Optimizing RF Gun Cavity Geometry within an Automated Injector Design System*

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Outline

- Problem overview
- Geometry description
- Geometry tuning
- Tuning and field flatness
- Future plans and conclusions

Progression of Injector Design Approaches

Semi-Automated Injector Design

- Parameter scans
- Injector Beam Dynamics Code

Injector Design Automation[1,3]

- General Purpose Evolutionary Algorithm Based System[2]
- Injector Beam Dynamics Code

S/RF Gun Injector Design Automation

- General Purpose Evolutionary Algorithm Based System[2]
- Injector Beam Dynamics Code
- Cavity Field Variation

[1] I. V. Bazarov and C. K. Sinclair, PRST-AB 8, 2005.
[2] S. Bleuler, *et al.*, Evolutionary Multi-Criterion Optimization (EMO 2003), Faro, Portugal, 2003.
[3] F. Hannon, *et al.*, PAC 2011, WEP288.

Cavity Field Variation

Theoretical (Cavity Independent)[1]

Optimization System

Vary Assumed Field Profile

More Realistic (Vary Cavity Geometry)

Vary Geometry Call Field Solver

Optimization System

Catalogue of Field Profiles

[2]

Optimization System

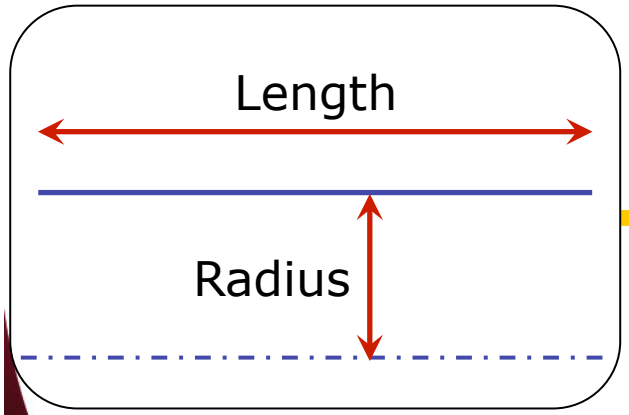
Vary Geometry Call Field Solver

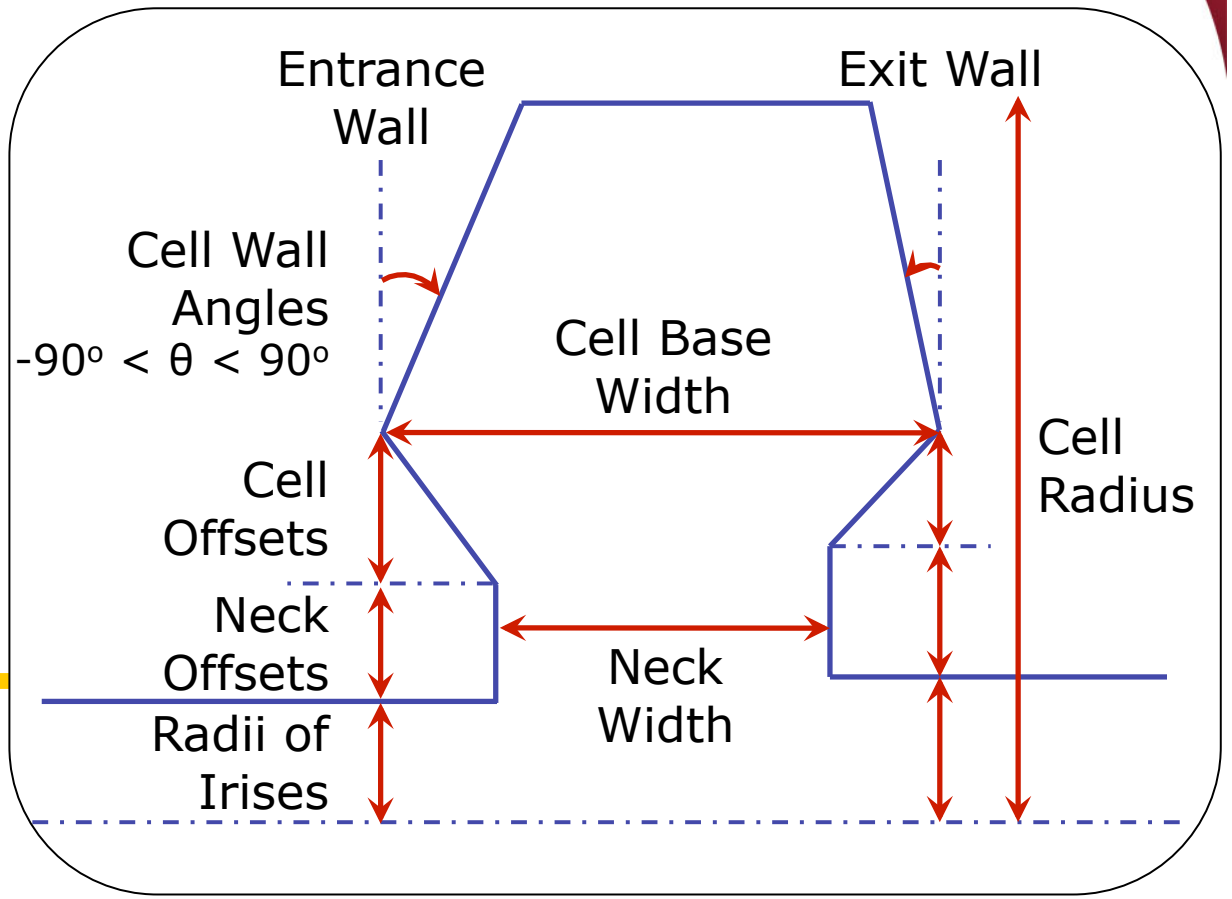
[1] A. Hofler, *et al.*, ICAP 2009.

