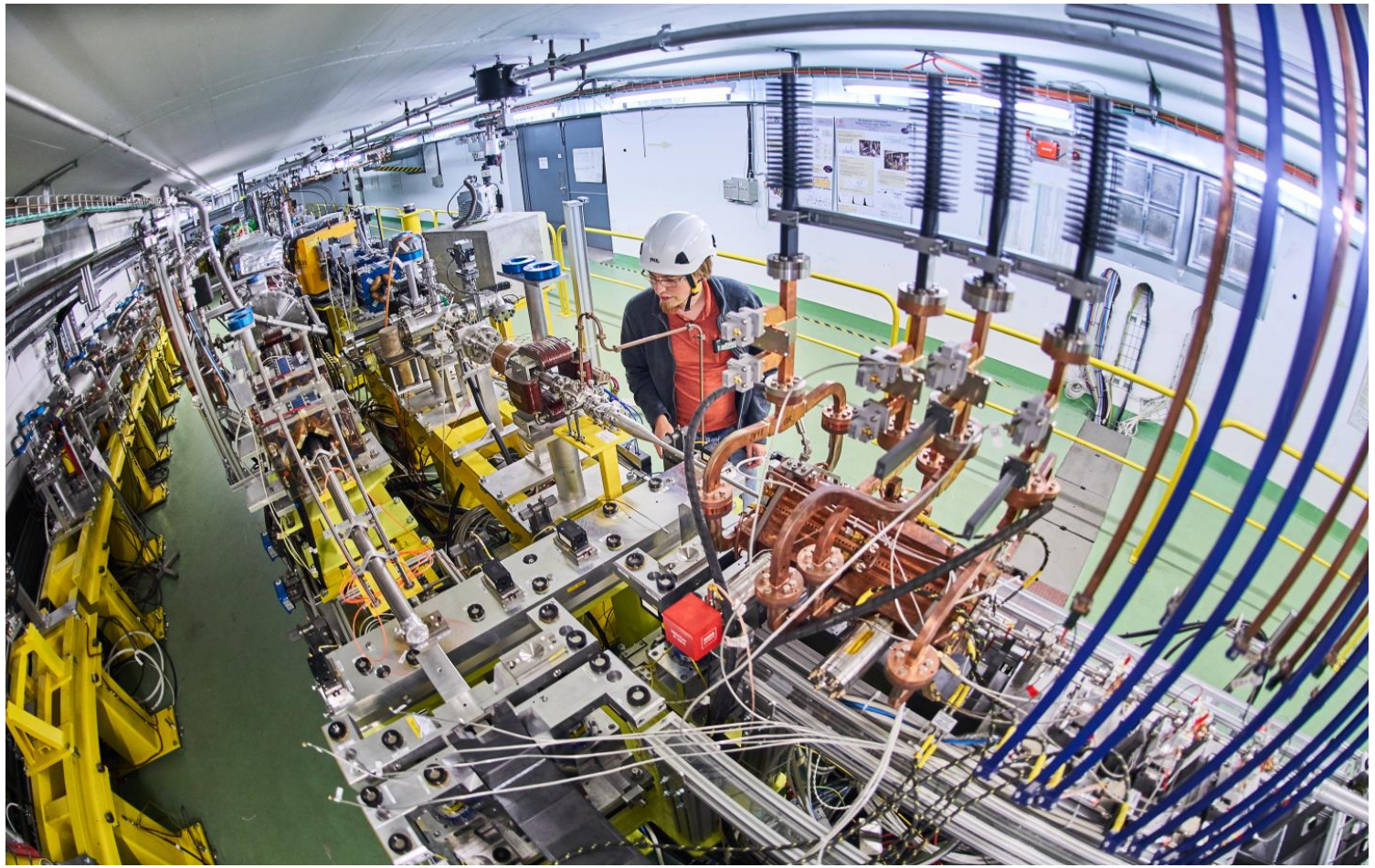
CLEAR BEAM TRAINING

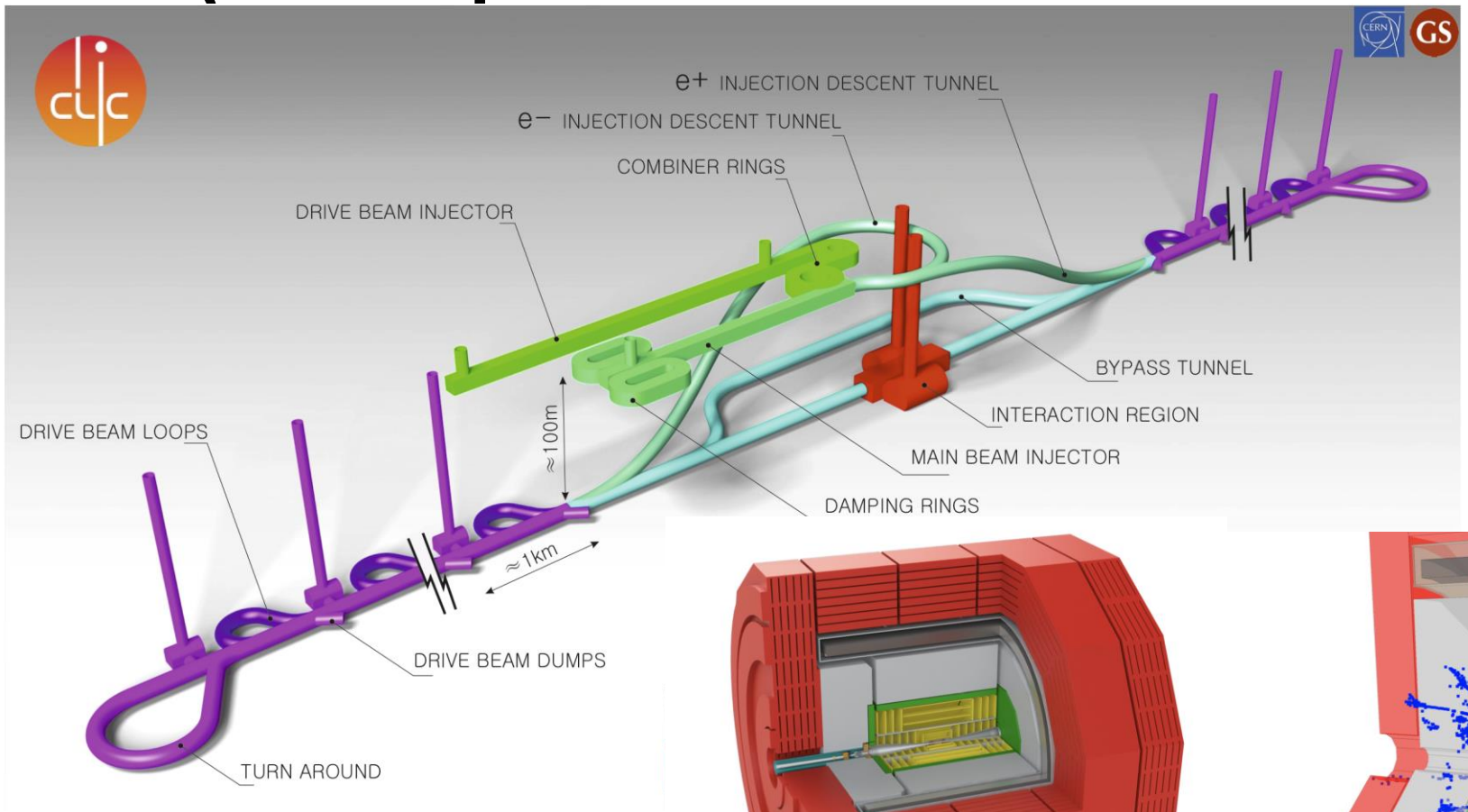
Have a chance to operate your own beam at CERN

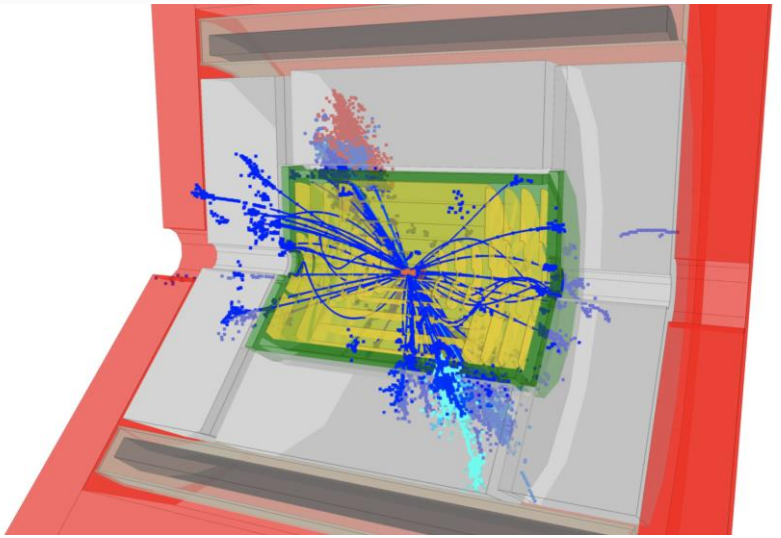
OUTLINE:

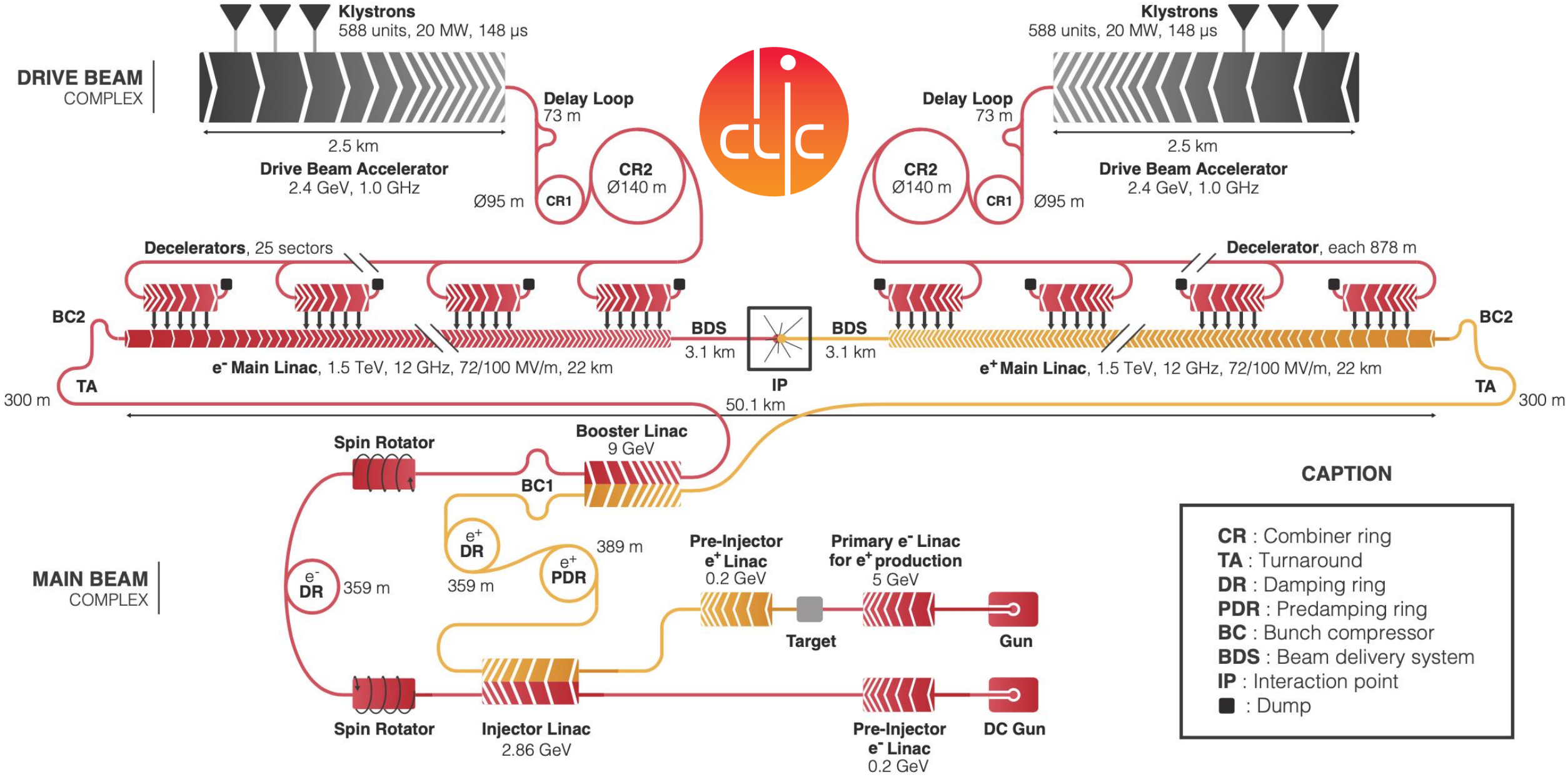
- History
  - CLIC
  - CTF3
- CLEAR
  - Layout
  - Experiment
- Proposed activity
- Contest



