# PLASMONX

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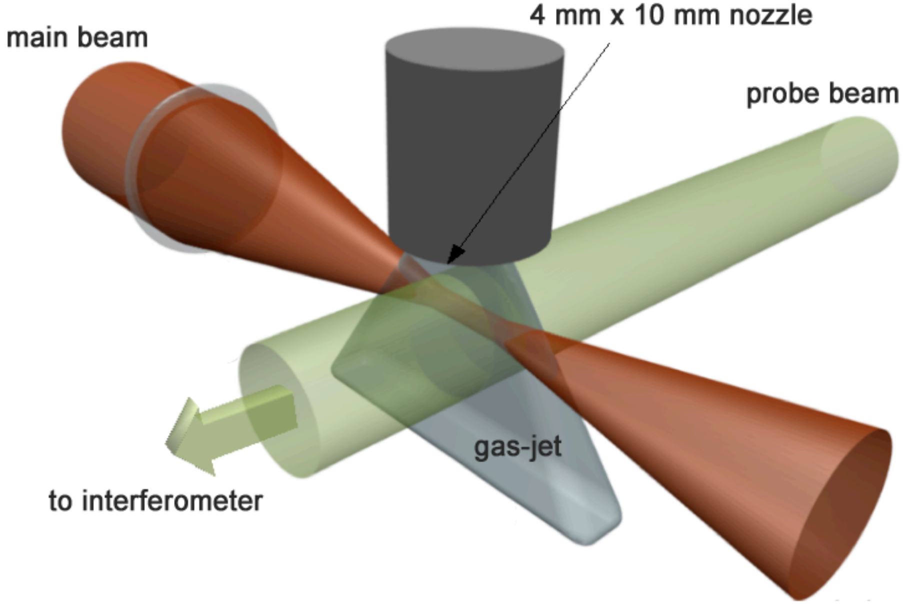
INFN, Pisa, Italy

# SELF-INJECTION TEST EXPERIMENT (SITE)

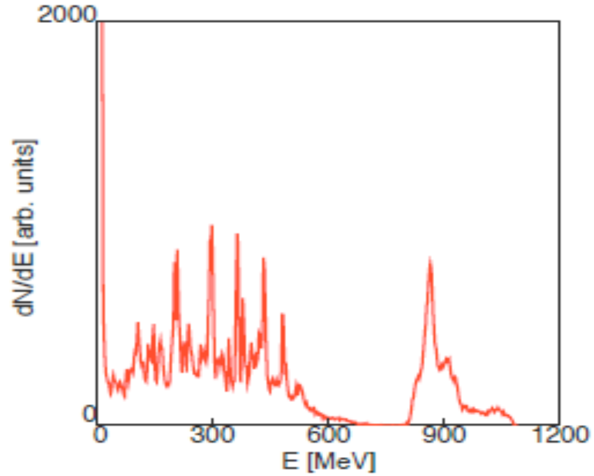
# GeV ELECTRON ACCELERATION

Main set up parameters

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




Calculated electron spectrum



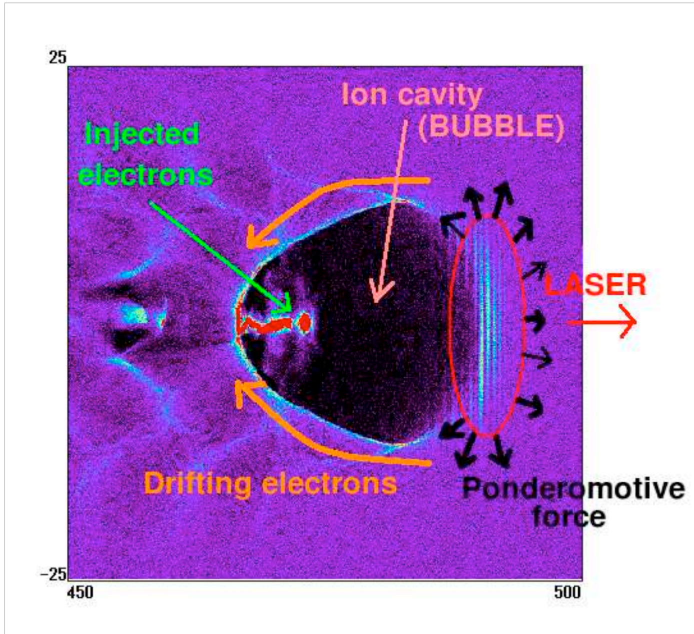

**Goal: 0.9 GeV in 4 mm**

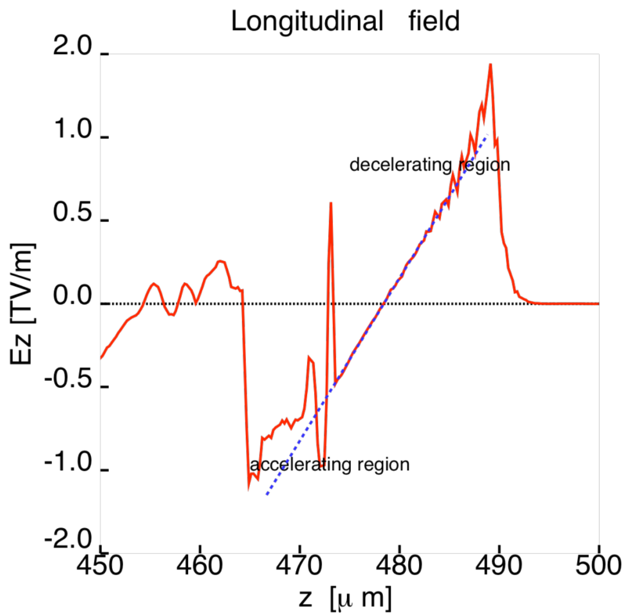
See: L.A. Gizzi et al., EPJ-ST, 175, 3-10 (2009)

Project acknowledgements: FISR "BLISS", INFN-CNR "PLASMONX"

# NUMERICAL SIMULATIONS

- **Nonlinear 3D regime (bubble)** [a]



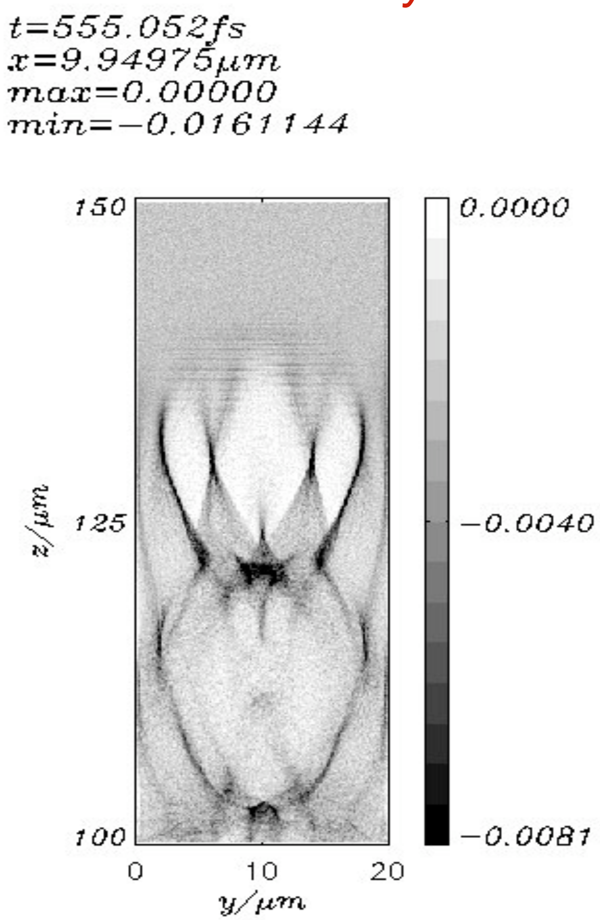

- $R_{bub} \simeq O(\lambda_p)$ $\quad E_z^{(max)} \simeq 100\sqrt{n_0[\text{cm}^{-3}] \times a_0}$ [V/m]
- $\begin{cases} v_{elect} \simeq c \\ v_{bub} \simeq c(1 - 3\omega_p^2/(2\omega_0^2)) < v_{elect} \end{cases}$ $\Rightarrow$ acc. length is finite + monochromaticity

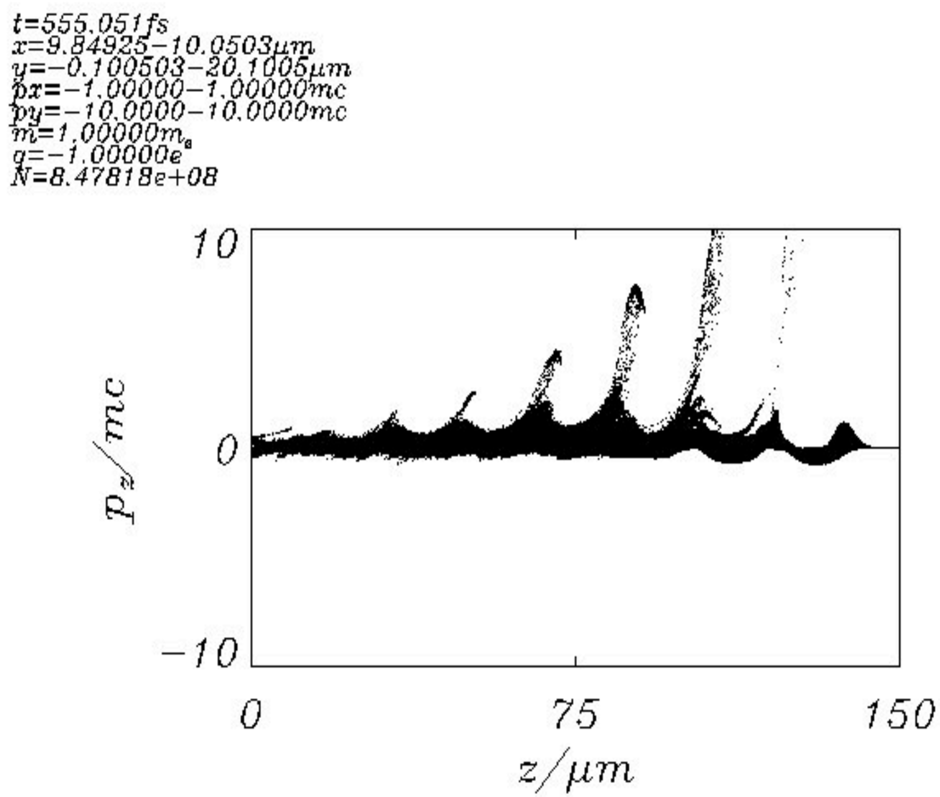
[a] S. Gordienko and A. Pukhov, Phys. Plas. 12 (2005) / W. Lu *et al.* PRSTAB 10 (2007)

