ILC-0.5 and ILC-1 TeV Required R&D and beam facilities

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Outline

- ILC 0.5 TeV
  - Collider parameters
  - Superconducting linac
  - Positron source
  - Damping rings
  - Ring to main linac
  - Beam delivery system and IR
  - Upgrade to 1 TeV center of mass

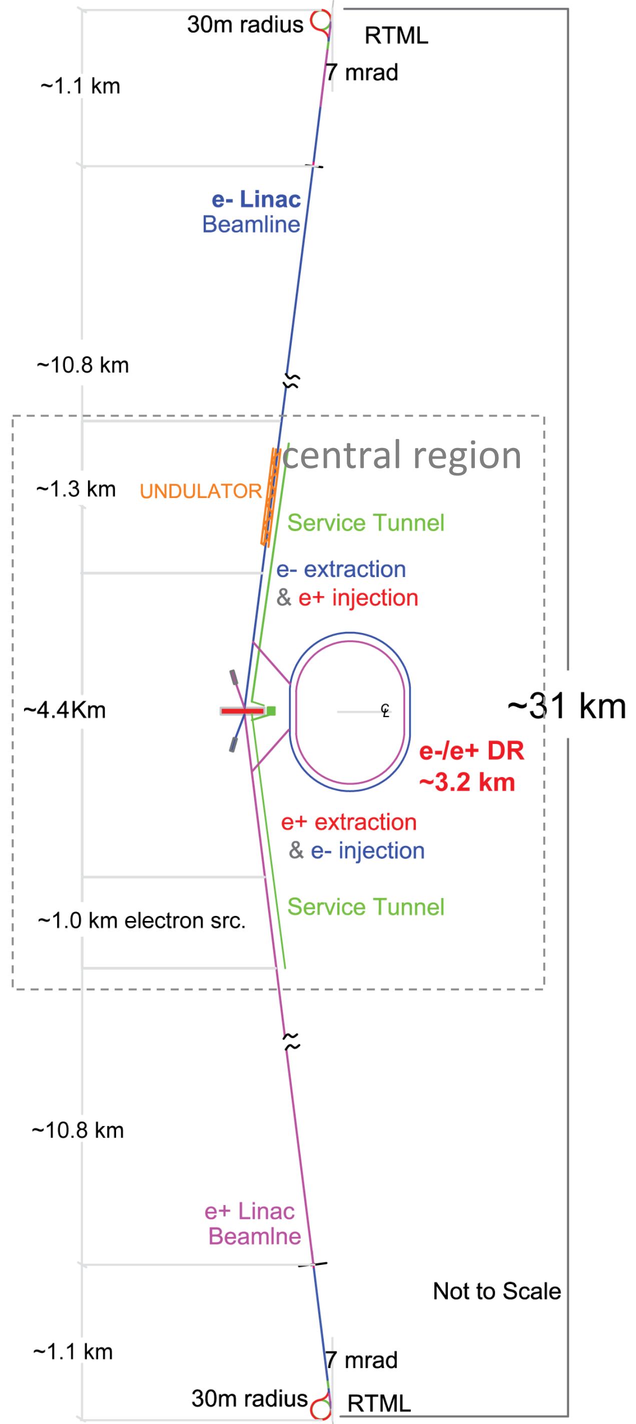
ILC Design Status

- With completion of TDR
  - Design is complete
  - R&D goals have been achieved (500 GeV cm)
    - High gradient, system tests, kicker tests, final focus performance, electron cloud mitigation, acceleration of ILC-like beams (FLASH)
  - Ready for engineering design – R&D complete.

