Elliptical Cavities: Proven SRF Option

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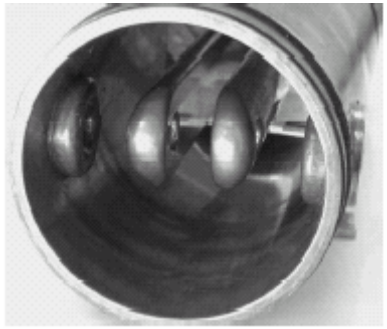
Outline

- Multi-cell elliptical cavities
  - Demonstrated for $\beta > 0.4$
  - Future trends
- Multi-spoke cavities
  - Limited experimental results
  - Comparison for RIA
  - Future applications

Multi-gap Structures

QWR



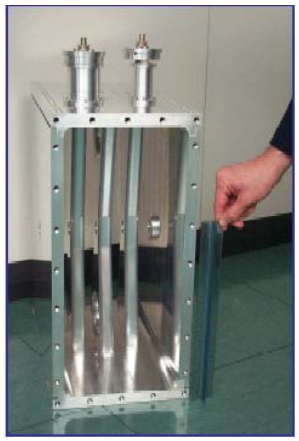
Australian Nat. Uni

Argonne, ATLAS

HWR

Argonne

Frankfurt



Legnaro

Cylindrical (Elliptical)

JLAB

JLAB, MSU

Legnaro

Multi-cell Elliptical Cavities

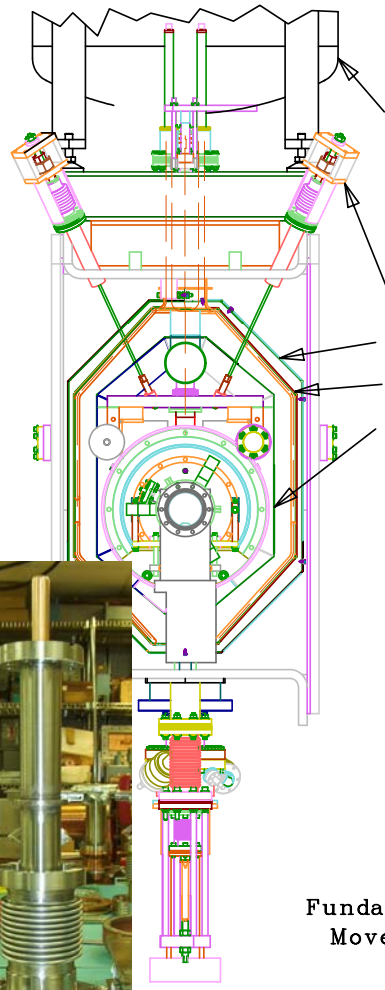
- **Many groups have developed reduced-β cavities**
  - **CERN, JLAB, JAERI/KEK, Los Alamos, MSU, Milan**
  - **Same issues as β=1 cavities**

    E_{acc} limited due to peak E and B fields
- **Several reduced-β cryomodules have been built**
  - **SNS, RIA, J-PARC**
  - **Tested in realistic operating conditions**

    Phase locked, tuner, power coupler, focusing elements, HOM dampers, microphonics control
  - **Same issues as β=1 cryomodules**

    No mechanical instability or limit reached
- **Elliptical cavities for β>0.4 are proven technology**
  - **All linac issues addressed (no boogyman)**

Prototype β=0.47 Cryomodule



PAC03
LINAC04

Elliptical – Future

- **Future trends for reduced-β**
  - **Apply advances from β=1 community**
    New shapes (low loss, reentrant, half-reentrant)
    High current – BBU/HOM
    ILC industrial/mass production
    cavities & cryomodules
  - **More cells with more velocity grading**
    9-cells with β=0.45, 0.55, 0.67 & 0.85
  - **More frequencies and sub-harmonics**
    1.3 GHz, 1.5 GHz, 650 MHz, 750 MHz, …….

