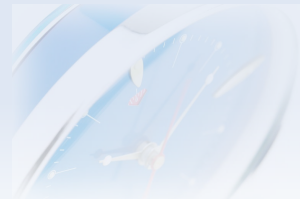


II LIFE meeting - 08/07/2009

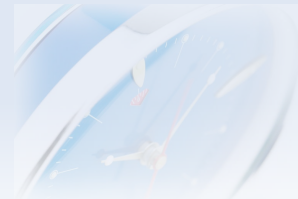
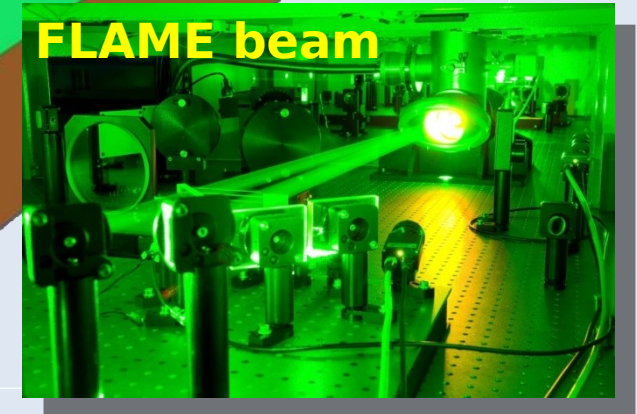
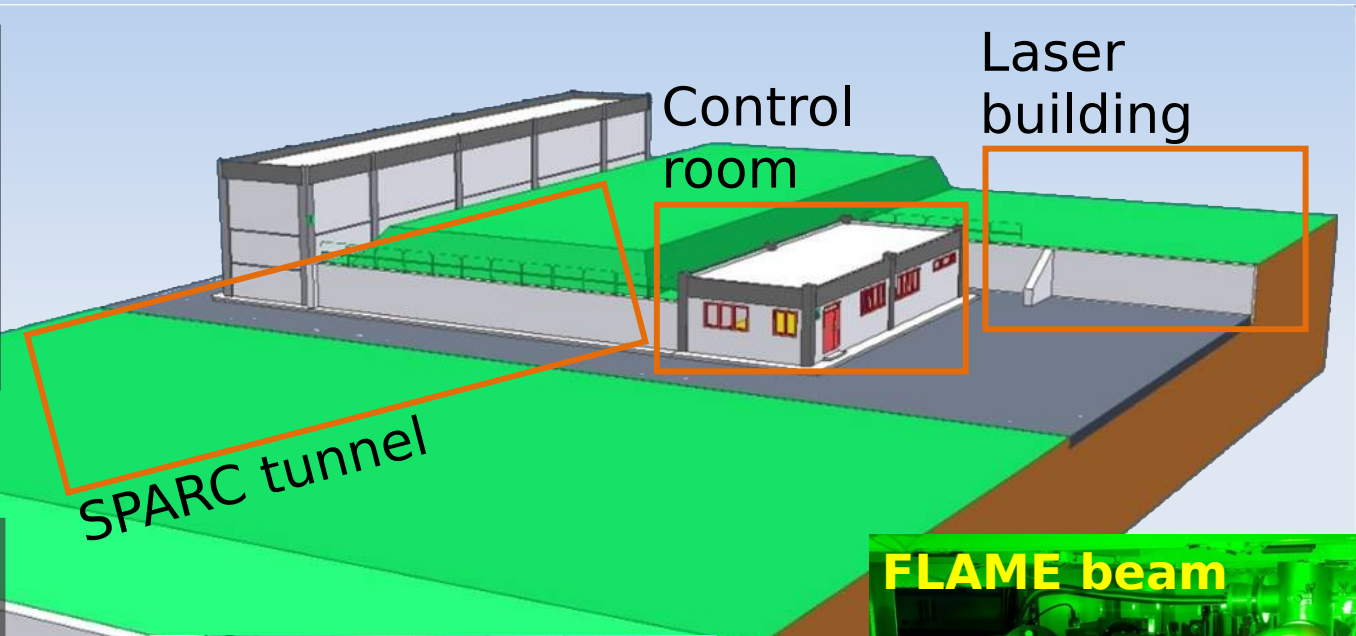
Stato del progetto di sincronizzazione per l'iniezione esterna nel plasma

