CTF3 COLLABORATION MEETING 2003

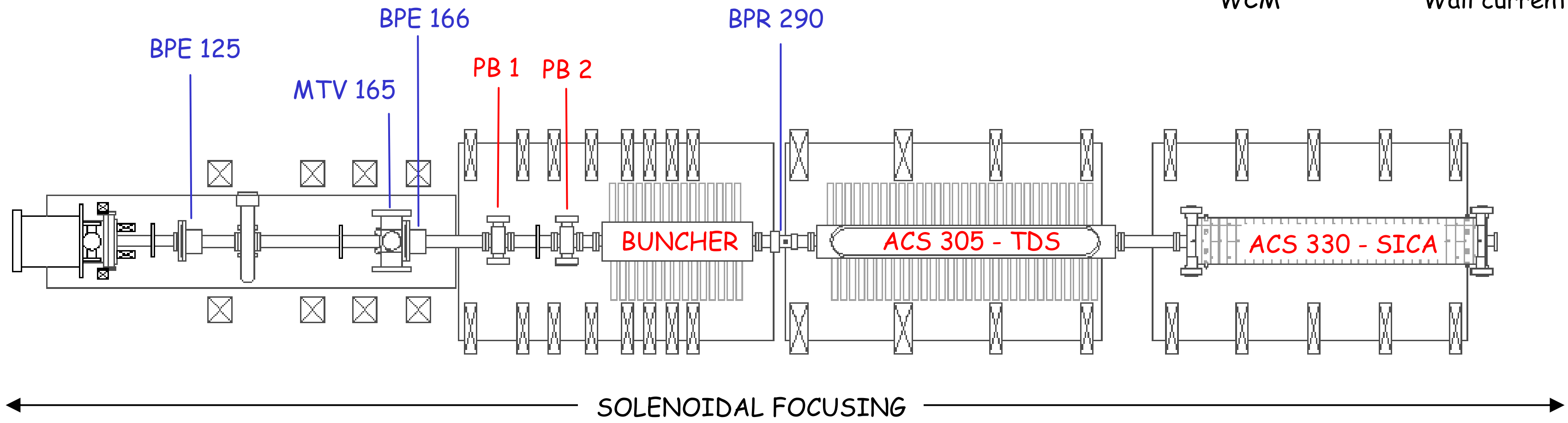
30 September 2003

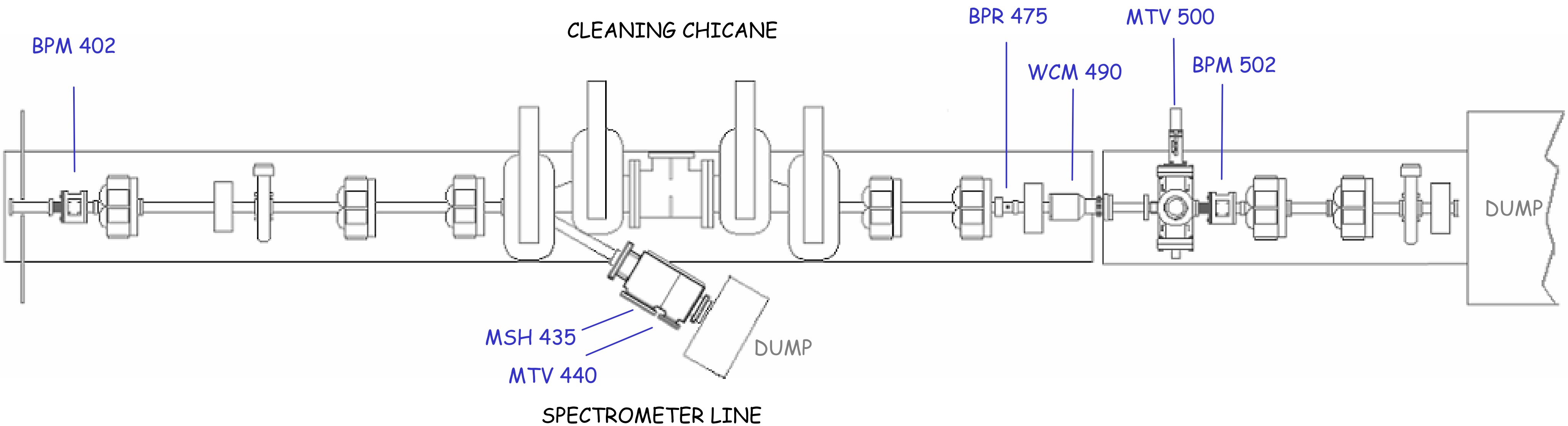
2003 Commissioning results and conclusions

R. Corsini for the CTF3 Team

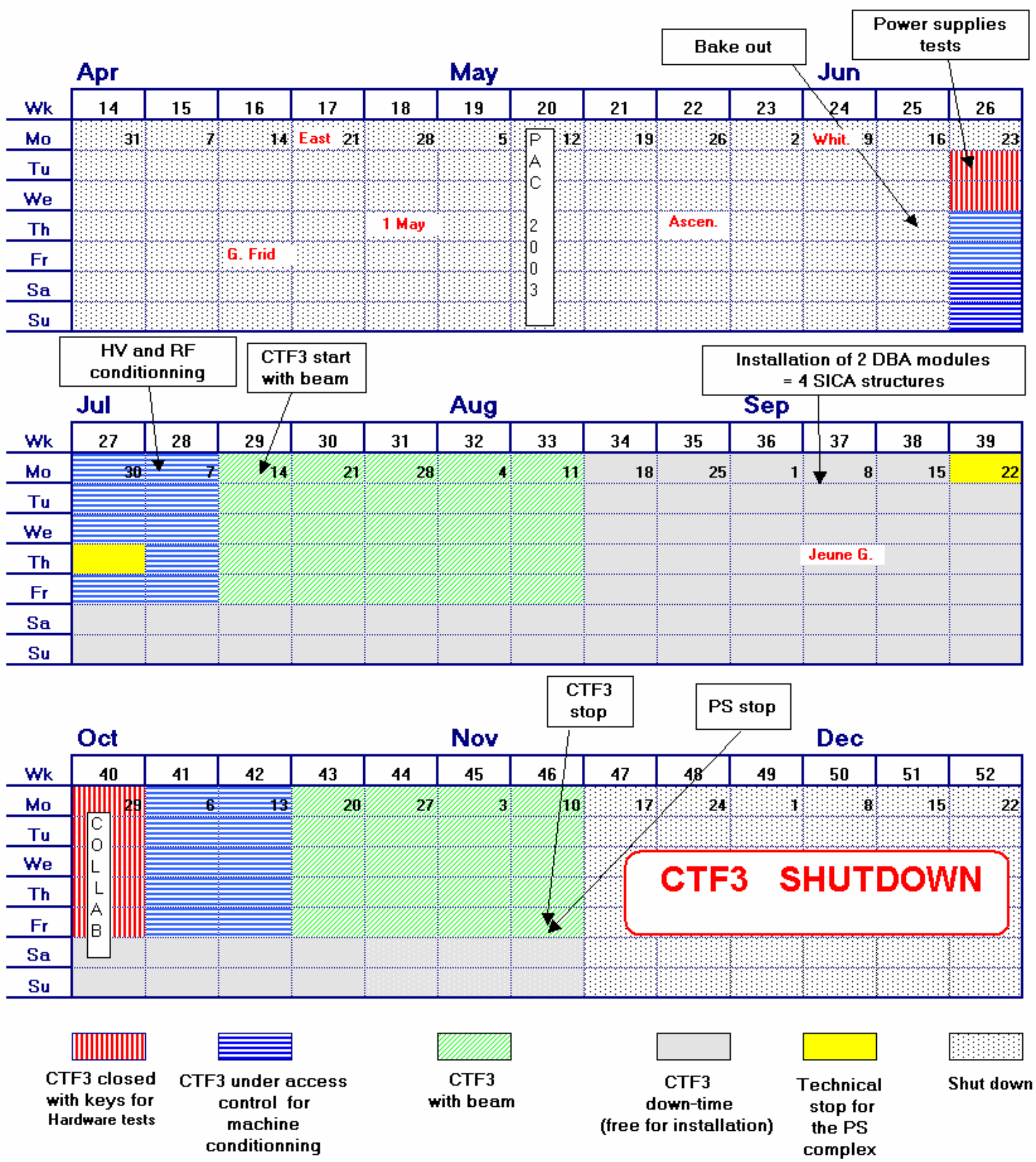
CTF3 layout (July-August 2003)

BPE, BPR, BPM	Beam position monitors
MTV	Screens
MSH	SEM-Grid
WCM	Wall current monitor





CTF3 commissioning schedule



R. Corsini – 29 September 2003

CTF3 commissioning program

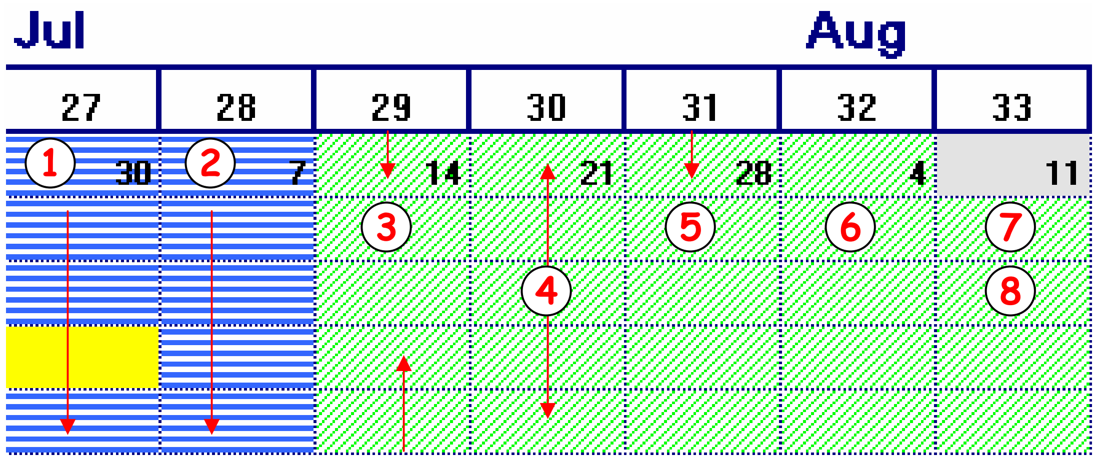
CTF 3 Main objectives for 2003

- 1st period (July 14th ⇒ August 15th)
  - Hardware commissioning

    Main items: gun, pre-bunchers, buncher, accelerating structures, RF pulse compression system, diagnostics
  - Nominal beam parameters (current and pulse length) at the end of the injector
- 2nd period (October 20th ⇒ November 14th)
  - Optimization and complete characterization of the nominal beam*

* No slits for beam cleaning available in the 1st period

Commissioning highlights



1. June 30th CTF3 closed, **start HV & RF conditioning** Gun HV to 140 kV **gun pulser problem**
2. July 7th **First beam (140 keV)** – but **pulse is unstable**
3. July 15th Pulse **stable**, low-energy, unbunched beam transported to **BPM 402**
4. July 17th – 28th **Gun HV power supply broken, multipacting problems in PB1 & PB2**
5. July 29th **First accelerated beam** 0.5 A, 300 ns, 20 MeV
6. August 5th **Nominal current, short pulse – full beam loading** 3.5 A, 300 ns, 20 MeV
7. August 12th **Nominal current, nominal pulse length** 3.5 A, 1.5 μs, 20 MeV
8. August 13th **Higher current beam** (70 MW RF compressed pulse) 4.5 A, 1.5 μs, 20 MeV

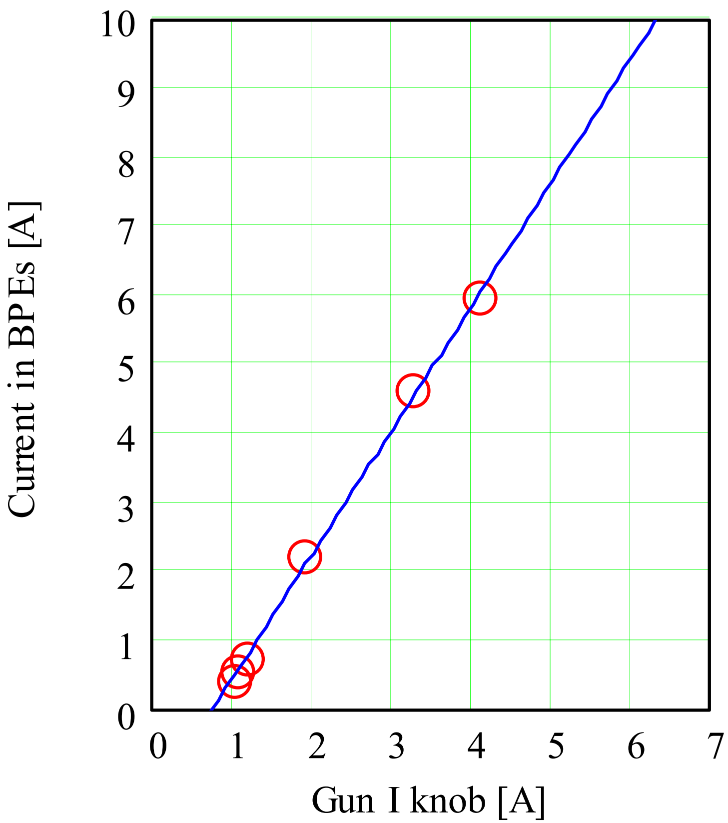
Beam performances

Main beam parameters

	Nominal	Achieved
I	3.5 A	4.5 A
τ_p	1.5 μs	1.5 μs
E	20 MeV	20 MeV
$\varepsilon_{n,rms}$	100 π mm mrad	60-90 π mm mrad *
$\tau_{bunch,rms}$	5 ps	~ 6.5 ps *

