NSLS-II RF Systems

James Rose, Radio Frequency Group Leader

PAC 2011

Outline

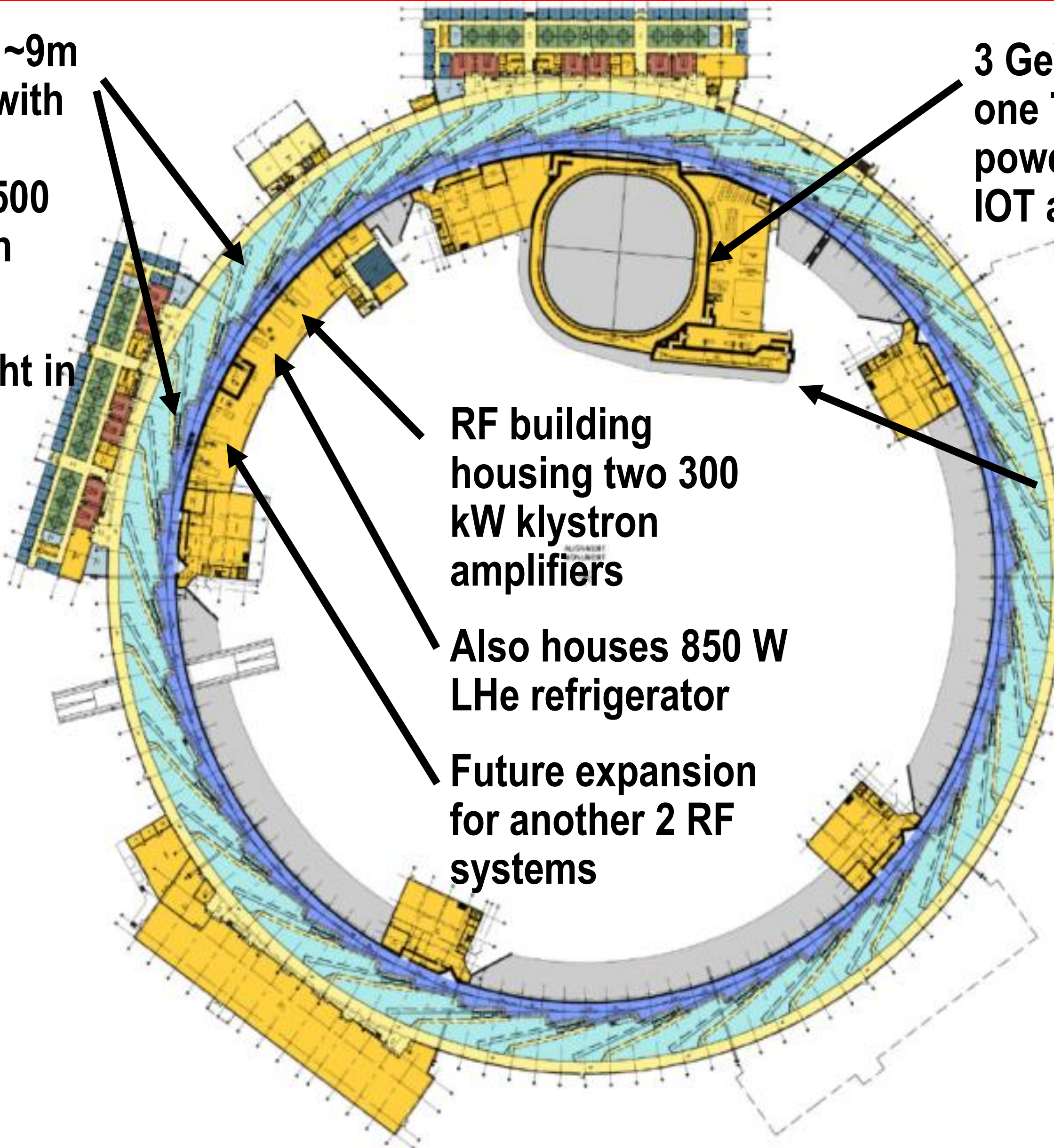
- Introduction
- Linac
  - RF cavities and klystrons
- Booster
  - Cavity-Transmitter
- Storage Ring
  - 500 MHz SRF cavity
  - 300 kW RF transmitter
  - Cavity Field Controller
  - 1500 MHz Landau cavity
  - Cryogenic system
- Summary

NSLS-II RF Systems

Storage Ring: Two ~9m RF straights each with two 500 MHz SRF cavities and one 1500 MHz passive bunch lengthening cavity

Only one RF straight in initial operations

3 GeV booster with one 7-cell cavity powered by 80 kW IOT amplifier



RF building housing two 300 kW klystron amplifiers

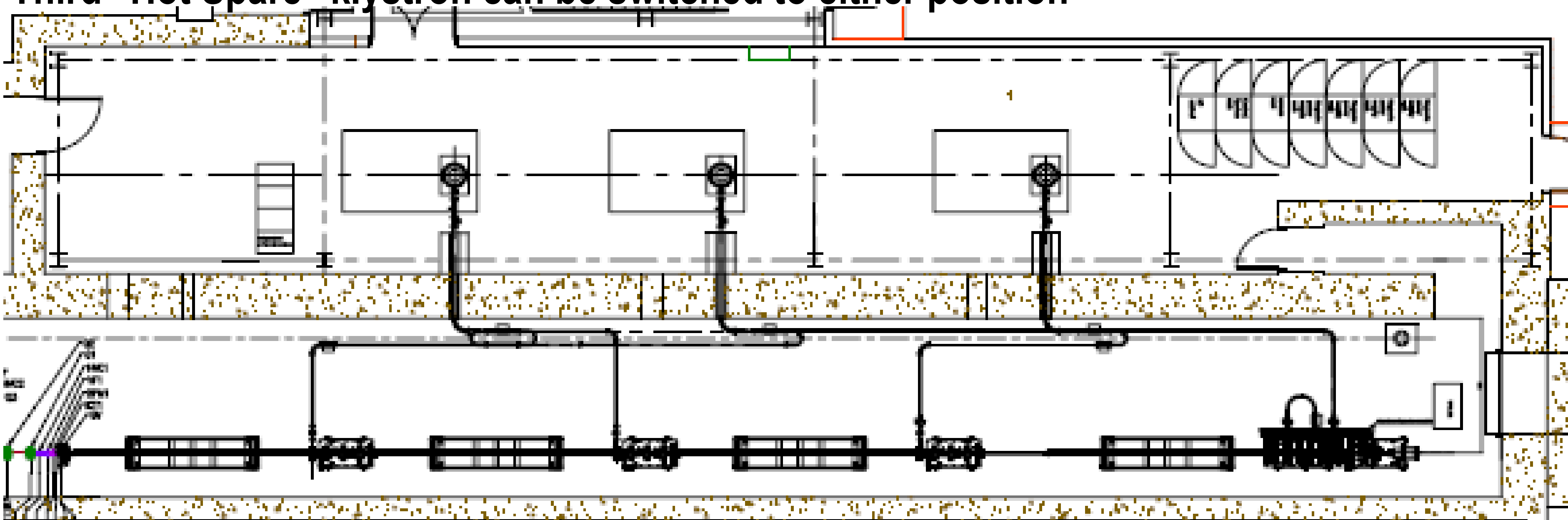
Also houses 850 W LHe refrigerator

Future expansion for another 2 RF systems

200 MeV linac with four 5.2 m TW structures powered by two 42 MW klystrons with SS modulators and third “hot spare”

Linac RF Systems

- 200 MeV S-band linac: 15 nC/pulse requires beam loading compensation using a feedforward algorithm in the cavity field controller
- 500 MHz modulated gun with 500 MHz buncher, 3 GHz pre-buncher, 3 GHz TW buncher and four 5.2m TW structures
- Two 42MW klystrons with Solid State Modulators using IGBT switches on multiple-primary, split-core pulse transformer
- Third “Hot Spare” klystron can be switched to either position

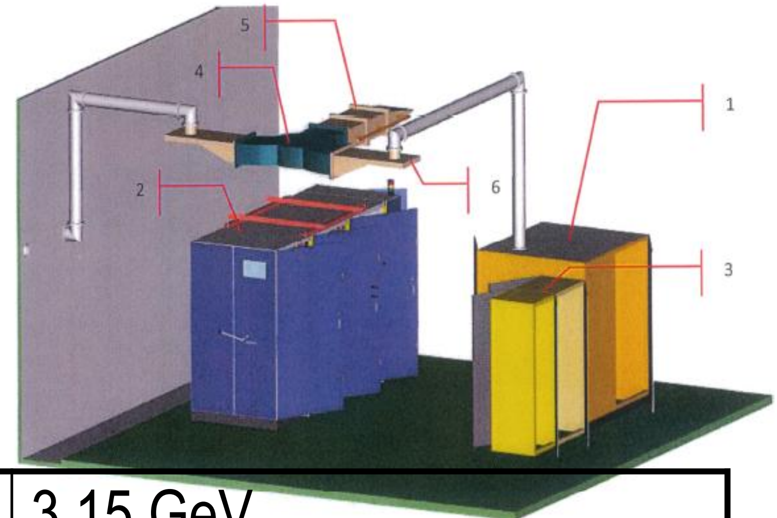


Booster RF: 7-cell PETRA cavity + 80 kW IOT

- Booster energy: 200MeV →3 GeV
- RF frequency: 500 MHz
- Repetition rate: 1 Hz
- Energy loss per turn: 625 keV
- Beam current = 28 mA (15nC)→ Beam power 18 kW
- Energy acceptance: 0.7% at 3 GeV → 1.2 MV booster RF voltage = 36 kW cavity power for 7-cell cavity
- Total power requirement ~54 kW for PETRA-type 7 cell RF cavity

BOOSTER 500 MHz Transmitter

- **Booster 7 cell cavity power requirements well matched to 80 kW IOT amplifier**
- **Contract awarded for 80 kW IOT transmitter with Pulse Step Modulated high voltage power supply**
- **Performance exceeds specification of 1.2 MV and synchrotron losses for 10 nC at 3 GeV, allowing flexibility in operations**

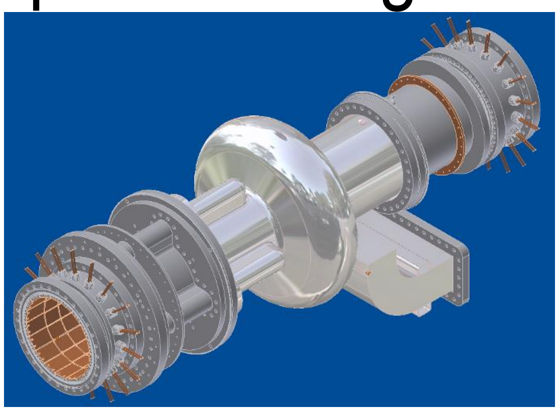


	3.0 GeV		3.15 GeV	
	10 nC	15 nC	10 nC	15 nC
1.2 MV	47.9 kW	53.8 kW	50.5 kW	57.7 kW
1.3 MV	53.9 kW	59.8 kW	56.5 kW	63.7 kW
1.4 MV	60.9 kW	66.8 kW	63.5 kW	70.7 kW
1.5 MV	67.9 kW	73.8 kW	70.5 kW	77.7 kW

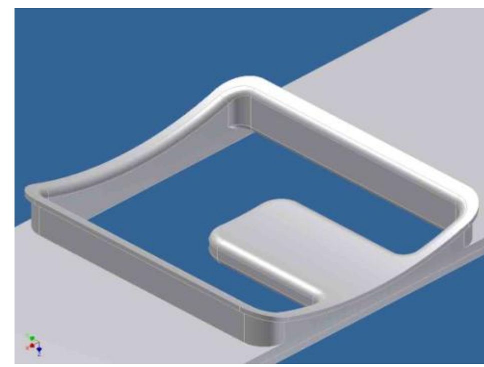
Assuming 10% transmission losses and 10% tube degradation ~64kW available from transmitter

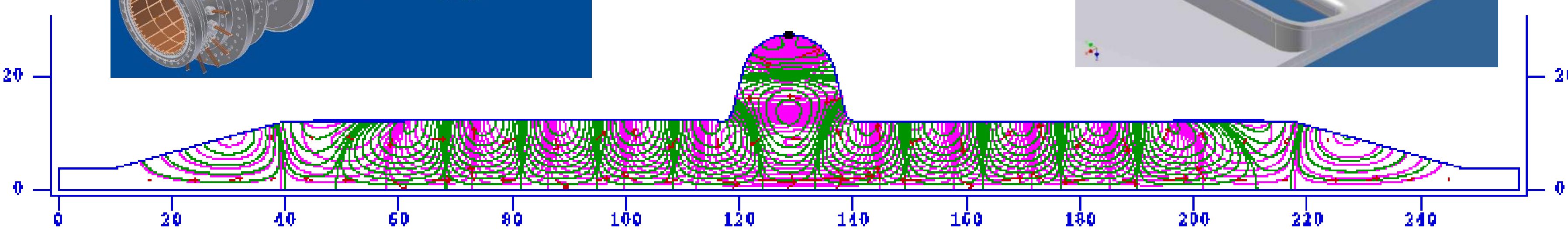
Storage Ring Cavity

- CESR-B Cavity baseline: Commercially produced, 12 in service in storage rings around the world
- Highly damped HOM free cavities: HOM Driven CB instabilities unconditionally stable.
- Coupler re-designed for Q_{ext} = 65000

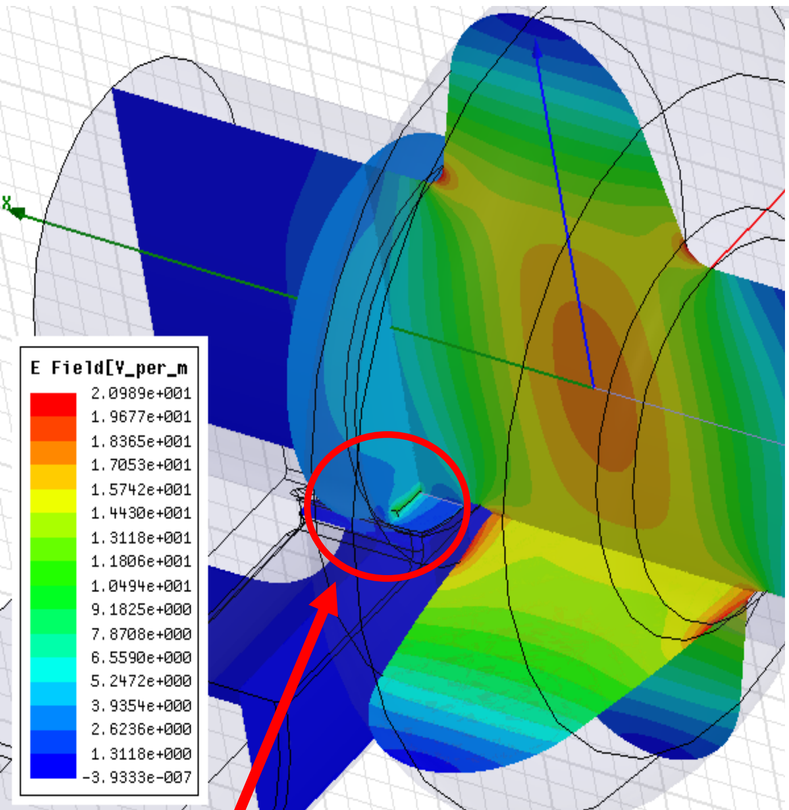


Waveguide aperture coupling with capacitive tongue to cavity beam pipe

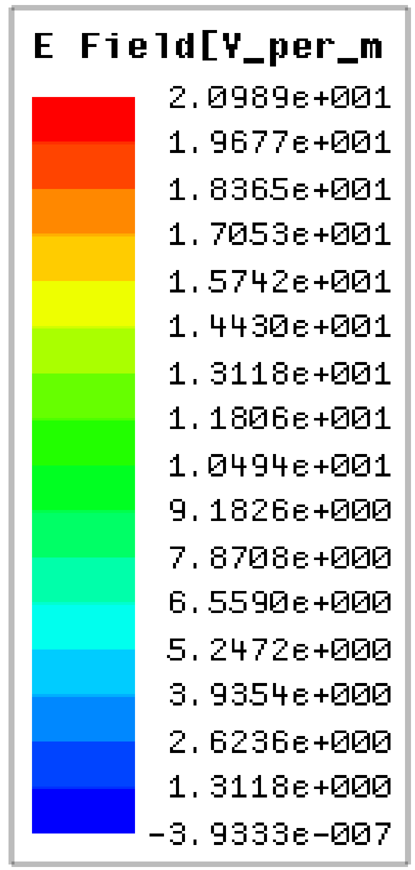


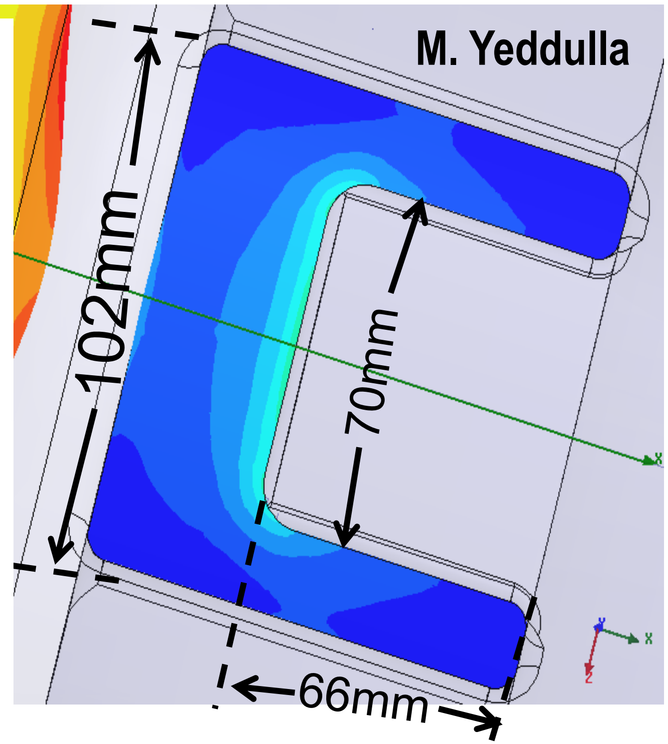


Modified CESR-B Coupler for Q_{ext} = 65000



Coupler location in CESR-B cavity





Modified coupler aperture between waveguide and cavity beam-pipe

Widen aperture from 91 mm to 102 mm, lengthened, widened tongue

SR RF 500 MHz TRANSMITTER

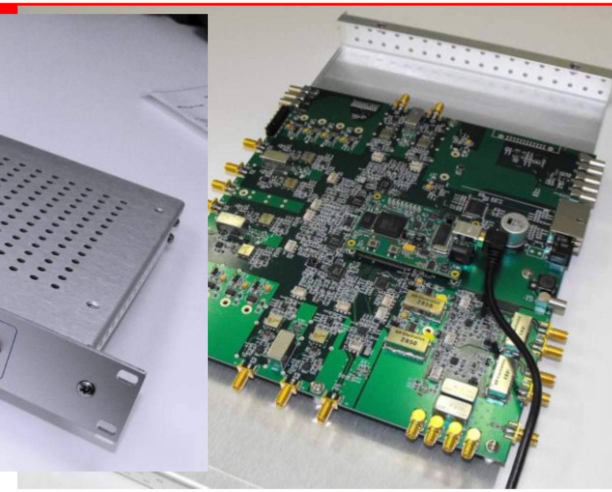
- Two 300 kW Klystron amplifiers with switching power supply: established at CLS, BEPC, Shanghai, TPS and PLS-II
- Tight tolerances on RF amplitude and phase requires fast feedback around klystron and cavity
- Measurements at CLS with a similar klystron/cavity system as proposed for NSLS-II led to modification of the switching frequency and filtering to suppress switching harmonics at the NSLS-II synchrotron frequency of ~3 kHz by an additional -10 dBc
- In addition, PS switching frequency is tunable to steer clear of the synchrotron frequency

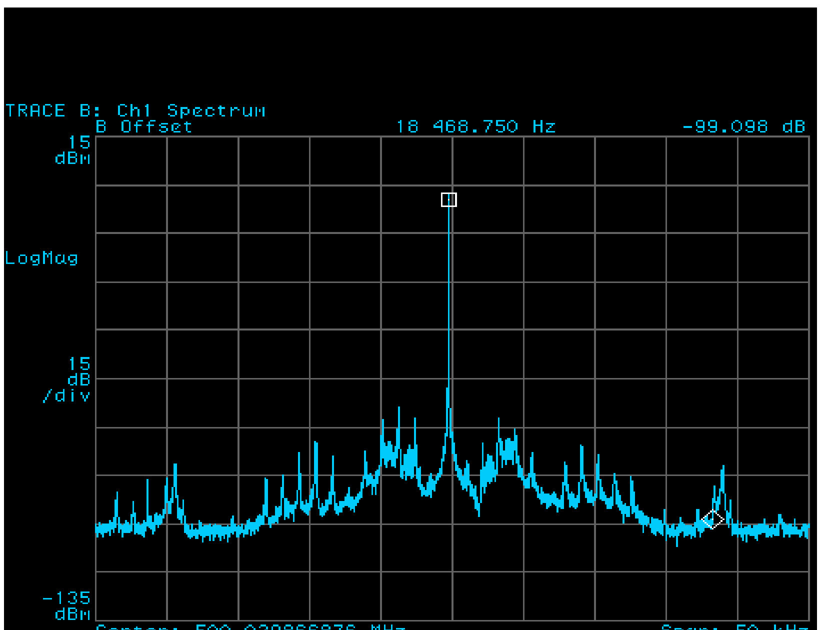
Similar PSM power supply with 300 kW klystron at BECP

Successful Development of Cavity Controller

- **Digital Field Controller**
- **50 MHz IF**
- **Tested at CLS on hardware nearly identical to NSLS-II: 300 kW klystron and CESR-B SRF cavity**
- **Meets NSLS-II field spec. of 0.15 degree and 0.05%**

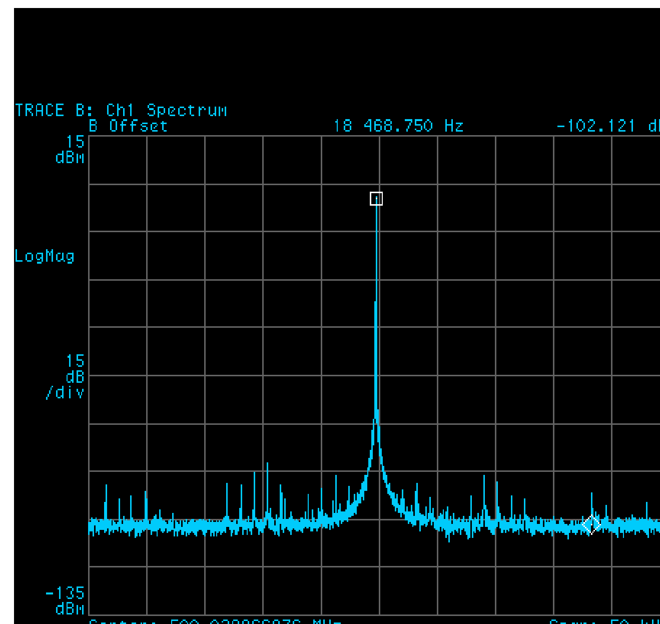
H. Ma





CLS Analog
A=0.073%rms
φ=0.12° rms

NSLS-II
A=0.026%rms
φ=0.02°rms



U.S. DEPARTMENT OF ENERGY

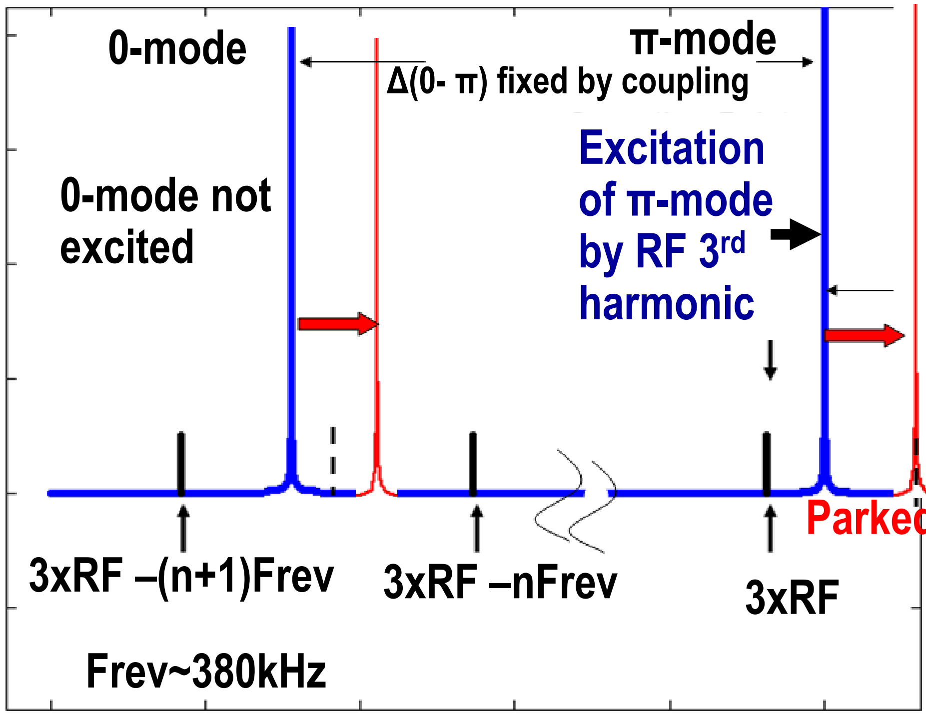
CLS tests courtesy M. de Jong

BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES

NSLS-II 3rd Harmonic Cavity

Coupled-two cell cavity allows 1 MV in compact cryomodule with external tuner and small heat leaks however it requires care in controlling the 0 andπ-mode frequency separation to avoid exciting the 0-mode

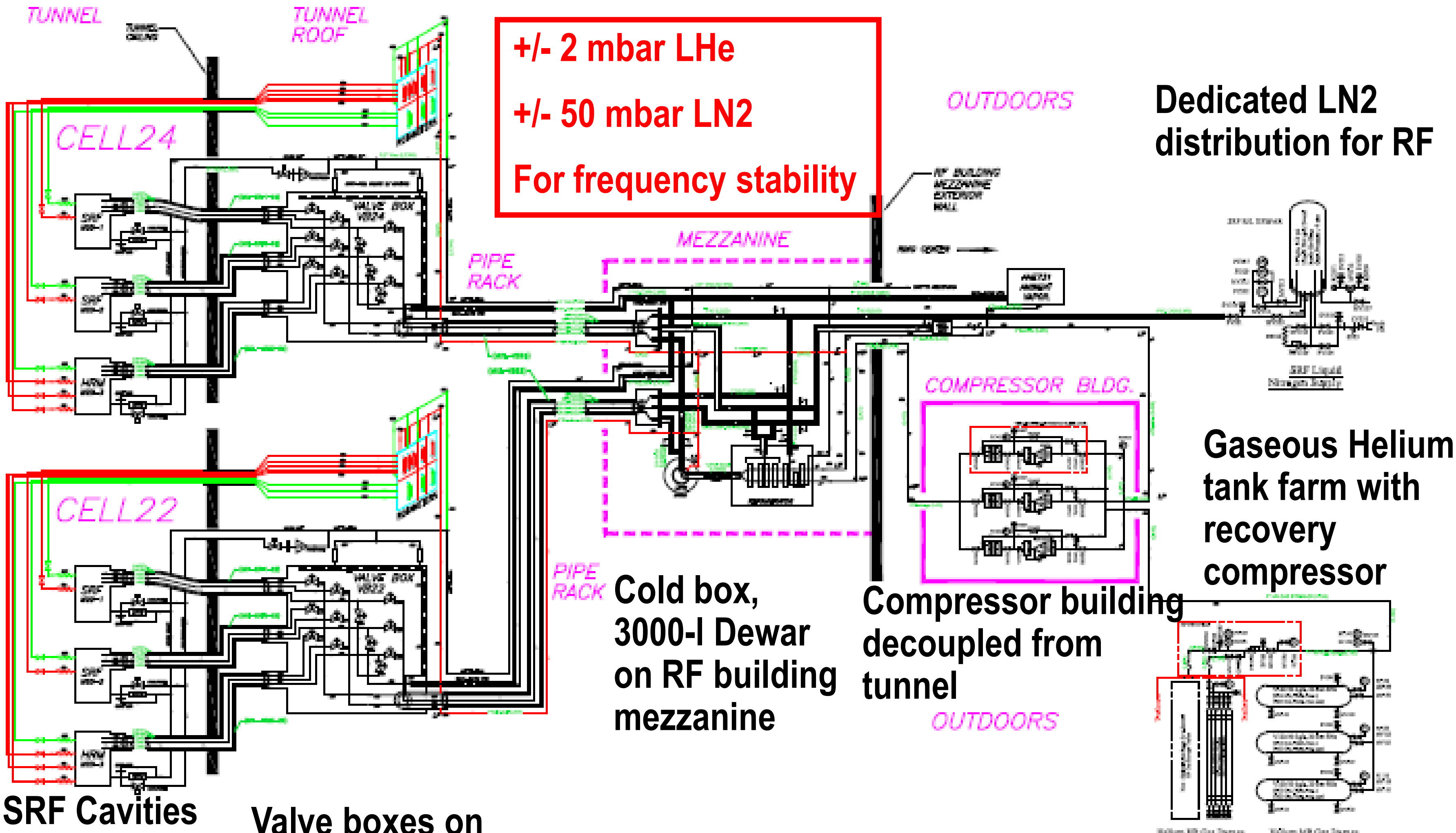
Two 2-cell cavities



Cryomodule

Cryomodule is complete and initial cold-test conducted verifying the frequency tuning over a 1 MHz band while keeping 0 and π mode frequency separation constant to within 10 %.

RF Cryogenic System: Dedicated 850 W Helium refrigerator and LN2



+/- 2 mbar LHe

+/- 50 mbar LN2

For frequency stability

Dedicated LN2 distribution for RF

Gaseous Helium tank farm with recovery compressor

Cold box, 3000-l Dewar on RF building mezzanine

Compressor building decoupled from tunnel

SRF Cavities in tunnel

Valve boxes on tunnel roof

U.S. DEPARTMENT OF ENERGY

BROOKHAVEN NATIONAL LABORATORY

BROOKHAVEN SCIENCE ASSOCIATES

NSLS-II RF Systems Summary

- **200 MeV LINAC** 15nC- Feedforward for beam loading required
- **Booster RF System:** Petra cavity delivering 1.2 MV for 0.7% acceptance powered by 80 kW IOT amplifier capable of accelerating >10nC charge
- **Storage Ring 500 MHz System:** Two 500 MHz SCRF cavities delivering up to 4.0 MV powered by two 300kW klystron amplifiers capable of storing 500mA with feedback incorporated in a digital RF cavity controller and one 1500 MHz two cell passive SRF cavity. Future upgrades will double RF capabilities by populating a second RF straight
- **Liquid Helium Refrigerator System:** 850+ Watts at 4.5K for meeting requirements of four 500MHz and two 1500MHz cavities (fully built out system)

Acknowledgements

This work was performed by and under the guidance of

Alexei Blednykh, John Cupolo, Ray Fliller, Bill Gash, B. Holub,Y. Kawashima, Hengjie Ma, Andy Marone, Bob Meier, Payman Mortazavi, George Mulholland, Jorge Oliva, Satoshi Ozaki, Ed Quimby, Jim Rose, Timur Shaftan, Bob Sikora, Nathan Towne, Ernst Weihereter, Ferdinand Willeke and Takeshi Yanagisawa as well as the support of the entire NSLS-II team.

We would also like to thank the SCRF groups at Cornell, KEK, CLS, TPS and DLS for their continuing help and encouragement, in particular Hasan Padamsee, Sergie Belomestnykh, Valery Shemelin, Takaaki Furuya, Mark de Jong, Chaoen Wang and Morten Jensen

We would like to acknowledge the excellent work by Niowave Inc. in the fabrication of the 3 HC under the DOE SBIR

U.S. DEPARTMENT OF ENERGY

BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES