State of the Art Power Couplers for Superconducting RF Cavities

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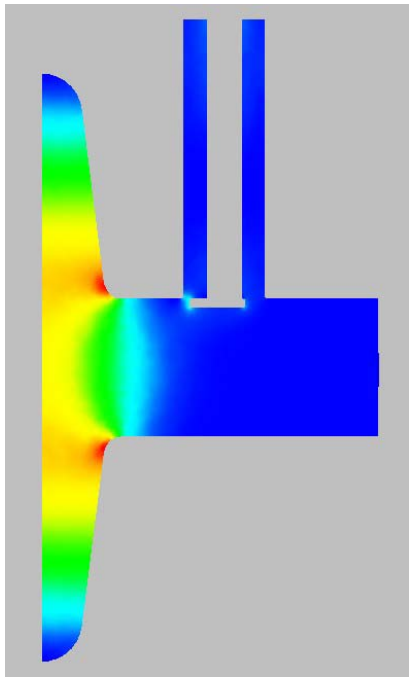
Outline

- Couplers are complicated objects because they must perform several functions
- Couplers are an integral part of a cavity, not just an appendage
- Coupler reliability and design tools have made great progress recently
- Power handling above 1 MW is available
- It is time to be bold and think of new technologies and new concepts

What is a coupler?

A coupler is a **transition region** in a transmission line designed to provide the proper rate of energy transfer to a resonator.

Characterized by a Q_{ext}



Example: RIA (THPDO025)

New Requirements

As cavity performance increases and as RF superconductivity is applied to more and more diverse accelerators, the requirements on couplers' parameters become more difficult to meet:

- Higher gradients: more standing wave power
- Higher beam currents: more traveling wave power, tighter cavity-coupler interaction
- Pulse power: transient conditions, transient gas loading

Question

Why is it so difficult to make power couplers for **superconducting cavities**?

Functions

A power coupler interfaces to a superconducting cavity:

- Establish electromagnetic fields
- Support high thermal gradients
- Provide a vacuum barrier
- Prevent contamination

Must not hinder cavity performance

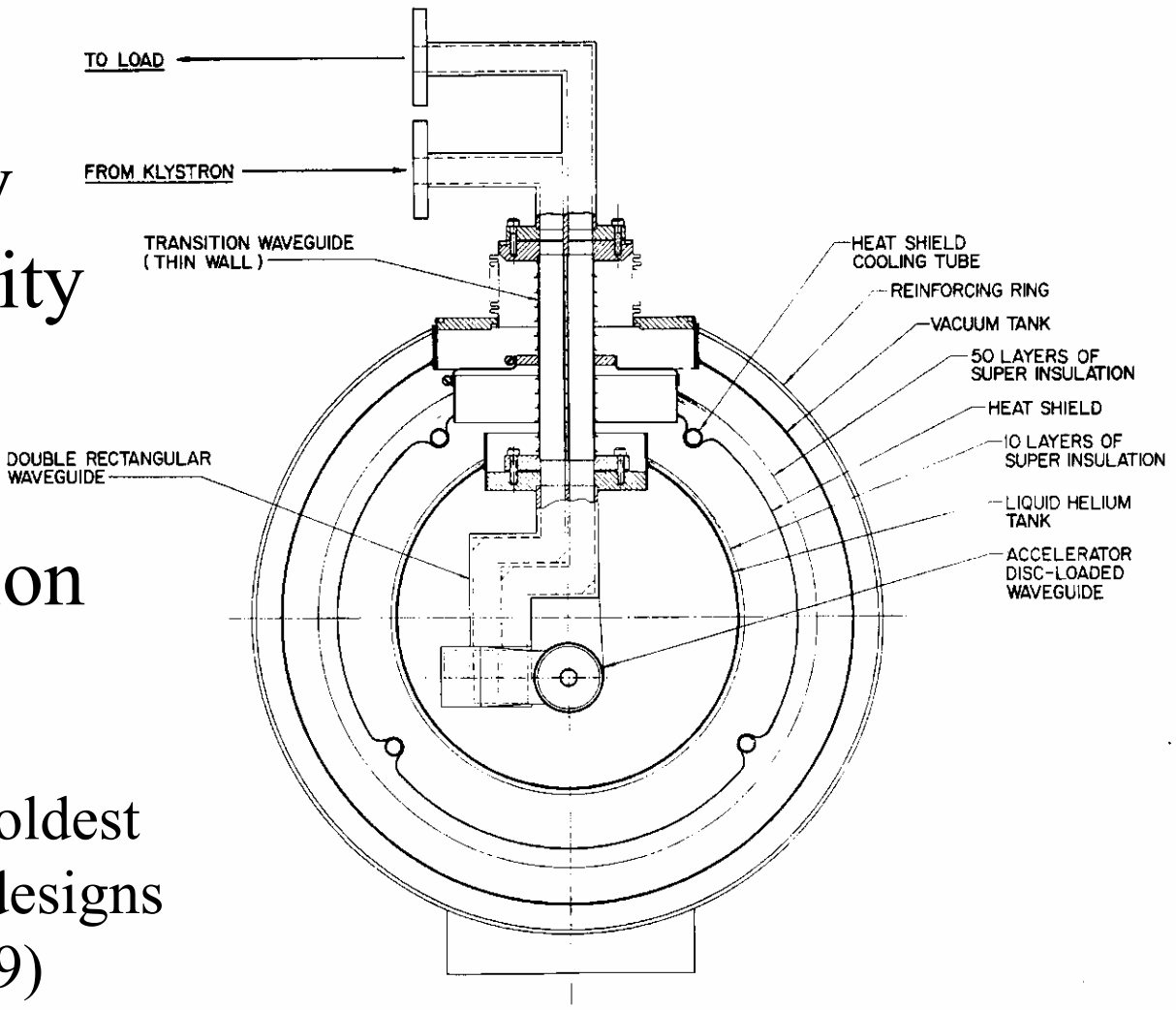
Electromagnetic Coupling

Most common types of coupling for high power:

- Waveguide
- Coaxial capacitive

Waveguide Coupling

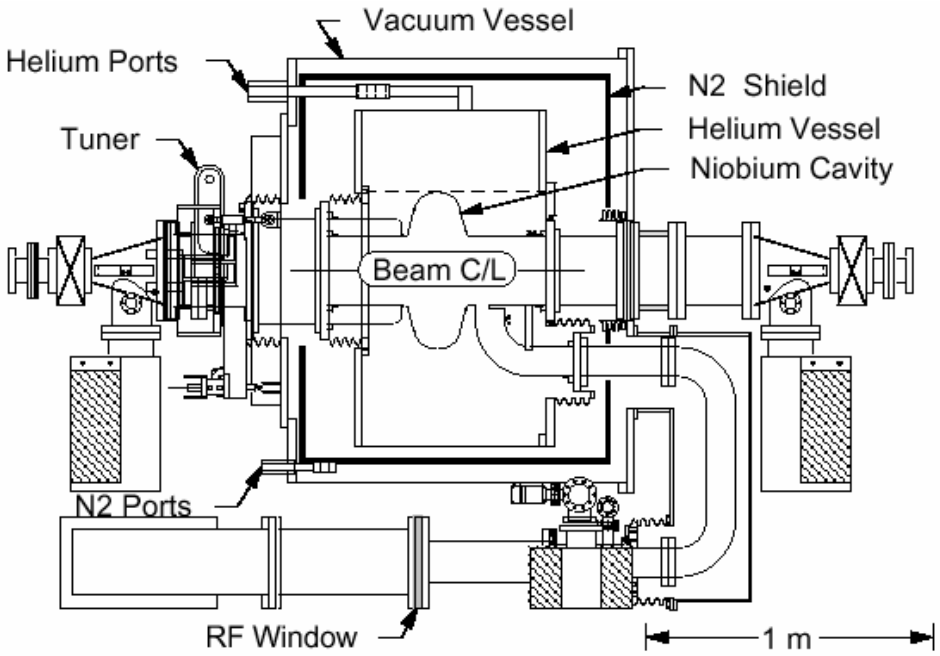
Simple geometry
Low power density



Large cross section
Large heat load

Example: One of the oldest waveguide coupling designs (Leapfrog SLAC 1969)

