Status of Top-off Upgrade and Future Plans

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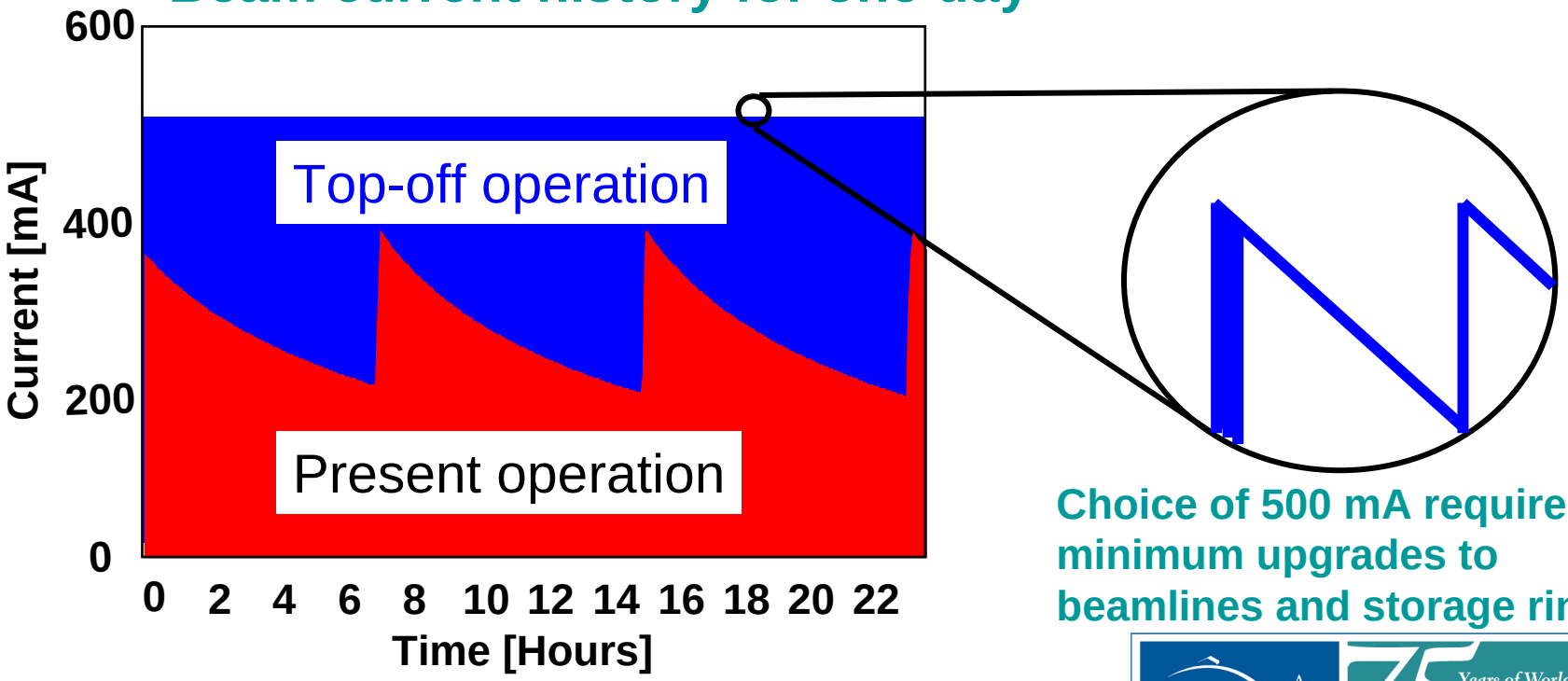
Outline

- **Top-off**
  - **Why**
  - **What needs to be done**
  - **Status**
- **Areas of Interest**
  - **Injection Transients**
  - **Beamdynamics: EPUs; small vertical gaps**
  - **Radiation Safety**
- **Future Plans**
  - **Fall shutdown**
  - **Next year/top-off parameters**

What is Top-off operation of the ALS?

Top-off operation is quasi-continuous injection into the storage ring

Beam current history for one day

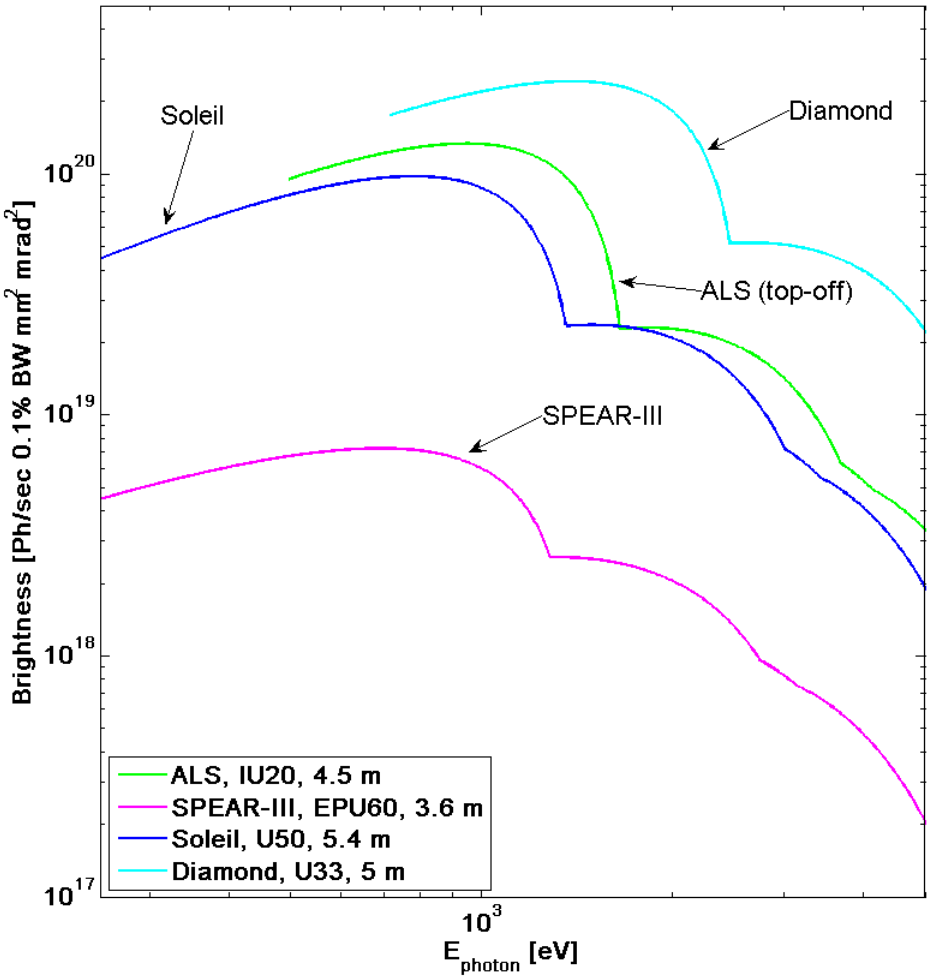


Choice of 500 mA requires minimum upgrades to beamlines and storage ring

Motivations for Top-off

- **Increased Brightness**
  - **2x higher time average current**
  - **Smaller vertical emittance (0.25x)**
  - **Smaller undulator gaps**
    - **First two changes would result in unacceptably short lifetimes without top-off**
- **Better (thermal) stability**
  - **Accelerator (thermal)**
  - **Beam diagnostics (current dependence)**
  - **Beamline optics (especially bend magnet/wiggler beamlines, but also undulators)**

Brightness comparison 2007+

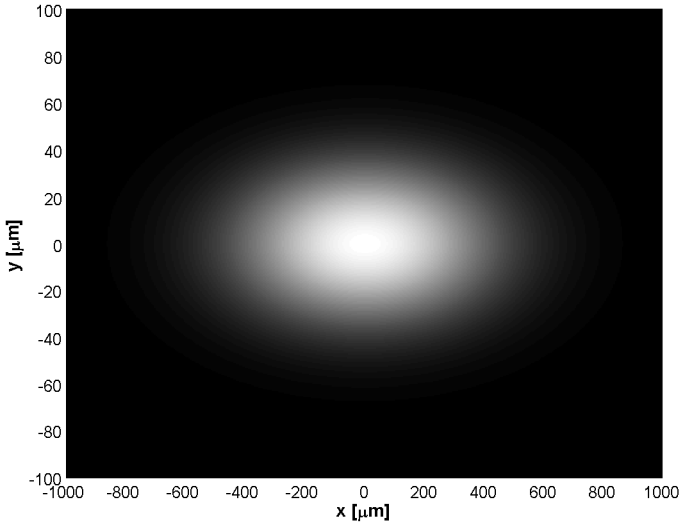


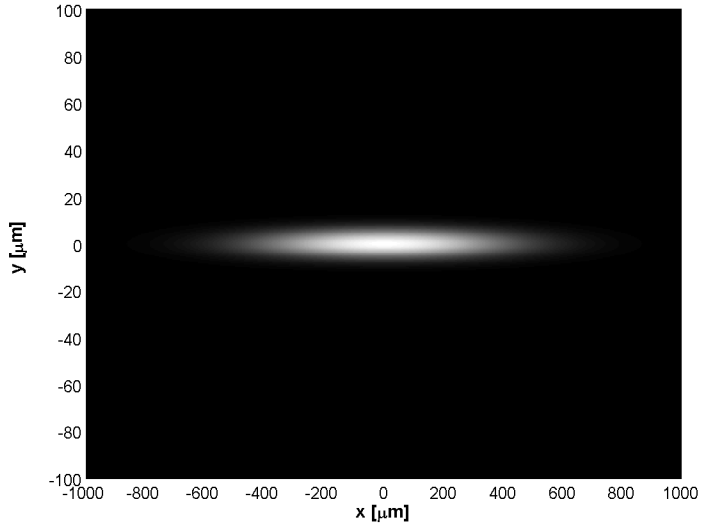
- **Top-off upgrade and current undulator technology: ALS competitive with best newer light sources around 1 keV**
- **Detailed beam parameters for comparison listed on next slide**
- **Beam parameters expected for 2007 are plotted**

Beam parameters, ALS and other Light Sources

Param. \ Ring	ALS (top-off)	Diamond	Soleil	Spear III	APS
E [GeV]	1.9	3.0	2.75	3.0	7.0
I [mA]	400 (500)	300	500	500	100
ε_x [nm] (effective)	6.4	3.0	5.6	18.9	3.0
σ_x [μm]	299	123	384	450	276
σ_x' [μr]	21.4	24.2	14.5	42.0	11.3
ε_y [pm]	140 (30)	27	37	174	25
σ_y [μm]	23 (8)	6.4	8	29	11.2
σ_y' [μr]	6 (3.6)	4.2	4.6	6	2.2
Energy Spread [%]	0.097	0.096	0.1016	0.096	0.096

Achieved Emittance Reduction



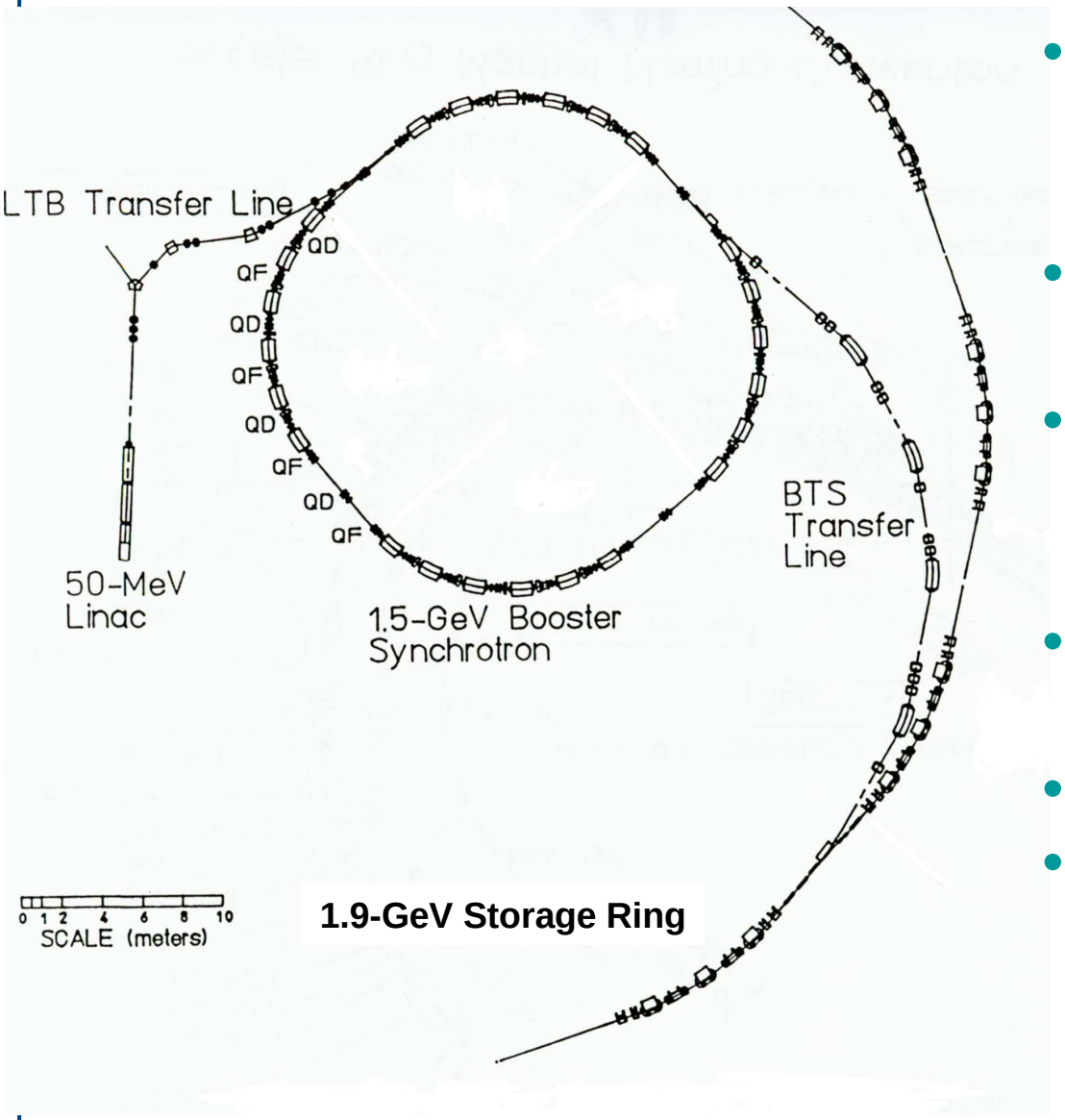


- Using LOCO and an optimized (based on simulations) skew quadrupole distribution with 18 skew quadrupole we achieved an emittance reduction from 150 pm (routine ALS operation) to about 5 pm (pictures on the right illustrate size reduction for insertion device straights)