# PSC RUNS FOR S.I.T.E.

*by N.Pathak, L.Labate, T. Levato …*

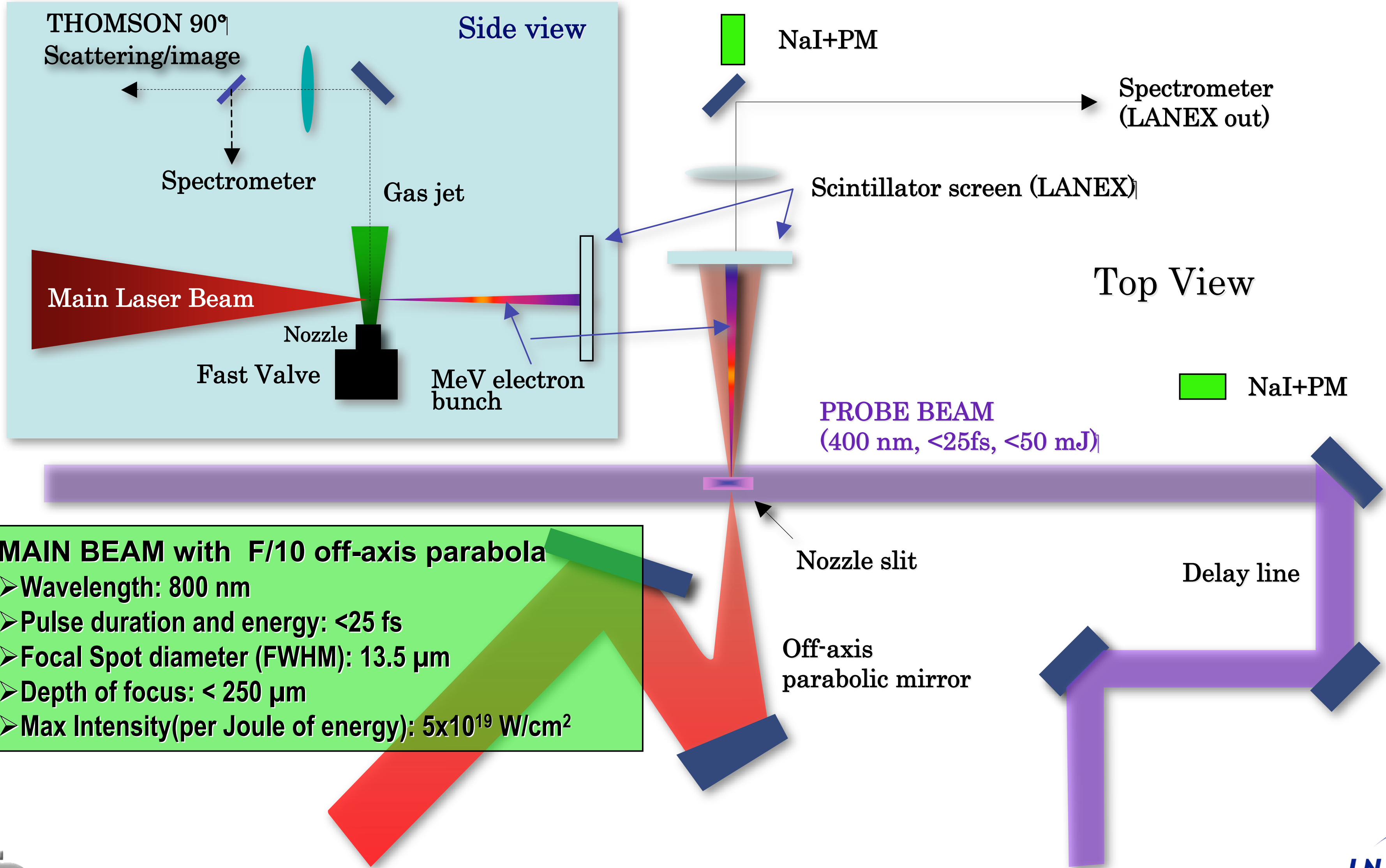
**IN PROGRESS …**




Need to run for longer axial and transverse length

# SCHEMATIC EXPERIMENTAL SET UP



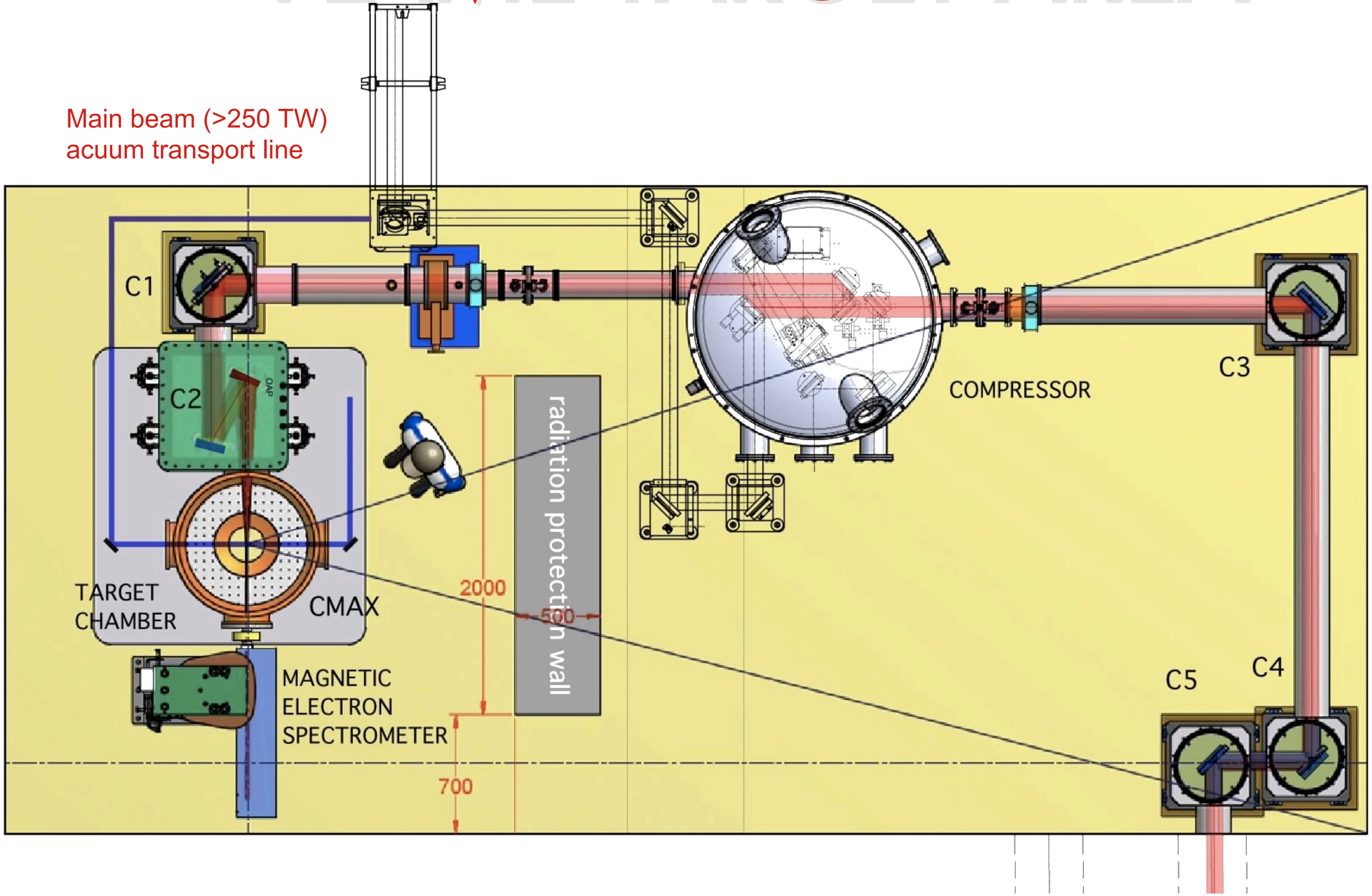

**MAIN BEAM with F/10 off-axis parabola**

- 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): $5\times10^{19}$ W/cm$^2$

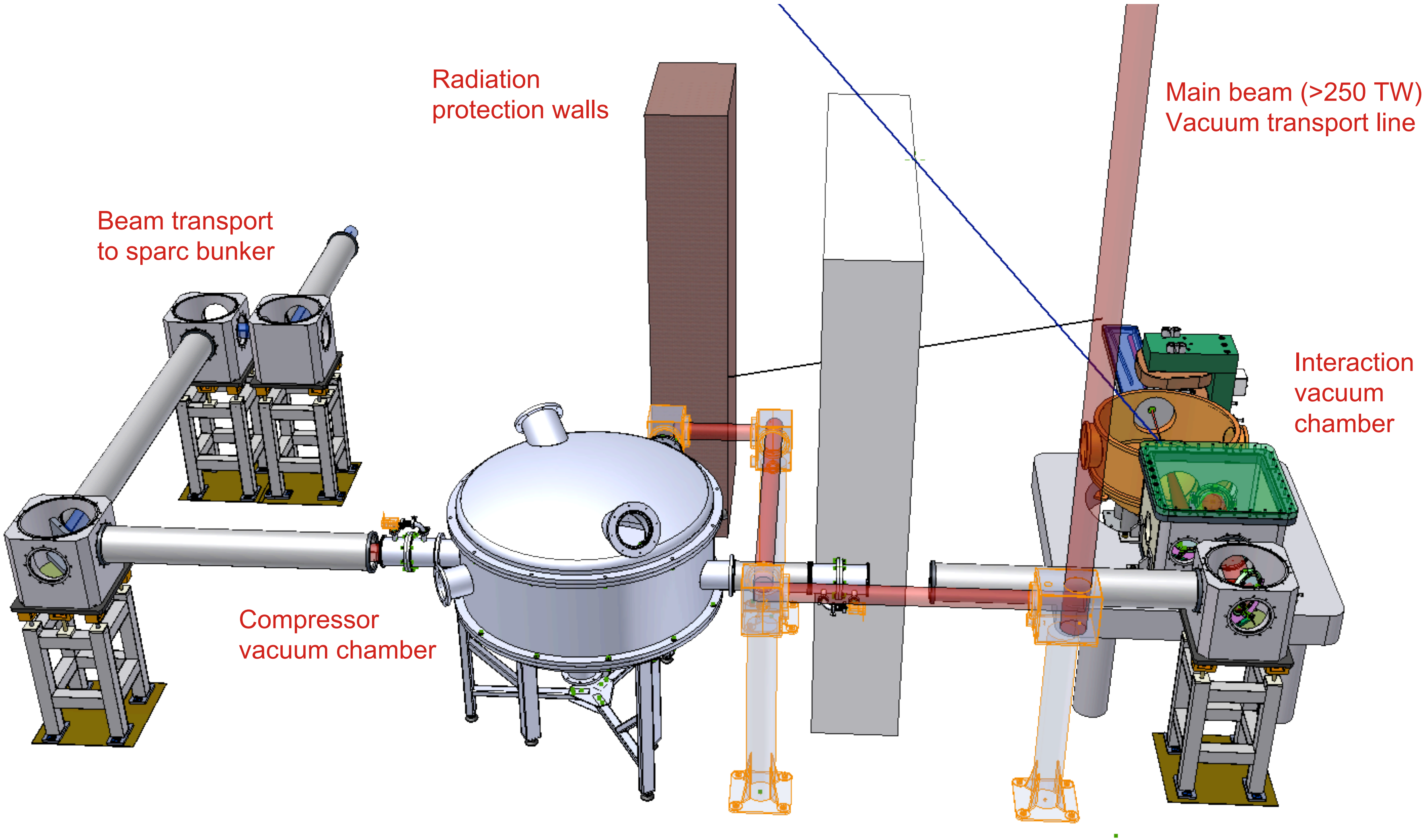
# FLAME TARGET AREA
# (FOR *S.I.T.E.*)

