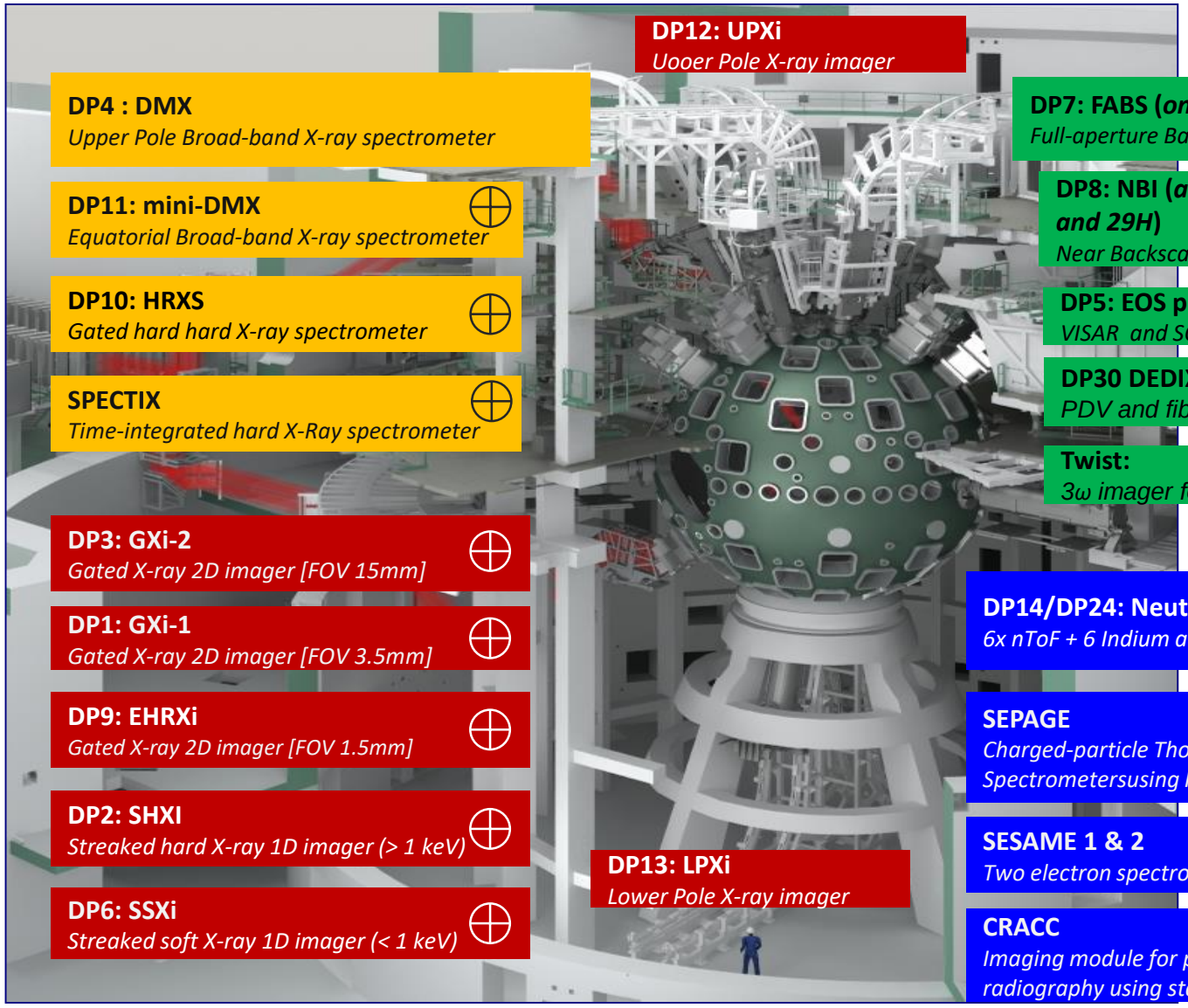
Plasma diagnostic status

Second LMJ/PETAL User Meeting

2023-06-09

G. BOUTOUX, CESTA/DCRE

Overview of LMJ/PETAL diagnostics



DP12: UPXi
Uooer Pole X-ray imager

DP4 : DMX
Upper Pole Broad-band X-ray spectrometer

DP11: mini-DMX ⊕
Equatorial Broad-band X-ray spectrometer

DP10: HRXS ⊕
Gated hard hard X-ray spectrometer

SPECTIX ⊕
Time-integrated hard X-Ray spectrometer

DP7: FABS (*on quad 28H*)
Full-aperture Backscattering Station

DP8: NBI (*around quad 28H and 29H*)
Near Backscattered Imager

DP5: EOS pack
VISAR and SOP 1ω/2ω

DP30 DEDIX:
PDV and fibered VISAR

Twist:
3ω imager for PETAL

DP3: GXi-2 ⊕
Gated X-ray 2D imager [FOV 15mm]

DP1: GXi-1 ⊕
Gated X-ray 2D imager [FOV 3.5mm]

DP9: EHRXi ⊕
Gated X-ray 2D imager [FOV 1.5mm]

DP2: SHXI ⊕
Streaked hard X-ray 1D imager (> 1 keV)

DP6: SSXi ⊕
Streaked soft X-ray 1D imager (< 1 keV)

DP13: LPXi
Lower Pole X-ray imager

DP14/DP24: Neutron pack
6x nToF + 6 Indium activation samples

SEPAGE ⊕
Charged-particle Thomson Parabola Spectrometersusing IP

SESAME 1 & 2
Two electron spectrometers using IP

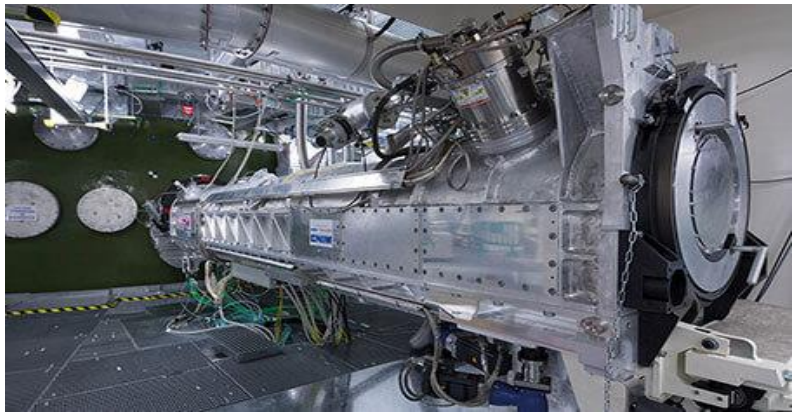
CRACC ⊕
Imaging module for proton or X-ray radiography using stacks of IP or RCF

- **22 diagnostics in operation**
- **1 polar SID**
- **5 equatorial SID**

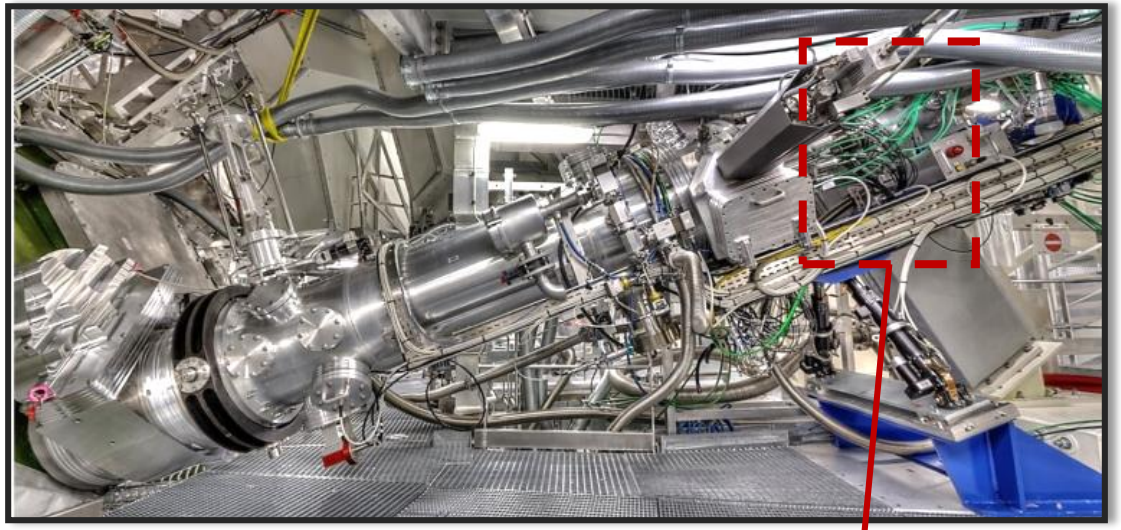
Diagnostics families:

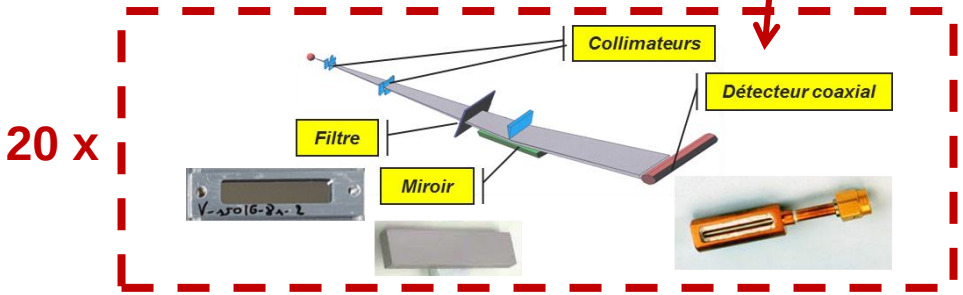
X-ray spectrometers
X-ray imager
Optical diagnostics
Nuclear diagnostics

