

# *Applications at the interface between Lasers and Accelerators*

*Focus on high energy  
Non-Destructive Testing*

LA<sup>3</sup>NET Conference  
Mallorca, 26/03/2015

## Source LAB

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### Laser Plasma Technologies

| François Sylla, PhD

# SourceLAB :develop and commercialize solutions for laser plasma sources

## Products and services

### Targetry - Sources for interaction

Our line of solid and gas targetry products provides you with solutions for:

- Attosecond plasma physics
- Plasma mirror contrast cleaning
- Control of particle injection and energy in Laser Plasma Accelerator schemes
- ...



### Laser filtering solutions

The XPW line of products, optimized to your beam line front end, enables:

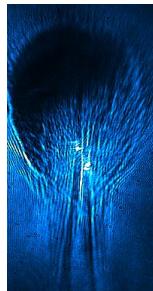
- Energy-scalable high-efficiency laser temporal contrast filtering
- Post-compressing for ultra-short laser pulses
- ...



### Diagnostic and Characterization

Plug-and-play solutions for interaction characterization and laser diagnostic:

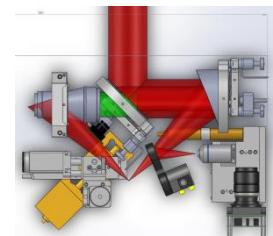
- Plasma and neutral gas density characterization (solution by Phasics, in collaboration with SourceLAB)
- Laser beam interaction suitability diagnostic
- Laser referencing
- ...



### Engineering services

Based on our team unique expertise, we provide services and solutions for your experiments:

- Beam line design and optimization
- Mechanical engineering
- Expertise on laser plasma interaction control
- Training
- ...



## Outline

# **Foreword : application, innovation, network**

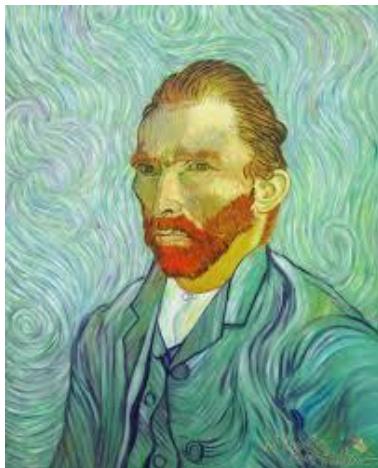
## Applications vs applications

- Not **endogenous** meaning:
  - ✓ LWFA
  - ✓ Ion acceleration (TNSA, RPA)
  - ✓ X-ray/Betatron radiation
  - ✓ Proton radiography
  - ✓ Electron diffraction
- **Exogenous** meaning:
  - ✓ Use beyond academic field
  - ✓ Societal innovation



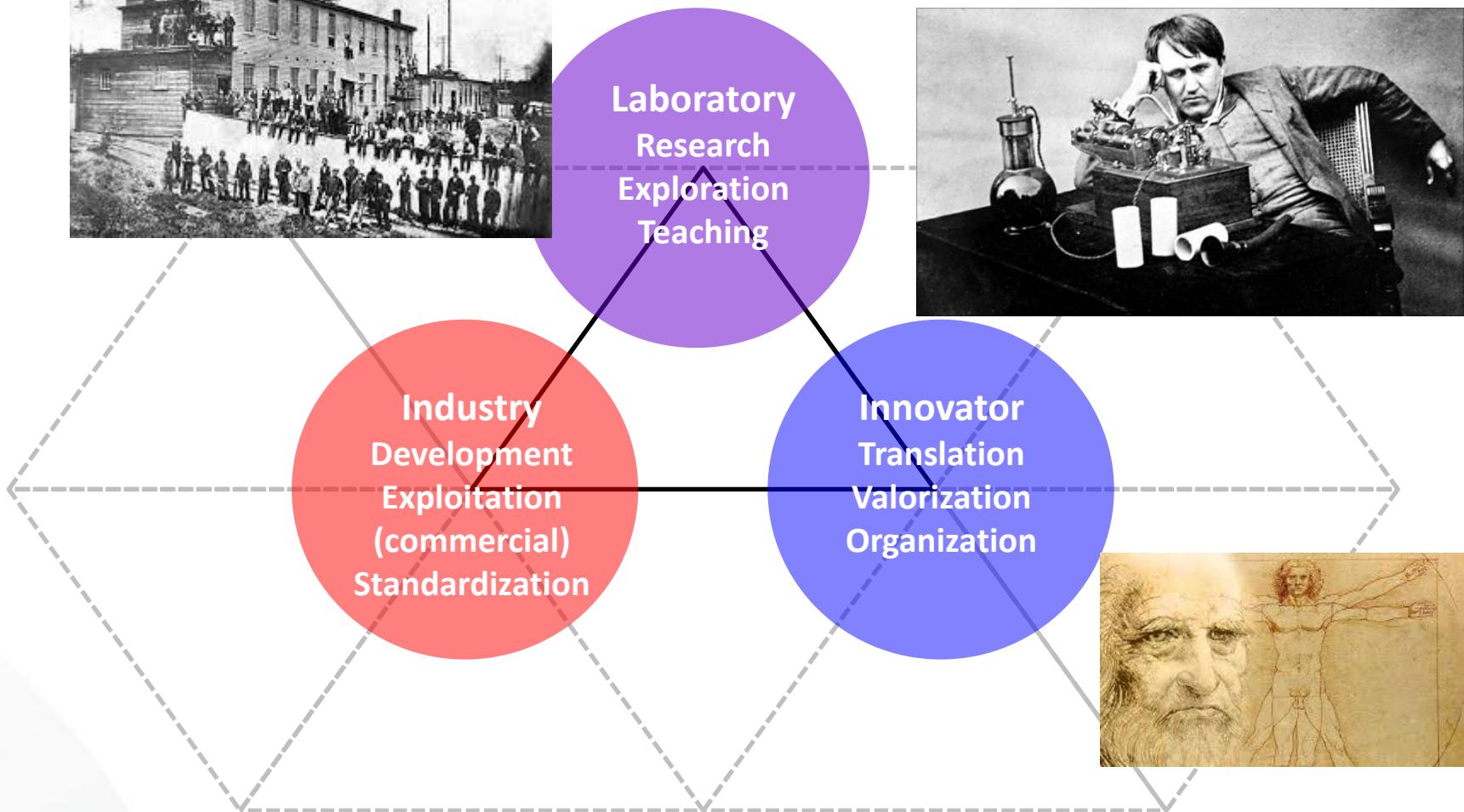
## Theory of innovation *actor-network theory*

- **Art:** Howard S. Becker, *Art Worlds*, California Press (1982).
  - Innovation **only** emerges when a dense network of actors (artists, manufacturers, critics, gallerists, theoreticians, advertisers etc.) collaborate to stabilize a new corpus of values.



