LA-UR-04-5180

ENGINEERING AND BUILDING RF STRUCTURES - THE WORKS

DALE SCHRAGE

LOS ALAMOS NATIONAL LABORATORY

THE FIELD HAS EVOLVED

- THINGS HAVE CHANGED DURING THE PAST 20+ YEARS
- THE PERFORMANCE REQUIREMENTS HAVE INCREASED
- WE HAVE BETTER TOOLS TO MEET THOSE NEEDS
  - ENGINEERING & PHYSICS CODES
  - HIGHER PERFORMANCE COMPUTERS

INCREASED PERFORMANCE REQUIRED

- **THE PERFORMANCE REQUIREMENTS OF ACCELERATOR CAVITIES HAVE CONTINUED TO INCREASE**
  - **HIGHER BEAM CURRENT**
  - **HIGHER DUTY FACTORS**
  - **HIGHER GRADIENTS**
  - **HIGHER BEAM & CAVITY POWER**
  - **LOWER EMITTANCE**

INCREASED PROGRAMMATIC PRESSURE

- **THERE IS INCREASED PRESSURE ON COST AND SCHEDULE**
- **WE HAVE TO SIMULTANEOUSLY DELIVER:**
  - **GOOD**
  - **FAST**
  - **CHEAP**
- **LITTLE TIME OR TREASURE FOR EXPERIMENTATION**

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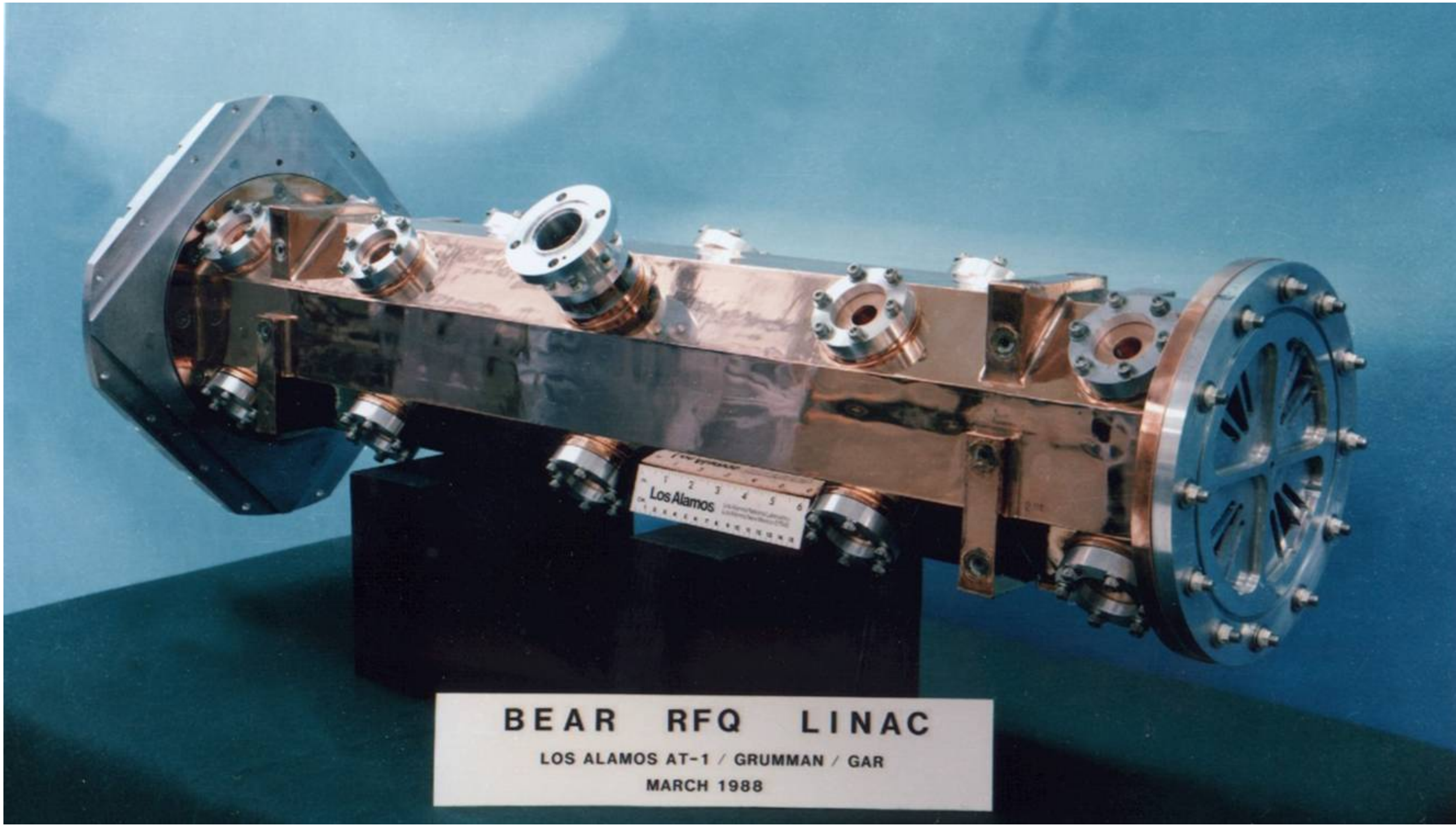
THE BEAR RFQ



