Summary of Relative RF Distribution Costs with Gradient Considerations
(Work in Progress)

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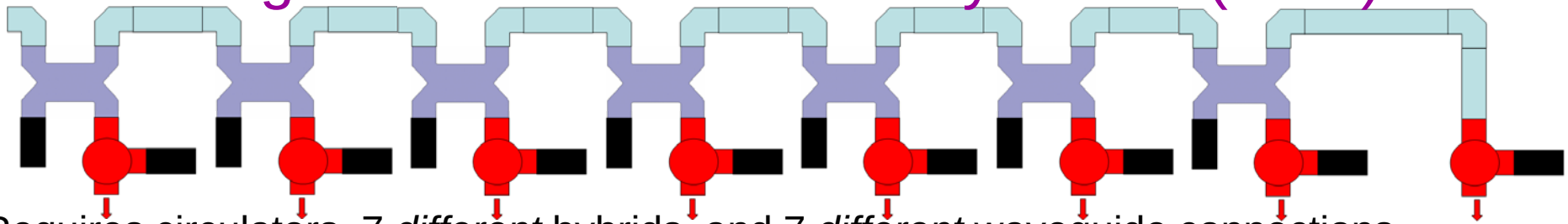
Cost of Power and Qext Control

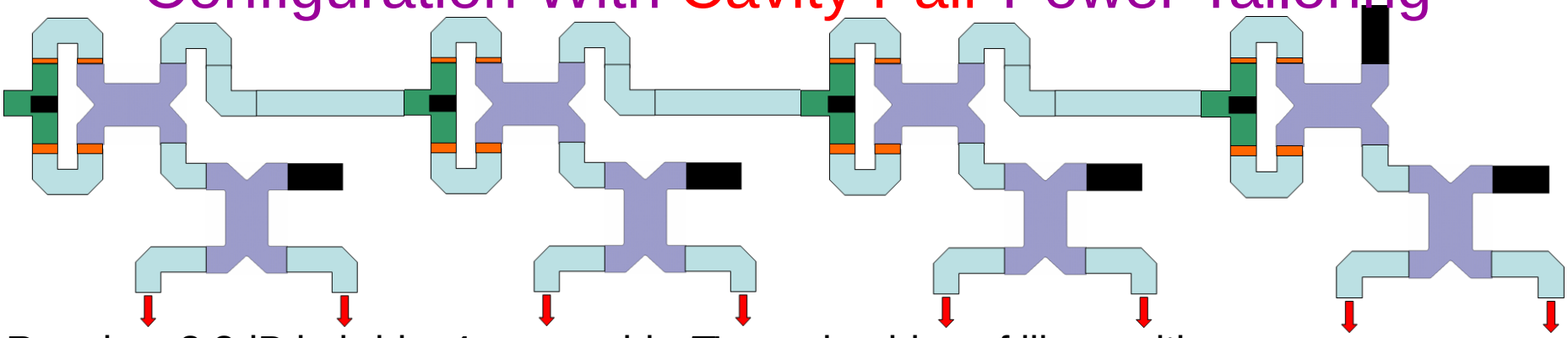
- RDR Linac Cost with Labor
  - 3.89 B$ + 59% of 14 khr*140 k$/hr = 5.0 B$
  - So 1% gradient = 50 M$
- RDR TTF3 Coupler Cost Including Processing
  - RDR (DESY) Estimate = 11.5 k$ (9.5 kEuro with 1.2 E/$)
  - FNAL Estimate = 13.6 + 2.6 = 16.2 k$ (13.4 kEuro)
  - LAL ILC goal = 28 k$ (14 kEuro for parts * 1.2 / .6)
- Cost of Qext Control
  - Number of Main Linac Couplers = 14560
  - Cost savings with fixed Qext = 11% (Serge's worst case)
  - So Qext cost with RDR Estimate = 18 M$
- Cost of Power Control
  - T + WG = 10.3 k$ * 14560 / 3.1 (RDR discount) = 48 M$