- **Science/Technology:** Michel Callon, *La Science et ses réseaux, Genèse et circulation des faits scientifiques*, Editions La Découverte (1989).
  - « A technical innovation depends upon the existence of a network that will integrate it, and gives an **original/contingent** sense to it » (Philippe Bernoux, *La Sociologie des organisations*, chap. 8, p. 250, Editions Points (2009)

## Actor-Network



source: Ronald W. Clark, *Edison*, George Rainbird Limited (1977)

# Applications of industrial accelerators

## Opportunity for innovation

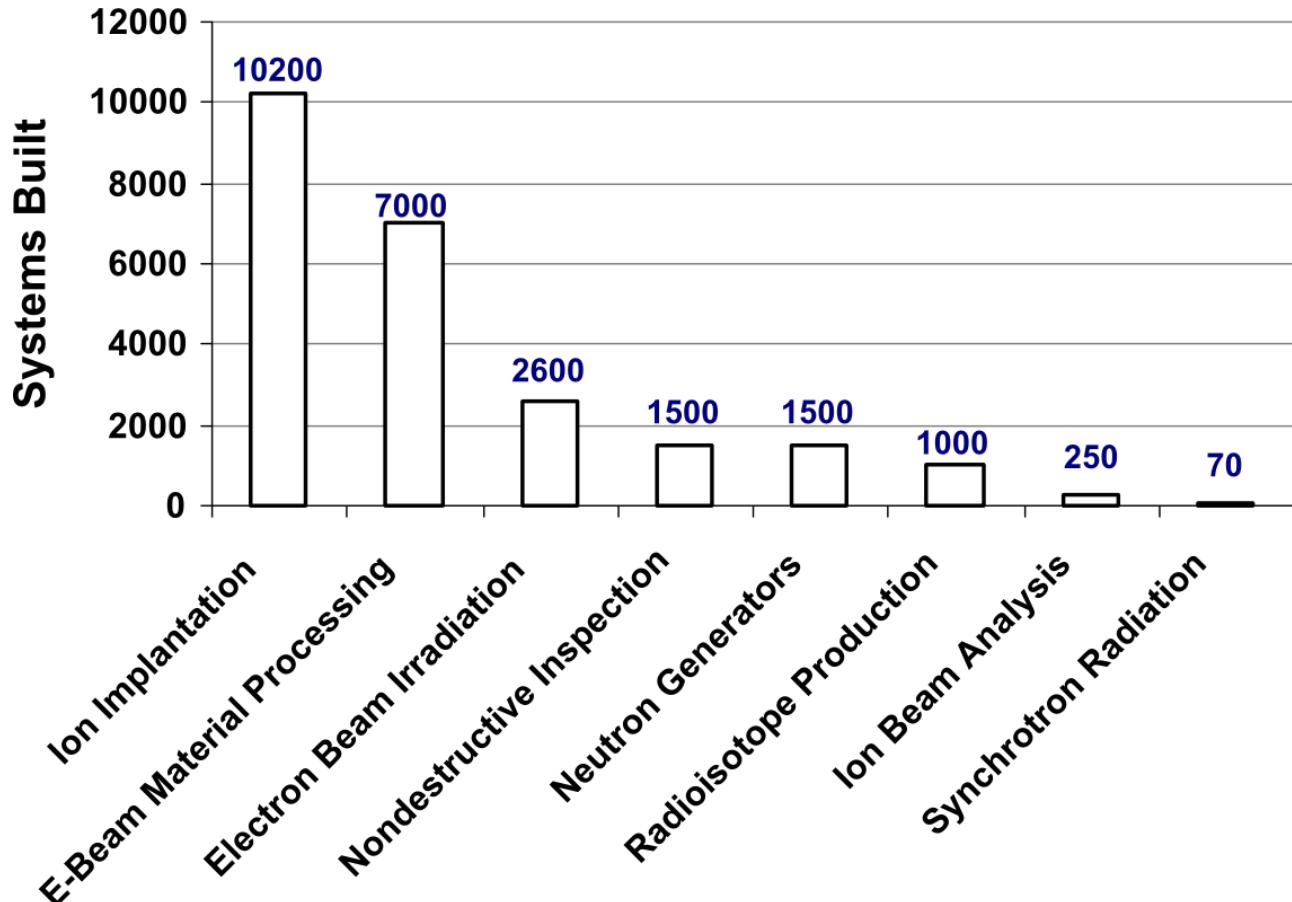
### Field distribution

35000 units in the world

24000 units for industry and R&D

