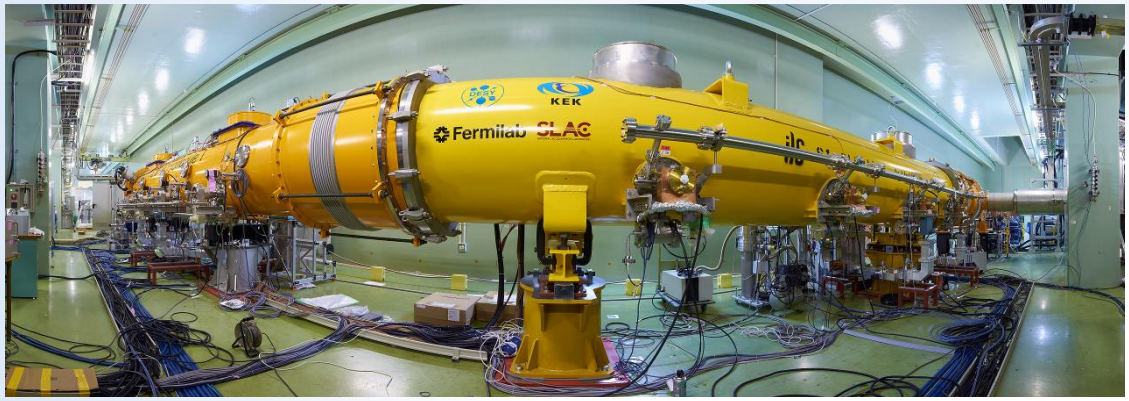
RESULTS ACHIEVED BY THE S1-GLOBAL COLLABORATION FOR ILC



H. Hayano, M. Akemoto, S. Fukuda, K. Hara, N. Higashi, E. Kako, H. Katagiri, Y. Kojima, Y. Kondo, T. Matsumoto, S. Michizono, T. Miura, H. Nakai, H. Nakajima, K. Nakanishi, S. Noguchi, N. Ohuchi, T. Saeki, M. Satoh, T. Shidara, T. Shishido, T. Takenaka, A. Terashima, N. Toge, K. Tsuchiya, K. Watanabe, S. Yamaguchi, A. Yamamoto, Y. Yamamoto, K. Yokoya, KEK, Tsukuba, Japan

K. Jensch, D. Kostin, L. Lilje, A. Matheisen, W. -D. Moeller, M. Schmoekel, P. Schilling, N. Walker, H. Weise, DESY, Hamburg, Germany

T. Arkan, S. Barbanotti*, M. Battistoni, H. Carter, M. Champion, A. Hocker, R. Kephart, J. Kerby, D. Mitchell, Y. Pischalnikov, M. Ross, T. J. Peterson, W. Schappert, B. Smith, FNAL, Chicago, USA

A. Bosotti, C. Pagani, R. Paparella, P. Pierini, INFN, Milano, Italy

C. Adolphsen, C. Nantista, SLAC, Menlo Park, USA

Contents

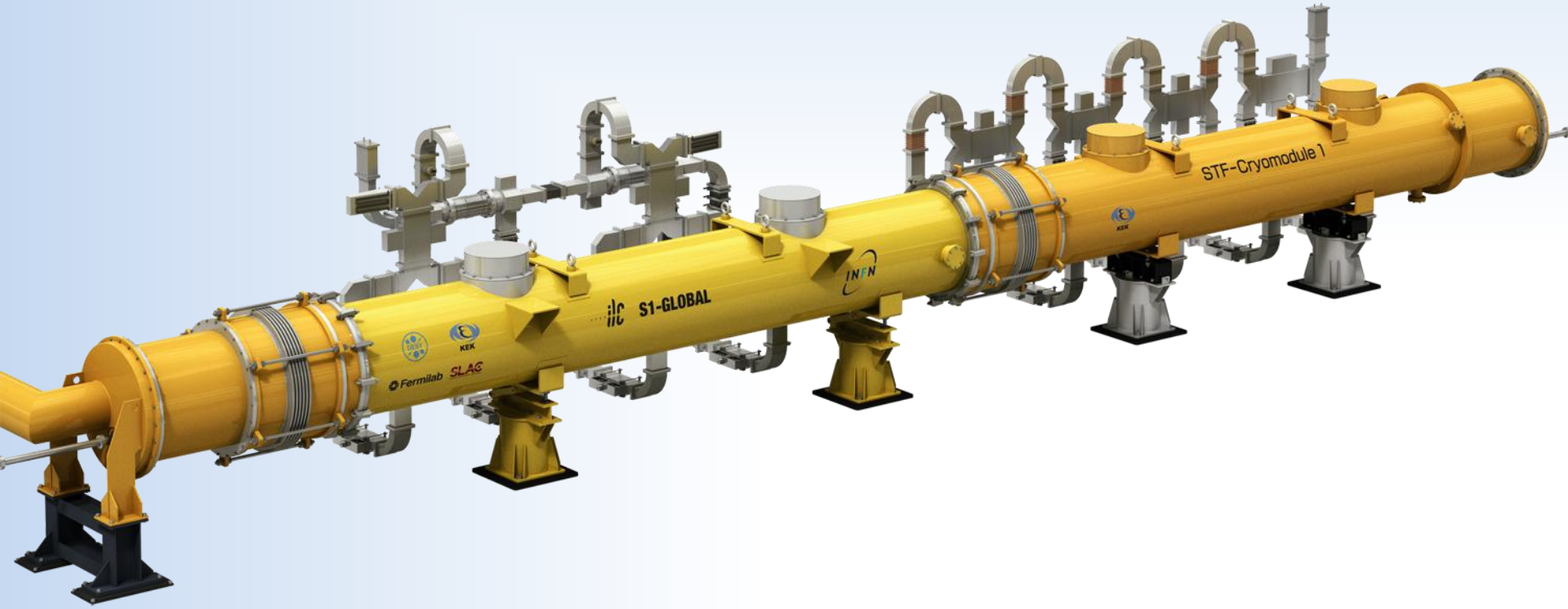
Introduction

- **The S1-Global cryomodule experiment by ILC-GDE (International Linear Collider, Global Design Effort) was planned to achieve “S1” goal, which is to operate at least one of cryomodule with 31.5MV/m ILC average gradient.**

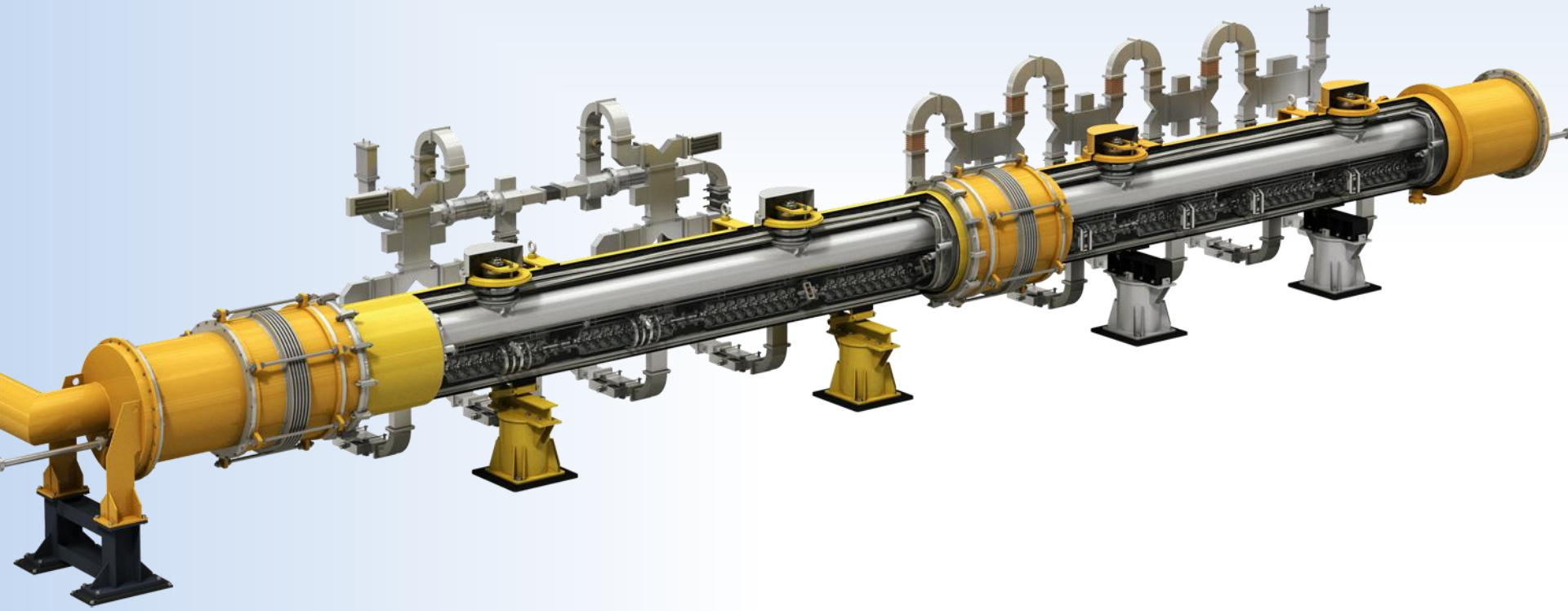
- **The design, fabrication, assembly, experiment, and disassembly were done by the international collaboration based on ILC-GDE.**

- **The experiment hosted by KEK STF (Superconducting RF Test Facility at KEK) was performed from June 2010 to February 2011.**