Configuration With Fixed Cavity Power (BCD)



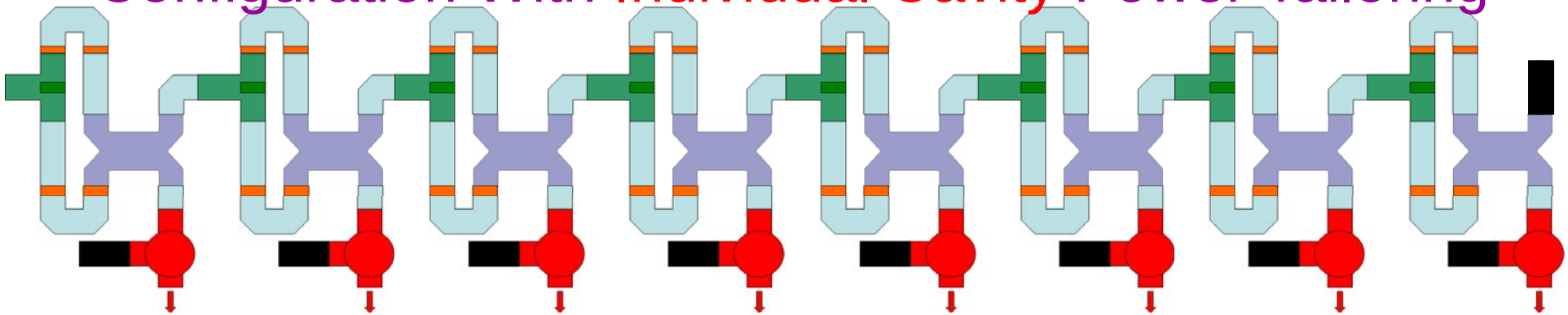
Requires circulators, 7 *different* hybrids, and 7 *different* waveguide connections.

Configuration With Cavity Pair Power Tailoring



Requires 8 3dB hybrids, 4 waveguide *T*'s, and pairing of like cavities.

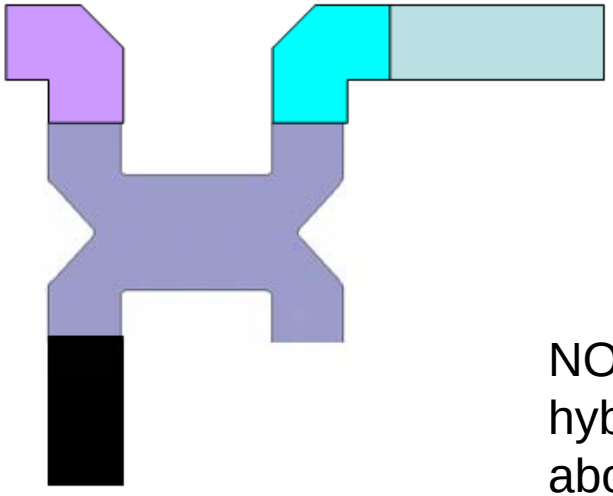
Configuration With Individual Cavity Power Tailoring



Requires circulators, 8 3dB hybrids, and 8 waveguide *T*'s.

Fixed vs. Variable Coupling Cost

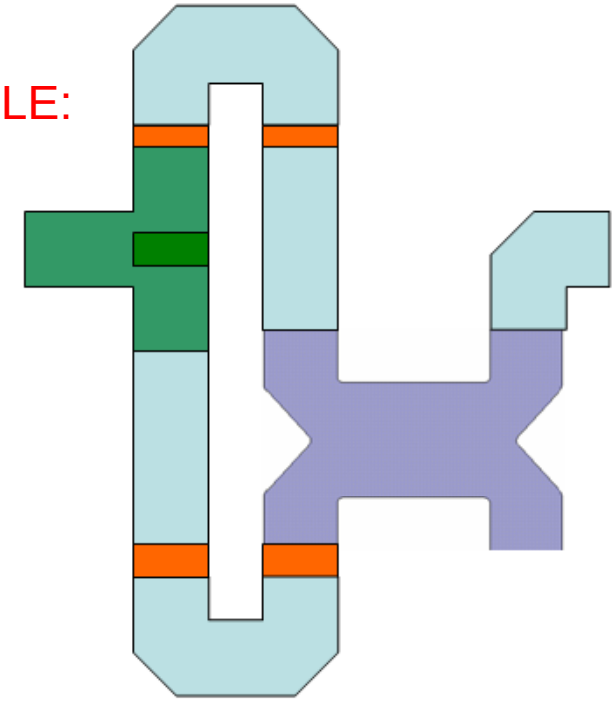
FIXED:



Hybrid	$6,650	$6,650
H-plane bend	2×$1,236	$2,472
Spool	$700?	$700
Gaskets	6 × $78.95	$474
		$10,296

NOTE: Hybrids and bends (to accommodate various hybrid lengths and output phases) of various designs above, but all identical below, which can affect prices.

VARIABLE:



Hybrid	$6,650	$6,650
Magic Tee	$5000?	$5,000?
H U-bends	2 × $2,000?	$4,000
H-plane bend	$1,236	$1,236
Spacers	4×$400?	$1,600
Spools	2×$500?	$1,000
Gaskets	14 × $78.95	$1,105
		$20,591

Cost of Variability: ~$10,295/cavity ?

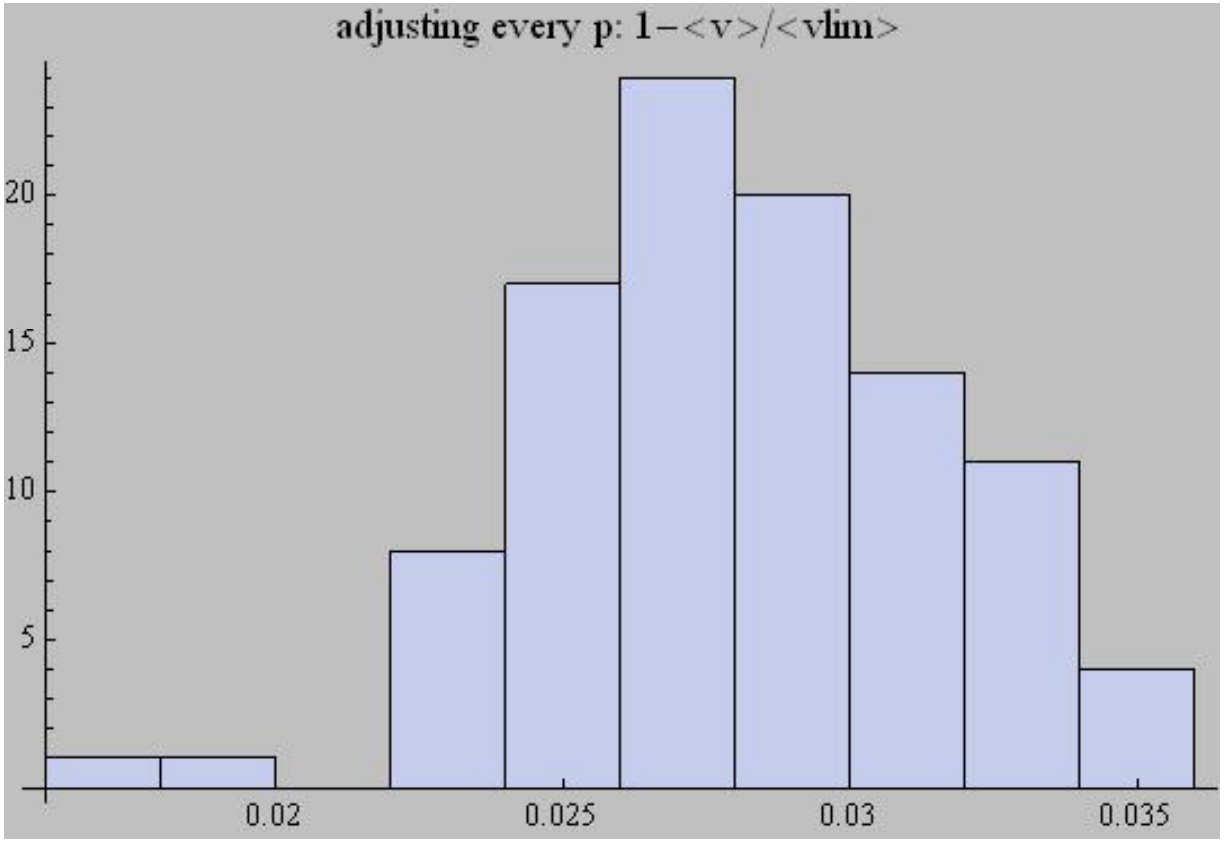
Cost Comparisons for Single Feed Systems