CLIC (Compact LInear Collider)

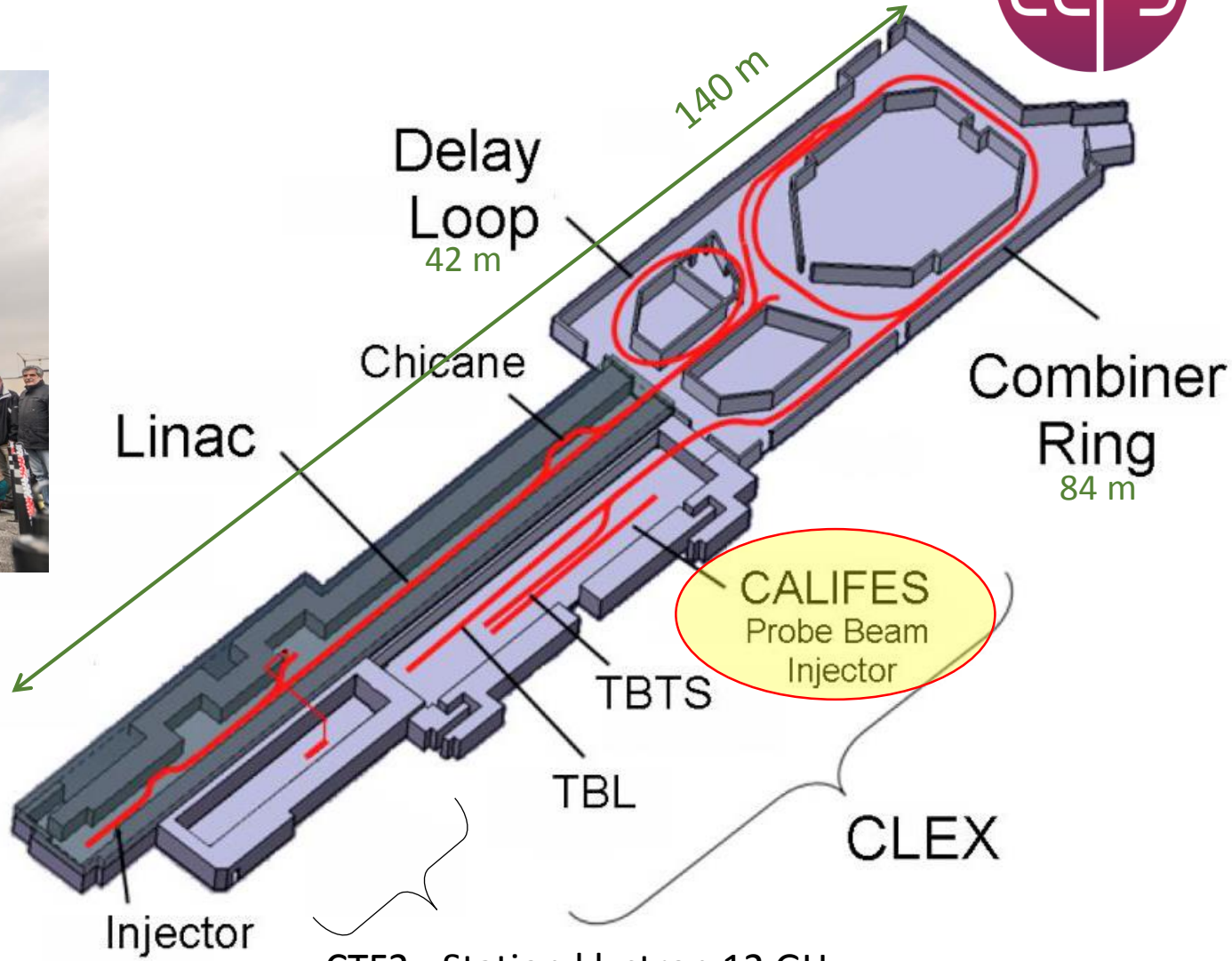





DRIVE BEAM
COMPLEX
Klystrons
588 units, 20 MW, 148 μs
2.5 km
Drive Beam Accelerator
2.4 GeV, 1.0 GHz
Delay Loop
73 m
Ø95 m
CR1
CR2
Ø140 m
Klystrons
588 units, 20 MW, 148 μs
2.5 km
Drive Beam Accelerator
2.4 GeV, 1.0 GHz
Delay Loop
73 m
CR2
Ø140 m
CR1
Ø95 m
Decelerators, 25 sectors
Decelerator, each 878 m
BC2
BDS
3.1 km
BDS
3.1 km
BC2
e⁻ Main Linac, 1.5 TeV, 12 GHz, 72/100 MV/m, 22 km
e⁺ Main Linac, 1.5 TeV, 12 GHz, 72/100 MV/m, 22 km
300 m
TA
IP
50.1 km
TA
300 m
Spin Rotator
Booster Linac
9 GeV
BC1
e⁺
DR
389 m
e⁻
DR
359 m
359 m
e⁺
PDR
Pre-Injector
e⁺ Linac
0.2 GeV
Primary e⁻ Linac
for e⁺ production
5 GeV
Target
Gun
MAIN BEAM
COMPLEX
Spin Rotator
Injector Linac
2.86 GeV
Pre-Injector
e⁻ Linac
0.2 GeV
DC Gun
CAPTION
CR : Combiner ring
TA : Turnaround
DR : Damping ring
PDR : Predamping ring
BC : Bunch compressor
BDS : Beam delivery system
IP : Interaction point
■ : Dump

CTF3 (CLIC Test Facility)

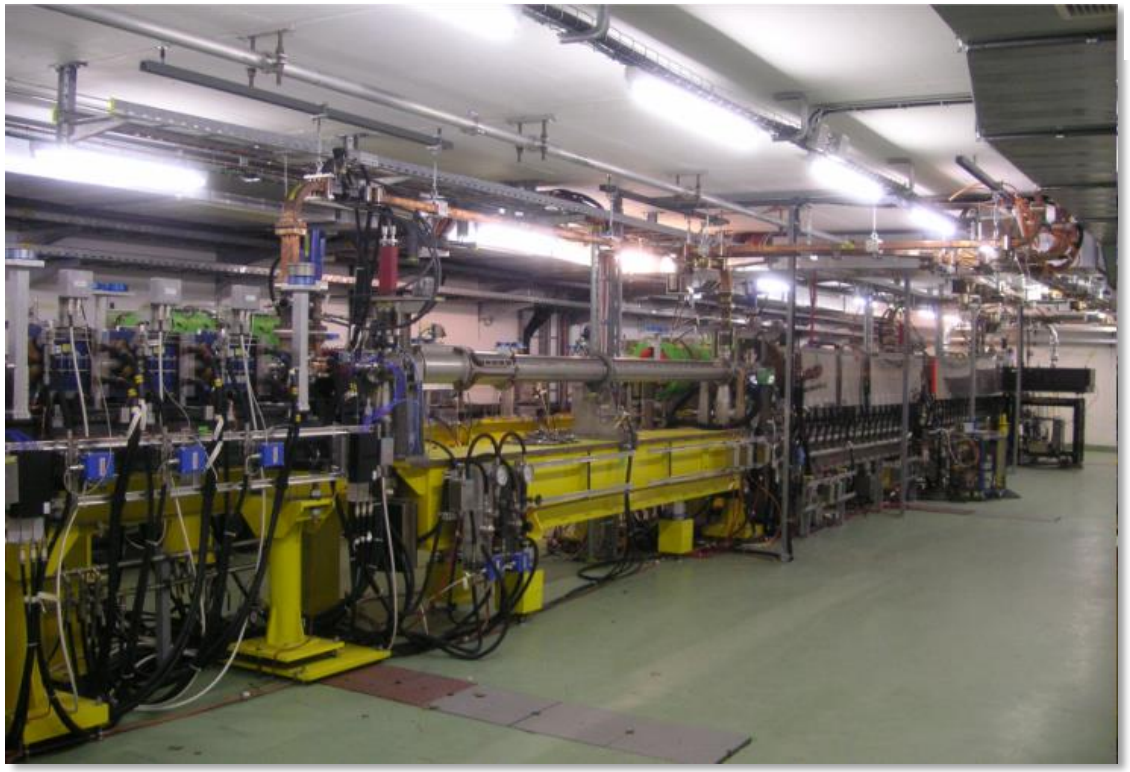
A (small) mock-up of the CLIC



CTF2 - Station klystron 12 GHz

CTF3 scientific program completed as planned in December 2016

What to do with CTF3 hardware & building? ➔



Expression of Interest for the future operation of the CALIFES linac

Prepared by: E.Adli (Univ. of Oslo), P.Burrows (Univ. of Oxford), R.Corsini (CERN), S. Stapnes (CERN)

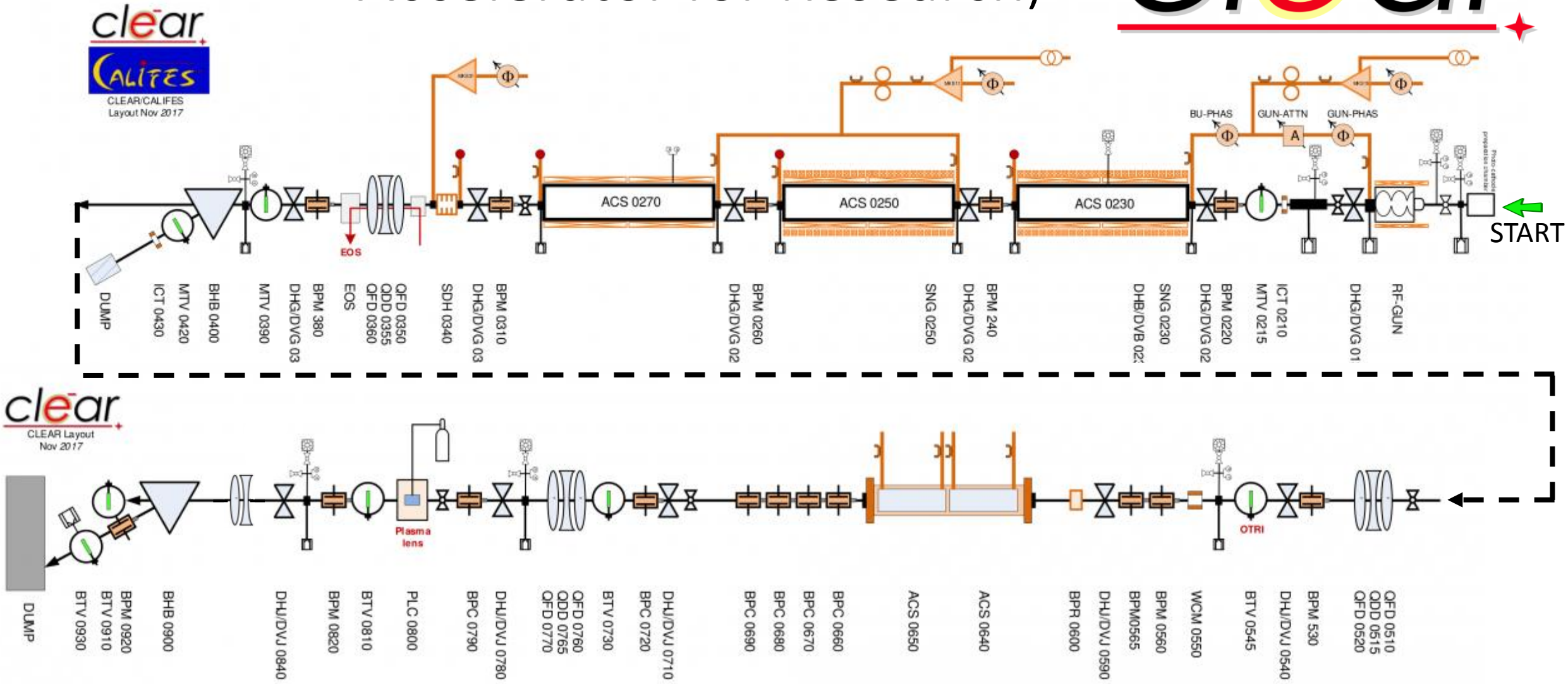
Abstract

In this document we propose to operate the CALIFES electron linac at CERN, presently used as the probe beam line of CTF3, as a stand-alone user facility from 2017 onwards when CTF3 is closed down. The possible uses include general accelerator R&D and studies relevant for existing and possible future machines at CERN, involving a potentially large external user community. The resources required are around 2 MCHF/year (M+P).