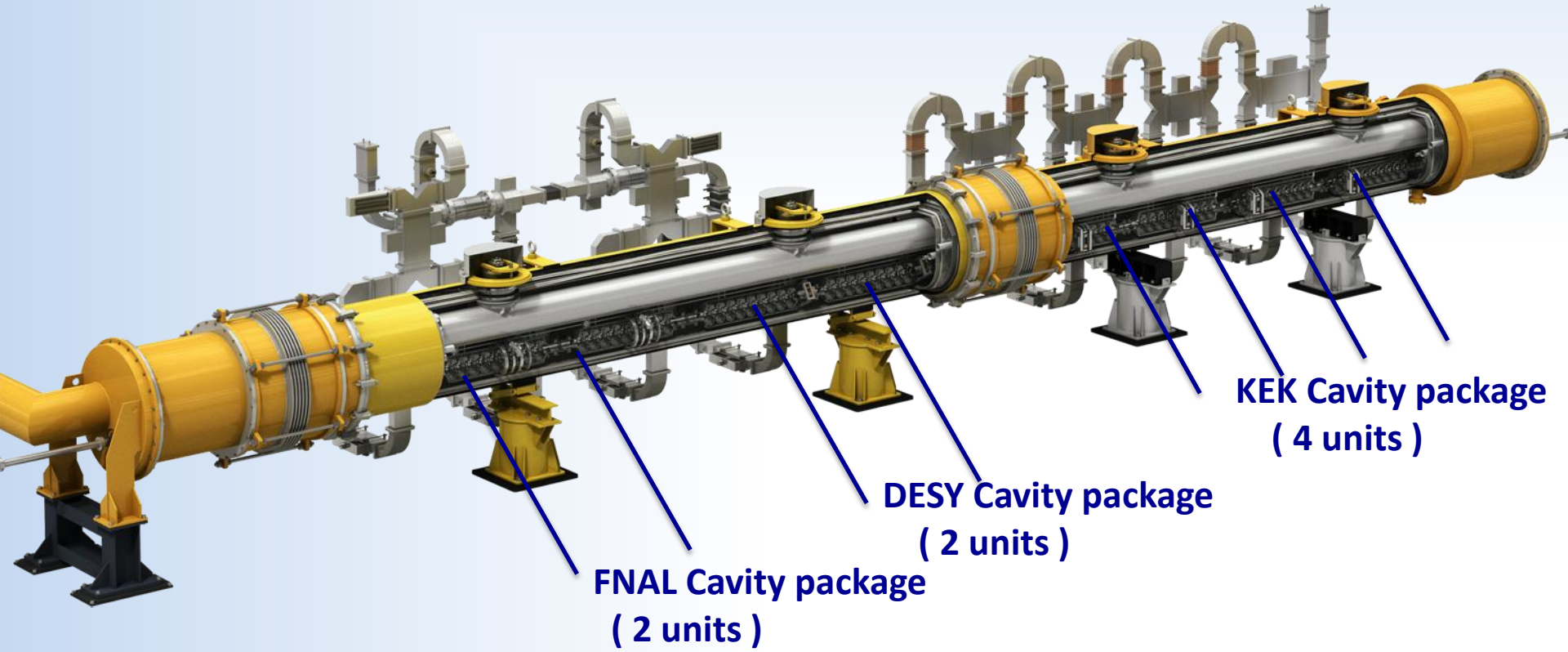
S1-Global Cryomodule



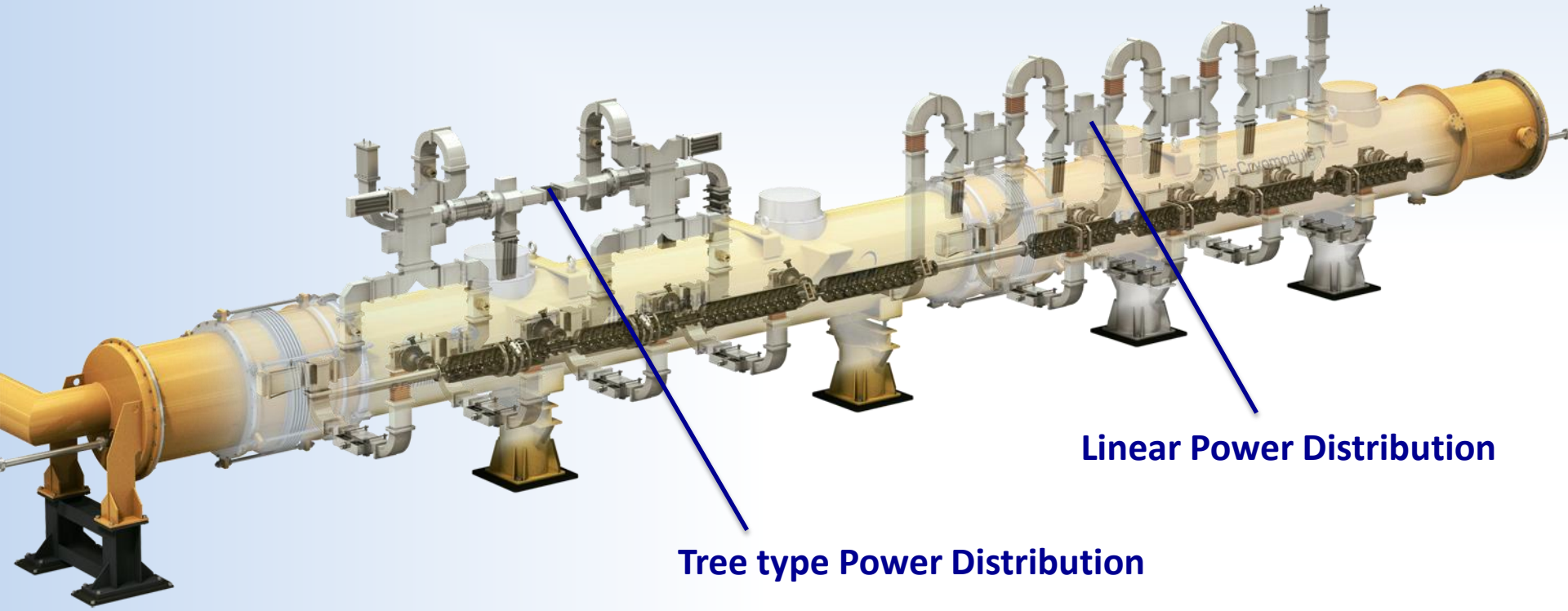
S1-Global Cryomodule



S1-Global Cryomodule



S1-Global Cryomodule



S1-Global Cryomodule

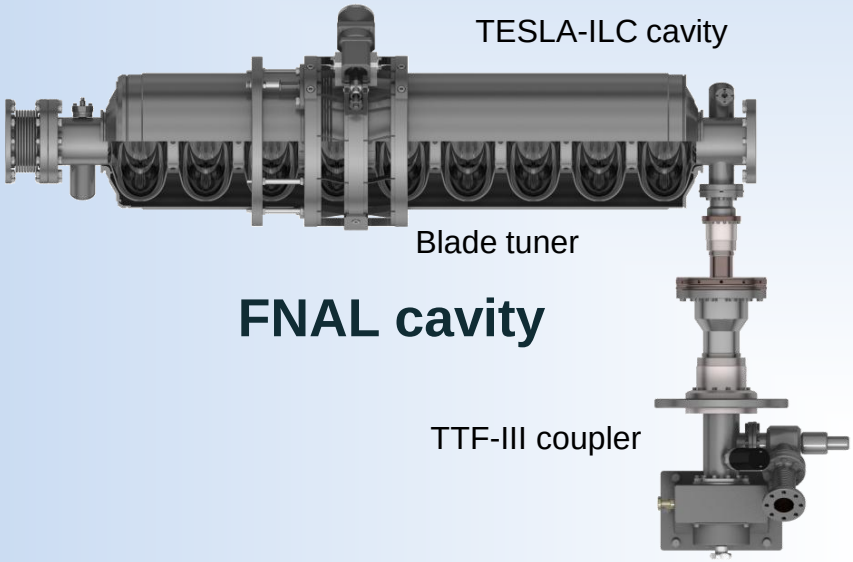
SLAC VTO (Variable Tap-Off)

