The Baseline Configuration and the Reference Design Report

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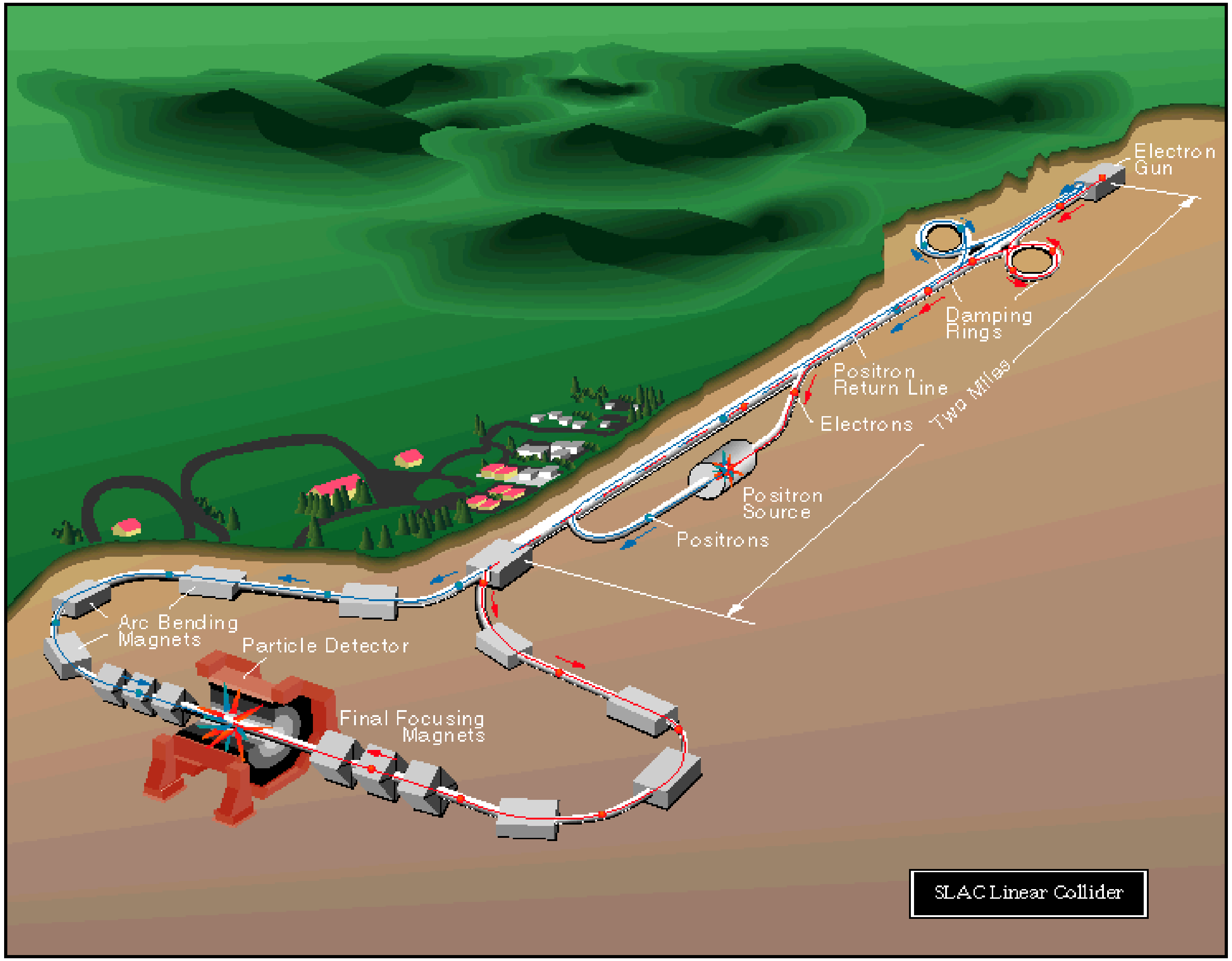
The ILC Accelerator

