# SPX Project Overview and Status

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SPX Study Mini-Workshop
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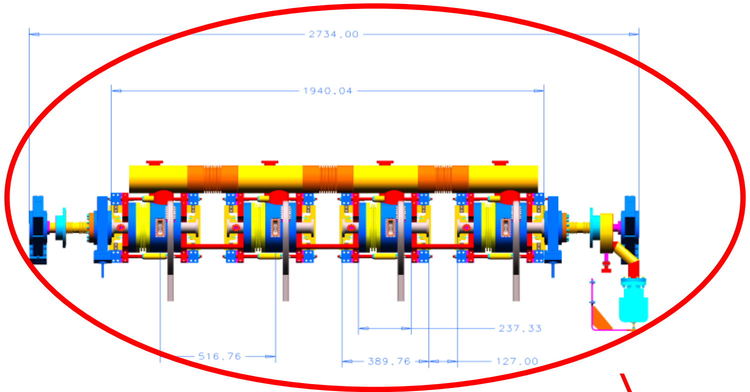
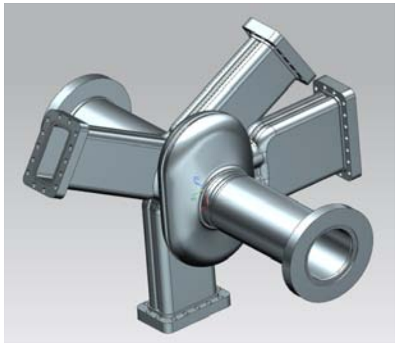
# Outline

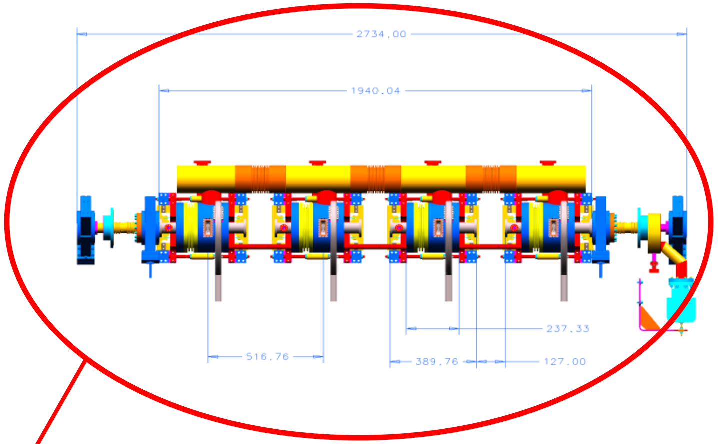
- Scope
- Expected performance
- Major challenges
- SPX0
- Highlights and Status

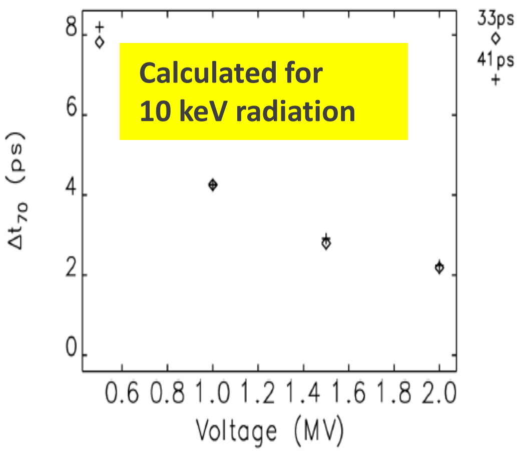
# SPX Scope

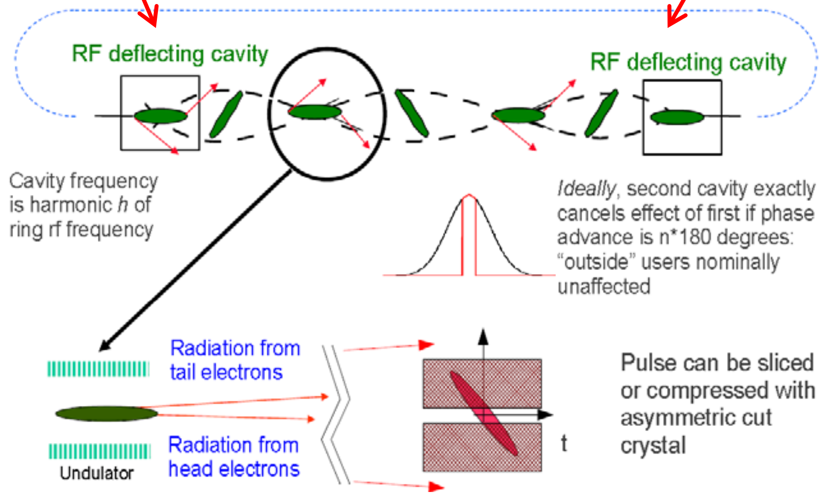
**Scope : 2 MV deflecting voltage, ~2ps (FWHM) x-ray pulses**