(Reduced) Scope of the Top-off Upgrade

- Upgrade injector to enable full energy injection
- Improve diagnostics and other existing systems where necessary for reliability
- Upgrade radiation safety system to allow injection with shutters open
- Minimize injection transients to reasonable levels and provide a gating signal
- Migrate to higher current and smaller vertical beamsizes
- Transition to Top-off with minimal negative impact to users
- Delayed/dropped bunch cleaning in booster

Upgrade injector for full energy injection



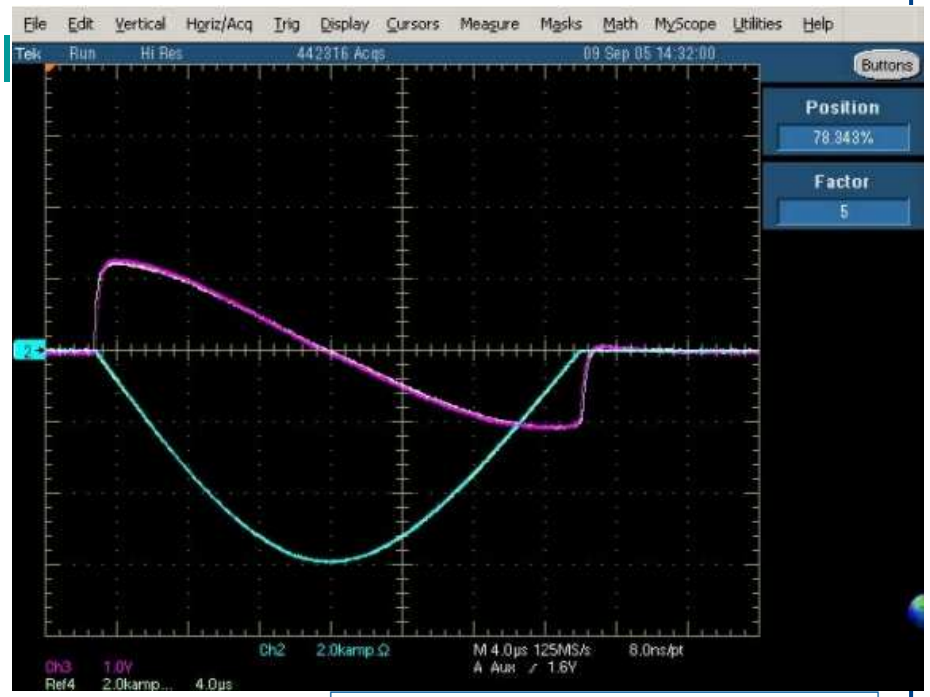
- New booster+BTS DC Power Supplies and Controls
- Upgrade of the booster RF system (e.g. power)
- Modifications of the Pulsed Magnets and Supplies
- Timing System, Controls, Diagnostics
- User Gating Signal
- Radiation Interlocks, Collimators, …

Status of Top-off Project

- Conceptual Design Review of the Project in November 2004, CDR in December 2004
- Received funding in March 2005
- Testing of Pulsed Magnet Systems 2005/2006
- Finished Design work on major systems 2006
- Long Lead Items ordered, several delivered
- Radiation Safety Studies/System Design
- In house fabrication of smaller systems 2006

Tests of the Pulsed Magnet Systems

- Successfully tested each of the Pulsed Magnets at full energy



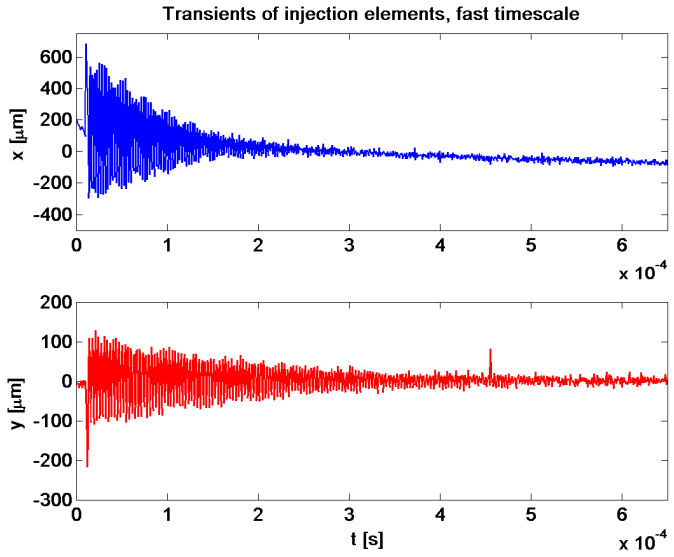
Thin Septum Test Setup

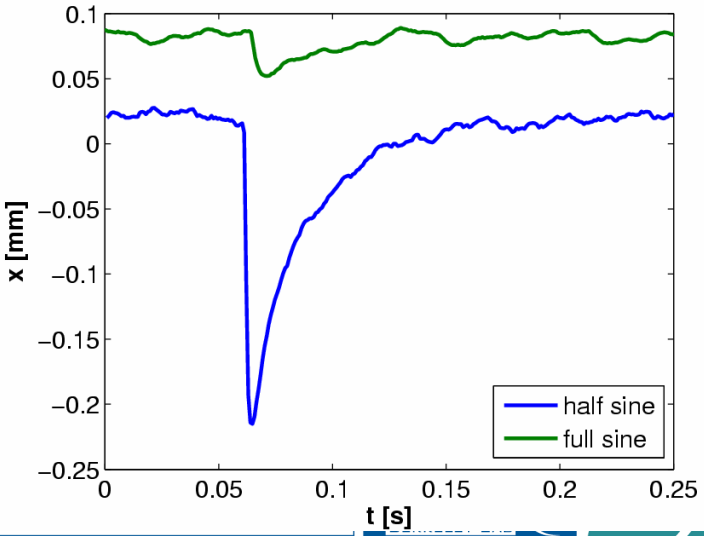
New Booster RF system

- New transmitter is IOT based
- Delivered last week – test installation under way

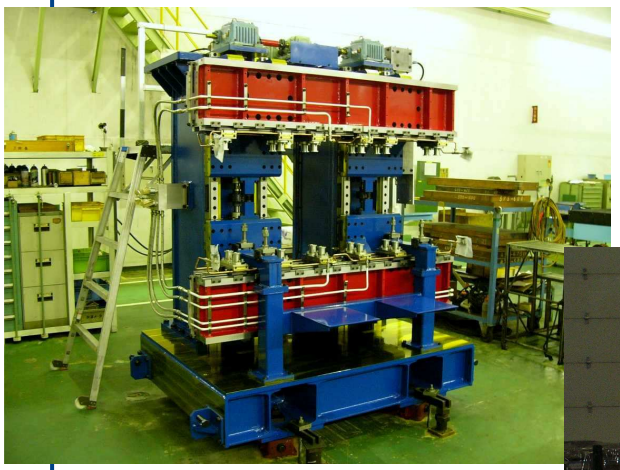
Orbit distortion due to injection elements

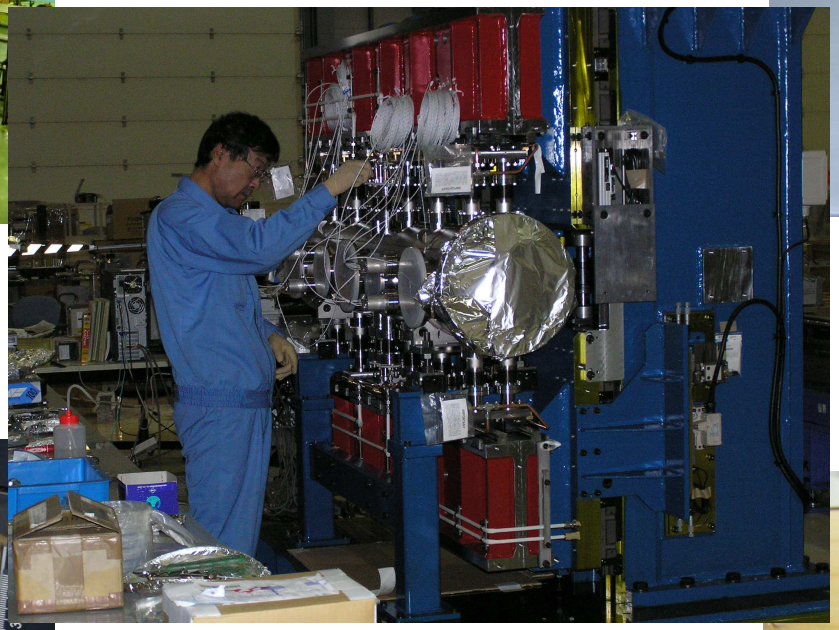
- Similar problem at all top-off facilities – we try to combine best mitigation approaches
  - Incoming beam is only small fraction of total intensity
  - But injection elements also perturb stored beam
- Conducted experiments with users
  - Most experiments insensitive to any distortion
  - Very few experiments (STXM, IR) see no-closure of bump and will require gating