⊕ Compatible with inserter



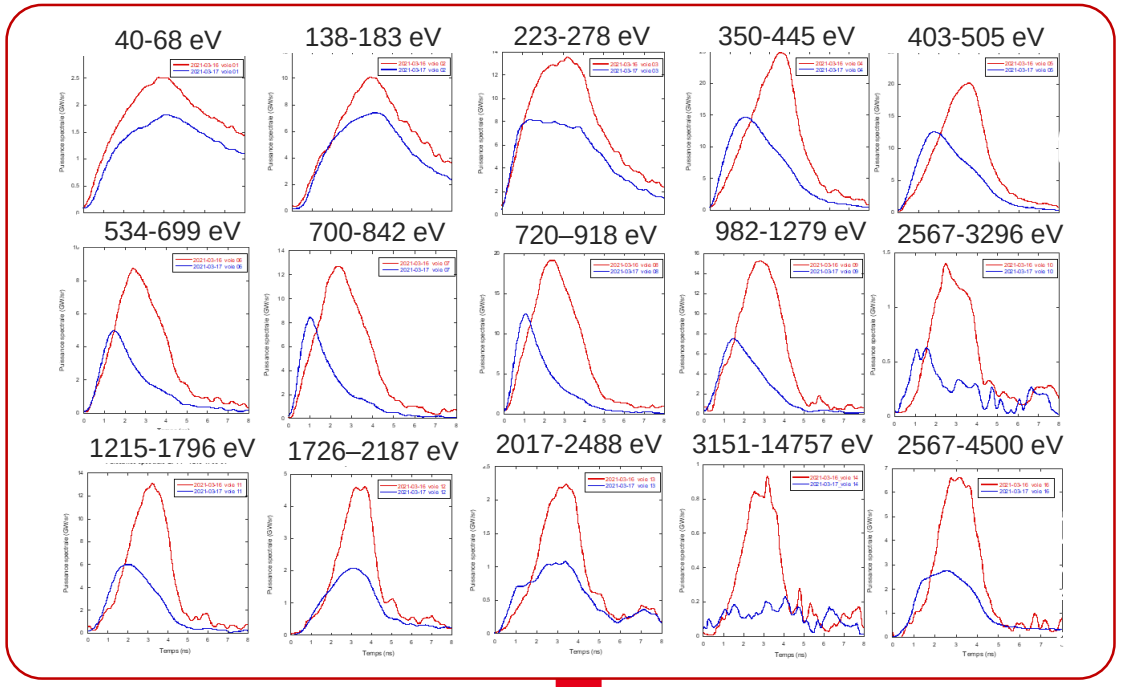
X-ray spectrometers



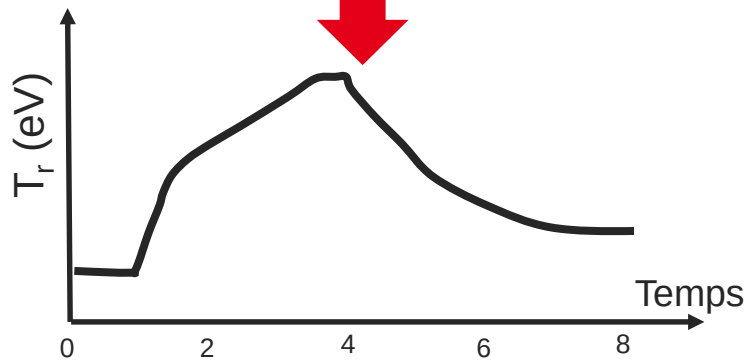


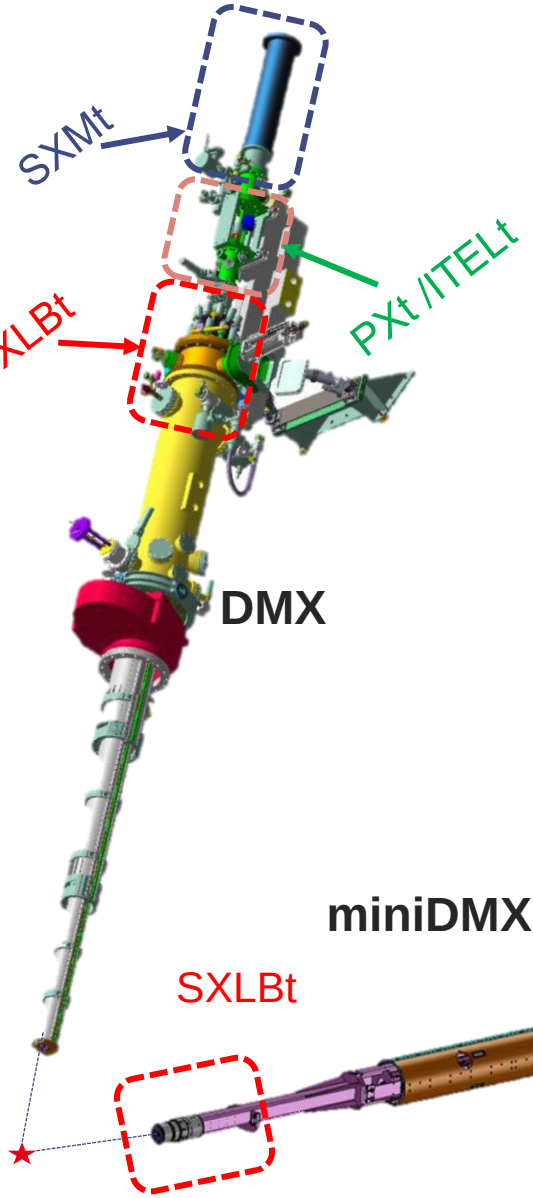
- **DMX (Upper view) – MiniDMX (Equatorial SID):**
  - Time-resolved broad-band channels
    - Up to 10 channels < 1 keV (mirrors + filters)
    - Up to 10 channels in the [1; 20] keV range (filters only)
    - Filters, mirrors, detectors and acquisition are metrologized
  - 1 grating X-ray spectromer dedicated to Au M-band [1.5; 4] keV
  - 1 time-resolved soft X-ray laser entrance hole imaging with a hCMOS camera (2 frames)
  - Dedicated to absolute X-ray spectrum measurements, as well as radiative temperature within hohlraum.
- **HRXS (Equatorial SID):**
  - 2 reflective-crystals in the [1; 15] keV range
  - Resolving power: ≈ 500
  - Images using a framing camera (4 spectra with time exposure ≈ 120 ps at different times)
  - Dedicated to atomic physics (NLTE and opacity measurements)
- **SPECTIX (Equatorial SID):**
  - 2 transmissive-crystals in the [7; 150] keV range
  - Resolving power: ≈ 100
  - Integrated-image using IP
  - Dedicated to K-shell spectroscopy and PETAL physics
  - C. Reverdin et al, *SPECTIX, a PETAL+ X-ray spectrometer: design, calibration and preliminary tests*, JINST **13**, C01005 (2018)