* for 3.5 A, 1.5 μs beam

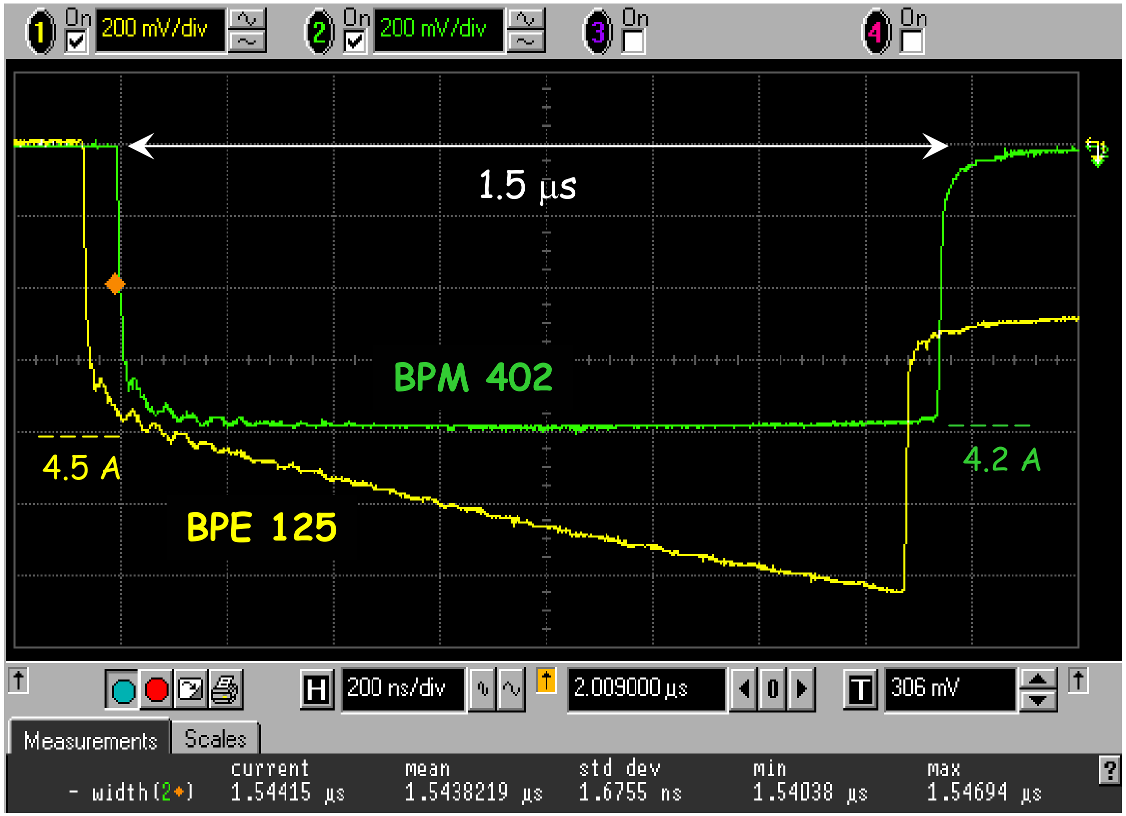
Gun current - pulse length



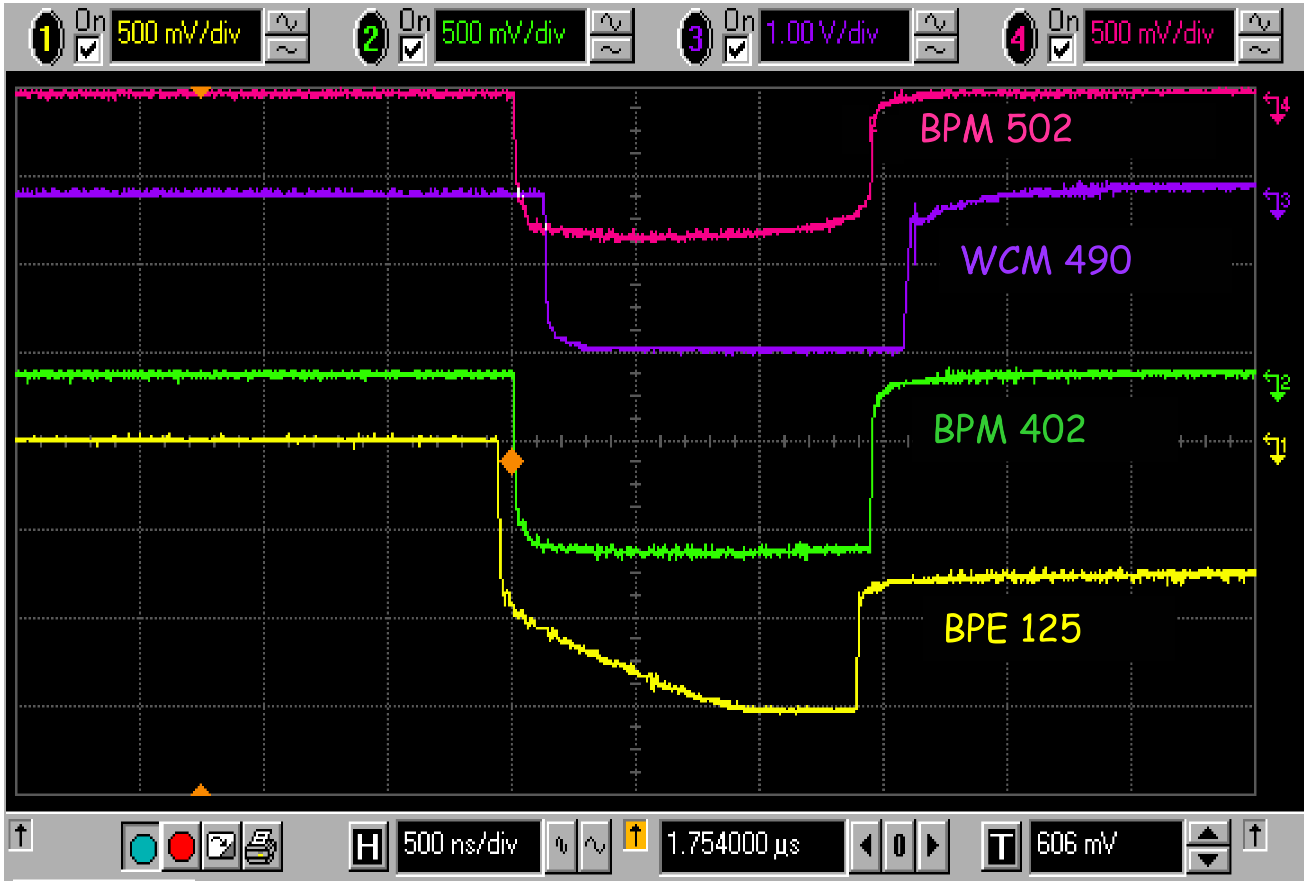
Data (BPE 125)

