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# HIGH REPETITION RATE, DEBRIS-FREE TARGET DELIVERY SYSTEM FOR ION ACCELERATION BY LASER

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182 21 Prague 8, Czech Republic



beamlines

Introduction

Elise 1: Description

Tests with ELISE1, and improvements

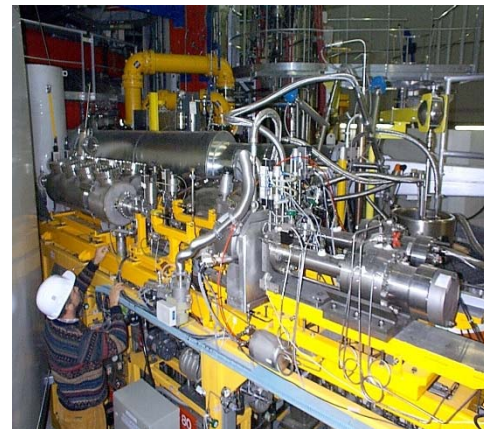
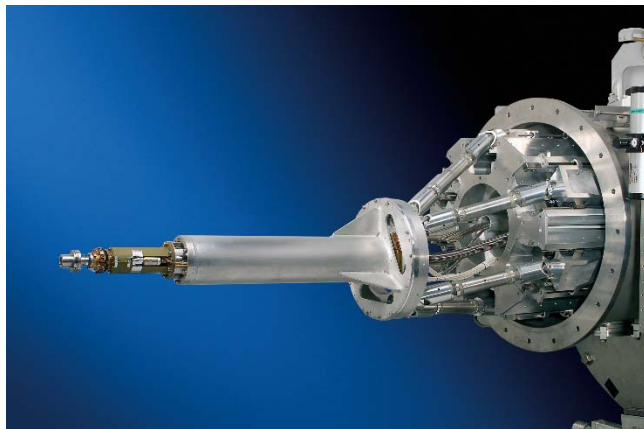
Elise 2: Description

Conclusion & Prospects

Based on our experience at CEA Grenoble:

20 year experience with studies on cooling LMJ cryotarget

10 year experience on Pellet Injection System for mag. Fusion

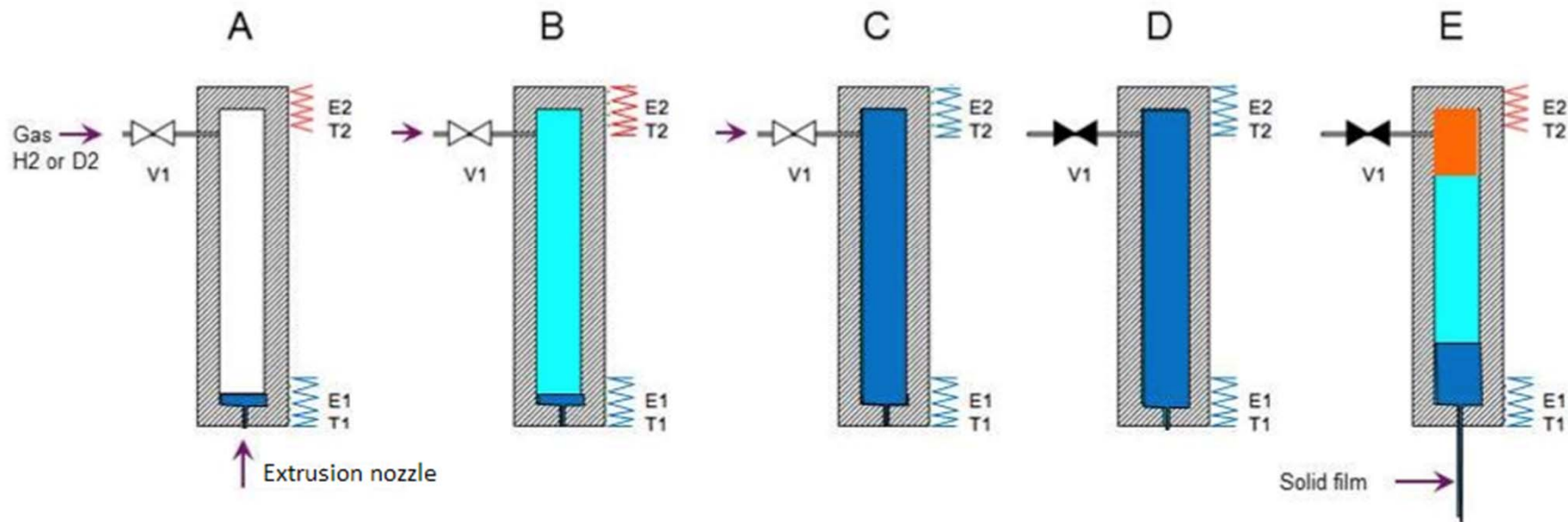


and more generally in cryogenics,

we started the study on continuous solid hydrogen cryotargets.

Interest of **high repetition rate, debris free targets** for most advanced lasers

