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Consiglio Nazionale
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First experiments in a new 250TW laser laboratory devoted to laser-plasma acceleration and Thomson scattering studies

Presented by
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[†] *PLASMONX national representative*
[††] *FLAME commissioning manager*

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The PLASMONX project

Pisa, 19 Marzo 2005

PLAsma acceleration and MONochromatic X-ray production

PLASMONX

Conceptual Design Report

Combining the high brightness LINAC accelerator of the SPARC project with an ultra-short, high energy, >250TW laser system (FLAME)

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PLASMA ACCELERATION AND MONOCHROMATIC X-RAY PRODUCTION

Scheduled activity

- LWFA with both externally injected and self-injected e-bunches
- Linear and Nonlinear Thomson scattering X/γ-ray sources: backscattering of the laser pulse on both LINAC e-beams and LWFA e-beams
- Intense laser-matter interactions, proton acceleration

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PLASMONX Units

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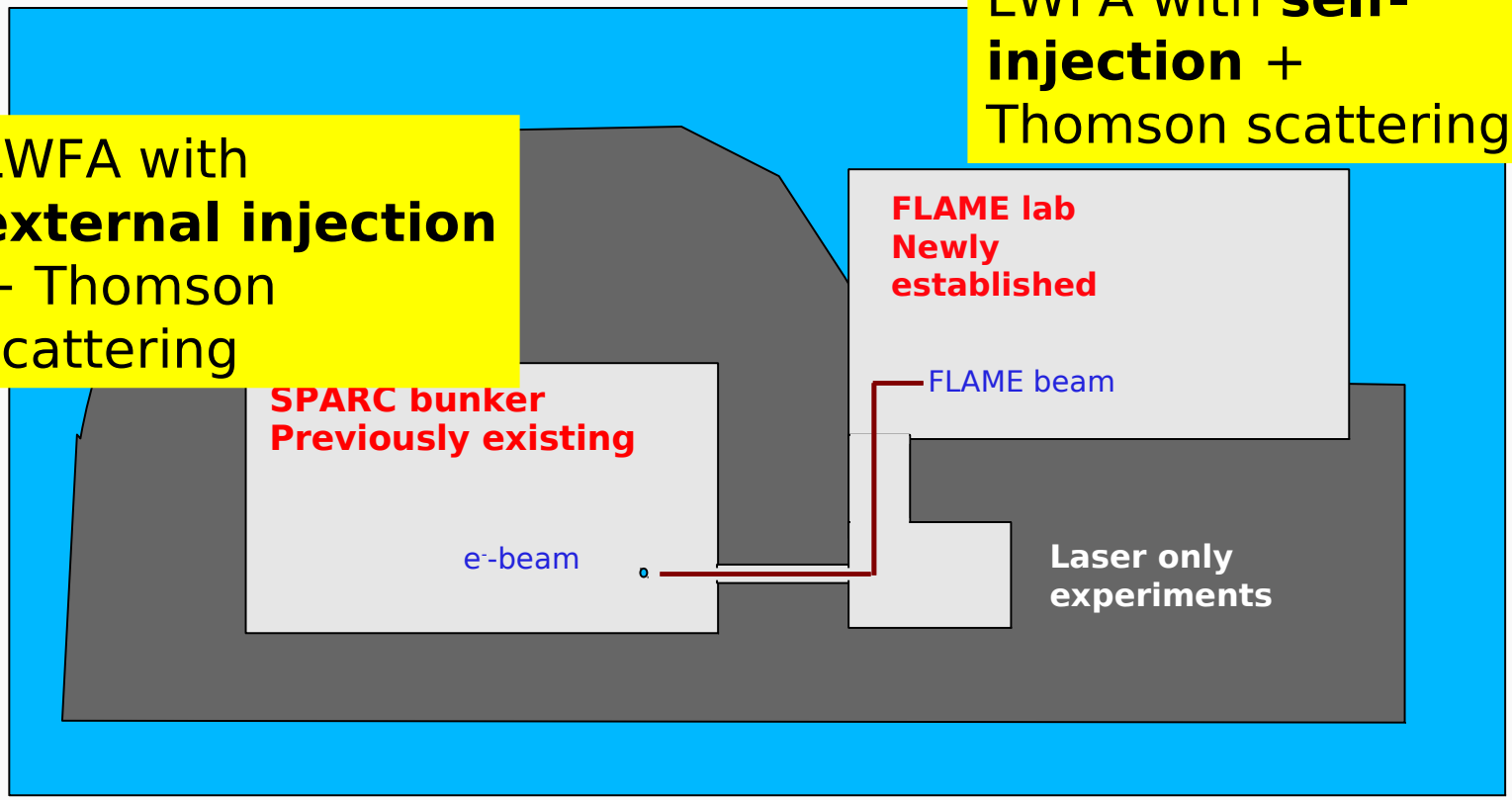
Schematic view of the "LIFE" (laser+linac) labs

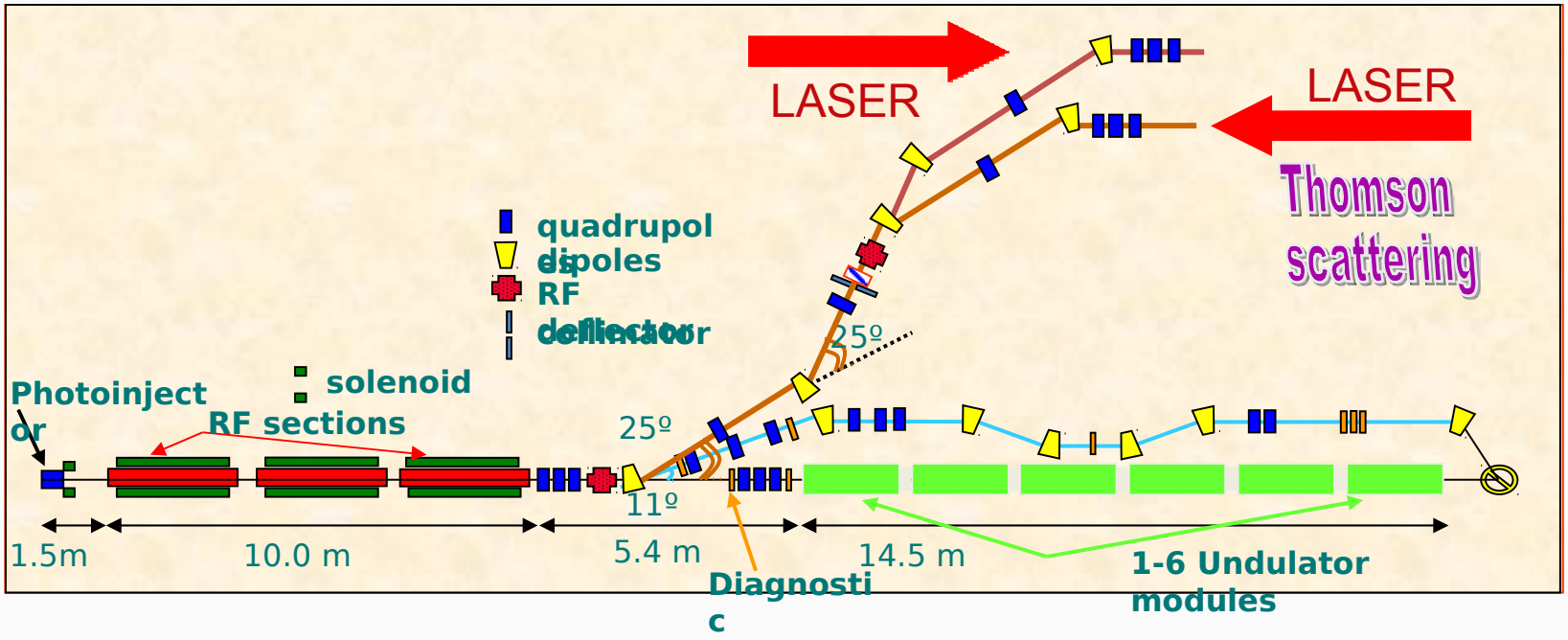
LWFA with **external injection** + Thomson scattering

