



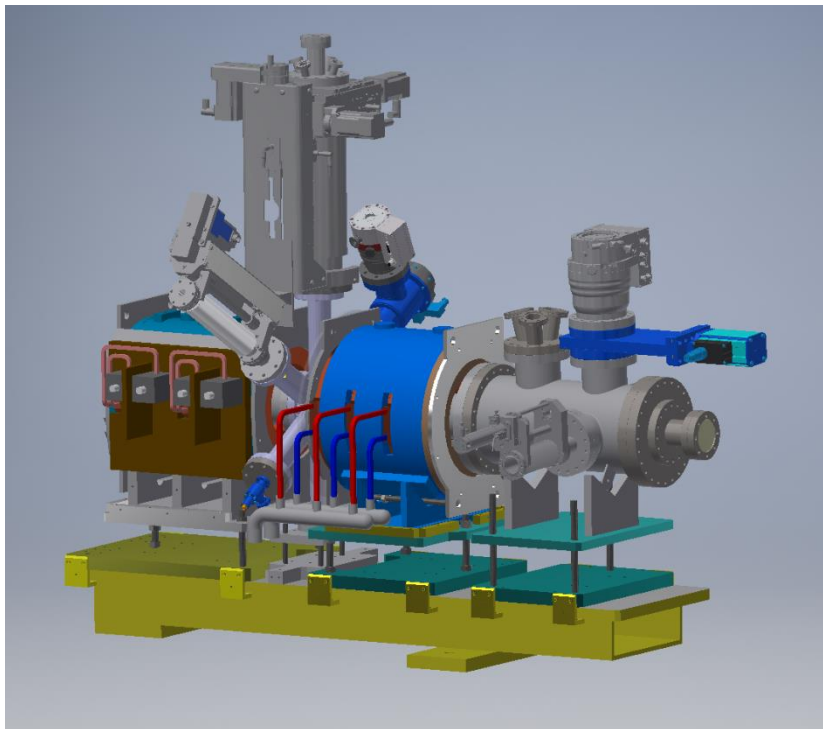
Electron lens test facility and e-beam simulations

S. Sadovich, A. Rossi



9th HL-LHC Collaboration Meeting

E-lens test stand at CERN



Hollow Electron Lens (HEL) at HL-LHC

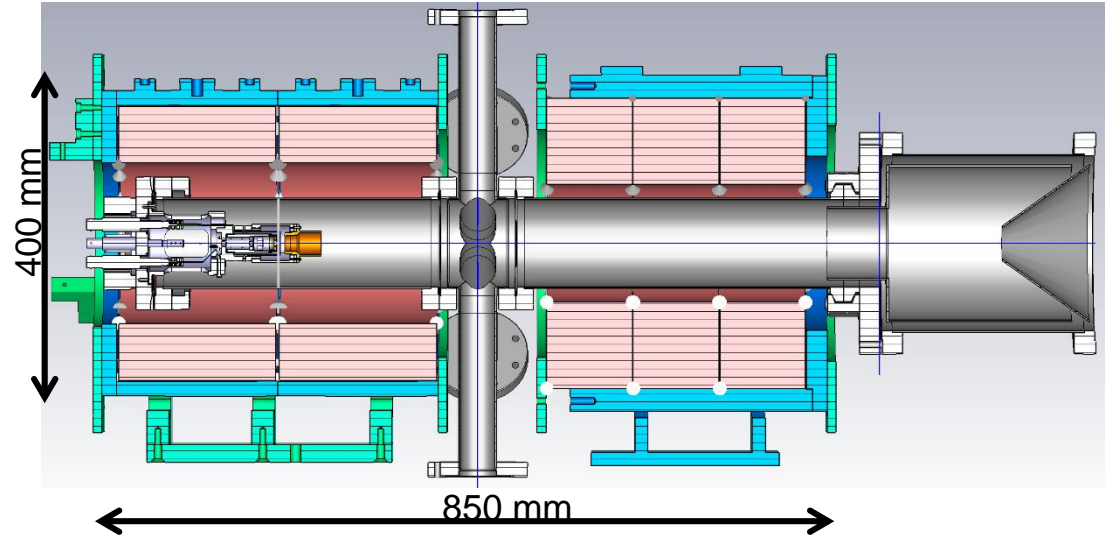
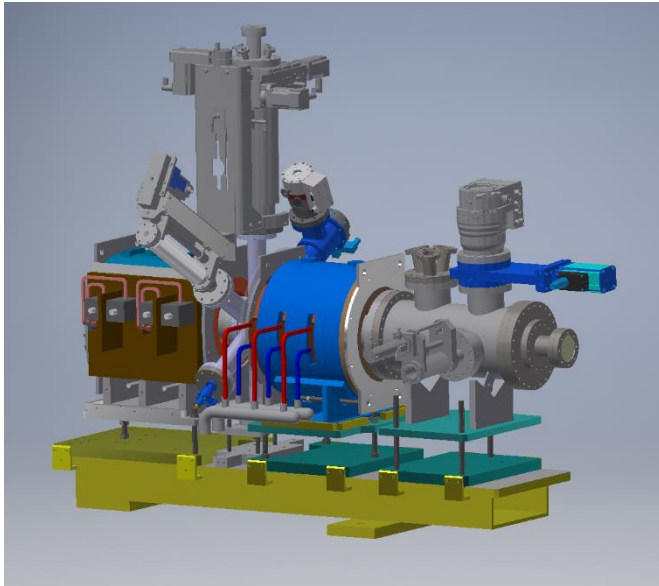
- Gun measurements (5A, 10kV extraction, 15kV energy):
 - Electron gun tests: characterization (current as function of temperature and extraction voltage, profile measurements)
 - Anode modular (200ns rise time, up to 86us)
- Diagnostics for electrons and hadrons:
 - Beam Gas Curtain Monitor
 - Beam Position Monitor

WP16: Intense, RF modulated E-beams (IRME) in the framework of the ARIES* project:

- Designing and manufacturing an RF modulated electron gun for space charge compensation (~10A, 30kV extraction voltage, ~1MHz modulation) and its power modulator
- Measuring properties of RF modulated electron beam