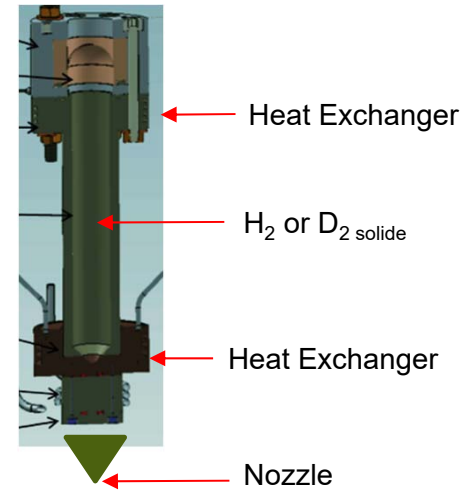
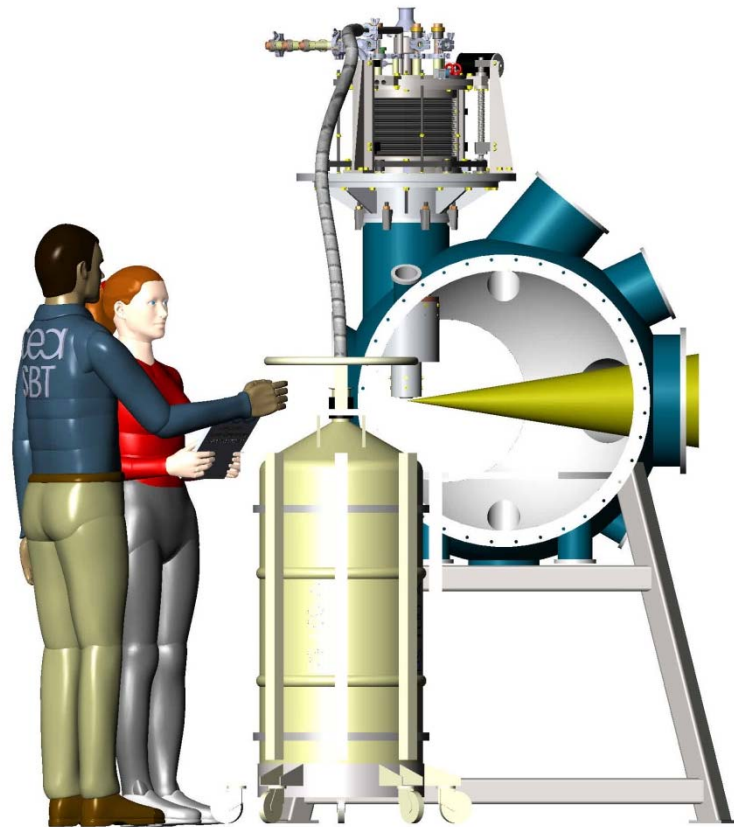
- Extrusion of solid hydrogen ribbon without any mobile part (=> no vibration)



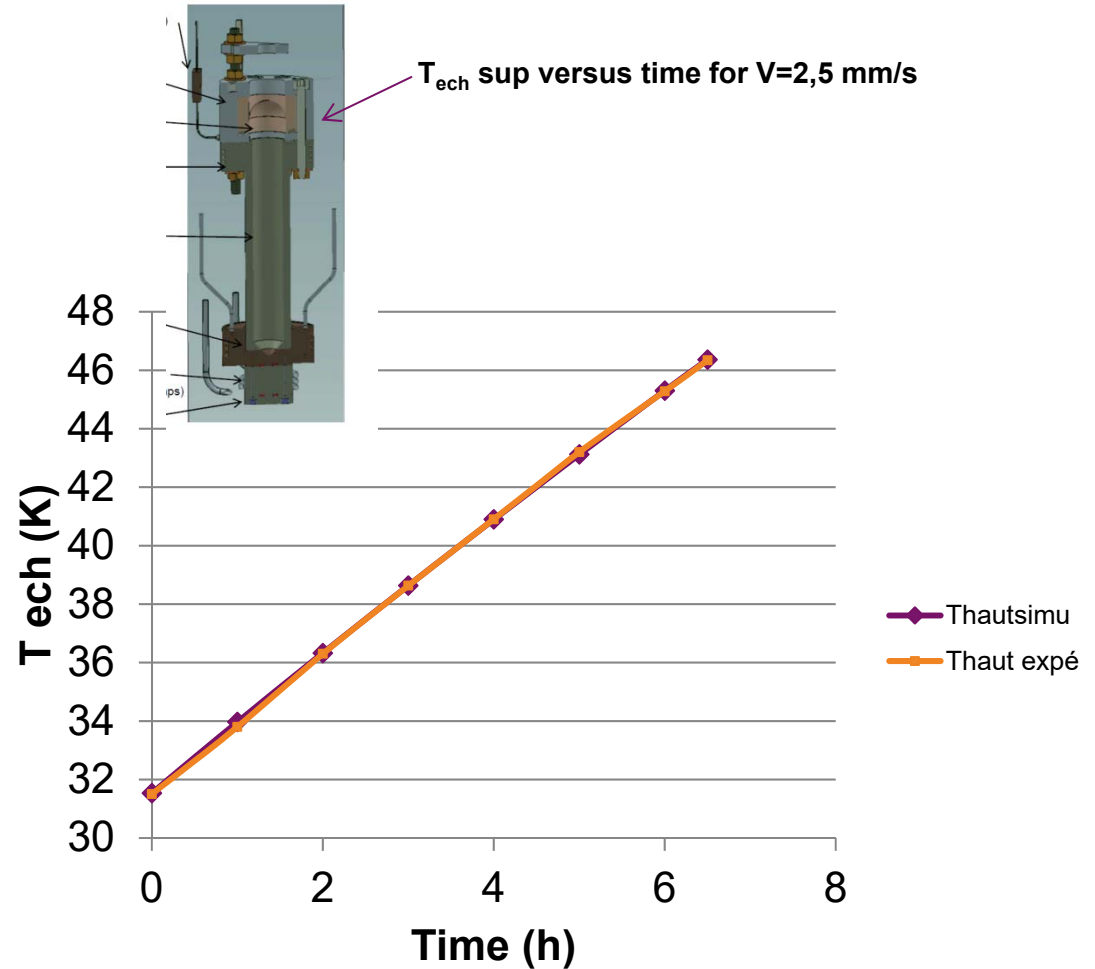
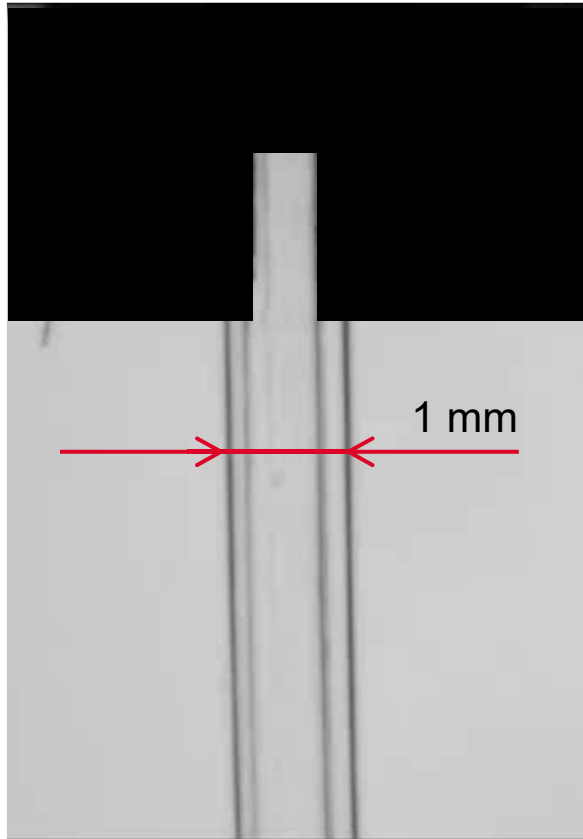
The pressure increase due to liquefaction of hydrogen at E2 allows to push a ribbon of solid hydrogen from the tank of SH<sub>2</sub>

