Accelerator summary

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LCWS2012

Arlington 26th October 2012

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)**

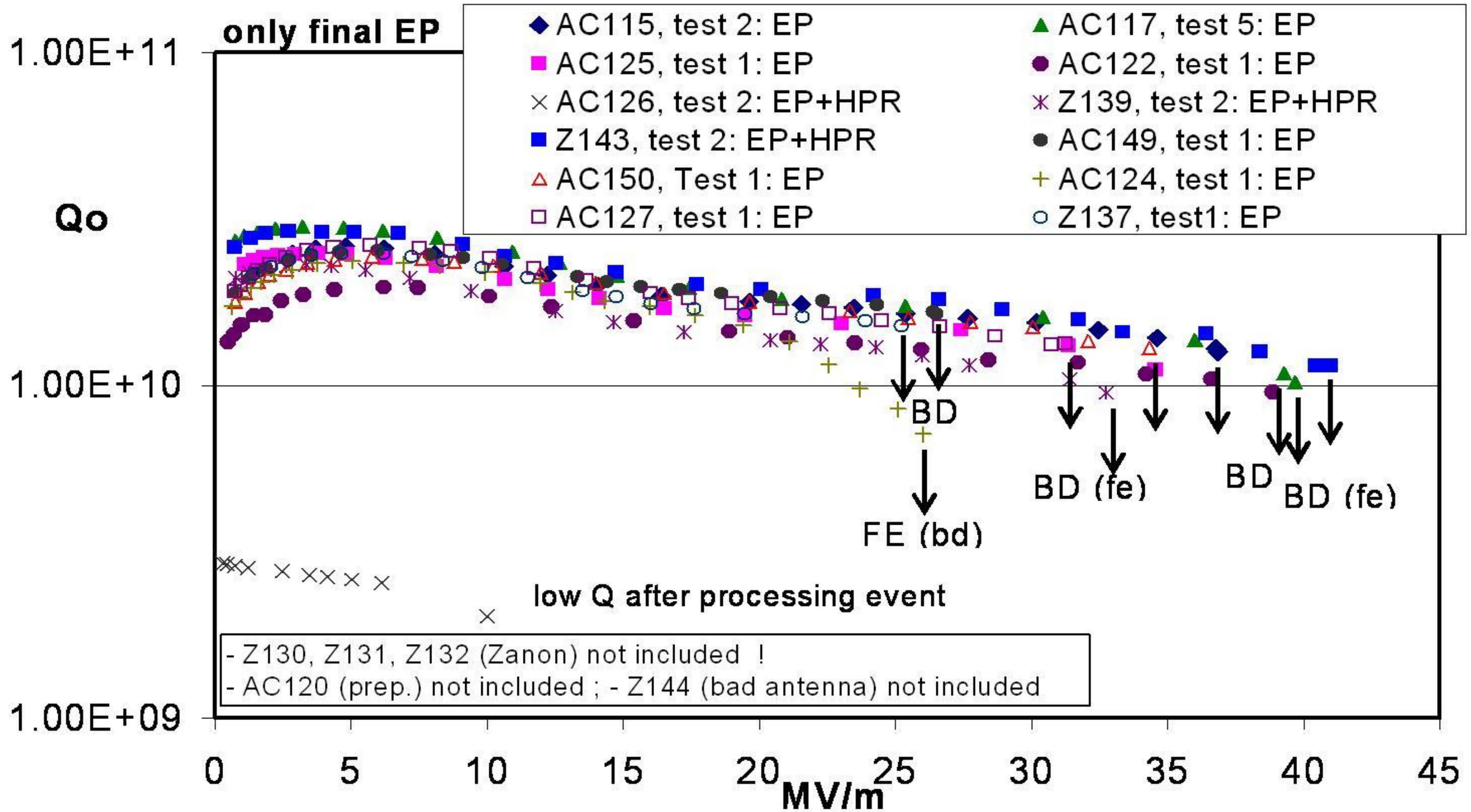
The ILC SCRF Cavity

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

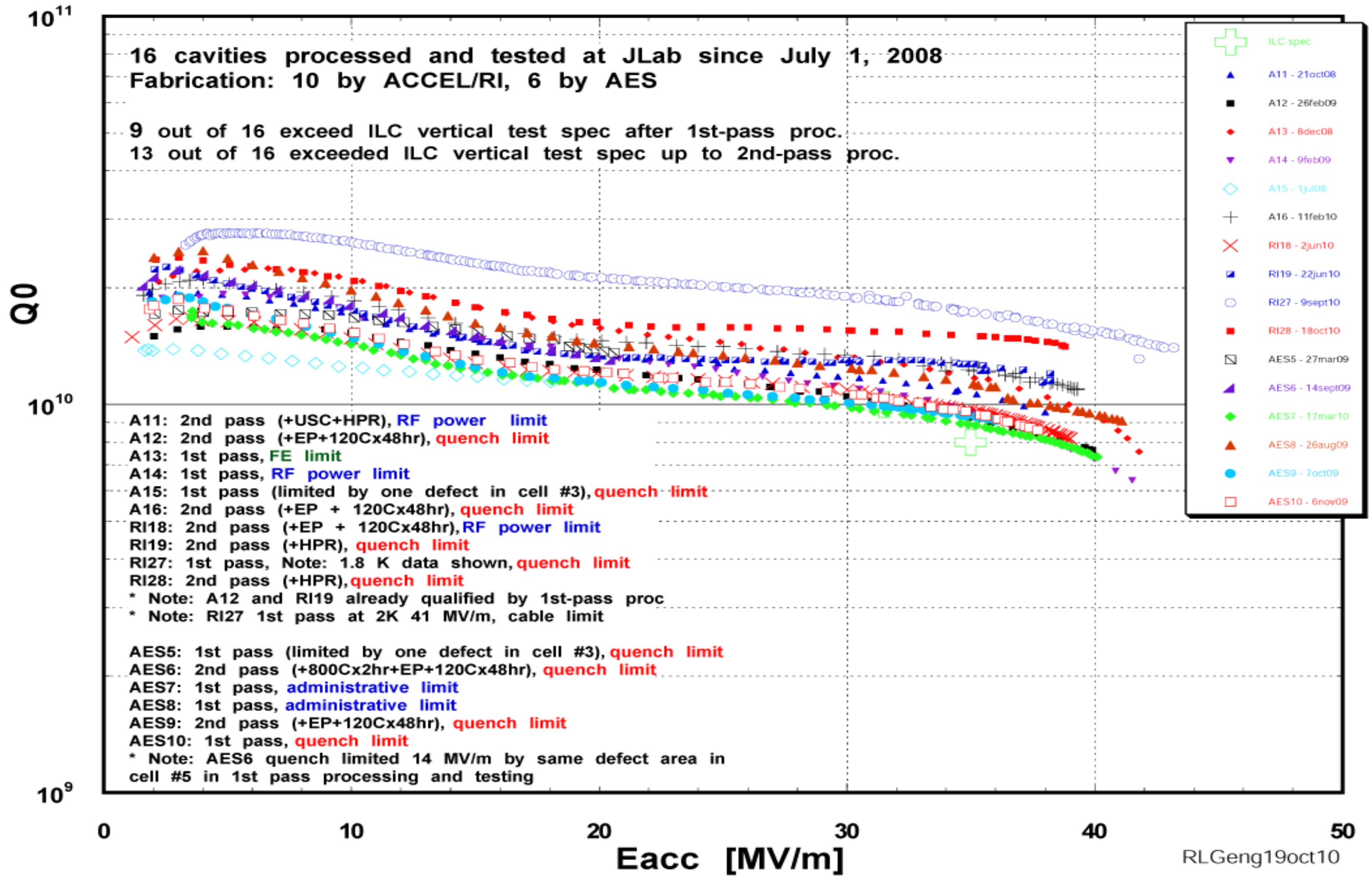
- Focus is on high gradient; production yields; cryogenic losses; radiation; system performance

Global Cavity Gradient Results - EU



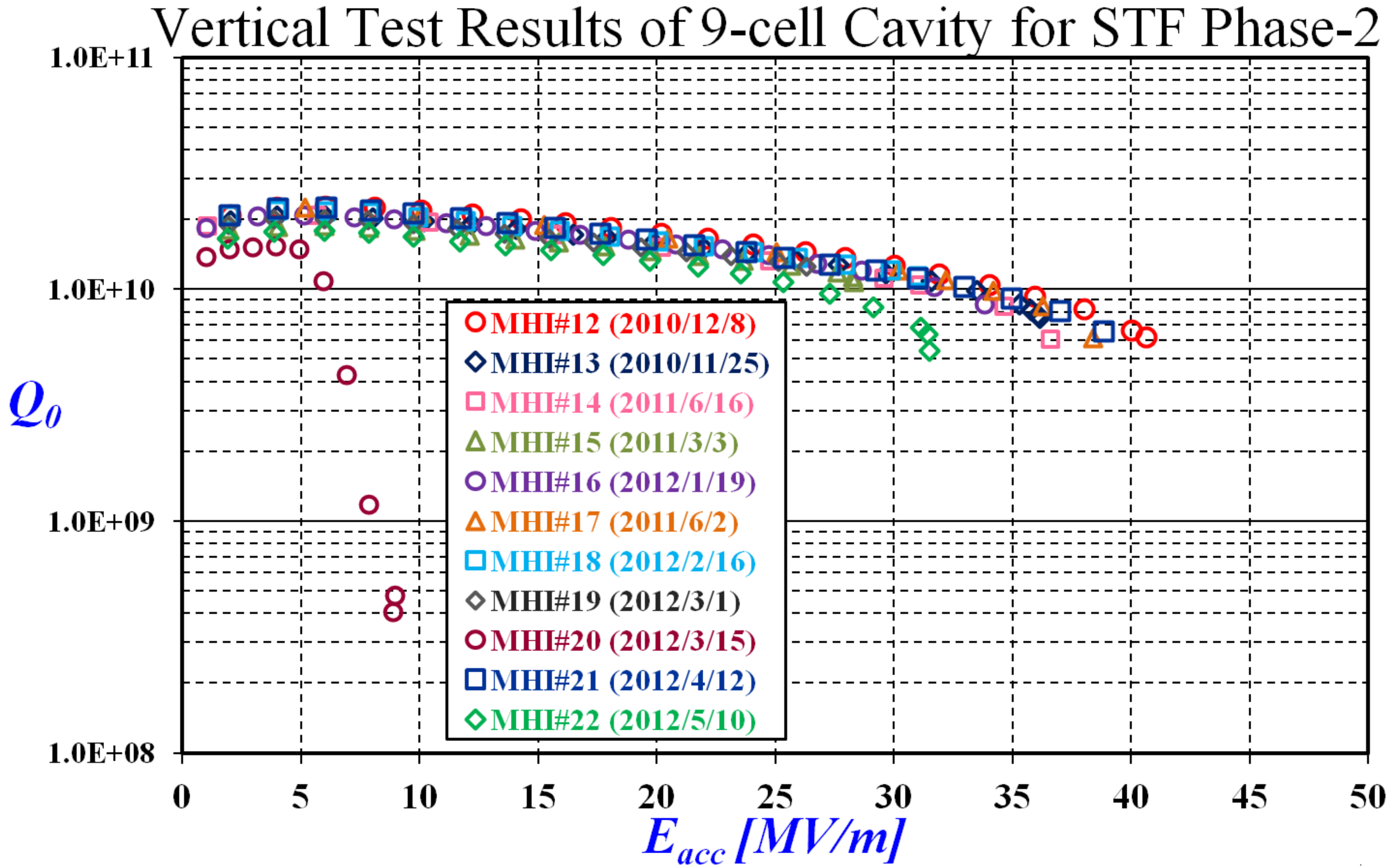
DESY data, D. Reschke et al., SRF2009, TUPPO051.

Global Cavity Gradient Results - Americas



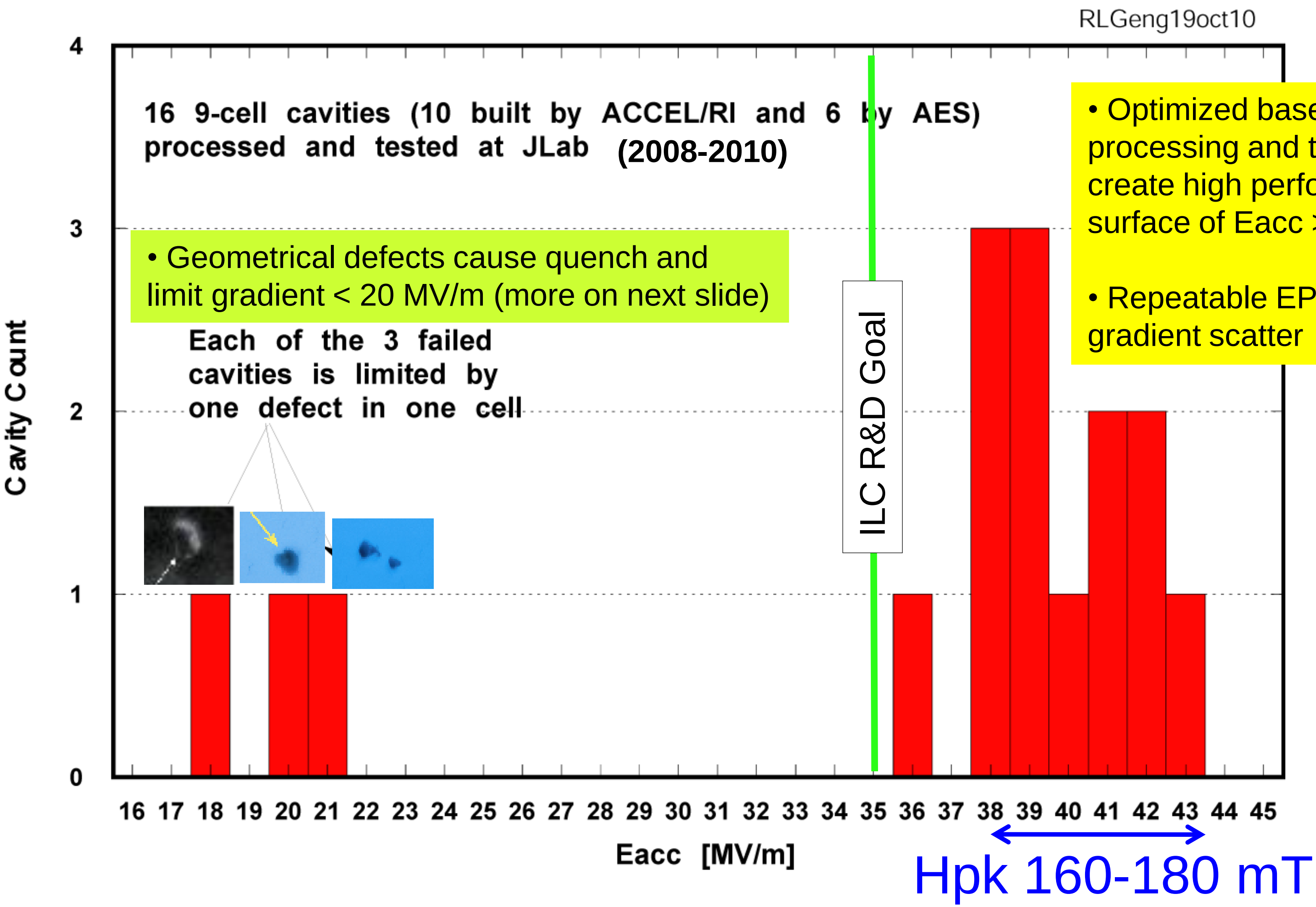
JLAB data, R.L. Geng et al., IPAC2011, MOPC111.