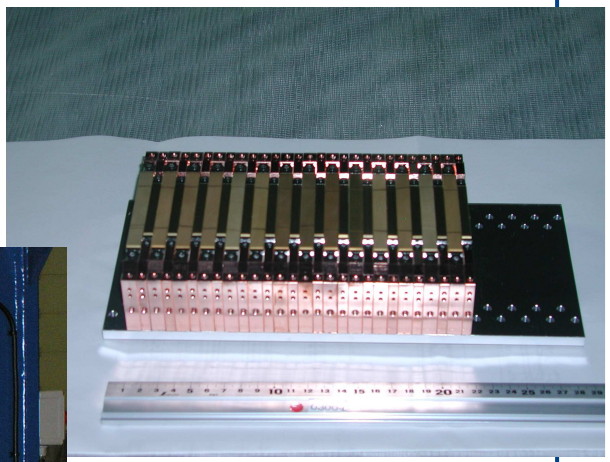


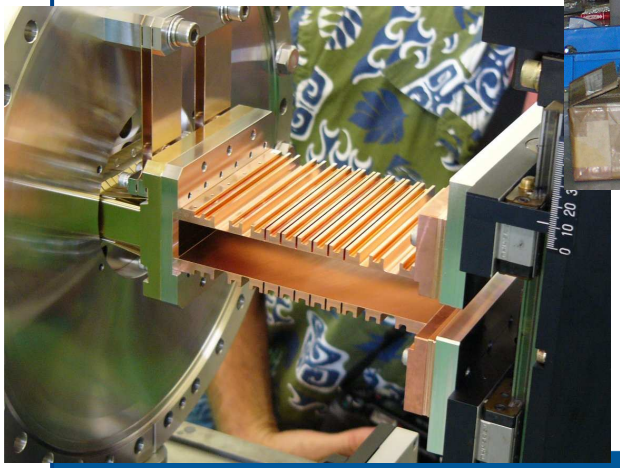


Small Gap Undulators





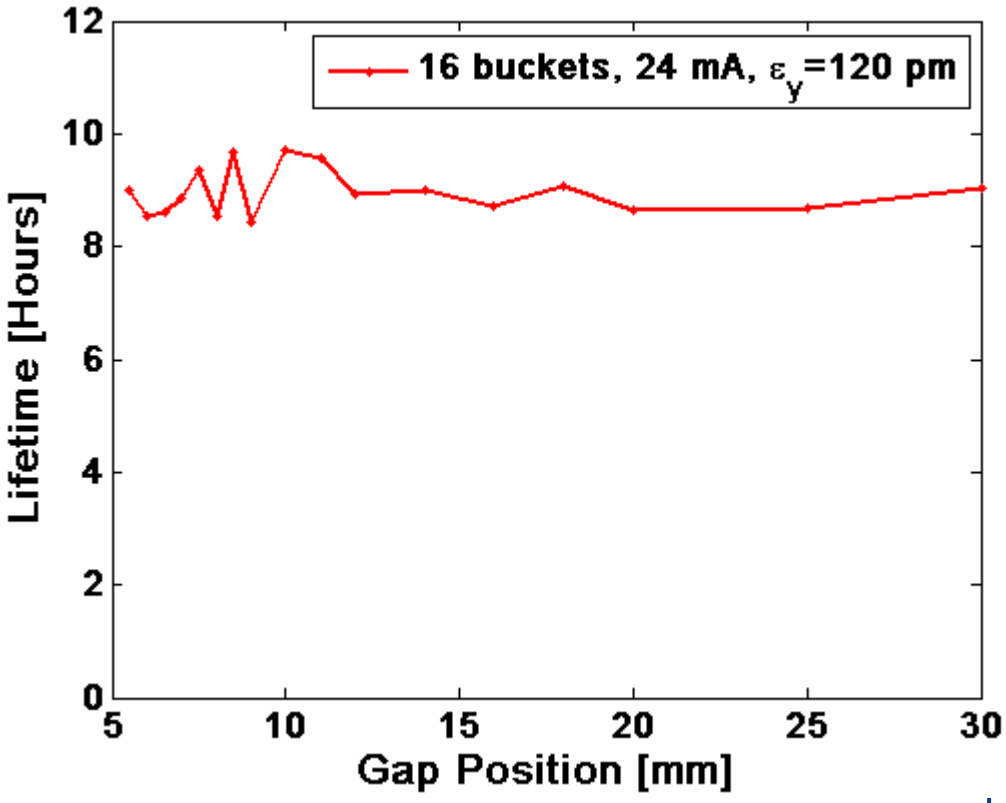




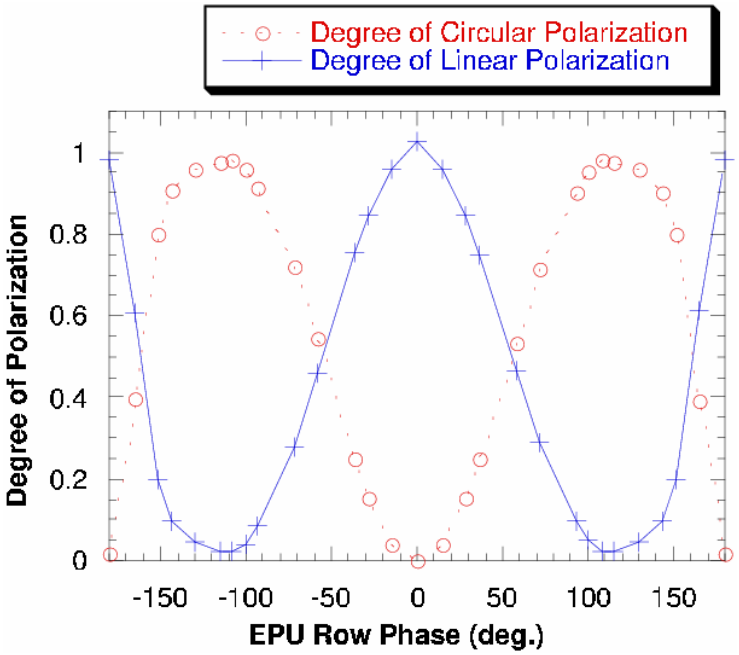
- 30 mm period, hybrid
- 50 periods
- 5.5 mm min. magnetic gap
- 1.52 T peak field

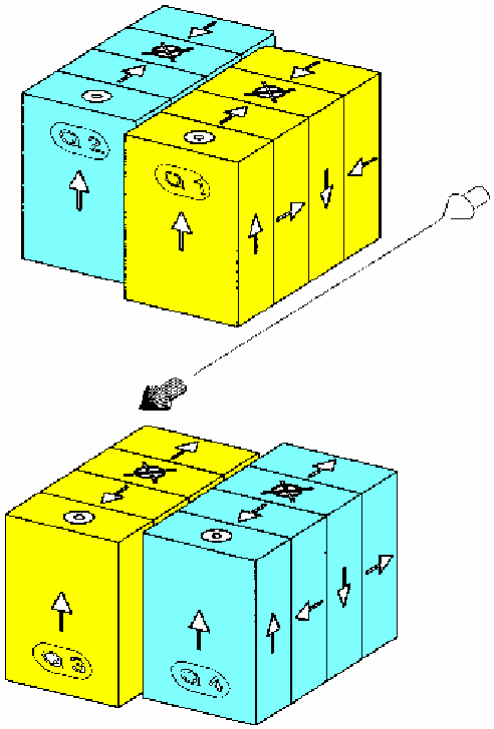
Closing IVID to minimum aperture

- Closed (magnetic) gap down to 5.5 mm
- No Touschek lifetime degradation for normal/small coupling at 1.5 mA/bunch
- No TMCI instability in two-bunch mode at 50 mA
- Are using scrapers elsewhere to avoid demagnetization (1st already installed)



APPLE-II type EPUs





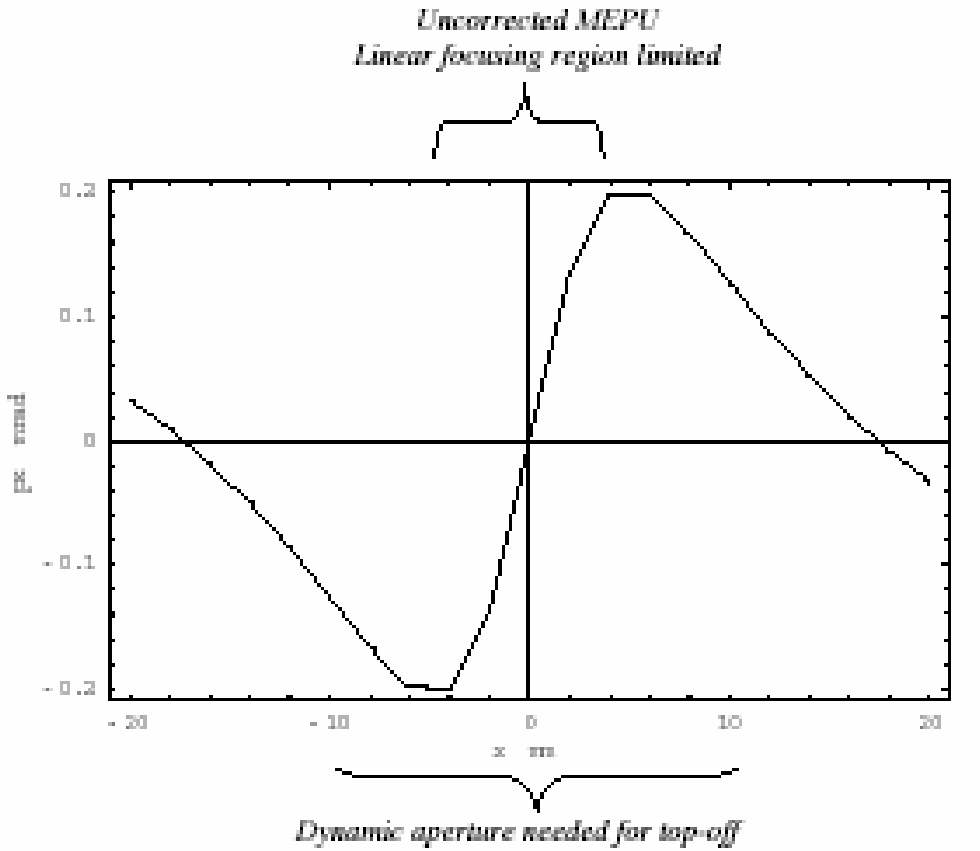
Longitudinal phase of two quadrants selects polarization (linear, elliptical, circular) + energy

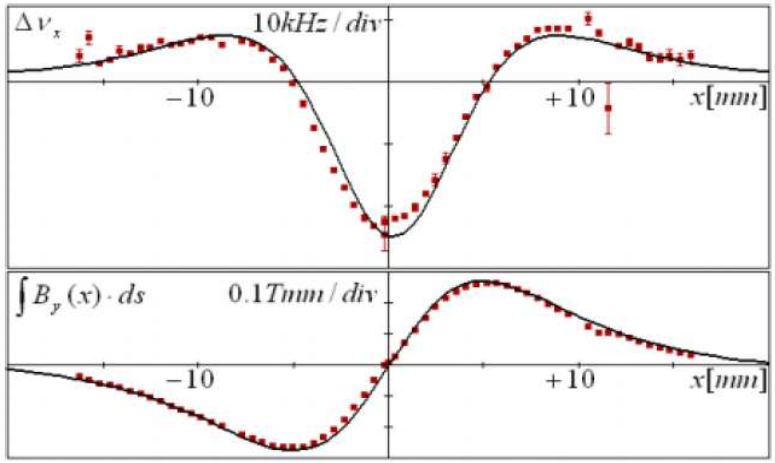
- **Important for many of core ALS science applications**
- **Expansion of number of EPUs**

EPU effects

1. Variation of on axis field integrals with EPU phase (causing orbit distortions).
2. Variations of the (mostly vertical) beamsize (both with gap and with phase):
   - Due to focusing changes (systematic focusing terms from the bulk of the undulator).
   - Due to coupling terms (skew quadrupole like or solenoid like).
3. Higher order effects impacting the dynamic (or momentum) aperture---due to the field roll-off, which is significant and systematic in circular/vert. polarization mode.

EPU Dynamic Multipole Fields





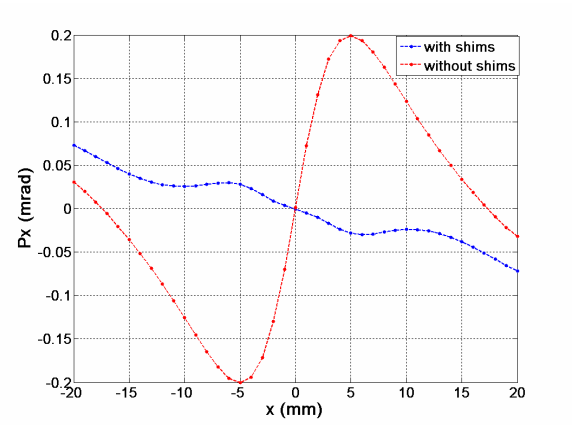
BESSY, UE52, calculated and measured dynamic field integrals

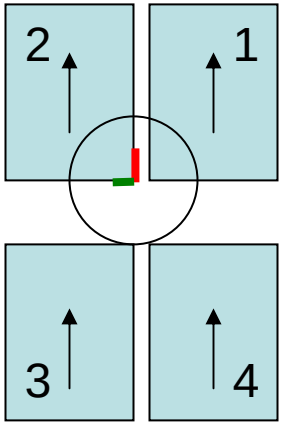
Nonlinear Kick

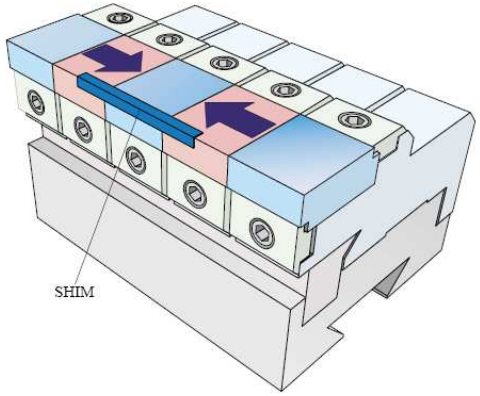
- ***Spoils Dynamic Aperture***
  - ***Worse for large period EPUs***
- ***Impacts Lifetime and Injection Efficiency***
- ***Bad for Top-off***

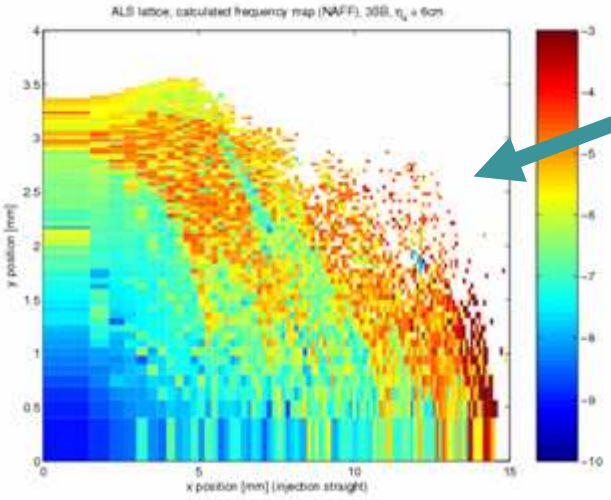
Correction via passive shims

- **Dynamic multipoles partially compensated by magnetic shims**



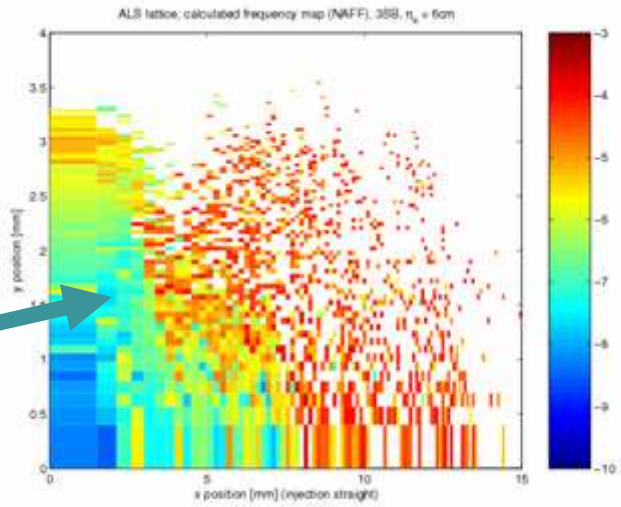






- **Works well for circular polarization**

- **A problem with variable linear polarization at small gaps**



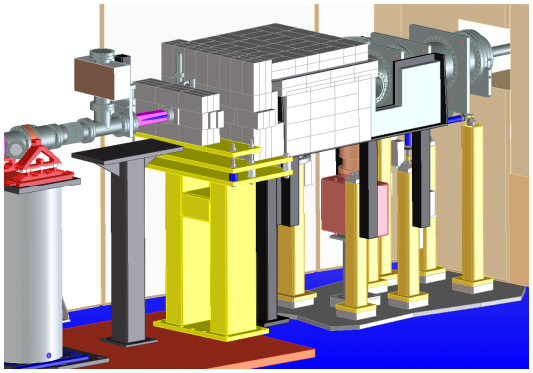
Upgrading our Radiation Protection Systems