# FLAME TARGET AREA

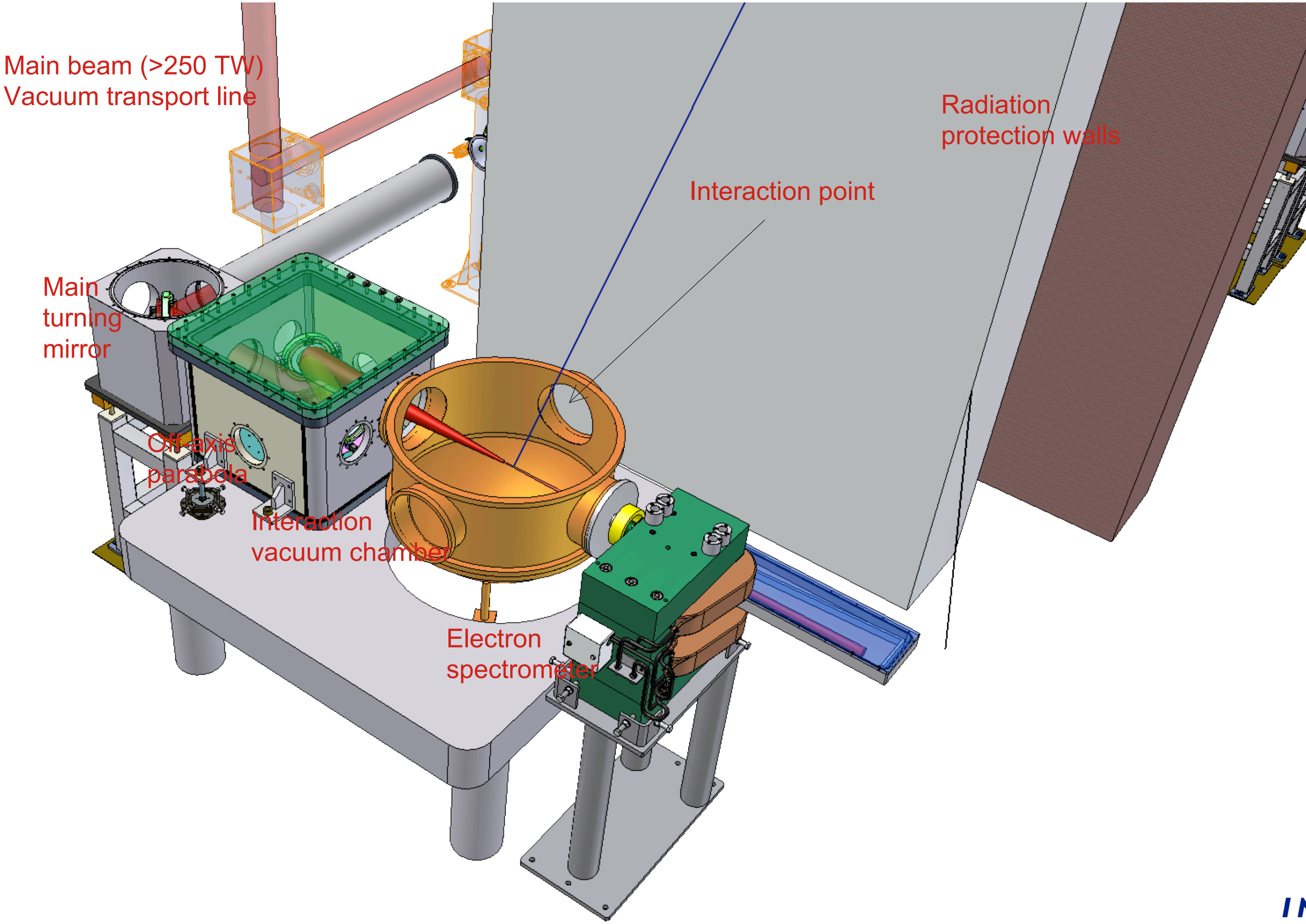
Main beam (>250 TW)
acuum transport line



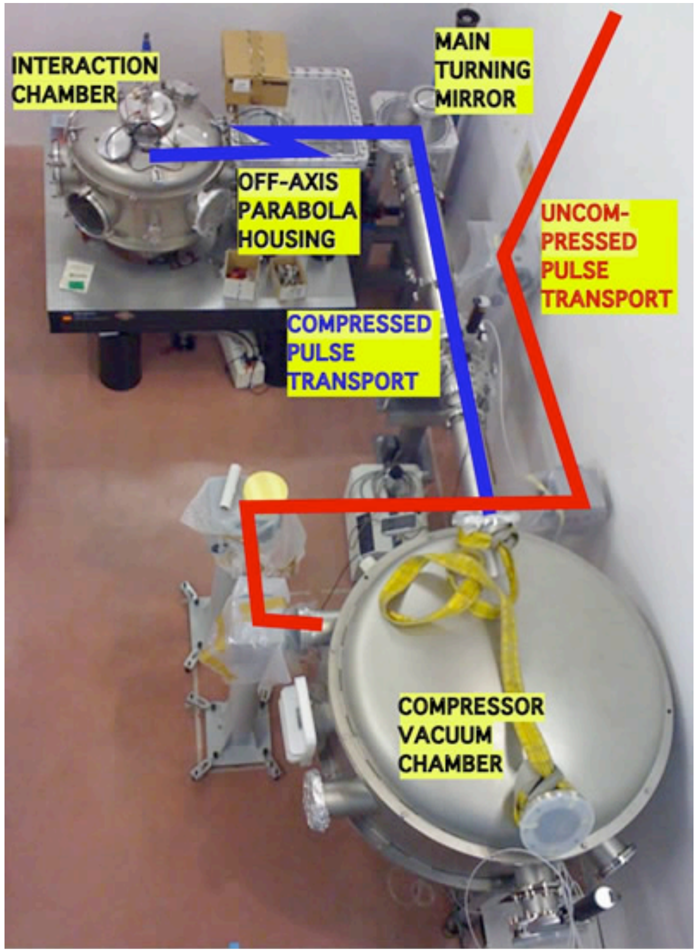
# FLAME TARGET AREA



# FLAME TARGET AREA



# FLAME TARGET AREA (SITE)




INFN

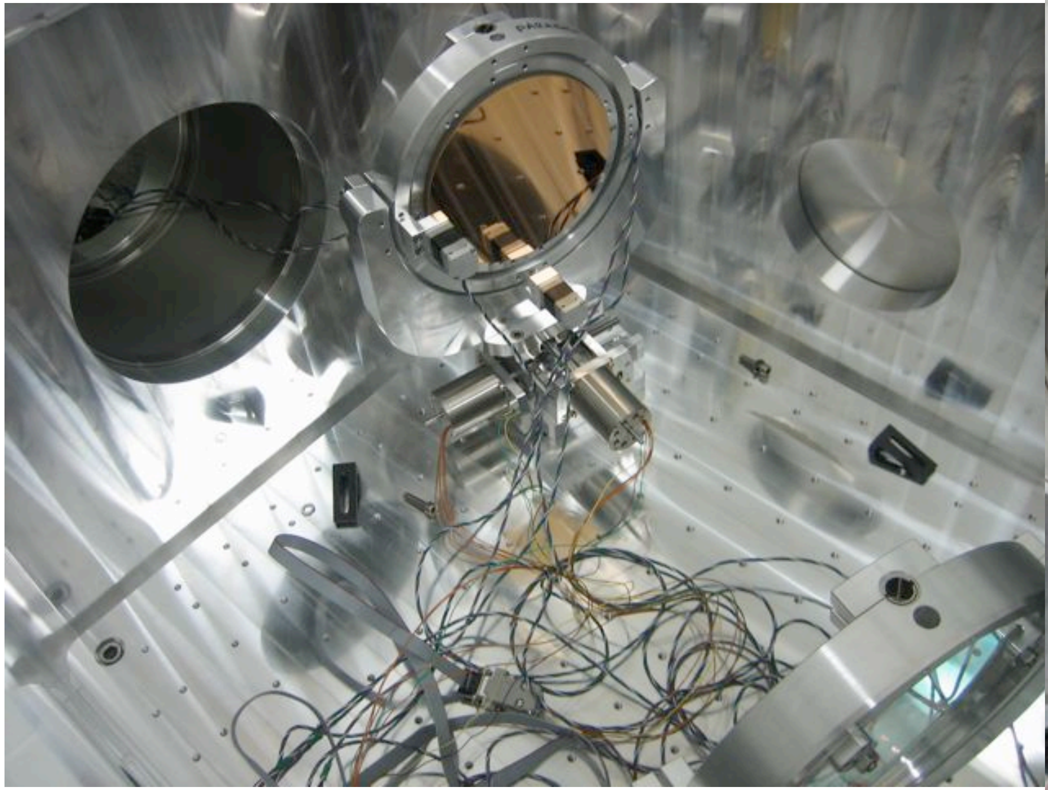
# VERT. AND HORIZ. SHIELDING


# MAIN BEAM OPTICS IN PLACE

45 AND 15° TURNING MIRROR MOUNTED

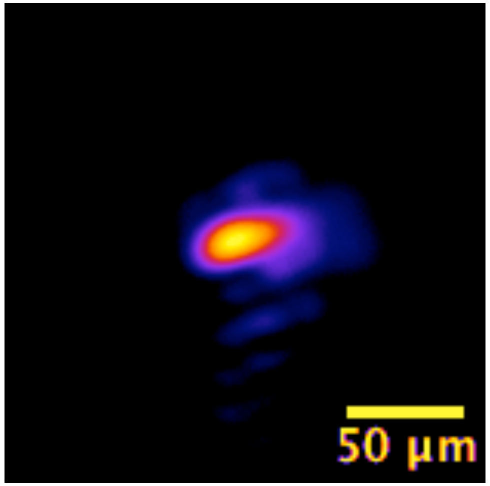
# FOCUSING LASER

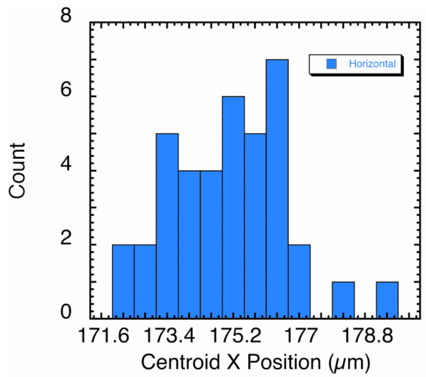
1 m focal length, 15° Off Axis Parabola (SORL)