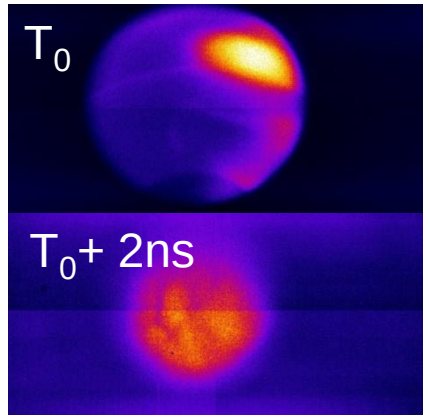
DMX - MiniDMX

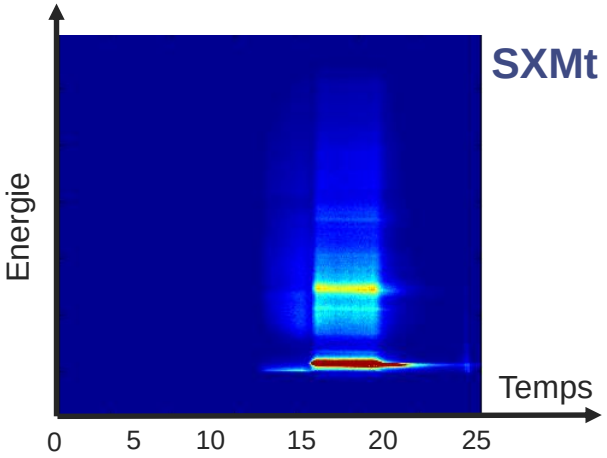


SXLBt





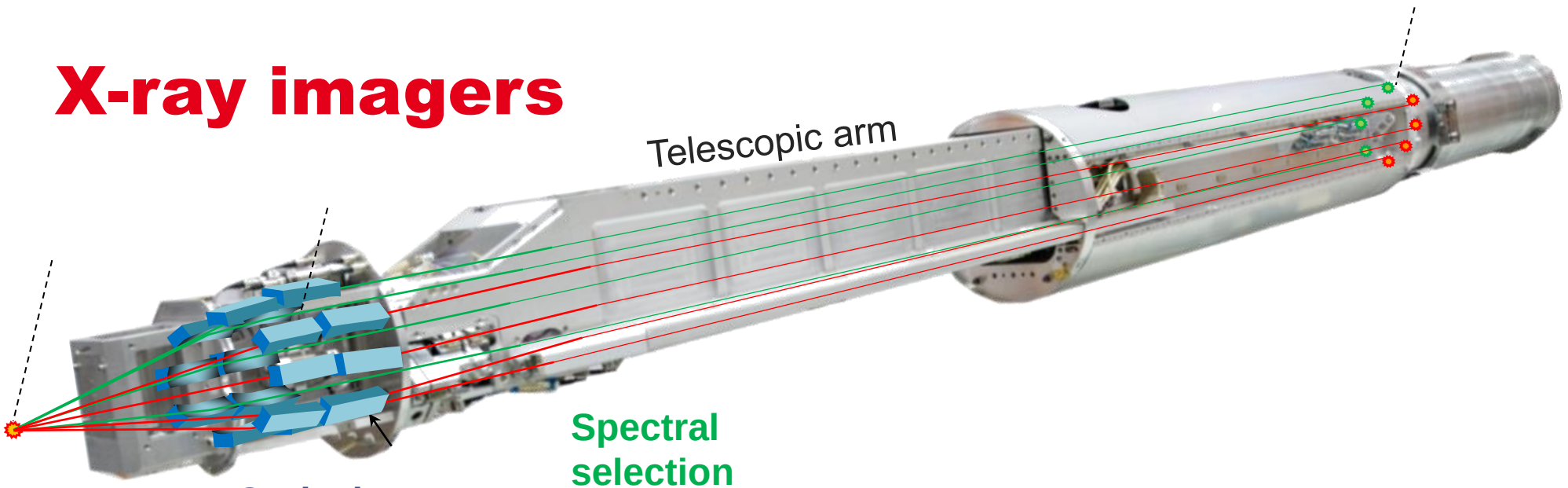




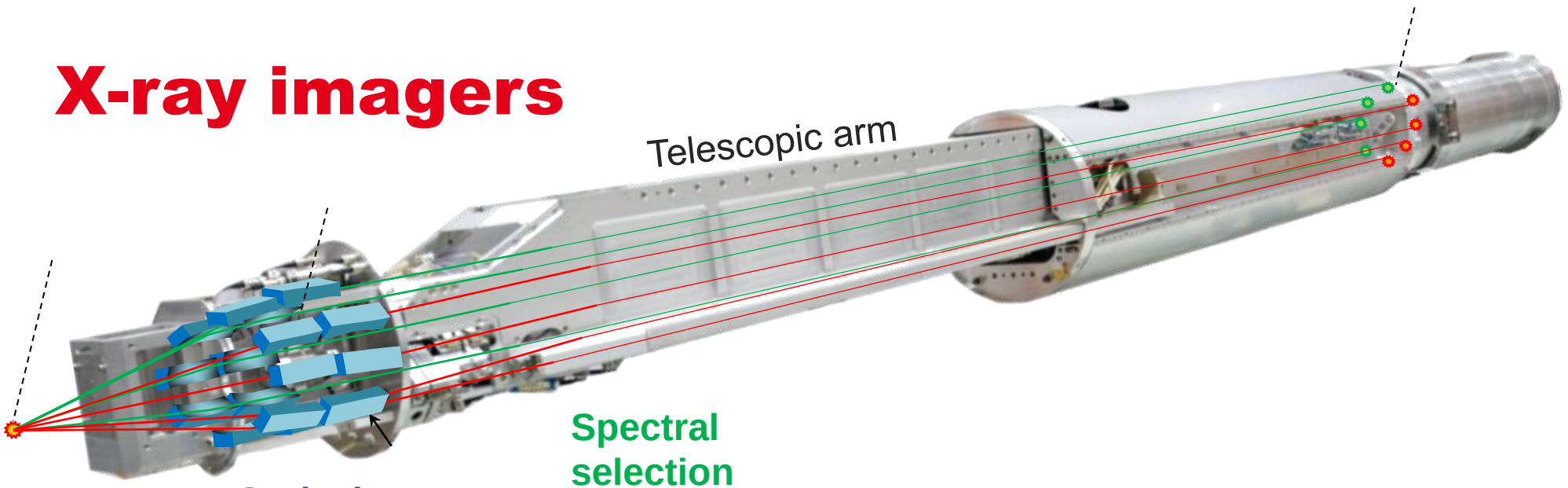
- J.L. Bourgade et al, *DMX: An absolutely calibrated time-resolved broadband soft x-ray spectrometer designed for MJ class laser-produced plasmas*, RSI **72**, 1173-1182 (2001)

