Niobium R&D

- **fine grain (in-stock & lower cost)**
- **chipless forming of large grain (ingot)**

Terry L. Grimm

February 2010

NIOWAVE

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Fine grain niobium

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- Current challenges for standard fine grain
  - Stringent specifications
  - Long lead time
  - High cost
- Proposed solutions
  - In-stock material and components
  - Modified specifications

In-Stock 9-Cell Cavity

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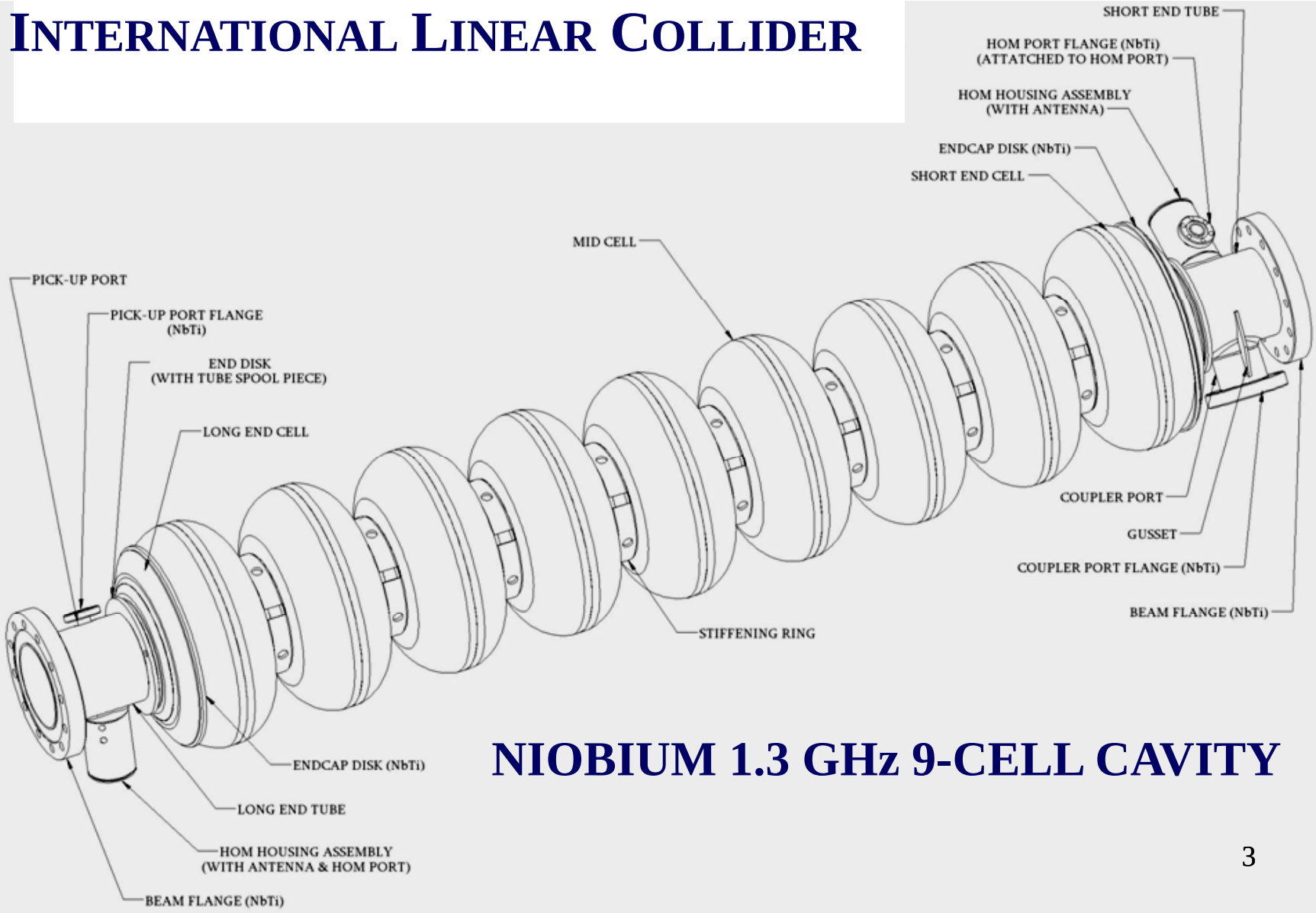
INTERNATIONAL LINEAR COLLIDER



