# NEUTRINO FACTORY
# POWER SUPPLIES

**BOOSTER**

- **Kickers?**
- **Magnet Systems**
  - **Main PS's – phase control**
  - **Quad Trims – Switchmode**
  - **Power Requirements: 15 MW, 30 MVA**

**LINAC SYSTEMS**

- **Magnets (Solenoids) - DC Loads**
  - **Transrex-type sufficient**
  - **Number of supplies depends on di/dt one can tolerate**
- **Quench Protection – straightforward**
- **Power Requirements: Probably less then 2 MW, 4 MVA**

## DESIGN CONSIDERATIONS FOR QUENCH PROTECTION AND POWER SUPPLIES

Data for Russian Design of the SC magnetics for 4 Channels of Neutrino Factory

| Channel | ID# | 1 | 2 | 3 | 4.1 | 4.2 |
|---|---|---|---|---|---|---|
| **PARAMETERS:** | | | | | | |
| Length | m | 50 | 40 | 100 | 100 | 100 |
| Total Stored Energy | MJ | 12 | 72 | 19 | 1830 | 7310 |
| Excitation Current | KA | 6 | 6 | 6 | 6 | 6 |
| Total Inductance | H | 0.67 | 4 | 1 | 102 | 406 |
| Total Number of Magnets | # | 5 | 20 | 83 | 90 | 90 |
| Magnet Inductance | H | 0.133 | 0.200 | 0.013 | 1.130 | 4.512 |
| Number of Power Supplies | # | 1 | 1 | 1 | 1 | 1 |
| Power Supply Voltage | KV | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Total Power Supply Voltage | KV | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Ramp Time | sec | 40 | 240 | 63 | 6100 | 24367 |
| Number of Dumps | # | 1 | 3 | 2 | 6 | 6 |
| Max Voltage Stress | KV | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Total Dump Voltage | KV | 1 | 3 | 2 | 6 | 6 |
| Dump Time Constant | sec | 4 | 8 | 3 | 102 | 406 |

**RECIRCULATING LINACS**

- PS Specs unknown at this time
- Usually just DC loads – nothing new

**STORAGE RING**

- Kickers – significant, expensive
- Power supplies – DC loads
  - High current
  - Underground at one end
- Quench Protection
  - Straight forward and relatively inexpensive if:
    - Arcs can be broken into 2 Quench Units
    - Backup to dump switch failure: fire all heaters

# Mu SR Kicker System

The Muon Storage Ring has need of an injection kicker system that will deflect the incoming beam on orbit. The main parameters for the system are:

| | | |
|---|---|---|
| Type | - | Horizontal |
| Clear Gap | - | 308 mm(w) by 246 mm(h) |
| Integral BL | - | 0.6 Tesla•Meters |
| Field Flattop | - | 2.0 μsec |
| Field Fall | - | 4.0 μsec |
| Field Variation | - | 10% |
| Rep Rate | - | 15 Hz |

The proposed system has two engineer defined limits that will be treated as design criteria. Our experience has suggested that the maximum system voltage should be limited to 50k volts and the maximum switch tube current should be limited to 5k amps. These two requirements imply the system impedance of 5 ohms.

The above constraints are such that the peak field will be:

$$B_{max} = \frac{\mu_0 \times I_{max}}{h} \qquad B_{max} = 0.0255 Tesla$$

And the total length of the magnet system will be:

$$Length = \frac{\int Bl}{B_{max}} \qquad Length = 23.5 Meters$$

On a per meter basis the inductance, capacitance and the field drift time of the magnet is:

$$L = \mu_0 \times 1 \times \frac{w}{h} \qquad L = 1.573 \mu H / meter$$

$$C = \frac{L}{Z_o^2} \qquad C = 62.93 nF / meter$$

$$drift = \sqrt{L \times C} \qquad drift = 0.315 \mu sec / meter$$

From the above numbers, we are tempted to install two 12 meter magnet strings each driven by a pulser. We will take a conservative approach at this point and assume that the kicker system will be made up from four 6 meter magnet strings each driven by a pulser.

Figure 1 is included as a proposal for the cross section of the magnet. The mechanical design for the support structure and vacuum vessel is non-existent and will need to be addressed for the next level design. The actual magnet length and number of pulsers will need to be nailed down at that time.

The PFN that will be used to drive each magnet will have:

| | |
|---|---|
| $Z_0 = 5.0\Omega$ | $Length = 2.25\mu sec$ |

A ***SPICE*** simulation of both the PFN and magnet has been completed and the normalized magnet input/output voltage and normalized integral of field is included for reference. Figure 2 is a simplified schematic of the kicker system that was modeled in ***SPICE***.

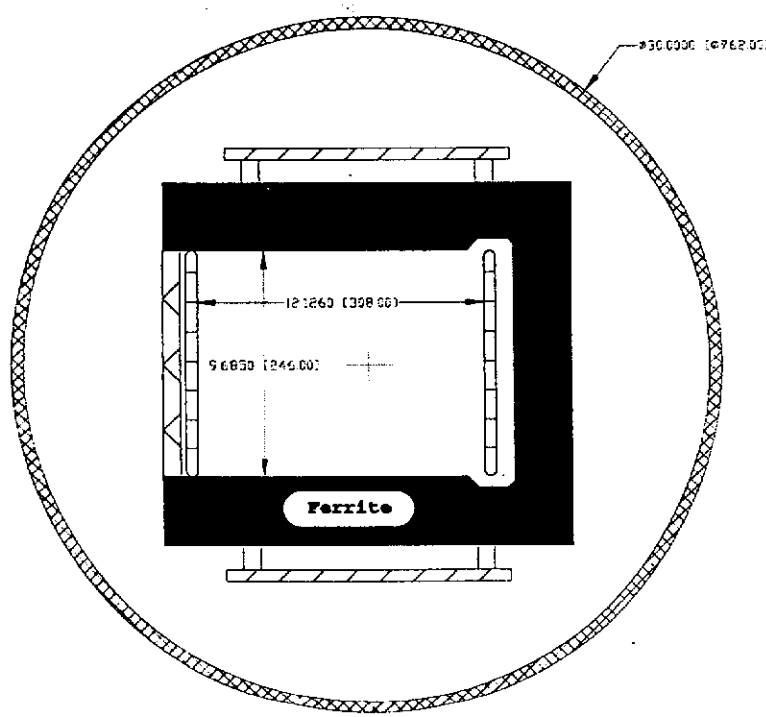



**Figure 1 - Proposed Magnet Cross Section**

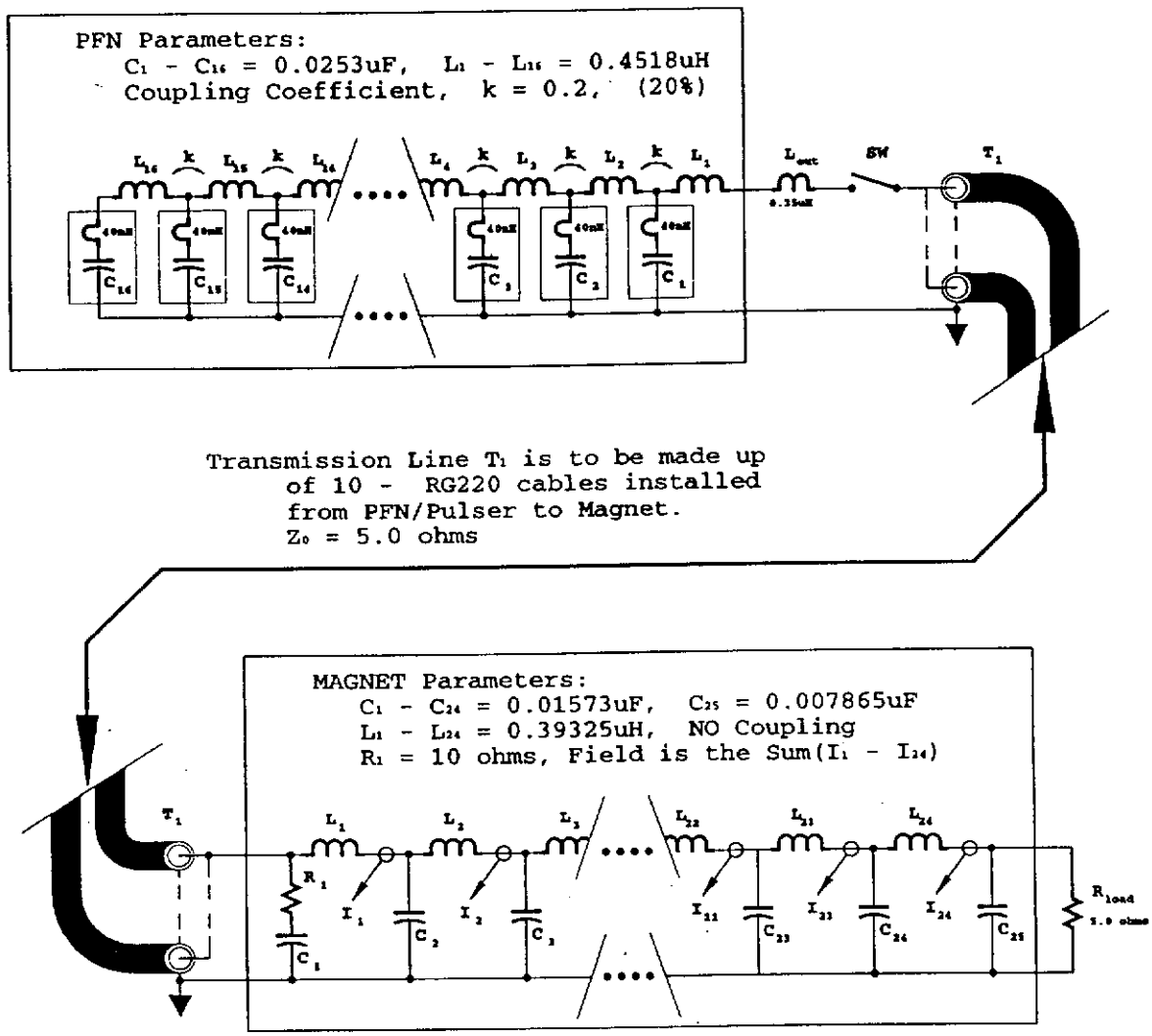
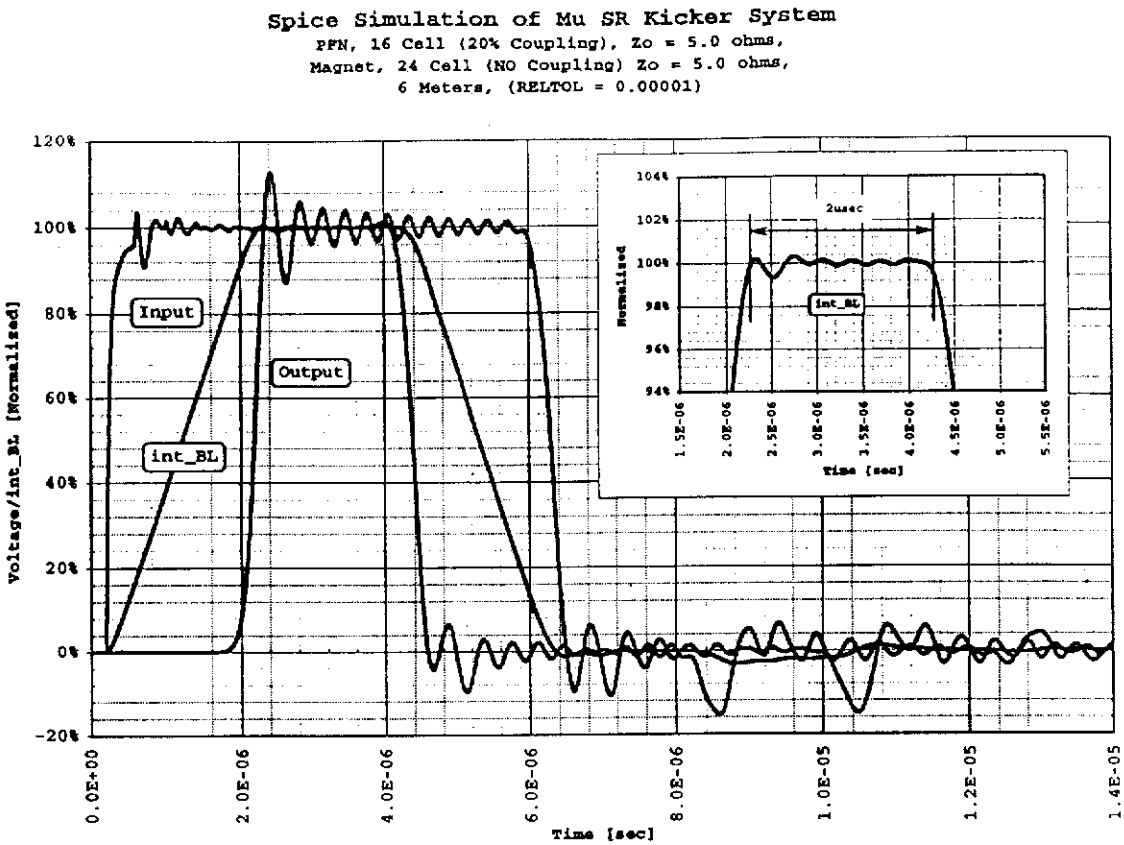



Figure 2 - Simplified Diagram of Mu SR Kicker System (used for ***SPICE*** Simulation)




The cost of the system at this point will need to have a large contingence that can be refined at the next stage of design with the input of mechanical support personnel.

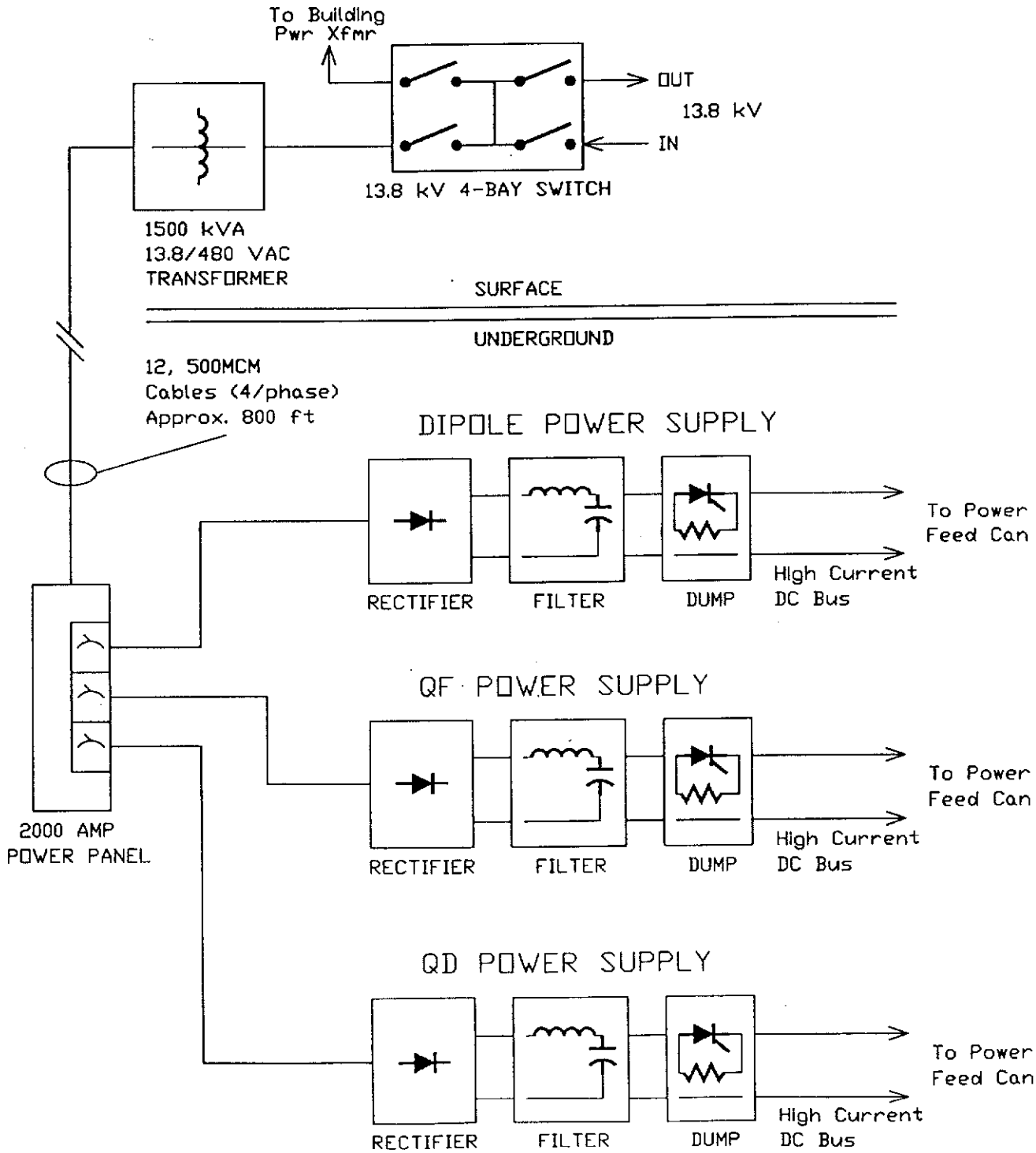
The magnets are larger and longer than the MI 52 extraction kickers built in '93 - '95. These magnets cost about $90k per meter. An initial quote (for budget purpose) from our ferrite vendor put the ferrite at a little over twice the cost of the MI 52 ferrite. Therefore with inflation and the larger size I am putting the cost of the magnet at $200K per meter.

The pulsers should be similar to MI 52 pulser with the exception of rep rate. Since the MI 52 pulser cost $400k in the same '93 - '95 time frame, I am putting the cost of each pulser at $500K.

Therefore 24 meters of magnet and 4 pulsers puts the cost of the system at about $6.8M.

# NEUTRINO FACTORY STORAGE RING POWER SUPPIES

## Single-line Layout

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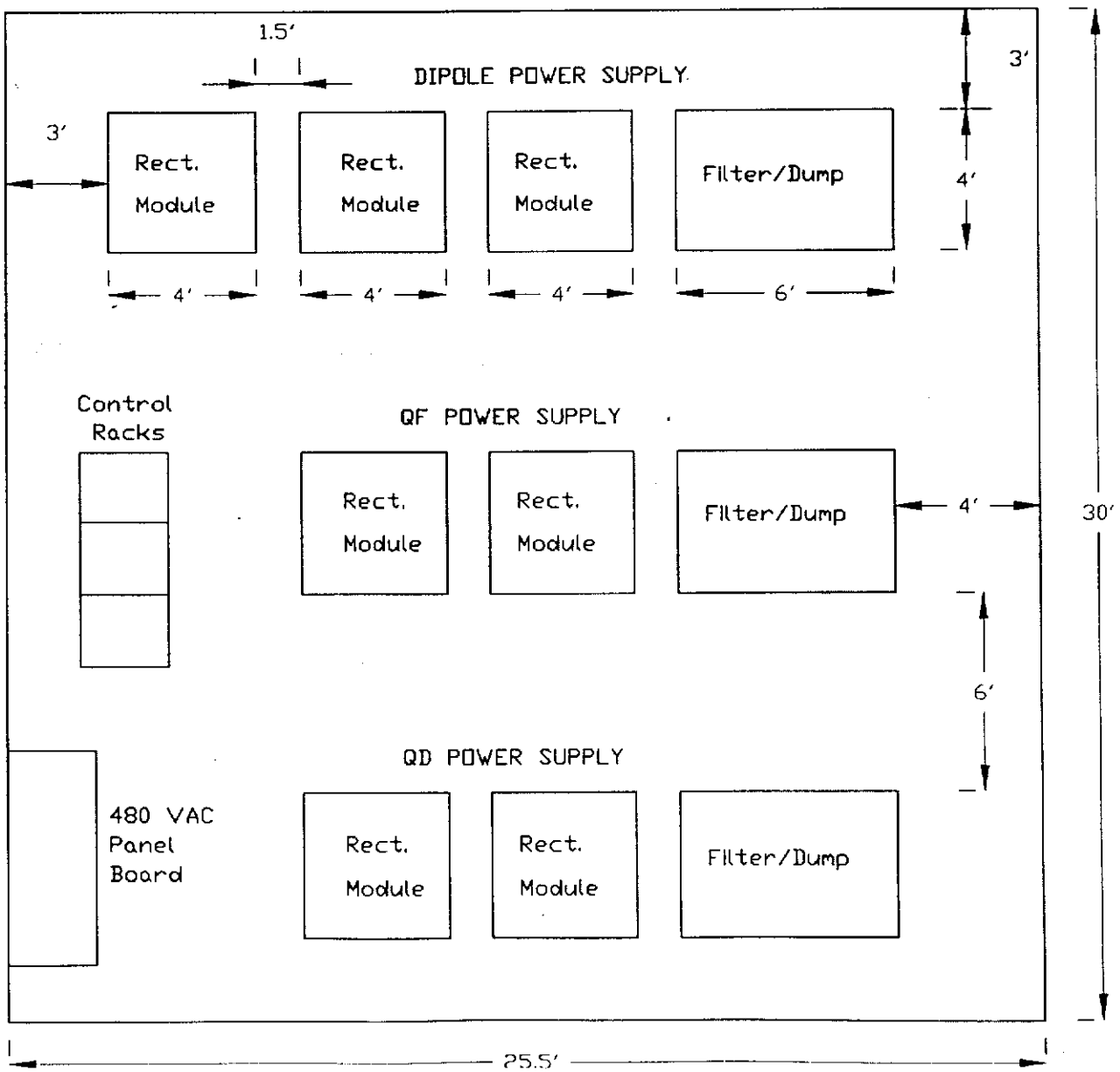
# NEUTRINO FACTORY STORAGE RING POWER SUPPIES

## Space Requirements

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# NEUTRINO FACTORY
# POWER CONSUMPTION/DISTRIBUTION

## POWER REQUIREMENTS (?)

### SOURCE
Unknown but assume same as present

### BOOSTER
Magnets: 16 MW, 30 MVA
RF Systems: 16 MW, 20 MVA

### LINAC RF AND CRYO SYSTEMS
Unknown (50 MW?, 60 MVA?)

### STORAGE RING
Modest: 6 MW, 10 MVA
Including PS's and Cryo

## INSTALLED FNAL CAPABILITY - Transformers

**KAUTZ ROAD SUBSTATION**

- 106/166 MVA available (excluding Main PS's)
- Less then 40 MVA being used

**MASTER SUBSTATION**

- 160/264 MVA available (including TEV PS's)
- Less then 60 MVA being used
- 2, 345 kV pads presently vacant

**Available capacity - transformers: 166/330 MVA**

**FEEDERS**

- Usually sized to existing loads – not much spare capacity
- Many feeders approaching 30 years old
- New feeders required for new machines

**COST:**

- $0.5/kw-hr: $440k/MW-yr