ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

THE CERN ACCELERATOR SCHOOL

The Beam Measurements at PHIN Photo-Injector at CERN

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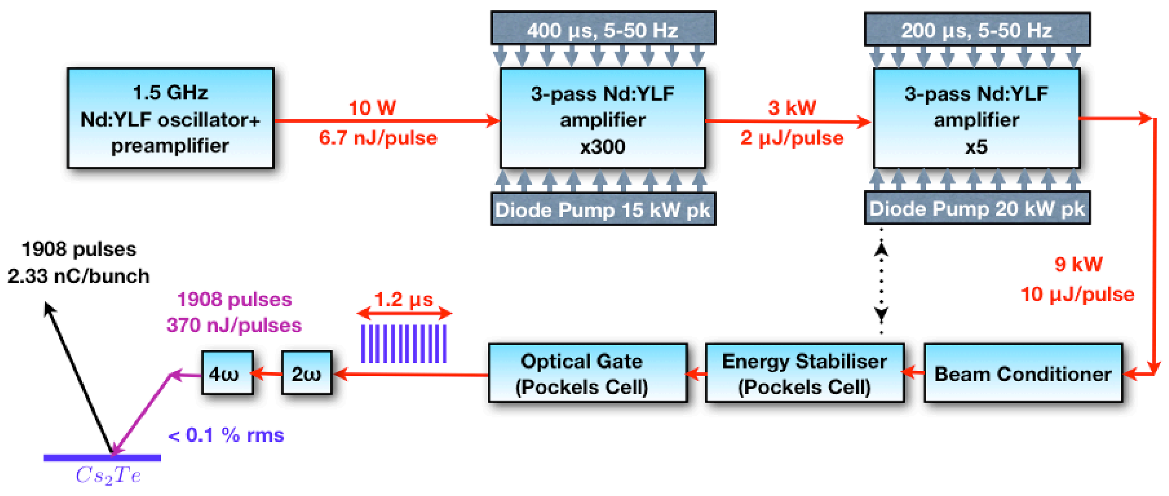
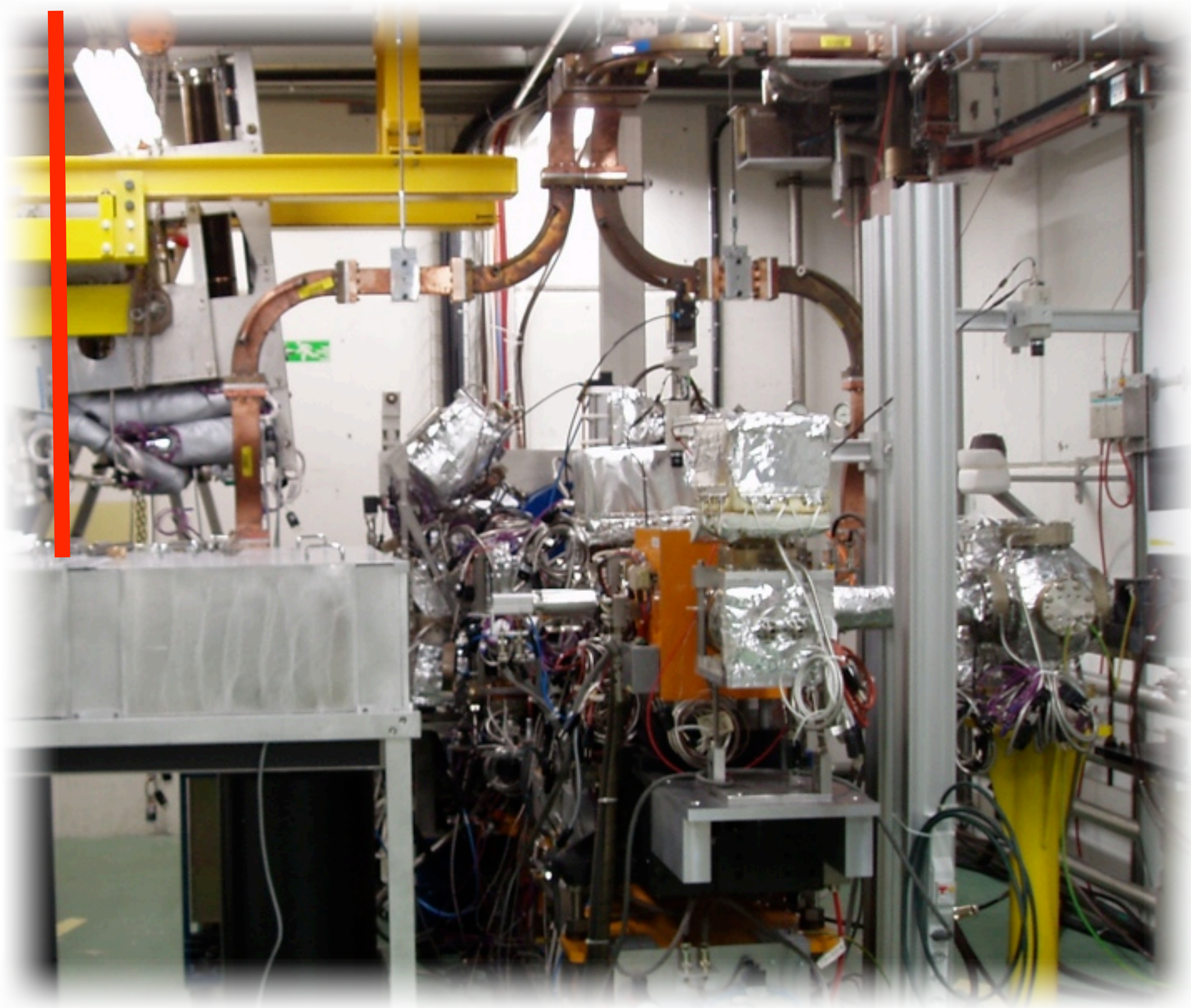
The demonstration of the high charge and the stability along the pulse train are the important issues for CTF3 and the CLIC drive beam. A new photo-injector for CTF3 and CLIC drive beam has been designed and installed by collaboration between LAL, CCLRC and CERN within the framework of the CARE program. Beam based measurements have been made during the commissioning runs of the PHIN 2008 and 2009 including measurements of the emittance, using multi-slit technique. After the first beam measurements, the results were analyzed and compared with PARMELA simulations, an optimum working point has been proposed for the photo-injector.

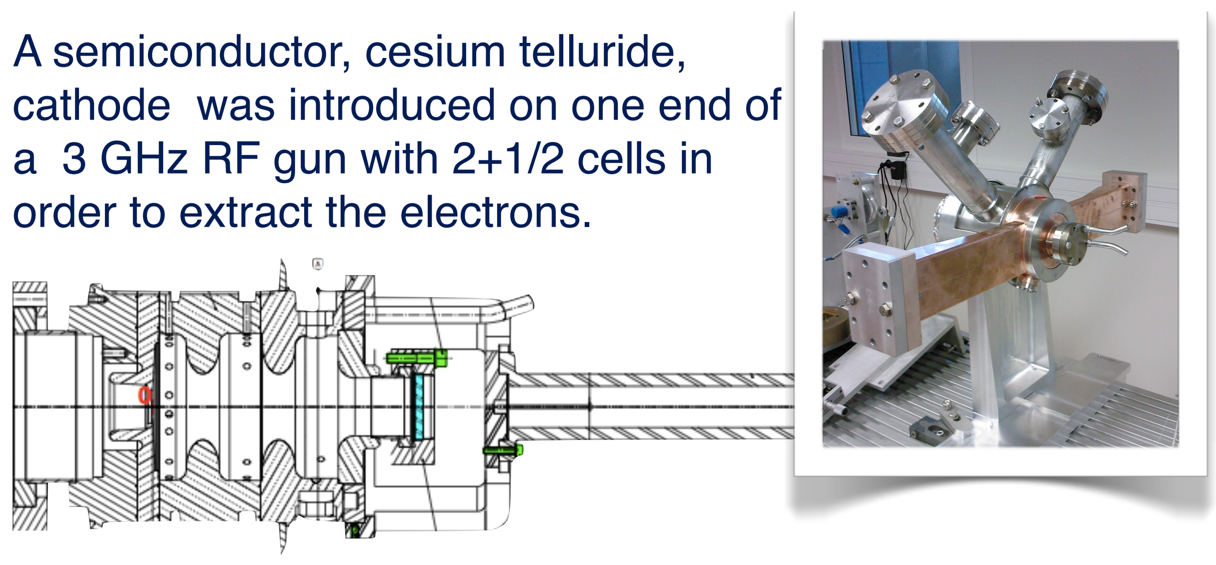
Laser





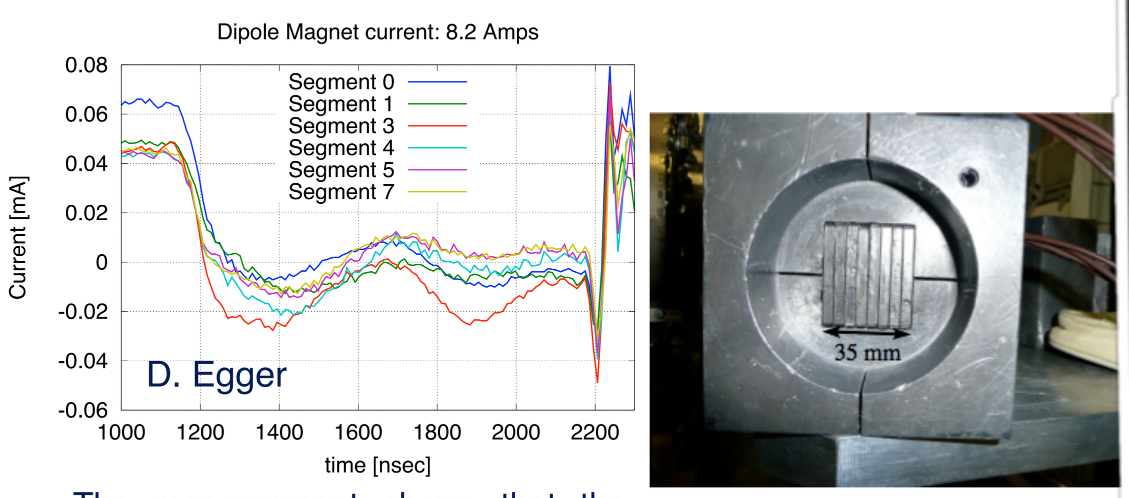
RF Photo Gun

A semiconductor, cesium telluride, cathode was introduced on one end of a 3 GHz RF gun with 2+1/2 cells in order to extract the electrons.

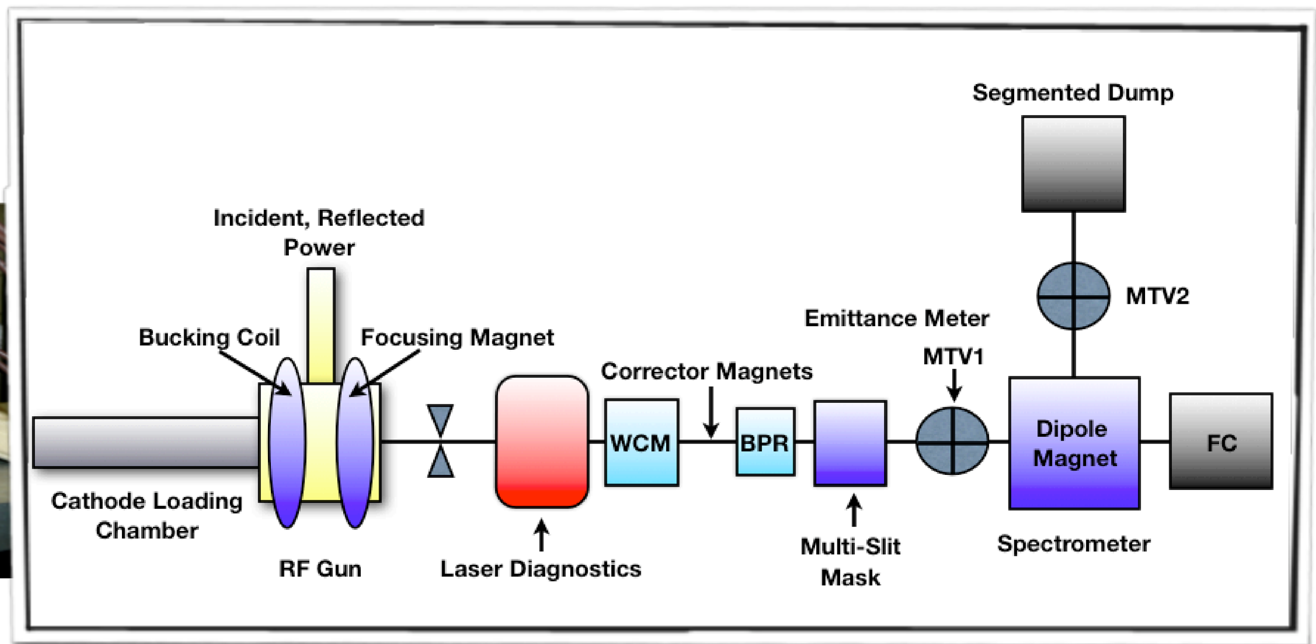


Spectrometer

Time resolved energy of the beam was measured by using a segmented dump. Regarding the time resolved aspect of the measurement, the goal was to measure the time variation of the energy along the pulse train.

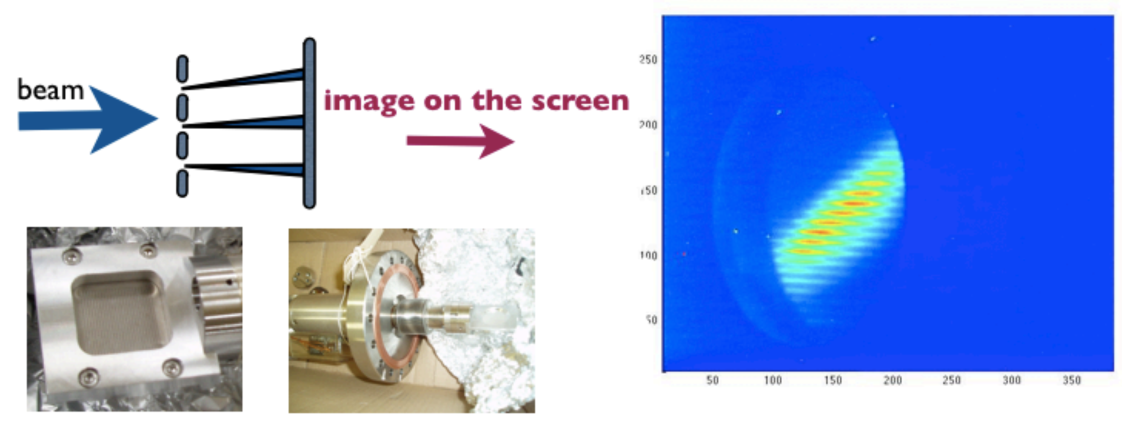


The measurement shows that the energy along the train is stable confirming the stability of the RF system.



Emittance Meter

- ☑ Slice up the beam into 'beamlets'.
- ☑ Let the beamlets drift.
- ☑ Observe the momentum distribution with an OTR screen.
- ☑ Reconstruct the phase space out of these info.

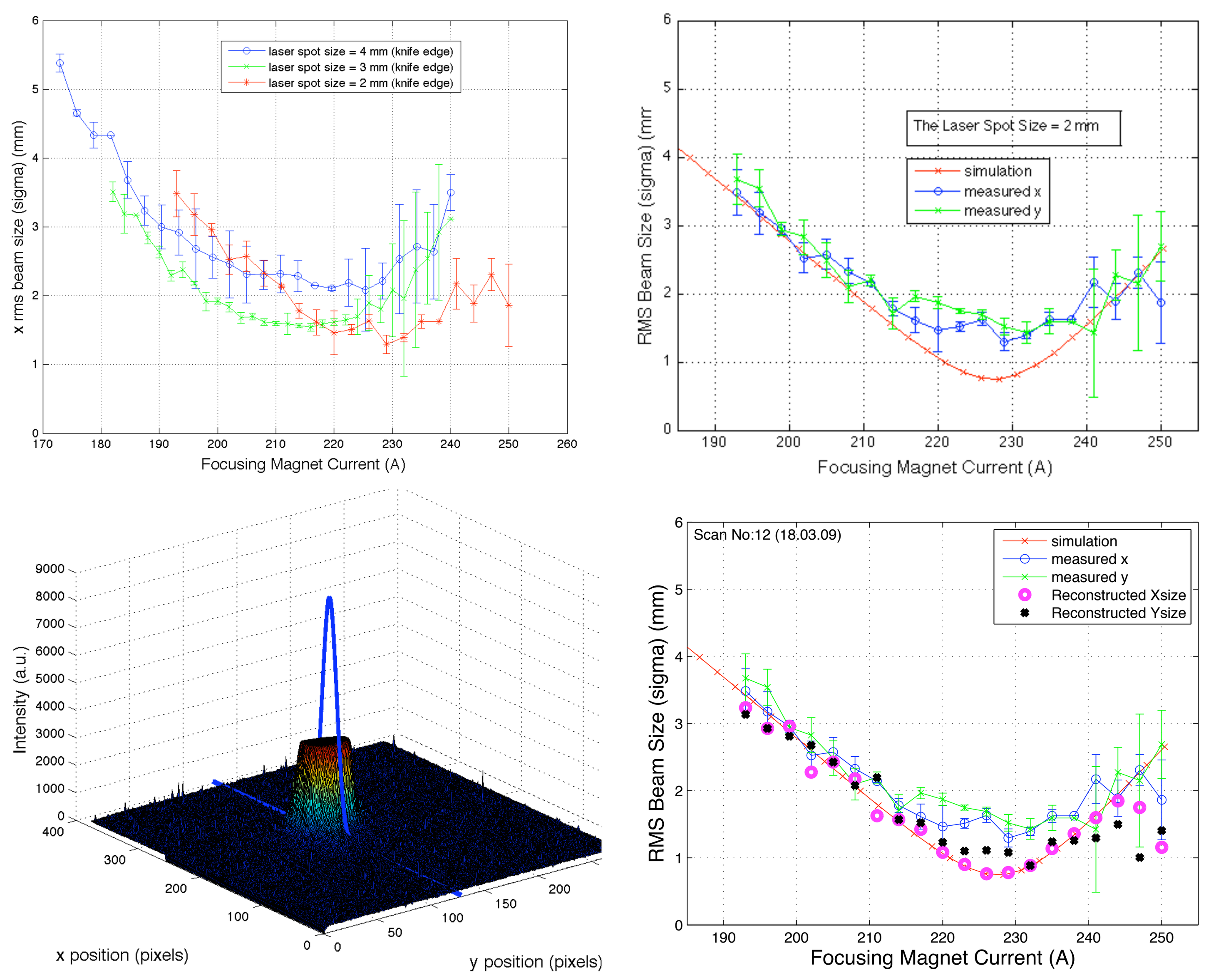


for details of the method

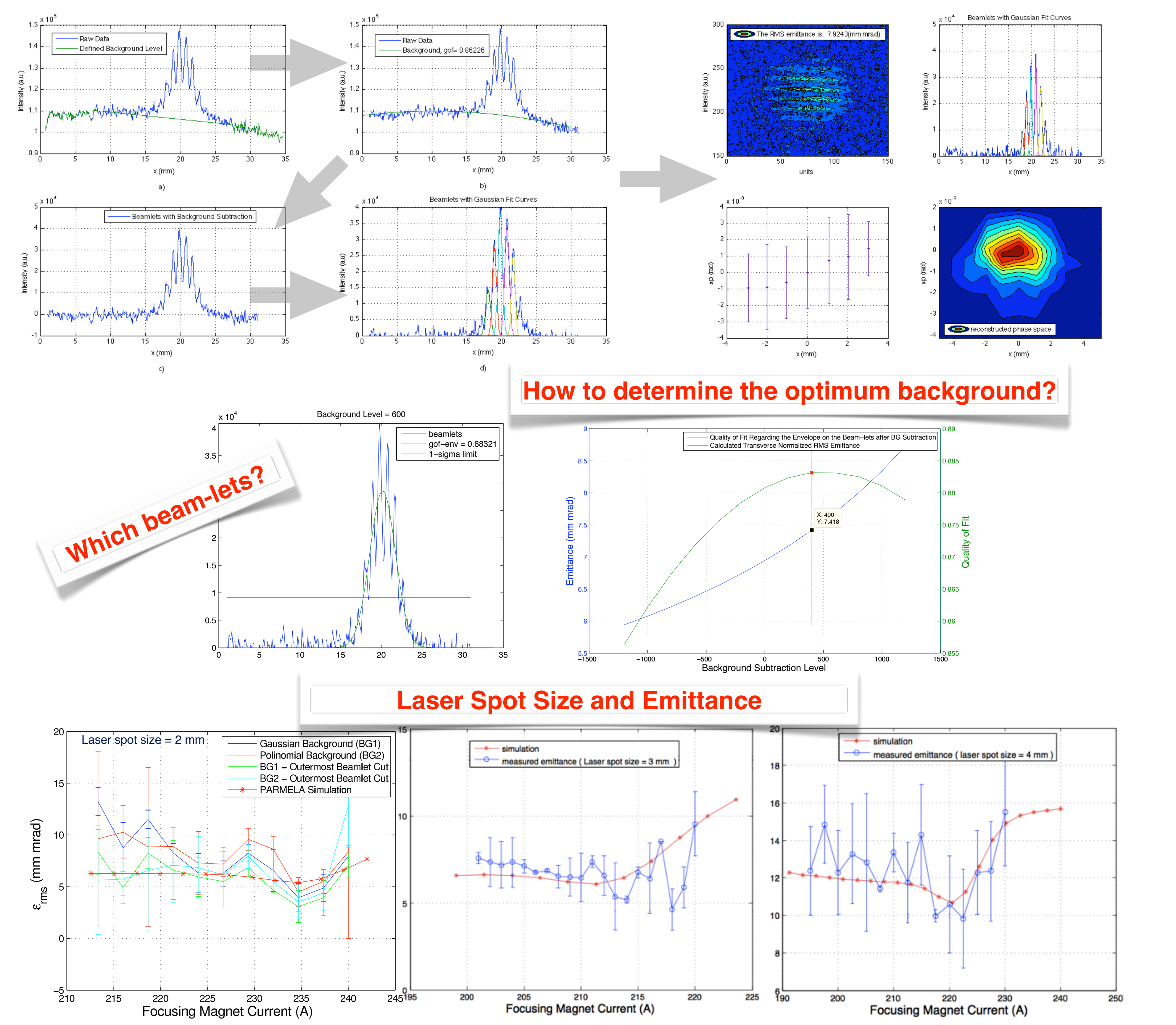
- S.G. Anderson et al., Phys. Rev. Vol 5, 014201 (2002)
- Min Zhang, Fermilab-TM-1988

Beam Size Measurements

During the 2009 run beam scans have been performed with respect to different laser spot sizes of 2, 3, 4 mm at 5.5, 5.2 and 5.7 MeV, respectively. The asymmetric behavior that has been observed in the previous run was no longer present. Although the discrepancy at the focus region is still under investigation, it could be related to the limited resolution of the optical system or a saturation effect.



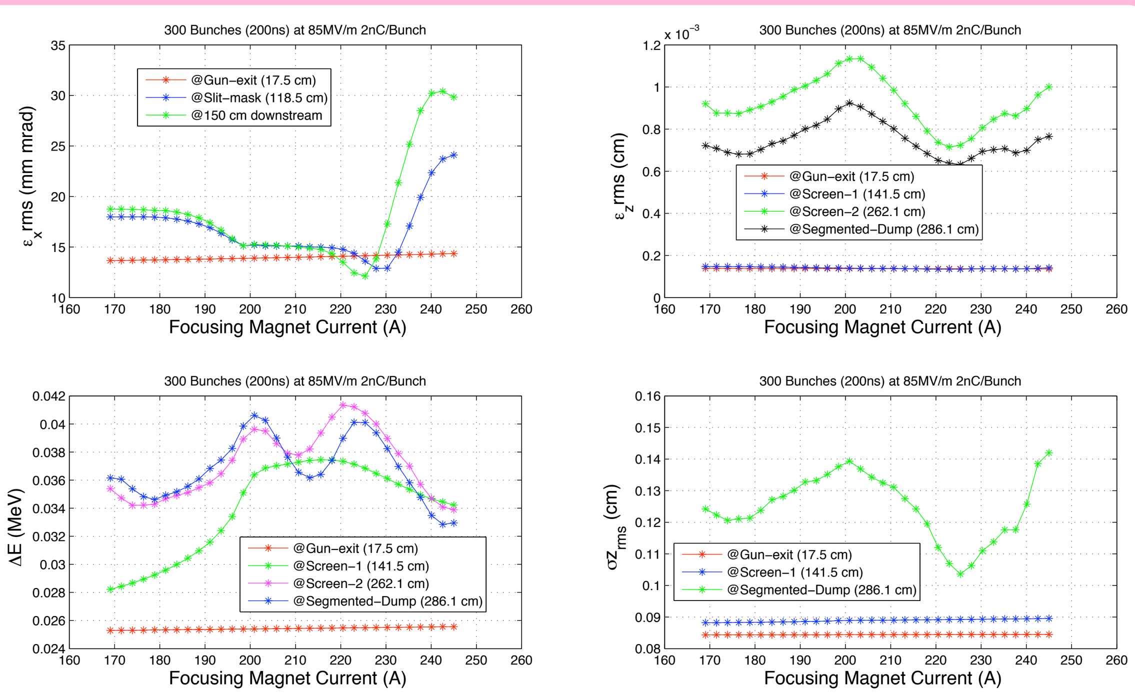
Data Analysis of Multi-Slit Method for Emittance Measurement



Optimum Settings

Table 1. Summary of the optimum parameters for the given electron beam properties.