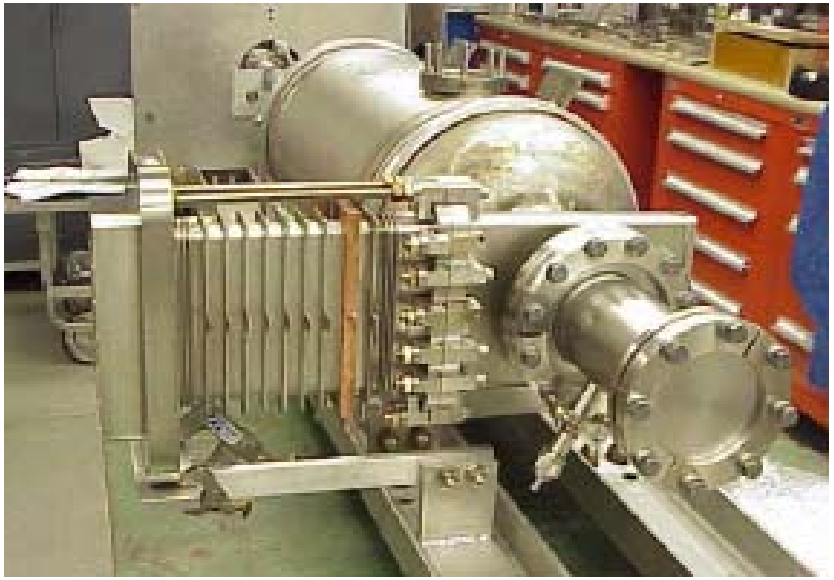
Waveguide Coupling

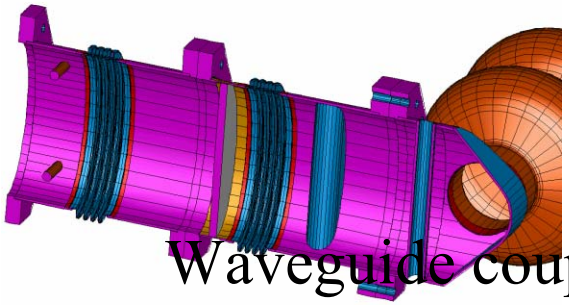


CESR-B SC cavity
WR1800 WG
500 MHz
294 kW in operation

CEBAF Upgrade cavity

1.5 GHz, up to 14 kW input power
(FEL variation will go up to 100 kW)



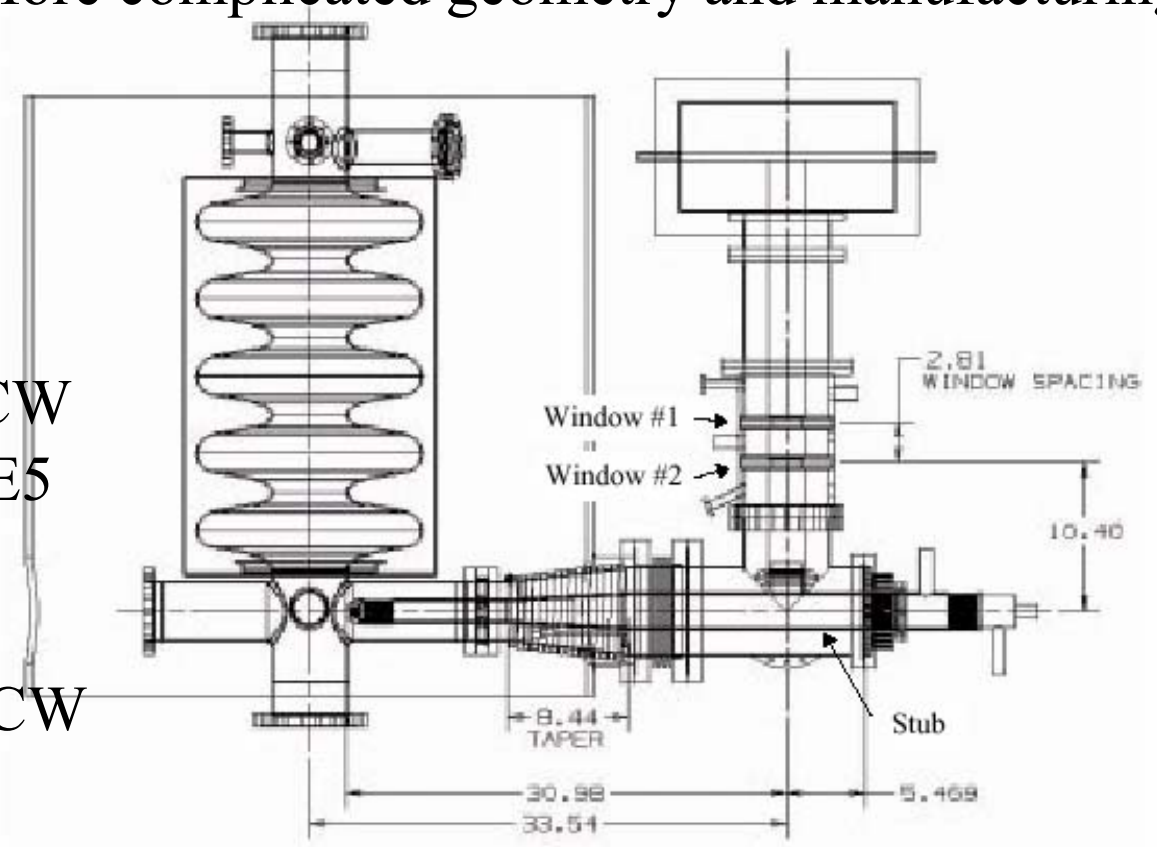


Waveguide coupling has also been considered for TESLA

Coaxial Coupling

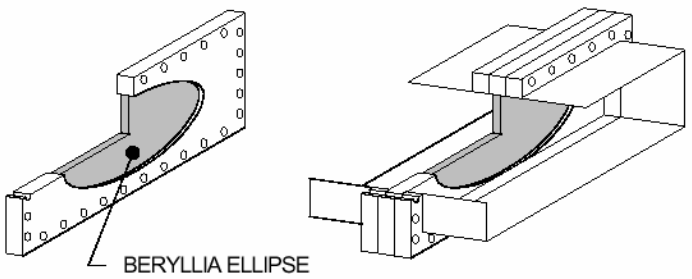
More compact at lower frequencies than WG
Allows variability

More complicated geometry and manufacturing



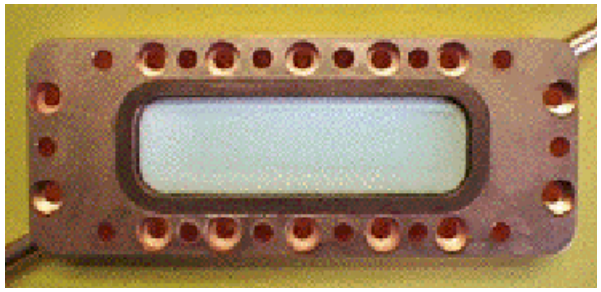
High Power: > 400 kW CW
Variable coupling: 2 - 6 E5
High-speed pumping
Double window
Tested up to 1 MW TW CW
850 kW SW

