SIRT

Strategic Integrated Research in Timber

Edinburgh Napier UNIVERSITY

Timber grading
Graddio Pren

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Centre for Wood Science and Technology

Ganolfan ar gyfer Gwyddoniaeth a Thechnoleg Pren

"Tree Breeding and Forest Products - An update on current research"

"Bridio Coed a Chynnyrch Coedwigoedd – Y Diweddaraf am waith ymchwil cyfredol"

Garwnant, 9/5/2017

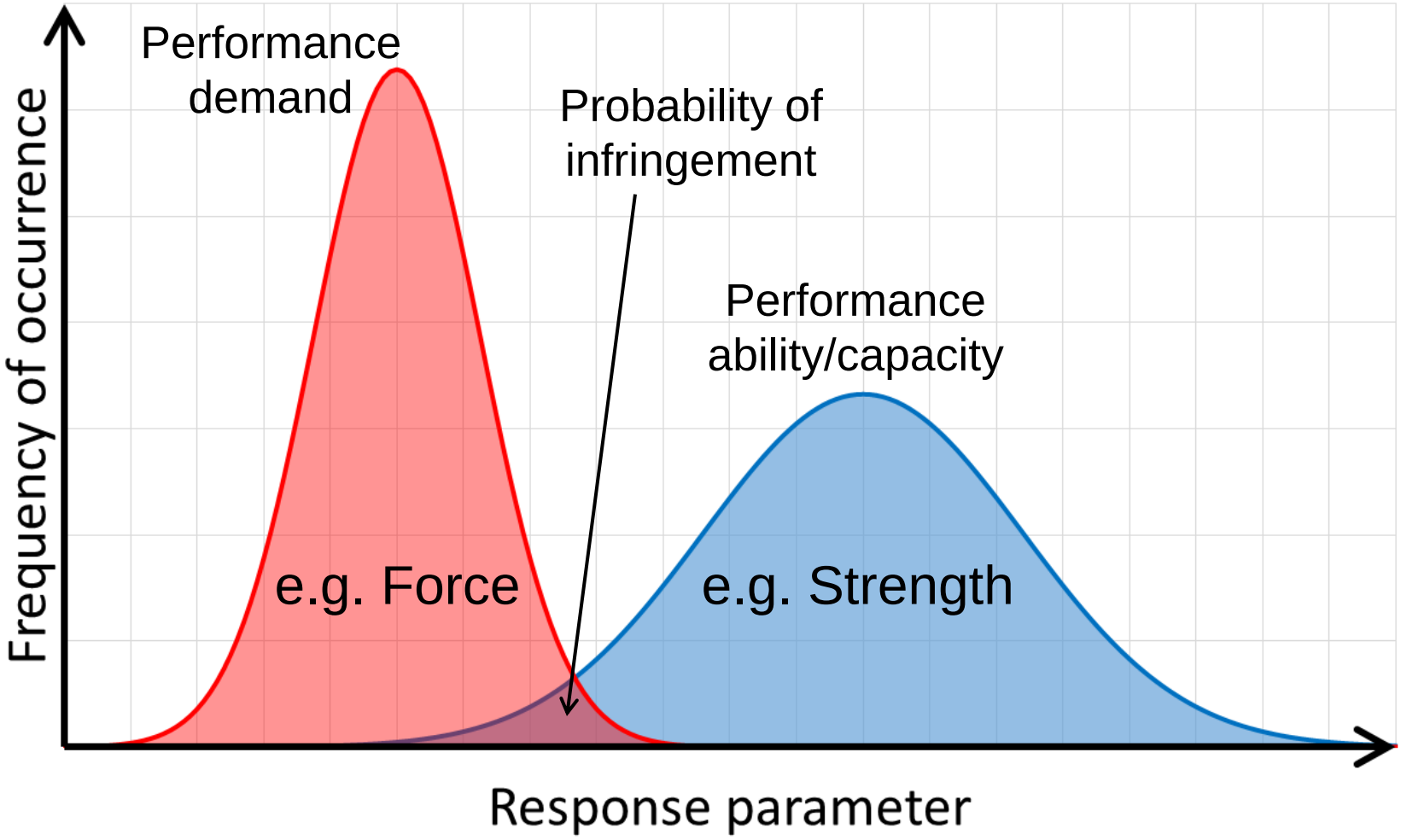
The Queen's Anniversary Prizes
For Higher and Further Education
2015