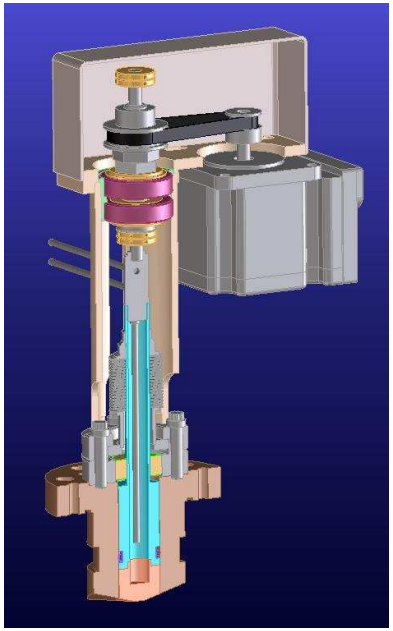
Changes in operation after Top-Off

- Injection with the personnel safety shutters open
- Higher stored beam losses
- Injection with undulators closed

The radiation protection systems (interlocks, collimation, local shielding) will be upgraded to ensure safe operation with Top-off

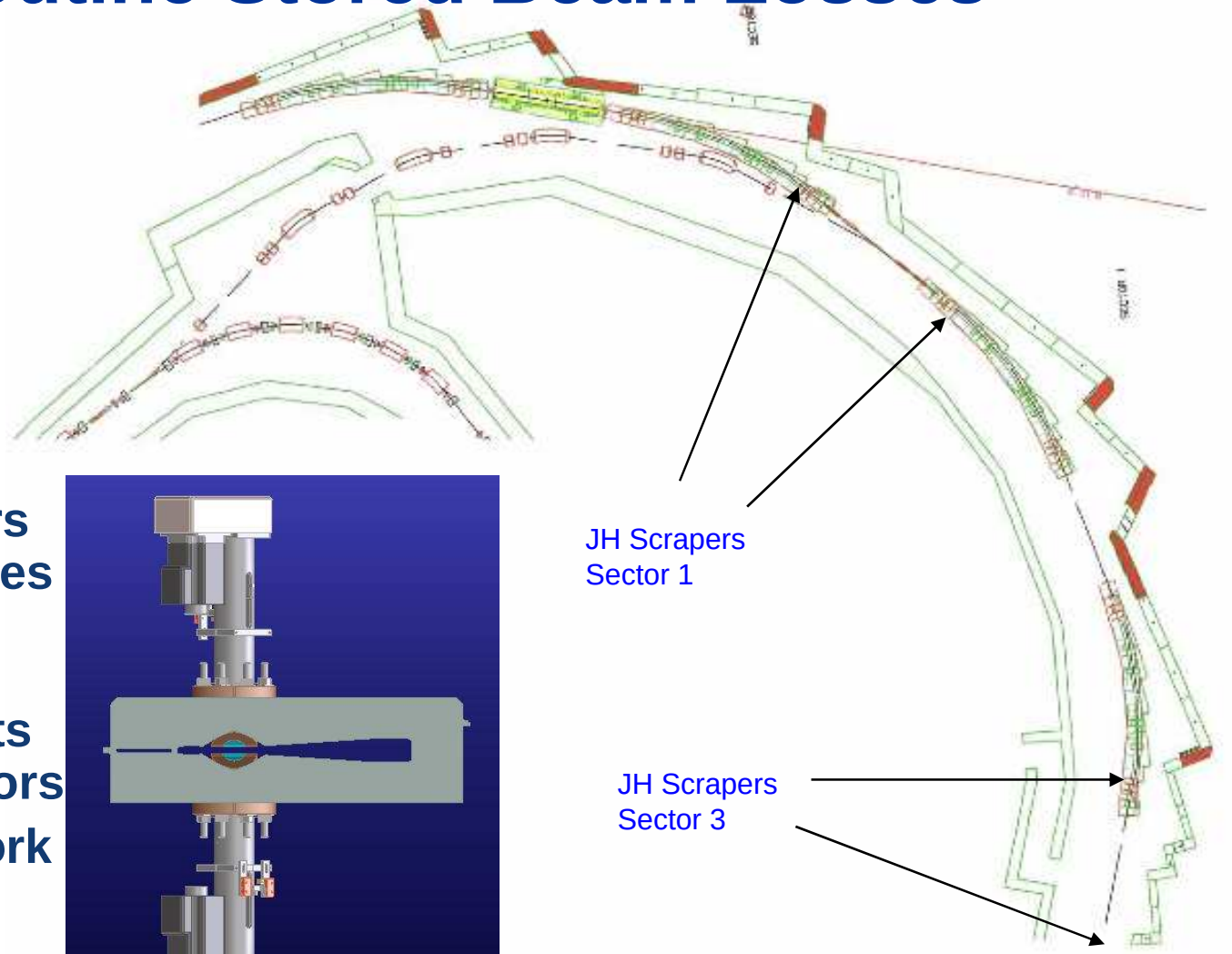
Upgrading our Radiation Protection Systems





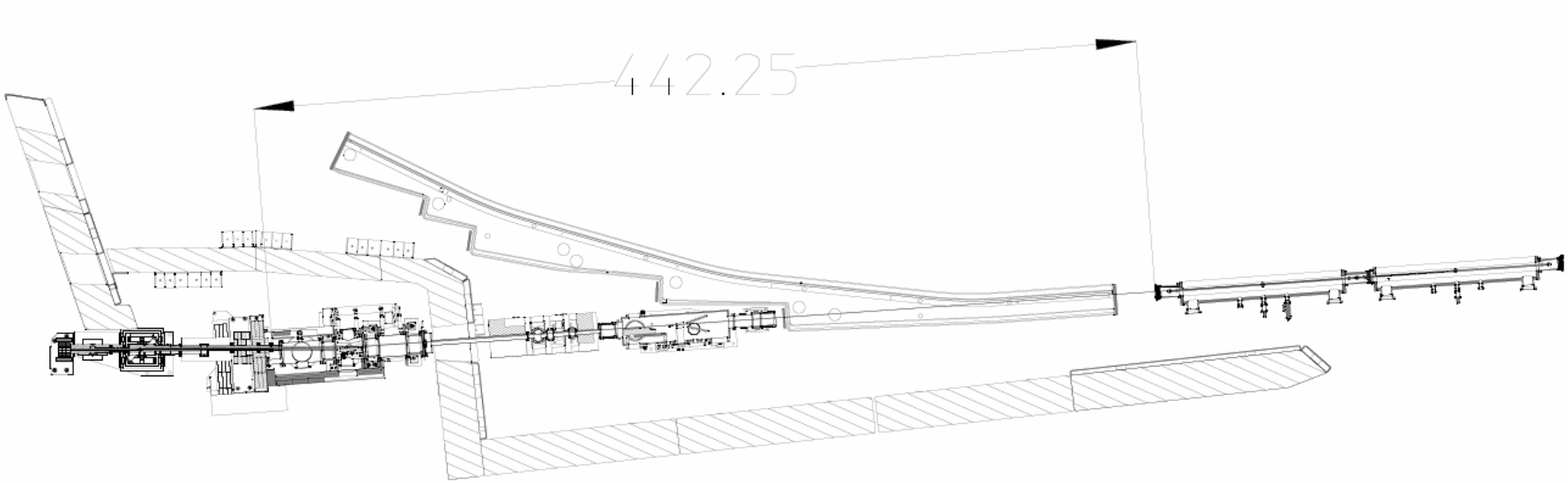
- Extensive testing on beamline 4.0
  - (already tested 1.5 GeV top-off with beamline 4.0 open)
- Working closely with DOE
- (External) Review in Winter 06/07
- ALS Safety Analysis Document (SAD) will be modified

Routine Stored Beam Losses



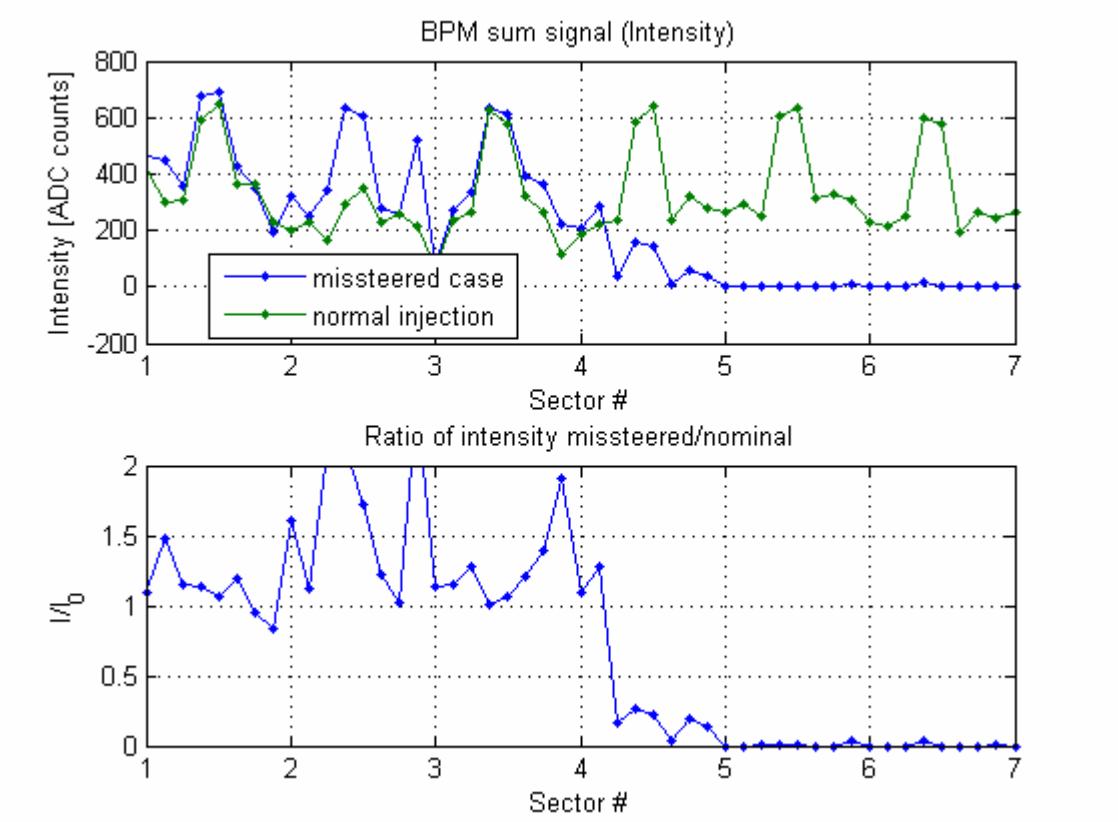
- New scrapers localize losses away from beamline source points and undulators
- Installed+work very well

