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# X-ray synthetic diagnostics for laser-driven implosions

## 36th European Conference on Laser Interaction with Matter

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**Frascati 19-23 September 2022**

# Outlines

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# 1. Motivation & Aims

# Motivations

laser-plasma modelling

**Laser-plasma modelling**

Provides quantities like temperature, pressure, density...

# Motivations

laser-plasma modelling

experiment

## Laser-plasma modelling

Provides quantities like temperature, pressure, density...

## Experiment

We cannot measure the simulated quantities directly and independently

# Motivations

laser-plasma modelling

?

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**Laser-plasma modelling**

Provides quantities like temperature, pressure, density...

**Experiment**

We cannot measure the simulated quantities directly and independently

# Aims



laser-plasma modelling

synthetic diagnostics

experiment

## Synthetic diagnostic

- diagnostic development
- experiment design
- data analysis

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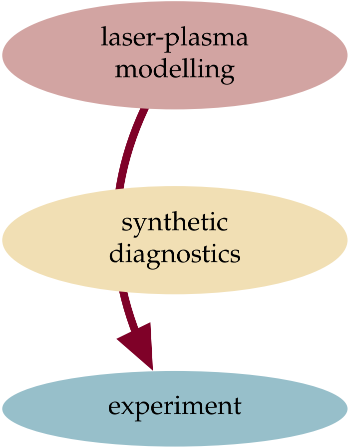


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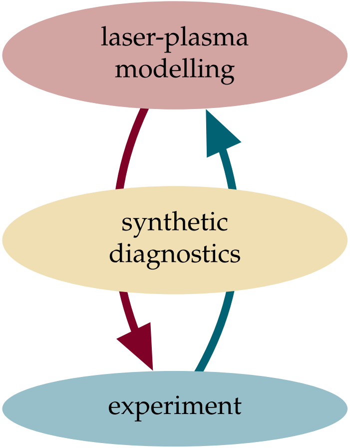
# Aims




**Synthetic diagnostic**

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- experiment design
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# 2. Synthetic diagnostics

## 2.1 PhaseX

## 2.2 EmXI

# Our portfolio



## Back-lighted imaging

- X-ray Absorption Contrast Imaging (XACI)
- X-ray Phase Contrast Imaging (XPCI)

# Our portfolio



PhaseX

EmXI

## Back-lighted imaging

- X-ray Absorption Contrast Imaging (XACI)
- X-ray Phase Contrast Imaging (XPCI)

## Emission imaging

- Framing camera
- Streak camera
- Spectral emissivity (qualitatively)

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## 2. Synthetic diagnostics

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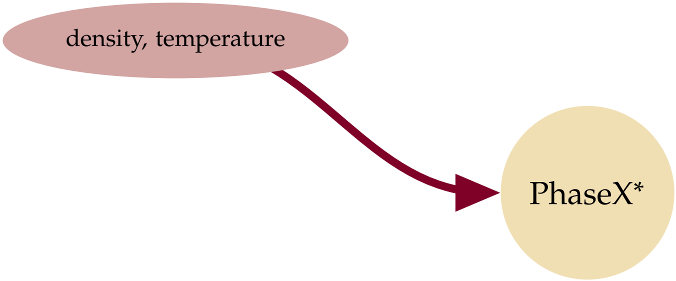
### 2.2 EmXI

PhaseX*

*F. Barbato, et al. Optics Express 30.3 (2022)

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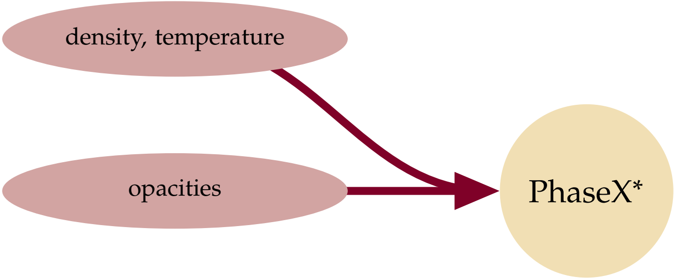


