RF Distribution Summary

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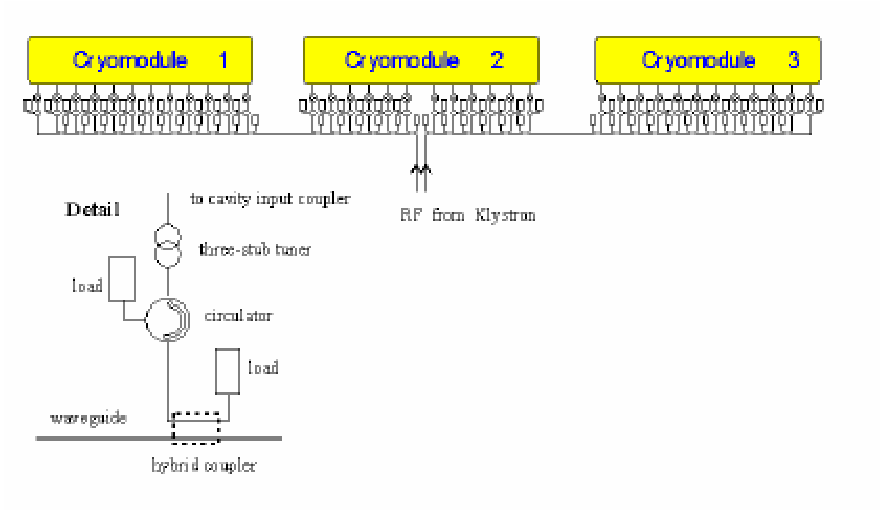
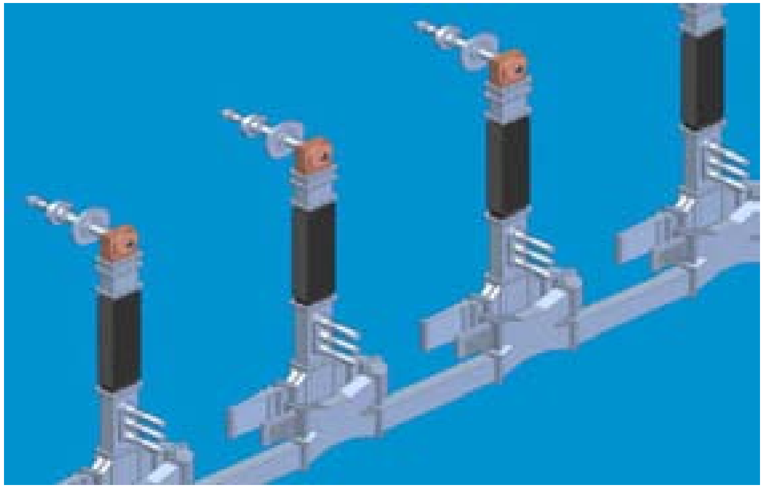
BCD Choice for RF Distribution

- **XFEL / TDR RF distribution concept should be used for the BCD**
  - it is a mature design
  - it does not need significant R&D to work
  - it is possible to cost with contingency
  - there is a clear path forward to validate design ==> XFEL





BCD RF Waveguide Components

3 Stub Tuner (IHEP, Bejing, China)

Changing phase, degree	±60
Impedance matching range	$1/3Z_w \div 3Z_w$
Max power, MW	2

* Z_w – waveguide impedance

E and H Bends (Spinner)

Circulator (Ferrite)

Type	WFHI 3-4
Peak input power, MW	0.4
Average power, kW	8
Min isolation at 1.3 GHz, dB	>30
Max insertion loss at 1.3 GHz, dB	≤0.08
Input SWR at 1.3 GHz (for full reflection)	1.1

Hybrid Coupler (RFT, Spinner)

Directivity, dB	>30
Return loss, dB	>35
Coupling factor, dB (due to tolerance overlapping only 13 different coupling factors instead 18 are necessary)	12.5; 12.0; 11.4; 10.7; 10.1; 9.6; 9.1; 8.5; 7.8; 7.0; 6.0; 4.8; 3.0
Accuracy of coupling factor, dB	±0.2

RF Load (Ferrite)

Type	WFHLL 3-1
Peak input power, MW	1.0
Average power, kW	0.2
Min return loss at 1.3GHz, dB	32÷40
Max VSWR at 1.3 GHz	≤1.05
Max surface temperature, ΔT °C (for full average power)	50
Physical length, mm	230

RF Load (Ferrite)

Type	WFHL 3-1	WFHL 3-5
Peak input power, MW	2.0	5.0
Average power, kW	10	100
Min return loss at 1.3 GHz, dB	32÷40	32÷40
Max VSWR at 1.3 GHz	<1.05	<1.05
Max surface temperature, ΔT °C (for full average power)	20	30
Physical length, mm	385	850

BCD Choice Assessment

- **Pros (technically solid)**
  - Benefits by 10 years experience on TTF
  - Has been well developed for XFEL start and will continue
  - Circulators provide high degree of isolation to protect klystrons
- **Cons (costly)**
  - A few too many knobs, e.g. 3 stub tuner AND adjustable coupler
  - A big number of more expensive components: circulators, stub tuners, high power loads
- **Potential Modifications / r&D**
  - Combine functionality to reduce piece-part count (presently at ~ 220,000 parts!)
  - Need new manufacturing approaches to reduce effort in fabrication
  - Need to better understand where tolerances can be relaxed
  - Manage design margin on entire system, not individual pieces (applies across ILC…)

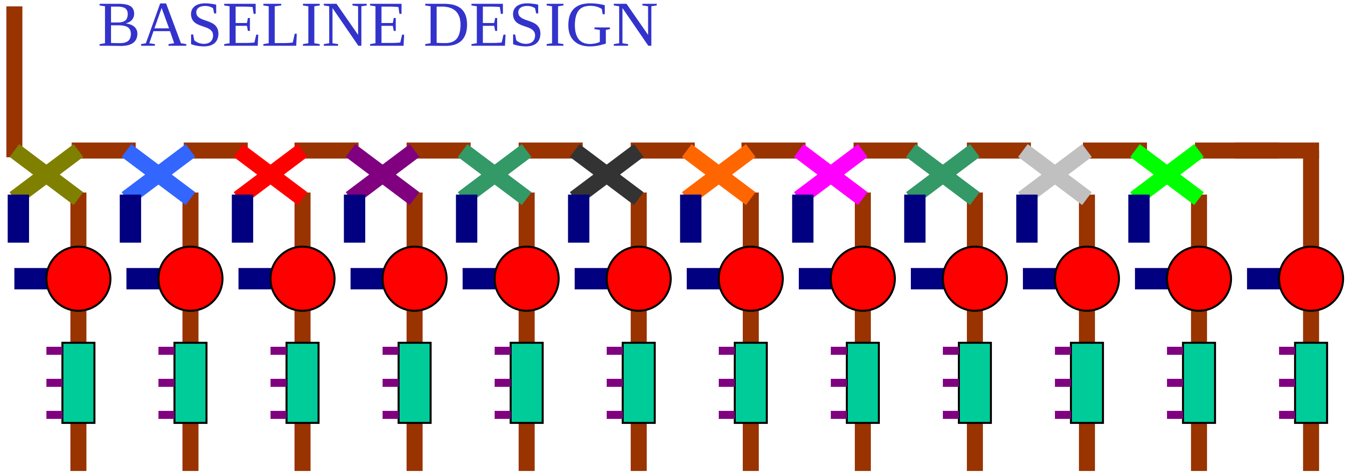
ACD Choices

- **Alternative splitting schemes to eliminate the circulators and reduce cost**
  - 2 level splitting with hybrids at the cavity
  - Larger reflection minimization schemes (Tantawi)

- **Technology improvements to increase efficiency and operability**
  - More optimized splitting schemes to take best advantage of power (Choroba)
  - Circulator load energy converter to take 1.3 GHz to DC (Foster)
  - Increase distribution agility to take advantage of available gradients

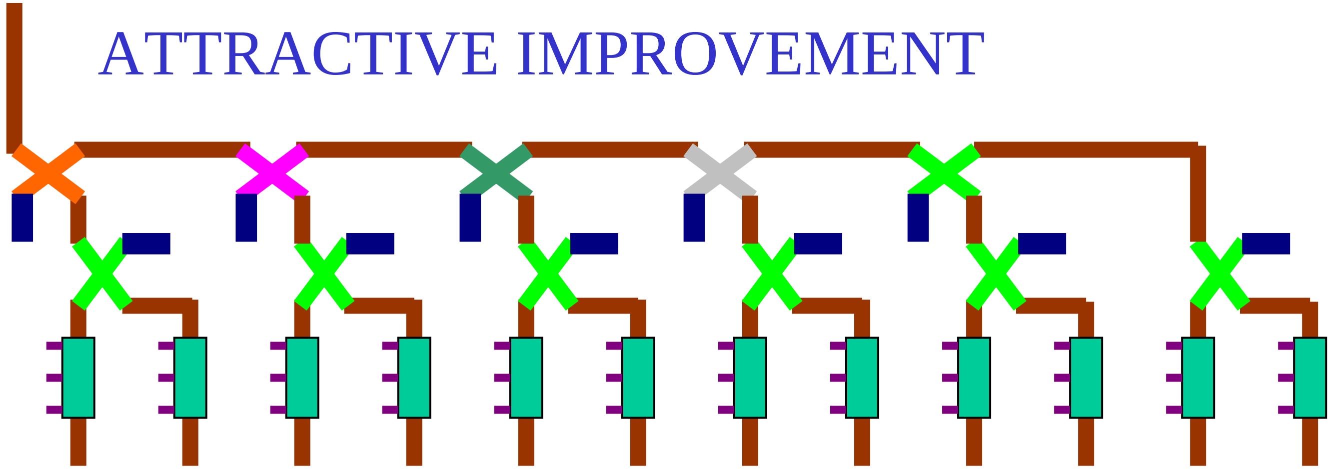
- **Present choices for ACD not sufficiently developed for Pros/Cons/Impact/R&D/Time Scale assessment**

BASELINE DESIGN



Similar to TDR and XFEL scheme.

ATTRACTIVE IMPROVEMENT



With two-level power division and proper phase lengths, expensive circulators can be eliminated. Reflections from pairs of cavities are directed to loads. Also, fewer types of hybrid couplers are needed in this scheme. There is a small increased risk to klystrons. (Total reflection from a pair of cavities sends <0.7% of klystron power back to the klystron.)

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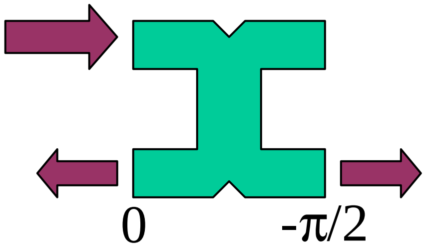
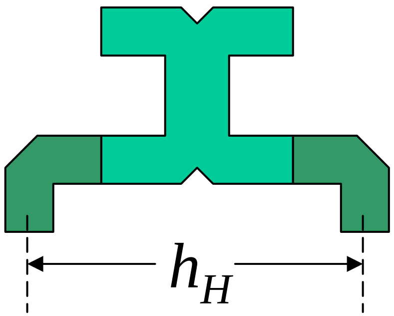
Phase Length Considerations



For cavity phasing: $-\frac{\pi}{2}-\beta(P-h_H)=-k_0P+2n\pi$

For reflection cancellation: $\beta(P-h_H)=m\pi$



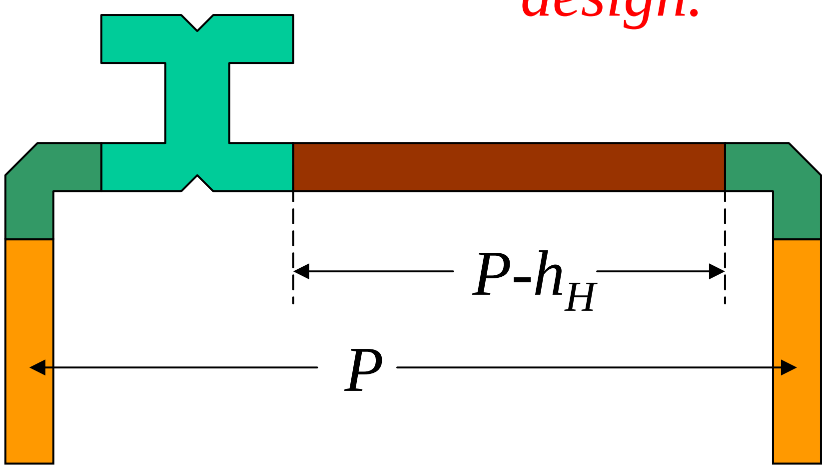
Note impact on cavity design.

$$P=\frac{(2n+m+1/2)\pi}{k_0}$$

$$=(2n+m+1/2)\times 0.115305\text{m}$$

$$h_H=P-\frac{k_0P-(2n+1/2)\pi}{\beta}$$

$$=P-\frac{m\pi}{\beta}=P-m\times 0.161104\text{m}$$



n=3, *m*=5: → **P=1.3260m** = 52.205”, **h_H=0.52049m** = 20.492”

Since 3-stub tuners have limited range, phase lengths between pairs of cavities must also be considered, but this should be doable with directional coupler and waveguide design without impacting the cavities.

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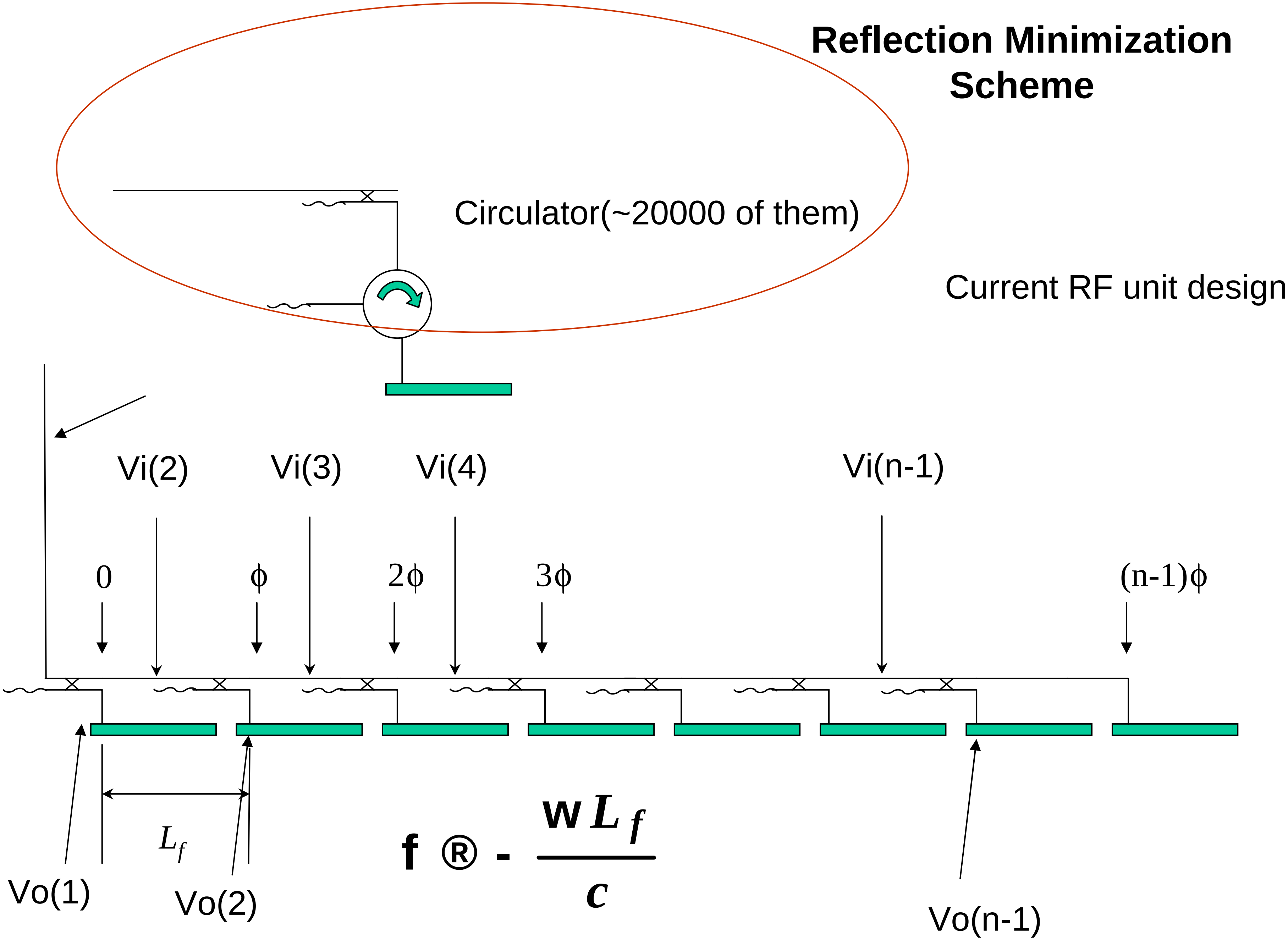
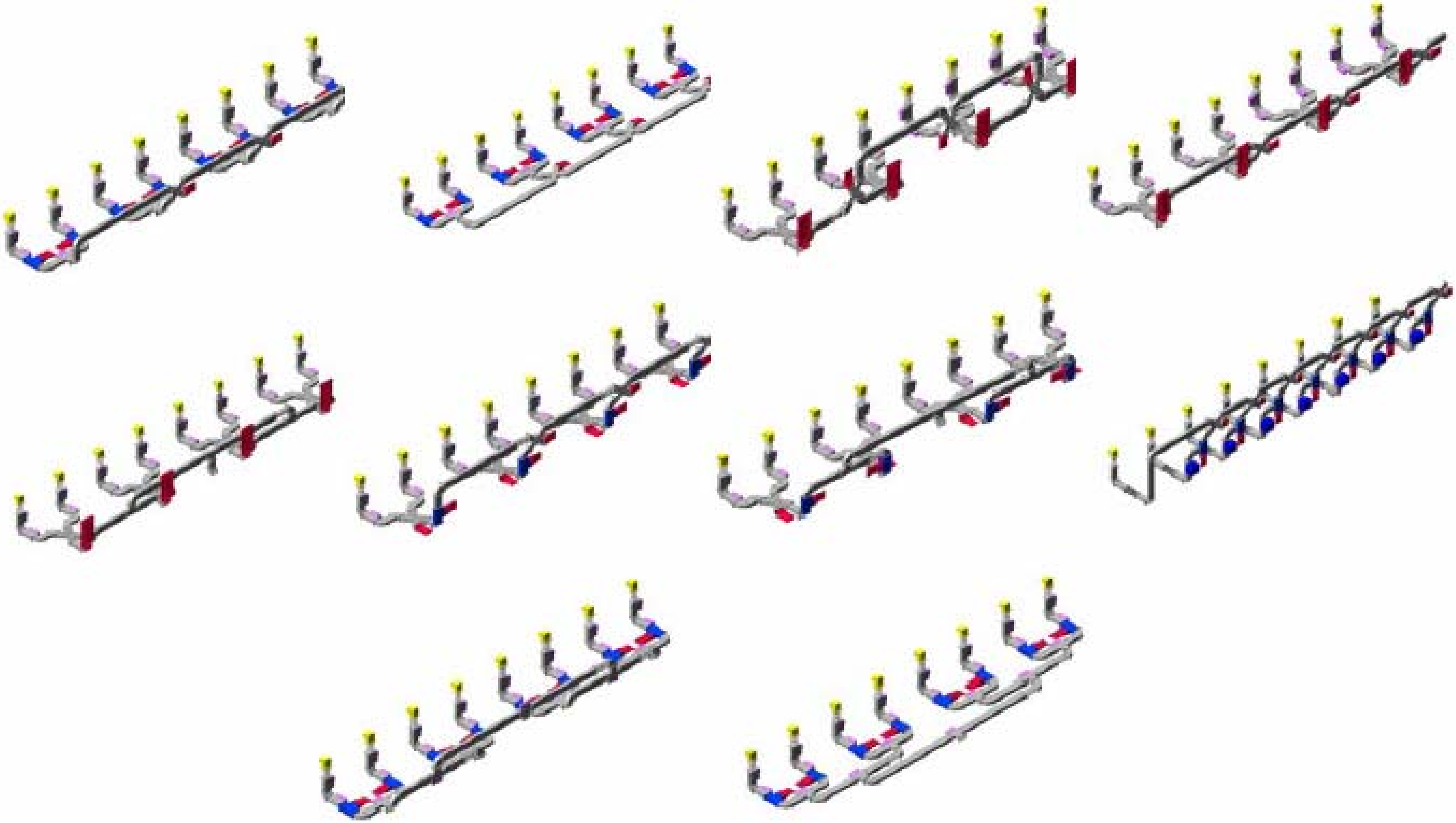
Reflection Minimization Scheme



$$\phi \rightarrow -\frac{\omega L_f}{c}$$

Alternative Waveguide Distribution Schemes



RF Distribution Conclusions

- **BCD**
  - The TDR / XFEL RF distribution scheme is a reasonable choice for the BCD
  - It is a technically workable approach that will be expensive
  - R&D on the BCD is mainly on reducing cost and part count

- **ACD**
  - Alternative splitting schemes need to be evaluated further for reducing cost
  - Additional technology evaluations to increase system efficiency and fault agility need to be done