*ARIES – Accelerator Research and Innovation for European Science and Society

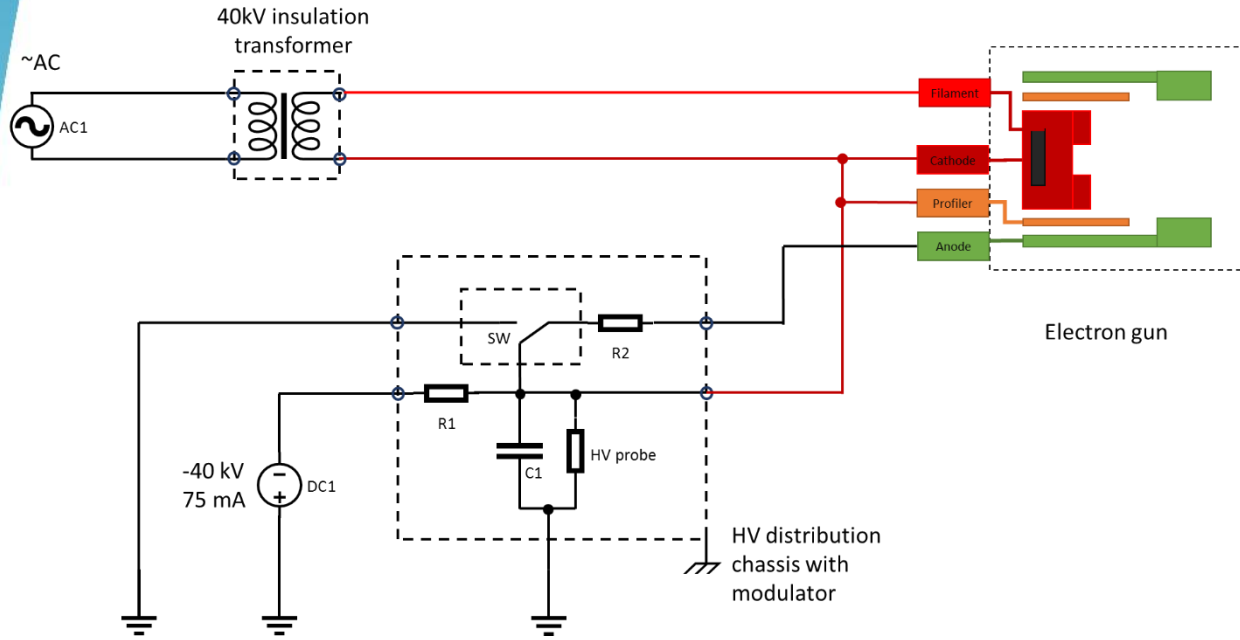
E-Lens Test Stand – design of current stage



Parameters of the E-lens test stand :

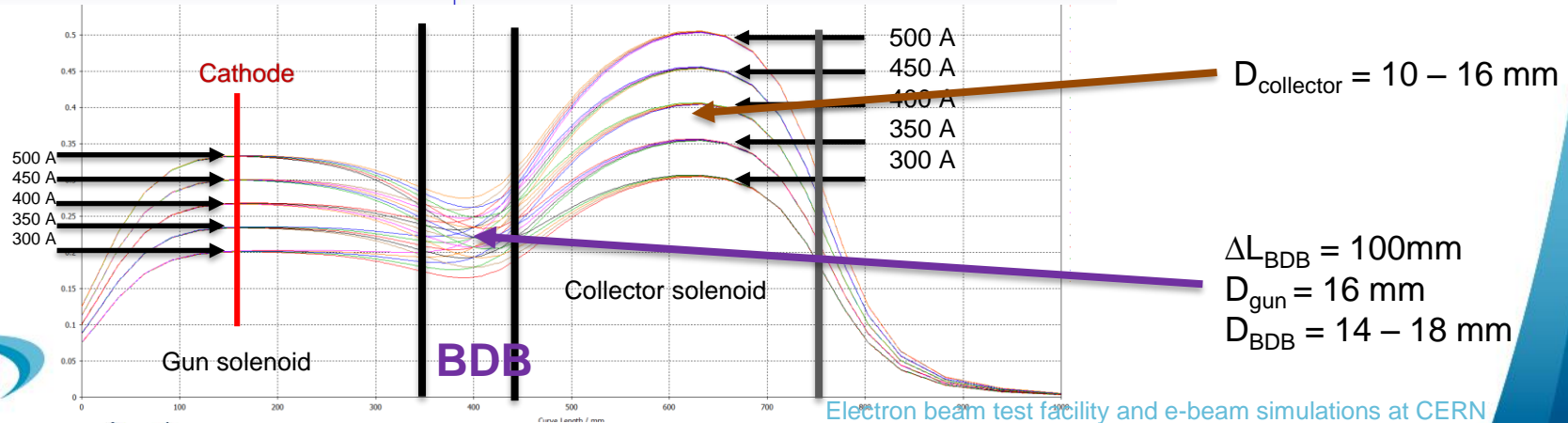
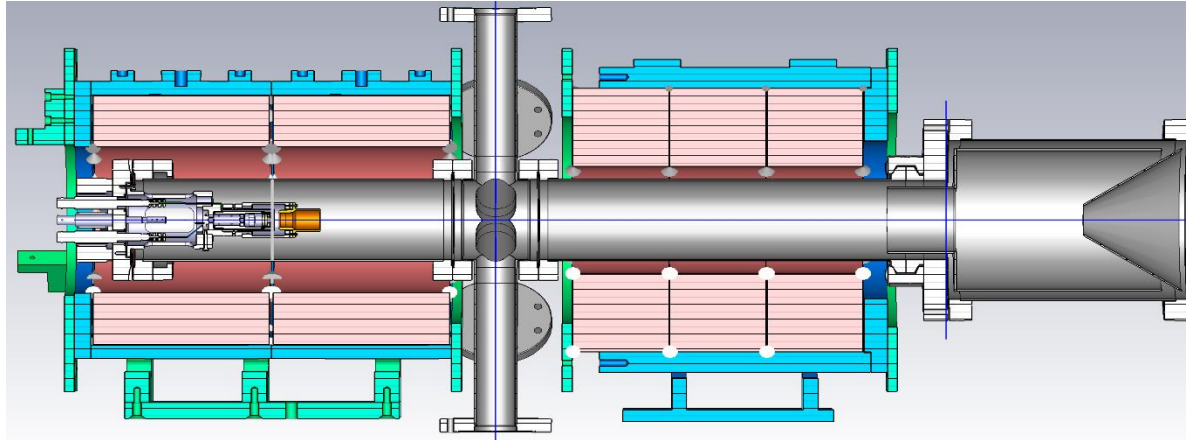
- Gun Solenoid 0.3 T (at 450 A)
- Collector Solenoid 0.45 T (at 450 A)
- Gun acceleration voltage up to 40kV
- Pulsed mode of operation

HV schematics (simplified)

