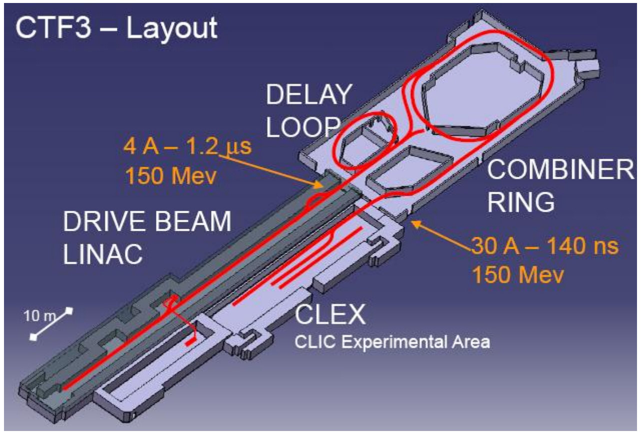
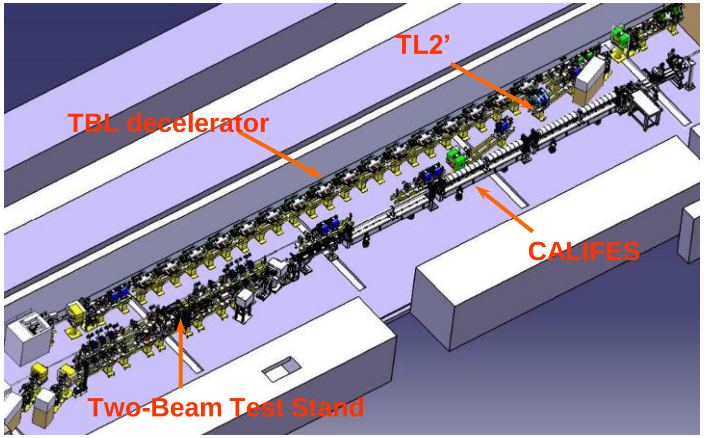
CTF3 Probe Beam Status

What is CALIFES ?

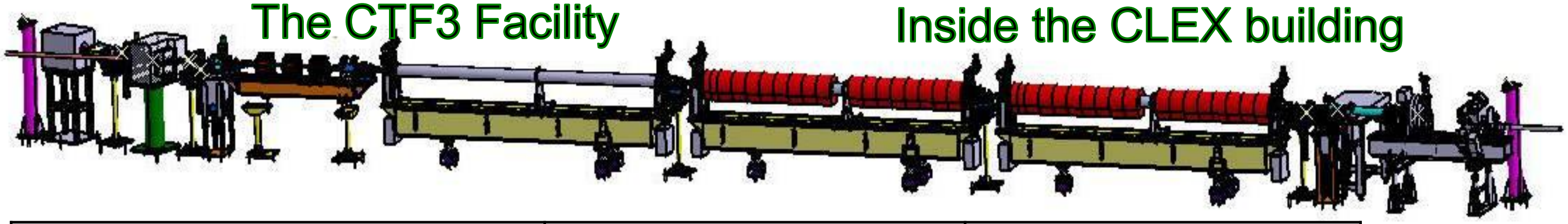
Probe beam LINAC for the TBTS



The CTF3 Facility

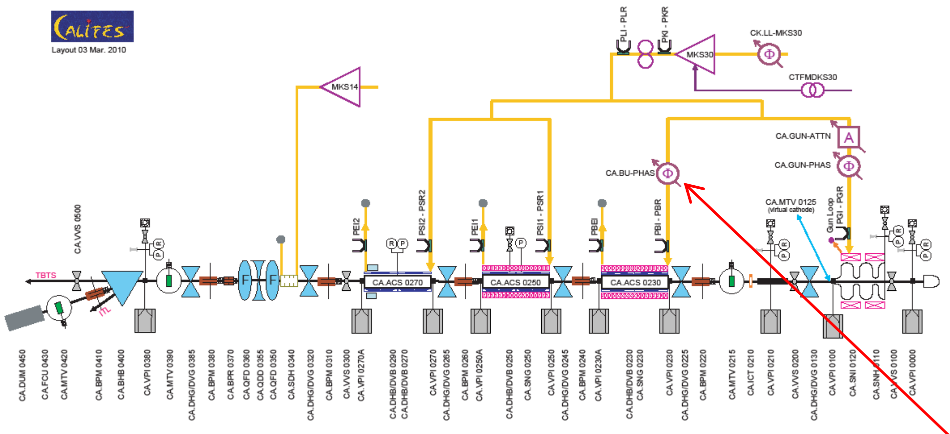


Inside the CLEX building



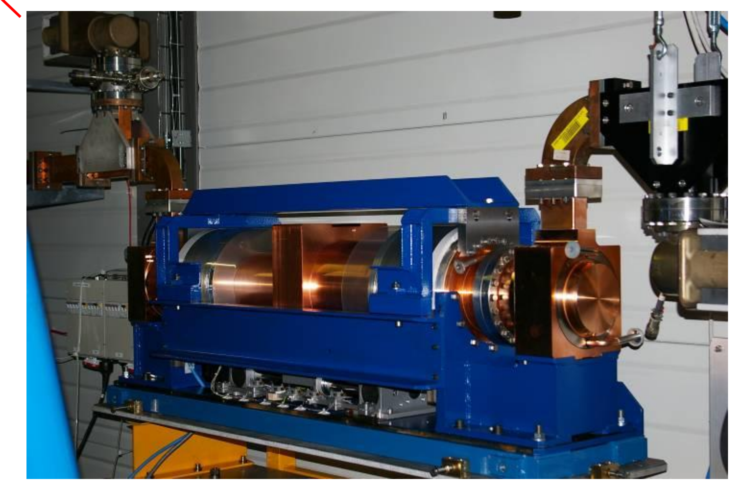
Parameters	Specified	Tested
Energy	200 MeV	185 MeV
Norm. rms emittance	< 20 π mm.mrad	8 π mm.mrad
Energy spread	< 2 %	0.5 %
Bunch charge	0.6 nC	0.65 nC
Bunch spacing	0.667 ns	0.667 ns
Number of bunches	1-32-226	from 1 to 300
rms. bunch length	< 0.75 ps	1.4 ps

