THE LASER MEGAJOULE FACILITY: THE COMPUTATIONAL SYSTEM PARC

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Abstract

The Laser MegaJoule (LMJ) is a 176-beam laser facility, located at the CEA CESTA Laboratory near Bordeaux (France). It is designed to deliver about 1.4 MJ of energy to targets, for high energy density physics experiments, including fusion experiments. The assembly of the first line of amplification (8 beams) was achieved in October 2014.

A computational system, named PARC, has been developed and is under deployment to automate the laser setup process, and accurately predict laser energy and temporal shape. PARC integrates the simulation software MIRO. For each shot on the LMJ, PARC determines the characteristics of the injection laser system required to achieve the desired main laser output, checks the machine fine-tuning for equipment protection, determines the required diagnostic setup, and supplies post-shot data analysis and reporting.

This document gives the first results obtained with PARC. We also describe results obtained with the PARC demonstrator during the first experience on the LMJ facility.

PARC FUNCTIONALITIES

PARC must guarantee the laser performance according to a shot request. To achieve this goal, PARC is based on the simulation software MIRO which models each laser beam. PARC manages and updates one data model for each beam and validates them at the end of each shot.

Contribution in Experiment's Chronology

The LMJ monitoring system orchestrates the whole sequence of operations. It invokes PARC at each step of the sequence to deal with specific process.

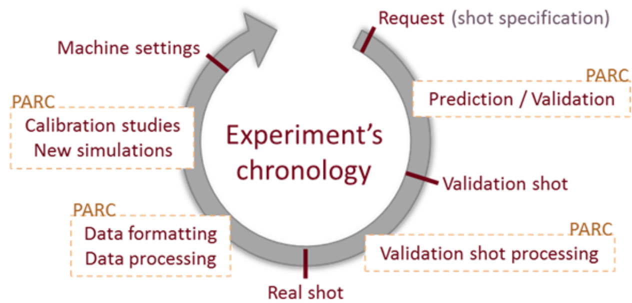

Figure 1: PARC in experiment's chronology.

The first step in the sequence is the production of a request that identifies all the desired laser output characteristics.

Predictive simulation is the first set of operations in the sequence chronology. It determines the LMJ equipment configuration and settings required to achieve the desired main laser output. The behaviour is performed by the software MIRO.

Validation is performed to check the ability of the machine to perform the shot in security and safety. Validation is also based on a simulation realized by MIRO.

Once the prediction and the validation are accepted, the sequence is composed of one or more validation shots to fine-tune data and equipment settings. A validation shot is like a real shot without the main amplifiers.

Data-processing of validation shot follows each validation shot. PARC performs data processing and provides parameters to check if the settings are compatible with the real shot. We also check that equipment's and diagnostics are operating normally.

The next step in the sequence is the real shot.

Data-processing of the real shot consists of supplying post-shot data analysis and reporting. Among other things, PARC compares the measurements to the request, to the results of simulations, performs new MIRO simulations from shots results to fine-tune calibration.

Calibration of computation models is performed at the end of each shot to correct the drift. The calibration uses the results and reports of several shots.

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Autonomous Working

PARC provides an autonomous mode that allows operators to perform simulations and processing apart from the shot sequence.

Operators can prepare new shot campaigns and check the ability of a request thanks to dedicated prediction and validation algorithms.

They can calibrate MIRO simulations and PARC setting with specific data-processing codes from shots results.

PARC STAKES

PARC Position

Interfaces are a major issue in PARC. PARC has three main interfaces (Figure 2): the LMJ monitoring system, the users and the MIRO software.

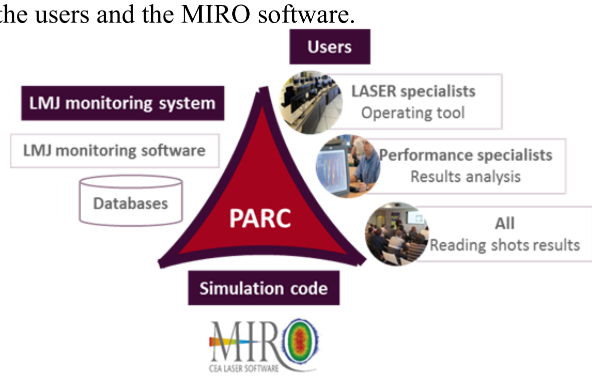

Figure 2 : PARC interfaces.

The LMJ monitoring system software (also called Supervisory system) invokes PARC, which provides reports in return. The LMJ monitoring system relies on several databases where raw data, shots results, settings and characteristics of the equipment are stored. PARC extracts and translates these data into its own formalism. The data are hence civilized to be used in processing and simulations.

Several types of users are interested in PARC functionalities.

Laser specialists, the main users, use PARC as an operating tool. They execute new simulations, study the results and reports, integrate new algorithms and modify existing codes and configuration data.

Performance specialists export the results processed by PARC to perform more analysis on separated systems.

