Low-Z Materials for Beam Intercepting Devices at CERN

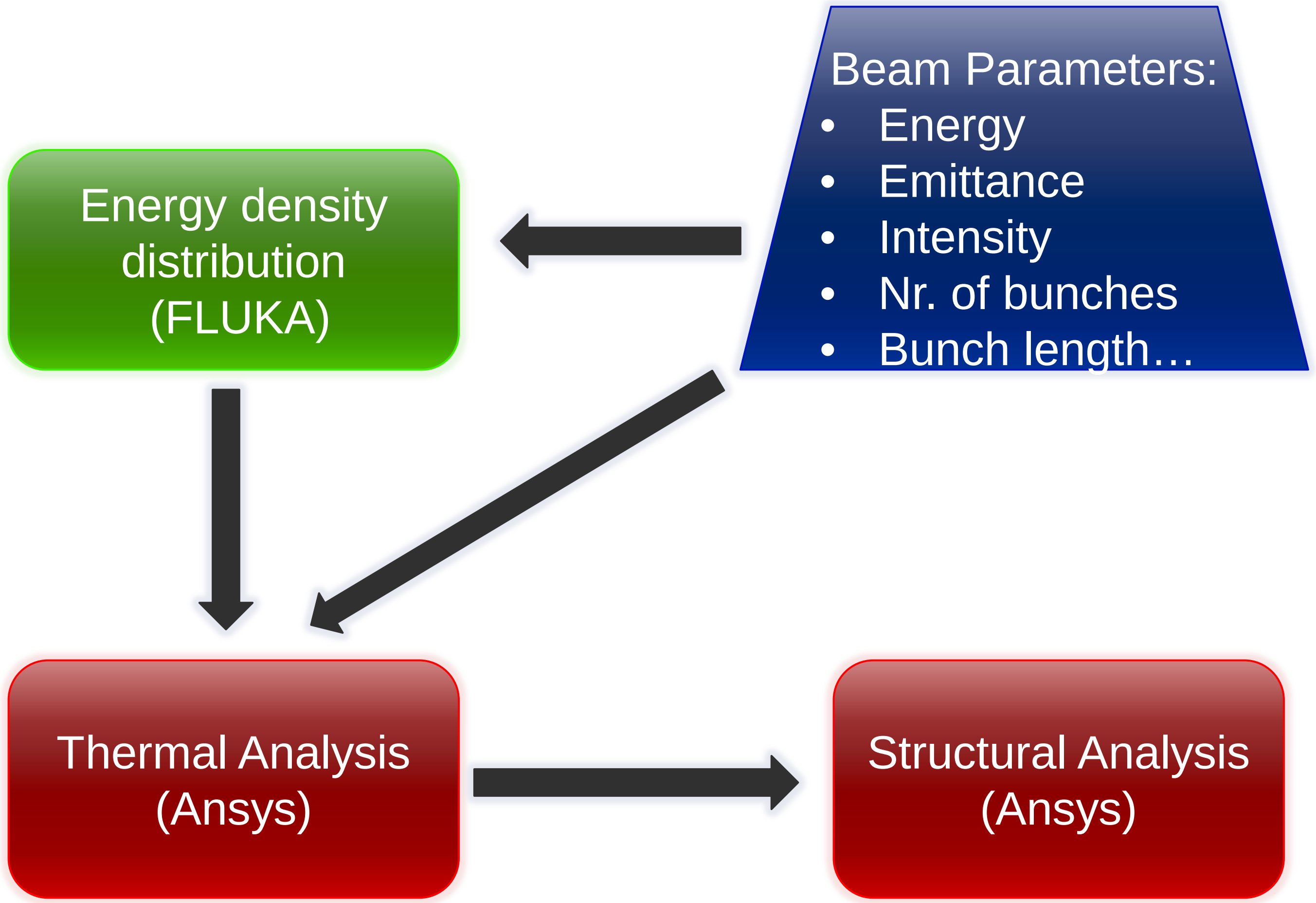
A. Perillo-Marcone, F. Maciariello, A. Lechner, N. V. Shetty, G. Steele.