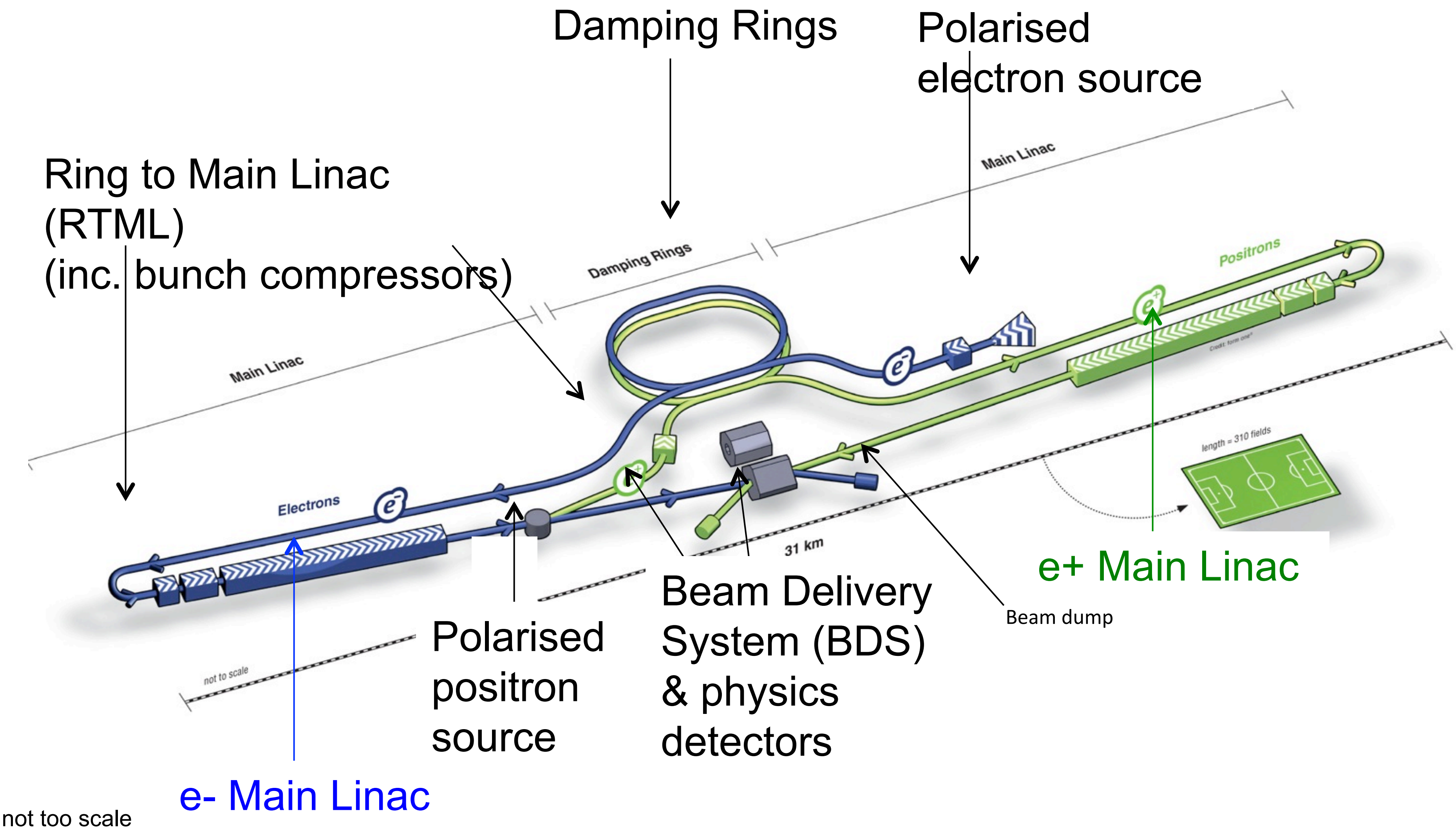
However: Additional beam tests can help strengthen design, reduce risk and cost, improve performance

Collider

- Polarized electron source based on photocathode DC gun
- Undulator based polarized positron source
- 5GeV damping rings – 3.2 km circumference in common tunnel
- Transport from damping rings to main linac, acceleration from 5-15 GeV, with spin rotator and bunch compression
- Two 11 km, 1.3 GHz superconucting linacs with <G> = 31.5 MV/m
- 2.25km long BDS/beam with 14mrad crossing angle at IP


30m radius
RTML
7 mrad
~1.1 km
e- Linac
Beamline
~10.8 km
central region
~1.3 km
UNDULATOR
Service Tunnel
e- extraction
& e+ injection
~4.4Km
~31 km
e-/e+ DR
~3.2 km
e+ extraction
& e- injection
Service Tunnel
~1.0 km electron src.
~10.8 km
e+ Linac
Beamlne
Not to Scale
~1.1 km
7 mrad
30m radius
RTML

