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Numerical Modeling for Intense Laser Physics

Edouard AUDIT and Guy Schurtz

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Institut Laser et Plasmas (ILP)

ILP Recherche

- Ø Inertial Fusion for energy
- Ø Lasers
- Ø Advanced concept for fusion
- Ø fusion plasmas diagnostics
- Ø **Physics in extreme conditions**
- Ø **Numerical Modelling**

Opening of large Laser facilities

- § LIL, LMJ
- § LULI2000, Alisé, PALS, …

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- **Inertial Fusion for energy**
- Laboratory Astrophysics
- Physics of warm dense matter
- Particles acceleration
- EOS and Opacities
- …

La ligne d'Intégration Laser (LIL)

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Ø The LIL is the prototype of the LMJ

Ø It has 4 beams (soon 8).

Le bâtiment LIL c'est :

- 8500 m^2 de surface au sol
- 150 m de long
- 70 m de large
- Salle d'expérience 500 m^2 20 m de haut
- Chambre d'expérience : sphère ϕ 4,5 m

Physics on the LIL has started

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First experiments have started in 2005

The laser mégajoule (LMJ)

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Ø 240 laser beam,

Ø 1.8 MJ on target at λ_{laser} = 351 nm

The Laser Mégajoule (LMJ)

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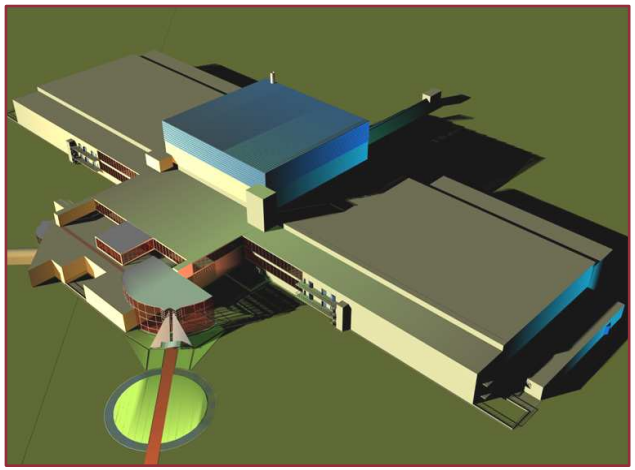
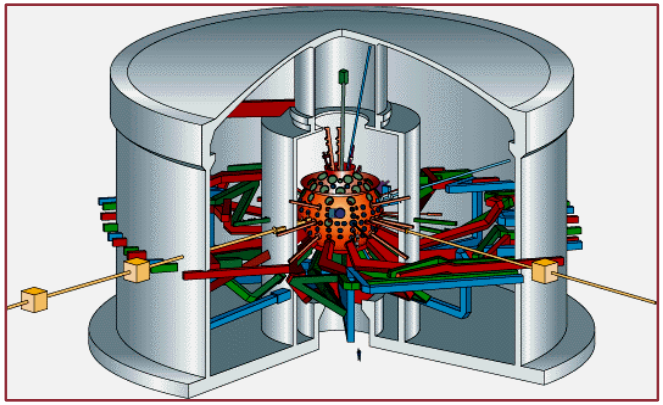
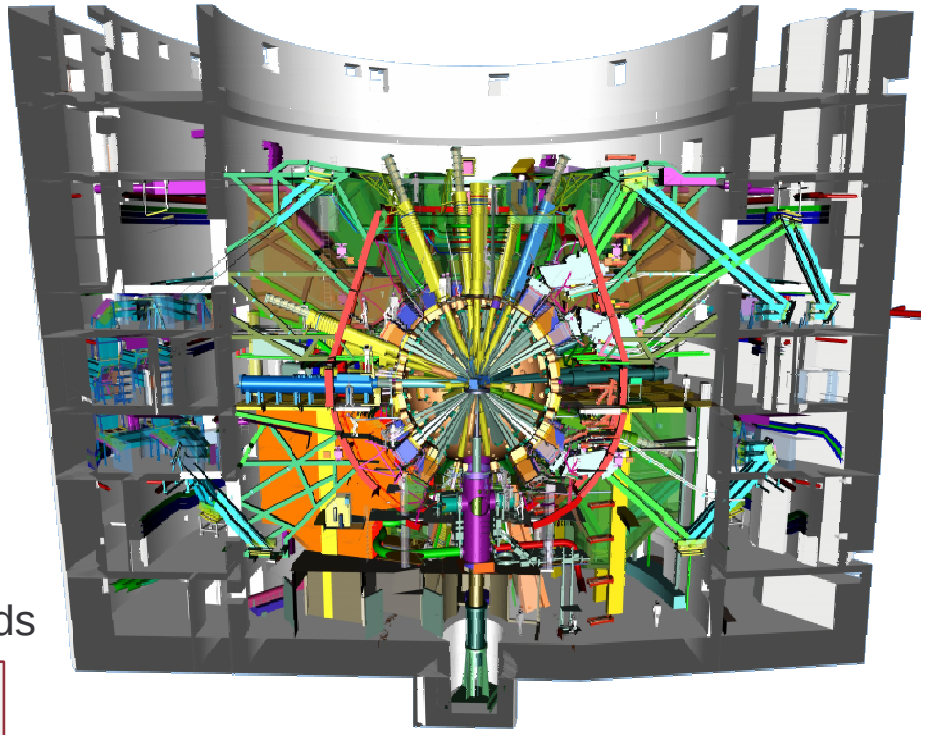


