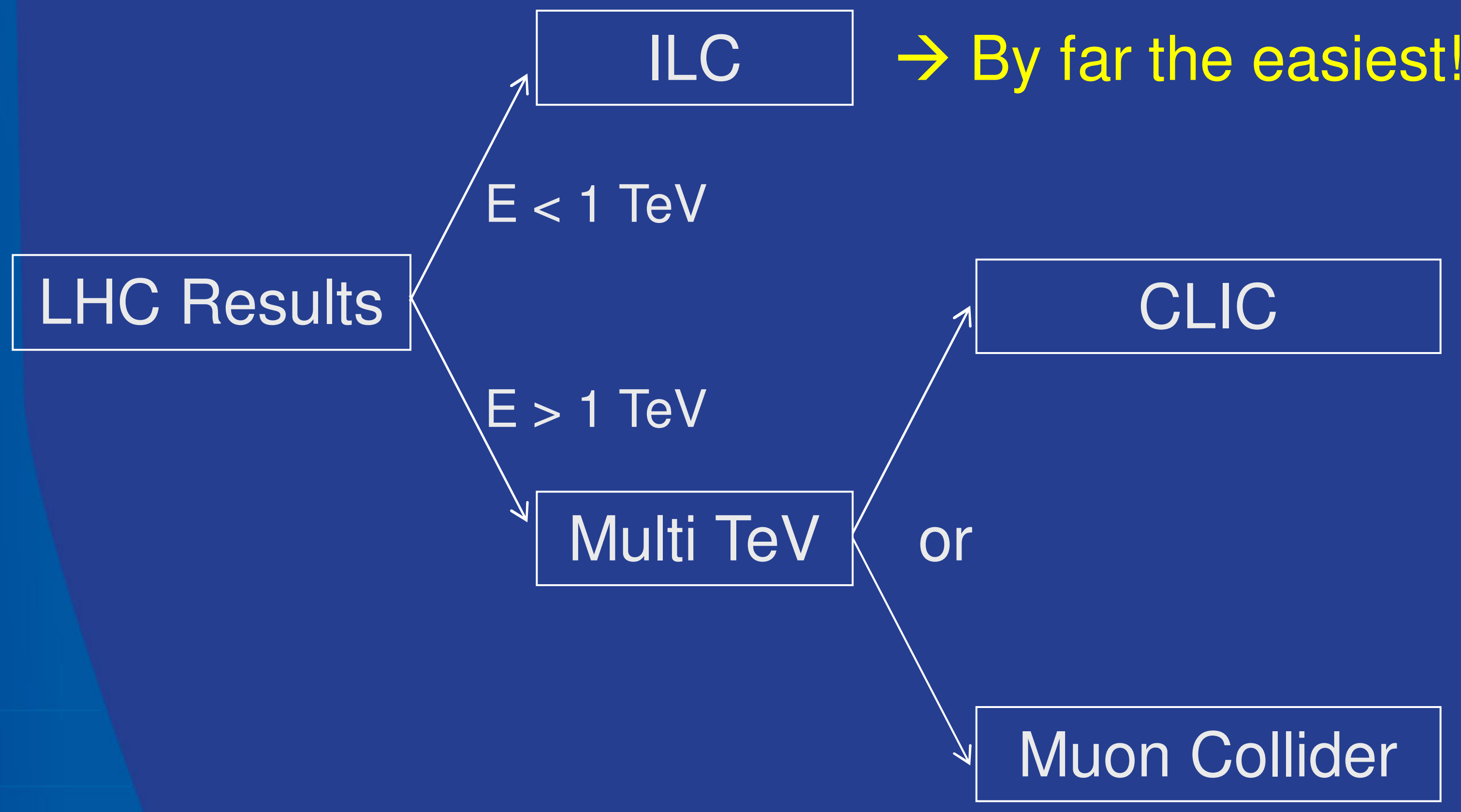
ILC Accelerator R&D Status

Marc Ross
Nick Walker
Akira Yamamoto

Lepton Colliders beyond LHC



RDR → 2012 Technical Design

- **Strong Basis for SCRF technology in each ILC region**
  - Cavity fabrication and test: Each region
  - Global Cryomodule: KEK +
- **Large scale *Costed* technology demonstration**
  - EU XFEL (5% of ILC); first beam mid-2014
- **Siting: adaptation to best suit potential hosts**
- **Beam – based studies and demonstrations**
  - High power SCRF linac operation: DESY +
  - Electron-cloud beam dynamics: Cornell +
  - Beam delivery technology: KEK +

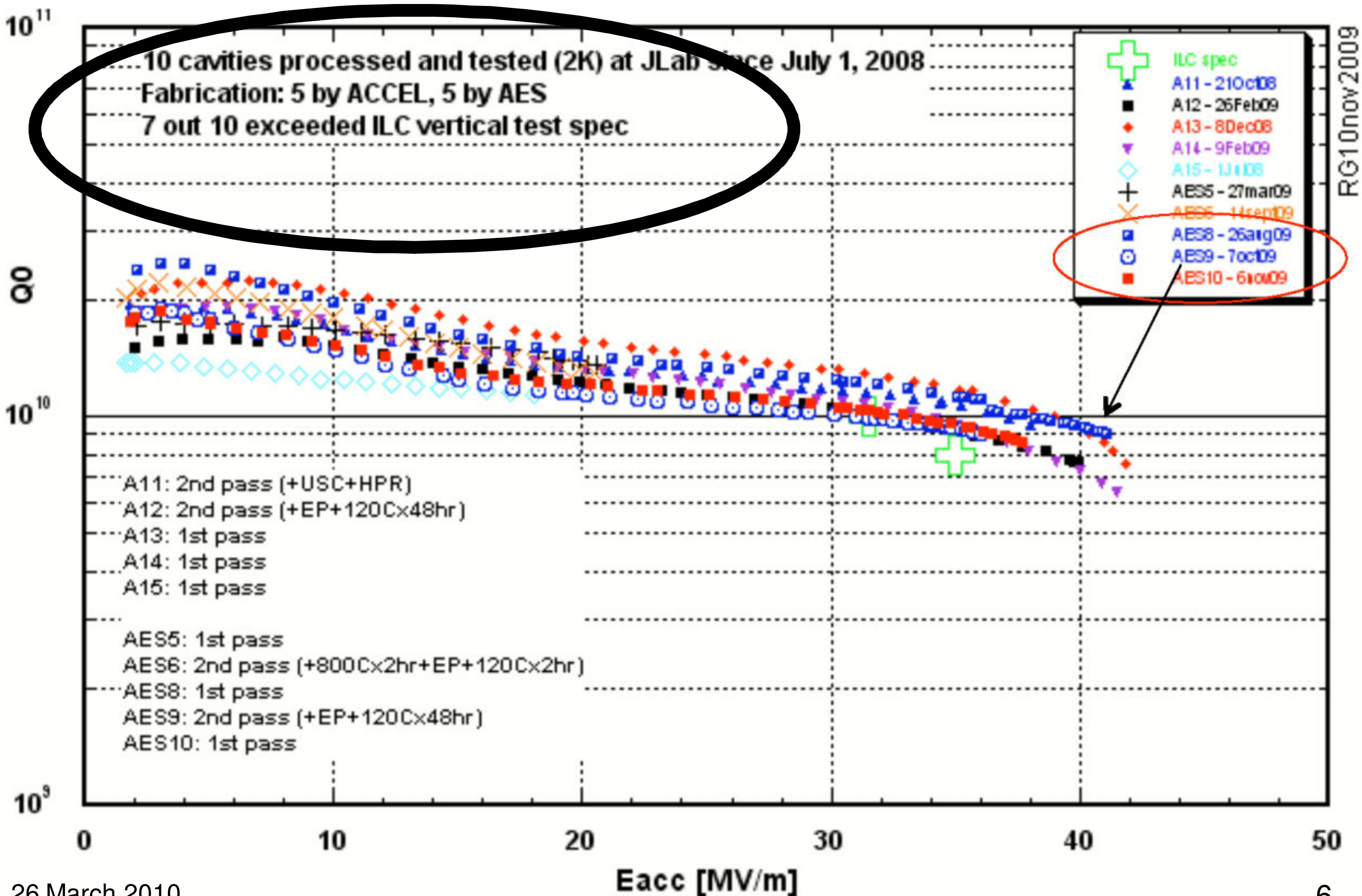
ILC R & D – 2010: Outline

- **Superconducting RF**
  - Cavities
  - Cryomodules
  - Linac 'system': High power beam tests
  - Construction of EU-XFEL (13 partners, including China)
    - Critically useful guidance for ILC SCRF Industrialization
- Conventional Facilities / Siting
- Beam Test Facilities: CESR TA / ATF2
- Integrated Design: AD & I

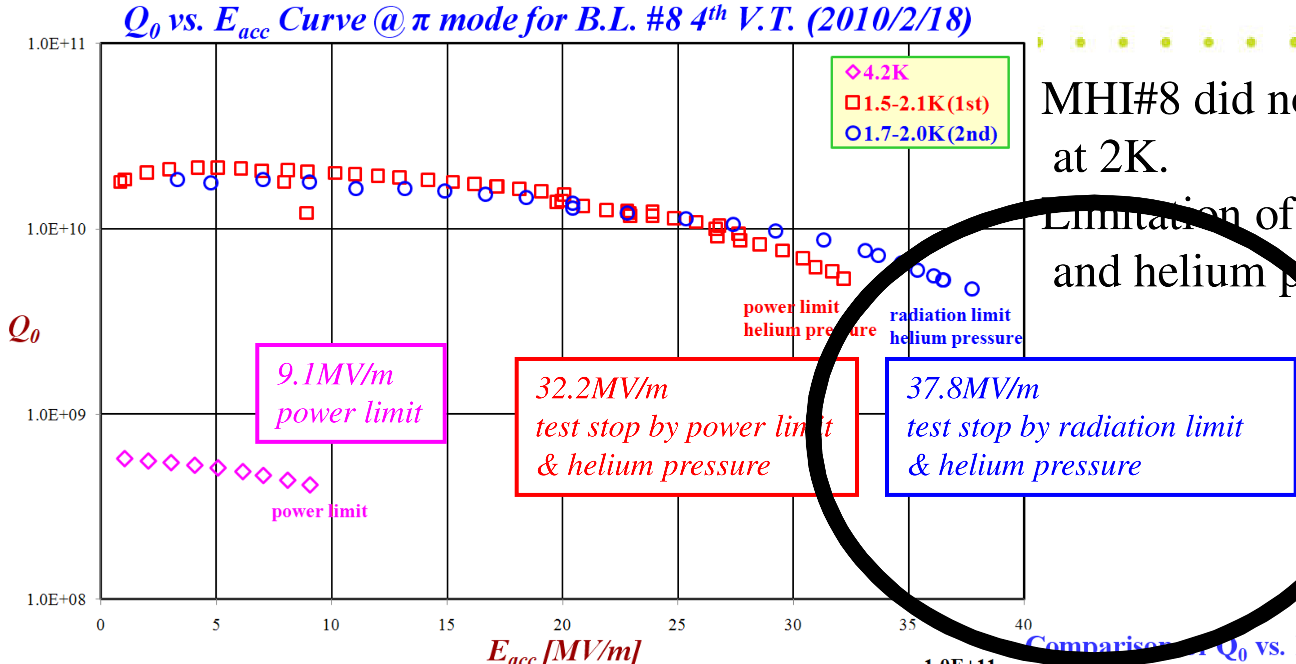
Cavities:

- **Full ILC gradient performance in each region**
  - 2009 achievement
  - Production yield assessment process defined
- **Specified: <u><Gradient_average ></u> 35 MV/m in low power test**
  - ***2009 Assessment:~ 44% production yield***
    - *(2010 R & D Plan goal: 50%)*
- **Diagnostic: *imaging welds* from the inside**
  - Precision imaging – Kyoto 2007
  - Now deployed at each major lab

FY09 Results from JLab/FNAL



V.T. Results of MHI#8 – KEK 2010

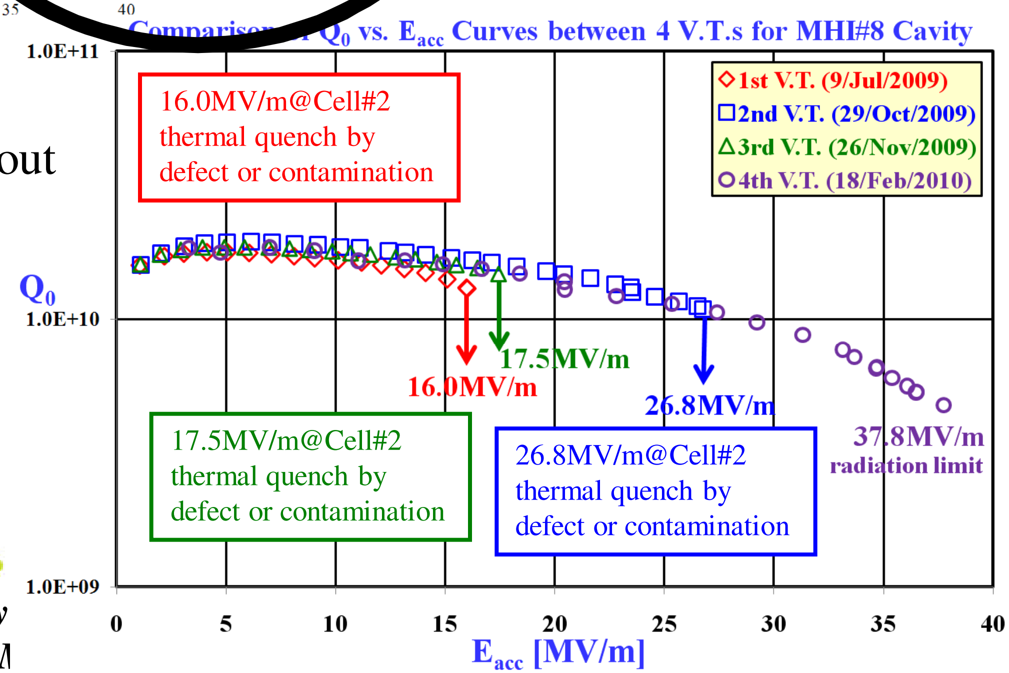


MHI#8 did not have any quench in pi-mode at 2K.

Limitation of RF test was the radiation level and helium pressure.

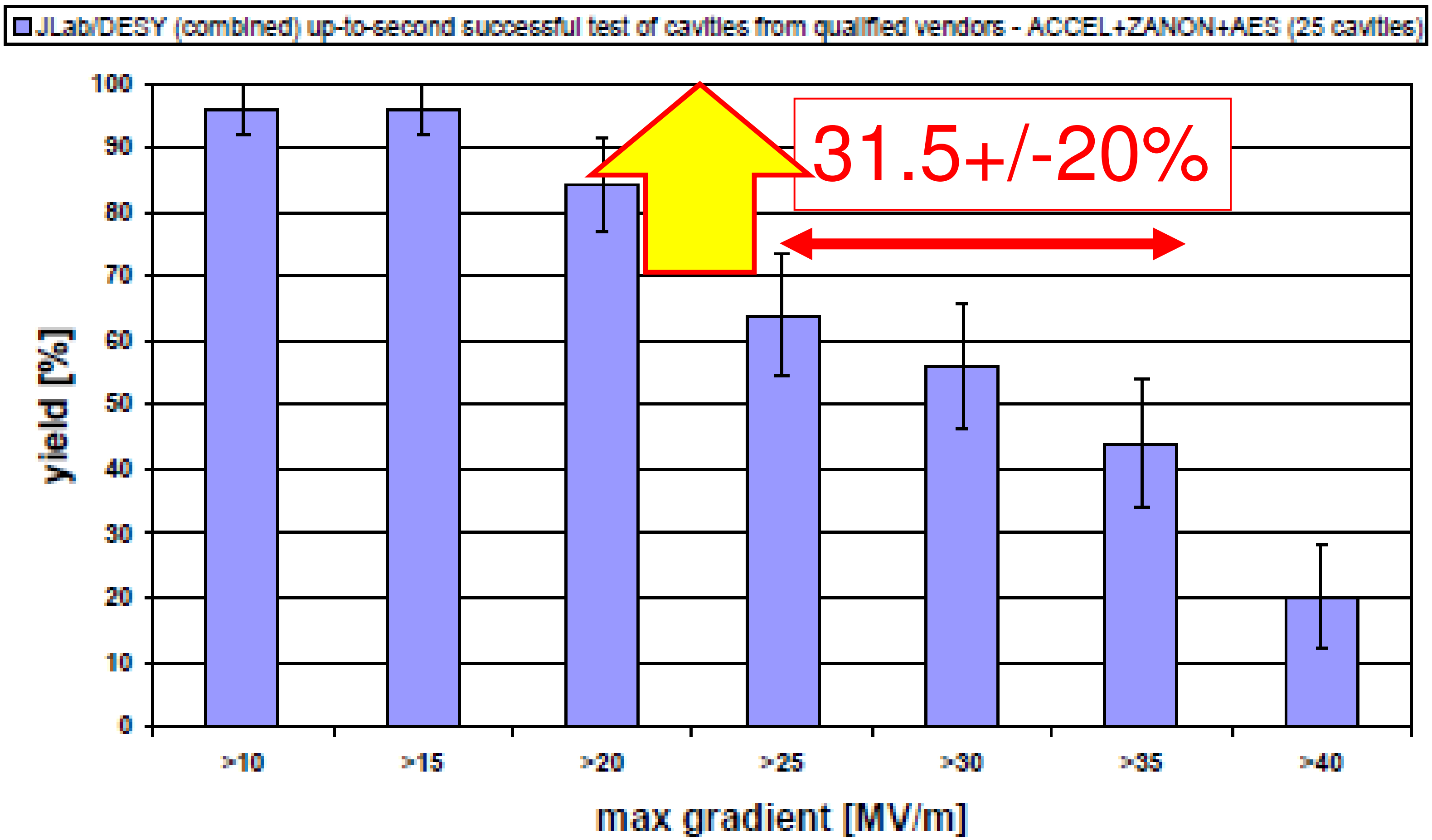
After the first V.T., local grinding was carried out and the pit at heating location was removed.

After the second V.T., no grinding was done.



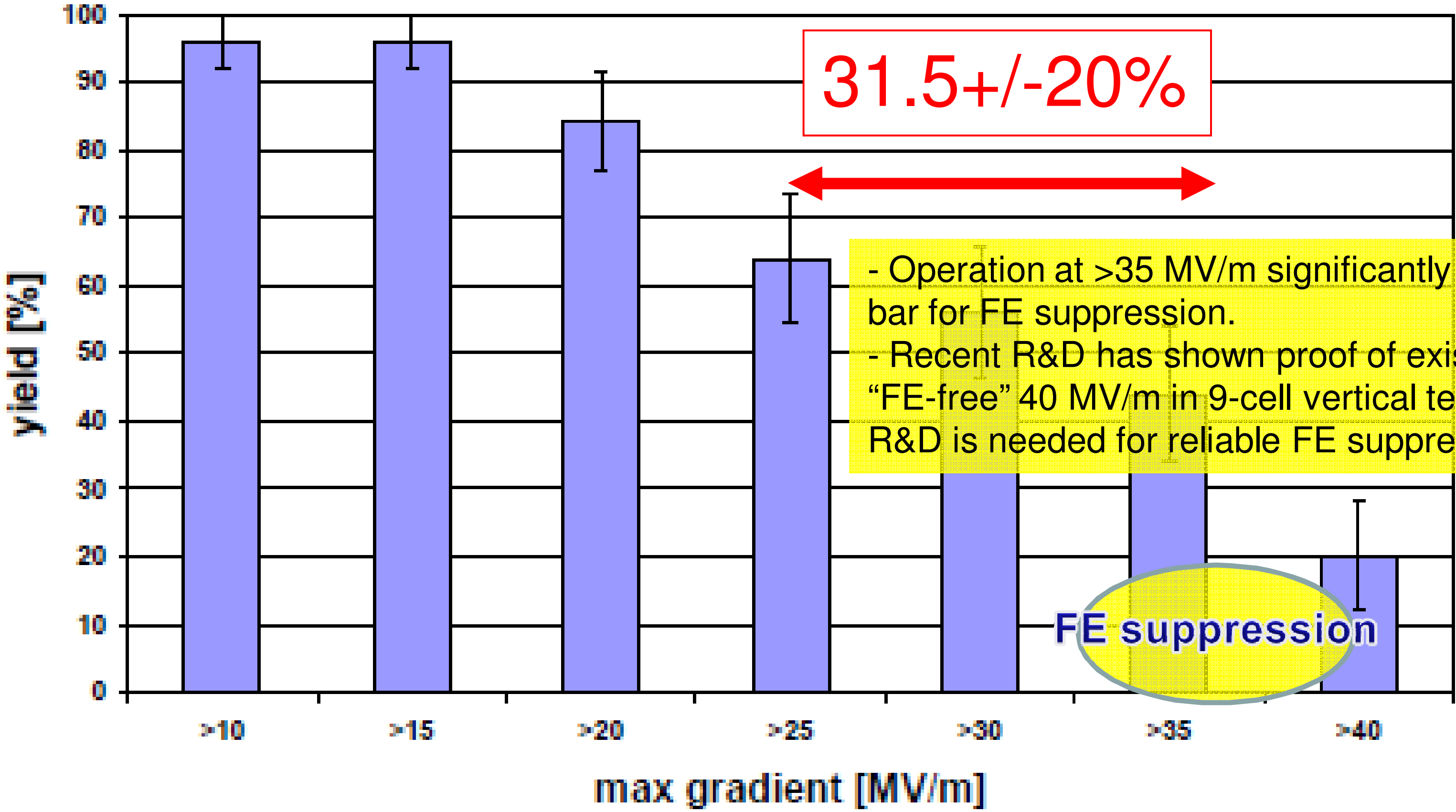
The Next Battles (1): Eliminate the Yield Drop near 20MV/m

Despite increased acceptance thanks to more flexible HLRF



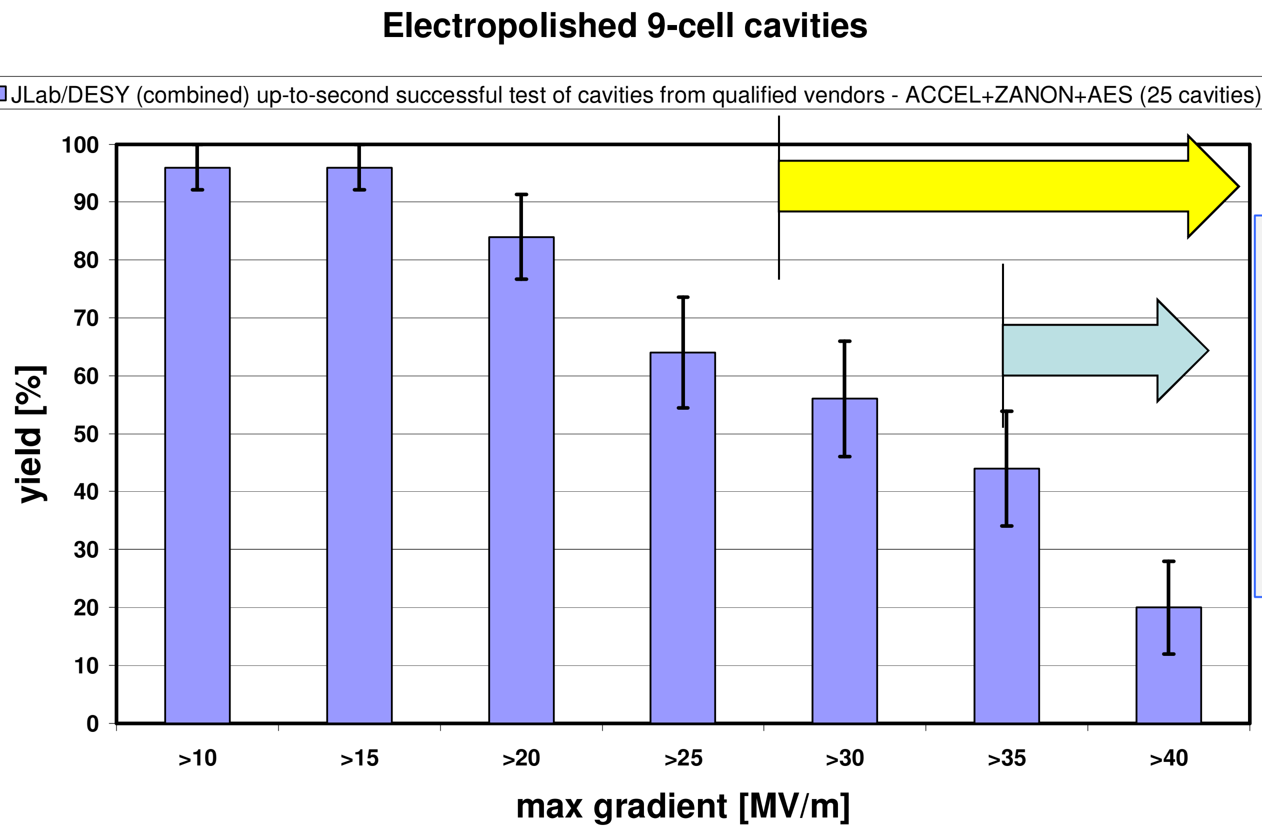
The Next Battle (2): Further Reduce Field Emission up to 40 MV/m

Flexible HLRF opens up possibility of some individual cavity operations up to 38 MV/m



- Operation at >35 MV/m significantly raises the bar for FE suppression.
- Recent R&D has shown proof of existence of "FE-free" 40 MV/m in 9-cell vertical test – further R&D is needed for reliable FE suppression

‘Production Yield’ – 2009

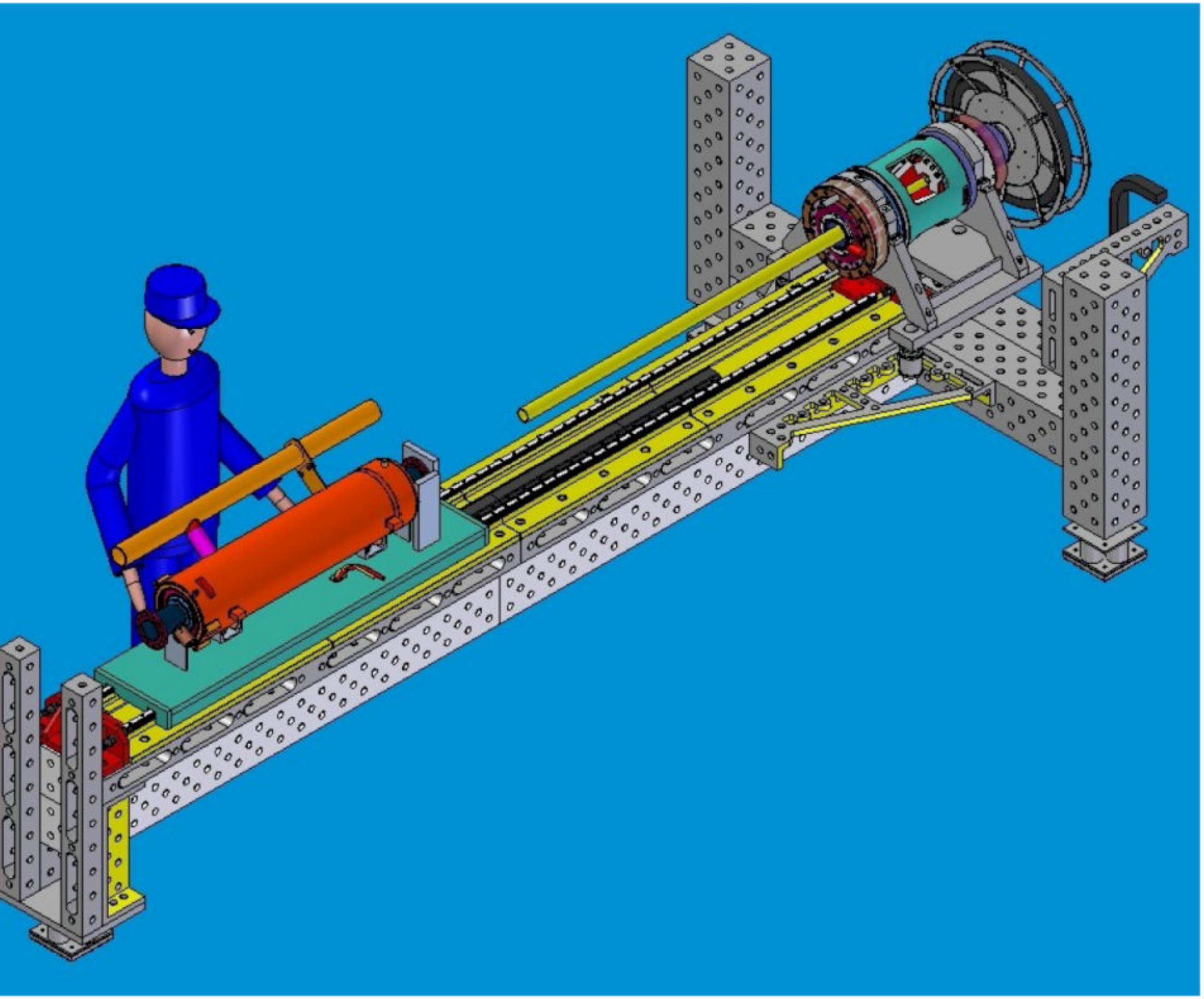


>35MV/m
35-41.8MV/m
44% yield
(RDR definition)