1.796 * I_knob - 1.33

Beam signals in BPE 125 and BPM 402
nominal pulse length



Beam current measurements

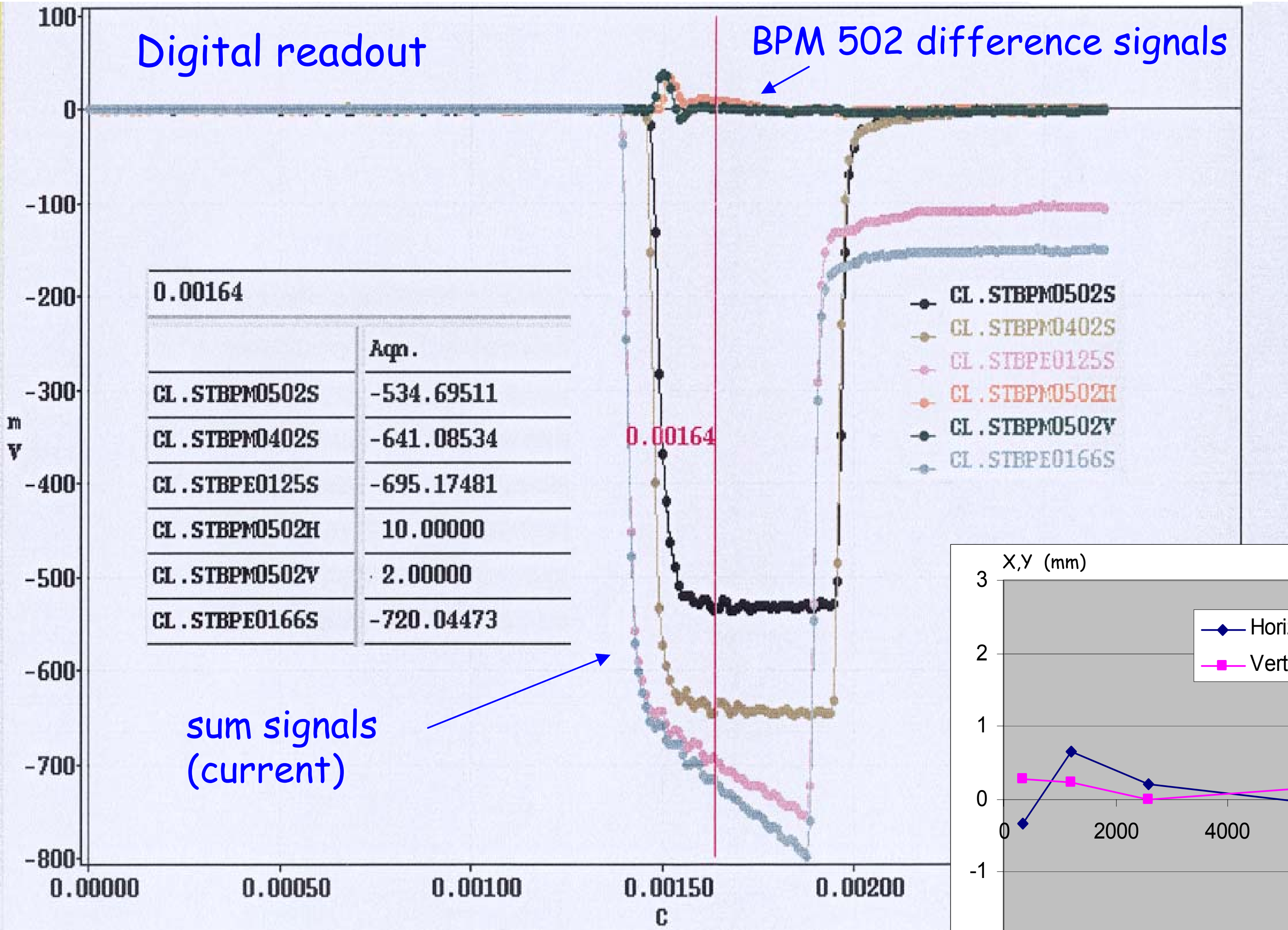


August 13th

6 A from gun
1.5 µs

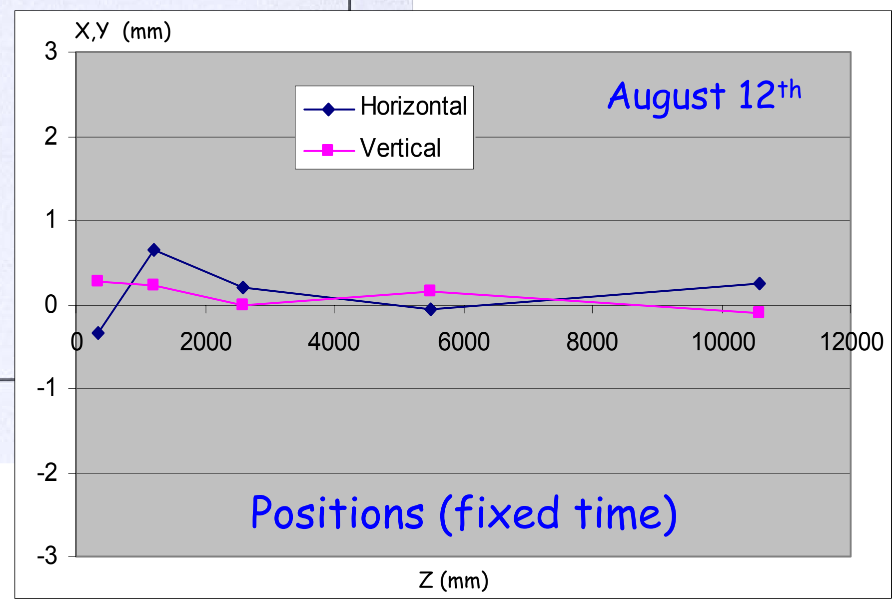
Analog signals from scope read-out

Beam position measurements

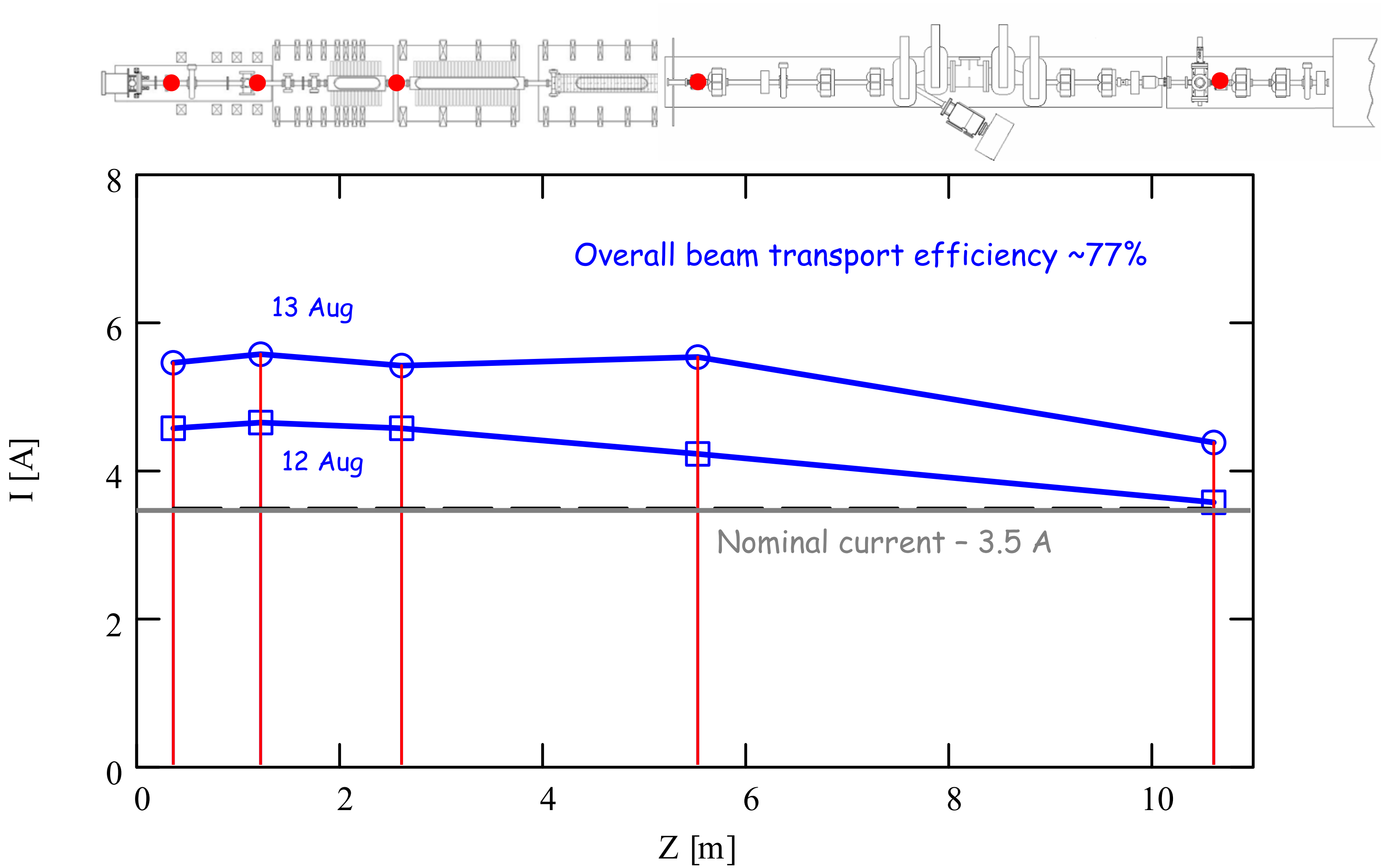


August 12th

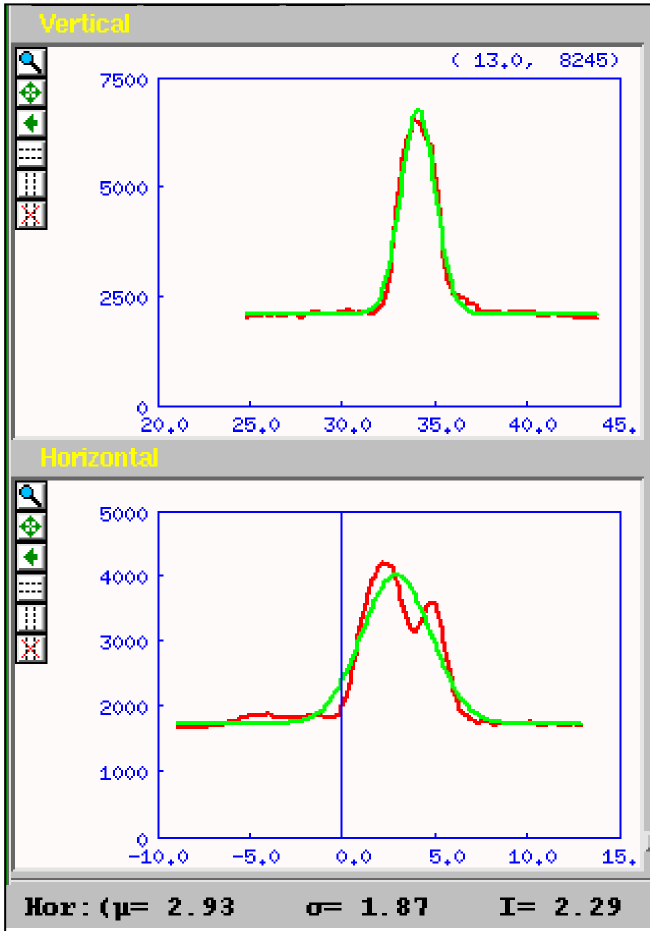
4.5 A from gun
1.5 μs

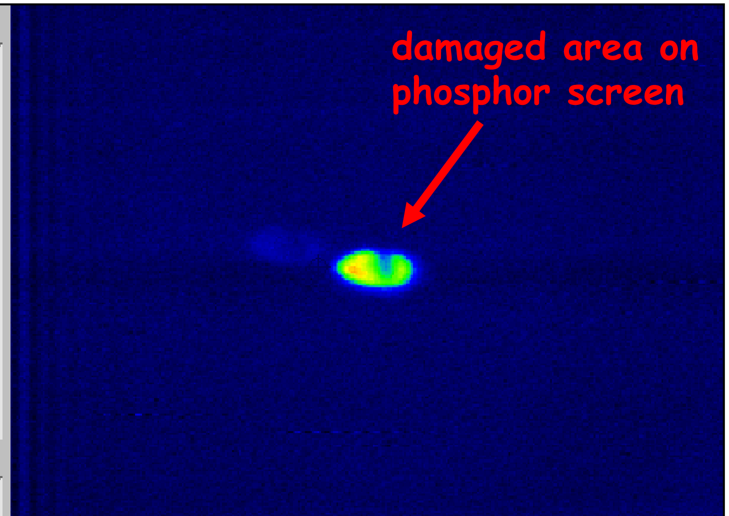


Beam transport



Diagnostics: screens



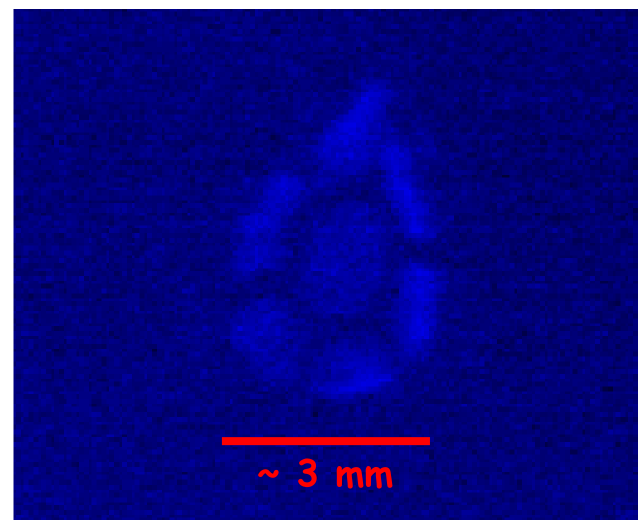


MTV 165 – Vidicom – phosphor screen

August 5th

MTV 165 – Vidicom phosphor screen

Dark current (pulsing off)



Diagnostics - SEMgrid

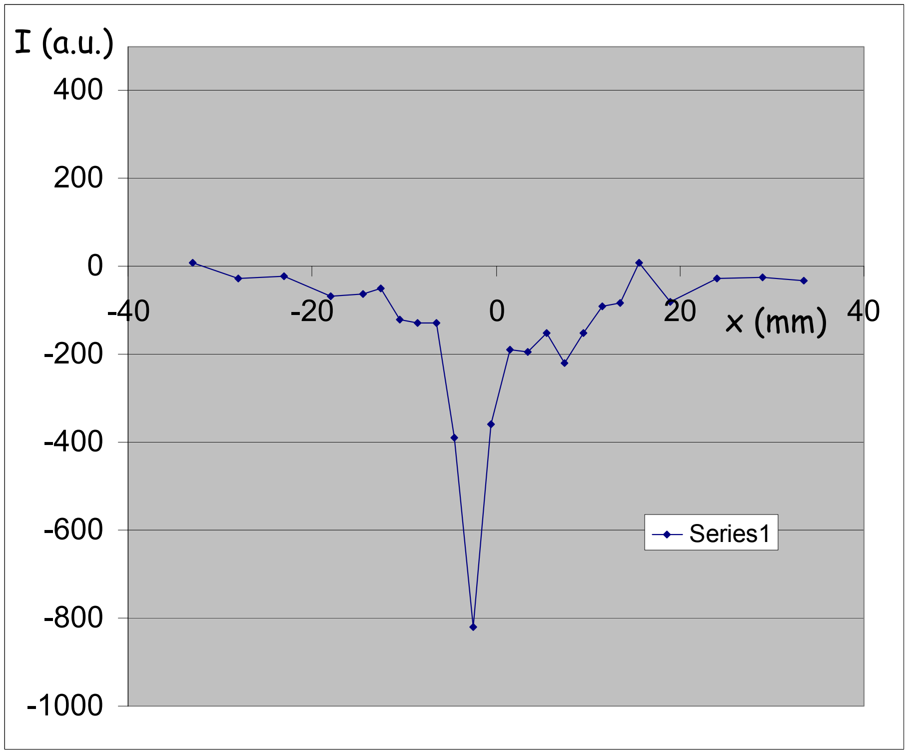
Problems at high current:

Under investigation

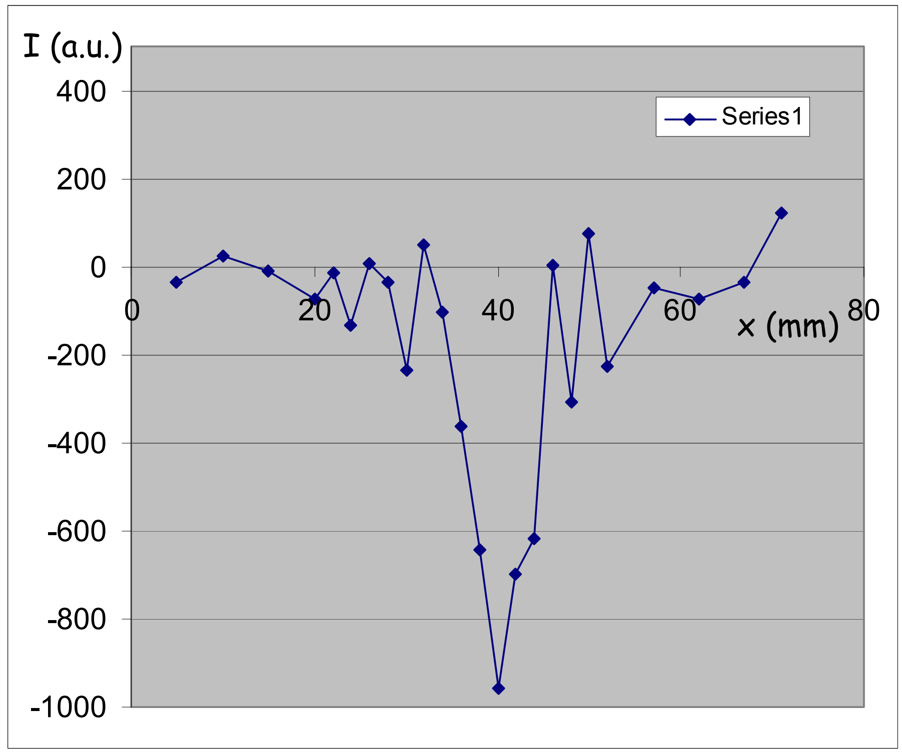
- parasitic signals
- both negative and positive signals
- strange pulse shapes (in time)
- saturation problems

