Damping Rings Baseline Magnet and Power Supply Designs and EDR Planning

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Outline

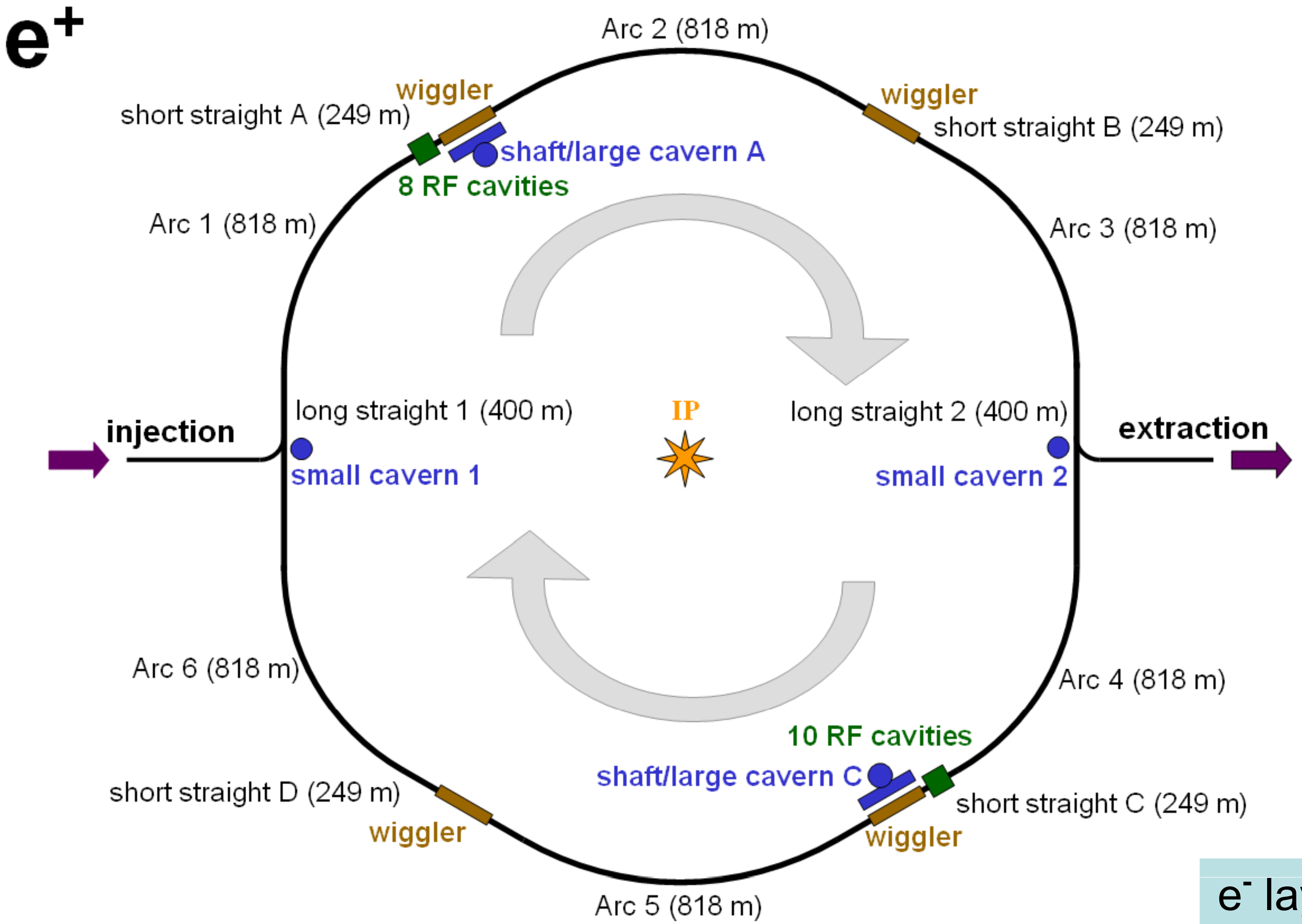
- Overview
- System Requirements
- Reference Design &
  Developments since the RDR
- EDR Planning

Overview

- Scope of this talk
    - DC ring magnets
    - Damping wigglers
    - DC Power system
    - Pulsed magnets and power supplies will be covered separately
- In general, conventional magnet specifications for the damping rings are not terribly different from those for light sources
    - **But field quality requirements are typically more stringent than for other ILC Area Systems**
- Special challenges do exist, for example:
    - **Large aperture damping wigglers**
    - **Size of ring**

Magnet Requirements

- System specifications based on OCS6 TME Lattice



e⁻ layout similar

ILC Magnet Summary Table
250Gev X 250Gev - Final Costing

LOOK HERE for DR Summary

Magnet Type	Grand Totals		Sources			Damping Rings			2 RTML		2 Linacs		2 BeamDel	
	Styles	Quantity	Styles	e- Qty	e+ Qty	Styles	e- DR Qty	e+ DR Qty	Styles	Qty	Styles	Qty	Styles	Qty
Normal Conducting Dipole	22	1356	6	25	157	2	129	129	6	716	0	0	8	190
Normal Conducting Quad	37	4182	13	93	871	4	759	759	5	1368	0	0	15	204
Normal Conducting Sextupole	7	1050	2	0	32	2	480	480	0	0	0	0	3	10
Normal Cond Solenoid	3	50	3	12	38	0	0	0	0	0	0	0	0	0
Normal Cond Corrector	9	4047	1	0	871	3	540	540	4	2032	0	0	1	64
Pulsed/Kickers/Septa	11	227	0	0	19	5	68	68	1	52	0	0	5	64
NC Octupole/Muon Spoilers	3	8	0	0	0	0	0	0	0	0	0	0	3	8
Room Temperature Magnets	*92*	*10920*	*25*	*130*	*1988*	*16*	*1976*	*1976*	*16*	*4168*	*0*	*0*	*35*	*540*
Superconducting Quad	16	715	3	16	51	0	0	0	0	56	3	560	10	32
Superconducting Sextupole	4	12	0	0	0	0	0	0	0	0	0	0	4	12
Superconducting Octupole	3	14	0	0	0	0	0	0	0	0	0	0	3	14
Superconducting Corrector	14	1374	0	32	102	0	0	0	0	84	2	1120	12	36
Superconducting Solenoid	4	16	1	2	2	0	0	0	1	8	0	0	2	4
Superconducting Wiggler	1	160	0	0	0	1	80	80	0	0	0	0	0	0
Superconducting Undulator	1	42	1	0	42	0	0	0	0	0	0	0	0	0
Superconducting Magnets	*43*	*2333*	*5*	*50*	*197*	*1*	*80*	*80*	*1*	*148*	*5*	*1680*	*31*	*98*
Overall Totals	**135**	**13253**	**30**	**180**	**2185**	**17**	**2056**	**2056**	**17**	**4316**	**5**	**1680**	**66**	**638**

Overall Magnet Totals

250Gev X 250Gev - Final Costing

Category	*Styles*	*Totals*
Total Normal Conducting	92	10920
Total Superconducting	43	2333

This table summarizes the quantities of magnets as the ILC beamlines were configured in the Reference Design Report. These quantities are changing.