NIOBIUM 1.3 GHz 9-CELL CAVITY

In-Stock Components

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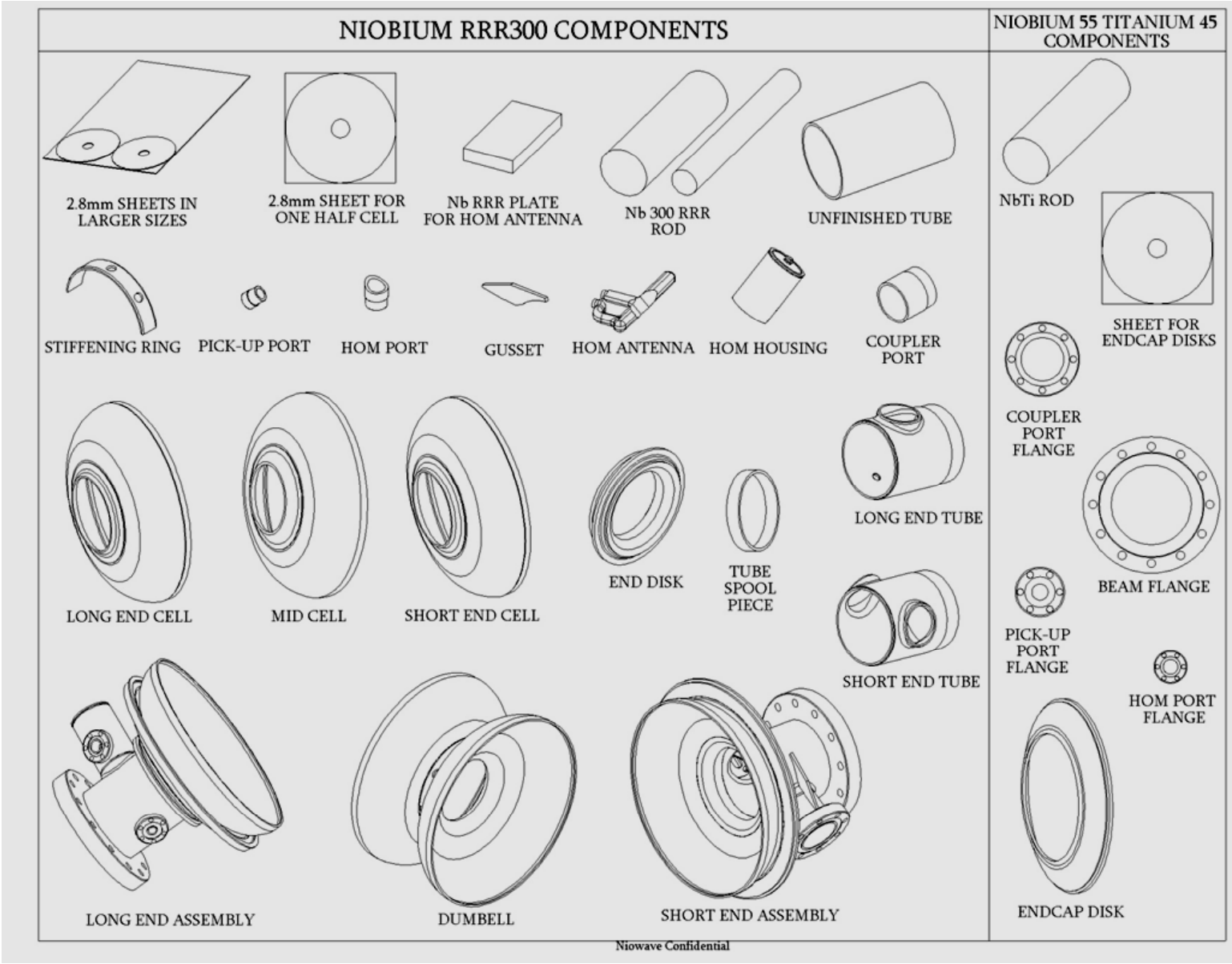

Modified specifications

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- Modify specifications to simplify sheet production, thereby decreasing cost and delivery time
  - RRR value
  - Grain size
  - Yield strength
  - Uniformity