Structural engineering design

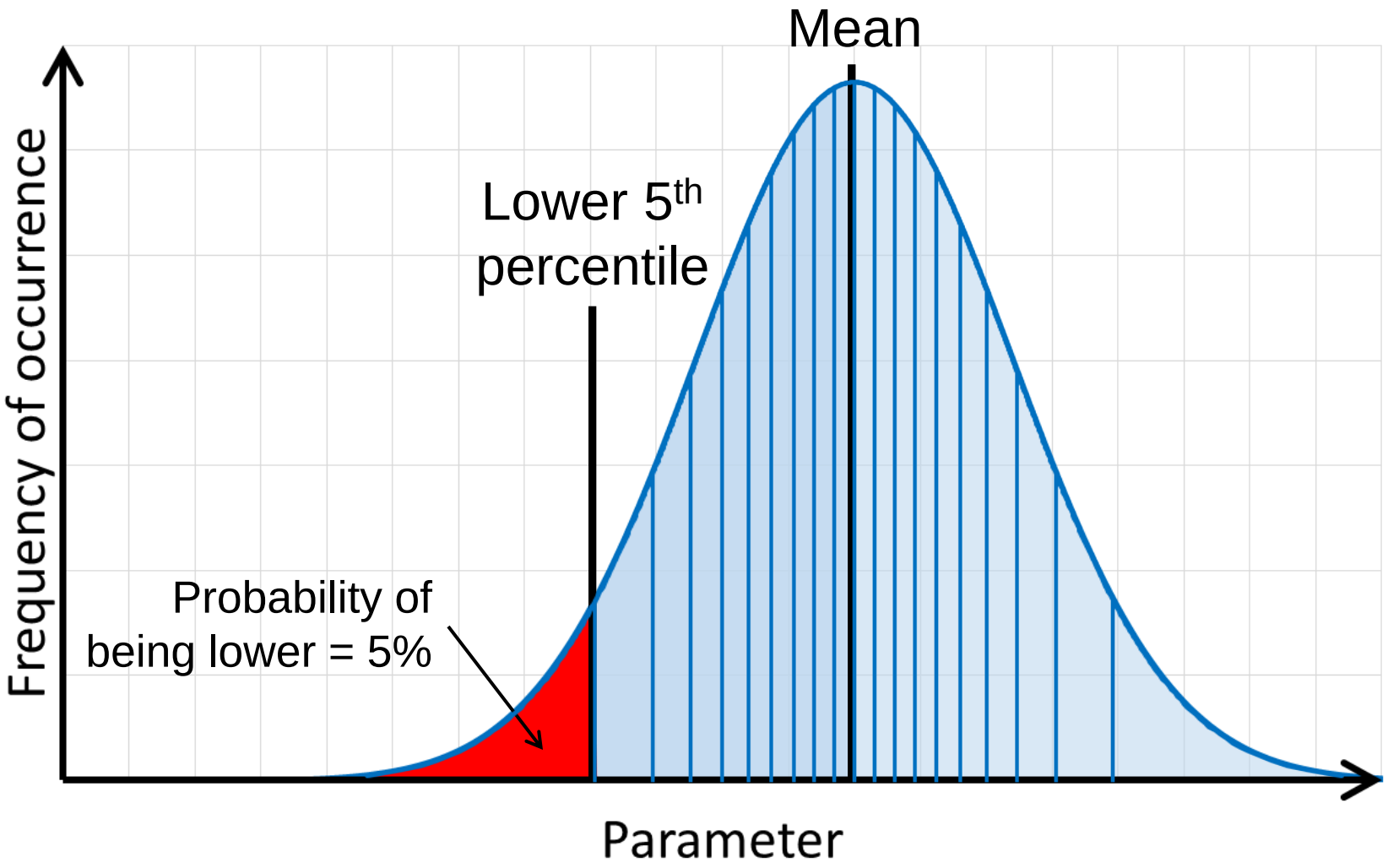
- About buildings
  - Staying safe
  - Staying fit for use
- Dealing with uncertainty
  - Of material
  - Of the actions on a structure
  - Of analysis and construction
- True irrespective of the material

  (There is always some uncertainty)

Dealing with uncertainty



Characteristic values



(Some) standards for grading

- EN 14081 strength graded structural timber
- EN 338 sizes and permitted variations
- EN 384, EN 408, EN 14358 testing & calculations
- Machine grading settings ("ITTs" or "AGRs")
- Visual grading rules
  - e.g. BS 4978, IS 127, DIN 4074
- EN 1912 visual grading assignments
- Other assignments
  - Private & e.g. PD 6693

Grade-determining properties

(definition of a strength class: EN 384 for EN 14081)

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- Strength
  - Bending or tension strength
  - Characteristic is the 5th percentile
- Stiffness
  - Bending or tension stiffness
  - Characteristic is the mean
- Density
  - Used for indirect measure of strength / fire resistance (this is not density for dead weight)
  - Characteristic is the 5th percentile

Grading aims that GDP requirements are met (subject to various adjustments)

Declaration of performance usually via

Strength classes (or "grades")

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e.g. EN 338:2016

	Class	C14	C16	C18	C20	C22	C24	C27	
Strength properties in N/mm²									
Bending	$f_{m,,k}$	14	**16**	**18**	20	22	**24**	27	
Tension parallel	$f_{t,0,k}$	7,2	**8,5**	**10**	11,5	13	**14,5**	16,5	
Tension perpendicular	$f_{t,90,k}$	0,4	**0,4**	**0,4**	0,4	0,4	**0,4**	0,4	**0**
Compression parallel	$f_{c,0,k}$	16	**17**	**18**	19	20	**21**	22	**24**
Compression perpendicular	$f_{c,90,k}$	2,0	**2,2**	**2,2**	2,3	2,4	**2,5**	2,5	**2,7**
Shear	$f_{v,k}$	3,0	**3,2**	**3,4**	3,6	3,8	**4,0**	4,0	**4,0**
Stiffness properties in kN/mm²									
Mean modulus of elasticity parallel bending	$E_{m,0,mean}$	7,0	**8,0**	**9,0**	9,5	10,0	**11,0**	11,5	**1**
5 percentile modulus of elasticity parallel bending	$E_{m,0,k}$	4,7	**5,4**	**6,0**	6,4	6,7	**7,4**	7,7	
Mean modulus of elasticity perpendicular	$E_{m,90,mean}$	0,23	**0,27**	**0,30**	0,32	0,33	**0,37**	0,38	
Mean shear modulus	G_{mean}	0,44	**0,50**	**0,56**	0,59	0,63	**0,69**	0,72	
Density in kg/m³									
5 percentile density	ρ_k	290	**310**	**320**	330	340	**350**	36	
Mean density	ρ_{mean}	350	**370**	**380**	400	410	**420**	4	