Linear Power Distribution

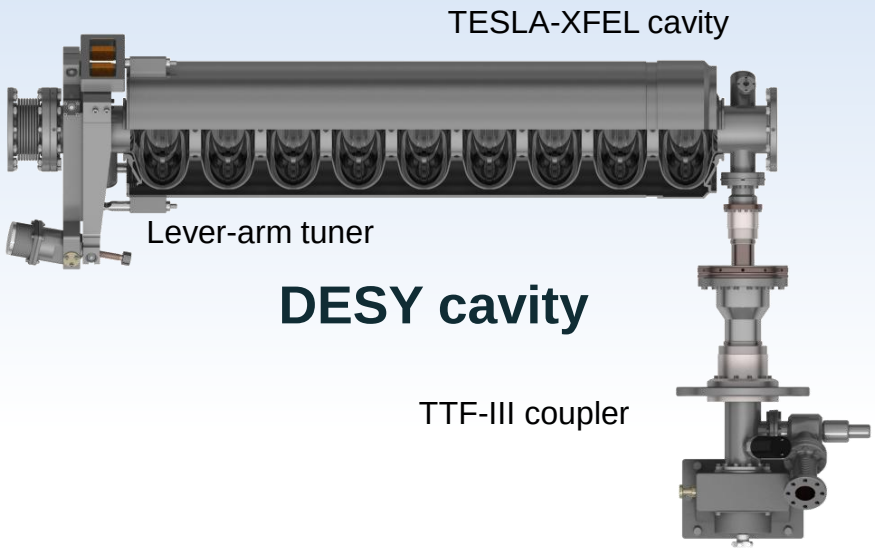
RF Power
From 5MW Klystron

Tree type Power Distribution

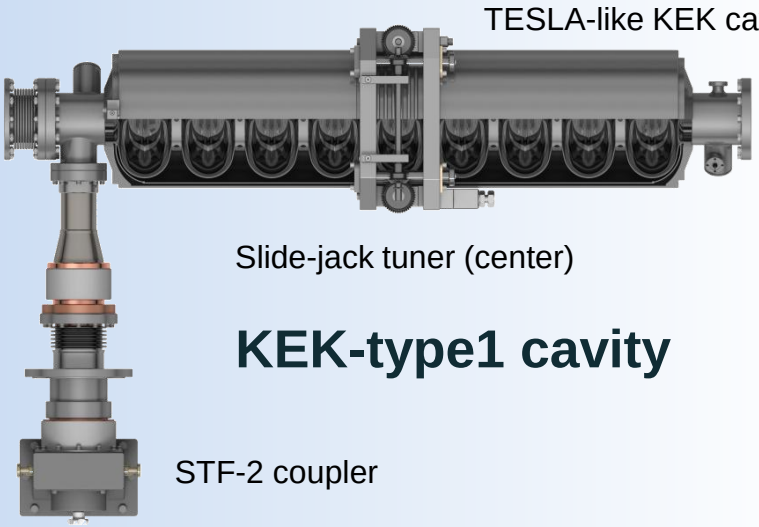
S1-Global Cavity Packages



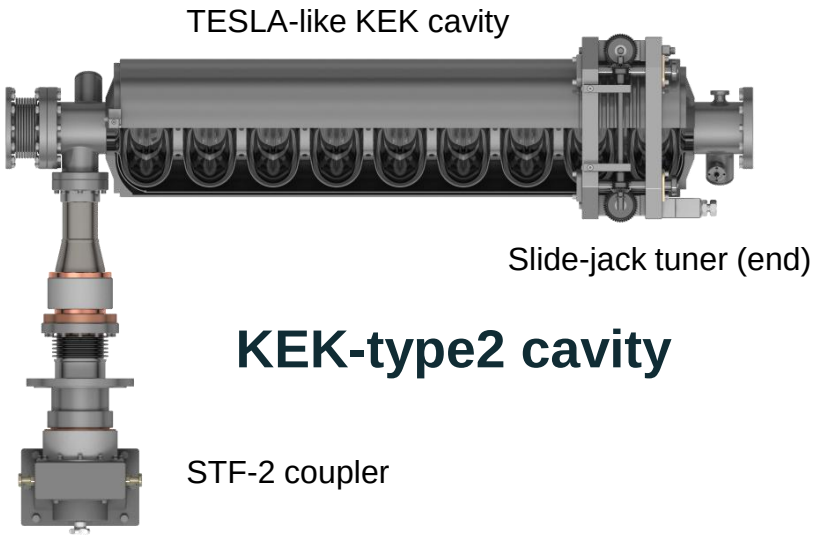
FNAL cavity



DESY cavity



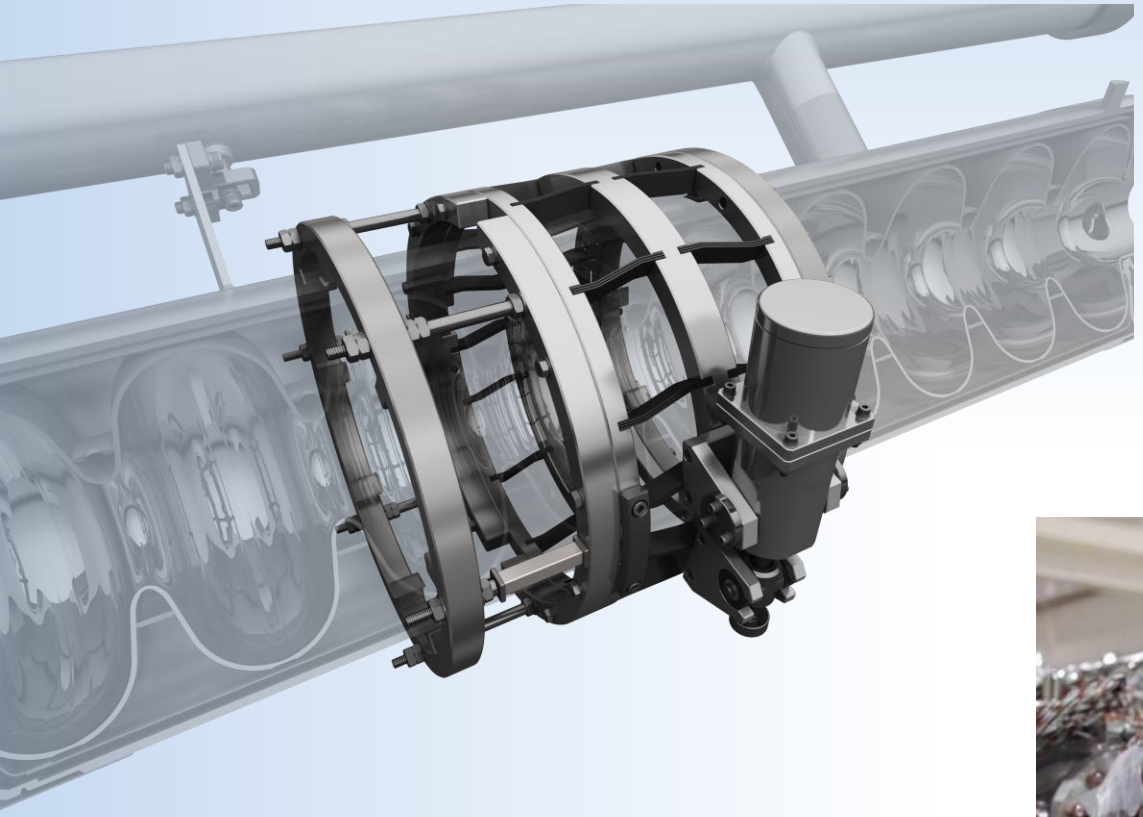
KEK-type1 cavity



KEK-type2 cavity

S1-Global Tuners

Blade tuner (INFN/FNAL)

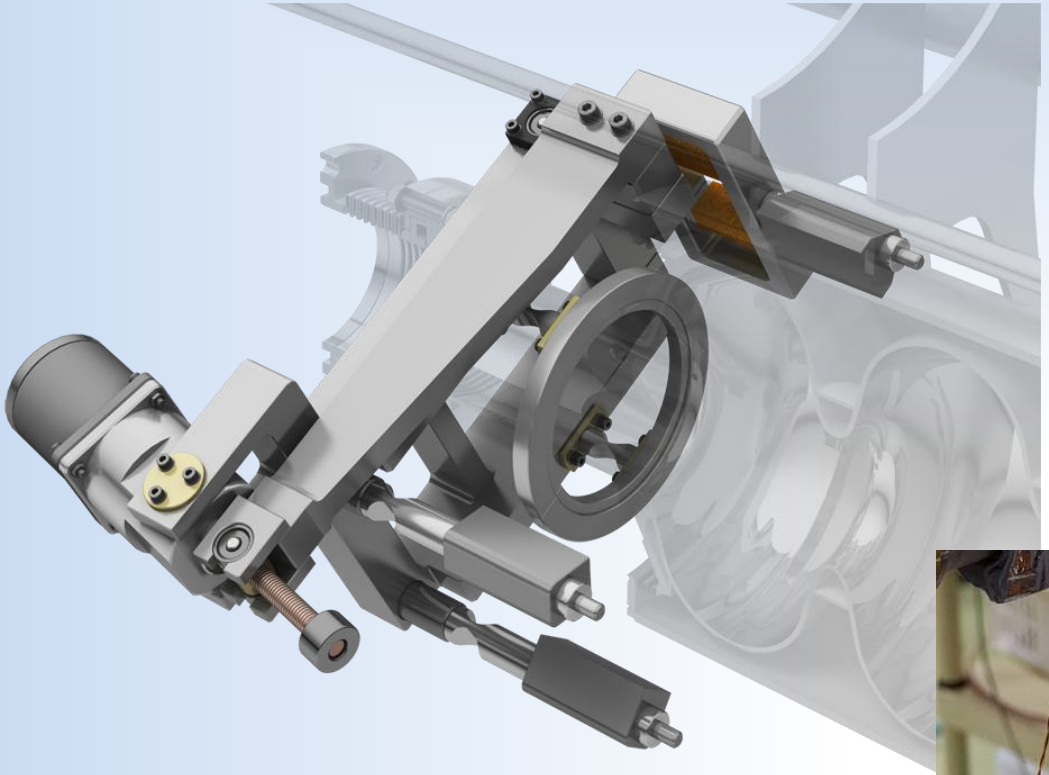


Location: middle of He vessel
Motor: inside of module,
low temperature
Piezo: two low-voltage piezo

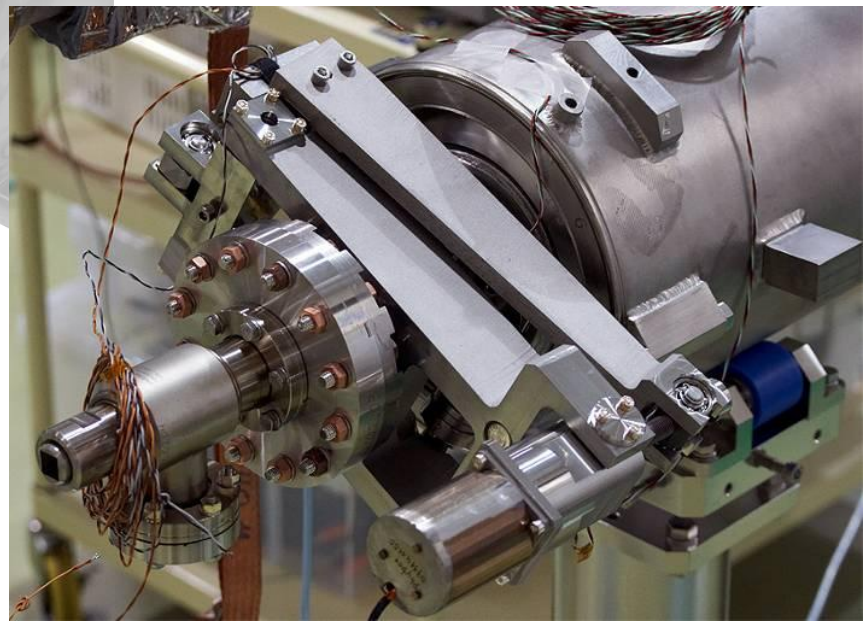
Design Stiffness: 30kN/mm
Nominal sensitivity: 1.5Hz/step
Piezo stroke at RM: 55 µm

S1-Global Tuners

Lever-arm tuner (DESY/Saclay)

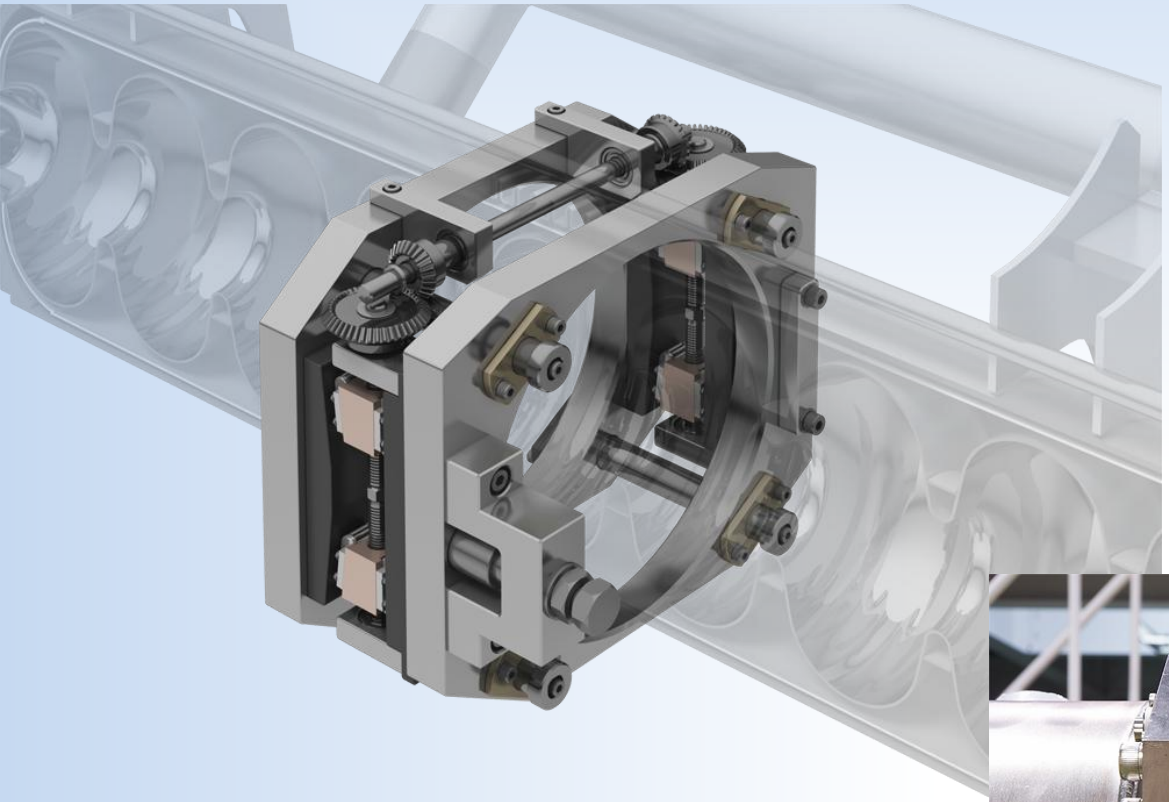


Location: end of He vessel
Motor: inside of module,
low temperature
Piezo: two low-voltage piezo