Ring Magnet Requirements I

- Dipoles
  - 2 physical styles for ring
  - Use an RTML style for inj/ext/abort lines (3 dipoles/ring)
- Quadrupoles
  - 34 families in OCS6 lattice
  - Estimate 4 physical styles required – detailed vacuum design required to finalize
  - 2 basic physical styles costed (distinguished by field strength requirements)
  - Use DR high field quads for inj/ext/abort lines (12 quads/ring)
  - Individual control for tuning ring
- Sextupoles
  - 4 families in OCS6 lattice
  - 1 physical style
- Correctors
  - H & V dipoles
  - Skew quadrupole
- Wiggler
  - Superconducting

Type	No.	Power method
Dipoles (6 m)	114	6 strings[a)]
Dipoles (3 m)	12	6 strings[a)]
Quadrupoles	747	Individual
Sextupoles	504 480	Individual Adjusted value
Horizontal correctors	150	Individual
Vertical correctors	150	Individual
Skew quadrupoles	240	Individual
Wigglers[b)]	80	Individual
Kickers	64	Individual
Septa	4	Individual

[a)]one per arc
[b)]superconducting magnets

Ring Magnet Requirements II

- Design guidance for DR preliminary magnet designs
- Apertures:
  - 30 mm pole tip radius except in wiggler
  - Chamber constraints around inj/ext/abort lines not yet specified
    - Extra quadrupole types specified for this reason
    - Source of extra cost uncertainty beyond basic design/fabrication uncertainty

Type	Max. *KL*	*L* (m)	Max. field error	No. of types
Dipoles	0.0524	6; 3	2×10^{-4}	2
Quadrupoles (Lo Field)	0.1 m^{-1}	0.3	2×10^{-4}	1
Quadrupoles (Hi Field)	0.31 m^{-1}	0.3	2×10^{-4}	3
Sextupoles	0.24 m^{-2}	0.25	2×10^{-3}	1
H correctors	0.002	0.25	5×10^{-3}	1
V correctors	0.002	0.25	5×10^{-3}	1
Skew quadrupoles	0.03 m^{-1}	0.25	3×10^{-3}	1
Wigglers[a)]	—	2.5	$+0;-3 \times 10^{-3}$	1

[a)] Transverse roll-off limit at ±20 mm (H)

RDR DR Magnet Design Approach

- Conventional Magnets
  - **2D models for each magnet style were developed**
    - Quads/Sextupoles – LBNL, SLAC
    - Dipoles/Correctors – JINR, Efremov Institute
  - **Coils utilized standard design methodology (eg, conductor choice) as specified by magnets group**
  - **Cost estimates based on a combination of scaling from recently constructed designs and the use of standardized cost coefficients**
- Superconducting Wigglers
  - **3D model of DR variant on CESR-c design**
    - Dynamic aperture evaluation
    - Also in use for electron cloud simulations
  - **Cost estimate for this relatively complex magnet was generated based on recent construction methods (using materials costs and required manpower) employed at Cornell with suitable extrapolation for ILC DR design modifications**

General Comments on Costing I

- Magnet group assumptions for costing:
  - **Magnet modeling, design and engineering carried out at HEP labs (e.g. SLAC, FNAL, JINR, LBL, BNL etc)**
  - **All magnet drawings created at same HEP labs**
  - **All but a very few complex magnets will be fabricated by industry to ILC prints**
    - i.e. NOT being fabricated based only on specifications
  - **Quality Control and magnetic measurements for nearly all magnets carried out at an ILC facility**
    - So magnet engineering hours include magnetic design; working with mechanical designer, manufacturer, PS engineer, Alignment, Installation team; writing travelers & measurement plan; following incoming QC and magnetic measurements

General Comments on Costing II

– **Material costs and fabrication labor costs were merged into two fixed costing coefficients**
  - Copper cost in our RDR estimates was $3.59 per lb (that's just the copper itself, added the fabrication into conductor cost, insulation cost and epoxy cost to get a conductor cost / lb)
  - Steel cost in our RDR estimates was $0.5 per lb of raw low carbon steel plate
  - Used low (non-USA) hourly labor rates for the fabrication labor : one could argue with rates chosen
  - Analyzed past machines' magnet costs to develop the present-day fixed costing coefficients

Cost Uncertainties I

- In general cost uncertainties were estimated at the 20-40% level
  - **Asymmetric error bars common**
    - Some in each direction
  - **Typical error bar of 30%**
  - **This appears consistent with the DR estimates being fairly standard designs and/or magnets of recent construction**

Cost Uncertainties II

- Uncertainty in future material prices:

Copper price risk mitigation :

If commodity prices continue to climb buy Cu for all magnets as soon as possible

Copper vendor to hold inventory, release as needed to magnet fabricators

This requires front loaded funding profile- funds needed EARLY on, not spread equally through the ~ 7 year construction period

5 year copper prices:

Copper has gone up by 4.5 times its 2002 cost.

No one can say ~~what~~ it will be by ~ ~~2010~~ 2015, 2020…

Cost Uncertainties III

- Variation in estimates from magnet vendors
  - **Test case: RTML quadrupole magnet submitted for "budgetary quotes":**
    - 3 experienced vendors
    - ~25% spread in quotes
    - Even though the quote was for a very large quantity: 1650 quads.
  - **Give them longer to prepare their bids [establish their material availability etc] and the spread in costs will decrease**
    - Might expect to decrease the ±20-30% to ±10-20% if we have a significant increase in engineering & design resources to carry out more detailed estimates
  - **Significant systematic cost drivers:**
    - Reliability and radiation lifetime requirements will increase cost
    - Rapidly increasing Cu cost
    - Number of physical families
    - Changes in the design
      - Lattice
      - Magnet specifications (eg, aperture)

Risk Assessment for the DR Magnets

- Risks affecting the magnet performance
  - **Technical issues – none are judged to be particularly difficult**
    - Alignment, mechanical and thermal stability tolerances are similar to those of light sources
    - Will need to review materials choices in high radiation areas to evaluate radiation resistance requirements and expected lifetimes
  - **Reliability, Reliability, and Reliability**
  - **Magnet group has proposed that a DR magnet would be an excellent candidate for detailed Failure Mode and Effect Analysis (FMEA)**
    - Determine critical components
    - Plan lifetime tests, R&D studies for improvement of materials & components
  - **Potential for cost adjustments during risk optimization process (some downwards as well as upwards)**

Evolution in Concepts Since the RDR

- Conventional magnet concept essentially static
  - **Optimization for a distributed power supply system has been *discussed* (see later slides)**
- Wiggler magnets
  - **Baseline was a simple lengthening of the CESR-c design to fit within the lattice cell (history of default wiggler length)**
  - **Introduces some technical issues**
    - Expect that these can be dealt with in straightforward fashion as part of the detailed engineering design
    - Some risks can be lessened, however, by optimizing the design

