Update on the ALS-Upgrade Project

25.09.18, POCPA 2018

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BERKELEY LAB

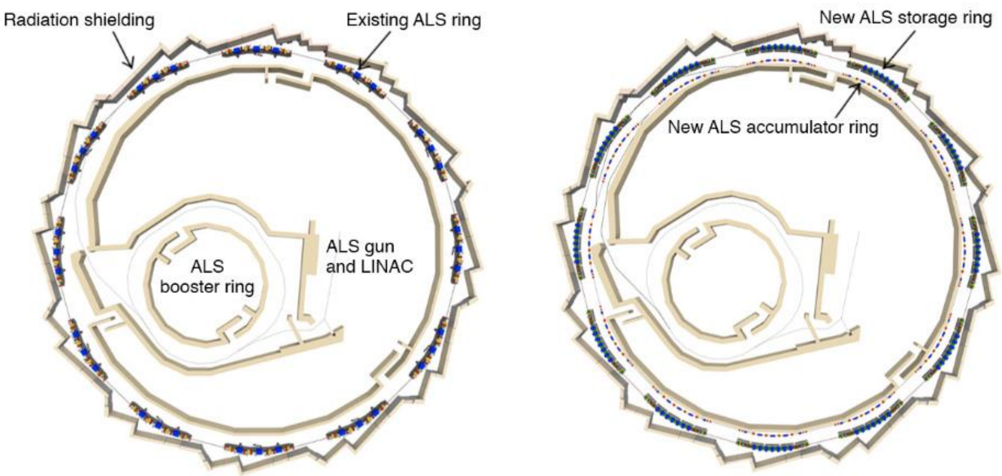
U.S. DEPARTMENT OF ENERGY | Office of Science

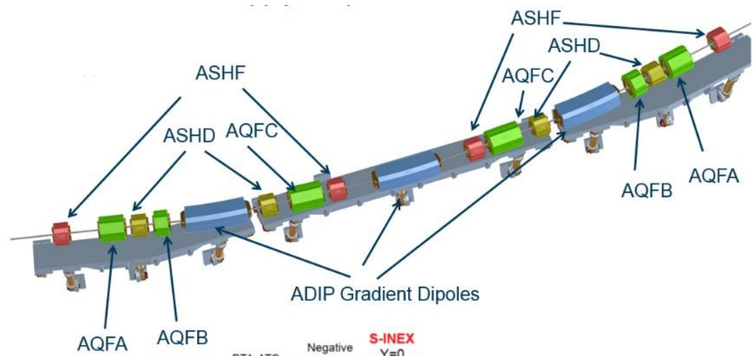
ALS-U ADVANCED LIGHT SOURCE

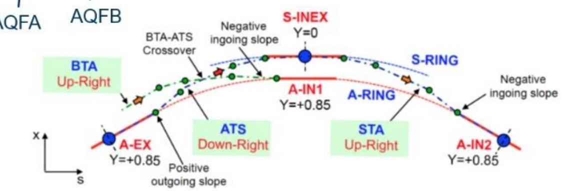
Outline

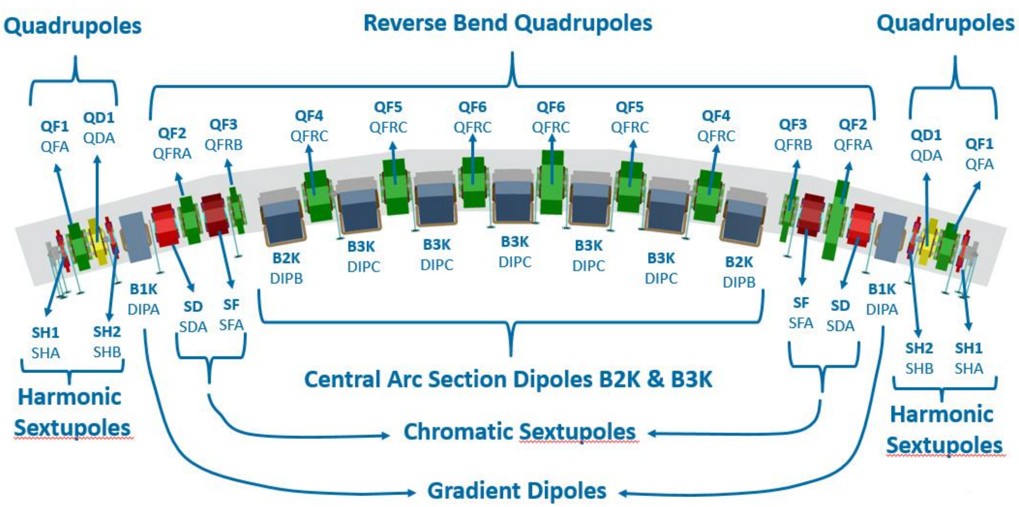
- ALS-U Overview
- Power Supply Requirements
- Power Supply Solutions
- Facilities Requirements
- Kickers
- Linac Upgrade
- Conclusions

ALS-Upgrade Overview









Replace existing ALS with a new storage ring and an accumulator ring. The source, linac and booster remain unchanged.

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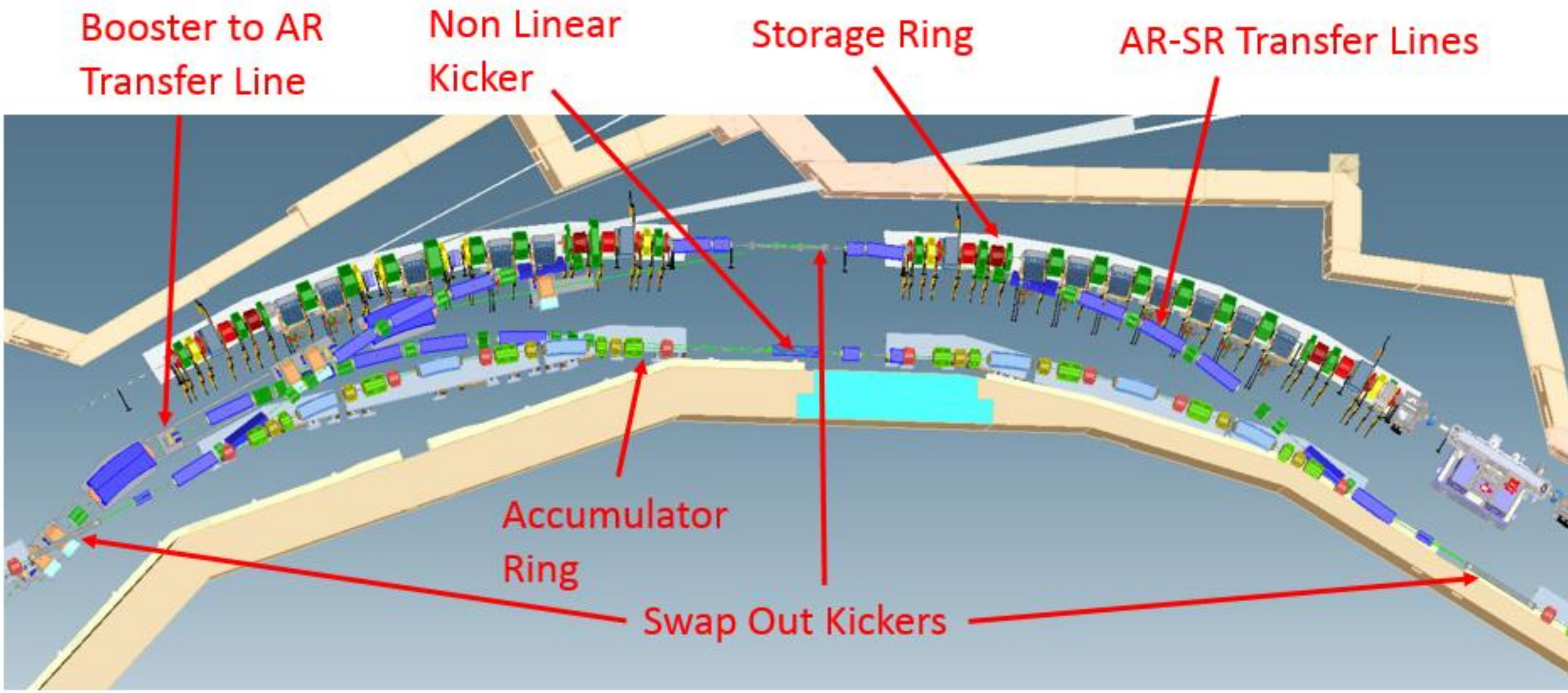
Swap-Out Injection



With the small emittance, the beam lifetime is too short for our injectors to keep up with losses. The solution (proposed by M. Borland) is to use an accumulator ring, and transfer bunches between the two rings. Requires a fast kicker and on axis injection.

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Physics and Magnet Requirements for ALS-U Power Supplies

Requirements are for the V20 reverse bend lattice.

Magnet designs are still maturing (Transfer Lines).

Need to iterate on final magnet designs to reduce cable losses and costs since some magnets have high currents and very low voltages.

Allowances for cable drops and magnet ramping are estimated.

Stability & bandwidth need to be better defined, especially if redundant supplies are used. Requirements are based on conversations with accelerator physics and calculated attenuation from the chamber to be approximately 0-3 kHz.

SR V20 RB Magnet Requirements

Magnet PS Type	Parameter	Range
Unipolar High Stability	Power	To 5 kW
	Stability	< 10 ppm
Unipolar Low Stability	Power	To 2500 W
	Stability	< 100 ppm
Bipolar Slow	Power	To 650 W
	Stability	< 100 ppm
Bipolar Fast	Power	To 330 W
	Stability	< 100 ppm

- 942 Power supplies in total for the storage ring, all magnets individually powered.
- Allowances have been made for ramping the magnets and cable drop.
- The bandwidth of the harmonic sextupole corrector coils is approximately 1 kHz.
- Some magnets have < 1 VDC at terminals, resulting in higher cost, reduced efficiency & stability. Adding turns to the coils is being investigated.
- Many of the magnets listed have similar but not exact requirements, and can likely be powered by identical supplies to reduce costs and number of spares.

AR & TL Magnet Requirements

Magnet PS Type	Parameter	Range
AR Bend, QFA, TL Bend, Quads	Power	To 250 kW
	Stability	< 10 ppm
AR Sextupoles, TL Lambertsons	Power	To 15 kW
	Stability	< 100 ppm
AR Correctors	Power	< 400 W
	Stability	< 100 ppm

- AR Dipole, QFA and sextupole magnets are in strings, all others powered individually.
- Total of 262 power supplies required for AR and TLs, 1204 for the ALS-U project.
- TL magnets are yet to be designed, and most sextupoles magnets are currently being assessed to achieve better current/voltage ratios.

Power Supply Solutions & Possible Vendors

SR Supplies

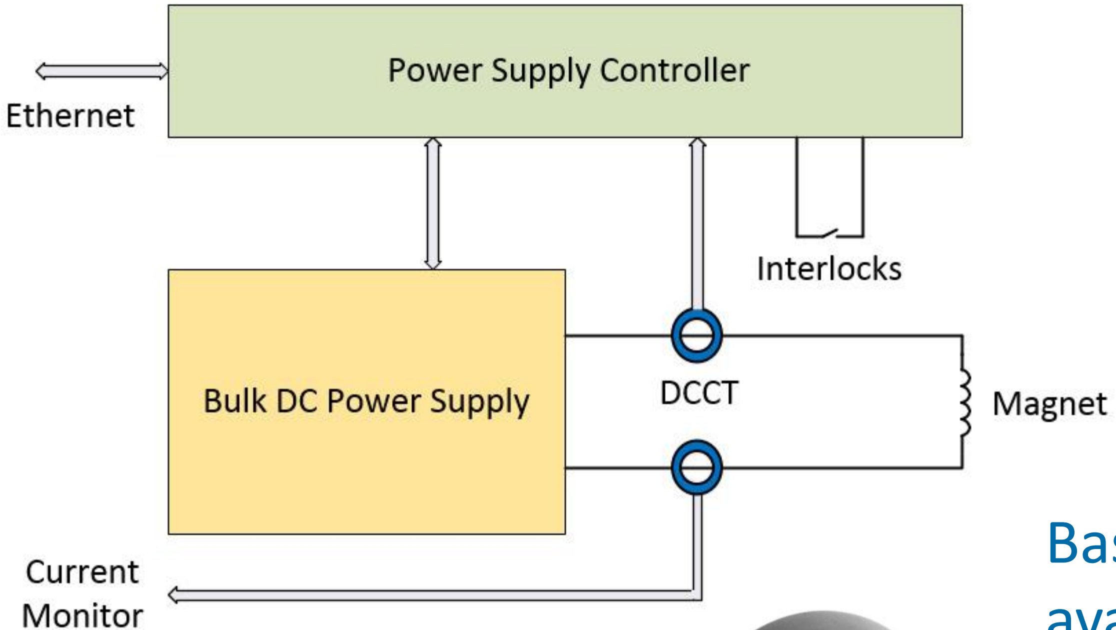
AR, TL Supplies

Proto type Magnets and Test Plan

Redundant Supplies

ALS-U SR Power Supply Design

High Stability Unipolar Supplies



Bipolar Supplies

Baseline is to use commercially available power supplies, and external controllers and DCCTs for high stability unipolar supplies. String magnet supplies will be built to spec.

