Status of the Fermilab
Cold BPM R&D

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Current BPM R&D Status

- **SLOW, but moving…**
  - Fermilab mid-term focus:
    - energy frontier (ILC) -> intensity frontier (Project X)
  - R&D activities:
    - ILC test accelerator at NML (ILC-like 3 MHz e-beam)
    - HINS: Project X front-end R&D (high intensity H⁻ beam, 325 MHz)
  - Project X (neutrino, kaon & muon physics), based on ILC SCRF:
    - 2 GeV SCRF CW linac & RCS (ICD-2, preferred, 162.5 MHz H⁻ beam)
    - 8 GeV SCRF pulsed linac (ICD-1, 325 MHz H⁻ beam)

- **Cold BPM**
  - Project X does not need an ultra high resolution BPM
  - ILCTA(NML) CM1 & CM2: button style BPM pickup
  - BUT: Continue common-mode free cold cavity BPM R&D at Fermilab!
Cold BPM for an ILC Cryomodule

• ILC beam parameters, e.g.
  – Macro pulse length $t_{\text{pulse}} = 800 \, \mu\text{s}$
  – Bunch-to-bunch spacing $\Delta t_b \approx 370 \, \text{ns}$
  – Nominal bunch charge $= 3.2 \, \text{nC}$

• Beam dynamic requirements
  – $< 1 \, \mu\text{m}$ resolution, single bunch
    (emittance preservation, beam jitter sources)
  – Absolute accuracy $< 300 \, \mu\text{m}$
  – Sufficient dynamic range (intensity & position) and linearity

• Cryomodule quad/BPM package
  – Limited real estate, 78 mm beam pipe diameter!
  – Operation at cryogenic temperatures (2-10 K)
  – Clean-room class 100 and UHV certification
Fermilab L-Band Design

Window –
Ceramic brick of alumina 96%
\( \varepsilon_r = 9.4 \)
Size: 51x4x3 mm

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency, GHz, dipole monopole</td>
<td>1.468</td>
</tr>
<tr>
<td></td>
<td>1.125</td>
</tr>
<tr>
<td>Loaded Q (both monopole and dipole)</td>
<td>~ 600</td>
</tr>
<tr>
<td>Beam pipe radius, mm</td>
<td>39</td>
</tr>
<tr>
<td>Cell radius, mm</td>
<td>113</td>
</tr>
<tr>
<td>Cell gap, mm</td>
<td>15</td>
</tr>
<tr>
<td>Waveguide, mm</td>
<td>122x110x25</td>
</tr>
<tr>
<td>Coupling slot, mm</td>
<td>51x4x3</td>
</tr>
</tbody>
</table>

N type receptacles, 50 Ohm
HFSS Simulations: Dipole Mode

**Frequency, [GHz]** | 1.480
---|---
**Q, External** | 500
**Q, Surface (Cu)** | 22000
**Q, Ceramic(AL₂O₃)** | 5600

**Test charge, [coulomb]**
(X=0, Y=1mm) | 1E-9

**Stored energy, [joule]** | 5.9.0E-11

**Output Voltage at T=0*, [V]** | 0.24

* Normalized to 50 Ohm,
The total signal combines with two ports
Simulations: Monopole Mode

<table>
<thead>
<tr>
<th>Frequency, [GHz]</th>
<th>1.120</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q, External</td>
<td>550</td>
</tr>
<tr>
<td>Q, Surface (Cu)</td>
<td>19500</td>
</tr>
<tr>
<td>Q, Ceramic(AL₂O₃)</td>
<td>7.9E6</td>
</tr>
</tbody>
</table>

Test charge, [coulomb] (X=0, Y=1mm) 1E-9

 Stored energy, [joule] 6.1E-8

Output Voltage at T=0*, [V] 6.1

Coupling with TM₁₁ port, Output Voltage at T=0*, [V] 5.6E-5

* Normalized to 50 Ohm, The total signal combines with four ports
CM Type III+ BPM Real-Estate

Section View showing BPM
Shortened Waveguides

Vacuum coaxial feedthrow for TM$_{01}$ mode output

Ceramic slab

Coaxial feedthrow for TM$_{11}$ mode output

Ceramic vacuum window

Features:
1. Ceramic (Al$_2$O$_3$) brazed vacuum windows
2. Common TM$_{11}$ and TM$_{01}$ cavity
3. Symmetrical signal processing
4. Time resolution: 1 µs (bunch by bunch)
5. Position resolution: < 1 µm (± 1 mm)

Cavity diameter: 113 mm
Gap length: 15 mm
Pipe diameter: 78 mm
Waveguide: 120 x 25 mm
Construction Details
Next Steps...

- All brazing procedures successfully completed!
- Finalize cavity BPM
  - Waveguide lids (ceramics are ready for installation)
  - Weld monopole mode signal feedthrough flange adapters
  - Mount dipole mode signal ports
- Setup for RF measurements
  - Check / tune resonant frequencies and Q-value
  - Tune to minimize xy cross talk (dimples)
- Complete BPM for beam tests
  - Weld beam pipe and flanges
  - Vacuum certification
- This prototype ILC cavity BPM has “warm” dimensions
  - To be tested in a warm accelerator environment, e.g. A0PI, ATF
Cold ILC BPM in a Type III+ CM
Cold Button BPM for NML CM2

- ASSEMBLY TO BE VACUUM TIGHT, NO LEAK SHALL BE DETECTABLE ON THE
  MOST SENSITIVE SCALE OF A HELIUM MASS SPECTROMETER LEAK DETECTOR
  WITH A MINIMUM SENSITIVITY OF 2 x 10^-10 ATM·CC·SEC FOR HELIUM.
- ASSEMBLY TO BE ASSEMBLED AND PACKAGED SO AS TO ASSURE NO
  CONTAMINATION FROM FOREIGN MATERIALS, METAL CHIPS OR OTHER
  CONTAMINANTS. CLEANING PROCEDURE TO BE APPROVED BY Fermilab.
- ALL DESIGN, ASSEMBLY, AND HANDLING IS TO CONFORM TO STANDARDS ULTRA
  HIGH VACUUM PRACTICE.