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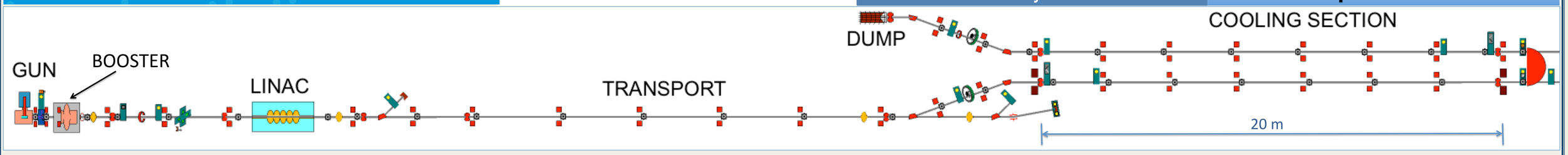
BROOKHAVEN NATIONAL LABORATORY

RHIC Relativistic Heavy Ion Collider

Collider-Accelerator Department

Accelerator Research & Development Division




Paper ID: 1561

# Multifunction Instrument Designs with Low Impedance Structures for Profile, Energy, and Emittance Measurements for LEReC at BNL

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*Abstract*

The low energy RHIC electron cooling (LEReC) upgrade project [1], being installed over the next two years will require a low impedance beam line so that the soft 1.6MeV electron beam will not be perturbed by induced electric fields, especially in the instrumentation chambers. Novel designs of the Profile Monitors, Emittance Slit Scanners and BPMs are presented along with Particle Studio simulations of the electron beam wake-field induced electric potentials. The design of a new instrument incorporating a button beam position monitor (BPM) and YAG screen profile monitor in the same measuring plane is presented as part of a method of measuring beam energy with an accuracy of $10^{-3}$. .

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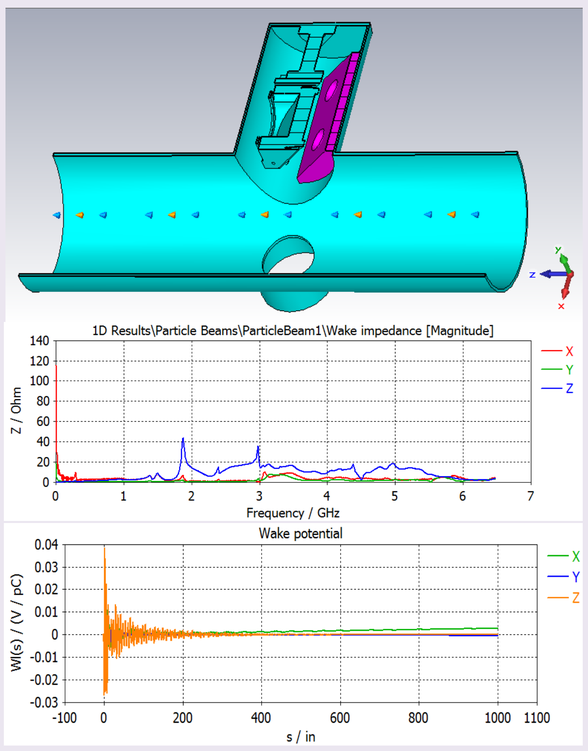
## Vacuum Chamber Design



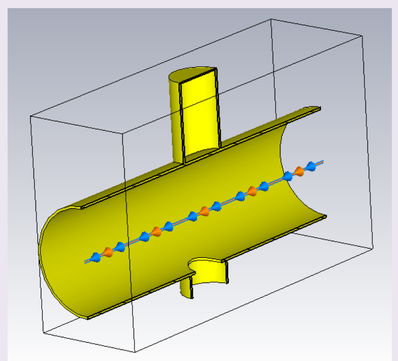

Specialized design of the vacuum chambers for low impedance

Typical 6-way cube or cross was abandoned. Starting from a cylindrical design, matching the 4.78" I.D. beam pipe, orthogonal ports were added to accommodate the insertion of detectors and viewports.

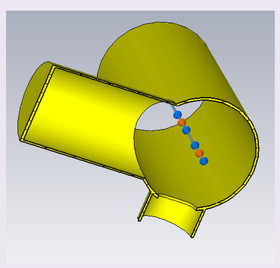
An iterative refining process of the design was composed of numerical simulation of the wake-field induced electric potentials by a short electron bunch followed by adjustments to the mechanical design resulted in a final design with low a wake potential.

Simplified 3D models used in the simulation are shown below.

Emittance Slit Scanner



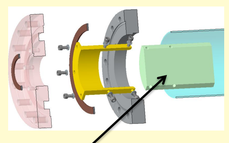
Profile Monitor



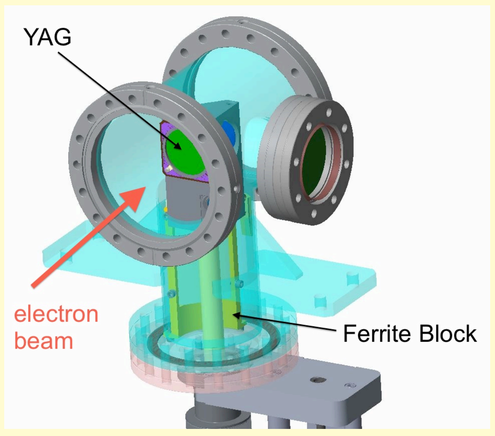
## Profile Monitor

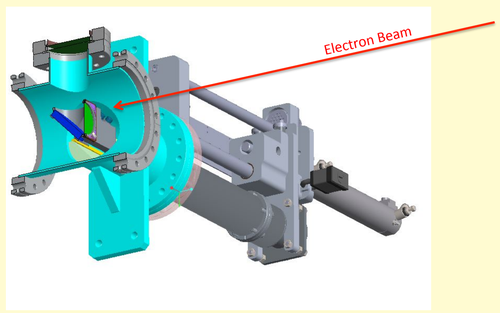
Required resolution for profile: 10%
- 10% of the beam size of 23 mm (@ 3σ or 99% full width – cooling section only)
- beginning and end of each of the two cooling sections.

**Key Parameters:**
- Cylindrical Vacuum Chamber
- 45 mm screen aperture
- YAG crystal 0.1 X 50 mm
- Aluminum coating
- Normal to beam
- Copper mirror @ 45° behind YAG



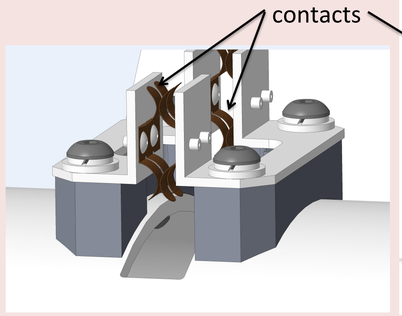
NiZn ferrite absorbing block, type CMD5005, with a surface area of 23.42 $in^2$ and volume of 4.83 $in^3$ and positioned in the actuator port.

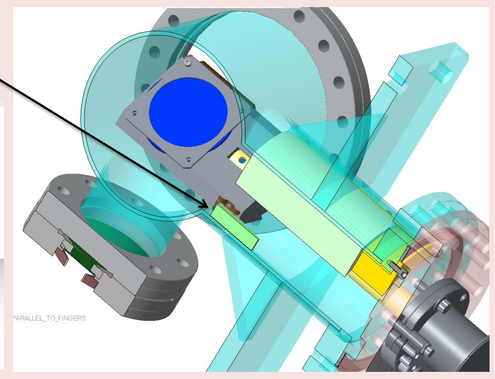


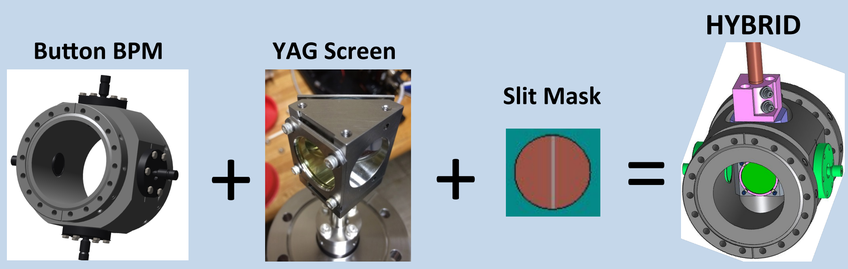

## RF Grounding

Wake-field induced potentials on beam intersection components are mitigated with grounding contacts. These voltages can set up large "ringing" "L-C" oscillations on YAG crystal and Emittance Slit Mask that can be significant enough to distort the electron beam; thereby corrupting the attempted measurement.



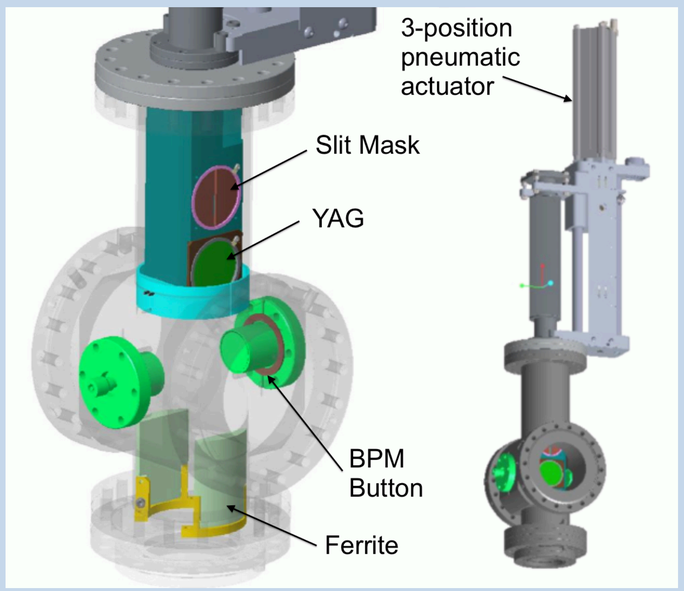



## HYBRID BPM + Profile Monitor + Slit Mask




**Combined Functions:**
- Absolute Enrgy
- Beam Profile
- Energy Spread

**Key Parameters:**
- Cylindrical Vacuum Chamber
- 3-Position actuator
- 45 mm YAG screen
- 30 mm conical BPM (H-plane)
- Defining Slit




### Electron Beam Parameters (Cooling Section Only)

| Parameter | Value |
|---|---|
| Beam Energy | 1.6 – 5 MeV |
| Bunch Charge | 100 – 300 pC |
| Macrobunch Charge ($\gamma_{ion}$ = 4.1 – 10.7) | 3 – 5.4 nC |
| Average Beam Current | 30 – 50 mA |
| Bunch / Macrobunch Rep. Rates | 704 / 9.1 MHz |
| Bunch Length | 120 ps |
| Max. Allowable Energy Spread (Δρ/ρ) | $5\times10^{-4}$ |
| Beam Transvers Size | σ = 3.84 mm |

### Emittance Slit Scanner

Required resolution for emittance measurement: 10%
- 10% of the beam size of 23 mm (@ 3σ or 99% full width – cooling section only)
- beginning and end of each of the two cooling sections.

**Key Parameters:**
- Cylindrical Vacuum Chamber
- Single scan H + V slice emittance measurement
- 150 µm wide slit
- 2.0mm thick Tungsten mask
- 60s scan (40µs exposures)
- 10 W limit per scan (no water cooling in vacuum)

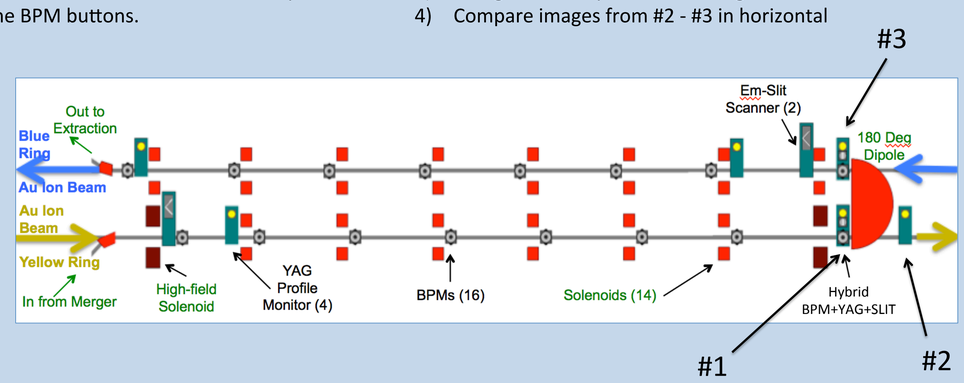
***Absolute Energy Measurement***

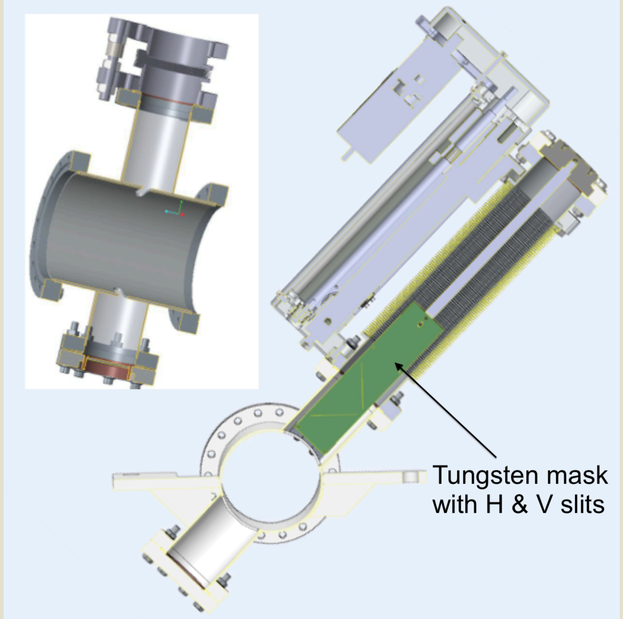
➔ BPM accuracy requirement: 50 µm

Two BPMs will be used with the 180° dipole magnet in the cooling section as a spectrometer. For absolute calibration, a YAG screen profile monitor is inserted into the BPM chamber in the same X-Y plane as the BPM buttons.

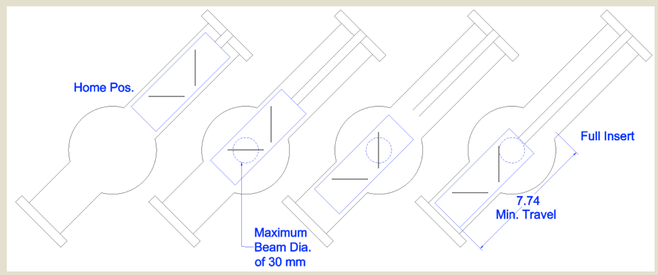
***Energy Spread Measurement***

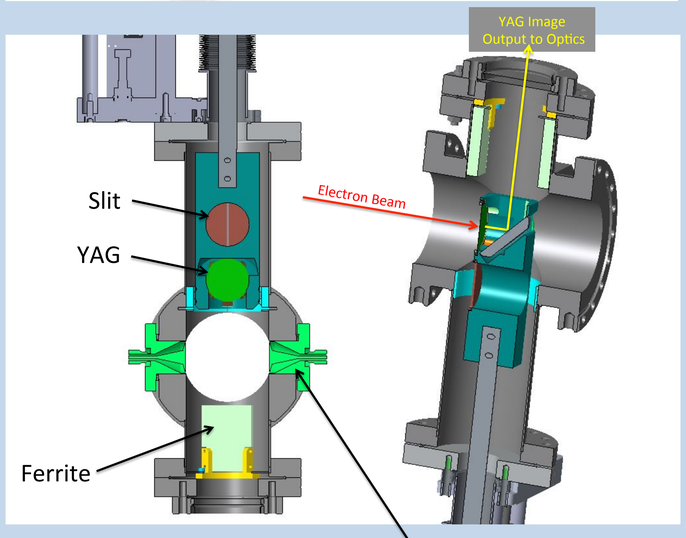
An energy spread measurement is required with a resolution of better than 10% of the maximum Δp/p of $5\times10^{-4}$.
1) Insert slit in #1 ,turn off 180° Dipole, energize high field solenoid
2) Take Profile on #2
3) Energize 180° Dipole & take image on #3
4) Compare images from #2 - #3 in horizontal



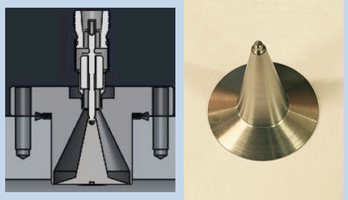

Detail of the emittance slit mask in four key positions through the combined horizontal & vertical scan with the beam spot shown.



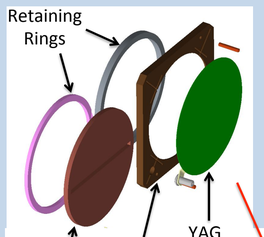

***Conical BPM Button Design***

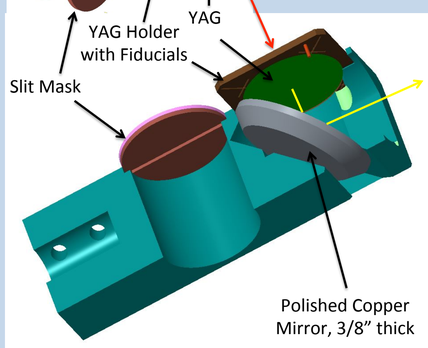
A large diameter 30mm button PUE has been designed for the large aperture beam pipe and to profile large puck-up surface area. The conical design has been developed for high bandwidth and improved matching.



**"Opposing Optical" Layout**

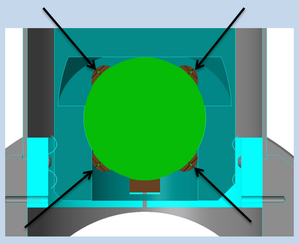
The optics viewport opposes the actuator, requiring a special design of the YAG and mirror holder




***Optical Fiducial Points***

Four optical features on the YAG holder are provided for BP M calibration



***BPM Calibration Procedure***

Pre-surveyed YAG holder provides optical reference for comparison of beam spot center to BPM position data. Four optical features on the YAG holder are imaged along with a beam profile. Center of gravity (CoG) weighted beam center is compared in position to the center of the reference circle drawn through the optical features. The two resulting X and Y offset values are fed into the BPM data processing as offsets from actual center.

**BPM Calibration Procedure**