US-ILC Waveguide Industrialization Study

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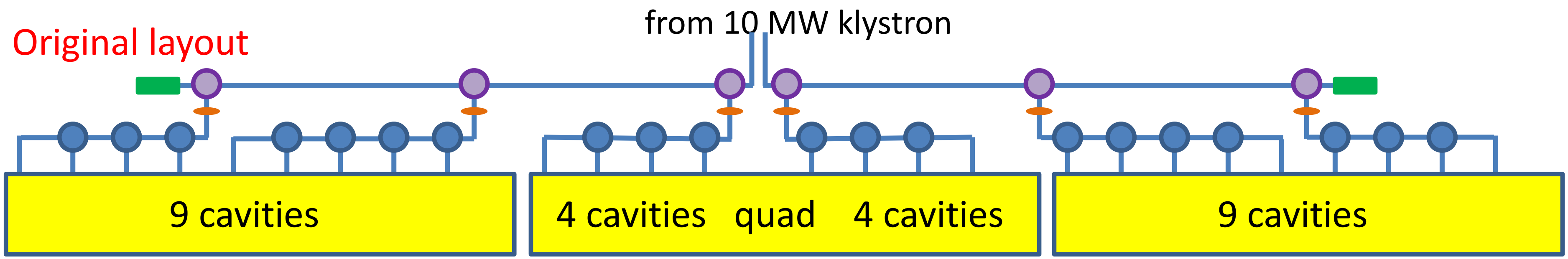
ILC Local Power Distribution System (LPDS)

- variable power divider, pressurizable, 0-100%, phase stable
- pressure window
- variable H-hybrid, non-press., limited range
- 5 MW load

Original layout

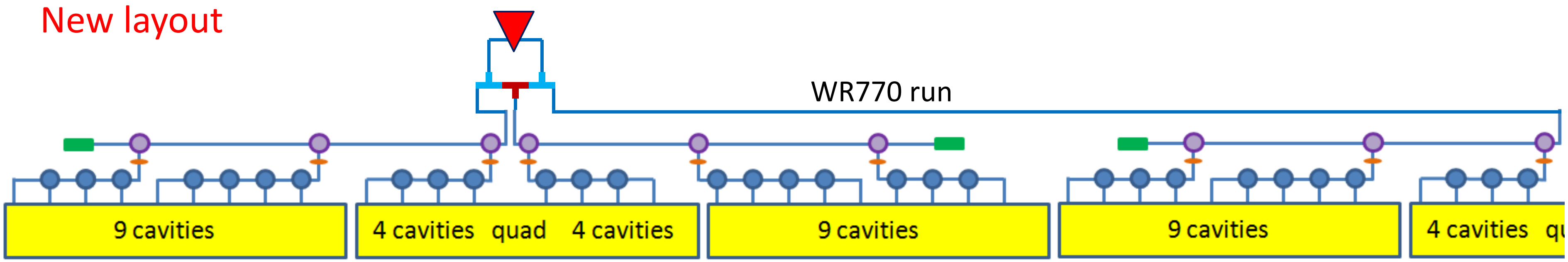


6 windows
(assuming ~2 MW capability)

RF UNIT: 3 cryomodules (26 cavities)

Beam current lowered, 1/3 of klystrons eliminated

New layout

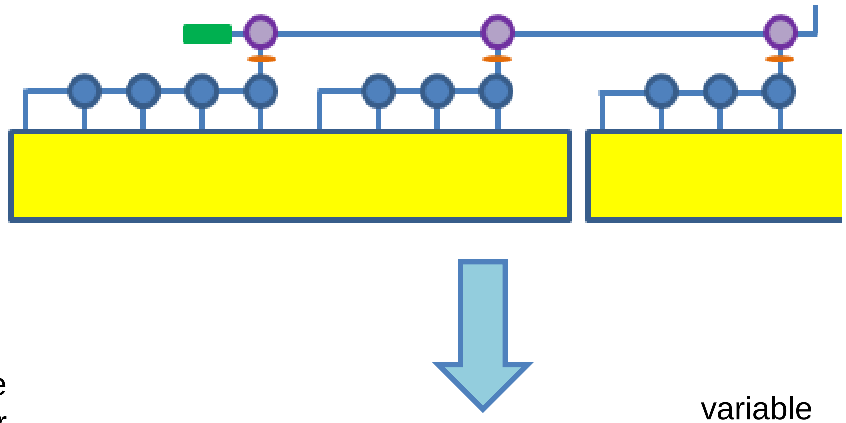


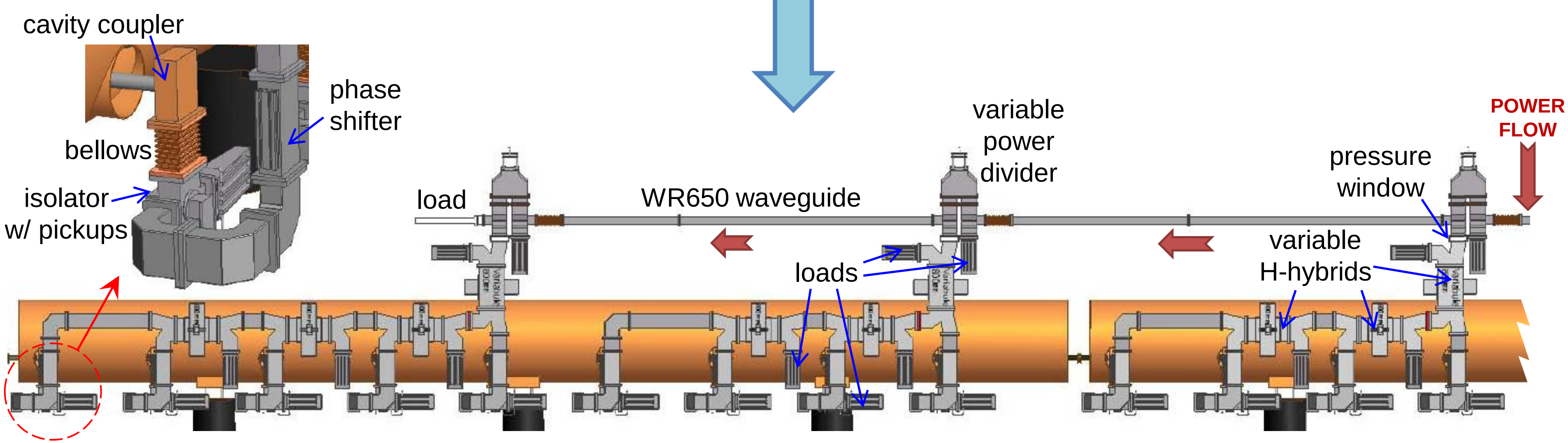
For low power RDR-like option, one klystron powers 1 ½ “rf units” or 4 ½ cryomodules.

Detailed View of 13-Cavity LPDS Unit

Power to each ½ cryomodule is fully adjustable via VPD's without affecting phases.

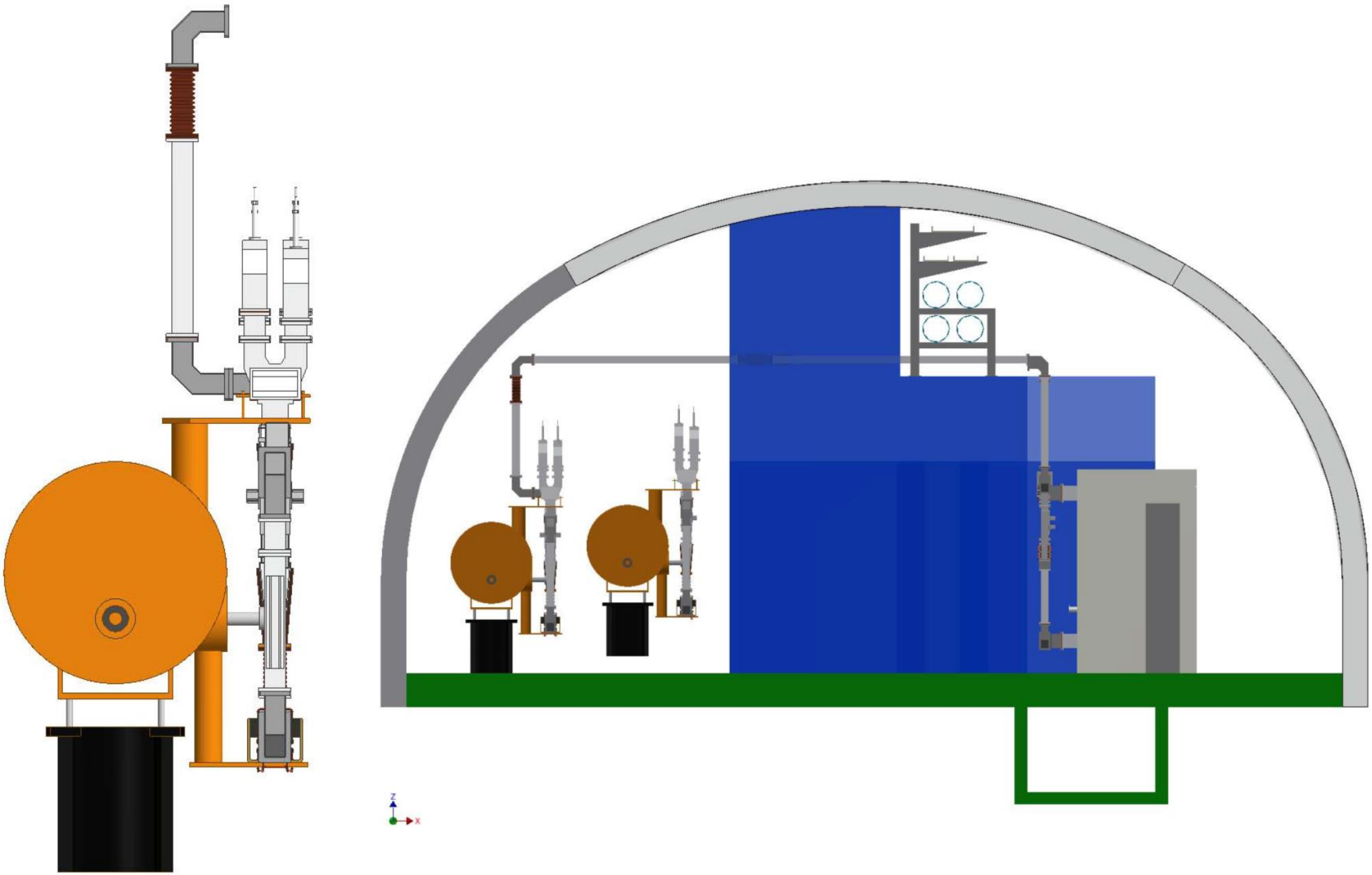
Unused power can be dumped to the end load.





