HAL
open science

# A computational framework for certified reduced basis methods: applications to multiphysics problems

Vincent Chabannes, Cécile Daversin, Christophe Prud'Homme, Abdoulaye Samake, Christophe Trophime, Stéphane Veys

## To cite this version:

Vincent Chabannes, Cécile Daversin, Christophe Prud'Homme, Abdoulaye Samake, Christophe Trophime, et al.. A computational framework for certified reduced basis methods: applications to multiphysics problems. Eccomas'12 MS403-2 - Reduced order modeling strategies for parametrized PDEs, Sep 2012, Vienna, Austria. hal-00762449

**HAL Id: hal-00762449**

**https://hal.science/hal-00762449**

Submitted on 9 Dec 2012

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# A computational framework for certified reduced basis methods: applications to multiphysics problems

**Vincent Chabannes**[*], **Cécile Daversin**[†], **Christophe Prud'homme**[*‡], **Abdoulaye Samake**[*], **Christophe Trophime**[†], **Stéphane Veys**[*]

[*]Université Grenoble 1 / CNRS, Lab. Jean Kuntzmann, UMR 38041 Grenoble Cedex 9, (France)
(vincent.chabannes@imag.fr, christophe.prudhomme@ujf-grenoble.fr, abdoulaye.samake@imag.fr, stephane.veys@imag.fr)
[‡]Université de Strasbourg / CNRS, IRMA / UMR 7501. Strasbourg, F-67000, (France)
[†]LNCMI-G, CNRS-UJF-UPS-INSA, 25 Av. des Martyrs, Grenoble, F-38042, (France)

**Keywords**: certified reduced basis methods, automated computational framework, reduced order modeling in multiphysics applications

## ABSTRACT

Over the last few years we have been developing an open-source computational framework for certified reduced basis methods [1] based on the Feel++ framework [5]. The latter provides (i) a very wide range of arbitrary order Galerkin methods (fem, sem, cG, dG) in 1D, 2D and 3D (ii) an interface to modern linear algebra framework PETSc/SLEPc and Trilinos and (iii) a language embedded in C++ for Galerkin methods with a syntax following closely the mathematical one. Our recent advances in the former allow to (i) treat a wide range of problems as exercised later, (ii) provide an (almost) automated framework including the use of reduced basis element methods [3, 4], *hp* reduced basis approximations, empirical interpolation method, the successive contraints methods, a posteriori error estimation for linear and non-linear parametrized partial differential equations.

The exposition is organized as follows, first we present the advances in our framework for certified reduced basis methods since [1], in particular in two areas (i) automation of the reduced basis method using a domain specific language [5] and (ii) coupling of the reduced basis methods coupled with domain decomposition methods or multiscale methods. Then we apply our framework to two large multi-physics applications (i) high field magnet design (ii) aerothermal modeling in an airplane cabin. Note that the objective is to identify the bottlenecks in the methodology to be applied to industrial problems. Full results may not be expected but we shall report the scaling issues encountered as well as the intermediary results.

Regarding the first application, the Laboratoire National des Champs Magnétiques Intenses (LNCMI) is a French large scale facility enabling researchers to perform experiments in the highest possible magnetic field (up to 35 T static field). High magnetic fields are obtained by using water cooled resistive magnets (cf. fig. 1) connected with a 24 MW power supply [2]. As to the second application, its purpose is to build reduced order models aimed at replacing some 0D models in the energy control system of an airplane, see fig. 2. The design, optimization or control of these magnets or the energy control system require from an engineering point of view solutions of a multi-physics model involving combination of electro-thermal, magnetostatics, electro-thermal-mechanical and thermo-hydraulics models. It should be noted that these models are non-linear. In practice the parametric and physical spaces induce huge computational costs.

**Acknowledgements** The authors thank M. Fouquembergh from EADS-IW for supplying the second application.

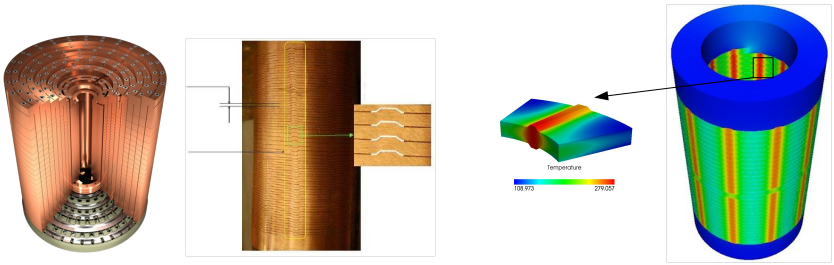

Figure 1: A high field magnet: (left) exploded view; (center) detailled view of the inner part; (right) temperature of the inner part with a zoom on a “turn”.

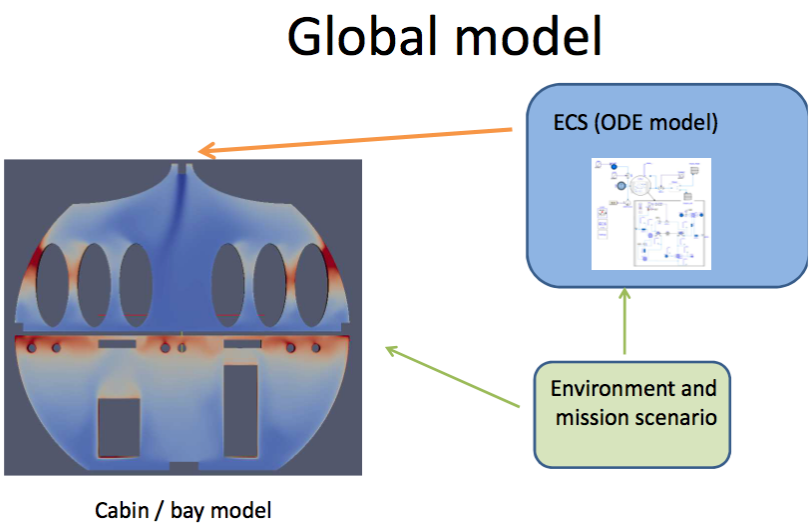


Figure 2: Energy control system in an airplane

## References


[1] Vallaghé S., Prud’homme C., Fouquemberg M., Le-Hyaric A., Veys. S. *A computational framework for certified reduced basis methods, applications to uncertainty quantification in heat-transfer and biology*, Springer Enumath 2011 Proceedings, Jan 2012

[2] C. Trophime et al., *Magnet calculations at the GHMFL*, IEEE Trans. Applied Superconductivity 12, 1, 1483-1487, 2002

[3] Y. Maday and E. M. Ronquist *The Reduced Basis Element Method: Application to a Thermal Fin Problem* SIAM J. Sci. Comput. 26, pp. 240-258 (19 pages)

[4] DBP Huynh, DJ Knezevic, and AT Patera, *A Static Condensation Reduced Basis Element Method: Approximation and A Posteriori Error Estimation.* Mathematical Modelling and Numerical Analysis (submitted May 2011)

[5] C. Prud’homme, V. Chabannes, V. Doyeux, M. Ismail, A. Samake: Feel++, A Computational Framework for Galerkin Methods and Advanced Numerical Methods, *submitted Jan. 2012 to ESAIM proc.*