Multi-Spoke Cavities – Experimental Results

- **First cavities recently tested**
  - **Double-spoke (1) – 2004**
  - **Triple-spoke (2) – 2005**

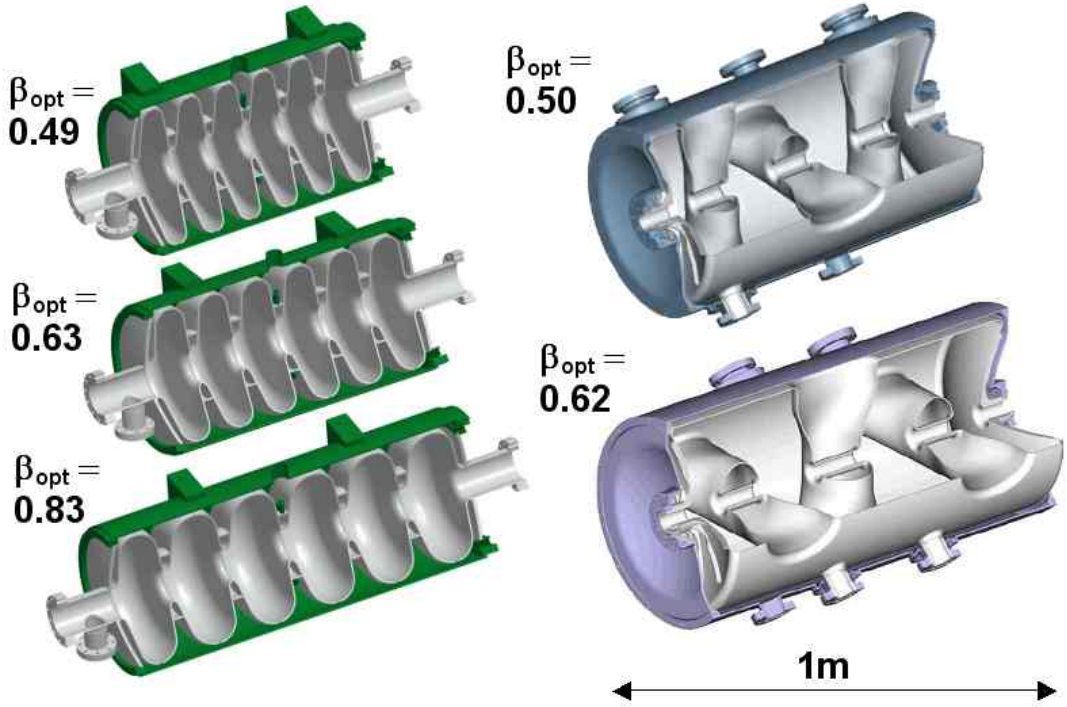
- **No cryomodule tests under realistic conditions**
  - **Tuner**
  - **Superconducting solenoid and shield**
  - **Microphonics control**
  - **High load per cavity at 4 K**
  - **HOM couplers and analysis**

Elliptical vs. Spoke for RIA [1]

- **Detailed Comparison for the Rare Isotope Accelerator**

  V. Andreev, Y. Cho, C. Compton, M. Doleans, D. Gorelov, T.L. Grimm, W. Hartung, M. Johnson, F. Marti, S. Schriber, X. Wu, R.C. York, Q. Zhao, "Comparison of Elliptical and Triple-Spoke Cavities for the Rare Isotope Accelerator", pp. 1-28, NSCL-RIA-2004-001, www.nscl.msu.edu (January 2004).

  - **"The proposed alternative based on triple-spokes does not offer any credible advantage over elliptical cavities. Specifically, the merits of the elliptical design compared to the triple-spoke are summarized below …."**



Elliptical vs. Spoke for RIA [2]

- **Cost estimates nearly identical**
  - **Elliptical – more cavities, but more per cryomodule**
  - **Spoke – more niobium, electron beam welding and complicated helium vessel**
- **Prototype elliptical cryomodule demonstrated**
- **Design peak magnetic field on surface for cw operation**
  - **Elliptical – 70 mT at 2 K**
  - **Spoke – 82 mT at 4.5 K**
- **Cryogenic requirement**
  - **Elliptical – 7 kW at 2 K**
  - **Spoke – 25 kW at 4.5 K**
  - **Cost & electrical usage are comparable**

Elliptical vs. Spoke for RIA [3]

