Corso per Operatori

LNF

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SPARC_Lab Test Facility

Description

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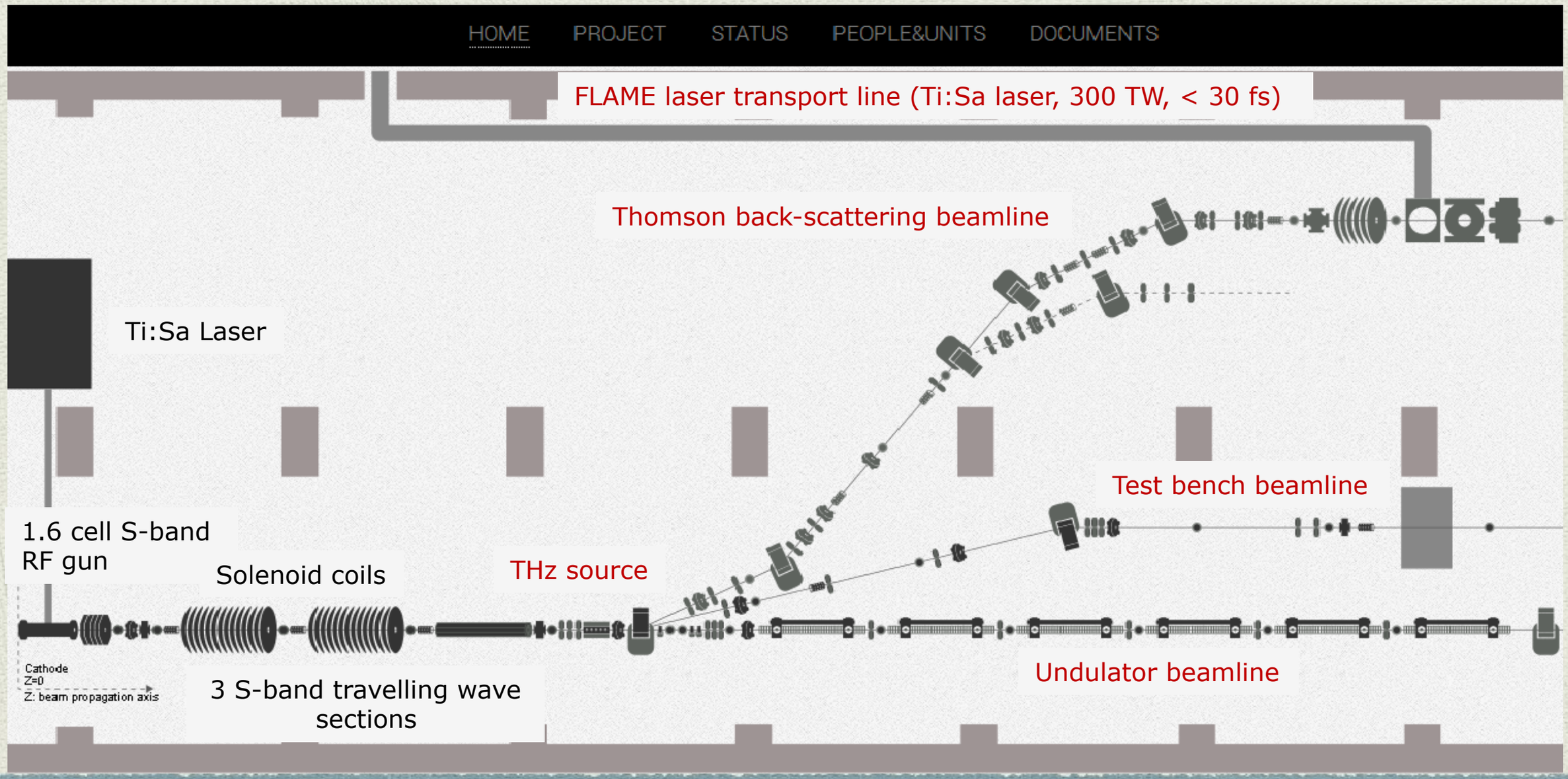
SPARC_LAB Layout

SPARC_LAB (**S**ources for **P**lasma **A**ccelerators and **R**adiation **C**ompton with **L**asers **A**nd **B**eams) is a **Test Facility** consisting in a **High Brightness photo-injector** able to deliver high quality electron beams to drive a **FEL**, a **plasma-based accelerator** and high intensity **advanced radiation sources**, e.g. THz and Thomson ones.



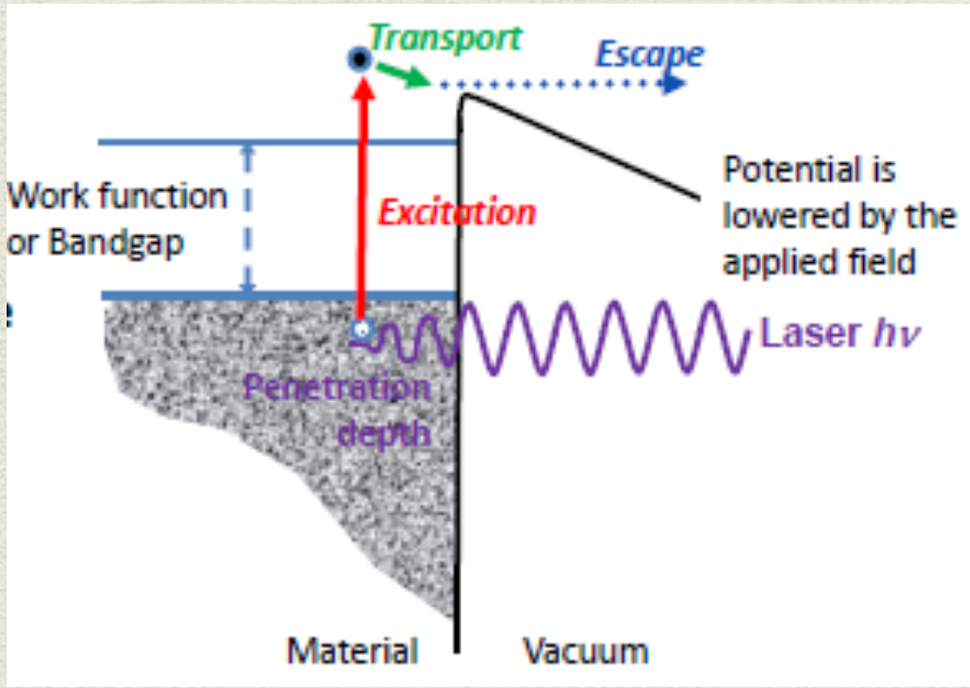
Radio-Frequency Photo-injector

- **Radio-Frequency (RF) Photo-injector**
  - RF guns are able to provide **high peak current** (ultra-short pulse length, i.e. ps down to few fs) and **low emittance** beams (~ mm mrad)
    - **high brightness beams**
  - **Electrons are generated by photoemission** from a metal or semiconductor material when illuminated by a laser pulse
- **Electrons are extracted out of** the material (i.e. the **cathode**) upon absorption of photons with energy higher than the work function
- Both **transverse and longitudinal beam characteristics** can be manipulated by properly **shaping the laser pulse**
- **High fields** are necessary to preserve the initial beam quality

Components of a Photo-injector

A RF photo-injector consists of a **laser generated electron source** followed by an electron beam optics system which preserves and matches the beam into a high-energy accelerator

- **Emission and initial acceleration**
  - **Drive laser**
    - to gate the emission of electrons from the cathode
  - **Photocathode**
    - to produce ps down to fs electron bunches when illuminated by laser pulses
  - **Electron gun**
    - to accelerate electrons from their rest energy up to few MeV
- **Beam focalization**
  - **Solenoid** for emittance optimization
- **Acceleration**
  - **Linac cavities**
    - to mitigate the space charge emittance growth, therefore preserving the beam quality