LWFA with **self-injection** + Thomson scattering



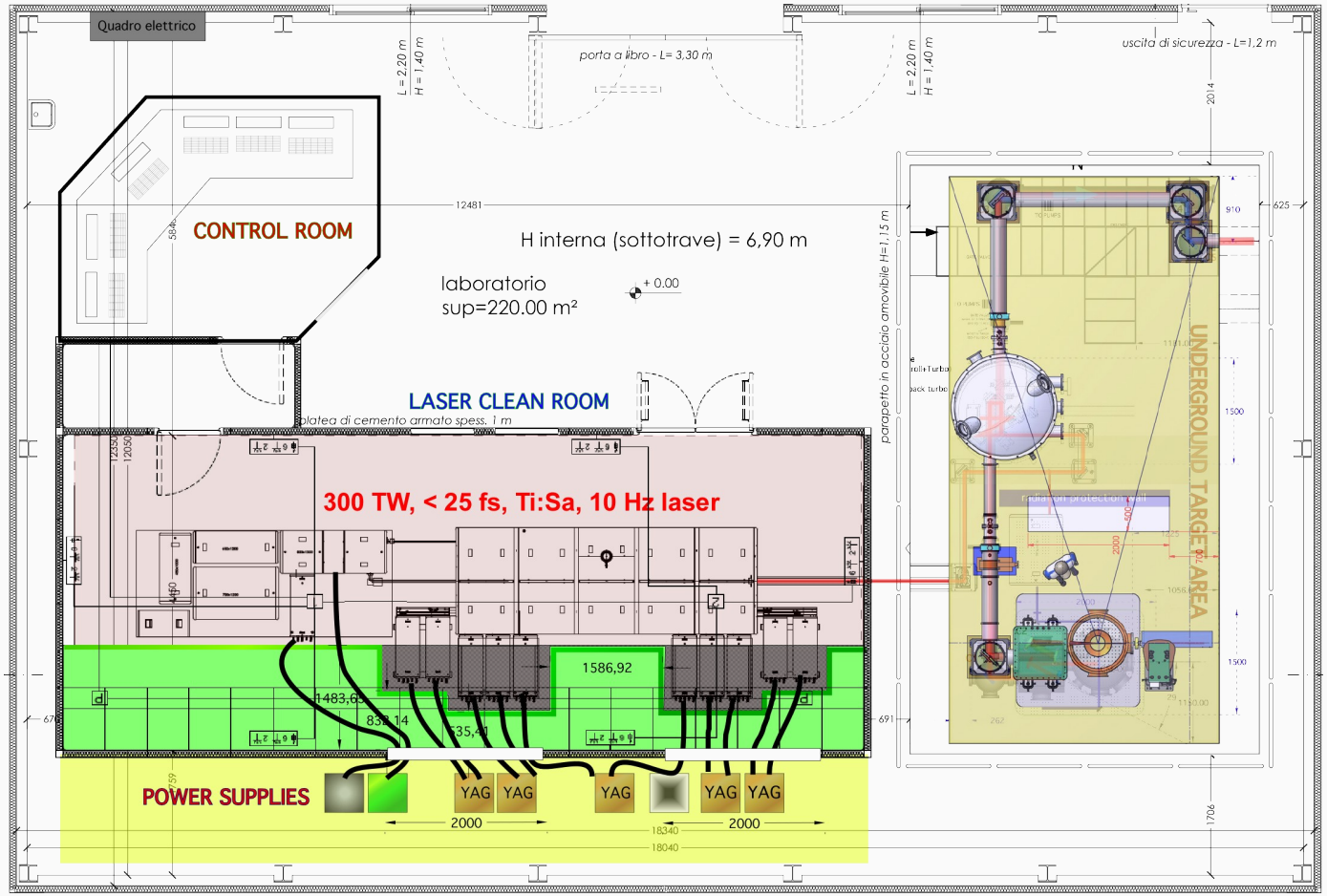
The *SPARC* LINAC at LNF

Parameter	value
Bunch charge(nC)	$1 \div 2$
Energy (MeV)	$28 \div 150$
Length (ps)	$15 \div 20$
$\epsilon_{nx,y}$ (mm-mrad)	$1 \div 5$
Energy spread(%)	$0.05^{1} \div 0.2$
Spot size at interaction point rms (mm)	$5 \div 10$



The FLAME laser laboratory

The FLAME (*Frascati Laser for Acceleration and Multidisciplinary Experiments*) laboratory includes the FLAME laser system, a radioprotected target area for laser-target experiments and transport of laser to the SPARC bunker



The FLAME lab – history 1/2

27th March 2007 – beginning of construction

23rd June 2008 – Building completed

The FLAME lab – history 1/1

12th March 2009 –
delivery of laser

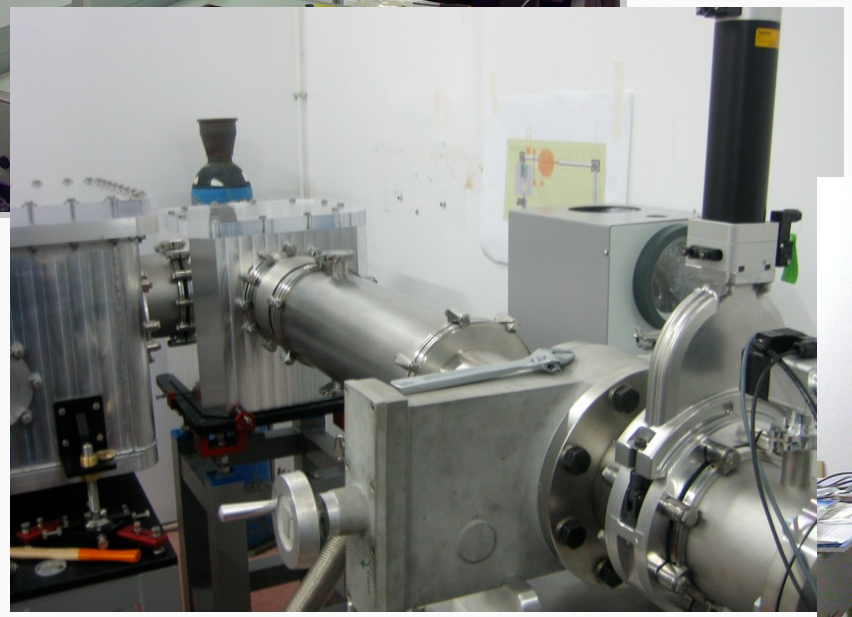
18th May 2009 –
start of Installation of clean room