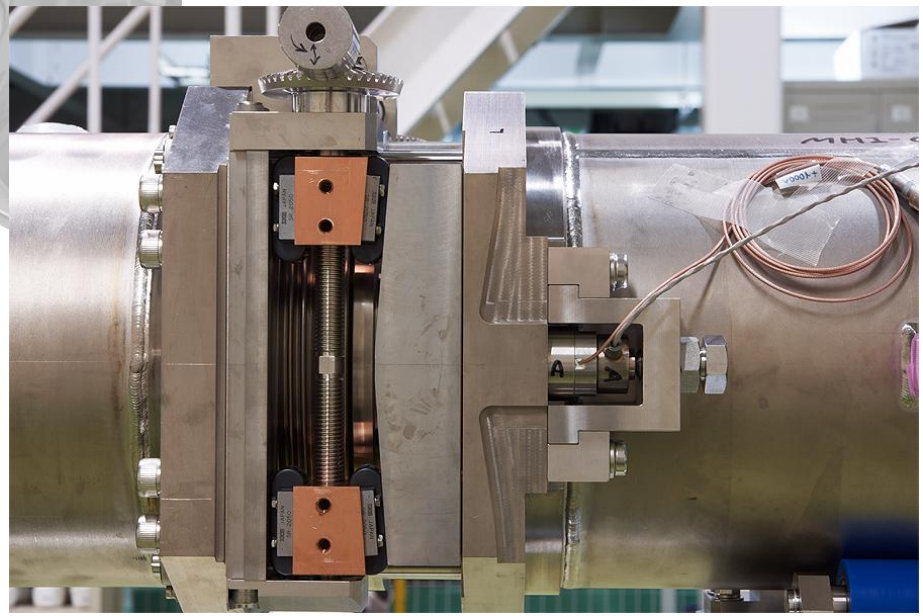


Design Stiffness: 40kN/mm
Nominal sensitivity: 1.0Hz/step
Piezo stroke at RM: 55 µm

Slide-jack tuner (KEK)



Location: two types,
middle of He vessel
end of He vessel
Motor: outside of module,
room temperature
Piezo: one high-voltage piezo



Design Stiffness: 290 kN/mm
Nominal sensitivity: 3 Hz/step
Piezo stroke at RM: 40 µm

S1-Global Input Couplers

TTF III coupler (LAL)

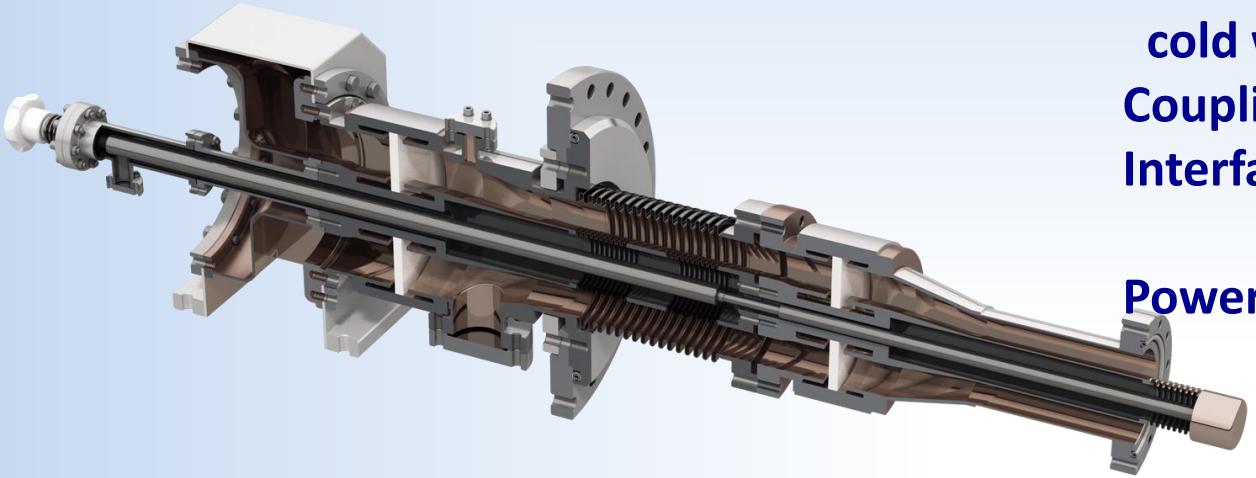
Type: coaxial to antenna
Window: two cylindrical,
cold window & warm window
Coupling: tunable
Interface: 40mm dia. cavity port
WR650 for waveguide
Power: 350kW, 1.5ms, 5Hz

TTF & FLASH (& FNAL) experience in many years,

Complicated assembly procedure is required.

S1-Global Input Couplers

STF-2 coupler (KEK)



Type: coaxial to antenna
Window: two disk-type,
cold window & warm window
Coupling: tunable
Interface: 60mm dia. cavity port
WR650 for waveguide
Power: 350kW, 1.5ms, 5Hz

Extension of TRISTAN(CW) coupler,

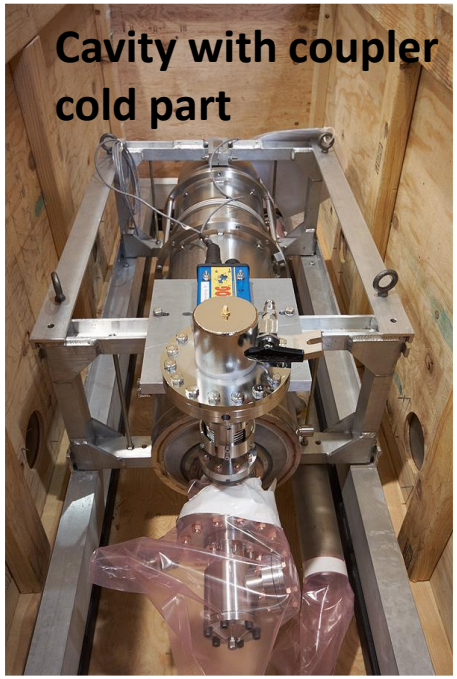
Simple assembly procedure by no bellows in cold part.
However, static heat loss increased 4 times.

Assembly work

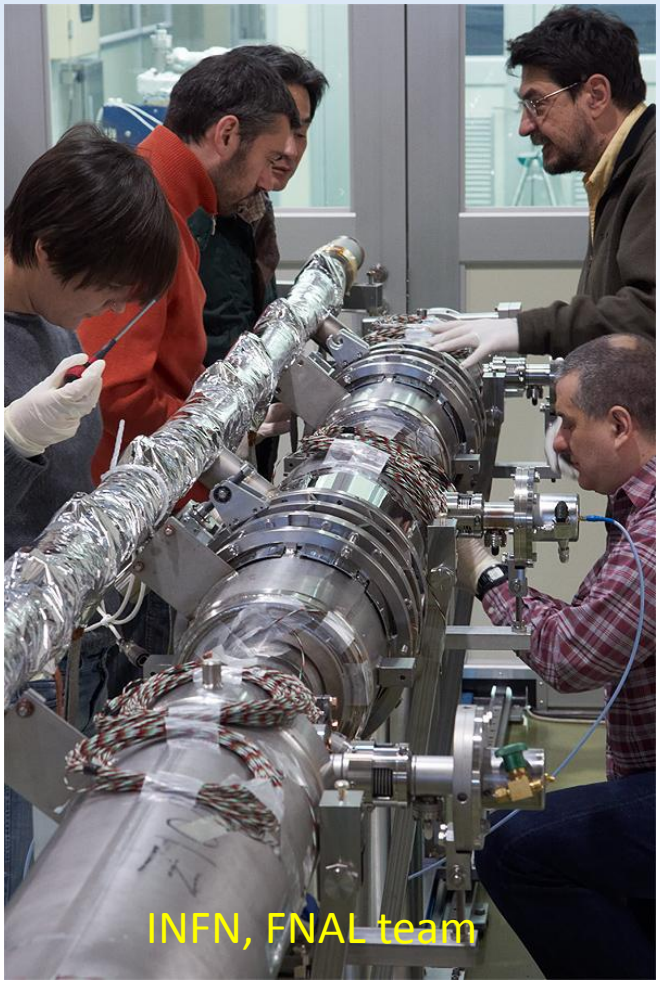
(December 2009 – May 2010)

Arrival of contributed components

December 2009



Assembly work

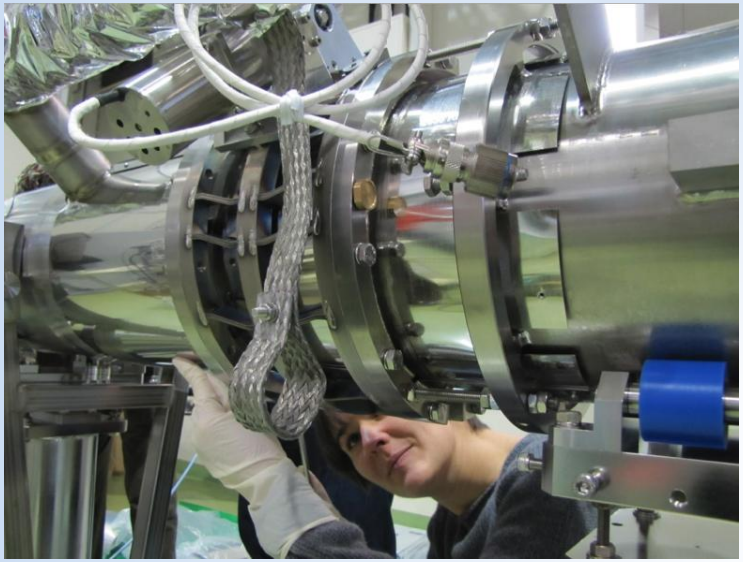


Tug Arkan
Brian Smith
Marco Battistoni
from FNAL

Manuela Schmoekel
Patrick Schilling
from DESY

Carlo Pagani
Angelo Bosoti
Rocco Pararella
from INFN
Serena Barbanott
from FNALi

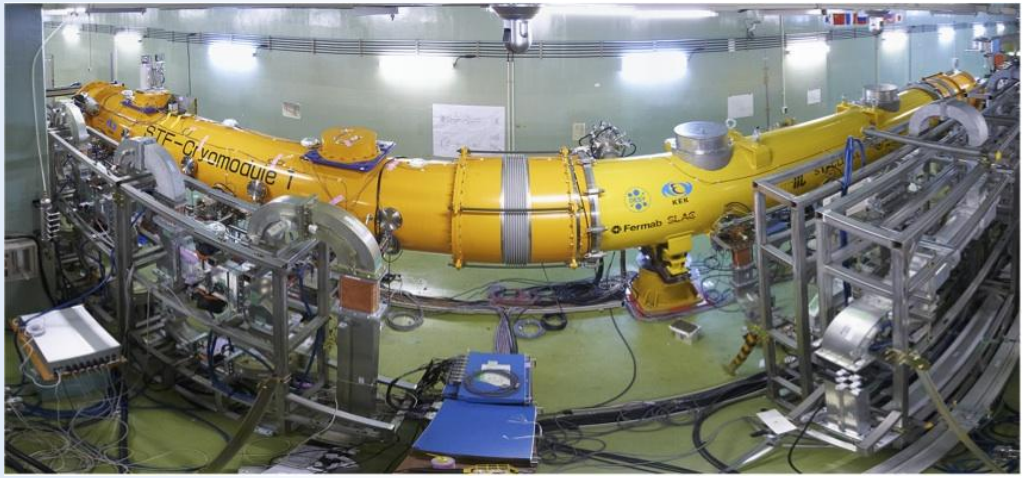
Assembly work



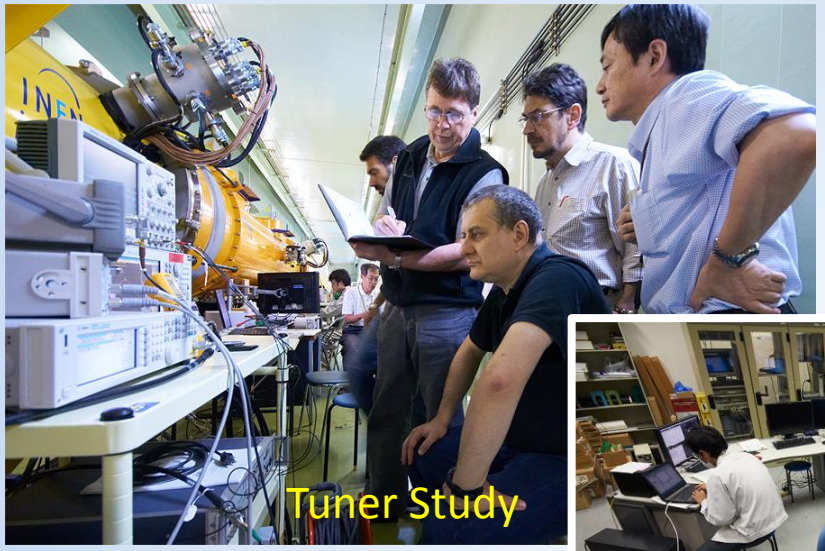
Serena Barbanotti from FNAL installed magnetic shield