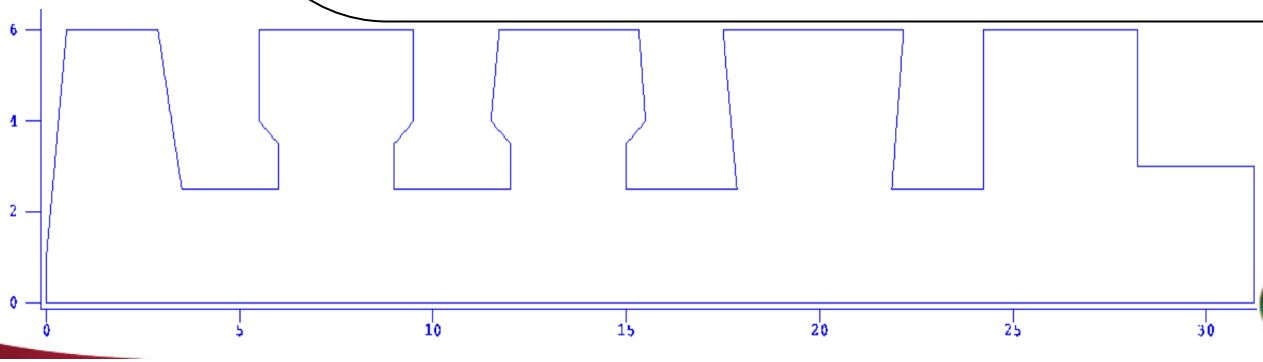
[2] I. V. Bazarov, *et al.*, ERL 2009.

Geometry Description

- Assumptions
  - Cylindrically symmetric
  - Two components
    - Beam tubes
    - Cells







Geometry Tuning

- Goals:
  - π mode at desired resonance frequency
  - reasonable to build

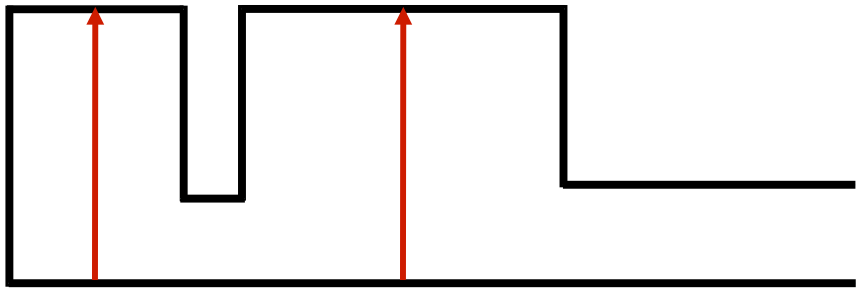
$$\text{field flatness}^{*} = 100\frac{\left|E_{peak}\right|_{\max} - \left|E_{peak}\right|_{\min}}{\frac{1}{n_{cells}}\sum\left|E_{peak}\right|}$$

  - quick and reliable

- Algorithm
  - Tunes whole structure
  - Assumes linear relationship between tuning parameter and tuning goal
  - Iterative
  - Alternates between tuning goals
- Findings
  - Tuning for frequency alone insufficient → poor flatness
  - Alternating between goals does not always converge
  - Consider multi-variable methods
  - Need "independent" cavity tuning parameters

* S. An and H. Wang, JLAB-TN-03-043 or SNS-NOTE-AP119, 2003.