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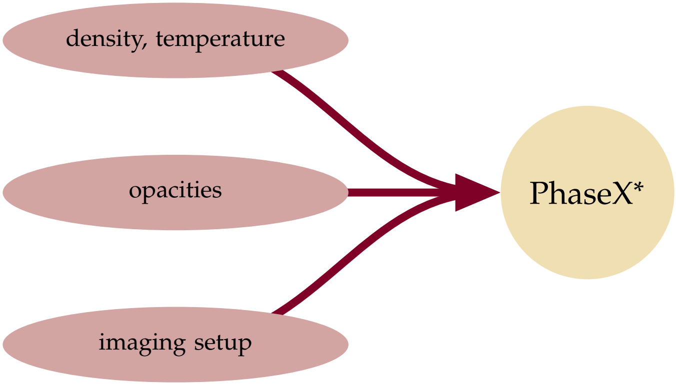


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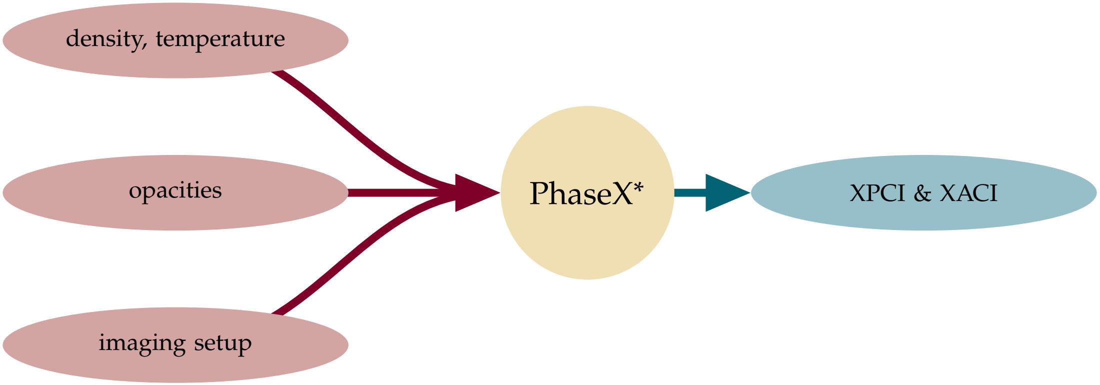


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# PhaseX: specs

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## An hybrid code

- Python + FORTRAN (OpenMP)
- ray + wave optics

## Refractive index

$$n = 1 - \delta + i\beta = n^{\star} + i\kappa$$

- solid-cold
- pure phase ($n = n_e/(2n_c)$)
- warm
- hybrid

## Ray-optics → Complex wave

- projection approximation ($\sqrt{T\lambda}$)
- 1, 2, 3 dimensions object
- mono/poly-chromatic

## Wave-optics → Image

- Fresnel-Kirchoff in the Fourier space
- cone/collimated beam
- system resolution

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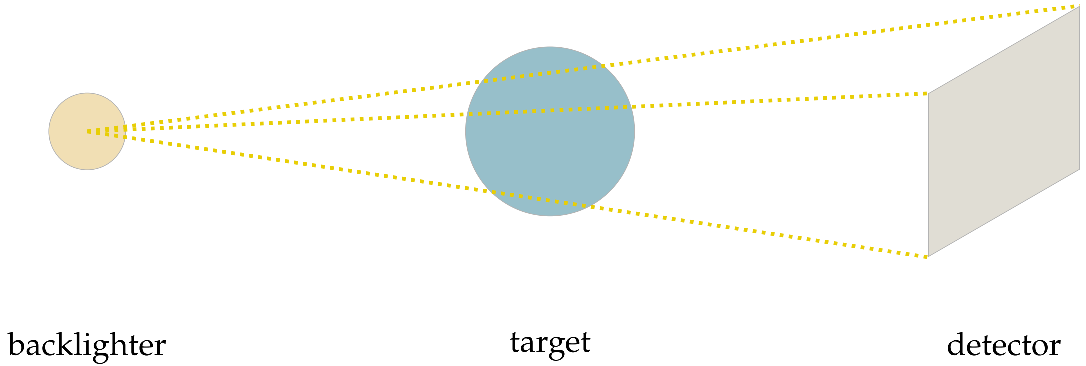
F. Barbato, et al. Optics Express 30.3 (2022)

