ILC Energy Efficiency

Marc Ross and Ewan Paterson, SLAC

CFS-ADI Joint Meeting

ICEPP University of Tokyo

9 April 2014

Three examples: 1) higher quality (hotter) water that can be put to secondary use, 2) lower cryogenic loss, 3) power management

Are there significant energy efficiency opportunities ?

Previous work – ***GDE CFS Value Engineering***: 1

(balance between capital cost and operations cost ***poor***)

GDE Meeting - ILC Conventional Facilities and Siting Workshop,
Joint Institute for Nuclear Research, June 4 to 6, 2008

- http://agenda.linearcollider.org/conferenceDisplay.py?confId=1117

First ILC Value Engineering Workshop, Fermilab, November 27 to 29, 2007

- http://agenda.linearcollider.org/conferenceDisplay.py?confId=2328

Value Engineering Wkshp Agenda

Workshop Agenda:

Tuesday Nov. 27, 2007 1:00 to 5:30

1:00	**Information Phase**	
Welcome and Introductions		Tom Lackowski
Opening remarks		Vic Kuchler
ILC Project Overview		Marc Ross
ILC Conventional Construction		Tom Lackowski
VM Process Overview		Richard Lambert – OVEST
Main Linac Equipment power and cooling Criteria		Mike Neubauer
3:00-3:30	Coffee break	
3:30-5:30	**Function Analysis Phase**	
Shaft 7 CF&S supplied Power and Cooling		Emil Huedem
HVAC		Lee Hammond
Power		Tom Lackowski
FAST Diagram		Richard Lambert
5:30	Adjourn	

Wed. Nov. 28, 2007 9:00 to 5:30

9:00-10:30	**Speculation Phase**	Richard Lambert
10:30-11:00	Coffee Break	
12:30-1:30	Lunch	
1:30-3:00	**Speculation Phase Continued**	
3:00-3:30	Coffee Break	
3:30-5:30	Speculation Phase Continued or Start Analysis Phase	
5:30	Adjourn	

Thursday Nov. 29, 2007 9:00 to 5:30

9:00-10:30	**Analysis Phase**	
10:30-11:00	Coffee Break	
11:00 -12:30	**Development Phase Planning**	
12:30-1:30	Lunch	
1:30-3:00	**Development Phase Planning Continued**	
Presentation Phase Planning		
Workshop Close Out		Tom Lackowski
3:00-3:30	Coffee Break	
3:30-5:30	**Development of EDR Work Packages**	
5:30	Adjourn	

ILC Power Consumption

	Ecm	**GeV**	**500**
	Matched Q_L	$x10^6$	5.5
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	RF pulse length	ms	1.65
	RF to beam P eff.		44%
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	Total RF AC power	**MW**	**58.1**
	Total efficiency		17%
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Cryo	Static cryo power	MW	11.2
	RF load		13.8
	Input coupler		3.8
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Total Main Linac		**MW**	**109.2**
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RTML		MW	8.6
BDS		MW	11.4
Dumps		MW	1.0
IR		MW	4.1
Grand total		**MW**	**163**

POST RDR

Specific V.E. List

		DESCRIPTIONs & "color" legend (DRAFT Dec 18 2007)	Who to develop short description
		(Gut-Feel) may **not** result to large savings (Gut-Feel) may result to savings. Will be evaluated? (potential cost savings TBD) MARC ROSS DEC 04, 2007 DIRECTION (*LIST TO BE EVALUATED*) Will be evaluated By Others(HLRF), not CFS, whether high cost savings impact or not (not shaded) = Items that im Not Sure	
1	1	Provide one high efficiency cogen power / cooling plant on site and distribute power and 33 degree F chilled water throughout the facility, remove the power generation and chilling cost from the project cost	Steve
1	4	Eliminate one piping system by using process water as primary rejection for chilled water system w/#1 (using refrigerated heat pump as fancoils and standalone chillers for racks)	Emil
	4b	Eliminate one piping system by using process water as primary rejection for chilled water system w/#1 (using process cooled fancoils), warmer tunnel (item 6_15)	
1	5	Increase the delta T in the LCW and chilled water systems to 30 degrees, reduce flow, pipe size w/#1	Emil
5	10	Centralize the HVAC and reconfigure air flow from the ends	Lee
6	13	Let the temperature in the tunnel go to 104 degrees F during normal operation and local cool to 85 degrees where people are (consider increased cost for more frequent replacement)	Keith
6	15	Raise tunnel temperature to 103 degrees at all times (meets OSHA requirements) w/#13	Keith
8	16	Redesign the RF loads for more optimal process water flow	Mike
9	21	Modify top shaft HVAC to only process make up air, add blowers down shaft for recirculation	Lee
10	24	Reduce lighting level to egress limits	Tom
11	25	Reduce water pressure drop across components, minimize head pressure	Mike
12	35a	Consider using low mineral content water instead of LCW w/28 (design water system for low mineral water)	Keith
13	31	Allow different types of pipe materials: PVC, CPVC, HDPE, carbon fiber wrapped PE, etc in lieu of stainless steel	Rick
16	46	Use water cooled waveguide in the accelerator tunnel in lieu of air cooling	Mike
19	50	Develop loads that do not require low conductivity water	Fukuda
20	54	Use the waveguide pressurization system for cooling the waveguide (flow cooled gas inside the waveguide)	Mike
2	8	Define the maximum hydrostatic pressure for the collectors	Mike
4	27	Reexamine the hot changeout of modulator power supplies	Keith
8	41	Use a dessicant to dehumidify ventilation air	Lee
9	51	Evaluate each load individually to determine requirements	Keith / Mike
10	52	Establish power budgets for the relay racks (400 W / RF + 10% of power supplies)	Keith
11	53	Provide power supply that will work with warm water if necessary (quasi militarized)	Keith
NEW	NEW1	Eliminate Rack Skid and replace with just pump	Tom/Emil
NEW	NEW2	*Eliminate one piping system by using chilled water only as primary rejection, eliminate process water distribution*	Tom/Emil