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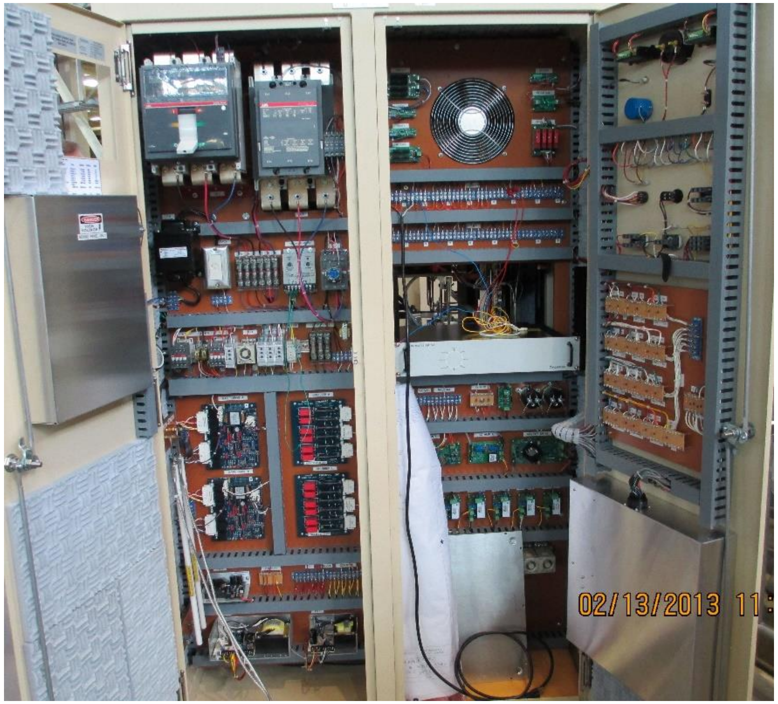
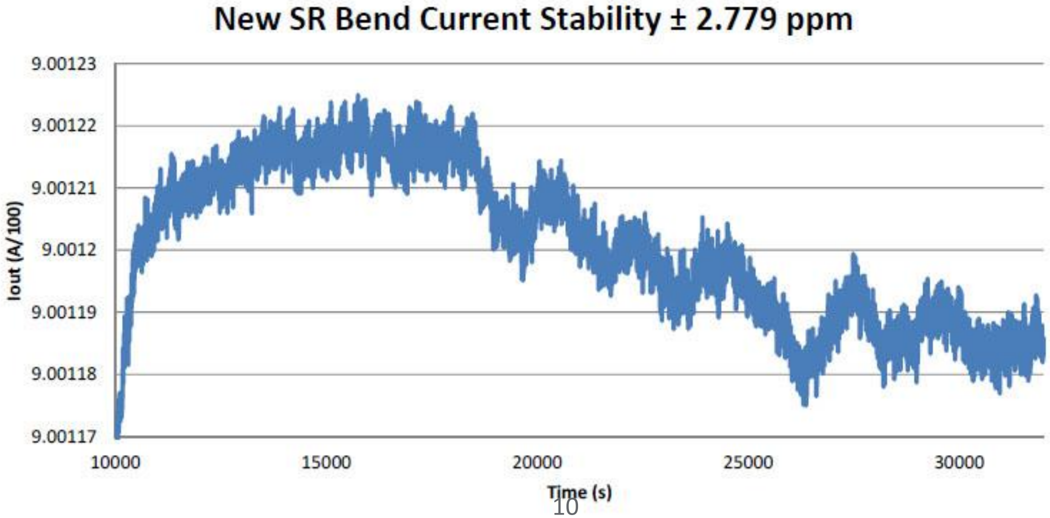
ALS-U – AR&TL Power Supply Design

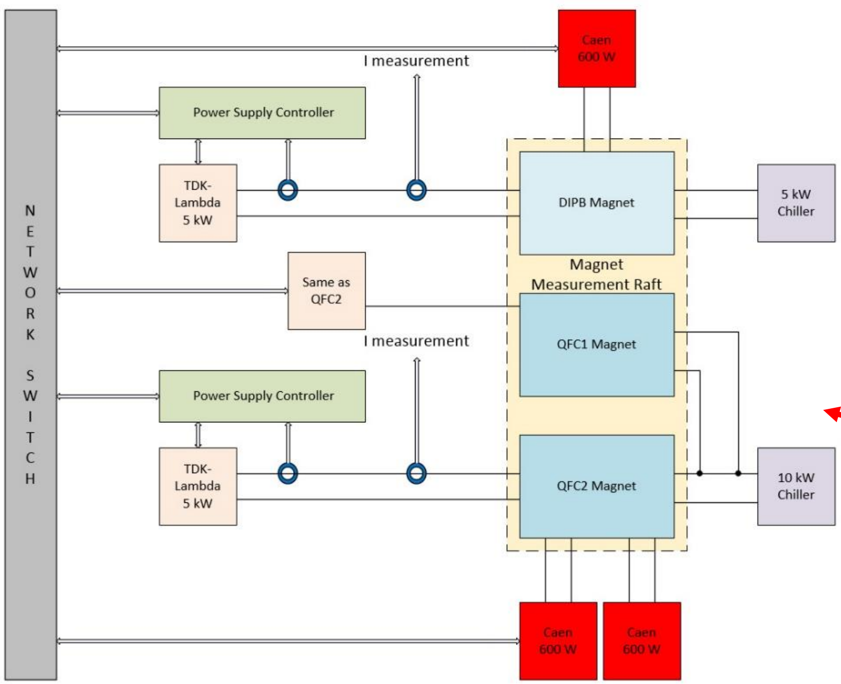


AR Bend & QFA string magnet supplies are similar to the recent QFA upgrade at ALS.

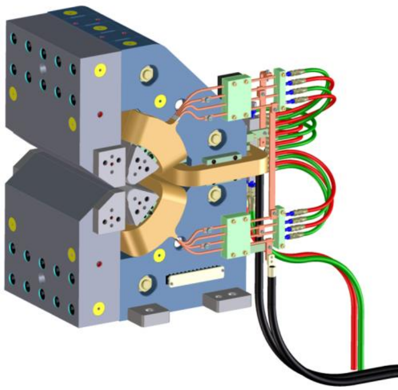


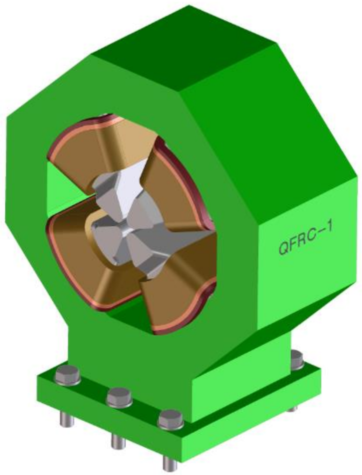
Prototyping & Magnet System Testing

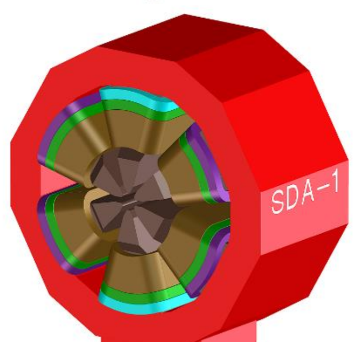
- Several magnet designs will be prototyped and system testing is planned including the power supplies.
- The large # of supplies raises concerns about reliability, plan to test redundancy and transients when one supply turns off, and ways to limit the transient.
- Also plan some prototyping of LBNL designed topologies and controllers.



A three magnet test raft is being prepared now.

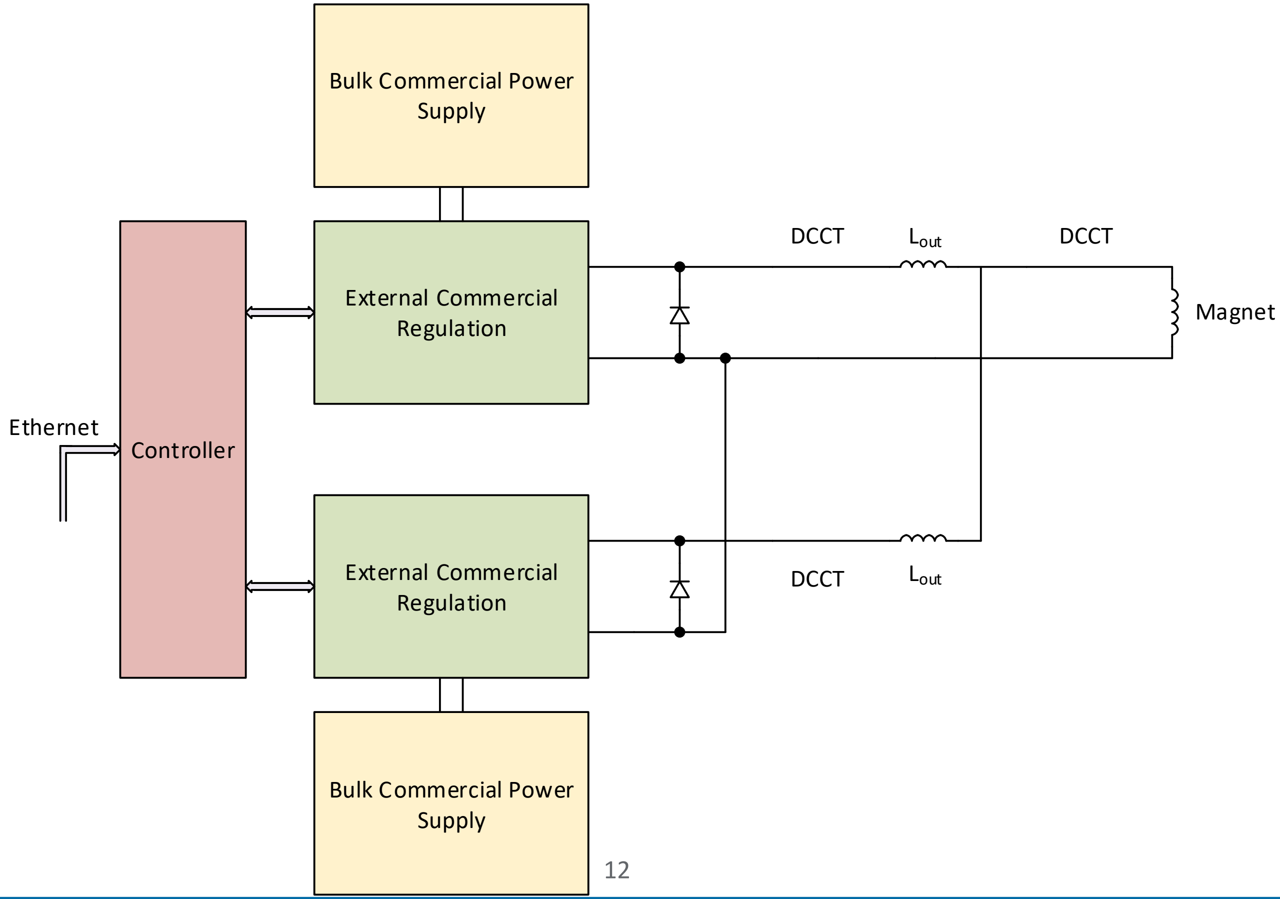






Redundant Power Supplies

- Redundancy may be required for acceptable user times. Some technique for limiting a transient in the event of one supply failing will be needed. Use of high bandwidth supplies or using an external component to limit the transient are possibilities. Cost has not been evaluated.