bâtiment : 300 x 150 m^2
4 halls laser
240 faisceaux 40x40 cm^2 en 60 quads



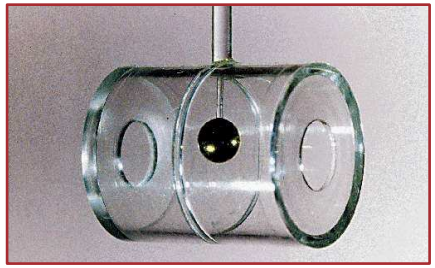
hall d'expériences :
h 40 m - Φ 60 m

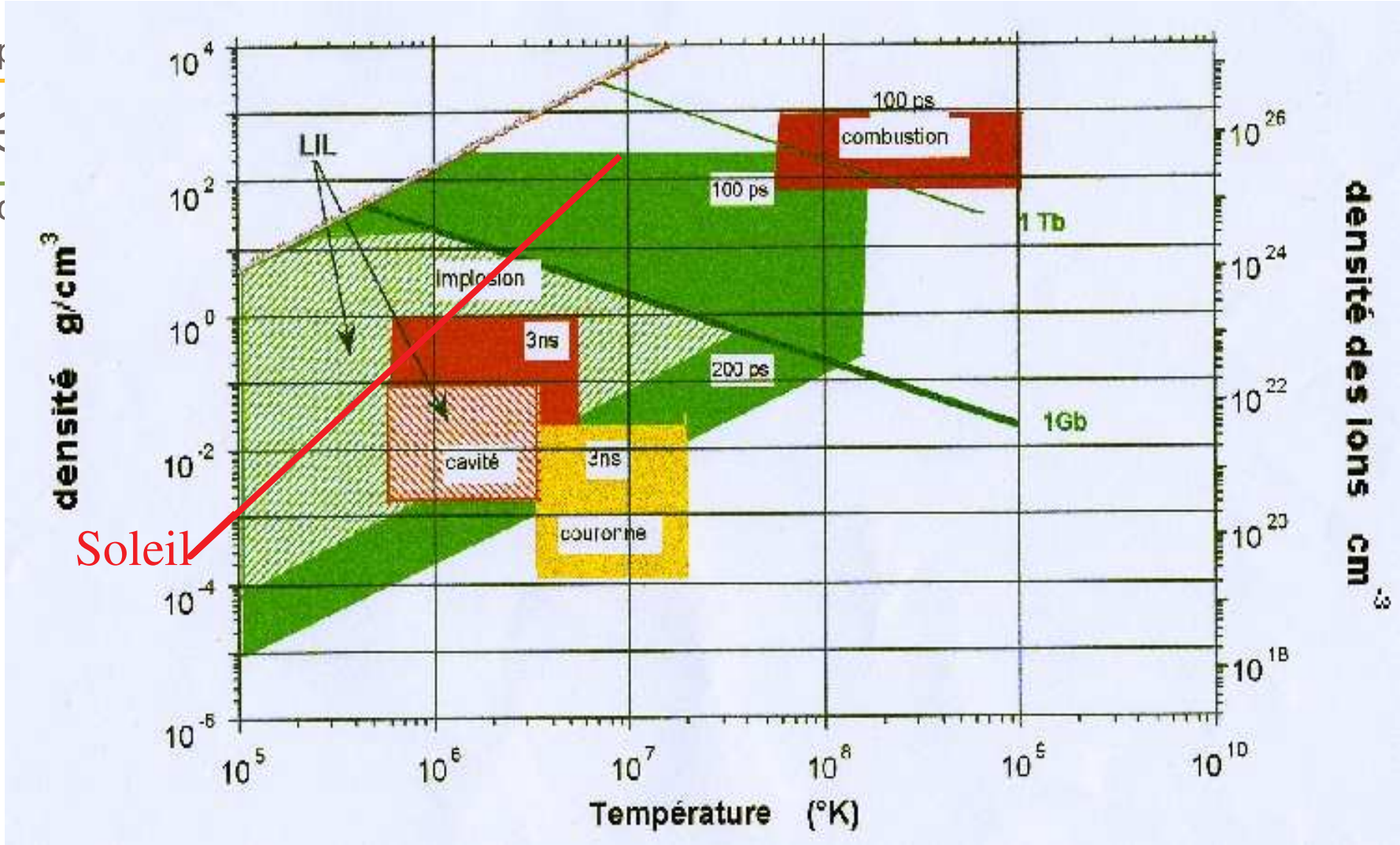


Salle d'expérience
∅ ~ 60 m,H ~ 40 m

600 tirs / an
dont 20 avec fusion

cible : Φ 2.5 mm




densité g/cm3
densité des ions cm-3
Température (°K)
LIL
100 ps
combustion
100 ps
1 Tb
implosion
3ns
200 ps
1Gb
cavité
3ns
couronne
Soleil

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Micro-physics Studies :

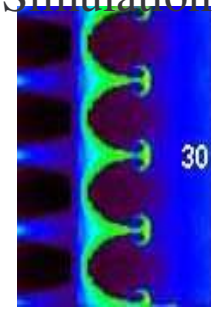
- Opacities
- EOS
- Transport Coefficients, …

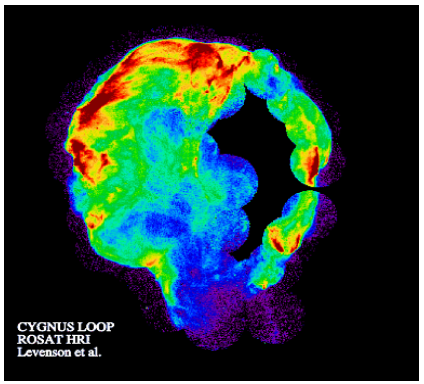
Simulation Experience

« Dynamical » studies :

The objective is to scale down flows of interest to reproduce them in a laboratory experiment.

- Radiative shocks
- Hydrodynamical Instabilities
- Jets, …





Observation

The codes developped at ILP address

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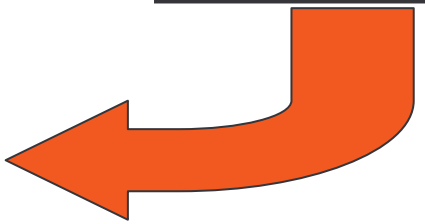
- Hydrodynamics
- Radiative Transport
- Conduction
- Transport by particules
- Combustion physics

§ EOS

§ Opacities

§ Transport coefficients

§ Reaction rates



The objectives are :

- Target design
- Interpretation of experiments
- Theoritical studies

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A 1 G€ project requires a **predictive** design code.

The simulations tools must be validated against dedicated experiments and theoritical benchmarks

These tools must be used by a large community which should gain confidence in there predictiveness.

<u>In order to achieve these goals the ILP promotes:</u>

Ø Code developments for the ILP community

Ø Benchmark program for these code

Ø Dedicated validation experiments.

Radiation-hydrodynamics codes

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CHIC

- 2D lagrangian (ALE), godunov type method
- multi-material hydro, non-local electron heat conduction, radiation transport (multi-groups diffusion), 3D laser raytracing, combustion
- tabulated EOS and opacities.
- developped at CELIA
- code dedicated to target design

HERACLES

- 3D eulerian code, godunov type method
- hydro, heat conduction, radiation transport (grey moment model), combustion
- tabulated EOS and opacities
- developped at SAp (CEA)
- code used both for astrophysics and laser experiment studies

The CHIC code (CELIA)