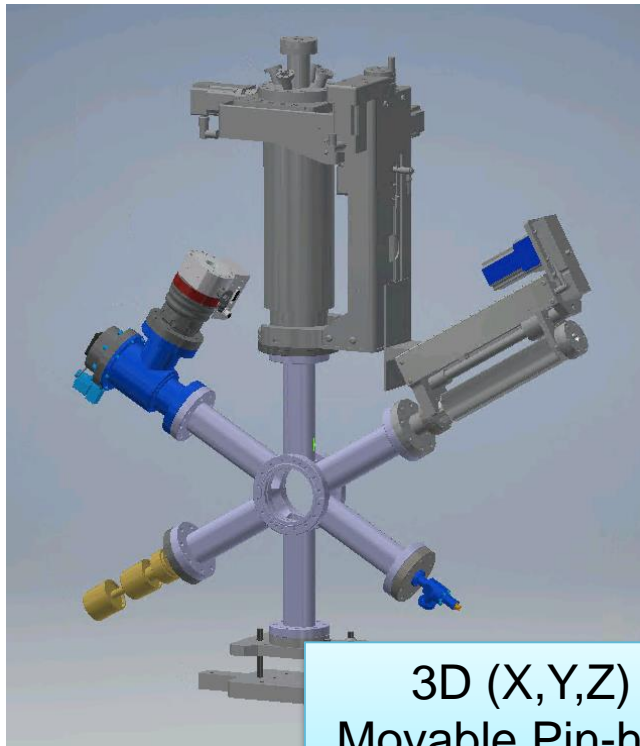


- Operation in pulsed mode (up to 40kV extraction voltage)
- BELHKE HV switch (HTS 401-10-GSM) for pulses (10 Hz)
- E-Beam for HEL:
 - 5A peak current,
 - 10 kV extraction voltage,
 - 10 us,
 - 10 Hz

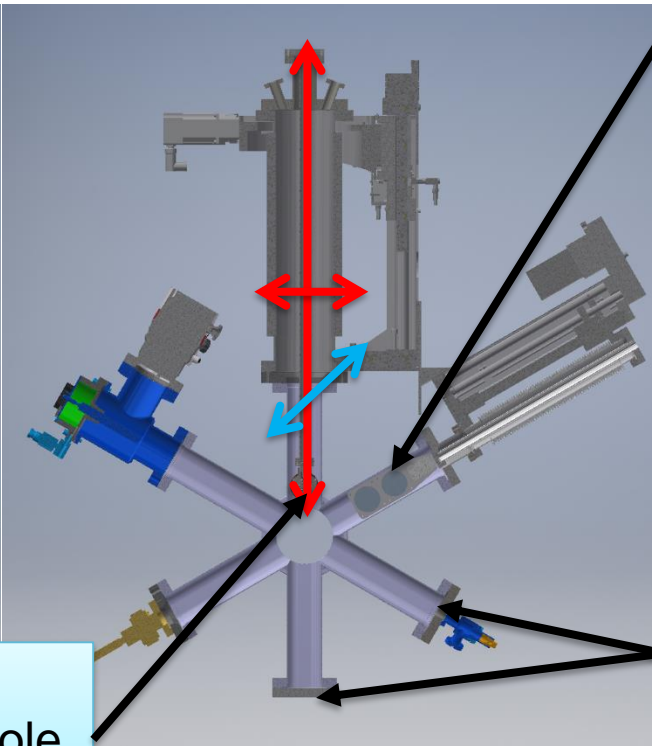
E-lens Test Stand – Beam properties



E-lens test stand: Diagnostic box



3D (X,Y,Z)
Movable Pin-hole
Faraday Cup

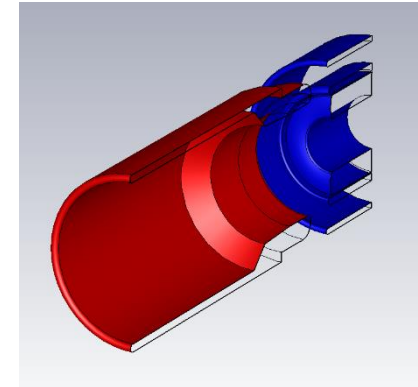
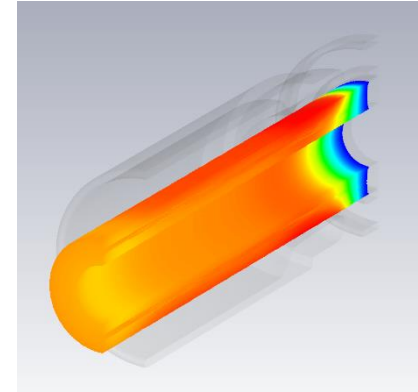


YAG:Ce screen

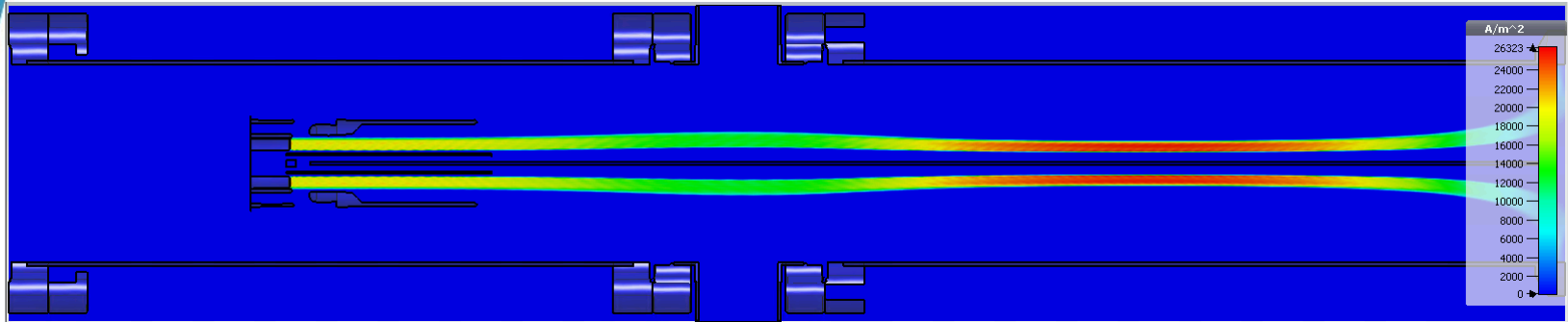
Additional ports
(OTR, Langmuir
probe)