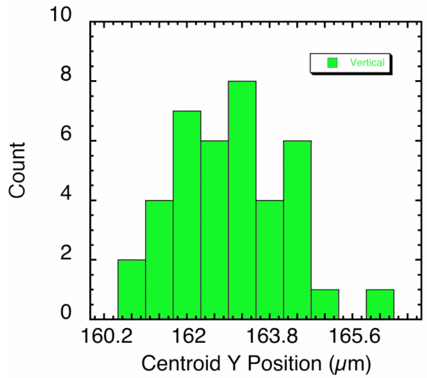


# LASER AT TARGET CHAMBER CENTER

## Pointing stability at TCC

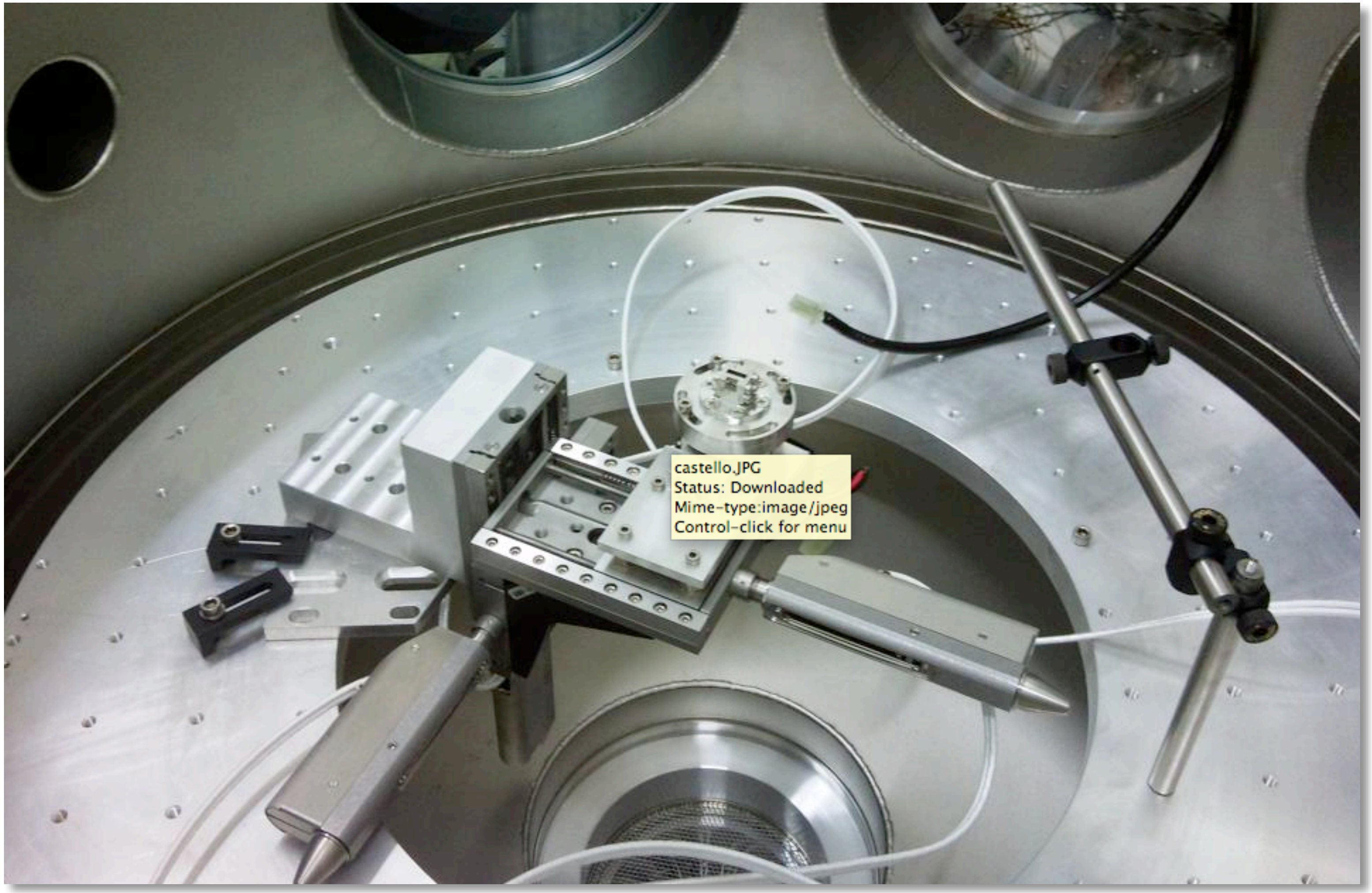



| | Centroid Y | Centroid X |
|---|---|---|
| Minimum | 160,89799 | 172,12 |
| Maximum | 166,22099 | 179,614 |
| Points | 39 | 39 |
| Mean | 162,9351 | 175,0372 |
| Median | 162,995 | 175,244 |
| RMS | 162,93927 | 175,04455 |
| Std Deviation | 1,18026 | 1,6241748 |
| Variance | 1,3930138 | 2,6379437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

# GAS JET TARGET IN PLACE



# AGENDA FOR NEXT WEEKS

- Full power FLAME test: transport, compression, OAP focusing (no target);
- Laser performance test at output: far field, contrast, width, phase distortion, measurements … prepare for adaptive optics;
- Completion and 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.

# PLANNED ACTIVITY 2/2

| 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 | | | | | | | | | ■ | ■ |

# SUMMARY

- FLAME commissioning entering experiment phase;
- Requirements on peak power, contrast, stability are challenging;
- Measurements to date show that parameters are within specs;
- Radiation protection measures in place – awaiting authorization
- Rapidly approaching self-injection LPA measurements

# “TEST” EXPERIMENT DIAGNOSTICS

OPTICAL DIAGNOSTICS FOR LASER PROPAGATION STUDIES

- Thomson scattering
- Femtosecond optical probing
- Transmitted and scattered beam spectroscopy

ELECTRON DIAGNOSTICS FOR ELECTRON ACCELERATION MEAS.

- Establish self-injection acceleration conditions
- Provide benchmarking for modelling

# Agenda for next 6-8 months

- Completion and commissioning of subsystems:
  - Clean room, Cooling network, Ethernet (before end of July '09)
- Full laser installation (Sept. 15th – December 2009, in phases;)
- Assembling of transport line from optical compressor to experimental target chamber (July – September '09)
- Assembling of self injection test experiment diagnostics (September – December '09)
- Laser on (gas-jet) target at >50 TW lavel Feb-March 2010.

# Conclusions

- Installation of main subsystems in progress
  Clean room, Laser, Cooling, Conditioning;
- Components of beam transport line in production;
- Design of test experiment completed;
- Construction of electron spectrometer in progress;
-

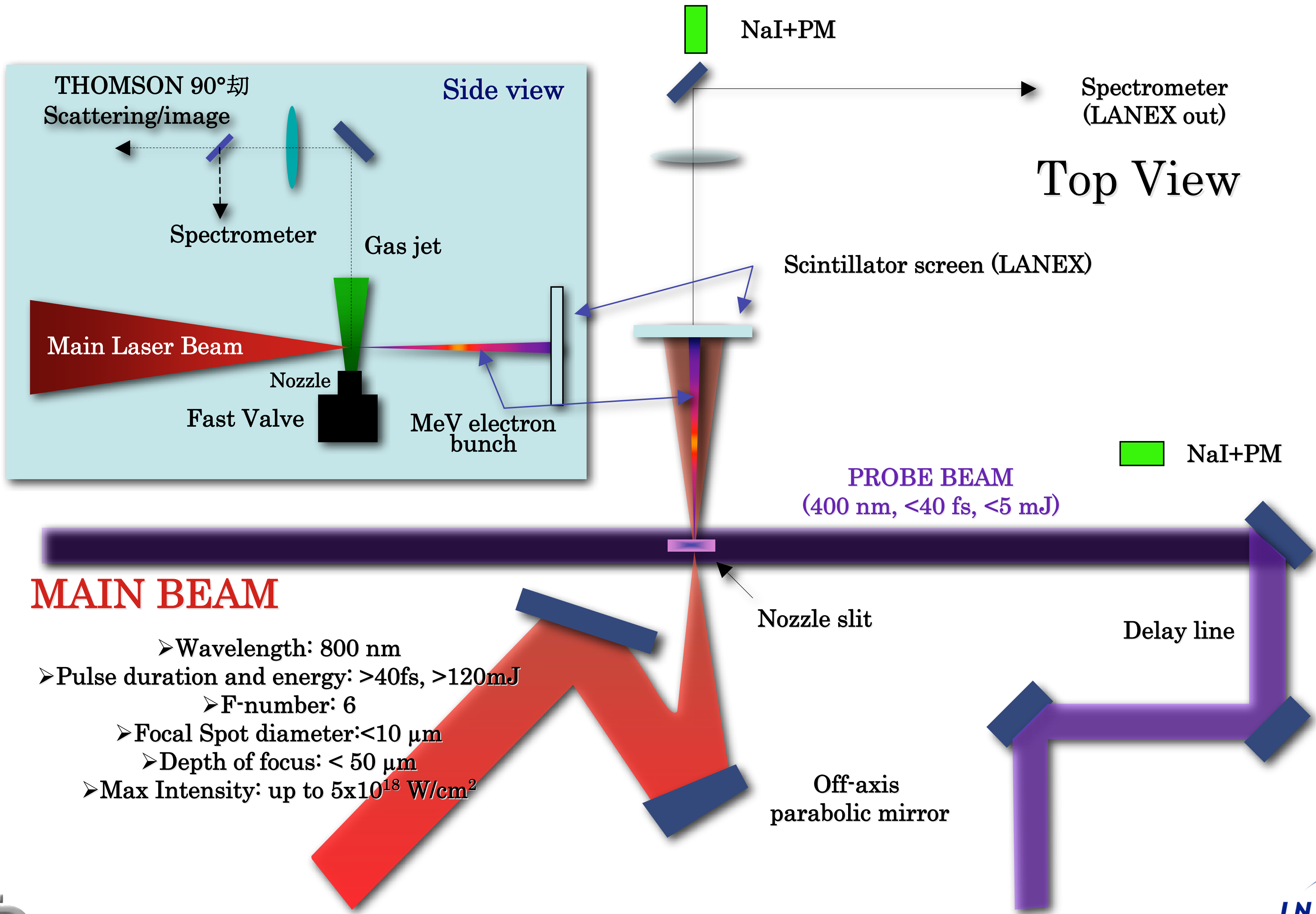
# Attività PLASMONX a Pisa

L'attività Pisana continuerà a svolgersi presso il laboratorio ILIL-INO-CNR dove è operante un sistema laser Ti:Sapphire da 3TW.

