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INTENSE LASER IRRADIATION LAB., INO, CNR, PISA

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ISTITUTO NAZIONALE DI OTTICA

CONSIGLIO NAZIONALE DELLE RICERCHE

ISTITUTO NAZIONALE DI FISICA NUCLEARE

Laser-plasma acceleration with self-injection: first electron bunches from the FLAME commissioning test experiment at LNF

Leonida A. GIZZI

Istituto Nazionale di Ottica (INO)
CONSIGLIO NAZIONALE DELLE RICERCHE
&
ISTITUTO NAZIONALE DI FISICA NUCLEARE
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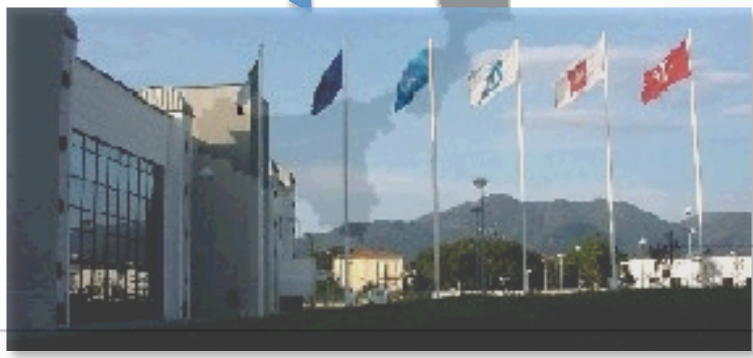

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The Intense Laser Irrad. Lab @ INO-Pisa

CNR - DIPARTIMENTO MATERIALI E DISPOSITIVI (Dir. M. Inguscio)
Progetto: OPTICS, PHOTONICS AND PLASMAS (Resp. S. De Silvestri)
Unit (Commessa): HIGH FIELD PHOTONICS (Head: Leo A. Gizzi)

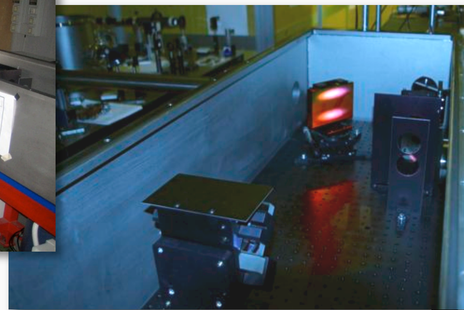
- **High field photonics for the generation of ultrashort radiation pulses and high energy particles;**
- **Development of broadband laser amplifiers for stategic studies on Inertial Confinement Fusion;**

PEOPLE

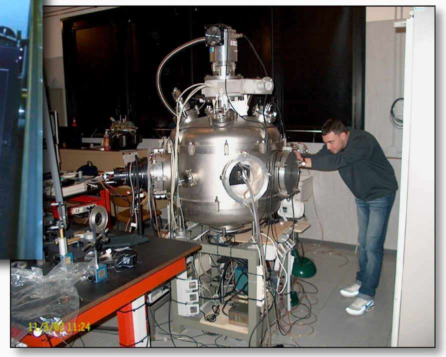
- Antonio GIULIETTI (CNR)*
- Leonida A. GIZZI (CNR)*
- Danilo GIULIETTI (Univ. Pisa, CNR)*
- Luca LABATE (CNR)*
- Petra KOESTER (CNR & Univ. of Pisa)*
- Carlo A. CECCHETTI (CNR)*,
- Giancarlo BUSSOLINO (CNR)
- Gabriele CRISTOFORETTI (CNR)
- Moreno VASELLI (CNR-Associato)*
- Walter BALDESCHI (CNR)
- Antonella ROSSI (CNR)
- Tadzio LEVATO (now at LNF-INFN)
- Naveen PATHAK (UNIPI & CNR), PhD

* Also at INFN

The 3TW aser



The compressor



The Laboratory

View of Lungarni

Marina di Pisa

Chiesa della Spina

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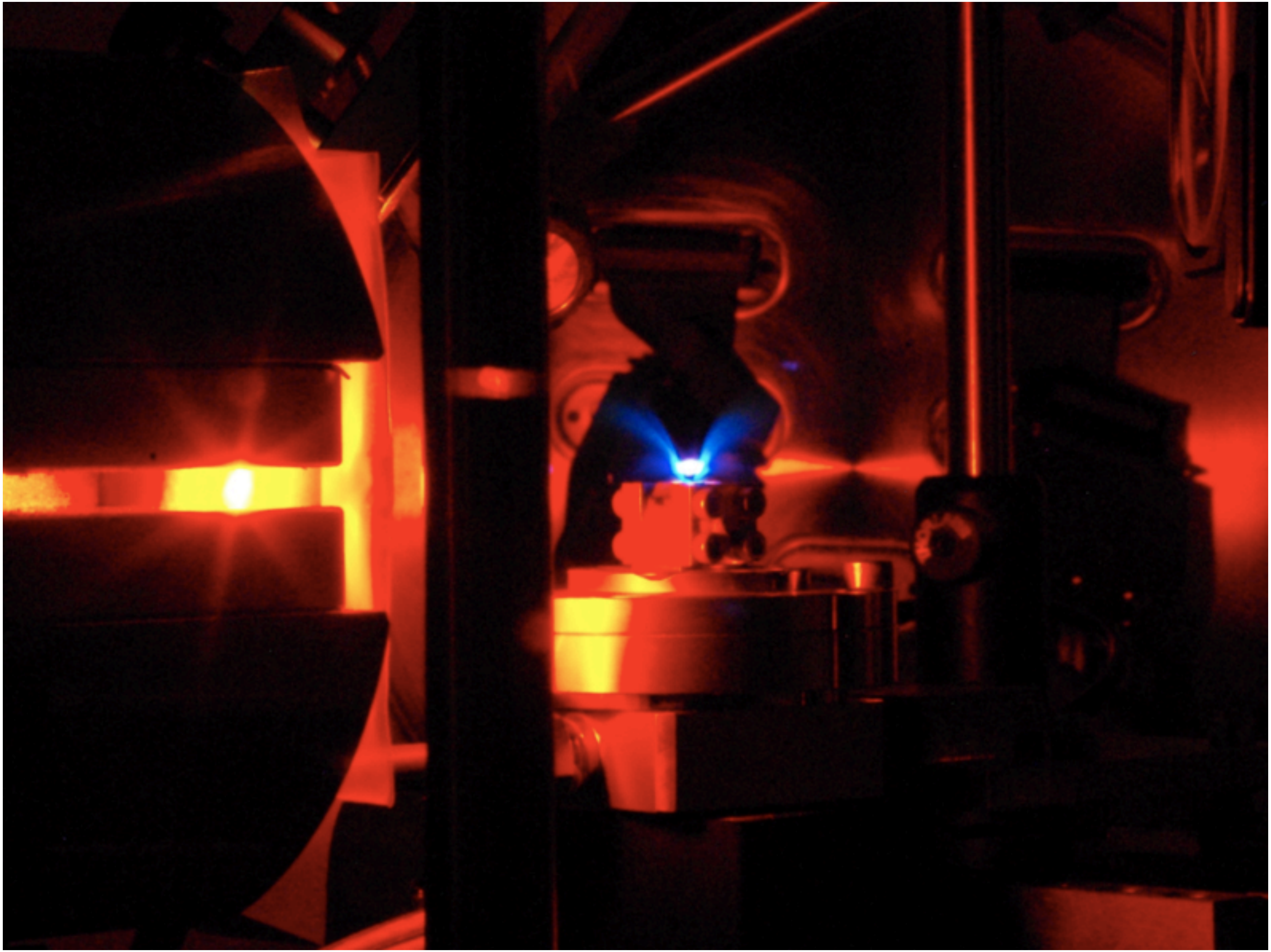

CONTENTS

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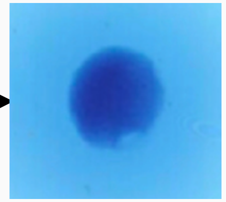
PARTICLE ACCELERATION WITH LASERS

ENERGY SOURCE:
Laser

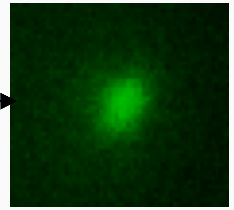
Laser focusing and control

OVERDENSE PLASMA
Laser-solid interactions

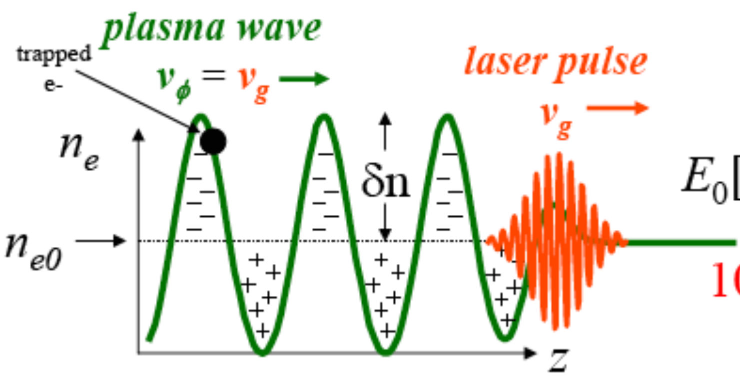


Protons, ions,
e^-, e^+,
broad spectrum,
lower E,

UNDERDENSE PLASMA
Laser-gas interactions



e^-,
narrow spectrum,
Up to GeV energy



$$E_0[V/cm] = \frac{mc\omega_p}{e} = 0.96(n_e[cm^{-3}])^{1/2}$$

10^{11} V/m

10^{18} cm^{-3}

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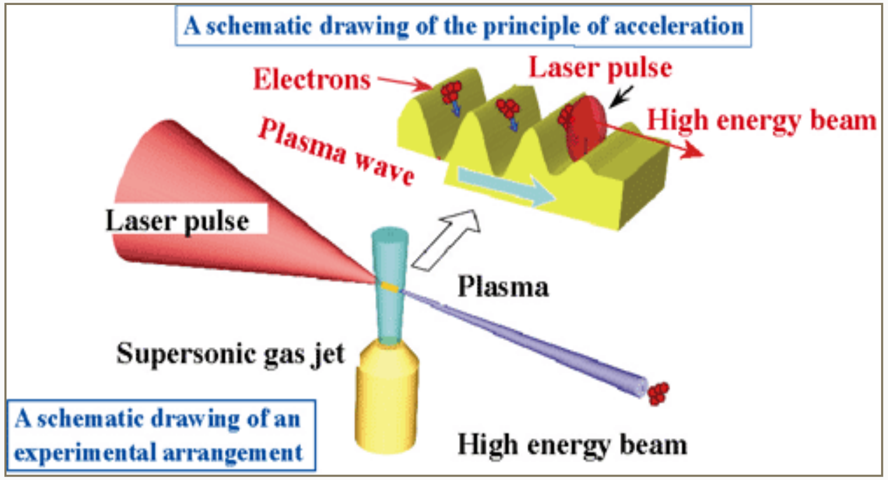
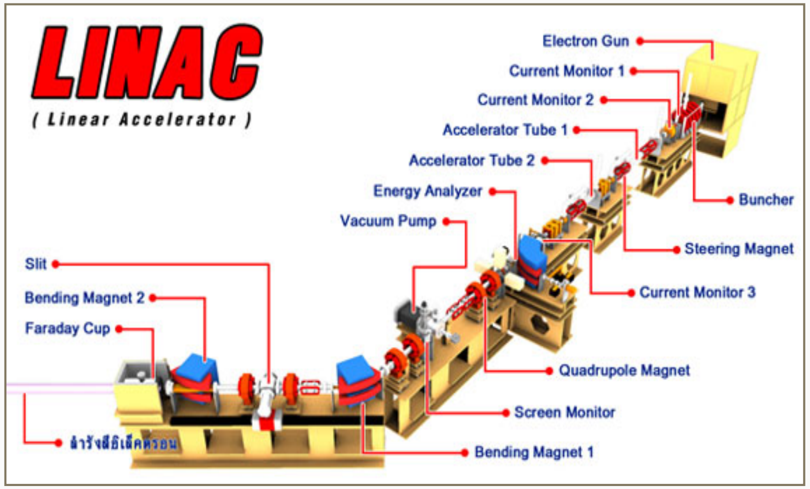
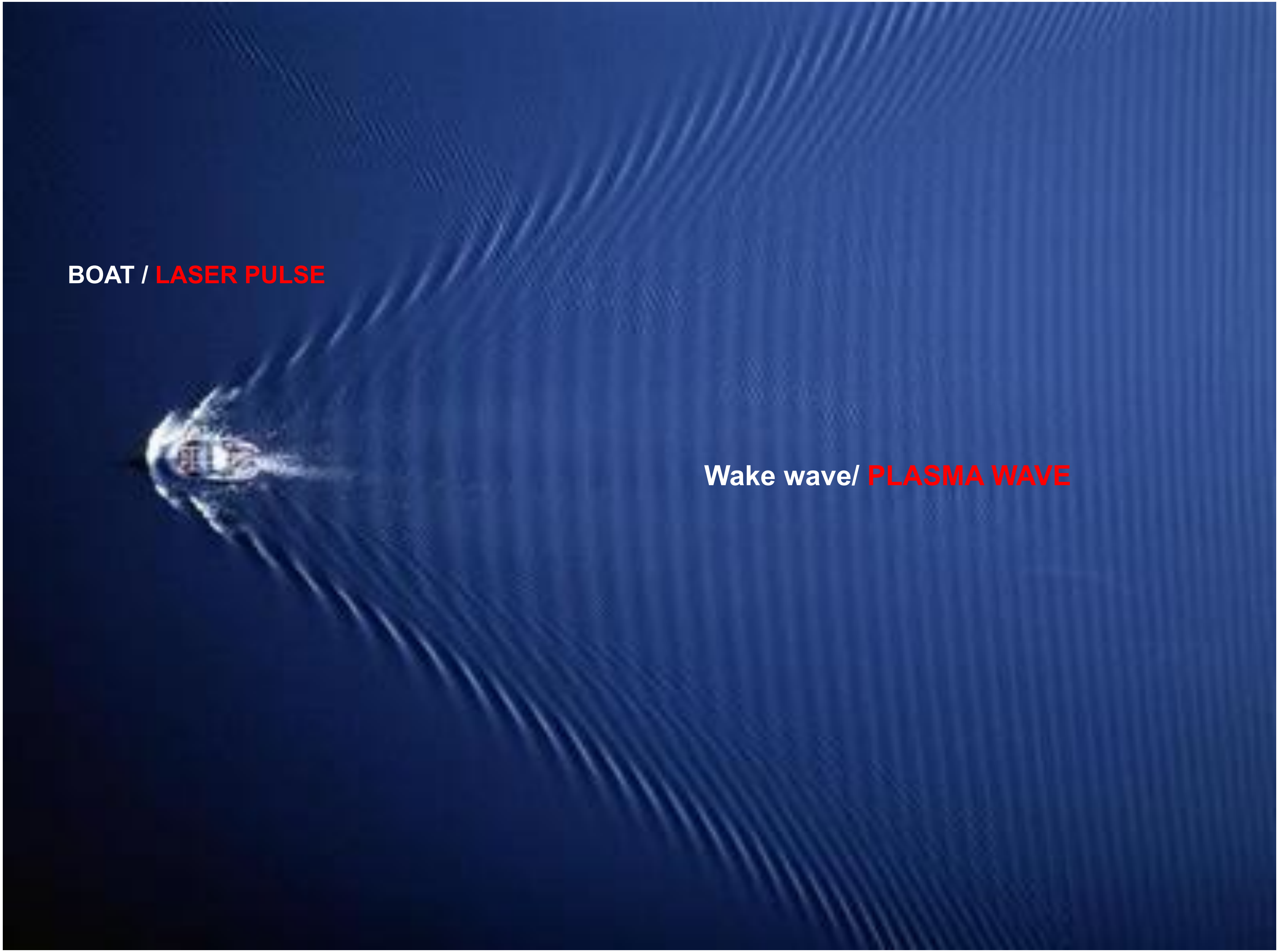
MINIATURE ACCELERATORS?

- CONVENTIONAL ACCELERATORS:
  - ELECTRON GUN (LASER PHOTOCATHODE) + ACCELERATING CAVITIES (RF)
  - accelerating fields $\approx$ 15 MV/m
- LASER-PLASMA ACCELERATORS
  - PLASMA MEDIUM (GAS …) + ELECTRON PLASMA WAVES (INTENSE LASER)
  - Accelerating fields > tens of GV/m





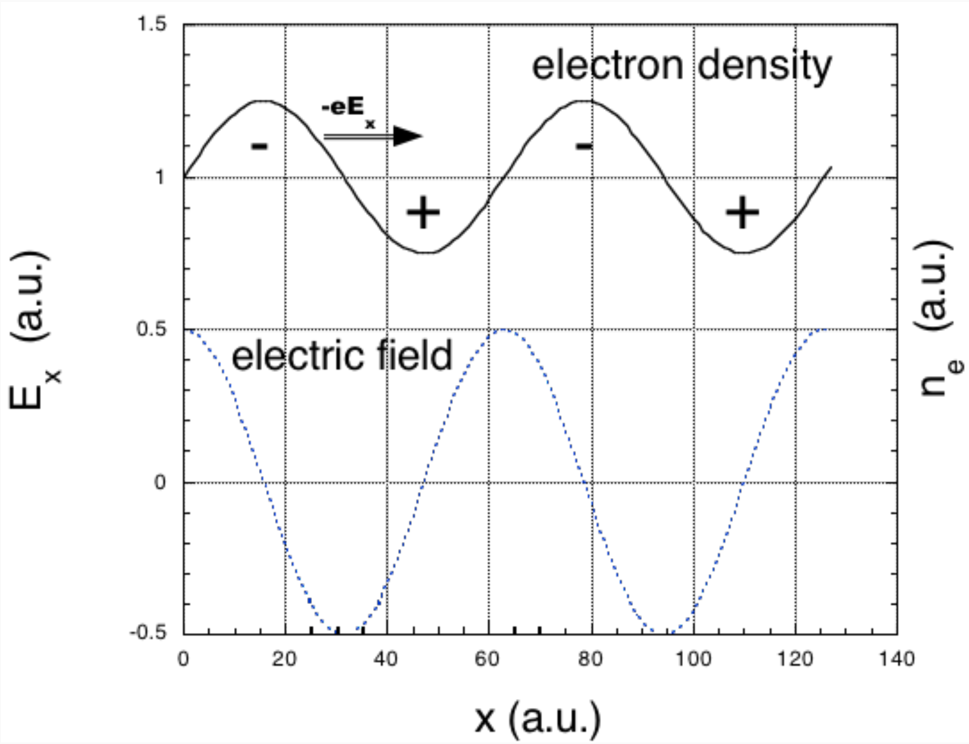

BOAT / LASER PULSE
Wake wave/ PLASMA WAVE

WHY A PLASMA?

• no structural limits to the accelerating electric fields;

• electron plasma waves (e.p.w) fit requirements for particle acceleration:

- intense longitudinal electric fields;
- phase velocity very close to the speed of light;



How to create high amplitude e.p.w. ?

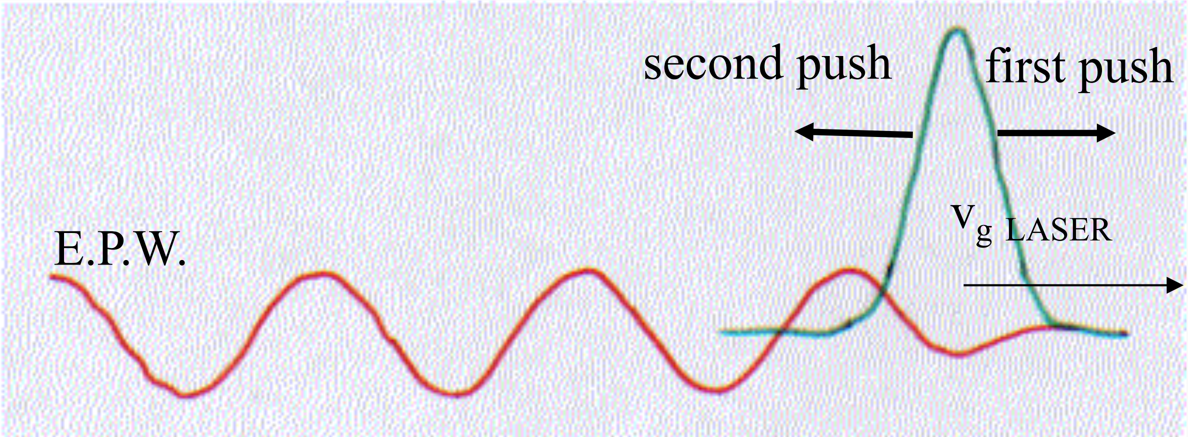
• Ponderomotive force;

• Coulomb force;

• Use charged particles or laser pulses;

LASER WAKEFIELD

Electron plasma wave excitation by laser wakefield



electron plasma frequency $\quad f_{pe} = \omega_{pe}/2\pi = 8.98 \times 10^3 n_e{}^{1/2}$ Hz

$$\omega_{pe} = (4\pi n_e e^2/m_e)^{1/2}$$
$$= 5.64 \times 10^4 n_e{}^{1/2} \text{ rad/sec}$$

$$\tau \cdot c \approx \frac{\lambda_p}{2} \quad \Leftrightarrow \quad \tau \approx \frac{T_p}{2} \quad \Rightarrow \quad n_e\left(cm^{-3}\right) \approx \frac{3 \cdot 10^{-9}}{\tau^2_{(s)}}$$

$$example: \quad \tau = 30\, fs \quad \Rightarrow \quad n_e \approx 3.3 \cdot 10^{18}\, cm^{-3}$$

$$v_{\phi,epw} = v_{g,laser} = c(1 - \frac{\omega^2_{pe}}{\omega^2})^{\frac{1}{2}} = c(1 - \frac{n}{n_c})^{\frac{1}{2}}; \; n_c(cm^{-3}) = 1.1 \times 10^{21} \left[\lambda(\mu m)\right]^{-2}$$

BEYOND CLASSICAL WAKEFIELD

At ultra-short, ultra intense laser conditions:

- Laser pulse self-focuses and self-compresses and creates an electron evacuated cavity (bubble)* surrounded by a high density wall of electrons;
- At sufficiently high density at the walls, electrons are driven at the back of the wall and <u>injected in the bubble</u> until the density of the injected electrons equals the wall density;
- The faster the process the higher the <u>localisation</u> of the injected electrons, with consequent reduction of energy spread.
- Self-injection, however, is non-linear and hard to control => <u>reproducibility</u> and energy stability is limited;
- All optical schemes** can be used to control injection to a significant degree;
- External injection using high-quality electron bunches can ultimately be used to boost energy while preserving quality (energy spread, emittance, charge etc. …)
- Deal with limiting **d-**factors: **d**iffraction, **d**ephasing, **d**epletion …

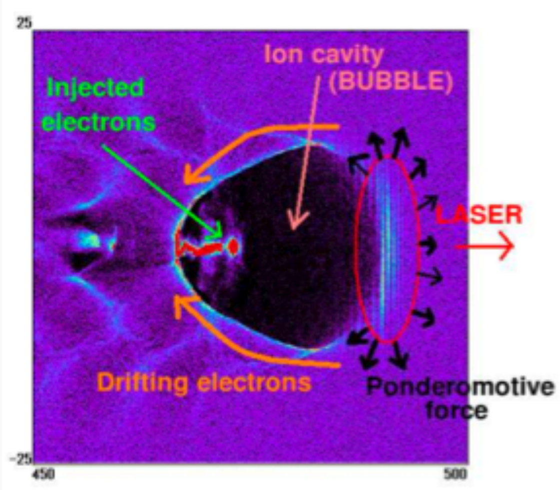
•Refs.: *A. Pukhov, Appl. Phys. B, **74**, 355 (2009), **J. Faure et al.,,Nature **444,** 737 (2006).

TOWARDS HIGHER QUALITY BEAMS

Ultrashort, ultraintense laser pulses can drive a new, highly non linear regime with a powerful injection mechanism that leads to a reduced energy spread.