CALIFES layout



CALIFES Layout

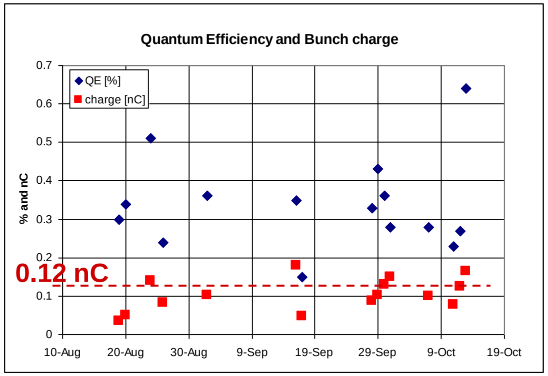
CALIFES in the CLEX

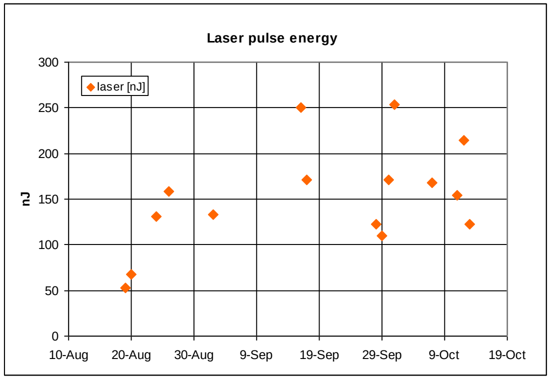


Newly installed 3GHz power phase shifter
(Franck Peauger and al. IRFU Saclay)

Based on:
- Photo-injector (LAL Orsay)
- Laser line (using the same laser as for PHIN)
- 3 former LIL accelerating structures
- A single klystron 45 MW, RF distributed to the structures and the gun through WG, splitters, phase-shifter and attenuator.
- A complete set of diagnostics

Laser, bunch charge and QE



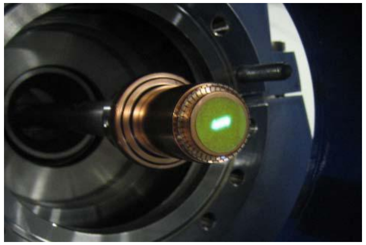


QE, bunch charge and laser energy 3 months record

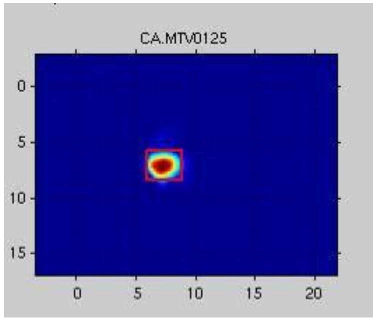
Photo-injector developed by LAL

- CsTe photo-cathode quantum efficiency was measured around 1% only during few days after regeneration one year ago.
- Now it varies between 0.2 and 0.6 % (depending on laser spot position).
- Laser beam needs to be shaped by a hard aperture thus limiting energy per pulse around 250 nC.
- In order to achieve reliably the requested bunch charge (0.6 nC) a dedicated laser system with a short beam transport line and capable to deliver 1 μJ per pulse is under development

[see next talk by Marta]

