TERAFERMI

A THz Beamline at the Fermi-FEL

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TERAFERMI - Timeline

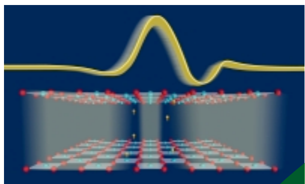
June 2007	**1st letter of intent:** A letter of intent for Coherent Terahertz Spectroscopy at FERMI
June 2008	**2nd letter of intent:** TERAFERMI - The Terahertz Beamline at the Fermi FEL **SAC executive summary report** *"The SAC considers the scientific case strong enough […]* *[…] The Terahertz beamline will require human and financial resources from FERMI that are unlikely to be available"*
December 2010	**Submission of the FIRB - Futuro in Ricerca project:** TERAFERMI - A Terahertz Beamline at the Fermi FEL
September 2011	**FIRB project approval:** 1.007.786 €
March 2012	**Official start of the FIRB project:** 36 months duration
October 2012	One-day meeting on *New THz Sources* in Trieste **Final decision on TeraFermi project**

FUTURO IN RICERCA

Program funded by Italian Ministry of Education and Research in order to support emerging scientific excellence.
The TERAFERMI project is among the 105 selected projects out of 3792 proposals in the various fields of science and humanities:
→ **success rate of 2.7 %**
2nd largest financing awarded to one single research unit

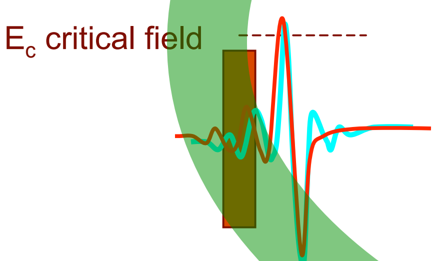
Non-linear THz optics at MV/cm

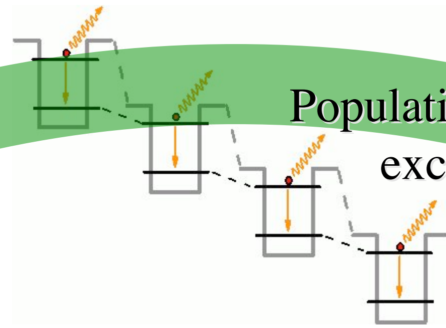
THz light couples to both electronic and lattice excitations



Dienst, 2011

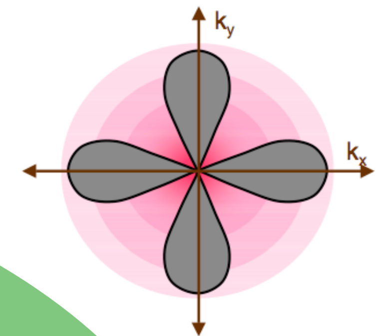
Electronic response under giant quasi-static fields



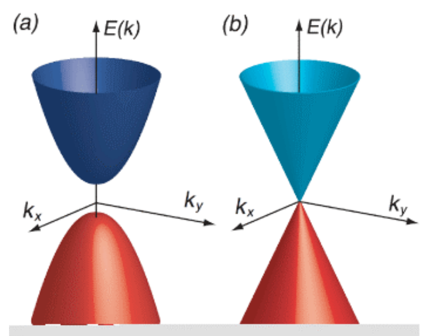


Populating low-energy excited states

Narrow-band THz excitation to limit starting population energy



From L. Carr



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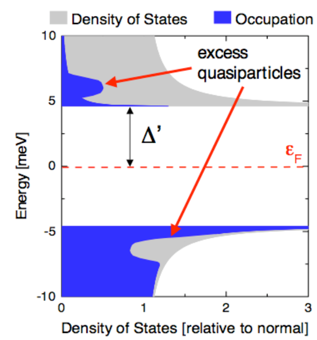
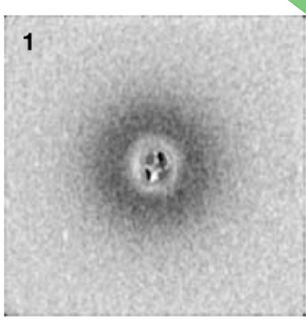
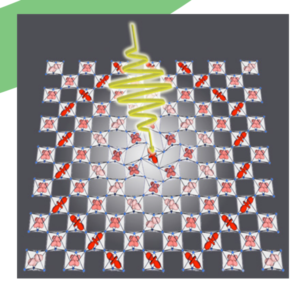


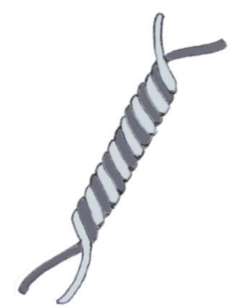
Ultra-fast structural distortions and lattice control

Ultra-fast magnetic switching (B~0.3 T)



Tudosa, 2004





Rini, 2007

The TeraFermi concept

Exploiting the properties of the FERMI-FEL electron beam to produce:
- Short (sub-ps)
- Powerful (MV/cm)
- Broadband (0.1-10 THz)