# PhaseX: point-like scheme



## Benchmark

- L. Antonelli, *et al.*
  "**X-ray phase-contrast imaging for laser-induced shock waves.**"
  EPL (Europhysics Letters) 125.3 (2019)
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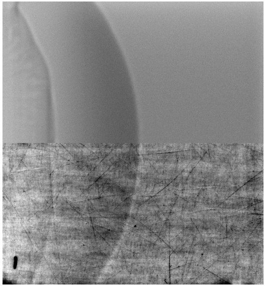
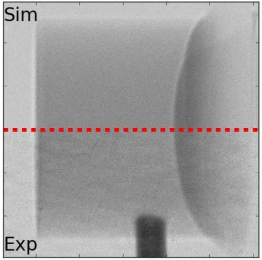




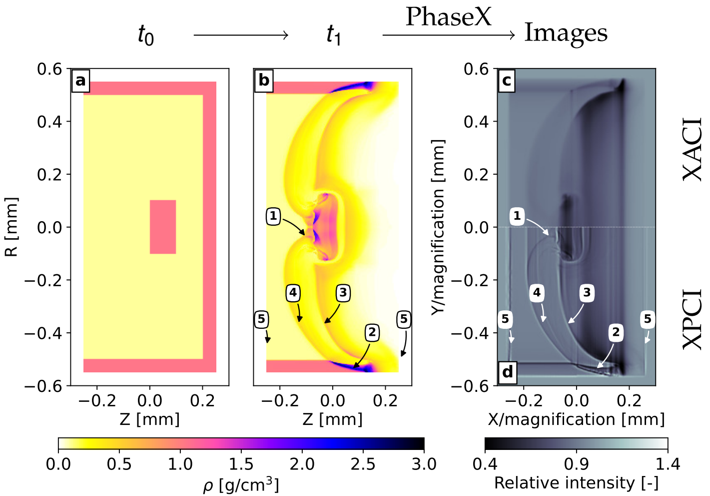

## Work in progress...

Planar shock @ OMEGA
In collaboration with L. Antonelli *et al.* at Uni. of York

# PhaseX: possible applications

**Perturbations**

Interaction of a laser-driven shock-wave with an obstacle

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# PhaseX: possible application

## Dynamic shell formation*

The shell is created by irradiating a foam sphere with a specific pulse shape

- radius 320 $\mu$m
- density 0.15 g/cc

*V. Goncharov, *et al* Physical Review Letters 125.6 (2020)

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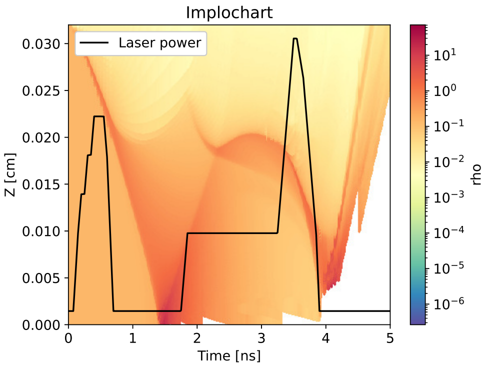


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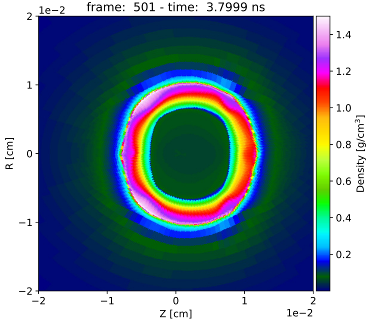


## Non-ideal case

The target is irradiated with a non-uniform laser illumination

In collaboration with V. Goncharov *et al* @ LLE

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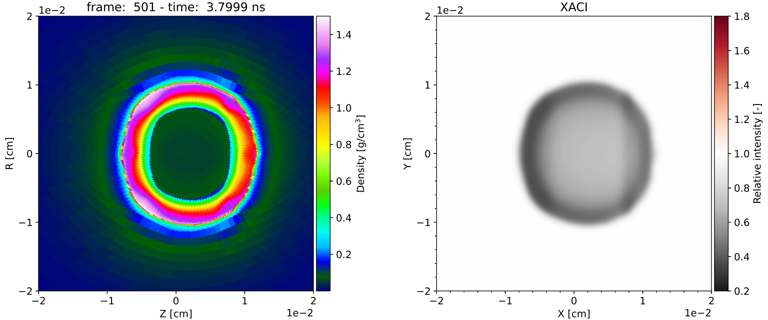