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	4b	Elimin proce	
1	5	Increa	
5	10	Centr	
6	13	Let the people	
6	15	Raise	
8	16	Redes	
9	21	Modify	
10	24	Redu	
11	25	Reduc	
12	35a	Consi	
13	31	Allow	
16	46	Use w	
19	50	Devel	
20	54	Use th	
2	8	Defin	
4	27	Reexa	
8	41	Use a	
9	51	Evalu	
10	52	Establ	
11	53	Provid	
NEW	NEW1	Elimin	
NEW	NEW2	*Elimin*	

Red Item (Marc's selection from VE list)

Eliminate chilled water, use process water only for heat rejection

Consider using 30F water Delta T in RF

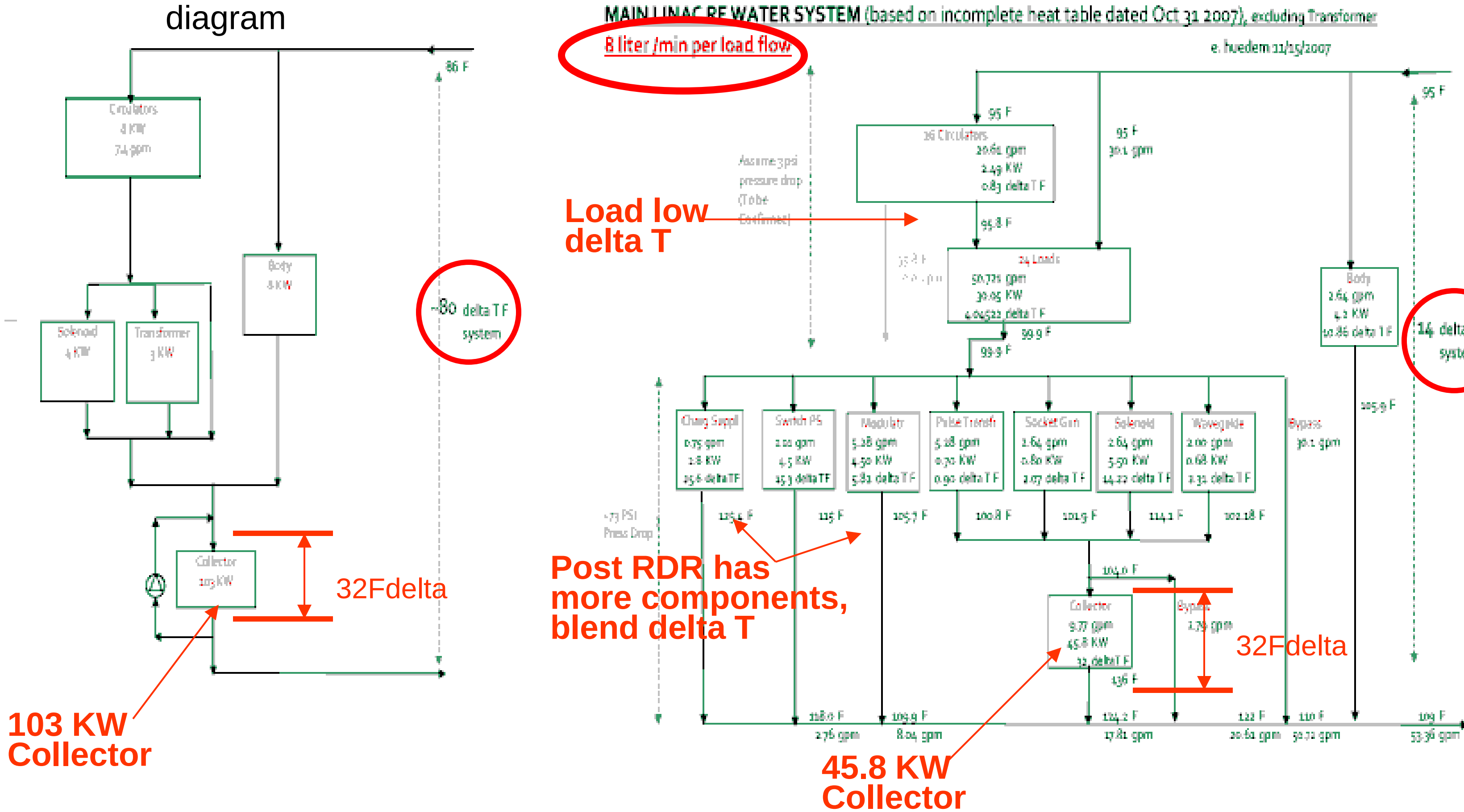
Warmer tunnel temperature to 104F during operation and local cool during maintenance