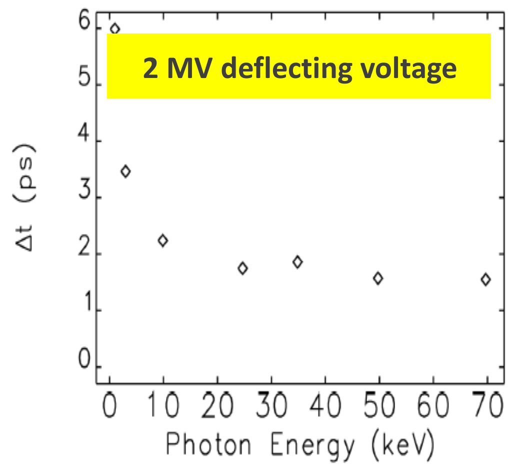




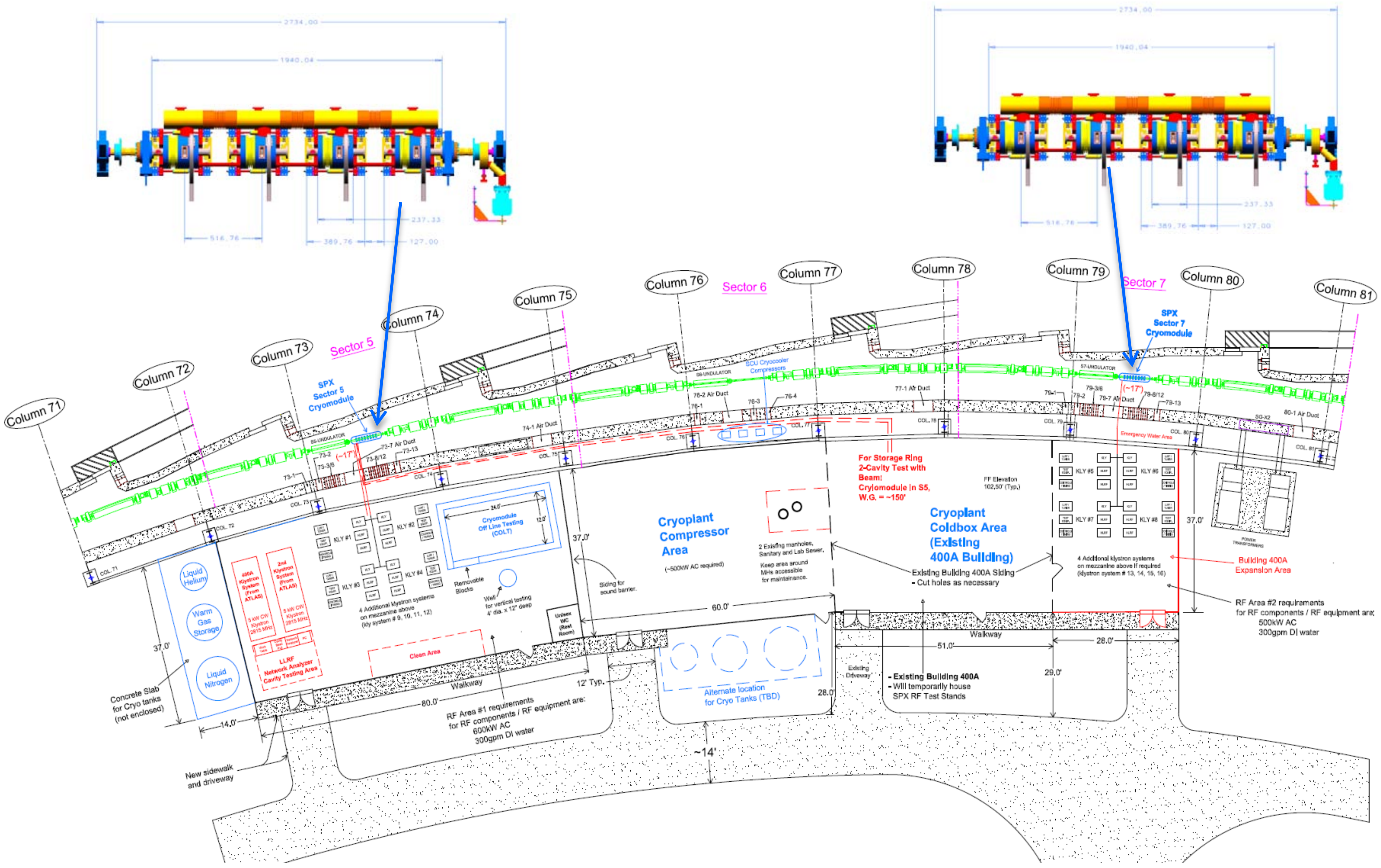




**Long Term Goal: 4 MV deflecting voltage, ~1ps (FWHM) x-ray pulses**
**Requires 8 cavities per sector**

[1] A. Zholents et al., NIM A 425, 385 (1999).

# Sector 5/7



Column 71
Column 72
Column 73
Column 74
Column 75
Column 76
Column 77
Column 78
Column 79
Column 80
Column 81
Sector 5
Sector 6
Sector 7
SPX Sector 5 Cryomodule
SPX Sector 7 Cryomodule
Cryoplant Compressor Area
(~500kW AC required)
Cryoplant Coldbox Area (Existing 400A Building)
For Storage Ring 2-Cavity Test with Beam: Cryomodule in S5, W.G. = ~150'
Existing Building 400A Siding - Cut holes as necessary
- Existing Building 400A
- Will temporarily house SPX RF Test Stands
Building 400A Expansion Area
RF Area #2 requirements for RF components / RF equipment are: 500kW AC 300gpm DI water
RF Area #1 requirements for RF components / RF equipment are: 600kW AC 300gpm DI water
Alternate location for Cryo Tanks (TBD)
Concrete Slab for Cryo tanks (not enclosed)
New sidewalk and driveway
Liquid Helium
Warm Gas Storage
Liquid Nitrogen
Walkway
Clean Area
Siding for sound barrier.
2 Existing manholes, Sanitary and Lab Sewer. Keep area around MHs accessible for maintainance.
4 Additional klystron systems on mezzanine above (kly system # 9, 10, 11, 12)
4 Additional klystron systems on mezzanine above if required (klystron system # 13, 14, 15, 16)
60.0'
80.0'
37.0'
51.0'
28.0'
29.0'
14.0'
~14'
12' Typ.

# Expected Performance Parameters*

| Parameter | Scope Goal | Long -Term Goal |
|---|---|---|
| Pulse duration (central 70% of beam) | 2 ps | 1 ps |
| Pulse duration fluctuation | 10% | 10% |
| Pulse intensity fluctuation | 10% | 1% |
| Pulse timing jitter (fraction of pulse duration) | 10% | 10% |
| Max. vertical emittance outside SPX zone | 50 pm | 50 pm |
| Vertical emittance variation outside SPX zone | 10% | 10% |
| Rms beam motion outside SPX zone (as fraction of beam size/divergence) | 10% | 10% |

| Parameter | 2 MV Scope Goal Rms value | Driving Requirements |
|---|---|---|
| Common mode voltage amplitude variation | 1% | Keep intensity and pulse length variation under 1% rms |
| Common mode phase variation | 4.0 deg | Keep intensity variation under 1% rms |
| Voltage amplitude mismatch error between sectors | 1.1% | Keep rms emittance variation outside SPX under 10% of normal 40 pm |
| Voltage phase mismatch error between sectors | 0.18 deg | Keep rms beam motion outside of SPX under 10% of beam size/divergence |

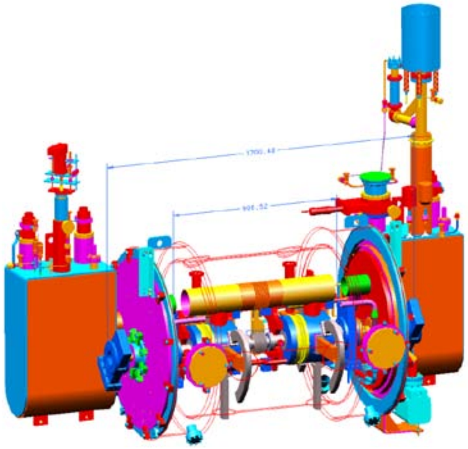
*Sajaev, Borland, Emery, Nassiri, Physics Requirement Document

# Major Technical Challenges

- LOM/HOM dampers
  - Damping materials issues
  - High heat load in LOM
  - Broad-band rf window option
- Precision cavity alignment ( 100 $\mu$m)
  - Can it be relaxed? Implications on other systems
- Meeting vertical compliance of cavities interconnect bellows
  - Low-loss formed bellow vs. shielded bellow
    - Particulate generation of shielded bellows
      - KEK and DAFNE designs
- Achieving 0.18   rms sector-to-sector differential phase spec
- Design and implementation of rf and optical tilt monitors
  - X-band cavity BPM
      - Damping of LOMs and HOMs outside deflecting zone
  - Diamond  x-ray fluorescence

# SPX0 Goal

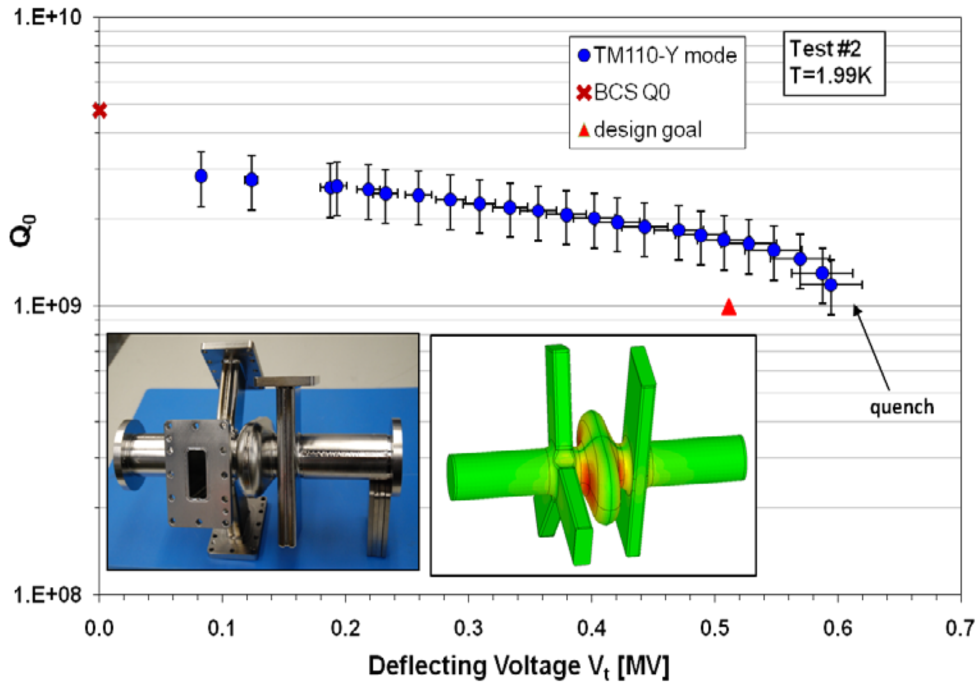
- Demonstrate proof of concept
  - System is too complex and untested
  - Learn as much as possible as how will this would work in storage ring
- Identify and mitigate technical risks
  - Risk on operation impacting users
  - Validating LOM/HOM damping with beam
    - Assessing performance
      - Thermal load and mechanical integrity of SiC
      - Safety margin



- Understand all possible operating modes with 2-cavity system
- Assess the effects of operating the cavities detuned
- Assess heating and impedance effects at 80K and 300K
- Test and ring out technical systems
  - LLRF controllers
  - Control of beam offset and cavities vertical misalignment
  - Beam loading and rf power management

# Highlights - Cavity

- Mark I cavity tests performed at JLab. It meets rf performance with 10% safety margin on deflecting voltage.



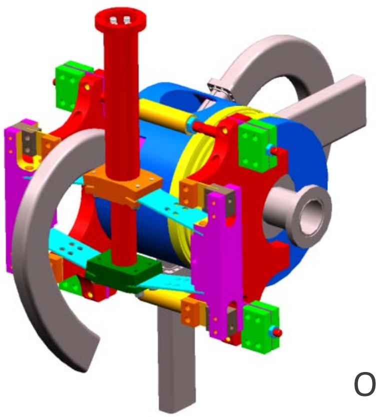
# Highlights - Cavity

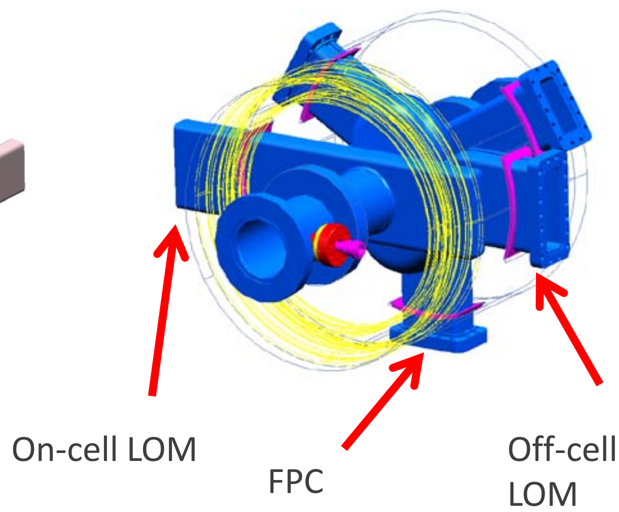
- Fabrication and preliminary test of Mark II cavity has been completed at JLab. Mark II cavity reached a surface magnetic field of 120 mT ( 0.5 MV) with $Q_0 \sim 5\times10^8$.

- More tests are planned in July.

# Highlights – cavity system

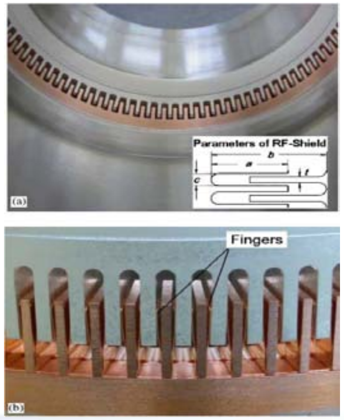
- Down selected  JLab-style scissor jack tuner scaled to SPX cavity
- Active cavity alignment scheme
  - Mockup test at JLAB promising
- Designed cavity helium vessel that is compatible with both Mark I and Mark II cavities





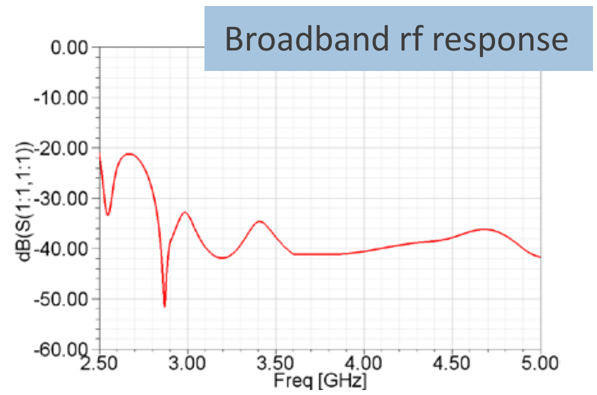

# Highlights - bellows

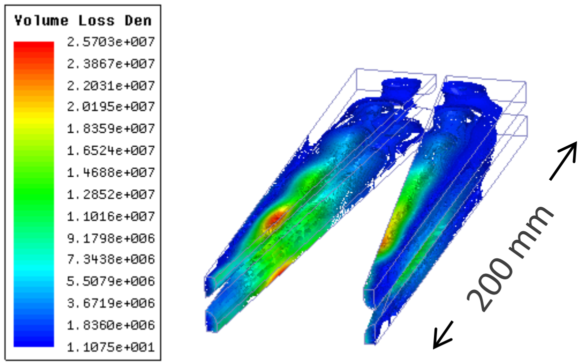
- Investigation of bellows
  - Shielded bellow (KEK and DAFNE)
  - Formed bellow ( shallow convolution, possibly cooled)
- Five bellows will be required for the 4 cavity cryomodule
  - Three interconnect bellows (between cavities)
  - Two warm to cold transition bellows (end cavities)
- Bellows must allow for thermal contraction of the string and active alignment of individual cavities
- Issues are vertical movement compliance and particulate generation
- Plan is being developed to test bellows in the storage ring before SPX0 installation.

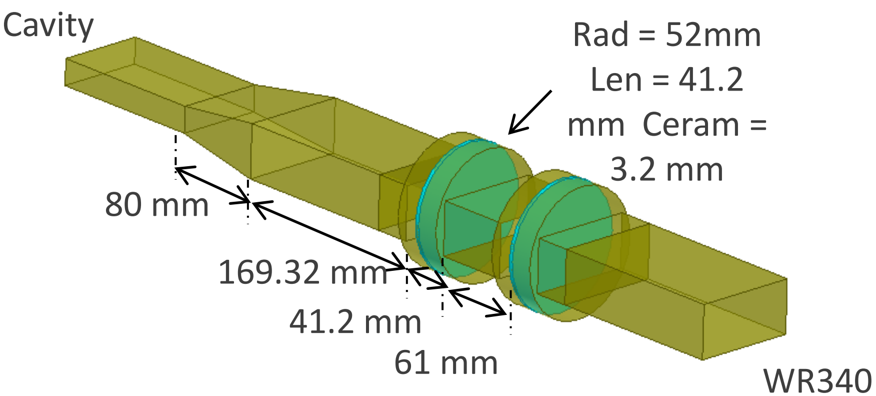


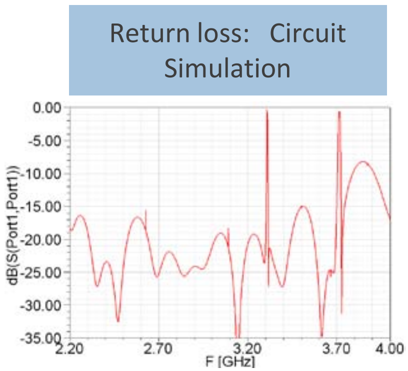

# Highlights - dampers

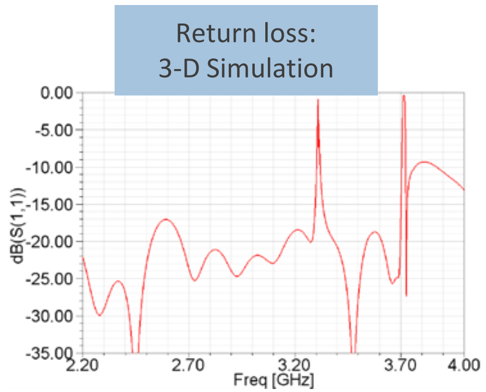
- 4-wedge HOM damper is broadband to 8 GHz.
- LOM double window uses two WR340 pillbox window assemblies.
- Window assembly transitions from the cavity with an 80mm taper.
- Dampers tests are planed
  - RF and thermal
  - Particulates



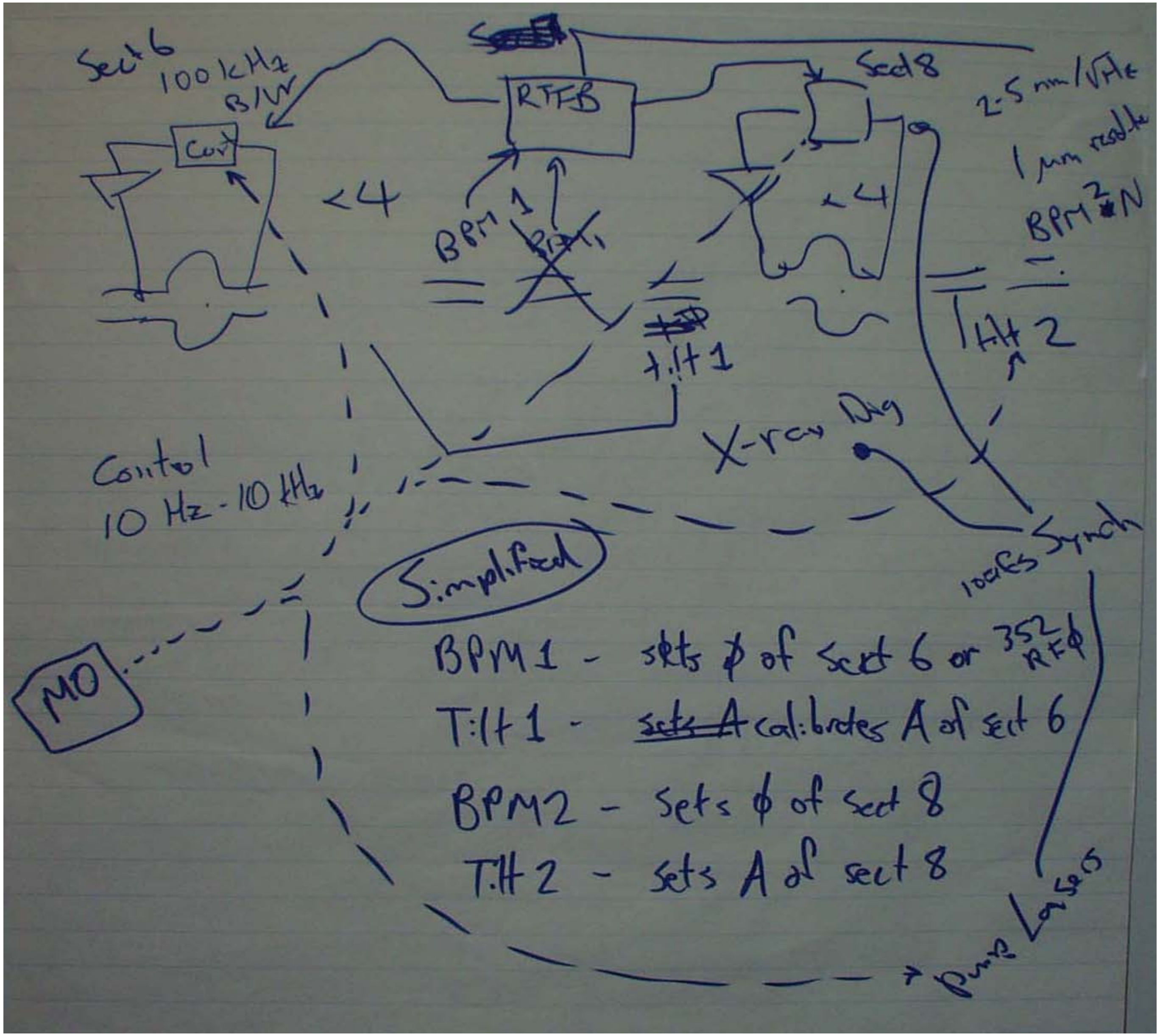



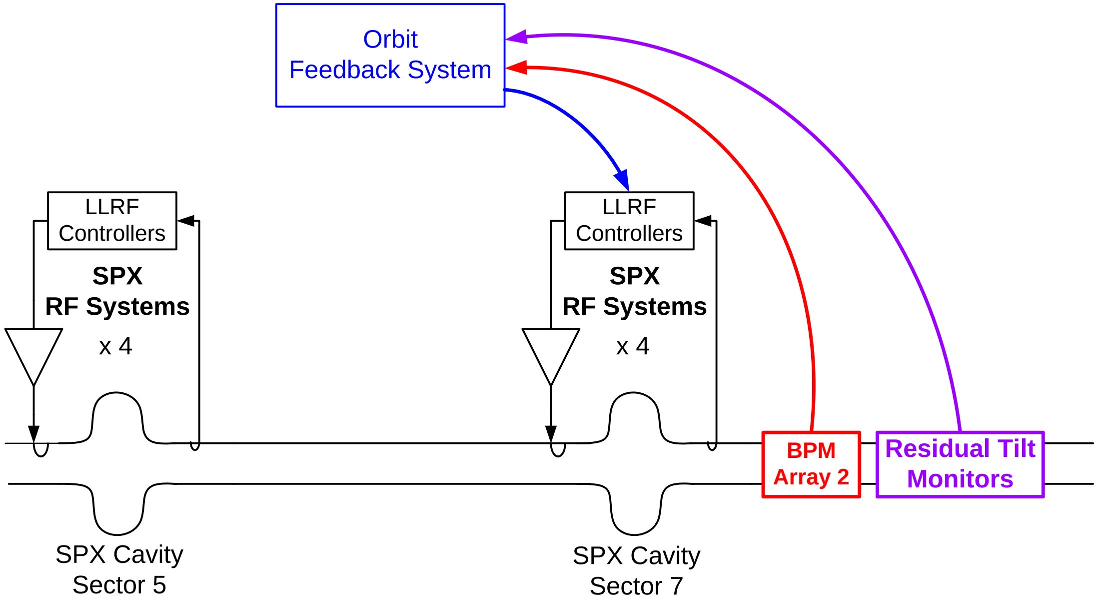



# Highlights - Conceptual Design Strategy (CDS)



# Highlights -CDS:  Differential Specs

- Orbit Feedback System provides long-term stability …
  - via Beam Position Monitor (BPM) Array 2 sets differential phase < 100(200) Hz
  - via Residual Tilt Monitors sets differential amplitude < 100(200) Hz
- LLRF System on its own > 10 Hz
  - 10 Hz – 100(200) Hz overlap with Orbit Feedback

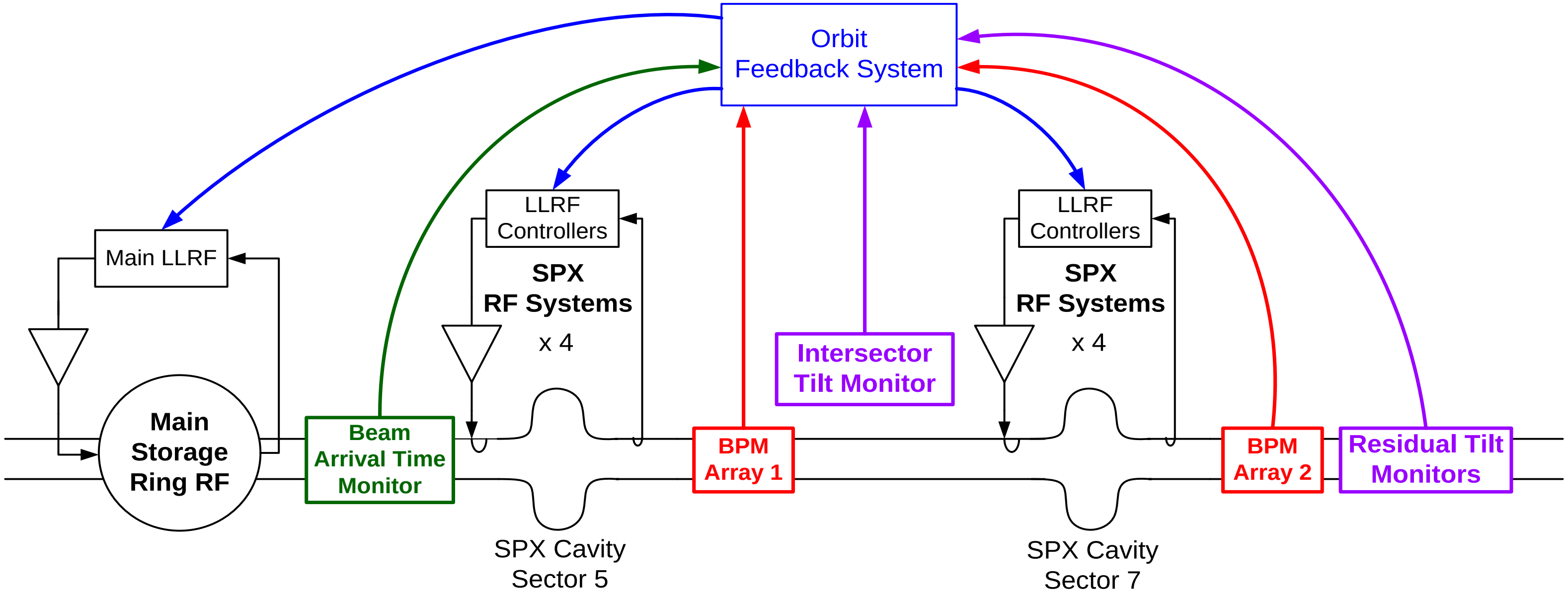



BPM Array 2:  sets phase of Sector 7

Residual Tilt Monitors:  sets amplitude of Sector 7

# Highlights - CDS: Common Mode Specs

- **Main storage ring rf used to lock beam to master osc. via Beam Arrival Time diagnostic**
- SPX follows master oscillator, orbit feedback…
  - via BPM Array 1 sets common mode phase < 100(200) Hz
  - via Intersector Tilt Monitor sets common mode amp < 100(200) Hz
  - LLRF on its own > 10 Hz

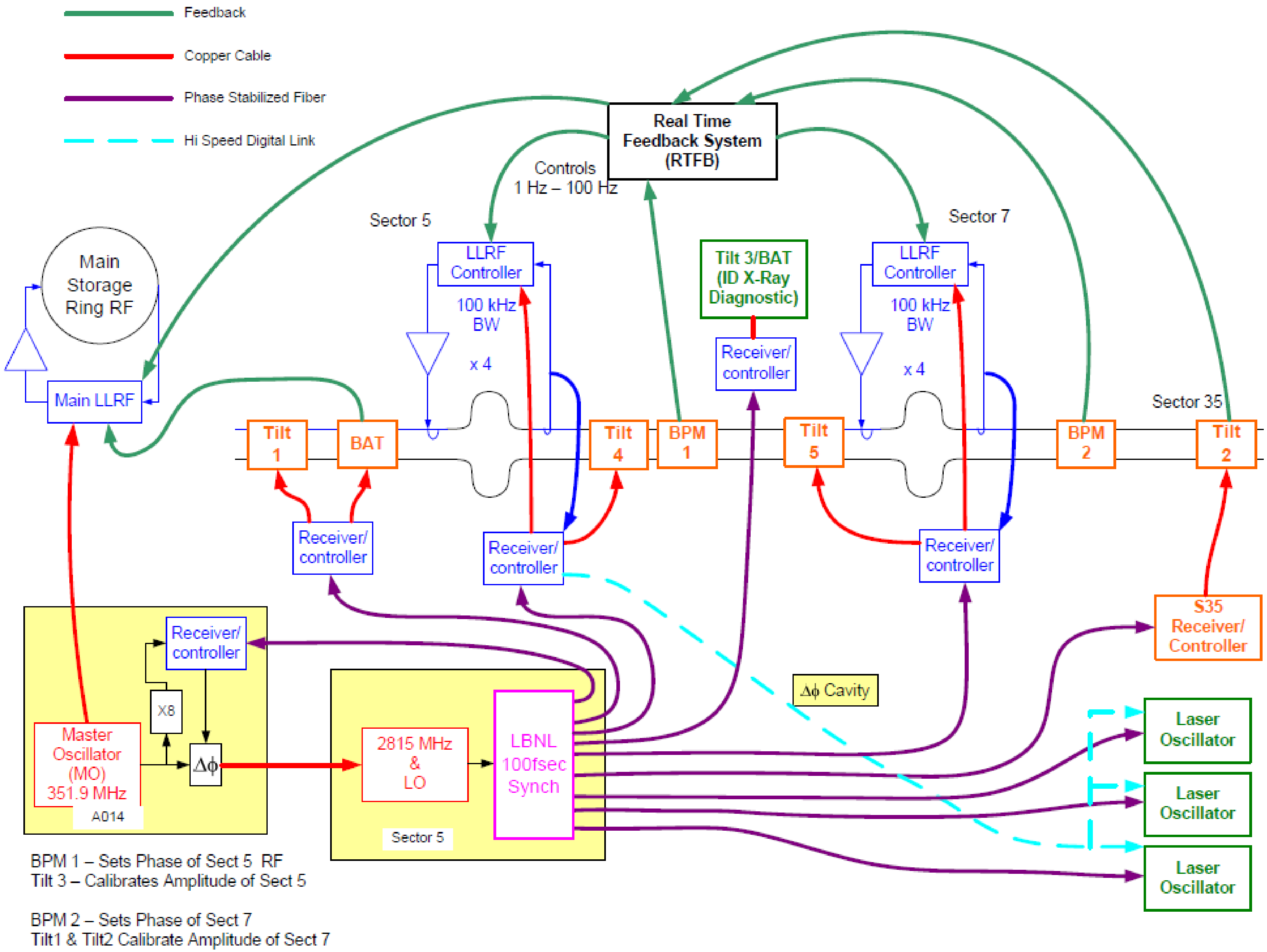



BPM Array 1: sets phase of Sector 5
BPM Array 2: sets phase of Sector 7

Intersector Tilt Monitor: sets amplitude of Sector 5
Residual Tilt Monitors: sets amplitude of Sector 7

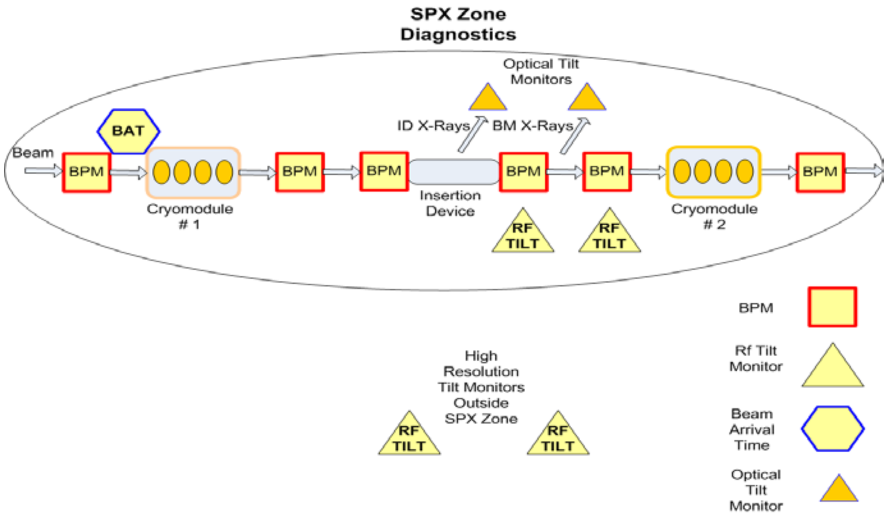
Beam Arrival Time Monitor: sets phase of Main Storage Ring RF

# Highlights CDS: Possible Phase Stable Fiber Distribution



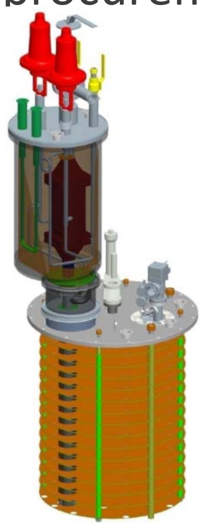
# Highlights

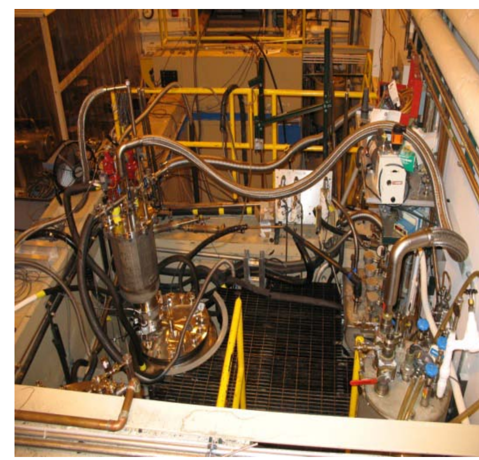
- LLRF
  - LBNL Collaboration – Phase I ( joint with timing/synchronization)
    - Differential stability of two high-Q cavity emulators
    - Production of LLRF4 based controllers to support SPX R&D
  - LBNL Collaboration – Phase II
    - Demonstration of timing/synchronization concepts between rf cavity and user laser
- Diagnostics
  - Will need new types of diagnostics
    - Ongoing R&D on optical, rf tilt monitors, and beam size monitors