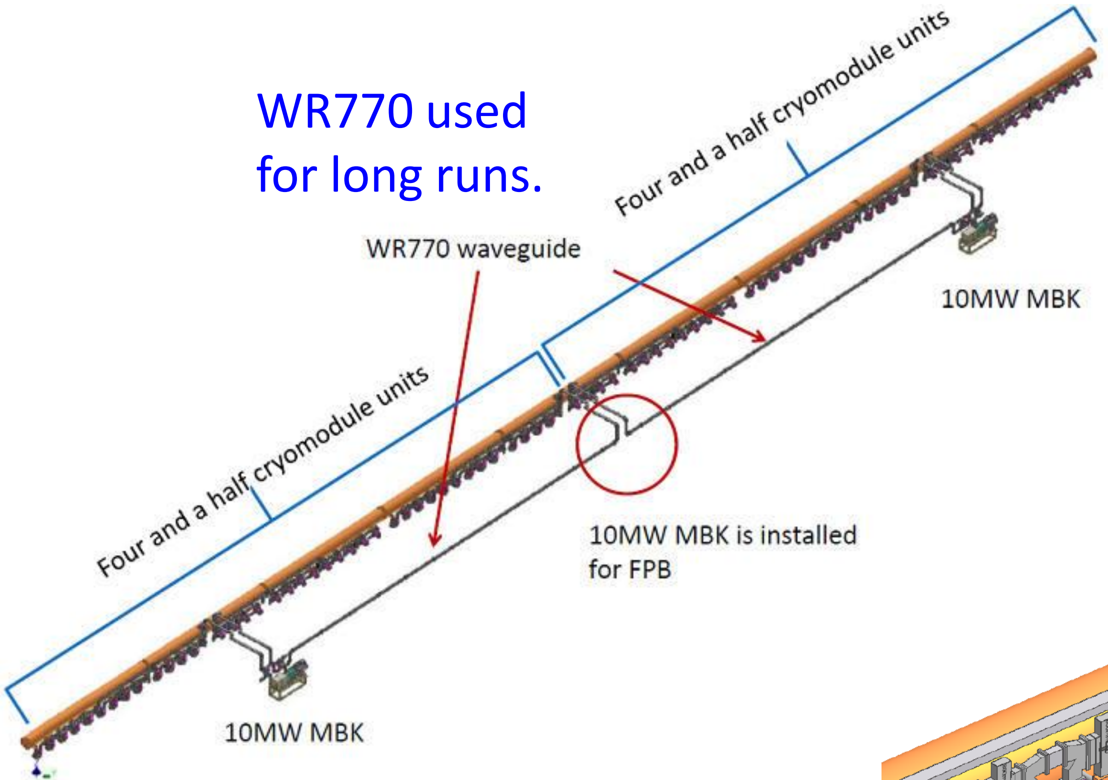
Each cavity feed line has a **phase shifter**, isolator w/ bi-directional coupler, and flex guide

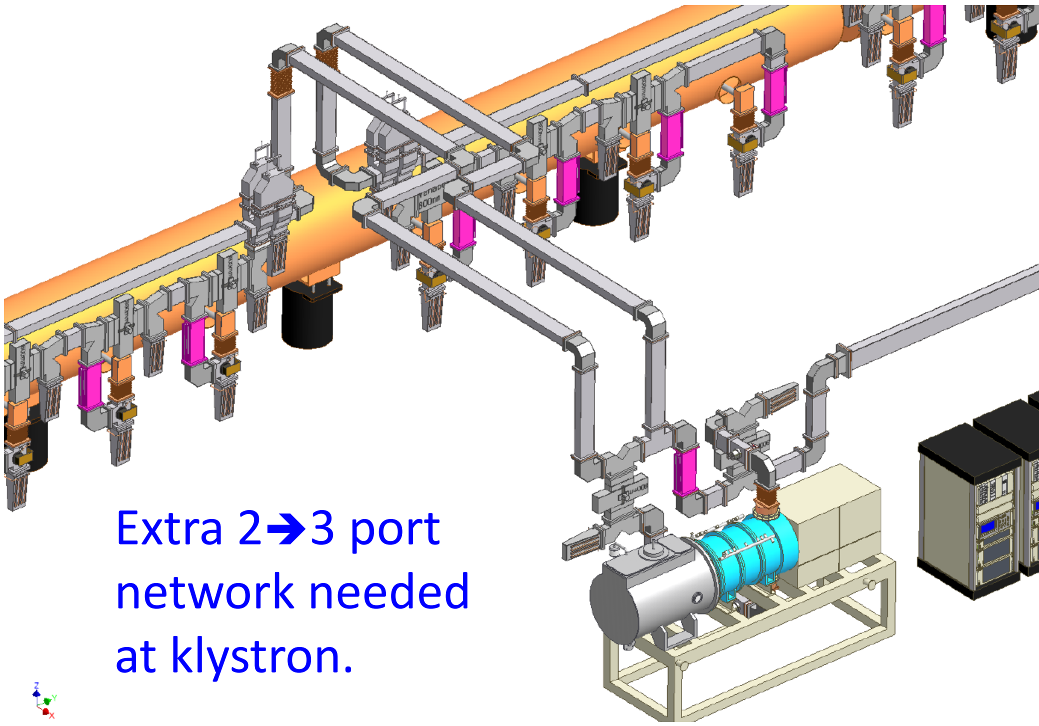
Tunnel End View



Feeding 3 Stations with 2 Klystrons

WR770 used for long runs.





