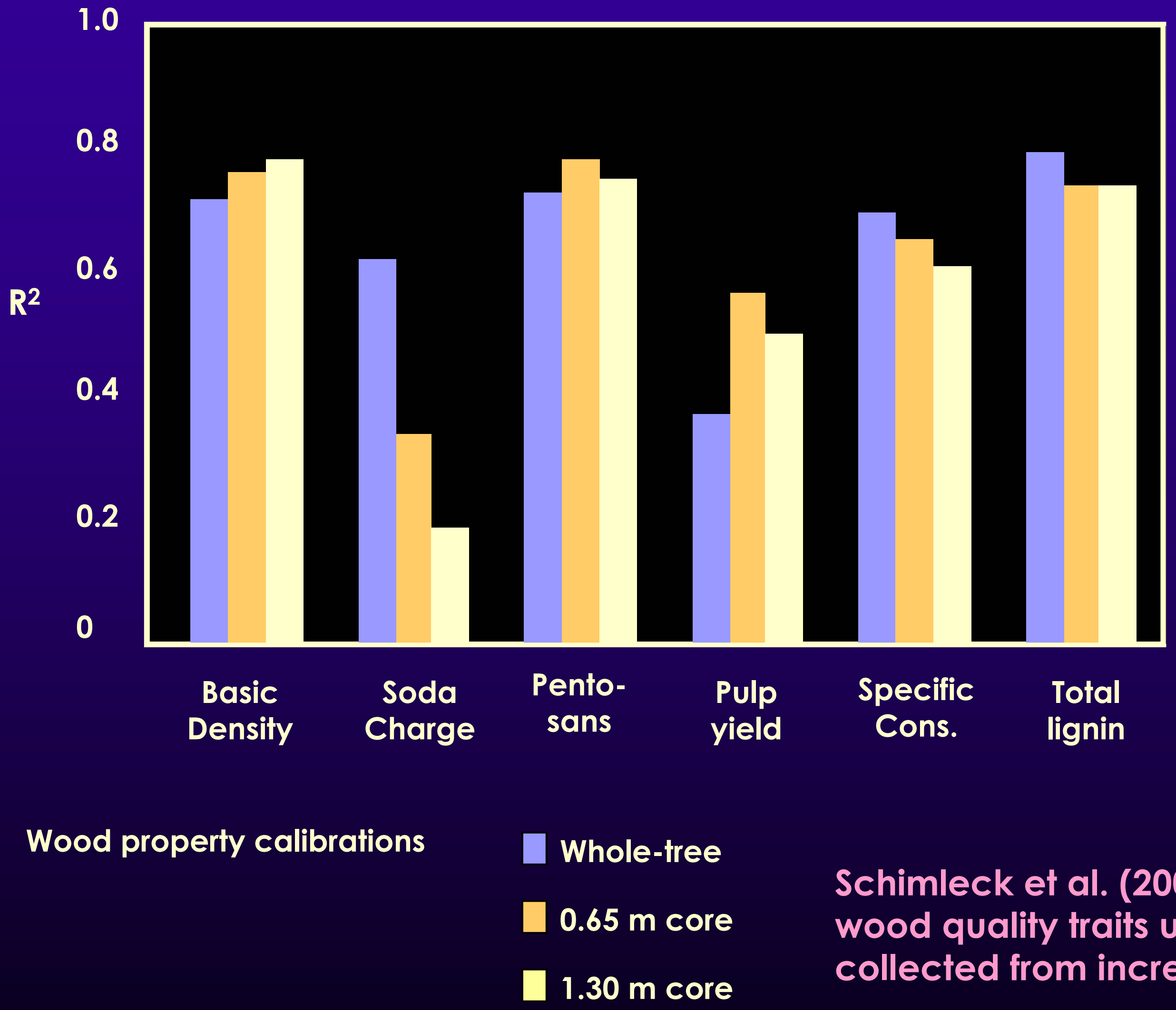
- Many studies, since late 1980's
- Pulp yield, cellulose, lignin, extractives
- Based on whole-tree composite chips
- Examination of within-tree variation of PY
- Studies have shown that breast height cores provide similar calibration statistics to composite chips for whole-tree properties
- = nondestructive estimation of whole-tree properties

Within-tree variation of pulp yield

- Little is known about the within-tree variation of pulp yield. NIR predictions of pulp yield can be used to obtain maps that show the variation



Whole-tree chip versus core calibrations



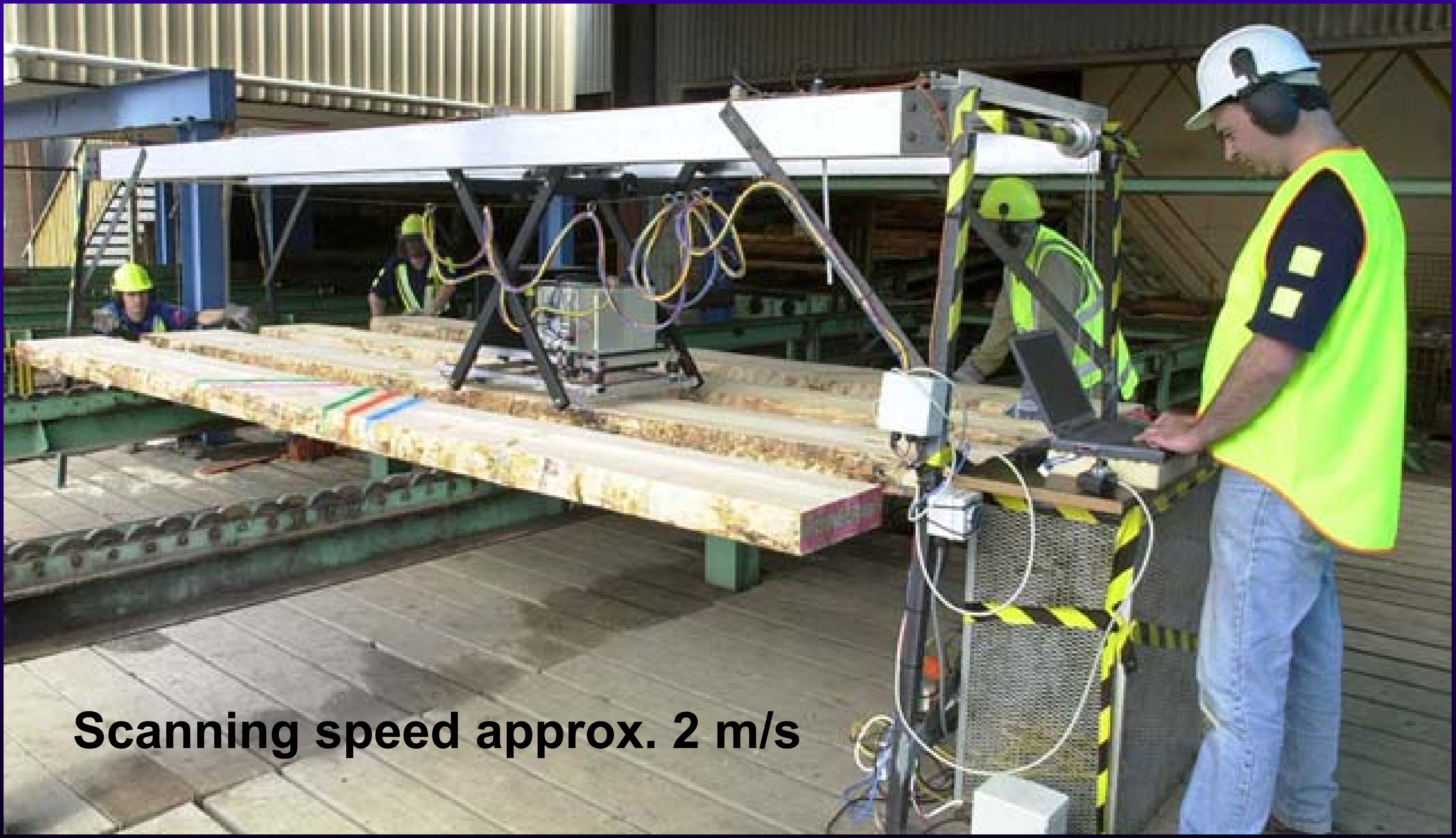
- Core and whole-tree calibrations were similar for basic density, pentosans, specific cons and total lignin
- Core calibrations could be used to rank trees
- 1.30 m identified as the most suitable sampling height