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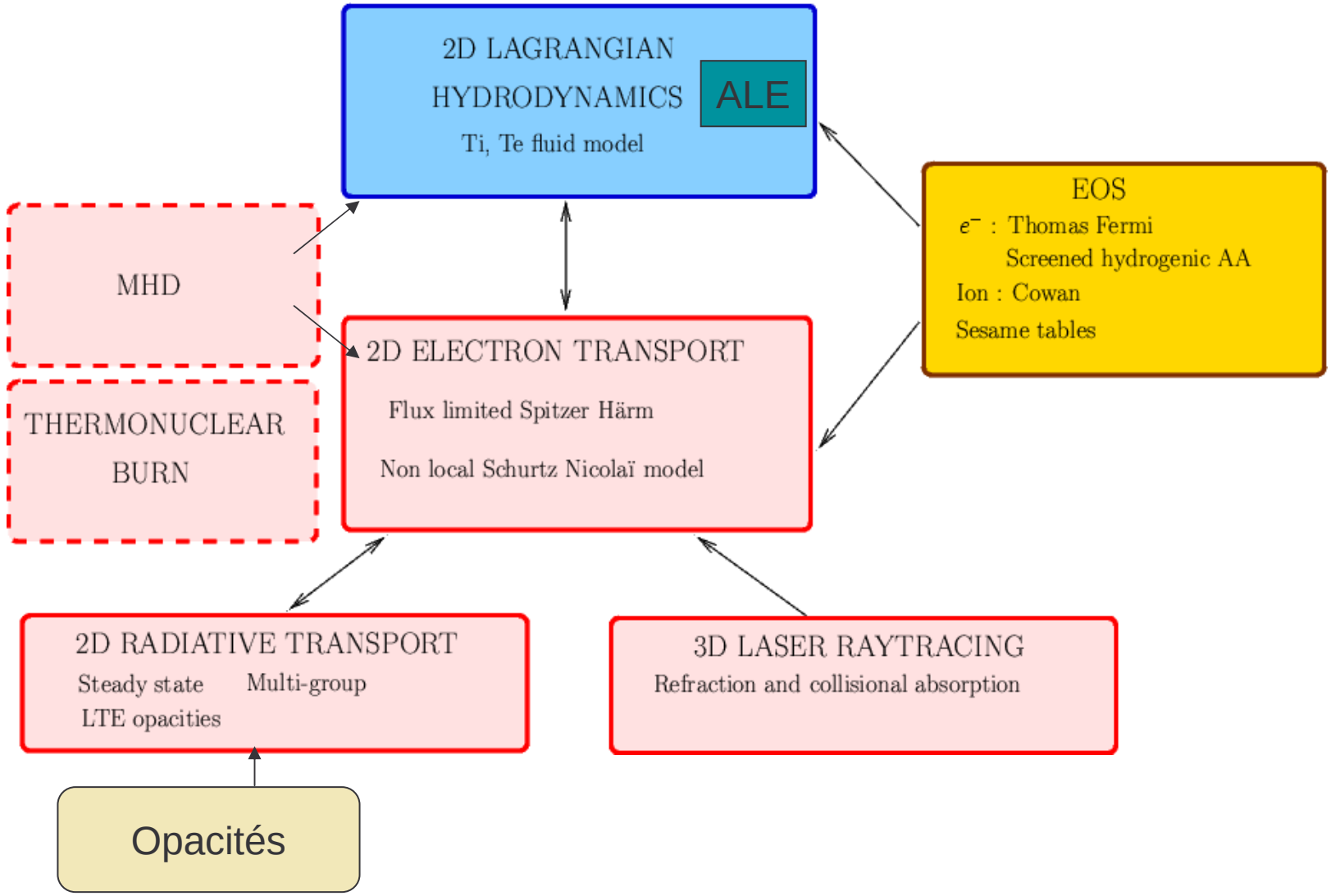

Physics of Inertial Confinement fusion (ICF)

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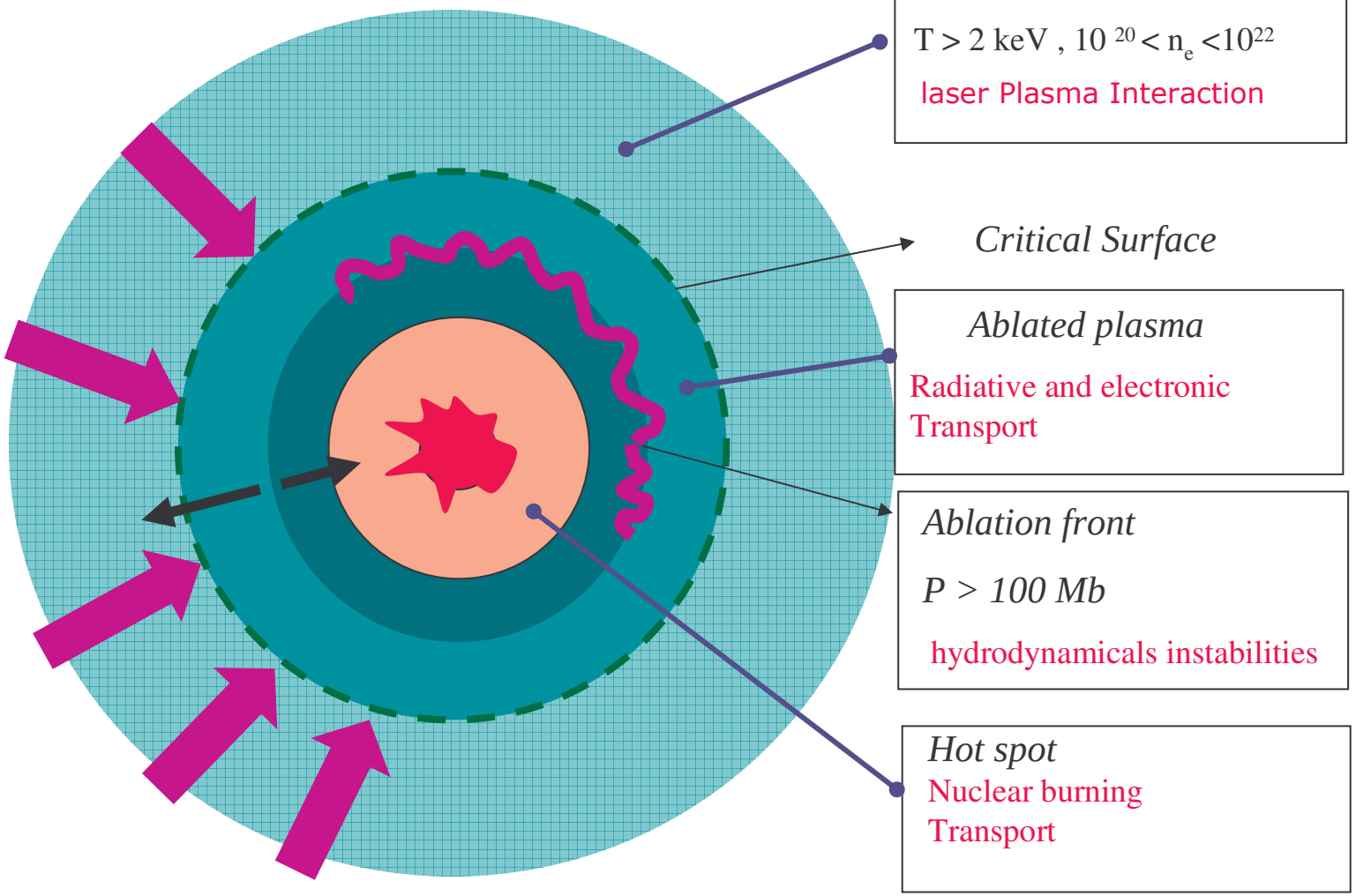