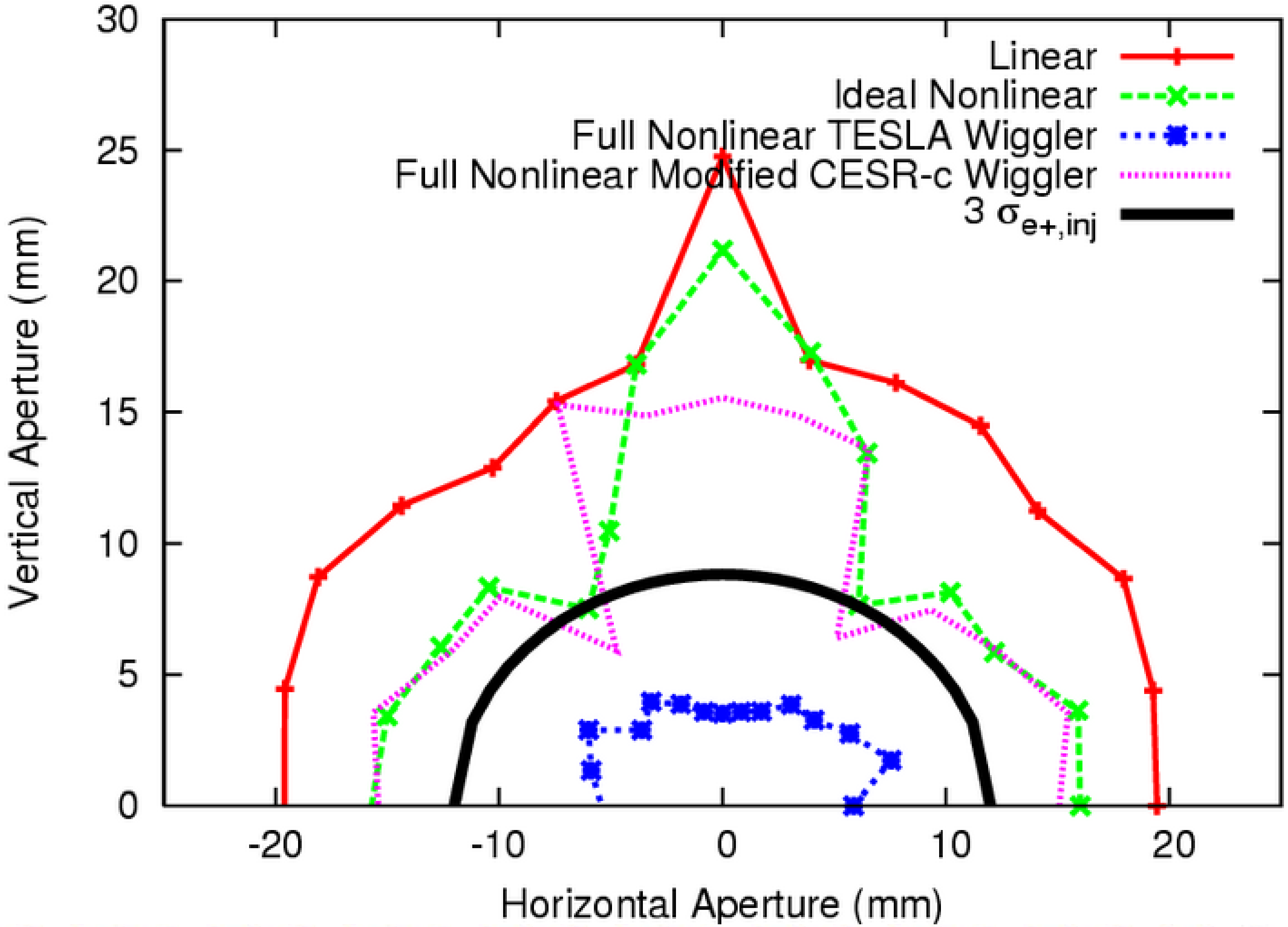
Baseline Wiggler Configuration

- Basic Requirements
  - **Large Aperture**
    - Physical Acceptance for injected e+ beam
    - Improved thresholds for collective effects
      - Electron cloud
      - Resistive wall coupled bunch instability
  - **Dynamic Aperture**
    - Field quality
    - Wiggler nonlinearities

Wiggler Comparison

	TESLA	CESR-c	Modified CESR-c (RDR)
Period	400 mm	400 mm	400 mm
$B_{y,peak}$	1.67 T	2.1 T	**1.67 T**
Gap	25 mm	76 mm	76 mm
Width	60 mm	238 mm	238 mm
Poles	14	8	**14**
Periods	7	4	**7**
Length	2.5 m	1.3 m	2.5 m