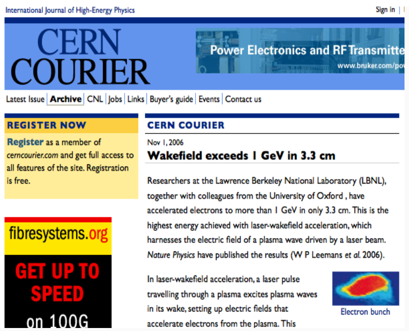
S.P.D. Mangles et al., Nature, 431, 535 (2004); C.G.R. Geddes et al., Nature, 431, 538 (2004); J. Faure et al., Nature, 431, 541 (2004);

Since 2004, systematic production of electron bunches with energy in the hundreds of MeV range and moderate energy spread (5-10%):



- Miura, Appl. Phys. Lett. 86, 251501 (2005)
- Hsieh, Phys. Rev. Lett. 96, 095001 (2006)
- Hidding, Phys. Rev. Lett. 96, 105004 (2006)
- Hosokai, Phys. Rev. E 73, 036407 (2006)
- Giulietti et al., Phys. Rev. Lett. 101, 105002 (2008)

and many, many more …



International Journal of High-Energy Physics

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CERN COURIER

Nov 1, 2006

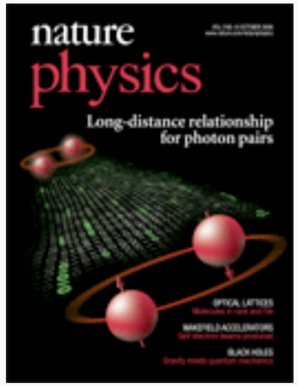
Wakefield exceeds 1 GeV in 3.3 cm

Researchers at the Lawrence Berkeley National Laboratory (LBNL), together with colleagues from the University of Oxford, have accelerated electrons to more than 1 GeV in only 3.3 cm. This is the highest energy achieved with laser-wakefield acceleration, which harnesses the electric field of a plasma wave driven by a laser beam. *Nature Physics* have published the results (W P Leemans *et al.* 2006).

In laser-wakefield acceleration, a laser pulse travelling through a plasma excites plasma waves in its wake, setting up electric fields that accelerate electrons from the plasma. This

Electron bunch

Most recent results from LBL LOASIS group: 1 GeV



"GeV electron beams from a cm-scale accelerator," by W. P. Leemans, B. Nagler, A. J. Gonsalves, Cs. Toth, K. Nakamura, C.G.R. Geddes, E. Esarey, C.B. Schroeder, and S.M. Hooker, October 2006 issue of Nature Physics.

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POTENTIAL APPLICATIONS OF LASER-DRIVEN GeV e^-

- Radiotherapy with tunable, high-energy electrons, including IORT

DeRosiers, "150-250 MeV electron beams in radiation therapy,"Phys. Med. Biol. 45, 1781 (2000) Glinec, "Radiotherapy with quasi-monoenergetic laser-plasma accelerators,"Med. Phys. 33, 155 (2006)

- Table-top, fs X-ray FELs

Nakajima, "Toward a table-top free-electron laser,"Nature Phys. 4, 846 (2008)

- γ-ray radiography for bio-medical and materials science

Glinec, "High-resolution γ-ray radiography produced by a laser-plasma electron source," Phys. Rev. Lett. 94, 025003 (2005); (MAMBO-BEATS);

- Efficient on-site production of radio-isotopes;

Reed, "Efficient initiation of photonuclear reactions using quasi-monoenergetic electron beams from laser wakefield acceleration," J. Appl. Phys.102, 073103 (2007); Giulietti et al., Phys. Rev. Lett. 101, 105002 (2008)

- Compact injectors for HEP accelerators
- On-site production of site production of short short-lived isotopes for medical imaging
- All-optical, tunable, monochromatic (Thomson-scattering) X-ray source for medical applications;
- …

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OUR PLANS FOR LPA

Pursue LPA for

a) **establishing LPA for future high energy accelerators**;

• Seek conditions for "all-optical" ultra-high gradient, multi-GeV acceleration under controlled laser-plasma interaction conditions;

• Also, explore "hibrid" schemes to enhance output of sources based upon existing conventional accelerators;

b) **bio-medical applications of table-top configurations**;

• Explore the physics of LPA at <u>TW level </u>and 10s of MeVs and find optimum conditions for efficient acceleration with long term operation and stable averaged output;

PLASMONX project

PLASma acceleration and MONochromatic X-ray radiation

COMBINING THE HIGH BRIGHTNESS LINAC ACCELERATOR OF THE *SPARC* PROJECT WITH AN ULTRA-SHORT, HIGH ENERGY, >250TW *FLAME* LASER.

Scheduled activity:

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

PLASMONX PROJECT UNITS

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L.I.F.E. AREA AT LNF-FRASCATI

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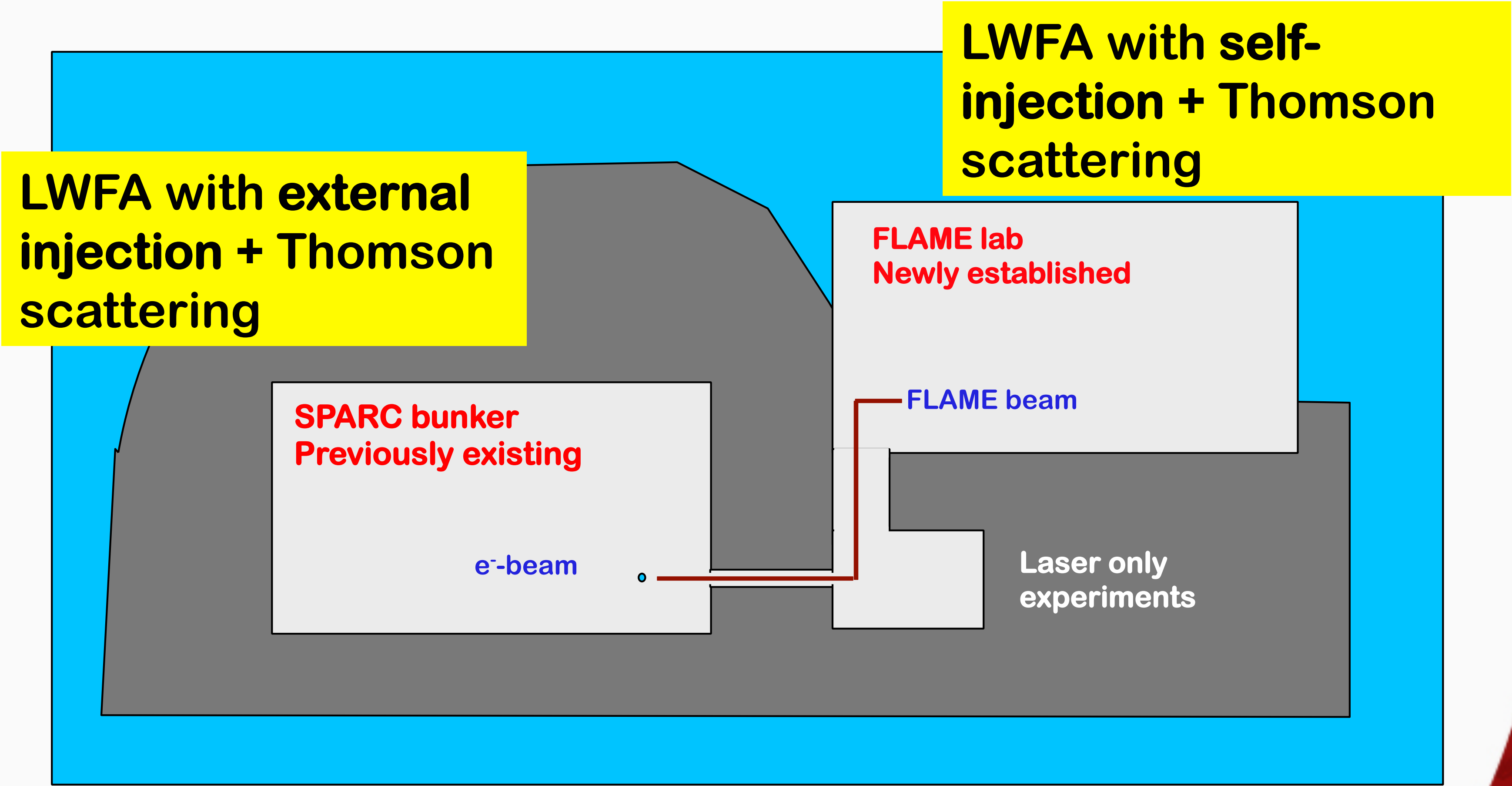
L.I.F.E. AREA AT LNF-FRASCATI

A dedicated area for LINAC and LASER combined operations



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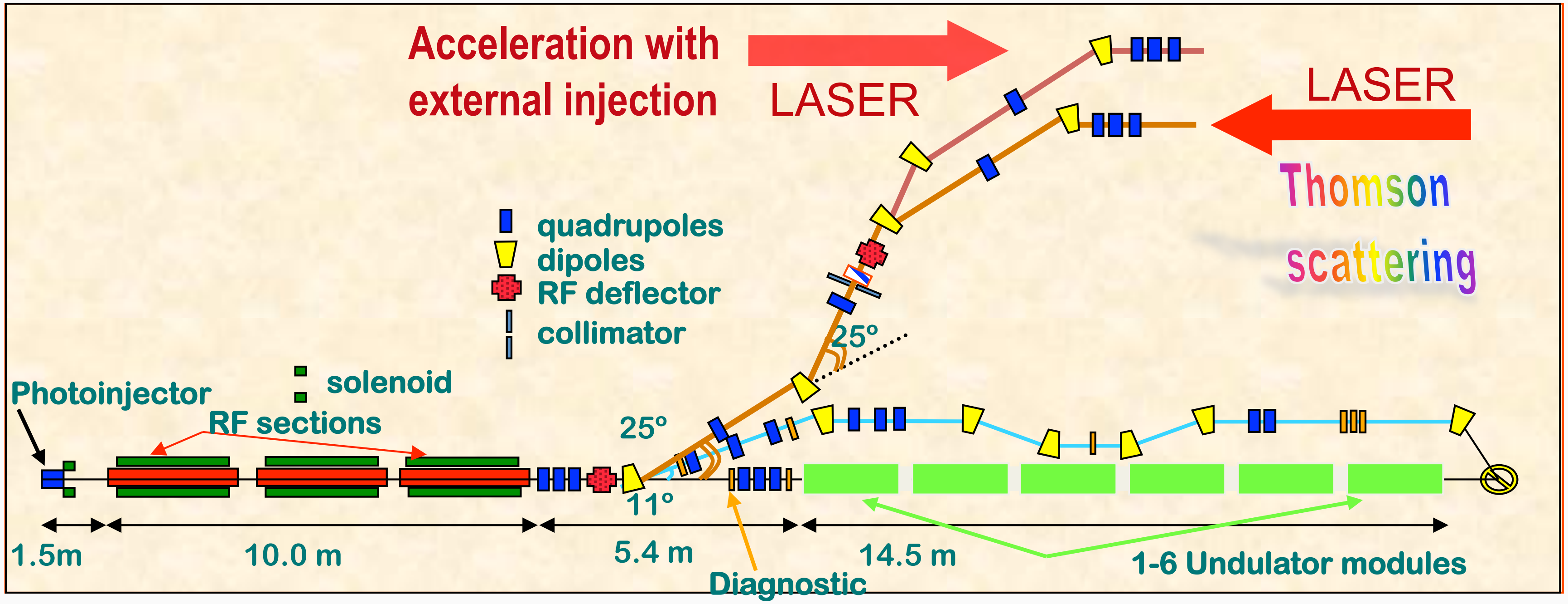
SPARC LINAC at LNF

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)	$5 \div 10$

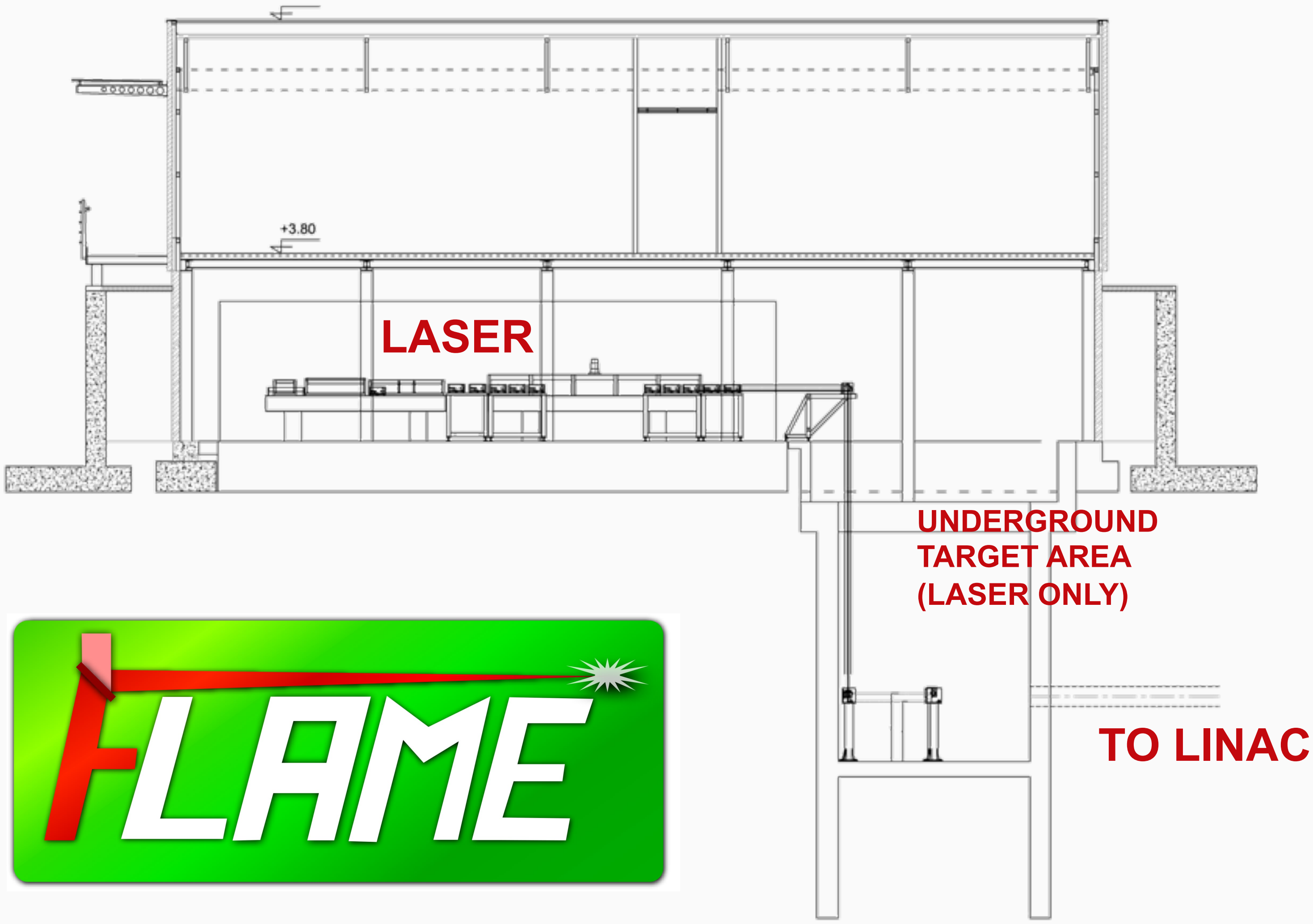


FLAME – A NEW LASER INSTALLATION

Frascati Laser for Acceleration and Multi-disciplinary Experiments

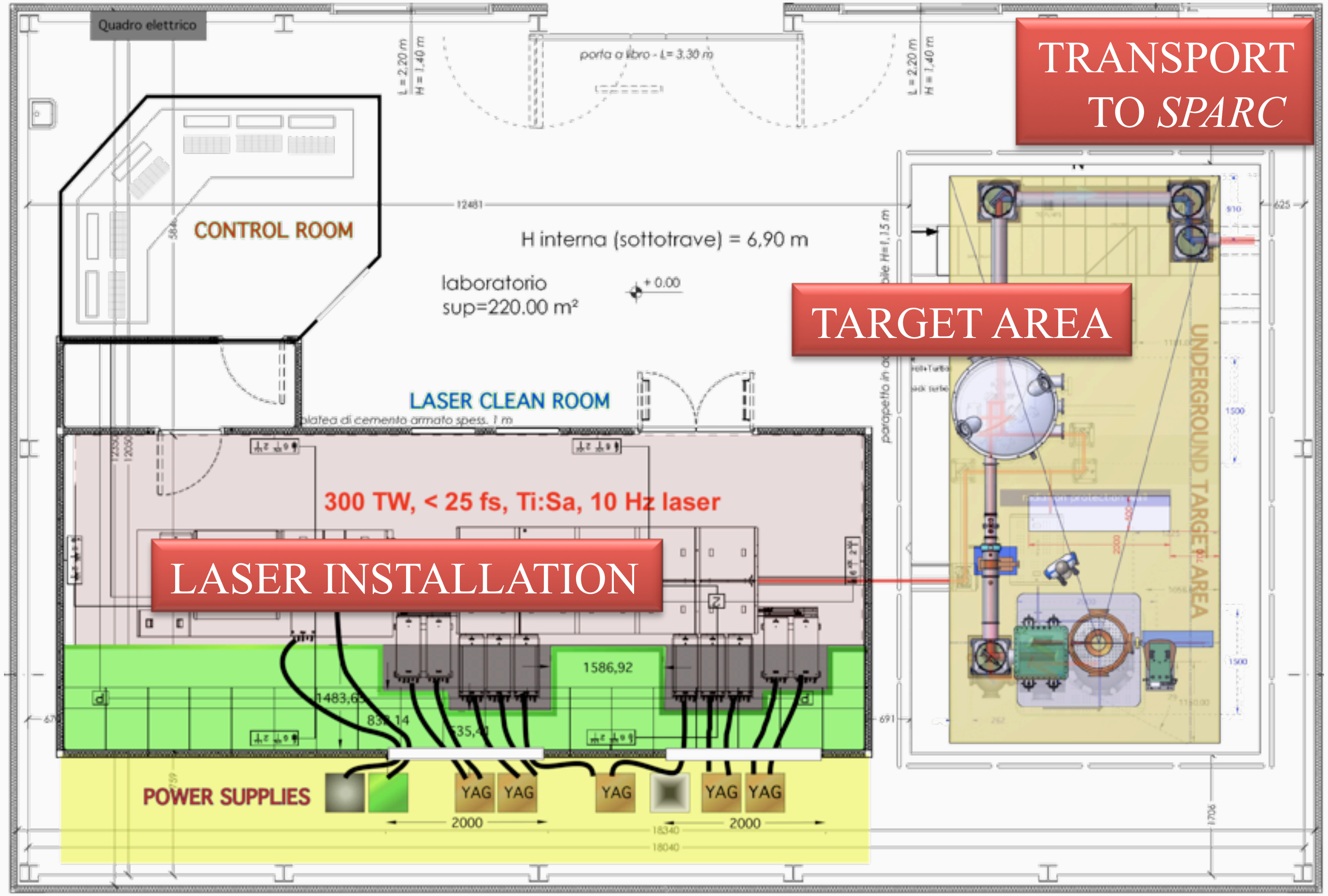
FLAME – A NEW LASER INSTALLATION

Frascati Laser for Acceleration and Multi-disciplinary Experiments



FLAME LAB: OVERVIEW

LAB INCLUDES *LASER*, RADIOPROTECTED *TARGET AREA* FOR LASER-TARGET EXPERIMENTS AND TRANSPORT OF LASER TO SPARC FOR LASER-LINAC OPERATION



THE FLAME LAB. – HISTORY 1/1

27th March 2007 –
beginning of construction

23rd June 2008 –
Building completed

FLAME – HISTORY 2/2

12th March 2009 –
delivery of laser

18th May 2009 –
start of Installation of clean room

10th June 2009 –
"Cold" laser installation

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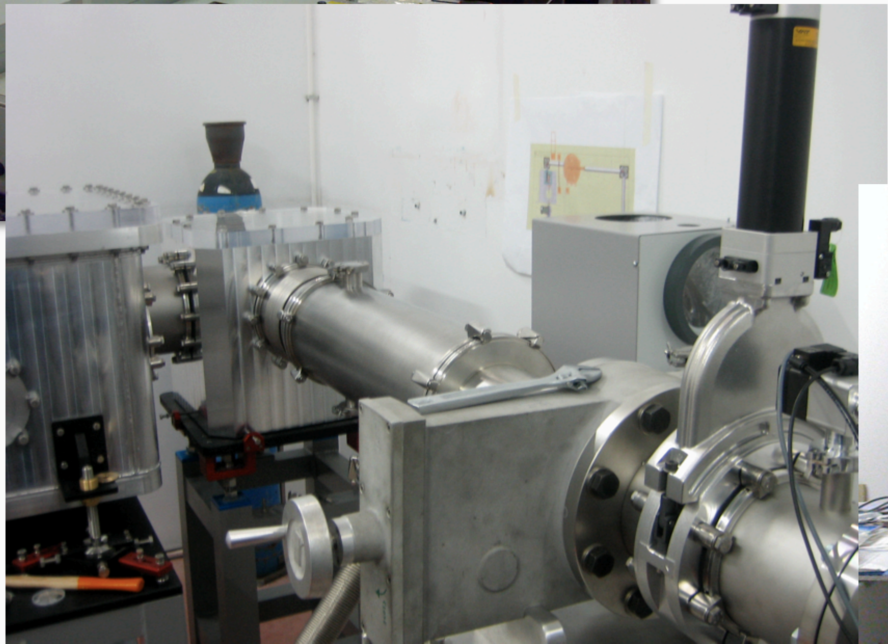
FLAME – RECENT PAST



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

December 2009 –
1st vacuum transport line completed;

July 2010 -
Laser at target point;

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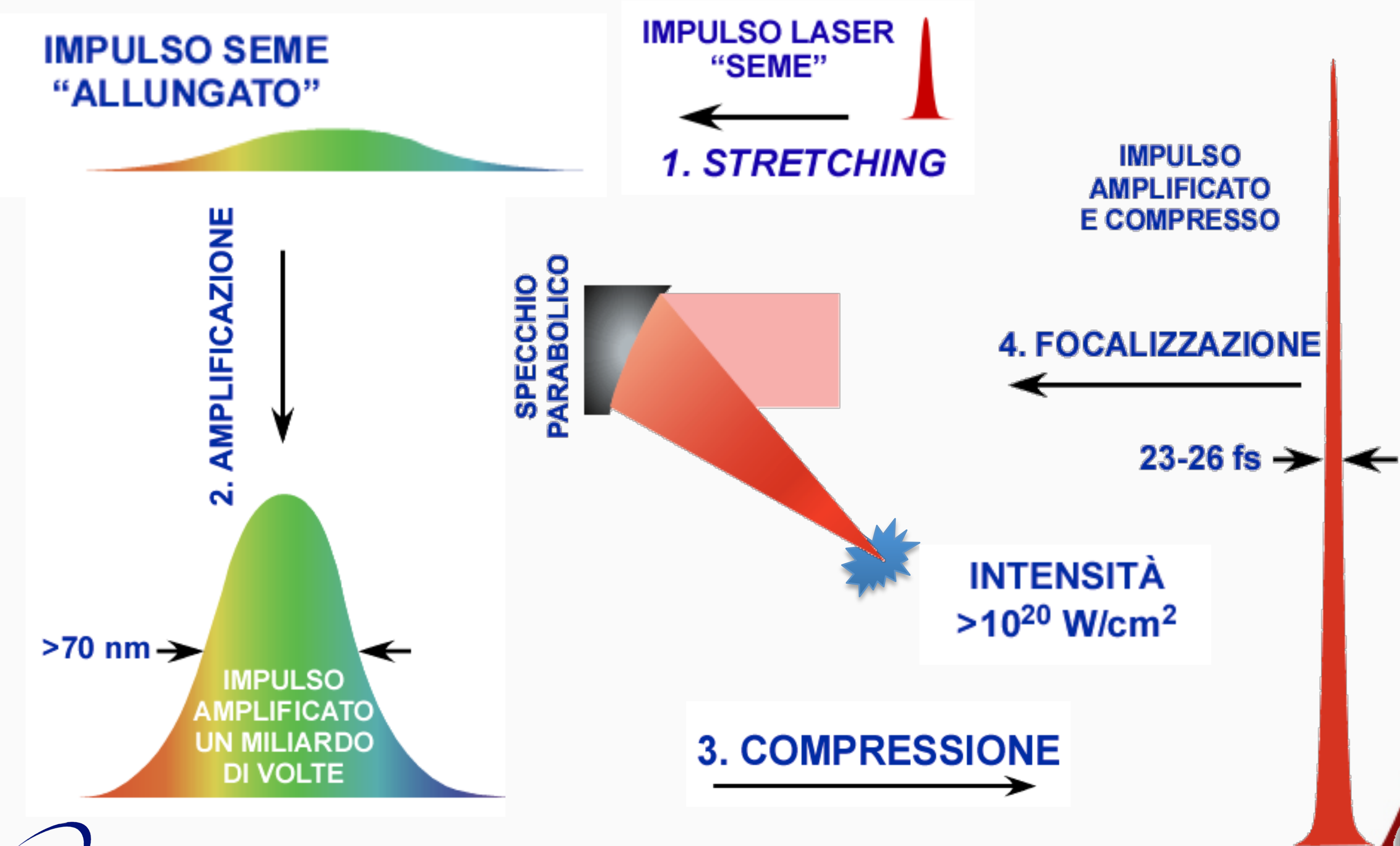
FLAME: DIAGRAMMA A BLOCCHI



