Pathways to Fusion Beyond NIF: the perspective of the French Academic Community

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CEA – Commissariat à l'energie atomique et aux energies alternatives
CEA- DAM (Direction des Applications Militaires):

- **Simulation Program: Stewardship of the Nuclear Stockpile**

Academic Community: CNRS, Universities, "Civilian" side of CEA, …
Organised within the ILP

- **Study of the Physics of High Energy Density Physics,**
- **Study of Direct-Drive approach to Inertial Fusion for Energy Production (IFE)**
- **Study of "Advanced Ignition Schemes" (Shock Ignition, Fast Ignition)**

Region Aquitaine has funded PETAL (Petawatt Aquitaine Laser) the high-intensity short-pulse companion to LMJ.

The Agreement between CEA and Region Aquitaine implies that 20 to 30% of the installation time will be dedicated to Civilian Research performed by the European Academic Community)

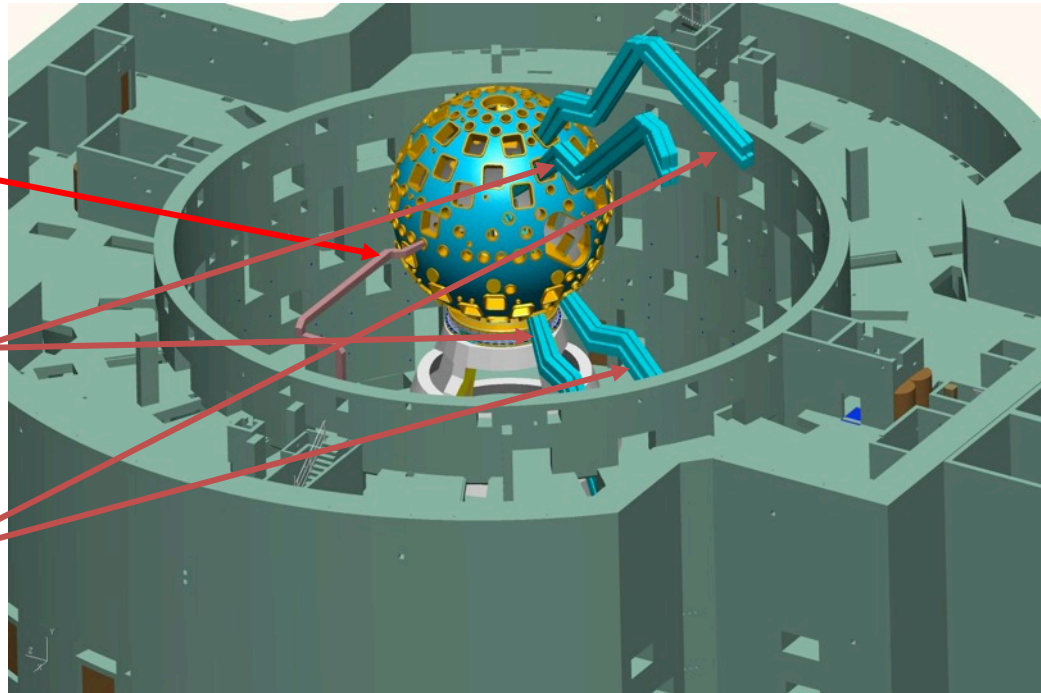
PETAL - Energy ≈ 3.5 kJ, Wavelength: 1053 nm,

Duration: 0,5 ps to 10 ps, Intensity on target: > 10^{20} W/cm^2

Quad LMJ - Energy > 30 kJ, Wavelength: 351 nm,

Duration: a few ns, Intensity on target: > a few 10^{15} W/cm^2

Configuration 2017



Elaborate a scientific programme for the Academic Research on LMJ/PETAL

4 "pillars" of the programme…

1) Fusion: we will have a full-scale facility where it will be possible to demonstrate shock ignition of fusion targets (D.Batani, V.Tikhoncuk)

