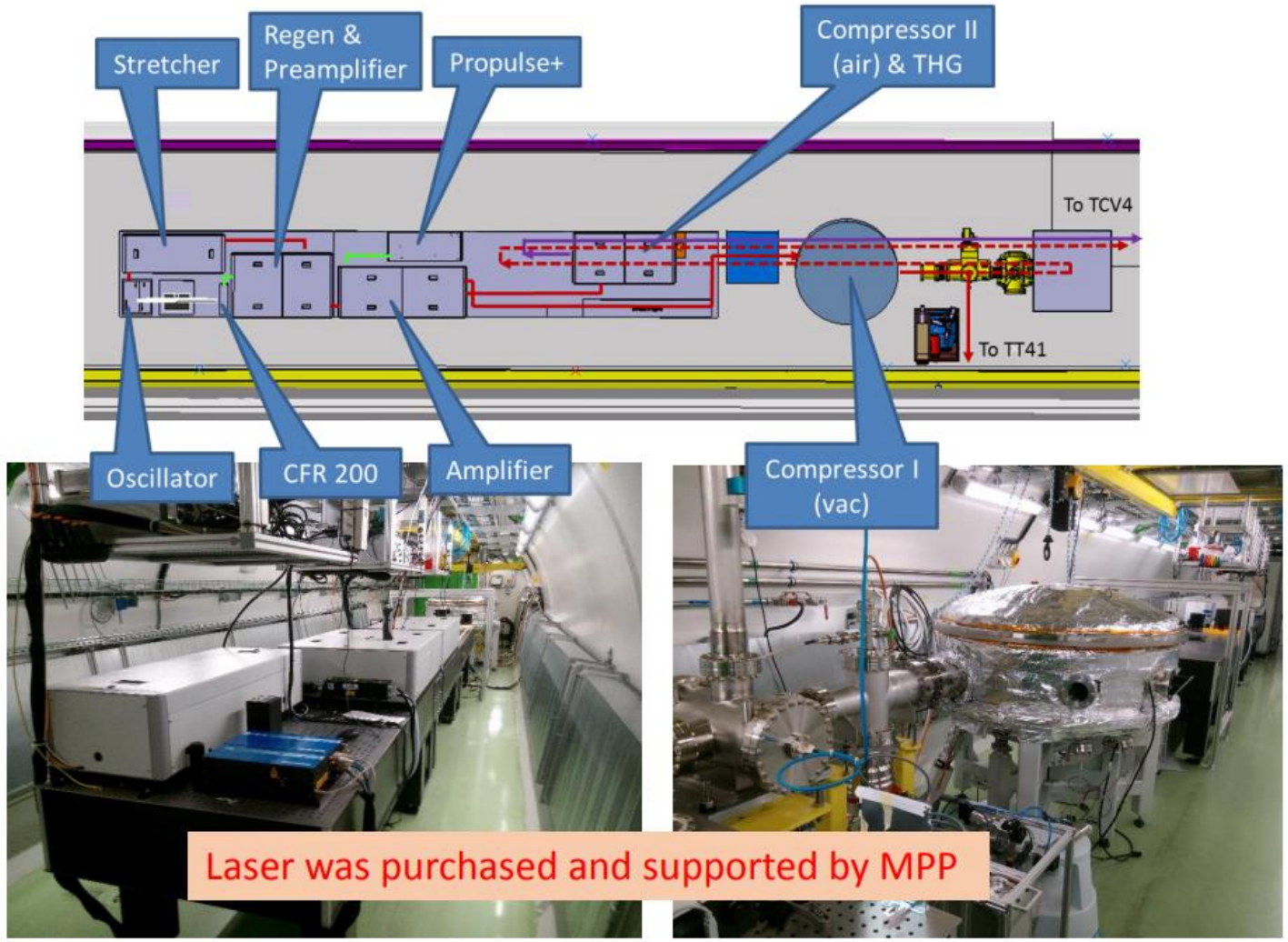
AWAKE laser baseline

Eduardo Granados
SY-STI-LP

AWAKE Run 1 laser beamlines



Laser beam to plasma cell

- λ = 780 nm
- t pulse = 120 fs
- E = 450 mJ

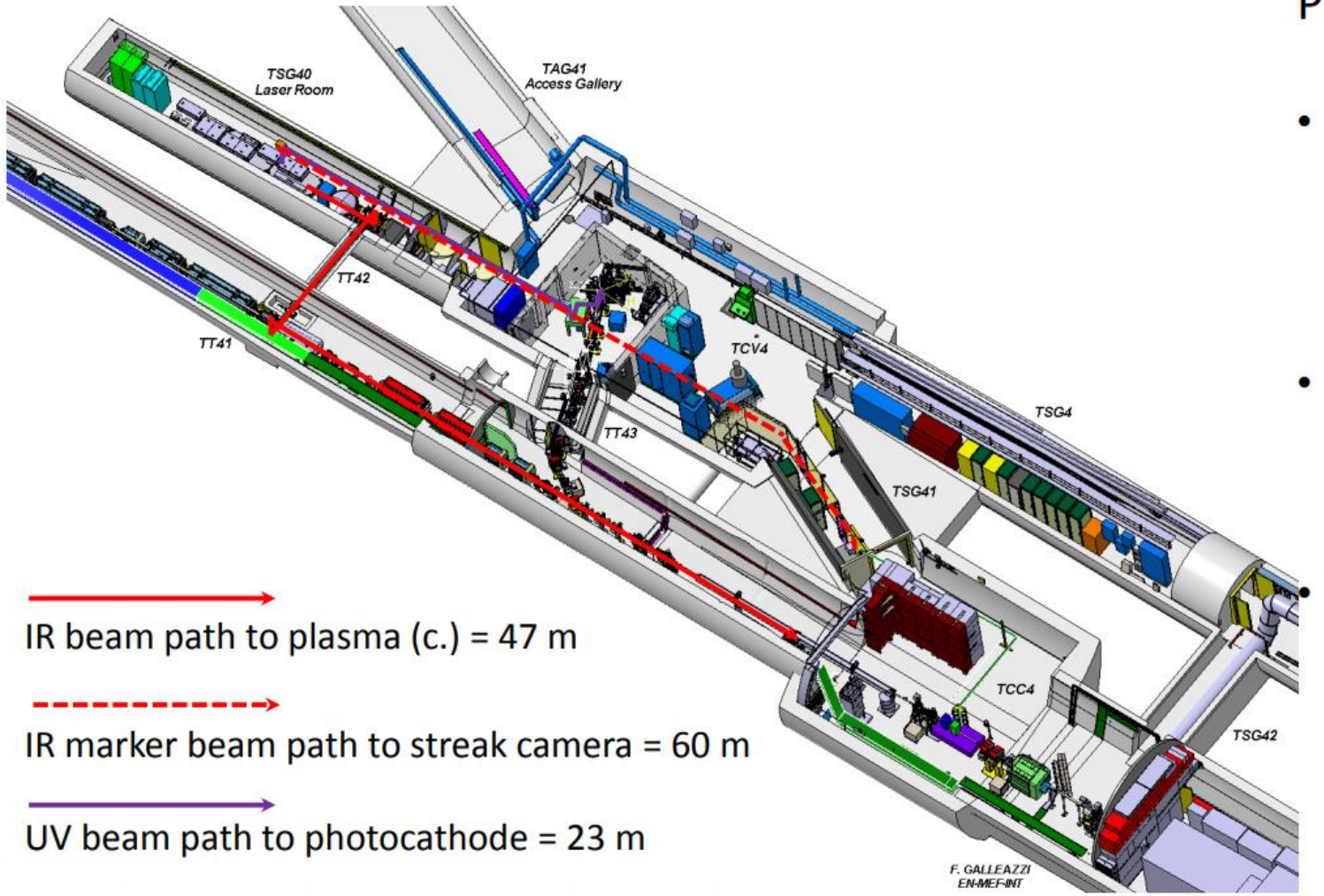
Laser beam to streak camera ("time marker")

