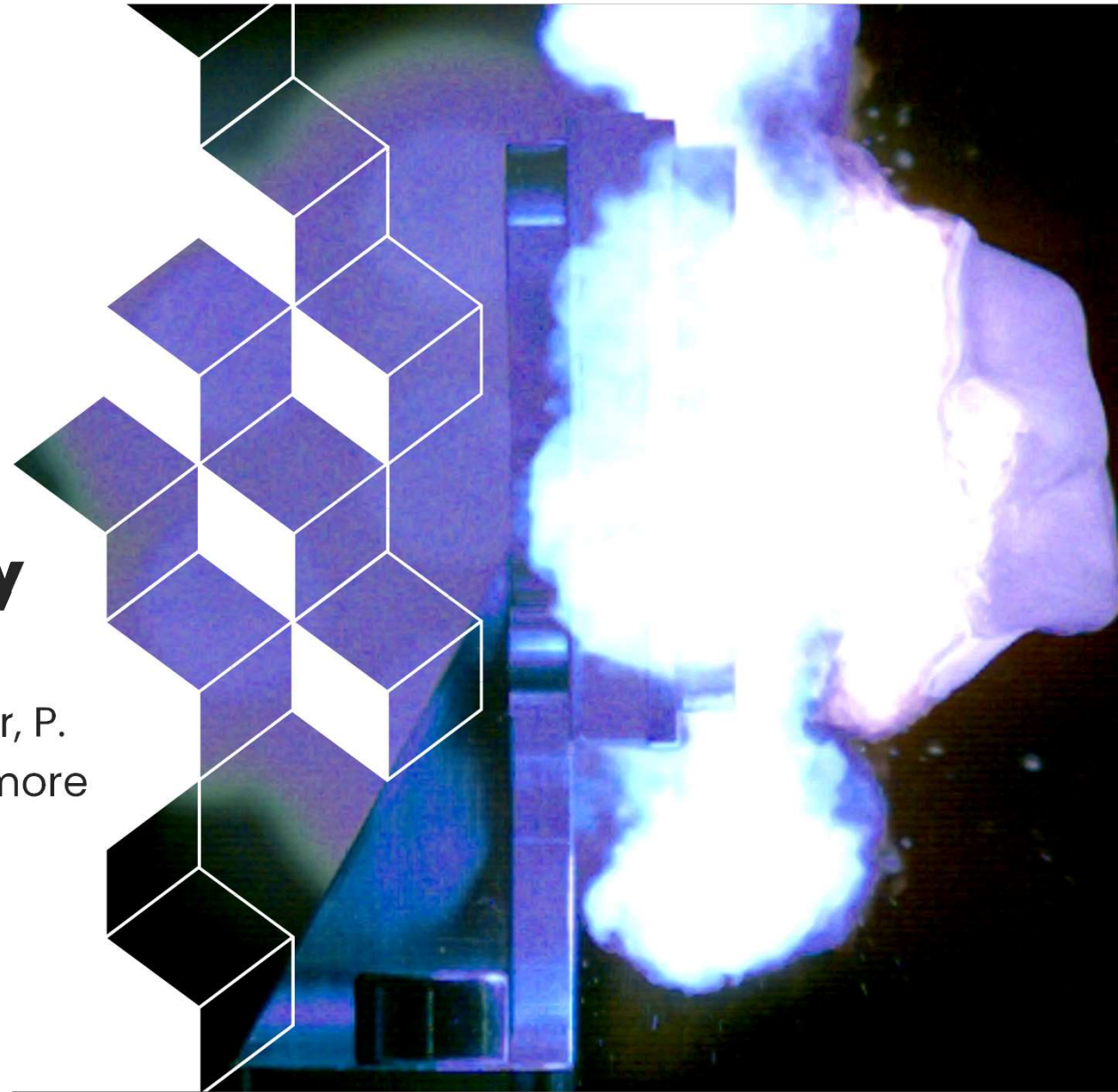# Experimental and numerical study of heavy targets on LMJ facility

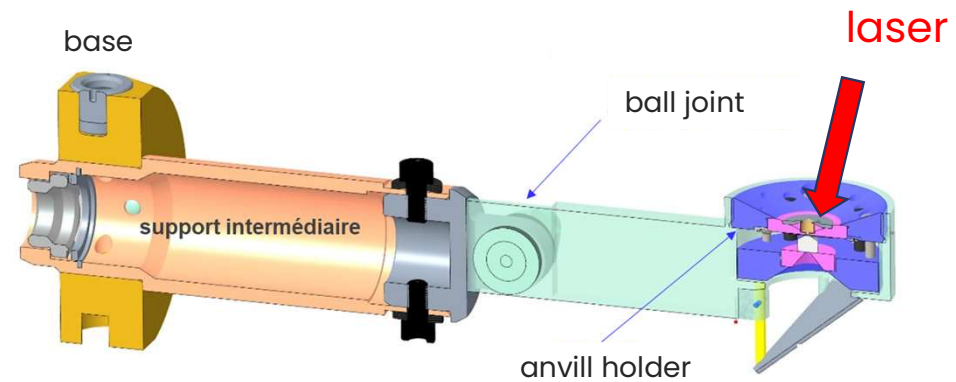D. Hébert , E. Lescoute, J.-M. Chevalier, P. Pradel, G. Boutoux, C. Le Bras, … and more

