Particle Accelerator Conference
March 26 -April 1, 2011

ATLAS UPGRADE

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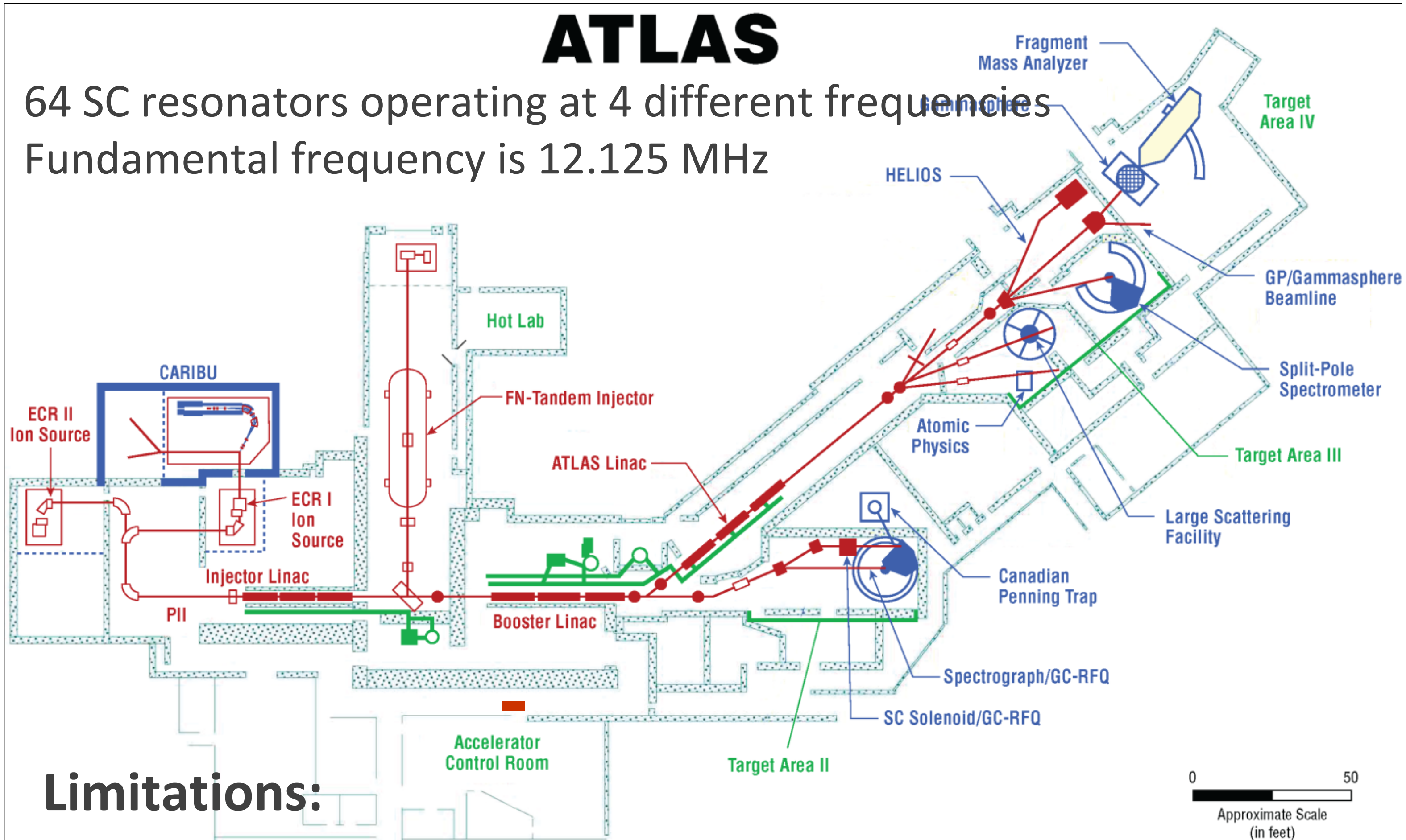
Argonne Tandem Linac Accelerator System (ATLAS)

64 SC resonators operating at 4 different frequencies

Fundamental frequency is 12.125 MHz



Limitations:

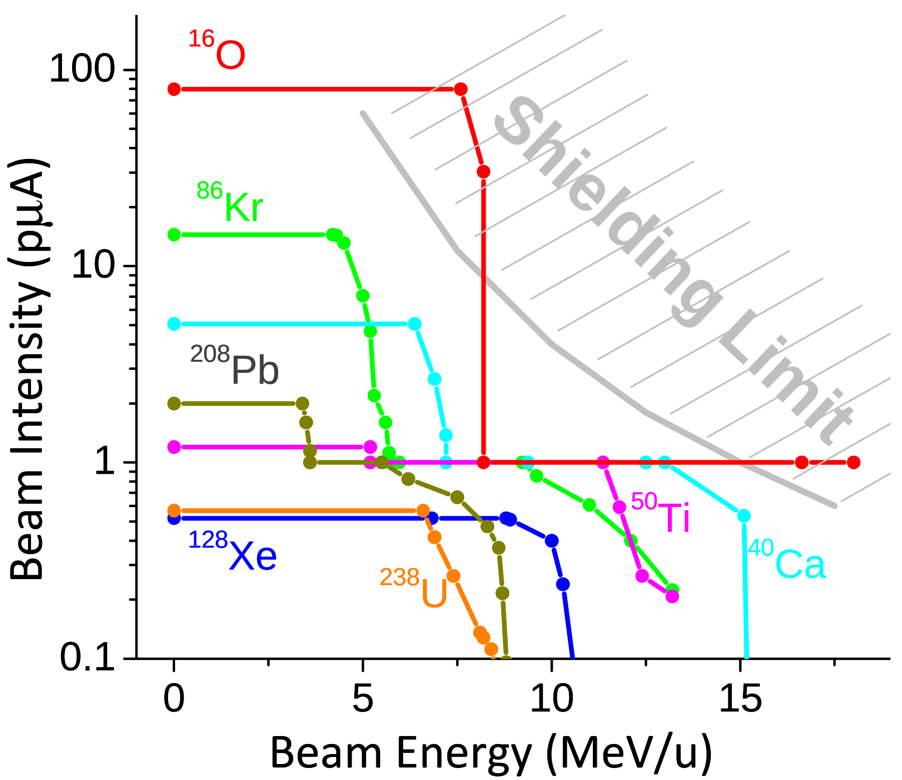
Low transmission due to low acceptance and steering by split-rings

Low current ~1pμA

Low accelerating gradients, limited space for new experiments

Scope of the ATLAS Upgrade Projects

- Increase the overall transmission to 80%
- Deliver ≥6 MeV/u high-intensity (~10 pμA) medium mass ion beams (A<100) for experiments
- Increase energy of light ion low intensity beams to ~18-20 MeV/u
- Increase energy of heaviest ions, A/q=7, to ~9 MeV/u without additional stripping