- 2009 proposal: high (> 35 MV/m) performance retained in system
- ‘Gradient spread’ – to ~20%

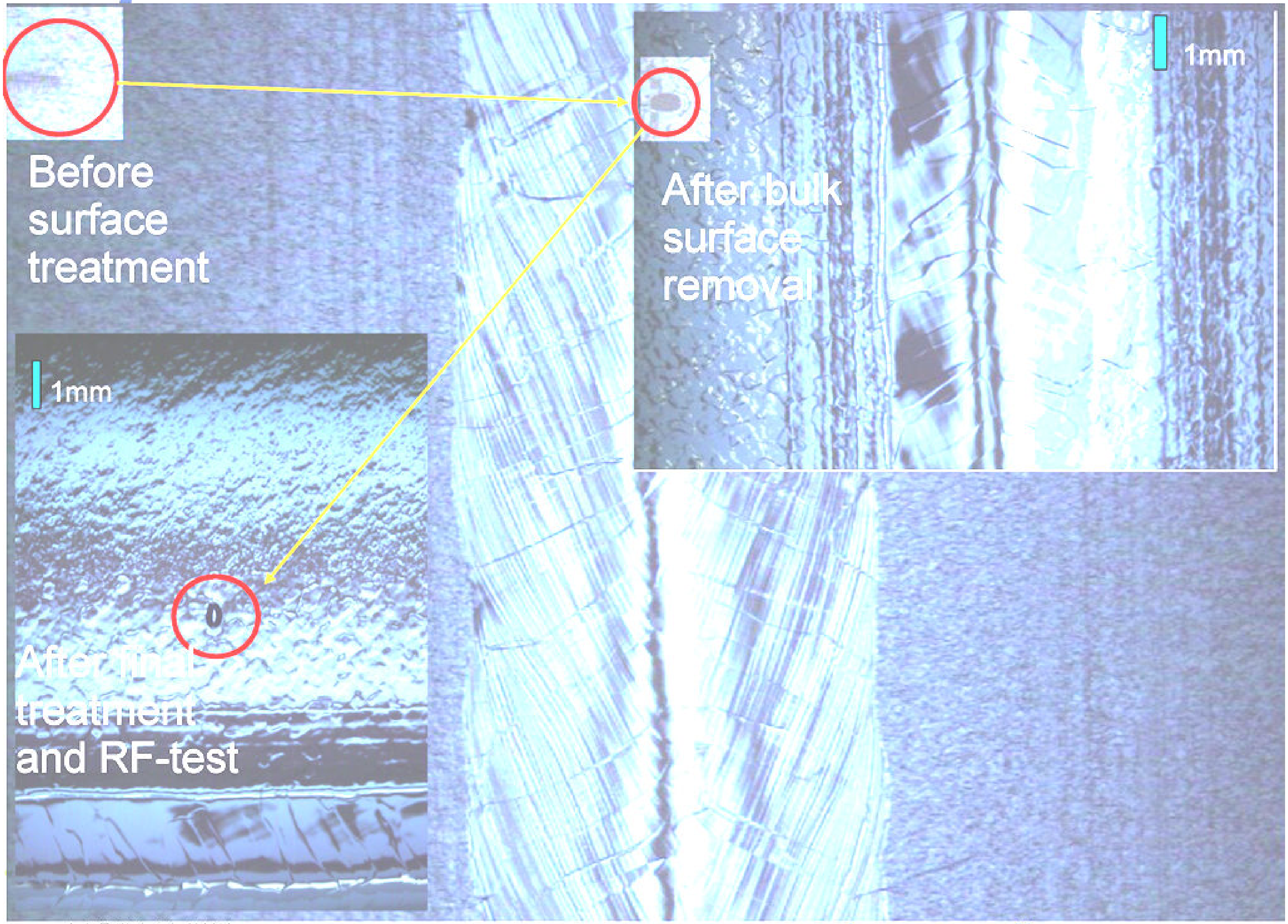
<36.5MV/m>
27.9-41.8MV/m
64% yield

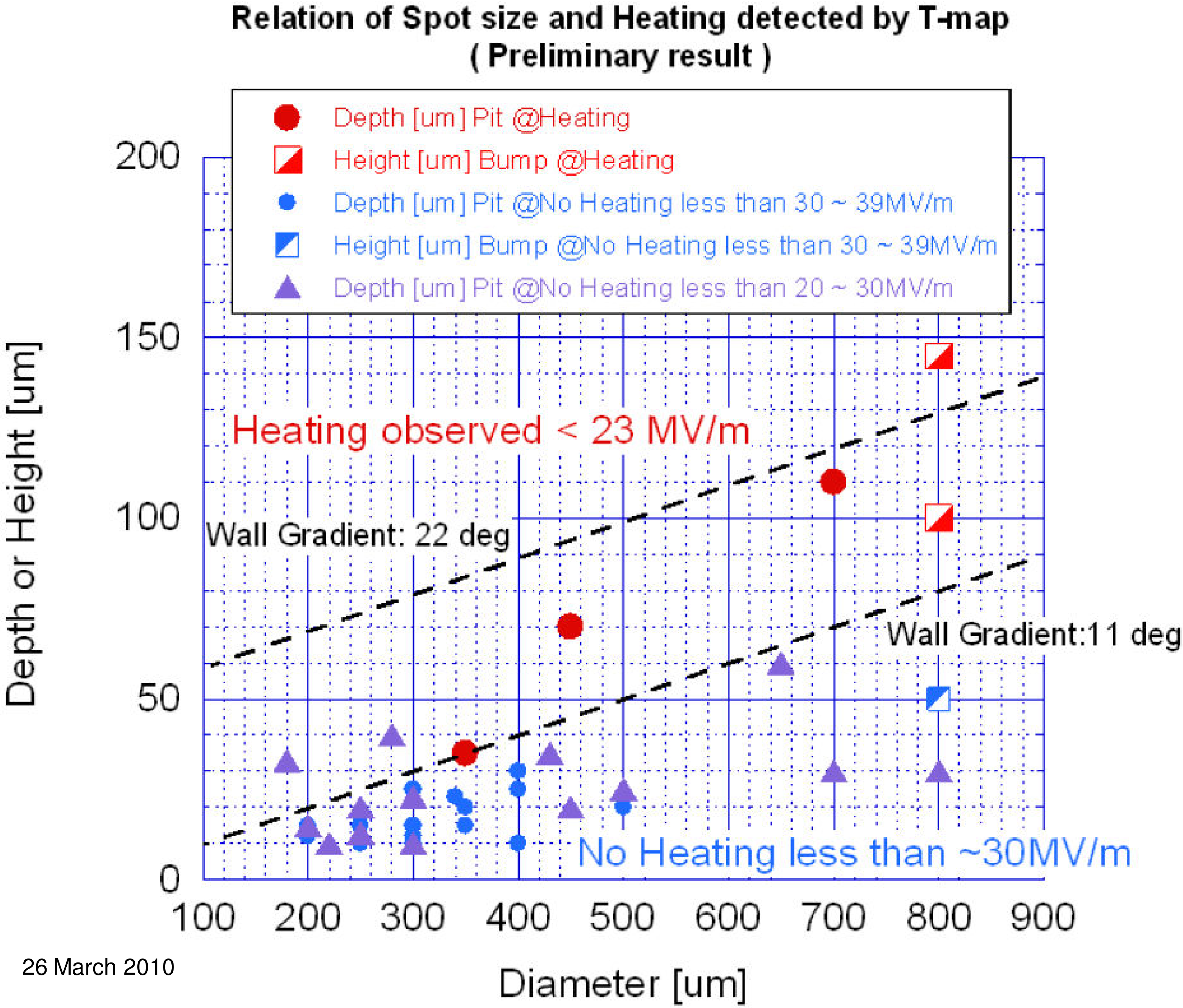
Optical inspection



- Automated setup prototype
- High precision positioning
- Easy to operate
- Fast inspection

  ~2-3h/cavity


Before
surface
treatment
After bulk
surface
removal
1mm
1mm
After final
treatment
and RF-test


Relation of Spot size and Heating detected by T-map
(Preliminary result)
Depth [um] Pit @Heating
Height [um] Bump @Heating
Depth [um] Pit @No Heating less than 30 ~ 39MV/m
Height [um] Bump @No Heating less than 30 ~ 39MV/m
Depth [um] Pit @No Heating less than 20 ~ 30MV/m
Heating observed < 23 MV/m
Wall Gradient: 22 deg
Wall Gradient:11 deg
No Heating less than ~30MV/m
Depth or Height [um]
Diameter [um]
0
50
100
150
200
100
200
300
400
500
600
700
800
900

Progress and Prospect of Cavity Gradient Yield Statistics

	Initial qualified set: Oct 2009	New cavities added: Dec 2009	Coming Prod/Test Jun 2010	Research cavities
DESY	14 (AC/ZA)	4	5	8 (large grain)
JLAB FNAL/ANL/Cornell	7 (AC)	5 (AE) 1 (AC)	12 (RI) 6 (AE) 2 (AC)	6 (NW) (including large-G)
KEK/IHEP/PKU	0	0	2 (MH)	~5 (LL) 1 (IHEP) 2 (PKU)
Sum	21	10	27	~ **22**
Total		31	58	

Statistics for Production Yield in Progress to reach ~ 60, within TDP-1.
We may need to have *separate* statistics for 'production' and for 'research',

S1-Global cryomodule test preparation

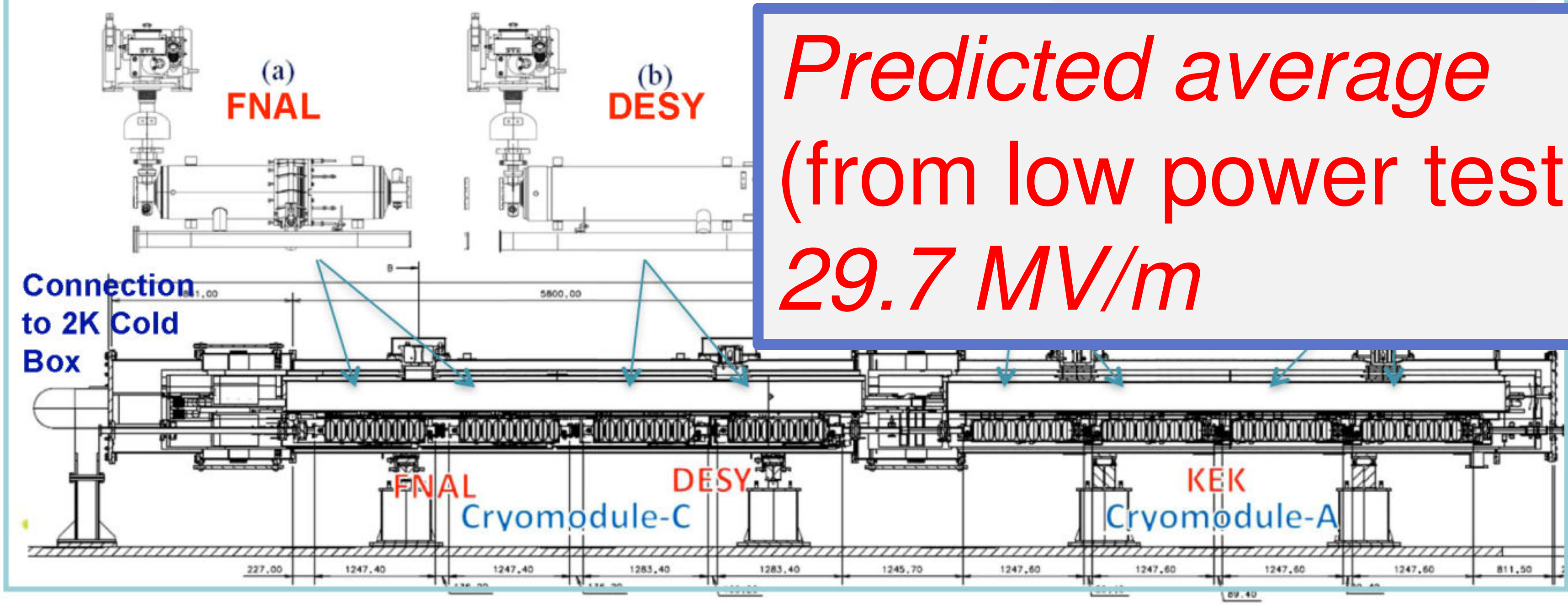
In attempt to demonstrate the average gradient of 31.5MV/m (ILC specification) and the realization of ILC plug-compatibility concept in the international collaboration.