(Assumes 22-34 MV/m Flat Gradient Distribution)

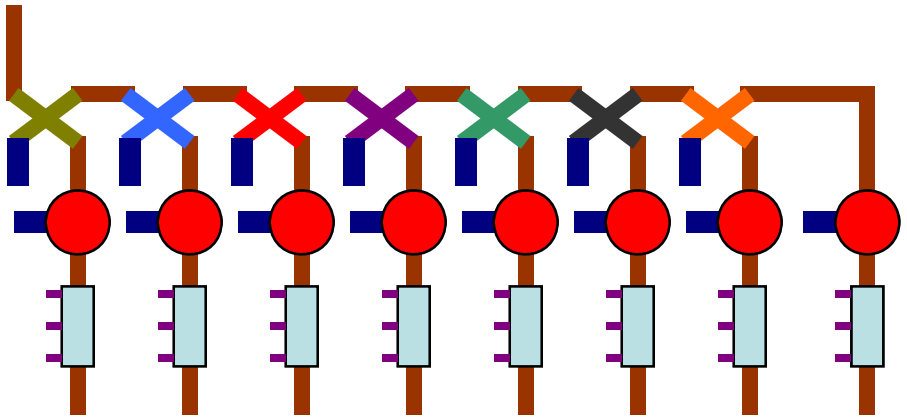
Adjustability	Cost of P+Q	Loss of Grad	Cost Of Grad	Net (M$)
P + Q	48 + 18	0	0	66
P, No Q Narrow G*	48	1.5%	75	123
No P, Q Baseline	18	2.7%	135	153
P+Q but Q common	48 + 18	3.0%	150	216

* Assumes Gaussian (4.5% sigma) gradient spread (no sorting), full wall plug power if run at lower currents and increased cooling water overhead.

Check of J. Branlard et al estimate of a 3.2% gradient loss with P adjustment but common Q: Karl Bane computes 2.8 +/- .03%



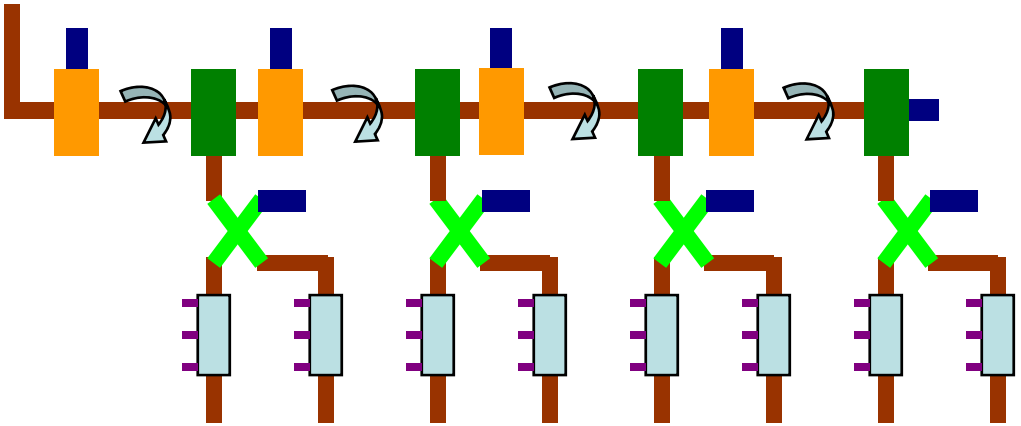
Baseline RF Distribution System



Fixed Tap-offs

Isolators

Alternative RF Distribution System



Variable Tap-offs (VTOs)