Denis Kostin from DESY installed warm couplers

Installation into STF tunnel

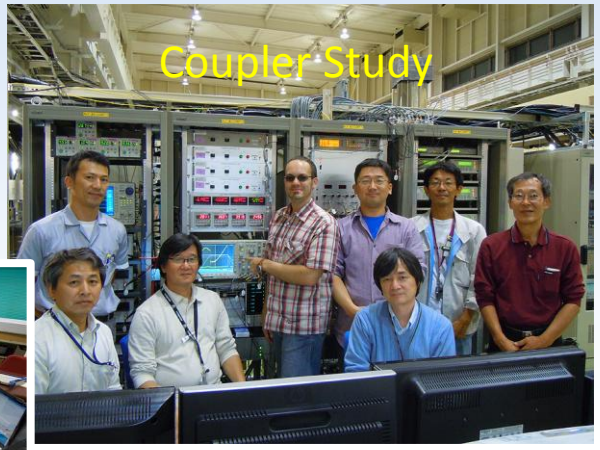


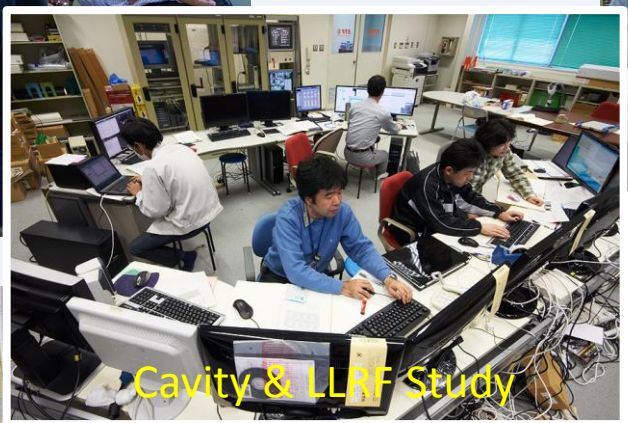
Cryomodule experiment

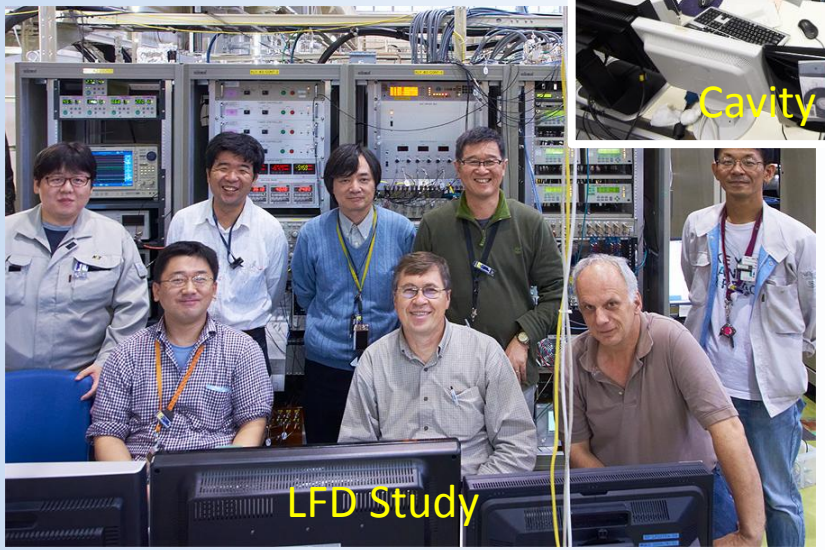


Carlo Pagani (INFN)
Angelo Bosoti (INFN)
Rocco Pararella (INFN)
Yuriy Pischalnikov (FNAL)

Denis Kostin
(DESY)







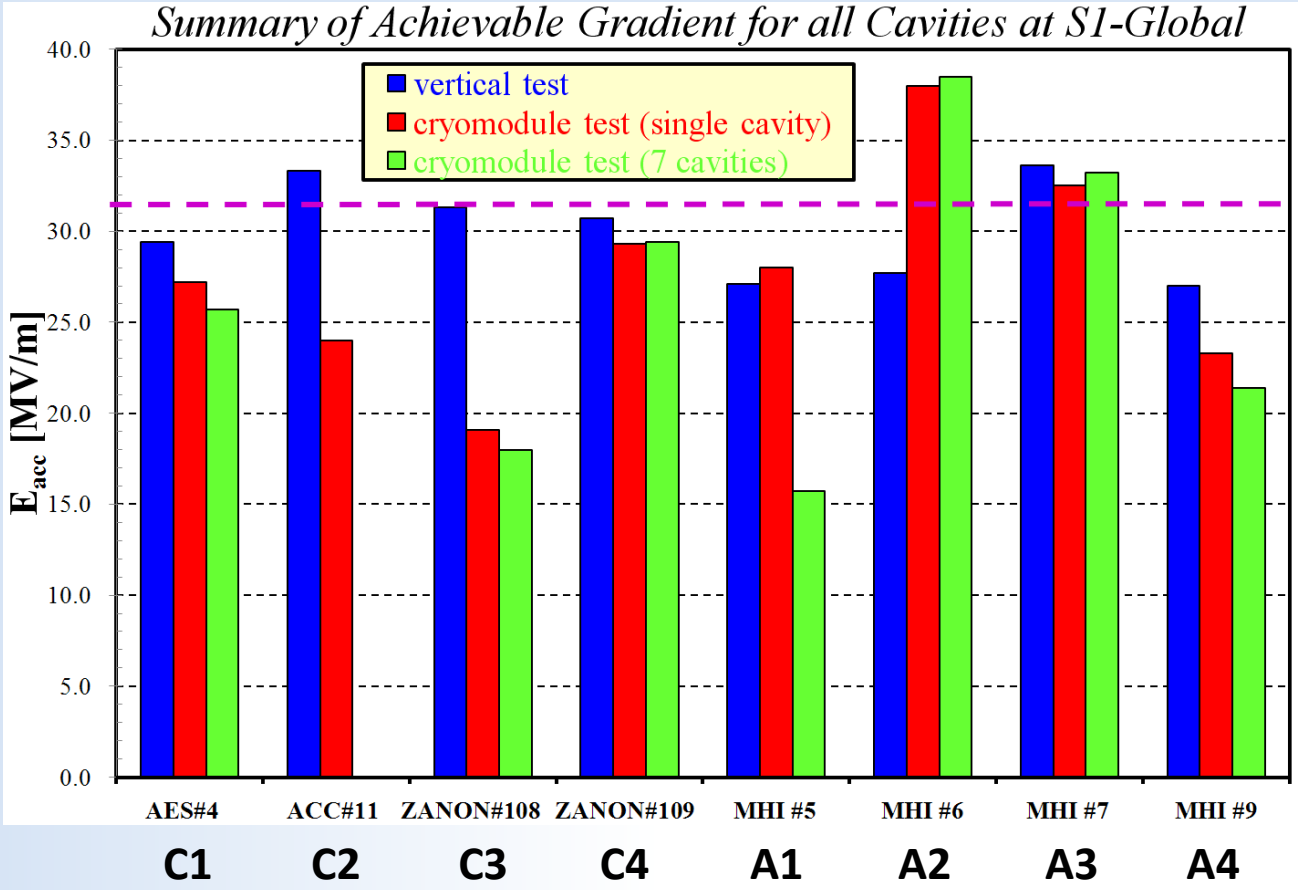
Yuriy Pischalnikov (FNAL)
Warren Schappert (FNAL)

Results of Performance Test

(June 2010 – February 2011)

Cavities Performance

gradient



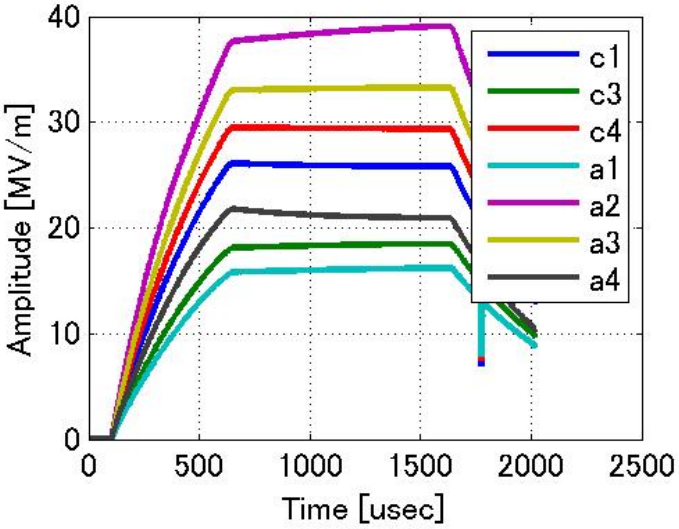
31.5 MV/m

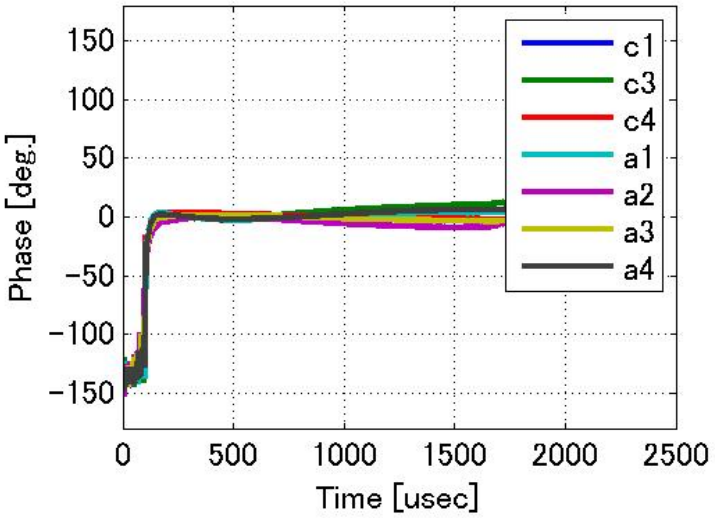
Before cryomodule installation	Average 30.0MV/m
after cryomodule installation	Average 27.7MV/m
7 cavities combined operation	Average 26.0MV/m

