Experience from JUAS

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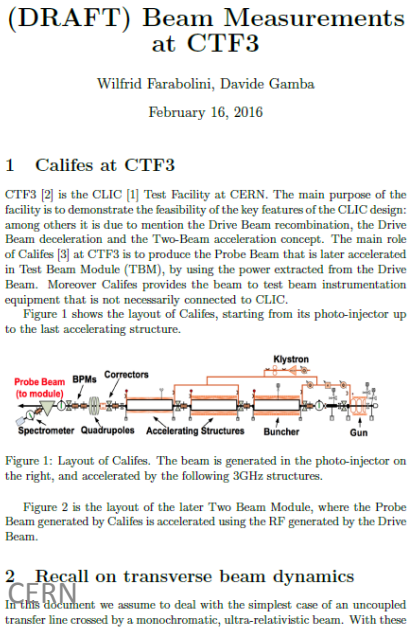
Genesis of an idea

- First discussions with Louis Rinolfi in 2015, based on our experience with technical students
- Presentation during the practical works days at Archamps 15-Feb-2016
- Preparation of a 9 pages document sent to the students (Davide)
- Two days of practical works (2 x 9 students) on 26-27 Feb-2016 under the supervision of 4 accelerator experts (Namra, Sumera, Davide, myself)
- 12 reports delivered by the students and corrected independently by Davide and myself



(DRAFT) Beam Measurements at CTF3

Wilfrid Farabolini, Davide Gamba

February 16, 2016

1 Califes at CTF3

CTF3 [2] is the CLIC [1] Test Facility at CERN. The main purpose of the facility is to demonstrate the feasibility of the key features of the CLIC design: among others it is due to mention the Drive Beam recombination, the Drive Beam deceleration and the Two-Beam acceleration concept. The main role of Califes [3] at CTF3 is to produce the Probe Beam that is later accelerated in Test Beam Module (TBM), by using the power extracted from the Drive Beam. Moreover Califes provides the beam to test beam instrumentation equipment that is not necessarily connected to CLIC.

Figure 1 shows the layout of Califes, starting from its photo-injector up to the last accelerating structure.

Figure 1: Layout of Califes. The beam is generated in the photo-injector on the right, and accelerated by the following 3GHz structures.

Figure 2 is the layout of the later Two Beam Module, where the Probe Beam generated by Califes is accelerated using the RF generated by the Drive Beam.

2 Recall on transverse beam dynamics

In this document we assume to deal with the simplest case of an uncoupled transfer line crossed by a monochromatic, ultra-relativistic beam. With these

Risks and difficulties

- Date for practical days only 1 week after the programmed restart of CALIFES (winter shutdown)
- Risk of beam unavailability (it's accelerator life…)
  - Files were recorded for quad scan beam dynamic study, just in case.
- A lot of students for only 1 beam, but many screens
  - Actually Drive Beam team gave also an help (thanks Piotr)
- It was not possible to visit the CLEX

CALIFES strengths for students works

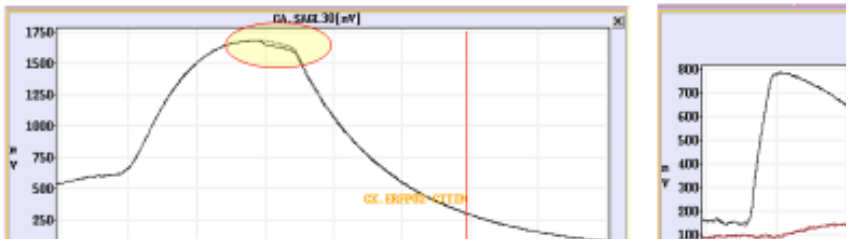
- Perfect size and complexity of the accelerator: not too simple, not too complex.
- Totally safe in case of wrong action:
  - limited beam power,
  - no interactions with the rest of the CERN complex
- Great flexibility of the beam characteristics
- Great availability and experience of the team
- Easy access to the technical gallery
- An unique opportunity for students to operate an accelerator at CERN

What was proposed

- Gun with dark current only (field emission):
  - Optimize dark current extraction using profile monitor.
  - Transport of the dark current through the accelerating structures.
  - Energy, charge and Twiss parameters measurement.
  - Preparation of a large beam for the irradiation test stand.
- RF power in the accelerating structure,
  - measure of the filling time,
  - observation of the beam loading at the output port.
- Charge measure vs. phase scan of the gun, photo-cathode quantum efficiency measurement
- Energy measure at the gun output using corrector,
- Observation of the gun beam loading on the gun E field antenna.
- Transport of the beam, phase to inject the bunches in the structures, alignment using the BPMs
- Alignment of the beam in the quadrupole observing the kick
- Energy measure in the spectrometer line
- Emittance measurement using the quad scan method
- Use of a simple model to optimise the beam transport, test of focusing on various screens
- Measures in Two Beam Module: Beam losses detection, wakefield RF power generation, WFM signals

Details about proposed activities

Beam loading

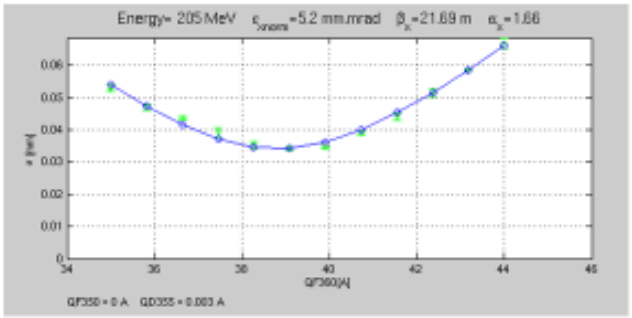


Quadrupole scan

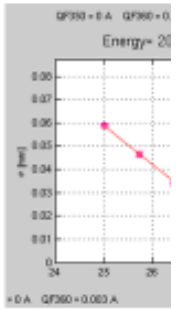
$$\begin{pmatrix} \beta_s & -\alpha_s \\ -\alpha_s & \gamma_s \end{pmatrix} = \begin{pmatrix} A_{0S} & B_{0S} \\ C_{0S} & D_{0S} \end{pmatrix} \begin{pmatrix} \beta_0 & -\alpha_0 \\ -\alpha_0 & \gamma_0 \end{pmatrix} \begin{pmatrix} A_{0S} & C_{0S} \\ B_{0S} & D_{0S} \end{pmatrix}$$

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

Screen

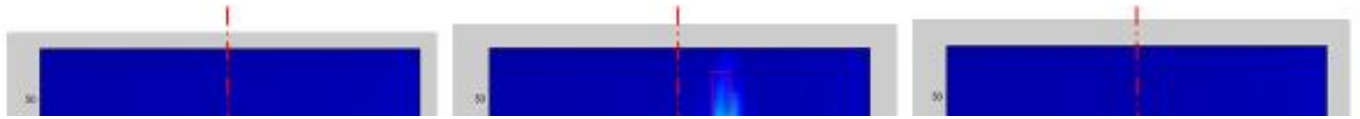


Horizontal beam size as function of quadrupole current

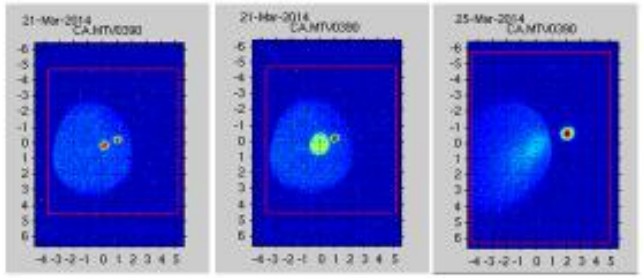


Vertical beam

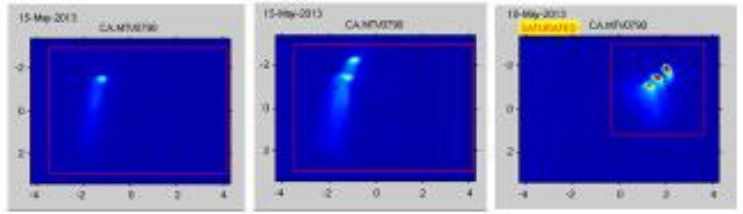
Alignment of the beam inside quadrupoles