ILC TDR Layout

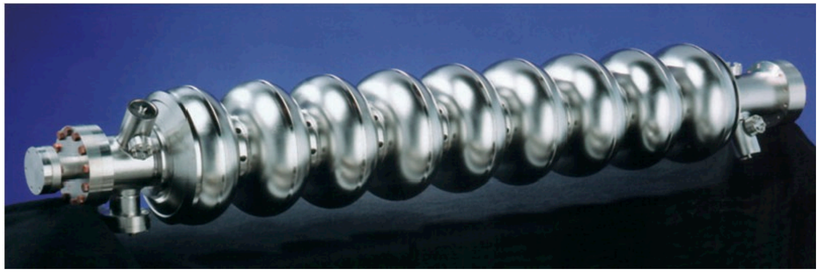


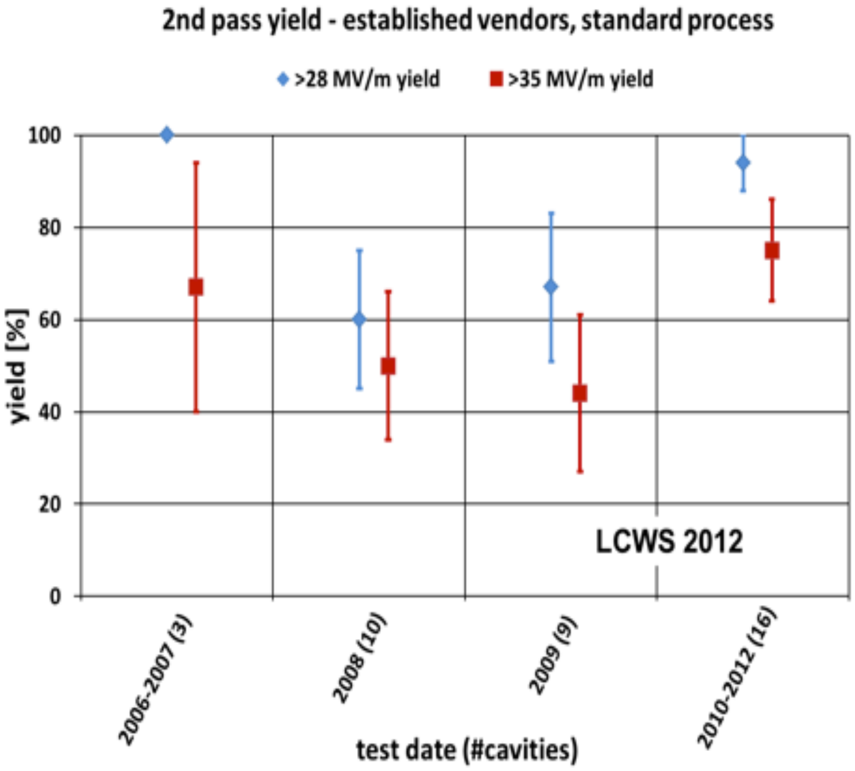
ILC Scheme | © www.form-one.de

ILC parameters 200-500 GeV

Centre-of-mass energy	E_{CM}	GeV	200	230	250	350	500
Luminosity pulse repetition rate		Hz	5	5	5	5	5
Positron production mode			10 Hz	10 Hz	10 Hz	nom.	nom.
Bunch population	N	$\times 10^{10}$	2	2	2	2	2
Number of bunches	n_b		1312	1312	1312	1312	1312
Linac bunch interval	Δt_b	ns	554	554	554	554	554
RMS bunch length	σ_z	µm	300	300	300	300	300
Normalized horizontal emittance at IP	$\gamma\epsilon_x$	µm	10	10	10	10	10
Normalized vertical emittance at IP	$\gamma\epsilon_y$	nm	35	35	35	35	35
Horizontal beta function at IP	β_x^*	mm	16	14	13	16	11
Vertical beta function at IP	β_y^*	mm	0.34	0.38	0.41	0.34	0.48
RMS horizontal beam size at IP	σ_x^*	nm	904	789	729	684	474
RMS vertical beam size at IP	σ_y^*	nm	7.8	7.7	7.7	5.9	5.9
Vertical disruption parameter	D_y		24.3	24.5	24.5	24.3	24.6
Fractional RMS energy loss to beamstrahlung	δ_{BS}	%	0.65	0.83	0.97	1.9	4.5
Luminosity	L	$\times 10^{34}$ cm^{-2} s^{-1}	0.56	0.67	0.75	1.0	1.8
Fraction of L in top 1% E_{CM}	$L_{0.01}$	%	91	89	87	77	58
Electron polarisation	P_-	%	80	80	80	80	80
Positron polarisation	P_+	%	30	30	30	30	30
Electron relative energy spread at IP	$\Delta p/p$	%	0.20	0.19	0.19	0.16	0.13
Positron relative energy spread at IP	$\Delta p/p$	%	0.19	0.17	0.15	0.10	0.07