- Longer document send in February 2016 CALIFES_document.pdf
- Positive statement by the CLIC Review Panel in March 2016
- CALIFES Workshop, October 2016

  CLEAR (ED) : Cern Linear Electron Accelerator for Research (and Education)
- Final proposal (CLEAR) and approval in December 2016

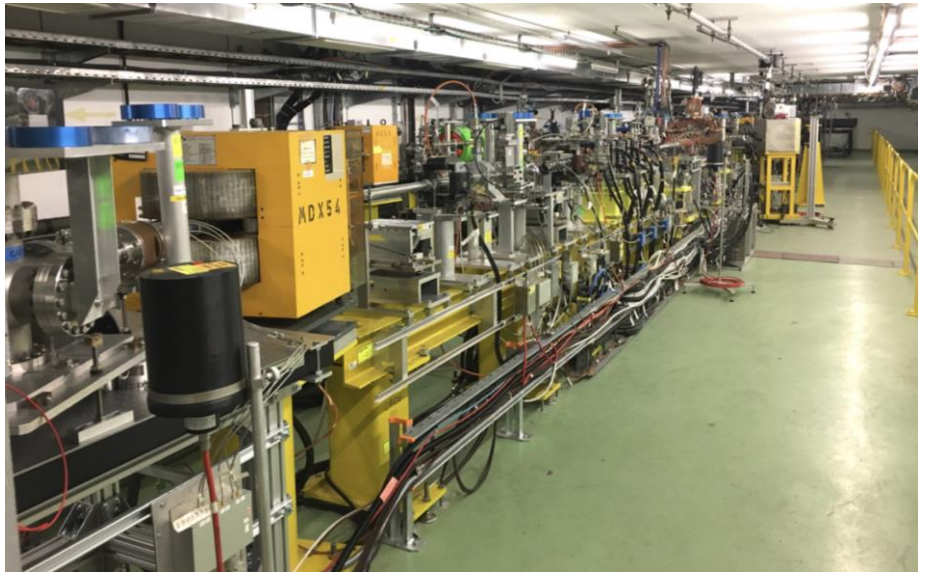
CLEAR (CERN Linear Electron Accelerator for Research)



Main activities:

- CLIC & high-gradient X-band
- Instrumentation R&D
- VESPER irradiation test station
  - Electronic components for space applications with ESA (soon with NASA)
  - Medical applications (VHEE)
  - Electronic components for accelerators and detectors
- Plasma
  - Focusing
  - Wakes
- THz
  - Dielectric structures

A REALLY FLEXIBLE TEST FACILITY



Beam parameters	Range	Comments
Energy	60 – 220 MeV	More flexible with 2 klystrons. > 220 MeV with pulse compression.
Energy Spread	< 1 MeV (FWHM)	
Bunch Charge	1 pC – 400 pC	Photocathode changed - laser improvement - ongoing studies
Bunch Length	0.2 ps – 10 ps	0.1 ps with velocity bunching
Normalized emittances	3 μm to 30 μm	Bunch charge dependent
Repetition rate	0.8 to 5 Hz	25 Hz with klystrons and laser upgrade
Number of micro-bunches in train	1 to >150	Single bunch capability assessed
Micro-bunch spacing	1.5 GHz (Laser)	3.0 GHz: Dark current

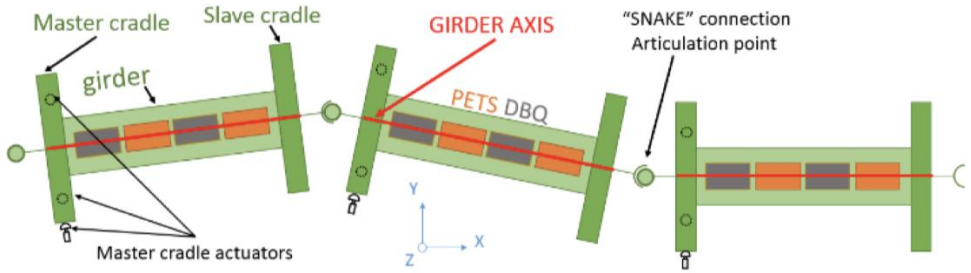
CLIC & high-gradient X-band

Present experiments:

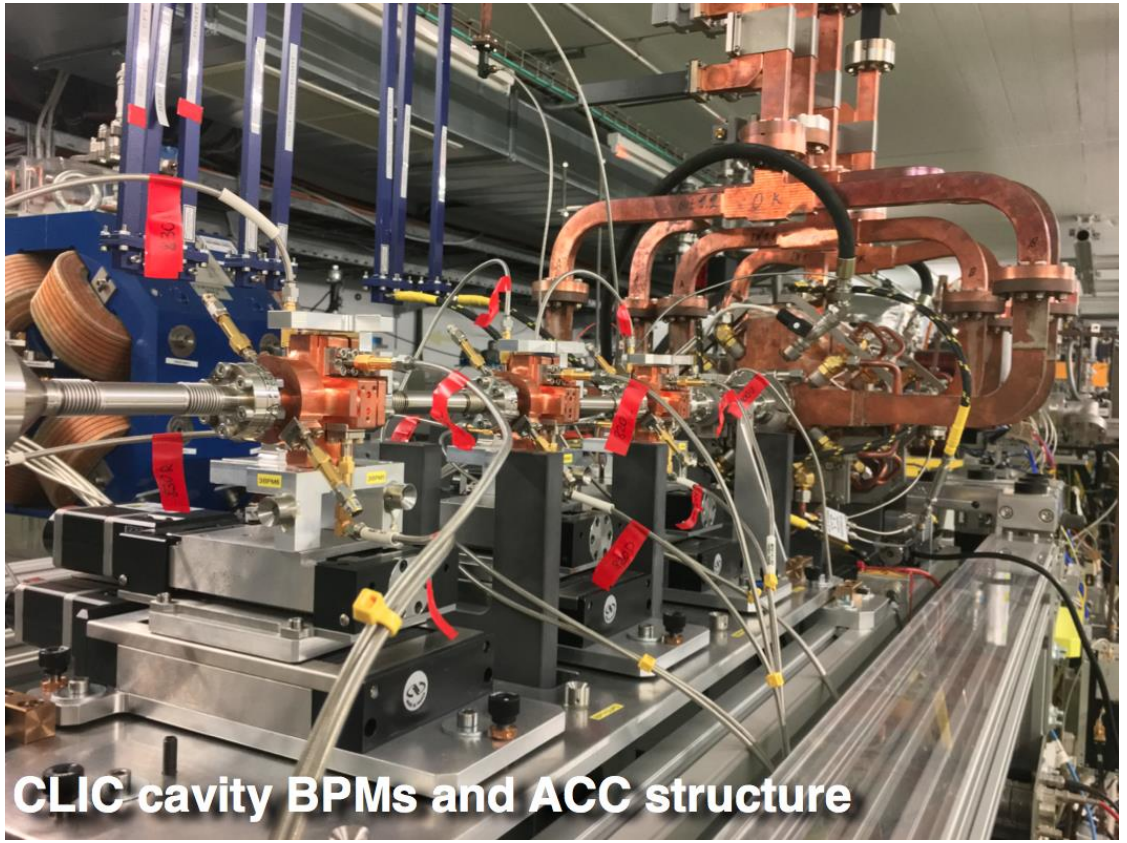
- Wake-Field monitors
- Wake-field kicks
- CLIC cavity BPMs

Possible tests:

- RF kicks
- Breakdown kicks
- RF effect on WFMs
- Stability & reliability runs



Former CLIC Module



R. Corsini

XBAND Power source will be connected

Beam Instrumentation R&D

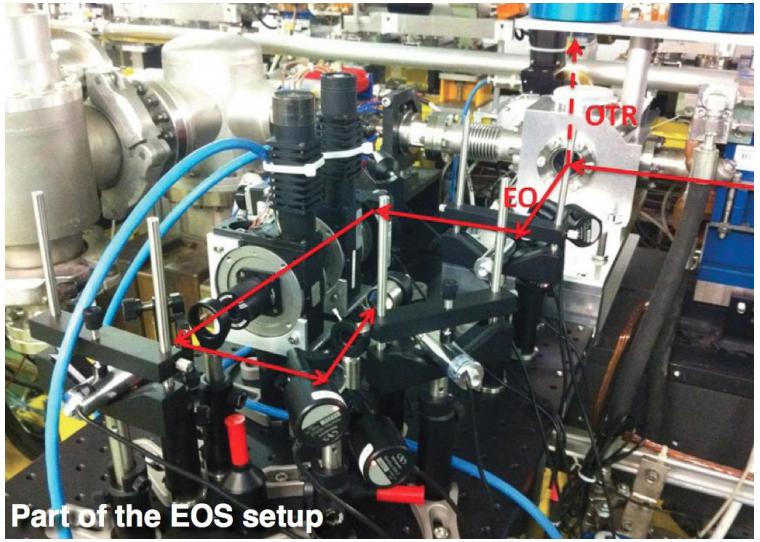
Many activities planned (most ongoing)

Two main goals:

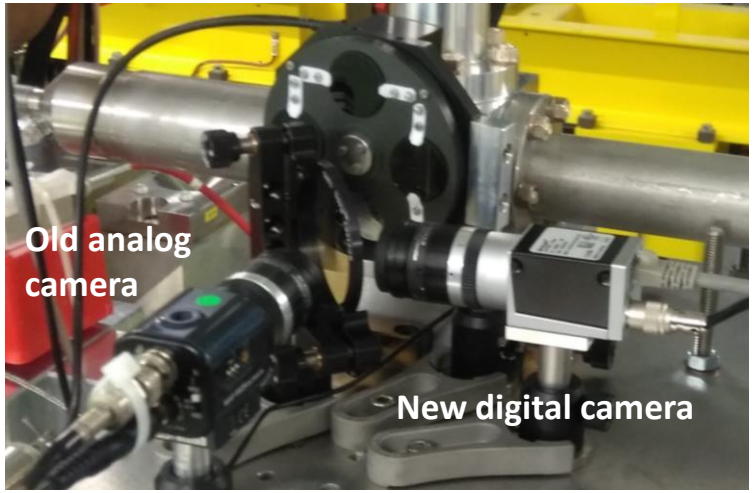
1) Consolidate and improve beam instrumentation for CLEAR

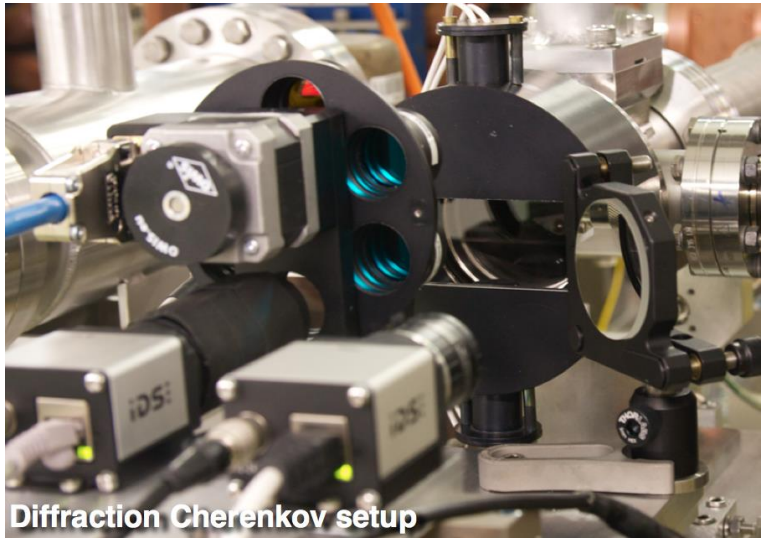
2) Diagnostics R&D

Direct applications to CERN accelerator complex & potential for future applications



Electro-Optical monitors





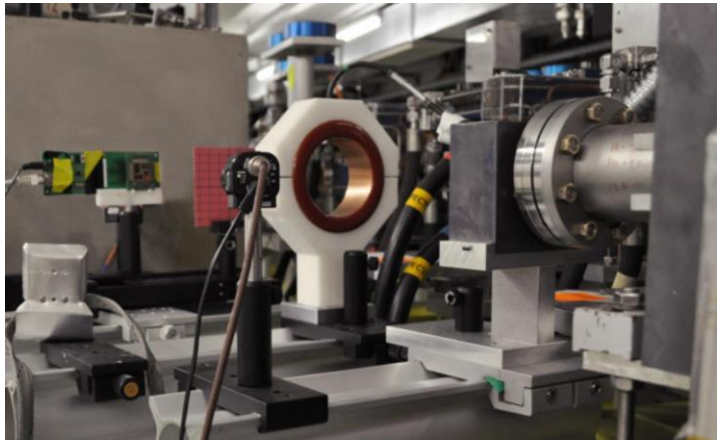
Very energetic Electron facility for Space Planetary Exploration missions in harsh Radiative environments