Global Cavity Gradient Results - Asia



KEK data, Y. Yamamoto et al., IPAC2012, WEPPC013.

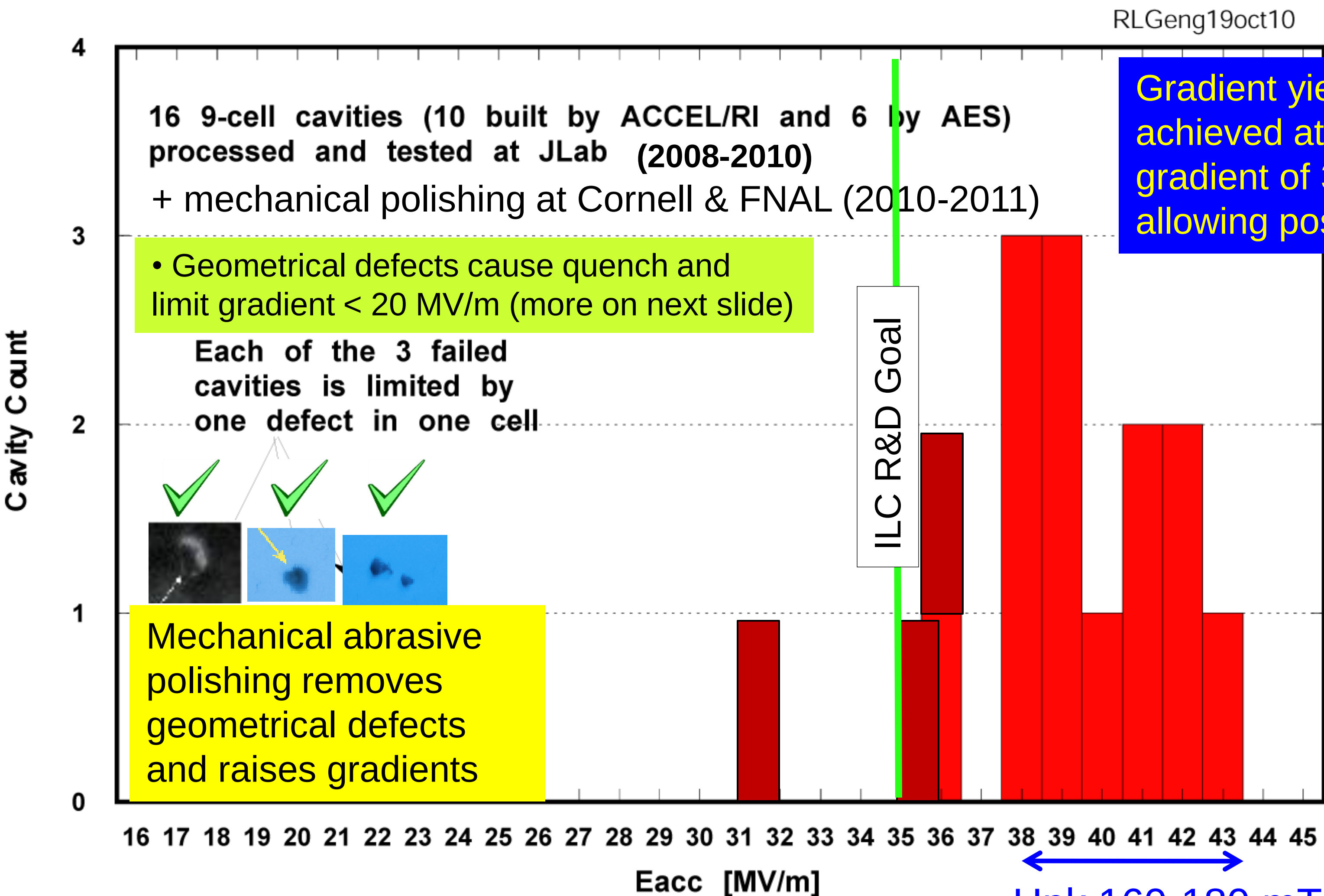
Gradient Limit Understanding and Control



- Geometrical defects cause quench and limit gradient < 20 MV/m (more on next slide)

- Optimized baseline surface processing and treatment create high performance surface of Eacc > 38 MV/m.
- Repeatable EP controls gradient scatter

Gradient Limit Understanding and Control

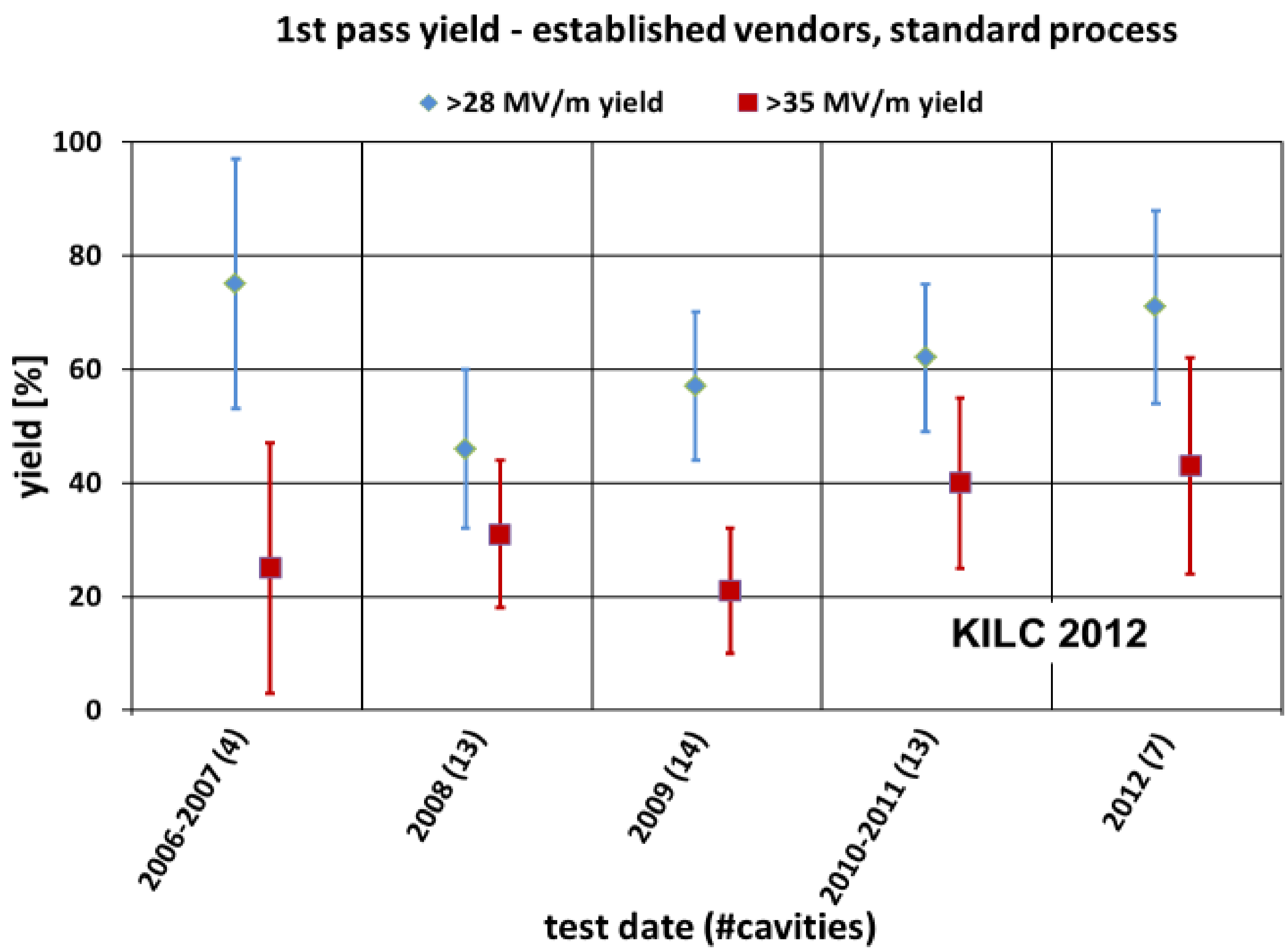


Gradient yield of 100% achieved at an average gradient of 39 MV/m when allowing post-cycle repair

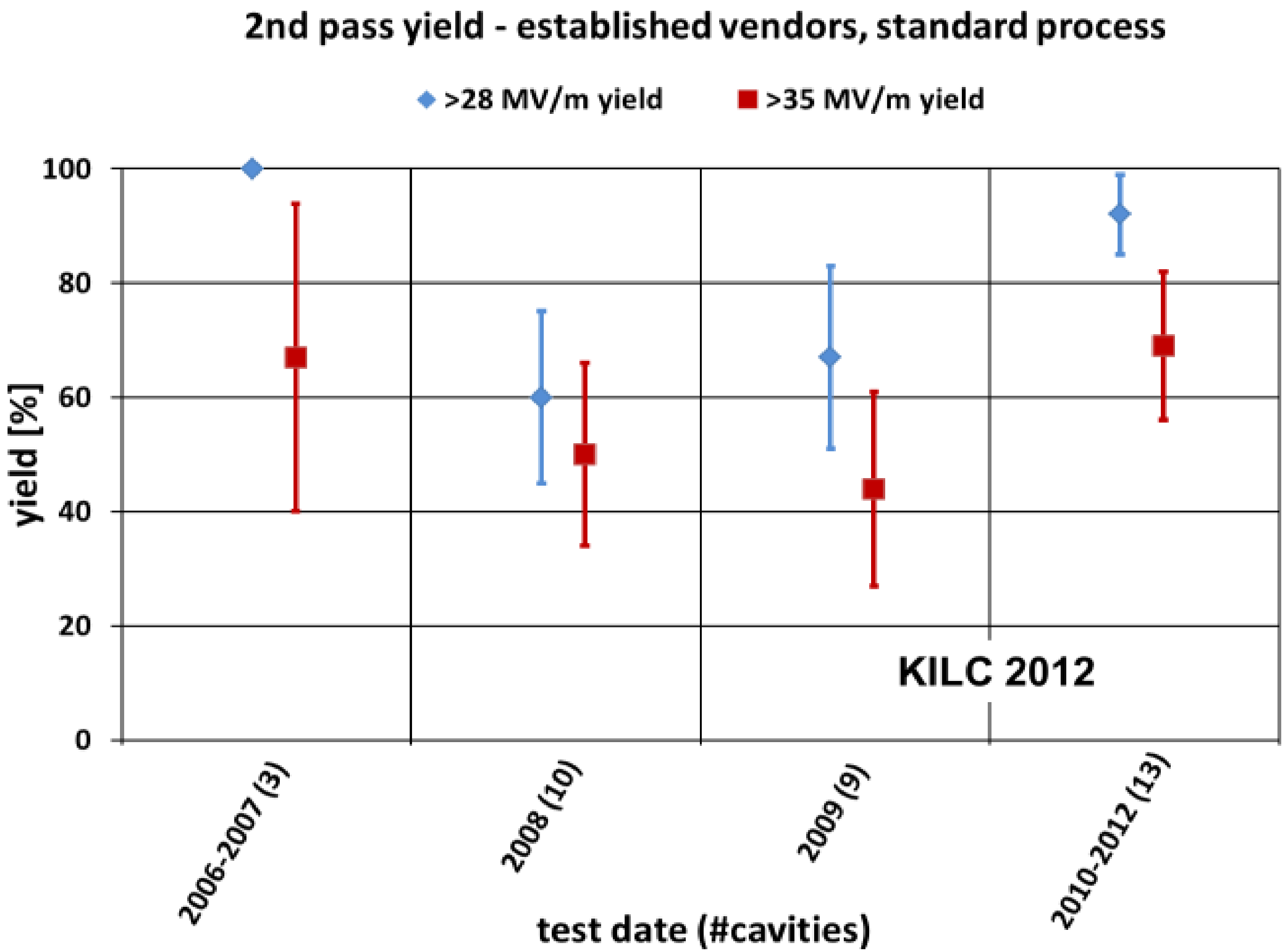
Hpk 160-180 mT

Average gradient 39 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

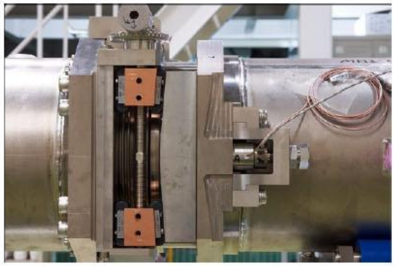
TESLA Cavity (DESY/FNAL)