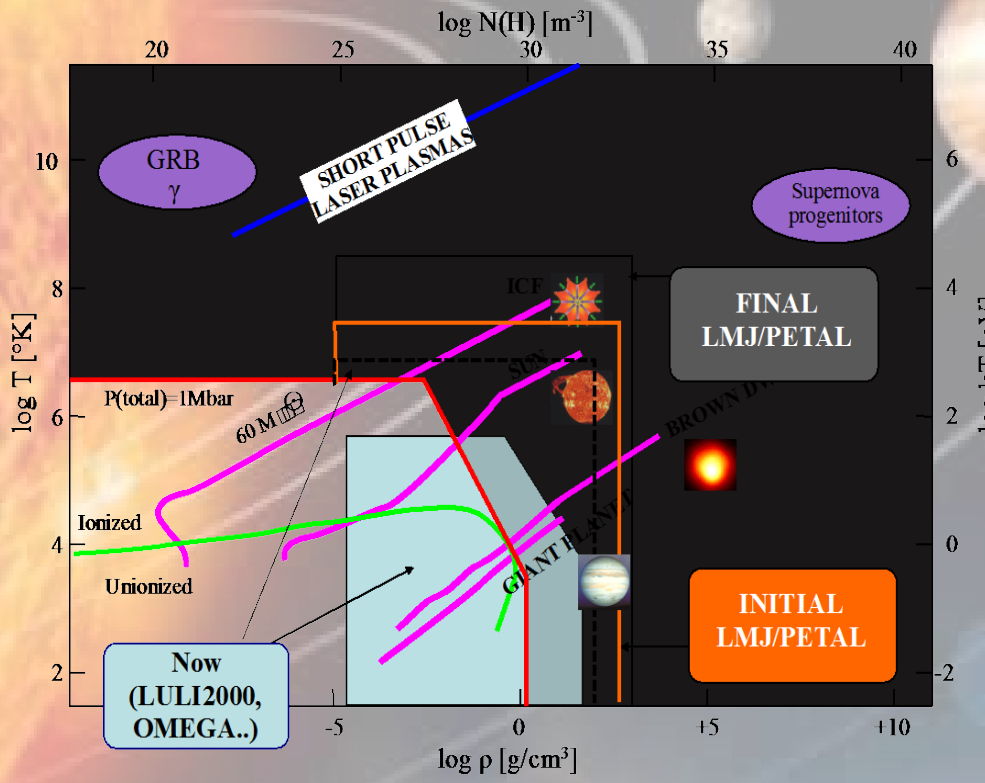
2) Studies of matter in extreme conditions & High Energy Density Physics (A.Benuzzi, F.Guyot)

3) Laboratory Astrophysics Experiments (M.Koenig, J.P.Chieze)

4) Acceleration and High Energy Physics (G.Mourou, B.Cros)

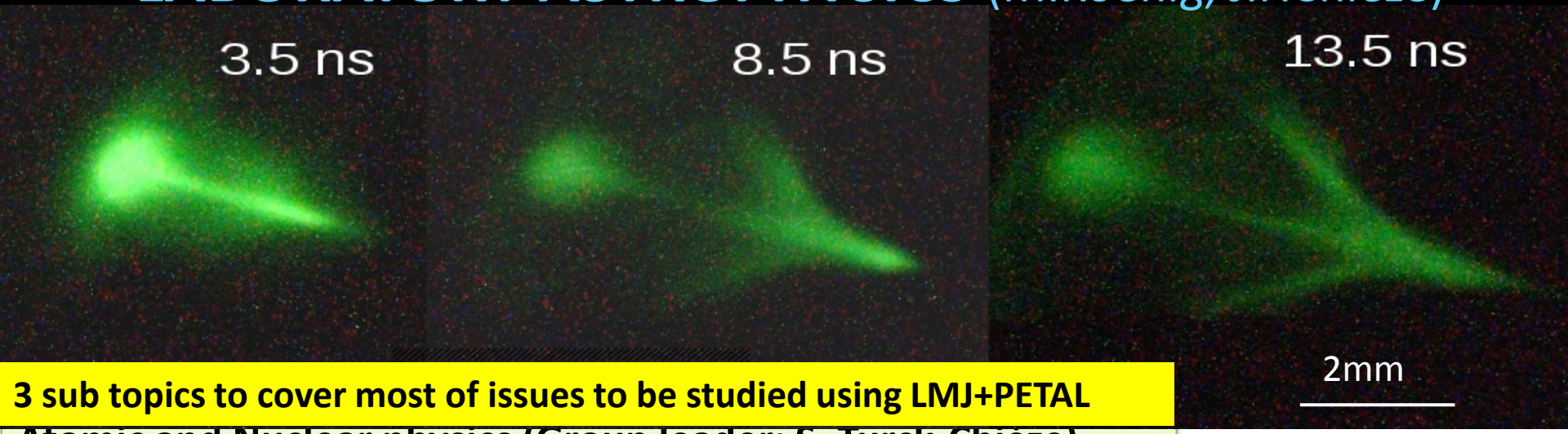
Working group
MATERIALS AND HIGH ENERGY DENSITY PHYSICS

(A.Benuzzi-Mounaix, F.Guyot)



- Planetary and star matter physics
- Chemistry and materials at ultrahigh pressures
- Pathways to reach extreme states
- Diagnostic & simulations development

Working group
LABORATORY ASTROPHYSICS (M.Koenig, J.P.Chieze)



3 sub topics to cover most of issues to be studied using LMJ+PETAL

Atomic and Nuclear physics (Group leader: S. Turck-Chièze)

- **Transport and interaction of photons with matter**
- **Production of elements through reaction rates**

Radiation Magneto Hydrodynamics (Group leader: A. Ciardi)

Extreme radiation hydrodynamic regimes relevant to **the physics of supernovae explosion, accretion and ejection processes**

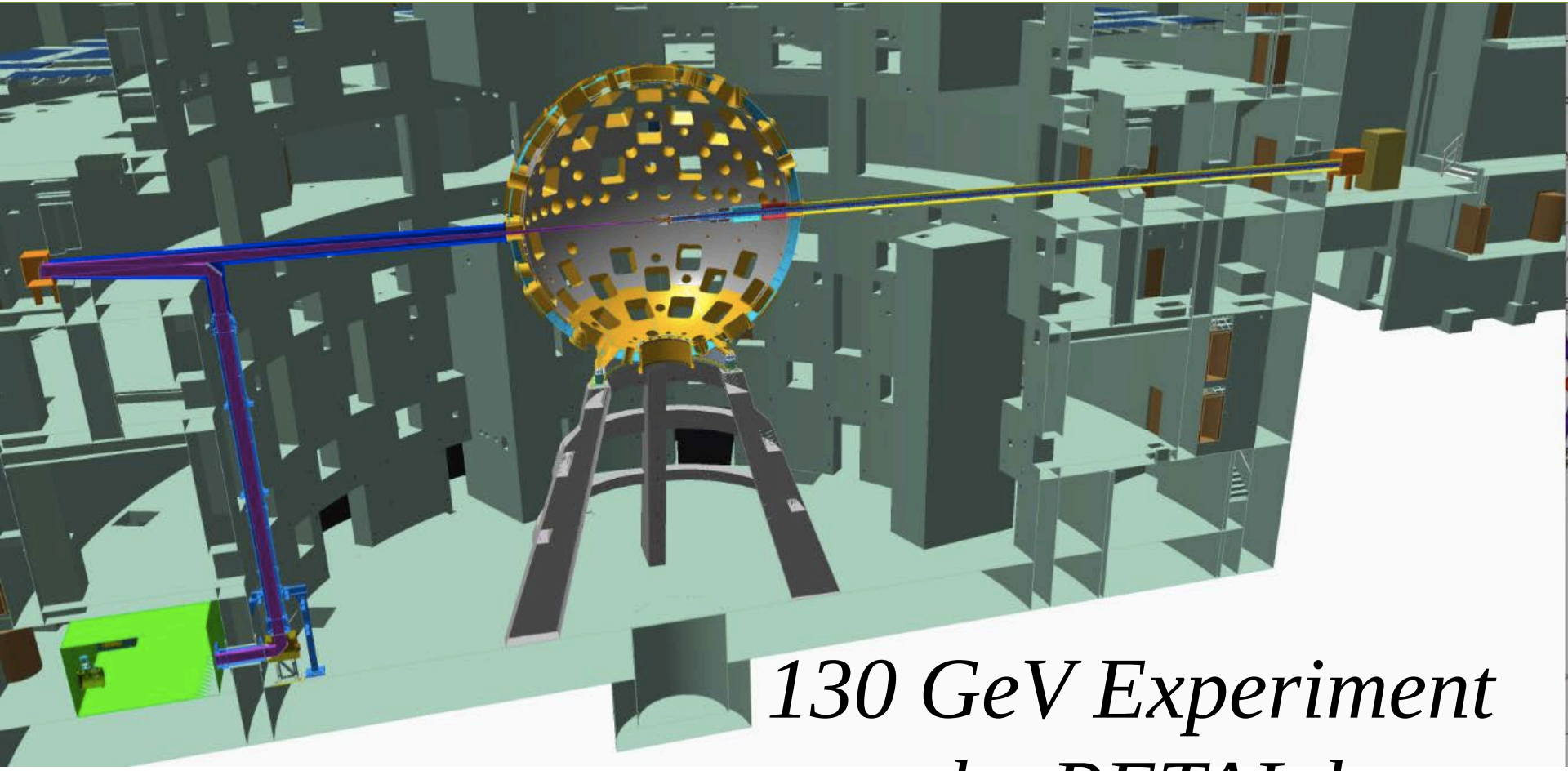
Relativistic Plasmas (group leader: G. Gregori)