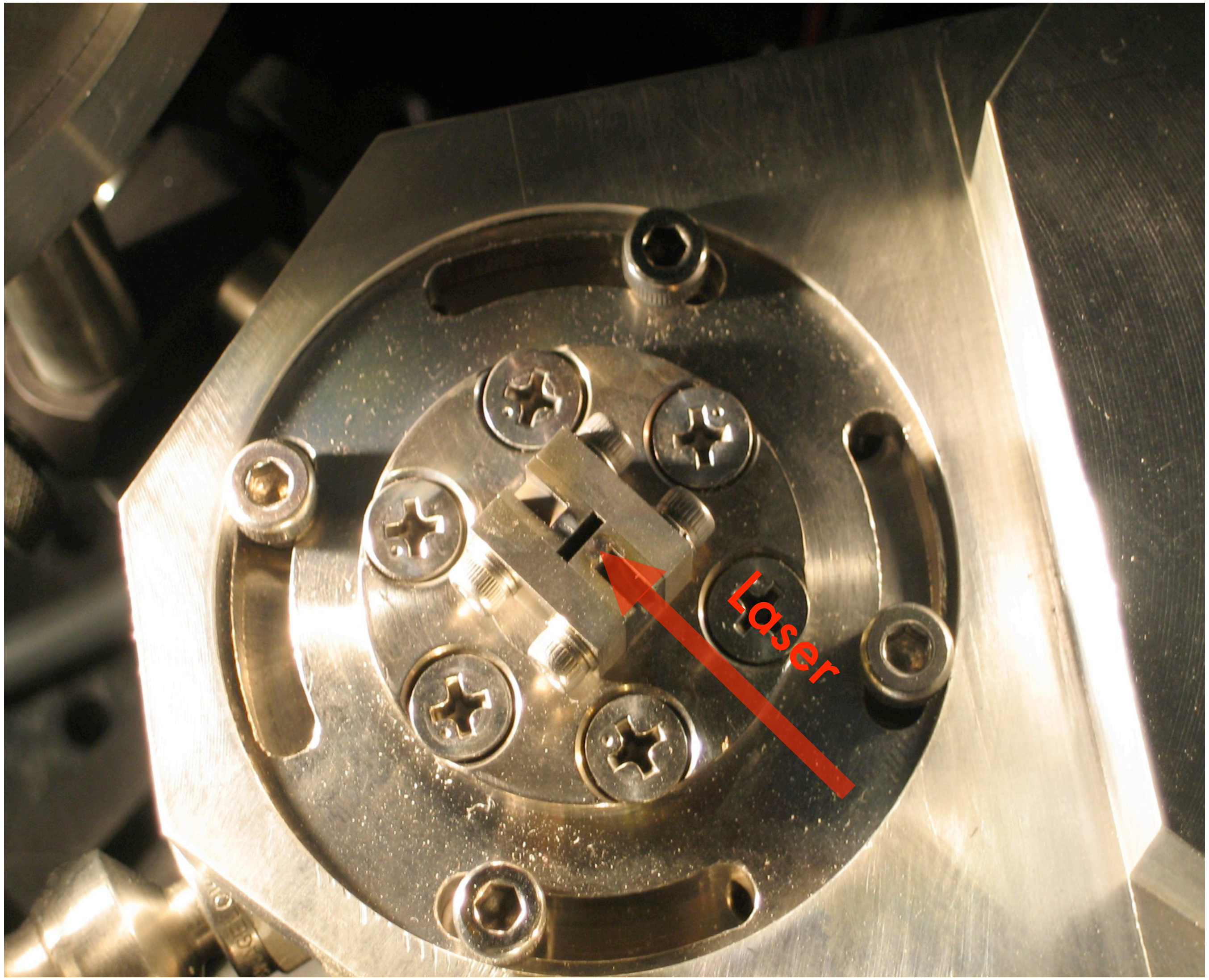
Essa consisterà nella messa a punto di nuove diagnostiche per la caratterizzazione degli elettroni accelerati mediante LPA e del plasma in cui l'accelerazione si sviluppa.

L'Unità PLASMONX-Pisa continuerà a svolgere un cruciale ruolo nella  formazione di giovani ricercatori nel campo dell'interazione laser-plasma ad alte intensità finalizzata allo sviluppo di Nuove Tecniche di Accelerazione

# ELECTRON ACCELERATION EXPERIMENT



# Gas-Jet nozzle

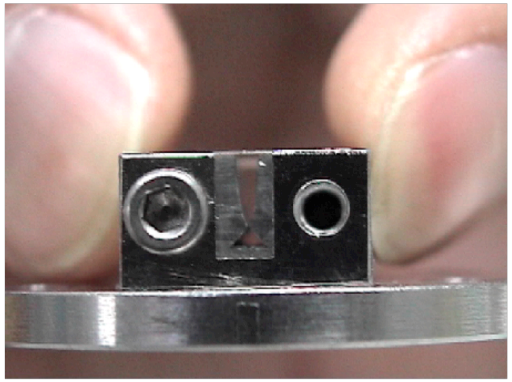


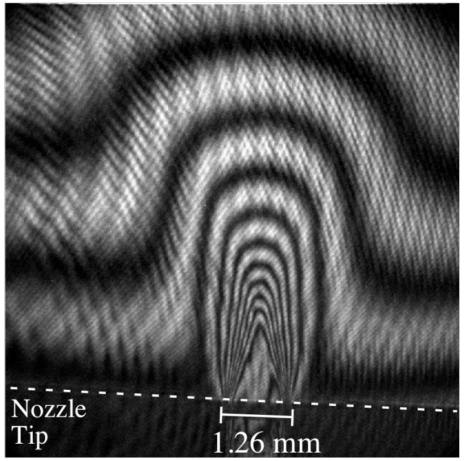
# High-density well-defined gas jet (1)

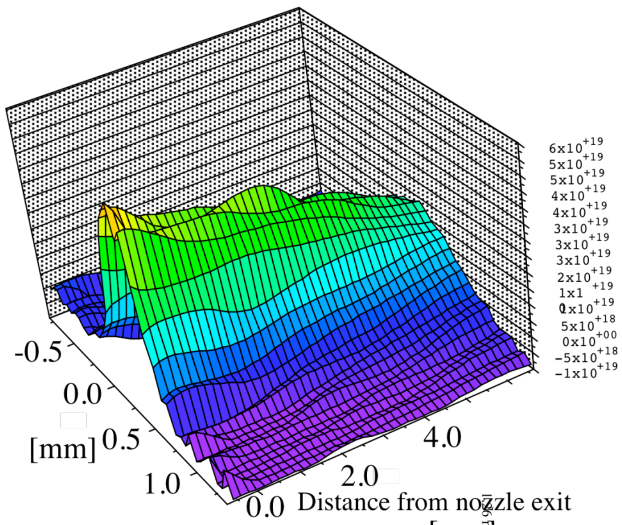
## Shockwave free supersonic nozzle

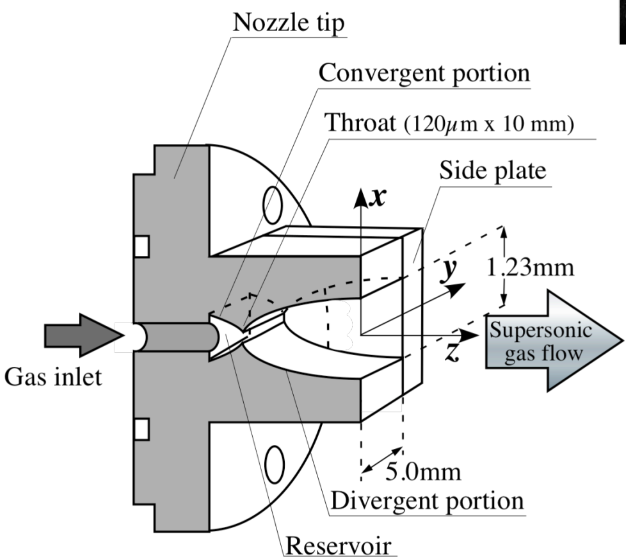
# Gas-Jet nozzle

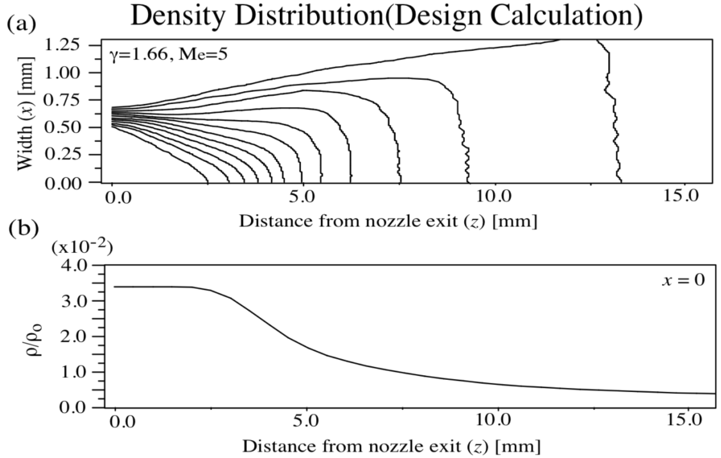
Nuclear Engineering Research Laboratory
Graduate School of Engineering
University of Tokyo