All users want to see the reports on separated systems to show them in meetings for example.

The Miro software simulates the Laser propagation with numerical models. PARC prepares data and simulation characteristics, executes MIRO and reads and processes the results.

LMJ Structure and Variables

The particularities of LMJ structure have an important part in PARC algorithm structure. The LMJ is characterized by:

- 4 sections (Figure 3): pre-amplification, amplification, conversion and target,

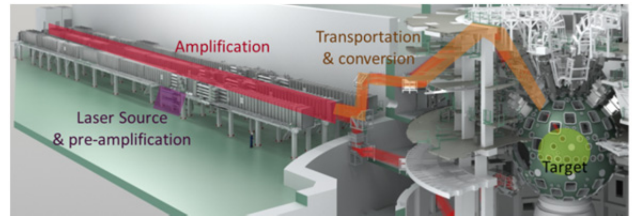

Figure 3 : LMJ sections.

- 4 levels of granularity: beam, quad (4 beams), line (2 quads) and the whole system,
- 3 main characteristic variables: energy, temporal shape and spatial shape,
- 3 levels of data: prediction results, request, measurement results.

These four components form four dimensions in the architecture of PARC processing codes.

ARCHITECTURE

Hardware Architecture

PARC is a complete ecosystem of tools and technologies working together to achieve its objectives. The hardware platform consists in three components.

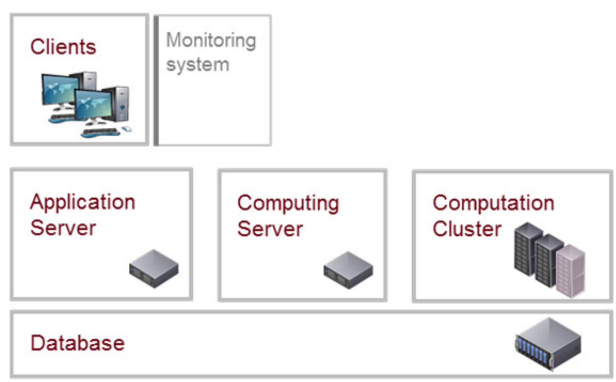

Figure 4 : Hardware architecture.

The Application Server is a server accepting connections from the various clients,

The Computing Server is a server orchestrating algorithm executions. It distributes tasks among the cluster nodes,

The Computation Cluster is a cluster of nodes performing the high-demand computation tasks such as MIRO beam propagation code. The modular structure of the cluster in racks allows high flexibility to gradually add laser lines with their installation and high performance regardless of the number of laser beams (a prediction simulation takes about 20 minutes).

These hardware components access the same distributed file system to share the data. The data are previously converted by a dedicated software civilizing

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the various data types (file formats, units) injecting these into the PARC database.

Software Architecture

PARC software architecture is threefold:

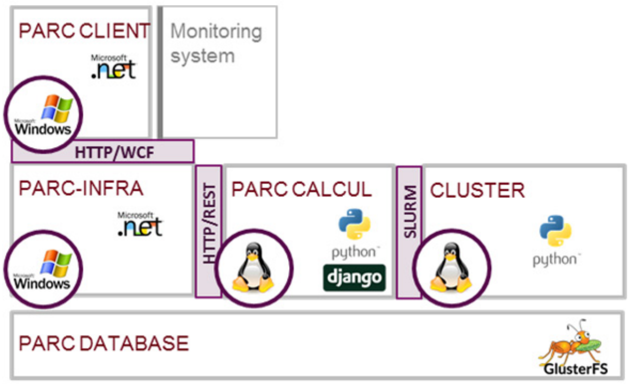

Figure 5 : Software architecture.

- PARC-INFRA: application server dealing with all the contextualization of scenario execution. Web application hosted by an IIS Web server, it exposes a set of WCF web services mainly to fine-tune data and initiate scenarios,
- PARC-CALCUL: Web Frontend to the computation cluster. Python Django application, it exposes a Rest web service interface to segregate the computing from the application management, running task orchestration, and perform task distribution,
- PyParc: Python library underpinning the execution of the elementary computation tasks.

FUNCTIONS COMPONENTS

Algorithm Components

In PARC, the algorithm associated with a function is named scenario. Scenarii are Python scripts based on two computation libraries.

The modules library is composed of elementary computation codes. We distinguish several kinds of modules:

- Basic calculation codes (two scalars relative comparison for example),
- Generic codes which implement generic functions as the execution of MIRO simulation for instance,
- Reading / writing data in PARC database,
- More complex codes which implement a part of a scenario algorithm. These modules manage data and elementary calculation codes.

The PyParc library is composed for generic functions which manage the scenario execution and provide tools for the implementation of modules. For instance, the distribution of modules is managed by PyParc functions.

