ILC – Status, TDR and Costs

Technical Design Report

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LCWS12
Arlington, TX
22-Oct-12

GDE Status & Plans

- Update on major ILC accelerator R&D goals
- ILC Systems Tests
- The Technical Design Report
- Japanese plan and candidate sites
- Cost estimate and RDR comparison
- Staged approach? Higgs Factory → ILC

Major R&D Goals for Technical Design

SCRF

- **High Gradient R&D - globally coordinated program to demonstrate gradient by 2010 with 50%yield; improve yield to 90% by TDR (end 2012)**
- **Manufacturing: plug compatible design; industrialization, etc.**
- **Systems tests: FLASH; plus NML (FNAL), STF2 (KEK) post-TDR**

Test Facilities

- **ATF2 - Fast Kicker tests and Final Focus design/performance EARTHQUAKE RECOVERY**
- **CesrTA - Electron Cloud tests to establish electron cloud mitigation strategy**
- **FLASH – Study performance using ILC-like beam and cryomodule (systems test)**

The ILC SCRF Cavity

Figure 1.2-1: A TESLA nine-cell 1.3 GHz superconducting niobium cavity.

- Achieve high gradient (35MV/m); develop multiple vendors; make cost effective, etc

- Focus is on high gradient; production yields; cryogenic losses; radiation; system performance

Global Plan for ILC Gradient R&D

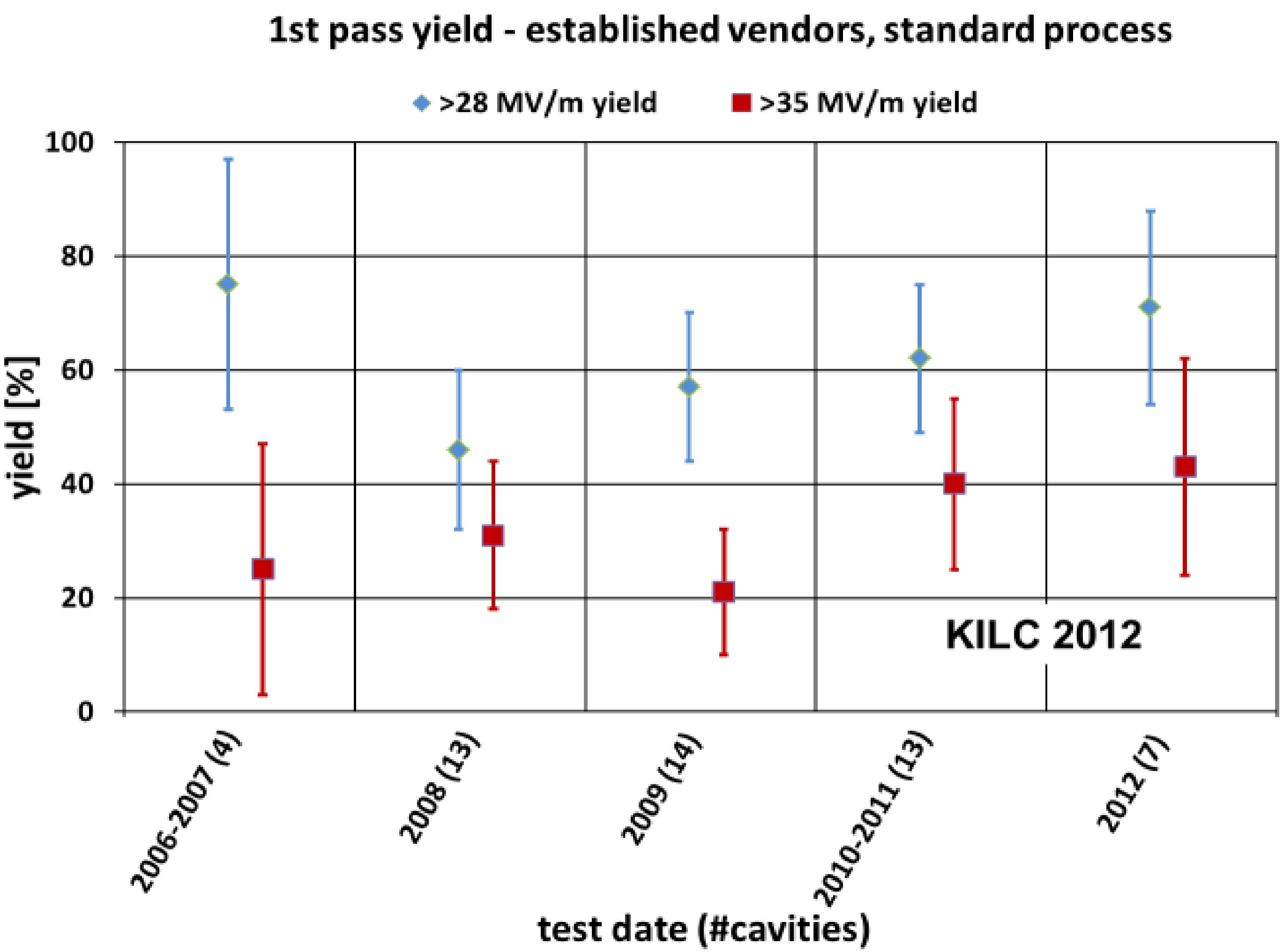
Year	07	2008	2009	2010	2011	2012
Phase	TDP-1				TDP-2	
Cavity Gradient in v. test to reach 35 MV/m	→ Yield 50%				→ Yield 90%	
Cavity-string to reach 31.5 MV/m, with one-cryomodule		Global effort for string assembly and test (DESY, FNAL, INFN, KEK)				
System Test with beam acceleration			FLASH (DESY) , NML (FNAL) STF2 (KEK, test start in 2013)			
Preparation for Industrialization				Production Technology R&D		

New baseline gradient:

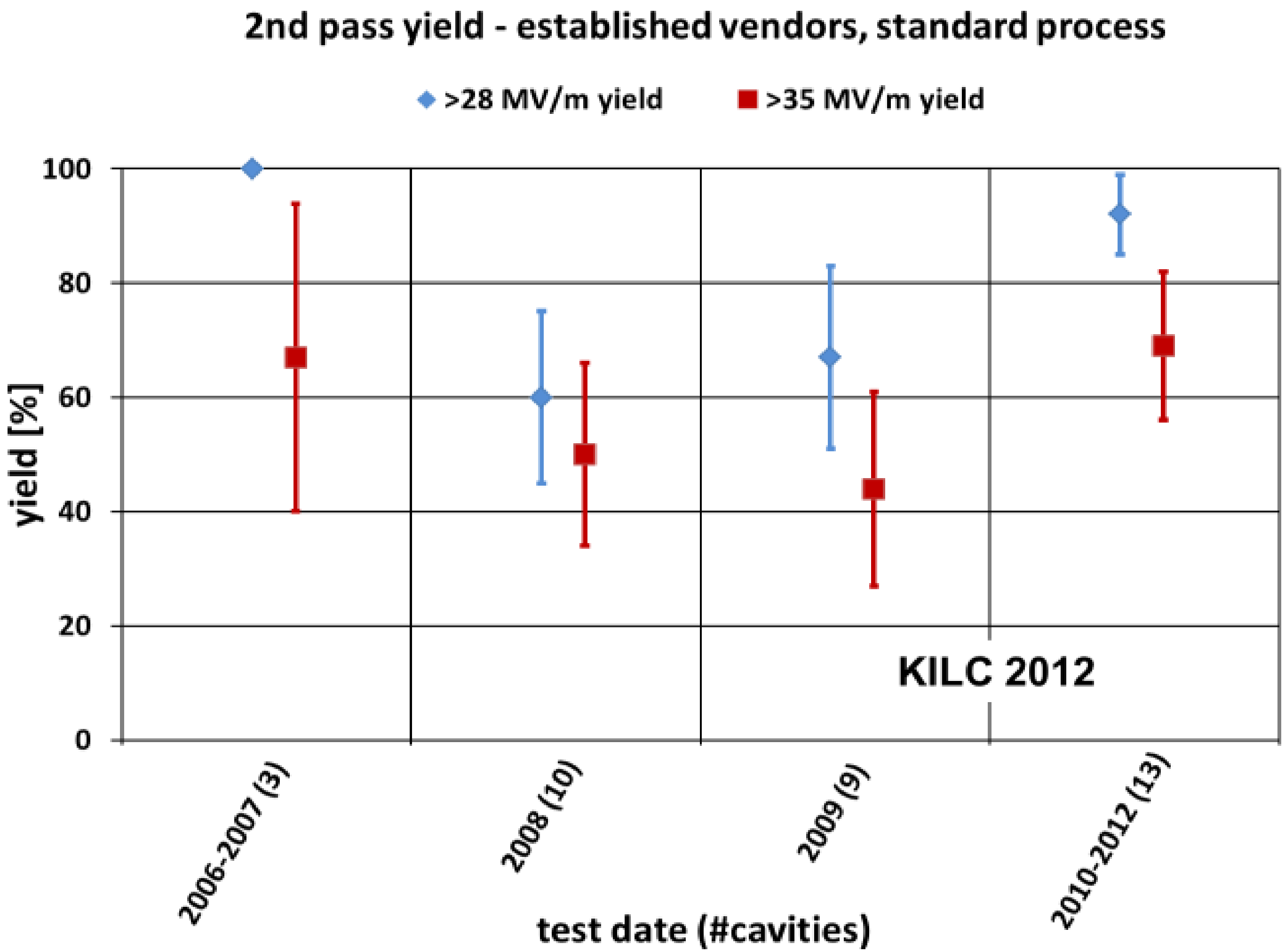
Vertical acceptance: 35 MV/m average, allowing ±20% spread (28-42 MV/m)

Operational: 31.5 MV/m average, allowing ±20% spread (25-38 MV/m)

Yearly Progress in Cavity Gradient Yield



Yearly Progress in Cavity Gradient Yield



S-1 Global – plug compatible

Cavities, Tuners, Couplers in S1-G Cryomodule

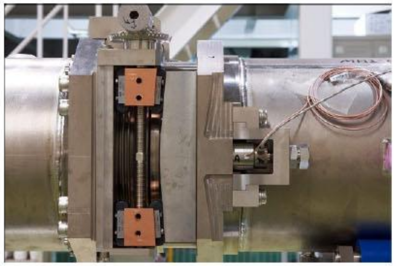
TESLA Cavity (DESY/FNAL)

Blade Tuner (FNAL)

Saclay Tuner (DESY)

TTF-III Coupler (DESY/FNAL)

Tesla-like Cavity (KEK)



Slide-Jack Tuner (KEK)

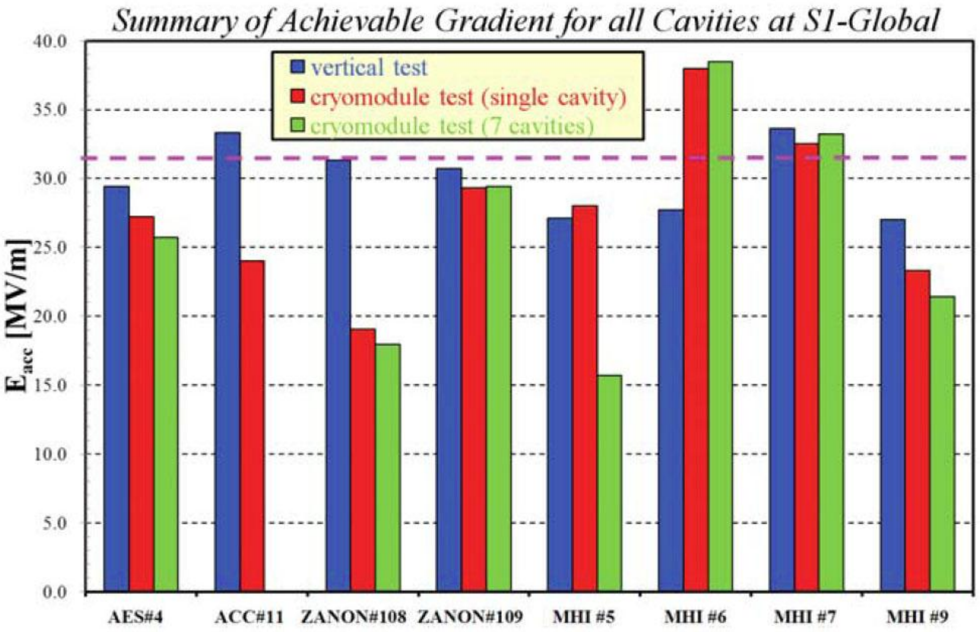
STF-II Coupler (KEK)

E. KAKO (KEK)

S-1 Global – plug compatible

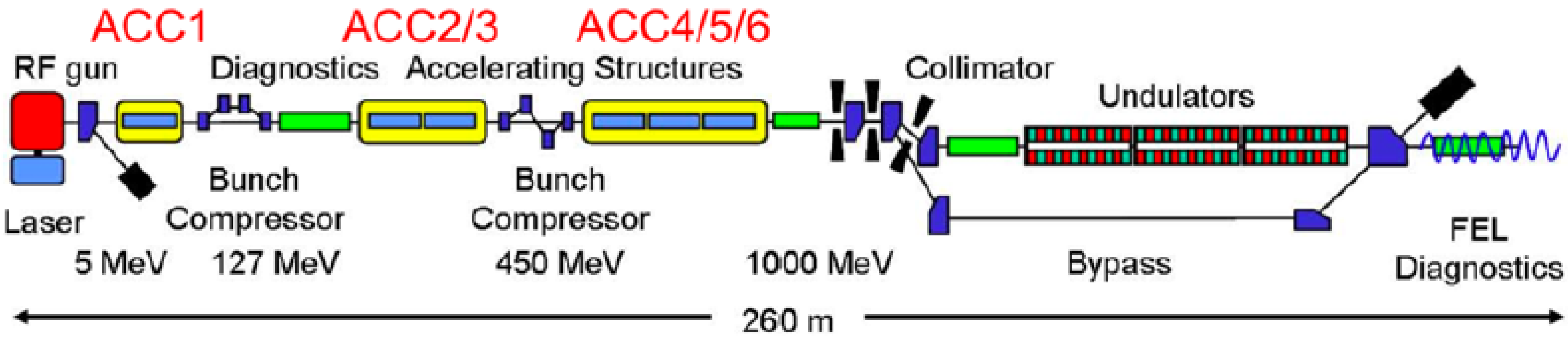
S-1 Global cryomodule assembly

S-1 Global
Achieved gradients



TTF/FLASH 9mA Experiment

Full beam-loading long pulse operation → "S2"