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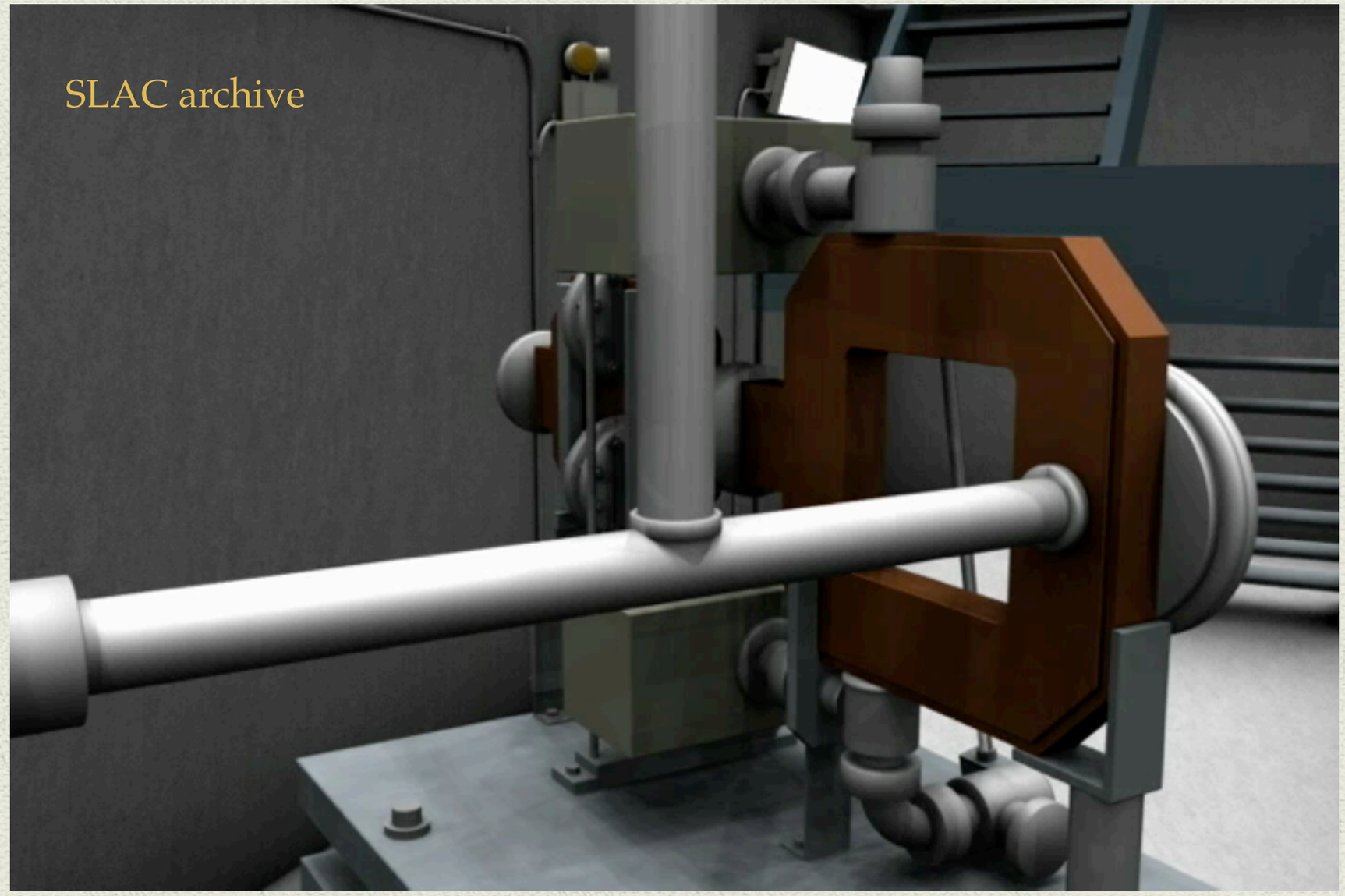
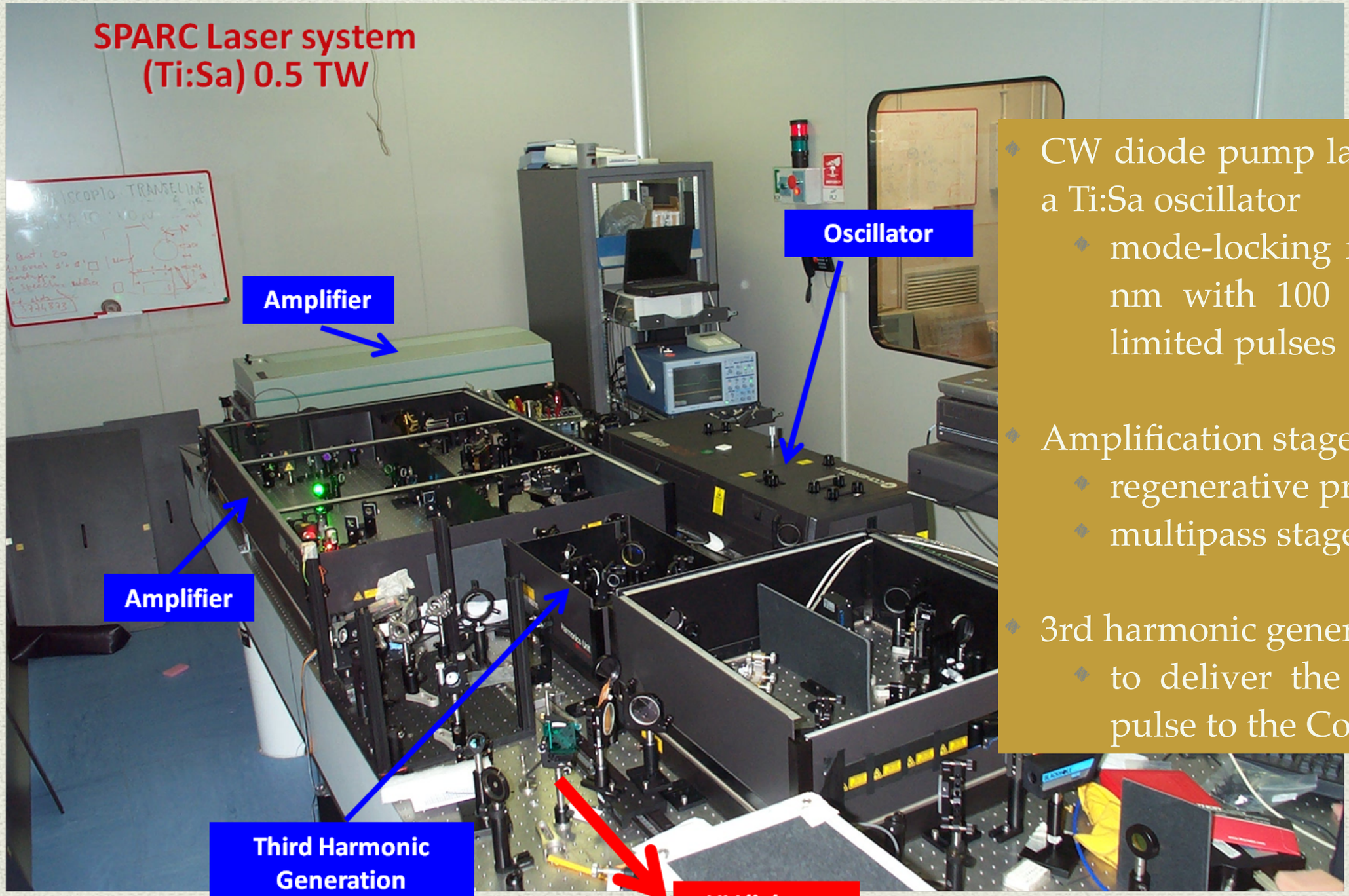
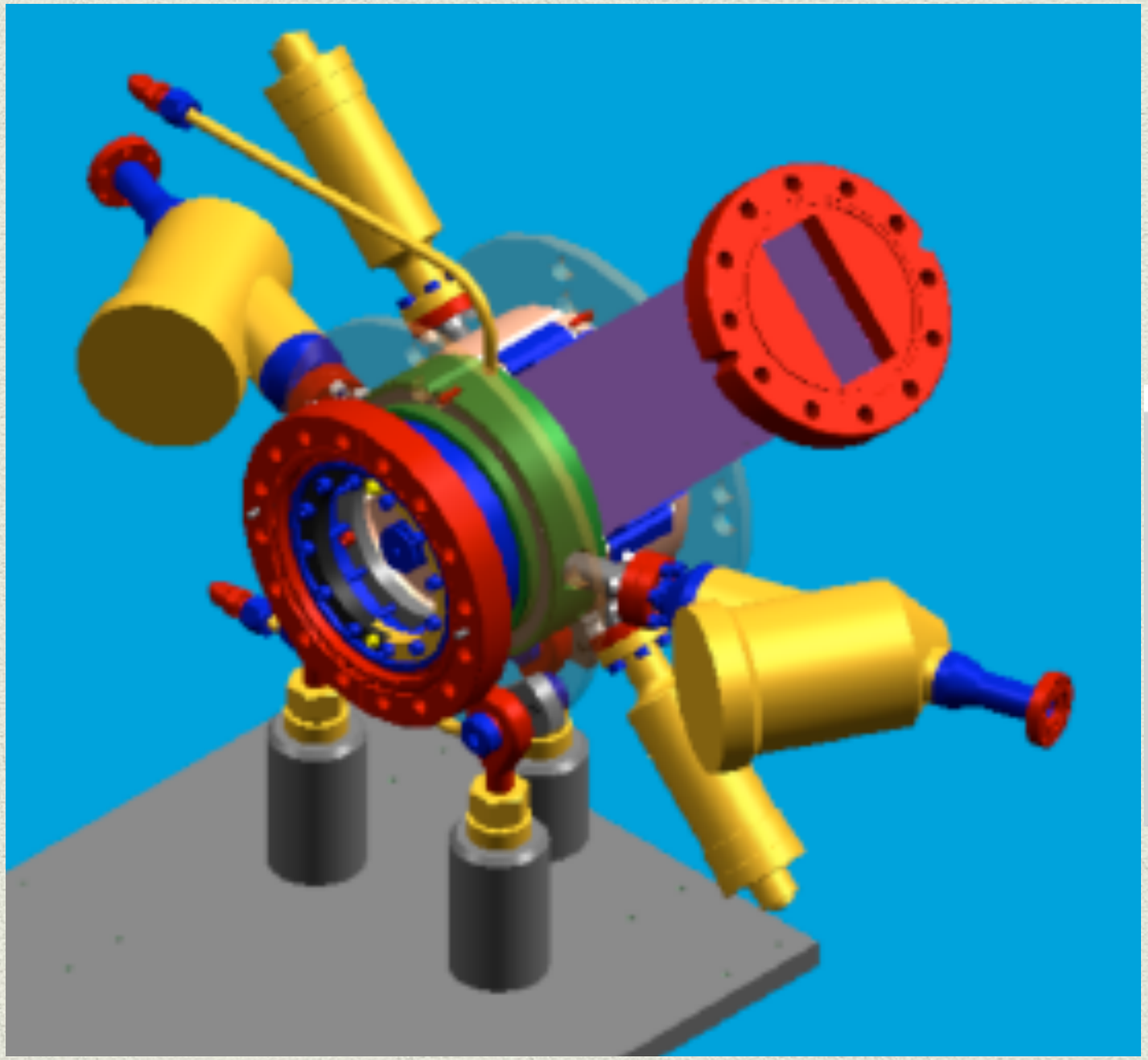