Measurements at Stage 1

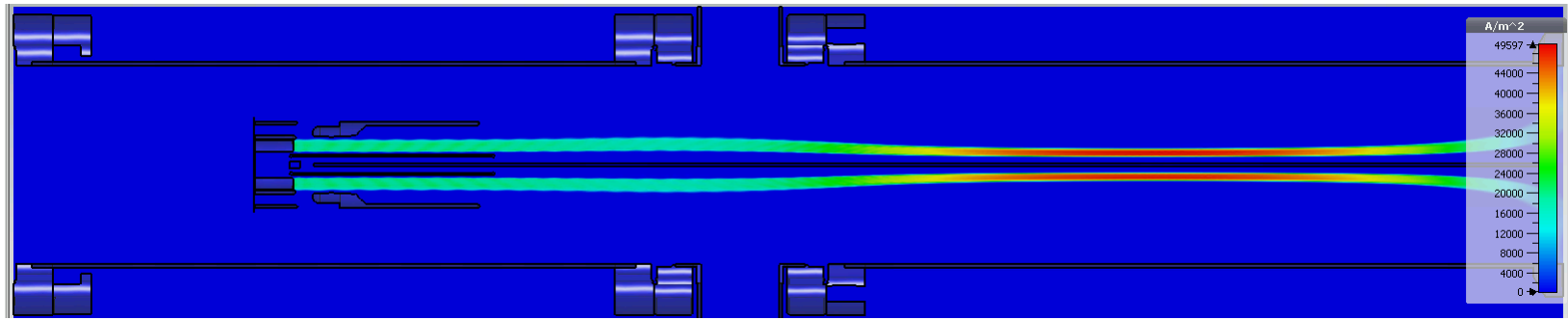
- Current yield as function of temperature of the filament and extraction voltage
- Profile of the electron beam after 250 mm of drift
- Anode modulator: rise time and fall time



Beam current density

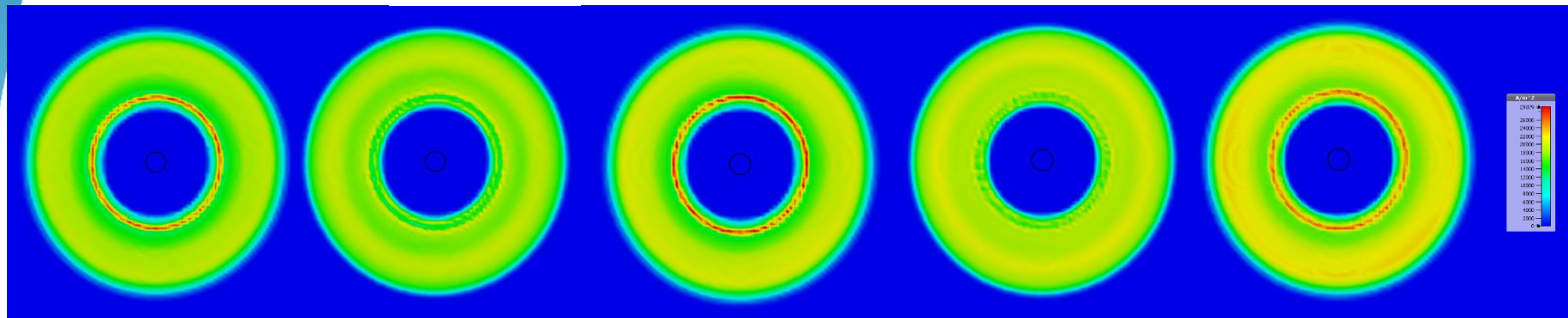


$B_{\text{gun}} = 0.3\text{T}$



$B_{\text{gun}} = 0.15\text{T}$

Beam profile evolution



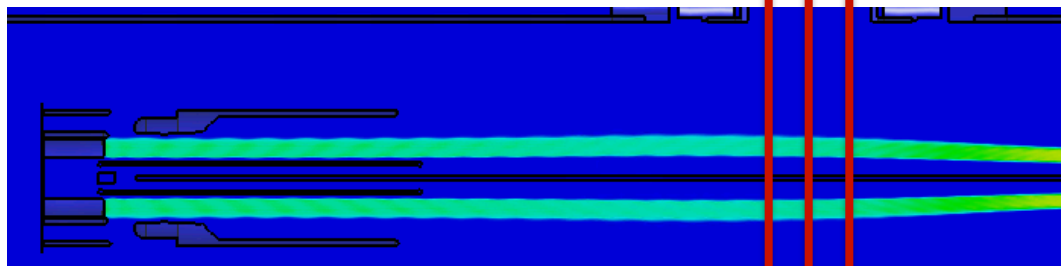
-10 mm

-5 mm

0 mm

+5 mm

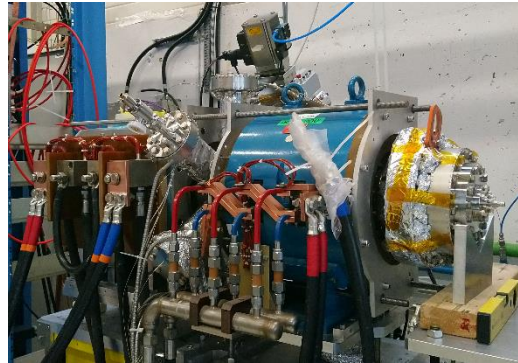
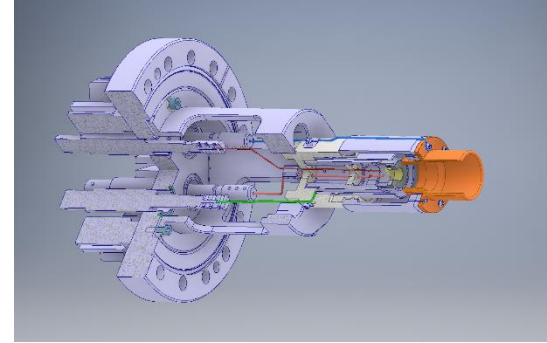
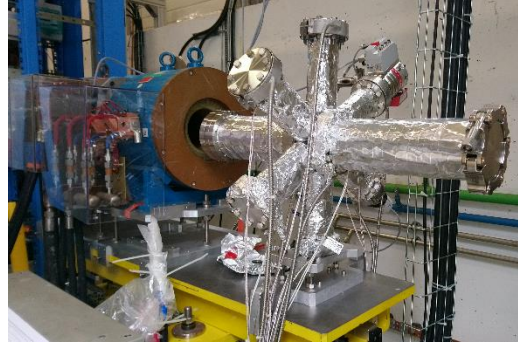
+10 mm



