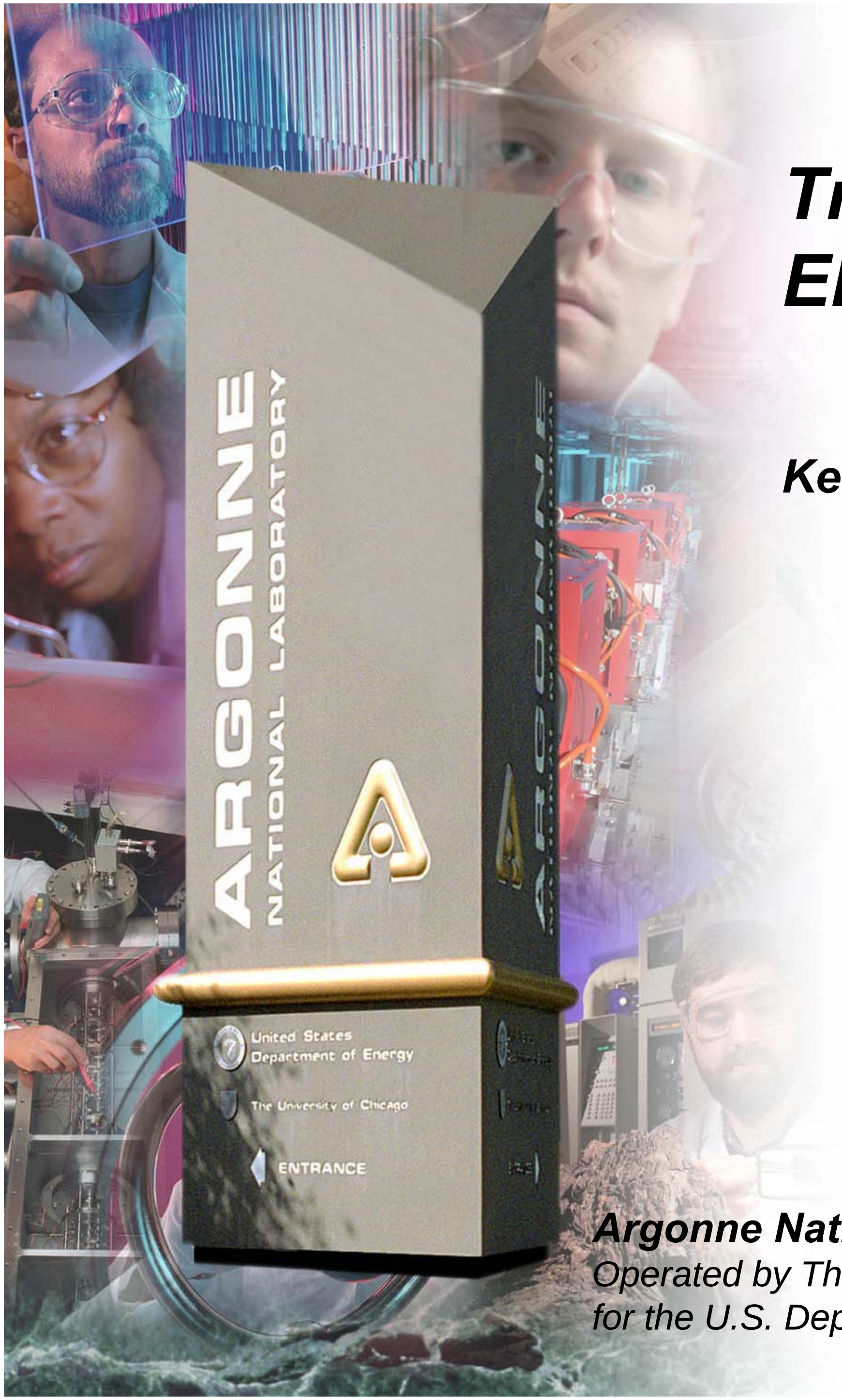

Triple-spoke compared with Elliptical-cell Cavities

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12th International Workshop on RF Superconductivity

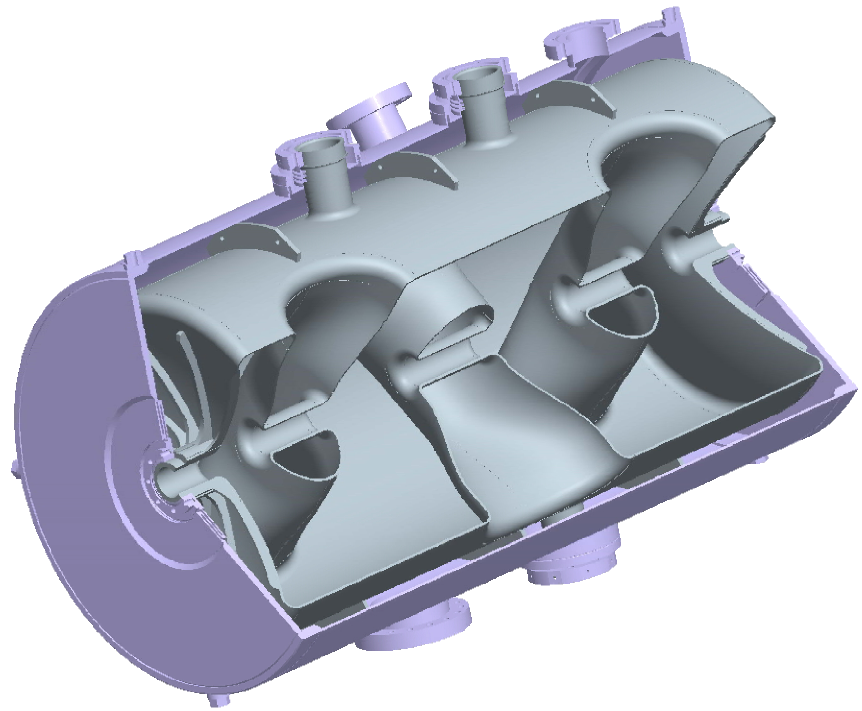
Argonne National Laboratory
Operated by The University of Chicago
for the U.S. Department of Energy