Marco Bellaveglia

on behalf of the LNF Timing & Synchronization group



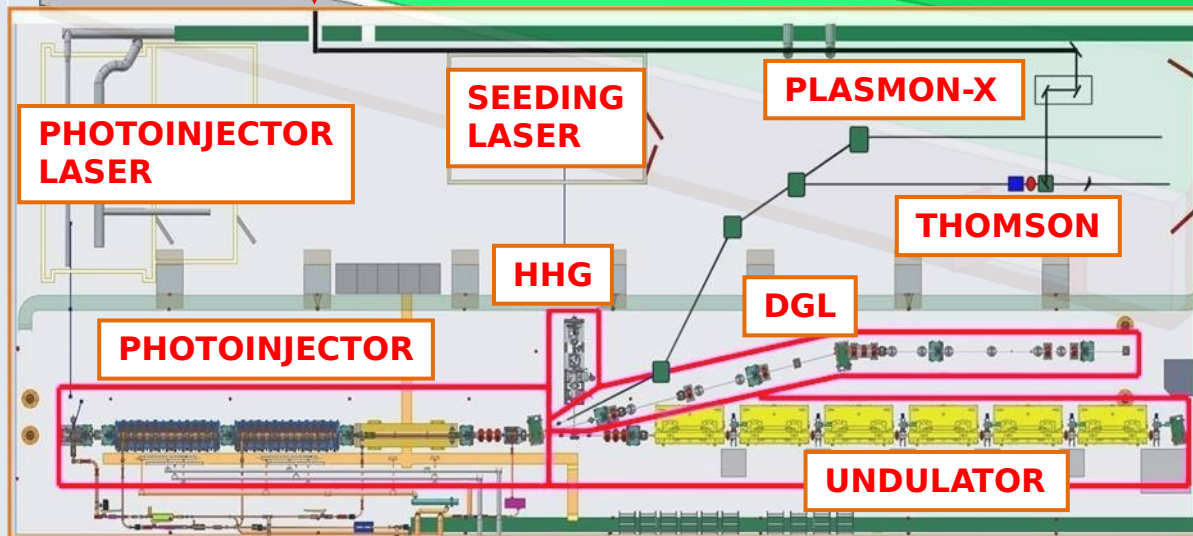
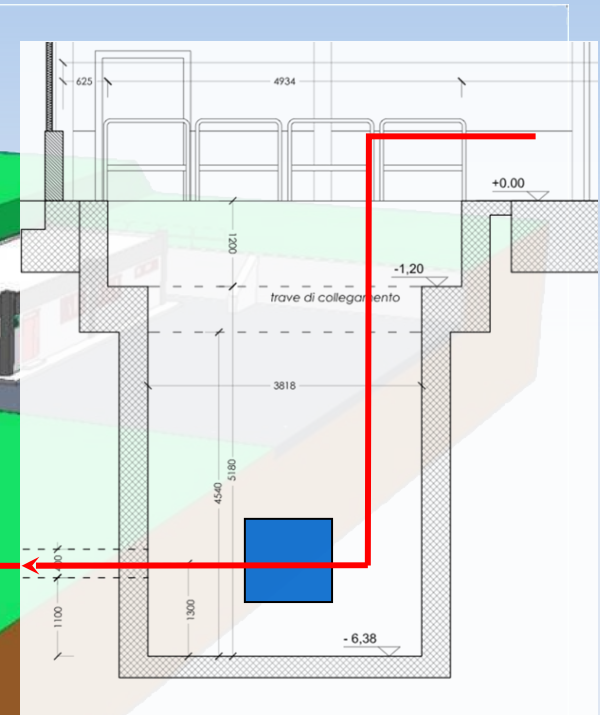
LIFE area – Main buildings



LIFE area – Experiment layout

SPARC parameters

Electron energy	155	MeV	Emittanza normalizzata trasversa RMS	<2	mm mrad
Bunch charge	1.1	nC	Emittanza slice normalizzata RMS	<1	mm mrad
Repetition rate	10	Hz	Energy spread totale correlato	0.2	%
Photocathode laser spot size	1.1	mm	Energy spread totale incorrelato	0.06	%
Laser pulse duration	10	ps	Spot size del bunch	0.4	mm
Laser pulse risetime (10-90%)	1	ps	Lunghezza del bunch RMS	1	mm
Bunch peak current (50% of the beam)	100	A			

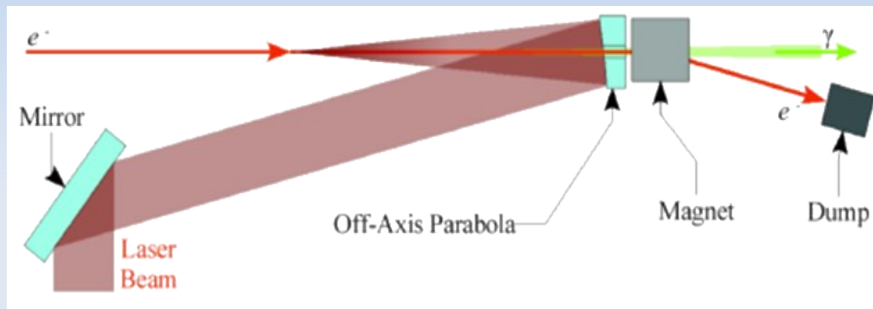


FLAME parameters

Wavelength	800	nm
Compressed pulse energy	5	J
Pulse duration (bandwidth)	30 (80)	fs (nm)
Energy stability	1	% _{RMS}
Pointing stability	<2	urad

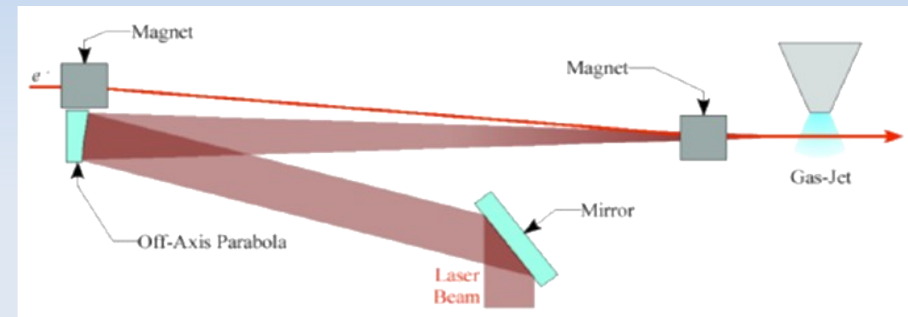
Experiment Synchronization

- Thomson scattering

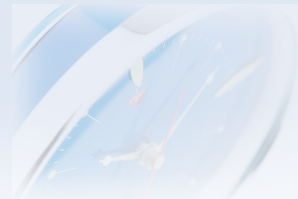


- Requires physical overlapping of SPARC and FLAME beams within the depth of focus of the laser focusing optics.
- Experiments: PLASMONX, MAMBO
- **Request: $\Delta t < 1\text{ps}_{\text{RMS}}$**

- Plasma acceleration

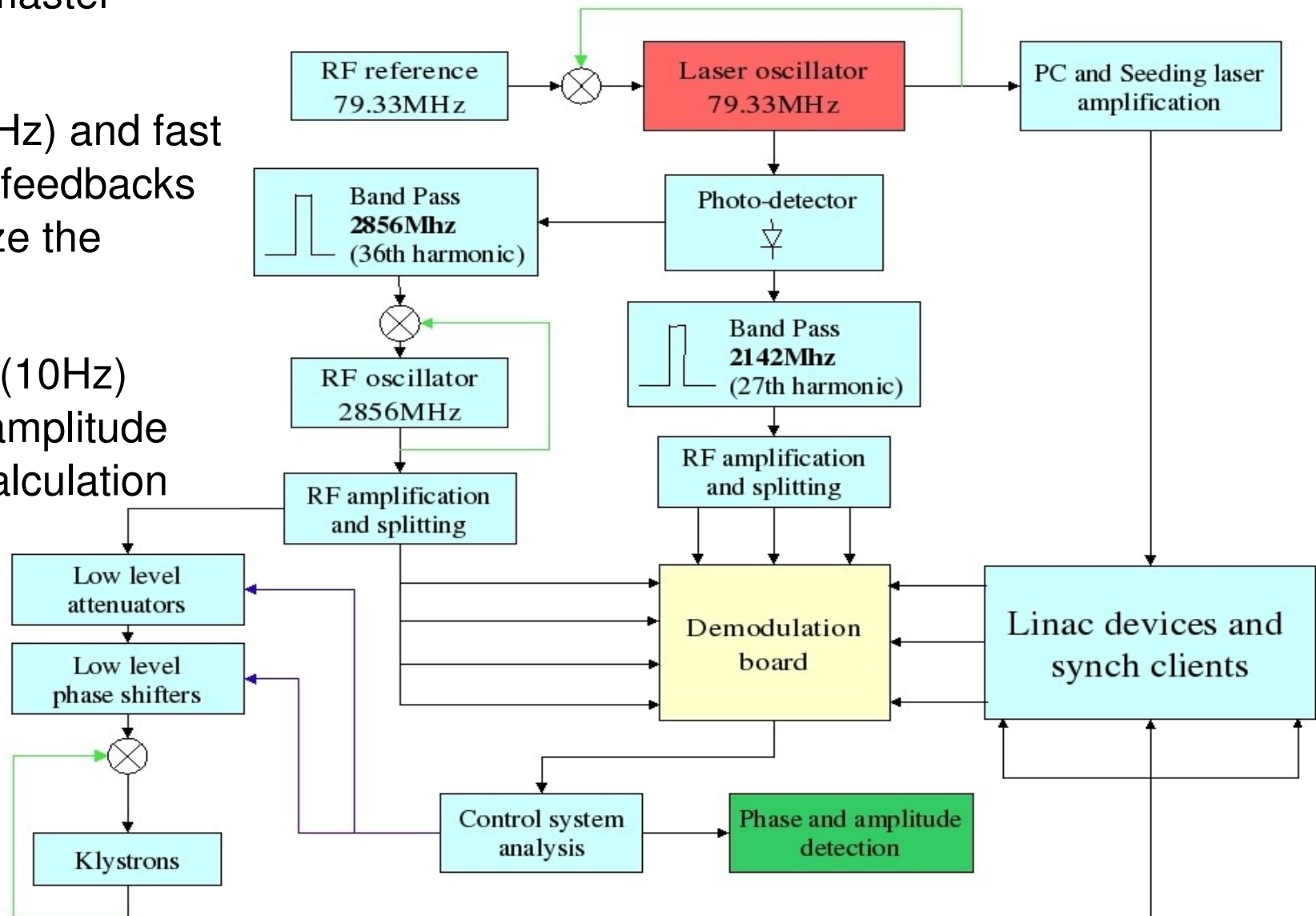


- SPARC and Flame pulses injected in a gas jet, requires synchronization at the level of the period of the plasma wave.
- Experiments: PLASMONX
- **Request: $\Delta t < 100\text{fs}_{\text{RMS}}$**



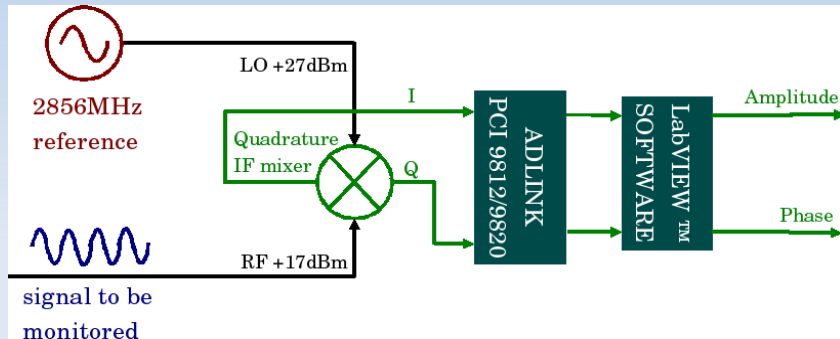
Actual SPARC synchronization

- One optical master oscillator
- Slow ($BW < 1\text{Hz}$) and fast ($BW \sim 1\text{MHz}$) feedbacks to synchronize the subsystems
- Shot-to-shot (10Hz) analysis for amplitude and phase calculation