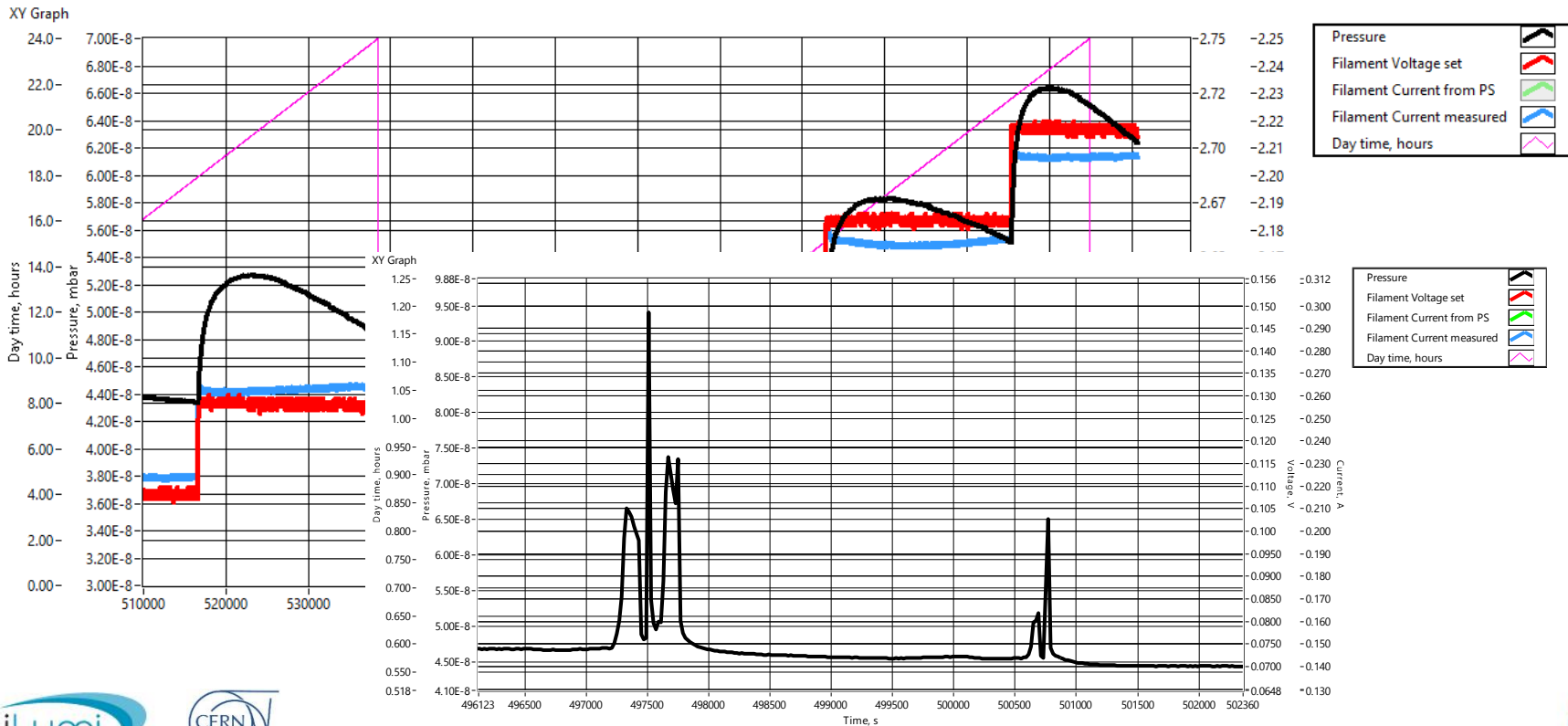
$$B_{\text{gun}} = 0.15 \text{ T}$$

E-lens test stand at CERN: current status

Assembling



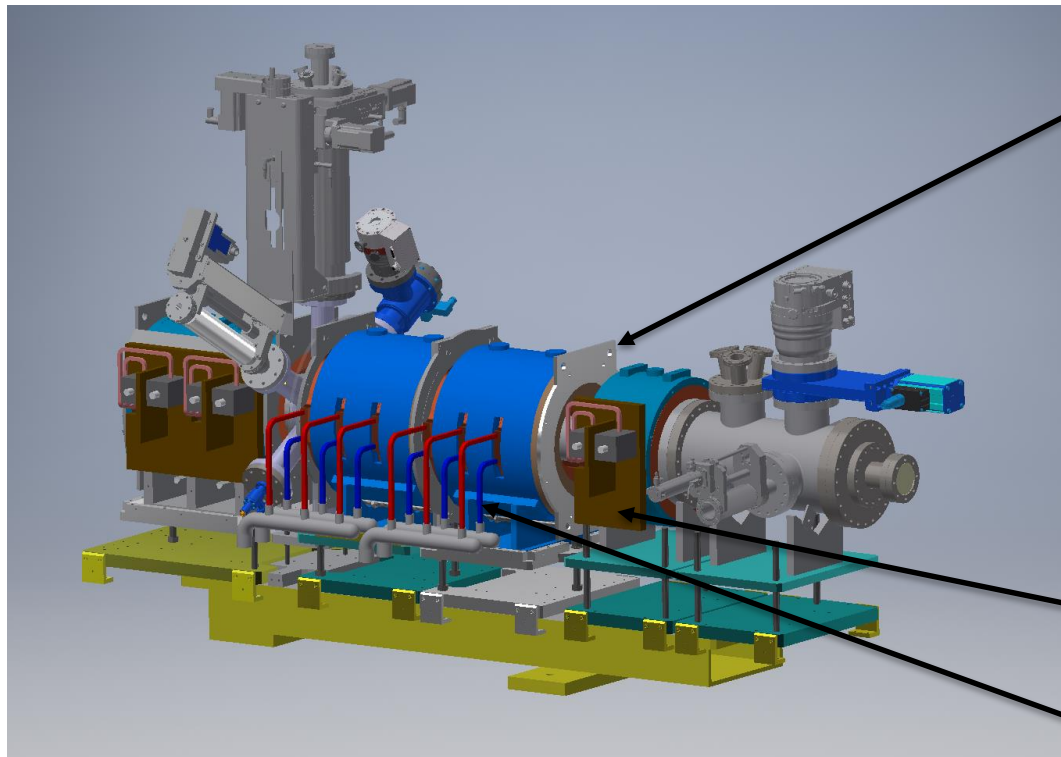
Filament Current/Voltage vs time



Next steps

- Heating cathode to the nominal temperature (end of October 2019)
 - Measuring current yield depending on extraction voltage and temperature of the cathode
- Installation diagnostics instruments
 - Measuring profile of the electron beam depending on magnetic field in the gun solenoid, extraction voltage
- Upgrade Stage 2.