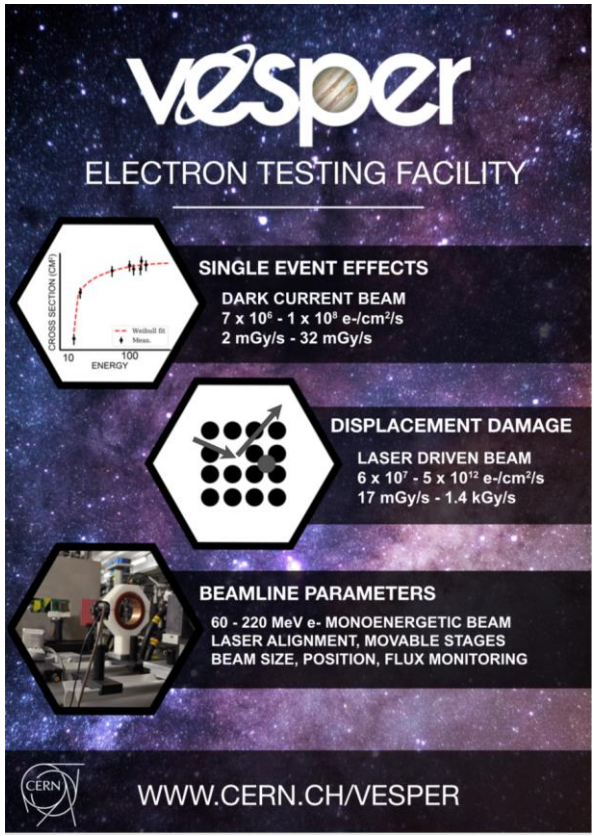
Beam line already developed and tested in CALIFES

- Improved diagnostics, stability and energy range (60 - 220 MeV)

Scientific program

- ESA collaboration
- Used also for test of AWAKE spectrometer screen
- Interest for detector electronics (Uppsala/ATLAS - wireless communication)
- Several medical applications as VHEE
- Contact with NASA (pencil beams)

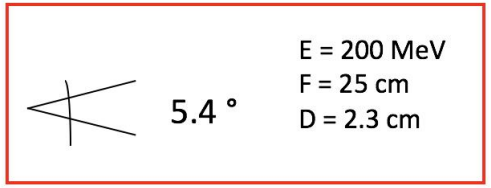




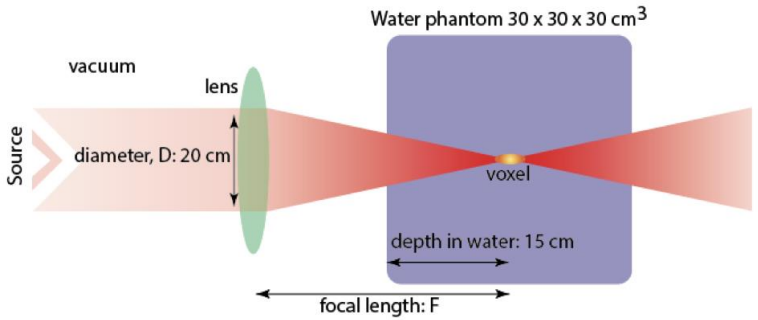
Medical irradiation tests

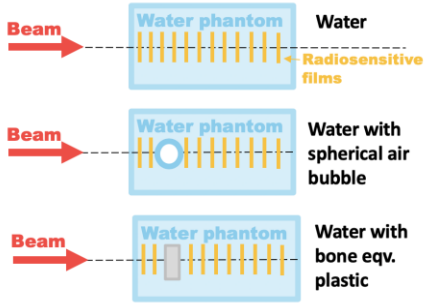
Scope of the experiment

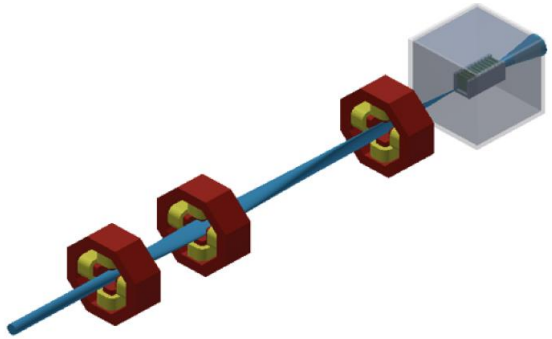
Focus the beam on the tumour to minimize the dose on the nearby healthy tissues

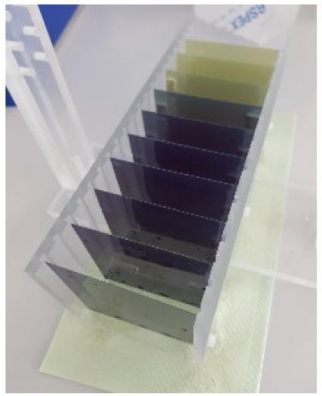


E = 200 MeV
F = 25 cm
D = 2.3 cm









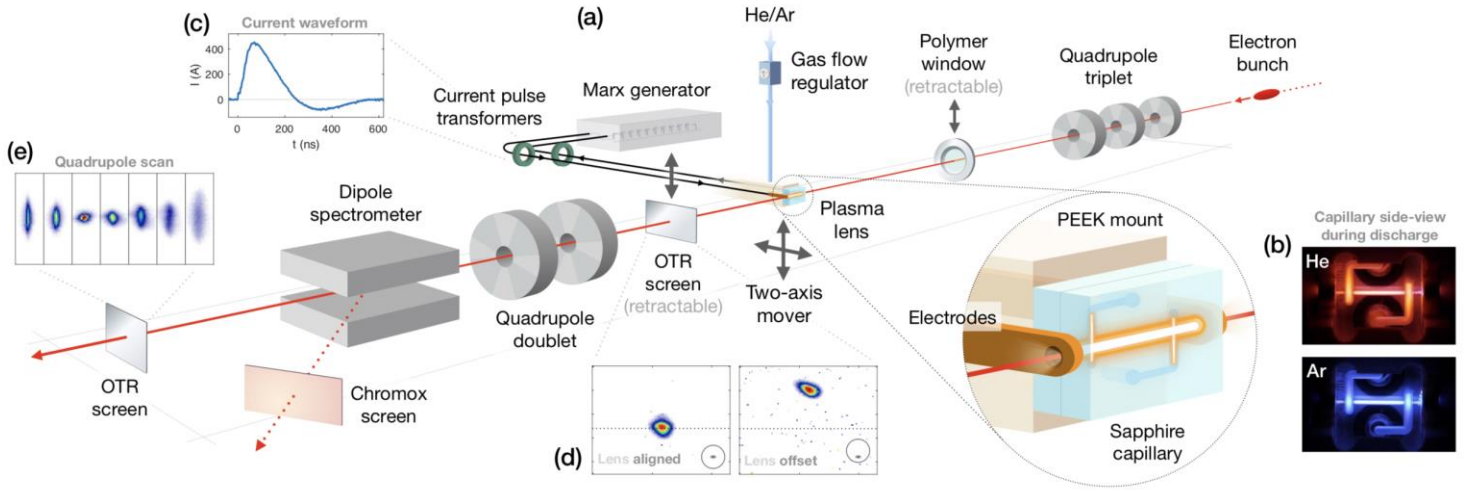
Plasma lens

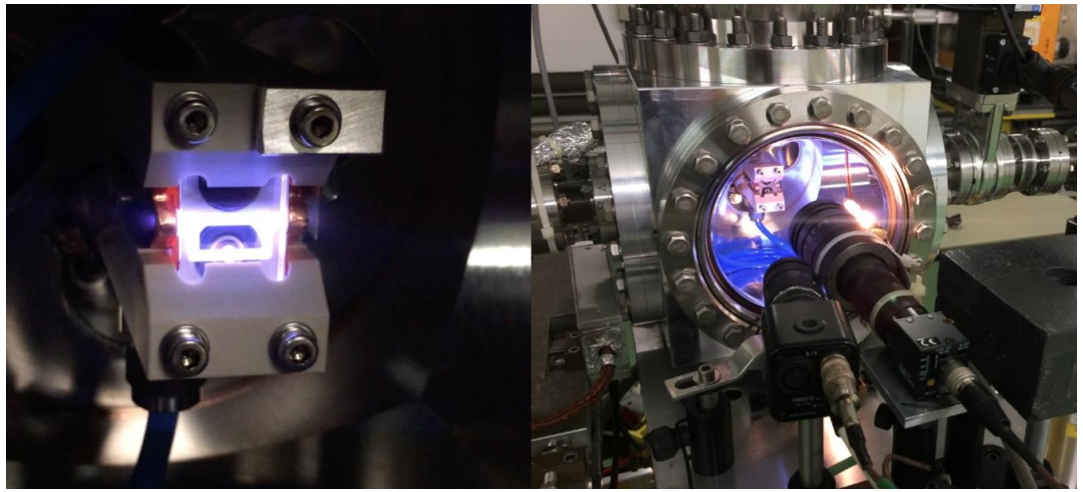
1 mm X 15 mm gas fill sapphire capillary
Marx Bank to break down the gas and to send up 500A in the gas channel.

Measured the magnetic kick in a plasma channel with different gases.

Observed a linear focusing and emittance preservation with argon. And a spherical aberration in helium (as was predicted by theory)

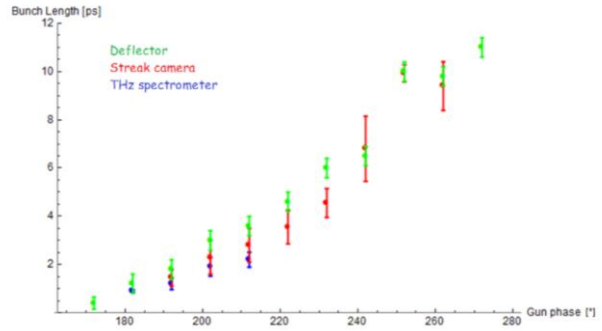
Also studying self beam self focusing by wavefields for intense beam

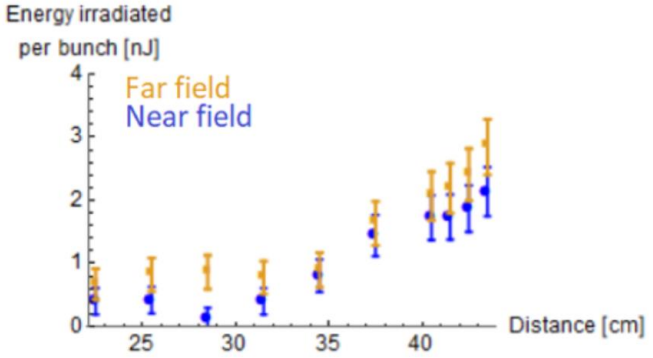


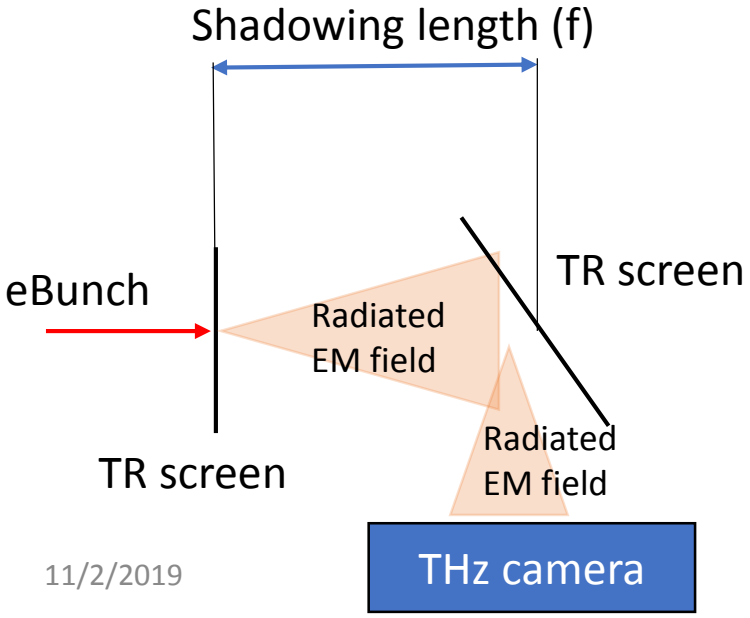


THz studies

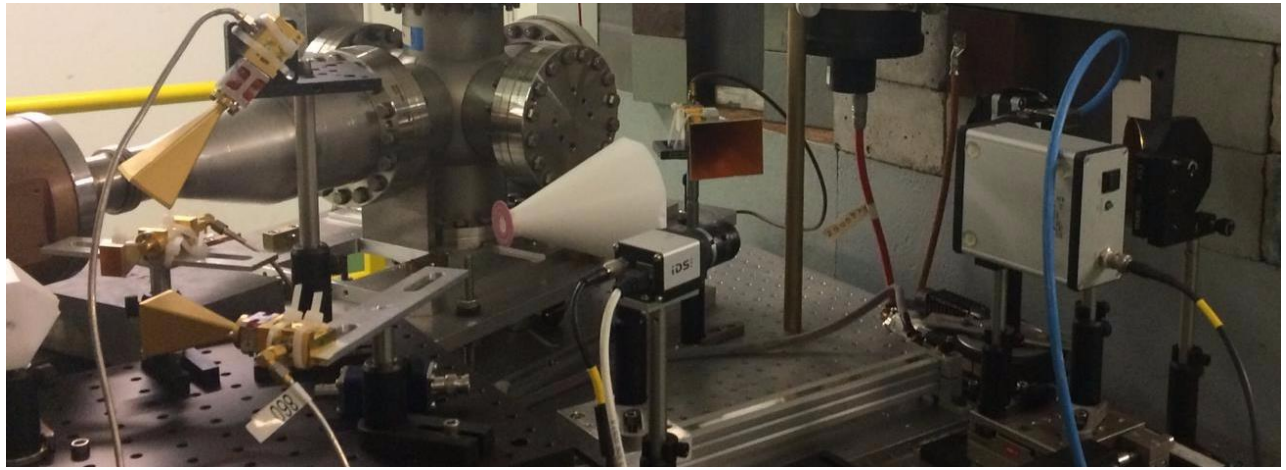
- First tests in sub-THz region, demonstrated use as bunch length diagnostics
- Characterization of beam-produced THz radiation from transition radiation (TR) screen + shadowing studies, using THz camera
- Bunch length diagnostics for CLEAR
  - Close to be operational - Teflon conical Cherenkov diffraction radiator, 4 frequency detection bands.
- High power THz from different sources
  - Tested so far: diamond, TR screens, Teflon, gratings, metamaterials







Actual Shadowing setup



Proposed activity:

- What do we do before starting an accelerator?
- GUN setup & transport the beam
  - CLEAR photo-injector characterisation
  - CLEAR LINAC characterisation
    - Energy measurements
    - Twiss parameter measure
    - Bunch length measure

What we do before start an accelerator?