Niobium Expertise

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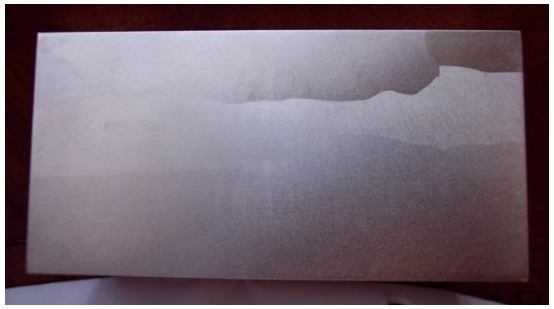
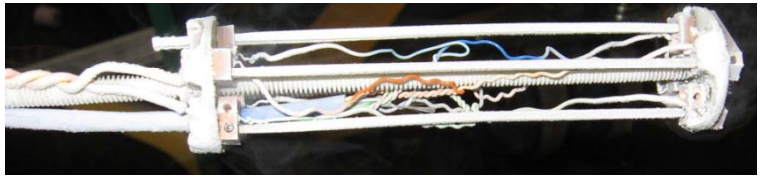
- Large Grain Nb Supplier
  - Offer large grain niobium at reduced costs compared with fine grain



- RRR measurements
  - Only company in the world that offers service
  - Qualified Cabot, CBMM, Heraeus, HC Starck, Plansee, Wah Chang



Large Grain Ingot

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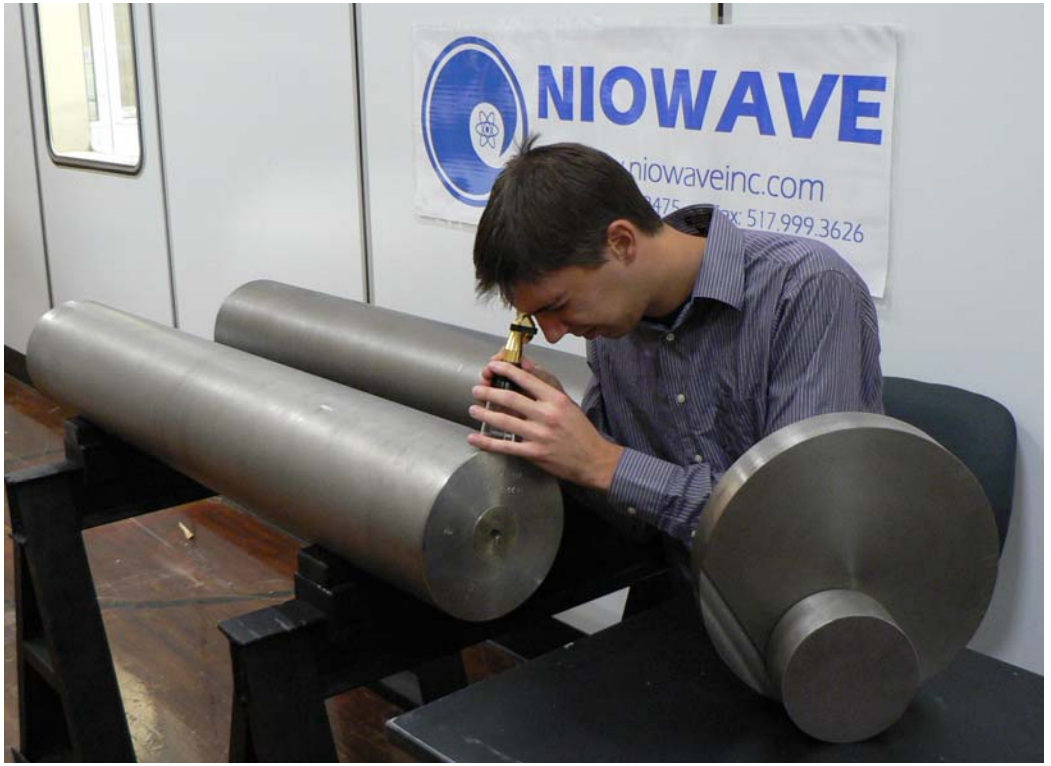
- Electron beam vacuum furnace
  - Re-melt multiple times to increase purity
- Parent material for all high purity applications
  - Large grain ingot processed into other forms



Chipless Forming

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- Use industrial metal forming processes for plastic deformation
  - Forging, extrusion, deep drawing, rolling, spinning, flow forming, etc.
  - Reduce number of components & welds
- Techniques used extensively in other industries
  - Especially for ductile metals like niobium
  - Examples: aluminum rims, baseball bats, pots & pans