Introduction

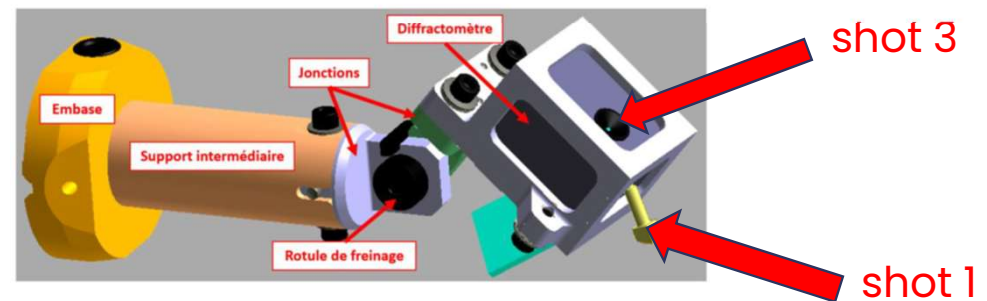**EOS_Hli**
Diamond anvill cell experiment

Brambrink (shot 1 and shot 3)
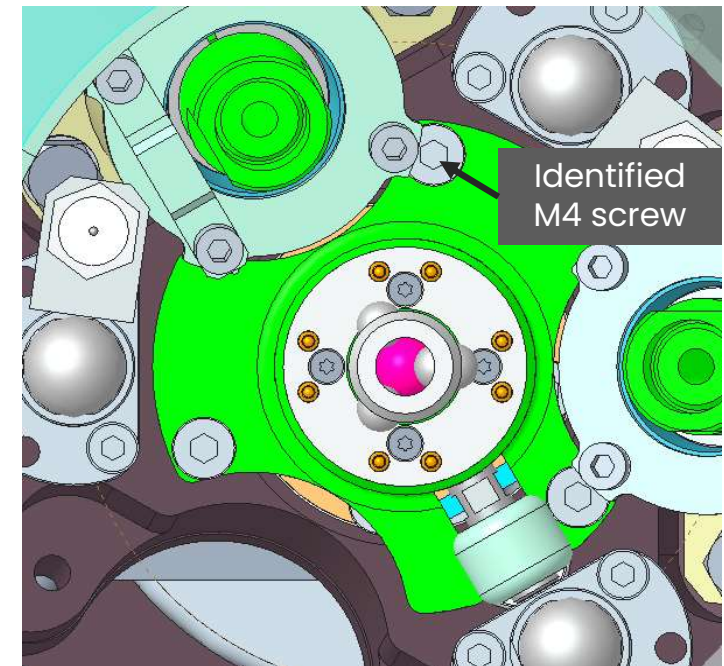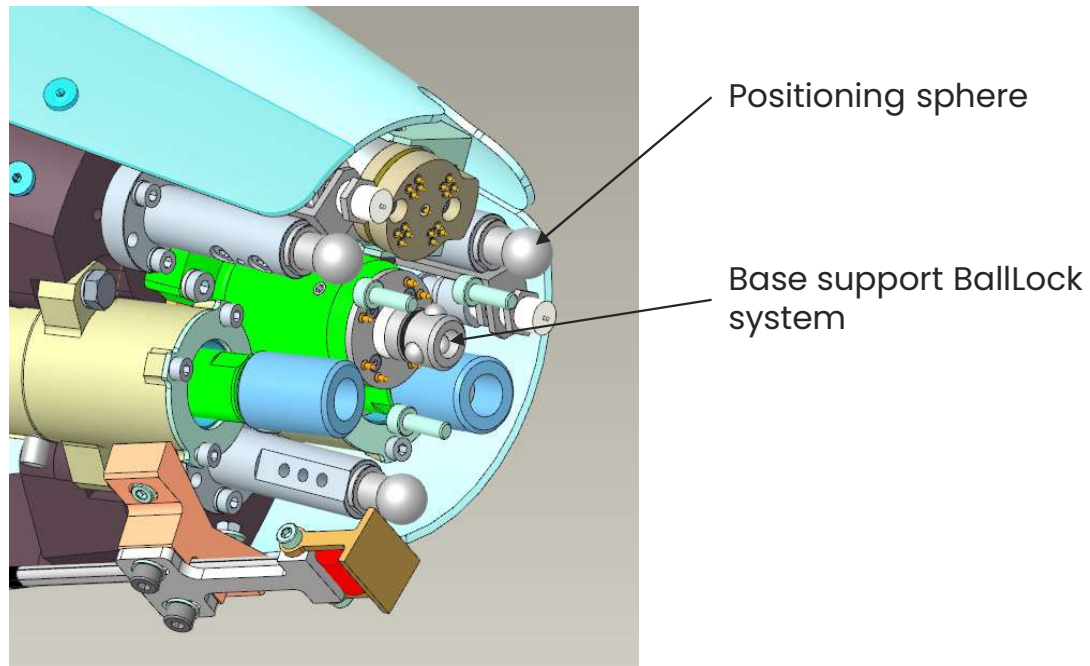Diffractometry experiment

- Heavy targets : fragments generation.

- Mechanical sollicitation of the PCNC.