Extra 2➔3 port network needed at klystron.

Standard Waveguide and Waveguide Components

Straight sections

E-plane and H-plane bends

T-splitters and magic T's

folded magic T

Semi-flex waveguides

Need pressurizable and non-pressurizable versions, for stress relief in upper waveguide runs and at cavities.

Isolator and Loads

S.P.A. Ferrite, Ltd. (Russia)

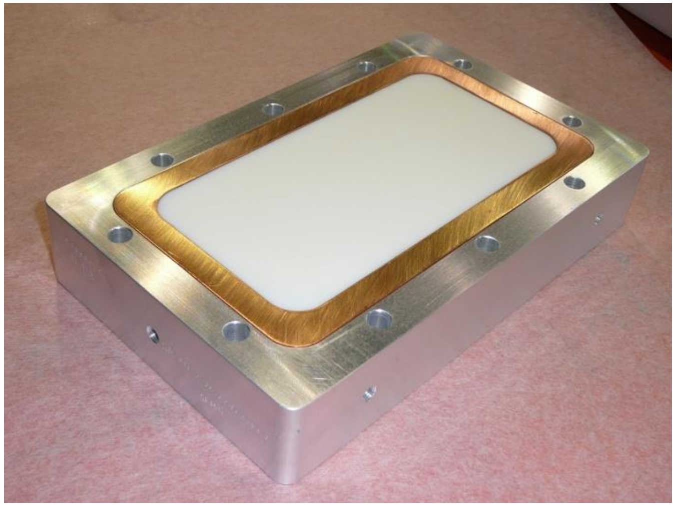
Newer model includes forward and reflected pick-ups, eliminating the need for a separate bi-directional coupler (reflectometer)*.

* But costed as separate components

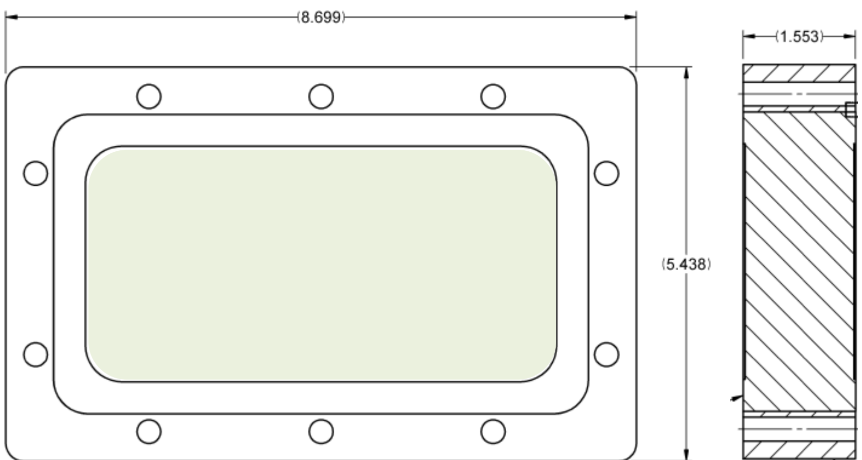
Water cooled (2 types)

P_{pk}	P_{av}
2 MW	10 kW
5 MW	100 kW

SLAC Air-to-Air Window



High power tested up to **3 MW, 1 ms**.



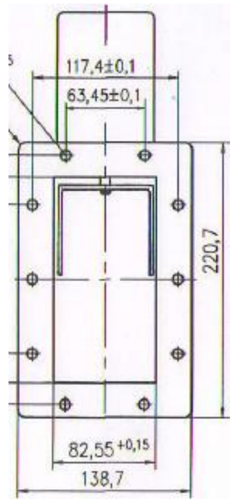
Ceramic Plug Pressure Window

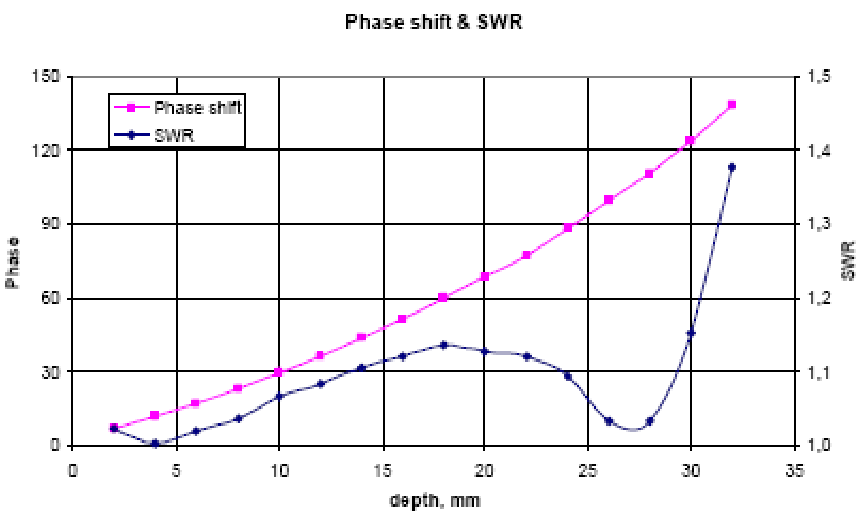
Bi-Directional Couplers (Reflectometers)

May be largely eliminated by use of isolators with built-in pick-ups.