Windows



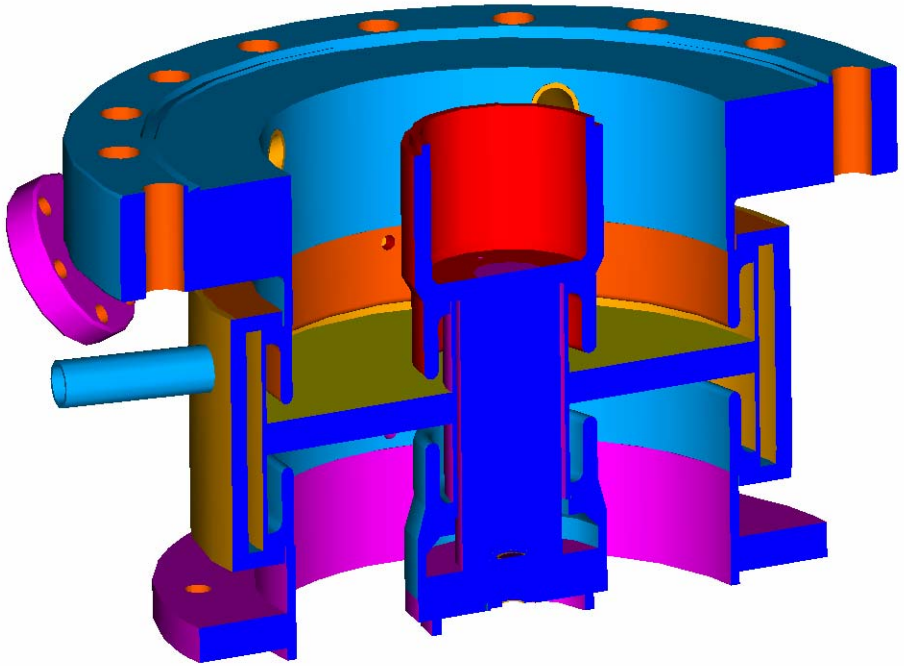
Cornell 500 MHz (WG)

- Warm windows
- Cold windows



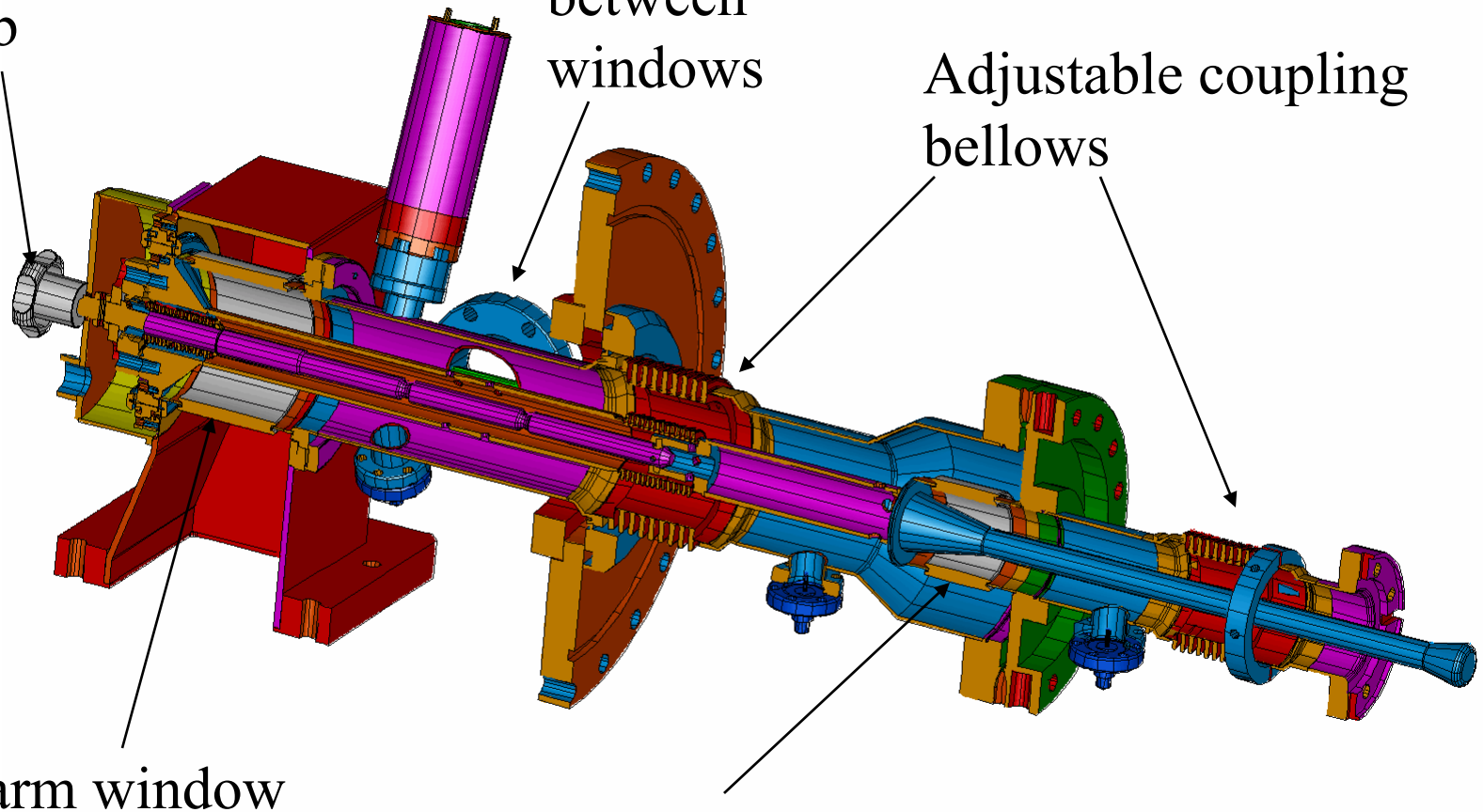
JLab FEL 1.5 GHz

- Single window
- Multiple windows



"Choke" window

TTF III


Adjustable Coupling Knob
Pumpout port between windows
Adjustable coupling bellows
Warm window
Cold Window