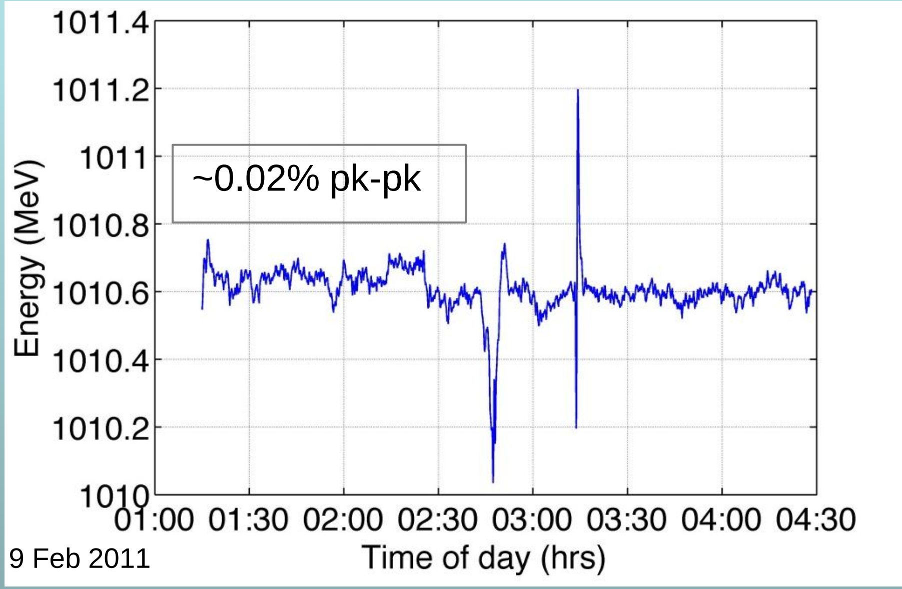


		XFEL	ILC	FLASH design	9mA studies
Bunch charge	nC	1	3.2	1	3
# bunches		3250	2625	7200'	2400
Pulse length	μs	650	970	800	800
Current	mA	5	9	9	9

- Stable 800 bunches, 3 nC at 1MHz (800 μs pulse) for over 15 hours (uninterrupted)
- Several hours ~1600 bunches, ~2.5 nC at 3MHz (530 μs pulse)
- >2200 bunches @ 3nC (3MHz) for short periods

FLASH: Stability

Energy stability over 3hrs with 4.5mA



- 15 consecutive studies shifts (120hrs), and with no downtime
- Time to restore 400us bunch-trains after beam-off studies: ~10mins
- Energy stability with beam loading over periods of hours: ~0.02%
- Individual cavity “tilts” equally stable

FLASH 9mA achievements: 2009 → present

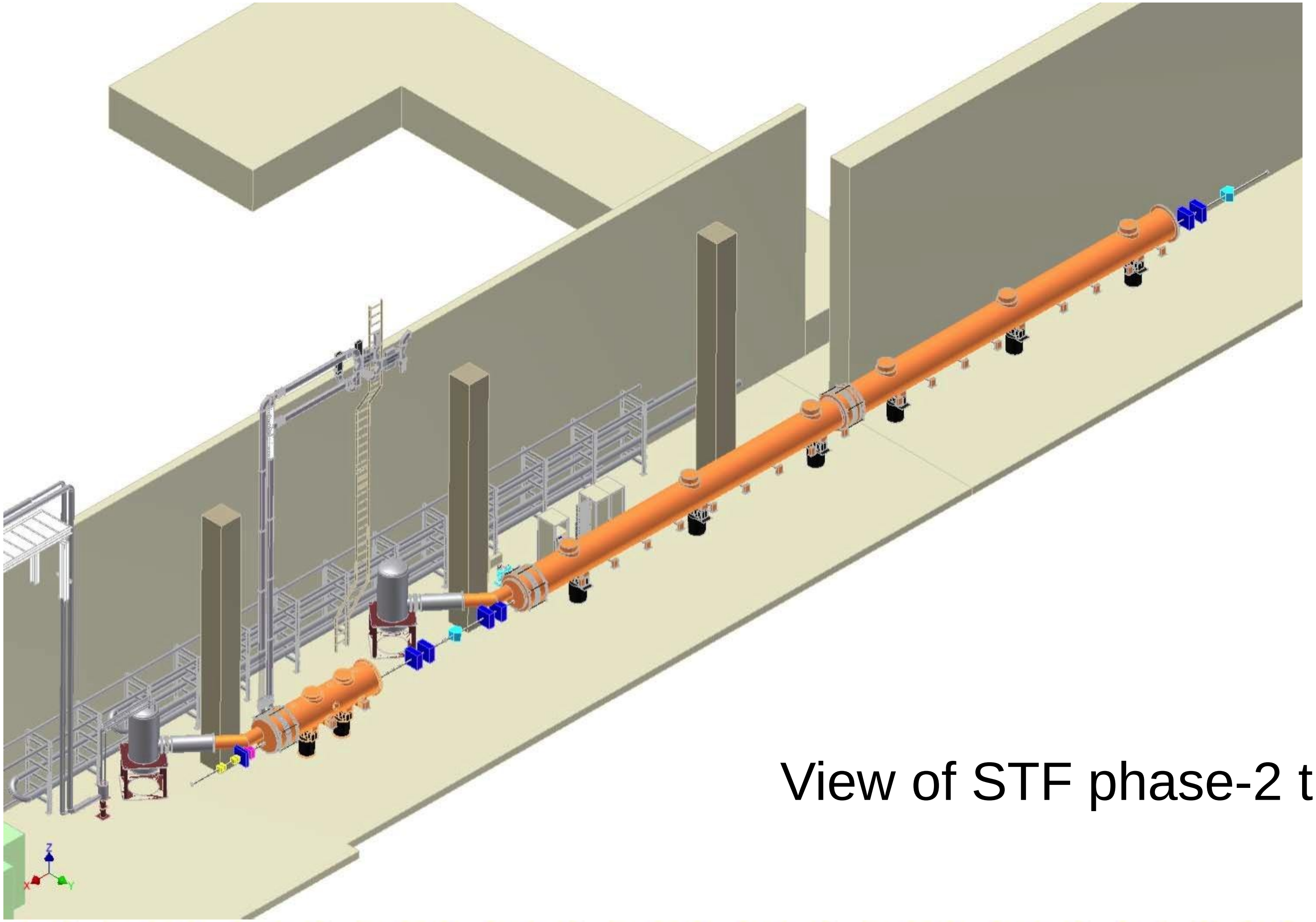
High beam power and long bunch-trains *(Sept 2009)*

Metric	ILC Goal	Achieved
Macro-pulse current	9mA	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 *(Feb 2012)*

Metric	ILC Goal	Achieved
Cavity gradient flatness (all cavities in vector sum)	2% ΔV/V (800μs, 5.8mA) (800μs, 9mA)	<0.3% ΔV/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)