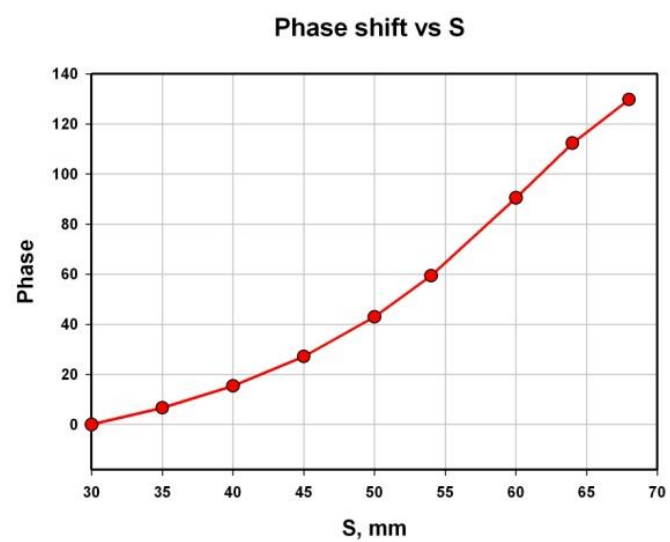
Phase Shifters

DESY/SPA Ferrite

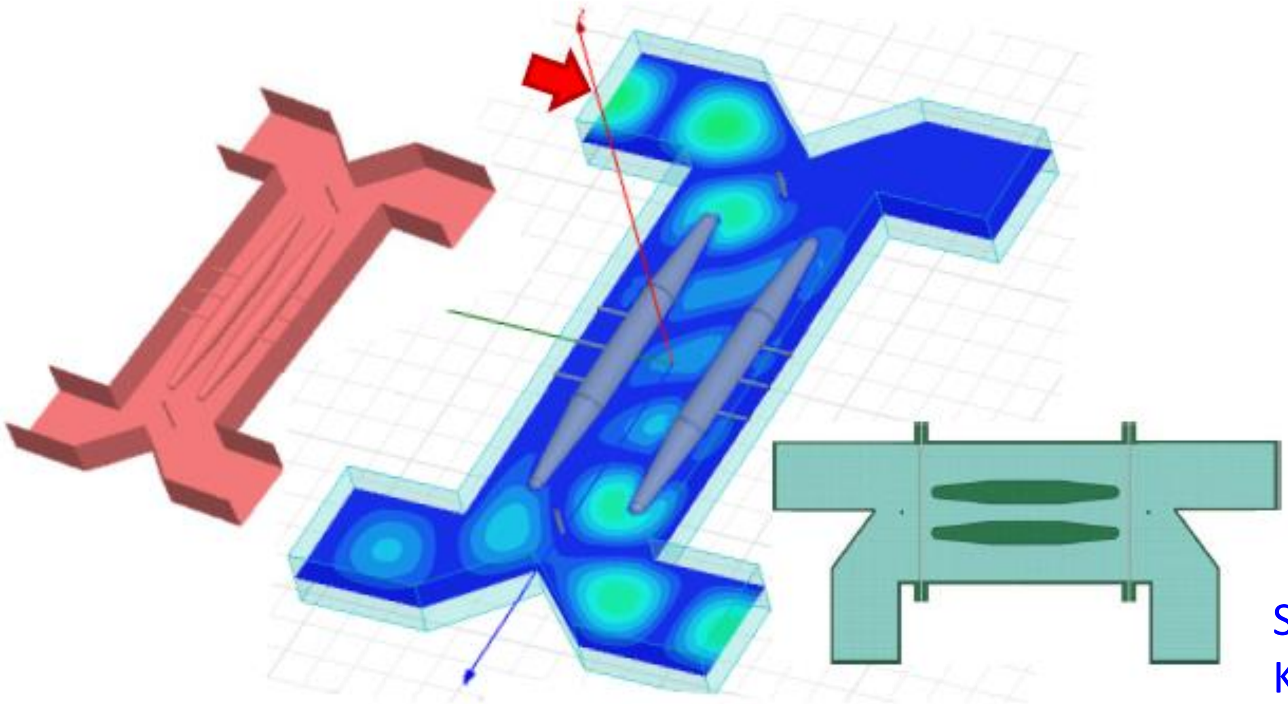




KEK/Toshiba



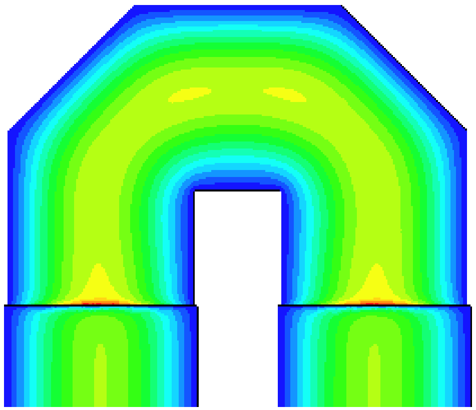
KEK Variable H-Hybrid (Power Divider)



Sergey Kazakov

Variable H-hybrid geometry, sample field pattern and in-line port design modification. Moving the two suspended conductors in and out perturbs the relative phase between the two modes supported in the interior section while retaining match, resulting in a varying power split at the output ports.