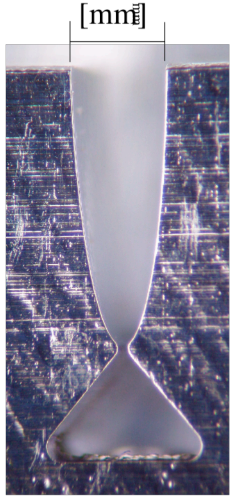




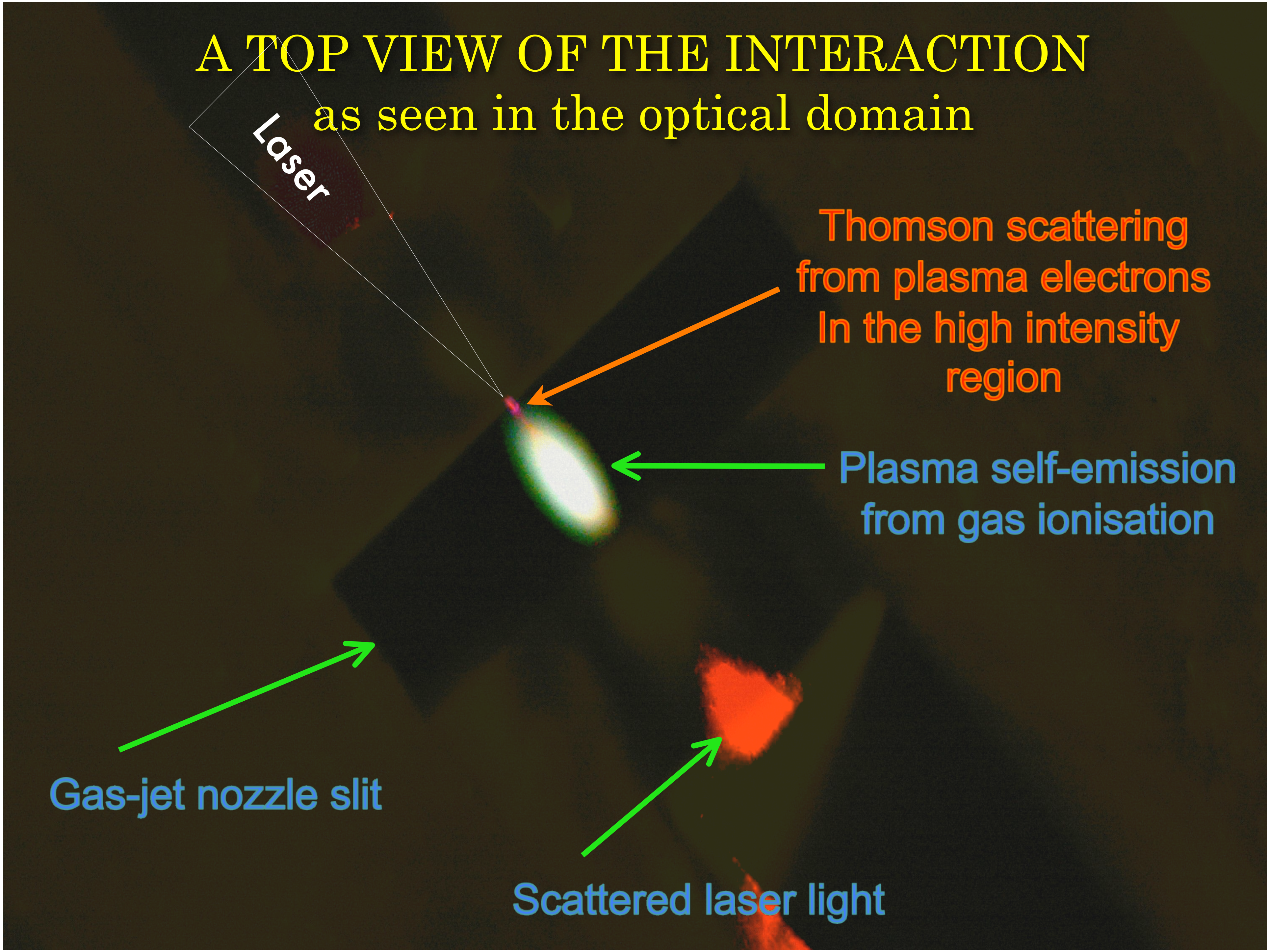



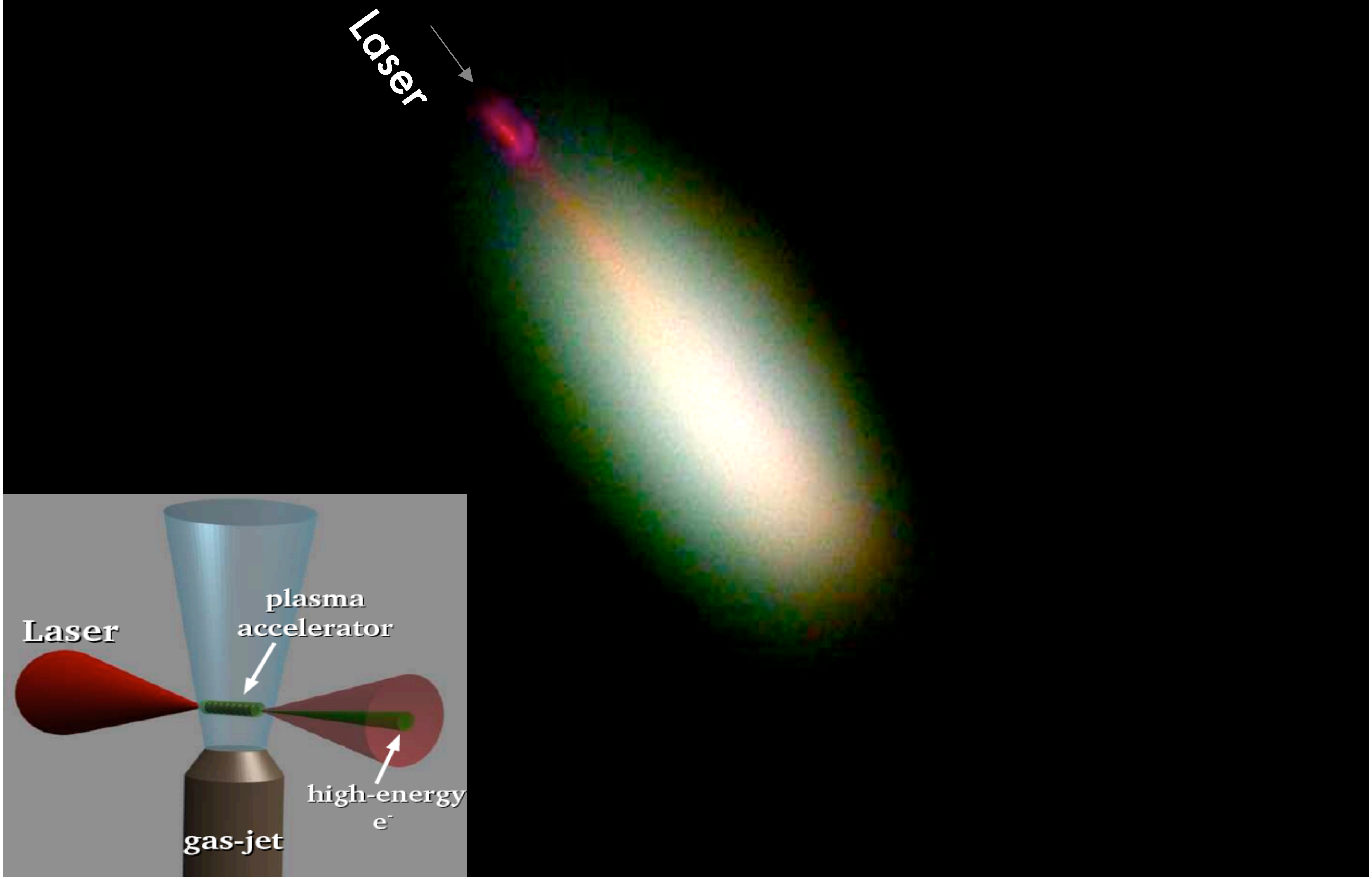



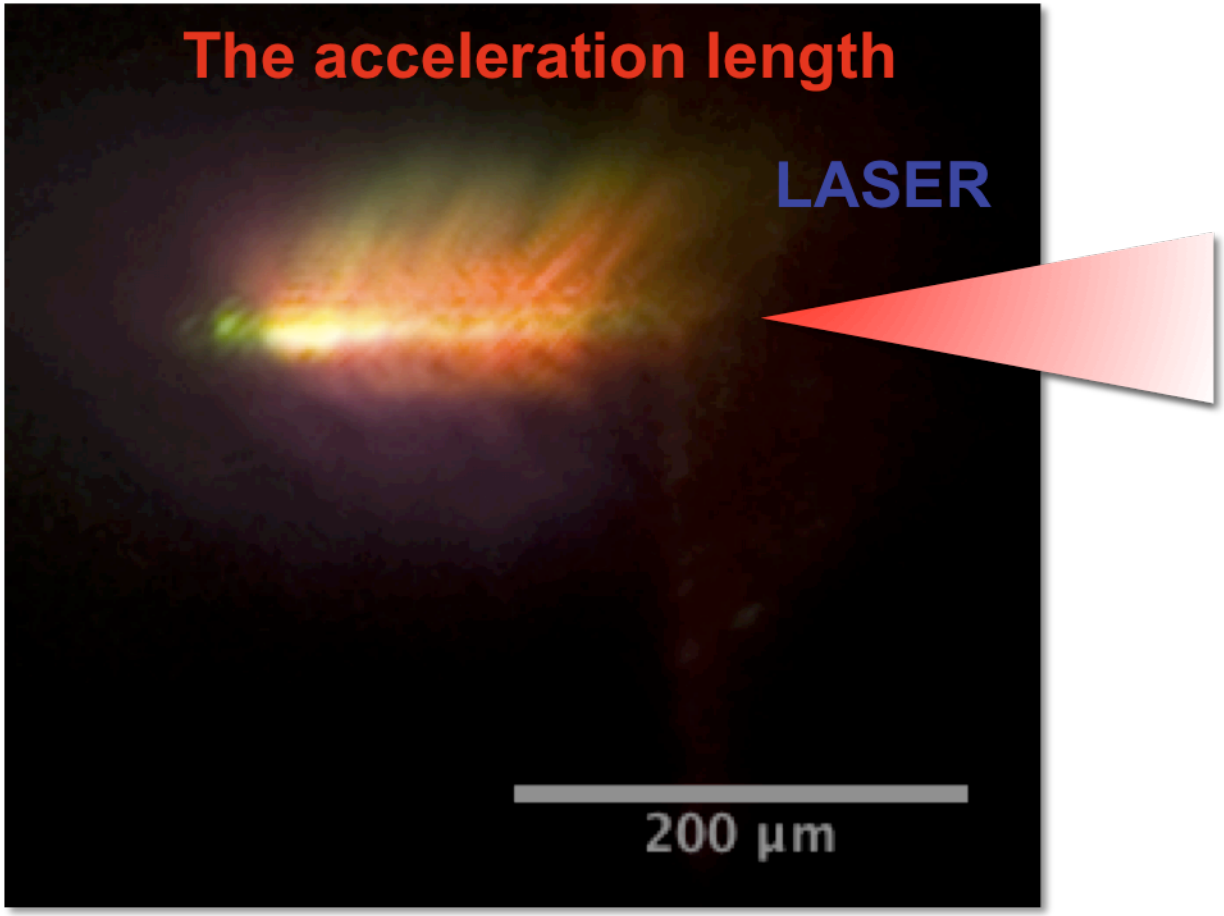
Courtesy of T. Hosokai, Tokyo Institute of Technology


A TOP VIEW OF THE INTERACTION
as seen in the optical domain
Laser
Thomson scattering from plasma electrons In the high intensity region
Plasma self-emission from gas ionisation
Gas-jet nozzle slit
Scattered laser light