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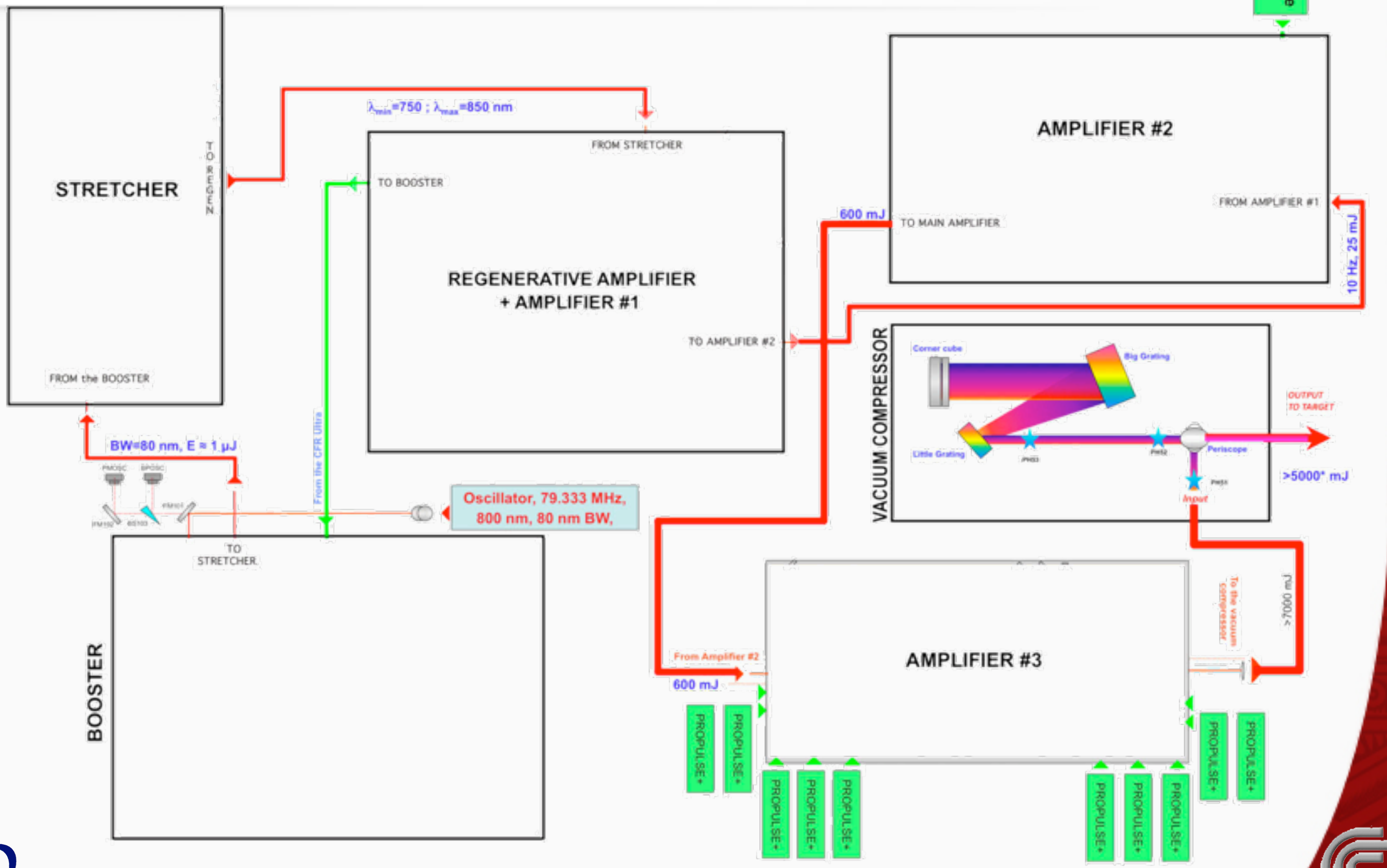
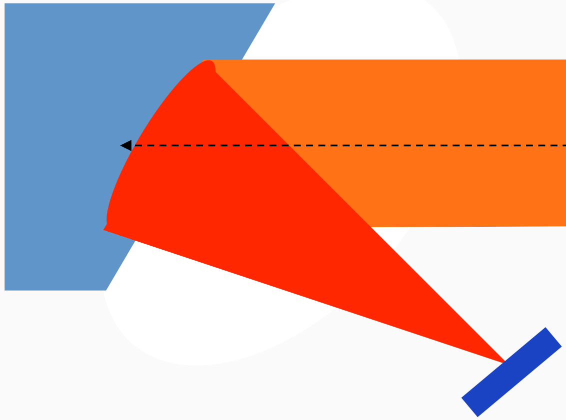
FLAME laser optical layout



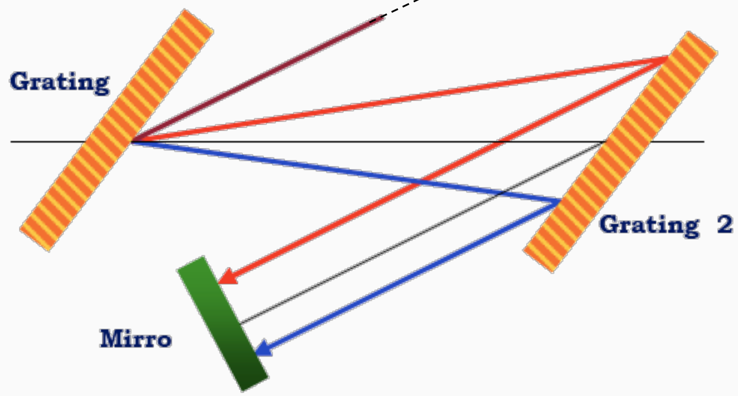
CPA: ENABLING TECHNOLOGY …

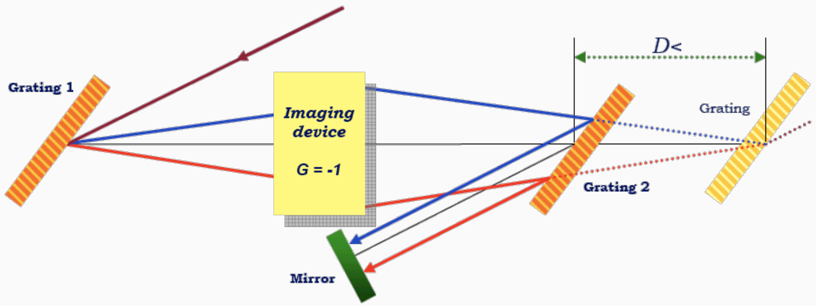
Off-Axis parabolic mirror

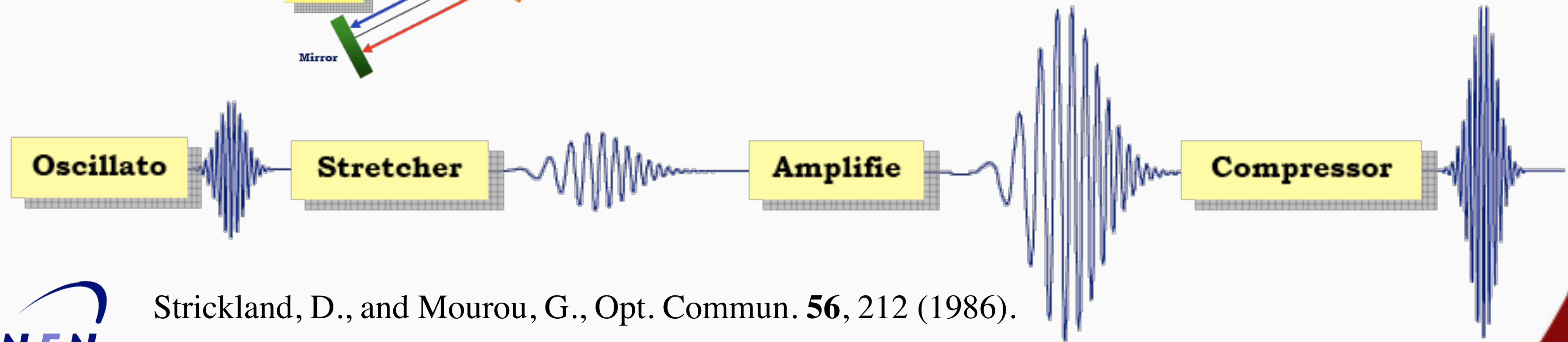


Intensity on target up to 10^{20} W/cm^2

λ_L= 800 nm, T <100 fs, E>1J







Strickland, D., and Mourou, G., Opt. Commun. **56**, 212 (1986).

FLAME: A FEW CHALLENGES …

- FLAME to operate a 250 TW, 10 Hz system
- Basic issues/challenges (project driven):
  - Pulse contrast ($>10^{10}$)
  - Pulse duration (<30 fs)
  - Performance stability to compare with LINAC
  - Mechanical stability (2 μm at focal spot)
  - …

CRITICAL ISSUES

BANDWIDTH 1/2

Ultrashort pulse duration with chirped pulse amplification requires large bandwidth gain medium;

Ti:Sa combined with bandwidth and phase control devices (dazzler, mazzler) are used to overcome gain narrowing and keep flat phase distribution over a 70-80 nm bandwidth;

Optical parametric CPA is rapidly being developed for a new generation of ultra-high bandwidth (up to 3x Ti:Sa) front-end;

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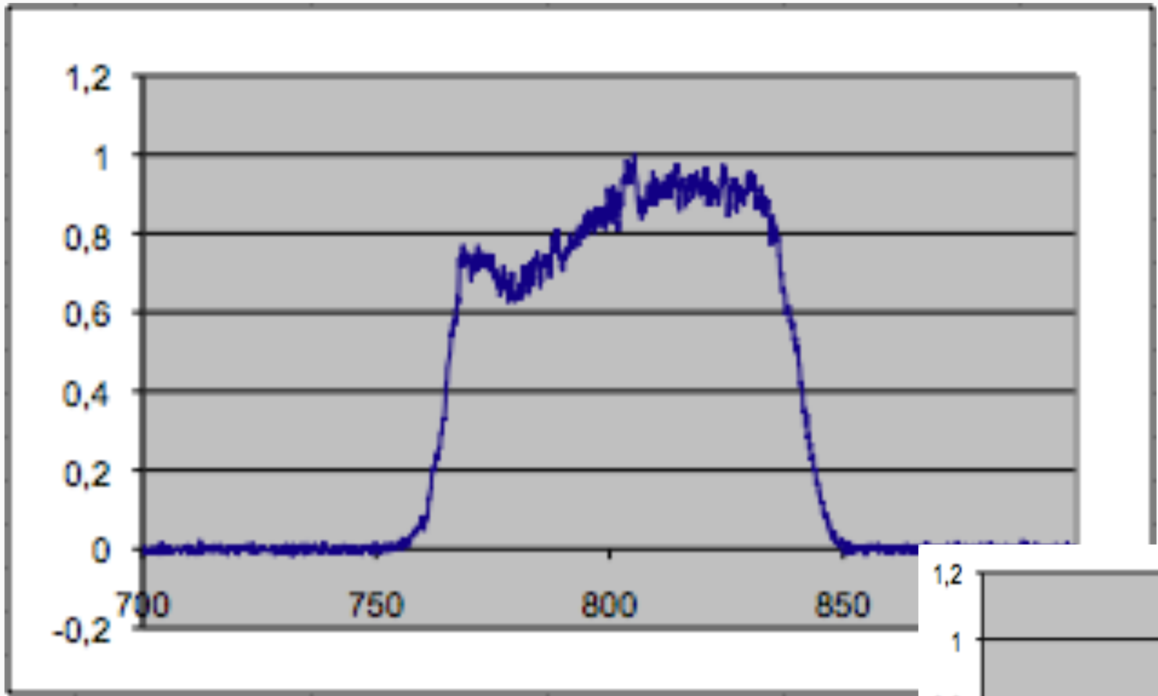
CRITICAL ISSUES

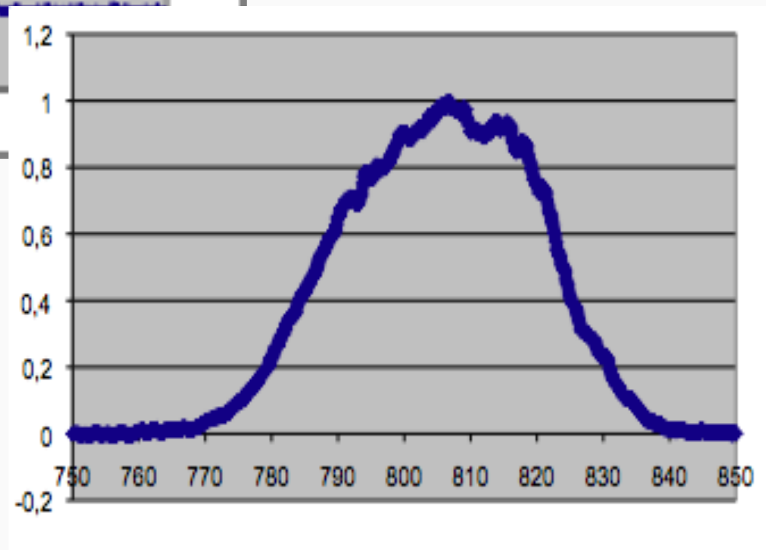
BANDWIDTH 2/2



7J FLAME spectrum

With mazzler

Without mazzler



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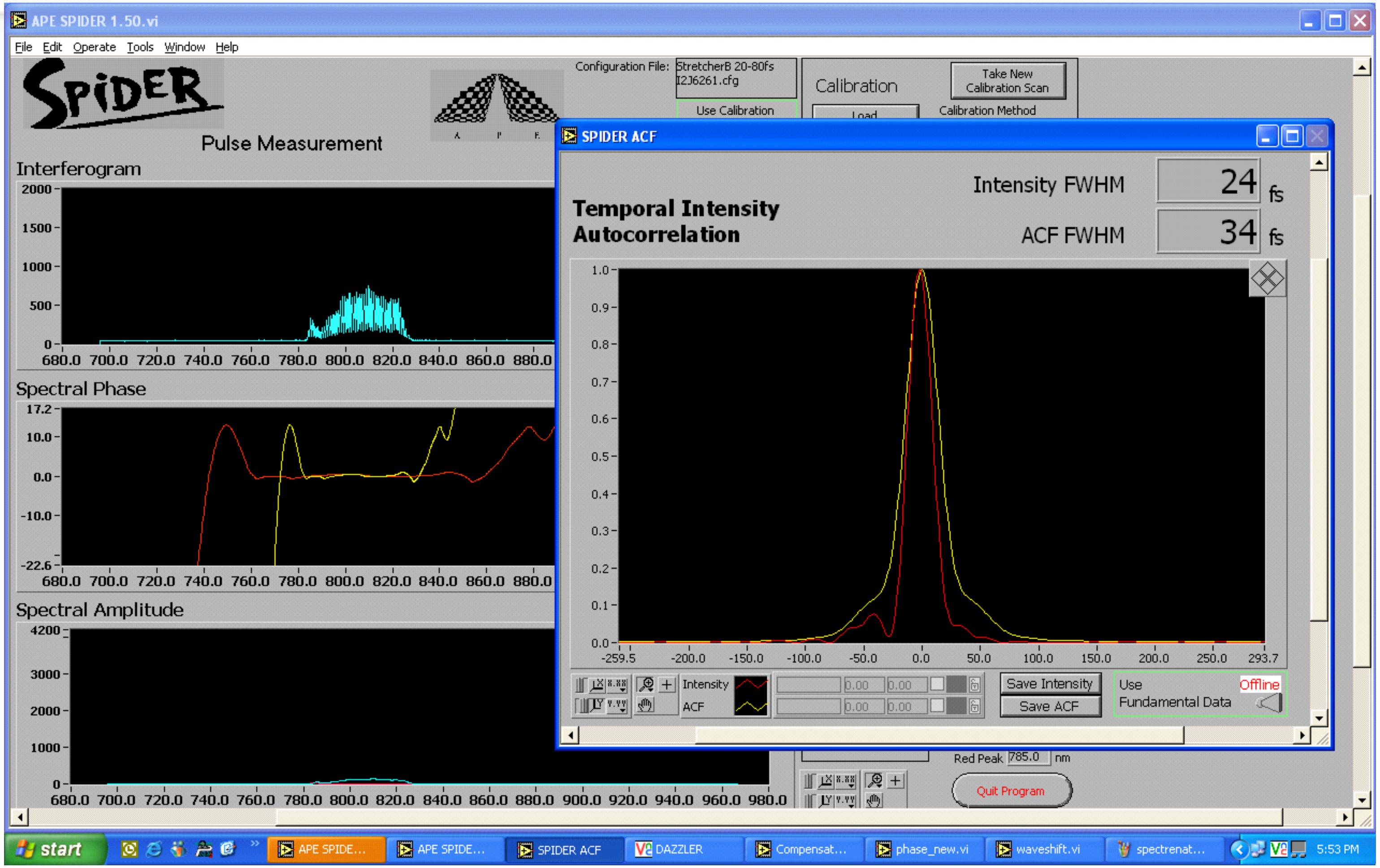
PULSE COMPRESSION



Pulse duration with the test compressor
Spider measurements

- natural duration < 55 fs
- corrected duration < 25 fs

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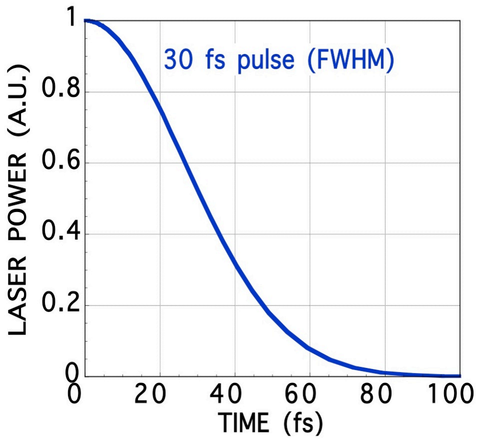
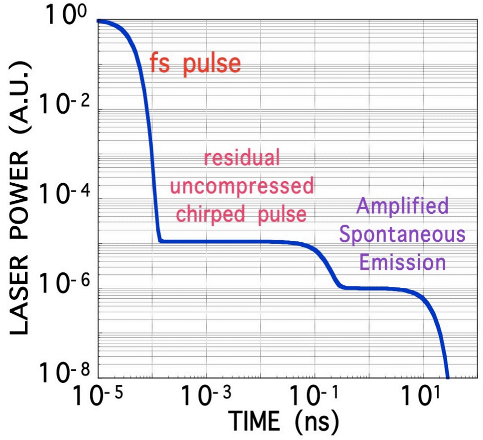
CRITICAL ISSUES

CONTRAST

Temporal contrast (ASE) in excess of 10 orders of mag. required for peak intensities on target of $>10^{20}$ W/cm^2.

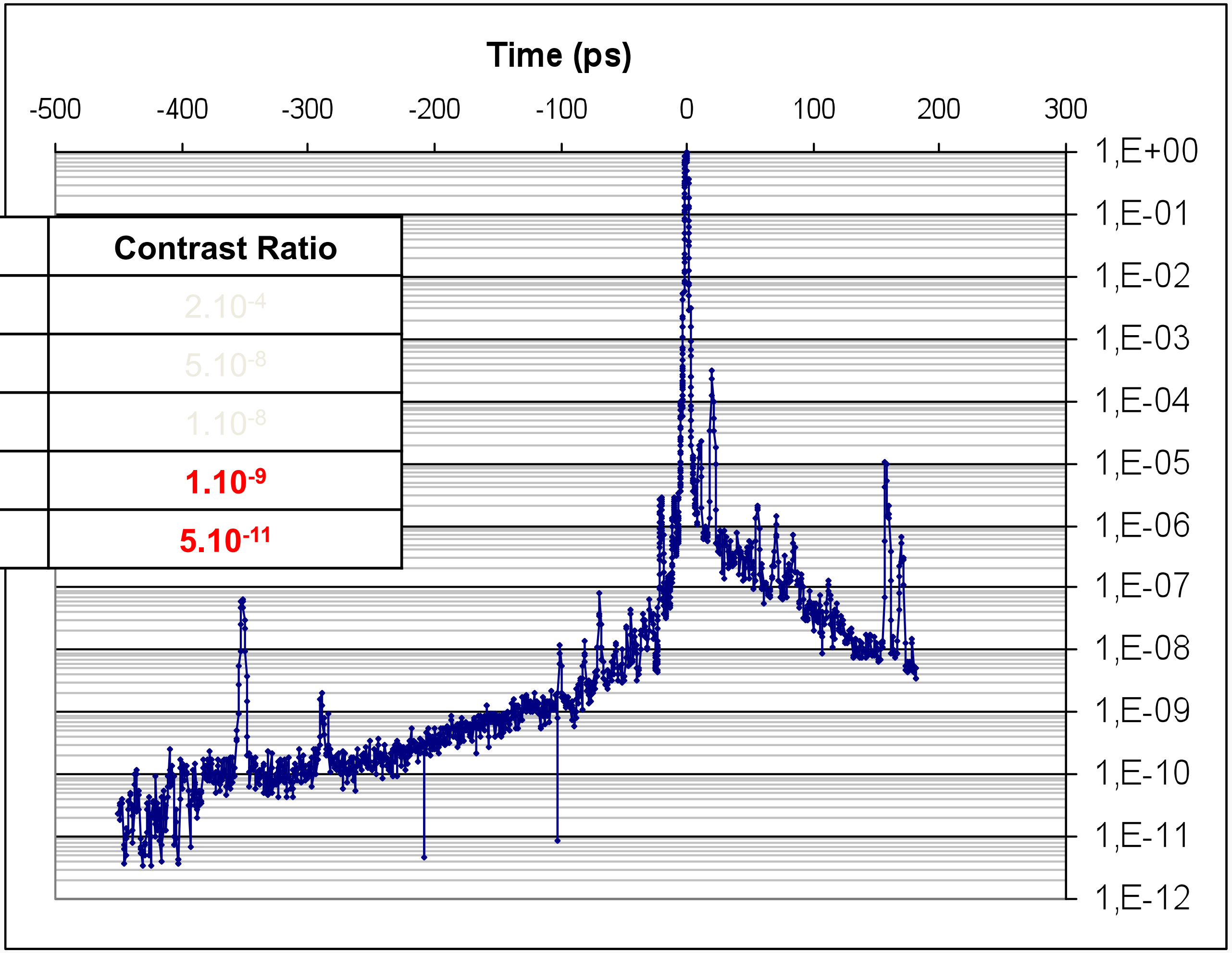




Established techniques include

- electro-optic devices (Pockel cells) for prepulse reduction;
- moderate gain in front-end and saturable amplifier for ASE management;
- Other advanced techniques (e.g cross-polarized wave generation) again for front-end contrast enhancement;

ASE CONTRAST: ACCEPTANCE TEST (DEC ’08)