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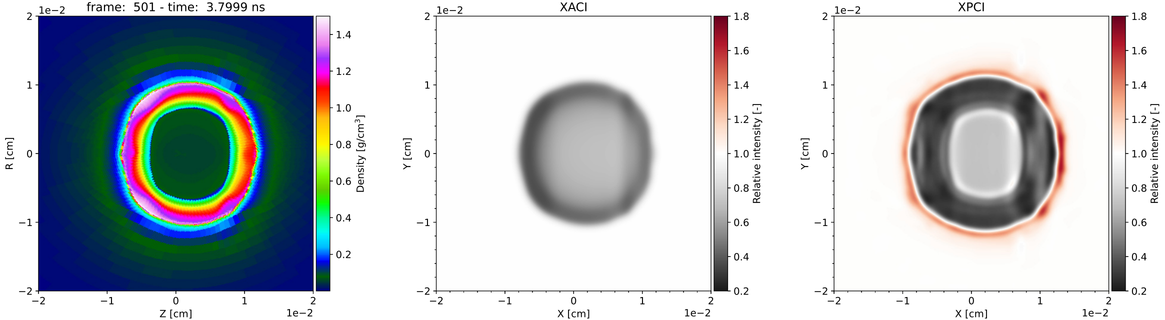


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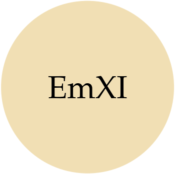

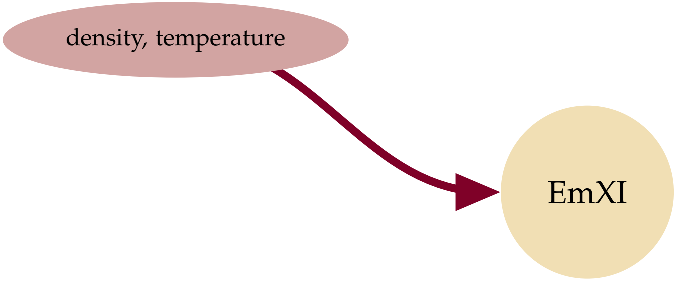
density, temperature
EmXI

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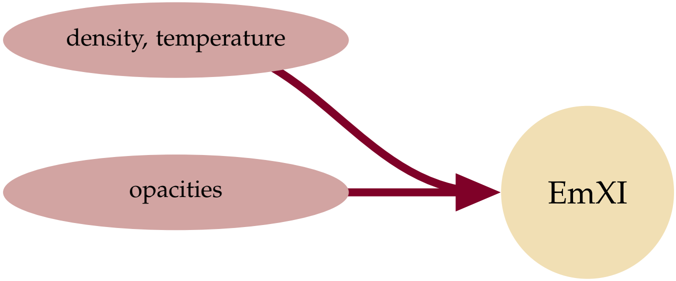
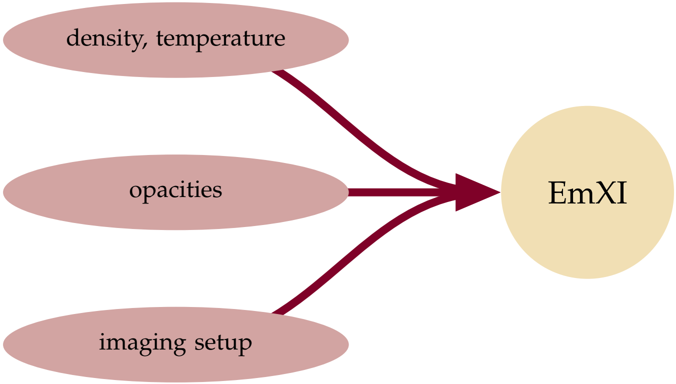
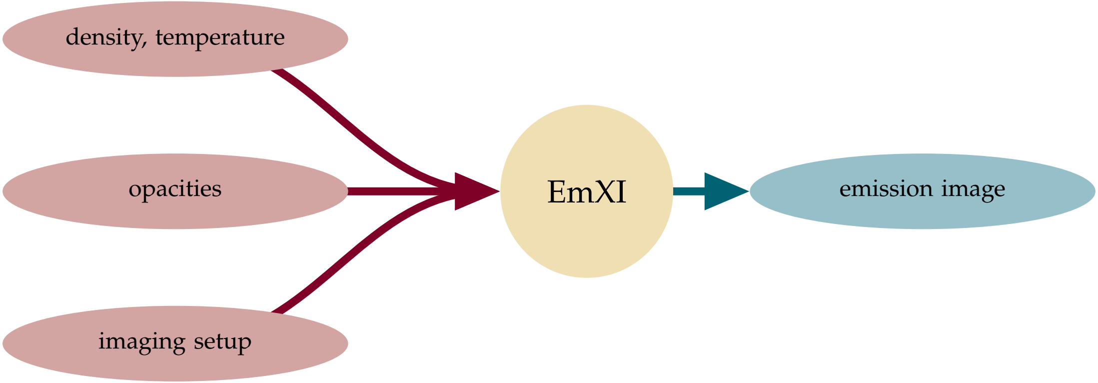



