NSCL

MICHIGAN STATE UNIVERSITY

# Beam Dynamics Studies for RIA at Michigan State University

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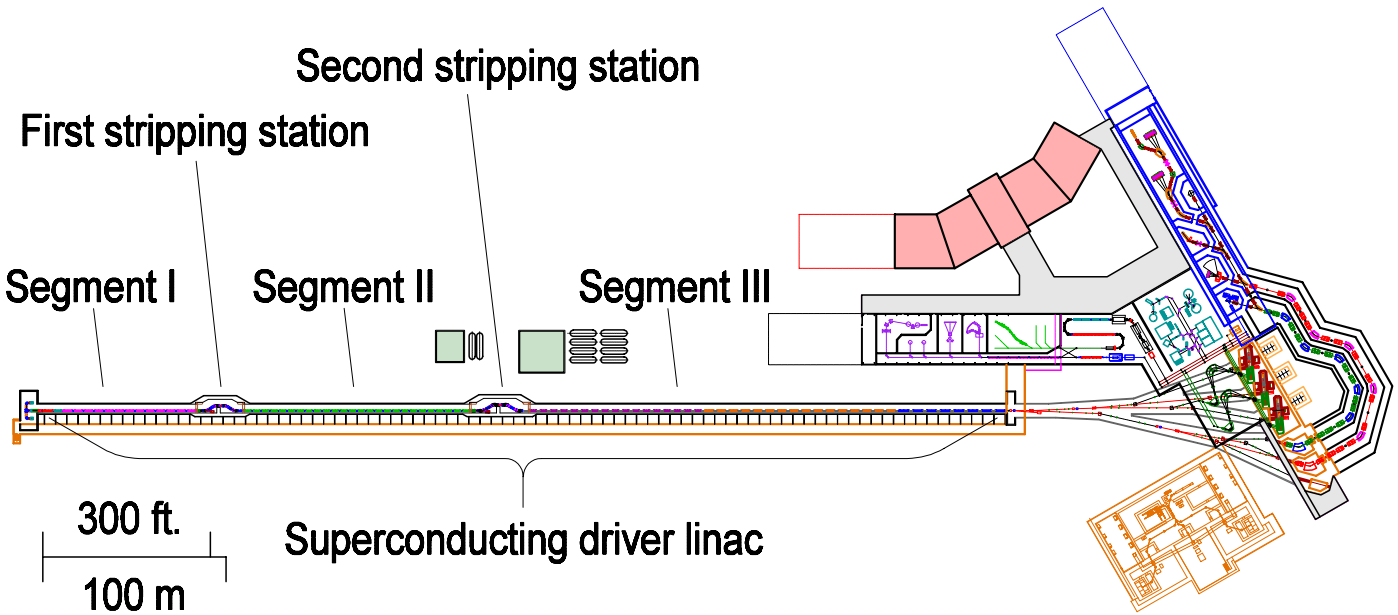
# Beam Dynamics studies for RIA