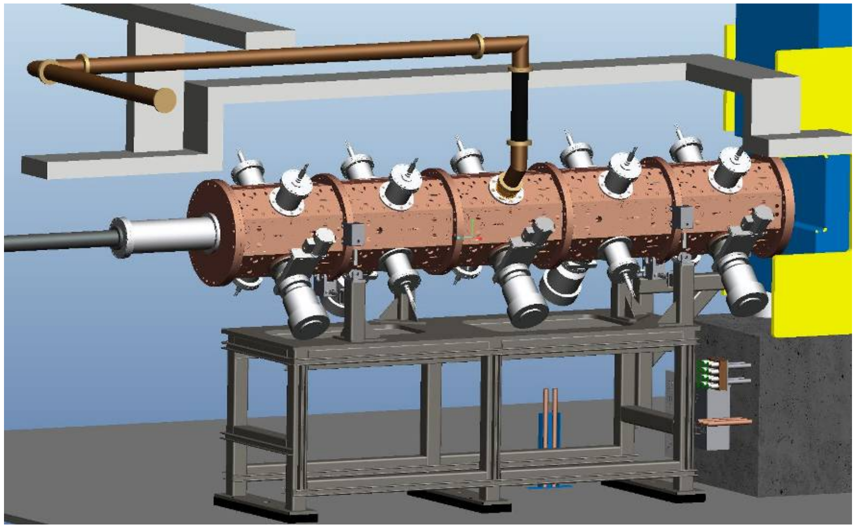


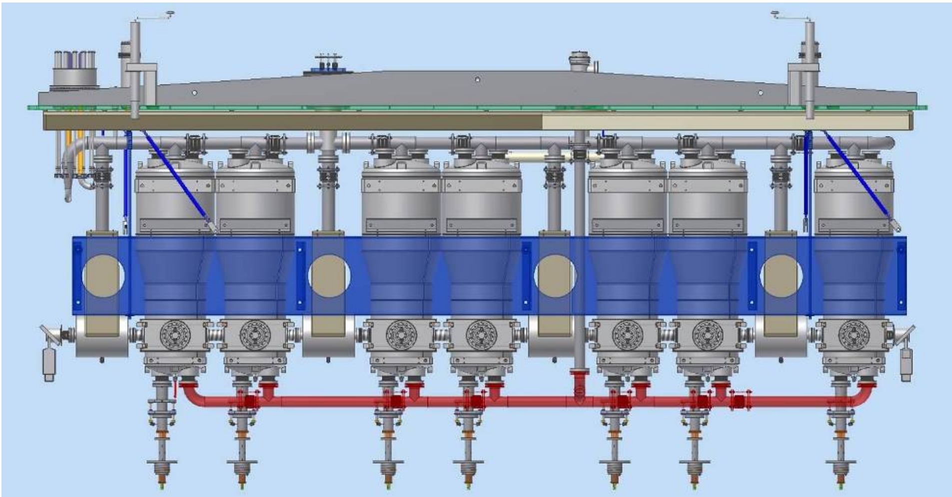
- Increase intensity of heaviest ions, A/q=7, to ~1 pμA

ATLAS Upgrade: CW RFQ and Cryomodule

- 60.625 MHz RFQ

70.75 MHz Cryomodule

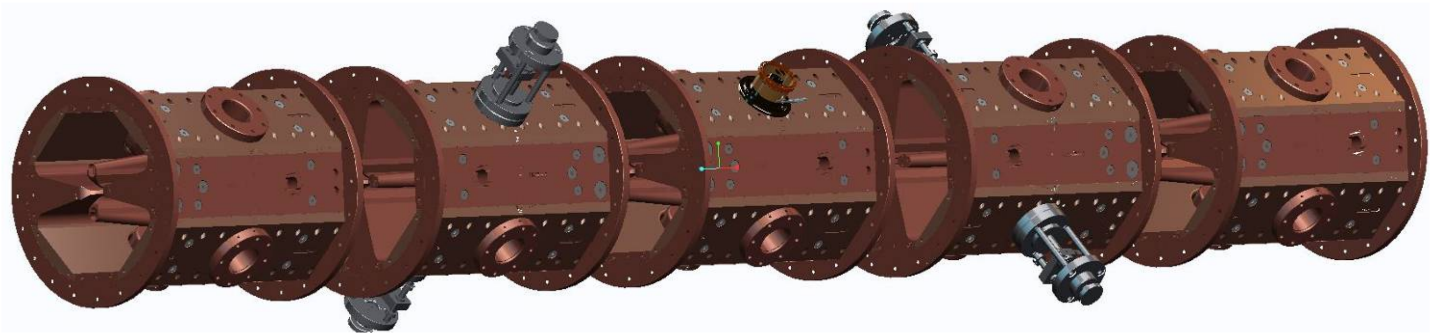




	RFQ	Cryomodule
Length	4 meters	5 meters
Voltage	2.1 MV	17.5 MV
q/A = from 1/7 to 1		Seven β_G=0.077 QWRs
5 segments		Four 9-T solenoids

RFQ

	Parameter	Value
1	Duty cycle	100%
2	q/A	1/7 to 1
3	Input Energy	30 keV/u
4	Output Energy	295 keV/u
5	Average radius	7.2 mm
6	Vane Length	3.81 m
7	Inter-Vane Voltage	70 kV
8	RF power consumption	60 kW

