Hall C beam quality

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Outline

- Introduction
- 12 GeV Project's out-year physics promise
- Beam envelopes at first, third and fifth passes
- Latest measurements within CEBAF
- Conservative estimates of beam properties
- Summary

Introduction

A team consisting of four APELs (Roblin, Tiefenback, Benesch and Satogata), Bogacz, Suleiman and T. Larrieu has been charged with producing a 12 GeV Beam Parameter table like the 2001 page produced by Cardman and Denard.

The group has been meeting monthly.

Completion due 3/31

I will not discuss parity quality beam specifications as there are no parity experiments approved for Hall C. The Parity Quality Beam group under Riad will define those.

This talk solicits input to the process.

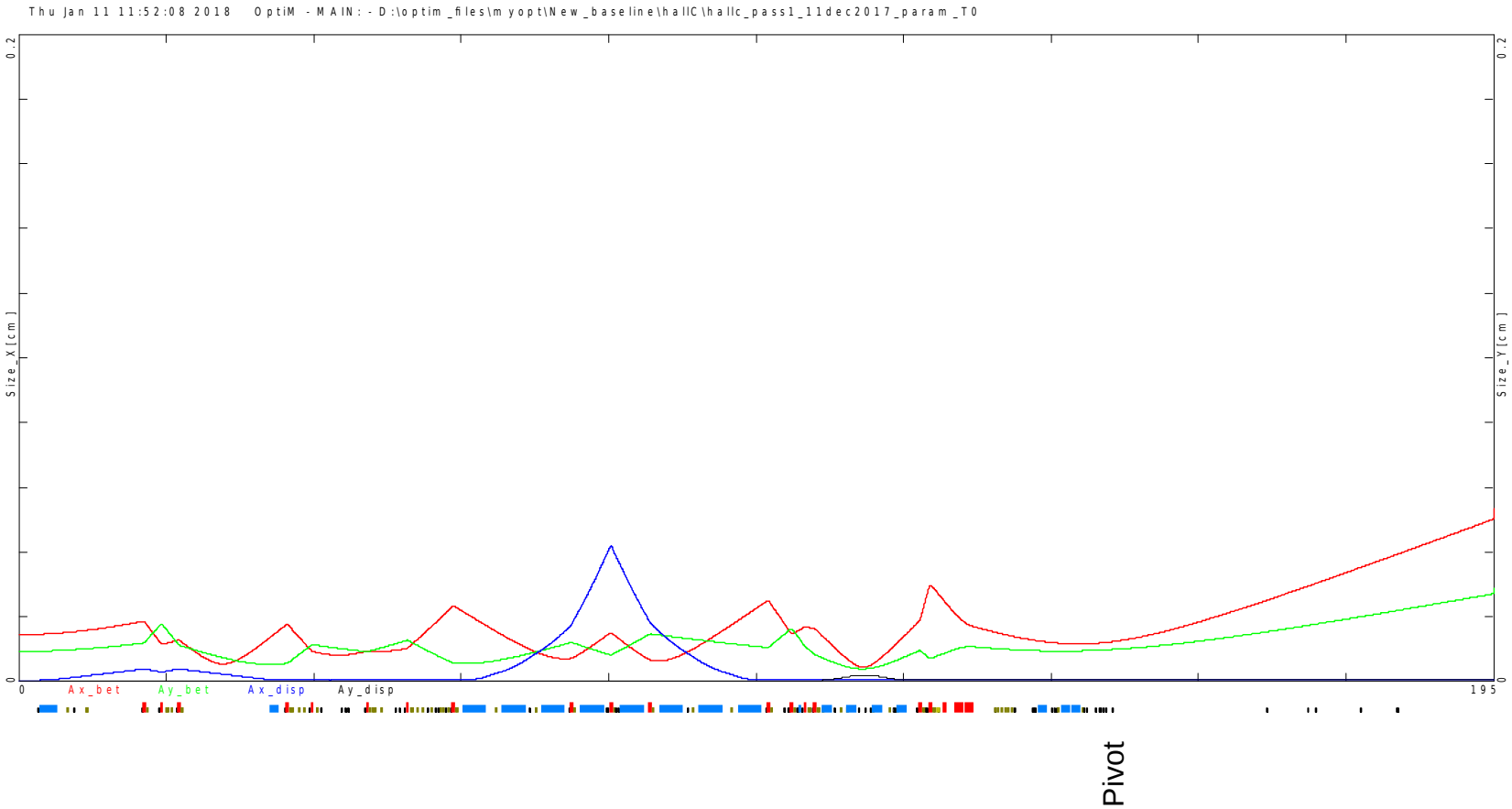
2007 Lehman review Out-year parameters

- EmittanceX < 1E-8 m, EmittanceY <5E-9m
- Spot size (sigma) X < 400 microns, Y< 200 microns
- Halo (residual) less than 1E-4 of integral of Gaussian core
- Energy spread at 11 GeV less than 5E-4; 1-3 pass 3E-4
  (Assumed we could continuously phase cavities in background. We likely can't.)