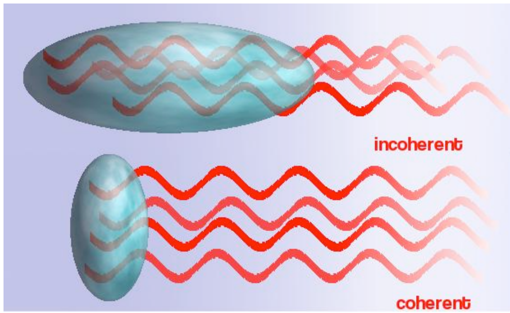
THz pulses to be used as a **Pump** beam for ultrafast nonlinear spectroscopies

Leveraging over the already existing FERMI LINAC
Reduced construction and operation costs

Working in parasitic mode
TeraFermi will not affect overall FEL available beamtime
THz light always available

Accelerator-Based Coherent THz emission

Extending the FEL's advantages into the THz region

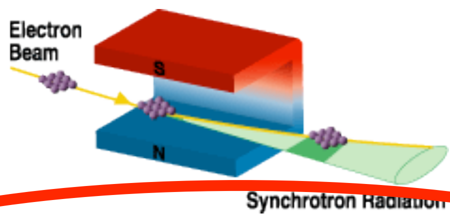


$$N\left[1+Nf(\omega)\right] \qquad f(\omega)=\int_{-\infty}^{+\infty}\rho(t)\exp(-i\omega t)\,dt$$

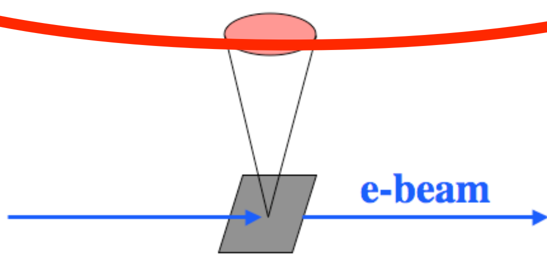
$N \sim 6.24*10^{7}$ @ 1pC Storage-Rings

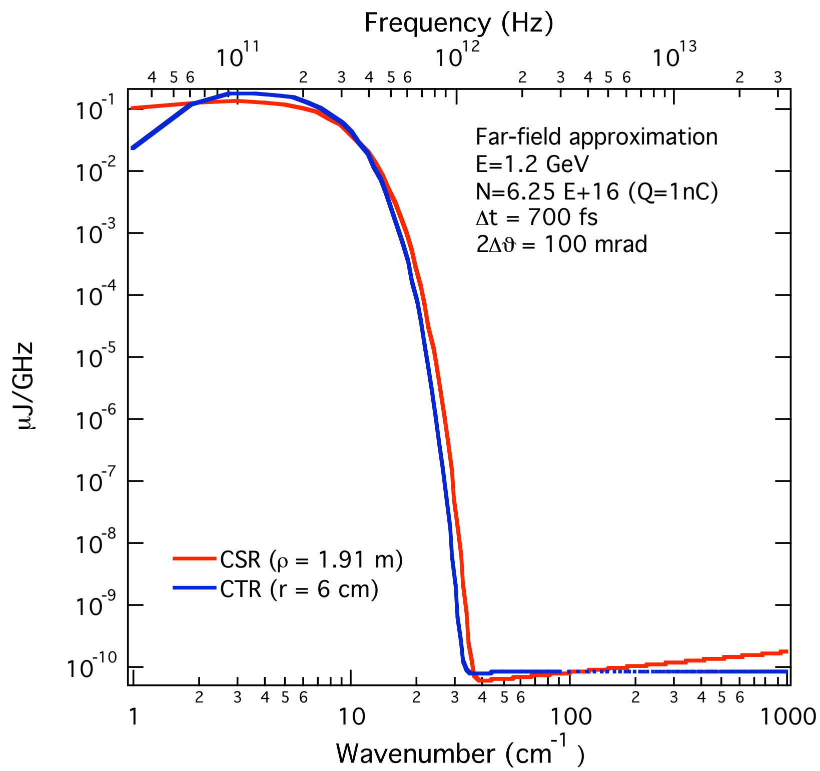
$N \sim 6.24*10^{10}$ @ 1nC Single-pass accelerators

Coherent Synchrotron Radiation (CSR)

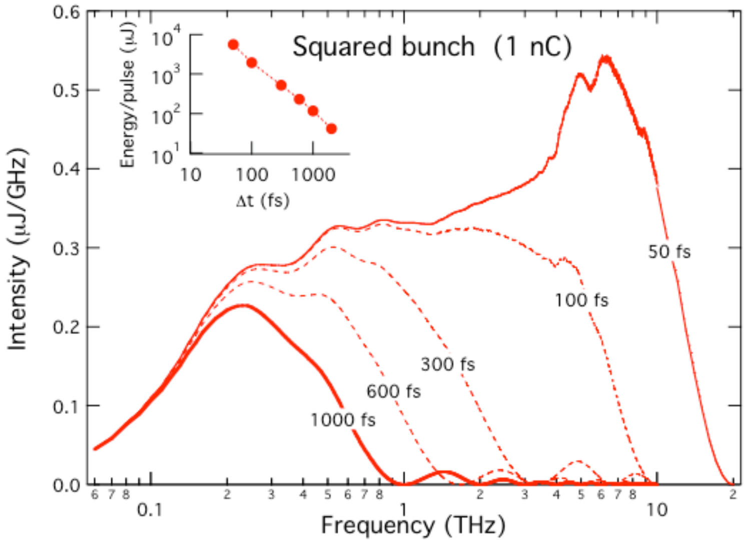


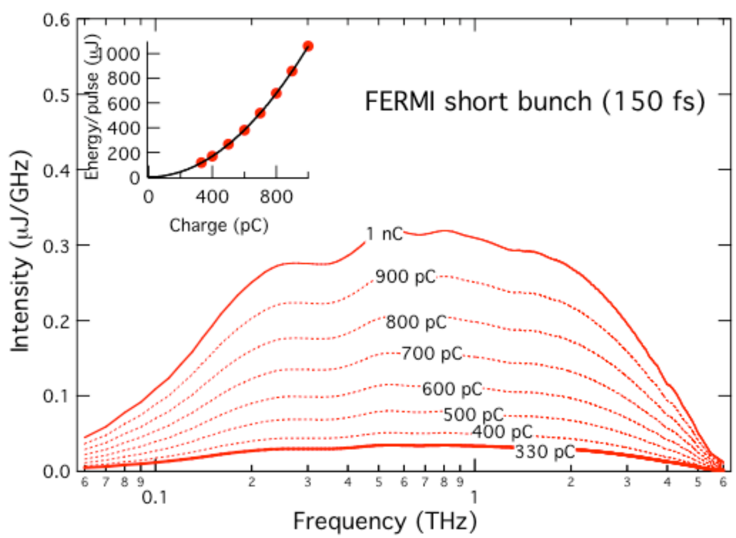
Coherent Transition Radiation (CTR)

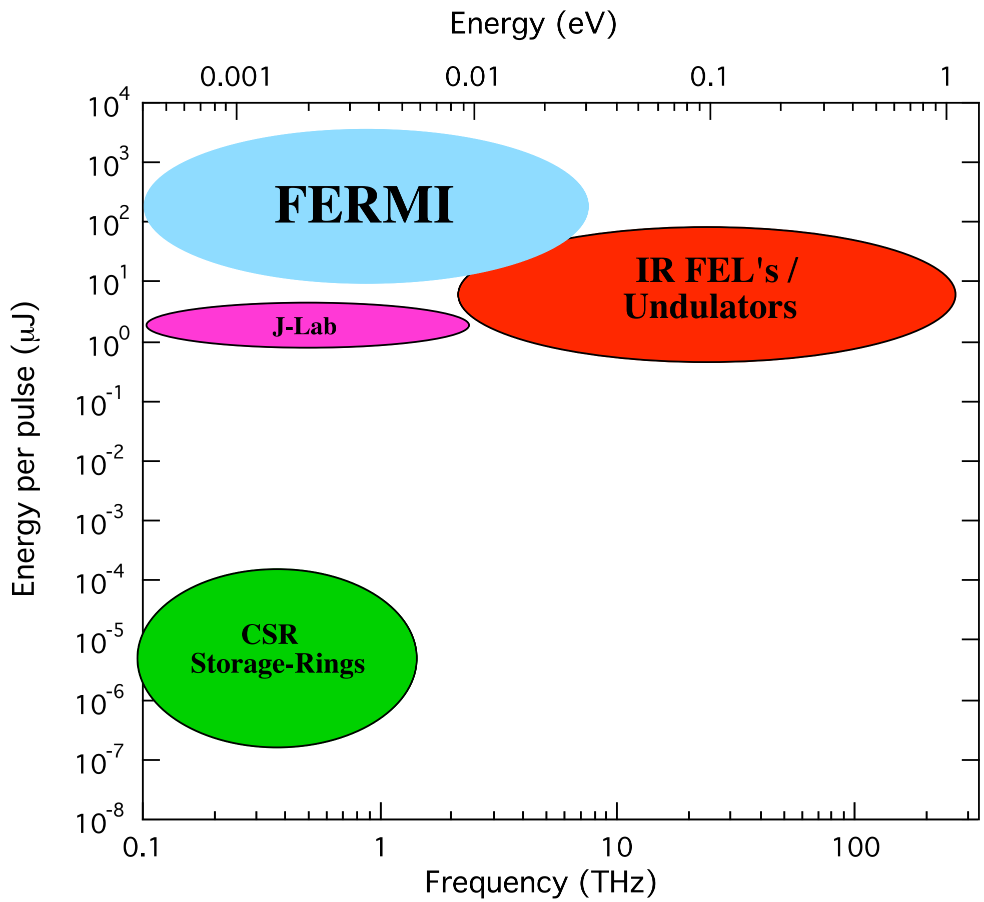




Expected Performance

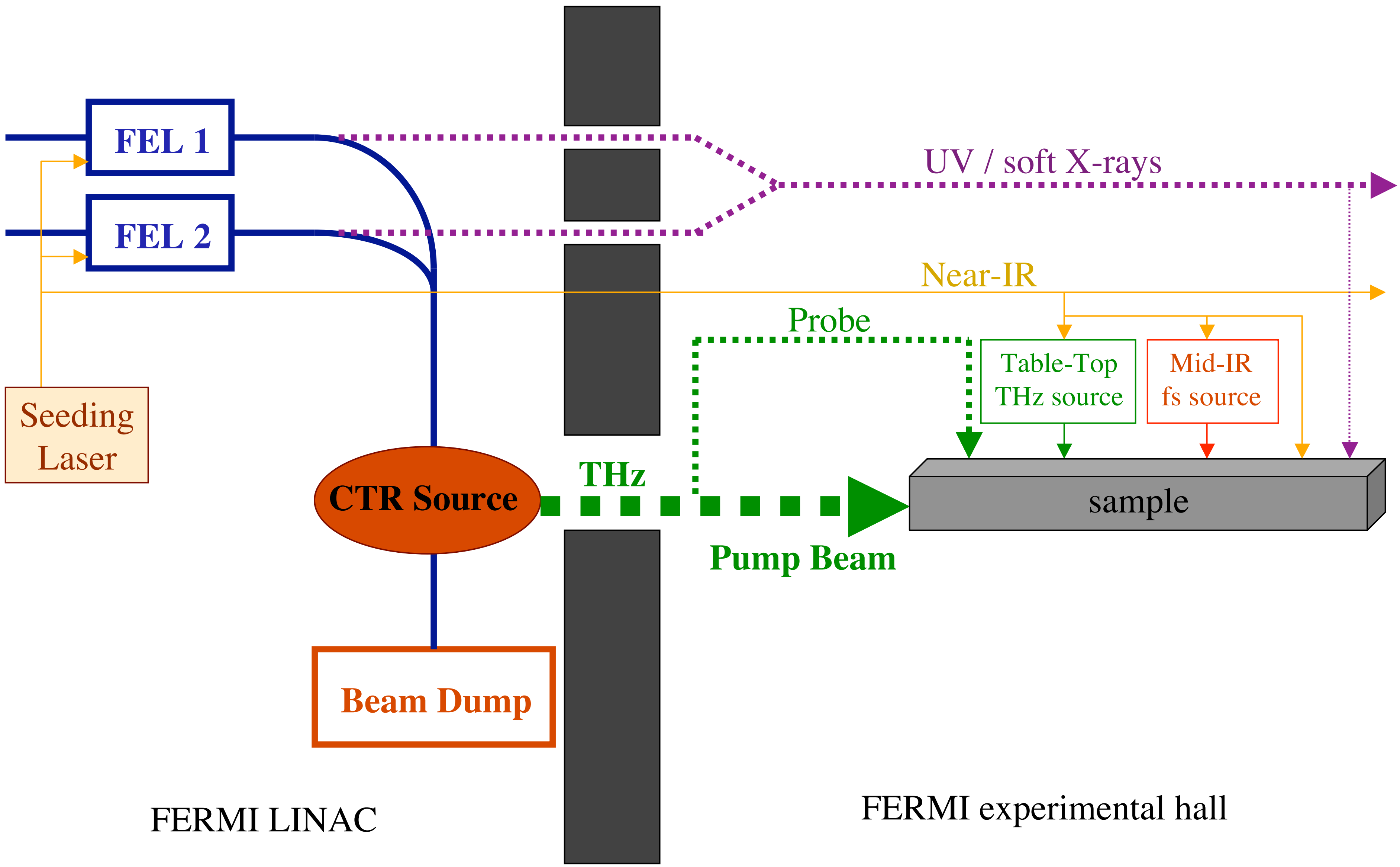






- Energy ≥ 100 μJ / pulse
- Peak Power ~ MW
- Electric Fields ≥ 1MV/cm
- Magnetic Fields ~ 0.3 T

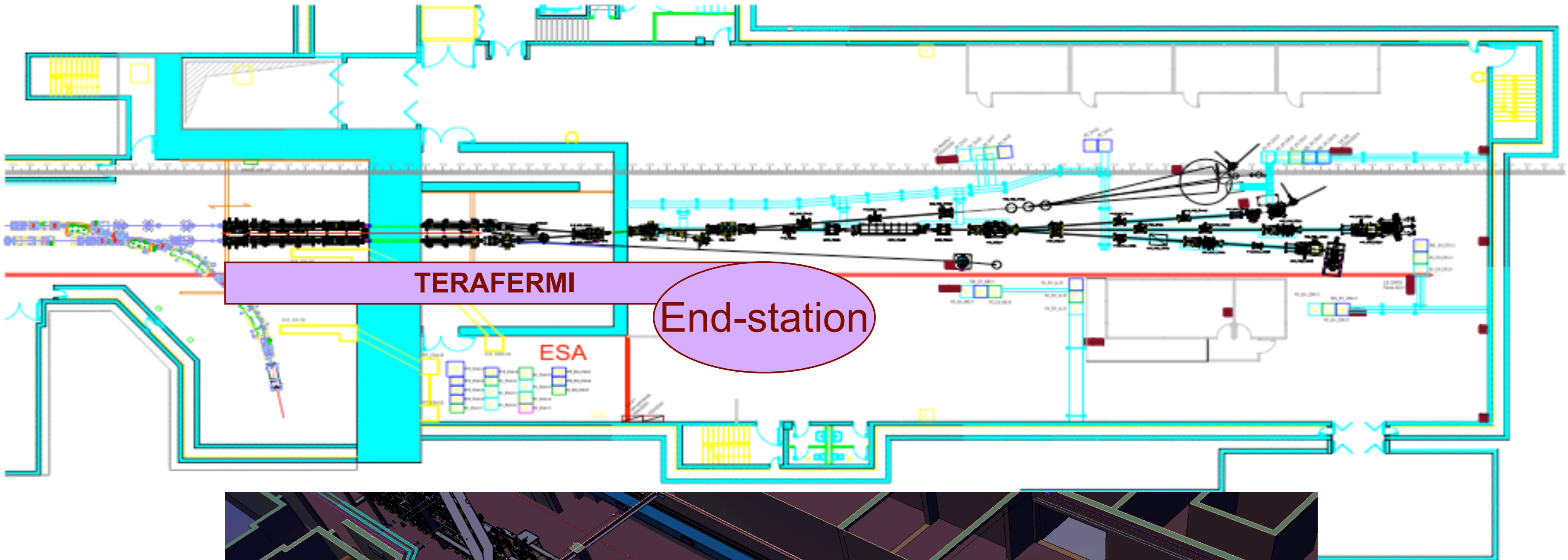
TERAFERMI scheme

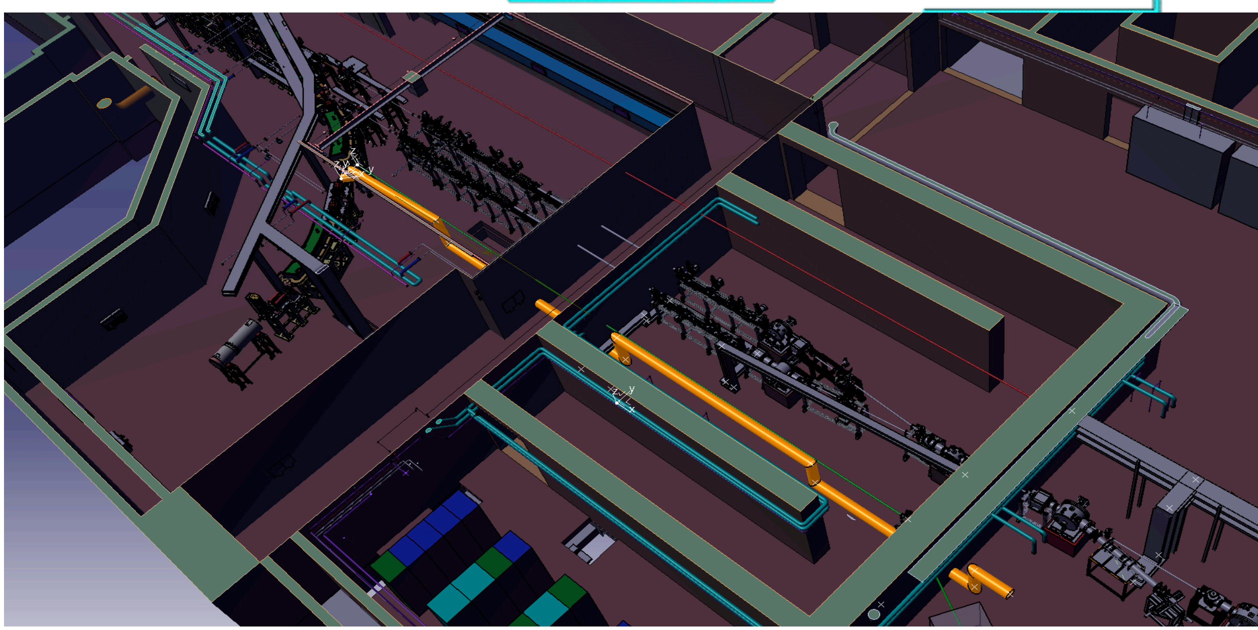


Resources - 3 years

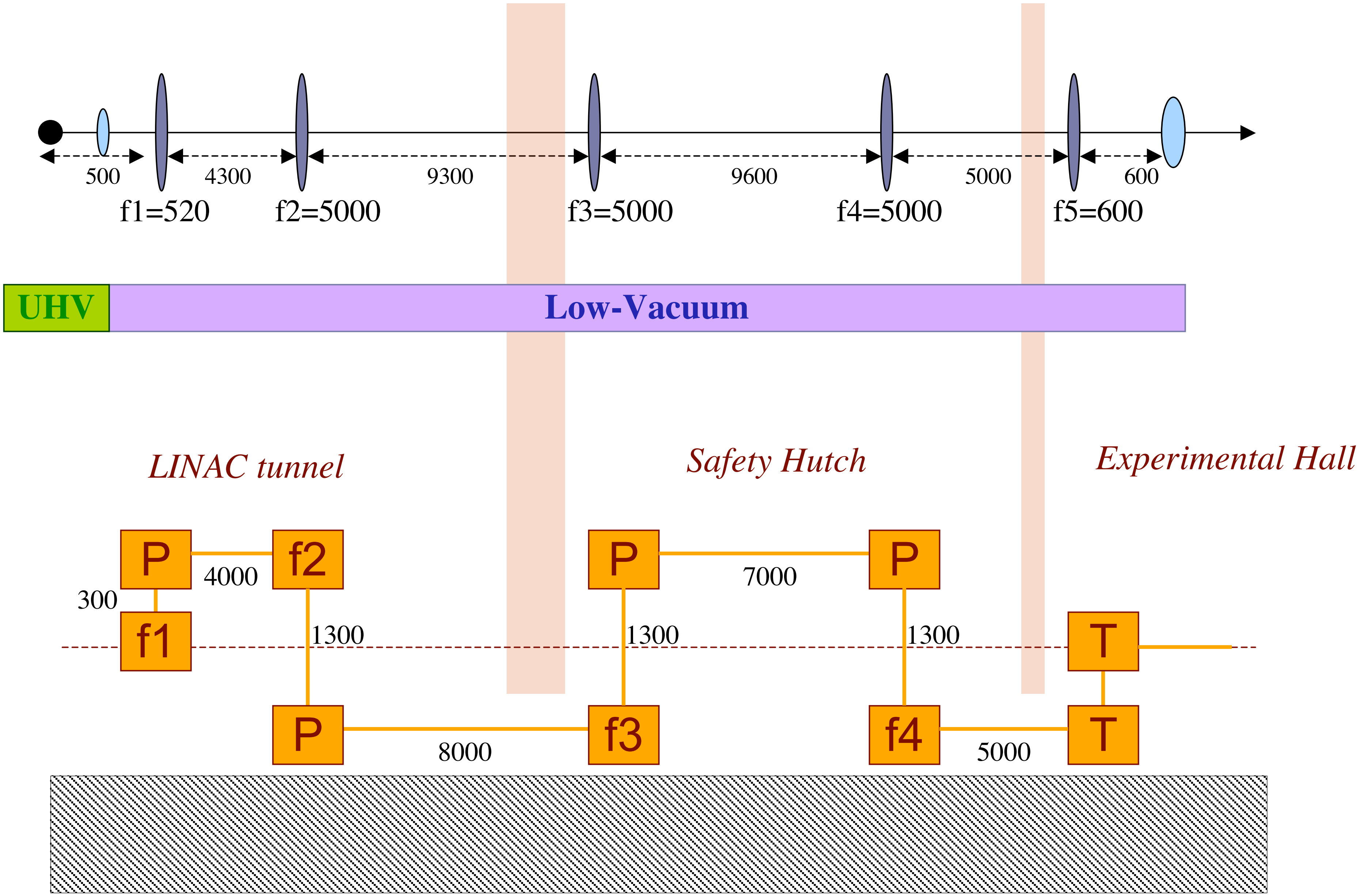
Human Resources	A.P. (Principal Investigator) Scientist ***Sub-total***	150 k€ 120 k€ ***270 k€***
Human Resources *Already hired staff* *~26 months/person*	Accelerator Group Mechanics/Vacuum/Technical Drawings Controls/Software Laser Group ***Sub-total***	***110 k€***
Equipment	Source Chamber Beamline Experimental Station ***Sub-total***	30 k€ 220 k€ 150 k€ ***400 k€***
General Costs		***228 k€***
Total	**Charged to MIUR** **Charged to INSTM**	**1008 k€** **786 k€** **222 k€**

TeraFermi - Layout





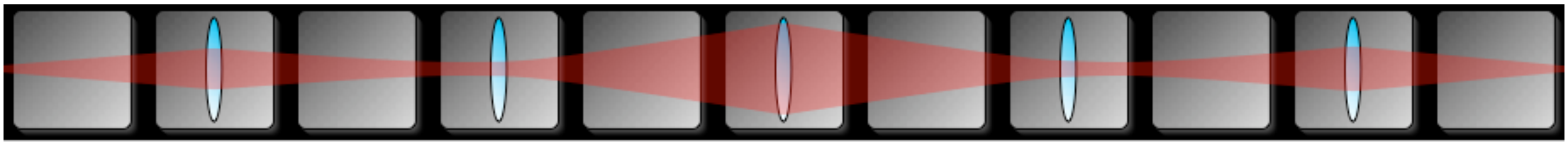
Optical scheme



Beam Transport Efficiency

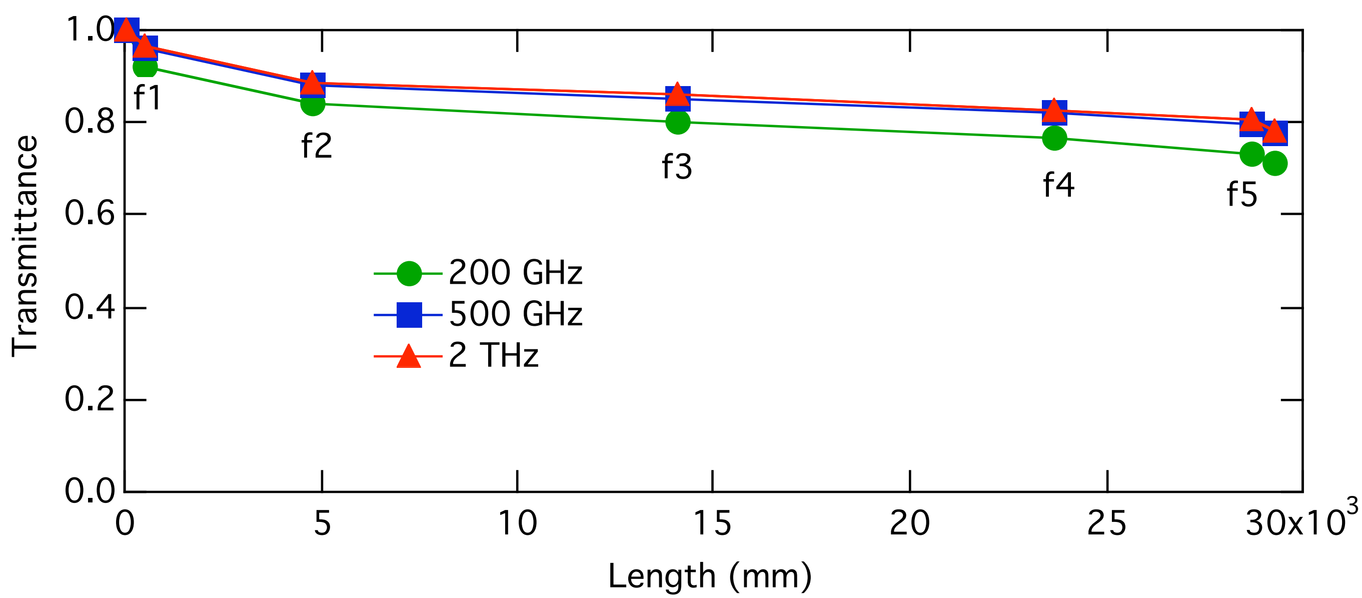
ABCD optics (Gaussian beams)

λ = 1 mm



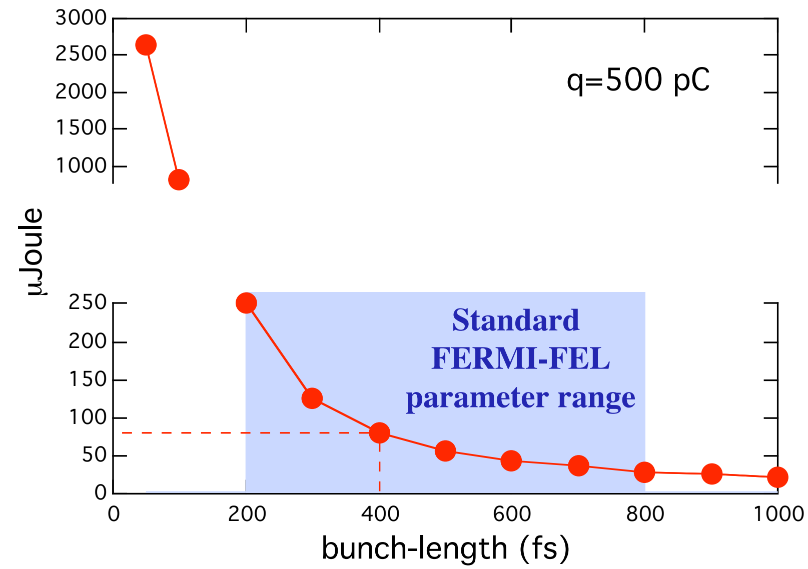
f1=520 f2=5000 f3=5000 f4=5000 f5=600

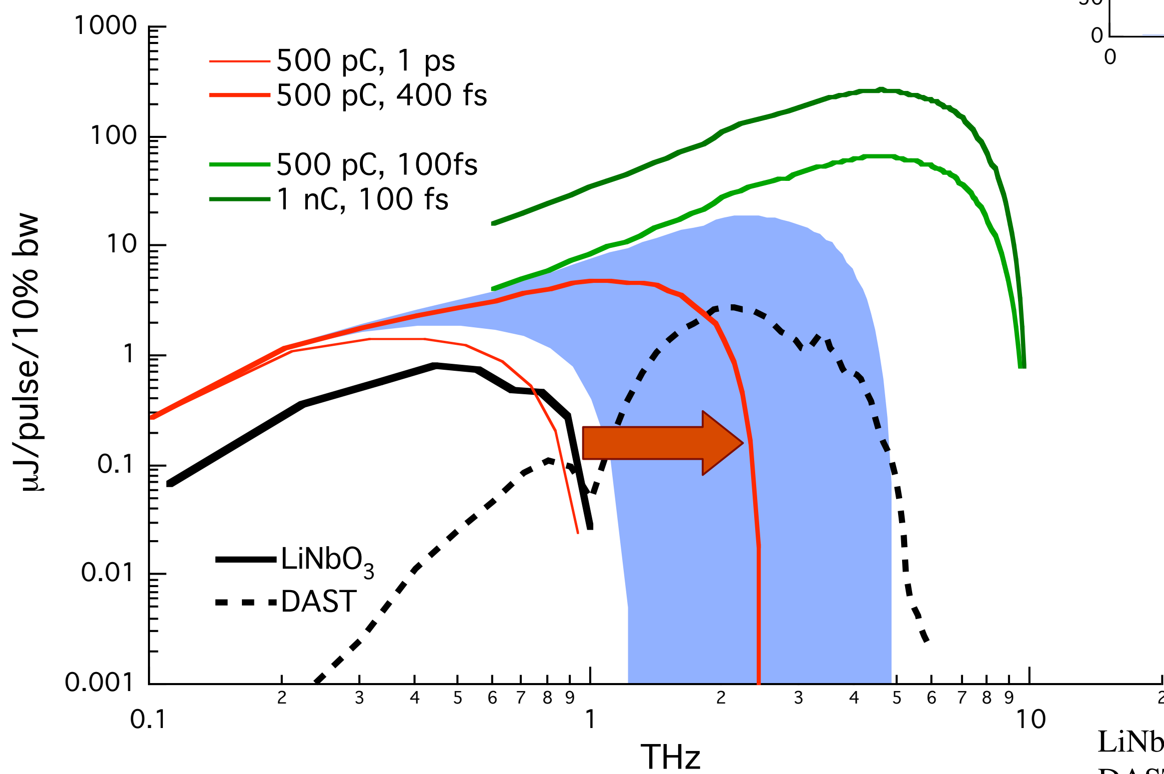
THz Transport (CTR source)

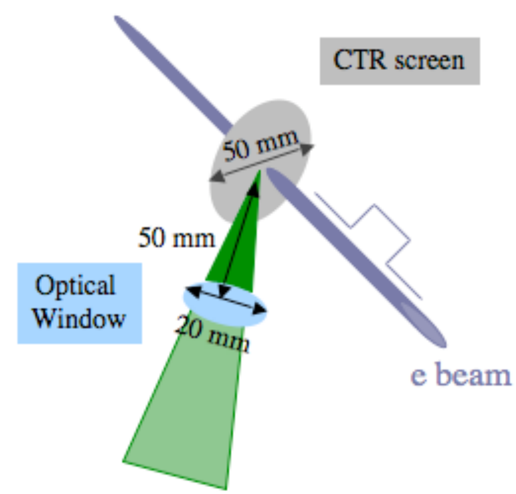


Performance under FEL operation

FERMI-FEL
electron bunch structure can be shorter than expected !!!
from 1 ps to the 200-800 fs range







$LiNbO_3$ data from Yeh *et al*. APL (2007) - 10 μJ/pulse
DAST data from Hauri *et al*., APL (2011) - 20 μJ/pulse

STRENGTHS

- Low construction costs / easy operation
- Present FEL operating condition allow emission up to 5 THz
- Energy per pulse can range from 100 μJ to several mJ per pulse

WEAKNESSES

- Performances at the foreseen location of the source are still to be evaluated, based on realistic electron beam properties and modeling of the distribution of electrons after lasing

OPPORTUNITIES

- Optimizing e- beam for THz emission
- Quasi-monochromatic tunable emission (modulating cathode/seeding laser)
- Self synchronized THz pulse/UV probe

THREATS

- FERMI operating conditions can drastically affect THz beamline performances both in terms of maximum frequency and pulse energy. **Is parasitic mode the best choice ?**

Conclusion

A unique playground for THz accelerator-based emission in a seeded FEL-facility

A very competitive facility under FEL working conditions

Optimized beam for THz operation

THz pump / UV probe

Acknowlegments

Stefano Lupi (coproposer) - University of Rome “La Sapienza”

ELETTRA staff

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B. Schmidt (DESY)

D. Fausti (University of Trieste)

And many others…

Proposed Flow-Chart