Blade Tuner (FNAL)

Saclay Tuner (DESY)

TTF-III Coupler (DESY/FNAL)

Tesla-like Cavity (KEK)



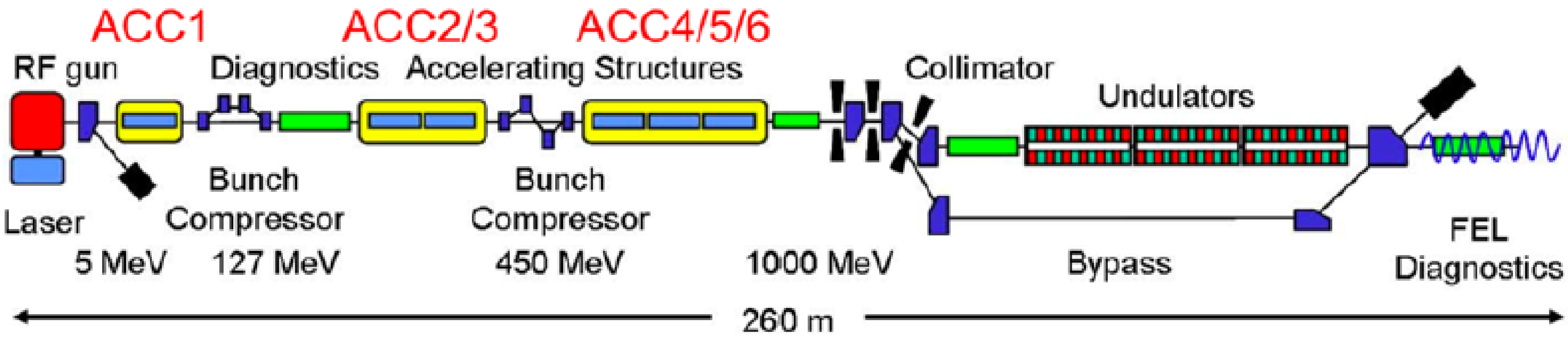
Slide-Jack Tuner (KEK)

STF-II Coupler (KEK)

E. KAKO (KEK)

TTF/FLASH 9mA Experiment

Full beam-loading long pulse operation → "S2"

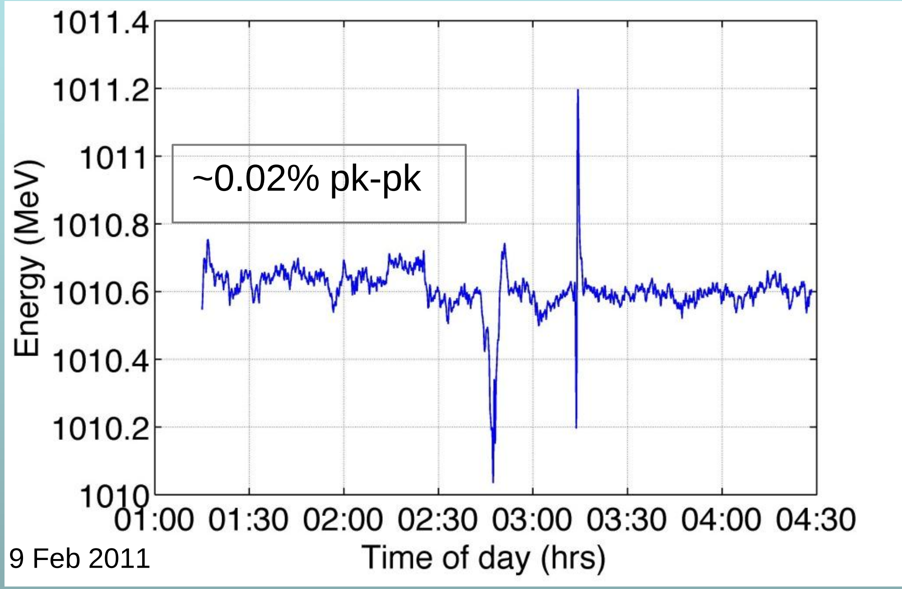


		XFEL	ILC	FLASH design	9mA studies
Bunch charge	nC	1	3.2	1	3
# bunches		3250	2625	7200'	2400
Pulse length	μs	650	970	800	800
Current	mA	5	9	9	9

- 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

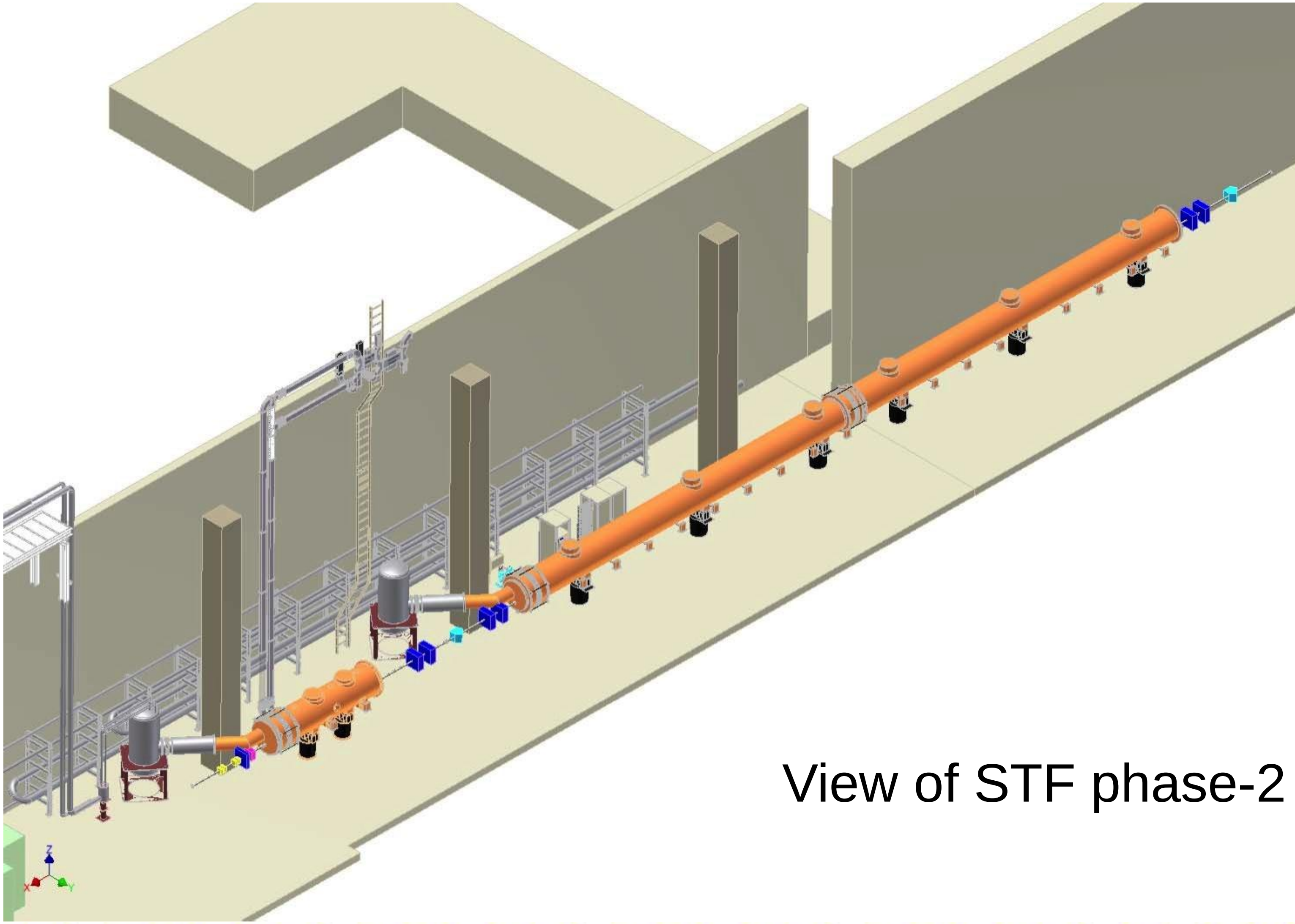
High beam power and long bunch-trains (Sept 2009)