# Thomson Scattering

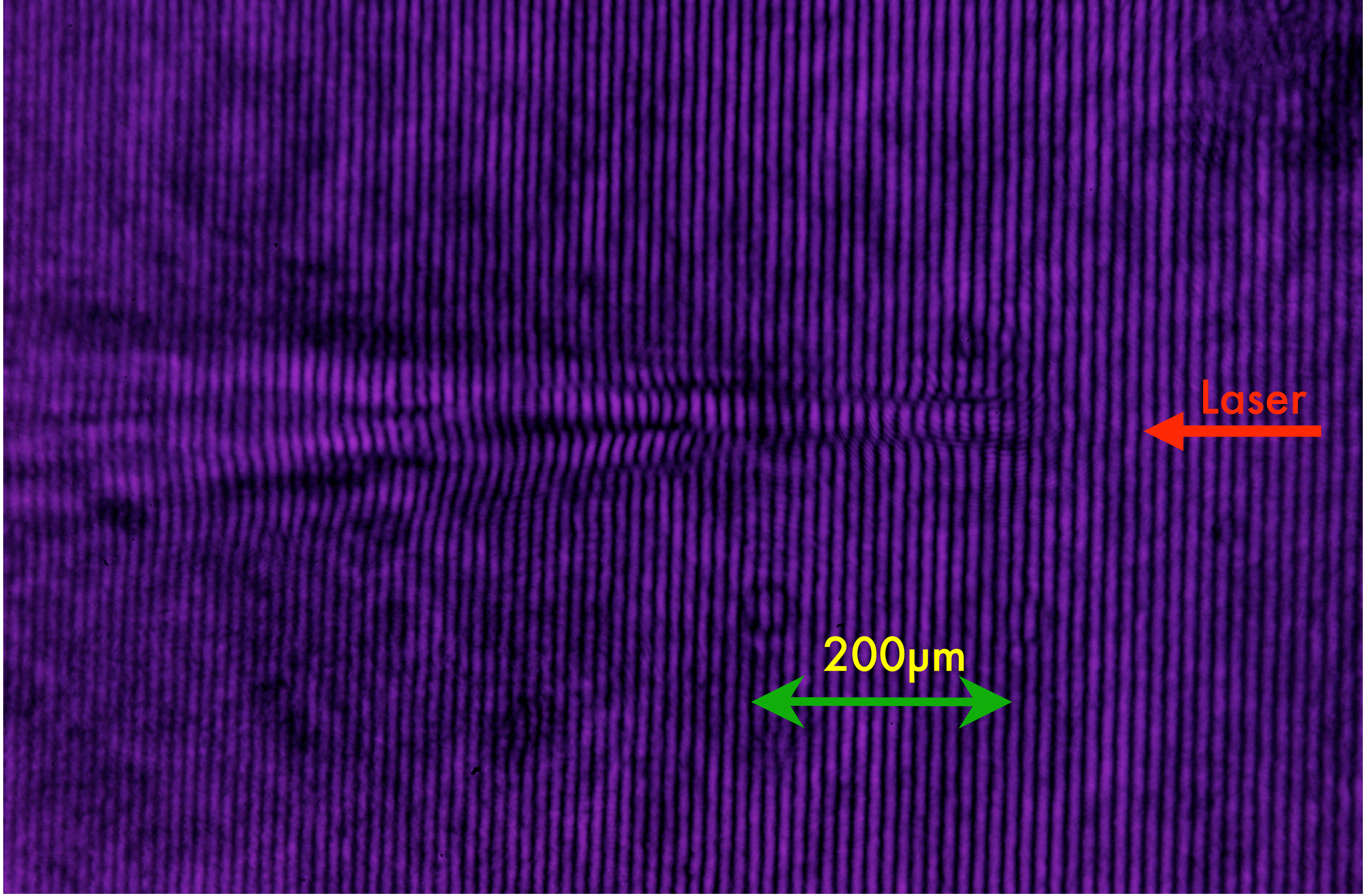


# ACCELERATION LENGHT



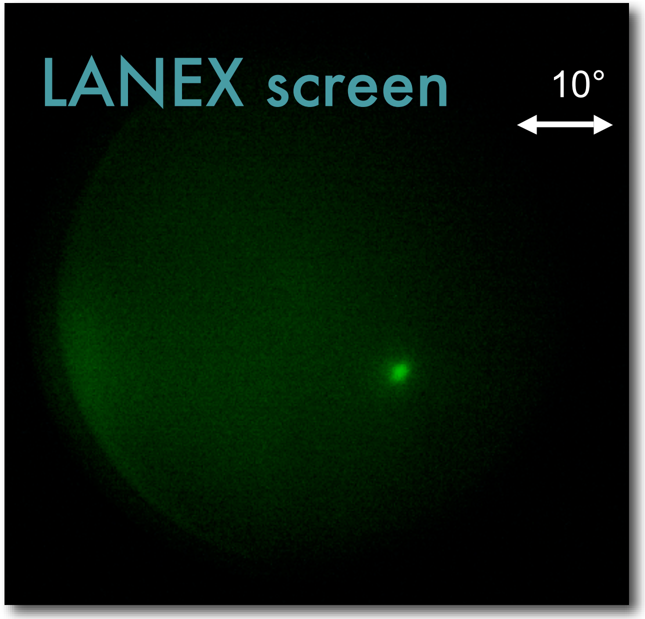

Thomson scattering clearly shows the region of propagation of the laser pulse, with evidence of self-guiding over a length approximately three times the depth of focus (+/- 50 $\mu$m).

