



DØ High Voltage System Tutorial

J. Frederick Bartlett

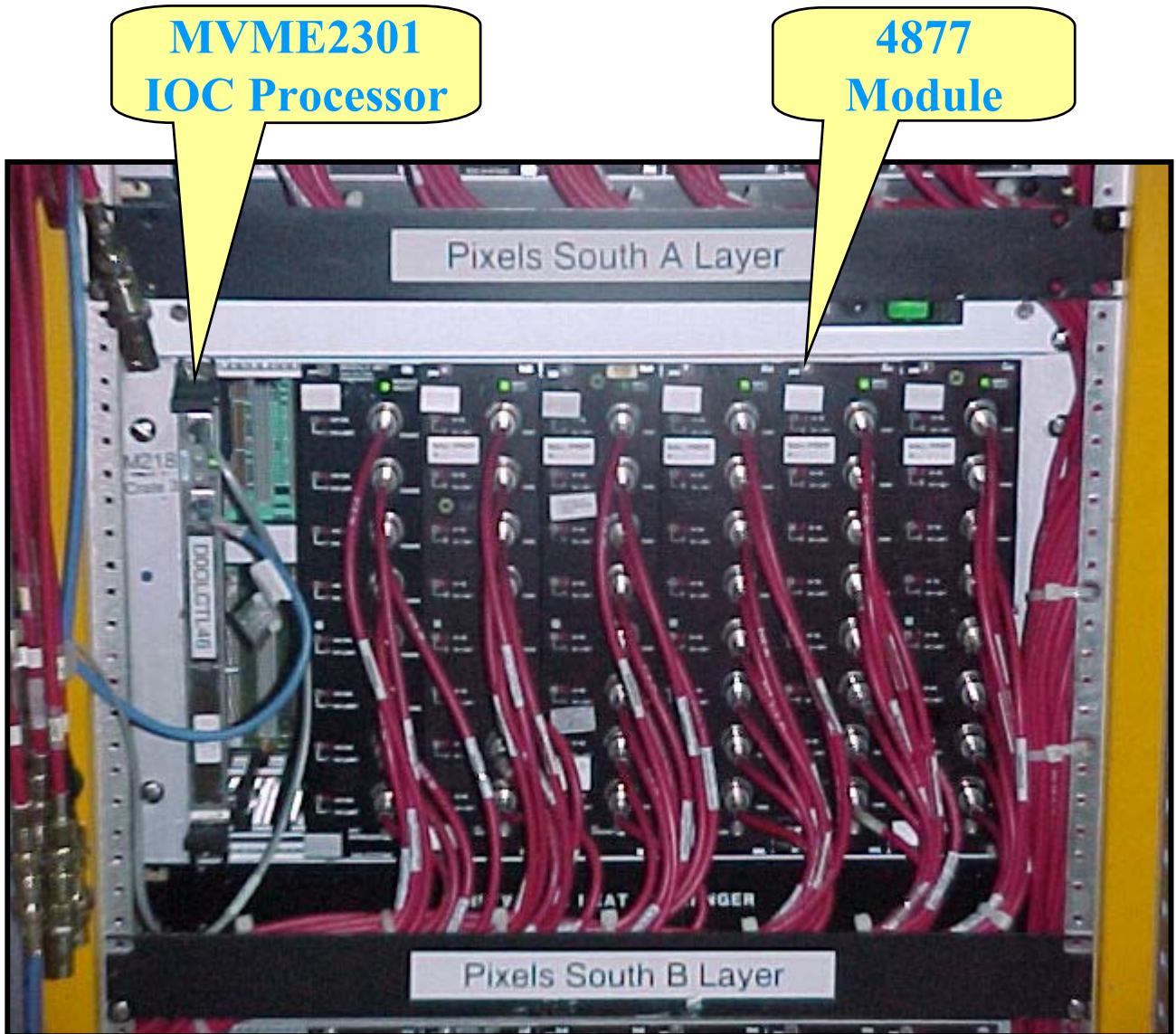


Outline

- **Hardware**
- **EPICS Support**
 - ◆ HV Record
 - ◆ HV Alarms
- **Operator GUI Programs**
 - ◆ HV Utility Display
 - ◆ Global HV Display
 - ◆ HV Channel Display
- **Diagnostic Guidelines**
- **Ref:**
 - ◆ \\D0server4\projects\Online_Computing\Tutorials\HvTutorial.ppt



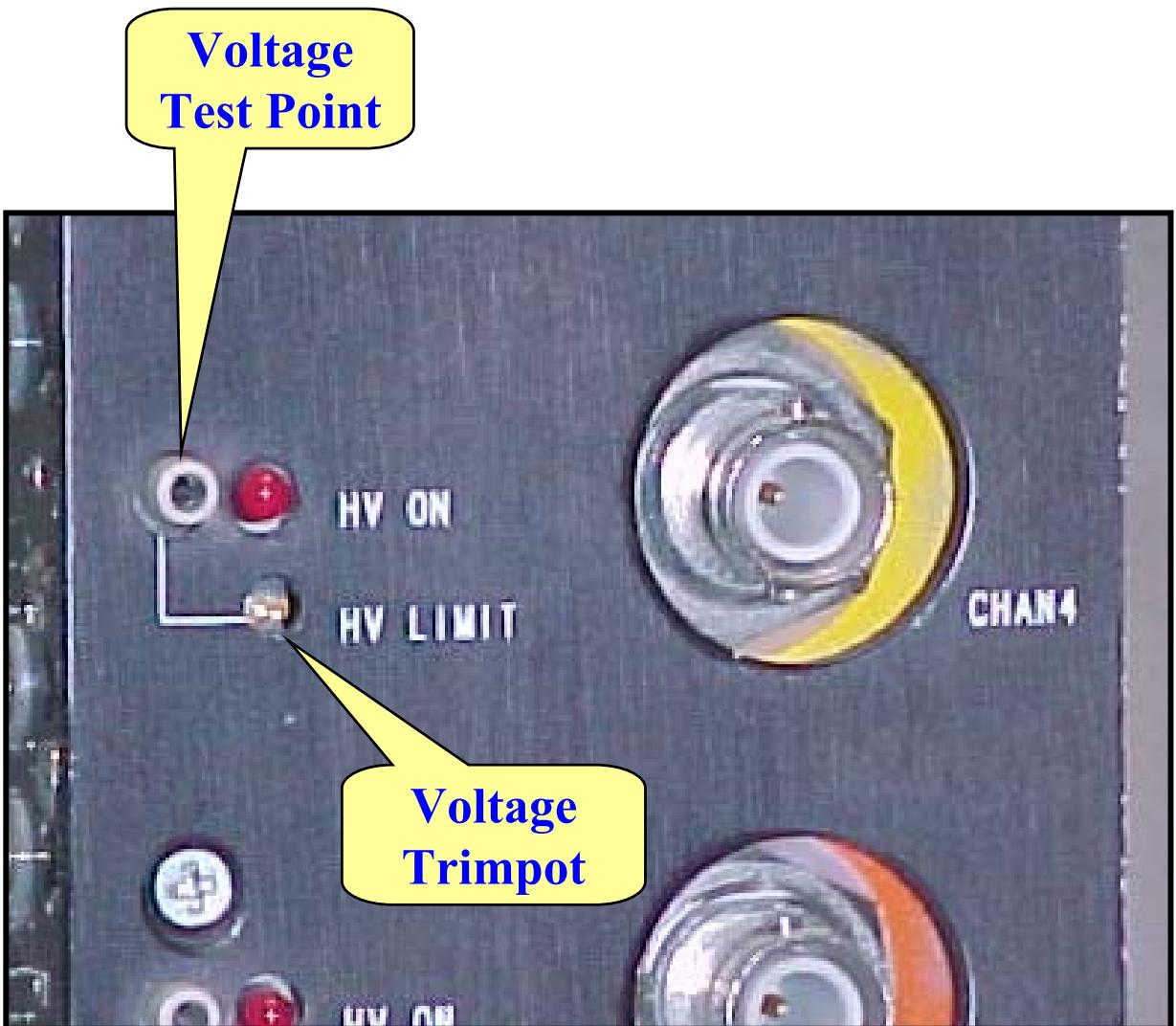
Hardware - HV Crate



Hardware - HV Module



Hardware - HV Channel



Hardware

- **VME crate**
 - ◆ 6U size
 - ◆ Custom backplane
 - ◆ Additional voltage supplies
 - +5V Digital, +- 12V Analog, +12 V Bulk(Unfiltered)
- **Fermilab/BiRa 4877 module**
 - ◆ Cockcroft-Walton generator
 - ◆ Six modules per VME crate
 - ◆ 8 channels per module
 - ◆ 10 voltage generator pod types
 - ◆ Backplane trip links
 - ◆ Backplane module address encoding (geographical)