Consider low mineral content water instead of LCW

Consider using plastic pipe instead of steel/stainless steel

Comparison – Tesla and Post RDR

Simplified Tesla lcw diagram



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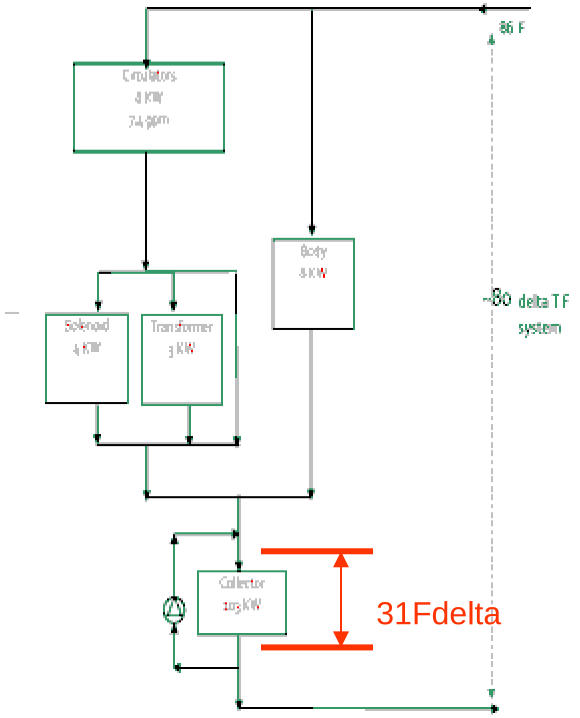
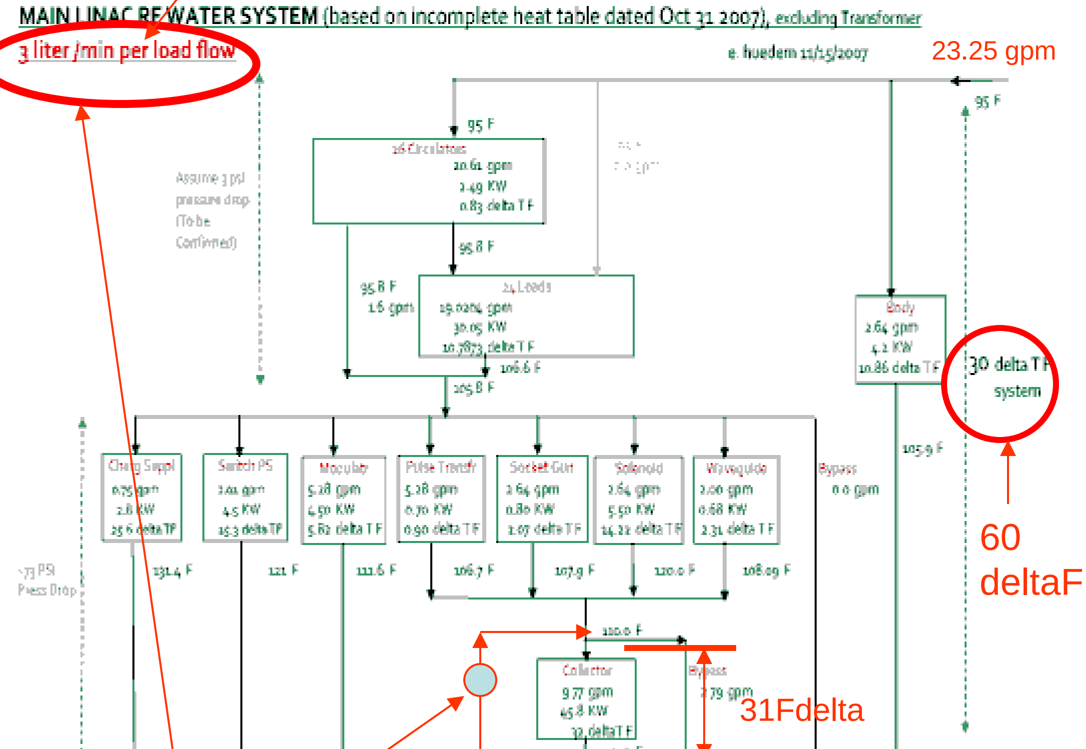


Change to low flow-high delta T



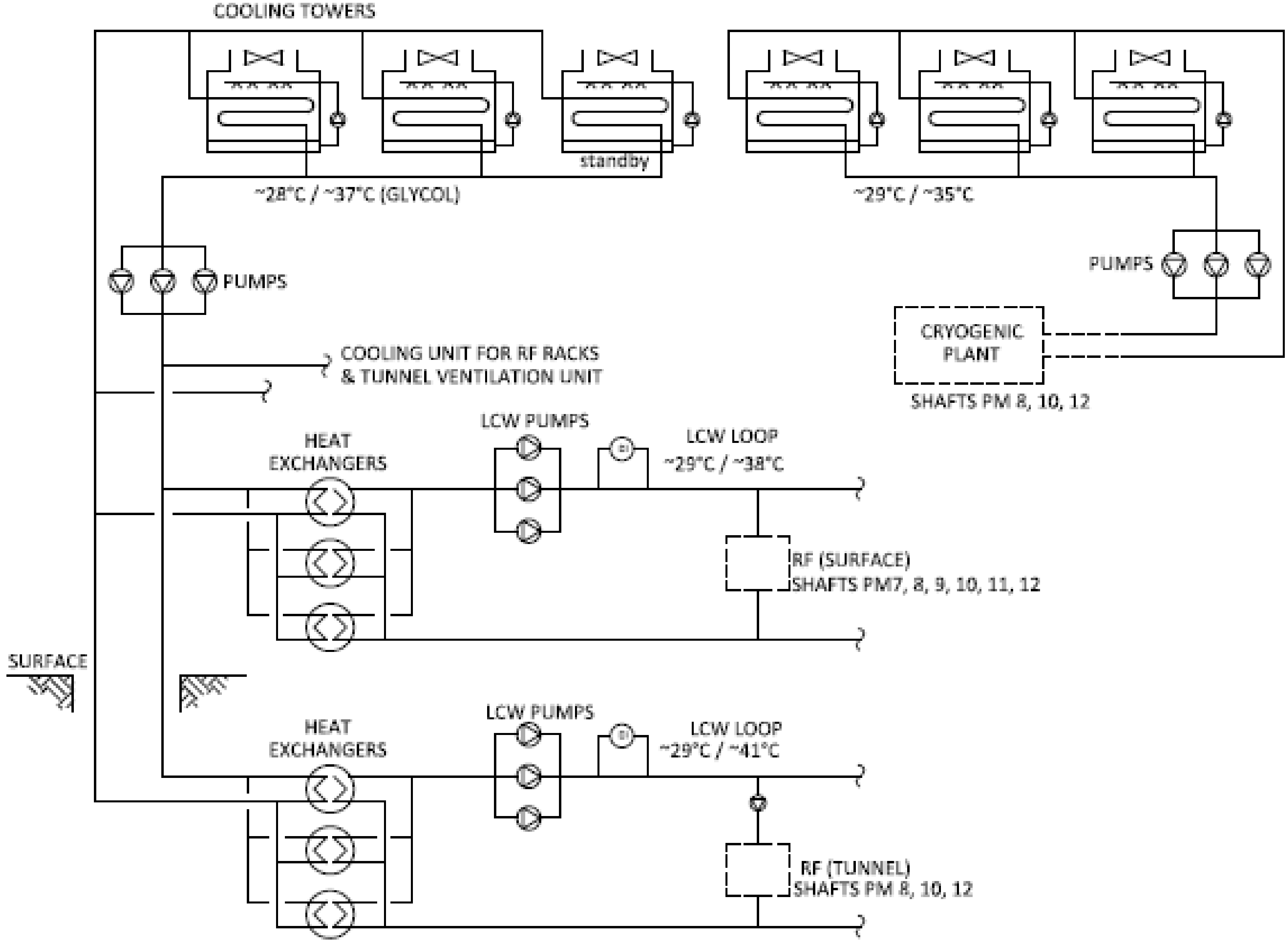
1-1/2"	1-1/2"	pipe main to one rf
23.3	23.3	gpm main to one rf
30	60	delta T system
102	204	KW total
45.8	**150**	KW collector
36.64	120	l/min collector
9.7	31.7	gpm collector
32	32	delta T F collector