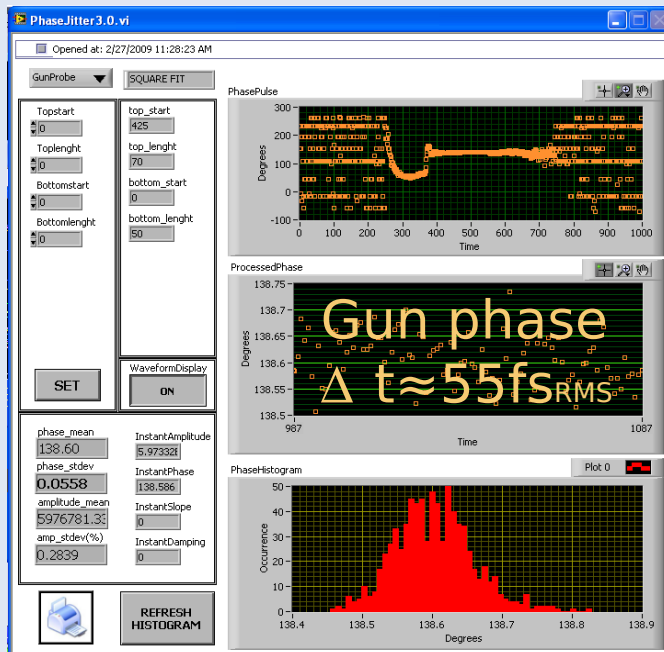
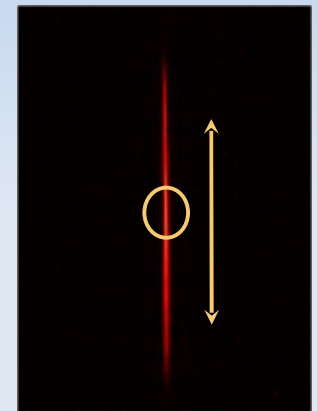
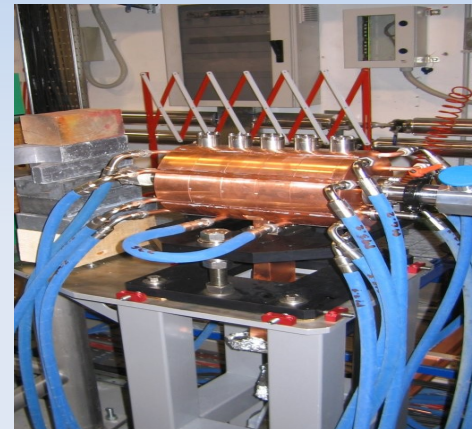


Phase detection @ SPARC 1/2

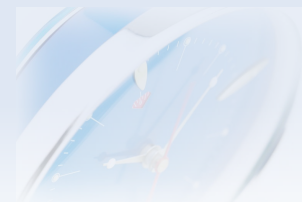
- Standard mixing and base band analysis technique



- RF deflector centroid jitter

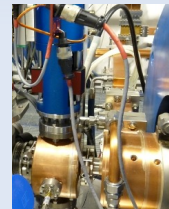
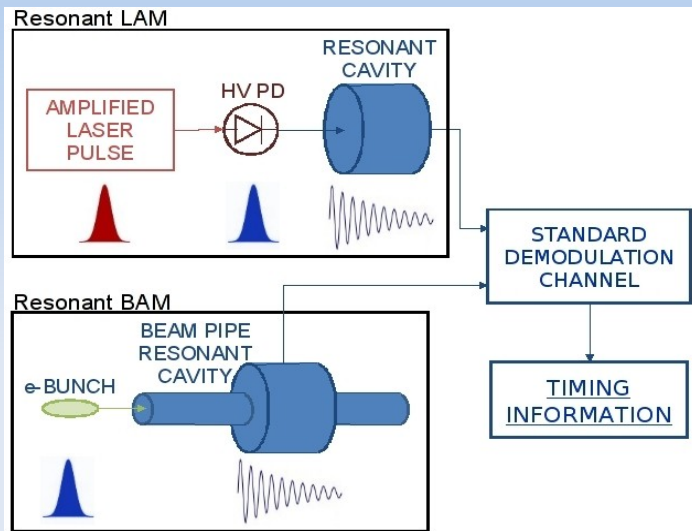


- Image analysis needed
- Measurement is affected by the RF phase noise inside the deflector (but it can be subtracted offline)

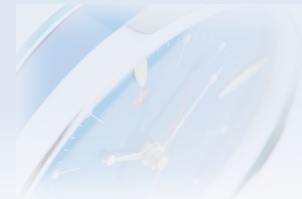
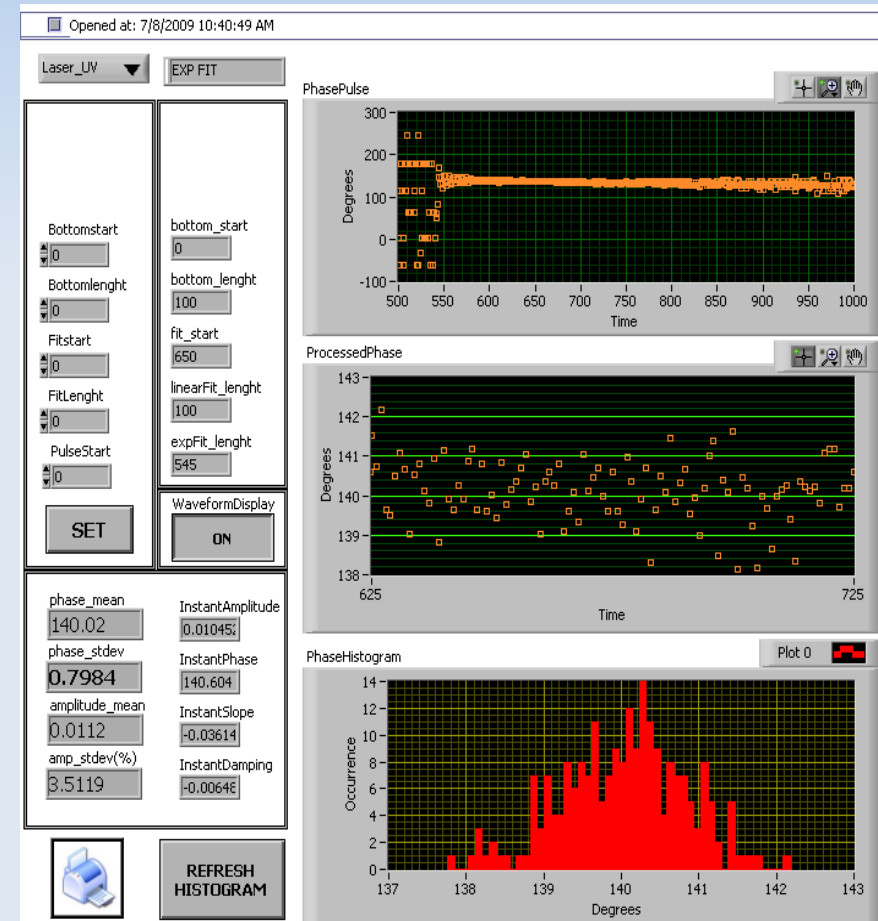