Injection Studies with BL 4.0 Open



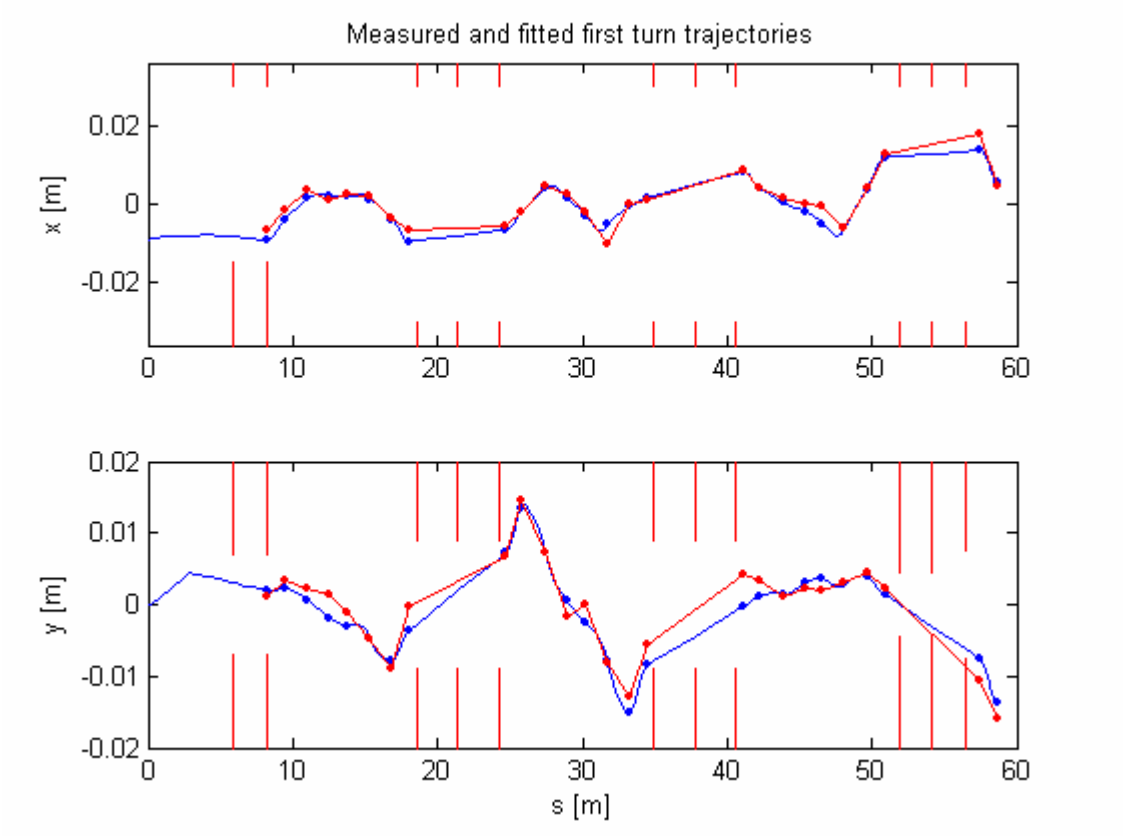
- **Drawing does not show all Bremsstrahlung shielding or the radiation monitors**

First turn intensity data



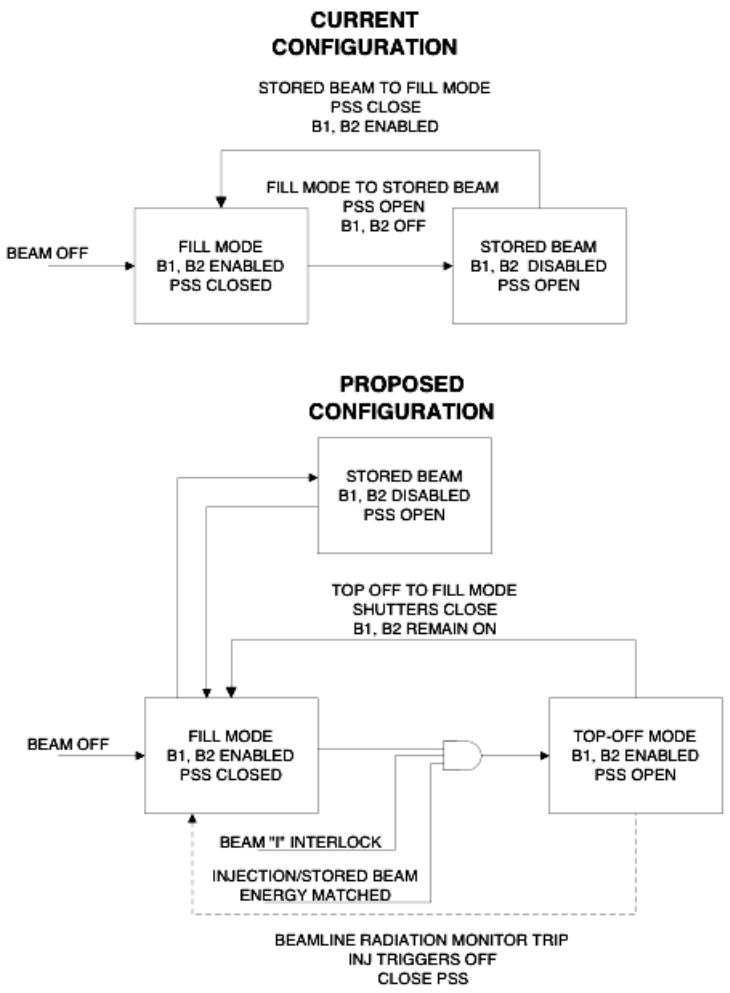
- **Sum signal (beam intensity) shows most loss occurrs after BPM #2 in arc 4, i.e. somewhere between QD1 and the end of B1 – consistent with hitting the EPU mask.**

Measured injection trajectory + model



- **Fit can reproduce measured injection trajectory quite well.**

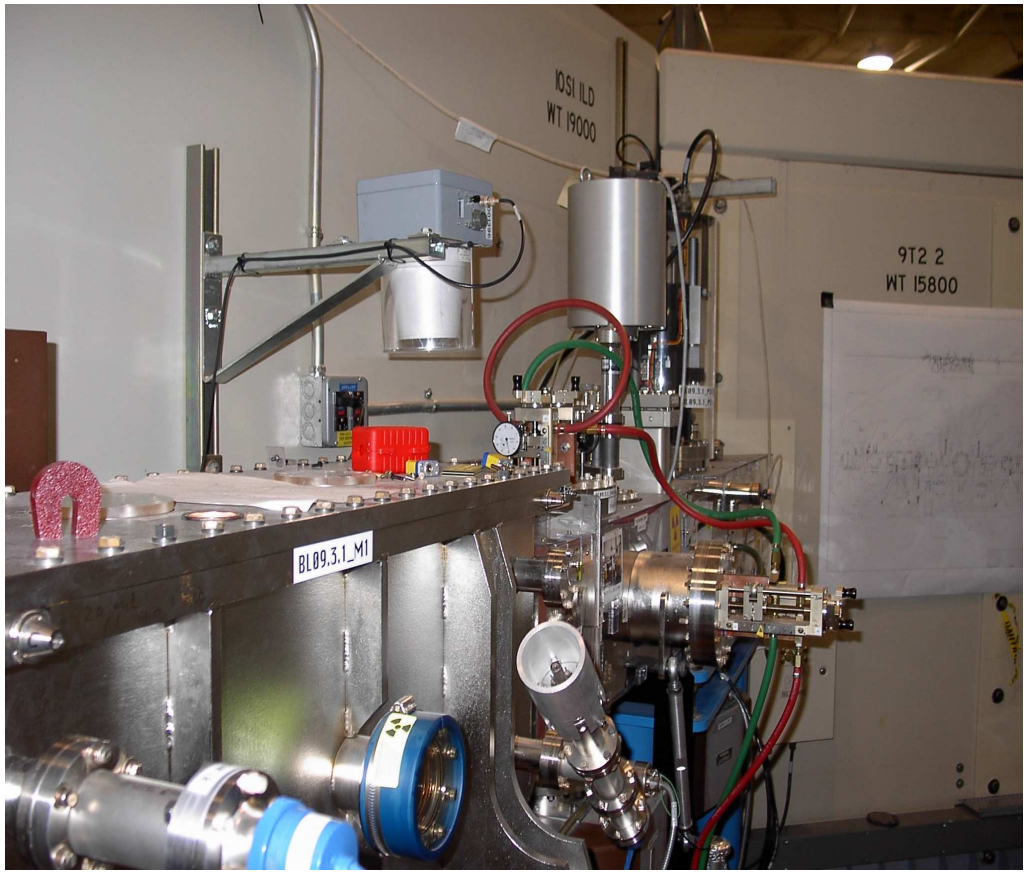
Interlock Changes



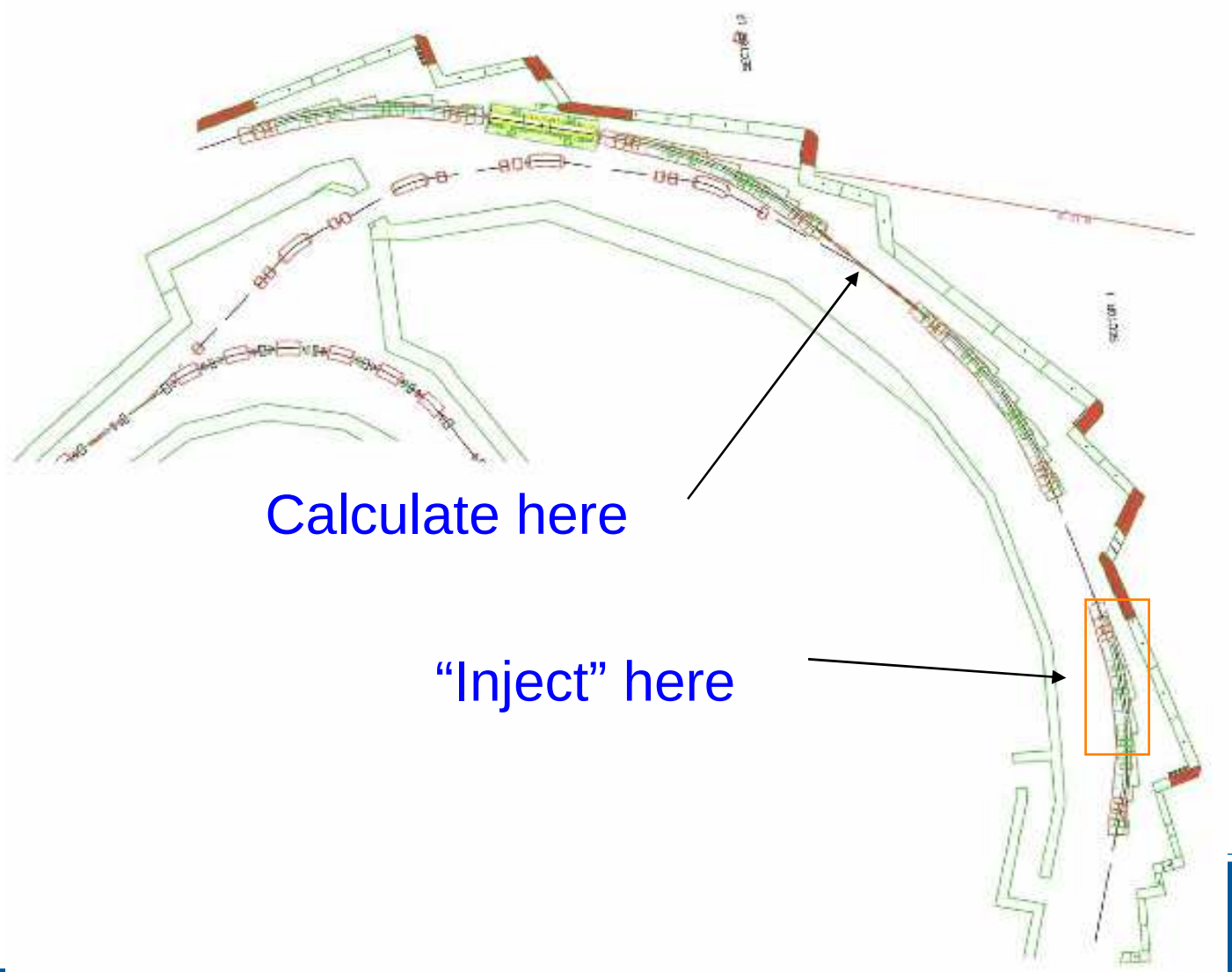
- **Injection will only be allowed with shutters open if**
  - **There is stored beam**
  - **The energy of the injected beam matches the stored beam**
- **Additionally we will have active interlocked monitors on beamlines**

Beamline Interlocked Monitors

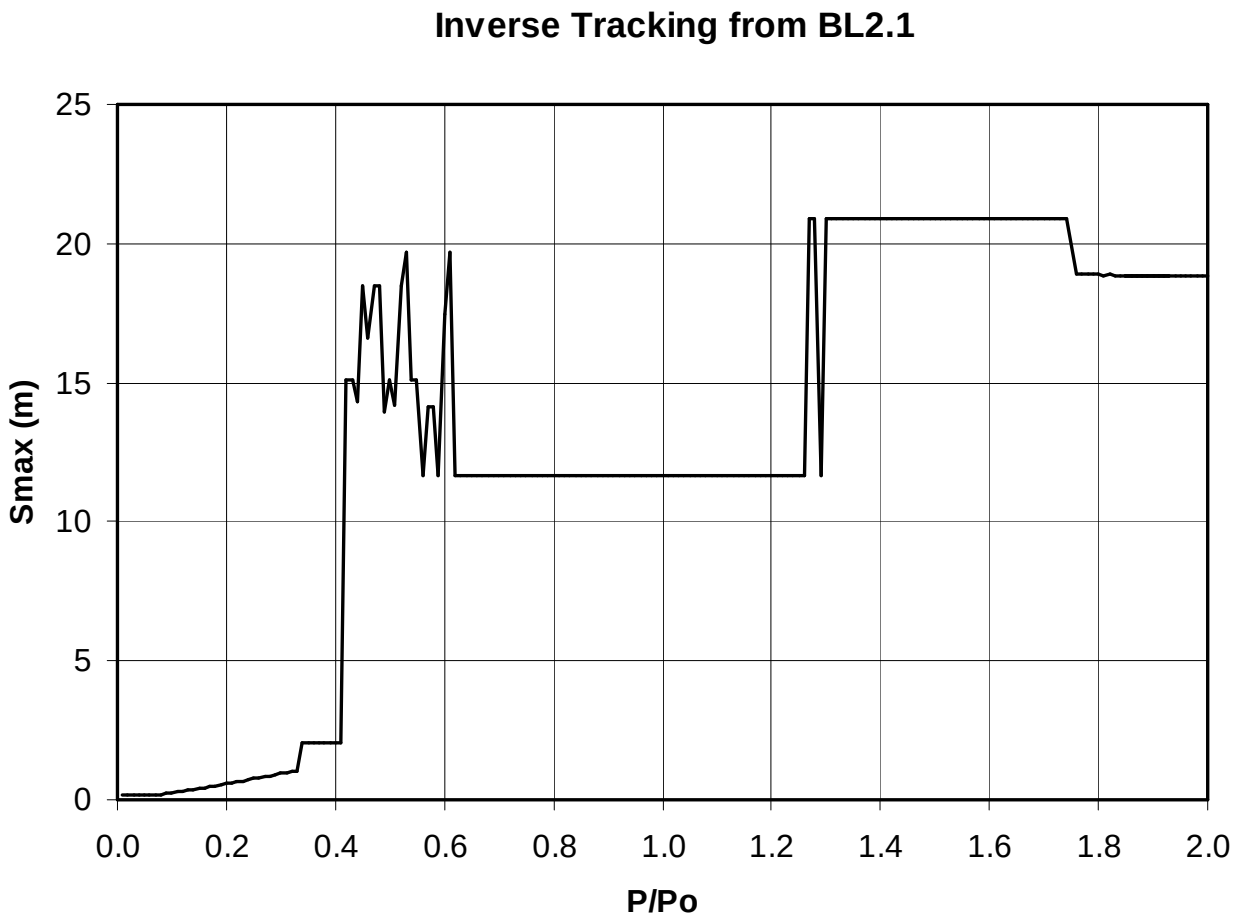
- Monitors have been installed on beamline frontends for years
- So far only used for monitoring
- Will be interlocked (safety gain independent of top-off)
- New electronics, new monitoring applications, tested saturation behavior



