The MuSun Experiment

Electronics Energy Resolution

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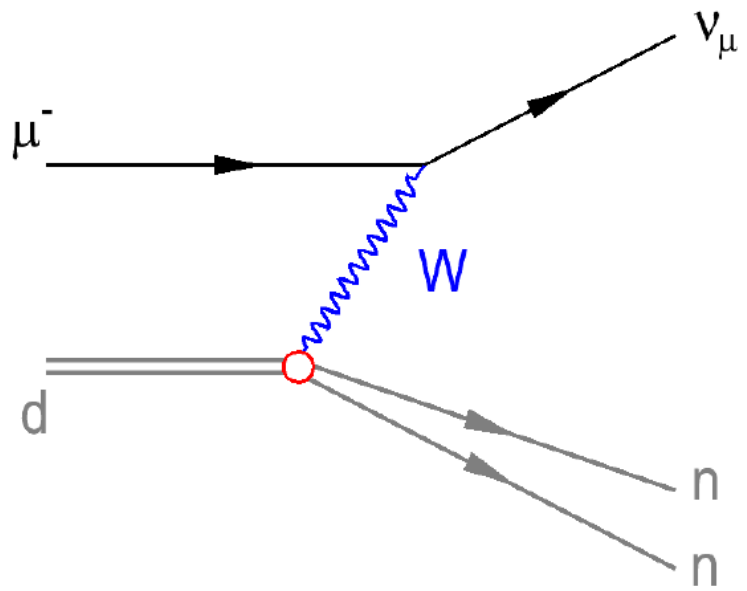
MuSun Introduction

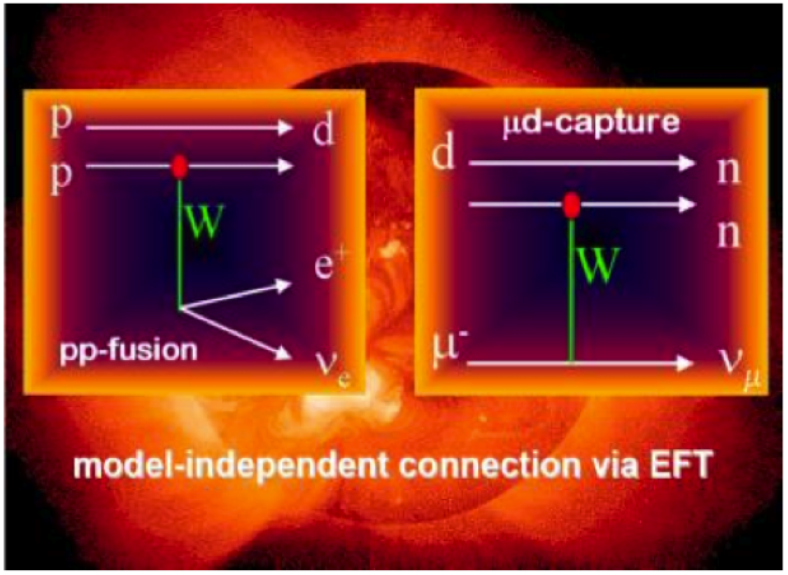
Goal: Measure rate of muon capture on deuterium atom to 1.5% precision

- $\mu^- + \mathrm{d} \rightarrow \nu + \mathrm{n} + \mathrm{n}$
- Expected rate: 400 s^{-1}

Measure strong interaction effect

- pp-fusion

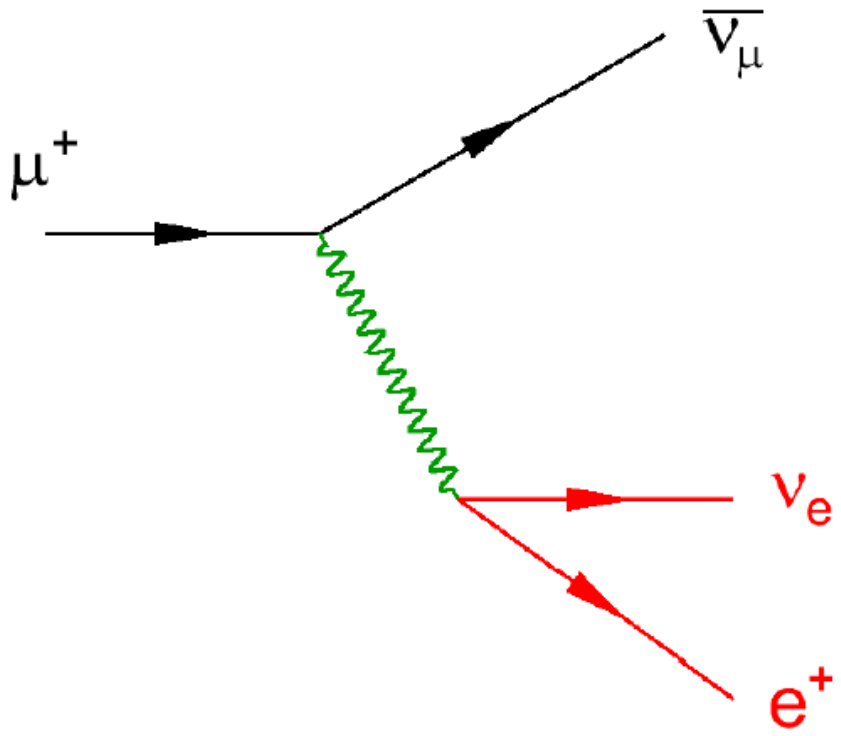




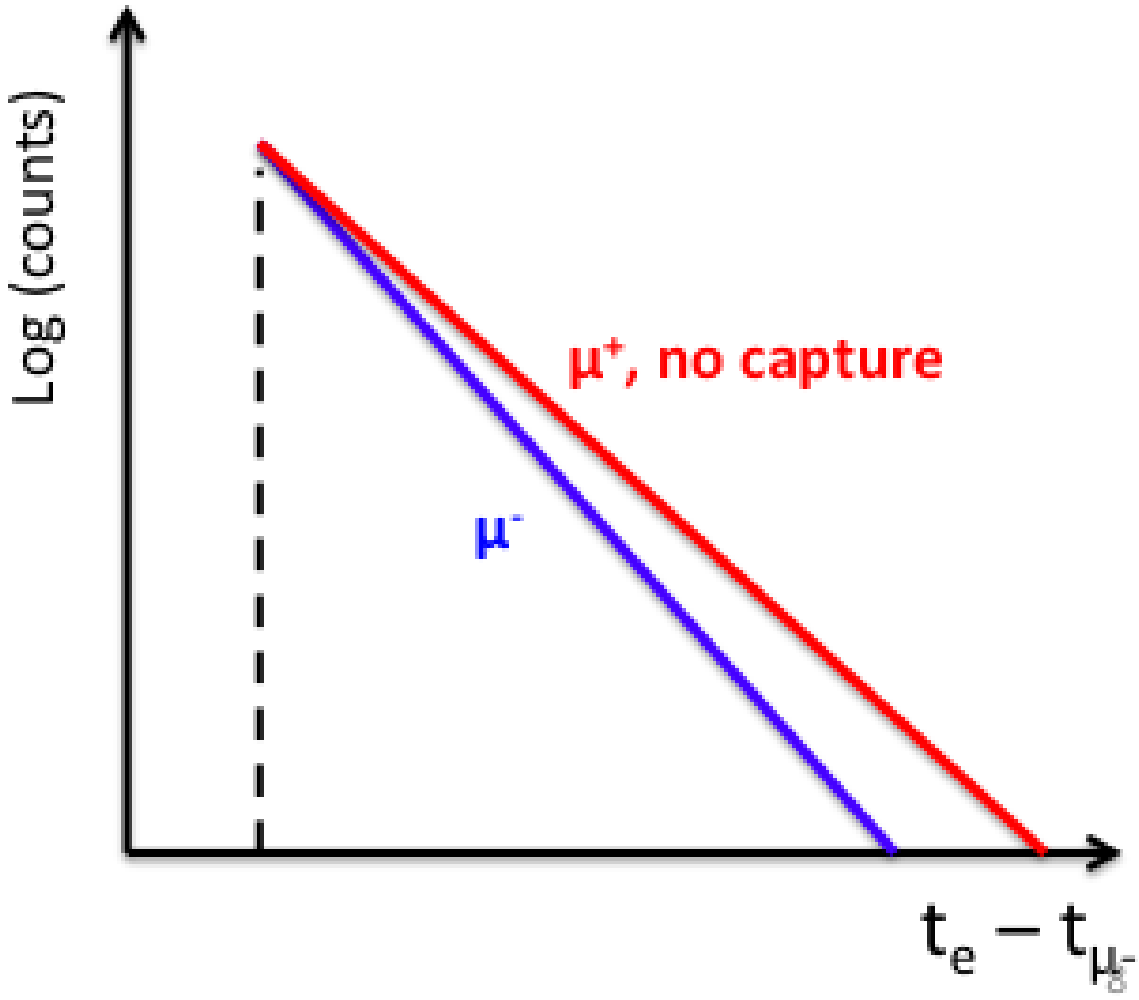
Muon Decay

$\mu^+ \rightarrow e^+ + \nu_e + \overline{\nu_\mu}$

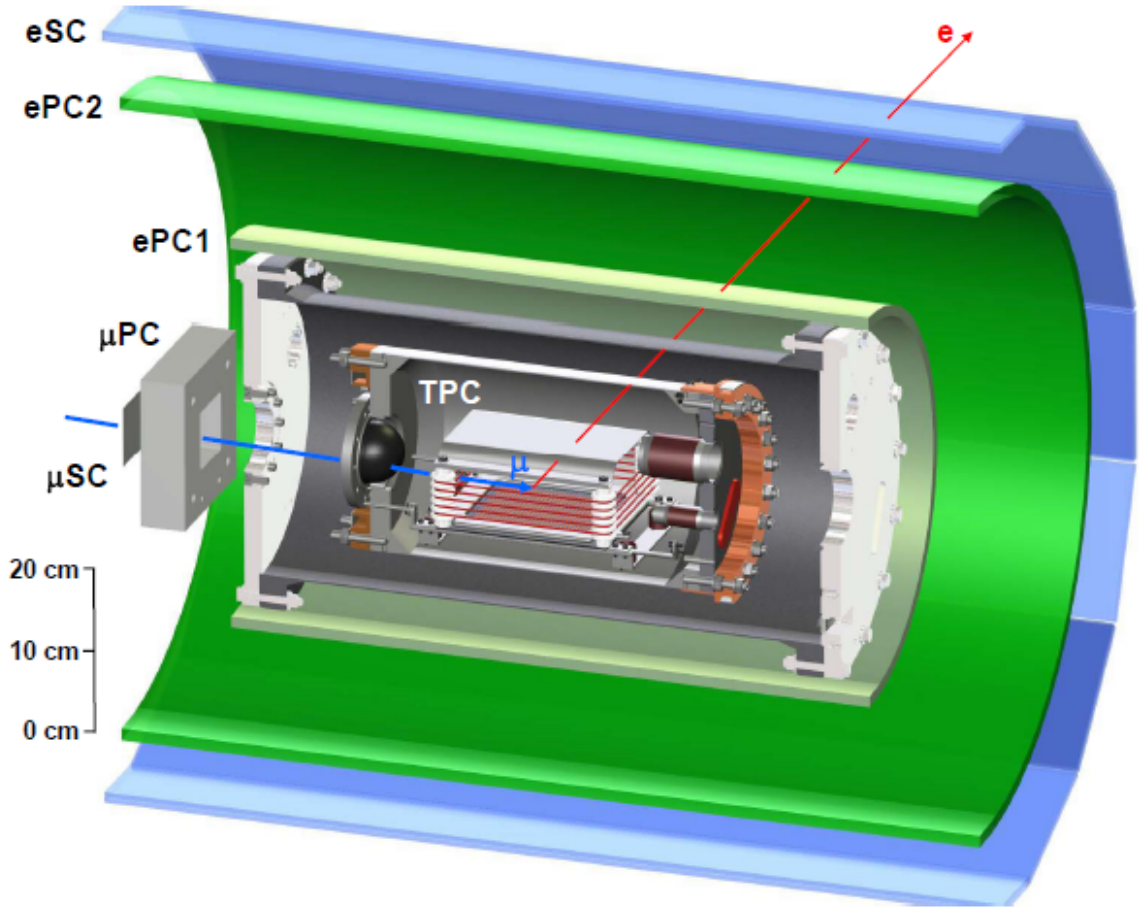
Decay rate (MuLan):
$455170.2 \pm 0.42 s^{-1}$



Lifetime Method



Experimental Setup



TPC (Time Projection Chamber)

Cryogenic ionization chamber

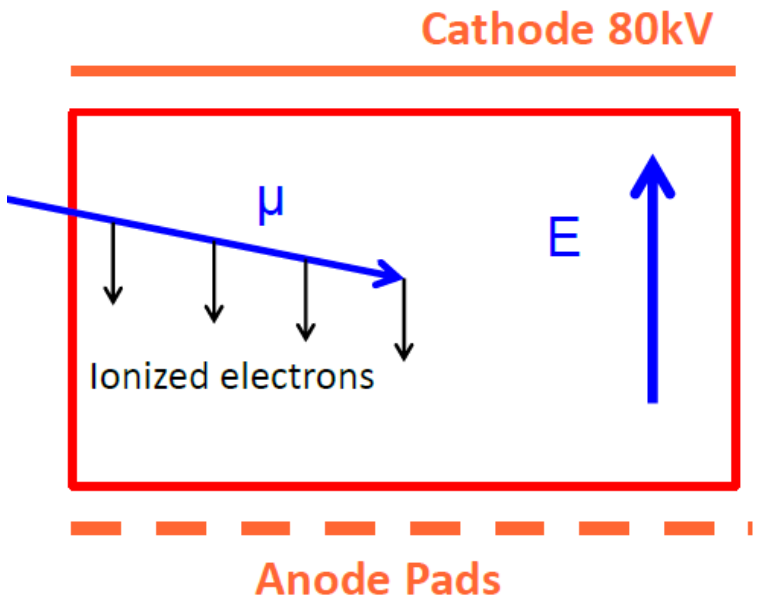
Filled with ultra-pure Deuterium

Allows for 3D reconstruction of muon stops

Sensitive volume: 10cm x 12cm x 8cm

Applied field of 80 kV

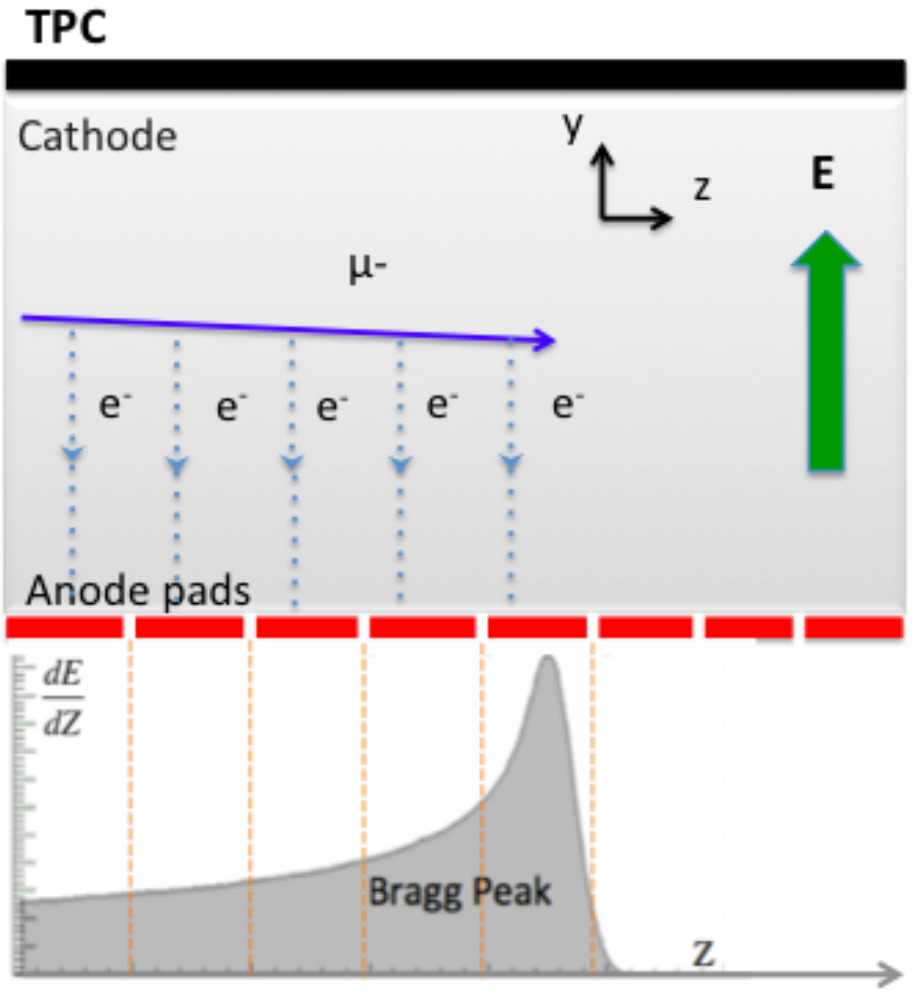
- Causes ionization electrons to drift downwards towards anode



Pulse Generation

Energy is deposited onto TPC pads and is converted into a charge pulse

Each TPC pad is separately read out through a waveform digitizer channel



Electronics Chain

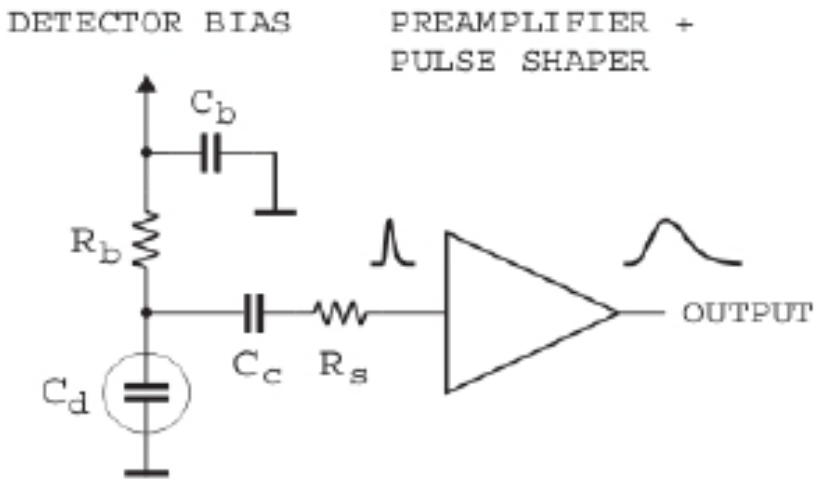
Preamplifier: charge sensitive configuration integrates the current to produce a voltage step proportional to the deposited charge

Shaping amplifier converts preamp output signal to a form suitable for measurements

- Helps improve signal-to-noise ratio

Shaping Time

- Good energy resolution requires long pulse width
- High counting rates require short pulse width



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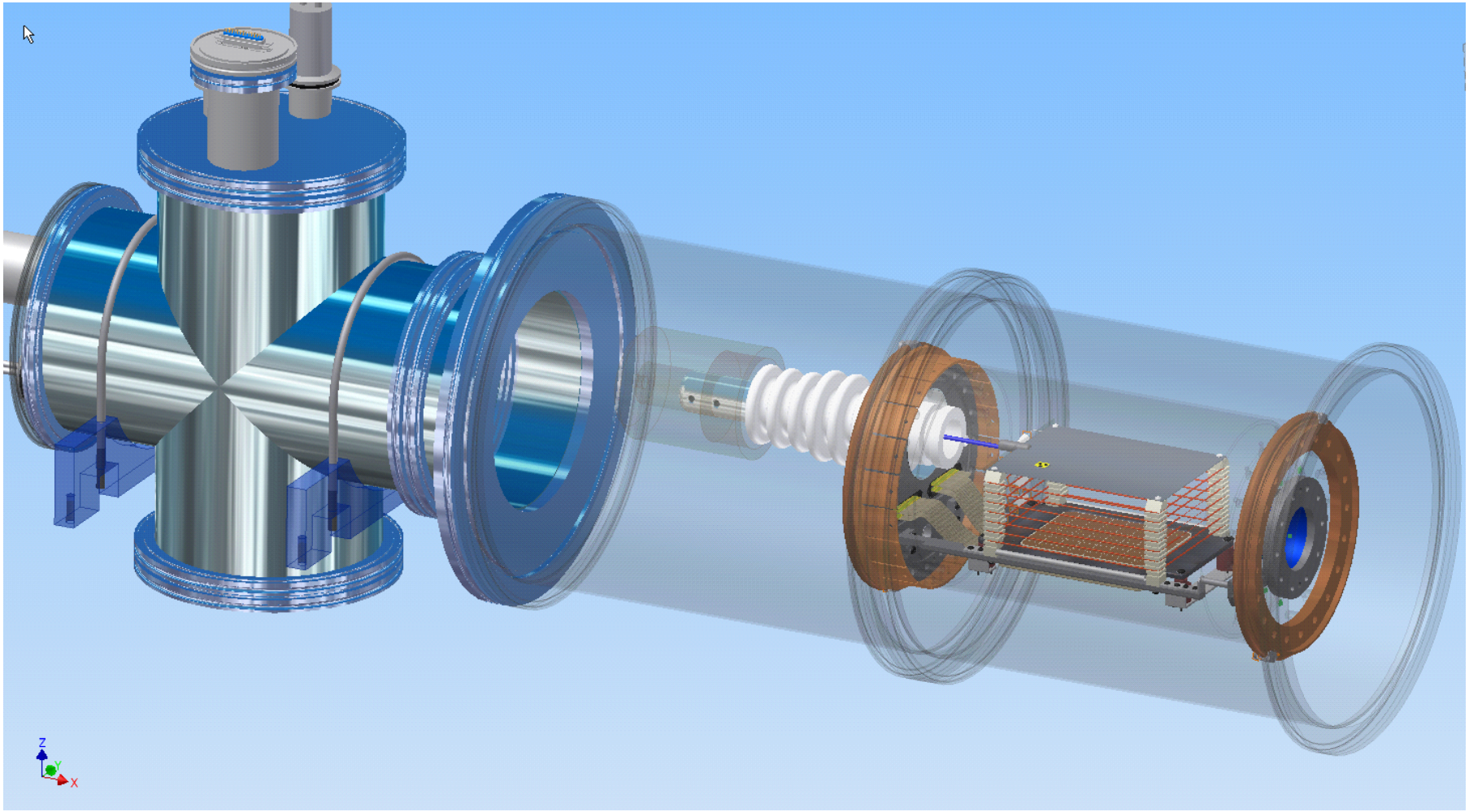
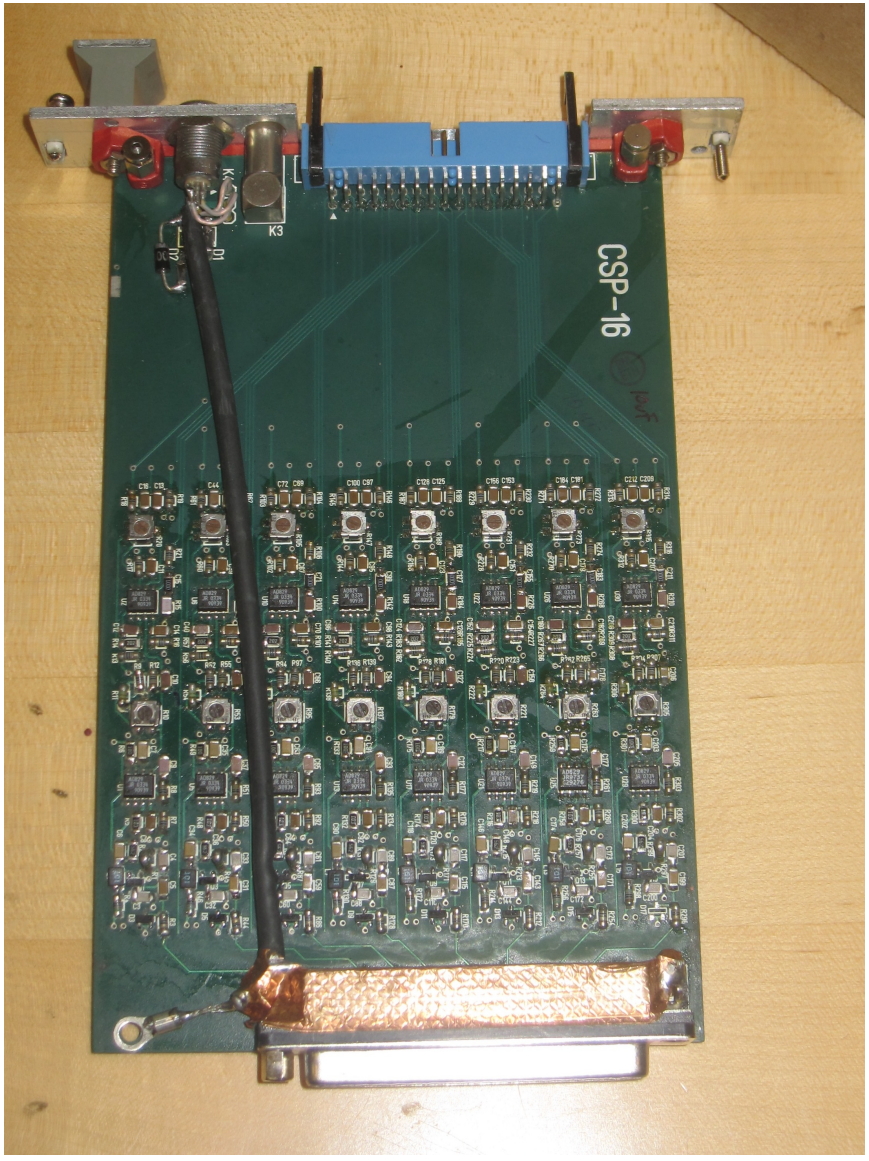
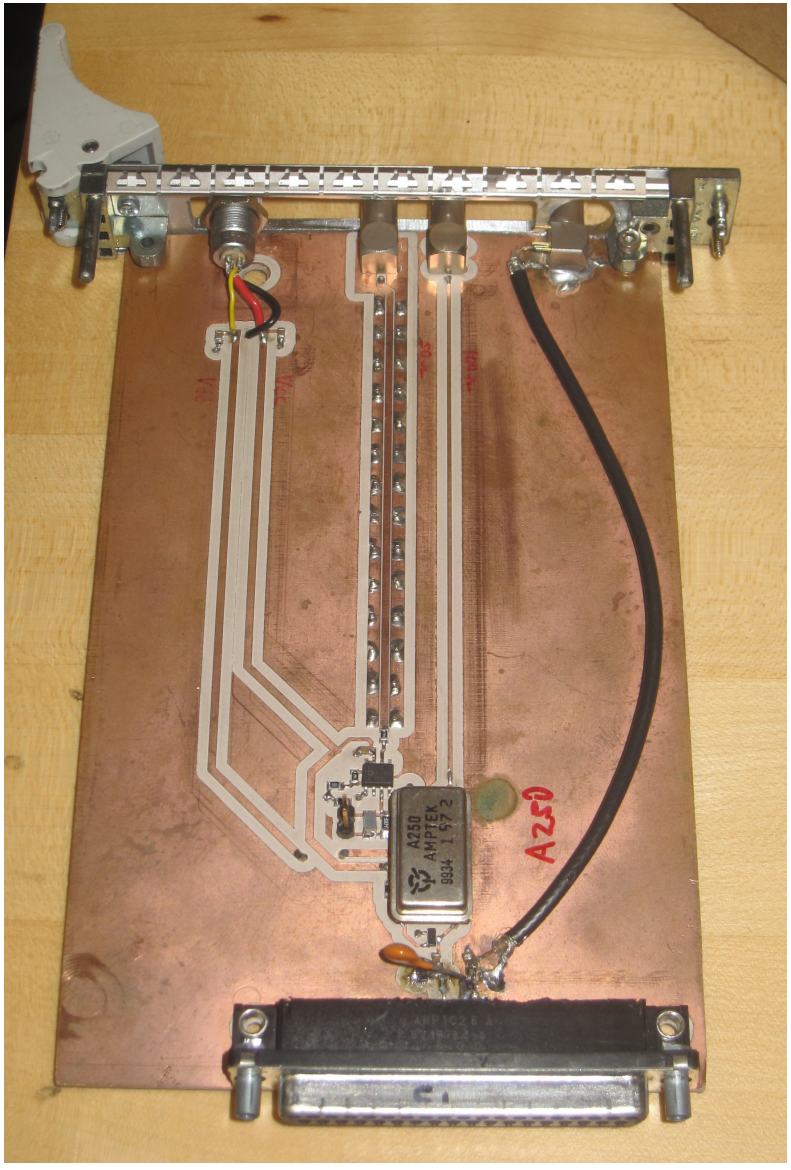


2 Preamp Boards: MuSun and Amptek



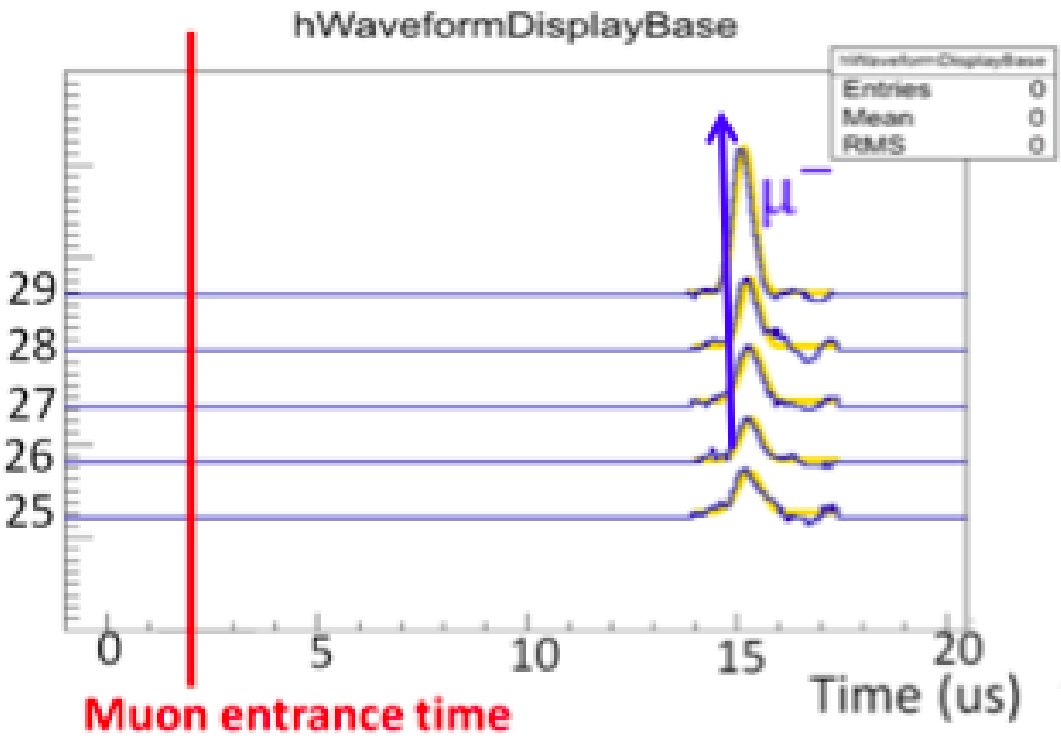


Energy Resolution Status

Previous energy resolution (Musun): 60 keV

Current energy resolution (MuSun): 12 keV

Current energy resolution (Amptek): 6.7 keV



Electronics Energy Resolution

$$EnergyResolution(keV) = \frac{InputEnergy}{Baseline - Amplitude} * RMS$$

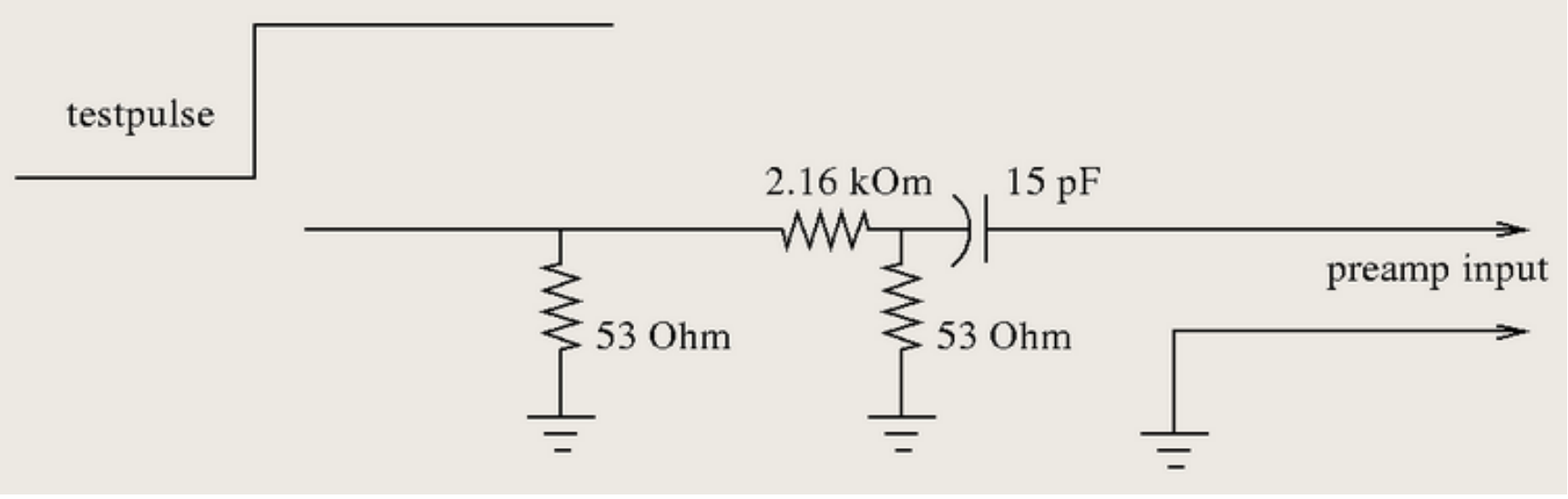
Different Methods:

- Experimental Data (Load Capacitance and Diodes)
- LabVIEW Program
- Theoretical Analysis
- SPICE simulations

Calculating Input Energy

Send a pulse through a voltage divider and capacitor

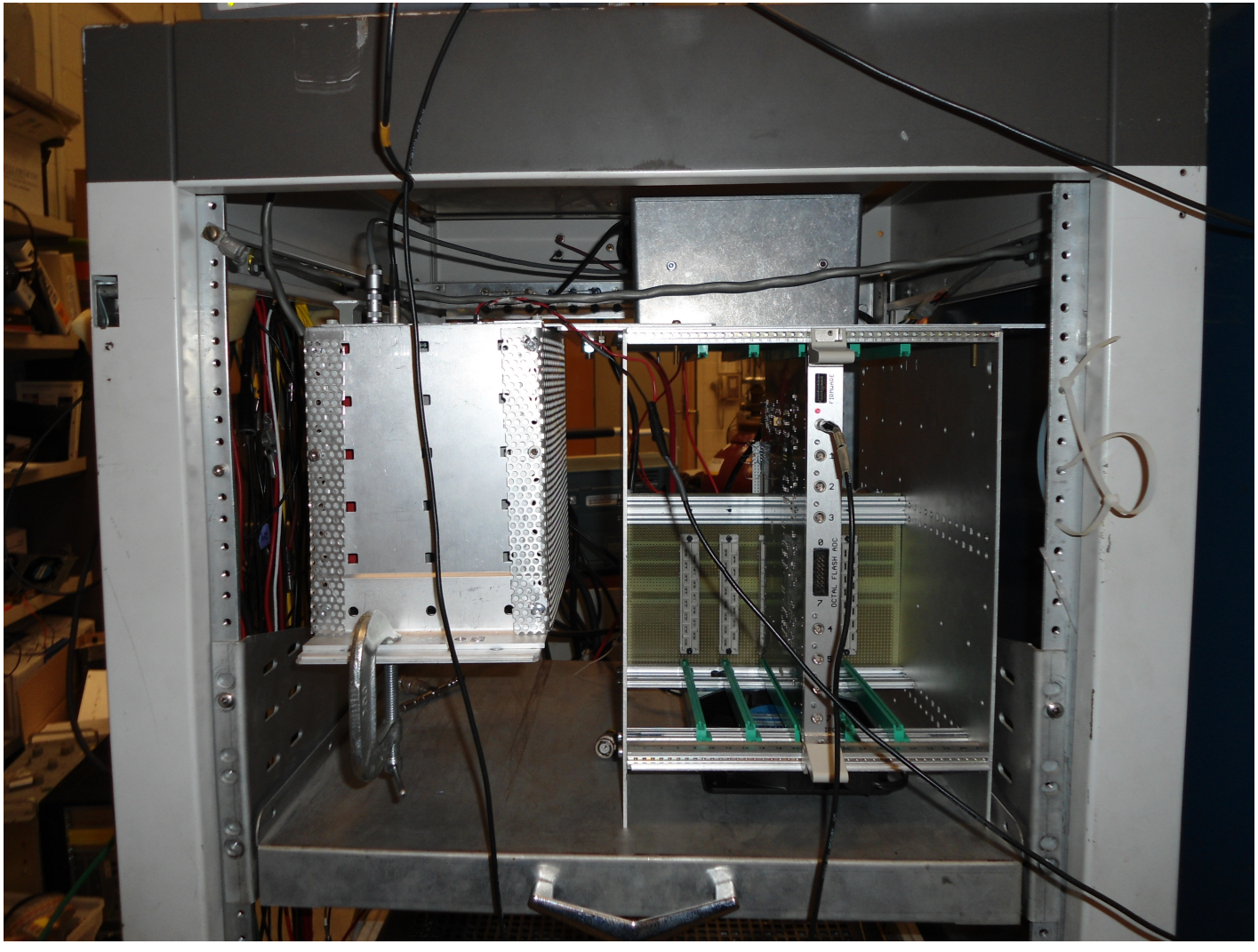
- Calculate number of injected electrons
- Record output amplitude
- Replace capacitor



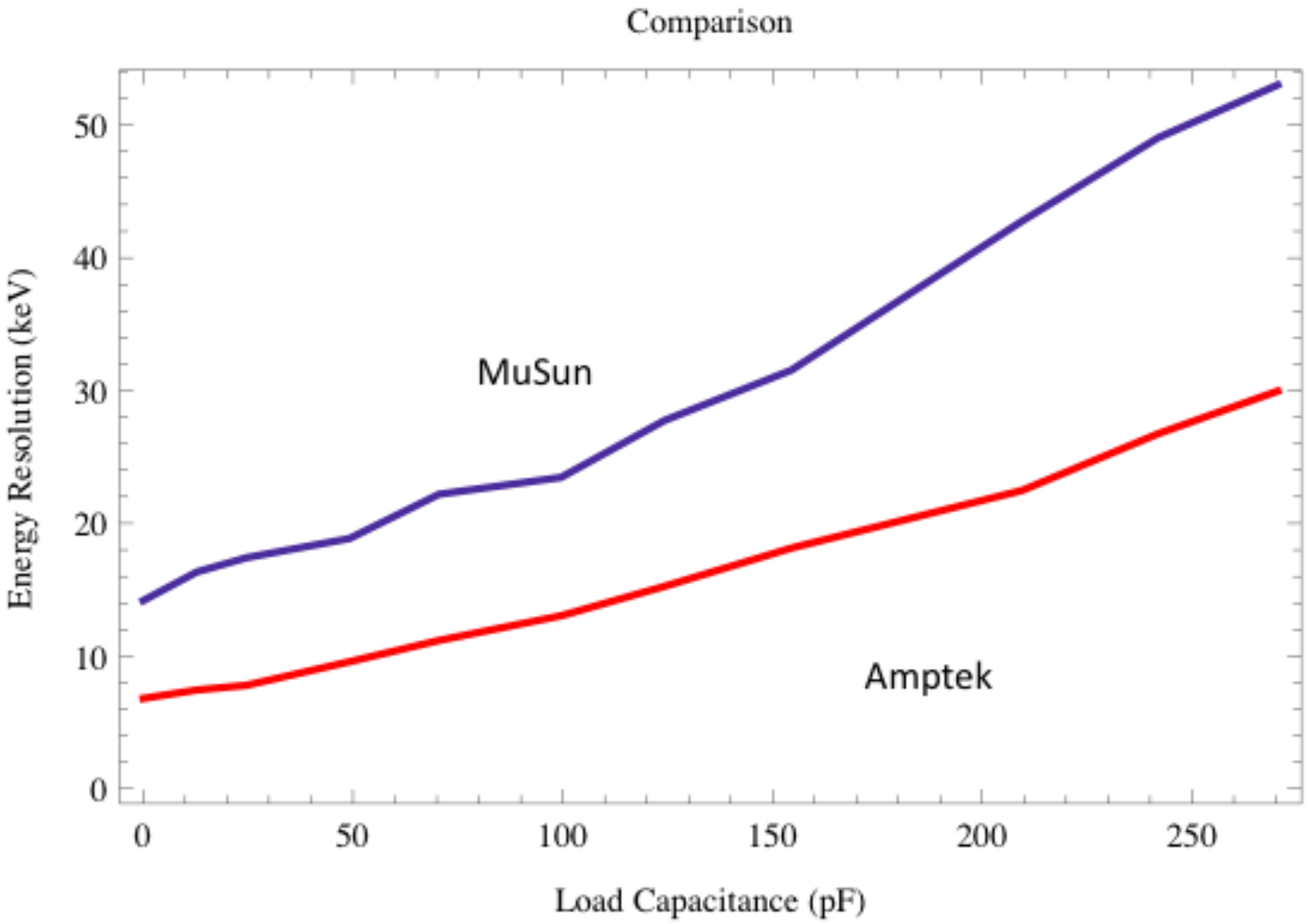
“Clean” Setup: Ideal Values

All components grounded together

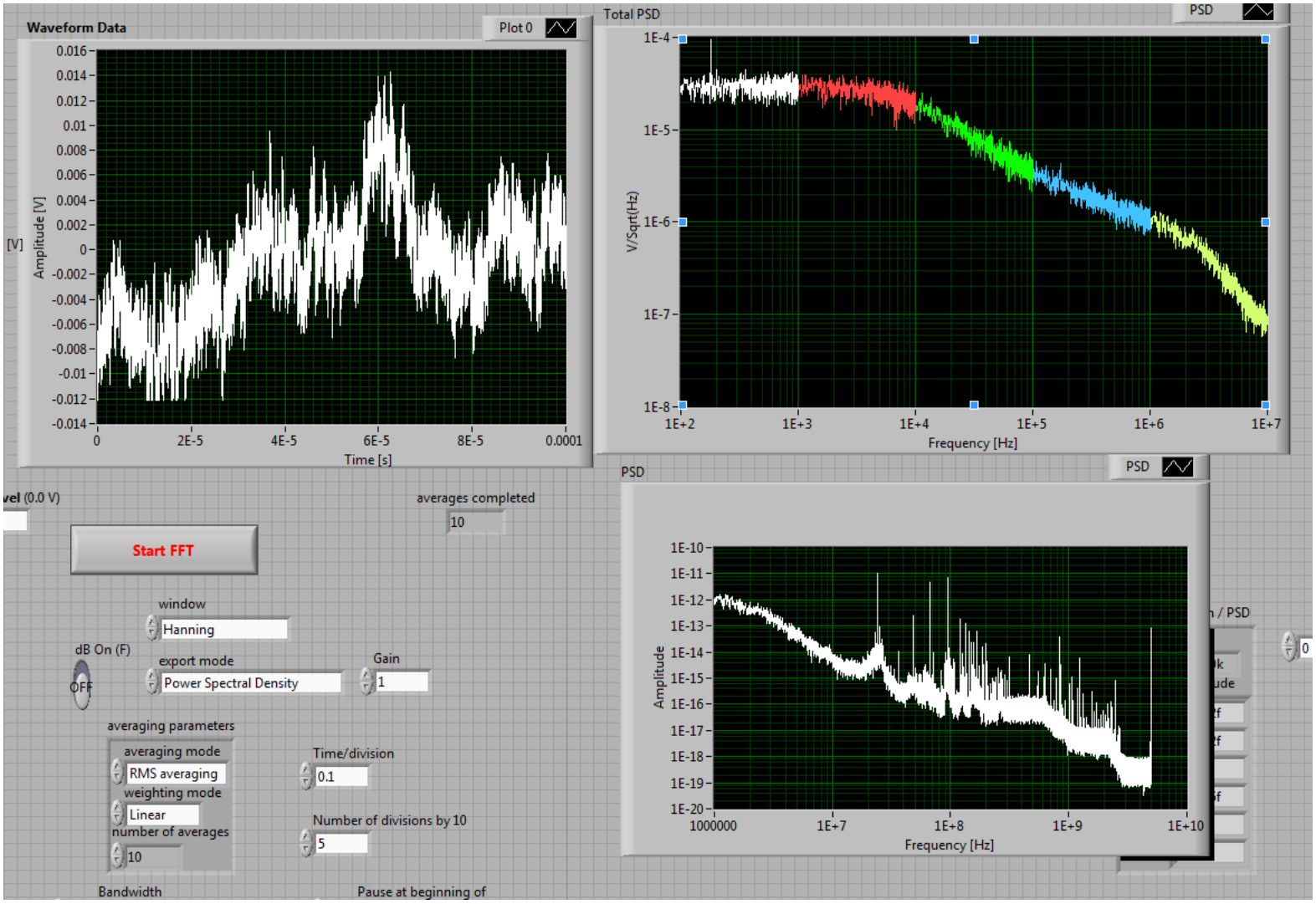
Well shielded



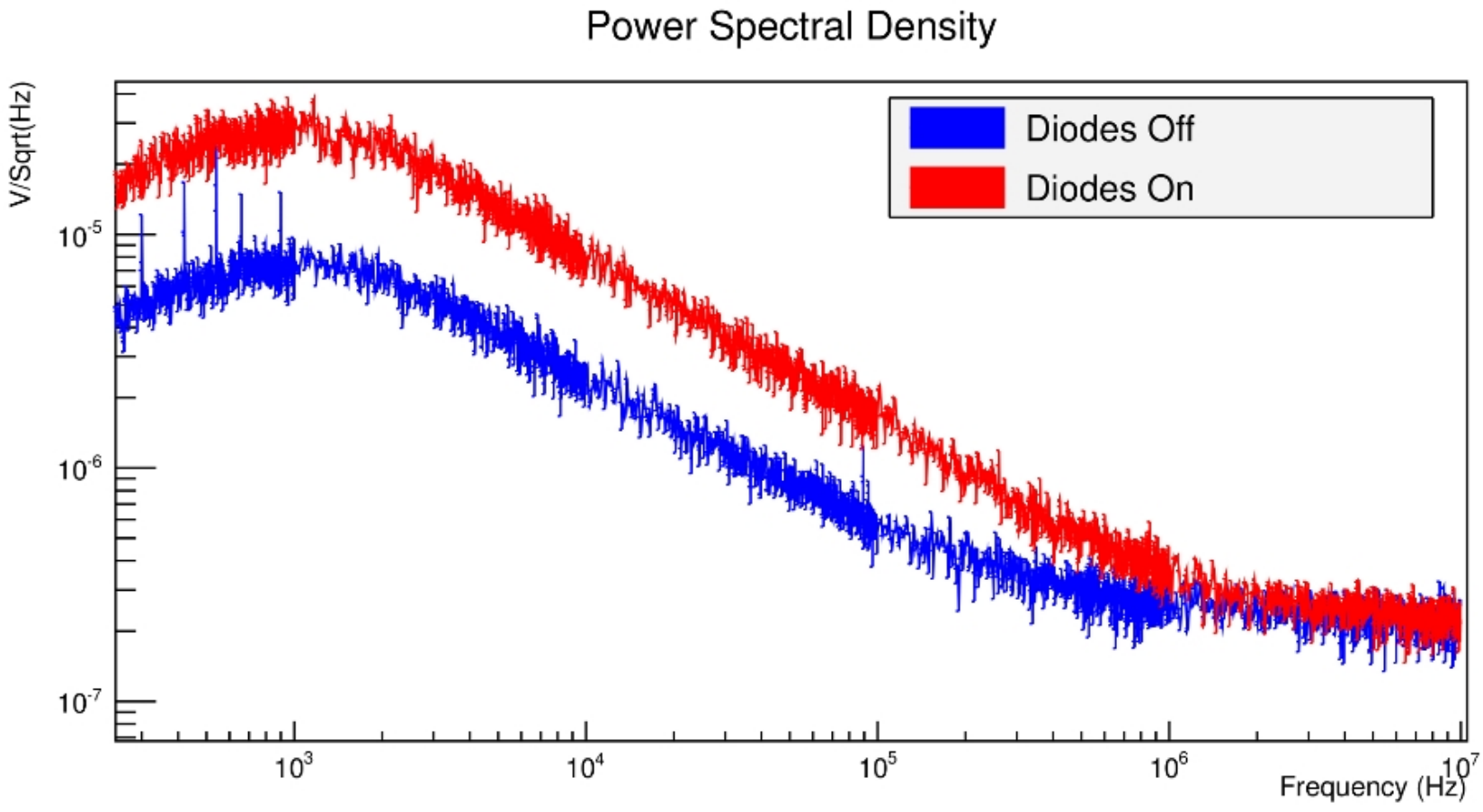
Effect of Capacitive Loads



LabVIEW


Waveform Data
Plot 0
Amplitude [V]
[V]
Time [s]
Total PSD
PSD
V/Sqrt(Hz)
Frequency [Hz]
PSD
PSD
Amplitude
Frequency [Hz]
averages completed
10
Start FFT
window
Hanning
dB On (F)
OFF
export mode
Power Spectral Density
Gain
1
averaging parameters
averaging mode
RMS averaging
weighting mode
Linear
number of averages
10
Time/division
0.1
Number of divisions by 10
5
Bandwidth
Pause at beginning of

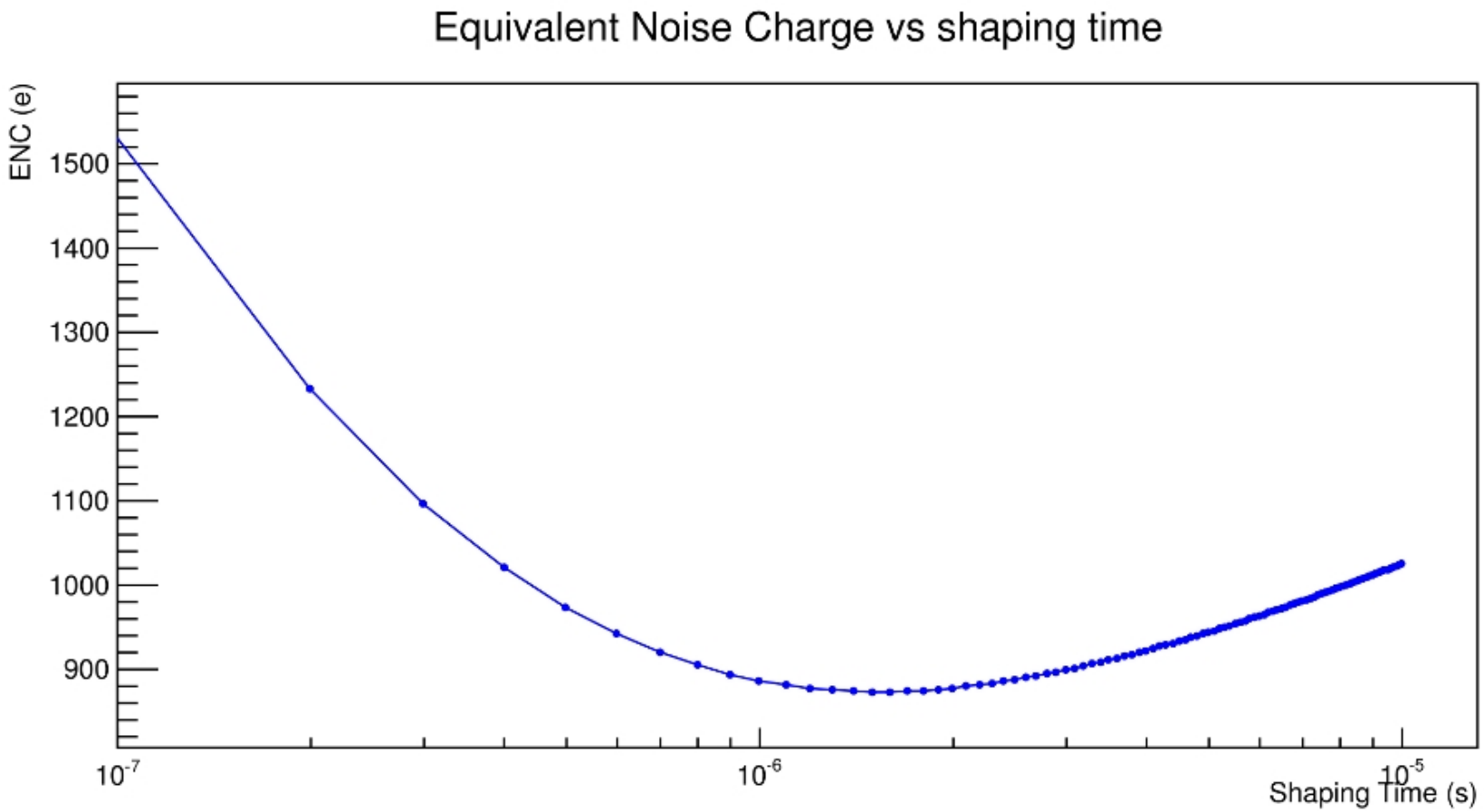
Effect of Protection Diodes



Noise Curves

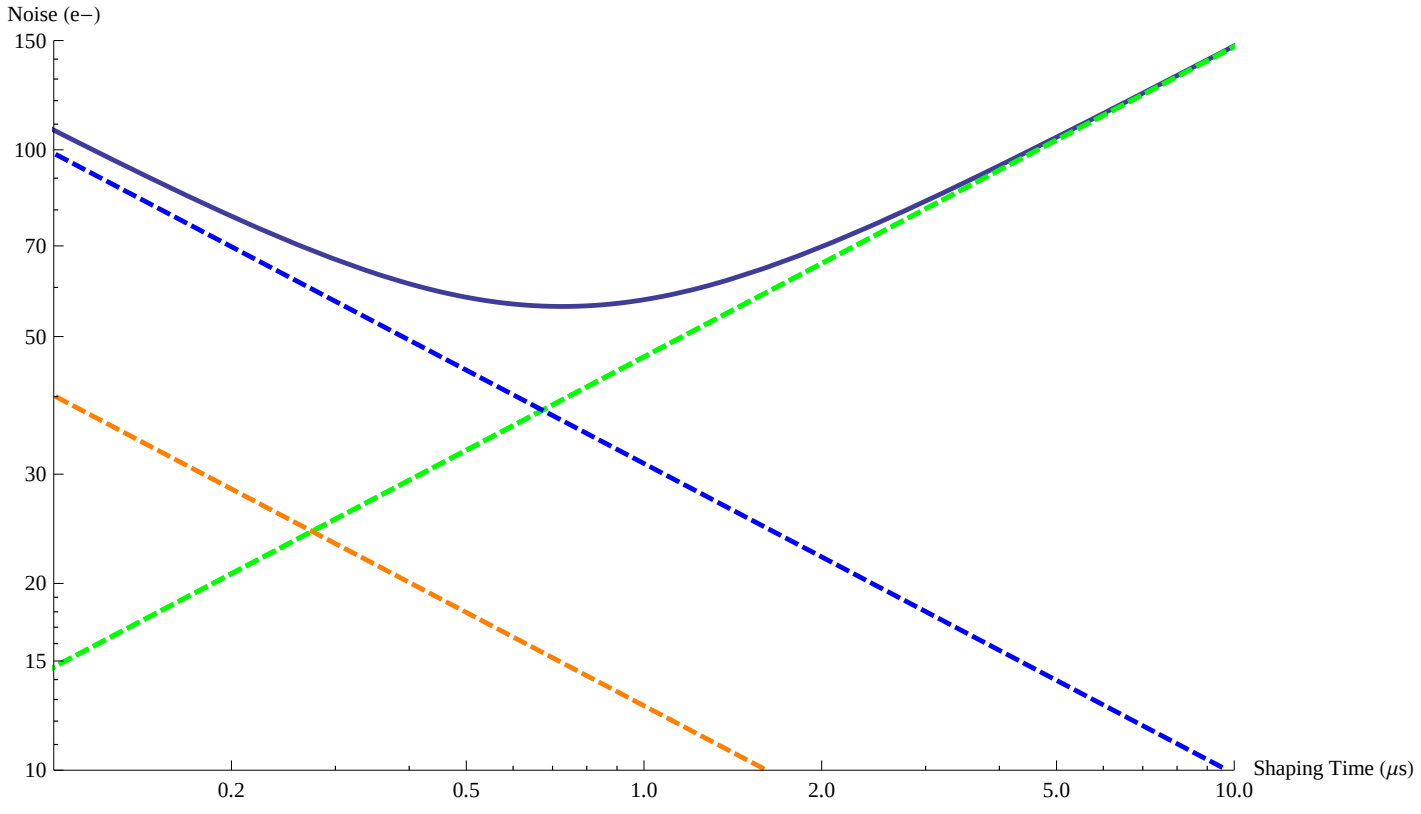
Take PSD data using LabVIEW

Integrate PSD, multiply by transfer function and scaling factor

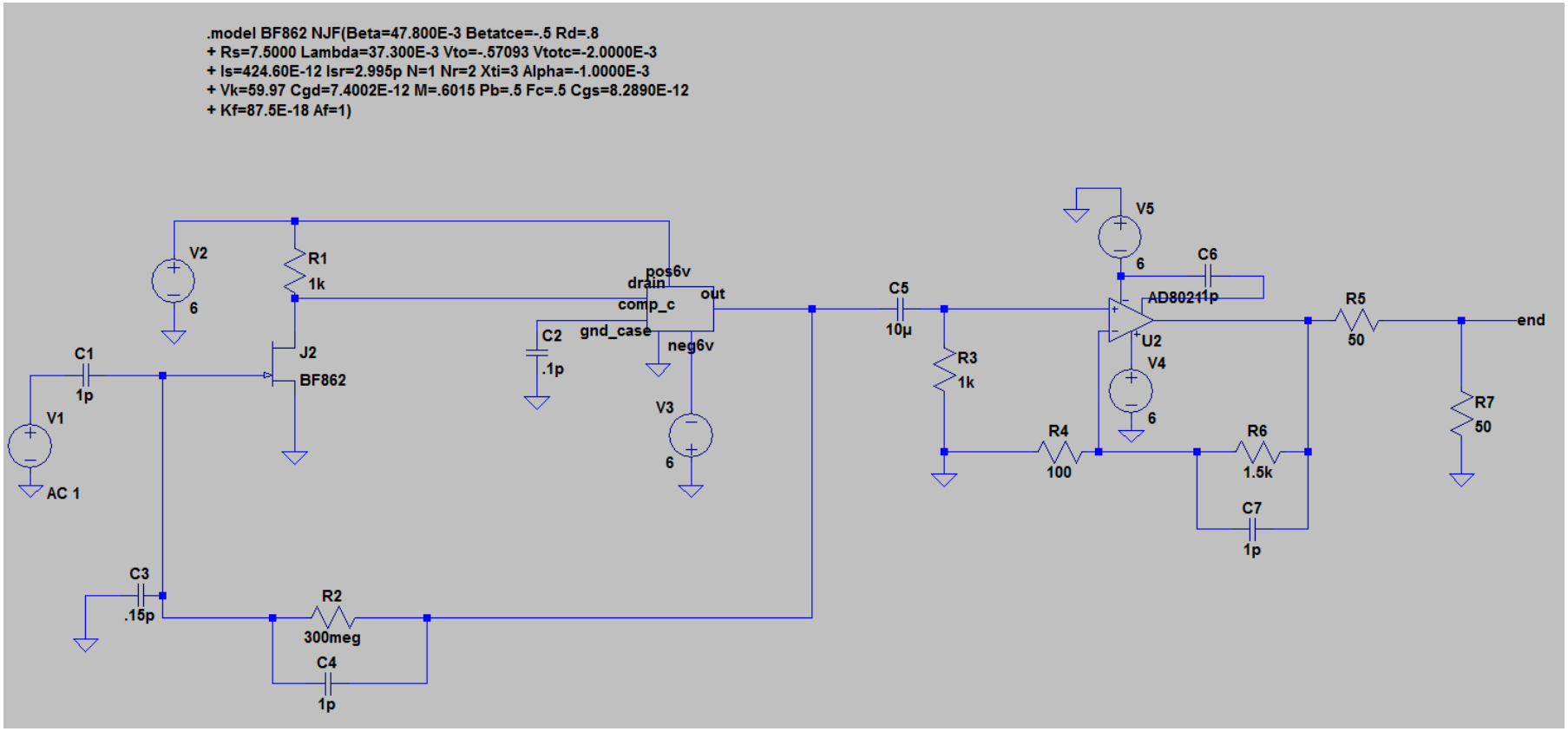


Analytical Model

Solid Blue: Total, Dashed Blue: Amplifier Voltage Noise, Dashed Orange: Series Resistance , Dashed Green: Parallel Resistance



SPICE Simulations



Future Work

Continue working on SPICE model

Improve analytical model

Make decision about preamp

Find a good way to mount preamp on TPC

Acknowledgements

Many thanks to:

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Questions?