Preliminary Draft Summary 3rd BBLR MD in 2003, Thursday 21 August

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Set Up

Initially the tunes were 0.1744 and 0.1499. Large beam losses at ~1000 ms were cured by raising $\xi_{V,}$ which introduced a rather strong decoherence. The intensity was 1.25×10^{12} in 12 bunches. We asked the PS to lower it by 30%. We launched cmonJPK application. This program was found in /tmp_mnt/nfs/bom_lep/vol2/u1/biswop/bin/hpux/.
Cycle and location were wrong at first, but this problem could be fixed by changing extraction area to BA5 and time of first event to 11225 ms (needs to be changed at each PMT). Tunes were adjusted to 0.1743 and 0.1529. We used BCT3. We applied vertical kicks of 2 mm after 2000 ms. The intensity at this time was 8.5×10^{11} in 12 bunches.
We tried to lengthen the decoherence time and lowered the ξ_V setting from 0.01 to 0. We asked the PS to further reduce the intensity, and obtained 4×10^{11}. This was done to optimize the signal from the Q meter (10:51). We saved both PMT and Q meter data (the latter to the directory BBLR-210803, i.e., /user/slops/data/SPS_MD/BLR-210803).
We now selected the timings for x and y on the Q meter at 1950 and 2000 ms, applying a 0 kick in x and a 7 mm kick in y.
The supercycle numbers on the cmonJPK and Qmeter/BCT were not the same: 49679 on cmonJPK corresponded to 573968 on Qmeter/BCT. On SSC 573975 we applied a 2 mm kick, on SSC 573977 a 4 mm kick (small losses). There was a disk space problem for cmon application. Jorg gzip-ed many files. The cmon data were saved to /user/slops/data/bi_sps_colmon/.
We performed linear wire scans with BWSL421V, and obtained identical emittances of about 1.1 (normalized) for IN and OUT scans.

Kicks with&w/o bump and with&w/o BBLR excitation

The beam was kicked without BBLR excitation and w/o any bump. We took 1000 turn BPM data at the time of the kick (2000 ms after injection). The SSC numbers for the 1000–turn data were again different (in this case13220). The multi-turn data for the first (6 mm) kick were saved to /SPS/storage/SPS_MD_latest/… 12:16:11_21_August_2003. The following table summarizes the **kick measurements without bump and without LRBB excitation**. In parallel, linear wire scans were saved at 2100 ms and 3100 ms. The beam intensity was 3.5×10^{11} in 12 bunches. Also BCT, 1000-turn BPM readings (6-mm kick ASCII data from 12:16 generated on 03/09/03 at 14:21:28, a second set from 12:19 at 14:21:02), and Q meter signals were recorded.

Time	Kick amplitude	Supercycle number
12:26	2 mm	
12:31	4 mm	
12:33	6 mm	574244

	8 mm	574252

The extrapolated vertical offset at the BBLR was +0.64 mm for the reference orbit (H: –0.55 mm). At 12:44 we applied a –5.6 mm vertical bump to have an absolute offset of –5 mm. The SSC ending number was 293, and cmonJPK number 500004. The following table summarizes the data **taken for different bump amplitudes without kicks (no wire excitation)**.

Time	Absolute bump amplitude	Supercycle number
12:44	-5 mm	574293
	-7.25 mm	574304
	-10.6 mm	574307
12:53	-11.76 mm	574312

For the bump of –10.6 mm we already observed a small drop in current at the BCT. We reduced the bump amplitude to –7.2 mm (SSC 574341).
Next, we kept this **bump amplitude of –7.2 mm** (absolute) and **applied kicks of various amplitudes**, always taking data with Q meter, wire scans, and 1000-turn application. BBLR was still off.

Time	kick amplitude	Supercycle number
13:01	8 mm	
	6 mm	574355
13:07	4 mm	574364
13:10	2 mm	574374

A second plateau was observed in the PMT signal, starting at 14350 ms with bump and w/o wire excitation, and also later with wire excitation at 67 A. Structure disappeared after correcting the tune during the bump (sensitivity to some perturbation?).
Now the wire was excited to 67 A; orbit and tunes were corrected. Kicks of various amplitudes were applied, as compiled in the table below. The SSC 574449 with BCT corresponds to #50160 for the PMT.

Time	kick amplitude	Supercycle number
13:30	2 mm	574449
13:34	4 mm	574459
13:36	6 mm	574469
13:41	8 mm	574482?
13:44	8 mm	574490

1000-turn data were recorded as follows:

Time	kick amplitude	Bump/BBLR	Supercycle number
13:03:05 (14:17:01)	8 mm	-7 mm, 0 A	574350
13:05:05 (14:17:43)	6 mm	-7 mm, 0 A	574356
13:05:35 (14:18:34)	4 mm	-7 mm, 0 A	574364
13:10:02 (14:19:11)	2 mm	-7 mm, 0 A	574374
13:31:42 (14:19:28)	2 mm	-7 mm, -67 A	574457
13:34:13 (14:19:44)	4 mm	-7 mm, -67 A	574459
13:38:50 (14:20:03)	6 mm	-7 mm, -67 A	574469
13:41:23 (14:20:22)	8 mm	-7 mm, -67 A	574485

The data were converted from MOPS to ASCII format on 03/09/03 using the 1000-turn-analysis application program. The associated conversion times are indicated on the left-hand side in parentheses. ASCII data are in the directory /user/slops/data/sps_multiturn/.

Beam-wire Separation at 67 A

At 14:41 we lowered QID199 by 10 A to blow up the emittance to about 3. This required some re-steering. (SSC 574702).
The wire scans are now performed at +100 and 3200 ms (setting delays of 100 and 3100 ms in the application program). At 14:44 the emittances are about 5 with quadrupole current change of –15 A.. Jorg corrected injection oscillations.
The bump amplitude was varied. No kick was applied. The results are summarized in the next table. The wire excitation was 67 A.