KEK-JAERI Project

Couplers for 972 MHz cavities

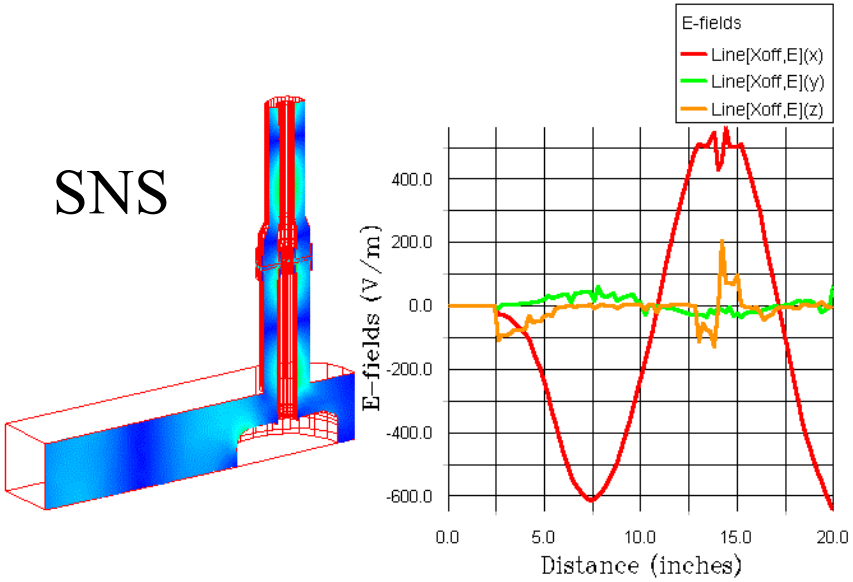
Q_{ext} 5x 10^5

300 kW

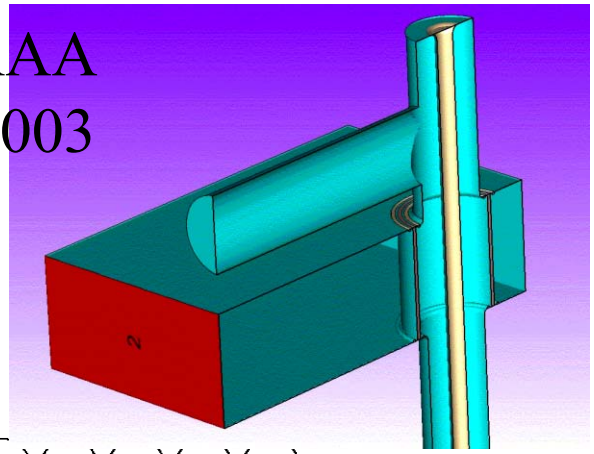
Ready to be tested

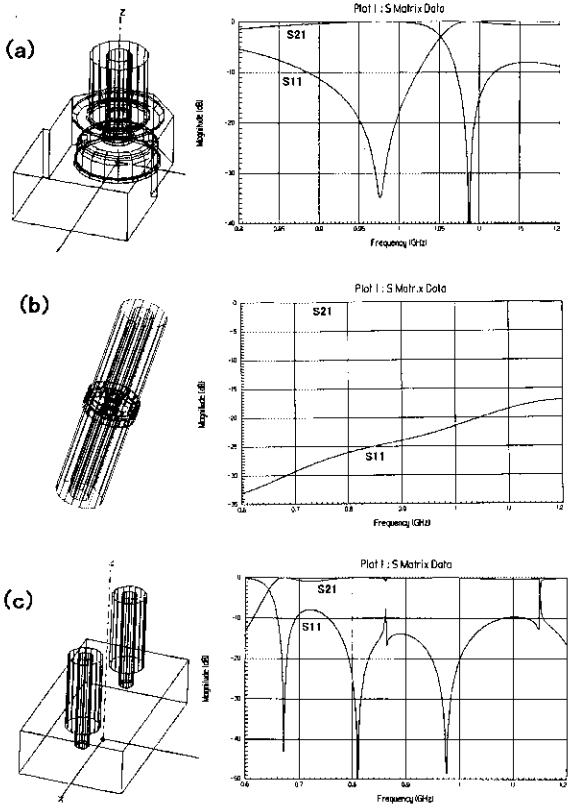
Simulations: Matching

SNS



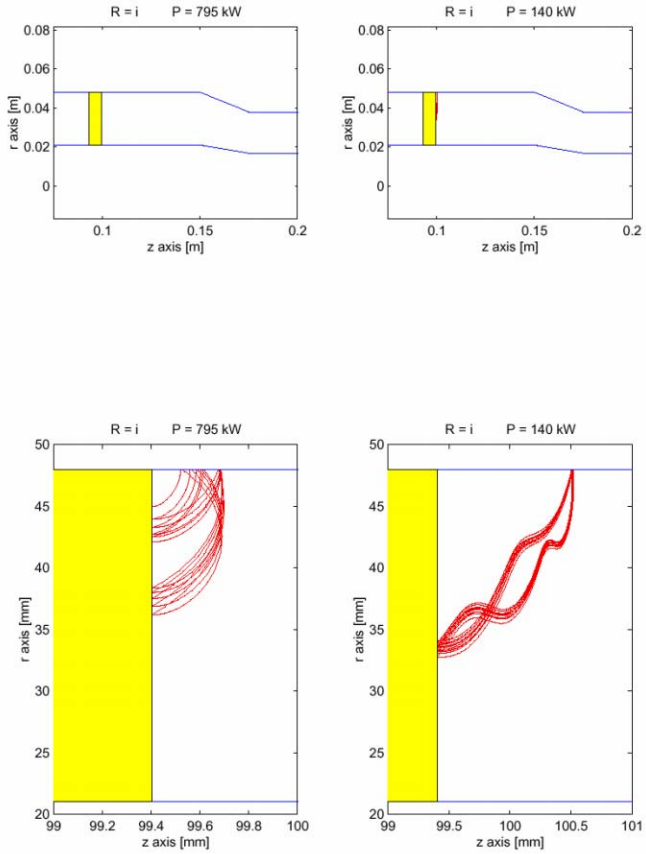
LANL AAA
WEBLA003



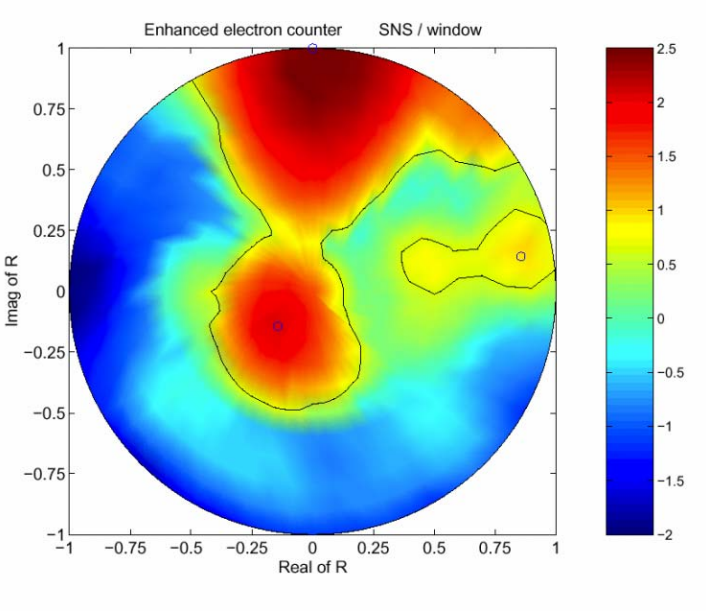


JAERI-KEK
THPDO017

Multipacting: Simulations



Ylä-Oijala et al.



Similar Calculations carried out at:

Saclay (TESLA) (Devanz,Travier), Cornell (WG) (Geng, Padamsee, Shemelin), LANL (Krawczyk)

Multipacting: Coatings, Handling, Processing

- Simulations provide guidance on the choice of **geometry**

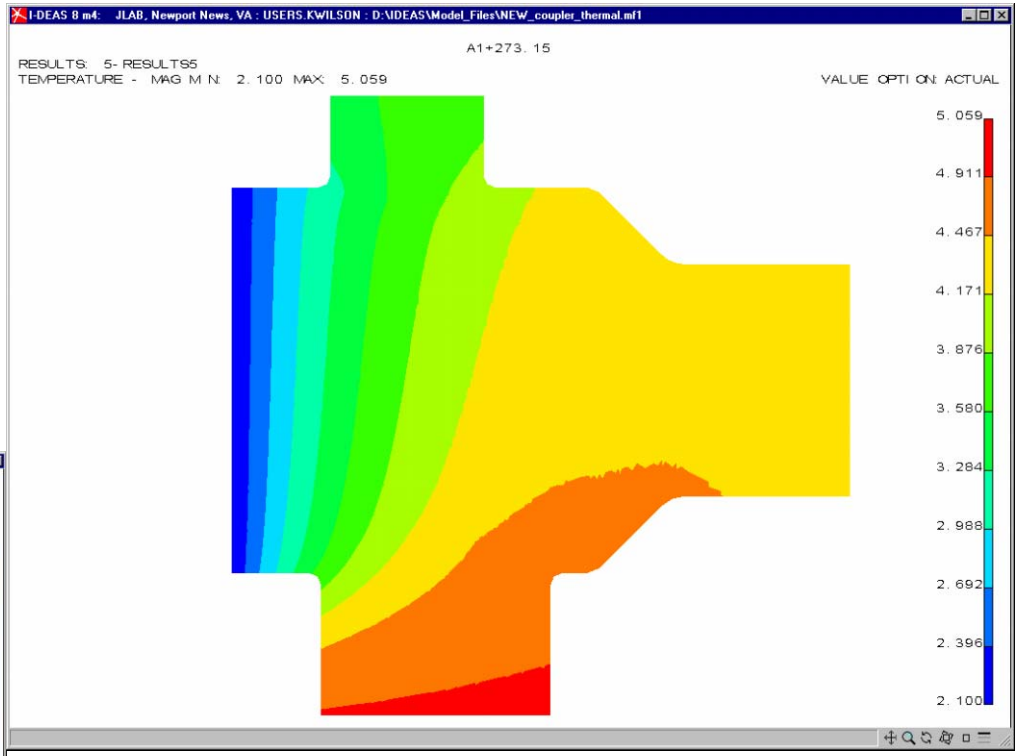
but more is needed:

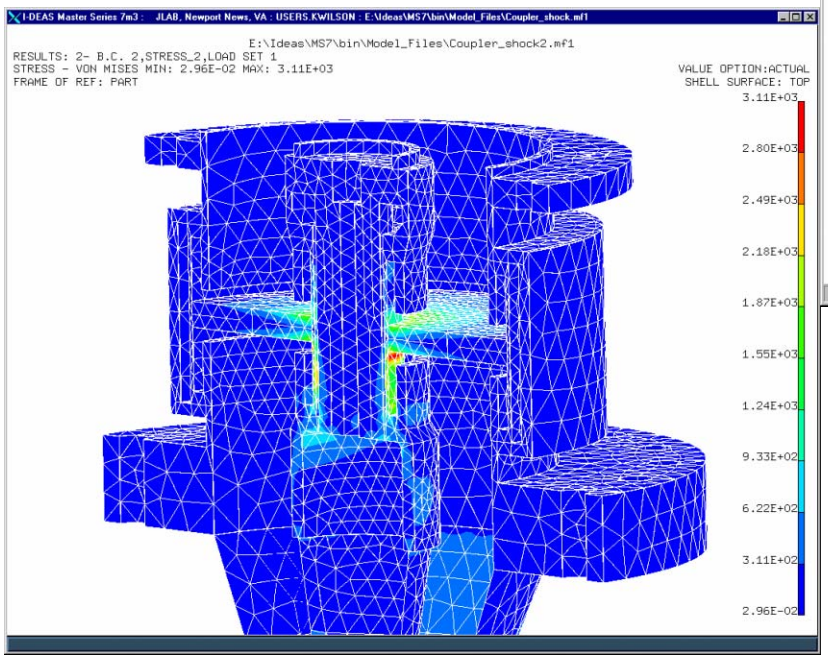
- **Coating** of critical surfaces with low SEE coefficient films
- Proper **cleaning** and handling
- **Bias**: electric for coaxial, magnetic for WG (Geng et al. THPDO006)
- **Conditioning** to decrease the effects of multipacting before the couplers are used under real conditions.

Simulations: Thermal and Mechanical

(K. M. Wilson)

Beamline temperature distribution due to coupler thermal radiation (with RF by S.H. Kim)





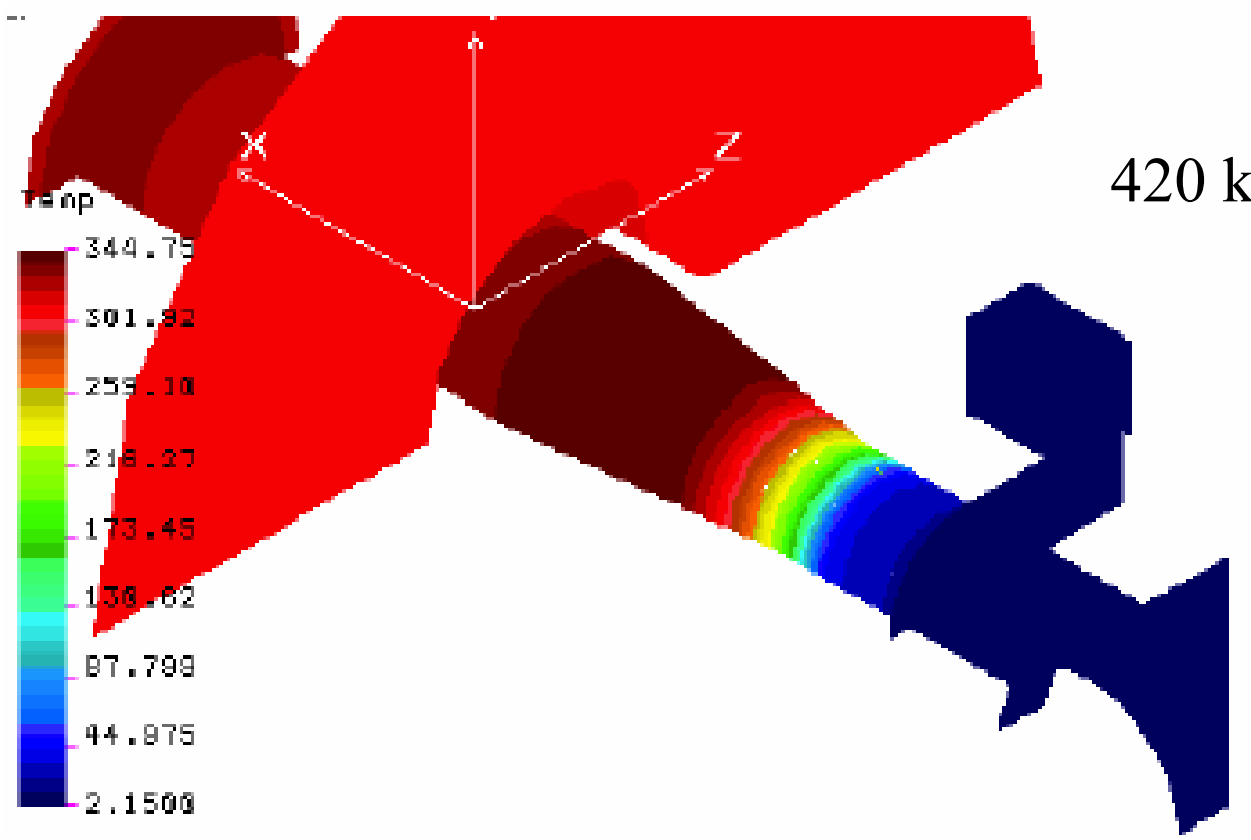
SNS

Window mechanical stresses (K. M. Wilson)

Simulations: Thermal

APT

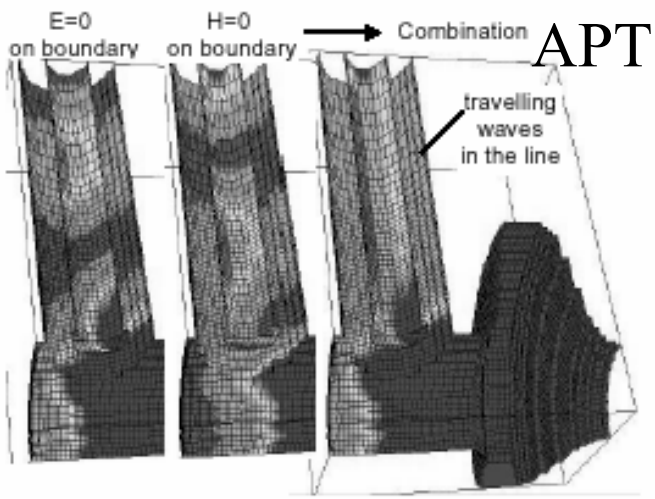
Coupler Thermal Distribution (Bourque and Laughon)