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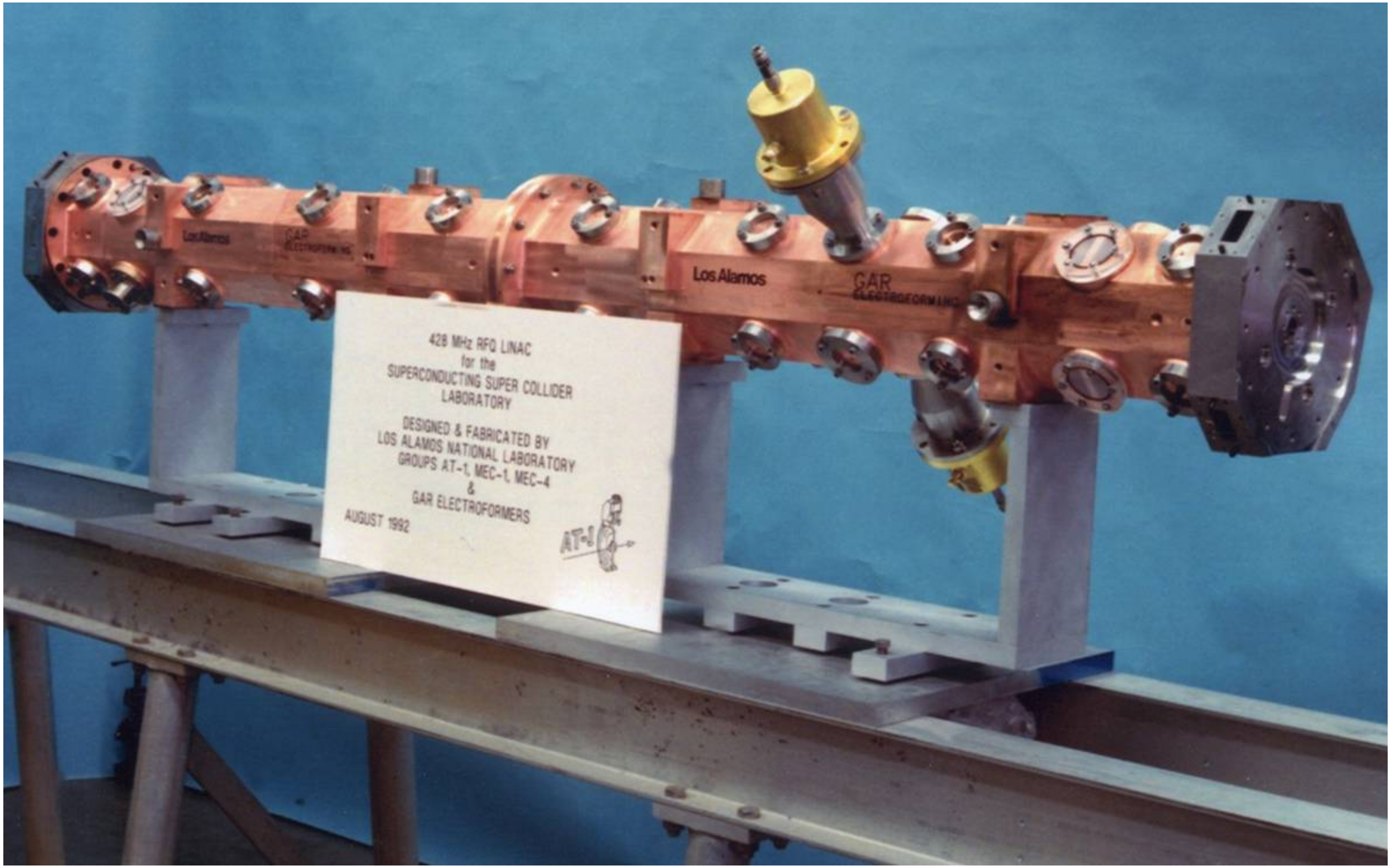
THE SSC RFQ