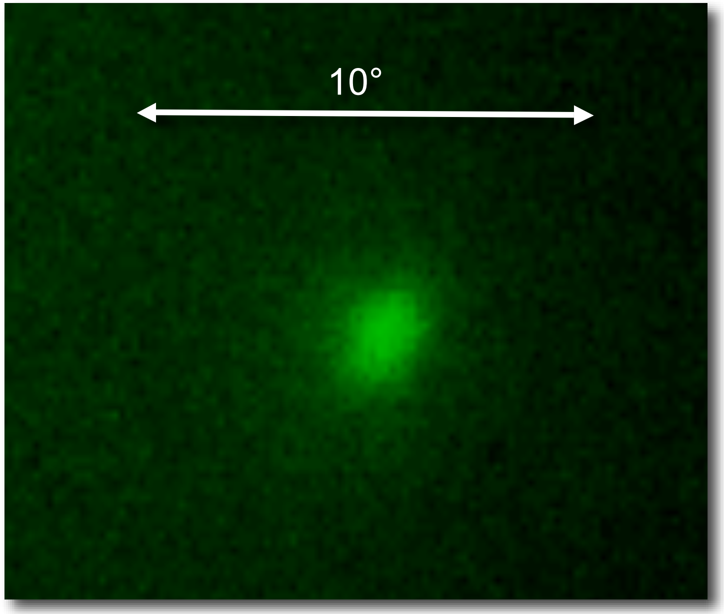
# Corresponding interferometry map



# ELECTRON BEAM

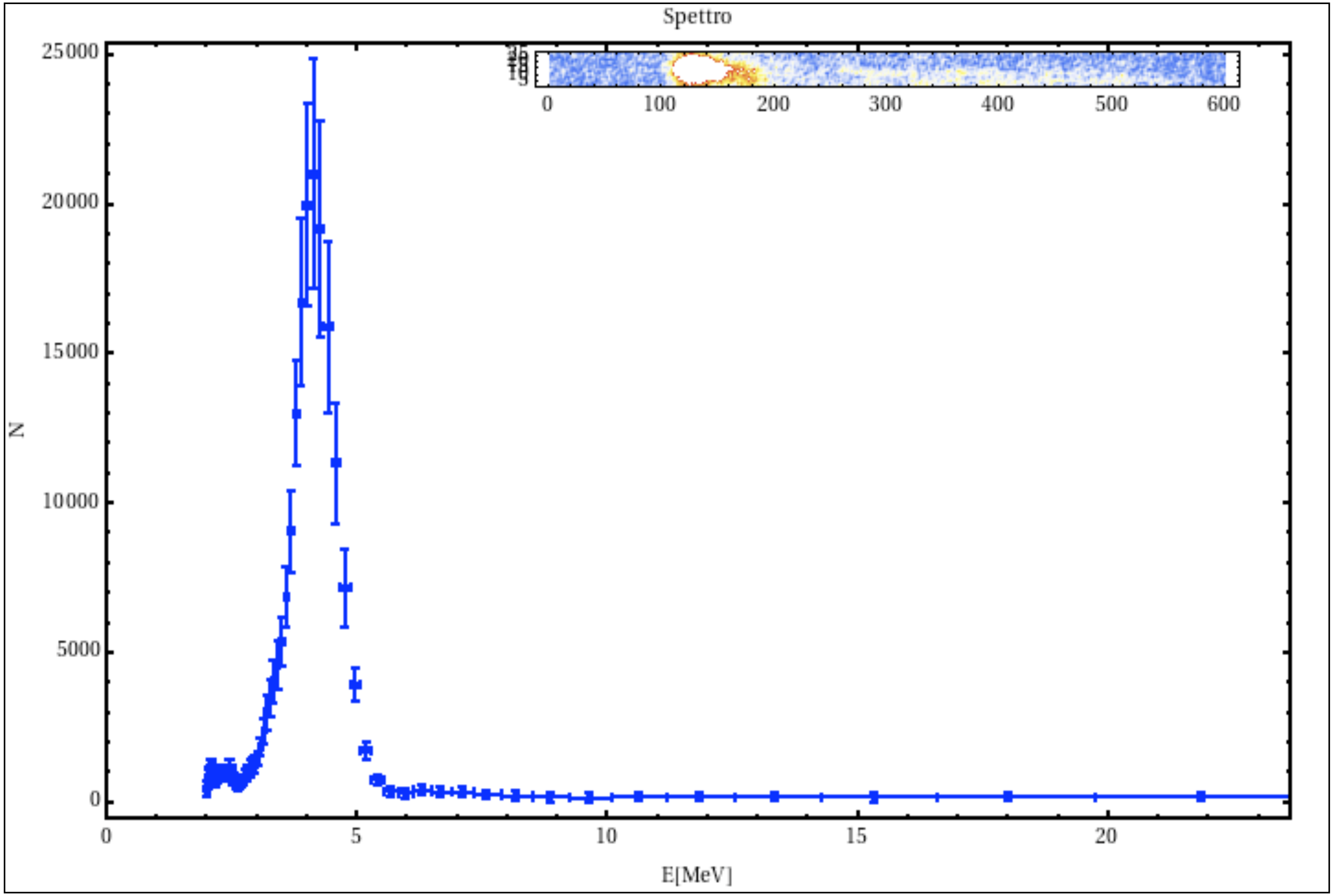
## He@50 bar



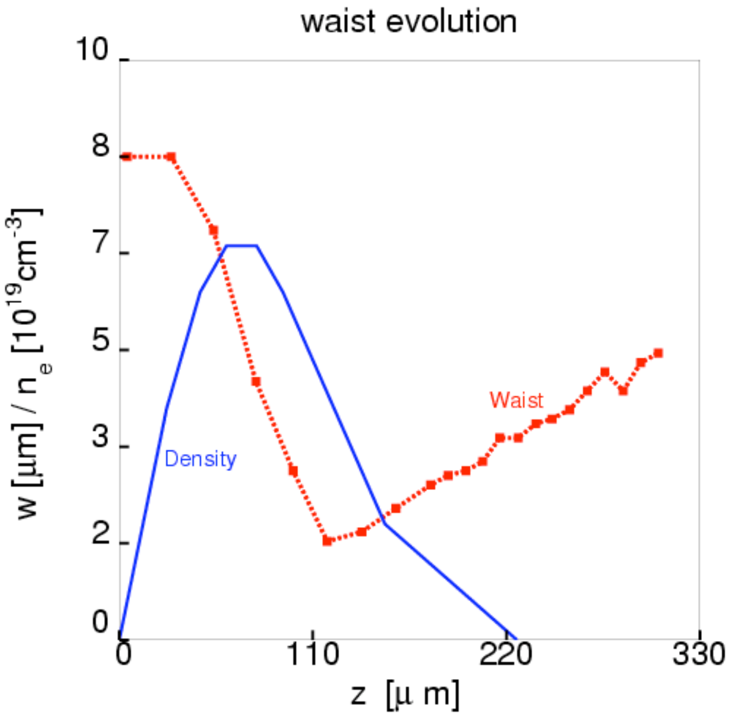

The LANEX screen shows a collimated electron beam.

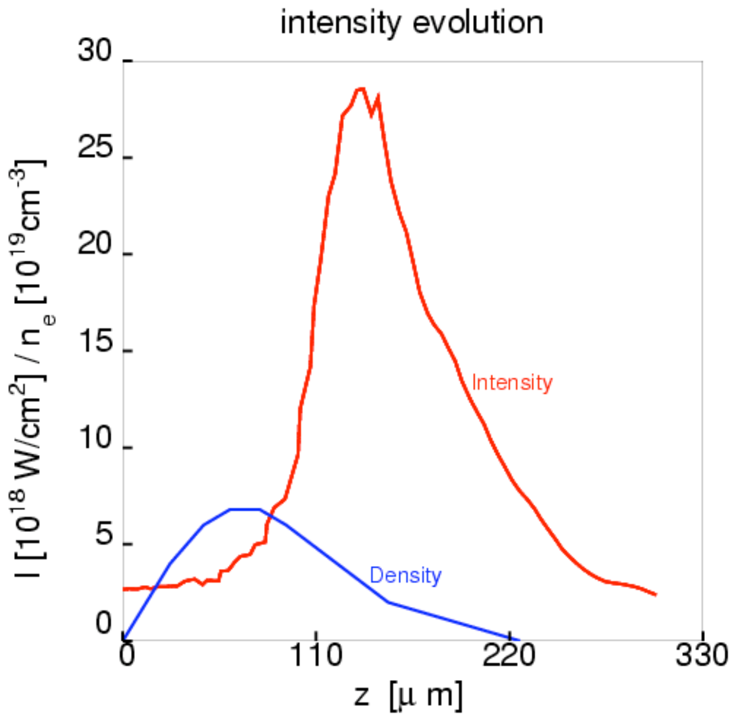
# Electron spectrum



# LASER BEAM EVOLUTION IN MEASURED DENSITY PROFILE

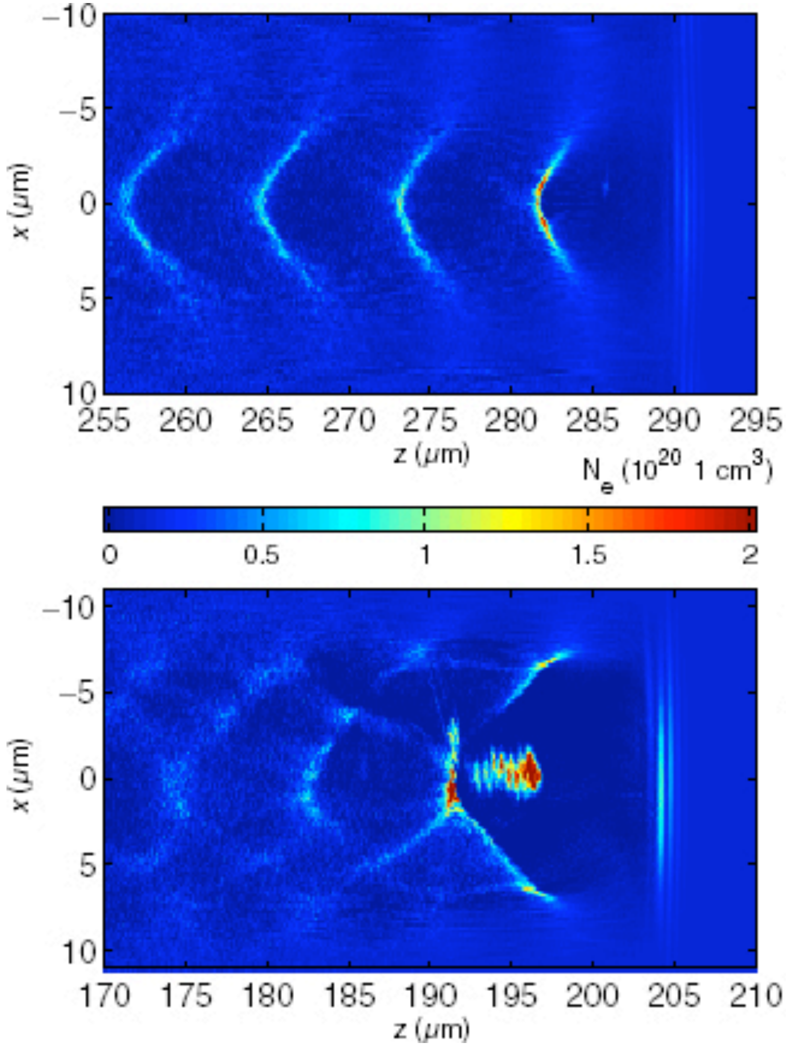
Aladyn numerical simulations (di C. Benedetti et al.,)




Strong self-focusing occurs on a longitudinal scalelength of approx. 50 μm leding to a 10-fold increase of the local intensity

# ACCELERATION REGIME




from Geisser et al.,
New J. Phys. 8 (2006) 186

- Numerical modelling shows that, in spite of the relatively low laser intensity, a single acceleration cavity develops;
- This behaviour resembles the so-called bubble-regime originally proposed by A. Pukhov & J.Meyer-ter-Vehn, (Appl. Phys. B, 74, p.355 (2002));
- Bubble regime differs from traditional wake field acceleration in that one drives the plasma far beyond the wave-breaking limit, such that a single wake, rather than a regular plasma wave train is formed (M. Geissler et al., New J. Phys. 8 (2006) 186);

# ANAGRAFICA

## Ricercatori

| | Nome | CF | Contratto | Qualifica | Aff. | % |
|---|---|---|---|---|---|---|
| 1 | **Cecchetti Carlo Alberto** | CCCCLL76H03G702A | Associato | **Tecnologo** | CSN V | **50** |
| 2 | **Ciricosta Orlando** | CRCRND84C16I441C | Associato | **Laureato** | CSN V | **50** |
| 3 | **Giulietti Danilo** | GLTDNL49E14F513H | Incarico di ricerca | **Professore** | CSN V | **80** |
| 4 | **Giulietti Antonio** | GLTNTN44H25G148Y | Associato | **Dirigente di Ricerca** | CSN V | **20** |
| 5 | **Gizzi Leonida Antonio** | GZZLDN65A24L086F | Associato | **Primo Ricercatore** | CSN V | **50** |
| 6 | **Koester Petra** | KSTPRM70D54Z112I | Associato | **Assegnista** | CSN V | **30** |
| 7 | **Labate Luca Umberto** | LBTLMB71T30H224E | Associato | **Ricercatore** | CSN V | **50** |
| 8 | **Pathak Naveen** | PTHNNC80L15Z222S | Associato | **Dottorando** | CSN V | **80** |
| 9 | **Vaselli Moreno** | VSLMRN39S20G702U | Associato | **Dirigente di Ricerca** | CSN V | **20** |

**Numero Totale Ricercatori 9** FTE : **4.3**

| Capitolo | Descrizione | Parziali | | Totale | |
|---|---|---|---|---|---|
| | | Richiesta | SJ | Richieste | SJ |
| INTERNO | **1.** missioni a LNF; coordinamento con le altre Unità del Progetto; congressi e meetings nazionali | 35.00 | | **35.00** | 0.00 |
| ESTERO | **1.** missioni a : AMPLITUDE TECHNOLOGIES (Evry); Ecole Polytechnique; CEA Saclay; RAL; PALS.Congressi e meetings internazionali. Attività nei progetti Europei. | 15.00 | | **15.00** | 0.00 |
| CONSUMO | **1.** ugelli per gas-jet | 5.00 | | | |
| | **2.** gas per gas-jet | 2.00 | | | |
| | **3.** fogli di radiocromico | 3.00 | | | |
| | **4.** fogli metallici di vari spessori per filtraggio raggi X | 3.00 | | | |
| | **5.** capillari per gas-target | 10.00 | | | |
| | **6.** filtri ottici | 1.00 | | | |
| | **7.** filtri ottici interferenziali | 3.00 | | **27.00** | 0.00 |
| SEMINARI | | | | | |
| TRASPORTI | | | | | |
| PUBBLICAZIONI | | | | | |
| MANUTENZIONE | **1.** manutenzione pompe da vuoto | 5.00 | | | |
| | **2.** componentistica ottica per manutenzione laser 3TW CNR-INFN | 3.00 | | | |
| | **3.** flashlamps per manutenzione laser 3TW CNR-INFN | 10.00 | | | |
| | **4.** diodi di pompa per manutenzione laser 3TW CNR-INFN | 15.00 | | | |
| | **5.** cartucce per filtri di depurazione acqua circuito di raffreddamento laser 3TW CNR-INFN | 2.00 | | **35.00** | 0.00 |
| INVENTARIO | **1.** elettronica di sincronizzazione laser Nd e Ti:Sa | 5.00 | | | |
| | **2.** CCD X retro-illuminata | 45.00 | | **50.00** | 0.00 |
| APPARATI | **1.** mazzler | 45.00 | | | |
| | **2.** dazzler | 45.00 | | **90.00** | 0.00 |

Totale 252 KEURO

# RICHIESTE IN SEZIONE

| | |
|---|---|
| OFFICINA MECCANICA | **2 mese-uomo** |
| ELETTRONICO | **1 mese-uomo** |