Cylindrical Implosion using the CHIC code

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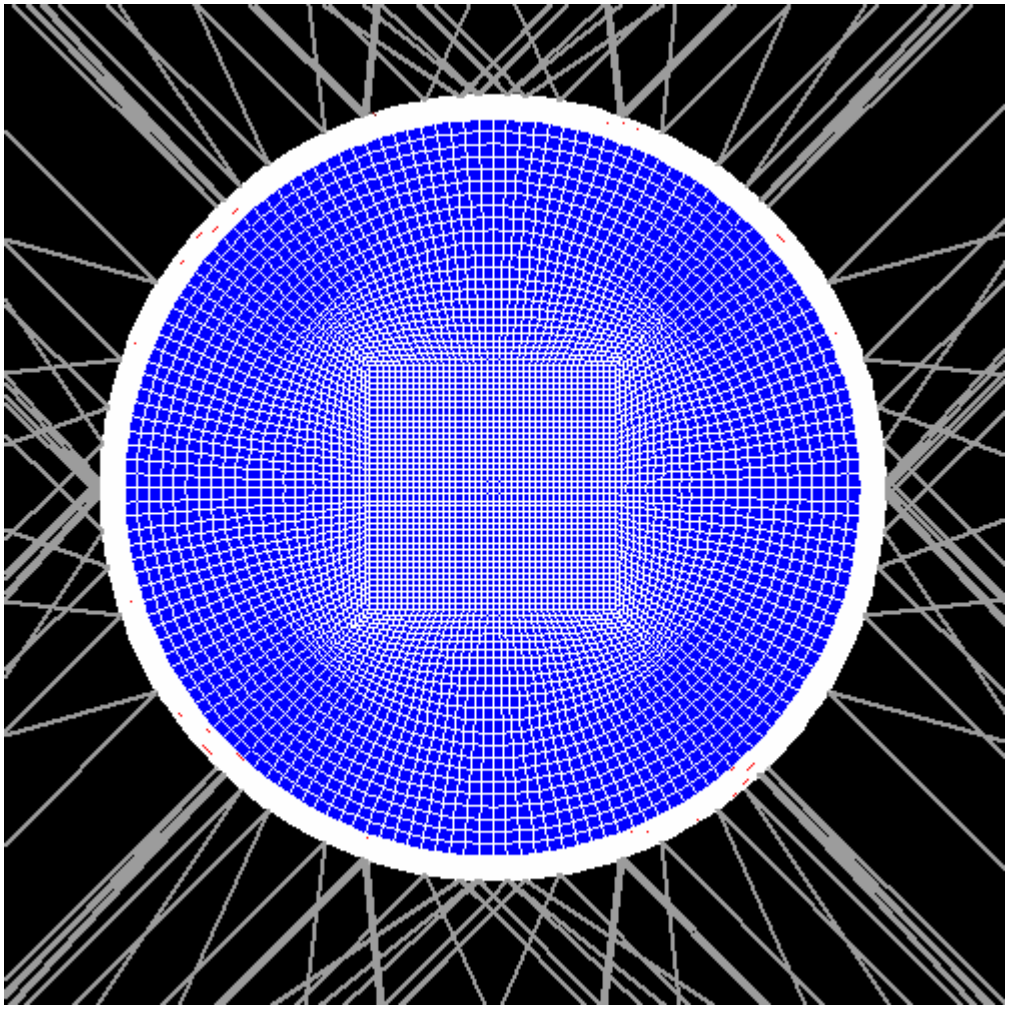

Opacities Measurements

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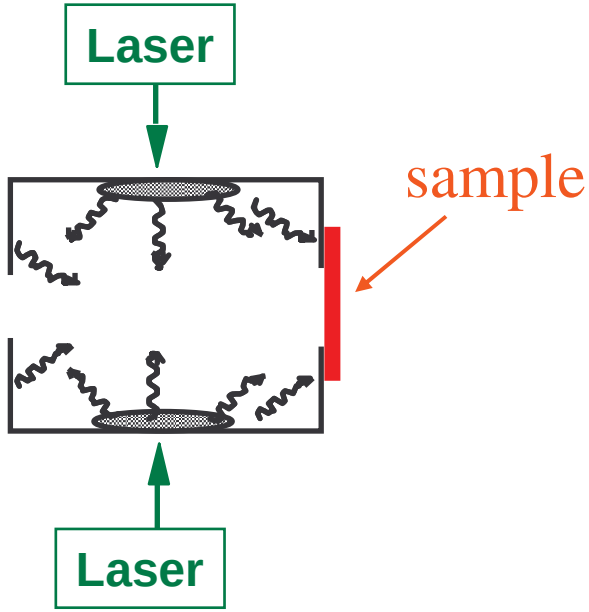
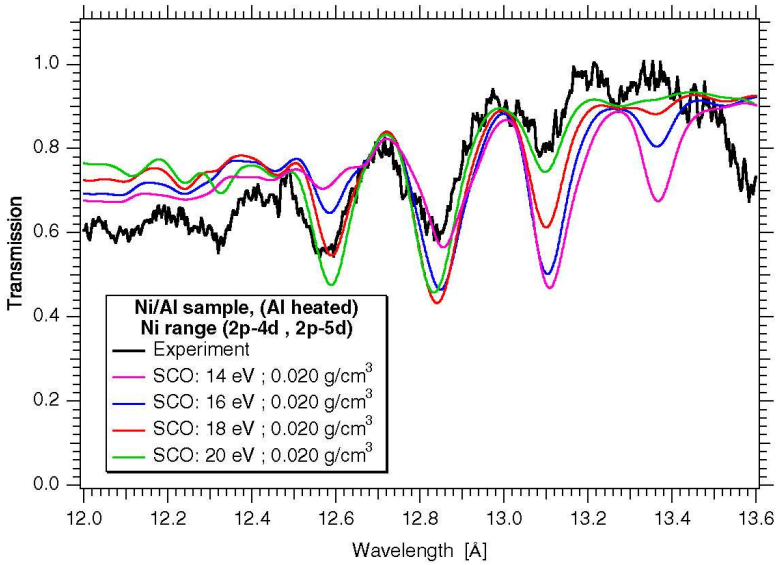


- Test numerical codes and methods used to compute opacities
- Often hydrodynamics is needed to determine the density and the temperature