Hardware

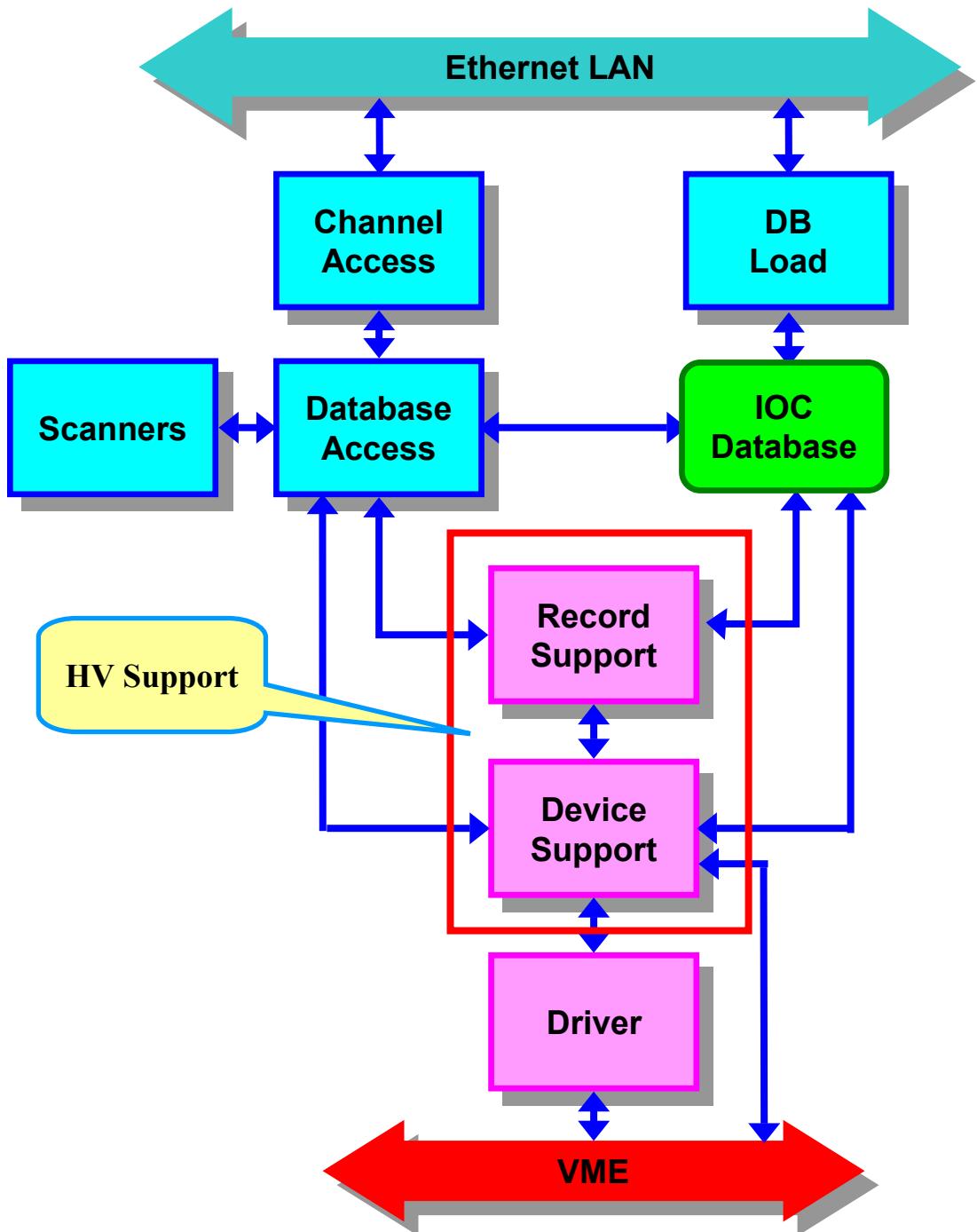
• Reference

- ◆ Bi Ra - “Model VME 4877PS High Voltage Power Supply System Manual”



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EPICS High Voltage Support

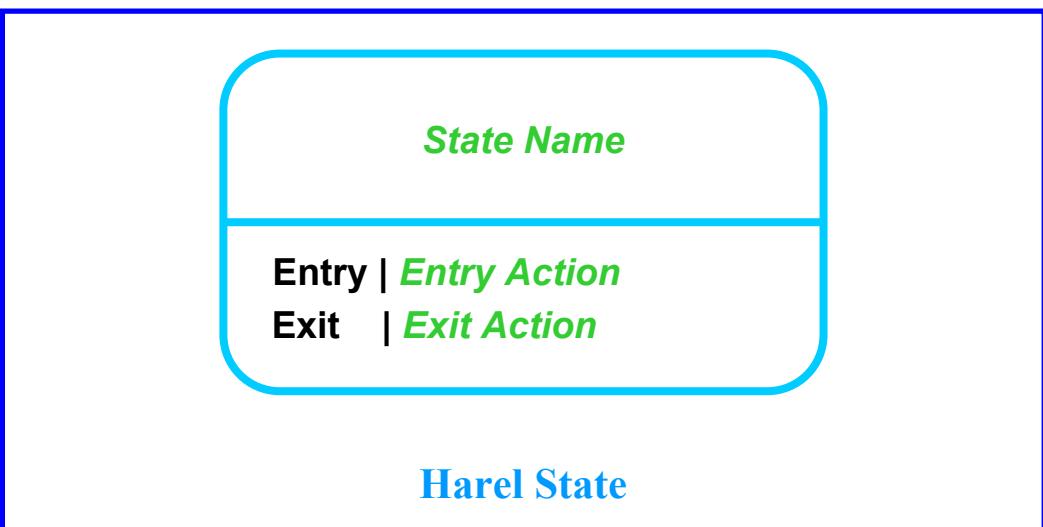
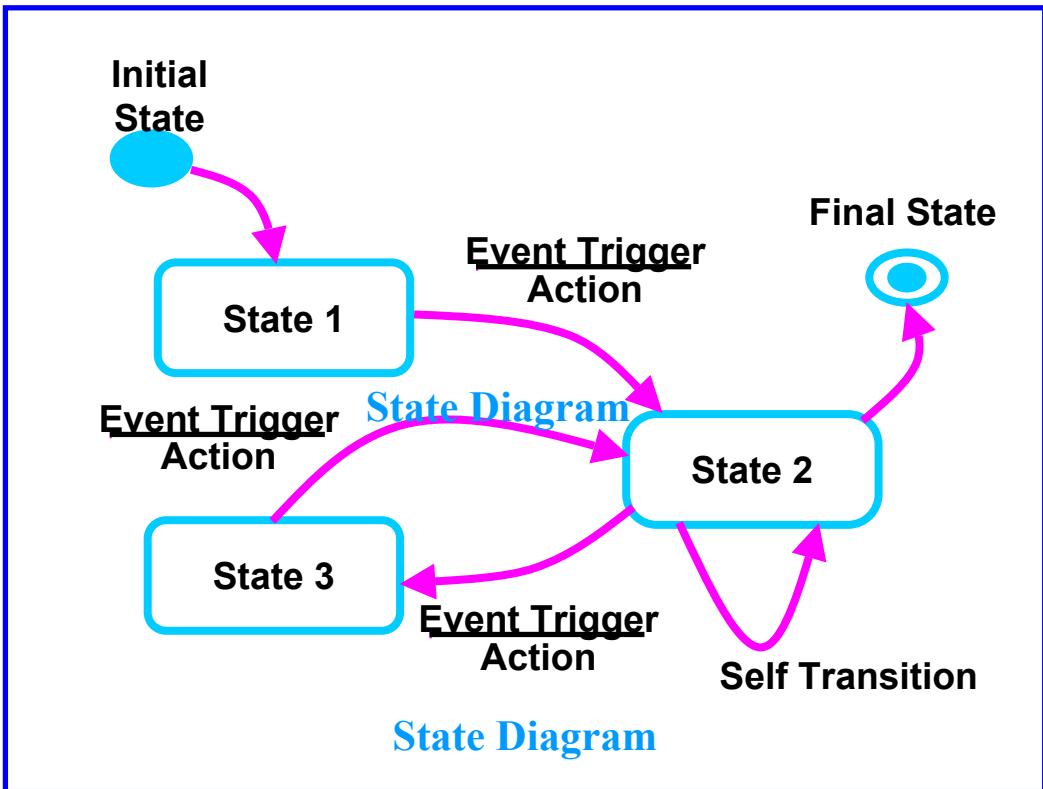