Schimleck et al. (2005). Estimation of whole-tree wood quality traits using near infrared spectra collected from increment cores. Appita J. (in press)

Application of NIR to lumber

- Meder et al. (2003)
- 185 *P. radiata* cant centers scanned by NIR in mill scale trial
- Aim to ID corewood stiff enough to be graded as MGP 8 (lowest structural grade)
- MGP 8 worth $80/m^3$ more than non-structural
- Data from 409 boards available for regression
- Calibration $R^2 = 0.54$ (big logs)
- Calibration $R^2 = 0.57$ (small logs)
- Sufficient for economic segregation of cants

Bruker Matrix-F scanning a cant



Picture courtesy A. Thumm and R. Meder, Forest Research, New Zealand

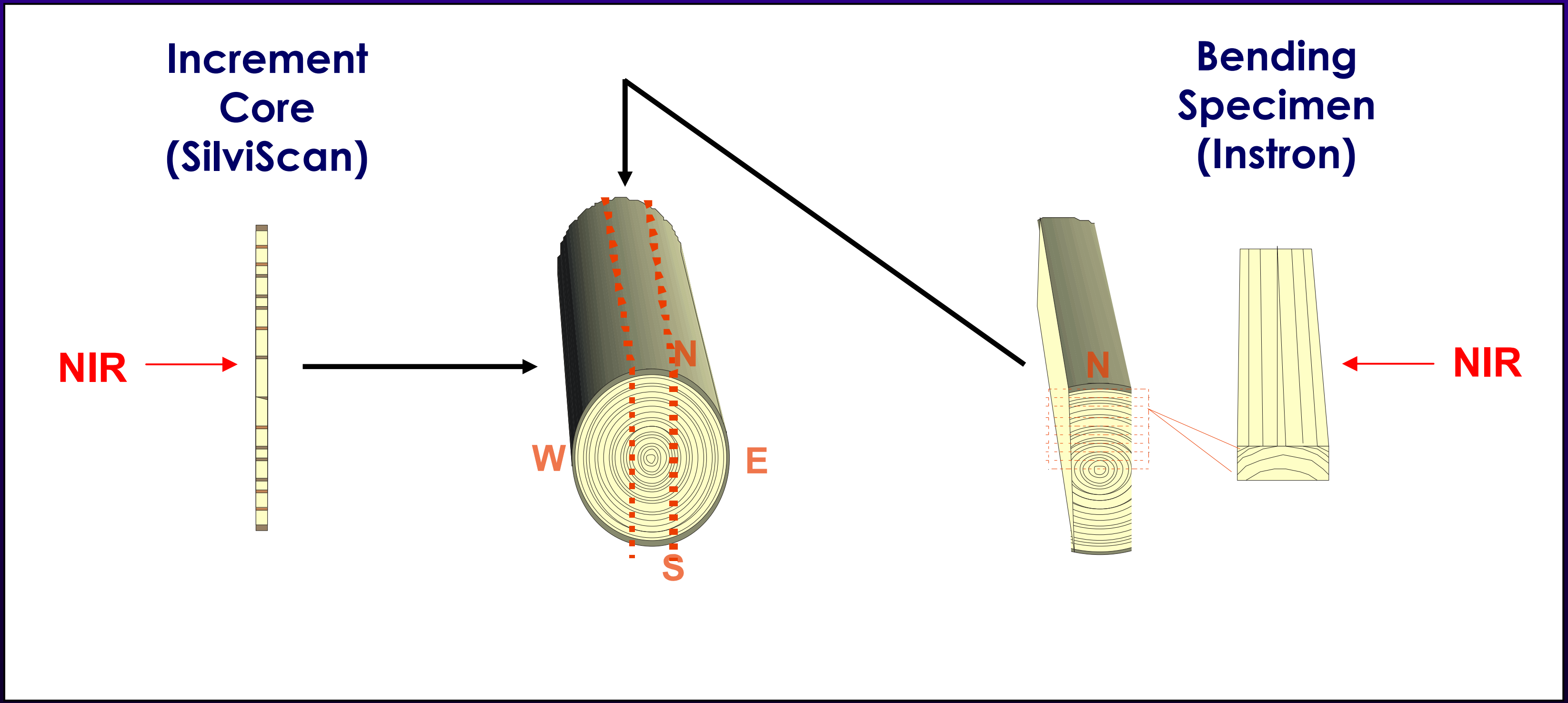
Application of NIR to lumber

- Meder et al. (2003) cont.
- Based on stiffness, 50% of central boards could be upgraded to MGP 8
- Further calibration expected to increase percentage of upgraded boards
- Many upgraded boards were unstable
- Both stiffness and stability (twist) must be predicted for NIR to be useful for segregating radiata pine structural timber
- Calibration for twist investigated (R^2 = 0.26)

Application of NIR to short-clears

- Several studies reported, different species and approaches
- Hoffmeyer and Pedersen (1995) *P. abies*
- Gindl et al. (2001) *L. decidua*
- Thumm and Meder (2001) *P. radiata*
- Schimleck et al. (2001) *E. delegatensis*, Schimleck et al. (2001) *P. radiata*
- Via et al. (2003) *P. palustris*
- Kelley et al. (2004) 6 softwood species
- Density, MOE and MOR examined