density, temperature
opacities
imaging setup
EmXI

# EmXI




density, temperature
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emission image

# EmXI: specs

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## Code

- Python + FORTRAN (OpenMP)
- ray optics

## Ray-optics

- $dI = -\mu_\nu I_\nu + \mu_\nu(exp(-u))I_\nu + j_\nu$
- thermodynamic equilibrium
- pinhole, slit
- system resolution

## Tools

- 2D framing camera
- streak-camera
- spectral analysis*

*It depends on the multigroup opacity tables

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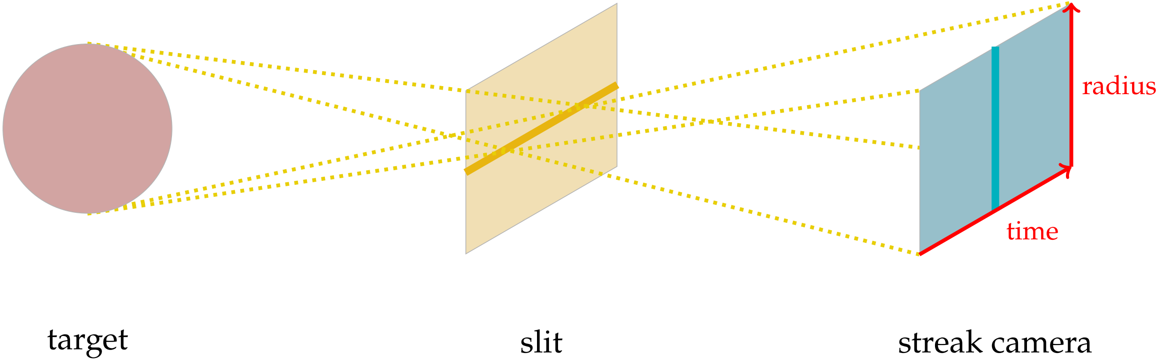
# EmXI: streak scheme



# EmXI: application

## Dynamic shell formation

A scaled-down proof-of-principle, on the formation of a dense shell from a laser irradiated homogeneous-foam shell. Experiment performed at OMEGA on Aug. 9, 2022*

- radius 320 $\mu$m
- density 0.144 g/cc

*Foamball collaboration **LLE**: W. Theobald, I. V. Igumenshchev, V. N. Goncharov, C. Stoeckl, R. Shah, D. Bishel, D. Chin, L. Ceurvors, W. Trickey, N. Shaffer; **CELIA**: A. Colaitis

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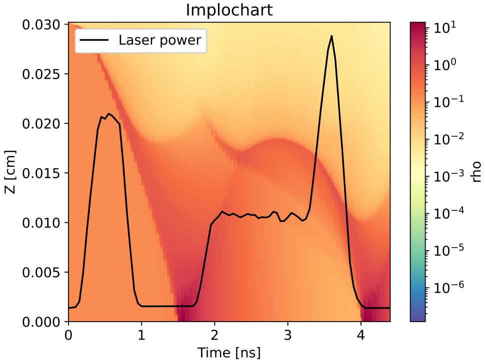