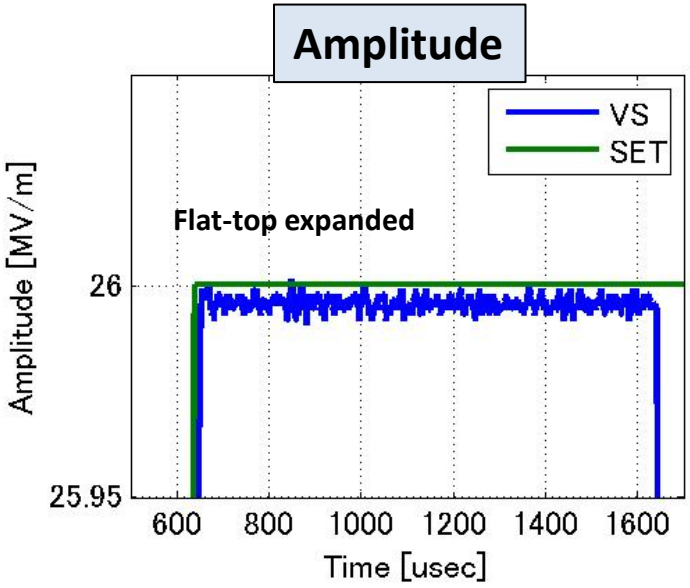
Cavities Performance

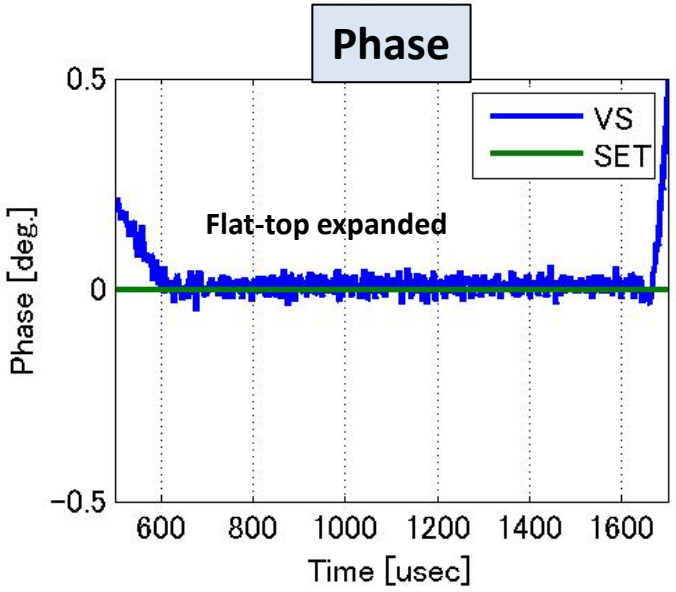
Combined & feedback control

Vector sum operation of 7 cavities with LLRF control







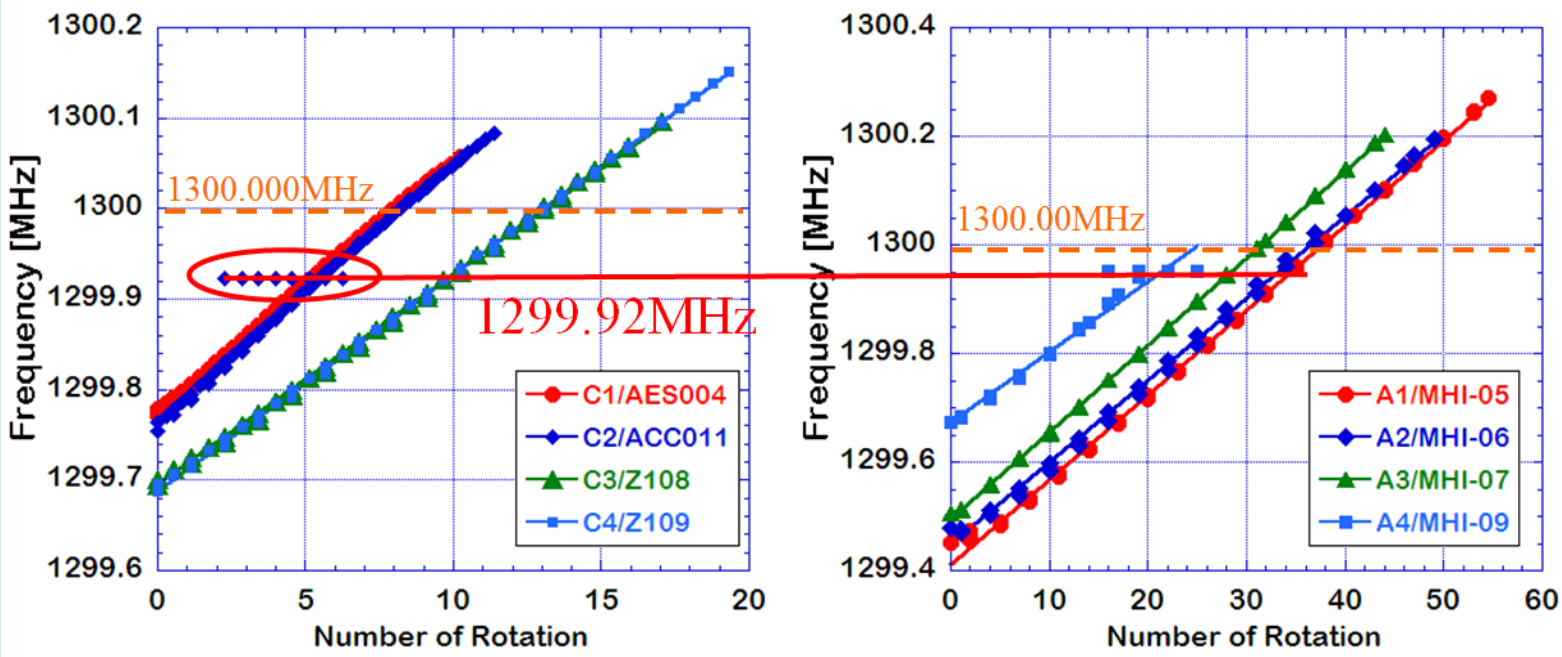


0.005%.rms amplitude stability

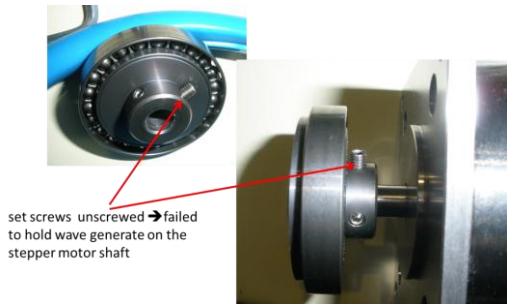
0.015degree.rms phase stability

Tuners Performance

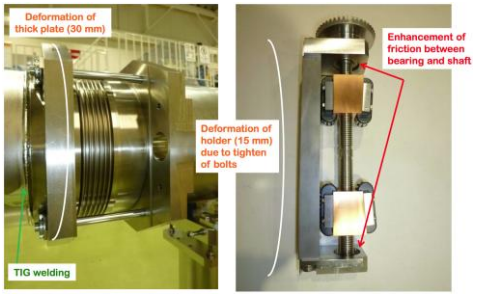
Mechanical tuner



C2 Blade tuner: failed after single excursion,
later, found set-screw slipping
-> improved in the next production



A4 Slide-jack tuner: failed during first excursion,
later, found jack-slope bending
-> improved in the next production