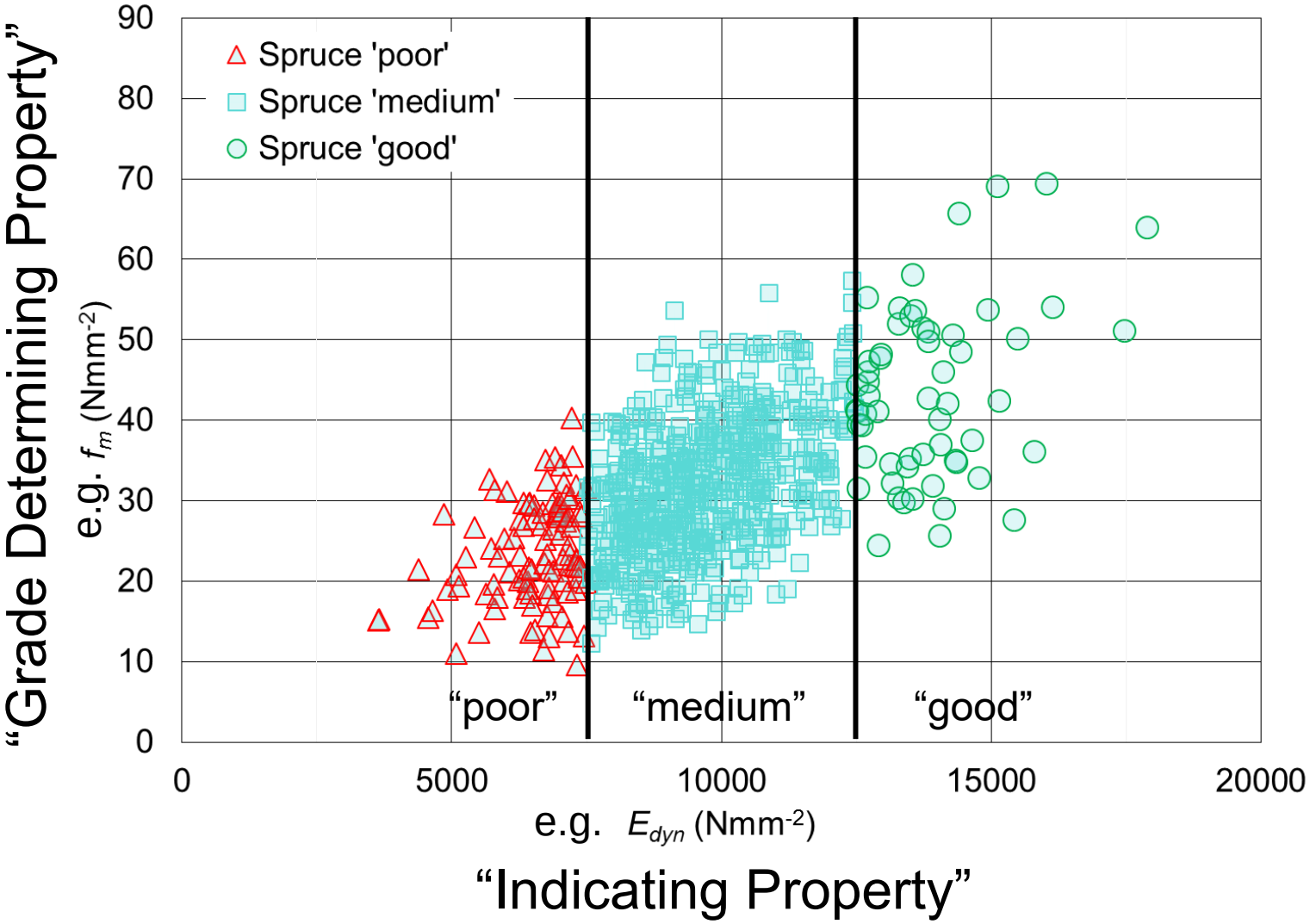

Based on testing
EN 408
EN 384
EN 14358

Current methods in Europe

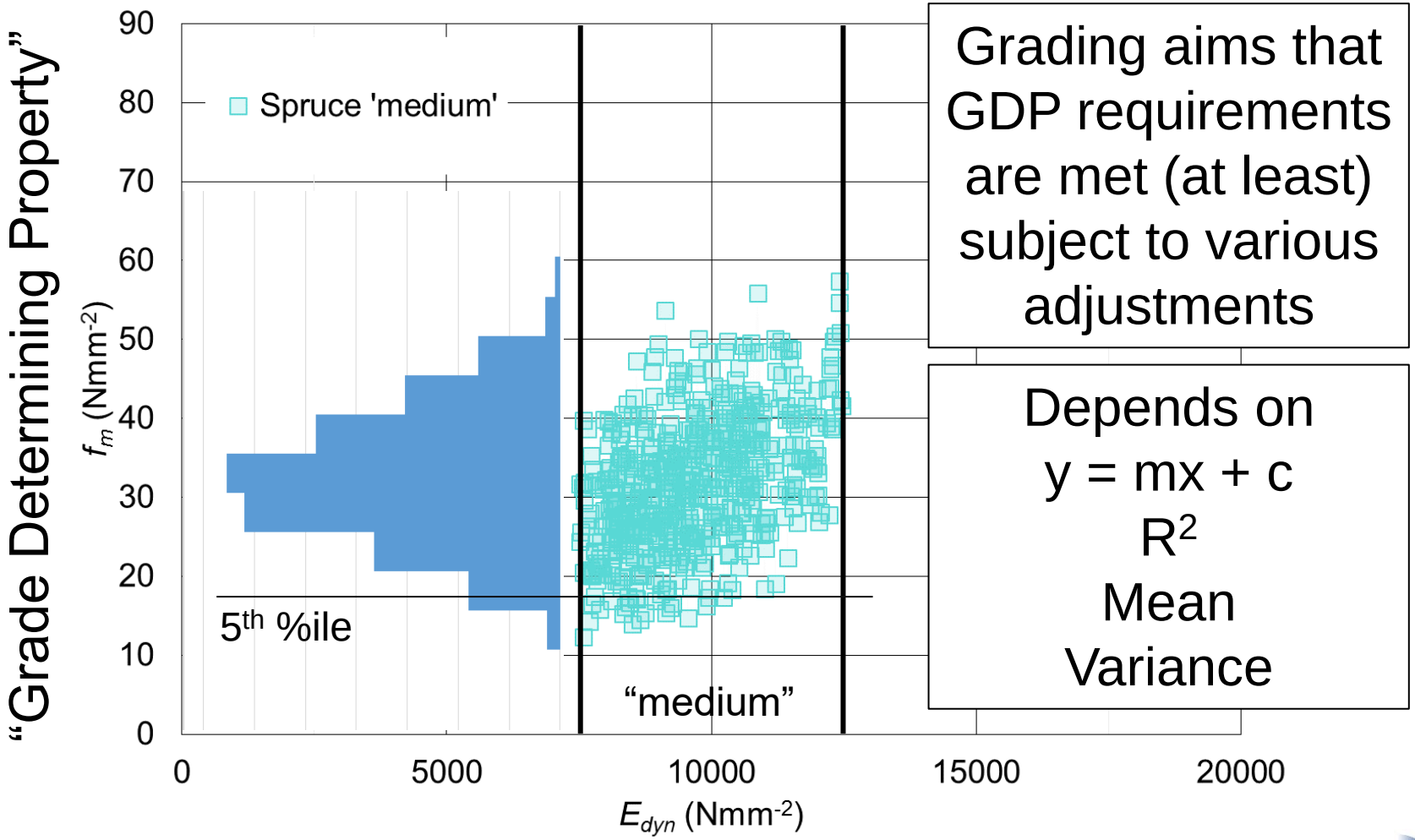
- Visual grading
  - Visually grade – then assign to strength class
- Machine grading
  - Machine control (large initial testing, fixed settings)
  - Output control (regular testing, settings can change)