Dynamic Aperture

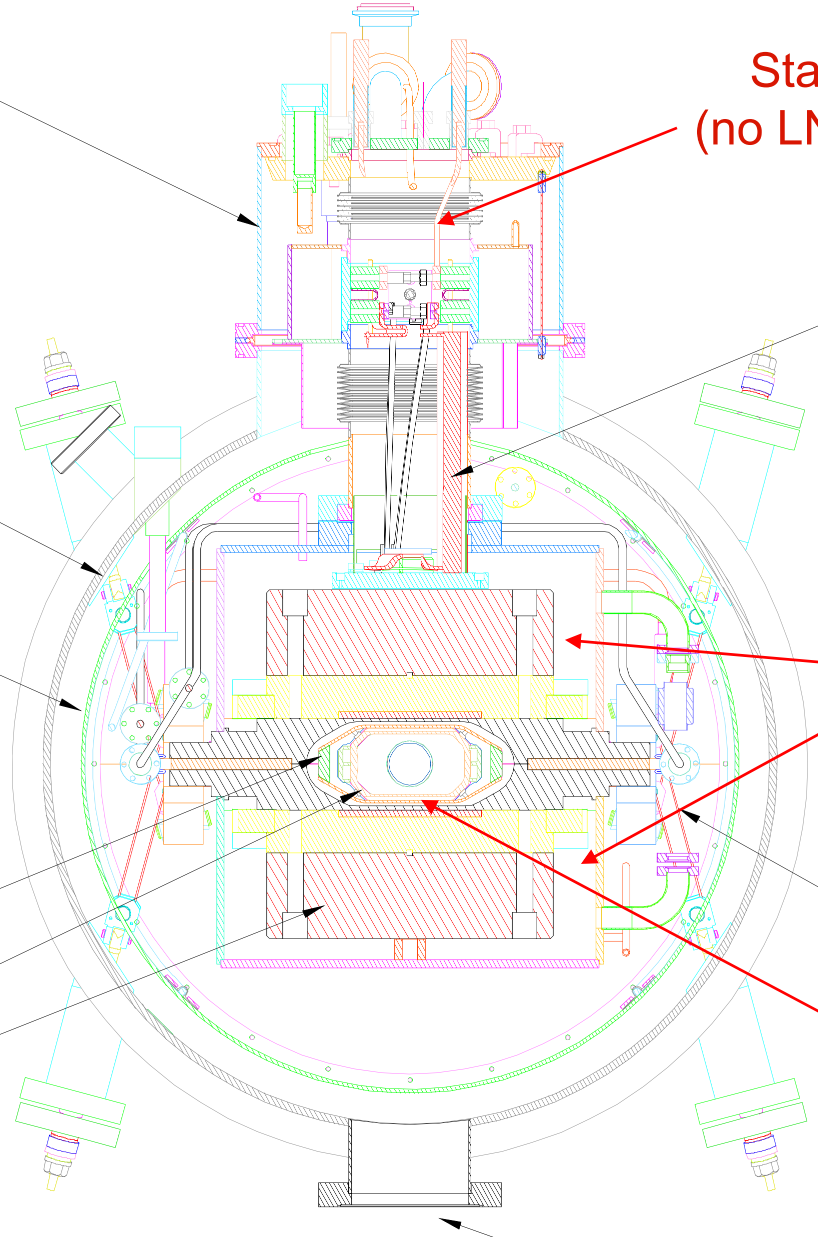


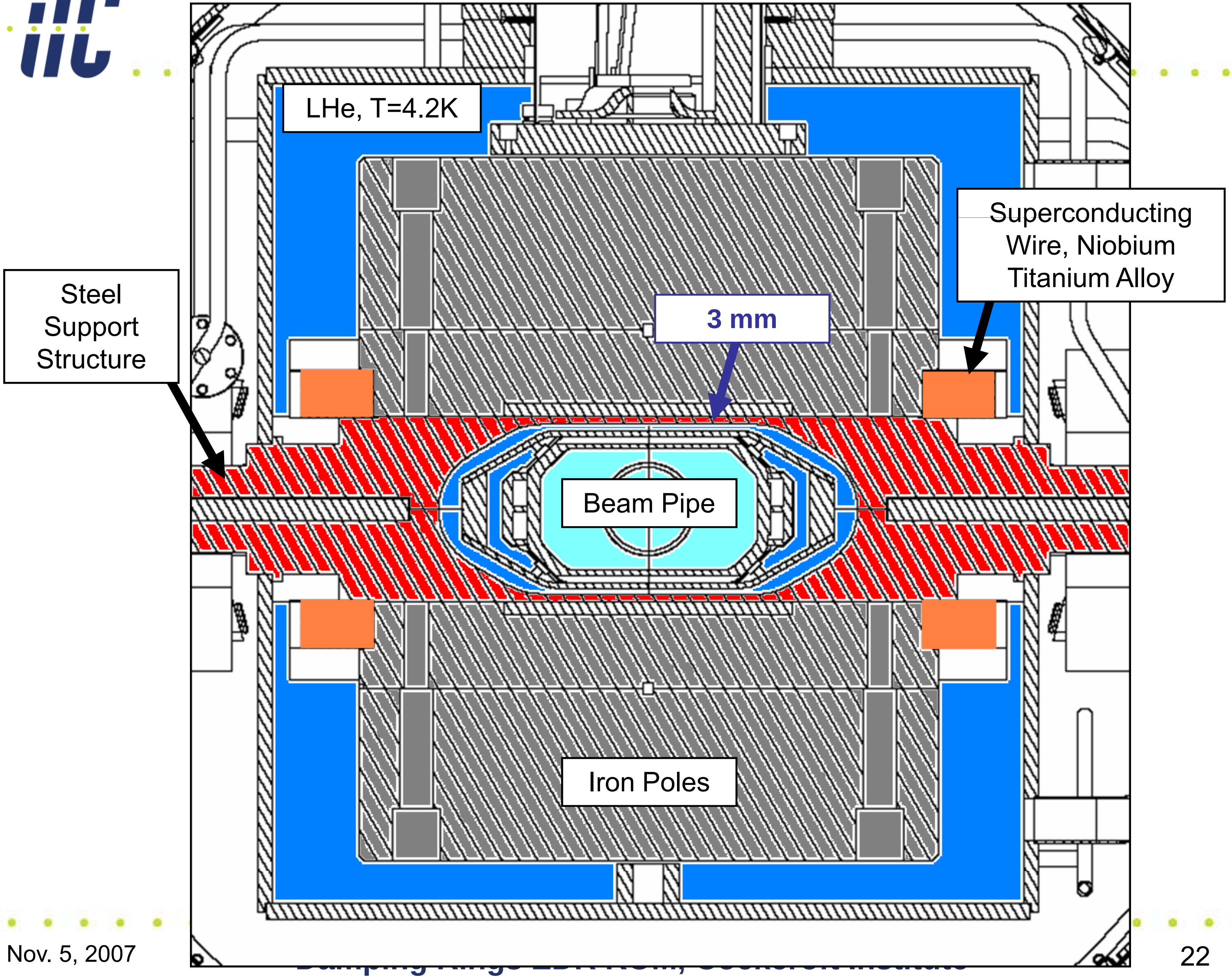
Configuration/Costing for the RDR

- Design/Costing Reference
  - **Modified CESR-c Wiggler**
    - 14-pole
    - 2.5 m
- Costing Basis
  - **Based on detailed information from CESR-c wiggler production run**
  - **Documented M&S Costs**
    - Adjusted for additional poles
    - Adjusted for increased cold mass and cryostat length
    - Inflated for intervening years
  - **Production Techniques**
    - Fabrication and production line manpower requirements analyzed on a step-by-step basis
    - Adjusted for modified design
    - FTE requirements then re-calculated
  - **ED&I estimates**
    - Design work and documentation assume modified version of Magnet Group standard rates for complex devices
    - Inspection requirements based on CESR-c wiggler quality control procedures

Optimized Superferric Wiggler

- Superferric Wiggler Physics Optimization
  - **Poles**
  - **Period**
  - **Gap**
  - **Width**
  - **Peak Field**
- Engineering Design and Optimization
  - **Increased Length vs CESR-c design**
  - **Cryostat Vacuum Chamber Interface**
  - **Design modifications to conform to ILC DR needs**
    - Vacuum chamber interface
    - Modifications to eliminate LN_2 use in the design
  - **Value engineering and risk mitigation**
    - Bath cooling ⇨ Indirect cooling
    - Ensure that the impact of ILC DR driven modifications to design are fully evaluated
    - Optimize for large scale production (eg, coil winding)

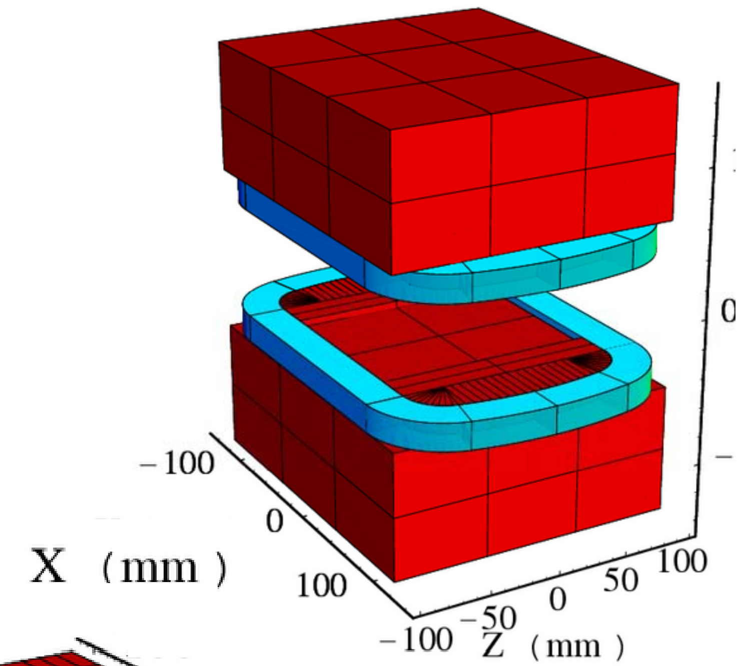

LHe stack
Stack Modifications
(no LN_2, indirect cooling)
Current lead
Vacuum vessel
Radiation
outer shield
Vessel,
LHe Bath
Beam-pipe shield
Cu beam-pipe
Cold mass
Suspension strap
Support Structure,
Aperture,
Vacuum Chamber
Interface
Pump port

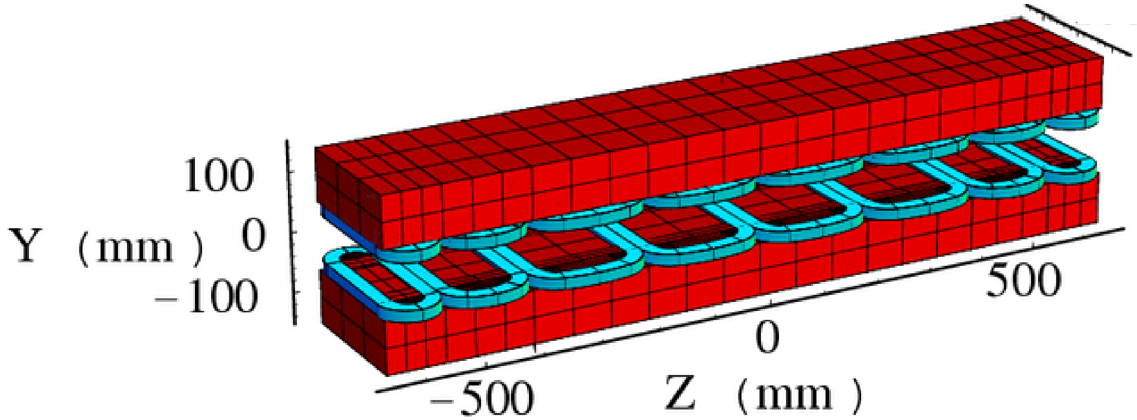


LHe, T=4.2K
Superconducting Wire, Niobium Titanium Alloy
Steel Support Structure
3 mm
Beam Pipe
Iron Poles

Magnet Modeling (J. Urban, J. Crittenden)

- OPERA 3-d & Radia
- Optimizations:
  - **Number of poles**
  - **Pole width**
  - **Pole gap**
  - **Period**
  - **Peak field**



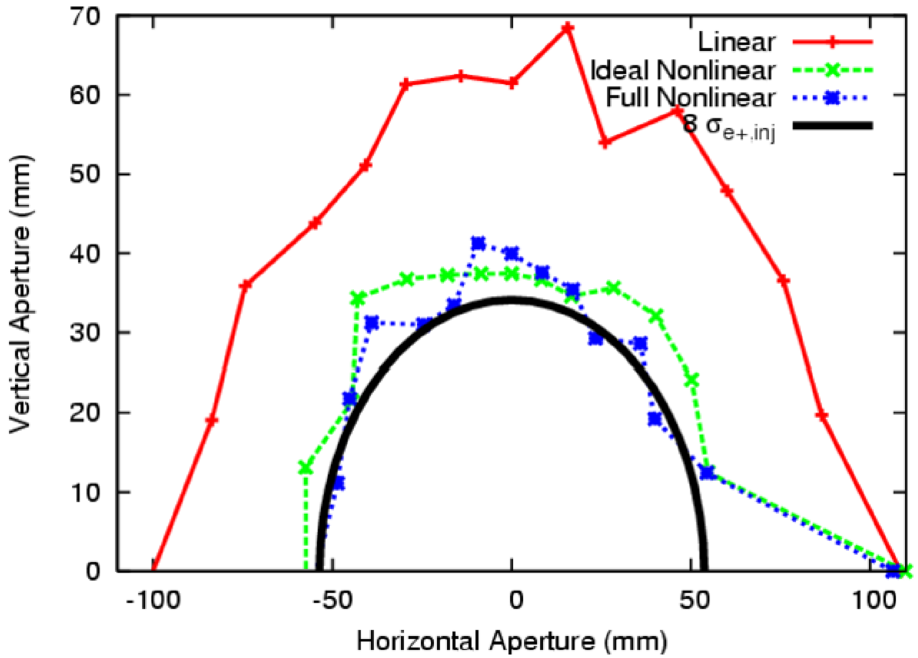


Recommendation

- Superferric ILC-Optimized CESR-c Wiggler
  - **12 poles**
  - **Period = 32 cm**
  - **Length = 1.68 m**
  - **$B_{y,peak}$ = 1.95 T**
  - **Gap = 86 mm**
  - **Width = 238 mm**
  - **I = 141 A**
  - **τ_{damp} = 26.4 ms**