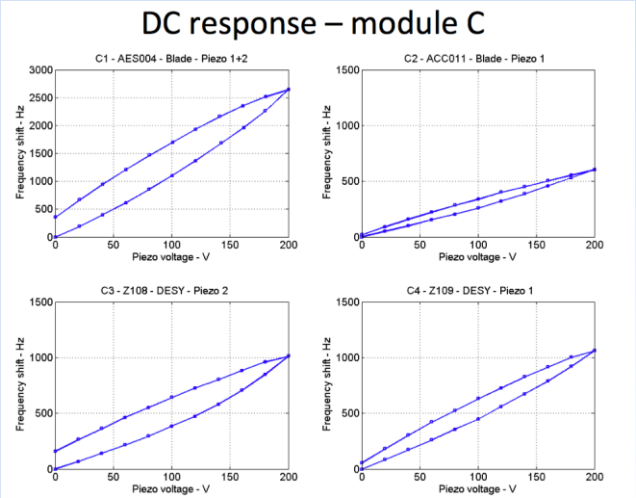


Tuners Performance

Piezo tuner

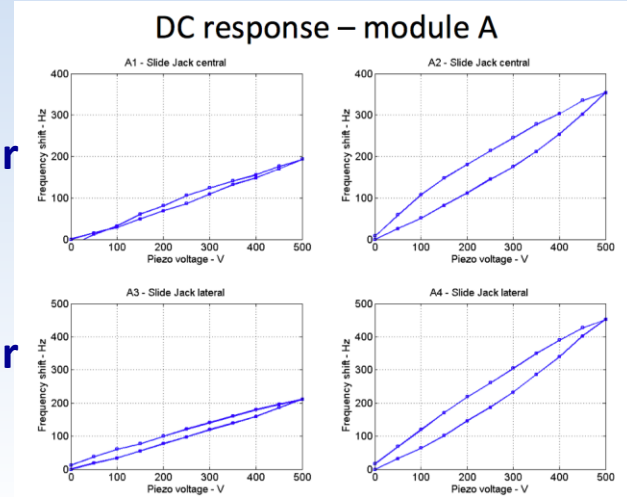
Blade tuner

Lever-arm tuner

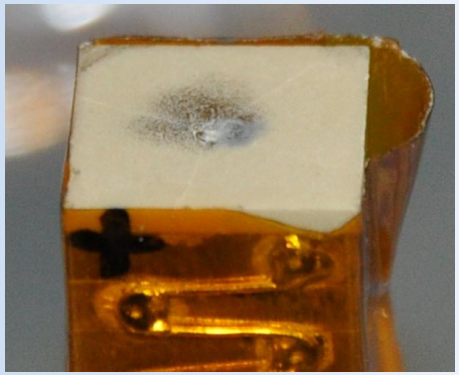


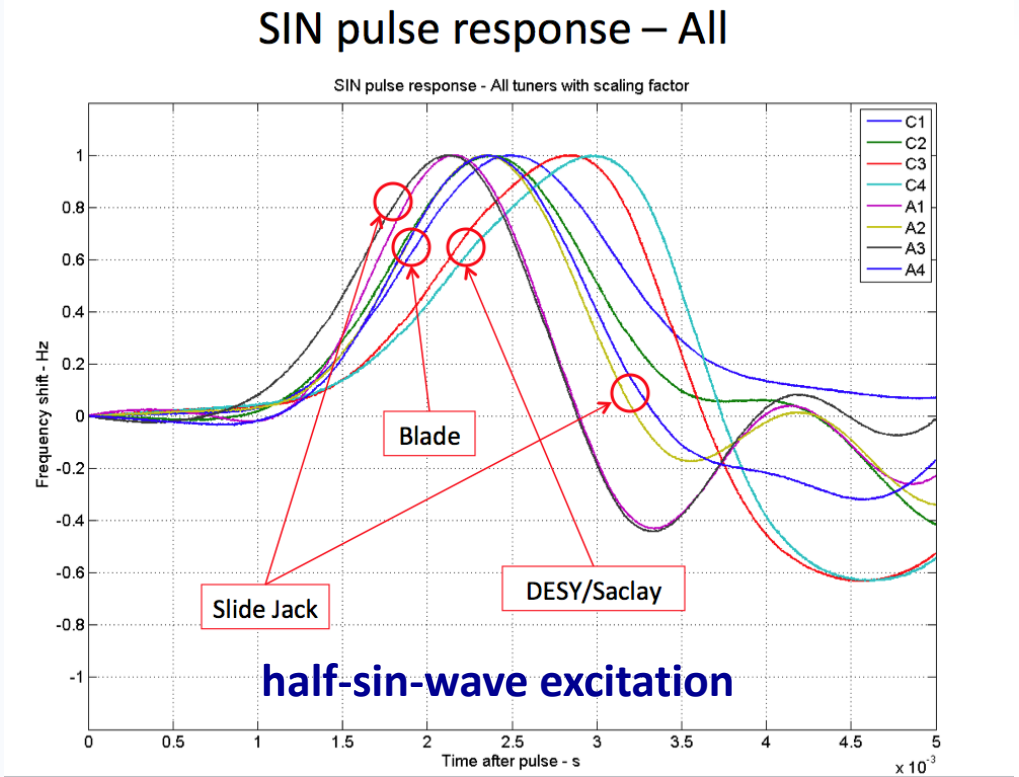
Slide-jack tuner In center

Slide-jack tuner In end

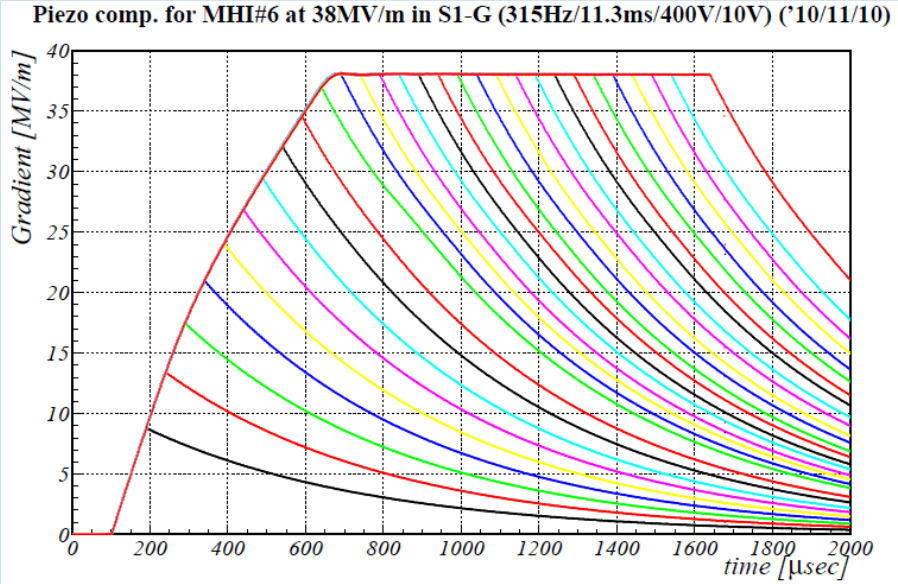


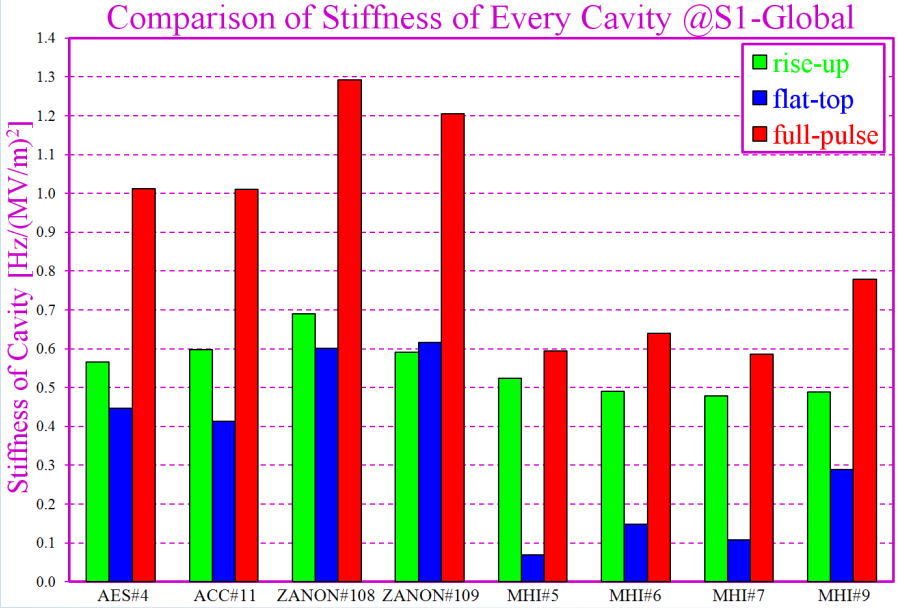
C2 Blade tuner: one piezo breakdown, later, found crack on piezo -> improved in the next production





Tuners Performance



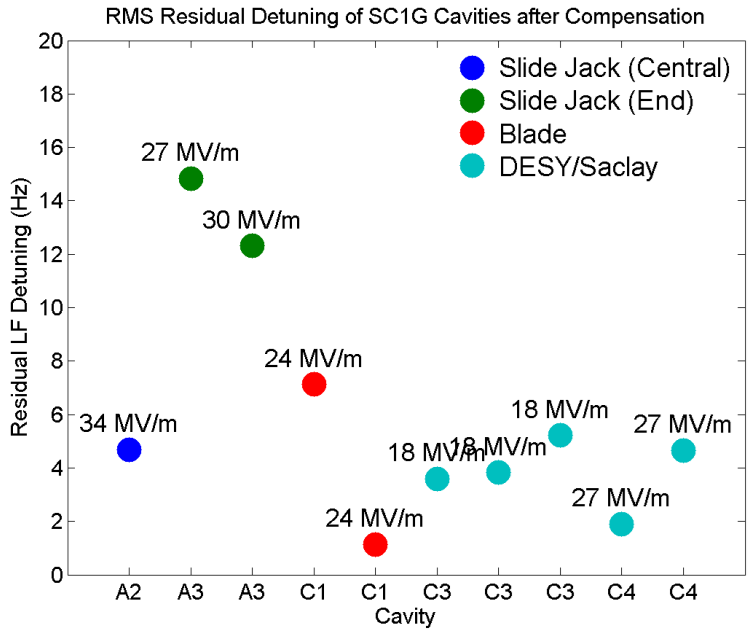


LFD measurement

Lorentz Force Detuning (LFD) were measured By Pulse-cut method.

Slide-jack tuners were 4 – 5 times stiffer than other tuners.

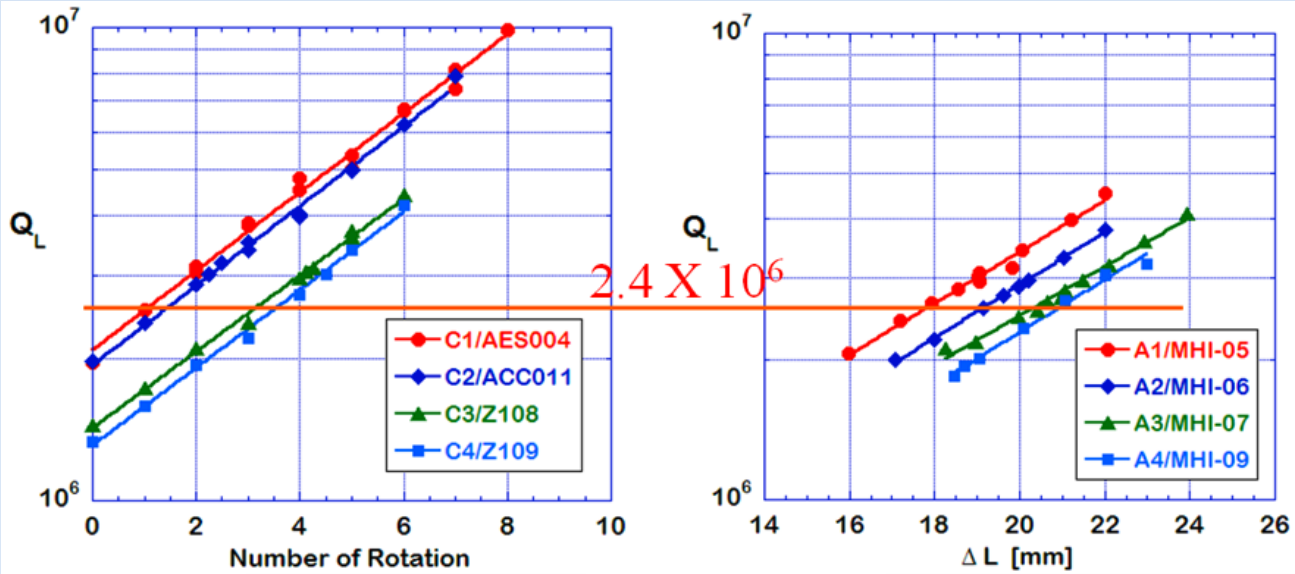
Residual LFD were less than 15Hz for all tunes, by adaptive feed-forward control.