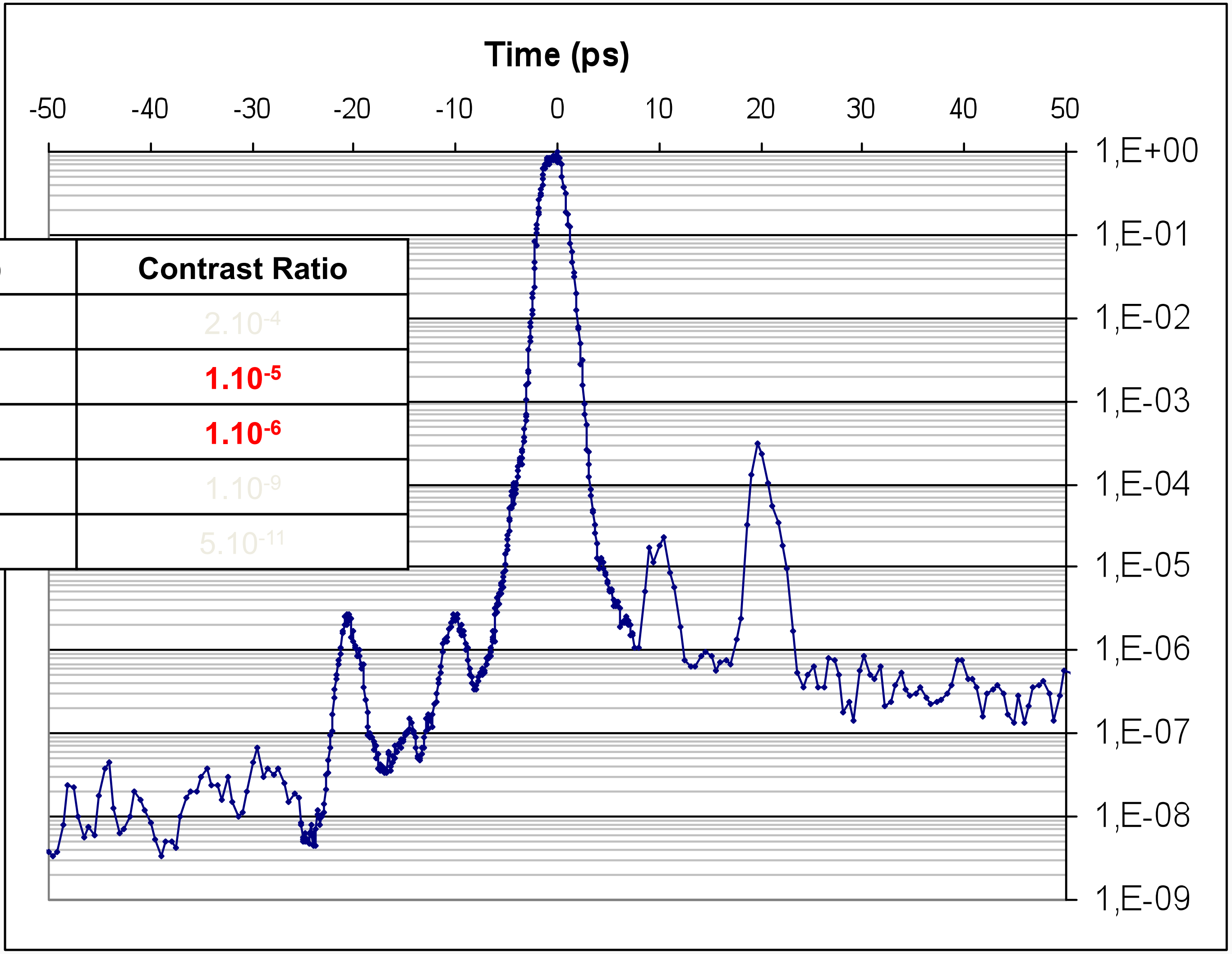


Time Delay (ps)	Contrast Ratio
-1	2.10^{-4}
-5	5.10^{-8}
-10	1.10^{-8}
-150	**1.10^{-9}**
-450	**5.10^{-11}**

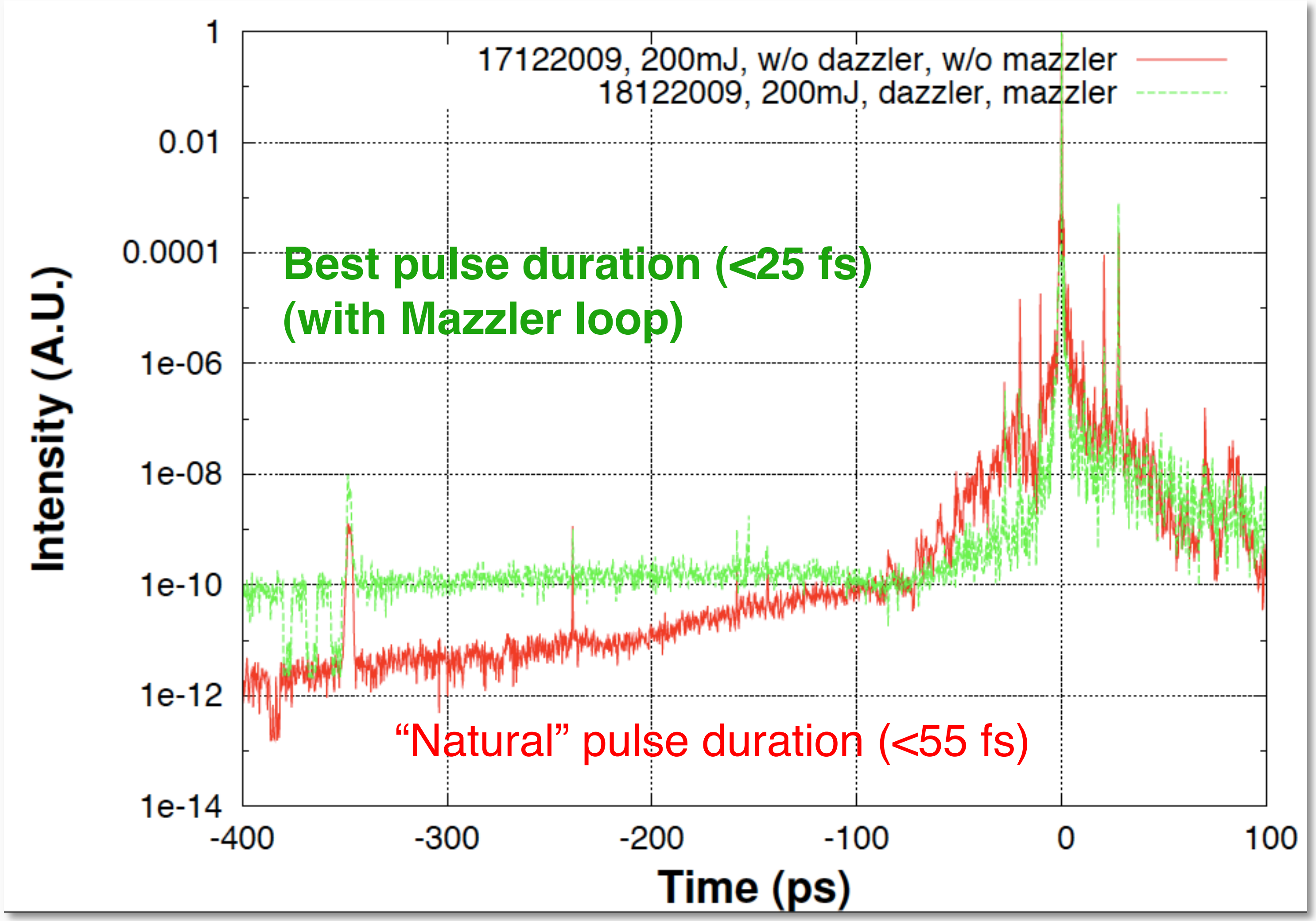
Full energy

ASE CONTRAST: ACCEPTANCE TEST (DEC '08)

Time Delay (ps)	Contrast Ratio
-1	2.10^{-4}
-5	**1.10^{-5}**
-10	**1.10^{-6}**
-150	1.10^{-9}
-450	5.10^{-11}



NEW CONTRAST MEASUREMENTS AT LNF



- Contrast level@200mJ well within specs;
- ASE contrast at natural pulse duration compares with plasma mirror!

CRITICAL ISSUES

BEAM QUALITY 1/2

A high beam quality is required to achieve high laser intensity in the focal spot.

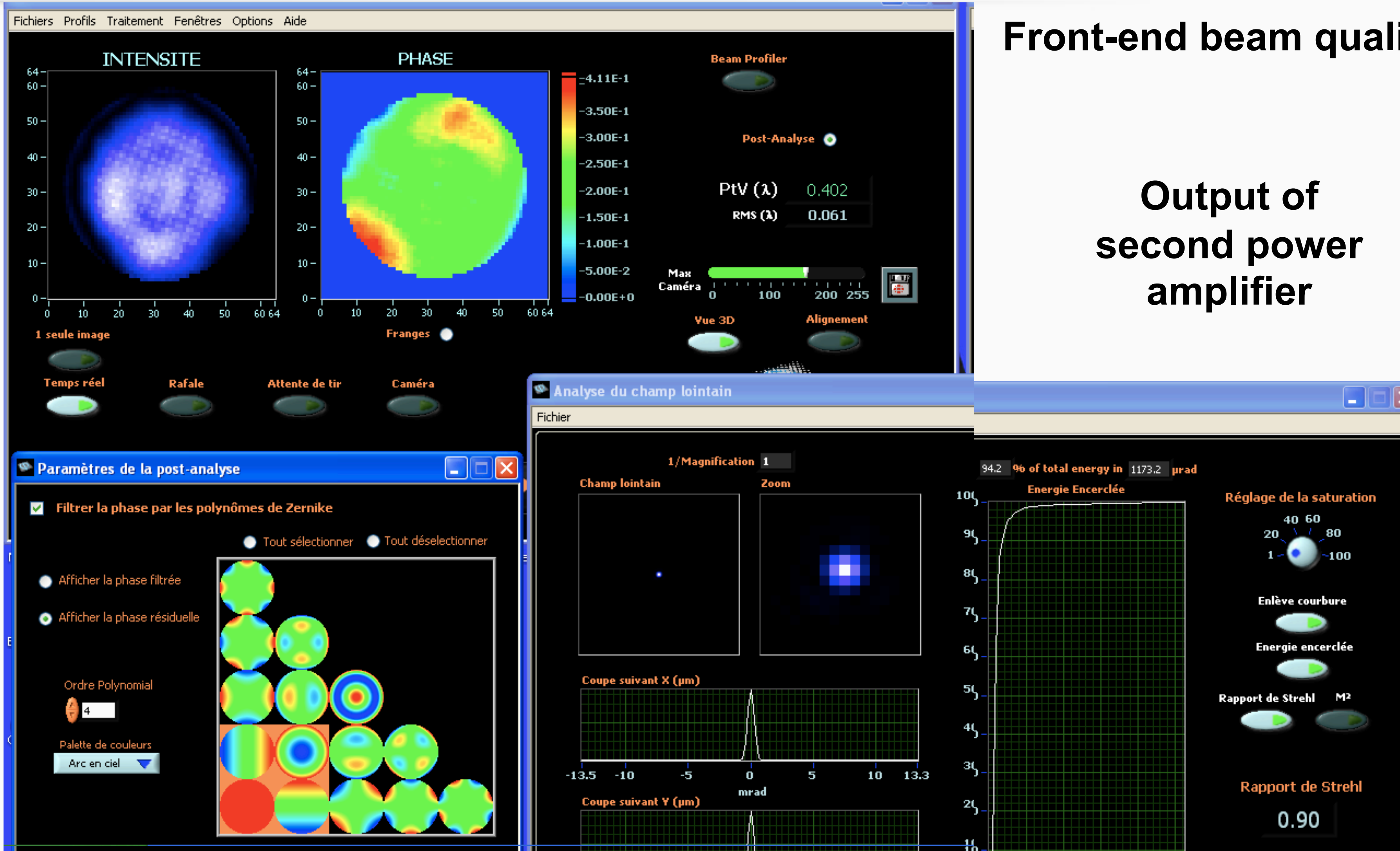
Strehl ratio (energy in the focal spot/total energy) and M^2 (deviation from the Gaussian shape) are used to measure beam quality;

Multi-pass and regenerative amplification implies large number of reflections off mirrors, passes through optics, gain medium and air;

Small imperfections of optics and air turbulence impose white-spectrum spatial scale distortions of the phase-front.

PHASE FRONT CHARACTERIZATION

Front-end beam quality



Output of second power amplifier

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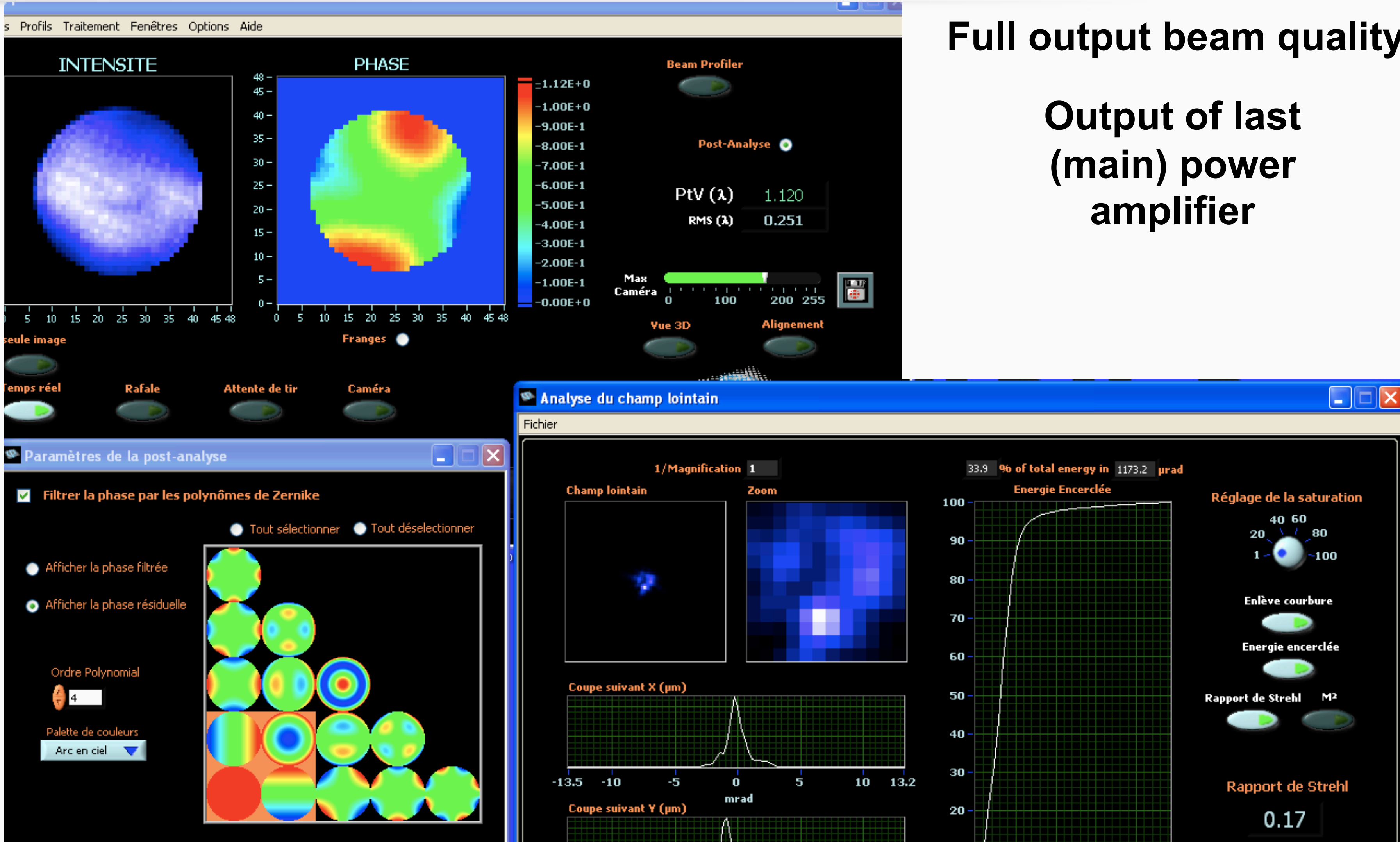
PHASE FRONT CHARACTERIZATION



Full output beam quality

Output of last (main) power amplifier

Correction required for optimum performance

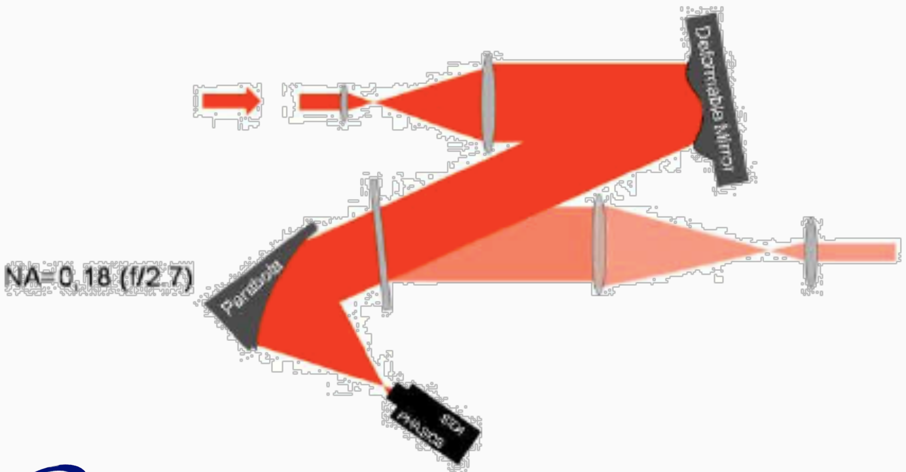
CRITICAL ISSUES

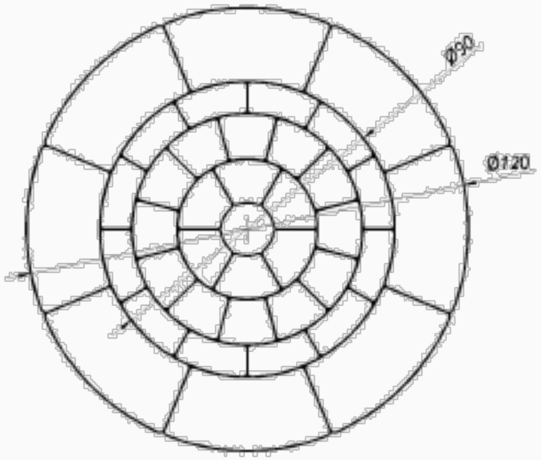
BEAM QUALITY 2/2

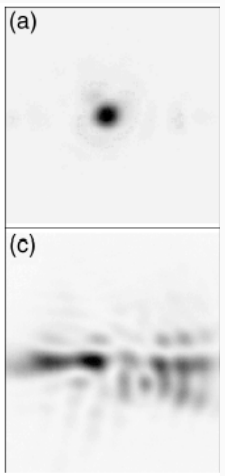
Active spatial phase control technique can be used to correct moderate distortions;

Sensors are used to measure intensity and phase map of the beam;

Deformable mirrors are used to correct the measured wave front distortions in a close loop;





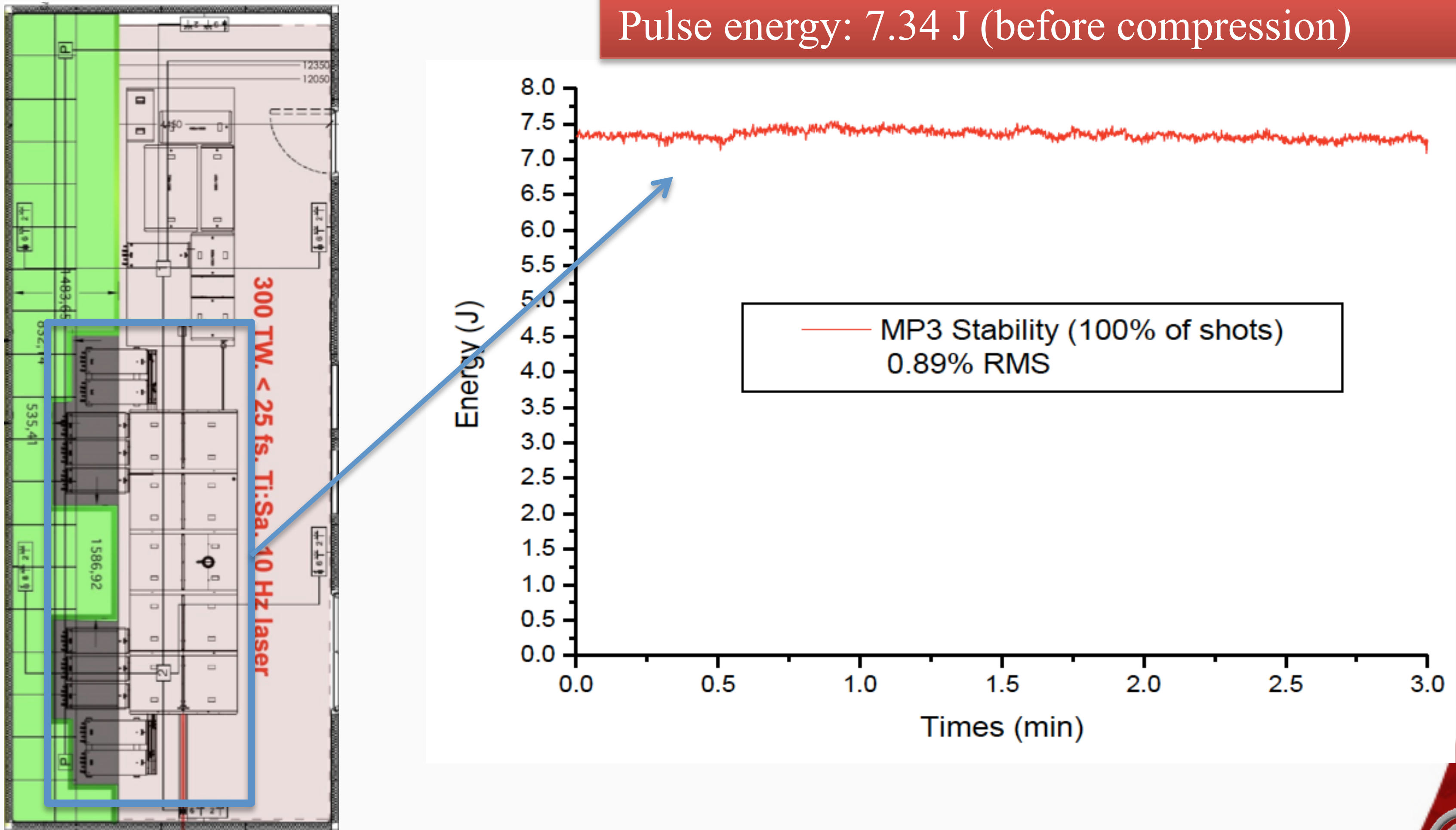


S.-W. Bahk et al., Optics Letters **29**, 2837 (2004)

FINAL AMPLIFIER: FULL ENERGY

Final amplifier operational with all YAG pump lasers

Pulse energy: 7.34 J (before compression)



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SUMMARY OF FLAME LASER

Summary of performance (to date)

- Energy before compression @ 7.3 J
- Vacuum compressor transmission > 70%
- Pulse duration down to 23 fs
- ASE Contrast ratio: better than $2x10^9$
- Pre-Pulse Contrast better than 10^8
- RMS Pulse Stability @ 0.8 %
- Pointing Stability (incl. path) < 2μrad
- Phase front correction needed;

➢Full vacuum compression planned before end of the year;

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TREND IN ULTRAINTESE LASERS

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Laser technology is rapidly progressing towards higher peak power × higher repetition rate:

Systems undergoing commissioning w.w. include (e.g.):

- 1.3 PW, 30 fs, 1 Hz repetition rate (LBNL, USA) => **10 GeV e^-**
- 1 PW, < 30 fs, 1 Hz repetition rate (CLPU, Salamanca, Spain)
- 10 PW ≈500 fs (CLF, Rutherford Appleton Lab, UK)

Still based upon Chirped Pulse Amplification and using flash-lamp pumped, frequency doubled Nd:YAG pump lasers. Future: DPSSL?