Infrastructure Requirements for ALS-U Power Supplies

Power Distribution

Floor & Rack Space

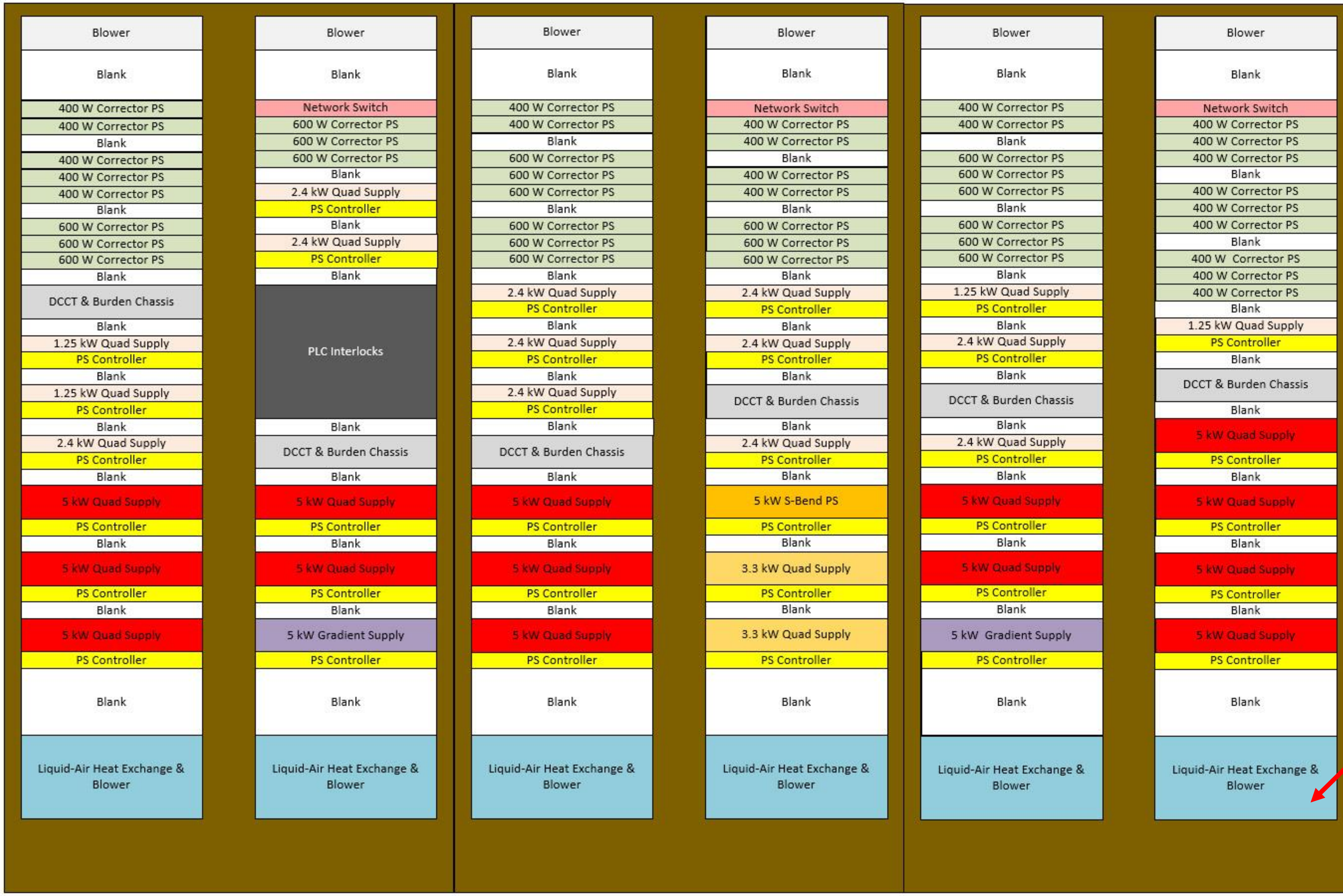
Cooling

Cabling

Power Distribution

- Total installed power requirements for the ALS-U SR magnet power supplies is approximately 1.78 MVA per sector. 560 kVA is required for the AR and TLs.
- Power for ALS is distributed in most sectors with a 480/208/120 VAC, 150 kVA transformer and switchgear, which need to be upgraded.
- ALS SR sector power is feed from a 2 MVA transformer. A 1 MVA transformer which powered “old town” can be utilized, and we can switch some loads to other banks. Also investigating upgrading to a 3 MVA transformer, which might be required as later iterations on magnet designs require higher power.

Storage Ring Rack Space Requirements



Note water cooled racks

All sectors in ALS have at least 12 racks now. Space does not appear to be an issue.

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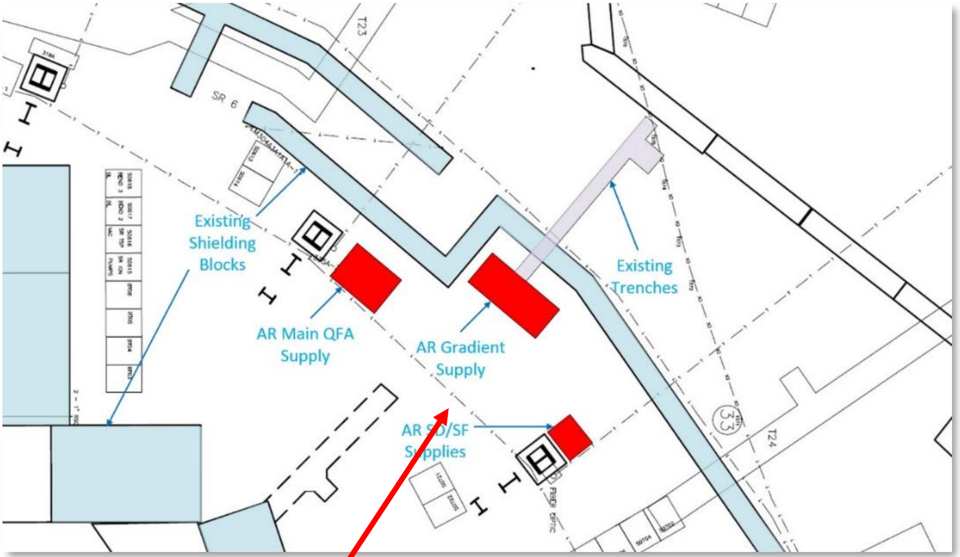
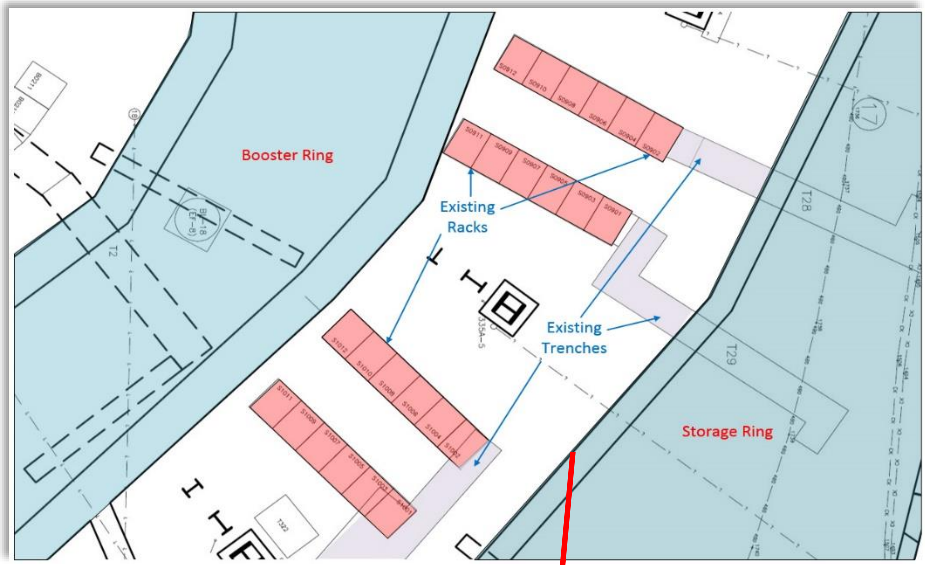
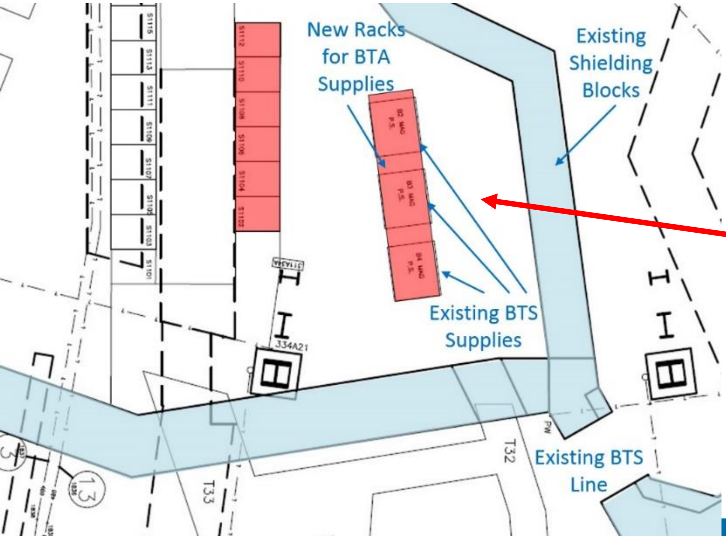
Space Requirements





Several possibilities exist for placement of the AR supplies in the existing ALS.

SR supplies will easily fit in the rack space used at the ALS. Other equipment needs are recently being considered.



Possible location for TL racks in sector 11.

Beam Injection
Injector Upgrades

AR Injection

Swap-Out Kickers

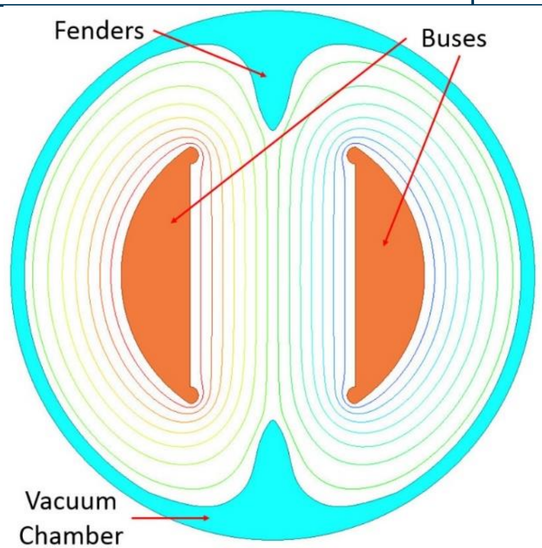
Linac Modulator Upgrade

Booster Kicker Upgrade

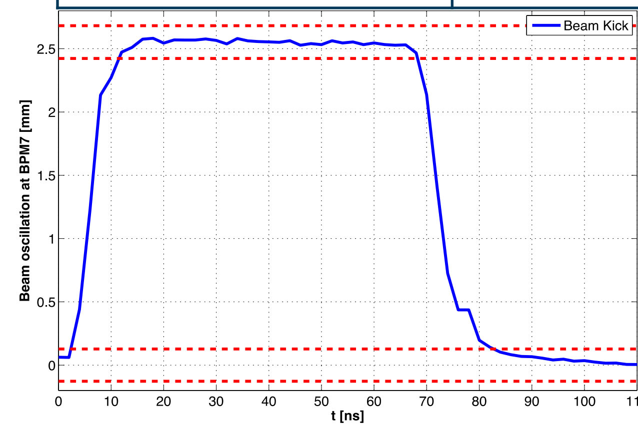
Swap-Out Kickers

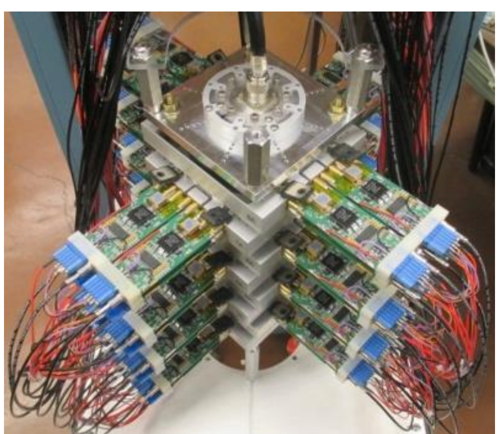
Beam Energy	2 GeV
Bend Angle	3.5 mrad
Distance Between Striplines	6 mm
Total Magnet Length (4 modules)	2 m
Stripline Length	0.5 m
Stripline Impedance	50 ohms