2000 units sold/year

Revenue > 2,2 G\$ et 4% CAGR

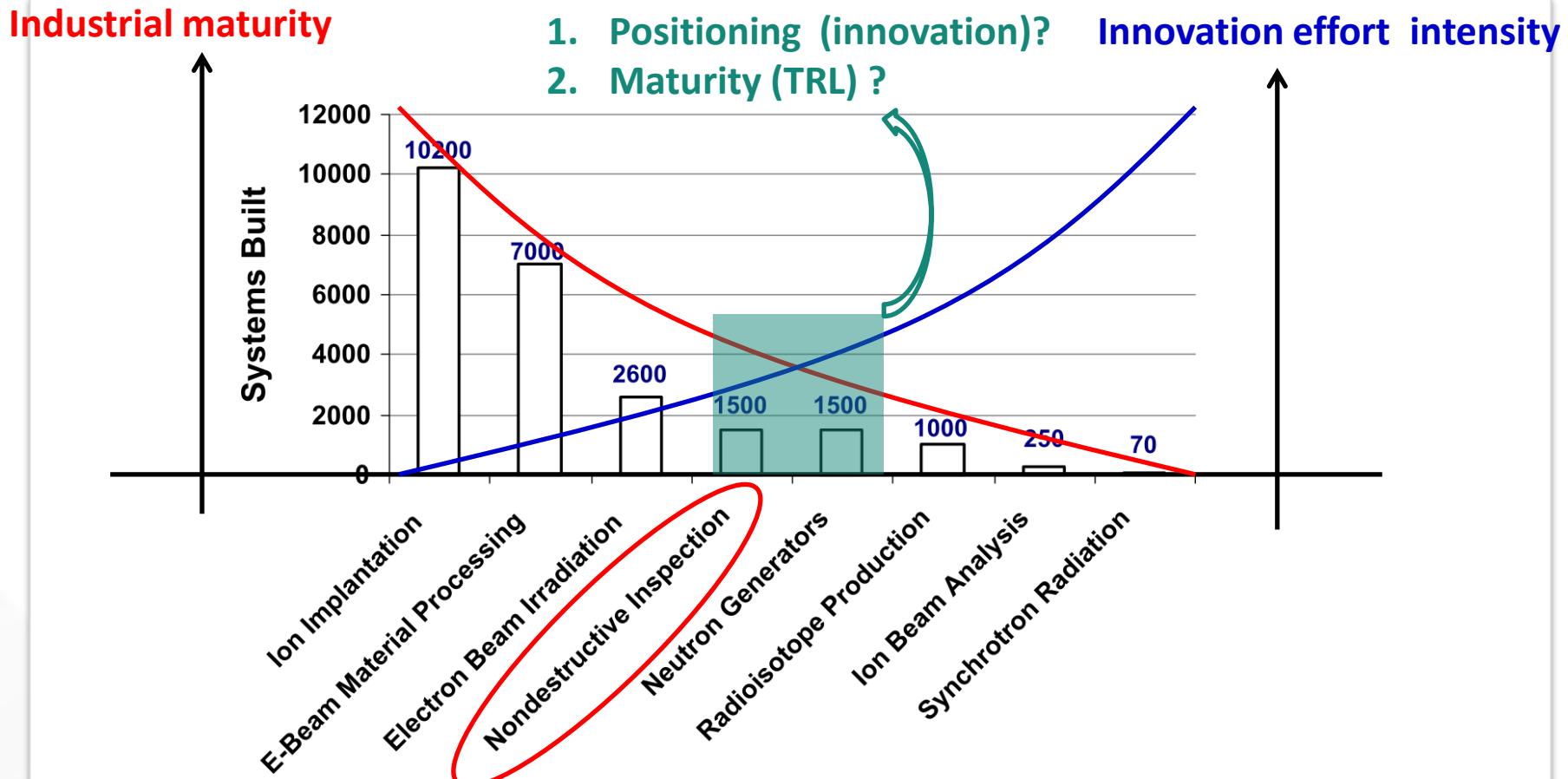


source: Hamm, *Industrial Accelerators and their applications*, World Scientific (2012)

# Applications of industrial accelerators

## Opportunity for innovation

### Field distribution

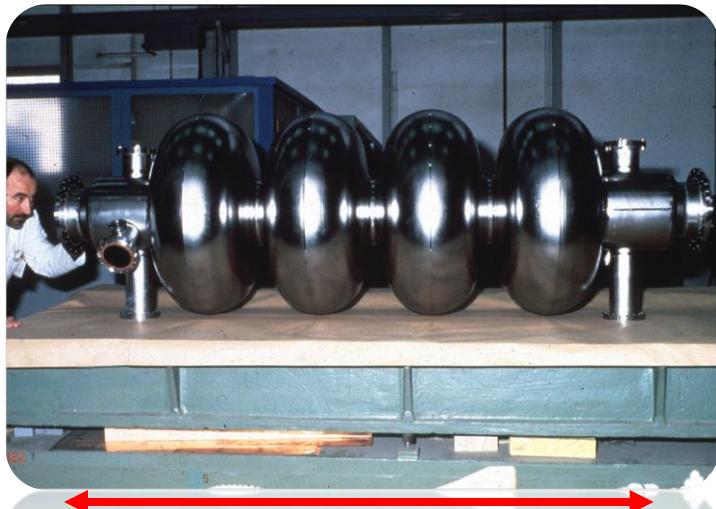


source: Hamm, *Industrial Accelerators and their applications*, World Scientific (2012)

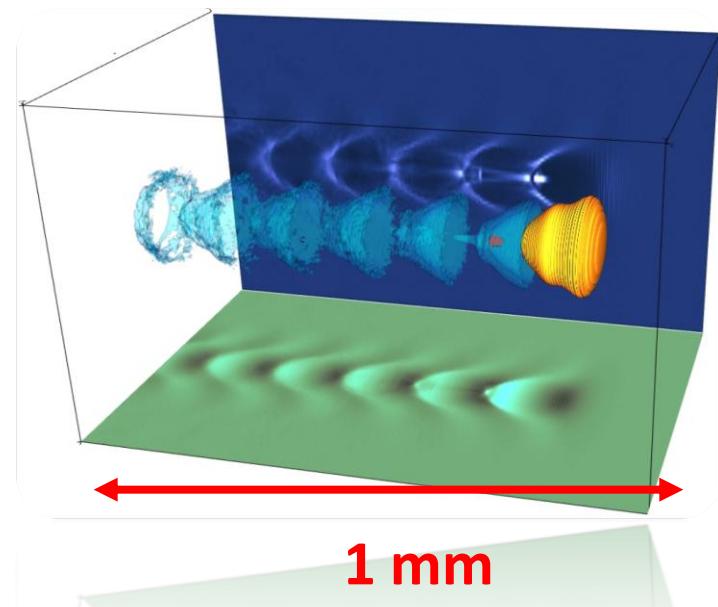
## Outline

# Laser plasma accelerator for NDT

## Linear accelerator vs Laser Plasma Accelerator



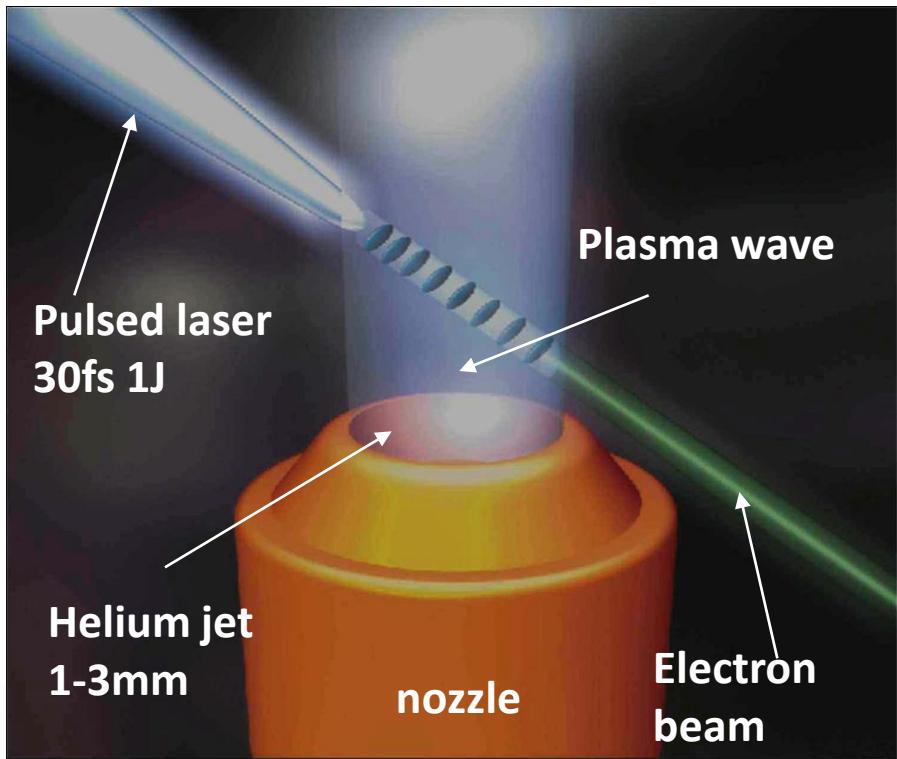
**RF cavity  $\sim$  m**  
 **$E = 10\text{-}100 \text{ MV/m}$**