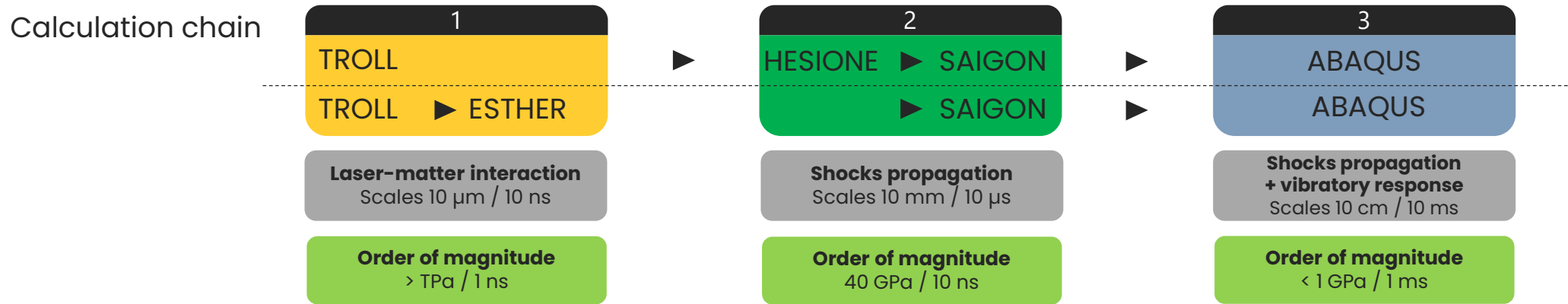- Proposed solution: dissipation of a part of the energy in a ball joint.

Mechanical strength of the MRG

- Designed to hold target for fusion experiments.

- Risk of screw plasticization and thread damage at a static load of **9 kg**.

- First calculations: dynamic load of a ton.

Positioning sphere

Base support BallLock system

Identified M4 screw

Calculation chain

Calculation chain

1		2		3
TROLL	▶	**HESIONE ▶ SAIGON**	▶	**ABAQUS**
TROLL ▶ ESTHER	▶	**▶ SAIGON**	▶	**ABAQUS**

Laser-matter interaction Scales 10 µm / 10 ns	**Shocks propagation** Scales 10 mm / 10 µs	**Shocks propagation + vibratory response** Scales 10 cm / 10 ms
Order of magnitude > TPa / 1 ns	**Order of magnitude** 40 GPa / 10 ns	**Order of magnitude** < 1 GPa / 1 ms

- Calculation of mechanical sollication from laser-matter interaction

EOS_HLi

Infinite tightening torque	→ load 2600 kg	→ rotation 0°
Tightening torque 40 N.m	→ load 1000 kg	→ rotation 15°
Tightening torque 20 N.m	→ load 500 kg	→ rotation 26°

Brambrink tir 3

2 quads + infinite tightening torque	→ load 150 kg	⎫
1 quad + infinite tightening torque	→ load 100 kg	⎬ → rotation 0°
1 quad + tightening torque 0.5 N.m	→ load 30 kg	⎭

Calculation chain

Calculation chain

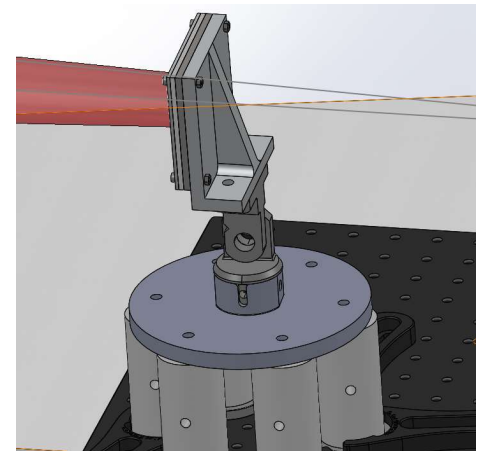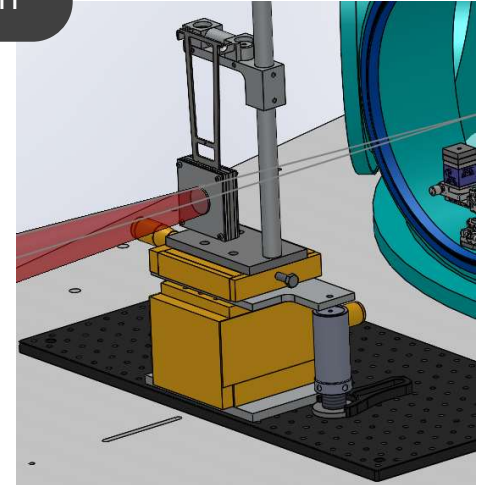| 1		2		3
TROLL	►	HESIONE ► SAIGON	►	ABAQUS
TROLL ► ESTHER		► SAIGON	►	ABAQUS
Laser-matter interaction Scales 10 µm / 10 ns		**Shocks propagation** Scales 10 mm / 10 µs		**Shocks propagation + vibratory response** Scales 10 cm / 10 ms
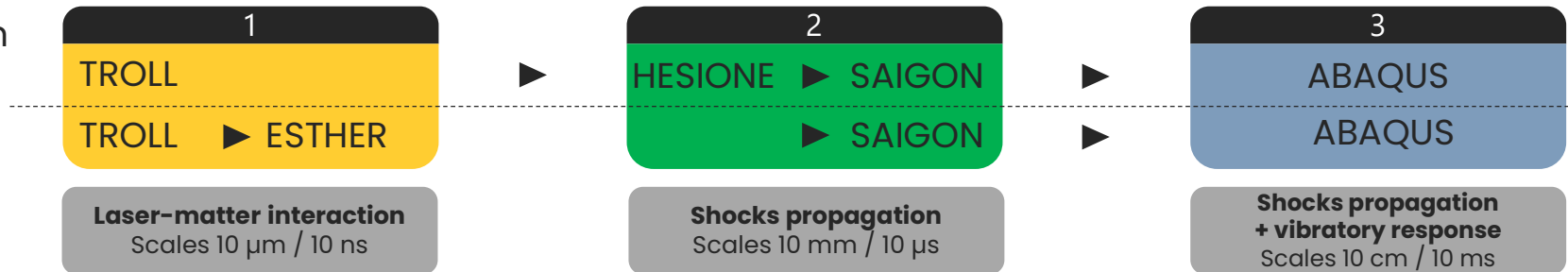
- Many points to upgrade.