Load Impedance (2 parallel 50 ohms)	25 ohms
Stripline Voltage	+/- 5.25 kV
Stripline Current	+/- 105 A
Rise/Fall Time (5-95%)	7 ns
Flattop (99-99%)	50 ns
Flattop Ripple	+/- 1%
Repetition Rate	<0.1 Hz



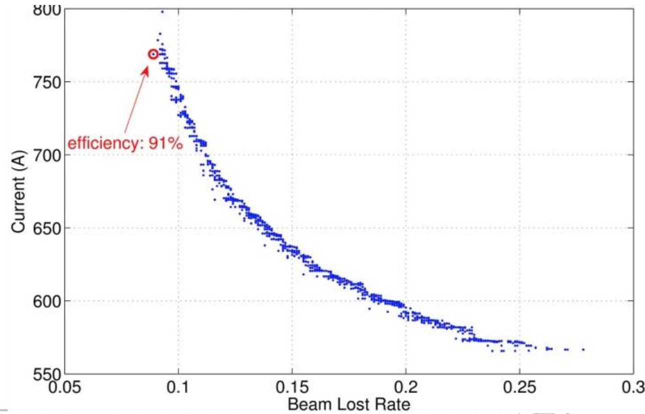
Swap-out kickers are strip line magnets driven by a SS inductive adder.

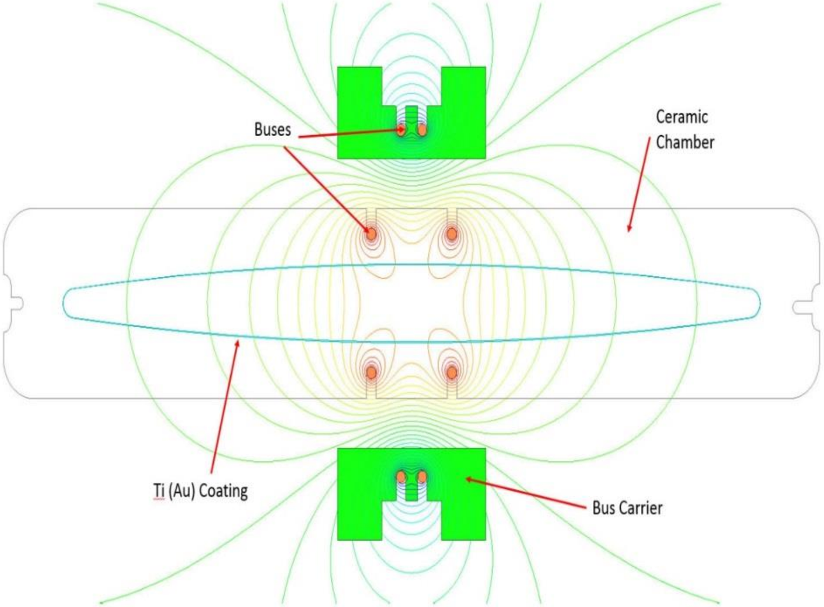


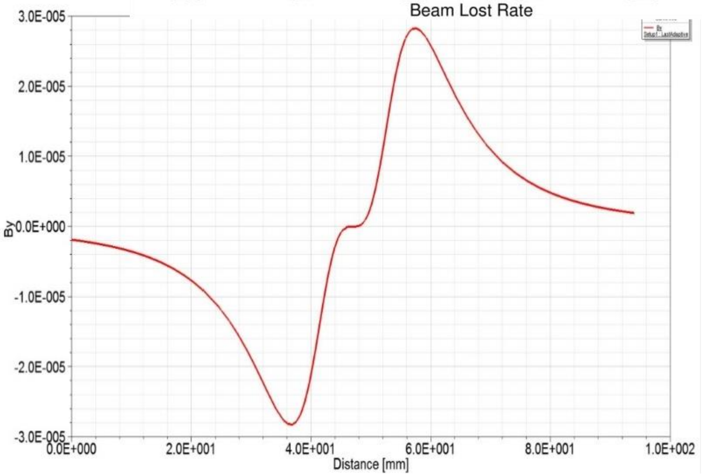


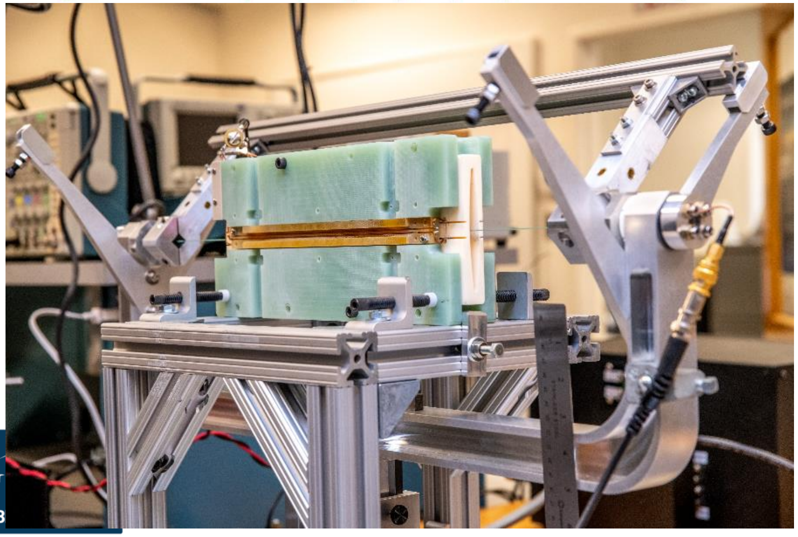
Non-Linear Kicker

Magnet geometry was optimized to give > 90 % injection efficiency using a MOGA tracking routine.





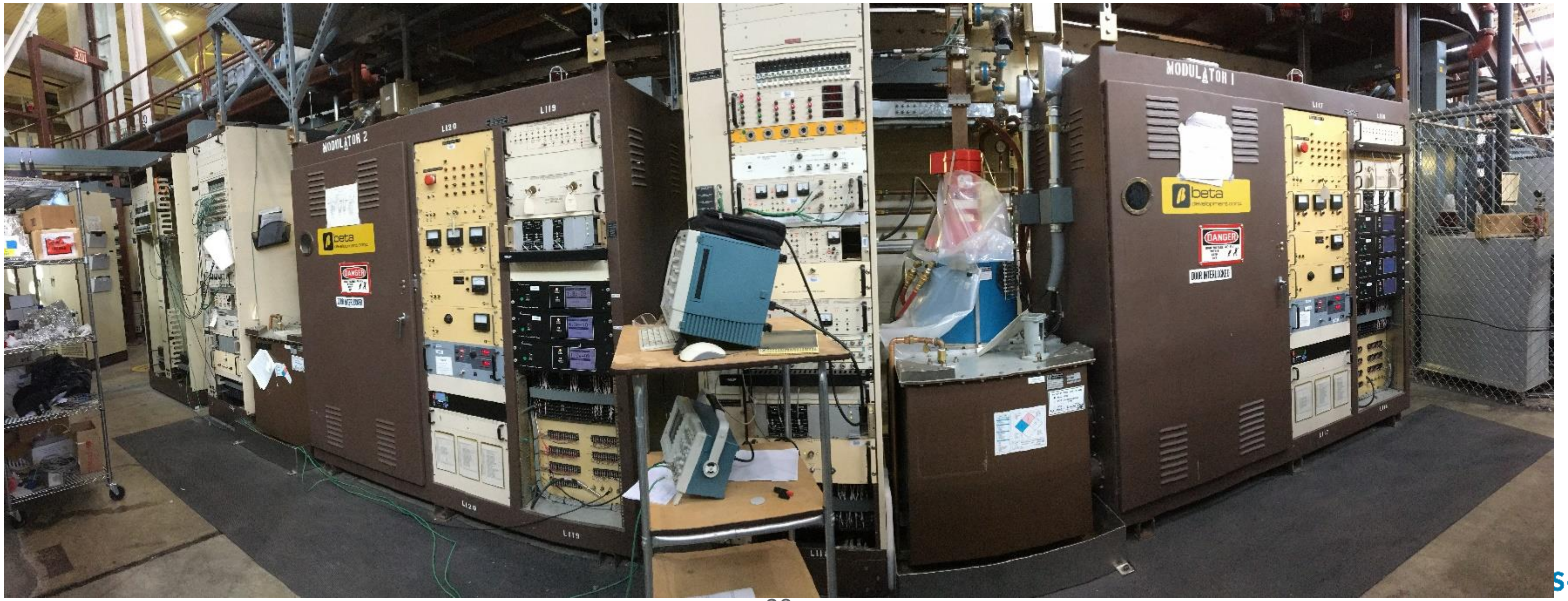




Design Parameter	Value	Units
Magnet Current	1000	A
Half Sine Width	1.3	µs
Magnet/Cable Inductance	2	µH
Charge Voltage	6	kV
PRF	1	Hz

Linac Klystron Modulator and Booster Kicker Upgrades

- We are still running from the original thyratron/PFN based klystron modulators from the 1980s for our linac.
- A specification is written and an RFP sent for a solid state replacement with modern controls.
- We also have the original thyratron/PFN based kickers for booster injection/extraction.
- Plan is to replace them with solid state inductive adders, but not beyond the conceptual design at this time.



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Conclusion

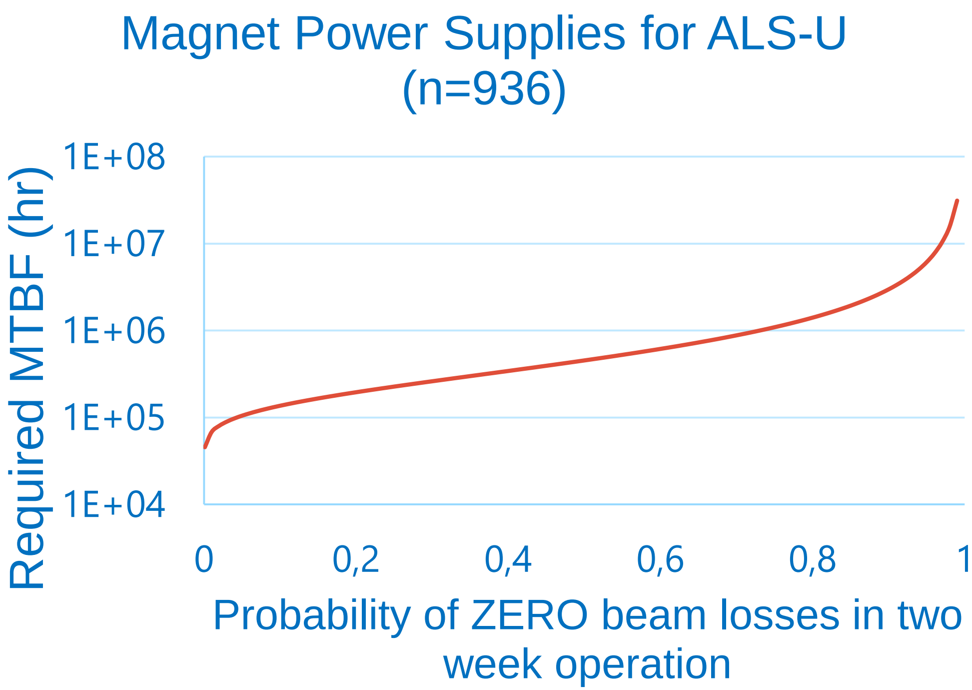
- Several options exist for storage ring magnet power supplies.
  - Use of commercially available products is the baseline, may need some R&D to achieve stability & reliability.
- There is some impact on infrastructure
  - Power distribution for SR supplies.
  - Penetrations for cabling.
  - Is cooling water adequate.
- Reliability is a concern, but experience at other labs shows it is manageable.