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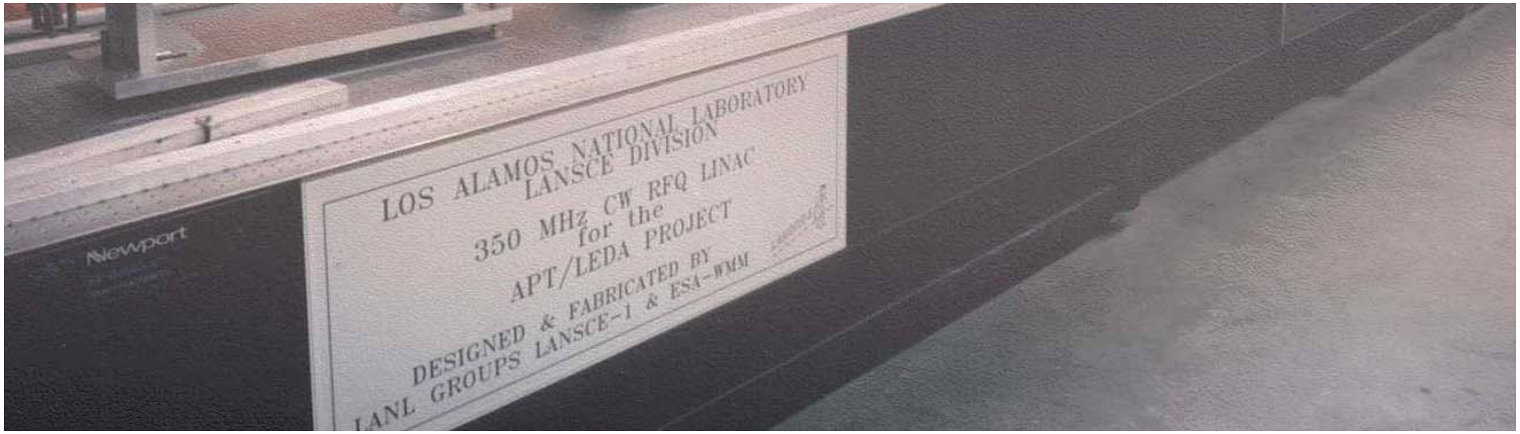
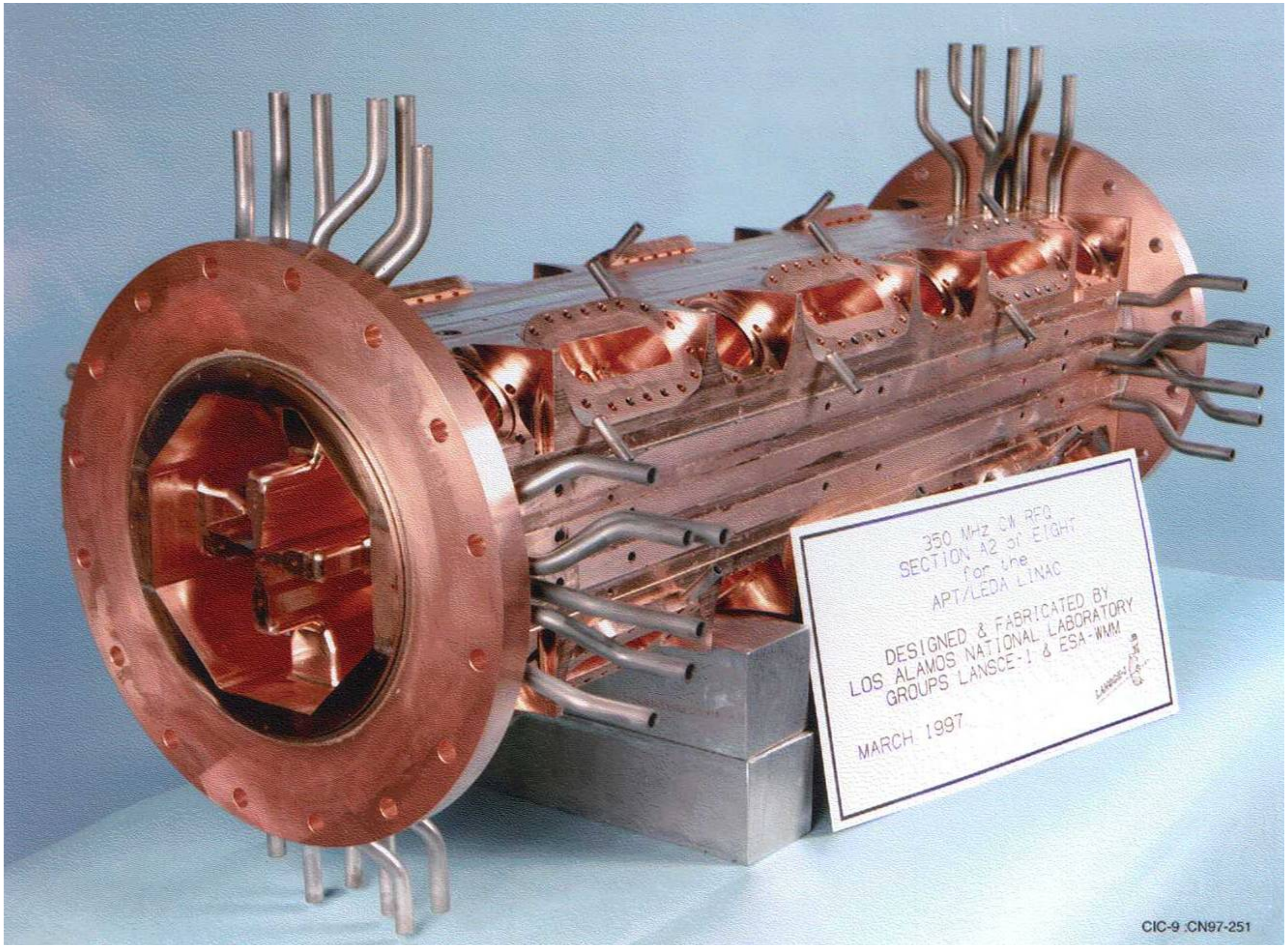
THE LEDA RFQ



LEDA RFQ SECTION



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NC CAVITY PERFORMANCE REQUIREMENTS HAVE INCREASED PRODUCING HIGHER THERMAL LOADS

	SSC 1992		LEDA 1995	
	DESIGN	OPERATED	DESIGN	OPERATED
DUTY FACTOR	0.05%	3%	CW	CW
ENERGY MeV	2.5	2.5	6.7	6.7
PEAK CURRENT mAmp	27	27	100	100
AVERAGE CURRENT mAmp	0.014	0.81	100	100
BEAM POWER kWatts	0.034	2	670	670
CAVITY POWER kWatts/meter	0.06	3.7	150	182
AVERAGE HEAT FLUX watt/cm^2	0.01	0.63	13	16
PEAK HEAT FLUX watt/cm^2	0.05	3.2	65	79

SC CAVITY PERFORMANCE REQUIREMENTS HAVE INCREASED PRODUCING HIGHER STRUCTURAL LOADS

- **CRYOMODULE GRADIENTS OF $\beta = 1$ PULSED ELLIPTICAL CAVITIES NOW APPROACH 40 Mvolts/Meter**
  - **LORENTZ FORCE DETUNING $\propto E^2$**
- **LOADED Q OF LOW-β CAVITIES NOW EXCEEDS 10^7**
  - **MICROPHONICS IS NOW A GREATER CONSIDERATION**

WE HAVE POWERFUL NEW TOOLS

- **2-D LINKED RF CAVITY-THERMAL-STRUCTURAL CODES**
- **3-D LINKED RF-CAVITY-THERMAL-FLUID DYNAMICS-STRUCTURAL CODES**

ABILITY TO CALCULATE

- **FREQUENCY SHIFTS DUE TO:**
  - **RF THERMAL LOADS**
  - **VACUUM LOADS**
  - **LORENTZ FORCE**
- **MECHANICAL RESONANT FREQUENCIES**
- **TUNING SENSITIVITIES**
- **RF FIELD DISTRIBUTIONS DUE TO CAVITY DEFORMATIONS**

2-D CODES FOR CAVITIES

- **THE FREQUENCY SHIFTS ARE CALCULATED BY CONVOLVING THE SLATER PERTURBATION FREQUENCY SHIFTS AT EACH SUPERFISH NODE WITH THE NODAL DISPLACEMENTS FROM THE STRUCTURAL ANALYSIS**
- **RUNNING SUPERFISH WITH DISPLACED GEOMETRY WOULD YIELD LOWER ACCURACY**
- **Q/A CHECK IS TO CALCULATE THE FREQUENCY SHIFT DUE TO A FREE THERMAL EXPANSION OF THE CAVITY**

2-D CODES FOR CAVITIES

- **2D & AXISYMMETRIC RF CAVITY CODE (SUPERFISH) LINKED TO COMMERCIAL FINITE ELEMENT STRUCTURAL/THERMAL CODE (COSMOS/M)**

2-D CODES FOR CAVITIES

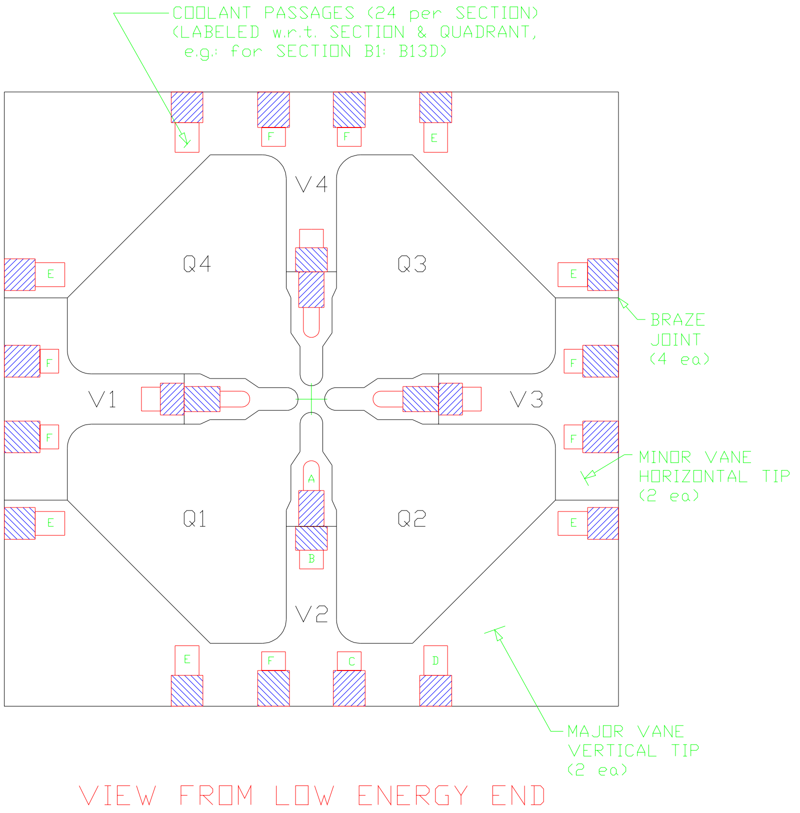
- **OUTPUT FILES OF THESE CODES ARE IN ASCI FORMAT AND CAN BE READ BY FORTRAN AND C PROGRAMS**
- **PROGRAMS CAN BE RUN FROM COMMAND LINE SO HIGH LEVEL CODE CAN BE WRITTEN FOR SUCH THINGS AS ITERATIVE SOLUTION FOR COOLANT TEMPERATURE**

2-D CODES FOR CAVITIES

FOR ANALYSIS OF NORMAL CONDUCTING CAVITIES:

1. **RUN RF ANALYSIS**
2. **RUN CAVITY THERMAL ANALYSIS WITH RF THERMAL LOADS**
3. **RUN STRUCTURAL ANALYSIS WITH THERMAL LOADS**
4. **CALCULATE FREQUENCY SHIFT**

2-D CODES USED TO DETERMINE COOLANT PASSAGE SIZES & LOCATIONS



2-D CODES FOR CAVITIES

FOR ANALYSIS OF SUPERCONDUCTING CAVITIES:

1. **RUN RF ANALYSIS**
2. **RUN STRUCTURAL ANALYSIS SEPARATELY WITH LORENTZ FORCE PRESSURE, VACUUM LOAD, & END DISPLACEMENT OR FORCE**
3. **CALCULATE LORENTZ FORCE DETUNING, BCP FREQUENCY SHIFT, VACUUM FREQUENCY SHIFT, AND TUNING SENSITIVITY**

2-D CODES FOR SUPER-CONDUCTING CAVITIES

- **INFN/MILANO HAS DEVELOPED A LINKED 2-D CODE FOR SUPERFISH AND ANSYS ANALYSIS OF SINGLE- & MULTI-CELL ELLIPTICAL CAVITIES**
- **CODE IS INTERFACED TO A DATABASE THAT FACILITATES PARAMETRIC STUDIES TO OPTIMIZE CAVITY GEOMETRY**
- **USED TO DESIGN THE SNS SC CAVITIES**

3-D CODES FOR CAVITIES

- **COMMERCIAL 3D RF CAVITY CODE LINKED TO FINITE ELEMENT STRUCTURAL, THERMAL, & CFD MODULES**
- **THERE IS A CODE GROUP AVAILABLE FROM SRAC (MICAV & COSMOS/M) AND ONE FROM ANSYS (ANSYS)**
- **BOTH CODE GROUPS CAN ALSO BE USED FOR 2-D AND AXI-SYMMETRIC CAVITIES**

3-D CODES FOR CAVITIES

- **A SINGLE SOLID MODEL, CREATED USING A CAD SYSTEM (UNIGRAPHICS, PRO-ENGINEER, etc), IS USED FOR BOTH THE PHYSICS DESIGN AND ENGINEERING ANALYSIS OF THE CAVITY**
- **THIS IS A SIGNIFICANT ADVANTAGE IN MODELING SPEED AND QUALITY ASSURANCE**
- **THE MODEL CAN LATER BE USED TO GENERATE THE MANUFACTURING DRAWINGS**

BENCHMARKING OF CODES

ANALYSIS OF THE ANL β = 0.34, 2-GAP CAVITY DEMONSTRATED THAT THE 3-DIMENSIONAL CAVITY CODES HAVE VERY GOOD AGREEMENT

	MAFIA	STAR	MICAV	MWS	ANSYS	MEAS.
Freq MHz	340.01	340.50	340.33	340.56	340.77	339.70
Q_o	4621	4694	4799	4554	4463	4815
TTF	0.905	0.906	0.900	0.905	0.886	N/A

3-D CODES PROCEDURE

- **GENERATE MODEL**
- **MESH CAVITY VOLUME & STRUCTURAL VOLUME**
  - **CAVITY & STRUCTURAL NODES MERGE AT CAVITY WALL**
- **RUN RF ANALYSIS**
- **RUN THERMAL ANALYSIS (IF NORMAL CONDUCTING**
- **RUN STRUCTURAL ANALYSIS**
- **EXPORT CAVITY WALL DISPLACEMENTS TO CAVITY MESH**
- **RUN RF ANALYSIS FOR FREQUENCY SHIFT**

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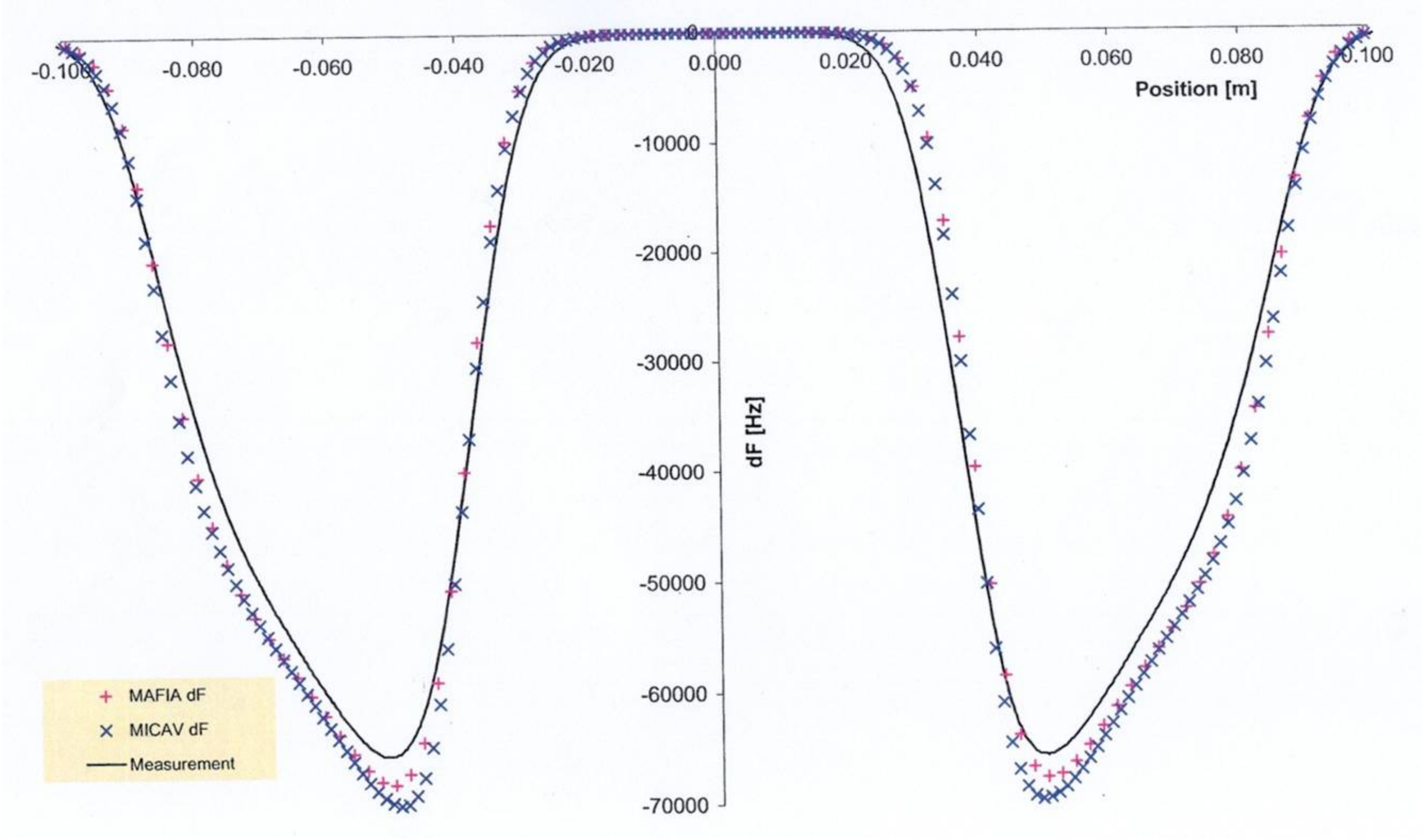
COMPARISON OF MAFIA, MICAV, AND ACTUAL BEADPULL OF ANL β = 0.34 SPOKE CAVITY



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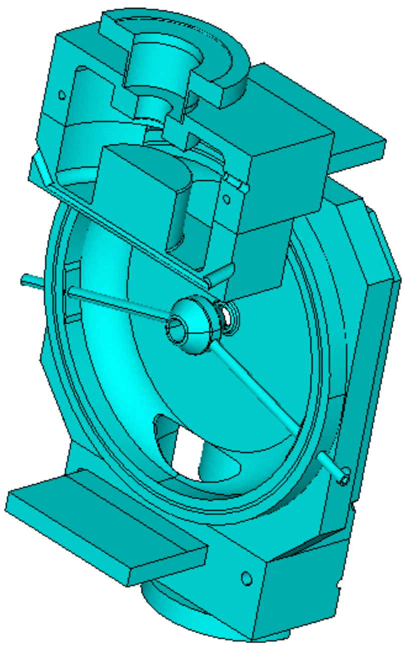
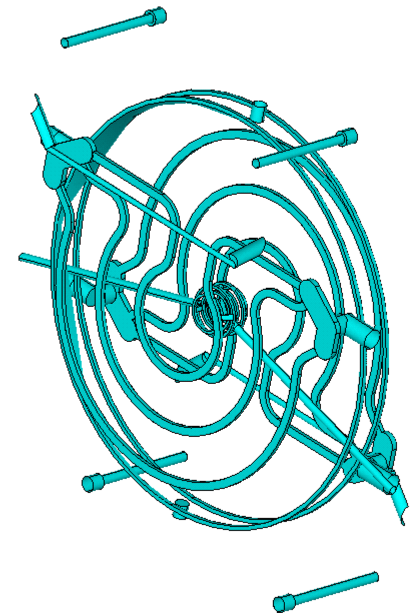
LINKED CFD/THERMAL ANALYSIS



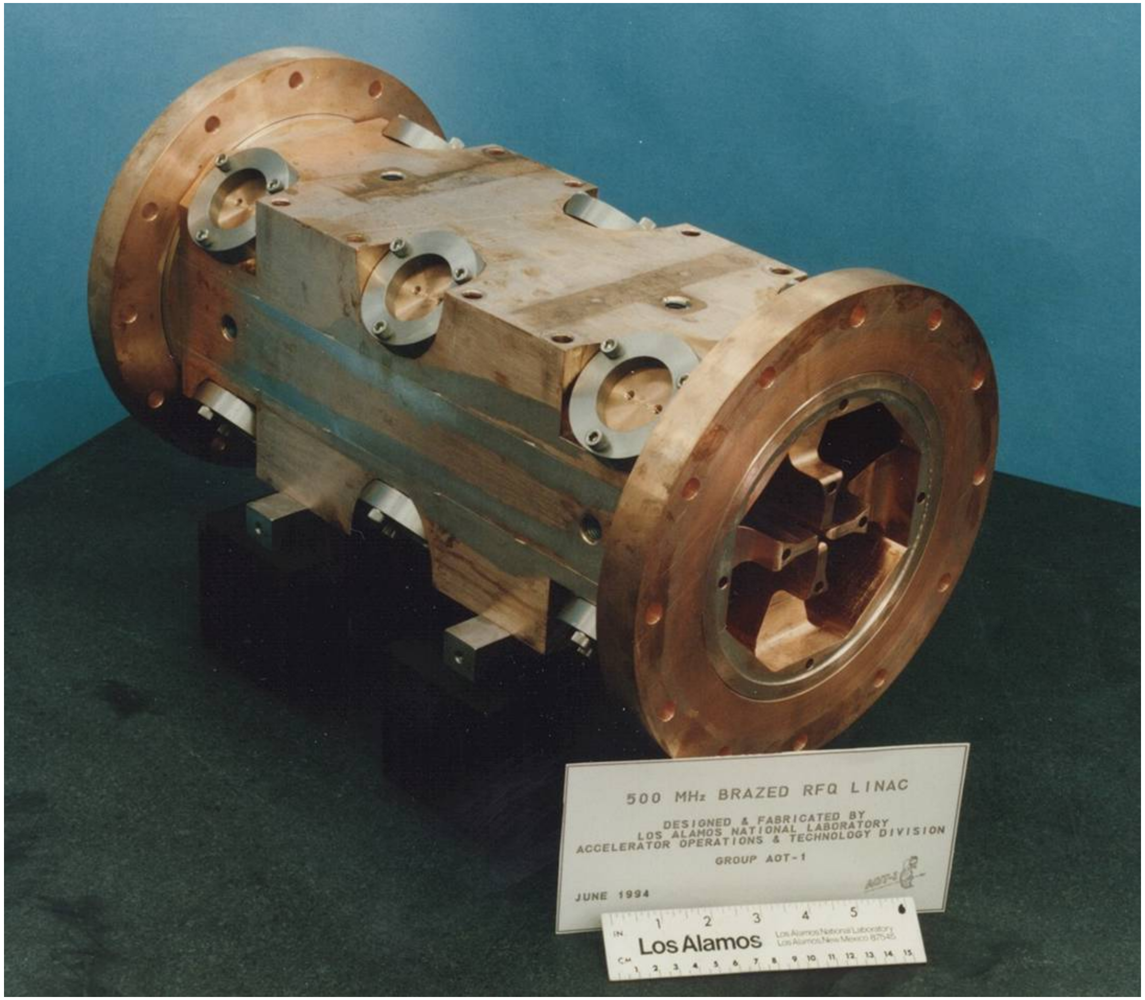


APT/LEDA CCDTL CAVITY COURTESY OF AES

PROBLEMS WITH 3-D CODES

- **SMALL MARKET**
  - **CODE VENDORS MAY BE NON-RESPONSIVE TO BUGS**
- **OCCASIONAL DIFFICULTIES IN EXCHANGE TO/FROM CAD SYSTEMS**