**Plasma cavity  $\sim$  mm**  
 **$E = 100\text{-}1000 \text{ GV/m}$**

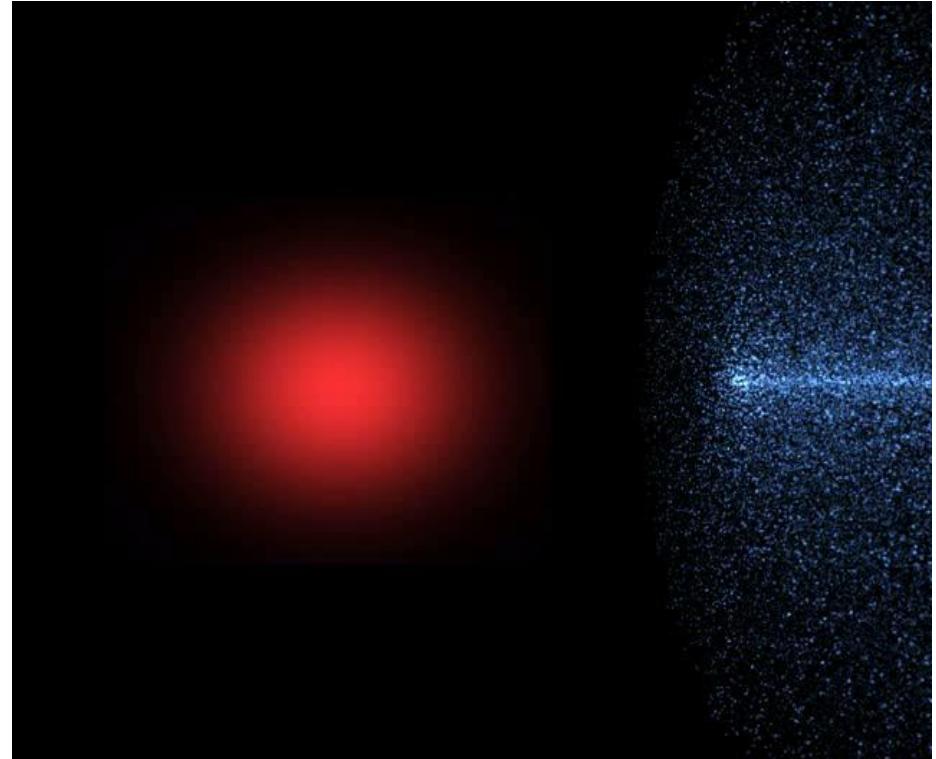
V. Malka *et al.*, Science, 298, 1596 (2002)

## Relativistic electron acceleration *Implementation in the bubble regime*



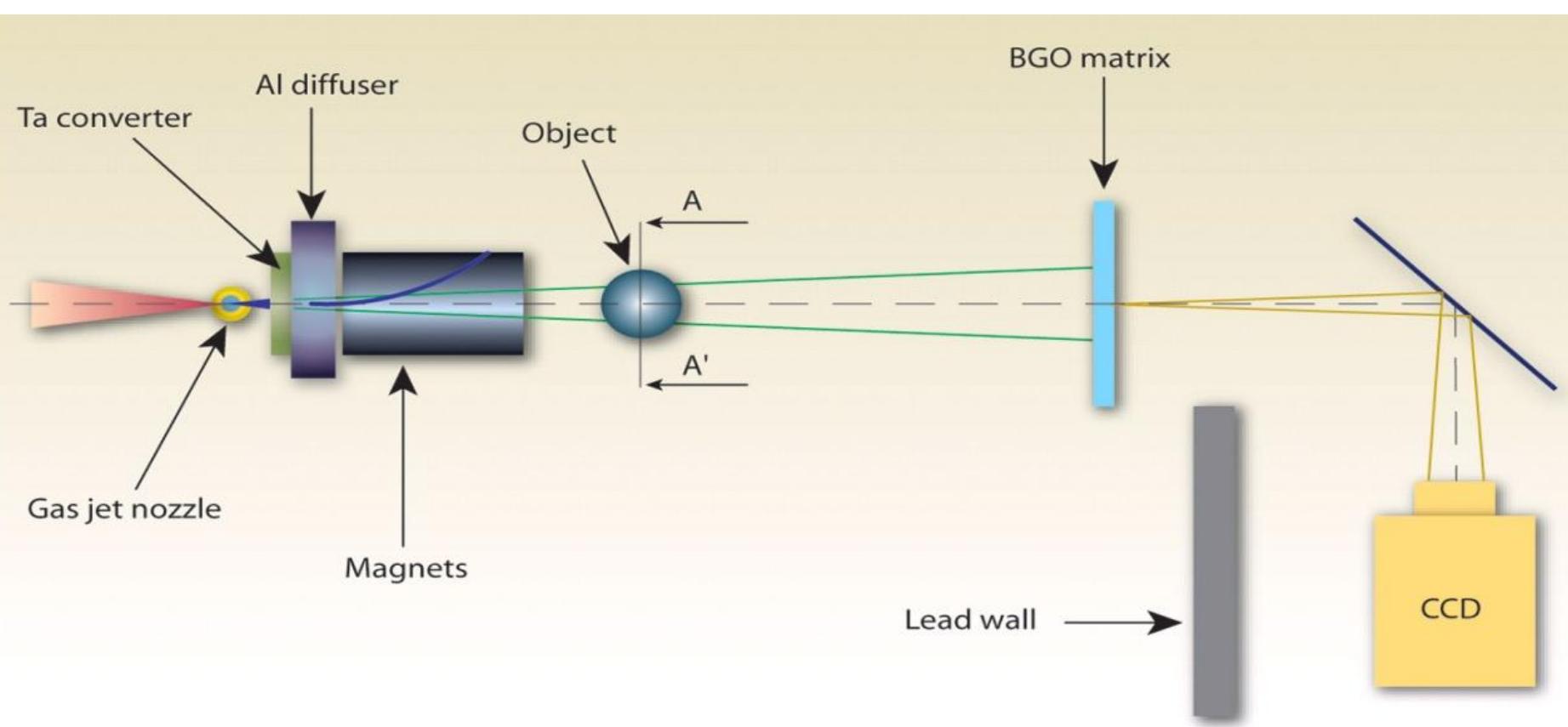
**Functional scheme**

Faure *et al.*, Nature, 431, 541 (2004)



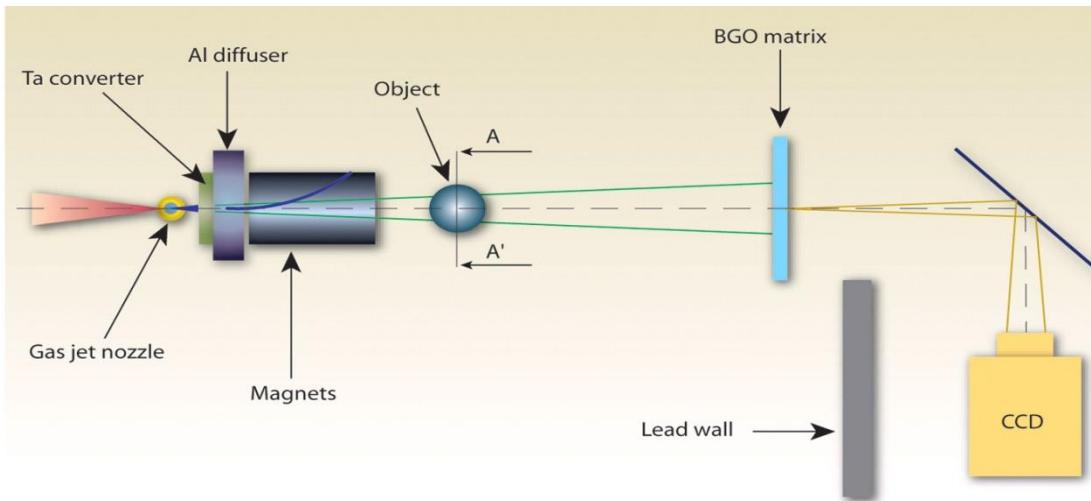
**Numerical simulation  
(3D solving of Maxwell equations)**