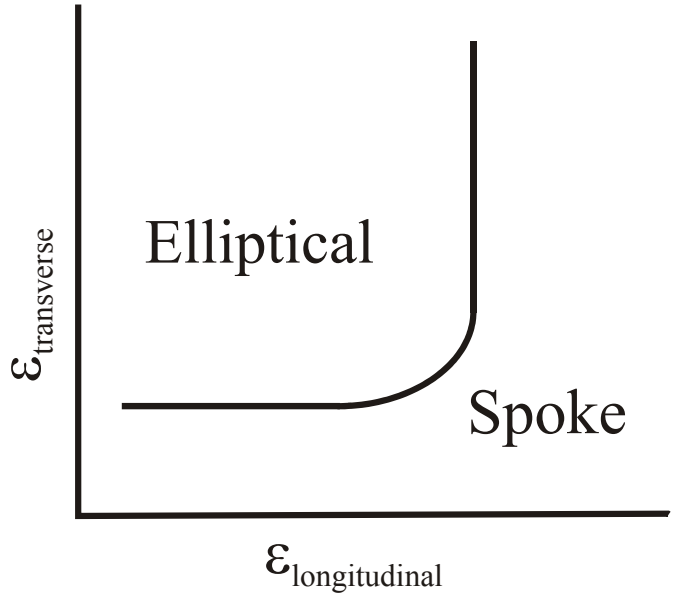
- **Liquid He type – operational stability & microphonics control**
  - **Elliptical – 2 K superfluid with improved heat transfer and small pressure fluctuations**
  - **Spoke – 4.5 K with cryoplant pressure fluctuations and large boiling of ~100 W per cavity**
- **Higher proton energy using elliptical (1030 vs. 960 MeV)**
- **Beam dynamics (both acceptable)**
  - **Elliptical – room temperature quad doublets (easier alignment)**
    – larger transverse acceptance
  - **Spoke – supeconducting solenoids**
    – larger longitudinal acceptance

Multi-Spoke Advantage?

- **Offer advantage for certain niches around β~0.5**
  - **Low transverse emittance – small aperture**
  - **High longitudinal emittance – low frequency**
  - **Low current**