- **collisionless shocks**
- **particle acceleration**
- **magnetic field generation, small-scale dynamo**
- **extreme radiation of these plasmas under electromagnetic turbulent state**

"Laboratory Astrophysics" experiment at PALS, Prague: Image in the X-ray range of a Cu plasma jet propagating in He gas at 15 bar

Working group
ACCELERATION AND HIGH ENERGY PHYSICS

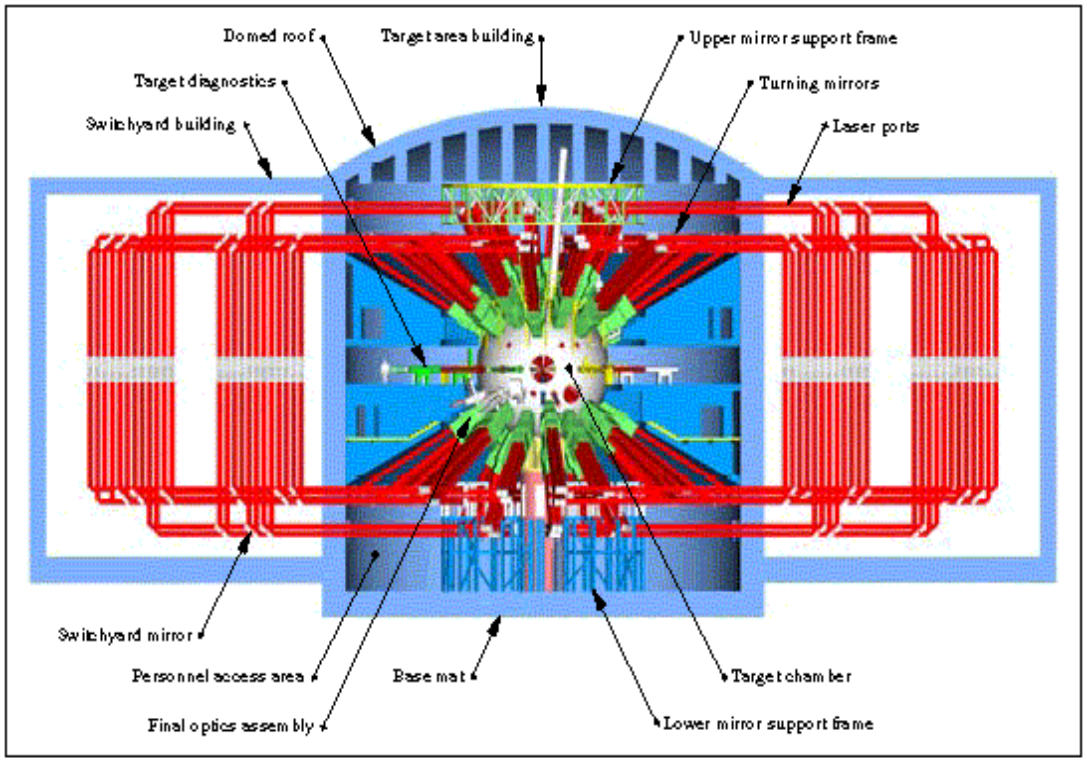
(B.Cros, G.Mourou)