Phase detection @ SPARC 2/2

- Resonant method for short pulses



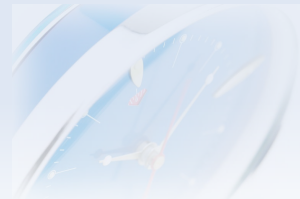
- 2142MHz cavity design to avoid RF interference with accelerating structures
- Cavity exited by very short pulses: (i) e.m. field of the beam or (ii) output of a high voltage PD excited by the UV laser
- Phase detection is possible using the decay time of some us inside the cavity



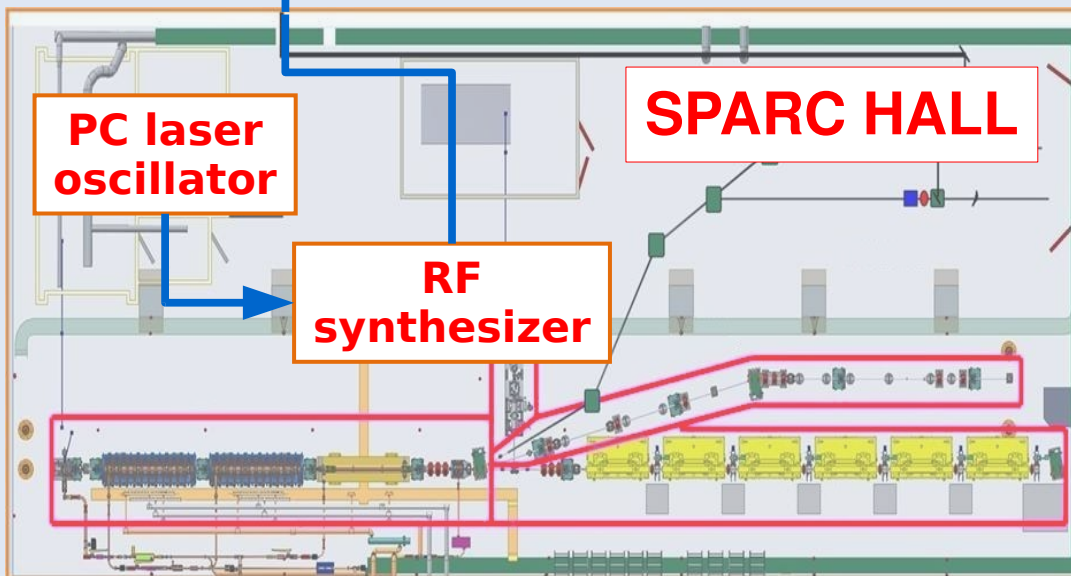
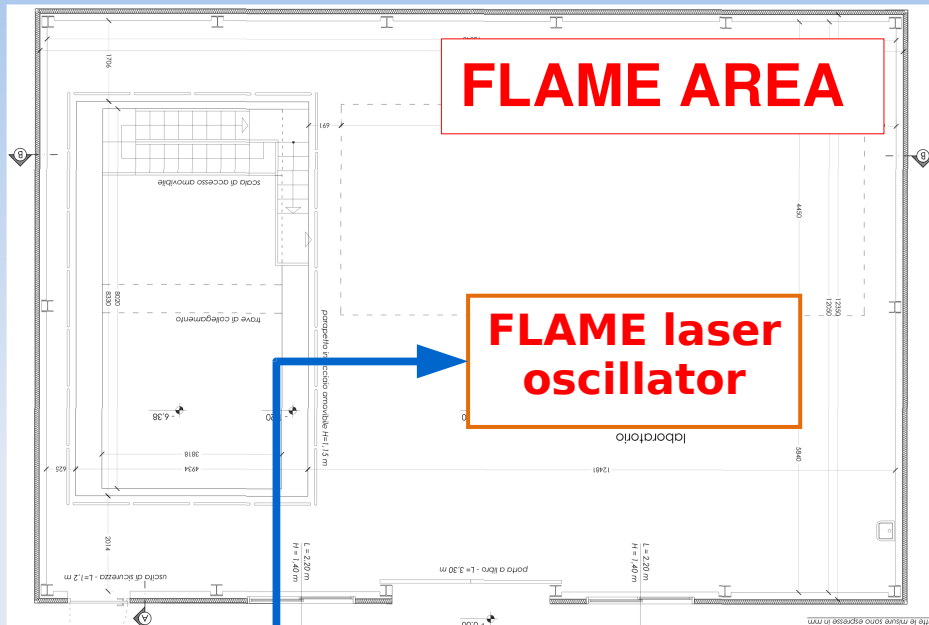
Performance of the system

