



Turn-by-Turn Electron Injection Trajectories and Efficiencies with Injected-beam Energy Offset Including Effects of BBI and CCU Field Integrals

-- Lattice: chess20150106_ele827_newund_10mA (SW) --

-- Single electron injection against current operating positron bunch train configuration --

-- Five positron trains @ four bunches with 10 mA/e⁺ bunch (170% of present operating current) --

-- Includes effects of ring magnet multipoles --

**** Found backswing bump HBump 65 at Q28E previously had wrong sign ****

**** New results now compatible with Suntao's analyses ****

-- 31 March 2015: Updated with suggestions received during presentation --

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Horizontal Clearance Definitions

σ_x (Synch, e-, 34E): 3.6 mm

Nr σ_x Synch wall clearance: 2.0

Septum wall thickness: 3.0 mm

Injection error tolerance: 2.0 mm

==> Injected beam position: -57.1 mm

σ_x (CESR e-, 34E): 2.5 mm

Nr σ_x CESR wall clearance: 4.0

Pretzel amplitude (e-, 34E): 14.2 mm

==> Pulsed bump amplitude: 20.7 mm

Injection
Oscillation Amplitude

$$57.1 - 34.9 = 22.2 \text{ mm}$$

Suntao's definition
X_INJ

$$57.1 - 20.7 = 36.4 \text{ mm}$$



Same as SW tune scan injection simulations

(See ST talk at CHESS retreat on 20 June 2008 describing measurements from 8 January 2008 at 2 GeV extrapolated to 5.3 GeV)

	<u>H</u>	<u>V</u>		
β (m)	20	20	$\sigma_x = 3.6$ mm	$\sigma_Y = 1.3$ mm
α	0	0		
γ	0.05	0.05	$\sigma_{x'} = 0.18$ mrad	$\sigma_{Y'} = 0.066$ mrad
η (m)	1.2	0	$\sigma_Z = 17.3$ mm	$\sigma_E / E = 6.6e-4$
η'	0.094	0		
ϵ (m-rad)	0.6e-6	0.086e-6		

On-energy 40-turn efficiency

$25.6 \pm 1.6\%$



Effect of CCU on 40-turn survival efficiencies

Injection efficiency with
CCU elements on

Tunes H/V: 98/317 kHz

Injection efficiency with
CCU elements off

Tunes H/V: 99/317 kHz

No energy offset

$25.6 \pm 1.6\%$

$27.8 \pm 1.6\%$

-0.3%

$22.6 \pm 1.7\%$

$23.9 \pm 1.6\%$

-0.5%

0%

$7.8 \pm 0.7\%$

The effect of the CCU elements is small, except at large energy offset.

**The improvement with
energy offset measured
for single-bunch injection
is not apparent in this model.**

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0 MeV (-0%)	15%
-10 MeV (-0.19%)	20%
-15 MeV (-0.28%)	20%
-20 MeV (-0.38%)	16%
-30 MeV (-0.57%)	0%



Undulator field integral population (Electrons reach CCU 2 before CCU 1)

Incoming and outgoing coordinates for all turns are plotted for CCU2.

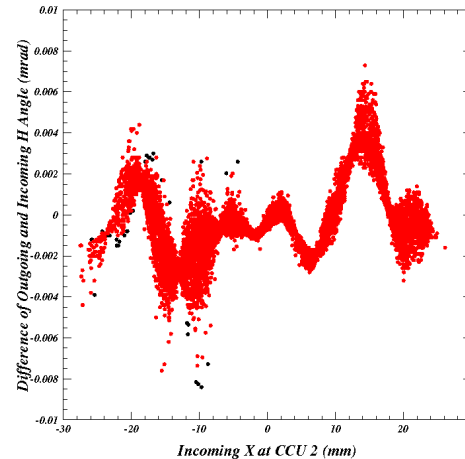
The black points indicate electrons which were lost between the CCU2 entrance and L0.

With field integrals

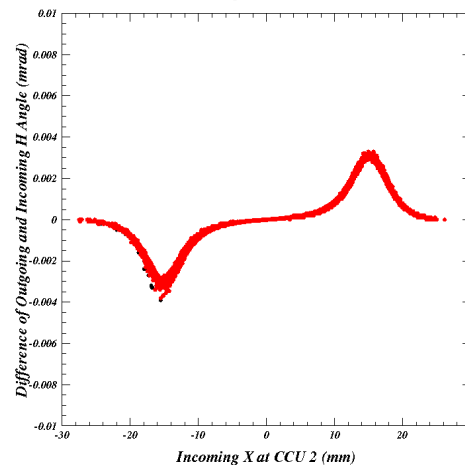
Without field integrals

$$\Delta\theta_x(X)$$

Horizontal variation of vertical field integral



Efficiency
 $25.6 \pm 1.6\%$



Efficiency
 $26.1 \pm 1.6\%$

The CCU field integrals do not pose a significant limit on the injection efficiency in the model.