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



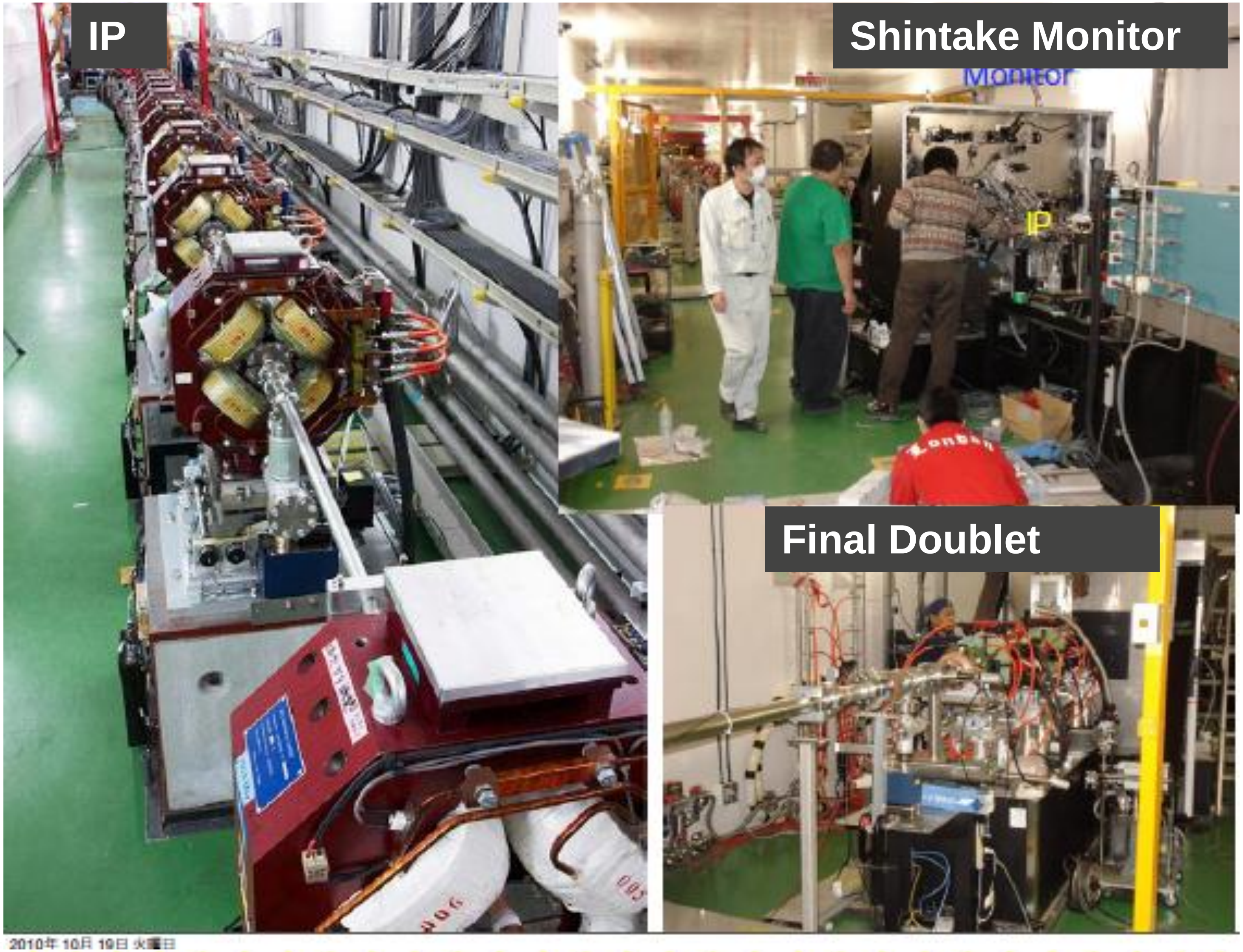
View of STF phase-2 tunnel

Fermilab – NML SRF

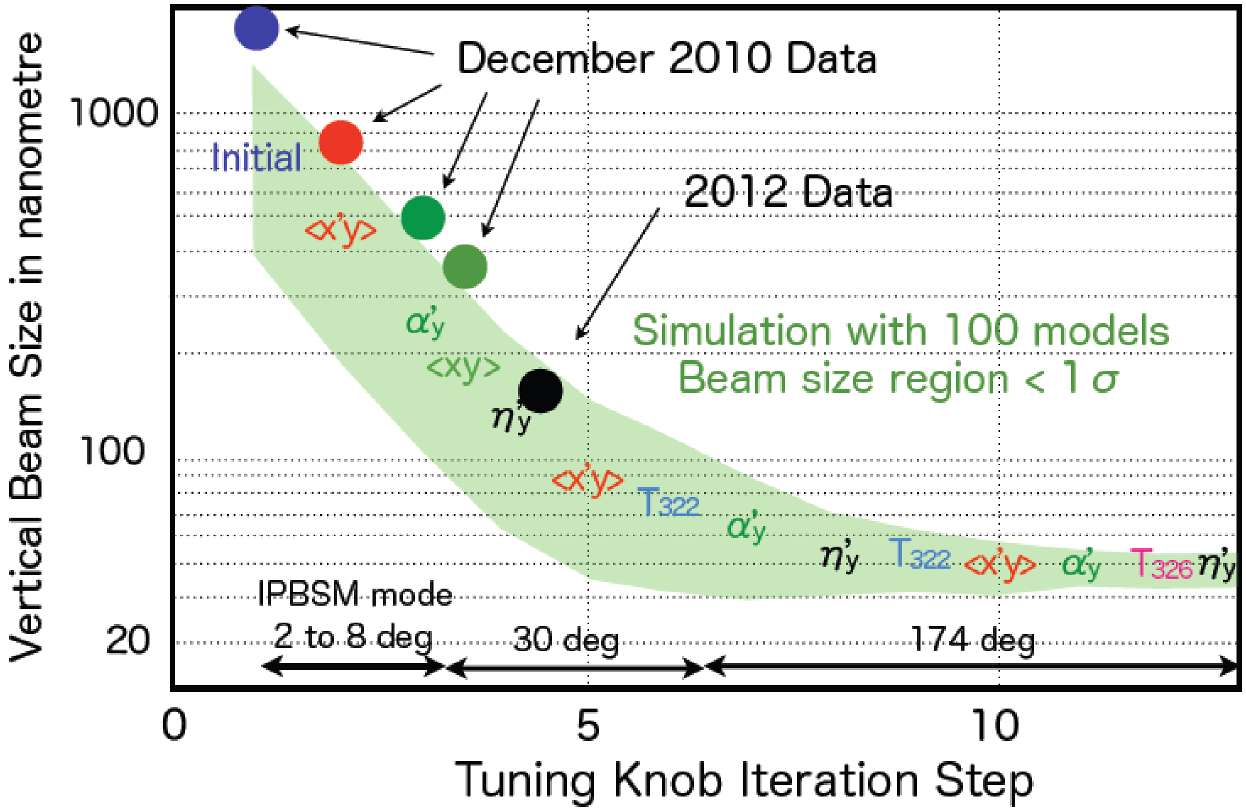
Systems Tests

Fermilab NML: RF Unit Test Facility

ATF2 – Beam size/stability and kicker tests



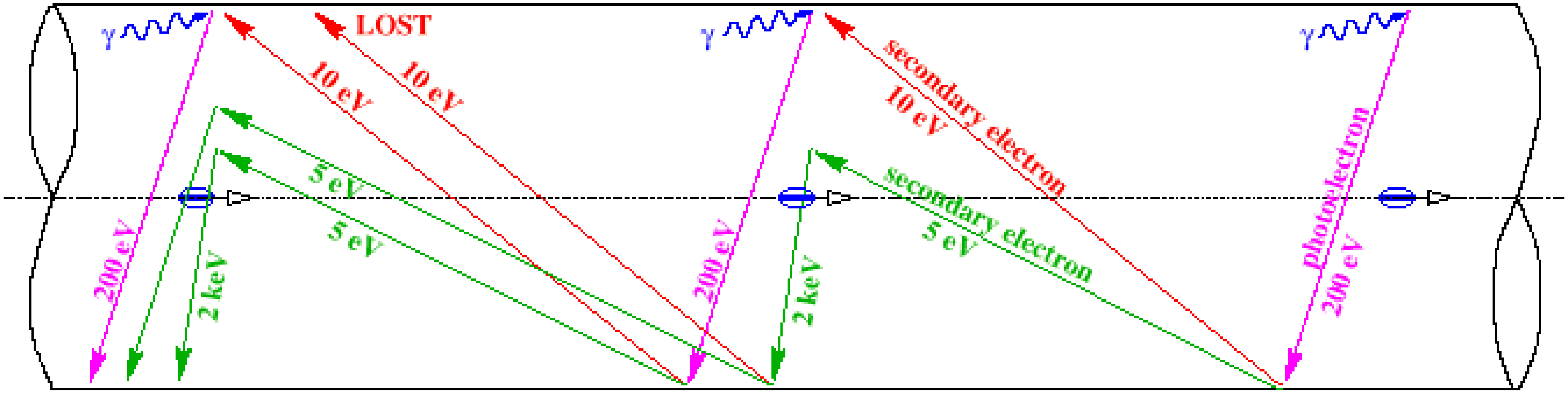
ATF-2 earthquake recovery



- **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**

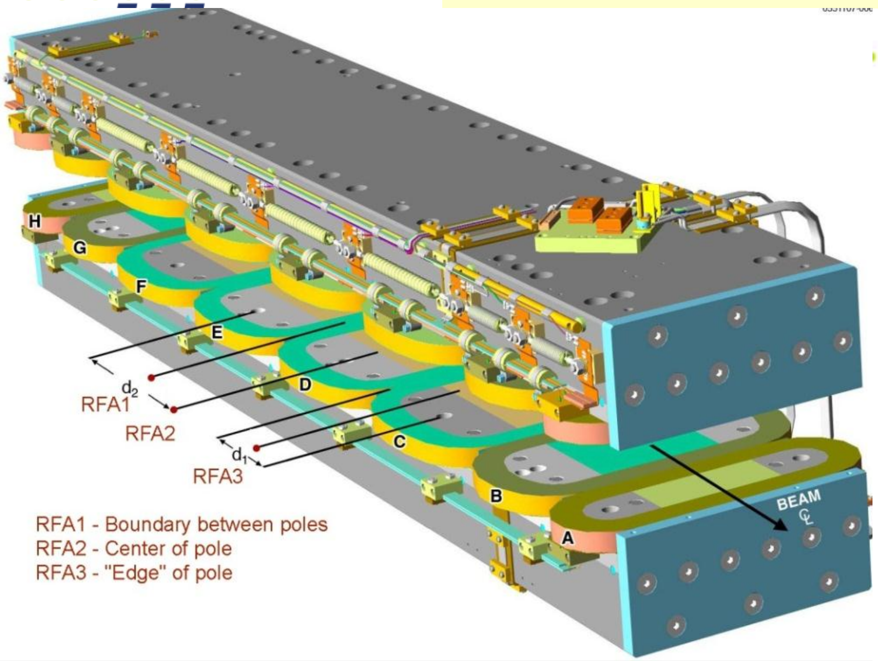
eCloud R&D

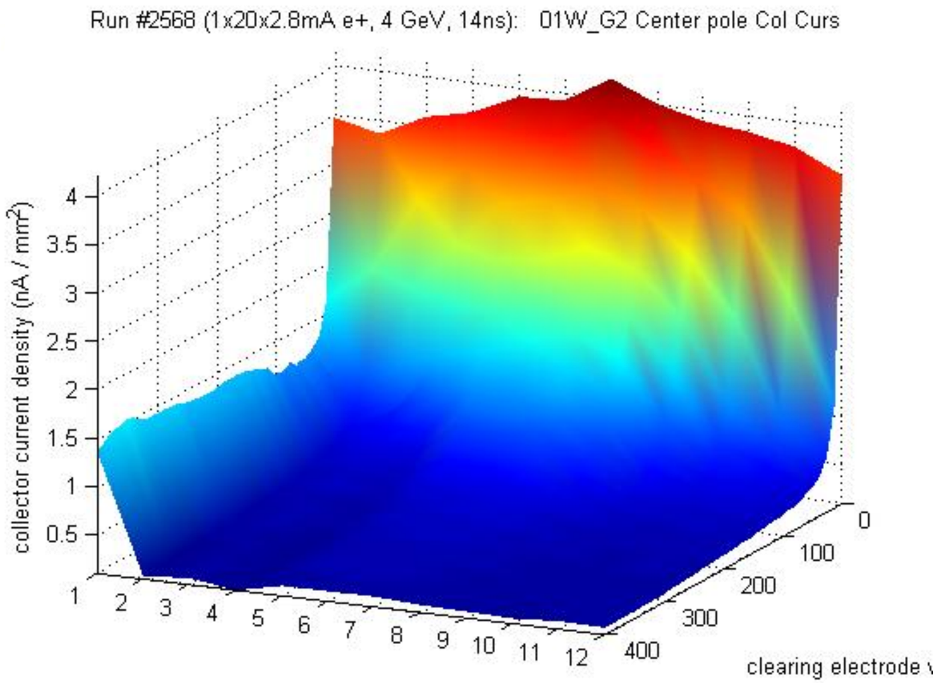
- **Mitigating Electron Cloud**

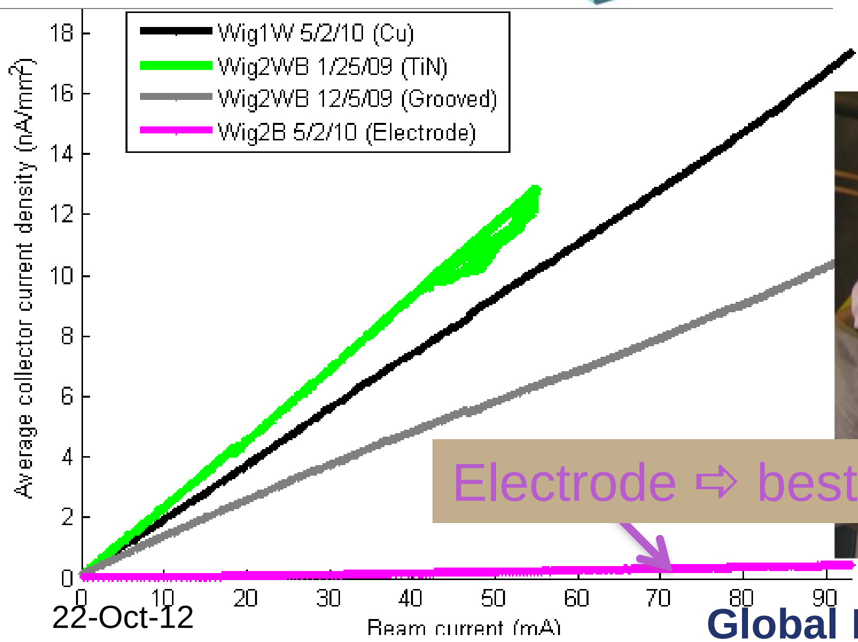


- **Simulations – electrodes; coating and/or grooving vacuum pipe**
- **Demonstration at CESR critical tests**

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**

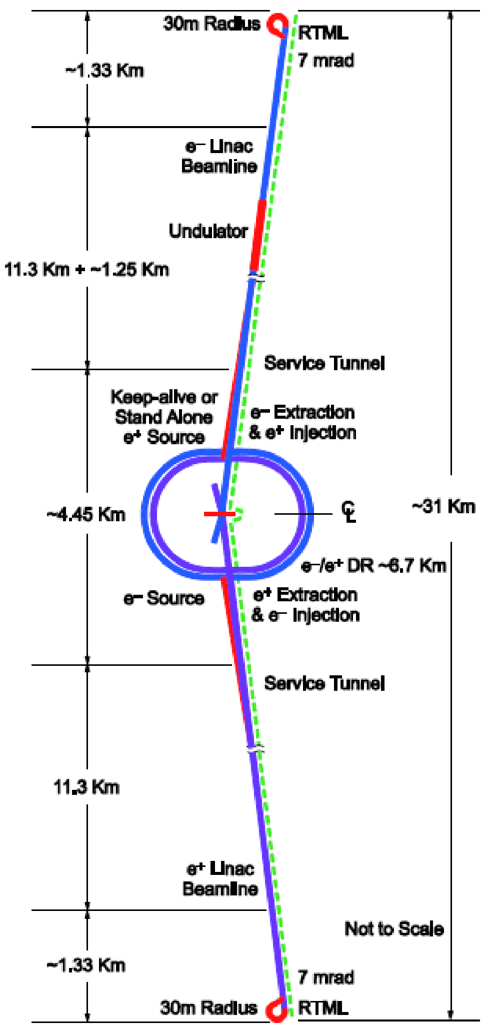
*Drift and Quadrupole chambers in arc and wiggler regions will incorporate antechambers

- 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

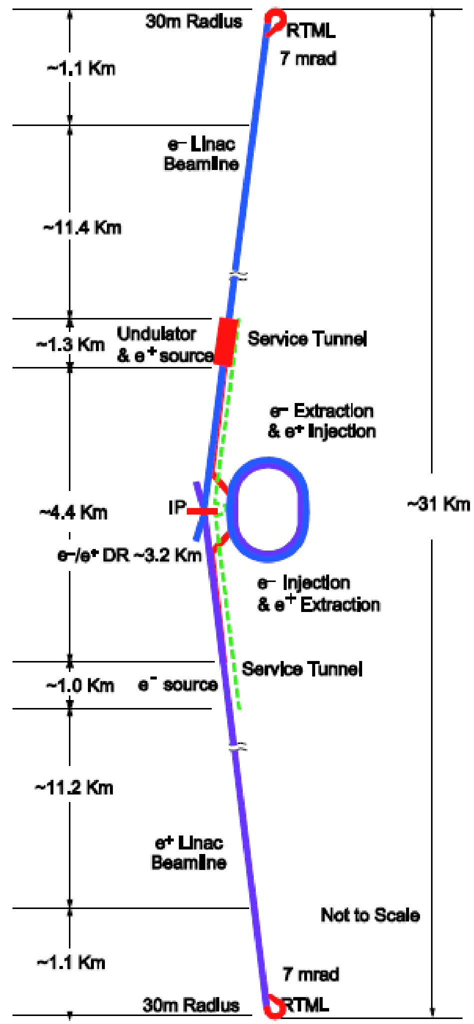
S. Guiducci, M. Palmer, M. Pivi, J. Urakawa on behalf of the ILC DR Electron Cloud Working Group

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

TDR Technical Volumes

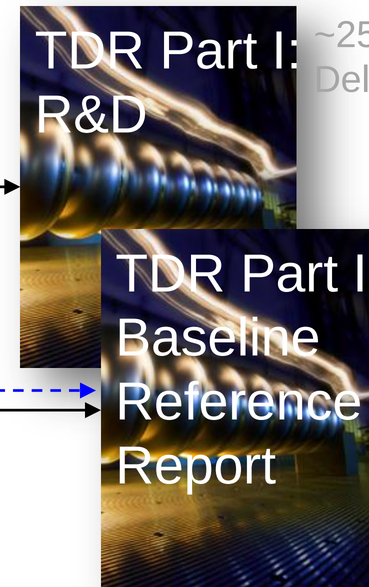
2007

2011

2013*

ILC Technical Progress Report ("*interim report*")

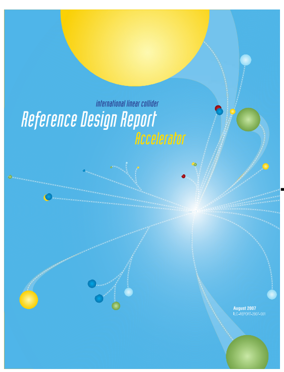
AD&I



~250 pages Deliverable 2

~300 pages Deliverables 1,3 and 4

Technical Design Report



Reference Design Report

* end of 2012 – formal publication early 2013

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….?