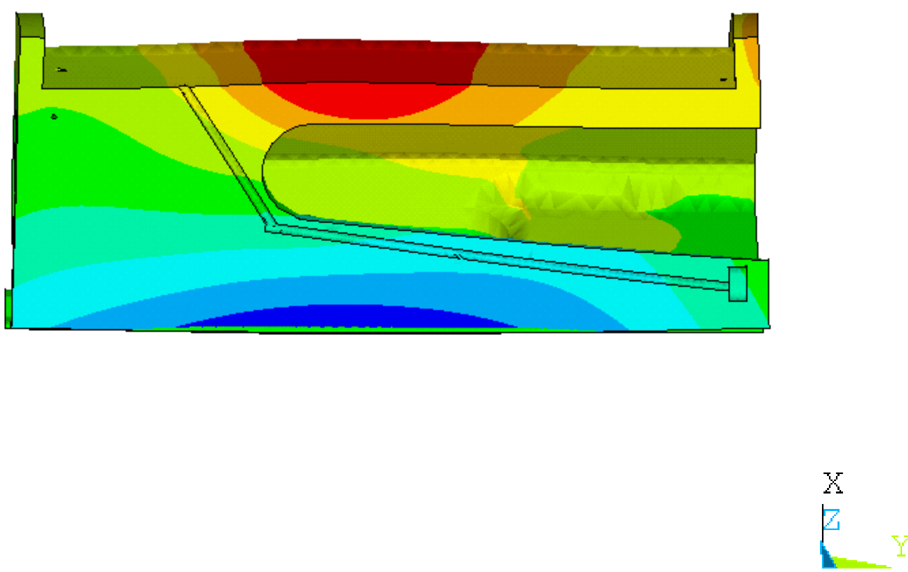


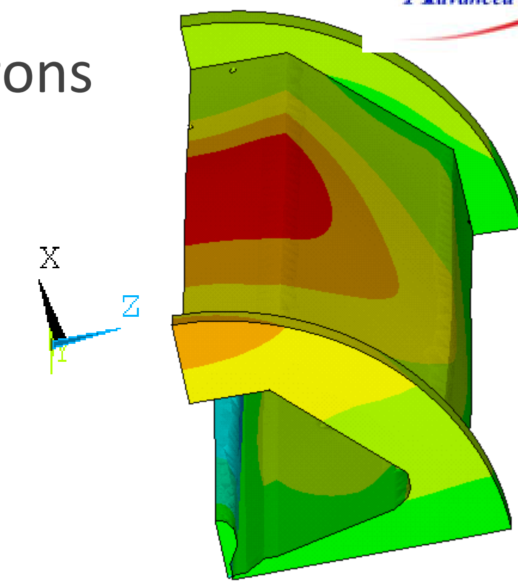
Design and Fabrication Features

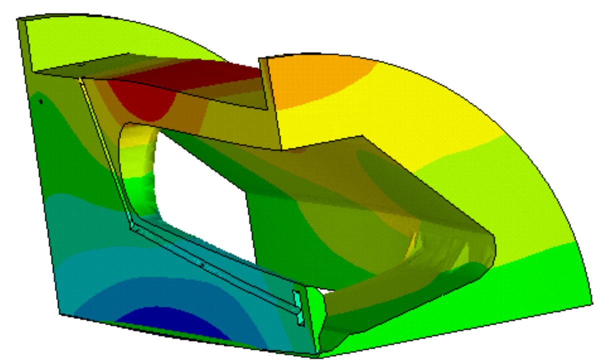
- A 4-vane structure with windows: reduces transverse dimensions to 18” and moves neighboring frequencies by ~11 MHz
- A very short exit radial matcher with the length of 0.8$\beta\lambda$ forms an axially-symmetric beam for injection into the SC cryomodule with solenoidal focusing.
- Low longitudinal emittance, external multi-harmonic buncher
- The effective shunt impedance is increased by 40% by introducing a trapezoidal shape to the vane modulation in the accelerating section instead of a traditional sinusoidal modulation;
- Optimized cooling to reduce frequency sensitivity to RF power
- Fabrication technology: OFE copper, 2-step high-temperature furnace brazing

Displacement & Frequency Results

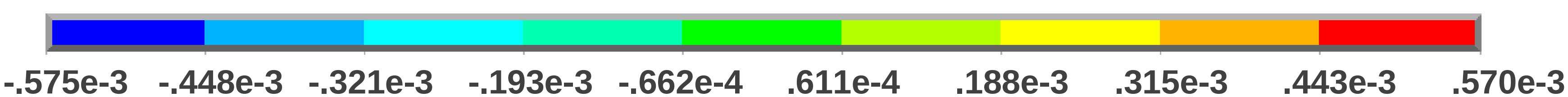
- Vane tip distortions are less than 54 microns
- Frequency shift is -29.7 kHz