    $\varepsilon_{x,rad}$ = 0.56 nm·rad

    σ_δ = 0.13 %



Nominal target ⇨ 25 ms

Wiggler Engineering Issues

- Cryogenics Modifications
  - **Indirect cooling for cold mass**
  - **Switch to cold He gas for cooling thermal shields**
  - **42% of manpower for inner cryostat and stack assembly ⇨ significant cost reduction expected**
- Shorter Unit
  - **Simplified and more robust yoke assembly**
  - **Significant cost reduction**
    - 14 % fewer poles
    - 30% reduction in length
- Larger aperture
  - **Relaxed constraints on warm vacuum chamber interface with cryostat**

Impact of Optimized Design

- Optimized design satisfies core physics requirements
- Expected to offer significant cost savings over RDR design
  - **Initial estimates of impact of simplified construction give a cost reduction of ~25% relative to RDR estimate**
- Optimized configuration will simplify final engineering design and provide more flexibility with the vacuum chamber interface
- Wiggler Information:

https://wiki.lepp.cornell.edu/ilc/bin/view/Public/CesrTA/WigglerInfo

DR DC Magnet Power Supply Design

- Overview of DC Power System Requirements

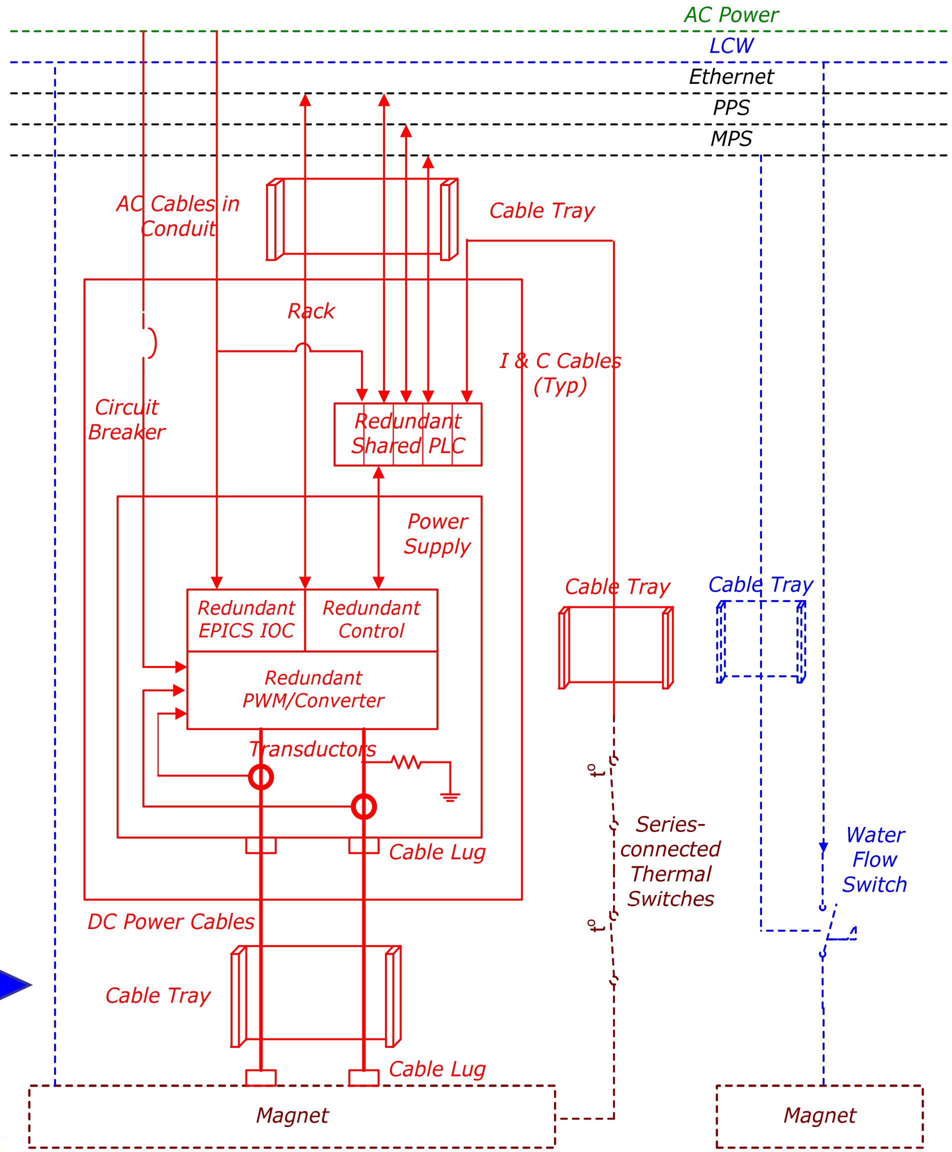
Single Ring Quantities (without inj/ext lines)

Type	**No.**	**Power Method**	**Polarity**
Dipoles (6 m)	114	6 strings (one per arc)	Unipolar
Dipoles (3 m)	12		
Quadrupoles	747	Individual	Unipolar
Sextupoles	480	Individual	Unipolar
Horizontal correctors	150	Individual	Bipolar
Vertical correctors	150	Individual	Bipolar
Skew quadrupoles	240	Individual	Bipolar
Wigglers[b)]	80	Individual	Unipolar

Overview of Costed System

- Bulk supplies for dipole strings
- Small or Intermediate, rack-mounted, unipolar or bipolar power supply, powers an individual, normal temperature magnet or wiggler magnet
- All power supplies located in alcoves.

Conceptual layout showing all interfaces



Power Supply Summary

Power Supply Output Ratings	Total Quantity	Unipolar	Bipolar
$5 \le V_R \le 30$, $I_R \le 125A$	3,712	2,632	1,080
$V_R > 30V$, $I_R > 125A$	196	196	0
All ratings	3,908	2,828	1,080

Notes:

1.The above quantities are from the RDR cost report submitted in December 2006 (OCSV6)

2.The above quantities do not account for the 4 large bulk power supplies in the two alcoves.

3.The 196 power supplies with ratings > 30V consist of power supplies for 12 large dipole magnet strings, 2 large Inj/Ext dipole magnets, and 182 strong quadrupole magnets

4.It appears that the majority of magnets will fit the distributed power supply model with ***little or no*** redesign. Several of the strong quadrupoles are candidate for "tweaking" to fit the currently conceived distributed power supply model (see later slides)

Cost Estimate Basis

- RDR estimates of EDIA and Assembly labor costs were based on reviews of recent large accelerator magnet and power supply projects at SLAC and Fermilab, where material, fabrication and EDIA labor fractions are well known
- The fractional distribution of EDIA and Assembly among several types of laborers, was assigned on the basis of project management experience
- Labor rates were those standardized by the Magnet Technical Group

PS controllers, embedded EPICS IOC, redundant Ethernet interface	**Cost estimates for similar controllers developed at SLAC, LBL, and PSI**
PLCs, PACs, redundant Ethernet connections	**On-line price lists – Allen-Bradley, Siemens, recent purchase for LCLS**
AC input, DC output (54km), control cable, cable trays and conduits	**Vendor quotes, recent experience, RS Means Electrical Cost Data 30th Edition.**
Power supplies	**Extrapolation of vendor price lists, quotes**
Quench protection, dump circuit	**Cornell University, FERMILAB, SLAC BaBar,**
Racks	**Recent SPEAR3 and LCLS purchases**

RDR PS Completeness Summary

- RDR focused magnet/power supply list and concepts
- All designs conceptual, very little is on paper. Written specifications, building/equipment layouts, rack profiles, wiring diagrams, cable tray or raceway layouts do not exist
- Accurate estimate of racks cannot be made until layouts and profiles are made
- Estimates include M&S for cable trays and conduits., but not raceway supports
- Environmental, facility, seismic and other Project specifications needed for design are not available
- PS RDR cost estimate is about 95% complete. All major components identified and estimated. But design detail is at a 15% level.