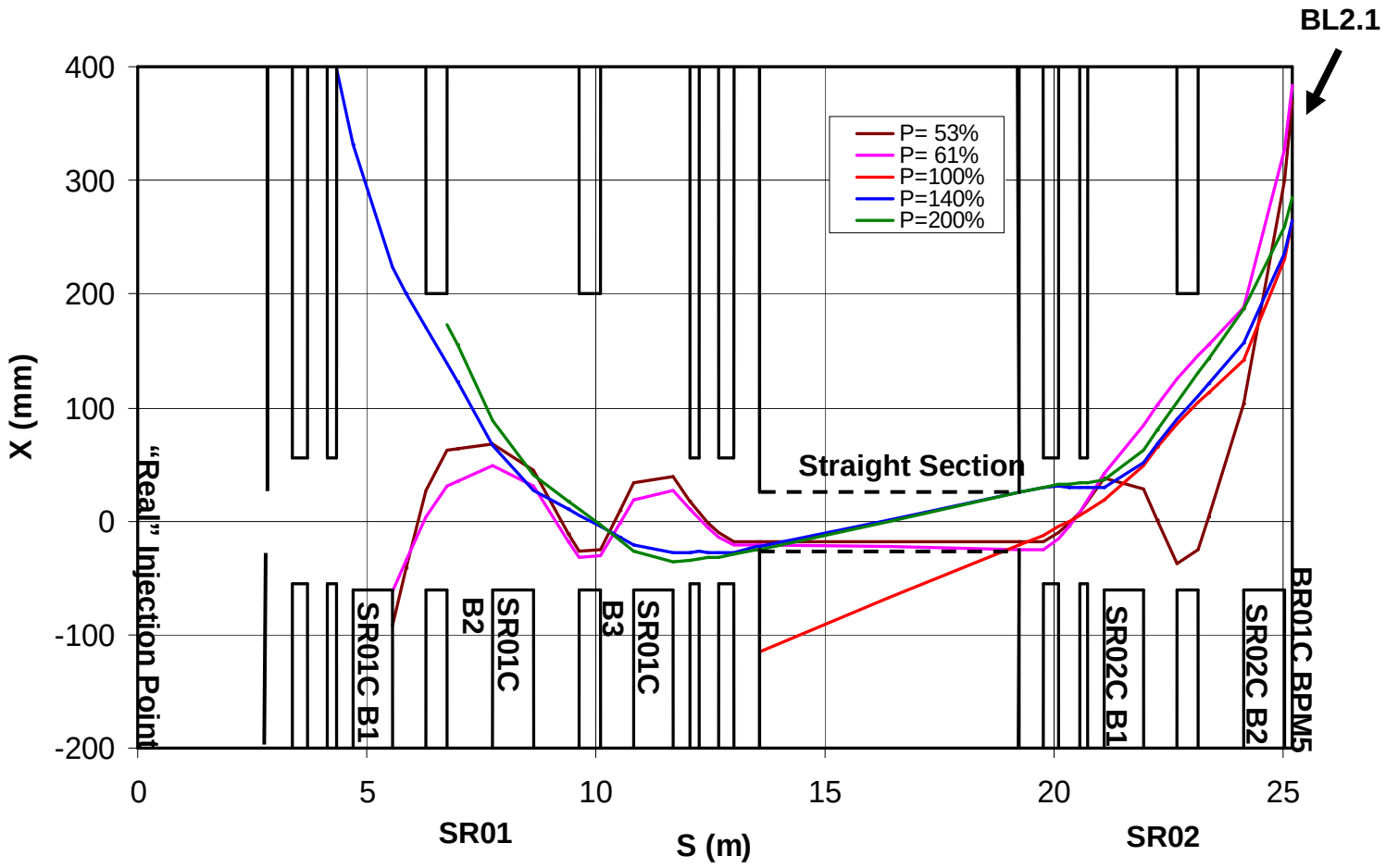
(Inverse) Tracking Studies



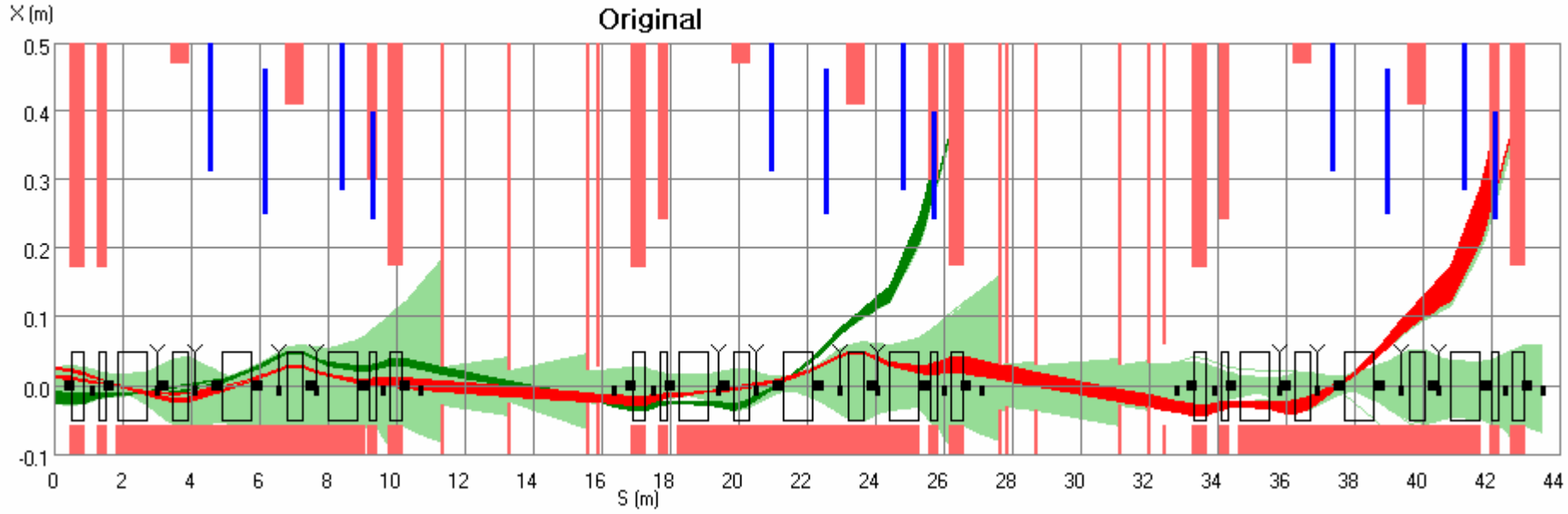
Tracking Studies



Inverse Tracking from BL2.1



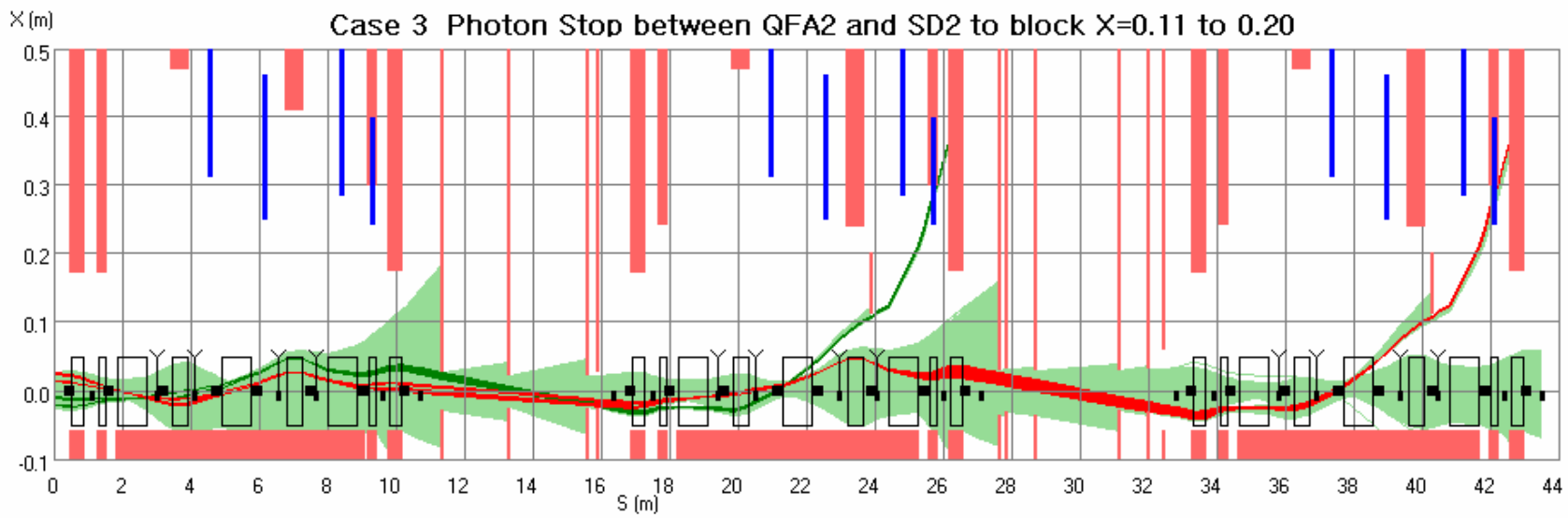
Original

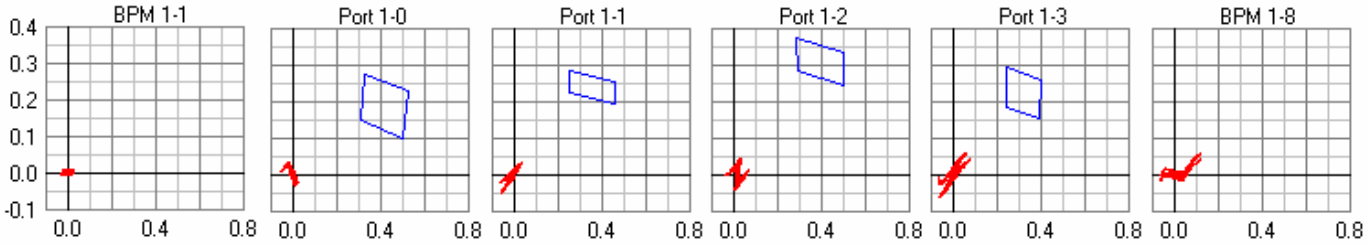


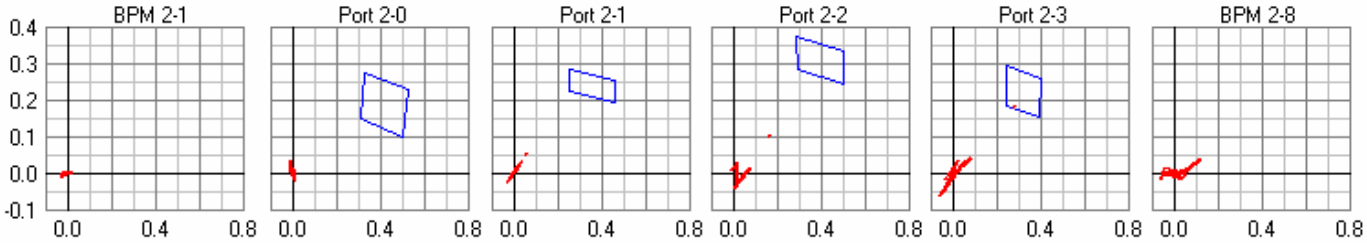
Xo= -25.4 ~ 25.4 mm by 0.1 mm

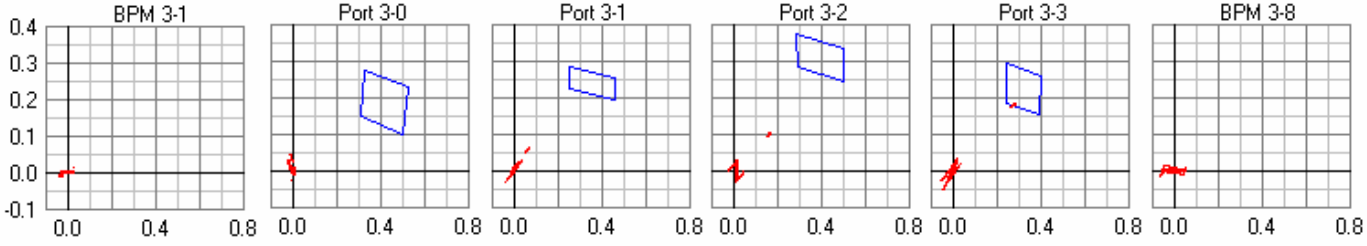
Pxo=-5.0 to 5.0 mrad n=by 1.0 mrad

dP/P = -5.0 to 5.0 % by 0.1 %

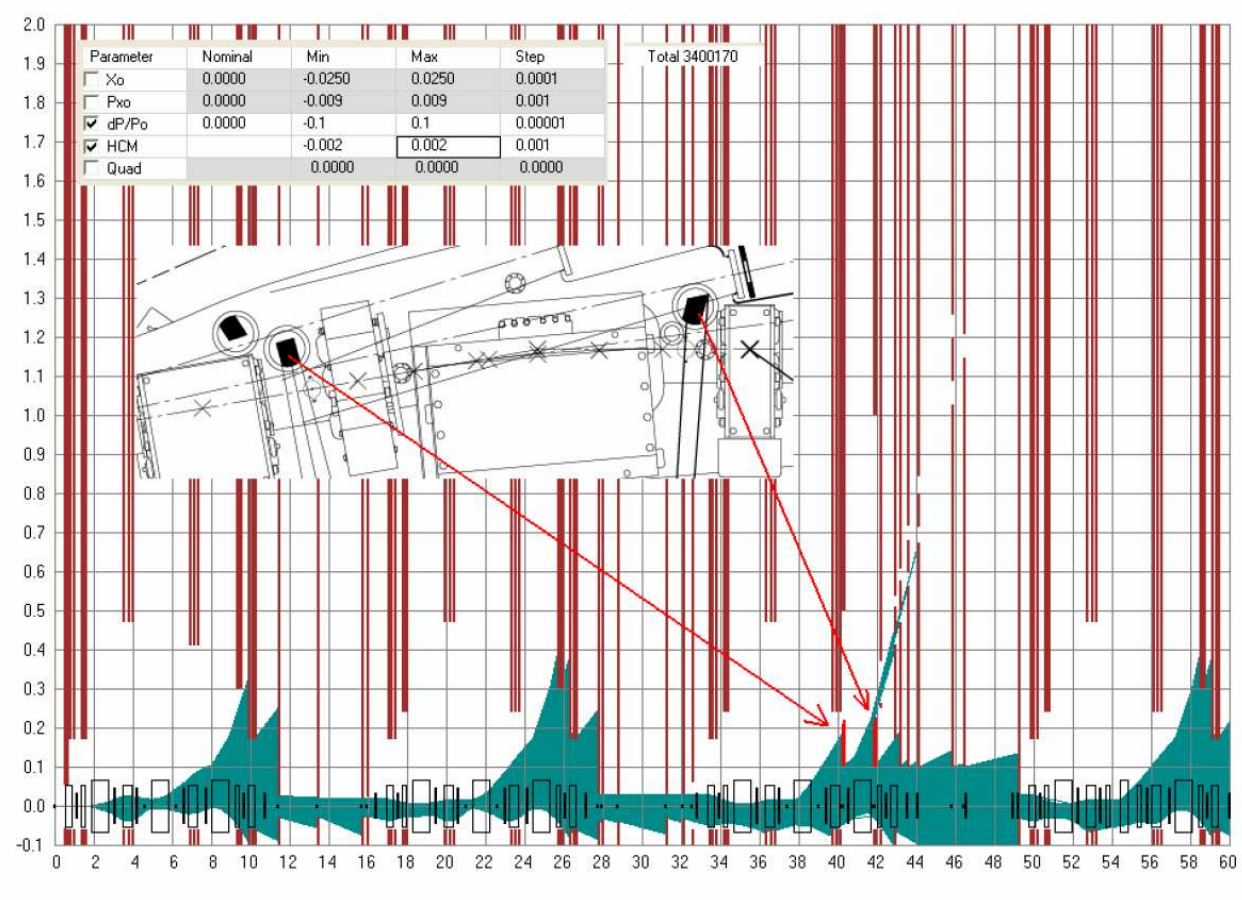

Case 3 Photon Stop between QFA2 and SD2 to block X=0.11 to 0.20
X (m)
S (m)


BPM 1-1
Port 1-0
Port 1-1
Port 1-2
Port 1-3