ELI Pillars (Czech Rep., Romania, Hungary…)

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LASER-PLASMA ACCELERATION WITH SELF-INJECTION A TEST EXPERIMENT (*S.I.T.E.*)

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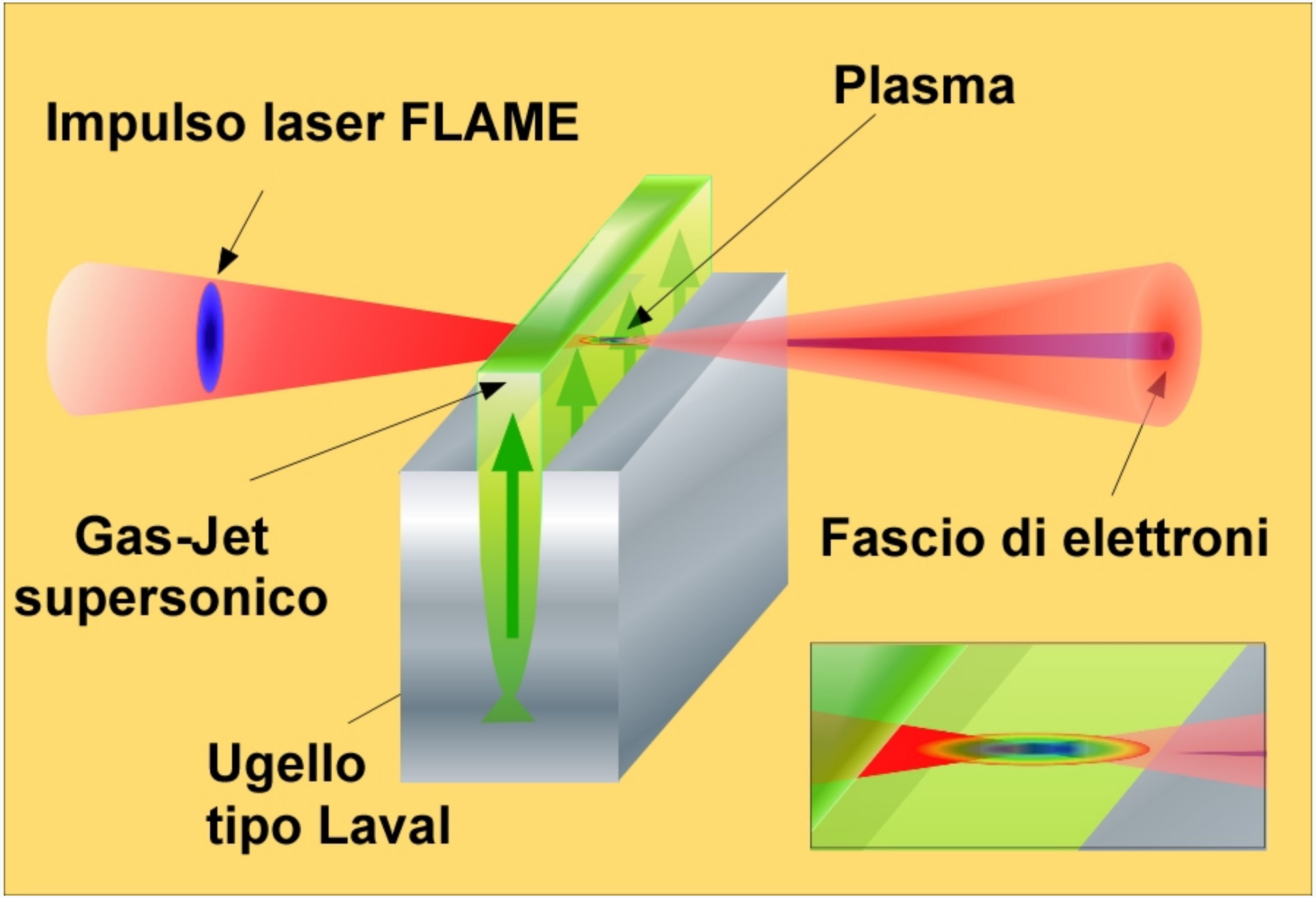
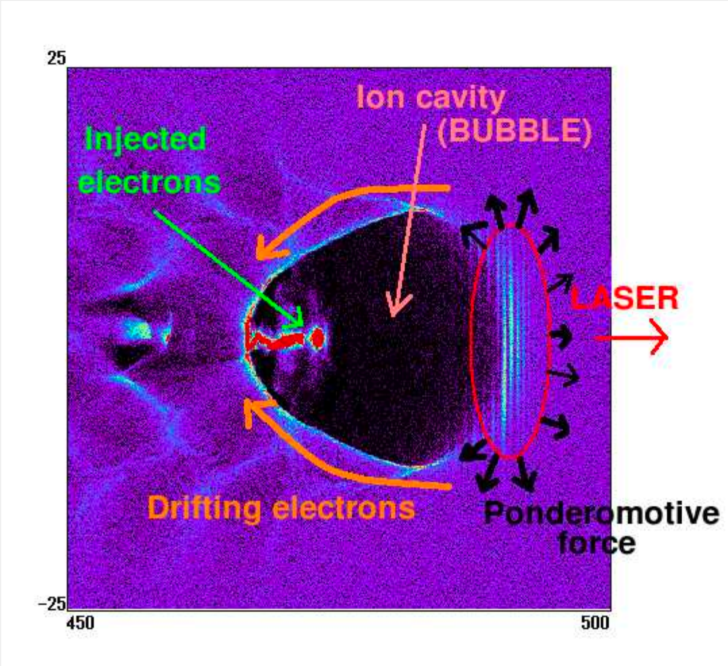
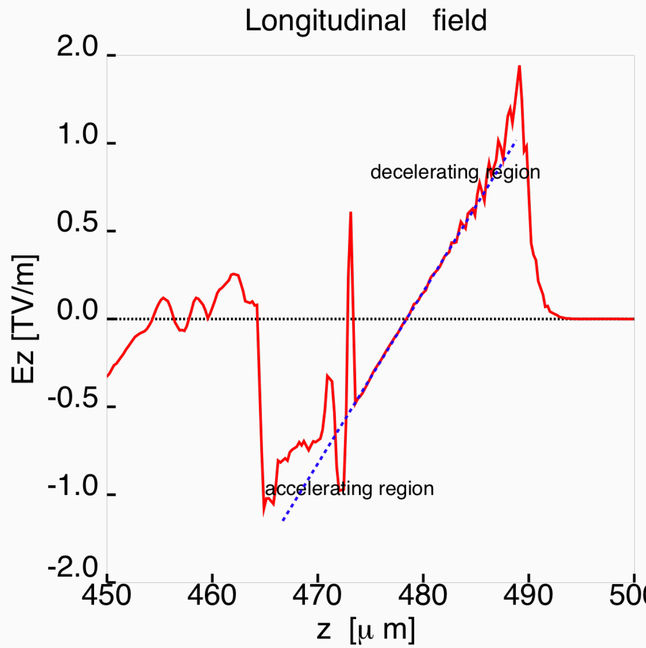
SELF-INJECTION – CONCEPT



SELF-INJECTION TEST EXPERIMENT

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





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

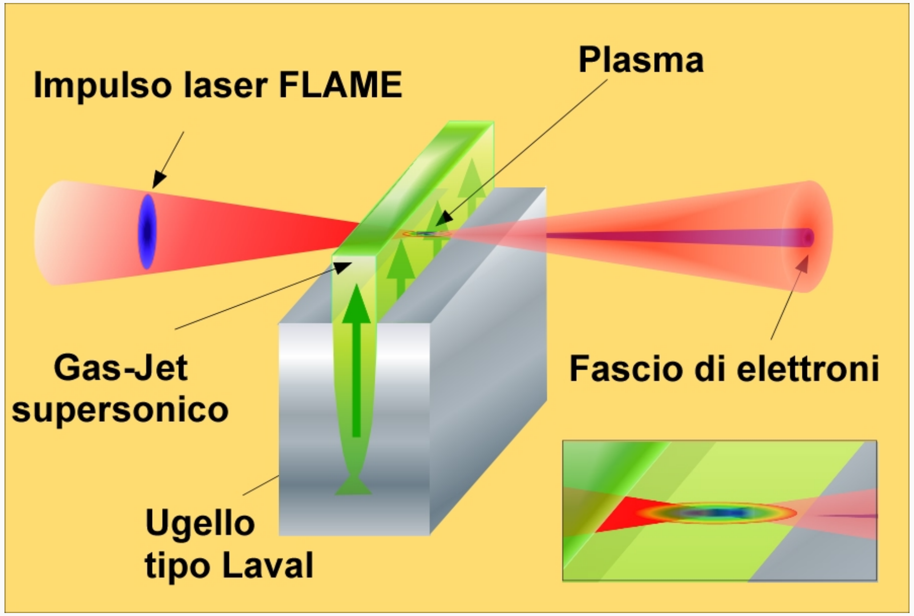
---

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

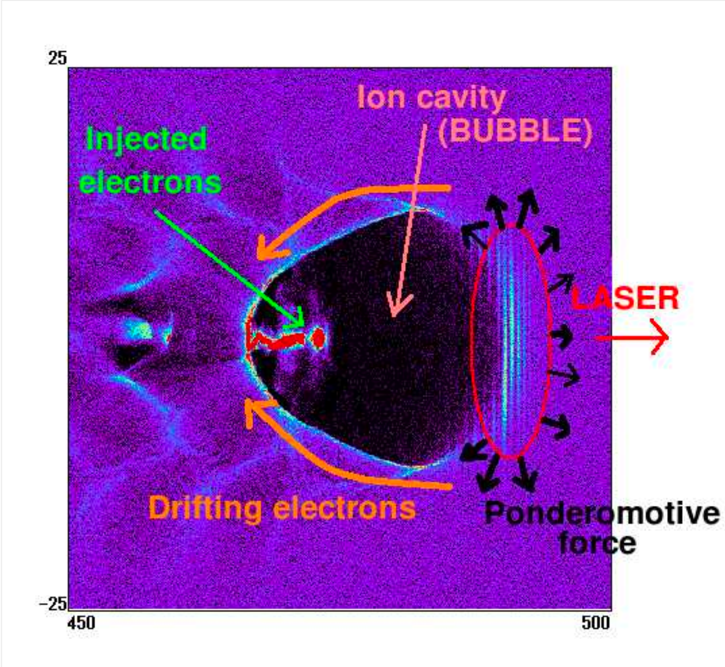
MAIN EXPERIMENTAL PARAMETERS

Main set up parameters

$L_{gas\ jet}$ [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

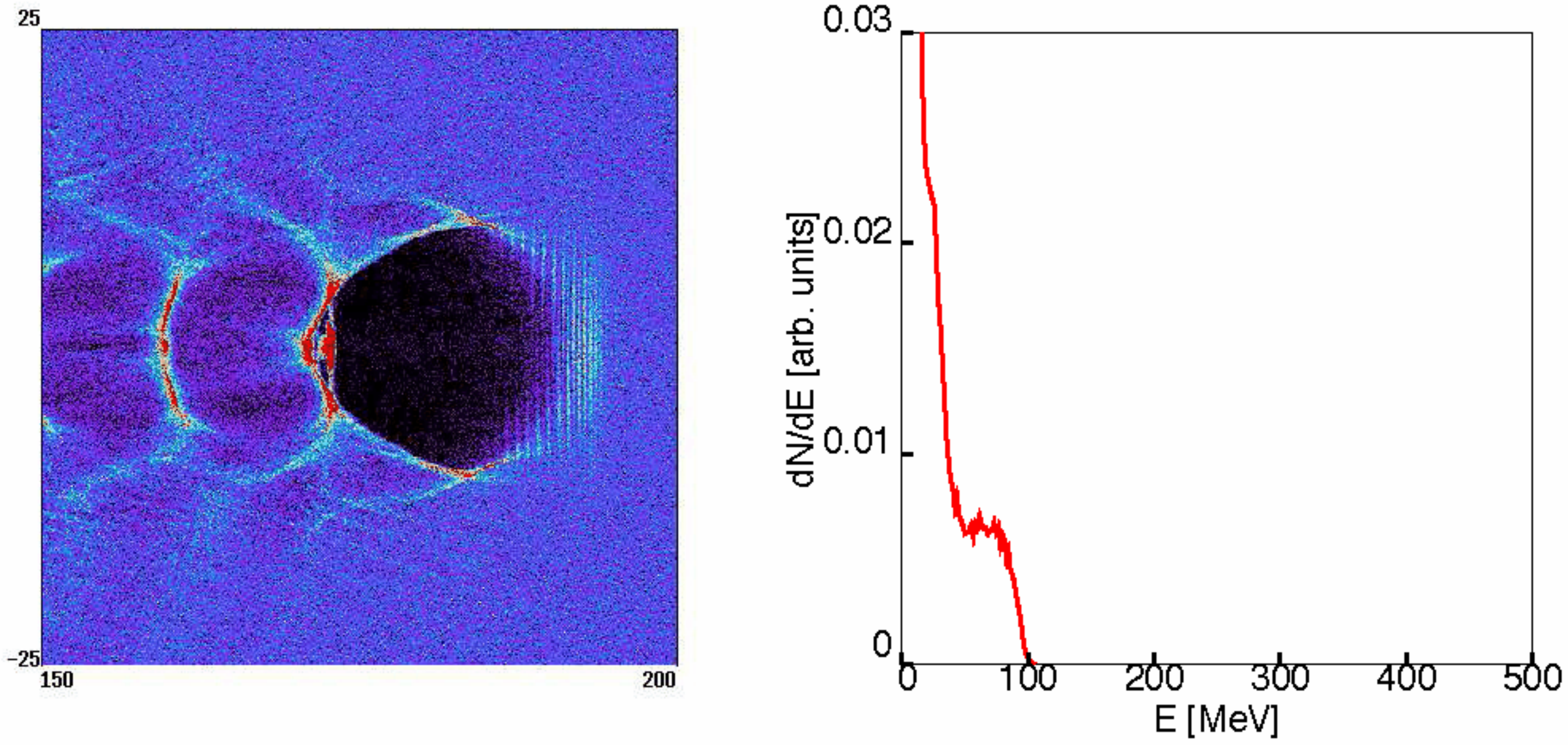


Nonlinear 3D regime (bubble) [a]



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

Particle-in-cell simulations



Numerical simulations by C. Benedetti for self-injection test experiment at FLAME

HIGHER ACCELERATION GRADIENTS

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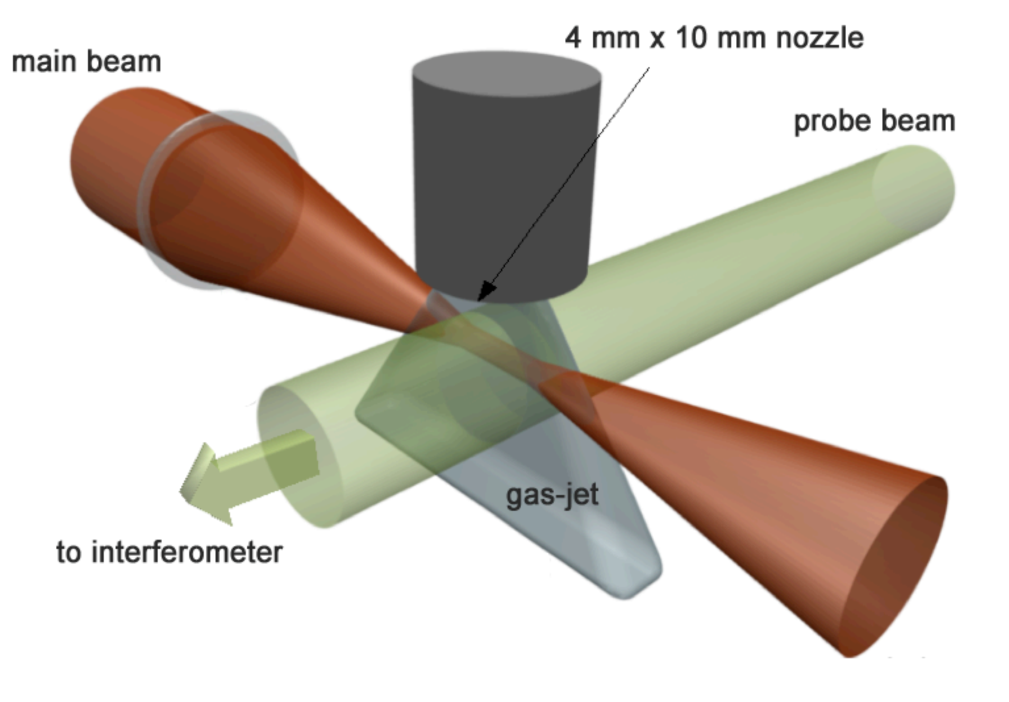
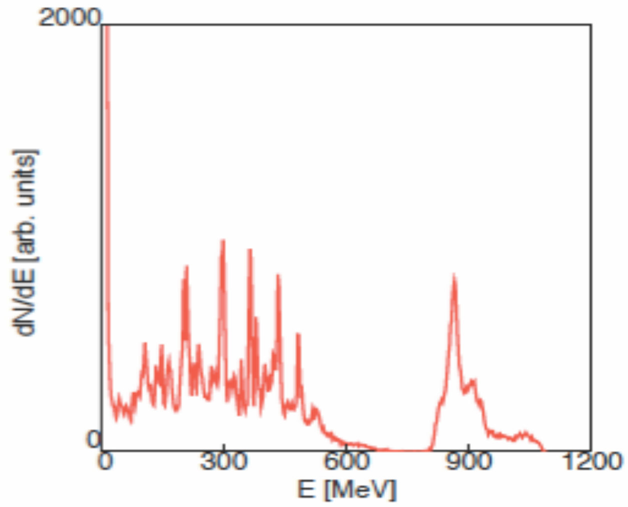
Main set up parameters

$L_{gas\ jet}$ [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



Calculated electron spectrum



Goal: 0.9 GeV in 4 mm

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

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Project acknowledgements: FISR “BLISS”, INFN-CNR “PLASMONX”

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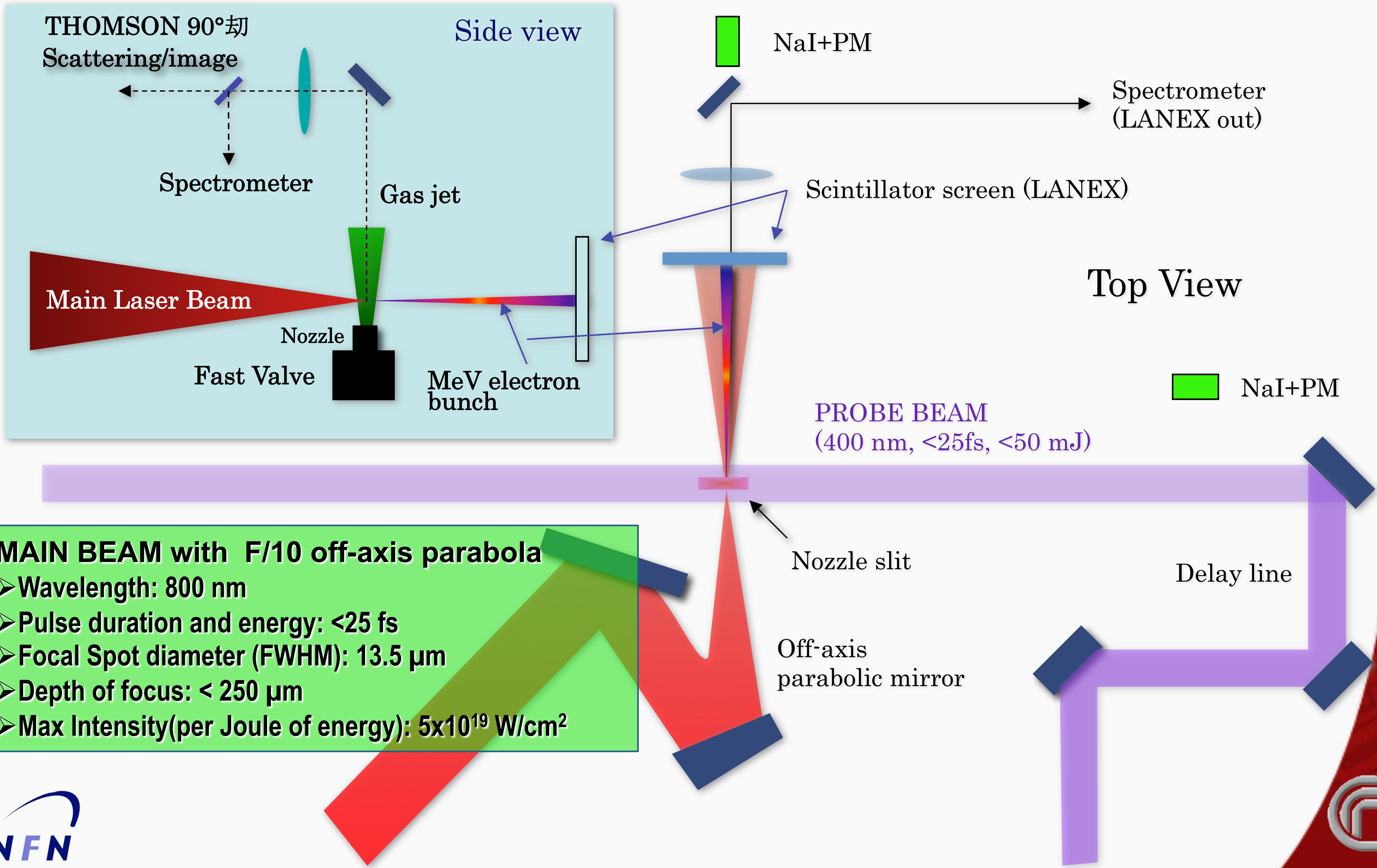
SCHEMATIC EXPERIMENTAL SET UP



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): $5x10^{19}$ W/cm^2

PISA EXPERIMENT: SELF-FOCUSING DOMINATED REGIME

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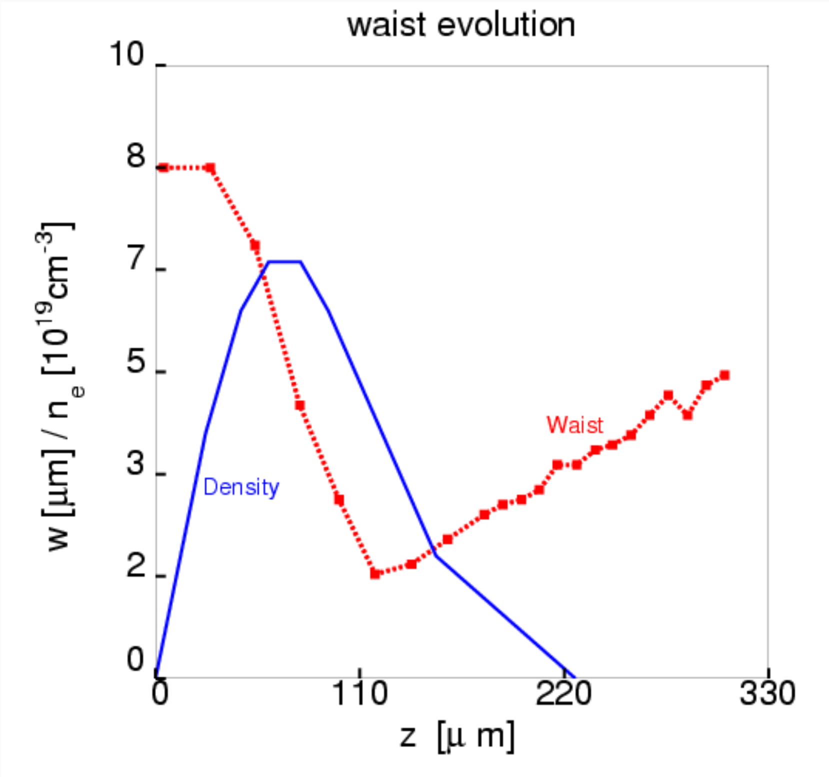
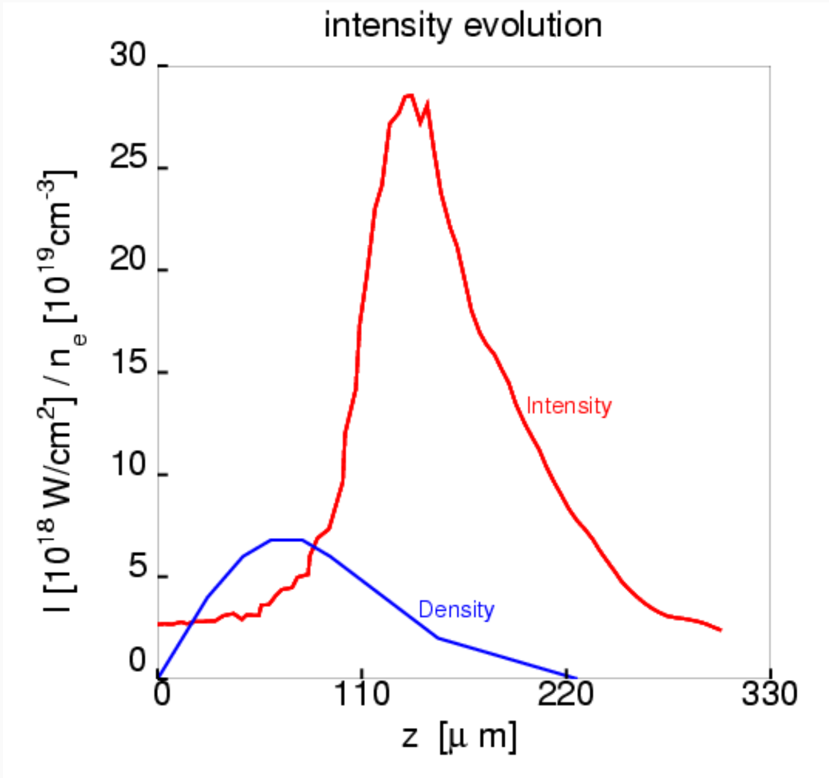
Aladyn numerical simulations (di C. Benedetti et al.,)