- 2^{nd} generation electron-positron Linear Collider
- Parameter specification
  - **E_{cms} adjustable from 200 – 500 GeV**
  - **Luminosity → $\int Ldt$ = 500 fb^{-1} in 4 years**
  - **Ability to scan between 200 and 500 GeV**
  - **Energy stability and precision below 0.1%**
  - **Electron polarization of at least 80%**
  - **Options for electron-electron and γ–γ collisions**
  - **The machine must be upgradeable to 1 TeV**
- Three big challenges: energy, luminosity, and cost

SLC: The 1st Linear Collider



Built to study the Z_0 and demonstrate linear collider feasibility

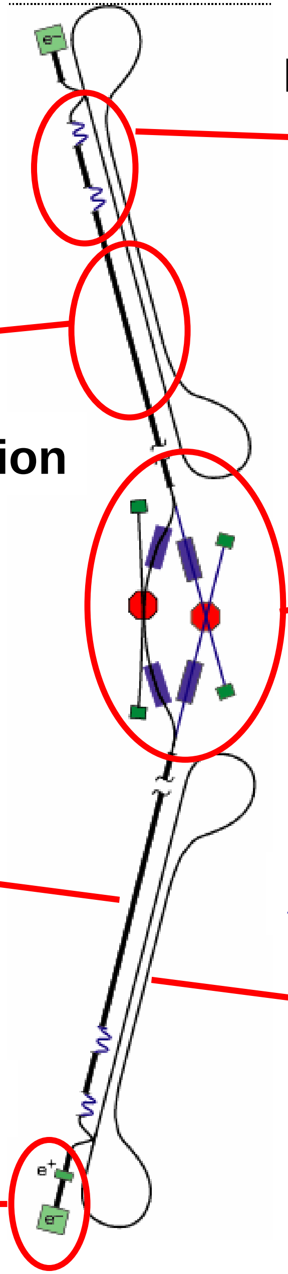
Energy = 92 GeV

Luminosity = 3e30

Had all the features of a 2nd gen. LC except both e+ and e- shared the same linac

Much more than a 10% prototype

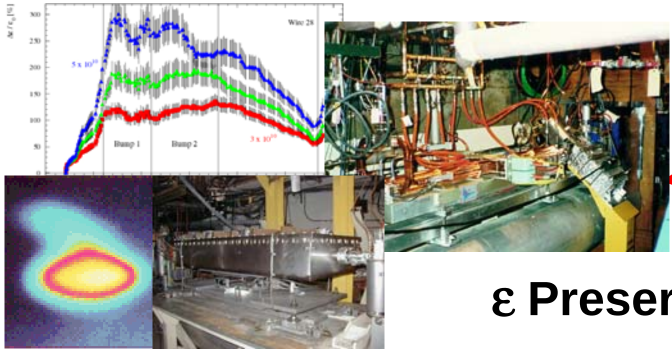
Experimental Basis for the ILC Design



Bunch Compression

SLC and FEL's

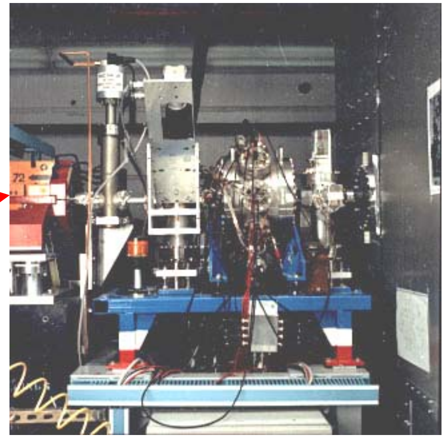
SLC, FFTB, ASSET, E-158



ε Preservation

SLC and FFTB
(ATF2 in the future)

BDS & IR



TESLA Test Facility
(SMTF & STF in the future)