CW RFQ ENGINEERING MODEL



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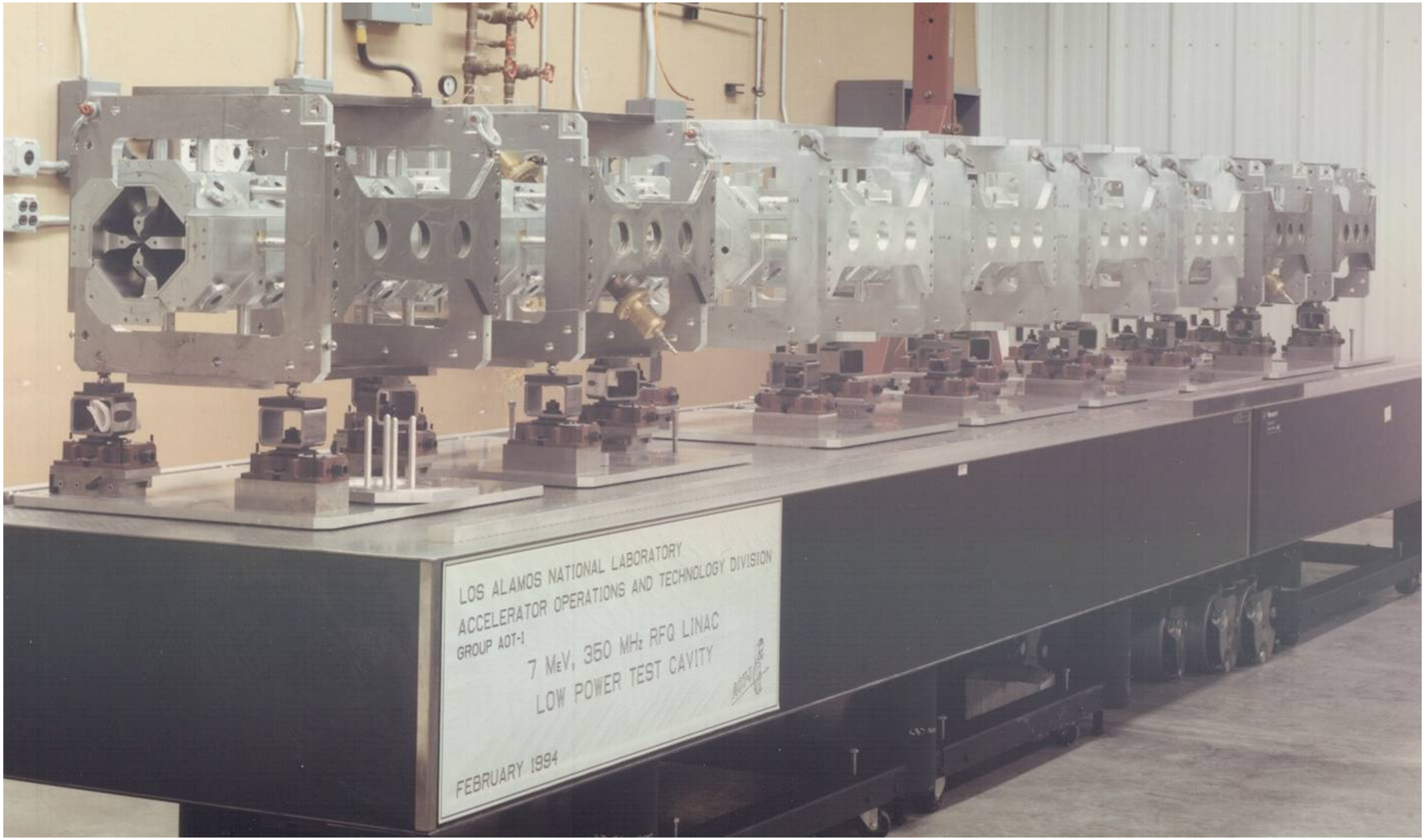
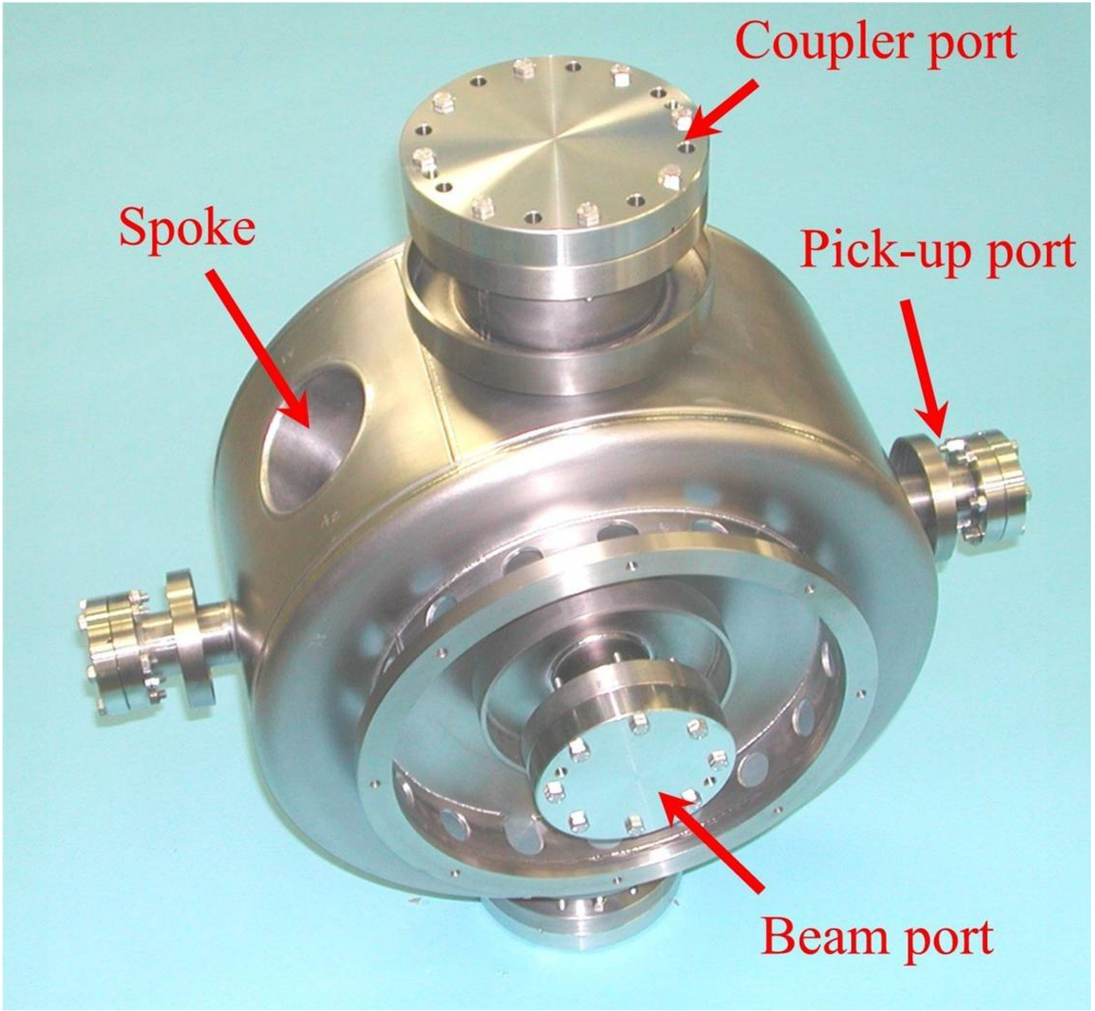
RFQ COLD MODEL



LANSCE-1

β = 0.175 SPOKE CAVITY



CONCLUSIONS

- **LINKED RF CAVITY/THERMAL/CFD, STRUCTURAL CODES ARE AVAILABLE FROM COMMERCIAL SOURCES**
- **THEY REDUCE THE COST OF DEVELOPMENT OF NEW HIGH-POWER & HIGH GRADIENT ACCELERATORS**

ACKNOWLEDGEMENTS

- **Frank Krawczyk of LANL/LANSCE-1**
- **Richard LaFave formerly LANL**
- **Tom Schultheiss of Advanced Energy Systems**
- **Rick Wood of LANL/LANSCE-1**
- **Lloyd Young of TechSource**