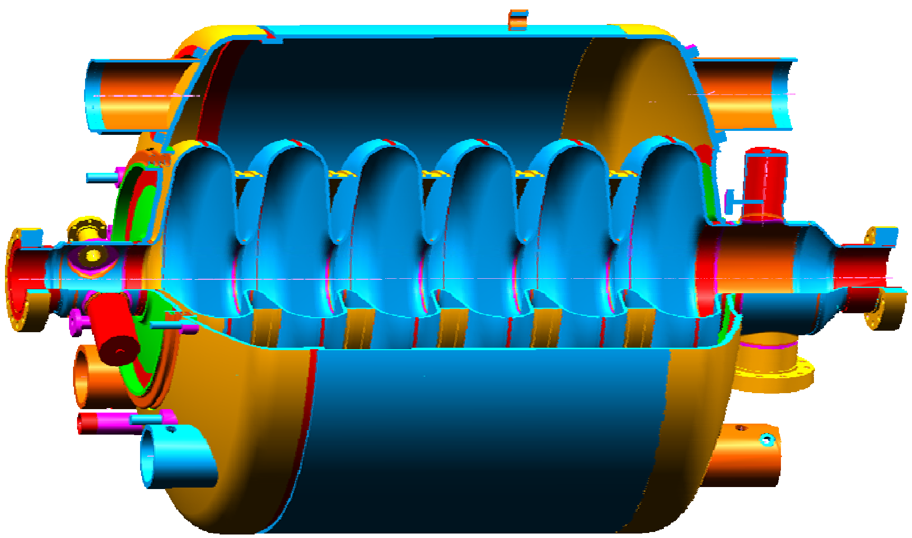
Office of Science
U.S. Department of Energy

RIA Driver: Elliptical Cell or Triple Spoke Option?

- **Frequency**
- **Voltage**
- **Cryogenics**
- **Microphonics**

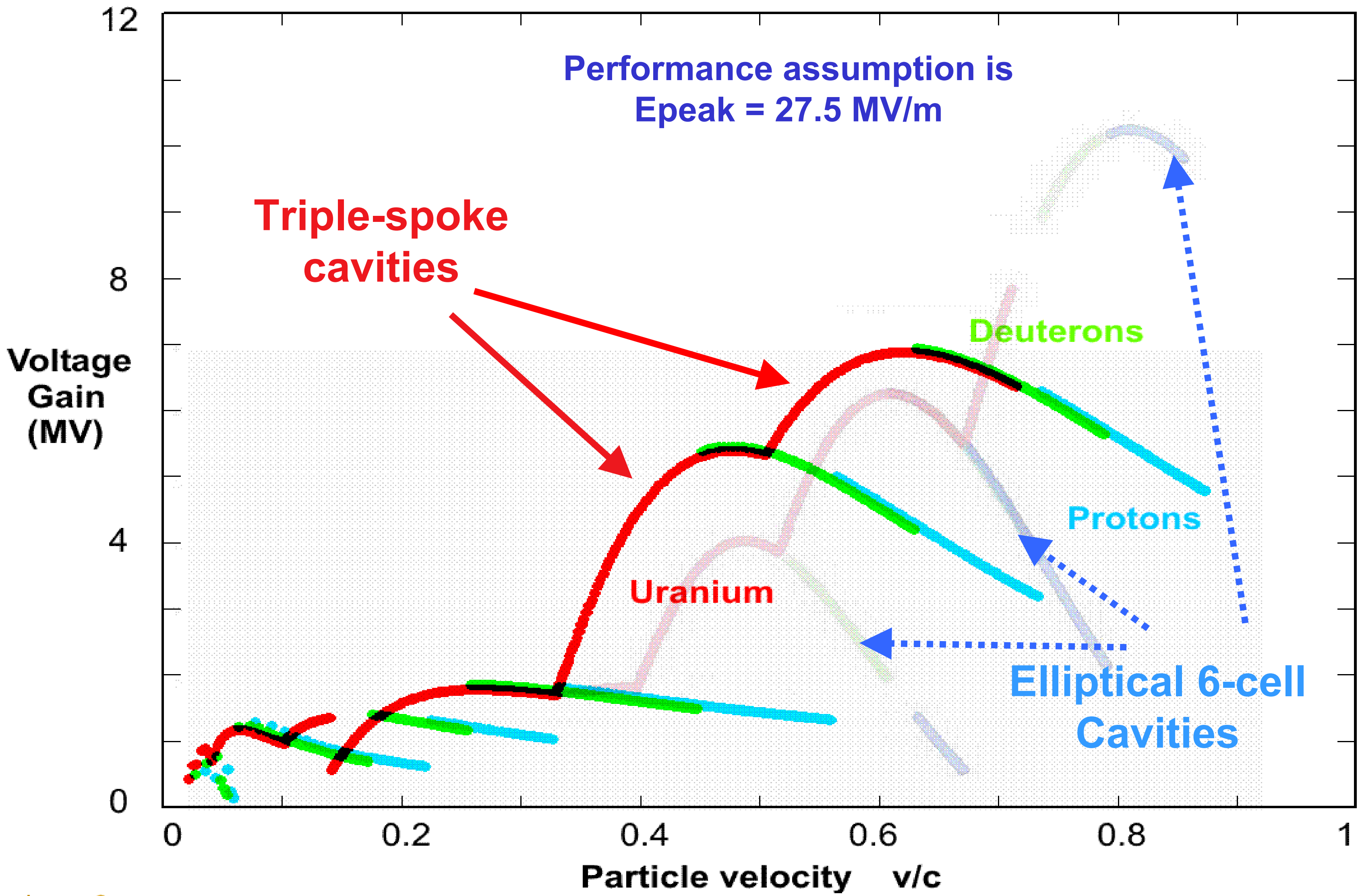
345 MHz at 4K





805 MHz at 2K

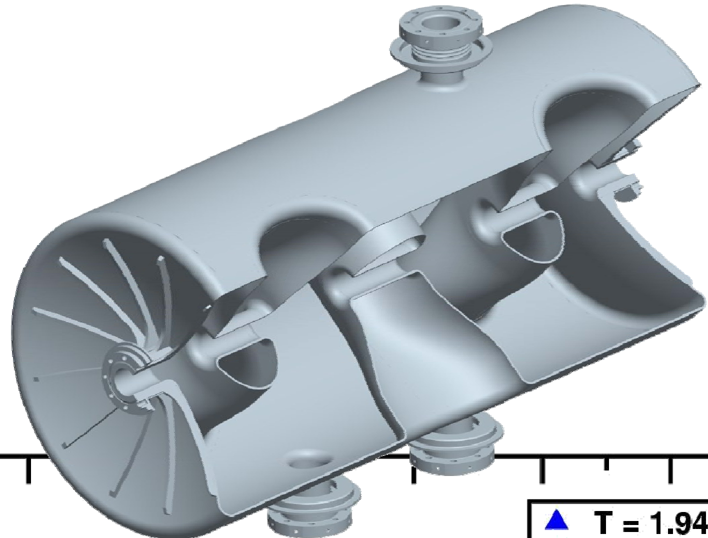
Triple-spoke vs E-cell for the RIA Driver