Ingot/Sheet Comparison

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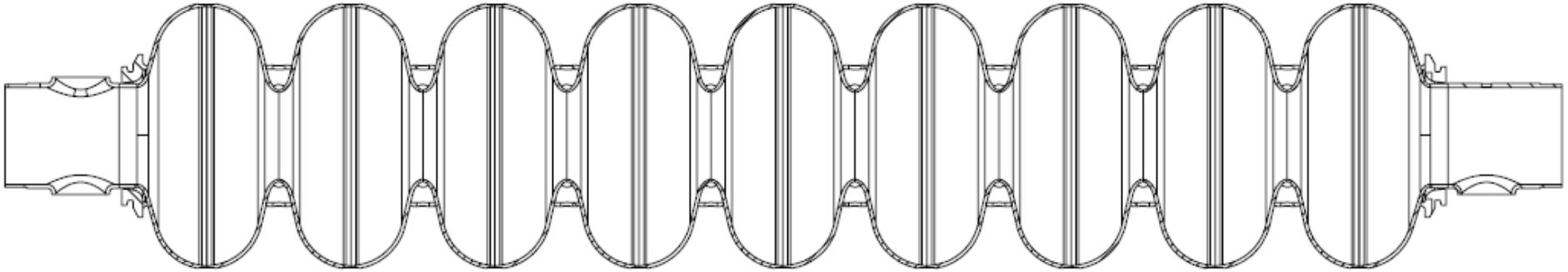
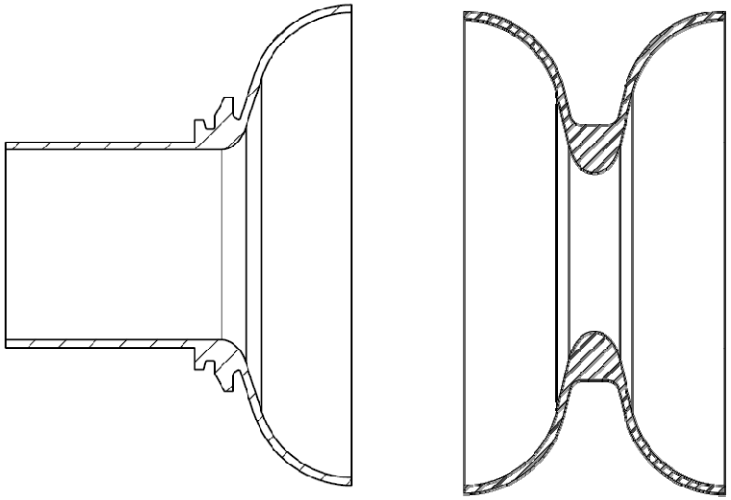
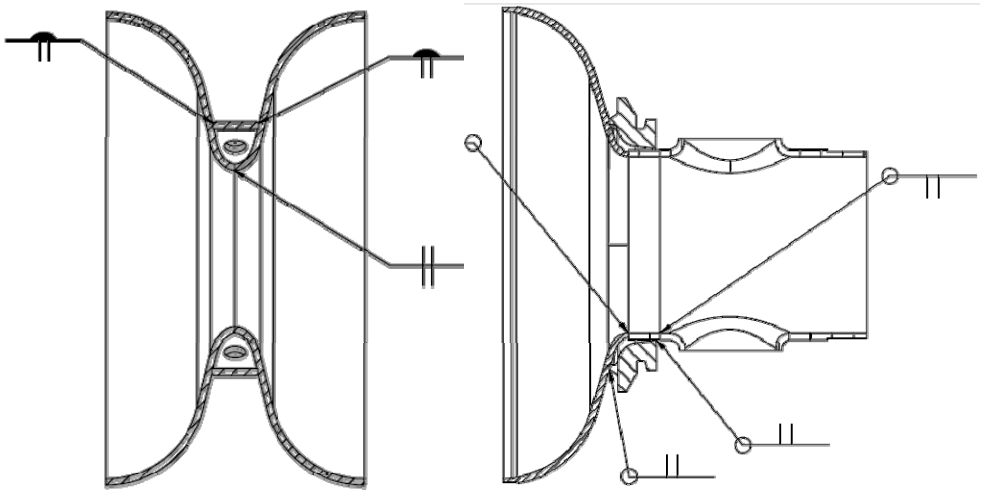