Strange beam contest

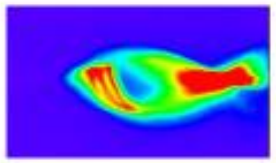


3 bunches of various charge and emittance

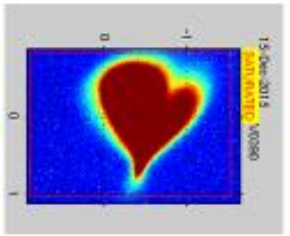


1, 2, 3... bunches with transverse space separation

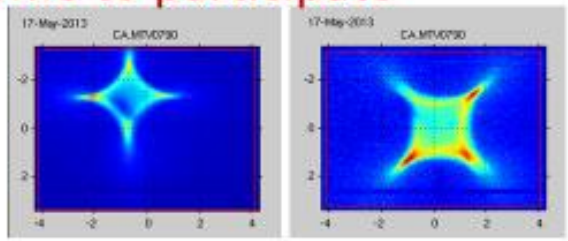
You are very welcome to participate



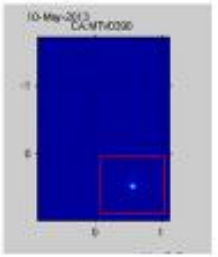
Fishy beam



Valentine's day beam

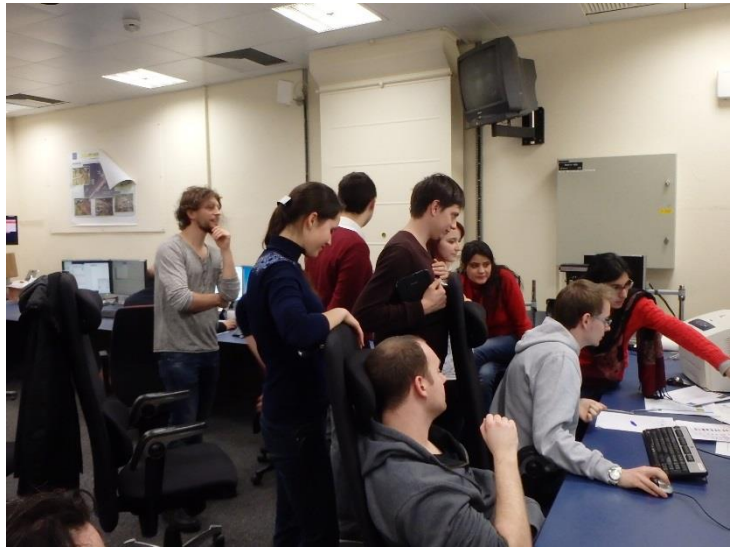


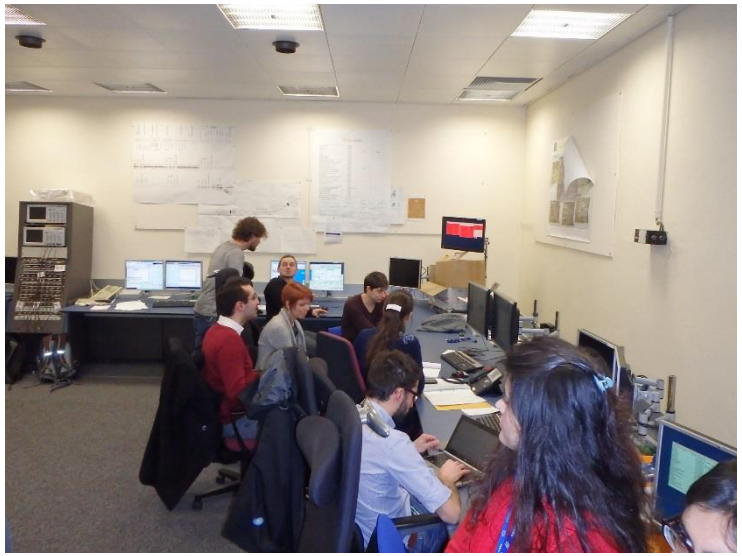