Working group
DIRECT-DRIVE INERTIAL CONFINEMENT FUSION

(V.Tichonchuk, D.Batani)

Shock Ignition has been selected as the main route to IFE being promising and compatible with present day's laser technology

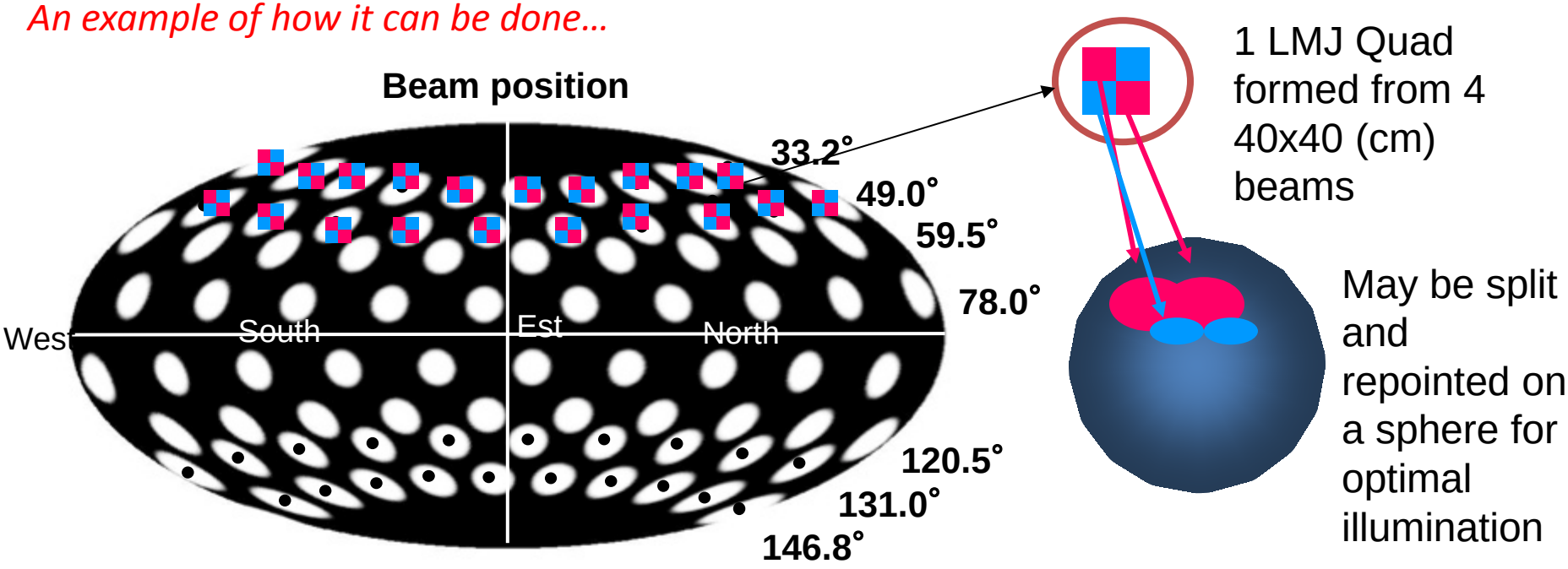


Nd:glass
2 MJ
10 ns
160 beams

Goal: Performing shock ignition demonstration experiments within the next decade

Necessary prerequisite:
Realising Polar Direct Drive (PDD)

An example of how it can be done…



40 quads pattern : - uses quad splitting, defocusing and repointing (Polar Drive)