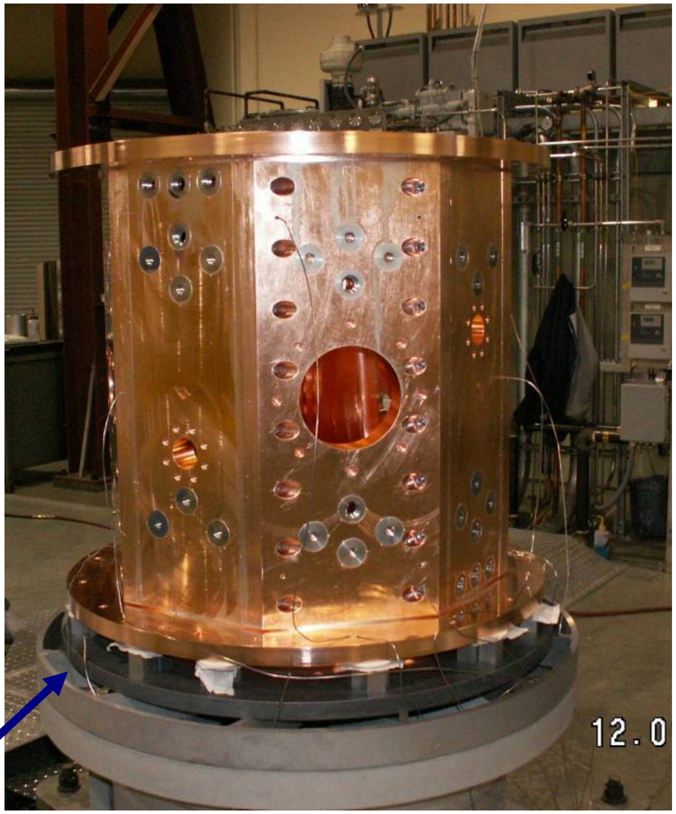


Vertical Displacements inches



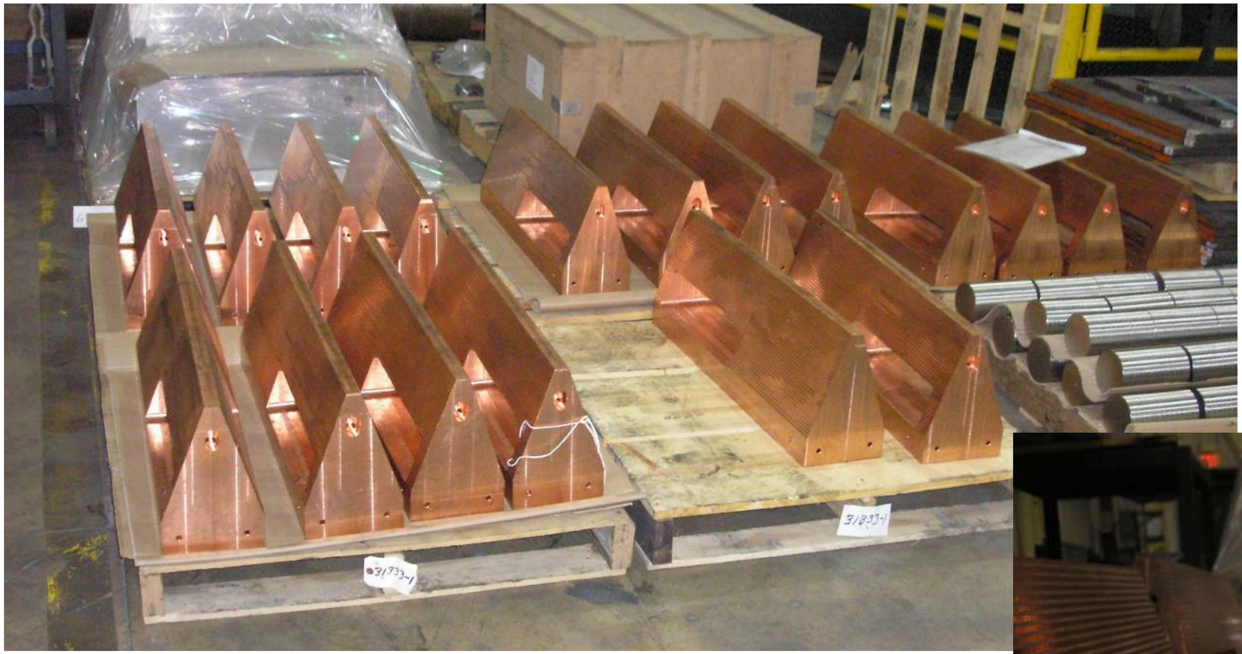
Fabrication Procedure

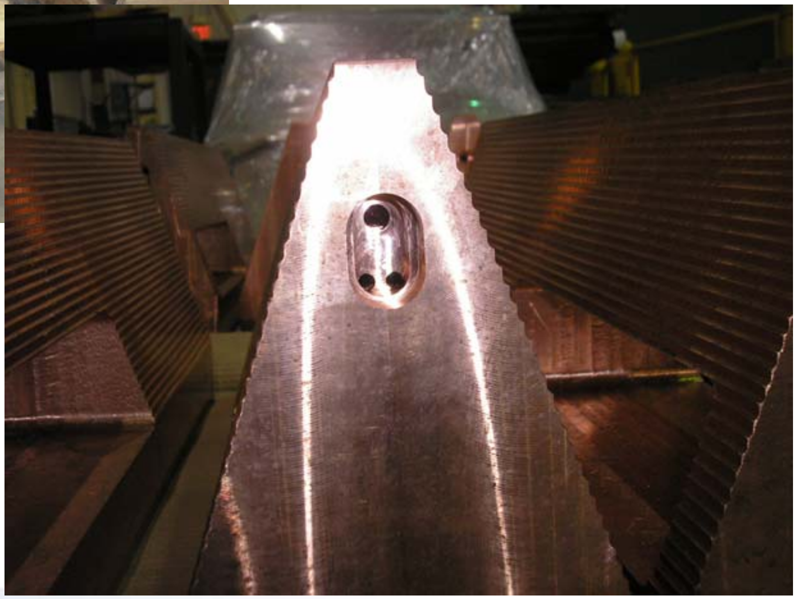
- Forging OFE copper to near-net-shape;
- Rough machining components;
- Drilling coolant passages;
- Brazing coolant passage plugs & SS inserts. Hydrotests of the cooling channels (150 atm.);
- Finish machining components. Modulation of vane tips;
- Pre-braze assembly to check fit and frequency;
- Brazing segment and vacuum test;
- Final machining.



Brazing, Step I

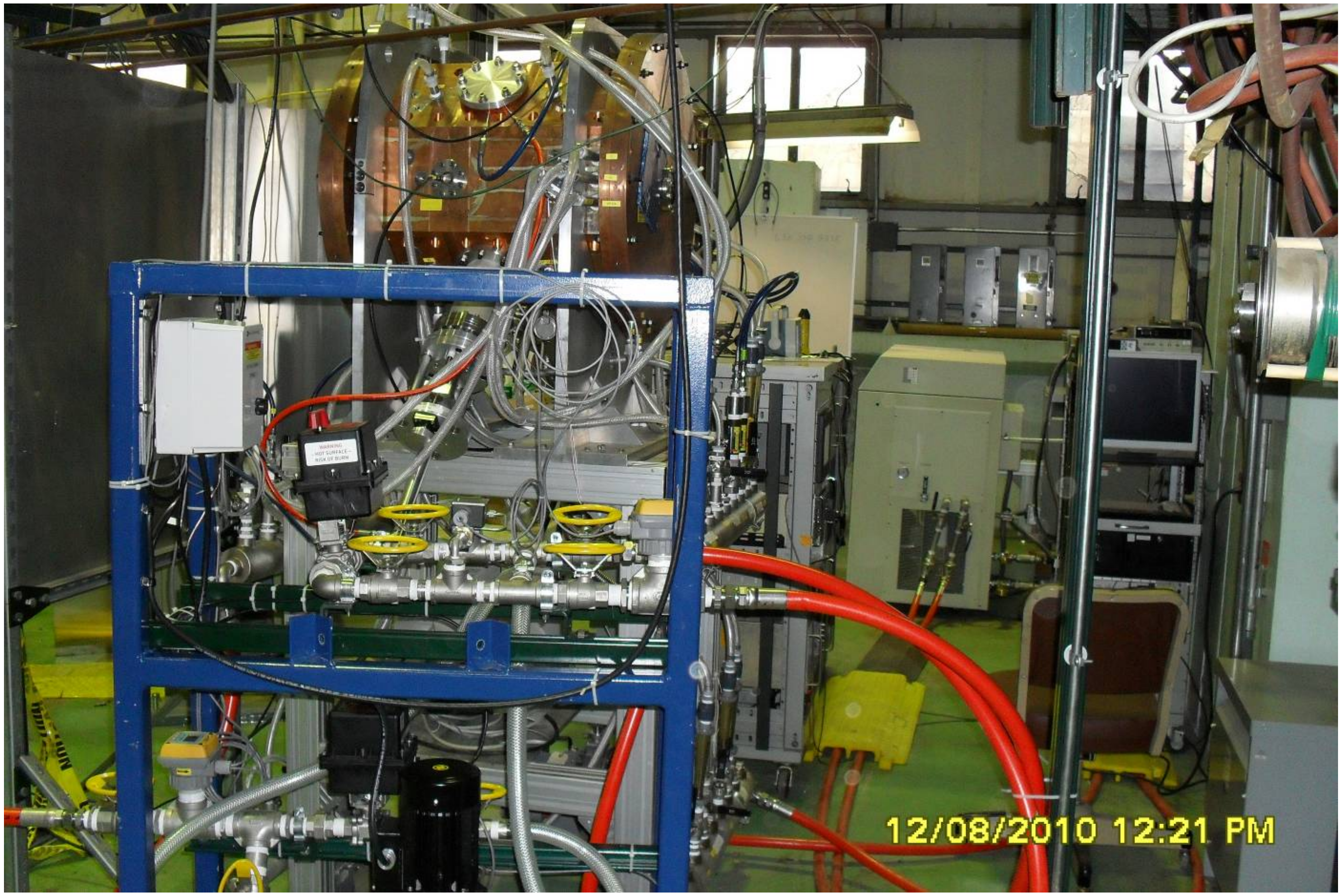
- Vane blocks and quadrants are ready for first brazing step: water plugs and SS inserts for cooling tubes





Resonance Control Cooling System

- RFQ body temperature is dynamically regulated by mixing chilled water from the external system and hot water of the RFQ body. Temperature of vanes is constant.