Superconducting Linac





Production yield: 94 % at > 28 MV/m,

Average gradient: 37.1 MV/m

A. Yamamoto

SRF R&D
System tests at FLASH

J. Carwardine

High beam power and long bunch-trains *(Sept 2009)*

Metric	ILC Goal	Achieved
Macro-pulse current	9mA (5.8mA)	9mA
Bunches per pulse	2400 x 3nC (3MHz)	1800 x 3nC 2400 x 2nC
Cavities operating at high gradients, close to quench	31.5MV/m +/-20%	4 cavities > 30MV/m

Gradient operating margins *(updated following Feb 2012 studies)*

Metric	ILC Goal	Achieved
Cavity gradient flatness (all cavities in vector sum)	2% $\Delta V/V$ (800μs, 5.8mA) (800μs, 9mA)	<0.3% $\Delta V/V$ (800μs, 4.5mA) *First tests of automation for Pk/Ql control*
Gradient operating margin	All cavities operating within 3% of quench limits	Some cavities within ~5% of quench (800us, 4.5mA) *First tests of operations strategies for gradients close to quench*
Energy Stability	0.1% rms at 250GeV	<0.15% p-p (0.4ms) <0.02% rms (5Hz)

System tests

- During the TD Phase, we have verified the key fundamental technology issues of operating an SC linac at ILC-like parameters
  - Long pulse high power beam operation
  - High average gradient, gradient spread
  - Operation close to limits of gradient and rf power

- Post-2012, move to engineering and system integration
  - Establish a base of experience for building and operating a large-scale high power linear collider, eg
    - Machine protection, exception handling
    - 'Gradient management'
    - Startup & machine tuning, achieving stable operation
    - Characterize and optimize control strategies
    - Operation of multiple cryomodules at top gradient
    - High gradient cavity stabilizaiton
    - HLRF controls

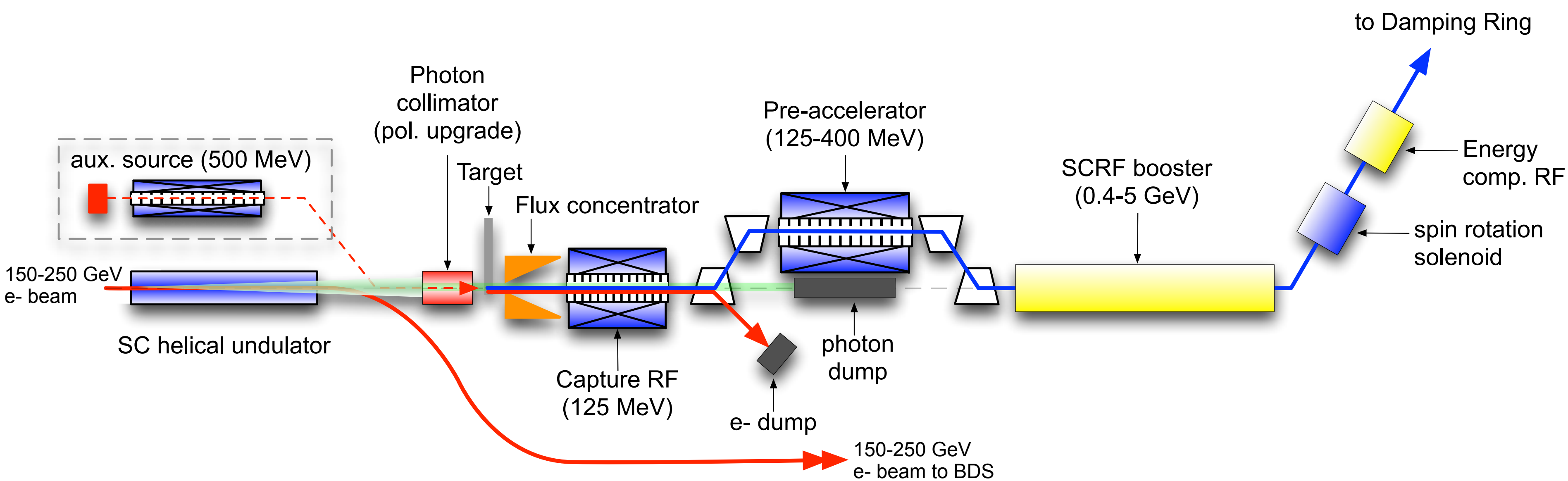
-> ASTA – with ILC cryomodules and ILC beam/bunch parameters
is the ideal laboratory for systems tests