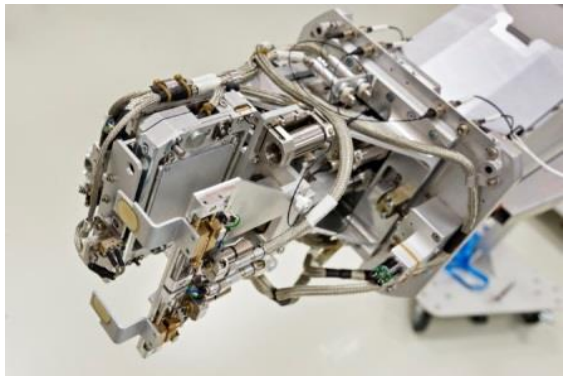
X-ray imagers

X-ray imagers

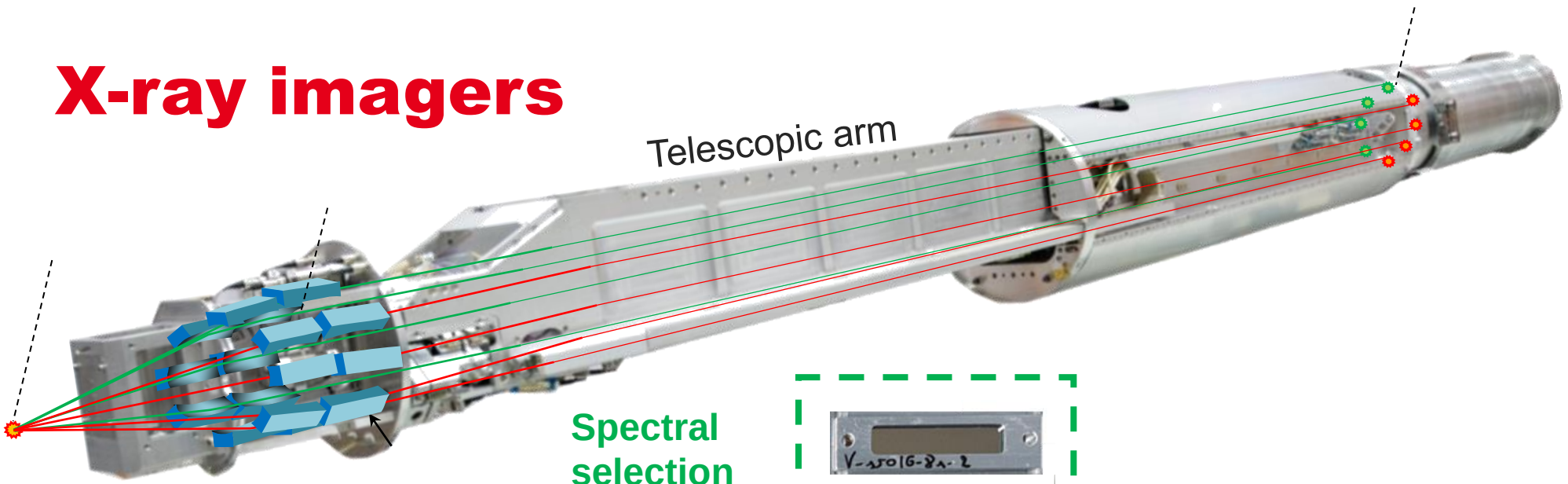


X-ray imagers



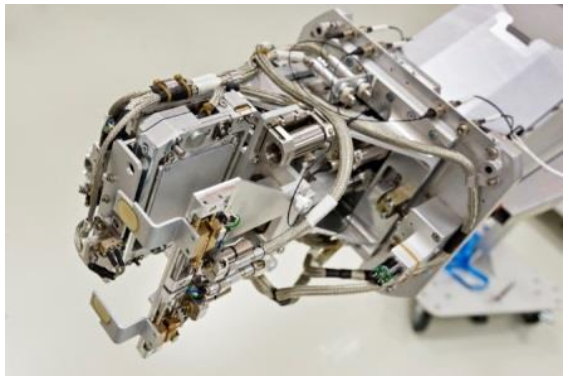


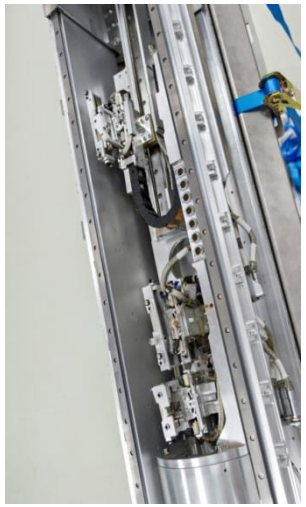
X-ray imagers



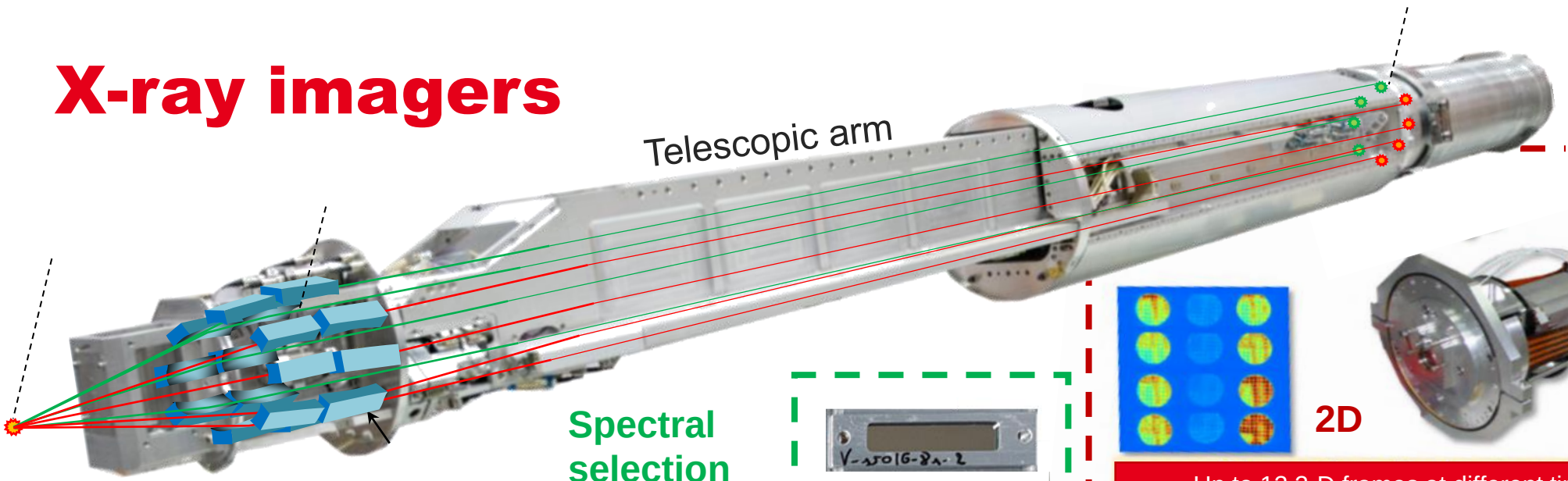
Optical frame

Spectral selection

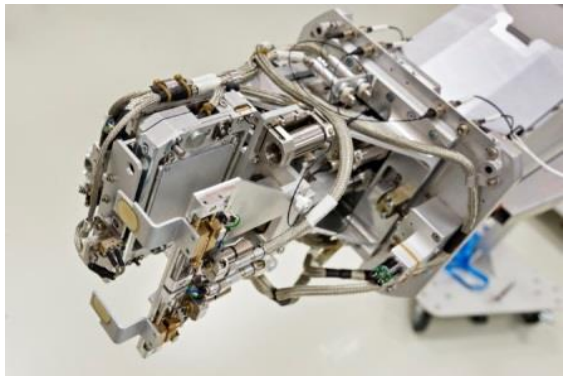




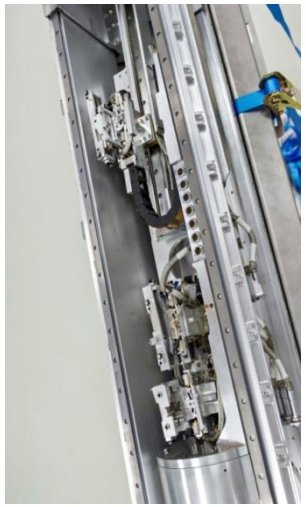
X-ray imagers



Optical frame

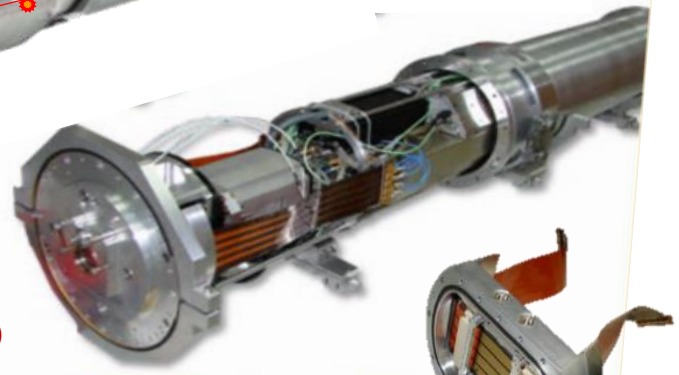


Spectral selection

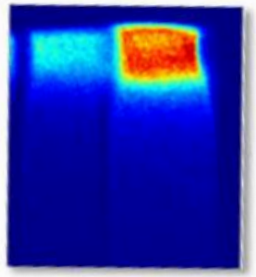


Camera

2D



Up to 12 2-D frames at different times
Spatial resolution ≈ 100 µm over 10x10 mm^2
Time exposure for each frame ≈ 120 µm



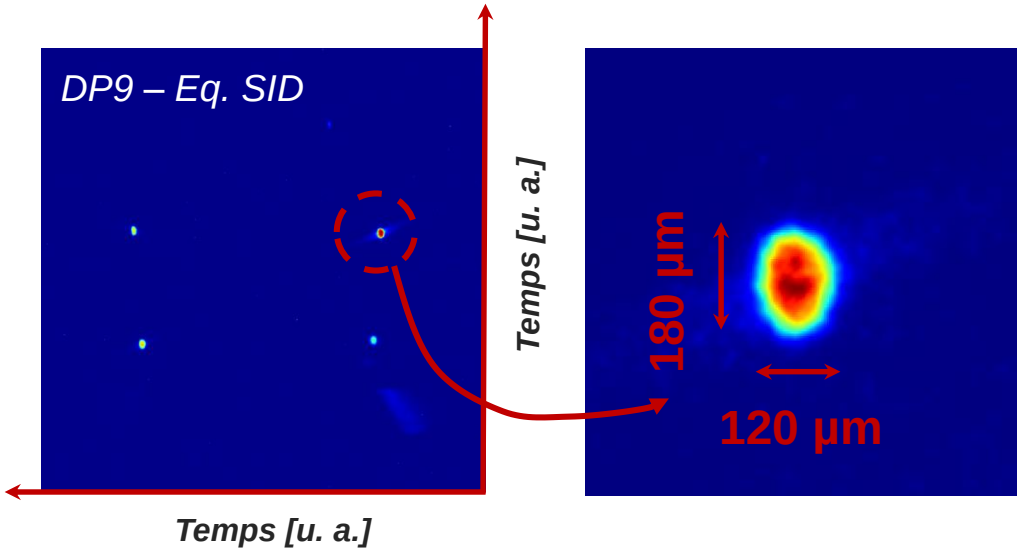
1-D image (line) + streak camera
Spatial resolution ≈ 50 µm over 15 mm
Temporal resolution ≈ 20 ps over 2 ns

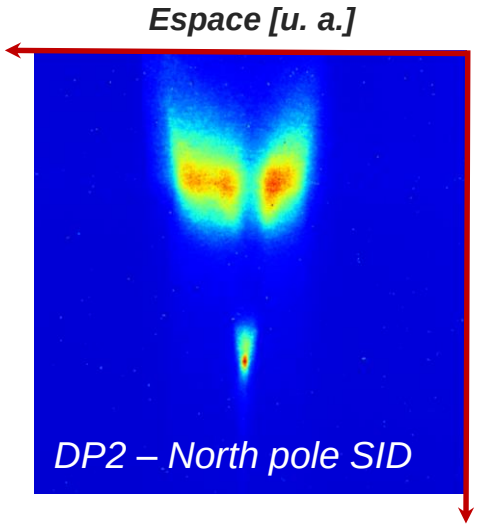
1D

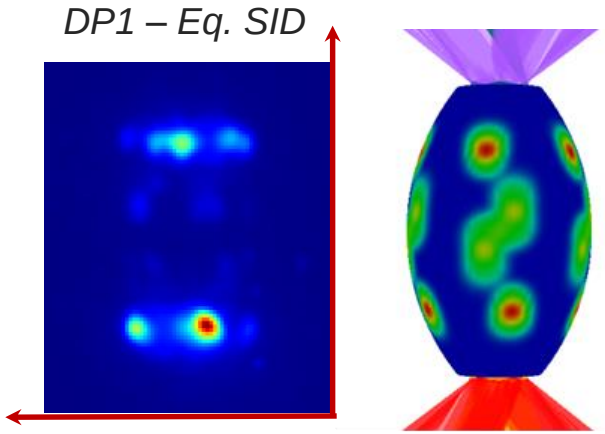
Typical images in a FCI experiment

	Spectral range	Spatial resolution	Field of view	Camera
GXI-2	> keV	150 µm	15 mm	Framing (2D)
GXI-1	> keV	35 µm	3 mm	
ERHXI	> keV	15 µm	1 mm	
SHXI	> keV	50 µm	5 mm	Streak (1D)
SSXI	< keV	30 µm	5 mm	

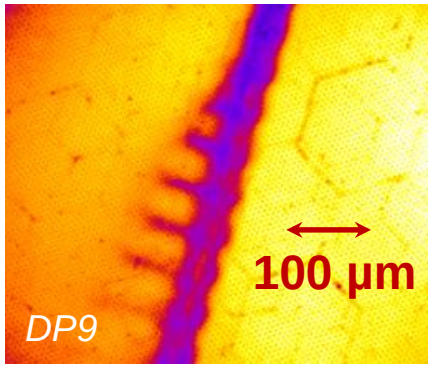
- R. Rosch et al., *First set of gated x-ray imaging diagnostics for the Laser MegaJoule*, RSI **87**, 033706 (2016)

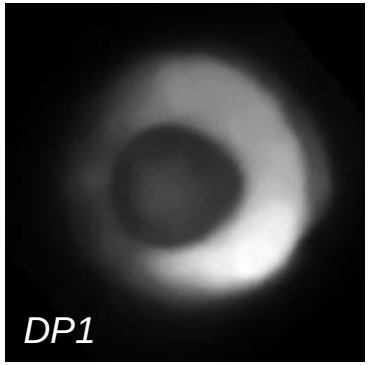






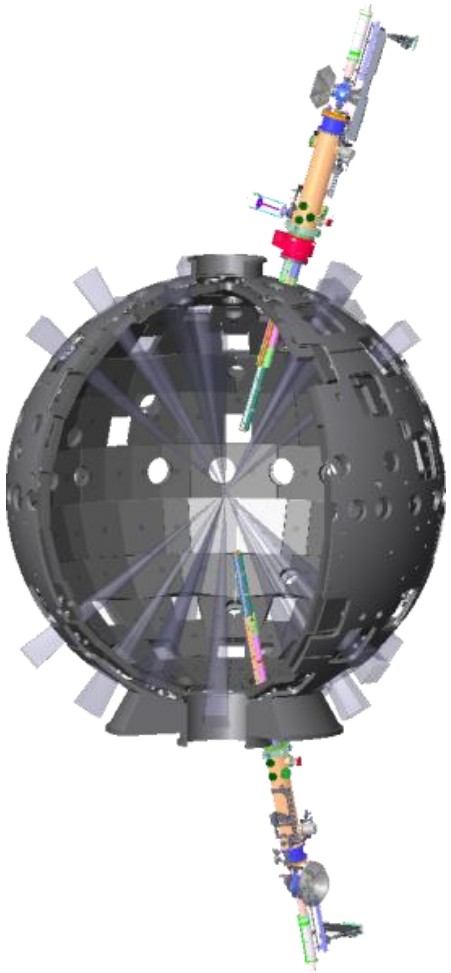
Radiography mode

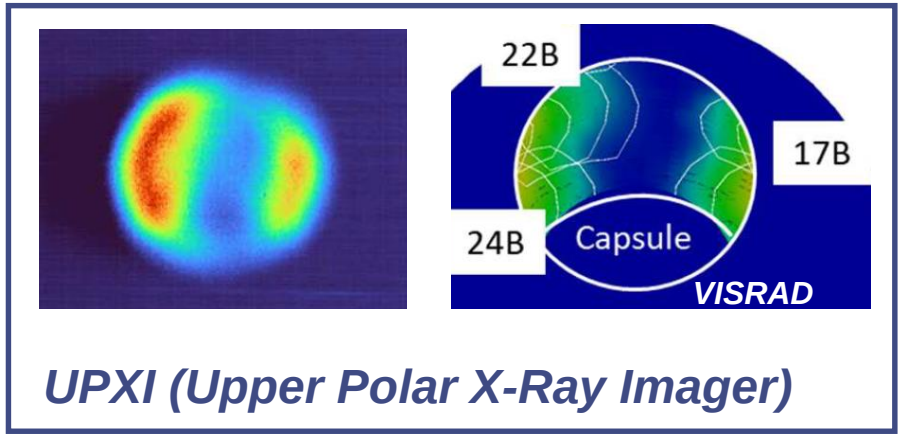




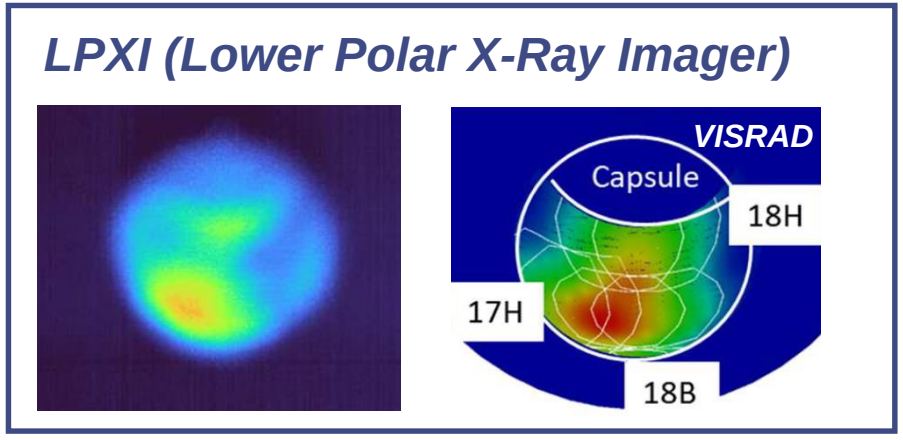
- Dedicated to imaging plasma self-emission or for radiography applications using a LMJ quad as backlighter