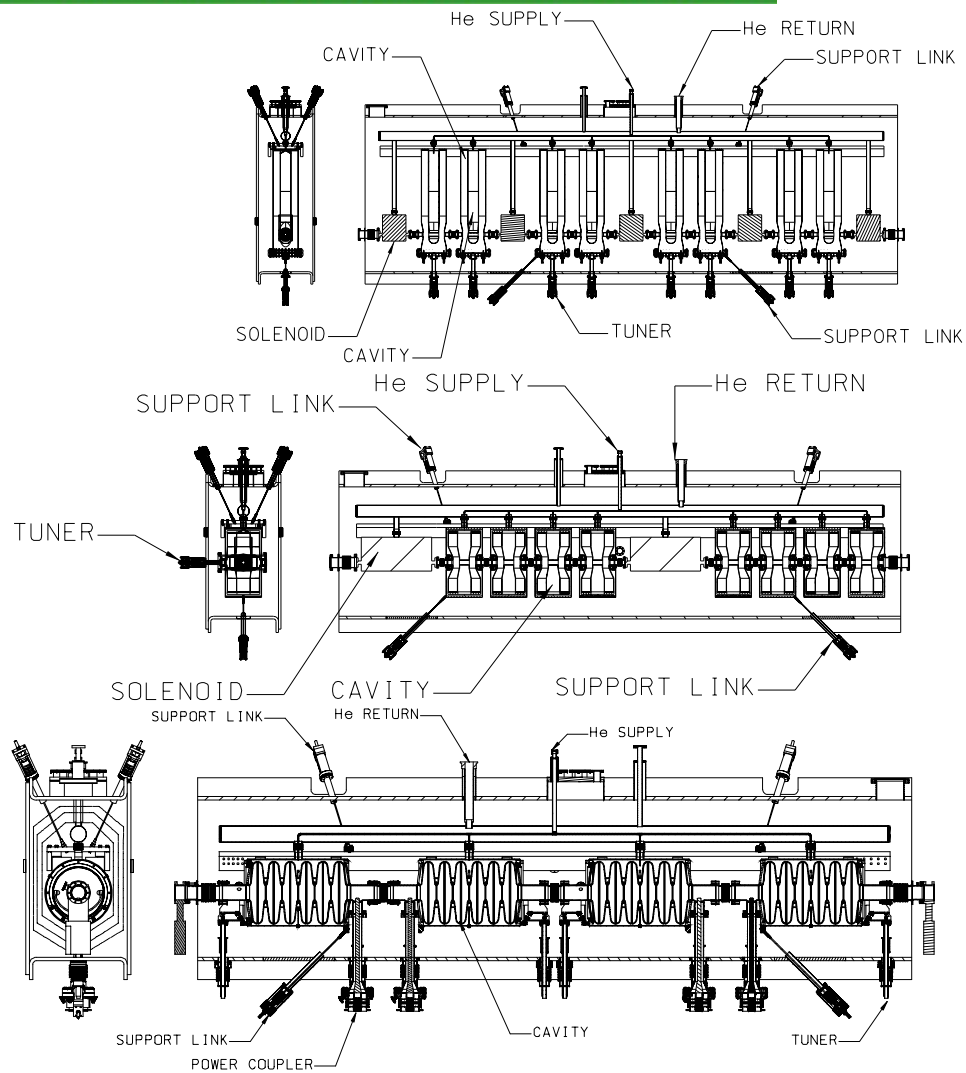
- **Performed at NSCL/MSU since 1999**
  - **Part of an overall effort to establish a comprehensive design for RIA at Michigan State University**
  - **In support of the on-going SRF R&D program**
  - **Simulation tools development for RIA**
- **Beam simulations for all sub-systems of RIA driver linac**
  - RIA Front-end
  - RIA driver linac segments
  - Charge-stripping chicanes
  - Beam switchyard

# RIA Layout at NSCL/MSU



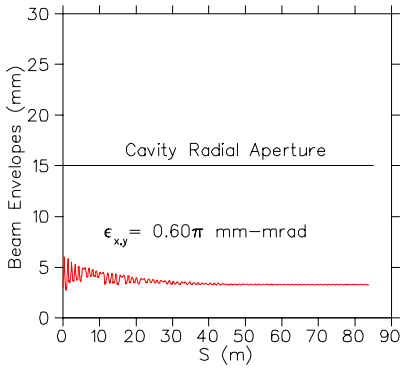
# RIA Driver linac Lattice

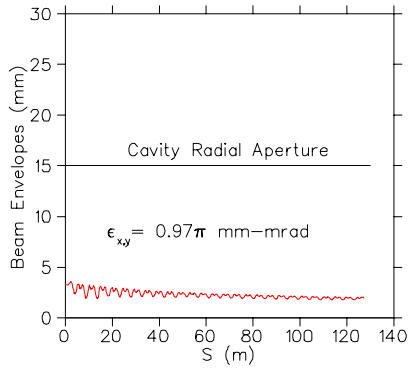
- **Segment I: 0.292 – 11.8 MeV/u**
  - 80.5 MHz (0.041, 0.085) SRF QWC, 30 mm aperture
  - SC solenoid magnets, L=0.1 and 0.2 m
- **Segment II: 11.6 – 88.9 MeV/u**
  - 322 MHz (0.285) SRF HWC, 30 mm aperture
  - SC solenoid magnets, L=0.5 m
- **Segment III: 83.8 – 400 MeV/u**
  - 805 MHz (0.49, 0.63, 0.83) 6-cell elliptical cavities, 77 mm aperture
  - Room-temperature quadrupole magnets, L=0.25 m