10th June 2009 –
"Cold" laser installation

The FLAME lab – recent past

October 2009 –
Laser wiring and connections completed
Oscillator start-up;

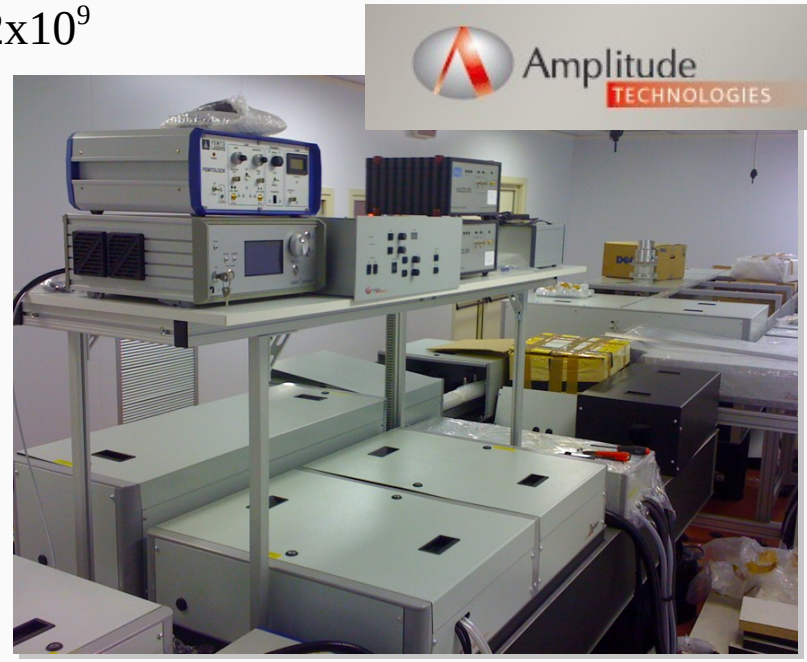
December 2009 –
1st vacuum transport line completed;



July 2010 -
Laser at target point;

The FLAME laser: performances to date

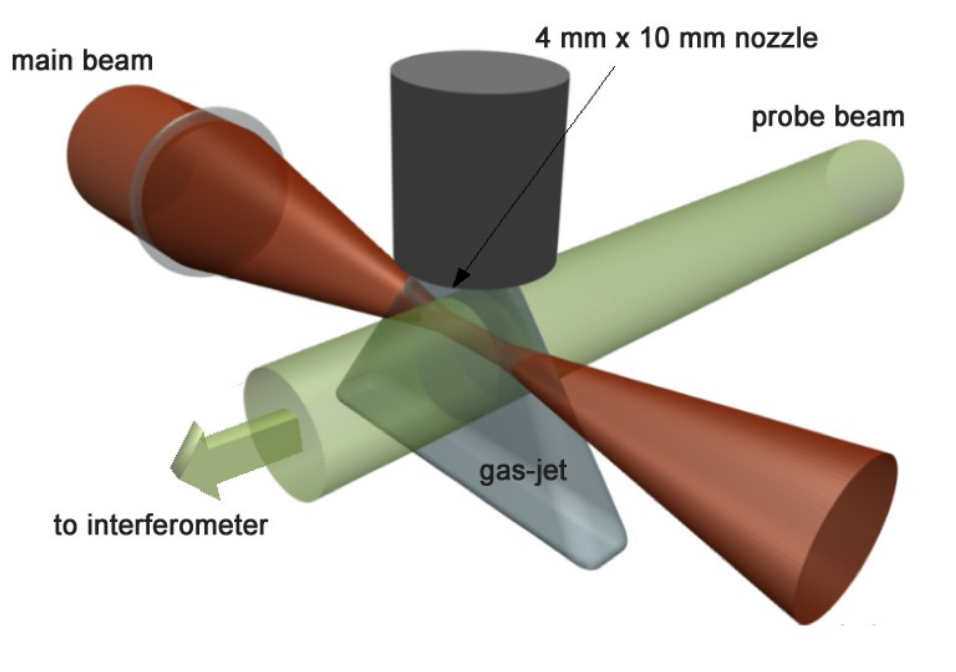
Repetition Rate	10 Hz
Energy (after compression)	up to 6 J (typ. exp. 5.6J)
Wavelength	800 nm
Pulse duration	down to 21 fs (typ.23 fs)
Peak power	up to 300 TW
ASE contrast ratio	better than $2x10^9$
RMS pulse energy stability	0.8%
Pointing stability (including path)	< 2µrad



The "SITE" experiment

The SITE (self-injection test experiment) is the first "laser only" scheduled experiment, mainly conceived to assess the laser performances

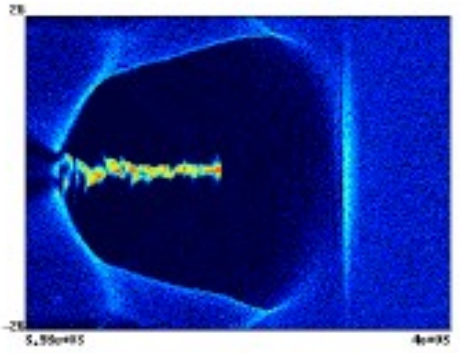
$L_{gas\ jet}$ [mm]	n_e [e/cm^3]	τ [fs]	I_0 [W/cm^2]	w_0 [μm]
4	$3 \cdot 10^{18}$	30	$5.2 \cdot 10^{19}$	16

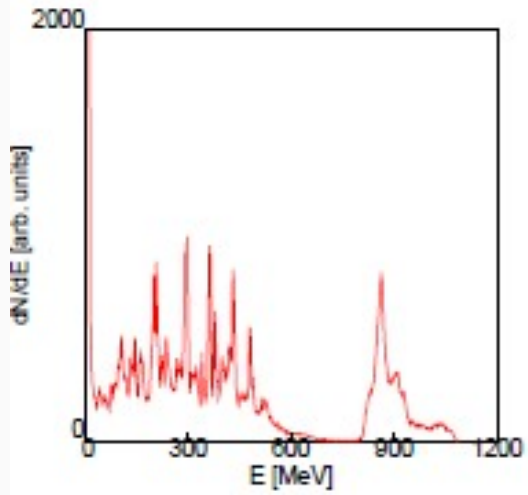


PIC simulations performed using the code AlaDyn by C. Benedetti
See: L.A. Gizzi et al., EPJ-ST, 175, 3-10 (2009)