## Laser-based $\gamma$ -radiography principle

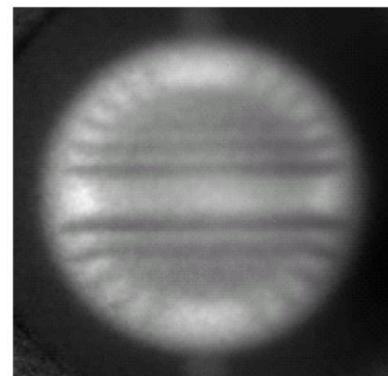
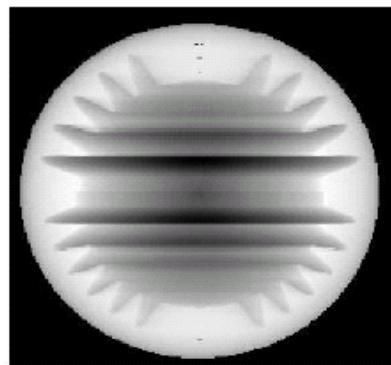
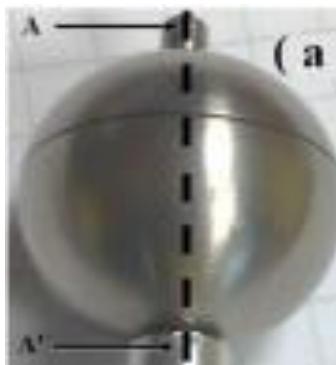