Backup Slides

- Possible R&D for new power supply topologies
  - Possibility of redundant supplies without switching transients when one supply fails.
  - Improved reliability and stability.
  - Lower cost and fewer spares required.
- Improved maintenance program.
- Magnet designs.

Power Supply Reliability and Availability

Is a concern, but seems manageable.



Operating at reduced power, climate control, and an robust maintenance program will all improve MTBF. Planned for ALS-U.

- TDK-Lambda publishes calculated MTBF for the Genesys series supplies in the range of 40 khr.
- ALS experience is ≈110 khr MTBF for the sextupole upgrade supplies during the past year.
- Bellomo (SLAC) reports other labs with power supply MTBF up to 1 Mhr.
- Redundancy is being considered. Could result in more beam losses from switching transient, but faster recovery.

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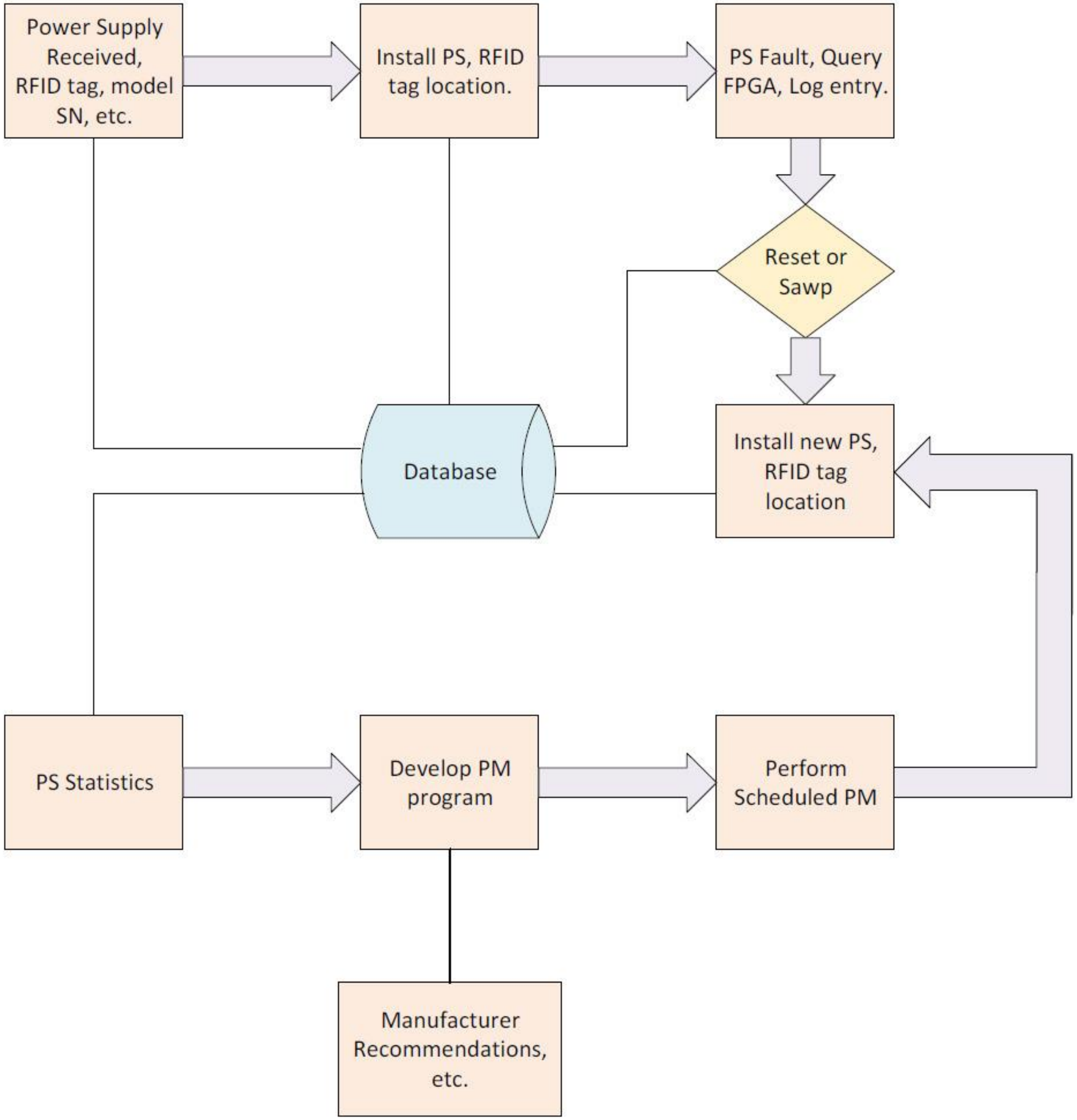
A Robust Maintenance Program

Need to find better way to keep reliability statistics than used at ALS. The diagram shows tracking of all supplies from installation, and would automatically update a database for each failure or maintenance. Idea is for the system to learn to predict when maintenance is needed.



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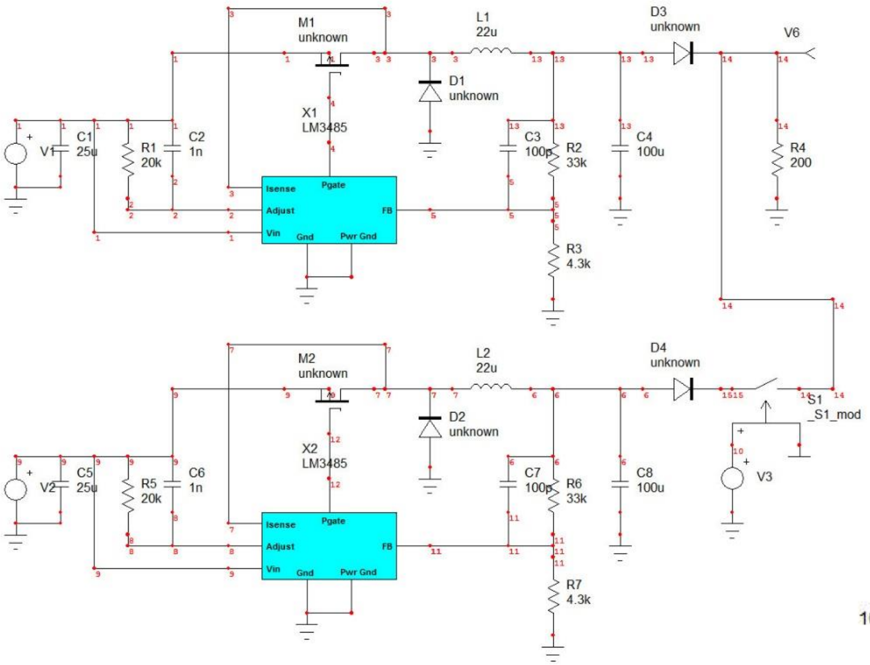
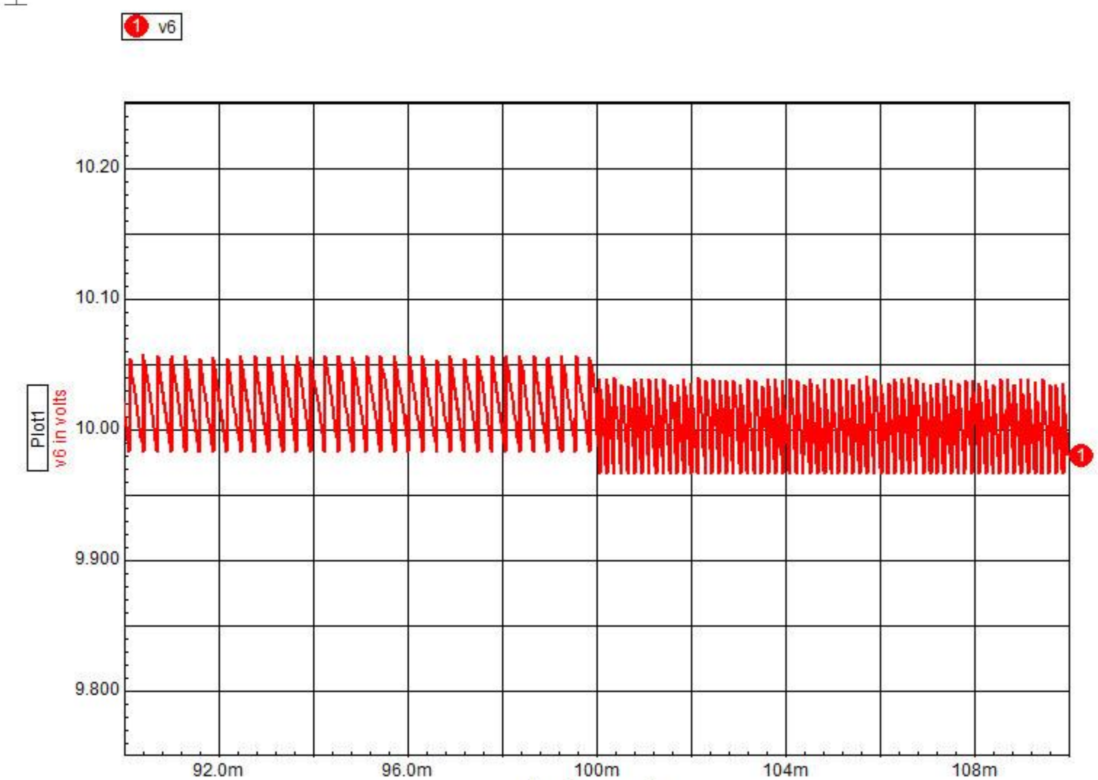
Redundant Supplies

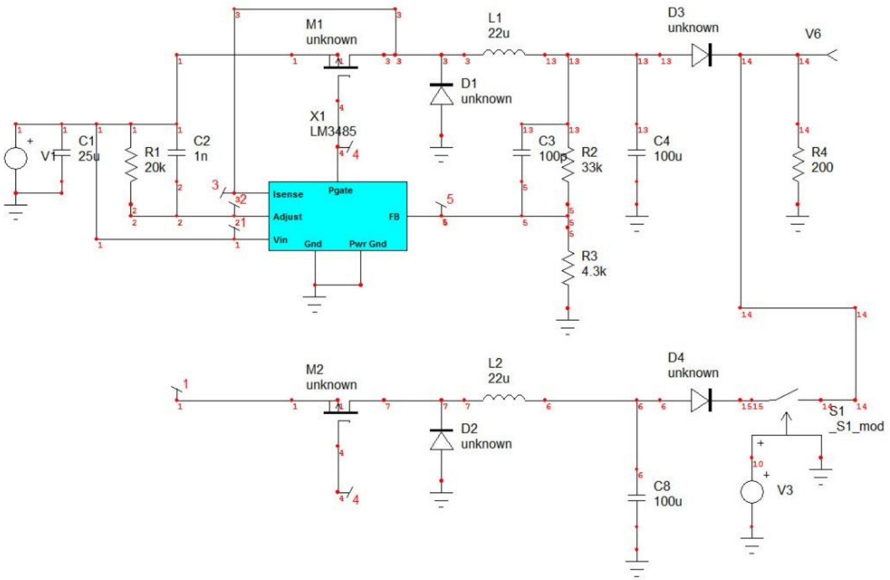


Simply using redundant supplies could essentially double the number of events where beam is lost, although it would improve recovery time.