**Injection efficiency with
BBI 100% (200 mA)**

Tunes H/V: 98/317 kHz

$25.6 \pm 1.6\%$

**Injection efficiency with
BBI 60% (120 mA)**

Tunes H/V: 99/316 kHz

$34.5 \pm 1.9\%$

**Injection efficiency with
BBI off**

Tunes H/V: 102/313 kHz

$29.9 \pm 1.7\%$

Lattice is apparently optimized for non-zero positron current.

The modeled efficiency is somewhat better than observed for operating conditions.

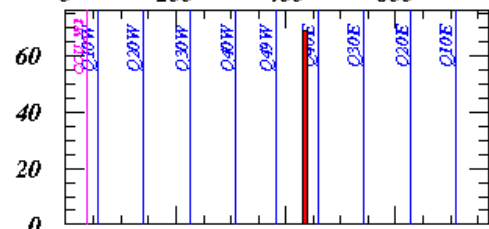
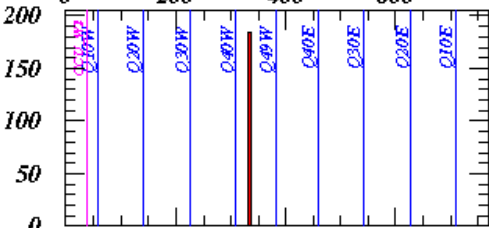
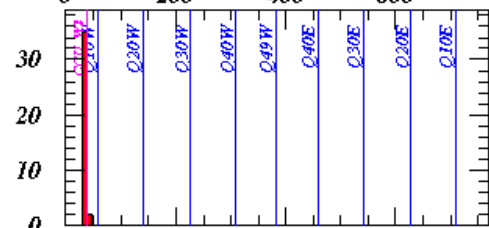
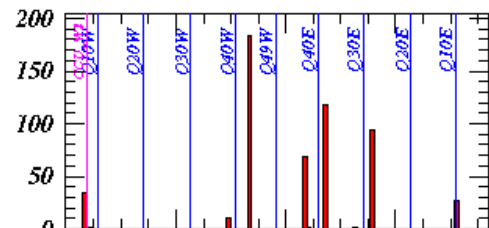
The effect is not large.

Have we over-emphasized the BBI effects in the lattice design?

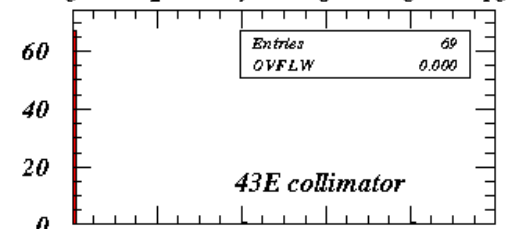
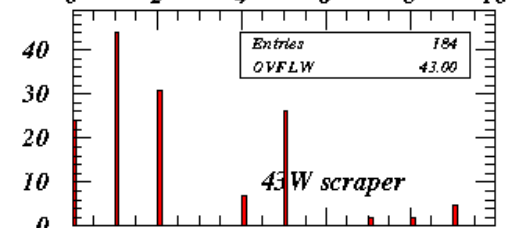
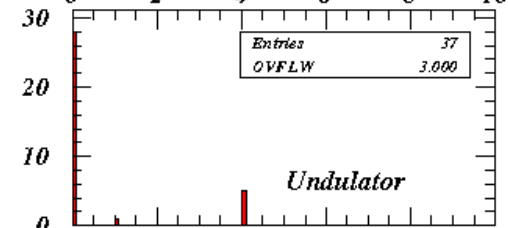
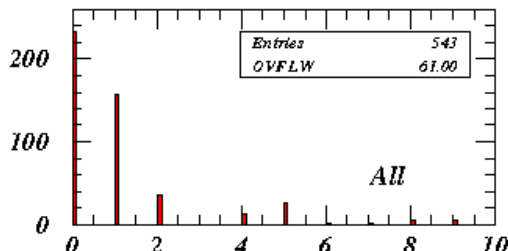


Turn-by-turn critical apertures for electron injection

Energy Offset 0%



S Position Where Lost (m)



Turn When Lost

The losses occur predominantly during the first three turns.

The modeled vertical aperture is ± 3.5 mm at the scraper and ± 5 mm at the collimator.

The modeled upper and lower apertures at the two ends of each undulator range between 2.0 and 2.5 mm.

