HighQ
(High Quality laser-plasma acceleration)

Bando 2019 per proposte progettuali “Call” della CSN5 dell’INFN

Responsabile nazionale

M. FERRARIO (LNF)

Unità partecipanti

PISA - Resp L. A. GIZZI

INFN ROMA TOR VERGATA - Resp A. CIANCHI

Background 1/2

- This proposal
  - follows the perparatory work done for the design study of the EuPRAXIA infrastructure;
  - builds on the work carried out at the participating labs LNF (Sparc-lab) and Pisa (ILIL) where plasma acceleration has been demonstrated and Eupraxia developments are in progress;
- The project deals with high-gradient plasma acceleration of electrons driven by high intensity lasers, namely laser-wakefield acceleration (LWFA);
- The focus of the proposal is the control of electron bunch properties, namely energy spread and emittance at electron energies starting at >200 MeV (Eupraxia injector);

Background 2/2

- The proposal will demonstrate feasibility of a new acceleration and injection scheme (ReMPI) that has already passed a complete start-to-end modelling test;
- The objective is to demonstrate feasibility of a laser-driven scheme with energy spread below 1% and emittance below 1 mmm rad.
- The project will develop and test the main components required for the proposed scheme and will integrate them for a pilot demonstration activity;

BEYOND HIGH GRADIENT

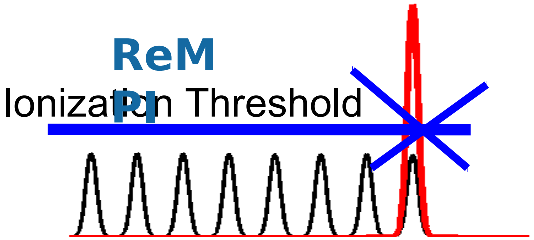
Since 2004, systematic production of *self-injected* electron bunches with energy up to GeV range and moderate energy spread (5-10%)
Exploration of applications ongoing worldwide.
Main goal: X-ray FEL => EuPRAXIA

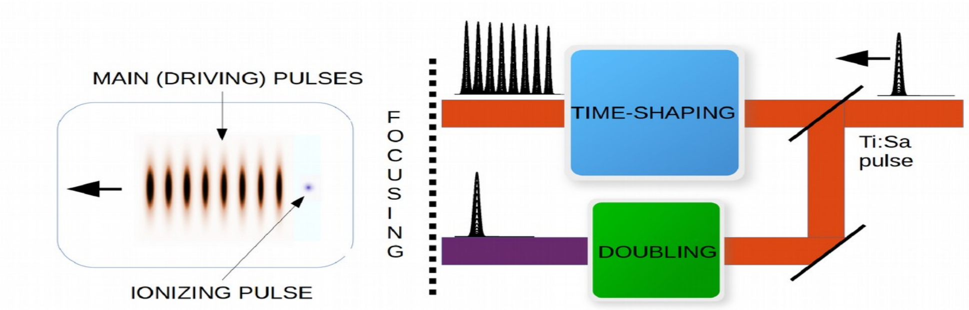
Self-injection powerful but uncontrollable;
Need of controlled injection of electrons in a well-formed wake wave

BUNCH QUALITY: energy spread, emittance, beam divergence …
=> CONTROL WAKEFIELD GENERATION AND INJECTION SEPARATELY

OUR ACCELERATION/INJECTION SCHEME

- The Resonant Multi-Pulse Ionization injection [**P. Tomassini et al., Phys. Plasmas 24 (2017)**] is a new bunch injection scheme aiming at generating extremely low-emittance bunches [as low as 0.06 mm mrad]
- ReMPI requires ONE short-pulse 100-TW class (e.g Ti:Sa) laser system. Since a unique very large-amplitude Ti:Sa pulse would fully ionize the atoms (N5+ or Ar8+), the pulse is shaped as a <u>resonant</u> sequence of sub-threshold amplitude pulses.