80 beams for compression + spike (PDD) 3.8 kJ,

80 beams for spike only (DD, tight focus) 0.75 kJ

"combined" approach: no beam is only used for compression

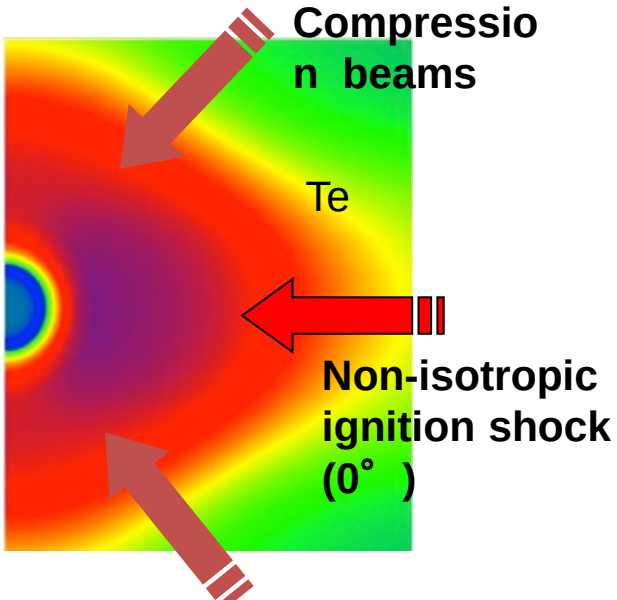
How to approach the demonstration of shock ignition on LMJ?

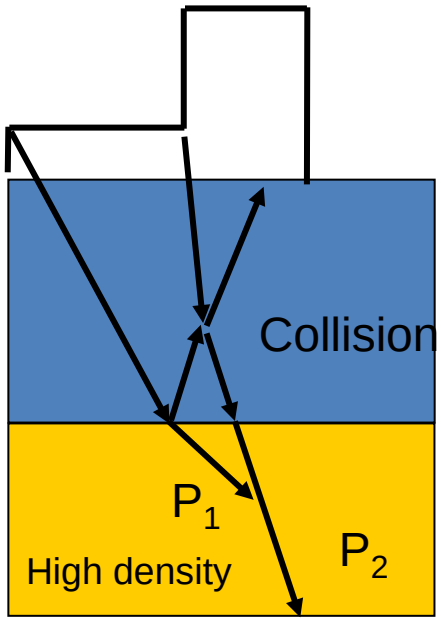
Many issues can be addressed on intermediate facilities

Related to "basic physics":
Capability of generating 300 Mbar shocks / Impact of hot electrons
Impact of parametric instabilities / Smoothing / Shock collision / Shock isotropization and smoothing by e-conduction

Related to "Polar Direct Drive":
Absorption at oblique incidence / Dynamic pointing / Validate code platform

