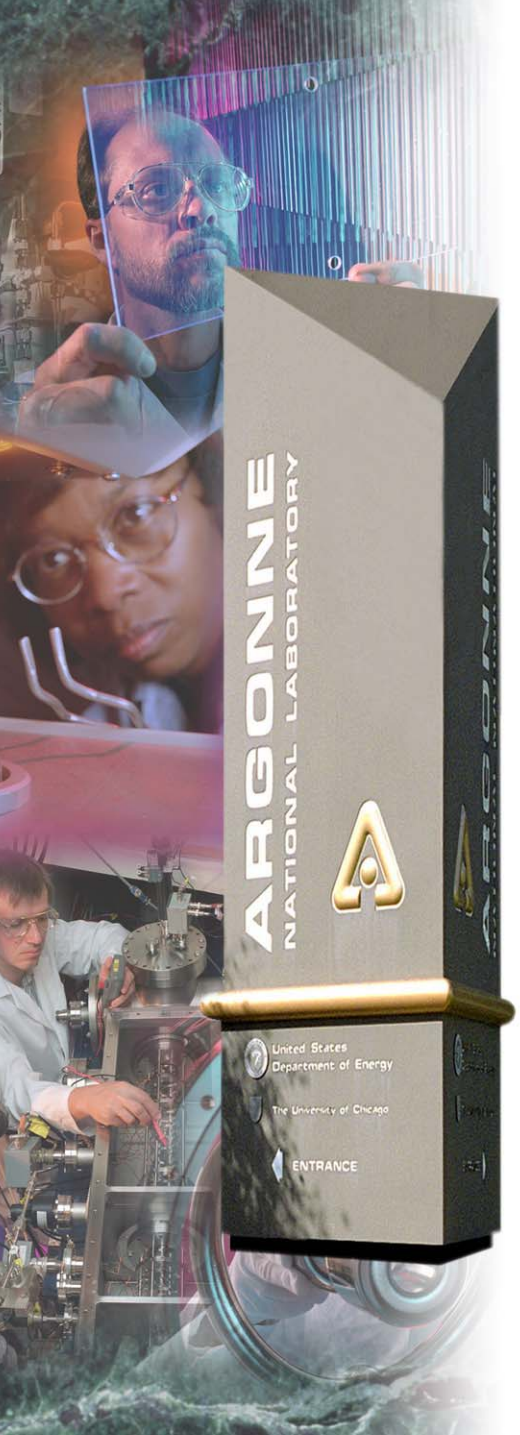


ANL Updates to the RIA Baseline Design

Presented at the ***RIA Workshop 2003***
Bethesda, Maryland
August 26, 2003

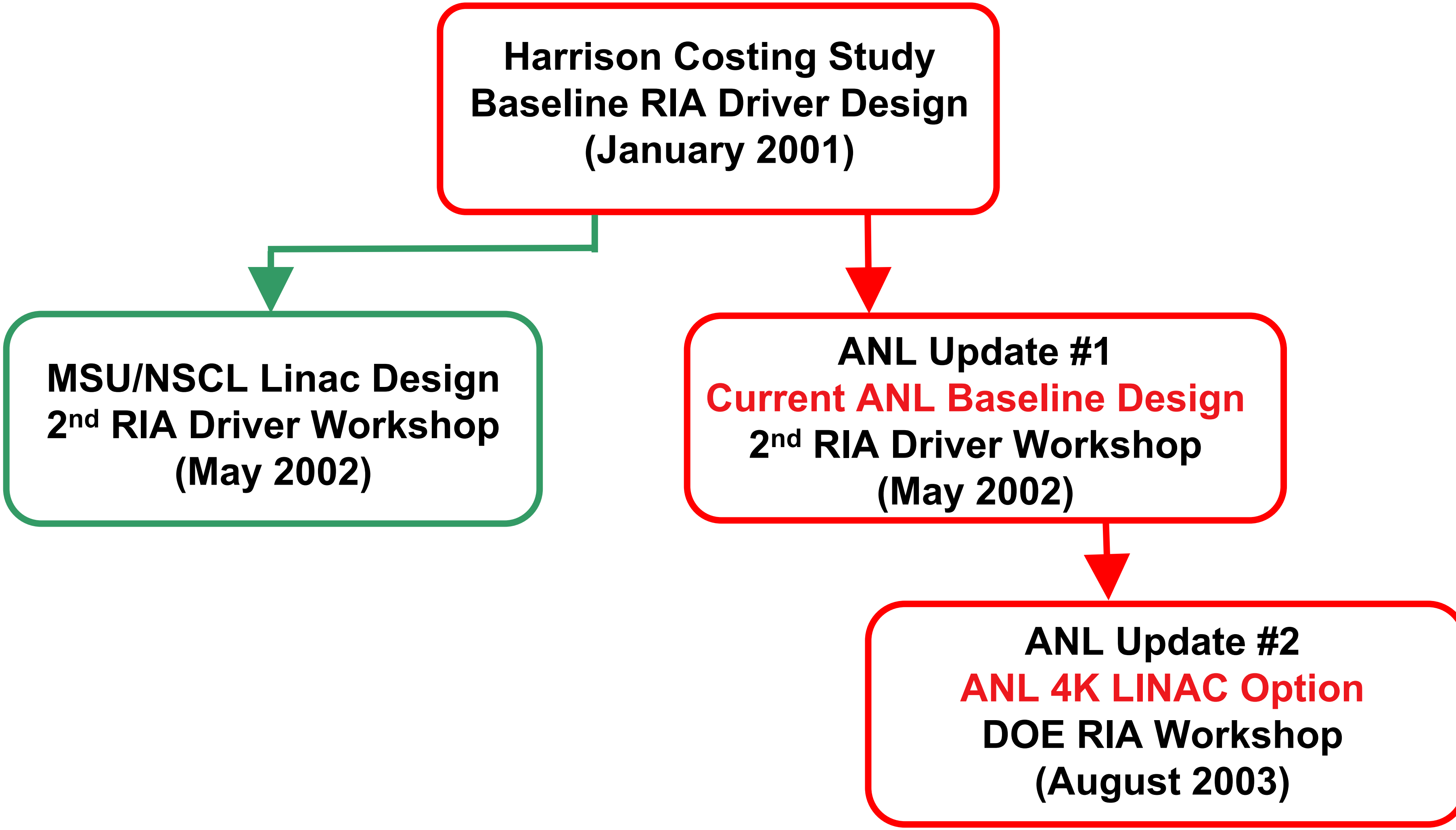
Kenneth W. Shepard
Physics Division

Argonne National Laboratory

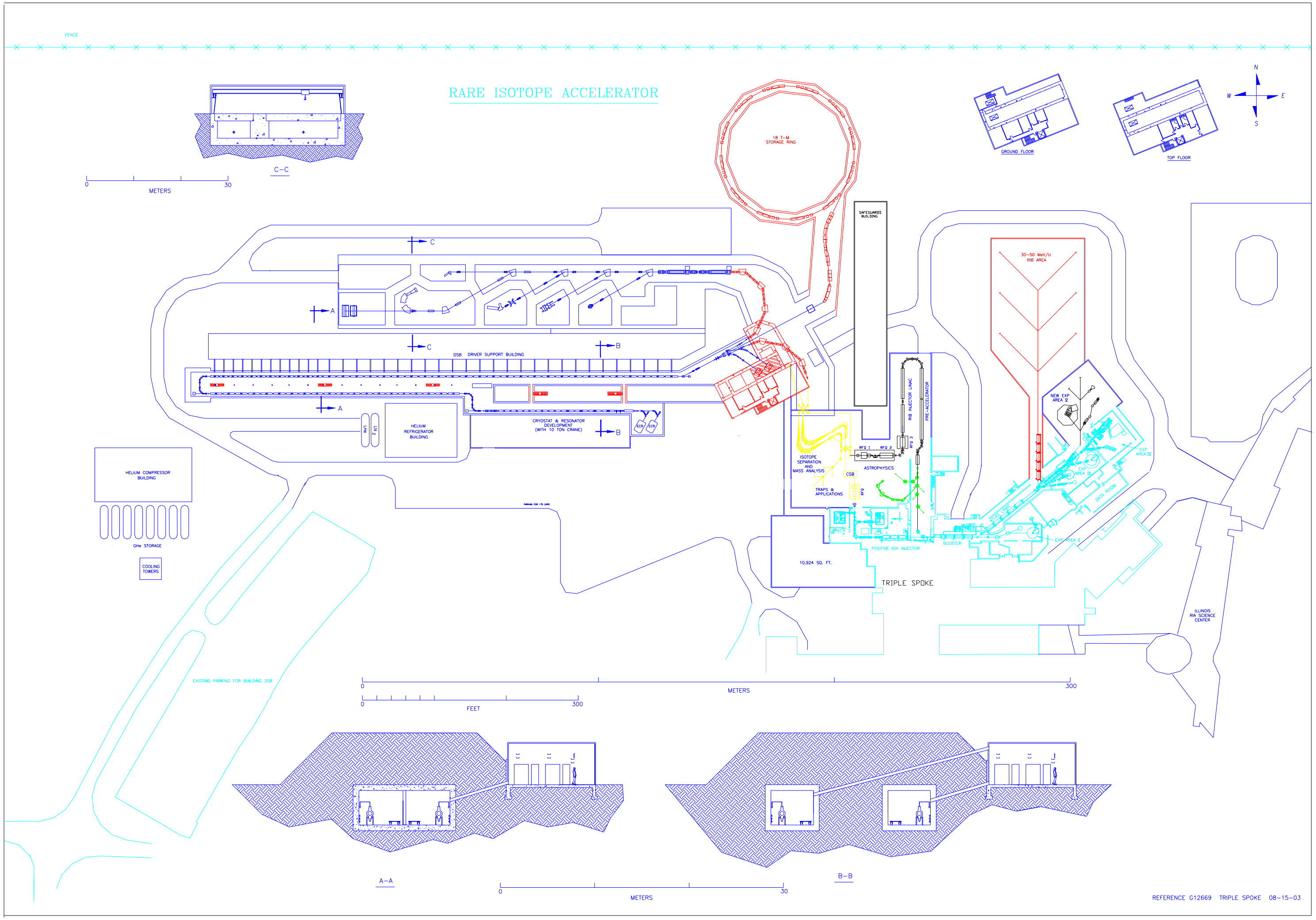
Office of Science
U.S. Department of Energy