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

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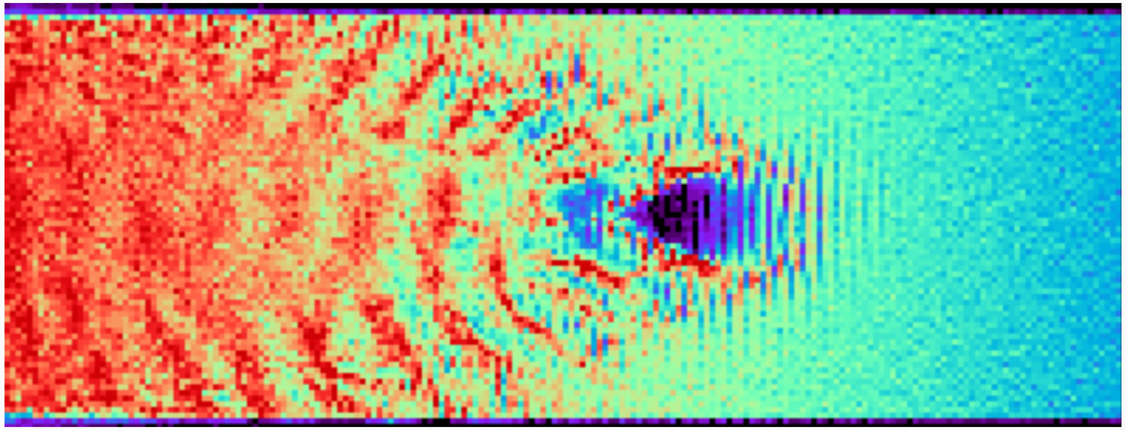
INJECTION MECHANISM AT TW LEVEL

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

➢In these conditions, trapping of electrons may be explained invoking transverse wave breaking due to the curved plasma wave front. This is expected to occur at reduced threshold values compared to the longitudinal wave breaking process. Aladyn simulations indeed suggest this scenario:



In this case, the much longer pulse duration (65fs) compared to the ideal bubble-like regime (≈10 fs), leads to interaction of the accelerated electrons with the the laser pulse itself;

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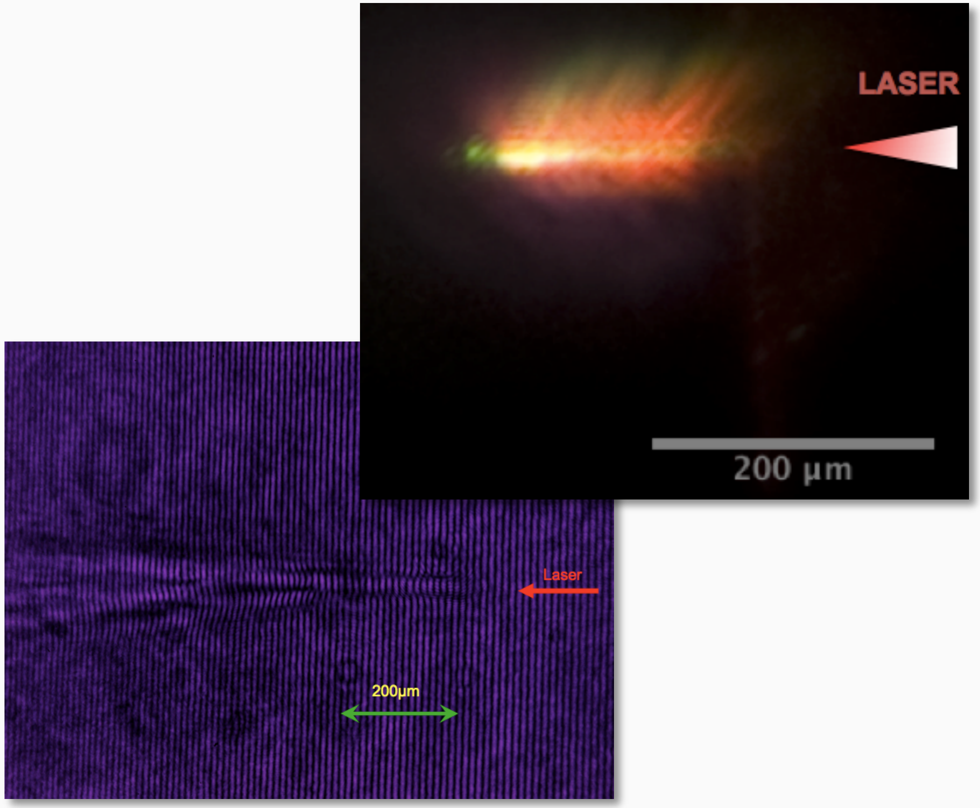
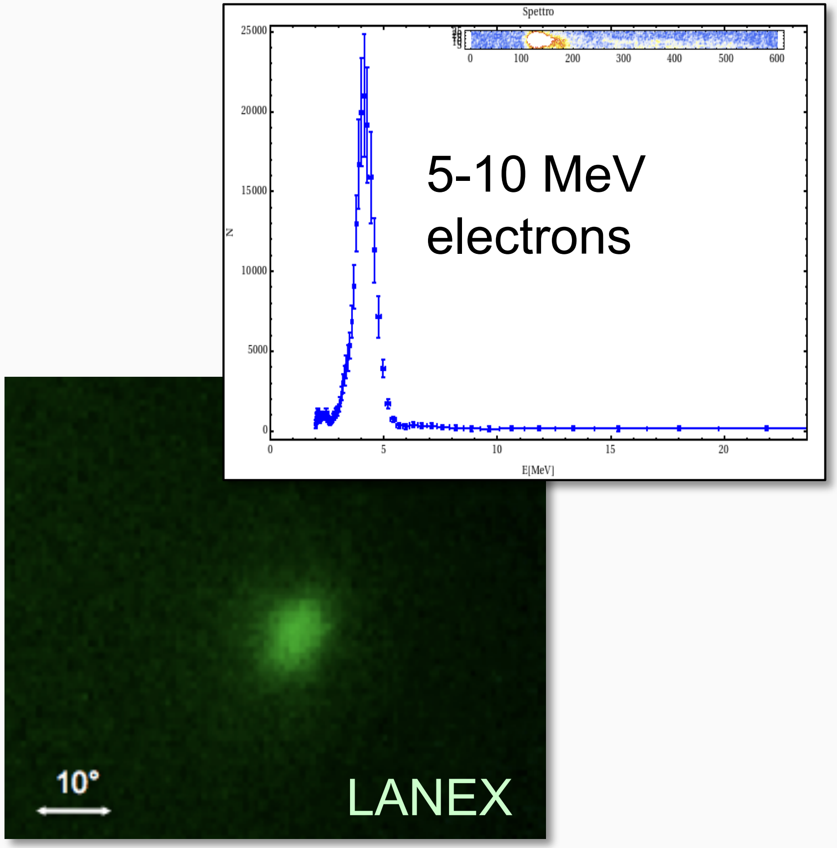
ELECTRON BEAM at TW level

TS and interferometry show self-guiding



Electron bunch from He



- Acceleration regime compatible with laboratory bio-medical applications;
- Rep-rated operation required to enable dose comparison with hostpital LINACs.
- Upgrade in progress to reach IORT energy range 15-30 MeV.

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

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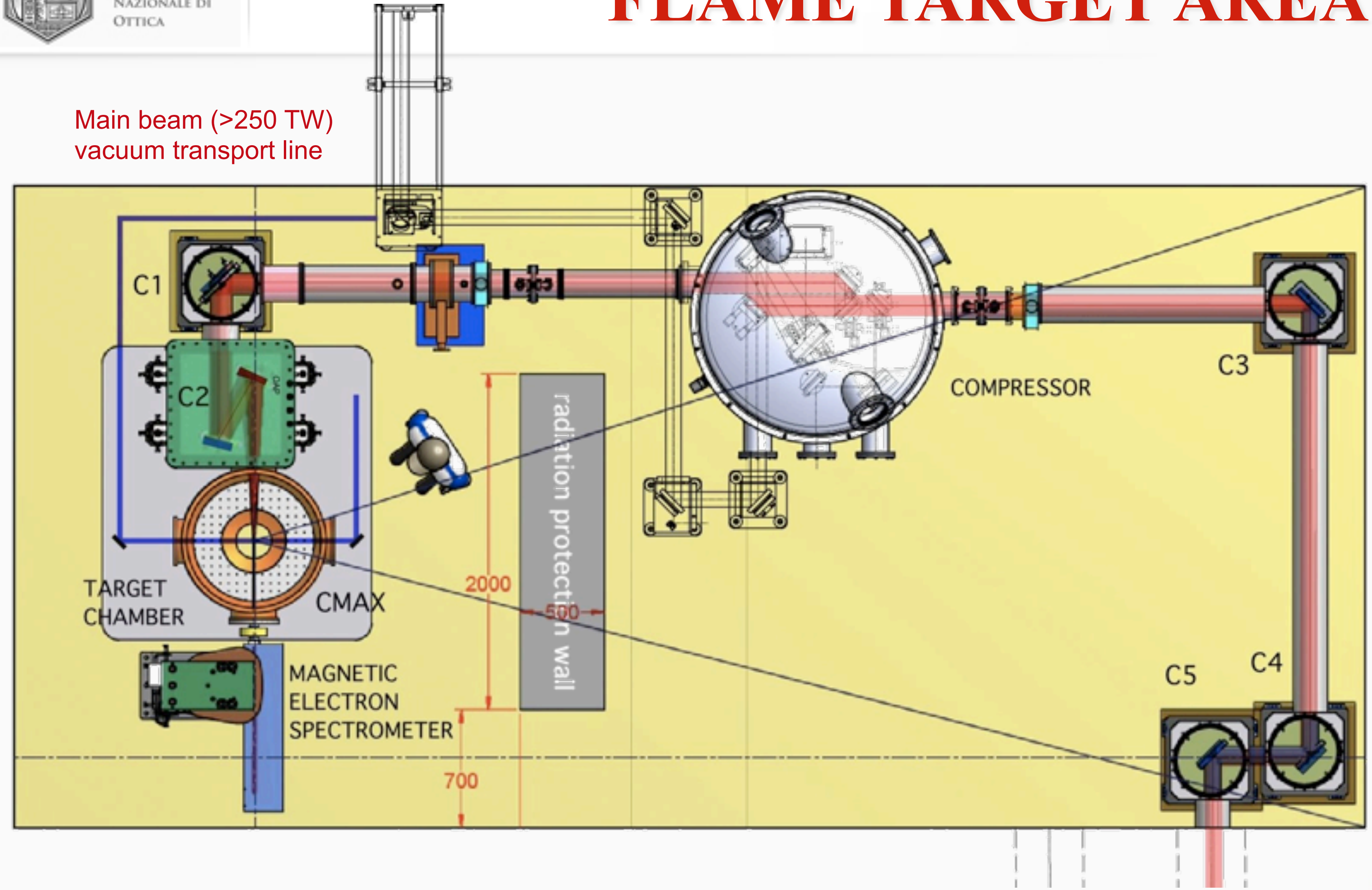
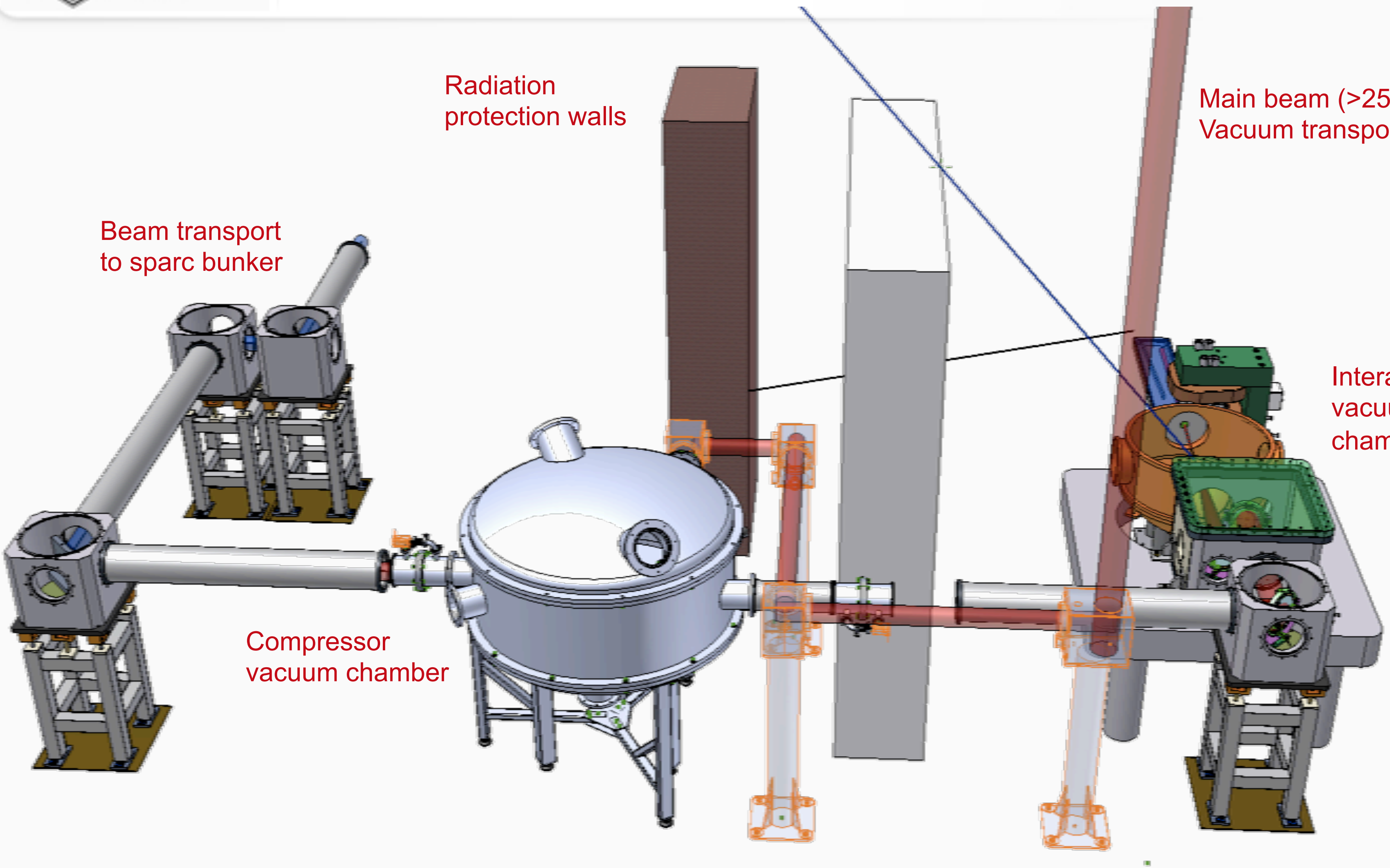
FLAME TARGET AREA

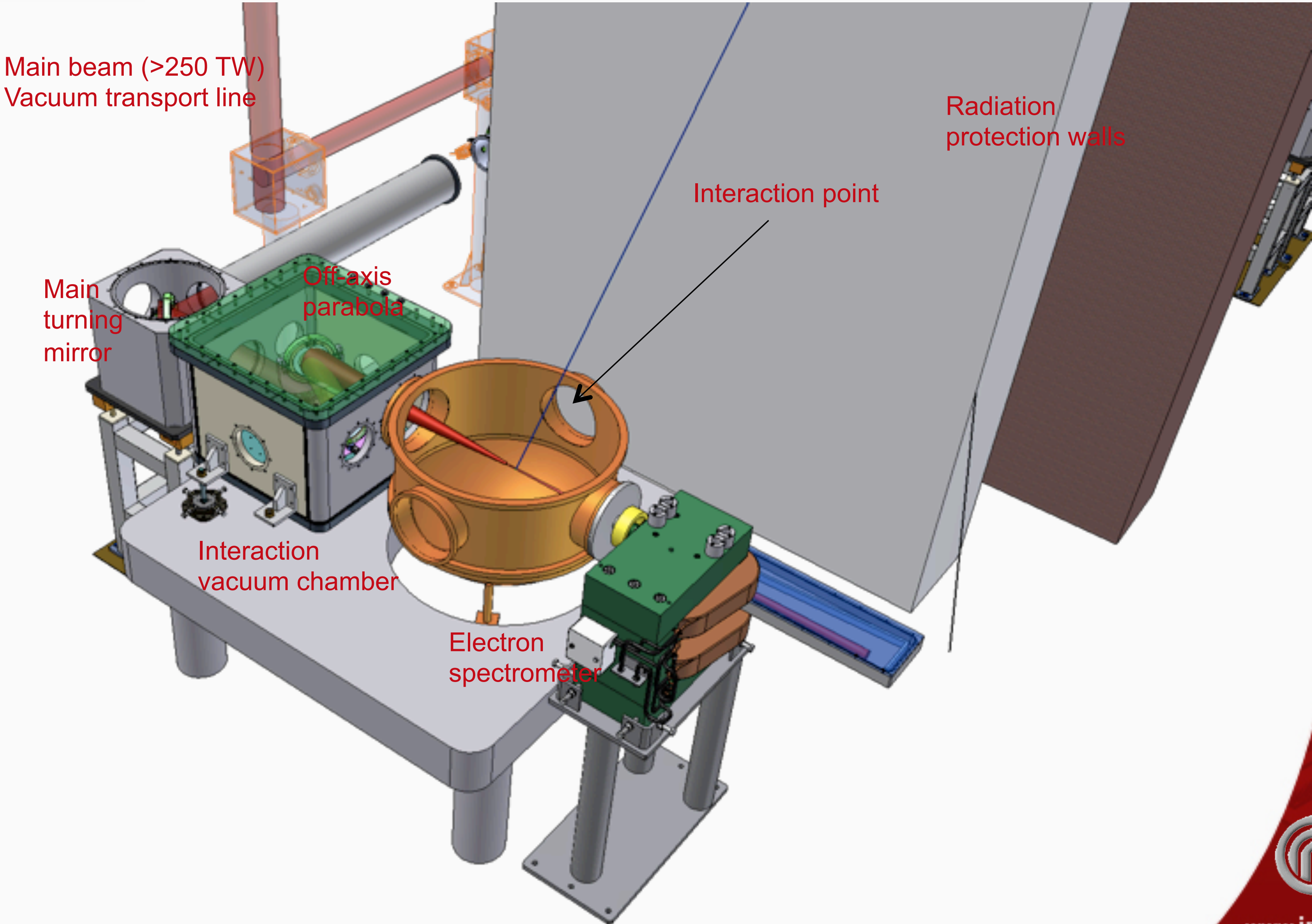
Main beam (>250 TW)
vacuum transport line



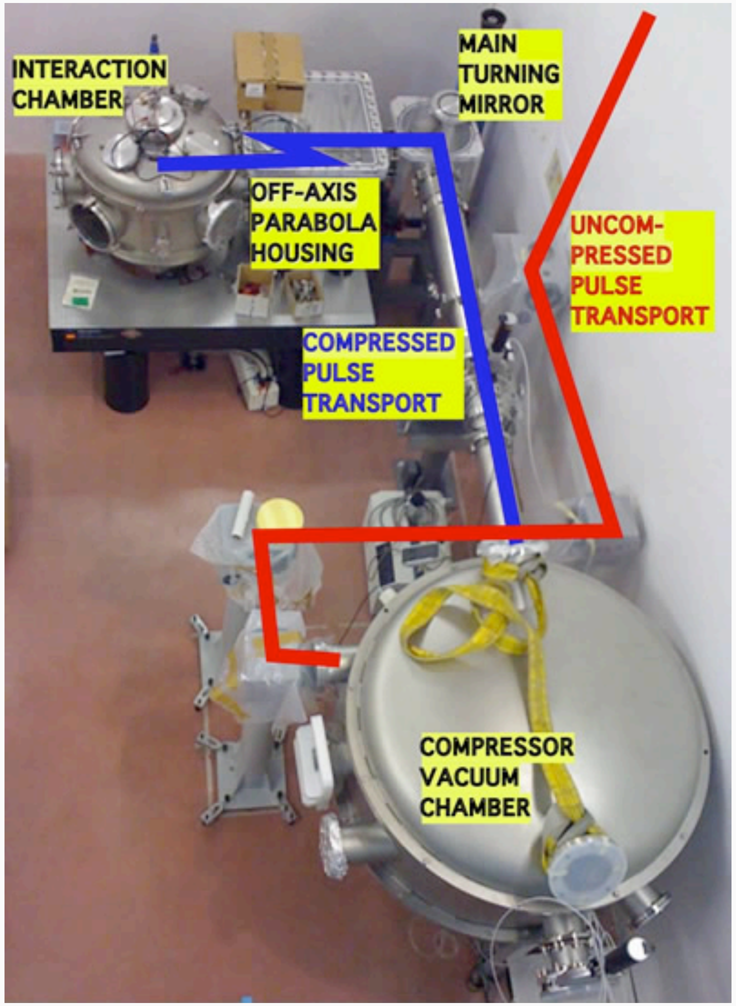
FLAME TARGET AREA



FLAME TARGET AREA: SHIELDING



FLAME TARGET AREA (SITE)



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VERT. AND HORIZ. SHIELDING

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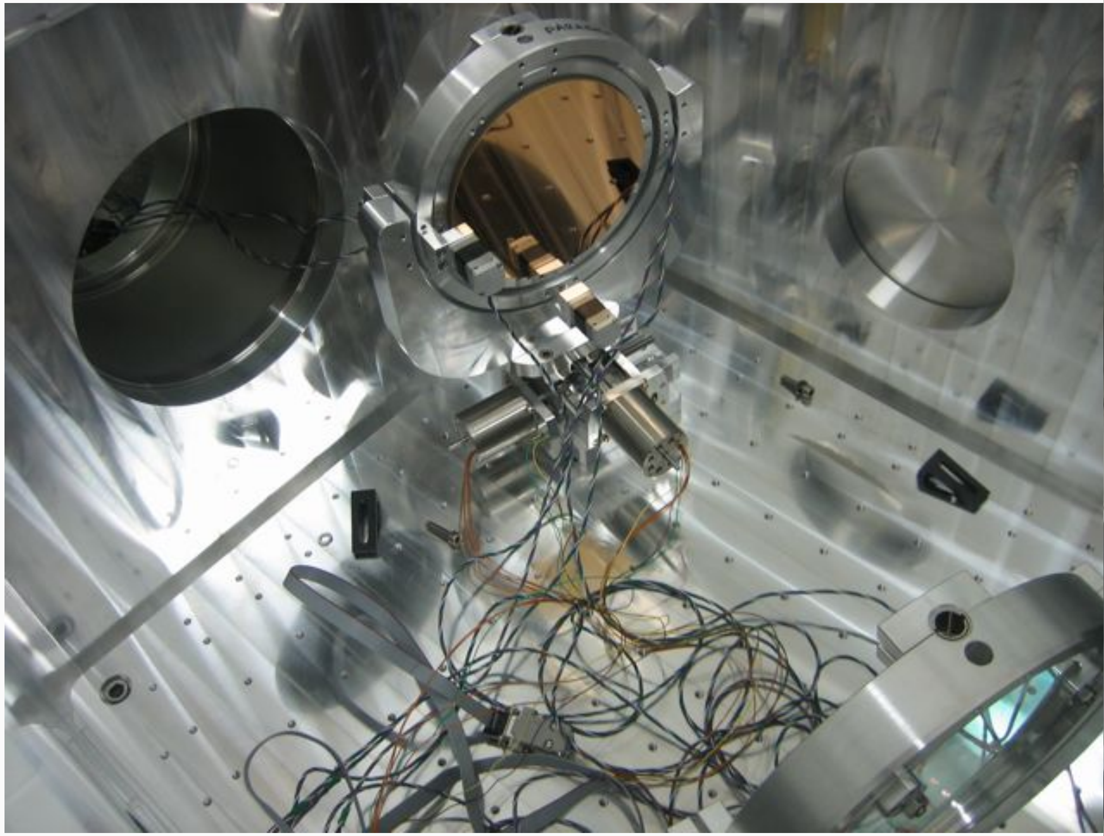
MAIN BEAM OPTICS IN PLACE

45 AND 15° TURNING MIRROR MOUNTED

FOCUSING LASER

1 m focal length, 7”, 15° Off Axis Parabola (SORL)