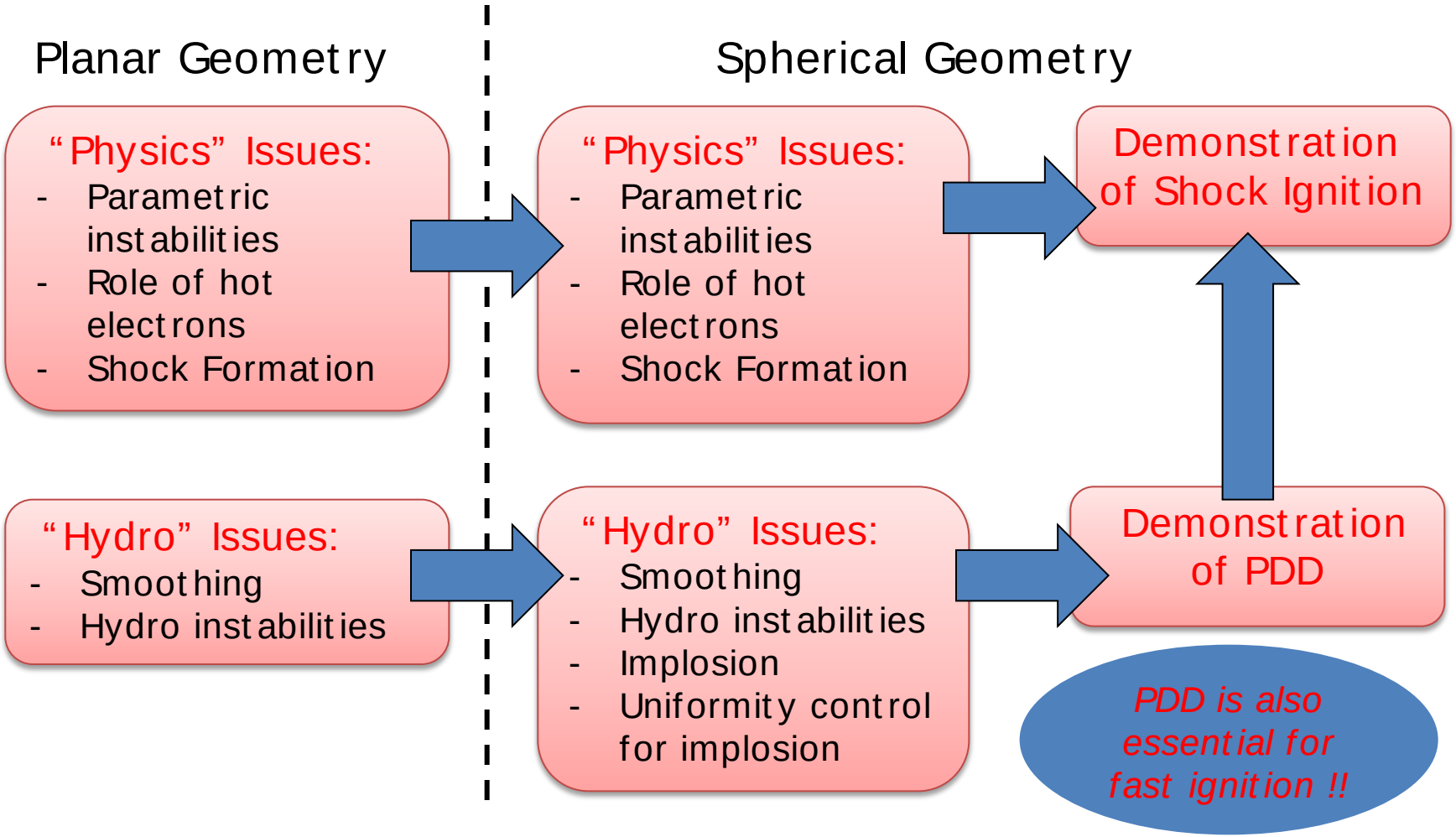
Related to LMJ in particular:
How to realize PDD and shock spike on LMJ





Road map to shock ignition

How to reliably approach the final goal of "Performing shock ignition demonstration experiments" on LMJ?