- λ = 780 nm
- t pulse = 120 fs,
- E ≈ 0.01 mJ

Laser beam to electron gun

- λ = 260 nm
- t pulse = 0.3-10 ps
- E = 0.1 - 2 μJ

AWAKE Run 1 laser beamlines



IR beam path to plasma (c.) = 47 m

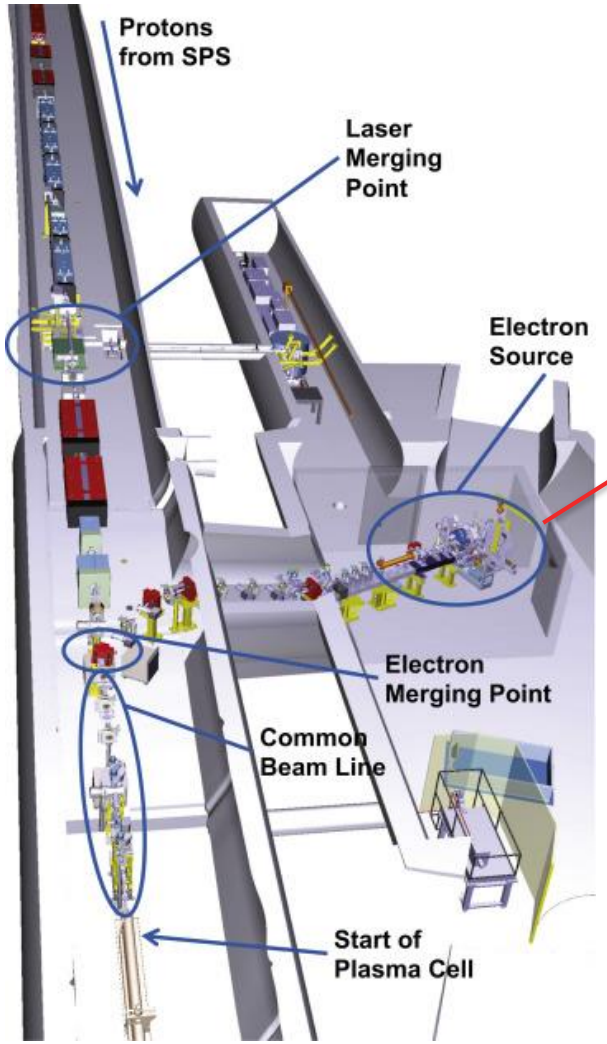
IR marker beam path to streak camera = 60 m

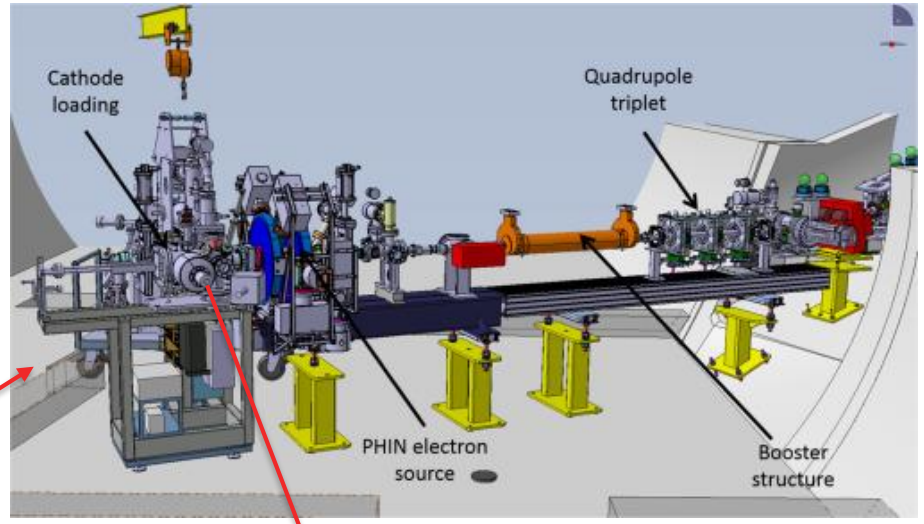
UV beam path to photocathode = 23 m

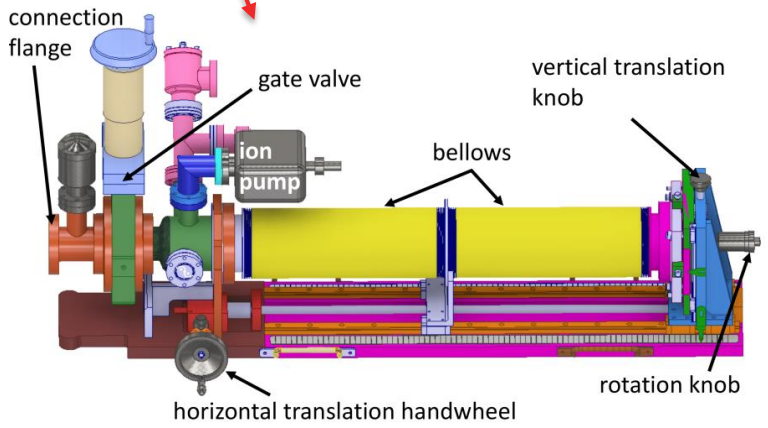
Problems and their mitigation

- Pointing instability
  - Use of rigid support for optics
  - Applying beam imaging
  - Transport in vacuum
- Beam drifts
  - Temperature stabilization
  - Alignment algorithm
- Optics damage
  - Beam size increasing
  - Decreasing the pulse energy within the possible margin:
    E (IR) < 200 mJ