Module-C : INFN Cryostat + 2 FNAL cavities + 2 DESY cavities
Module-A : STF short cryostat + 4 KEK TESLA-style cavities
power distribution : 2 SLAC VTO + STF waveguides

1	AES004	27MV/m(VT) 25?MV/m(HT)
2	ACC011	33MV/m
3	Z-108	31.3MV/m
4	Z-109	30.7MV/m
5	MHI-05	27.1MV/m
6	MHI-06	27.7MV/m
7	MHI-07	33.6MV/m
8	MHI-09	27.0MV/m

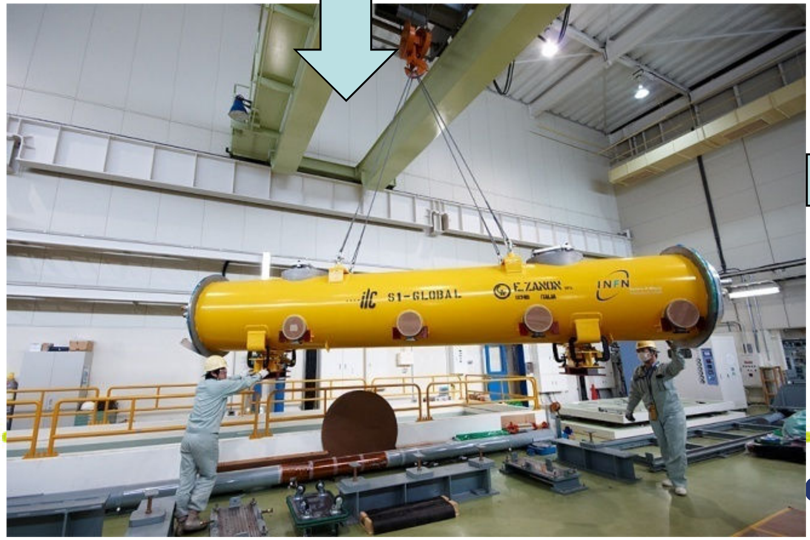
Assembly: Jan 2010 - May 2010
Operation: June 2010 – December 2010

Predicted average (from low power test): 29.7 MV/m



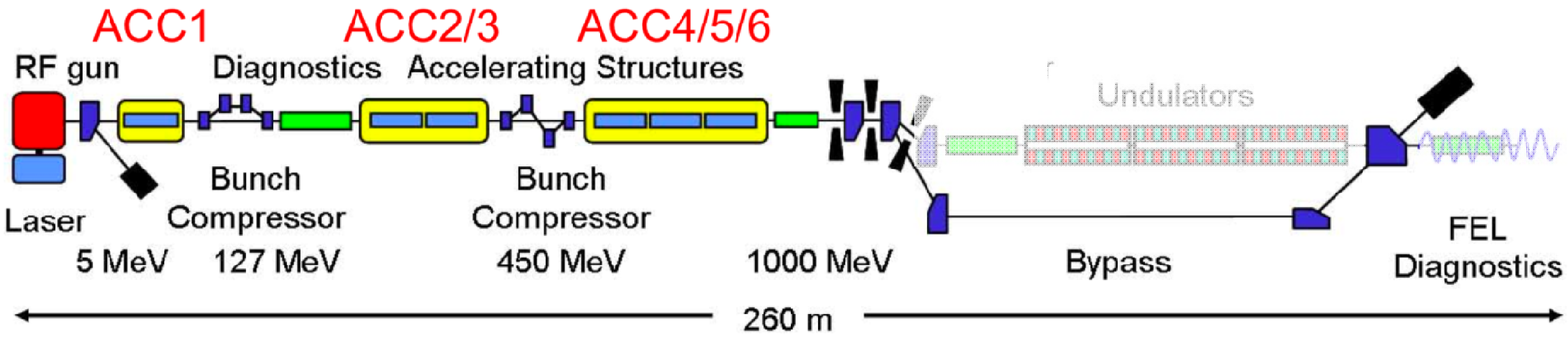
2010: Assembling the ‘S1’ *Global ILC Cryomodule* (at KEK)

- Two 4-cavity half-CM:
  - **INFN/DESY/FNAL half installed 19.03**
  - **KEK half now in assembly**



High Power SCRF Linac Operation

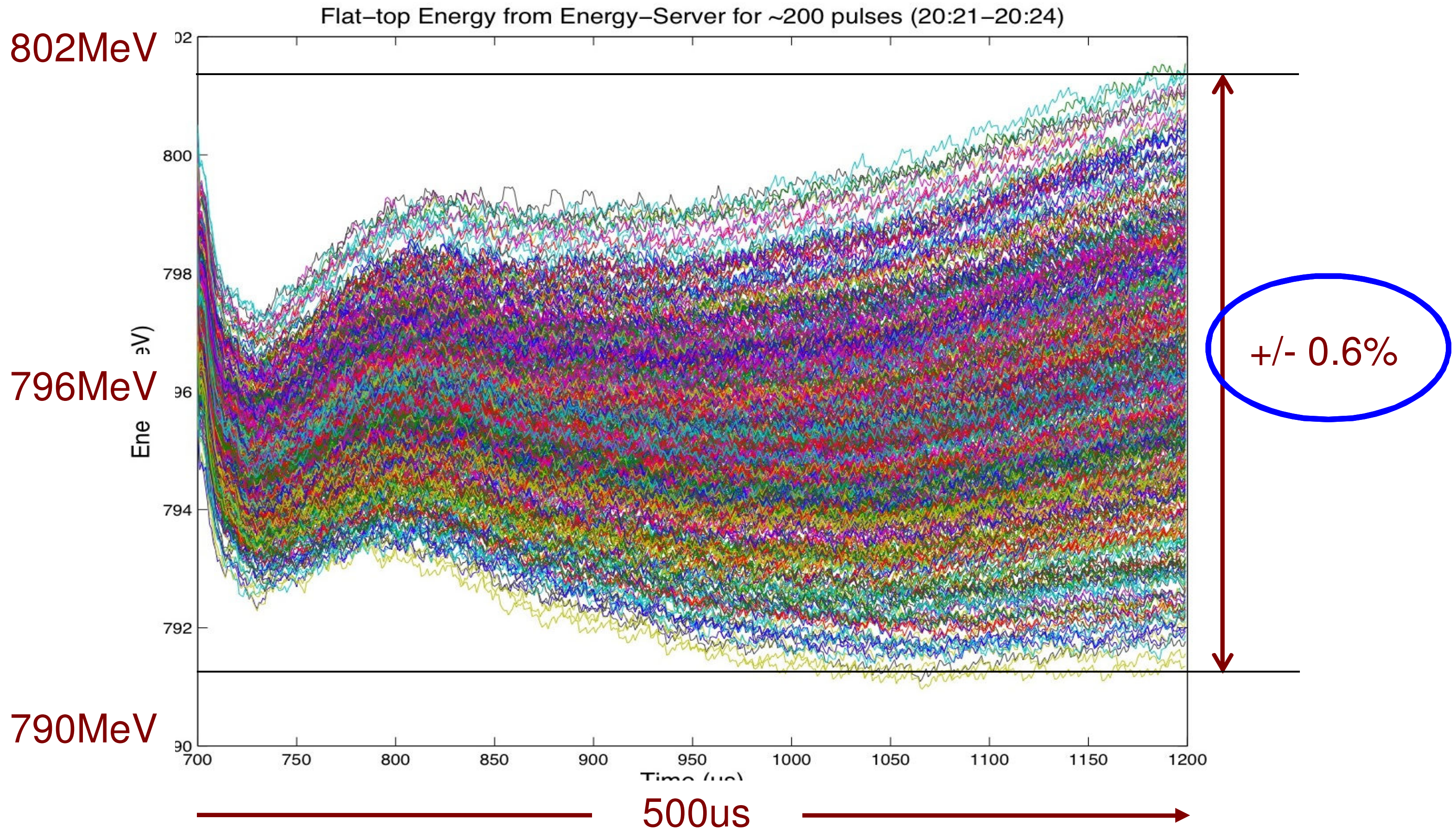
DESY/FLASH 9mA – 36 kW



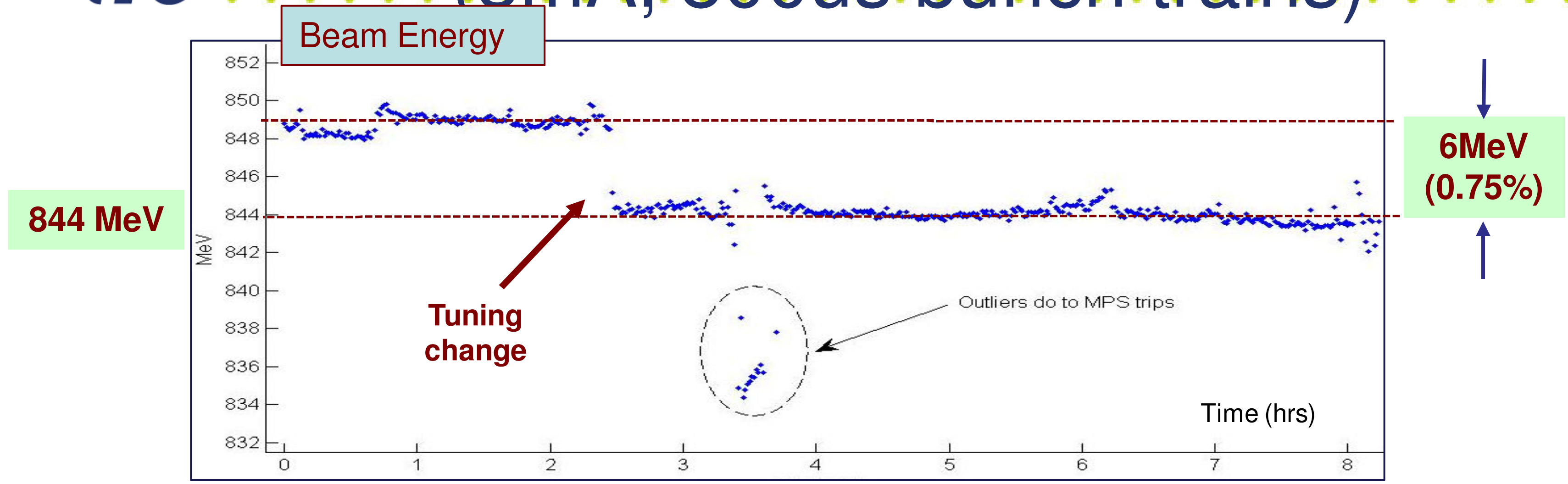
		XFEL X-Ray Free-Electron Laser	ilc	FLASH design	FLASH experiment
Bunch charge	nC	1	3.2	1	3
# bunches		3250*	2625	7200*	2400
Pulse length	μs	650	970	800	800
Current	mA	5	9	9	9

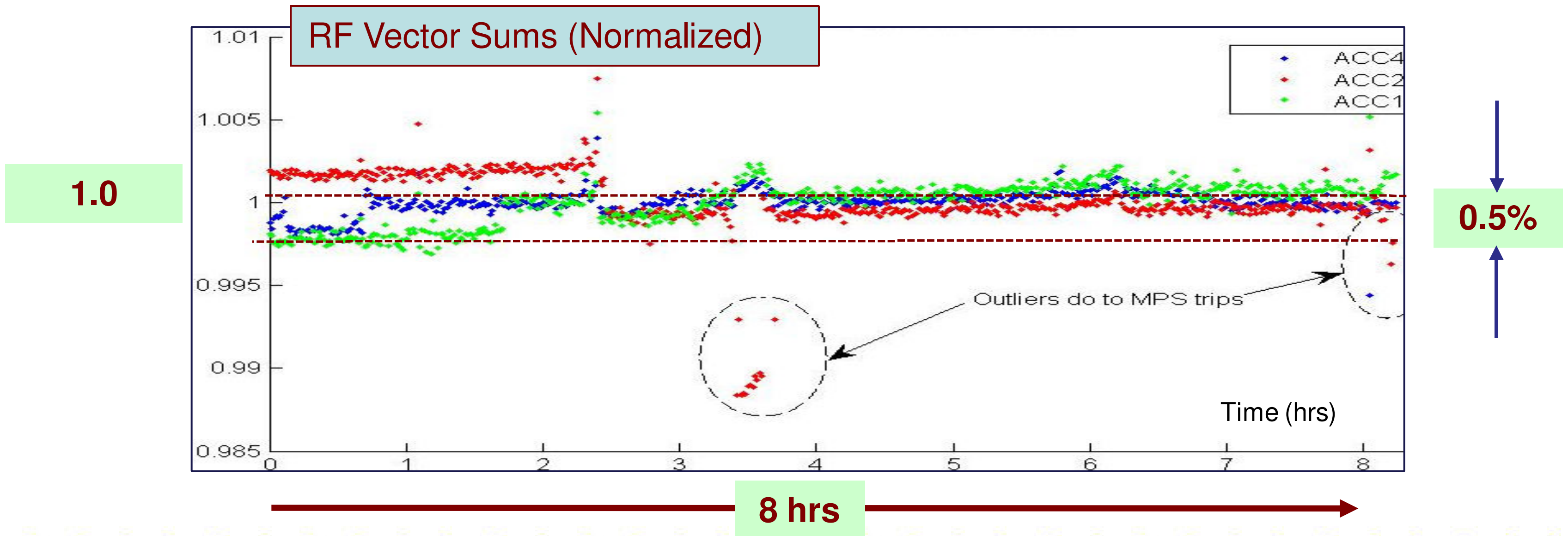
DESY, ANL, FNAL, SLAC, KEK

Example of pulse-to-pulse energy jitter (500us, ~3mA, 200 pulses overlaid)