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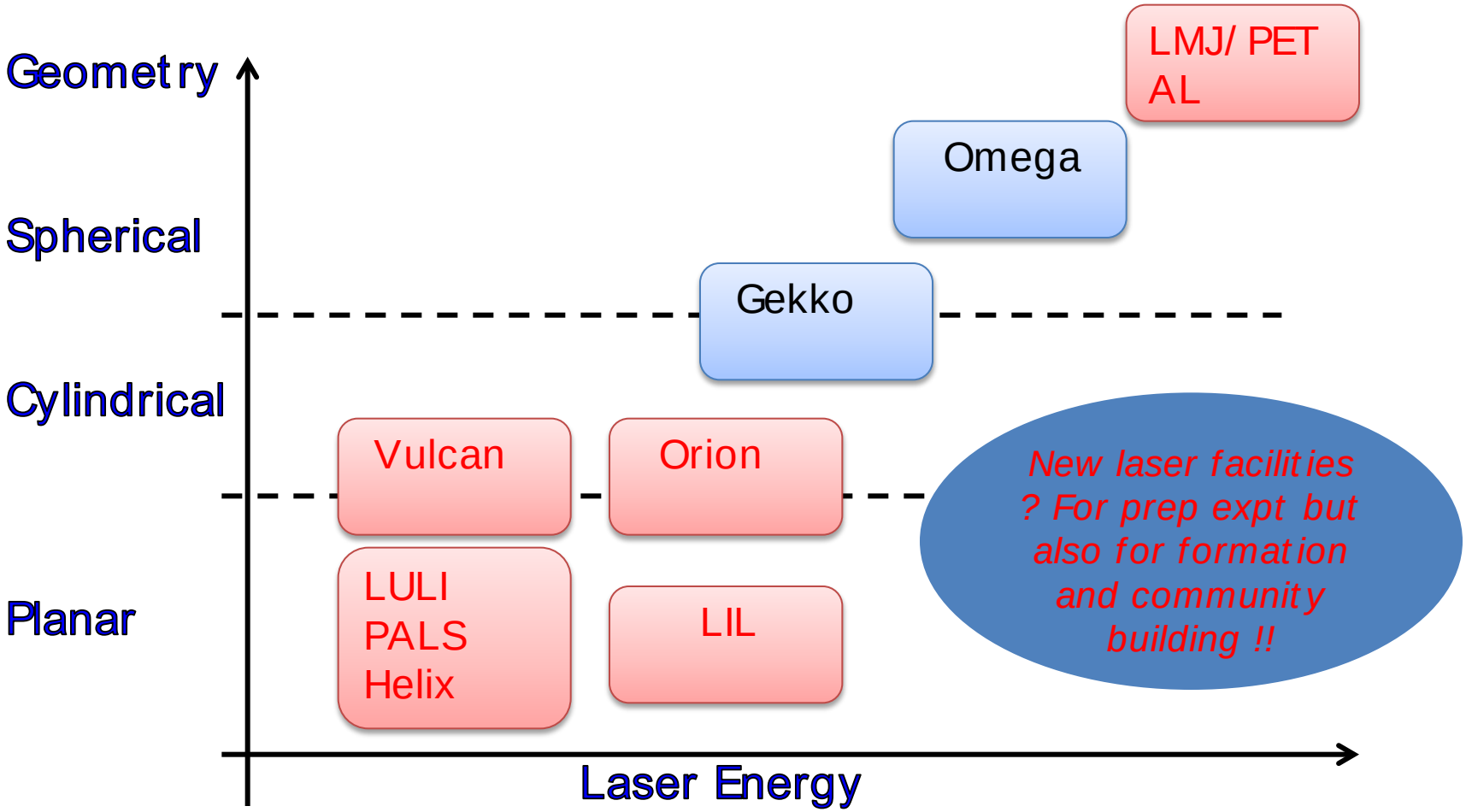


The Future

European Laser
"Rainbow"

Un laser petawatt couplé à des lasers nanosecondes construit en Aquitaine

LIL Ligne d'intègration laser
Orion, UK

Vulcan, RAL
LULI 2000
PALS, Prague

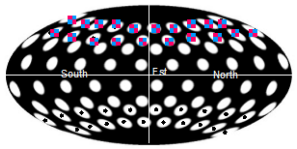
In Europe we have unique possibilities to perform a full series of experiments progressing form small to big lasers:

Synergies

Studying Shock Ignition Physics and preparing SI demonstration experiments on LMJ is also the objective of

HiPER

cost



INSTITUT LASERS ET PLASMAS

Petal

REGION AQUITAINE
EN AQUITAINE & EN AVANCE

COST Action 1208 - Developing the Physics and the Scientific community for Inertial Confinement Fusion

Objective: Developing the Physics and the Scientific community for ICF, via networking activities. This implies: 1) Common experiments both in Europe and overseas (Japan, US), 2) Catalyze the formation of new scientists competent in this field, 3) Study important physical problems related to the physics of ICF

ILP - Preparing the Academic Scientific Programme for LMJ/PETAL for the years to come

1) Fusion: LMJ will be a full-scale facility where it is possible to demonstrate shock ignition of fusion targets
2) Studies of matter in extreme conditions & High Energy Density Physics
3) Laboratory Astrophysics Experiments
4) Acceleration and High Energy Physics

Access to the European Academic Community