Sources, Targets and Interactions Group

Introduction

- Upstream sections of beam intercepting devices at LHC and SPS require low density materials
- Future beams will become more intense and with a lower emittance; hence, higher energy density deposited in materials
- These materials must withstand high temperatures and dynamic stresses without significant degradation/melting
- Only few materials meet the requirements

Methodology (Numerical Simulations)



Beam Parameters

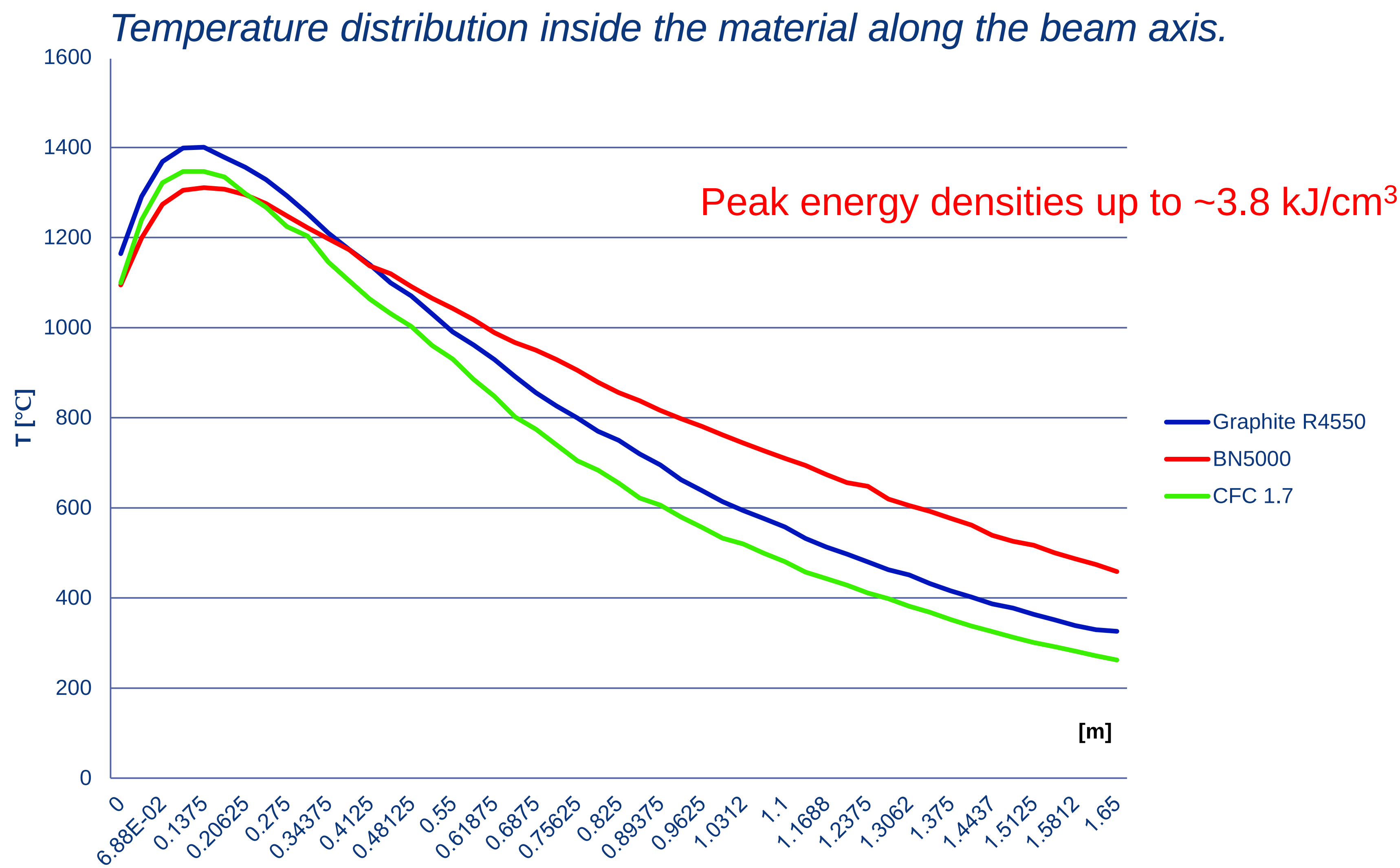
Beam parameters expected for the HL-LHC – BCMS (ε=1.3μm)	
Time [μs]	7.2
Number of Bunches	288
Bunch Spacing [ns]	25
Protons per Bunch	$2.0*10^{11}$
Sigma x*y [mm*mm]	0.328*0.534