Patent EP 2320528

## Laser-based $\gamma$ -radiography proof-of-concept (2005)



Taille de la source/ resolution : **500  $\mu$ m**



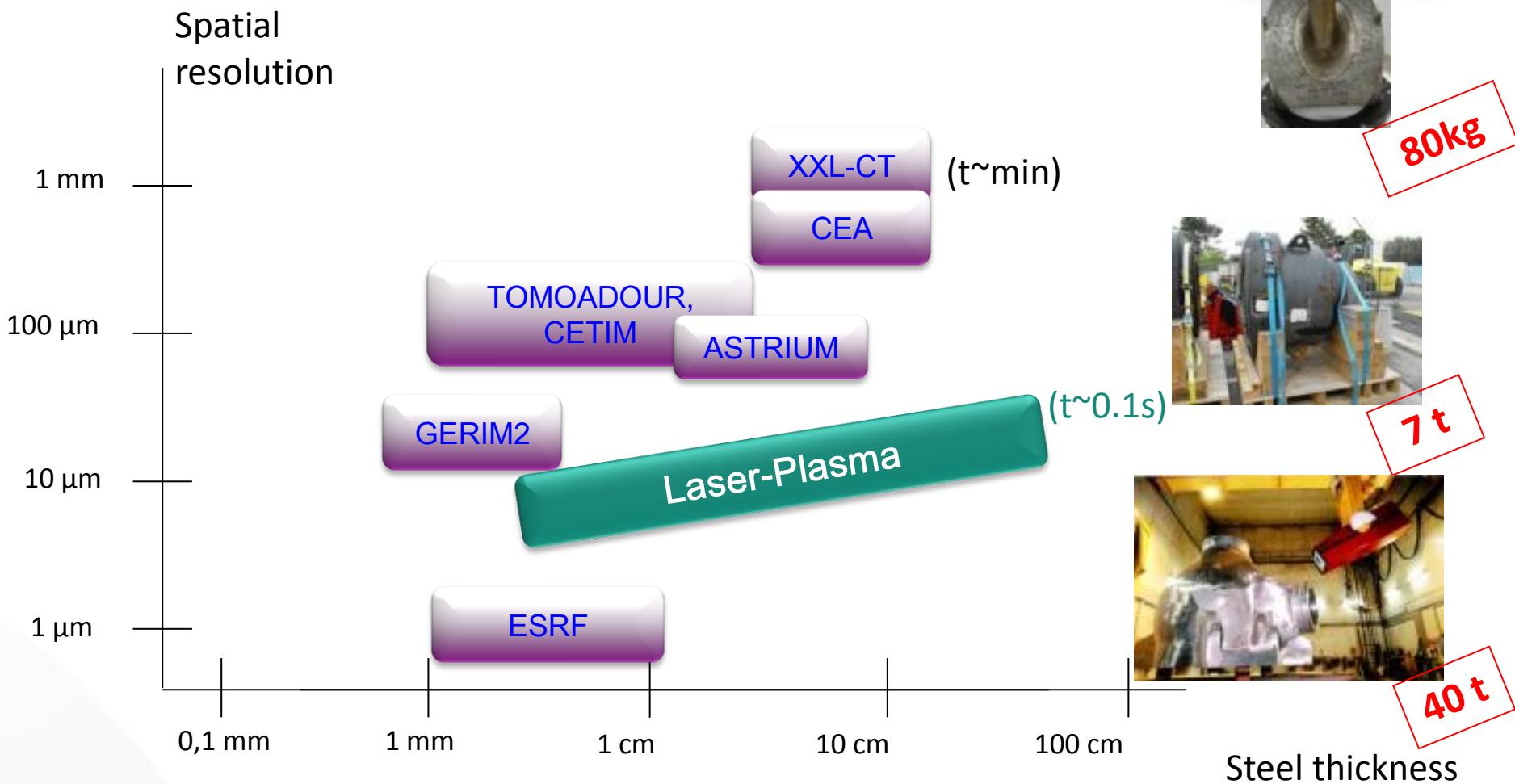
**20mm**

**Computed**

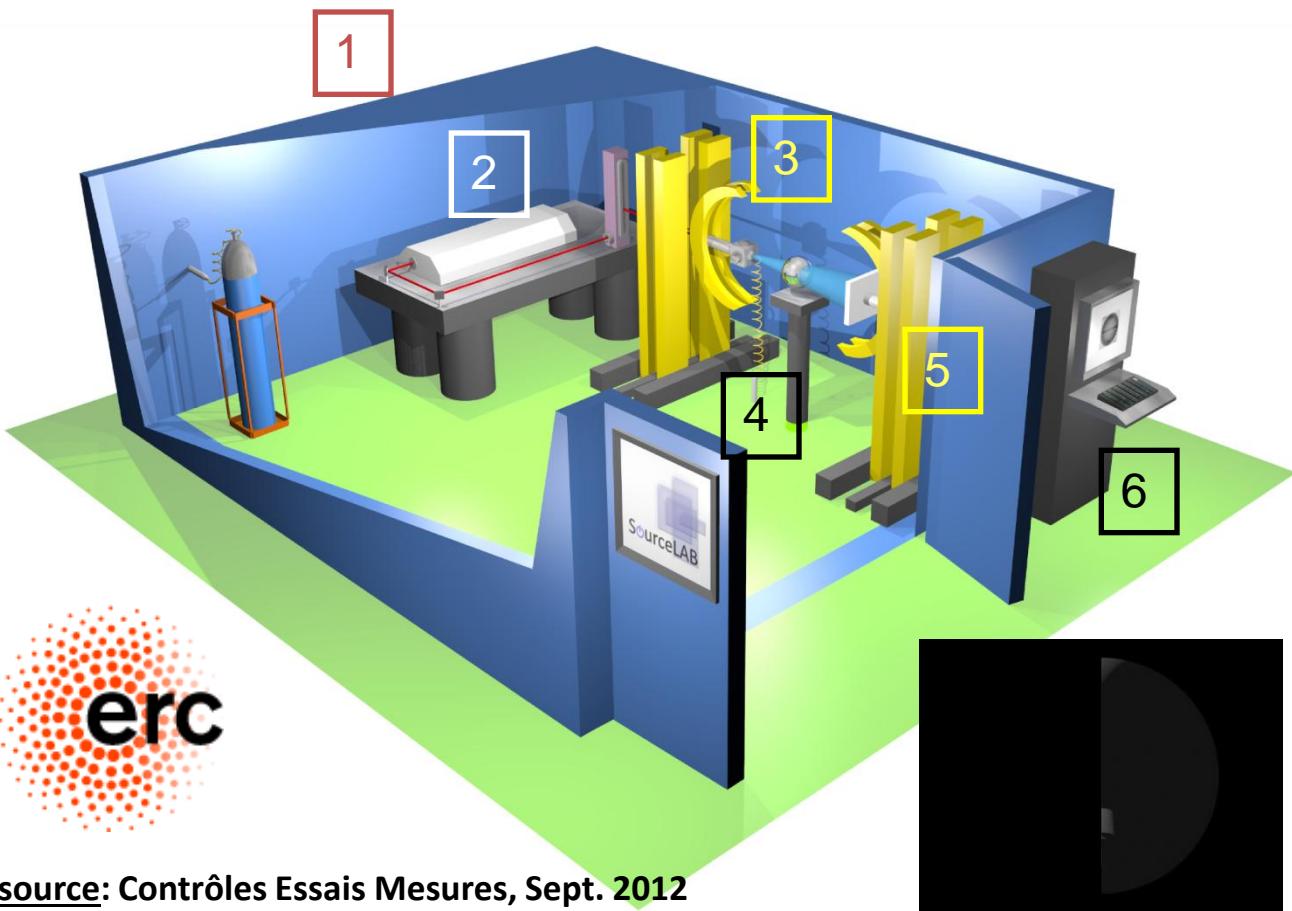
**Measured**

Glinec *et al.*,  
PRL 94 025003 (2005)