High Gradient SRF R&D

- Higher gradient 45 MV/m and higher Q0 2E10 R&D for 1 TeV upgrade
  - Alternative shape cavity
    - Excellent 1-cell and 2-cell cavity demonstration of Hpk > 2000 Oe in hand
    - >>> ILC 1 TeV SRF cavity goals are reachable
  - Highest priority is to reduce field emission at Epk ~ 100 MV/m
    - Require improved understanding to guide development of counter measures
    - Like we did for quench limit improvement in ILC Technical Design Phase
  - Second priority is to understand the physics of medium-field and high-field Q-slope and develop new treatment for reduced Q-slope
- Lowering cost of SRF technology
  - Evaluate acceptable RRR and Tantalum content
  - Seamless cavity (bulk Nb and Nb-Cu clad material)
  - Large-grain material
  - Mechanical polish

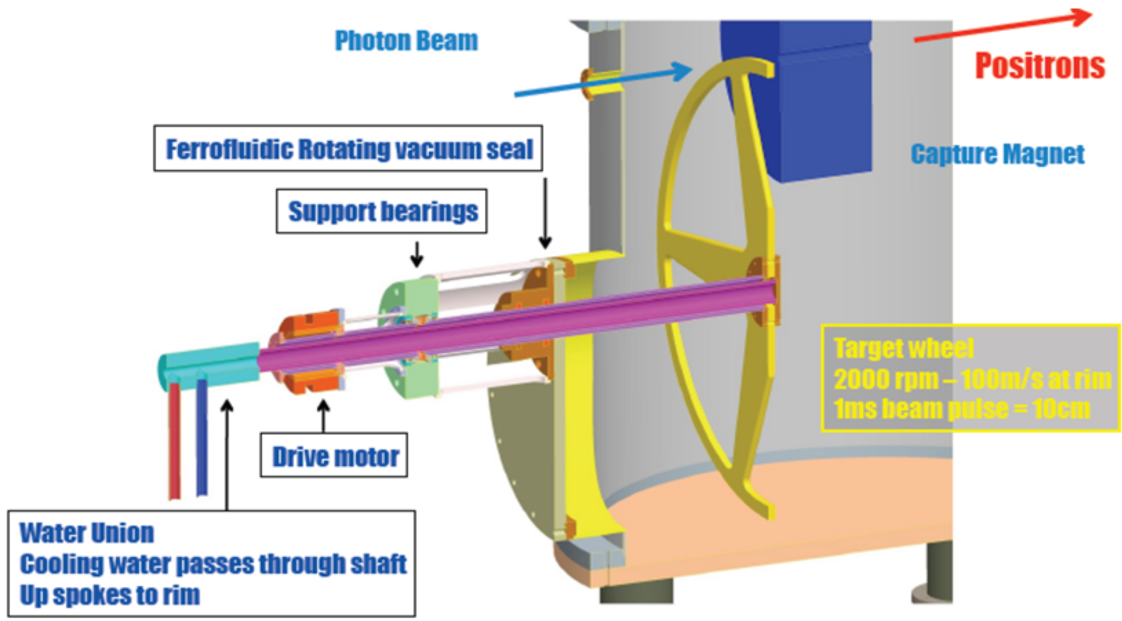
Jim Kerby

Positron source



Positron source

- Target physics/technology/polarization
- Rotating seal test stand and flux-concentrator -LLNL



- The positron-production target is a rotating wheel made of titanium alloy (Ti6Al4V).
- The diameter of the wheel is 1m and the thickness is 0.4 radiation lengths (1.4 cm).
- During operation the outer edge of the rim moves at 100 m/s.