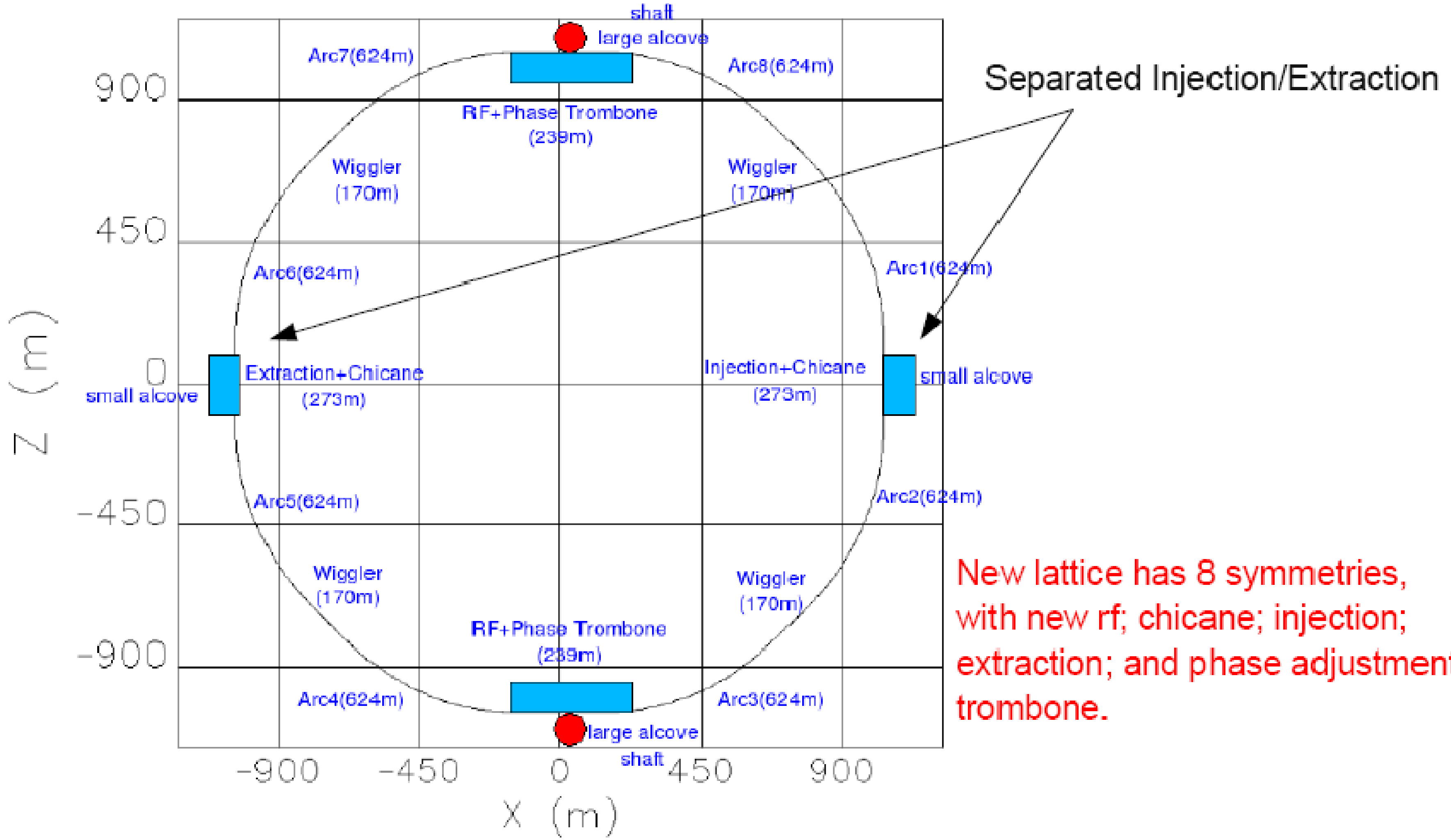
Tunnel Loss Estimates

- Power loads in tunnel estimated for 4 alcove configuration
  - **Cable Losses: 343 kW per ring (excludes inj/ext/abort)**
    - Using ***very generous*** cable sizes
    - Major cost driver
  - **Air-cooled magnets: 103 kW per ring**
  - **Total: ~450 kW per ring**
- Central Injector Complex
  - **Reduction to 2 alcoves**
    - Increases cable losses
    - Not clear whether a viable raceway design exists
  - **Target of 50W/m with two rings in single tunnel**

    ⇨ Maximum of 335 kW to air (both rings combined)

Present Picture of the Central DR Layout

ILC Damping Ring RDR Lattice (OCS8) – Ring's Layout

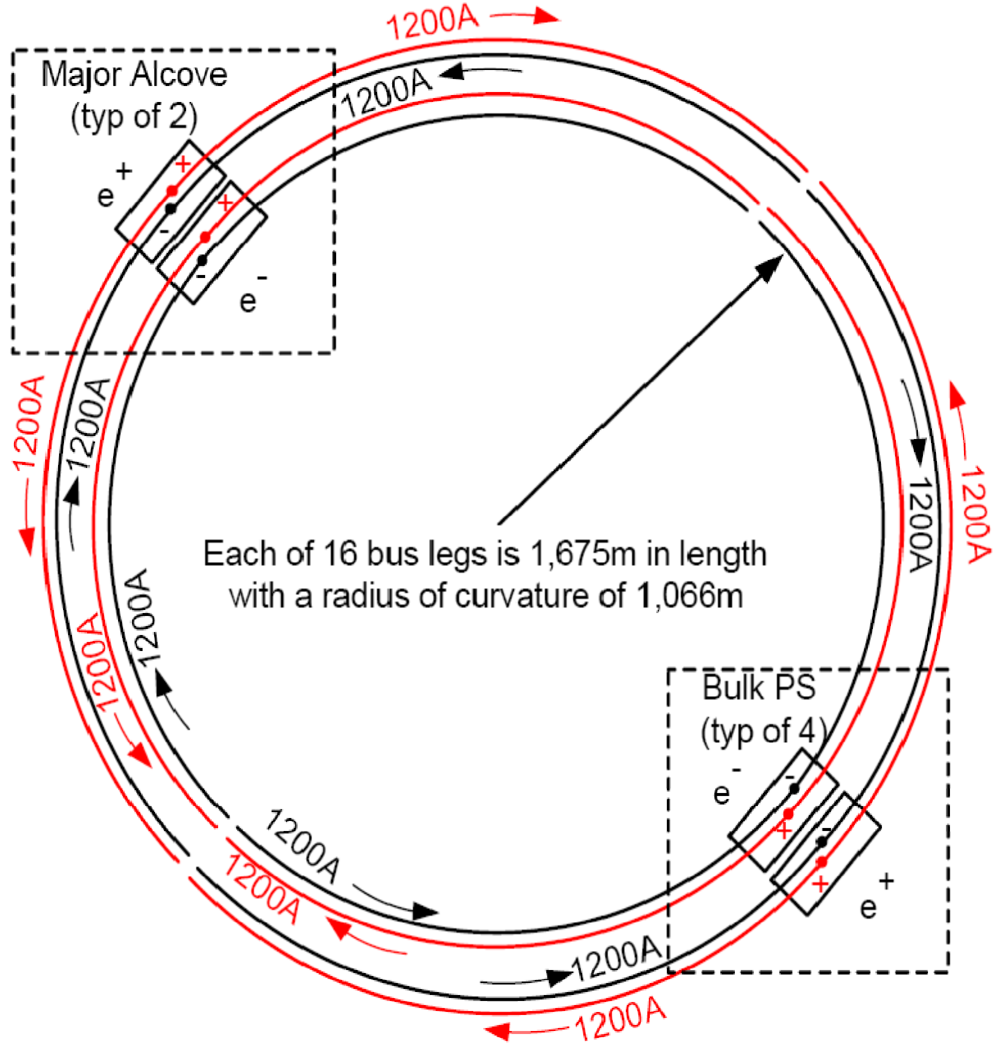


New lattice has 8 symmetries, with new rf; chicane; injection; extraction; and phase adjustment trombone.