## Positioning



## Towards laser-based $\gamma$ -tomography



source: Contrôles Essais Mesures, Sept. 2012

1: radioprotection

2: laser

3:  $\gamma$ -source

4: manipulator

5: detector

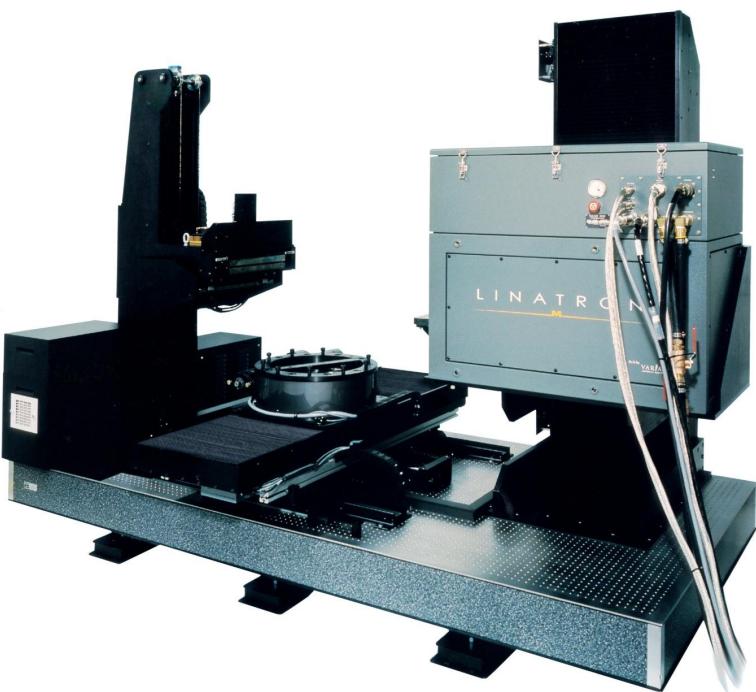
6: analysis

Initial implantation at  
LOA

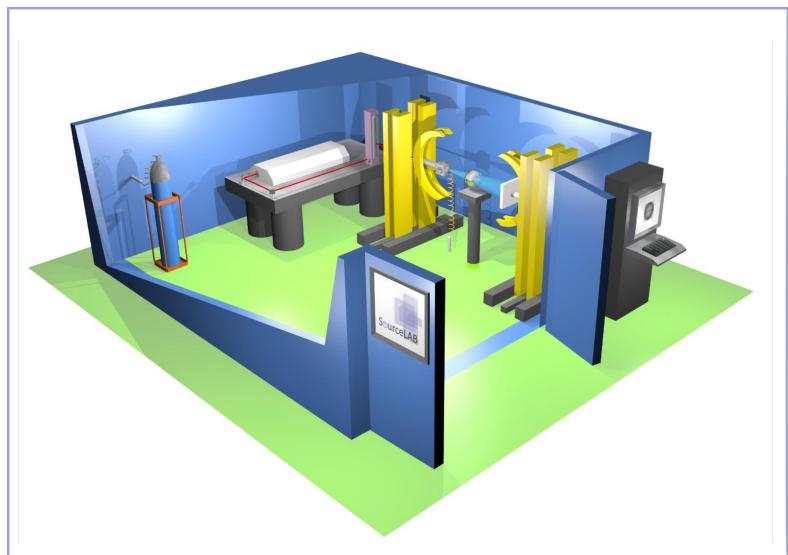


# Maturity How far from application?

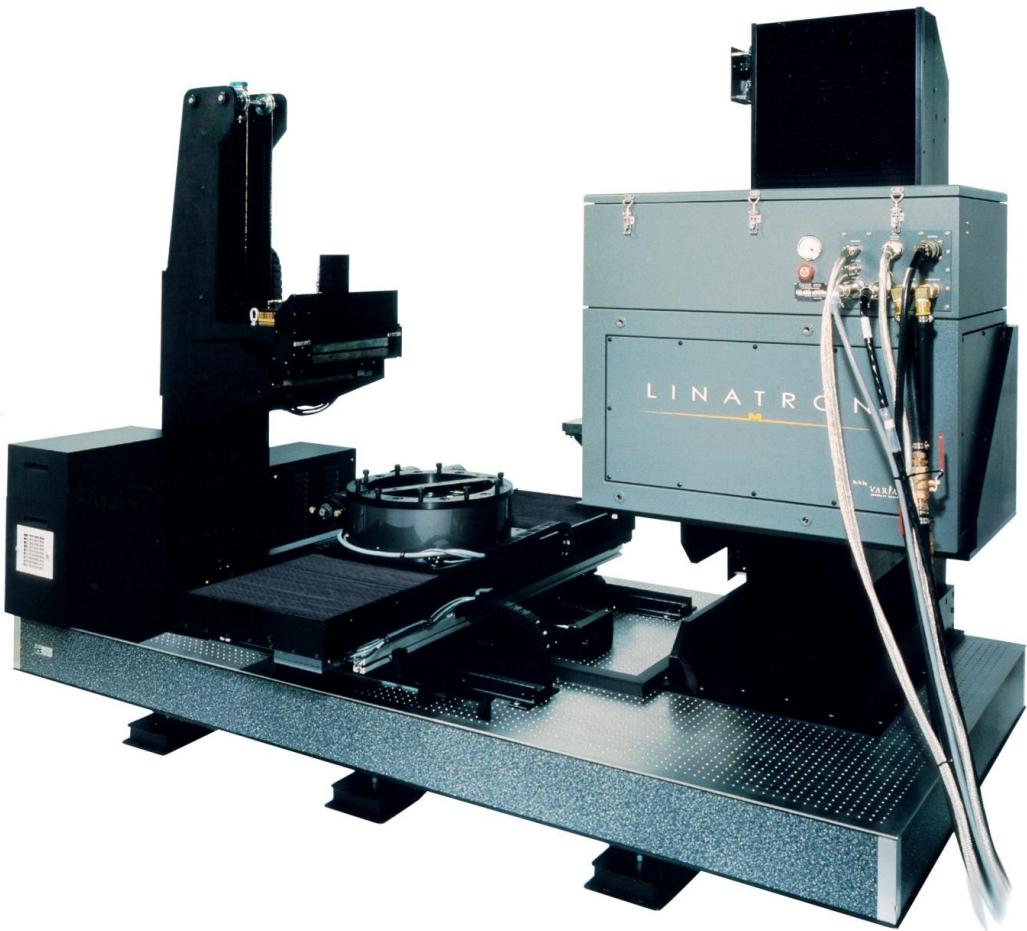
Linac-based tomography (state of the art)



Laser-plasma  $\gamma$ -tomography

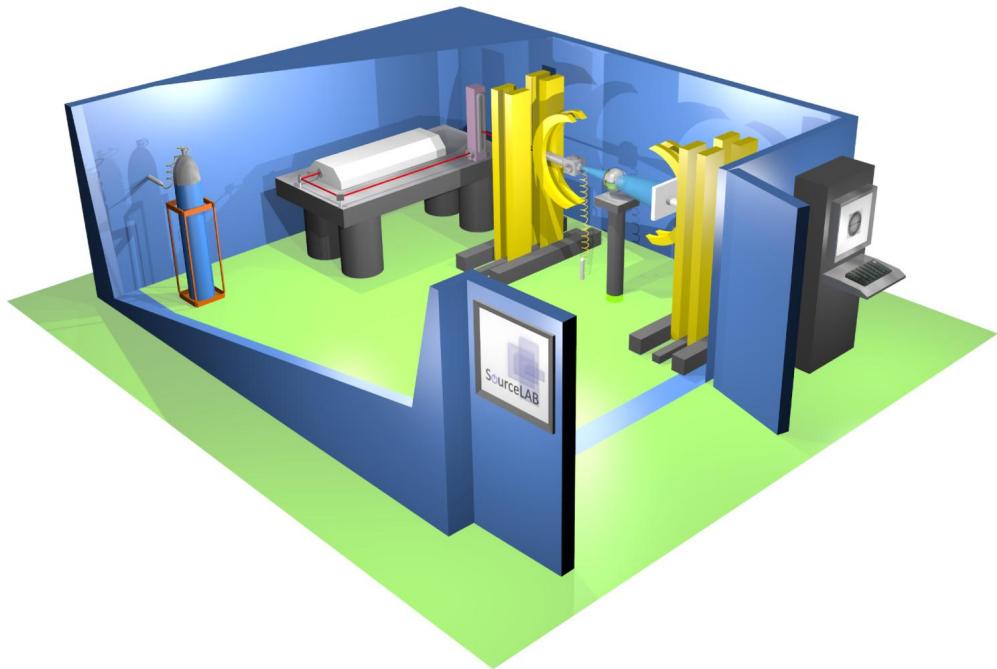


## Maturity Linac-based tomography



- **Source :** linac+ Bremsstrahlung  
(maxwellian spectrum)
- **Max energy (fixed):** 15 MeV
- **Source size:** 3 mm
- **Duration:** 4  $\mu$ s
- **Dose rate:** 30 Gy/min @ 1m  
(~1.7mGy/shot)
- **Repetition rate:** 300 Hz
- **Source cost:** 900 k€