LEH imaging





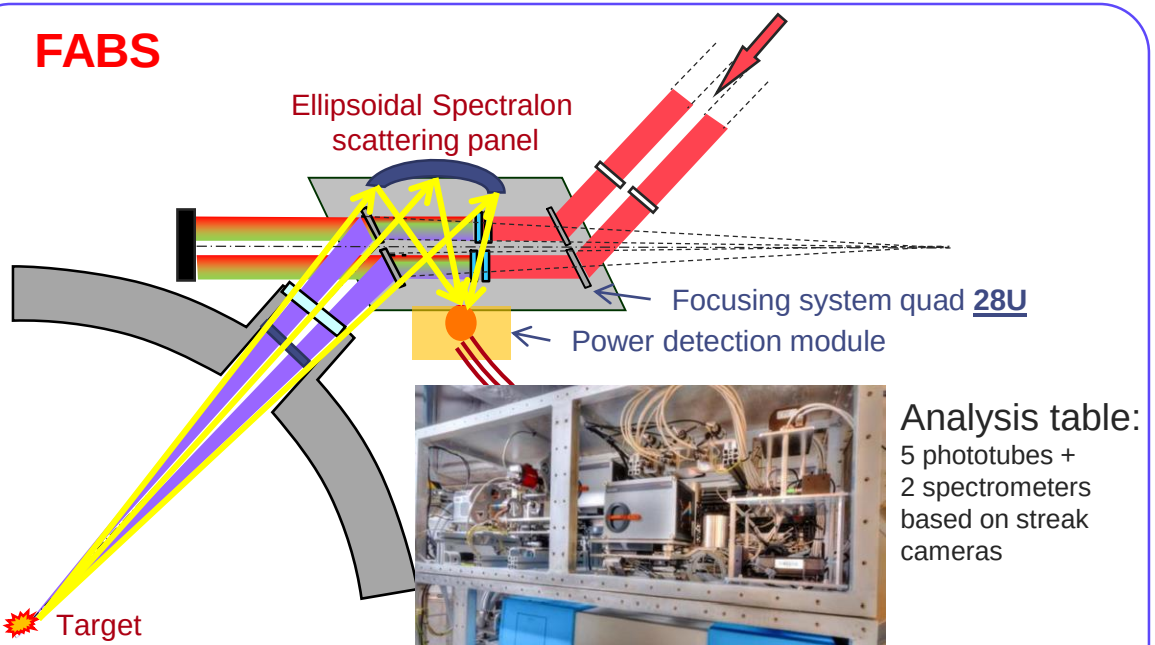
UPXI (Upper Polar X-Ray Imager)



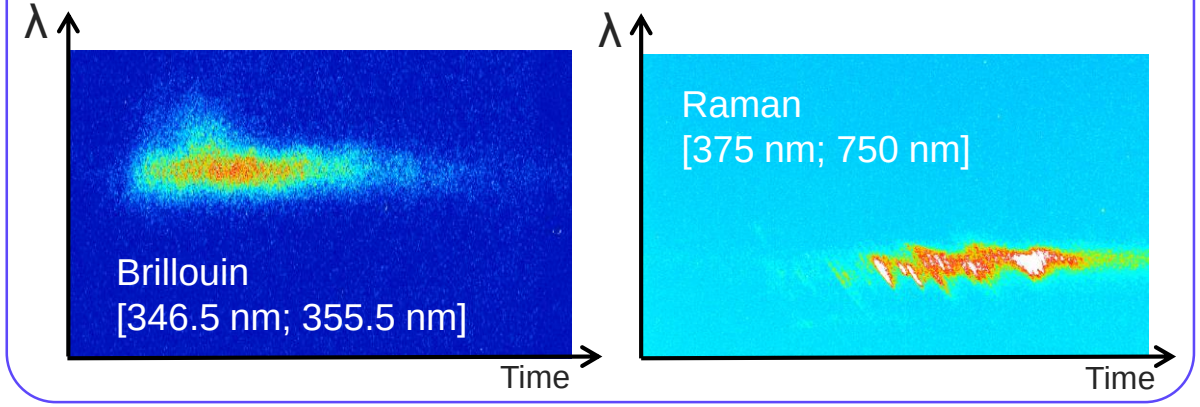
- Time-integrated 2D images, dedicated to precision pointing of LMJ laser.

Backscattering diagnostics

FABS



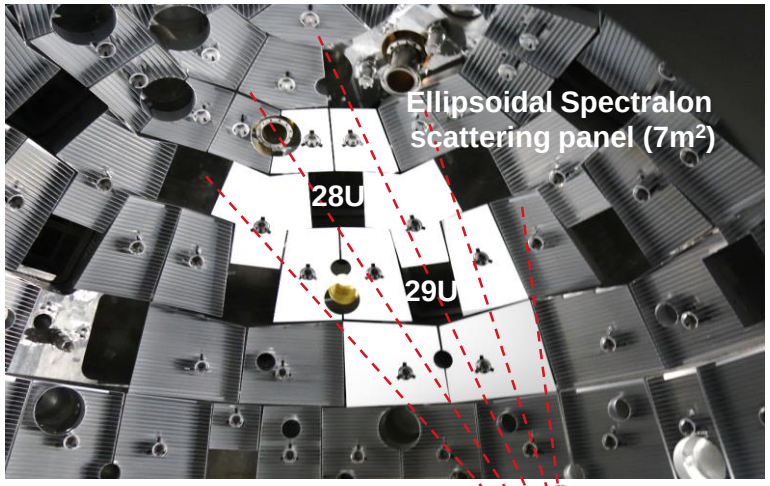
Analysis table:
5 phototubes +
2 spectrometers
based on streak
cameras

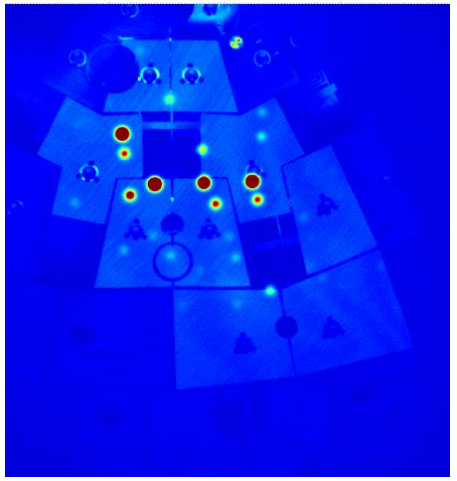


- Dedicated to energy balance and LPI studies

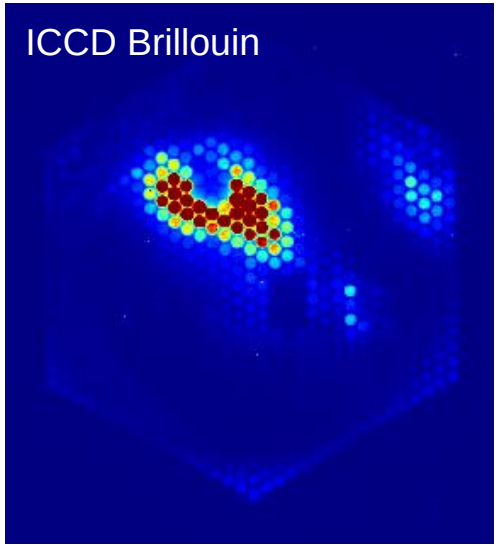
NBI

- V. Trauchessec et al., *Time-resolved NBI system on Laser MegaJoule*, RSI **93**, 103519 (2022)





Optical system

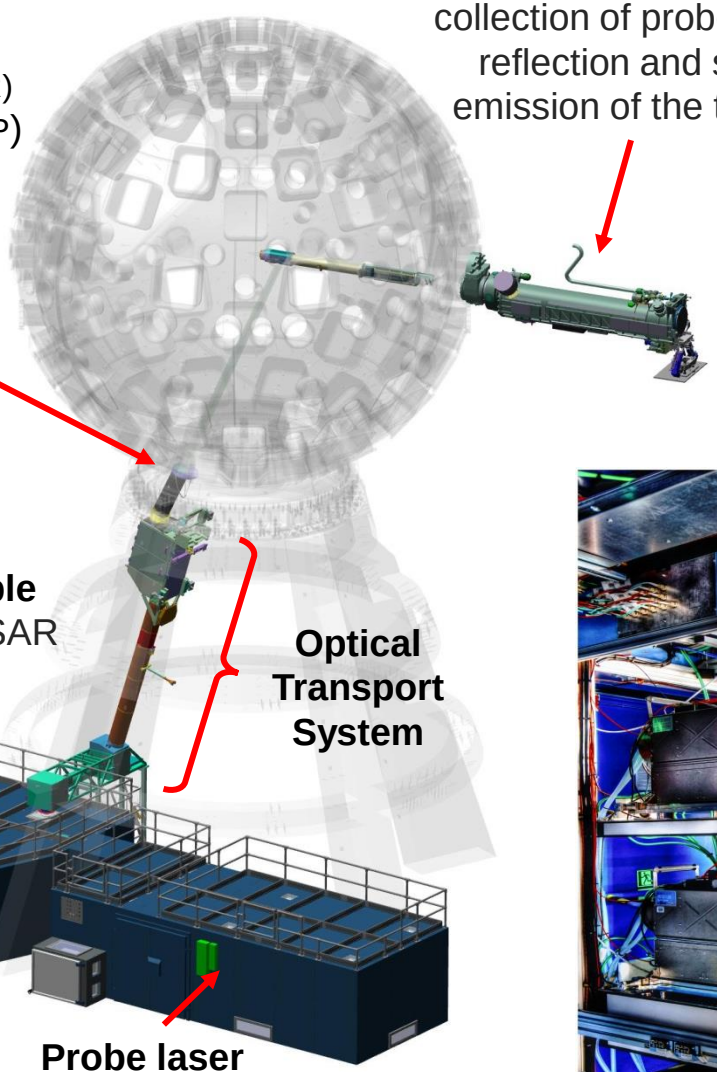


Analysis table:
4 phototubes (power & energy) +
40 fast photodiodes (time) + 2 ICCD