STF Systems Tests at KEK



View of STF phase-2 tunnel

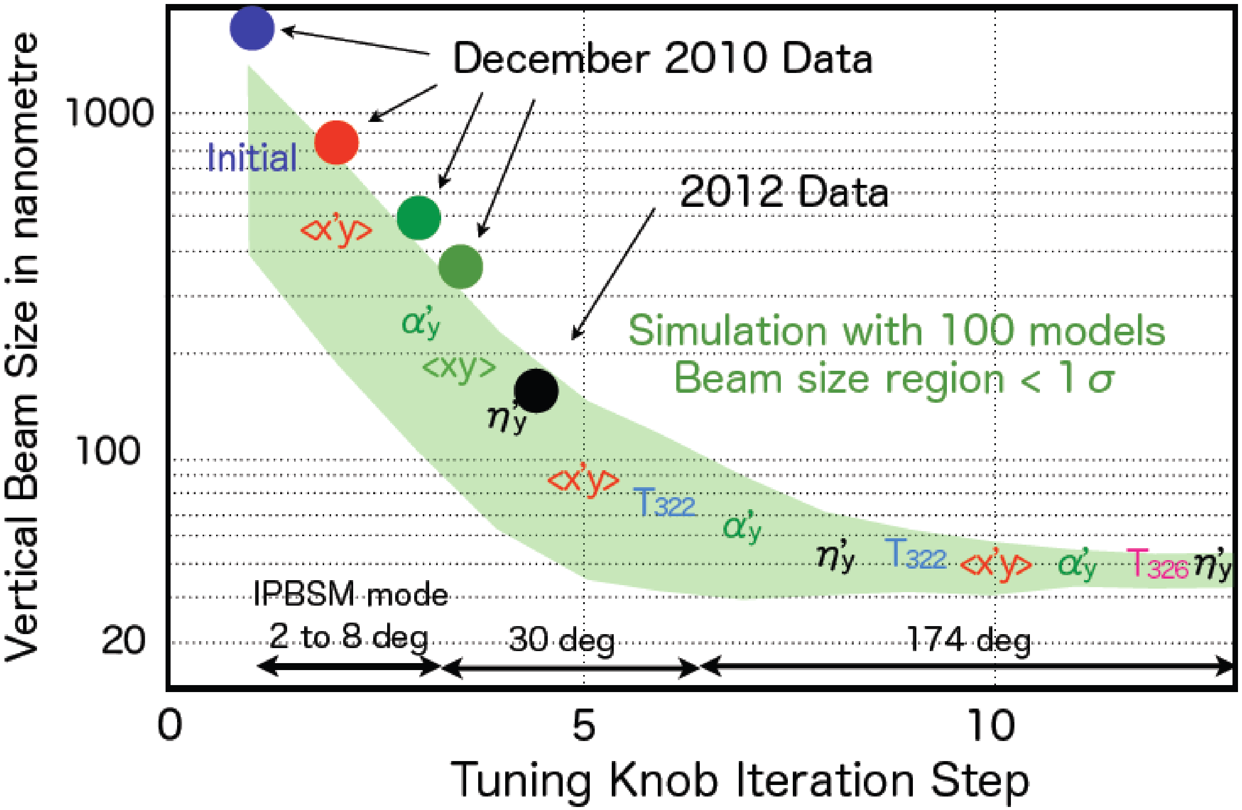
Fermilab – NML SRF

Systems Tests

Fermilab NML: RF Unit Test Facility

ATF2 – Beam size/stability and kicker tests

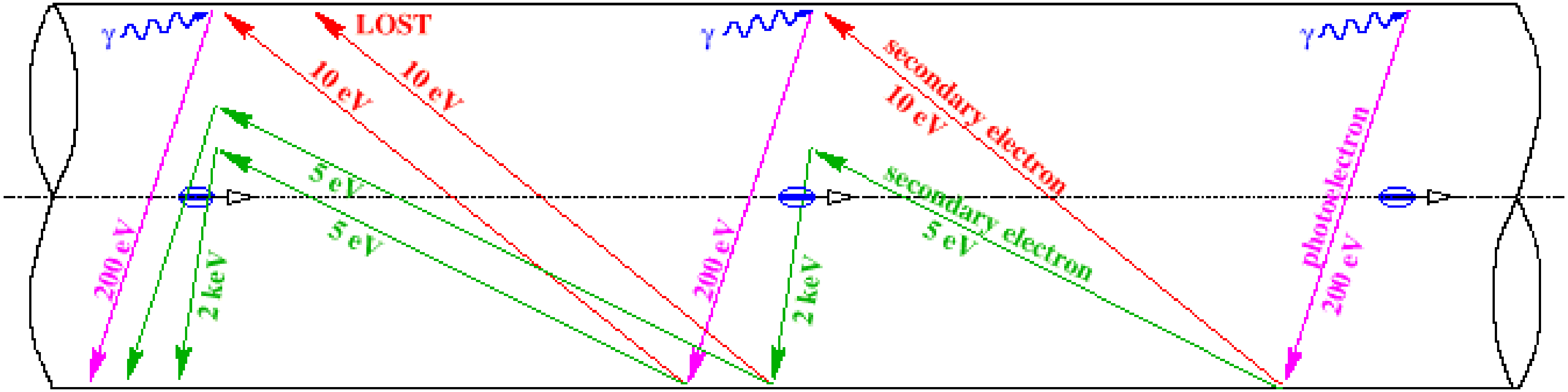
ATF-2 earthquake recovery



- **Vertical beam size (2012) = 167.9 plus-minus nm**
- **1 sigma Monte Carlo**
- **Post-TDR continue to ILC goal of 37 nm + fast kicker**
- **Stabilization studies**