The "SITE" experiment: PIC simulation

$ct = 4000\ \mu$m





$W_{peak} \simeq 900$ (as predicted !)
$\Delta W/W = 3.3$ %

Considering the particles with $|W - 900| < 90$ MeV

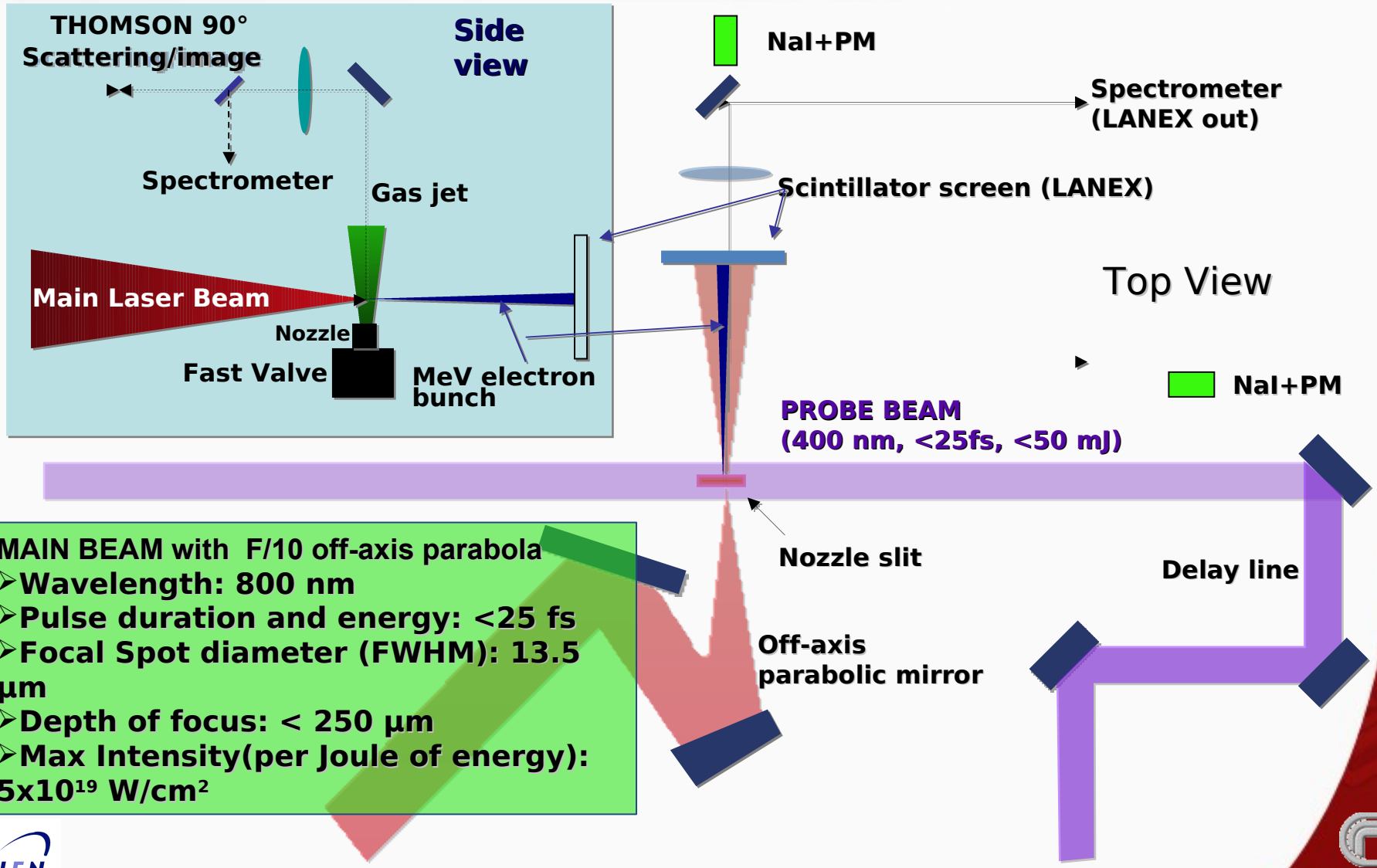
$\sigma_x \simeq 0.47\ \mu$m
$\epsilon_{xn} \simeq 2.3$ mm mrad
$\sigma_{x'} = \epsilon_{xn}/(\gamma_{peak}\sigma_x) \simeq 2.8$ mrad

$\sigma_y \simeq 0.53\ \mu$m
$\epsilon_{yn} \simeq 2.8$ mm mrad
$\sigma_{y'} = \epsilon_{yn}/(\gamma_{peak}\sigma_y) \simeq 3.1$ mrad

$Q = 0.62$ nC
$\sigma_z \simeq 1.8\ \mu$m
$I_{aver} \simeq 45$ kA

PIC simulations performed using the code AlaDyn

The "SITE" experiment: setup layout



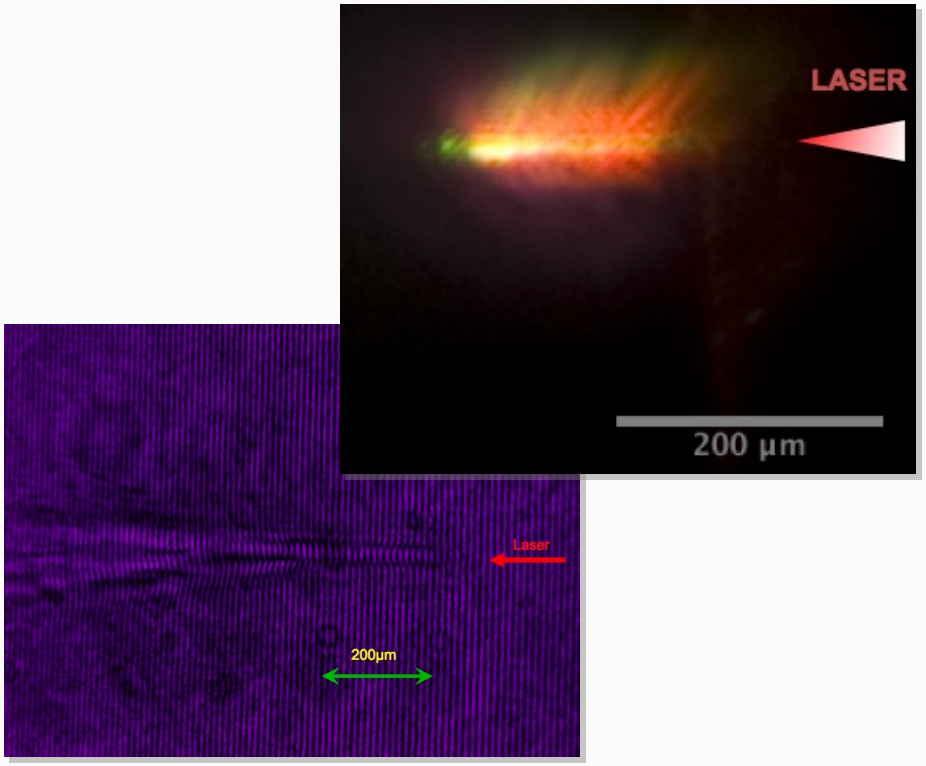
MAIN BEAM with F/10 off-axis parabola

- **Wavelength: 800 nm**
- **Pulse duration and energy: <25 fs**
- **Focal Spot diameter (FWHM): 13.5 µm**
- **Depth of focus: < 250 µm**
- **Max Intensity(per Joule of energy): 5×10^{19} W/cm²**

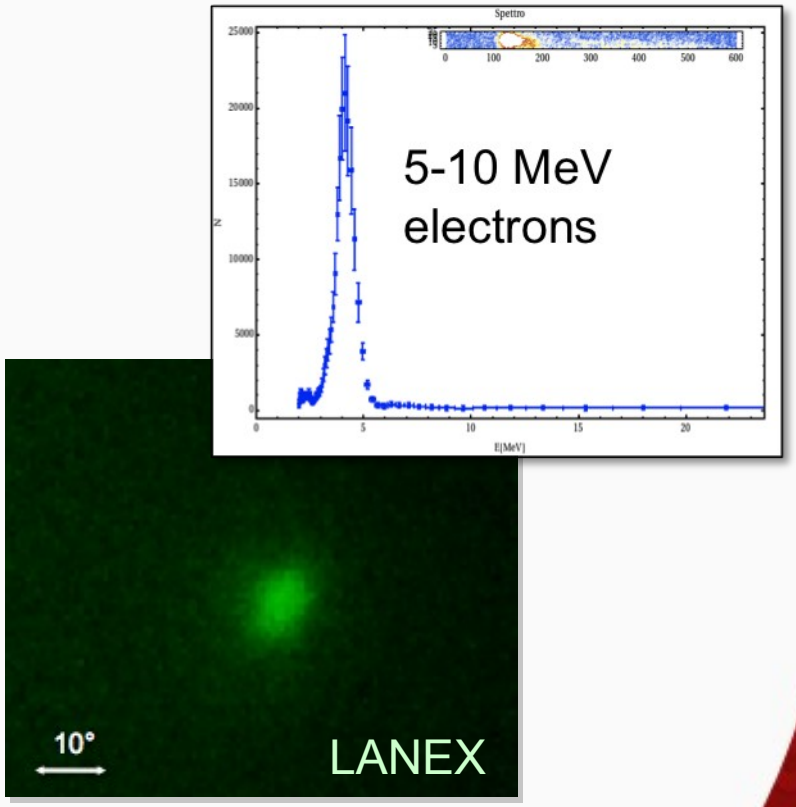
Results from a 2TW system at CNR - Pisa

A complementary experiment has been carried out at the Intense Laser Irradiation Laboratory of the INO-CNR in Pisa, demonstrating e- LWFA using a smaller scale (2TW) laser system

TS and interferometry show self-guiding



Electron bunch from He gas-jet



Work in progress now on possible applications (e.g., radiobiological studies, IORT)

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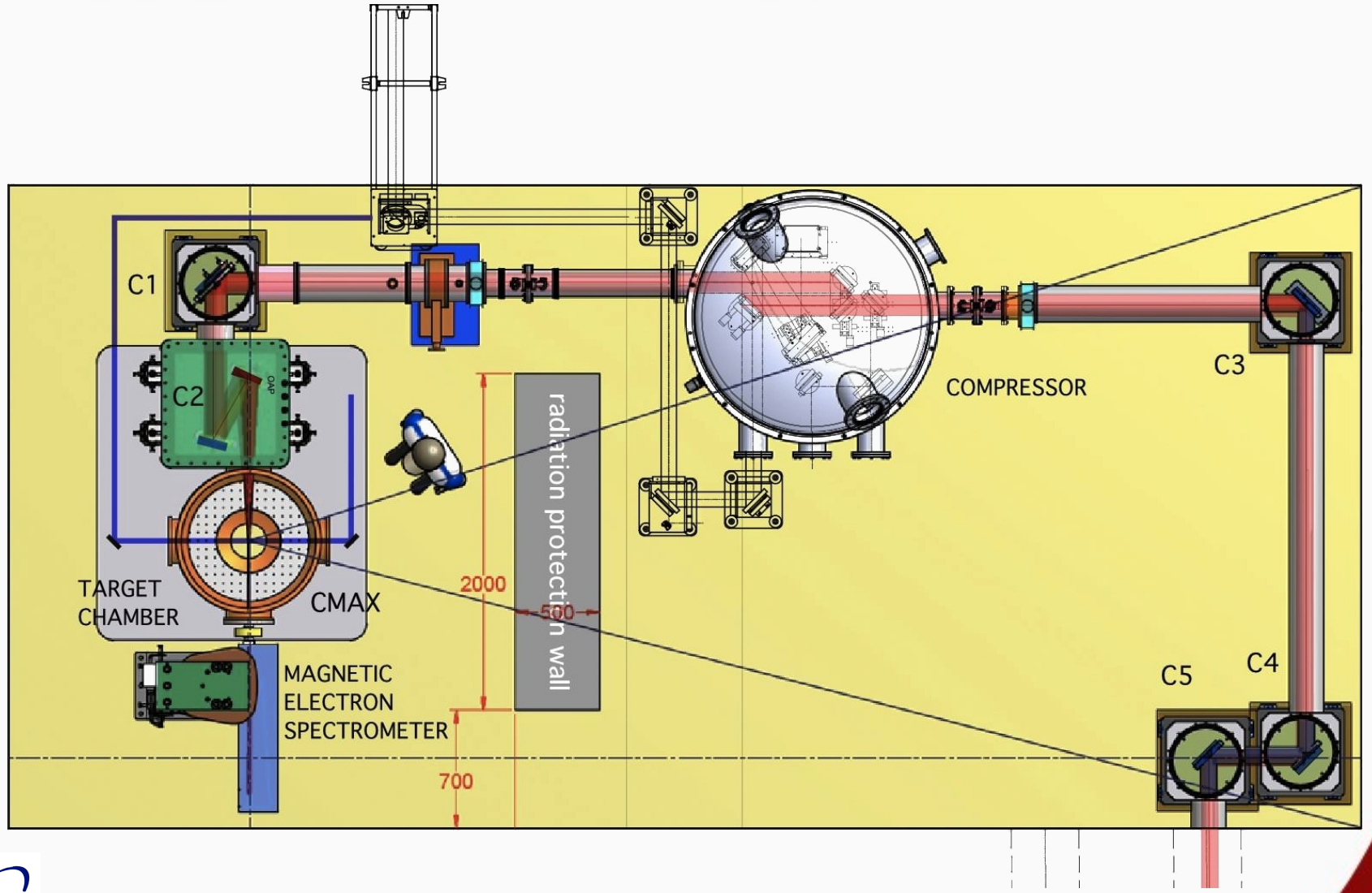
The FLAME "laser-only" Target Area



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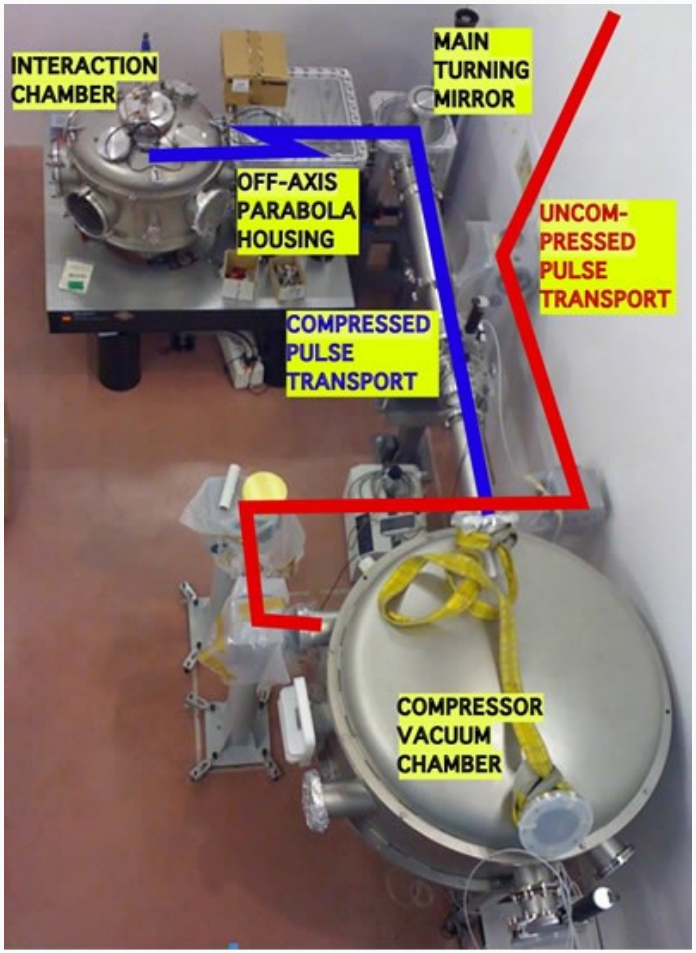
The FLAME "laser-only" Target Area



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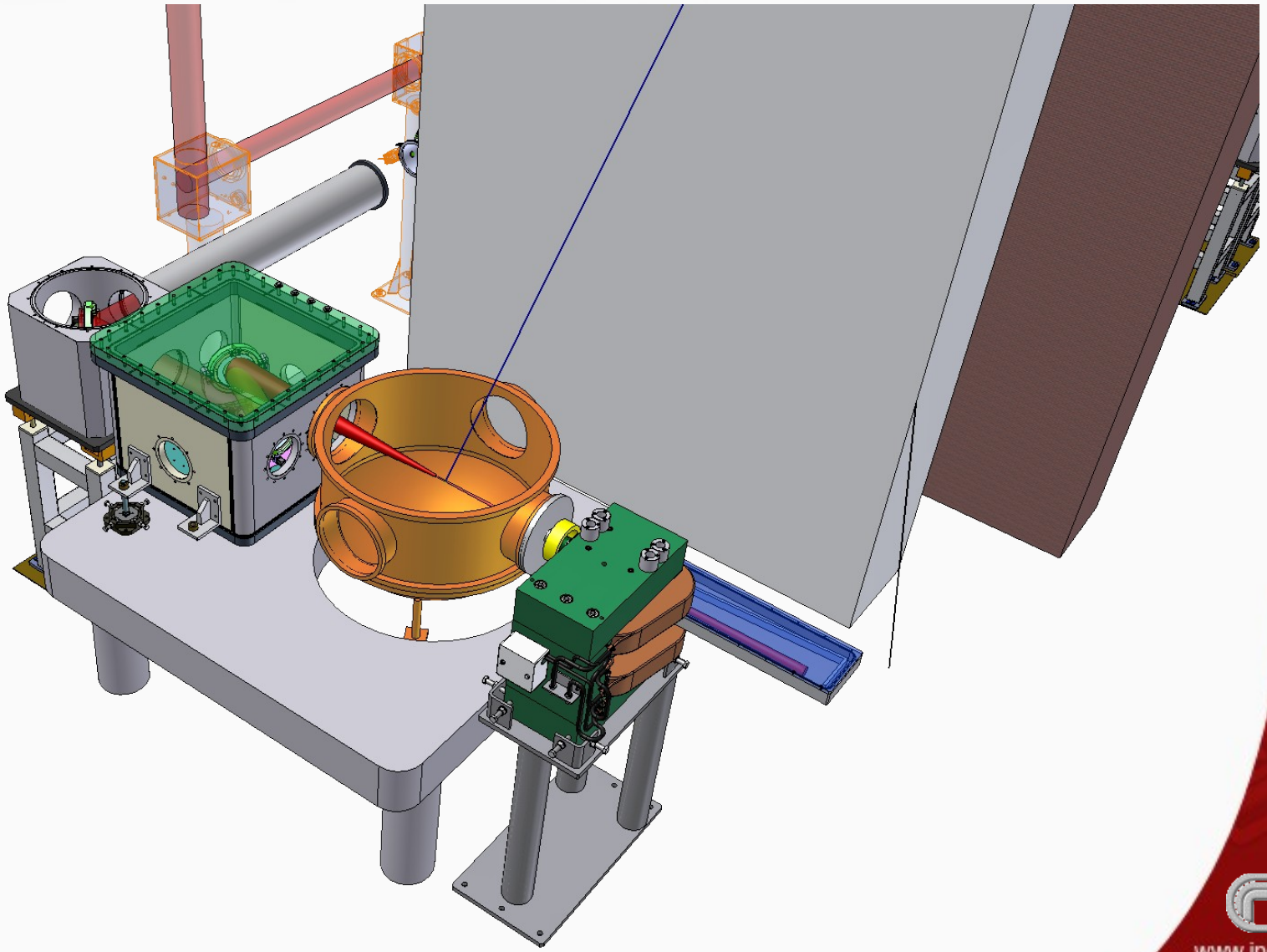
The FLAME Target Area: shelding



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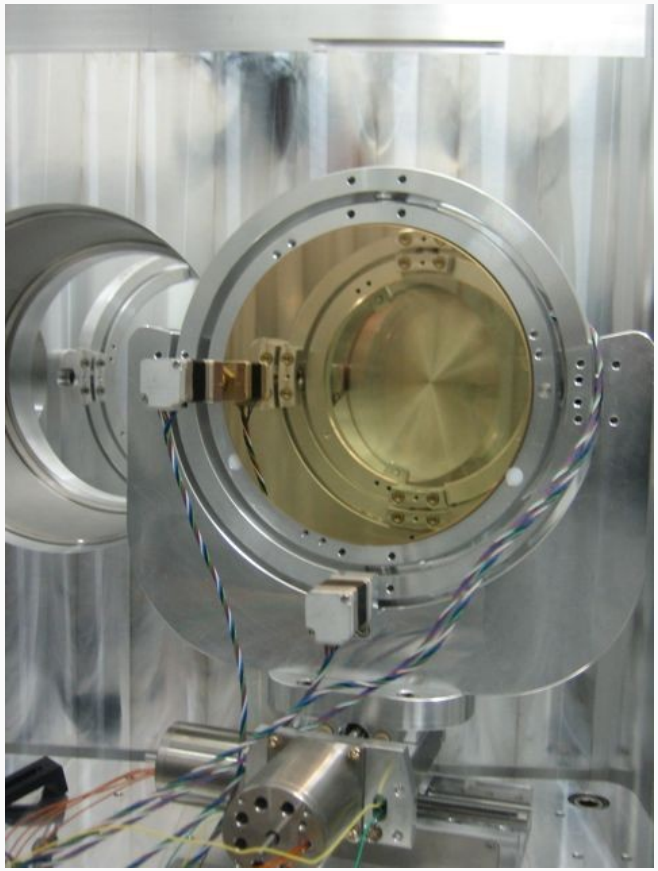
The FLAME Target Area: vertical/horizontal shielding