BPM 1-8


BPM 2-1
Port 2-0
Port 2-1
Port 2-2
Port 2-3
BPM 2-8


BPM 3-1
Port 3-0
Port 3-1
Port 3-2
Port 3-3
BPM 3-8

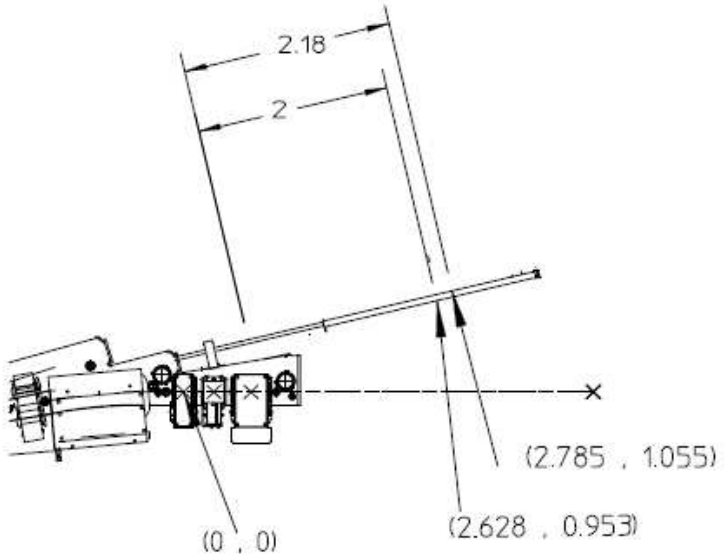
Including Photon Stops and Beamline Apertures …



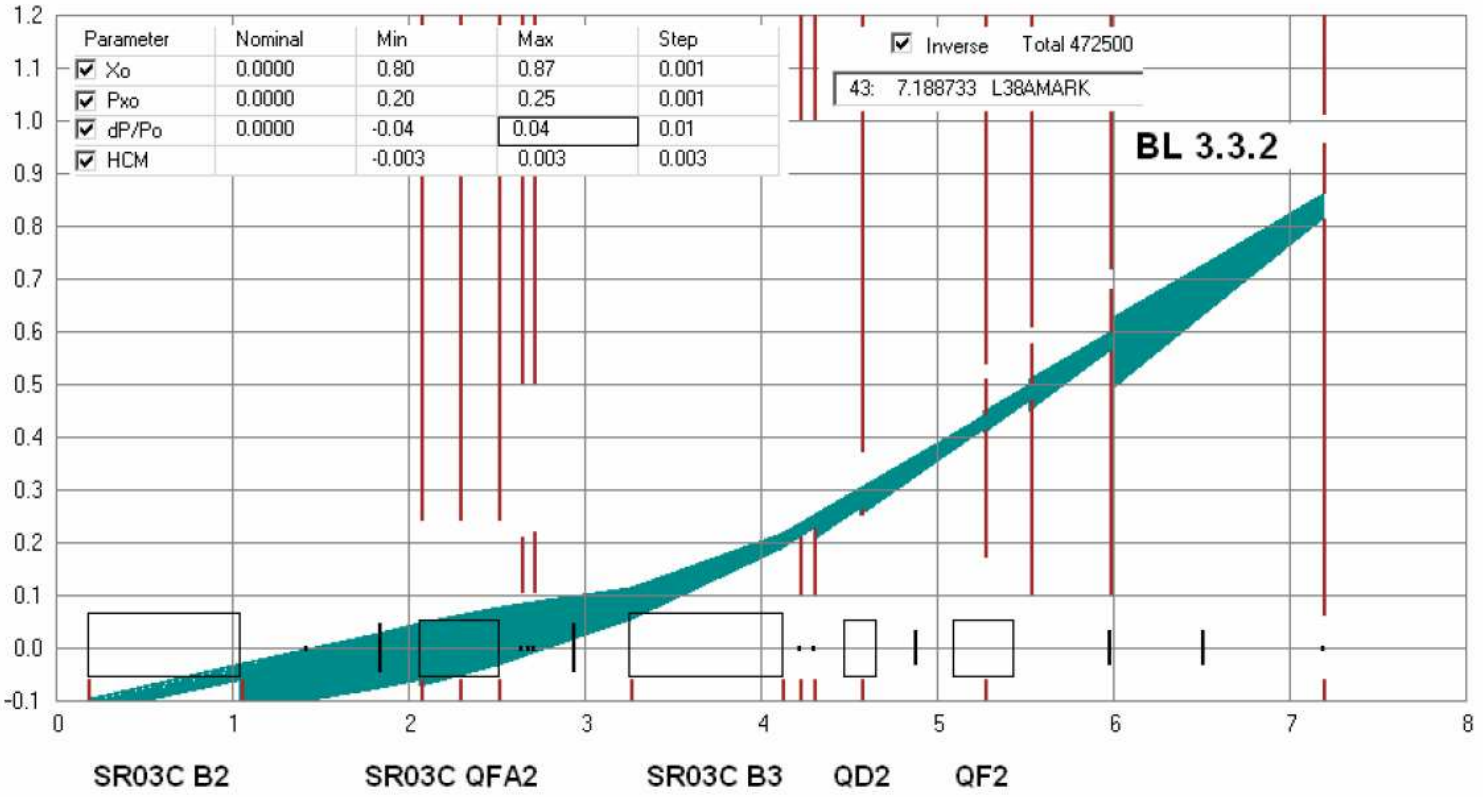
- **Safe, but loss point could still be too close to wall …**

Backward Tracking from Safe Point

- Determine Point in Beamline where normal Bremsstrahlung shielding would still catch all radiation produced
- Carry Out backward tracking from there using all apertures

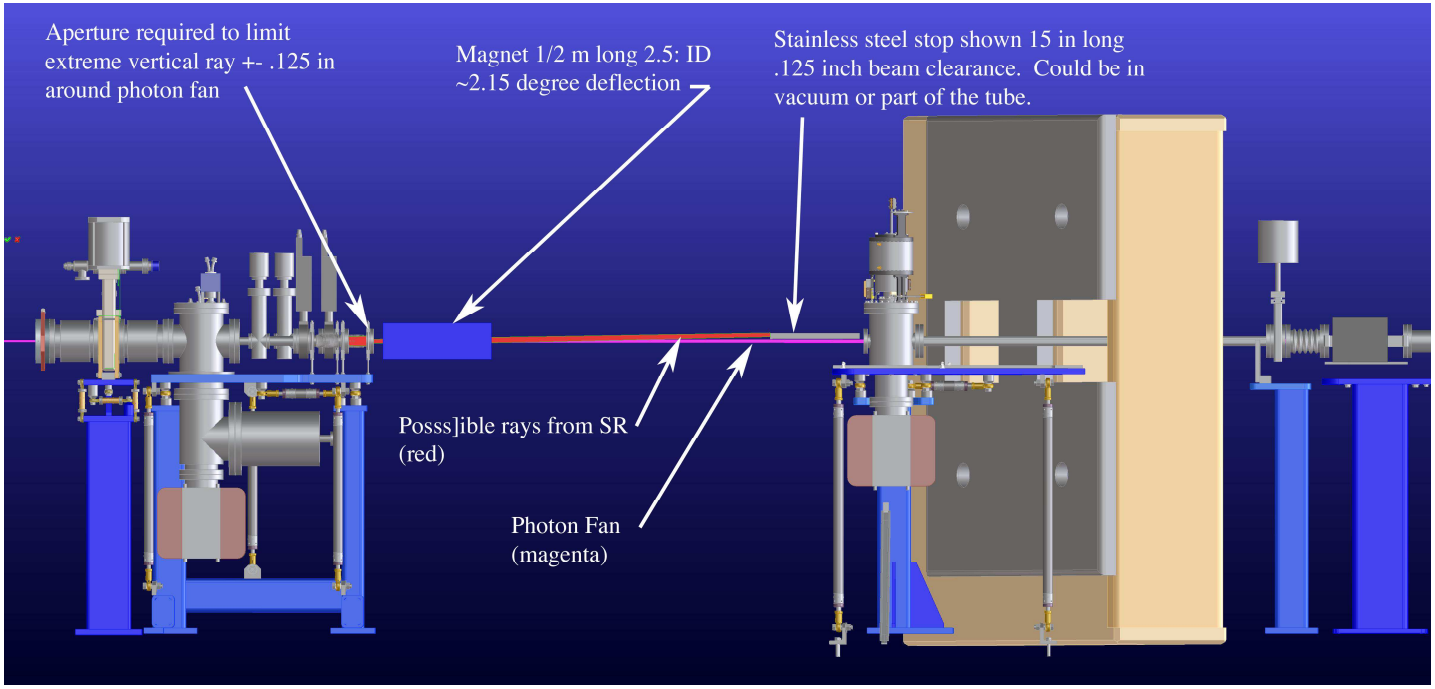


Result for 3.3 is now Positive!