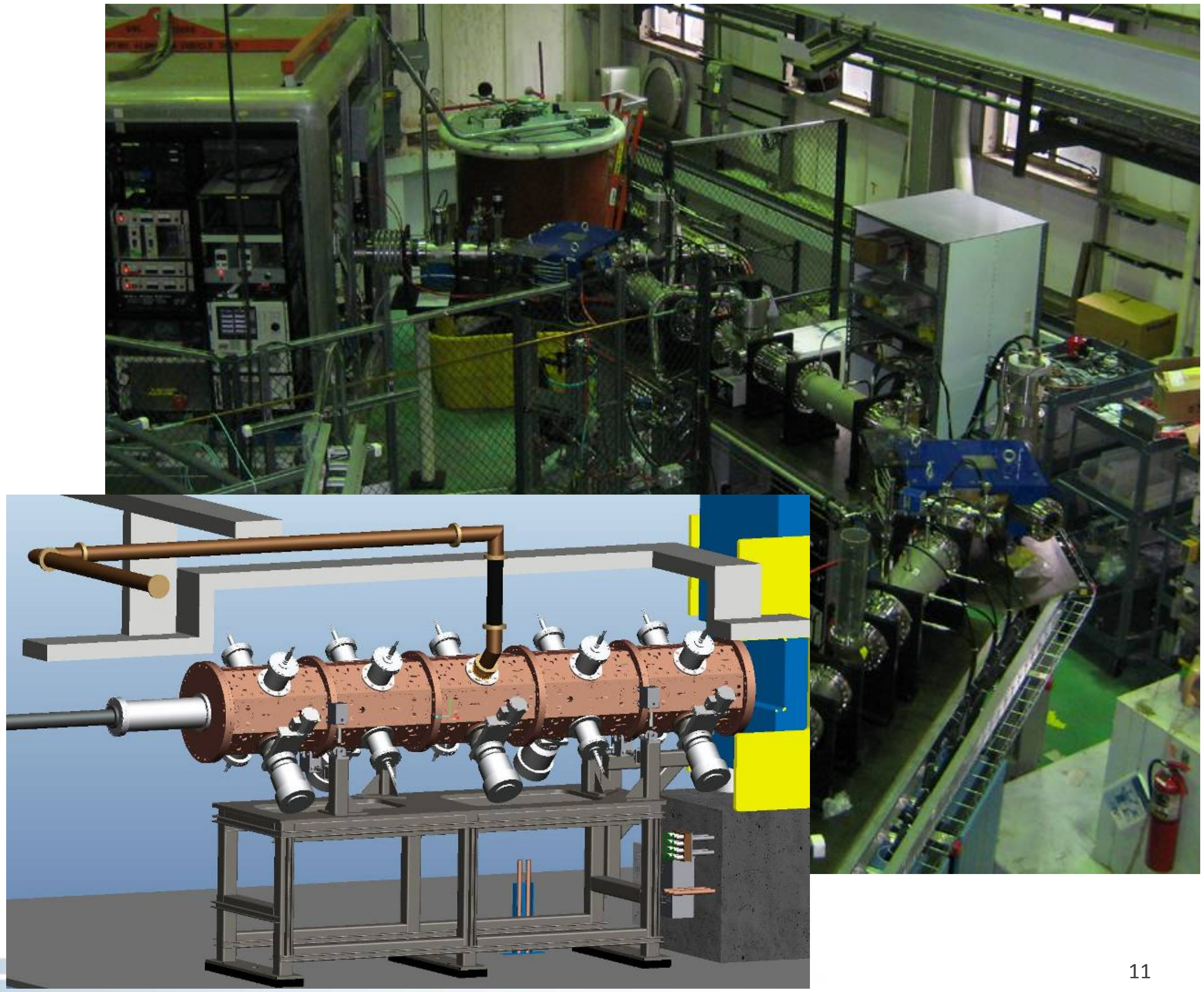
Off-line Beam Commissioning

- Scheduled – March 2013
- Expected – January 2012

Will be commissioned using:

• ≈ 30% of nominal RF power (≈ 20 kW)

•~ 1 mA DC He^{2+} ion beam extracted from ECR

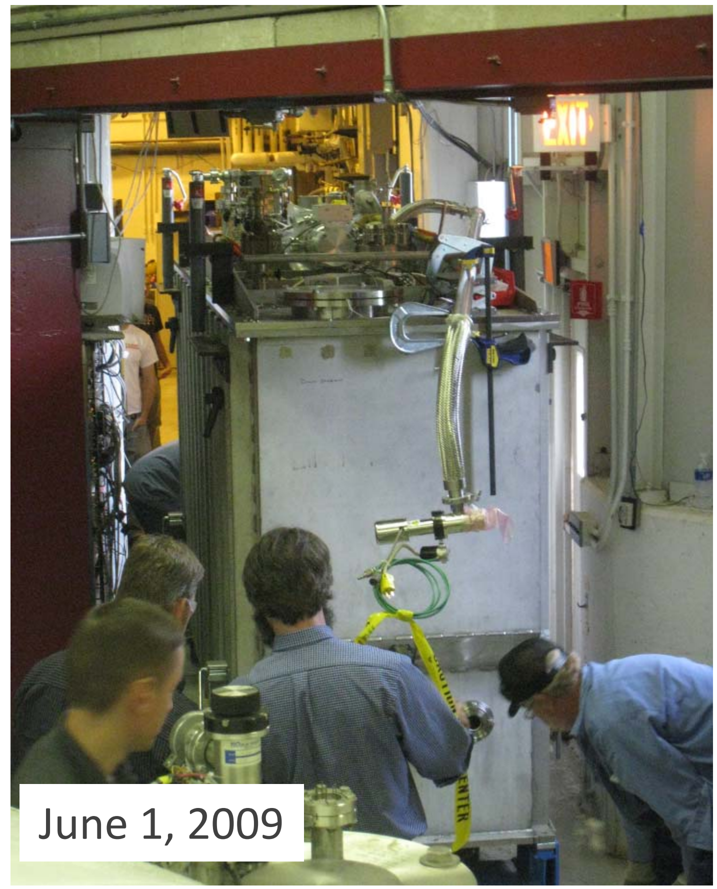


ATLAS Energy Upgrade

- Seven β_G=0.15 QWRs, f=109.125 MHz
- Operational since July 2009
- Provides 14.5 MV accelerating voltage

January 23, 2009

March 13, 2009



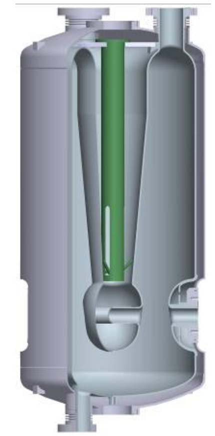
June 1, 2009

New QWRs Compared to Recently Commissioned QWRs

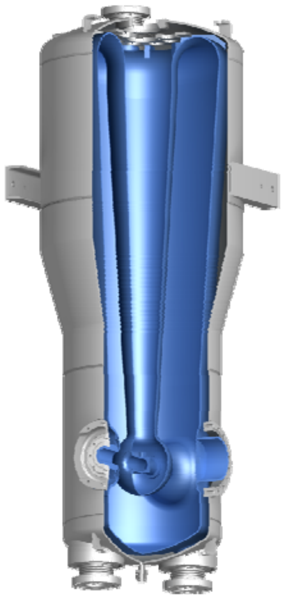
- New cavity outer conductor is conical in shape
- Drift tubes are highly optimized to reduce E_{PEAK}
- 2.5 deg drift tube face tilt to compensate beam steering effect