Opacities Measurements



Measurement of the spectral opacity of nickel on the LULI laser

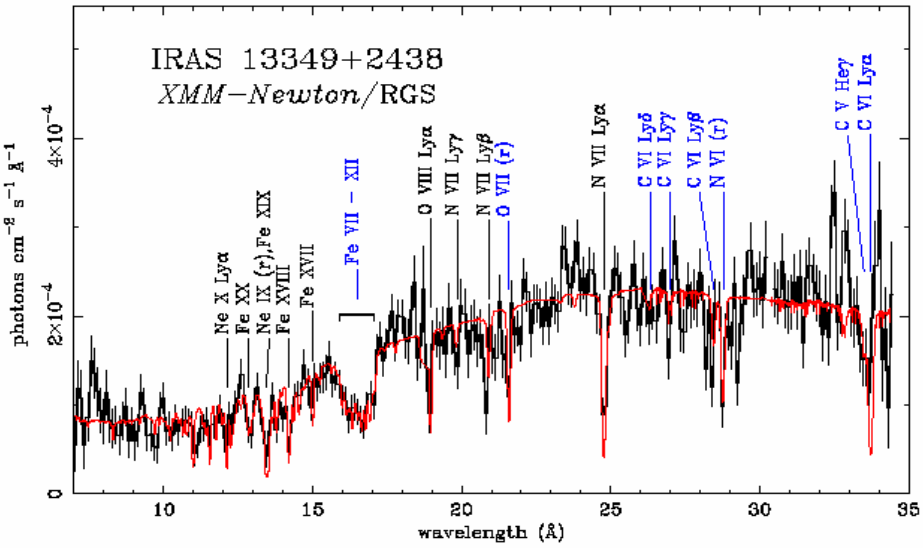
↓

Validation of the DRECAM opacity code

Computation of Iron opacities after validation of the code

↓

Identification of two spectral lines in the quasar IRAS 13349+2438



Radiative Shock experiment

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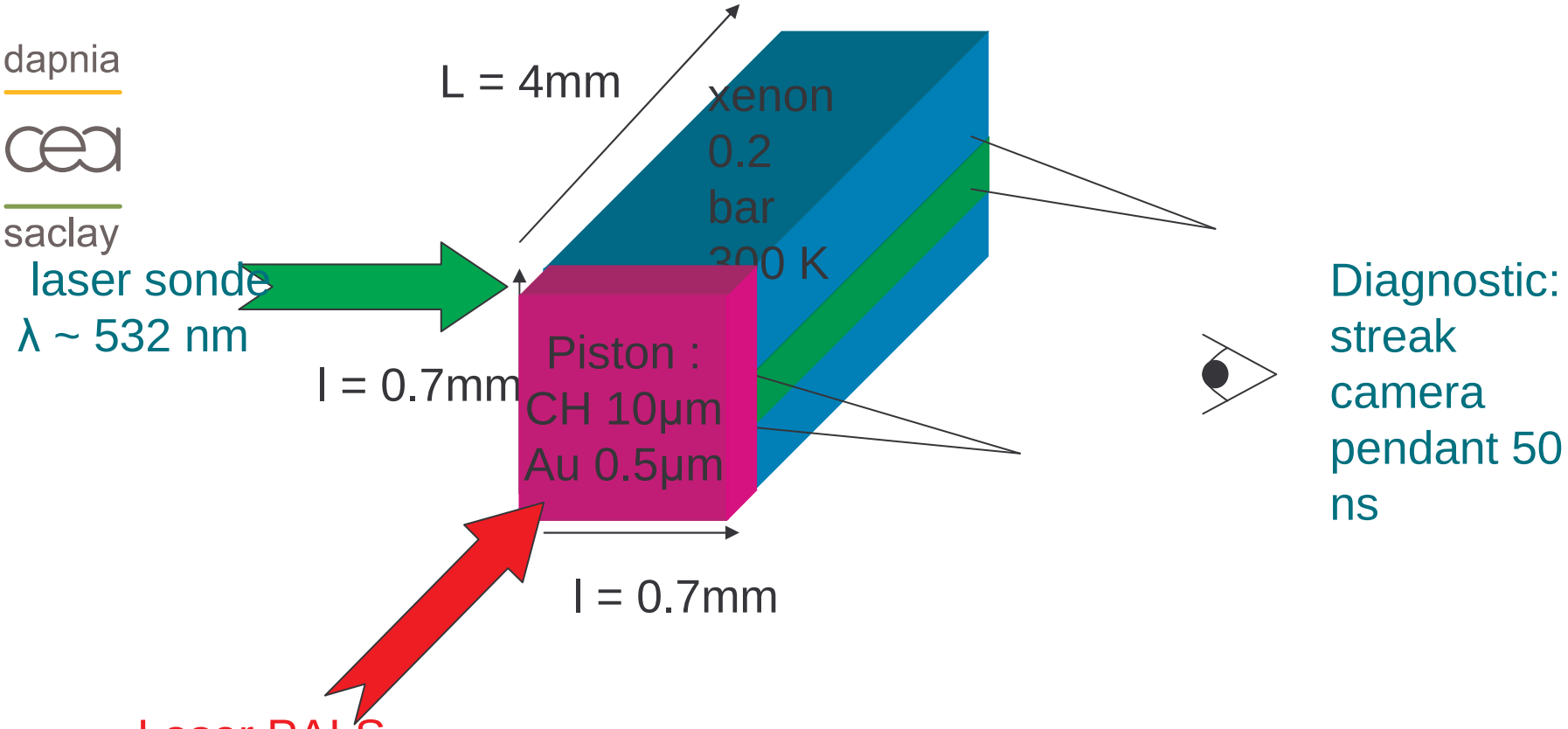

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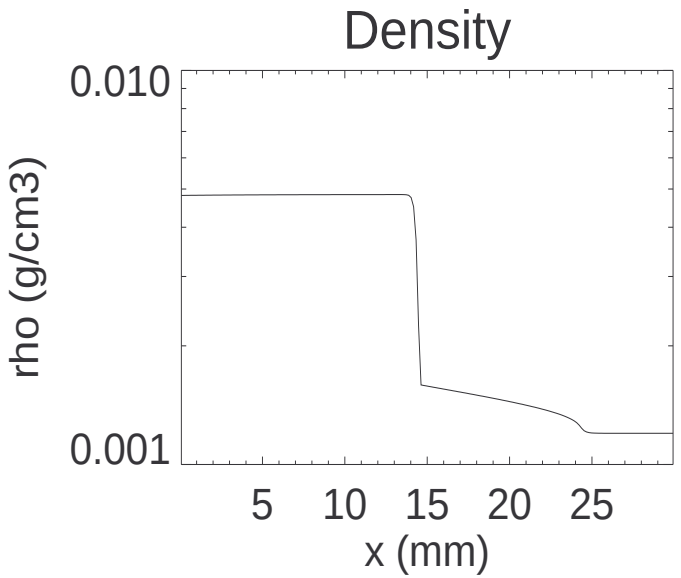