The Laser System



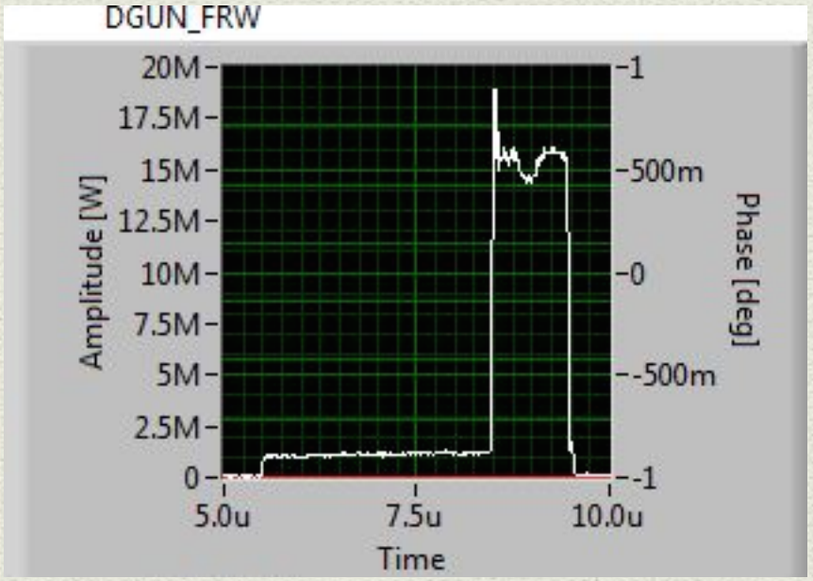
- CW diode pump laser to pump a Ti:Sa oscillator
  - mode-locking regime at 800 nm with 100 fs transform-limited pulses
- Amplification stages
  - regenerative pre-amplifier
  - multipass stage
- 3rd harmonic generation
  - to deliver the required UV pulse to the Copper cathode