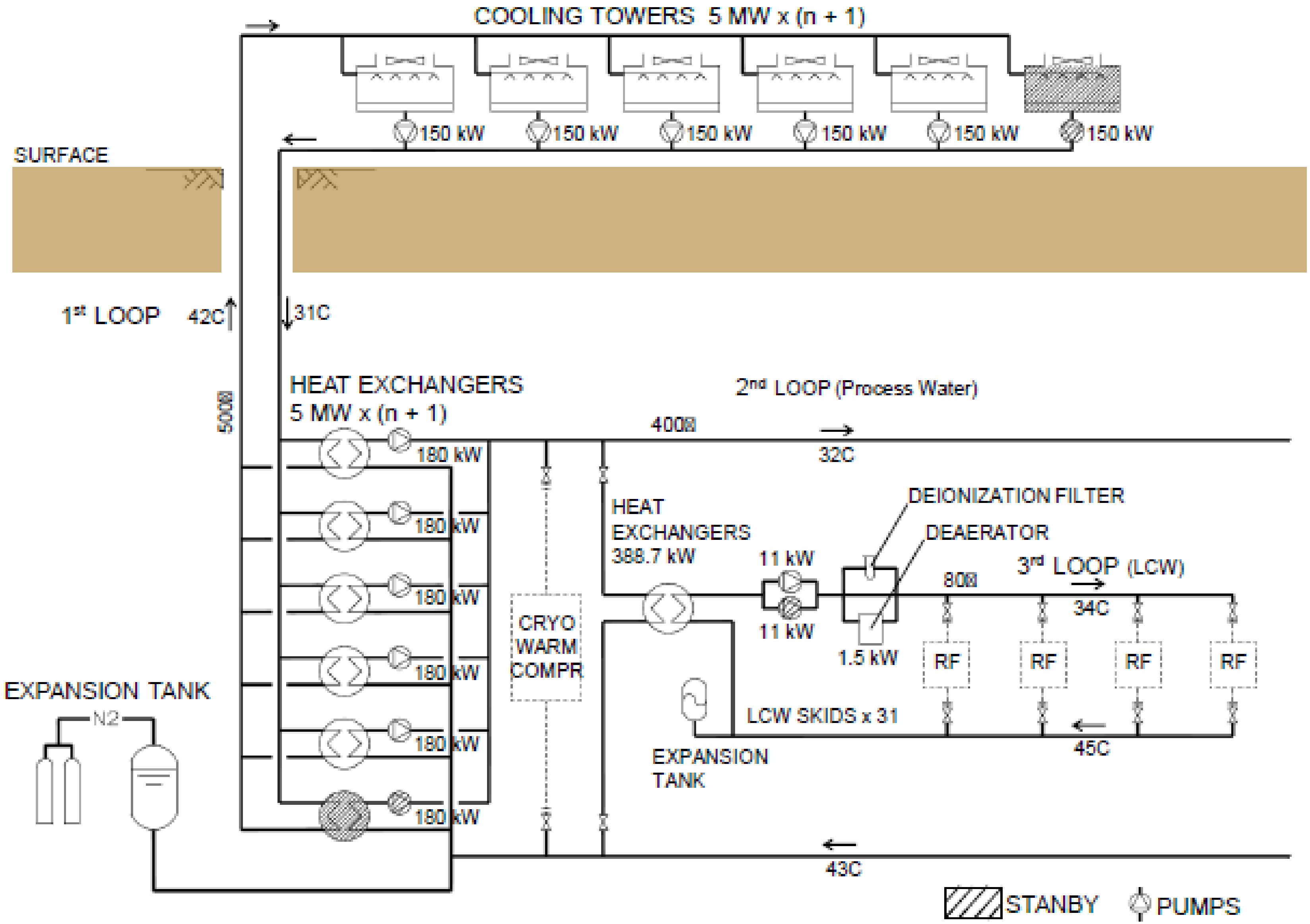
For 45.8 KW collector, <u>system</u> delta T= 30 F

For 150 KW collector, <u>system</u> delta T=60F

Delta T = Total RF Heat Load (BtuH) / (500 * gpm flow)

pipe main <u>already consider this</u>, just need to add feedback piping loop, and ensure Heat rejection design for the higher load