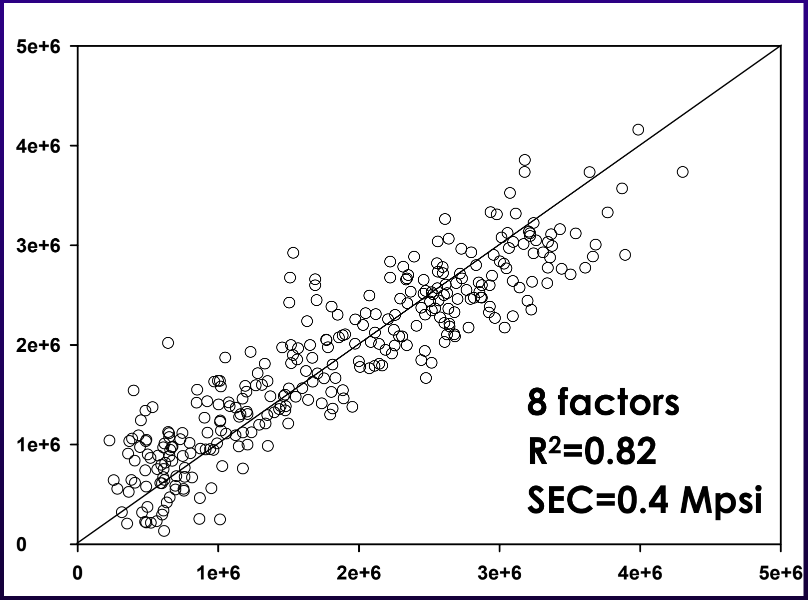
Measuring Mechanical Properties

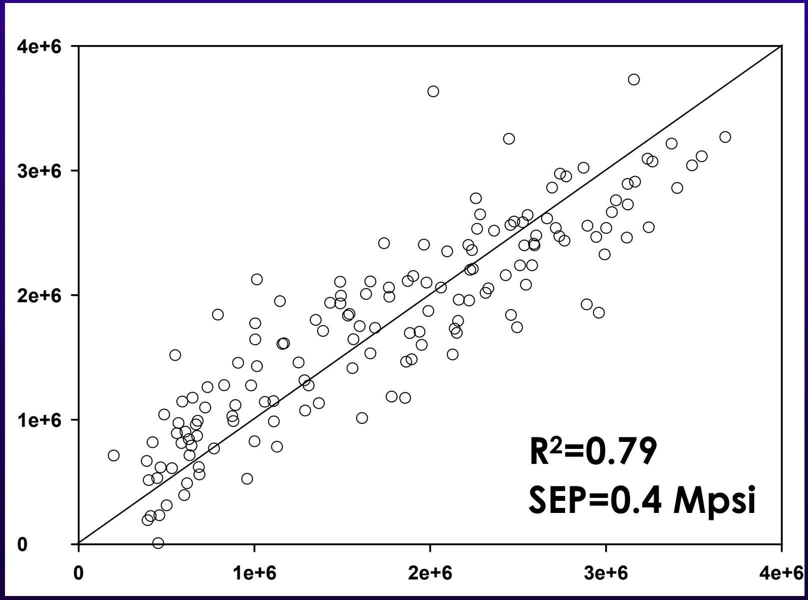


Stiffness (Bending Specimens)

Calibration (313 spectra)

Prediction (156 spectra)



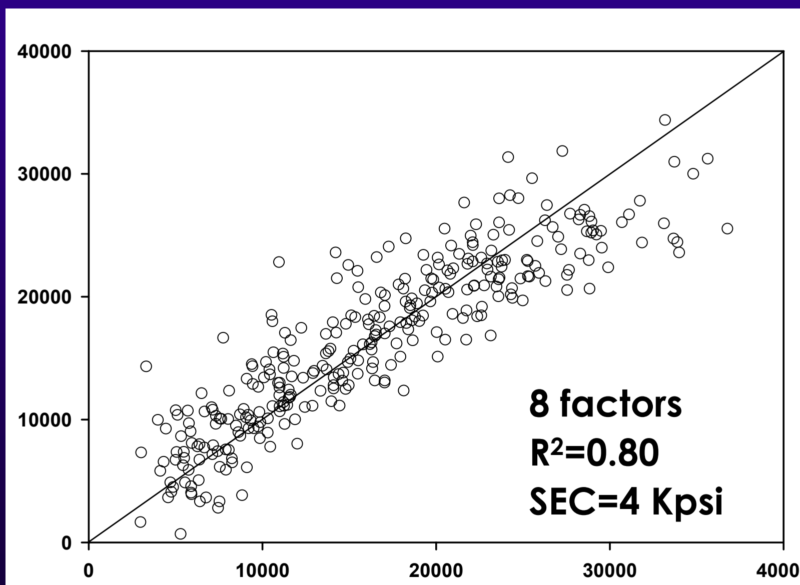


NIR-MOE

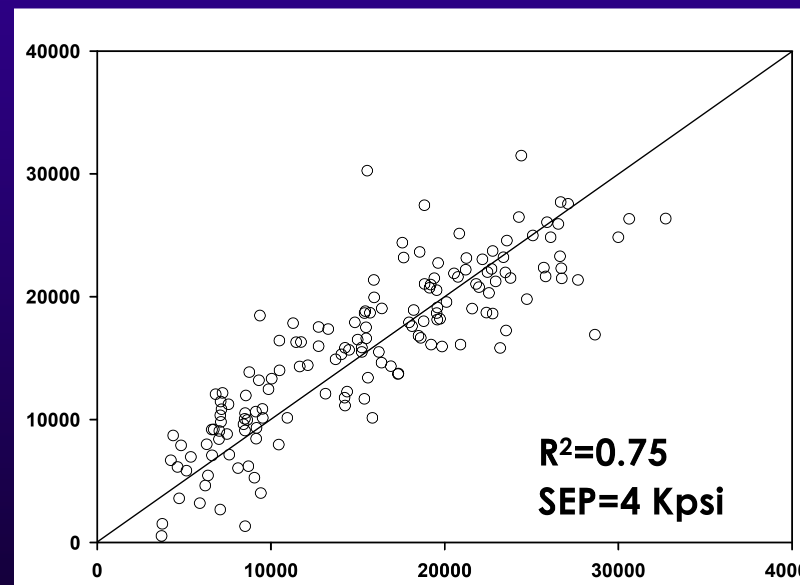
Instron-MOE

Strength (Bending Specimens)

Calibration (313 spectra)



Prediction (156 spectra)



NIR-MOR

Instron-MOR

Application of NIR to cores

Properties examined :

Tracheid length (FQA)

Cellulose, sugars, lignin (wet chemistry)

Air-dry density, MFA, stiffness, tracheid properties (SilviScan)