- Slightly different basis
- …but same fundamentals

Grading – IP boundaries



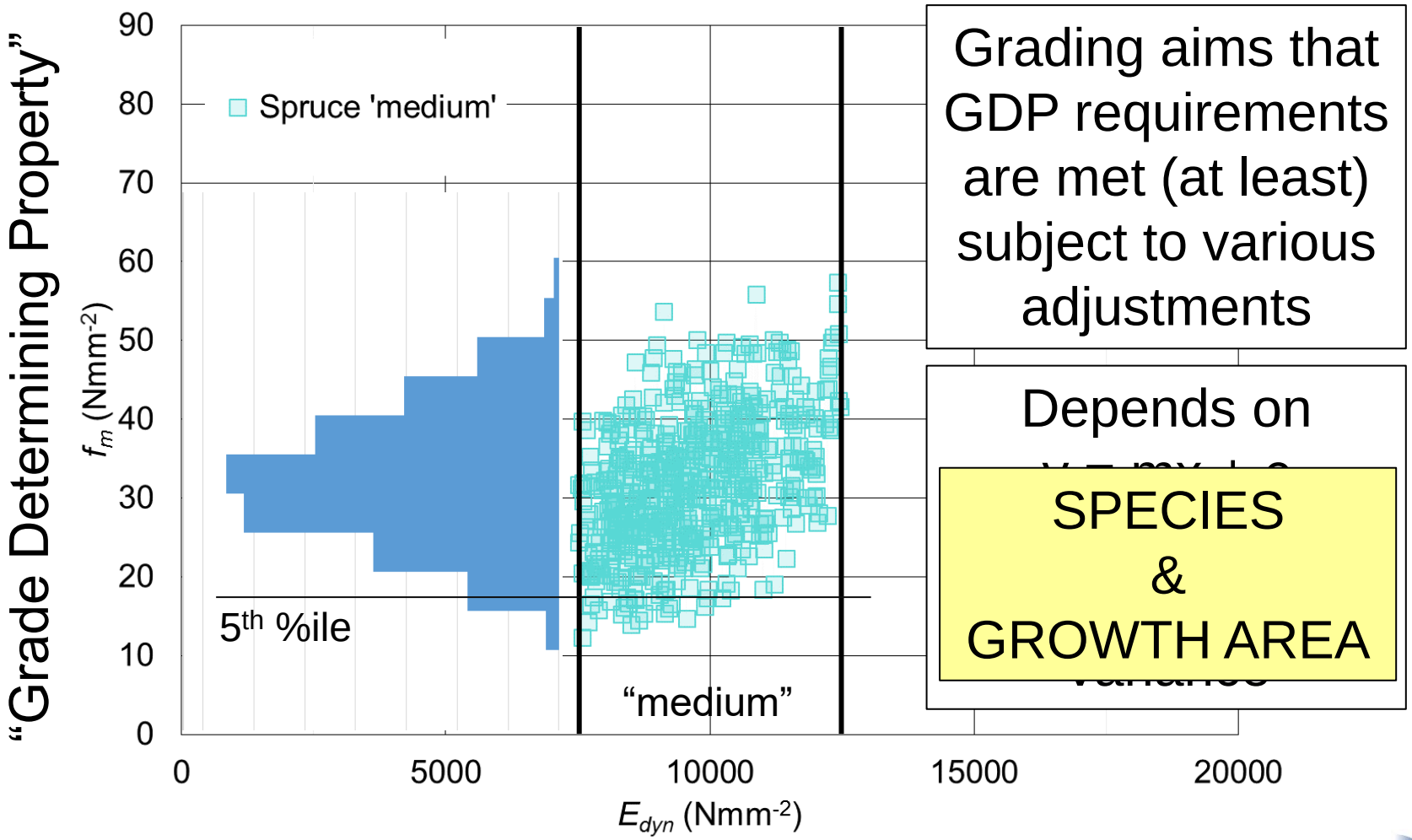
Grading – IP boundaries



Grading aims that GDP requirements are met (at least) subject to various adjustments

Depends on
$y = mx + c$
R^2
Mean
Variance

Grading – IP boundaries



Grading aims that GDP requirements are met (at least) subject to various adjustments

Depends on

SPECIES
&
GROWTH AREA

Means that…

- Grading not about properties of individual pieces
- Often only one of the GDPs is limiting
- …indeed sometimes none of them are
- So quite usual for some properties to exceed what is stated for the strength class
- …especially true of the secondary properties

But that's not everything

- "Visual" override
  - Distortion
  - Fissures
  - Wane (note that genuine wane does not cut the grain)
  - Soft rot and insect damage
  - Knots and slope of grain on any portion that cannot be machine graded (i.e. the ends of the timber for bending type machines)
  - Anything else that causes concern

If assessed below 20% moisture content: "dry-graded"

So how do we machine grade?