E-lens test stand upgrade: stage 2

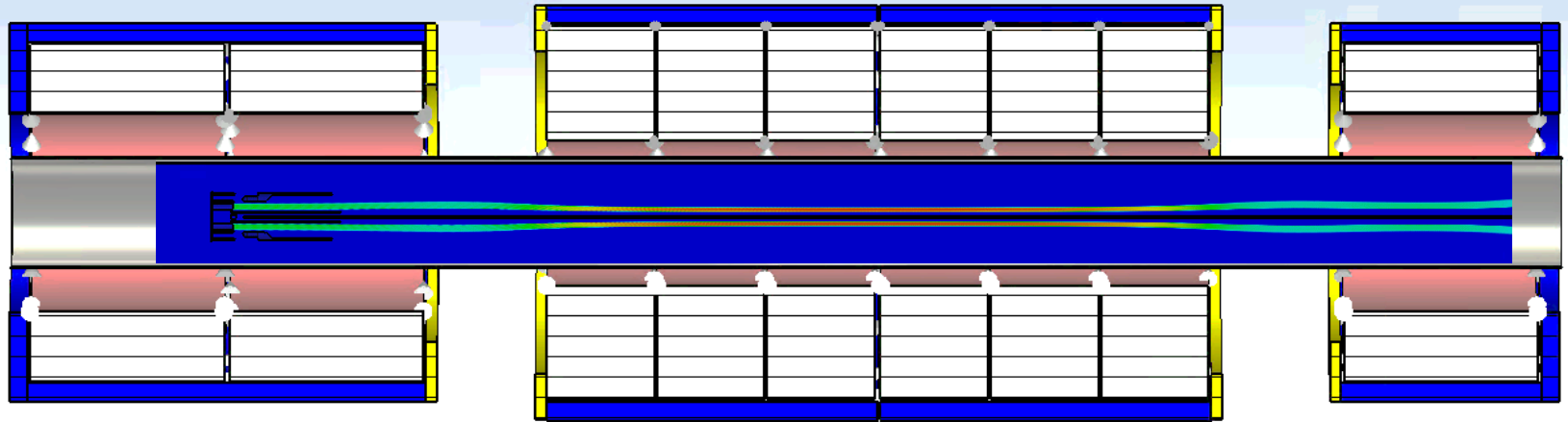


Room for beam diagnostics (BGC)

Collector solenoid

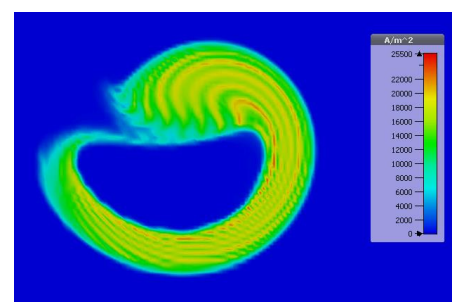
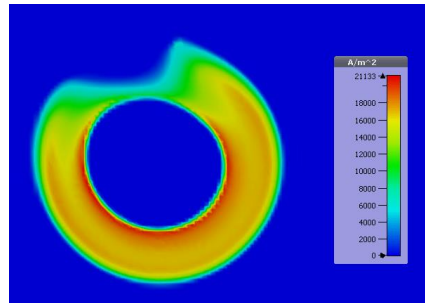
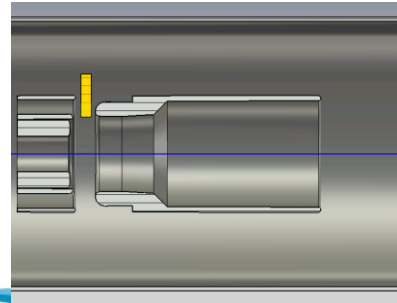
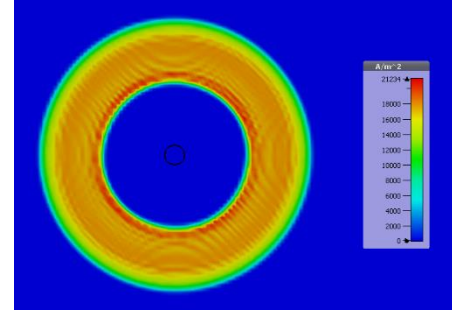
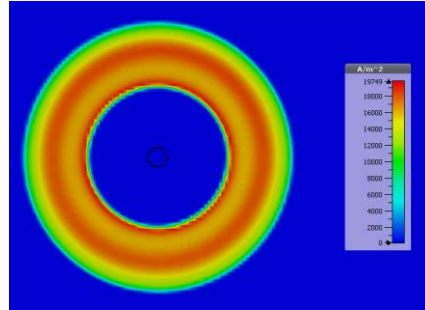
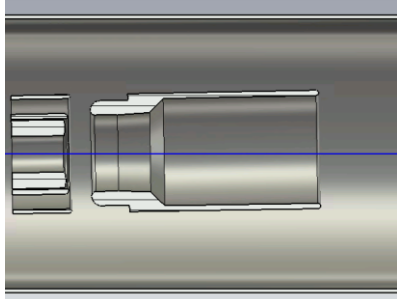
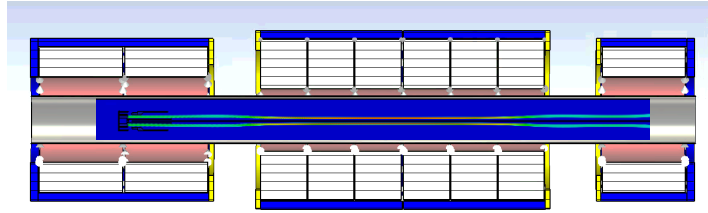
Second drift solenoid + correctors