SEMgrid profiles

August 13th 0.7 A – 300 ns – 21.5 MeV



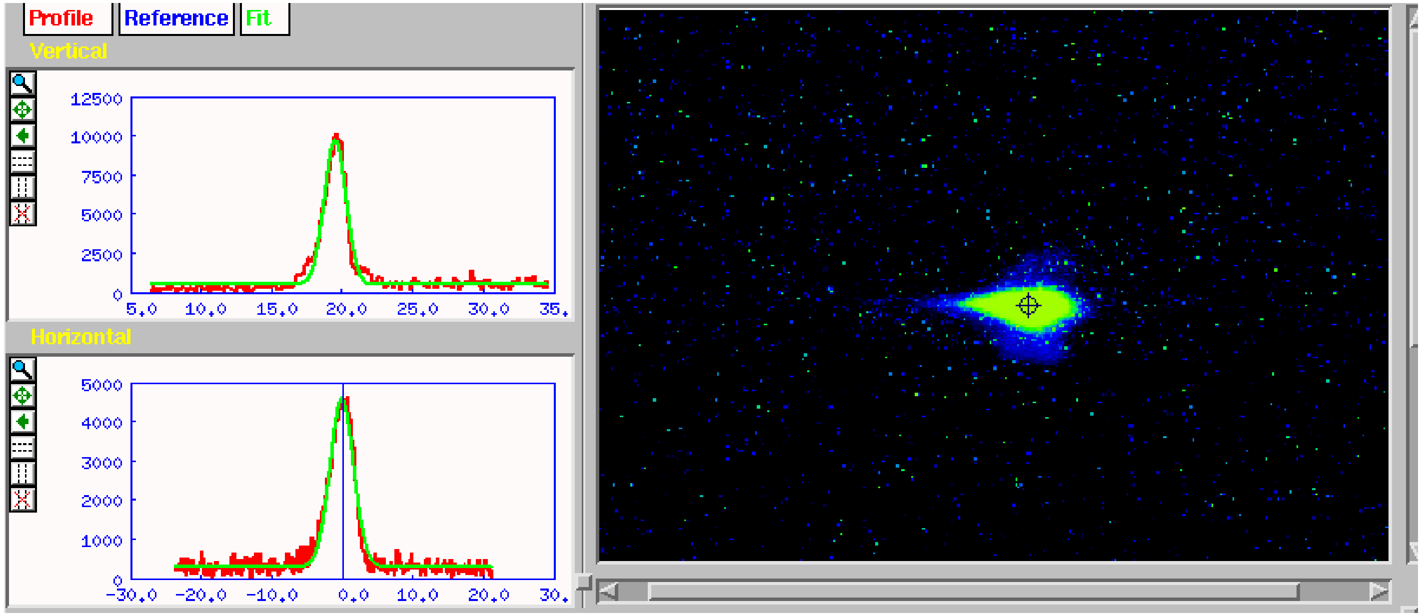
July 31st 1 A – 320 ns – 25.5 MeV

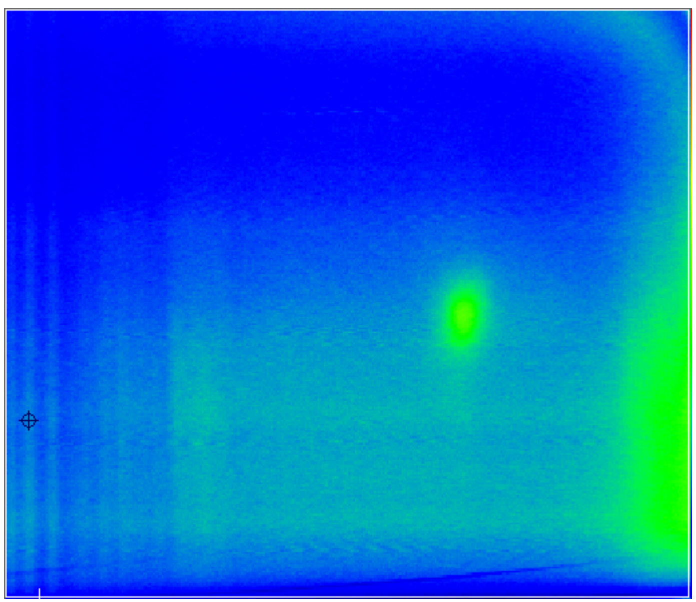


Diagnostics: screens

MTV 500 – CCD camera
carbon screen

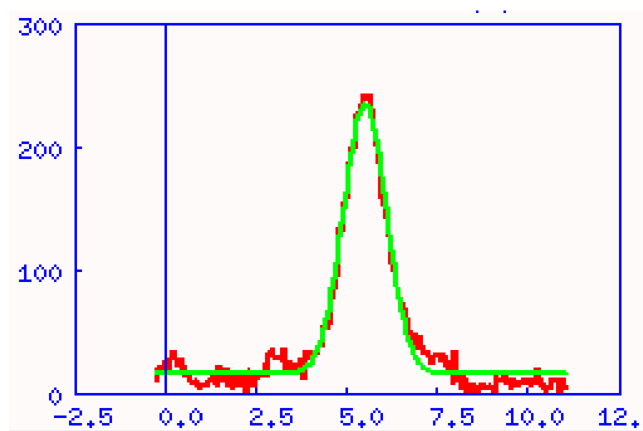
quad scan of August 13th





MTV 440 – Vidicom – aluminum screen

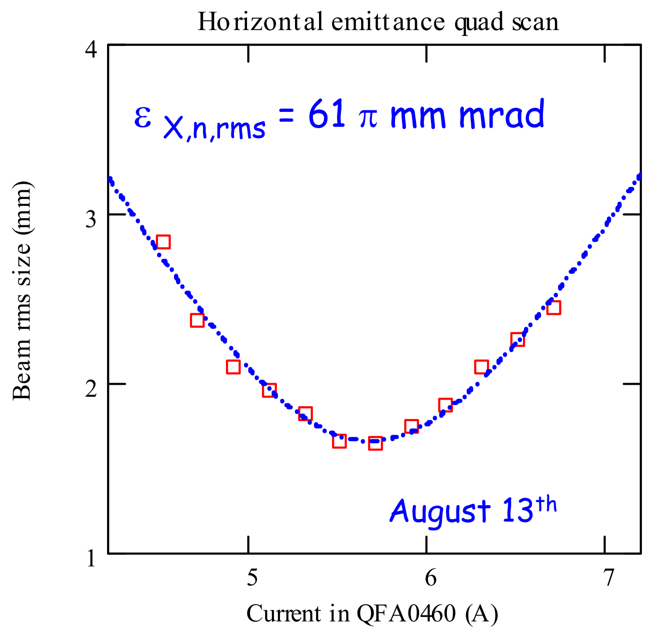
phase scan of August 5th

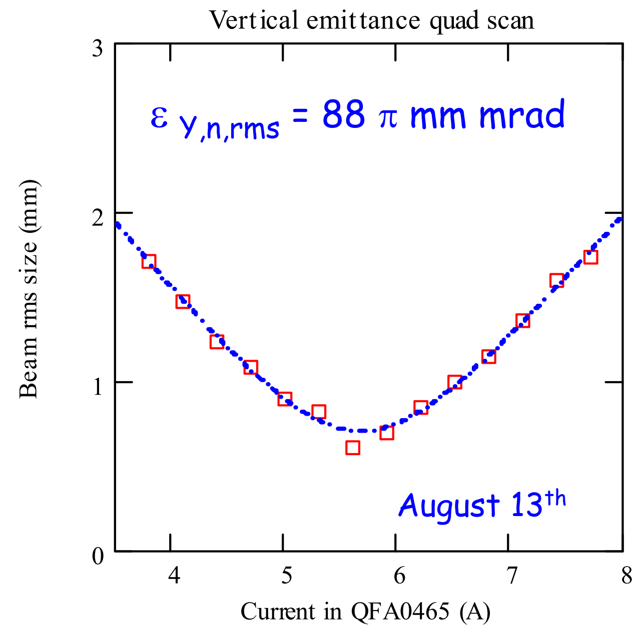


Beam emittance

Two scans were performed using MTV500 (CCD camera), in different conditions on August 8th and 13th

In the 2nd scan, two series of images have been taken, with and without a baseline offset in the video signal, in order to eliminate the beam halo (low energy component ?)





Aug 8th 1.4 A, 320 ns, 20 MeV saturation in mtv500 ?

* Horizontal:
- emittance (norm rms) = 160 mm.mrad
- betax = 4.05 m
- alphax = -4.53

* Vertical:
- emittance (norm rms) = 330 mm.mrad
- betay = 0.77 m
- alphay = +0.58

Aug 13th 4.5 A. 650ns, 20 MeV

Halo included

* horizontal:
- norm emittance (rms) = 128.4 mm.mrad
- betax = 2.90 m
- alphax = -3.21

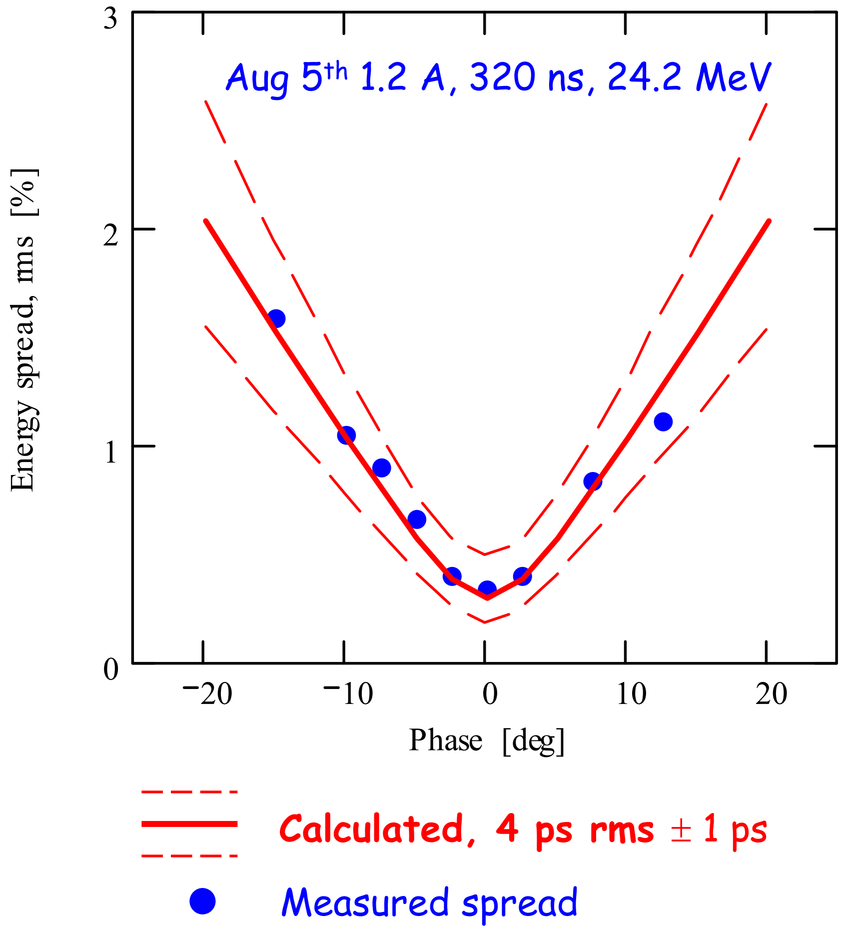
* vertical:
- norm emittance (rms) = 144.6 mm.mrad
- betay = 0.74 m
- alphay = +0.46