AWAKE Run 1 e- injector





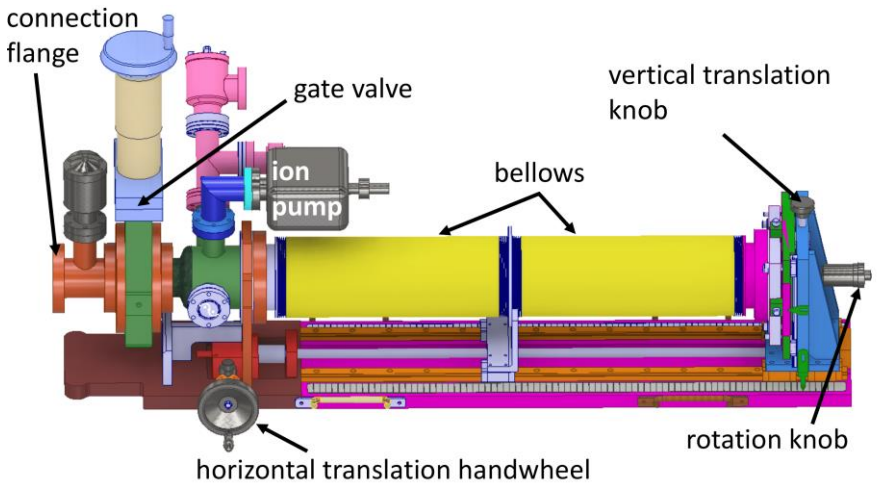


Cs_2Te cathodes produced in the Photoemission lab

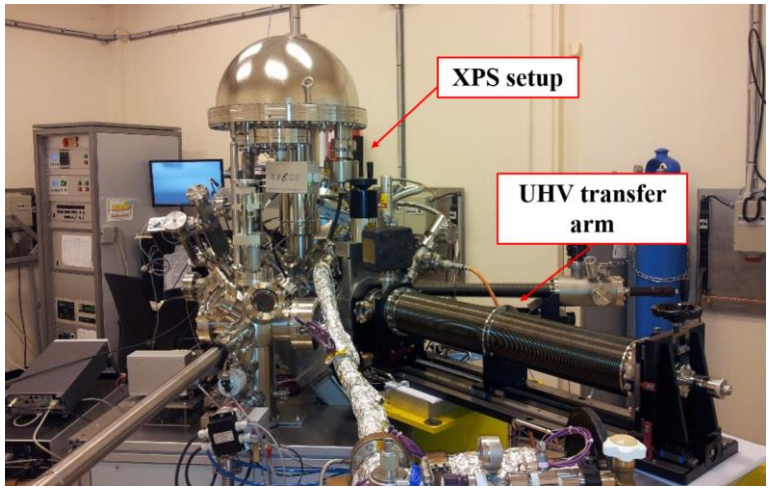
Parameter	Value
Beam energy	18.5 MeV
Energy spread	0.5 %
Stability	10^-2
RMS bunch length	2-3 ps
Bunch charge	100-600 pC
Emmitance	2-5 um
Beam size plasma focus	~190 um