Relative jitter summary

- Linac RF devices phase noise: $40 \div 100 \text{ fs}_{\text{RMS}}$
(standard phase detection)
- PC laser time jitter: $\sim 250 \text{ fs}_{\text{RMS}}$
(resonant arrival monitor)
- e-bunch time jitter
 - Resonant arrival monitor: $\sim 250 \text{ fs}_{\text{RMS}}$
 - RF deflector centroid jitter: $\sim 150 \text{ fs}_{\text{RMS}}$

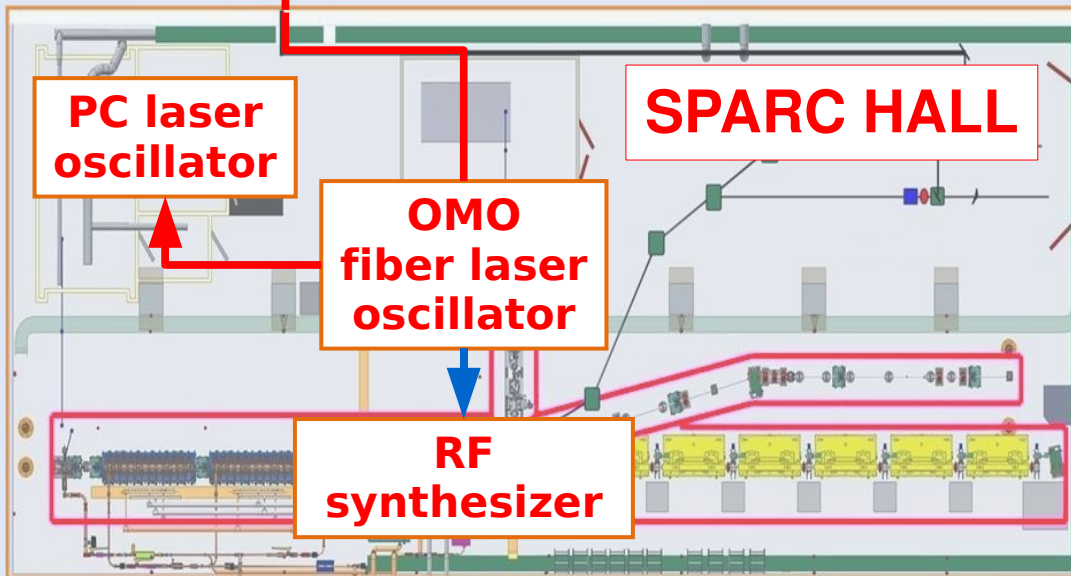
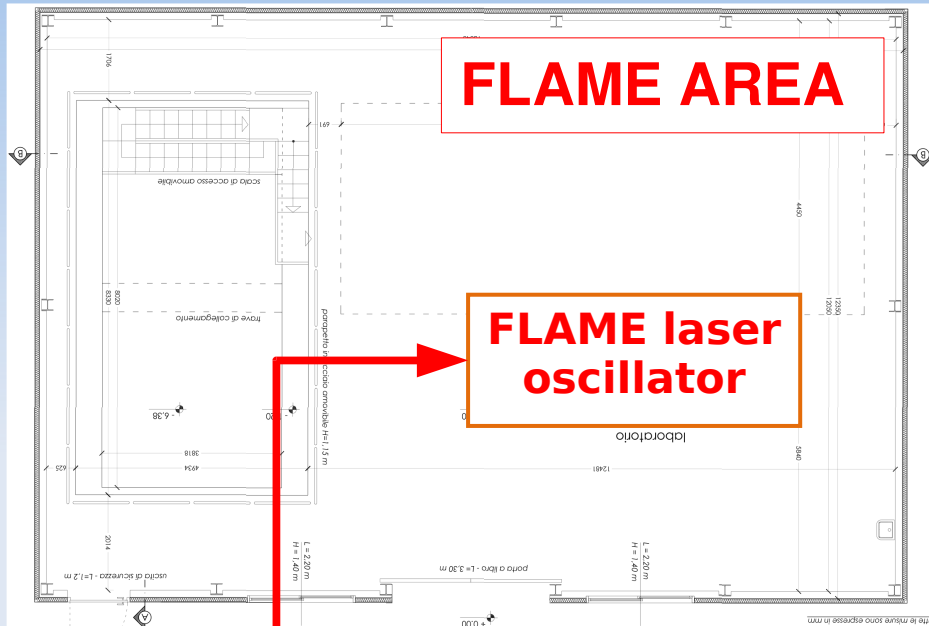


LIFE synchronization layout 1/2



- 1st solution – electrical distribution
 - Easiest and quickest
 - Low cost
 - Coaxial cables sent from RMO to FLAME laser oscillator
 - Possible temperature stabilized cable bundle
 - Hundreds of femto-seconds performance