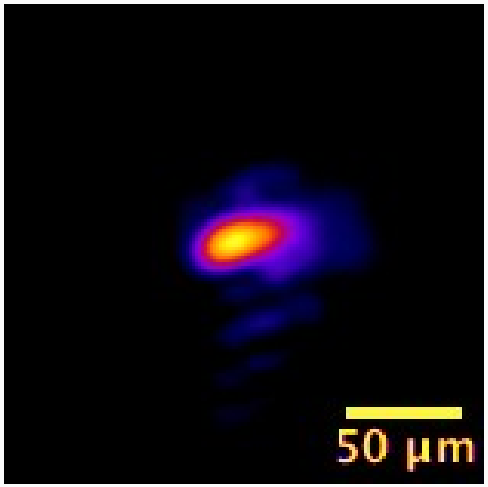
Main beam transport and OAP in place

Last turning mirror and OAP vacuum chamber

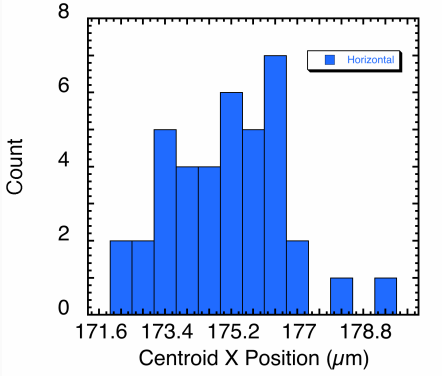
1m focal length, 15deg OAP

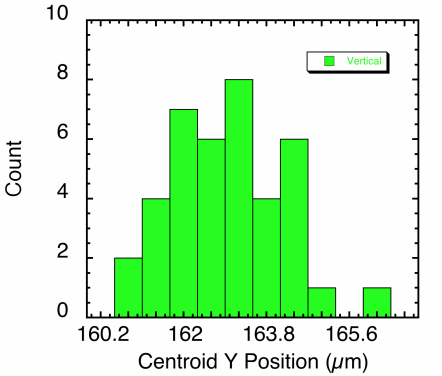


Laser pointing stability at TCC



Pointing stability at TCC





	Centroid Y	Centroid X
Minimum	160,89799	172,12
Maximum	166,22099	179,614
Points	39	39
Mean	162,9351	175,0372
Median	162,995	175,244
RMS	162,93927	175,04455
Std Deviation	1,18026	1,6241748
Variance	1,3930138	2,6379437
Std Error	0,18899286	0,26007611

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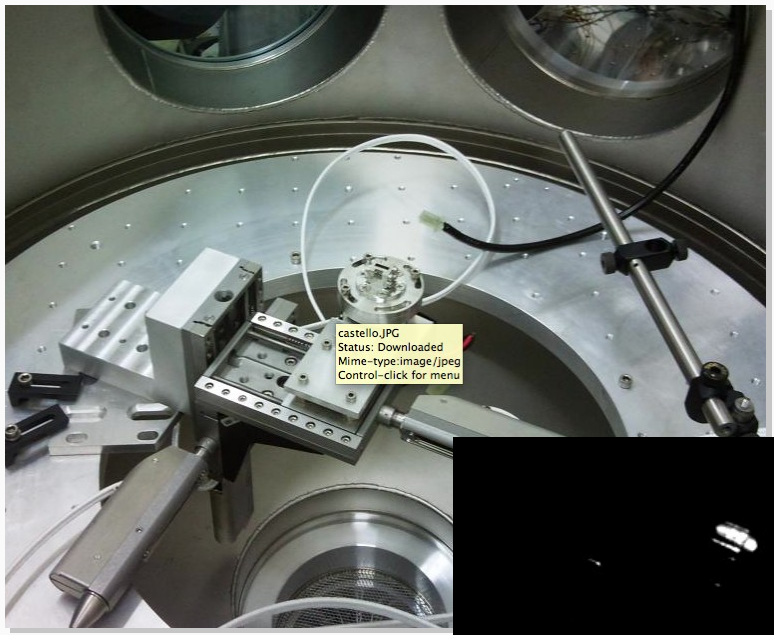
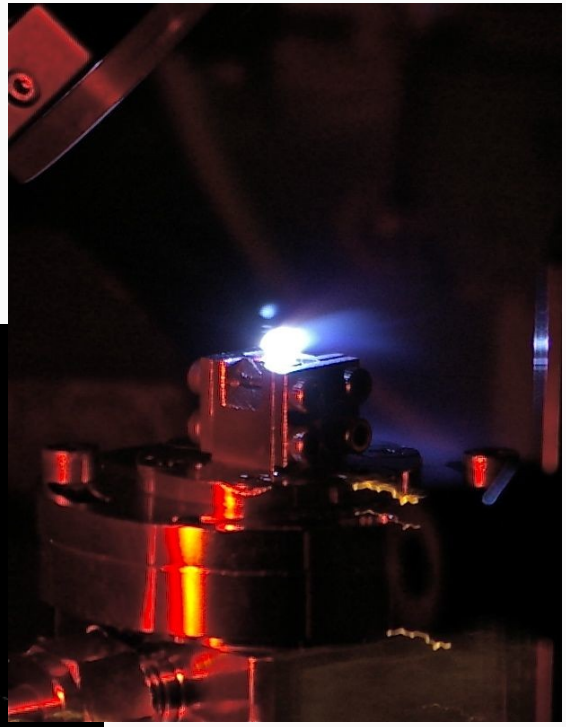
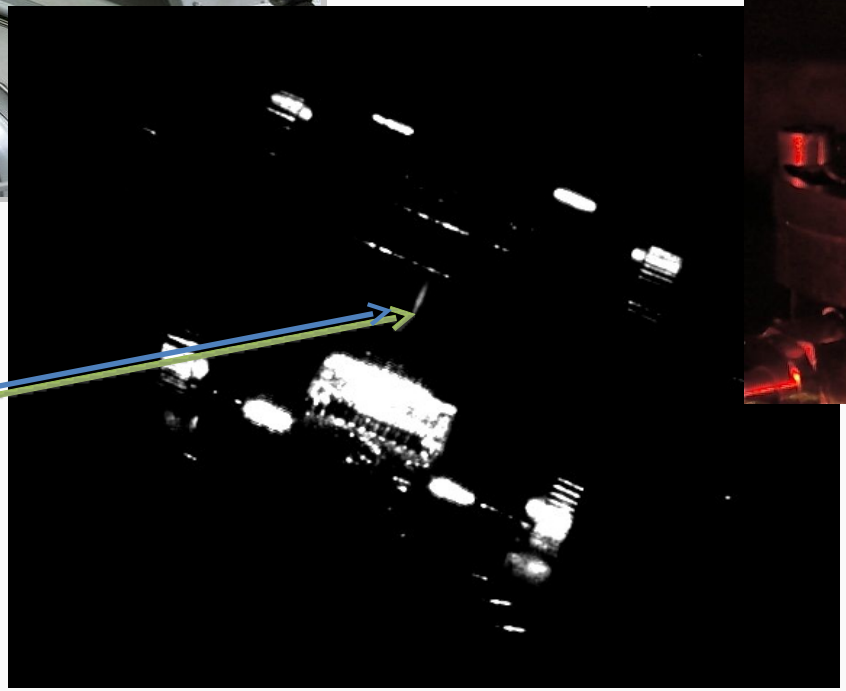
Latest: gas-jet target in place