- First Abaqus calulation initialized in pressure ► problem of meshes.

- New method: Initialization in velocity.

- Calibration and validation with an experimental campaign.

Objectives of the HERA campaign

- Campaign divided in two parts: pendulum and ball joint.

- Plasma confined by a plastic.

- Factor 100 expected compared to direct interaction

- **Pendulum configuration**

  - **Measure the linear momentum as a function of the laser energy**
  - Instrumentation :
    - PDV for momentum measurement
    - Visualization (fast camera) for plastic ejection

- **Ball joint configuration**

  - **Measure the rotation as a function of the tightening and the laser energy**
  - Instrumentation :
    - Visualization (fast camera) for rotation and plastic ejection
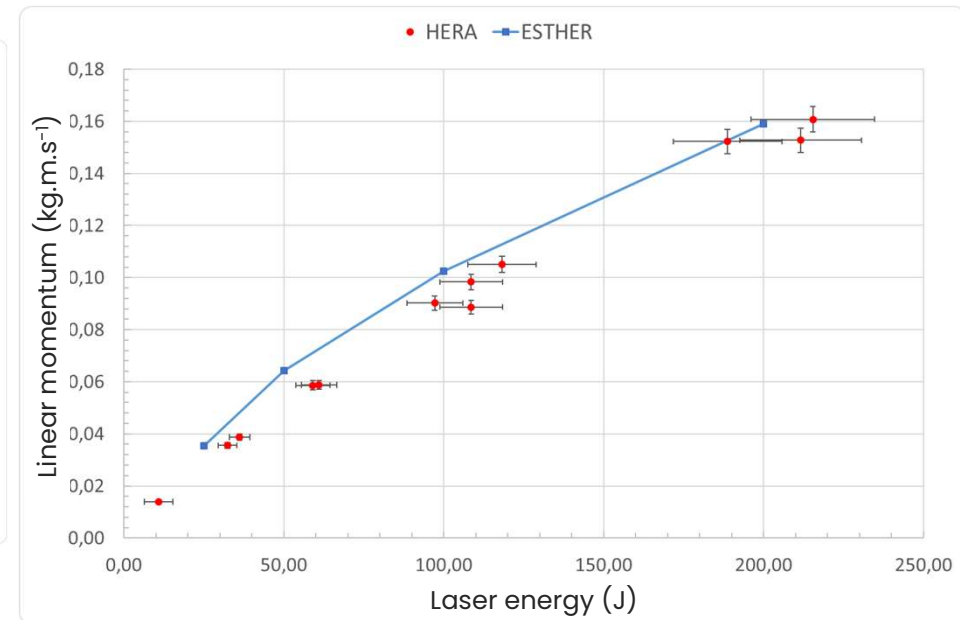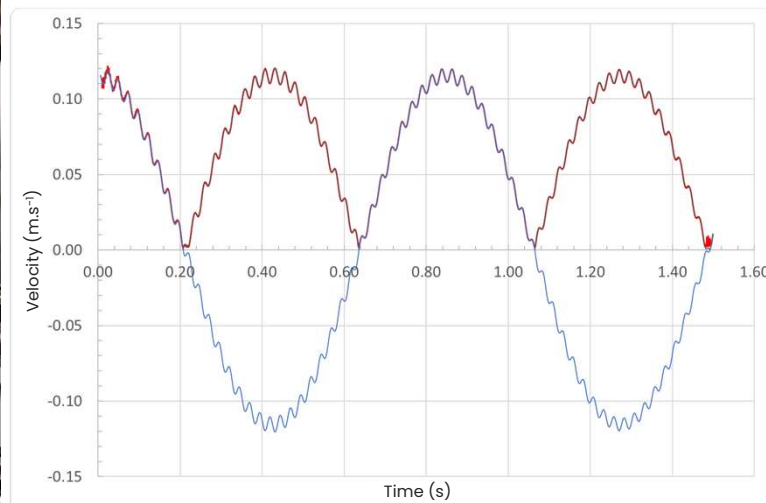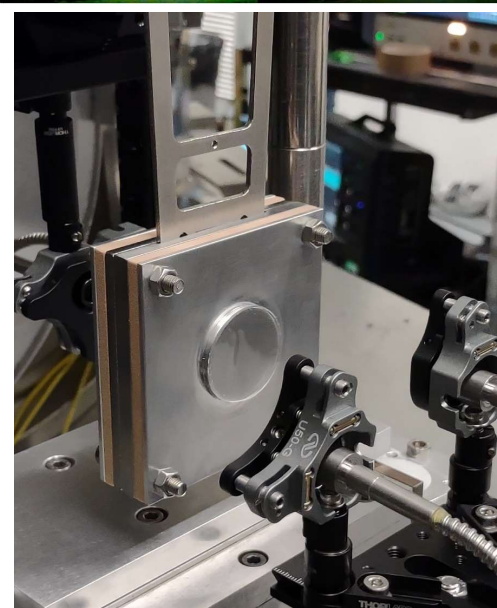   - PDV for initial velocity and displacement
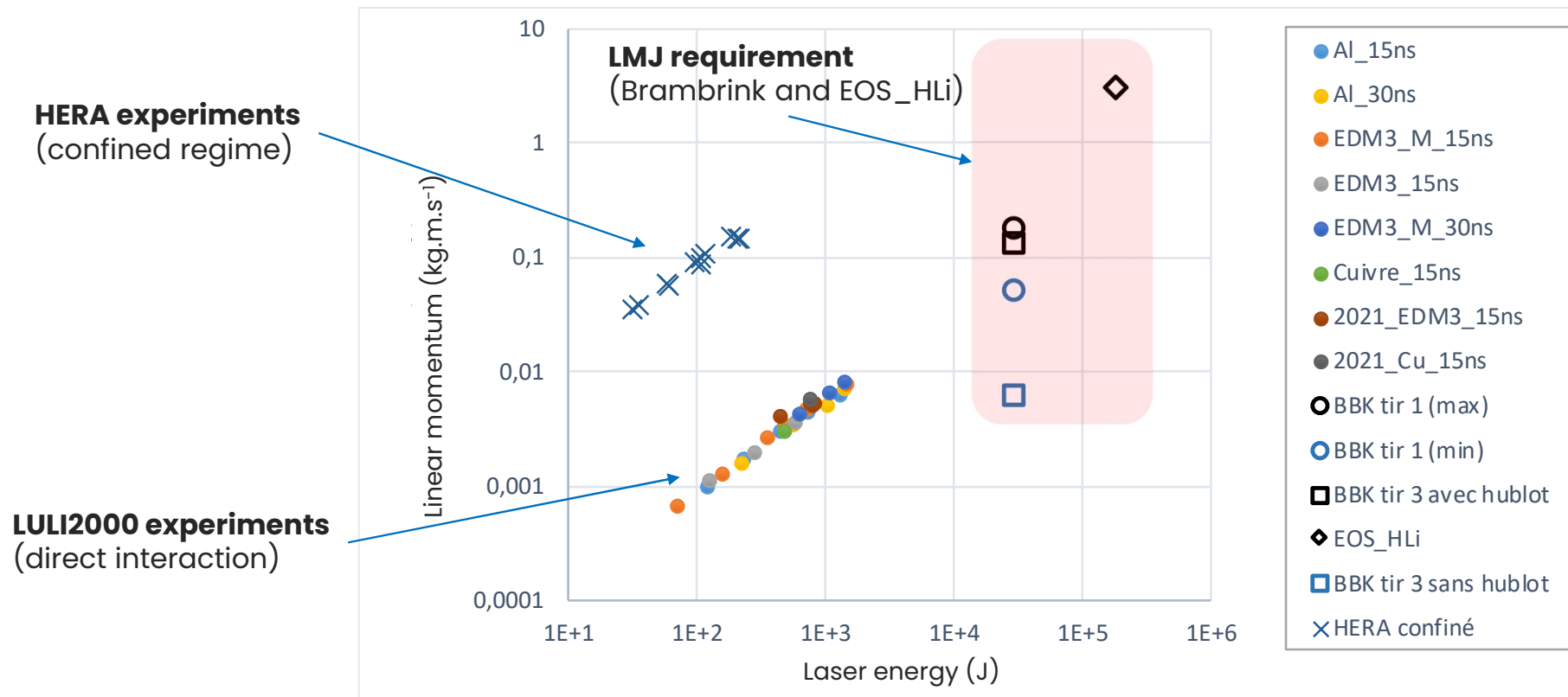   - Instrumented screws

Pendulum shots

5 cm

Shot n°10 – 97 J

t_0 | $t_0 + 30\ \mu s$ | $t_0 + 60\ \mu s$ | $t_0 + 90\ \mu s$ | $t_0 + 120\ \mu s$ | $t_0 + 150\ \mu s$