Distributed Power Supply Concept

- 4 bulk supplies
  - **2 in each major alcove**
  - **Feed 8 buses (4 per ring)**
  - **Individual DC-to-DC converters for each magnet**
    - Water-cooled racks distributed around the ring
    - Magnets
      - Quadrupoles
      - Sextupoles
      - Correctors (dipole, skew quad, other)
  - **Distribute AC to local wiggler power supplies**
  - **Reduce heat load around tunnel due to cable losses to air to <50W/m**
- Main dipoles powered in 6 strings per ring
  - **6 dipole supplies per alcove**
- Injection/Extraction lines
  - **Same as for RDR**

Quadrupole, Sextupole & Corrector Bus



Sampling of Specifications

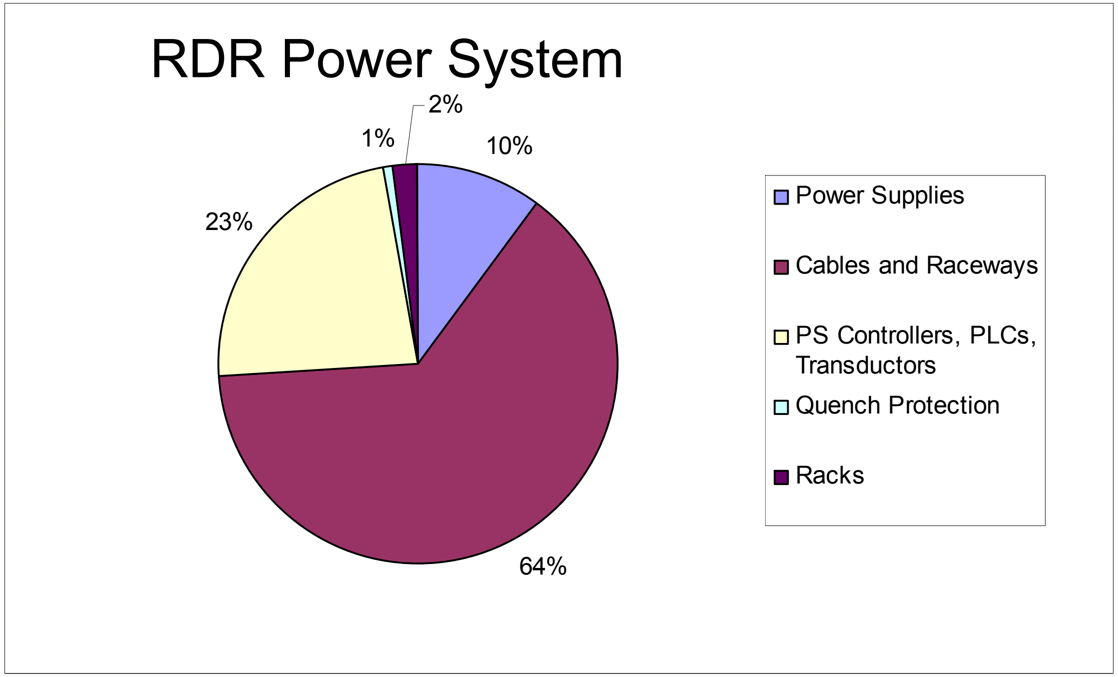
- Air heat load
  - **Solid conductor magnets (~100kW/ring)**
  - **Short cables between DC-to-DC converters and:**
    - Bus
    - Magnets

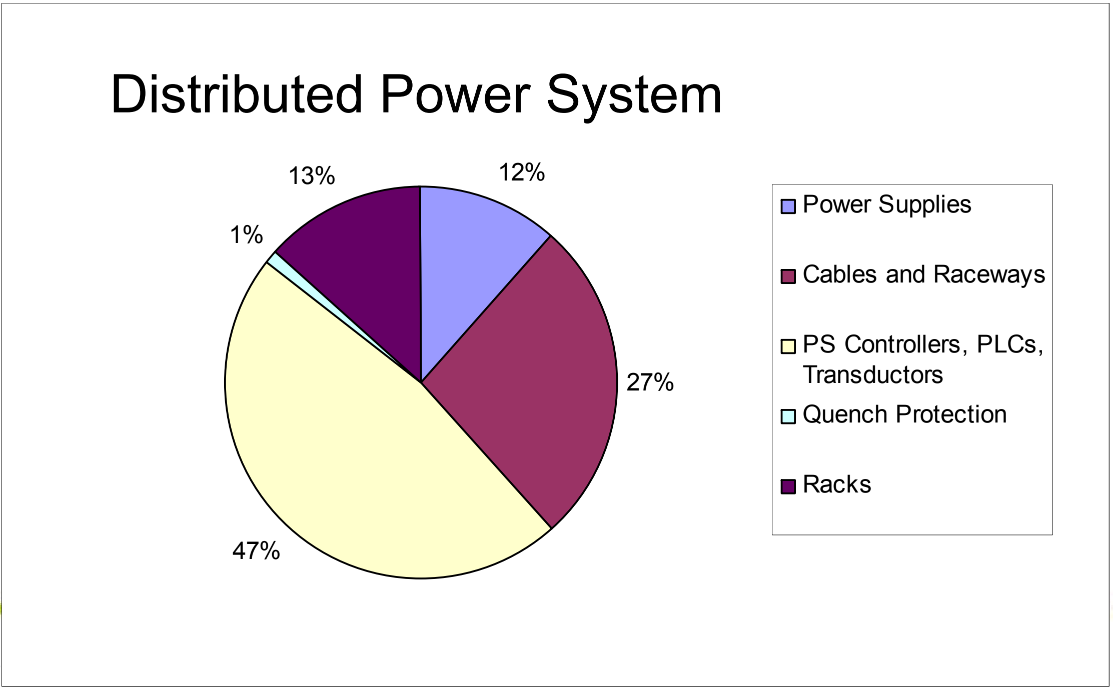
⇨ ~40W/m

Bulk Power Supplies (4 units)	
Output Power	120 kW
Output Voltage	50 VDC (voltage regulated)
Output Current	2400 A
Input	480 VAC, 3 phase
DC Bus	
Min/Max Voltage	40V/50V
Max Resistance	17 mOhm
Min Cross Section	5372 mm^2 Al
DC-to-DC Converter Cabling	
Max distance to magnet	7m
Max distance to bus	5m
Magnets	
Max Operating Voltage	30 V

Cost Impact

- Cable costs greatly reduced!
- 35% cost savings relative to RDR
- Controls-related hardware now dominant cost
  - **Some obvious further work to reduce costs in this area**





Entering the EDR Phase

- Three DR work packages have been proposed for DC Magnets and Power Supplies
  - **WP 3: Damping Wiggler Design**
  - **WP 8: Power Systems**
  - **WP 11: Magnets and Supports**
- Each package is focused on developing detailed, documented and costed designs on the timescale of the EDR
  - **Dominant fraction of effort is expected to be design work**
  - **Some small scale sub-component prototyping expected as part of the design process**
  - **Overall effort will be manpower dominated**

EDR Magnets & Supports WP

- Proposed Coordinator: Steve Marks (LBNL)
- Overall Goal:
  - **Provide a complete set of engineering designs and costing**
- Key Tasks and Deliverables:
  - **Magnets**
    - Specifications
    - Develop technical magnet designs
    - Optimize magnet designs
  - **Magnet supports**
    - Specifications
    - Develop technical stand designs
    - Vibration analysis of stands and supports
    - Optimize stand design
  - **Cost Estimate**