Radial strips cut from cores used but core surface OK for NIR spectroscopy

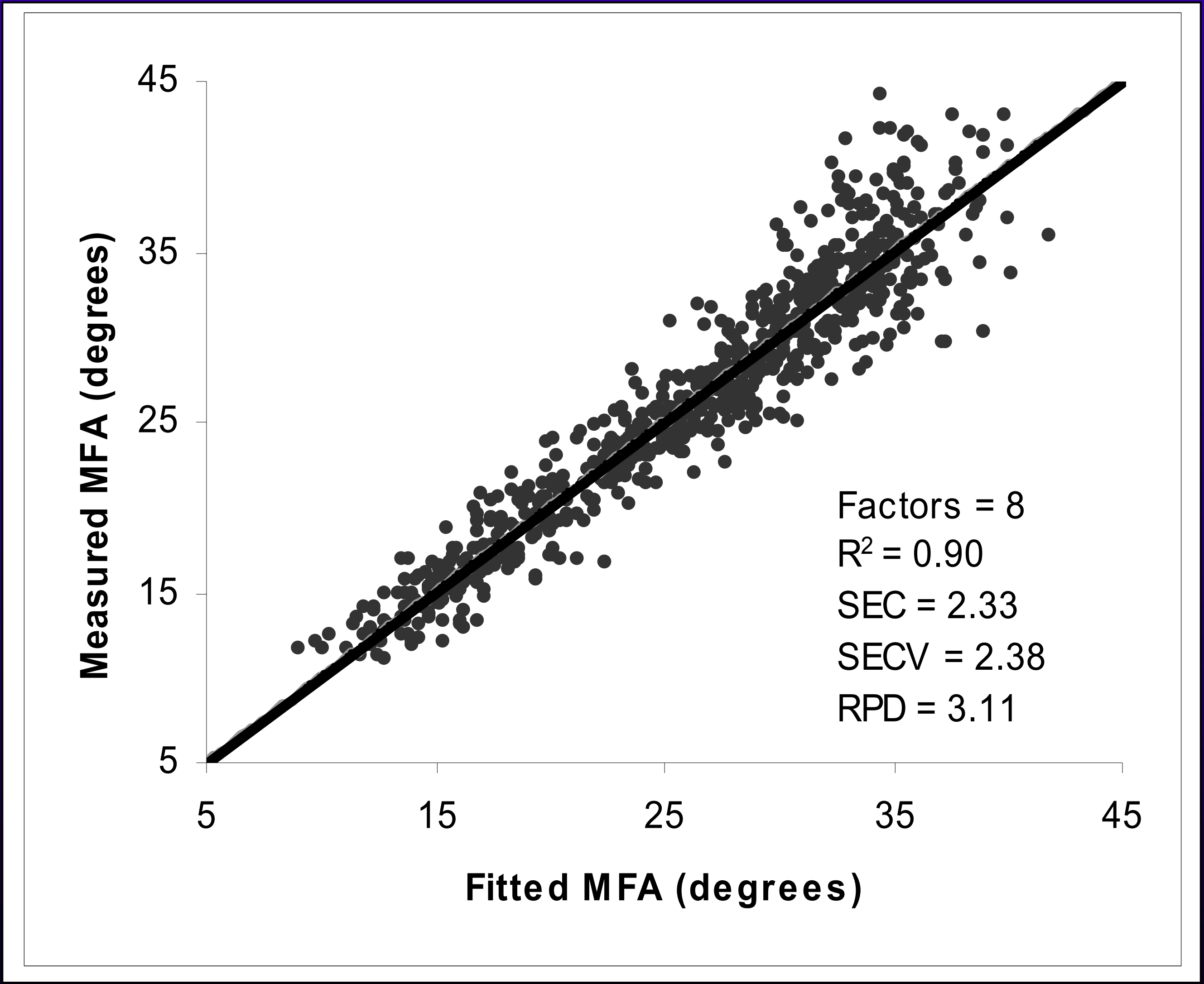
Georgia-wide calibrations

- *P. taeda* grown in 3 regions in Georgia
- Three sites selected as being representative of each region
- Selection based on site index
- Ten trees selected per site representing a range of breast height diameters
- Pith-bark breast height samples obtained

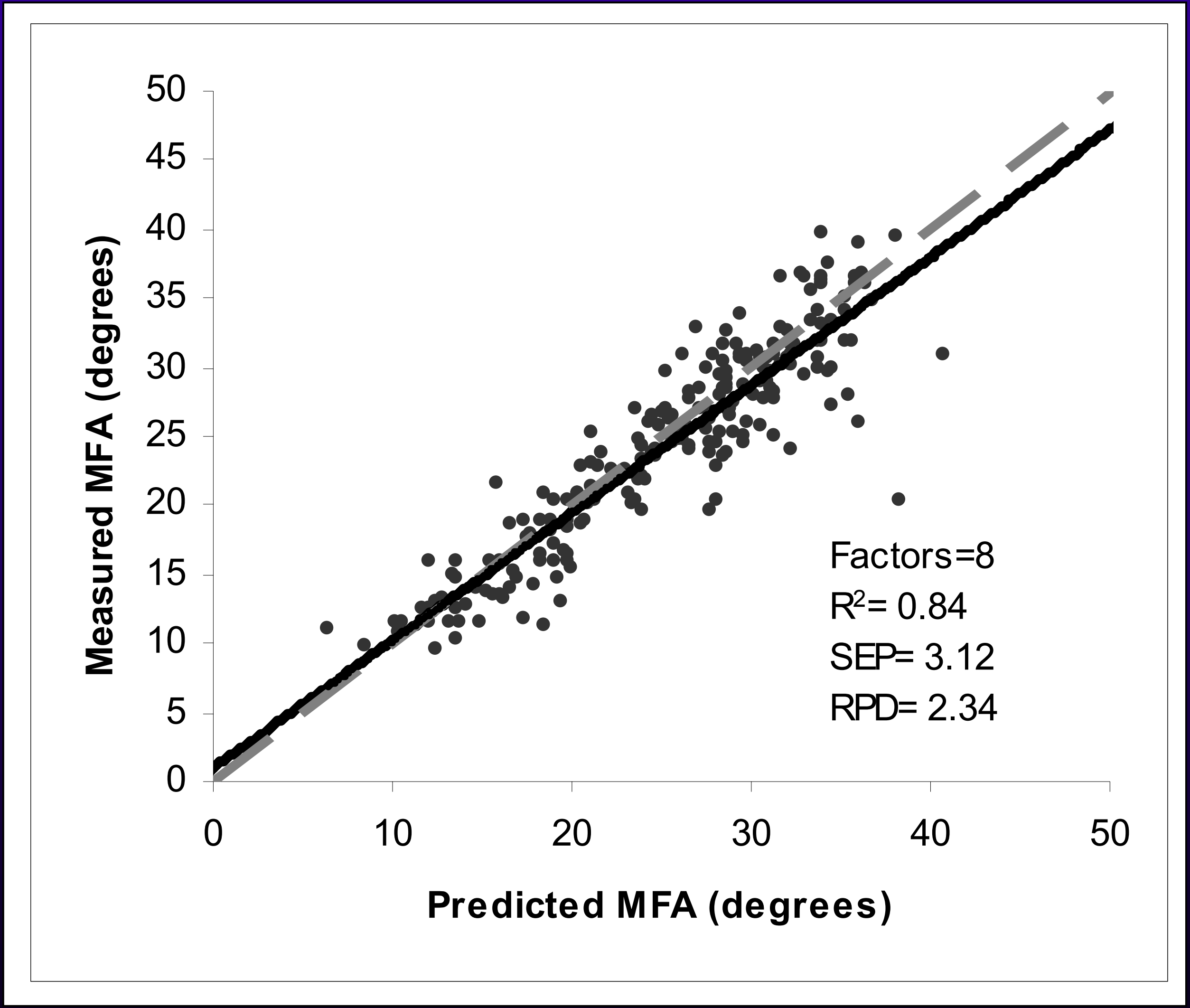
Georgia-wide calibrations

- Strong calibrations for density, MFA, stiffness and tracheid coarseness, length and wall thickness
- These calibrations performed well on the separate test set
- Strong calibrations for cellulose, lignin, glucan, arabinan, mannan and xylan
- Moderate prediction accuracy - possibly due to the small number of samples