# The Elise (1) cryostat

(Experiment on Laser Interaction with Solid hydrogEn targets 2014)



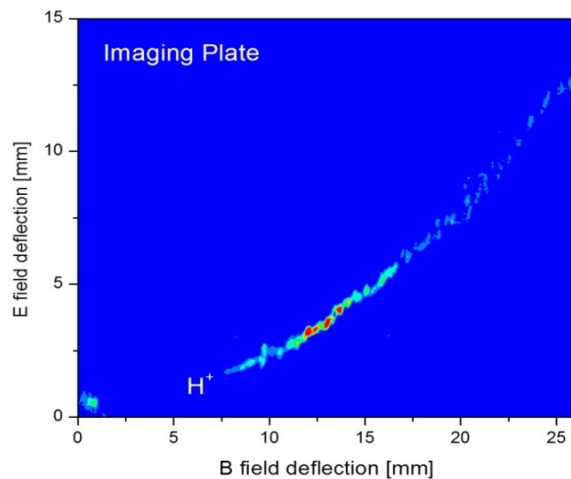
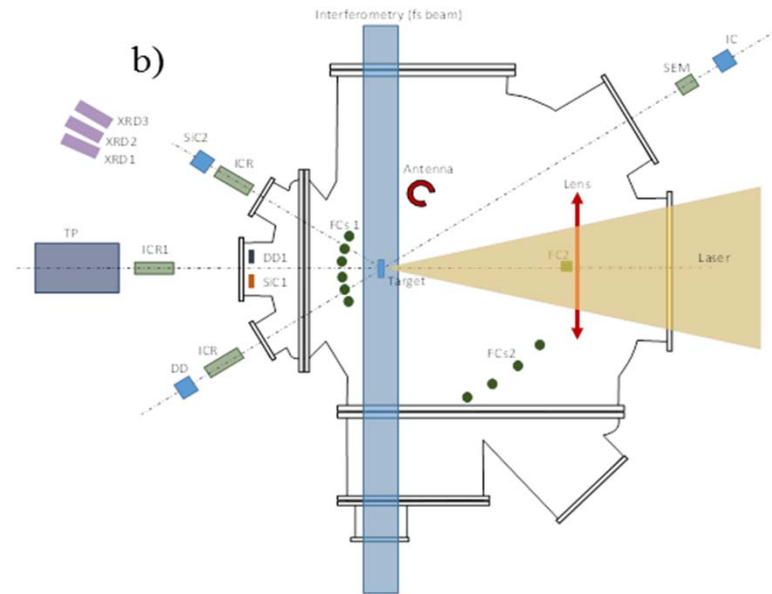
S. Garcia, D. Chatain, and J. P. Perin,  
Laser Part.Beams (2014)



Ribbon 1mm x 100 $\mu\text{m}$  (0,9 mg/cm<sup>2</sup>)

Thanks to advanced control, hours of operation are possible

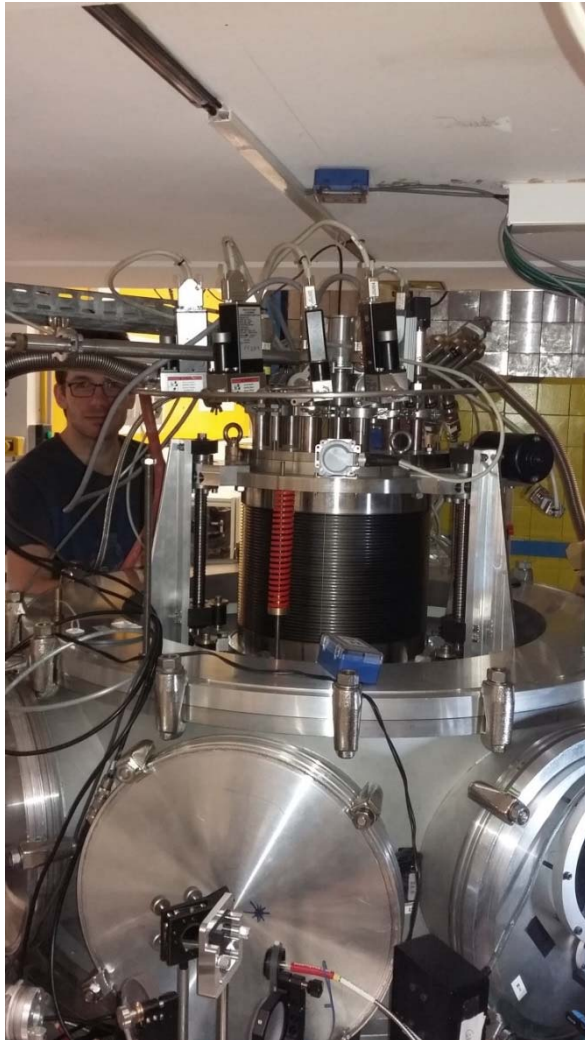
## Experiments on PALS: 1kJ – 330ps – 3TW (dec 2015) PI: D. Margarone