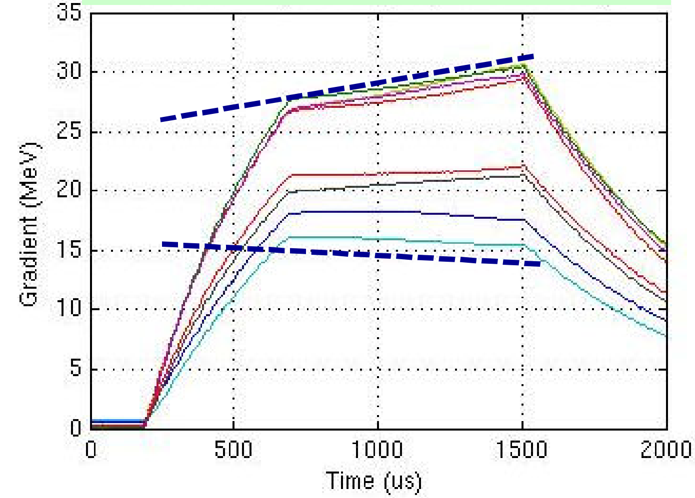
Energy stability over 8hrs (3mA, 800us bunch trains)



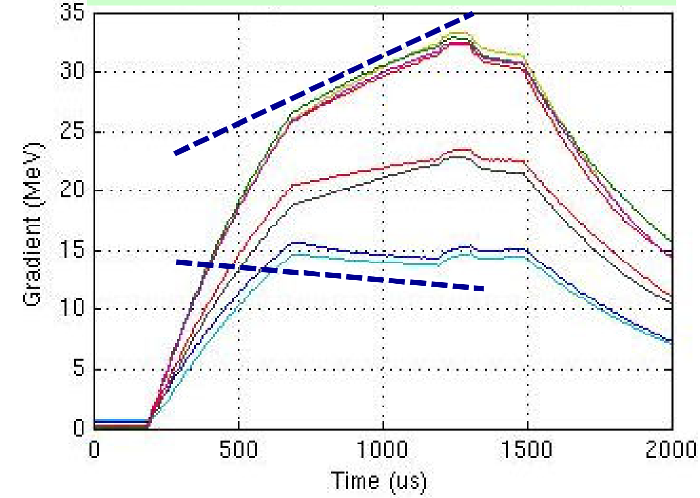


Cavity tilts with long bunch trains and heavy beam loading (3mA and 7.5mA, long bunch trains)

ACC6 gradients (3mA, 800 us)



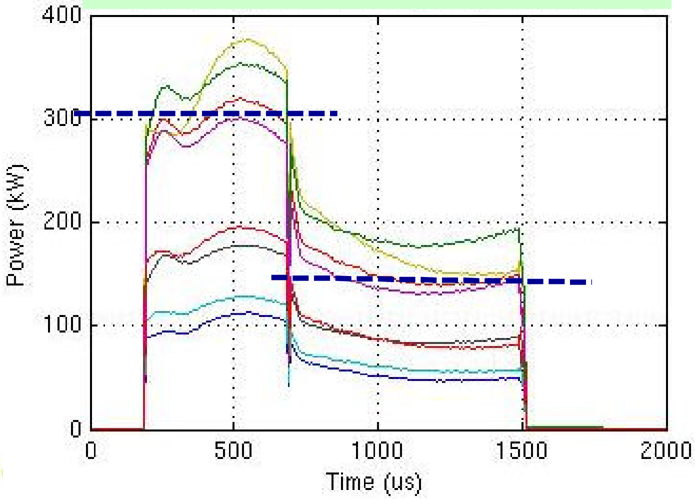
ACC6 gradients (7.5mA, 550 us)



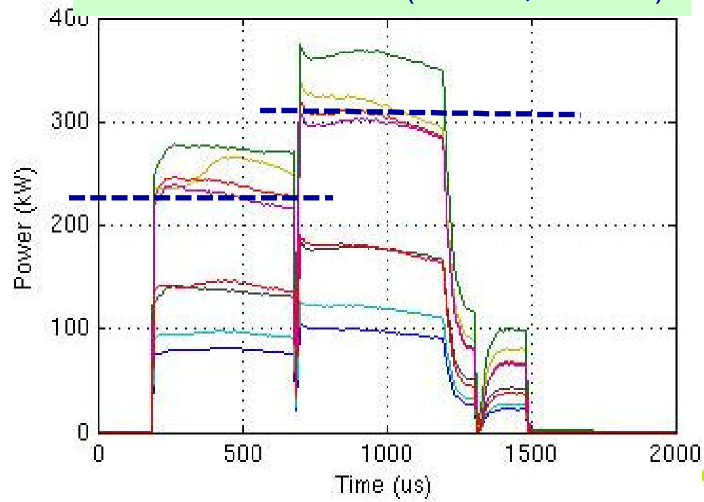
Gradient tilts are a consequence of using a single RF source to power cavities running at different gradients

At 7.5mA, ACC6 cavities #1 and #2 approached their quench limits at the end of the pulse

ACC6 Fwd Power (3mA, 800 us)



ACC6 Fwd Power (7.5mA, 550 us)



The RF power during flat-top is higher than the fill power for the 7.5mA case

ILC R & D - 2010

- Superconducting RF
- **Conventional Facilities / Siting**
  - Trade-offs: technology v/v civil design – *in each region*
    - “Bringing the RDR to the surface”
  - Design: 3D and layout – *in each region*
  - Interaction region design: 2010 effort – see parallel session
- Beam Test Facilities: CESR TA / ATF2
- Integrated Design: AD & I

Focus for Design Optimization: Reduce CFS cost and 'risk'

- **(CFS 'risk' ≡ unknowns inherent in underground construction)**
- *consolidate and reduce underground construction*
  - Reference Design focused on technical / R & D 'risk'
    - RDR technical design is fundamentally sound and technically conservative
  - 2009 → Offset Civil construction through innovative accelerator / technical design →
  - Necessarily an ***'integration'*** effort…
    - Because multiple 'top-level' groups are critically involved

At a glance: ILC CFS 2009

- **Comparison: RDR vs SB2009 →**

	RDR	SB2009	RDR-SB		% change
Tunnel length	72.3	38.4	33.9	km	47%
Drill & Blast volume	264.7	233.1	31.6	*1000 m^3	12%
Total (TBM + D&B) volume	1,415.0	843.8	571.2	*1000 m^3	40%
(D&B % of total)	19%	28%	6%		

- **Tunnel (TBM) length approaching minimum**
  - ≈ set by beamline enclosure length
- **To do: Analyze and consolidate Drill and Blast volume**

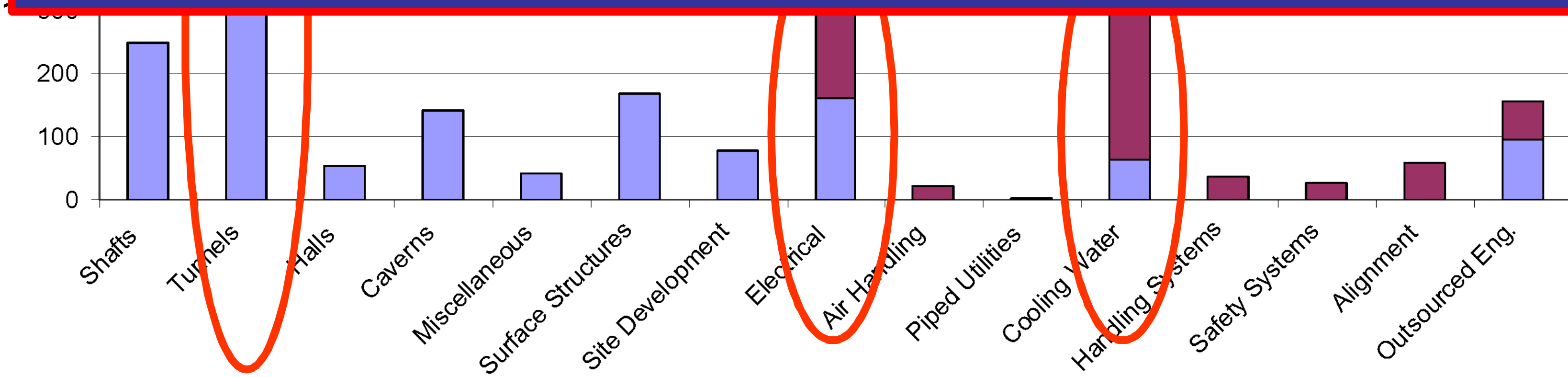
Conventional Facilities

Underground volume reduction of 40% considered in 2009

(Support tunnel and Damping Ring circumference)

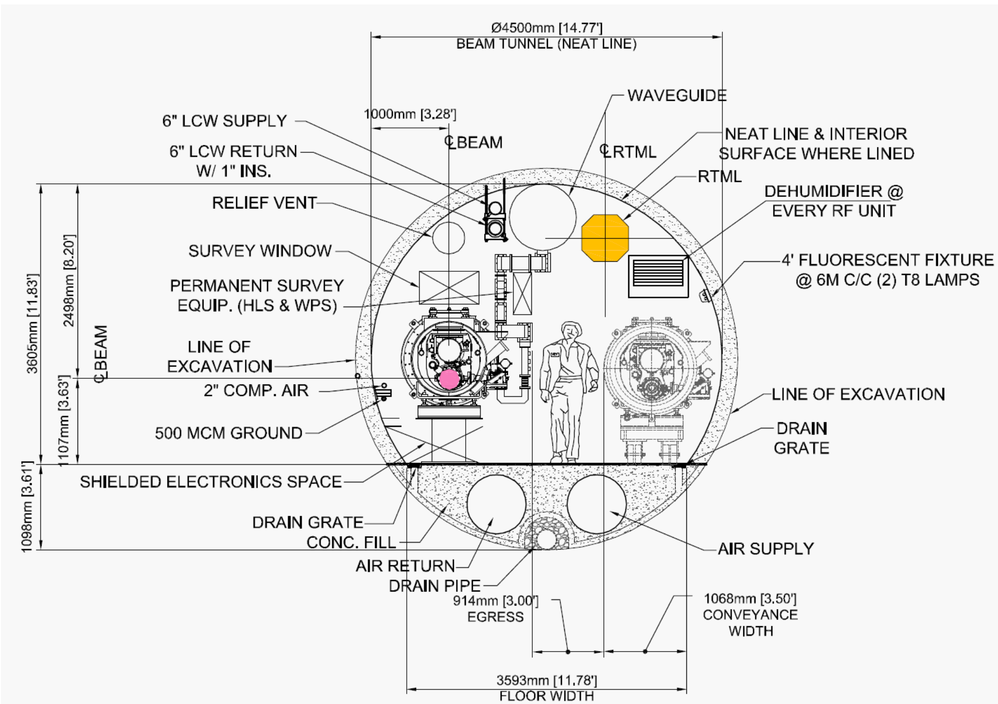
0.4* 900MILCU ~ 400M ‘savings’ (6%)

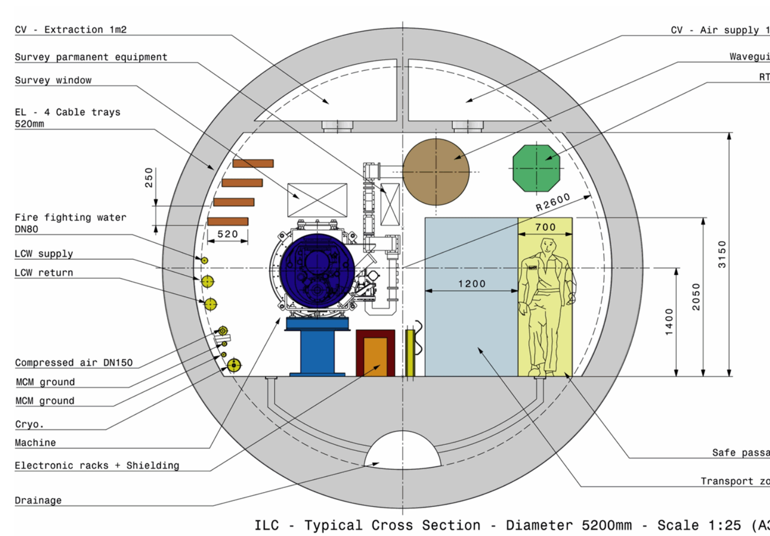
(offset by technical and surface cost increase)



Regional / RF Power differences: 'Klystron Cluster Scheme'