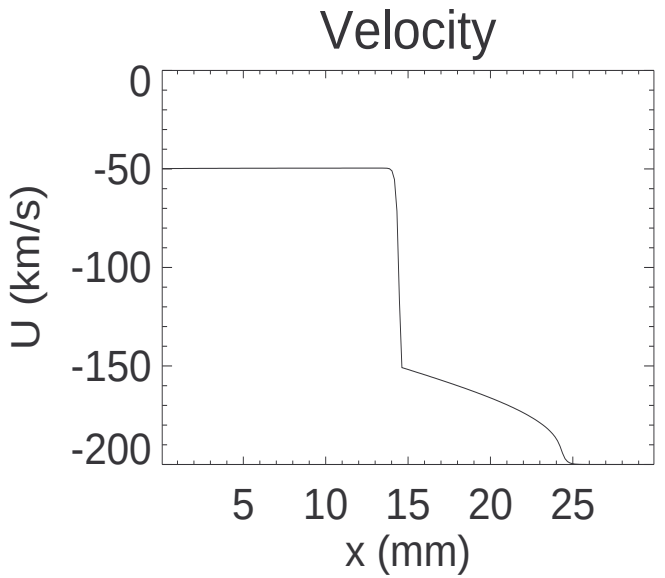

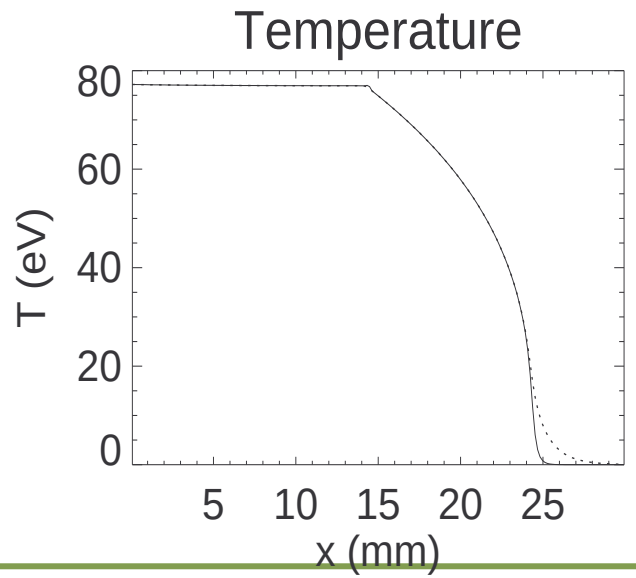

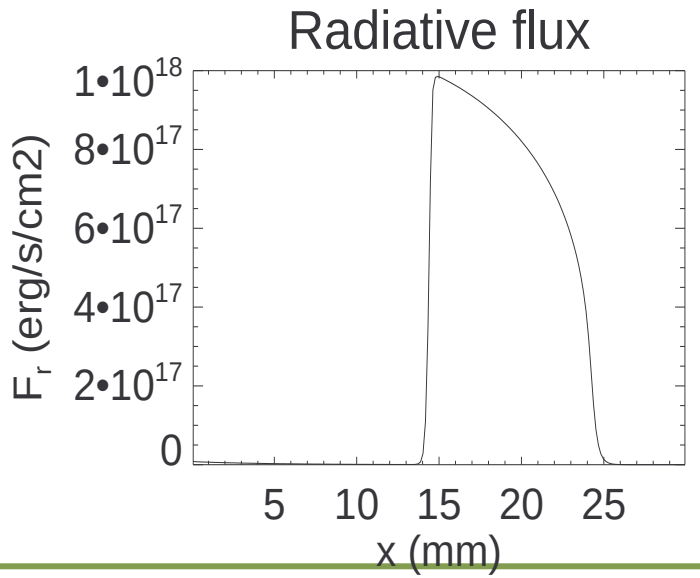

Modelling of the experiment using HERACLES

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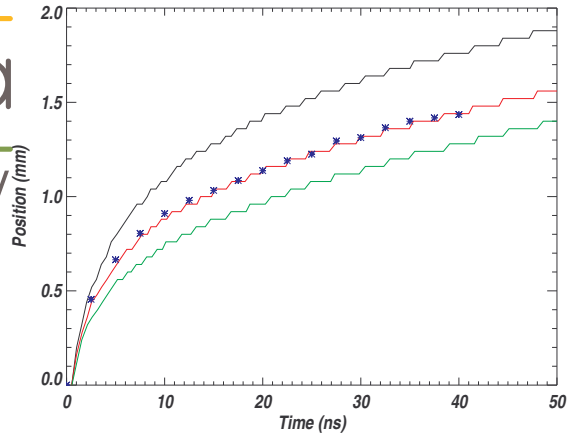