- But, still to be completed:
  - Needs to be repeated for all beamlines
  - By independent person/code
  - With more magnet error settings
  - Tolerance studies for apertures

Fallback Solution



- **If all our efforts to demonstrate that apertures protect injected beam down photon beamlines with stored beam should fail**
  - **Fallback solution is to add permanent magnets on (subset) of frontends (x.3 beamlines ?)**

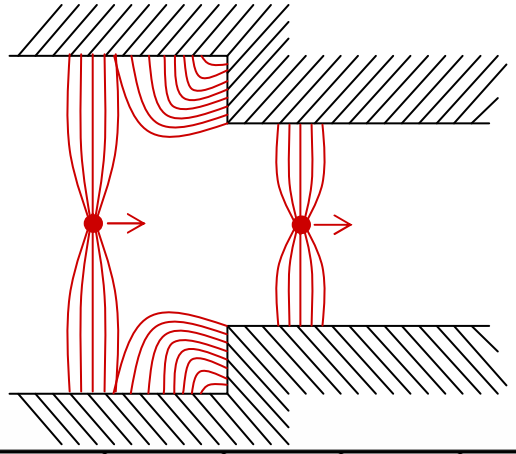
Top-Off and 2-Bunch Operation

- The present baseline scope of the Top-off upgrade does not include provisions for injecting “clean” bunches into the storage ring anymore
  - Using top-off injection during two-bunch operation, there would be some current in “untargeted bunches” that may not be acceptable for some 2-bunch users
- Techniques exist (SPRING-8, ESRF) for “cleaning” the bunches in the injector $\Rightarrow$ expensive, part of delayed scope
- It is possible to clean bunches in storage ring during top-off, but:
  - Beam will be slightly unstable during cleaning
  - Might require users to use gating signal (>100 ms)

The Old Cleaning Technique

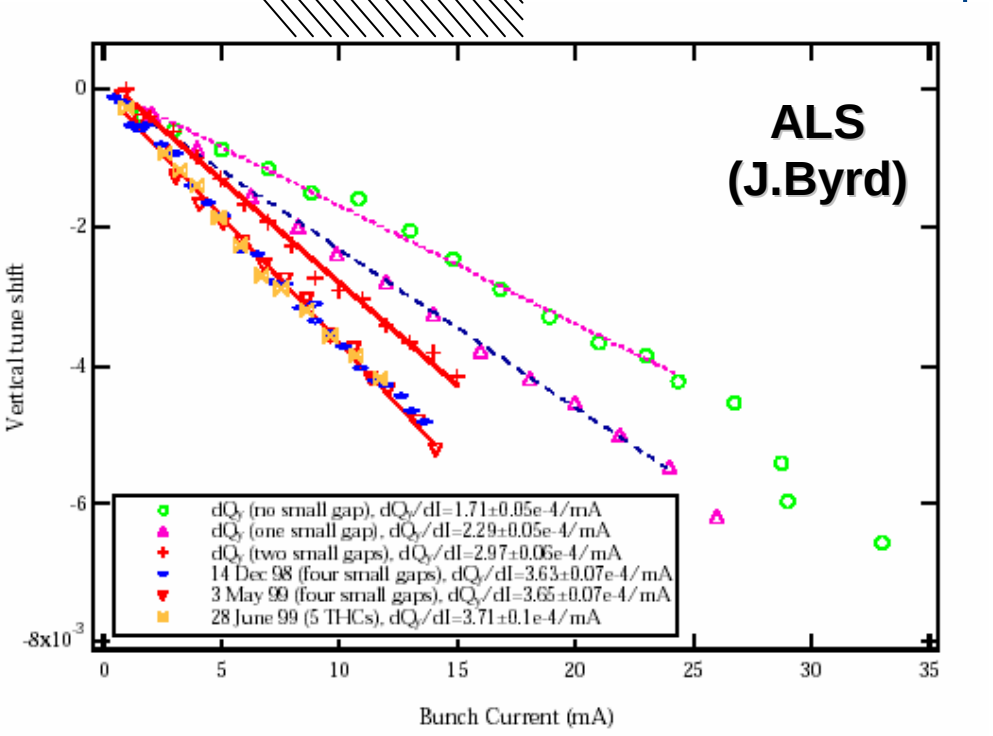
This cleaning technique exploits the tune shift on current

Vacuum chamber wakes create current dependent (de)focusing fields that change the betatron tunes

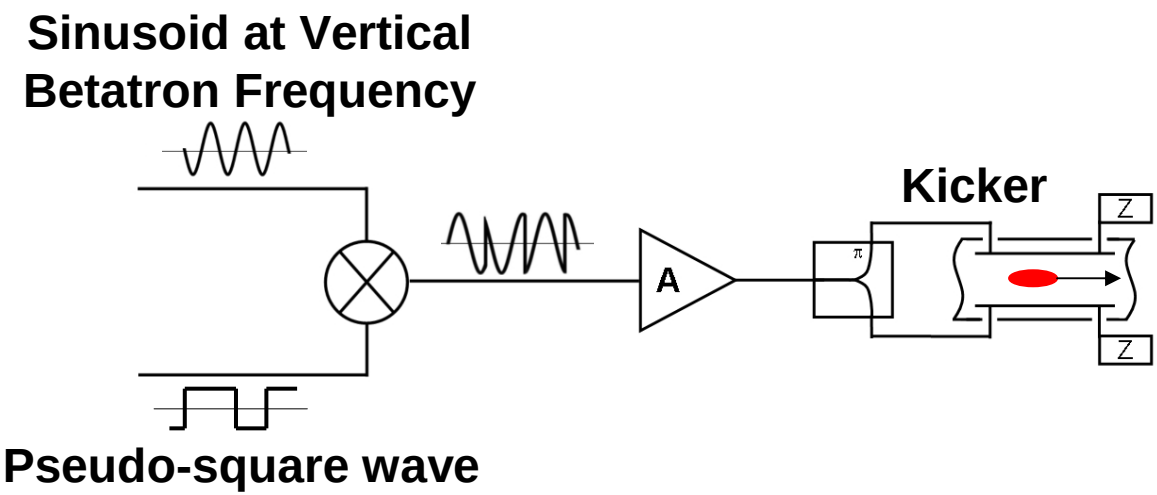


Low current bunches present a tune significantly different from the high current ones ~ 10 kHz.

By exciting the beam at the low current bunches tune, these will undergo to bigger oscillation than the large current ones.
By inserting a scraper is possible to perform the cleaning.

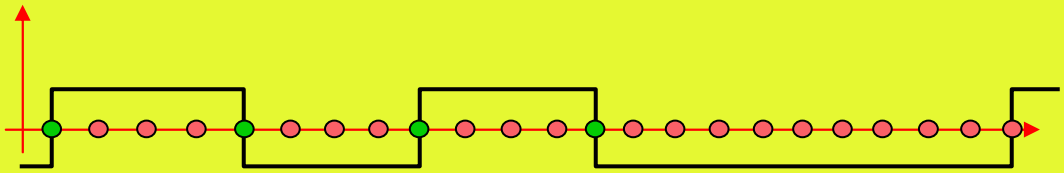


The New Cleaning Technique



Green dots:
Bunches to save

Red dots:
Buckets to clean

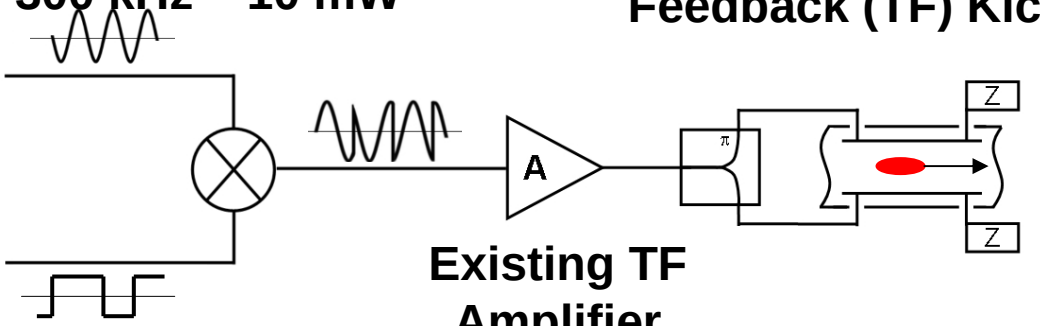


H. Suzuki, *et al.*, NIM A 444 (2000) 515-533.

Our Implementation

Existing Sinusoidal Generator
300 kHz – 10 mW

Existing Transverse
Feedback (TF) Kicker (Stripline Type)



No scraper required!

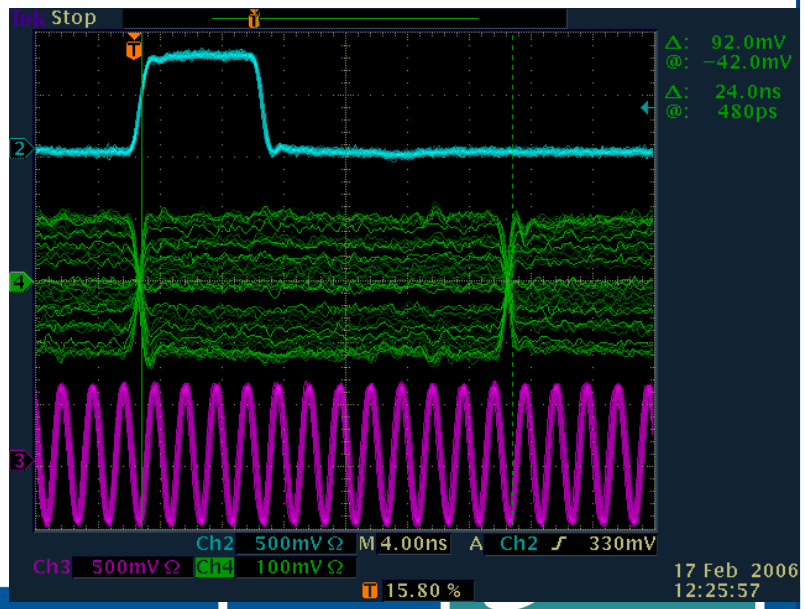
New FPGA
General Purpose Board
~ 500 MHz BW

Existing TF
Amplifier
~ 150 W
250 MHz BW

Multi-purpose board (W. Barry, M. Chin, J. Weber):

- B-Factory transverse feedback
- ALS Control System CPUs
- Arbitrary function generator

Very large bandwidth, no timing drift, very reliable, easy to program, …



Future (Top-off) Plans

- Extended shutdown will be in Fall 2006
  - Starts just after User meeting (middle of October), commissioning November+December
- Plan to operate with full-energy injection immediately following the shutdown
- Will slowly migrate to full top-off operation during the following six to nine months
- Move to 500 mA and smaller emittances within 2007 (maybe intermediate steps based on user responses, …)

Shutdown+Commissioning Schedule

									Users Mtg																					
Oct-06	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T
0000-0800		AP	I							AP						IT	I	I	I	I	I	I	I	I	I	I	I	I	I	I
0800-1600		M	I						AP							I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
1600-2400		I	S/T						AP							I	I	I	I	I	I	I	I	I	I	I	I	I	I	I

Nov-06	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T	W	Th
0000-0800	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	H	H	X	X	S/T	S/T	S/T	S/T
0800-1600	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	H	H	X	X	S/T	S/T	S/T	S/T
1600-2400	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	H	H	X	X	S/T	S/T	S/T	S/T

Dec-06	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	F	S	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su
0000-0800	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	BLC	BLC	BLC	X	X	H	H	H	H	H	X	X
0800-1600	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	BLC	BLC	BLC	X	X	H	H	H	H	H	X	X
1600-2400	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	S/T	BLC	BLC	BLC	X	X	H	H	H	H	H	X	X

Jan-07	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T	W
0000-0800	H	X	MS						AP						H	IT							AP						IT	I	
0800-1600	H	M	AP	BLC				AP							H	M						AP						AP	M	I	
1600-2400	H	S/T	AP	BLC				AP							H	S/T						AP						MS	I	S/T	

How will Top-Off look like (draft)

- Injection about every 30 s (at 500 mA and smaller emittances), initially less frequent
- Most injections with 5-10 bunches, 1.5 mA total
- 1 in 10 injections will target camshaft (0.5-0.75 mA).
- In two-bunch operation will have to find acceptable current (equipment damage), maybe 40 mA?
- With emittance as now and injection increment up to 0.5 mA -> 40 s

Summary

- Top-off project is well under way
- Had some bumps in the road (RSC/SSC, vendors)
- On schedule for shutdown in October-December 2006
- Full energy injection (reduced refill duration, better thermal stability of storage ring) immediately thereafter
- As soon as approval is obtained and all interlocks installed full top-off (2007)
- Much higher Brightness!