Linac rf system

ATF, 3rd Gen Light Sources, SLC

Damping Rings

SLC, E-158

e+ / e- Sources

ILC GDE Program

- The present GDE ILC program has two portions:
  - **Reference Design Report (RDR)**
    - A conceptual design based on sample sites with a cost estimate
    - Accelerator physics and engineering efforts are being developed
  - **R&D Program**
    - Presently administered through the different regions
    - ILC Global Design Effort will coordinate effort more globally
- ILC design timeline
  - **RDR at end of CY2006 (1st draft)**
  - **TDR based on supporting R&D in ~2009**
- ILC Americas
  - **Effort spread between RDR and R&D programs**
  - **Some redistribution may be needed to complete the RDR**

Reference Design Report

- What exactly is the RDR?
  - **A 1st attempt at an international cost estimate for the ILC using ‘reasonable’ extrapolations from present technology**
    - Baseline design mostly established at Snowmass, Aug. 2005
    - Not TESLA and not USTOS
  - **Must document sufficiently to estimate cost**
  - **Cost estimate based on sample sites from different regions**
  - **Goal of completing the estimate in CY2006**
    - Need to use existing information: TESLA TDR, USTOS, Japanese ITRP estimate
    - New information from US industrial estimates, DESY XFEL estimates, Japanese industrial estimates but most of these will be late → provide calibration but not a basis
    - Need to make laboratory estimates for cost drivers

Baseline Configuration (BCD)

- BCD developed by ILC Working Groups established at KEK ILC Workshop (2004)
  - **Many working meetings during 2005**
  - **Discussed extensively at Snowmass ILC Workshop (2005)**
    - Working groups summarized Snowmass Workshop with bulk of the BCD
  - **White papers on contentious issues by GDE members in fall 2005**
    - Energy upgrade; Positron source; Number of tunnels; Interaction region configuration; Laser straight versus curved or terrain following tunnels
  - **Basic form ratified at Frascati GDE meeting**
- BCD has little consideration on cost minimization
  - **BCD will evolve as the cost estimates are developed**