Ingot Flow Forming



Standard Sheet Metal

Dumbbell Comparison

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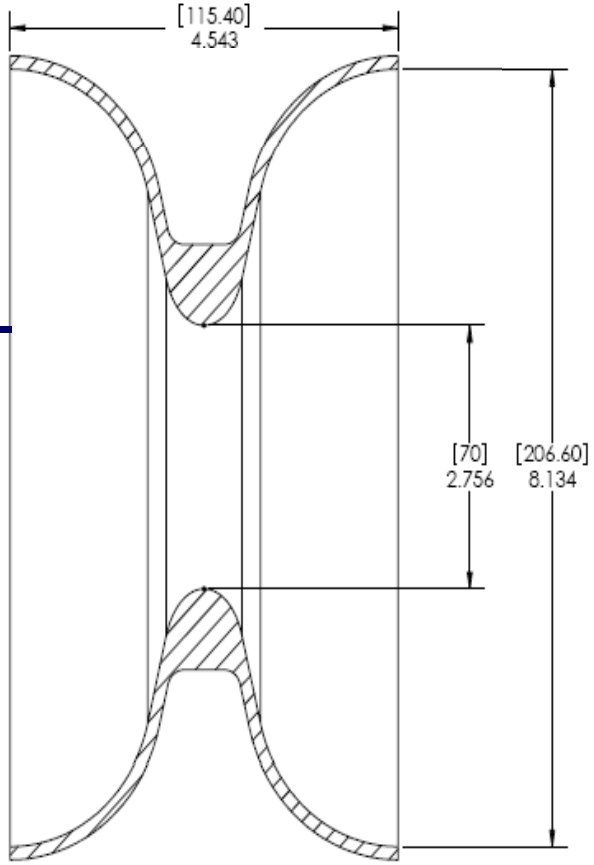
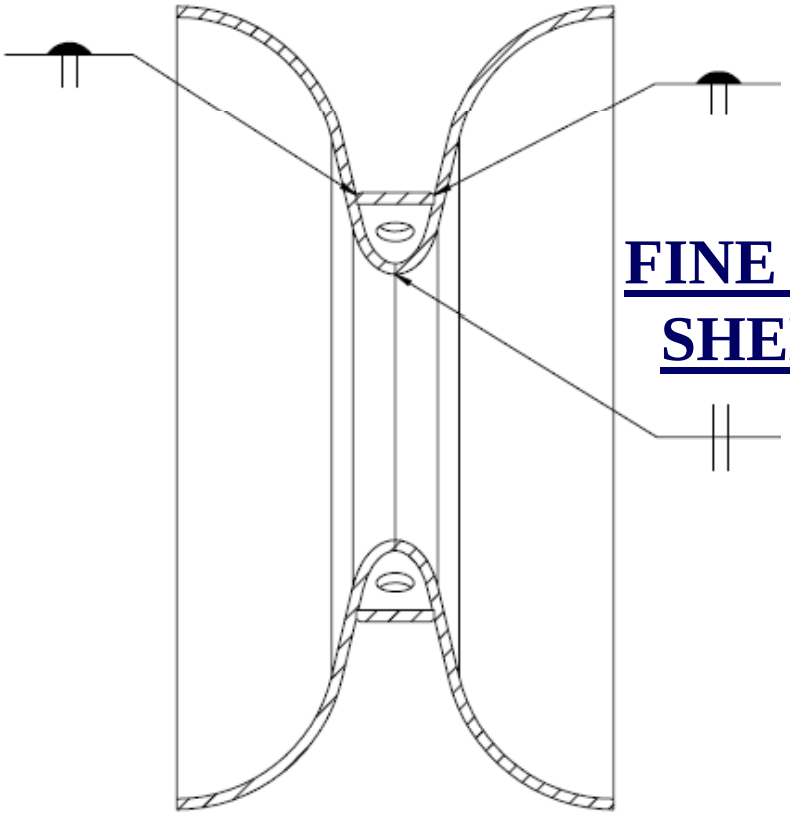
INGOT Nb



- Single piece of ingot material
- No EB welds
- Improved surface tolerance

FINE GRAIN SHEET Nb



- Multiple sheets of fine grain material
- Multiple pump downs & EB welds
- Multiple dies and fixtures