Material Properties

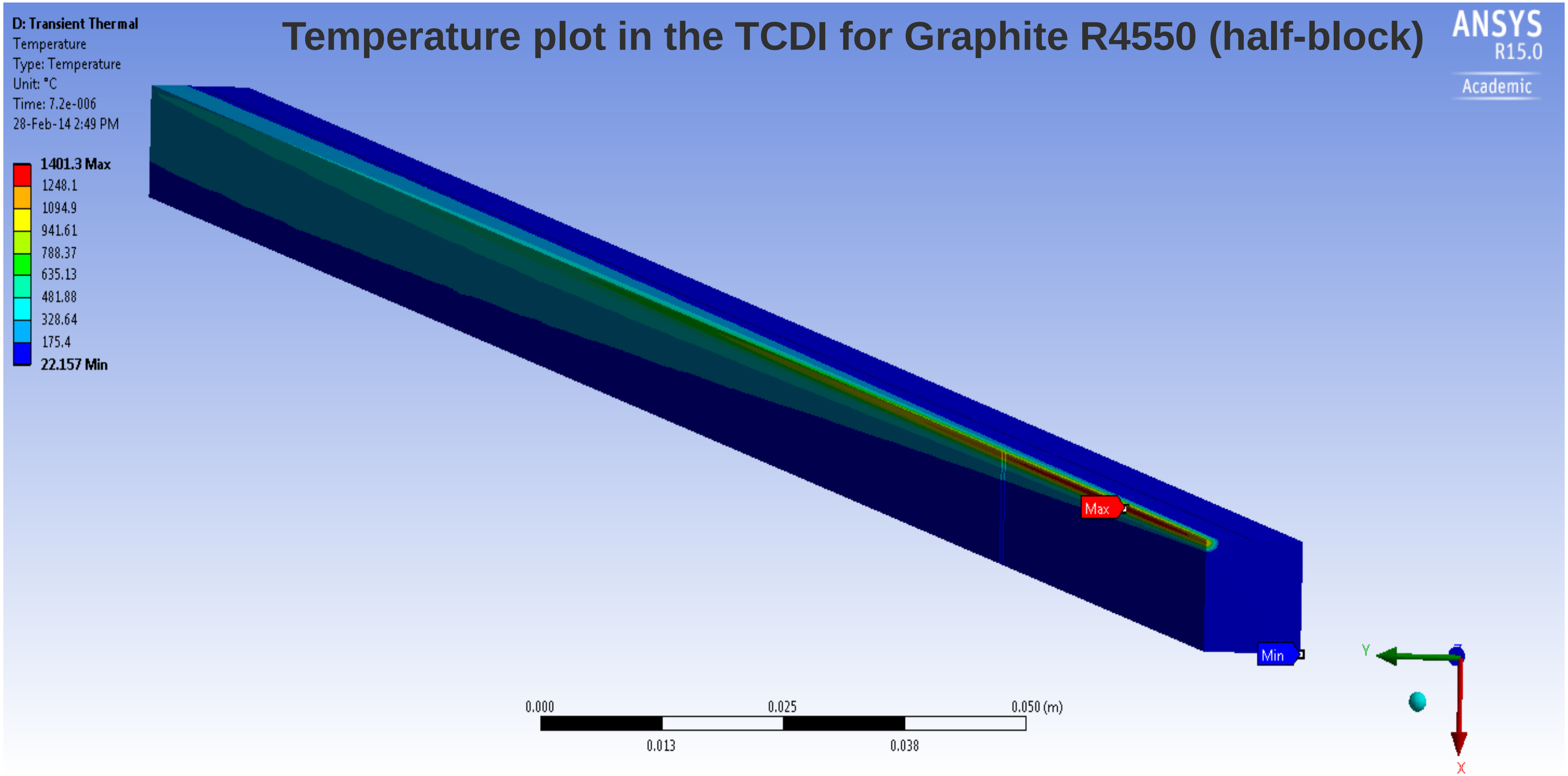
Properties of materials currently used in devices at the SPS and LHC.					
	Graphite R4550	BN 5000	2D C/C		
Density [g/cm^3]	1.83	1.9	1.7		
CTE [C^-1] ($x10^{-6}$)	4	2	2.8	5.3	2.8
Young's Modulus [MPa]	12000	35000	7800	3400	7800
Poisson's Ratio	0.1	0.2	0.2	0.1	0.2
Tensile Strength [MPa]	30	3*	48	12	48
Compressive Strength [MPa]	118	110	144	98	144
Thermal Conductivity W m^-1 C^-1	70	30	110		
Specific Heat J * Kg^-1 C^-1	1500	1700	1600		

*BN5000 showed extremely low mechanical properties at high temperatures in tests performed in the past. (To be verified)