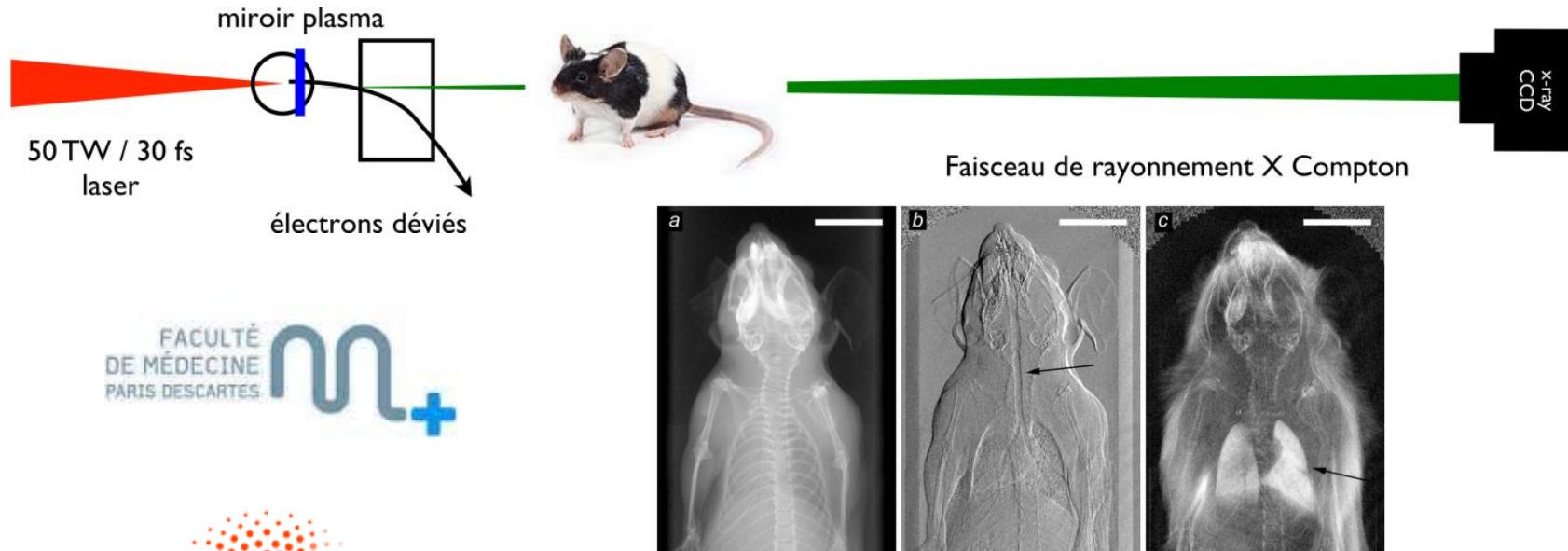
## Maturity Laser-based tomography



- **Source :** Laser Plasma accelerator+ Bremsstrahlung (maxwellian)
- **Energie (tunable):** 0.1-100 MeV (1 J laser)
- **Source size:** <200 µm
- **Durée:** ~100 fs
- **Dose rate:** 0.25 Gy à 60cm/shot
- **Repetition rate:** 1 Hz
- **Source cost:** 1000 k€

## Perspectives

- SourceLAB and partners to build within the next three years the **first laser-based tomographer** for industrial applications
- SourLAB will continue to explore exogenous applications of laser plasma technology
  - Starting same network study for medical field (**phase contrast X-ray imaging**)



Bech et al., Scientific Report, 03209 (2013)

## Acknowledgments

# Source LAB

- Aurélien Ricci, Guillaume Bouchon, Cedric Sire, Jacob Meissner, Antonin Borot

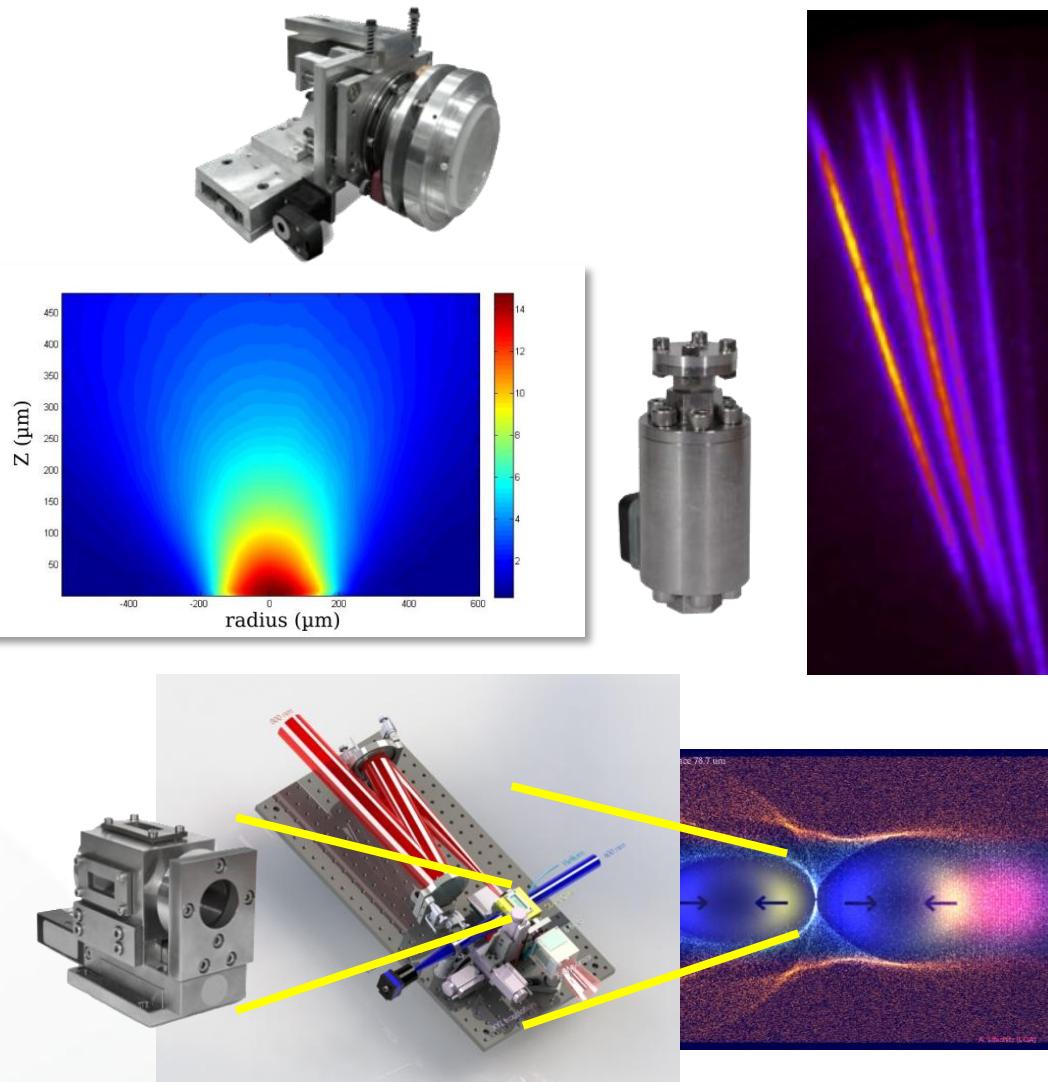


- Victor Malka, Rodrigo Lopez-Martens, Agustin Lifschitz, Andreas Doepp, Jean Marcel Rax, Antoine Rousse

## Other close partners



# Targetry workshop



29/03/2015

SourceLAB | Laser Plasma Technologies

Targ<sub>2</sub>Plasma 2015

## 2nd Laser Plasma Targetry Workshop Paris, April 20-22, 2015

Targetry for Laser-driven particle accelerator sources  
and attosecond science

Organizers:

R. Lopez-Martens (LOA)  
J. Schreiber (LMU)  
B. Vodungbo (UPC)  
F. Sylla (SourceLAB)

Location:

Réfectoire des Cordeliers  
15 rue de l'Ecole de Médecine  
Amphithéâtre Gustave Roussi  
2<sup>nd</sup> floor, stairs B



### TOPICS

- Innovative targetry: from gases to solids
- Target recycling & debris management
- Secondary particle & radiation sources
- High repetition rate capability
- Integrated plasma diagnostics
- Challenges for future R&D
- Potential for industry and SMEs





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Laser Plasma Technologies

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