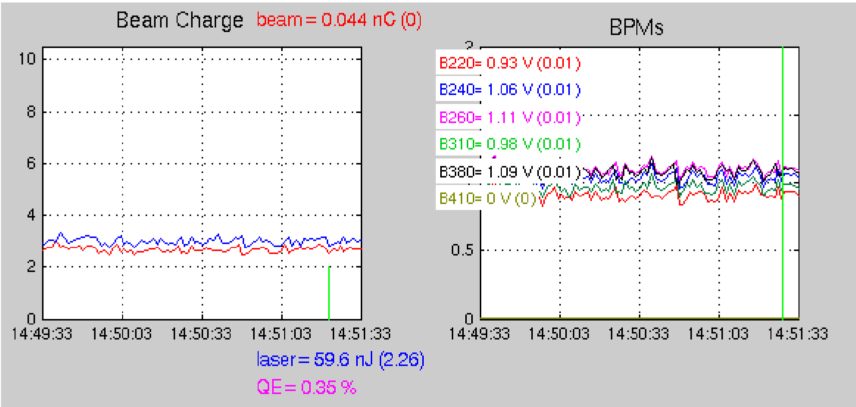


CsTe photo-cathode

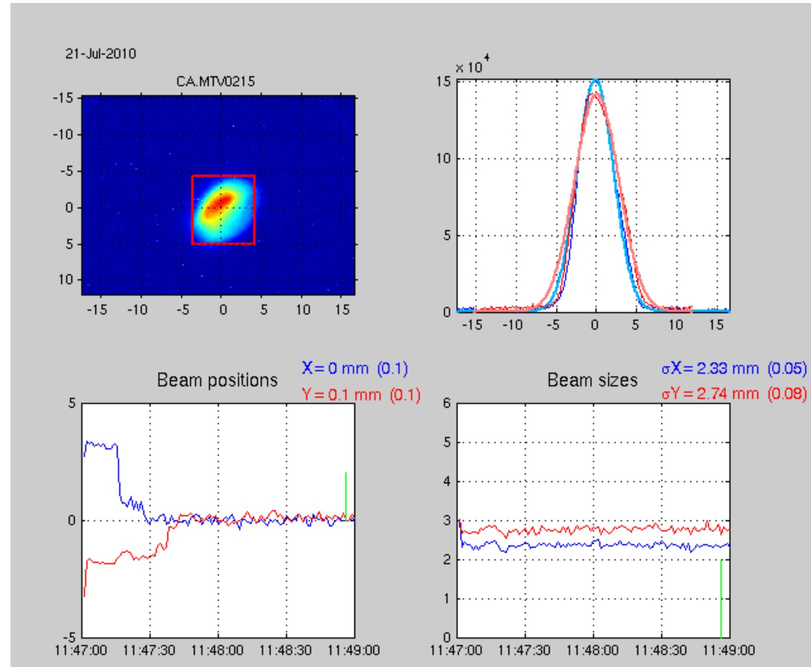


Shaped laser profile on virtual cathode

Laser and beam stability



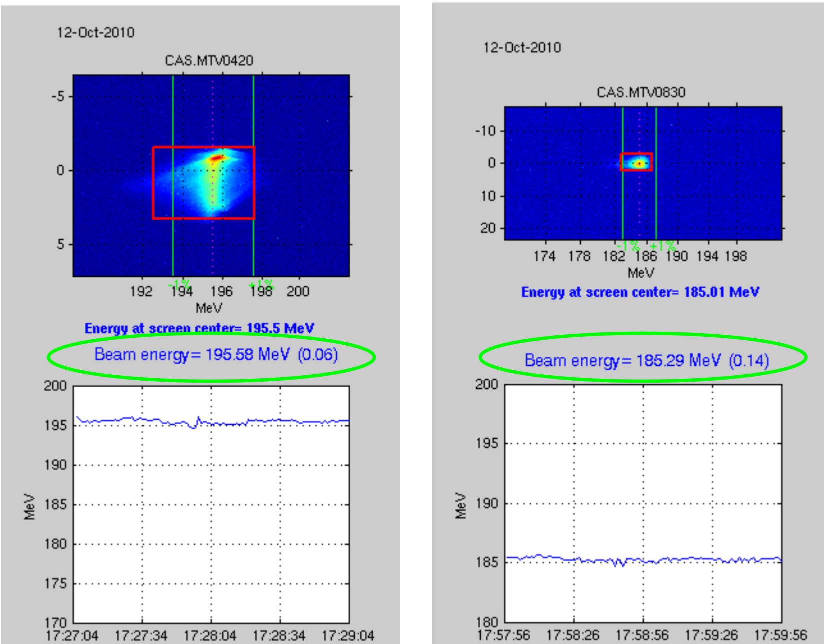
Strong correlation between laser energy and beam charge fluctuations



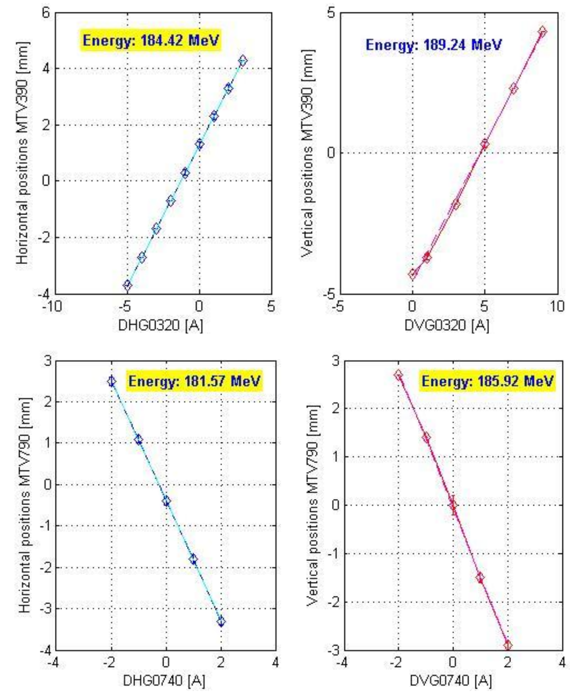
Beam position and size jitters

- Laser energy and beam charge fluctuate accordingly around 4 % rms.
- Beam position at gun output also fluctuates by 0.1 mm (1σ)
- Again a dedicated laser with a short beam transport will help to fix the problem. [Marta's talk]

Energy



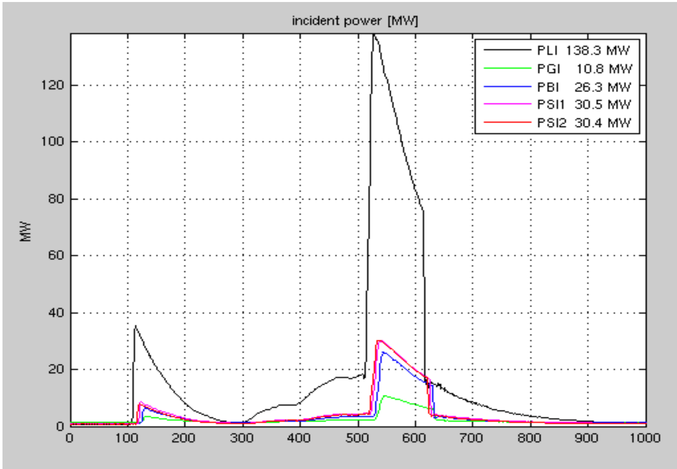
Energy measured with CALIFES and with TBTS spectrometer lines



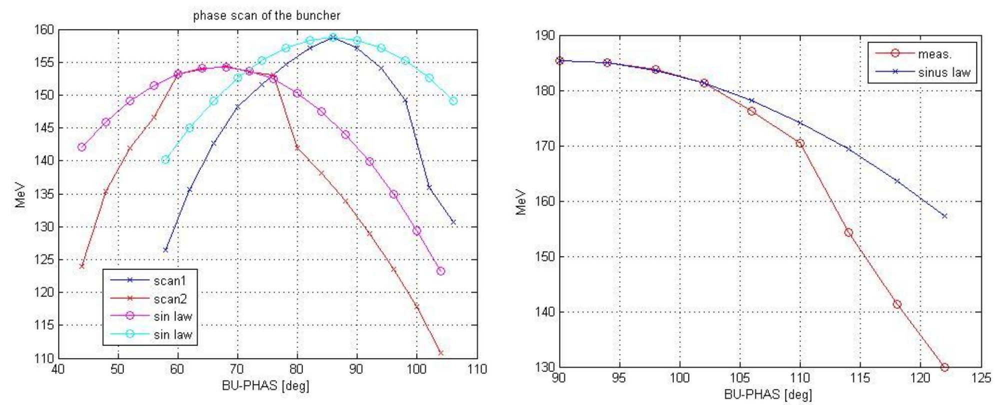
Energy measured with beam deviation by correctors

- Discrepancy between energy values provided by the 2 spectrometers lines:
  ΔE = 10.3 MeV, (5.6 %)
- Correctors beam displacements vs. current agree with the TBTS one.
- Max energy is obtained with buncher on crest acceleration but at the expense of bunch length

Expected energy



Forward power levels from RF couplers



Energy as function of buncher phase shifter position

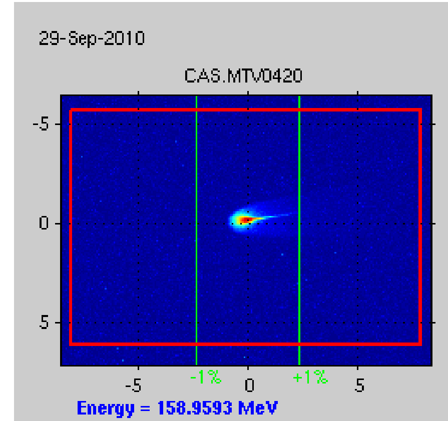
- Compressed pulse (1.2 μs) : 138 MW peak (from 45 MW 5.5 μs klystron)
- RF network loss : 1.5 dB
- Considering the energy gain theoretically provided by the LIL structure

$$E_{[MeV]} = 15.34 \, (P_{[MW]})^{1/2} - 0.087 \, I_{[A]}$$

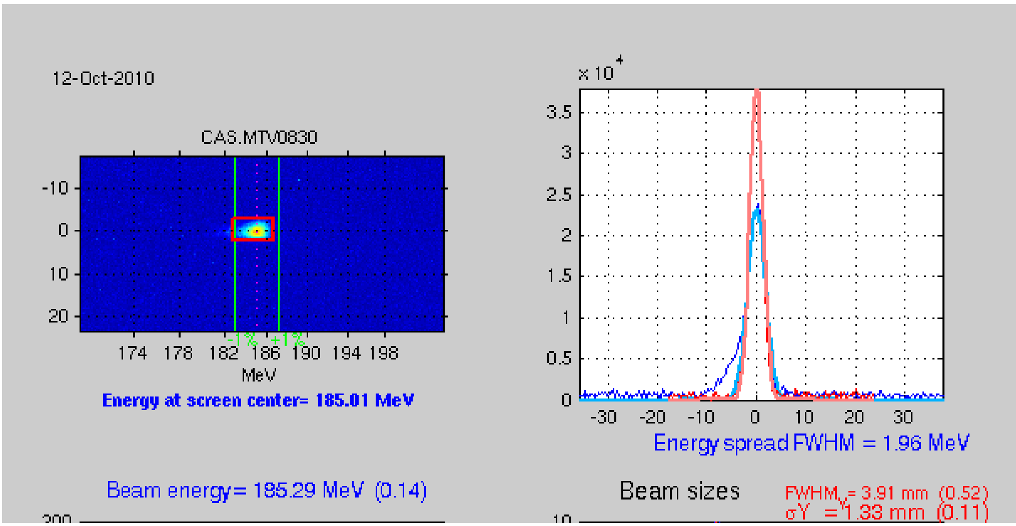
The maximum energy expected should be 215 MeV not 185 MeV

- The reason of this discrepancy is still under investigation (phase shift due to the pulse compression ?)
- In addition buncher phase/energy scans do not fit with a sinus law (bunch drift in the buncher at low β ?)

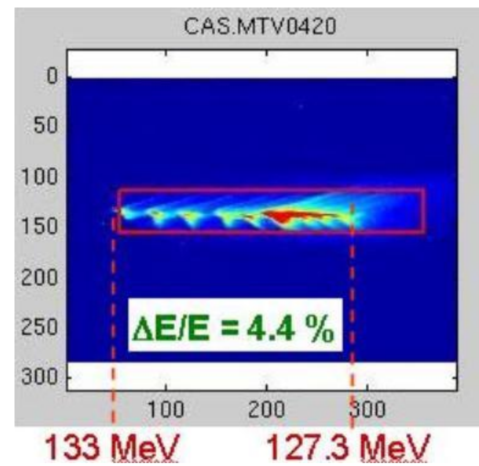
Energy spread



Settings with very low energy spread



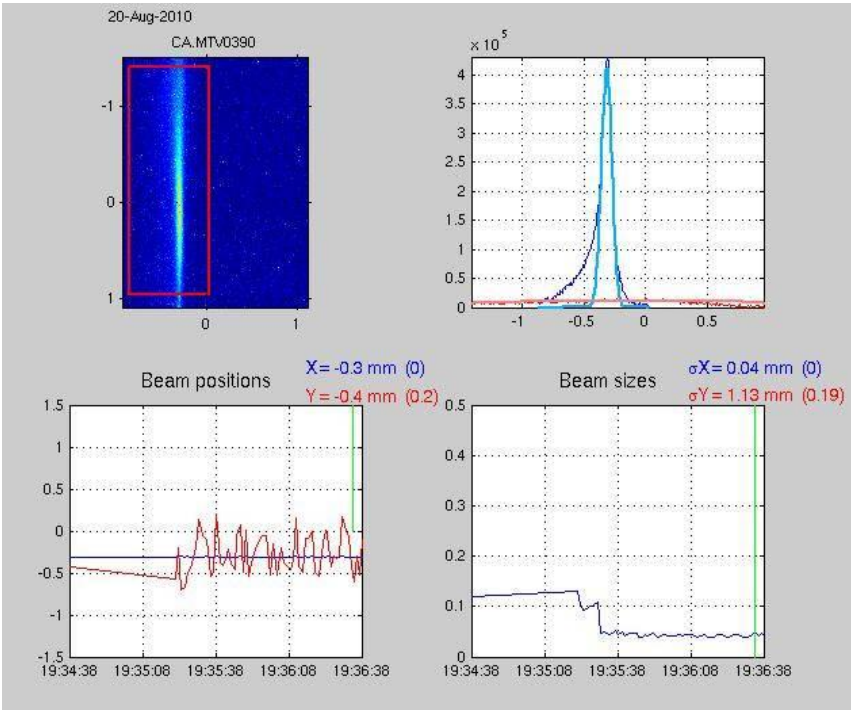
Energy spread around 1% FWHM



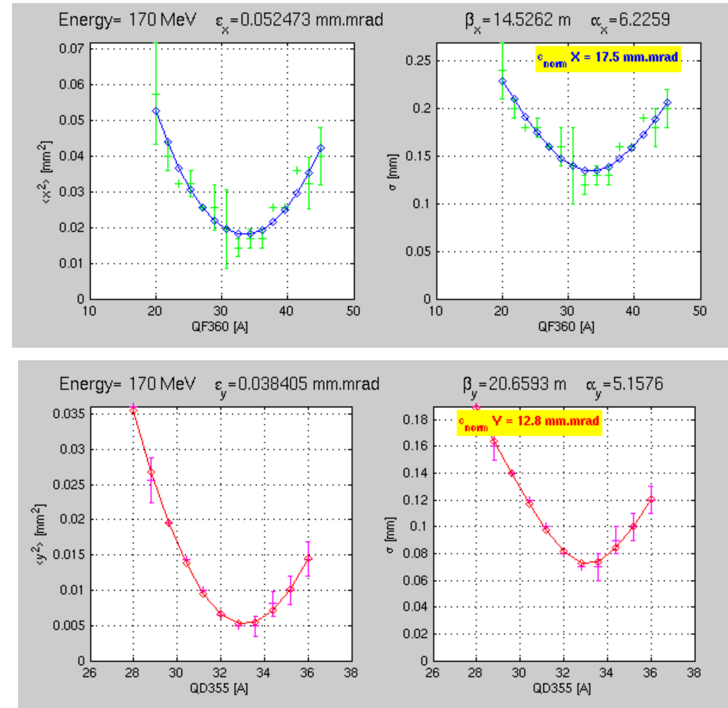
Settings with large energy spread separating various bunches

- Energy spread can easily be lower than ± 0.5 % by tuning accurately RF phases in gun and structures.

Emittance



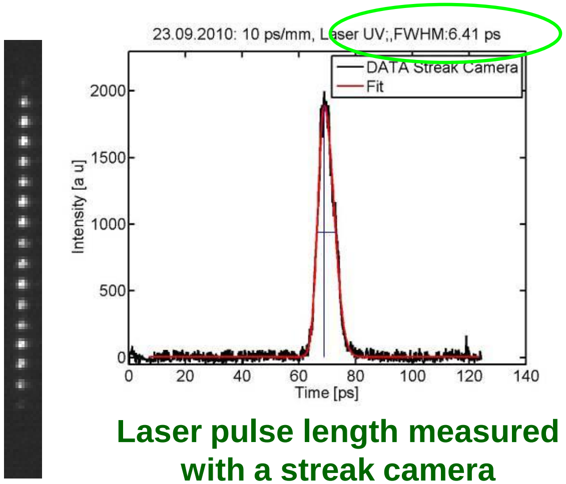
Control screen during quad scan



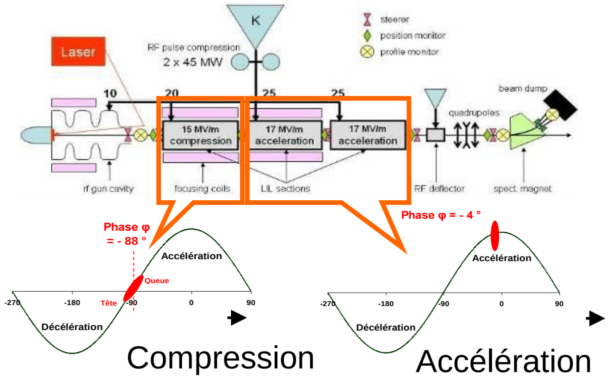
Horizontal / vertical quadrupole scan fit and derived beam parameters