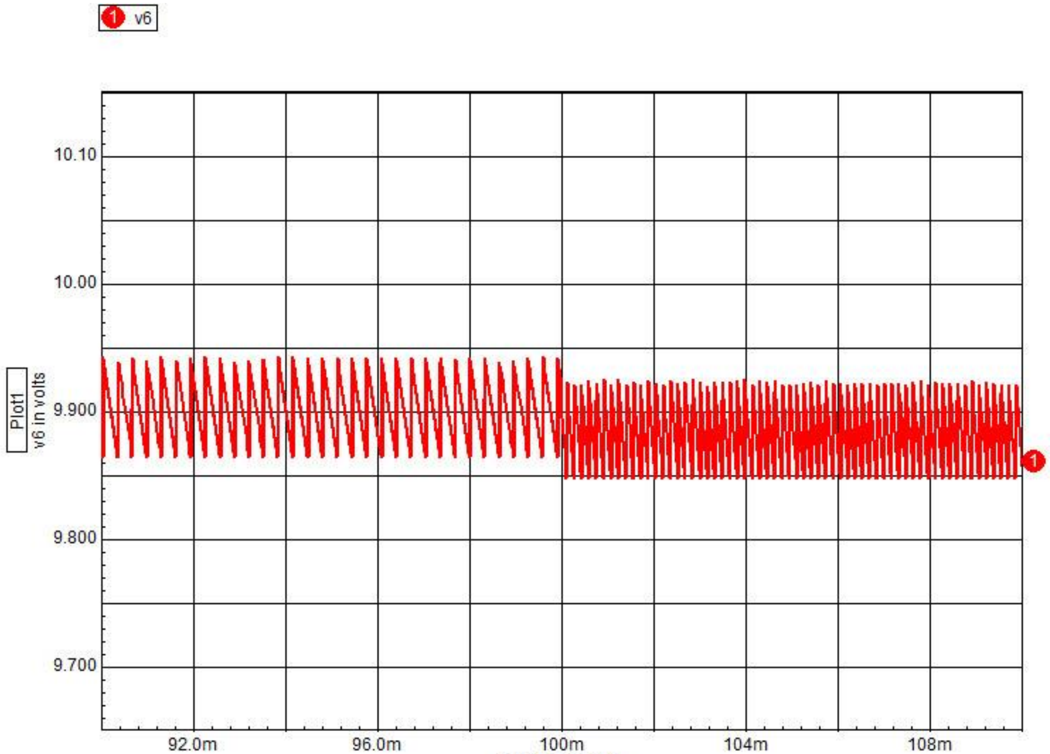
Bottom supply faults, beam is lost.

Master-Slave Supplies



Even when operating in a master slave arrangement, a large transient is generated when the bottom supply faults.

In both above cases, the transient can be limited by adding an inductor to the output of each supply.



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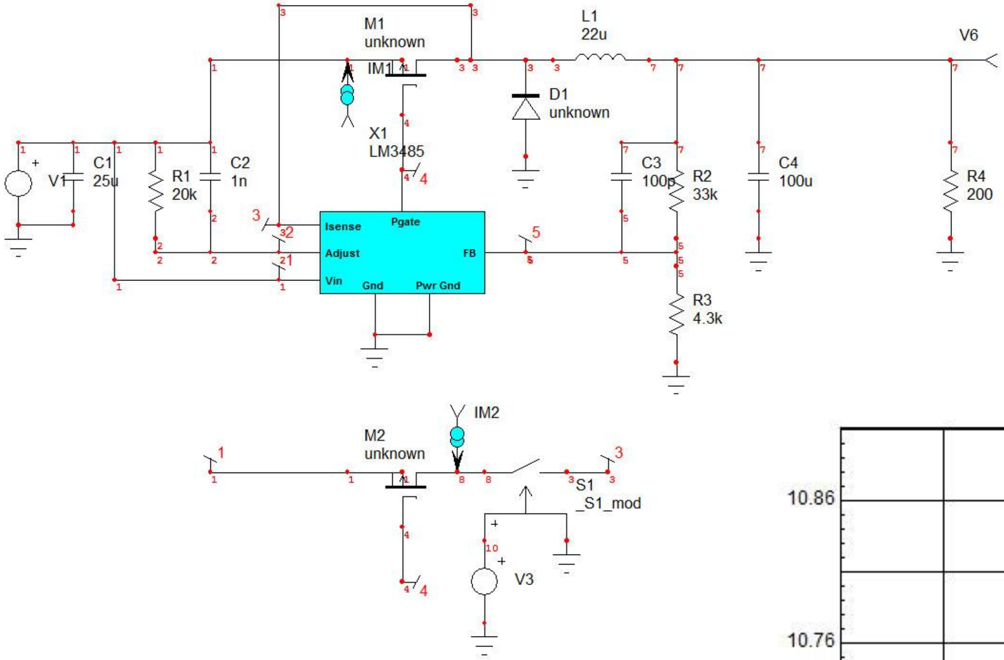
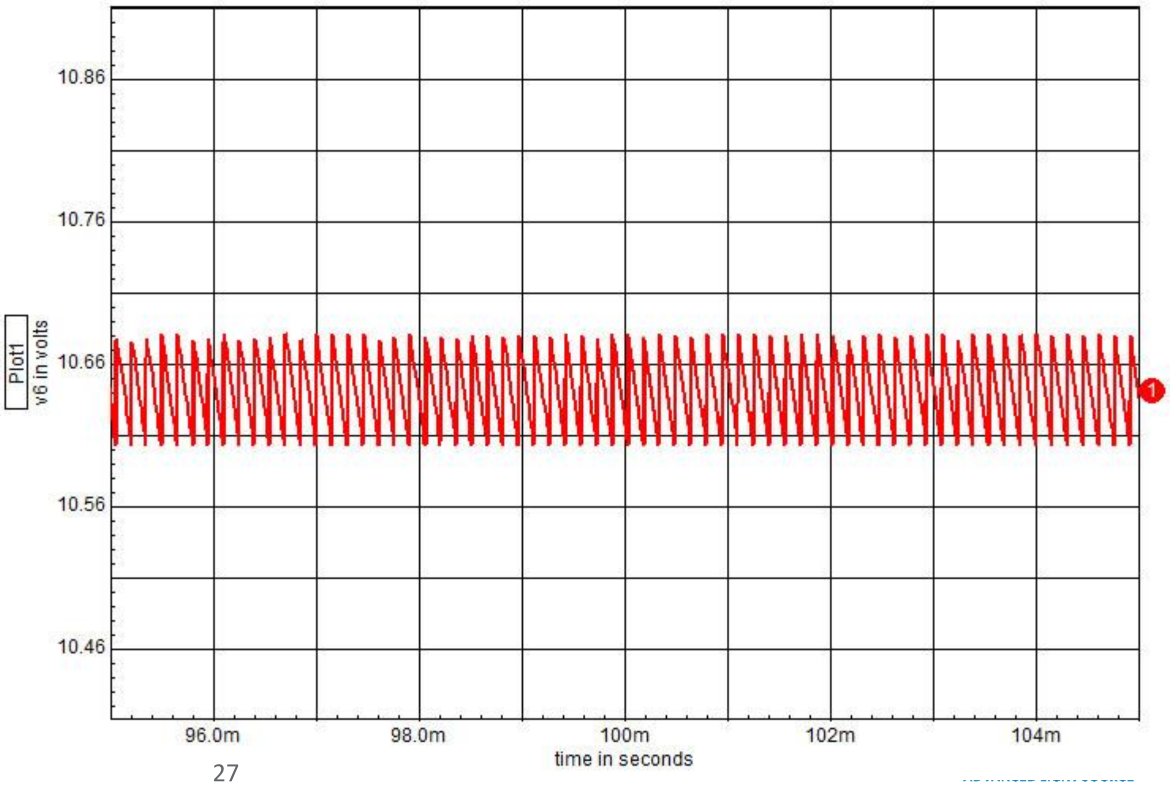
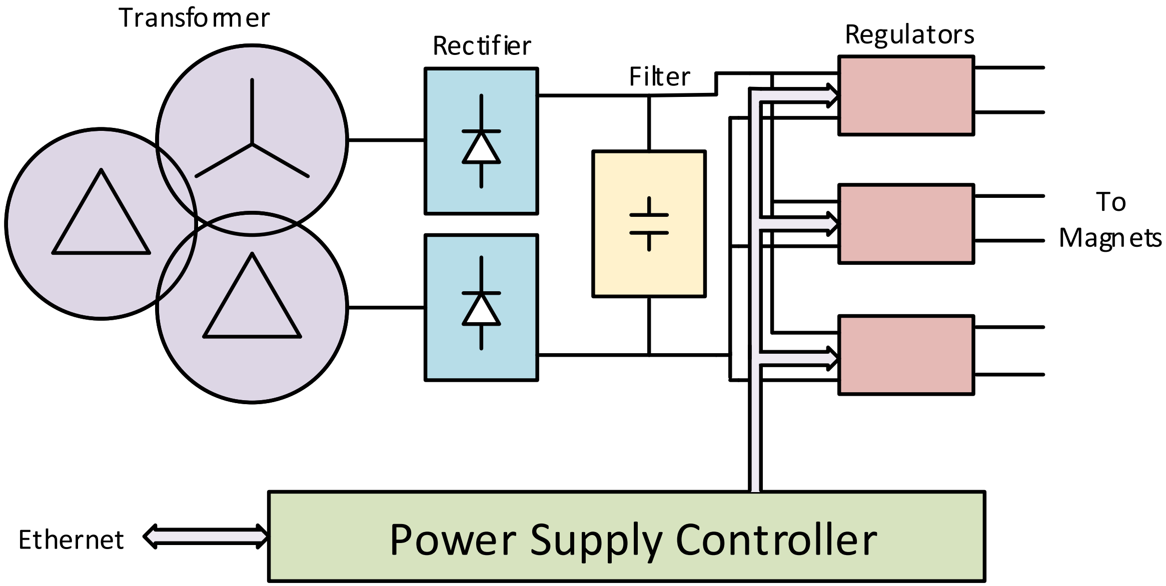
Redundancy Built into Supply



In order to minimize the fault transient of a redundant system, the redundancy should be at the component level in the supply.

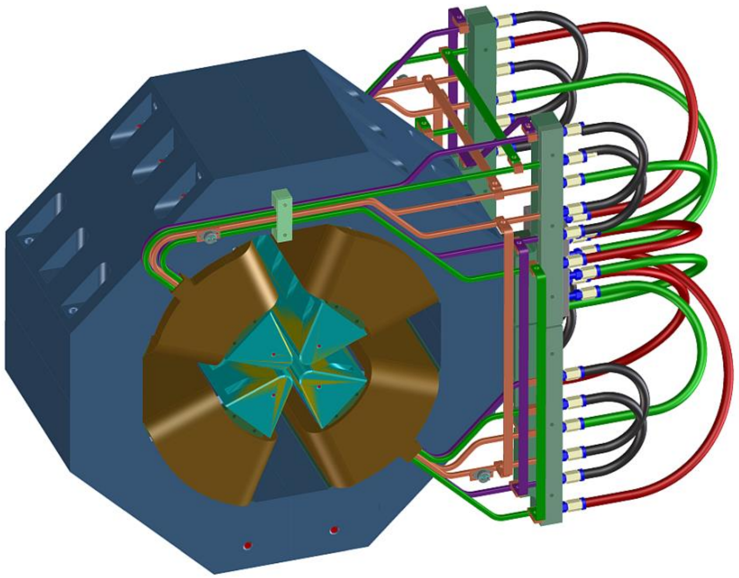


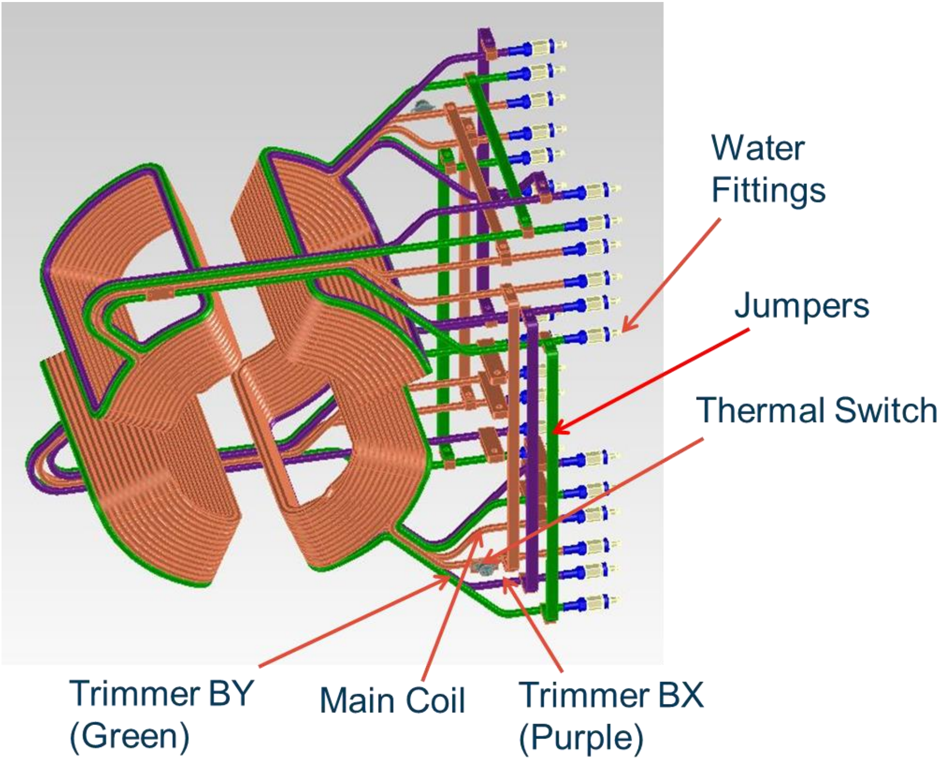
LBNL Designed Supplies?