Photoemission lab

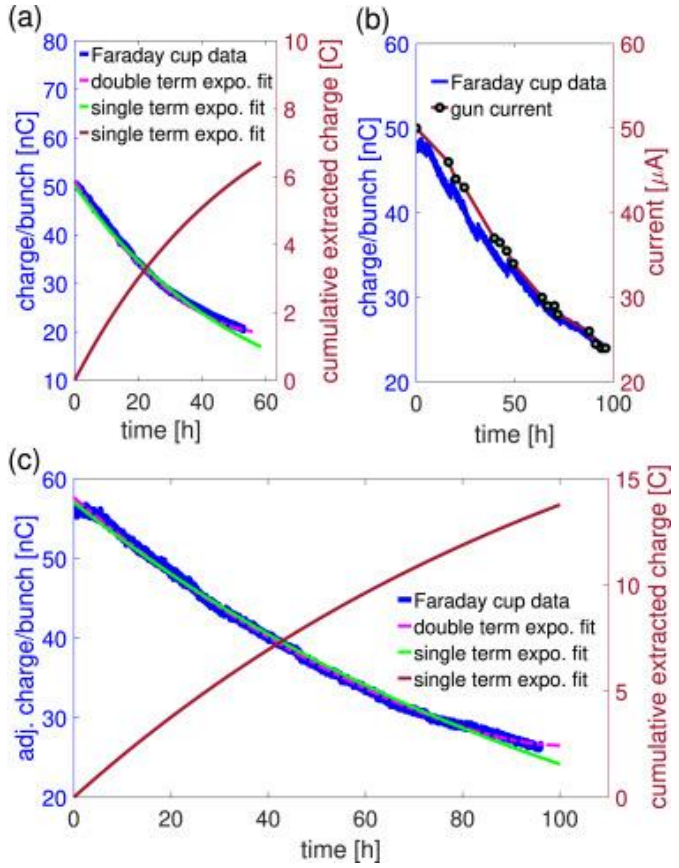
Photocathode transport device



XPS Analysis system



Lifetime studies

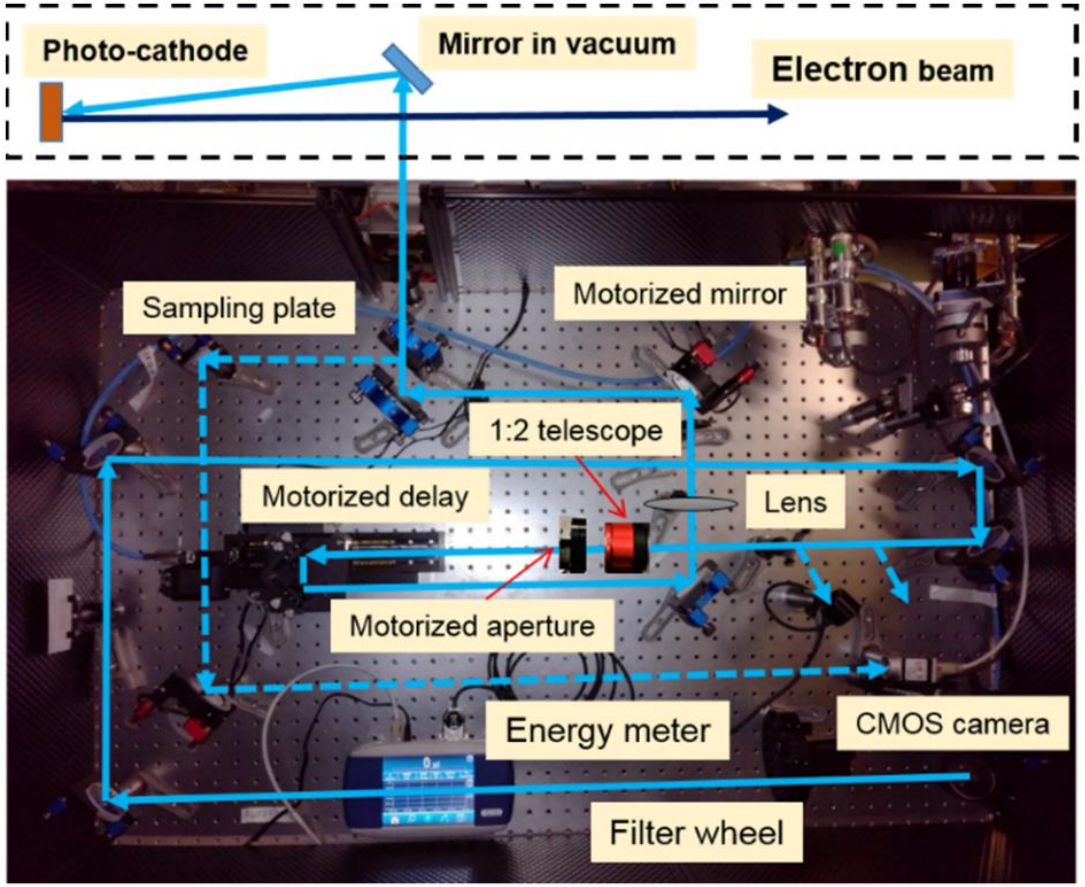


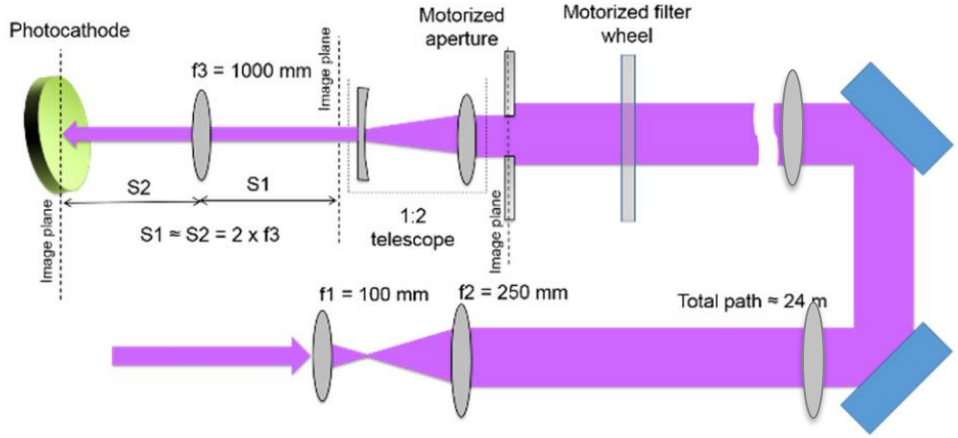
Collaboration

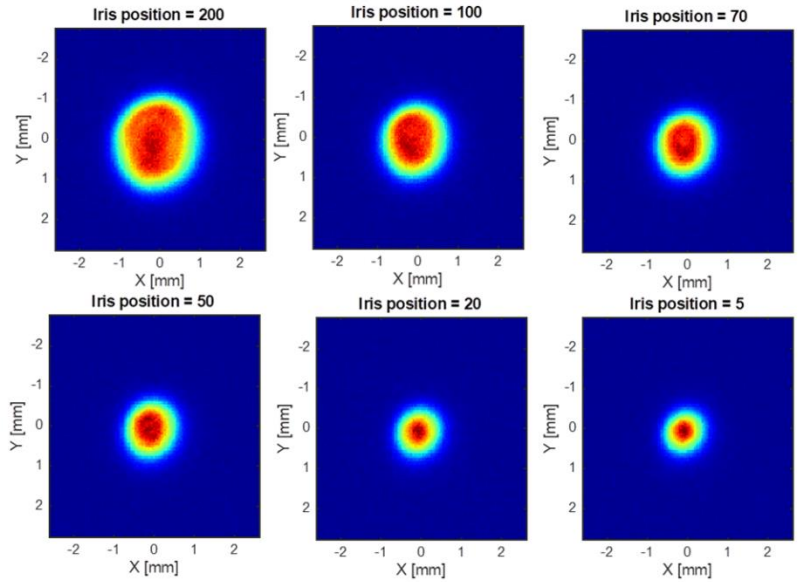
Science & Technology Facilities Council
Daresbury Laboratory

H. Panuganti, E. Chevallay, V. Fedosseev, M. Himmerlich, Synthesis, surface chemical analysis, lifetime studies and degradation mechanisms of Cs-K-Sb photocathodes, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 986, 2021

AWAKE injector

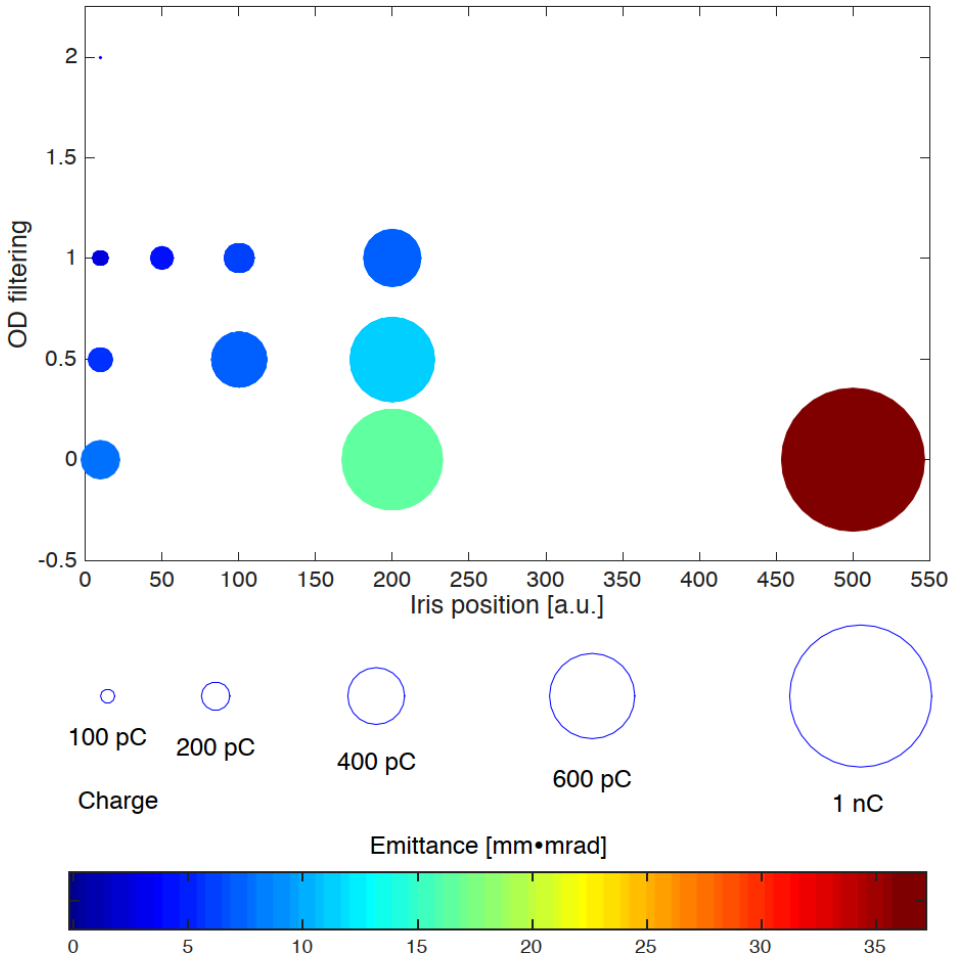


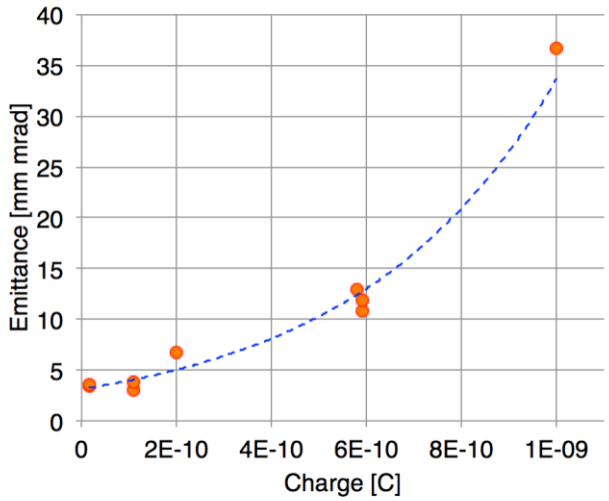


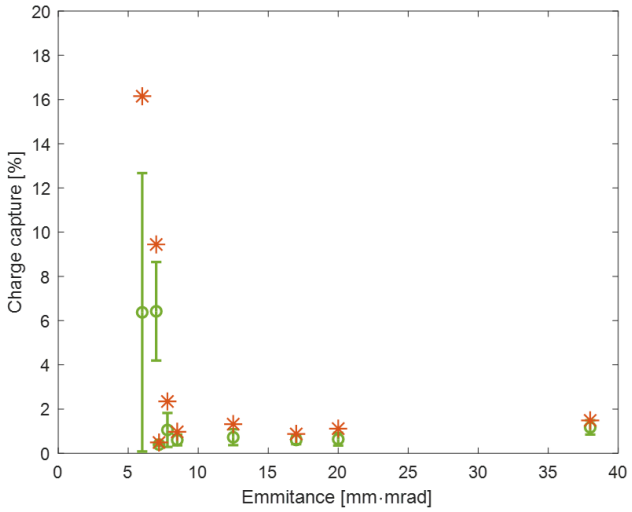


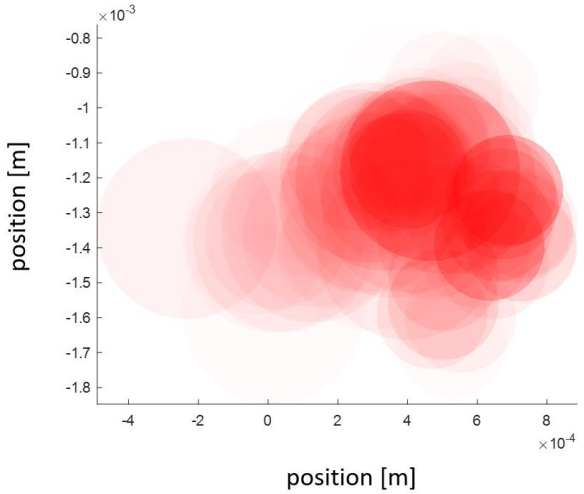
V. Fedosseev et al “Generation and delivery of an ultraviolet laser beam for the RF-photoinjector of the AWAKE electron beam”, 10th International Particle Accelerator Conference (2019)