Parameters in 2001 Cardman/Denard spec

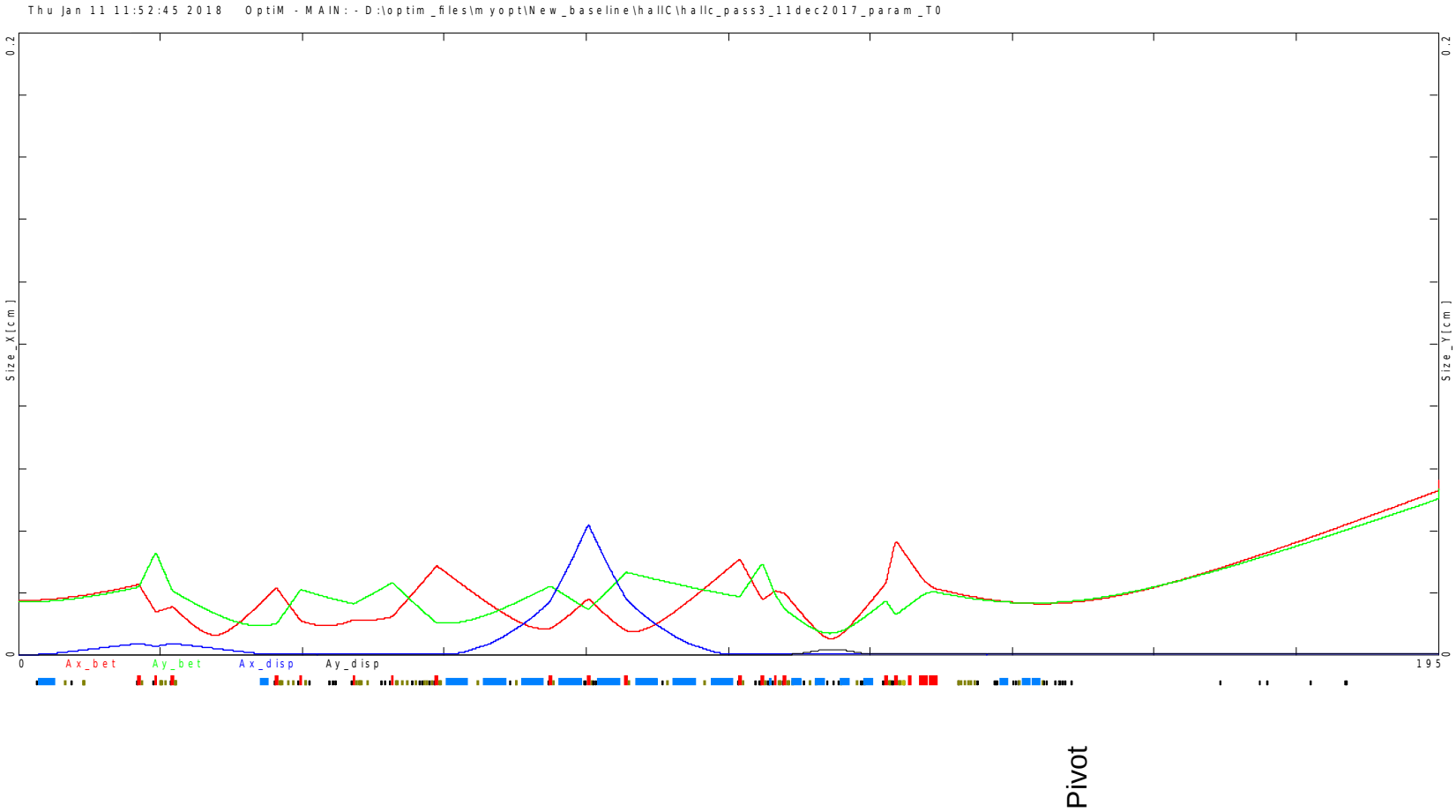
- Angular divergence at target
- Beam position and stability
- Allowed off-nominal beam direction
- Spot size at target
- Energy spread
- Beam halo outside 5 mm radius
- CW current range and stability (e.g. at 60 Hz, helicity flip)
- Polarization
- Effective duty factor given trips

Beam envelope at first pass (ideal)



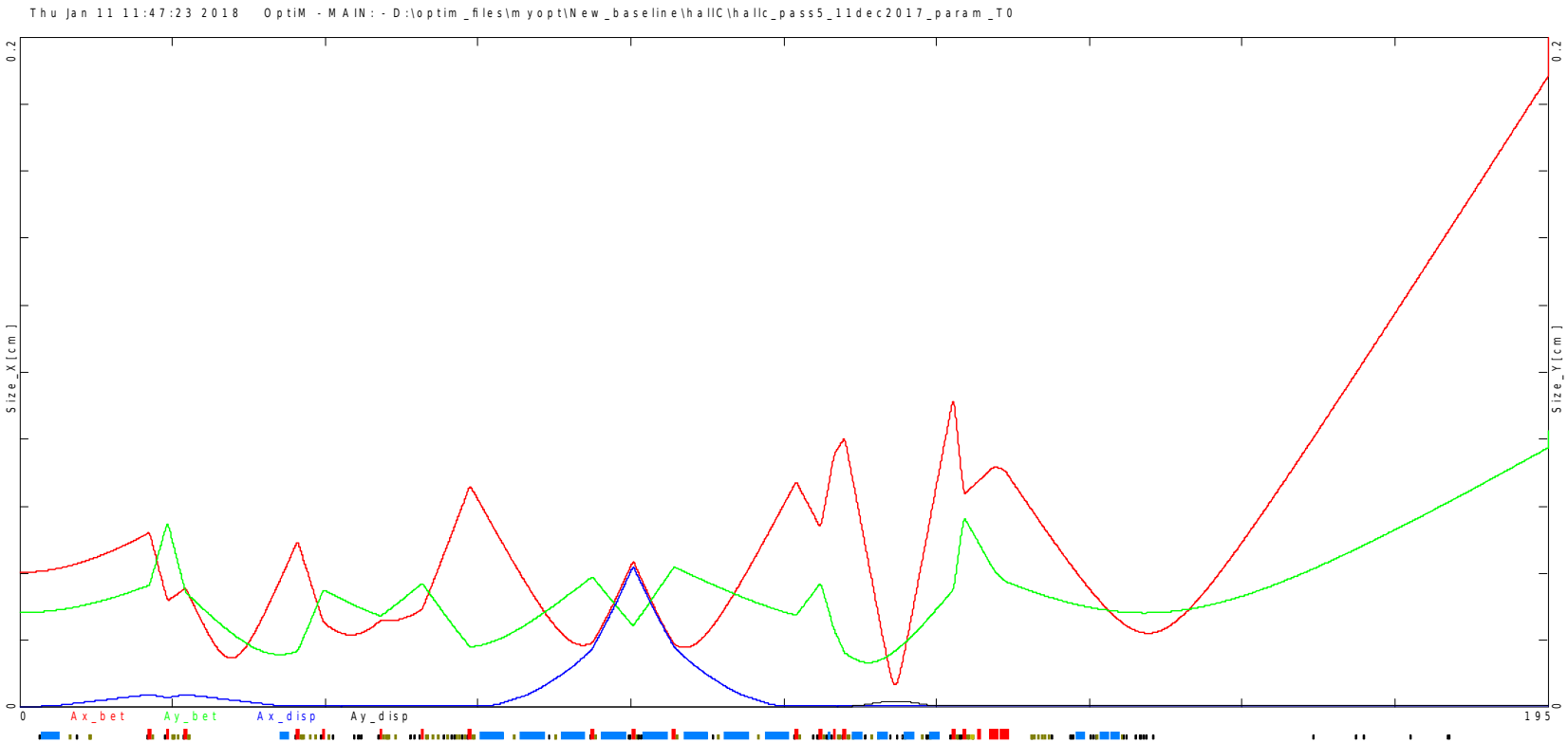
Vertical axis 2 mm, horizontal axis 195 m, Lambertson to dump entrance.
Red horizontal size (sigma), green vertical size,
Blue dispersion effects (dp/p 0.01%) which must be added in quadrature to red.

Beam envelope at third pass (ideal)



Vertical axis 2 mm, horizontal axis 195 m, Lambertson to dump entrance.
Red horizontal size (sigma), green vertical size,
Blue dispersion effects (dp/p 0.01%) which must be added in quadrature to red.

Beam envelope at fifth pass (ideal)



Vertical axis 2 mm, horizontal axis 195 m, Lambertson to dump entrance.
Red horizontal size (sigma), green vertical size,
Blue dispersion effects (dp/p 0.01%) which must be added in quadrature to red.

Recent measurements

- Beam size calculated as √(emittance*beta)
- measured January 7 at 0L08, 118.5 MeV/c

location	elogX	emittanceX	betaX	alphaX	X size (m)
Design		**3.24E-09**	**9.4978**	**-0.99914**	**176E-06**
Inj_A	3508990	7.68E-09	41.688	-2.8612	566E-06
Inj_B	3508995	8.93E-09	29.442	-1.5605	513E-06
Inj_C	3509002	3.81E-09	20.315	-1.5295	278E-06
inj_D	3508981	5.75E-09	34.78	-2.0448	447E-06

location	elogY	emittanceY	betaY	alphaY	Y size (m)
Design		**3.24E-09**	**4.3671**	**-0.15912**	**119E-06**
Inj_A	3508992	4.06E-09	4.5381	0.11741	136E-06
Inj_B	3508998	4.30E-09	8.2299	0.11059	188E-06
Inj_C	3509004	1.92E-09	8.1664	-0.20709	125E-06
inj_D	3508985	3.31E-09	8.7	0.1616	170E-06

D beam size at extraction points

- Machine setup was done with D beam
- Hall C05 harp is ~145 m downstream of extraction E01

	X size meas	X size design	Y size meas	Y size design
2E01_D	221E-06	114E-06	168E-06	99E-06
4E01_D	91E-06	61E-06	199E-06	40E-06
6E01_D	237E-06	154E-06	270E-06	95E-06
8E01_D	65E-06	45E-06	324E-06	125E-06
AE01_D	314E-06	389E-06	308E-06	203E-06

Estimating beam sizes at target

- Fractional factorial exploration of α/β parameter space used to provide input range to Optim models. Values chosen from best quartiles in 6 GeV era. Method was used to design the Hall D line, which works.
- Allowed Optim to match at entrance to Hall arc, as is done with Ops tool driven by elegant.
- Tweaked last quad by hand to round up large beams
- Additional matching may be done with quads before Compton (4-6 hours) and then the four at the end of the line (another 4-6 hours) to reduce spot size at Compton and pivot
- Conservative emittance values used: 2-3 times extraction

Estimated beam sizes (sigma) at pivot

- Pass 1: X, Y 100-190 microns
- Pass 2: X, Y 150-260 microns
- Pass 3: X, Y 175-300 microns
- Pass 4: X, Y 200-275 microns
- Pass 5: X, Y 230-500 microns
- Beam won't be round at pivot when matched only with data taken at dumplet. Manual tweek with last quad to get it round, hence maxima above.
- X and Y waists are not Z-coincident at Compton with match using only dumplet data

Example: 1/12/2018 Pass 3 tune beam

- Matched at dumplet before beam to hall
- At 1714, 3H07A σ_x 101 μm σ_y 84 μm
- At 1715, 3H07B σ_x 89 μm σ_y 250 μm
- changed MQE3M03, ending 20% stronger
- At 1753, 3H07A σ_x 127 μm σ_y 136 μm
- At 1756, 3H07B σ_x 144 μm σ_y 142 μm
- 1.90 m between harps
- x divergence $17/1.9 * 10^{-6} = 9$ μRadians
- y divergence $6/1.9 * 10^{-6} = 3$ μRadians

Energy Spread (sigma)

- 12 GeV promise: under 3E-5 passes 1-2, 5E-4 passes 3-5. These are ideal numbers, no RF phase errors, just synchrotron radiation. This assumes phasing software running in background to minimize effects of RF curvature.
- Reality: Per test, Phaser software requires 8 samples at 1E-3 for accurate results with 1.1 GeV linacs. A new test will be run with 40 samples at 3E-4 dp/p, ~5 min/cavity. Will this be tolerable in quadrature with lattice-inherent dp/p?
- NL Phaser compatible with energy FFB; SL not
- For hypernuclear experiments at 4.5 GeV, ~150 keV with Phaser off - but will have to turn it on when experiment's dp/p upper bound is reached. Need real time monitor.

Beam current

- Beam dumps are limited to 1 MW each by design and CEBAF to 900 kW total by Final Safety Assessment Document (FSAD)
- Environmental assessment was done for 2.06 MW total, 1 MW each to A and C dumps and 60 kW to D.
- FONSI limits total power in CEBAF to 1000 kW
- A written request by Lab Director to ORO would likely result in a memo to file clarifying FONSI wording to allow ~2 MW. FSAD would then have to be changed.
- C100 modules were built to accelerate 465 μA max. Since they are producing only 80 MV each, an effort to reduce input Q would allow more current if ORO clarifies FONSI. How much more is unclear.