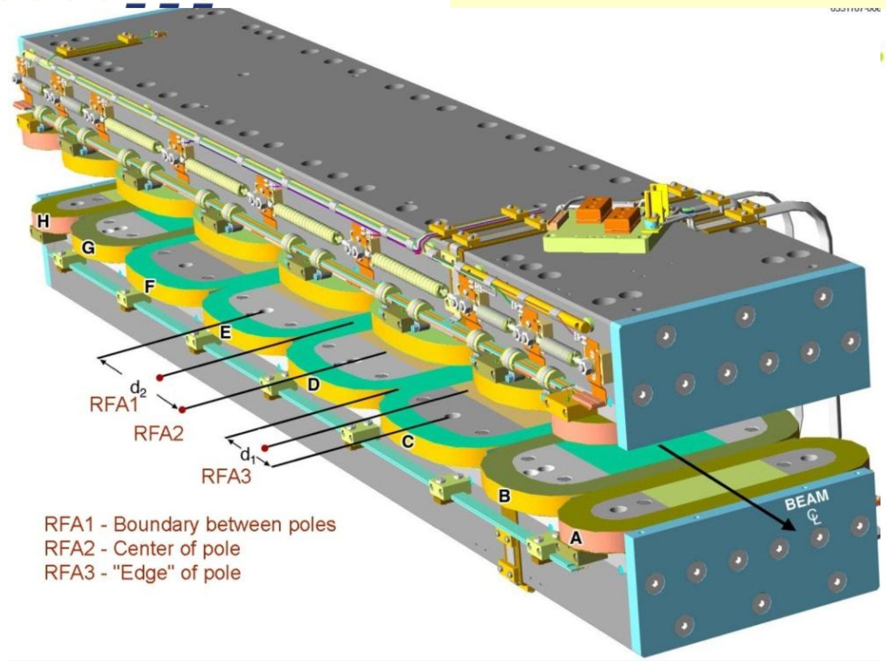
eCloud R&D

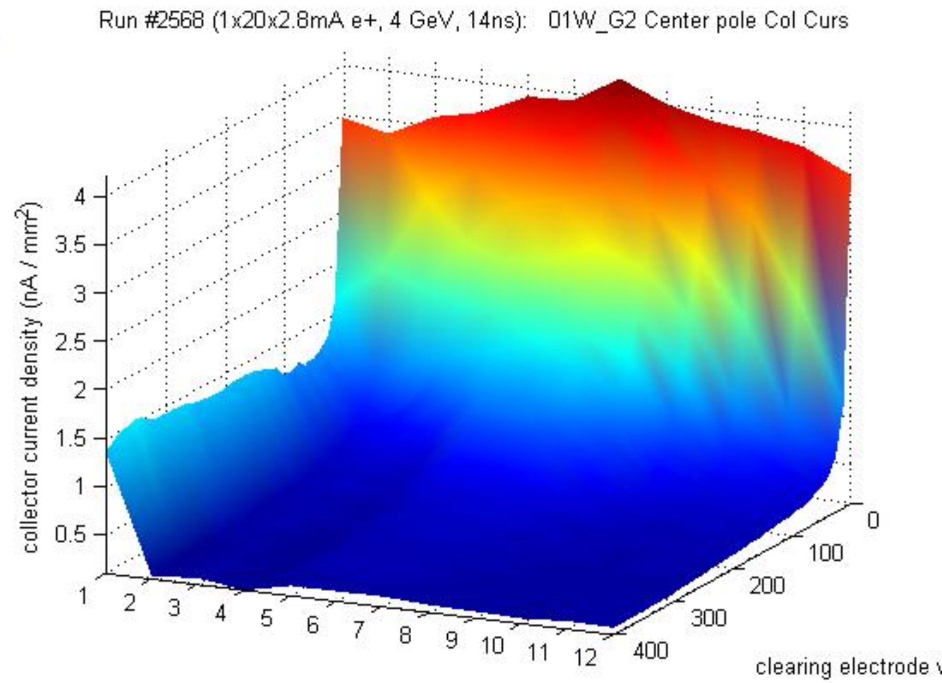
- **Mitigating Electron Cloud**

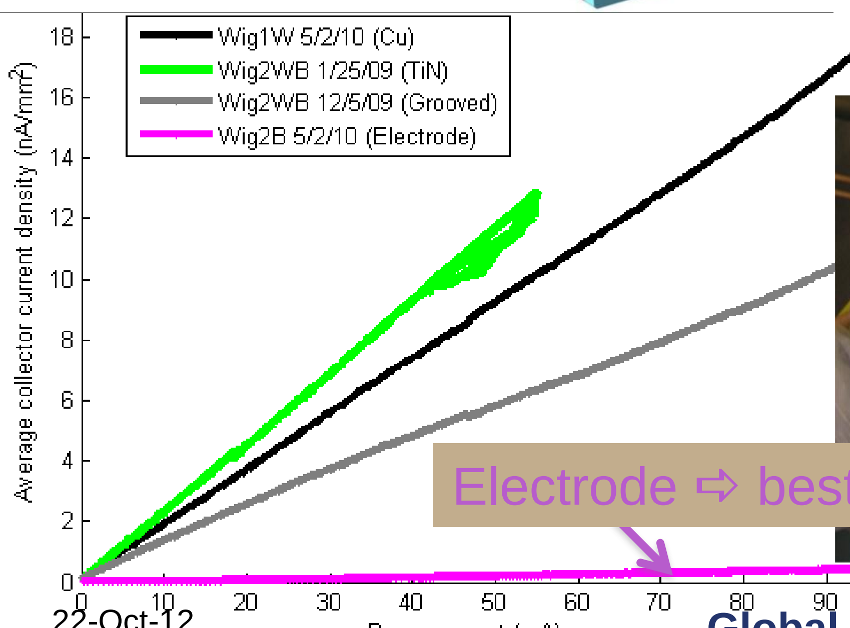


- **Simulations – electrodes; coating and/or grooving vacuum pipe**
- **Demonstration at CESR critical tests**

CesrTA - Wiggler Observations







Electrode ⇨ best performance

EC Working Group Baseline Mitigation Plan

EC Working Group Baseline Mitigation Recommendation				
	Drift*	Dipole	Wiggler	Quadrupole*
Baseline Mitigation I	**TiN Coating**	**Grooves with TiN coating**	**Clearing Electrodes**	**TiN Coating**
Baseline Mitigation II	**Solenoid Windings**	**Antechamber**	**Antechamber**	
Alternate Mitigation	**NEG Coating**	**TiN Coating**	**Grooves with TiN Coating**	**Clearing Electrodes or Grooves**

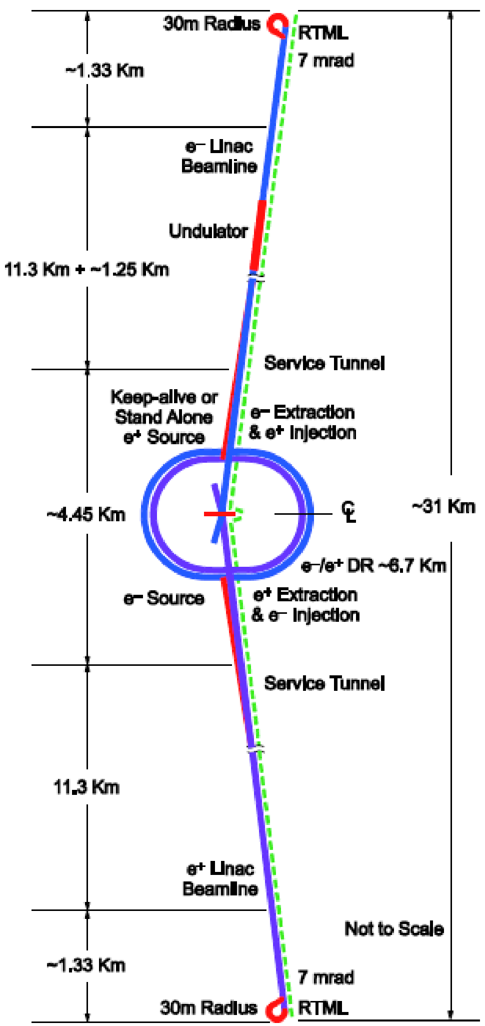
*Drift and Quadrupole chambers in arc and wiggler regions will incorporate antechambers

- Preliminary CESRTA results and simulations suggest the presence of *sub-threshold emittance growth*
  - Further investigation required
  - May require reduction in acceptable cloud density ⇨ reduction in safety margin
- An aggressive mitigation plan is required to obtain optimum performance from the 3.2km positron damping ring and to pursue the high current option