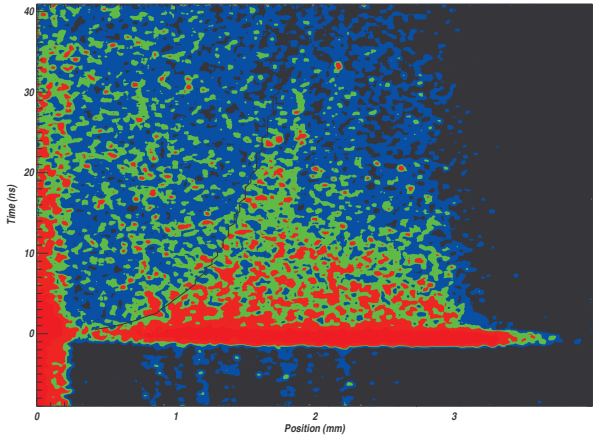

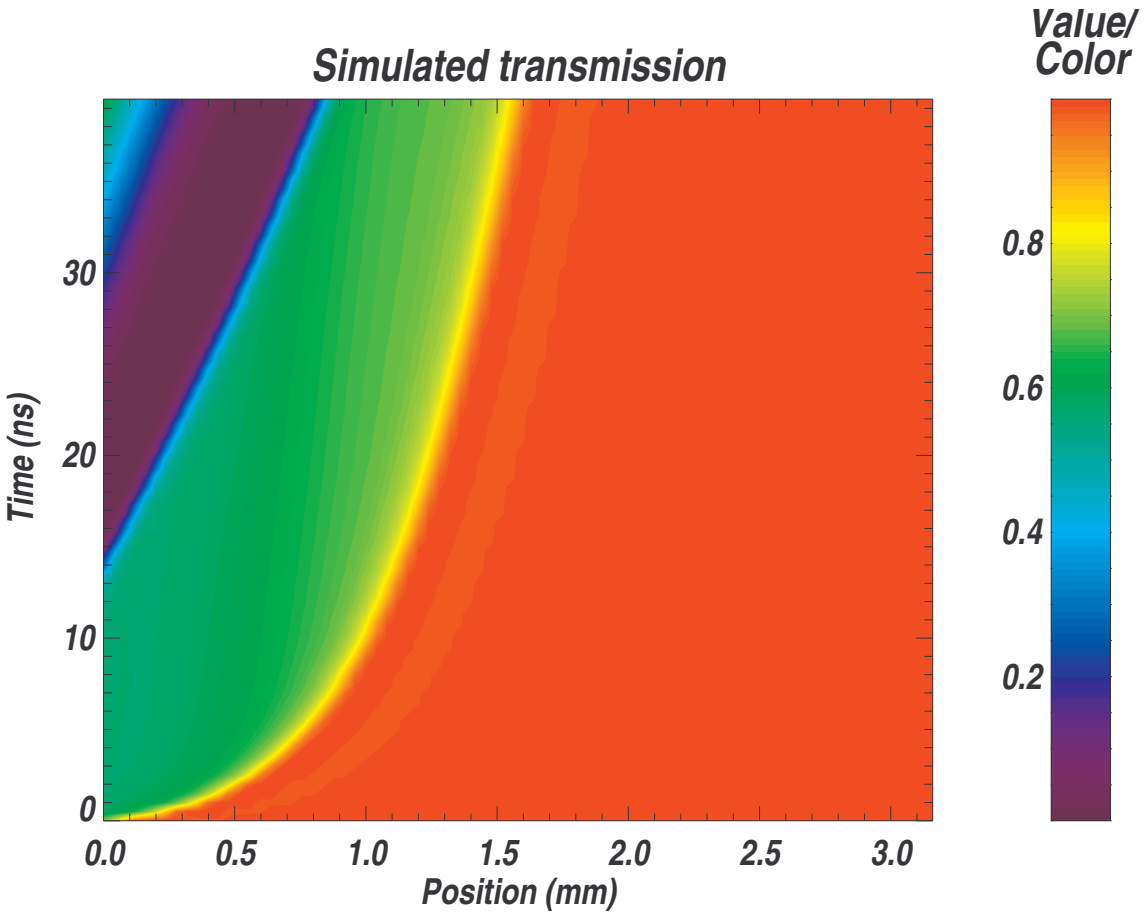

Electron heat flow experiment on LIL

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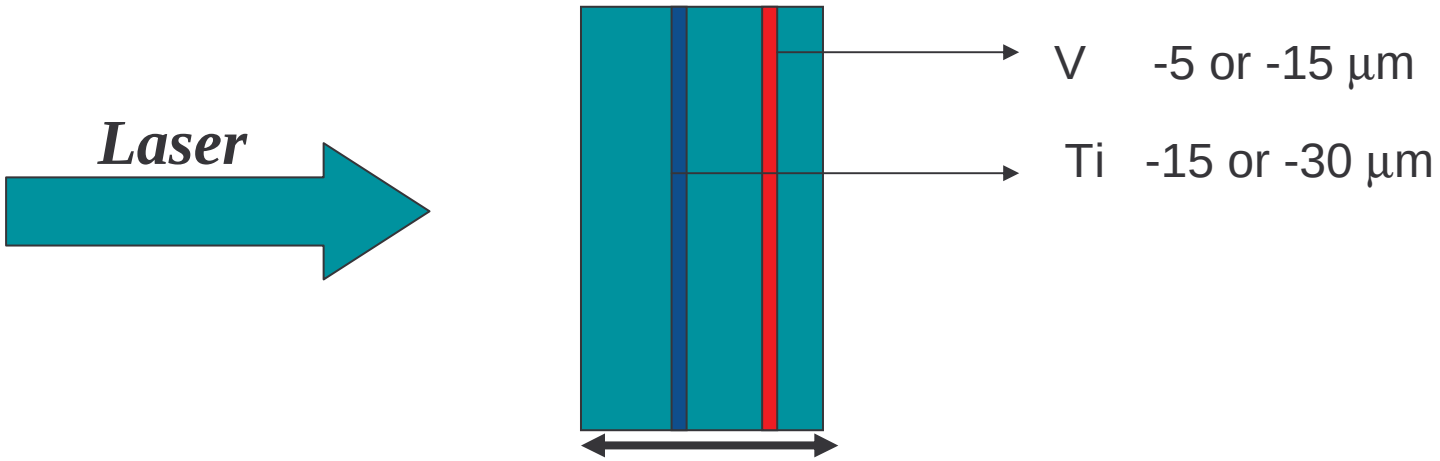
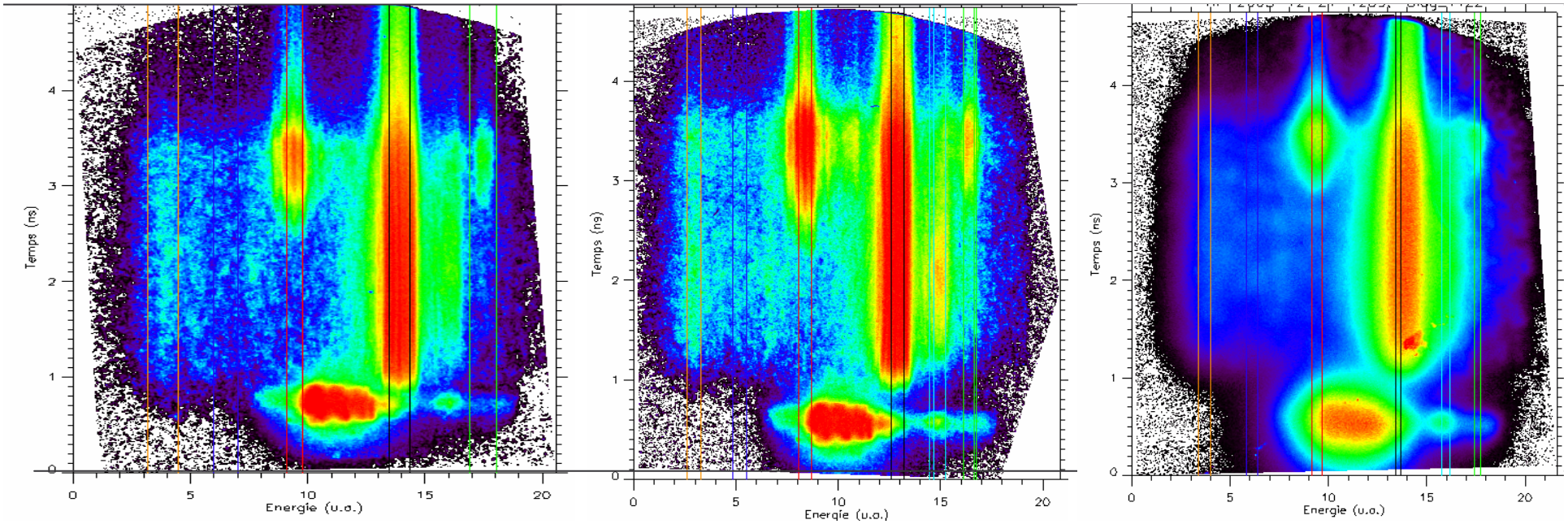
Test theoretical heat flow model with include non maxwellian and magnetic fields effect

Schurtz – Nicolai¨(2000) Nicolai-Feugeas-Schurtz (2005)



Time resolved spectra for 3 laser energies

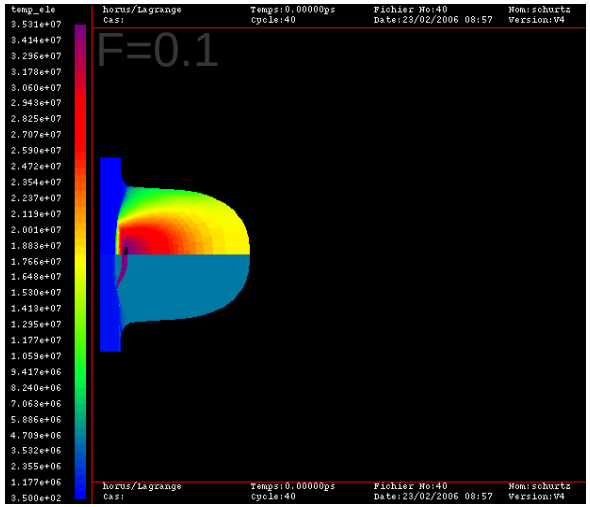


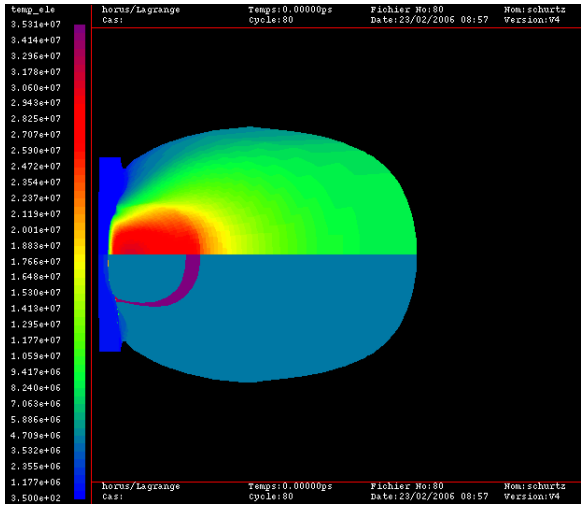
13/ 12/ 2005
2000 Å @ -5 / -15 µm,
7.2 kJ

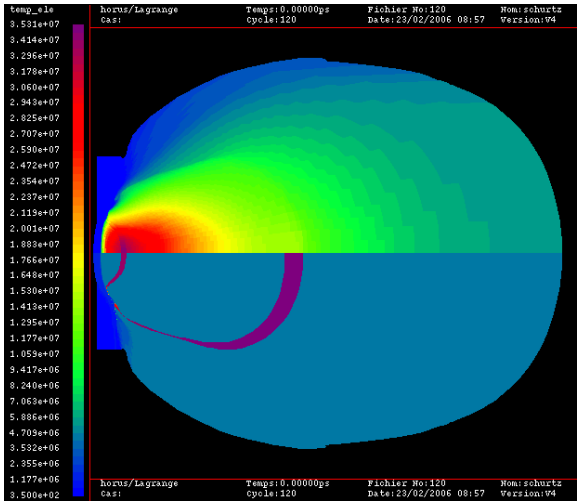
16/ 12/ 2005
2000 Å @ -5 / -15 µm,
10 kJ