Adaptive feed-forward compensation

Couplers Performance

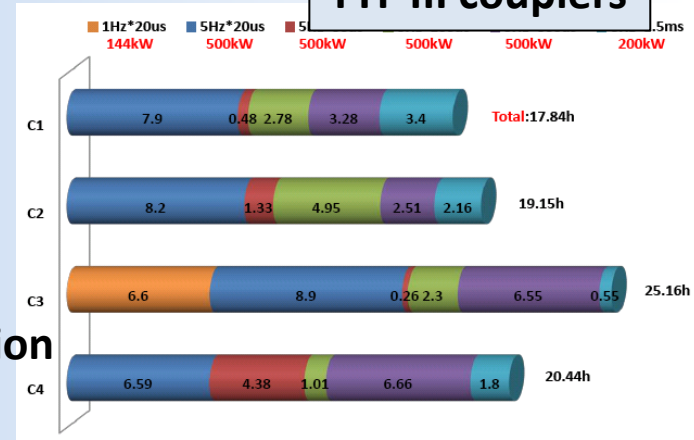
Q_L tuning range

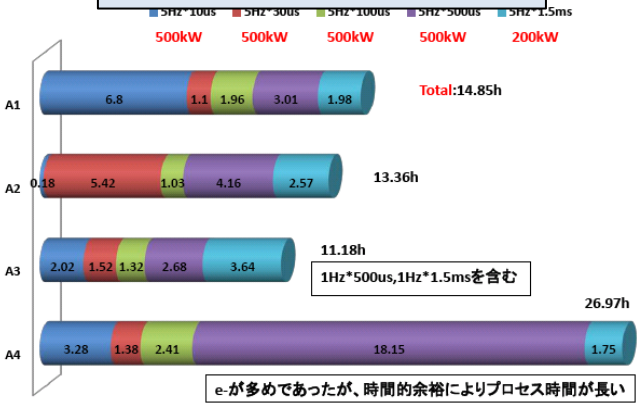


TTF III couplers

STF-2 (KEK) couplers

Process Time After installation





Average process time=21 hours

Average process time=15 hours

A1 (KEK) coupler: trip at 15MV/m by vacuum increase. -> reason not yet identified

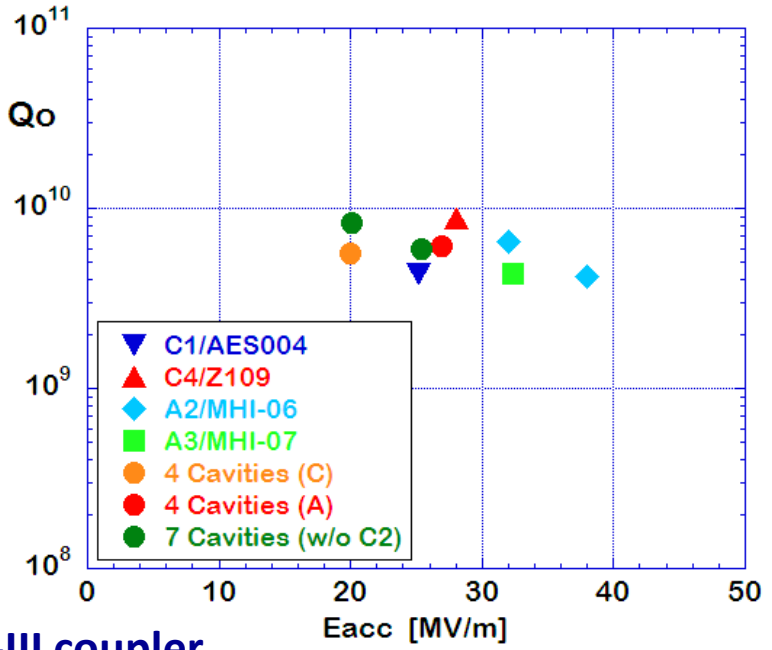
Thermal Performance

Static, dynamic loss

Static loss	Module-C(INFN,FNAL,DESY)	Module-A (KEK)
2K	7.2 W [6.8 W estimation]	
5K	5.3 W [4.1 W]	7.3 W [7.2 W]
80K	34.4 W [35.3 W]	48.7 W [44.3 W]

The static loss were consistent with the estimation.

Dynamic loss	Module-C (4 cavities)	Module-C (4 couplers)	Module-A (4 cavities)	Module-A (4 couplers)
Gradient	20 MV/m	32 MV/m	26.9 MV/m	32 MV/m
Tune/detune	tune	detune	tune	detune
Q_D [W]	2.7	NA	6.9	NA
$Q_{D\text{-}det}$ [W]	0.2	0.5	2.5	4.6
$Q_{D\text{-}cav}$ [W]	2.5	NA	4.4	NA



STF-2 (KEK) coupler had 9x large dynamic loss than TTF-III coupler.
Later, it was found it came from Cu 3µm inner coating layer heating.
→ It was improved in the next model, already.

Disassembly

(May 2011 – December 2011)

Disassembly

Moved from tunnel


Module-A disassembly


Module-C disassembly


FNAL, DESY cavities were sent back

Conclusion

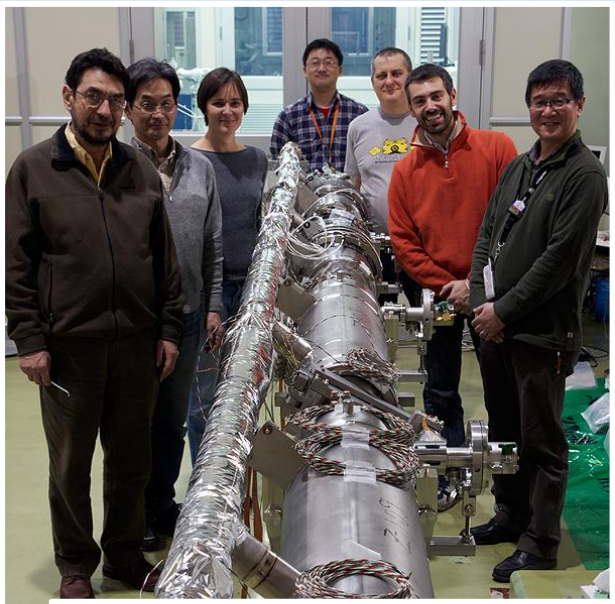
- **The design, fabrication, assembly, experiment, and disassembly of S1-Global were done by the international collaboration based on ILC-GDE, hosted by KEK STF.**

- **The achieved gradient performance of the contributed cavities was average 30.0MV/m before installation, 27.7MV/m for single cavity operation after installation, and 26.0MV/m for 7 cavities simultaneous operation.**

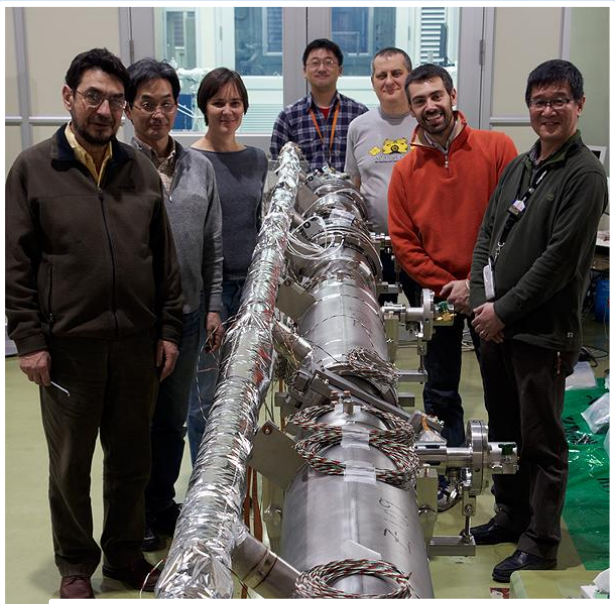
- **The plug-compatibility concept was demonstrated by building one set of cryomodule from brought-in cavities and couplers of each laboratories.**

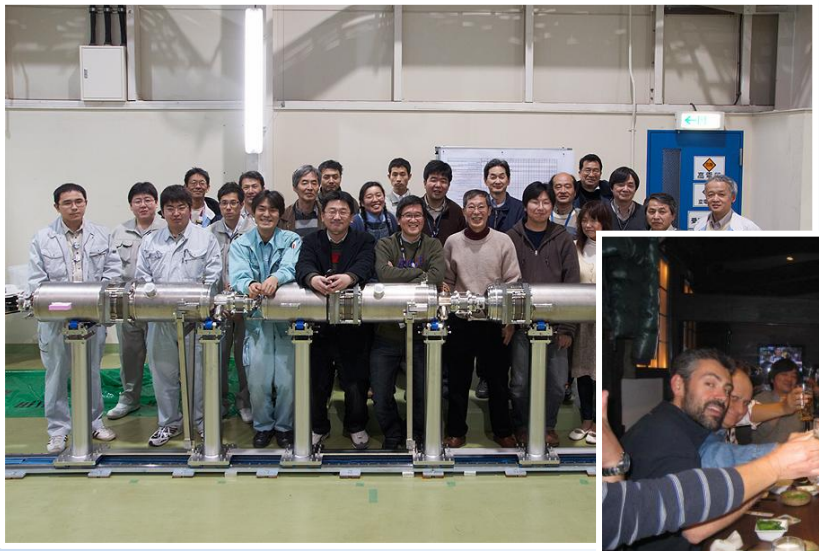
- **Several important issues were identified and improved right after the experiment.**

Collaboration

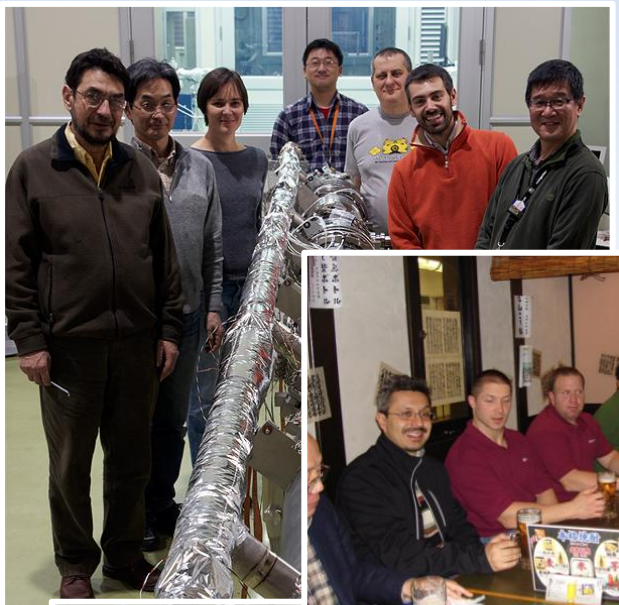


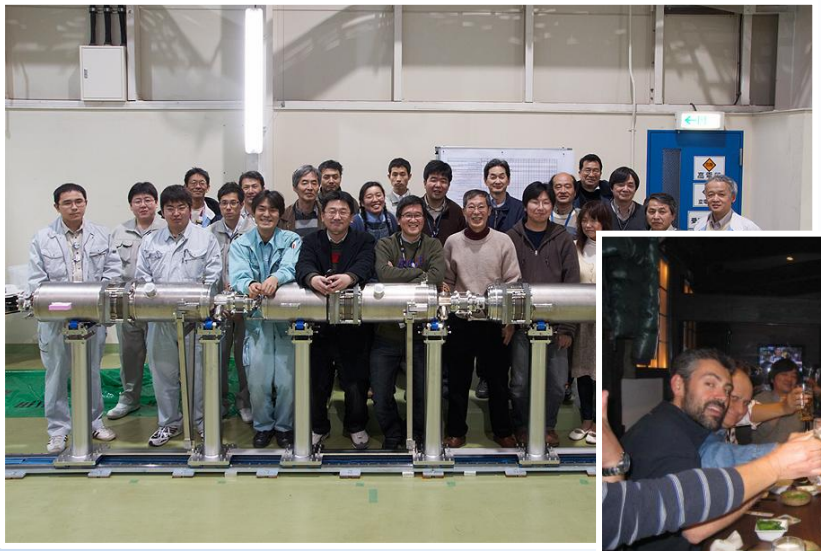
Collaboration





Collaboration





Thanks to all the collaborator of ILC-GDE.
And, we wish to realize ILC, soon.

ILC image of mountainous site

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