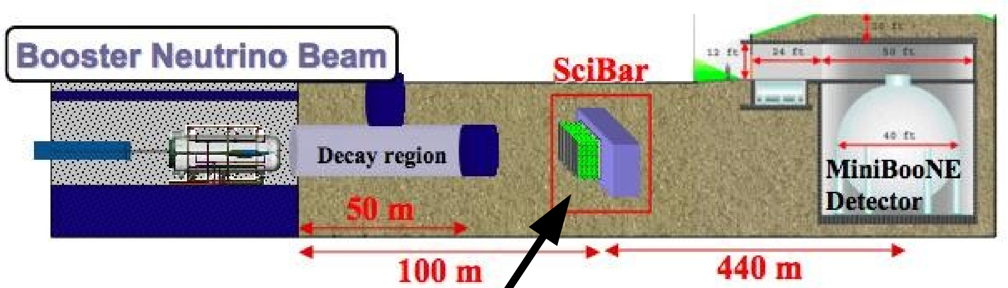
Fun With Phototubes

Work on the SciBooNE MRD

Hannah Newfield-Plunkett, Summer 2006

What is SciBooNE?

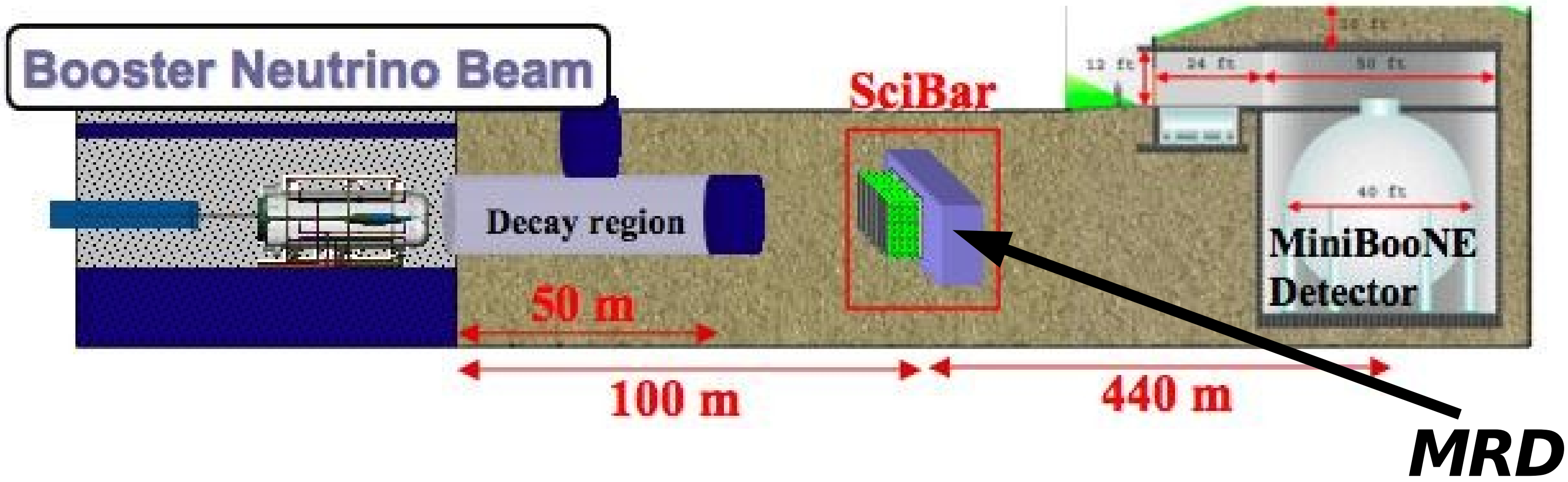


- SciBooNE (E954) consists of placing the SciBar detector from K2K in the Booster Neutrino Beam at Fermilab
- SciBooNE will measure neutrino cross-sections with greater accuracy
- This will help neutrino oscillation experiments such as T2K, and SciBar will also serve as a near detector to help MiniBooNE

The detector consists of three parts:

1. SciBar itself (shipped from Japan)
2. The Electromagnetic Calorimeter (EC) – also shipped from Japan
3. The Muon Range Detector (MRD) – built at Fermilab

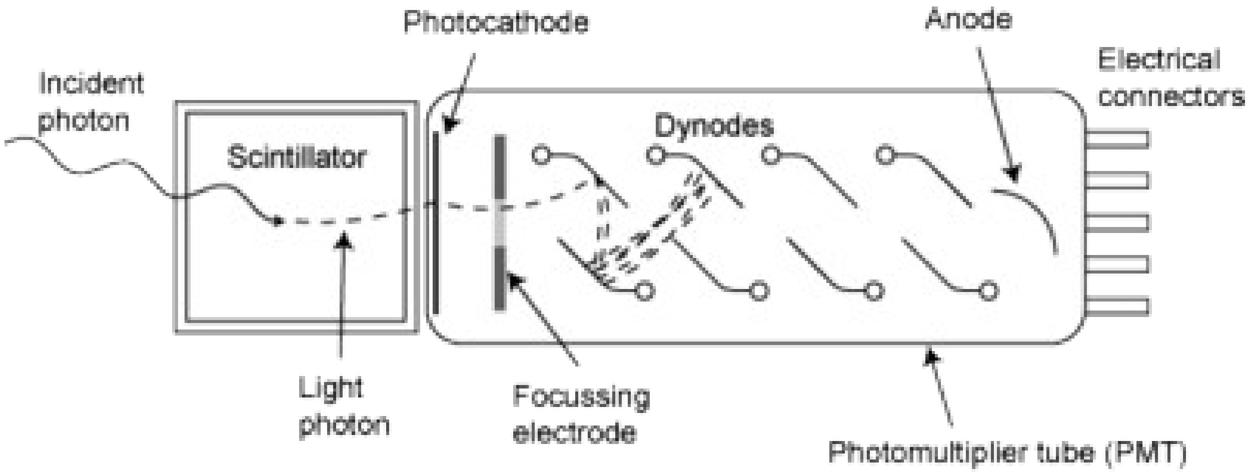
What is the MRD?



- The MRD (Muon Range Detector) consists of iron plates sandwiched with layers of plastic scintillator. It is intended to "range out" muons so their energy can be determined by how far they penetrate into the detector
- This detector is being constructed at Fermilab, from available components to save cost
- Columbia is responsible for testing the PMTs for the MRD (which come from previous experiments)

What does a PMT do?

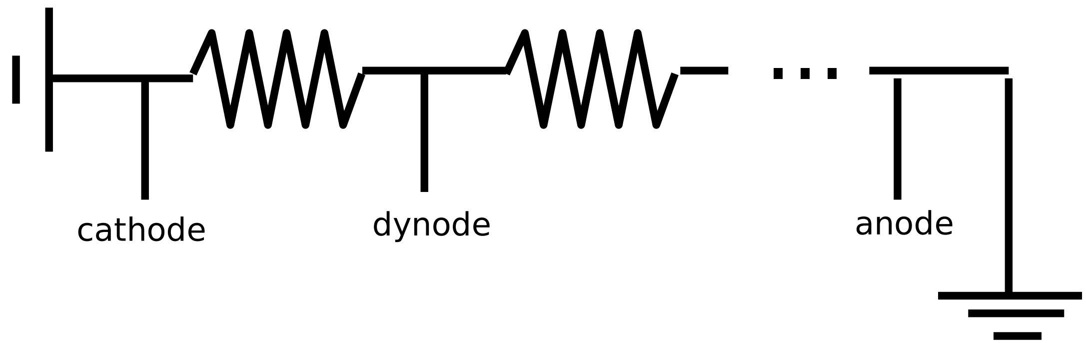
- A PMT (photomultiplier tube) converts a photon which enters the tube into an electrical signal
- When the photon hits the photocathode, the photocathode emits a photoelectron
- The electron is then pulled by an electric field set up between each dynode
- Each dynode is set at a different voltage. As the photoelectron hits the first dynode, it starts an electron cascade
- The electrons which leave the first dynode (or stage) are pulled along to the second, where each of them starts a new cascade, and so forth
- Most PMTs have a gain of about 10^6, so a single photoelectron can be amplified to give a measurable electronic signal
- PMTs give large gain and have a fast response time



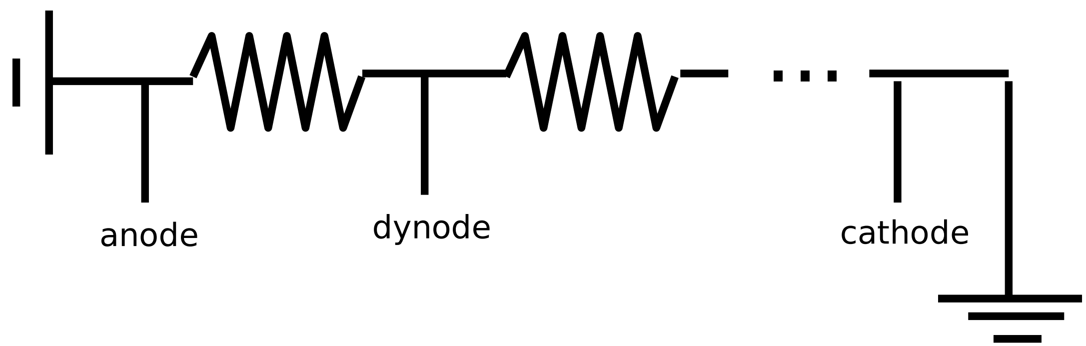
Why do PMTs need bases?

- The base of a PMT takes a high voltage input and splits it to pins leading to the various dynodes
- A resistor chain in the base puts the dynodes at different potentials to create the electric fields that draw the electron along the dynode chain
- Bases can run on either positive or negative high voltage, but the anode is always positive relative to the cathode

Negative HV base



Positive HV base



What PMTs do we have?

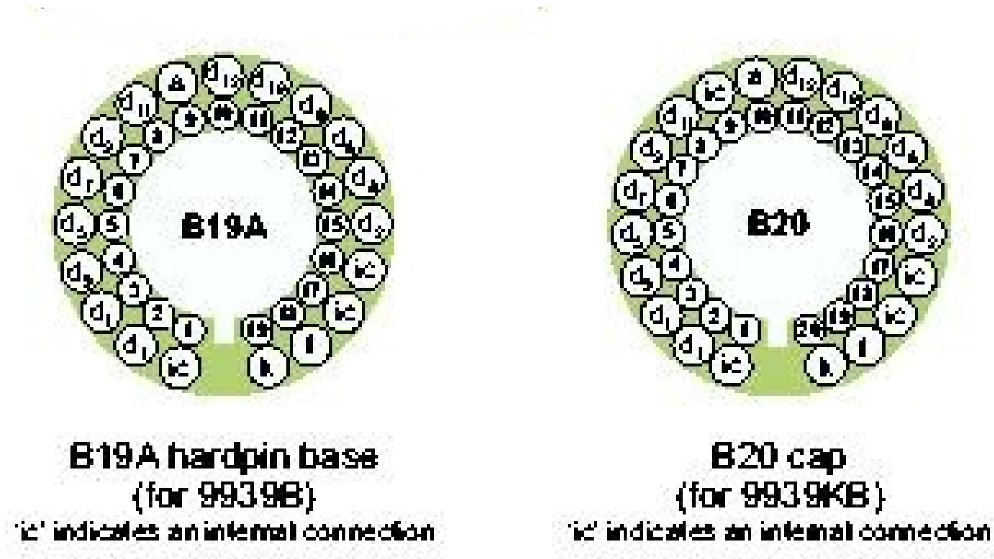
- We have four main makers of tubes: EMI, RCA, Hamamatsu, and Amperex
- We hope not to need to use the Amperex tubes, since we do not have good bases for them

Type of Tube	How many do we have?	HV polarity
RCA 6342A	44	negative
Hamamatsu R2154-05	9	negative
EMI 9954KB (KTeV)	149	negative
EMI 9939B, 9839B, 9954B	70	positive
EMI 9839KB	29	negative
Amperex 56AVP	15	negative

- We expect 60-70 RCA6342A tubes from CCFR and about 50 Hamamatsu R2154 tubes from NuTeV
- Both + and – HV bases will have to be used

EMI tubes

- There are five types of EMI tubes, but they are extremely similar
- The 9954KB and 9839KB tubes have wider-set pins so they connect to different bases than the 9954B, 9939B, and 9839B tubes



The larger and smaller bases for the "B" versus "KB" tubes in the series

- Because the tubes are otherwise almost identical, we expect them to have similar quantum efficiencies and pulse shapes (more on this later)
- These are 14-stage tubes

RCA 6342A and Hamamatsu R2154 tubes

RCA tubes out at Lab 6

- Both of these are 10-stage tubes with compact bases which are convenient for space considerations
- We are expecting more of these tubes to arrive soon and they will form another major component of the detector

PMT Testing Setup

At Lab 6…

Counter Testing Setup

Four PMTs can be put in the dark box at once. We have NIM electronics and a digital oscilloscope at the testing setup, as well as a standard LED which can be run either in DC mode or pulsing for tests.

Dark Box for PMT Testing

What tests do we do?

There are five tests in the PMT testing procedure:

(1) Voltage testing in the PMT base
(2) Current vs. Voltage measurement
(3) Dark rate measurement
(4) Pulse Shape test
(5) Afterpulsing test

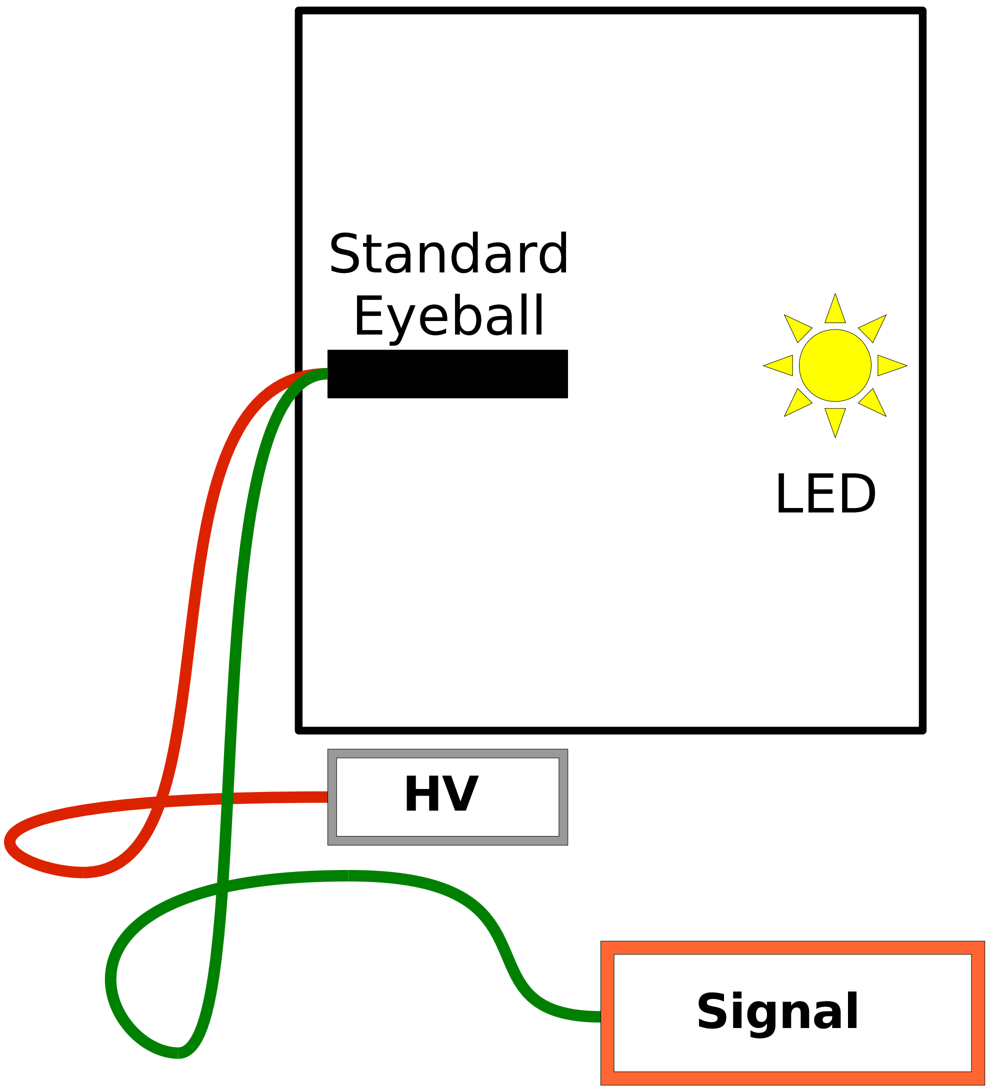
Base Testing, Dark Rate Test, Pulse Shape Test, and Afterpulsing Test

- To test bases, we put a voltage on the base and check the voltage coming out of each pin
- After the tube has dark-adapted in the dark box, we set it at the operating voltage determined from the current vs. voltage test and count the number of pulses in the dark in 10 seconds
- The other tests use a pulsing standard LED

- The pulse shape is checked to make sure it looks reasonable for that type of tube
- Gas contamination in the tube can cause afterpulsing, so in 100 main pulses, we look for pulses >5mV within 1 microsecond of the main pulse. This number is generally <10 out of 100 trials.

Current vs. Voltage Test

- The main test we are conducting is to determine an approximate operating voltage of the PMT
- To do this, we use a "standard eyeball" PMT
- The standard eyeball was built into a counter and its operating voltage was measured at the plateau of the voltage vs. efficiency curve
- Then the standard eyeball was put in the dark box with the LED on in DC mode, and the current coming out of it at its operating voltage was measured
- Each other tube of that type will have its voltage adjusted until it gives the same current when exposed to the LED
- Because of differences in quantum efficiency and pulse shape which could affect the current, each type of tube (EMI, Hamamatsu, RCA) will have a separate standard eyeball



Conclusions

- The testing procedure described above has been implemented and PMT Testing is in progress
- Construction on counters for the MRD is also underway
- So far, testing seems to be progressing smoothly, with most tubes operating well
- More documentation on the PMT testing procedure can be found at home.fnal.gov/~hannahnp/sciboone/sciboone.html