A U.S. Department of Energy
Office of Science Laboratory
Operated by The University of Chicago

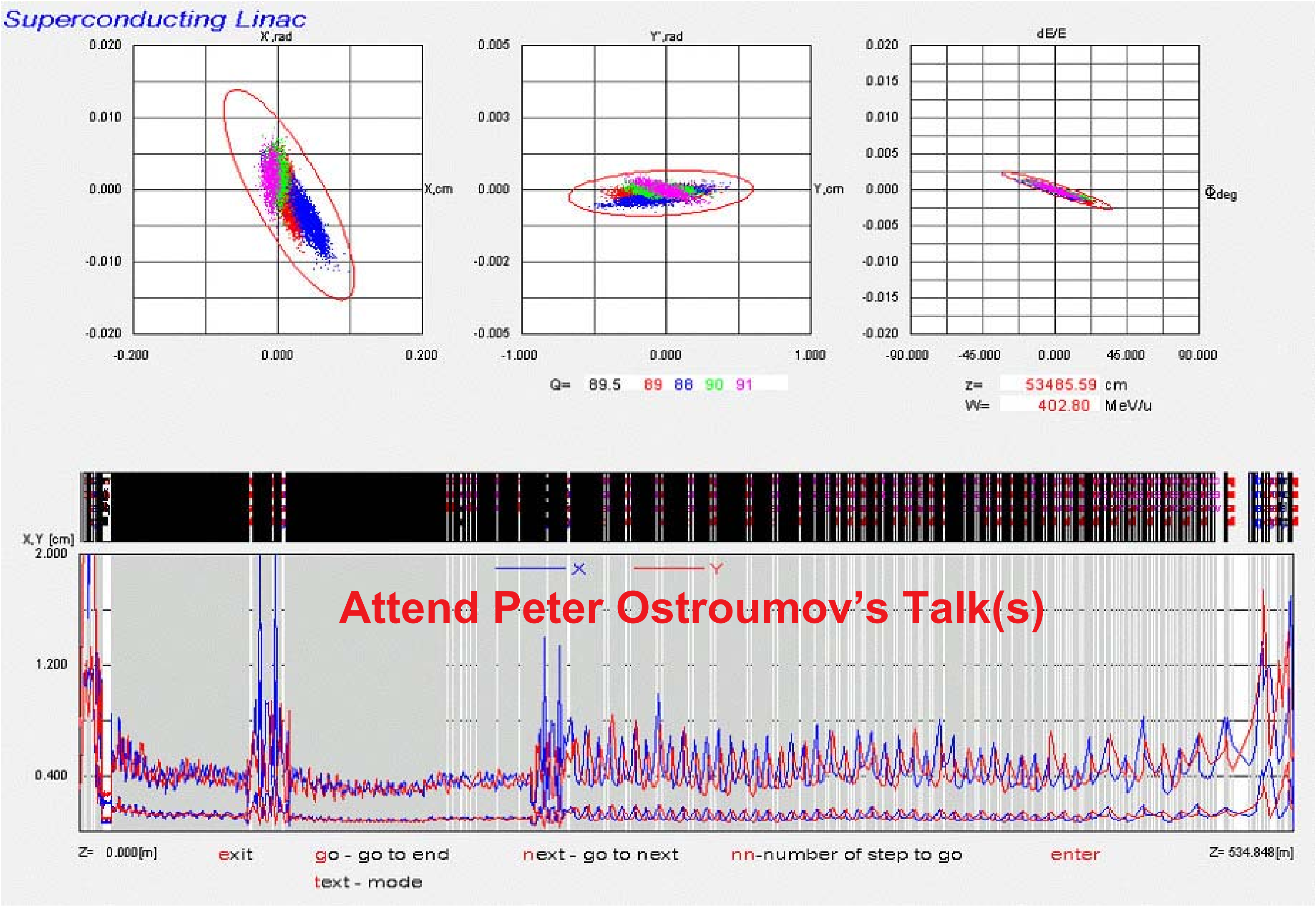
Updates reflect ongoing R&D-driven assessment of risks and opportunities



Much work will be reported on all systems – This talk focusses on the driver linac



Design based on full end-to-end 3D simulation of beam dynamics from ECR source to Target



TRACK CODE (complete and comprehensive)

1) Integration of particle trajectories of multi-component ion beams in 6D phase space.
2) Electrostatic, magnetostatic and electromagnetic fields of all RIA elements are obtained from 3-dimensional external codes.
3) Misalignments and random errors are included. Beam steering procedure is applied in the linac with misaligned components.
4) Space charge of multiple component ion beams is obtained from 3D Poisson equation.
5) Beam passage through stripping foils&films is included, SRIM data of particle distribution in 6D phase space is incorporated.
6) Parallel computing on multiprocessor computer cluster JAZZ at ANL.
7) Simulation of total 10^7 particles in 15 hours is demonstrated.

RIA Beam Dynamics at ANL

11:00 ***Driver Linac Beam Dynamics***, **P.N. Ostroumov**

11:15 ***Large Scale Computing for Beam Dynamics Simulations and Target Modeling***, **B. Mustapha**

10:25 ***Multiple-Charge-State-Beam Steering in the RIA Driver Linac***, **E. S. Lessner**

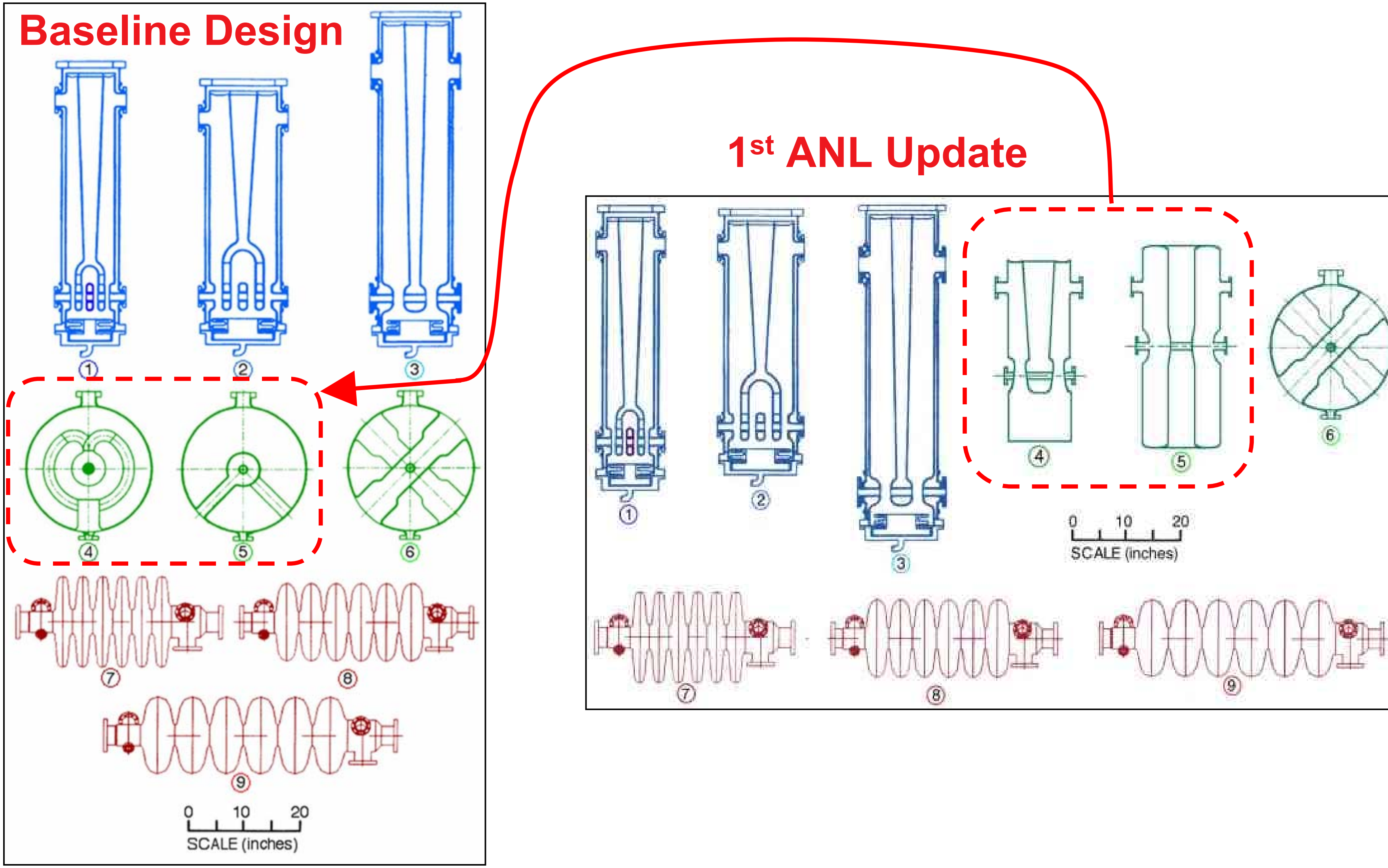
11:30 ***Front End of the RIA Driver Linac***, **P.N. Ostroumov**

16:35 ***Development of a Low Charge-to-Mass Ratio Post-Accelerator for the RIA Project***, **P.N. Ostroumov**

First ANL Update (Second RIA Driver Workshop):

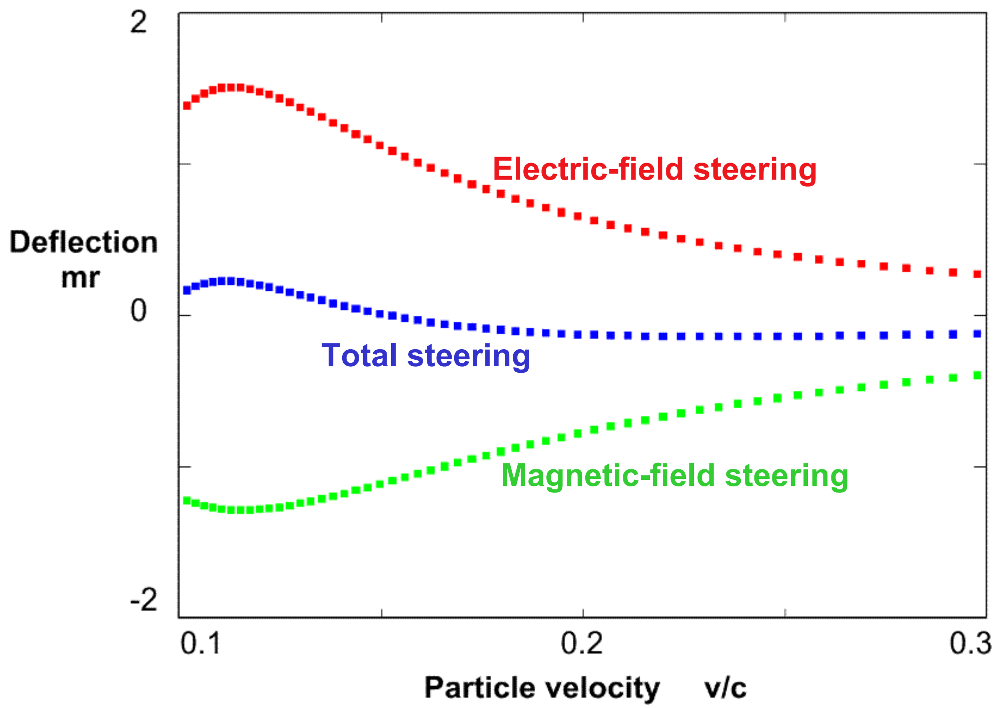
1. Both the 1st and 2nd updates involve just the driver linac
2. Two changes were made in the 1st update:
   a) Replace 2-drift-tube cavities with 1-drift-tube cavities to eliminate rf magnetic steering and reduce peak surface magnetic field (increased cavity count)
   b) Change specified performance for drift-tube cavities from E_{acc} = 4-5 MV/m to E_{pk} = 20 MV/m (decreased cavity count)

Change two cavity types to eliminate steering and increase accelerating gradient

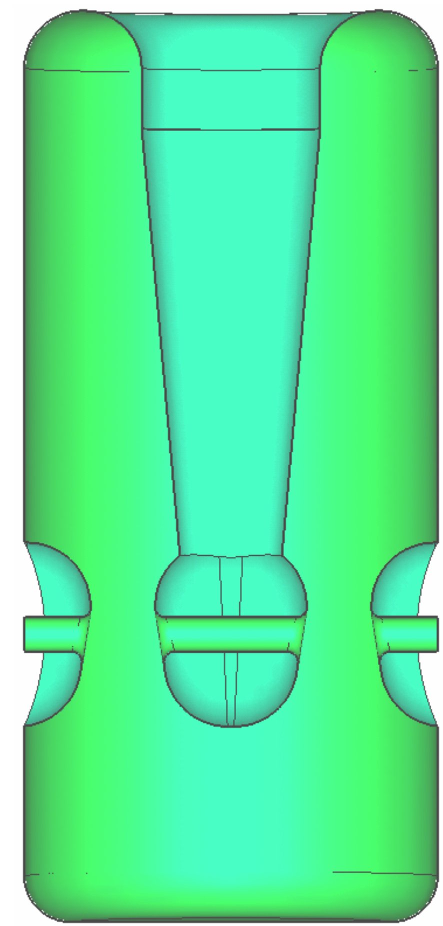


RF magnetic field steering

Steering can be effectively eliminated in single drift-tube QWR's by shaping the drift-tube to introduce appropriate transverse RF electric fields



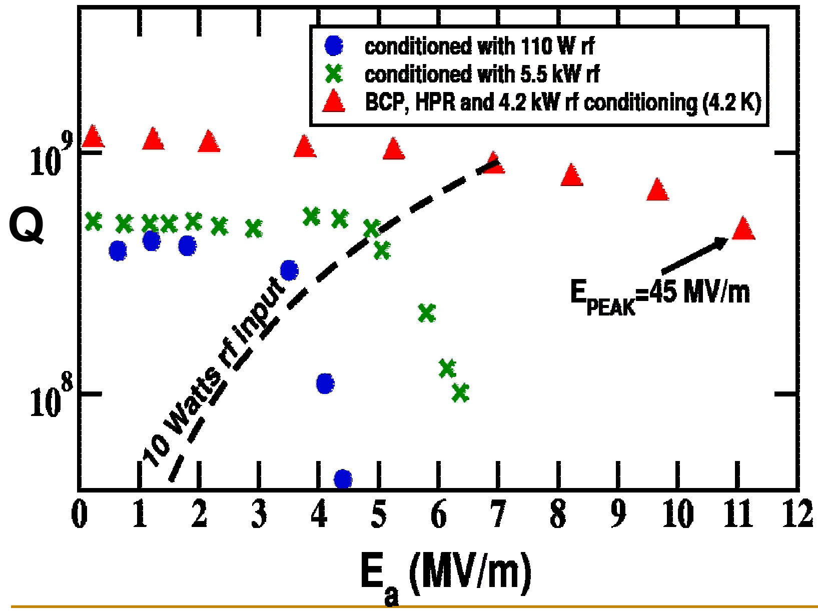
Steering of proton beam in operation at 5 MV/m and –30 degrees synchronous phase



115 MHz QWR

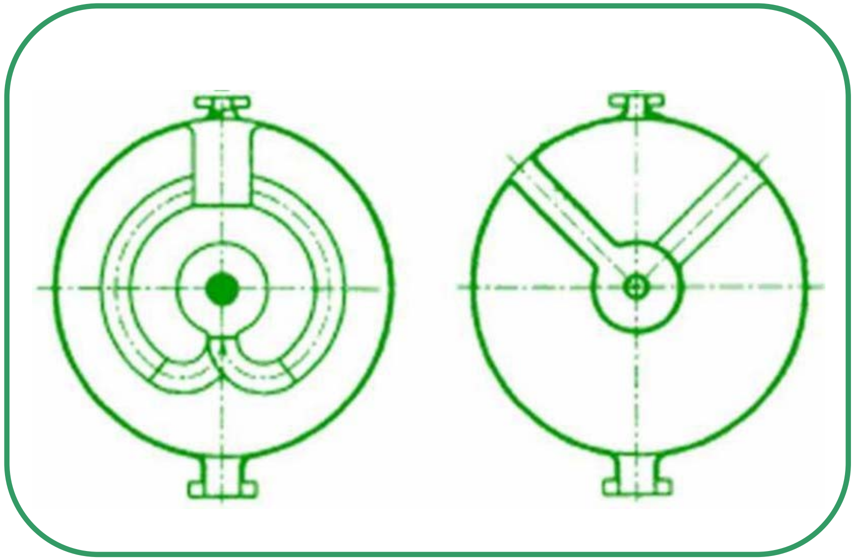
High-pressure water rinsing gives a dramatic improvement in performance

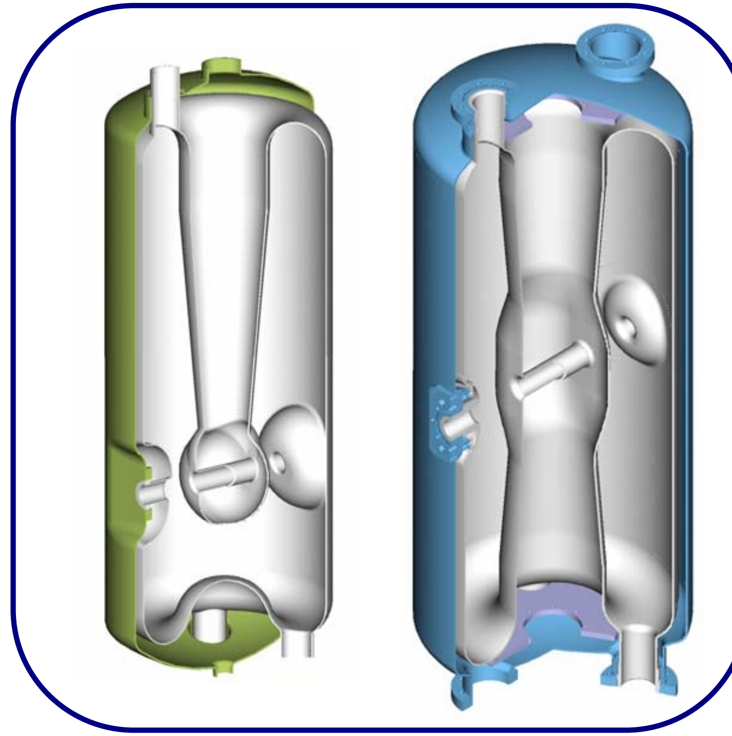
Mike Kelly's talk will detail cavity processing and test results



Excellent performance of drift-tube cavities at 4.2 K is consistent and repeatable when the cavity is kept clean (April 2001)

Changed cavity parameters





Freq (MHz)	Type	β	Length (cm)	RF Energy (mJ)	Epk (MV/m)	Bpk (A/m)	QRs (ohm)	R/Q (ohm)
115	Split-ring	0.13	36	165	3.9	190	22	1087
	QWR	0.15	25	177.9	3.2	58	40	486
172.5	Lollipop	0.19	36	127	3.5	144	47	942
	HWR	0.26	30	345.2	2.9	78	58	241

ANL 1st Update: Driver Linac Cavity List

Type	Freq (MHz)	Length (cm)	Eacc (MV/m)	Voltage (MV)	Number of Cavities	
3 DT	57.5	18	4.0	0.62	2	2
3 DT	57.5	26	4.0	0.90	5	5
1 DT	57.5	20	5.0	0.87	32	
			6.8	1.17		28
2 DT	115.0	36	4.0	1.25	40	
1 DT	115.0	25	6.3	1.43		48
2 DT	172.5	36	5.0	1.56	72	
1 DT	172.5	30	6.9	1.79		80
2 DT	345.0	36	5.0	1.56	96	
			6.0	2.07		56
6 Cell	805.0	55	8.1	3.67	76	54
6 Cell	805.0	68	10.2	5.99	84	88
6 Cell	805.0	91	12.6	9.85	28	32
		Total Number of Cavities =			435	393

Increase Emax 14%

Change Cavity Type

Baseline → 435

Update #1 → 393

Output energies for a few ion species

RIA Driver Linac - Beam Parameters

(Assumes 80% bunching efficiency, 3.9% energy loss in second stripper, 1998 ECR performance extrapolated to lower charge states)

Species	Ion Source		1st Stripper		2nd Stripper		OUTPUT	
	Q	I	Energy	Qstrip	Energy	Qfinal	Energy	Power
		pmicroA	MeV/A		MeV/A		MeV/A	kW
H	1	548	70.7	-	268.3	-	912	400
He^{3}	2	233	52.4	-	198.6	-	716	400
D	1	423	42.2	-	159.2	-	590	400
O^{18}	6	58	30.8	8.0	139.0	-	537	400
Kr^{86}	14	16	16.5	34-35	116.9	36.0	497	400
U^{238}	28-29	2	12.1	74.5	88.2	88-91	407	110

Hardware Development at ANL

14:00 ***Medium Beta Cavity and Cryomodule Prototyping for RIA*, J.D. Fuerst**

14:15 ***Cavity Development for RIA*, M.P. Kelly**

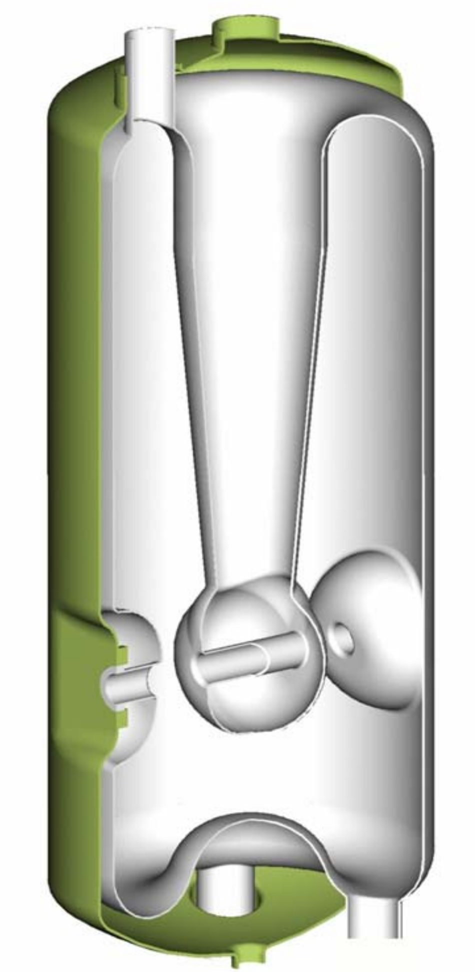
15:50 ***RF Coupler and Tuner Design for the RIA Superconducting Cavities*, G.P. Zinkann**

12:15 ***Progress with the Room Temperature Structures for the RIA Linacs*, N.E. Vinogradov**

16:50 ***Driver and RIB Linac Diagnostics and Beam Tuning*, R.C. Pardo**

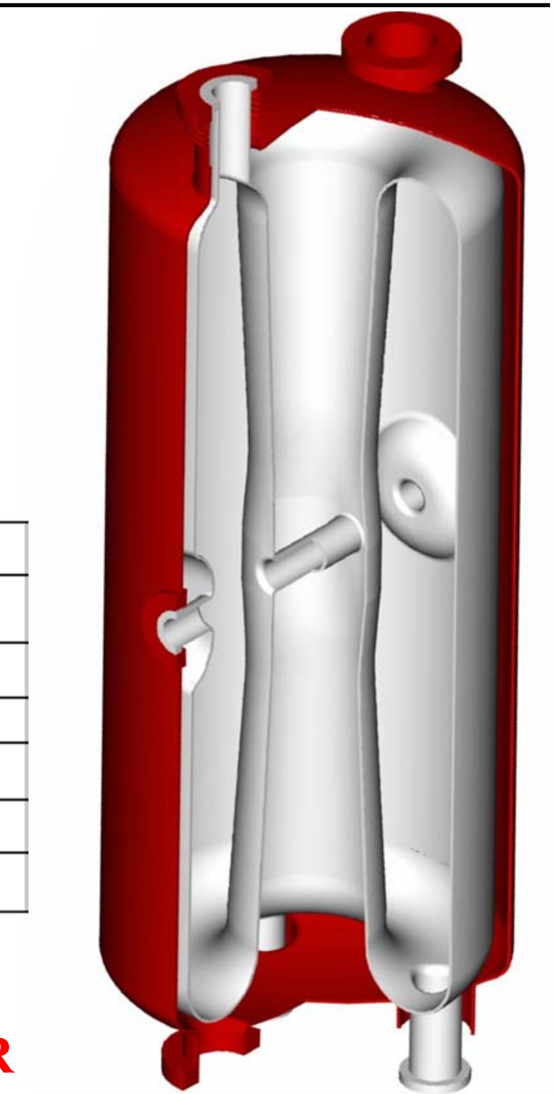
Intermediate-velocity cavities for RIA

115 MHz QWR



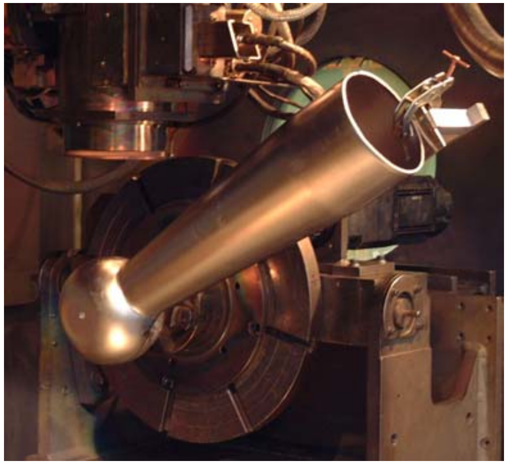
QR_S =	42
β_{Geom} =	0.15
Eff. Length =	25 cm
At 1 MV/m	
RF Energy =	170 mJ
E_{peak} =	3.17 MV/m
B_{peak} =	57 G

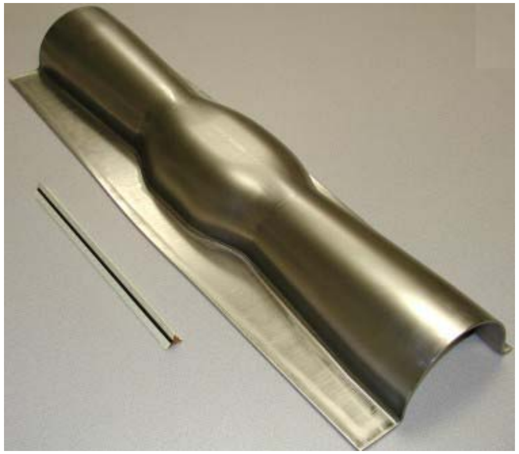
QR_S =	58
β_{Geom} =	0.26
Eff. Length =	30 cm
At 1 MV/m	
RF Energy =	345 mJ
E_{peak} =	2.9 MV/m
B_{peak} =	78 G



172.5 MHz HWR

Prototype niobium β=0.26 half-wave and β=0.15 QWR near completion

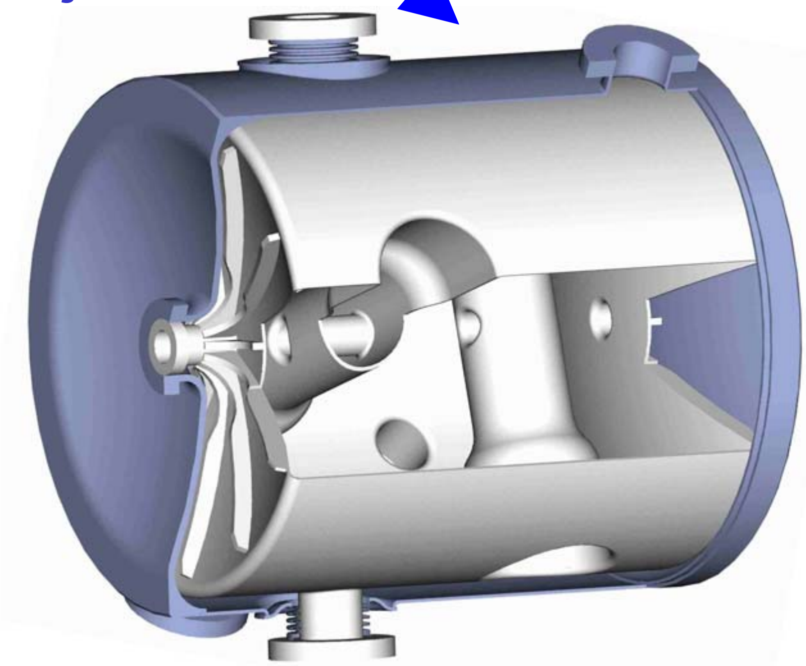




Prototype 345 MHz $\beta = 0.4$ double-spoke cavity has been completed and tested

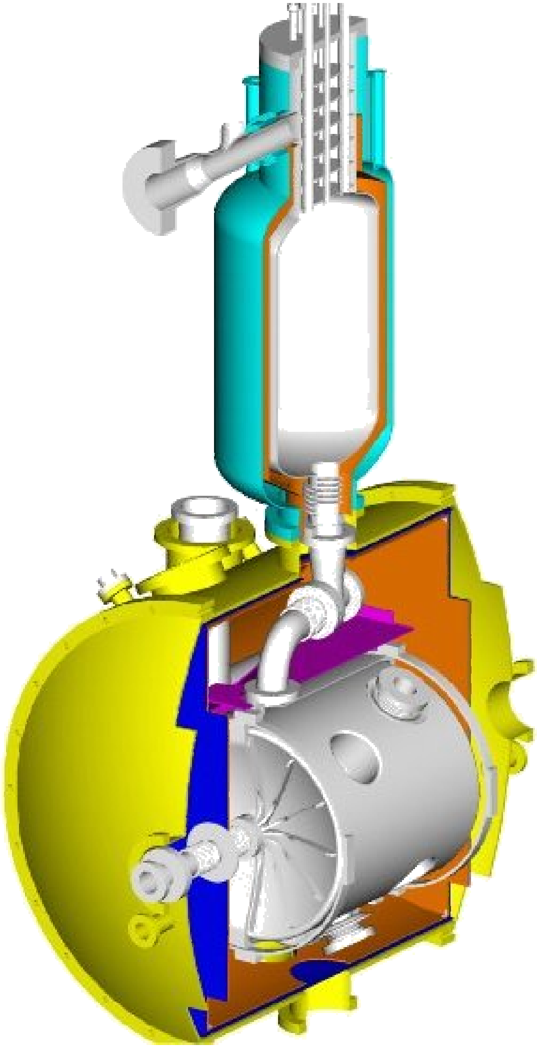
Niobium shell after EP

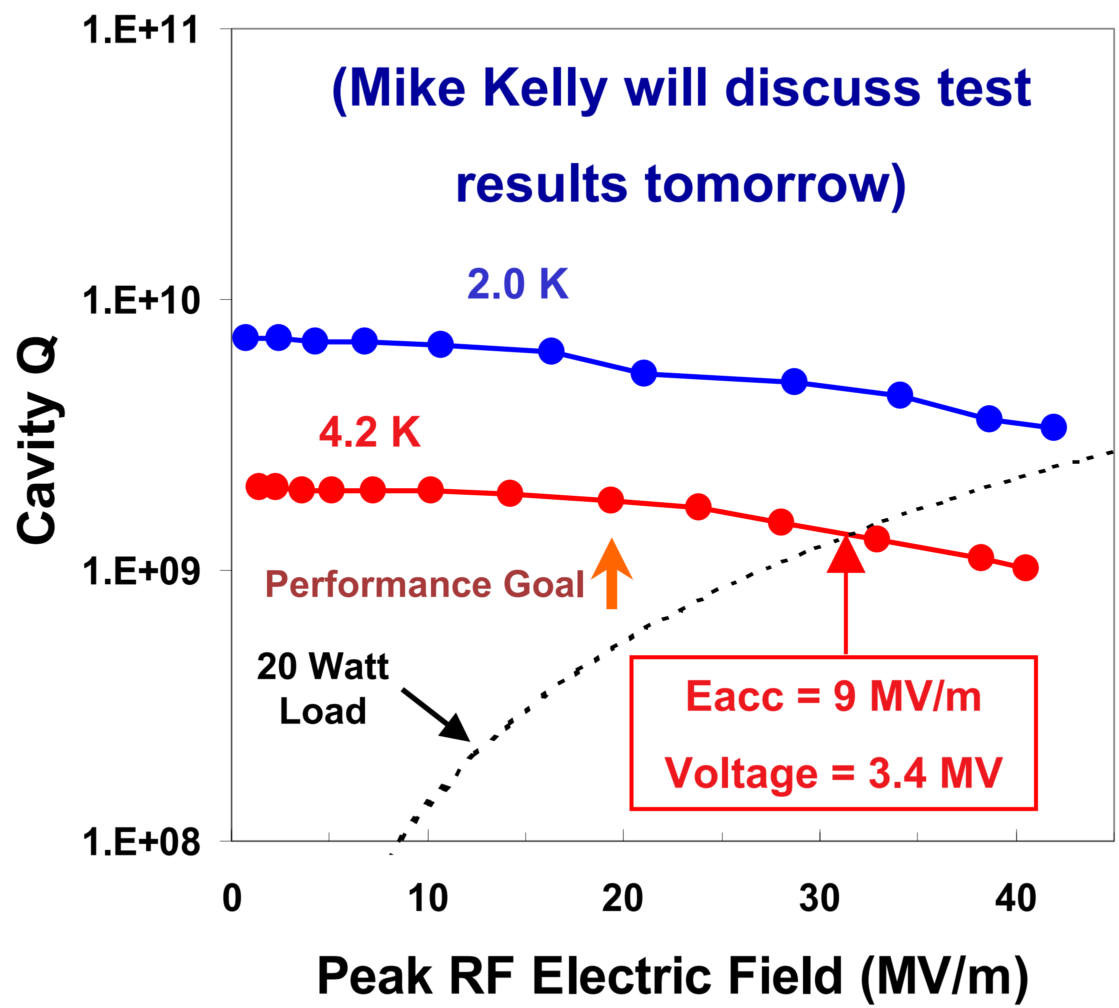
Completed cavity includes integral stainless-steel helium jacket



QR_S =	71
β_{Geom} =	0.393
Eff. Length =	38.1 cm
At 1 MV/m	
RF Energy =	151 mJ
E_{peak} =	3.47 MV/m
B_{peak} =	69 G

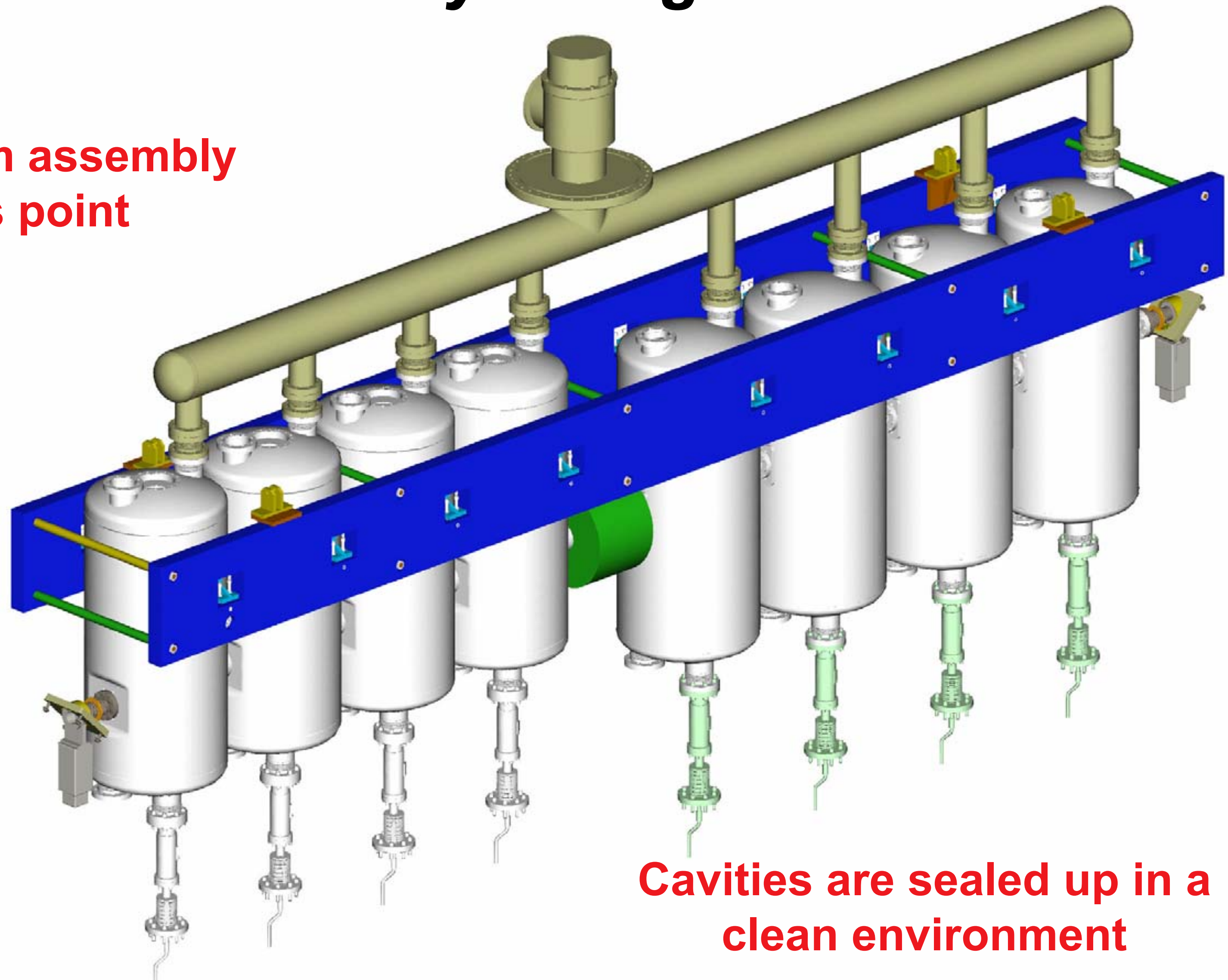
Recent test results for the fully-jacketed, 345 MHz Double-spoke cavity





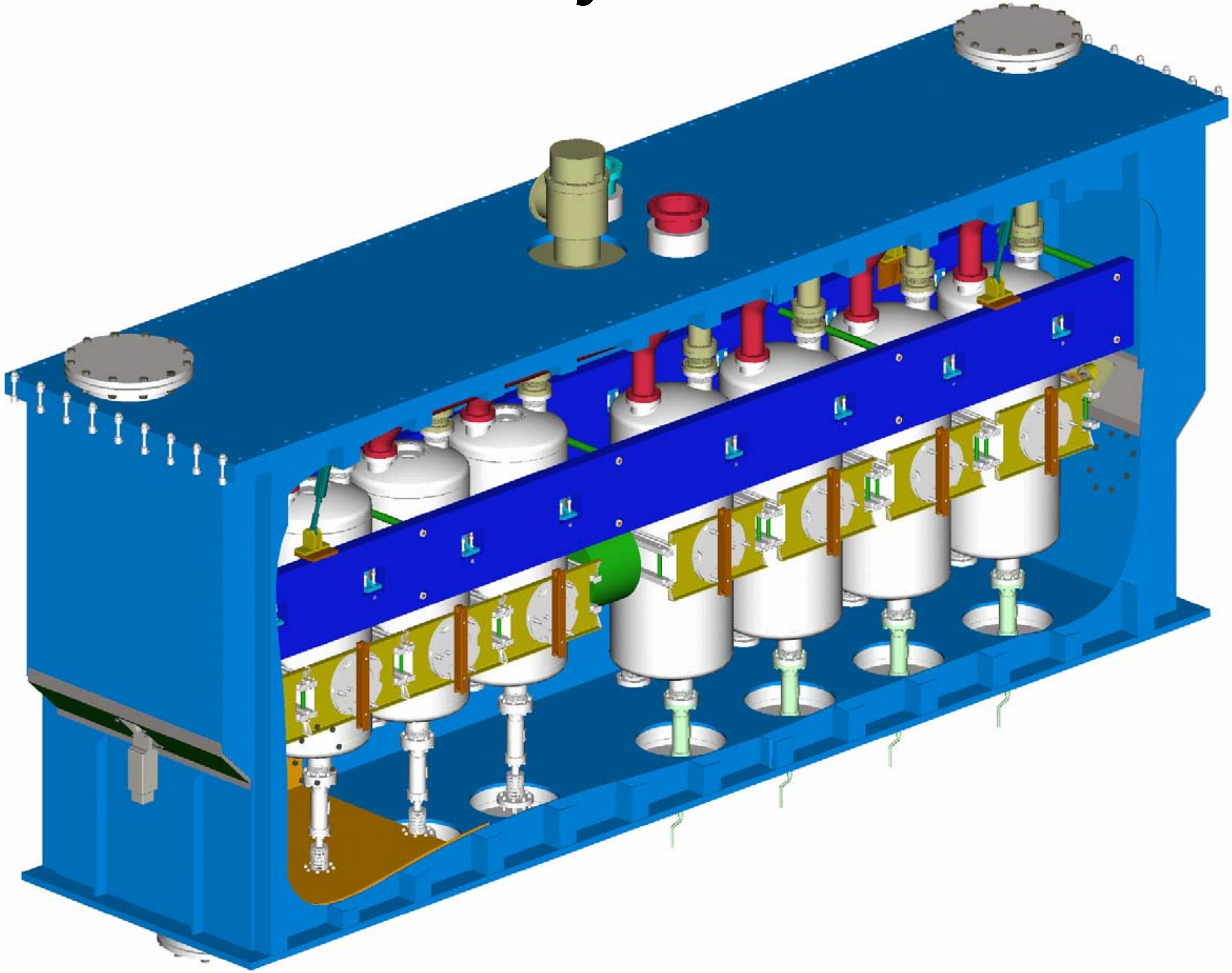
RIA Cryomodule Cavity String

Clean-room assembly to this point



Cavities are sealed up in a clean environment

RIA Cryomodule Assembly

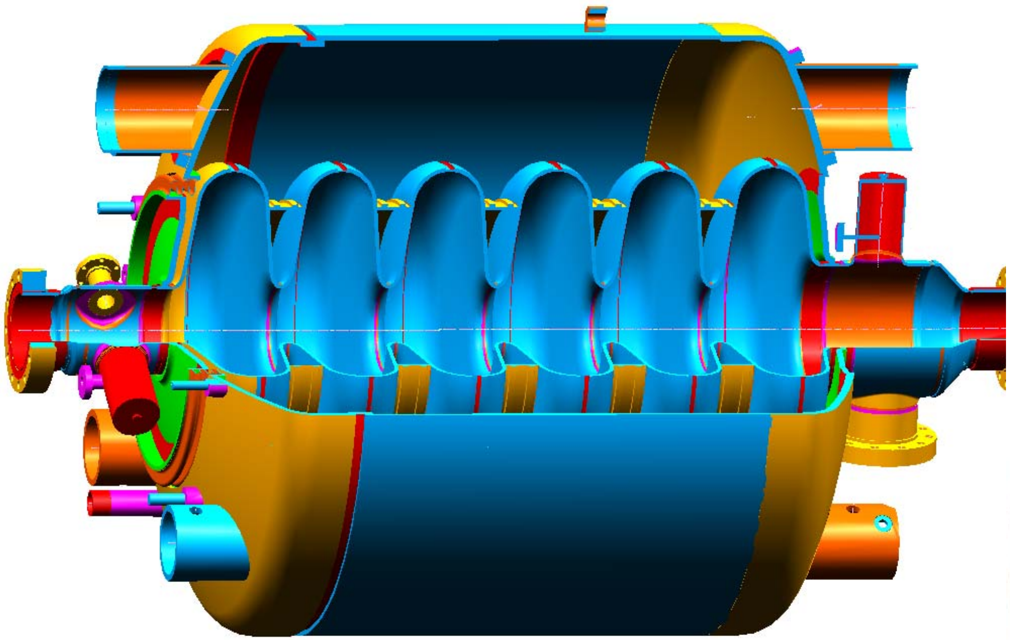


Second ANL Update: Use the R&D results

- We have developed the elements and techniques to enable drift-tube loaded cavities to operate at 20 – 30 MV/m peak surface electric field

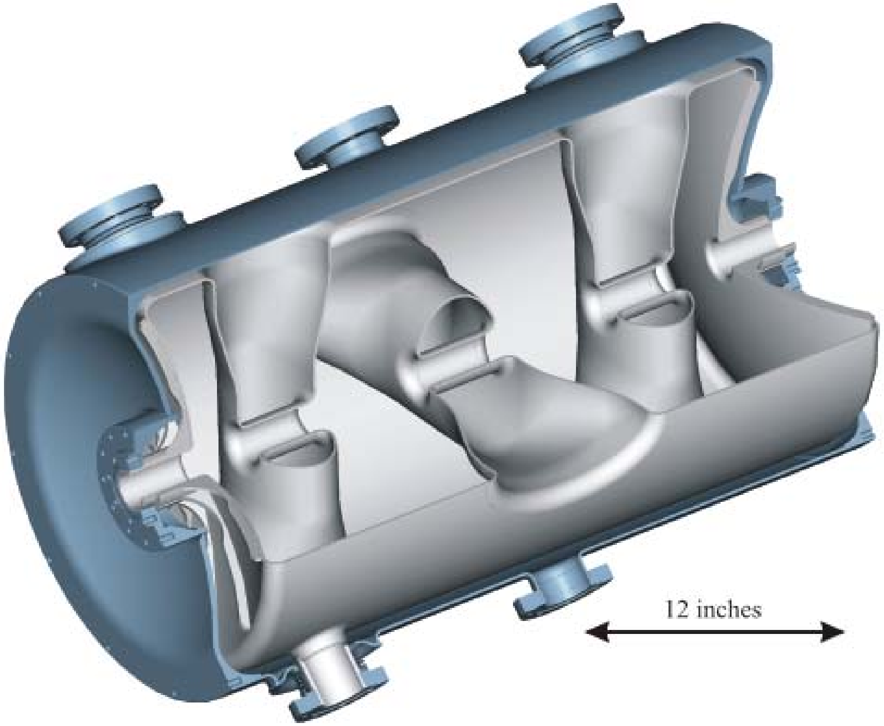
- Spoke cavities can operate at half the frequency of elliptical-cell structures:
  - develop 345 MHz triple-spoke cavities for $0.4 < \beta < 0.7$
  - replace 805 MHz elliptical-cell cavities with 345 MHz spoke-loaded cavities

Elliptical-Cell or Triple-Spoke for the RIA Driver Linac?



805 MHz at 2K

345 MHz at 4K

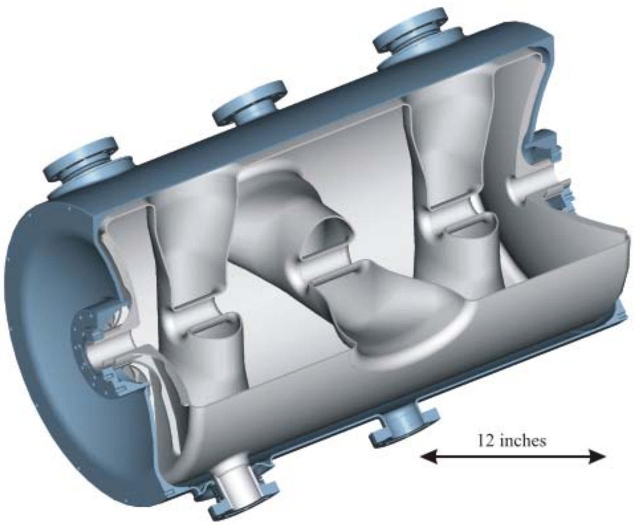


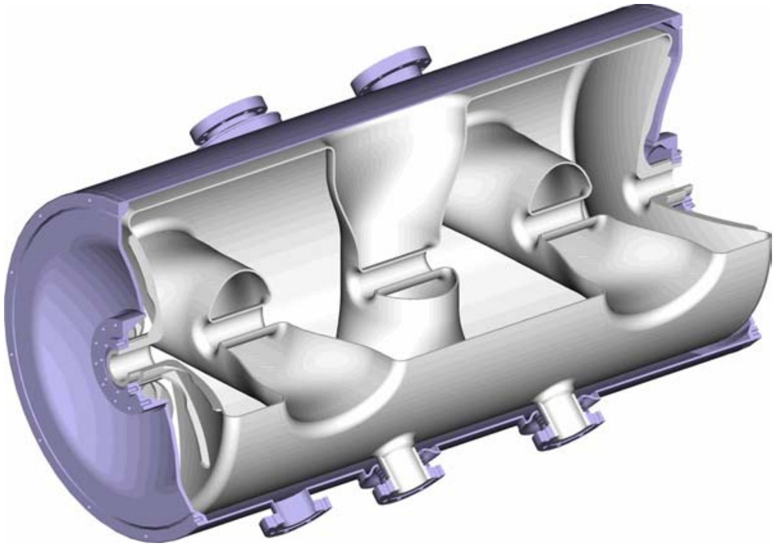
Why use triple- spoke cavities for RIA?

1) Reduce number of cavities (by 12 cryomodules worth)
2) Operate at 4.2K and eliminate sub-atmospheric helium
3) Reduce refrigerator heat load (nearly twofold)
4) Increase acceptance / reduce beam loss
5) Increase proton energies
6) Improve mechanical stability and reduce microphonics

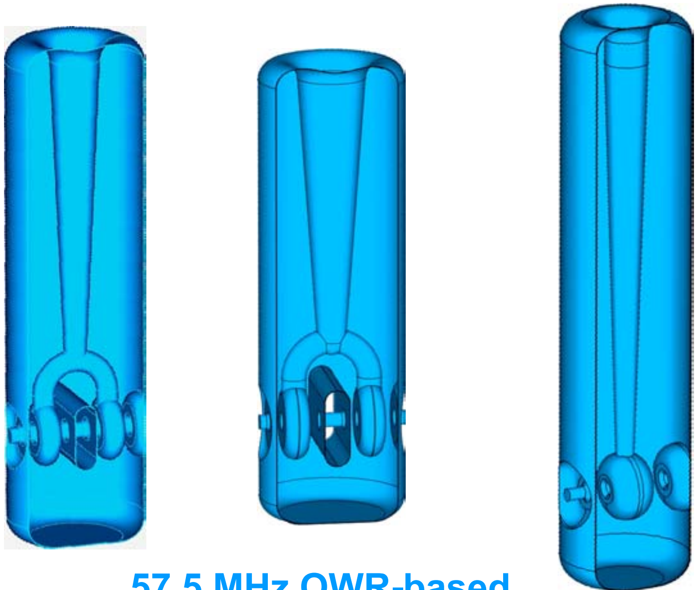
Two triple-spoke cavities for 0.4 < β < 0.8

Freq (MHz)	Beta (geom)	Lngth (cm)	U (mJ)	QRs (ohm)	R/Q (ohm)	Epk (MV/m)	Bpk (MV/m)
345	0.50	65	397	85.7	494	2.9	86
805	0.47	53	341	137	160	3.4	69
345	0.63	81	580	93	520	3.0	89
805	0.61	68	330	179	279	2.7	57





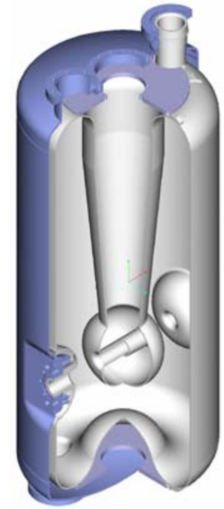
RIA Driver Linac Nb SC Cavity Array

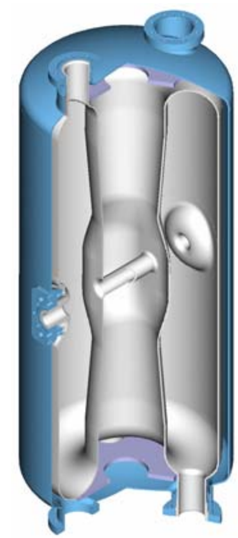


57.5 MHz QWR-based structures .02< β <0.14

115 MHz β=0.15

Corrected QWR

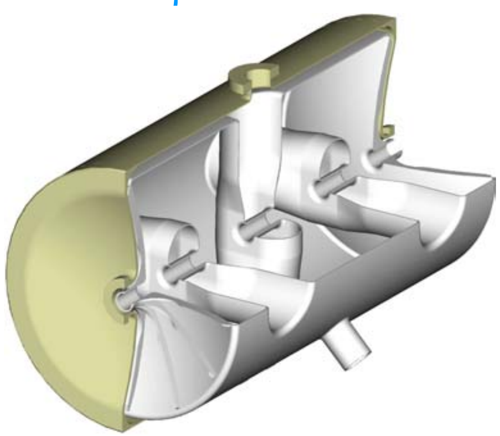


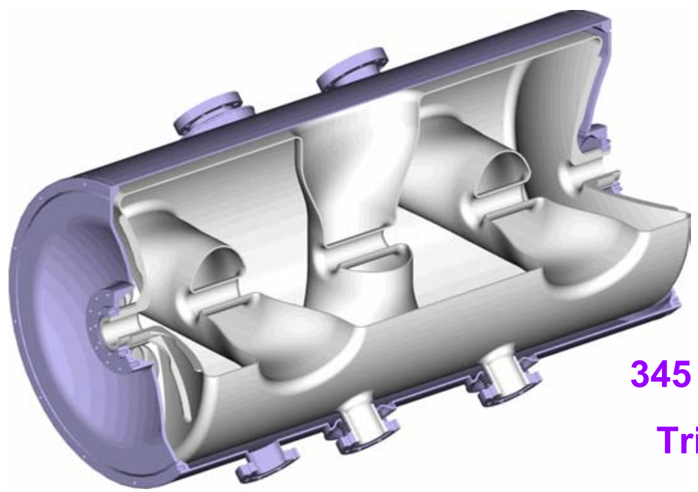


172.5 MHz β=0.14 HWR

345 MHz β=0.5

Triple-spoke

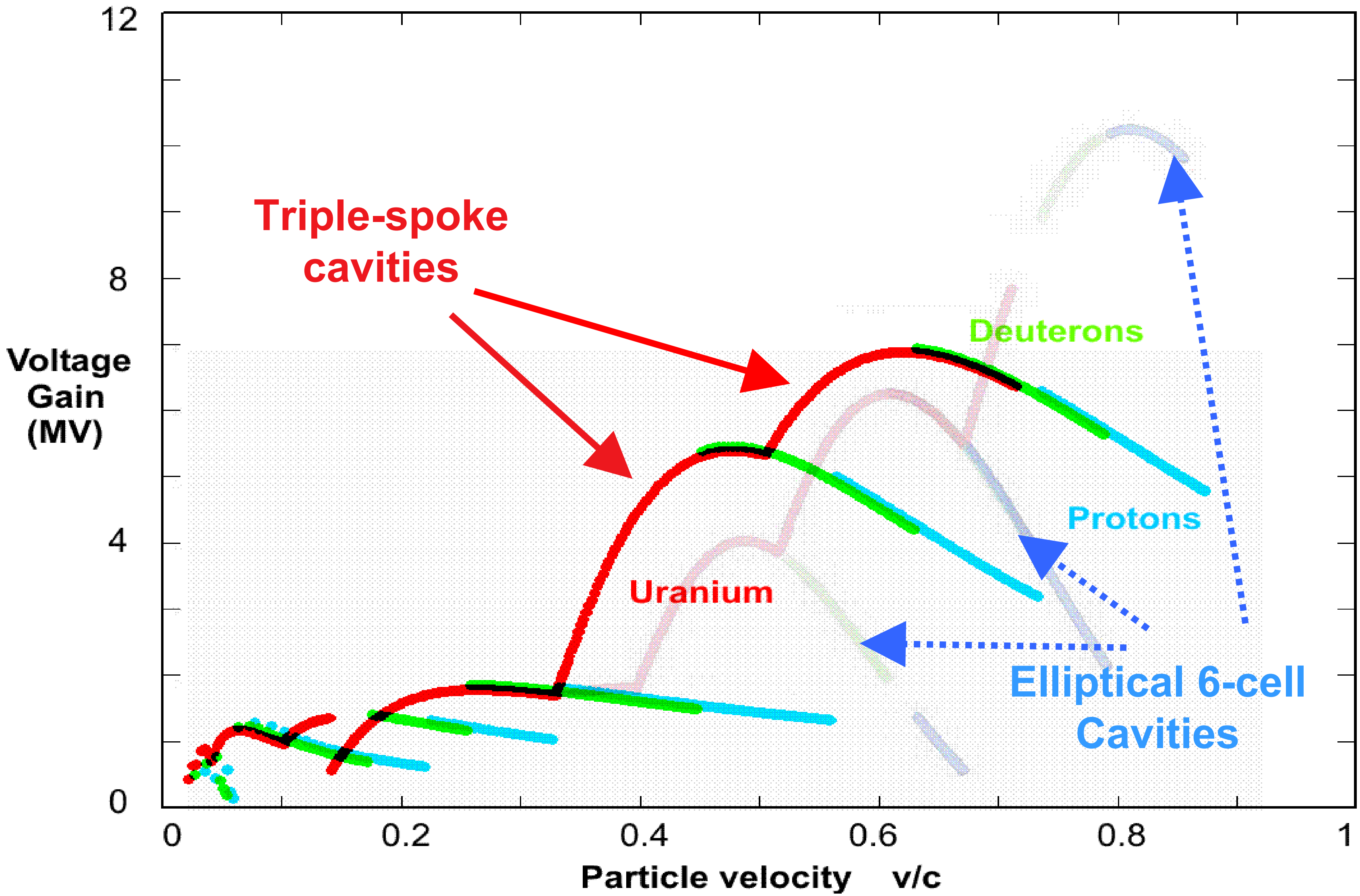




345 MHz β=0.62

Triple-spoke

Voltage gain per cavity vs. velocity for 345 MHz spoke cavity option



ANL 2nd Update Cavity List

Type	Freq (MHz)	Length (cm)	Eacc (MV/m)	Voltage (MV)	Number of Cavities	
3 DT	57.5	18	4.0	0.6	2	2
3 DT	57.5	26	4.0	0.9	5	5
1 DT	57.5	20	6.8	1.2	28	28
1 DT	115.0	25	6.3	1.4	48	48
1 DT	172.5	30	6.9	1.8	80	96
2 DT	345.0	36	6.0	2.1	56	
6 Cell	805.0	55	8.1	3.7	54	
6 Cell	805.0	68	10.2	6.0	88	
6 Cell	805.0	91	12.6	9.9	32	
3DT	345.0	65	9.6	5.6		69
3DT	345.0	81	9.3	6.8		96
		Total Number of Cavities =			393	344

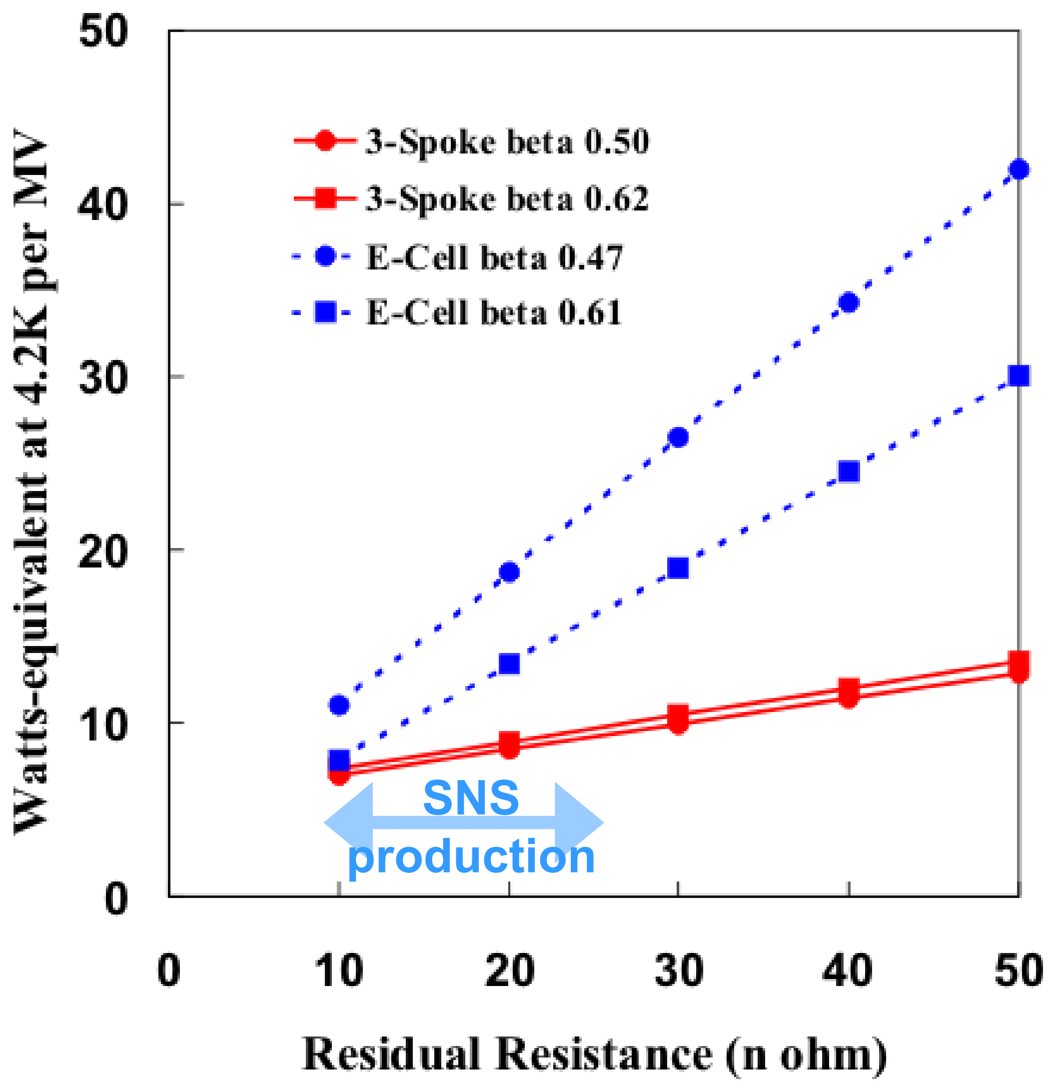
Remove these cavities

Add these cavities

Update #1

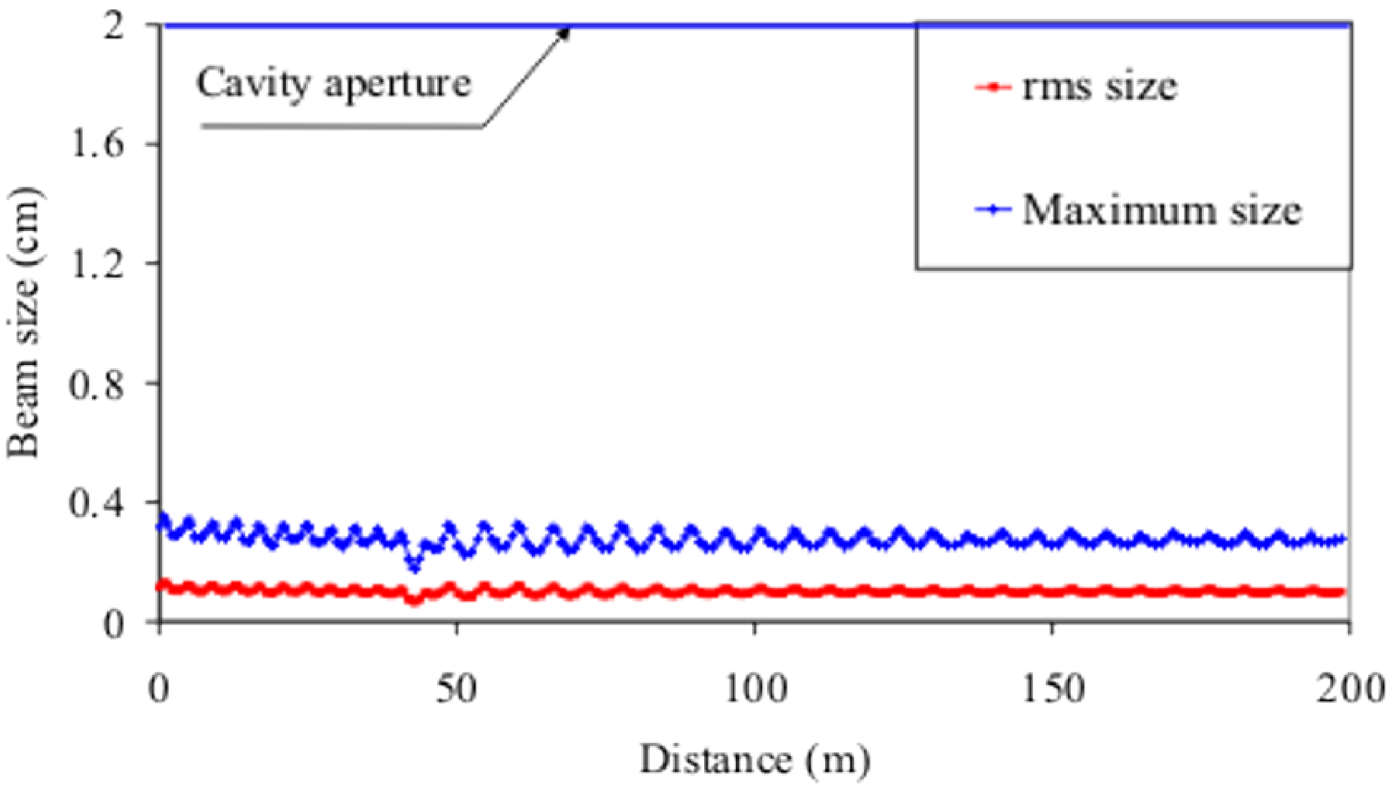
Update #2

Refrigerator Heat Load: Triple-Spoke vs. Elliptical-cell



Longitudinal and Transverse Acceptance

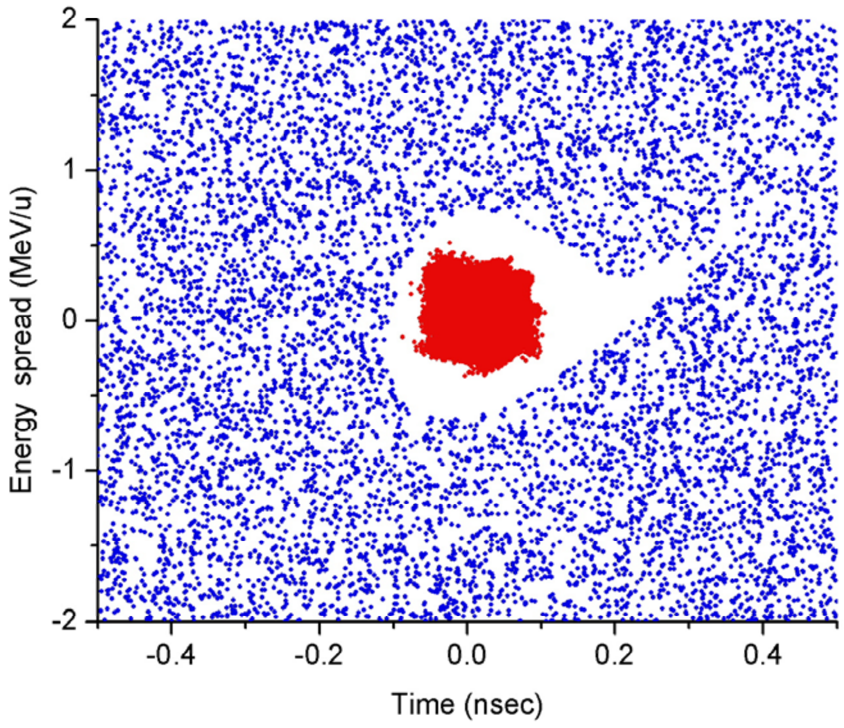
Acceptance (Norm.)	*Triple-spoke*	*Elliptical-cell*
Trans. (π·mm·mrad)	**35**	**70**
Long. (π·keV/u-nsec)	**280**	**60**



Comparison of Longitudinal Acceptance

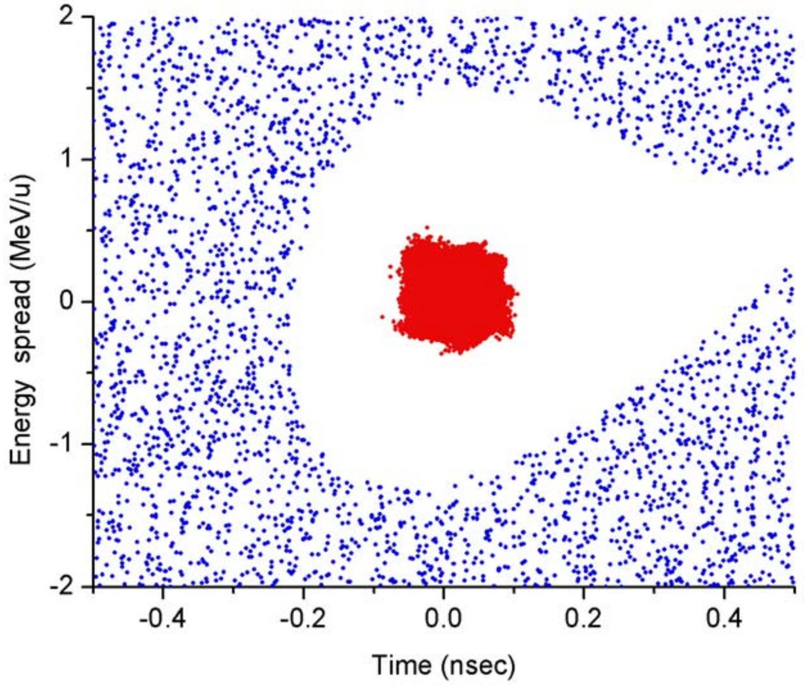
805 MHz Elliptical-Cell

φ_S=-30°



345 MHz Triple-Spoke

φ_S=-25°



Conclusions

- Harrison review design was viable, but we can achieve better performance in a more compact package at a lower price.
- An R&D priority is to operate prototype cavities and ancillary systems to shake down systems design. (This is the way to achieve high reliability early in the life of the RIA facility)