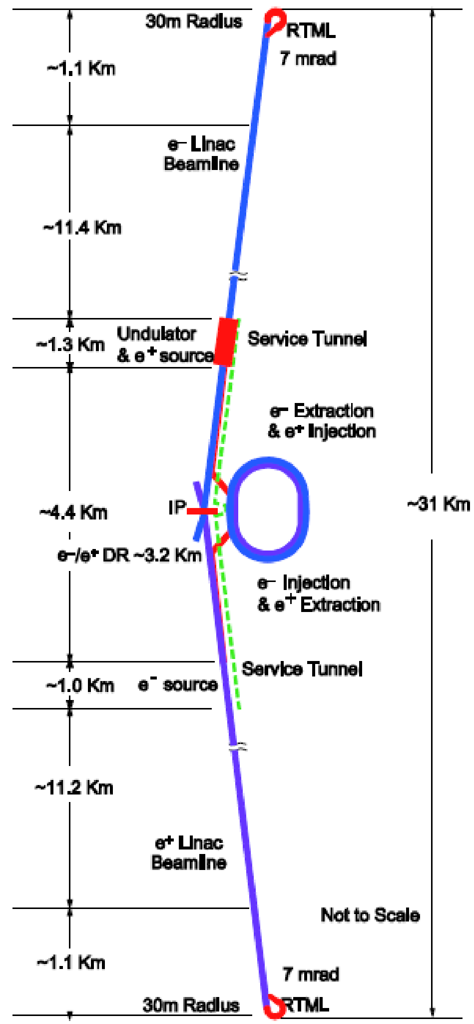
S. Guiducci, M. Palmer, M. Pivi, J. Urakawa on behalf of the ILC DR Electron Cloud Working Group

Proposed Design changes for TDR

RDR

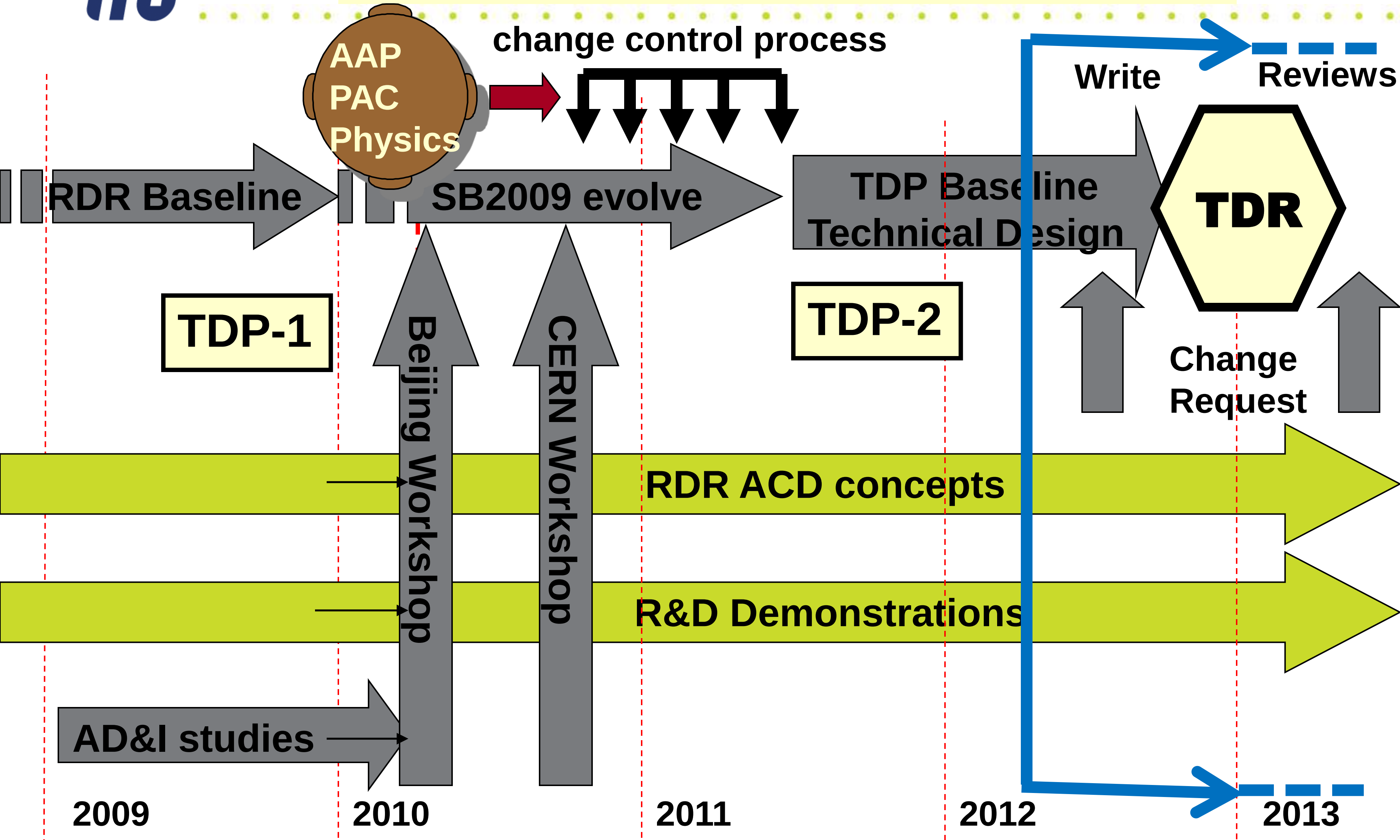


SB2009



- **Single Tunnel for main linac**
- **Move positron source to end of linac *****
- **Reduce number of bunches factor of two (lower power) ****
- **Reduce size of damping rings (3.2km)**
- **Integrate central region**