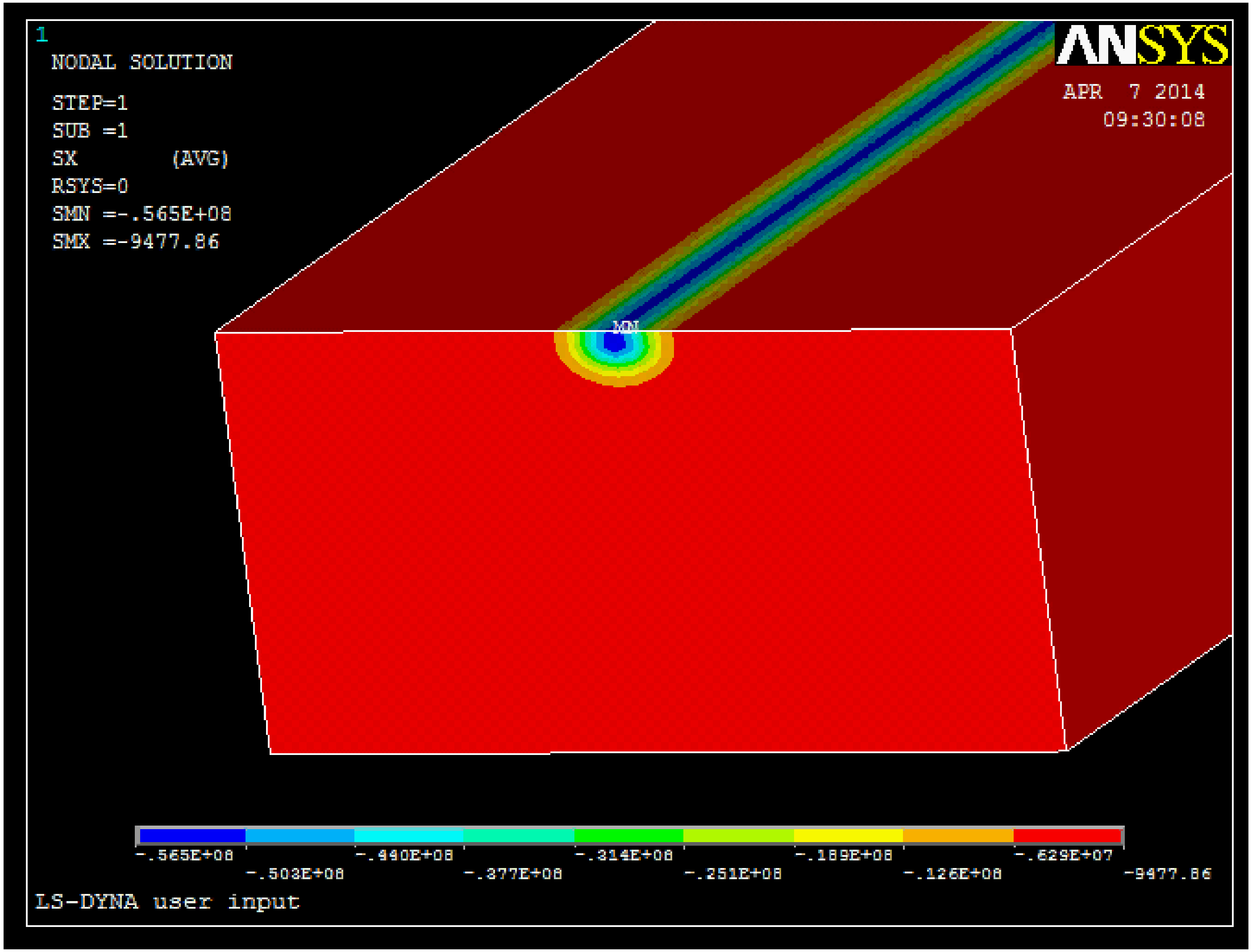
Results (FLUKA)



Results (Ansys)



Results (stress wave propagation)



Results (stresses)

Summary of thermo-structural behaviour at the end of the pulse.					
Material	Density [g/cm3]	Mohr-Coulomb S.F.	Max T [° C]	Tens. Strength / Max. Princ. Stress	Comp. Strength / Min. Princ. Stress
BN5000	1.9	0.46	1311	3/11	59/104
Graphite R4550	1.8	0.9	1400	29/32	118/81
CFC	1.7	_	1370	12.8/20	132/38

Mohr-Coulomb (must be >1)

$$F_s = \left[\frac{\sigma_1}{\sigma_{Tensile\ limit}} + \frac{\sigma_3}{\sigma_{compressive\ limit}}\right]^{-1},$$

Max.-Min. Principal Stresses

$$\left.\frac{mpressive\ limit}{\sigma_3}\right]$$

Future Work

- HiRadMat tests. Expose materials to a similar beam (radiation facility at CERN). To verify the response materials by means of specific instrumentation (temperature/vibration sensors, cameras, strain gauges, etc).
- Mechanical tests at high temperatures and high strain rates.
- Outgassing tests (to observe the material behaviour in ultra-high vacuum environment).
- Thermal properties determination vs. temperature (characterisation to be performed at CERN).

Conclusions

- Future Hi-Lumi LHC beams are extremely demanding, pushing the limits of the materials and knowledge of their properties.
- A methodology is being used and simultaneously developed to assess the behaviour of materials under such beams
- A comprehensive testing campaign is being launched in order to better characterise materials at such high temperatures and strain rates

CERN

YEARS / ANS CERN

EN

ENGINEERING DEPARTMENT