- Now many types of grading machines
  - Bending stiffness
    - Bending about the minor axis
  - Dynamic (acoustic/vibration)
    - Essentially a measure of stiffness
    - May or may not include density
  - X-rays
    - A combination of knots and density
    - Perhaps with optical camera
  - Assessment of slope of grain
  - Mixtures of the above

- See http://blogs.napier.ac.uk/cwst/grading-machines-speeds/

Example, UK larch with MTG

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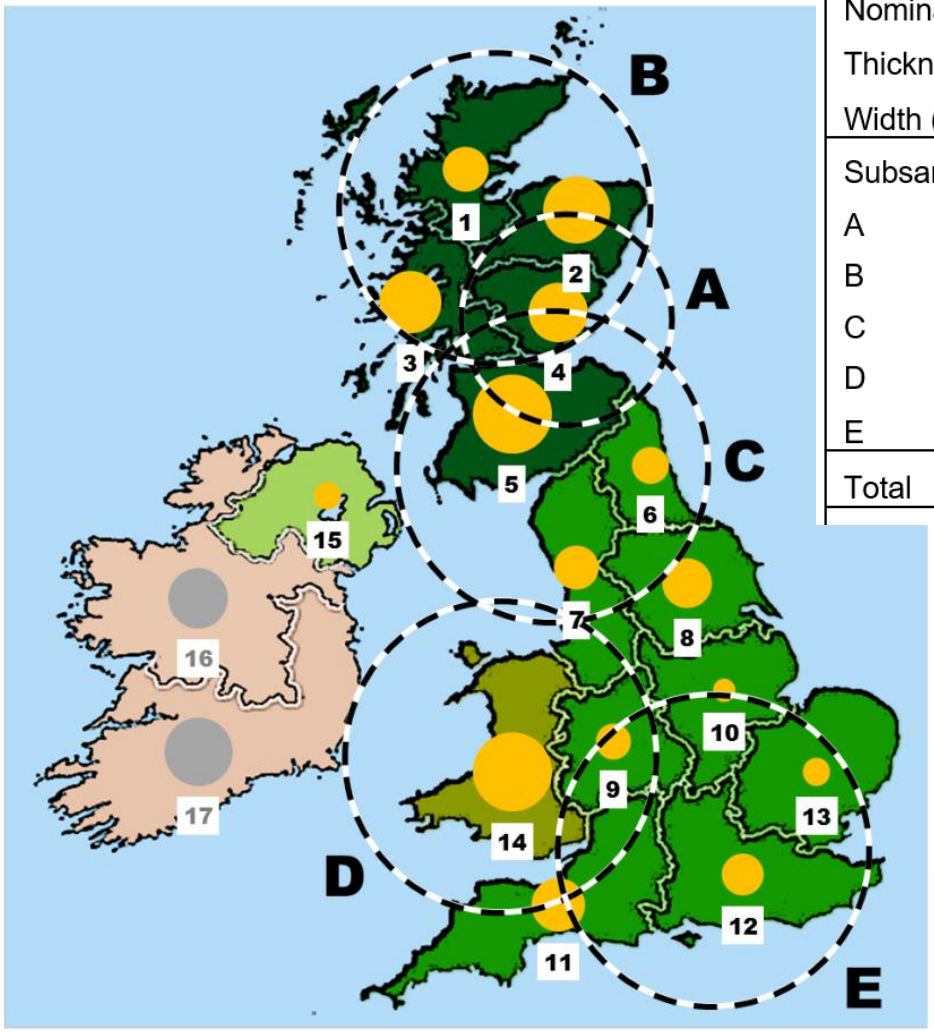
The Brookhuis MTG is a resonance type machine

Sampling (Report: TG1 / 201703 / 26rev2)



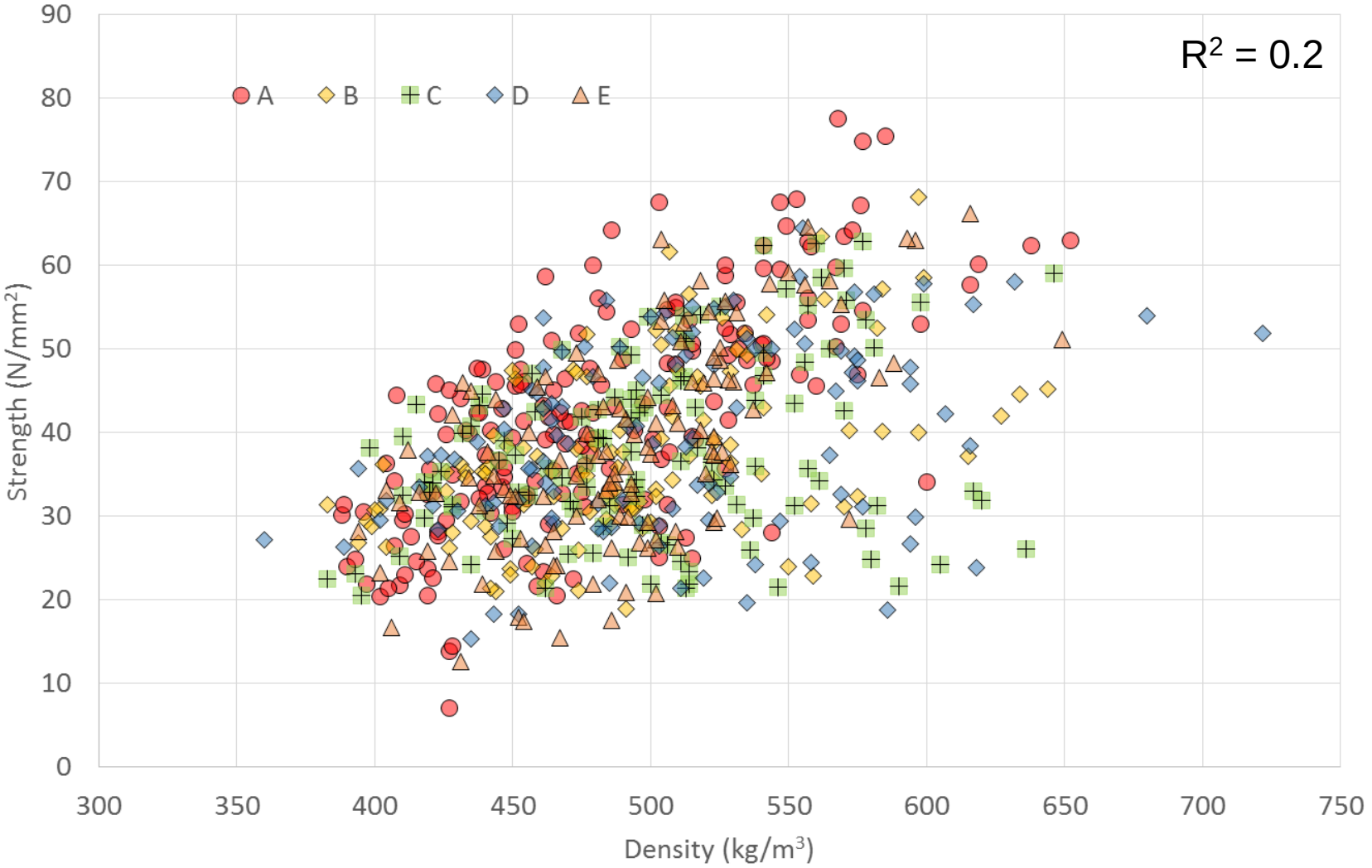
Nominal dimensions		Included in grading analysis (number of pieces)				
Thickness (mm)		47	47	75	100	Total
Width (mm)		100	150	150	275	
Subsample	Country					
A	UK	166	17	0	0	183
B	UK	63	0	40	13	116
C	UK	63	0	40	14	117
D	UK	63	0	40	13	116
E	UK	63	0	40	14	117
Total		418	17	160	54	649