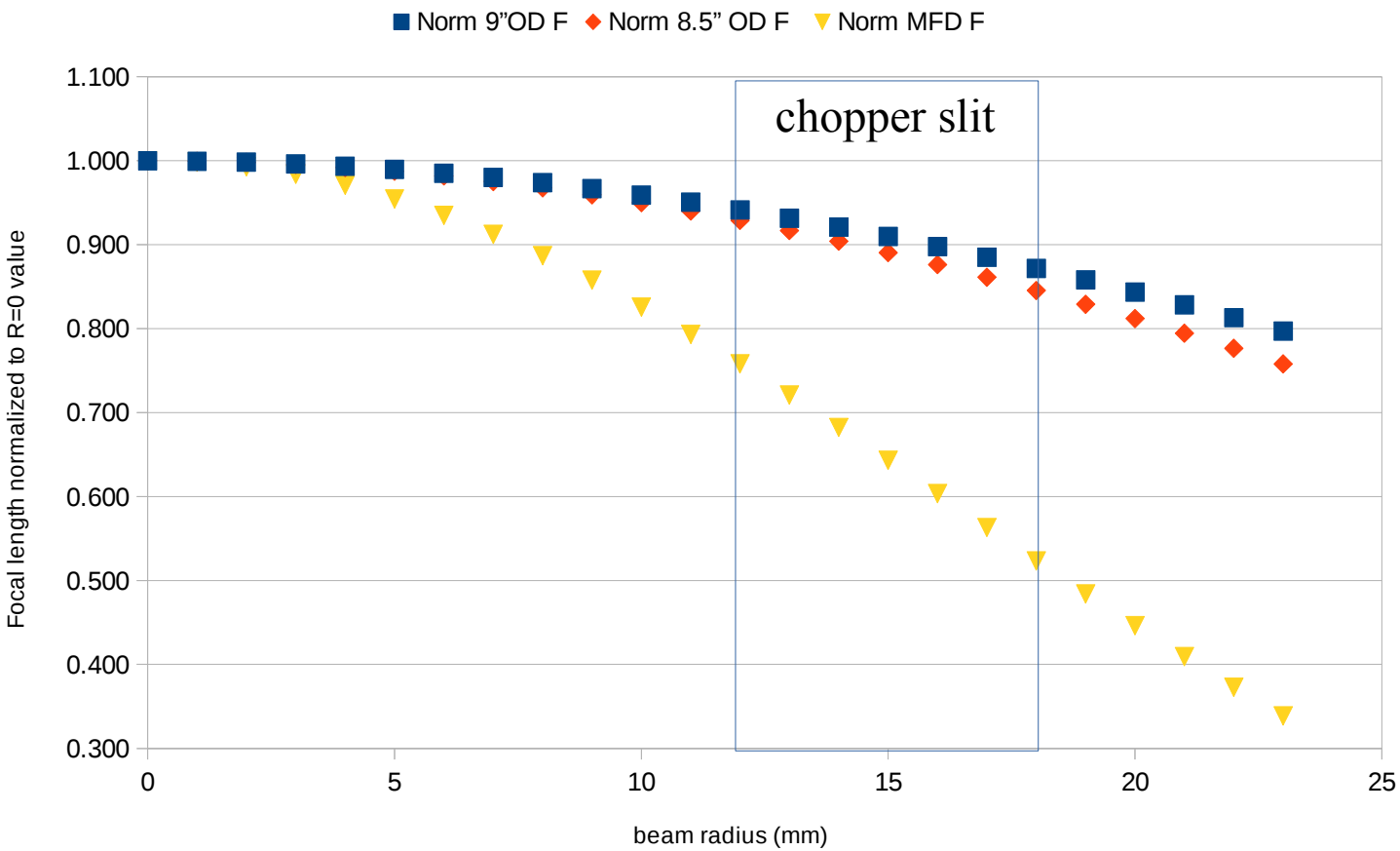
Other parameters

- Divergence at target ±25 μRadians maximum, all passes
- Beam position: offsets parallel to diagnostic girder axis within 2.5 mm radius.
- Beam direction: beam divergence, dump aperture and raster combine to limit imposed angles under 800 μRadians, a 2 mm vector offset across diagnostic girder BPMs (2.4 m δ).
- Polarization: fraction of the ~85% off the strained lattice cathode provided by experiment scheduling committee
- Energy accuracy: 3E-3, set by errors in dipole field measurements, until sufficient measurements are made in Halls and CEBAF to modify Arcs 1 and 2 field maps.

Concluding remarks

- Are you sufficiently depressed?
- Input additional to that provided by your comments here may be emailed to me benesch@jlab.org

Why do four beams differ so much?



I assert, without particle tracking support as yet, that the large changes in focusing across the chopper slit propagate through the rest of the machine. TN-18-04