MFA – 729 MSC treated spectra



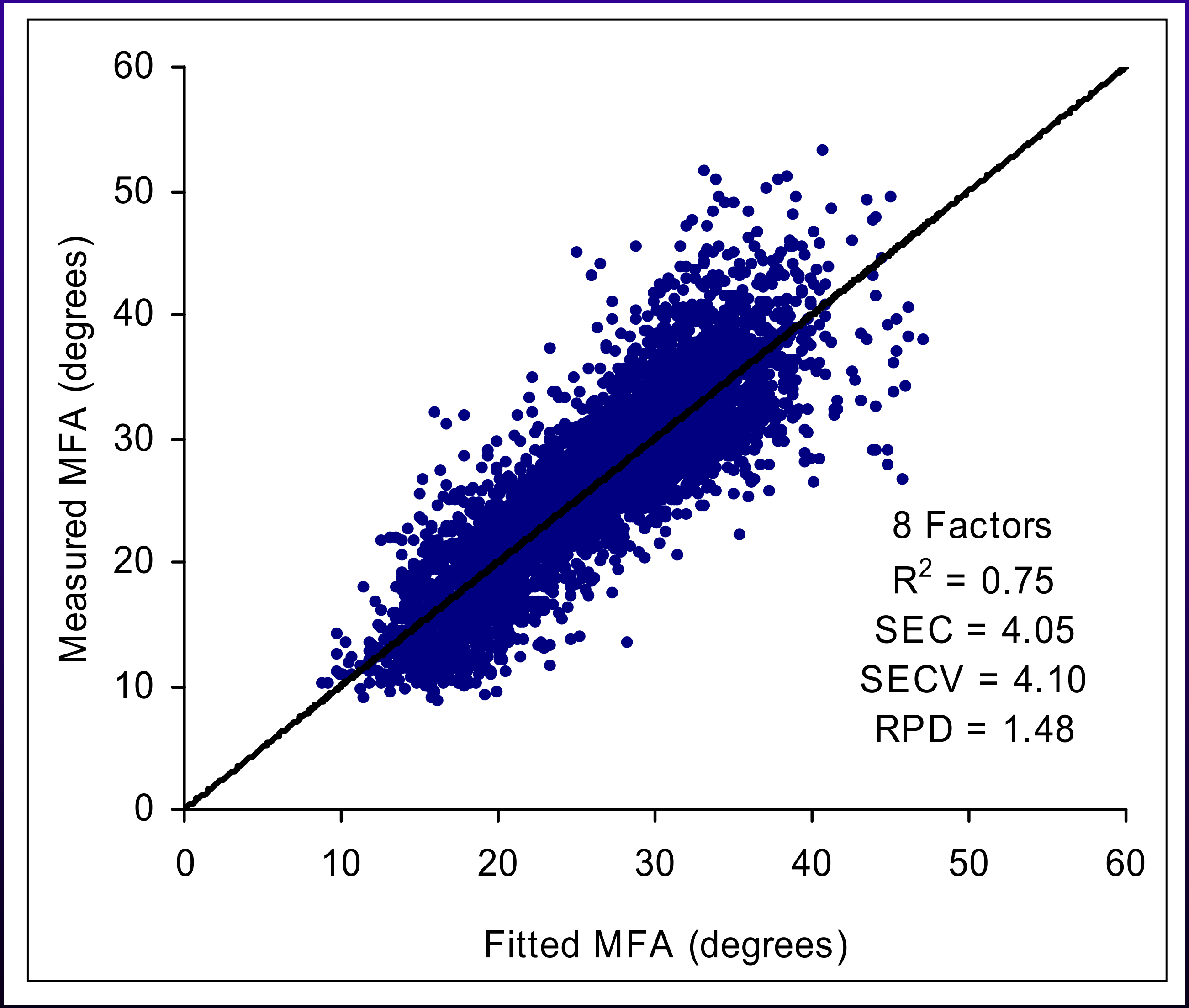
Predicted MFA (225 spectra)



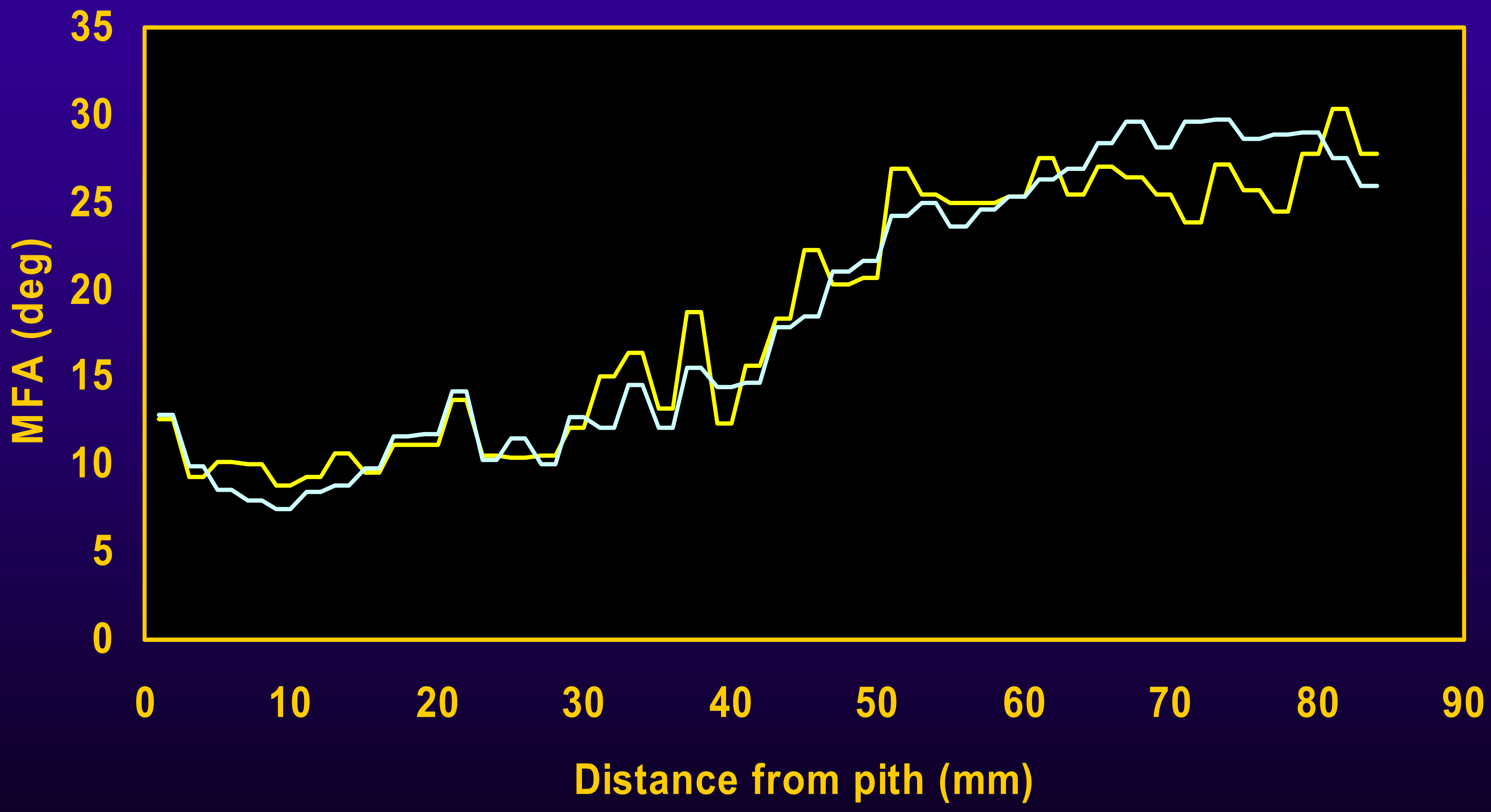
What resolution??

