Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

LER 2016
26-28 October 2016 - Synchrotron SOLEIL, France

The CESR/CHESS Upgrade at Cornell University

Jim Crittenden

LER 2016
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CHESS Cornell High Energy Synchrotron Source

Upgrade of the Cornell Electron Storage Ring as an X-ray Source for the Cornell High-Energy Synchrotron Source

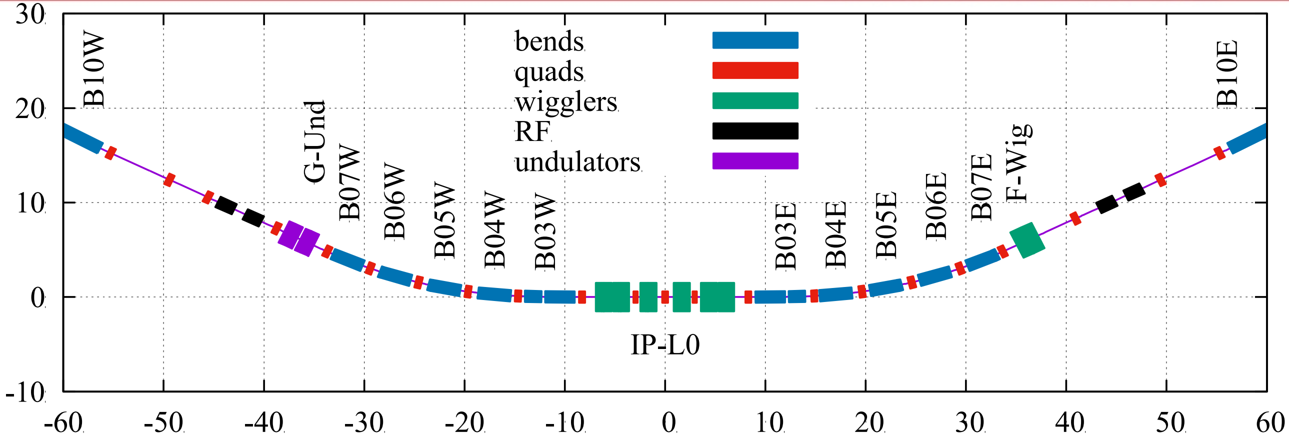
* Increase beam energy and decrease emittance from 100 nm-rad at 5.3 GeV to 30 nm-rad at 6.0 Gev

* New optics in 1/6 of ring around former e+e- collision point, including six double-bend achromats, each comprising two combined-function magnets and two horizontally focusing quadrupoles and accomodating a pair of 1.5-m canted undulators

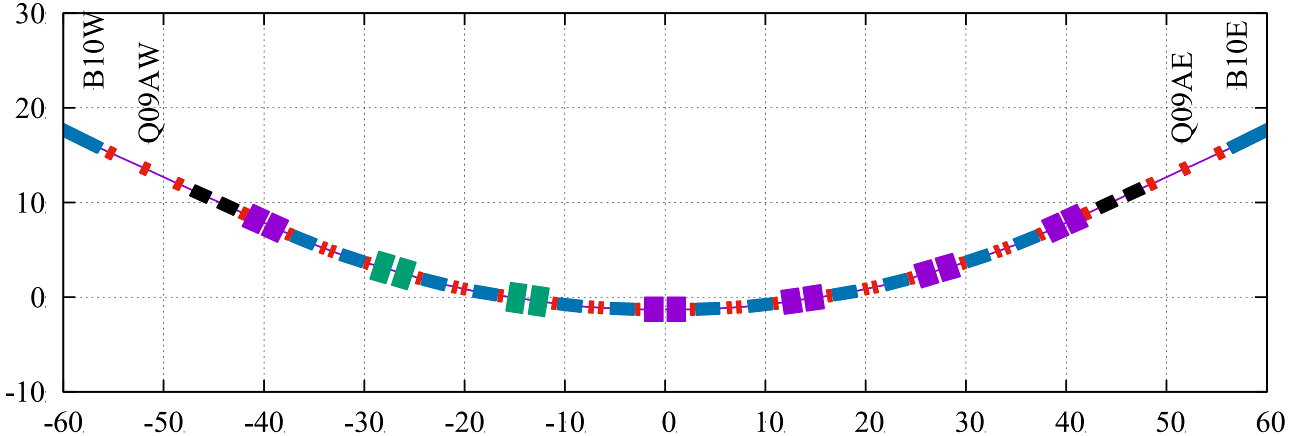
* Operations with a single positron beam of 200 mA rather than e+/e- beams of 120 mA each. The choice of positrons necessitated by the orientation of one major CHESS beam-line. ===> Electron cloud buildup in the new, smaller vacuum chambers for the combined-function magnets and undulators should be estimated to see if mitigation strategies are needed.

D.L. Rubin, et al., "Upgrade of the Cornell Electron Storage Ring (CESR) as a Synchrotron Light Source", NAPAC'16, October 9-14, 2016, Chicago, IL, USA, paper WEPOB36