Source country or countries: United Kingdom of Great Britain and Northern Ireland

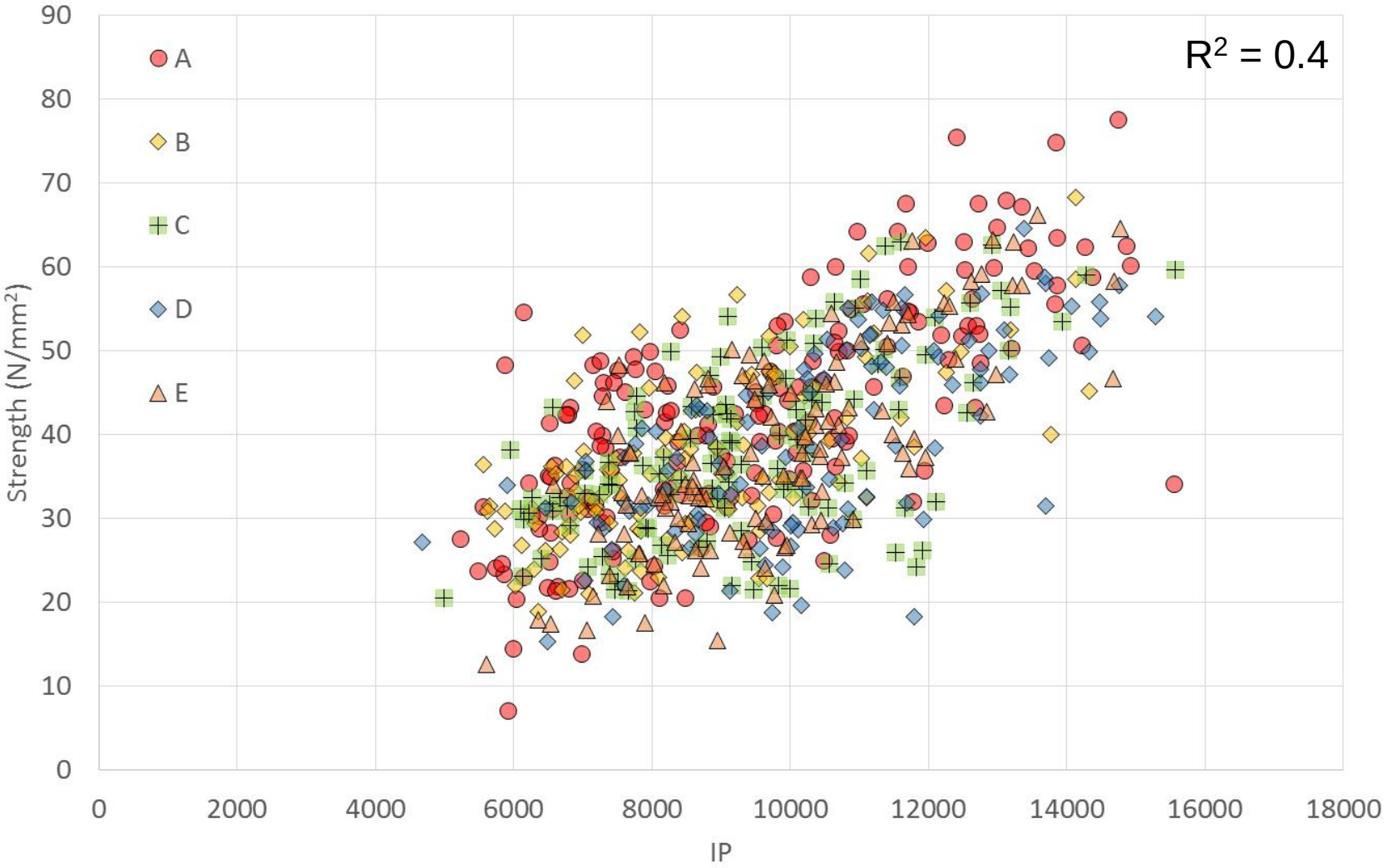
Species:
European larch *Larix decidua*
Hybrid larch *Larix x eurolepsis*
Japanese larch (WLAD) *Larix kaempferi*