Energy Upgrade Path

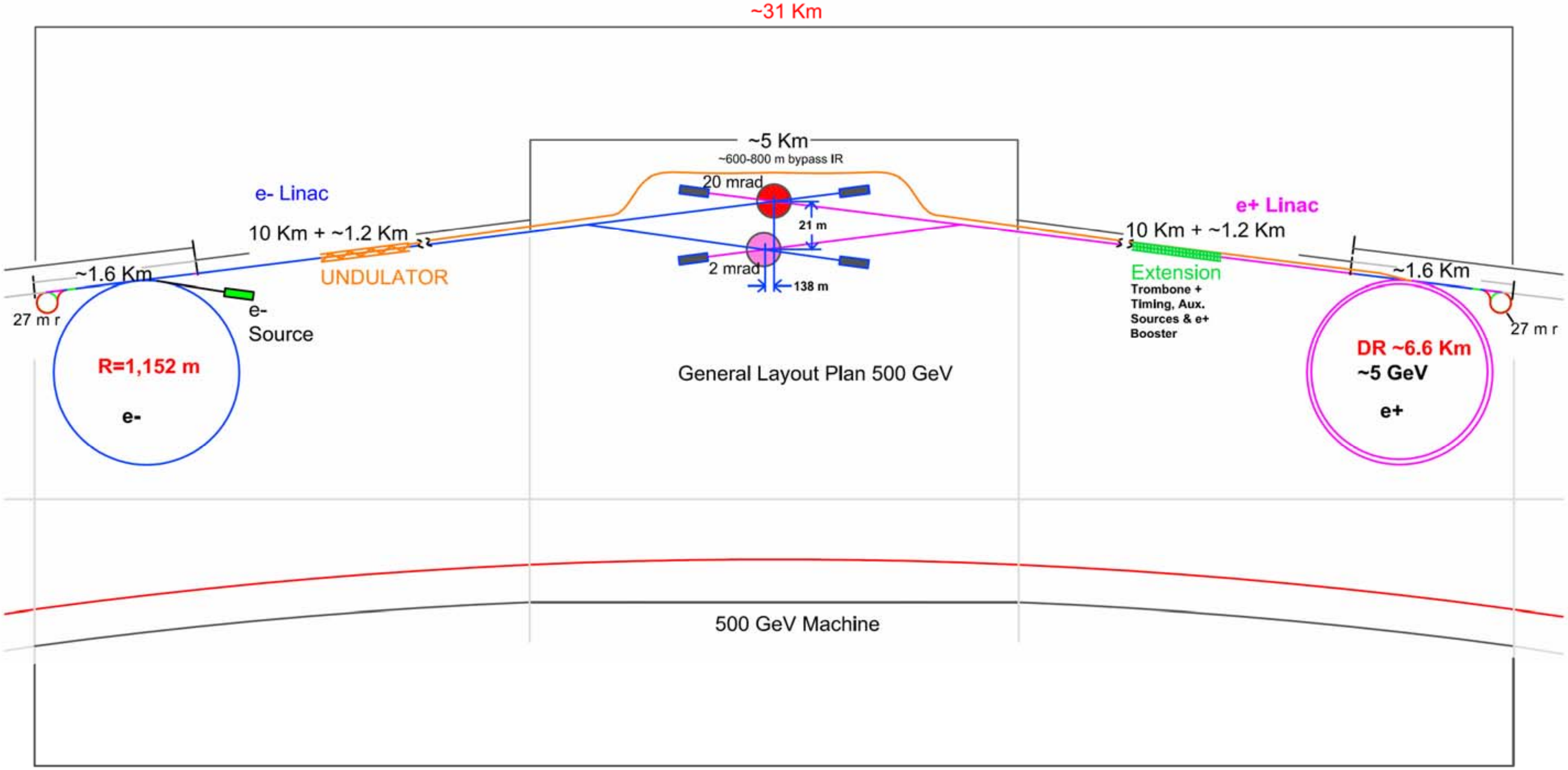
- Linac energy upgrade path based on empty tunnels hard to ‘sell’
  - **Empty tunnels obvious cost reduction**
- Lower initial gradient increases capital costs

- Baseline has tunnels for 500 GeV cms with a linac gradient of 31.5 MV/m
- Geometry of beam delivery system adequate for 1 TeV cms
  - **Require extending linac tunnels past damping rings, adding transport lines, and moving turn-around → ~50 km site**

Availability Issues

- ILC is ~10x larger than previous accelerators
- Developed availability monte carlo AvailSim
  - **Working to compare against operating acc.**
- Predict very little integrated luminosity using standard accelerator MTBFs and MTTRs
  - **Stringent requirements on component and sub-system availability**
    - Improvements ~10x on magnets, PS, kickers, etc
  - **Drives choices of redundant sources (dual electron source & backup positron source) and dual linac tunnels**
    - Large impact on project and cost – needs further study

Schematic of the BCD



General Elevation View

Elements of the BCD (1)

- Parameter plane established
  - TESLA designed for 3.4e34 but had a very narrow operating range
  - ILC luminosity of 2e34 over a wide range of operating parameters
    - Bunch length between 500 and 150 um
    - Bunch charge between 2e10 and 1e10
    - Number of bunches between ~1000 and ~6000
    - Beam power between ~5 and 11 MW
- Superconducting linac at 31.5 MV/m
  - **Cavities qualified at 35 MV/m in vertical tests**
  - **Some cavities and cryomodules would be pulse-power tested**
  - **Expect an average gradient of 31.5 MV/m to be achieved**
    - Poor performing cavities would be detuned
    - Rf system must be able to support 35 MV/m cryomodules
  - **This still requires extensive R&D on cavities and rf sources**