3 dB Hybrids

Gradient Optimization with and Without VTOs and Circulators

Consider uniform distribution of gradient limits $(G_{lim})_i$ from 22 to 34 MV/m in a 26 cavity rf unit - adjust cavity Q's and/not cavity power (P) to maximize overall gradient while keeping gradient uniform (< 1e-3 rms) during bunch train

Optimized $1-\langle G\rangle/\langle G_{lim}\rangle$; results for 100 seeds

Case	Not Sorted [%]	Sorted [%]
Individual P's and Q's (VTO and Circ)	0.0	0.0
1 *P*, individual *Q*'s (Circ but no VTO)	2.7 ± 0.4	2.7 ± 0.4
P's in pairs, *Q*'s in pairs (VTO but no Circ)	7.2 ± 1.4	0.8 ± 0.2
1 *P*, *Q*'s in pairs (no VTO, no Circ)	8.8 ± 1.3	3.3 ± 0.5
G_i set to lowest G_{lim} (no VTO, no Circ)	19.8 ± 2.0	19.8 ± 2.0

Cost Estimates for Various 8-Cavity Distribution System in ‘Small’ Quantities

Use Results to Gauge Whether Eliminating Isolators Is Cost Effective

Parts Cost for Baseline RF Distribution

No Power Adjustability, includes Phase Shifters Instead of 3 Stub Tuners

Hybrids (pressurizable)	8 × $6,650	$53,200
Isolators	8 × $6,500	$52,000
Pressure windows	8 × $5,663.57	$45,309
Support frame	4 × $7,500	$30,000
Phase shifters	8 × $3,300	$26,400
H-plane bends	15 × $1,236.48	$18,547
Loads (1 MW)	8 × $2,000	$16,000
Directional couplers	10 × $1,150 ($1,205MEGA)	$11,500
Gaskets	110 × $78.95	$8,685
E-plane U bends (atm.)	8 × $800?	$6,400
Flex guide (atm.)	8 × $588	$4,704
Load (5 MW)	1 × $4,000	$4,000
Spools (press.)	7 × $371	$2,597
Pressure section+inlet flange	1 × $1,000	$1,000
Nuts&bolts	4 × $250	$1,000
Flex guide(press.)	1 × $756.75	$757
TOTAL		**$282,100**

