Improved Multi-Dimensional Bunch Shape Monitor

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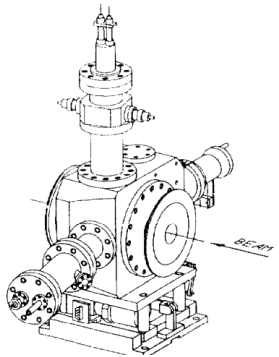
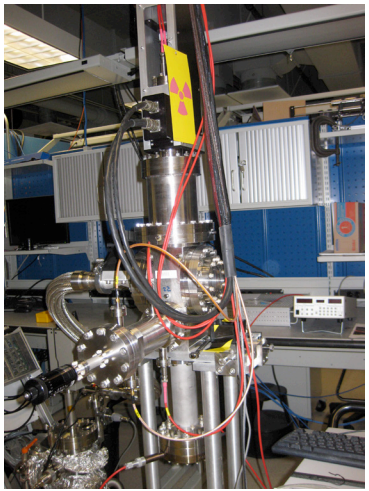
Introduction: Bunch Shape Monitor (BSM)

- BSM is used to measure the longitudinal bunch distribution in hadron linacs
- Developed and manufactured by Institute for Nuclear Research in Moscow (A. Feschenko)
- Used Word-wide
  - CERN, ORNL SNS, FRIB MSU, GSI, Argonne - ATLAS, PIP-II, among others

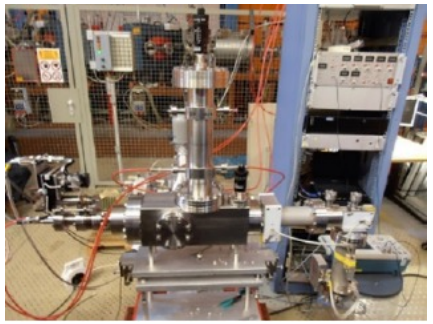
CERN



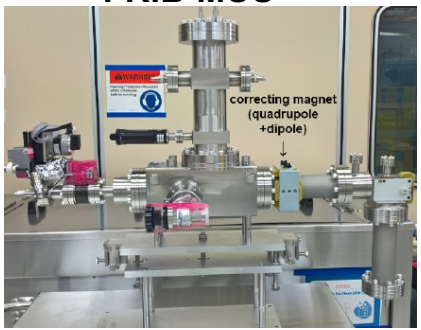
ORNL SNS



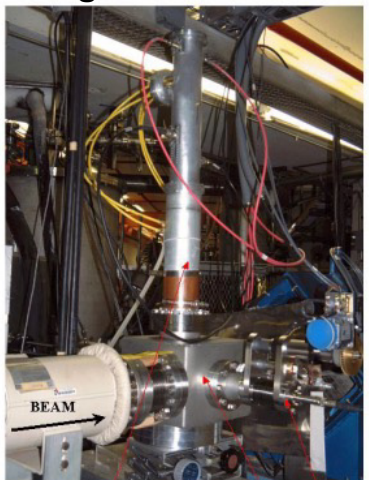
GSI



FRIB MSU



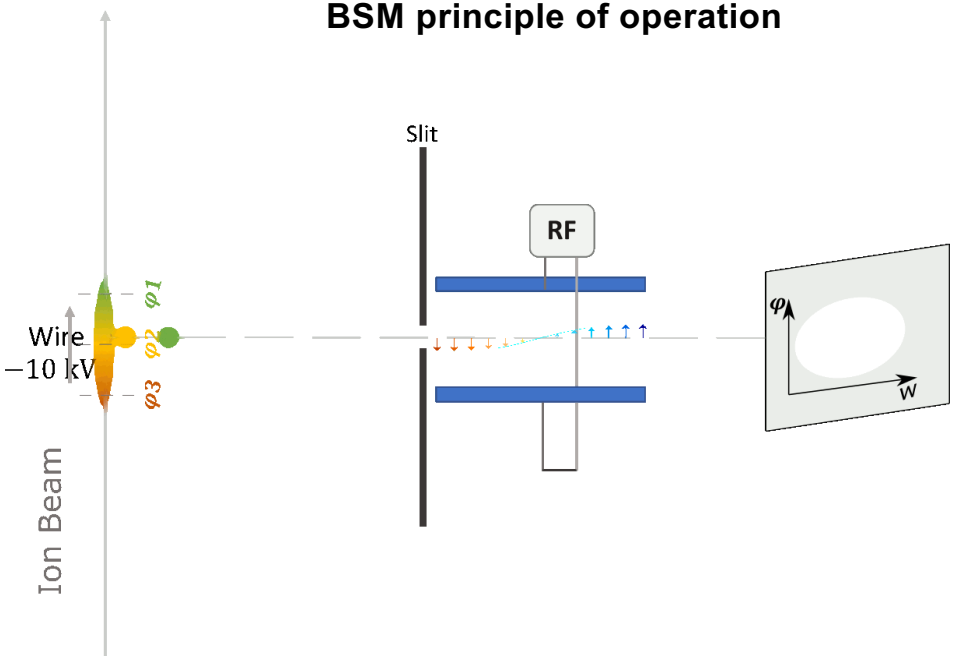
Argonne-ATLAS



Improved multi-dimensional BSM

- Main issues with existing BSM models
  - Poor electron collection efficiency
  - Non-linear longitudinal beam mapping
  - Availability; manufactured in Russia
- In response, RadiaBeam developed an improved multi-dimensional BSM in collaboration with ORNL/SNS (A. Aleksandrov).
- Major innovations:
  - Focusing system to improve collection efficiency
  - New RF deflector design to improve beam linearity
  - Moving-wire mechanism to enable measuring the transverse profile

BSM principle of operation



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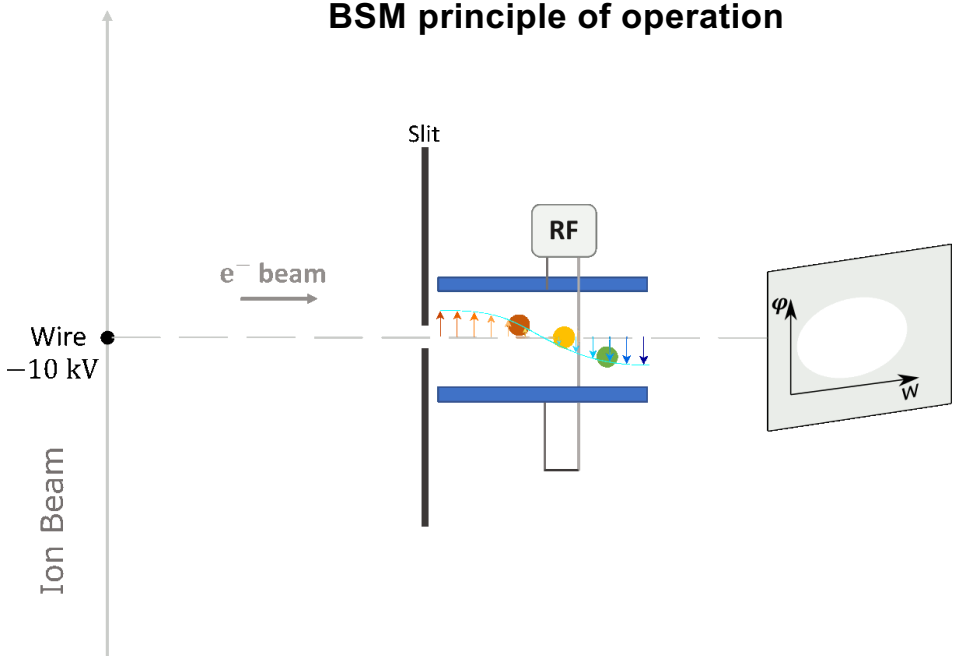

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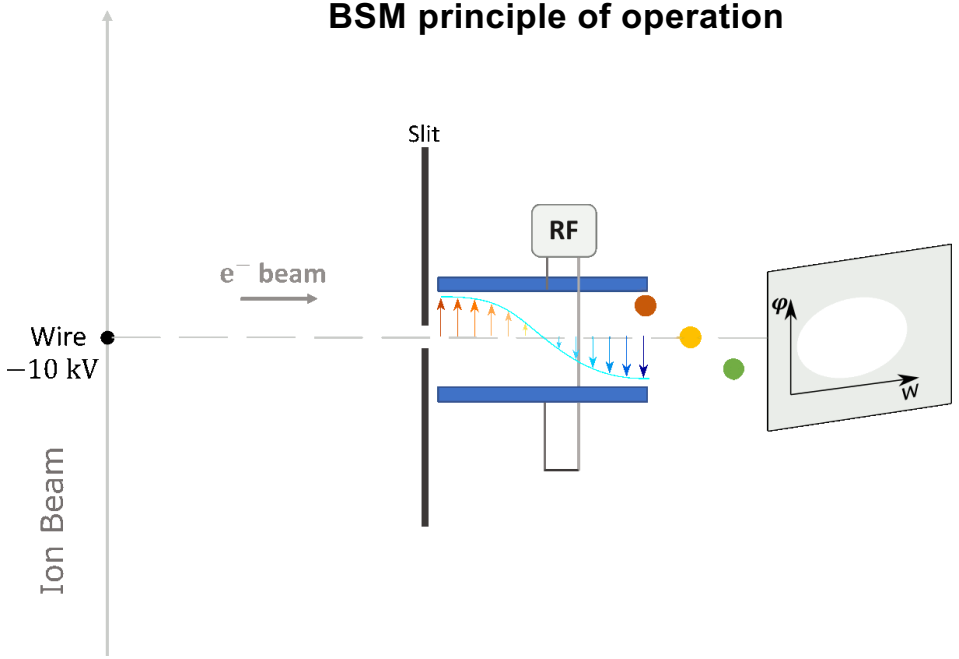

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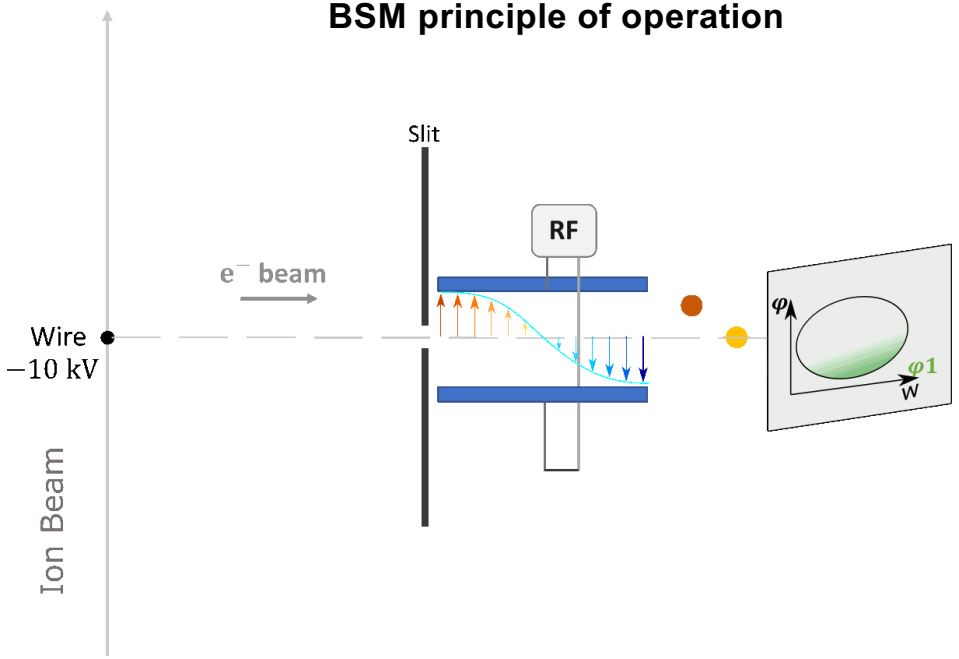
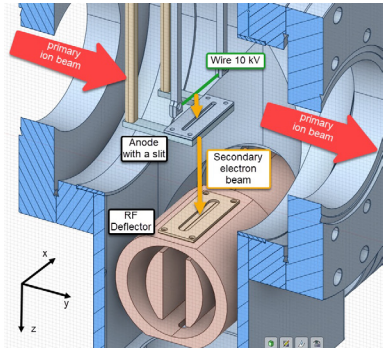


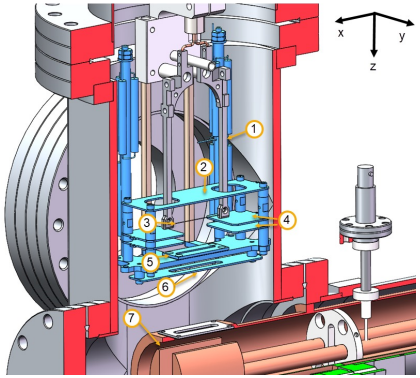
Focusing system

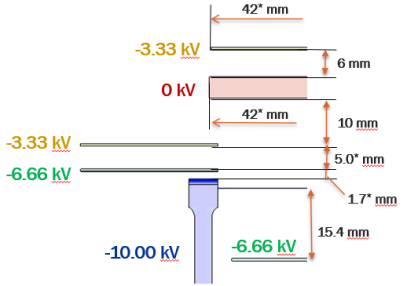
- Design to improve electron collection efficiency and horizontal linearity
  - 2.9x collection efficiency gain

Original design of the BSM at SNS



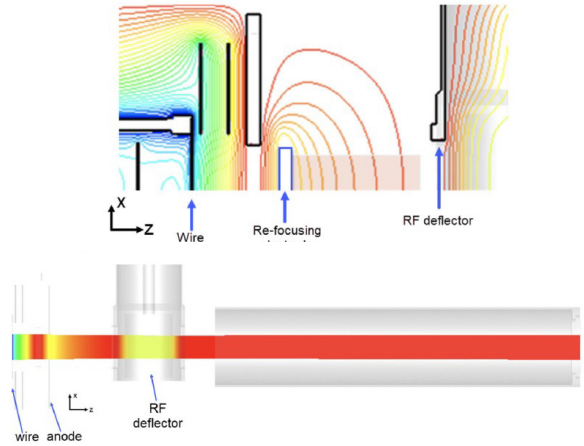
BSM with the focusing system



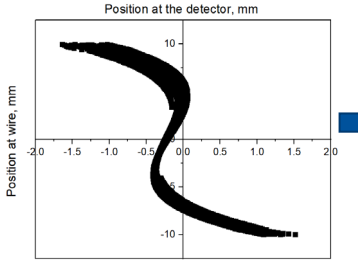


Design	Number of electrodes	Collection improvement
Original	0	1.0
Improved	2	2.9

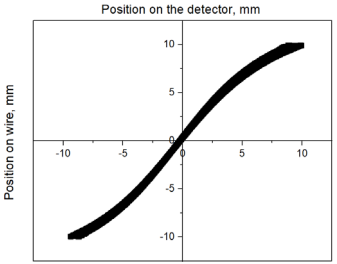
Electric potential lines and horizontal beam trajectory with the focusing system



Initial electrons horizontal coordinates vs electrons horizontal coordinate at the detector (**no electrodes**)

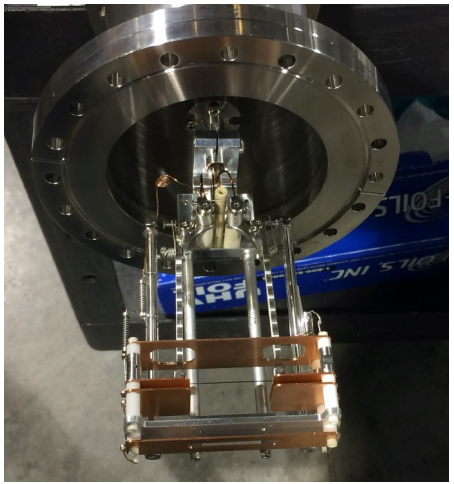


Initial electrons horizontal coordinates vs electrons horizontal coordinate at the detector (**with the electrodes**)



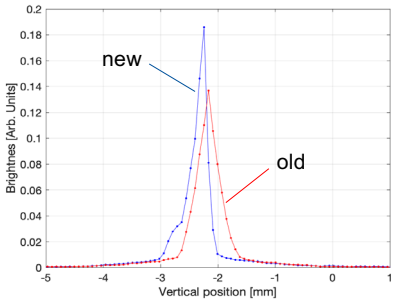
Focusing system prototype tested at SNS

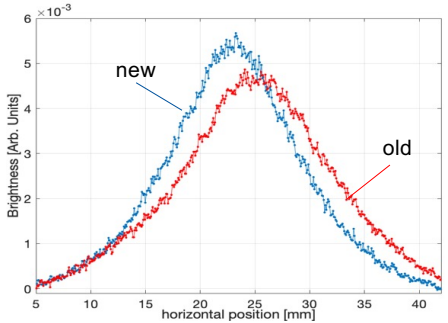
- The focusing system prototype was fabricated by RadiaBeam and tested at ORNL's SNS Beam Test Facility (BTF)
- New focusing system demonstrated excellent vertical focusing and improved electron collection efficiency (~2 times better)



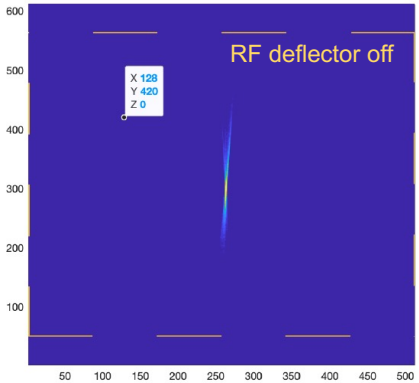
Focusing system on the BSM actuator at SNS

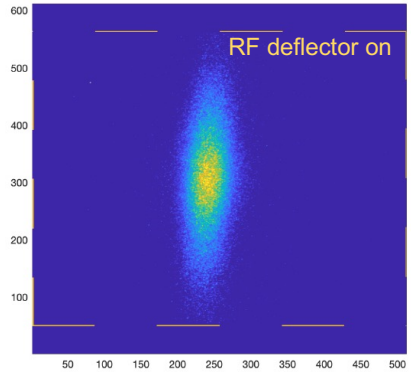
Profiles of the wire image





Beam image from BSM detector

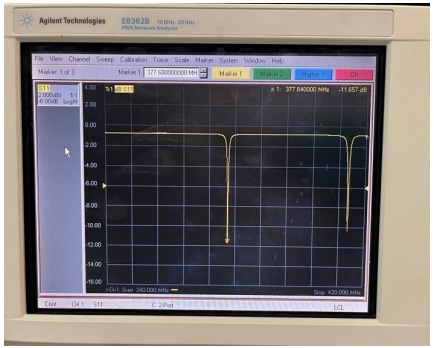




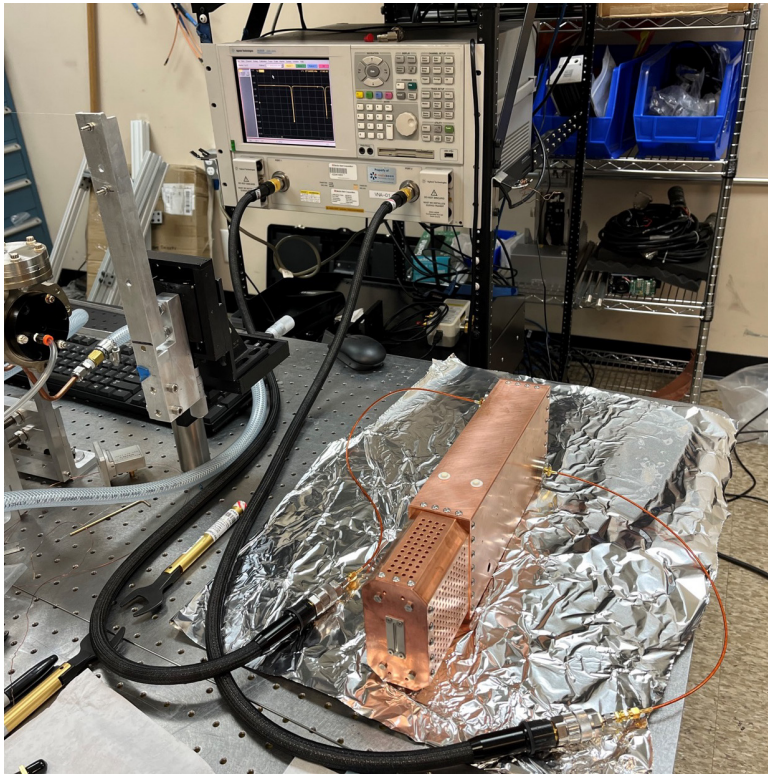
New RF deflector design

- New RF deflector was fabricated by ORNL to allow:
  - Moving wire and deflector together
  - Symmetric geometry of the deflector to improve beam focusing
- BSM characteristics
  - RF cavity to operate at 402.5 MHz
  - Phase resolution <1 deg
- RF cavity was measured at RadiaBeam
  - 20 MHz shift upon receipt from ORNL

S11-Measurement



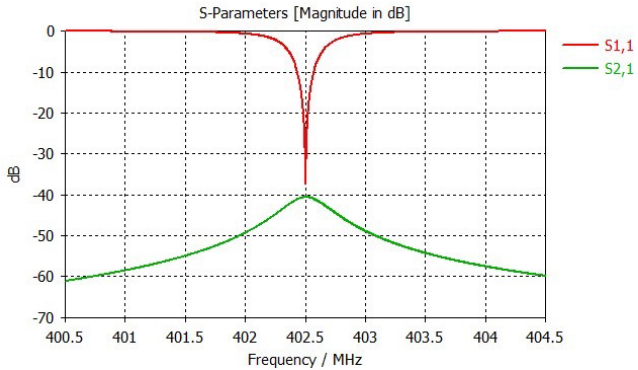
Parameter	Measurement result
Frequency	377.64
S11	-11.74 dB
Q-factor (unloaded)	1582

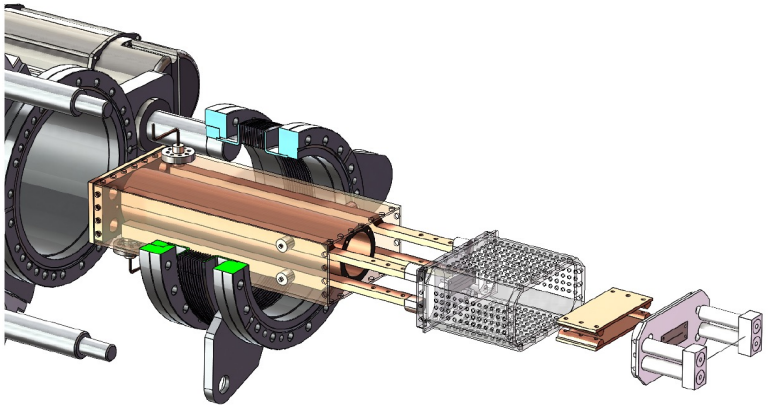


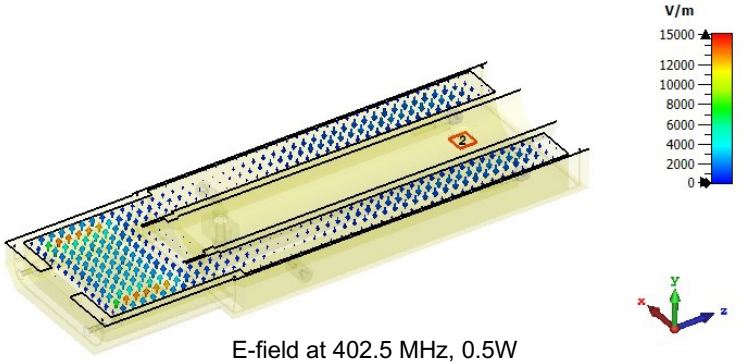
Modifications to the ORNL RF deflector design

- RF deflector cavity model has been modified
  - Tuned to the proper frequency 402.5 MHz
  - Adjust coupling

Parameter	Simulation result
Frequency	402.5 MHz
Q-factor	2367
Coupling	1.03



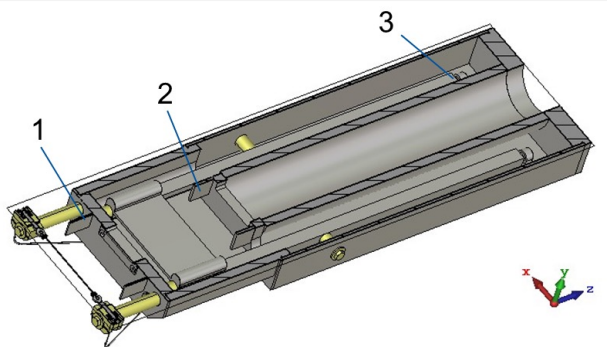




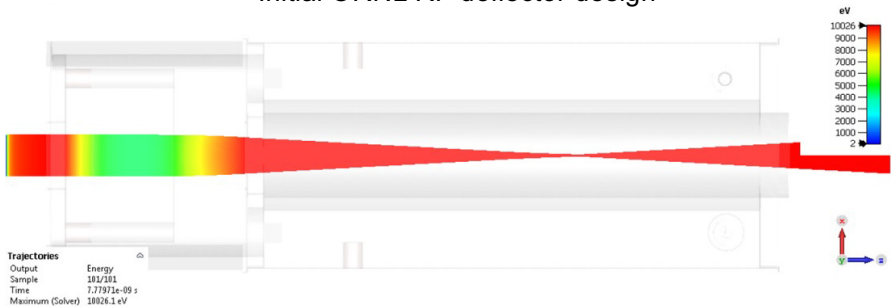
E-field at 402.5 MHz, 0.5W

Additional improvements to the ORNL RF cavity

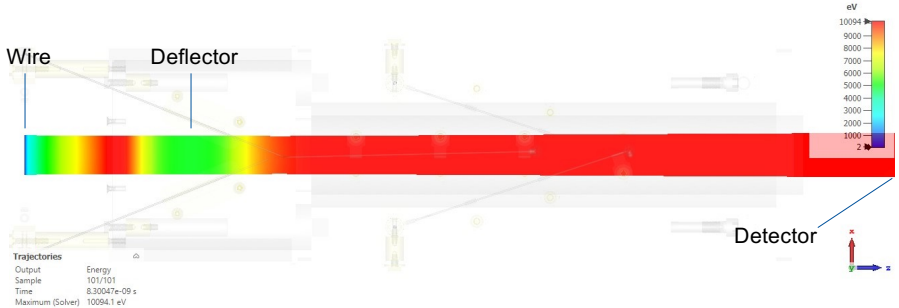
- We have modified the ORNL RF cavity to improve the horizontal focusing and linear horizontal mapping from the wire to the detector



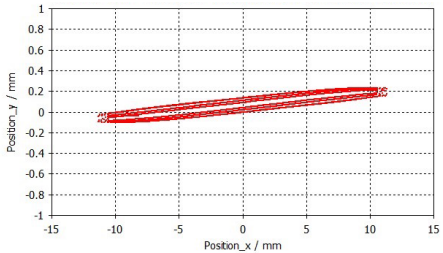
Initial ORNL RF deflector design



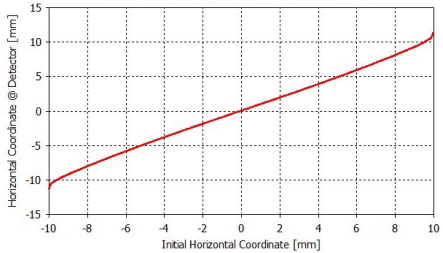
Optimized RF deflector design



Beam position at detector

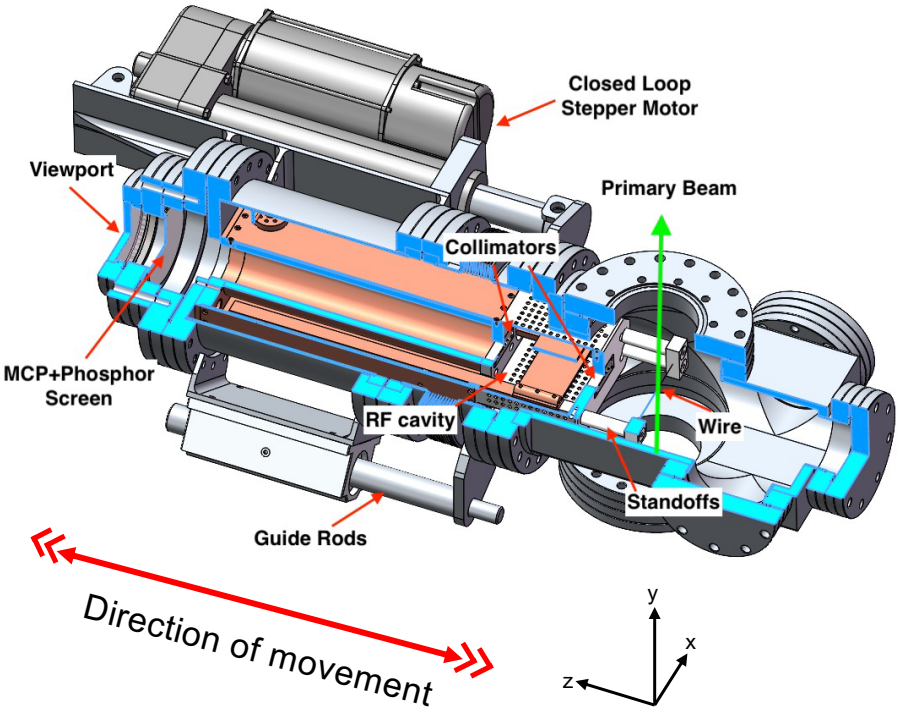


Horizontal mapping from wire to detector



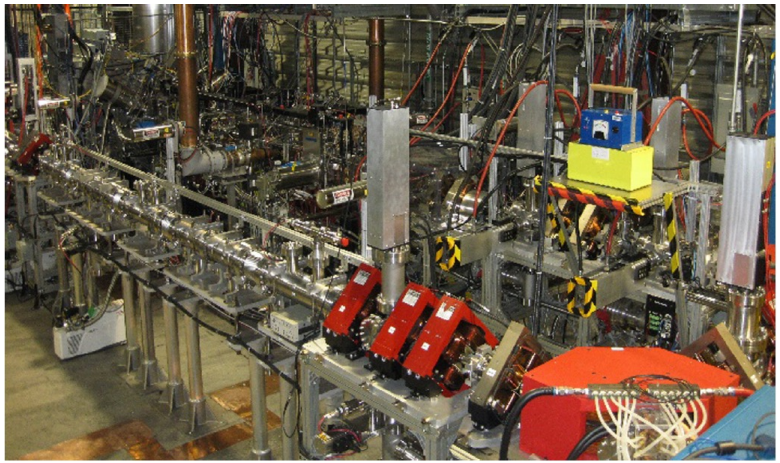
Design of movable wire system

- Three-dimensional bunch shape measurement can be obtained with a horizontal movement of the wire across the beam
- We have designed a movable wire system for 3D measurement
  - Wire and the entrance slit distance is constant
  - Actuator and vacuum bellows system with guide rods are wrapped around the RF cavity / wire assembly design



Future work

- We will complete the commissioning of the new BSM prototype and deliver it to ORNL for tests by early 2023. Remaining work includes
  - Tuning the cavity frequency
  - Implementing the mechanical changes for beam focusing and linearity
  - Build and assemble the BSM including focusing elements and moving mechanism
  - Install and test BSM at SNS
- Upgrading the prototype to a standard product that includes
  - RF deflecting cavity
  - Wire moving mechanism
  - Control/electronic system



SNS Beam Test Facility

Acknowledgements

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- RadiaBeam team:
  - Aurora C. Araujo
  - Sergey Kutsaev
  - Ronald Agustsson
  - Adam Moro
- ORNL
  - Alexander Aleksandrov
  - Alexander Menshov

S.V. Kutsaev et al., *Advanced focusing system for secondary electrons in a bunch shape monitor*, Nuclear Inst. And Methods in Physics Research, A 1019 (2021), 165846

Thank you!