Dumbbell Flow Forming

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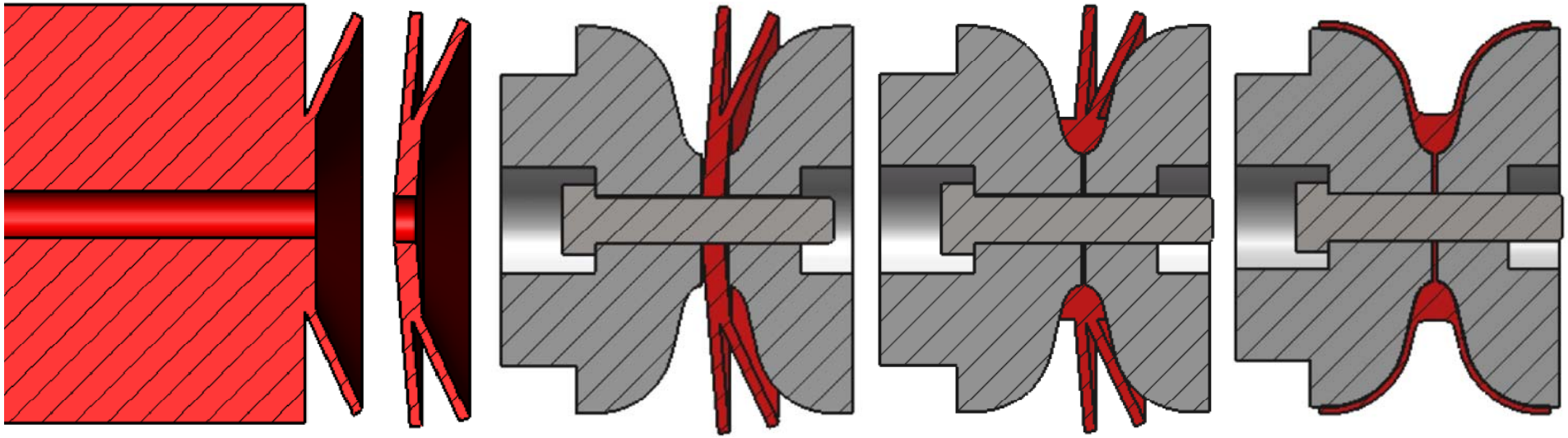
Dumbbell fabrication directly from large grain/ingot



Large Grain Ingot

Dumbbell

End Assembly Comparison

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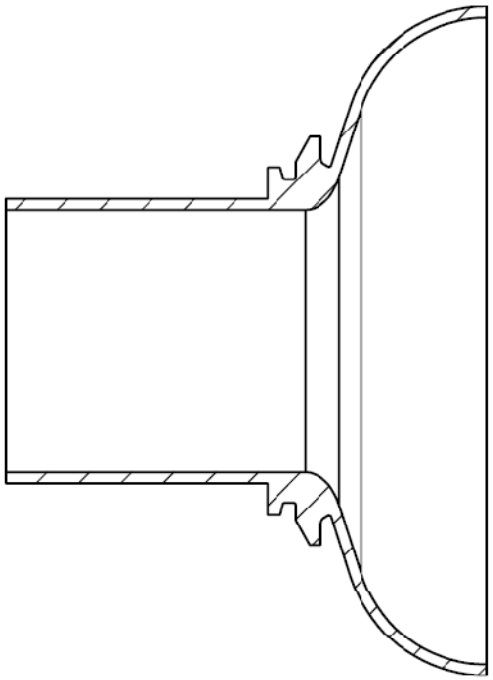
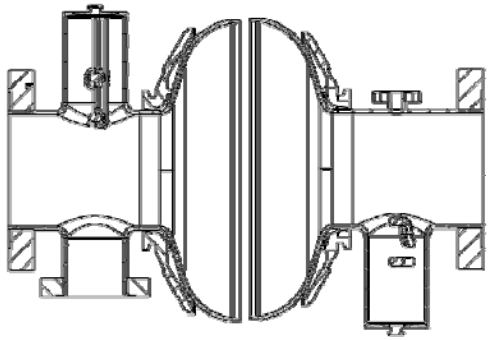
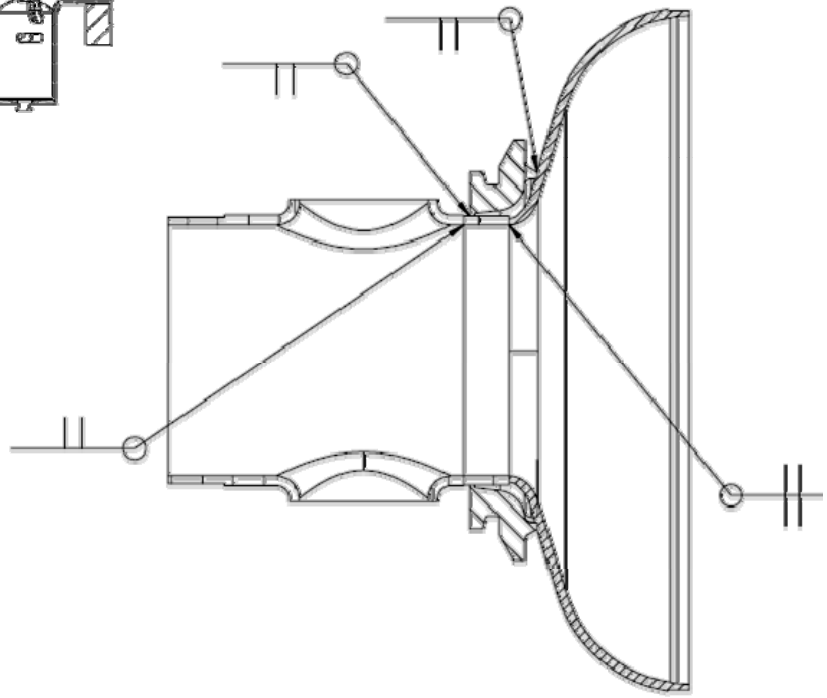
INGOT Nb