- Increasing resolution = decrease in calibration accuracy
- Management of spectra becomes difficult owing to large number of spectra
- Fiber optic probes with a small spot size provides options

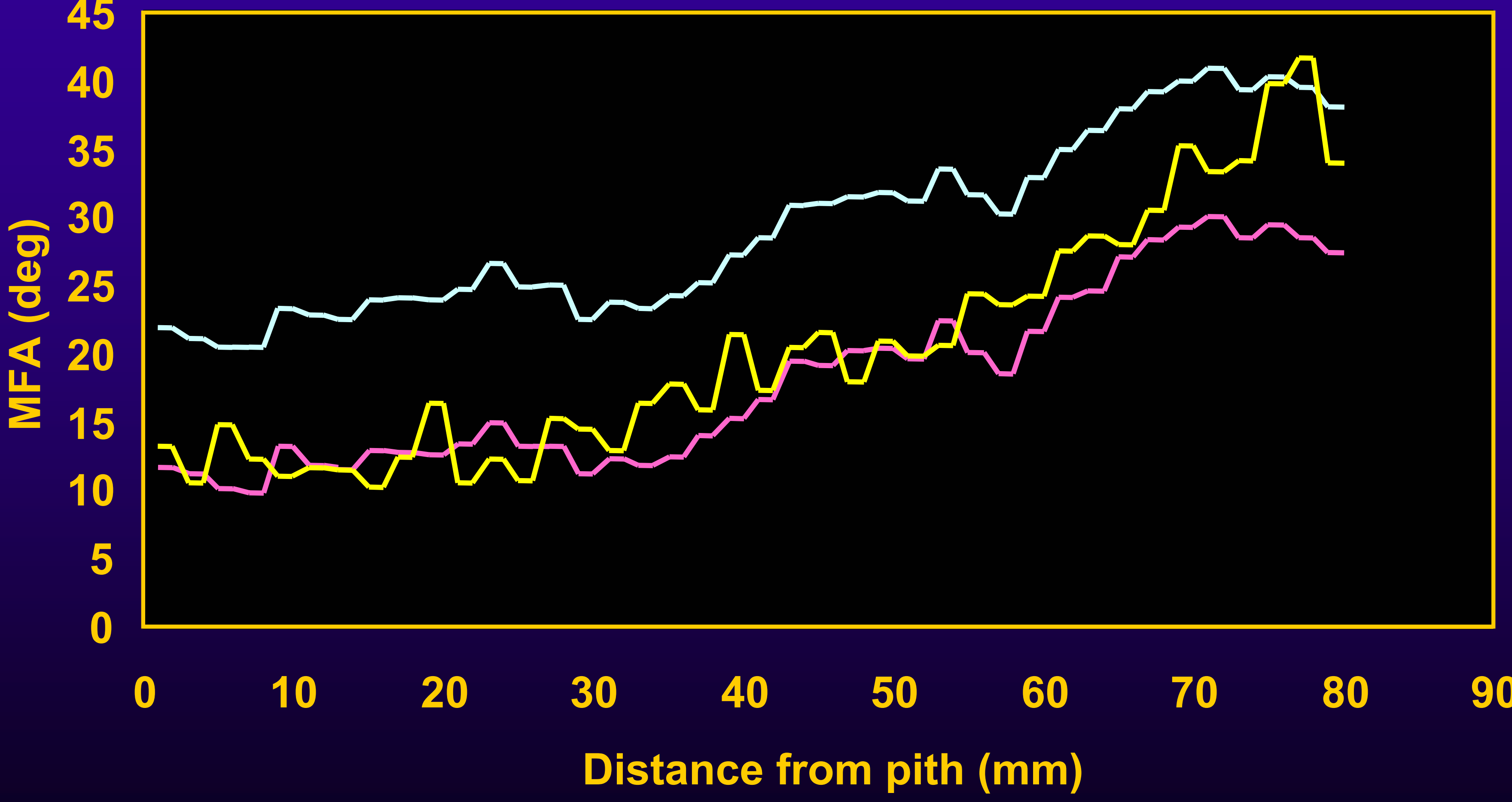
2 mm MFA calibration (4156 spectra)



