Brief Overview of SRF at JLab

C. Reece

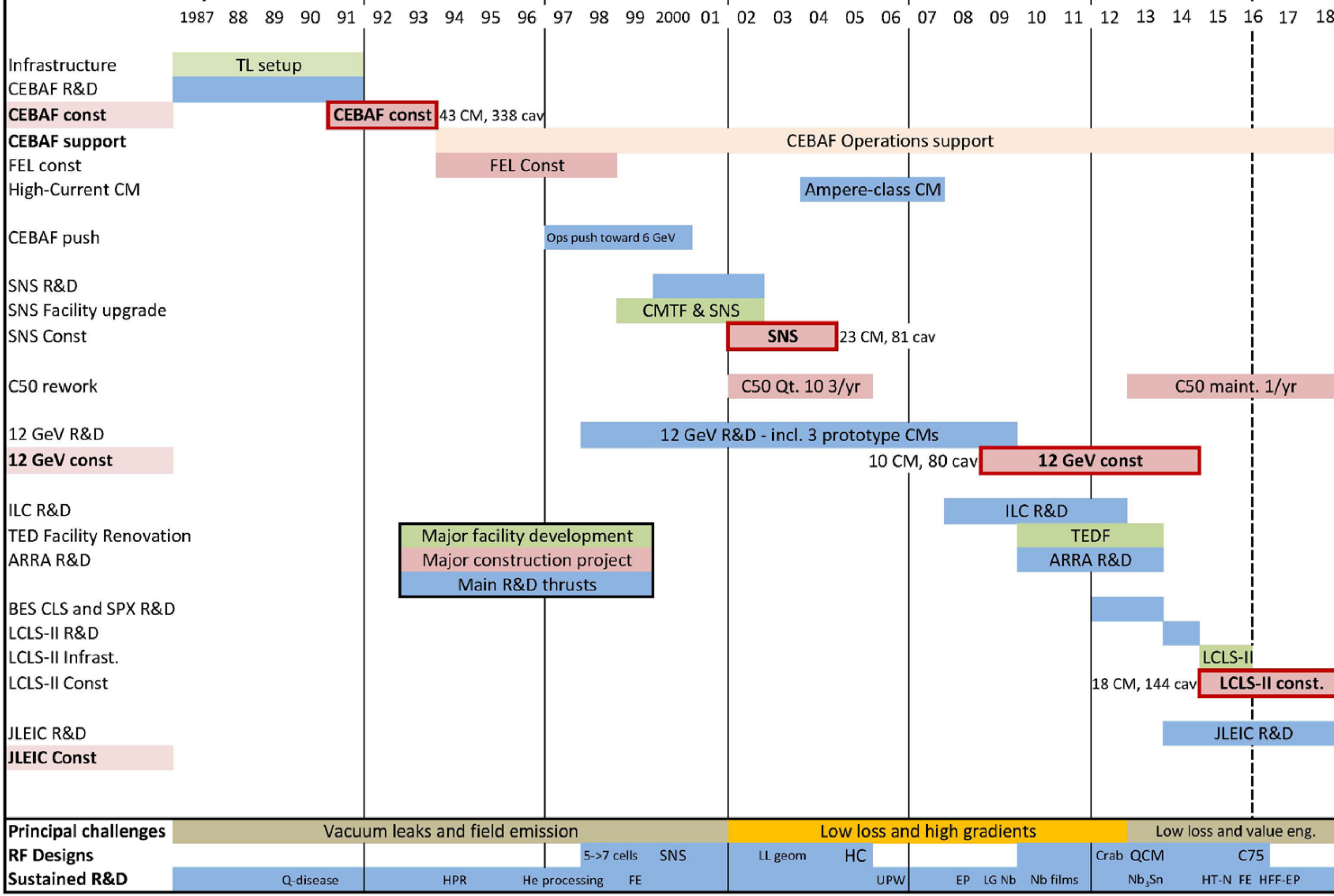
SRF at Jefferson Lab

- Develop and design SRF accelerator systems
  - Cavities, supporting systems (tuners, rf loads, etc.)
  - Cryomodules