Parameters

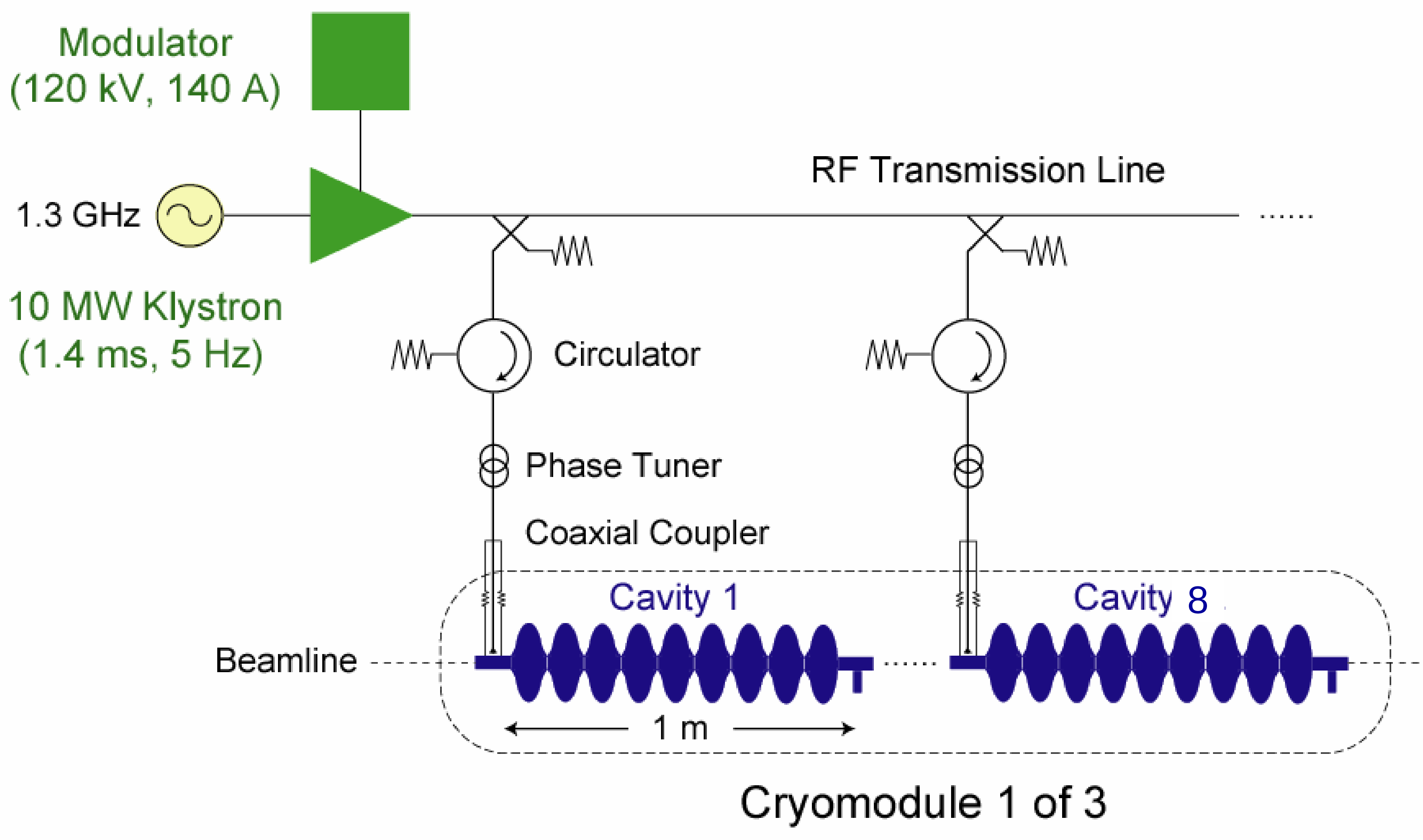
Parameter range established to allow operating optimization

		nom	low N	lrg Y	low P	High L
N	$\times 10^{10}$	2	1	2	2	2
n_b		2820	5640	2820	1330	2820
$\varepsilon_{x,y}$	µm, nm	9.6, 40	10, 30	12, 80	10,35	10,30
$\beta_{x,y}$	cm, mm	2, 0.4	1.2, 0.2	1, 0.4	1, 0.2	1, 0.2
$\sigma_{x,y}$	nm	543, 5.7	495, 3.5	495, 8	452, 3.8	452, 3.5
D_y		18.5	10	28.6	27	22
δ_{BS}	%	2.2	1.8	2.4	5.7	7
σ_z	µm	300	150	500	200	150
P_{beam}	MW	11	11	11	5.3	11

Main Linac

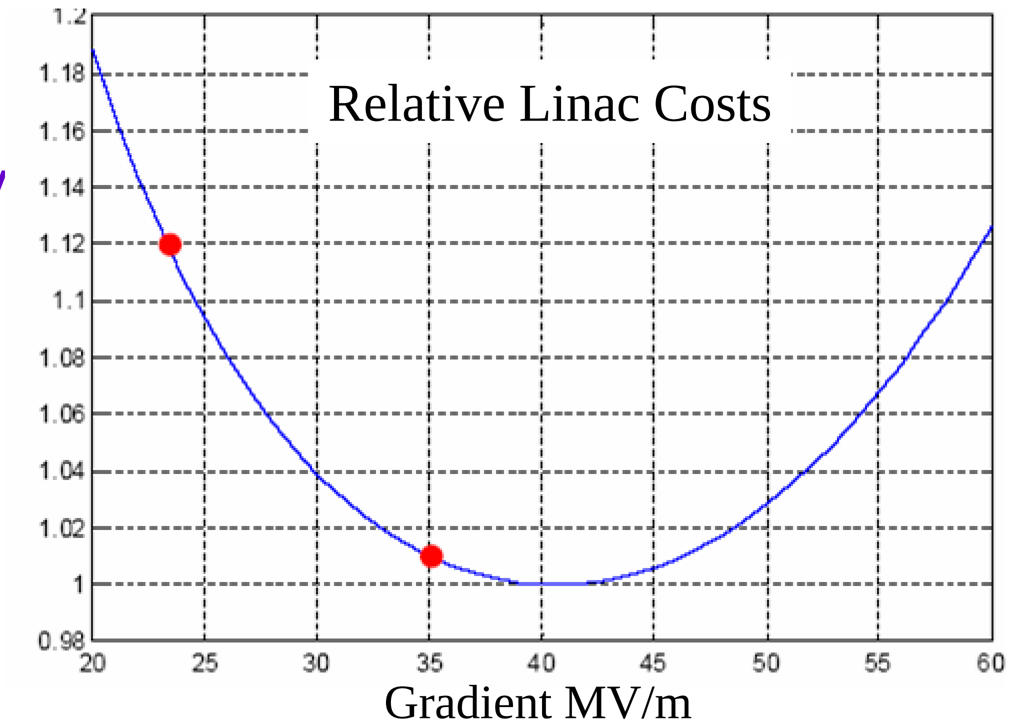
- Discussed in depth by Chris Adolphsen
- Main features:
  - **Gradient of 31.5 MV/m**
    - Qualify cavities at 35 MV/m in vertical tests
    - ~5% overhead for variation in installed cryomodules
    - ~5% overhead for operations (1~2 MV/m below quench)
  - **Packing fraction ~70%**
    - Based on Type-IV cryomodule
      - Shorter cavity-cavity spacing (1.2λ vs $3\lambda/2$)
      - Quadrupole in center of cryomodule
    - Type-III cryomodules installing in TTF
  - **Rf power for 35 MV/m**
    - 9.5 mA average current
  - **3% additional rf units for repair & feedback**

Main Linac RF Unit



Gradient Choice

- Balance between cost per unit length of linac, the available technology and the cryogenic costs
- Optimum is fairly flat and depends on details of technology



	Cavity type	Qualified gradient MV/m	Operational gradient MV/m	Length Km	Energy GeV
initial	TESLA	35	31.5	10.6	250
upgrade	LL	40	36.0	+9.3	500

Elements of the BCD (2)

- Circular damping rings 6.6 km in circumference
  - **5 GeV ring like TESLA and USTOS but shorter**
  - **Rf frequency of 650 MHz = ½ main linac 1.3 GHz**
    - Allows for greater flexibility in bunch train format
    - Allows for larger ion and electron cloud clearing gaps
  - **Shorter rings have large dynamic aperture compared to dogbone**
  - **Single electron ring; two rings for the positrons**
- Dual stage bunch compressor
  - **Dual stage system provides flexibility in IP bunch length**
  - **Allows for longer damping ring bunch length**
  - **Turn-around allows for feed-forward from damping ring to ease kicker tolerances**
  - **Pre-linac collimation system to remove beam tails at low energy**

Elements of the BCD (3)

- Positron source based on helical undulator
  - **Undulator located at ~150 GeV for energy flexibility and tuning stability**
  - **Hot spare located on e+ side to provide positrons when problems with electron beam**
    - Provide sufficient charge to operate diagnostics well
    - Could be used for commissioning is necessary
- Dual interaction regions
  - **Crossing angles of 2mrad and 20 mrad**
    - 2mrad has better hematicity while 20 mrad has better accelerator performance
  - **Optimize both to understand performance trade-offs**
    - Prepare a cost study of a single IR to understand cost trades

RDR Working Groups

- Established working groups to complete RDR effort
  - Organized by Area around regional sections of LC
    - Sources; damping rings; main linac; beam delivery; …
  - Technical design provide by technical groups that reach across Areas
    - Coordinates technical resources but makes communication harder
    - Uniform technical standards applied across collider
    - Similar to style used for NLC Lehman design and TESLA TDR
  - Some groups provide technical support for Areas but also have system-wide responsibility → Global groups
    - Conventional Facilities and Siting (CF&S)
    - Control systems; Operations; Installation; …
  - Costs get rolled up to the Area groups so that they can study cost versus performance trades
  - Costs get output to Cost Engineers so they can study cost basis across systems

RDR Matrix

- Matrix of Area Systems and Technical Systems to develop cost estimate
  - International representation in all working groups

	Area Systems					
	e- source	e+ source	Damping Rings	RTML	Main Linac	BDS
		Kiriki	Gao	ES Kim	Hayano	Yamamoto
			Guiducci		Lilje	Angal-Kalinin
	Brachmann	Sheppard	Wolski	Tenenbaum	Adolphsen	Seryi
	Logachev		Zisman		Solyak	
Technical Systems						
Vacuum systems	Suetsugu	Michelato	Noonan			
Magnet systems	Sugahara		Thomkins			
Cryomodule	Ohuchi	Pagani	Carter			
Cavity Package	Saito	Proch	Mammosser			
RF Power	Fukuda		Larsen			
Instrumentation	Urakawa	Burrows	Ross			
Dumps and Collimators	Ban		Markiewicz			
Accelerator Physics	Kubo	Schulte				
Global Systems						
Commissioning, Operations & Reliability	Teranuma	Elsen	Himel			
Control System	Michizono	Simrock	Carwardine			
Cryogenics	Hosoyama	Tavian	Peterson			
CF&S	Enomoto	Baldy	Kuchler			
Installation	Shidara	Bialwons	Asiri			

Summary

- Baseline configuration is well thought out
  - **Based on decades of R&D**
  - **Technology reasonable extrapolation of the R&D status**
  - **Inclusion of availability and operational considerations**
  - **Conservative choices (for the most part) to facilitate rapid cost evaluation**
- Working to develop designs with engineering and civil layout
  - **Translation of design specifications in process**
- Will need additional work on cost reduction
  - **System and sub-system optimization as well as component level**
  - **Need industrial estimates to benchmark our numbers**