U-Bend Phase Shifter

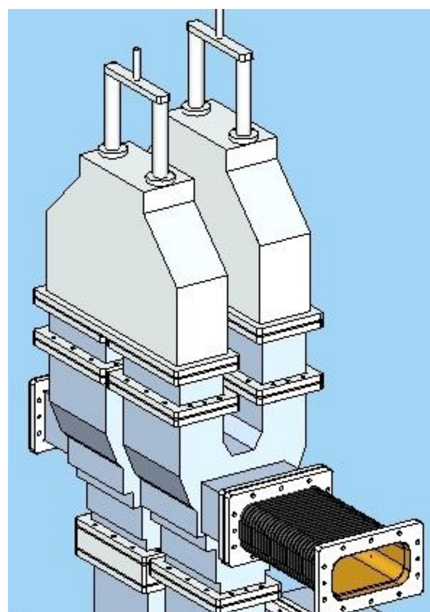


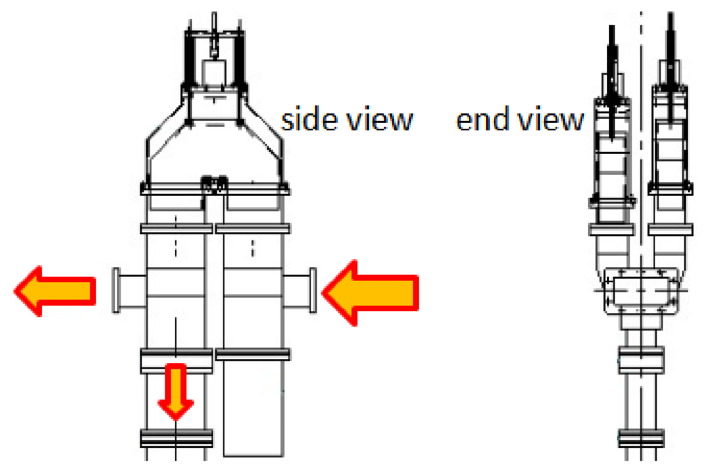
simulation field plot

C. Nantista

SLAC Variable Power Divider (VPD)

= 2 U-bend phase shifters
+ 2 folded magic-T's





XFEL PDS:

PRESS RELEASE

MEGA RF Solutions
INDUSTRIES, LLC

For Immediate Release:

14 January 2013 – GORHAM, MAINE USA

MEGA Industries Awarded Record Contract

Mega Industries LLC (Mega), an Anania & Associates Investment Company LLC (AAI) portfolio company and a world leader in high power RF equipment, is pleased to announce the receipt of an award for waveguide components totaling more than $4.1 million, a record for this company. The 3,938 individual components requested will be delivered over a 16 month period.

The ultimate customer, the European XFEL, will generate ultrashort X-ray flashes – 27,000 times per second and with a brilliance that is a billion times higher than that of the best conventional X-ray radiation sources. The outstanding characteristics of the facility are unique worldwide. Starting in 2015, it will open up completely new research opportunities for scientists and industrial users.

XFEL – Mega: ~ 7K$ / cavity

ILC PDS:

- Three kinds of parts:

1. Catalog items (cost basis from Mega/Furukawa; LC=0.95)

   (modification may be required for pressurization)
2. Loads / Circulators (cost basis SPA Ferrite – St. Petersburg; same LC)
3. SLAC / KEK in-house designs with integrated electro-mechanical actuator; based on WR650 hardware (cost basis from first article; same LC)

TDR cost distribution for the above three kinds:

27% 29% 44% (including K-PDS)

ILC Industrialization Study Part Count

-P = pressurizable
-NP = non-pressurizable

Assume all LPDS's like standard ML – klystron feeding 39 cavities:

Nc = # of cavities = 16,024

ITEM	FORMULA	QUANTITY
Isolator -NP	Nc	16,024
Semi-Flex guide -NP	Nc	16,024
Semi-Flex guide -P	3*Nc/13	3,698
Reflectometer -NP	Nc	16,024
Reflectometer -P	2*Nc/39	822
Phase Shifter -NP	Nc	16,024
Phase Shifter -P	Nc/39	411
Pressure window -P	3*Nc/13	3,698
1 MW load -P	3*Nc/13	3,698
5 MW load -P	Nc/13	1,233
U-bend Phase Shifter -P	6*Nc/13	7,396
Folded magic-T -P	6*Nc/13	7,396
Variable hybrid -NP	10*Nc/13	12,326
3-dB Hybrid -P	Nc/39	411
E-plane shunt T -P	Nc/39	411
E-plane bend -P	15*Nc/39	6,163
H-plane bend -P	7*Nc/39	2,876
H-plane bend -NP	Nc+3*Nc/13	19,722
E-plane U-bend -NP	Nc	16,024
WR650-770 converter -P	2*Nc/39	822
WR770 straight 120' -P	Nc/39	411
WR650 straight 4' -P	10*Nc/39	4,109
WR650 straight 8' -P	7*Nc/39	2,876
WR650 straight 12' -P	6*Nc/39	2,465
WR650 straight 3' -NP	9*Nc/39	3,698
WR650 straight 8" -NP	27*Nc/39	11,093
Nut/bolt/washers	10*(tot+Nc)	1,918,790

Post-TDR MEGA Cost Study Scope

- Twelve production schemes considered:
  - deliver full, only standard waveguide, only circulators and loads, and only electromechanical devices
  - at 3 varied production levels (25%, 50% and 100%)
  - over a period of 6 years with up to 2 additional years for the following to be completed:
    a. Casting and extrusion tooling and process development / qualification
    b. Facility build-out
    c. Equipment and workstation installation and pre-production verification / release
    d. Production tooling and process development and qualification
- The results of this study include plant layouts, time planning for equipment and labor, work flow diagrams, and costs for the industrial components of plan estimated at 2013 prices and rates

Specific Report Items (1):

- Plant equipment requirements, including building, technical equipment, and layout of equipment in building. Costs, in 2013 dollars, to create such a facility, and time required to build, prepare, and prove the plant is ready for production.
- A production plan, including labor and machine hours required.
- Identification of the top 3 throughput bottlenecks in the plant, and the remedy for each.
- Analysis of alternatives for each production step, and identification of the top 3 alternatives which should be pursued with R&D to have the greatest economic effect on the production.

