MuCool Test Area Update

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Mission and Current R&D
Role in Muon Accelerator Program

• Advance *Technology Development* for ionization cooling
  – help design, prototype, test components
    • grid windows, modular pillbox, dielectric-loaded HPRF
• Inform machine *Design & Simulation* studies
  – provide performance envelope
    • vacuum RF in external magnetic field
    • HPRF in beam
• Support *Systems Demonstrations*
  – MICE
    • Single-Cavity Module assembly, instrumentation, testing
805-MHz Vacuum RF Program: All-SeasonCavity

• Last run complete
  – 25 MV/m at B=0
  – 20-22 MV/m @ B=0.25-5T [preliminary]
    (sparking rate ≤ 1 in 10^5)
  – cavity removed from MTA

• Inspection
  – similar spots on endplates
  – more around coupler
  – scanner & microscope tested

• Data analysis in progress
  – publication draft soon
805-MHz Vacuum RF Program: Button Pillbox Cavity

- Final test in progress
- Windows: low radiation length, good electrical and thermal conductivity
  - Flat thick Cu ✔
  - Thin pre-stressed flat Be ✗
  - Thin curved TiN/Be ✔
  - Exploring alternative: gridded tube windows
    - Solid Al prototype for test
    - Electro-polished
    - TiN coated (one face)
    - Cavity assembled with grids (and spacer), installed in solenoid – running now
805-MHz Vacuum Cavity Program

Moving forward

• New modular cavity for detailed systematic studies (SLAC, LBNL)
  – Modular design for easy assembly, inspection, parts replacement
  – Removable endplates (initially Cu; Be, other materials, treated surfaces)
  – Coupling iris moved to center ring and field reduced (*more realistic design for cooling channel*)
  – RF design validated by detailed simulation
  – Ports for instrumentation
  – Inspection setup under preparation
  – Fabrication close to completion
  – Expected delivery to MTA: FY14 Q2
• Incorporates all lessons learned
201-MHz Single-Cavity Module

- MICE cavity in vacuum vessel for MTA test
- Components
  - 1st MICE cavity EP’ed at LBNL
  - Vacuum vessel built at Keller
  - Be windows to be reused
  - Actuators built at LBNL
  - Tuner forks built at FNAL
  - New coupler fabrication in progress at LBNL
• Assembly/integration
  – Clean room prepared in Lab-6
  – Main assembly complete
  – Plan in place for handling and transport to MTA
  – Tuner system tested

  • Hall infrastructure
    – Services mostly in place
    – Overhead crane installation to start soon

  – Expect operation Spring 2014
    • depending on coupler delivery, hall infrastructure and RF source availability

  – beam test also under consideration

• Ultimately to be tested with the first Coupling Coil Magnet
  – Requires 6-month MTA shutdown (2015)
805-MHz HPRF Cavity Program

- HPRF previously tested at the MTA
  - Dense H₂ gas buffers dark current while serving as ionization cooling medium
  - No B-field effect, 1 MV/m per atm H₂
- 2 beam tests to evaluate response to high-intensity beam
  - Beam-induced plasma loads cavity
  - Mitigate with electronegative dopant
  - Wide range of parameters explored
  - Demonstrated operation with beam in 3T field
- Initial results published
  - Quantitative theory validated by measurement of energy loss in H₂/D₂+dopant
  - Dopants turn mobile ionization electrons into heavy ions, reducing RF losses by large factor
- Results extrapolate well to Neutrino Factory operation and a range of Muon Collider beam parameters
  - Plasma loading < beam loading
  - Bunch intensity limits being evaluated
- Also preparing for dielectric-loaded HPRF cavity test to enable smaller coils in HCC

Measured (for H₂/D₂+dry air)
- Energy loss/e-ion pair/RF cycle
- e attachment time to oxygen
- Ion-ion recombination rates
Analysis of rest of the data close to completion
Plasma Loading in HPRF Beam Test

- Graphs showing the effect of loading on plasma in HPRF beam test.
- Various conditions tested:
  - No Loading
  - Pure $H_2$
  - $H_2 + DA$
  - $H_2 + DA + 3T$
  - $D_2 + DA$

- Data points for different pressures and conditions:
  - $H_2$, 100 atm
  - $H_2$, 78 atm
  - $H_2$, 54 atm
  - $H_2$, 34 atm
  - $H_2$, 20 atm

- Graphs illustrating the relationship between plasma loading and various parameters.

- Additional graphs showing $dW$/cycle/pair as a function of $X_0$ (V/cm/Torr) for different pressures and conditions.

- Graph showing the relationship between $\tau$ (ns) and $p$ (atm) for different concentrations of DA.
Dielectric-loaded HPRF

- Need to shrink transverse cavity size to reduce magnet apertures in HCC
- Proof-of-principle test: HPRF test cell + alumina
  - suppression of breakdown up to surface breakdown limit of material
- Other samples to be measured at low power
- High power test in MTA for promising candidates (suitable dielectric constant, low loss tangent)
- Beam test if successful
- Also looking at reentrant cavity design (Muons Inc)
Beamline commissioning
(M. Backfish, C. Johnstone)
Next generation

- MTA program continued to support steady stream of students in FY13
  - Ben Freemire, IIT
    - Ph. D., May 2013 (HPRF beam test)
  - Peter Lane, IIT
    - Working toward Ph. D. (breakdown localization with acoustic sensors)
  - Luca Somaschini, INFN Pisa
    - About to receive M. Sc. (MICE cavity tuner system)
  - Jared Gaynier, Kettering U. (Fermilab coop)
    - Undergrad, major contribution to MICE SCM assy
  - Logan Rowe, John Sobolewski (coop)
    - Components for button pillbox and ASC
  - Lisa Nash (U. Chicago), Yiqing Ding (Purdue U.)
    - Grad, dielectric loaded HPRF design/testing

- Students first author on several IPAC13 and NAPAC13 abstracts
Recent publications

- **High Pressure Gas-Filled RF Cavity for Use in a Muon Cooling Channel**, B. Freemire *et al.*, NA-PAC13 proceedings
- **Investigation of Breakdown Induced Surface Damage on 805 MHz Pill Box Cavity Interior Surfaces**, M. Jana *et al.*, NA-PAC13 proceedings
- **Multipacting Study for the RF Test of the MICE 201 MHz RF Cavity at Fermilab MTA**, T. Luo *et al.*, NA-PAC13 proceedings
- **Modeling Vacuum Arcs in Linac Structures**, J. Norem *et al.*, NA-PAC13 proceedings
- **Fermilab MuCool Test Area Cavity Conditioning Control Using LabVIEW**, D. Peterson and Y. Torun, NA-PAC13 proceedings
- **Algorithms and Self-consistent Simulations of Beam-induced Plasma in Muon Cooling Devices**, R. Samulyak *et al.*, NA-PAC13 proceedings
- **Tuner System Assembly and Tests for the 201-MHz MICE Cavity**, L. Somaschini *et al.*, NA-PAC13 proceedings
- **Assembly and Testing of the First 201-MHz MICE Cavity at Fermilab**, Y. Torun *et al.*, NA-PAC13 proceedings
- **Analysis of Breakdown Damage in an 805 MHz Pillbox Cavity for Muon Ionization Cooling R&D**, D. Bowring *et al.*, IPAC13 proceedings
- **A Modular Cavity for Muon Ionization Cooling R&D**, D. Bowring *et al.*, IPAC13 proceedings
- **Transient Beam Loading Effects in Gas-filled RF Cavities for a Muon Collider**, M. Chung *et al.*, IPAC13 proceedings
- **Beam Induced Plasma Dynamics in a High Pressure Gas-Filled RF Test Cell for use in a Muon Cooling Channel**, B. Freemire *et al.*, IPAC13 proceedings
- **Multipacting Simulation of the MICE 201 MHz RF Cavity**, T. Luo *et al.*, IPAC13 proceedings
- **High Power Tests of Alumina in High Pressure RF Cavities for Muon Ionization Cooling Channel**, L. Nash *et al.*, IPAC13 proceedings
- **The RF System for the MICE Experiment**, K. Ronald *et al.*, IPAC13 proceedings
- **RF Cavity Spark Localization Using Acoustic Measurement**, P. Snopok *et al.*, IPAC13 proceedings
- **Simulation of Beam-induced Gas Plasma in High Gradient RF Field for Muon Colliders**, K. Yonehara *et al.*, IPAC13 proceedings
- **Summary of Dense Hydrogen Gas Filled RF Cavity Tests for Muon Acceleration**, K. Yonehara *et al.*, IPAC13 proceedings
Outlook

- Operating point for 805-MHz vacuum RF in 0-5T established, ASC program concluded
  - preparations mostly complete for next step (modular cavity)
  - test program to start this year
- MICE cavity assembly complete
  - Installation/commissioning soon
- Plasma loading for HPRF in beam evaluated
  - looks promising
- Proof-of-principle dielectric loading test complete
  - follow-up program in progress
- Facility/infrastructure
  - beamline upgrade commissioning in progress
  - overhead crane installation next
  - framework for external user experiments being put in place (detector prototype irradiation)