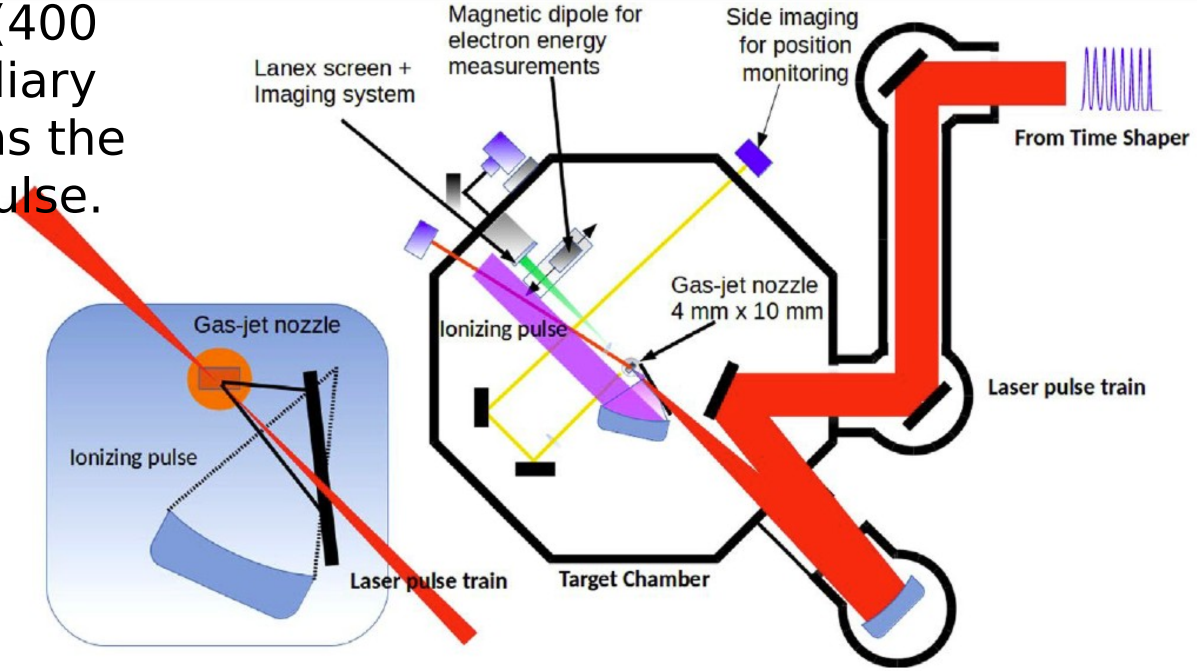




A new scheme to generate the train of pulse in a stable, efficient and feasible way « **Quasi Lossless Pulse Train generation by Early Amplitude division** » has been recently proposed by L. Labate et al. (submitted)

EXPERIMENTAL SET UP

A frequency doubled (400 nm) auxiliary pulse forms the ionizing pulse.



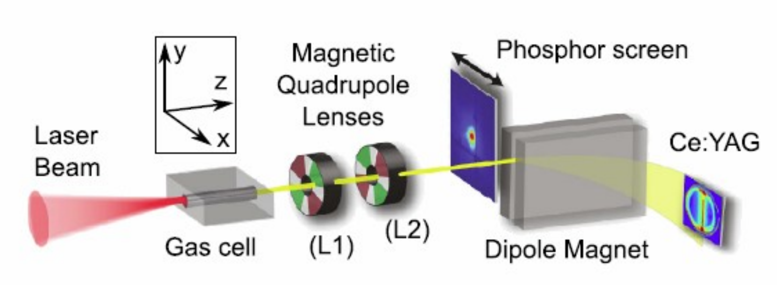
The pulse train is focused on the gas target with a long focal length off-axis parabolic mirror and drives a large amplitude plasma wave.

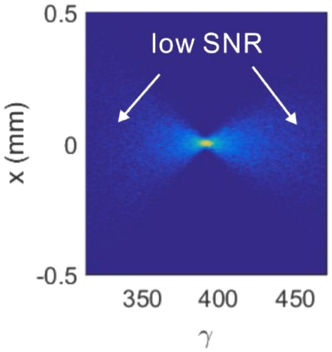
The set up is fully compatible with both the ILIL laser at CNR-INO and the FLAME laser at LNF

Electron diagnostics

Single shot diagnostics are highly desirable in plasma acceleration
The transverse emittance is the most difficult parameter to measure
We consider to explore several methods, more suited for self-injection

Permanent quadrupoles can produce, after a dipole, a focusing size different at different energies. It is a sort of quad scan in single shot.

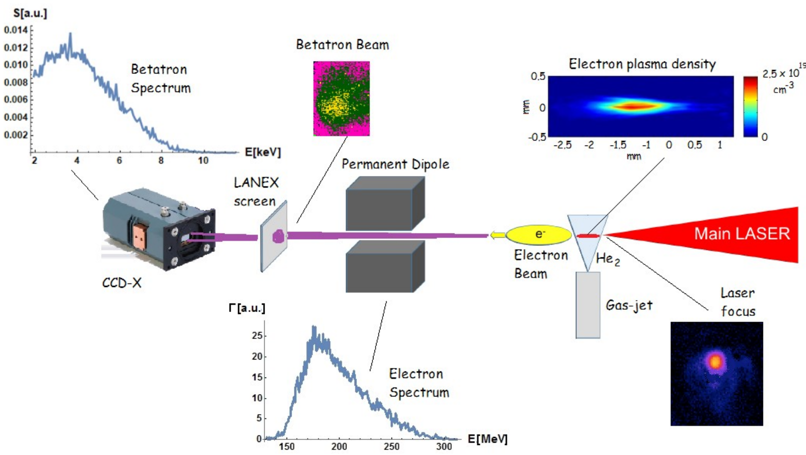


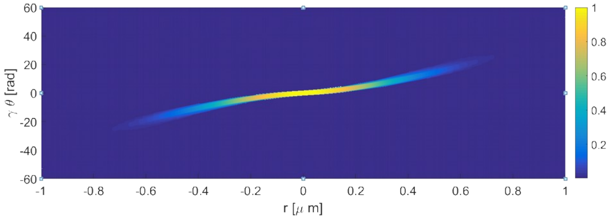


R. Weingartner and al., PRST-AB 15, 111302 (2012),
Barber, S. K., et al., Physical Review Letters 119.10 (2017): 104801

Betatron radiation

- Simultaneous measurement of the betatron spectrum, the beam energy spectrum and the plasma density
- Measurement of the emittance including the correlation term
- The beam profile is retrieved not simply the average dimensions
- An expression is given for the correlation function between the betatron oscillation amplitude and the divergence of the single accelerated electrons, i.e. the angle with respect the acceleration axis, in order to obtain the distribution of the electron divergences





Curcio, A., et al. "Trace-space reconstruction of low-emittance electron beams through betatron radiation in laser-plasma accelerators." *Physical Review Accelerators and Beams* 20.1 (2017): 012801.

STRUTTURA DEL PROGETTO – WP4

WP4 ELECTRON BEAM DIAGNOSTICS

- Responsabile C. Vaccarezza & A. Cianchi

M7 Modelling, design and construction of custom electron spectrometer
M8 Modelling, design and construction of custom electron emittance diagnostics

- Deliverables

D4 Technical design report on electron spectrometer
D5 Technical design report on emittance measurement

CRONO-PROGRAMMA

	0-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27	28-30	31-33	34-36
WP1		M1		M2		D1						
WP2		M3		M4		D2						
WP3				M5		M6		D3				
WP4				M7	M8			D4	D5			
WP5						D6	M9	M10				D7

ELI-ITALY INO-CNR (Pisa)

RICHIESTE FINANZIARIE PER UNITÀ

	WP1	WP2	WP3	WP4	WP5	TOT LNF	TOT PI	TOT INFN-TOV	TOT
Resp	PI	PI/LNF	PI/LNF	LNF/TOV	LNF/PI				
Y1	75	150	150	175	0	250	200	25	450
Y2	0	0	125	75	50	225	125	0	350
Y3	0	0	0	0	200	100	100	0	200
TOT	75	150	275	250	250	510	450	40	1000

RICHIESTE FINANZIARIE PER VOCE

	LNF			PI			INFN-TOV		
	Y1	Y2	Y3	Y1	Y2	Y3	Y1	Y2	Y3
Inventario	200	130	0	160	100	0	25	0	0
Consumabili	30	30	30	40	40	20	0	0	0
Missioni	5	5	5	5	5	5	5	5	5
Assegni di ricerca	25	25	25	25	25	25	0	0	0
TOT	260	190	60	230	170	50	30	5	5

PERSONALE

Nominativo	Unità	WP1	WP2	WP3	WP4	WP5
Anania M. P.	LNF-INFN		0,3	0,3		
Baffigi F.	PI-CNR		0,5			
Biagioni A.	LNF-INFN			0,2		
Bisesto F.	LNF-INFN		0,5	0,5		
Brandi F.	PI-CNR			0,5		0,5
Cianchi A.	TV-INFN				1,0	
Costa G.	LNF-INFN		0,3	0,3		
Ferrario M.	LNF-INFN					0,3
Fulgentini L.	PI-CNR		0,5			
Gizzi L.A.	PI-INFN & CNR			0,3		0,2
Koester P.	PI-CNR			0,5		0,5
Labate L.	PI-INFN & CNR	0,3	0,3			
Palla D.	PI-CNR			0,5	0,5	
Terzani D.	PI-CNR	0,5				
Tomassini P.	PI-CNR	0,5				
Vaccarezza C.	LNF-INFN				0,2	
Totale		**1,3**	**2,4**	**3,1**	**1,2**	**1,5**