# Highlights Cryogenics and Cavity/Cryostat test @PHY

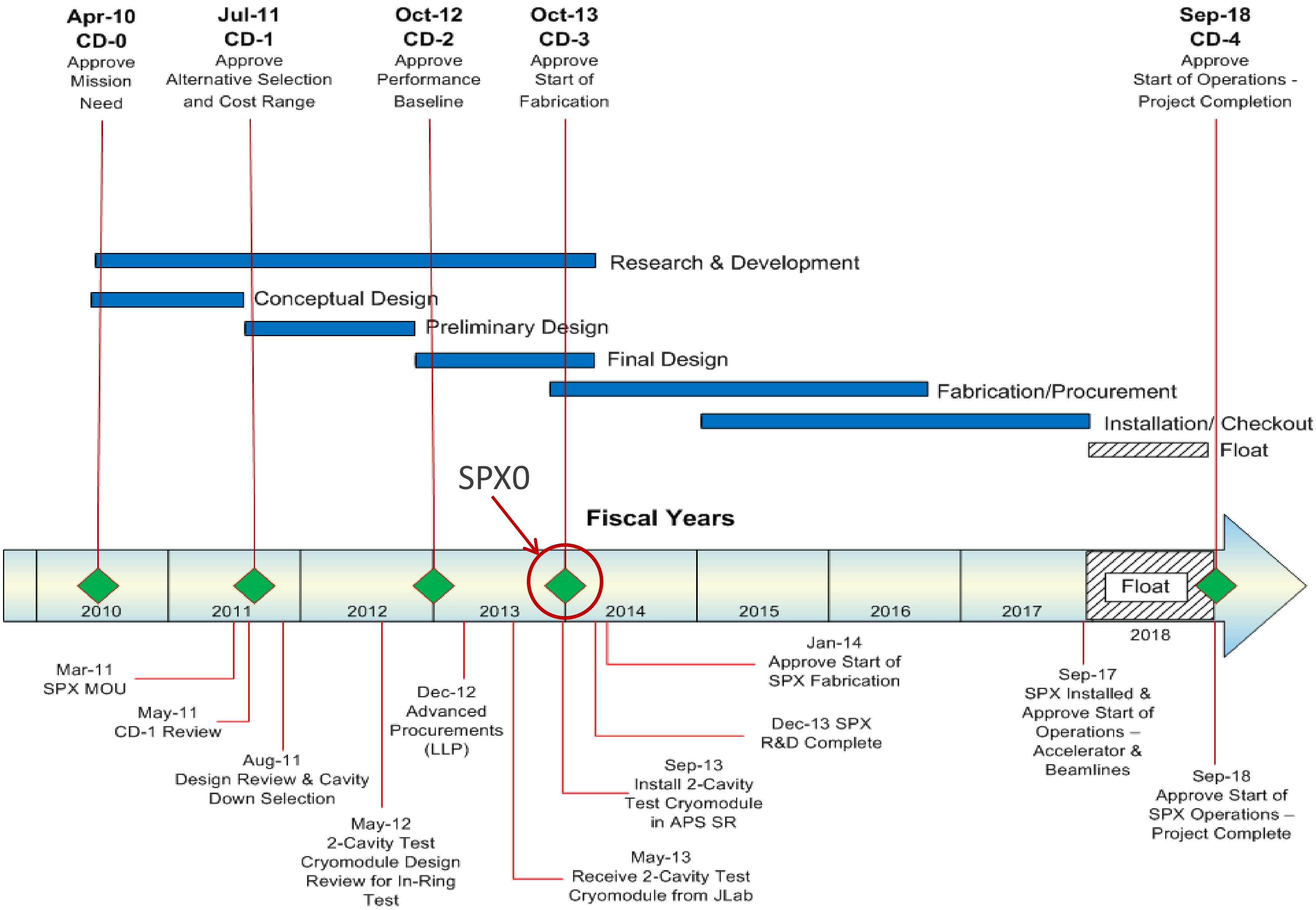
- New infrastructure is available
  - New 2.5g/s vacuum pump
  - Crogenics instrumentation
  - New JYHX feedcan and neck insert for a 24” dewar and new transfer lines
  - Vertical tests of single “bare cavity” in modified PHY 24” LHe vessel
  - Single “dressed cavity” V/H tests in modified PHY Tc2 vessel
- A draft technical specifications document for SPX cryoplant has been prepared.
  - Plan for an early procurement



Cave platform showing 24” dewar with feedbox (left) and cryoplant connection box (lower right)

# Timeline



Apr-10
CD-0
Approve
Mission
Need
Jul-11
CD-1
Approve
Alternative Selection
and Cost Range
Oct-12
CD-2
Approve
Performance
Baseline
Oct-13
CD-3
Approve
Start of
Fabrication
Sep-18
CD-4
Approve
Start of Operations -
Project Completion
Research & Development
Conceptual Design
Preliminary Design
Final Design
Fabrication/Procurement
Installation/ Checkout
Float
SPX0
Fiscal Years
2010
2011
2012
2013
2014
2015
2016
2017
Float
2018
Mar-11
SPX MOU
May-11
CD-1 Review
Aug-11
Design Review & Cavity
Down Selection
May-12
2-Cavity Test
Cryomodule Design
Review for In-Ring
Test
Dec-12
Advanced
Procurements
(LLP)
May-13
Receive 2-Cavity Test
Cryomodule from JLab
Sep-13
Install 2-Cavity
Test Cryomodule
in APS SR
Dec-13 SPX
R&D Complete
Jan-14
Approve Start of
SPX Fabrication
Sep-17
SPX Installed &
Approve Start of
Operations –
Accelerator &
Beamlines
Sep-18
Approve Start of
SPX Operations –
Project Complete

# Looking Ahead

- Cavity down select
- Fabrication of 3rd cavity
- Tuner prototyping
- Cavity active alignment
- SiC material test and characterization
- Design and in-ring test of a formed bellow
- Design and testing of a wideband rf window for LOM WG
- Completion of two high-Q emulators test
- Develop diagnostics for SPX0