$V_{plastic} \approx 140\ m.s^{-1}$
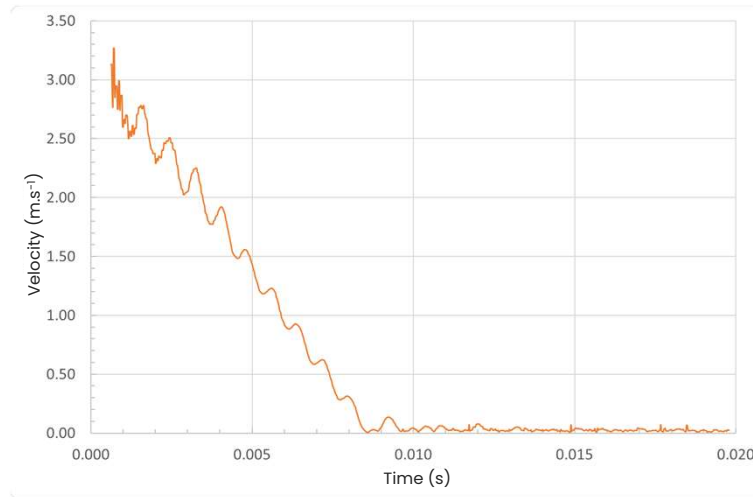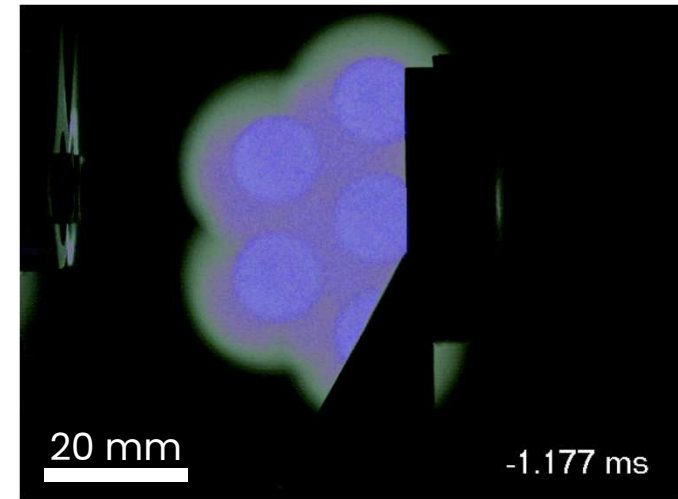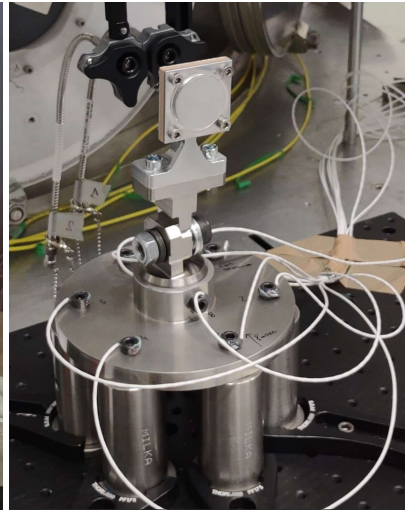
Comparison to LMJ requirements

Experimental validation of the factor 100 expected on the linear momentum in confined regime. Momentum levels on HERA cover requirements for the Brambrink campaign.
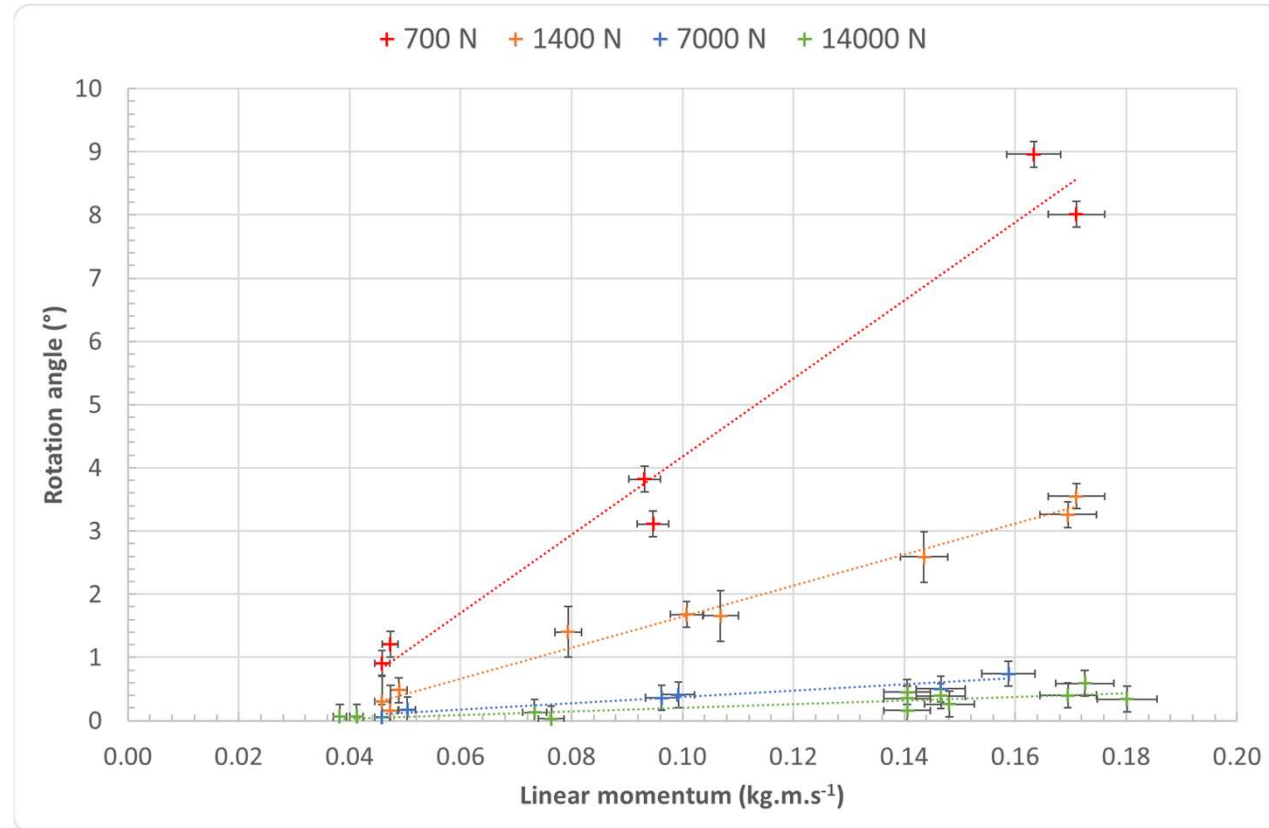
Ball joint shots

20 mm   -1.177 ms

Plastic ejection
+
Rotation
+
Vibration

Initial velocity
+
Slowdown
+
Vibration

Ball joint: rotation

- 4 tensile prestresses tested, corresponding to tightening torque of 2, 4, 20 et 40 N.m

- **Visible effect of the tightening torque**:
  - Laser energy ↗ Rotation angle ↗
  - Tightening ↗ Rotation angle ↘

- Initial conditions for Abaqus simulations.

Ball joint: comparison with Abaqus calculations

- Calculations of the HERA experiment performed with Abaqus.

- Calculations are initialized with:

  - **Initial velocity** of the target
  - **Tensile prestress** of the ball joint
  - **Coefficient of friction**

- Correct agreement between experimental and numerical angles of rotation and velocity profiles.
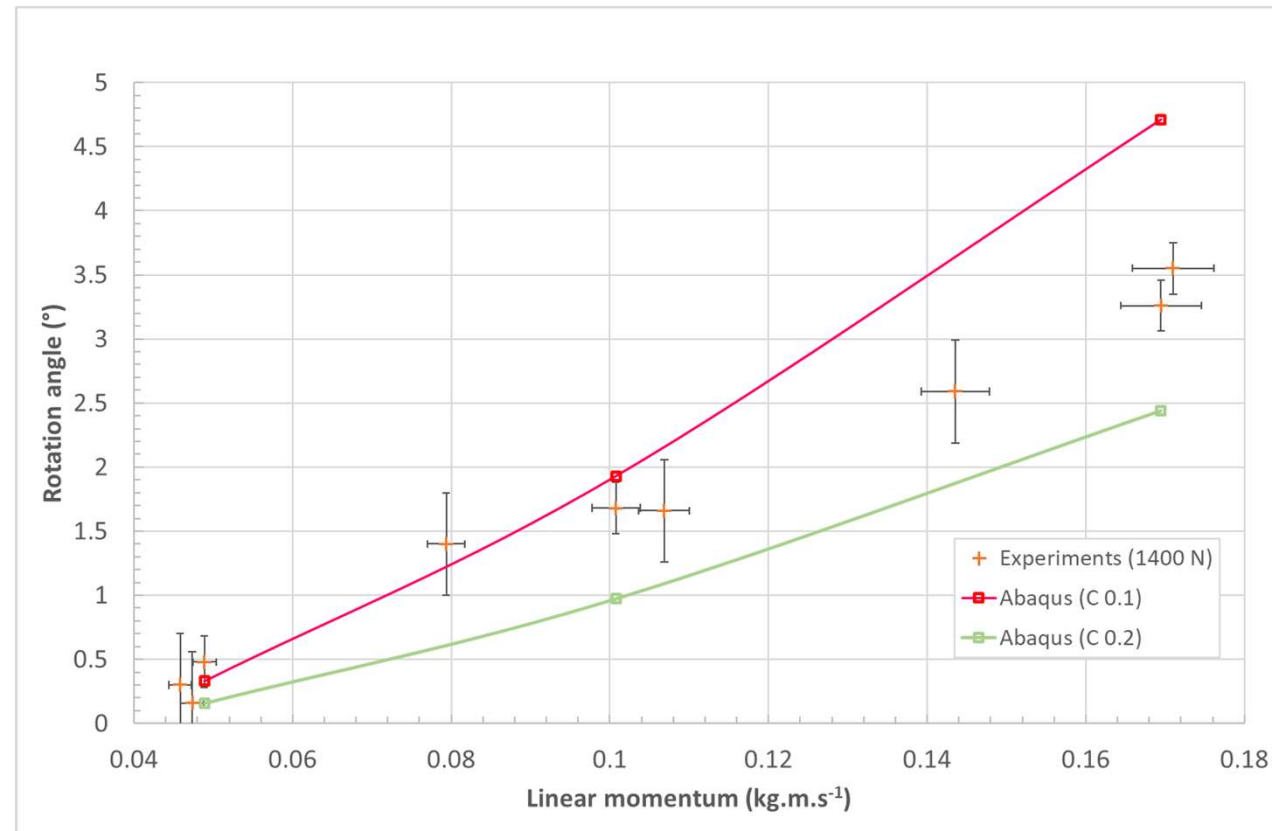
Ball joint: instrumented screws

- Instrumented screws in the base

- **Objective :** measure the effect of tightening

- Analysis in progress.