FINE GRAIN SHEET Nb



- Single piece of ingot material
- No EB welds
- Improved surface tolerance

- Multiple sheets of fine grain material
- Multiple pump downs & EB welds
- Multiple dies and fixtures

End Assembly Flow Forming

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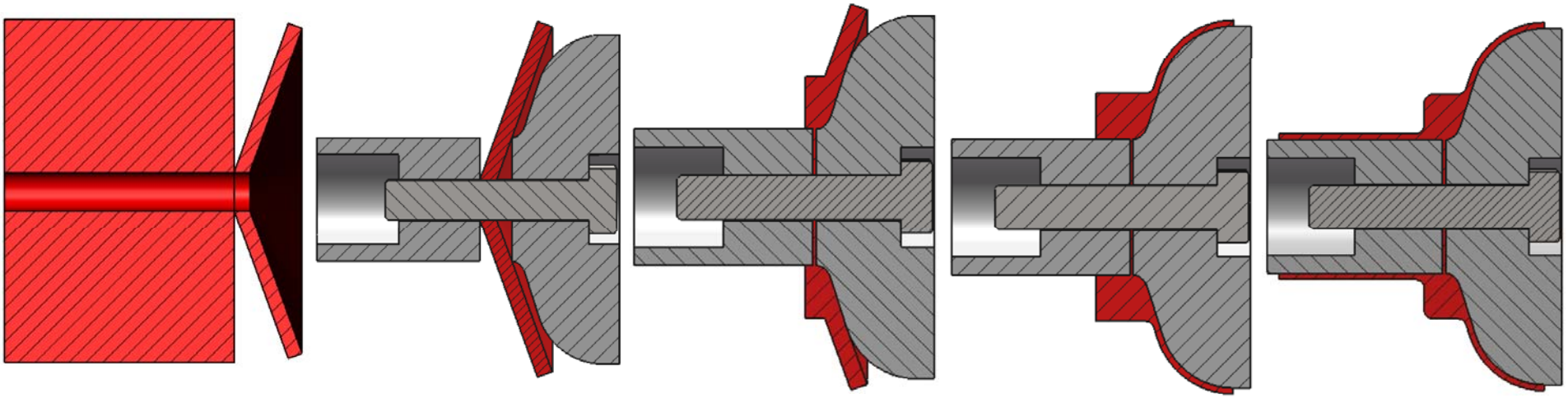
End group fabrication directly from large grain/ingot



Large Grain Ingot

End Group

Ingot Formed Cavity Welds

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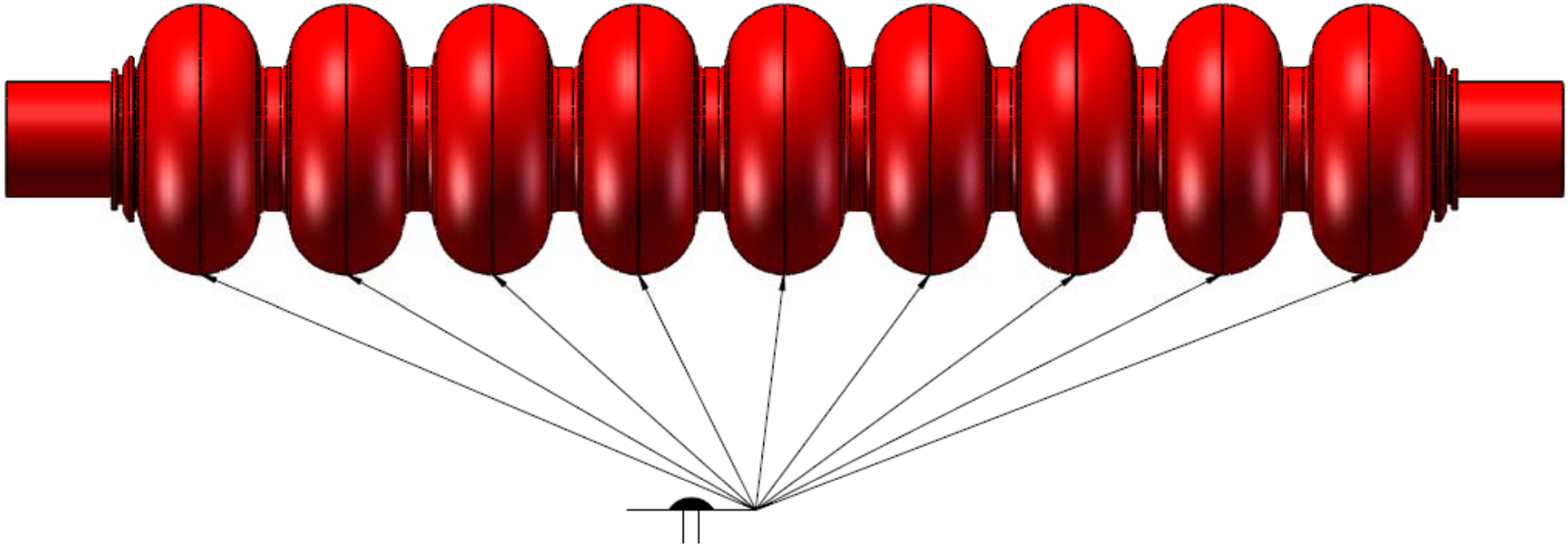
Only 9 electron beam welds in the high field region
(as opposed to 33 welds)