The RF Gun



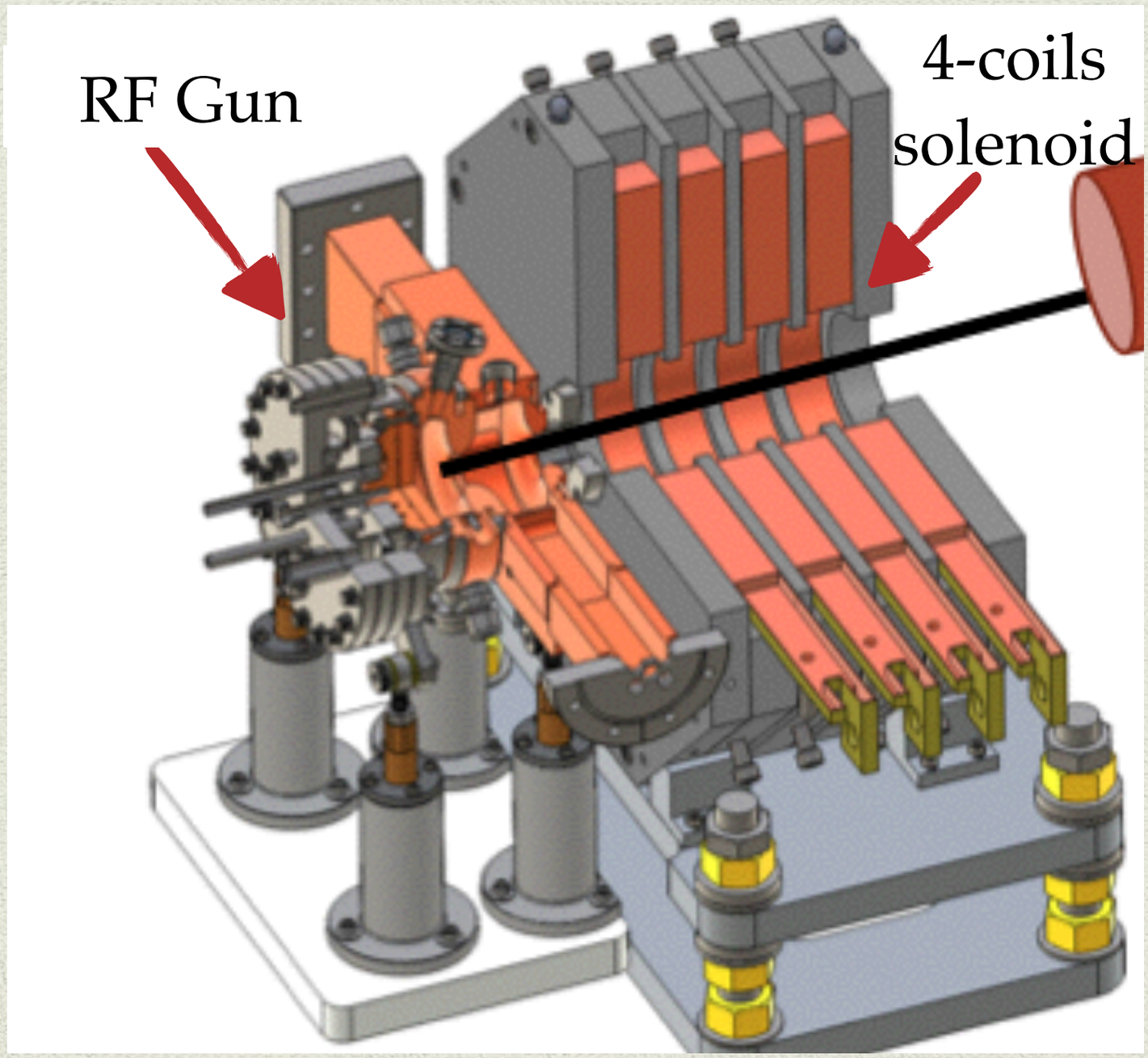
The SPARC RF gun (UCLA/BNL design) consists of a **1.6 cell S-band standing wave** cavity operating at **2.856 GHz**, with the embedded Copper cathode

Maximum Input Power = 14 MW



The gun acts as a strong defocusing lens, thus an equally strong focusing lens is needed to refocus the beam

Gun Solenoid



The beam wants to diverge for two reasons

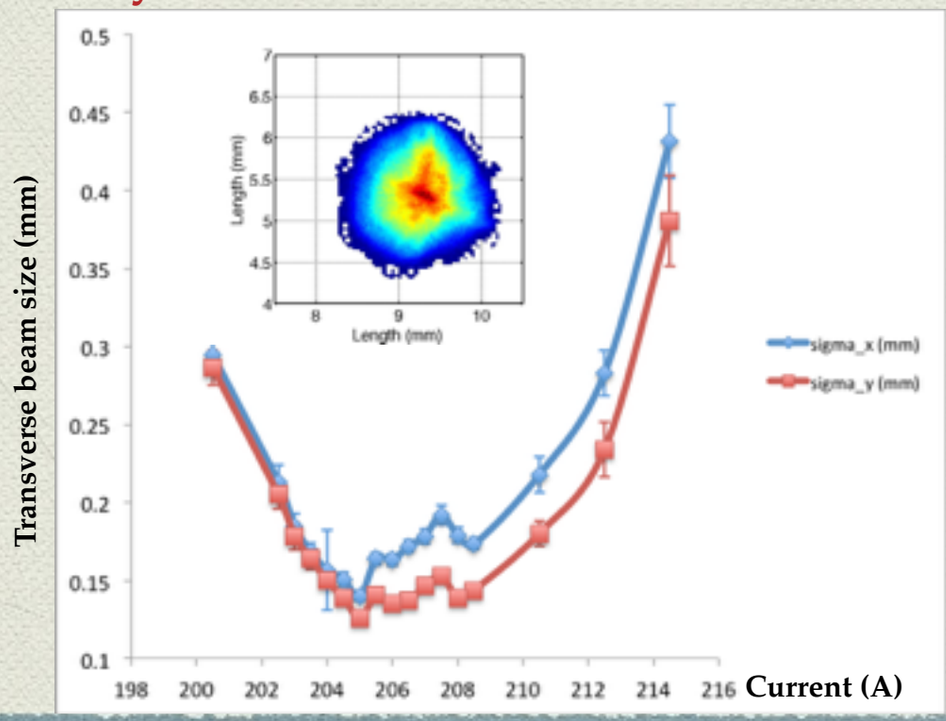
- **Space charge**

The electron bunch coming off the cathode is very dense and wants to expand violently due to the electrostatic force

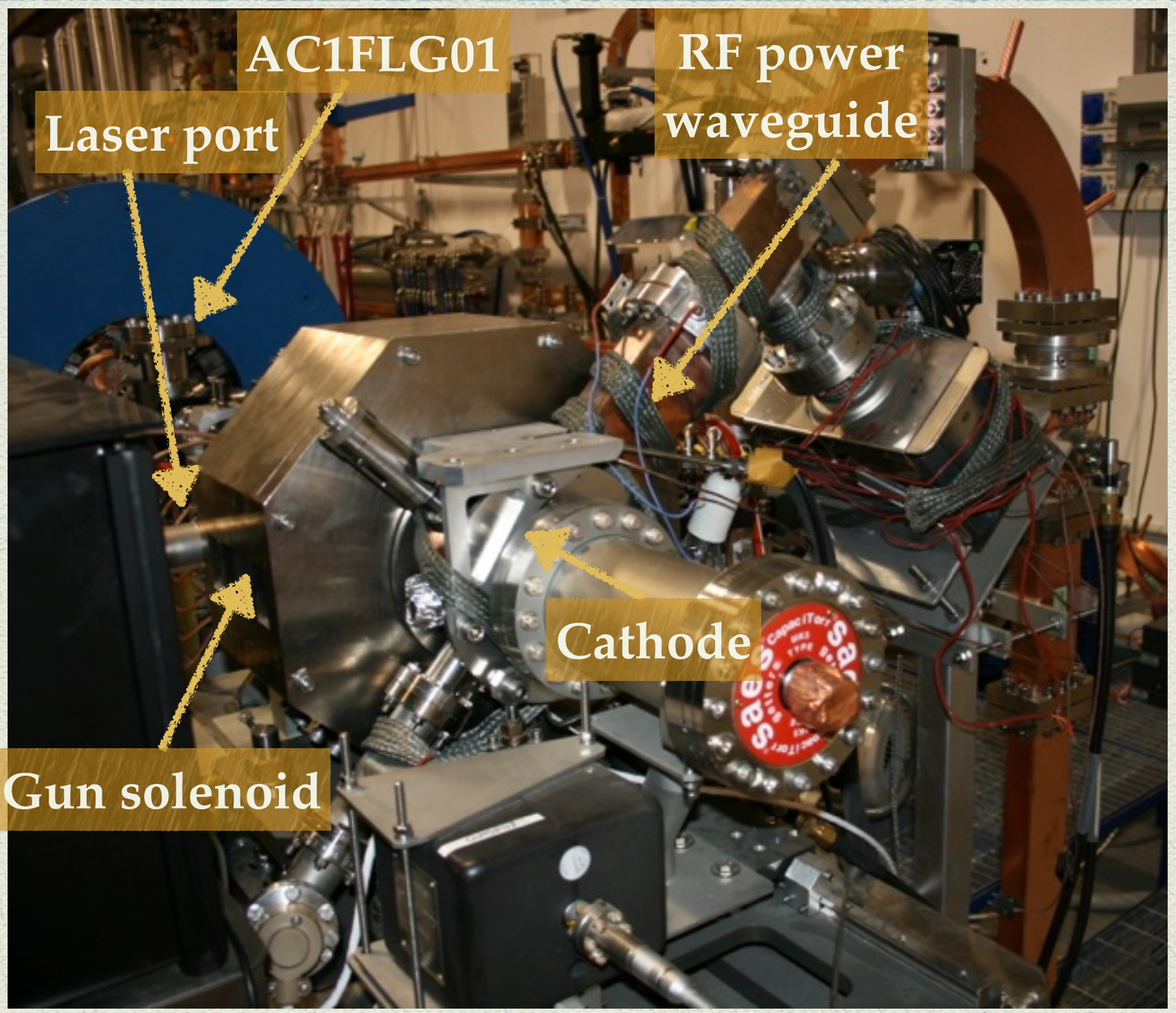
- **Divergent RF Fields within the RF gun**