South arc layout



Present CESR layout

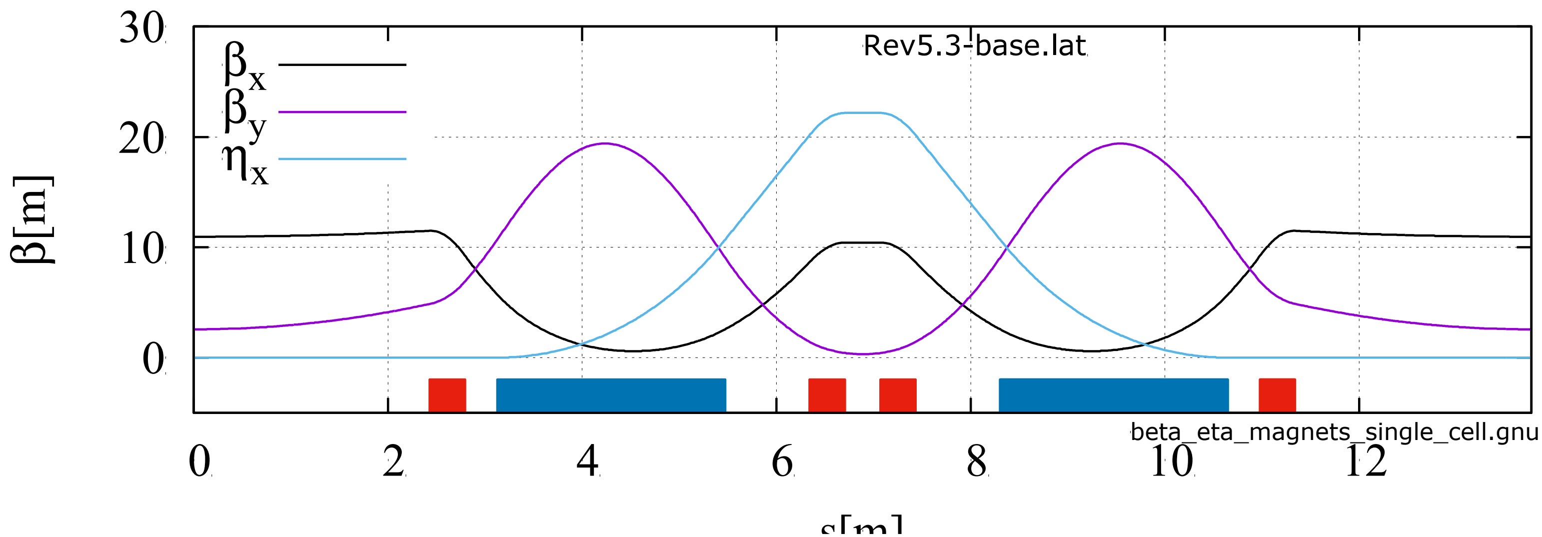


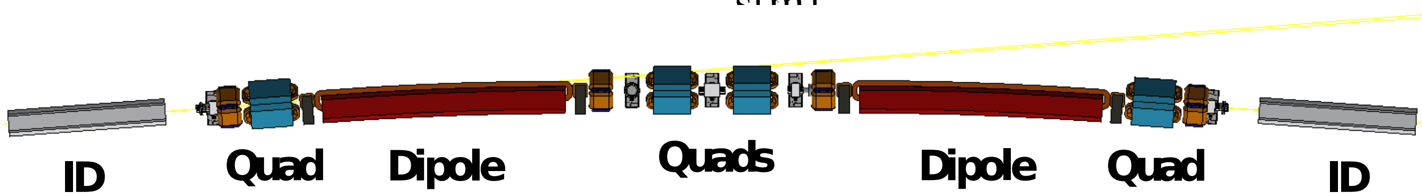
CESR/CHESS upgrade layout

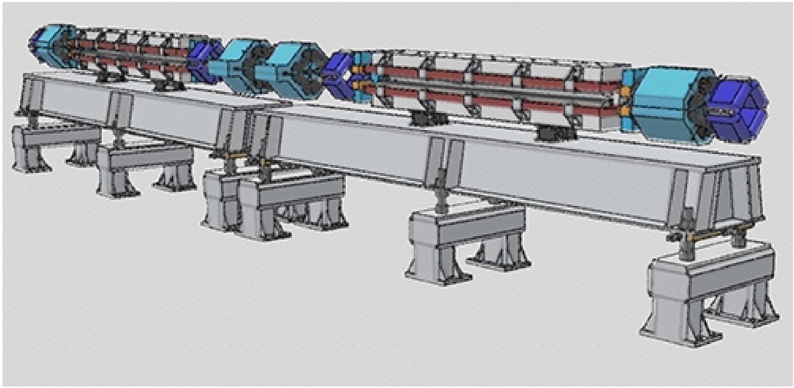
A major effort in design, engineering, production, field measurement, girder development and alignment strategy for 12 new combined-function and 12 quadrupole magnets is now underway.

The project leader and contact is Alexander Temnykh of Cornell University.