    No HOM couplers

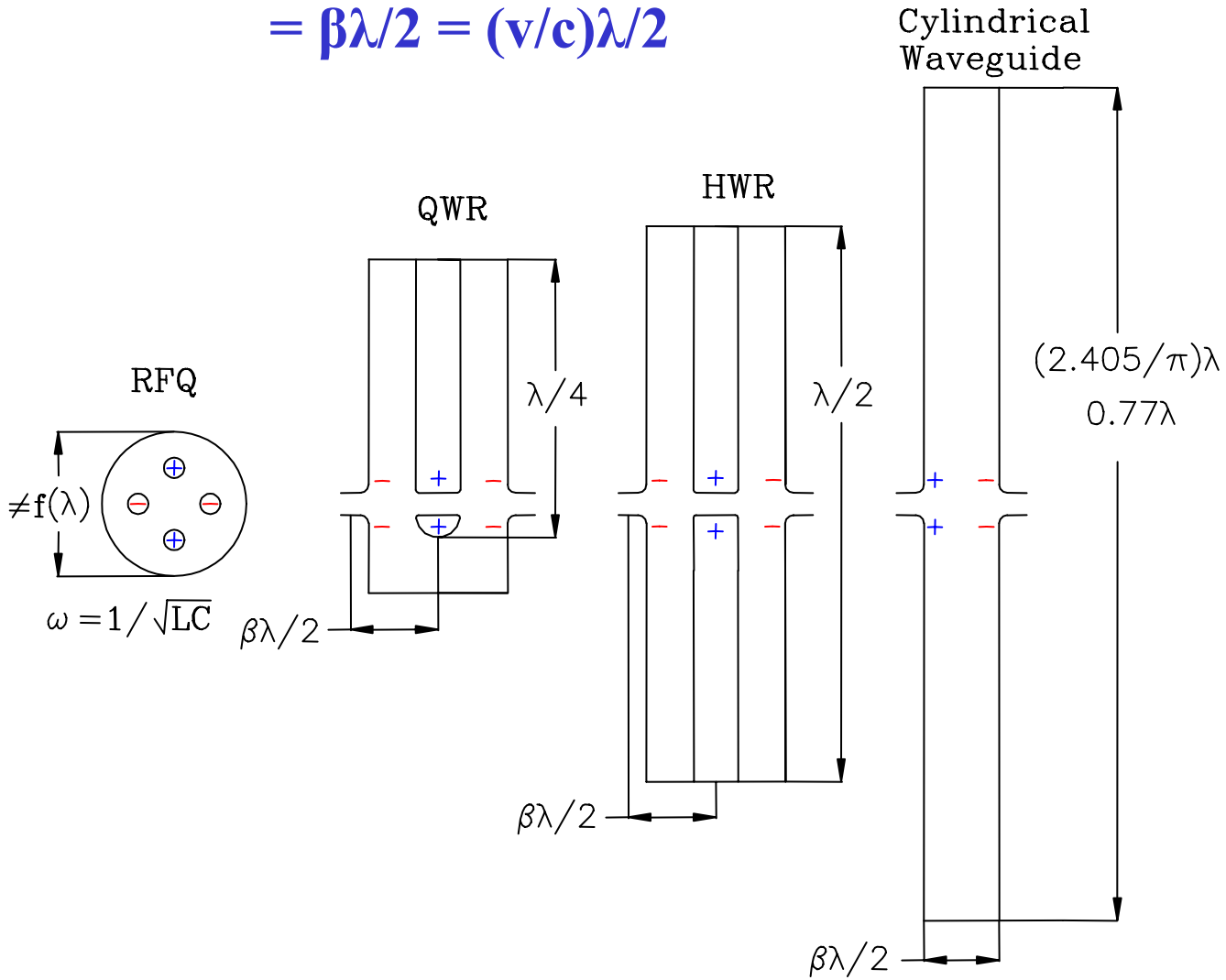
    Small aperture with loss



- **Example**
  - **10-20 gaps**
    - Each cavity is unique (gap changes with velocity)
    - Single rf system with focusing elements between or with rf focusing

Cavity Types & Dimensions

- **Gap length = distance traveled in half of an rf period**
  $= \beta\lambda/2 = (v/c)\lambda/2$



Single Resonators

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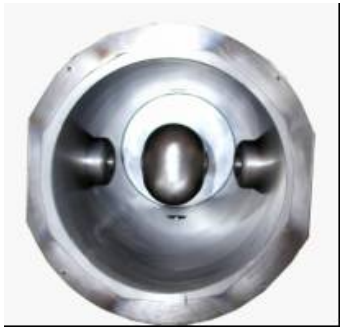


Legnaro/MSU

Argonne

HWR

Argonne

IPN Orsay

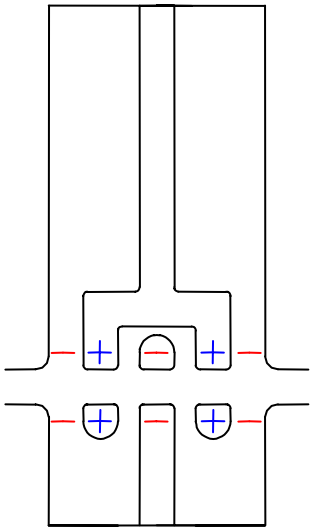
Cylindrical (Elliptical)

Legnaro

JLAB/MSU

Multi-gap Structures [1]

QWR



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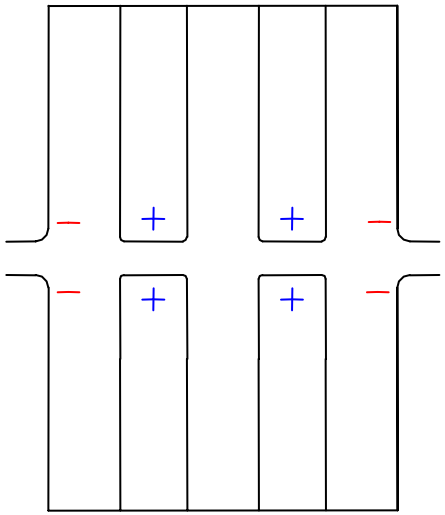
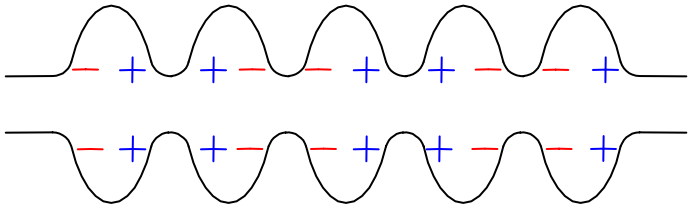
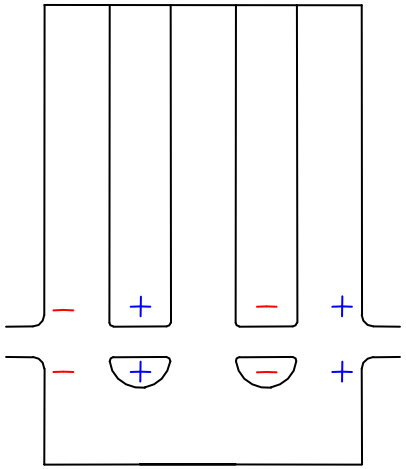
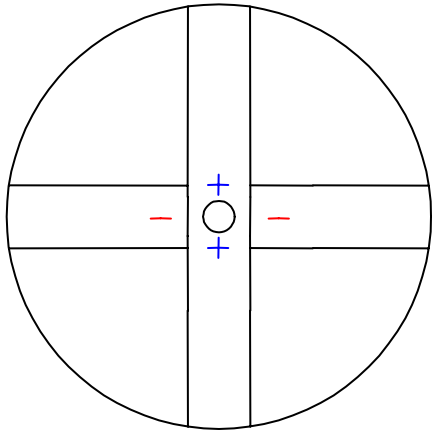