Permitted timber sizes
Thickness: 42 mm to 112 mm
Width: 88 mm to 307 mm

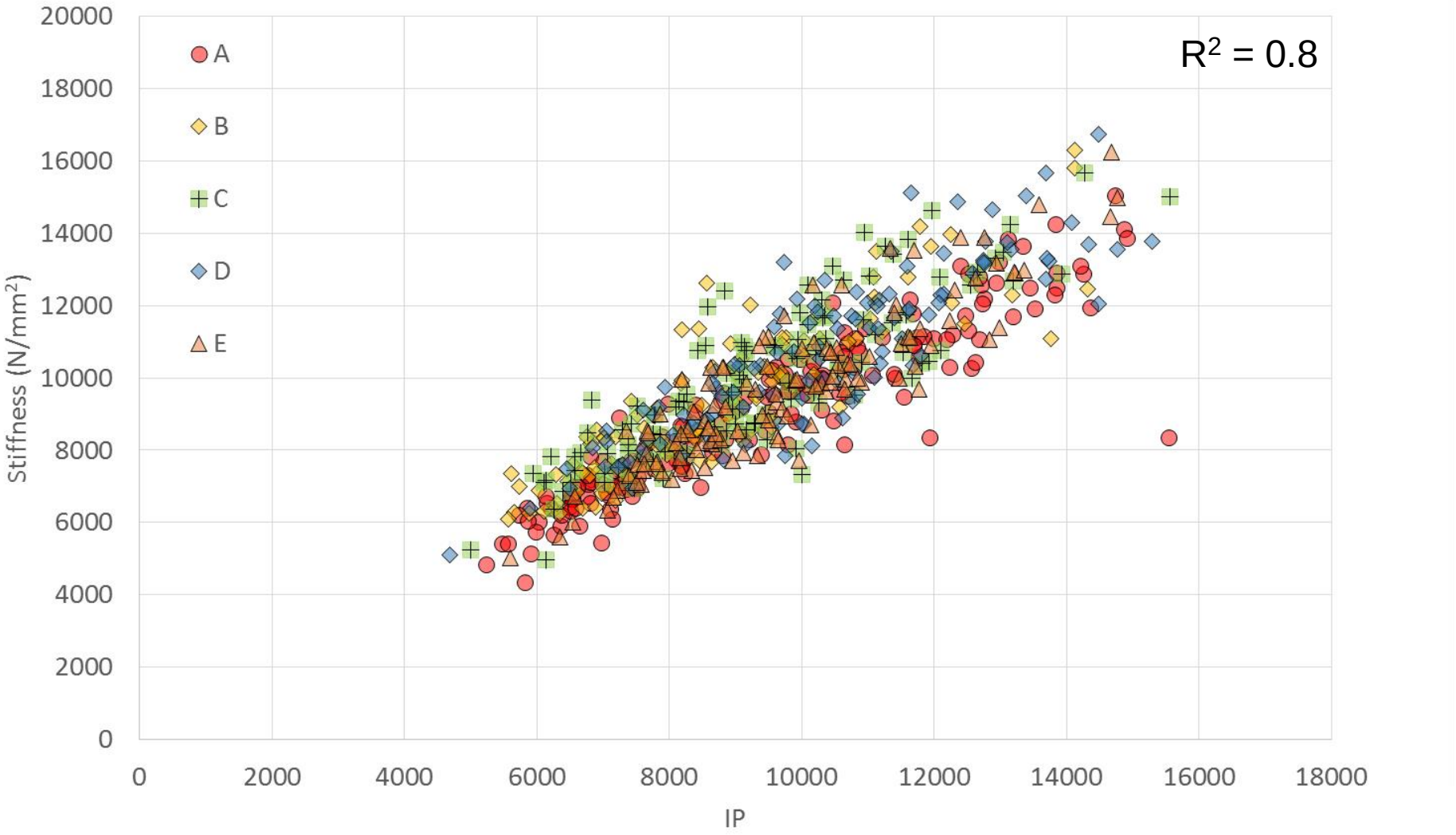
Strength and density



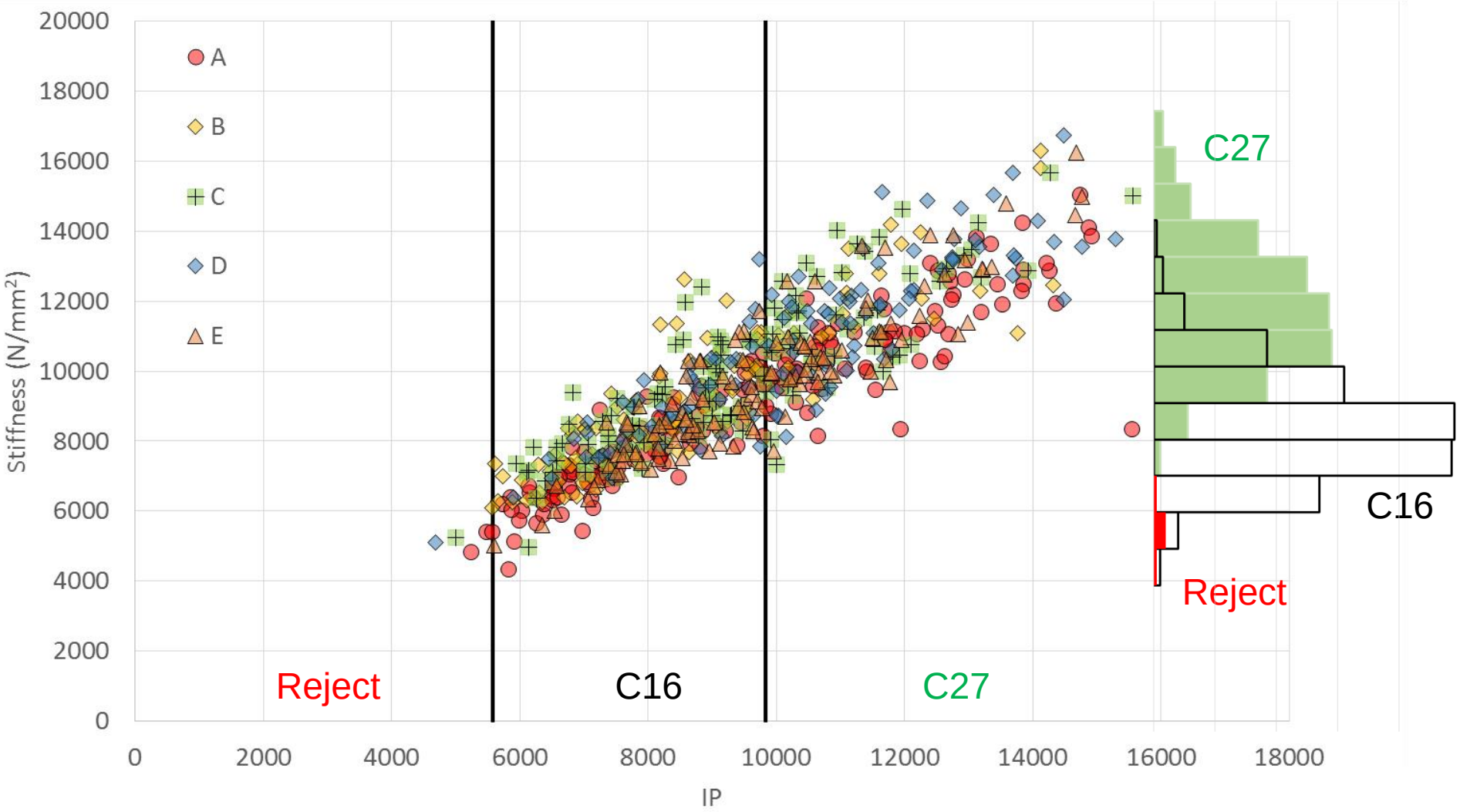
Strength and IP (Dynamic stiffness)