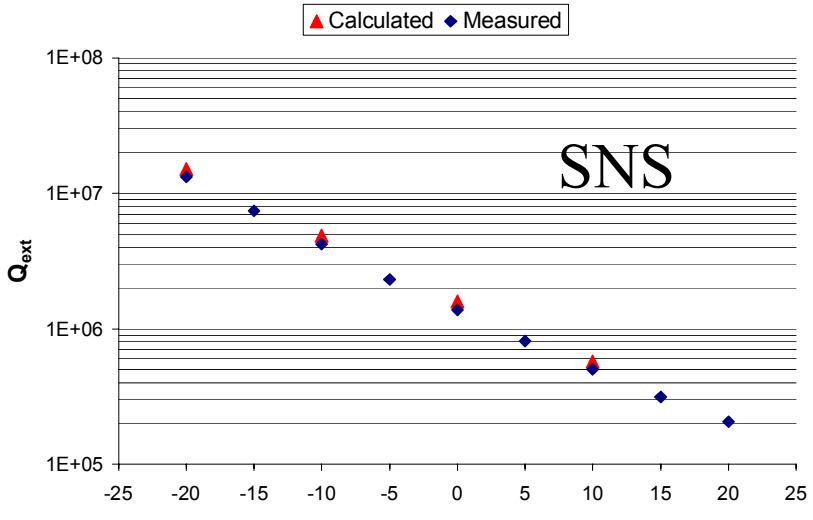
420 kW RF power

Simulations: Coupling

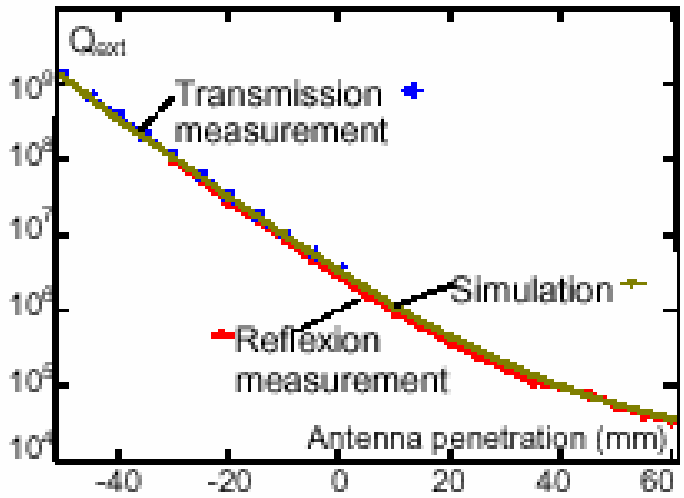
APT

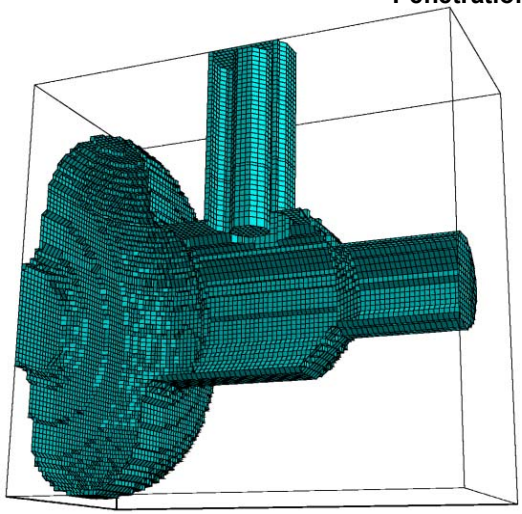


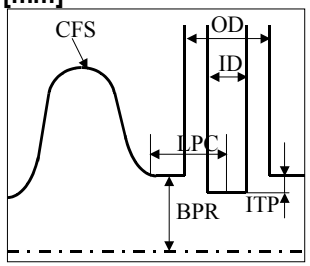
Kim, Doleans, Ciovati, Stirbet, Kang



Balleyguier



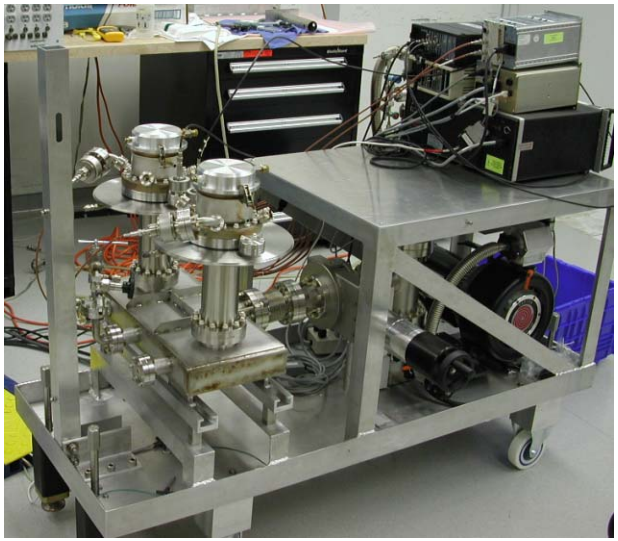




1) CFS
(Cell at the FPC Side)
2) BPR
(Beam Pipe Radius)
3) OD, ID
(Outer and Inner conductor diameters of FPC)
4) LPC
(Longitudinal Position of FPC)
5) ITP
(Inner conductor Tip Position)

Conditioning Test Stands

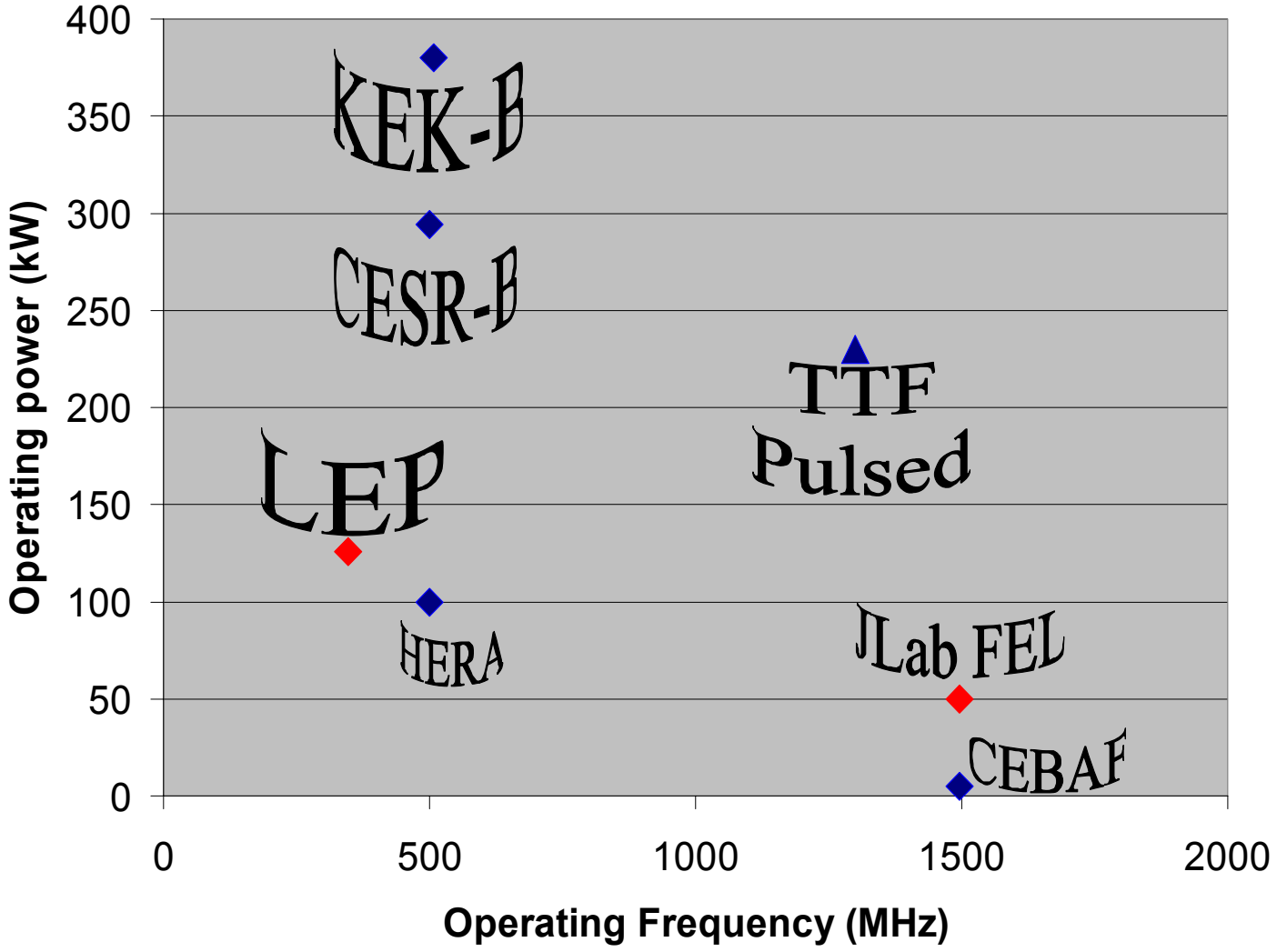
Conditioning can take up to several days and must be carefully controlled. Cryogenic Test Stands are necessary: e.g. CRYHOLAB (Bousson et al.THPDO036)