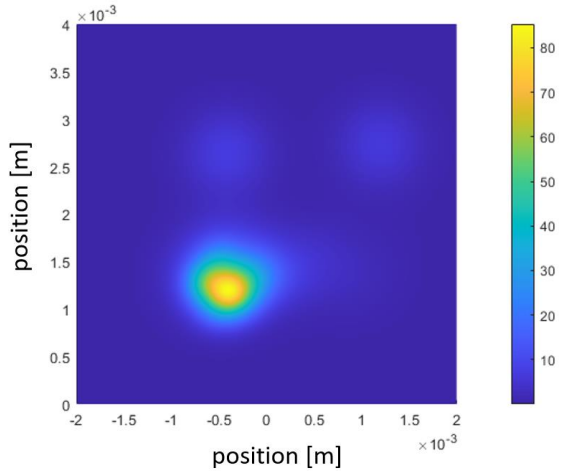
Mapping charge capture at AWAKE







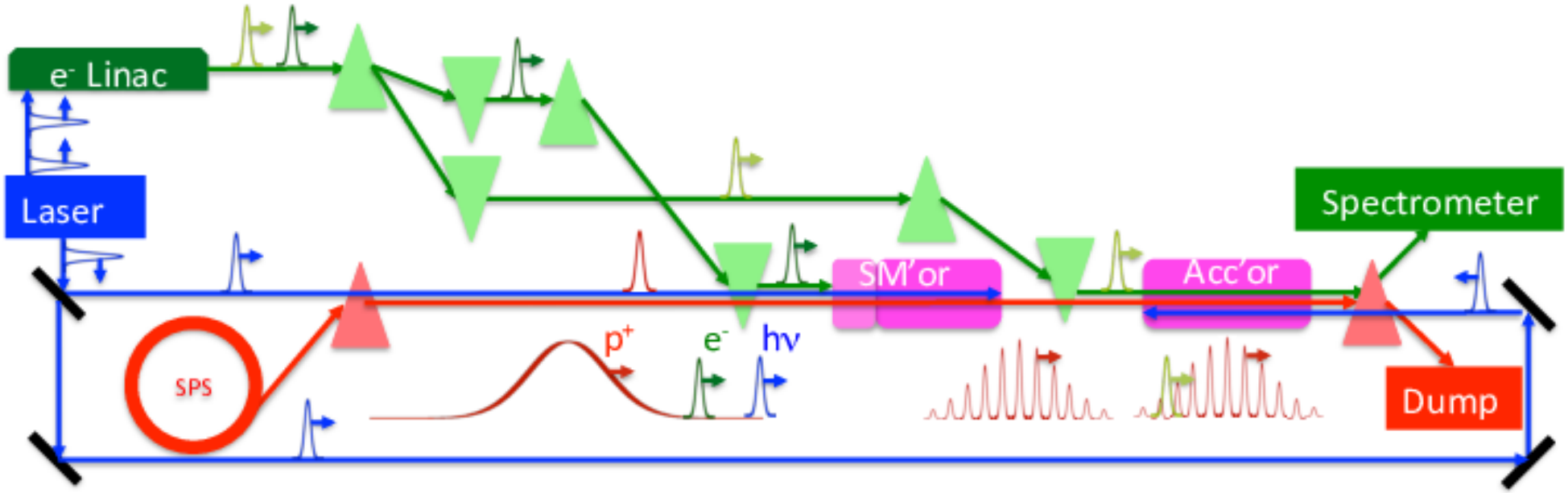




E. Granados et al “Mapping charge capture and acceleration in a plasma wakefield of a proton bunch using variable emittance electron beam injection”, in preparation (2021)

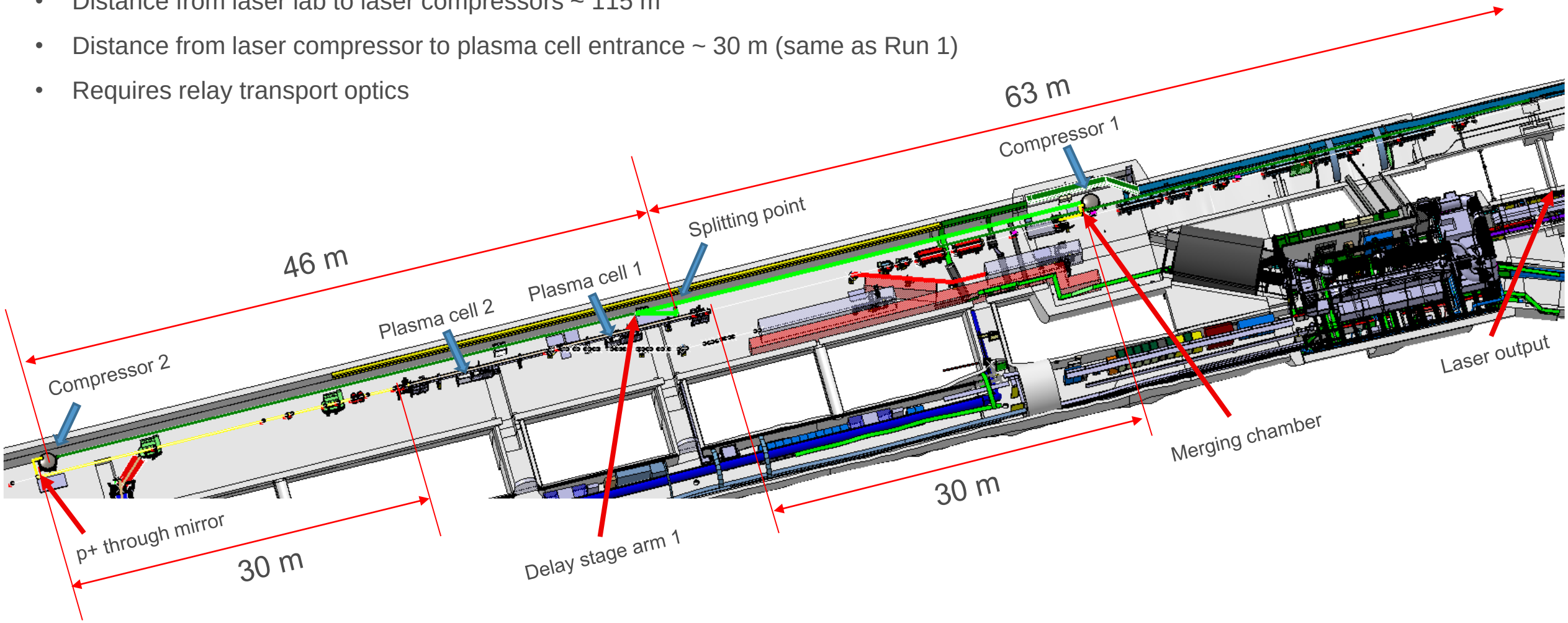
AWAKE 2

- The experiment will use two plasmas, electron bunchseeding for the SM process, on-axis external injection of an electron bunch and electron bunch parameters to reach plasma blow-out, beam loading and beam matching.