Cylindrical

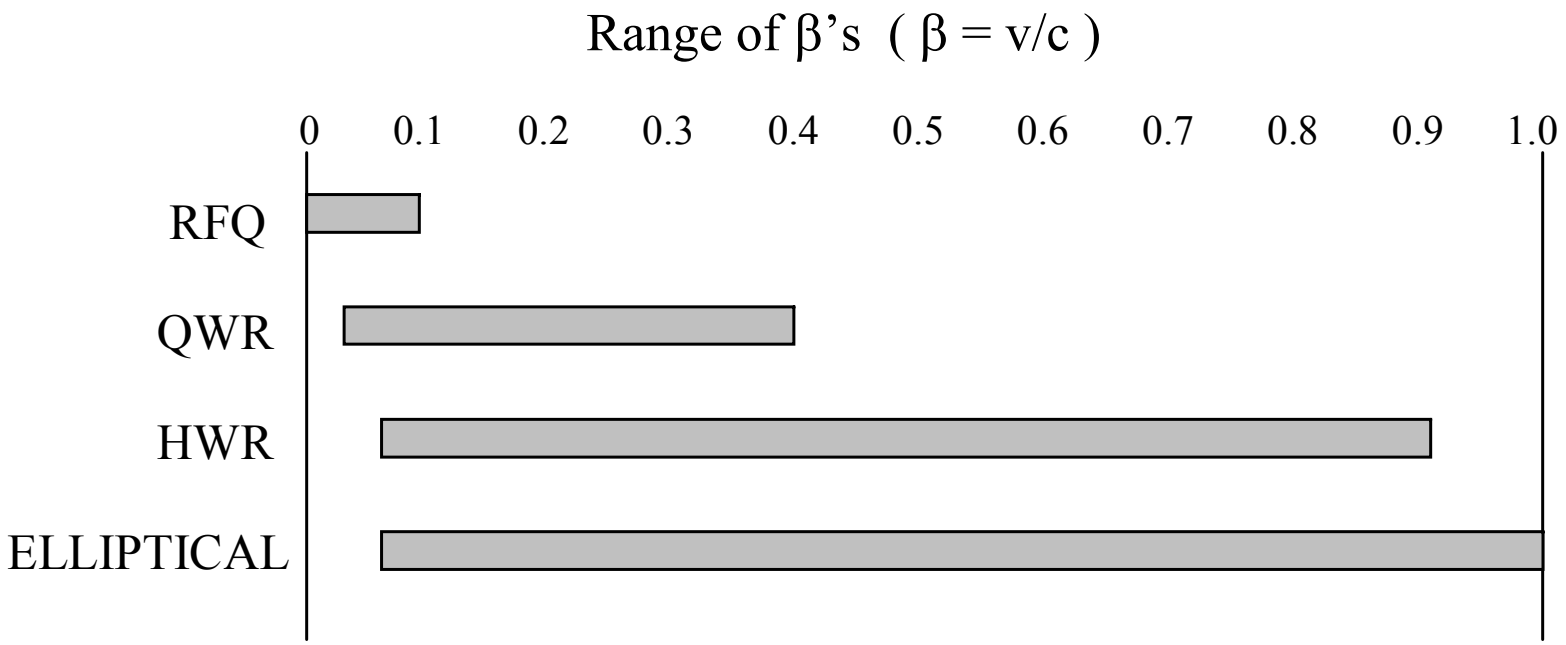
(Elliptical)







Range of Velocities



- **Application/requirements will drive cavity choice**
- **For electrons elliptical cavities used from rest to the speed of light (β=0 to 1)**
  - **Injector uses reduced-β elliptical**
  - **Main linac uses β=1 elliptical**