Decision 22 and 24: Modulator Options

What are the options?

Consider two main options:

1. TESLA style modulator with pulse generator, bouncer circuit to flatten the pulse, and low voltage parallel long cables to a step-up transformer located near the klystron in the beam tunnel.
2. Marx generator modular stack producing high voltage output directly, vernier IGBT cell correction for flat top, no transformer, cable to klystron cathode in equipment tunnel or through penetration to beam tunnel.

Pros and cons of Option 1 vs. 2

The TESLA style modulator is well demonstrated in the operation of up to ten units, with a total of approximately 10 years of run time. Improvements have been made and units are reliable. Additional improvements, such as a redundant IGBT switch, are planned. Costs are roughly in agreement between DESY and FNAL, and a vendor quote has been obtained by DESY for the full production run. This unit is the logical choice for Baseline Configuration Design (BCD).

The Marx is proposed as an alternative that promises considerable reduction of size, weight and cost, and possible improvement of reliability through redundant module and sub-module design. However the first unit is in early design and must be considered high risk until demonstrated. The first demonstration is planned for 2006. This is the Alternative Configuration Design (ACD). The options are depicted in Fig. 1.

FNAL Modulator at TTF

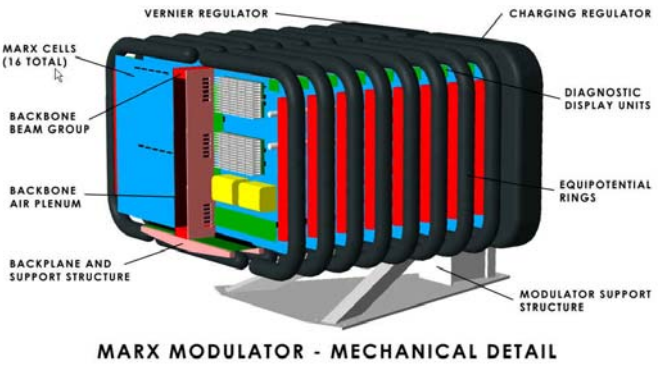

Fig. 1. Pulse Design and Marx Modulator Concept

Cost: favors 2. Estimated costs of three different designs were compared. The results are shown in Fig. 2. The first and second points are two different estimates made by FNAL, for the current design and an improved design in process. These each show a single unit and production quantity unit cost. The third point is a bottoms-up estimate of the Marx to get a single unit cost, plus two different learning curves for the quantity production, (95/95% and 90/85% M&S and Labor). The second of these compares fairly closely with the delta between unit and production units of the FNAL estimates. The bottom line is that the Marx appears to have potential to reduce costs by roughly a factor of 2, not including cable costs (which also favors the Marx).

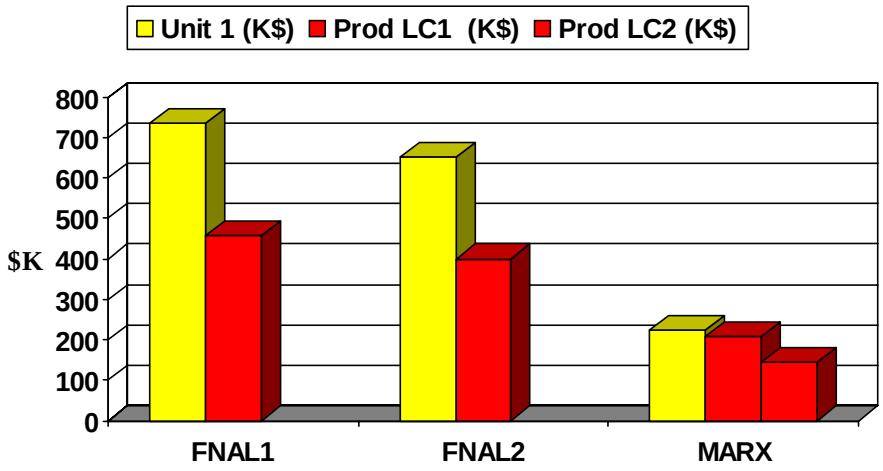

Fig. 2. Cost Estimates: FNAL & Marx Unit 1, Production Unit

Availability risk: favors 2. Assuming topology is two-tunnel side by side, modulator in service tunnel and accessible at all times, redundant system units, system availabilities would be comparable. However, internal redundancy in Marx with modular design should lead to fewer failures and much shorter MTTR, especially if robot module-swapping employed. Cost of robotics has not been estimated for this model.

Installation/Commissioning/upgrade: favors 2. For the 2 tunnel case, installation in support tunnel can go on while commissioning/running occurs in accelerator tunnel. Modular units are much lighter, less labor-intensive to install compared with multi-ton cabinets and transformer of pulse design. Smaller overall footprint increases working space in tunnel. Robotics may be used during installation phase to perform round-the-clock installation and operational repairs.

Extra R&D needed before making a decision

The Marx is an R&D project that needs demonstration proof of the following features:

- Reliable board, IGBT switch, capacitor & connector design, MTBF.
- Single cable HV transmission to klystron without increased damage risk in case of arcs.
- Adequate, clean cooling with air-water heat exchanger.

- Significant cost, size and weight improvements over conventional design.

Recommendation for the BCD

Conventional pulse transformer unit in parallel tunnel, short LV cables to klystrons preferably in parallel tunnel, short waveguide to cold structures in beam tunnel.

Recommendation for the ACD1

Marx design in parallel tunnel, modular design, intelligent diagnostics to manage internal failures, 1/n redundancy at board and sub-unit levels, robotic servicing option.

Recommendation for the ACD2

Marx design close to klystron in beam tunnel. Only of interest for single tunnel design. Evaluate radiation protection, service model using robotics, availability risks, overall cost impacts.