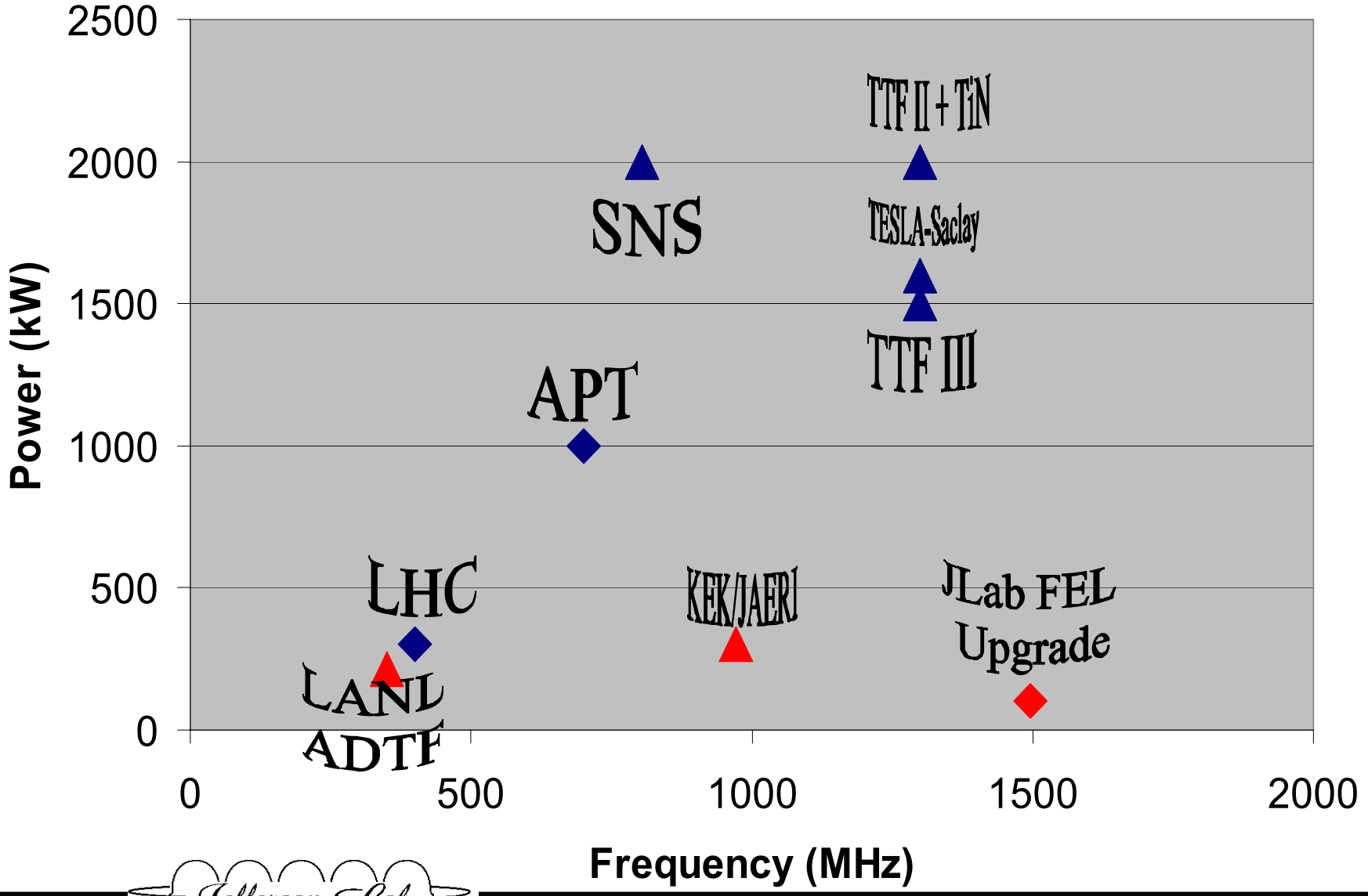
SNS Test Cart:Tested at LANL to 2MW Peak
JLab 1 MW Peak

