PLASma acceleration and MONochromatic X-ray production

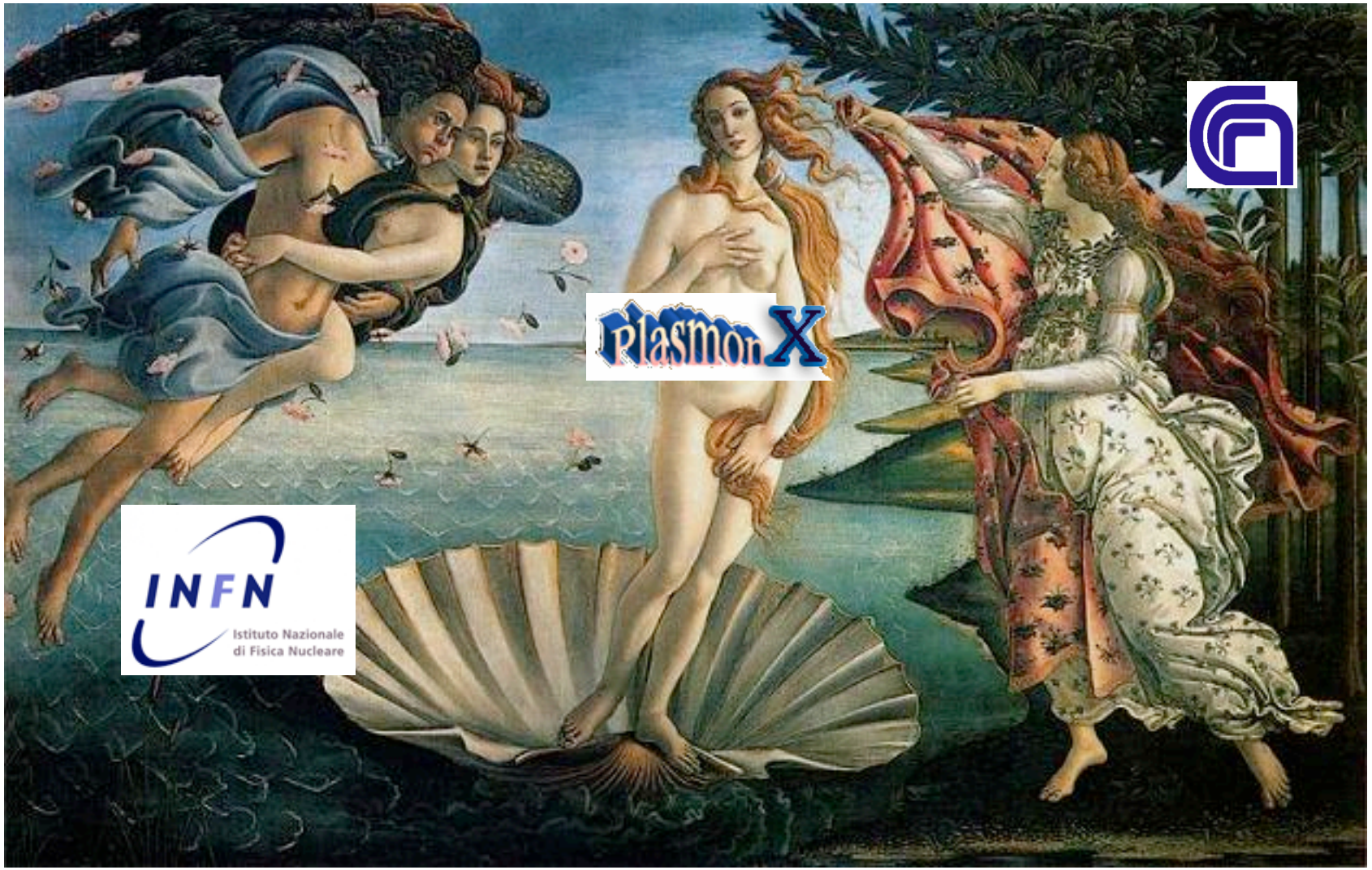
Danilo Giulietti

Physics Department of the University and INFN, Pisa, Italy

PLASMONX National Representative

2005

The birth of…. PlasmonX



Conceptual Design Report

PLASMA ACCELERATION AND MONOCHROMATIC X-RAY PRODUCTION

Acronym: PLASMONX

D. Giulietti

Università di Pisa e INFN-Pisa

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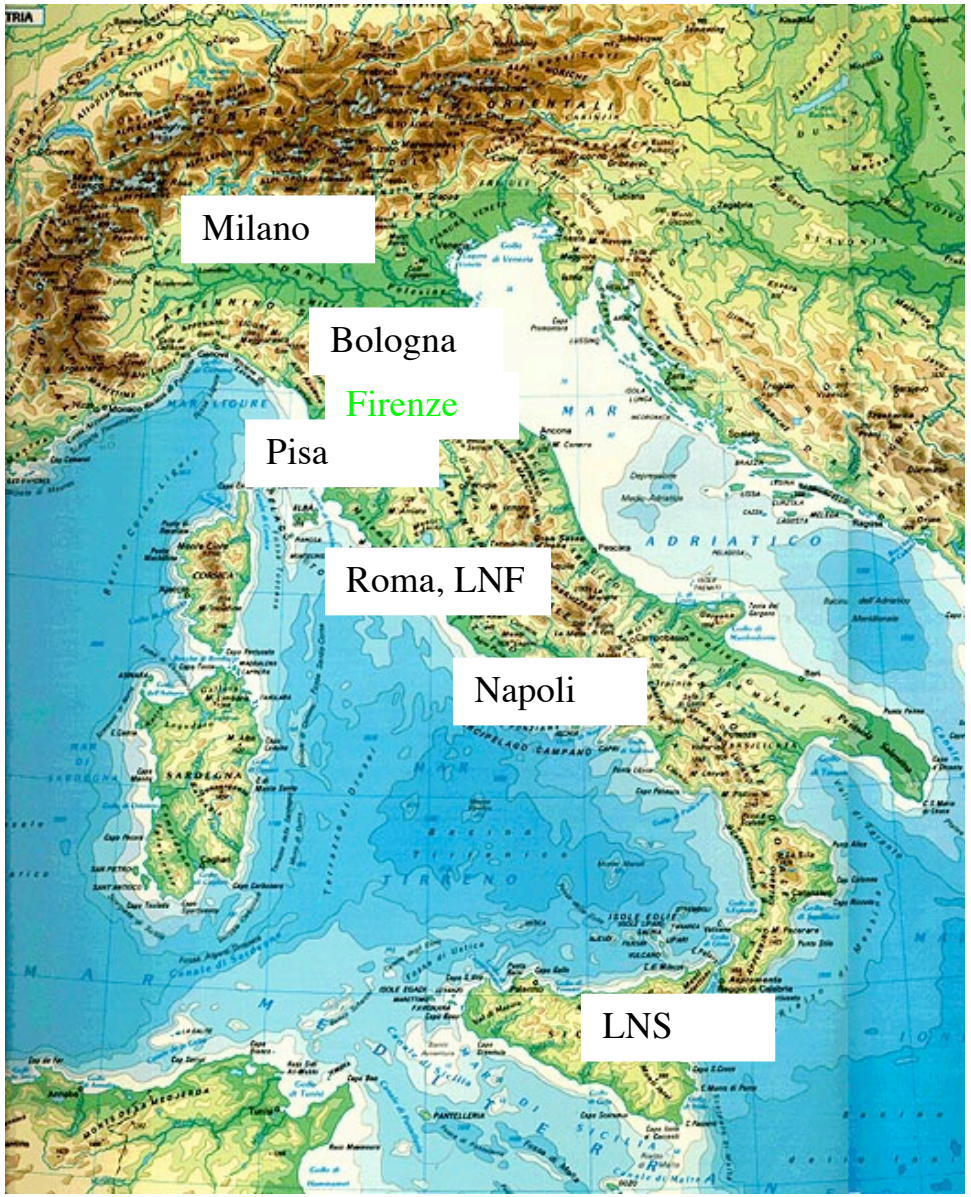
P. Koester, L. Labate, A. Rossi, P. Tomassini
ILIL Team @ **CNR/IPCF - Pisa**

D. Alesini, S. Bertolucci, M.E. Biagini, C. Biscari, R. Boni, M. Boscolo, M. Castellano, A. Clozza, G. Di Pirro, A. Drago, A. Esposito, M. Ferrario, V. Fusco, A. Gallo, A. Ghigo, S. Guiducci, M. Incurvati, C. Ligi, F. Marcellini, M. Migliorati, C. Milardi, A. Mostacci, L. Palumbo, L. Pellegrino, M. Preger, P. Raimondi, R. Ricci, C. Sanelli, M. Serio, F. Sgamma, B.Spataro, A. Stecchi, A. Stella, F. Tazzioli, C. Vaccarezza, M. Vescovi, C. Vicario, M. Zobov
SPARC- Project Team @ **INFN-LNF**

F. Alessandria, A. Bacci, I. Boscolo, F. Broggi, S.Cialdi, C. DeMartinis, D. Giove, C. Maroli, V. Petrillo, M. Romè, L. Serafini
SPARC Project Team @ **INFN-Milano e Università di Milano**

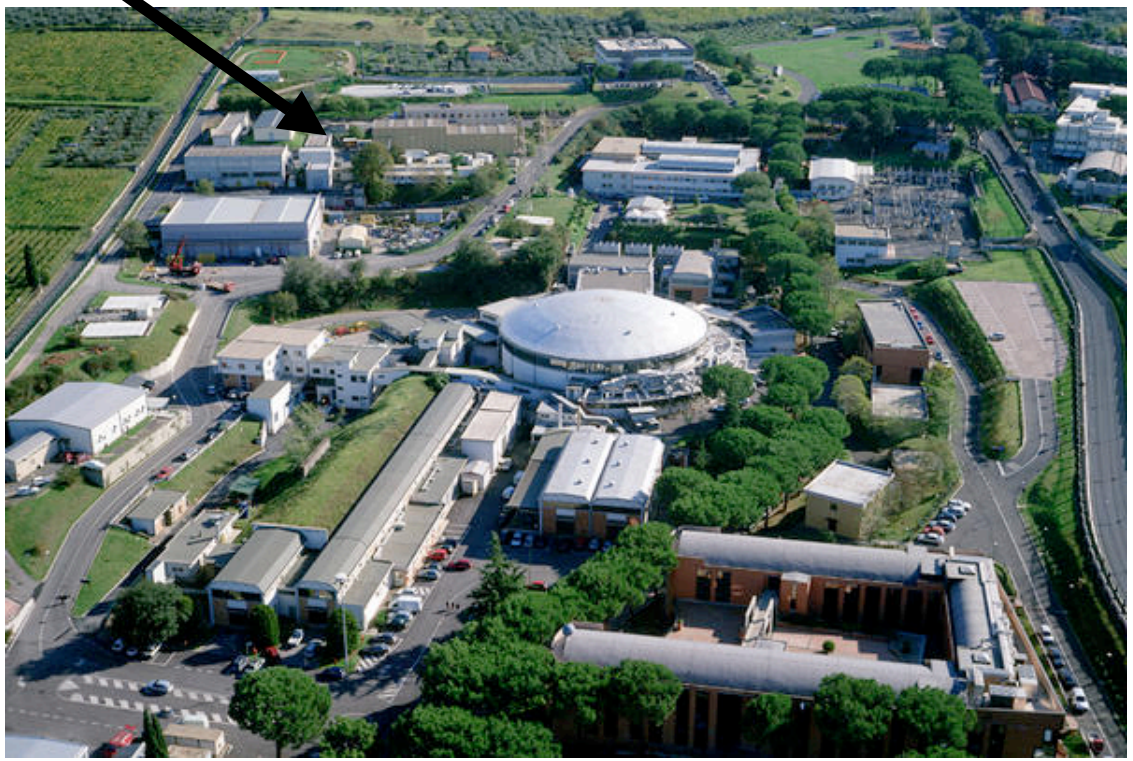
R. Bonifacio, N. Piovella, R. Pozzoli
Università di Milano e INFN-Milano

PLASMONX UNITS



PlasmonX

@ LNF-INFN

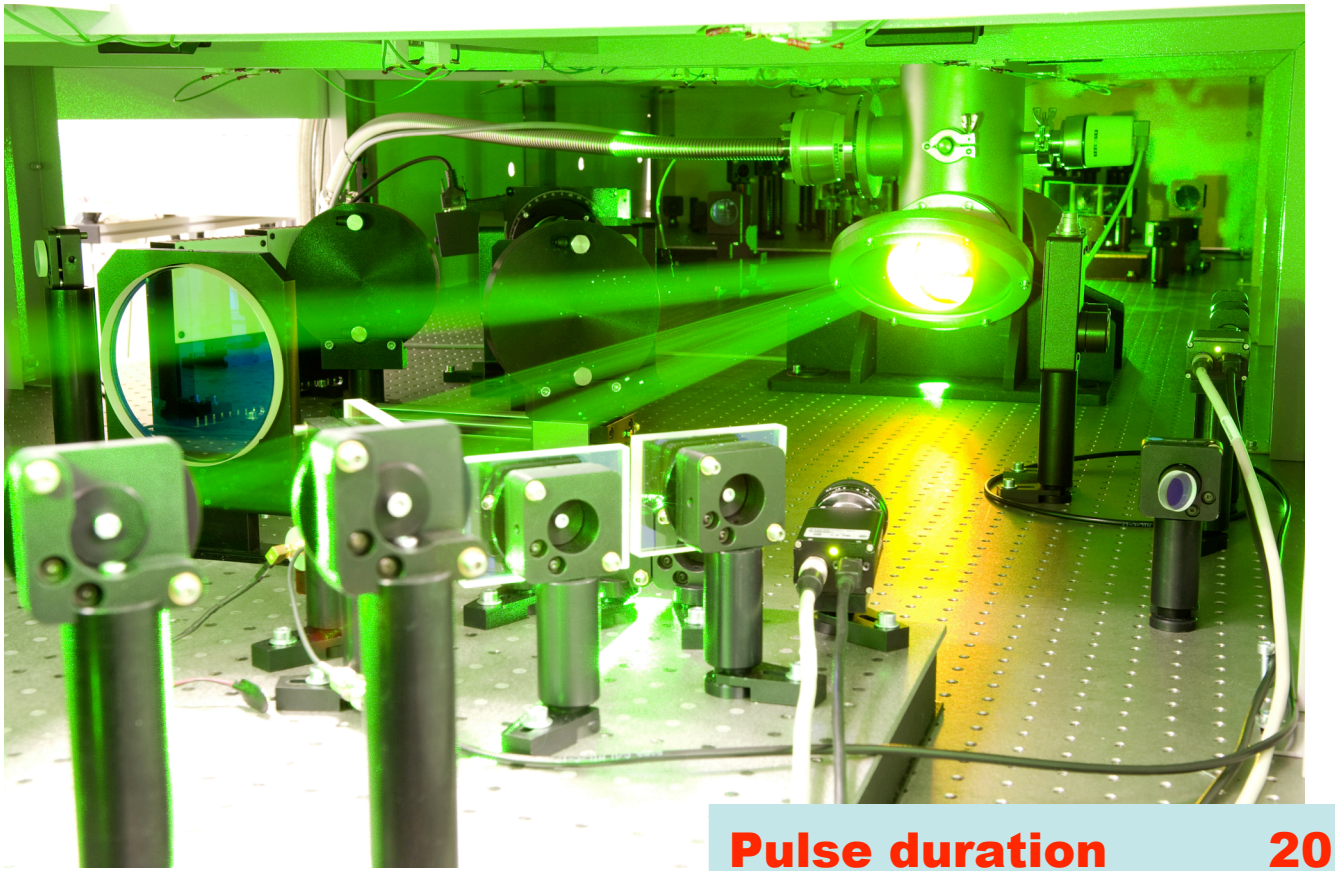


The site for the new INFN facility was chosen in LNF….

The 300TW LASER laboratory

…. the new lab replaced a small hill

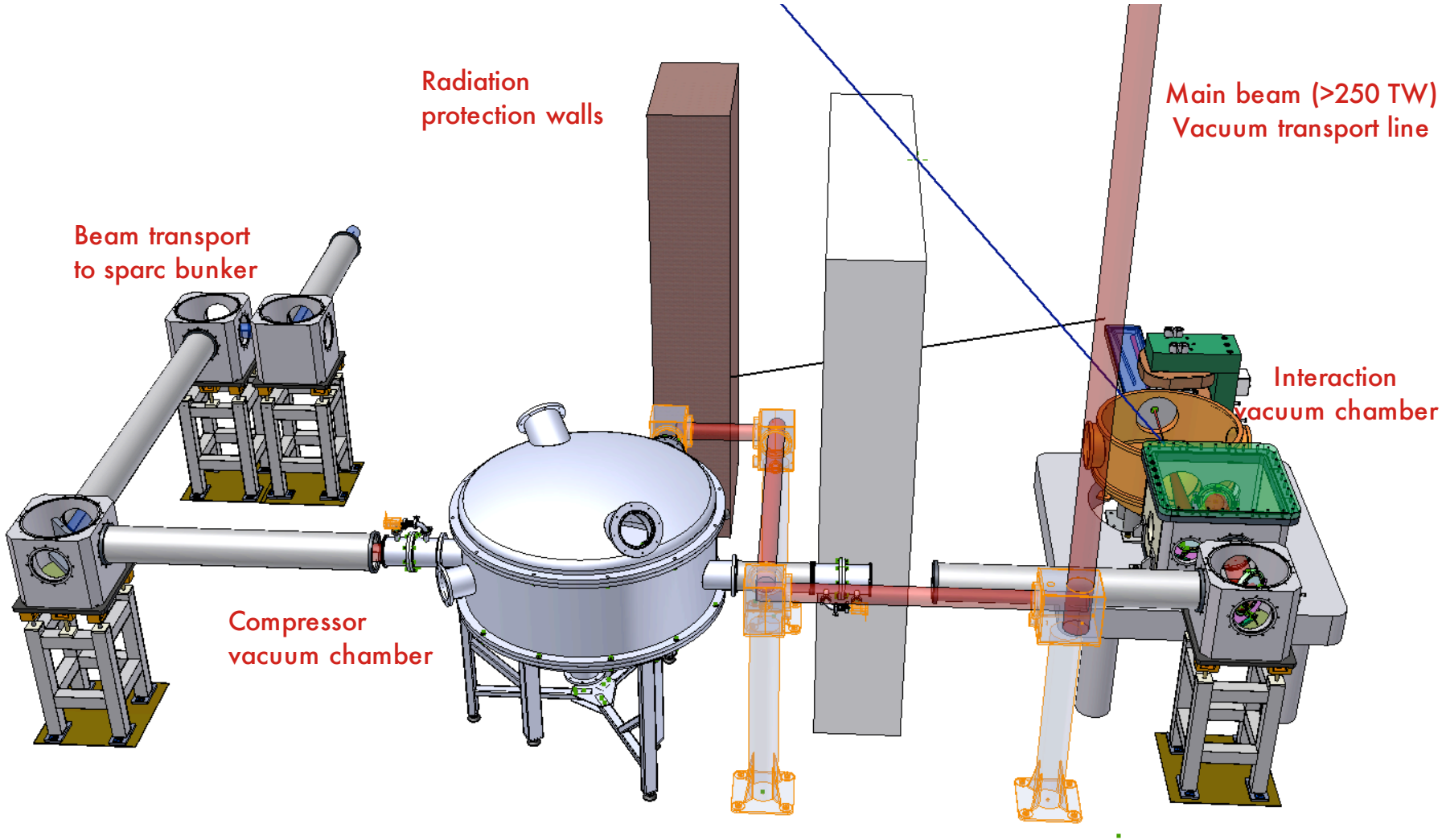
The final amplifier of the PLASMONX 300TW LASER



Pulse duration	20 fs
Pulse energy	6J
Rep. Rate	10Hz
Peak power up to	300 TW
ASE contrast	$\approx 10^{-10}$
Pre-pulse contrast	$< 10^{-8}$

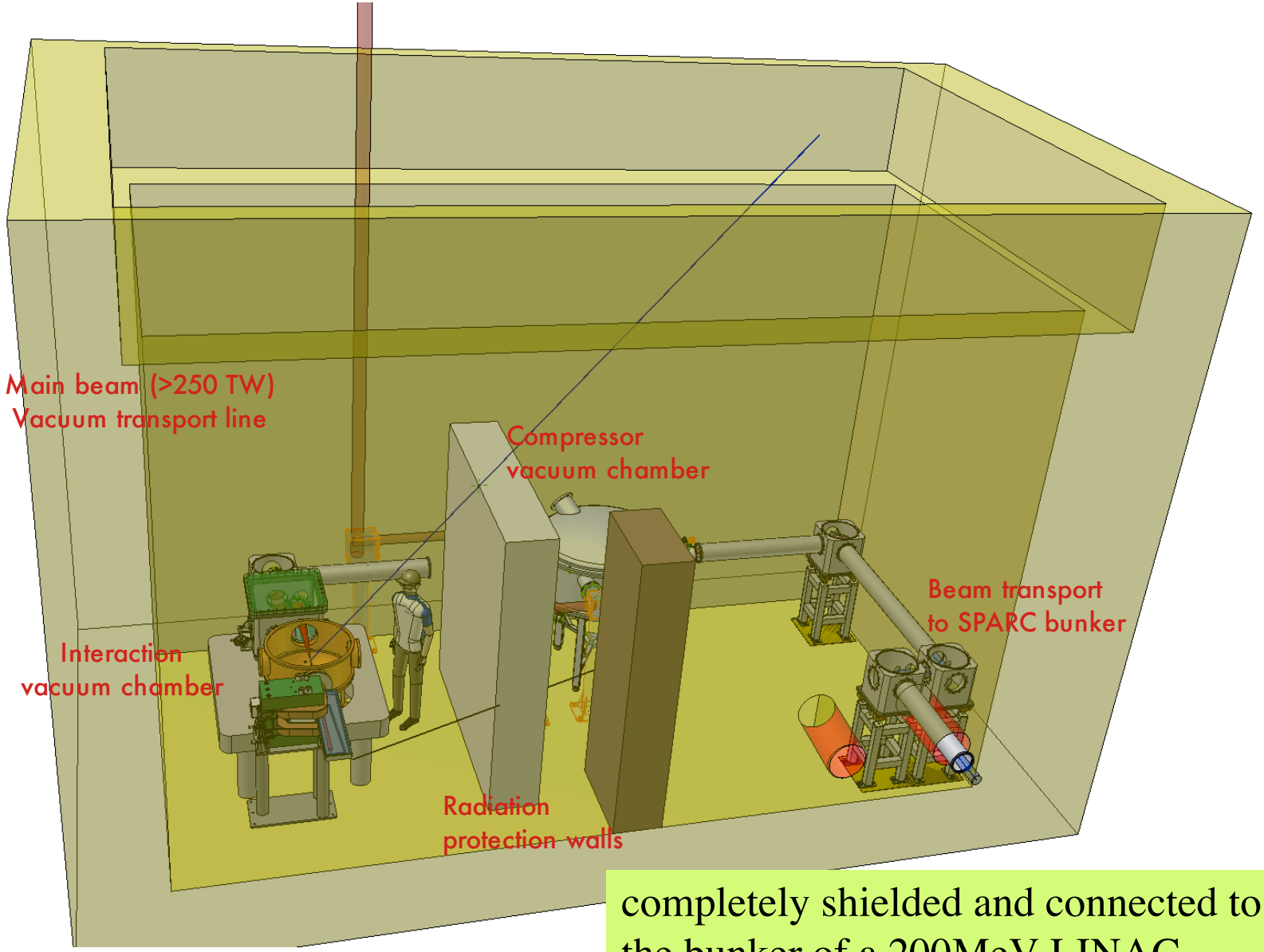
and a very powerful LASER was assembled …..

LPA Target Area



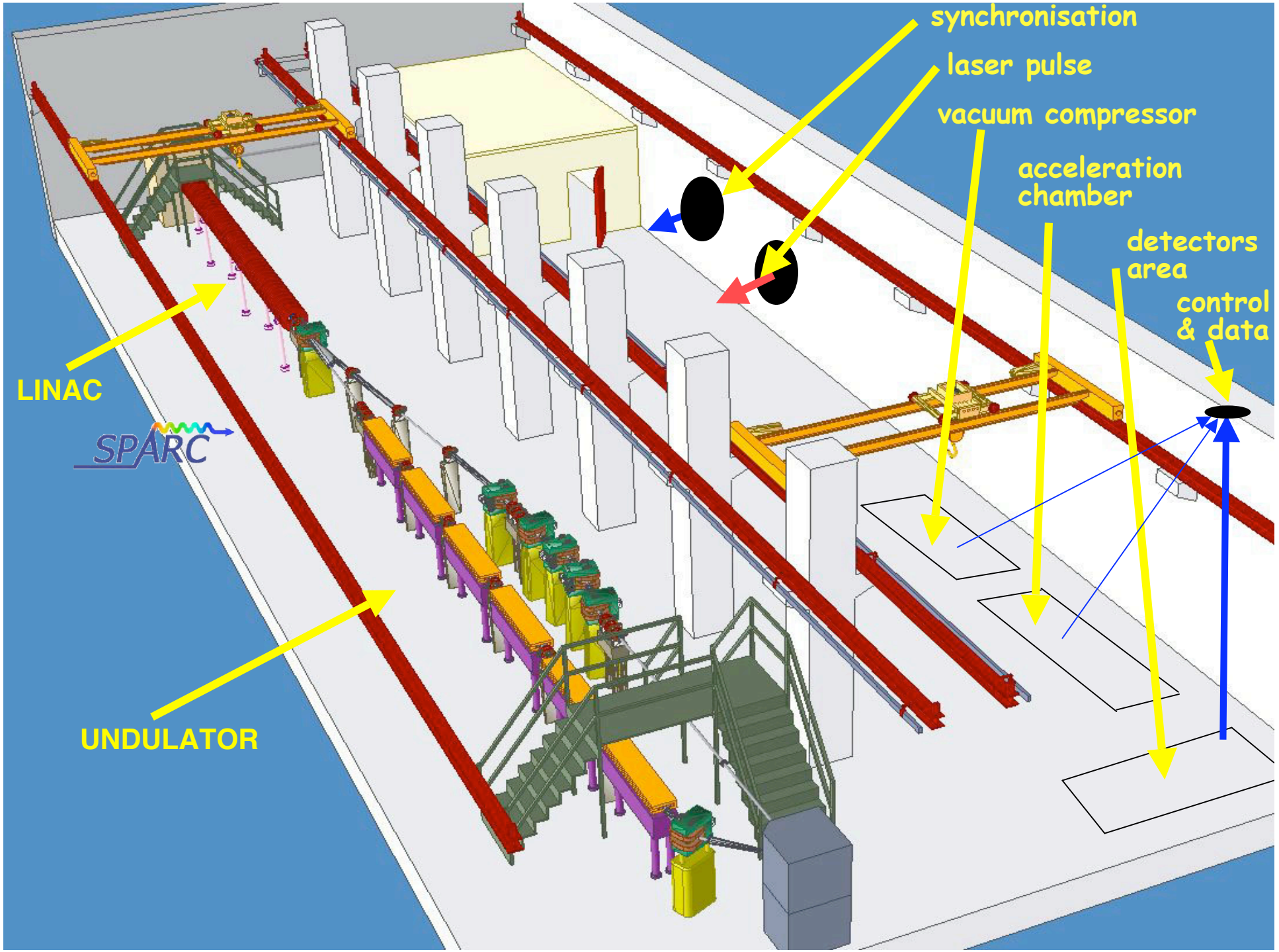
……with an underground LPA target area

LPA Target Area



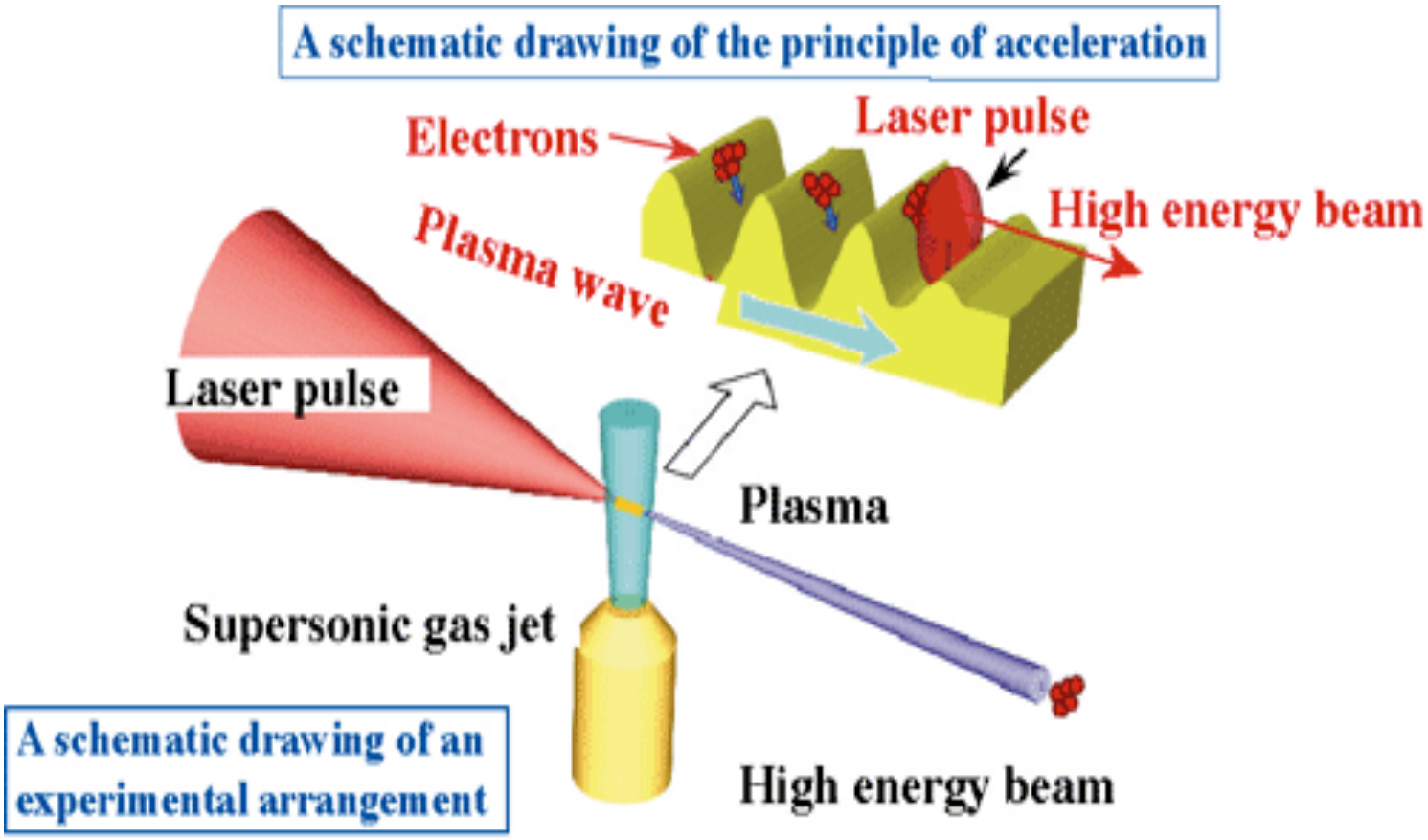
completely shielded and connected to the bunker of a 200MeV LINAC

VERT. AND HORIZ. SHIELDING


synchronisation
laser pulse
vacuum compressor
acceleration chamber
detectors area
control & data
LINAC
SPARC
UNDULATOR

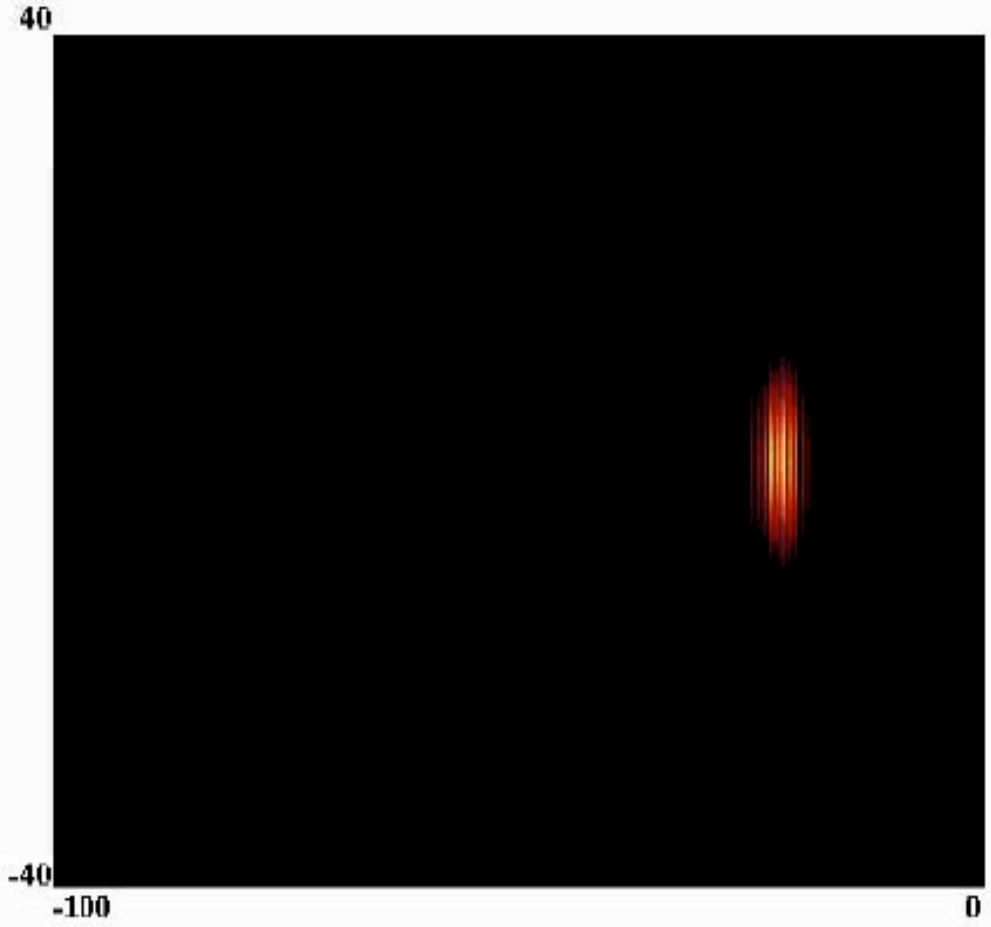

SPARC: the 200MeV
LINAC and the
UNDULATORS

Self-injection



The first experiments of SI-LPA offer also the possibility to test the LASER main parameters

LASER PLASMA ACCELERATION



$N_e = 10^{19} cm^{-3}$

L=1mm

T=20fs

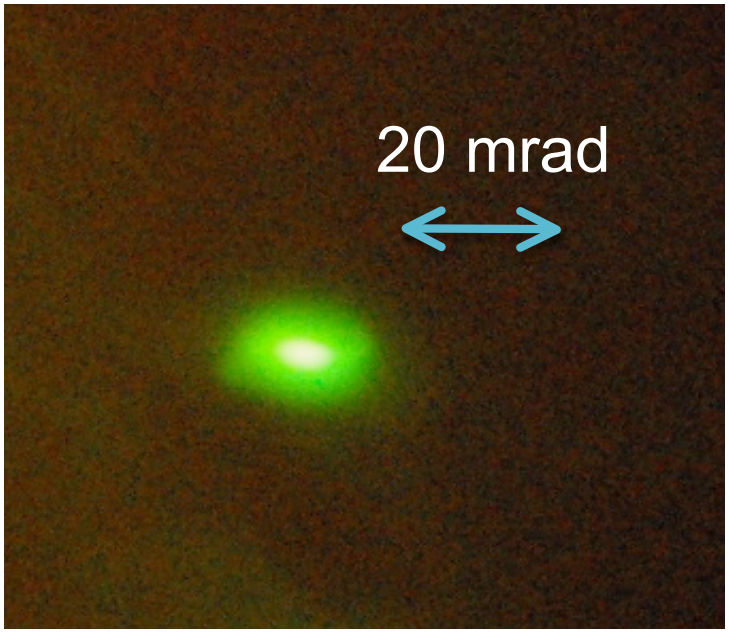
W=9μm

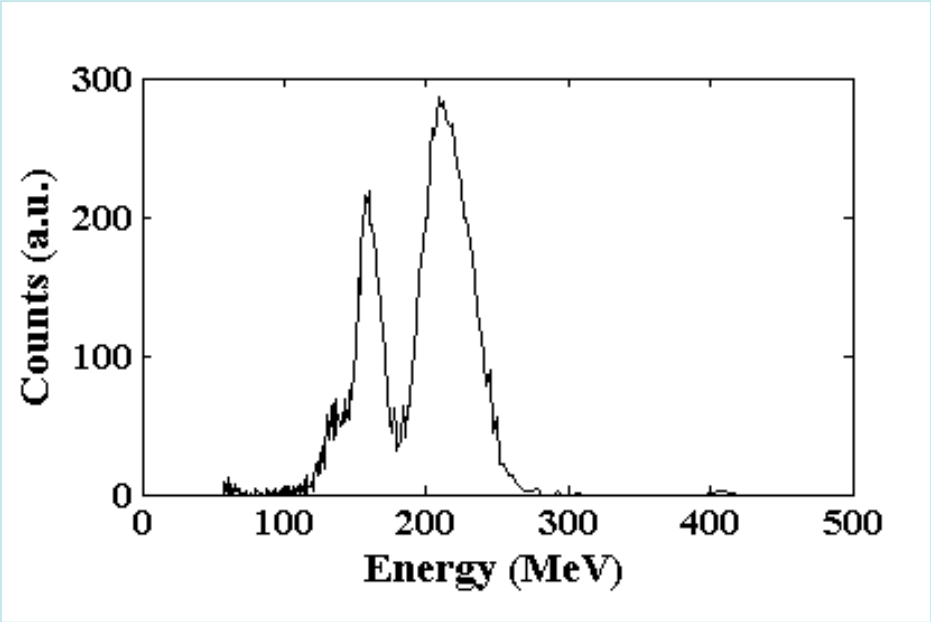
I=1.5 $10^{20} W/cm^2$

$U_{el} \approx 400 MeV$

PIC simulation for the first SI-LPA experiments @ LNF

LPA-Self Injection:first results

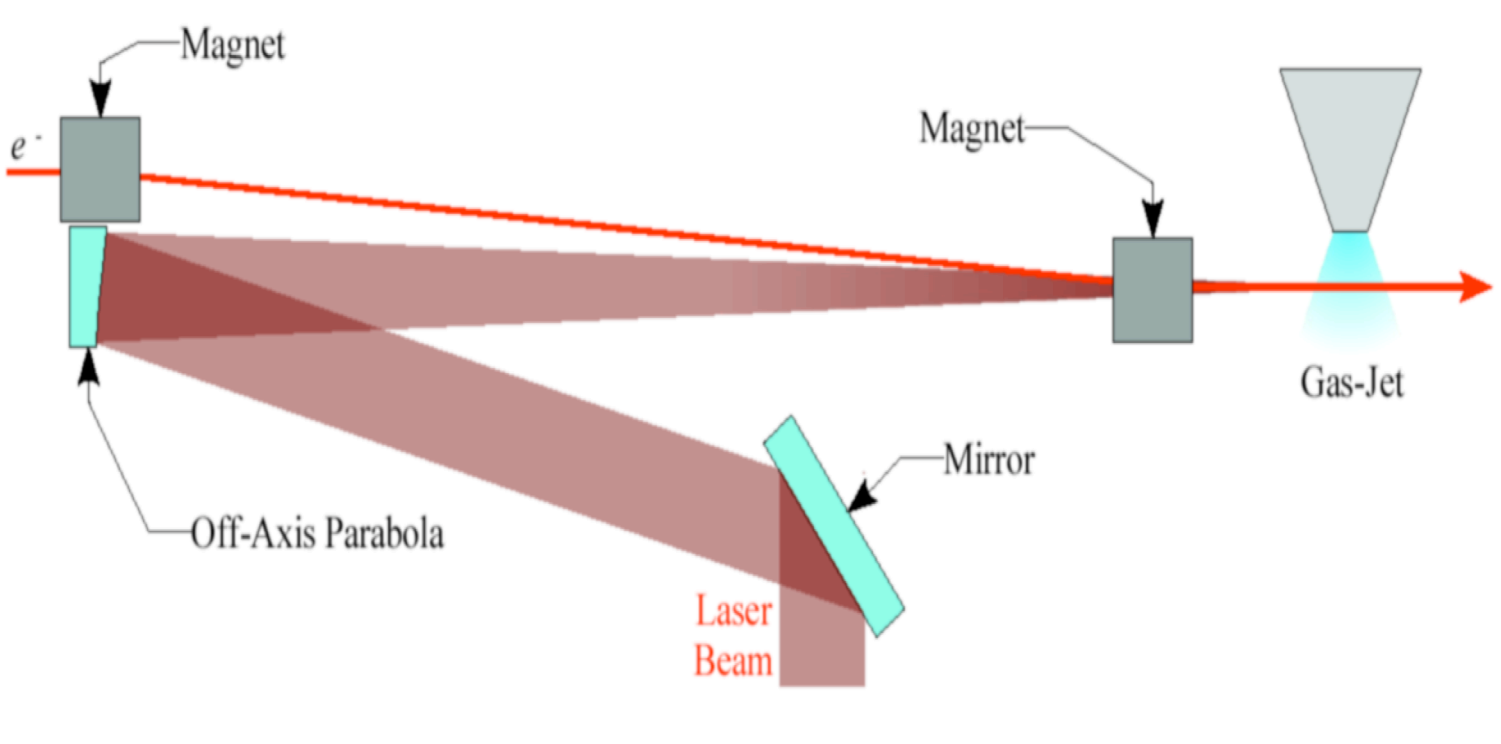




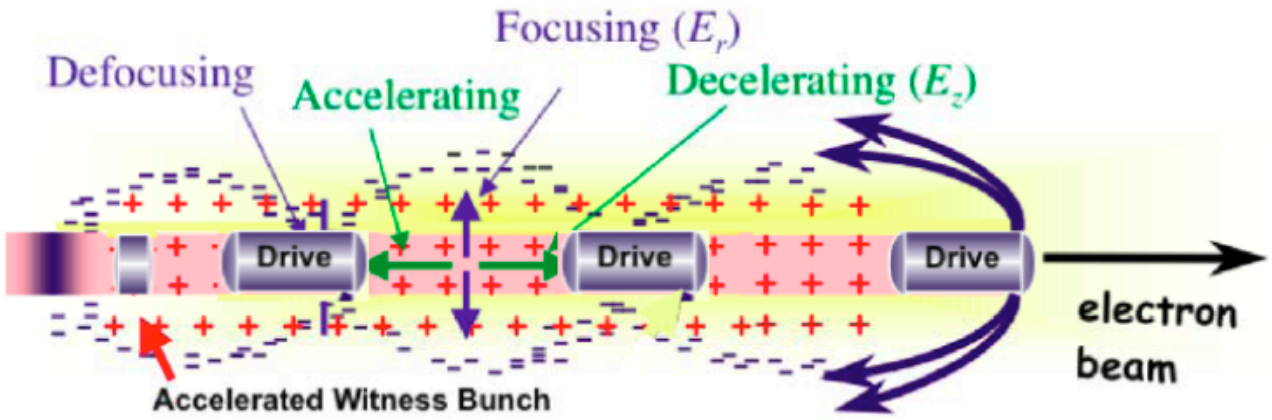
First results focusing less than 1/10 of the maximum LASER power in a supersonic gas-jet at about 10Atm of N_2

External injection

We intend also to inject monochromatic e-bunches into LPW excited by the powerful LASER to reduce the energy spread of the accelerated electrons. The experiment is challenging due to the required synchronization between LASER and LINAC (10fs) and the shortness of the e-bunches (few μm) with respect to the plasma wavelength.



COherent Multi e-Bunches for electron acceleration in plasmas

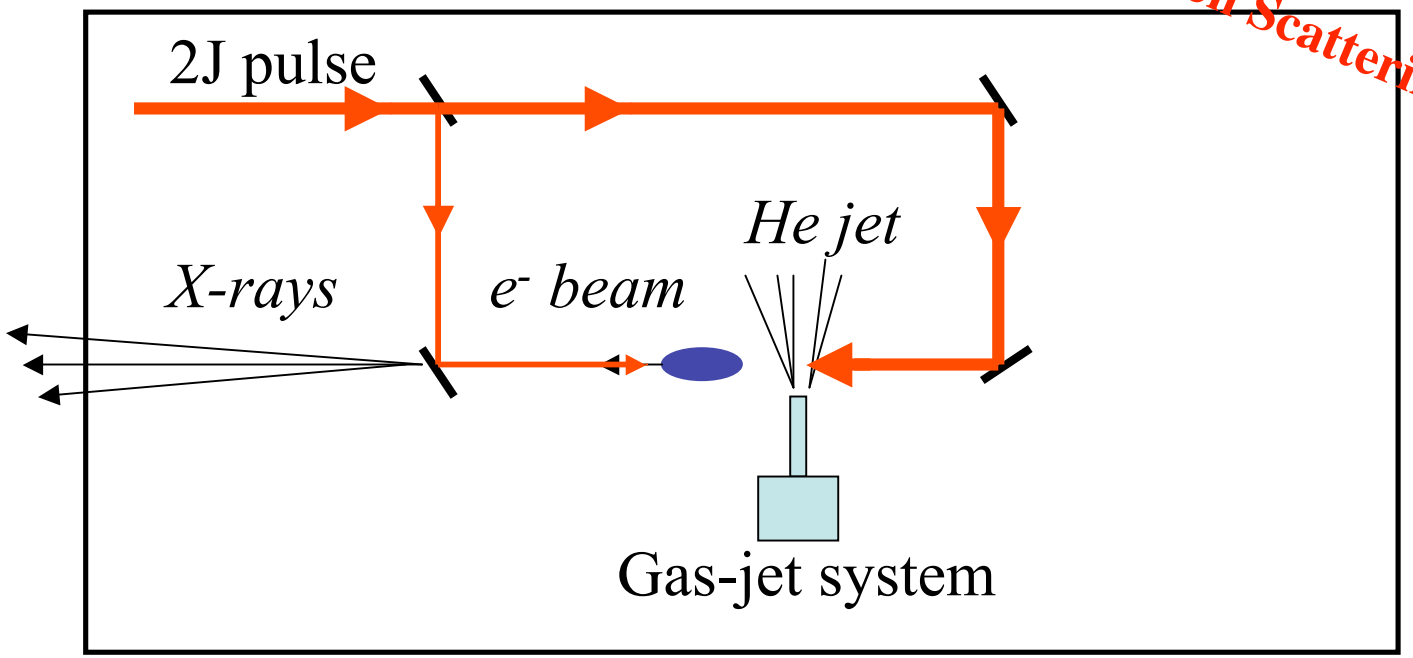


Due to the high control on the LINAC photo-injector we intend to accelerate electrons in a plasma wave resonantly excited by a train of e-bunches

Table-top source of ***femtosecond X-rays***

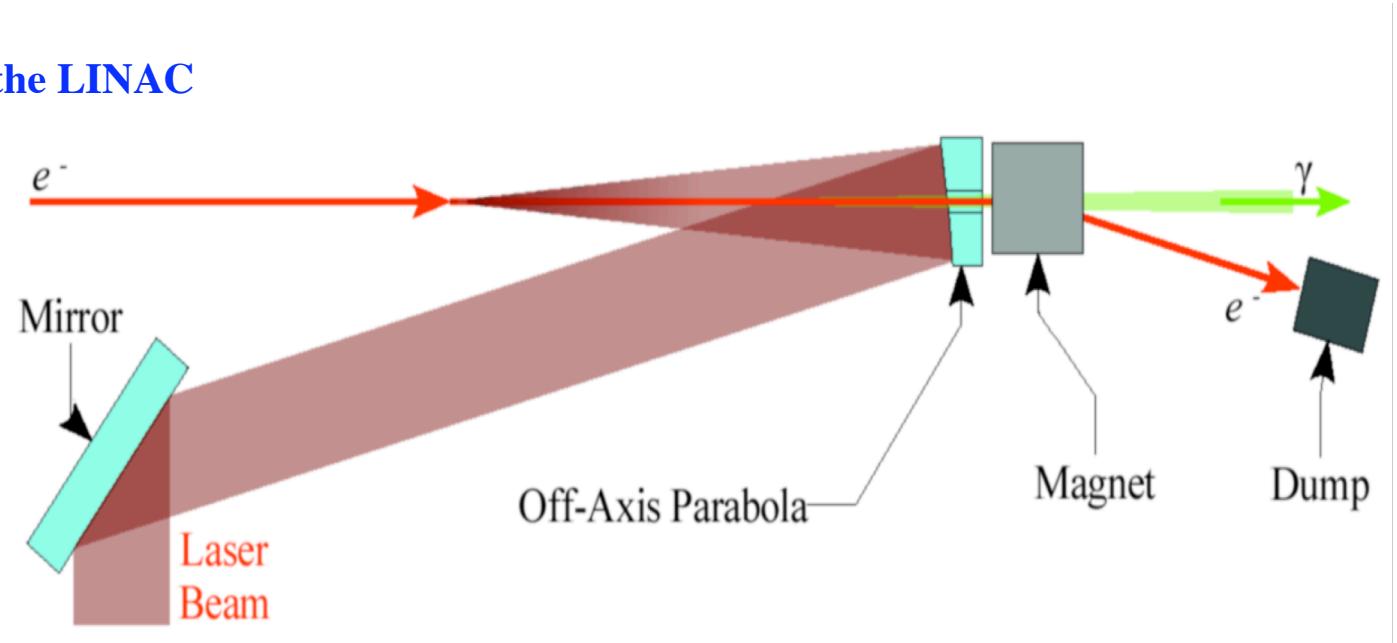
In the Project X-gamma ray sources will be developed based on the TS; using only the LASER …….

All Optical Thomson Scattering Source



Tuneable X-ray radiation source based on Thomson Scattering

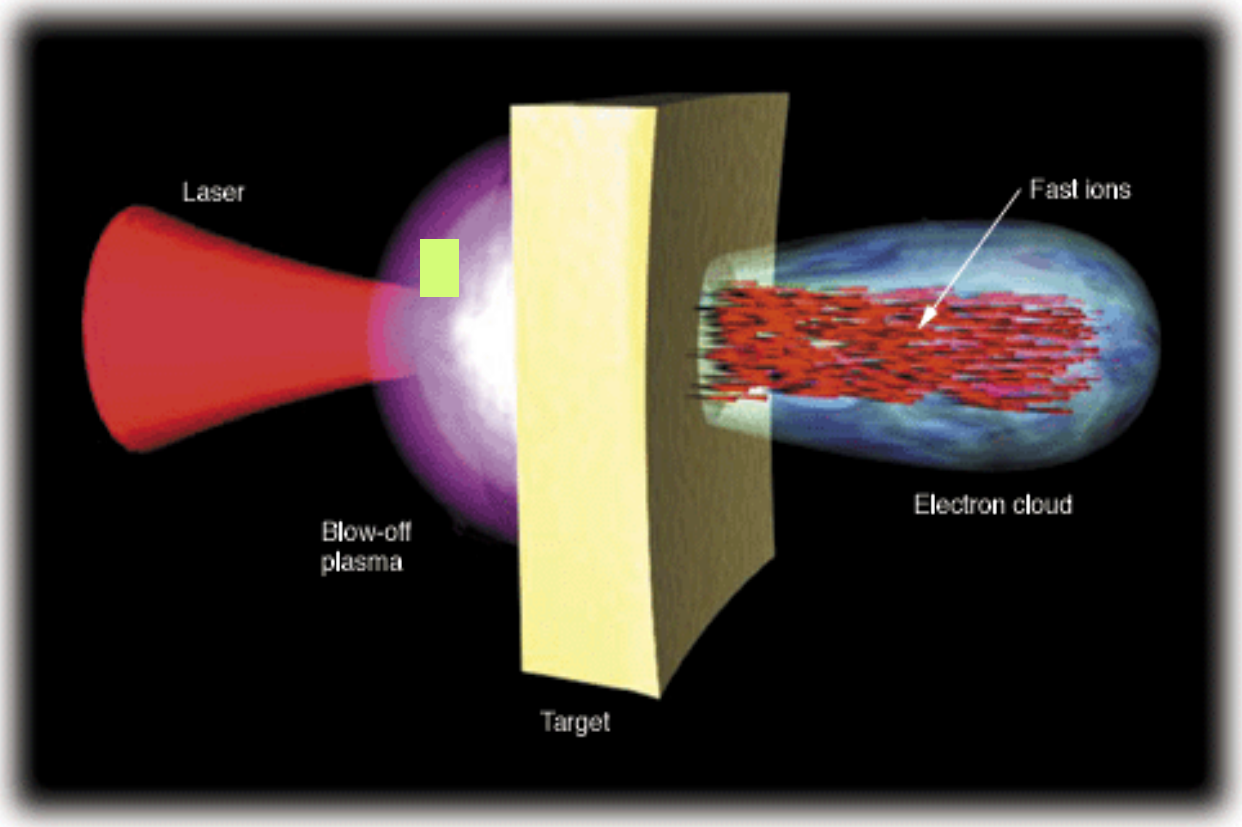
from the LINAC



……and LASER and LINAC

BEATS-experiment

LPA of ions



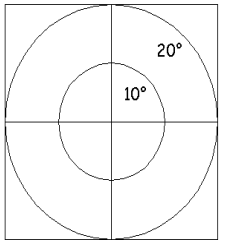
The LASER parameters are suitable also for ion LPA once the LASER is focused on solid targets

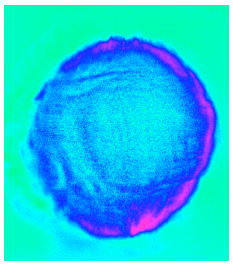
LILIA-experiment

Spectral distributions

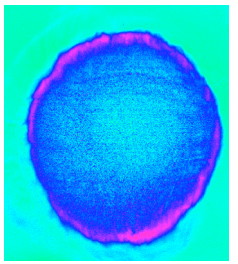
0 n°prot.MeV^{-1} sr^{-1} 2.2x10^{11}

Typical anular structures

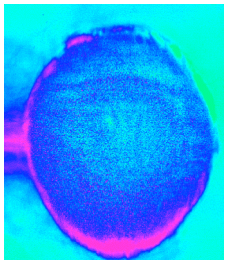




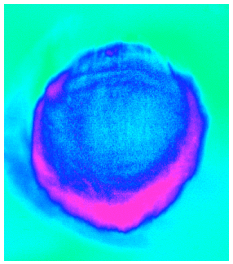
E_1 = 10.3 MeV



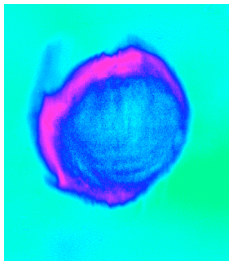
E_2 = 11.8 MeV



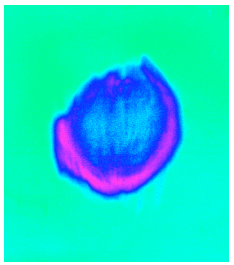
E_3 = 13.2 MeV



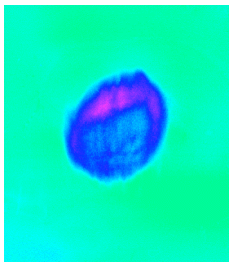
E_4 = 14.7 MeV



E_5 = 17.3 MeV



E_6 = 19.5 MeV



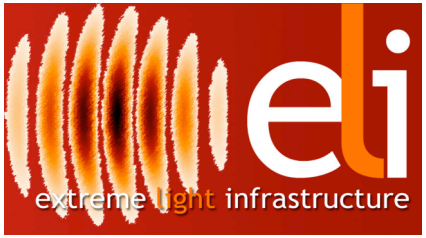
E_7 = 21.1 MeV

E_8 = 23 MeV

Angular divergence decreases as proton energy increases.

Goals and planned activity

- Control of LPA mechanism
- Development of new targets
- Multi stages
- External Injection
- Coherent multi e-bunches
- X-gamma secondary sources
- LPA of ions

FROM PlasmonX TO 

ELI would be the first infrastructure dedicated to the fundamental study of laser-matter interaction in a new and unsurpassed regime of laser intensity: the ultra-relativistic regime (I_L>10^{23} W/cm^2).

The infrastructure would serve to investigate a new generation of compact accelerators delivering energetic particle and radiation beams of femtosecond (10^{-15}s) to attosecond (10^{-18}s) duration.

ELI would afford wide benefits to society ranging from improvement of oncology treatment, medical imaging, fast electronics and our understanding of aging nuclear reactor materials to development of new methods of nuclear waste processing.

The PLASMONX activity naturally fits the one of the European Project ELI

Project leader
G. Mourou

Steering committee

Project manager
J.P. Chambaret +
System Engineer

SAFETY
Safety Manager

BUILDING

Laser system
P. Georges
S. Karsch

OPCPA
TiSa:ampli
Diode pumping
Coherent beam combining
Adaptative optic

Attosecond Science
G. Tsakiris, D Charalambidis
P. Audebert

Attosecond to zeptosecond Physics
Ultra relativisitc optics

Beam lines

Proposed Applications
Probe ultrafast dynamics (atom, molecule and plasma)
Ultra Non Linear X-UV phenomena
Electron dynamics

Laser plasma accelerator
D. Giulietti
V. Malka

Ultra relativistic plasma
Electron beam
Proton beam
Ions beam
Muons beam

Beam lines

Gamma imaging
Radiotherapy
Test and Calibration
Probing plasmas
Polarised beam
High energy physics
...

Ultrafast X-ray radiation beams
A. Rousse
B. Rus

Coherent (X,γ)-rays
(FEL, HHG & plasma)
Incoherent (X,γ)-ray beams
(synchrotron-like, atomic)

Beam lines

Probe ultrafast dynamics, high resolution image & create new states of matter

High field Science
D. Habs
D. Bernard

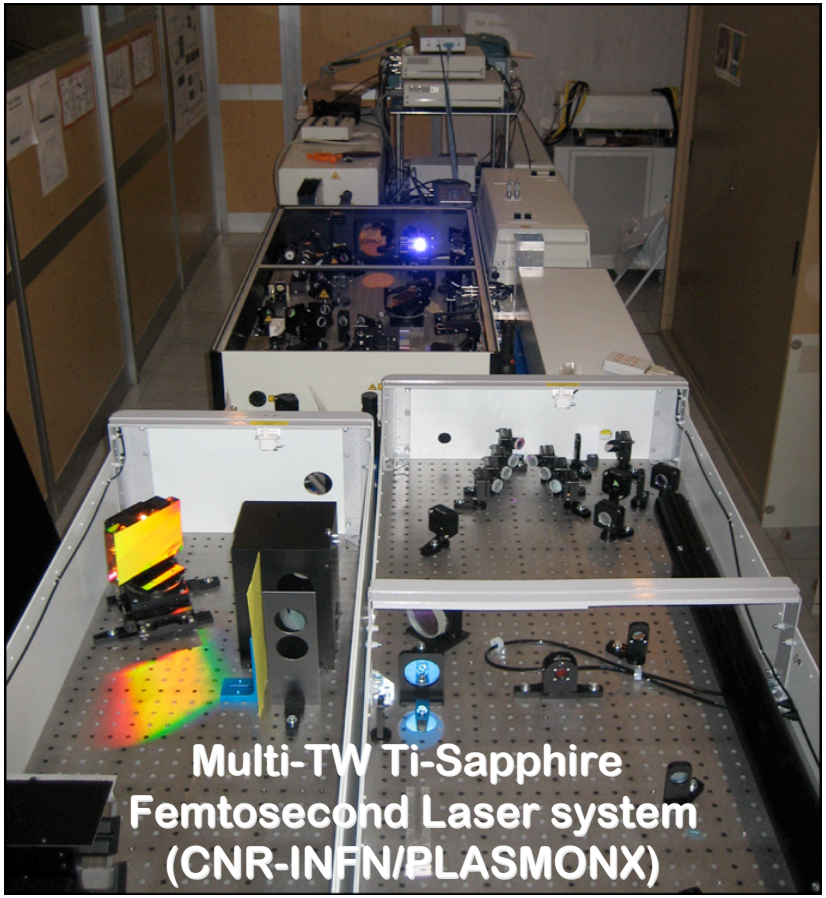
NLQED
Fundamendal physics
Exotic physics
Nuclear Physics

Transmutation induced by laser

Stato del Progetto

- Entro estate 2011 completamento istallazione laser
- Entro Ott. 2011 istallate O.A.
- Entro Dic. 2011 istallata linea elettr. TS, LASER nel bunker del LINAC, prodotti primi X a 20-30KeV

PLASMONX-PISA



PLASMONX-PISA FTE (%)

• Danilo Giulietti	Professore	80
• Ubaldo Bottigli	Professore	20
• Pasquale Delogu	Ricercatore	20
• Yuji Oishi	Ric. CRIEPI	100
• Leonida Gizzi	Ric. CNR	30
• Luca Labate	Ric. CNR	20
• Maria Pia Anania	Assegn. CNR	40
• Tadzio Levato	Assegn.CNR	30

ISTITUTO NAZIONALE DI FISICA NUCLEARE
Preventivo per l'anno 2012

Struttura
Pisa

CODICE	SIGLA	COMMISSIONE
	NTA-PLASMONX	P.S.
Resp. Loc.: Danilo Giulietti		

PREVENTIVO LOCALE DI SPESA (In K€)

Capitolo	*Descrizione*	Parziali		Totale	
		Richiesta	SJ	Richieste	SJ
INTERNO	**1.** missioni a LNF; coordinamento con le altre Unità di Progetto; congressi e meeting nazionali	35.00		**35.00**	0.00
INTERNO					
ESTERO	**1.** missioni ad AMPLITUDE TECHNOLOGIES (Evry); Ecole Polytechnique; CEA Saclay; RAL; PALS; CERN; Congressi e meetings internazionali;attività nei progetti Europei	15.00		**15.00**	0.00
ESTERO					
CONSUMO	**1.** LANEX	10.00			
	2. capillari per gas target	10.00			
	3. fogli metallici per filtraggio raggi X	3.00			
	4. cristalli per diffrazione raggi X	10.00		**33.00**	0.00
CONSUMO					
SEMINARI					
TRASPORTI	**1.** trasporto materiali a LNF	2.00		**2.00**	0.00
TRASPORTI					
PUBBLICAZIONI					
MANUTENZIONE					
INVENTARIO	**1.** 2 scintillatori accoppiati con fotomoltiplicatore e relativa alimentazione	15.00			
	2. diodo PIN e relativa alimentazione	2.00		**17.00**	0.00

INVENTARIO					
APPARATI					
LICENZE-SW					
SPSERVIZI					
			Totale NTA-PLASMONX Pisa	**102.00**	

Richieste in Sezione

- 1 posto in uno studio della Sezione per Yuji Oishi
- Lavorazioni mecaniche per set-up esperimenti LPA (15 giorni)