- Emittance was sometimes measured below 20 mm.mrad, other times much higher (> 40 mm.mrad).
- Quad scan data are difficult to obtain due to the small waist size (<0.1mm) and require the use of the OTR screen with a high optical magnification.
- Settings to minimize the emittance are not straightforward to obtain

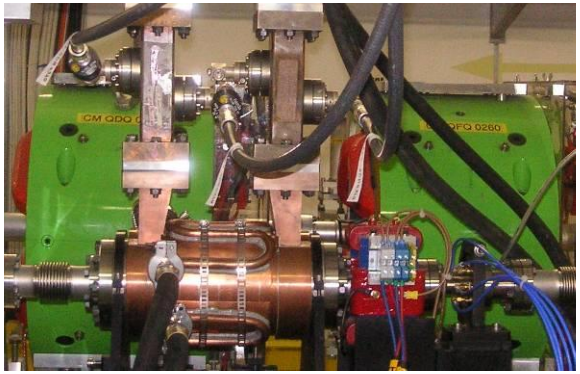
Bunch length



Laser pulse length measured with a streak camera

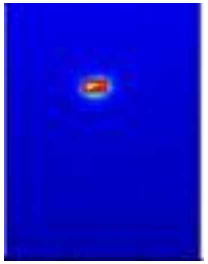


Velocity bunching scheme

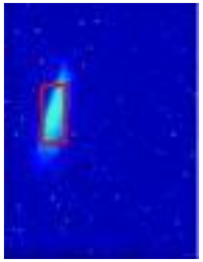


Deflecting cavity

Thanks to A. Dabrowski and M. Csatari



Cavity OFF
σy = 0.24 mm



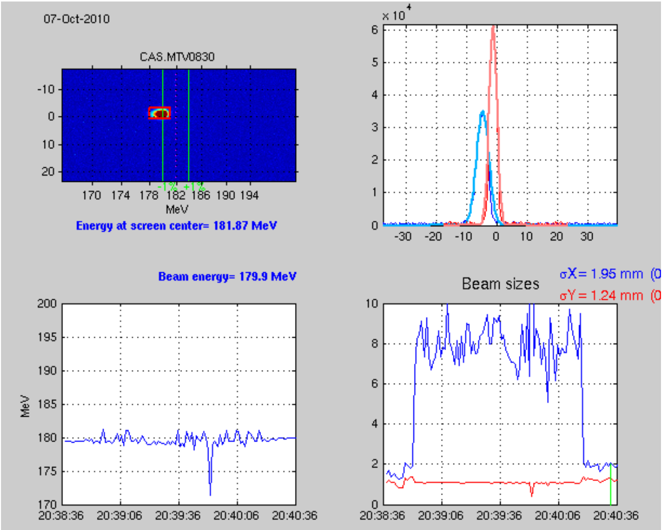
Cavity ON
σy = 1.47 mm

- 3 GHz Phase calibration gives 0.94 mm per degree (333 ps for 360 deg)
- Vert. beam size due to the deflecting cavity: 1.45mm

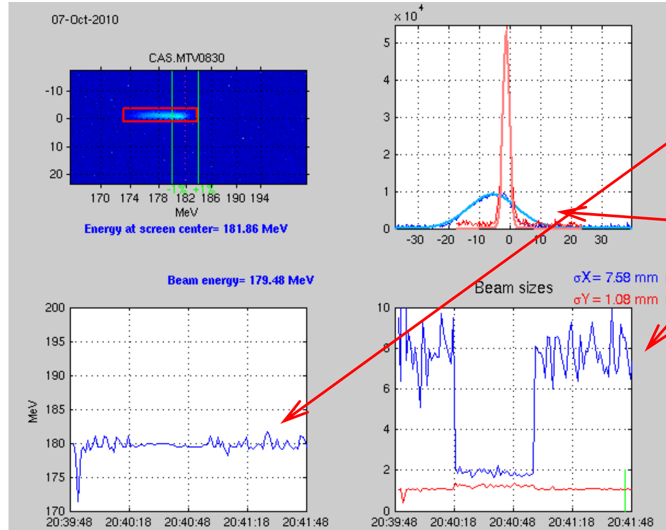
-> Bunch length 1.42 ps at 1 σ or 3.34 ps FWHM

- Bunches produces by the photo-injector need to be shorten using the first LIL structure on the raising slope.
- To measure bunch length, a deflecting cavity is used at zero crossing that allows to enlarge the vertical beam size as function of bunch length.