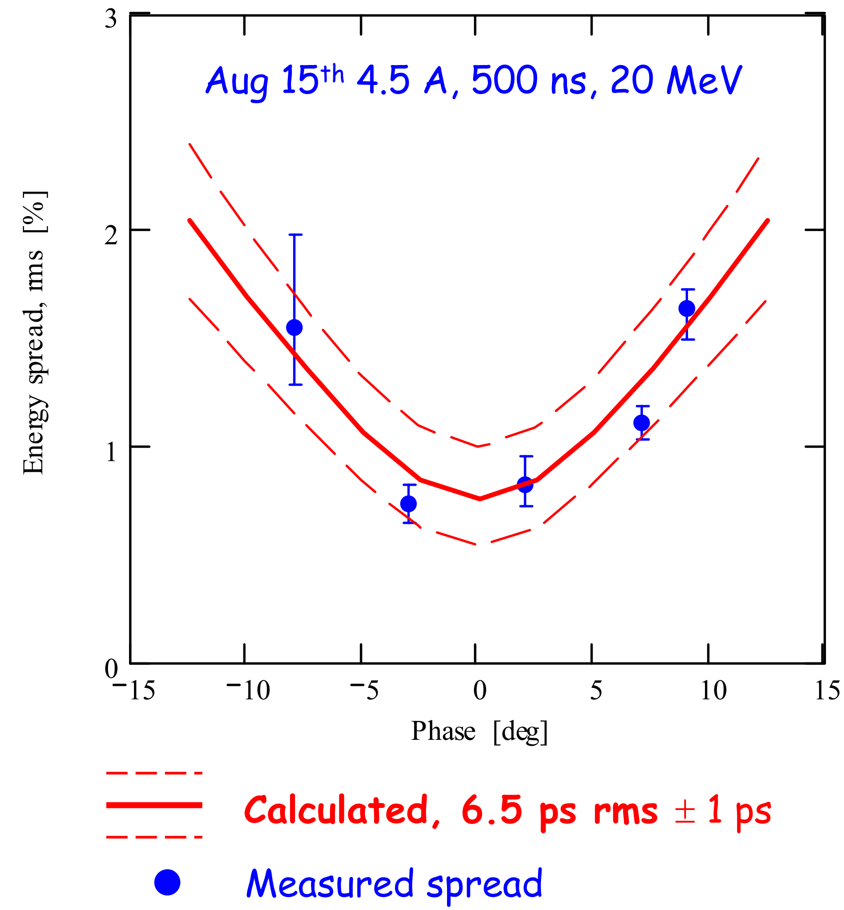
Halo suppressed

* horizontal:
- norm emittance (rms) = 60.9 mm.mrad
- betax = 2.36 m
- alphax = -2.75

* vertical:
- norm emittance (rms) = 87.9 mm.mrad
- betay = 0.66 m
- alphay = +0.43

Bunch length – phase scan method

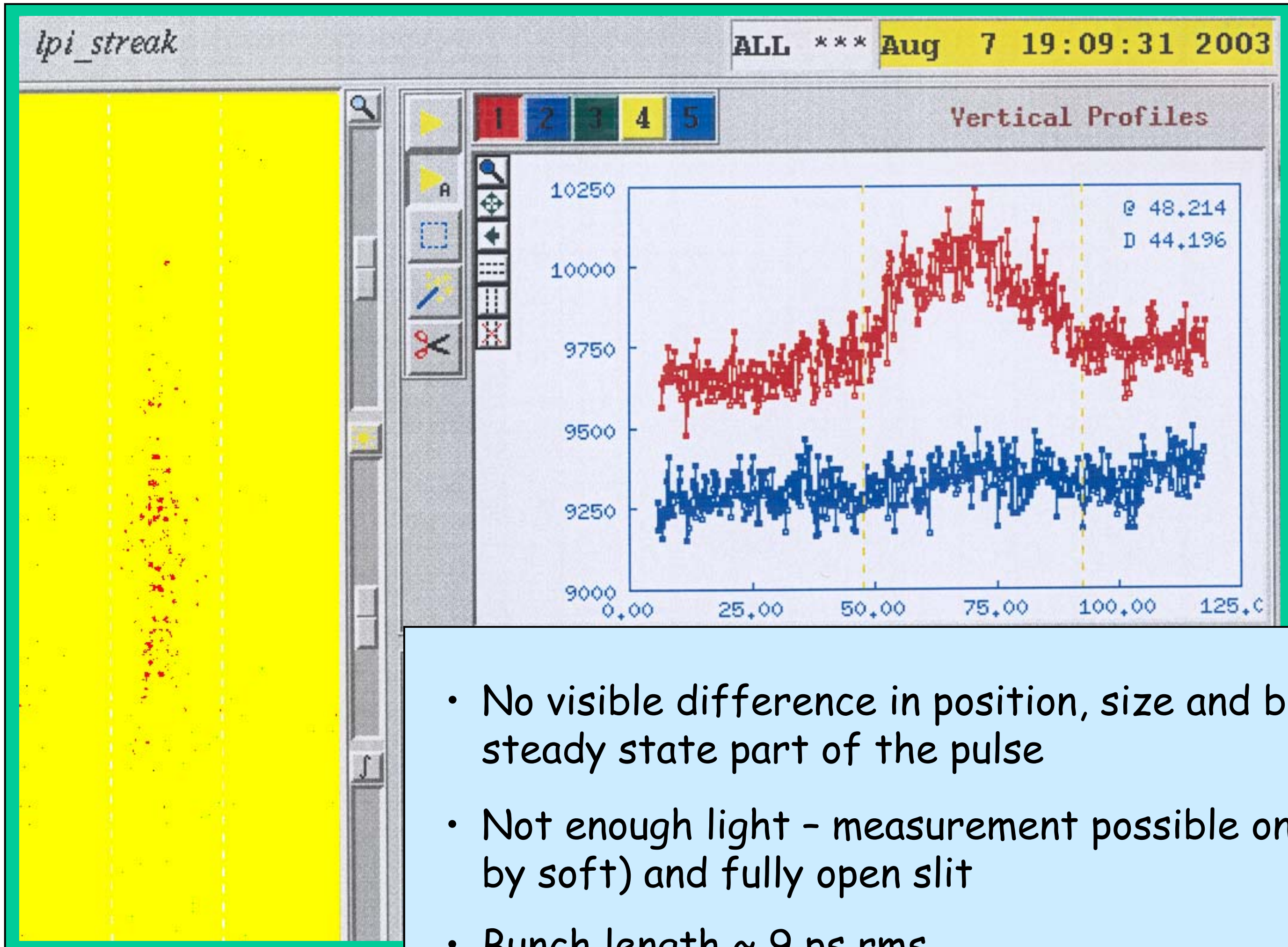




Two phase scans were performed measuring the beam energy spread with MTV440 in different conditions on August 5th (vidicom), and 15th (CCD camera).

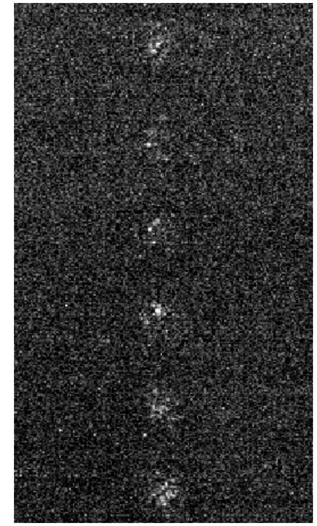
The minimum values of the measured energy spread were respectively 0.56 % and 0.87 %.
The best fit to the calculated curves is obtained correcting these values with an "uncorrelated spread" of 0.45 % and 0.3 %, yielding respectively 0.33 % and 0.74 % for the corrected values.

Bunch length – streak camera



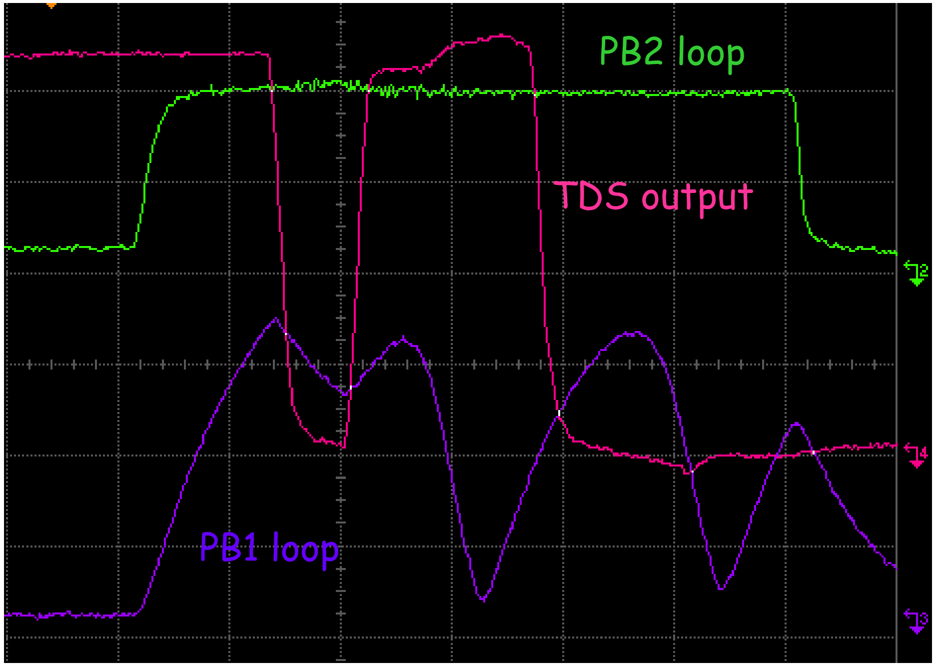
MTV500 carbon screen
2 A, 20 MeV
fast time scale,
accum.

MTV500 carbon screen
3.5 A, 20 MeV
slow time scale, no accum



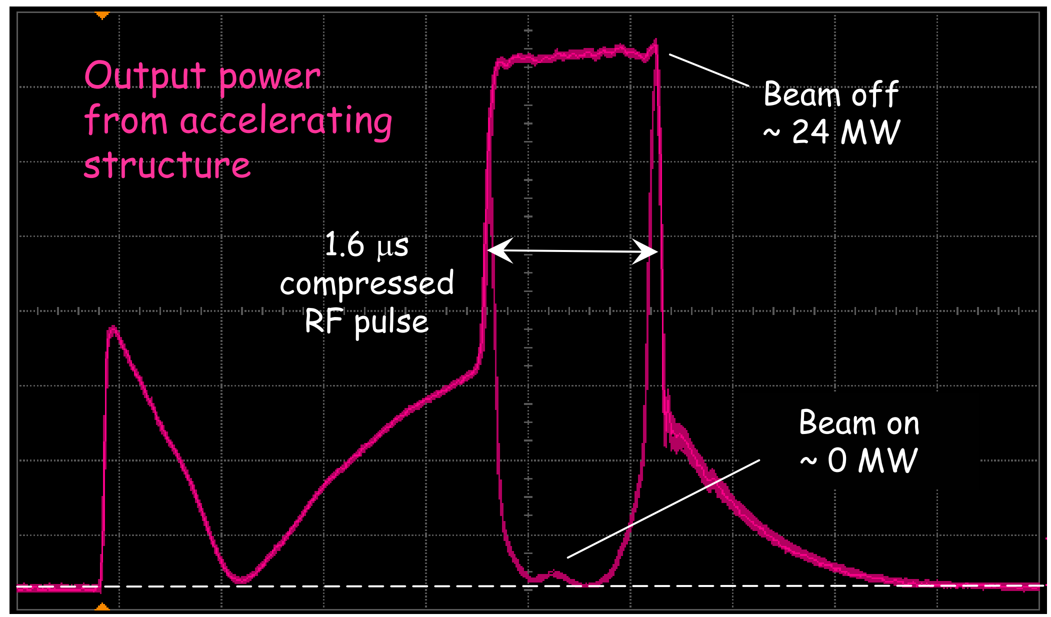
- No visible difference in position, size and bunch length within the steady state part of the pulse
- Not enough light – measurement possible only with accumulation (limited by soft) and fully open slit
- Bunch length ~ 9 ps rms
- Assuming 3 ps time jitter, 3 ps intrinsic resolution and 3 ps slit contribution, the estimated bunch length would be ~ 6 ps

Beam loading I



First CTF3 fully loaded operation – no RF compression

August 5th (~ 3 A)