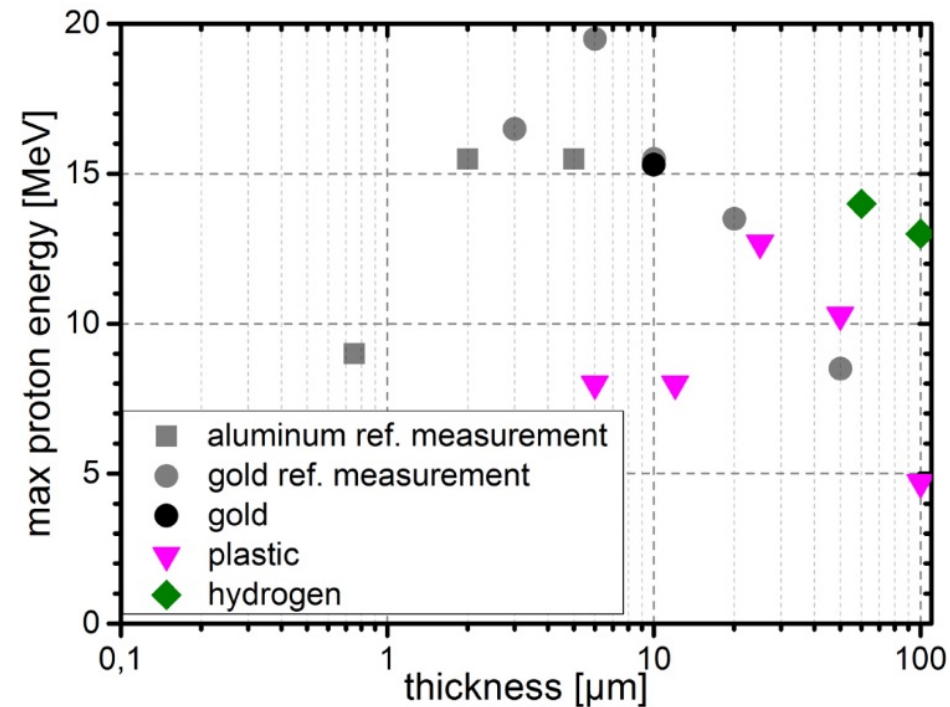
**30 shots @ 600J.  $3 \cdot 10^{16}$  W/cm<sup>2</sup>**  
**Protons @ ~ 1 - 1.4 MeV**  
 **$6 \cdot 10^{14}$  protons between 0,1 et 1 MeV**  
**Efficiency ( beam energy/ laser energy) = 5%**  
**No problem due to EMP**

D. Margarone,...,D. Chatain, JP Périn et al, Phys. Rev. X, 2016

Experiments on **ELFIE** : 20J – 200fs – 100TW (Fev 2016) (pi: S. Kraft)



40 shots Protons ~ 12-14 MeV

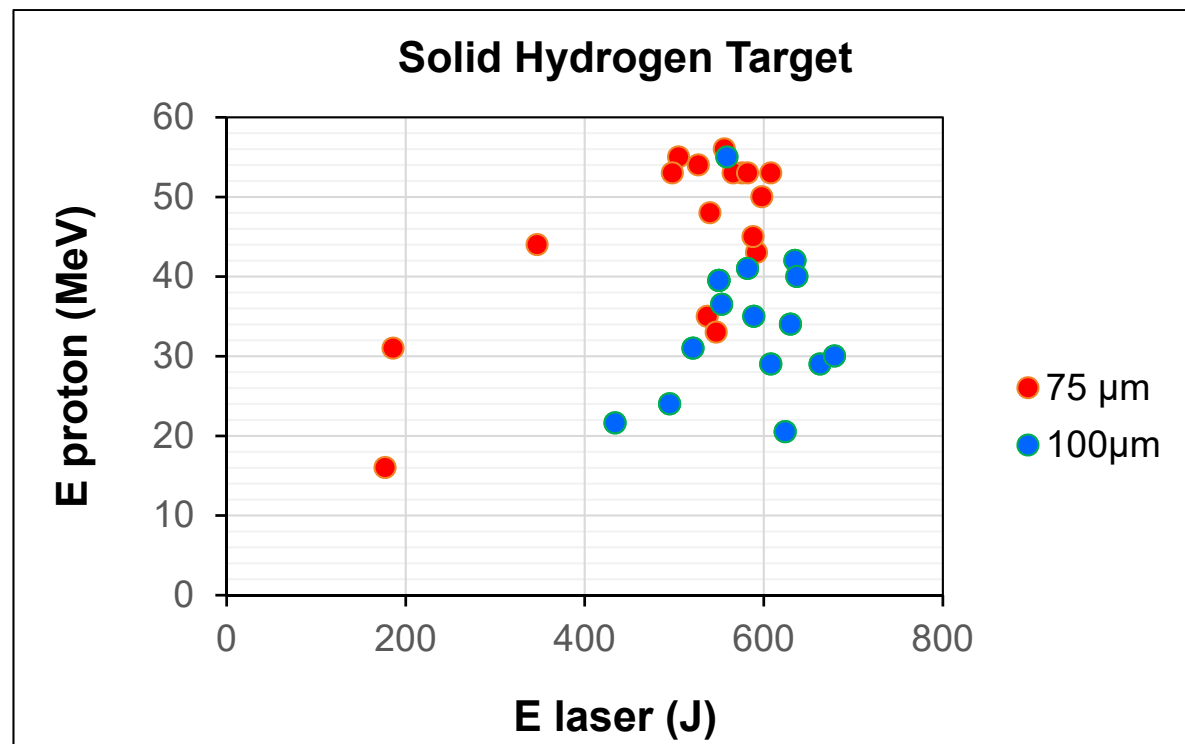


S. D. Kraft, ..., D. Chatain, JP Périn, et al. -  
Plasma Physics and Controlled Fusion 2017

## Experiments on VULCAN 1kJ – 1ps – 1PW (April 2017) pi: D.Margarone



600 J, 1 ps,  $3,5 \cdot 10^{20}$  W/cm<sup>2</sup>  
34 shots, 2 types of nozzles, protons up to 55 MeV  
Dispersion in energy possibly related to ribbon instability