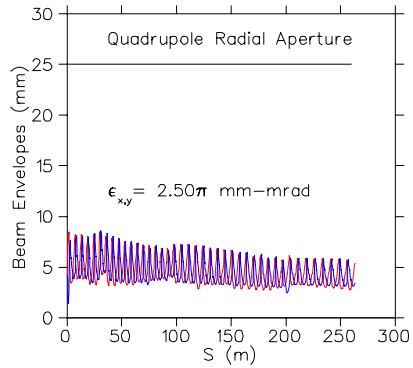


# RIA Driver linac Lattice

## Transverse acceptance

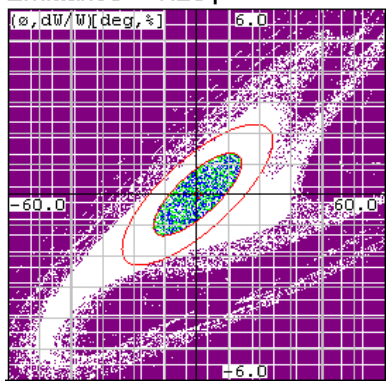


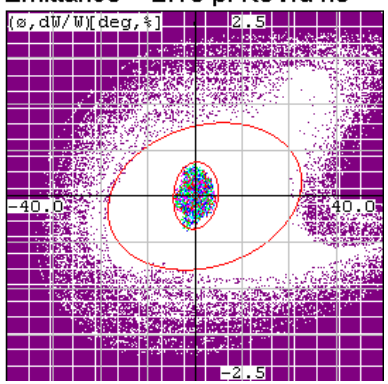




## Longitudinal acceptance

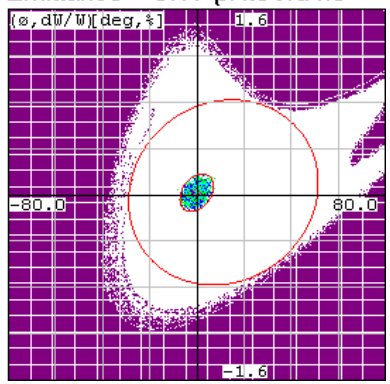
W kin = 0.291 MeV/u
Acceptance = 3.51pi keV/u ns
Emittance = 1.20 pi keV/u ns




W kin = 11.6 MeV/u
Acceptance=20.01 pi keV/u ns
Emittance = 2.15 pi KeV/u ns




W kin = 83.8 MeV/u
Acceptance=92.58 pi keV/u ns
Emittance = 3.17 pi keV/u ns



# Misalignment and rf Errors

| RIA Driver Linac | SRF Cavity Misalignment & rf Error | | | | Focusing Element Misalignment | |
|---|---|---|---|---|---|---|
| | $\sigma_{x,y}$ [mm] | $\sigma_{zr}$ [mrad] | Phase [deg] | Amplitude [%] | $\sigma_{x,y}$ [mm] | $\sigma_{zr}$ [mrad] |
| Segment I | 1.0 | - | 0.5 | 0.5 | 0.25 | - |
| Segment II | 1.0 | - | 0.5 | 0.5 | 0.5 | - |
| Segment III | 1.0 | - | 0.5 | 0.5 | 1.0 | 5.0 |

- Limited transverse and longitudinal rms emittance growth 10 ~ 25%
- No beam loss observed
- Proposed correction scheme works well

# Triple Spoke Cavity Option

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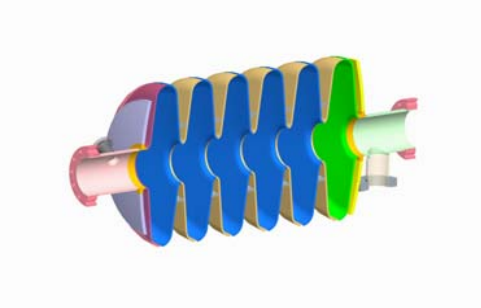
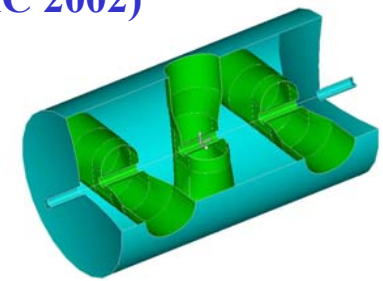
- **RIA driver linac Segment III (MSU Option)**



- Larger aperture (77mm)
  - 2-quadrupole focusing lattice
- Adequate transverse and longitudinal acceptance
- All three elliptical cavities have been successfully tested in 2003

- **Triple-Spoke Cavity Option (K. Shepard, LINAC 2002)**



- Smaller aperture (30 – 50 mm)
  - SC solenoid focusing lattice
- Lower frequency
  - Fewer cavities, larger longitudinal acceptance
- No triple-spoke cavity exists, more R&D required to verify its performance