Bunch length measurement with ACS



ACS 12GHz OFF



ACS 12GHz On at zero crossing

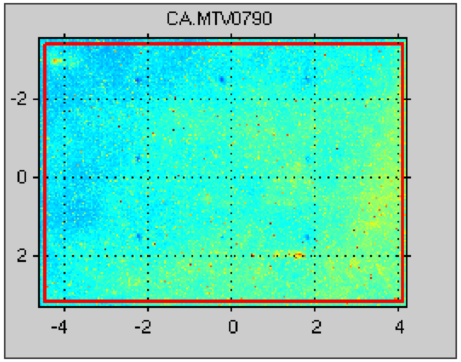
zero crossing: no energy variation

But energy spread increase

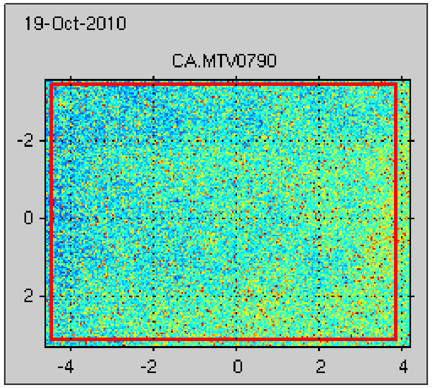
$$\frac{\Delta E}{2} = E_{acc} \sin\left(\omega \frac{\tau}{2}\right)$$

- The 12 GHz accelerating structure can be used to measure the bunch length, even more efficiently than the 3 GHz deflecting cavity.
- Measures done for various phases of the buncher give pulse length scaling from 1.46 ps to 5.6 ps.

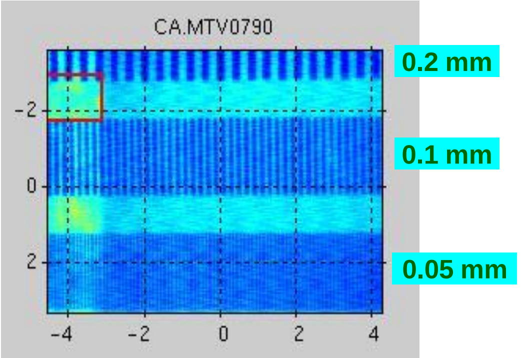
Cameras degradation due to radiations



Camera close to the dump at the installation



The same camera after 2 months

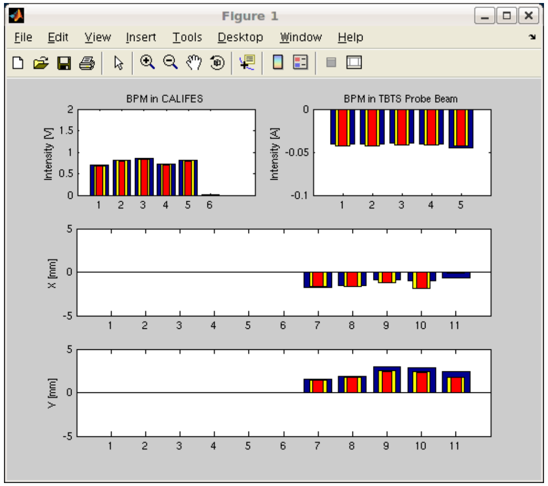


Pattern included in the screen

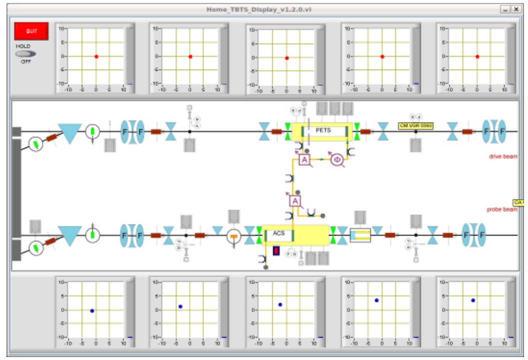
MTV0790 showing the lead shielding and the LED lighting

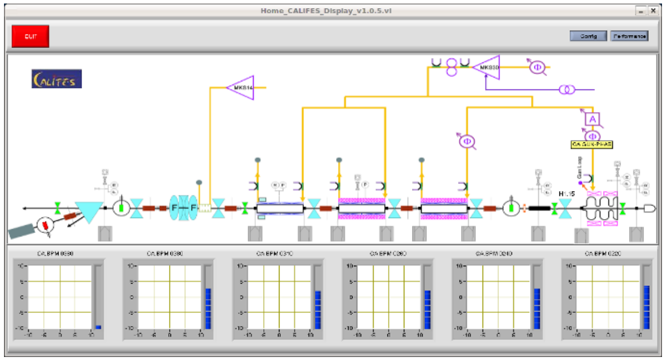
- Despite the thick lead shield (5 to 10 cm), cameras close to the TBTS dumps have suffered from radiations: high noise on CA.MTV0790 and no more signal from the CM.MTV0590.
- But the degradation is now stabilized, so it probably happened during a severe drive beam loss operation.