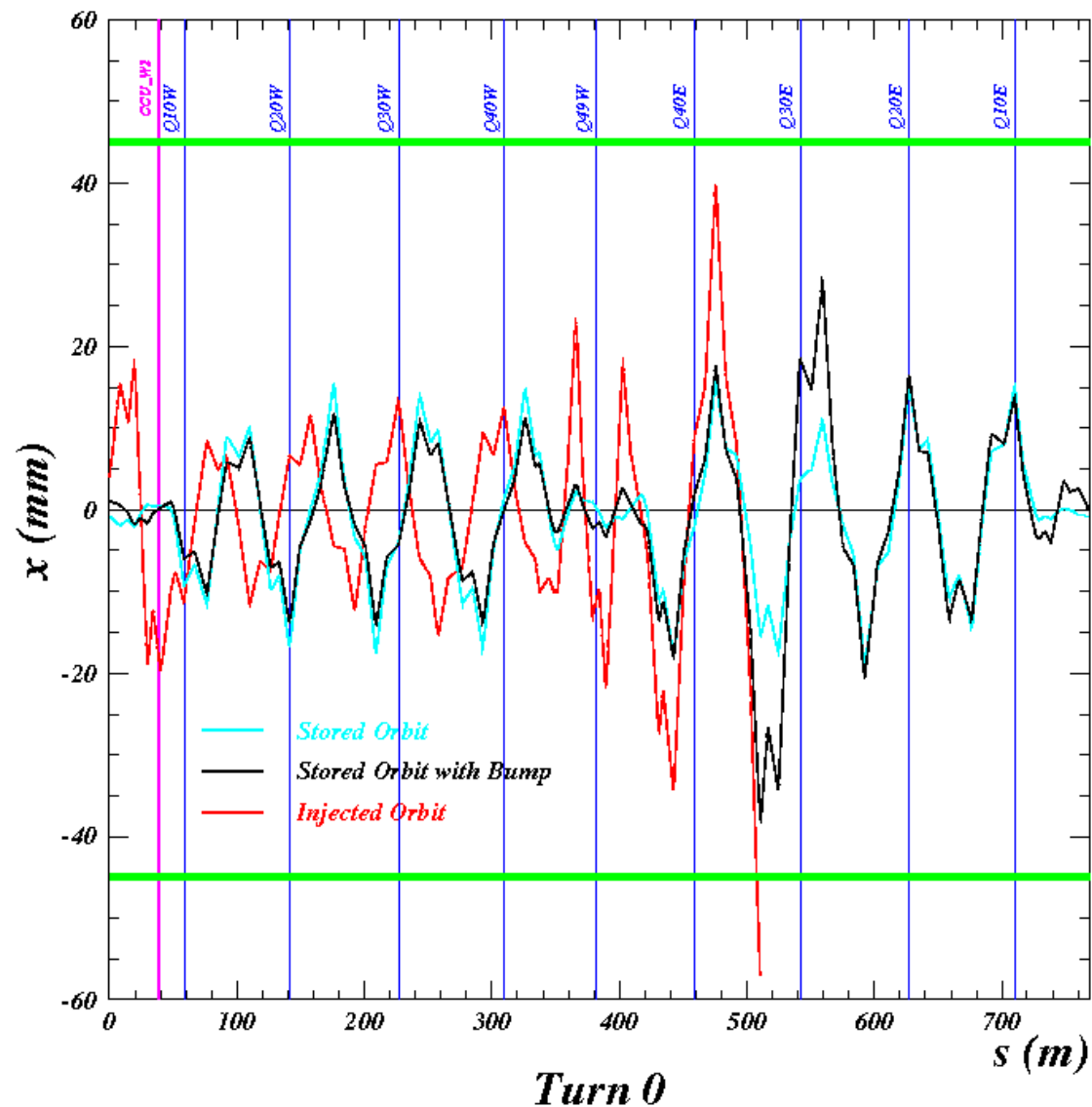
The horizontal aperture at Q28E is reduced to 40 mm and a backswing bump of -6 mm is included.

About 47% of the losses are at the 43W scraper or the 43E collimator.

About 50% of the losses are at the horizontal apertures at Q10E, Q28E and Q38E.

The losses at the undulator occur primarily on the injection turn.

29% of the injection-turn losses occur at the 43E collimator, 12% at the undulator, 10% at the 43W scraper, and about 50% at the Q38E horizontal aperture.



Are the losses at Q38E really necessary?

If we avoid them here will they show up at another downstream horizontal aperture?



The losses at the horizontal aperture at Q38E may be reduced by introducing a negative horizontal bump.

The losses at Q28E may be reduced by making the phase of the injection oscillation different than the stored orbit phase on the first turn, since the pulsed bump will have decayed more. Since the phase 28E-->34E is fixed at 180 degrees, this can only be done by varying the horizontal tune. At the present tune, they are out of phase on turns 1, 5, etc. So if one increases the tune by 1/4 integer, they should be out of phase on the first turn.

It should be verified that this simulation reproduces the 1/4-integer injection inefficiency band seen in Suntao's simulations. This simulation seems not to find the inefficiency at $f_h = 98$ kHz seen in Suntao's simulations. This might be an artifact of the detailed definition of the tune.

The effect of the BBI on the injection efficiency should be repeated holding the tunes constant when the BBI strengths are scaled.