APT Test Stand 1 MW CW

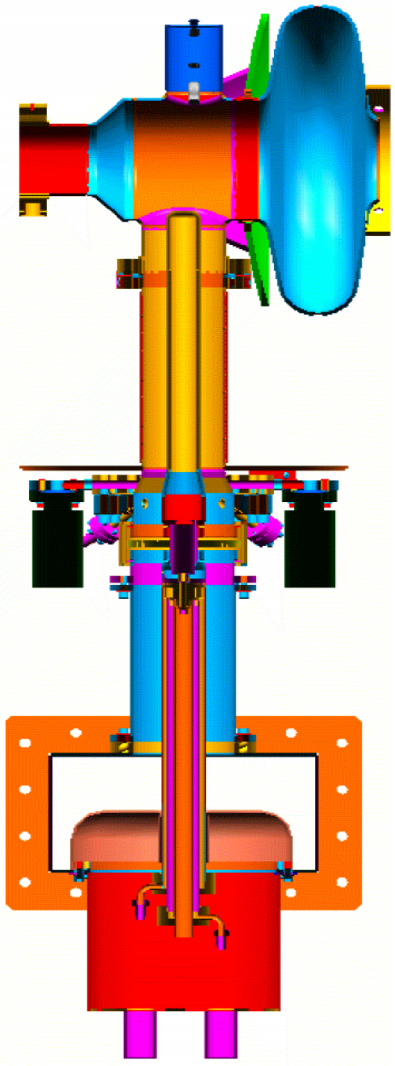
In Operation



Prototypes and Designs



SNS Prototype Coupler



Started project in Summer 2000

Peak power in operation : up to 550 kW

1.3 ms RF on, 60 pps

< 50 kW average power

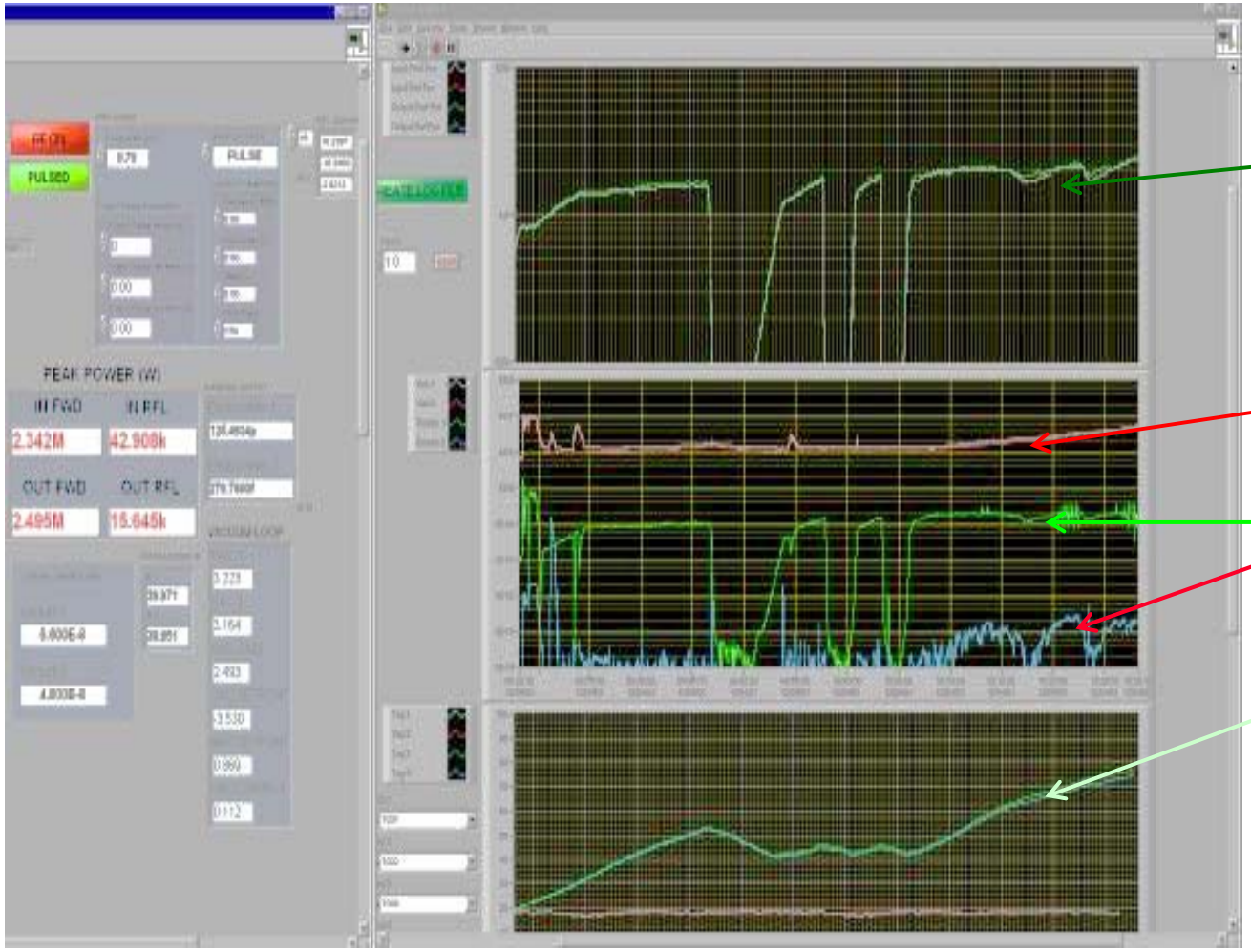
Q_{ext} ~ 7.3 and 7 x 10^{5}

300 K window

From KEK to SNS

- Scaled critical dimensions as 1/f
- Window location constraints
- No active cooling of center conductor
- Modified extensions
- Active He cooling on outer conductor

Test Results: SNS



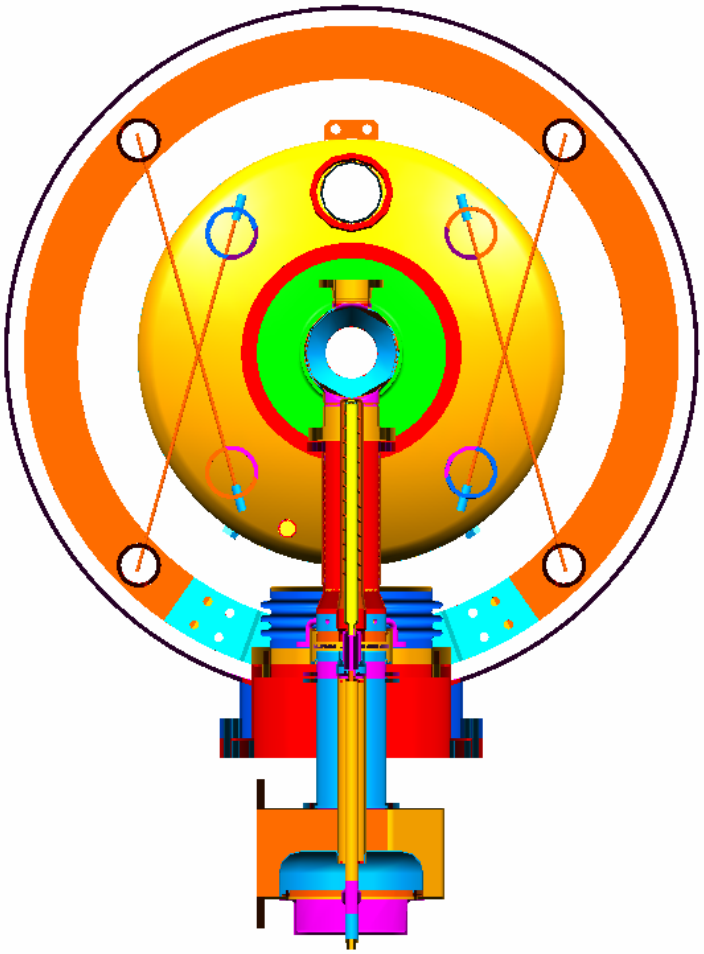
(Stirbet et al. THPDO016)

SNS: over 2 MW peak (December 2001 at LANL)

SNS Cryomodule Test

Three couplers installed in Prototype SNS Cryomodule

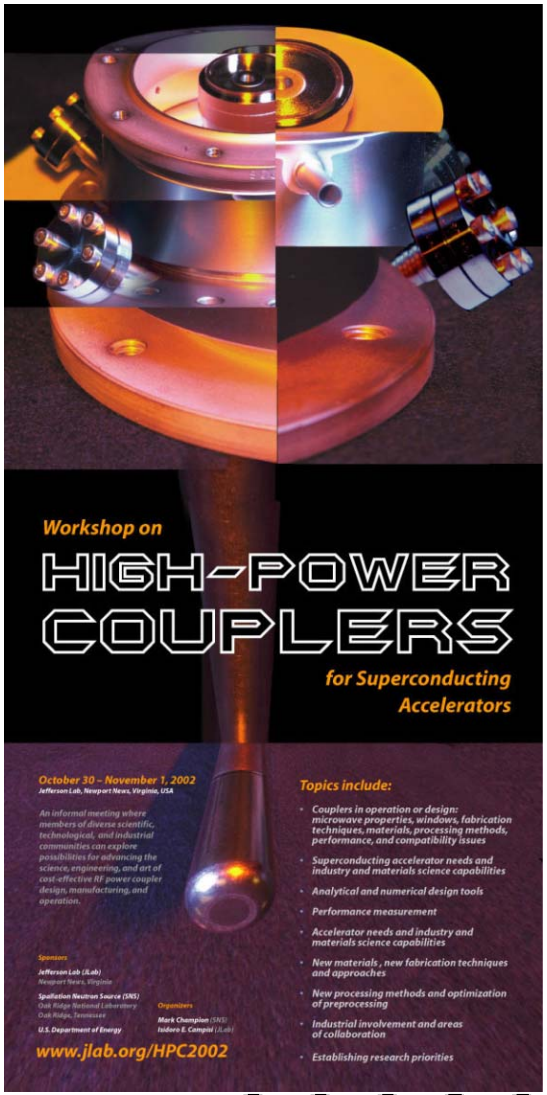
Being tested:
Reached over 350 kW peak (1.4 MW SW)



Conclusions

- Power couplers for superconducting cavities are very **complicated** structures which must perform at the limit in several technologies.
- In general, couplers are at least **as delicate and as expensive as cavities**.
- Great **progress** has been made in designing and implementing **new couplers** for different types of superconducting accelerators.
- Power levels in **excess of 1 MW** are now being achieved by several coupler designs on test stands.
- The technology is **mature** but it is now time address **cost** issues and **simplify manufacturing** methods.

Defining Future Needs and Technologies



Workshop on

HIGH-POWER COUPLERS

for

Superconducting Accelerators

Jefferson Lab

October 30-November 1, 2002

Addressing issues in technology and manufacturing

http://www.jlab.org/HPC2002