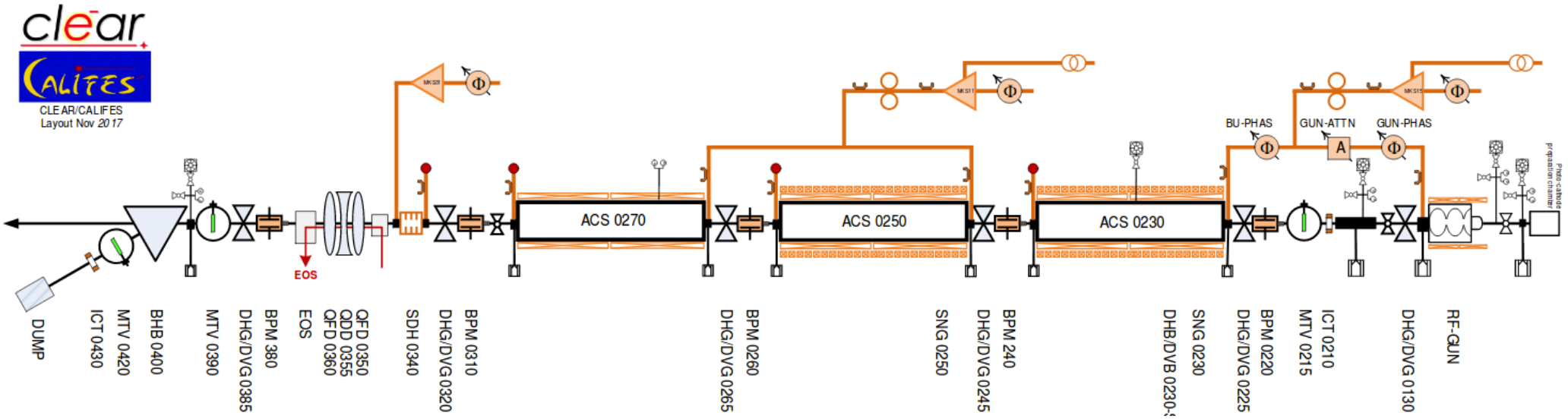
Interlock check!

Vacuum level!

RF check!

Laser Check!

CLEAR photo-injector characterisation



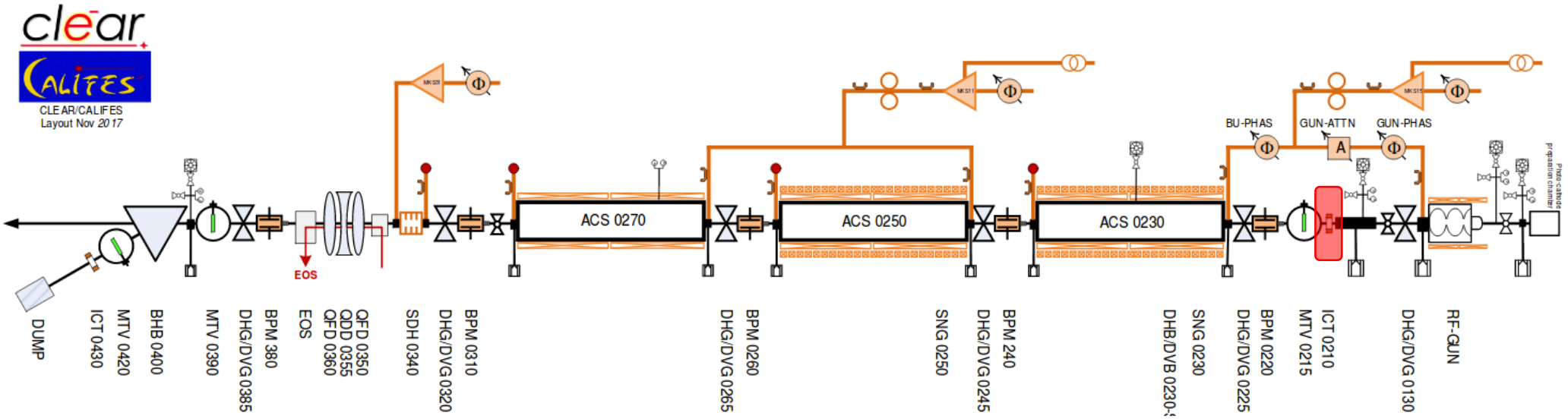
- Focus on electron emission:
  - Field emission - Dark current,
  - Photo-emission vs different laser characteristics: transverse size, laser energy, quantum efficiency (QE), solenoid current,

- Charge measurements vs RF Gun phase by ICT 0210:
  - z ≈ 1.6 m from the photo-cathode,

- RF Gun energy measurements by corrector scan DHG/DVG 0130 on screen MTV 0215:
  - Screen is at z ≈ 1.8 m from the photo-cathode,
  - Distance between the corrector and screen is Δz ≈ 1.52 m,

- Transverse beam size measurements by focusing solenoid scan CA.SNI0120 on screen MTV 0215,

CLEAR photo-injector characterisation



- Focus on electron photo-emission:
  - Dark current,
  - Photo-emission vs different laser characteristics: transverse size, pulse shape, quantum efficiency (QE),

- Charge measurements vs RF Gun phase by ICT 0210:
  - $z \approx 1.6$ m from the photo-cathode,

- RF Gun energy measurements by corrector scan DHG/DVG 0130 on screen MTV 0215:
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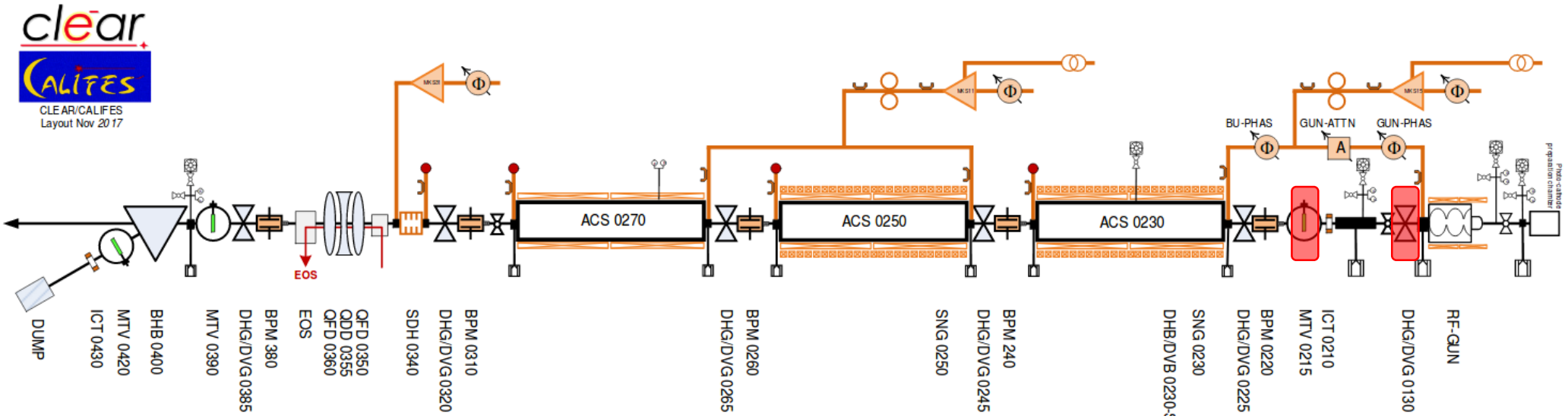

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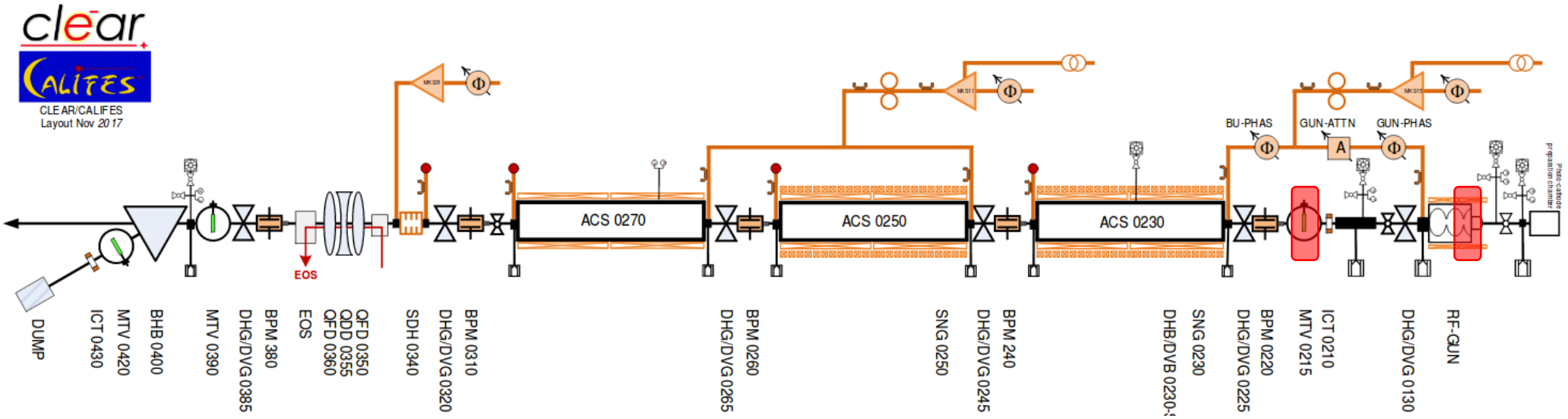

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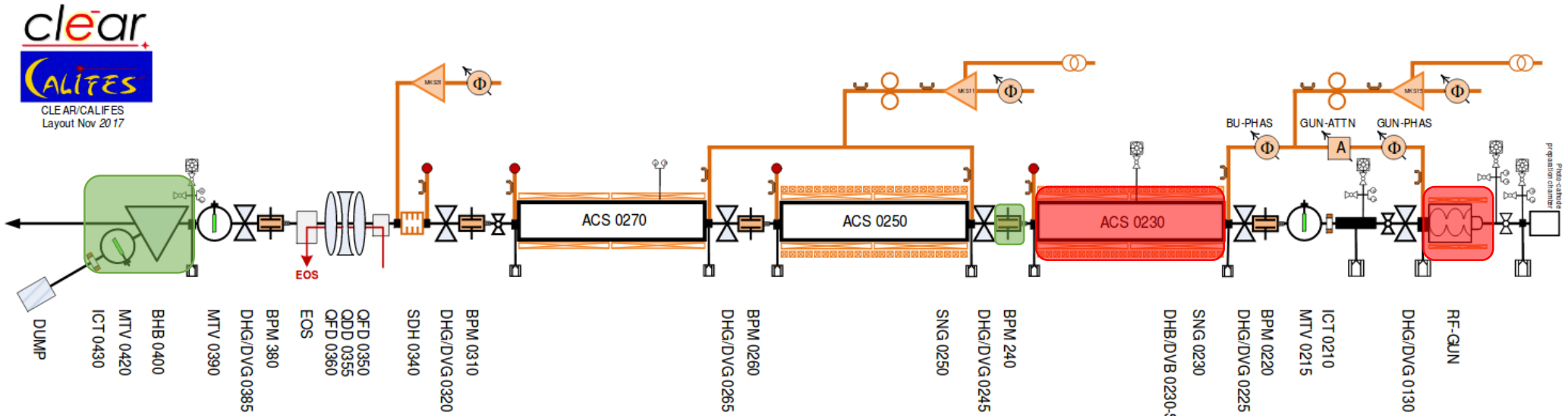
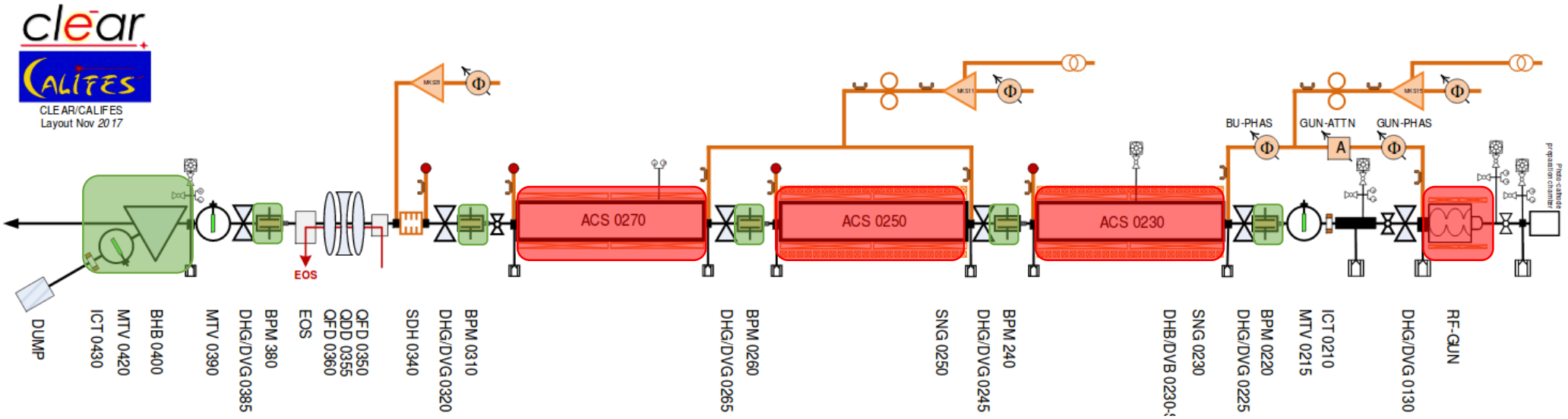
CLEAR LINAC characterisation



- LINAC transport, beam energy gain and energy spread measurements at VESPER spectrometer
  - Maximum beam energy (around 220 MeV):
    - RF Gun phase for maximum energy gain,
    - RF phase of the 1st TW accelerating section,
    - RF phase of the 2nd & 3rd TW accelerating sections,
- Emittance measurement: Quadrupoles scan at the Quads triplet,
- Bunch length measurement with deflecting cavity,

CLEAR LINAC characterisation



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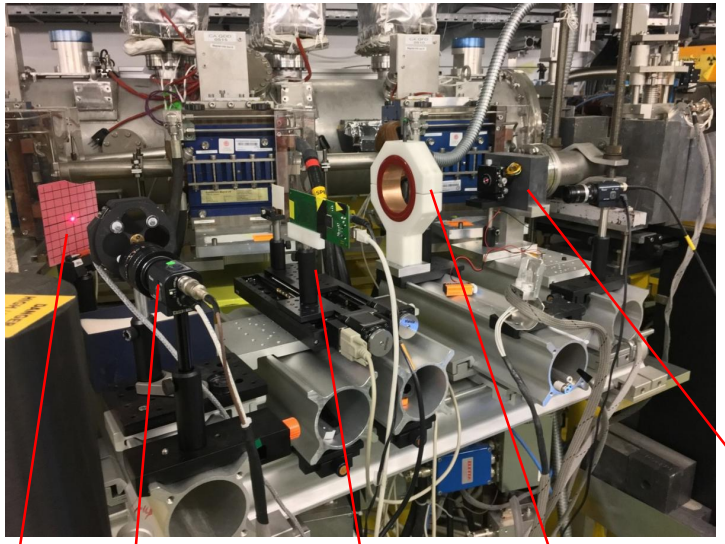
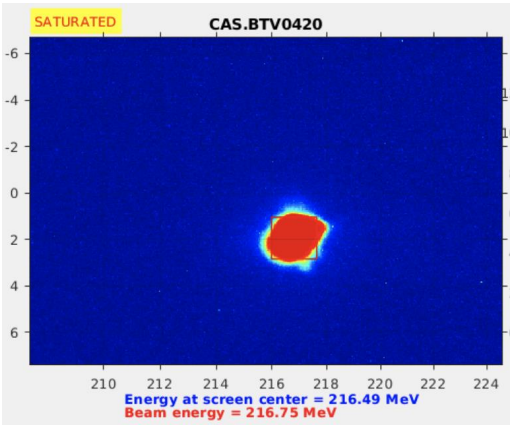
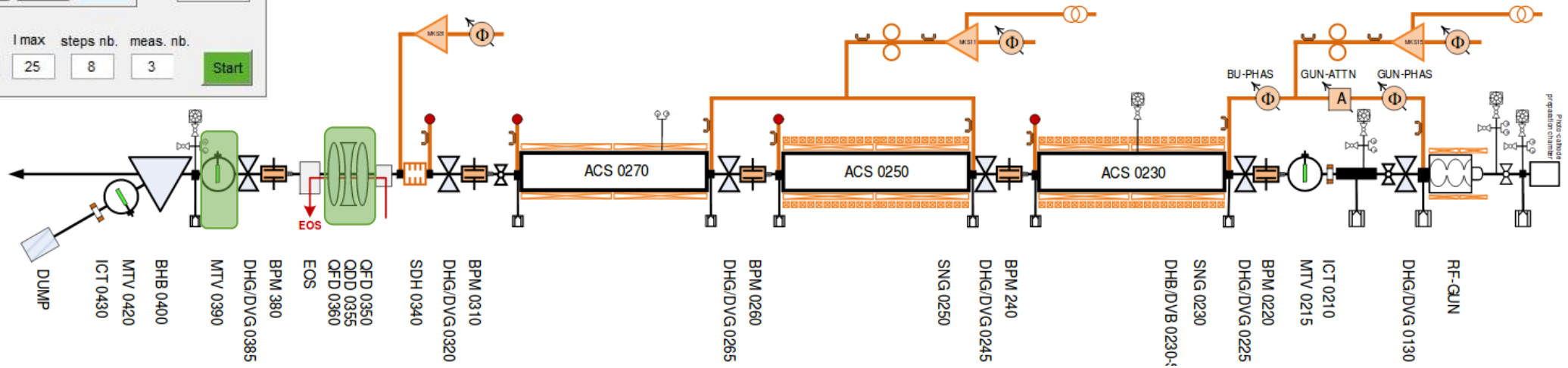




CLEAR LINAC characterisation

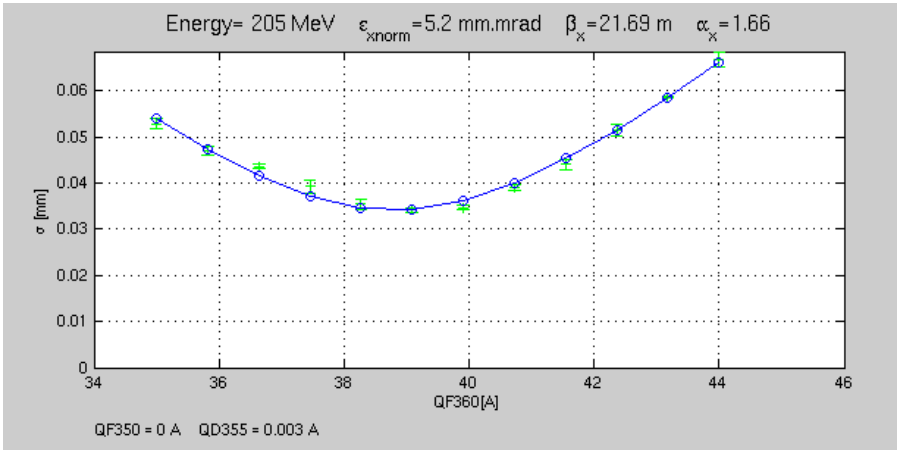


- Emittance measurement: Quadrupoles scan at the Quads triplet,

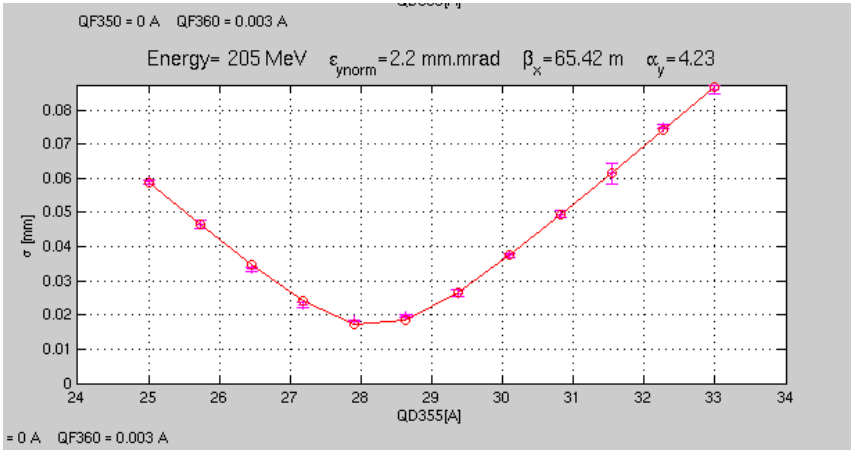
Twiss parameter measurement

$$\begin{pmatrix} \beta_s & -\alpha_s \\ -\alpha_s & \gamma_s \end{pmatrix} = \begin{pmatrix} A_{0S} & B_{0S} \\ C_{0S} & D_{0S} \end{pmatrix} \begin{pmatrix} \beta_0 & -\alpha_0 \\ -\alpha_0 & \gamma_0 \end{pmatrix} \begin{pmatrix} A_{0S} & C_{0S} \\ B_{0S} & D_{0S} \end{pmatrix}$$

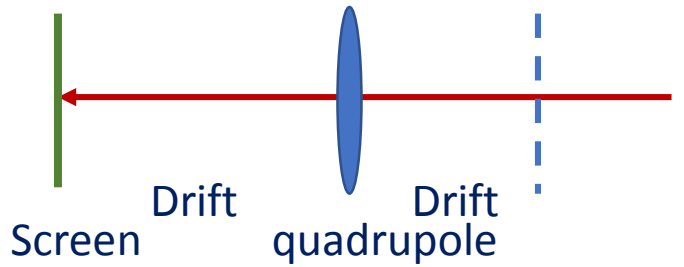
$$\begin{pmatrix} \beta_{s,1} \\ \beta_{s,2} \\ \vdots \\ \beta_{s,n} \end{pmatrix} \epsilon = \begin{pmatrix} A_1^2 & -2A_1B_1 & B_1^2 \\ A_2^2 & -2A_2B_1 & B_2^2 \\ \vdots & \vdots & \vdots \\ A_n^2 & -2A_nB_n & B_n^2 \end{pmatrix} \begin{pmatrix} \beta_0 \\ \alpha_0 \\ \gamma_0 \end{pmatrix} \epsilon$$



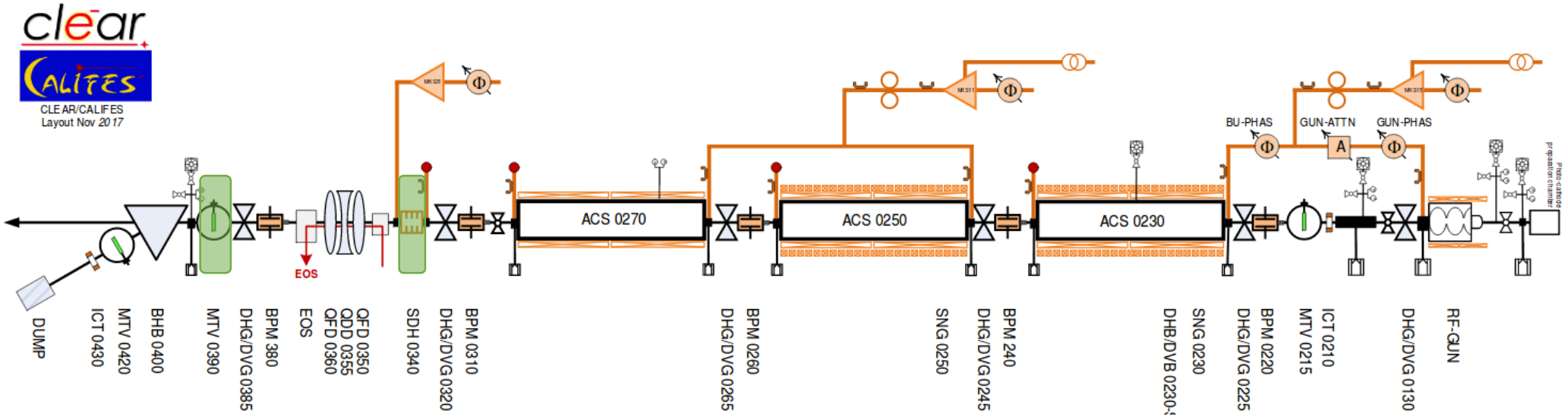
Horizontal beam size as function of quadrupole current



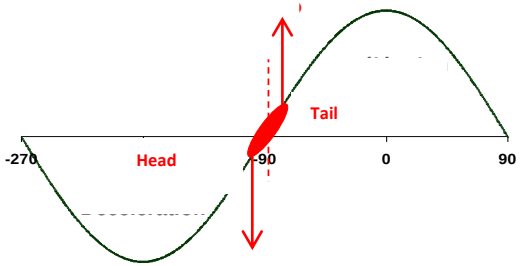
Vertical beam size as function of quadrupole current

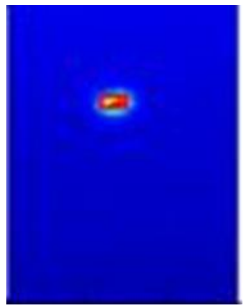


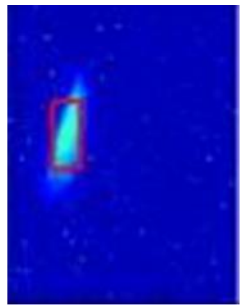
CLEAR LINAC characterisation



- Bunch length measurement with deflecting cavity,







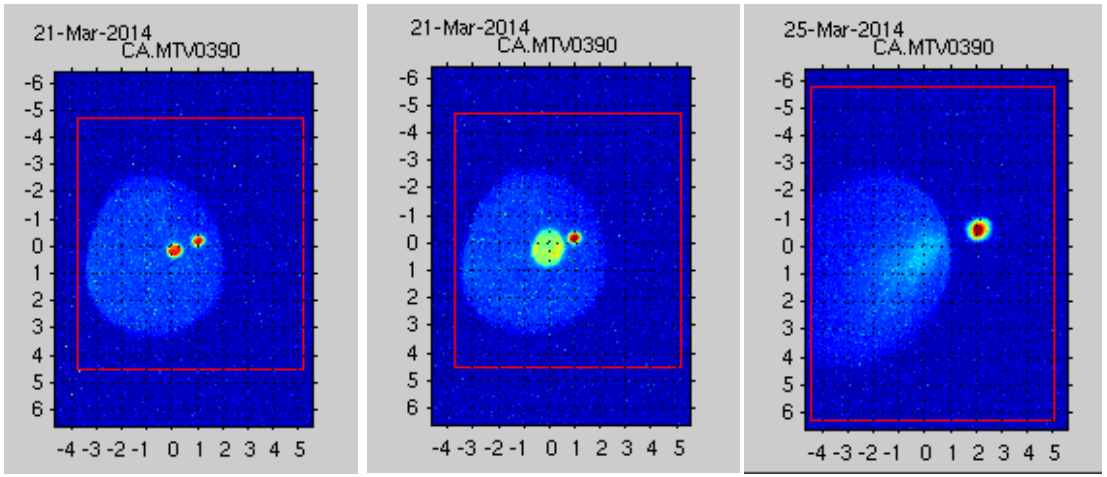
Cavity OFF
σy = 0.24 mm

Cavity ON
σy = 1.47 mm

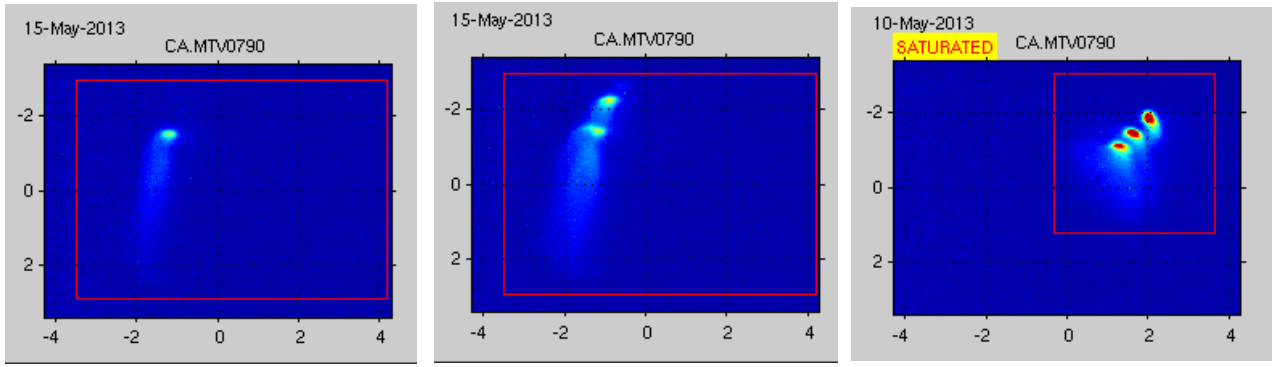
With a deflecting cavity

Operating principle:
- bunch pass at zero crossing in a deflecting cavity,
- bunch head experiences a transverse kick downward, bunch tail upward,
- bunch transverse size is then downstream measured on a beam profile monitor,
-Power phase shifter allows to vary the bunch length via the velocity bunching structure.

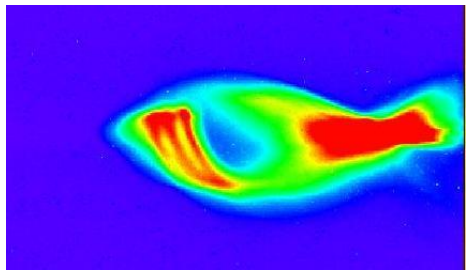
Contest (Strange beam contest)



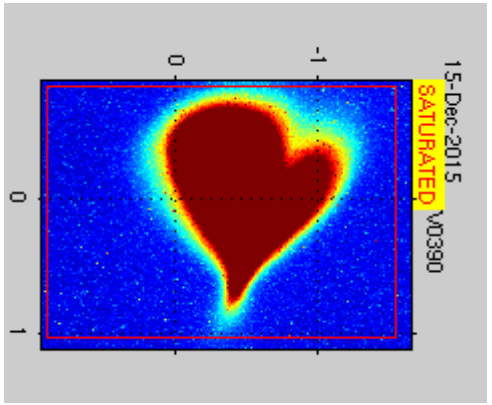
3 bunches of various charge and emittance



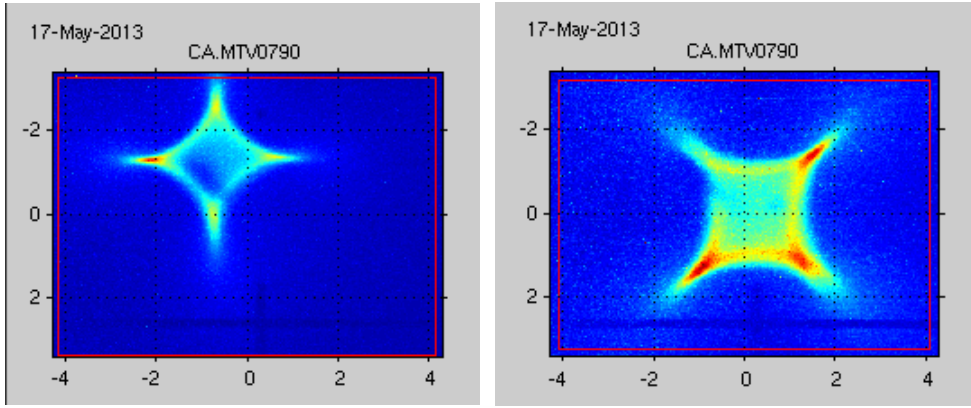
1, 2, 3… bunches with transverse space separation



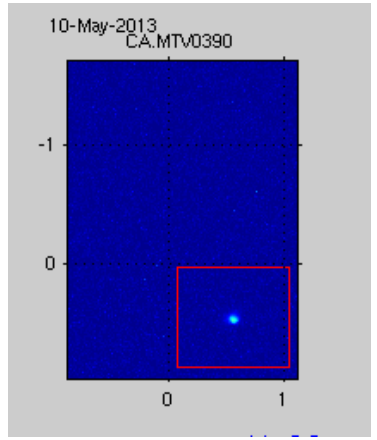
Fishy beam



Valentine's day beam



Octupolar fields beam shape



Beam size 37 x 33 μm

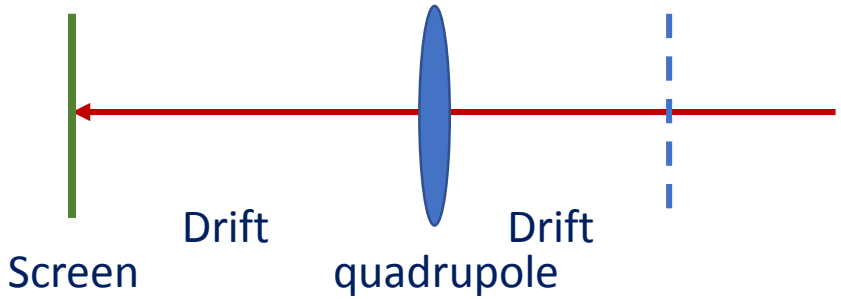
Thanks for the attention

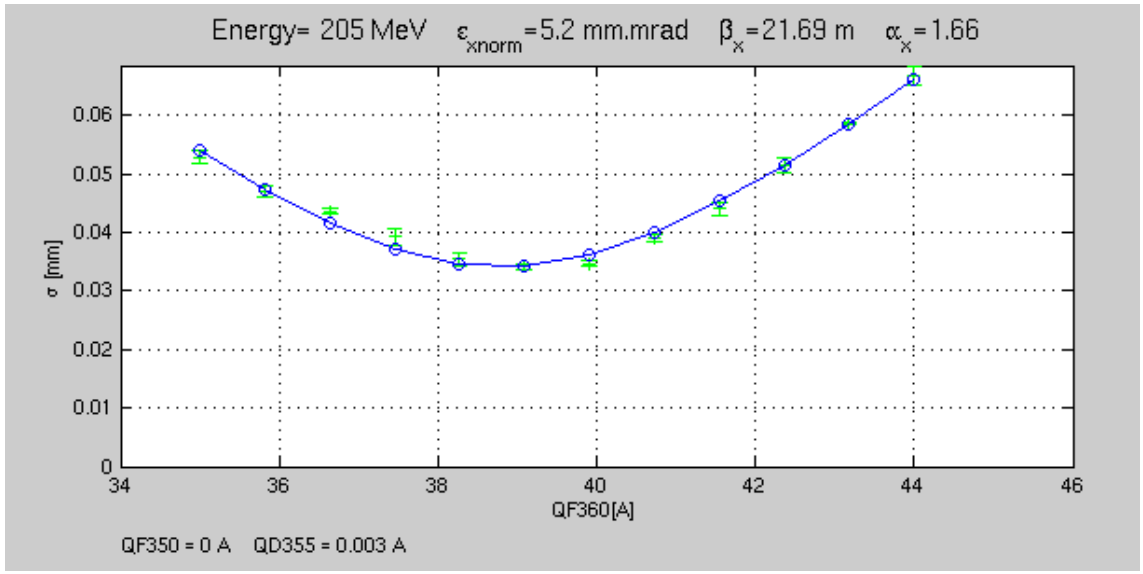
Back up slides

Twiss parameter measure

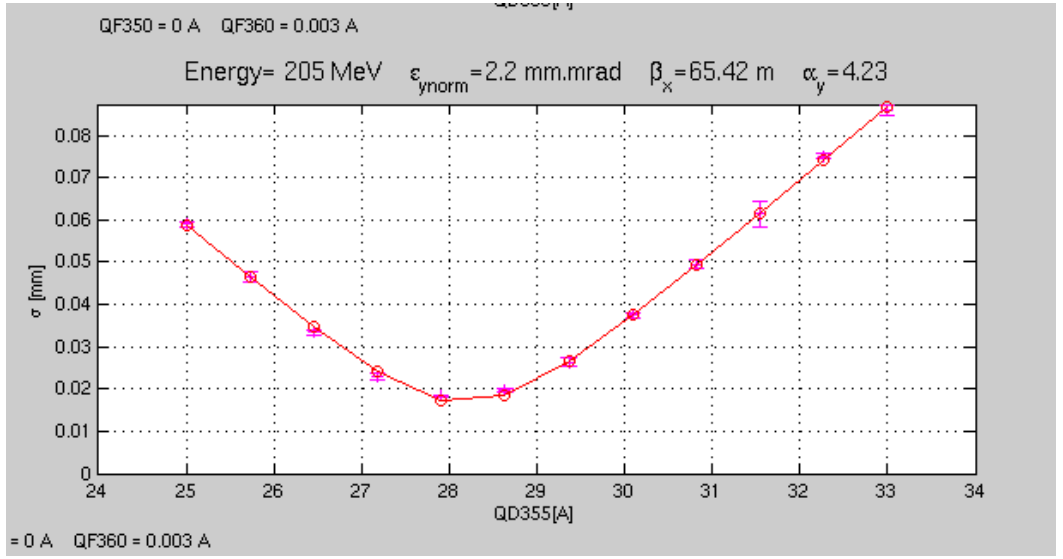
$$\begin{pmatrix} \beta_s & -\alpha_s \\ -\alpha_s & \gamma_s \end{pmatrix} = \begin{pmatrix} A_{0S} & B_{0S} \\ C_{0S} & D_{0S} \end{pmatrix} \begin{pmatrix} \beta_0 & -\alpha_0 \\ -\alpha_0 & \gamma_0 \end{pmatrix} \begin{pmatrix} A_{0S} & C_{0S} \\ B_{0S} & D_{0S} \end{pmatrix}$$

$$\begin{pmatrix} \beta_{s,1} \\ \beta_{s,2} \\ \vdots \\ \beta_{s,n} \end{pmatrix} \epsilon = \begin{pmatrix} A_1^2 & -2A_1B_1 & B_1^2 \\ A_2^2 & -2A_2B_1 & B_2^2 \\ \vdots & \vdots & \vdots \\ A_n^2 & -2A_nB_n & B_n^2 \end{pmatrix} \begin{pmatrix} \beta_0 \\ \alpha_0 \\ \gamma_0 \end{pmatrix} \epsilon$$



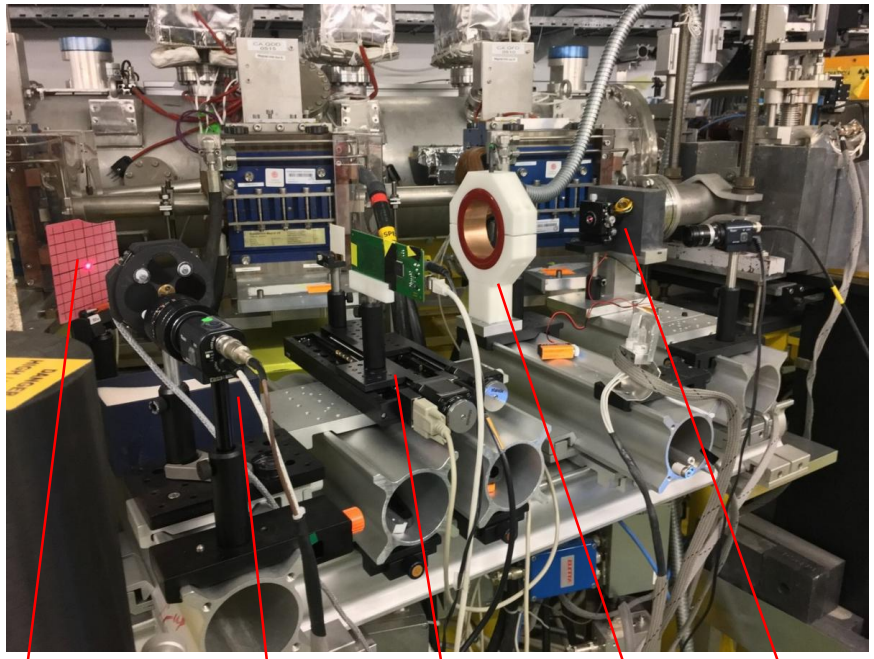


Horizontal beam size as function of quadrupole current

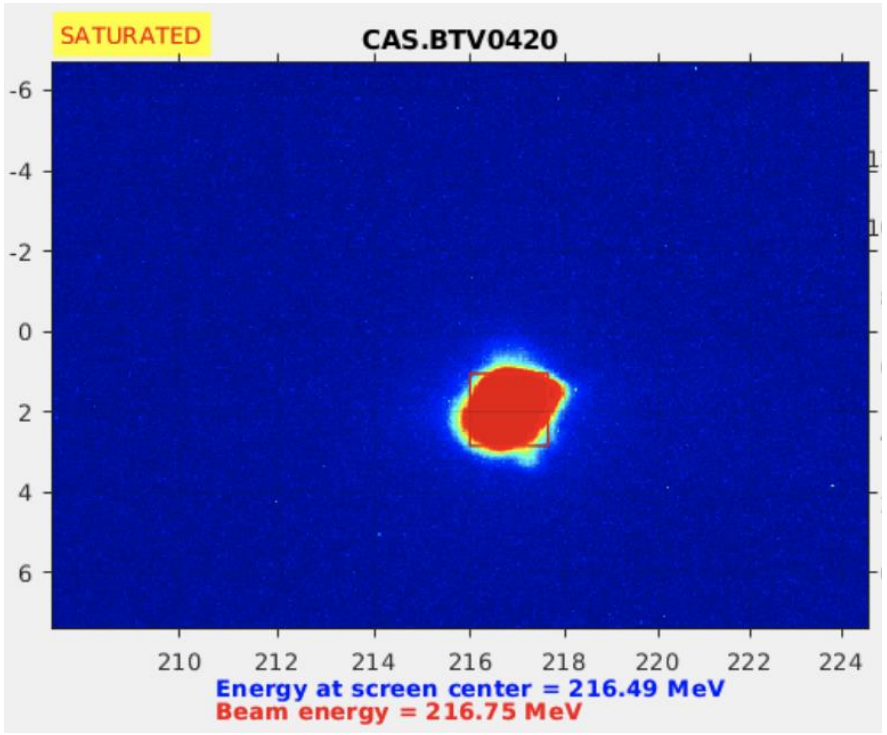


Vertical beam size as function of quadrupole current

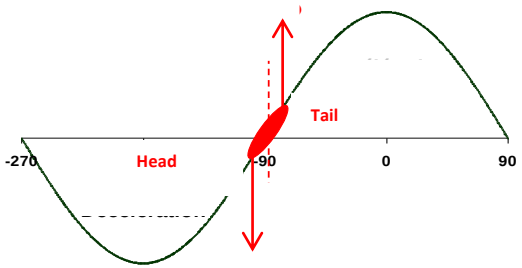
Energy measure

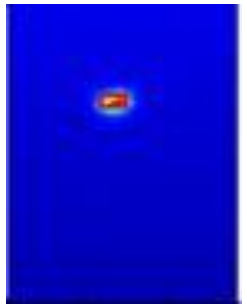


- Installed in a spectrometer line
- In air
- Fully equipped
- Large, homogeneus beam

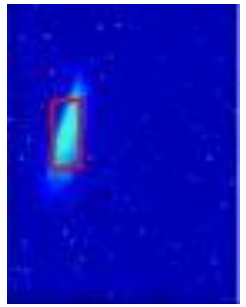


Bunch length measure





Cavity OFF
σy = 0.24 mm



Cavity ON
σy = 1.47 mm

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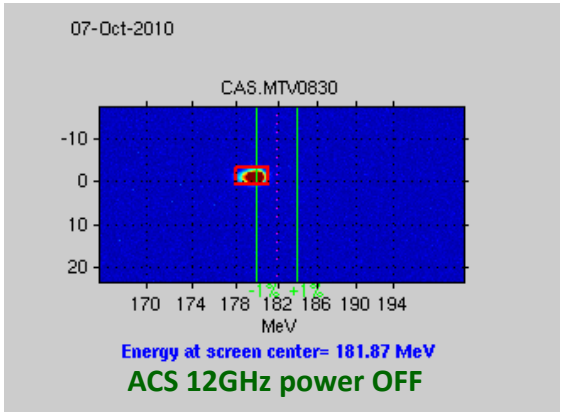
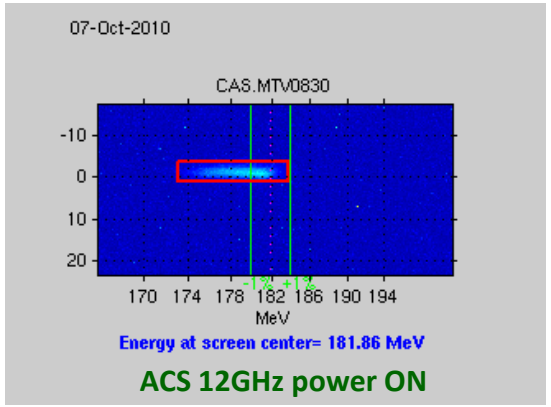
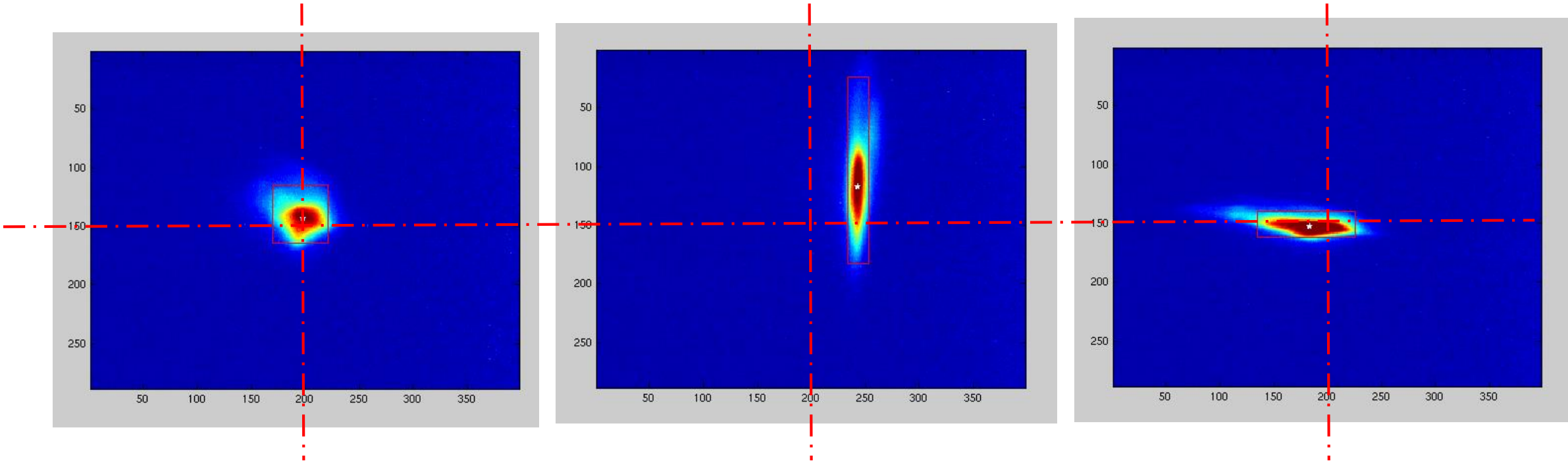
With a deflecting cavity





With an accelerating structure

Alignment of the beam inside quadrupoles



Quads Off

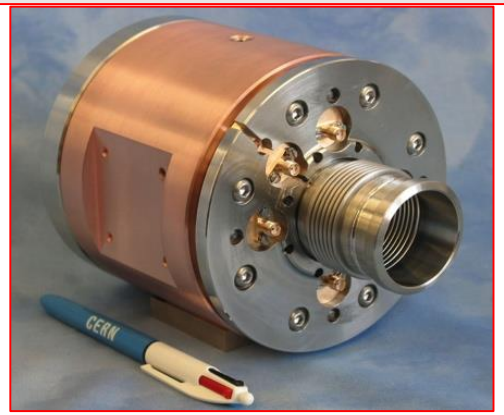
Horizontal focusing quad on
Beam offset in both axis

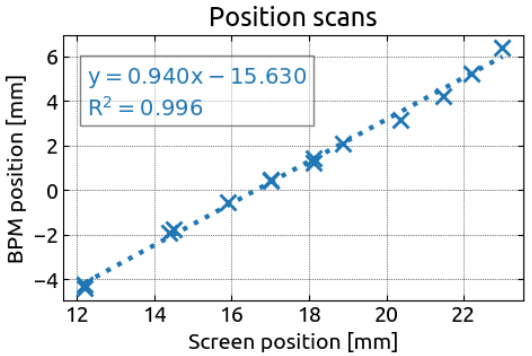
Vertical focusing quad on
Horizontal beam offset

BPM measure

Inductive BPMs

- Modified to increase sensitivity by factor 8
- Can provide position and intensity measurements





High resolution (sub-micron) cavity BPMs