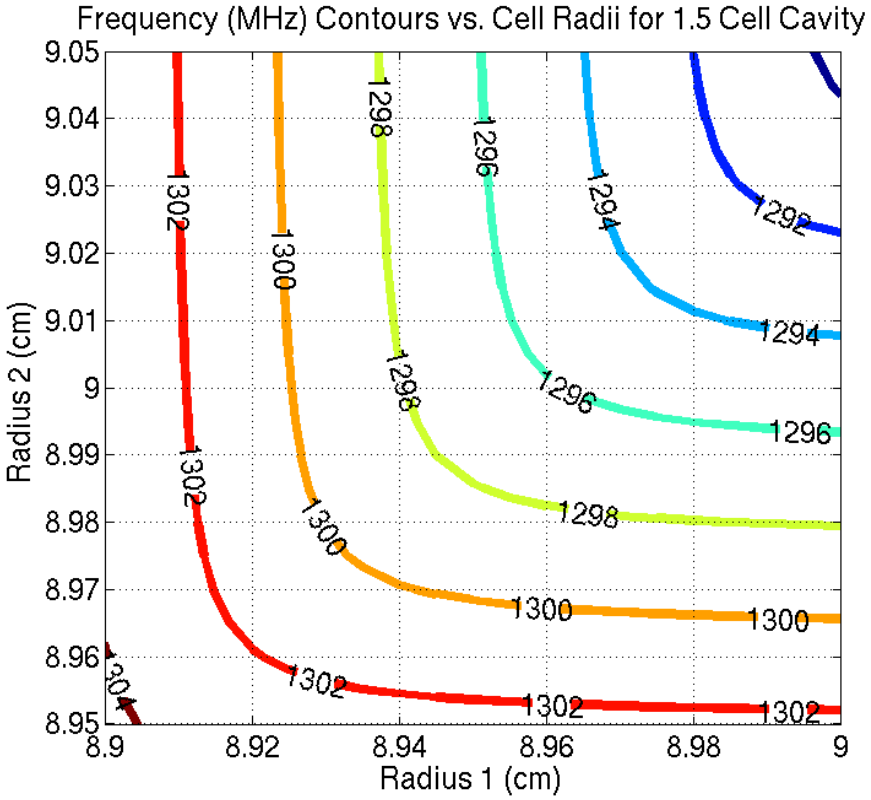
Dependence of π Mode Frequency on Cell Radii for 1.5 Cell RF Gun