Parts Cost For ACD System with Cavities Fed in Pairs

Includes Power Adjustability (VTOs) and Phase Shifters but no Isolators

Same as First Version for FNAL expect without Isolators

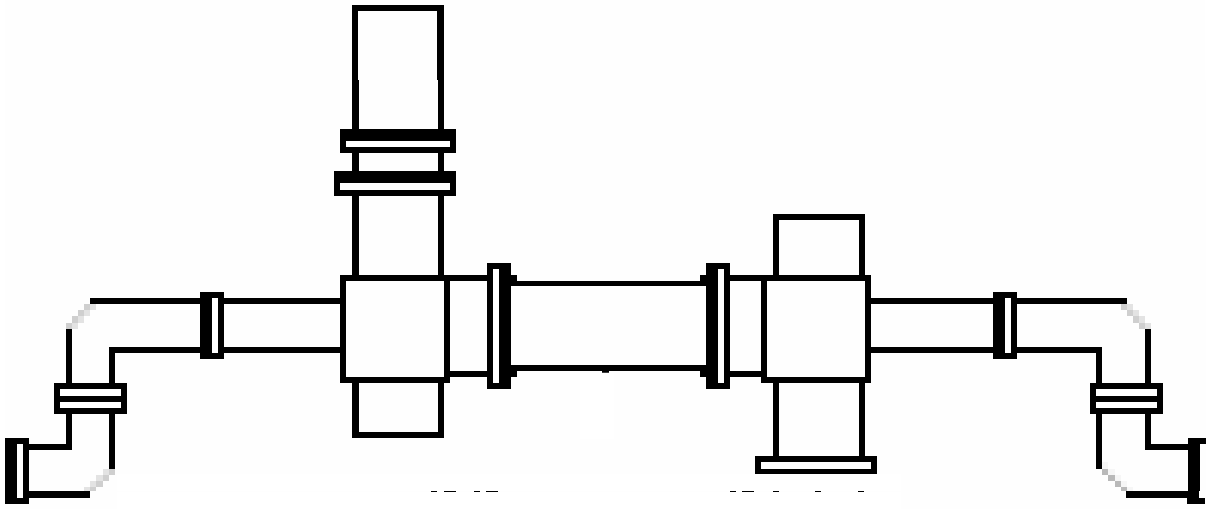
VTO's	4 × $16,900	$67,600
Support frame	4 × $7,500	$30,000
Hybrids	4 × $6,650 ($4,600MEGA)	$26,600
Phase shifters	8 × $3,300	$26,400
E-plane bends (cust.)	26 × $900	$23,400
Pressure windows	4 × $5,663.57	$22,654
Loads (1 MW)	8 × $2,000	$16,000
Directional couplers	10 × $1,150 ($1,205MEGA)	$11,500
Gaskets	112 × $78.95	$8,842
E-plane bends (6"×6")	6 × $841.12	$5,047
H-plane bends	4 × $1,236.48	$4,946
Flex guide (atm.)	8 × $588	$4,704
Load (5 MW)	1 × $4,000	$4,000
Flex guide(press.)	4 × $756.75	$3,027
~8" spools	8 × $371	$2,968
Pressure section+inlet flange	1 × $1,000	$1,000
Nuts&bolts	4 × $250	$1,000
TOTAL		**$259,688**

Economy ACD System with Cavities Fed in Pairs

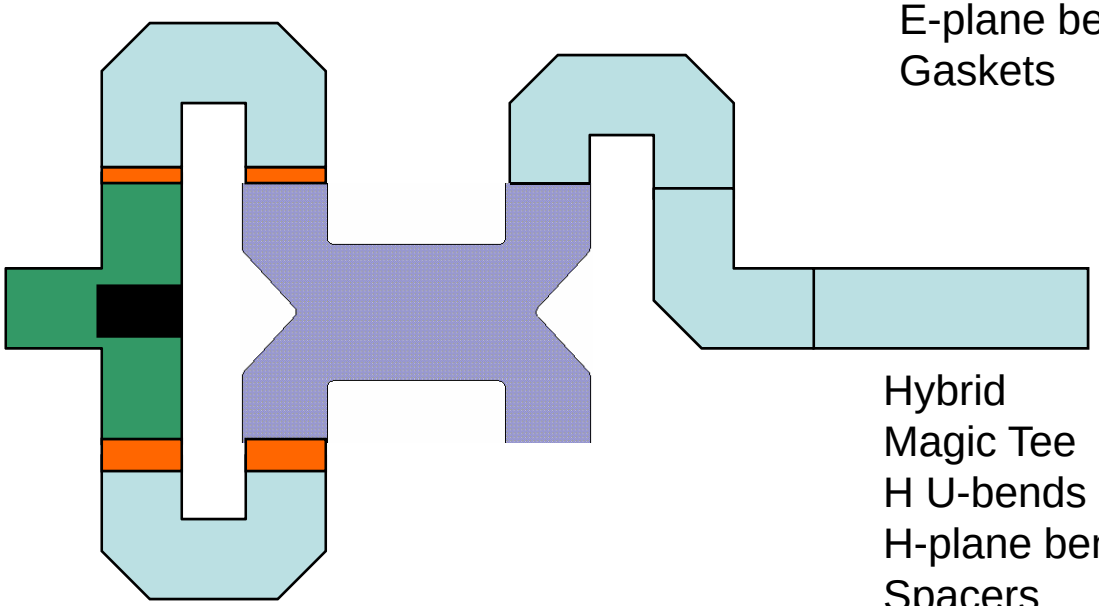
Eliminate Phase Shifters, Use Simpler Parts

VTO's	4 × $16,900	$67,600
Hybrids (atm.)	4 × $6,000?	$24,000
Support frame	4 × $7,500	$30,000
Phase Spacers	16 × $400?	$6,400
E-plane bends (cust.)	6 × $900	$5,400
Loads (1 MW)	8 × $2,000	$16,000
Directional couplers	10 × $1,150 ($1,205MEGA)	$11,500
Pressure windows	4 × $2,500 (SLAC block)	$10,000
Gaskets	112 × $78.95	$8,842
E-plane bends (6"×6")	6 × $841.12	$5,047
H-plane bends	4 × $1,236.48	$4,946
H-plane bends (atm., cust.)	8 × $747	$5,976
E-plane U bends (atm.)	8 × $800?	$6,400
Flex guide (atm.)	8 × $588	$4,704
Load (5 MW)	1 × $4,000	$4,000
Flex guide(press.)	2 × $756.75	$1,514
~8" spools (atm.)	8 × $250?	$2,000
Pressure section+inlet flange	1 × $1,000	$1,000
Nuts&bolts	4 × $250	$1,000
TOTAL		**$216,329**

VTO or Tee/Spacers/Hybrid



	$16,900	$16,900
E-plane bends	4 × $900	$3,600
Gaskets	7 × $78.95	$553
		$21,053



May be a wash!

Hybrid	$6,650	$6,650
Magic Tee	$5000?	$5,000?
H U-bends	3 × $2,000?	$6,000
H-plane bend	$1,236	$1,236
Spacers	4×$400?	$1,600
Spool	$500?	$500
Gaskets	13 × $78.95	$1,026
		$22,012

Post-installation changes easier, faster and more accurate (once replacement spacers are prepared)

Parts Cost for RF Distribution w/ Variable Coupling to Each Cavity – Economy Version

Hybrids (pressurizable)	8 × $6,650	$53,200
Magic Tee's	8 × $5,000?	$40,000
H-plane U bends (press.)	16 × $2,000?	$32,000
Coupling Spacers	32 × $400?	$12,800
Spools (press.)	24 × $400?	$9,600
H-plane bends	7 × $1,236.48	$8,655
Isolators	8 × $6,500	$52,000
Support frame	4 × $7,500	$30,000
Phase Spacers	16 × $400?	$6,400
Loads (1 MW)	8 × $2,000	$16,000
Directional couplers	10 × $1,150 ($1,205MEGA)	$11,500
Pressure windows	8 × $2,500 (SLAC block)	$20,000
Gaskets	153 × $78.95	$12,709
E-plane U bends (atm.)	8 × $800?	$6,400
Flex guide (atm.)	8 × $588	$4,704
Load (5 MW)	1 × $4,000	$4,000
Flex guide(press.)	1 × $756.75	$757
Pressure section+inlet flange	1 × $1,000	$1,000
Nuts&bolts	4 × $250	$1,000
TOTAL		**$322,095**

Summary of RF Dist Costs

(For RDR, 560 rf units at 296 k$ per system = 166 M$)

Configuration	8-Cavity Cost (k$) (small quantities)	Cost (M$) Differences Scaled to ILC	Cost (M$) due to Gradient Loss*	Net Cost Change (M$)
Baseline	282	-	135	135
ACD Two Feed	260	-13	40	27
ACD Two Feed Economy Version	216	-39	40	1
ACD One Feed Economy Version	322	+24	0	24

* For ACD Two Feed case, assume 0.8% grad loss if 26 cavities sorted in pairs by grad