Full beam loading – compressed RF pulse

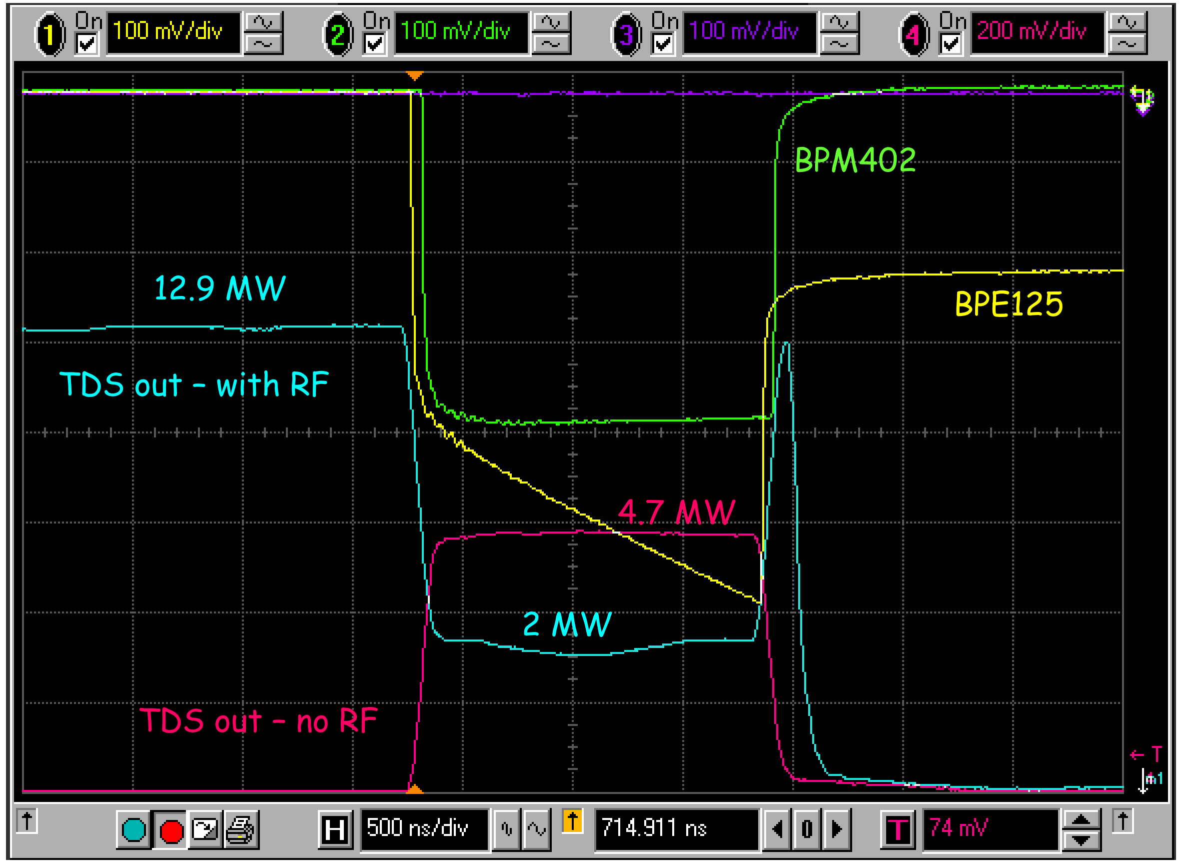
August 12th (3.5 A)

Beam loading II

Beam Loading experiment

- P_MKS03 = 31 MW
  no pulse compression

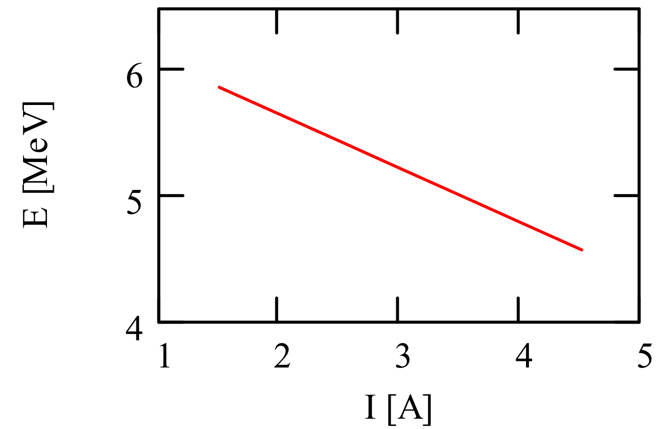
- E = 20 MeV
- I_BPE125 = 2.2 A
- I_BPM402 = 2.06 A
- I_BPM502 = 1.73 A
- Evaluate RF power out of TDS structure with and without RF, using output signals and peak power measurements at MKS03 output.
- *Assumed 5% losses in waveguides plus attenuation in structure calculated with Erk's spreadsheet.*

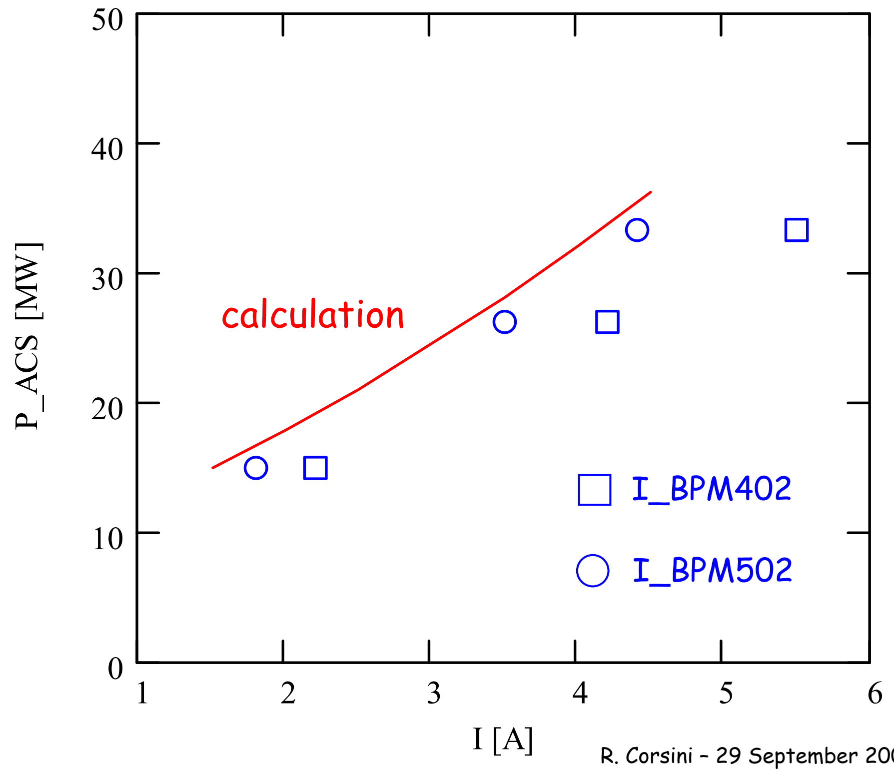


- Compare with calculations from Erk's spreadsheet:
  - With RF P_{out} = 2 MW for I = 1.8 A (ΔE = 13.26 MV)
  - Without RF P_{out} = 4.7 MW for I = 1.8 A (ΔE = -5.56 MV)

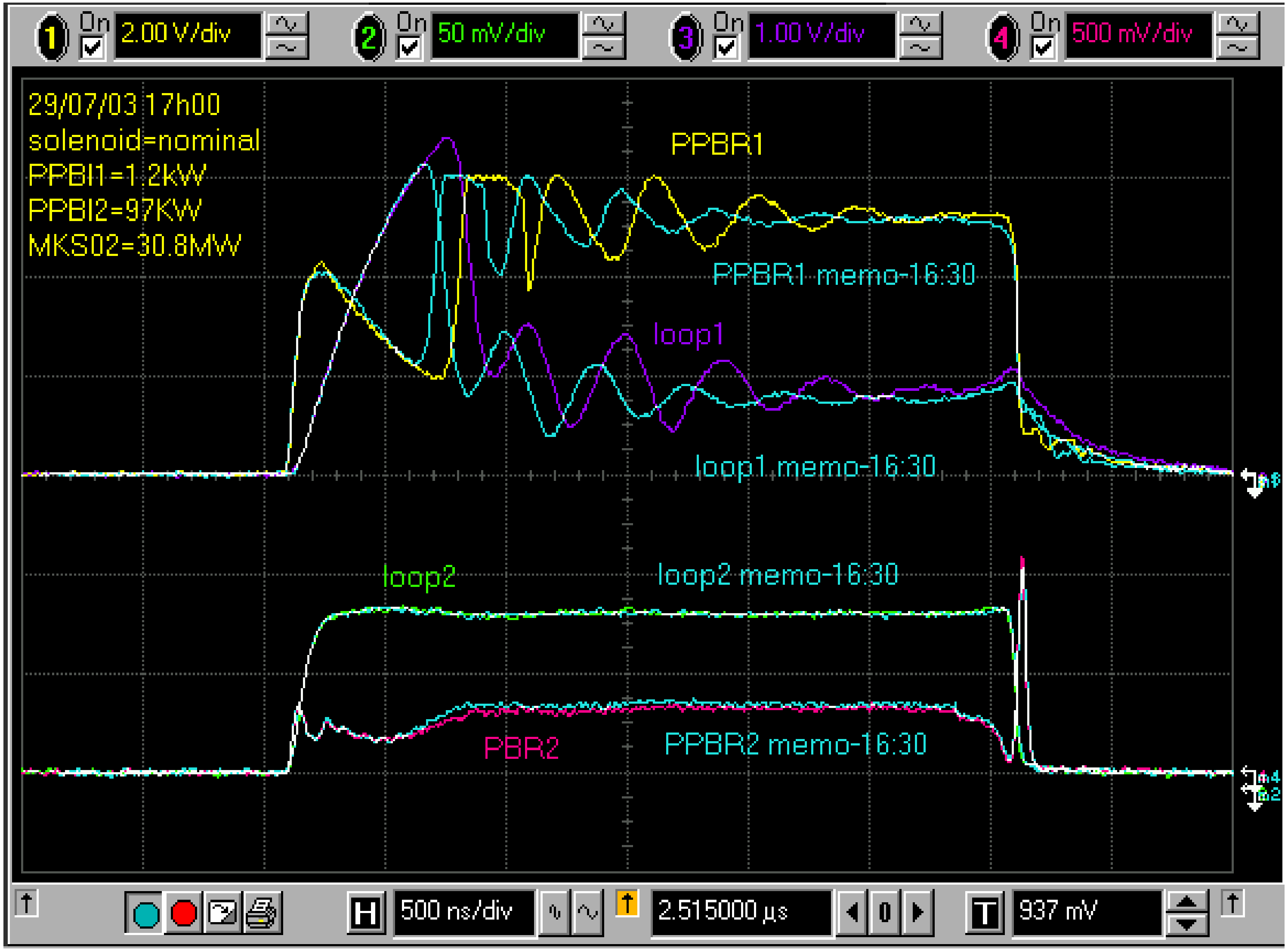
Beam Loading & Energy gain

- Assume energy gain in buncher as a function of beam current
- Calculate energy gain needed in ACS305 and ACS330 in order to reach 20 MeV (taking into account 5% losses in waveguides)
- Calculate (Erk's spreadsheet) power needed in each structure
- Compare with experimental data