	75 MV/m (4.8 MeV at 35°)			
Charge (nC)	**1.0**	**1.5**	**2.0**	**2.5**
$I_{focusing}(A)$	196	201	203	206
$\epsilon_x(mmmrad)$(@Gun-Exit/@150 cm)	7.44 / 7	10.8 / 9.6	13.9 / 11.9	16.2 / 13.8
ϵ_z (μm)(@Gun-exit/@Dump)	11.9 / 72	12.7 / 125	13.8 / 128	20.4 / 190
$\Delta E(KeV)$ (@Gun-exit/@141.5 cm)	26.8 / 38.3	31.5 / 48.9	36 / 59	40 / 68.4
$\sigma_z(ps)$ (@Gun-exit/@141.5 cm)	2.7 / 2.9	2.7 / 3	2.8 / 3.2	2.9 / 3.3
	80 MV/m (5.2 MeV at 35°)			
Charge (nC)	**1.0**	**1.5**	**2.0**	**2.5**
$I_{focusing}(A)$	206	211	213	216
$\epsilon_x(mmmrad)$(@Gun-Exit/@150 cm)	6.8 / 6.5	10 / 8.9	13 / 11.26	15.2 / 13.1
ϵ_z (μm)(@Gun-exit/@Dump)	11.5 / 62.2	13.7 / 99.8	13.3 / 138	14.5 / 167.4
$\Delta E(KeV)$ (@Gun-exit/@141.5 cm)	20.8 / 32.1	25 / 42.4	29.3 / 52.4	33.1 / 61.5
$\sigma_z(ps)$ (@Gun-exit/@141.5 cm)	2.6 / 2.8	2.7 / 2.9	2.8 / 3	2.9 / 3.3
	85 MV/m (5.5 MeV at 35°)			
Charge (nC)	**1.0**	**1.5**	**2.0**	**2.5**
$I_{focusing}(A)$	213	218	223	225
$\epsilon_x(mmmrad)$(@Gun-Exit/@150 cm)	6.3 / 5.9	9.2 / 8.2	12 / 10.6	14 / 12
ϵ_z (μm)(@Gun-exit/@Dump)	11 / 31	12.1 / 42.7	12.4 / 50.4	13.5 / 72.4
$\Delta E(KeV)$ (@Gun-exit/@141.5 cm)	15.1 / 19.1	18.7 / 25.3	22.4 / 31.4	25.5 / 36.8
$\sigma_z(ps)$ (@Gun-exit/@141.5 cm)	2.6 / 2.7	2.7 / 2.8	2.7 / 2.9	2.8 /3.4



Conclusion and Outlook

The beam measurements revealed the expected behavior agreeing with the simulations within the measured error ranges. The simulations for the beam size measurements are consistent with the measurements except the focus region. The envelope behavior at the small beam sizes had to be investigated considering the possible limitations from the instrumentation such as CCD saturation effect.

The emittance measurements have been improved with respect to the previous run by replacing the CCD camera with an intensified one enabling the usage of an aluminum OTR screen. The extensive study has been done on the appropriate analysis of emittance measurement with multi-slit method. A standard analysis algorithm has been developed. The Gaussian background has been used for the analysis. The systematic difference for the emittance is measured as \sim0.5 mm mrad higher than the result of the Gaussian background when a polynomial background subtraction is applied. A n algorithm has been implemented into the analysis code in order to determine the optimum background level. The beam-lets occupying the 1\sigma of the profile is determined as the relevant beam-lets for the emittance calculation. The outer particles' contribution to the emittance has been investigated. Under the proper focusing conditions this contribution is found to be minimized.

For the segmented dump, simulations showed that elements in the beamline such as the alumina screen significantly increases the transverse size of the beam, due to multiple scattering and energy loss, to the point this contribution is much larger than the dispersion due to energy spread. Although a reliable energy spread measurement was impossible under this condition, the issue will be solved easily in the next commissioning run by replacing the alumina screen with a thin aluminum OTR screen.

The focus of the next run will be on the stability measurements along the pulse train. The results will be compared with PARMELA simulations. The optimized beam parameters, deliverable from the photo-injector, will be determined and used as the input for drive beam PLACET simulations. The main goal will be to study the current limitations and future modifications in the set-up for the implementation of PHIN photo-injector as the CLIC drive beam electron source.