Another campaign in 2018, analysis in progress

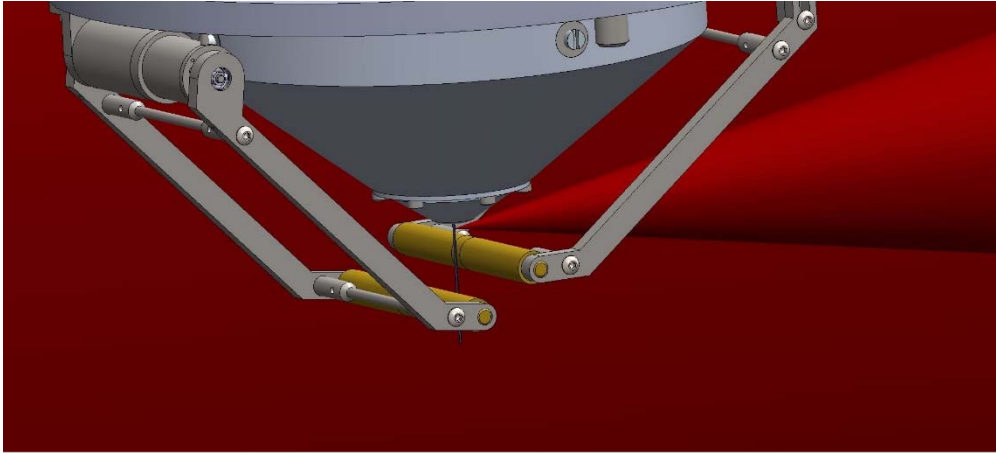
Nearly 100 laser shots, from 3 TW to 1 PW (last Vulcan campaign not included)

- Acceleration of pure proton beams, up to 55 MeV
- No debris
- No influence of EMP on the electronics/sensors
- A good vacuum is mandatory. Reduce outgassing.

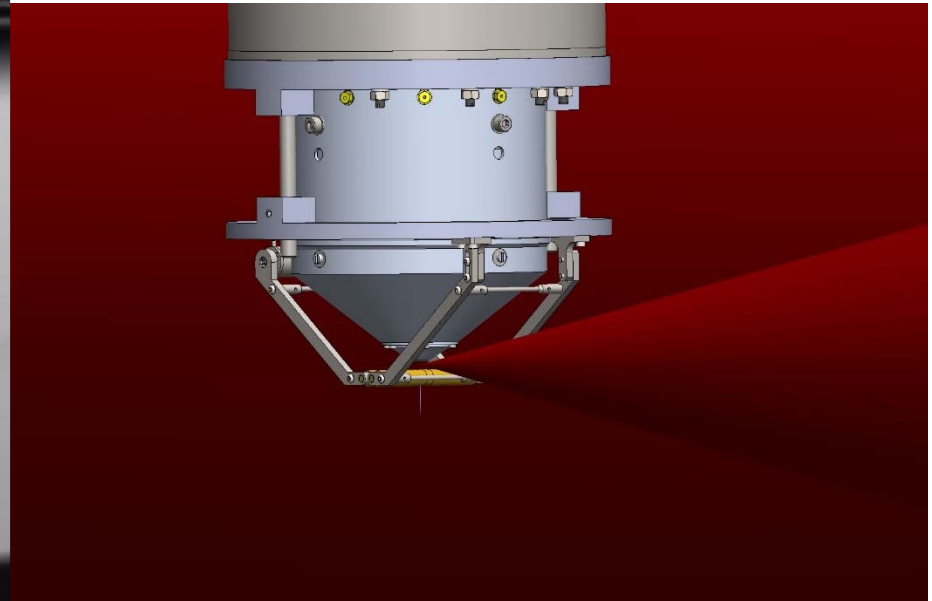
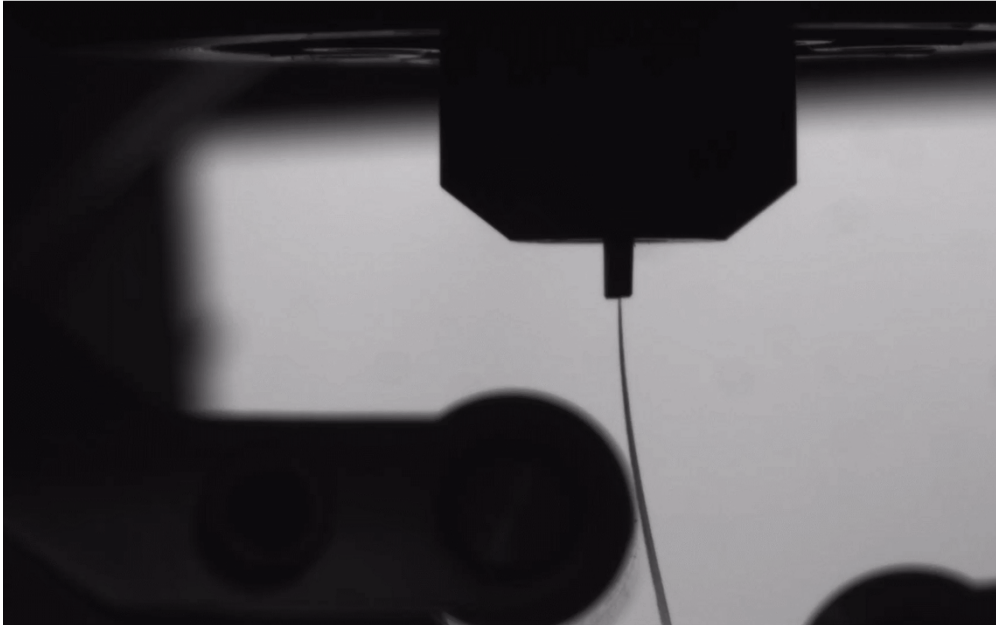
## To improve:

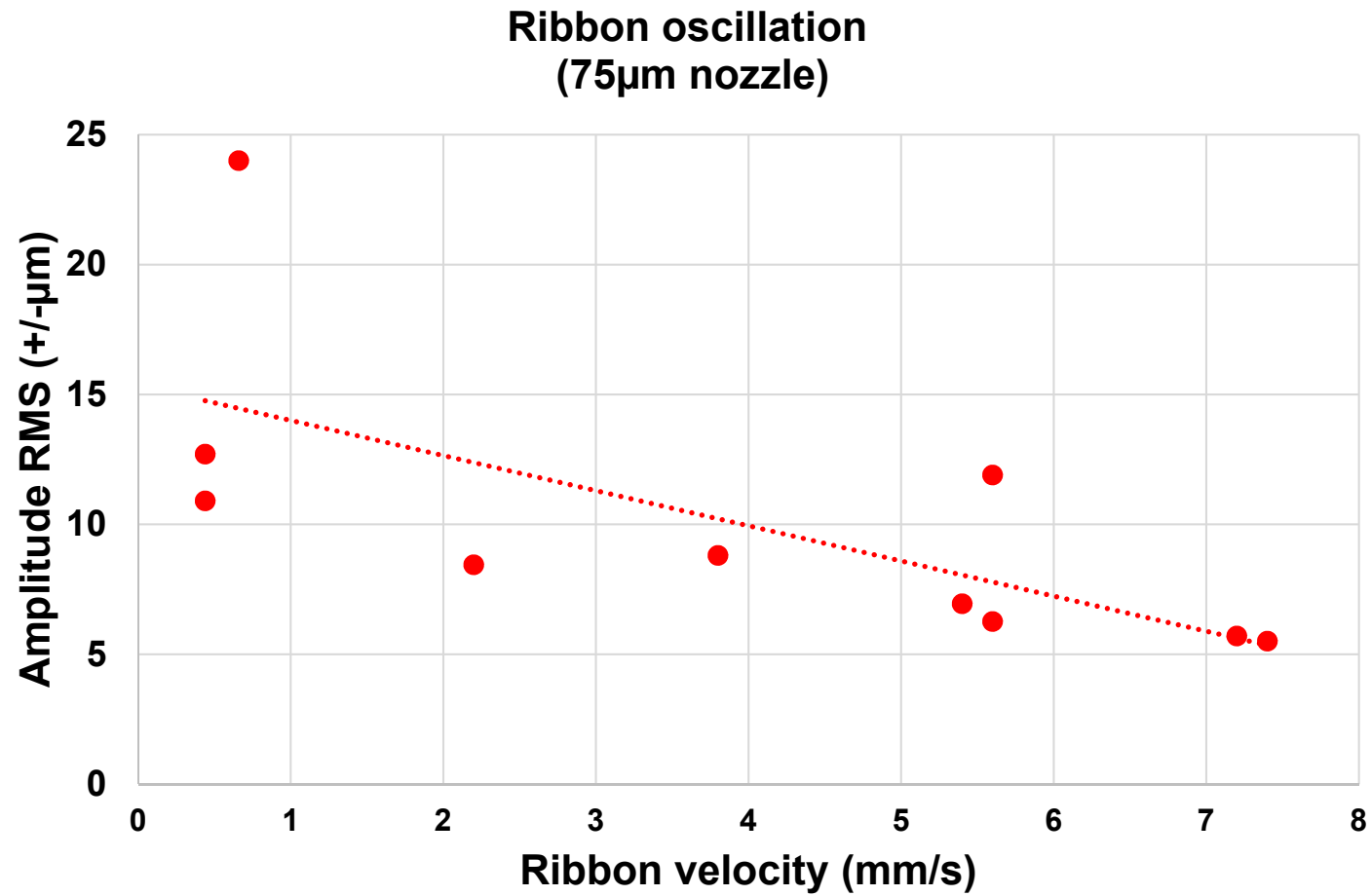
- Stability of the ribbon
- Optimisation of extrusion => data for modelling
- At high laser energy, the hydrogen tank is emptied: => management of transient heat load
- Thinner targets to answer requests from experimentalists
- Management of LHe is a constraint
- No tests so far with high repetition rate lasers