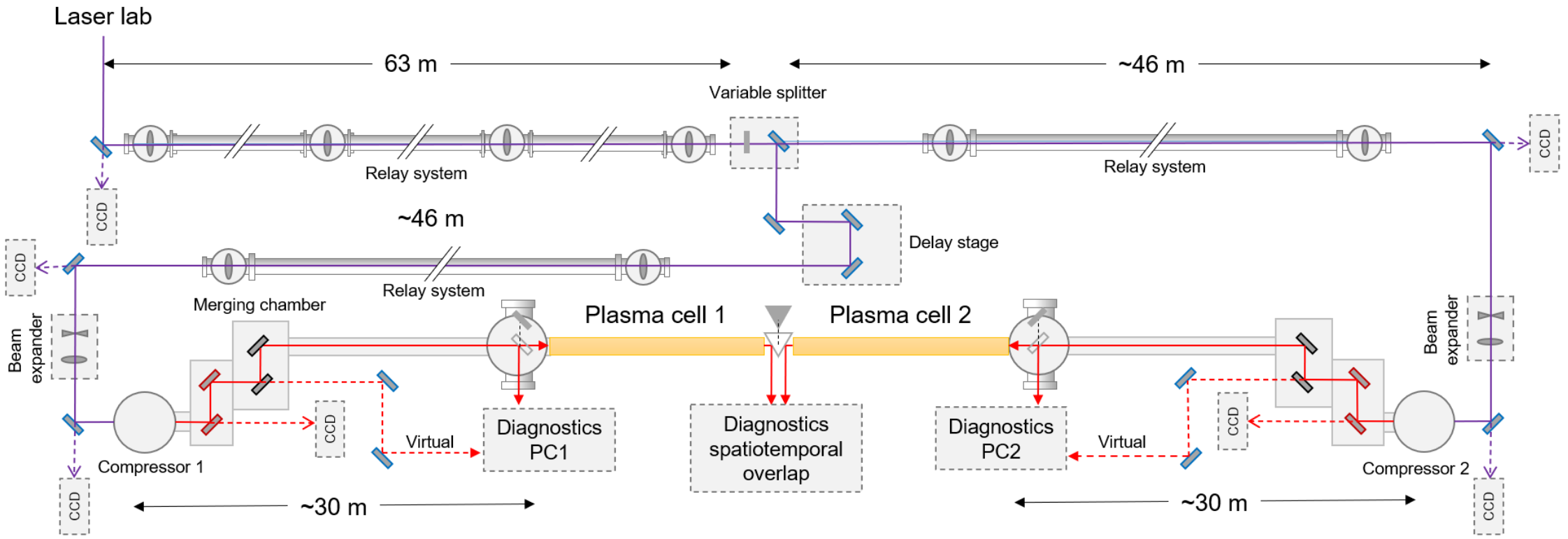


AWAKE 2

- Distance from laser lab to laser compressors ~ 115 m
- Distance from laser compressor to plasma cell entrance ~ 30 m (same as Run 1)
- Requires relay transport optics



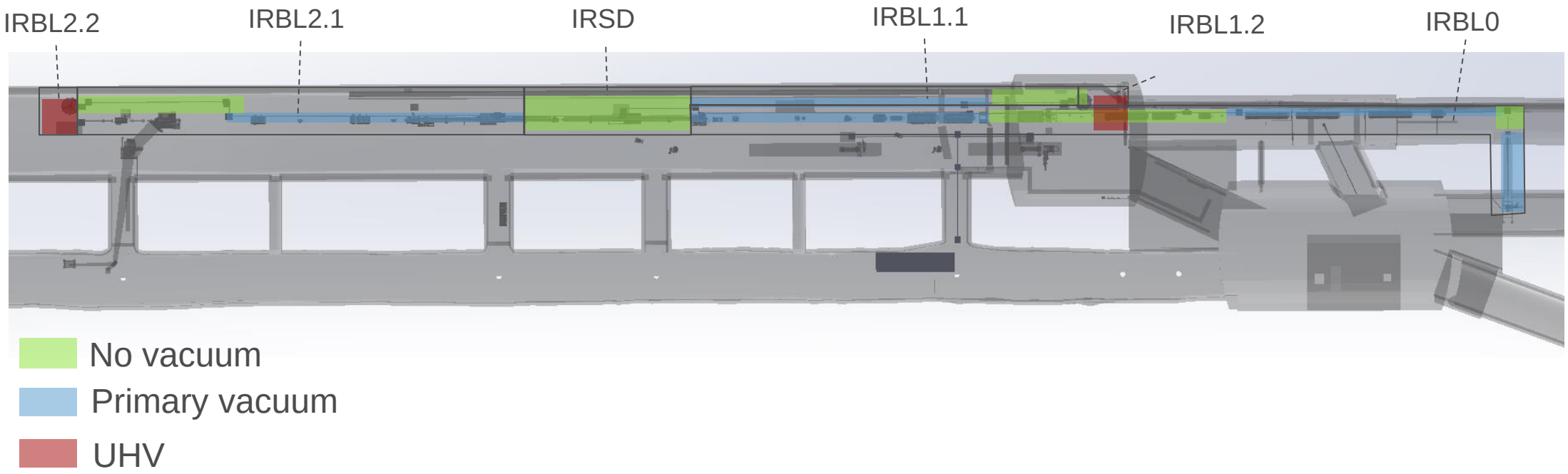
AWAKE 2



- Relay imaging systems require only low-level primary vacuum, blue mirrors are “in air”
- Focusing on plasma cell attained by mismatching beam expanders
- Content of diagnostics sets still to be determined, location of safety devices, etc.