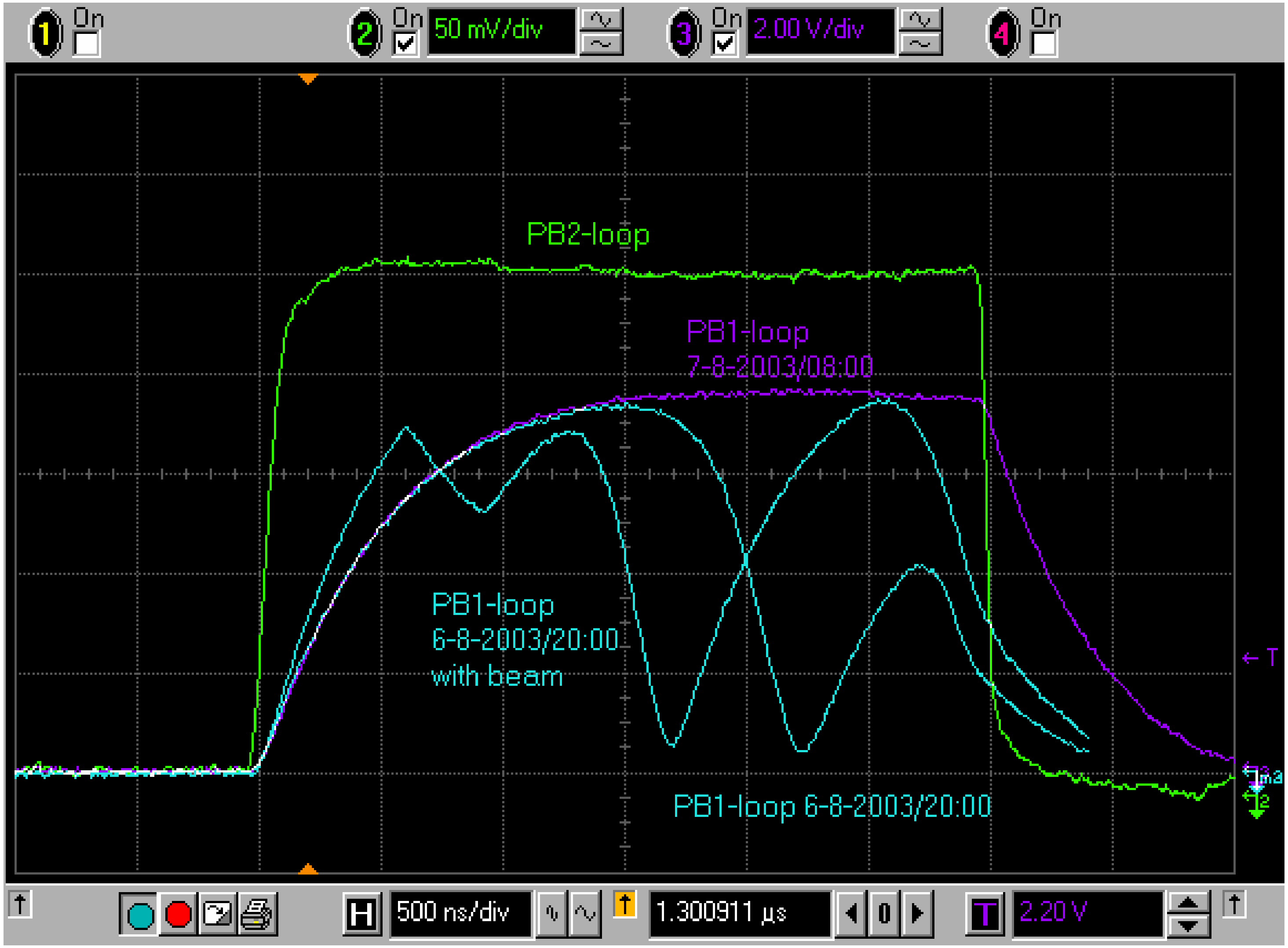




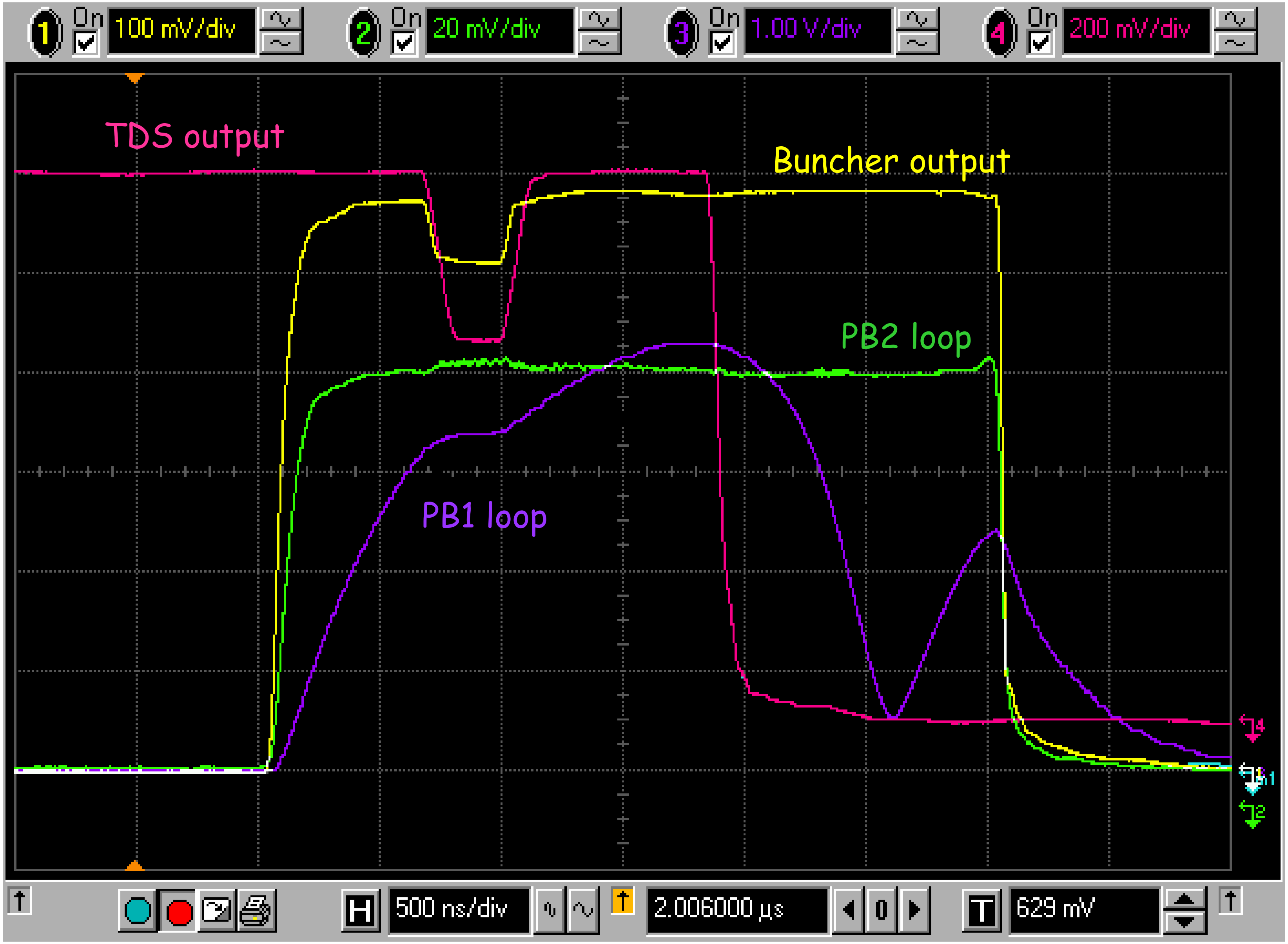
PB1 & PB2 Multipacting



Beam-induced detuning in PB1



RF signals - 31 July



Beam-induced detuning in PB1

$f = f_0 = 2.998\ 590\ \text{GHz}$

Beam-induced detuning in PB1

f = 2.998 390 GHz

Beam-induced detuning in PB1

f = 2.998 490 GHz

Beam-induced detuning in PB1

f = 2.998 590 GHz

Beam-induced detuning in PB1

f = 2.998 690 GHz

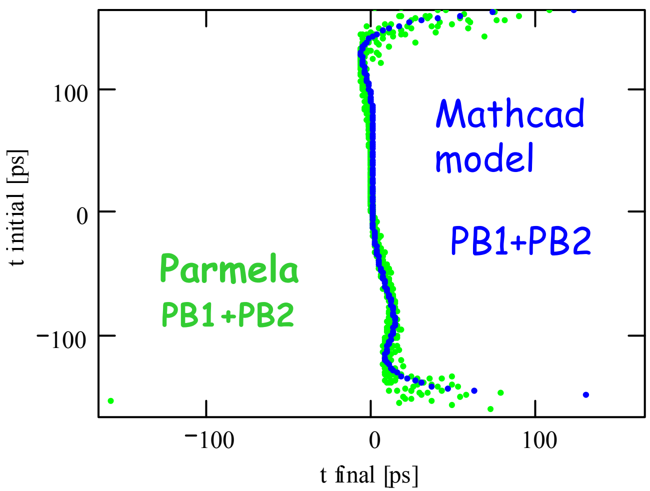
Beam-induced detuning in PB1

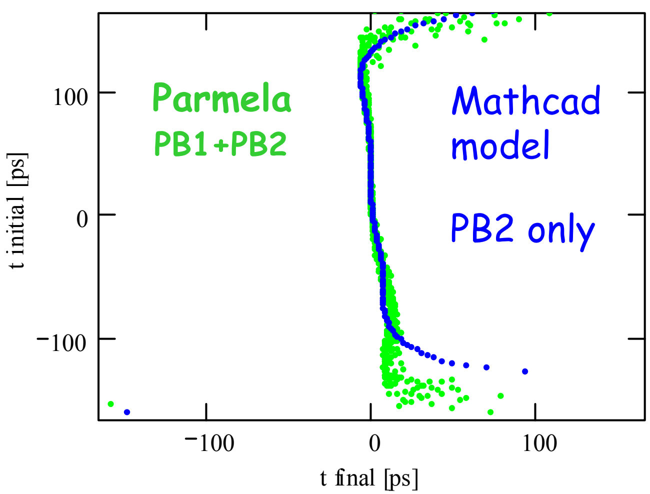
f = 2.998 790 GHz

Beam-induced detuning in PB1

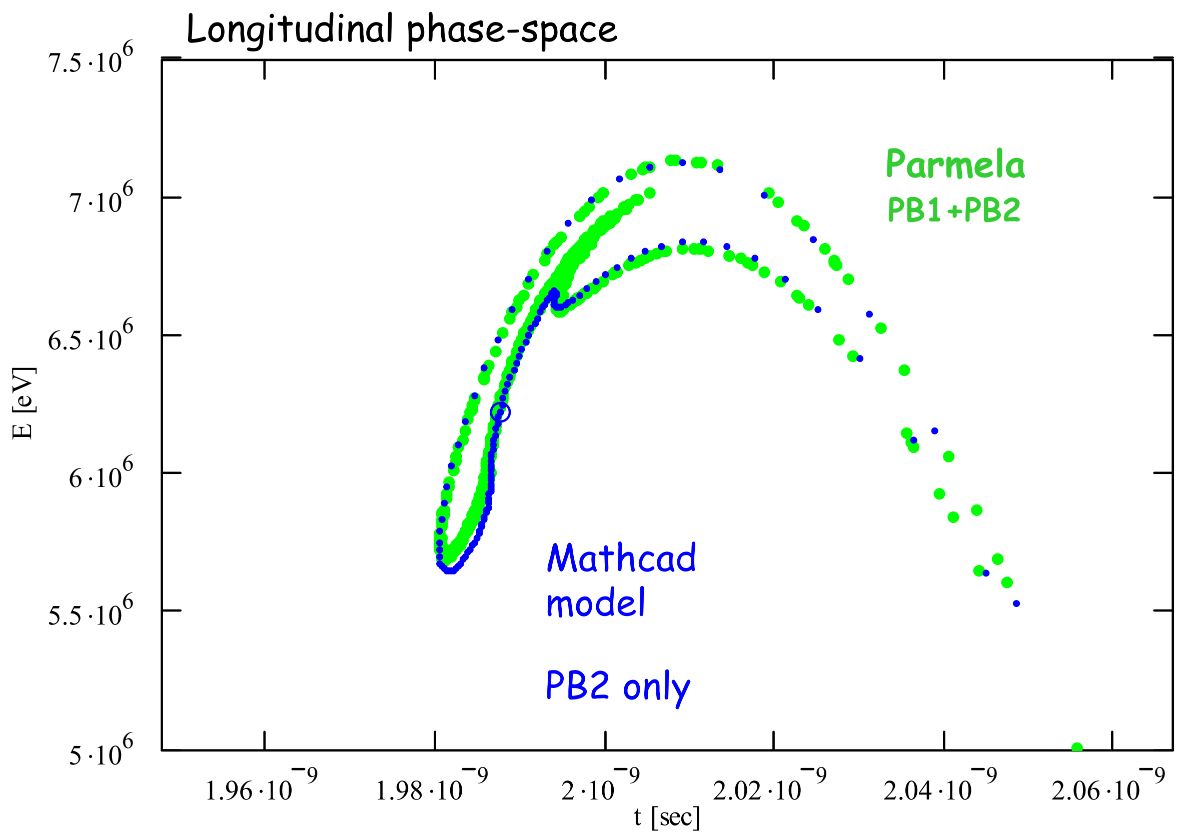
f = 2.998 890 GHz

Operation with PB2 only





Simulations - low current - beam at the buncher exit

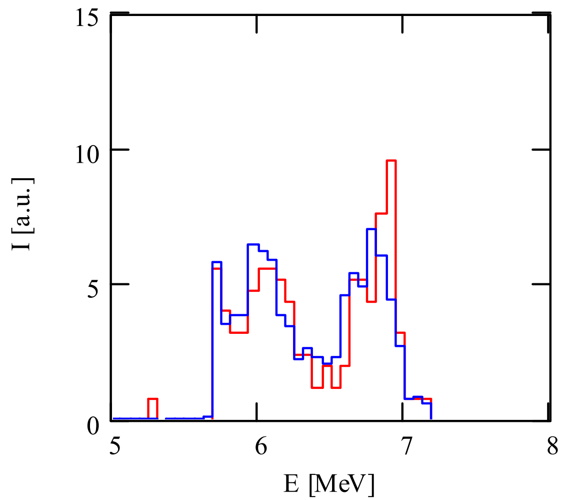


Operation with PB2 only

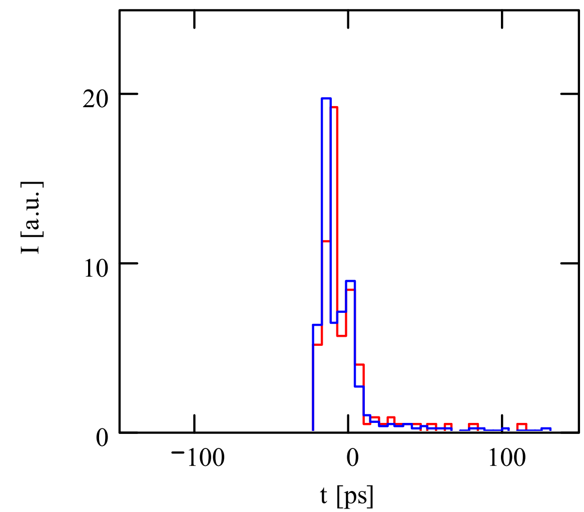
Simulations - low current - beam at the buncher exit

Mathcad model

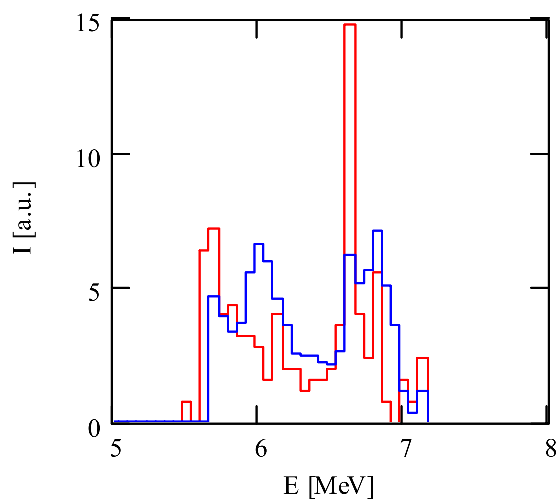
Parmela (PB1+PB2 always)



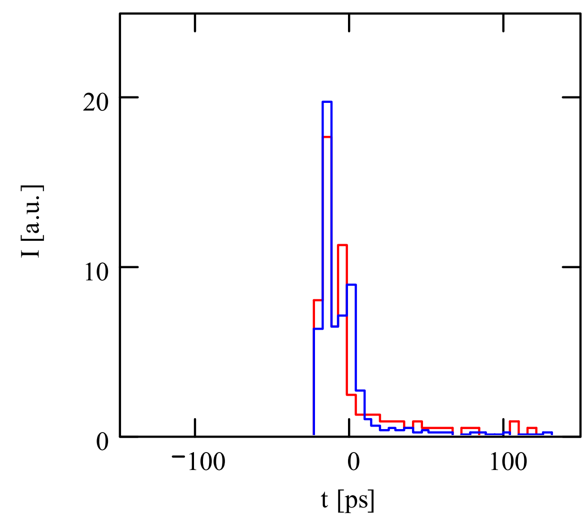
PB1 + PB2



PB1 + PB2

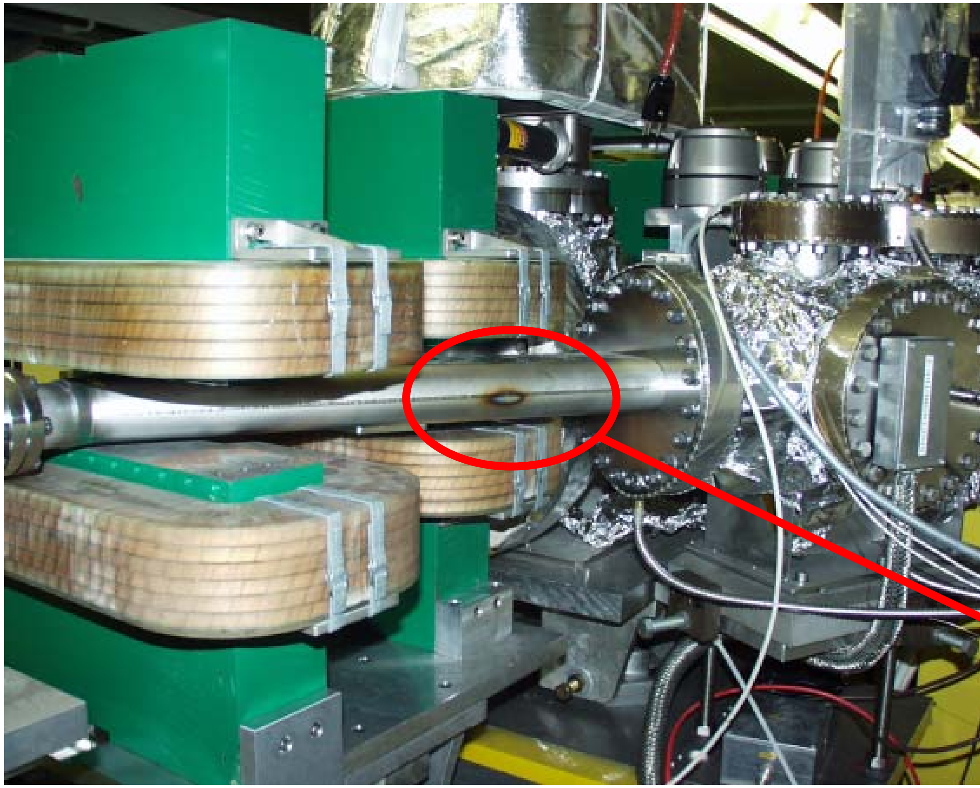


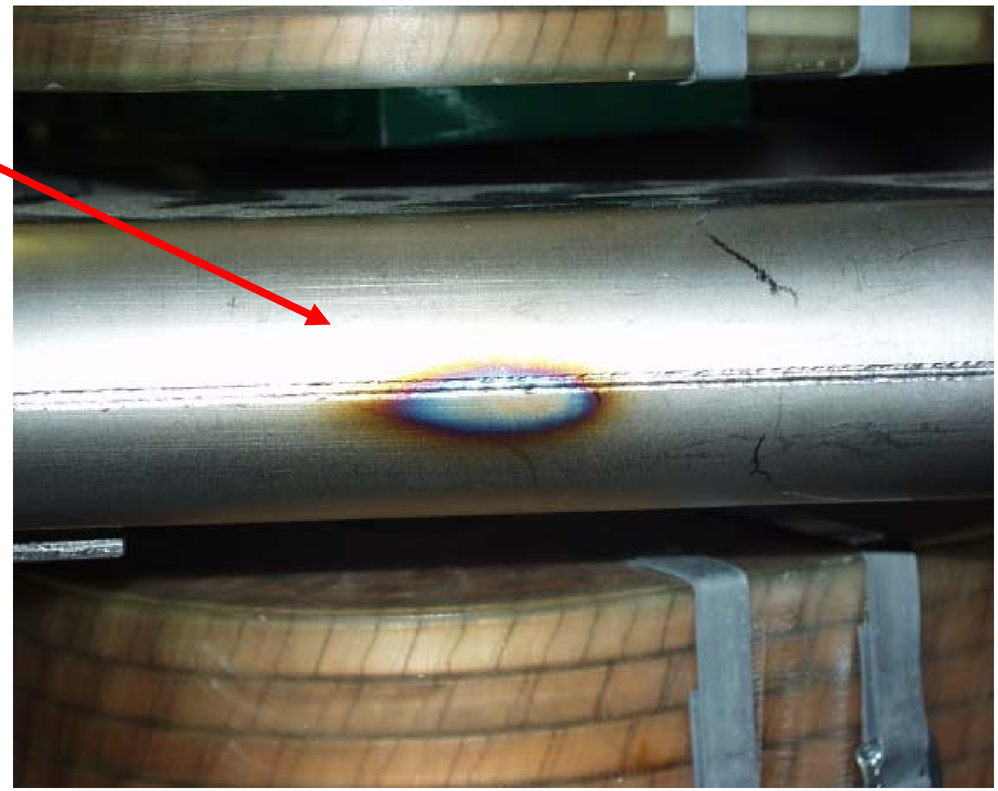
PB2 only



PB2 only

Beam damage in spectrometer vacuum chamber





Photographs: courtesy Ghislain Rossat ©

Radiation Measurements

Measurements performed in B.2001, Klystron gallery on 14/8/03, 11:30-13:30h

Beam conditions: pulse repetion rate 5 Hz, beam current 3.5 Amp

Measuring equipment: AD6, Babyline, REM counter type Studsvik, Ion chamber type PMI (yellow) - The measuring error for the instruments is about 20-30% of the measured value and about +/- 10 uSv/h for the REM counter (neutron dose rates).

Along the klystron gallery (above the beamline) no significant dose rates were measured. Feedthrough no.4 and 3 are the only weak points where higher dose rate levels were measured.

1. Beam to spectrometer

a) above wave guide feedthrough no.4

dose rate: **750 uSv/h** (100 uSv/h neutron + 650 uSv/h gamma)

The babyline instrument showed dose rates up to 5 mSv/h in the hole; a shielded measurement showed that this high dose rate is mostly due to low energy photons. The high dose rate is very localised above the hole;

b) beside wave guide feedthrough no. 4

dose rate: **57 uSv/h** (20 uSv/h neutron + 37 uSv/h gamma)

c) gangway beside wave guide feedthrough no. 4 no measurement done

d) above wave guide feedthrough no. 3

dose rate: **34 uSv/h** (30 uSv/h neutron + 4 uSv/h gamma)

e) CTF2, feedthrough for Laser

dose rate: **10 uSv/h**

f) CTF2, feedthrough for RF wave guide (not yet installed)

dose rate: not measurable

2. Beam to dump

a) above wave guide feedthrough no. 4

dose rate: **1.9 mSv/h** (200 uSv/h neutron + 1.7 mSv/h gamma)

The babyline instrument showed dose rates up to 10 mSv/h in the hole; a shielded measurement showed that this high dose rate is mostly due to low energy photons. The high dose rate is very localised above the hole;

b) beside wave guide feedthrough no. 4

dose rate: **108 uSv/h** (40 uSv/h neutron + 68 uSv/h gamma)

c) gangway beside wave guide feedthrough no. 4

dose rate: **18 uSv/h** (10 uSv/h neutron + 8 uSv/h gamma)

d) above wave guide feedthrough no. 3

dose rate: **24 uSv/h** (20 uSv/h neutron + 4 uSv/h gamma)

e) CTF2, feedthrough for Laser

dose rate: **5 uSv/h** (gamma/neutron)

f) CTF2, feedthrough for RF wave guide (not yet installed)

dose rate: not measurable

Although quite high dose rate levels were measured at some specific positions, the ambient dose rates were about or slightly above the limits for the permanent stay in the gallery (simple controlled area). The limits for transient conditions were not exceeded at the working places beside. Any stay above the feedthrough has to be avoided and a radiation warning sign was placed to warn people about the higher radiation levels.

The operational pulse repetition rate is currently at 0.8 Hz, ~ about a factor 5 lower as during the measurements. Since higher repetition rates and currents are possible and in order to optimise the radiological situation, the filling and shielding of the feedthroughs is recommended and should be done before the next run of CTF3. This should be also applied to all feedthroughs with higher numbers and which are not yet filled with shielding material.

CTF3 commissioning program

Other beam measurements & tests

- **Radiation levels** (in klystron gallery, CTF2 …) ✔
- **Momentum spectra**, time resolved (SEM-grid) ✘
- **Bunch length**, using streak camera ✔
- **Bunch length**, method with ACS phase scan + energy spectra ✔
- **Beam loading** measurement (beam momentum vs. current) ✔
- **Twiss parameters & emittance** (quad scan – limited by energy spread ?) ✔
- **Energy stability** from ACSs with pulse compression ~
- **Current stability** from gun ✔
- **Energy stability** from gun ? ✘
- **Transverse wakefields ?** ✘
- …

CONCLUSIONS & OUTLOOK

- 1st Commissioning period (July 14th ⇒ August 15th)
  - Nominal beam parameters reached (3.5 A, 1.5 μs, 20 MeV)
  - Preliminary measurements on emittance and bunch length within requirements
  - Successful full beam loading operation
  - Most of hardware & diagnostics commissioned
  - RF pulse compression system OK
  - Problems with SEM-grid (time resolved energy spectrum)
  - Problems with PB1 (multipacting and beam-induced detuning)

  But operation without PB1 possible (eventually build and install copy of PB2)

- 2nd Commissioning period (October 20th ⇒ November 14th)
  - Installation within schedule
  - Test operation without PB1, beam cleaning chicane, study SEM-grid problems
  - Optimization and complete characterization of the nominal beam
  - Test bunch compression with cleaning chicane
  - Obtain "power mode" beam parameters (5 A, 200 ns)