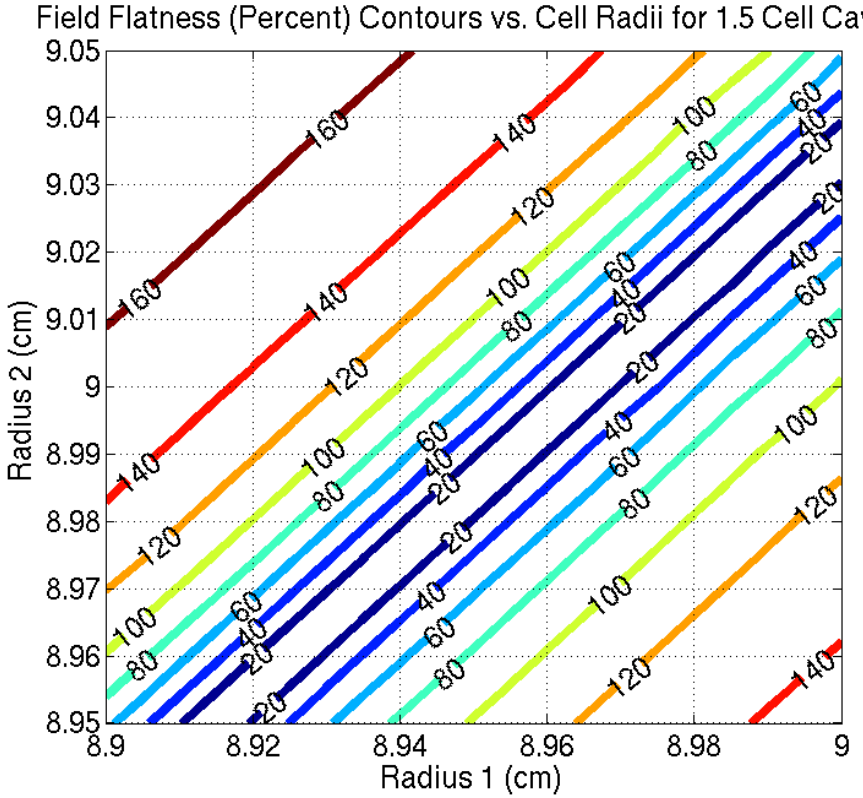
Varied Cell radii

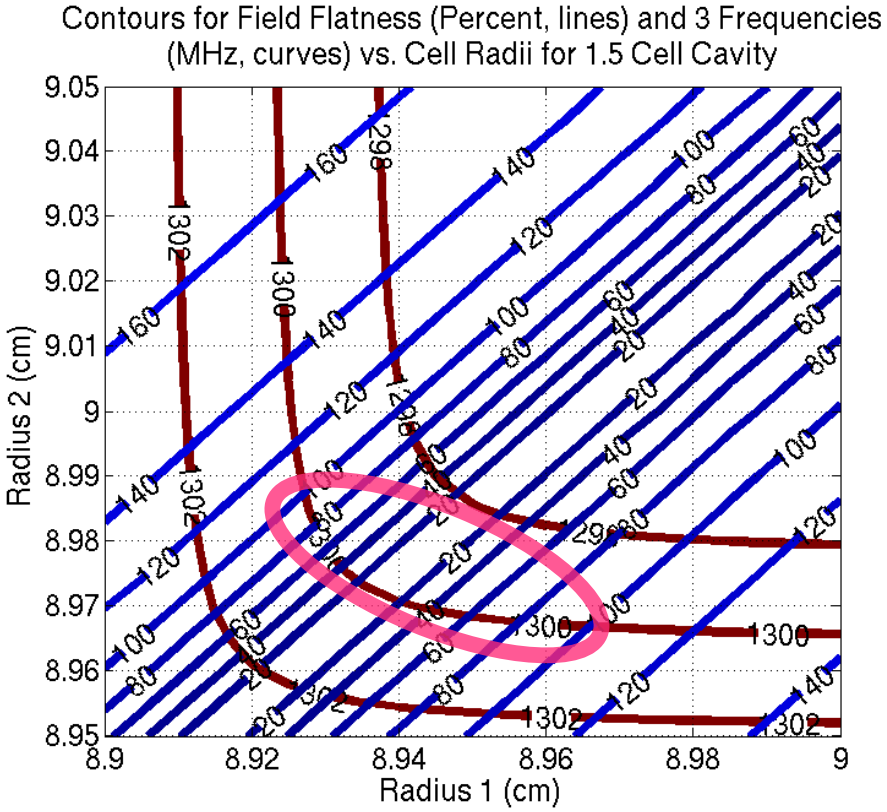
8.55 cm ≤ r ≤ 9.5 cm

Fixed Dimensions	Radius (cm)	Length (cm)
Total Length	-	26.5
Gun Cell (Cell 1)	-	5.5
Full Cell (Cell 2)	-	10.0
Inter-cell beam tube	2.5	2.0
Exit beam tube	3.0	9.0



Dependence of π Mode Field Flatness on Cell Radii for 1.5 Cell RF Gun





- Small set of radii produce 1300 MHz cavity with field flatness < 100 %

$$\text{field flatness} = 100\,\frac{\left|E_{peak}\right|_{max} - \left|E_{peak}\right|_{min}}{\frac{1}{n_{cells}}\sum\left|E_{peak}\right|}$$

Future Plans and Conclusions

- Framework for optimizing gun cavity geometry in injector design exists
  - Success depends on quick and reliable cavity tuning algorithm
    - Improved tuning algorithm
    - Resonance and field flatness tuning
- Continue tuning studies
  - Find cavity parameters to affect field flatness with minimal impact on resonance frequency
    - Beam tube radius
    - Beam tube length
  - Extend to 3.5 cell cavity

Thank you.