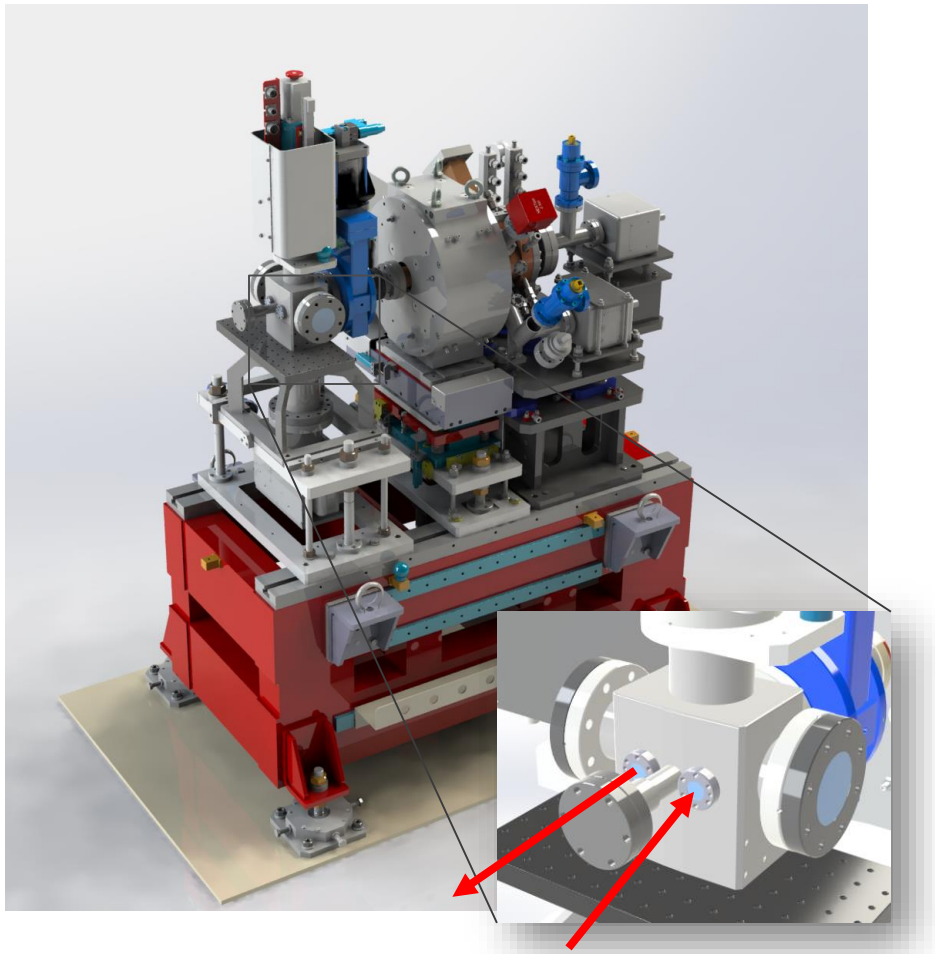
AWAKE 2

- IRBL0: IR Beamline from laser lab to IRSD (IR Split and delay sub-system)
- IRSD: IR Split and delay system, produces IR beams for each plasma cell
- IRBL1.1: IR Beamline from IRSD to Compressor 1
- IRBL1.2: Merging chamber for Compressor 1
- IRBL2.1: IR Beamline from IRSD to Compressor 1
- IRBL2.2: Merging chamber for Compressor 1

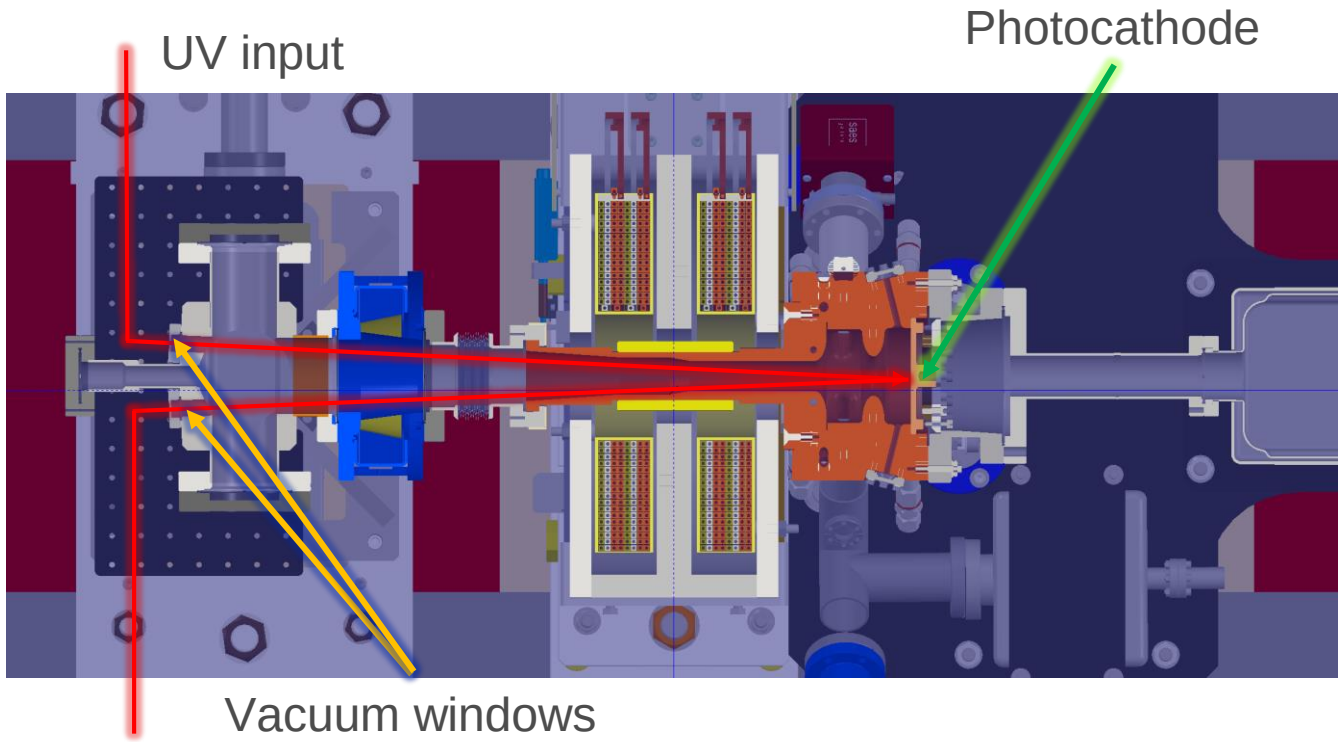


CTF2 femtosecond e- gun

Femtosecond gun from INFN

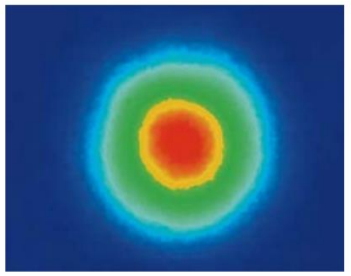


- Will be installed at CLEAR during 2021
- Possibility of *virtual* and *real* diagnostics
- Initially with Cu cathode, eventually Cs_2Te
- Compatible load-lock system

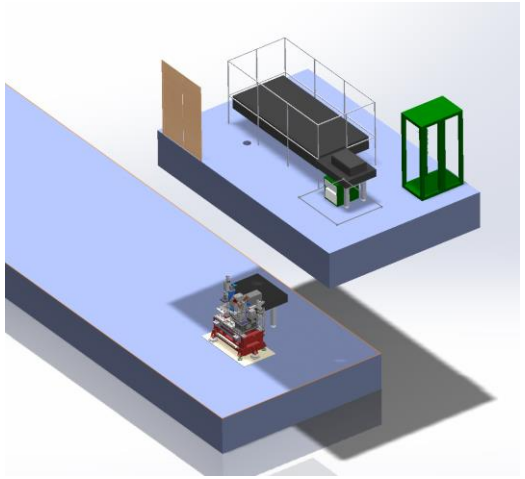


CTF2 femtosecond e- gun

- Light Conversion Pharos system already purchased (delivery Dec 2020, integration & commissioning mid-2021)
  - Yb-doped fiber technology
- Designed to operate with both Cu or Cs2Te
- Variable pulse duration from < 300 fs up to > 5 ps
  - Requires multiple harmonic stages or UV stretcher.
- Synchronizable to RF (1.5 GHz) reference
- Expected maximum charge production:
  - Cu cathode : **~ 400 pC**
  - Cs_2Te : > **1 nC**



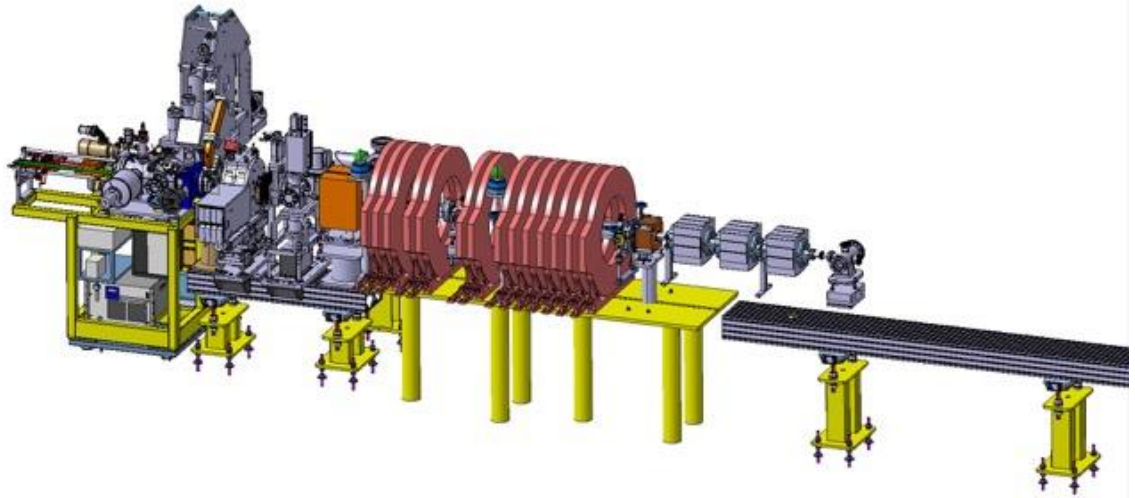
Typical PHAROS near field beam profile at 200 kHz