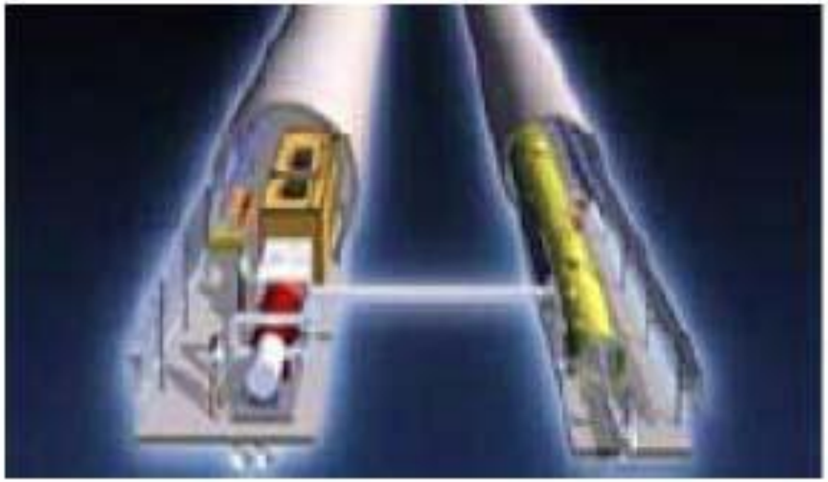
Technical Design Phase



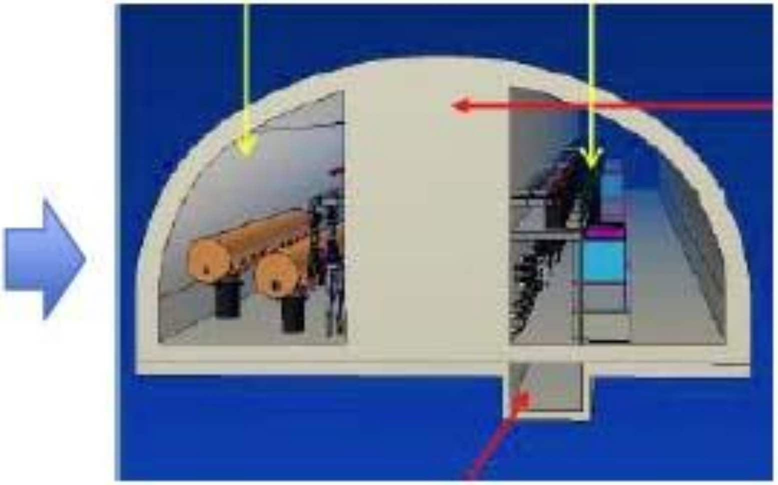
Conventional Facilities

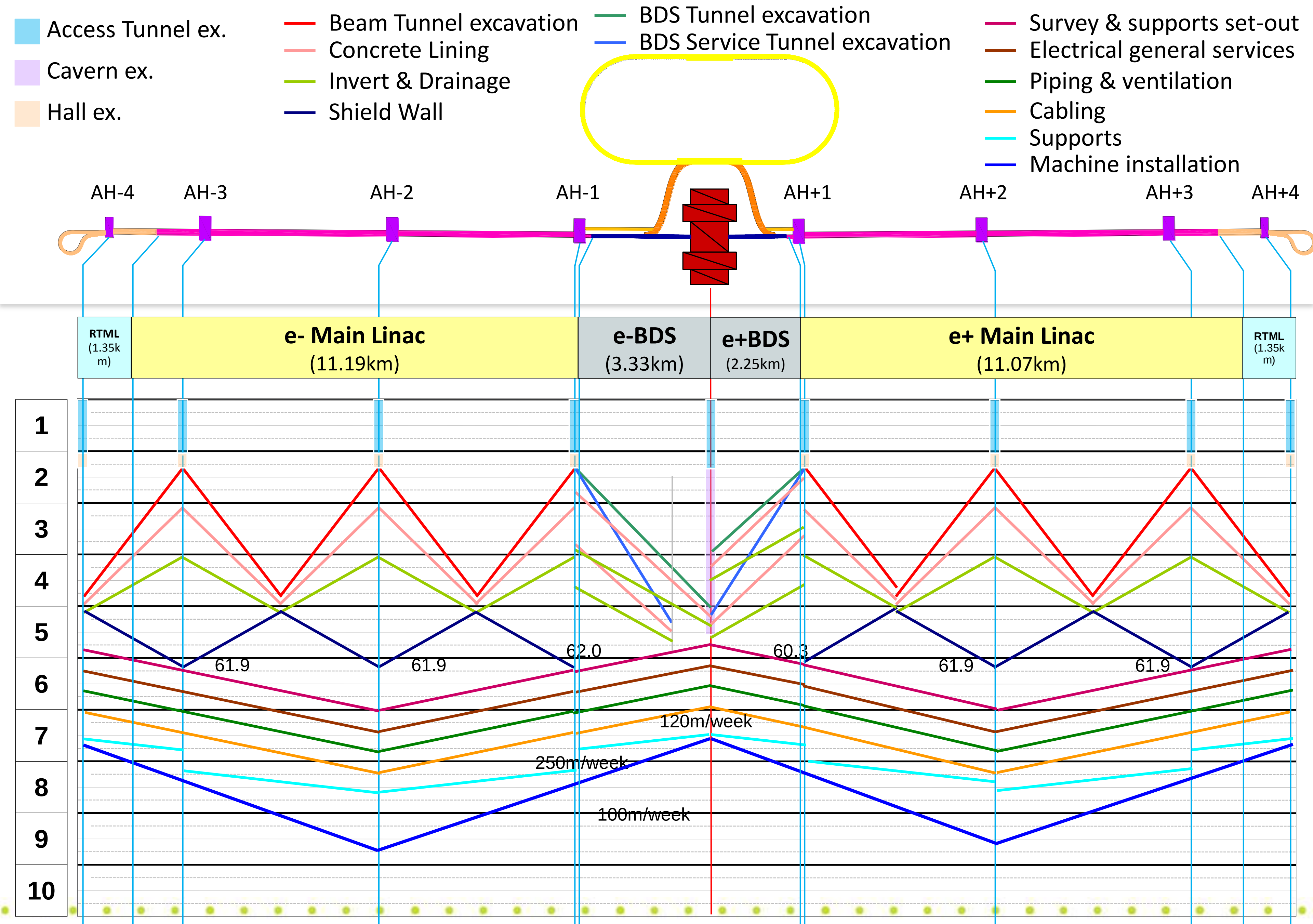
Japan -- New Tunnel Shape

RDR two tunnel design (2007)



TDR mountain sites





Access Tunnel ex.
Cavern ex.
Hall ex.
Beam Tunnel excavation
Concrete Lining
Invert & Drainage
Shield Wall
BDS Tunnel excavation
BDS Service Tunnel excavation
Survey & supports set-out
Electrical general services
Piping & ventilation
Cabling
Supports
Machine installation
AH-4
AH-3
AH-2
AH-1
AH+1
AH+2
AH+3
AH+4
RTML (1.35km)
e- Main Linac (11.19km)
e-BDS (3.33km)
e+BDS (2.25km)
e+ Main Linac (11.07km)
RTML (1.35km)
1
2
3
4
5
6
7
8
9
10
61.9
61.9
62.0
60.3
61.9
61.9
120m/week
250m/week
100m/week

TDR Technical Volumes

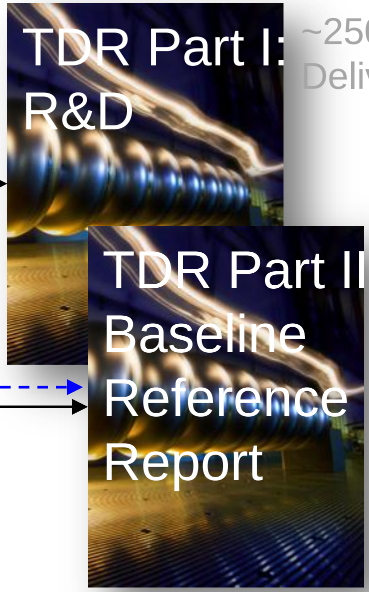
2007

2011

2013*

ILC Technical Progress Report
(“*interim report*”)

AD&I



~250 pages
Deliverable 2

~300 pages
Deliverables 1,3 and 4

Reference Design Report

Technical Design Report

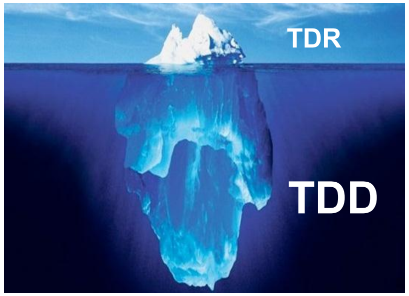
* end of 2012 – formal publication early 2013

EDMS & Tech. Design Documentation

TD Phase Deliverables

Technical Design Report (TDR)

- Documents primary TDR deliverables
  1. Results and status of Risk Mitigating R&D
  2. Updated Reference Design
  3. Updated VALUE estimate
  4. Project Implementation Plan
  5. Technical risk assessment and future R&D
- Readable
- 6-9 months to write