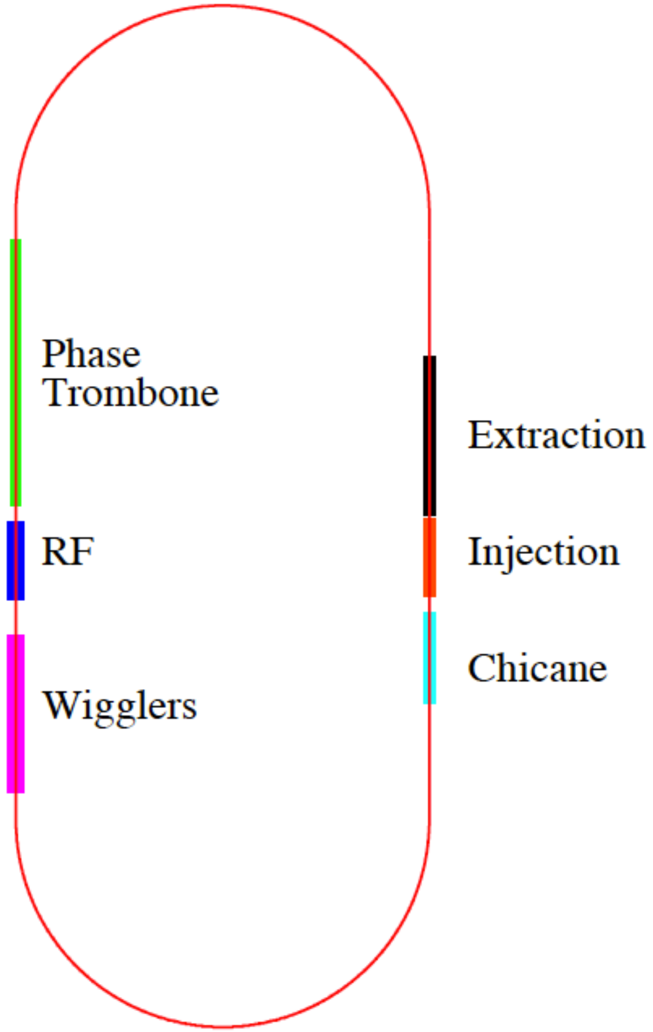
Wei gai

Target system issues

- Vacuum seal
  - Two types of vacuum seals, Rigaku and FerroTech, have been tested at LLNL. Rigaku seal wasn't able to run at 2000RPM. FerroTech seals each has its own individual personality; all have out gassing spike; off-the-shelf models do not seem to be well designed.
  - Need to partner with FerroTech to improve their design
  - However, a differential pumping can be used as a back up scheme
- Shockwaves and thermal dynamic
  - Energy deposition causes shockwaves in the material. If shock exceeds strain limit of material chunks can spall from the face
  - The SLC target showed spall damage after radiation damage had weakened the tungsten target material
  - Initial calculations from LLNL had shown no problem in Titanium target
  - ANSYS simulation at DESY is underway and need to be further confirmed by experiment and/or simulation from different institute.
- Future R&D
  - Target system prototype and test will continue at LLNL
  - Shockwave damage simulation will continue and need to develop and carry out an experiment