- Original CEBAF construction
- Free Electron Laser
- Spallation Neutron Source
- CEBAF 12 GeV Upgrade
- ILC R&D
- LCLS-II

- Planning for the future

JLab SRF Summary Timeline

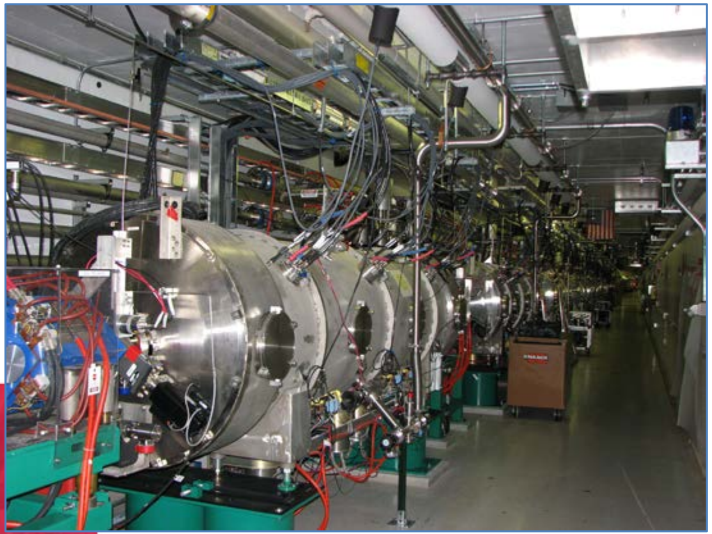


Technology Challenges

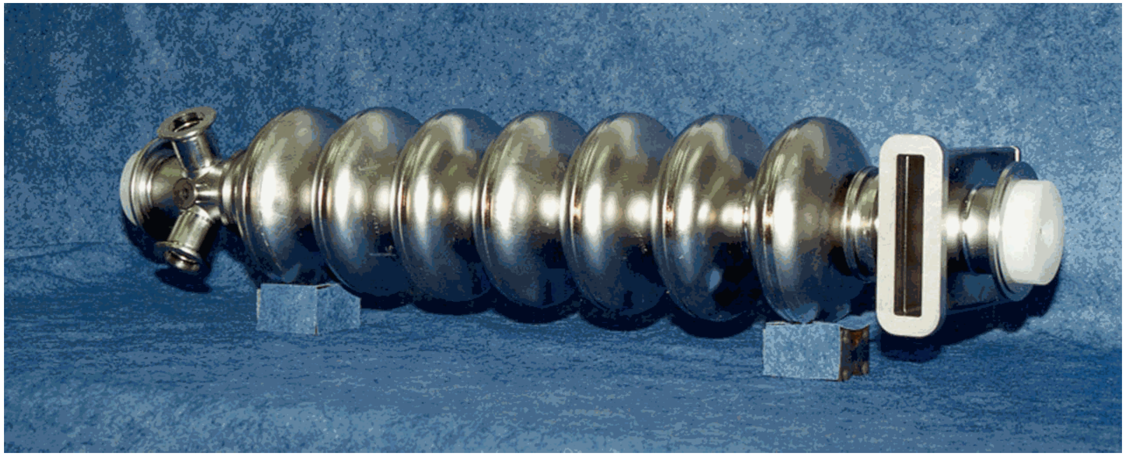
- SRF is inherently a multi-disciplinary challenge
  - RF structure design, beam physics, low temperature physics/cryogenics, mechanical engineering, materials science, chemical engineering, fabrication engineering, cleaning technology, UHV, RF controls and measurement engineering, superconductivity, process engineering, value engineering
  - Every new “simple” solution in one dimension is imbedded in a complex system that must adapt
- Improving technology creates new opportunities for fresh cost/performance optimization.
- JLab continues to press SRF technology forward.

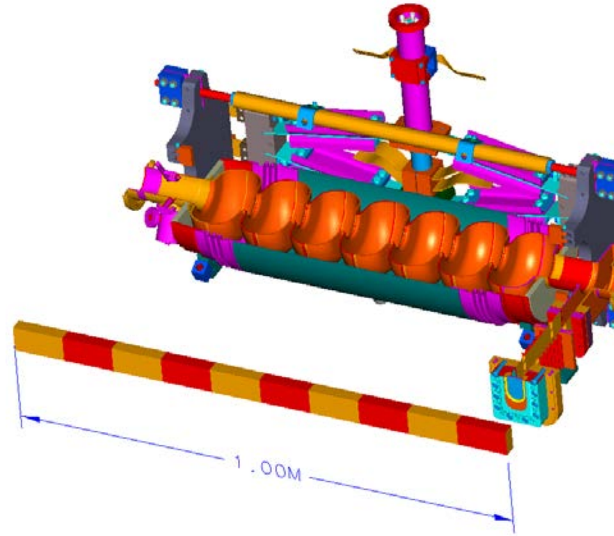
SNS Construction

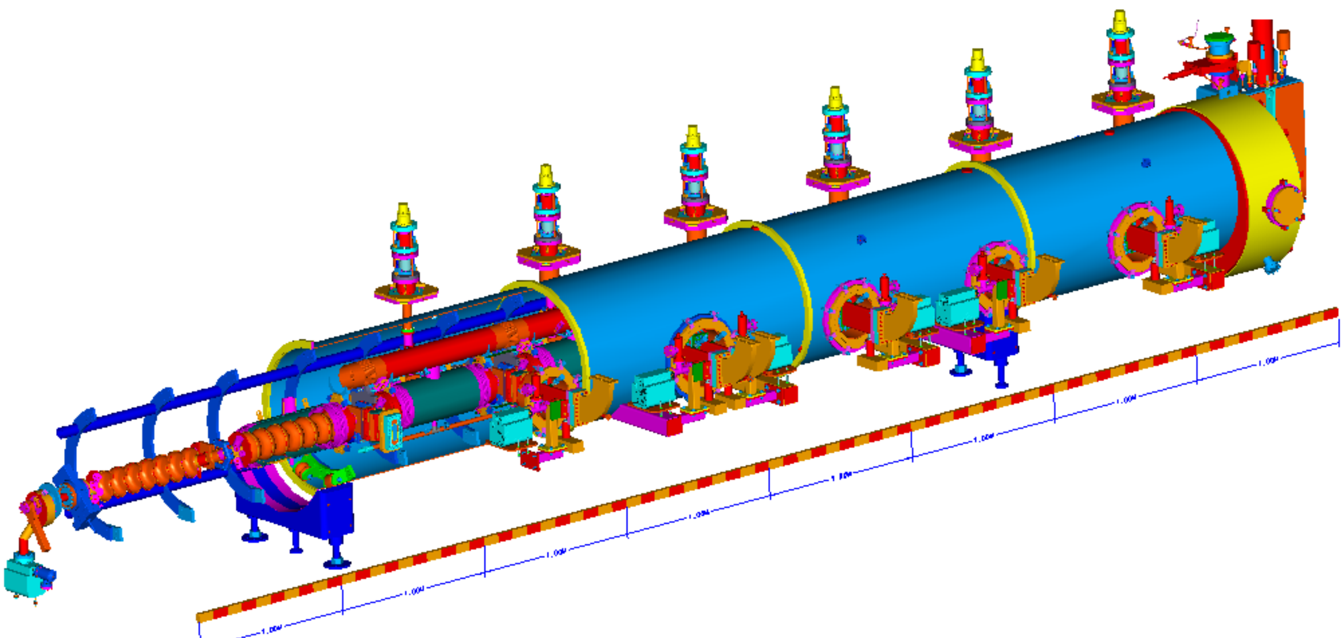
- Designed and prototyped β= 0.61 & 0.81 cavities with international collaboration
- Designed cryomodules based on CEBAF endcans and CEBAF upgrade spaceframe concept
- Assembled, tested and delivered 23 cryomodules containing 81 cavities



"C100" Cryomodule for CEBAF 12 GeV Upgrade

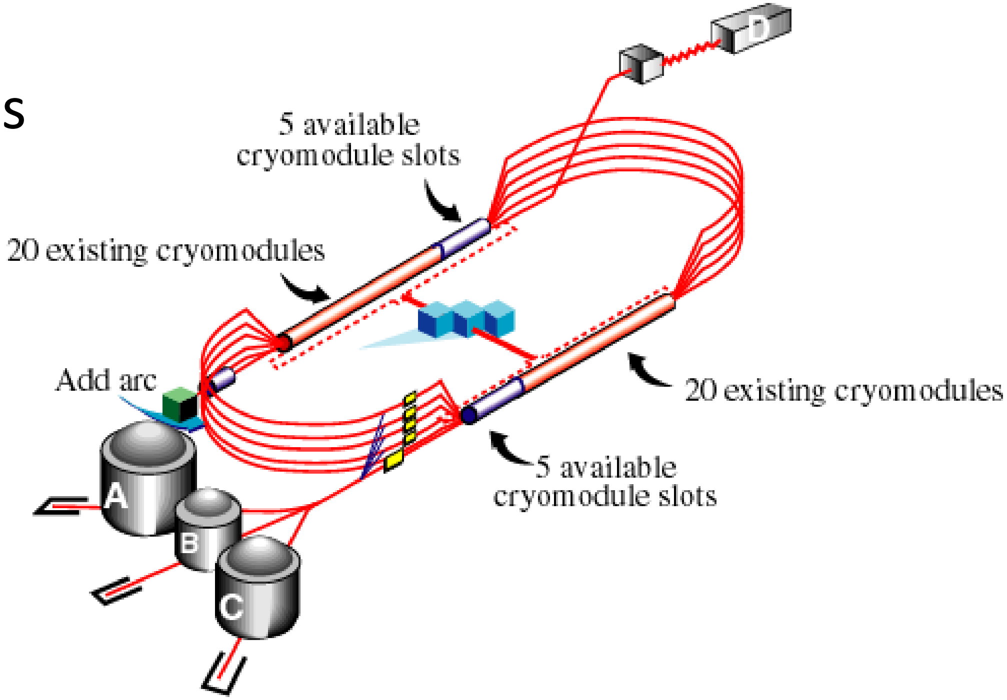






CEBAF 12 GeV Construction

- Design, procure, process, assemble, test, commission 10 new cryomodules providing 107.5 MV each (eight 19.2 MV/m, 0.7 m cavities each), < 300 W @ 2.07 K
- New cavity design "Low Loss"
- New tuner, HOM couplers, HOM probe feedthroughs
- New rf window design
- New cavity processing methods



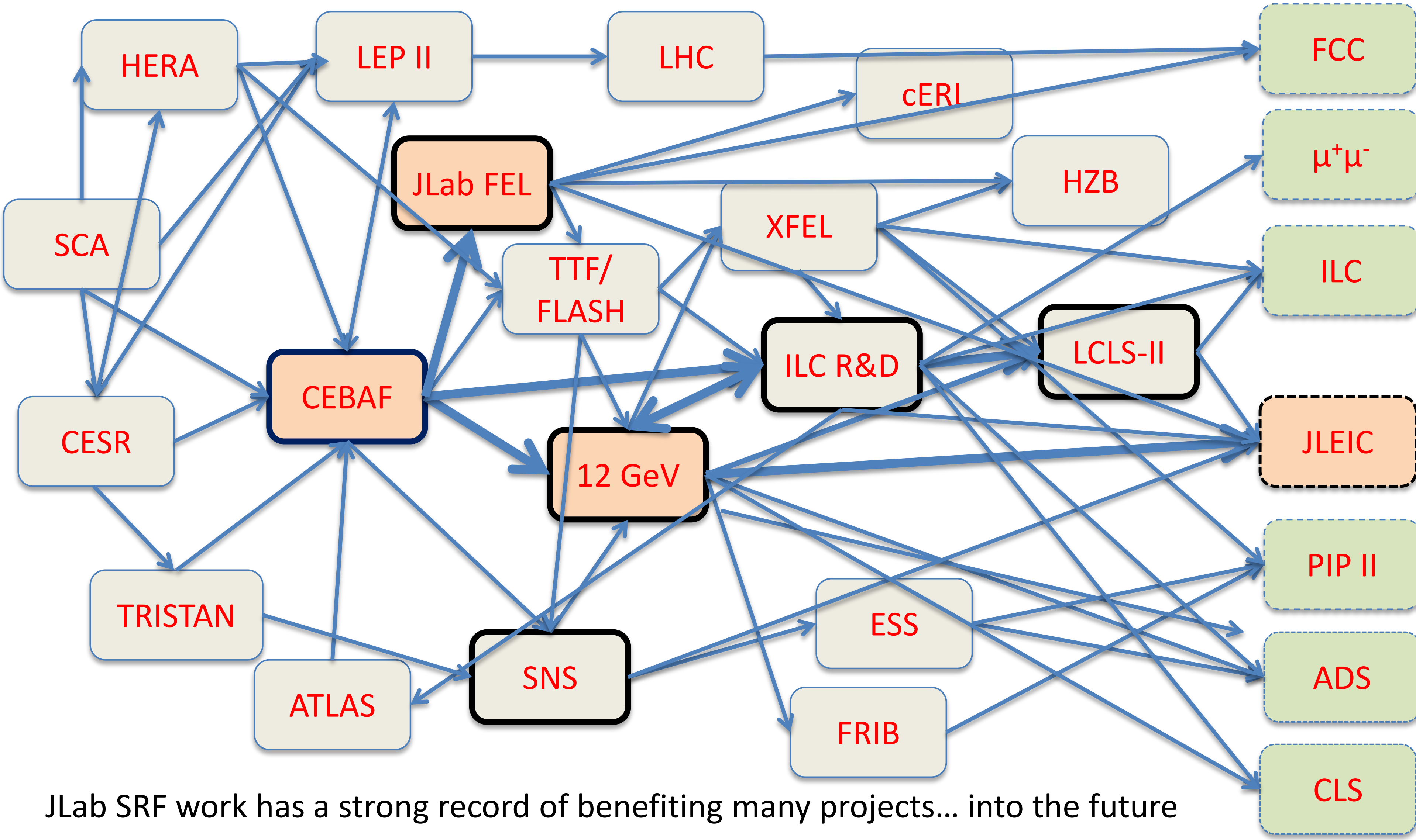
Upgrade Cryomodule Performance

- All ten C100 cryomodules were commissioned in CEBAF, each with over 100 MV total voltage
- Physics runs in the 12 GeV era have begun
- Further system optimizations will continue to tweak stability and maximum voltage

Present performance limitations

- **Microphonics**
  - Optimizing controls
  - Damping vibrations
- **Field emission**
  - Radiation and beamline heating effects
- **Heat management issues**
  - Need improvements to heater controls
- **Fault recovery times**
  - Optimizing controls

SRF Accelerator Technology Evolution

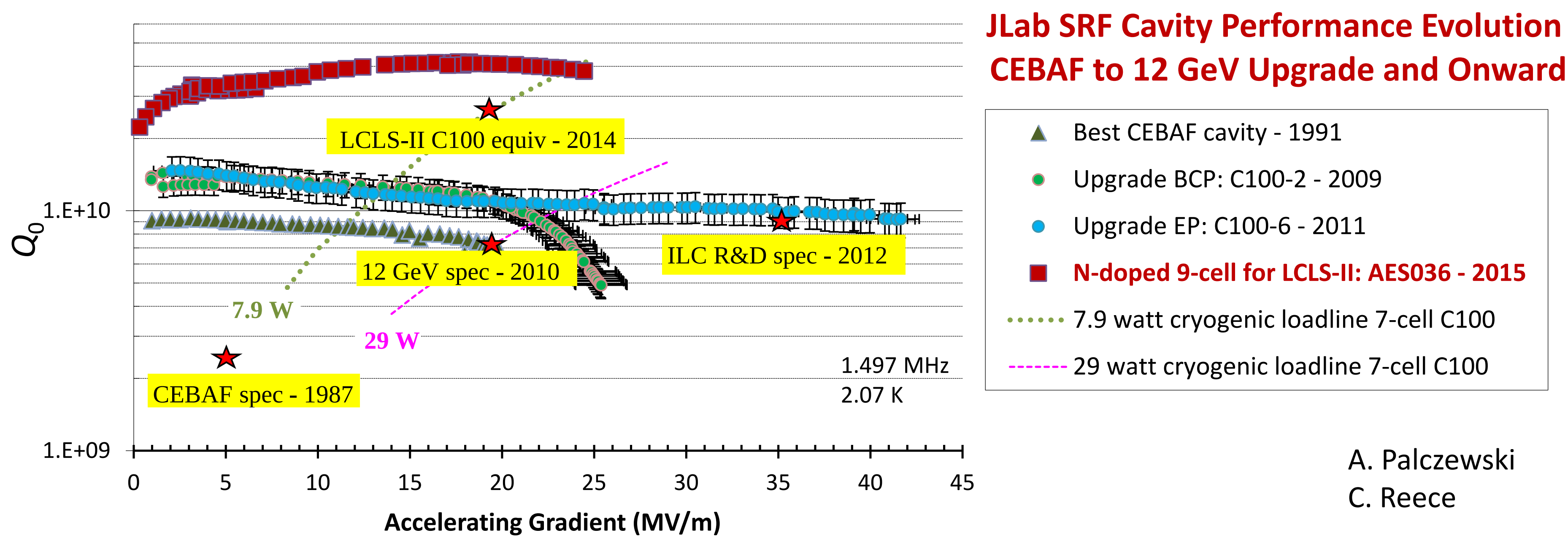


JLab SRF work has a strong record of benefiting many projects… into the future

Improving SRF Cavity Efficiency via Doped Materials

Learning how to minimize SRF losses (maximize cavity *Q*) via Nitrogen Doping of Niobium

- Collaborated with FNAL and Cornell to **secure High-*Q* process for LCLS-II**
  - Enabled >50% reduction in cryoload compared with previous methods
  - Transferred the protocols to vendors
- Systematically studying the doping protocols, material effects, and SRF properties
  - Involving university collaborators (including graduate students) in **detailed material characterization**
  - Beginning to interpret new RF performance in terms of latest basic SRF theory



A. Palczewski
C. Reece

Project	# of Cavities built @ Jlab	# of Cavities processed / tested	Frequency (MHz)	Beta	# of Cells	Duty Factor
CEBAF (OC cell shape)	20	358	1497	1	5	CW
CEBAF (OC) - C50 rework		102	1497	1	5	CW
CEBAF Upgrade Style (OC)	8	16	1497	1	7	CW
CEBAF Upgrade Style (LL)	5	5	1497	1	7	CW
CEBAF Upgrade Style (HG)	9	11	1497	1	7	CW
C100 - (LL)	10	96	1497	1	7	CW
QCM - 2-cell	1	1	1497	1	2	CW
QCM - 7-cell	1	1	1497	1	7	CW
FEL IR DEMO (OC)	10	10	1497	1	5	CW
FEL 10 kW Upgrade (OC)	8	8	1497	1	7	CW
FEL HCCM (HC)	3	3	1497	1	5	CW
FEL HCCM (HC)	1		750	1	5	CW
AES HC Inj		3	750	1	1	CW
AES HC Inj		1	1500		1	CW
APT	2	2	700	0.64	3	CW
APT		3	700	0.64	5	CW
SNS	4	44	805	0.61	6	Pulsed
SNS	1	52	805	0.81	6	Pulsed
RIA	2	2	805	0.47	6	Pulsed
INFN Legnaro - seamless		1	1500	1	5	CW
INFN Milan - TRASCO		1	703	0.5	5	CW
DESY - seamless		3	1300	1	2	CW
KEK	1	1	1300	1	10	Pulsed
ILC-like - superstructure	1	1	1497	1	10	Pulsed
BNL		1	704	1	5	CW
FLASH - FNAL/DESY	5		3900	1	9	Pulsed
Rossendorf - Injector	2	2	1300	1	3.5	CW
Darmstadt Univ.		1	2800		20	CW
[illegible]	4	4	1300	1	2	CW
Bessy		1	1300	1	1.5	CW
[illegible]	1	1	400	1	1	CW
PKU		1	450		1	Spoke
PKU		2	1300	1	2	CW
PKU		2	1300	1	9	CW
Argonne	2	2	2300		2	CRAB
Argonne	1	1	1400	0.8	1	CW
Radiabeam	3	3	3900	1	1	CW
FNAL	4	2	650	0.61	1	CW
Magnetron test	1	1	2450	1	1	CW
FZJ		1	760	1	1	Spoke
ILC - (TESLA)		27	1300	1	9	Pulsed
ILC - (LL)	1	1	1300	1	7	Pulsed
ILC - (Japan LL)		3	1300	1	9	Pulsed
ILC - (TESLA)	4	4	1300	1	9	Pulsed
LSF	1	1	1300	1	5	CW/pulsed
LCLS-II		15	1300	1	9	CW
Total	**115**	**801**				

Over 4300 VTA tests and counting

Multi-cell cavities through 4/16

Cavity Design Innovations

- 5-cell OC >> 7-cell OC >> 7-cell HG >> 7-cell LL
- Medium and high-beta cavities for SNS
- 750 MHz separator for CEBAF
- New injector low-energy 2-cell cavity for CEBAF
- New capture cavity for CEBAF
- FEL cavities, FEL booster upgrade
- SRF gun cavities
- Test vehicle cavities – two-mode cavity, triaxial, SIC, TE_{011} rod, TAMU, …

Cavity Material Innovations

- Ingot Nb for improved performance and potential cost
- High Ta content for lower cost
- Interstitial doping for high Q
- Seamless forming of cavity cells
- Thin film Nb for potential cost and (ultimate?) confidence
- Nb_3Sn for high Q at 4.2 K
- Multi-layer SIS for potential higher fields

Cavity Process Innovations

- *In-situ* **helium processing** to reduce field emission
  - Application to CEBAF cryomodules increased the maximum operating energy from 5.2 GeV to 5.7 GeV
- HPR
  - Championed early use of **high pressure rinse** with ultra-pure water to fight field emission – now standard
- Electropolishing Nb
  - Tian PhD mastered the electrochemistry process dynamics - informs production parameter choice – used for 12 GeV
- Improved US and 2nd HPR cleaning – further FE reduction
- 120°C bake
  - high field Q drop cure for EP'd cavities, PhD

Education and Training of SRF Experts

Active training of SRF experts

- PhD programs in SRF through regional universities since 1987 (16)
- In-service broadening of non-SRF PhD scientists into SRF expertise
- Extended in-service development of engineers into valuable SRF specialists
- In-service training of technical staff in highly skilled specialized task work
  - EBW, chemistry, cleanroom (none arrive with experience)
- Tutorial instructors at the biannual International SRF Conferences
- Course instructors for CERN Accelerator School
- Course instructors for US Particle Accelerator School