Supports

Summarises

Technical Design Documentation (TDD)

- Reference Documentation
- Structured and linked
- Basic design documentation
  - Parameter tables
  - Requirements
  - Specifications
  - Design documents
  - Drawings (2D)
  - CAD-3D models
  - ...
- Cost information → ICET
- Schedule

ILC-EDMS

Important goal to consolidate all technical documentation in EDMS in a structured fashion

ILC Costs -- Impact of Top Level Changes

• RDR estimate = starting point	6,618	Δ
• Caverns, DR & cool Value Eng.	-86	-1.3%
• 1 stage B.C. (not yet considered)	-33	-0.5%
• Alternative RF (1 tunnel for ML, ½ bunches)		
Klystron Cluster/DRFS	-400/-419	-6.2%
• DR (6.4 => 3.2 km, ½ bunches)	-191	-2.9%
• Central Injector Complex	-104	-1.6%
• Sub-total of SB2009 changes estimated		-10.7%

- Did not consider range of cavity gradients nor details of alternating e+ production at 150 GeV

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Starting Point is the RDR Costs

- ***6.6 Billion ILC Units*** (2007 US $) ***+ 24 Million hours*** of Institutional Labor (which includes laboratories and universities, but not vendors or contractors)
- TDR will quote estimate in 2012 US $, need consider:
- Difference in Exchange Rates

In 2006-07:	1 $ = 117 ¥	1 € = $ 1.20
1/1/2011:	1 $ = 81.5 ¥	1 € = $ 1.334
now 5/10/2011:	1$ = 80.6 ¥	1 € = $ 1.43

- 4 yr – escalation from 1/1/2007 => 1/1/2011 Index Links
  - US construction, technical goods -2.1%, 8.6%
  - Germany construct., indust. products 10.5%, 5.7%
  - Japan construction, industrial products 3.4%, 1.1%

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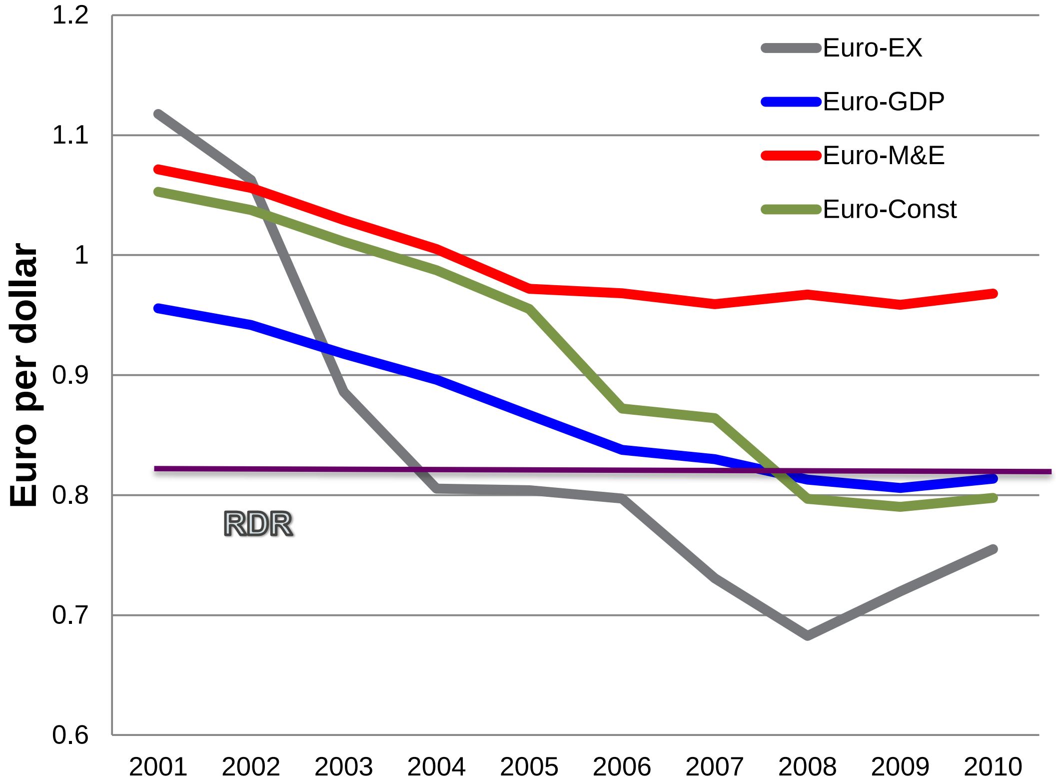
OECD PPP (Yen/USD)-annual average by year

PPP = Purchasing Power Parity



EX-exchange rate
GDP: PPP based on all goods/services in GDP of each region
M&E: PPP based on machinery and equipment
Const: PPP based on civil construction

Full PPP determinations were done for 2005 and 2008; other year points based on GDP inflation rates

Higgs Factory – Energy

Staging / Upgrading

- ~125 GeV from LHC
  - 125+91=216 GeV cm → 250 GeV
- 173 GeV Top quark
  - 2x173=346 GeV cm → 350-400 GeV
- Higgs self coupling (t-coupling) ???
  - ≥ 500 CM (up to 650 ??)
- TeV and beyond….?

250 GeV CM (first stage)
Relative to TDR 500 GeV baseline

Two stage compressor (5-<u>15 GeV</u>)

Half linacs solution
G = 31.5 MV/m

→ **POSITRON** linac straightforward
~50% ML linac cost (cryomodules, klystrons, cryo etc.)
~50% ML AC power

→ **ELECTRON** linac needs 10Hz mode for e+ production
ΔE = 135 GeV instead of 110 GeV (+25 GeV)
~57% ML linac cost (cryomodules, klystrons etc)

<u>Main Linac infrastructure</u>
Linac components: 50%
Cryogenics: 65%
RF AC power: 80%

10Hz needs (1/2 linac × 10Hz/5Hz):
100% ML AC power
(1/2 linac × 10Hz/5Hz)
80% cryo cost
(50% static + 100% dynamic)

Y. Okada - CPM12 Fermilab

ILC Plan in Japan

(After the discovery of a Higgs-like particle)

- Japanese HEP community proposes to host ILC based on the "staging scenario" to the Japanese Government.
  - ILC starts as a 250GeV Higgs factory, and will evolve to a 500GeV machine.
  - Technical extendability to 1TeV is to be preserved.

- It is assumed that one half of the cost of the 500GeV machine is to be covered by Japanese Government. However, the share has to be referred to inter-governmental negotiation.

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Two Candidate Sites in Asia/Japan

GDE Conclusions

- The major R&D milestones for TDR are in-hand
- The TDR will be a self-contained comprehensive R&D report; with a design based on new baseline; a new value costing; and a section on project implementation planning
- Submit: Dec 2012; Reviews of technical design & costs;
  - **Technical Review by augmented PAC (Dec 2012 at KEK)**
  - **Cost Review by international committee (Jan 2013 at Orsay)**
  - **TDR Overall Review by ILCSC (Feb 2013 at Vancouver)**
- Revise, rewrite as needed; finalize and submit to ICFA at LP2013 (June 2013)

GDE Mandate Complete

- Post–TDR ILC program: 1) extend energy reach; 2) systems tests; 3) evolve design based on technology development and LHC results; consider staged design, beginning with Higgs Factory.