COOLING TOWERS
standby
~28°C / ~37°C (GLYCOL)
~29°C / ~35°C
PUMPS
PUMPS
CRYOGENIC PLANT
SHAFTS PM 8, 10, 12
COOLING UNIT FOR RF RACKS & TUNNEL VENTILATION UNIT
LCW PUMPS
HEAT EXCHANGERS
LCW LOOP
~29°C / ~38°C
RF (SURFACE)
SHAFTS PM7, 8, 9, 10, 11, 12
SURFACE
LCW PUMPS
HEAT EXCHANGERS
LCW LOOP
~29°C / ~41°C
RF (TUNNEL)
SHAFTS PM 8, 10, 12



COOLING TOWERS 5 MW x (n + 1)
150 kW
150 kW
150 kW
150 kW
150 kW
150 kW
SURFACE
1st LOOP
42C
31C
500
HEAT EXCHANGERS
5 MW x (n + 1)
180 kW
180 kW
180 kW
180 kW
180 kW
180 kW
2nd LOOP (Process Water)
400
32C
CRYO
WARM
COMPR
HEAT
EXCHANGERS
388.7 kW
11 kW
11 kW
DEIONIZATION FILTER
DEAERATOR
1.5 kW
3rd LOOP (LCW)
80
34C
RF
RF
RF
RF
LCW SKIDS x 31
45C
EXPANSION
TANK
EXPANSION TANK
N2
43C
STANBY
PUMPS

	Q.ty	Average heat load (kW)	Heat load to LCW water (kW)	Max all. temp. (°C)	Supply temp. (°C)	Delta temp. (°C delta)	Water flow (l/min)	Max all. press. (bar)	Typical (wtr) press. drop (bar)	Accept. temp. variation (delta °C)	Racks heat load (kW)	Heat load to air (kW)
			To Low Conductivity Water								to CHW	to AIR
COMPONENTS IN THE SURFACE (listed per RF unit)												
RF components x (413)												
RF charging supply	413/ML	2.39	1.67		40	8.5	*2.84*	18	5	10	NA	0.72
Switching power supply	413/ML	5.5	3.3		35	6.25	7.6	13	5	10	NA	2.2
Filament transformer	413/ML	0.79	0.6	60	35	0.40	20		1	n/a	NA	0.2
Marx modulator	413/ML	4.96	3.0		35	2.14	20	10	5	n/a	NA	2.0
Klystrn sckt tank / gun	413/ML	0.99	0.79	60	35	1.14	10	15	1	n/a	NA	0.2
Focusing coil (solenoid)	413/ML	1.68	1.6	80	55	2	10	15	1	n/a	NA	0.1
Klystron collector	413/ML	38.43	37.1	87	38†	14	37	15	0.3	n/a	NA	1.29
Klystron body & windows	413/ML	3.37	3.4	40	25 to 40	5	10	15	4.5	±2.5°C	NA	
CTOs & combining loads/circulators	2/klstrn	11.71	9.36			6.04	22.28		*(80 psid)*			2.3
Relay racks (Instrument racks)		3.0	0	N/A	N/A	N/A		N/A	N/A	None	3	0.0
Subtotal surface heat load to LCW water			60.74	Total surface (heat to water and air)				69.82			3.0	9.1
COMPONENTS IN THE TUNNEL (listed per RF unit)												
RF components (x 567)												
RF pipe in shaft (shaft & bends)		1.89	1.70			10	*2.445*		*(80 psid)*			0.2
Relay racks (instrument racks)		5	5	N/A	N/A	N/A	N/A	N/A	N/A	None		0.0
Main tunnel wvgde & local wvgd		12.23	11.62			12	*13.9*		*(80 psid)*			0.6
Distribution end loads & Cavity reflection loads		31.80	31.3			20	*20.54*		*(80 psid)*	*±2.5°C*		0.5
Subtotal tunnel heat load to LCW water			49.62	Total tunnel (heat to water and air)				50.9				1.3

† (inlet temp 25 to 63)

Are there significant energy efficiency opportunities ?

2

Ongoing work – ***Cavity Cryogenic Loss***:

Using reproducible recipe (GDE) to study Q_0

TESLA Technology Collaboration semi-annual meeting, DESY, March 24-27, 2014

https://indico.desy.de/conferenceDisplay.py?ovw=True&confId=9637 and SRF 2013

https://indico.in2p3.fr/conferenceOtherViews.py?confId=8939&view=standard

Was 61% in RDR
Factor 1.4;
6.3MW reduction for given beam power
(SB2009 capital cost saving)