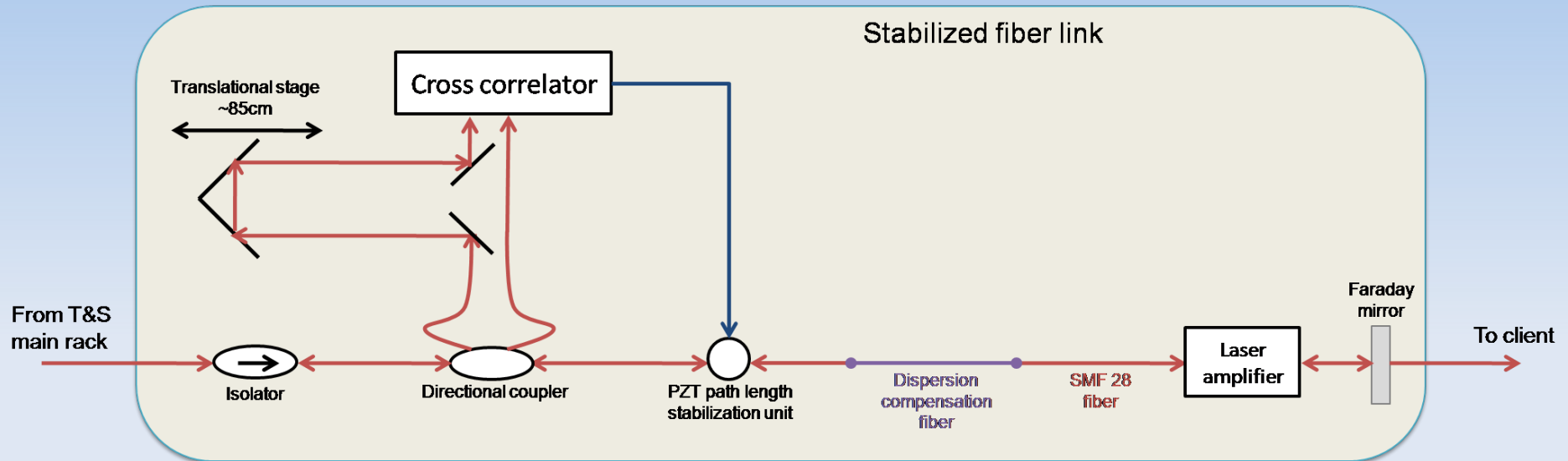
LIFE synchronization layout 2/2



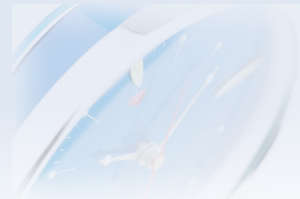
- 2nd solution – optical distribution
 - Fiber laser OMO
 - Major system modification needed
 - Higher cost
 - Fiber links to distribute the signal (active length)
 - Possible optical mixing for laser clients
 - Sub-100fs performance



Fiber links

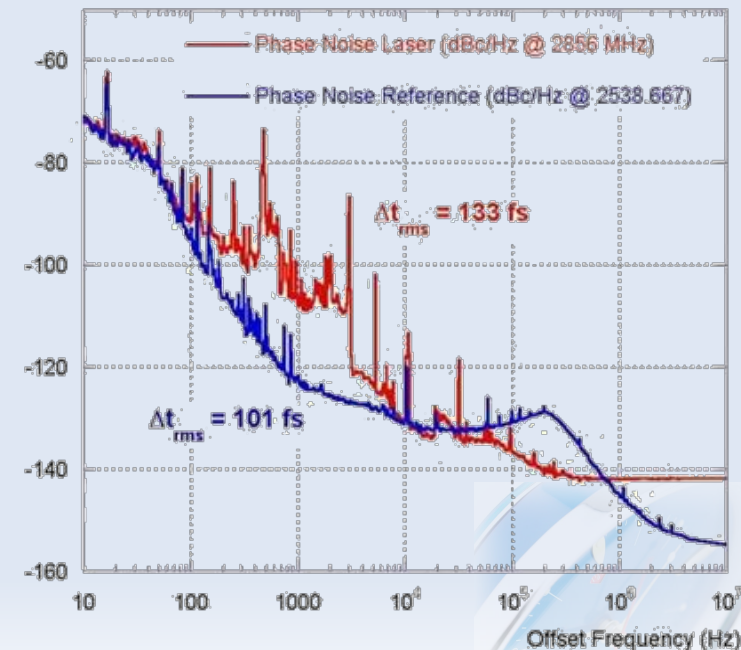


- All the noise in the DC÷10kHz band (thermal drifts, mechanical vibrations, mains disturbances, ...) can be corrected.
- No major noise contributions outside the loop BW of the link stabilizers are expected.

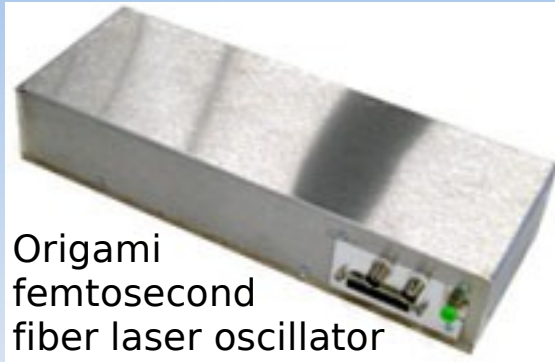


FLAME oscillator

- We measured the performance of the FLAME IR oscillator in terms of phase noise at the manufacturer site
- We measured with Agilent SSA E5052A an absolute phase noise of ~ 130 fs
- We measured a relative phase noise less than 90fs
- The external locking frequency was out of the specs, so we will perform again the measurement as soon as possible at LNF
- We have to measure also the jitter after the amplification chain