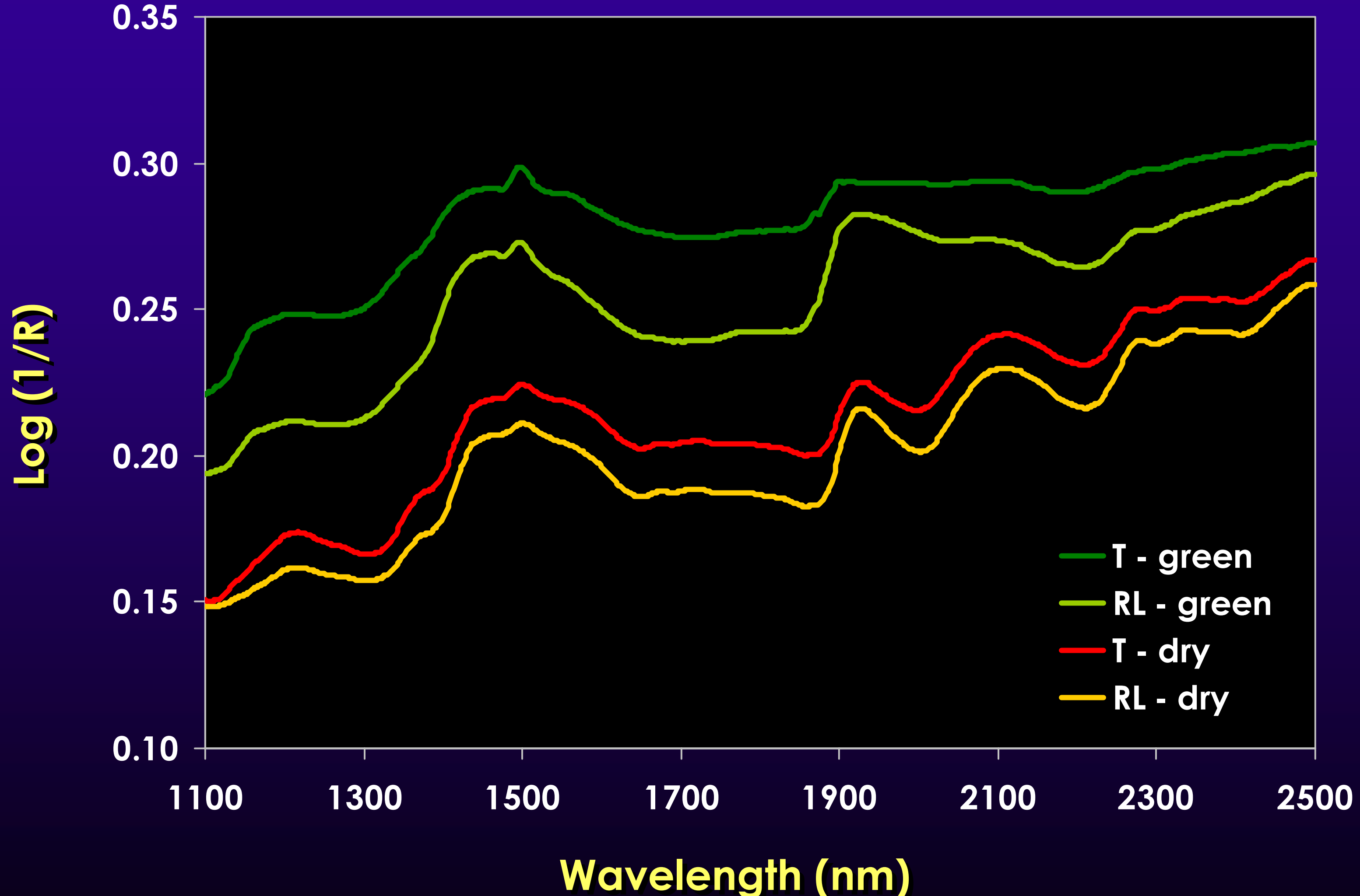
2 mm MFA prediction



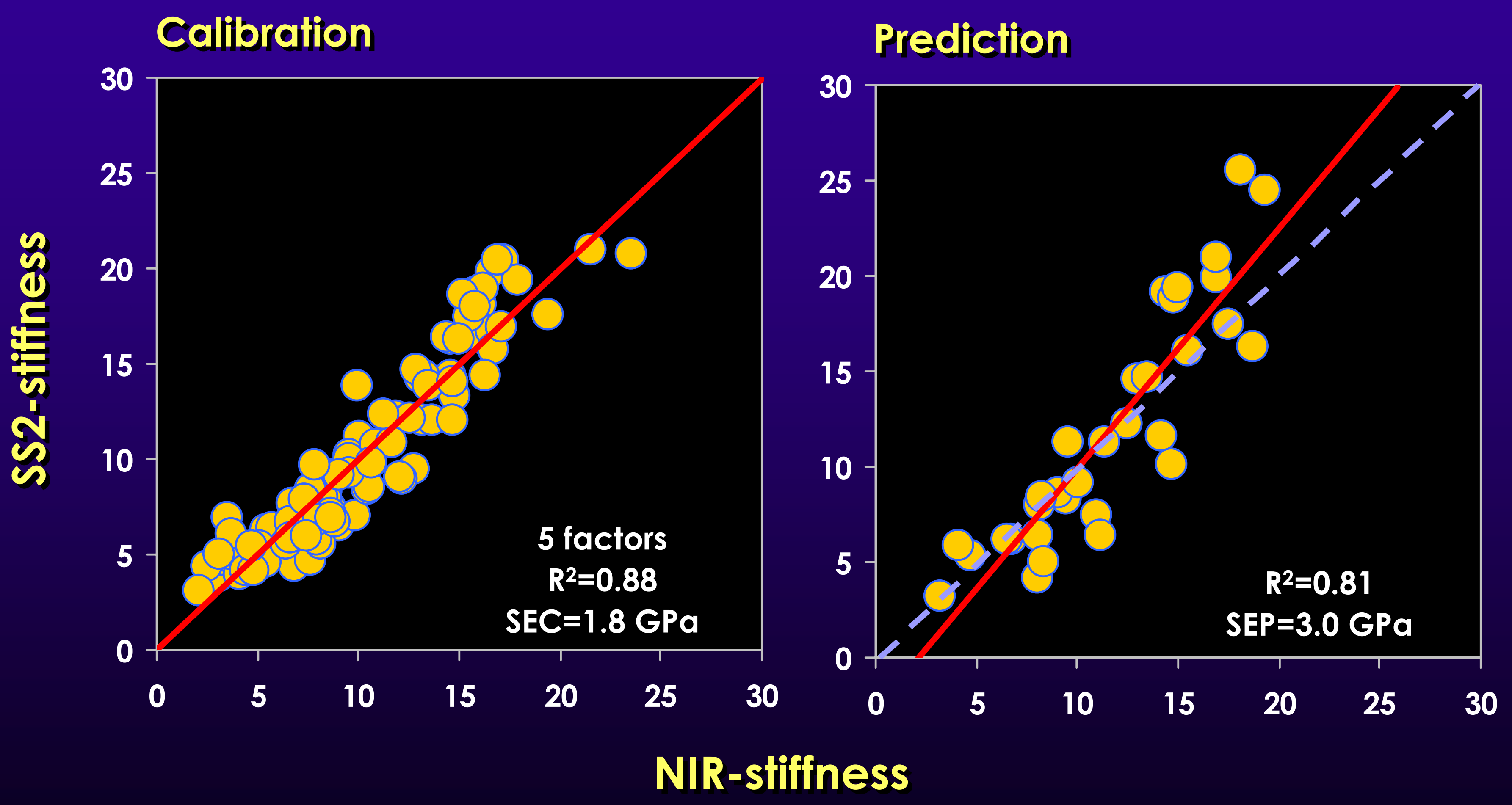
2 mm MFA prediction



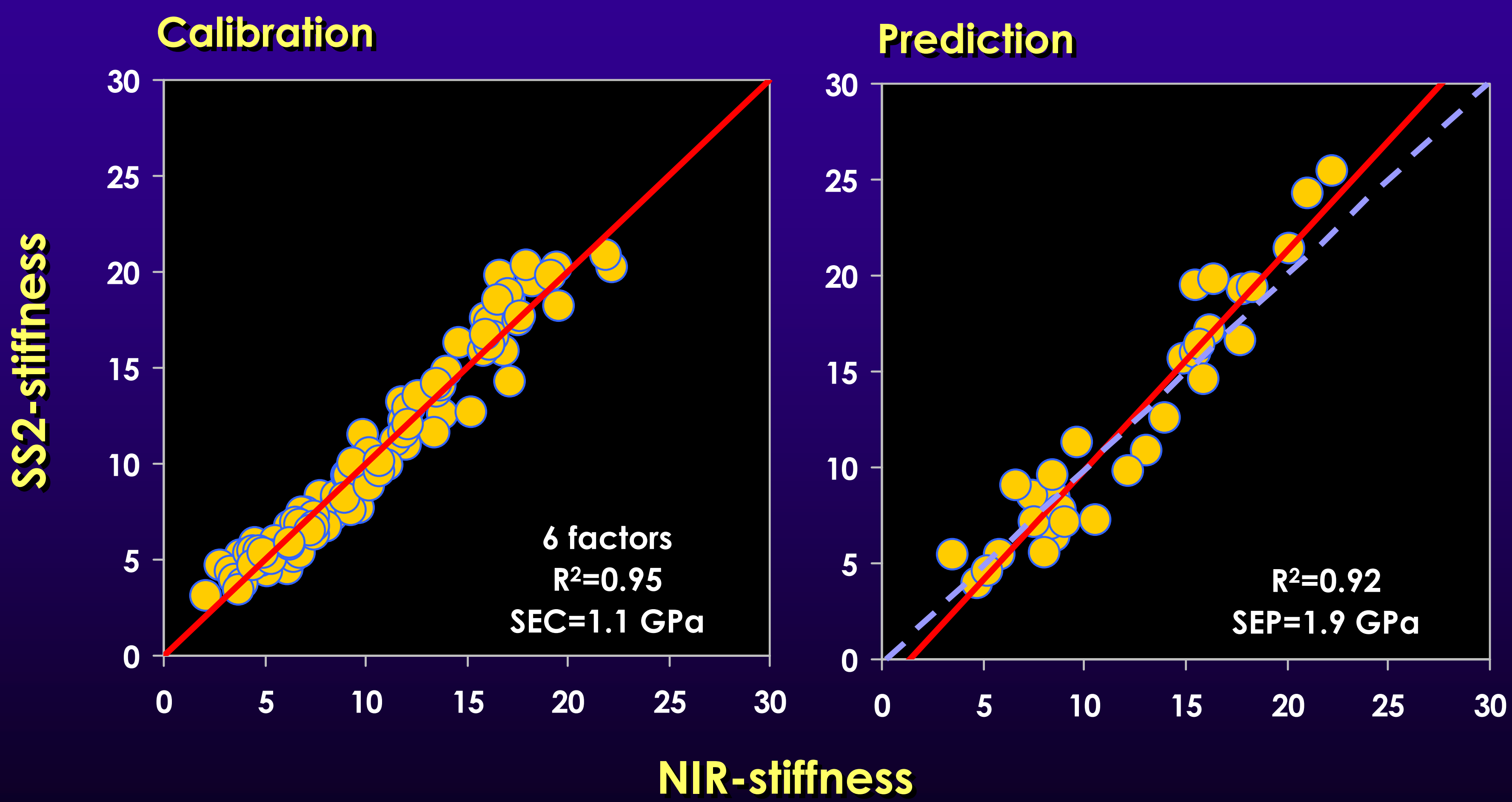
Wood property calibrations – green versus dry wood



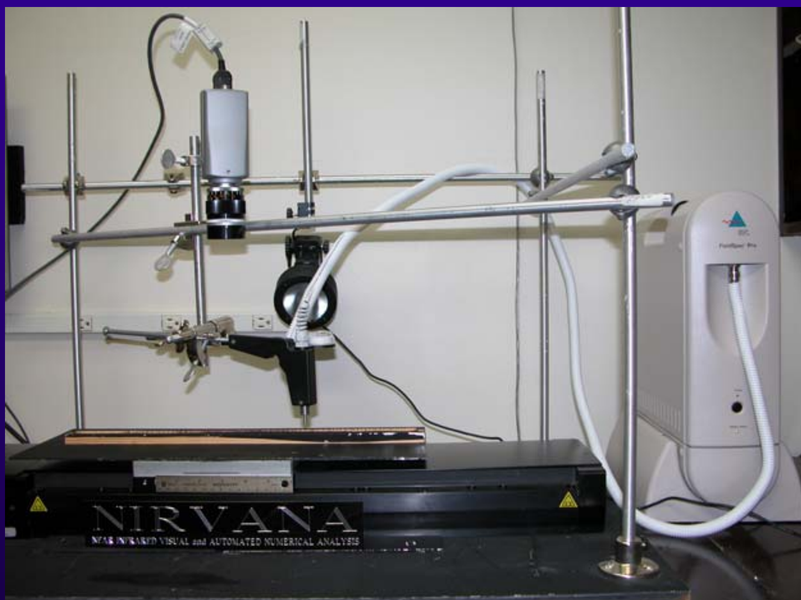
Stiffness (green wood spectra)



Stiffness (dry wood spectra)



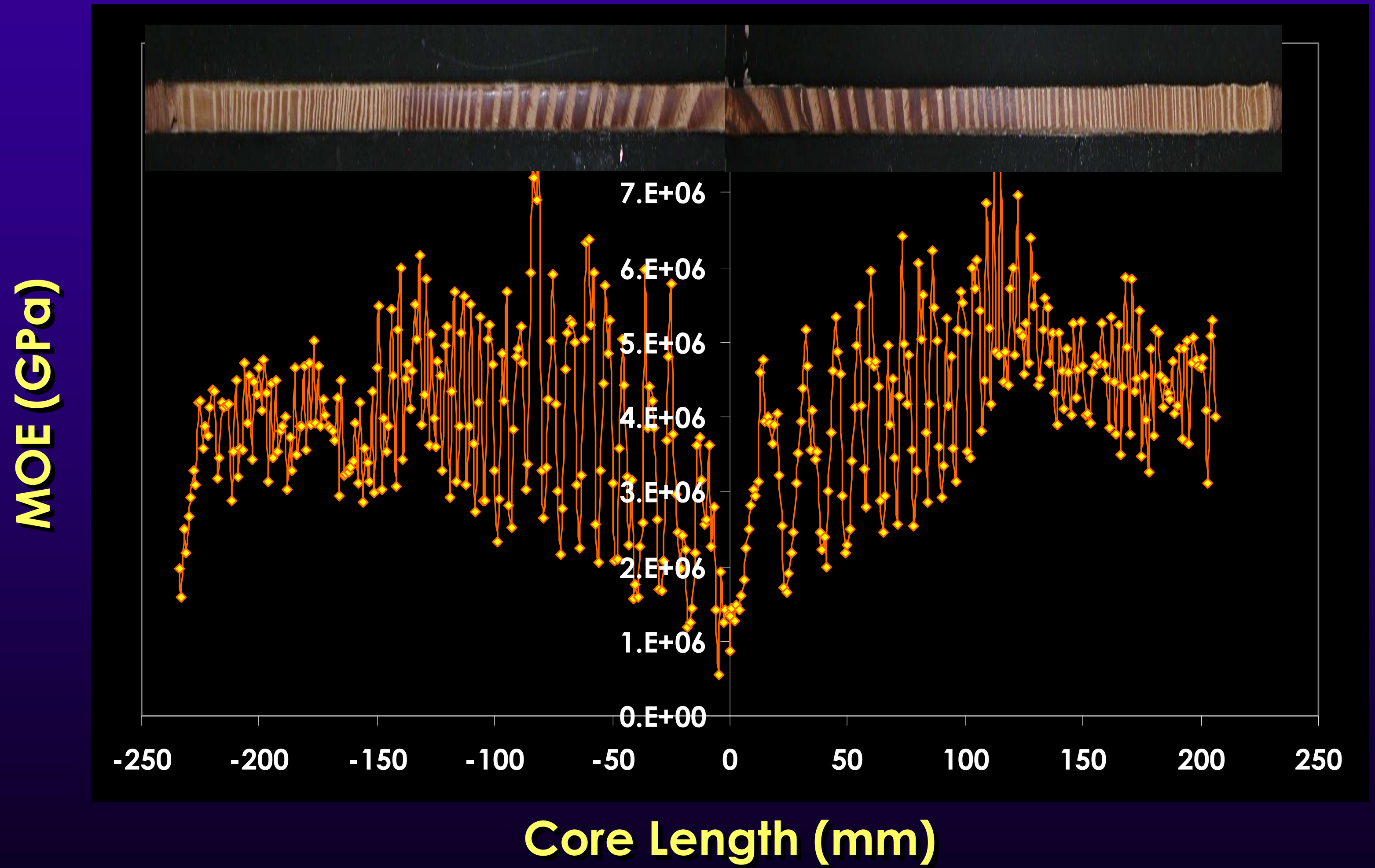
NIRVANA – Near Infrared Visual & Automated Numerical Analysis



NIRVANA
NEAR INFRARED VISUAL AND AUTOMATED NUMERICAL ANALYSIS

- Automated spectra collection
- High resolution video camera
- Real time property predictions
- Ideal for process monitoring & QC applications

MOE Variation



Conclusions – NIR spectroscopy

- Determination of within-tree variation
- Estimation of whole-tree properties
- Applicable to milled wood, short-clears, increment cores
- Automatic scanning of cores possible
- Important to improve resolution
- Green wood can be examined