Depends on Q0;
Substantial reduction may be possible

	Ecm	**GeV**	**500**
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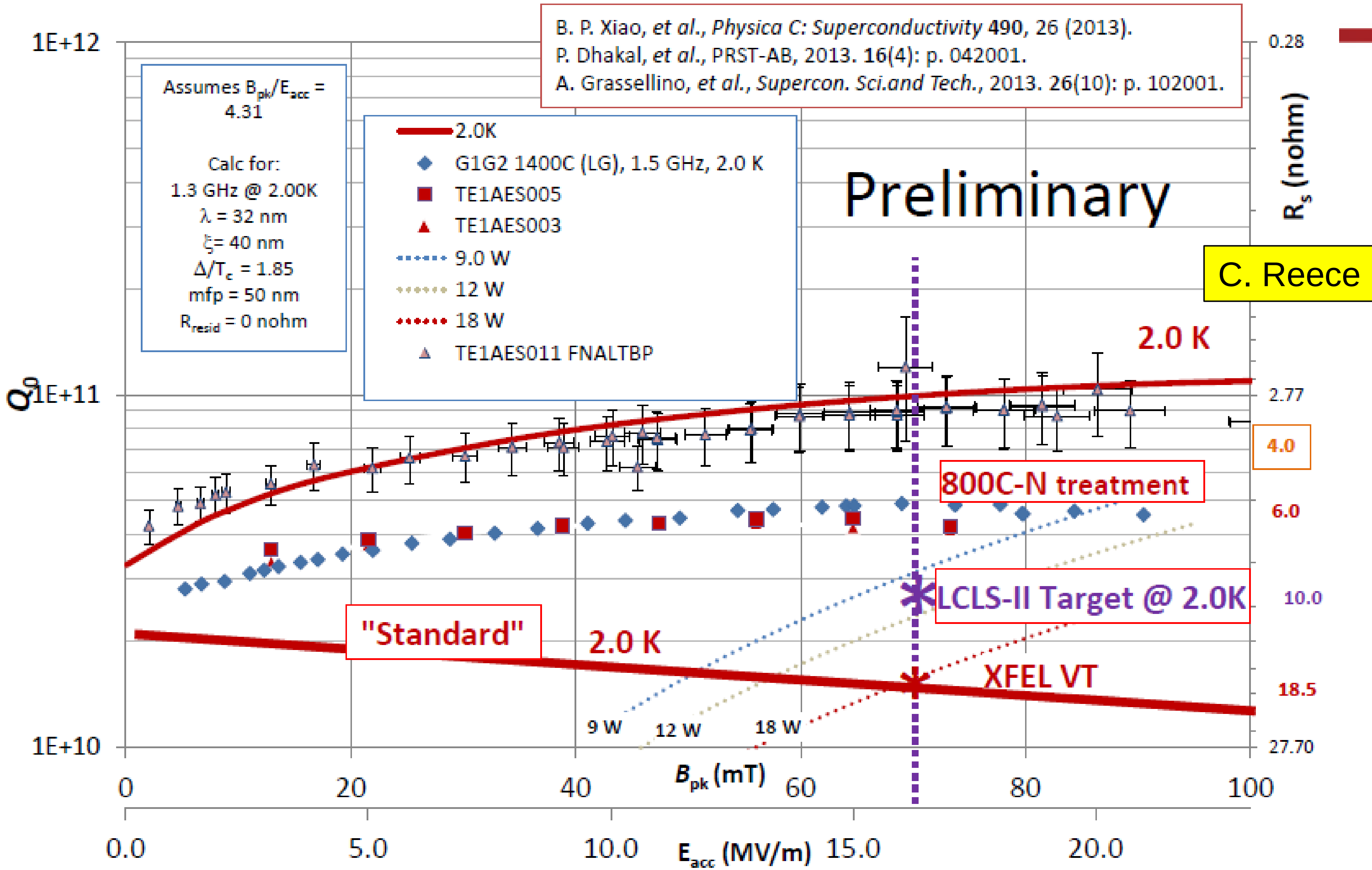
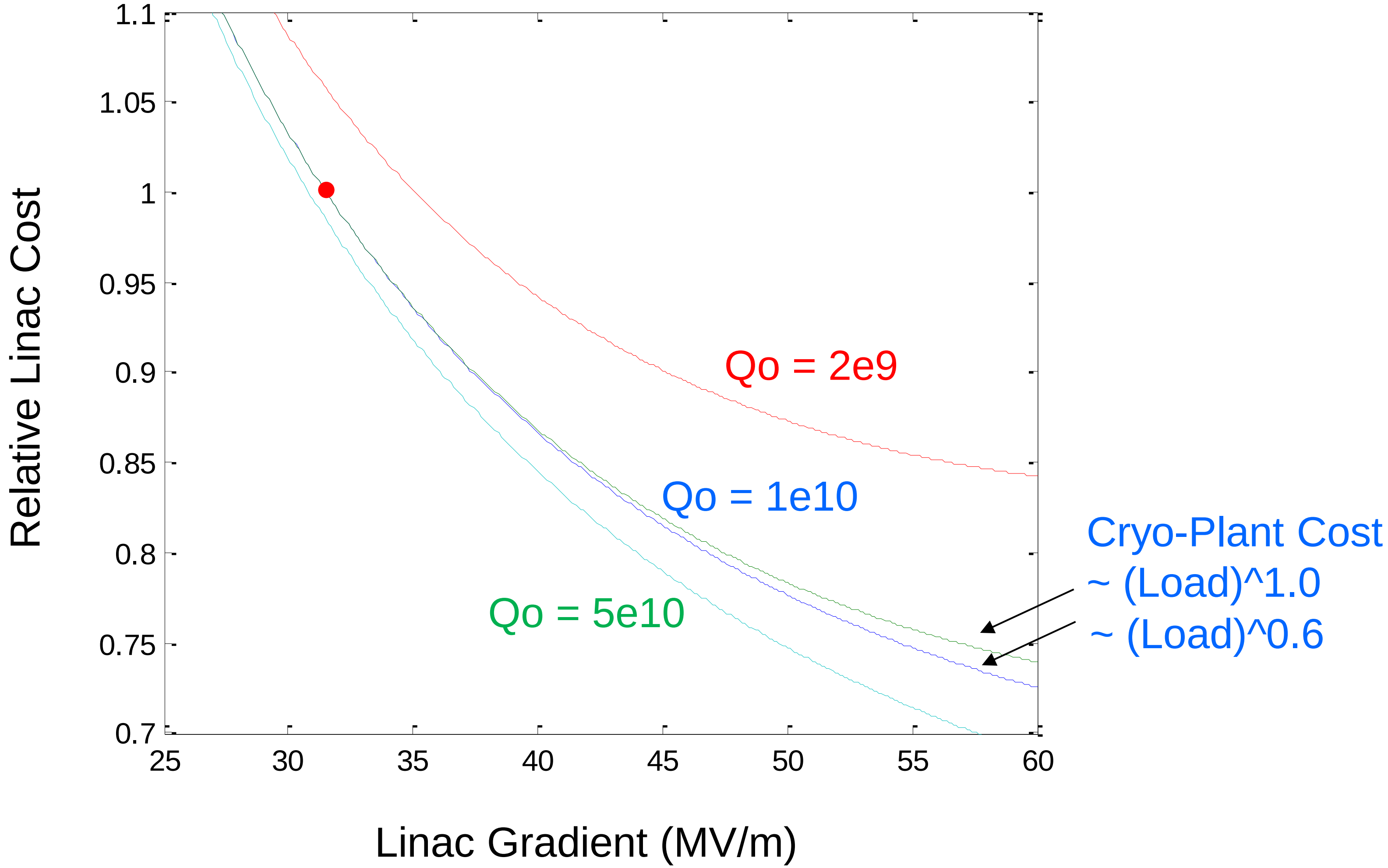
EDMS D*965055
10 March 2013