EOS Pack

Telescope
→ Injection and collection of probe laser reflection and self-emission of the target

Field of view:
1-2-5 mm (VISAR)
1-2-5-10 mm (SOP)

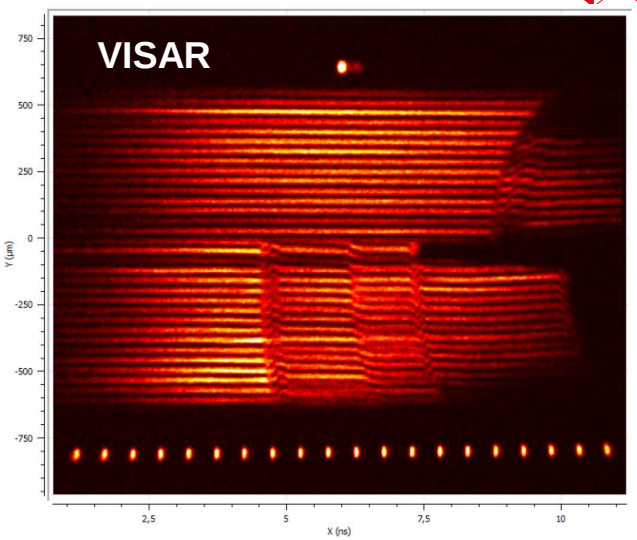


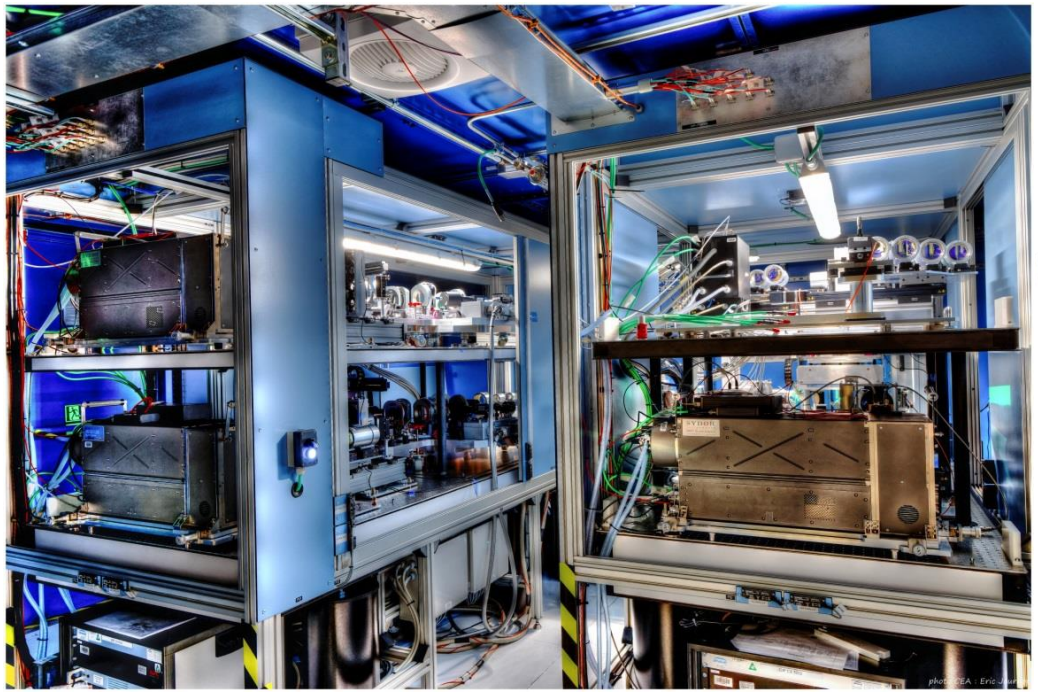
Window

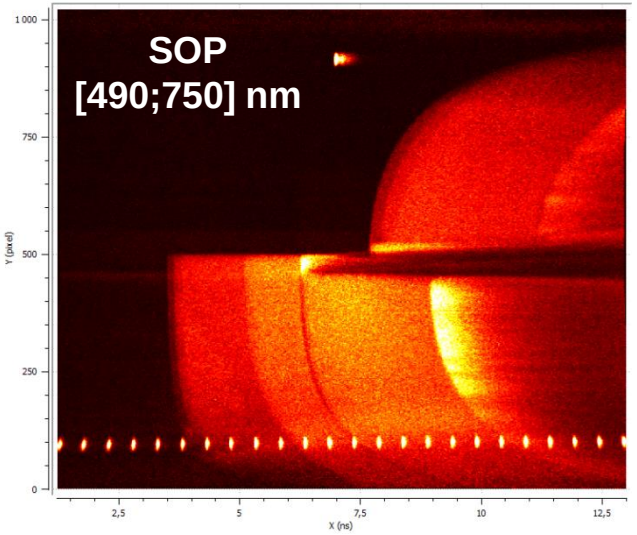
Analysis table
2 SOP + 2 VISAR

Optical Transport System

Probe laser
1064 nm and 532 nm - 5 → 100 ns – 50 mJ/pulse



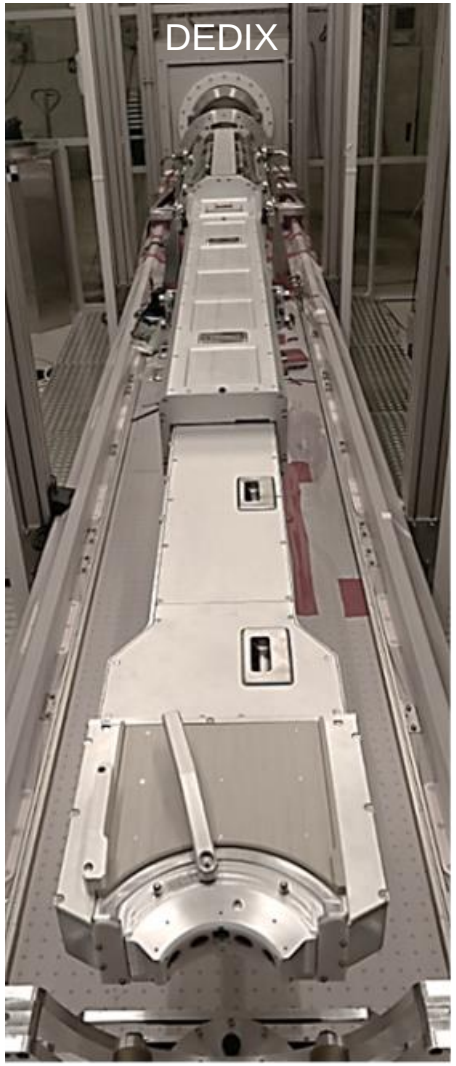


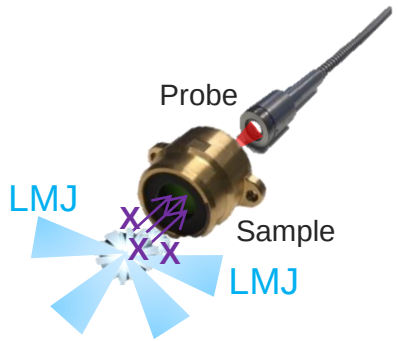


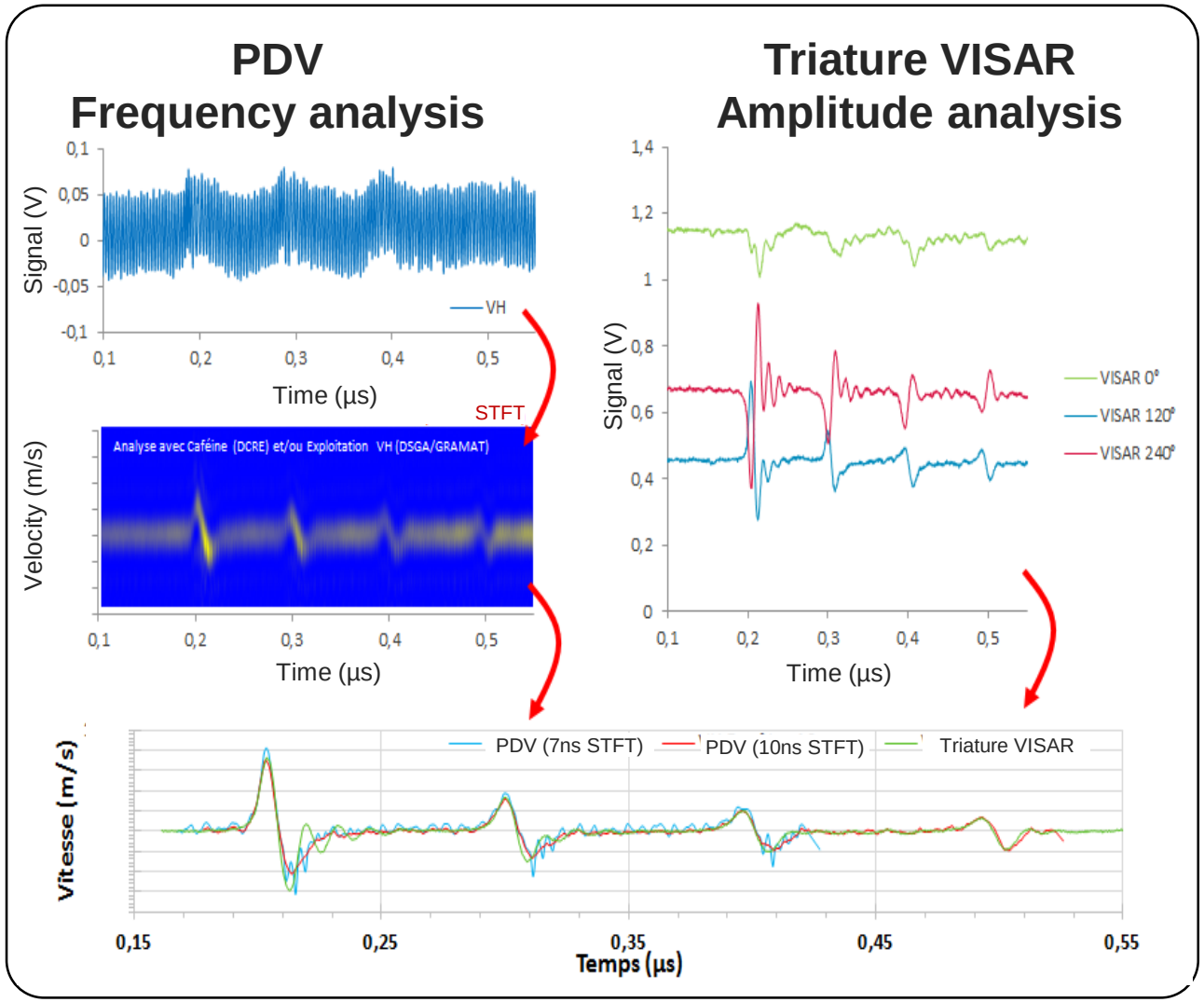
- Dedicated to EOS studies, with velocities in the [1; 200] km/s range and temperature > 0.1 eV

