Spokes vs. Elliptical Cavities for the Proton Driver Linac

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The Fermilab Proton Driver is organizing a collaboration to develop a complete suite of "Tesla-Compatible" $\beta<1$ SCRF Cavities:

- 1300 MHz Elliptical-Cell
- 325 MHz Spoke Resonators
“Open-Source Collaboration”

- Standardizing on ILC-Compatible Frequencies could produce standard building blocks for future beta<1 linacs:
  - Cavities, Klystrons, RF distribution..

- The Concept is for an “Open-Source” Collaboration
  - All design data, manufacturing, costs, etc. to be posted on the Internet
0.5 MW Initial
8 GeV Linac
11 Klystrons (2 types)
449 Cavities
51 Cryomodules

β<1 TESLA LINAC
1300 MHz 0.35-1.2 GeV
2 Klystrons
96 Elliptical Cavities
12 Cryomodules

TESLA LINAC 1300 MHz β=1
8 Klystrons
288 Cavities in 36 Cryomodules
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TESLA LINAC 1300 MHz β=1
8 Klystrons
288 Cavities in 36 Cryomodules

“PULSED RIA”
Front End Linac
325 MHz
0-110 MeV
3 MW
JPARC Klystron
Multi-Cavity Fanout at 10 - 50 kW/cavity
Phase and Amplitude Control w/ Ferrite Tuners

10 MW TESLA
Multi-Beam Klystrons
Elliptical $\beta=0.47, 0.61, 0.81$

$\beta=0.47$
- 8 Cavities, 6 cells/cavity
- 9 focusing quads

$\beta=0.61$
- 8 Cavities, 6 cells/cavity
- 5 focusing quads

$\beta=0.81$
- 8 Cavities, 8 cells/cavity
- 3 focusing quads

$\beta=1.0$
- 8 Cavities, 9 cells/cavity
- 1 focusing quad
Spokes vs Ellipticals for 110-400 MeV

- 6 cryomodules ~10 m long for either option
- Quadrupole focusing in both cases
- Transition from 325 MHz to 1300 MHz
  - 4:1 frequency jump has Accelerator Physics Implications

LINAC SEGMENT DETAILS

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<th>RFQ</th>
<th>Room Temp</th>
<th>SRF 1-spoke</th>
<th>SRF 2-spoke</th>
<th>Spoke Option</th>
<th>Elliptical Option</th>
<th>High</th>
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<td>0.065-3</td>
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<td>110-400</td>
<td>110-175</td>
<td>175-400</td>
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**Open Technical Choice: 3-spoke or Elliptical**

- 6 cryomodules ~10 m long for either option
- Quadrupole focusing in both cases
- Transition from 325 MHz to 1300 MHz
  - 4:1 frequency jump has Accelerator Physics Implications

- **Frequency, MHz**: 325, 0.065-3
- **Energy Range, MeV**: 0.065-3, 3-15, 15-33, 33-110
- **Beta geometrical**: -0.08 to 0.1
- **Number of cavities or resonators**: 4, 21, 16, 28, 42, 16, 32, 48, 288
- **Number of accelerating gaps / cavity**: -4, 4, 2, 3, 4, 6, 6, 8, 9
- **Epeak, MV/m**: 32.1, TBD, 32, 32, 32, 52, 52, 52, 52
- **Eacc, MV/m**: -2.3 to 3.7, 10.67, 10.67, 10.67, 15.2, 19.2, 19.2, 23.7, 26
- **Cavity effective length, cm**: -15 to 32, 13, 36.9, 85.8, 32.5, 42.2, 74.8, 103.8
- **Synchronous phase, deg (typ.)**: -40 to -30, -30, -30, -30 to -20, -30, -25, -20, -16
- **Length of Segment, m**: ~4, 10.4, 12.5, 17.2, 64, 18.8, 38.5, 70.1, 438.3
- **Number of Cryomodules**: - - 1 2 6 24 63 6
- **Cavities per Cryomodule**: - - 16 14 7 88 88
- **Magnetic Focusing Type**: Solenoid Solenoid Solenoid Quad Quad Quad Quad Quad
- **Coupler Power Initial {Ultimate}, kW**: 125, 40 (54), 9 (26), 34 (102), 80 (238), 42 (125), 72 (214), 133 (398), 220 (660)
- **Cavities per Klystron Initial {Ultimate}**: 72 (36), 42 (14), 48 (24), 48 (24), 36 (12)
- **Number of Klystrons Initial {Ultimate}**: 1 (2), 1 (3), 1 (2), 1 (3), 8 (24)
Cost Comparison Spokes vs. Ellipticals

1. Cost Estimate for Director’s review March ’05
   linked from:  http://protondriver.fnal.gov

2. Estimates (RFQ’s) from Experienced Vendors
   Costs estimates public but vendors remain anonymous

3. Assume Coupler Costs equal at 1300 and 325 MHz

4. In-House Estimates for Cryostats

CONCLUSIONS:

• Costs are equal within errors
• We will know more after the first prototypes
How We Are Proceeding

1. **Design and Prototype where Decision is Clear:**
   1. MSU / FNAL Collaboration for $\beta=0.81$ 8-cell Elliptical *(see posters)*
   2. ANL / FNAL Collaboration for Single-Spoke 325 MHz *(see posters)*
   3. ➔ Active Search for other “ILC-Compatible” Collaborators ⇐

2. **Preserving two technical options (110-400 MeV):**
   1. 325 MHz triple-spoke Resonators *(AP BASELINE)*
   2. 1300 MHz Elliptical Cavities $\beta=0.47, 0.61$ *(AP design in progress)*

3. **Our Decision will be based on:**
   1. Accelerator Physics
   2. Cost (looks like a wash for now)
   3. Collaboration