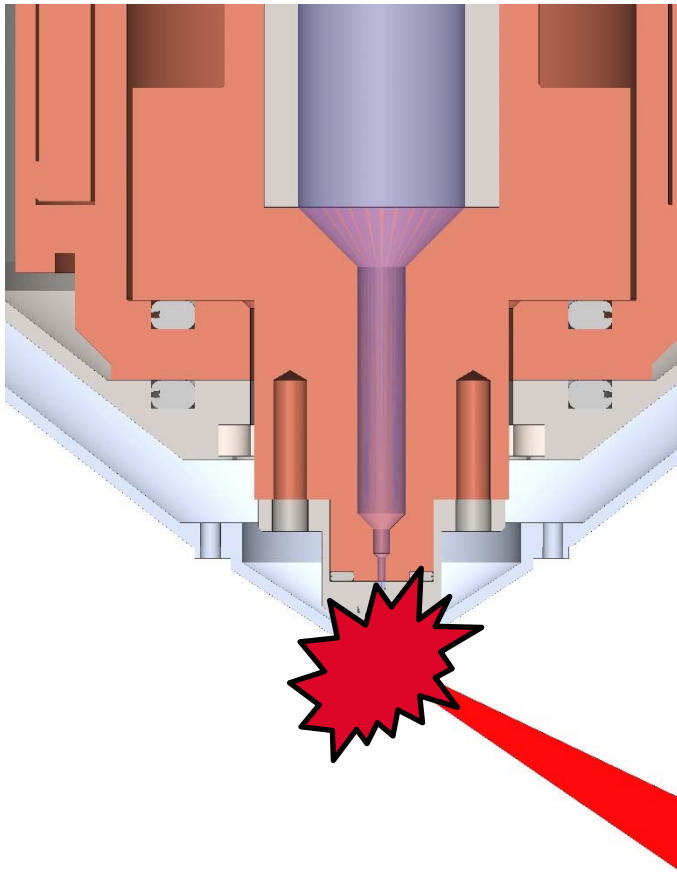
# Improvement of the stability



Need  $\pm 10\mu\text{m}$

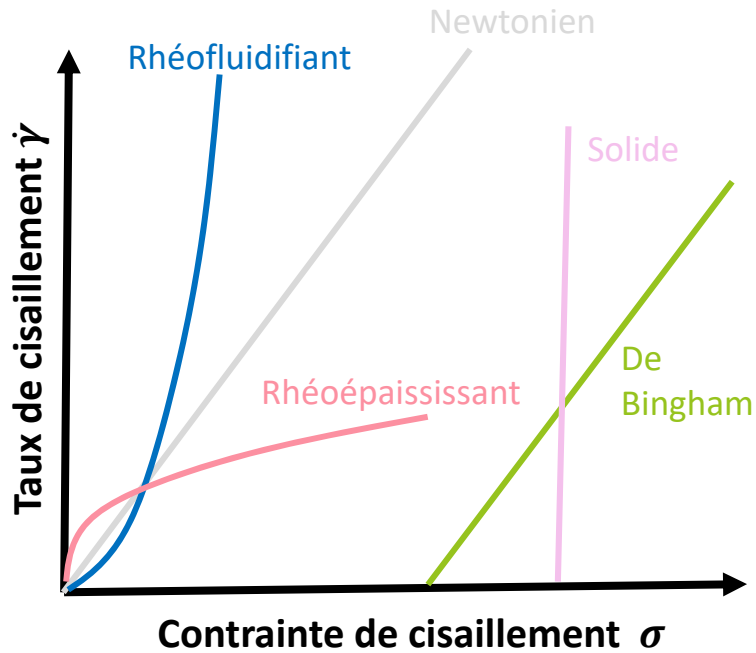




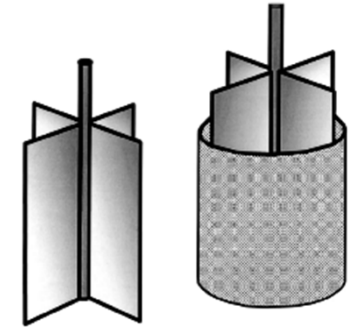


Heat generated by high energy shots leads to liquefaction of hydrogen in the nozzle, leading to emptying the cell

During last campaign at Vulcan we could reduce this effect by “anticipating” the heat load.



APRYL: low temperature Couette experiment



Détermination of the law:

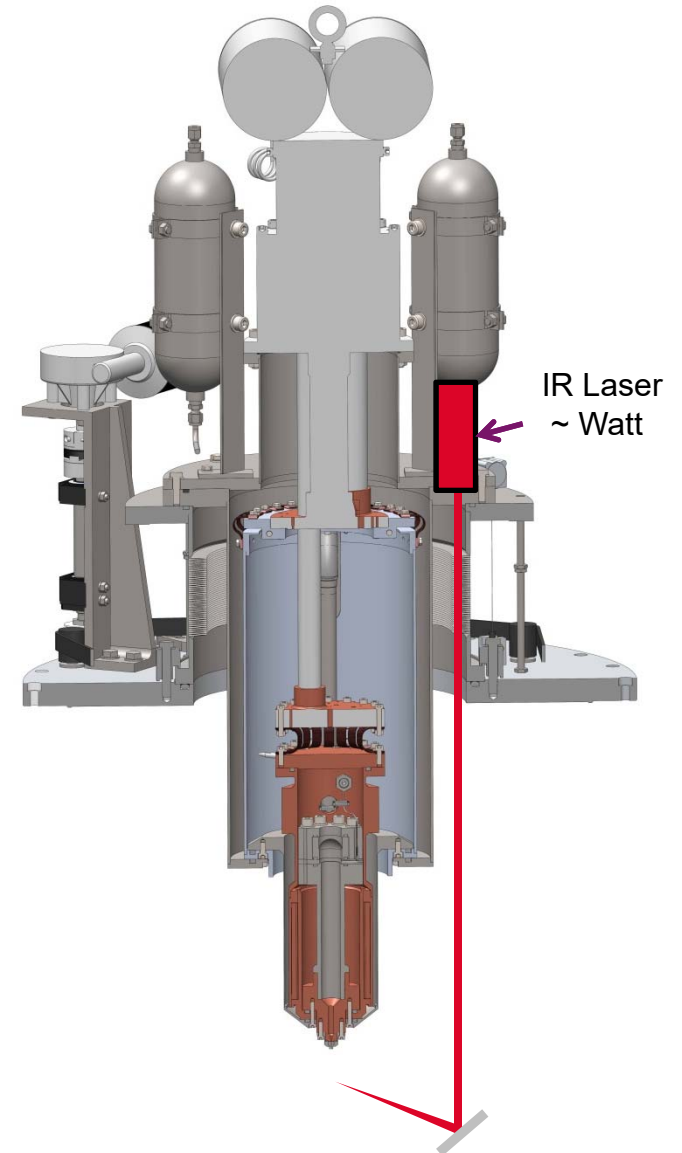
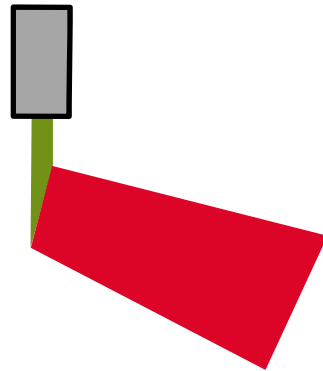
$$\sigma = \sigma_0(T) + \mu(T) \cdot \dot{\gamma}^n$$