PDV and fibered VISAR

- G. Boutoux et al., *Experimental evidence of shock-wave measurements with low velocity (<100 m/s) and fast dynamics (< 10 ns) capabilities using a coupled PDV and triature VISAR diagnostic*, RSI **94**, 033905 (2023)

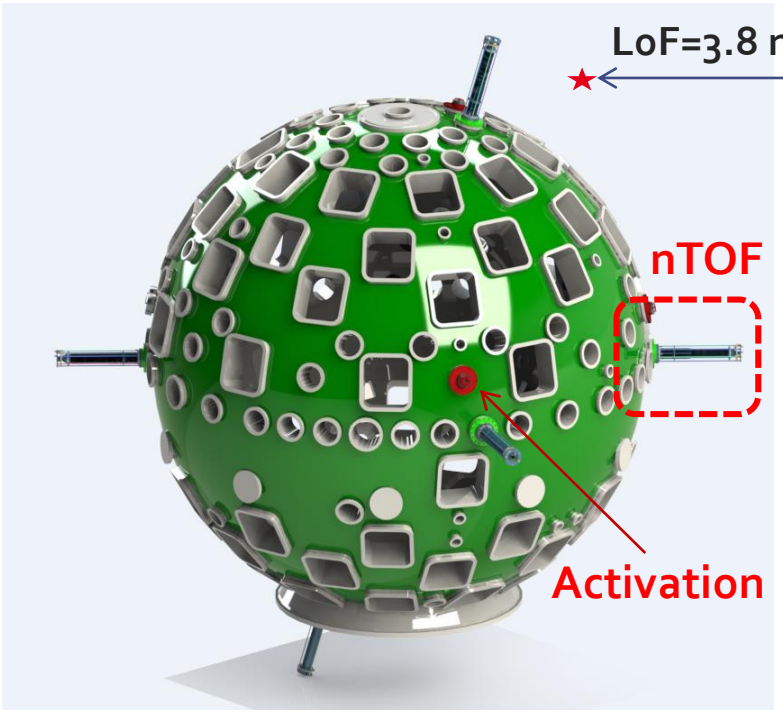


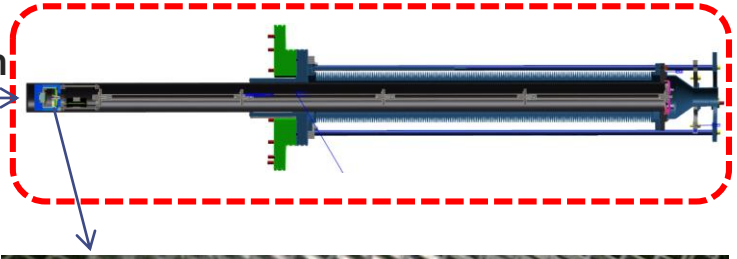


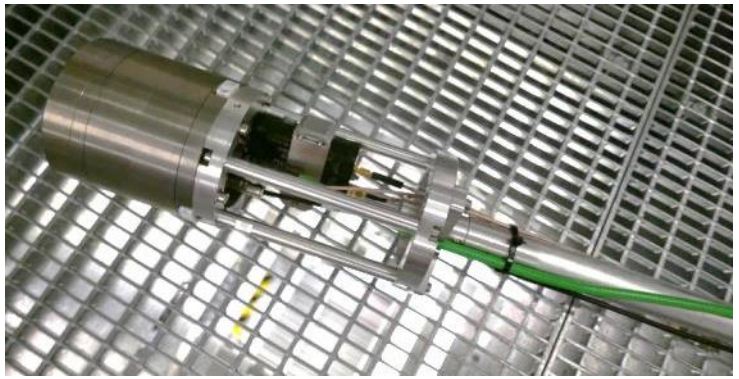


- Dedicated to study of materials under X-ray irradiation → EOS with velocities in the [1; 1000] m/s range

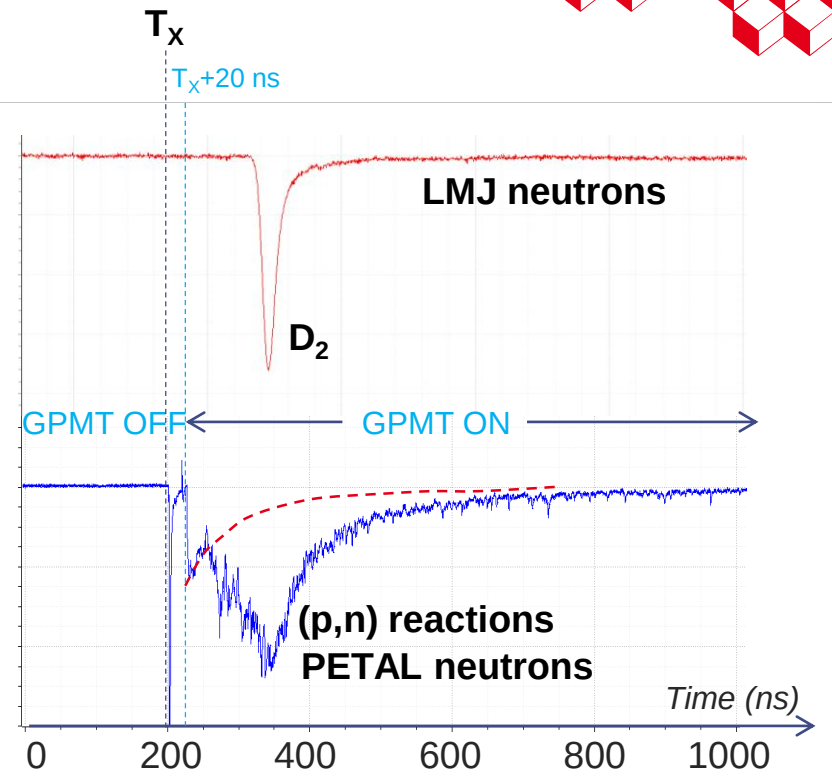
Neutron diagnostics

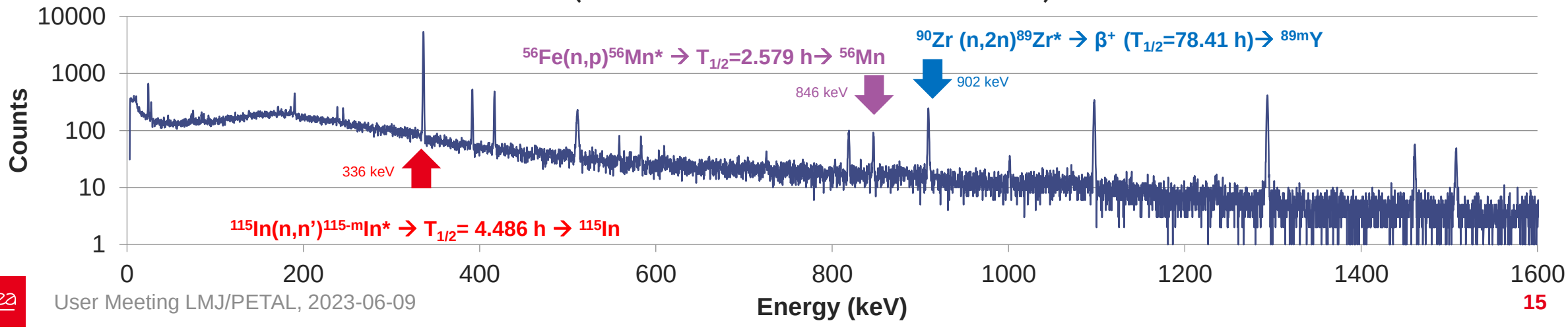






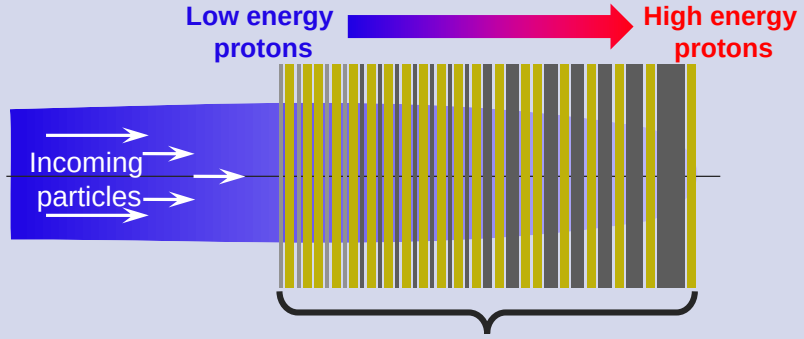
6x GPMT nToF + 6x Activation Samples
(Indium – Fer – Zirconium are available)