Octupolar fields beam shape

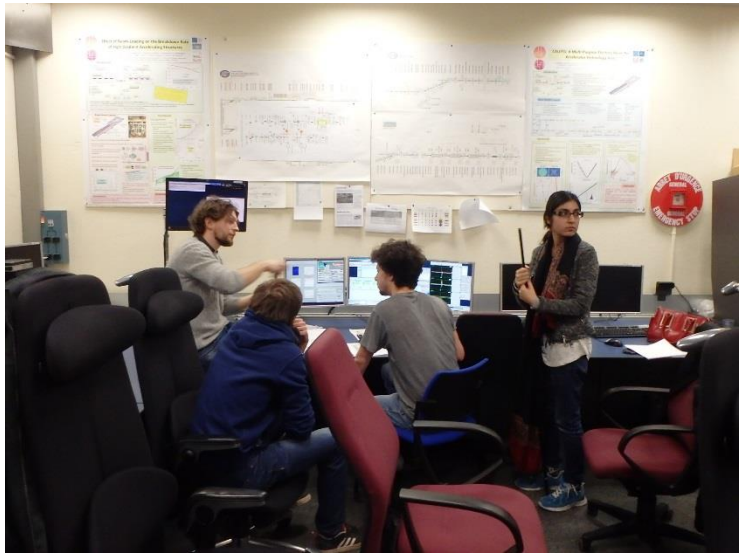


Beam size 37 x 33 µm

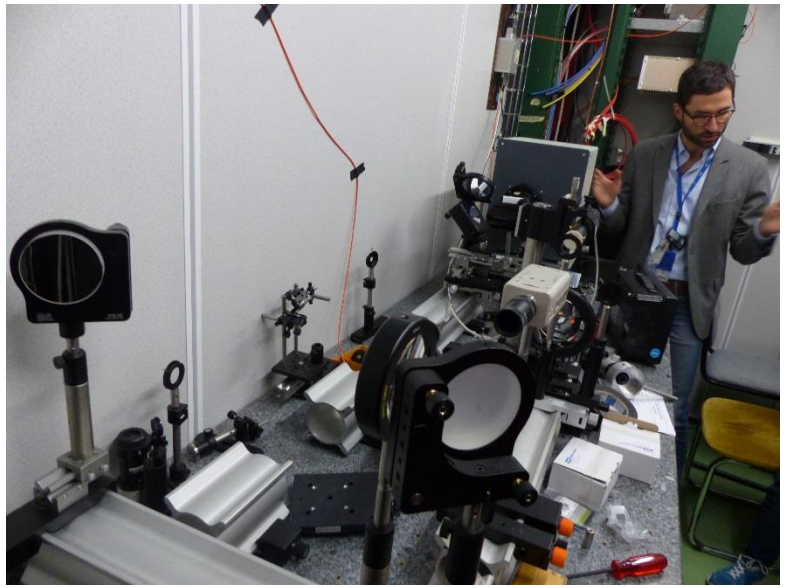
How it was conducted







And also



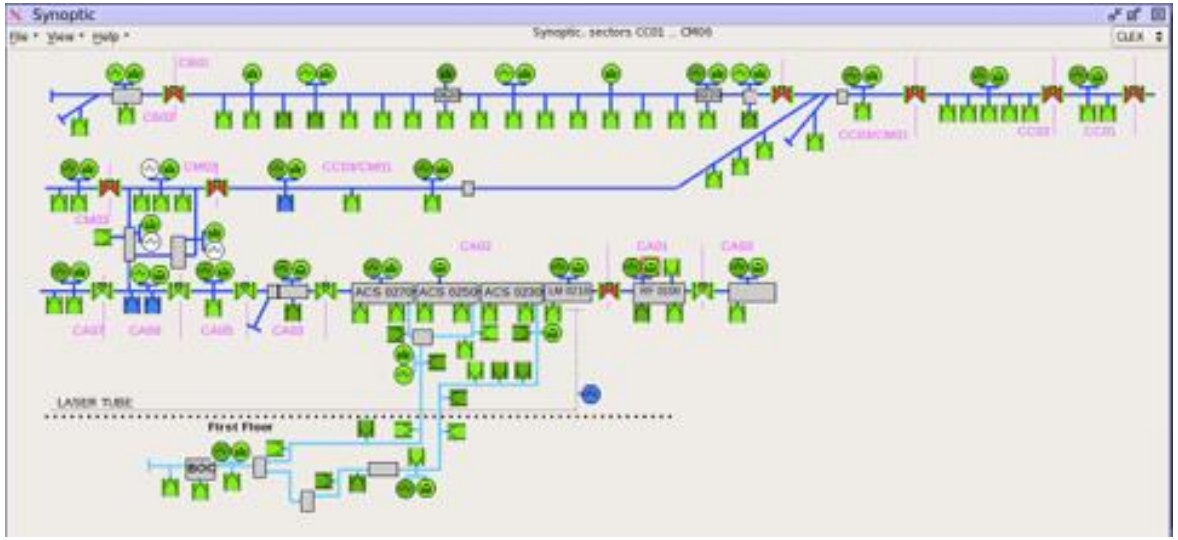
Visit of the streak camera lab. with Stefano

Demonstration of the Drive Beam by Piotr

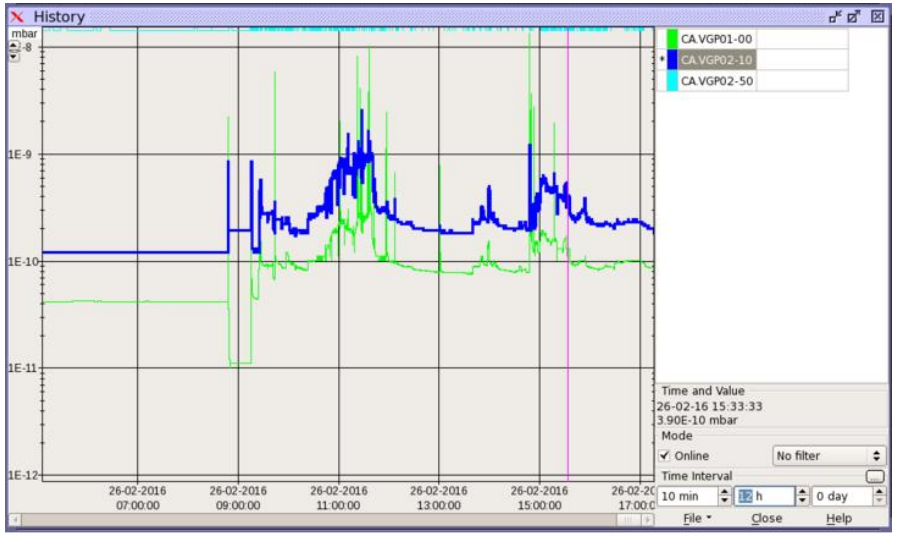
Explanations from JUAS director

Lunch time exchanges

What was done by the students (all from their reports)

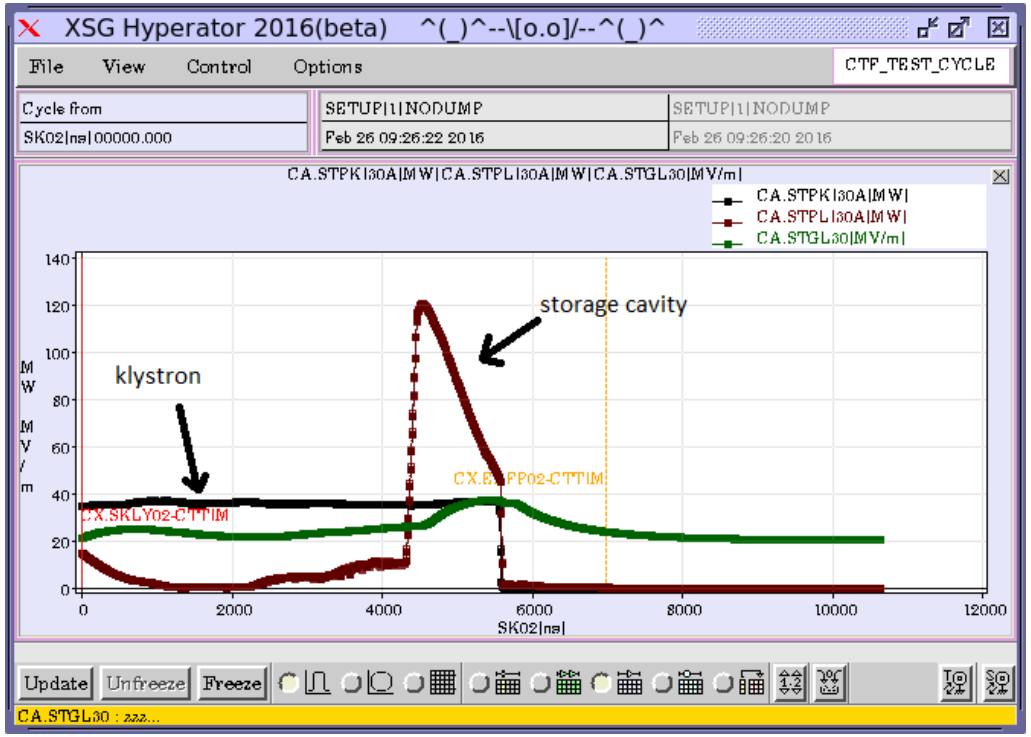


Vacuum scheme of the CTF3

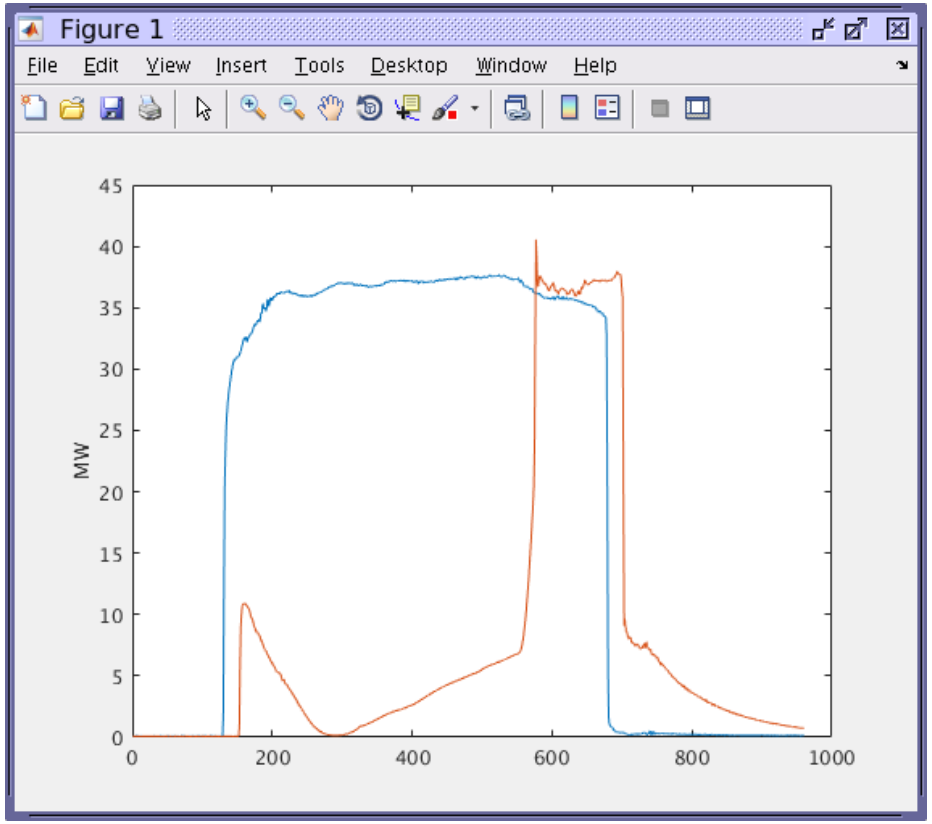


Plot showing the vacuum variation when the operation was carried out. Peaks indicate the beam loss condition.

Student reports (continued)

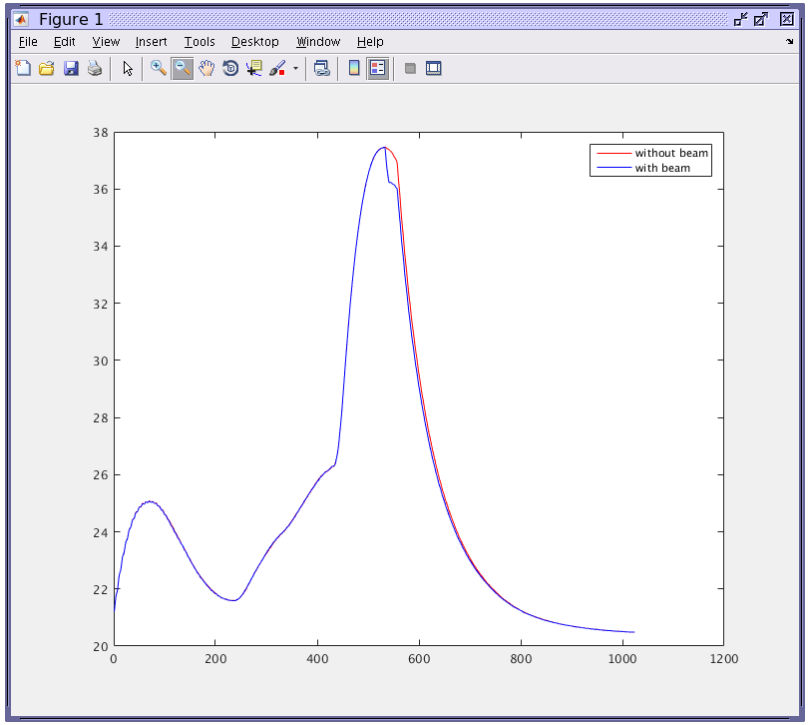


RF-power of one pulse.

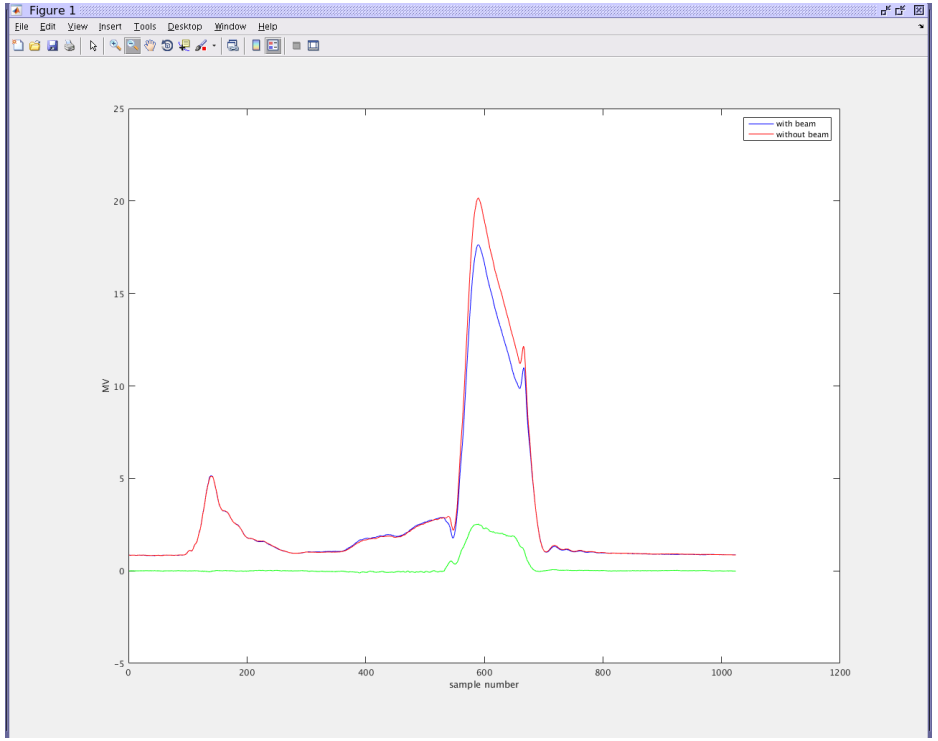


Measure of Klystron efficiency in the Drive Beam Linac

Student reports (continued)

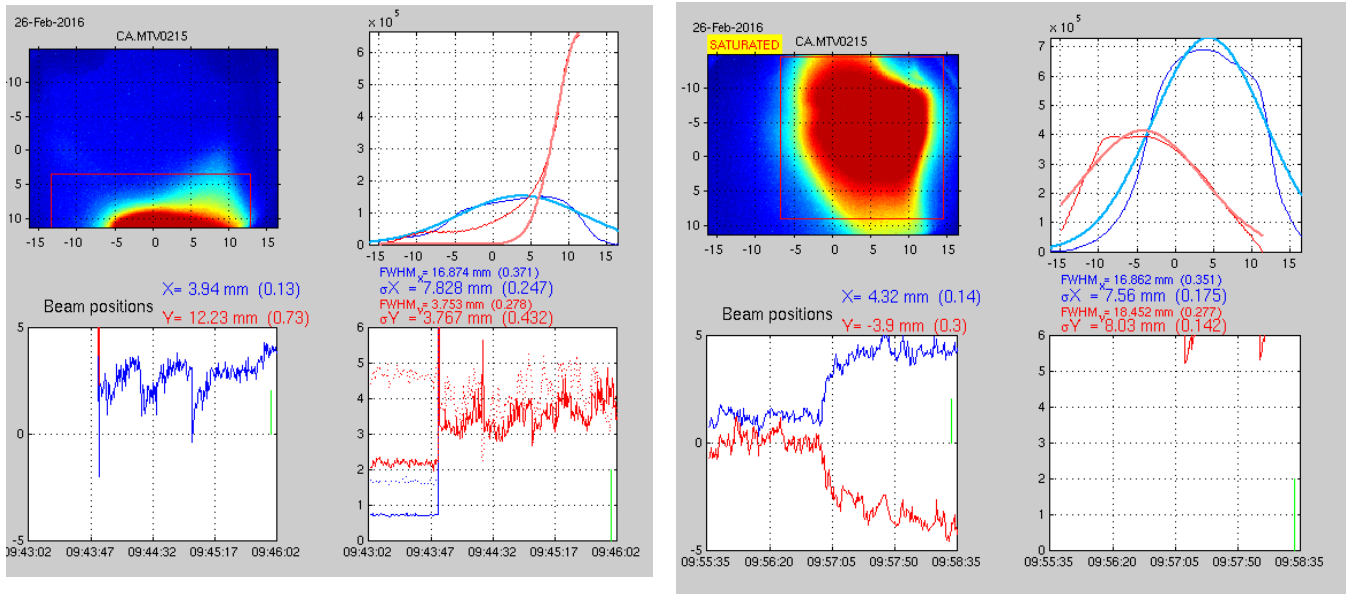


Effect of the beam loading on the RF gun signal. The plot shows the longitudinal electric field in [MV/m] as function of the time. The red line shows the electric field distribution without the beam and the blue line with the beam.

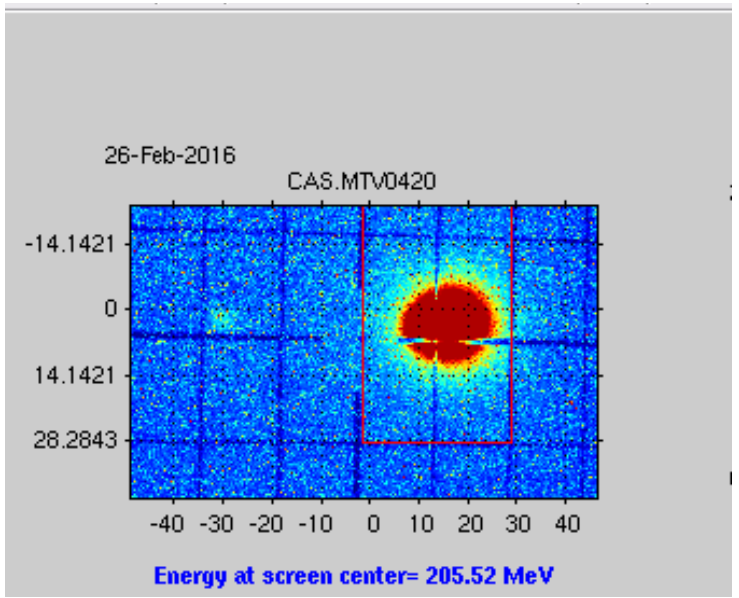


Power given by the RF to the beam with a bunch length of 136 ns. The red line shows the electric field distribution without the beam and the blue line with the beam.

Student reports (continued)

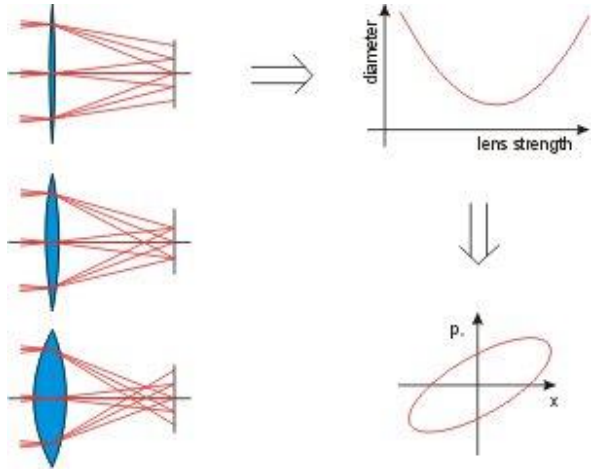


(a)Plot showing the beam prole without any tuning just outside the injector.(b)Plot showing the beam prole with tuning just outside the injector

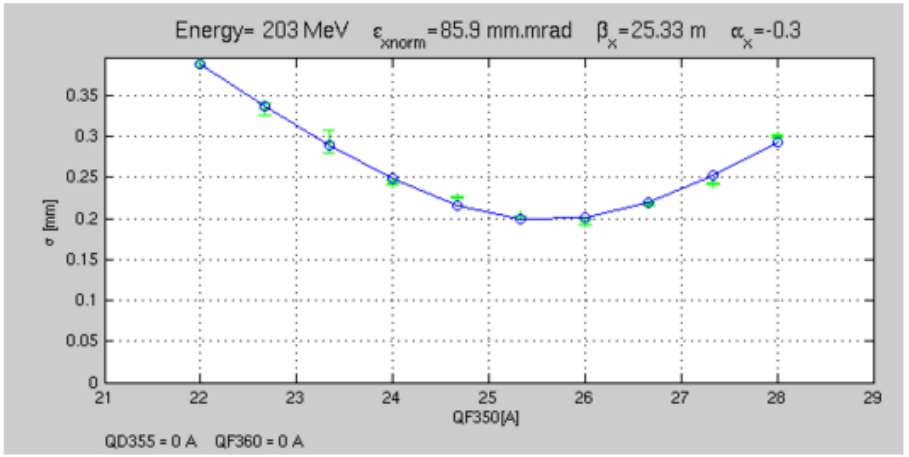


Beam energy after matching of the beam

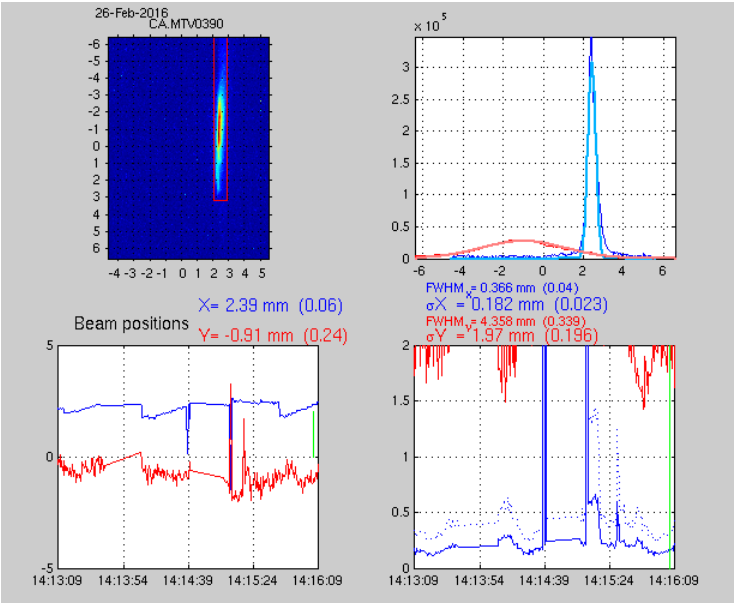
Student reports (continued)



Quad scan method for measuring the emittance

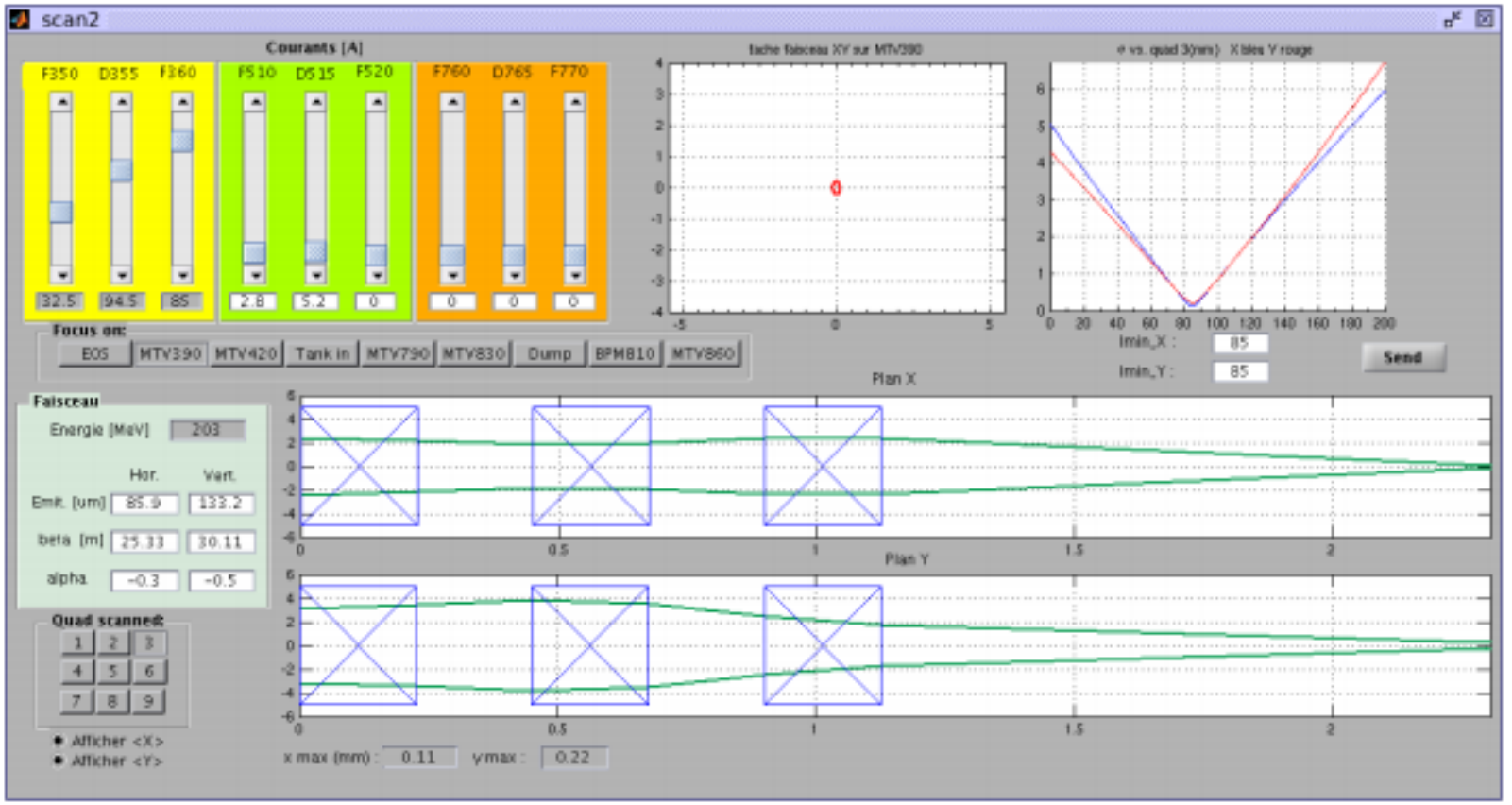


Horizontal Twiss parameters ε_x σ_x β_x from the quadrupole scan.



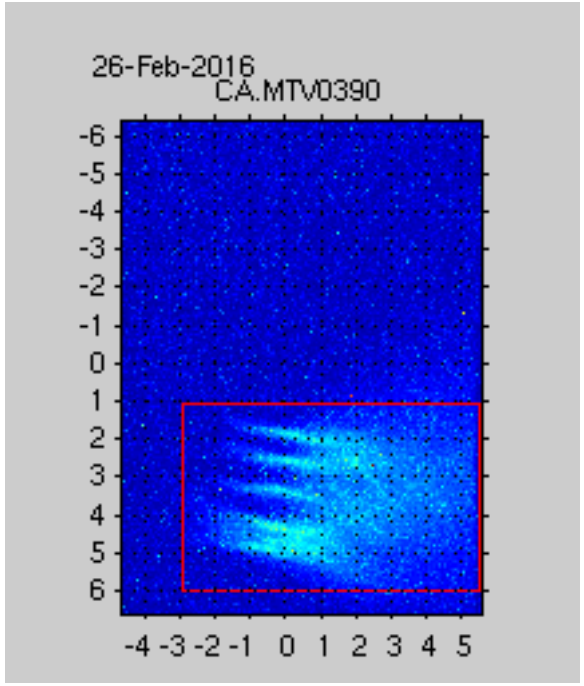
Horizontal Quad scan plots and beam profile

Student reports (continued)

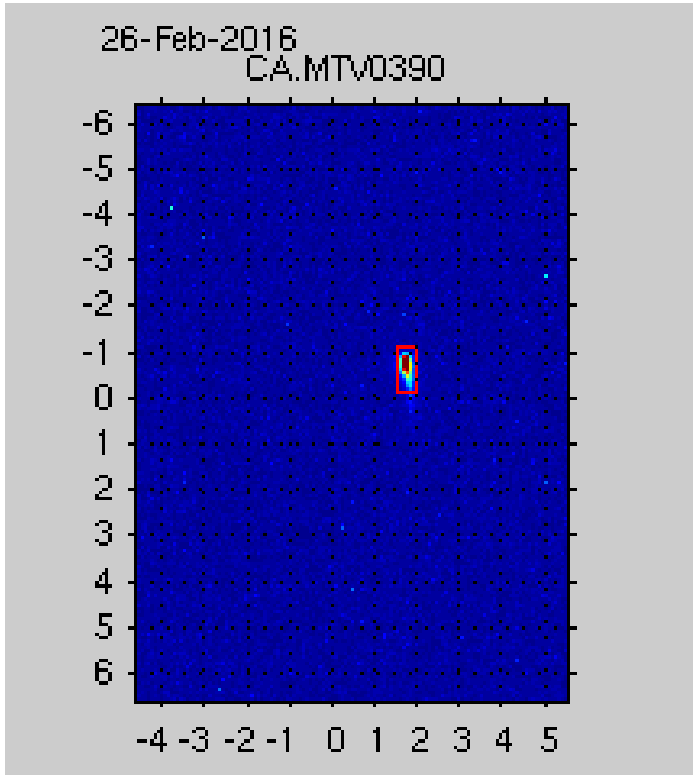


Optimization of the Triplet strengths

Student reports (continued)

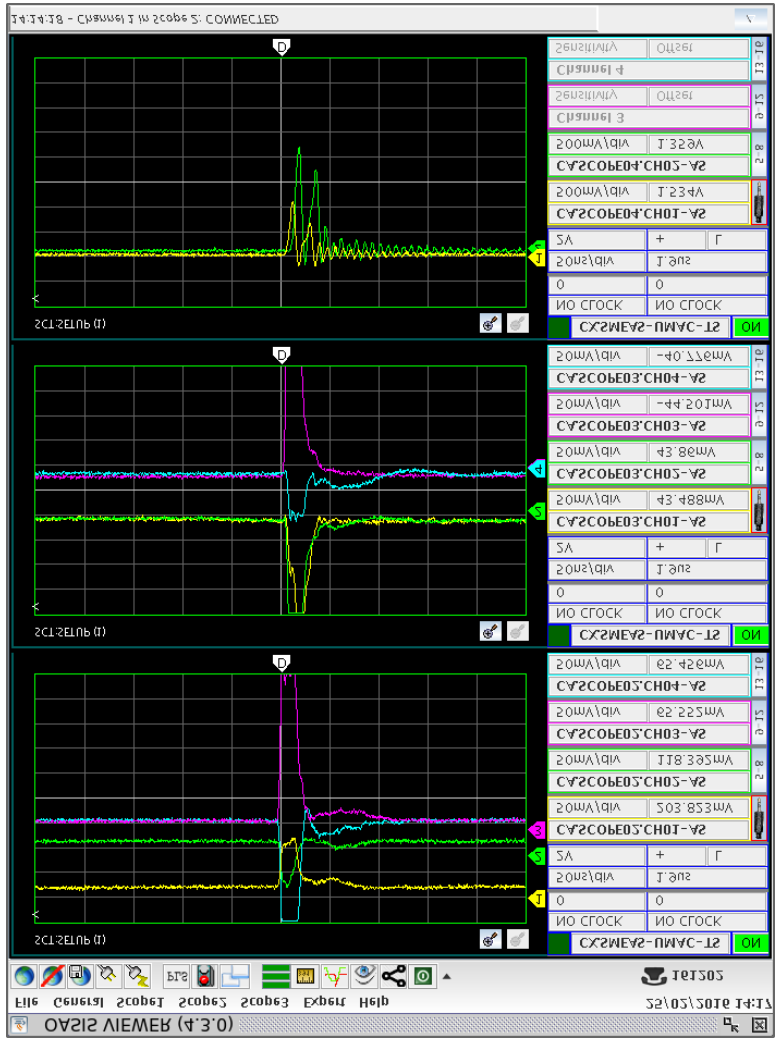


First transport of a few bunches with dispersion to the end of the beam line.

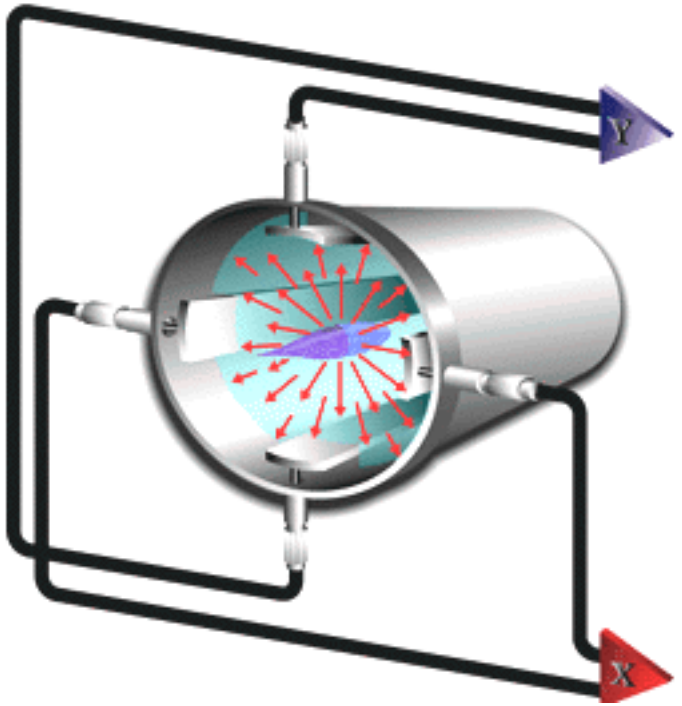


Focused beam at the end of the beam line.

Student reports (continued)



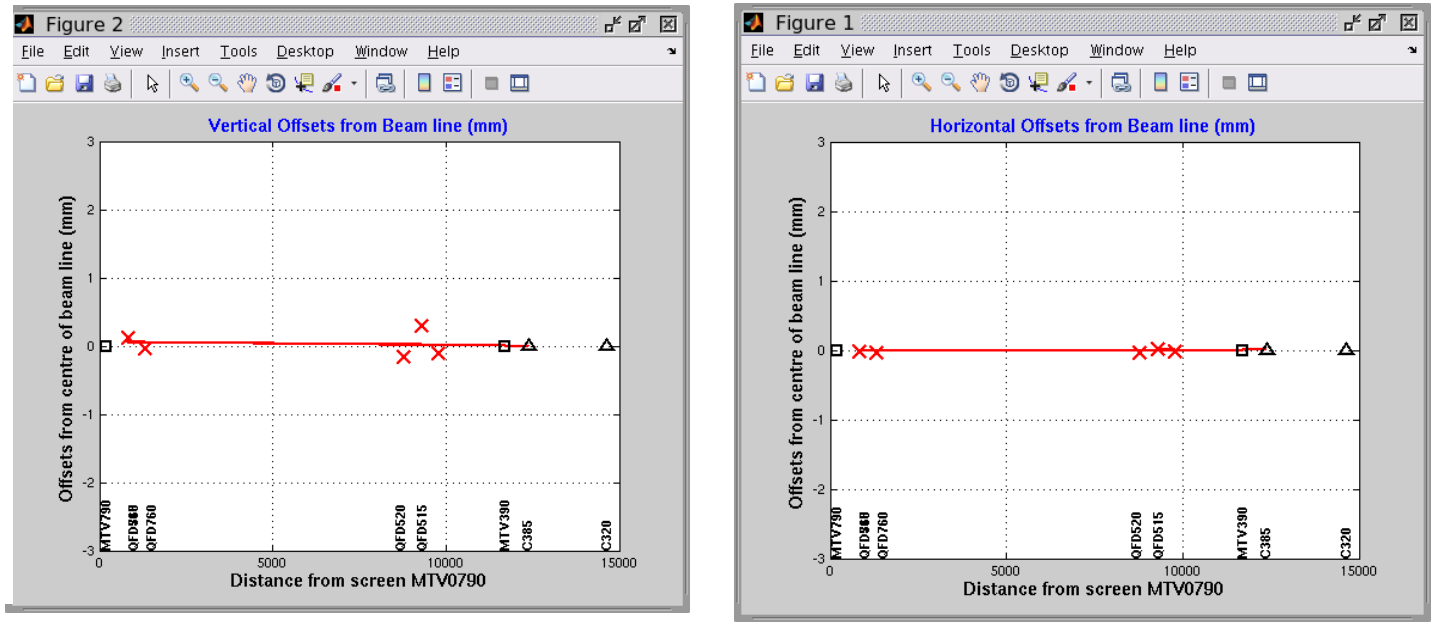
Signals from the cavity BPMs



Working principle of a Beam Position Monitor

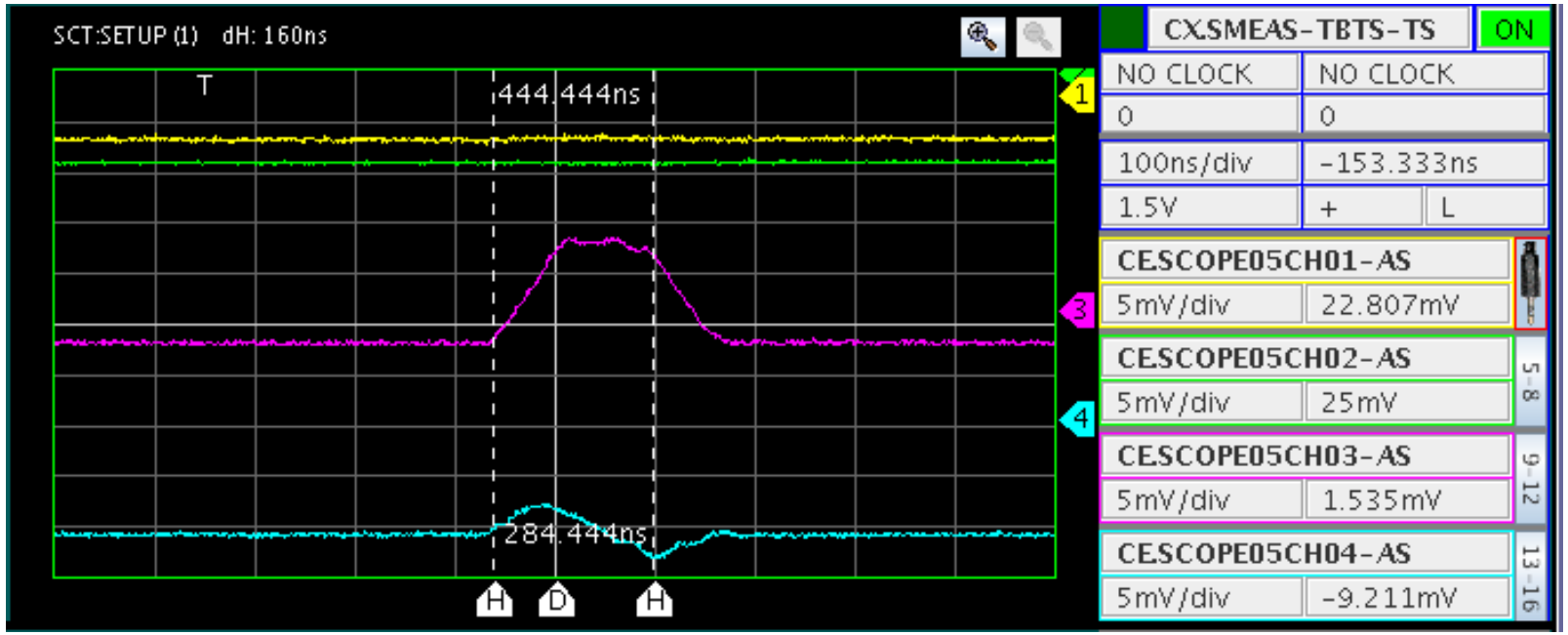
Student reports (continued)

Quadrupole alignment panel in TBM beamline.



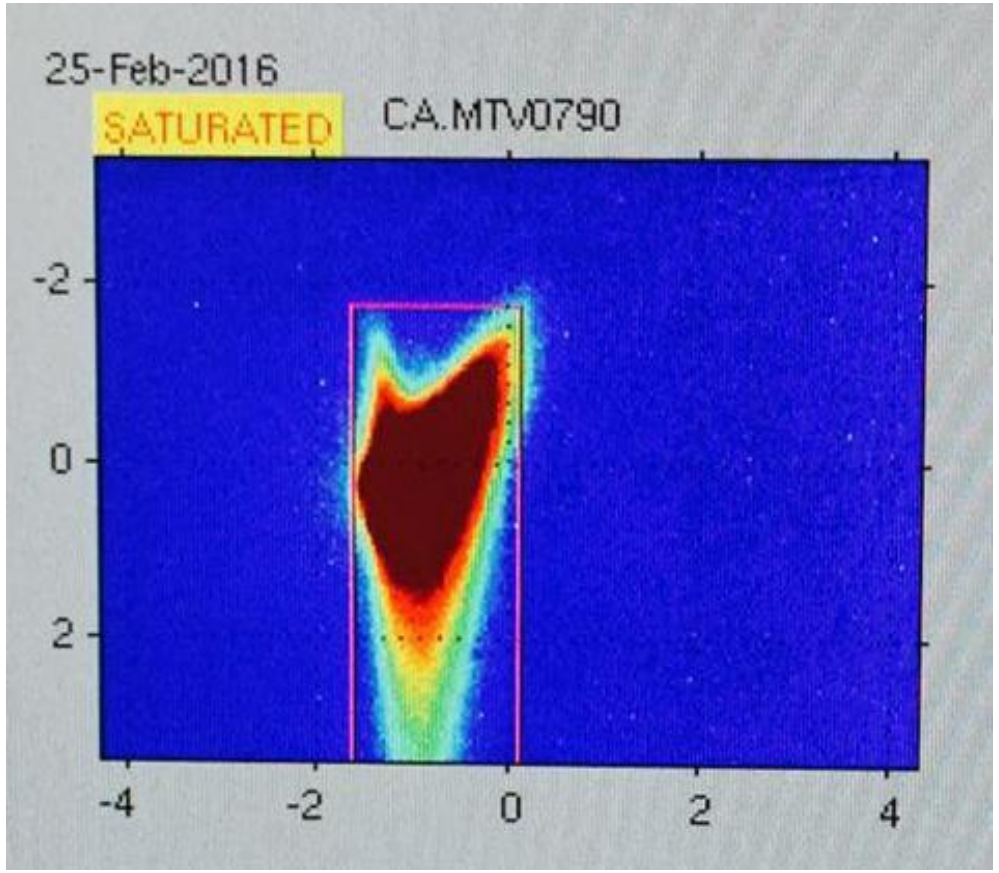
(a) Vertical and (b) horizontal offsets determined with beam alignment panel.

Student reports (continued)



Filling time measurement

Student reports



The "Cat Head"

CERN Accelerator Test Stand

or CALIFES-based Accelerator Test Stand

Conclusions

- Practical works on CALIFES with JUAS students is a valuable experience worth to be continued (unfortunately not possible next year).
- We can certainly improve our offer (all suggestions are welcome).

- Many thanks to the students for their reports: Davis Amorim, Benjamin Beringue, Simona Borrelli, Manuel Dutine, Gowrishankar Thalagavadi, Pierre Korysko, Fabien Plassard, Felix Schliessmann, Sonja Storck, Vincent Benjamin, Anna Vnuchenko, Mykola Zlygostiev