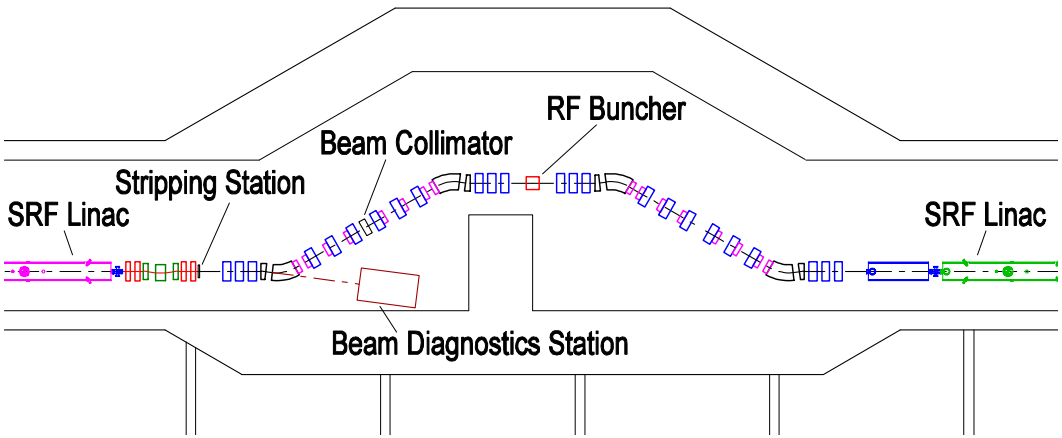
- Both option would in principle provide necessary multi-charge beam acceleration for RIA

# Parametric Resonance Studies

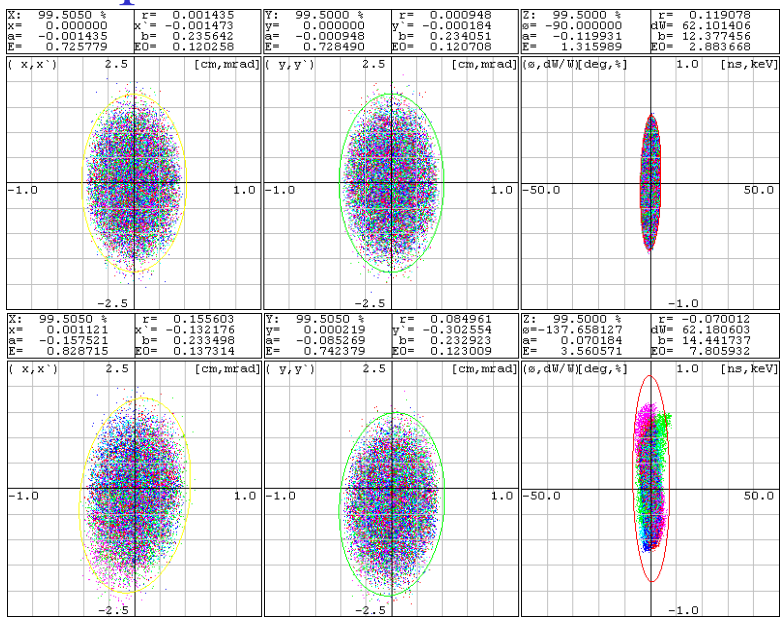
- RIA driver linac segment III (MSU design option):
  - 2-Quadrupole focusing lattice
  - Four 6-cell elliptical cavities per cryostat
- Beam dynamics studies (R. Duperrier, CEA Saclay, PAC 2003)
  - No beam emittance growth observed
  - Simulation results are in agreement with theory

# Charge-Stripping Chicanes

- 2nd order achromat with 4-fold symmetry
- Minimum transverse and longitudinal emittance growth
- Misalignment impact and reasonable specification




Layout of the 1st charge-stripping chicane



3-D particle tracking results using LANA

# Summary and Future

- **10th sub-harmonic (80.5 MHz) RIA driver linac option proposed by MSU has adequate transverse and longitudinal acceptance for multi-charge state beam**

- **Reasonable misalignment and rf error specifications provide no beam loss and acceptable emittance growth**

- **Future:**
  - **Self-consistent ECR-to-Target 3-D simulations**
  - **Equipment loss scenarios – accelerating structures, focusing & steering elements**
  - **Continue to support RIA R&D program**