Wei Gai

Damping rings



Circumference - 3238 m

5.6 μ-rad < $\gamma\varepsilon_x$ < 6.4μ-rad

54 Wigglers

- length 2.1 m
- B_{peak} 2.2 T
- Poles 14
- Period 30cm
- 24ms > τ_x > 12ms

Phase trombone ➔ ± 0.5 λ_β

Chicane ➔ ± 3mm pathlength

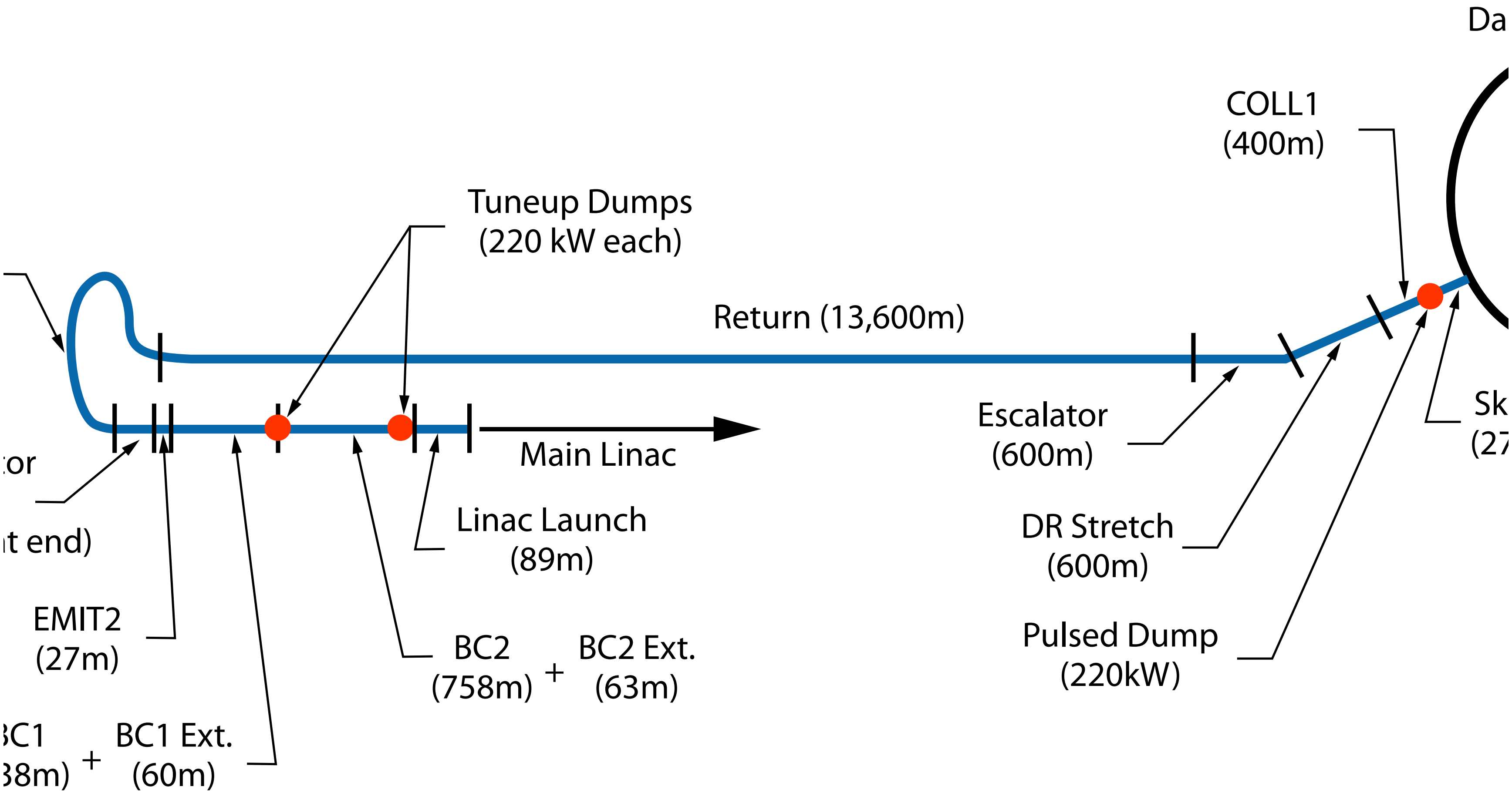
≤ 12 - 650MHz RF cavities

=> σ_l = 6mm

Damping rings

- Injection/extraction kickers – ATF
- Fast ion instability – CesrTA
- Instrumentation – beam size monitors, beam position monitors, feedback systems
- Electron cloud – extend measurement of thresholds for electron cloud instability and beam blowup to lower emittance beams
- Extraction optics – kicker septum channel multipoles and stability (ATF2)