21/ 12/ 2005
2000 Å @ -5 / -15 µm,
4.1 kJ

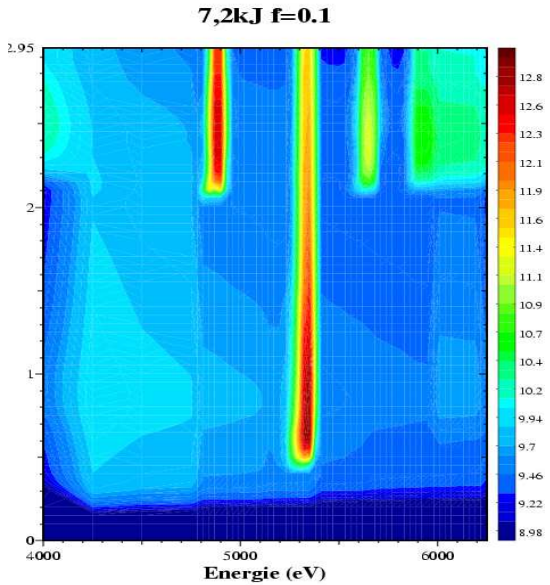
2D CHIC simulations







Radiation transfer along rays simulate X-ray diagnostics



Post processing of 2D simulations suggest a strong flux inhibition

conclusions

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« Non Local theory in itself fails. It has to be combined with magnetic fields calculations. In this case , the agreement with measurements is startling. »

The ODALISC Project

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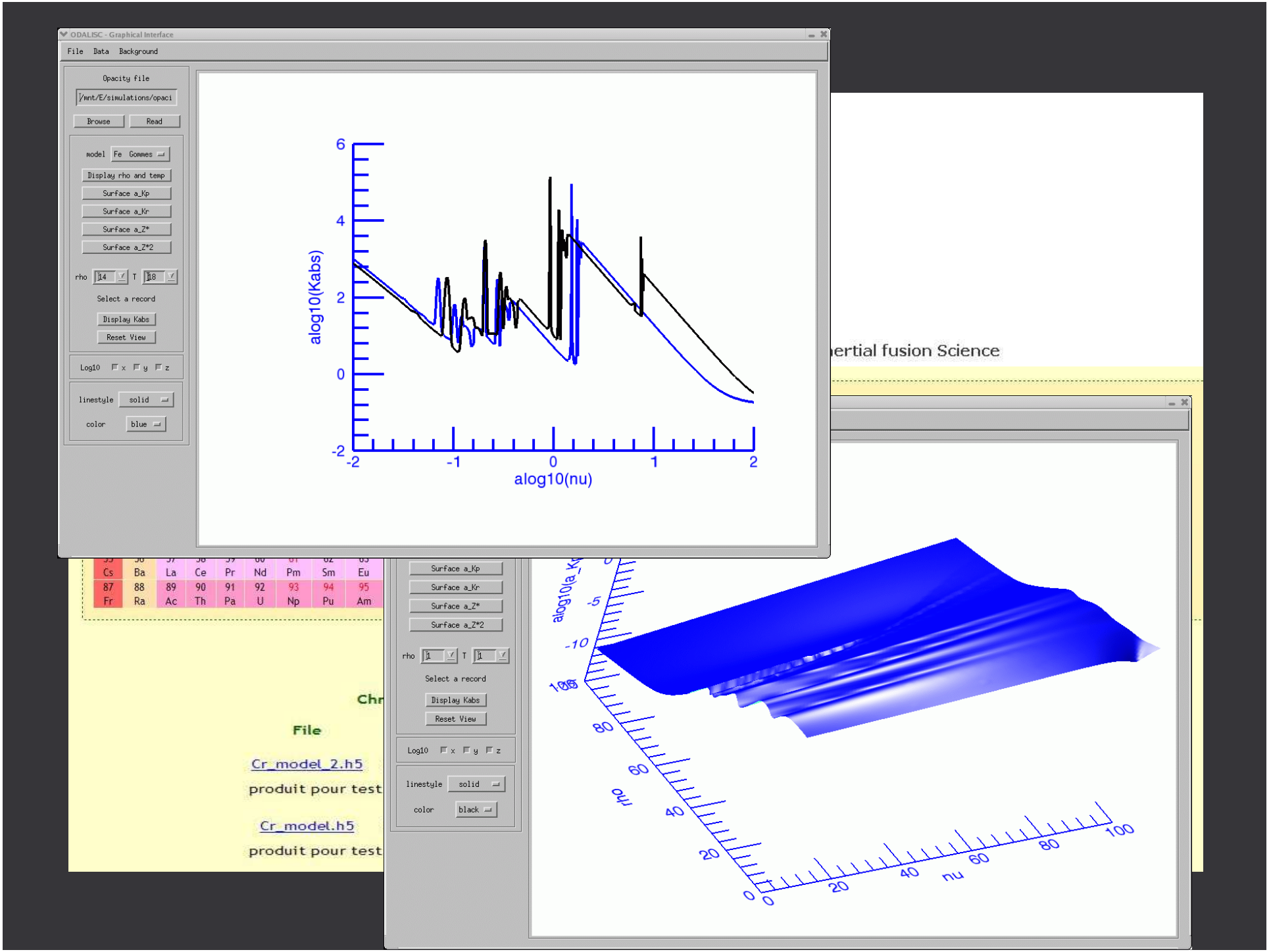
Opacity Database for Astrophysics, Laboratory astrophysics and Inertial fusion SCience

The objectives are to construct a shared spectral opacity database :

- Ødedicated to radiation-hydrodynamics calculations
- Ødifferent opacity model available with the same interfac
- Øshared between the co-working labs.


ODALISC - Graphical Interface
File Data Background
Opacity file
/mnt/E/simulations/opaci
Browse
Read
model Fe Gommes
Display rho and temp
Surface a_Kp
Surface a_Kr
Surface a_Z*
Surface a_Z*2
rho 14 T 18
Select a record
Display Kabs
Reset View
Log10 x y z
linestyle solid
color blue
alog10(Kabs)
alog10(nu)
ertial fusion Science
Cs Ba La Ce Pr Nd Pm Sm Eu
87 88 89 90 91 92 93 94 95
Fr Ra Ac Th Pa U Np Pu Am
Chr
File
Cr_model_2.h5
produit pour test
Cr_model.h5
produit pour test
Surface a_Kp
Surface a_Kr
Surface a_Z*
Surface a_Z*2
rho 1 T 1
Select a record
Display Kabs
Reset View
Log10 x y z
linestyle solid
color black
alog10(a_Kp)
nu
nu

People in ODALISC

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Bruno Thooris

§ CEA/DRECAM : Thomas Blenski, Michel Poirier, Frederic Thais

§ CEA/DAM/DPTA: Christophe Blancard, Philippe Cosse (see poster)

§ Observatoire de Paris (LUTH) : Frank Delahaye, Claude Zeippen

§ CELIA : Olivier Peyrusse, Guy Schurtz