Current ML KCS Tunnel Cross Sections

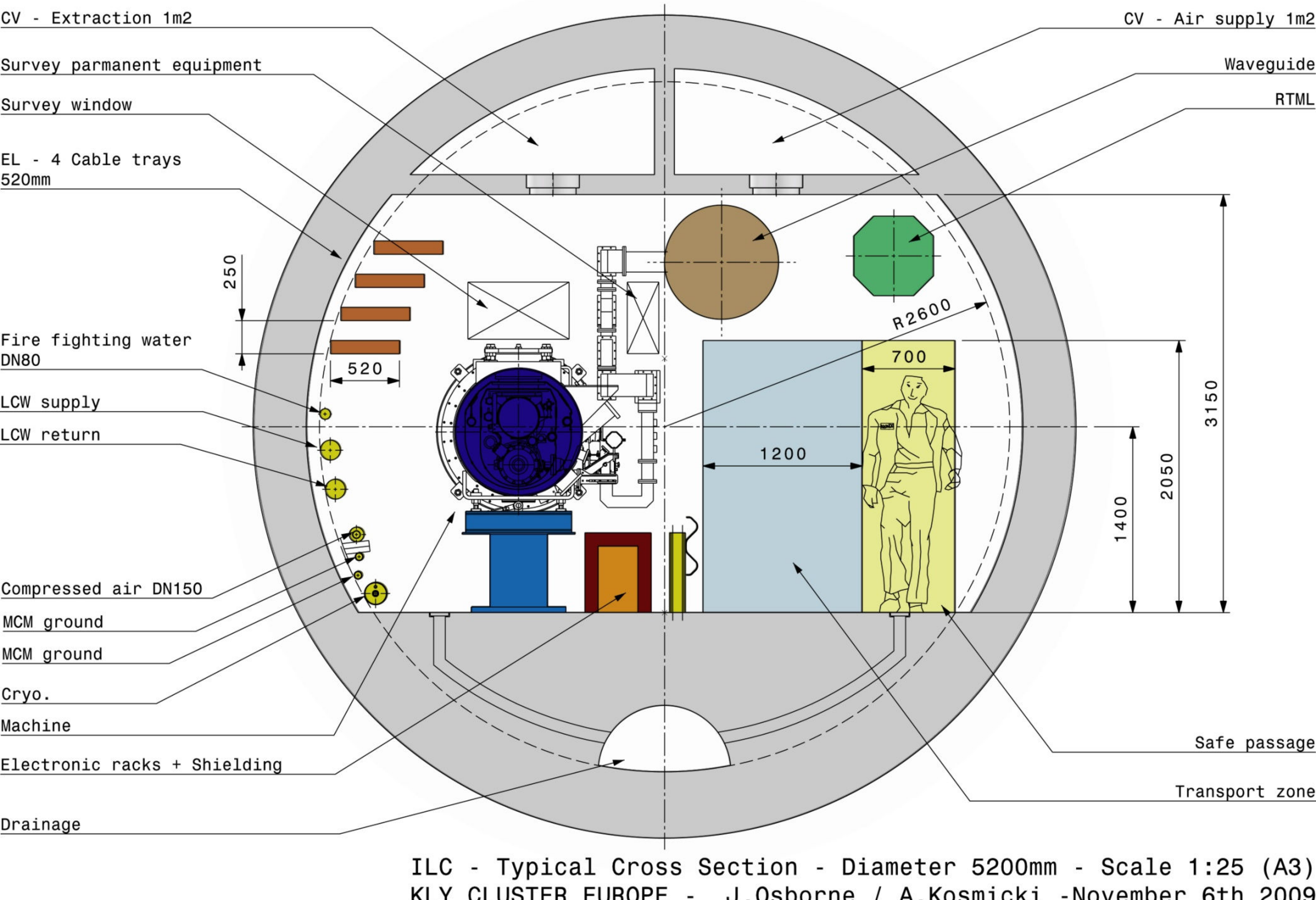




Cross section for Europe (CERN) 5.2m diameter for Kly Cluster

Americas Region 4.5 m Dia.

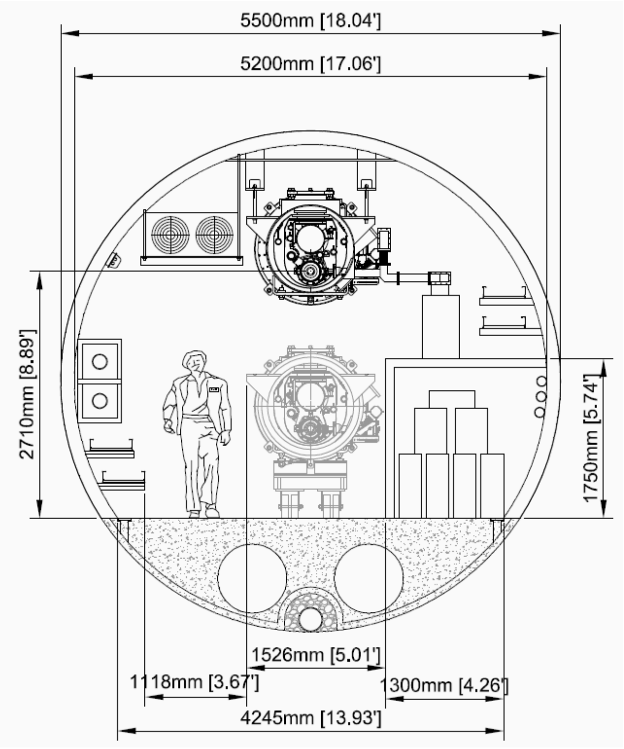
European Region 5.2 m Dia.



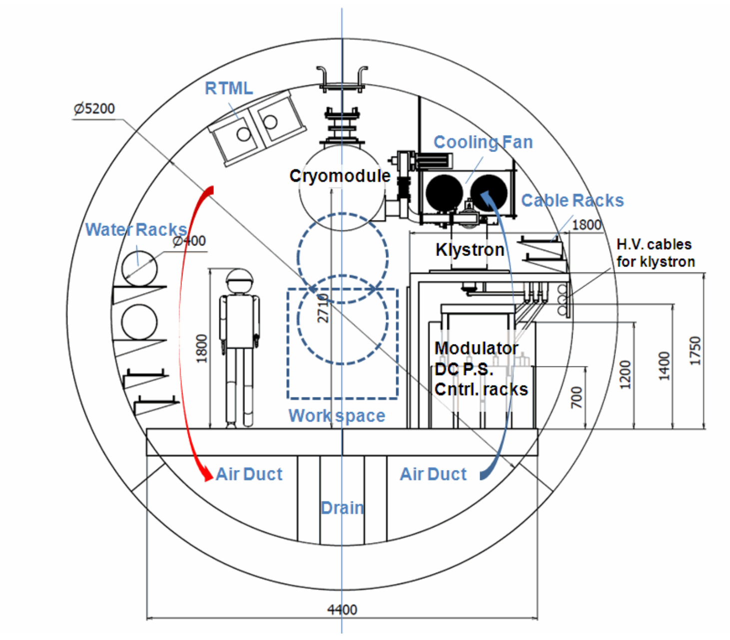
Cross section for Europe (CERN) 5.2m diameter for Kly Cluster

Regional / RF Power differences: 'Distributed RF Scheme'

Current ML DRFS Tunnel Cross Sections



Americas Region 5.2 m Dia.

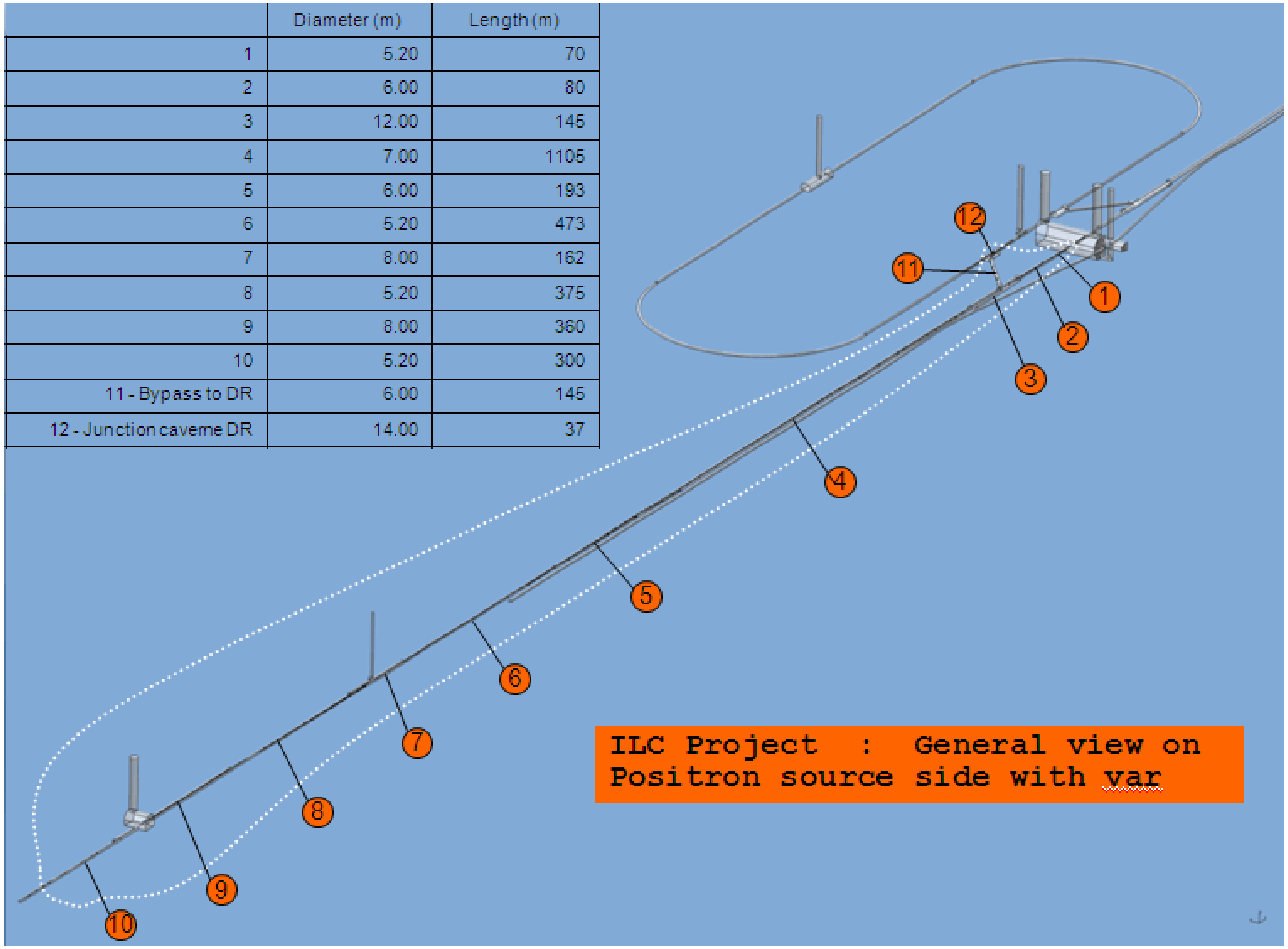


Asian Region 5.2 m Dia.

Central Region Design – 3D (1)

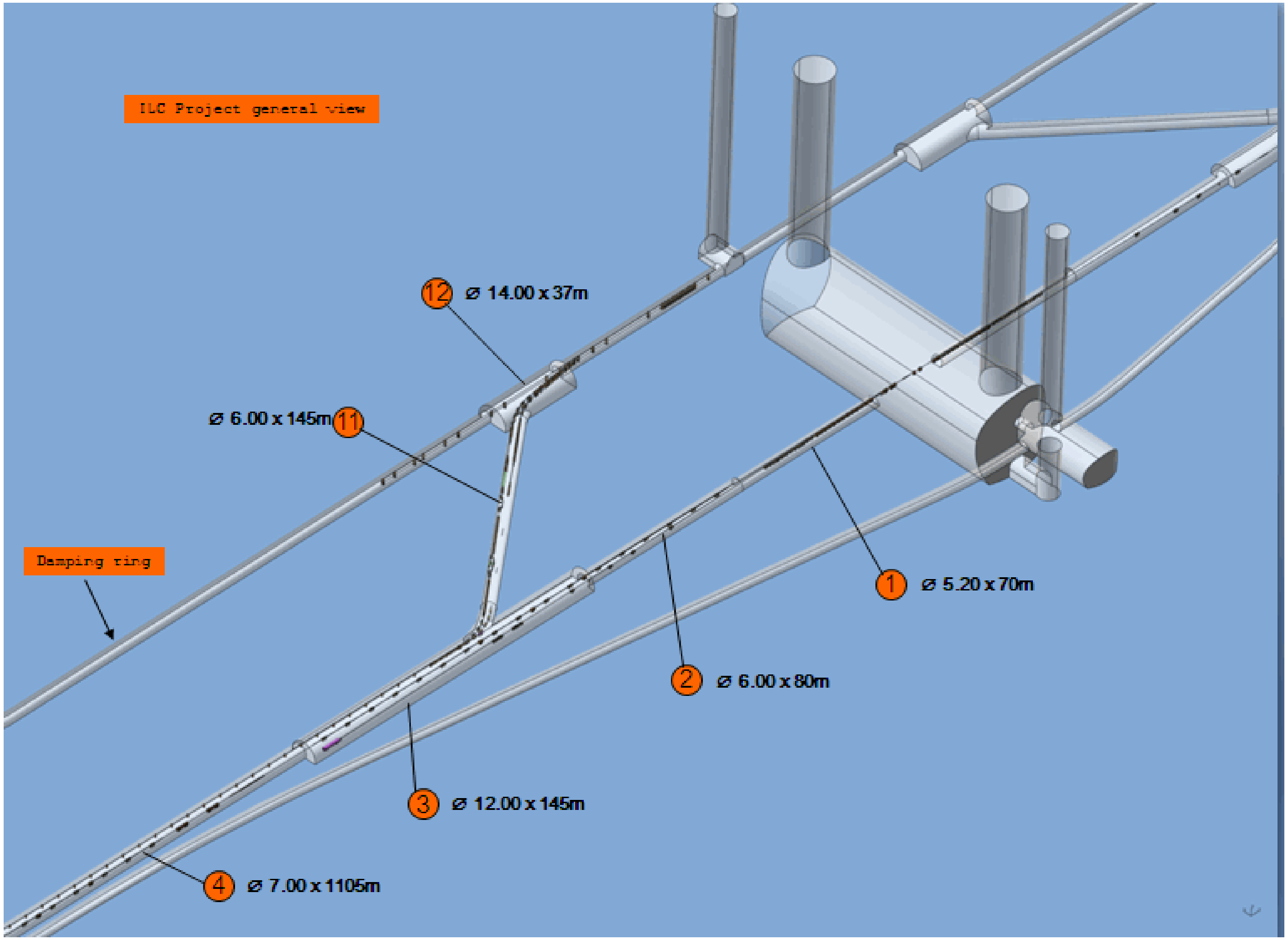
3D Examples Of Central Region Layout

	Diameter (m)	Length (m)
1	5.20	70
2	6.00	80
3	12.00	145
4	7.00	1105
5	6.00	193
6	5.20	473
7	8.00	162
8	5.20	375
9	8.00	360
10	5.20	300
11 - Bypass to DR	6.00	145
12 - Junction caverne DR	14.00	37



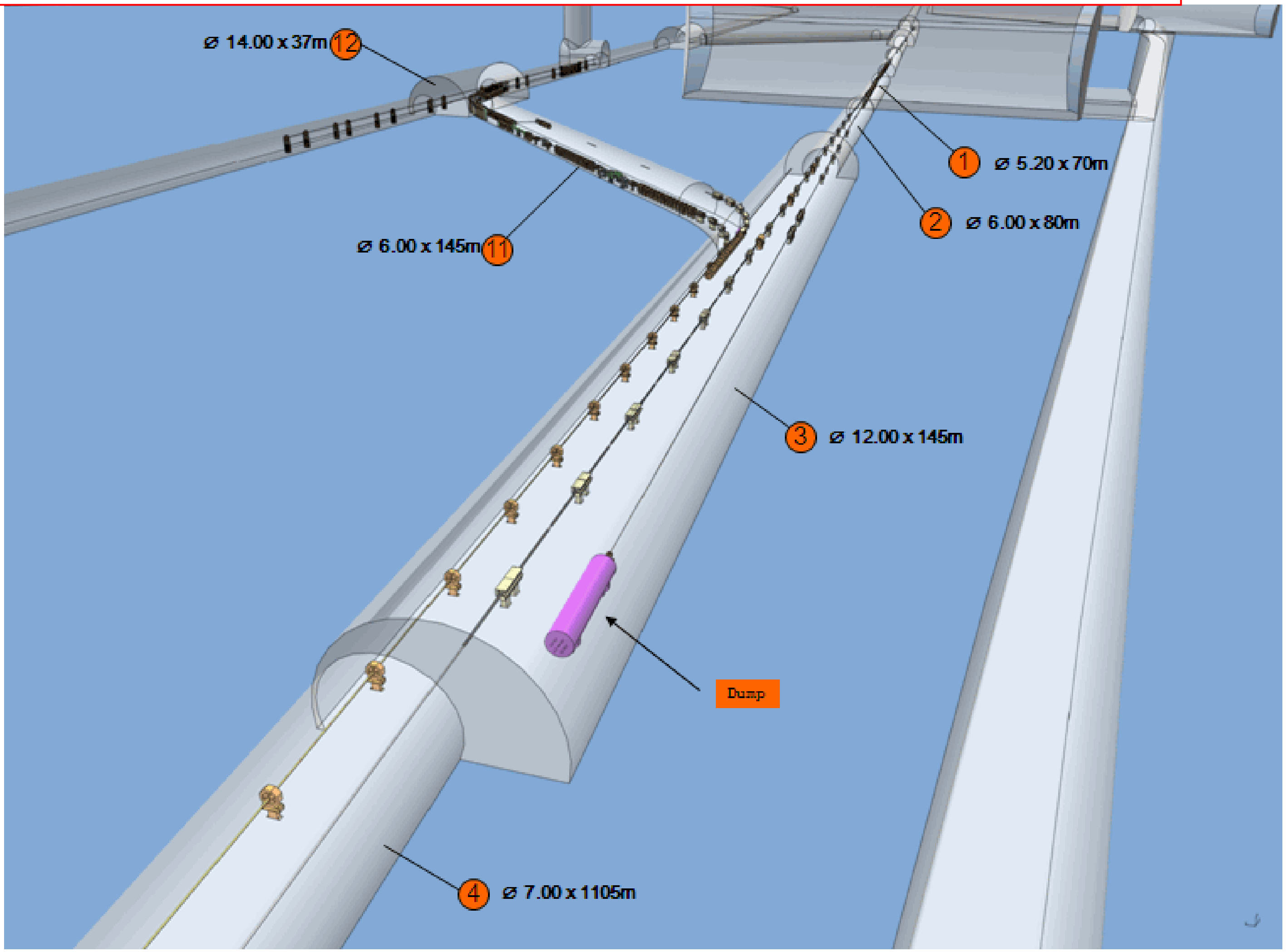
Central Region Design – 3D (2)

3D Examples Of Central Region Layout



Central Region Design – 3D (3)

3D Examples Of Central Region Layout



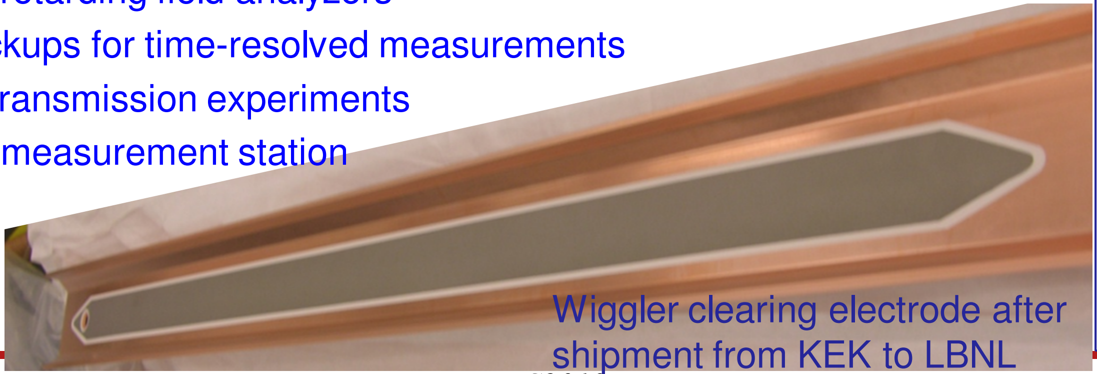
ILC R & D - 2010

- Superconducting RF
- Conventional Facilities / Siting
- **Beam Test Facilities: *CESR TA* / ATF2**
  - Develop and prove Electron Cloud models
  - Demonstrate vacuum chamber technology and related instrumentation
  - Develop integrated ILC DR design
- Integrated Design: AD & I

CESR Test Accelerator Status

- Reconfiguration as a damping ring completed in late 2008
  - Operation with bunch spacings as short as 4ns and with both positrons and electrons
  - Key instrumentation: upgraded turn-by-turn BPM system and high resolution x-ray beam size monitors for both beams – ring-wide digital BPM system and 2nd x-ray monitor online at end of 2009
  - Vertical Emittance target of 20pm by conclusion of program – measured vertical emittance at end of 2009. Major effort aimed at taking full advantage of precision instrumentation in 2010.
- Installation of 4 planned electron cloud experimental regions completed in mid-2009
  - **Test region1:** Wiggler straight with instrumented drifts and wigglers. Cu, TiN, and grooved surface mitigations tested to date - wiggler with clearing electrode presently being prepared for deployment
  - **Test regions 2&3 :** Arc sections have instrumented versions of standard CESR chambers (dipole and drift; Al and Cu surfaces) as well as 2 dedicated locations for EC mitigation tests/comparisons - presently carrying out comparison tests of chambers with TiN and amorphous carbon coatings.
  - **Test region 4:** PEP-II chicane, instrumented quadrupole chamber, and in situ SEY station. Al, TiN and grooved surfaces compared. NEG test chamber presently being prepared for deployment in early April.
- Ring EC instrumentation includes
  - Segmented retarding field analyzers
  - Shielded pickups for time-resolved measurements
  - Microwave transmission experiments
  - In Situ SEY measurement station

Contributing Institutes:
- ANL
- BNL
- Cal Poly
- CERN
- Cockroft Institute
- FNAL
- INFN-Frascati
- KEK
- LBNL
- Purdue
- SLAC
- Technion-Haifa



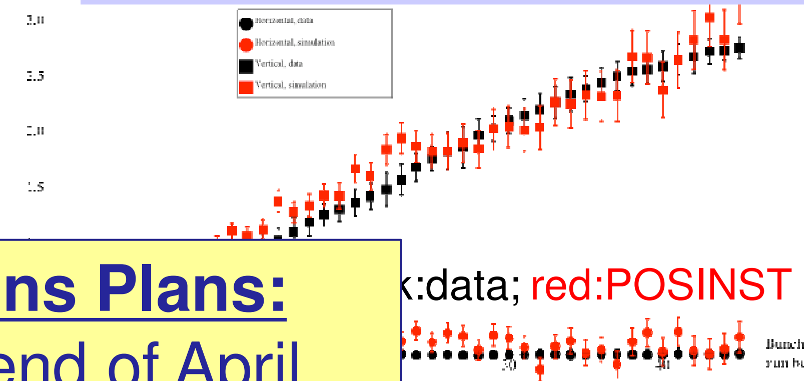
Wiggler clearing electrode after shipment from KEK to LBNL

Cornell University
Laboratory for Elementary-Particle Physics

CESRTA Electron Cloud

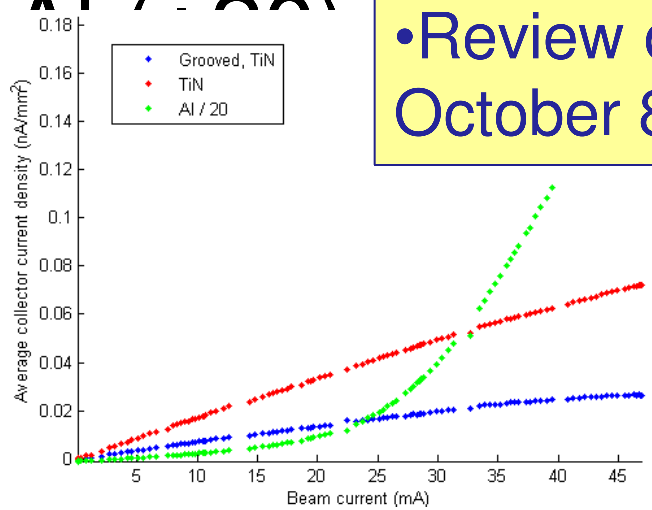
- Simulation effort – geared to detailed tests in CESRTA followed by application to DR:
  - Detailed 3D photon reflectivity model
    - Important for both local and ring-wide measurements
    - Key item for ILC DR evaluations
  - RFA data-simulation comparisons to provide detailed model parameters (eg, P
  - Ring-wide param
  - Studies of instabi *growth* issues

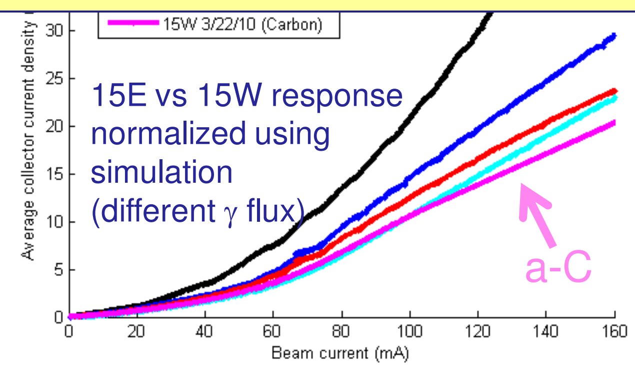
COHERENT TUNE SHIFTS
Positrons, 45 bunches with 1.2×10^{10} particles/bunch
2.09 GeV, 2.6 nm horiz. emittance, 14 ns bunch spacing



Upcoming Operations Plans:
- Next run begins at the end of April
- Additional running time planned for July, September and December
- Review of results at ECLOUD10 – October 8-12 at Cornell

EC Mitigations in





igations
- onfirm that grooves are ry effective in dipole d wiggler fields
  - me challenges for nufacture
- Amorphous C and TiN coatings show *similar* EC mitigation performance
  - Both coatings show somewhat poorer vacuum performance (dP/dI) than Al chambers
- Additional comparisons being prepared

CESRTA – EC: Main Deliverables

Recommendation for the reduction of the ILC Positron Damping Ring Circumference

By March 2010

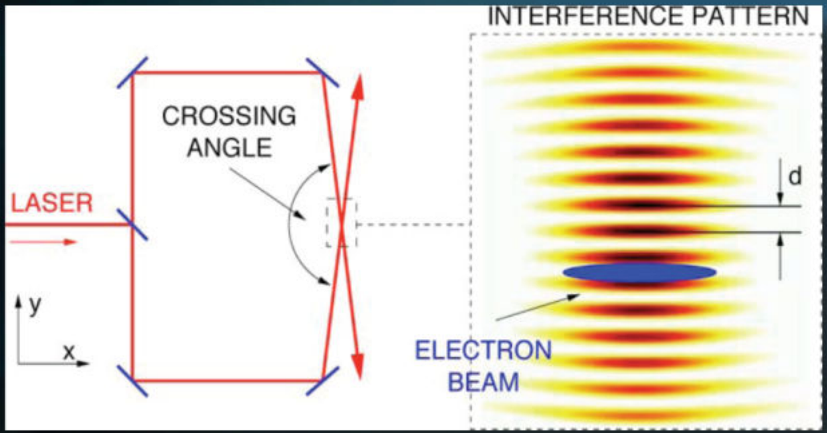
Recommendation for the baseline and alternate solutions for the electron cloud mitigation in various regions of the ILC Positron Damping Ring.

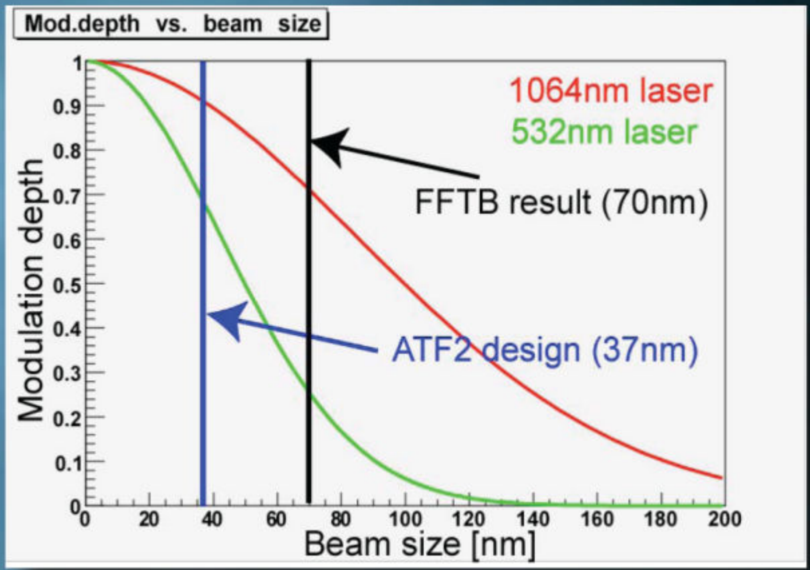
By Late 2010

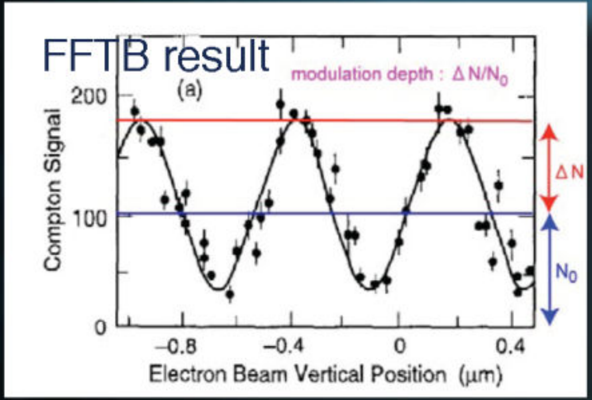
ILC R & D - 2010

- Superconducting RF
- Conventional Facilities / Siting
- **Beam Test Facilities: CESR TA / *ATF2***
  - Fast Kicker Studies: 30 bunch extraction successful
    - jitter stability about 0.1% ILC goal
    - Almost ready to deploy
  - IP carbon wire scanner for initial optics tuning
  - Recent results of 'fringe monitor' beam size measurements (see parallel session)
  - Superconducting quadrupole final doublet studies
- Integrated Design: AD & I

Laser Interference Monitor at ATF2 IP





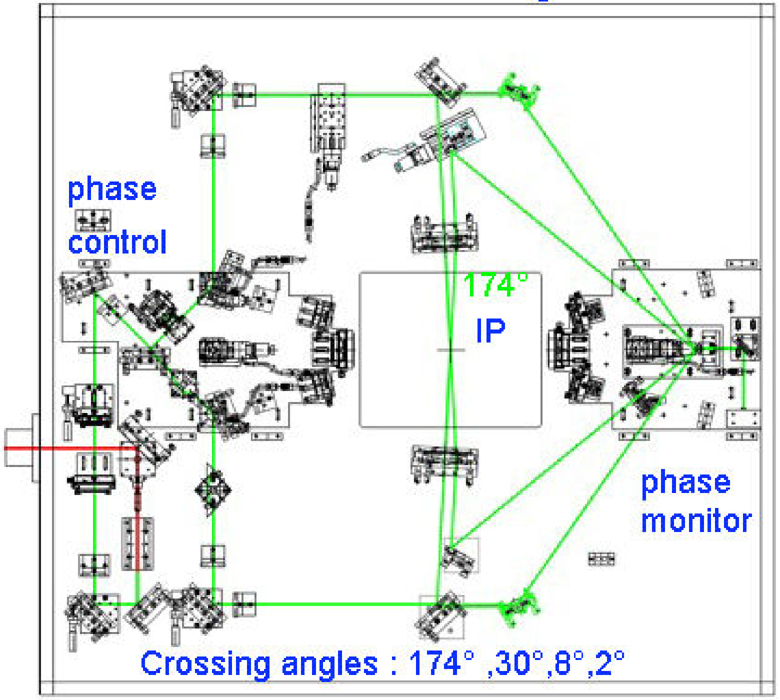


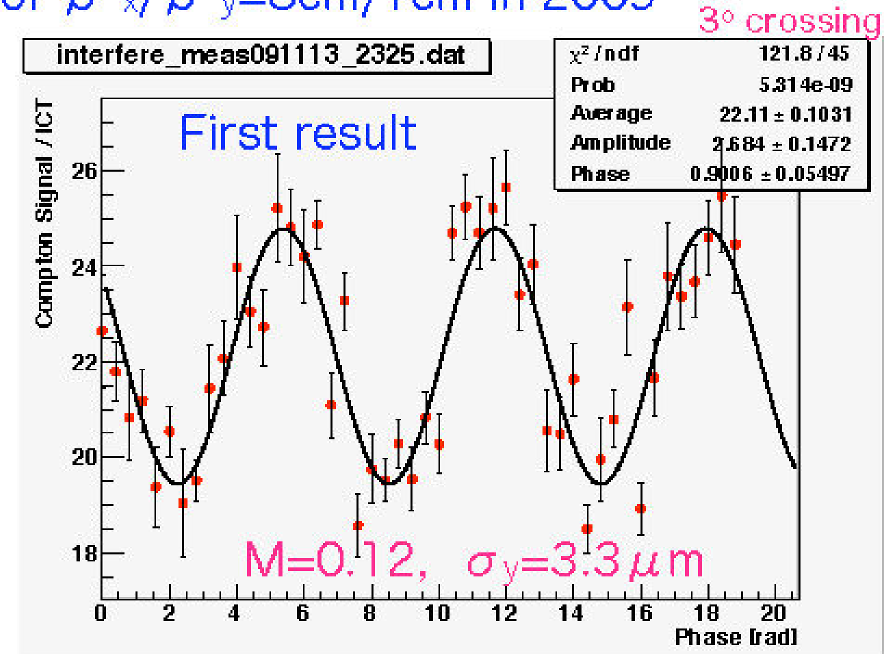
Shintake-monitor result in FFTB

Shintake-monitor from FFTB

FFTB ~70nm -> ATF2 37nm
modification : Laser wavelength
fringe stabilization FB
new gamma detector

Beam commissioning with the optics of β^*_x/β^*_y=8cm/1cm in 2009





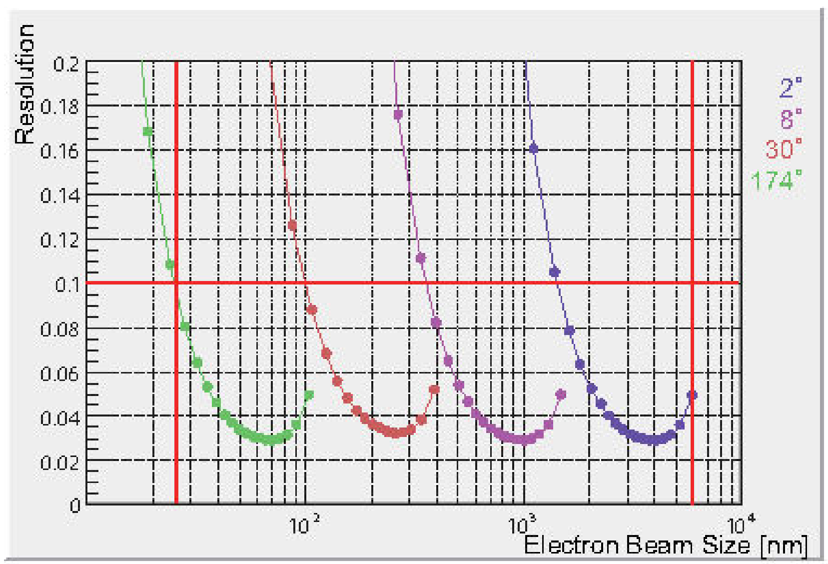
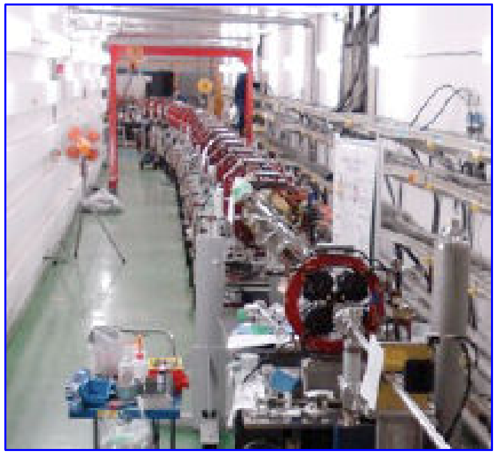
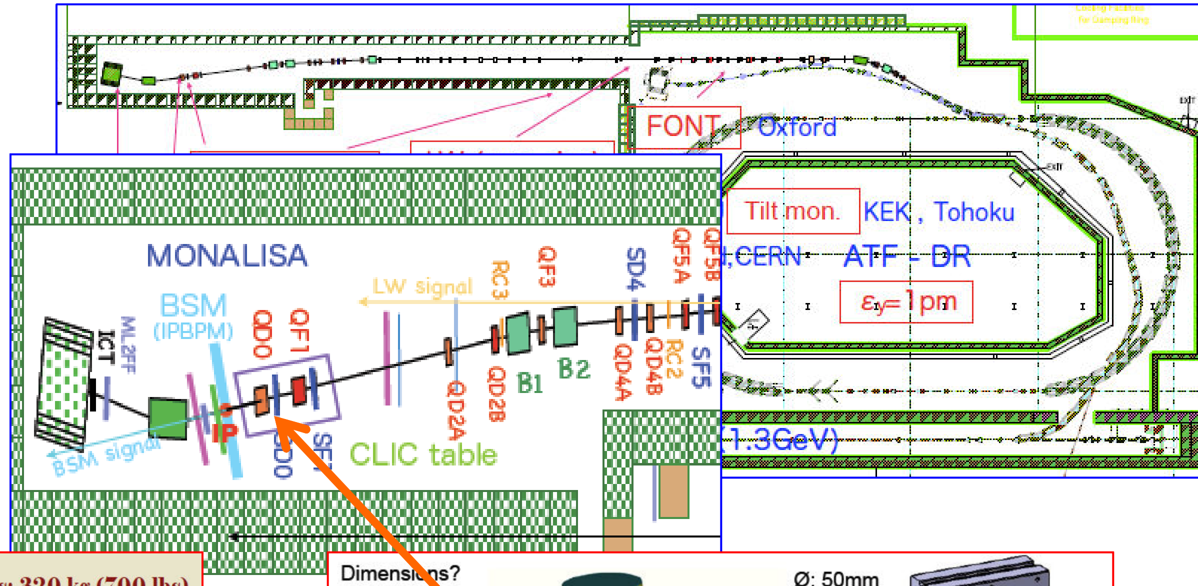
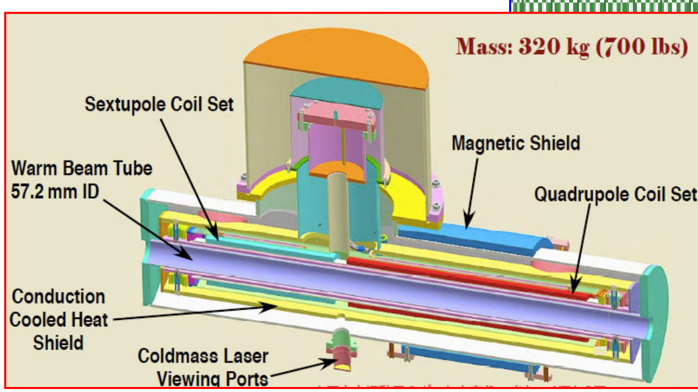


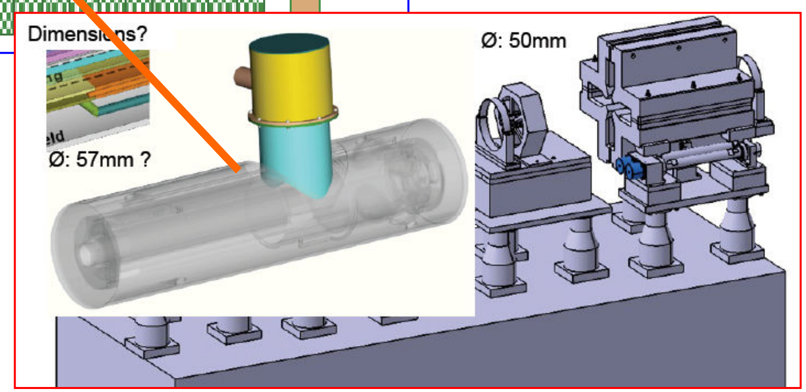
Fig. 33. The estimated beam size resolution. For the 25 - 6000 nm beam size, target resolution 10% can be achieved using 2°, 8°, 30° and 174° crossing angle modes.

Final Focusing with SC Quadrupoles expected to be studied at ATF2









- Proposed as a BNL-KEK collaboration prgram
- Focusing stability of < 50 nano-meters to be achieved

ILC R & D - 2010

- Superconducting RF
- Conventional Facilities / Siting
- Beam Test Facilities: CESR TA / ATF2
- **Integrated Design: AD & I**
  - **EU XFEL will inform us: accurate SCRF production cost information → 04.2010**
  - **'Performance Scope / Cost' study: SB2009 allows flexible response – while maintaining RDR cost-constraint**
    - This is an all-inclusive, cumbersome, task
  - **Detector/Accelerator community participation**

“By far the easiest”: *WHY*? →

- Proven International Basis – *necessary to make it*
  - Plug-compatibility / Industrial capability & support in each region
- Demonstrated full beam intensity
- Scalable energy →technology
- Consistent Regional Siting schemes
- Demonstrated key beam dynamics
- Costed and *cost-contained* design

RDR → <u>*2012*</u> Technical Design

- **Strong Basis for SCRF technology in each ILC region**
  - Cavity fabrication and test: Each region
  - Global Cryomodule: KEK +
- **Large scale <u>*Costed*</u> technology demonstration**
  - EU XFEL (5% of ILC); first beam mid-2014
- **Siting: adaptation to best suit potential hosts**
- **Beam – based studies and demonstrations**
  - High power SCRF linac operation: DESY +
  - Electron-cloud beam dynamics: Cornell +
  - Beam delivery technology: KEK +