Anytime the electric field varies longitudinally there is a radial field

The solenoid focuses the low energy beam radially



The SPARC_LAB Gun Area

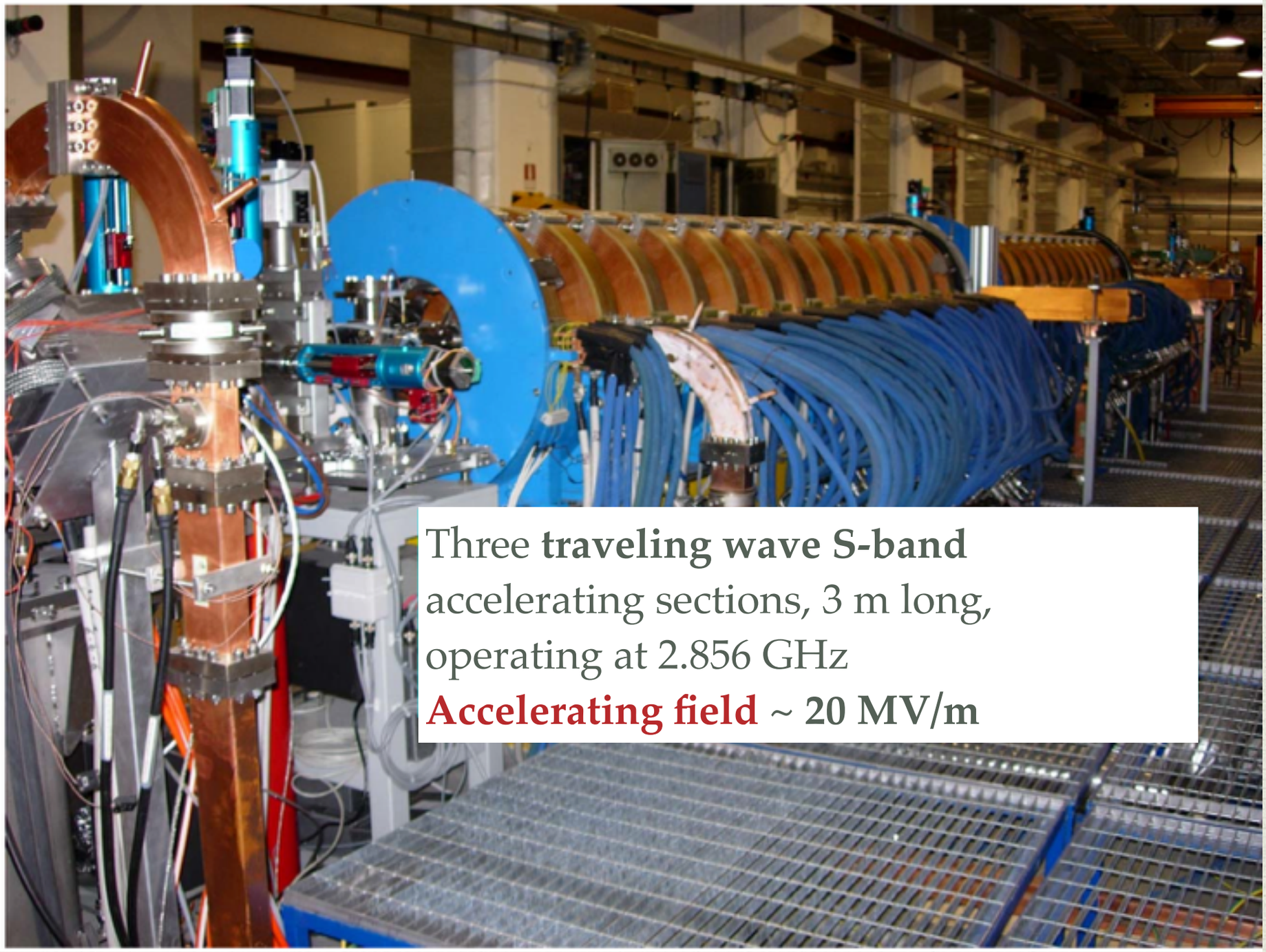


Measurements to be performed (once RF is turned ON)

Scintillating screen (AC1FLG01) inserted

- Phase scan
  - Charge VS RF gun launch phase
- Charge
  - Beam Current Monitor named as AC1BCM
- Energy measurement
  - Vertical beam centroid VS steering current

Accelerating Sections



Three **traveling wave S-band** accelerating sections, 3 m long, operating at 2.856 GHz

Accelerating field ~ 20 MV/m

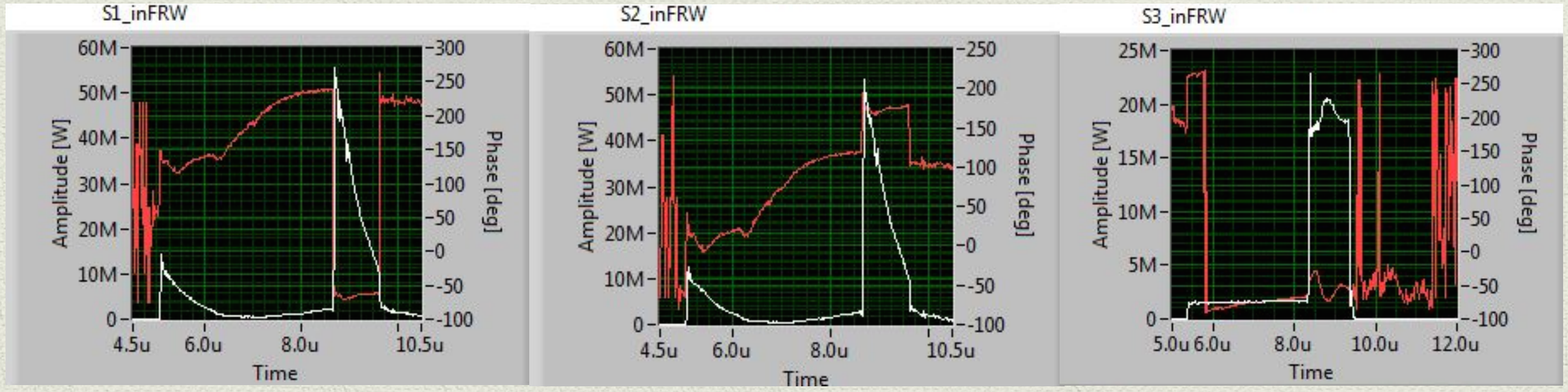
Accelerating Sections

- Three traveling wave constant gradient accelerating structures, operating at 2.856 GHz and consisting of 86 cavity cells coupled in the 2p/3 mode

- For these sections the following expression holds

$$E_{MeV} \sim 10\ \mathrm{sqrt}(P_{inMW}),$$

where P_{inMW} is the input RF power and E_{MeV} is the energy gained by the beam when traveling through the section



Accelerating Sections

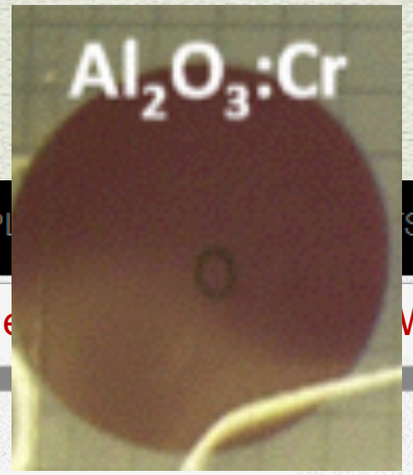
The first two TW sections are surrounded by 13 solenoid coils, powered as follows

- first coil as single
- last 12 coils as triplets

Diagnostic along the Linac

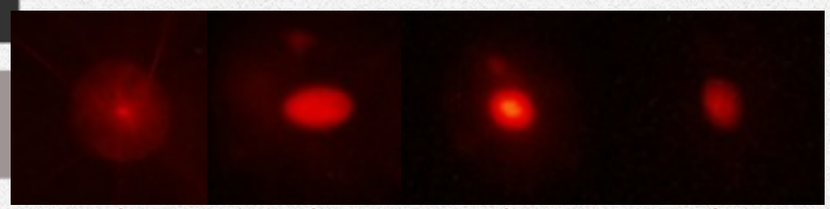
Fluorescent screens

- YAG:Ce
- Chromox (Al2O3:Cr)



Thomson back-scattering beamline

Ti:Sa Laser



1.6 cell S-band RF gun

Solenoid coils

THz source

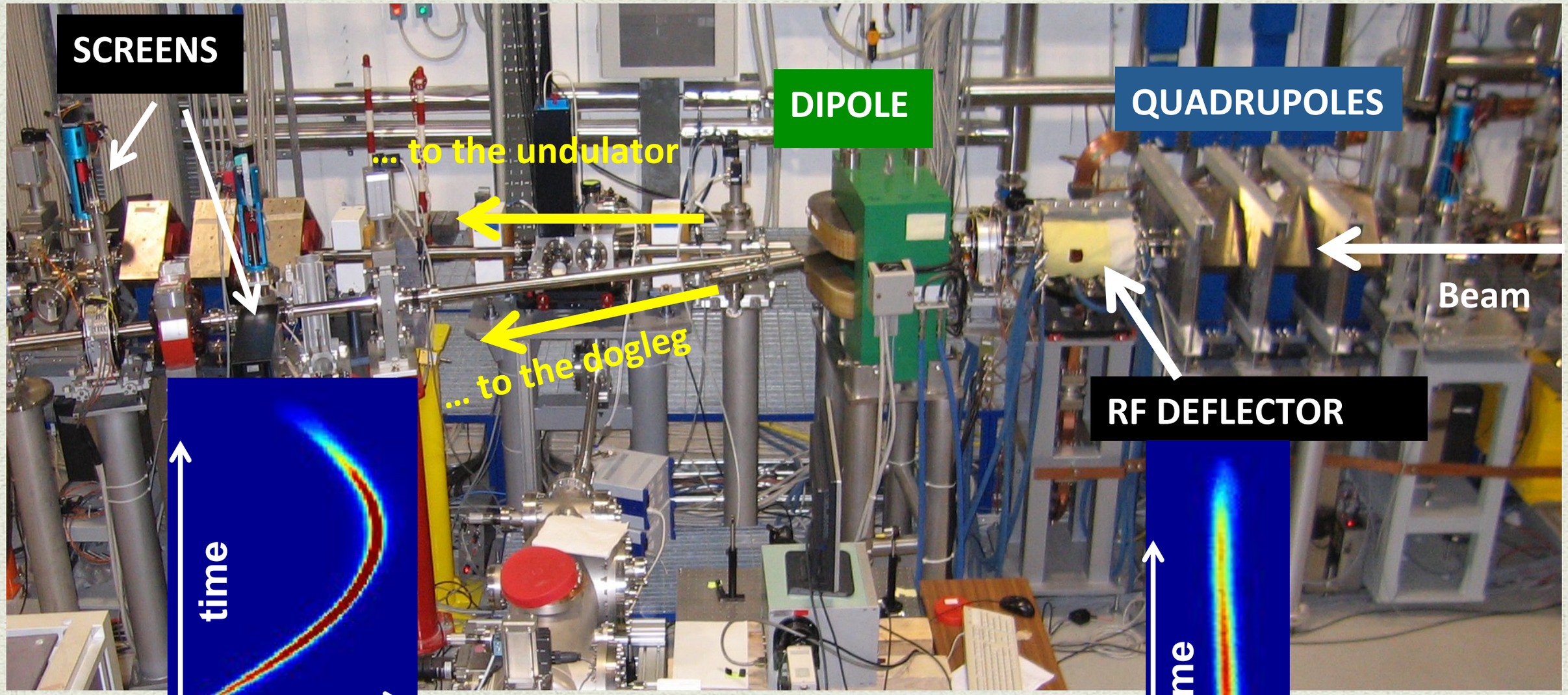
Test bench beamline

Undulator beamline

Cathode
Z=0
Z: beam propagation axis

3 S-band travelling wave sections

Diagnostic Section



Longitudinal Phase Space

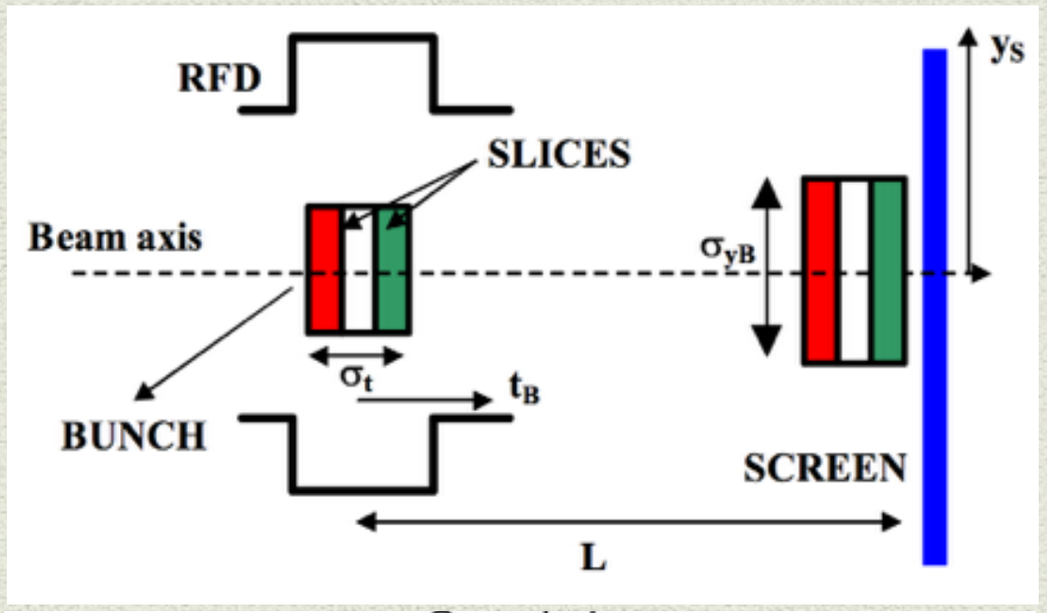
Longitudinal Profile

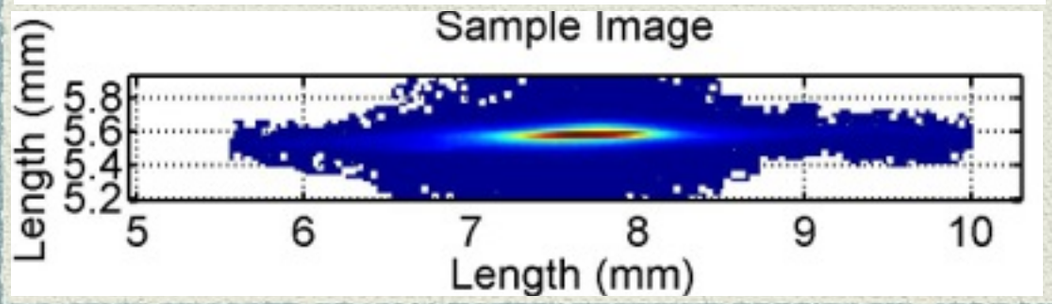
Electron Beam Diagnostics

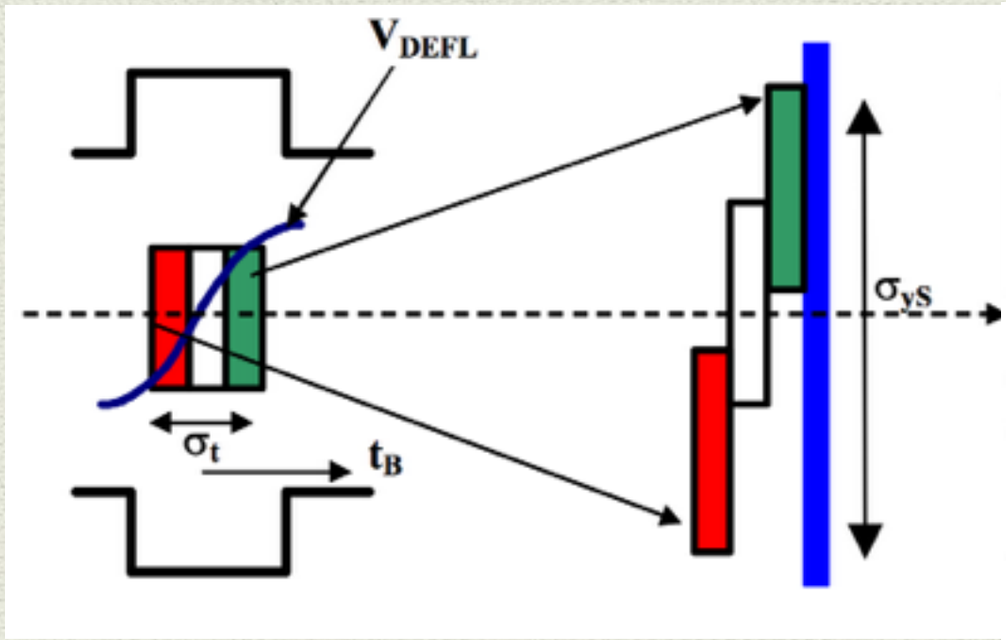
Longitudinal Beam Size

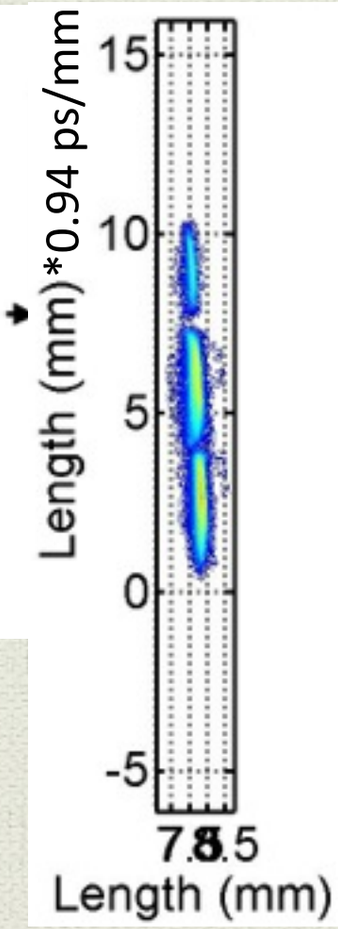
- RF Deflecting cavity

- The applied transverse voltage (V_{DEFL}) introduces a linear correlation between the longitudinal and transverse coordinate of the bunch





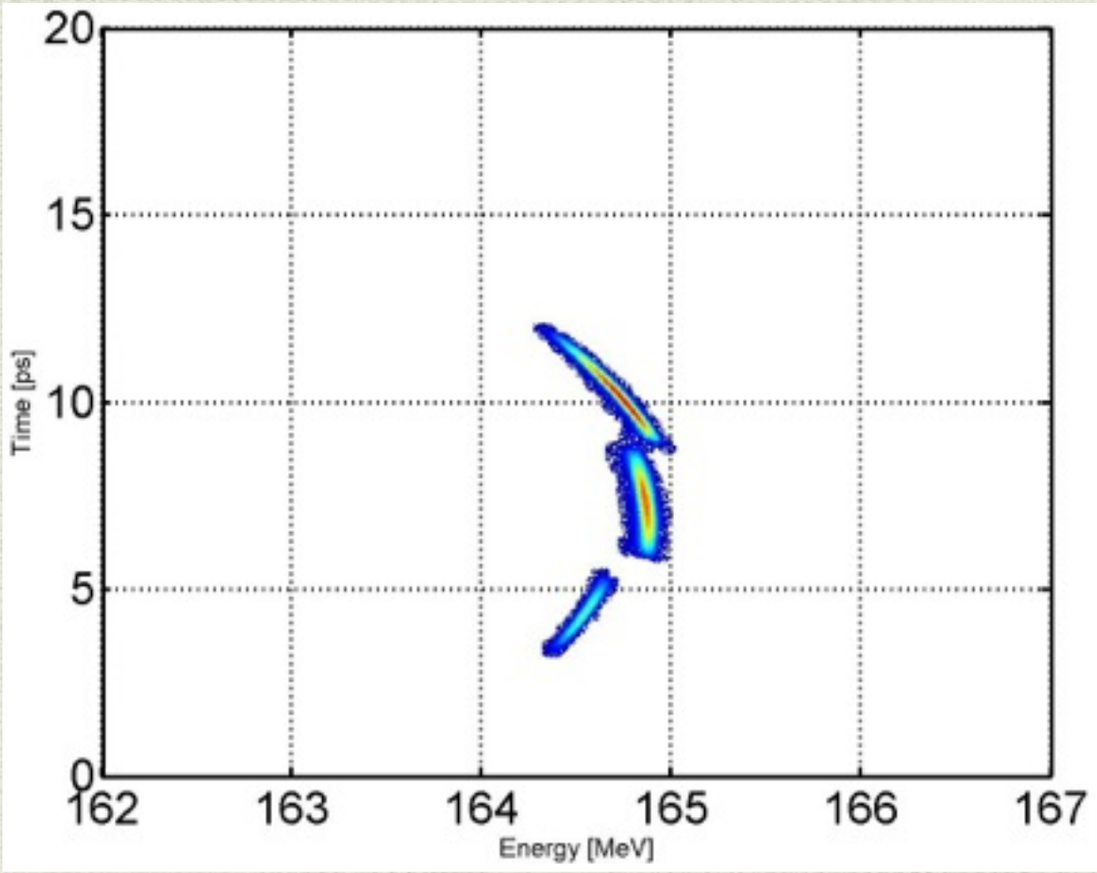


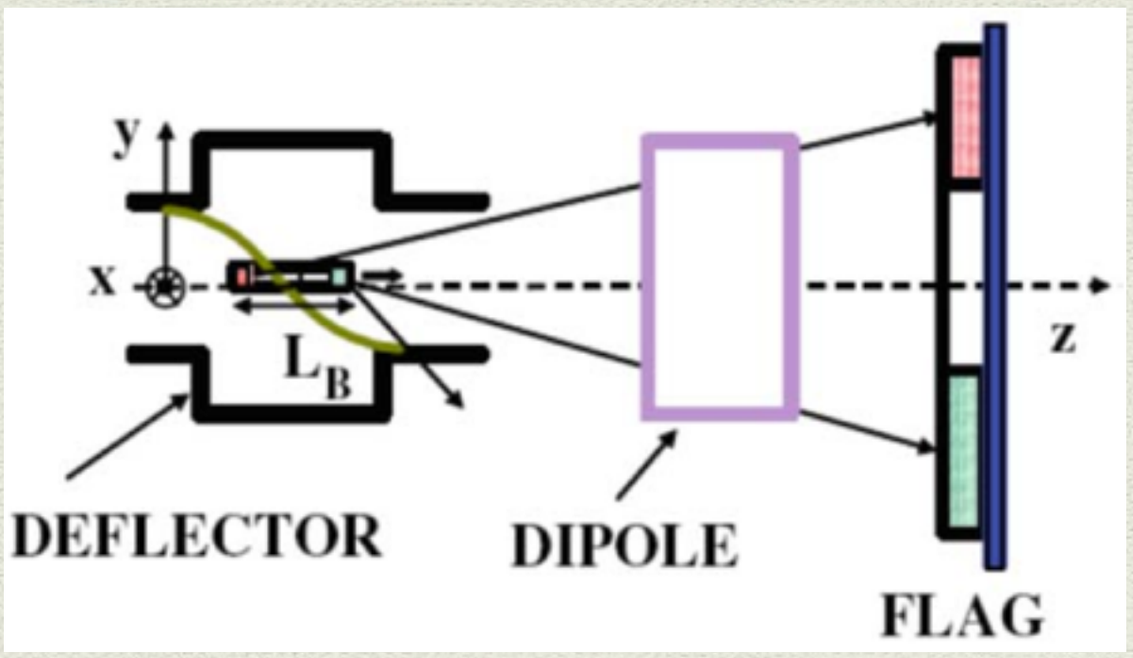


Electron Beam Diagnostics

Longitudinal Phase Space

- Using together a RFD with a dispersive element, i.e. a dipole magnet



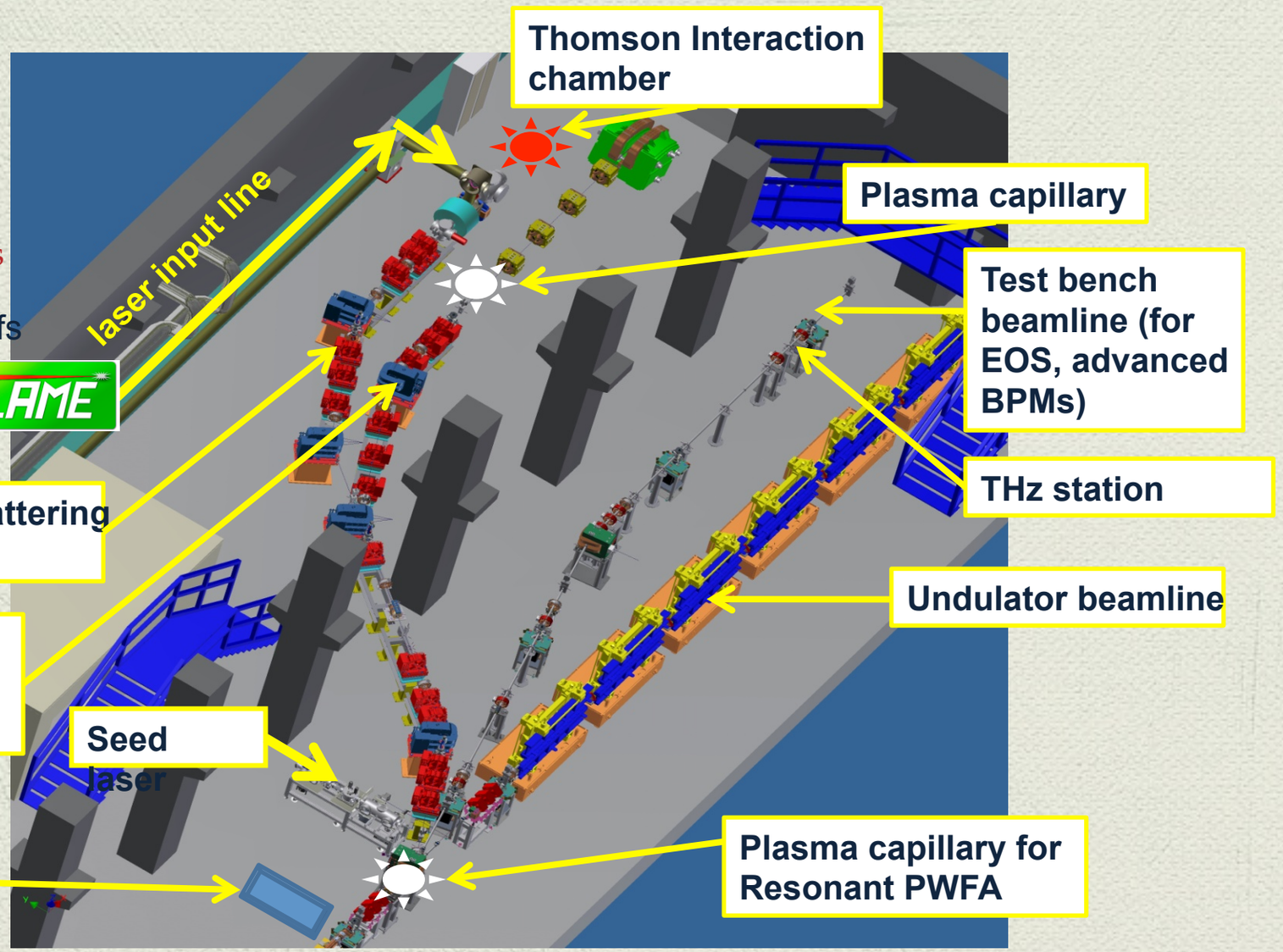


Applications

The **high brightness electron beams** so produced and characterized serve as **active medium in single pass Free Electron Lasers** in different schemes, e.g. SASE and SEEDED, serve **as source for THz radiation generation**, **for testing advanced electron beam diagnostics**, such as EOS and cavity BPM, **as source for gamma rays**, and **for novel acceleration concepts** based on laser and electron beam plasma interactions.

Beam energy	50 – 180 MeV
Bunch charge	20 – 500 pC
Rep. rate	10 Hz
ε_n	< 2 mm-mrad
σ_γ	0.05% - 1%
Laser Pulse length (FWHM)	150 fs – 5 ps

300 TW, < 25 fs
Ti:Sa laser



http://www.lnf.infn.it/~chiadron/index.php