



# ALS User Meeting 2008

## Top-off and Machine Status

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## Accomplishments in FY08

- **Full Energy Injection**
  - Injection energy increased from 1.5 GeV to 1.9 GeV
- **Increased Photon Flux**
  - Increased Current – 400 mA to 500 mA
- **Top-off Close to Completion**
  - Major milestones achieved
  - First tests in a few weeks with some beamlines
  - Expect Top-off Operation in early 2009
- **Installed MERLIN Insertion Device**
  - Novel Quasi-Periodic Elliptically Polarizing Undulator
- **Installation of Kicker for Quasi-Single Bunch Operation**
  - Hardware successfully commissioned
  - First Test of Quasi-Single Bunch Operation
- **Orbit and beamsize stability continue to be excellent**
  - Started testing candidate for BPM system upgrade



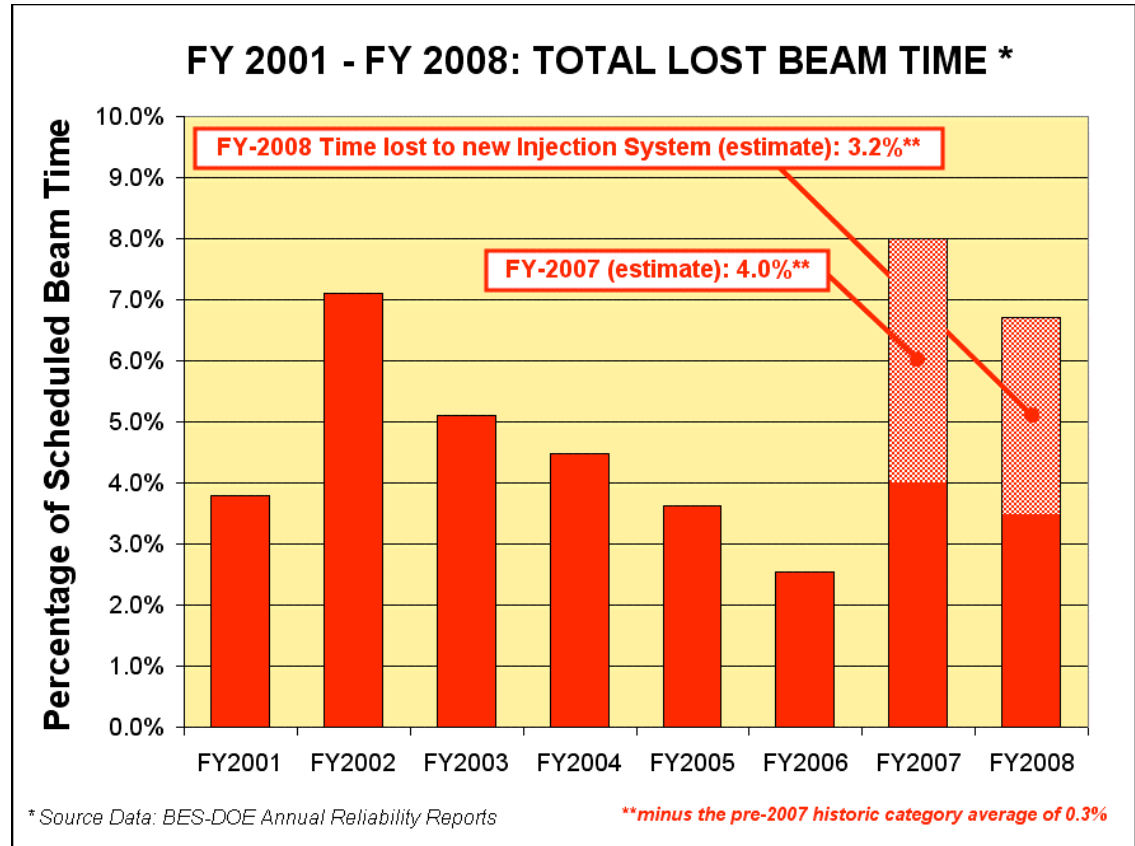
# Beam Availability

Availability not great, but better than previous year

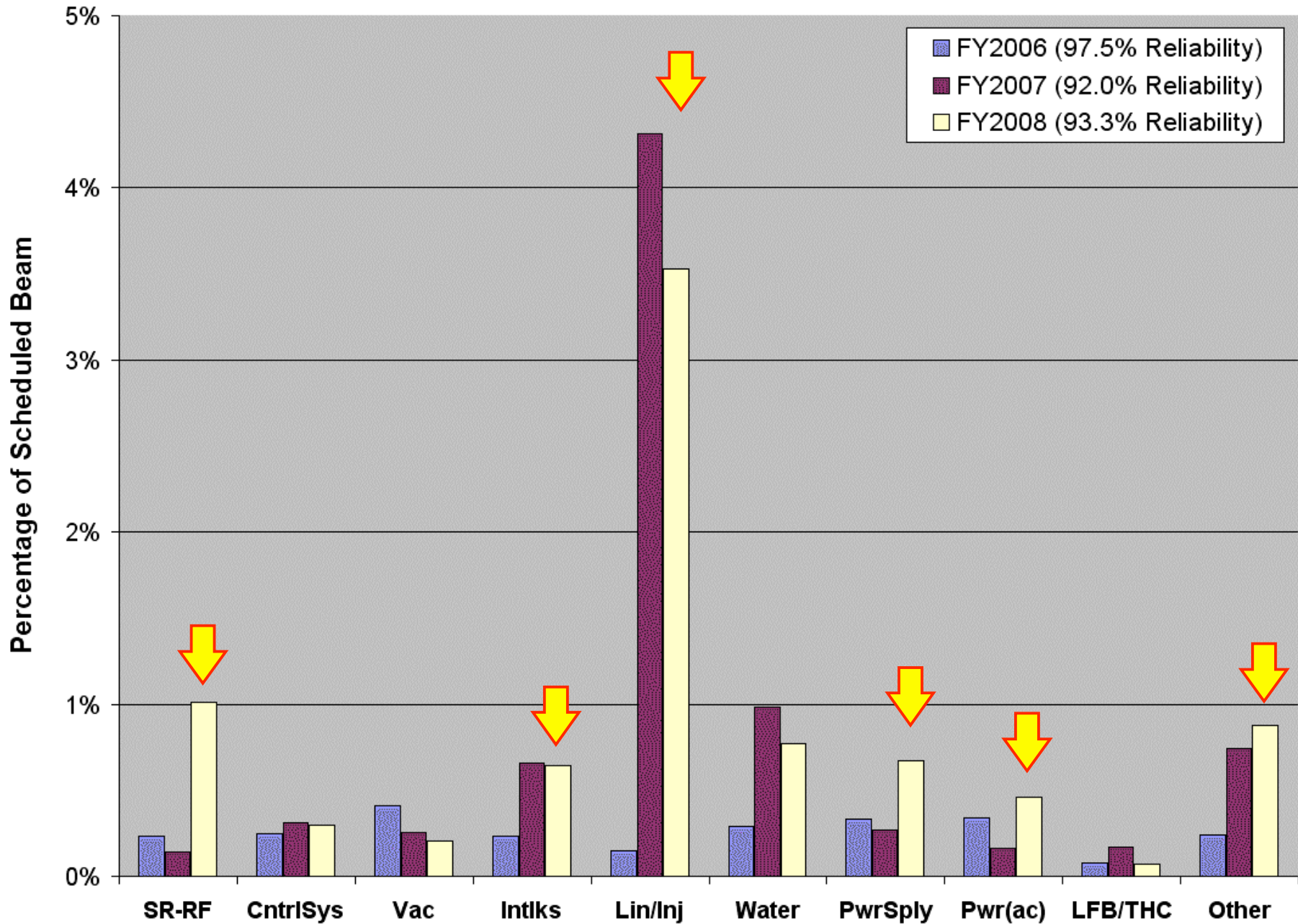
- Improvement in injector reliability after major upgrade

There is room for more improvement.

- Need to address the impacts of aging and increased complexity

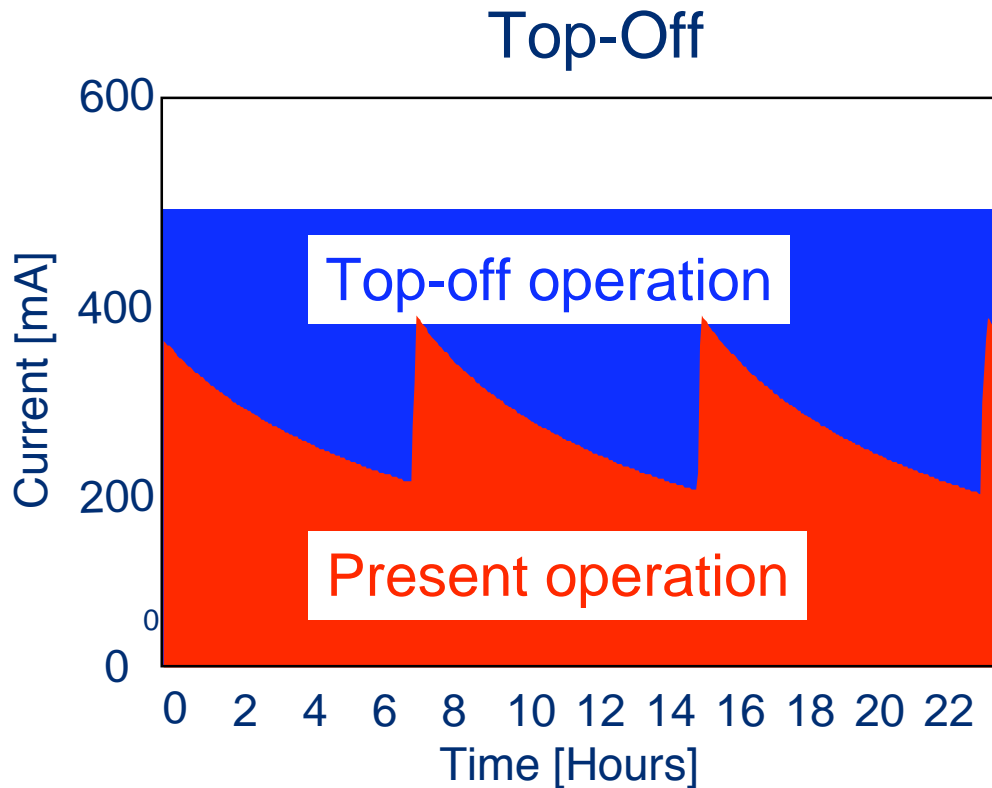


# Full Year Comparison FY-2006, FY-2007, FY-2008: Lost Beam Time





# ALS Top-off Upgrade



*Top-off is Quasi-Continuous injection mode that opens the door to large increases in brightness and improvements in beam stability*

