

LEReC  
INSTRUMENTATION  
DEVELOPMENT

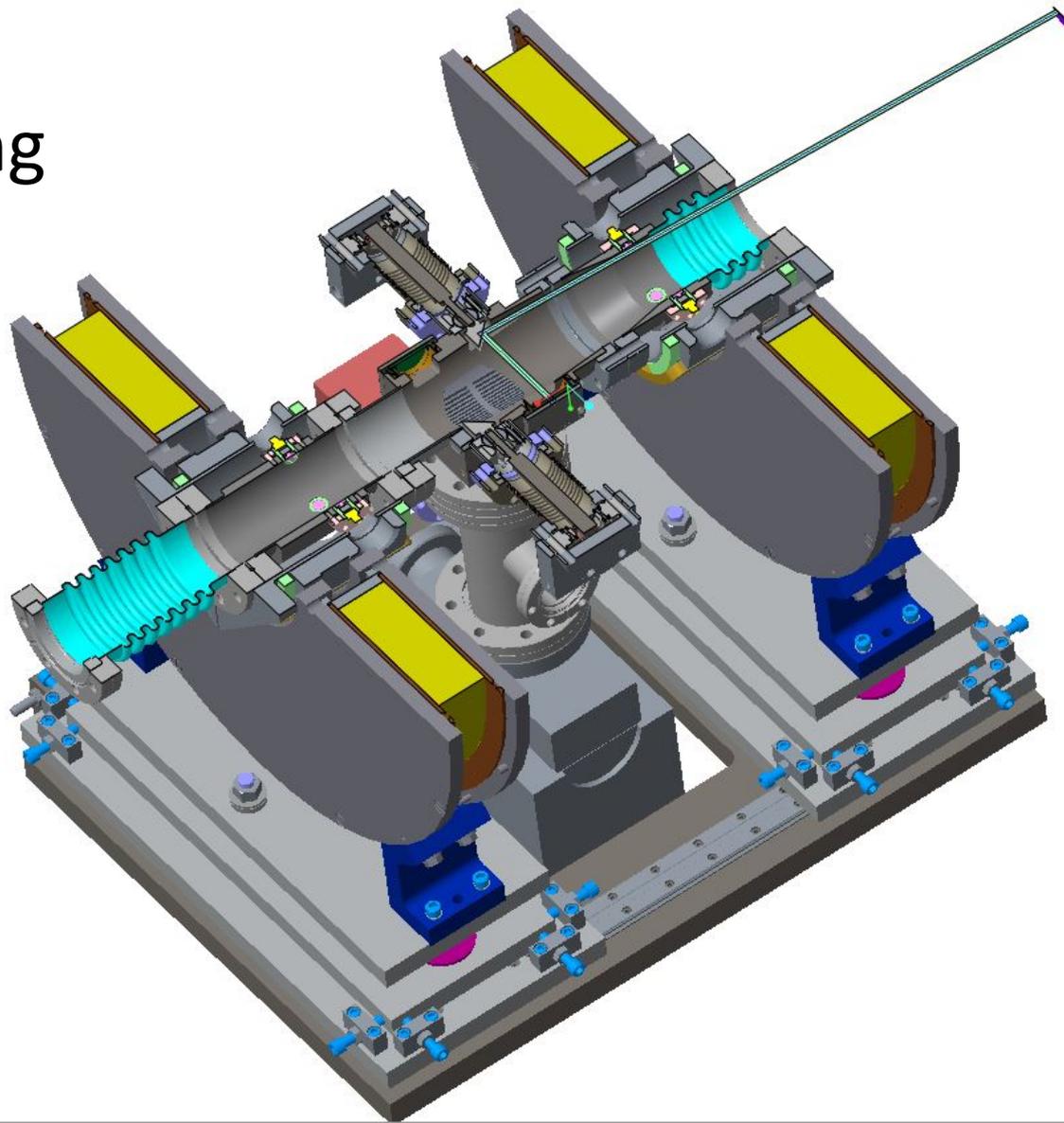
11-24-15

T MILLER

# Topics

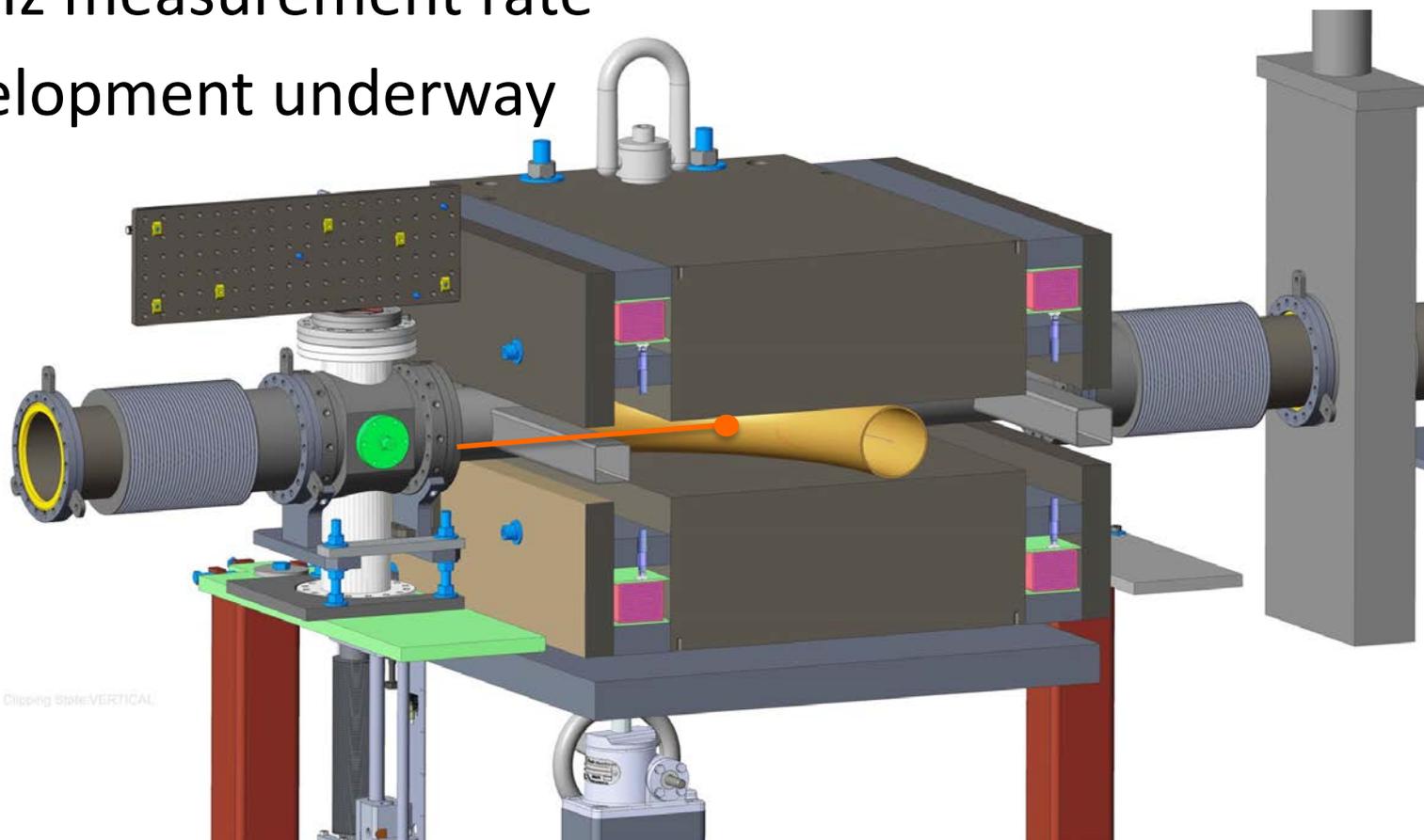
- Cathode Imaging
- 180 Dipole NMR Probe
- Transport Line BPMs
  - Button size / Signal strength
  - Temperature dependence
  - Ion/electron signal rejection
- CW vs Macrobunch structure
- Visit to JLAB
  - Instrumentation for MPS
  - Instrumentation for LLRF Feedback
- ERL PM modification
- Flying Wire PM
- Longitudinal Phase Monitor
  - Beam Line Optics design
  - Kicker design
  - Cavity design
  - RF Amp design
- Electrostatic Spectrometer
  - Deflector design
  - Scanning YAG design
- Recombination Monitor
  - Lattice Design with dispersion waves in arcs
  - Roman Pots Scintillation detector
  - Deuteron Telescope Recombination Monitor...

- Cathode Imaging



- NMR Probe

- 50mGauss/195 Gauss ( $3 \times 10^{-4}$ )
- 2.5 Hz measurement rate
- Development underway



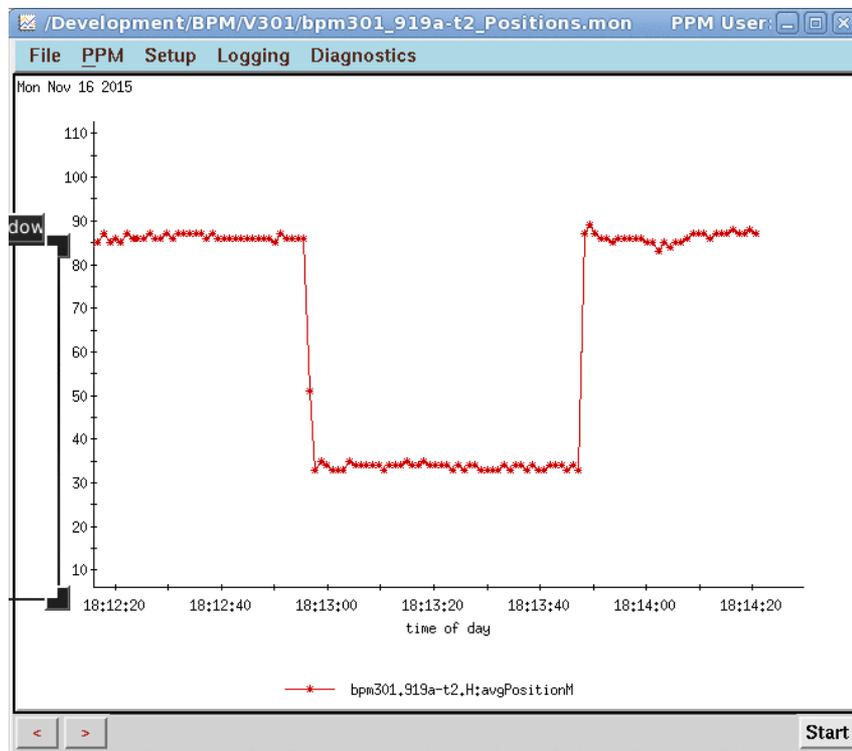
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# LEReC BPM Testing

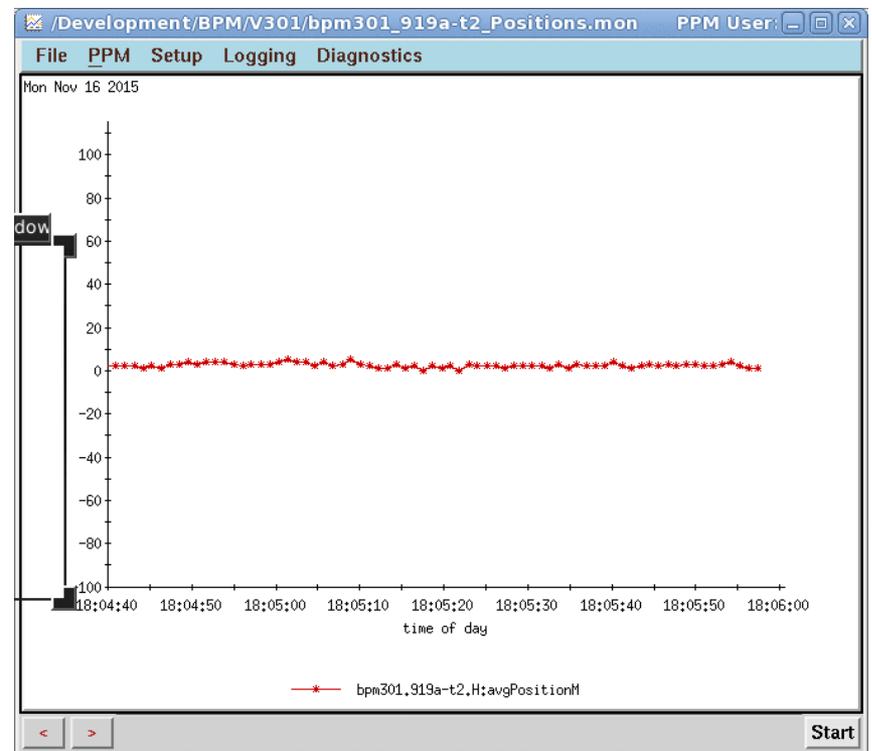
- Diplexers can remove e- signal from Ion signal
- Temperature effects are significant for e-
  - 503MHz BPF better than 707MHz SAW
  - 2 deg. C Oscillations in 1002A = 30 $\mu$ m ( $K_1=35000$ )
  - Ion signals show no significant temp. effects
- Lots more to understand about offsets!

# Effect of CW e- signal on Ion Measurement

## Wideband Splitter

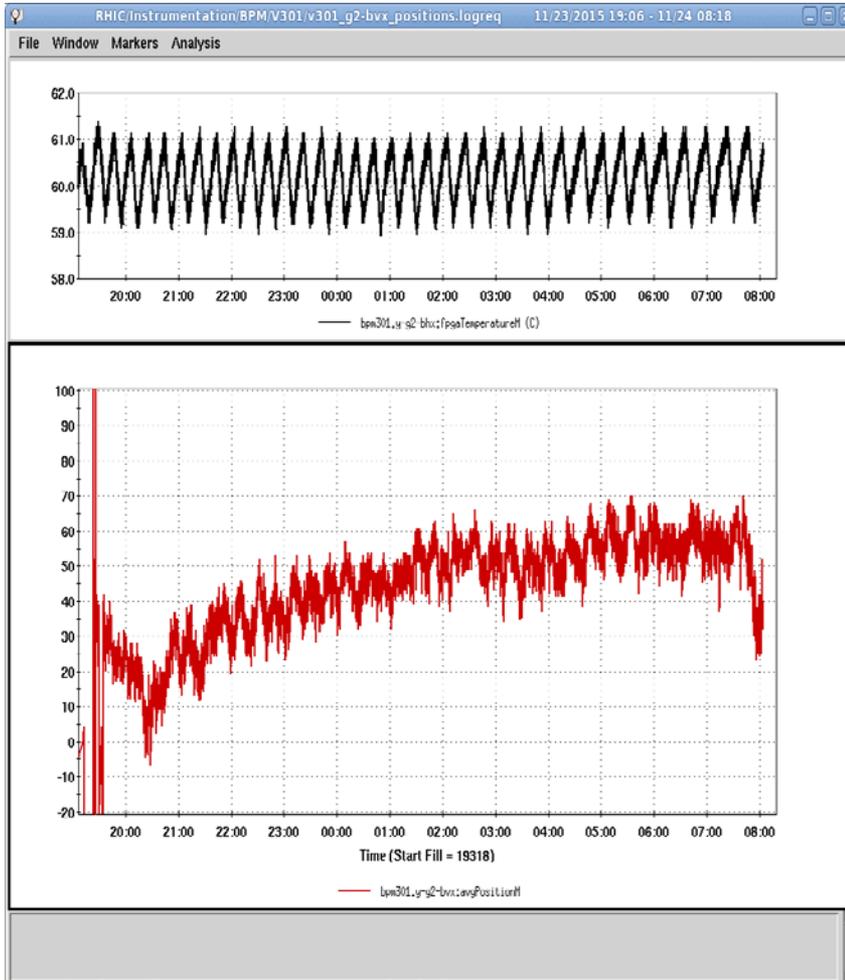


## Diplexer (<10MHz LPF)

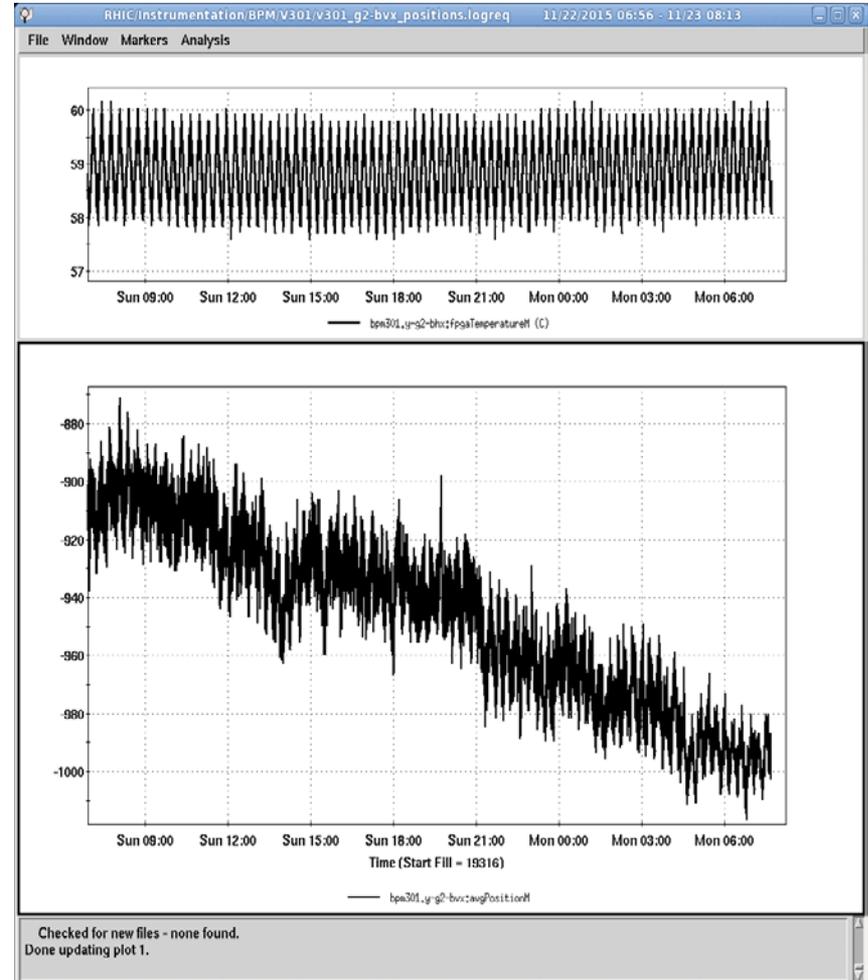


# Temperature Effects (Split signal in tunnel)

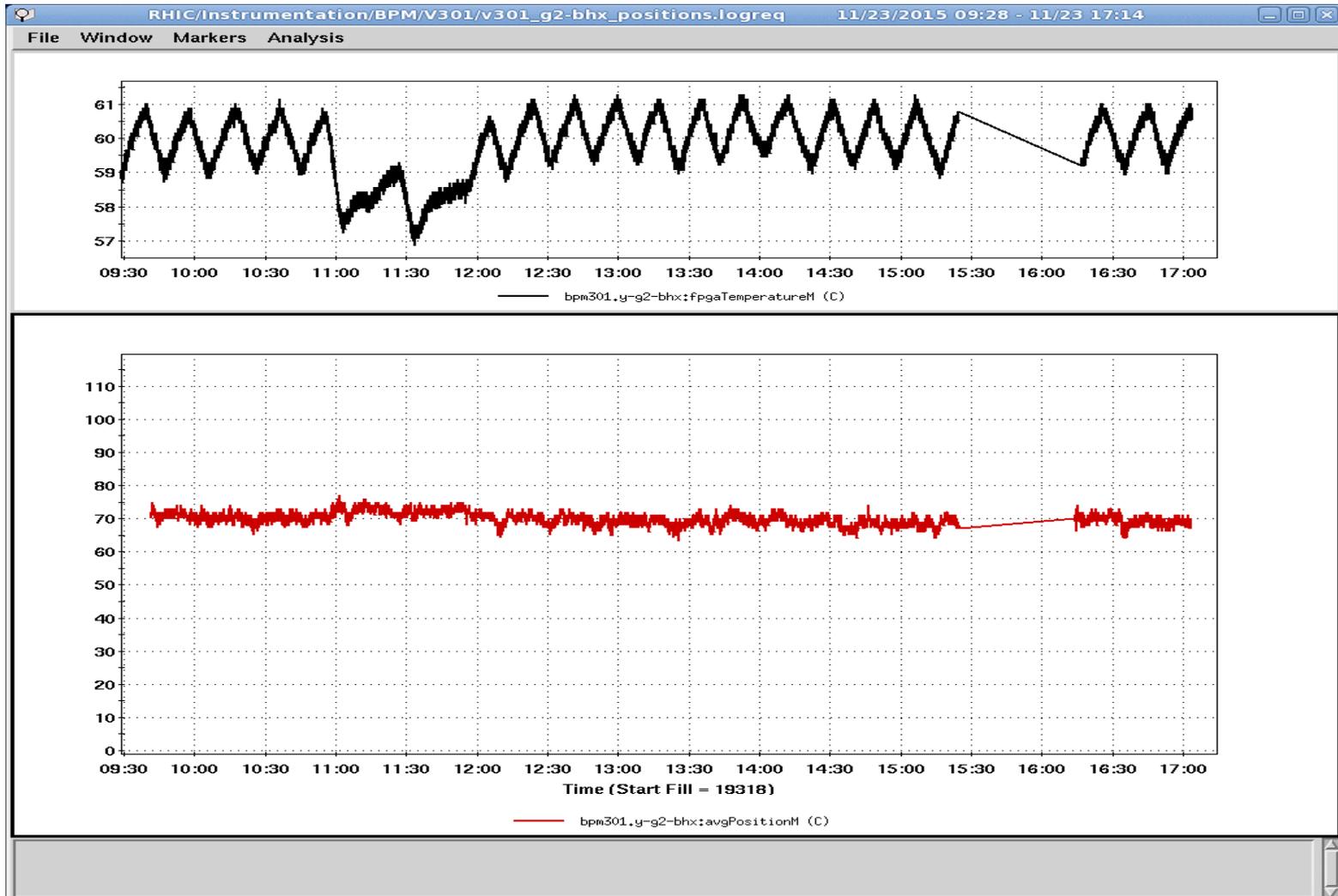
## 503MHz Bandpass



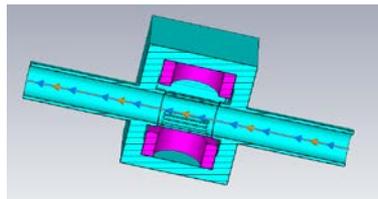
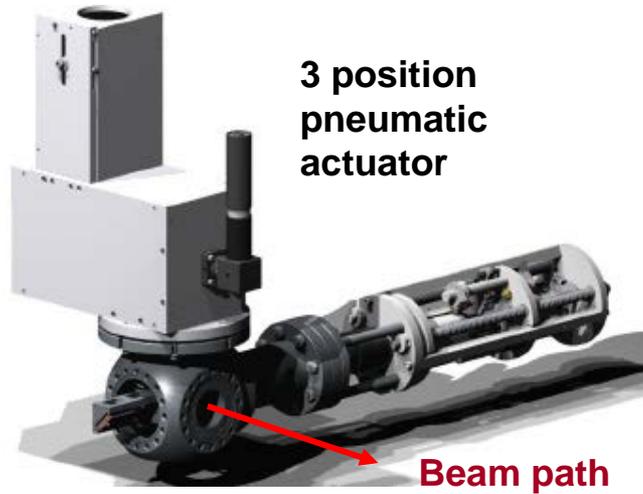
## 707MHz SAW Bandpass



# Ion Signal Temperature Effects



# Ferrite Mod's to ERL PM's

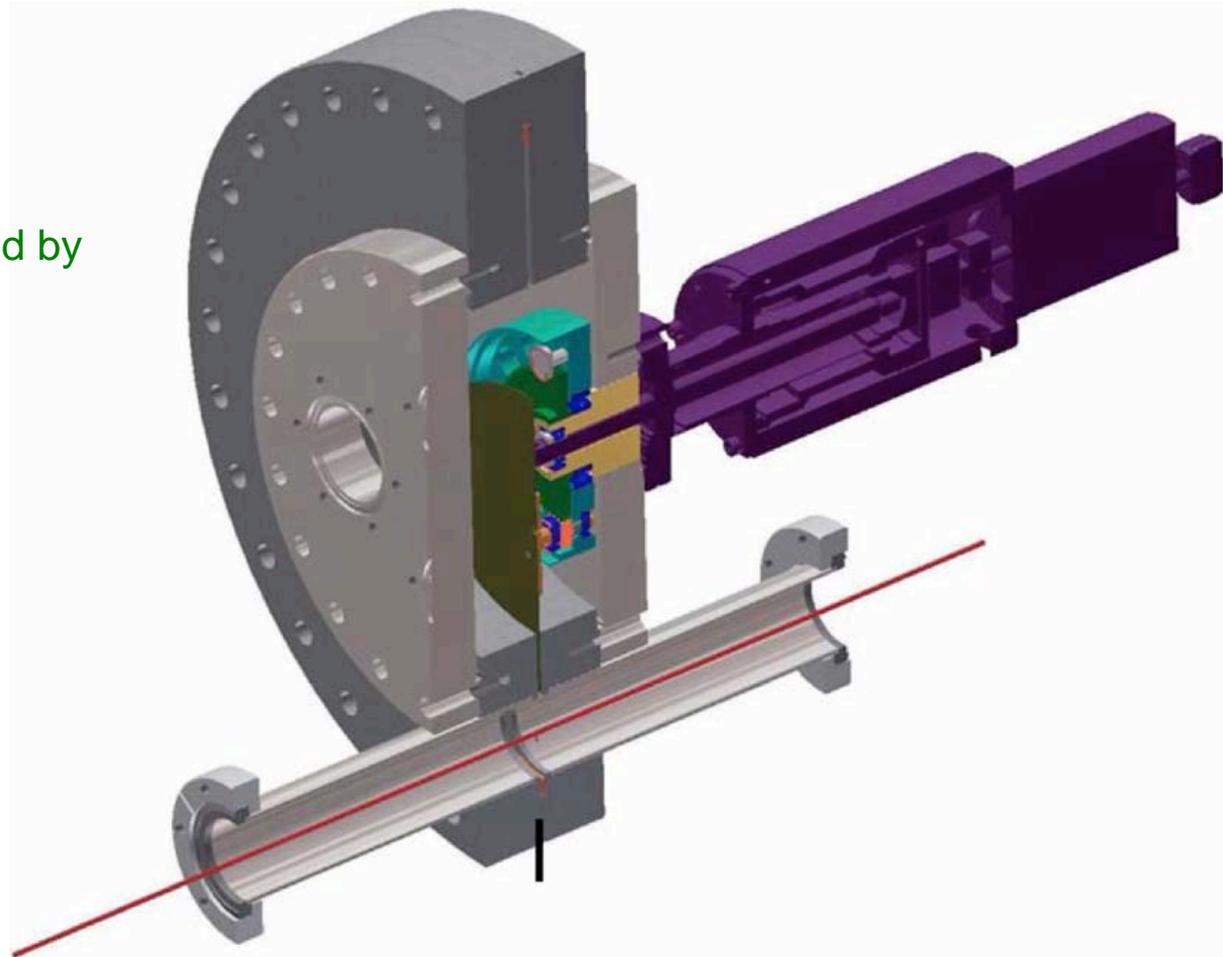


# High Power Profile Monitor

## High Power

- Compact offset cam design
- 9  $\mu\text{m}$  carbon fiber @ 20 m/s
- accelerate/coast/decelerate
- PMT detects X-rays generated by the scattered electrons

- **Design Reliability?**
- **Performance Study?**
- **Alternatives?**



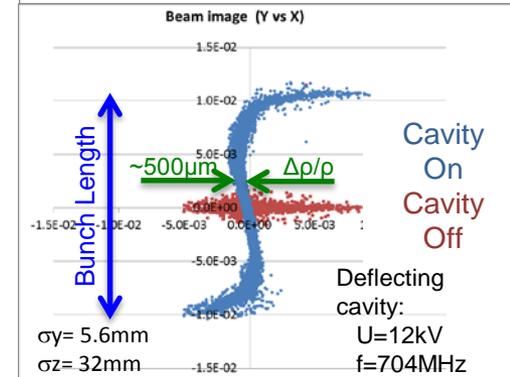
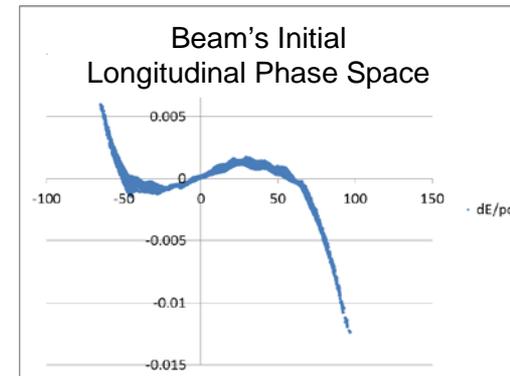
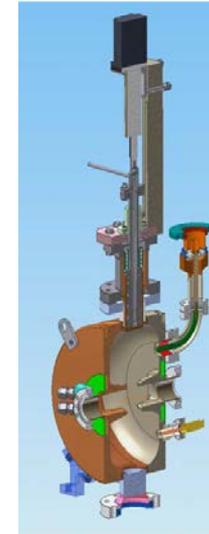
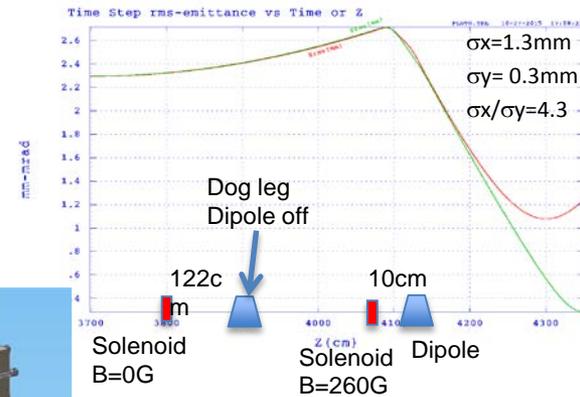
*Photo courtesy of B. Dunham, Cornell*

# Space Monitor

## – Commissioning Beam

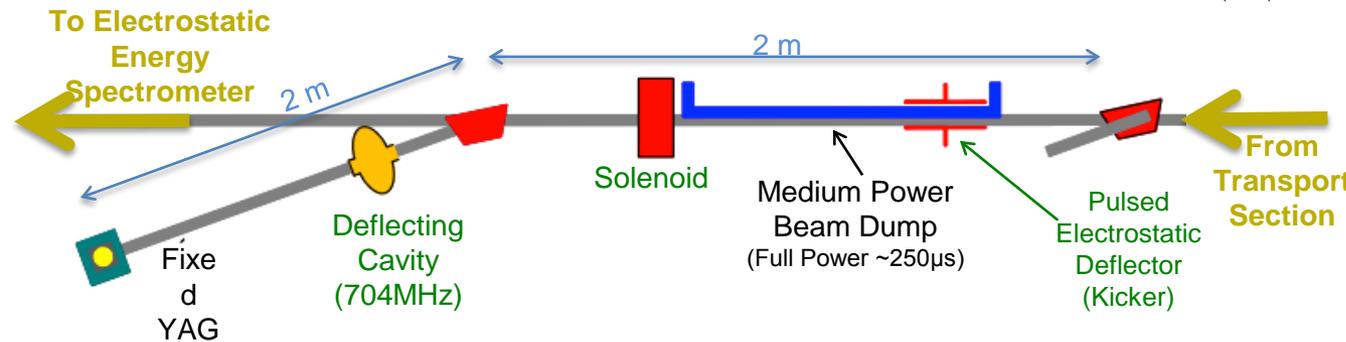
- **704 MHz Vertical Deflecting Cavity**
  - Used for optimization and monitoring of phase and amplitude of the LEReC RF systems.
  - Scaled from Cornell ERL Injector 1.3 GHz design.
  - Time varying vertical deflection of bunch from head to tail.
  - Combined with horizontal dispersion from bending magnet ( $D_x = 1\text{ m}$  at YAG) provides position (time) resolved energy spread along bunch.
  - Very low RF power <500W at highest beam energy.
- **Energy Spread**
  - 500 $\mu\text{m}$  width on YAG =  $1 \times 10^{-3}$  energy spread ( $\Delta\rho/\rho$ )
  - 100 $\mu\text{m}$  resolution on YAG = resolutions of 5% of max  $\Delta\rho/\rho$
- **Bunch Length**
  - 30mm on YAG (100 $\mu\text{m}$  resolution ) with 3 cm bunch length
  - Resolution of 30mm / 100 $\mu\text{m}$  = <0.5% of bunch length

# Line



Simulations Courtesy of D. Kayran

S. Belomestnykh, et al., "Deflecting cavity for beam diagnostics at Cornell ERL injector," *Nucl. Instrum. & Methods A* **614** (2010) 179-183.

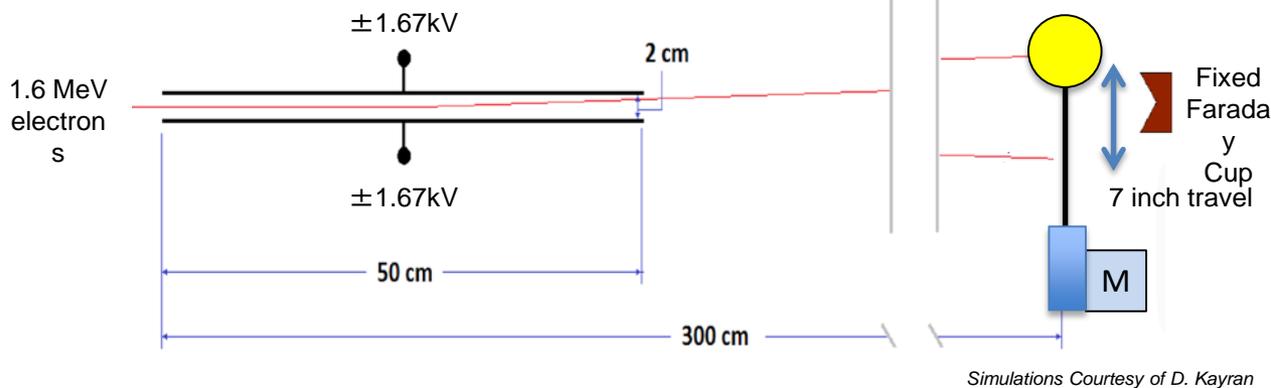
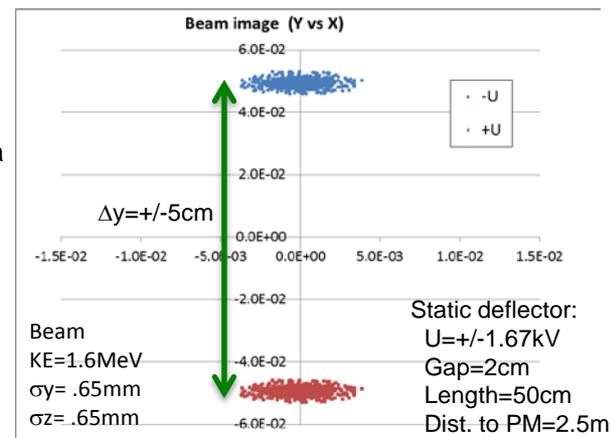
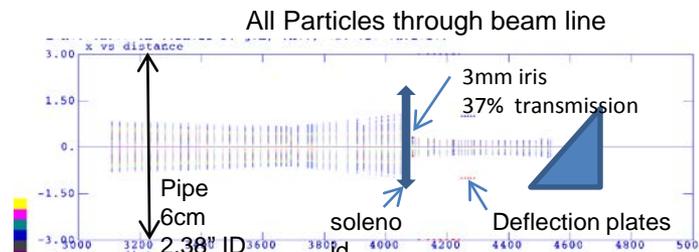
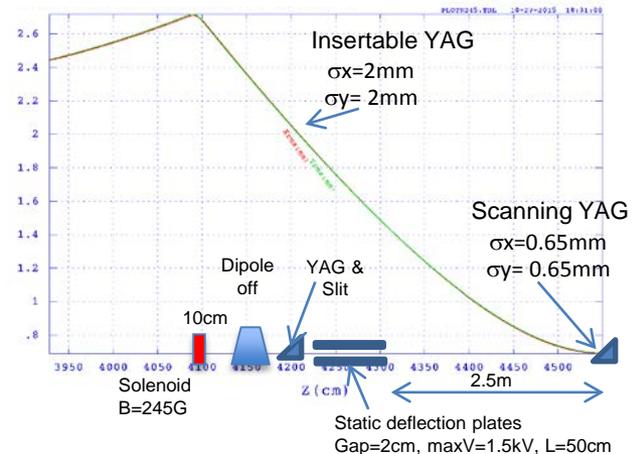


$$\sigma_{\Delta z} = pc / eU \cdot \lambda / 2\pi L \sigma_{\Delta t}$$

# Absolute Energy Measurement – Commissioning Beam

Current approach:

- ~2 kV electrostatic deflecting electrodes
- Scanning YAG screen (+/- deflection) over 100mm
- Calibration using Tandem ion accelerator
- Expected resolution:
  - 50 $\mu$ m optical resolution  $\div$  100mm deflection =  $5 \times 10^{-4}$  which can be improved to compensate for noise with a fixed zoom lens.
  - By centering the spot on the screen using Center-of-Gravity image analysis, the sub-micron scan position gives the absolute energy.

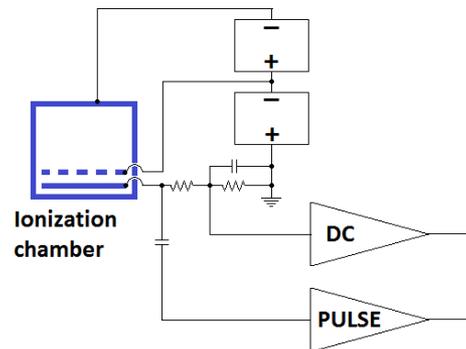
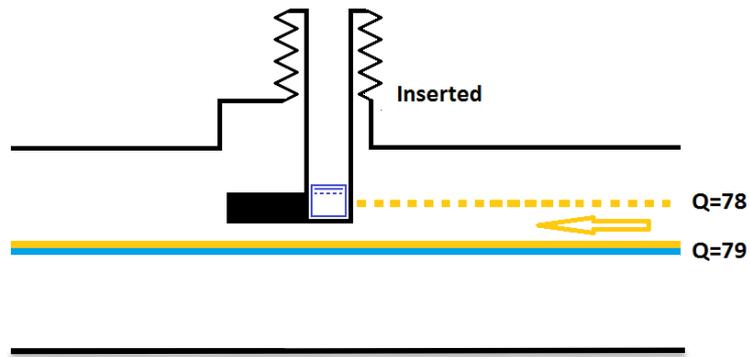


# Recombination Monitor: Ion Collection

## Recombination Detector – Secondary Cooling Indicator.

### Collection of recombined ions:

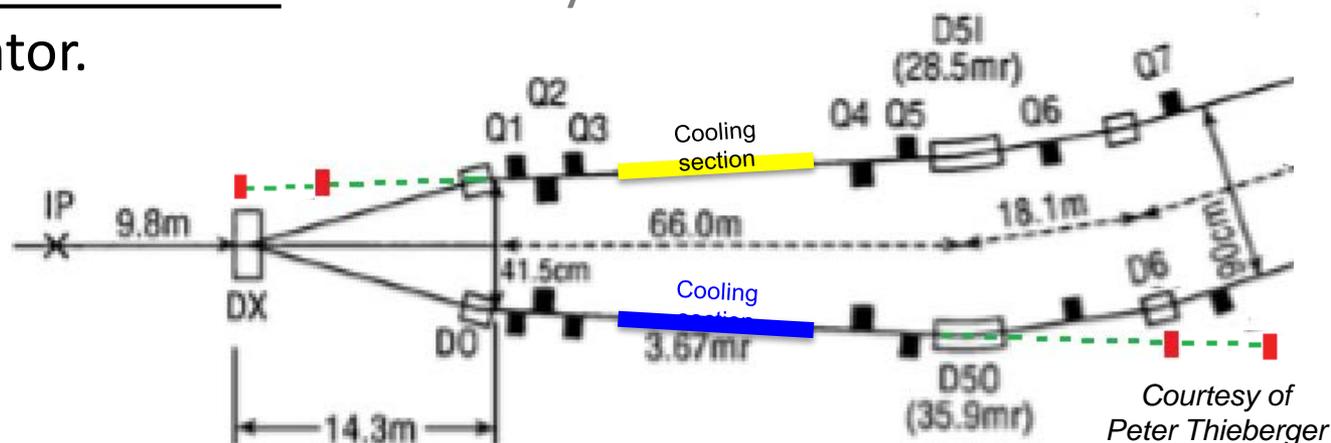
- Lost at predictable location
- Detector: PMT + Counter
- Development underway of a lattice with a dispersion waves in the cold arcs
- Roman Pot type detectors envisioned in the cryostat to collect the  $\text{Au}^{+78}$  ions.



*Courtesy of Peter Thieberger*

# Cooling Indicators – Recombination Detector

## Recombination Detector – Secondary Cooling Indicator.



- Investigating deuteron-electron recombination for initial electron beam alignment and energy calibration.
  - Strong, localized signals allow detection starting far from optimal alignment.
  - **Neutral** deuterons from deuteron-electron recombination are not deflected in the arcs.
  - Detectors located outside of the cryostat (red rectangles) will detect these particles and the showers they produce.
  - Detector telescopes can be used to reduce background if necessary.
  - The structure of the expected showers will be studied using MCNPX simulations.
  - A small deflection will result after the neutral deuterium loses its electron when traversing the beam-pipe. This deflection will be calculated and taken into account.

# Notes from this meeting 11-24-15

- **CW vs MacroBunch beam structure**
  - Alex reported that we are buying high power couplers capable of CW operation in the event that CW operation is required. Thus only additional RF power amplifiers would need to be added.
  - It is not yet clear if this is an advantage or disadvantage for BPMs. Certainly, CW operation would eliminate the possibility of using single electronics boards for ion & electron measurements. But, this would only strengthen the 700MHz electron beam position measurement.
- **Cathode Imaging**
  - Proposal to add cathode imaging to Cornell Gun design via a penetrated mirror in laser entry port to image cathode along the path of the laser. This depends on the useable aperture of the laser steering mirror that would also be used for imaging the cathode.
- **NMR Probe**
  - Caylar reported in a video conference this morning that they are making good progress with their NMR-20 instrument and is measuring 166Gauss with +/- 50mGauss noise at a 2.5 Hz measurement rate (400 msec sliding average window). Their goal is a resolution of 20 mGuass.
- **BPM Testing**
  - Rob H announced that test results have showed excellent rejection of the 700MHz electron signal while measuring the low frequency ion signal due to the use of the 10MHz duplexers (see slide 6).
  - Moreover, significant temperature dependence of the system shows the need for temperature controlled racks for the BPM electronics. One long term drift has yet to be correlated with a cause.
  - More testing with 700MHz trains of short bursts is necessary to investigate suspected frequency dependence of electrical center of the buttons in the cube. We are investigating faster picosecond pulses, 700MHz ARB's and perhaps a properly matched Goubau Line or alternative structure for testing the button cubes.
- **ERL Profile Monitors**
  - Joe explained during a discussion about the Ferrite modified chambers that we plan to move forward with totally new designs for the profile monitor chambers in order to match the beam line aperture and to correct for impedance.
- **Flying Wire Profile Monitors**
  - We decided to move forward with requesting a serious quote for the procurement of TWO units from Cornell. We may be fortunate enough that single macro bunch profile measurements of the beam are representative of the high power beam BUT the Flying Wire PM is the only instrument that can provide profile measurement during operation.
- **Longitudinal Phase Space Monitor**
  - Kevin Mernick explained that a recent meeting was held where the parts of the commissioning beam line were assigned to people to work on, as follows. Dmitry will present the beam line optics in a meeting next week. BPMs and solenoids may need to be added.
    - Fast Kicker – KM, MMB, KSS
    - Internal Beam dump – JT, MMB
    - Transverse Deflecting Cavity – BX, JT, VV (Cornell)
    - YAG Screens, Cameras – TM
    - Other Diagnostics (BPMs?) – RM, RH
    - Energy Measurement - MM
    - Beamline Optics – DK, JK
    - Magnet Power Supplies – DB (I'll at least clue Don in re: this minor side project)
    - Vacuum, Beamline Layout/Construction – JT
- **Electrostatic Energy Spectrometer**
  - Peter is working on the preliminary design of the deflector that an ME will be assigned to work on to aid in developing a cost estimate. I (Toby Miller) will work on estimating the YAG profile monitors and associated optics and scanning motion control for the beam line.
- **Recombination Monitor**
  - Felix has a promising RHIC lattice that can produce  $\sim 8\sigma$  separation between Au+78 and Au+79 ions in dispersion bumps in the cold defocusing quads set up using the gamma t quads.
  - A Roman Pots style detector will need to be designed to move a detector into the dispersive space of the beam.
  - CERN is experimenting with installing beam loss monitors inside their crystats. The results could be useful here in choosing a suitable detector.
  - Wolfram pointed out a US vendor of Diamond Detectors, Applied Diamond, Inc. He also suggested considering new Plasma Radiation Detectors being introduced by Integrated Sensors, LLC
  - We discussed installing the double coincidence detectors for deuteron recombination detection as the detectors are outside of the vacuum. The yellow detector in the IP should work well but the blue detector has lots of material impeding the signal and will require further simulation to determine its effectiveness.