Time	Bumpamplitude	ε IN	ε OUT	Supercycle number
14:53	- 7 mm	3.24	2.026	
15:01	-5.5 mm			574774
15:05	-4.5 mm	3.15	2.197	574786
15:08	-2.4 mm	3.20	2.567	574799 (PMT signal disappears)
15:12	-2.4 mm	3.20	2.523	(tunes adjusted)
15:16	0 mm	3.26	2.69	574826
15:21	+4.2 mm	3.29	2.71	
15:32	+9.1 mm	3.19	2.69	574876 (PMT sees aperture on other side?)
15:44	-9.1 mm	3.271	1.82	574930
15:49	-11.6 mm	3.21	1.22	574945

Now we redid the wire scans without wire excitation:

Time	Bumpamplitude	ε IN	ε OUT	Supercycle number
16:01	+0.7 mm	3.304	3.012	574988
16:06	+9.1 mm	3.263	2.999	575005
16:08	-10.6 mm	3.15	2.197	575012
16:11	-13.4 mm	3.144	1.805	575025

Calibration of Wire Scanner with Scraper

Calibration was performed at 1500 ms. The orbit was brought back to the initial 0 value. The beam was scraped 1500 ms after injection, which coincides with the time at which in other parts of the study the BBLR & bump were ramped up. The scraper data are summarized below.

Time	Scraper position	ε IN	ε OUT	Intensity drop	Supercycle number
16:16	+6.06 mm	3.172	2.789	0.935	575042 (PMT 50754)
16:21	+5.06 mm	3.284	2.556	0.865	575060
16:23	+4.06 mm	3.310	2.183	0.744	575070
16:27	+3.06 mm	3.197	1.705	0.625	575078
16:30	+2.06 mm	3.121	1.308	0.541	575092
16:32	+1.06 mm	3.285	0.811	0.344	575098
16:34	+0.56 mm	3.225	0.550	0.237	575106

16:36	+0.06 mm	3.294	0.320	0.129	575113
16:38	-0.44 mm	3.351	0.139	0.053	575119
16:40	-0.94 mm	3.255	0.037	0.007	575130

Beam-wire Separation at 267 A

We now repeated the beam-wire separation scan at a 4 times higher wire-current. The beam was again bumped to different amplitudes, and PMT's etc. recorded. With a wire current of 267 A there were always losses.

Time	Bumpamplitude	ε IN	ε OUT	Supercycle number
16:54	+0.5 mm	3.179	1.886	575180
16:57	-4.5 mm	3.440	2.063	575190
17:01	-4.5 mm	3.277	1.825	575203
17:05	-9.4 mm	3.403	1.145	575217
17:11	-10.8 mm	3.280	0.822	575238
17:20	+5.6 mm	3.295	1.995	575270
17:25	+9.1 mm	3.284	2.085	575282
17:30	+9.1 mm	3.237	2.848	575310 (after tune adjustment)

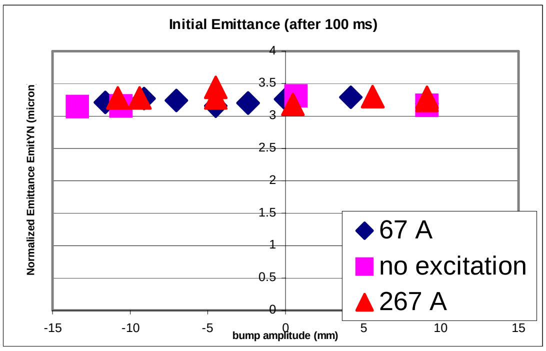
Attempt of Diffusion Measurement by Scraping at 267 A

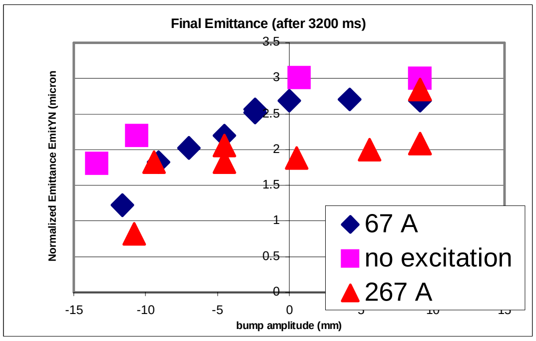
The wire was excited to 267 A, and the beam bumped to –5 mm. The scraper was applied at 2000 ms, i.e. 500 ms after the end of the BBLR ramp, with various amplitudes. PMT data were recorded.

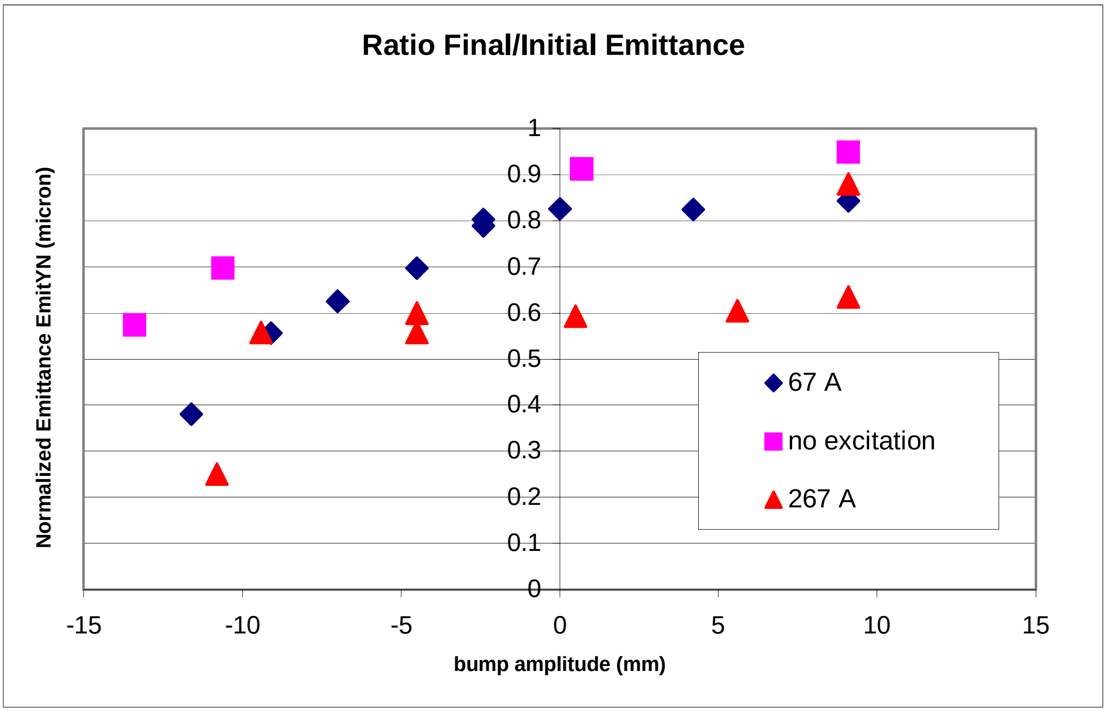
Scraper position	PMT number	Log start time	Log end time	Supercycle no.
+6.06 mm	51109-51114	17:56:01	17:57:25	575397
+5.06 mm	51124-51127	18:00:13	18:01:03	575412
+4.06 mm	51131-51133	18:02:10	18:02:44	575419
+3.06 mm	51137-51140	18:03:51	18:04:42	575425
+2.06 mm	51144-51147	18:05:49	18:06:39	575431

Display and Analysis of Some Data

<u>(1) Wire scans for different beam-BBLR separation with & without BBLR excitation.</u>
The following two figures show the measured initial and final emittances as a function of bump amplitude with 0 excitation, for 67 A and for 267 A. The emittance is smaller the higher the wire excitation. The spread for 267 A could indicate a significant sensitivity to the tune. The figure below displays the ratio of the final to initial emittance.

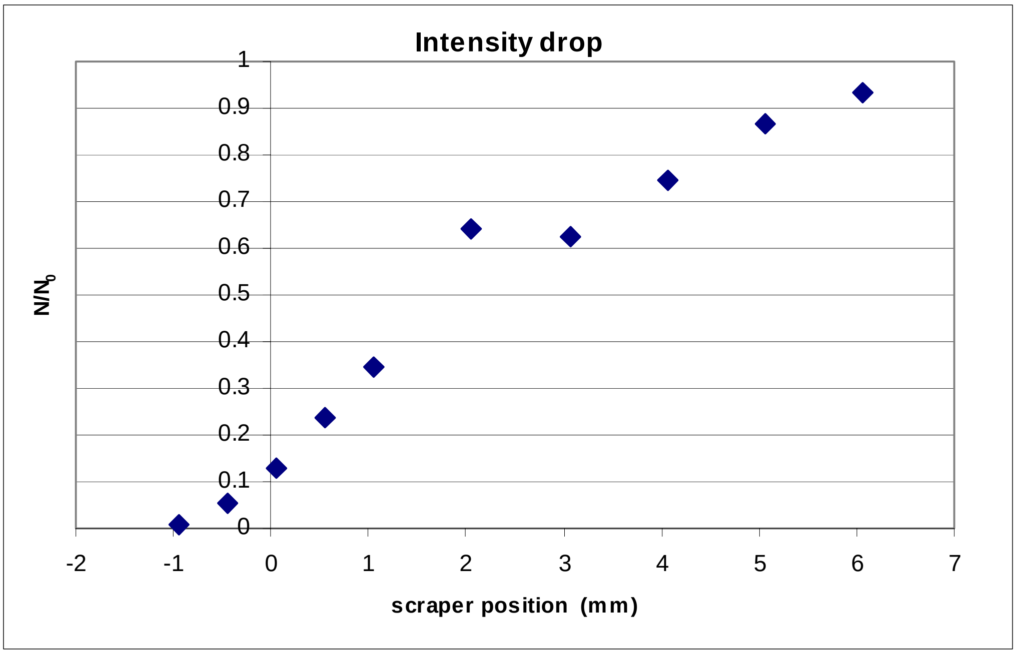






The reduction in emittance of the left outermost point without excitation is consistent with scraping at an amplitude of (19-13.4)mm = 5.6 mm, corresponding to 2.4 times the rms beam size of 2.3 mm. This is also the dynamic aperture for 267 A w/o bump.

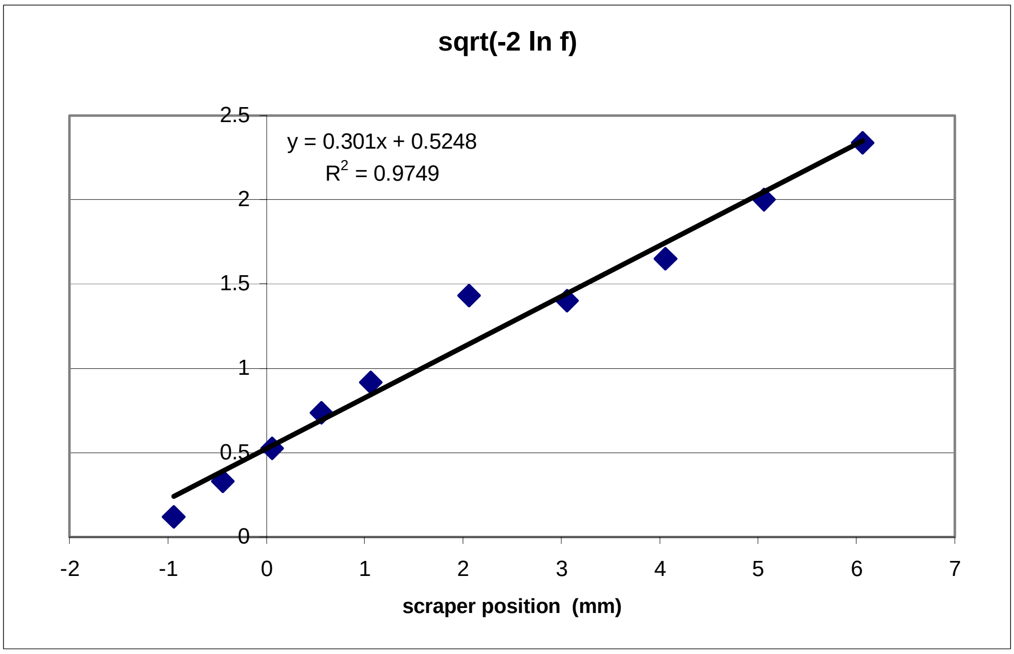
(2) Calibration with Scraper
The following plot shows the intensity reduction as a function of scraper position.



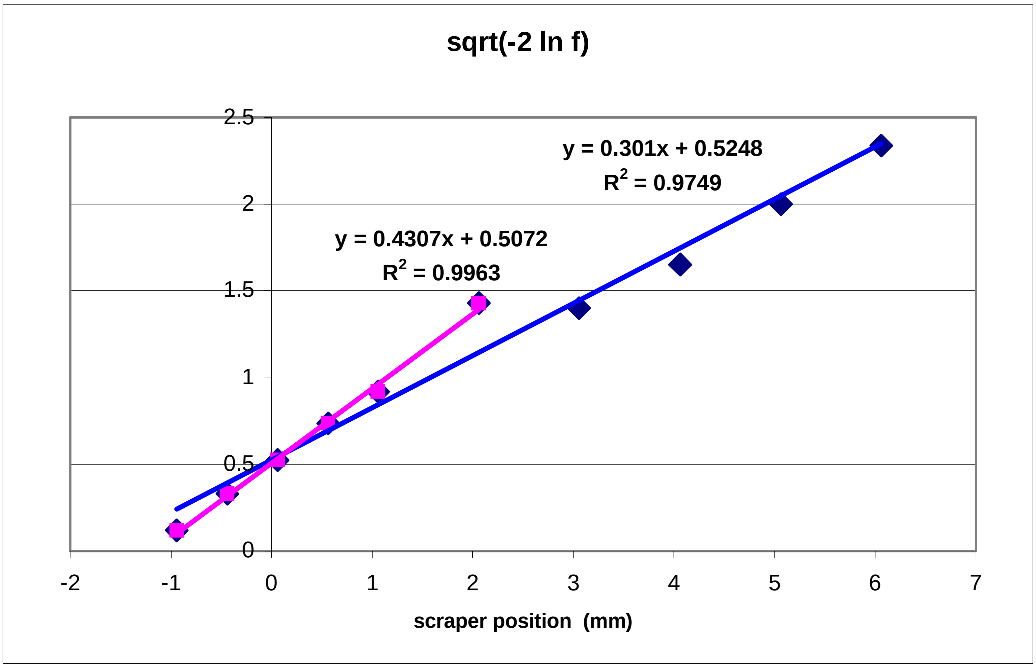
Considering a Gaussian beam, the intensity should vary with the scraper position *a* as

$$\frac{N}{N_0} = \left(1 - \exp\left[-\frac{a^2}{2\sigma^2}\right]\right).$$

Thus, the logarithm of the fraction of the beam that is lost, ln *f*, should be $(-a^2/(2\sigma^2)$. Plotting the square root of this logarithm multiplied by -2, i.e., sqrt(-2 *f*), against the scraper position *a* should give a straight line with slope $1/\sigma$:



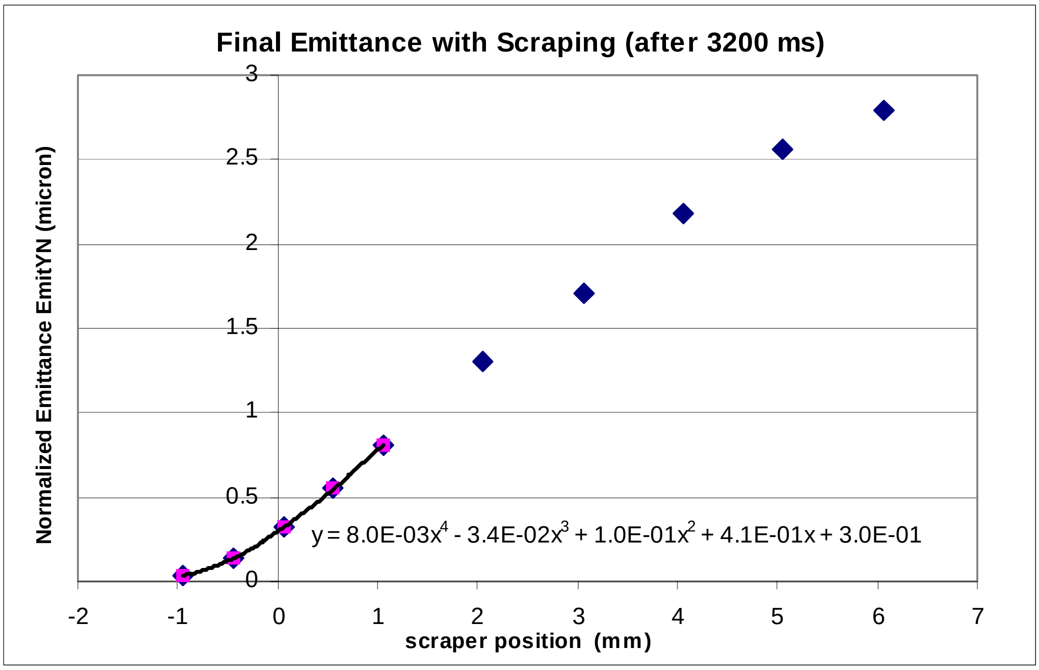
The intercept with zero is at –1.74 mm, which should correspond to the center position of the beam. The rms beam size at the scraper is inferred to be (1/0.301) mm=3.32 mm. Assuming a beta function at the scraper of β_V =45.6 m (?), the emittance is 0.242 µm, and the normalized emittance 6.7 µm, which is about two times larger than the values reported from the wire scanner. Could there be a factor of 2 in the beta function or a factor of sqrt(2) in the position of the scraper? Maybe the outer part of the beam is very non-Gaussian and we should fit only the inner part, e.g., from a scraper position of +2.5 mm downward? This is shown below. In this case, the intercept is at –1.1776 mm, and the rms beam size 2.32 mm, yielding a normalized emittance of 3.27 µm, not bad at all!



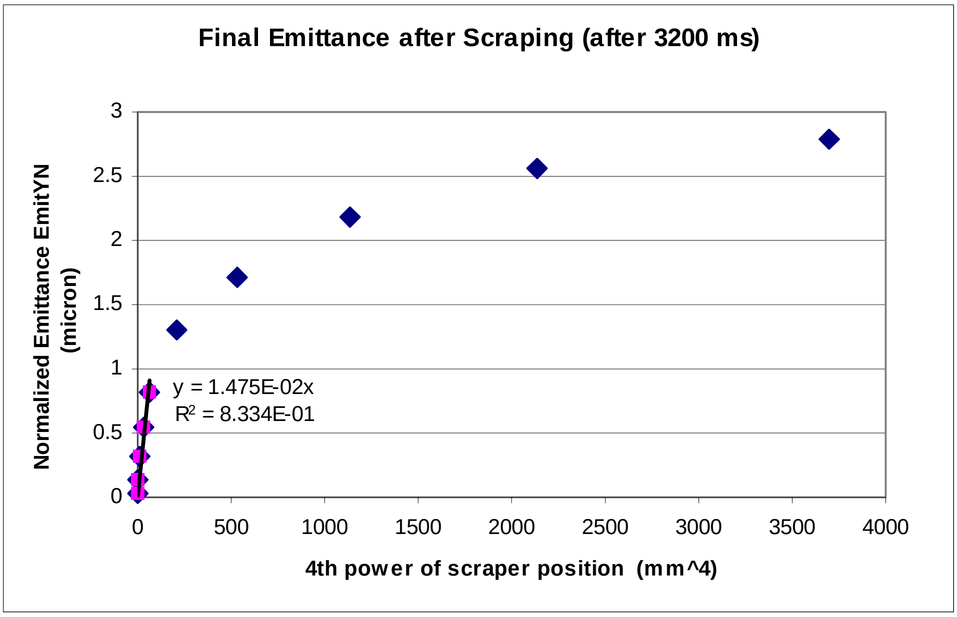
The rms emittance for a scraped Gaussian beam should be

$$\varepsilon \propto \left(1-\exp\left[-\frac{a^2}{2\sigma^2}\right]\left\{1+\frac{a^2}{2\sigma^2}\right\}\right) \approx \frac{a^4}{8\sigma^4},$$

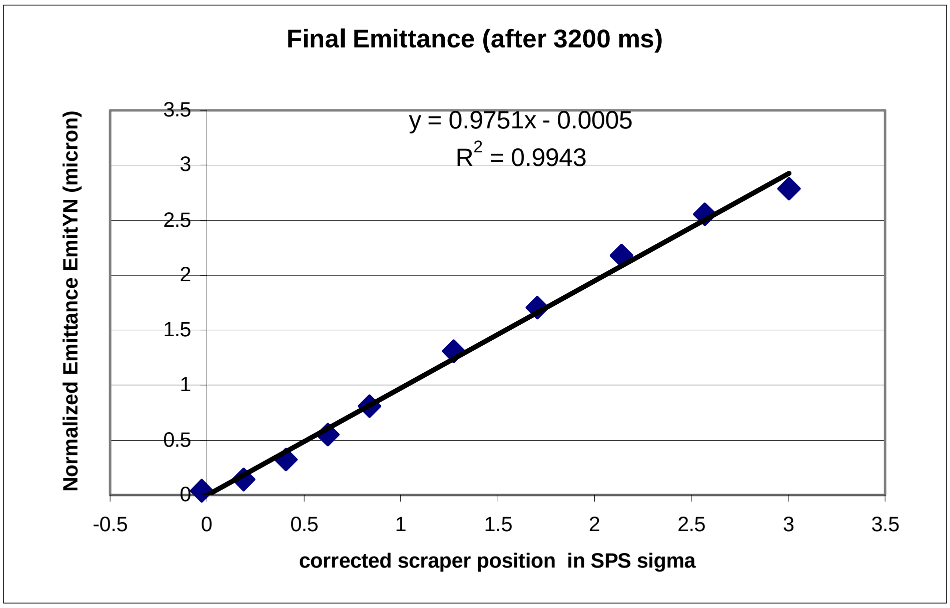
where the last approximation applies if the scraper position is close to the beam center. The figure below shows the emittance variation and a fit to a 4th order polynomial.



The fit is not very well constrained. To improve it, we shift the origin of the scraper position by 1.74 mm and plot the emittance as a function of the fourth power of this corrected position. We then expect a straight line, with slope $1/(8\sigma^4)$. Such a plot is shown in the next figure, together with a linear fit. We get a beam size of 1.70 mm, resulting in a normalized emittance of 1.75 μm, or almost a factor of 2 lower than the wire scan data and 3-4 times smaller than the number inferred from the intensity drop when including the points at large amplitudes. This inconsistency is not satisfying.



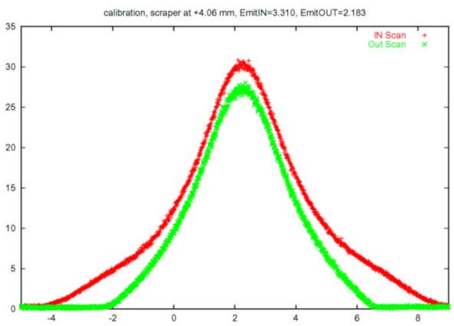
For calibration purposes we converted the scraper position into SPS rms beam sizes (assuming the nominal beta function of 45.6 m and a normalized emittance of 3.25 micron, resulting in 2.31 mm for the "nominal" SPS beam size during the second half of this MD) and plotted the final emittance after scraping against this normalized position. To fit a straight line passing through zero we also shifted the horizontal axis by 0.373 sigma, taking back half of the correction of 1.74 mm applied before.

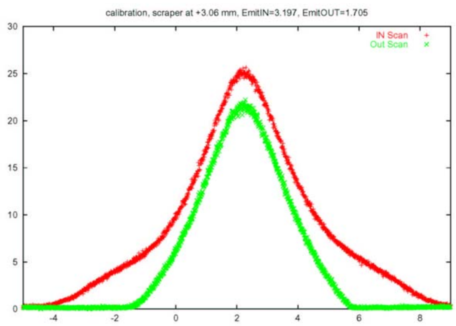


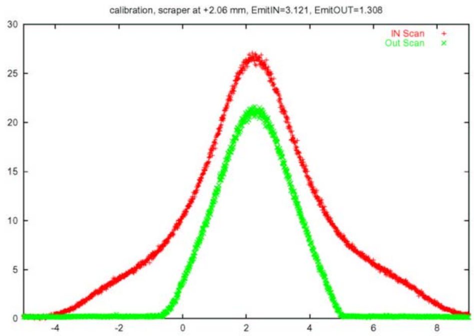
We obtain a rather simple relation between the final wire-scan emittance and the scraper position, which we can use to estimate the diffusive aperture observed when the BBLR was excited, namely the emittance divided by 0.975 gives the position in SPS-sigma.

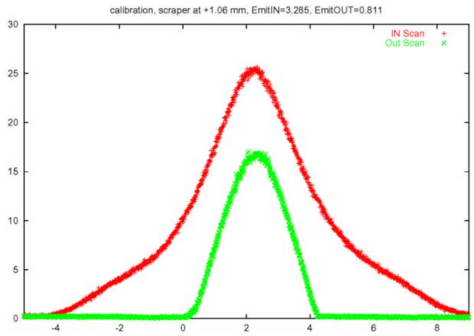
(3) Wire Scan Profiles with Scraping

The following 4 figures show wire-scan profiles taken before and after scraping the beam at 4 different amplitudes. The final emittances range from 2.2 μm (top left) for scraping at 4.06 mm to 0.811 μm (bottom right) for scraping at 1.06 mm.

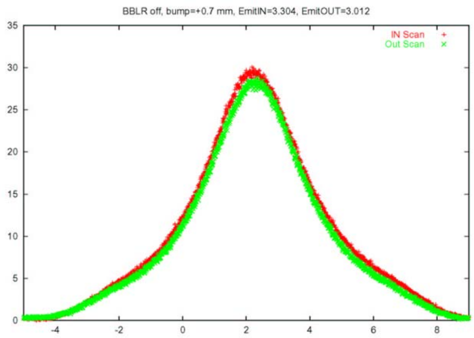


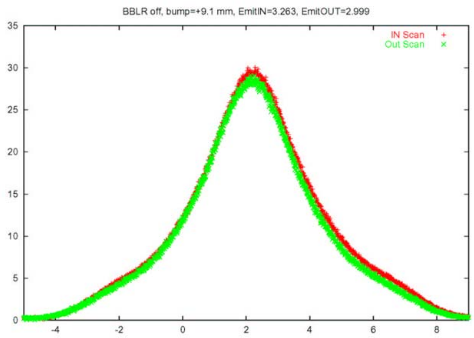




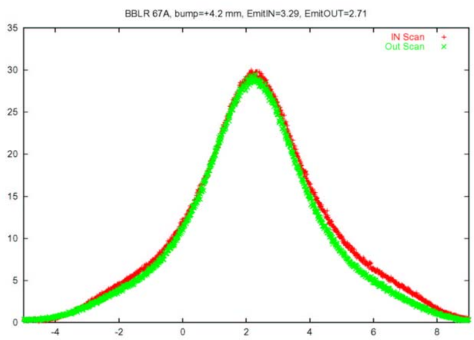


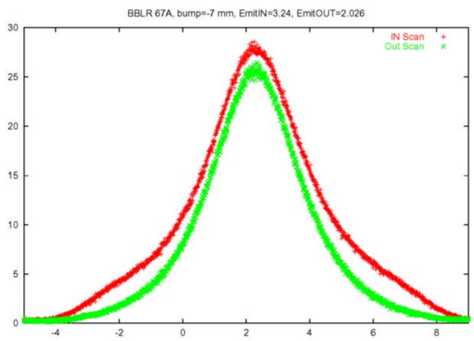
<u>(4) Wire Scan Profiles w/o & with BBLR Excitation and Orbit Bump</u>
The following two figures show IN/OUT wire-scan profiles taking with orbit bumps but no BBLR excitation.

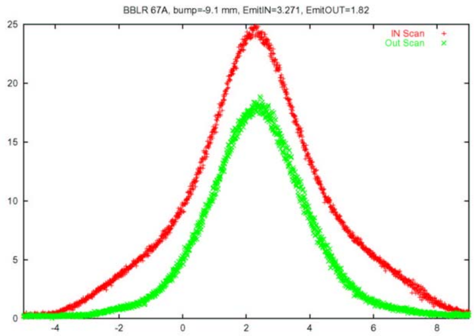


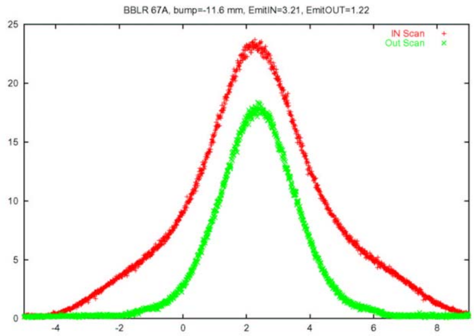


The next set of figures refers to different bump amplitudes for a 67-A BBLR excitation.

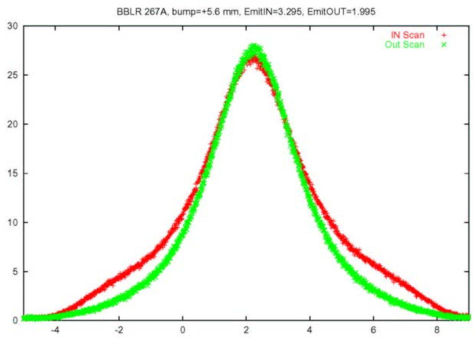


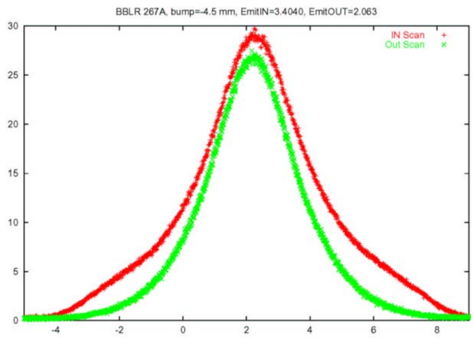


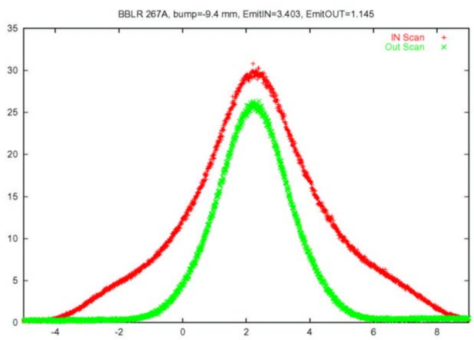


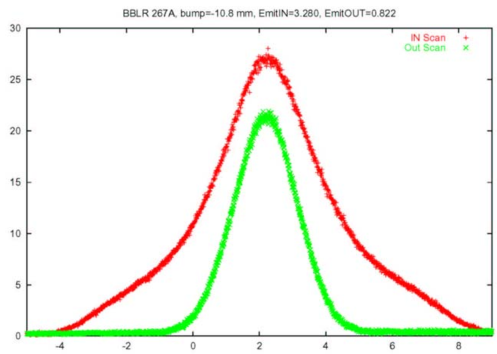


The figures below refer to different bump amplitudes for a 267-A BBLR excitation.







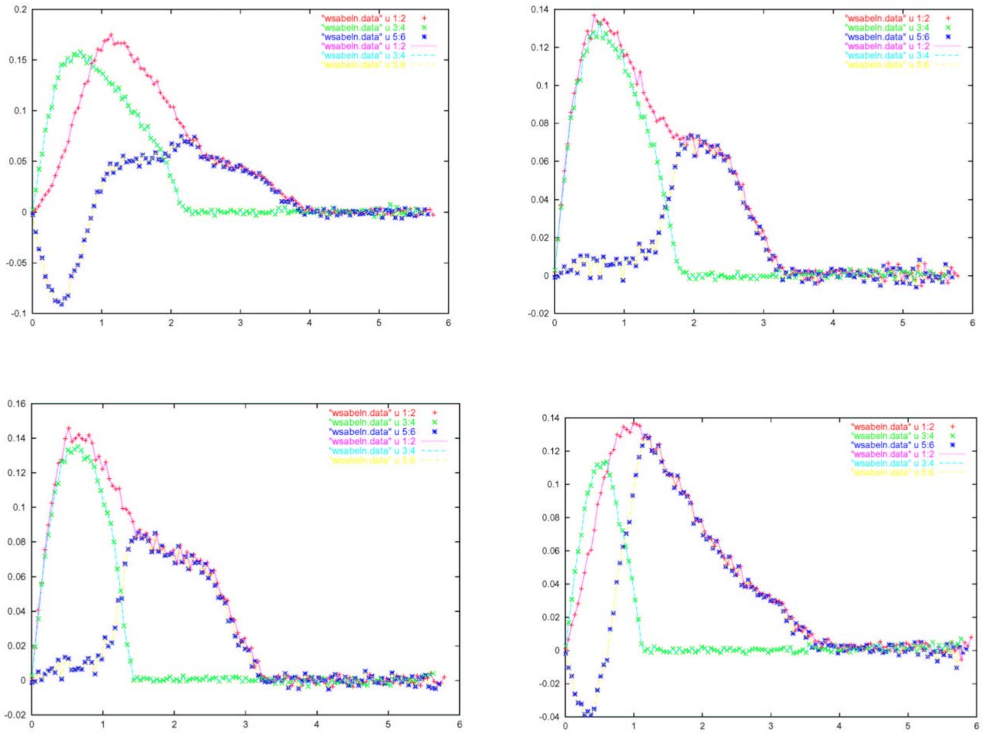


(5) Amplitude distribution

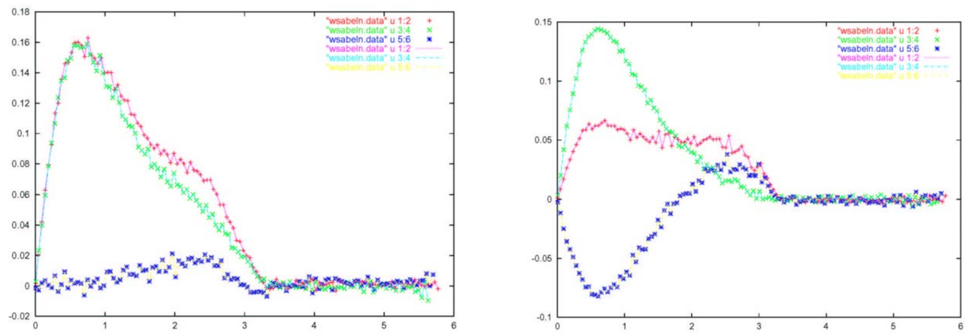
The distribution ρ in normalized amplitude $A = a/\sqrt{\beta}$ can be obtained from the derivative of the measured distribution g in normalized position $\eta = y/\sqrt{\beta}$, by means of an Abel transform:

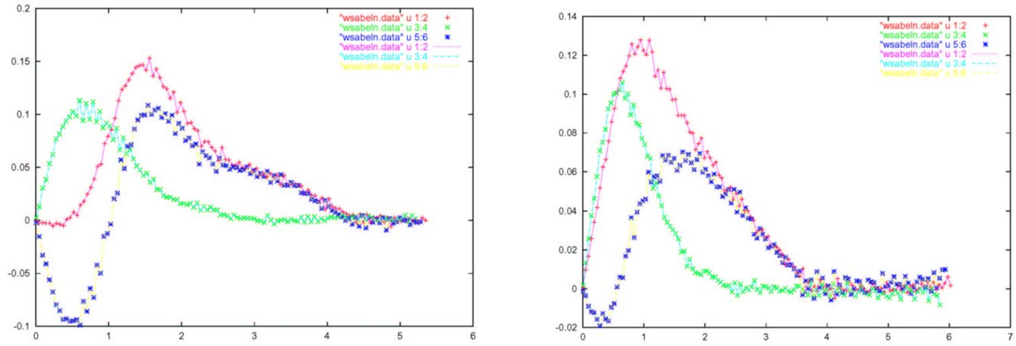
$$\rho(A) = -2A\int_A^R d\eta \frac{g'(\eta)}{\sqrt{\eta^2 - A^2}}.$$

Results from scraping for calibration (scraper positions at 4.06 mm, 3.06 mm, 2.06 mm, and 1.06 mm)

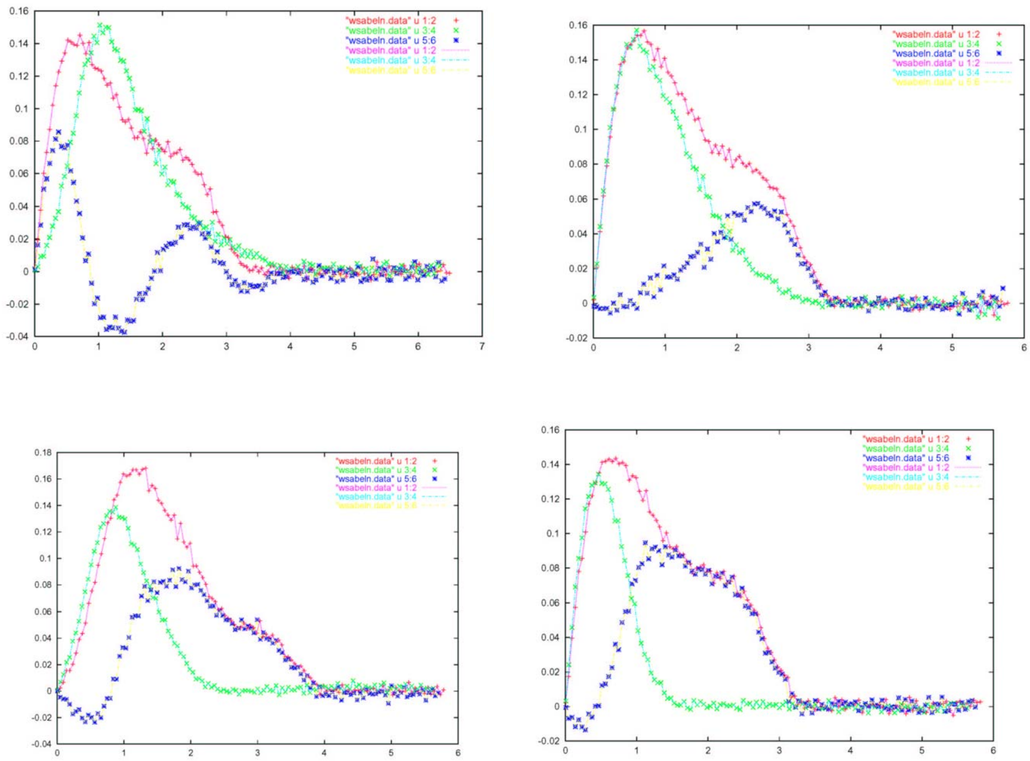


Results for 67 A: bumps at +4.2 mm, -7 mm, -9.1 mm, and –11.6 mm.





Results for 267 A: bumps at +5.6 mm, -4.5 mm, -9.4 mm, and –10.8 mm.



Decoherence of Qmeter data?
Resonance driving terms – Yannis?
Redo scraper position plot.