HV Record

- HV Record - hv
 - ◆ High-level device interface
 - ◆ Sequential state machine model (limited implementation of Harel state diagram)
 - ◆ Ramp algorithm
 - Parabolic end sections
 - Linear center section
 - ◆ Convergence algorithm
 - Repeat ramp until within tolerance limit
 - Enter PAUSE state if repeat limit exceeded



HV Record



HV Record



- Purpose
 - ◆ Control and monitor an individual HV channel
 - ◆ Add high-level operations to a basic voltage generator
- Implemented as a sequential state machine with states, transitions, actions, and events
- Ramping to a target voltage is a *software* function



HV Record - Pod Types

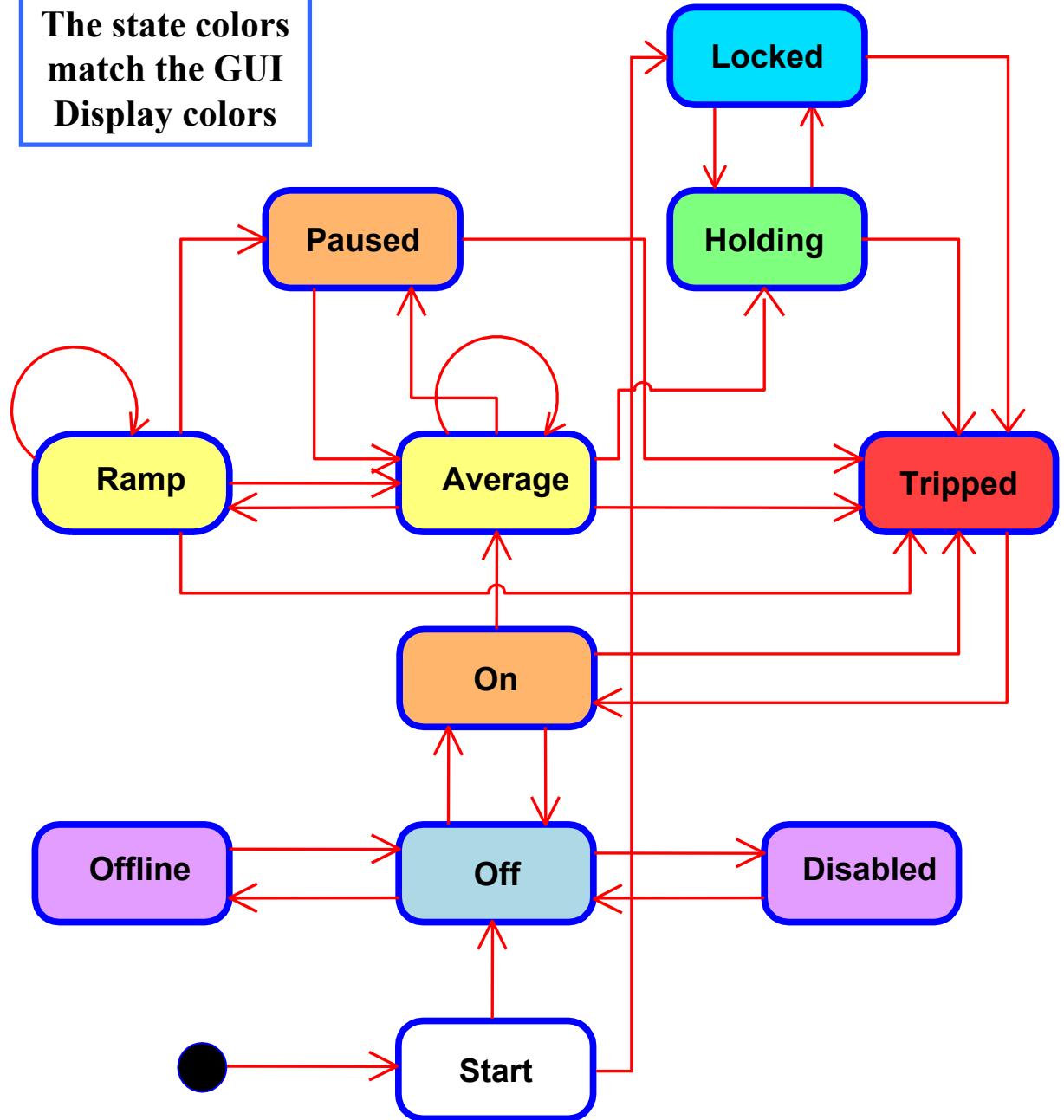
Pod Name	Max Voltage	Max Current
P5.5KV1	+5.5kV	2.3 mA
M5.5KV1	-5.5 kV	2.3 mA
P5.5KV2	+5.5 kV	1.0 mA
M5.5KV2	-5.5 kV	1.0 mA
P5.5KV3	+5.5 kV	0.1 MA
M5.5KV3	-5.5 kV	0.1 mA
P3.5KV	+3.5 kV	3.5 mA
M3.5KV	-3.5kV	3.5 mA
P2.0KV	+2.0 kV	3.2 mA
M10V1	-10 V	0.2 mA



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HV Record - State Diagram

The state colors match the GUI Display colors



HV Record - Ramp Algorithm

- Compute average voltage
- Compute voltage step size and number of steps to reach target voltage
- Execute ramp steps
- Compute average voltage
- Compare $\text{abs}(V_{\text{average}} - V_{\text{target}})$ with $V_{\text{tolerance}}$
 - ◆ less or equal - Enter HOLDING state
 - ◆ greater - Repeat ramp sequence