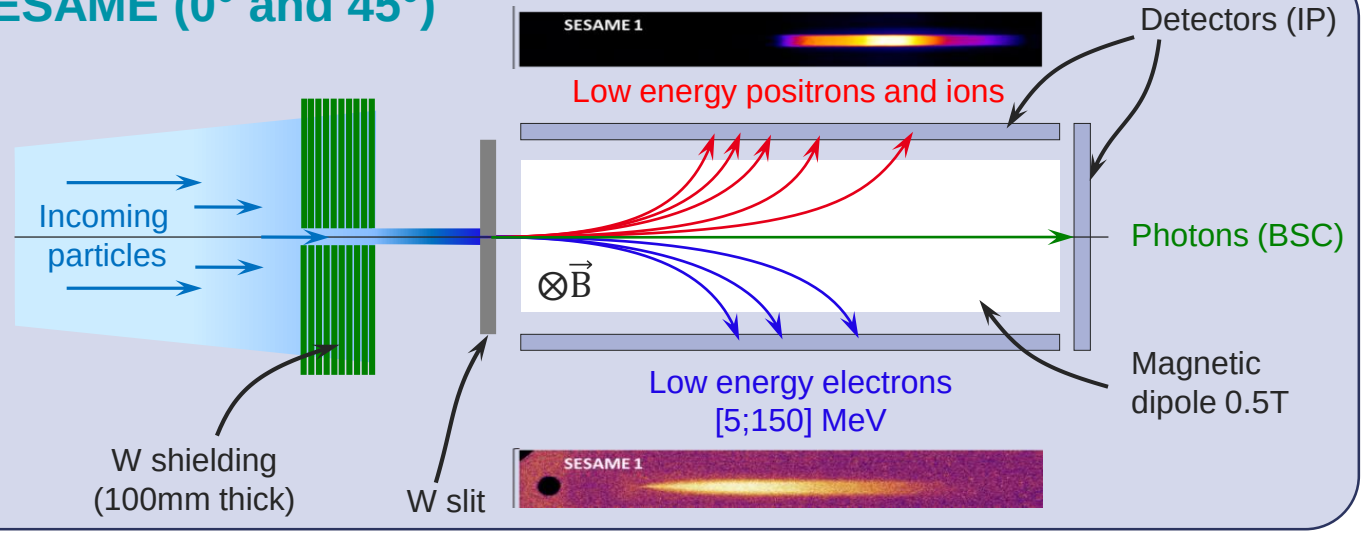
Charged particles diagnostics

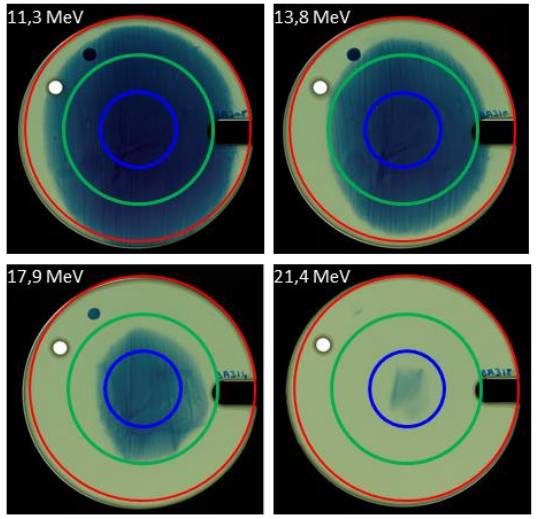
CRACC



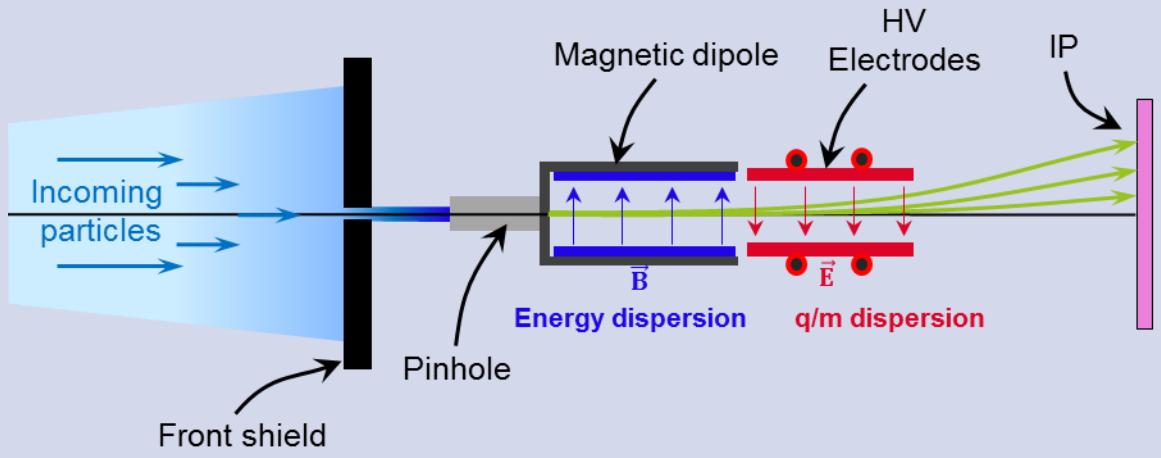
Stack composed of RCF and filters of various thicknesses and materials

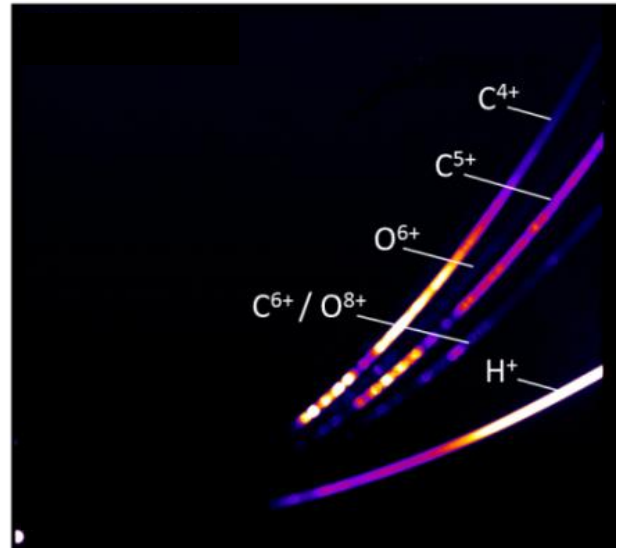
SESAME (0° and 45°)





SEPAGE



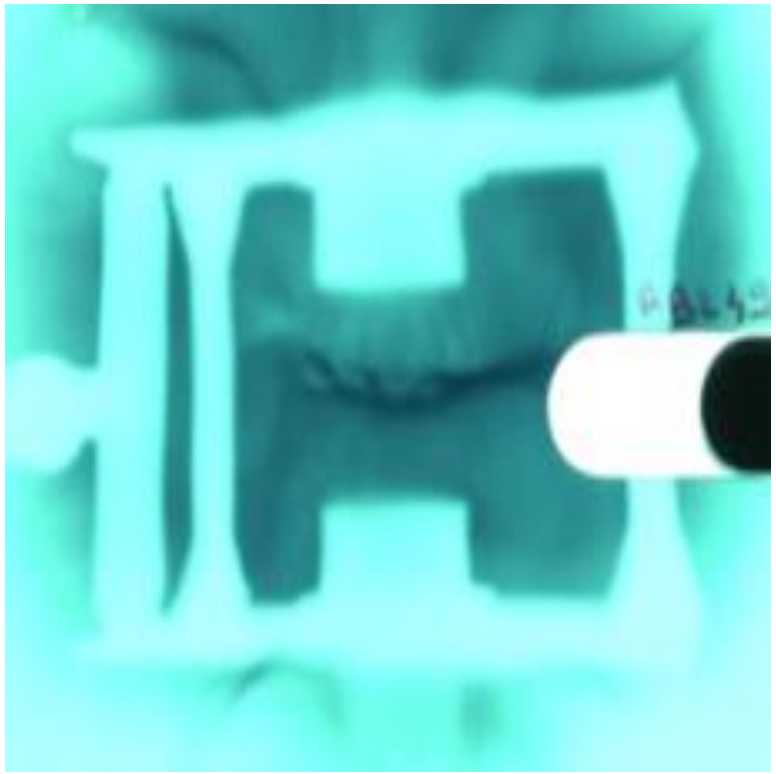


- I. Lantuejoul et al., *SEPAGE: a proton-ion-electron spectrometer for LMJ-PETAL*, Proc. SPIE 10763 (2018)

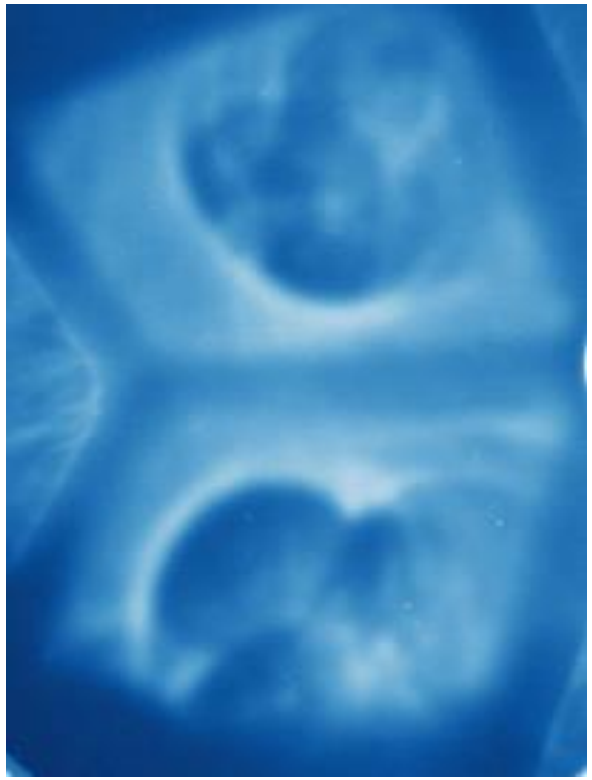
Radiography capabilities using PETAL

- D. Raffestin et al., *Enhanced ion acceleration using the high-energy petawatt PETAL laser*, MRE **6**, 056901 (2021)
  - TNSA proton acceleration as high as **51 MeV**

    → Proton radiography to probe magnetic fields



GREGORI (2018)



SMETS (2019)

FUJIOKA (2023)

Thank you for your attention

Platform name
SXR (Soft X-ray)
IMP (Implosion)
HXR (Hard X-ray radiography, UHI)
OPA (EOS, Opacity)

Diagnostics reconfiguration are time-consuming: do not forget to follow the proposed experimental platforms for your future proposals.

Guillaume BOUTOUX
guillaume.boutoux@cea.fr

CEA DAM

www-lmj.cea.fr/docs/2020/LMJ_PETAL_Users_guide_v2.0.pdf