Specific Report items (2)

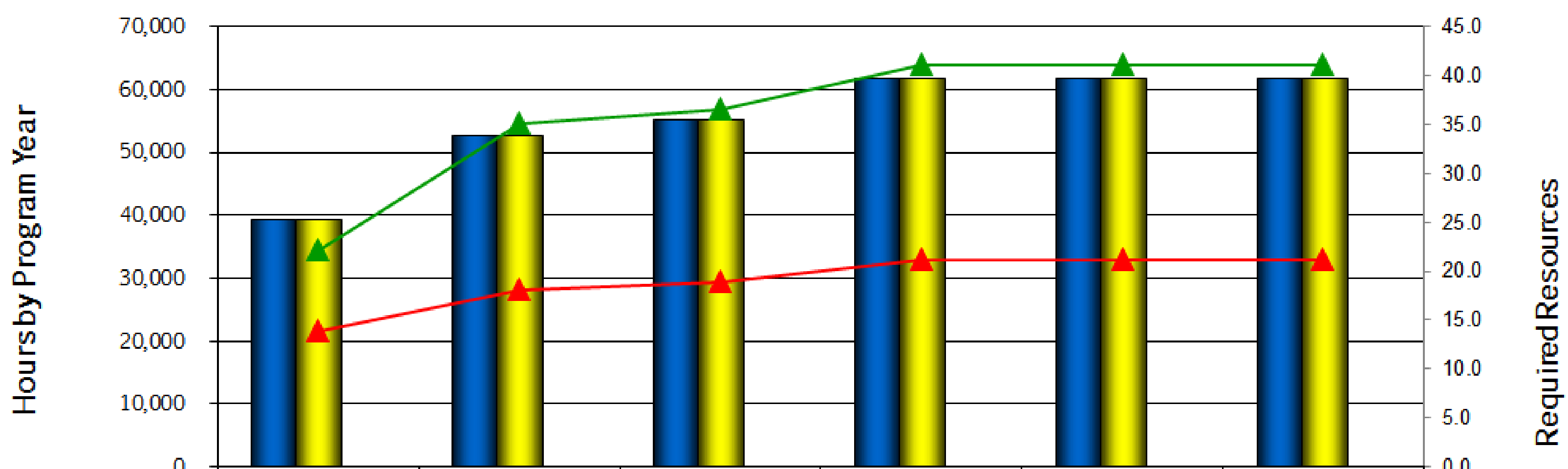
- Identification of components or subcomponents that are prime candidates for subcontracting, including description of existing companies that could fulfill such roles or a description of an industry where such subcontracting should be pursued.
- Identification of particularly economically burdensome production process requirements or component tolerances which are, and possible remedies for such.
- Identification of the hub Laboratory contributions, the reasoning for the choice, and a description of the technical criteria that would define such a handoff.

Fabrication Tasks

Assembly	630 mm HMC
Blending	630 mm VMC
Brazing	1,000 mm HMC
Manual Mills	Pack / Ship
Clean / Mask	Paint
Compression	Pressure Test
Convoluter	Rinse
Copper Plate	Router
Electrical Test	Saws
EMMEGI	Silver Plate
Final Inspection	Solder
Forming / Weld	300 mm Lathe
Heat Treat	Autowelder
In-Process Insp	TIG Welder