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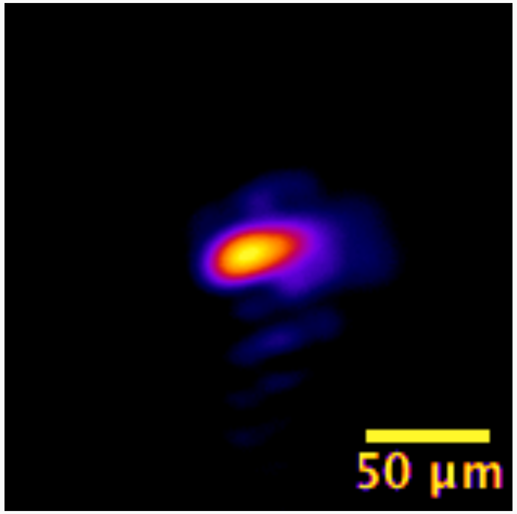
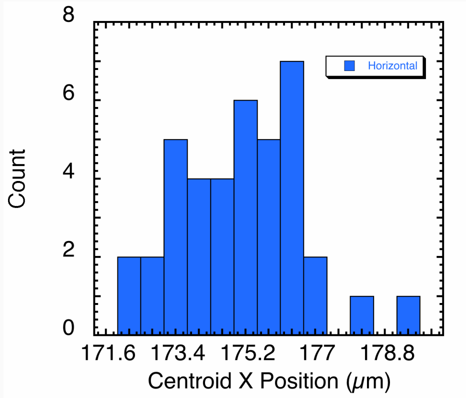
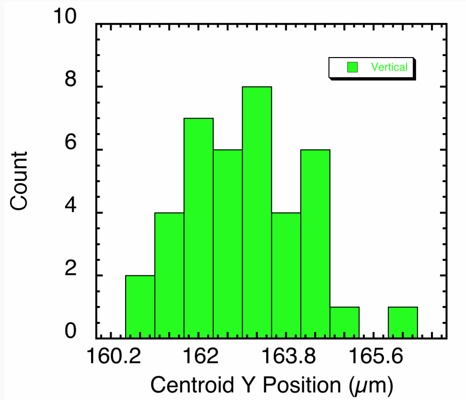
LASER AT TARGET CHAMBER CENTER

Pointing stability at TCC



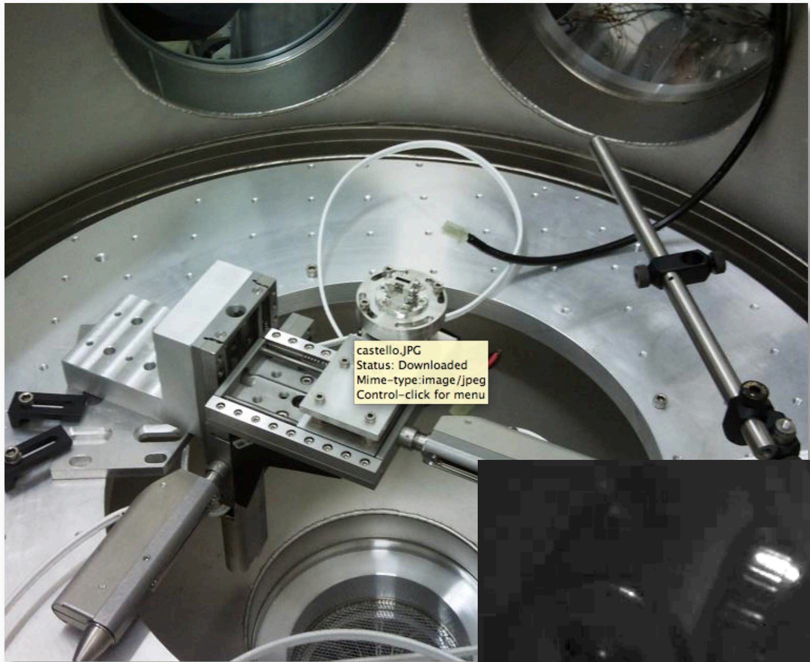


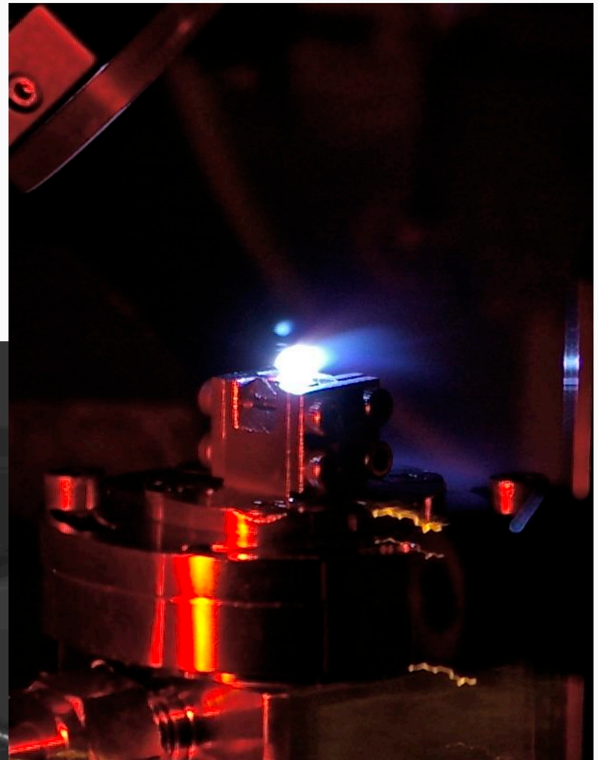


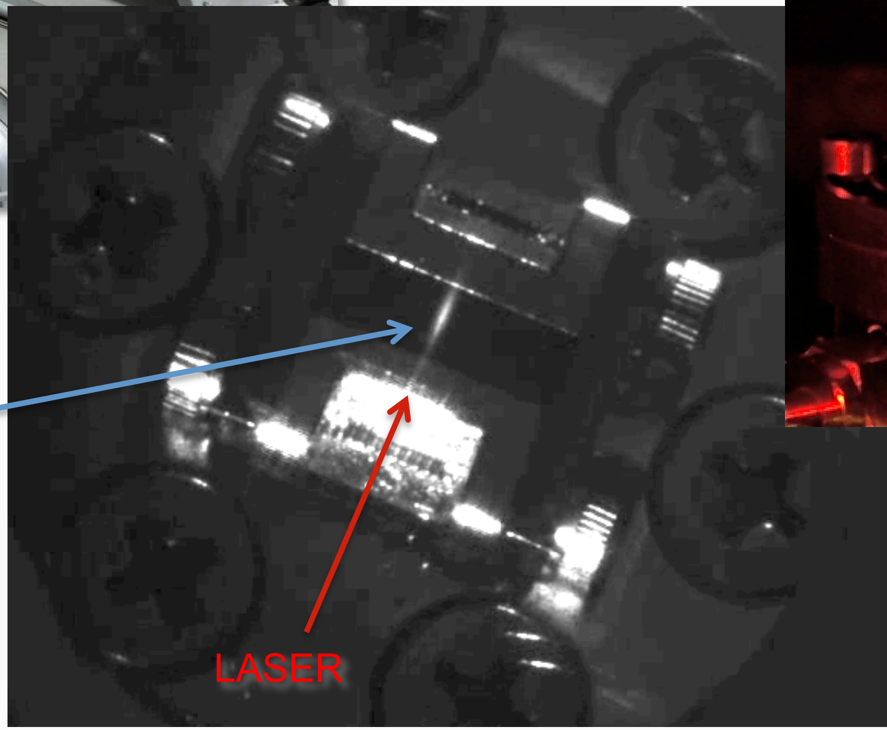
	Centroid Y	Centroid X
Minimum	160,89799	172,12
Maximum	166,22099	179,614
Points	39	39
Mean	162,9351	175,0372
Median	162,995	175,244
RMS	162,93927	175,04455
Std Deviation	1,18026	1,6241748
Variance	1,3930138	2,6379437
Std Error	0,18899286	0,26007611

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)

LNF-FLAME : first propagation test

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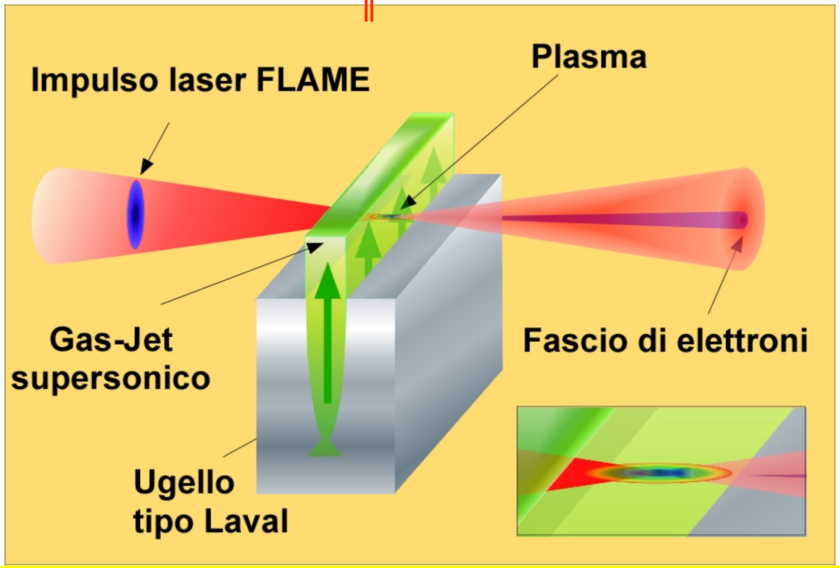
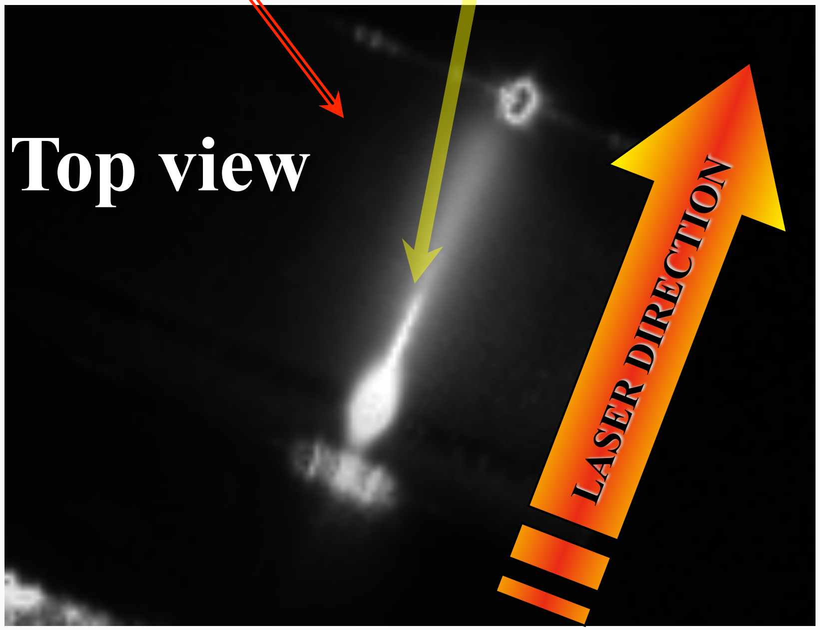


Set up

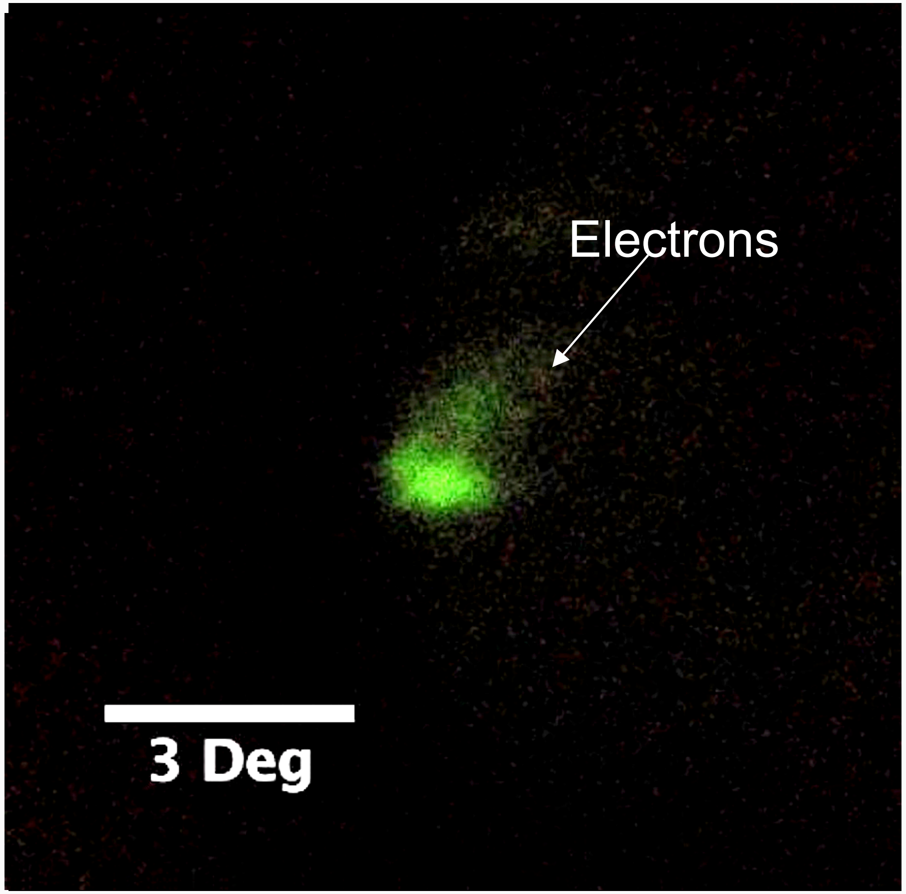
September 2010: propagation control

PLASMA - CHANNEL



FIRST ELECTRONS AT SCREEN

October 2010: first MeV e^- at low laser power



Basic Parameters for this dataset:

- →*Laser Energy before compression 550mJ*
- →*Laser pulse duration <40fs (FWHM)*
- →*Off-axis Parabola 1m focal length*
- →*Backing Pressure 17bar of N*
- → *4 mm length gas-jet*

LASER POWER ~ 7 TW

MAX LASER POWER will be~ 250 TW

Only 1 over 10 green pump laser are used in this case!
No focal spot and pulse duration optimization were performed!!

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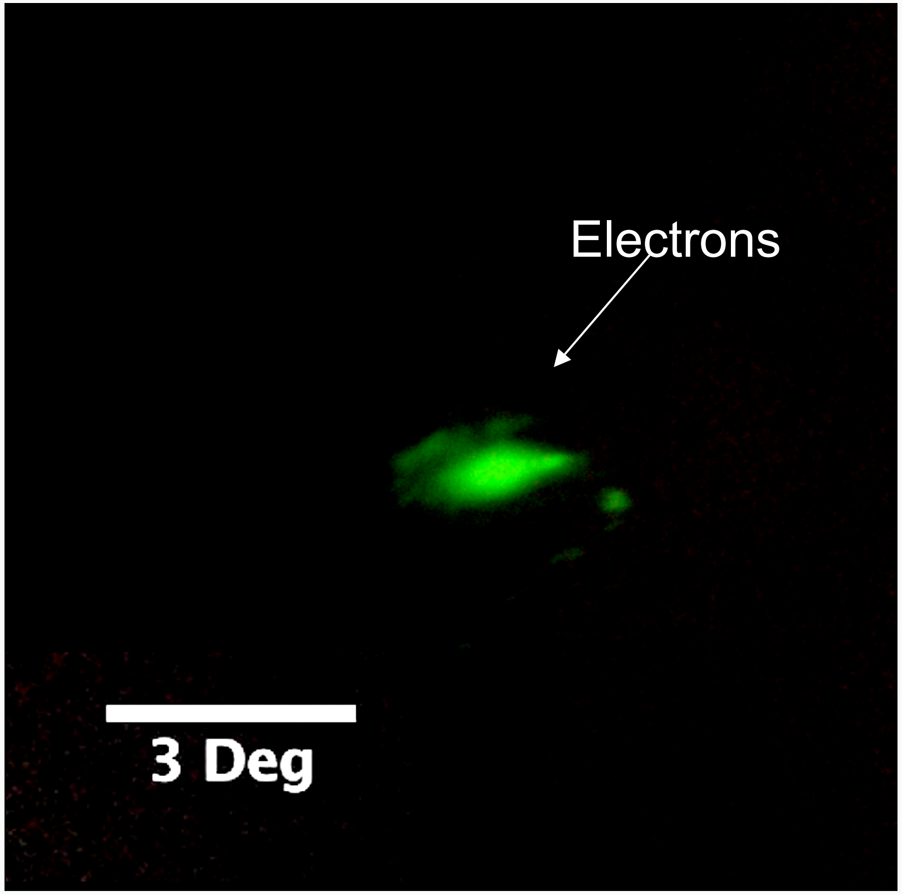
FIRST ELECTRONS AT SCREEN

October 2010: first MeV e^- at low laser power



Basic Parameters for this dataset:

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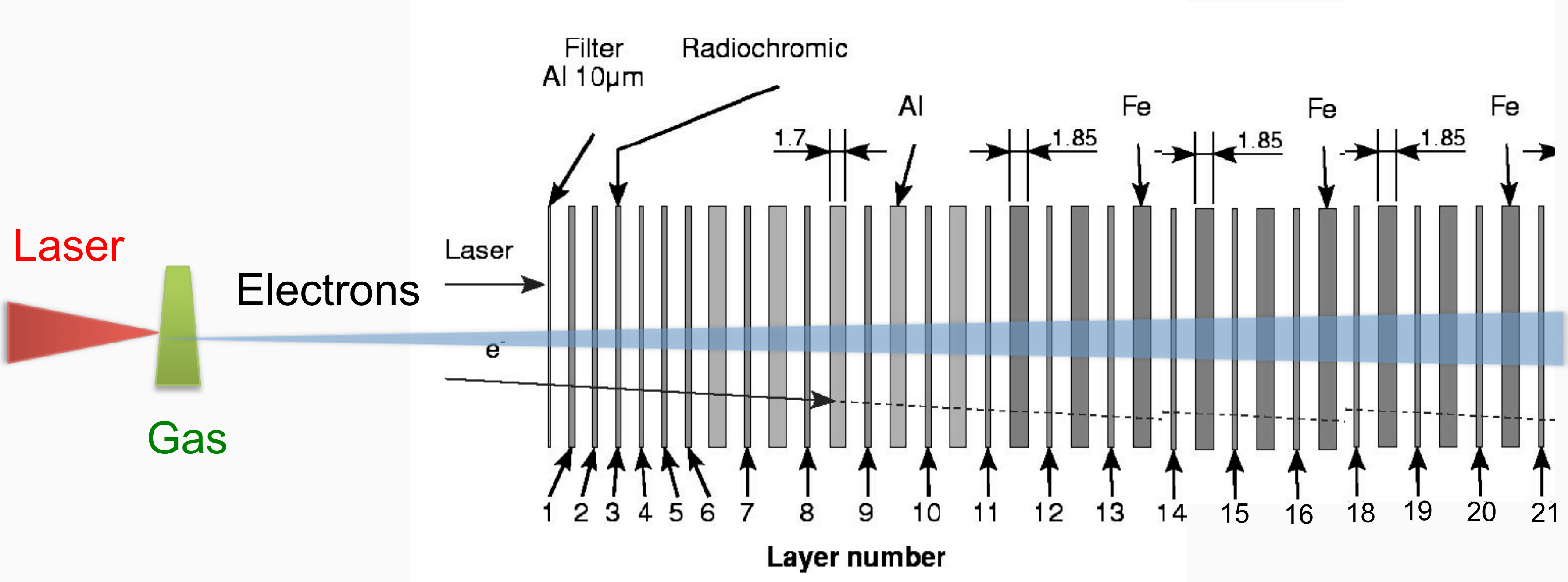
ELECTRON ENERGY

Performed using stack of Radiochromic films (RCF)



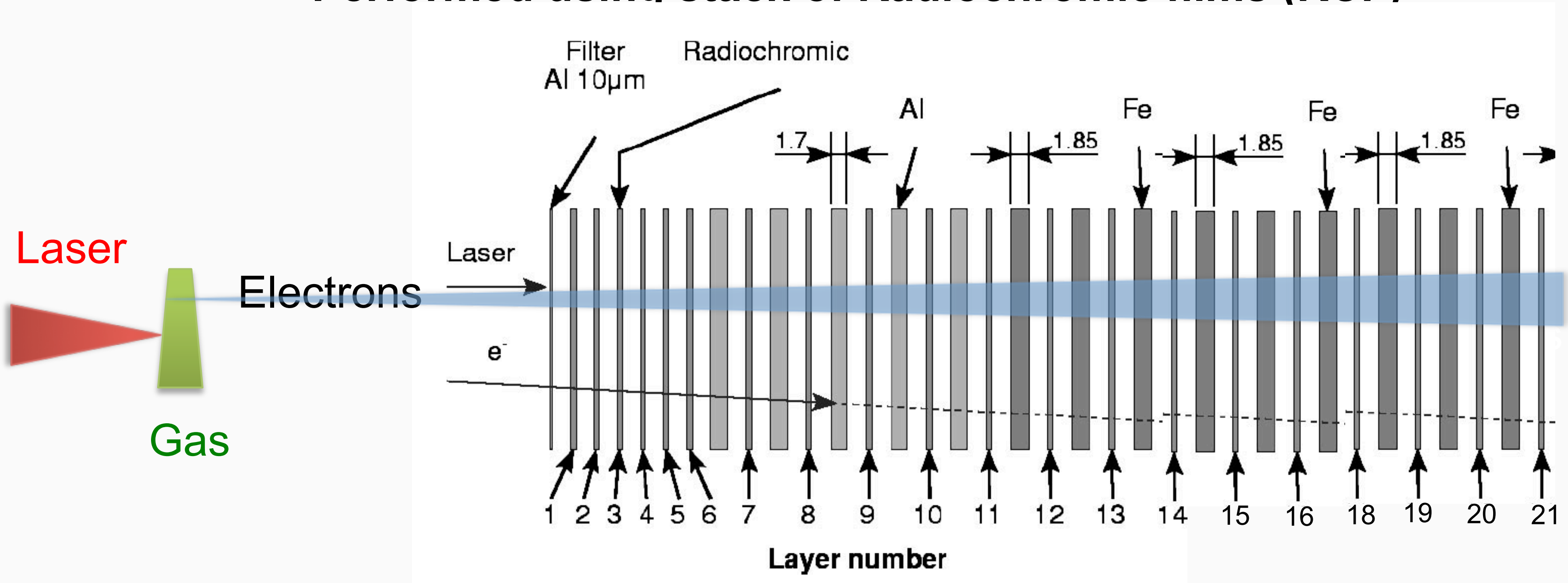
REVIEW OF SCIENTIFIC INSTRUMENTS **76**, 053303 (2005)

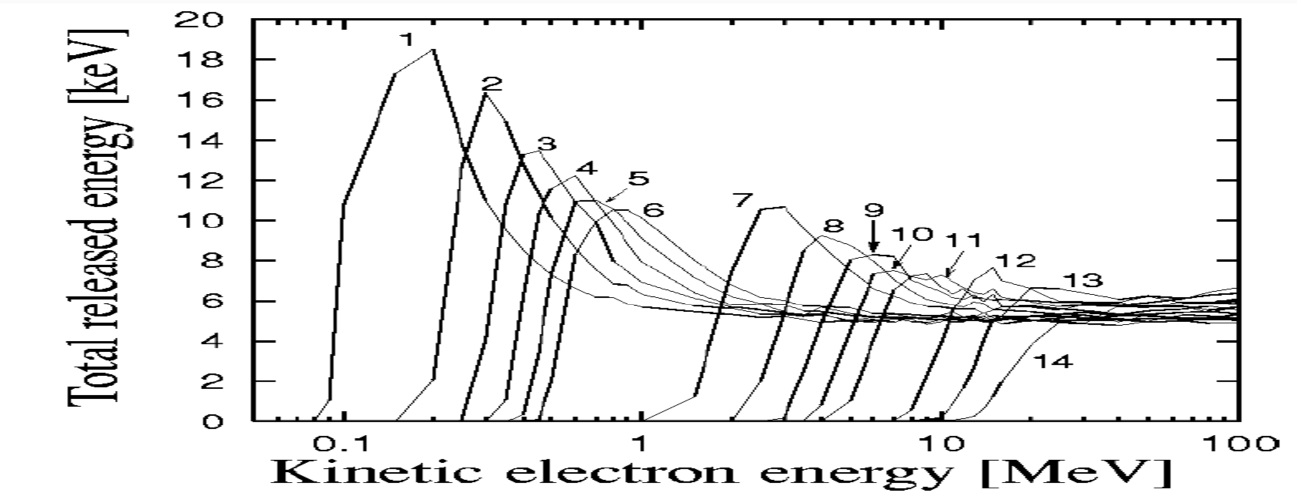
SHEEBA: A spatial high energy electron beam analyzer

Marco Galimberti,[a] Antonio Giulietti,[b] Danilo Giulietti,[c] and Leonida A. Gizzi[b]

ELECTRON ENERGY

Performed using stack of Radiochromic films (RCF)





ELECTRON ENERGY

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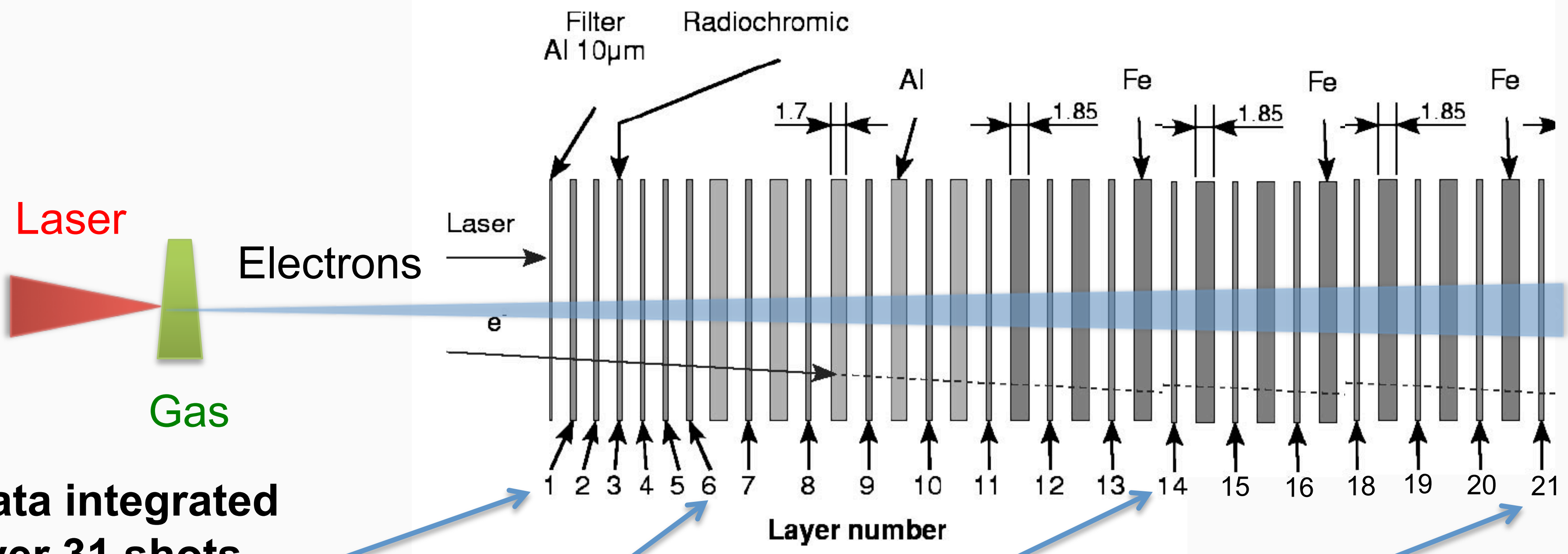
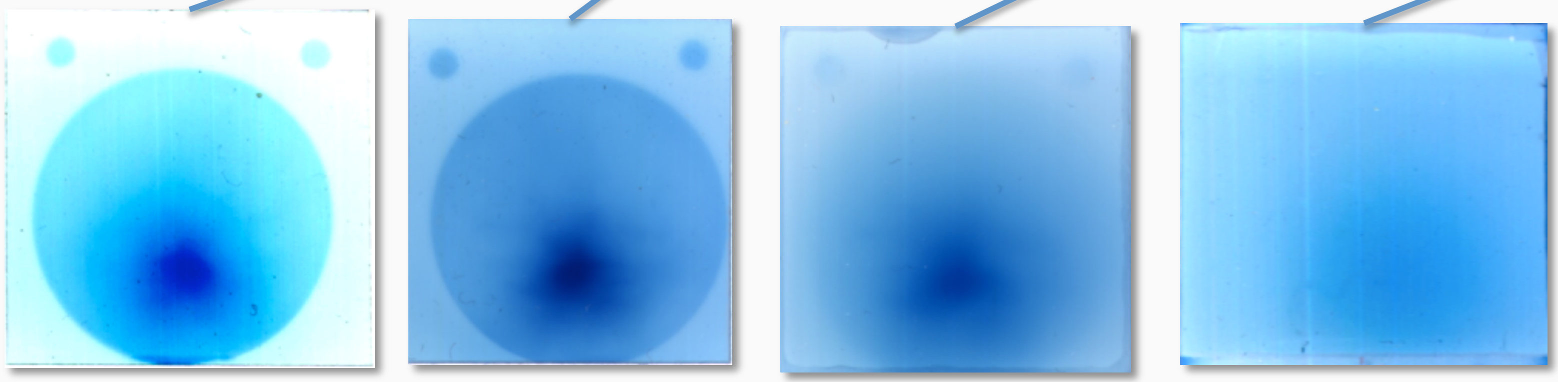
Performed using stack of Radiochromic films (RCF)

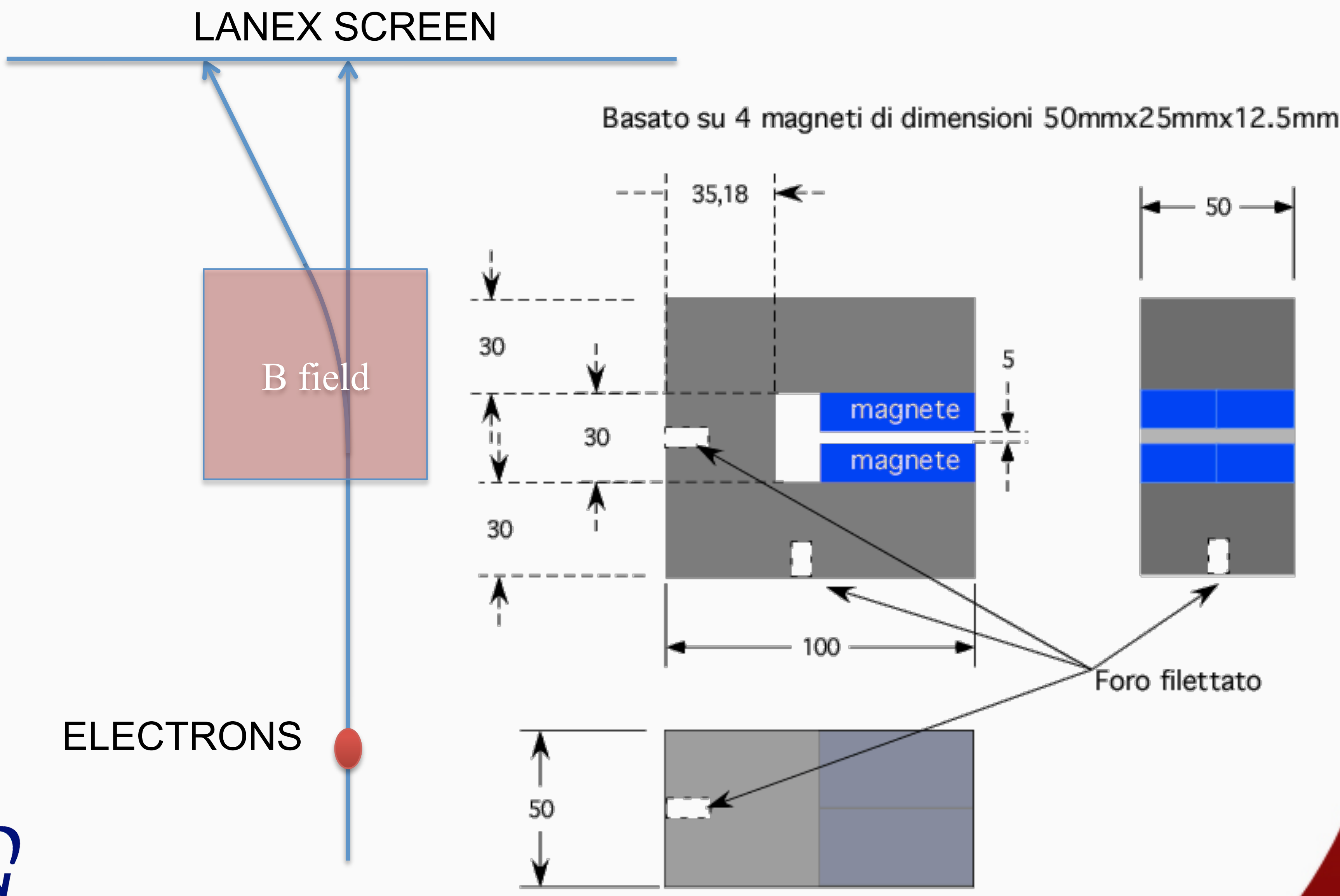


Data integrated over 31 shots

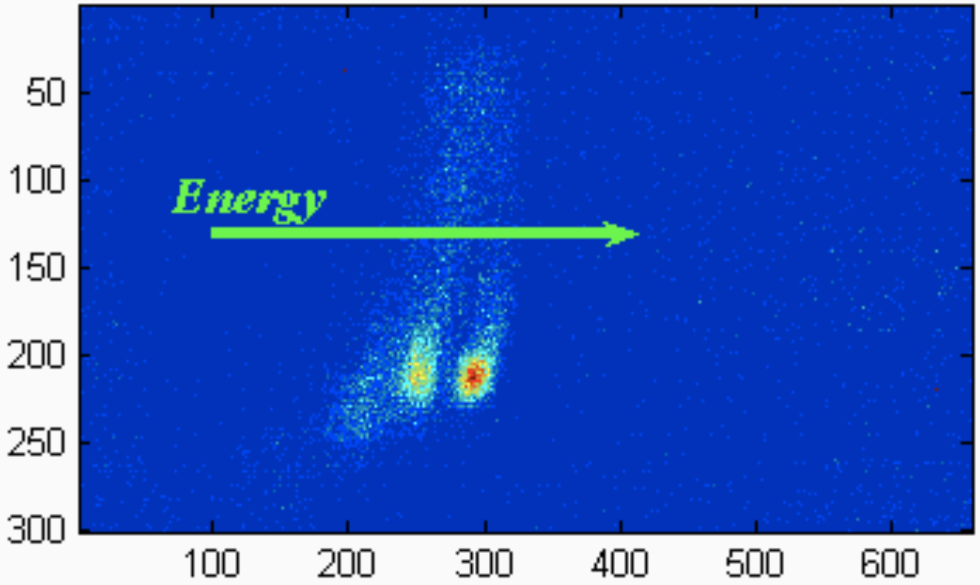


Signal well beyond layer 14 – new GEANT simulations in progress

LOW RESOLUTION SPECTROMETER



PRELIMINARY SPECTRUM

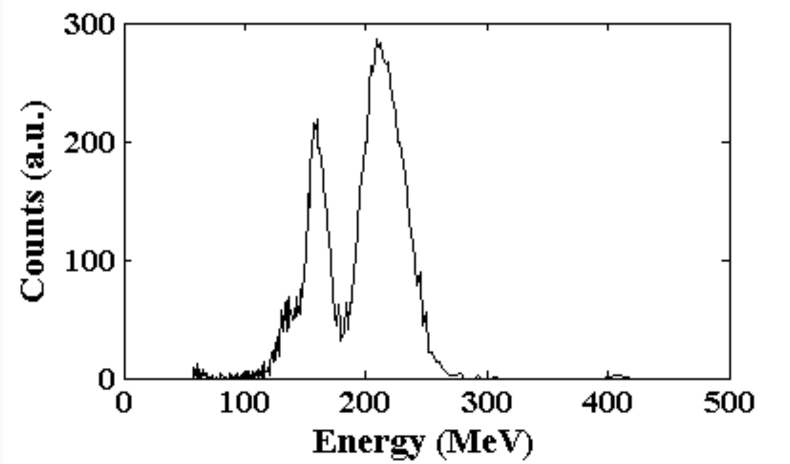


Energy (MeV)

Energy dispersion with a 0.9 T magnetic dipole

Electrons at lanex screen

Lineout



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AGENDA FOR NEXT WEEKS

- **Finalize characterization of FLAME at full power:** transport, compression, OAP focusing (no target), far field, contrast, width, phase distortion, measurements … prepare for adaptive optics;
- **Complete set up** and test of HW and SW control and diagnostics for self-injection test experiment;
- **Complete registration** for radioprotection, safety and control of operations;
- **S.I.T.E. -** Laser on (gas-jet) target at >50 TW level – electron spectra with magnetic spectrometer.

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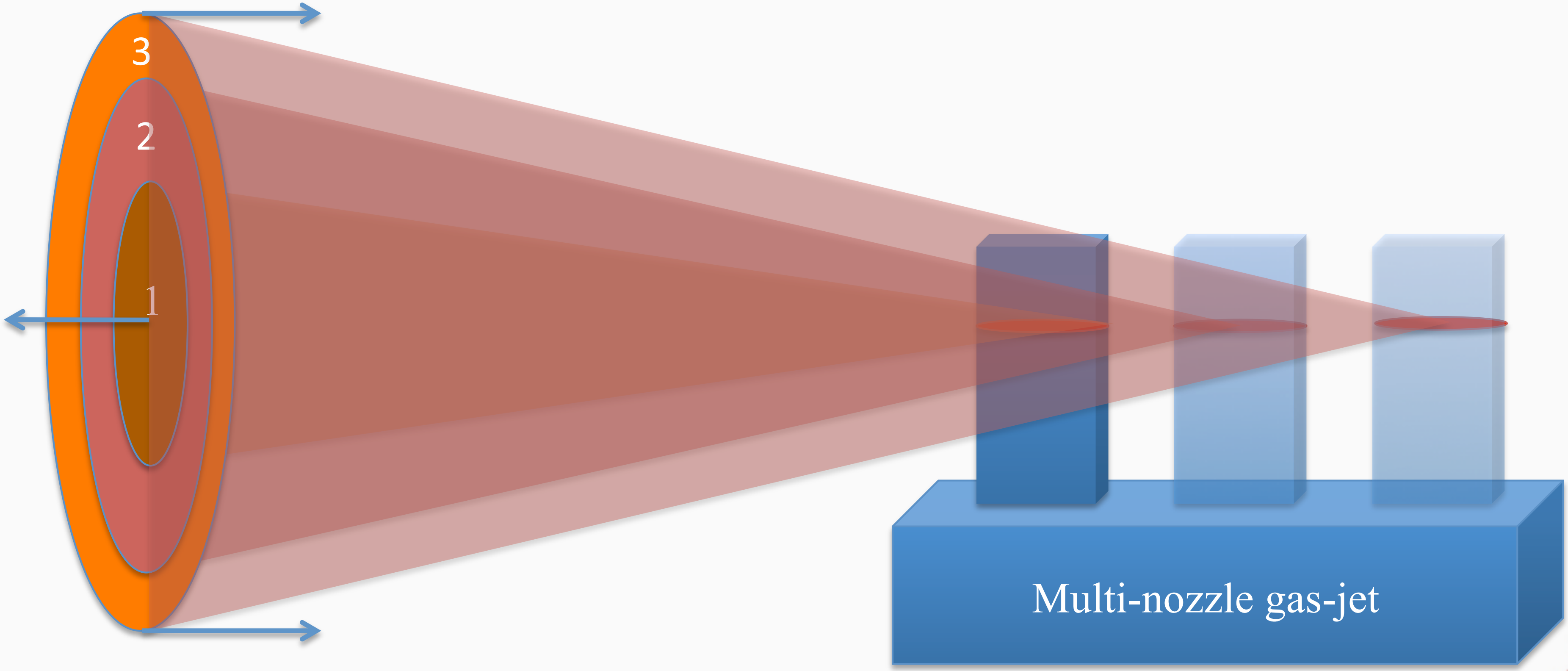
MULTI-STAGING CONCEPT

Custom-made OAP – 1: regular OAP, 2: Annular OAP, 3: Annular OAP
Relative motion along axis to match time of arrival on each gas-jet



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SUMMARY

- FLAME: an entirely new lab for LPA is now operational
- 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

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SELF-INJECTION MEASUREMENTS: PEOPLE

T. Levato, L. Labate, N. Pathak, F. Piastra, C.A.Cecchetti, D.Giulietti, L.A. Gizzi

ILIL-INO, CNR, Pisa, Italy, Sez. INFN, Pisa, Italy, LNF, INFN, Frascati, Italy, Dip. di Fisica, Univ. di Pisa, Italy,

N. Drenska, R. Faccini, S. Martellotti, V. Lollo, P. Valente,

Sez. INFN Roma-1, Roma, Italy, Dip. Fisica, Univ. La Sapienza, Roma, Italy,

C. Benedetti

LOASIS Group, LBNL, Berkeley, USA

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CONTACT PERSONS FOR FLAME COMMISSIONING

TECHNICAL MANAGER
Giampiero DI PIRRO (LNF)
SUBSYSTEMS (Contact persons)
Laser Installation
Leonida A. GIZZIand Danilo GIULIETTI ((DIP. FIS. UNIPI, IPCF-CNR, INFN-PI, LNF)
Laser operations and control command
Tadzio LEVATO(LNF) and Luca LABATE (CNR & INFN-PI)
FLAME-SPARC interfaces – Laser, Optical, Electronics, Mechanics
Giancarlo GATTI
FLAME systems: clean room, water cooling and air conditioning
Luigi PELLEGRINO(LNF, Servizio Impianti a Fluido della DT)
Electricity network
Ruggero RICCI (LNF, Servizio Impianti Elettrici della DT)
Ethernet network
Massimo PISTONI (LNF)
FLAME software interfaces
Elisabetta PACE (LNF)
Beam Transport air+ vacuum - FLAME buildings
Valerio LOLLO (LNF), Alberto CLOZZA (LNF, Servizio Vuoto della DA) & Andrea GAMUCCI (CNR & INFN-PI)
SAFETY
Sandro VESCOVI (LNF), Tadzio LEVATO (LNF), Carlo VICARIO(LNF)
SAFETY (Radiation protection)
Adolfo ESPOSITO (LNF)
FLAME Target Area - laser beams (main and probe) control, focusing and diagnostics
Luca LABATE (CNR & INFN-PI)
FLAME Target Area - test experiments diagnostics and remote control
Carlo A. CECCHETTI (LNF & IPCF-CNR Pisa)
FLAME web site and outreach
Leonida A. GIZZI & Luca LABATE
Logistics
Oreste CERAFOGLI (LNF, Servizio Edilizia della DT)
Technical and Engineering support
Luciano CACCIOTTI (LNF)

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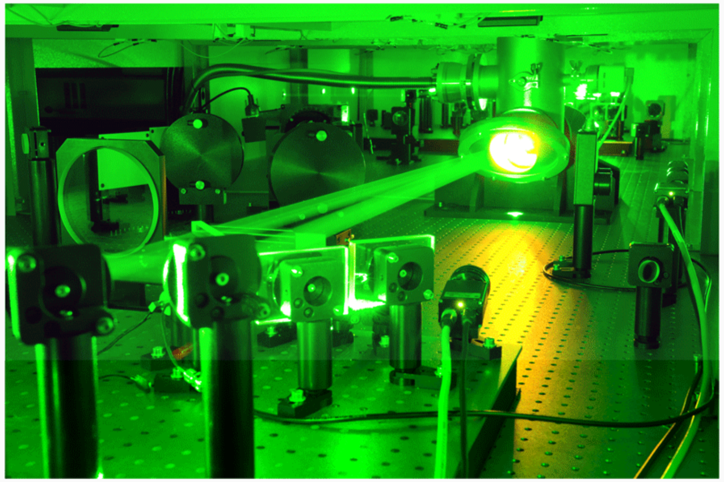
Nazionale di
Ottica

COMCLUSIONS



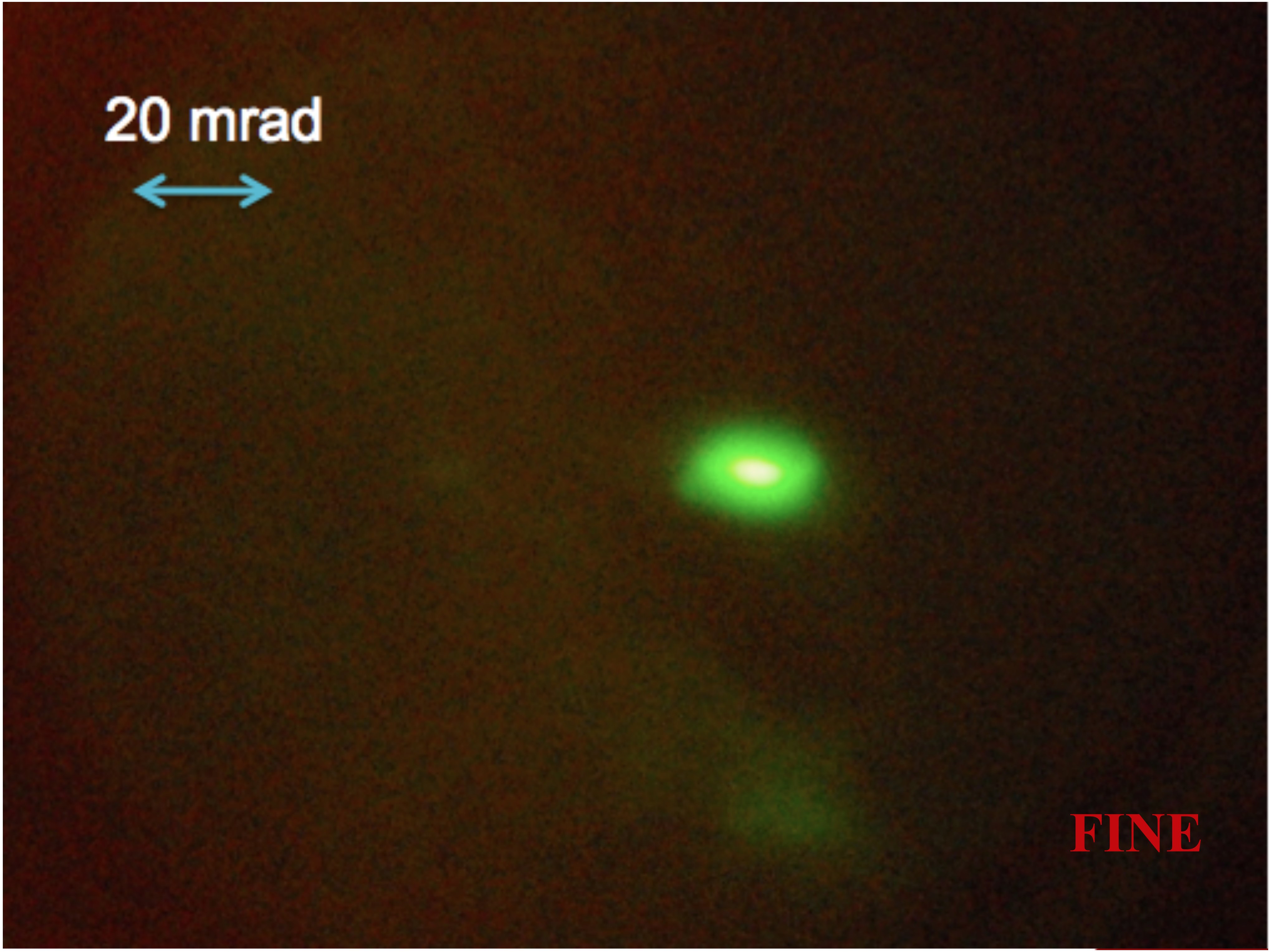
FLAME laser operational

FLAME target area operational

First multi-100MeV electrons from self-injection

INFN

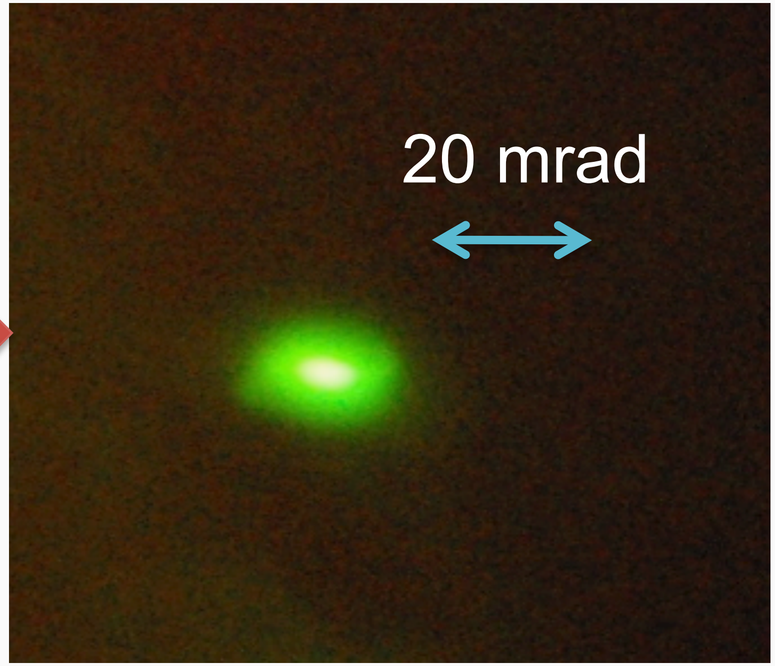
www.ino.it


20 mrad
FINE

SOMMARIO

Marzo 2007
Inizio lavori di costruzione

Ottobre 2010
Primi bunch di elettroni



- *FLAME*: STATUS
- TEST EXPERIMENT ON LPA (SELF-INJECTION)
- CONCLUSIONS