Bingham = threshold + linear

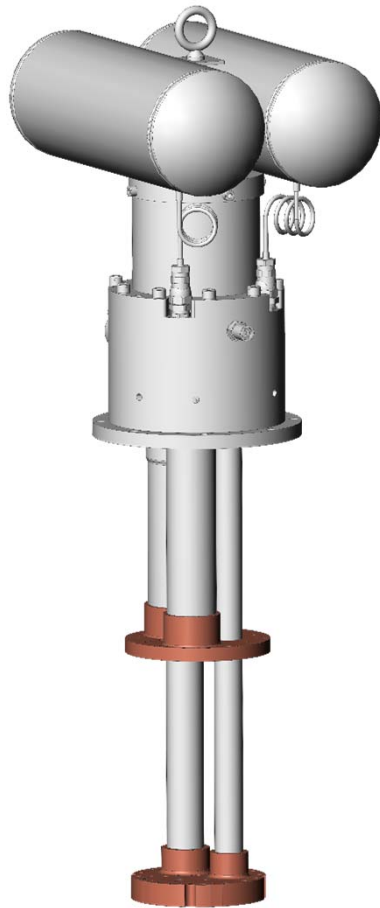


# Thinner ribbons: evaporation

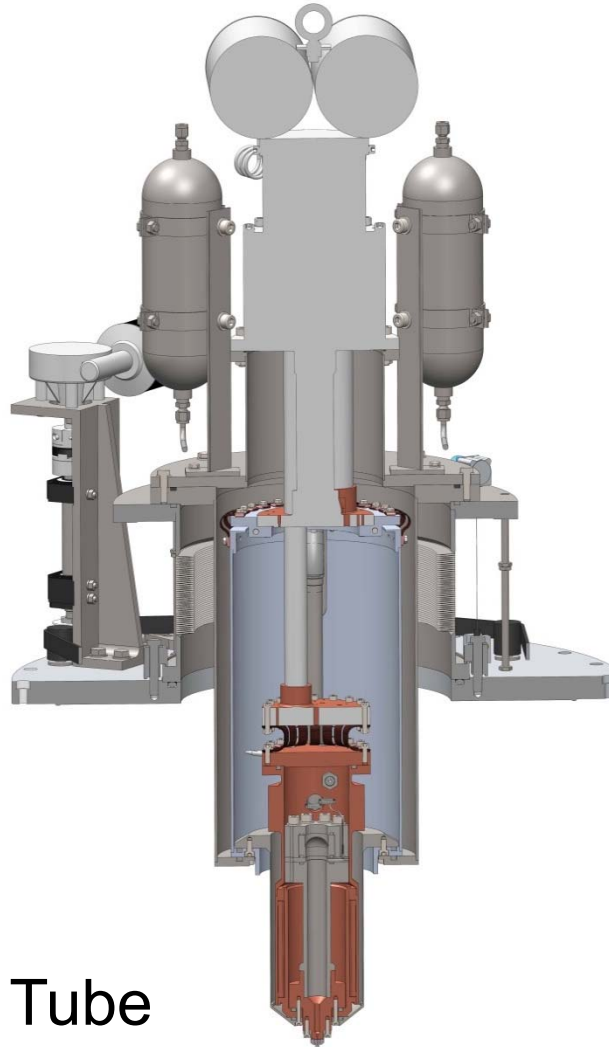
Evaporation of the part of the ribbon through absorption of radiation.



Merci à J. Bleuse PHELIQS-NPSC



Cold source: Pulse Tube  
1W @ 4.2 K,  $T_{lim} = 2.8$  K



2 independent cold  
temperature  
points needed (E1, E2)

⇒ A thermal switch  
is added, to allow to  
tune E2 independently

A thermal buffer is added  
to smooth any residual  
temperature oscillation  
at E1

Cool down: 5 h  
Hydrogen filling: 1 h



Control system modified  
with respect to Elise I  
(cold source different)

6 hour operation fulfilled  
without any problem

Very similar performances  
as Elise 1.

ELISE2@TERESA (L3 sub-aperture, 50 TW, 30 fs, 1-3 Hz): just installed



Two main questions: \* new ribbon ready after the shot ?  
\* thermal effects ( thermal load )

- Acceleration of pure proton beams, up to 55 MeV
- No debris
- No influence of EMP on the electronics/sensors
- A good vacuum is mandatory. Reduce outgassing.

Work to do:

- Stability of the ribbon: **rollers improve the stability**
- Optimisation of extrusion => data for modelling **coming soon**
- At high energy tank emptied: **medium (~100 J) loads should be managed**
- Management of LHe is no longer a constraint: **Elise 2**
- No tests so far with high repetition rate lasers: **Elise2@Teresa**
- Thinner targets to answer requests from experimentalists: **tests have started at Elise 2, hopefully next week with laser.**

CEA Grenoble: J.P. Périn, D. Garcia, B. Rousset, F. Viargues, F. Bancel, B. Rollet, JM Mathonnet, N. Luchier, J. Cezkowsky, J. Viswanathan, F. Souris

Institut Néel, CNRS Grenoble: M. Gibert

LANEF (local Grenoble Laboratory of Excellence): PhD S. Garcia

ELI beamlines: D. Margarone, T. Chagovets, A. Velyhan et al

Queen's University Belfast: H. Ahmed, S. Kar, M. Borghesi

PALS team.

HZDR Dresde: S. Kraft, T. Cowan, et al, and M. Gauthier (SLAC).

LULI: J. Fuchs and ELFIE team

Thank you for your attention