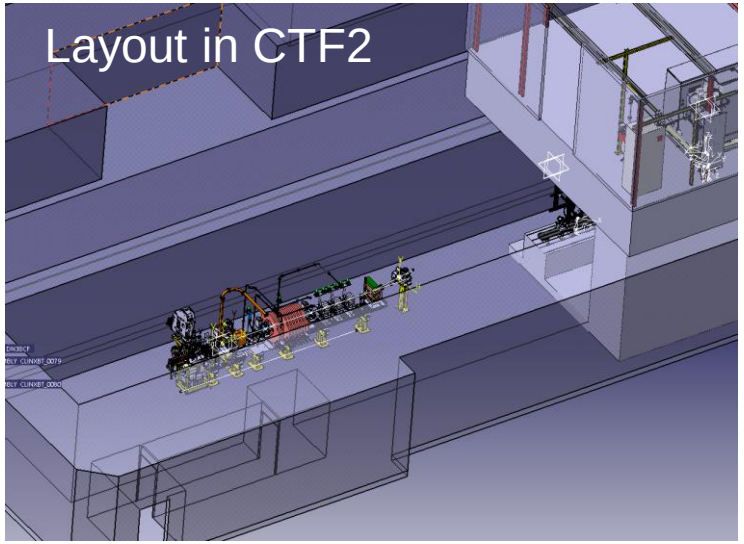


Pulse energy @ 1030 nm	2 mJ
Pulse energy @ 257 nm	~ 200 uJ *
Repetition rate	0 – 1 MHz
Average Power	20 W
M^2	<1.3
Pulse duration	190 fs – 10 ps

AWAKE Run 2 femtosecond e- gun goals

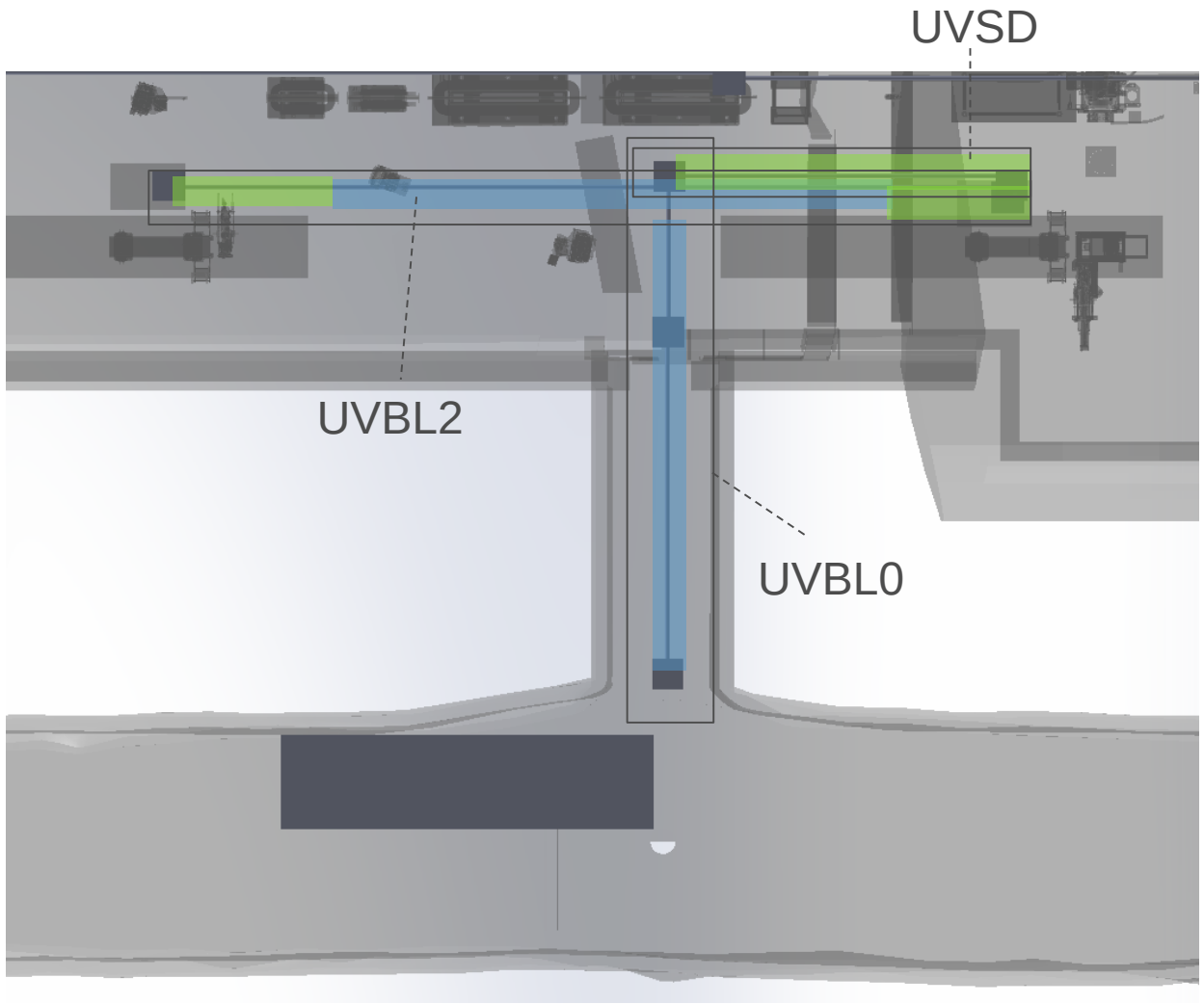
- **Demonstrate velocity bunching** with x-band and **emittance preservation/control**
- Show **reliable high gradient** x-band operation
- **Study mechanical/integration** aspects
- Test **diagnostics**
- **Optimise final design** for AWAKE
- Get team together, **gain momentum** for challenging AWAKE Run2 injector





Prototype injector in CTF2:
60-70 MeV and typically 100 pC single bunch, bunch length 200-300 fs (goal), emittance ~ 1 um, Laser osc. frequency 75 MHz, rep. rate up to 3 kHz, Length: 5 m

AWAKE Run 2 e- gun integration



- UVBL0: UV Beamline from UV laser lab to 1st electron gun (UV Split and delay sub-system)
- UVSD: UV Split and delay system, produces UV beams for each e- gun
- UVBL2: UV Beamline from gun 1 to gun 2

No vacuum
Primary vacuum
UHV

AWAKE/CLEAR Electron Injector timeline

AWAKE 150 MeV									
Schedule	2020	2021	2022	2023	2024	2025	2026	2027	2028
Final design									
Mechanical design/Integration									
Procurement									
Installation									
Commissioning									
Start experiments									

CTF2 prototype/CLEAR 60 MeV									
Schedule	2020	2021	2022	2023	2024	2025	2026		
Final design									
Mechanical design									
Procurement									
Installation									
Commissioning									
Start experiments in CTF2									
Move to CLEAR									
Exp in CEAR									

Installation in CLEAR

Thank you for
your attention!