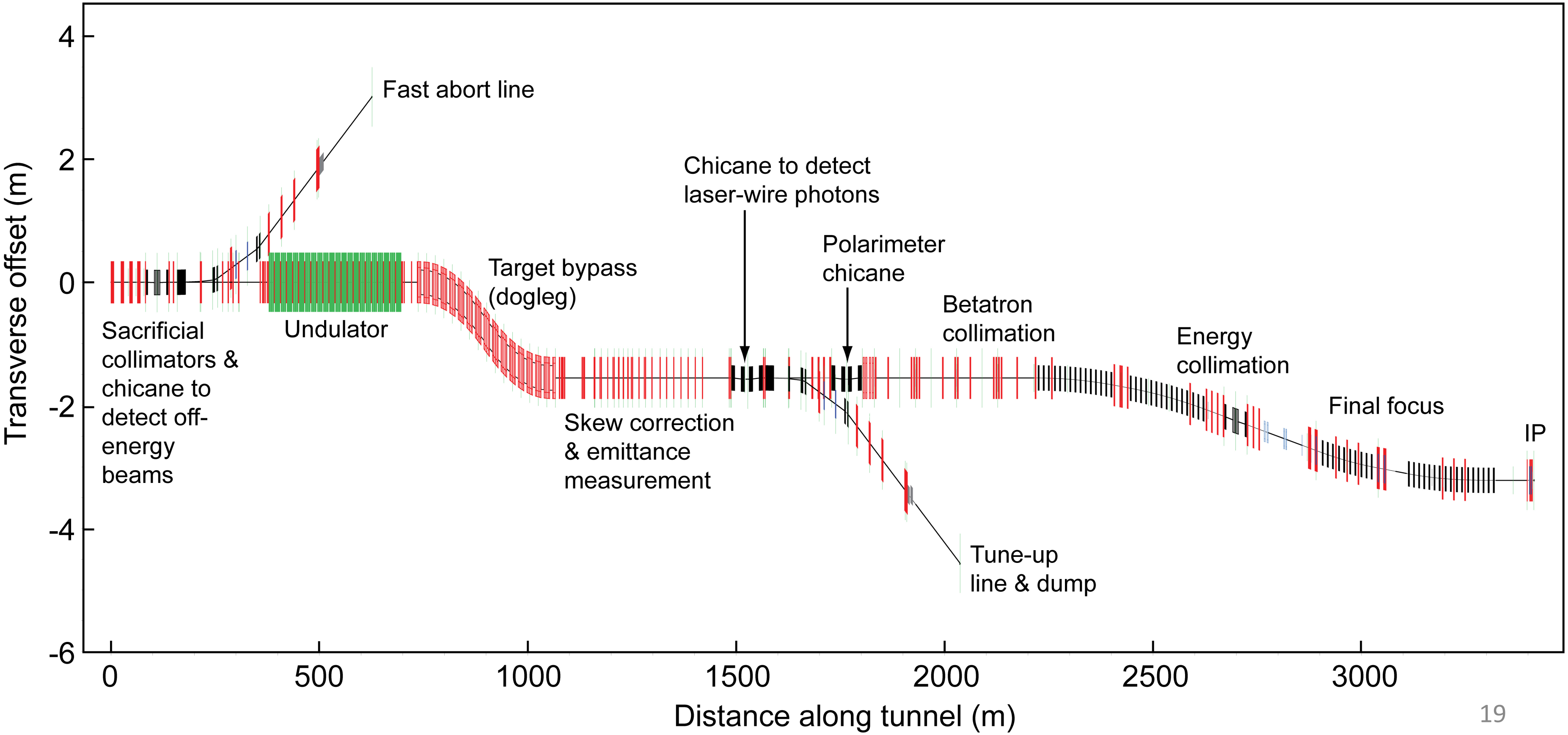
Ring to main linac



Ring to main linac

- Wake field driven emittance growth
- Explored at ATF2
- Design criteria for vacuum chambers
- Cavity alignment

Beam delivery system



Beam delivery system

- Wakefields
  - Strong dependence of beam size on charge and bunch length
  - => Identify and mitigate wakes

Glen White

Beam delivery system

- Beam size and stability
- ATF2 final focus system goals
  - Beam tuning procedures
  - Focus vertical spot at IP to ~37 nm (Measured 73nm to date at ~10% requisite bunch charge?)
  - Maintain IP vertical position with few nm precision
  - Demonstrate stability

Glen White

1 TeV

- Reduce repetition rate from 5 to 4Hz (AC power)
- Reduced bunch charge (1.74 vs 2.0 $X10^{10}$)
- Shorter bunch length (250µm – 225µm)
- Smaller β^*
- 2450 bunches/pulse (vs 1312)
- Extend main linacs to reach higher energy and increase cavity gradient to 45 MV/m

Summary – Beam tests

- Test beam requirements for ILC 0.5-1 TeV
  - SRF linac system tests, stability, optimization – ASTA/FLASH
  - Final focus – 37nm spot size & few nm position stability – intra-beam feedback – ATF2
  - Damping ring extraction preserving beam emittance – ATF
  - Injection/extraction kickers - ATF
  - RTML emittance dilution – wakefields – ATF
  - Damping ring – fast ion and electron cloud at low emittance, instrumentation – beam size monitor, feedback systems – CesrTA

R&D not requiring test beams

- SRF – higher yield and higher gradient
- Positron source – target engineering and tests
- Ring to main linac – cavity alignment, vacuum chamber design

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