- Use a single bulk for each sector-reduces part count & improves reliability.
- Build redundancy at component level in the DC-DC converters-reduces transient.
- Use a common building block for every supply-reduces cost, fewer spares required.
- Interleaving of PWM-reduces cost & ripple and improves transient response by increasing switching frequency.
- Controller will require an R&D effort.

Example Corrector Coil Engineering





- The corrector coils are integrated into each coil assembly.
- Design is a compact clean package.
- Allows for static and slow corrections.

Leads to low voltages because insulation reduces packing factor with higher # of turns

V20R Harmonic Sextupoles Exceed Physics Specifications

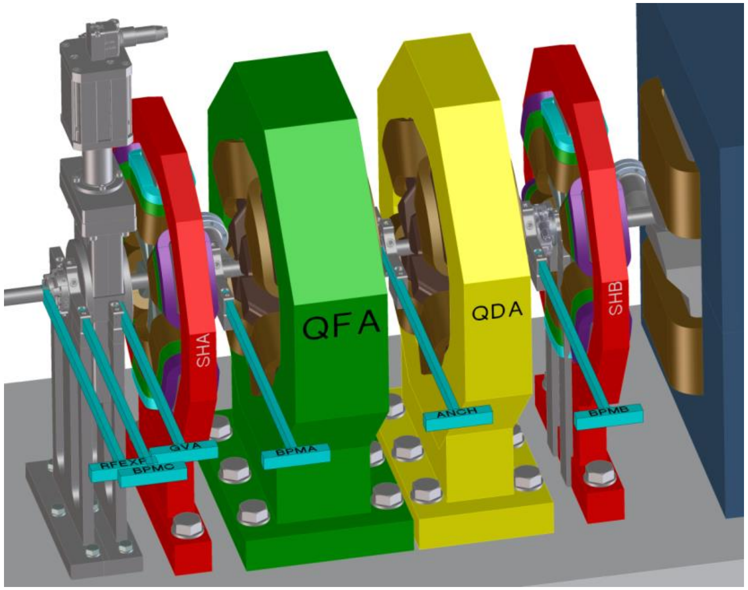
V20R Lattice Specifications

AP Attribute /Magnet	SH1	SH2
CAD Attribute /Magnet	**SHA**	**SHB**
Grad [K/Brho]	38.86	-578.19
Beam Path Length [m]	0.075	0.075
Working Pole Length [m]	0.055	0.055
Sextupole [T/m^2]	259.2	-3857.3
Sextupole Integral [T/m]	19.44	-289.30

Corrector Coil Specifications

AP Attribute /Magnet	SH1	SH2	
CAD Attribute /Magnet	**SHA**	**SHB**	Circuit
Skew Quad Corr Integral [T]	0.14	0.14	Slow
"x" Orbit Bump Correction [mRad]	0.81	0.81	Slow
"y" Orbit Bump Correction [mRad]	0.81	0.81	Slow
"By" Orbit Bump Corrector Field [G]	978.19	978.19	Slow
"Bx" Orbit Bump Corrector Field [G]	978.19	978.19	Slow
Chicane "x" Kick Angle [mrad]	1.25	0.00	Slow
Chicane "B_y" Kick Field [G]	1111.88	0.00	Slow
"x" Corrector Spec [mRad]	0.20	0.20	Fast
"y" Corrector Spec [mRad]	0.20	0.20	Fast
"B_x" Corrector Spec [G]	242.59	242.59	Fast
"B_y" Corrector Spec [G]	242.59	242.59	Fast
"X" Combination Kick [mRad]	2.26	1.01	Total
"Y"Combination Kick [mRad]	1.01	1.01	Total
"B_y" Corrector Combination [G]	2736.99	1220.79	Total
"B_x" Corrector Combination [G]	1220.79	1220.79	Total

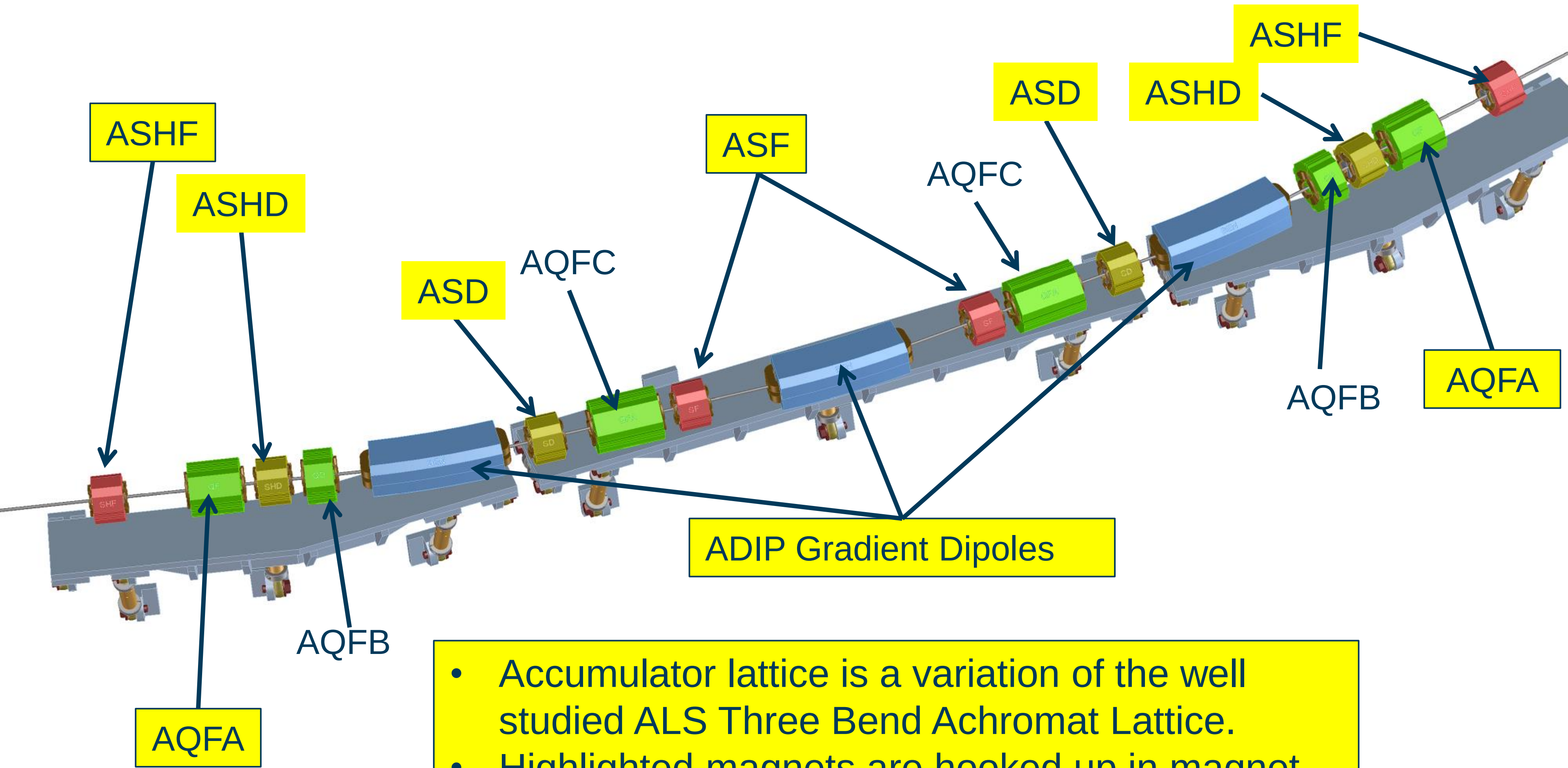
Twiss Matching Section



- **Developed a compact design meeting spec, using a bonded Co Fe alloy laminate.**
- **Design utilizes a 45 mm pole length.**
- **SH1 and SH2 windings will be different to satisfy different sextupole and corrector coil requirements.**
- **Compact design will allow further optimization of Twiss section potentially improving lattice.**

ARC Sector Magnets for Accumulator Ring

(AB.02.04.02) Accumulator Ring Magnets

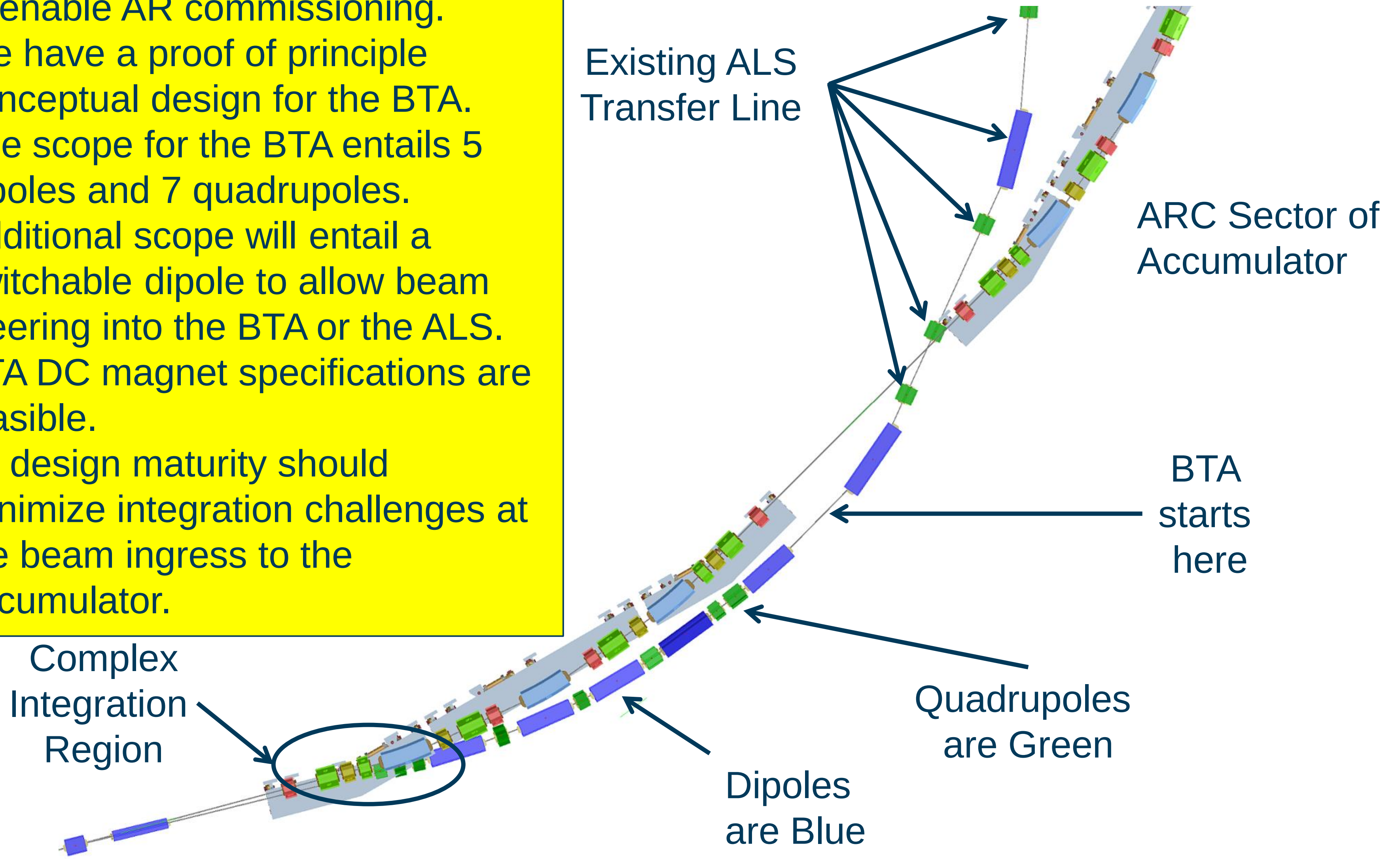


- Accumulator lattice is a variation of the well studied ALS Three Bend Achromat Lattice.
- Highlighted magnets are hooked up in magnet strings onto a common power supply.

Booster to Accumulator Transfer Line

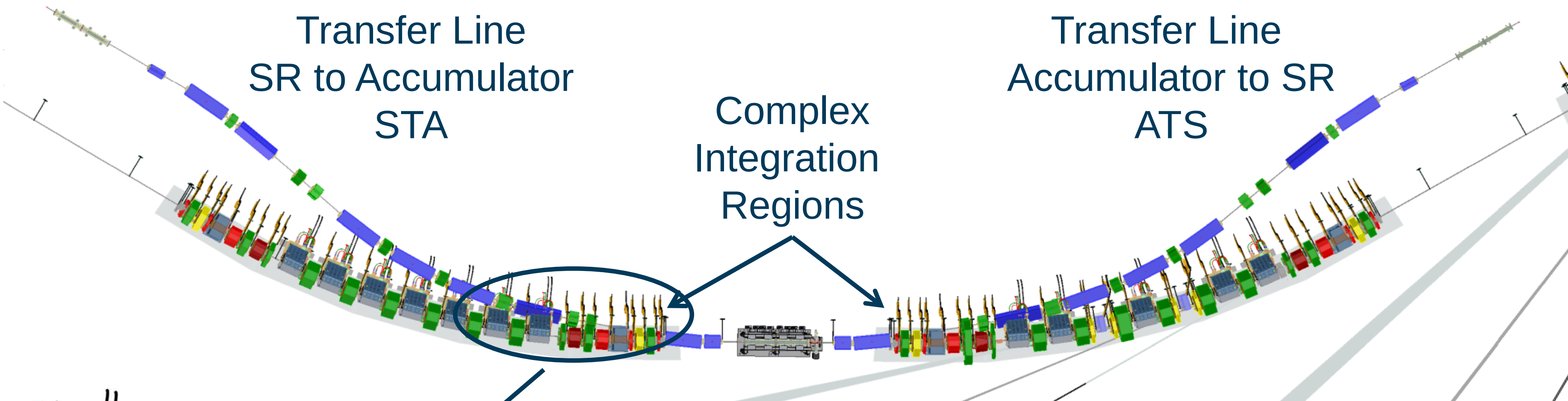
(A.B.02.06.02) Booster to Accumulator Transfer Line

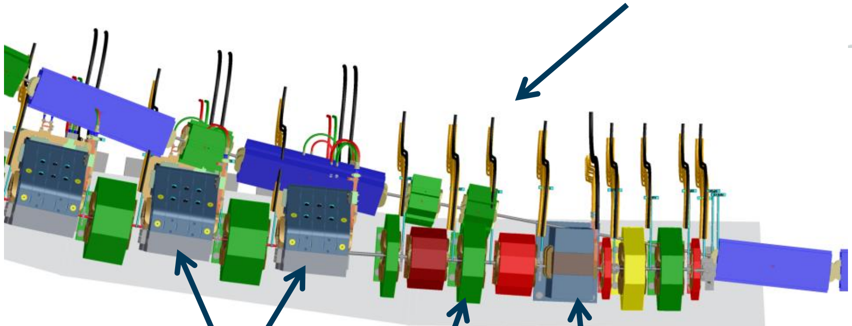
- The BTA will need to installed early to enable AR commissioning.
- We have a proof of principle conceptual design for the BTA.
- The scope for the BTA entails 5 dipoles and 7 quadrupoles.
- Additional scope will entail a switchable dipole to allow beam steering into the BTA or the ALS.
- BTA DC magnet specifications are feasible.
- TL design maturity should minimize integration challenges at the beam ingress to the accumulator.



Injection Extraction & ARC Sector Magnets for V20RS
Illustration of Evolving Subdivision

(AB.02.05.02) Storage Ring Magnets, (AB.02.06.02) Transfer Line Magnets

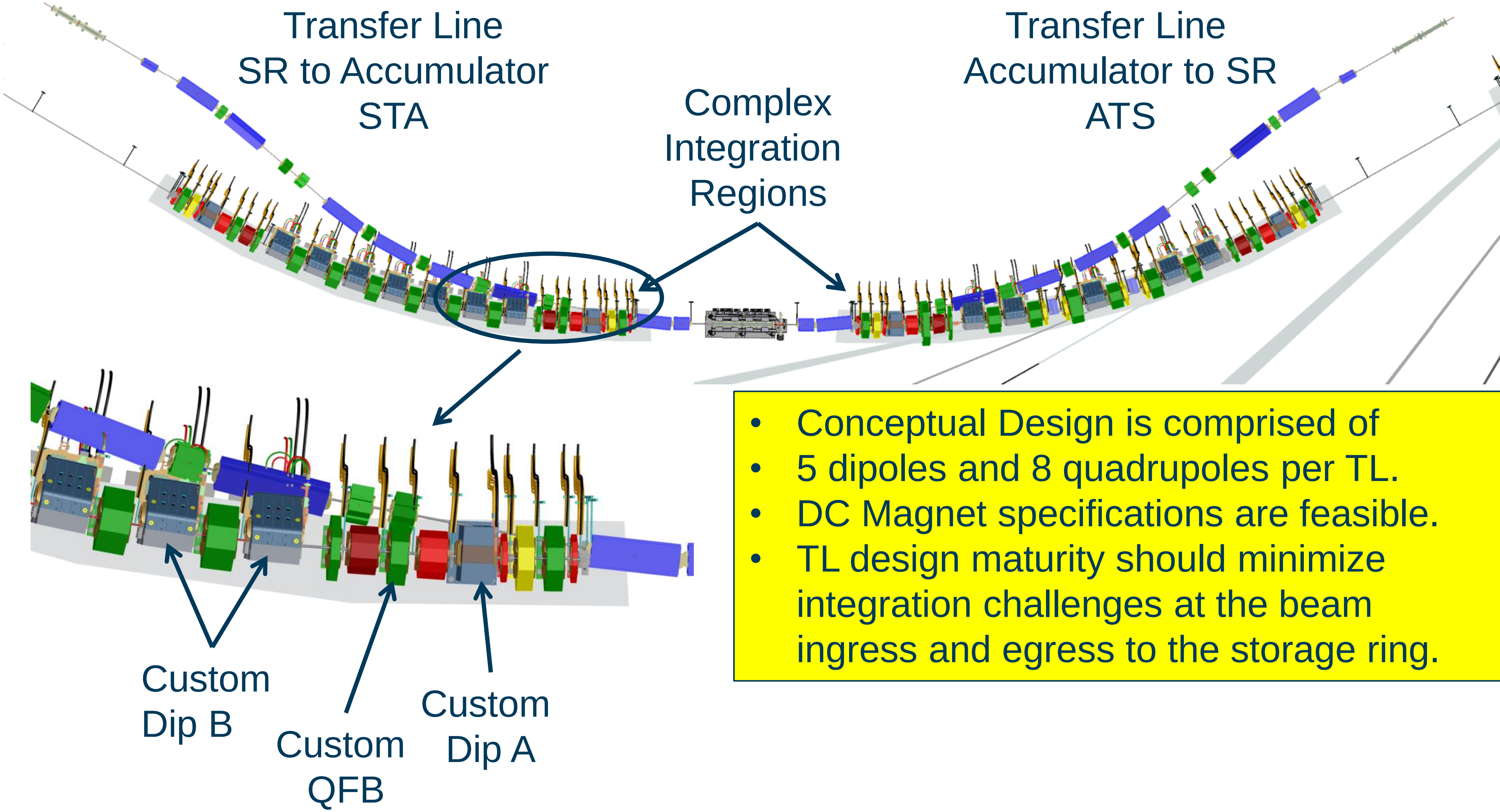




- Conceptual Design is comprised of
- 5 dipoles and 8 quadrupoles per TL.
- DC Magnet specifications are feasible.
- TL design maturity should minimize integration challenges at the beam ingress and egress to the storage ring.

Injection Extraction & ARC Sector Magnets for V20RS Illustration of Evolving Subdivision

(AB.02.05.02) Storage Ring Magnets, (AB.02.06.02) Transfer Line Magnets



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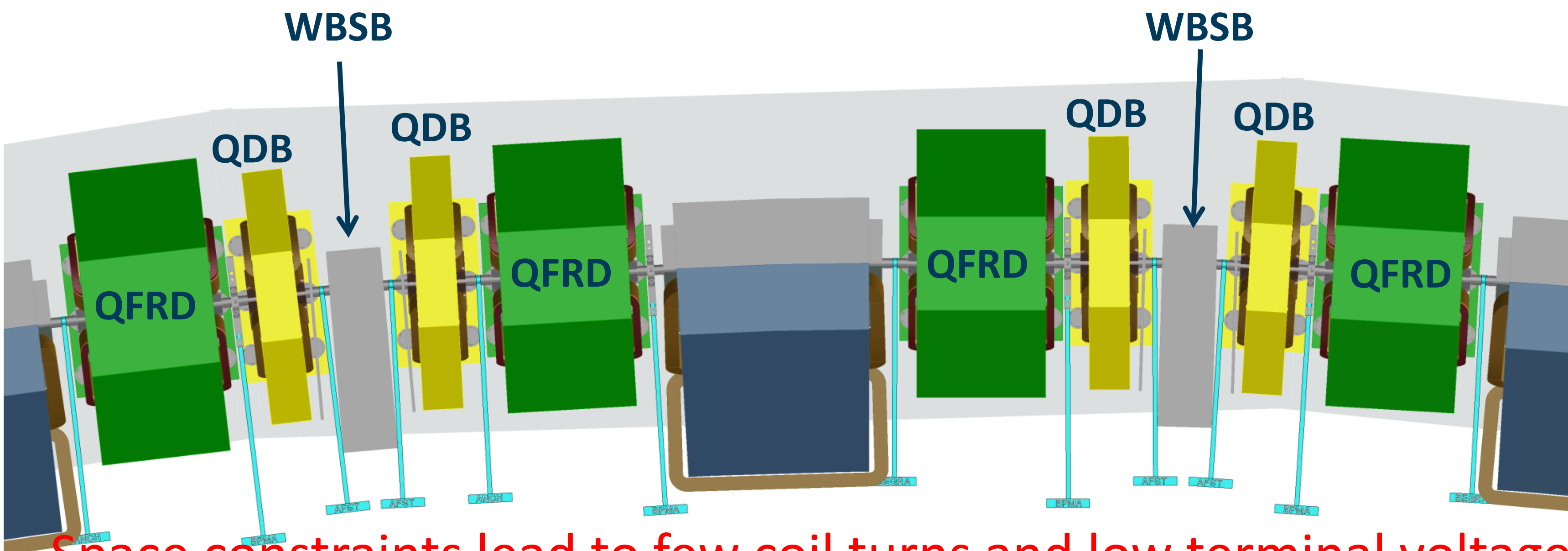
Super Bend Description in Lattice



Space constraints lead to few coil turns and low terminal voltages.

SB ASSY Magnets

- QFRD: 335 mm, $\dot{B}_{eff} = 108\frac{T}{m}, \int = 36.2\ T$
- QDB: 132 mm, $\dot{B}_{eff} = 100\frac{T}{m}, \int = 13.4\ T$
- WBSB: Multiple requirements. (See next few pages)
- QDB: 132 mm, $\dot{B}_{eff} = 100\frac{T}{m}, \int = 13.4\ T$
- QFRD: 335 mm, $\dot{B}_{eff} = 108\frac{T}{m}, \int = 36.2\ T$

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