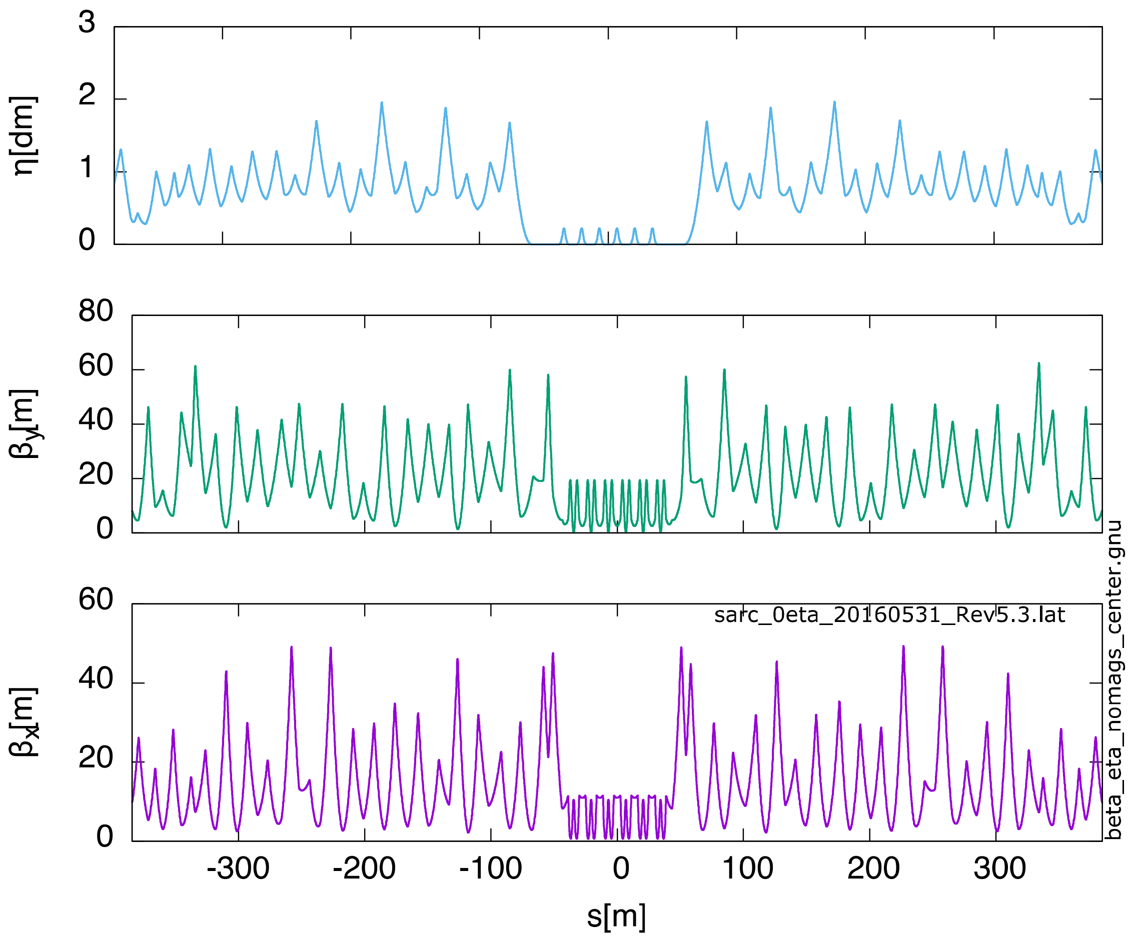
Double-bend achromat





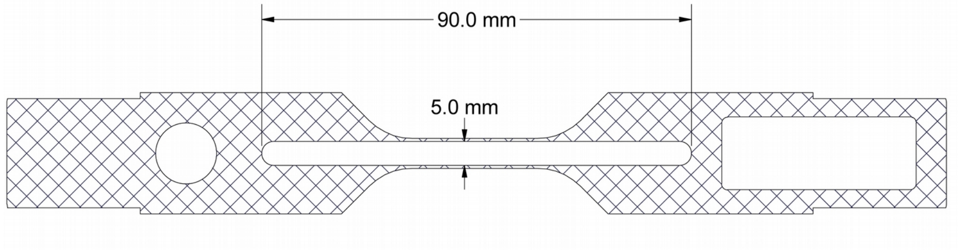


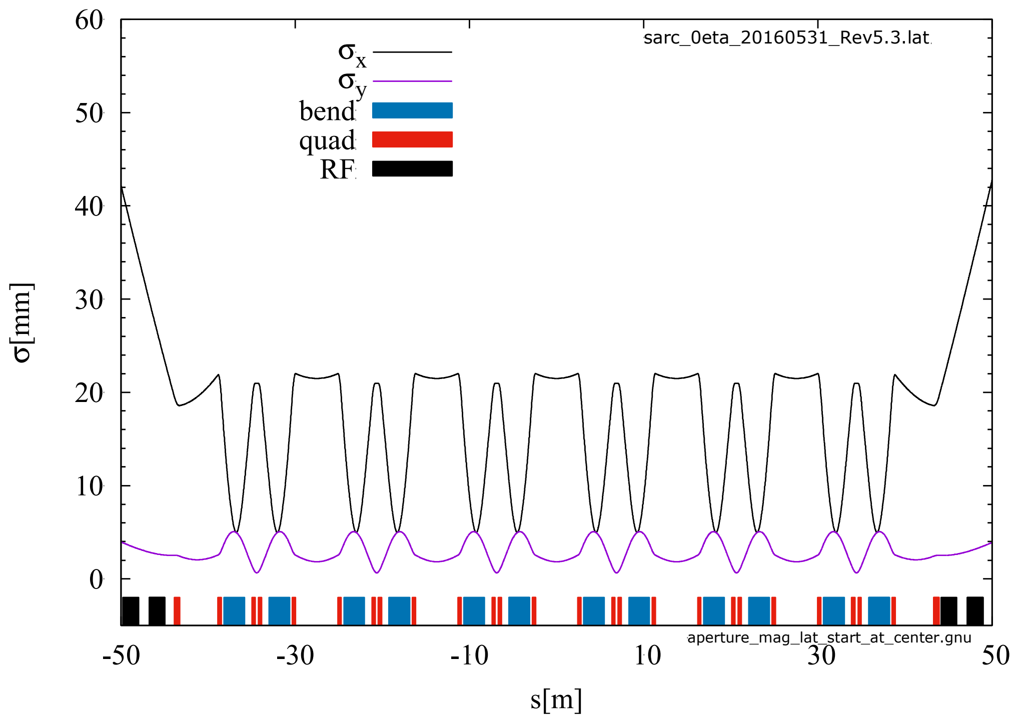
Full lattice twiss functions



The ring FODO lattice transports beam around the CESR tunnel to the new arc comprised of six double-bend achromats.

Aperture limits

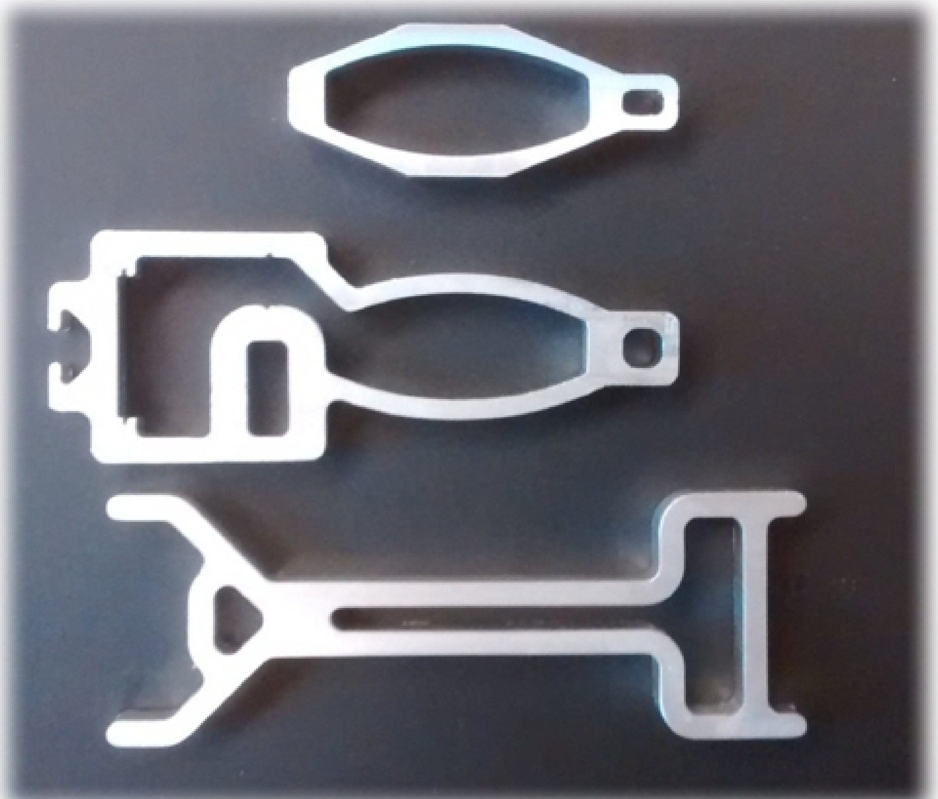




The vertical aperture is limited by the undulator vacuum chambers to +-2.3 mm.

The horizontal aperture is defined by the vacuum chambers in the CESR tunnel arcs to be +- 45 mm.

New vacuum chambers



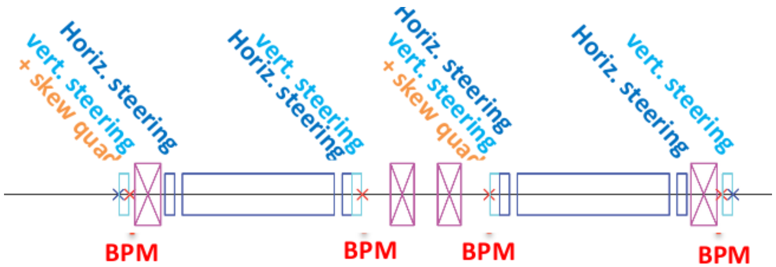
Quadrupole

Combined-function magnet

Undulator magnet

New quadrupole chamber (45x 25 mm) relative to standard CESR chamber (90 x 50 mm)

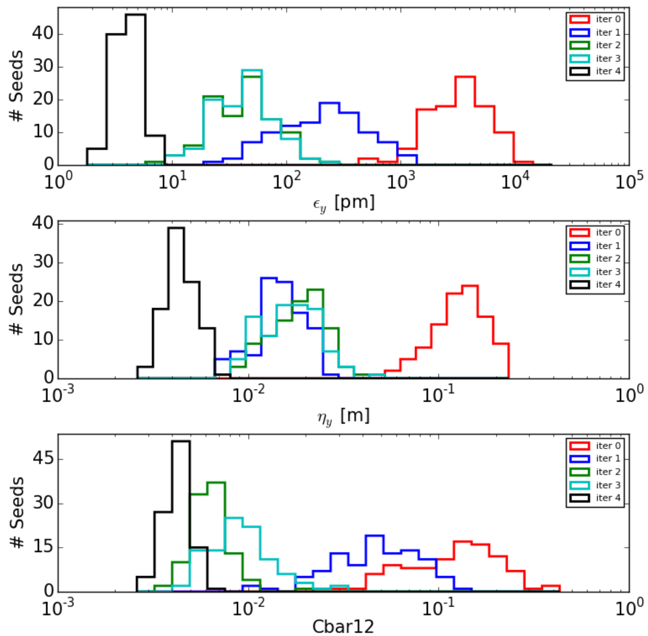
BPM alignment error correction and dynamic aperture study

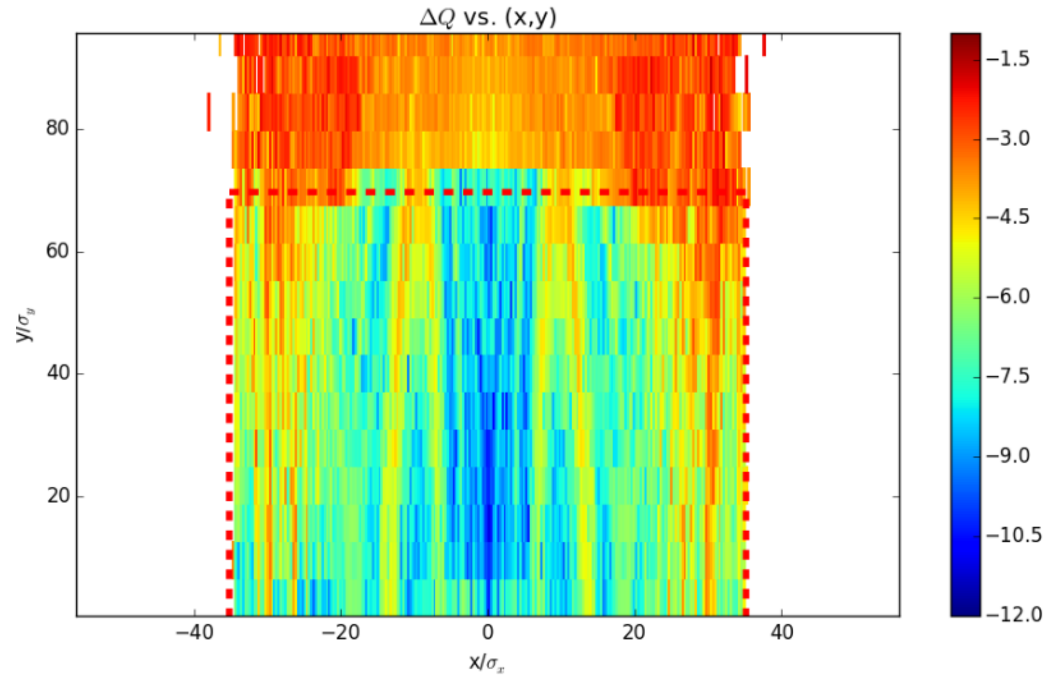


εY[pm]

ηY[m]

Cbar12

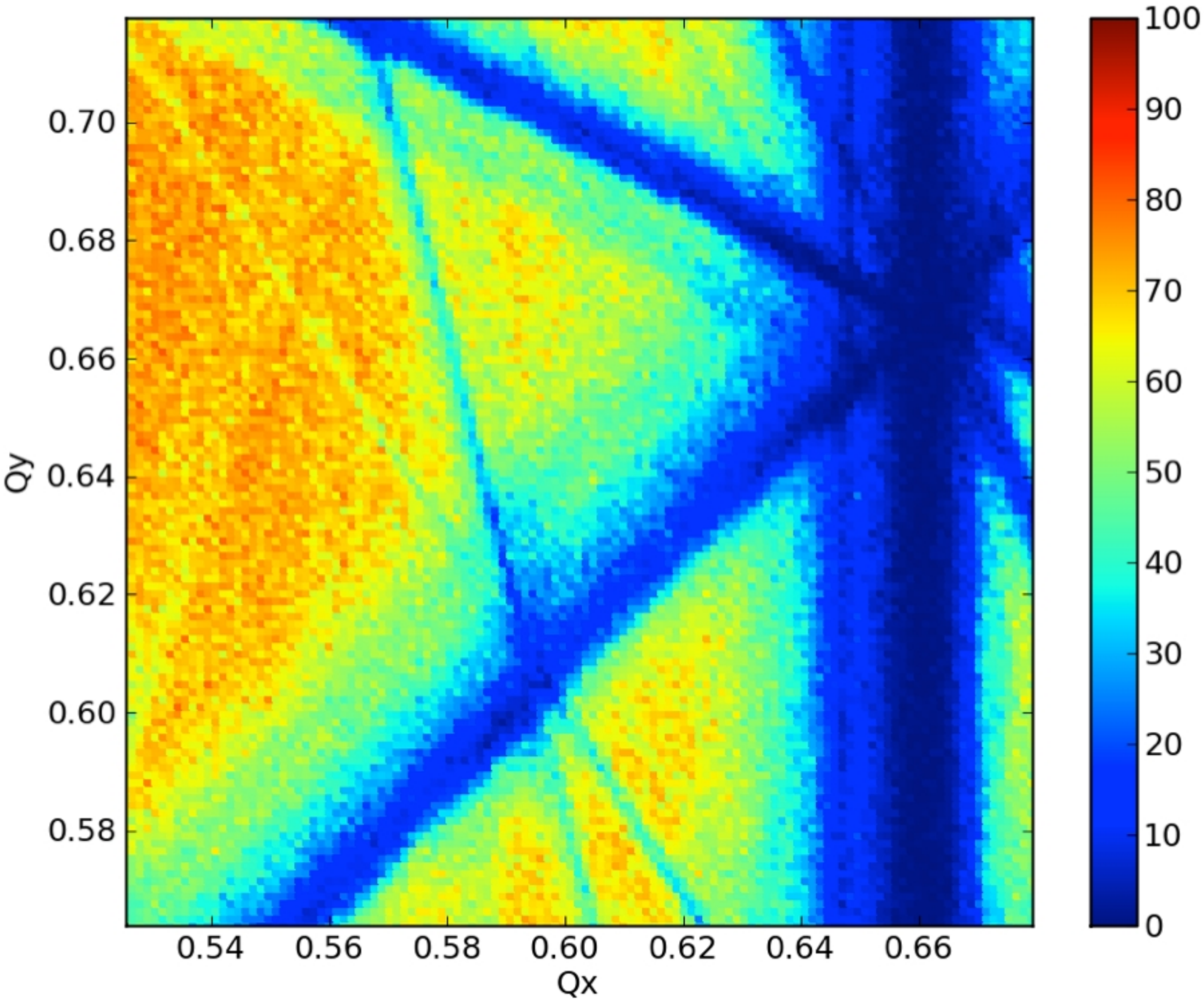




BPM misalignment iterative correction procedure restores beta functions to <1%, emittance to 10 pm, and coupling to <1%.

Frequency map for misaligned and corrected lattice including guide field multipole errors. Physical aperture shown by dotted red line. Nonlinearities do not limit acceptance.

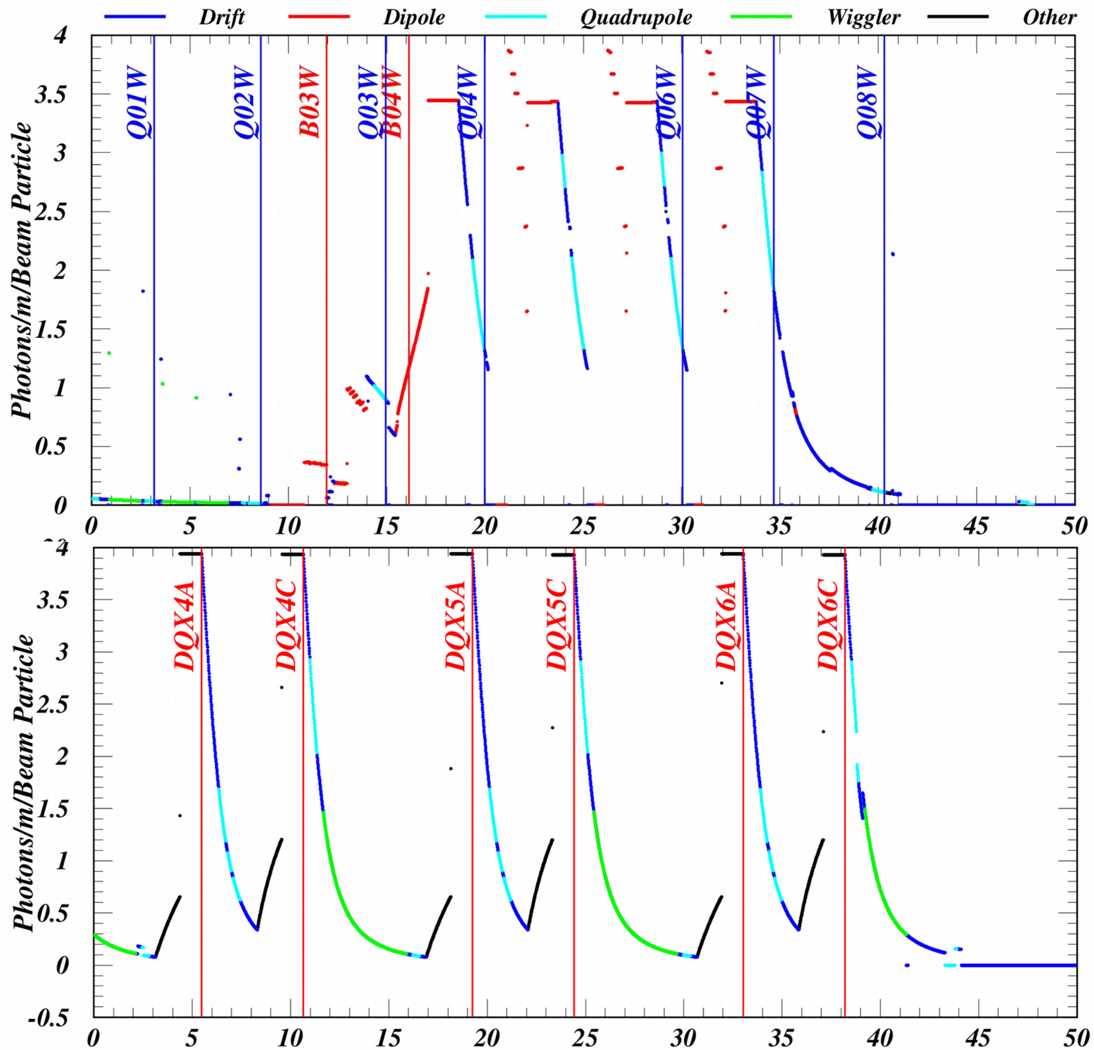
Injection efficiency



Injection efficiency found to be greater than 85% over a wide range of the tune plane in a model which includes field errors, misalignments and undulator multipoles.

This is a significant improvement over present CHESS two-beam operation.

Comparison of synchrotron radiation pattern in the south arc region



Present CESR layout

CESR/CHESS upgrade layout

There is a very high rate of synchrotron radiation photons on the combined-function magnet vacuum chamber walls.

Element-averaged beam size, beta functions and photon rates

Present CHESS lattice

Element	Nr Seg	<Length>	Tot Length	Fraction	<Beta X>	<Beta Y>	<Sig X>	<Sig Y>	<Phot/m/e>
Dipole	47577	0.010	475.5	61.6%	15.4	20.5	1.4443	0.1389	1.048
Drift	19478	0.010	188.5	24.4%	17.9	21.3	1.4934	0.1375	0.696
Wiggler	2171	0.010	21.6	2.8%	13.7	12.2	1.5101	0.1083	0.191
Quadrupole	6396	0.010	63.8	8.3%	18.5	22.6	1.5080	0.1402	0.790
Sextupole	2198	0.010	21.9	2.8%	18.5	22.5	1.5458	0.1416	0.739
Solenoid	0	0.000	0.0	0.0%	0.0	0.0	0.0000	0.0000	0.000
Octupole	76	0.010	0.8	0.1%	21.7	15.8	1.8705	0.1256	0.281
Non-dipole	30319	0.010	296.6	38.4%	17.8	21.0	1.5027	0.1362	0.682
Non-drift	58418	0.010	583.7	75.6%	15.8	20.5	1.4578	0.1380	0.976
Total	77896	0.010	772.4	100.0%	16.3	20.7	1.4662	0.1378	0.907

CESR/CHESS upgrade lattice

Element	Nr Seg	<Length>	Tot Length	Fraction	<Beta X>	<Beta Y>	<Sig X>	<Sig Y>	<Phot/m/e>
Dipole	43992	0.010	440.0	57.1%	13.4	21.2	0.8695	0.0771	1.145
Drift	19427	0.010	189.8	24.6%	16.4	19.3	0.8690	0.0701	0.734
Wiggler	970	0.010	9.6	1.2%	23.3	15.4	1.2779	0.0644	0.357
Quadrupole	6438	0.010	64.3	8.3%	17.1	21.0	0.8831	0.0707	0.866
Sextupole	2129	0.010	21.2	2.8%	18.2	24.5	0.9649	0.0801	0.861
Solenoid	0	0.000	0.0	0.0%	0.0	0.0	0.0000	0.0000	0.000
Octupole	78	0.010	0.8	0.1%	19.3	13.0	1.0158	0.0624	0.320
DQmagnet	2819	0.010	28.2	3.7%	1.8	15.9	0.2182	0.0688	2.149
CCU	1656	0.010	16.6	2.1%	10.8	3.3	0.5648	0.0313	0.413
Non-dipole	33517	0.010	330.5	42.9%	15.3	18.7	0.8193	0.0686	0.860
Non-drift	58082	0.010	580.9	75.4%	13.5	20.4	0.8410	0.0746	1.117
Total	77509	0.010	770.8	100.0%	14.2	20.1	0.8477	0.0735	1.023

Average synchrotron radiation rate incident in the combined-function magnets will be double that in the CESR dipole magnets.

Electron cloud simulation package
ECLOUD

* Originated at CERN in the late 1990's

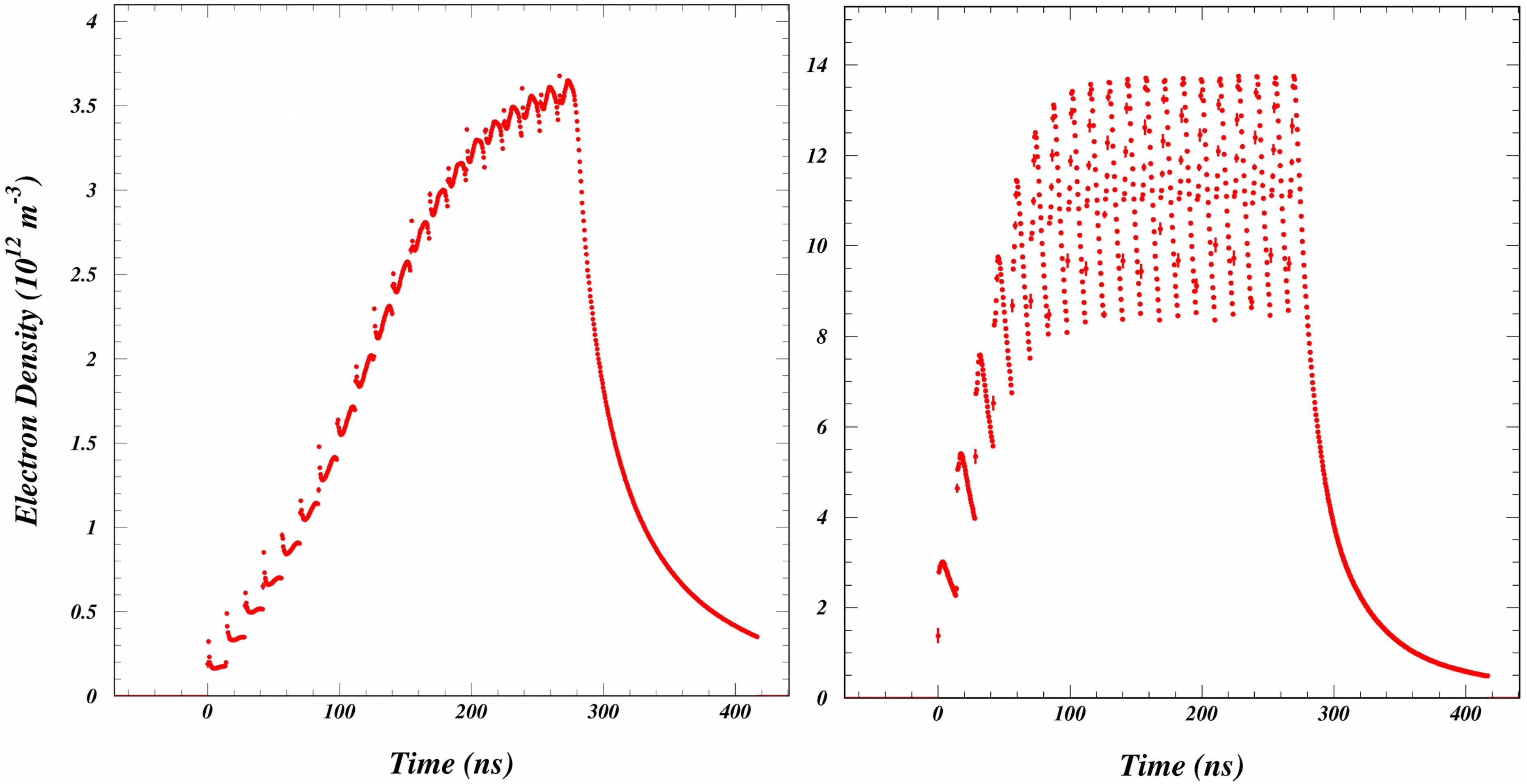
* Widespread application for LHC, KEK, RHIC, ILC …

* Under active development at Cornell since 2008

* Successful modeling of CESRTA tune shift measurements (2009-2016)

I. Generation of photoelectrons
   A) Production energy, angle
   B) Azimuthal distribution (v.c. reflectivity)
II. Time-sliced cloud dynamics
   A) Cloud space charge force
   B) Beam kick
   C) Magnetic fields
III. Secondary yield model
   A) True secondaries (yields > 1!)
   B) Rediffused secondaries (high energy)
   C) Elastic reflection (dominates at low energy)
IV. Additional magnetic field environments
   A) Sextupole fields
   B) Combined-function dipole/quadrupole fields

Comparison of modeled EC buildup

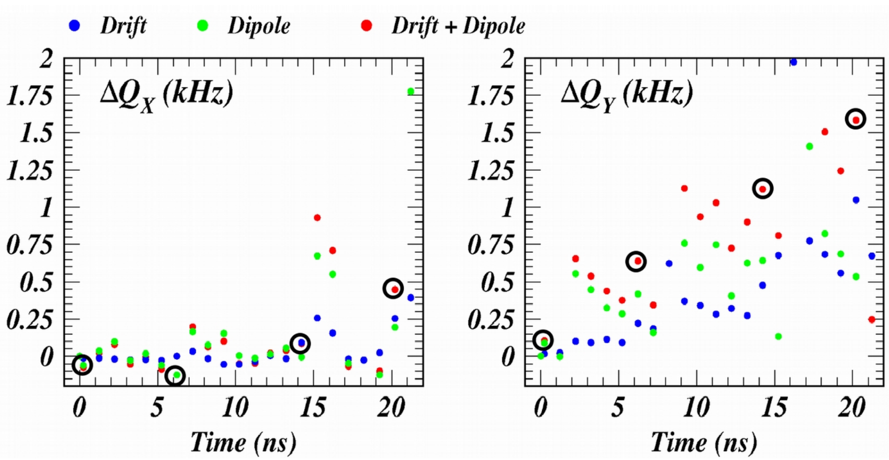


The cloud density in the combined-function magnets is predicted to be a factor of four higher than in the CESR dipoles now.

Modeled tune shift comparison

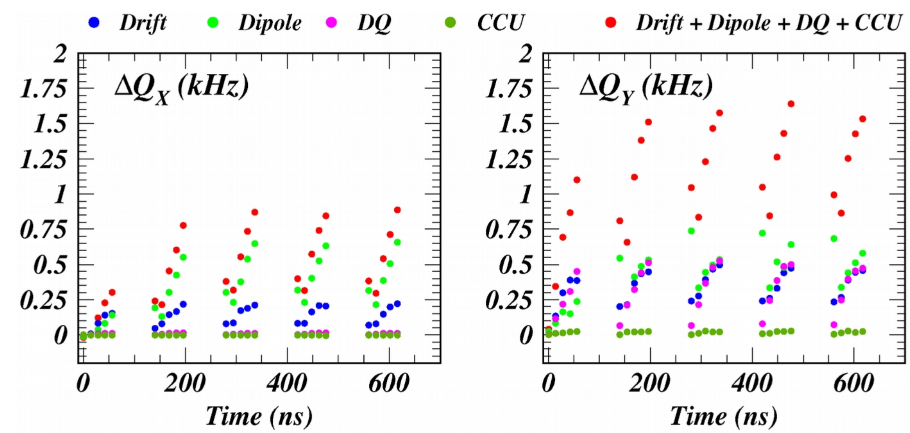
Validated Model Used to Calculate Tune Shifts Along Train in Present CHESS Operating Conditions

Presently using 4-bunch trains with 6-8-6-ns spacing



Tune Shifts Predicted for the Upgraded Ops

For 17 trains of 5 bunches each, the tune shifts are limited to values comparable to those in present operating condx

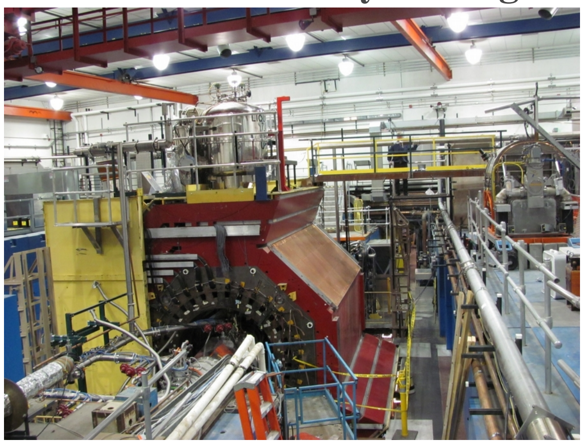


Our calculations are based on the beam-processed aluminum vacuum chamber surface properties typical of the present CESR ring, so we can conclude that special cloud mitigation techniques such as grooves or coatings will not be necessary in the new south arc region of the ring.

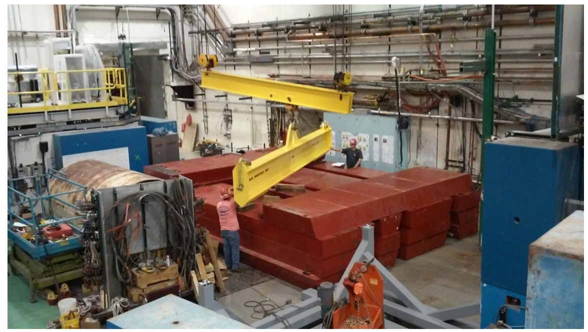
J.A. Crittenden, et al., “Electron Cloud Simulations for the Low-emittance Upgrade at the Cornell Electron Storage Ring”,
NAPAC’16, October 9-14, 2016, Chicago, IL, USA, paper TUPOB23

CLEO detector removal 2016

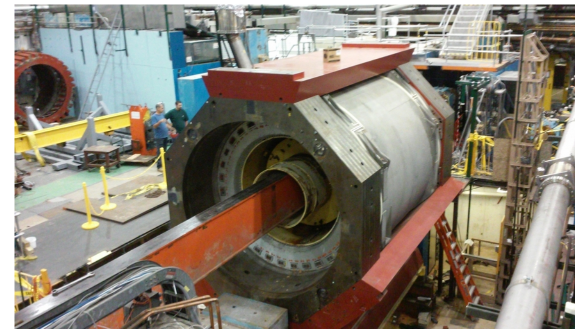
July: Final disassembly of 1000 tons of steel and crystal began



August 4: CLEO steel stockpile



August 10: Removal of crystal calorimeter

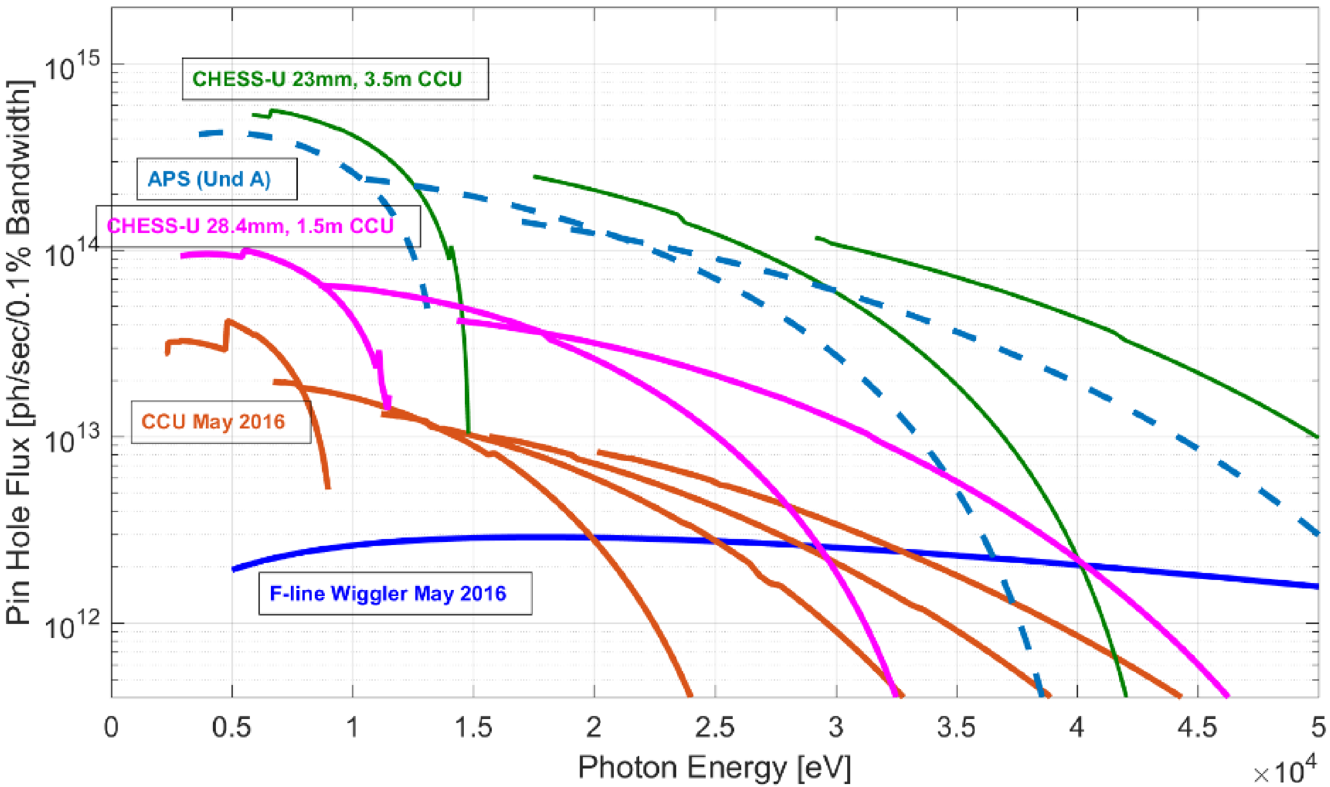


September 9: CLEO is gone

September 16: New bridge over CLEO pit

September 21: Restoring CESR

Beam brightness comparisons



Pin-hole flux [photons/sec/0.1% bandwidth]. Red lines are CHESS 1.5-m compact undulator as of May 2016. Purple lines are CHESS post-upgrade with 1.5-m compact undulator.

With a 3.5-m undulator, the CESR/CHESS upgrade pin-hole flux can be expected to exceed that of the APS with undulator A.

Operation of the upgraded CESR ring for CHESS is scheduled to begin during the summer of 2018, providing 20- to 150-keV X-ray beams for about 1300 user visits per year.