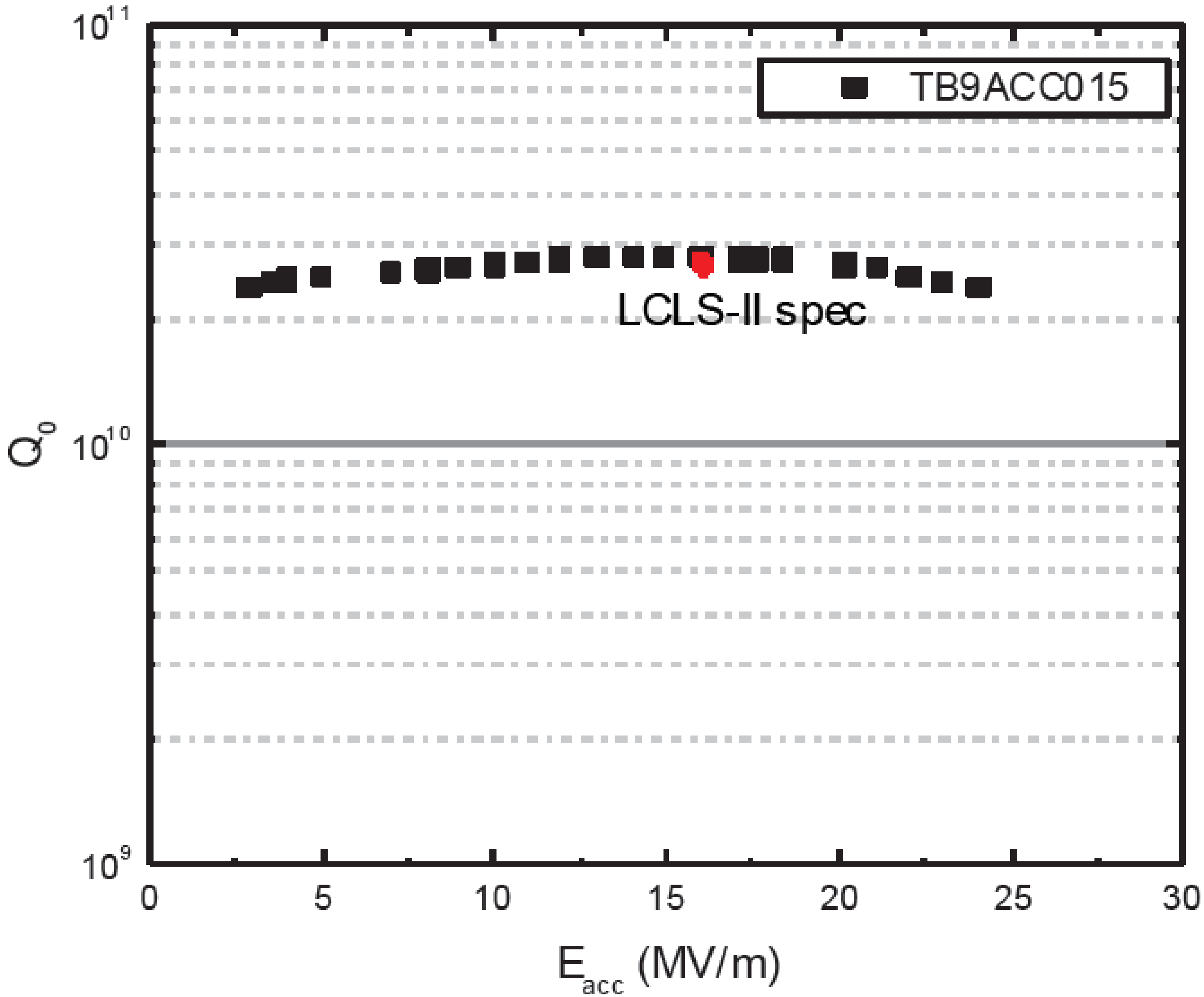
Theoretical, Previous Standard, and Recent - Q_0 Limit @ 1.3 GHz, Tesla cell Shape



Americas ILC Linac Cost Versus Cavity Gradient and Qo



LCLS-II nine-cell cavity test: Showing effect on high Q0 vs Eacc from gas-doping



Power Management

3

- There are only a few large power users who can easily and quickly cut there usage by 100 MW !
- We should consider working with the managers of the grid to implement this as an emergency relief procedure.
- We should study scenarios to minimize the impact.

Note :- SLAC used to do this under contract for lower power rates--- 60 to 20 MW

Scenario 1
Adjusting running schedule to match high demands on the grid. Summer or winter and short term weather extremes.