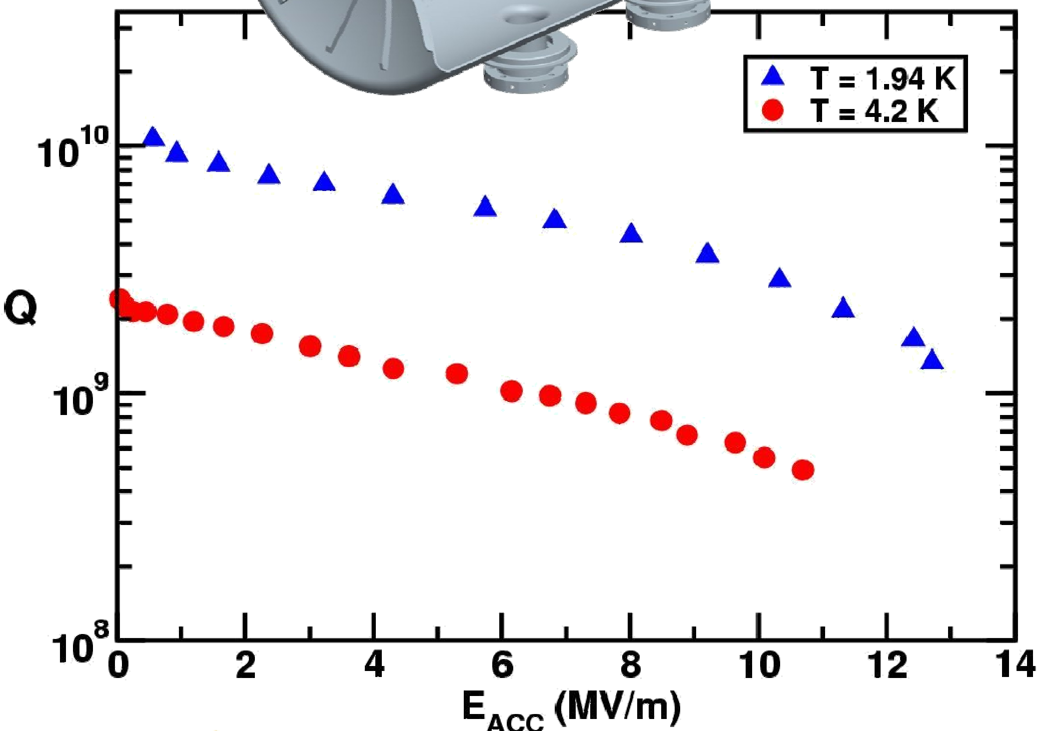


Triple-spoke vs E-cell RIA Driver: High-energy Section

CAVITY TYPE:		E-CELL			TRIPLE SPOKE	
Operating Temperature	K		2		4.2	
Beta Geometric		0.47	0.61	0.81	0.5	0.63
Frequency	*MHz*	805	805	805	345	345
Active Length	*cm*	52.6	68.2	90.6	65.2	82.15
QRs	*ohm*	155	179	260	86	97
R/Q	*ohm*	173	279	483	494	513
Epeak	*MV/m*	3.34	2.79	2.19	3.0	2.9
Bpeak	*Gauss*	66	57.2	47.2	88.9	90.3
RF Energy	*mJoule*	316	330	336	419	607

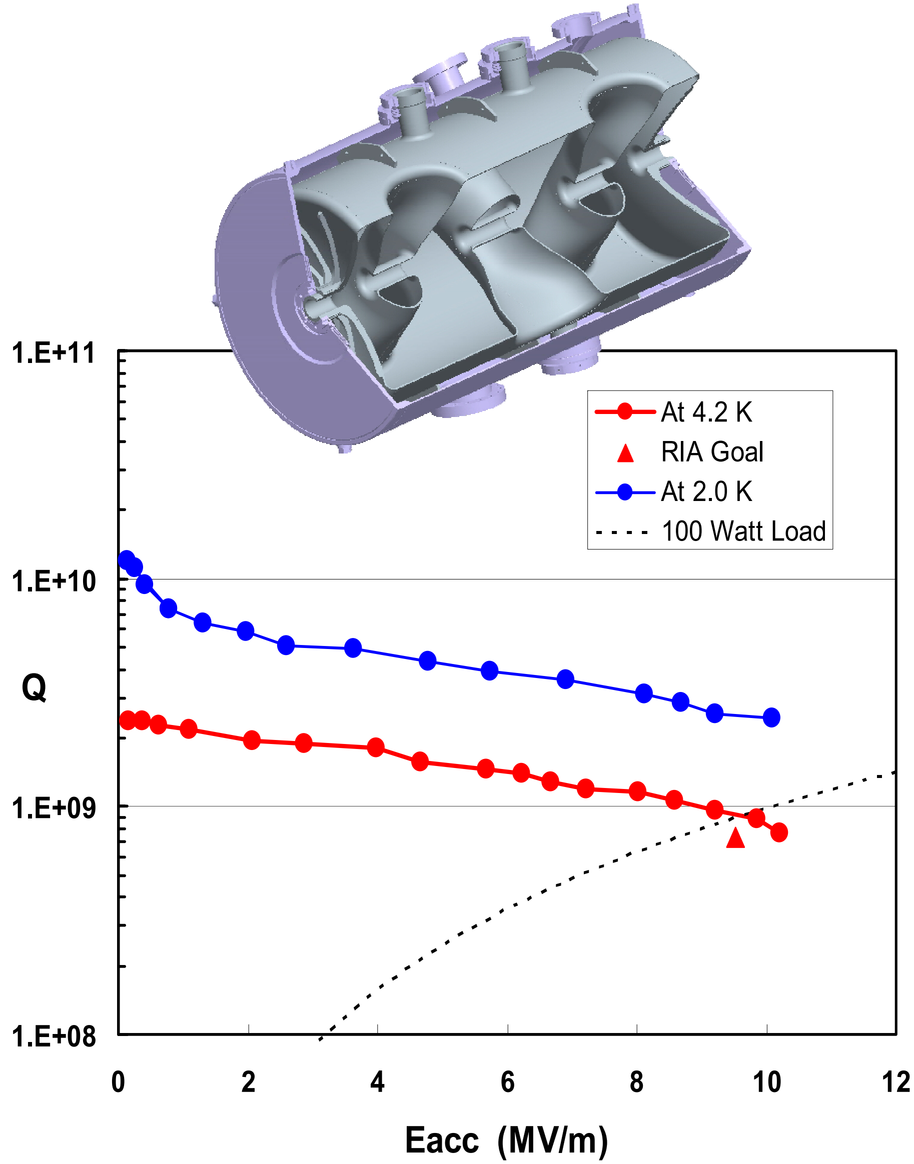
345 MHz β=0.63 Triple-spoke cold tests

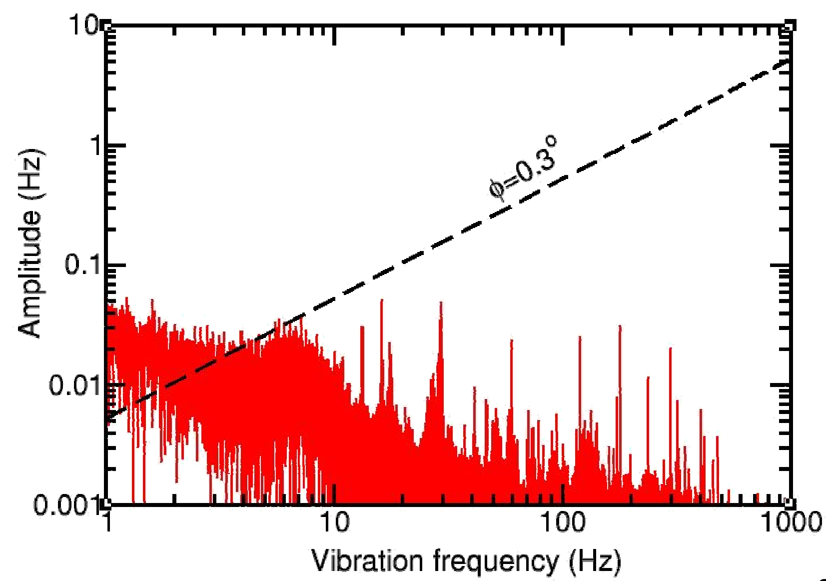




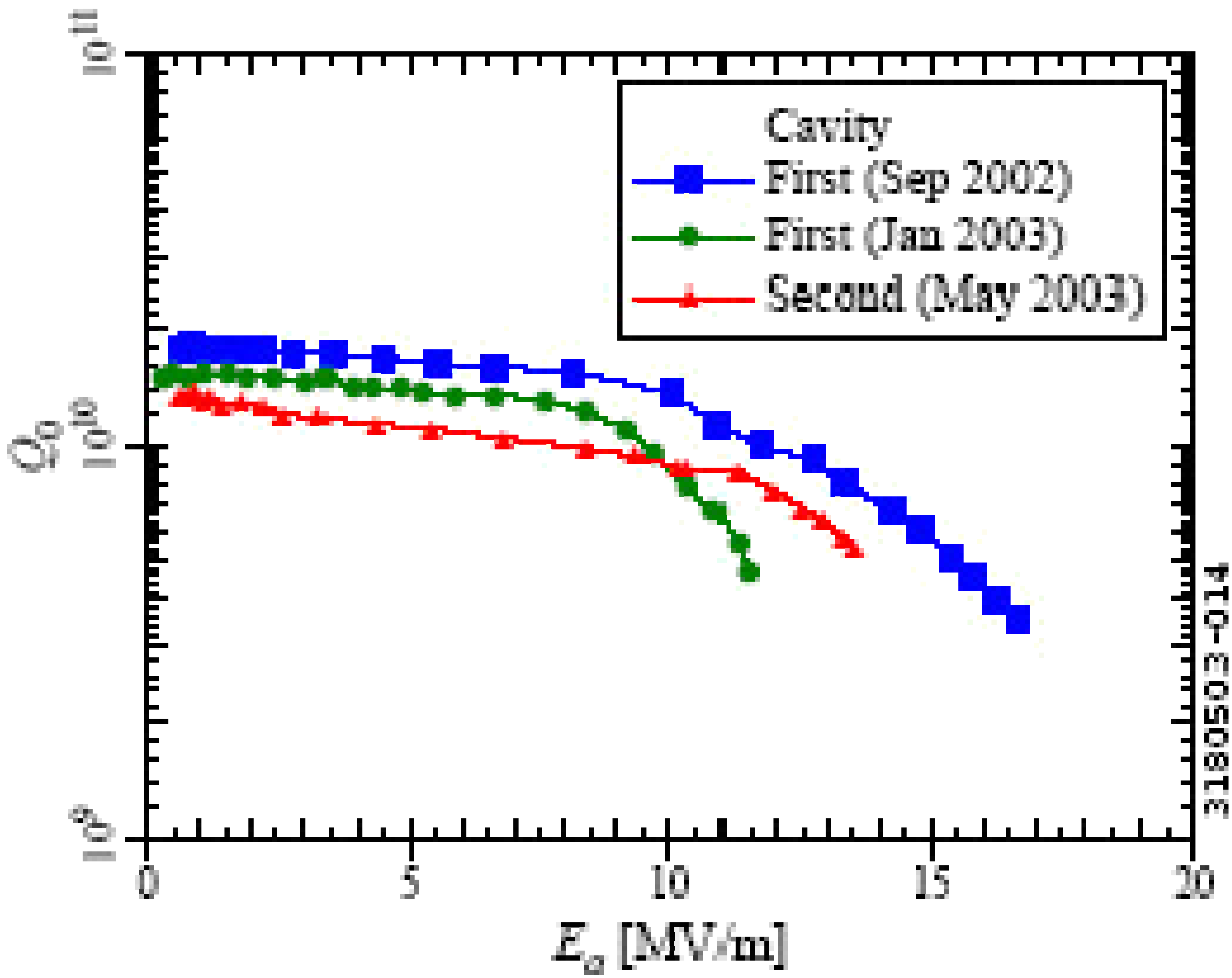
Frequency	**345 MHz**
β_0	**0.63**
L(3βλ/2)	**82 cm**
QR_S (G)	**93 Ω**
R/Q	**549 Ω**
below for E_{ACC} = 1.0 MV/m	
RF Energy	**0.565 J**
B_{PEAK}	**90 G**
E_{PEAK}	**2.93 MV/m**

345 MHz β=0.5 Triple-spoke cold tests





JLAB/MSU (2) β=0.47 Elliptical-cell at 2 K



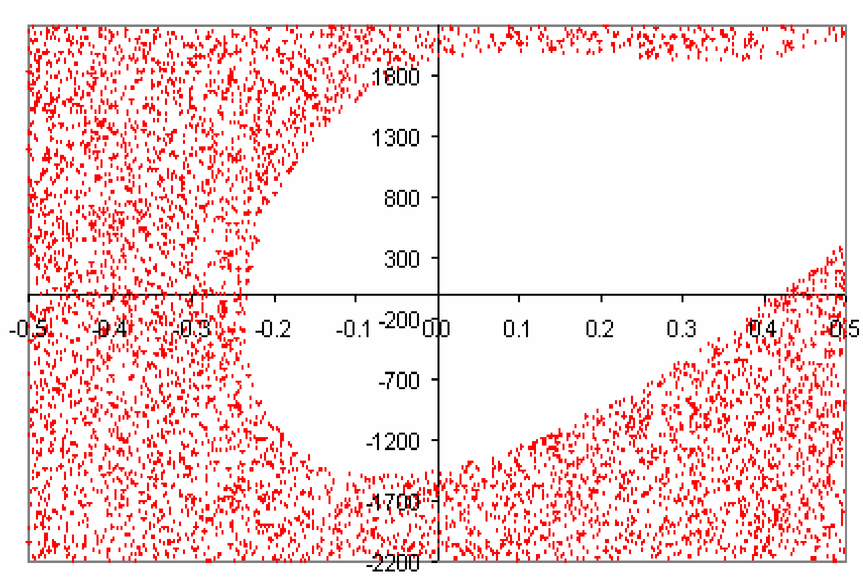
Present performance level 'bottom line'

Parameter	Six-cell Elliptical		Three-spoke	
	β = 0.47	β = 0.62	β = 0.50	β = 0.63
Frequency (MHZ)	805	805	345	345
Length (cm)	52.7	68.2	65.2	82.15
E_A (MV/m)	10	12	9.9	9.4
E_{PEAK} (MV/m)	33.4	32.5	27.5	27.5
B_{PEAK} (Gauss)	660	572	845	849
R/Q (Ω)	173	279	492	549
Q at E_A	9.50E+09	7.00E+09	8.80E+08	6.50E+08
Voltage (MV)	5.3	8.2	6.5	7.7
Temperature (K)	2	2	4.2	4.2
Heat Load*	12.8	16.8	14.9	21.6

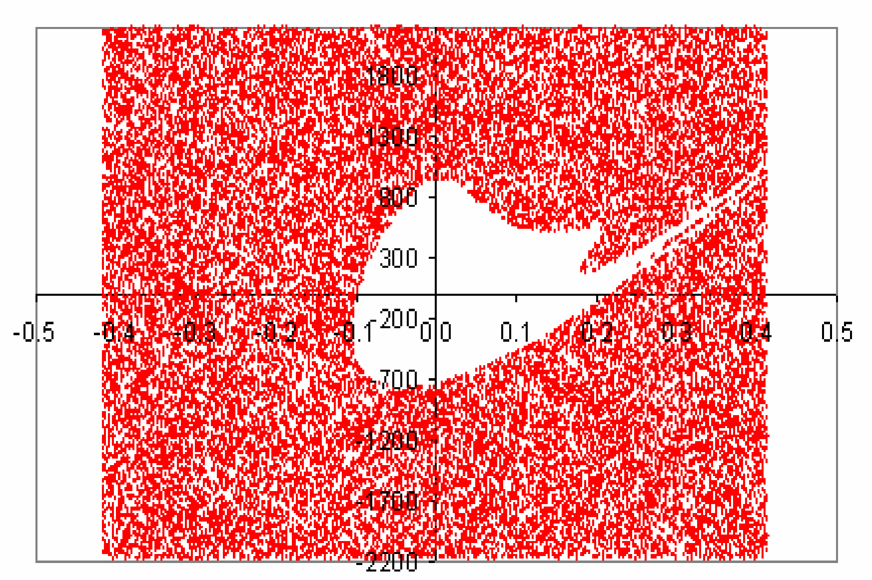
*Watts per MV - at 4.2 K

Longitudinal Acceptance: Spoke vs. E-cell

Triple-spoke resonators
345 MHz
E_{peak}= 27.5 MV/m



Baseline Design: 6-cell elliptical cavities 805 MHz
E_{peak}=27.5 MV/m



ANL: Triple-spoke option is favored for RIA

- **The beam dynamics are better**
- **Can operate at 4 K**
- **The mechanical stability is excellent**
- **linac costs will be less than for SNS, probably less than E-cell with re-designed cryostat**

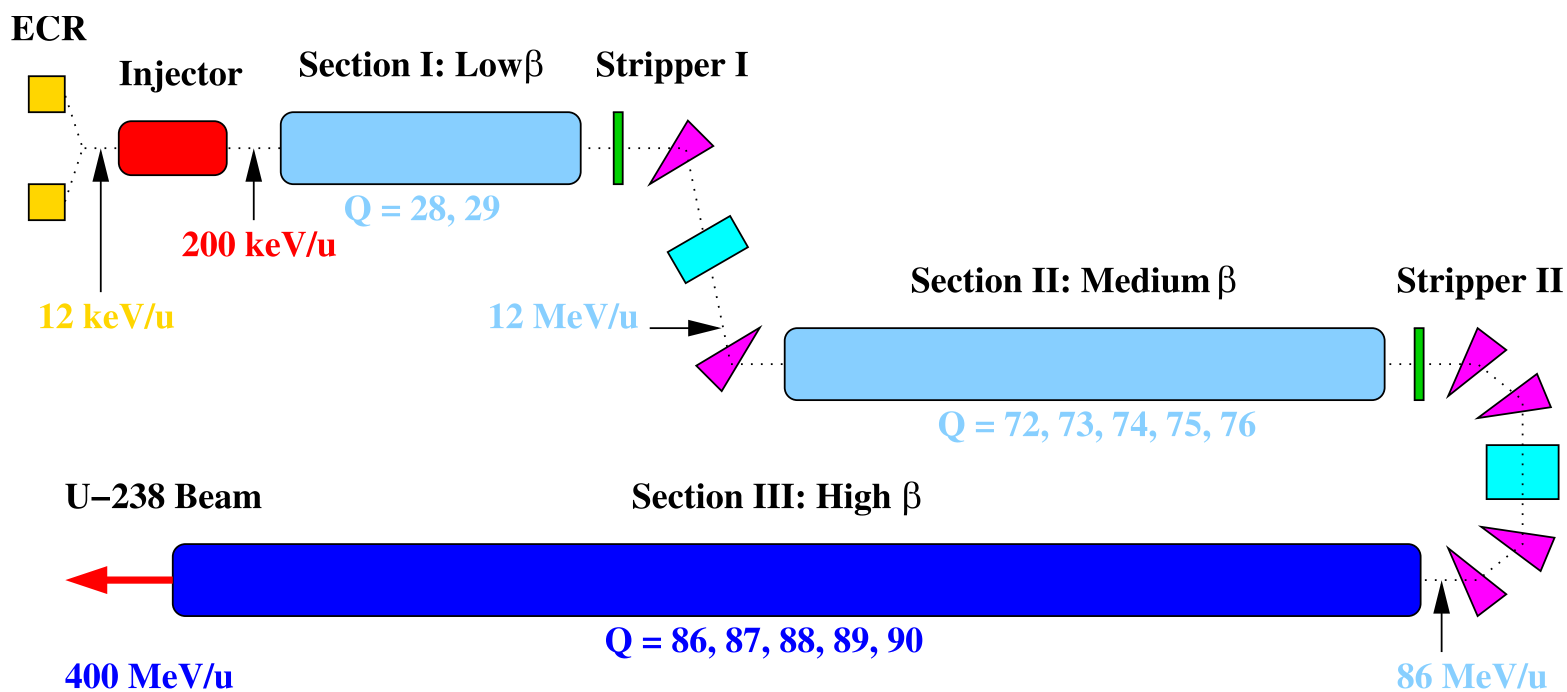
RIA Driver Partial beamlist: r-process beams

Ion (%)	Q_{source}	Q_{strip1}	Q_{strip2}	$I_{published}$ (pμA)	Energy/A	Power (kW)
^{1}H / ^{2}H	1	-	-	>>1000	900 / 600	>400
^{64}Ni (0.91%)	12	28	-	8*	530	174
^{70}Zn (0.6%)	13	29-30	30	12**	521	284
^{76}Ge (7.8%)	14	31-32	32	<1*	513	<22
^{82}Se (9.4%)	15	32-33	34	<1*	493	<23
^{86}Kr (17.3%)	15	33-34	36	18**	505	>400
^{96}Zr (2.8%)	15	37-39	40	<1*	504	<28
^{124}Sn (5.6%)	16	44-46	48-49	2.8**	468	90
^{136}Xe (17.3%)	18	47-49	52-53	11**	460	357
^{176}Yb (12.7%)	20-21	58-60	68-69	????	453	????
^{192}Os (41.%)	22-23	61-64	70-73	????	429	????
^{198}Pt (7.2%)	23-24	62-65	72-75	????	425	????
^{204}Hg (6.8%)	24-25	64-67	74-77	????	412	????
^{208}Pb (52.4%)	24-25	65-68	76-80	2x4.3**	429	359
^{232}Th (100%)	27-28	69-73	85-88	????	416	????
^{238}U (99.3%)	28-29	70-74	87-90	2x1.25	412	114

Beam-Loss Calculations

- **Final step of BD design studies**
- **Simulations on the multi-processor computer**
- **Up to 500 randomly seeded accelerators with all types of errors and misalignments, typically 200 seeds**
- **Beam steering is applied**
- **Wide range of rf errors, thickness fluctuation and their combinations have been studied**
- **Number of tracked particles:**
  - Up to 10^6, typically $2 \cdot 10^5$ in each seed
  - Total number of simulated particles 40 million, some cases up to 200 million.

The RIA Driver Linac

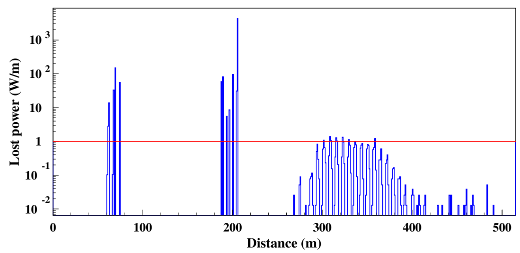


Baseline: **About 1200 beam line elements: ~ 400 rf resonators, 90 solenoids, 100 quads, 16 bending magnets, …**

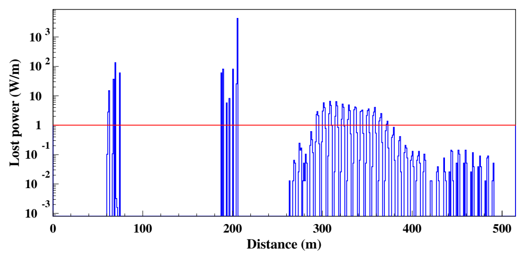
805 MHz Elliptical-cell design: Losses in Watts/m

Static /Dynamic err.

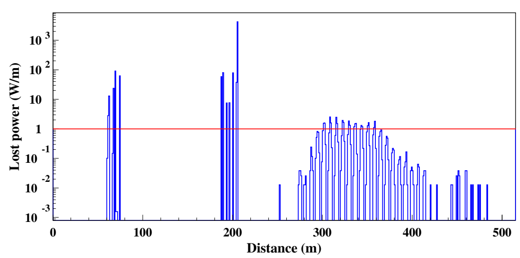
1.5 % / 0.3 %
1.5 deg / 0.3 deg



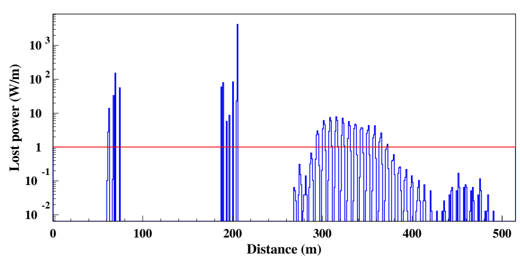
2.0 % / 0.3 %
2.0 deg / 0.3 deg



1.0 % / 0.5 %
1.0 deg / 0.5 deg



1.5 % / 0.5 %
1.5 deg / 0.5 deg



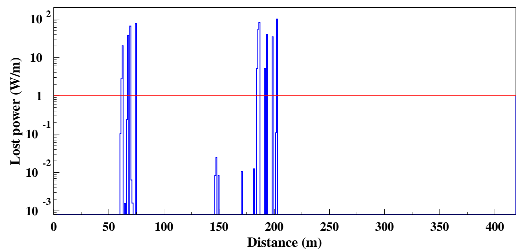
- **Misalignment errors are kept at their typical values.**
- **Stripper thickness fluctuation: 10% FWHM.**
- **Transverse correction applied**
- **Correction for RF static error applied**
- **Simulated: 50 seeds with 2E+5 particles.**

➢ **To keep the losses below the 1 W/m limit, the static errors should be about (1%, 1 deg) and the dynamic errors about (0.5 %, 0.5 deg).**

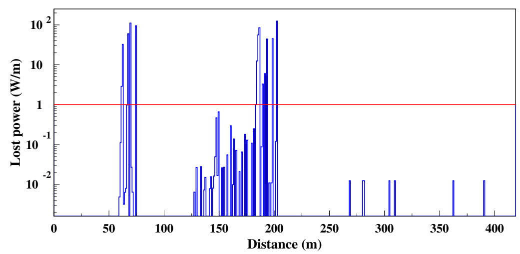
345 MHz Triple-Spoke design: Losses in Watts/m

Static /Dynamic err.

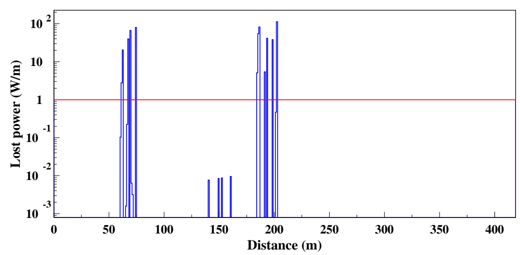
3.0 % / 0.3 %
3.0 deg / 0.3 deg



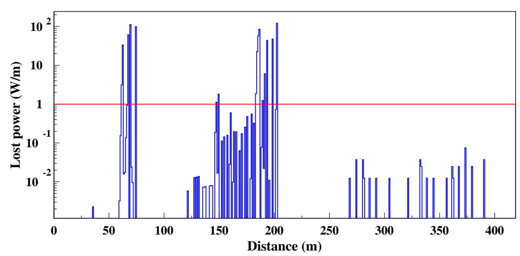
4.0 % / 0.3 %
4.0 deg / 0.3 deg



3.0 % / 0.5 %
3.0 deg / 0.5 deg



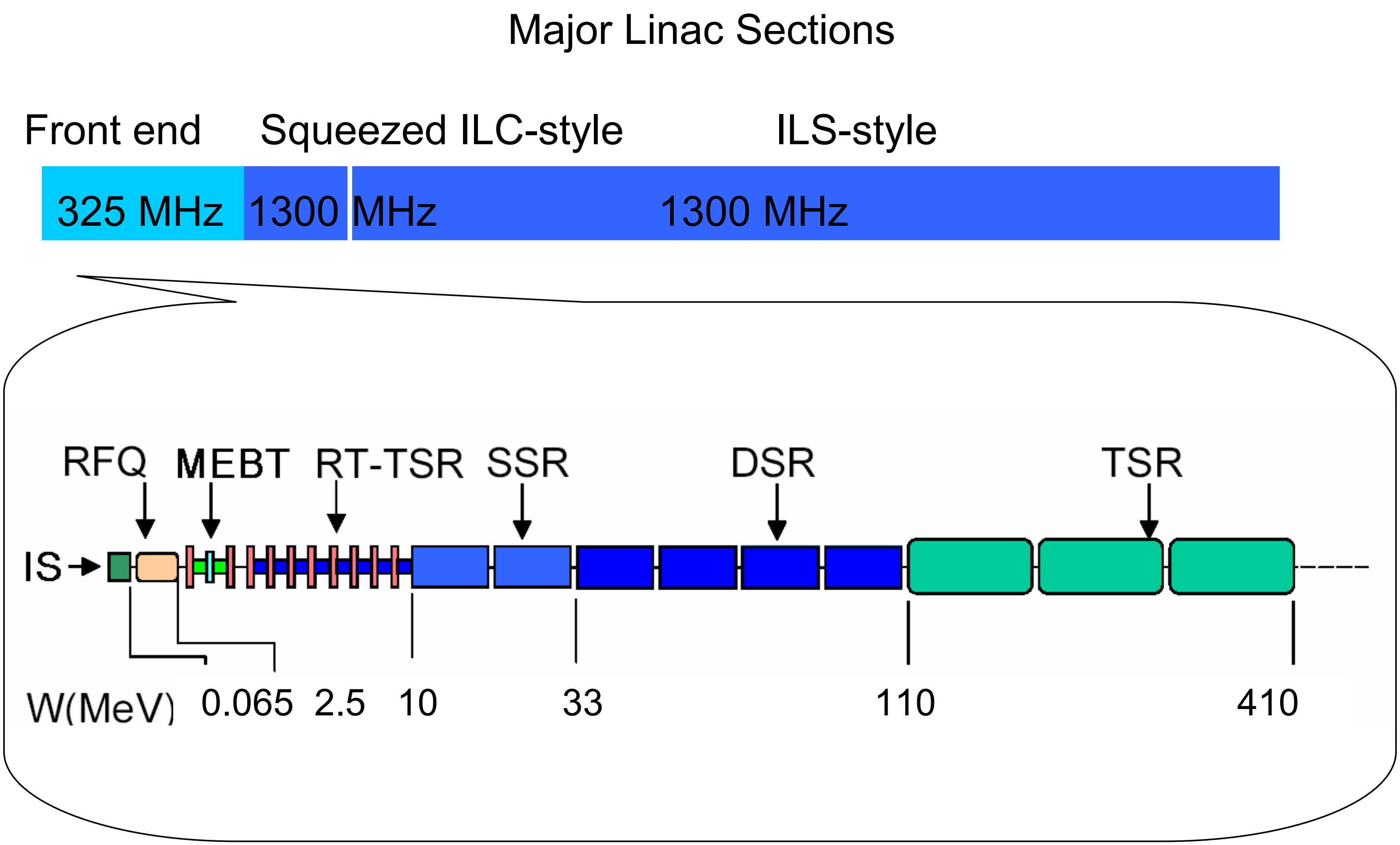
4.0 % / 0.5 %
4.0 deg / 0.5 deg



- **Same conditions as for the Baseline design except for RF static and dynamic err.**
- **Double the RF static & dynamic errors used for the Baseline design.**

- **No losses observed at the typical error values of (2%, 2 deg) static and (0.5%, 0.5 deg) dynamic**
- **Up to static errors of (4%, 4 deg) and dynamic errors of (0.5%, 0.5 deg) the losses are still below the 1 W/m limit.**
- **The Triple-Spoke design is more tolerant of errors**

Proton Driver Linac Structure – Spoke cavities to 410 MeV



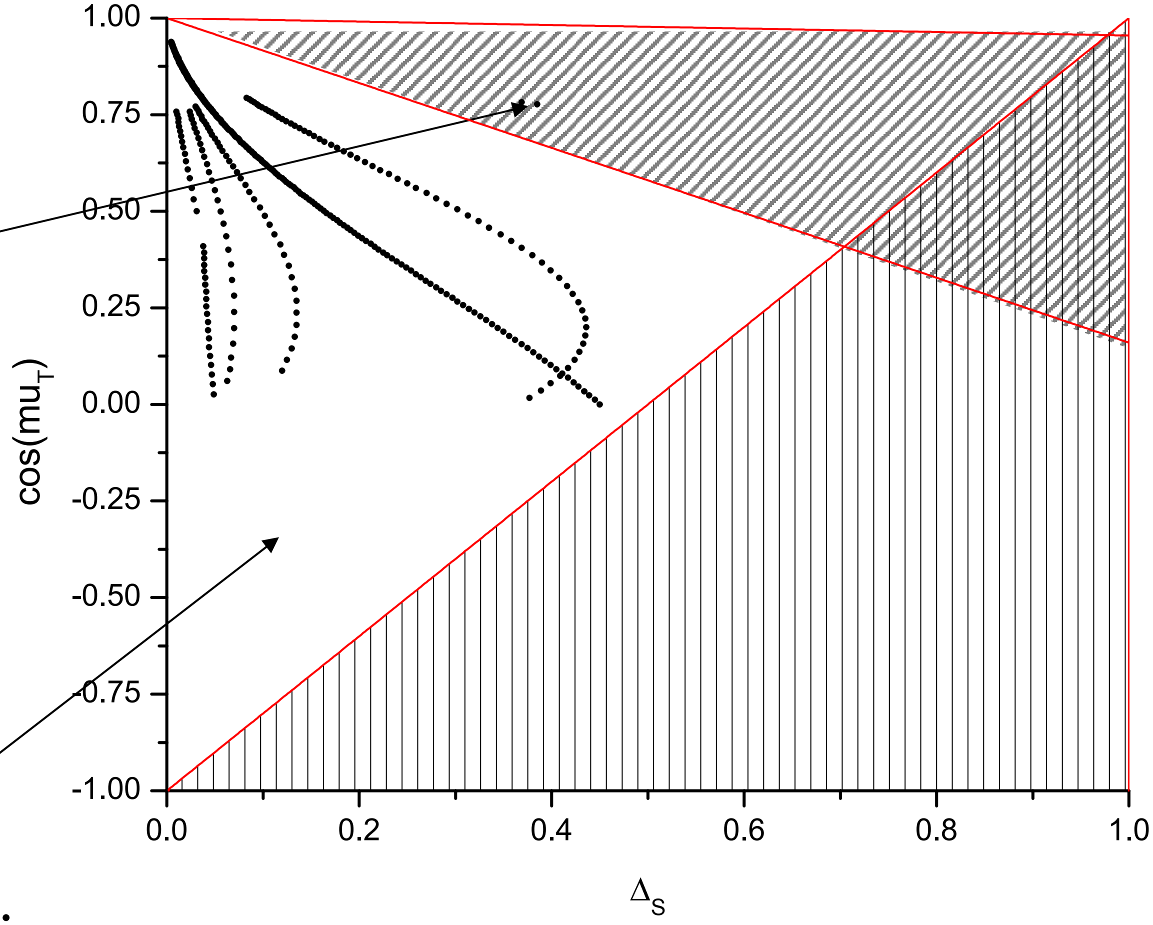
Stability Diagram (transverse motion)

Unstable due to parametric resonance

$$\mu_T = \frac{\mu_L}{2}$$

Linac operating tunes (black dots)

Stable for all particles inside the separatrix



$$\Delta_s = \frac{\pi}{2} \frac{1}{(\beta\gamma)^3} \frac{S_f^2}{\lambda} \frac{eE_m \sin\varphi_s}{m_0 c^2}$$

Defocusing Factor