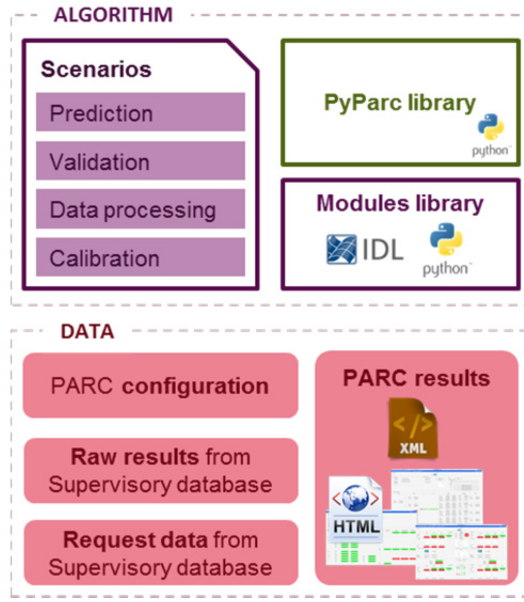

Figure 6 : PARC components.

Data Structure

PARC scenarios are run from different types of data files. PARC has its own configuration file including algorithm parameters and simulation data. But the main data is recovered from the monitoring system : the request data with equipment's settings and the raw results of the shots.

The scenarii results are stored in PARC database in XML (Extensible Markup Language) files and in the form of specific reports in HTML (Hypertext Markup Language).

PARC RESULTS

Prediction

Prediction algorithm performs simulations with MIRO to determine settings and equipment configuration for reaching the request. A report is generated at the end of the simulations using a specific GUI (Graphical User Interface). This report is composed of three synthetic views which gather the results. Each view corresponds with a level of granularity: system, quad and beam.

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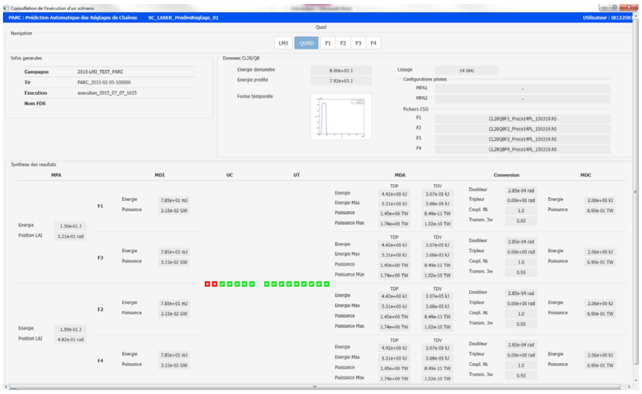

Figure 7 : Prediction quad results.

Validation

Validation algorithm checks the ability of equipment to perform the shot in security with the settings calculated by the prediction algorithm. A report is generated using a specific GUI. This report is composed of two synthetic views which gather the results for the system and for each beam.

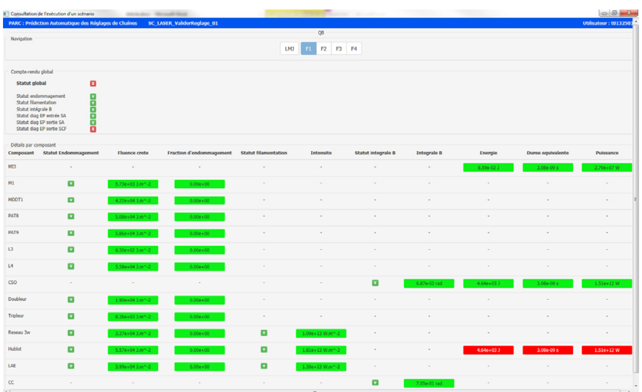

Figure 8 : Validation beam results.

Data Processing

Data processing algorithms perform calibration corrections, comparisons between measurements and prediction or between measurements and request, new simulations from the shot's results. A report is generated using a specific GUI. This report is composed by three synthetic views which gather the results. Each view corresponds with a level of granularity: system, quad and beam.

Figure 9 : Data processing quad results.

First Experiment

We use the PARC demonstrator during the first experiment on the LMJ facility. This tool uses computation codes which are now integrated in the modules library of PARC. The Quad Energy for the October 17th 2014 shot is illustrated on the figure bellow. The request was 10kJ at 3ω for each quadruplet. We measure respectively 10,2 et 9,8 kJ.

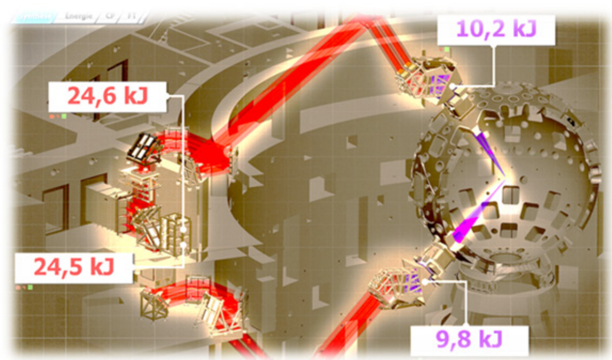

Figure 10 : First experiment.

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