Magnets & Supports Key Interactions

Requires input from:

- WP1 (Lattice design and acceptance)
- WP2 (Orbit, optics and coupling correction)
- WP8 (Power systems)
- WP12 (Systems integration and availability)
- WP13 (Vacuum system)
- WP14 (Injection and extraction systems)

Provides output for:

- WP1 (Lattice design and acceptance)
- WP2 (Orbit, optics and coupling correction)
- WP8 (Power systems)
- WP12 (Systems integration and availability)
- WP13 (Vacuum system)
- WP14 (Injection and extraction systems)

- Also has project-wide interactions
  - **Standards**
  - **Analysis**
  - **CF&S**

Magnets Group Targeted Level of Design

1. Design work
   - **2D (3D if needed) magnetic field simulations to confirm specified field quality and magnet performance**
   - **Pole profile and geometry optimization for better integrated field quality**
   - **Mechanical and thermal analysis**
2. Documentation
   - **Magnet specification with all needed parameters**
   - **Results of magnetic field analysis**
   - **Mechanical and thermal calculations**
   - **Magnet drawings with at least cross-sections and views transverse and longitudinal with all connections to the power, water, instrumentation and corresponding schematics**
   - **Description of all used materials: iron, copper, insulation, probes, cables, etc…**
   - **Description of magnet manufacturing technology: winding coil technique, epoxy impregnation, curing, stamping laminations, yoke and magnet assembly, etc…**
   - **Magnet support structure general views with adjusting mechanisms**
   - **Drawing of magnet mounting in the tunnel**

Magnets & Supports Resources

- Estimated design requirements
  - **Based on magnet design estimates developed by the magnets group**
  - **Estimate: 4.2 FTE-yrs of design effort**
    - Special Notes:
      - This assumes a stable lattice design
      - Iterations will require additional effort
      - Effective starting date of effort contingent on receipt of final specifications (DR lattice freeze targeted for 12/31/07)
      - This also assumes that the design of the RTML dipole used in the injection/extraction regions will be handled by the RTML group
- Proposed resources
  - **EOI information**
    - Identified support level of ~0.5 FTE
    - Discussions underway which would yield ~1.5 FTE for this effort
  - **If 1.5 FTE can be identified, this would imply a ~3 year timescale for the engineering design**
    - Late 2010
    - Compatible with the EDR?

Special Comments

- 5-10% contribution from magnet design groups for overall magnet coordination has been proposed
  - **Set and coordinate project-wide standards for magnets**
  - **Identify optimizations that span area group boundaries**
  - **Provide for testing that can be applied project wide**
    - Example: It has been proposed that one of the damping rings conventional magnets would be an ideal case for a detailed Failure Mode and Effect Analysis (FMEA)

EDR Wiggler WP

- Proposed Coordinator: Mark Palmer (Cornell)
- Overall Goal:
  - **Development of an engineering design and costing for a superconducting wiggler based on the CESR-c design**
- Key Tasks and Deliverables:
  - **Wiggler Engineering Design**
    - Provide Specifications
    - Optimize for use with ILC DR lattice
    - Optimize interface for vacuum system and electron cloud mitigation
    - Modify CESR-c design to meet ILC design requirements (eg, no LN_2 cooling)
    - Optimize for industrialization (may include some small sub-component prototyping)
  - **Cost Estimate**

Wiggler Key Interactions

Requires input from:

- WP1 (Lattice design and acceptance)
- WP7 (Electron cloud)
- WP12 (Systems integration and availability)
- WP13 (Vacuum system)

Provides output for:

- WP1 (Lattice design and acceptance)
- WP7 (Electron cloud)
- WP8 (Power systems)
- WP12 (Systems integration and availability)
- WP13 (Vacuum system)

- Also has project-wide interactions
  - **Standards**
  - **Analysis**
  - **Cryogenics**

Wiggler Resources

- Estimated design requirements
  - **Based on elements of complex magnet and superconducting magnet standards developed by magnets group**
  - **Estimate: 3.1 FTE-yrs of design effort**
- Proposed resources
  - **EOI indicates ~1.9 FTE available during EDR period**
    - The numbers are sensitive to potential adjustments in the funding situation
    - Also EOIs not 100% dedicated to design work
  - **Overall appears to be a close match for having component engineering work in hand on EDR timescale ⇨ ready to begin construction of a prototype unit during pre-construction phase followed by subsequent industrialization**
  - **Note: Present EOIs and WP plan do not support any significant work on pursuit of alternative designs. Some interest exists for further investigation of alternatives, but resource availability not clear.**

EDR Power System WP

- Proposed Coordinator: Paul Bellomo
- Overall Goal: Develop specifications and technical design for DC power converters and power distribution
- Key Tasks and Deliverables:
  - **Power system design**
    - Development of distributed power system topology
      - Bus design
      - High availability power supply design
    - Controls Interface Design
    - CF&S Interface Design
    - Raceway Design
    - Value Engineering
  - **Cost estimate**

Power System Key Interactions

Requires input from:
- WP3 (Damping wiggler design)
- WP4 (Instr, Diag, and Controls)
- WP11 (Magnets and supports)
- WP12 (Systems integration and availability)
- WP16 (Conventional Facilities and Cryogenics)

Provides output for:
- WP11 (Magnets and supports)
- WP12 (Systems integration and availability)

- Also has project-wide interactions
  - **Standards**
  - **Analysis**
  - **Key component design**
    - Controls and Monitoring
    - Power supply development - for example, development of a HA bipolar PS design
      - Needed for DR
      - WP submitted for RTML
  - **Global groups**
    - Controls
    - CF&S

Power System Targeted Level of Design

- Power supply specifications, detailing output power, stability and reliability requirements, and other pertinent features
- Control equipment specifications for control and protection of the power supplies, magnets and associated equipment
- Equipment layout and placement drawings
- Drawings of the required electrical power distribution systems, busses, cables, and raceways
- Drawing and specifications of lockout/tagout and other interlocks needed to ensure personnel and equipment safety
- An estimate of the overall system power draw, losses, system cost and the costs of the individual components
- Other input for the Engineering Design Report

Power System Resources

- Estimated design requirements
  - **Based on design estimates generated for magnets technical group**
  - **Estimate: 2.25 FTE effort for 3 years**
- Proposed resources
  - **EOI information**
    - Interest at the necessary FTE level has been expressed
    - Funding, however, has ***not*** been allocated at the necessary levels for a complete design on the 2010 timescale
  - **Requires evaluation and negotiations to provide the necessary resources to complete this work package to the degree necessary for the EDR**
    - What level of completeness is required?
    - What resources can be made available?

EDR Issues – Design, Cost

- Detailed distributed power system design
  - **Lower cost**
  - **Maintain flexible tuning capability for rings**
  - **Meet the high availability requirements of ring**
  - **Evaluate environmental conditions in ring**
- Work with magnets WP to jointly optimize magnet and distributed power system design
- Investigate smaller, less-expensive PLCs and PACs. Obtain additional vendor quotes based on supplying larger quantities – all components are ripe for economies of larger scale
- No differentiation in stability requirements for range of magnets:
  - **All have two expensive, zeroflux current transductors.**
  - **Define stabilities to eliminate transductors and use something less expensive**

DC Magnets & PS Summary

- Engineering Design phase planning is underway
  - **Plans for work on baseline designs are being developed in detail now**
  - **Level of resources required appears reasonable for design work on the right timescale (no major technical issues)**
- EOIs have been received to cover all areas…

  BUT not all EOIs are presently funded
  - **This will likely require important additional discussions (institutional and regional)**
- Present planning is focused on engineering for the baseline design
    - Need to review support level for alternative designs
    - Particularly for the damping wigglers
- Global coordination and communication with other area and global groups will be an important issue for these WPs
  - **Interfaces (and changes) are potentially major cost drivers**
  - **Important efficiencies for dual-use design work**
  - **Adherence to standards is key for the post-EDR phase**