August 2010: first plasma with f/10 OAP





Wide-field top view image of the plasma (Thomson scattering imaging)

Agenda for the next weeks

- Full power FLAME test: transport, compression, OAP focusing (no target)
- Laser performance test at output: far field, contrast, width, wavefront distortion measurements … prepare for adaptive optics
- Completion and test of HW and SW control and diagnostics
- Completion of hardware and registration for radioprotection, safety and control of operations
- Laser on (gas-jet) target at >50 TW level

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Planned activity for the PLASMONX project

ATTIVITÀ COMMISSIONING FLAME E PLASMONX 2010-2011	LUG	AGO	SET	OTT	NOV	DIC	1° TRI '11	2° TRI '11	3° TRI '11	4° TRI '11
Acceleration with self-injection (SITE) - Laser Beam and Plasma Diagnstics	■									
Acceleration with self-injection (SITE) - Bunch production and characterisation with 1.2 mm gas-jet	■	■								
Acceleration with self-injection (SITE) - Bunch production and characterisation with 4.0 mm gas-jet,		■	■	■						
Acceleration with self-injection (SITE) - Bunch stability and control vs laser stability				■	■	■				
Commissioning FLAME: Assessment and validation of laser performance at interaction focus point					■	■	■			
Thomson Scattering: Installation of additional e-beam line and delivery of laser beamline							■			
FAST: Installation of laser-linac sync							■			
Thomson Scattering: integration of target chambre components and X-ray source optimisation								■	■	
Thomson Scattering: X-ray beam to users (BEATS)									■	■
FLAME target area Maintenance + set up and preliminary tests for solid target experiments							■	■		
Ion acceleration (LILIA) at FLAME target area									■	■

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Summary

- A 250TW laser laser laboratory for LPA is now fully operational at LNF-INFN in the framework of the INFN project PLASMONX
- The lab is equipped with an underground, radiation shielded target area for “laser-only” experiments – awaiting authorizations
- A first “test” experiment has been conceived and is now under commissioning, mainly devoted to assess the laser system figures and performances
- PIC simulations shows that e- bunches should be obtained in such a test experiment with energy up to 900 MeV
- Rapidly approaching self-injection LPA measurements

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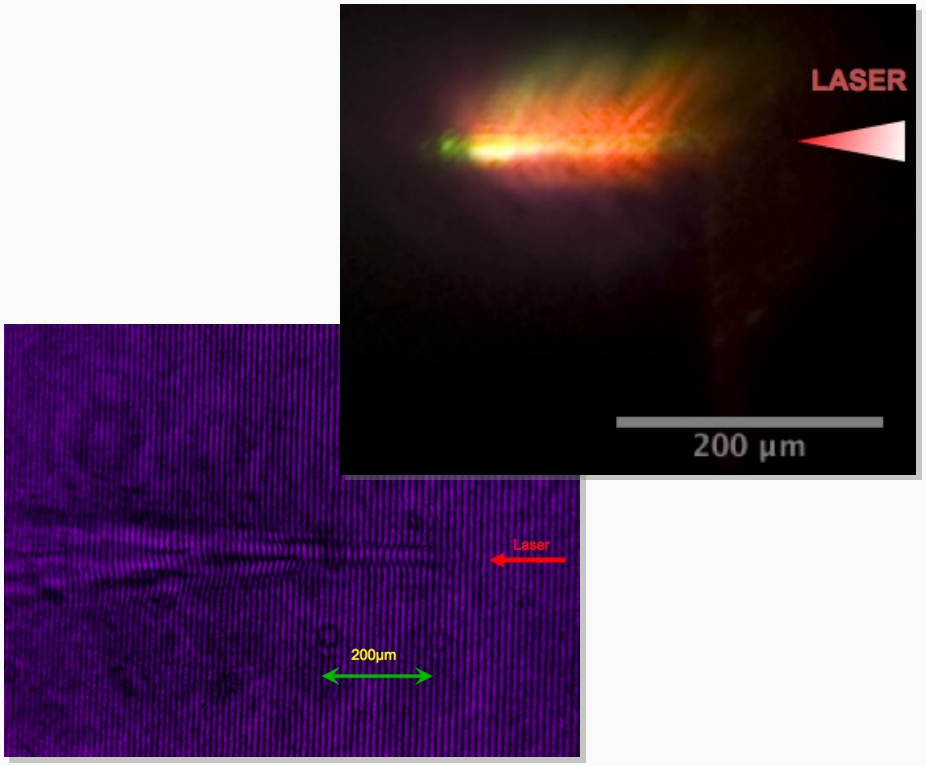
Summary

Summary

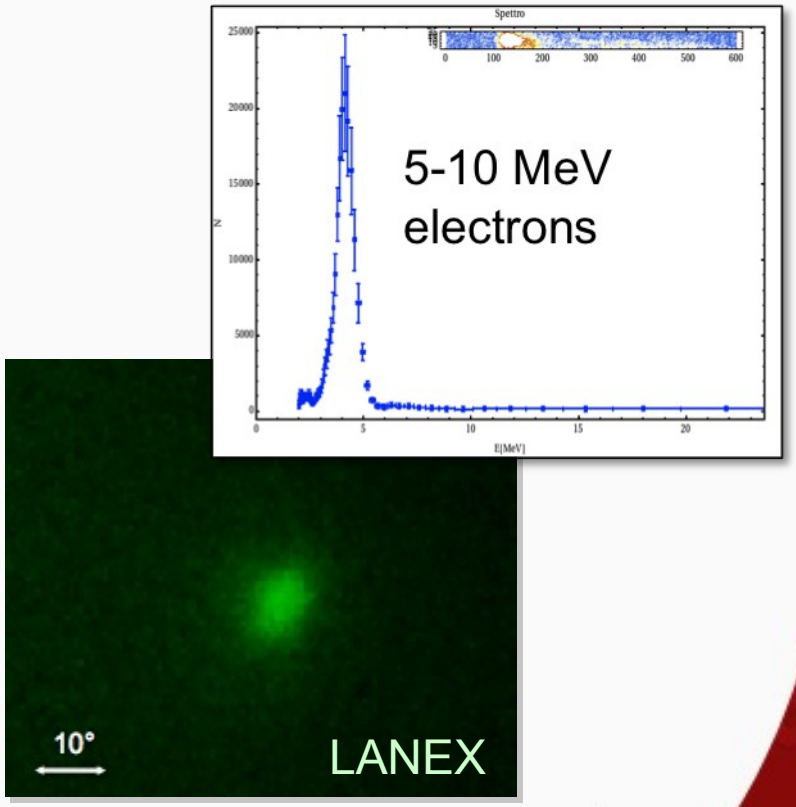
Preliminary e- acceleration experiment al ILIL-CNR

A (precursor) experiment has been carried out at the Intense Laser Irradiation Laboratory of the INO-CNR in Pisa, demonstrating e- LWFA for the first time in Italy, using a smaller scale (2TW) laser system

TS and interferometry show self-guiding



Electron bunch from He gas-jet



Conclusions and planned work

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- The lab is equipped with an underground, radiation shielded target area for “laser-only” experiments – awaiting authorizations
- A first “test” experiment has been conceived and is now under commissioning, mainly devoted to assess the laser system figures and performances
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