Stiffness and IP (Dynamic stiffness)



Stiffness and IP (Dynamic stiffness)



Settings calculation (EN 14081-2)

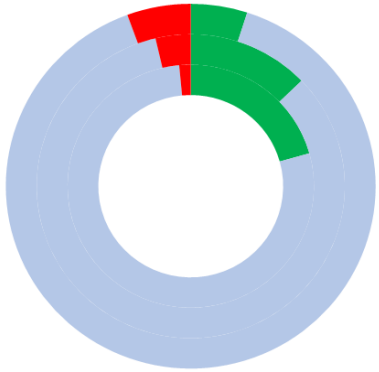
IP Grading for C27/C16/reject grade combination

C27	**9840**						**C16**	**5570**			

	n	Achieved strength $f_{m,k}$ N/mm^2	Achieved stiffness $E_{0,mean}$ kN/mm^2	Achieved density ρ_k kg/m^3	Required $f_{m,k}$ N/mm^2	Required $E_{0,mean}$ x 0.95 kN/mm^2	Required ρ_k kg/m^3	n %	% of required $f_{m,k}$ %	% of required $E_{0,mean}$ %	% of required ρ_k %
C27	271	27.5	11.6	461	27.00	10.93	360	41.8%	101.7%	106.3%	128.1%
C16	372	20.9	8.35	402	16.00	7.60	310	57.3%	130.8%	109.9%	129.7%
reject	6										
total	649										

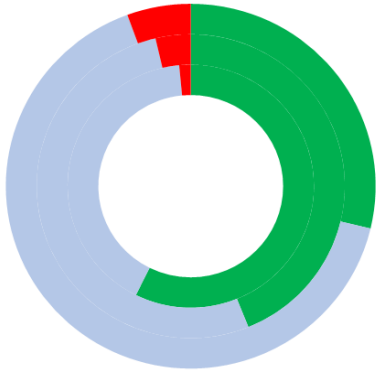
Required characteristic values are met
Indeed – some are exceeded by some way

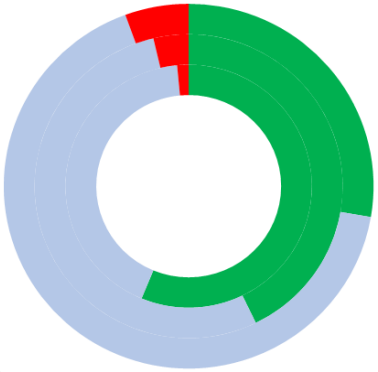
MTG 960 UK larch yields



Yields vary because the quality of incoming timber varies. Here are indications of yield for "good", "typical" and "poor" circumstances

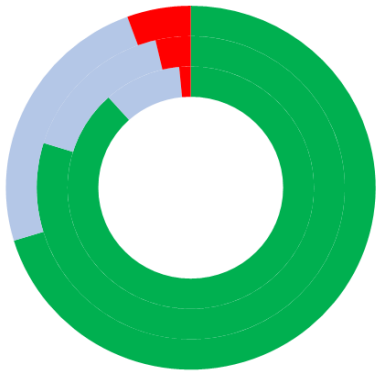
User defined strength classes give better design properties with similar yields





C27 +22% density

C16 +25% strength
+26% density



Could mark *down* the C27 to C24 to meet market demand (and have common strength classes C24 with C16)

Important things 1:

- Density is not as useful for predicting strength and stiffness as people think http://blogs.napier.ac.uk/cwst/growth-rate-and-wood-density/
- Strength grading isn't *always* about being good at predicting strength
- Strength grading isn't about properties of individual pieces – it's about collective properties of all pieces assigned to a grade
- Done as a combination of typically 1, 2 or 3 strength classes (with reject)

Important things 2:

- Strength grading is not about the EN 338 strength classes – they are just a convenience http://blogs.napier.ac.uk/cwst/why-grading-isnt-about-the-grade/
- If you are not placing timber on the open market, it could well be better to do things differently http://blogs.napier.ac.uk/cwst/beyond-grades/
- You cannot re-grade timber …including by visual grading (unless very special steps are taken) http://blogs.napier.ac.uk/cwst/regrading-of-timber/

Questions?

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For a fuller description of grading in Europe see:
Ridley-Ellis, D., Stapel, P., and Baño, V.: Strength grading of sawn timber in Europe: an explanation for engineers and researchers. *European Journal of Wood and Wood Products*, 74(3): 291-306, 2016.