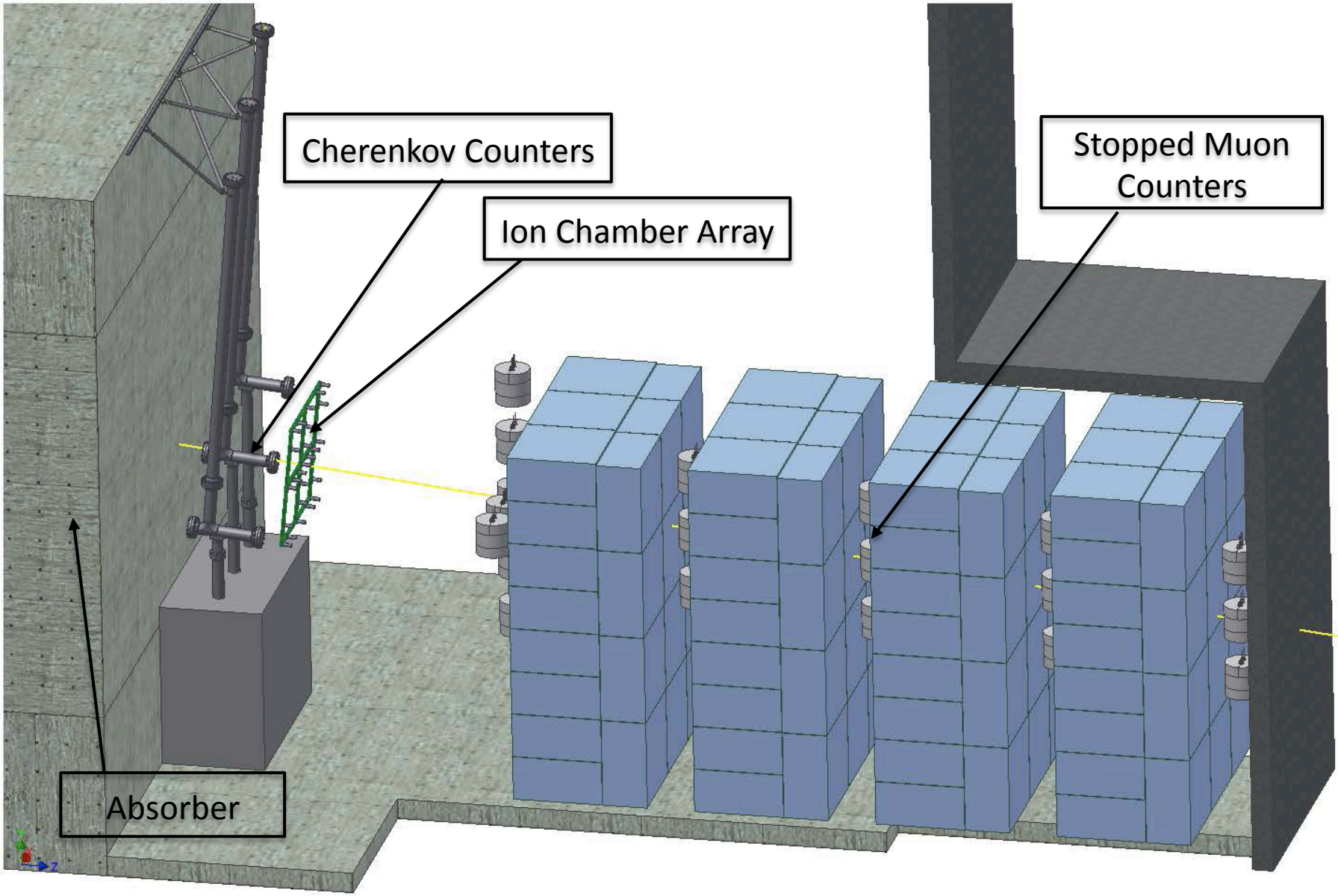
LBNE NuMI Muon Test Program

Introduction
Status of the Tests

G. Mills

LBNE BLM Muon Systems



LBNE Test Program

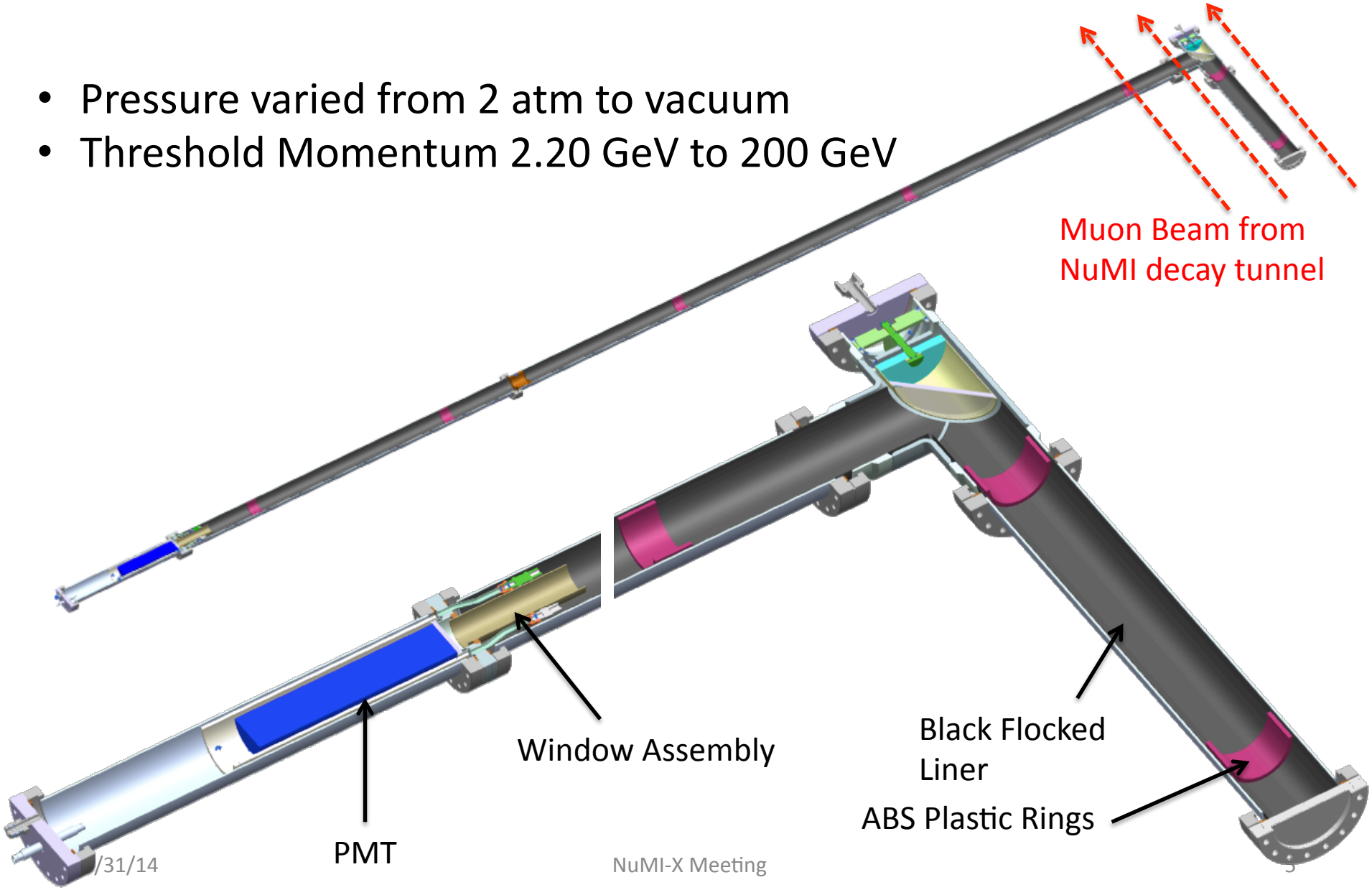
- Collaboration:
  - University of Colorado: A. Marino, Tianlu Yuan, and Eric Zimmerman +students
  - Drexel University: Chuck Lane +students
  - Los Alamos: Geoff Mills, Jan Boissevain + others
  - Fermilab: Cory Crowley, Paul Kasley, Mark Averett, Tom Zuchnik, Mike Andrews , and others
- Muon measurements after the absorber
  - Single particle environment (nearly)
  - Muons are created in pion and kaon decays and bear directly on neutrino production
  - Rely only upon knowing muon energy loss and scattering in the absorber material
  - Complements other flux measurements:
    - external hadro-production measurements don't include horn and decay tunnel
    - ND neutrino measurements rely on knowing neutrino-nucleus cross sections

LBNE Prototype Tests at NuMI

- Opportunity to test those devices in NuMI beam during the Nova run
  - Planning started August 2012
  - Infrastructure put into place spring 2013
  - First detector prototypes in place August-September 2013
  - First signals observed in October, 2013
  - Operational Readiness Review in February,2014

NuMI Cherenkov Counter

- Pressure varied from 2 atm to vacuum
- Threshold Momentum 2.20 GeV to 200 GeV



Cherenkov Gases

Table 1 Properties of several standard gases used in Cherenkov counters.

Gas	$(n-1)_{STP}$ $(\times 10^6)$	P_0^{STP} (GeV/c)	θ_c^{STP} (mrad), $P \to \infty$	Photons/m
Nitrogen	298	4.33	24.4	22
Oxygen	271	4.54	23.3	20
Argon	281	4.45	20.8	20.7
Neon	67.1	9.12	11.6	5.0
Helium	35.0	12.65	8.37	2.6
CO_2	449	3.52	30.0	33

Argon Gas as a Radiator

Table 2 The behavior of visible Cherenkov light from muons in Argon gas.

Pressure (atm)	P_0 (GeV/c)	θ_c (mrad) $P \to \infty$	Photons/m $P \to \infty$
5×10^{-4}	200	0.5	0.5
0.1	44.5	2.1	2.1
.5	6.29	6.6	6.5
1	4.45	14.7	14.6
3	2.57	20.8	20.7
10	1.41	36.0	35.9
20	1.00	93.0	92.6