- **Long Term :-** **Schedule annual two to three month downtimes to match peak power usage months.**

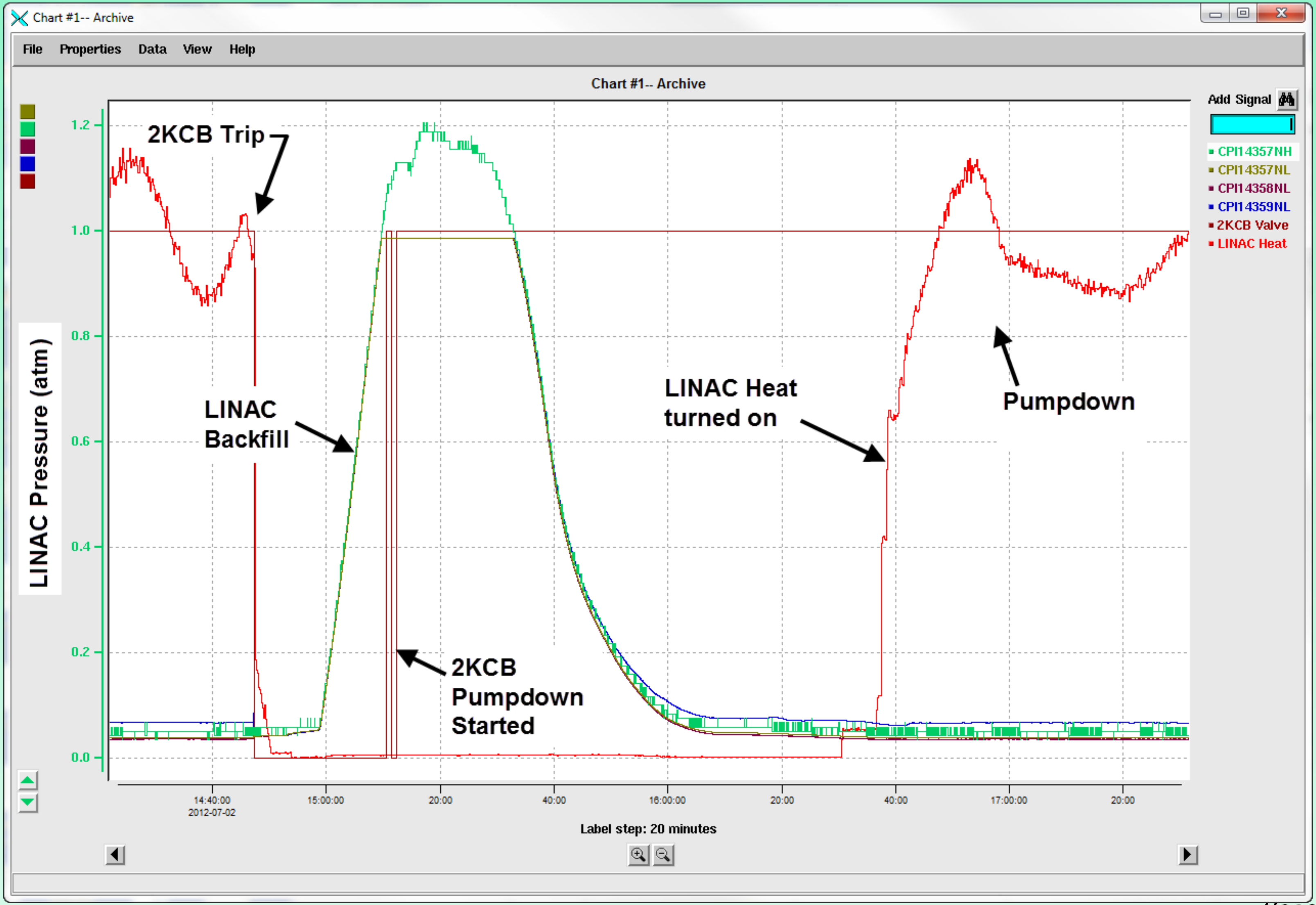
- **Short Term:-** **Plan on having "Brown Outs" of a few hours (<3) when extreme heat or cold is projected to overload the local grid. Be a good neighbor and turn off linacs only and maintain other systems in a state for rapid recovery!**
- **Negotiate some maximum number of events per year?**
- **This might require experience and using power to maintain some system temperatures. (E+ source and DR)** **SLAC experience?**

Scenario 2,
A Rare Unpredicted Emergency on Grid

In response to request for immediate help or possibly a signal from the grid?

- **Have control system automatically turn off all beams in seconds?**
- **Prepare to reduce power in cryogenic systems over hours depending on projected length of time for recovery of the grid.**

Pump Down Time and Stability



Workshop Energy for Sustainable Science

Energy Management for Large-Scale Research Infrastructures

CERN, the European Organization for Nuclear Research, ERF, the European Association of National Research Facilities, and ESS, the European Spallation Source, organised earlier in 2011 the first Joint Workshop on Energy Management for Large-Scale Research Infrastructures. The event took place on 13-14 October 2011 at Sparta in Lund, Sweden.

"

COMPLETE AND OPERATE THE BEST AND MOST POWERFUL NEUTRON SOURCE IN THE WORLD BY THE END

ESS: A green facility? →

Volatile energy costs, a tight budget climate and increasing environmental concerns are all inciting large-scale research facilities across the globe to develop mid- and long-term strategies aimed at achieving for the future a reliable, affordable and sustainable energy supply that is carbon neutral.

The workshop will bring together international experts on energy and representatives from laboratories and future projects all over the world in order to identify the challenges and best practice in respect of energy efficiency and optimization, solutions and implementation as well as to review the challenges represented by potential future technical solutions and the tools for effective collaboration.

Topics for discussion included:

- Technical challenges in availability and quality: efficiency and optimization of energy supply, energy recovery, storage and stability
- Strategic and financial challenges for the future: impact of GRID regulation, investment optimization, procurement strategy
- Challenges for heat recycling systems and water saving: energy conversion, heat recovery, high-temperature cooling loops