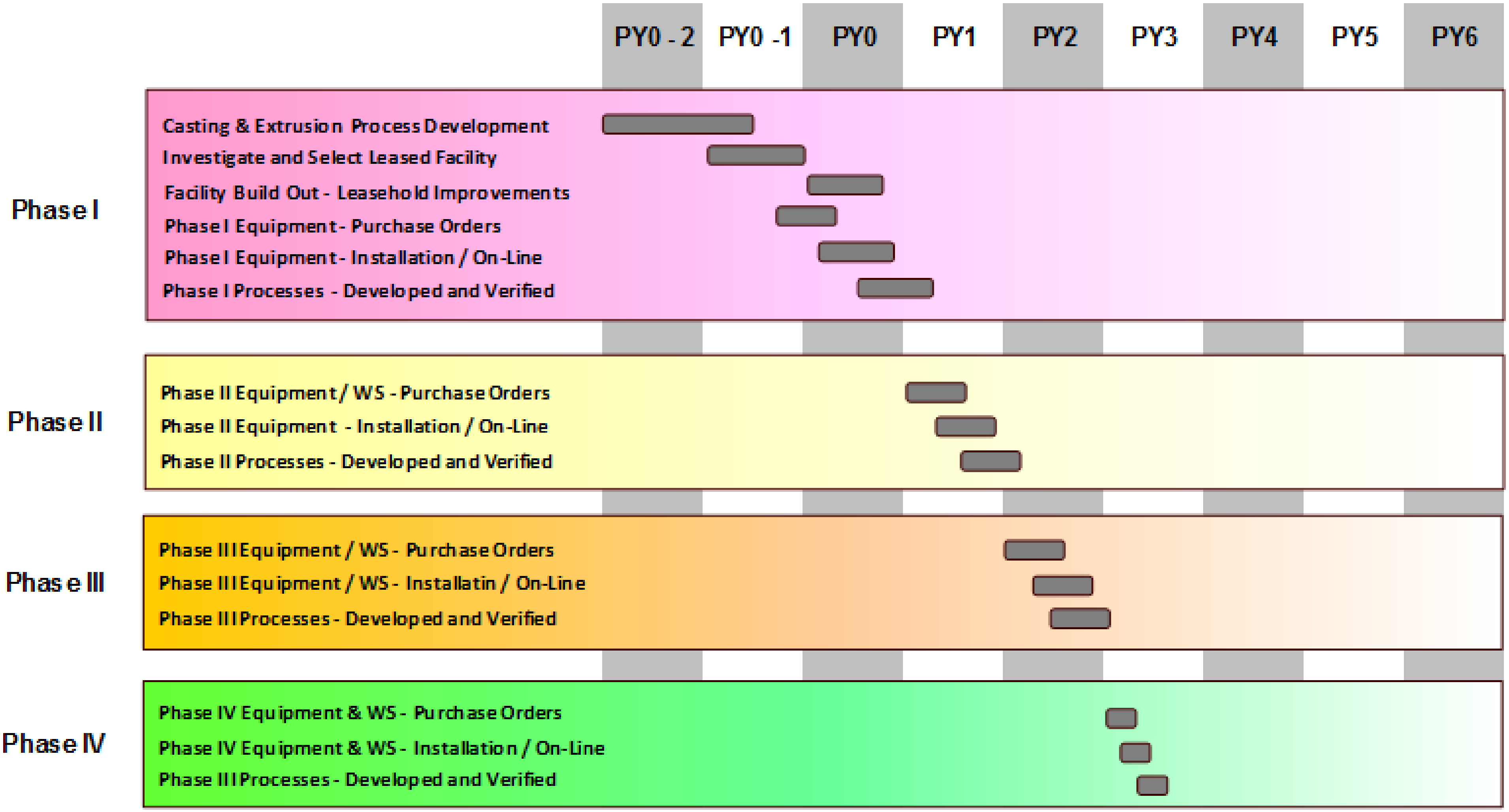
Example: TIG Welding

SLAC / ILC - Welding TIG
Load Profile - PY1 thru PY6



	PY1	PY2	PY3	PY4	PY5	PY6
Load Profile Hours	39,402	52,900	55,239	61,862	61,862	61,862
On-Site Hours	39,402	52,900	55,239	61,862	61,862	61,862
Off-Site Hours	0	0	0	0	0	0
On-Site Staffing	22	35	37	41	41	41
On-Site Work Stations	14	18	19	21	21	21

SLAC ILC - Project Timeline



The Project Timeline captures the major milestones of the facility build out and ramp up to meet the production demand timeline.

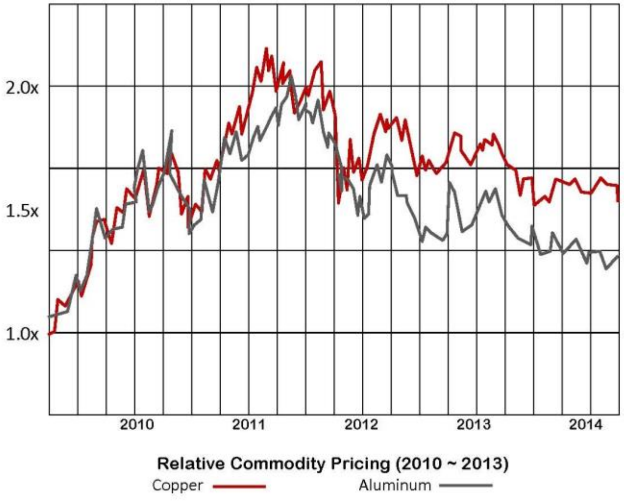
Learning Curves

- “The purely mechanical straights and sweeps will quickly hit a production plateau gaining potentially a 10% improvement over time as the workers become more comfortable with the serial production operations and techniques during the first year of production.
- The more complex components will take significantly more time to attain optimized throughput levels, but we believe a 20% or more improvement may be possible.”

Top 3 Processes

- Machining (assumes 85% machinery utilization over two 8 hour shifts per day, five days per week)
- Welding
- Testing (to be shared with hub – lab)

- These are also the three potential bottlenecks they identified – in particular, in regard to
  - Equipment up time (5% downtime in PY1 and 3% in years PY2 – PY6)
  - Employee availability
  - Raw material supply



Relative Commodity Pricing (2010 ~ 2013)

Hub Lab Tasks

- High power rf testing
- Electro-mechanical integration (final assembly of subassemblies with motorized drives)
- Final PDS integration and tuning

Possible Improvements

- Integration of special components
  - Electromechanical devices, typ. SLAC / KEK designs
- Extrusion
- Casting
- Testing automation

<u>May provide 20 to 30% cost reduction</u>

Summary

- Industrialization study of ‘non-high-tech’ components (PDS) completed March 2014
  - US PDS industry is small-business based
  - Substantial cost-reduction (~1% of ILC total) possible with nominal R&D investment