Beam dynamics for stage 2

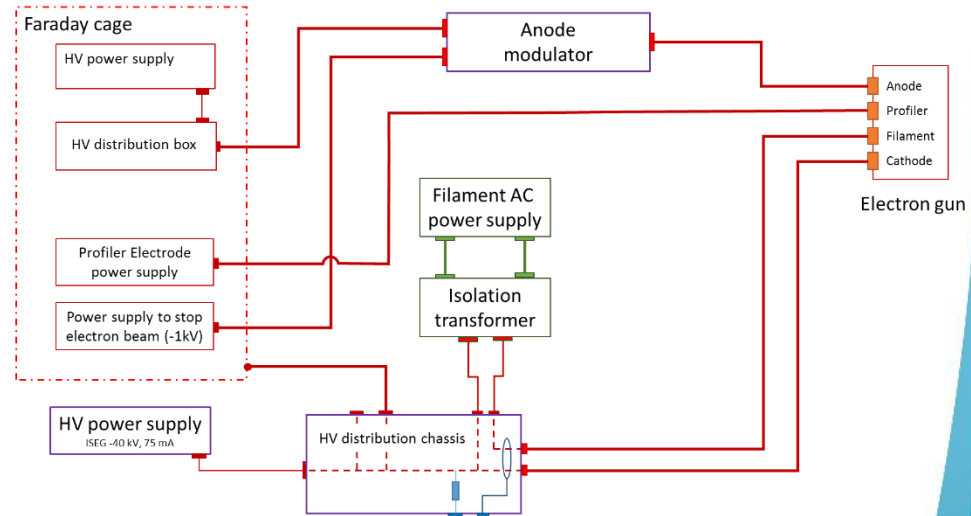
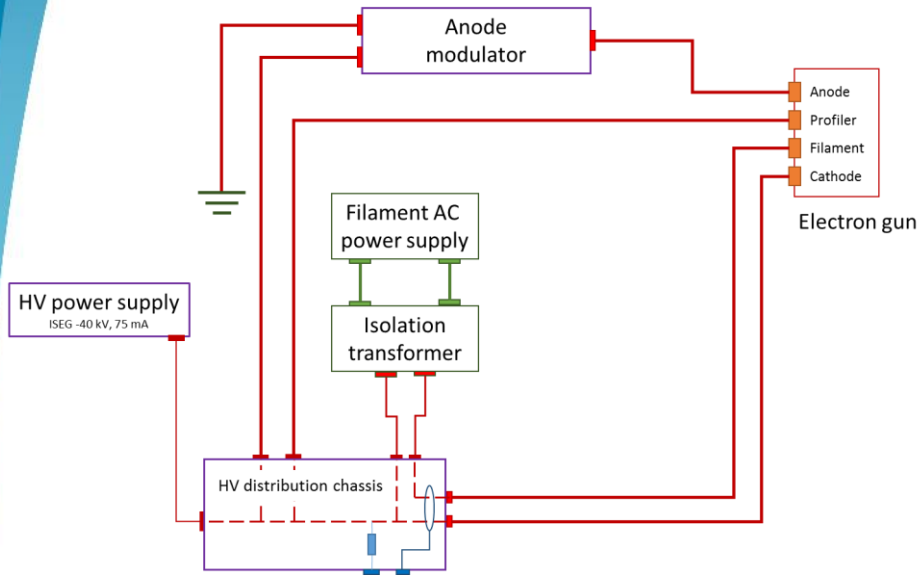


- Allow drift and see beam deformations/rotations/... computer model validation
- Study electron beam dynamics in regime close to virtual cathode
- Study electron beam dynamics with compression
- Two points for profile measurement

Beam dynamics for stage 2



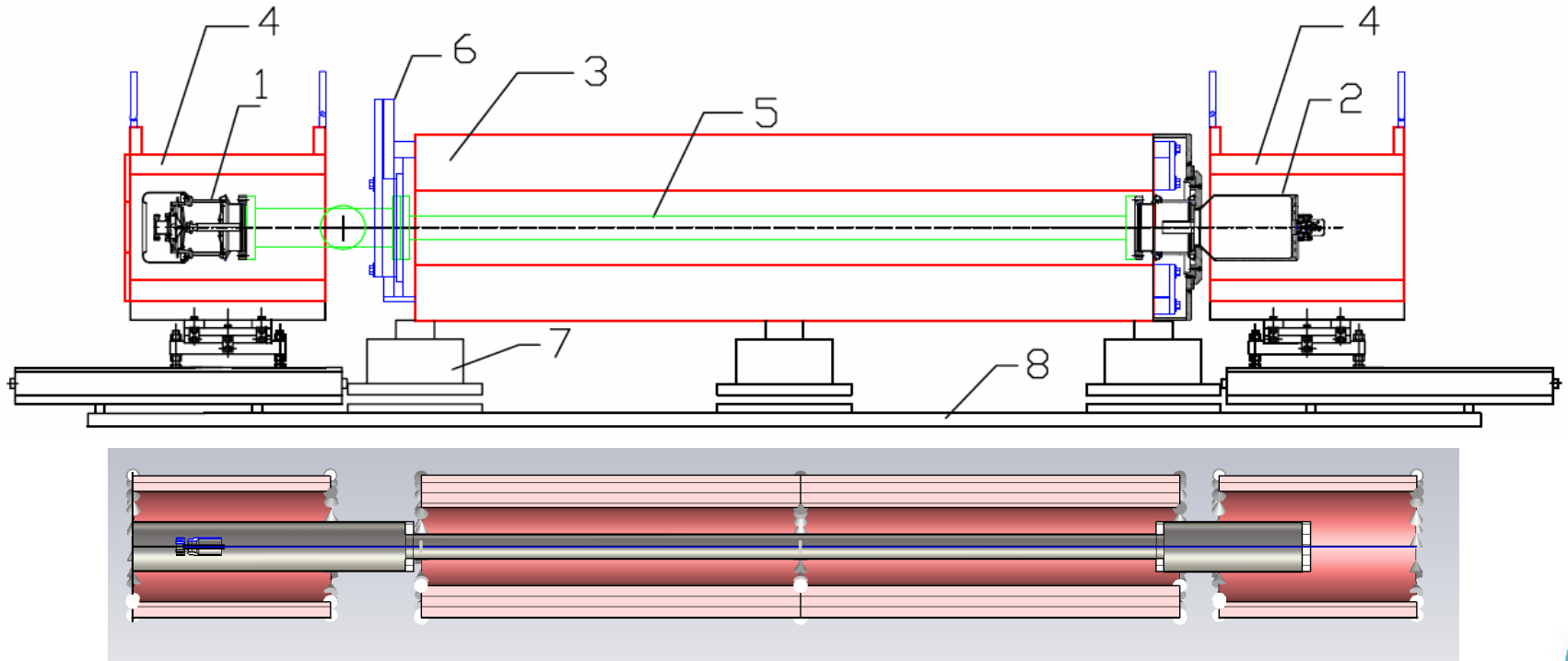
HV circuits upgrade



Extraction voltage is up to **40 kV**
Acceleration voltage is up to **40 kV**
Peak current is up to **5A**

