RF Sources for Project X

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Fermilab
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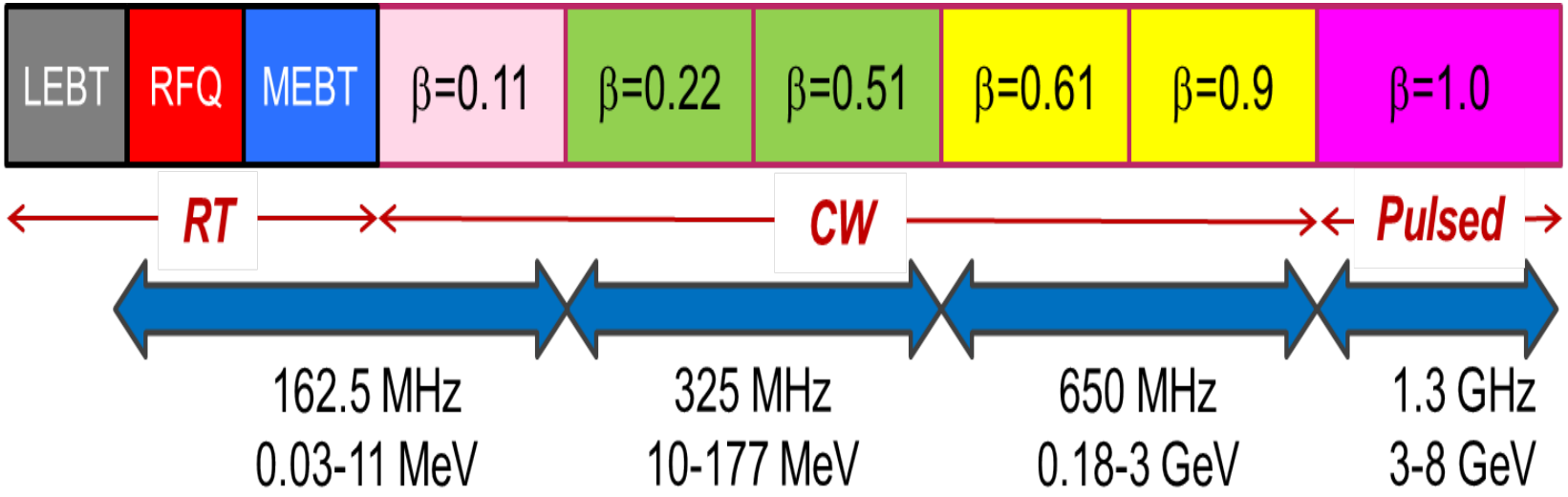
Outline

- List of RF systems for Project X
- Basic Block Diagram
- RFQ 162.5 MHz, 2 Bruker 75 kW solid-state
- Coupler test stand 162.5 MHz, 10 kW Thomson solid-state amp
- Coupler test stand 325 MHz, 10 kW Bruker solid-state amp
- 650 MHz IOT amplifiers
- 1.3 GHz Klystrons
- Separator cavities
- Solid-state R&D
- Injection Locked Magnetrons
- PXIE

Linac Layout

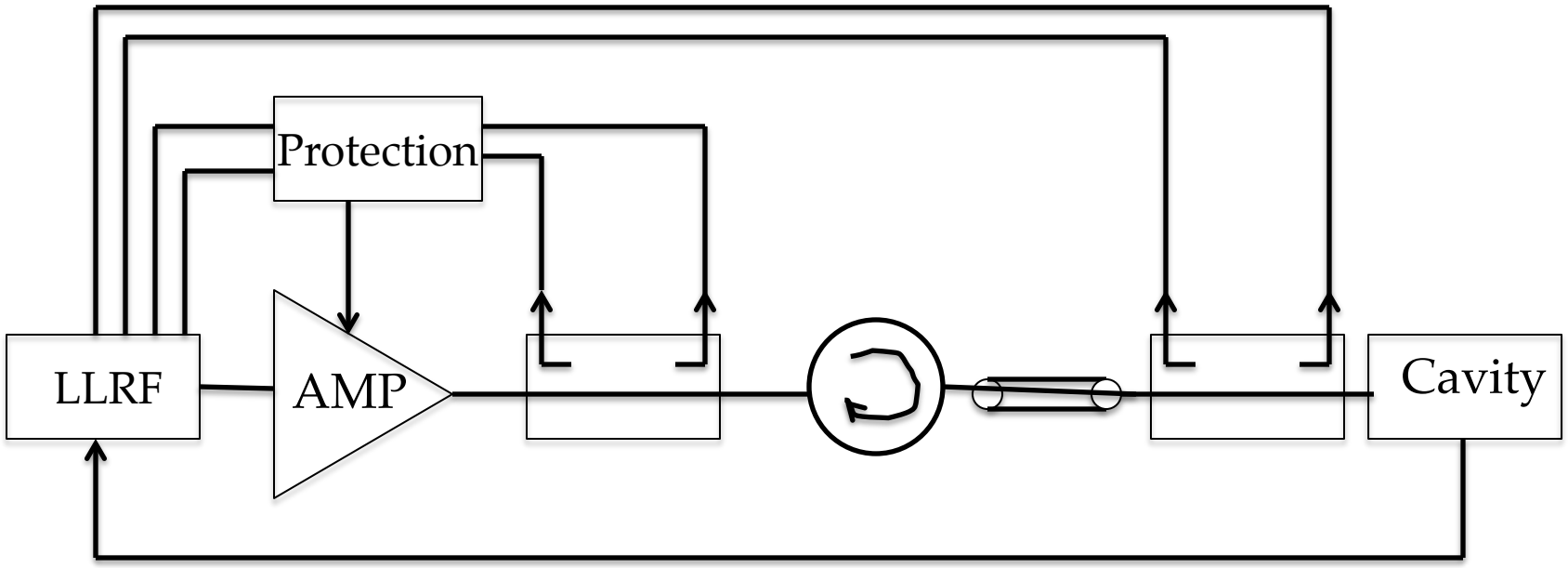


PXIE RF Power Sources

Project X: 2 mA to 1 GeV, 1 mA to 8 GeV

• RFQ:	2	75 kWatt solid-state 162.5 MHz
• Bunchers:	3	4 kWatt solid-state 162.5 MHz
• HWR:	8	4 kWatt solid-state 162.5 MHz
• SSR1:	16	7 kWatt solid-state 325 MHz
• SSR2	35	10 kWatt solid-state 325 MHz
• LB 650	30	60 kWatt IOT 650 MHz
• HB 650	42	60 kWatt IOT 650 MHz
• HB 650	120	30 kWatt IOT 650 MHz
• ILC 1.3	28	500 kWatt Klystron 1.3 GHz
• Separators	2	4-10 kW various frequencies
	286	Total RF systems

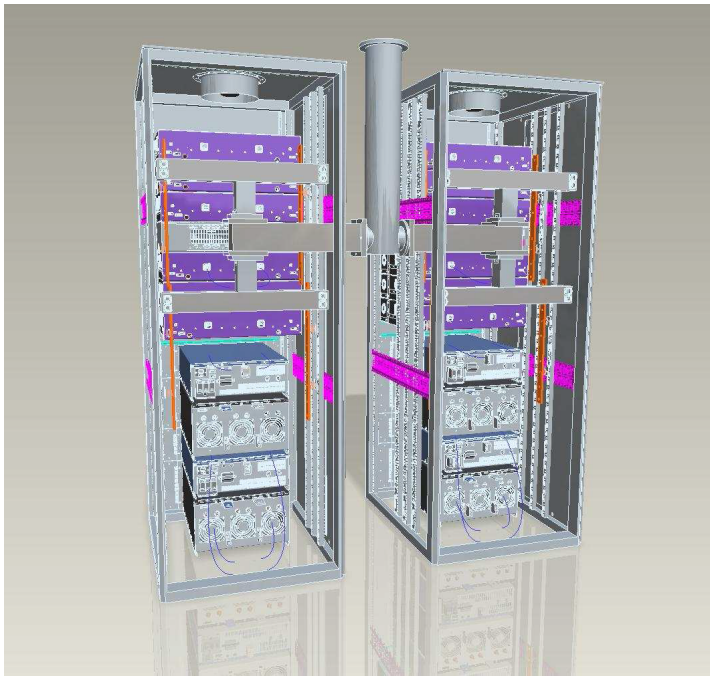
CW Basic RF Block Diagram



One Amplifier per Cavity

RFQ Amplifier

BRUKER *is now* SIGMAPHI ELECTRONICS

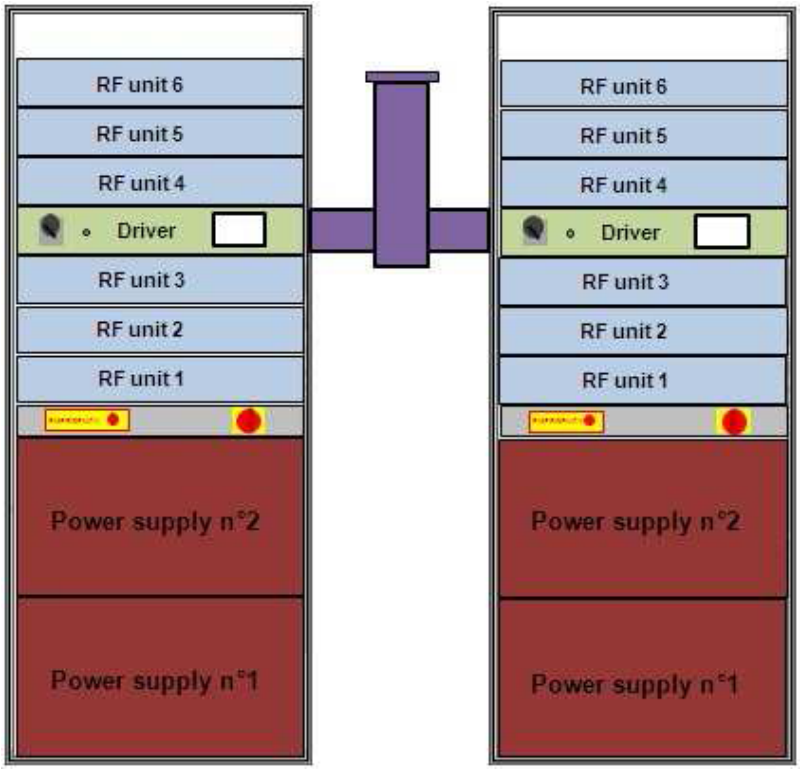


Front view Rear view

Solid-state 75 kW RFQ amplifier

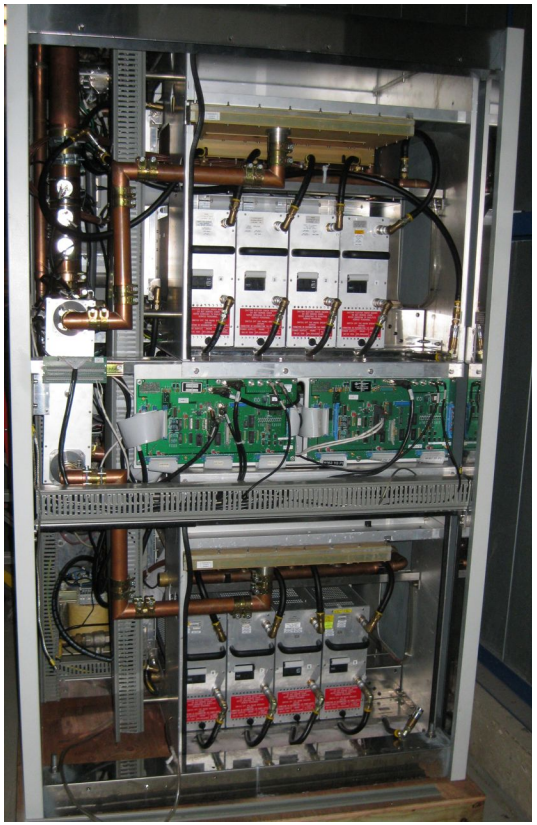
RFQ Amplifier

Each RF unit
Delivers approx 7 kW
RF modules and
Power supplies
Are water cooled
For enhanced reliability



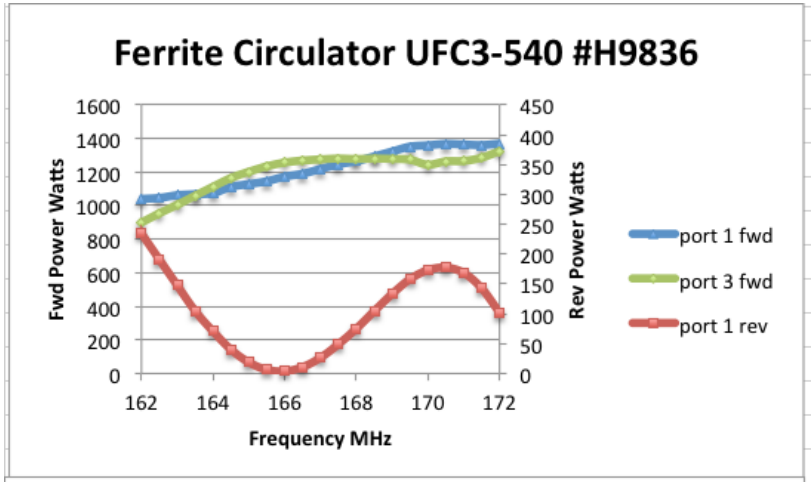
Front view

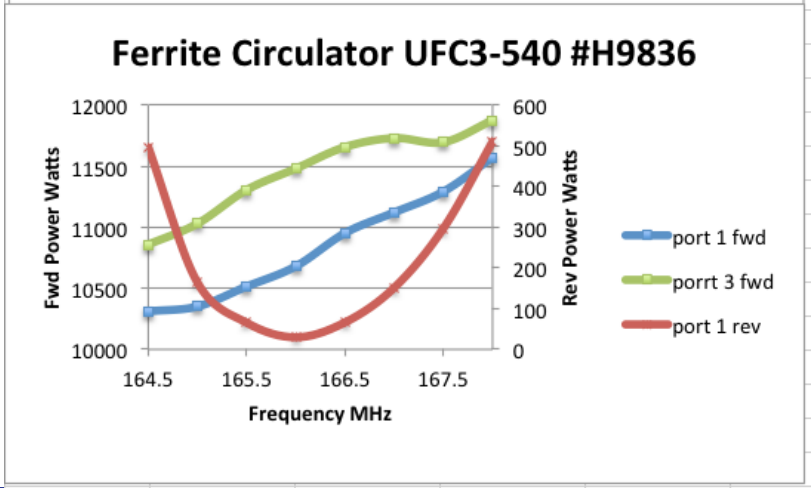
Refurbished 162.5 MHz VHF TV transmitter



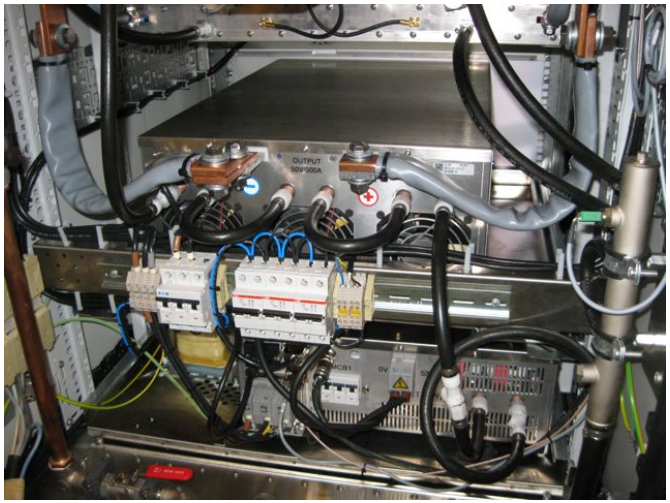
Thomson 10 kW Solid-state amp for testing HWR couplers at Argonne

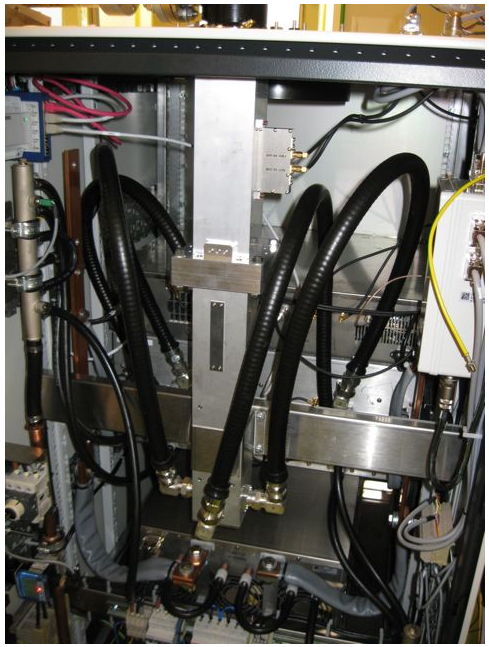
Preliminary Test of 75 kW 162.5 MHz Circulator





Solid-State Amps





10 kW 325 MHz coupler test stand solid-state amplifier

Solid-State Amps

325 MHz 10 kW Solid-state
amp for coupler test stand @ MDB

30 kW 650 MHz IOTs @ MDB

650 MHz 60 kW Circulator Test

1.3 GHz RF @ NML

Separator Cavity

Various Frequency Separator Cavities
1.5x162.5 MHz=243.75 MHz for PXIE (2 way split RT)
(n)x81.25 MHz for 1 GeV (two way split SC)
(n+1/4)x81.25 MHz for 3 GeV (three way split SC)
With individual solid-state amplifiers
Power levels varying between 4-10 kW
Driving a transverse deflecting cavity for
Measuring extinction ratio of adjacent buckets in PXIE
Kicking beam between experiments @ 1 GeV and 3 GeV

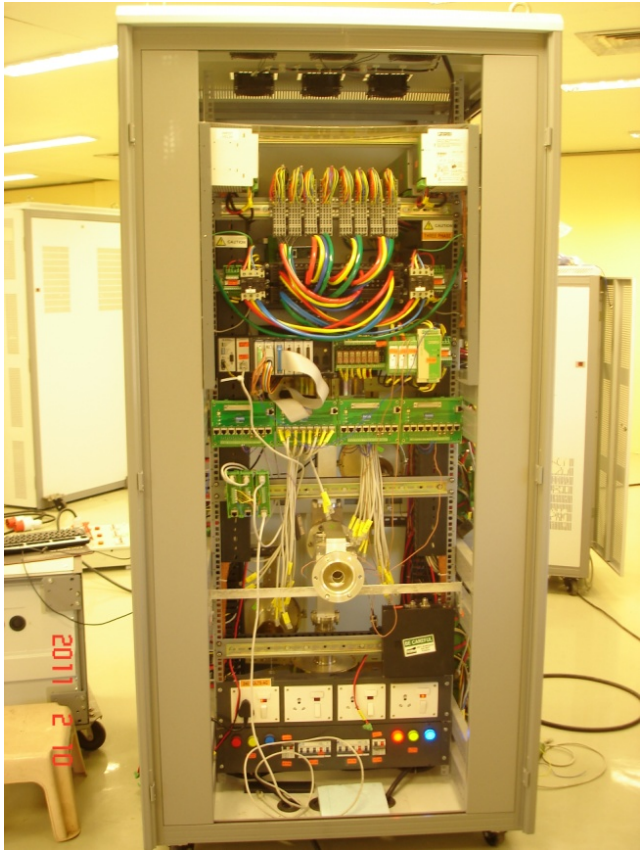
325 MHz @ BARC, Mumbai India

	Combined Output power (W)	Efficiency (DC/RF) %	Gain (dB)	comments
1	3000	69.76	21.5	Short term testing
2	3200	71.27	21.5	Short term testing

Four RF amplifier modules have been tested up to 900 Watt (max). Then, they are operated at 750 W and 800 W, combined to get 3 kW and 3.2 kW respectively.

RRCAT 8 kW ,505.8 MHz Amplifier Indore, India

Front View of 8 kW SSPA



Rear View of 8 kW SSPA

HIGH-EFFICIENCY RF POWER-AMPLIFIERS FOR PROJECT X

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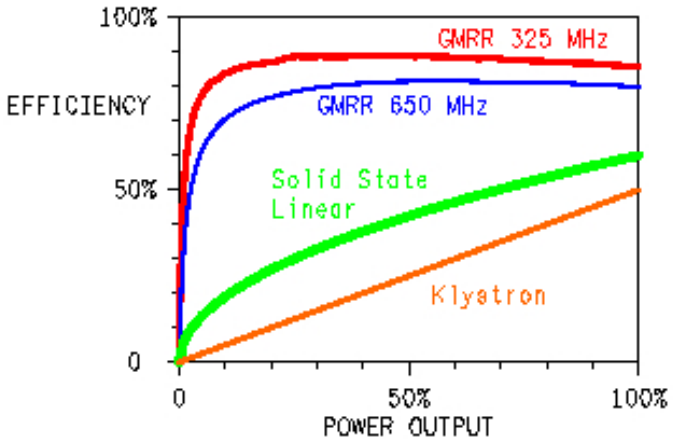
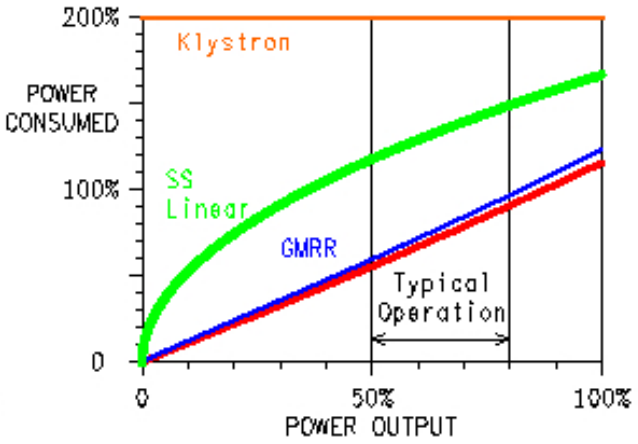
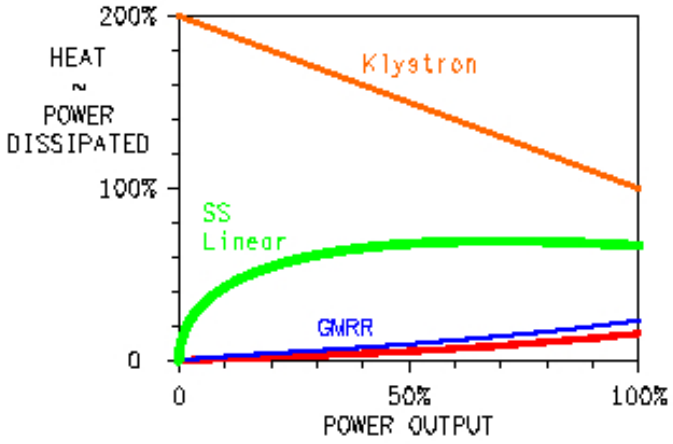
SBIR Phase I and Phase II -- DE-SC0006200

EFFICIENCY - WHY?

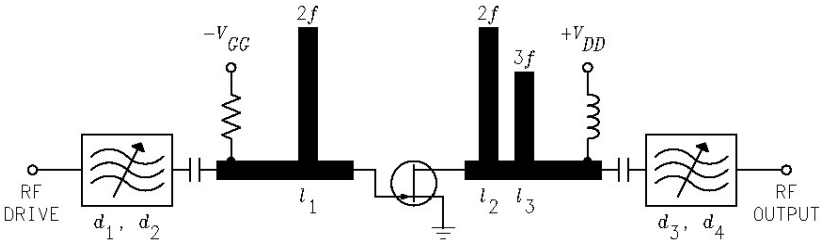




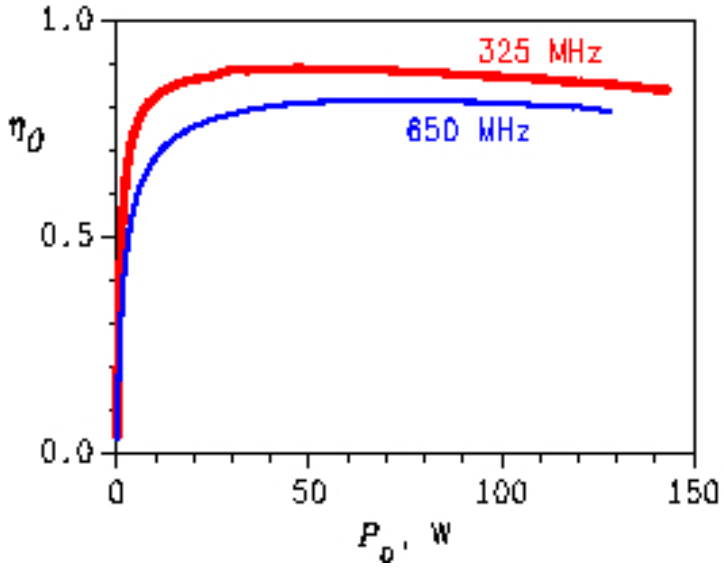


- ***Operating cost***
- ***Cooling requirements***
- ***Reliability***

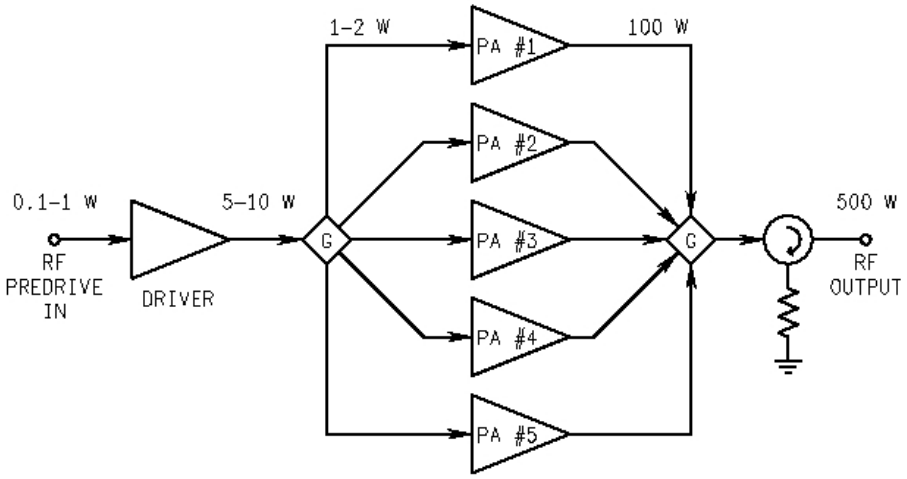
RF-POWER AMPLIFIER

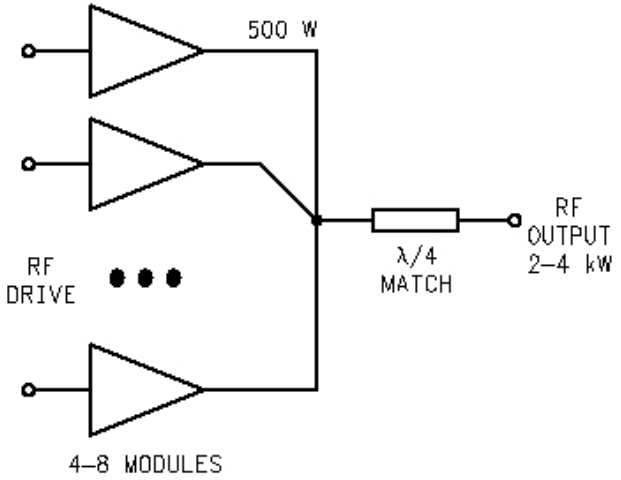


- 120 W
- GaN FET
- 325 MHz - 86%
- 650 MHz - 80%



COMBINING





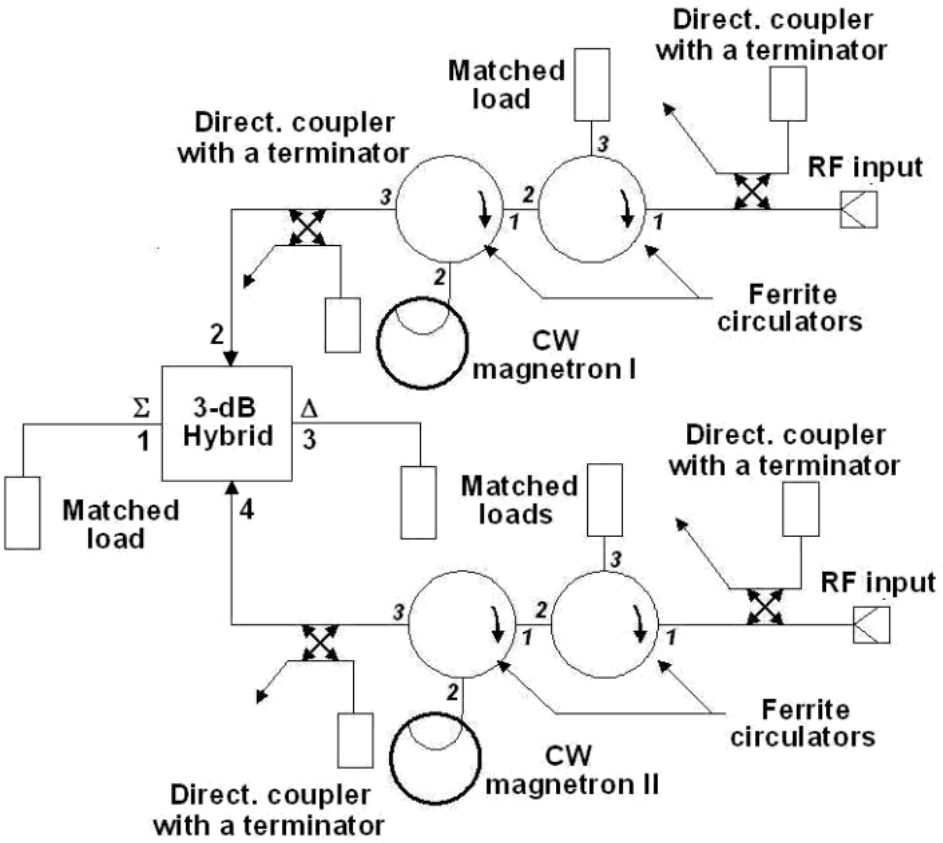
- BASIC MODULE
- 5 PAs
- Hybrid combiner
- 500 - 600 W

- HIGHER POWER
- 2 - 8 PAs
- Radial combiner
- 1 - 4 kW

Dual 650 MHz Injection Locked Magnetrons Paraphased 60 kW RF Source

Fermilab

Muons Inc.



Why magnetrons?

- *Magnetrons exceed 80% efficiency, goal 50% minimum in paraphase mode.*
- *In quantities of 50 plus 30 kW magnetrons cost drops to $8K $2-3 per Watt for system of two paraphased less than half the cost of other solutions*
- *Injection locking is proven technology*
- *Gain on order of 15-17 dB requiring 500-1000 watts drive power*
- *Drive could be solid-state or a second magnetron*
- *Proven highly sophisticated LLRF controls for paraphasing*
- *Acceptable phase noise performance?*

PXIE RF Distribution @CMTF