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.

CLIC Status and Outlook

October 2012

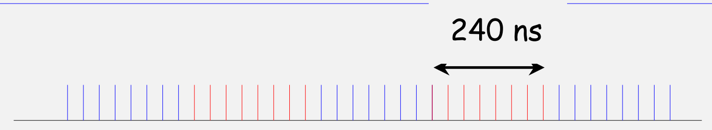
Covering:

- The CLIC accelerator studies
  - Feasibility studies and Performance studies
  - Documented in volume 1 of the CDR
- CLIC detector and physics studies
  - Documented in volume 2 and 3 of the CDR
- Project implementation studies
  - Including timelines and programme for the coming years
  - Mainly documented in volume 3
- Summary

CLIC Layout at 3 TeV

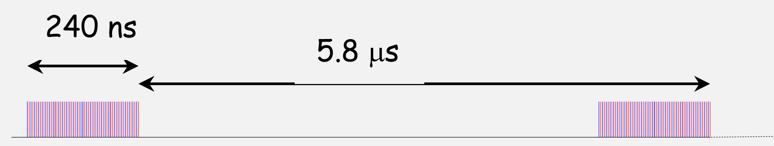
Drive Beam Generation

Drive beam time structure - initial

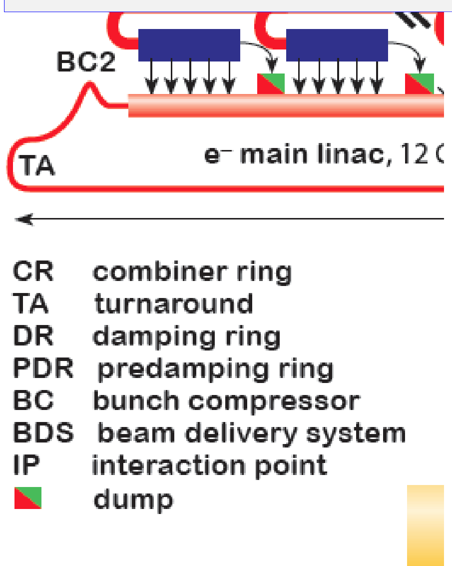


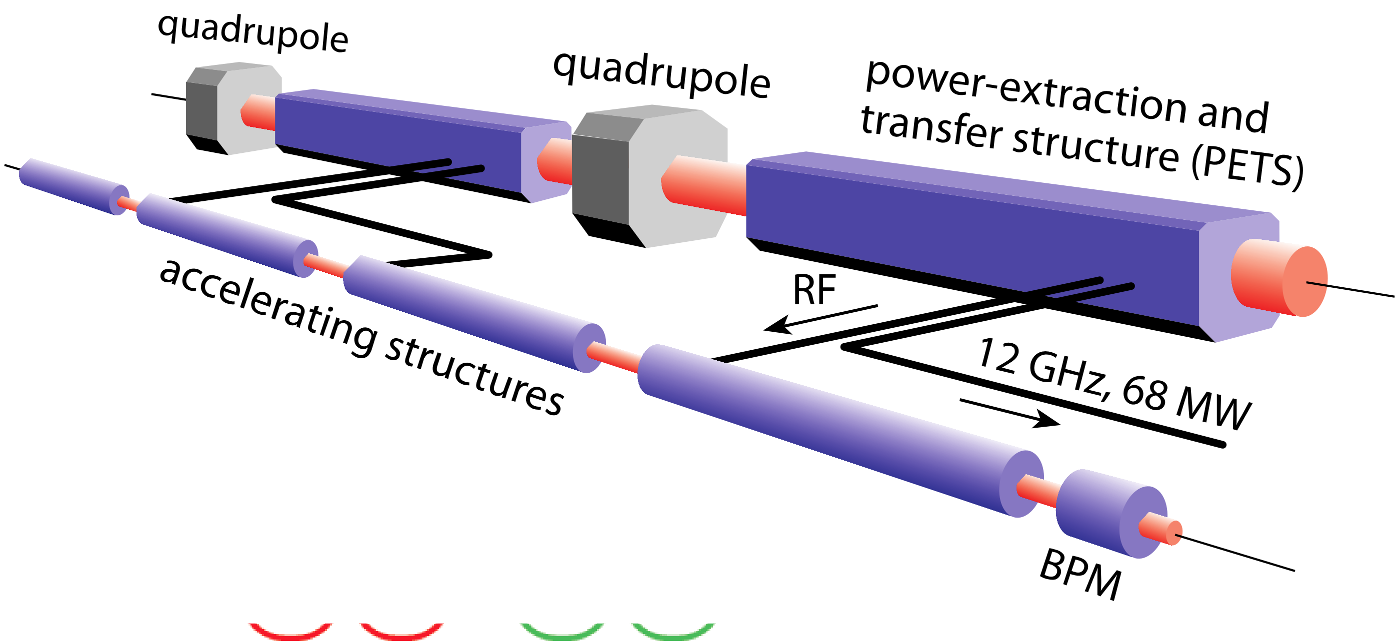
140 μs train length - 24 × 24 sub-pulses
4.2 A - 2.4 GeV – 60 cm between bunches

Drive beam time structure - final



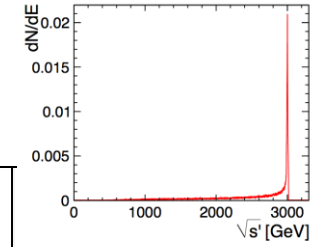
24 pulses – **101 A** – 2.5 cm between bunches





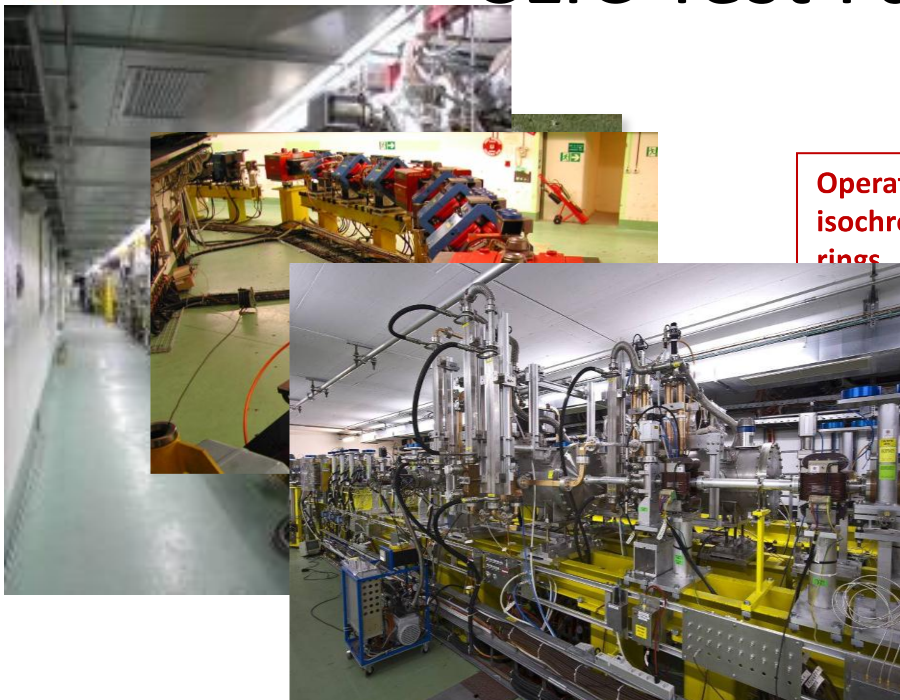
Main Beam Generation Complex

CLIC Main Parameters

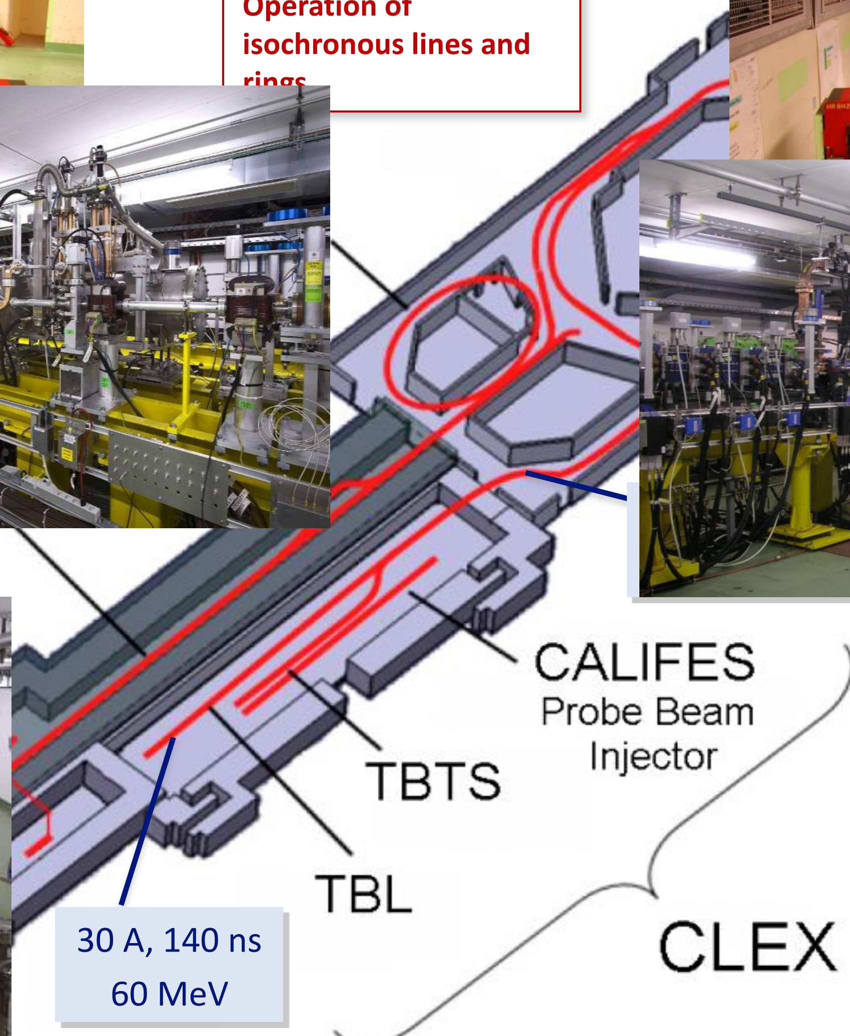


parameter	symbol		
centre of mass energy	E_{cm} [GeV]	500	3000
luminosity	$\mathcal{L}$ $[10^{34}\ cm^{-2}s^{-1}]$	2.3	5.9
luminosity in peak	$\mathcal{L}_{0.01}$ $[10^{34}\ cm^{-2}s^{-1}]$	1.4	2
gradient	G [MV/m]	80	100
site length	[km]	13	48.3
charge per bunch	N $[10^9]$	6.8	3.72
bunch length	σ_z [μm]	72	44
IP beam size	σ_x/σ_y [nm]	200/2.26	40/1
norm. emittance	ϵ_x/ϵ_y [nm]	2400/25	660/20
bunches per pulse	n_b	354	312
distance between bunches	Δ_b [ns]	0.5	0.5
repetition rate	f_r [Hz]	50	50
est. power cons.	P_{wall} [MW]	271	582

CLIC Test Facility (CTF3)



Operation of isochronous lines and rings



30 A, 140 ns
60 MeV

High current, full

and current multiplication by RF deflectors

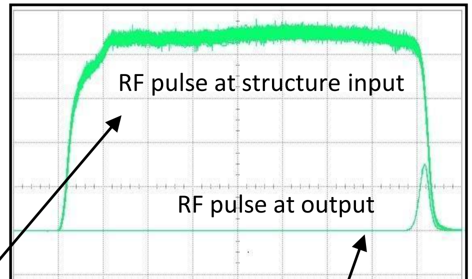
12 GHz power generation by drive beam deceleration

High-gradient two-beam acceleration

See talk of Roberto Corsini this afternoon

Drive Beam Generation

Full beam loading acceleration



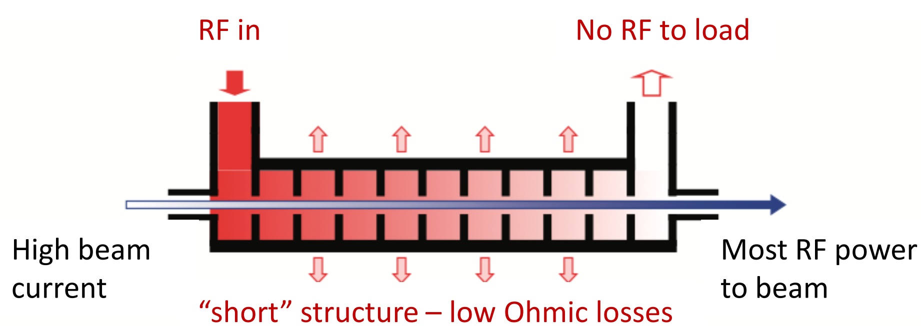
95.3% RF to beam efficiency

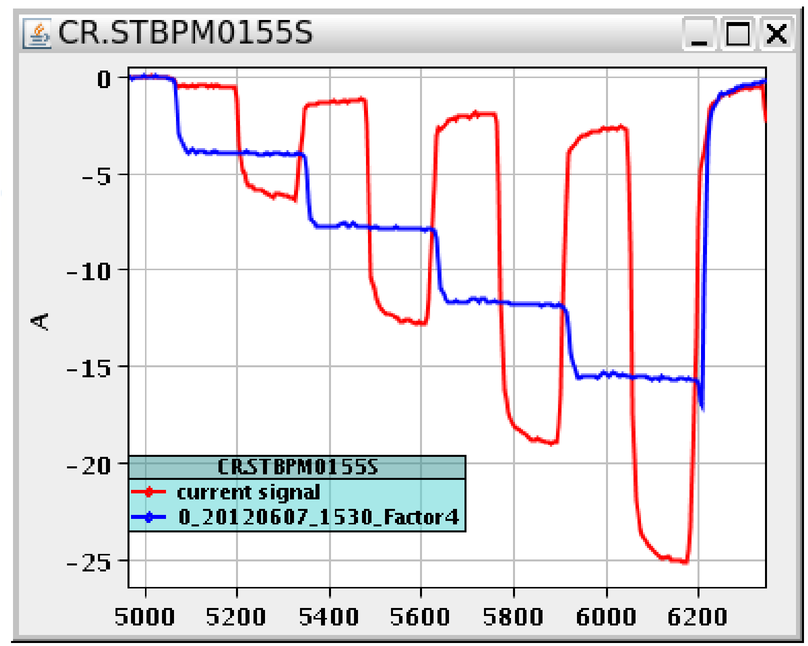
Stable high current acceleration

Current stability

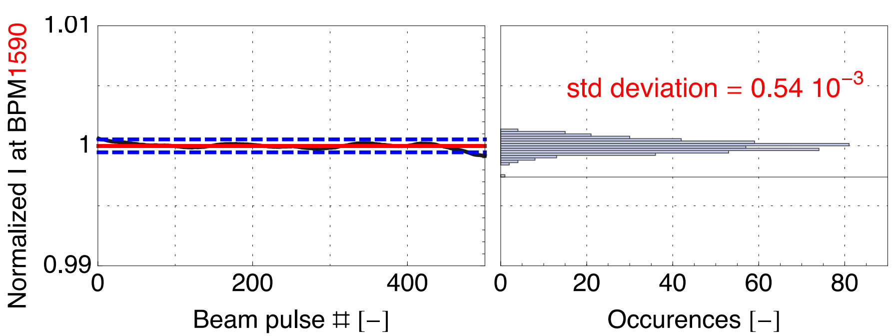
Isochronicity, phase coding

Factor 8 current & frequency multiplication





Pulse charge measurement

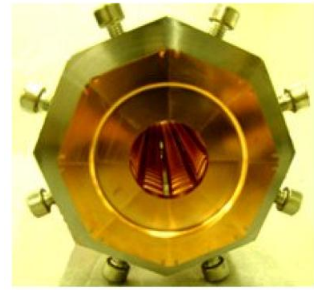
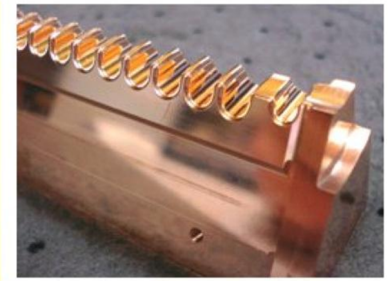
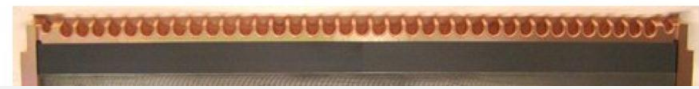


Factor 8 combination

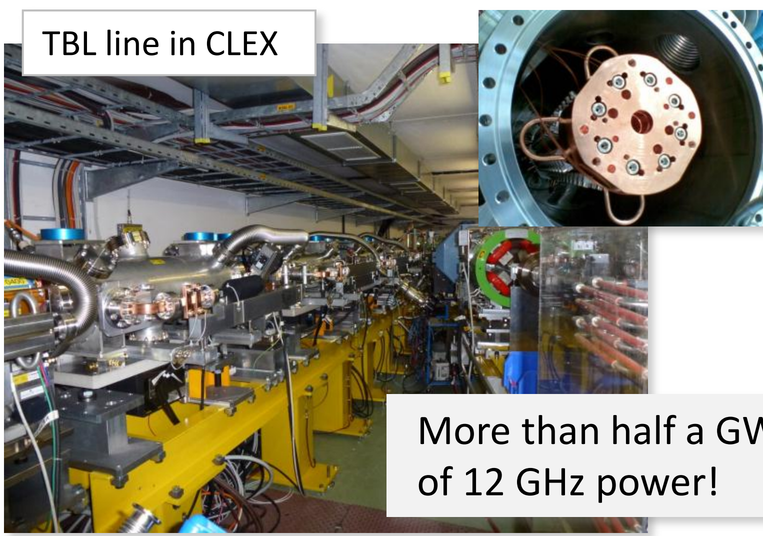
Power Production & Drive Beam Deceleration

TBTS:
Power production in PETS ($P_{out}\approx$ 200MW)
Breakdown rates checked
On-off mechanism tested successfully

TBL:
13 PETS installed
Up to 21 A current transported
optics understood - no losses
Good agreement current/RF/deceleration
~ 26% deceleration
(Final goal is 50% deceleration)

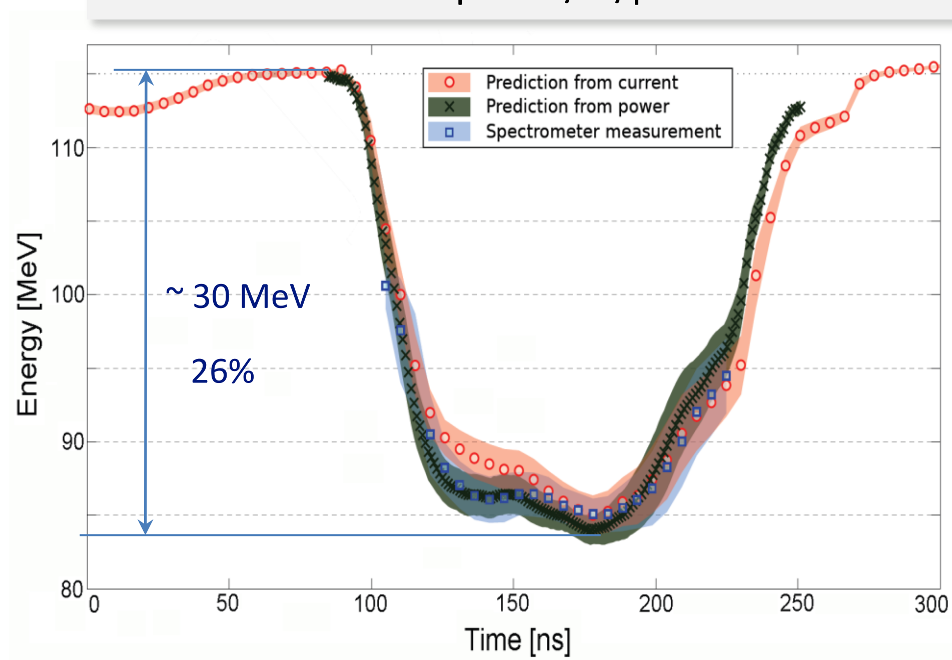




Measurements at SLAC:
No breakdown last O(8 10^6 pulses)
-> P consistent with p$\leq10^{-7}$/m/pulse



TBL line in CLEX

More than half a GW of 12 GHz power!

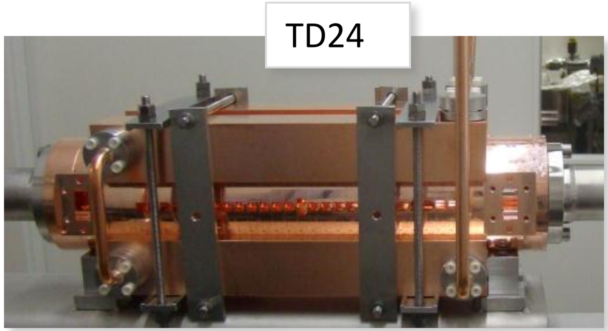


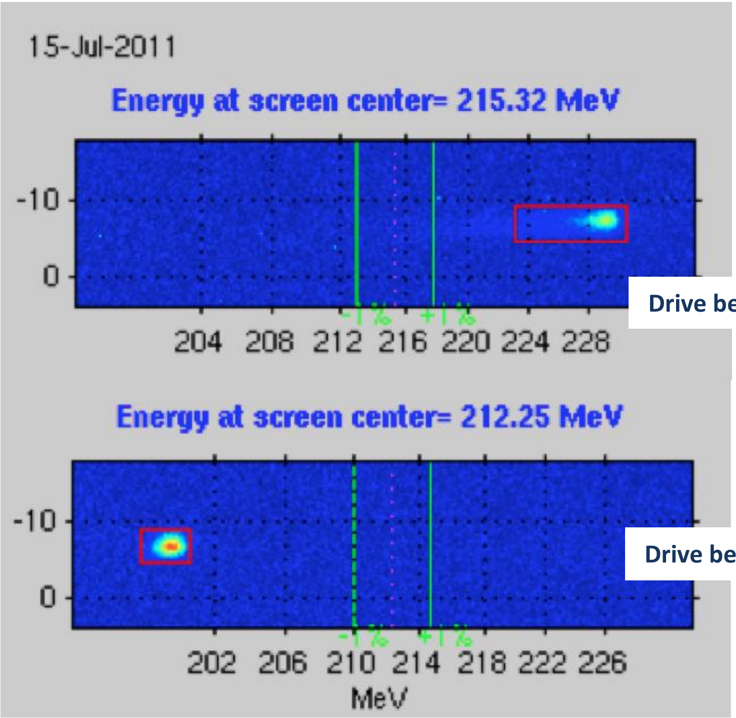
Two-Beam Acceleration

Two-Beam Acceleration demonstration in TBTS

Up to 145 MV/m measured gradient

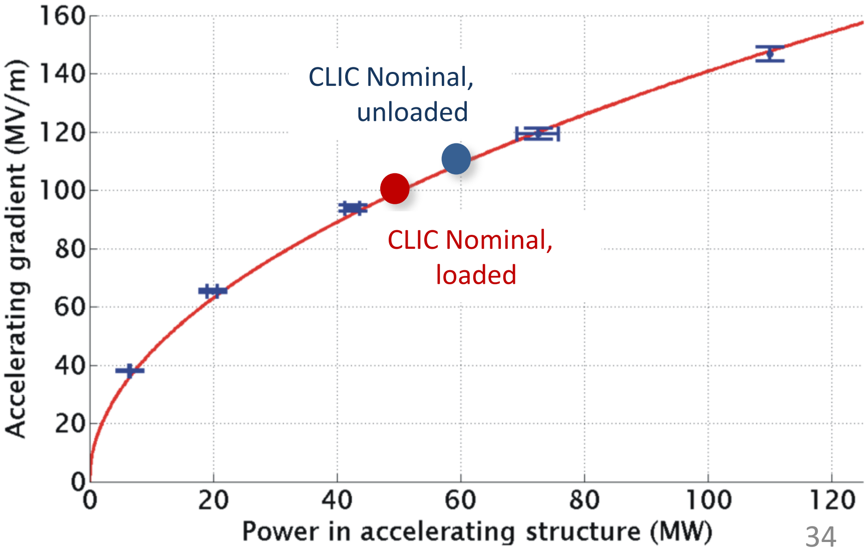
Good agreement with expectations (power vs. gradient)



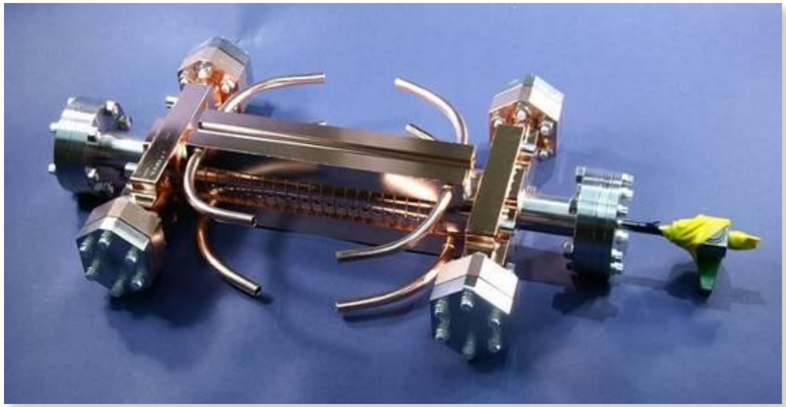


Maximum stable probe beam acceleration measured: 31 MeV

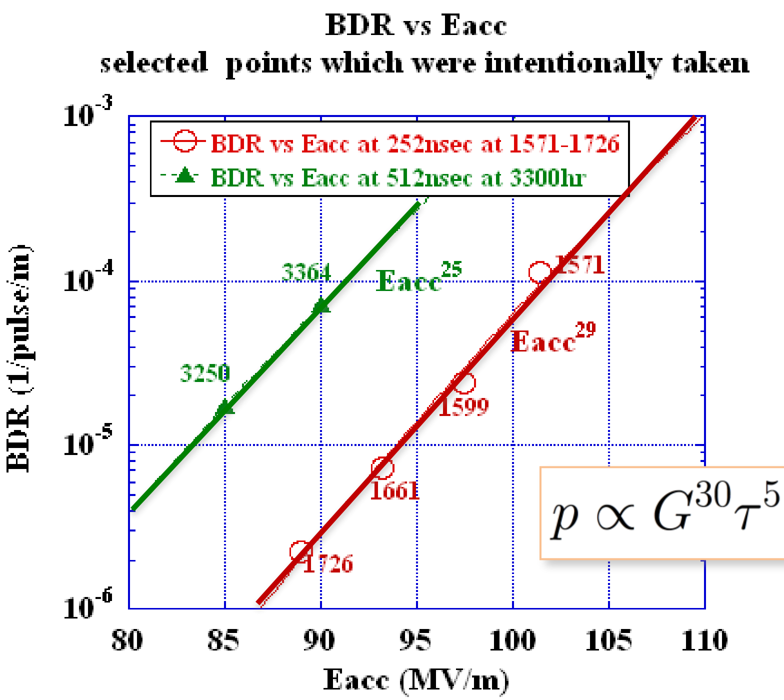
⇒ Corresponding to a gradient of **145 MV/m**



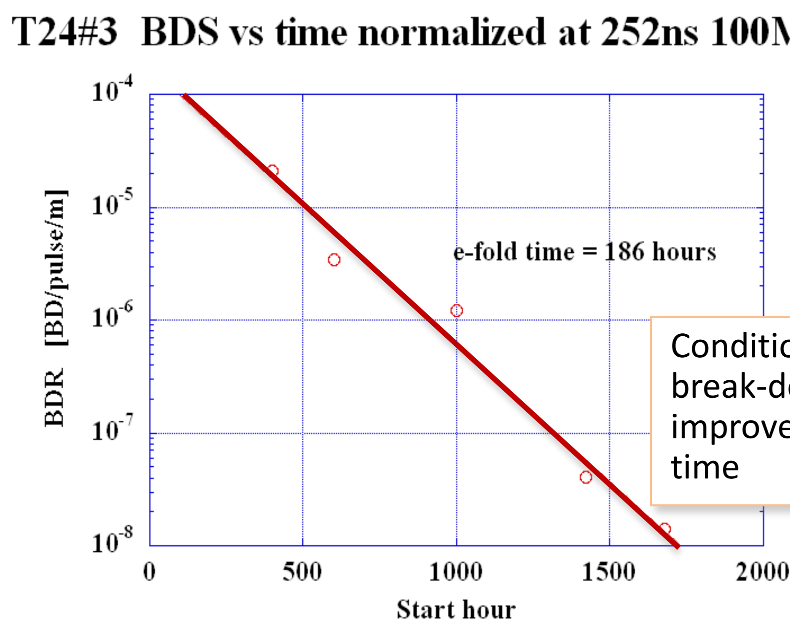
Accelerating Structures



- Gradient limited by break-down, must include HOM damping
- Require <1% probability of even a single break-down in any structure
  - $p \leq 3x10^{-7} m^{-1} pulse^{-1}$
- Design based on empirical constraints

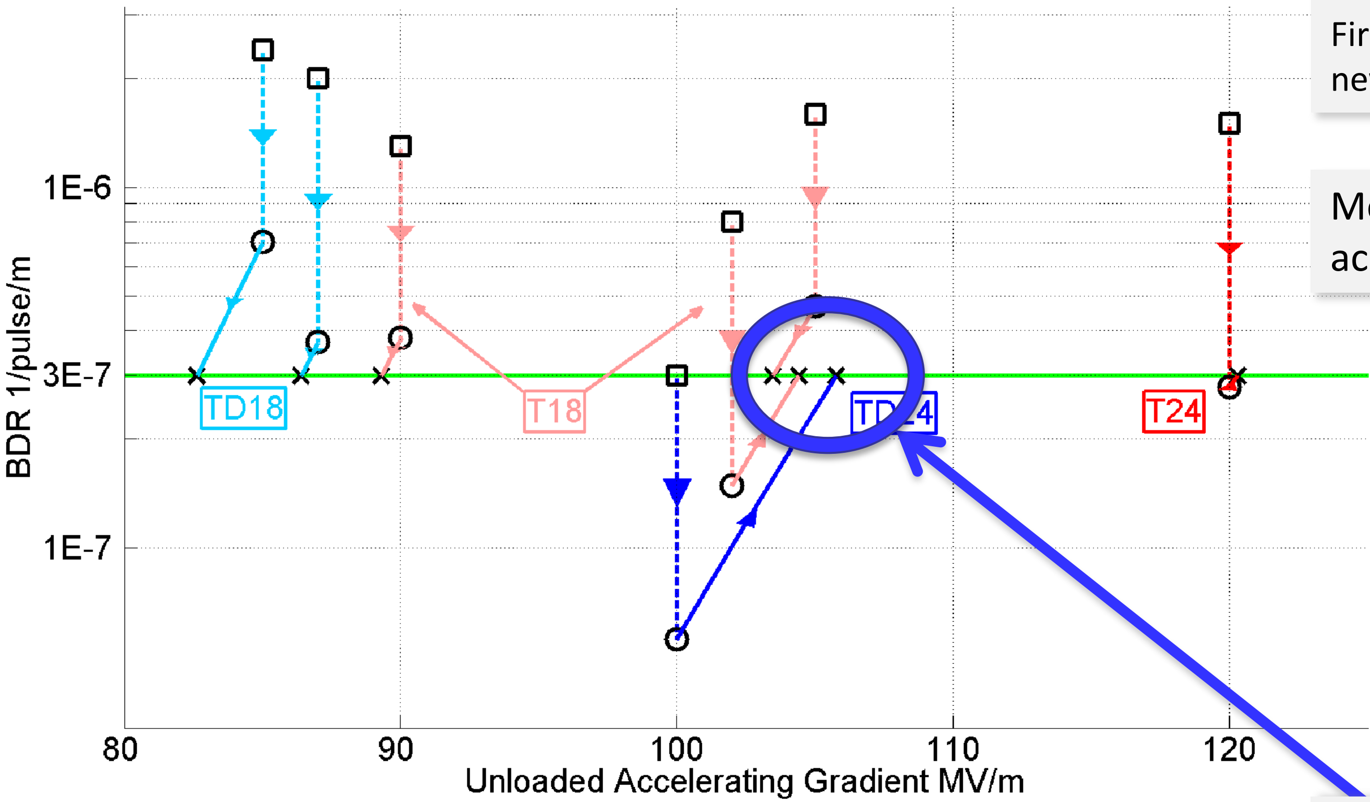


$$p \propto G^{30} \tau^{5}$$



Conditioning; break-down rate improves with time

Achieved Gradient



Tests at KEK and SLAC

First cavity test ongoing at new CERN test station

Measurements scaled according to:

$$p \propto G^{30} \tau^{5}$$

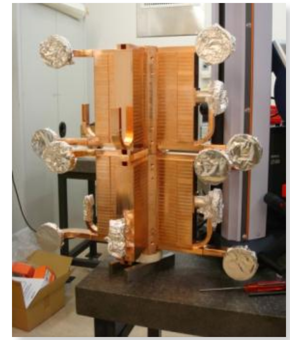
Unloaded 106 MV/m
Expected with beam loading 0-16% less

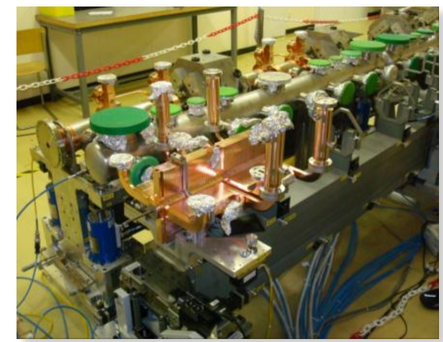
	Simple early design to get started	More efficient fully optimized structure
No damping waveguides	T18	T24
Damping waveguides	TD18	TD24 = CLIC goal

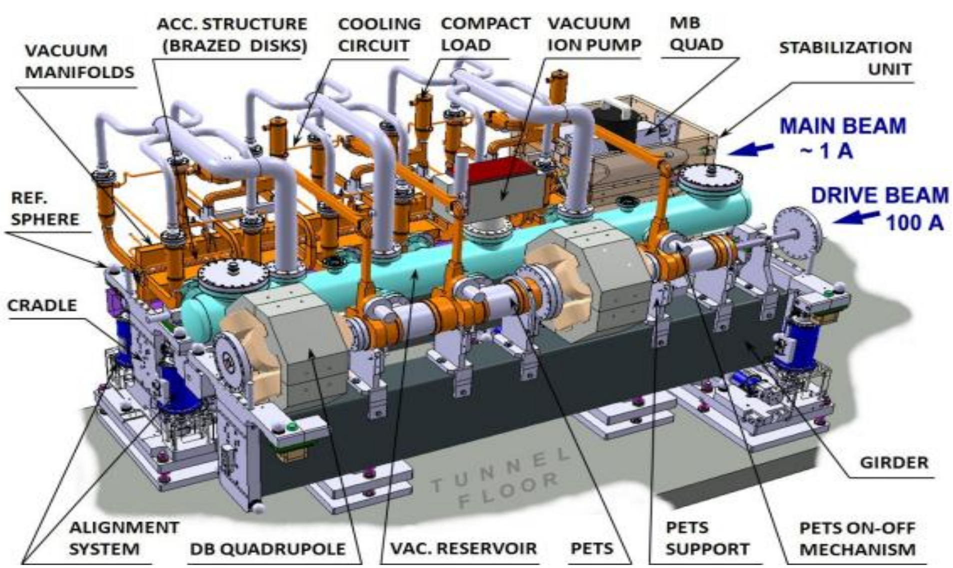
Two-Beam Acceleration

Next Steps:

- Complete modules being assembled in lab and for beam-tests
- Installation and test of full-fledged Two-Beam Modules in CLEX
- First module in development, installation end 2013
- Three modules in 2014-2016



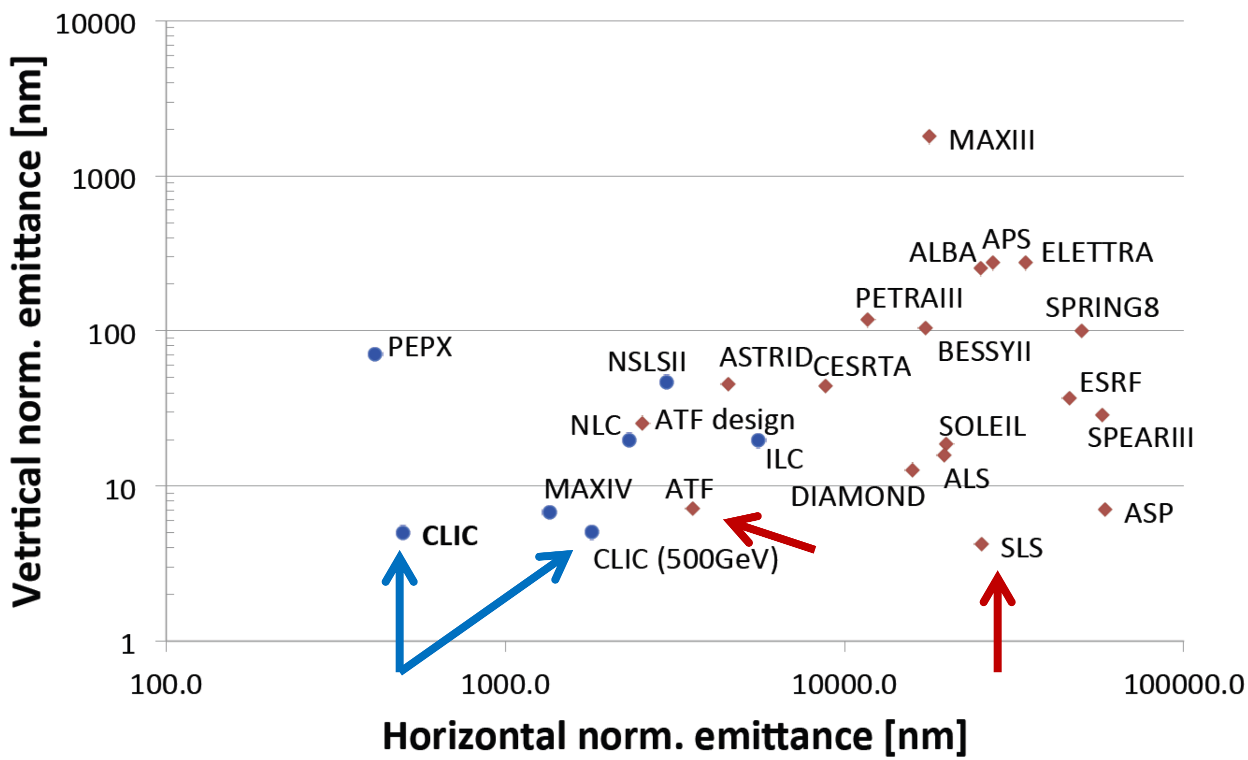




Emittance Generation

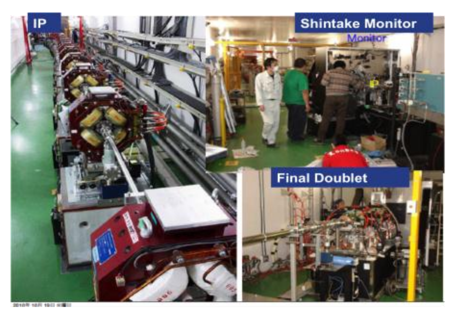
Many design issues addressed:
- lattice design
- dynamic aperture
- tolerances
- intra-beam scattering
- space charge
- wigglers
- RF system
- vacuum
- electron cloud
- kickers

In addition: wiggler and kicker developments



	ϵ_x [nm]	ϵ_y [nm]
Damping ring exit	500	5
RTML exit	600	10
main linac exit	660	20

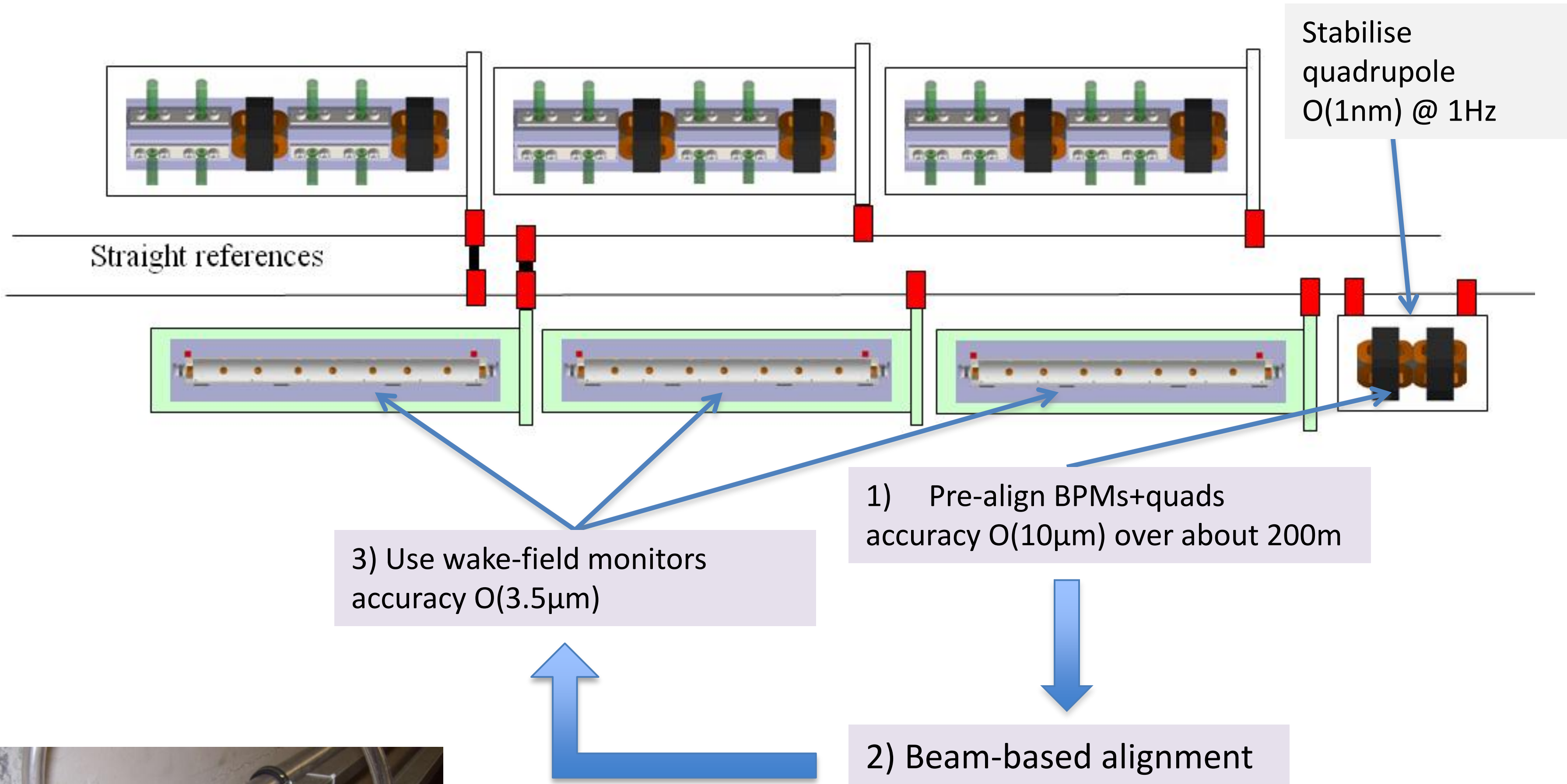
Damping ring design is consistent with target performance



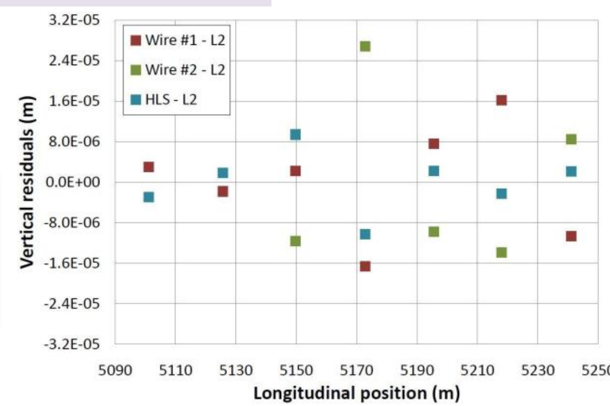
CLIC @3 TeV would achieve 1/3 of nominal luminosity with ATF performance

(3800nm/15nm@4e9)

Main Linac Tolerances



- Test of prototype shows
  - vertical RMS error of 11µm
  - i.e. accuracy is approx. 13.5µm



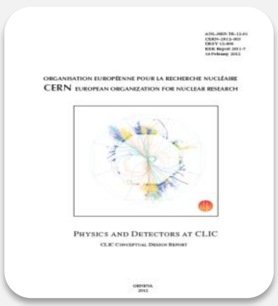
Conclusion of the CDR studies

Main linac gradient	– Ongoing test close to or on target – Uncertainty from beam loading
Drive beam scheme	– Generation tested, used to accelerate test beam, deceleration as expected – Improvements on operation, reliability, losses, more deceleration (more PETS) to come
Luminosity	– Damping ring like an ambitious light source, no show stopper – Alignment system principle demonstrated – Stabilisation system developed, benchmarked, better system in pipeline – Simulations seem on or close to the target
Operation Machine Protection	– Start-up sequence defined – Most critical failure studied – First reliability studies – Low energy operation developed

The CLIC CDR documents

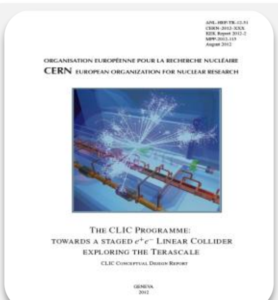
Vol 1: The CLIC accelerator and site facilities (H.Schmickler)

- CLIC concept with exploration over multi-TeV energy range up to 3 TeV
- Feasibility study of CLIC parameters optimized at 3 TeV (most demanding)
- Consider also 500 GeV, and intermediate energy range
- Complete, presented in SPC in March 2011, in print: https://edms.cern.ch/document/1234244/



Vol 2: Physics and detectors at CLIC (L.Linssen)

- Physics at a multi-TeV CLIC machine can be measured with high precision, despite challenging background conditions
- External review procedure in October 2011
- Completed and printed, presented in SPC in December 2011 http://arxiv.org/pdf/1202.5940v1

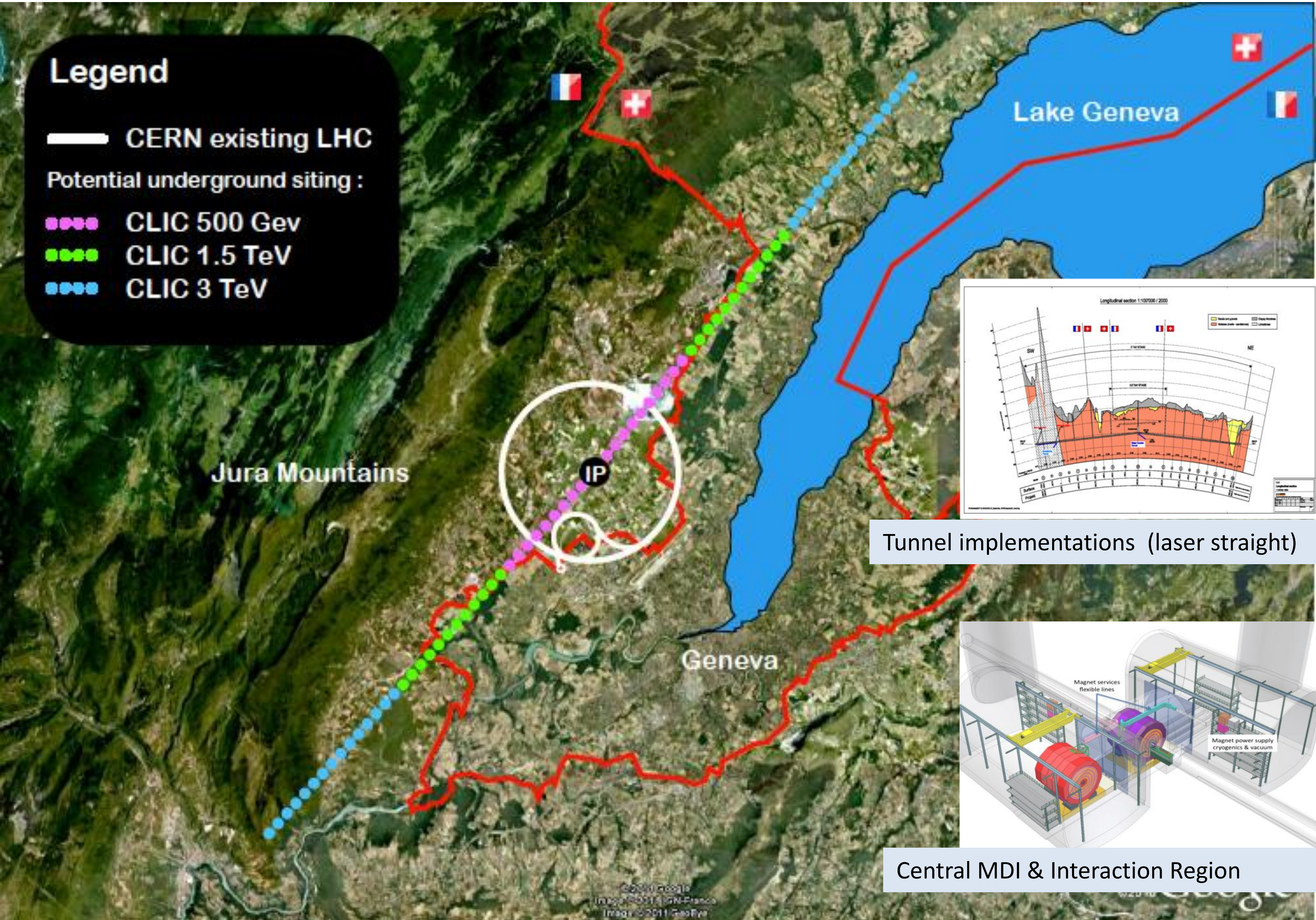


Vol 3: "CLIC study summary" (S.Stapnes)

- Summary and available for the European Strategy process, including possible implementation stages for a CLIC machine as well as costing and cost-drives
- Proposing objectives and work plan of post CDR phase (2012-16)
- Completed and printed, submitted for the European Strategy Open Meeting in September http://arxiv.org/pdf/1209.2543v1

In addition a shorter overview document was submitted as input to the European Strategy update, available at: http://arxiv.org/pdf/1208.1402v1

CLIC near CERN



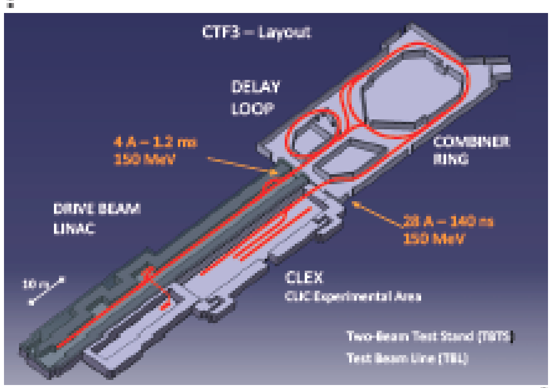
Tunnel implementations (laser straight)

Central MDI & Interaction Region

CLIC project time-line

2012-16 Development Phase

Develop a Project Plan for a staged implementation in agreement with LHC findings; further technical developments with industry, performance studies for accelerator parts and systems, as well as for detectors.



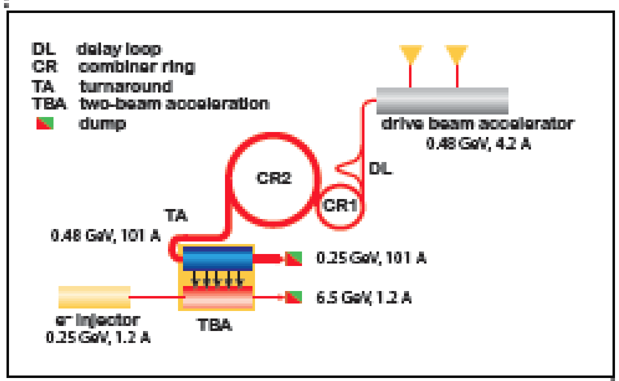
2016-17 Decisions

On the basis of LHC data and Project Plans (for CLIC and other potential projects), take decisions about next project(s) at the Energy Frontier.

2017-22 Preparation Phase

Finalise implementation parameters, Drive Beam Facility and other system verifications, site authorisation and preparation for industrial procurement.

Prepare detailed Technical Proposals for the detector-systems.



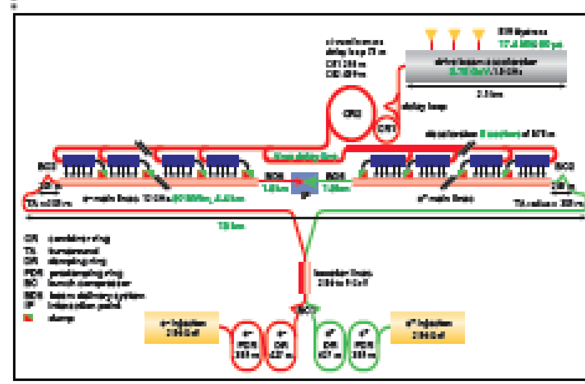
2022-23 Construction Start

Ready for full construction and main tunnel excavation.

2023-2030 Construction Phase

Stage 1 construction of a 500 GeV CLIC, in parallel with detector construction.

Preparation for implementation of further stages.



2030 Commissioning

From 2030, becoming ready for data-taking as the LHC programme reaches completion.

Future objectives

- Strongly support the Japanese initiative to construct a linear collider as a staged project in Japan.
- Prepare CLIC machine and detectors as an option for a future high-energy linear collider at CERN.
- Further improve collaboration between CLIC and ILC machine experts
- Move towards a “more normal” structure of collaboration in the detector community to prepare for the construction of two high-performance detectors.

Thanks

- From all of us to the organizers, support staff and students for an excellent Workshop and great hospitality.