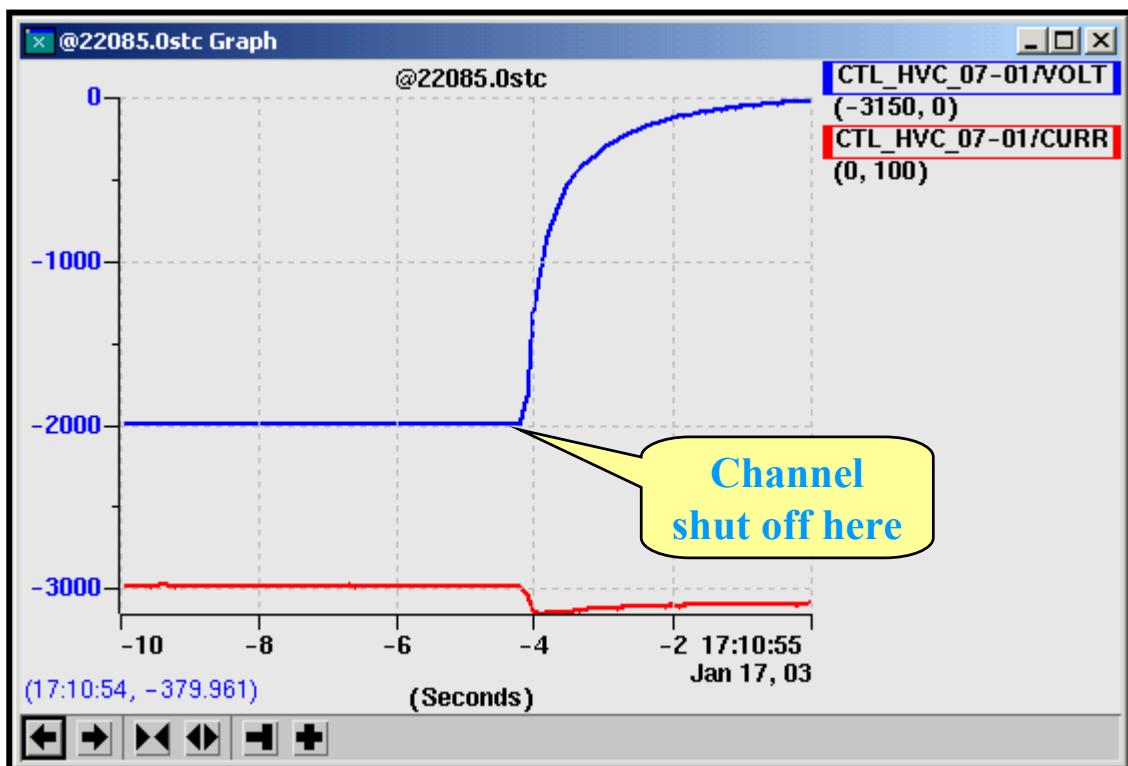
HV Record - Ramp Algorithm

- If the number of ramp cycles exceeds the limit, enter the PAUSE state and set an alarm condition



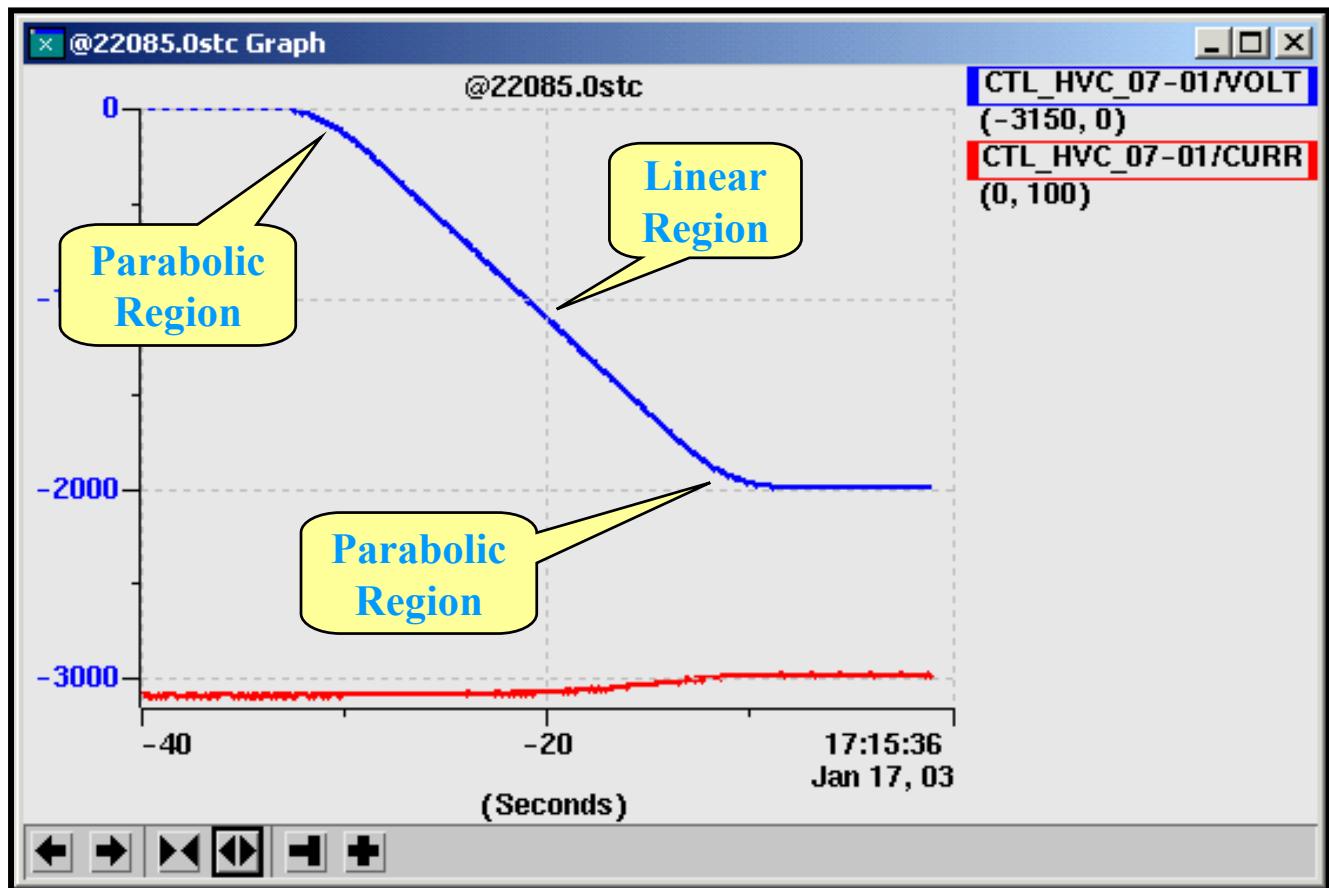
HV Record – Time Plots

- Decay profile
 - ◆ Capacitive load



HV Record – Time Plots

- Ramp regions
 - ◆ Parabolic ends
 - ◆ Linear center



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HV Record - Trips

- **Channel**
 - ◆ **Overvoltage**
 - Trimpot setting
 - ◆ **Overcurrent**
 - Register setting
 - ◆ **External**
 - Backplane connection
- **Module**
 - ◆ **Watchdog**
 - Access timeout (unused)
 - ◆ **Interlock**
 - Front panel connector (unused)
 - ◆ **External**
 - Backplane connection



HV Record - Parameters

- **ACCL**
 - ◆ Parabolic acceleration rate
(Volts/Sec2)**
 - RATE/ACCL = Duration of parabolic region (Sec)
- **CSCAL**
 - ◆ Ramping current scaling factor
 - Capacitive charging correction
- **MAXC**
 - ◆ Current trip level (uAmps)
- **RATE**
 - ◆ Ramp rate (Volts/Sec)
- **VTOL**
 - ◆ Voltage setting tolerance



HV Alarms

- **Invalid Alarm**
 - ◆ **Hardware access error**
 - ◆ **OFFLINE or DISABLED state**
- **Minor Alarm**
 - ◆ **OFF or PAUSED states**
 - ◆ **Current warning limit exceeded**
 - ◆ **Voltage warning limit exceeded**
- **Major Alarm**
 - ◆ **TRIPPED state**
 - The run will be *paused* by a trip
 - ◆ **Current fatal limit exceeded**
 - ◆ **Voltage fatal limit exceeded**



HV Alarms – SES Display

Alarm Display

File View Settings Help

Group Name	MAJOR	MINOR	INVALID	DISABLED	GOOD
Run Pause	0	562	0	0	0
HV	562	1686	0	0	0
MDT	0	0	1	0	0
PDT	0	1	0	0	2
SCINT	4	0	0	0	1
L1	0	0	0	0	0
PROC	0	4	0	0	0
All Muon	566	1691	1	1	3

Status: Connection to server started

Trip and major V and I limits

Minor V and I limits

Disabled and Offline states



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Operator GUI Programs

- HV Utility display
 - ◆ Monitor crate parameters (backplane voltages and temperature)
- Global HV display
 - ◆ Monitor channel state for multiple crates
 - ◆ Control state change for multiple crates
- HV Channel display
 - ◆ Monitor channel parameters for a single crate
 - ◆ Control state change for single channel or all channels in a crate



HV Utility Display

Paging
Tabs

The screenshot shows a Windows application window titled "HV Utility Monitor Display - v1.2 \". The menu bar includes File, View, Start, Help, and tabs for CAL, FPD, LUM, MUO (which is highlighted), and SMT. Below the menu is a table with columns for Crate, +5 Digital, +12 Analog, -12 Analog, +12 Bulk, -12 Bulk, and Temp DegC. The table is divided into two sections: Pixel and Central. The Pixel section contains data for crates M217C through M218E. The Central section contains data for crates M215B through M218B. A status bar at the bottom shows "Status:" and a "Reconnect" button.

Crate	+5 Digital	+12 Analog	-12 Analog	+12 Bulk	-12 Bulk	Temp DegC
Pixel						
M217C	4.98	12.29	-12.24	12.18	-12.27	20.26
M217D	5.16	12.15	-12.42	12.48	-12.36	21.79
M217E	5.09			12.36	-12.36	20.52
M218C	5.05			12.24	-12.29	22.84
M218D	5.16			12.43	-12.30	24.12
M218E	5.11	12.32	-12.30	12.42	-12.27	22.81
Central						
M215B	5.04	12.68	-12.53	12.40	-12.44	24.28
M215C	5.10	12.35	-12.41	12.50	-12.47	22.86
M215D	5.05	12.31	-12.24	12.41	-12.52	24.41
M215E	5.17	12.21	-12.21	12.23	-12.25	26.53
M217B	5.04	12.26	-12.14	12.21	-12.02	26.81
M218B	4.95	12.35	-12.34	12.33	-12.38	22.54

Status:

Reconnect



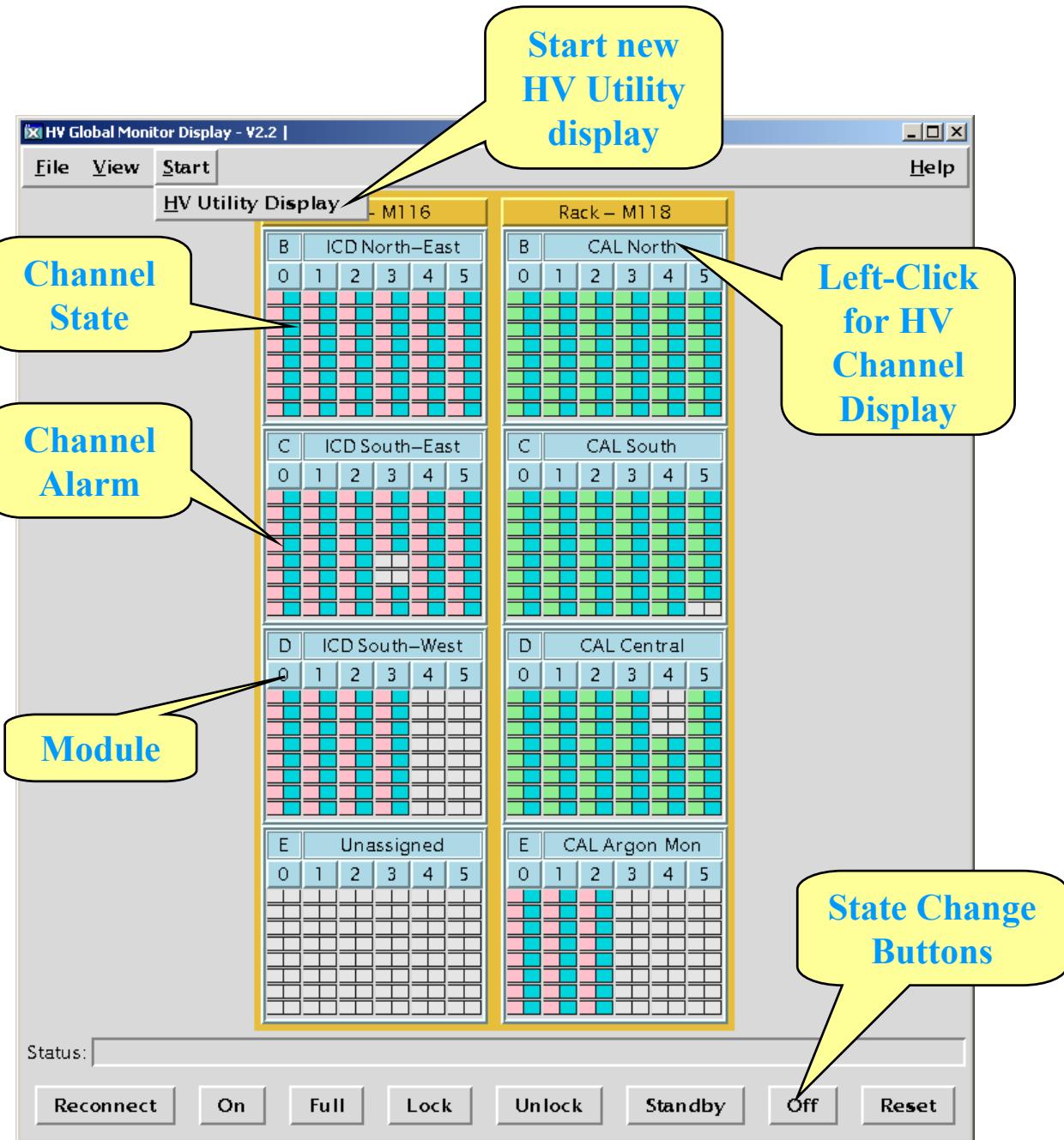
HV Utility Display



- **Purpose**
 - ◆ Monitor HV crate parameters
 - Backplane voltages
 - Temperature
- **Properties**
 - ◆ Organized by detector page
 - ◆ Read-only access
 - ◆ Background color indicates alarm state
- **Implementation**
 - ◆ Python script
 - ◆ Program name - HvuGui.py
 - ◆ Configuration scripts - xxx.hvu



Global HV Display



Global HV Display



- **Purpose**
 - ◆ Monitor state of channels in multiple crates
 - ◆ Execute multiple-crate actions
 - ◆ Initiate crate display
- **Properties**
 - ◆ Organized by crate
 - ◆ Multi-crate action buttons
- **Implementation**
 - ◆ Python script
 - ◆ Program name - HvgGui.py
 - ◆ Configuration script - xxx.hvg



Global HV Display

- Crate button
 - ◆ Start individual crate display
- Action buttons
 - ◆ OFF - set channels to OFF state
 - ◆ ON - set channels to ON state
 - ◆ RESET - reset tripped channels
 - ◆ FULL - set to a full (operational) voltage
 - ◆ STANDBY – set to standby voltage



Global HV Display

- Buttons for other target voltages may be added in the configuration file
- Channel state colors
 - ◆ Purple - OFFLINE, DISABLED
 - ◆ Blue - OFF
 - ◆ Orange – ON, PAUSED
 - ◆ Yellow - AVERAGE, RAMP
 - ◆ Green – HOLDING
 - ◆ Turquoise – LOCKED
 - ◆ Red - TRIPPED



HV Channel Display

Size Control

Page Cycle Control

Right-Click For Limits

HV Channel Monitor Display - V1.20										
File View Set Plot Start Help										
CAL		CAL South		CAL Argon Mon						
Char	V_Max	V_Set	V_Read	I_Read	State	Channel	V_Trip	I_Max	V_Max	
00N	2000	2002	2000.6	1.6	Locked	01N	3269	500	2000	
02N	3255	500	2000	2000.6	39.1	Locked	03N	3255	500	
04N	3255	500	2000	2000.6	11.4	Locked	05N	3256	500	
06N	3259	500	2000	2000.6	7.5	Locked	07N	3258	500	
08N	3260	500	2000	2000.6	1.2	Locked	09N	3254	500	
10N	3258	500	2000	2000.6	0.5	Locked	11N	3260	500	
12N	3334	500	2000	2002	2000.6	1.2	Locked	13N	3264	500
14N	3258	500	2000	2001	1999.4	1.1	Locked	15N	3257	500
16N	3254	500	2000	2002	1999.8	0.5	Locked	17N	3252	500
18N	3254	500	2000	2002	2000.9	0.4	Locked	19N	3253	500
20N	3255	500	2000	2002	2000.8	0.2	Locked	21N	3255	500
22N	5499	500	2000	2002	1999.8	1.2	Locked	23N	3257	500
24N	5499	500	2000	2002	1999.9	1.5	Locked	25N	5499	500
26N	5499	500	2000	2002	1999.6	45.4	Locked	27N	5499	500
28N	5499	500	2000	2003	1999.9	-0.3	Locked	29N	5499	500
30N	5499	500	2000	2003	2100.0	Limits	31N	5499	500	
32N	3269	500	2000	2002	1999.9	HIHI -1181.0	Locked	33N	3269	500
34N	3274	500	2000	2003	2100.0	HIGH -1670.0	Locked	35N	3267	500
36N	3268	500	2000	2002	1999.9	LOW -1690.0	Locked	37N	3269	500
38N	3271	500	2000	2002	1999.3	LOLO -1695.0	Locked	39N	3267	500
40N	3510	500	2000	2001	1999.4	1.1	Locked	41N	3509	500
42N	3507	500	2000	2001	2000.6	0.2	Locked	43N	3511	500
44N	3515	500	2000	2003	1999.6	-0.1	Locked	45N	3509	500
46N	3509	500	2000	2001	1999.3	22.0	Locked	47N	3512	500

Status:



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HV Channel Display

Start New GUI Displays

Left Click To Select New Channel State

Channel	V_Trip	I_Max	V_Max	V_Set	V_RMS	I_Read	I_Max	V_Max	V_Set	V_Read	I_Read	State			
00N	3261	500	2000	2002	1999.9		500	2000	2002	1999.6	1.1	Locked			
02N	3257	500	2000	2002	1998.8	39.1	500	2000	2003	2000.6	6.8	Locked			
04N	3255	500	2000	2002	2000.6	11.1	500	2000	2001	1998.9	7.2	Locked			
06N	3258	500	2000	2003	2000.6	0.1	500	2000	2003	2000.1	272.3	Locked			
08N	3260	500	2000	2002	1999.4	1.2	Locked	09N	3254	500	2000	2002	1999.9	0.9	Locked
10N	3258	500	2000	2003	2000.8	7.4	Locked	11N	3260	500	2000	2001	1999.6	68.5	Locked
12N	3333	500	2000	2002	2000.6	1.3	Locked	13N	3265	500	2000	2002	2000.3	1.3	Locked
14N	3258	500	2000	2001	1999.6	1.2	Locked	15N	3257	500	2000	2002	1999.1	1.3	Locked
16N	3254	500	2000	2002	1999.3	0.6	Locked	17N	3253	500	2000	2001	2000.1	0.6	Locked
18N	3254	500	2000	2002	2000.8	0.5	Locked	19N	3253	500	2000	2002	2001.1	-0.2	Locked
20N	3255	500	2000	2002	1999.9	-0.4	Locked	21N	3255	500	2000	2002	2000.8	1.2	Locked
22N	3258	500	2000	2001	1999.4	1.2	Locked	23N	3257	500	2000	2001	1999.3	1.2	Locked
24N	5499	500	2000	2002	2000.1	1.2	Locked	25N	5499	500	2000	2002	2000.1	1.3	Locked
26N	5499	500	2000	1999	1999.3	45.4	Locked	27N	5499	500	2000	2002	2000.6	1.6	Locked
28N	5499	500	2000	2003	1999.9	-0.4	Locked	29N	5499	500	2000	2002	2000.7	1.7	Locked
30N	5499	500	2000	2003	2000.9	37.1	Locked	31N	5499	500	2000	2002	126.7	1.3	Locked
32N	3268	500	2000	2002	1999.6	1.2	Locked	33N	3269	500	2000	2002	2000.3	1.2	Locked
34N	3274	500	2000	2003	2000.3	29.5	Locked	35N	3267	500	2000	2002	1999.9	97.7	Locked
36N	3269	500	2000	2002	1999.8	1.3	Locked	37N	3270	500	2000	1999	1999.1	1.5	Locked
38N	3272	500	2000	2002	1999.1	1.3	Locked	39N	3268	500	2000	2002	2000.4	12.1	Locked
40N	3510	500	2000	2001	1999.6	1.0	Locked	41N	3509	500	2000	2003	2000.3	0.9	Locked
42N	3507	500	2000	2001	2000.4	0.2	Locked	43N	3512	500	2000	2002	2000.3	40.8	Locked
44N	3514	500	2000	2003	1999.6	-0.2	Locked	45N	3508	500	2000	2002	2000.4	24.5	Locked
46N	3509	500	2000	2001	1999.1	21.7	Locked	47N	3512	500	2000	2001	2000.3	0.7	Locked

Status:

Reconnect Offline Online Off On Ramp Pause Resume Lock Unlock Reset



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HV Channel Display

Paging Tabs

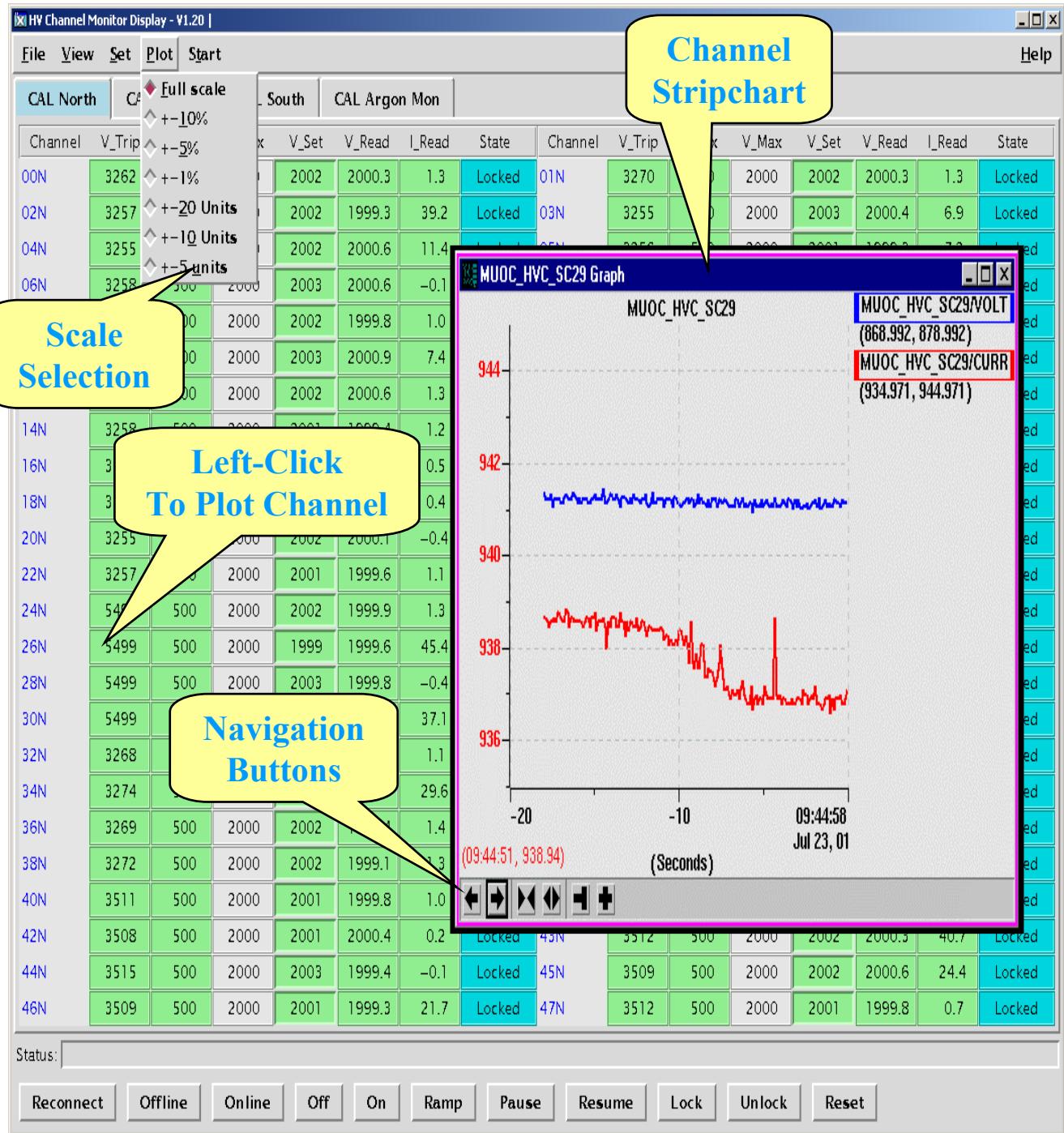
Standby Entry

State Change Buttons

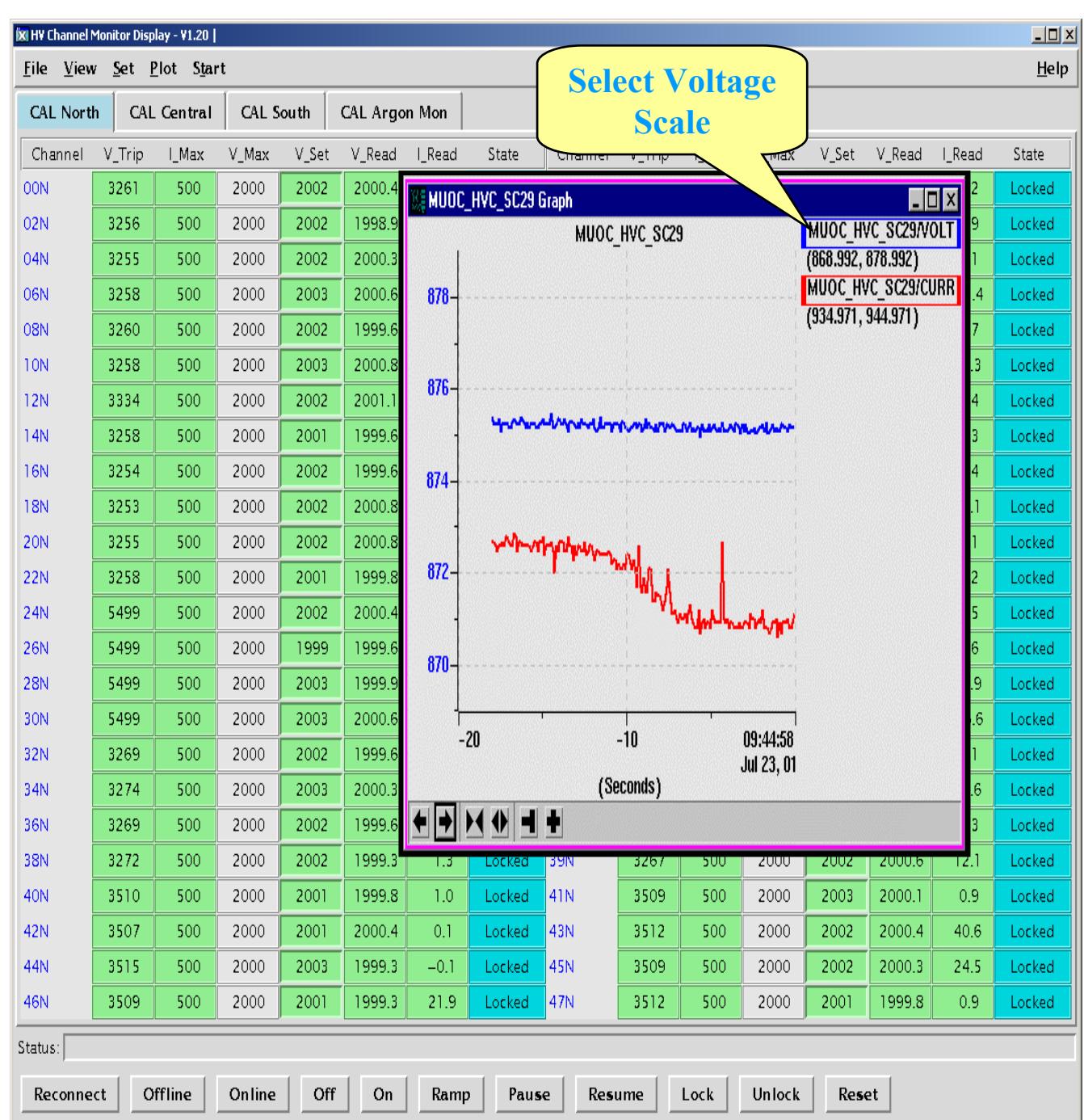
CAL North		CAL South				CAL Argon Mon									
Channel	Value	V_Max	V_Set	V_Read	I_Read	State		V_Max	V_Set	V_Read	I_Read	State			
00N	0%	2000	2002	2000.4	1.2	Locked	01N	3256	500	2000	2001	1999.3	7.1		
02N	10%	2000	2002	1998.9	39.1	Locked	02N	3258	500	2000	2003	2000.1	6.7		
04N	20%	2000	2002	2000.3	11.3	Locked	05N	3254	500	2000	2002	2000.1	0.8		
06N	30%	2000	2002	-0.1	Locked	07N	3260	500	2000	2001	1999.8	68.4			
08N	40%	2000	2002	2000.3	11.3	Locked	09N	3265	500	2000	2002	2000.4	1.3		
10N	50%	2000	2002	-0.1	Locked	11N	3257	500	2000	2002	1999.4	1.4			
12N	60%	2000	2002	2000.3	11.3	Locked	12N	3253	500	2000	2001	2000.4	0.6		
14N	70%	2000	2002	-0.1	Locked	13N	3254	500	2000	2002	2001.4	-0.1			
16N	80%	2000	2002	2000.3	11.3	Locked	14N	3254	500	2000	2002	2000.8	1.2		
18N	90%	2000	2002	2000.3	11.3	Locked	15N	3257	500	2000	2001	1999.1	1.2		
20N	100%	2000	2001	1999.4	1.3	Locked	16N	3259	500	2000	2001	2000.6	3.7		
22N	Standby	3255	500	2000	2002	1999.8	0.6	Locked	17N	3254	500	2000	2002	1999.6	15.8
24N		3254	500	2000	2002	2000.8	0.5	Locked	18N	3257	500	2000	2002	2000.4	127.2
26N		3255	500	2000	2002	2000.1	-0.3	Locked	19N	3254	500	2000	2002	2000.3	1.1
28N		3258	500	2000	2001	1999.4	1.1	Locked	20N	3254	500	2000	2002	1999.6	97.7
30N		5499	500	2000	2002	2000.1	1.3	Locked	21N	3267	500	2000	2002	1999.4	0.7
32N		5499	500	2000	2002	1999.4	45.5	Locked	22N	3270	500	2000	2002	2000.4	Lock
34N		5499	500	2000	2003	1999.9	-0.3	Locked	23N	3270	500	2000	2002	2000.6	Lock
36N		5499	500	2000	2002	2000.8	37.3	Locked	24N	3270	500	2000	2002	2000.1	0.9
38N		5499	500	2000	2003	1999.4	1.2	Locked	25N	3270	500	2000	2002	2000.4	40.7
40N		3269	500	2000	2002	2000.6	0.2	Locked	26N	3509	500	2000	2002	2000.1	24.4
42N		3272	500	2000	2002	1999.3	1.2	Locked	27N	3512	500	2000	2001	1999.9	0.7
44N		3274	500	2000	2003	1999.9	29.7	Locked	28N						
46N		3269	500	2000	2002	1999.6	1.4	Locked	29N						
		3272	500	2000	2002	1999.3	1.2	Locked	30N						
		3274	500	2000	2003	1999.8	1.0	Locked	31N						
		3510	500	2000	2001	1999.8	1.0	Locked	32N						
		3507	500	2000	2001	1999.4	-0.1	Locked	33N						
		3515	500	2000	2003	1999.4	-0.1	Locked	34N						
		3509	500	2000	2001	1998.9	21.8	Locked	35N						



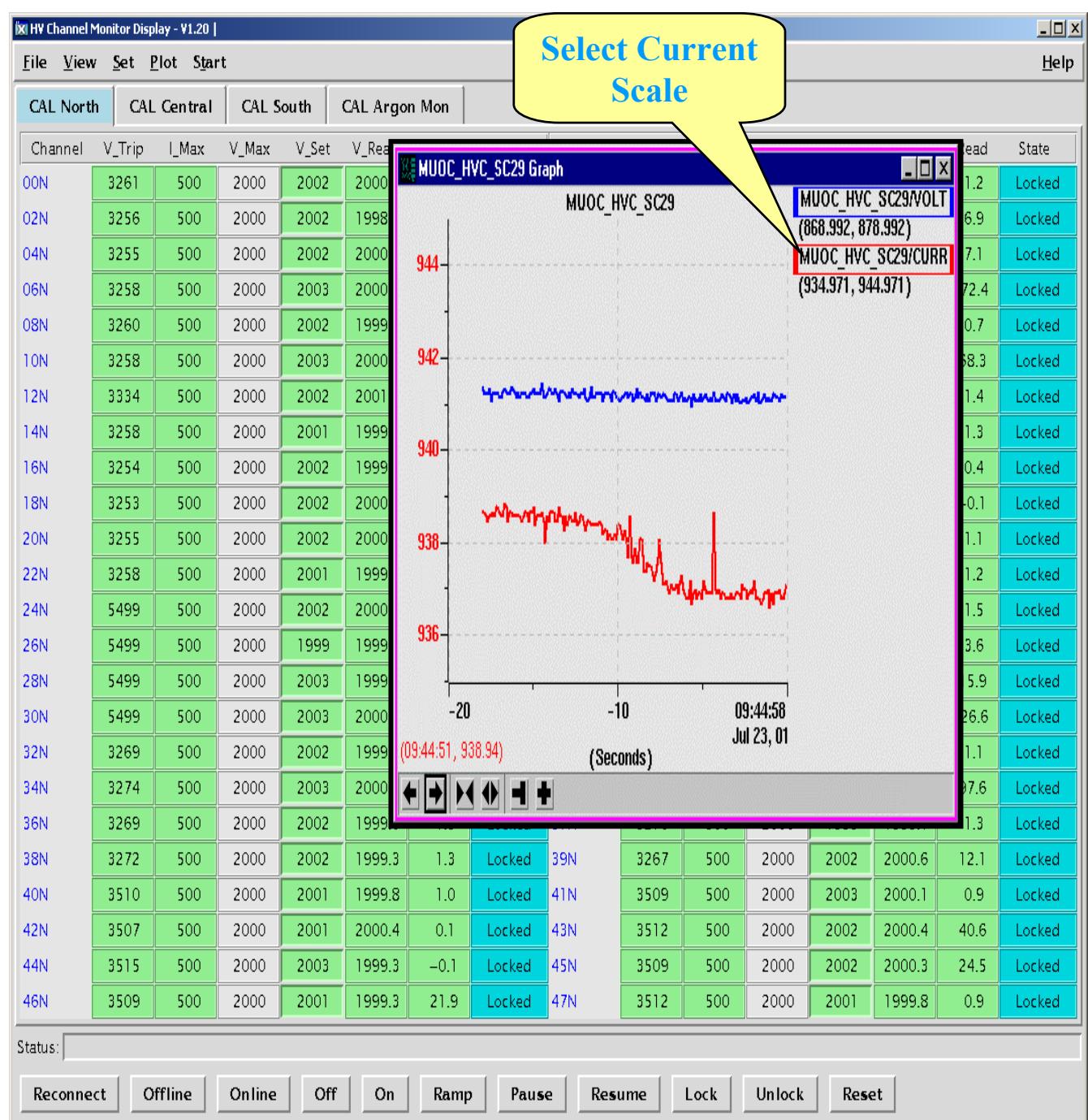
HV – Channel Display



HV Channel Display



HV Channel Display



HV Channel Display



- **Purpose**

- ◆ **Monitor individual channels**
 - State
 - Voltage and current readback
 - Target voltage
 - Voltage and current trip levels
- ◆ **Execute all-channel and individual channel actions**
- ◆ **Set all-channel and individual channel target voltages**
- ◆ **Usually displays a single crate**



HV Channel Display

- **Properties**
 - ◆ Organized by channel
 - ◆ Multi-channel action buttons
 - ◆ Channel action menu button
- **Implementation**
 - ◆ Python script
 - ◆ Program name - HvcGui.py
 - ◆ Configuration script - xxx.hvc
- **Action buttons**
 - ◆ Similar to global display +
 - OFFLINE/ONLINE
 - PAUSE/RESUME
 - LOCK/UNLOCK
- **Channel state colors**
 - ◆ Same as Detector display



Diagnostic Guidelines

- **Channel is in offline state**
 - ◆ Missing HV module
 - ◆ Incorrect module type in database
 - ◆ Faulty module
- **Module trips after transition from off to on state**
 - ◆ After a period with the power off, the channel may not be stable. Leave the channel in the ON state for ~1/4 hour, after which the channel may recover.
 - ◆ Faulty module



Diagnostic Guidelines

- **Module trips during ramp but has not exceeded either the voltage or current trip limit**
 - ◆ After a period in the off state, the channel may not be stable. Leave the channel in the ON state at zero output for ~1/4 hour, after which the channel may recover
 - ◆ Faulty module



Diagnostic Guidelines

- Ramp away from zero volts does not converge to target voltage
 - ◆ Record tuning parameters set incorrectly
 - ◆ Faulty module
- Current trip during ramp caused by capacitance charging
 - ◆ Reduce ramp rate
 - ◆ Increase current scaling factor parameter
 - ◆ Lengthen parabolic ramp region



Diagnostic Guidelines

- Ramp toward zero volts converges to the target voltage very slowly
 - ◆ Reduce load capacitance or increase shunt resistance
 - The Cockcroft-Walton generator is a charge pump and can only drive the voltage away from zero (positive or negative). Ramping toward zero requires a shunt resistance to discharge the load capacitance and the voltage divider resistance in the pod is ~10-50 Megohms.

