ECH/EBWSystem Devlopment Options for NSTX

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Near term experiments to further EBW/ECH research on NSTX

- Demonstrate coupling ASAP
  - Low cost experiments needed
  - O-X-EBW greatest priority but X-EBW of interest too
  - Use modulated medium power source and EBE to study coupling efficiency
  - Use reflected power for X-EBW to study coupling efficiency
  - Optimize launch angle, density profile
  - Use information gained to guide further development

Ideas

- Experiments with existing hardware
  - EBE coupling studies
    - Existing- improved launcher? 25K$?
  - 18 GHz ECH PI modulated experiments
    - Existing- improve launcher ? 25K$
- Experiments with new hardware
  - 14 GHz 50 kW,20 ms(?) (new;tube and PS exist) $100k
  - Design/build 14-28 GHz inside launcher $75K
  - 40 kW 15/28 GHz system (existing hardware) $150K
  - 200-800 kW 15/28 GHz system (existing hardware) $750-1500K
  - 500 kW 8 GHz system (investigate loan) $750K

Need proof of principle test ASAP

- Existing launchers could be improved
  - Pattern, Launch angle, Polarization
- O-X-EBW of greatest interest for off axis CD
  - 14-28 GHz frequency range can provide useful results
- X-EBW for heating & physics understanding
  - Simplest launcher configuration
  - Density profile may require more limiter work

18 GHz ECH-PI system tests

- Use ECH PI system with modulation
  - Existing system provides normal launch; decent beam pattern; 30 kW safely available (don't ruin preionization)
  - Limiter provided by ICRF BN
  - Polarization rotated to optimum X mode angle (0 & 90° used so far)
- Reroute waveguide to 30 degree location for O-X-B
- EBE system might show heating by looking for modulation
- Reflected power signals could indicate coupling
- Need ~ 2 man months to perform these experiments

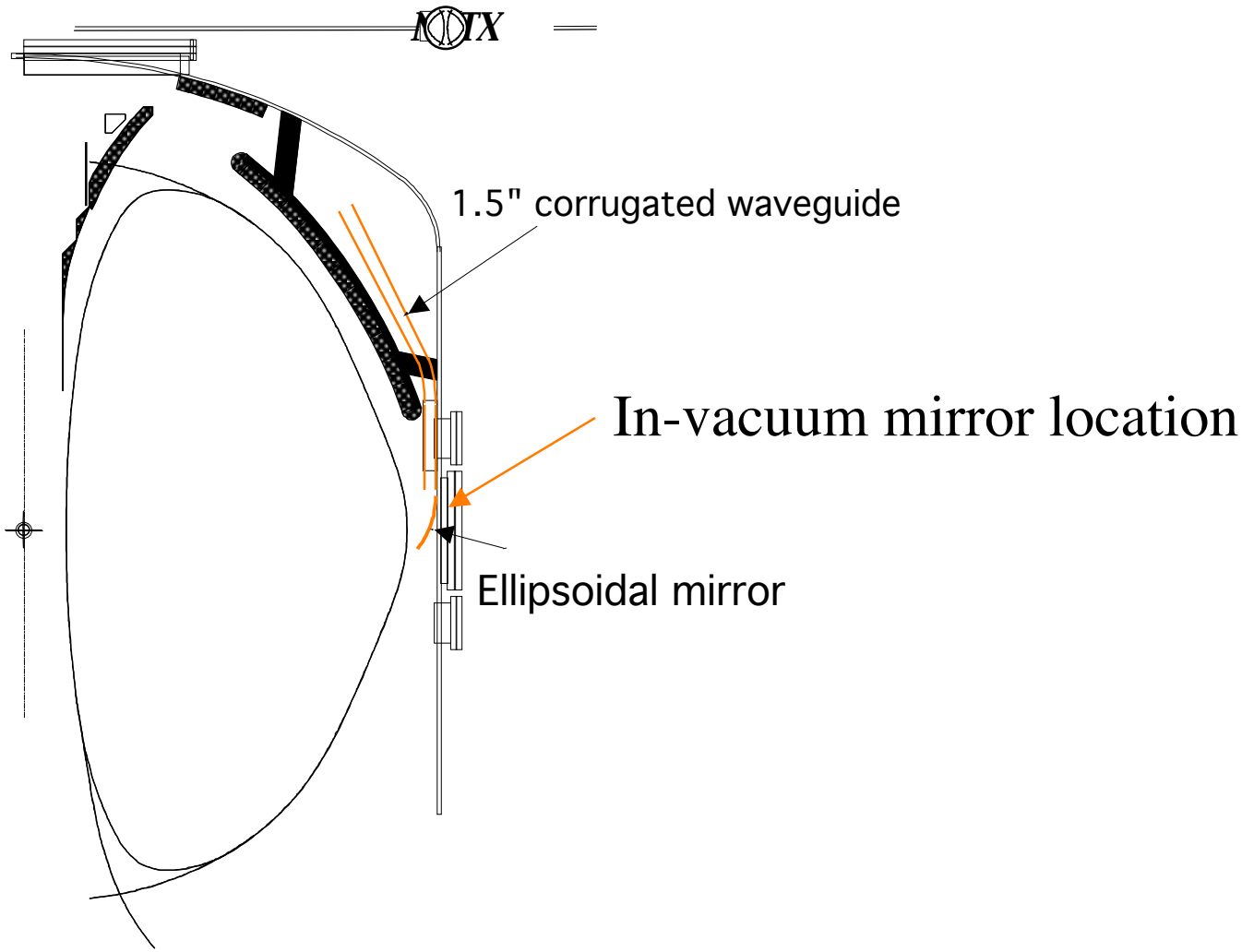
Advanced launcher design

- An in-vacuum launcher should be designed and built
- Optimum O-X-EBW angle 30-40° from normal and doesn't vary much
- In-vacuum provides best beam pattern for least port space
- Top or bottom ports available for waveguide feed
- Low cost initial fixed angle design has minimal risk but providesup to 90% coupling
- Several un-occupied regions available
- $75 K should provide useful hardware; need PPPL help for installation
  - Possibly move 1 internal water line
  - Vacuum testing and approval

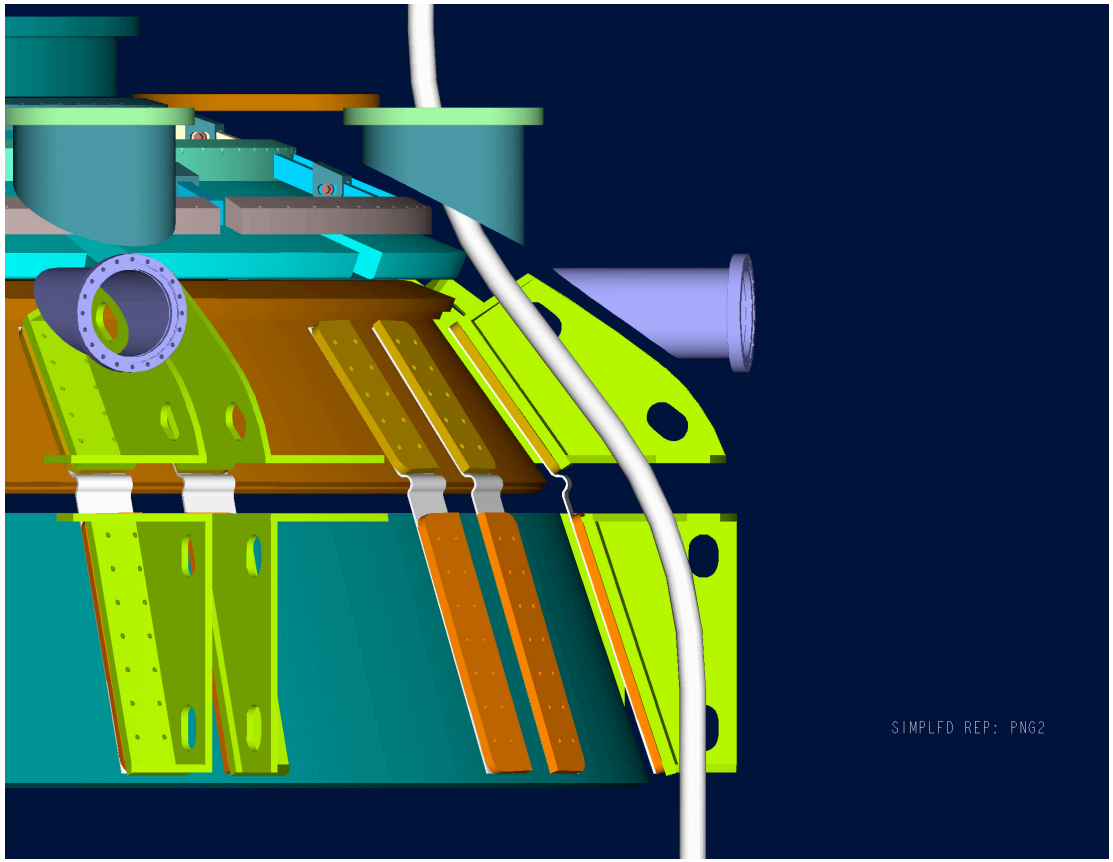
Advanced launcher design (continued)

- Polarization can be adjusted external to the vacuum with circular waveguide feed
- Frequency range of 14-28 GHz can be probably be handled
- Also useful for EBE experiments
- Beam patterns and waveguide bend performance can be calculated soon
- Window match and power level
- Later upgrade of pointing angle can be added with additional funds

Backup


1.5" corrugated waveguide
In-vacuum mirror location
Ellipsoidal mirror

Inside waveguide route looks feasible



Power system options

- 15/28 GHz 40 kW portable system
- Upgrade to 200 KW with bigger power supply
- Upgrade to 1.6 MW with more gyrotrons & PS modulator
- Upgrade to 4 MW with new gyrotrons; more power supply modulators

15.3/28 GHz 40 kW "portable" system

- Install medium power 28 GHz system in FY2004
- Perform coupling & startup experiments in FY2005
- Controls, magnet, waveguide compatible with later high power upgrade

Medium power 28 GHz recently available from Y12

- Small, self-contained “industrial heating” system
- Estimated pulsed power capability : 40 kW for 500 ms
- Allows initial EBW tests at 28 and possibly 15 GHz with minimal investment
- Allows 28 GHz ECH startup investigation
- Many components compatible with later >300 kW upgrade

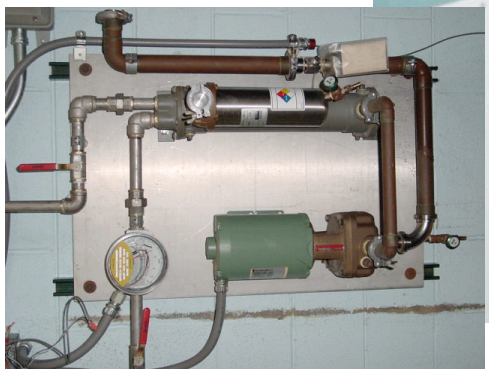
Gyrotron, HV Power supply
Socket, Magnet, water manifold

System description

- Existing Varian industrial microwave heating system
  - 28 GHz pulsed gyrotron
  - 45 kV, 1.25 A cw power supply
  - 28 GHz magnet, socket, power supplies
  - Control cabinet, cables
  - FC-75 window cooling system
  - Good documentation exists
- New waveguide and launching system
  - TE02 transmission, mode converter, launcher
- New remote controls

Control Cabinet

FC-75 Sys



Magnet Power Supplies

14 GHz systems

- A 5 kW cw 14 GHz klystron is available
- Can likely deliver 50 kW 20 ms pulses with an appropriate power supply
- Setup to perform modulated power experiments with EBE to study coupling
- Investigate ways to minimize cost (mainly power supply and controls)

Test 28 GHz gyrotron at 15.3 GHz

- Provides existing high power (>200 kW?) source for EBW CD experimens with minimal investment/time
- Cavity resonates in TE01 mode at 15.3 GHz
- Preliminary tests of beam transport at 0.6 T looked reasonable
  - Body current a little high; needs more adjustment
- CPI agreed to calculate optimum settings
- CW tube in socket at ORNL ready to test
- $ 30 K effort to perform dummy load test

8 GHz system ?

- Investigate loan of possibly unused Varian 8 GHz, 500 kW tubes (2 were built) from FTU
  - (they may be using newer Thomson tubes for current experiments)
- High power X-EBW heating experiment
- Stefano has provided contact info

CPI 14 GHz Gyrotron

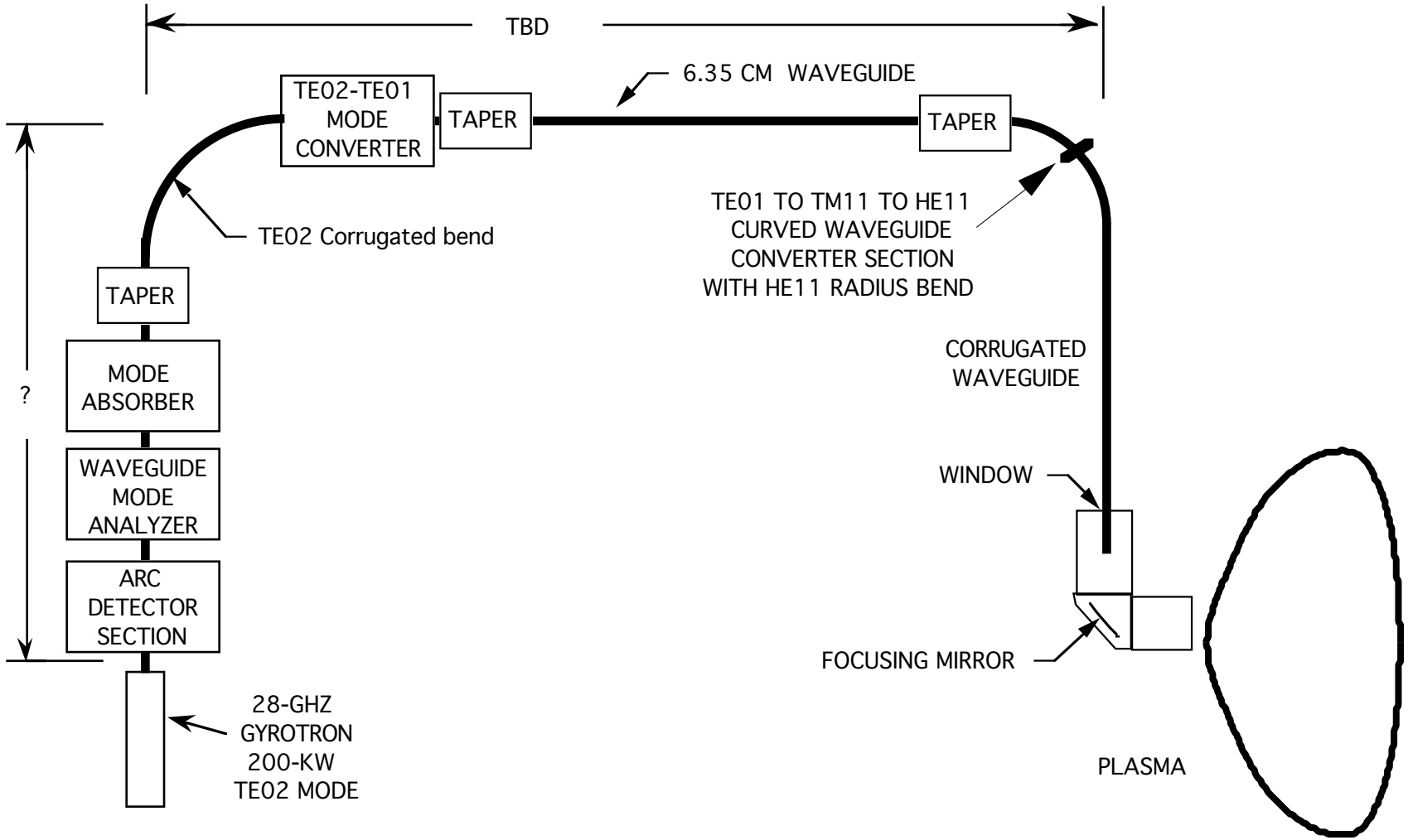
- Discussions with CPI have yielded preliminary recommendations
  - 1 MW 14 GHz design probably easy
  - Axial design with radial beam extraction
    - used on quasi successful 1 MW 110 GHz design
  - TE03 or TE62 mode
  - Double disk sapphire or alumina window
  - Will likely cost ~ 1 M,1year to design/build first unit
- External waveguide mode conversion to HE11
  - TE03 to TE01 to TM11 to HE11

Thomson 8 GHz gyrotron may work at 14 GHz?

- Thomson 8 GHz design exists
  - 1 MW cw
  - TE511 mode
- Could operate at ~14 GHz
  - TE521 mode
  - Tune output with double disk window
- FTU has 6 of them
  - Stefano has provided contact info

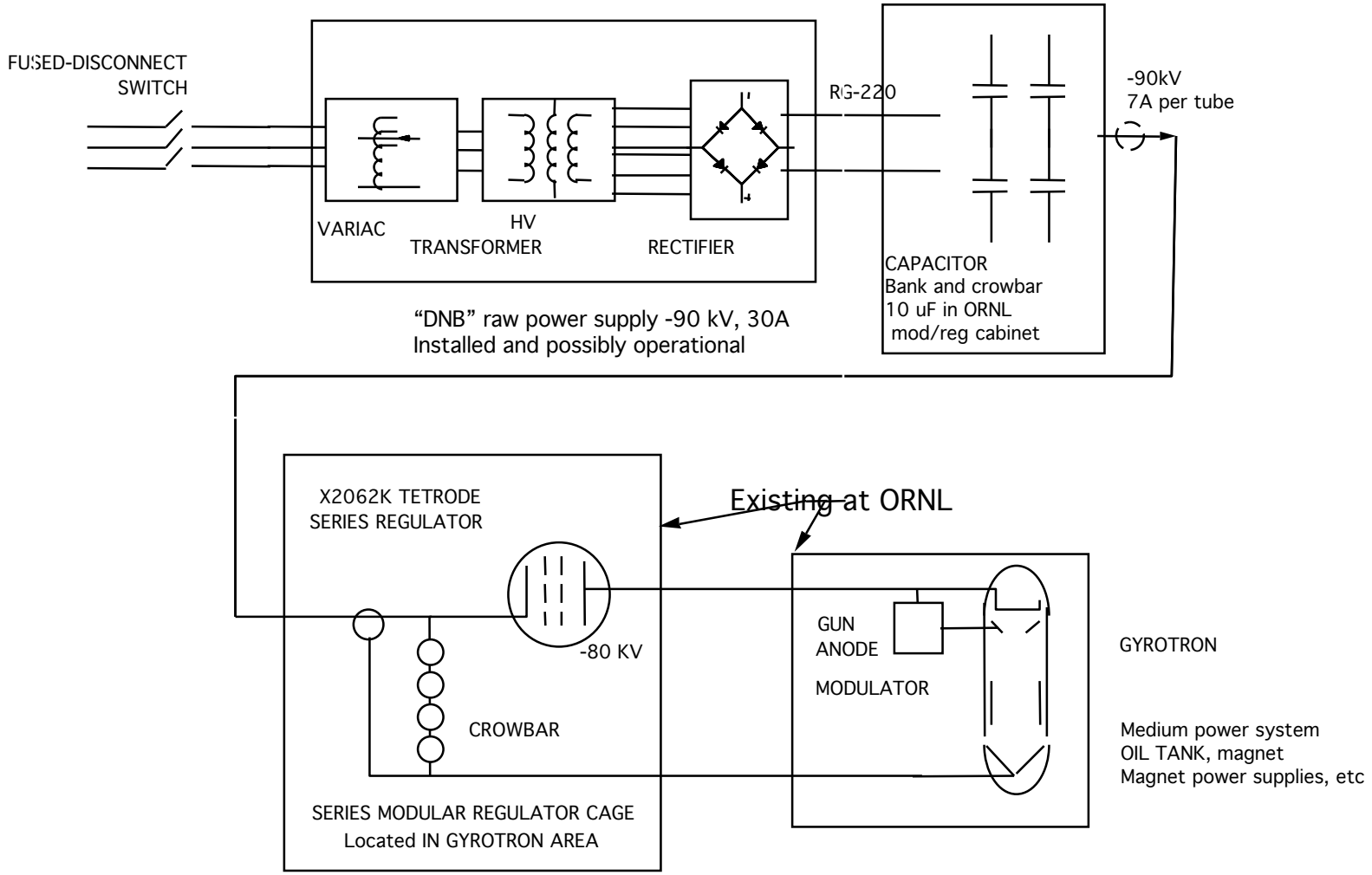
Transmission lines & launchers

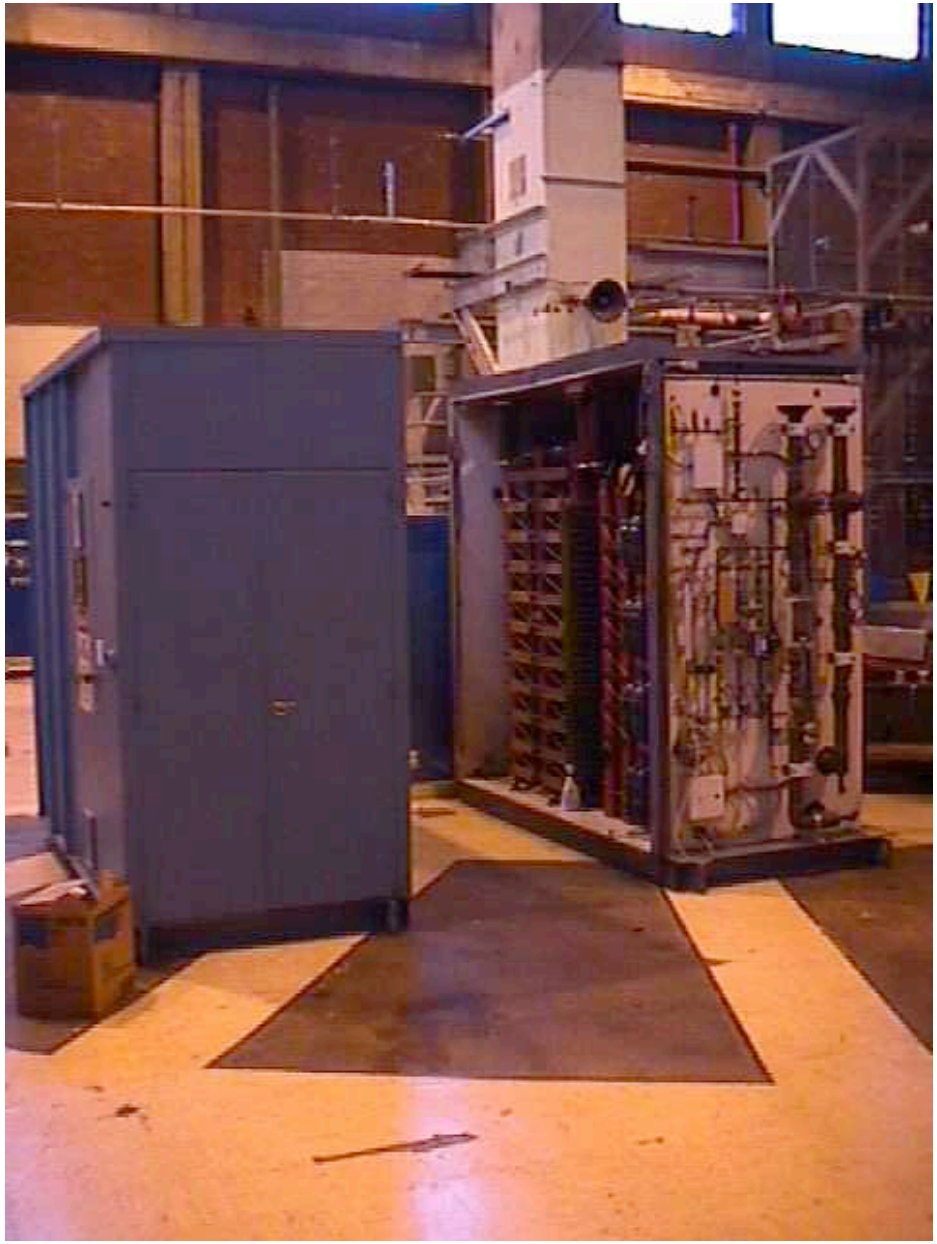
- Components can be designed to handle 15 & 28 GHz
- Maximum experimental capability requires high mode purity
- Utilize TE02, TE01 and HE11 (corrugated) transmission)
- Utilize HE11 gaussian-like launch into focusing mirror
- Place maximum size mirror as close to plasma for greatest capability
- Elliptical polarizer in waveguide for optimizing oblique launch
- High field launch option available



BLOCK DIAGRAM PROPOSED NSTX 28 GHZ ECH SYSTEM

Proposed ECH power supply configuration





ECH HVDC
Power supply

Modulator/
Regulator

at ORNL

Modulator Regulator at ORNL

- Built by UVC for plasma separation process
- x2062K tube
  - 50A, 150 kV capability
  - Capacitor bank sized with safety grounding hardware included
- 100 GPM at 50 psi cooling for full power
- Remote controls needed for control room operation

DNB Raw power supply

- Need input from Raki Ramakrishnan on status
  - Located outside near gyrotron site B
  - Controls once existed for TFTR operation
  - Portions of control can be supplied by mod/reg system
  - Cost estimate for getting operational ?
- TFTR NBI supply could be substituted
  - Needs polarity change
  - Has higher current capability for later expansion