Frequency, MHz	109.125	72.75
β_G	0.14	0.077
V, max. voltage gain, MV	2.1	2.5
U_0, stored energy, J	11.6	23.8
$\beta_G\lambda$, cm	38.5	31.7
E_{PEAK}, MV/m	27 (limit by VCX)	40
B_{PEAK}, Gauss	490 (limit by VCX)	600
G, Ohm	40	26
R_{sh}/Q, Ohm	548	575
Cryogenic load at 4 .5K, W	7.8 (measured)	5.4

109 MHz

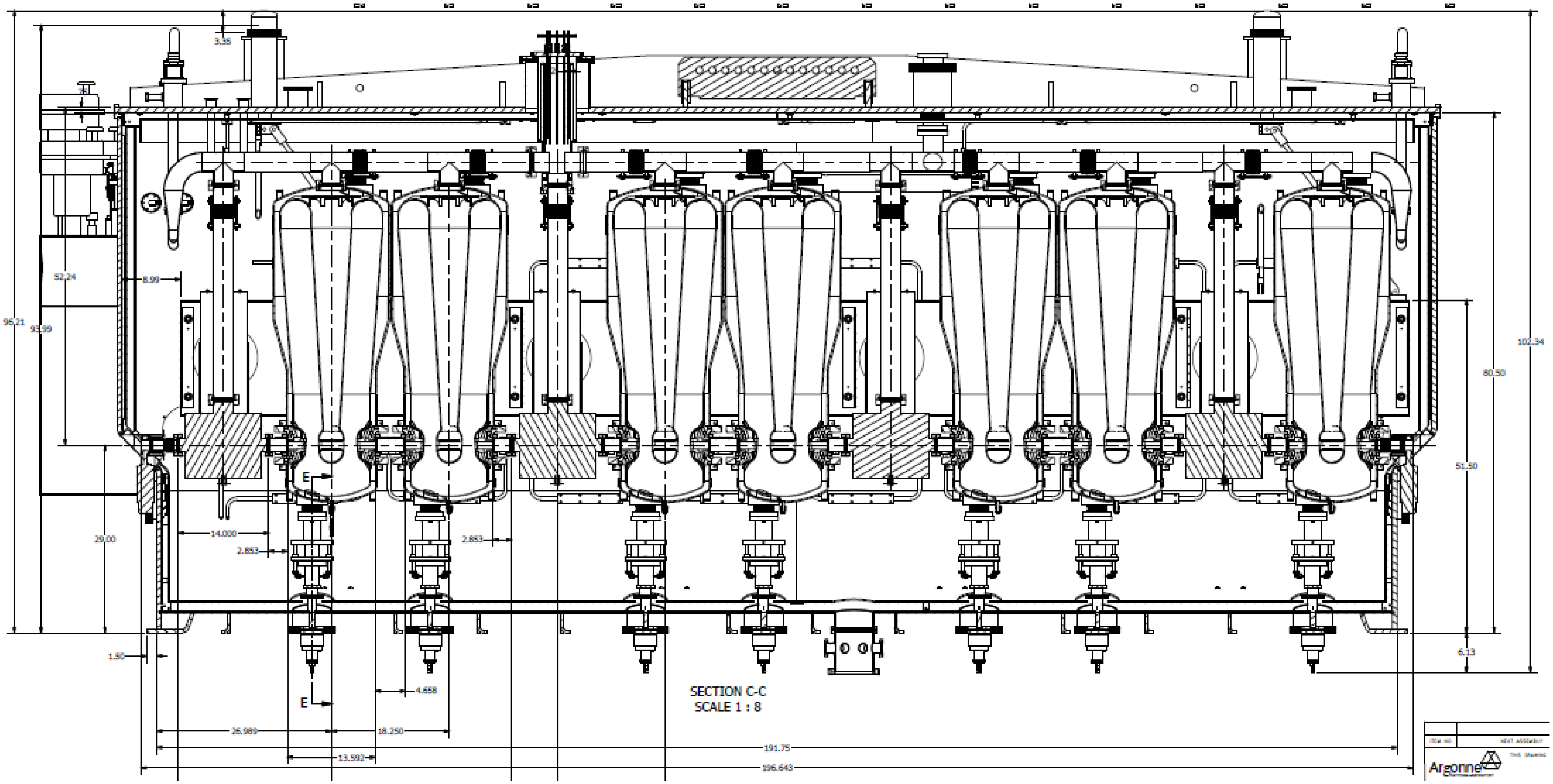


72.75 MHz



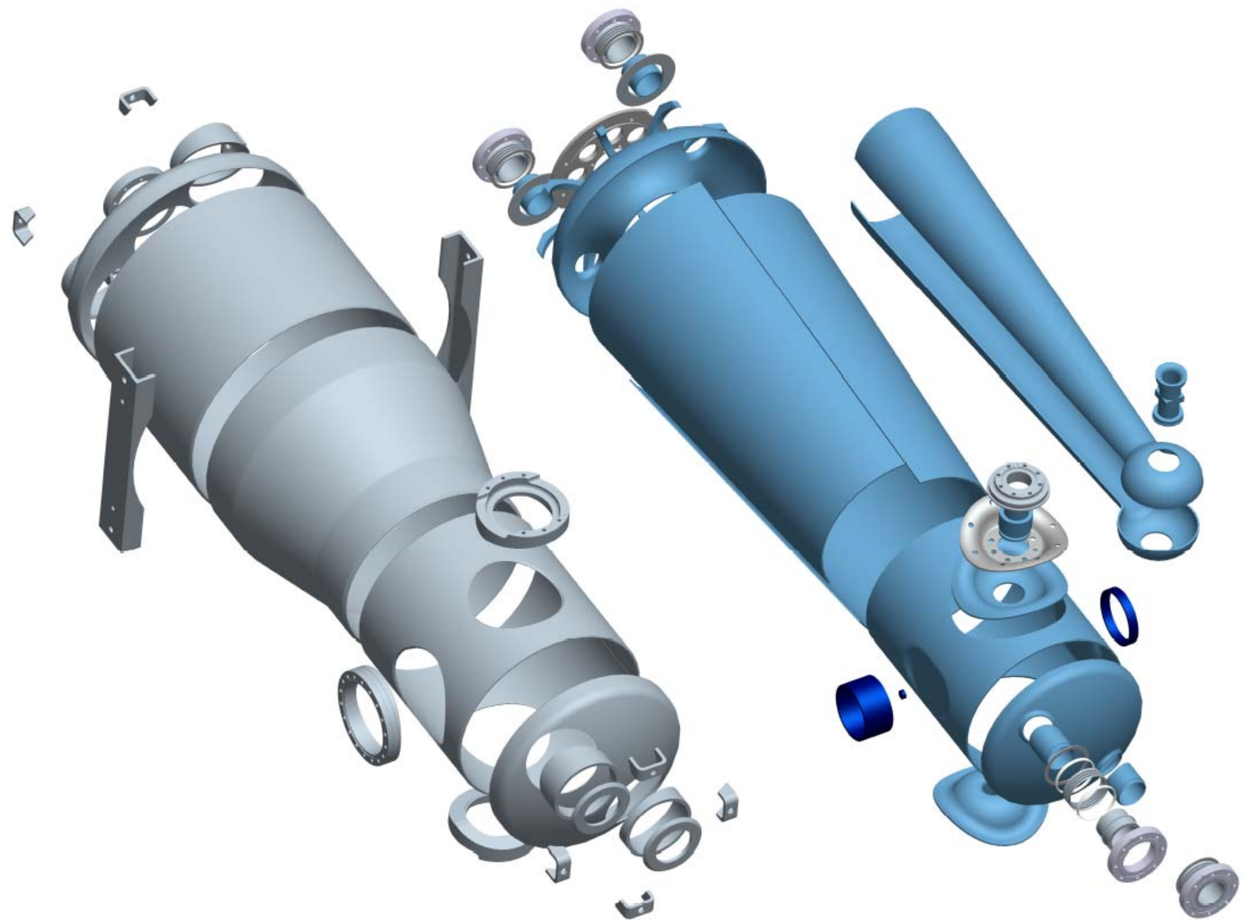
Cryomodule, side view

- Conical shape of the external conductor
- Increased real-estate accelerating gradients

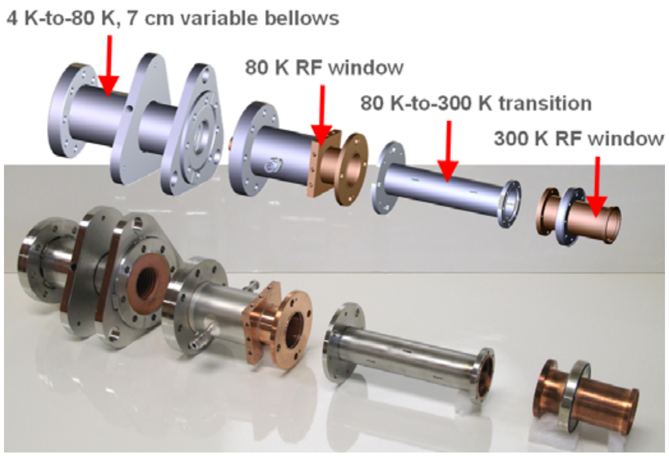


New 72.75 MHz QWR

- Design, fabrication of the first cavity took 17 months

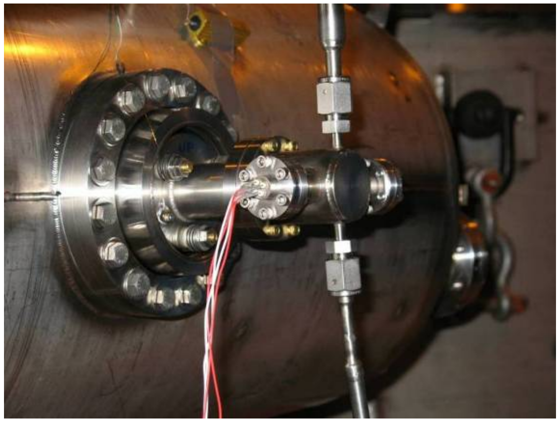


Resonator, RF-coupler and Piezoelectric Tuner



- High power coupler

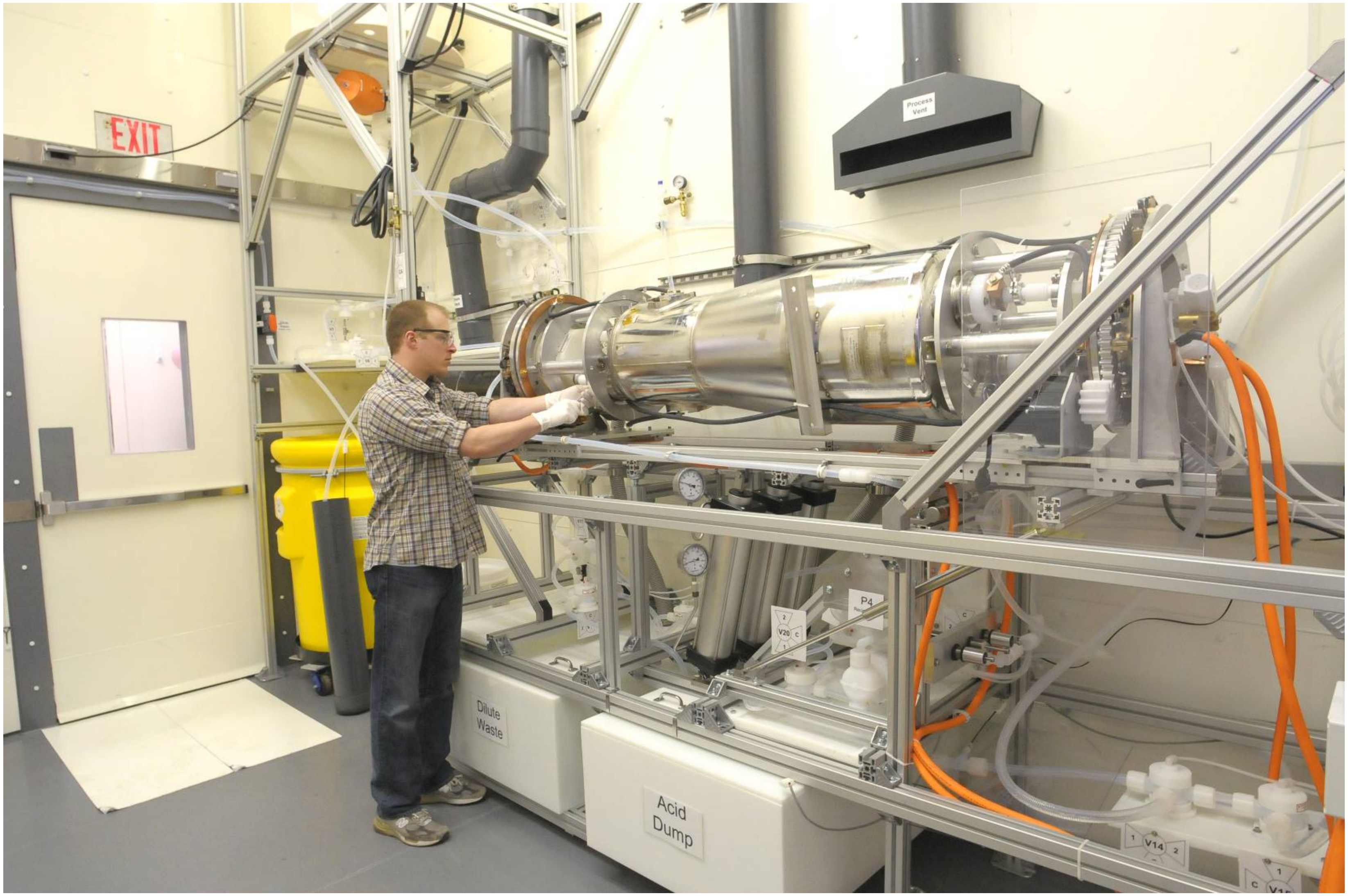
- Piezoelectric fast tuner



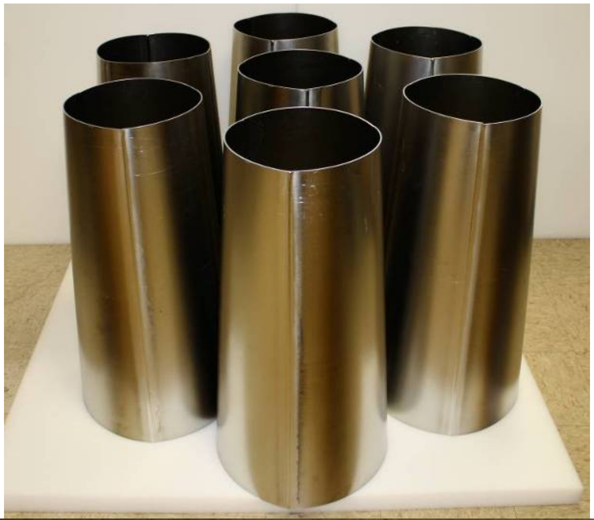
- RF test of the QWR prior final EBW

Stainless Steel LHe Vessel, Electron Beam Welding

Electropolishing

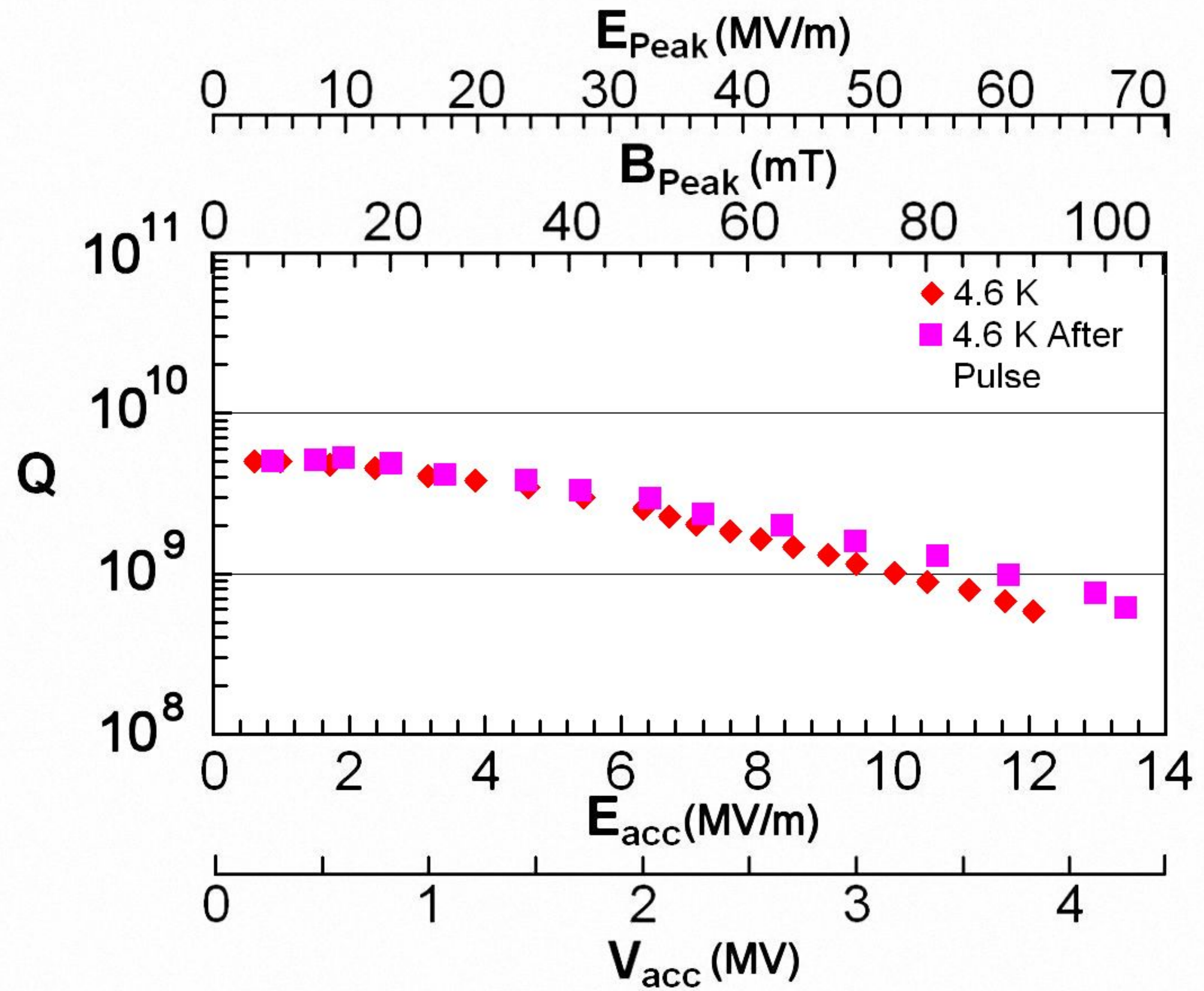


Production cavities
Niobium parts formed by Advanced Energy Systems



Initial Cold Test Results

- Peak fields are at the level of ILC specs



Initial Cold Test Results

- Initial cold test results at T=4.6 K show remarkably good performance, easily exceeding the ATLAS requirements.

Parameter	Design	Measured
Frequency, MHz	72.760	72.756
Voltage, MV	2.5	4.3
E_{PEAK} , MV/m	40	69
B_{PEAK}, mT	60	105
Q_0 at 4.5K	10^9	$2\cdot10^9$
$\Delta f/\Delta P$, Hz/Torr	-2.4 (ANSYS)	-2.6

Conclusions

- The ATLAS upgrade includes the development of a CW normal conducting RFQ and a SC cryomodule with low-beta QWRs. Installation and commissioning is scheduled in the second quarter of FY2013.
- The design of the system was developed for the acceleration of up to ~2 mA of beam current even though such high current is not required for ATLAS.
- This is a significant step towards Front Ends of multi-megawatt driver accelerators for protons and ions such as FNAL's Project X, FRIB and Accelerator Driven System (ADS).