E-lens test stand at FNAL

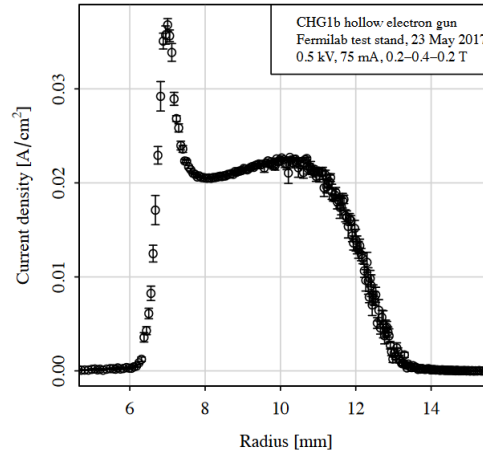
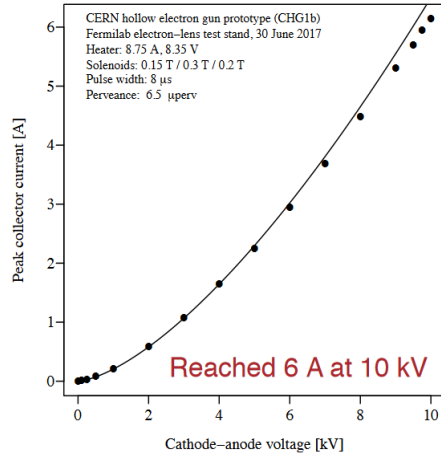
FNAL test stand – model in CST Particle Studio



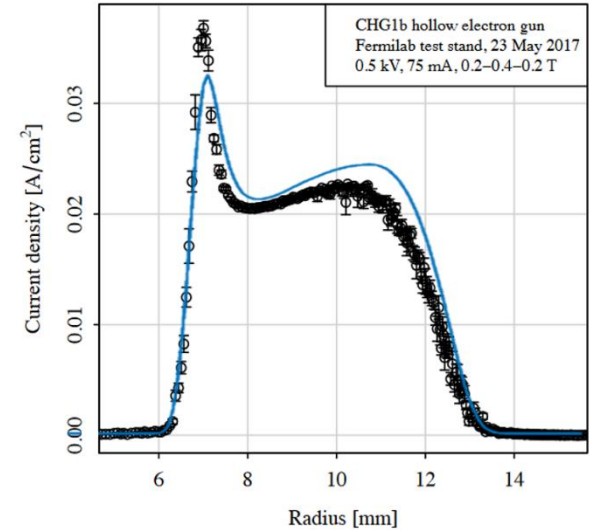
FNAL test stand – electron gun



Measured performance of CHG1b 25-mm e-gun



Data file: CHG1b_170523_8p75A_2-4-2kG_500V_75mA_hires.txt.gz



Courtesy of Giulio Stancari, FNAL

Profile evolution (results from FNAL test stand)

Total rotation phase φ of the hollow electron beam

$$\varphi \approx \Omega_D \Delta T \propto \frac{n_{e0} L}{B v_z}$$

$$\Omega_D - \text{diocotron frequency} = \frac{\omega_{pe}^2}{2\omega_{ce}} \propto \frac{n_{e0}}{B}$$

$$\Delta T - \text{transient time} \approx \frac{L}{v_z}$$

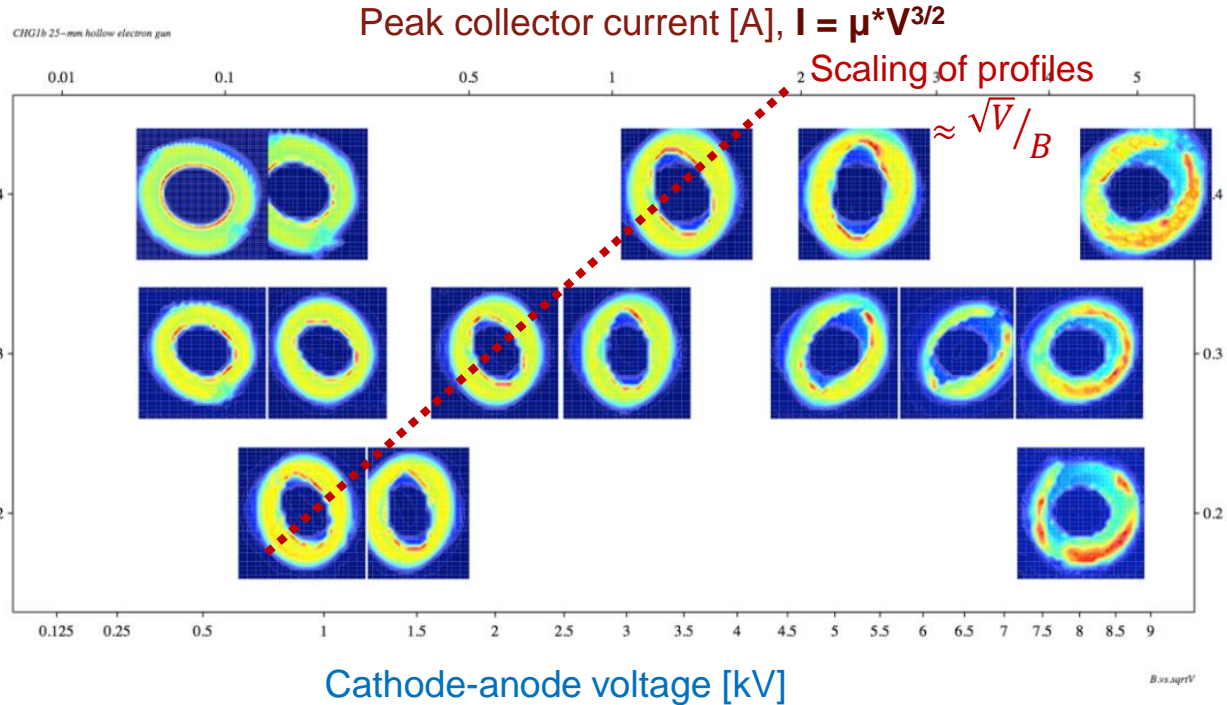
$$v_z \approx \sqrt{\frac{2eV}{m_e}} \propto \sqrt{V}$$

$$J = n_{e0} e v_z \propto V^{3/2}$$

Child-Langmuir law

$$\varphi \approx \text{const} \times \frac{\sqrt{V}}{B} L$$

Magnetic field in main solenoid [T]



Summary and future work

- Assembling of the E-lens test stand at CERN is ongoing
 - Electron gun is installed, filament is being heated, first beam (mA) was extracted
 - Installation of the beam diagnostics is foreseen by the end of this year (2019)
 - Can be used to test the BINP anode modulator (to see rise time and fall time of the beam pulse)
- Dynamics of the electron beam in the E-lens test stand was simulated using CST PS (TRK and PIC solvers), comparison with experimental data will allow to benchmark simulation technique and perform simulations to optimize parameters of the gun/electron lenses.
- Upgrade to stage 2 is foreseen in next year (2020): collector biasing, warm drift solenoid installation, HV upgrade
- Integration studies for installation BGC are ongoing

E-gun:

