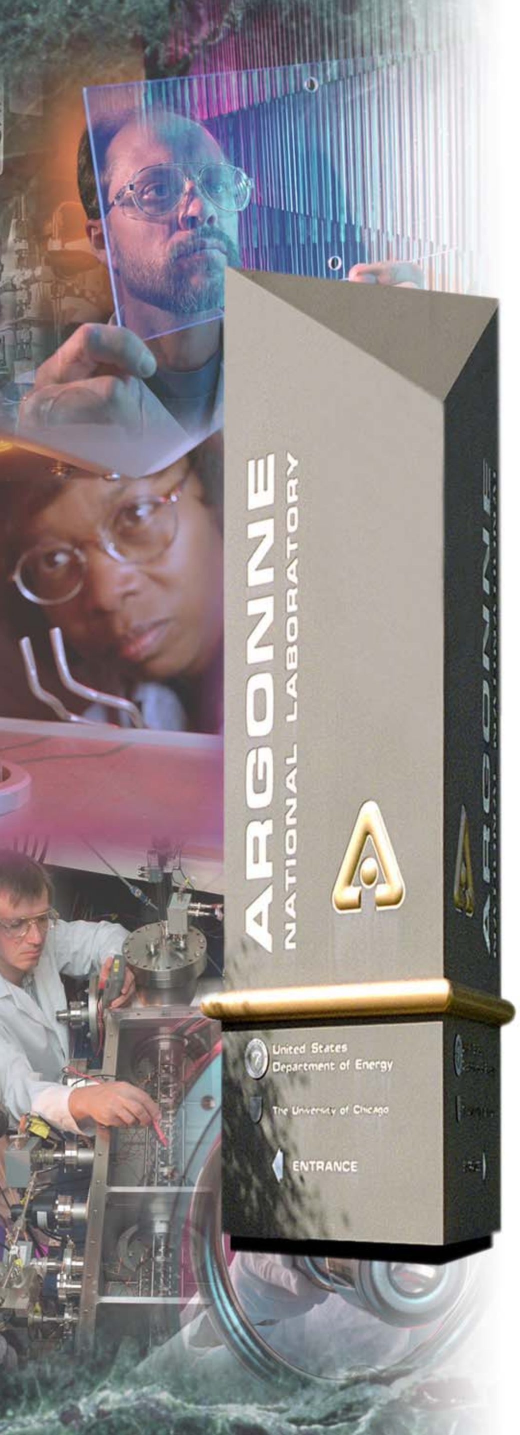

RIA Diagnostics Development at Argonne

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(paper 2.4.4)

Argonne National Laboratory

Office of Science
U.S. Department of Energy

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RIA Diagnostics Development at Argonne

Driver Linac: High Power, High Energy LINAC

- **Low beam losses required in linac**
  - ✓Deliver required currents to achieve beam power goals
  - ✓Typical 1 W/m losses in high energy portions to allow easy maintenance
- **Multiple charge-state acceleration**
  - ✓Requires low emittance growth
  - ✓Precise tune matching
  - ✓Removal of unused charge states at proper location

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RIB Linac: Low Intensity, High Precision LINAC

- Low beam losses required
  - ✓Efficient use of produced RIBs
- Low-emittance high-quality beam
- Possible multiple charge-state acceleration
- Beam current spans broad range: 1 to 10^{10} pps

These goals, require a well planned diagnostics system.

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Diagnostics Requirements

- ➢Longitudinal Diagnostics
  - ✓Beam phase (know to ~1°)
  - ✓Energy
    - ▪Time-of-flight (velocity →E/A)
    - ▪Absolute total energy to verify beam species
  - ✓Bunch shape and size
  - ✓Longitudinal emittance
- ➢Transverse Diagnostics
  - ✓Beam position (know to ~0.1 mm)
  - ✓Size
  - ✓Emittance

RIA Diagnostics Development at Argonne

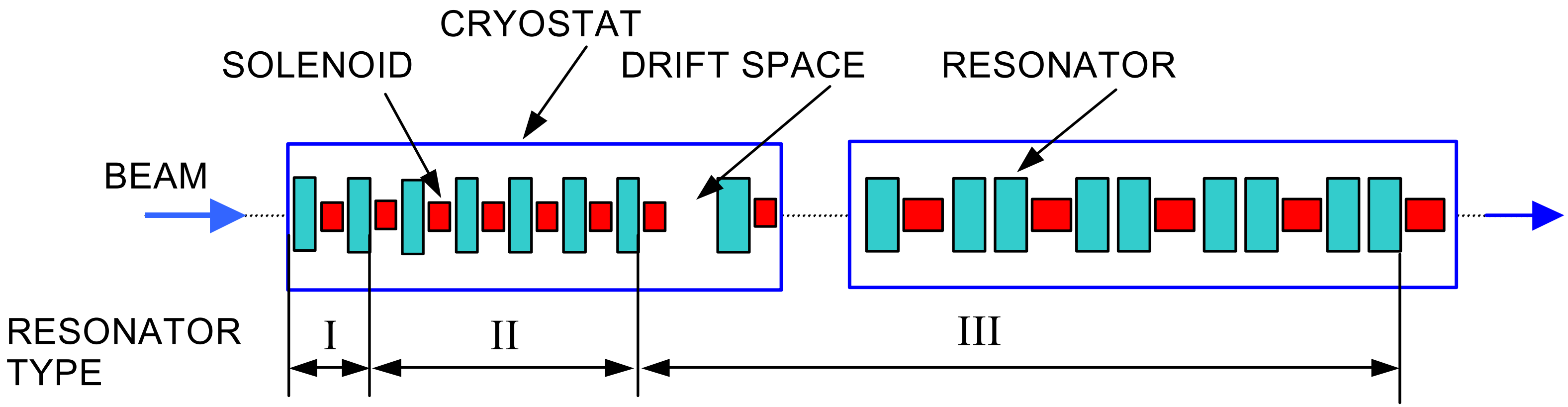
Diagnostic Development Activities at Argonne

- **Beam phase detection with a SC resonator**
- **Bunch length measurement**
- **Beam profile monitor for weak beams**

ATLAS has proven to be a valuable test bed for diagnostic developments

RIA Diagnostics Development at Argonne

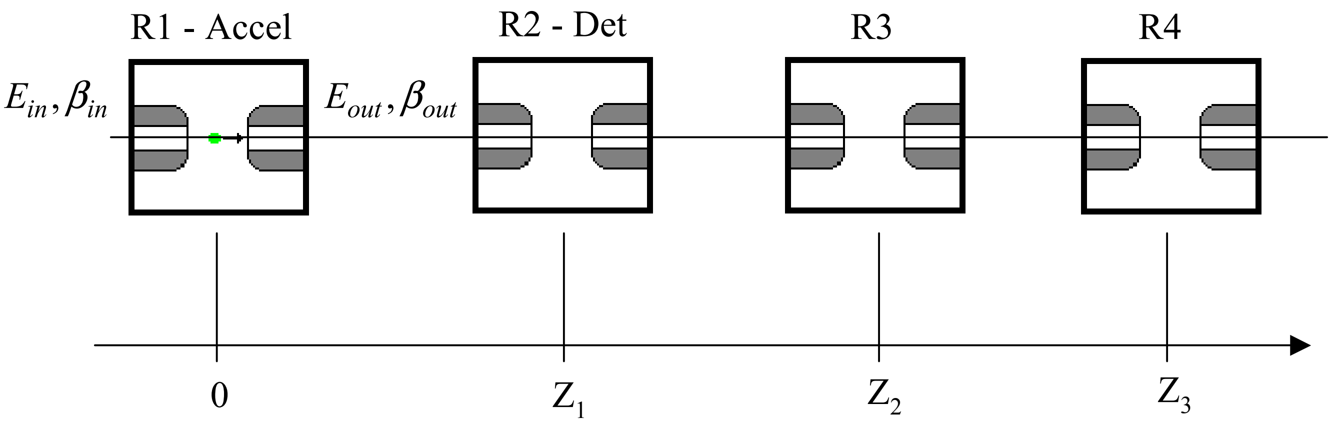
Beam phase detection with a SC resonator



- **Heavy-ion LINACs need a range of velocity profiles**
  - ✓ **Optimum acceleration over a wide q/m range.**
    - ***ATLAS q/m range is 0.1 to 0.5.***
    - ***RIA Driver q/m range is 0.12 to 1.0.***
- **Little room for diagnostics**
  - ✓ **Closely spaced lattice in low-energy section required**
    - ***Low emittance growth***
    - ***Low beam losses***

RIA Diagnostics Development at Argonne

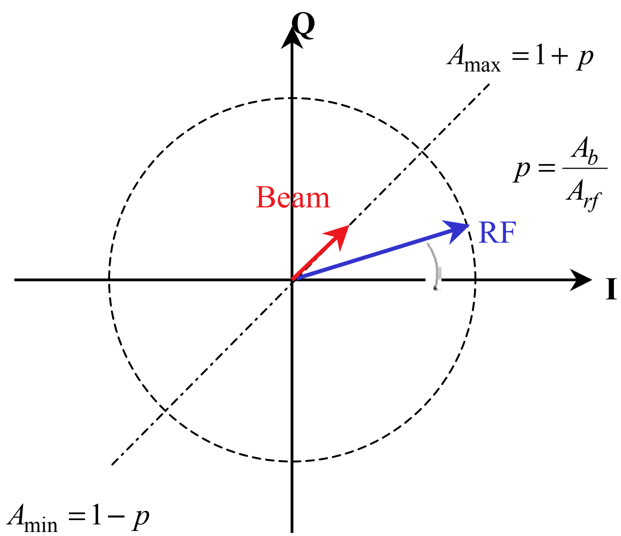
Beam phase detection with a SC resonator



- **Features of the Resonant Pickup**
  - ✓ **Turns every accelerating cavity into a beam phase monitor**
  - ✓ **Less sensitive to beam steering**
  - ✓ **Less sensitive to beam defocusing with energy change**
  - ✓ **Good centroid time accuracy: $\leq$ 1 degree**
  - ✓ **Energy measurement from phase shift possible**
  - ✓ **Phase width from normalized amplitude (in principle)**

RIA Diagnostics Development at Argonne

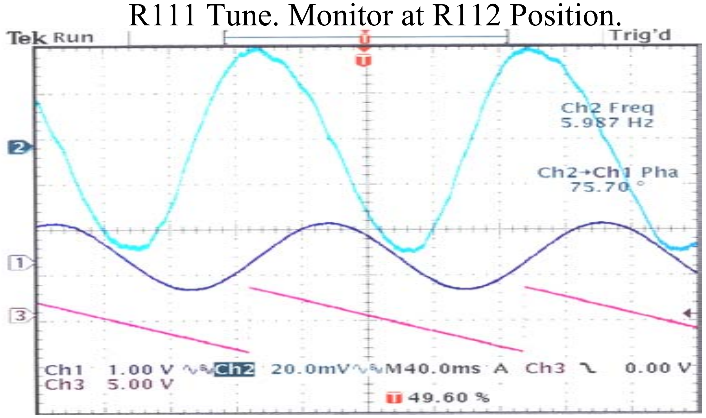
Beam phase detection with a SC resonator

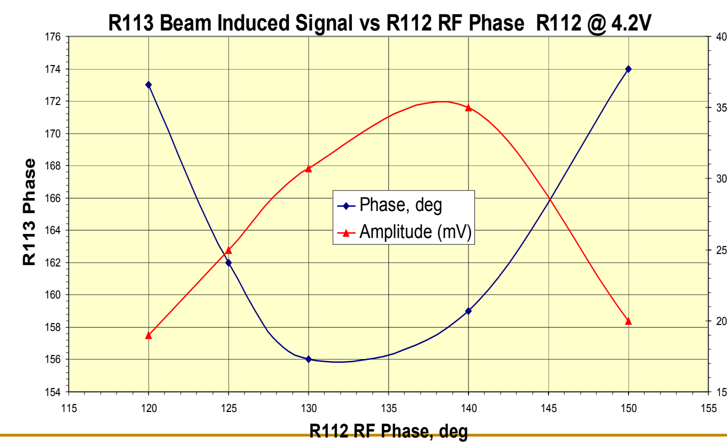


- Induced RF Field from beam:
  - 4-5 kV/m per μA
- Resonator must operate in order to match beam frequency
- Slow rotation of operating field allows phase of beam-induced field to be extracted

$$A_{\Sigma}(t) \approx A_{rf}\left(1 + p\cos(\phi_{rf} - \phi_b)\right)$$

R111 Tune. Monitor at R112 Position.





Beam phase detection with a SC resonator

Summary

The Resonant Beam Pickup Method has been developed at ATLAS using resonators similar to those planned for the low-velocity section of RIA.

The technique has been implemented for the low-velocity resonators in ATLAS.

Fully automated data acquisition being developed.

RIA Diagnostics Development at Argonne

Beam Bunch Length Measurement

- **Important for low-emittance beam tuning**
  - ✓**Based on time distribution of secondary electrons**
    - ▪**Produced by beam striking thin vertical wire**
    - ▪**Electrons accelerated, focused and RF swept onto detector**
      - •**Amplified by microchannel plate detector**
      - •**Light from scintillator response to electrons**
      - •**Measured by CCD camera interfaced to computer**

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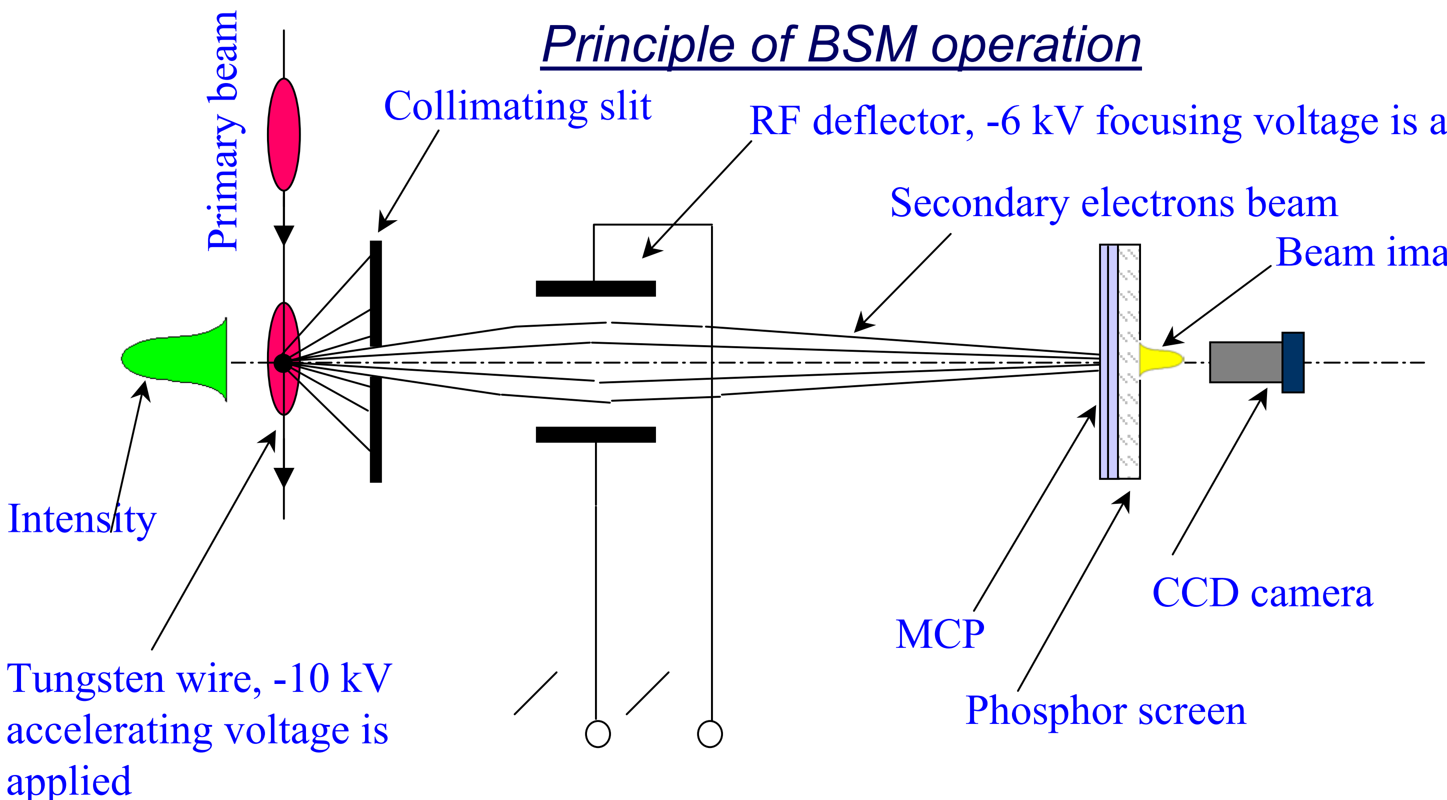
Beam Bunch Length Measurement



$$\Delta U_{st} + U_{RF}\sin(n\omega t + \varphi_0)$$

ΔU_{st} -steering voltage

$U_{RF}\sin(n\omega t + \varphi_0)$ -deflecting voltage

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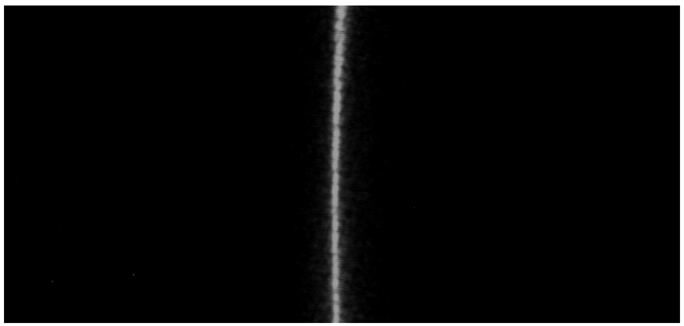
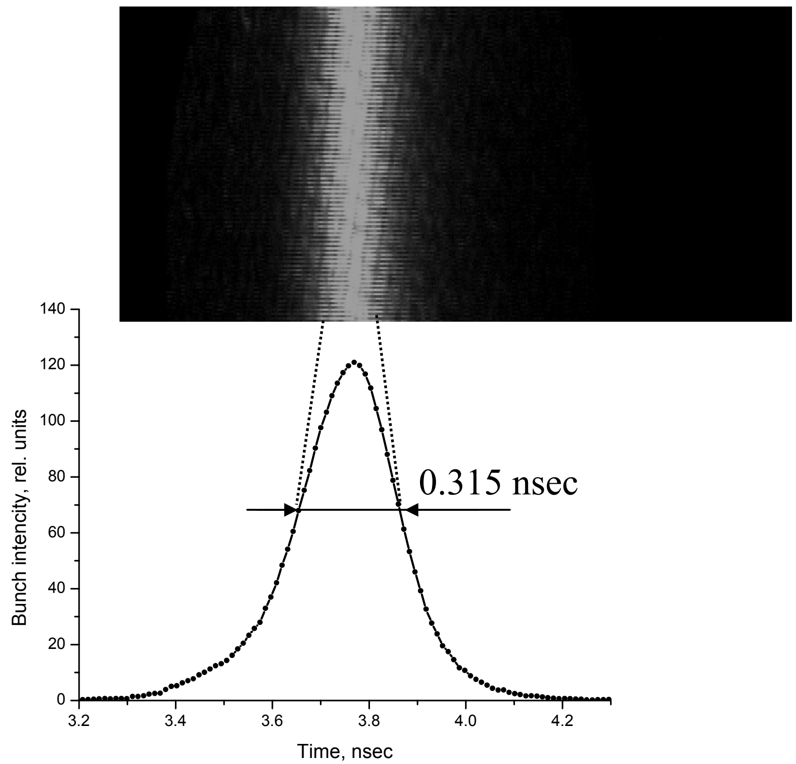
Beam Bunch Length Measurement

Bunch image without RF power in the deflector



Typical bunch image on the phosphor screen



Bunch shape for 185 MeV $^{54}Fe^{16+}$ beam

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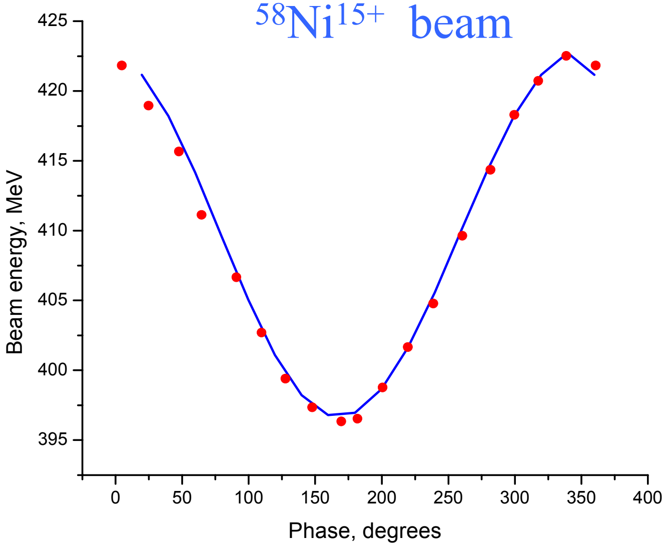
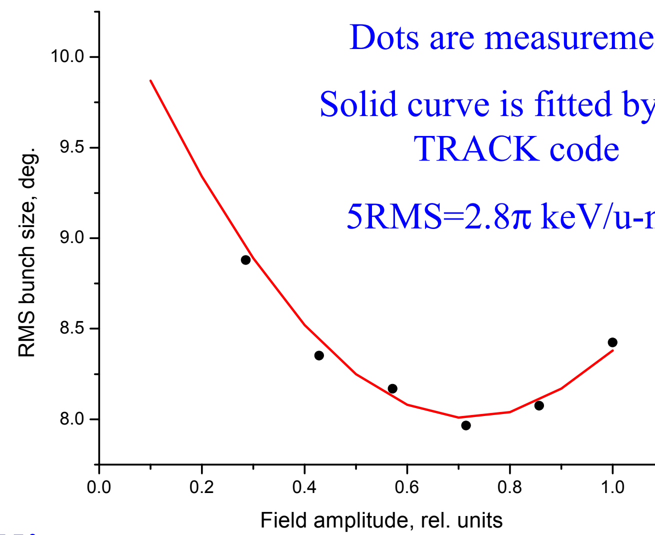
Beam Bunch Length Measurement

Longitudinal emittance measurements

Beam energy as a function of RF field phase in the last Booster resonator for 397 MeV $^{58}Ni^{15+}$ beam



Measurement of longitudinal emittance for 153 MeV $^{16}O^{8+}$ beam



Summary:

The BSM works and allows measurement of the bunch shape, longitudinal emittance and another characteristics of heavy ion beams in CW mode with 20 psec resolution

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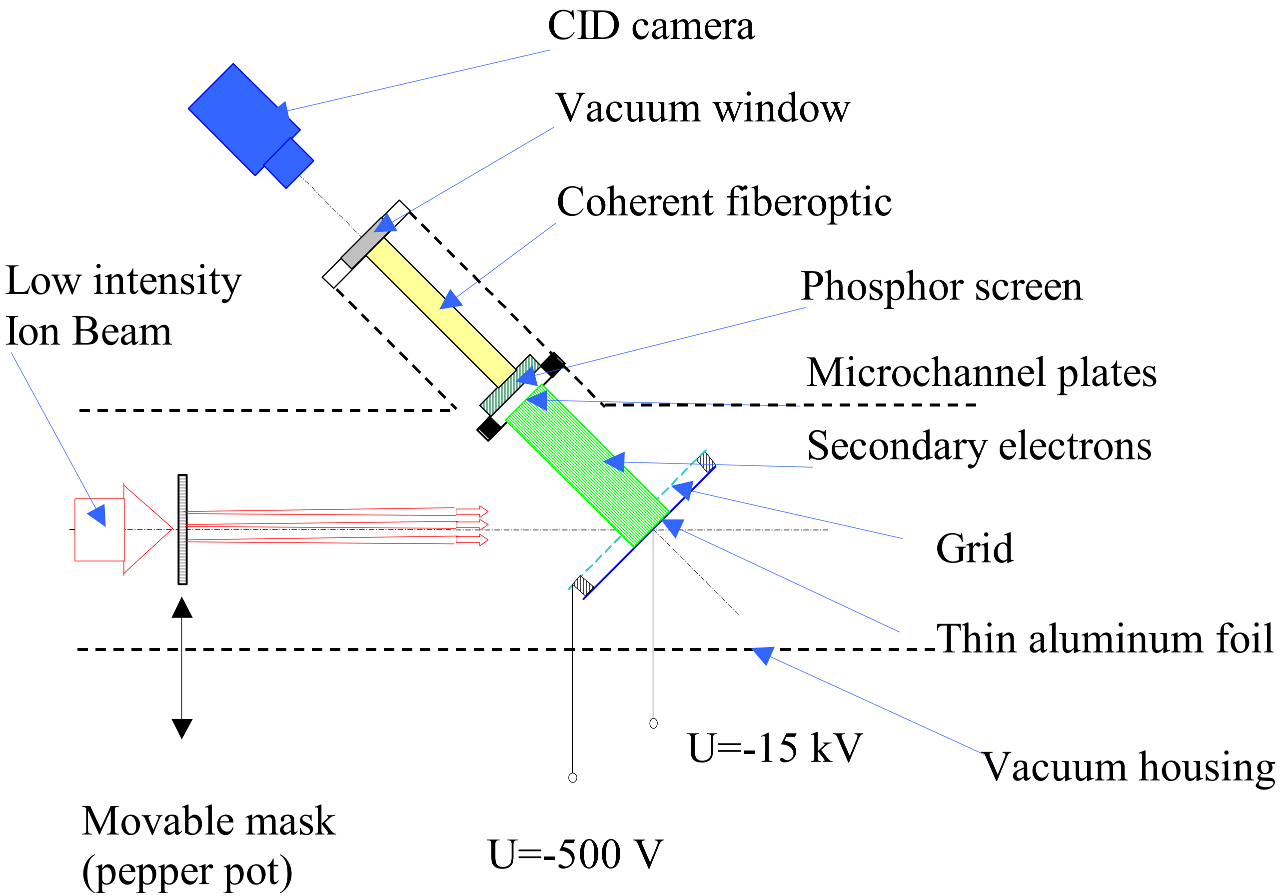
Beam Profile Monitor for Low Intensity Radioactive Beams

Sensitive at Intensities $\leq 10^3$ pps



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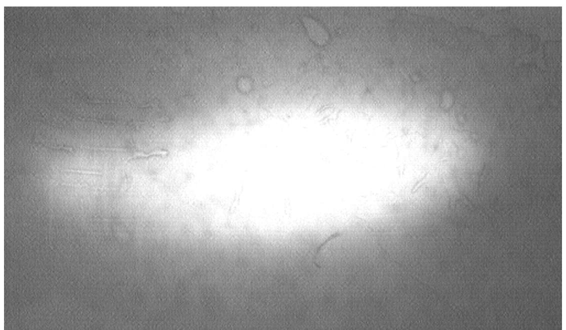
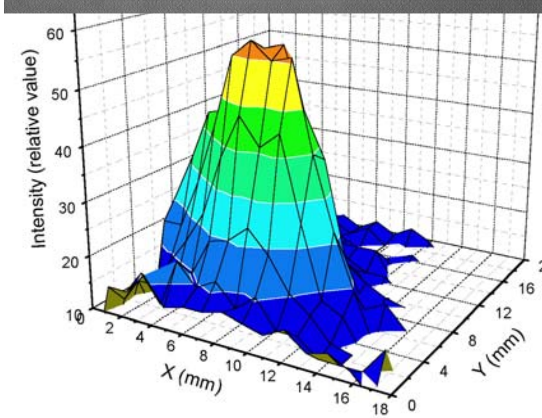
Beam Profile Monitor for Low Intensity Radioactive Beams

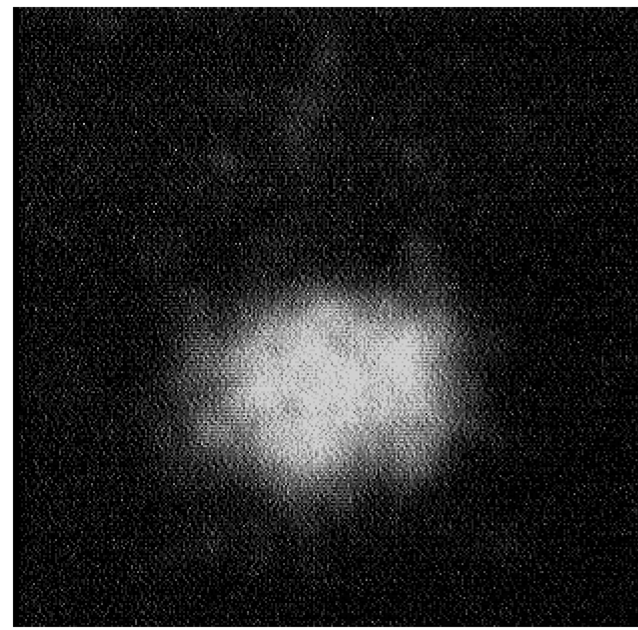
Profile monitor covers a dynamic range: >10^6

Krypton beam, 1 MeV, ~10^{10} pps





Krypton beam, 1 MeV, ~$2\cdot10^4$ pps



RIA Diagnostics Development at Argonne

Additional R&D Diagnostics Needs

- Driver beam position monitors
- Beam halo detector
- Develop and test compact diagnostic box
  - Intercryostat space limited
  - Diagnostics needed
    - Position monitor
    - Phase detector
    - Current toroid
    - Wire scanner
- High-Accuracy Beam Energy Determination for RIBs
  - Time-of-flight velocity measurement
  - Phase and energy control