Optical master oscillator

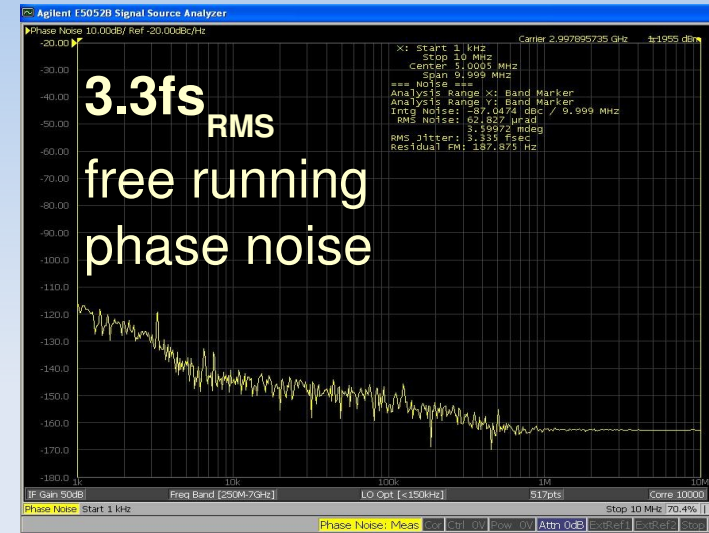


Origami femtosecond fiber laser oscillator

Pulse width	<i>tpulse</i>	< 200 fs
Wavelength 1	<i>l1</i>	1560 nm
Wavelength 2	<i>l2</i>	780 nm
Pulse rep rate	<i>frep</i>	89.250 MHz
Pulse energy	<i>Epulse</i>	> 2 nJ (~ 180 mW)
Phase jitter	<i>trms</i>	< 100 fs rms (SSB Df > 1 kHz)
Amplitude jitter	(D A/A)rms	< 0.05 % rms
Synchrolock BW	<i>fcutoff</i>	> 5 kHz
Phase jitter relative to reference	<i>trel</i>	< 10 fs rms (dc - 1 kHz)



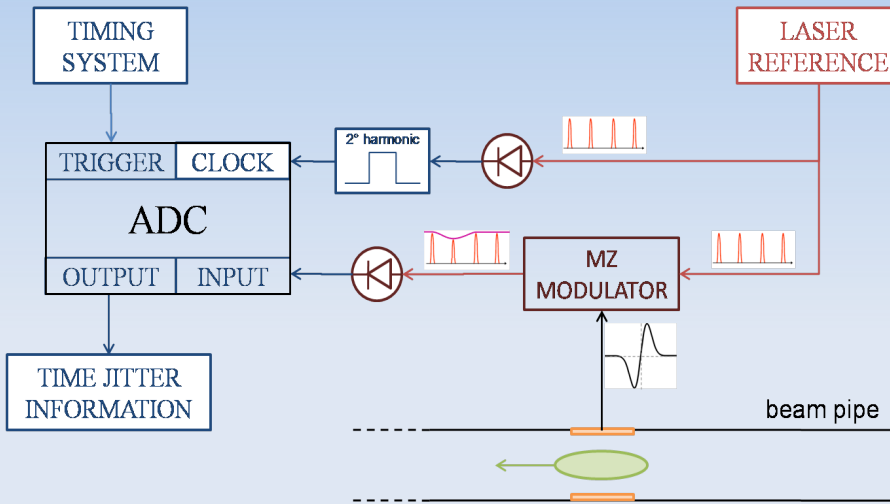
Synchronization unit



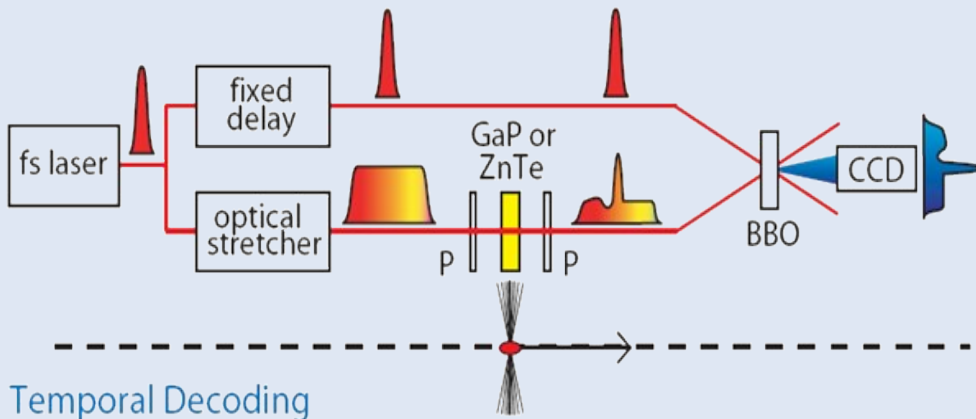
- In two weeks OneFive GmbH will ship the oscillator to LNF
- Phase noise world record achieved during the construction: 3.3fs_{RMS} free running integrated from 1kHz to 10MHz
- The repetition rate of 89.25MHz can be used for LIFE, but we plan to acquire another unit at the optimal frequency of 79.33MHz

New diagnostic techniques

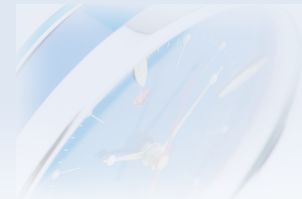
Electro Optical Modulation (EOM)



Electro Optical Sampling (EOS)



- EOM is a well-established measuring technique
- EOM use standard telecommunication devices
- EOS SPARC implementation in collaboration with CNR Pisa
- EOS FERMI test bench @SPARC in collaboration with Sincrotrone Trieste
- Also fs resolution with fully optical phase detection techniques (cross-correlation) for laser clients can be performed



Synchronization lab

- A synchronization lab is in preparation at LNF
- An optical table, many optics, fiber devices and fiber cables have been purchased and are ready to be used
- We are waiting for the OneFive laser oscillator to begin the tests



Conclusion

- good results for the SPARC synchronization system
 - Feedback systems work as expected
 - New devices (BAM and LAM) tested with success
- 2 options to upgrade the SPARC synchronization system to LIFE:
 - electrical reference distribution (hundreds of fs)
 - optical reference distribution (sub-100fs)
- FLAME oscillator seems to meet the requirements
- Fiber laser oscillator will be shipped in few weeks
- Synchronization lab is under way