Project has two components

- Upgrading the Injector to full energy - *Done*
- Upgrading the radiation safety systems – *Almost Done!*



# Injector Upgrade

*Largest upgrade to accelerator since initial operation in 1993*

- Most components installed in Fall 2006 shutdown
- Operating with the new equipment since 2006
  - **Some challenges with vendor supplied equipment along the way**

## New RF System



## Many New Power Supplies New Controls



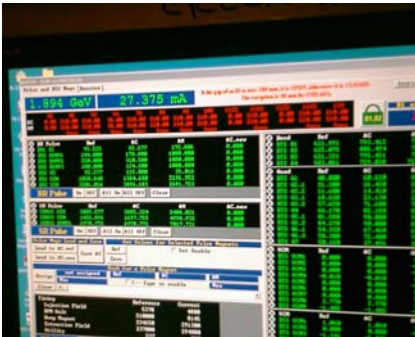
## Upgraded Pulsed Magnet Systems



# Full Energy Injection



- **Slow but steady progress during 2007:**
  - Developed in house expertise on power supplies
  - Supported vendor in trouble shooting
  - In the end took over responsibility/technical ownership



- **Success towards end of 2007:**
  - Power supply stacked and operated to 1000A in November 2007
  - 1.9 GeV injection into storage ring on 12/3/2007



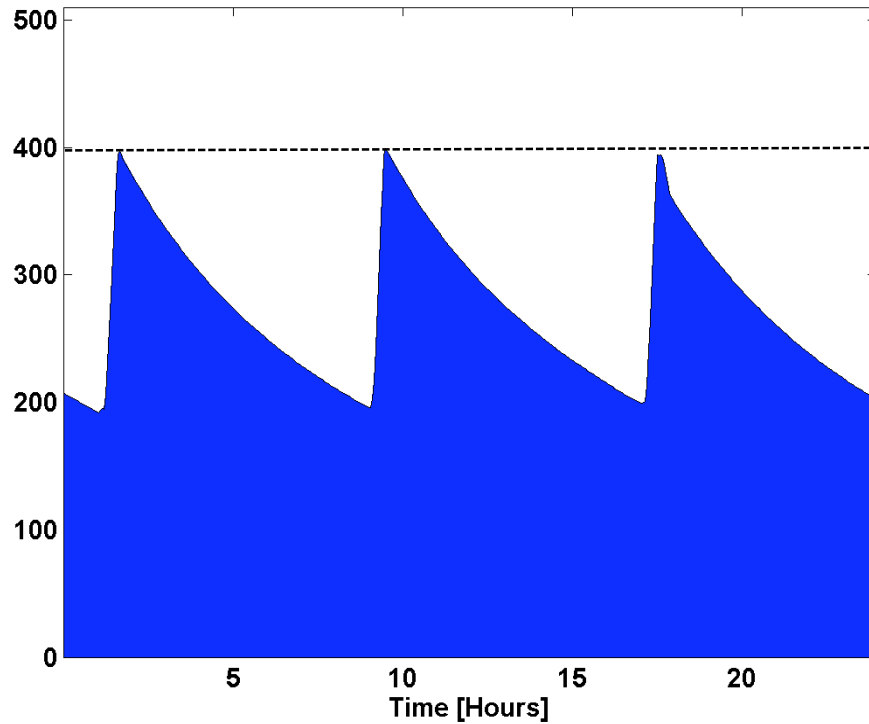
- **Since then:**
  - Migrated user operation to full energy injection
  - Steadily improved performance and replaced temporary controls with in house developed solution



# 500 mA Operation Since August 2008

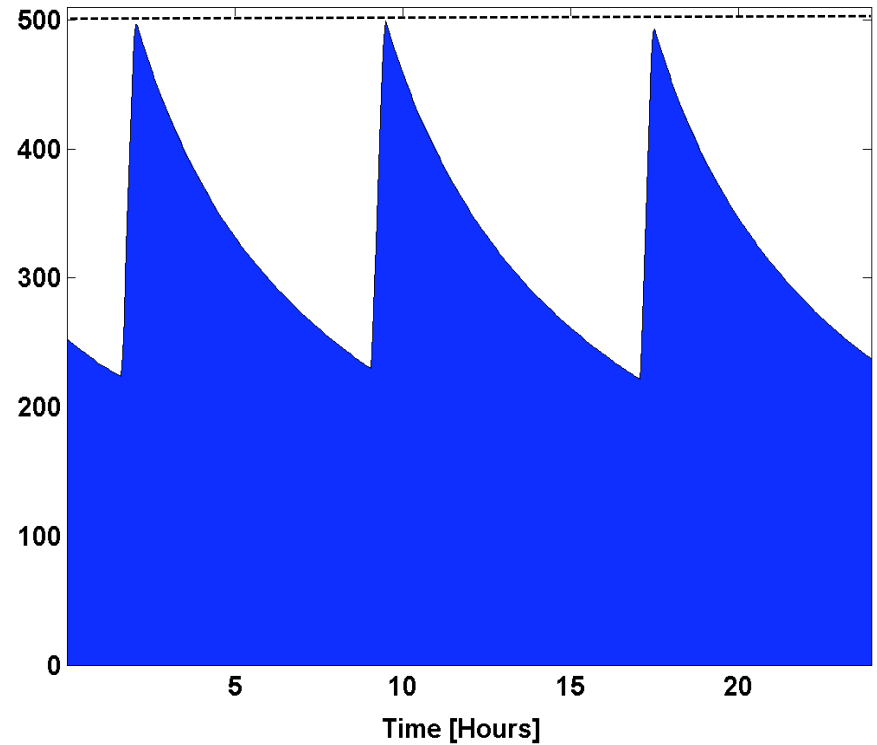
July 29, 2008

July 29, 2008



August 29, 2008

August 29, 2008



*At Full Energy Injection = better thermal stability*





# Status of the ALS Top-off Upgrade

## Present Status

- Operated in Top-off with photon safety shutters closed
- Obtained DOE approval
- Completing Interlock Testing
- Many beamlines approved for Top-off running

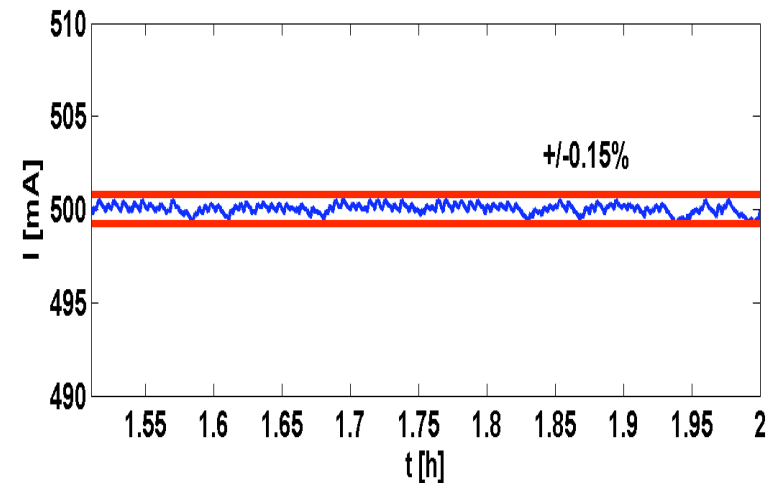
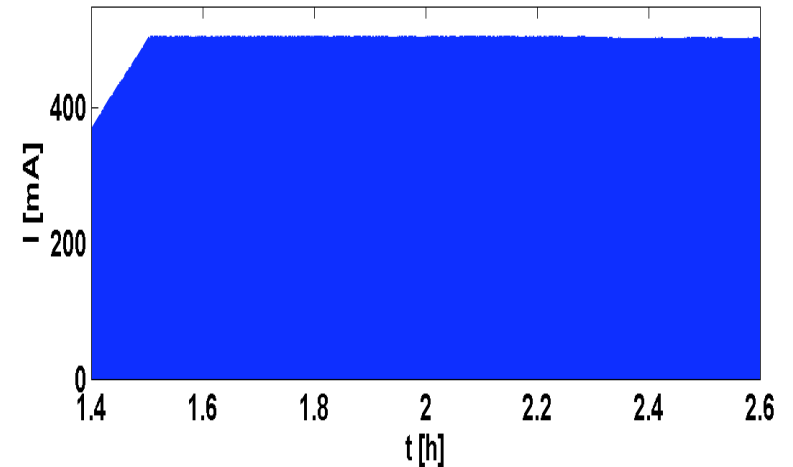
## Remainder of 2008

- Expect first operation in Top-off with some beamlines during Accelerator Physics Time

## Early 2009

- Complete approval of all beamlines (January 2009)
- First Top-off operation during User beamtime

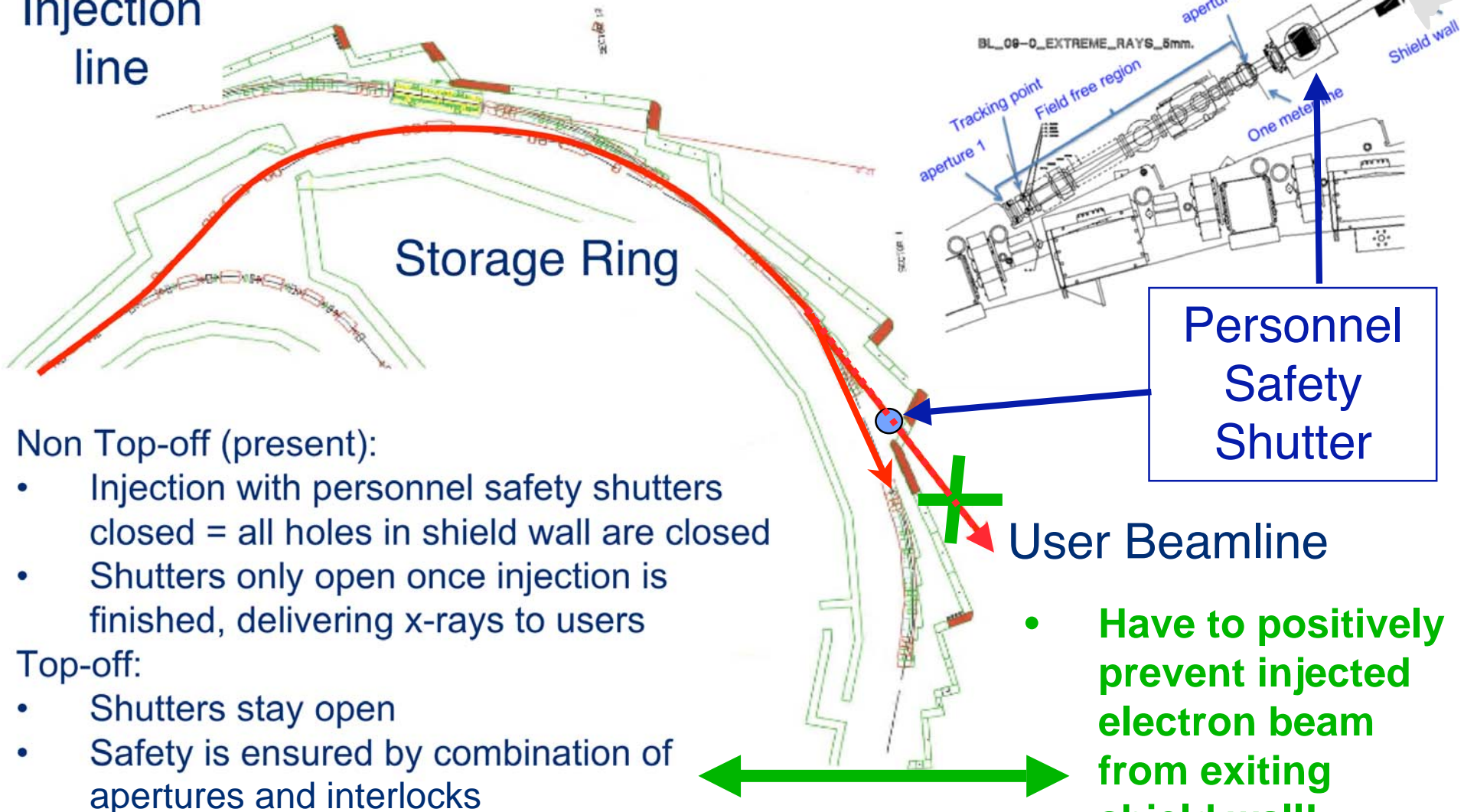
## Top-off Test (October 8)





# What is different in Top-off (safety-wise)?

Injection line



Non Top-off (present):

- Injection with personnel safety shutters closed = all holes in shield wall are closed
- Shutters only open once injection is finished, delivering x-rays to users

Top-off:

- Shutters stay open
- Safety is ensured by combination of apertures and interlocks

Personnel Safety Shutter

User Beamline

- **Have to positively prevent injected electron beam from exiting shield wall!**



# Top-off (Top-up) elsewhere

- Are we the first to do top-off?
  - No!
    - First example was Cornell University (CESR/CHESS) – late 1990s
    - First example of dedicated light source running top-off was APS (Argonne National Lab) – early 2000s
    - Now in use at about 10 light sources worldwide – other US DOE light sources (SPEAR-3, NSLS-II) are also moving towards top-off

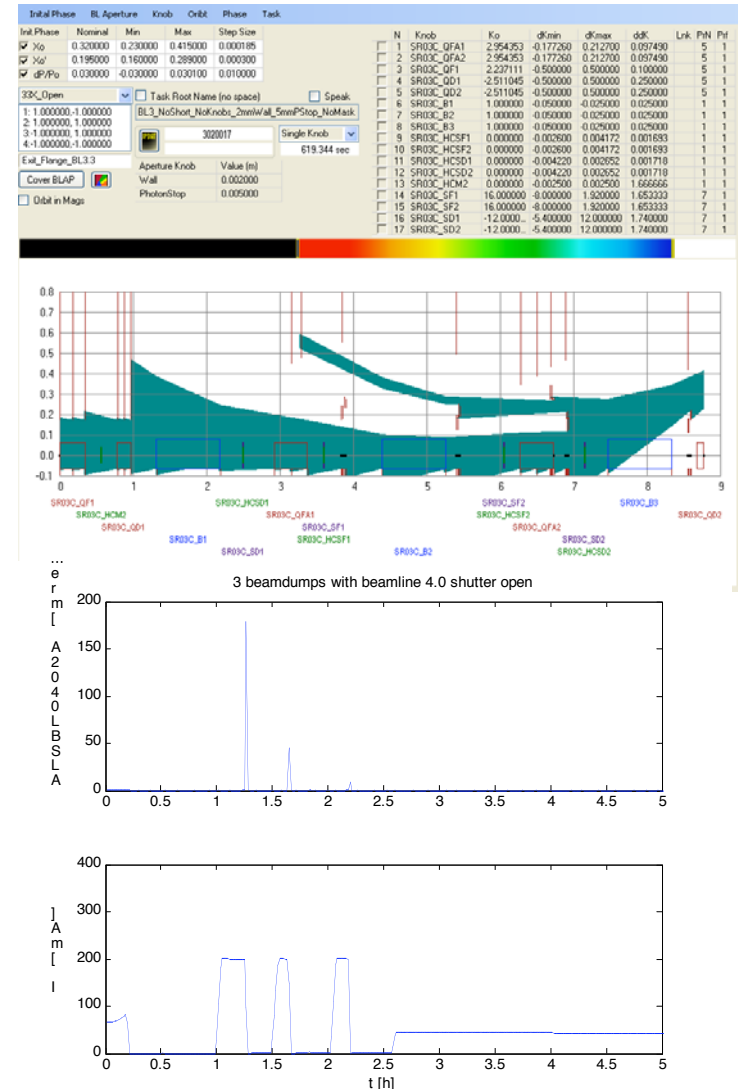


- Result of radiation monitoring at all those facilities:
  - No significant radiation exposure due to top-off so far
- ALS approach to top-off radiation safety:
  - Using the experience from all of those facilities, combining best practices and in several cases going beyond what has been done there.



# Top-off Radiation Safety at the ALS

- **Radiation Safety was one of the two main components of the top-off project right from the start**
  - Approach was based on best practices – relatively similar to APS, which is widely considered as the best so far
  - Traveled to relevant places elsewhere, invited worldwide experts here, collaborated with SSRL
  - All project reviews included safety as main part, starting with conceptual design review
- **Approach does include extensive simulations, as well as tests and measurements on accelerator**
  - Approach is very conservative (impact and probability classification, ...)
  - Worked with BSO and Oak Ridge on SAD and ASE change to allow top-off tests in 2005
- **Controls include apertures and interlocks**





# Major Top-off Reviews (Safety)

## Review Process:

- 2004 - Conceptual Design Review
- 2005 – Installation Readiness Review
- April 2007 - Technical review of radiation safety approach—predominantly of simulation studies (ALS+SSRL)
- November 2007 - Interlock Review
- February 2008 – Comprehensive Safety Review (ARSC)
- Reviews involved national and international experts
  - Accelerator Physics, Interlocks, Safety
- ALS approach was universally endorsed – it is regarded as the best and most complete approach used so far at any light source for top-off
  - September 2008: BSO/Oak Ridge approved SAD/ASE changes
  - October 2008: Accelerator Readiness Assessment
  - Still ongoing: Beamline Review Committee approving all beamlines



# Mitigation: Interlocks and Apertures

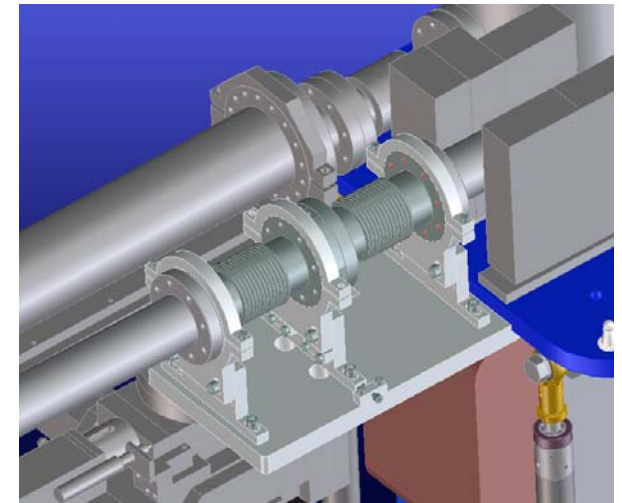
## Interlocks have multiple functions:

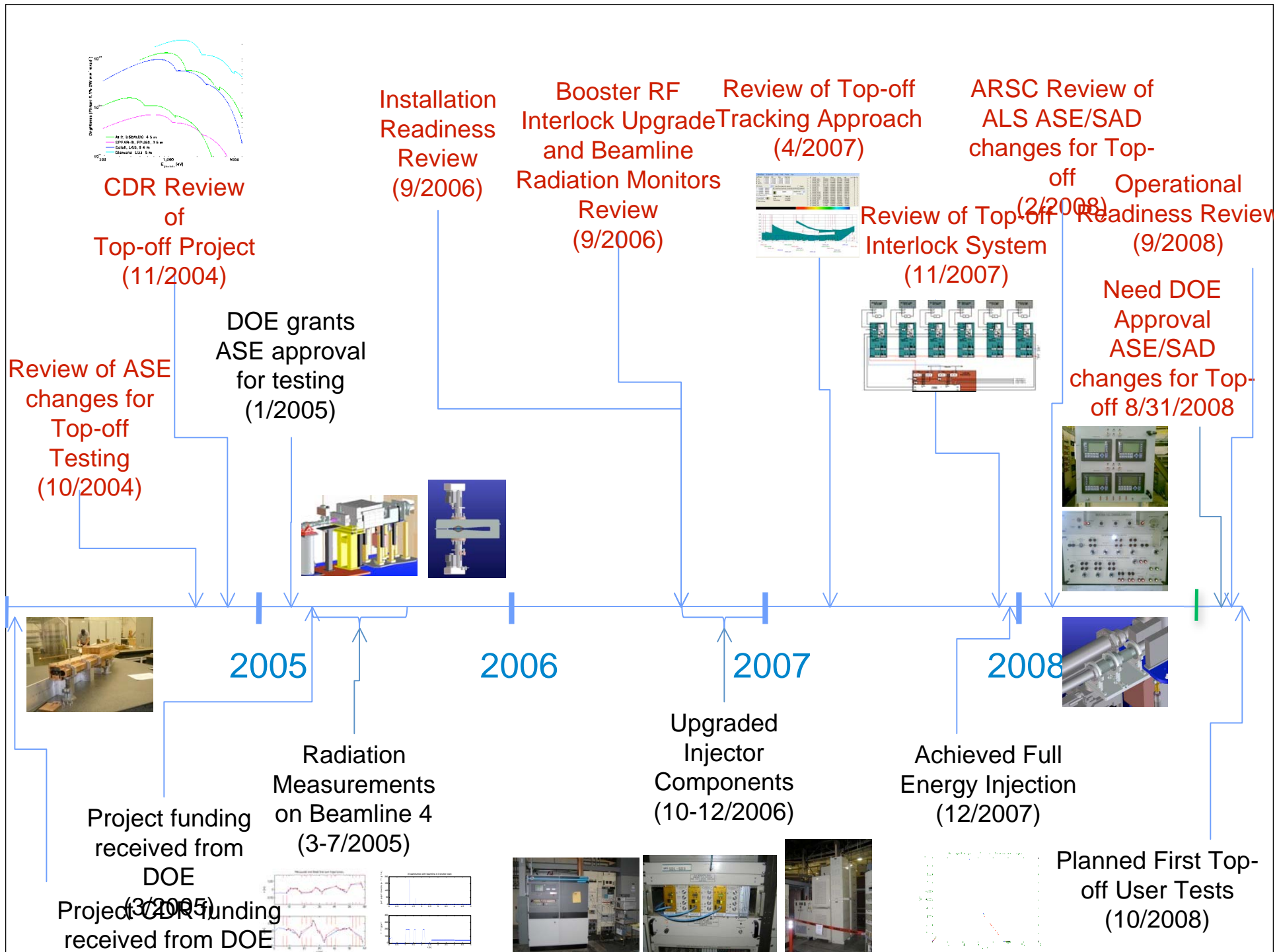
- Ensure that injected beam energy matches stored beam
- Ensure that all main magnets in ALS are close to nominal settings
- Ensure that injection with shutters open only happens when there is stored beam
- Constantly measure dose rate and close safety shutters if necessary



## Apertures:

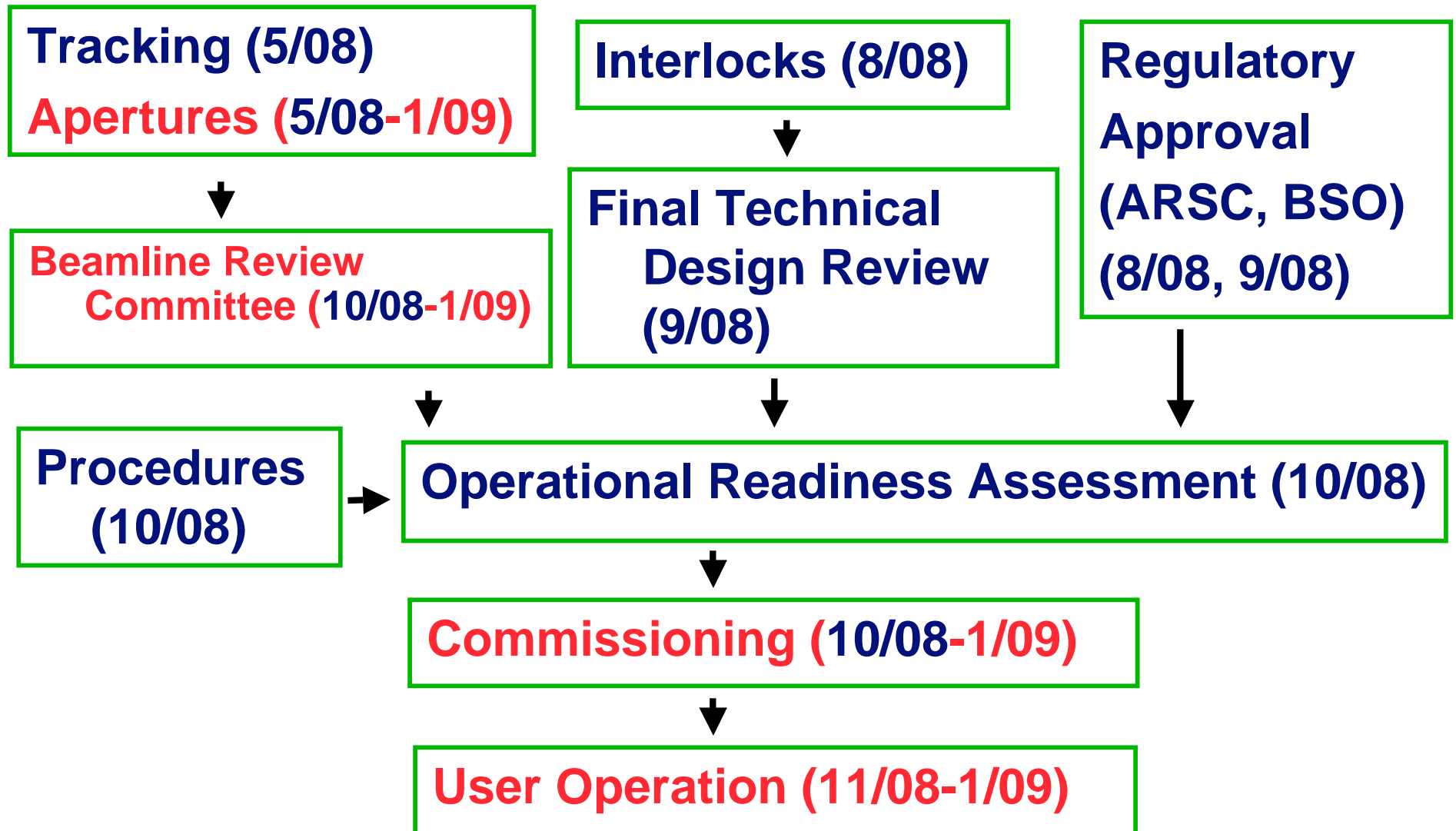
- Can be existing apertures of the beamline or newly installed ones
- Are placed under tight configuration control – regular position survey
- Each beamline is individually qualified for top-off operation by BRC
  - Same approval mechanism (and annual check) that has been used for years to verify mitigation of synchrotron radiation and bremsstrahlung hazards that also exist in non-top-off operation







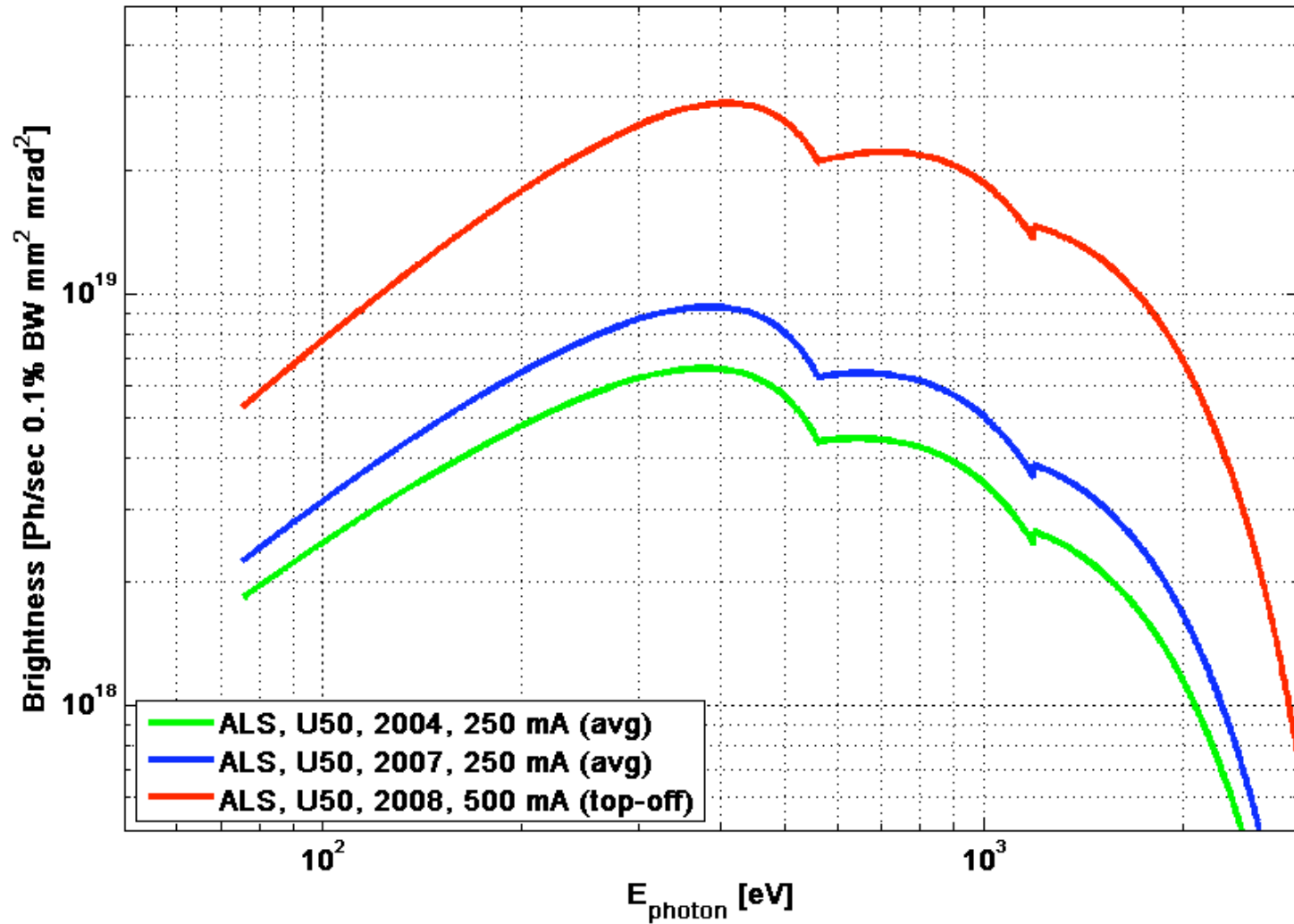
# Sketch of further schedule







# Brightness Now and After Top-off





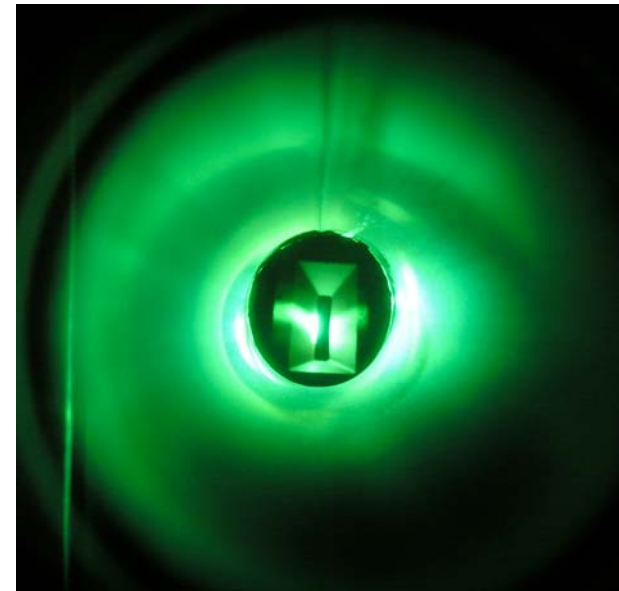
# MERLIN Quasi Periodic Undulator

## •Fabrication/Bench Measurements

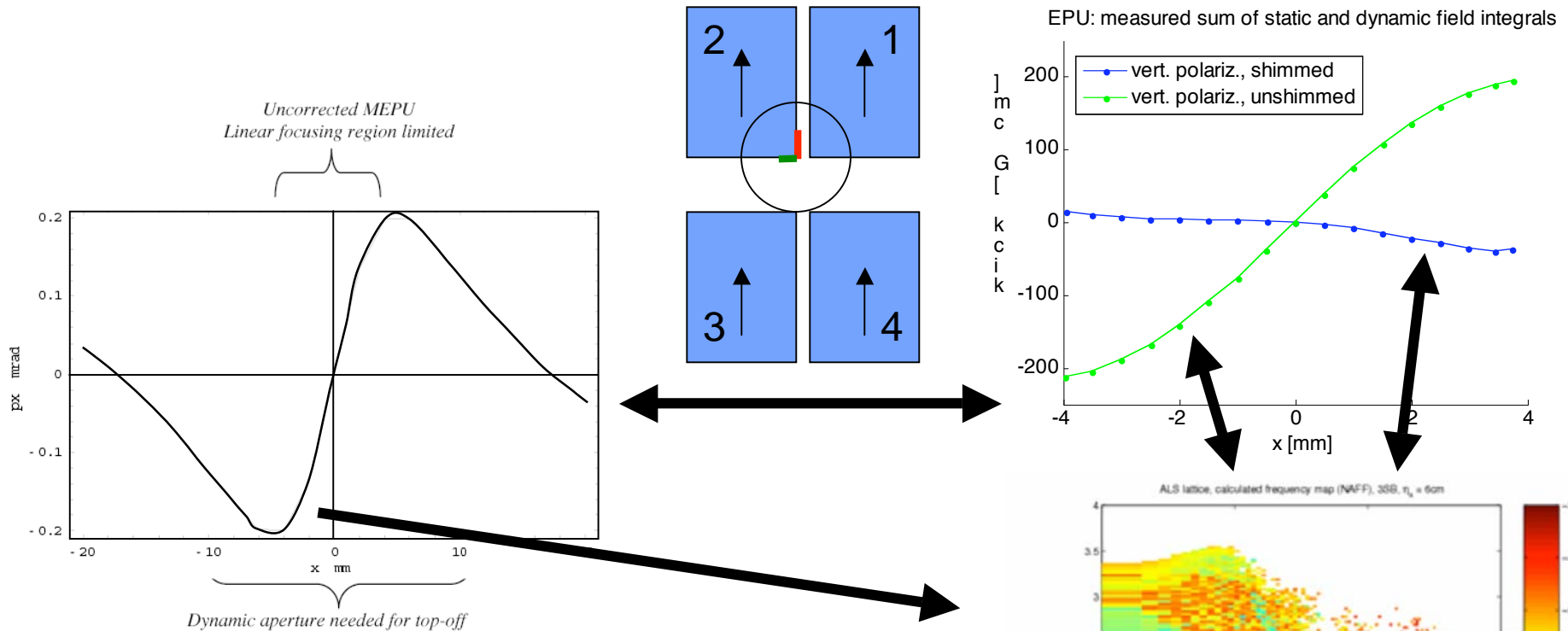
- Fully Assembled
- Extensively Measured on Bench
- First Set of Shims for Dynamics Correction Installed

## •Installation/Beam Commissioning

- Machine protection system upgrade installed in May/June 2007
- Undulator installed 10/29/07
- Undulator commissioning with beam started February 2008
- First light in MERLIN beamline in February 2008
- Routine beamline commissioning since April 2008



# EPU Dynamic Multipole Fields



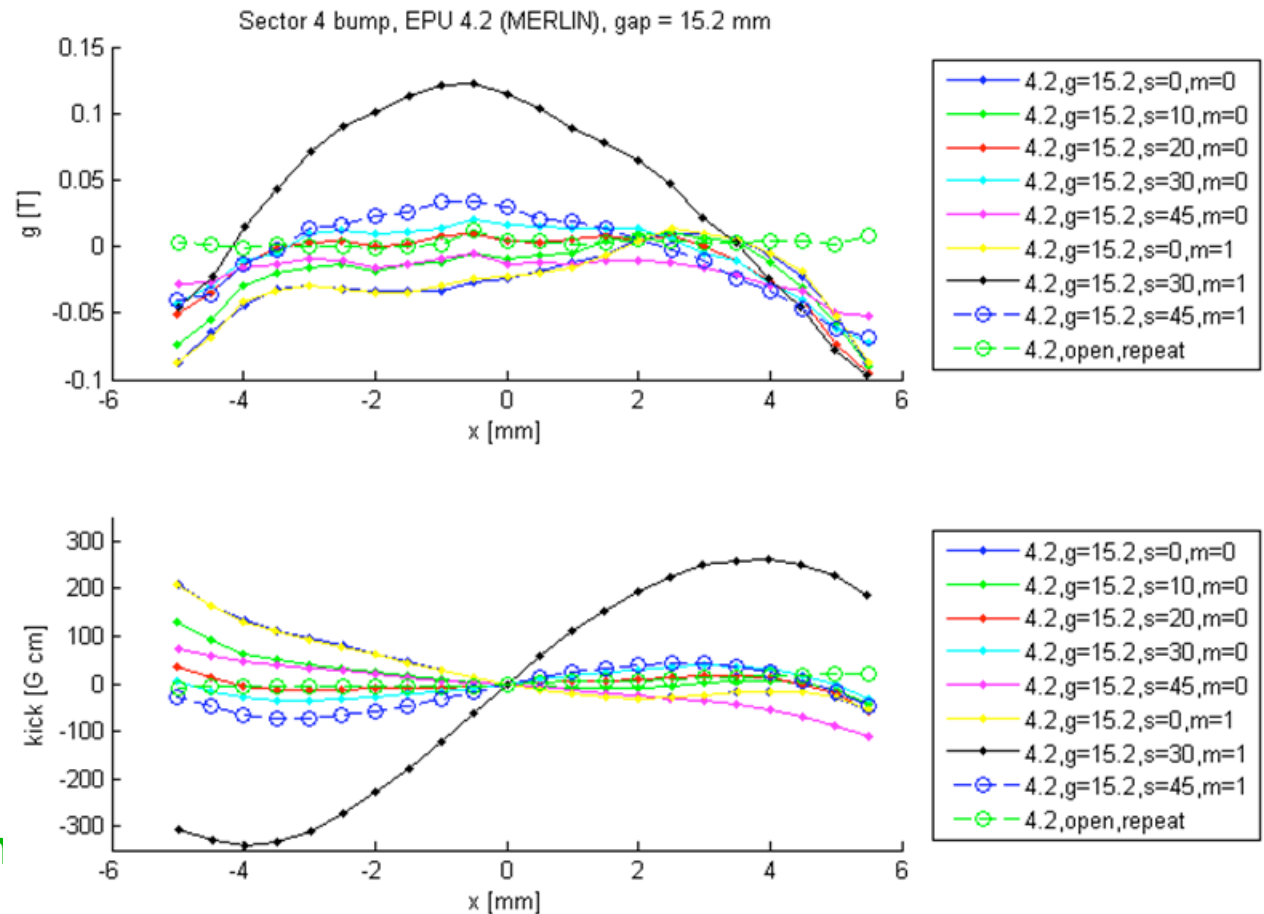
## Nonlinear Kick:

- Spoils Dynamic Aperture
  - **Worse for large period EPU**
- Impacts Lifetime and Injection Efficiency
- **Successfully compensated last year on 5 cm period EPU (where effect was smaller)**



# Characterizing MERLIN shim performance

- Shims correct nonlinearities for ALS Merlin long-period EPU.
- Shims are fairly ineffective for 45 degree linear mode (black)
  - Beamline science program does not require this polarization mode
- Results with shimmed device are:
  - Nearly no effect on beam lifetime (<5%)
  - No effect on injection efficiency
  - At all gaps and most polarizations

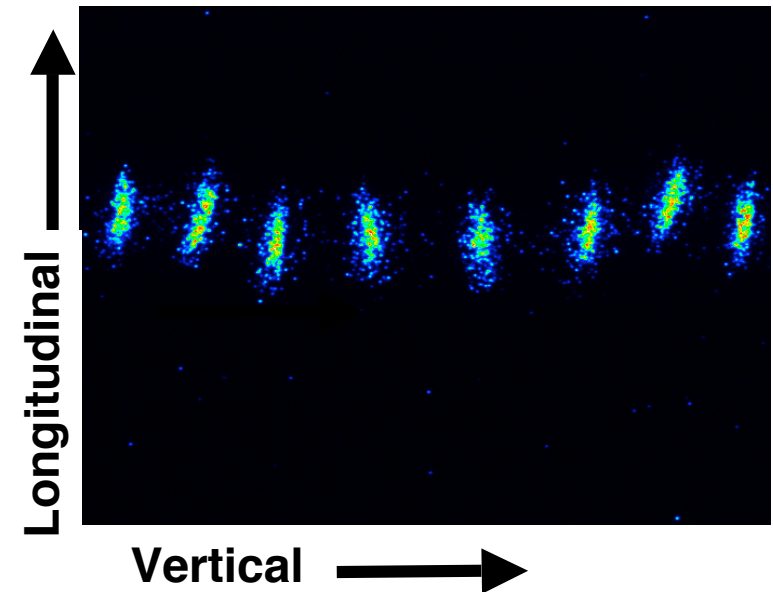
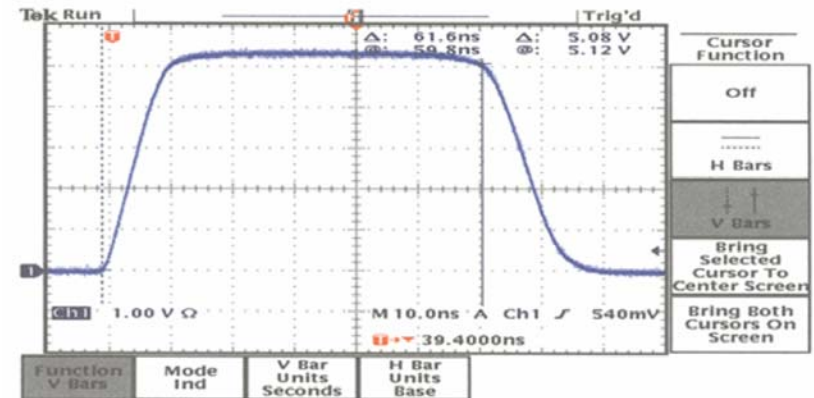




# Other Upgrades

Installed a short pulse high repetition rate kicker in January 2008

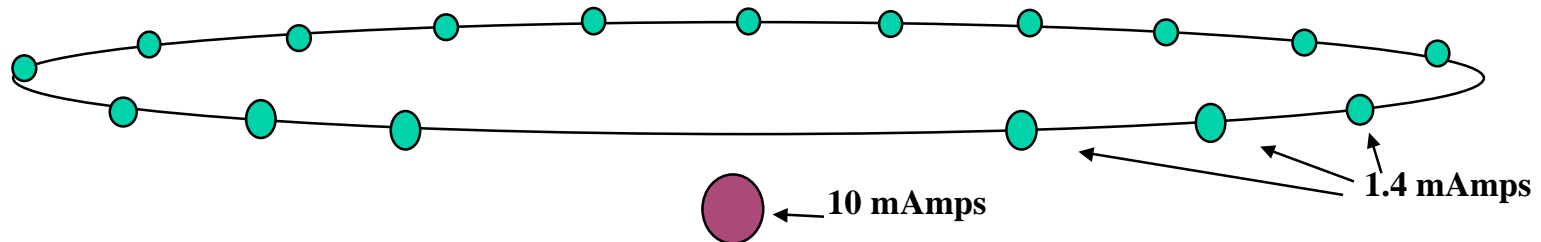
- Ability to change the orbit of a single bunch
- Potential to offer new modes of operation
  - Possibly a high current kHz picosecond source (Weiming Guo)





# Pseudo Single Bunch Operation at BL 6.1.2

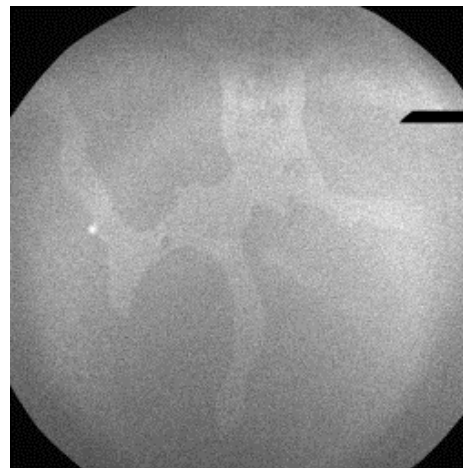
Goal: Overcome the bottleneck of limited 2bunch time by enabling time resolved magnetic soft X-ray microscopy of fast spin dynamics in regular MB operation mode of the ALS



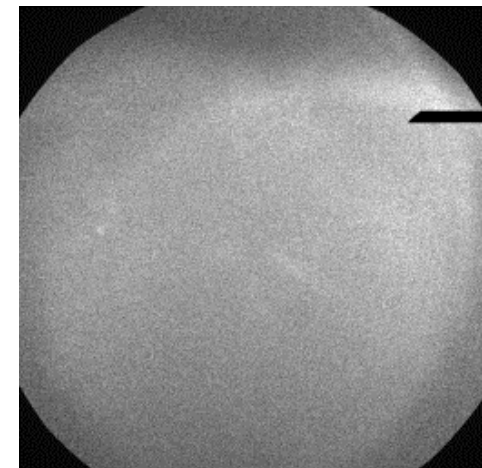
First results:

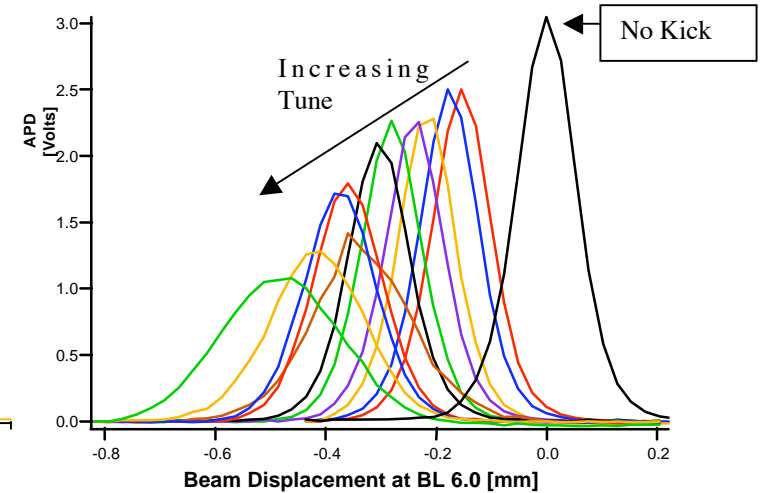
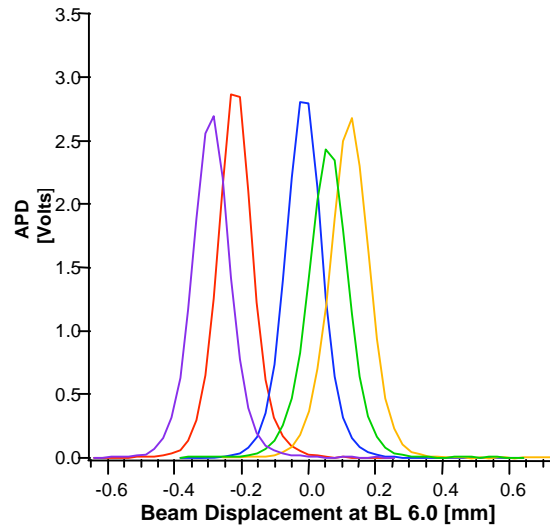
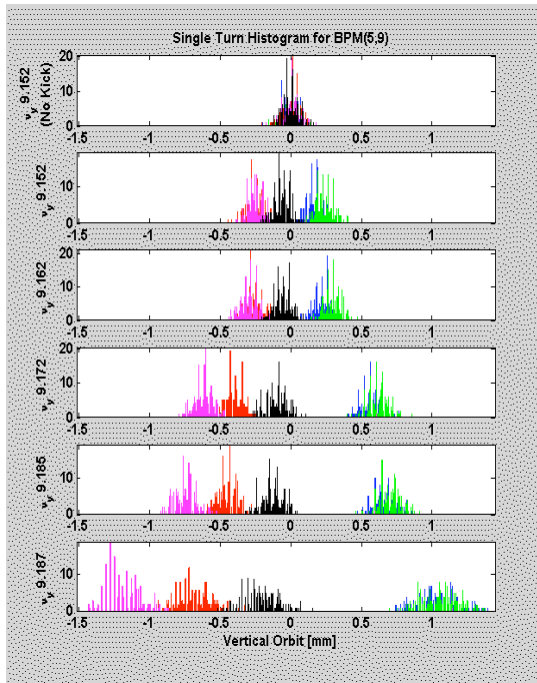
- XMCD contrast at Fe  $L_3$  edge (707eV)
- Sample: Ferromagnetic GdFe alloy film
- Off-orbit single bunch can be distinguished by offsetting the X-ray optic

Kicker **ON**



Kicker **OFF**





- Turn by turn data and profile measurements in beamline 6.0 agree (for small kicking amplitudes)
- At large kick amplitude (by moving vertical tune closer to 1/5. i.e. larger resonant amplification of kick), beamline observes additional increase in beamsize
  - Effect needs to be studied in more detail. Many possible reasons. Needs to be resolved for kicker to be of full use for beamline 6.0.

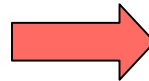


# Accelerator Upgrades Beyond Top-off

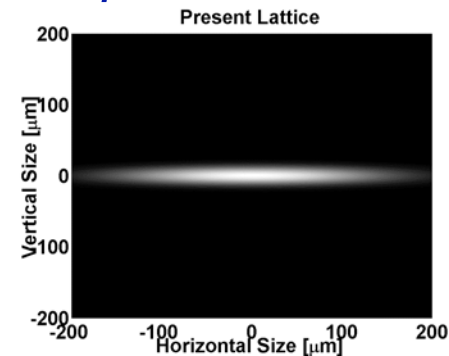
There are possibilities to significantly improve the source characteristics with minor upgrades

—Higher Brightness

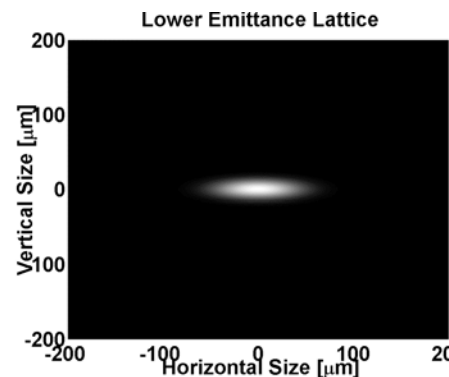
—Shorter Pulses



*Horizontal Beamsize at Superbends reduced to 30%*



223 microns (FWHM)

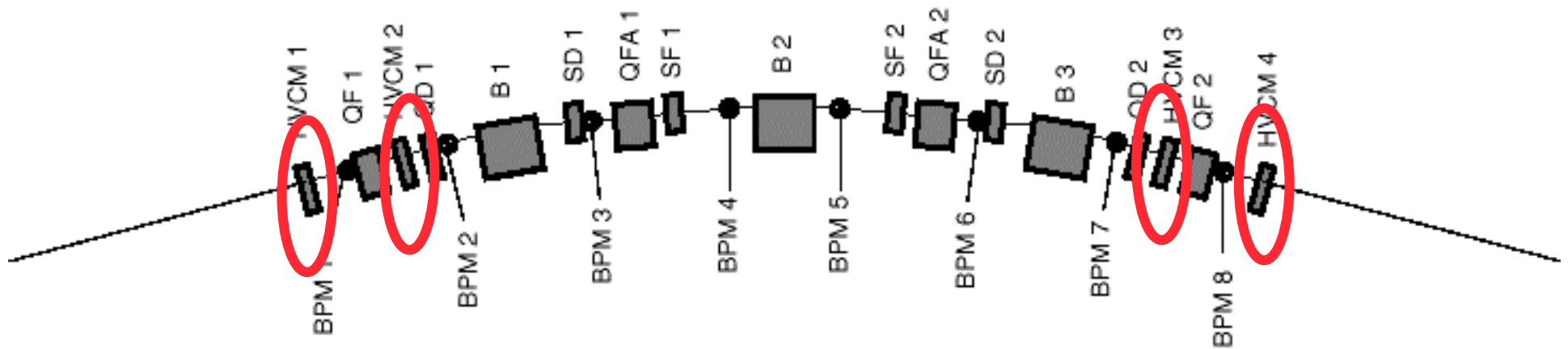


68 microns (FWHM)

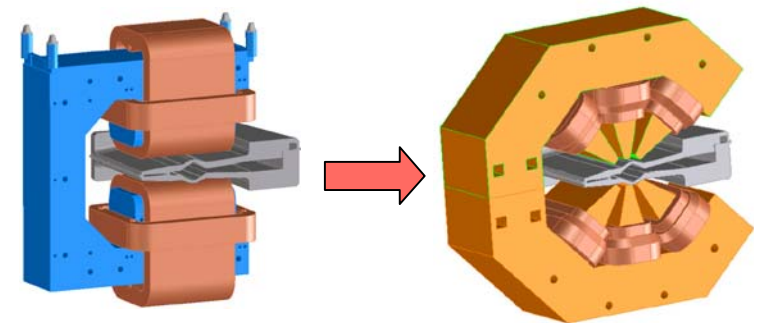


# Modified ALS Lattice

## Install New Sextupoles



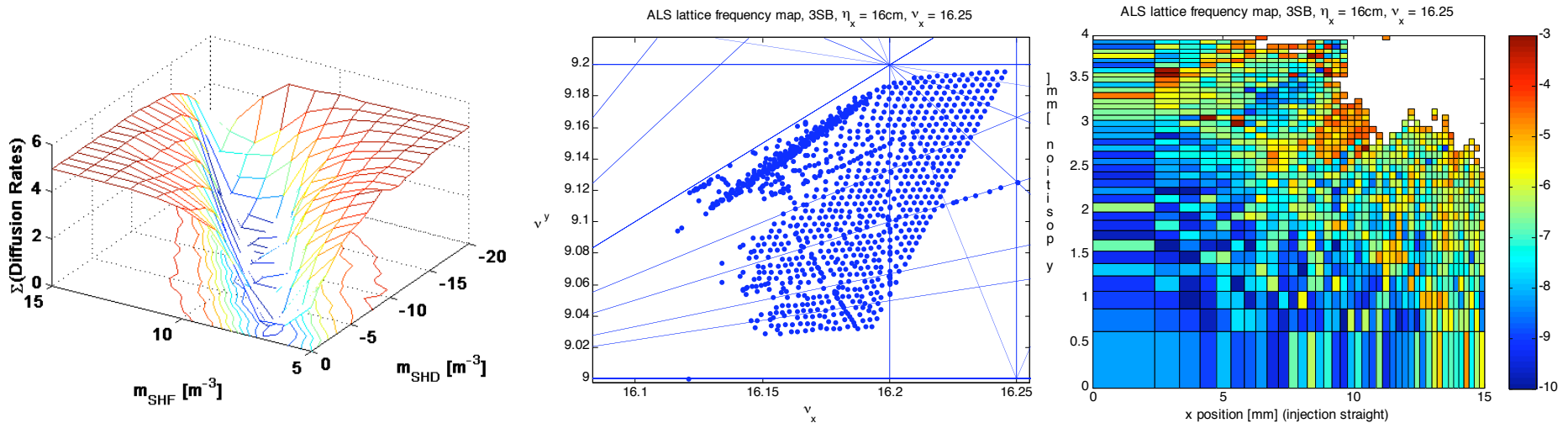
- Horizontal emittance is reduced to 1/3 from 6.3 nm rad to 2.2 nm rad
- *Emittance would be as low as any existing light source*
- Are starting to talk with potential vendors/partners
  - Using experience of ASP, ALBA, ... we are trying to minimize cost





# Preliminary Nonlinear Dynamics Optimization

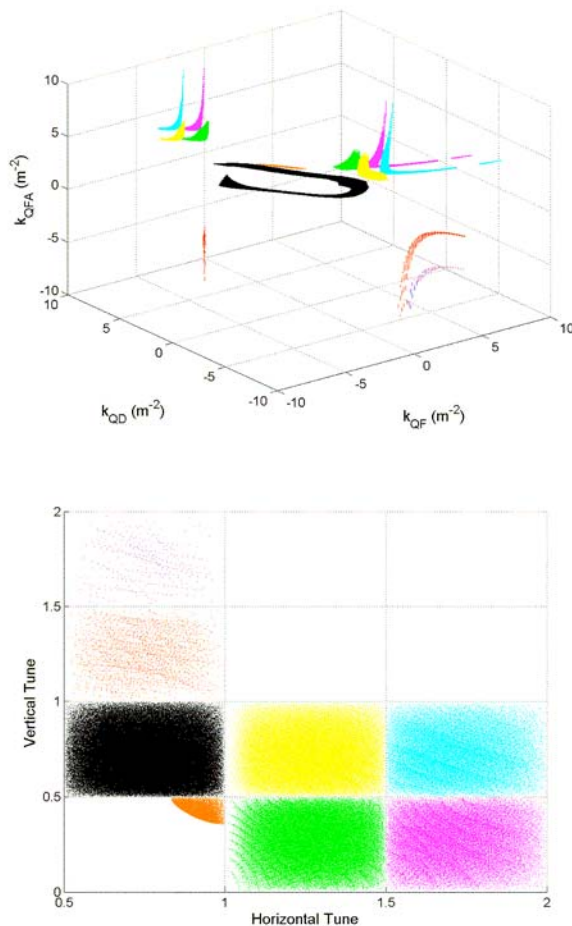
- Dynamic Aperture and Momentum Aperture of low emittance candidate lattices sufficiently large



- Need to complete studies of impact of insertion devices
- Will extend effort to find solutions with small horizontal beta functions in  $\frac{1}{2}$  (or most) of the straights



# Fundamental lattice optimization research



- LBNL (and ALS) has tradition of excellence in lattice design and understanding of nonlinear dynamics
- Recent fundamental studies are showing great promise for ALS lattice optimization
- **GLASS – Global Analysis of All Stable Solutions**
  - Reported on this last time: Tool to look for optimum lattice solution in few parameter space
- **New: MOGA – Multi Objective Genetic Algorithms**
  - Usefulness for accelerator design optimization first demonstrated in Cornell for photo injectors (Bazarov et al.)
  - Finds optimum solution with moderate computation time for larger dimensional parameter spaces
  - Could allow to integrate optimization of nonlinear lattice performance

L. Yang, et. al, 2008 European Particle Accelerator Conference, Genova, Italy, June 2008



# Genetic Algorithm (GA)

## A Typical GA with Nondomination Concept

Non-dominated Sorting Genetic Algorithm (NSGA-II):

### MOEA (Multi-Objective Evolutionary Algorithm)

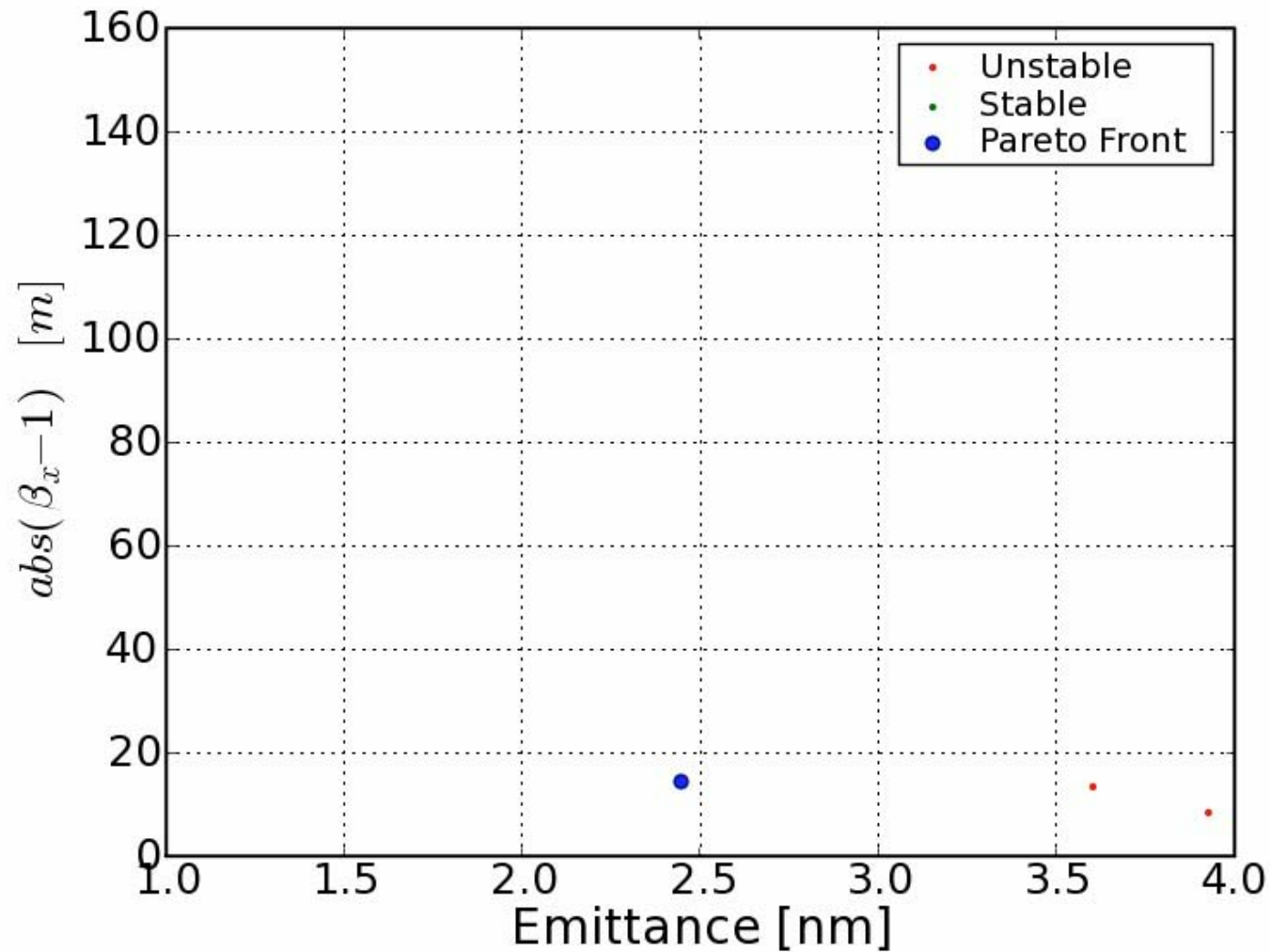
- 1: Initialize population (first generation)
- 2: **repeat**
- 3:   select parent to child (select+cross)
- 4:   mutation(child)
- 5:   evaluate(child)
- 6:   merge(parent, child) if preserve the elite solutions.
- 7:   nondominated sort()
- 8: **until** reach maximum generation

- **Elite-preserving operator:** preserve and use previously found best solutions in subsequent generations.





# Movie of Convergence





# User Meeting Workshop

*Workshop Tomorrow (10:30-12:00+13:15-16:30; 2-400F)*

*Current and Future Upgrades and New Techniques for Improving the Performance of the ALS*

Organized by Greg Portmann and Christoph Steier

## Topics:

- Using Quasi-Single Bunch Operation
  - First user experiments
- Preparing for Top-off
  - Transition to Top-off
  - What to expect as a user
- Higher Brightness Upgrade
- Next Generation Light Source at LBNL
  - Seeded FEL facility (RLS)



# Workshop Schedule

- **Overview & Low-Emittance Lattice Status – David Robin (10:30 – 11:00)**
- **Pseudo Single Bunch**
  - **Overview – Greg Portmann (11:00 – 11:15)**
  - **BL 6.1 results – Peter Fischer (11:15 – 11:45)**
  - **BL 6.0 results – Marcus Hertlein (11:45 – 12:00)**
- **Lunch Break**
- **Top-off**
  - **Overview, commission plan, and experience from other facilities – Christoph Steier (13:15 – 14:00)**
  - **User Gating System – Fernando Sannibale (14:00 – 14:20)**
  - **General top-off discussion (14:20 – 14:45)**
- **Next Generation Light Source – John Corlett (14:45 – 15:15)**
- **Break (15:15 – 15:30)**
- **Open Discussion (15:30 – 16:30)**



# Summary

- **Machine is operating very well**
  - After overcoming many difficulties of injector upgrade (for top-off)
  - Orbit and beamsize stability continue to be state of the art
- **Top-off upgrade is nearing completion**
  - Passed major safety reviews
  - Interlocks fully installed, final test to be completed
  - Retrofitting beamline apertures
- **MERLIN undulator was commissioned – beamline has started commissioning**
- **There are well defined paths for further enhancing the capabilities of the ALS – keeping it unique and on the frontier of synchrotron light sources**
  - **Brightness**
    - Using advanced lattice optimization techniques
  - **Short pulses/Arbitrary Bunch frequency**
    - Started experiments of test kicker with user beamlines