- Sensors modelled in Abaqus to get stresses.
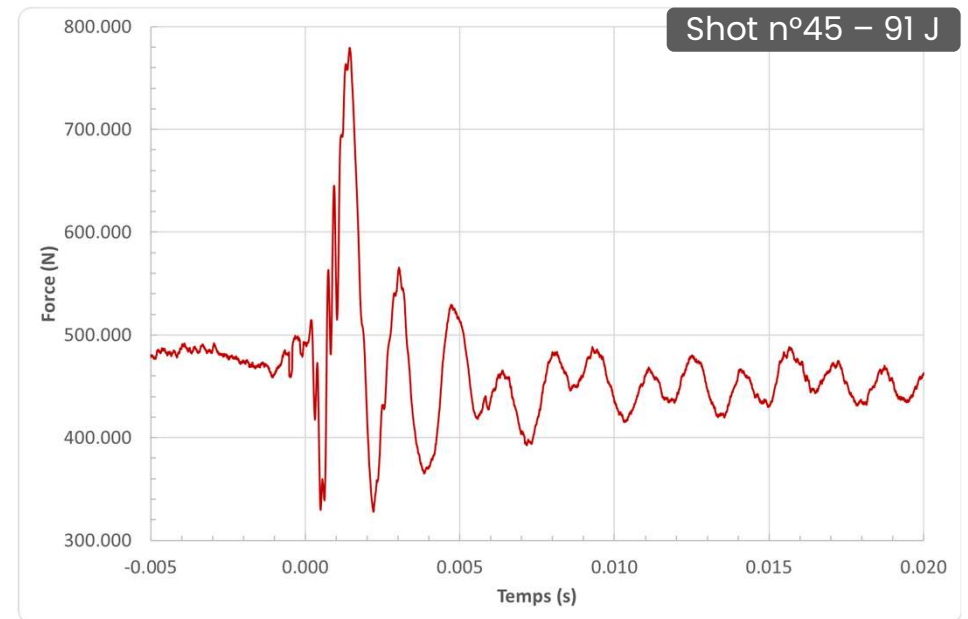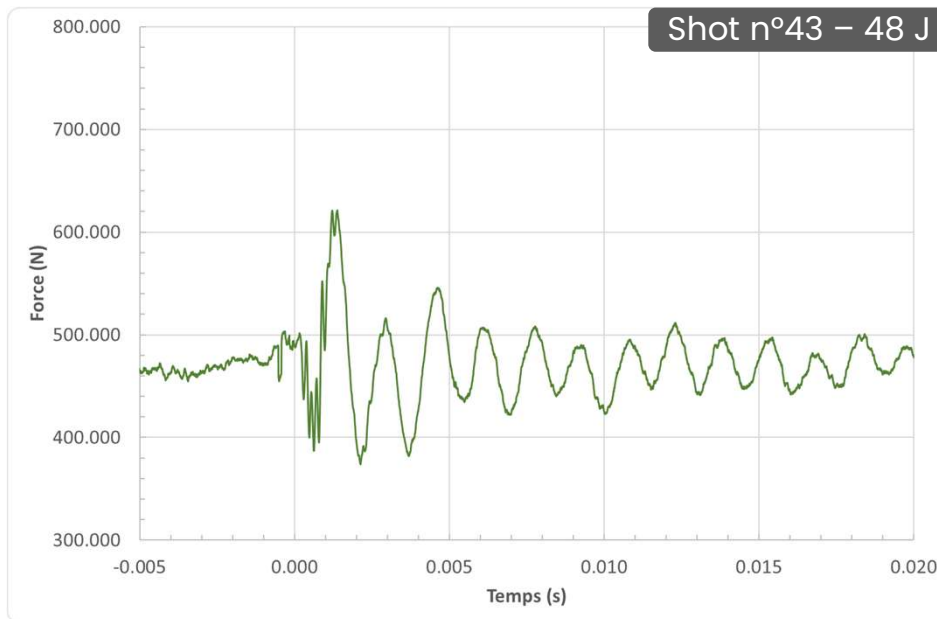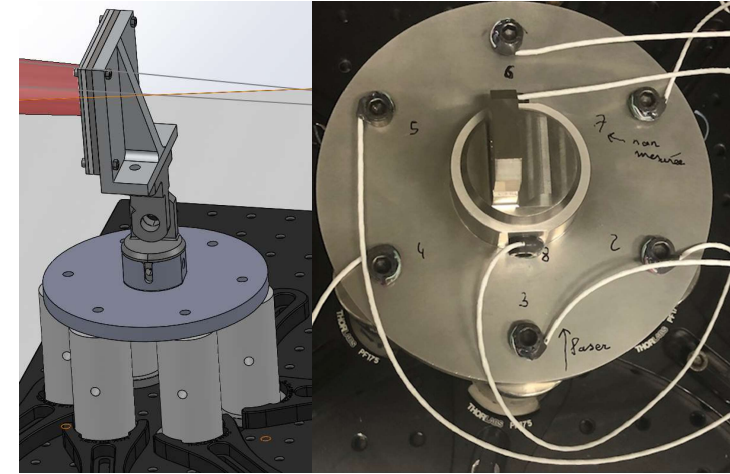
Conclusions and perspectives

Conclusion

- Calculation chain: from the laser-matter interaction to the mechanical sollication of the target holder.

- Many points to validate.

- Experimental data to calibrate / validate Abaqus simulations.

Perspectives

- **HERA**
  - Future experimental campaign scheduled for the end of 2023
  - Tests on representative target holder

- **LMJ**
  - Future campaign April 2024:
    - Calculation chain → **measurement of linear momentum obtained with 1 LMJ quad**
    - Validation of technical solution to limit fragments generation

  - Future experiments with heavy targets: HARMAND, …

Finally...

- Possibility to hold heavy targets with a SID instead of the PCNC.

- Limit static load: 200 kg.

- Need to validate the mechanical strength of a SID.

TOO WEAK

STRONGER