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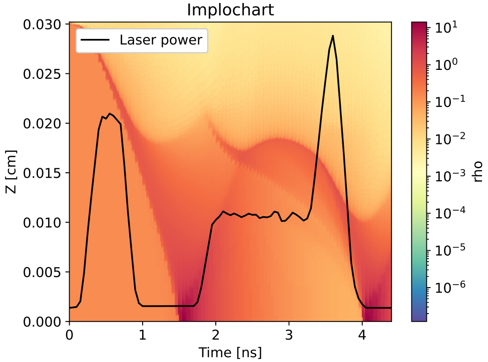


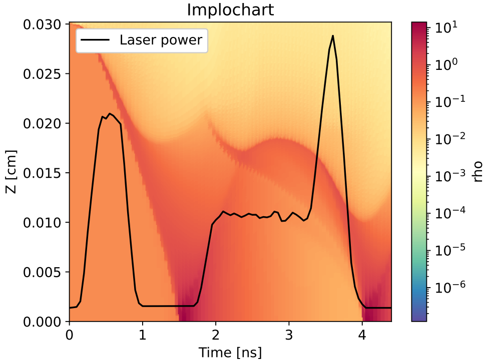

## Streak*

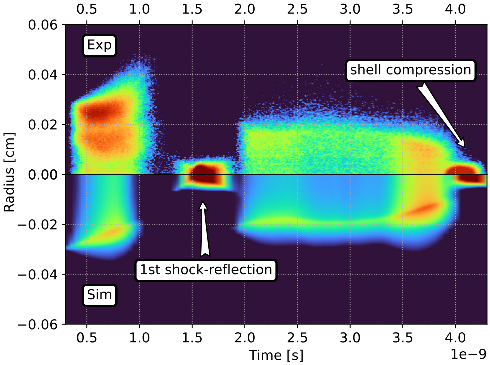
Time emission along the target diameter

*Foamball collaboration

# EmXI: application



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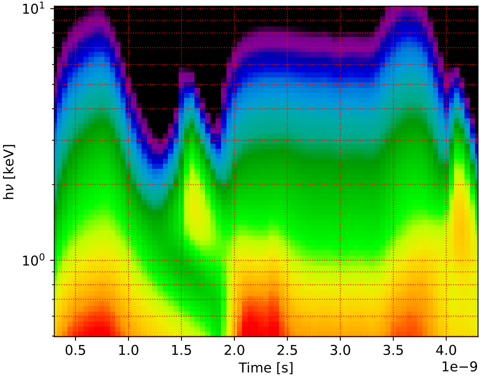
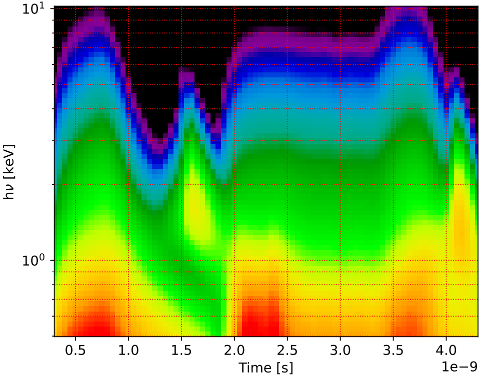


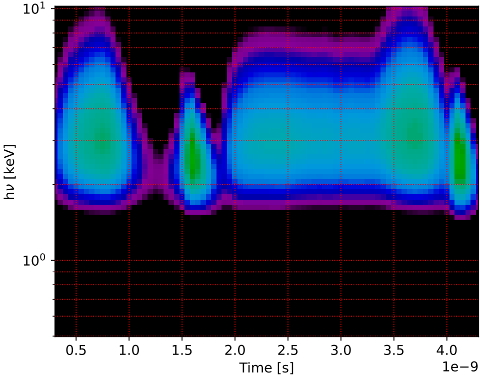

## Target

Time resolved spectral emission of the target with and without spectral response

# EmXI: application



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Time resolved spectral emission of the target with and without spectral response

# To summarise



## Modular design

Both codes have a modular design, they can be easily adapted to simulate different diagnostics, setup, etc..

## Target

The target is described with a set of density and temperature maps, it doesn't matter the source (hydro, PIC, MD, hand made)

PS: the input for the synthetic diagnostics shown above were generated by D·U·E·D·

# To summarise



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# Thank You for your attention

*No Codes were harmed in the making of this work