Radial coupler parts are fabricated the same
-Ingot forming methods can simplify

Chipless Ingot Slicing

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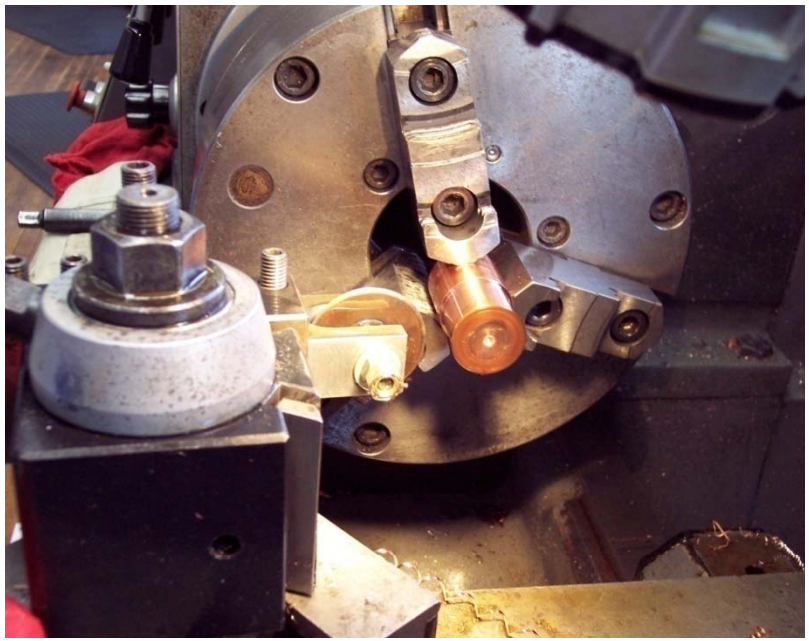

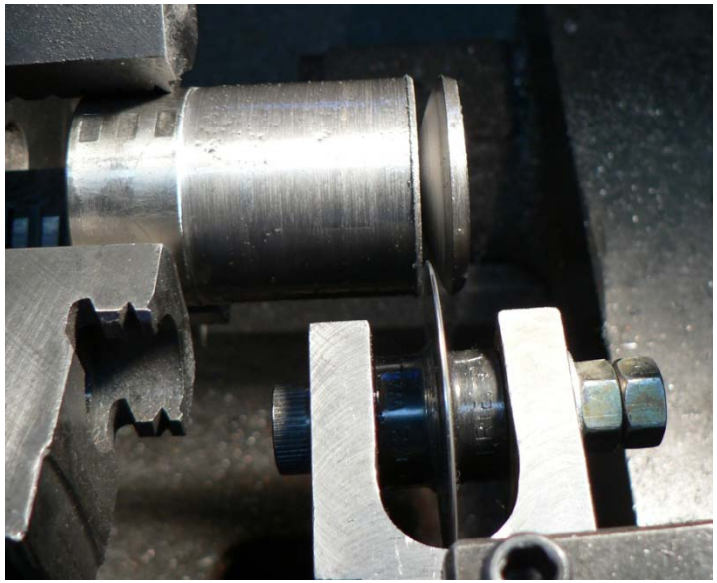

- Ingot slicing similar to pipe cutting
  - Slicing wheel geometry determined
  - Tooling developed to slice large grain ingots