Probe beam operational for TBTS studies

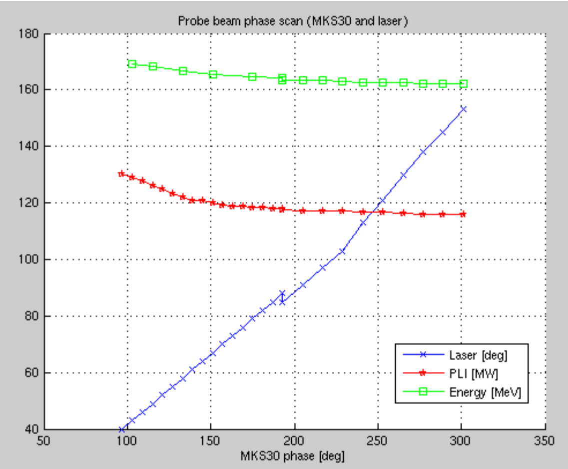


Good beam transport through TBTS

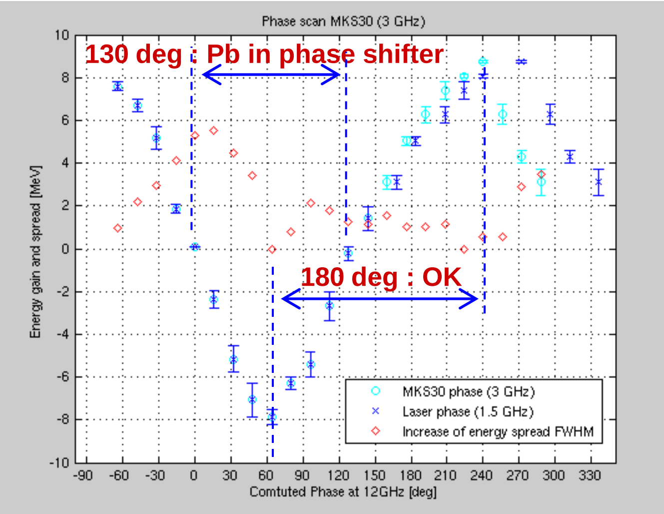




User friendly control panels
(Martin Nybo EN / ICE)



Capability to change the probe beam phase vs. drive beam

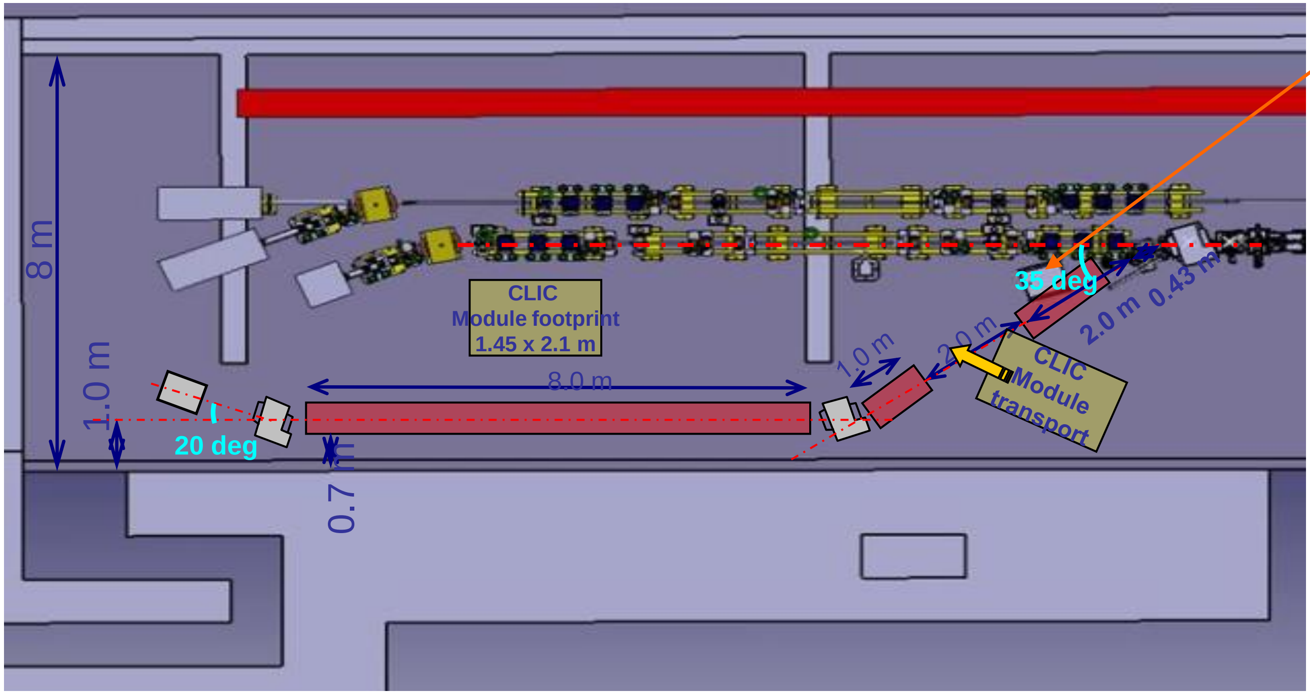


Energy gain and energy spread vs. phase

CALIFES foreseen improvements

- A dedicate laser system
- Accurate calibrations of the spectrum line, phase shifters, RF couplers…
- Extensive use of the BPMs (presently displacements are not calibrated)
- Installation of an RF pick-up to monitor the bunch length
- Installation of a moving slot in front of the first screen to measure gun emittance
- Development of a beam dynamic model type “flying simulator”
- Possible construction of a instrumentation test beam line (ITB) parallel to the TBTS (manifestations of interest are welcomed)

The Instrumentation Test Beam project



Beam dump to be removed

• First step: record the potential users for this line with their requirements in terms of performances and ancillaries. (Anne's talks about CTF3 instrumentation, opportunities and limitation, WG6).

• Not necessary the actual CALIFES performances: thanks to the chicane pulse length as short as 20 μm could be obtained (Volker's study Short Pulse Capabilities of the Instrumentation Beam Line, Uppsala University 6 may 2010).

• Feasibility, beam dynamic, drawings, equipments collections, construction…

Conclusions

• CALIFES probe beam is now routinely used for the TBTS operations and provides useful and trusty data about ACS behaviour.

• Good beam parameters are reasonably easy to obtain and then are stable in time.

• The operations suggest improvements in some characteristics that will be developed this year.

Many thanks to so many people from CERN and from the collaborations who have continuously shown their supports and encouragements.