At NuMI Alcove 2, about 10^5 muons/cm^2 are expected

Dispersion in Argon

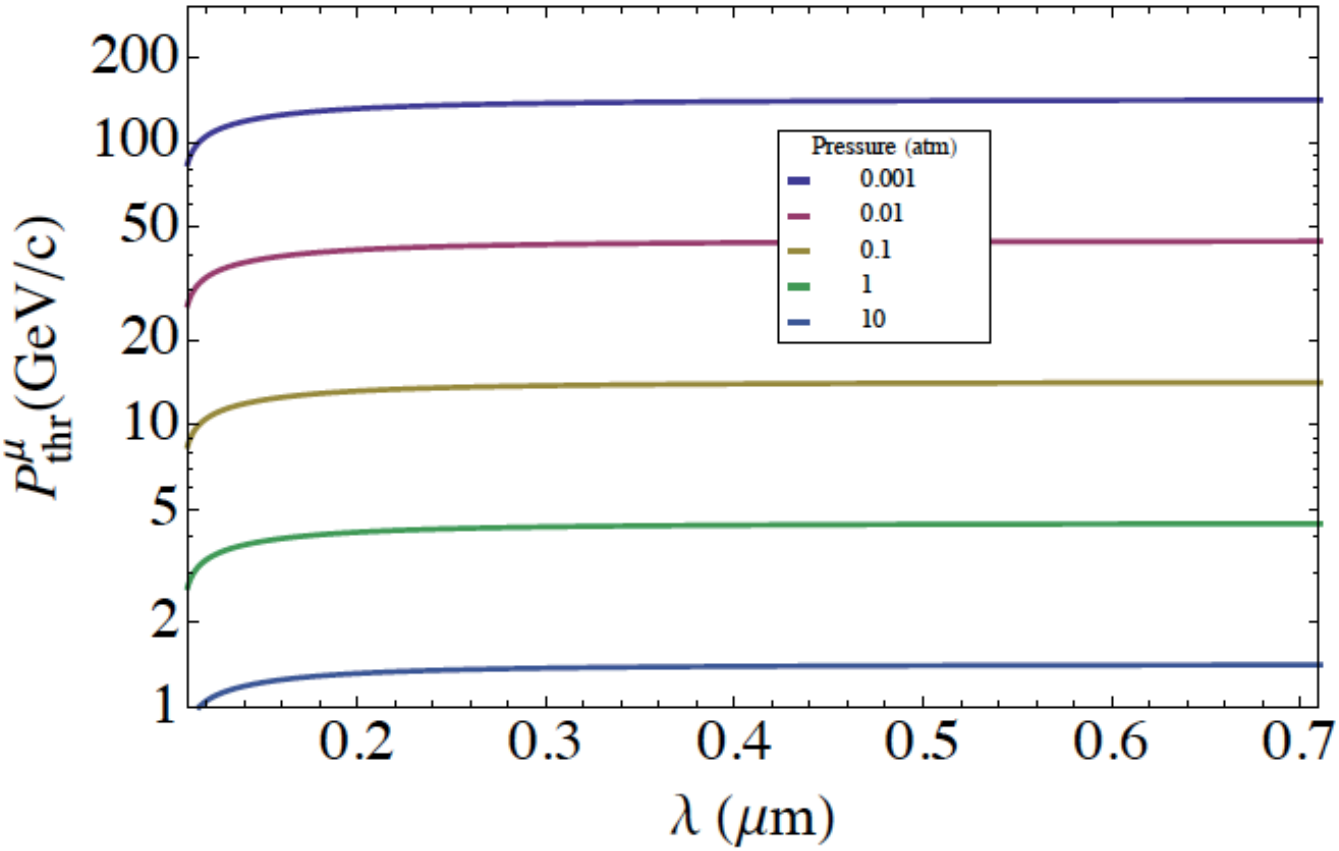
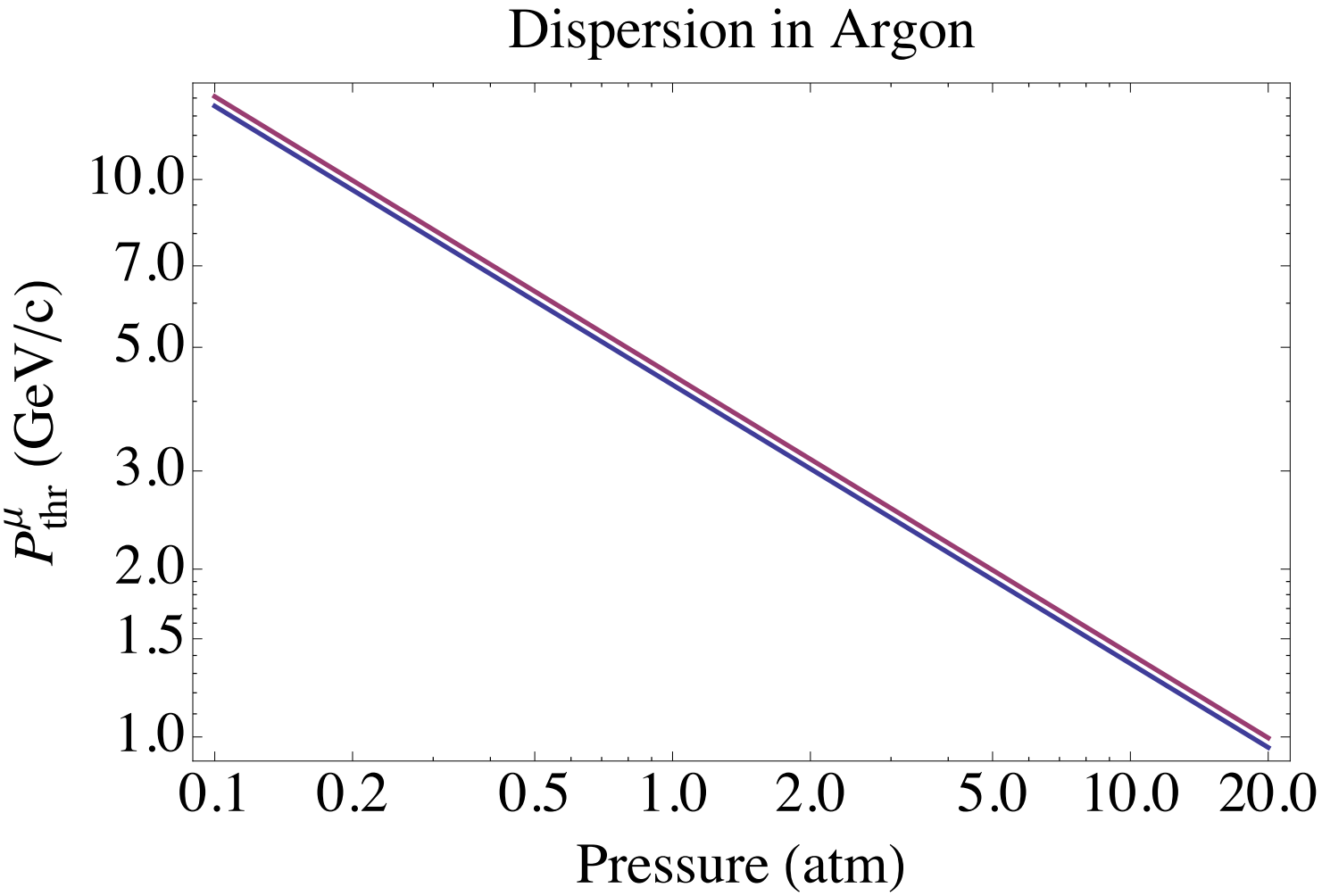
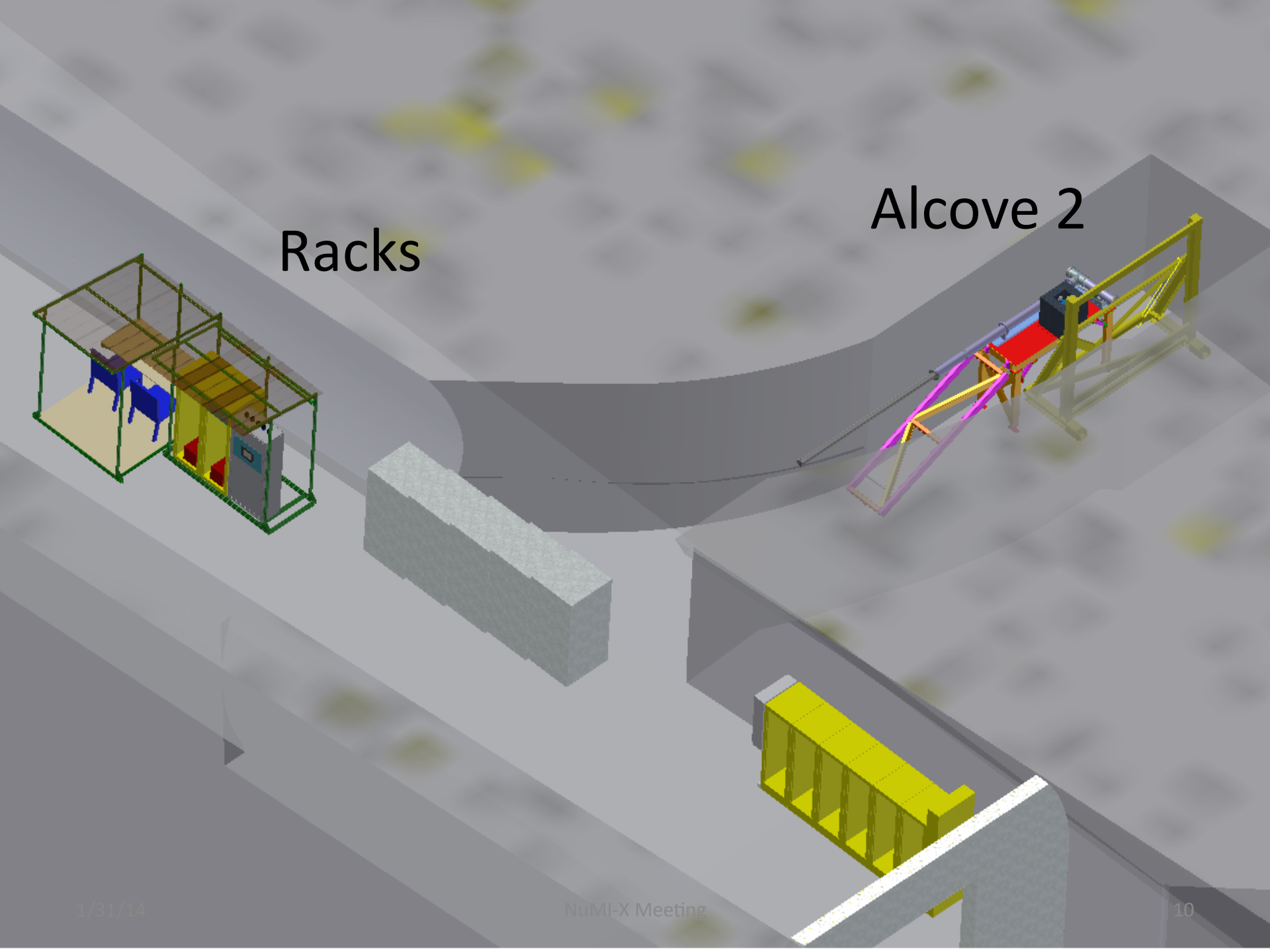


Figure 9 Wavelength dependence of the muon threshold momentum for argon for several gas pressures.

$\Delta P_{thr}/P_{thr}$~4% over 250nm-650nm




Racks
Alcove 2

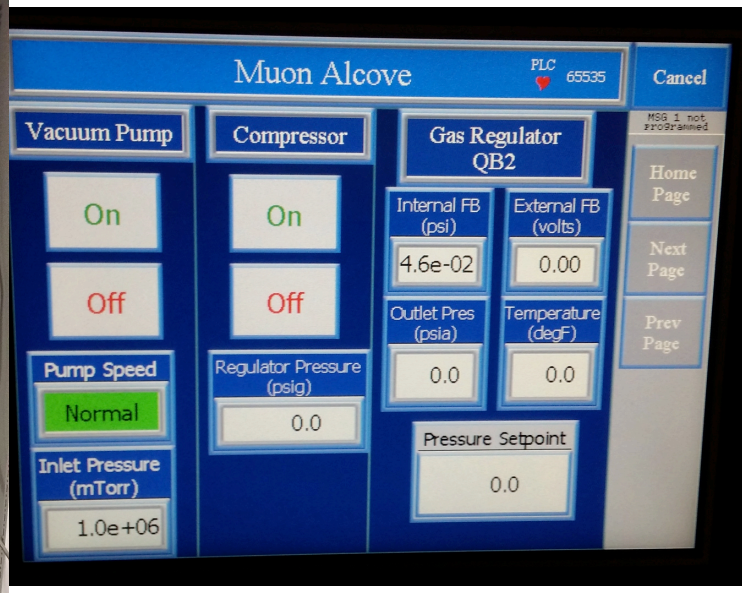
Operational Readiness

- Phase 1 operation
  - Unattended:
    - Actuators left in acquiescent state
    - Gas system at atmospheric pressure and valved off
    - PMT voltage on
    - Data acquisition operational
  - Attended
    - Actuators controlled locally
    - Gas system may be operated locally from vacuum to 2 atm
    - PMT voltage on
    - Data acquisition operational

Rack Area Outside Alcove 2

Gas Panel and Controls Rack Interior

Controls Panel and Touch Pad



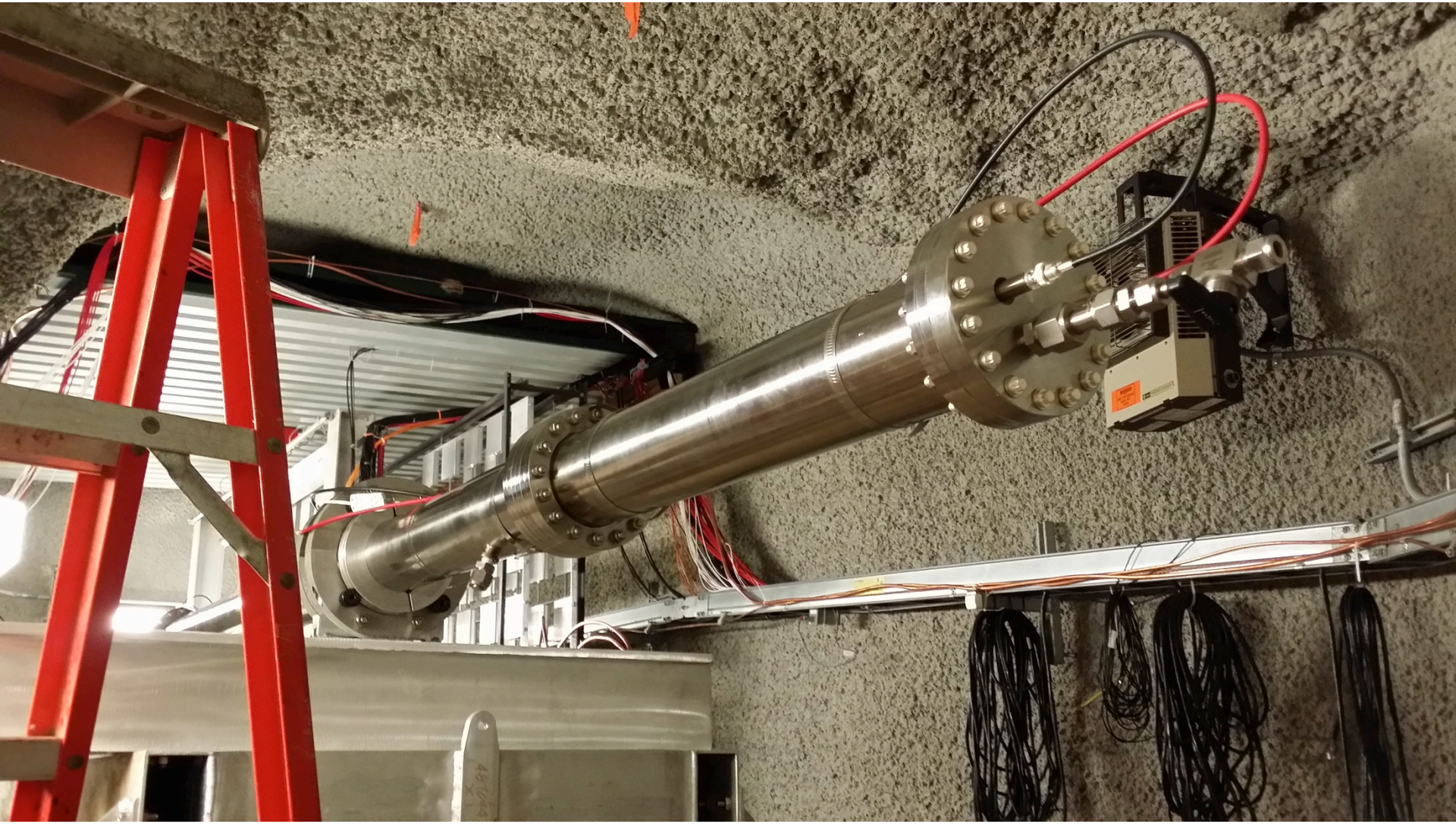
Compressor and Vacuum Pump

Work Area

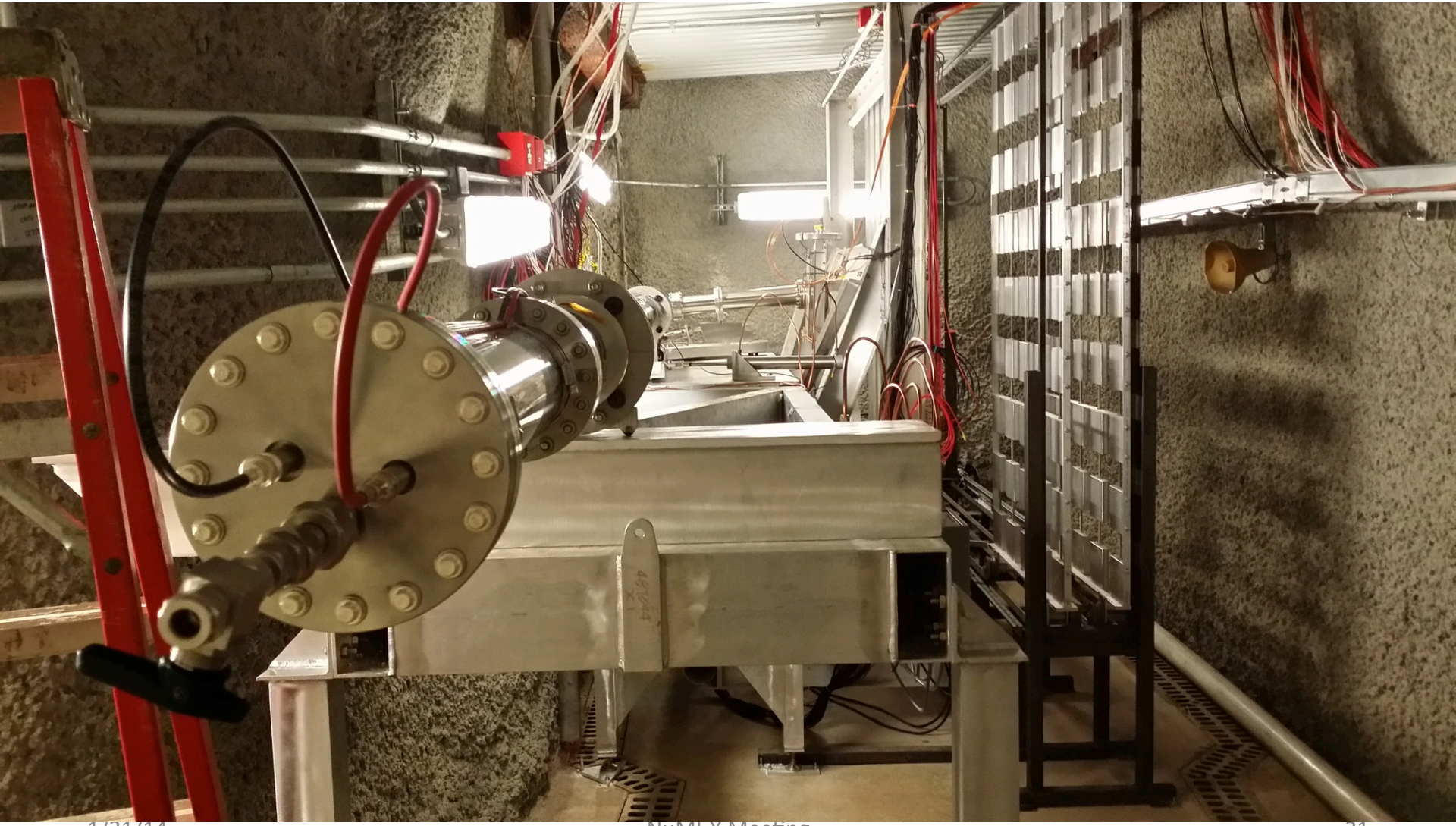
Test Stand Area 01/15/2014

STEIN

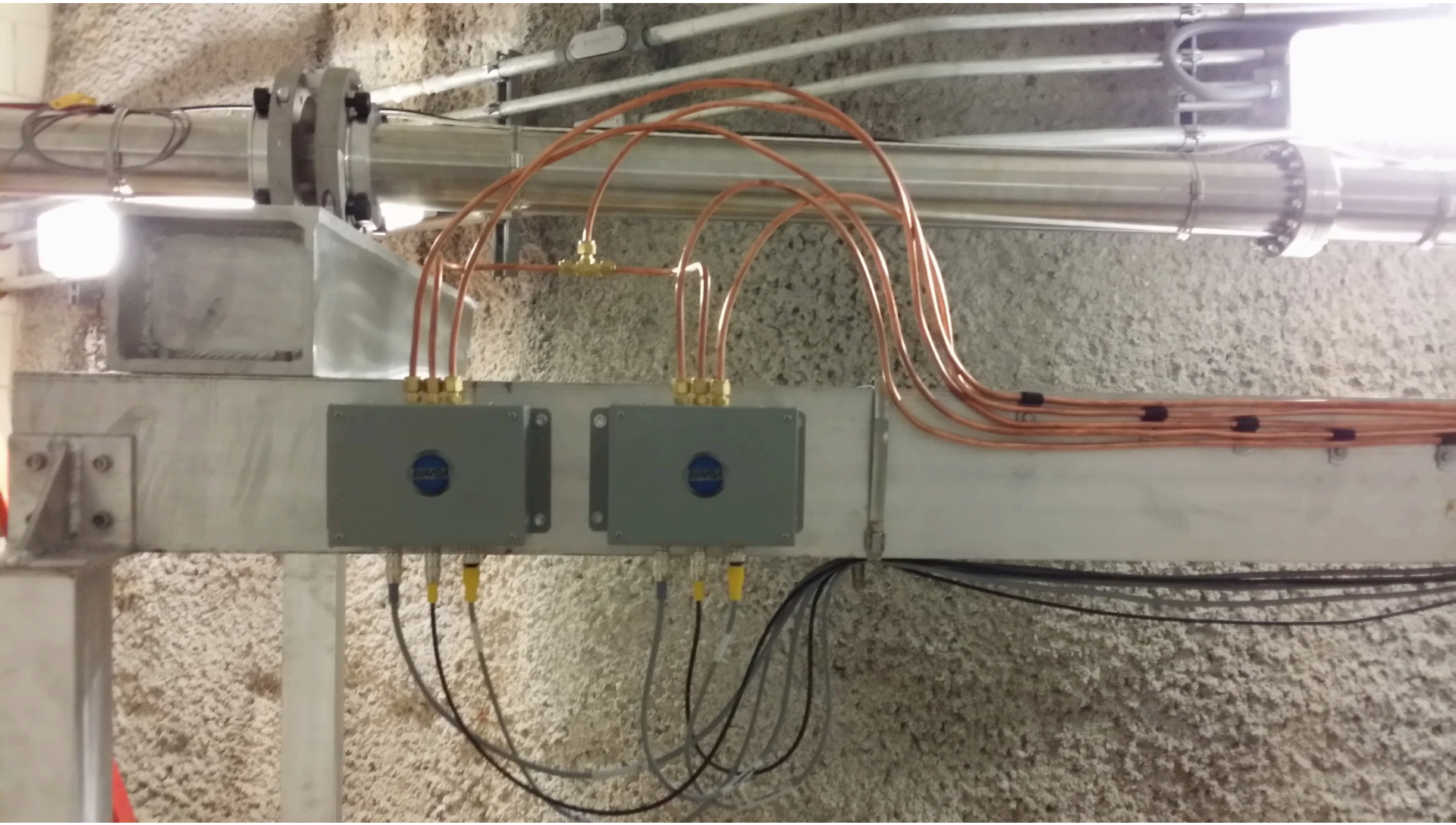
Window and PMT Section



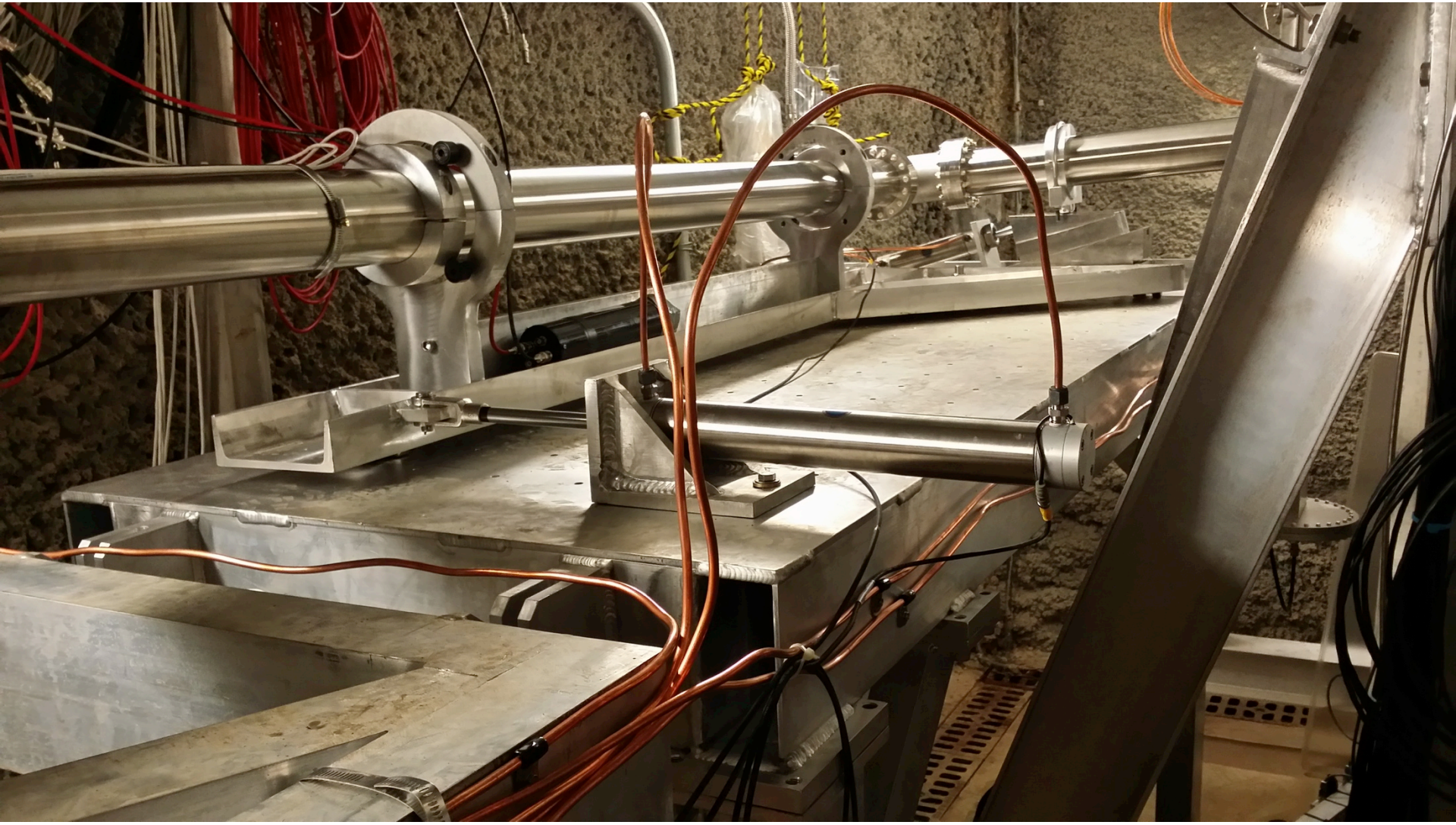
PMT Section and Exhaust Valve



Pneumatic “Bimba” Actuators



Pneumatic Lines



Elevation Rollers

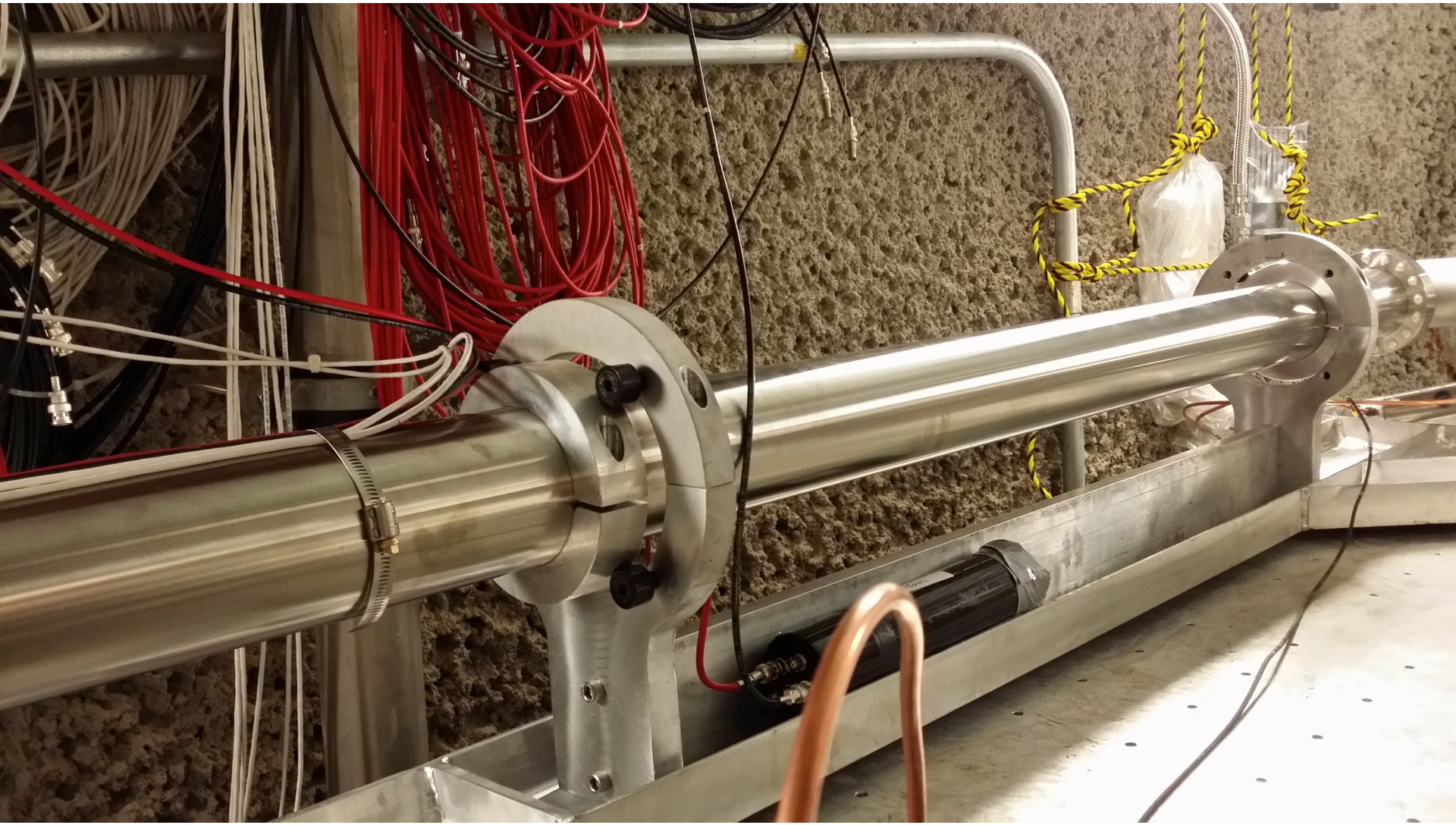
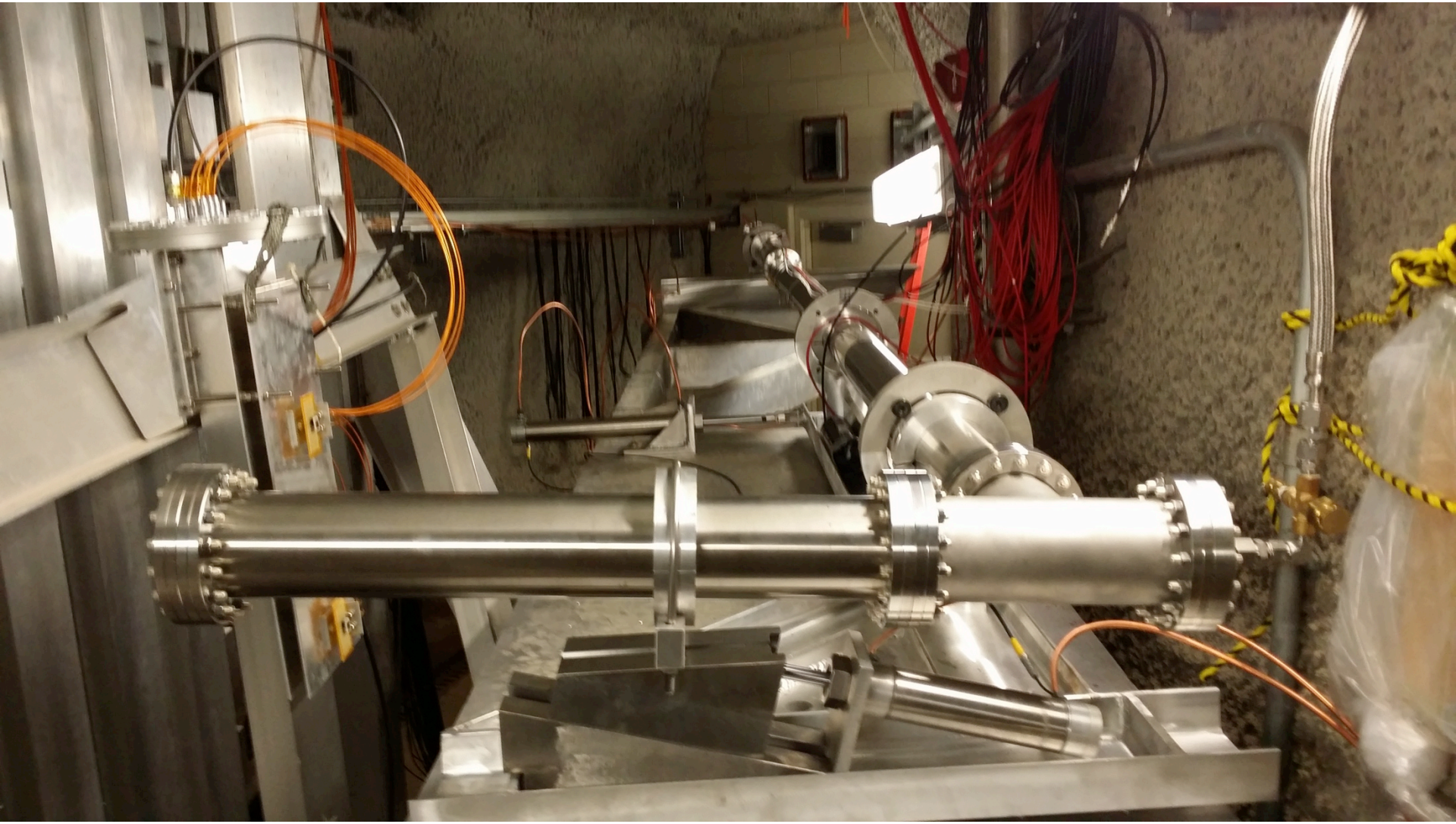


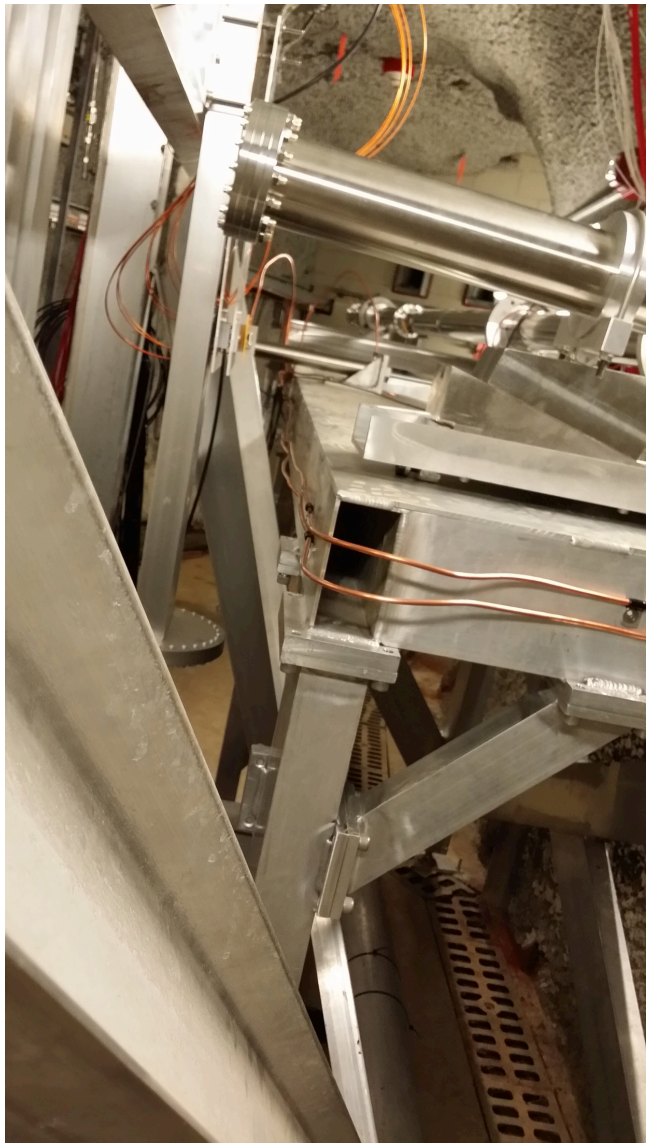
Table Top and Pivot

Radiator Section

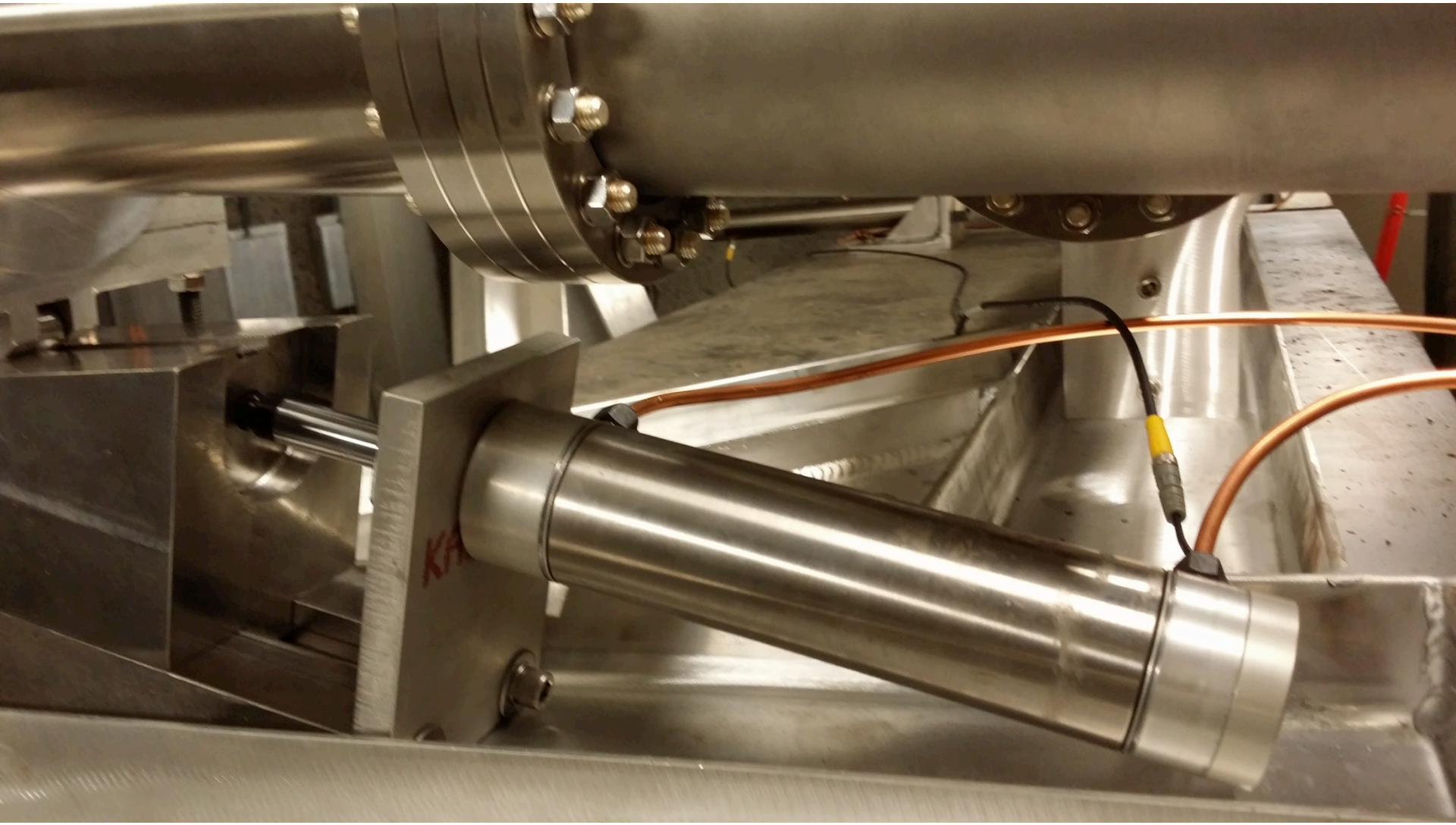


Detector Stand

Pneumatic Lines



Elevation Actuator

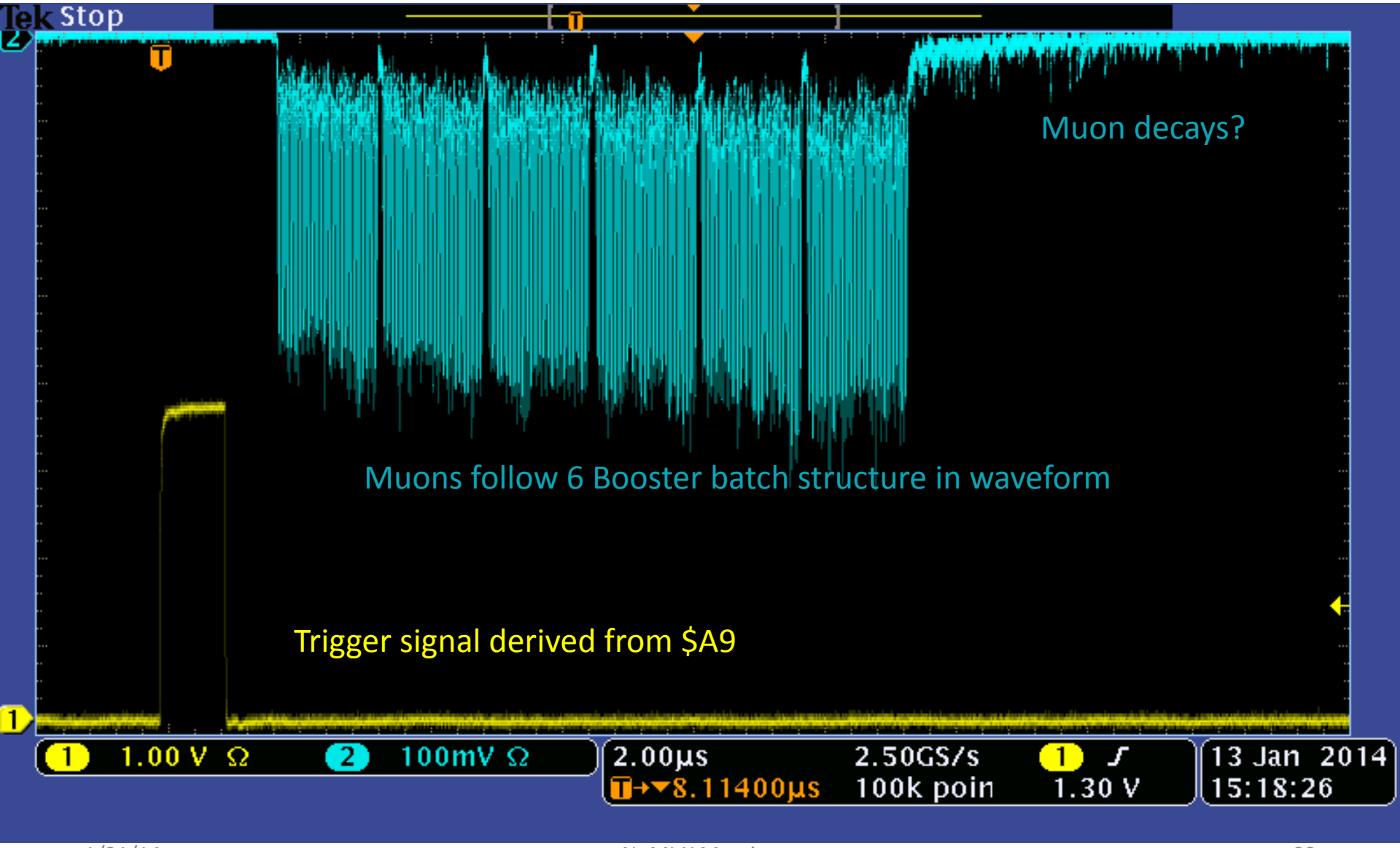


Elevation Roller

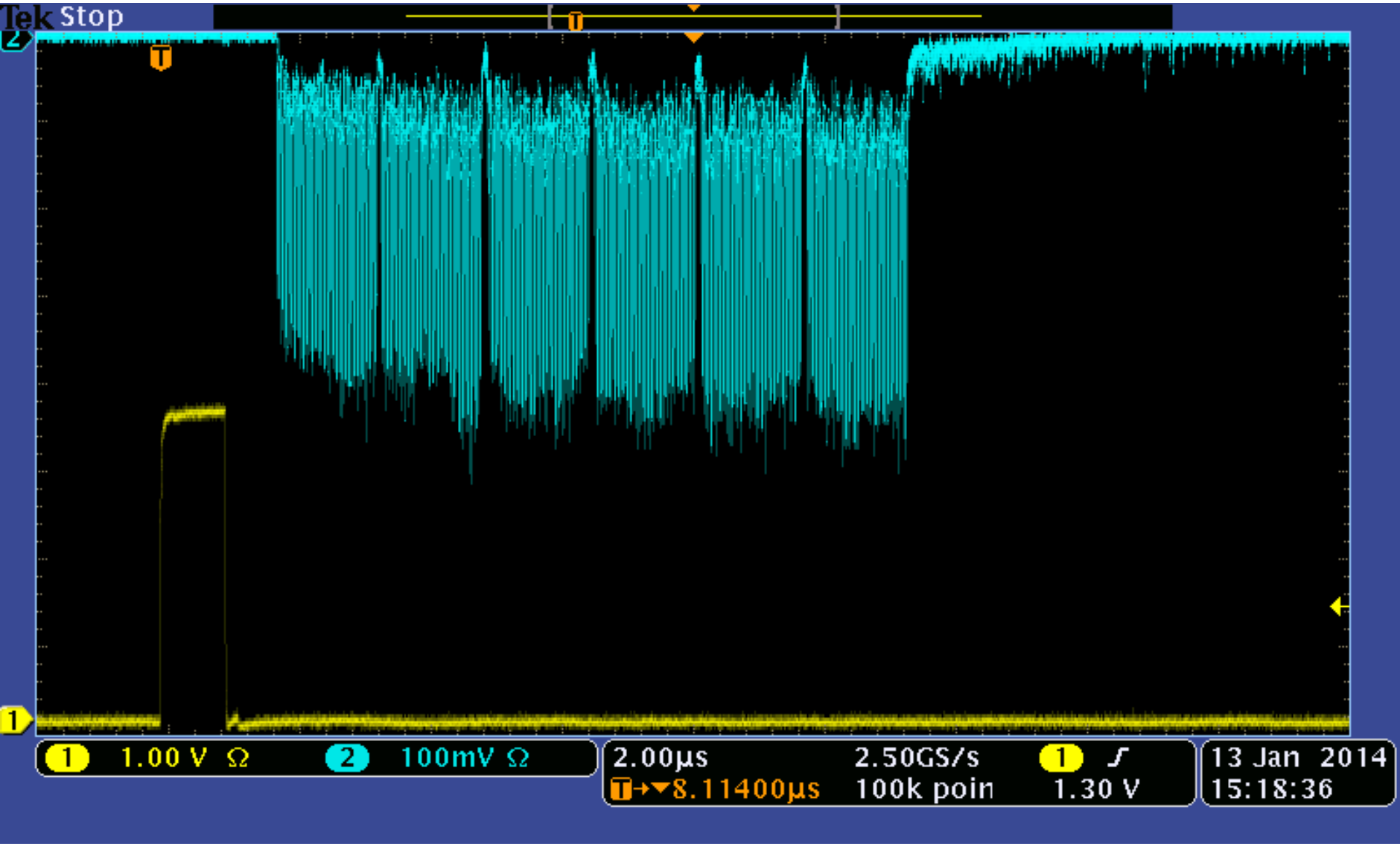
Data Recording

- Currently using Tektronix MSO3034 scope
- 2.5 GHz sample rate, 300 MHz bandwidth
- Network based so readout can happen remotely
- Developing Python-based automated DAQ
- The following data recorded manually
  - Threshold (Argon, 1 atm)
    - 4.45 GeV/c for muons
    - 22 MeV/c for electrons

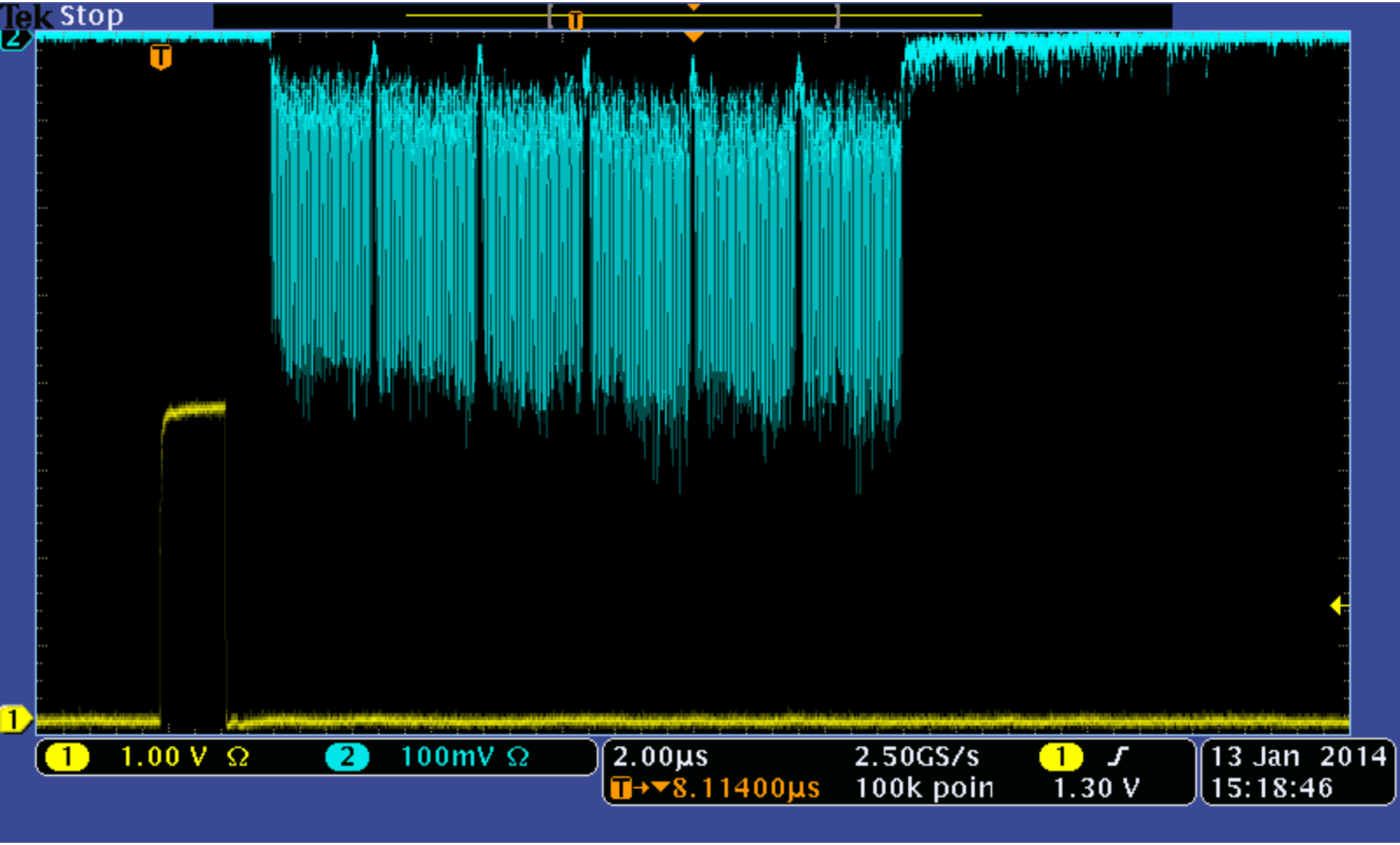
Typical NuMI Beam Pulse



Another…


Tek Stop
1.00 V Ω
100mV Ω
2.00µs
2.50GS/s
8.11400µs
100k poin
1.30 V
13 Jan 2014
15:18:36

And another ….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100k poin
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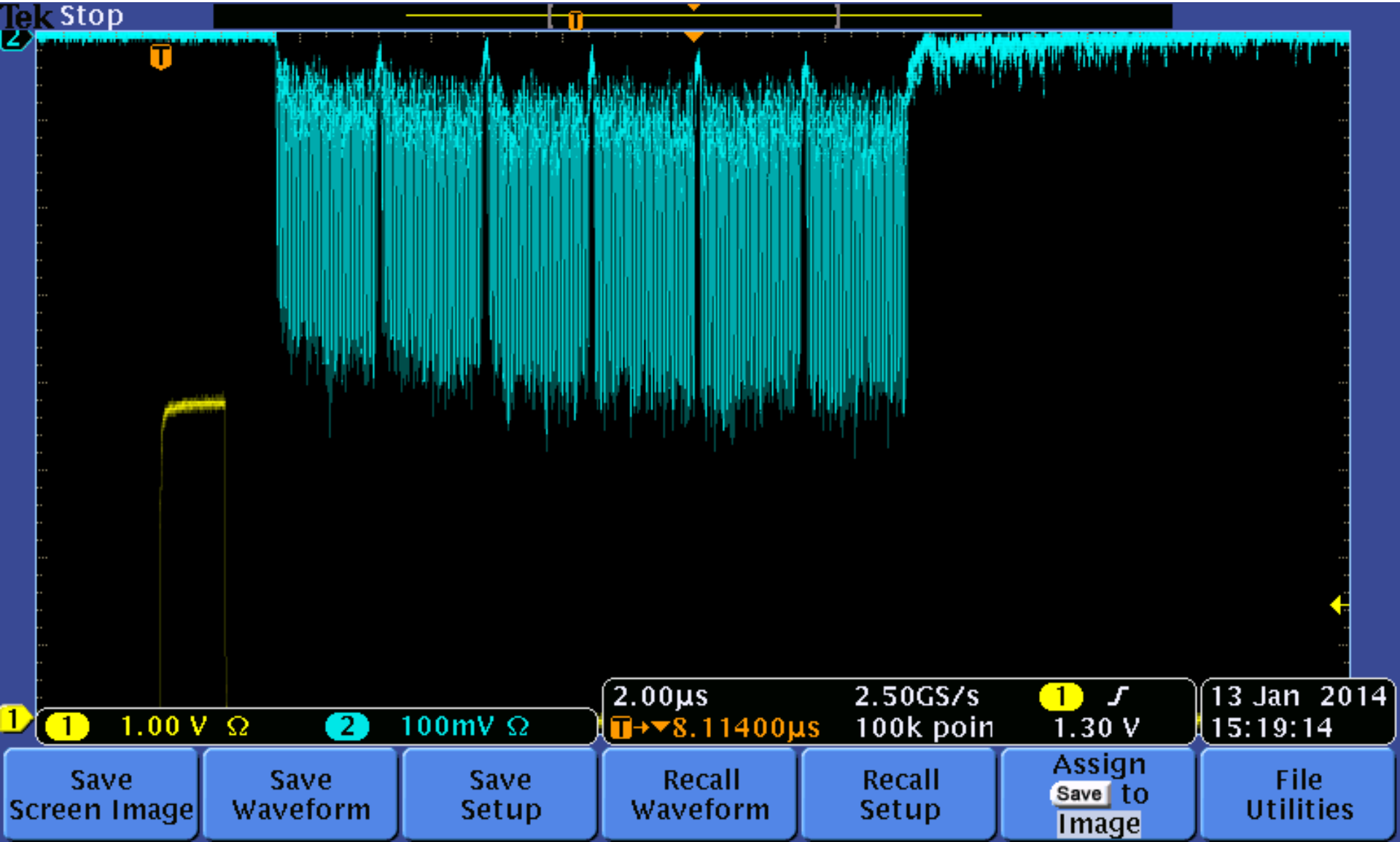
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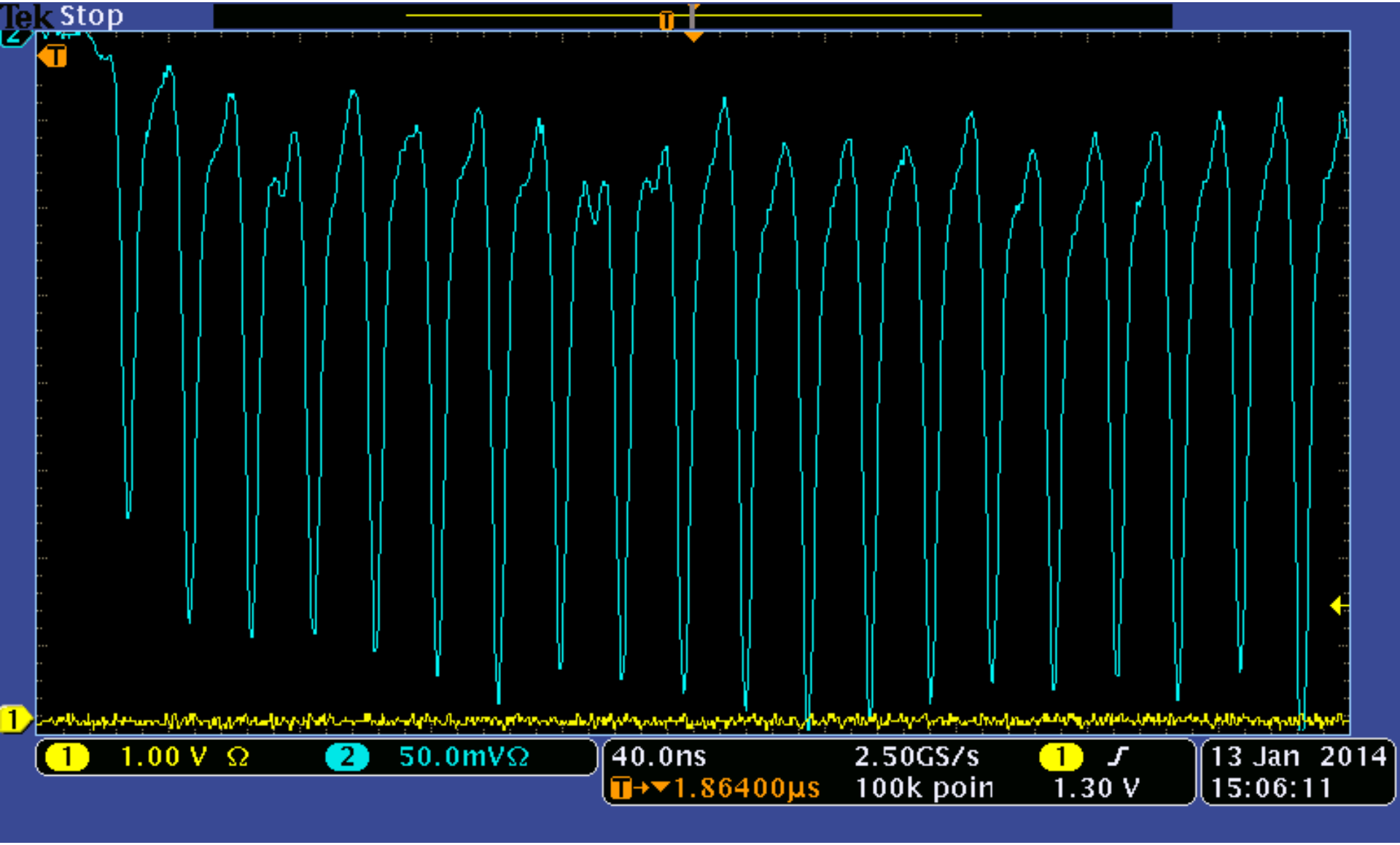
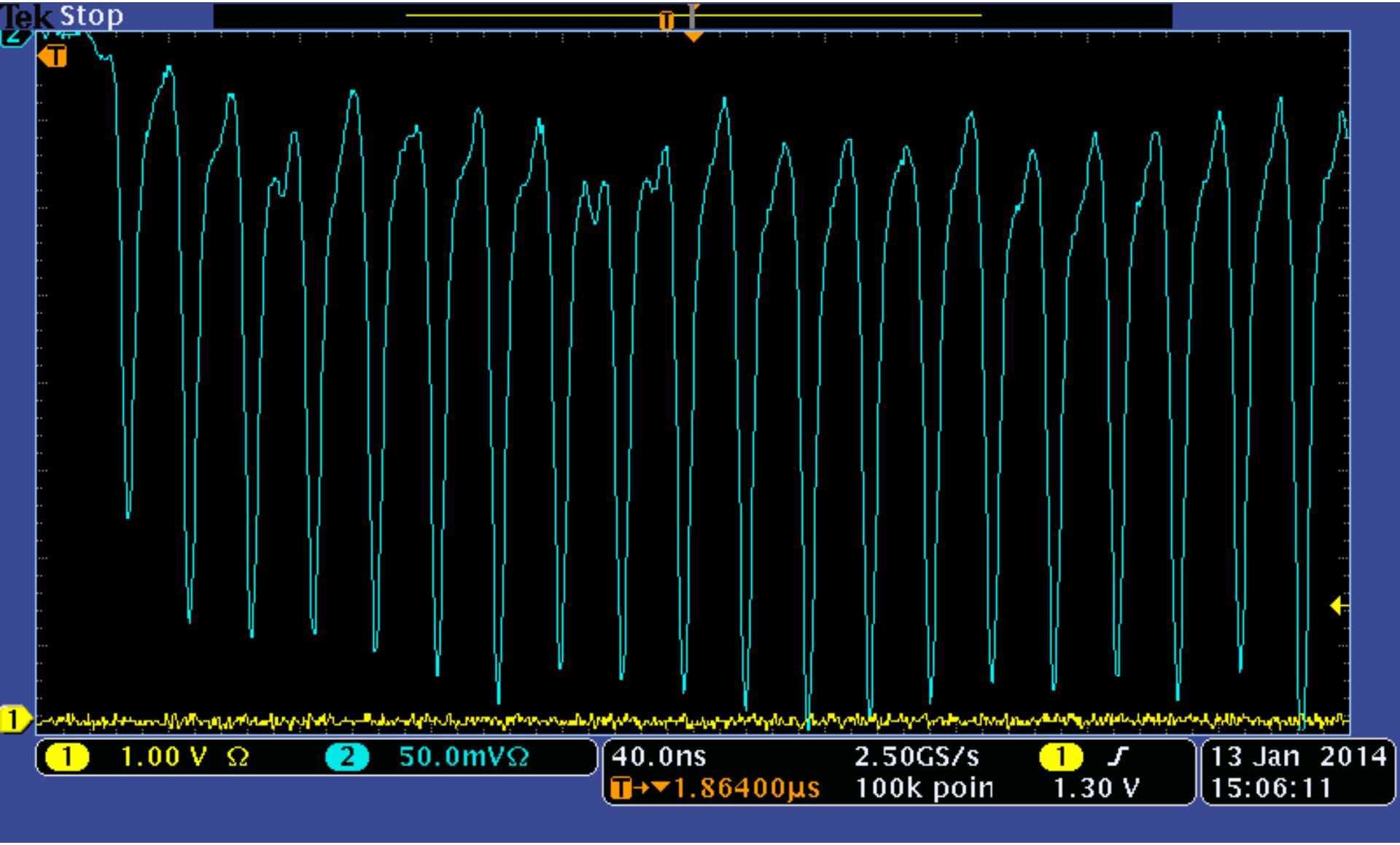
100mV Ω
2.00µs
2.50GS/s
8.11400µs
100k poin
1.30 V
13 Jan 2014
15:19:14
Save Screen Image
Save Waveform
Save Setup
Recall Waveform
Recall Setup
Assign Save to Image
File Utilities

Beginning of Pulse Train (50 MHz RF)




Tek Stop
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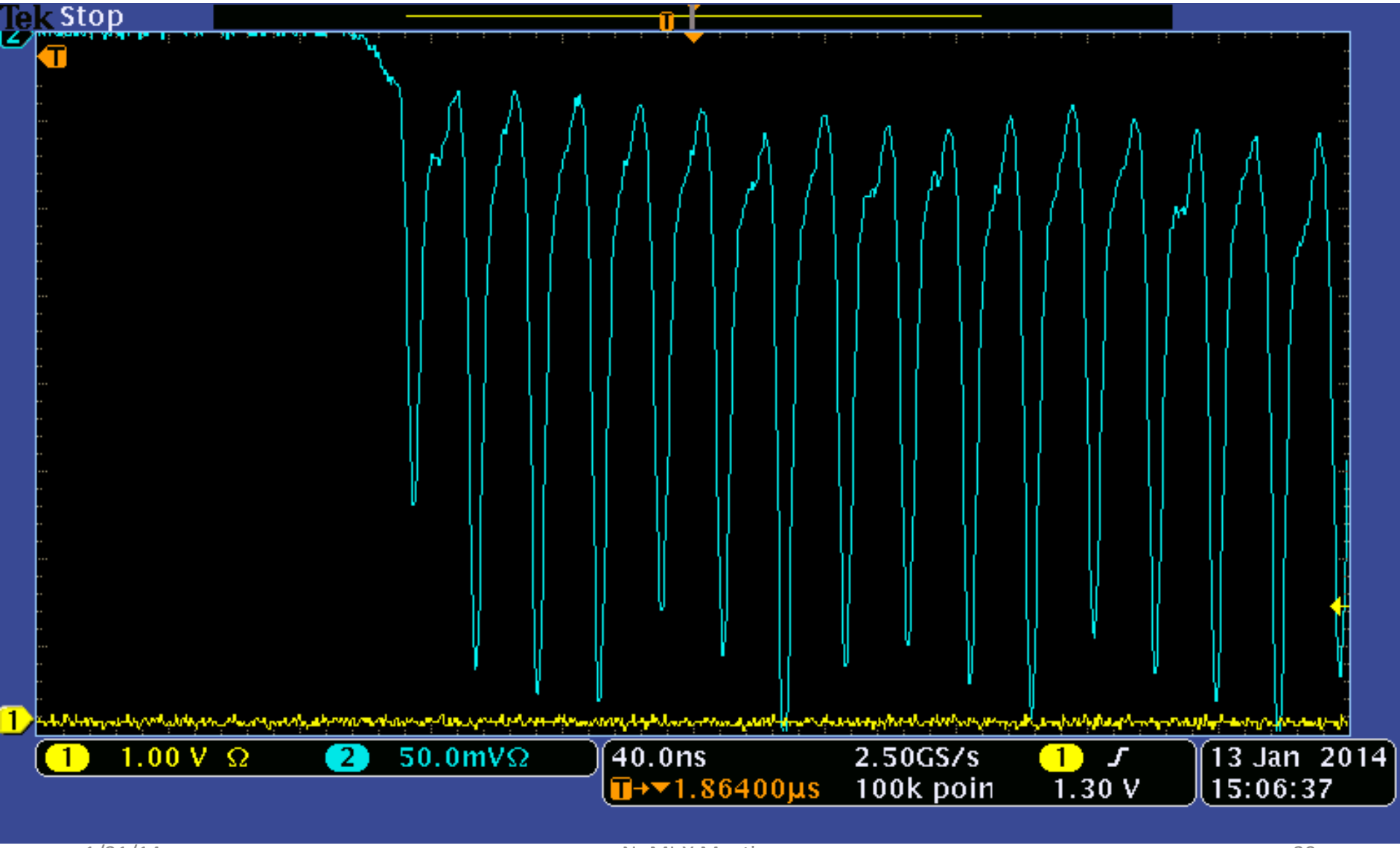
2 50.0mVΩ
40.0ns 2.50GS/s
1.86400µs 100k poin
1 1.30 V
13 Jan 2014
15:06:11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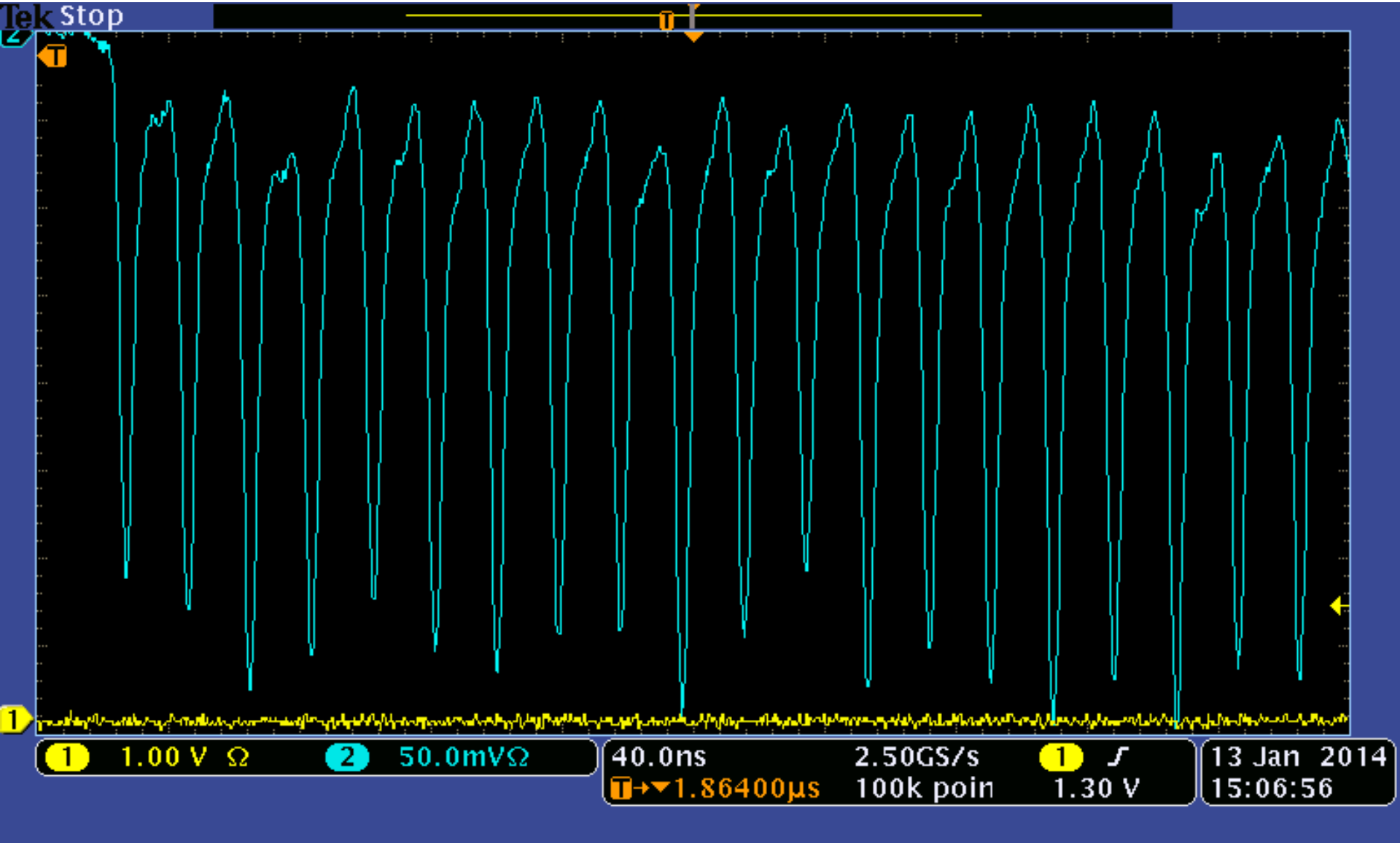
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1.86400µs 100k poin
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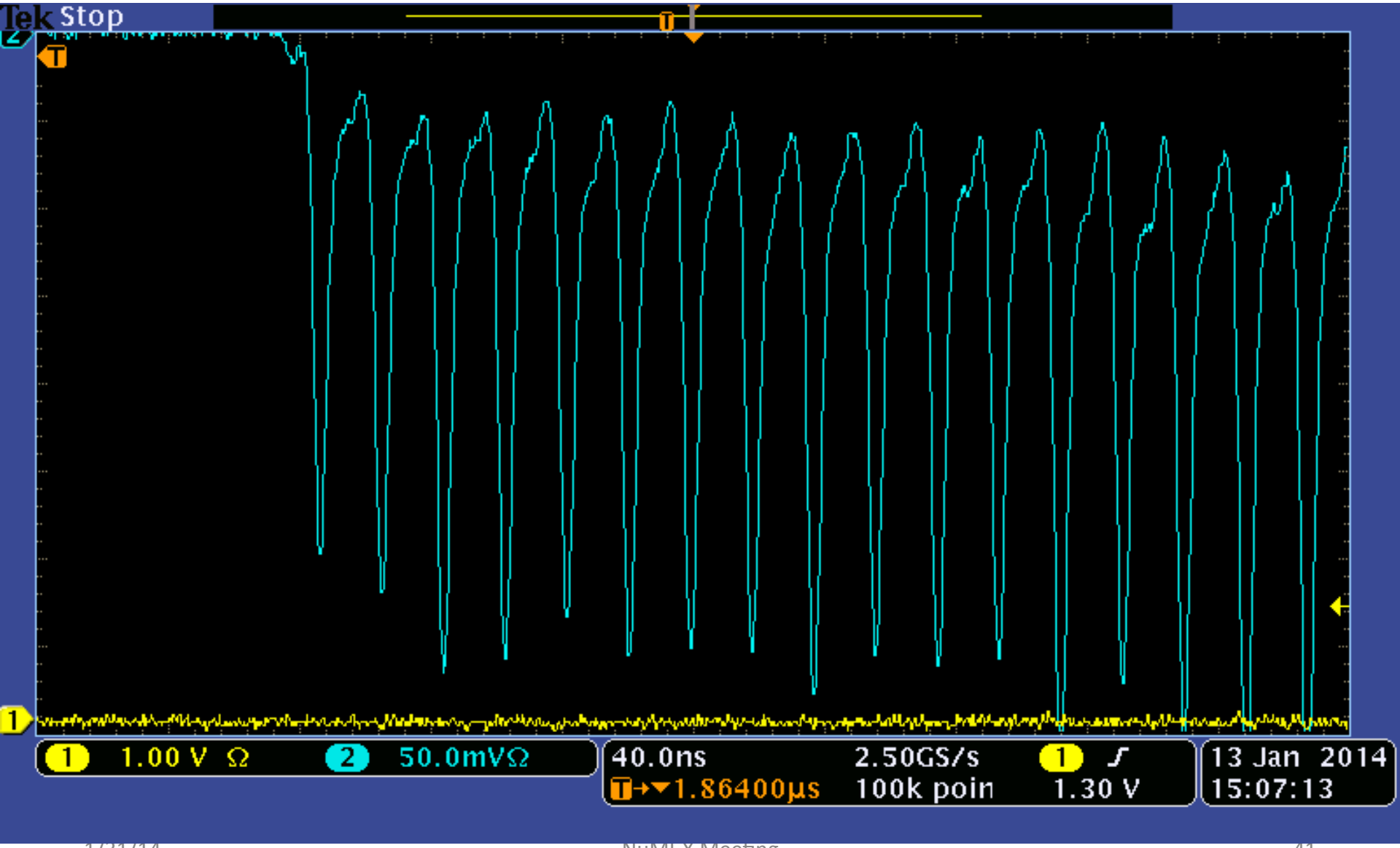
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40.0ns 2.50GS/s
1.86400µs 100k poin
1 1.30 V
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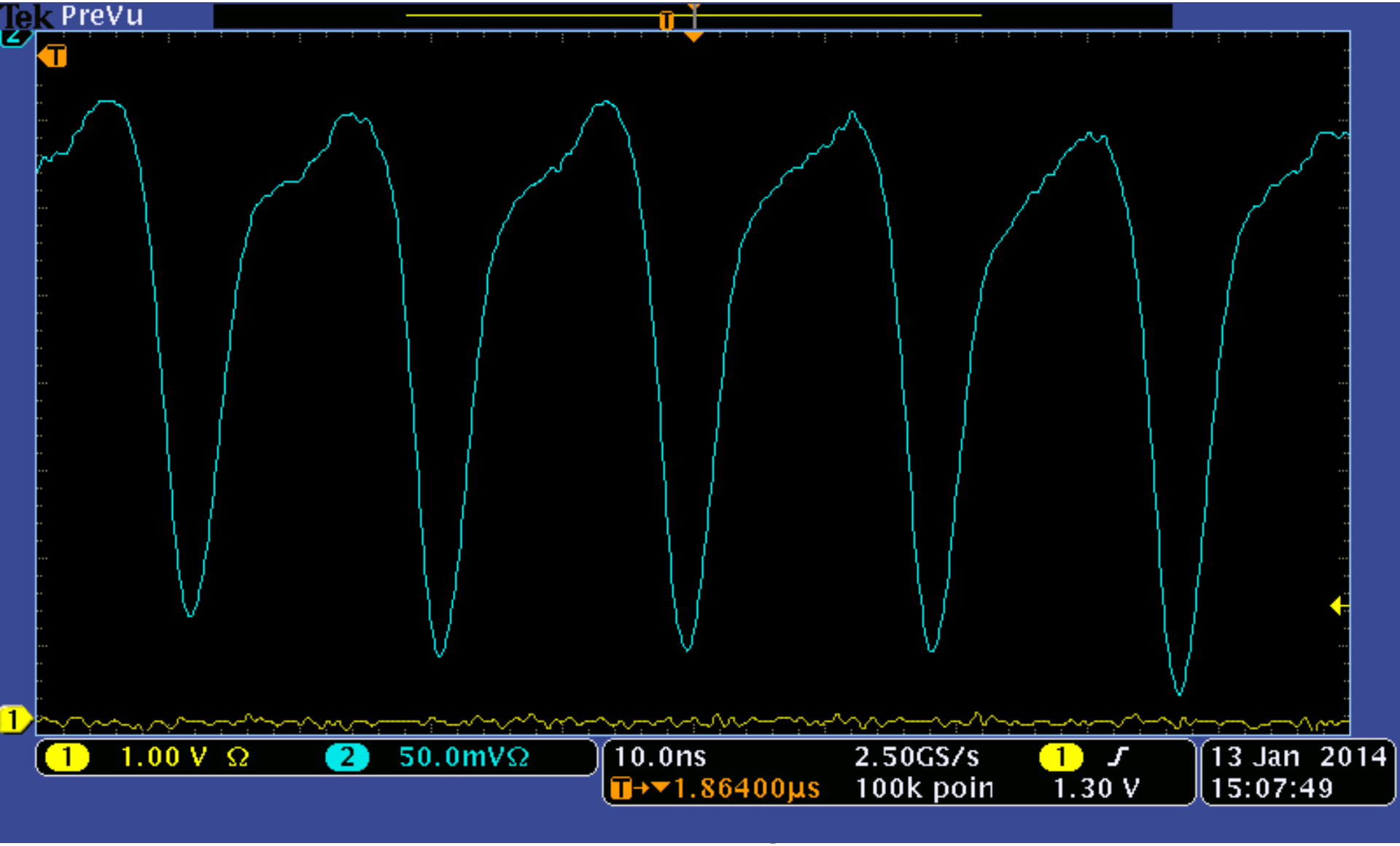
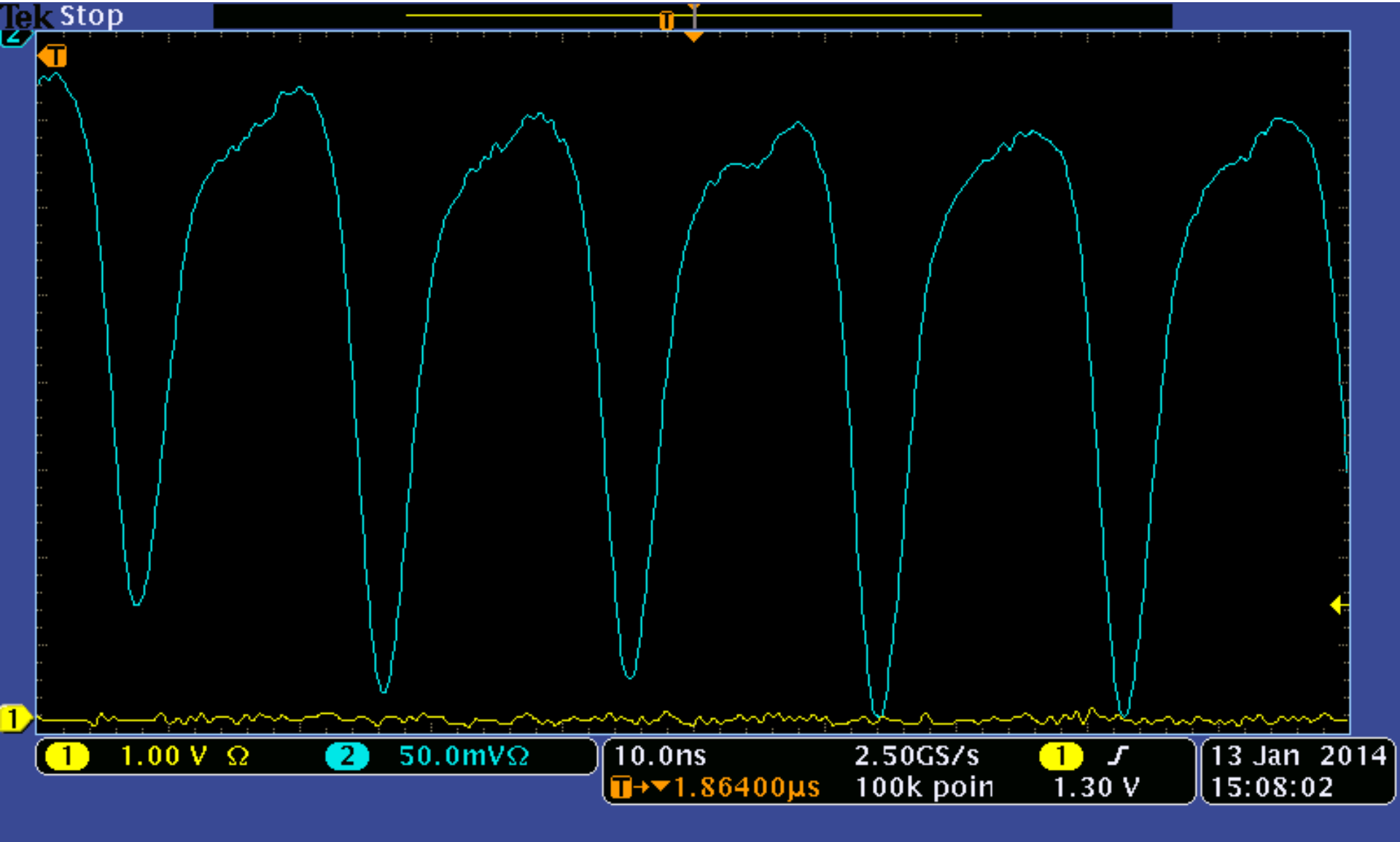
15:07:13

Individual RF Buckets




Tek Stop
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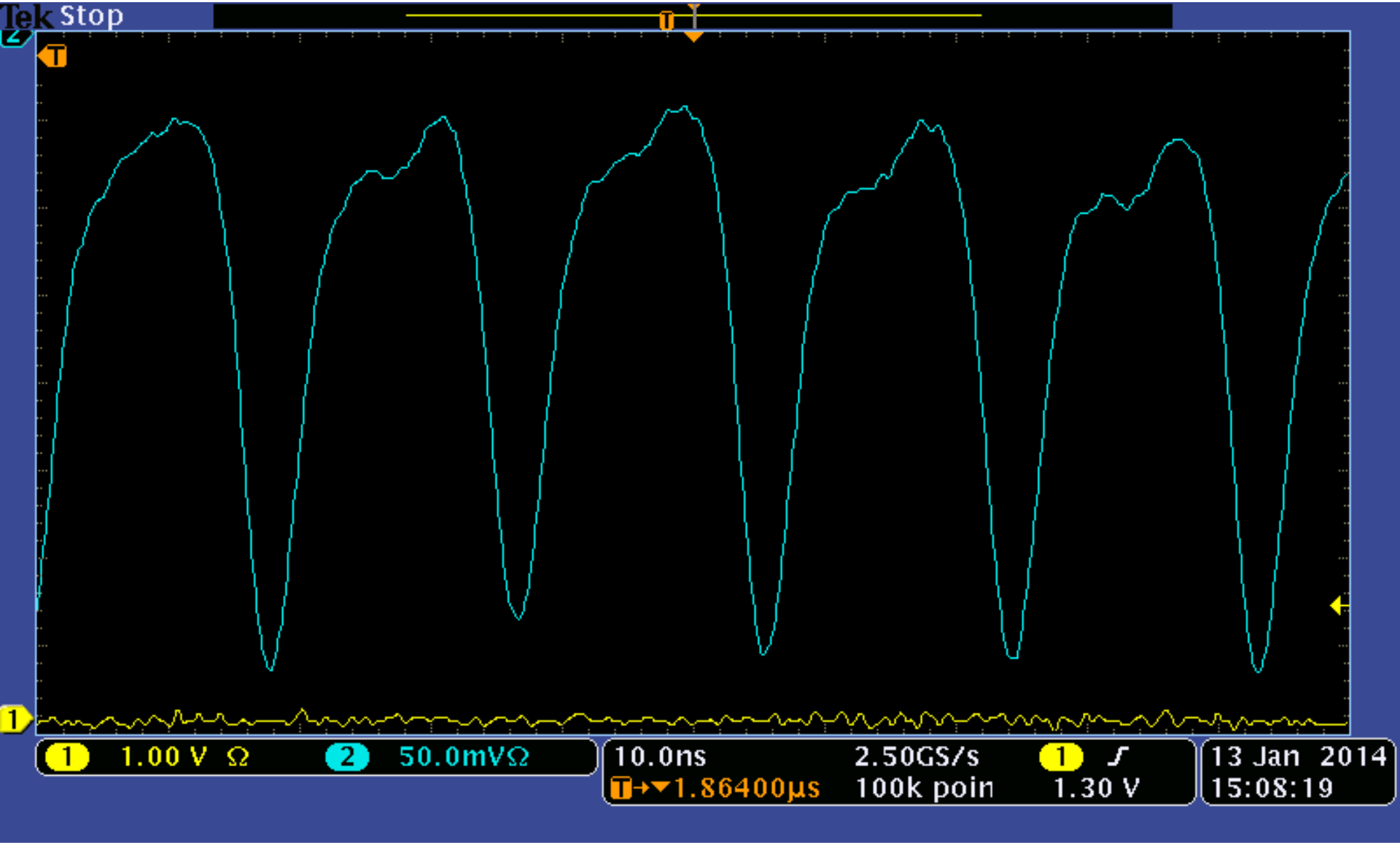
2 50.0mVΩ
10.0ns 2.50GS/s
1.86400µs 100k poin
1 1.30 V
13 Jan 2014
15:08:02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2 50.0mVΩ
10.0ns 2.50GS/s
1.86400µs 100k poin
1 1.30 V
13 Jan 2014
15:08:19

Planning for FY14

- Cherenkov Counter
  - Phase 1 operational readiness approval
  - DAQ software
  - *Joint horn-current scan and Cherenkov-pressure scan with Minerva/MINOS ion chambers at the end of February or March*
  - Phase 2 Op. approval this summer (?)
  - Engineering for Alcove 1 prototype
    - Transverse scan of profile (automated table)
    - High pressure operation (20 atm)

Summary

- Thanks to everyone who has helped!
- Cherenkov system is nearly complete
- Systems seem to function as planned
- Signals from Cherenkov counter look very encouraging
- Work needed to collect/process data into useful information
- Data interpretation will require significant simulation work which started started