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The BaBar LST detector High Voltage system

Design and implementation

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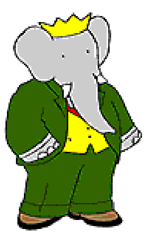
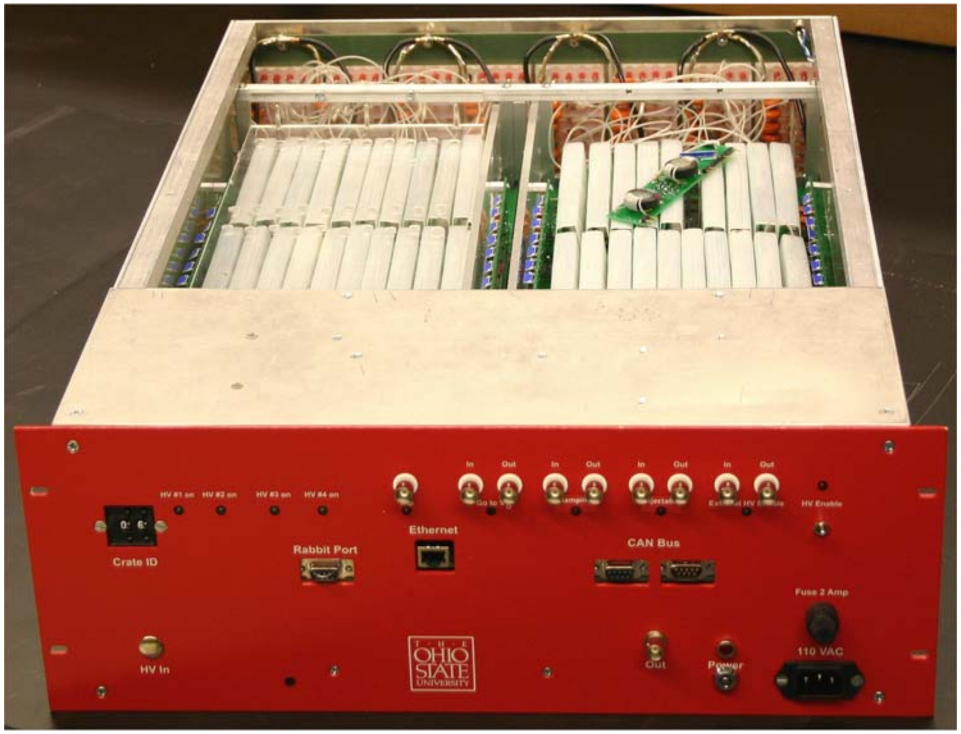


Outline

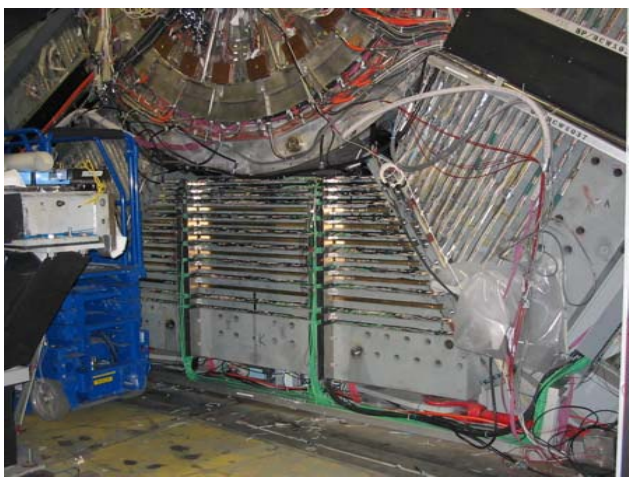


- HV requirements
- Design
- Features
- Controls and running experience
- Summary and conclusion

The BaBar LST detector

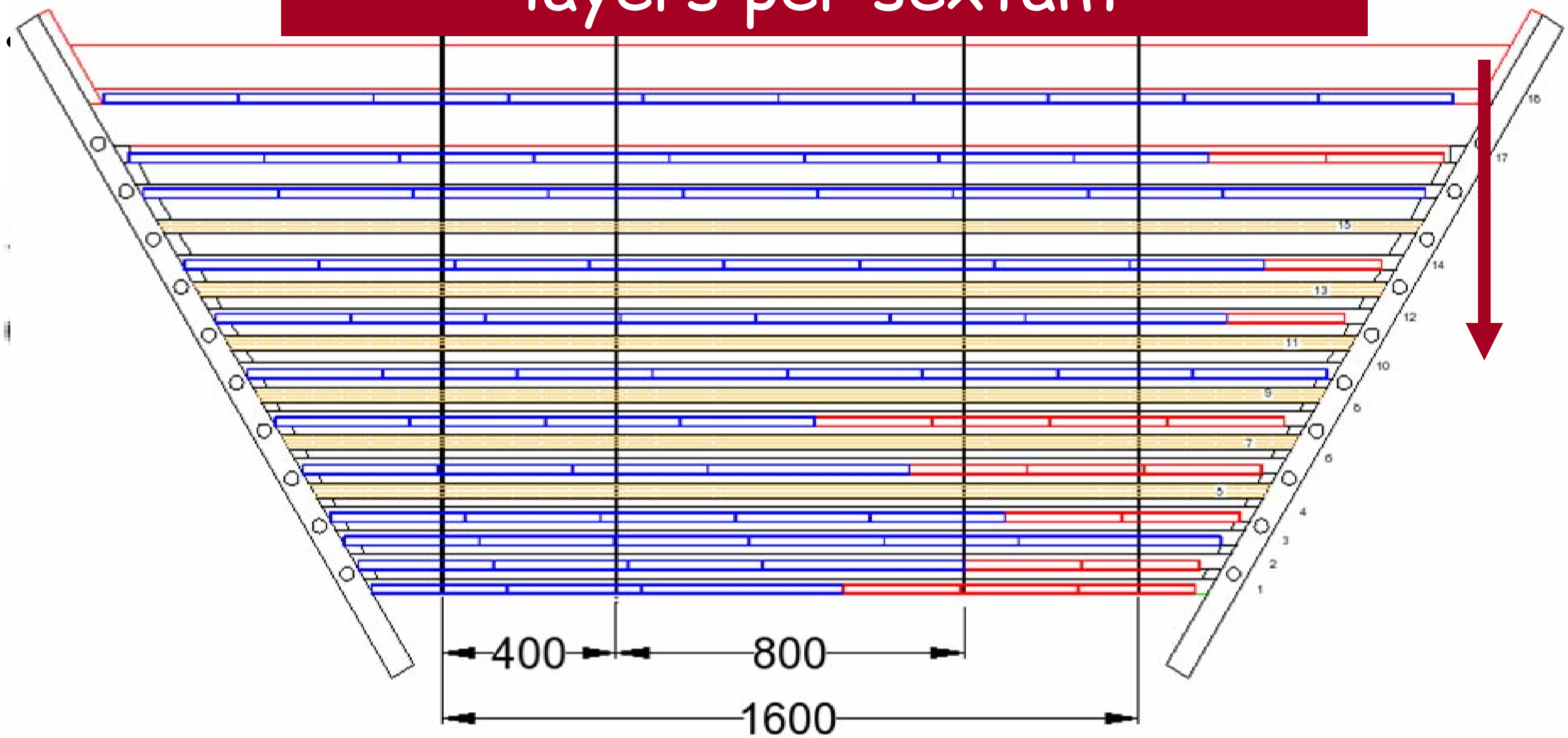
- Limited Streamer Tubes (LSTs) chosen to replace the rapidly ageing Resistive Plate Chambers (RPCs) in the BaBar Instrumented Flux Return (IFR) as muon detectors

- BaBar LSTs:
  - Tubes with 7 or 8 wires (cells) coupled in 4 HV channels
  - Active region between 5 and 6 kV
  - Readout signals AC coupled to HV channels



BaBar LST HV requirements

12 LST layers +6 absorber layers per sextant



Current increases

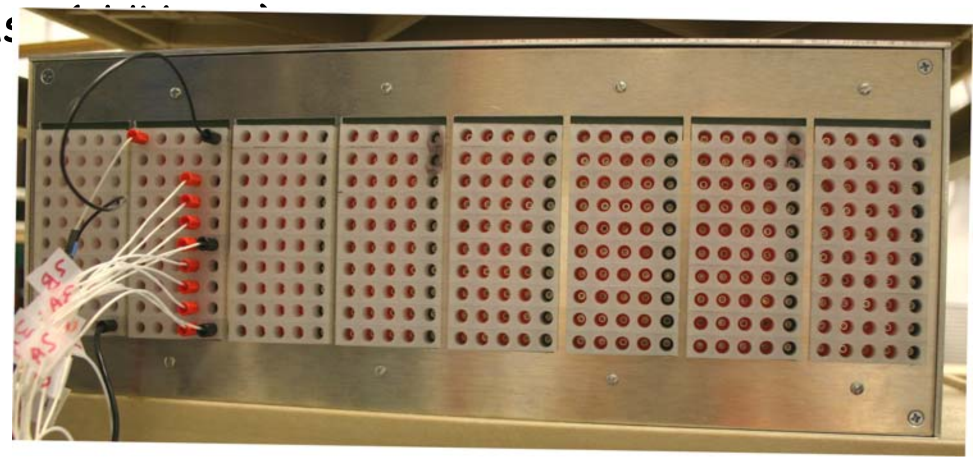
Single layer does not affect global efficiency

BaBar LST HV

- Typical currents at 5.5kV per tube:
  - No beam **15-100nA**
  - With beam **50-1000nA**
- Self-discharge mode:
  - Current rises up quickly to over **3000nA** due to one single HV output
- Monitoring current for whole tube (4 HV outputs) is sufficient:
  - Built-in flexibility to disconnect individual HV outputs and treat separately
- Overcurrent protection for self-discharge mode
- Trip logic

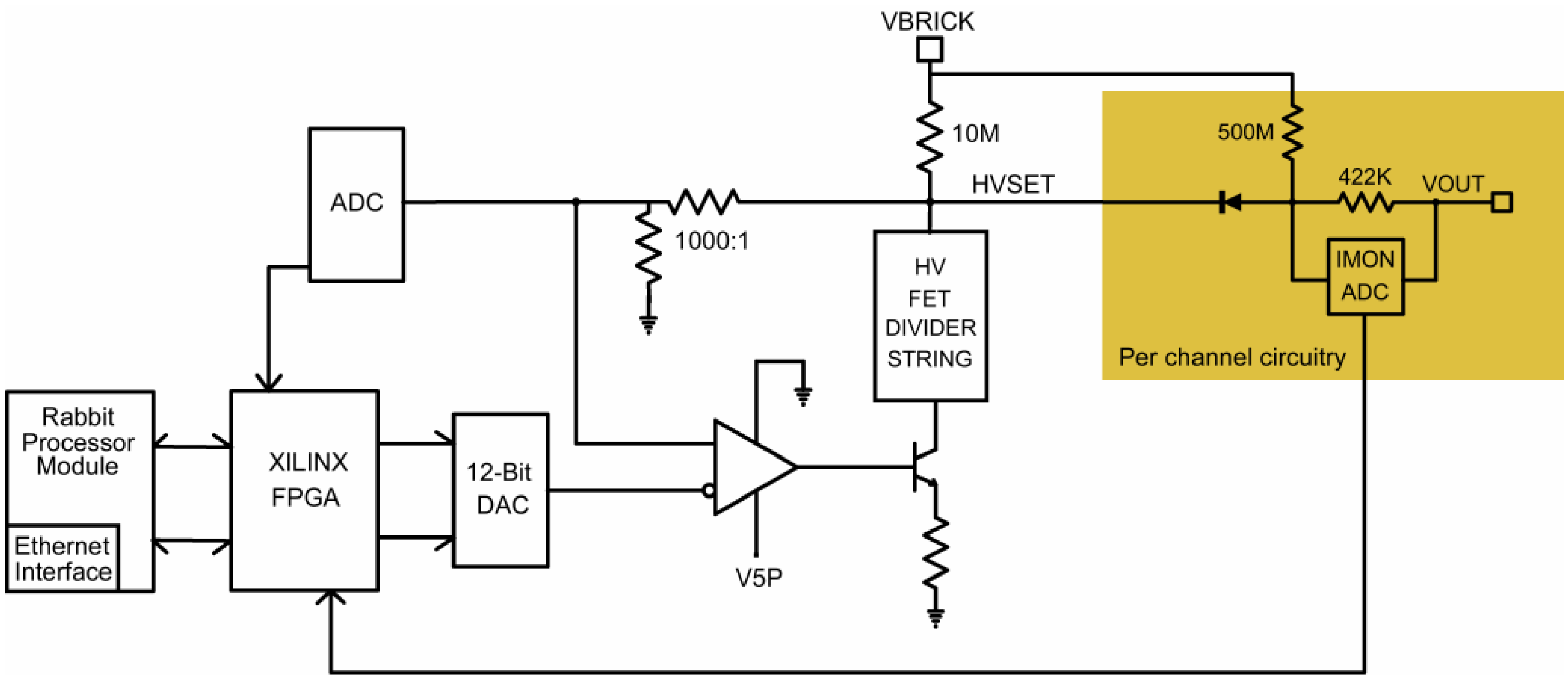
OSU HVPS features

- 320 HV outputs
- Variable output voltage 0-6kV
  - 4 independent HV groups of 80 HV outputs at same voltage setting
- 80 current measurement channels
  - 4 paralleled HV outputs per channel
- Add picture of back panel (This one for now, add animation or pointers for 1 tube->4 pins, 20 ch

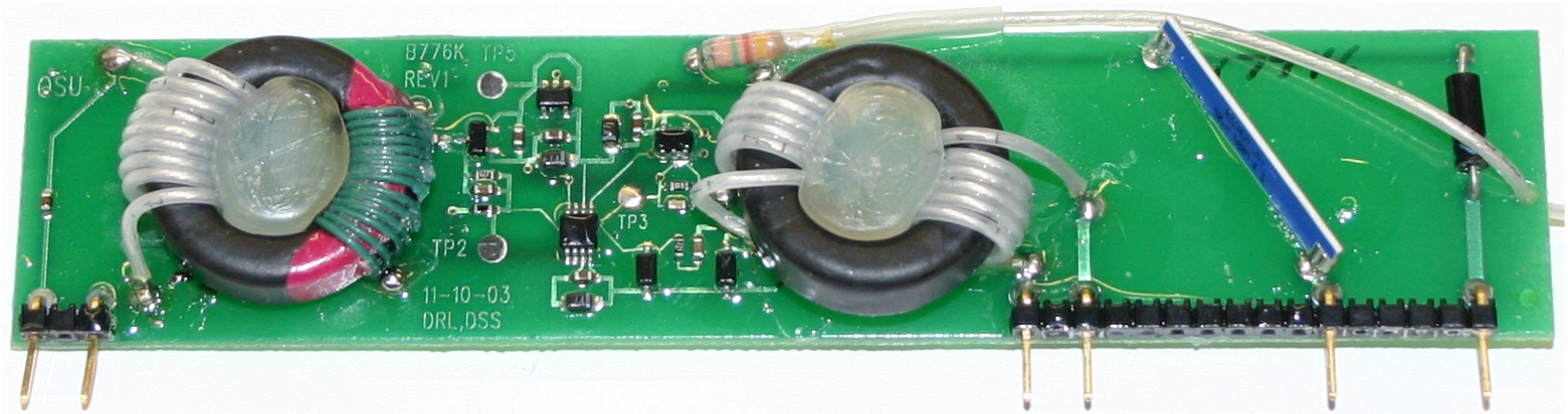


OSU HVPS ingredients

- Rabbit microcontroller
- Xilinx FPGA (data collection and control signal generation)
- Ultravolt DC-DC converter (internal HV power supply)
- 4 variable HV regulators
- 80 current measurement modules
- 320 2mm banana plugs connectors (+ grounds)

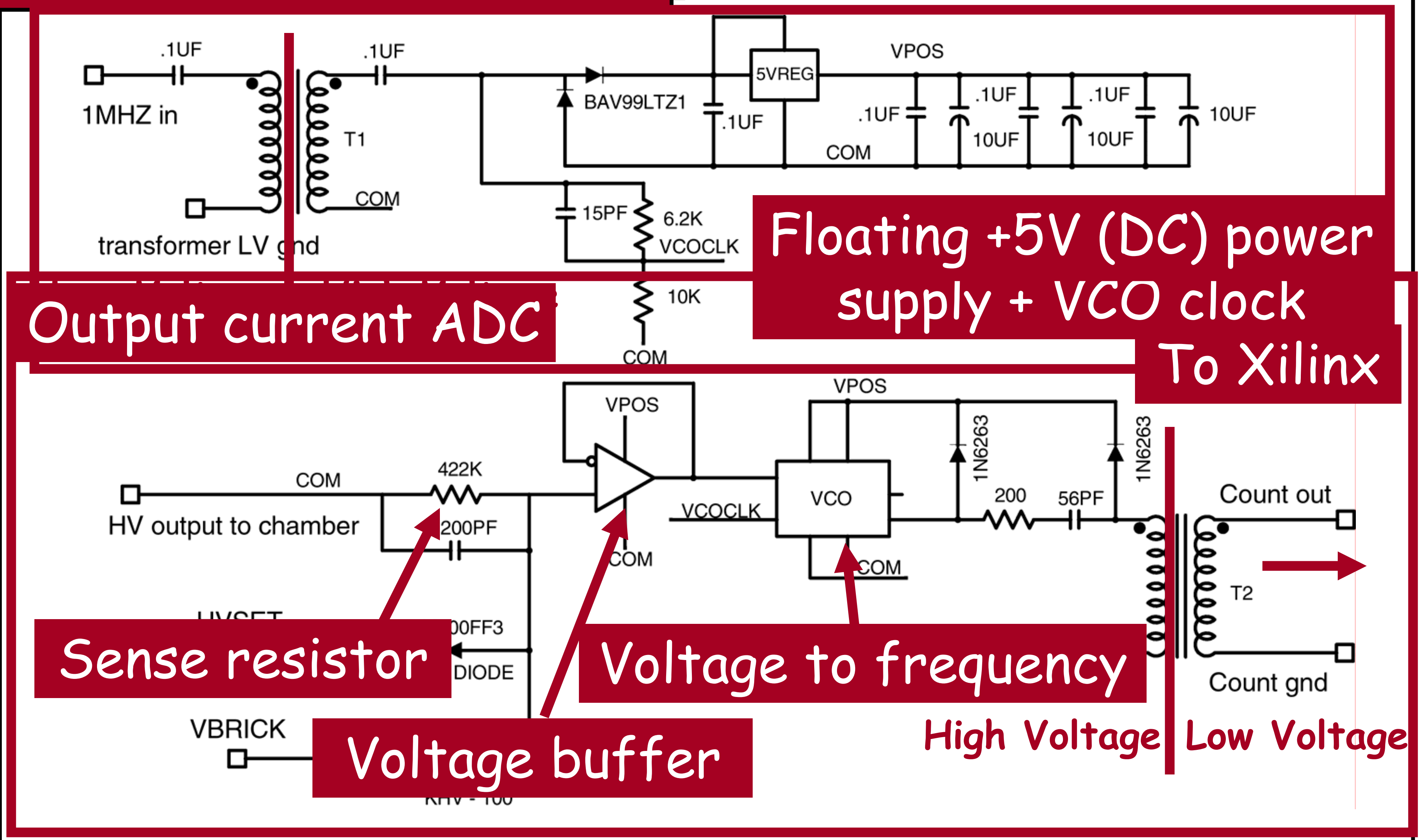


Current monitor module

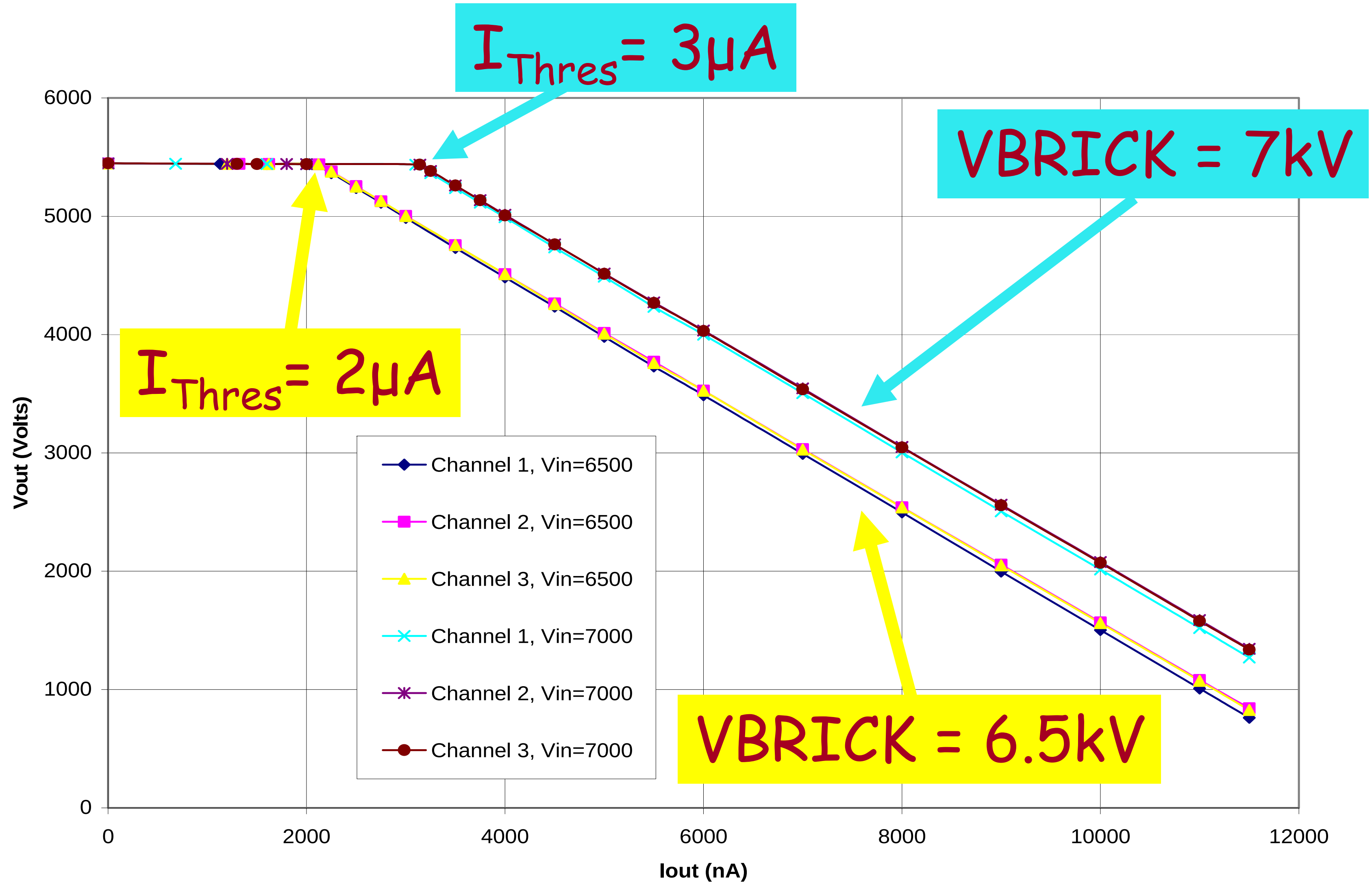


- 0-12 μA current measurement with 1nA resolution
- Floating power supply referenced to the module output voltage:
  - Operation at any output voltage
  - Floating circuitry survives unexpected output transients
- Low power ADC circuit using a voltage controlled oscillator (VCO)
- VCO frequency transformer coupled to low voltage for counting
- Frequency readout by Xilinx FPGA
- Output overcurrent protection

Current monitor diagram

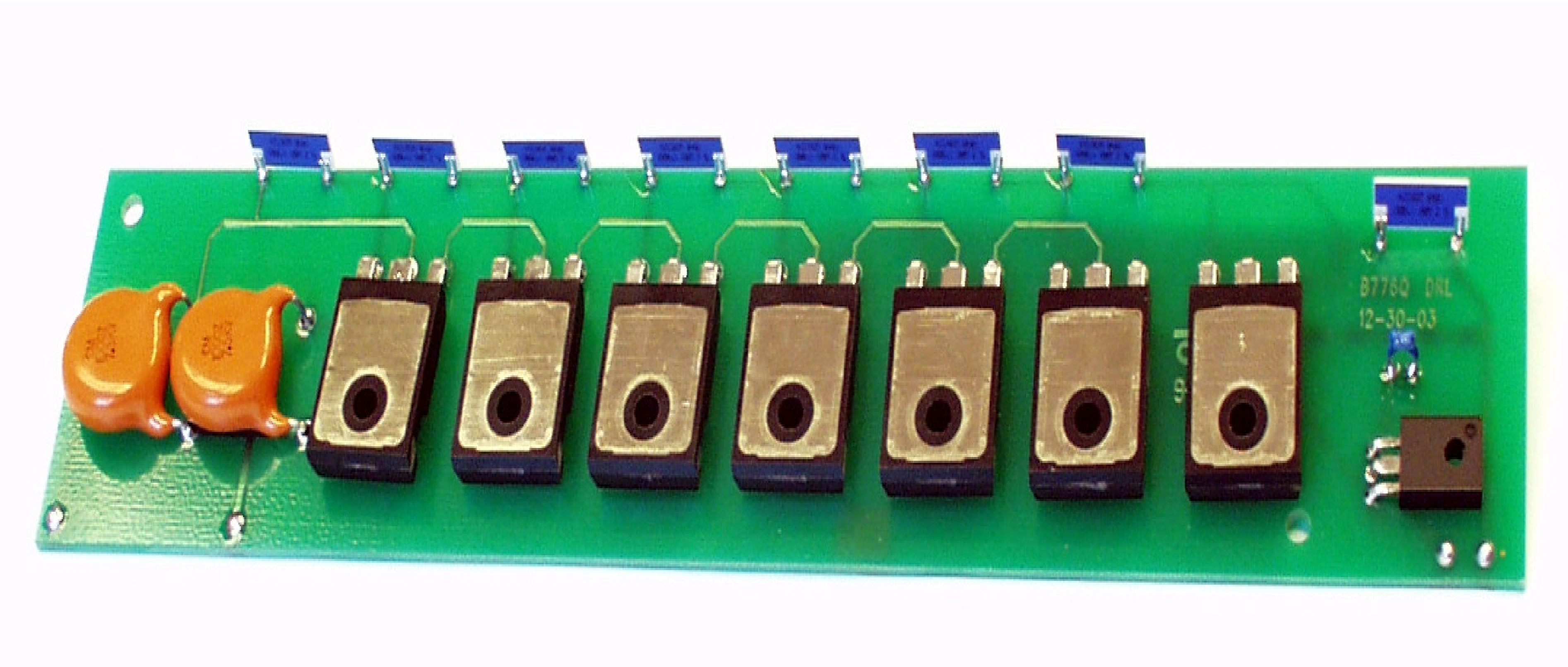


Overcurrent protection



Voltage regulation

- Internal Ultravolt DC-DC converter (0-10kV at 3mA)
- 4 independent HV group voltages set by 12-bit DACs through Xilinx FPGA
- HV group output voltage measured by VCO ADC circuit



Digital Board/Firmware

- **Rabbit RCM-3200** microcontroller with **Dynamic C** embedded software:
  - Monitoring and control algorithms
  - Ramping and trip logic
  - Detector controls integration
- FPGA (low level logic and signal conditioning): **Xilinx Spartan XCS-30**
- Input/Output through **Ethernet** or **CANbus**

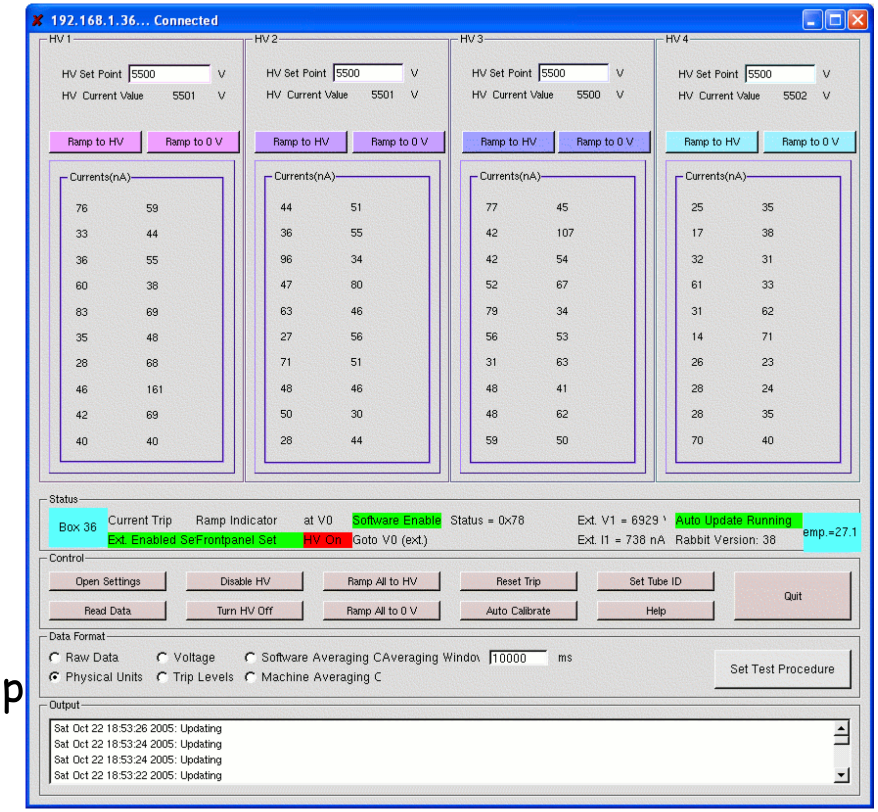
[ADD PIC OF DIGITAL BOARD]

Built-in Ramping and Trip Logic

- Configurable ramping logic:
  - Separate ramp up and ramp down speeds
  - Intelligent ramping (regulate speed to prevent spike trips from charging currents)
- Sophisticated trip logic:
  - Spike trip
  - Time over threshold trip:
    - Individual channel trip level
    - Individual HV group trip time
    - Ramping and stable HV trip level and trip time
  - Internal power supply trip
- Diagnostic:
  - CANbus and Ethernet:
    - Status reporting
    - Ad hoc diagnostic
  - Rabbit Serial output:
    - Operation log and debug diagnostic

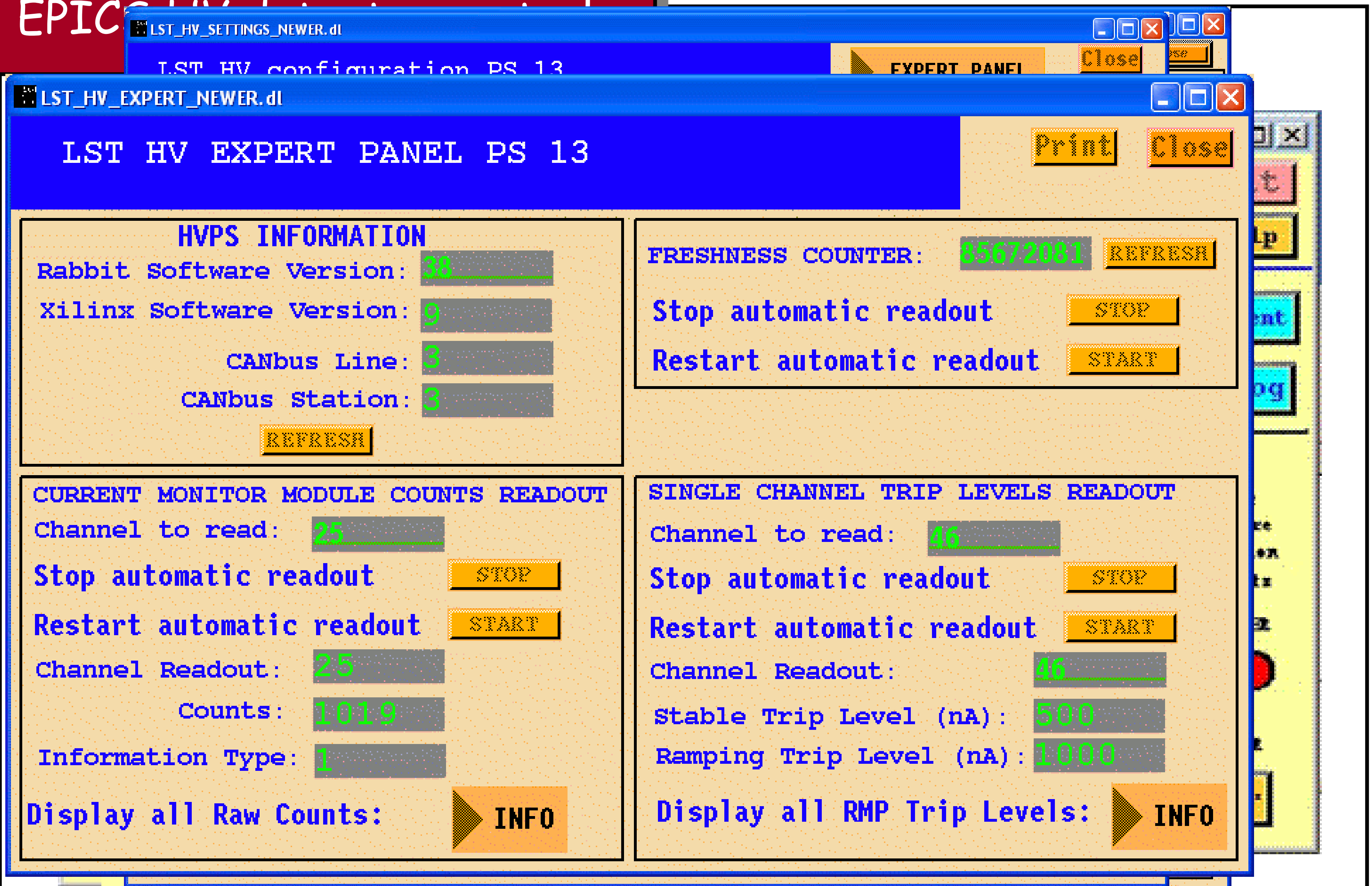
Detector Controls

- **Qt** standalone Ethernet GUI



- BaBar slow controls integration:
  - **MVME5500** IOC, running **RTEMS**
  - **EPICS** detector control software:
    - State machine sequencers, controls and p
    - Alarm handler
    - Database archiving

EPICS

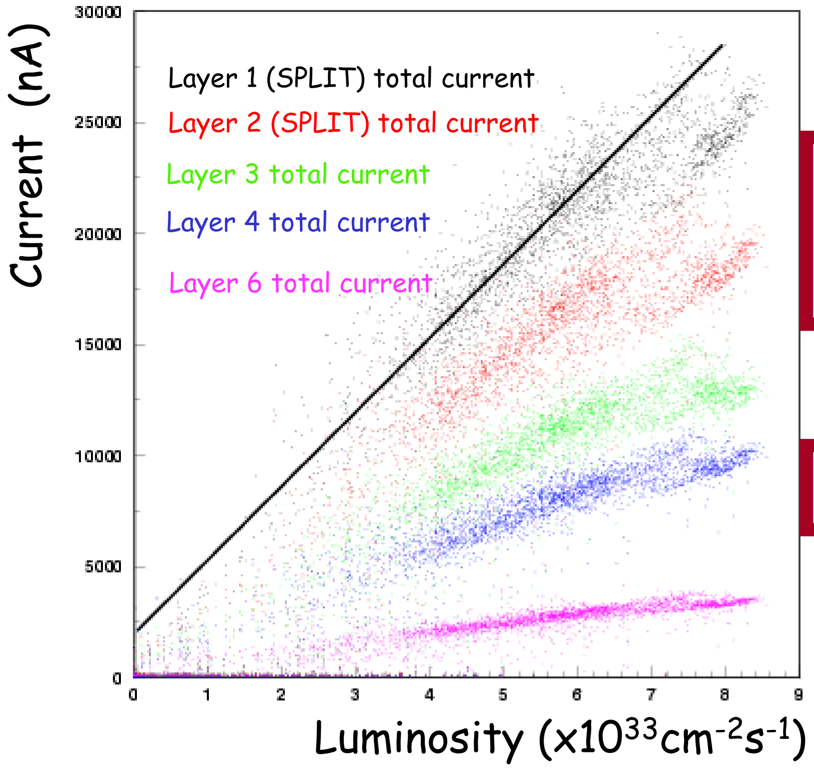

LST_HV_SETTINGS_NEWER.dl
LST HV configuration PS 13
EXPERT PANEL
Close
LST_HV_EXPERT_NEWER.dl
LST HV EXPERT PANEL PS 13
Print
Close
HVPS INFORMATION
Rabbit Software Version: 38
Xilinx Software Version: 9
CANbus Line: 3
CANbus Station: 3
REFRESH
FRESHNESS COUNTER: 85672081
REFRESH
Stop automatic readout
STOP
Restart automatic readout
START
CURRENT MONITOR MODULE COUNTS READOUT
Channel to read: 25
Stop automatic readout
STOP
Restart automatic readout
START
Channel Readout: 25
Counts: 1019
Information Type: 1
Display all Raw Counts:
INFO
SINGLE CHANNEL TRIP LEVELS READOUT
Channel to read: 46
Stop automatic readout
STOP
Restart automatic readout
START
Channel Readout: 46
Stable Trip Level (nA): 500
Ramping Trip Level (nA): 1000
Display all RMP Trip Levels:
INFO

QC and beam experience

- 25 HVPS have been built:
  - 18 will power the LST detector
  - 3 will be "hospital" supplies
  - 4 spares
- 23 HVPS currently at SLAC:
  - 6+2 used in BaBar to power top and bottom sextants
  - 15 used for QC and conditioning of the remaining uninstalled sextants
- They were used for QC (now complete)
- ....

Luminosity driven operational change

- Beam experience:
  - Innermost layers tubes drew high currents as a function of luminosity
  - First two layers tubes were split into two HVPS channels
  - Extrapolating to higher luminosity shows the overcurrent protection threshold in the HVPS needs to be increased



Estimate for 2x10^34 luminosity is 8000 nA per tube

With a firmware upgrade, already planned, the LST HVPS will be able to power the inner tubes in this scenario

An advantage of a flexible custom HV system!

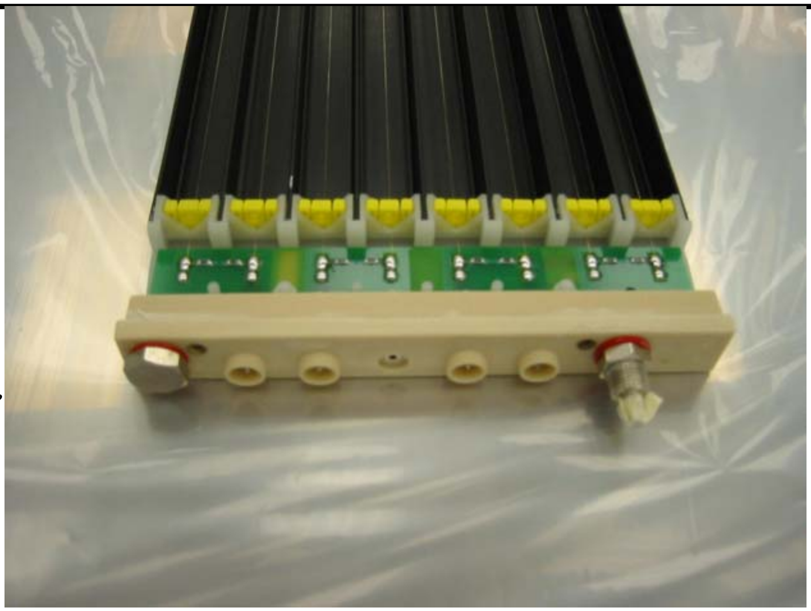
Summary and conclusions

- The OSU HV system provides the BaBar LST detector with a versatile and robust solution
- Excellent performance and flexibility experienced during QC and data-taking
- Ready for the rest of the LST installation in Summer 2006

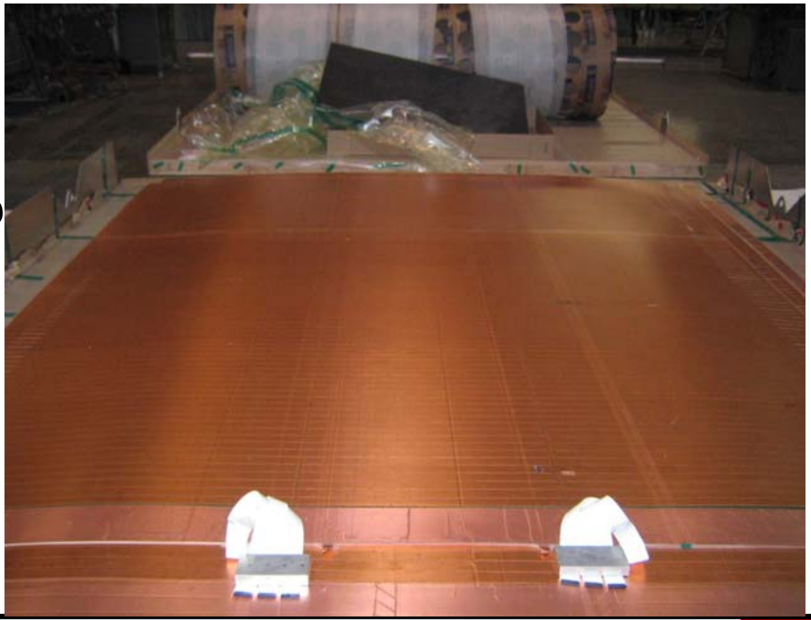
BACK-UP SLIDES

- BACK-UP SLIDES

The BaBar LST detector



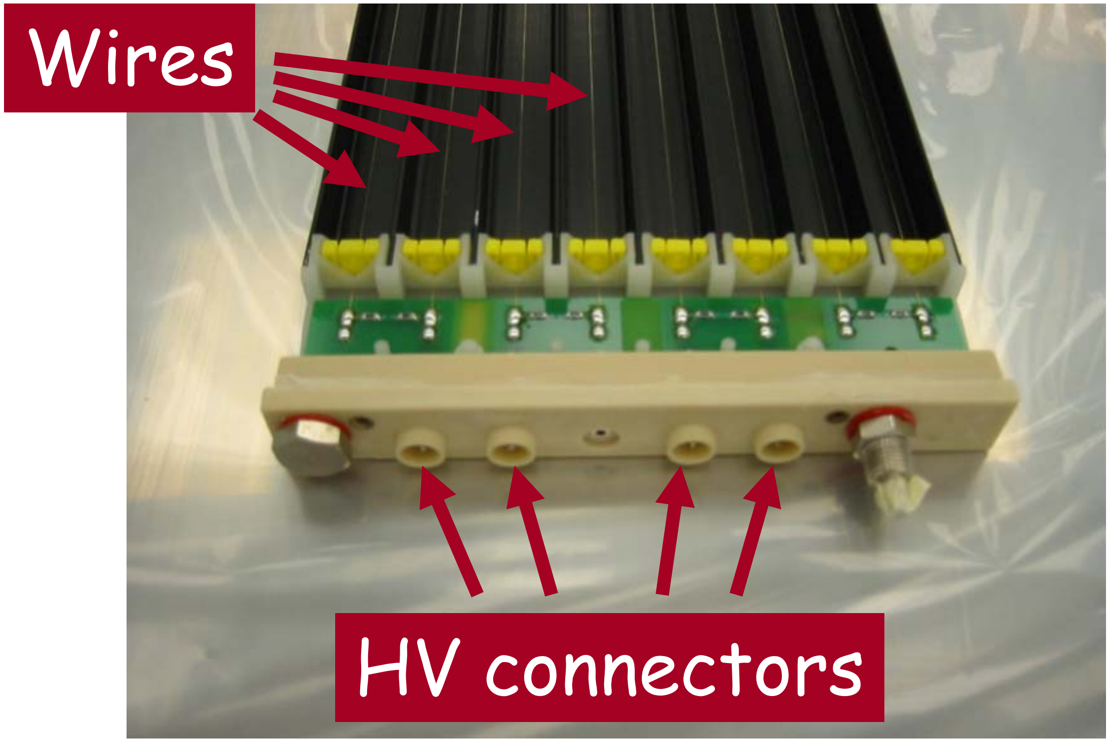
- BaBar Limited Streamer Tubes (LSTs):
  - Tubes with 7 or 8 wires (cells)
  - Cells are (1.75x1.75)cm^2 and 358cm long
  - Wires coupled in 4 HV channels per tube
  - The 4 HV channels are readout channels
  - Operated at 5500V, with Ar/Iso/CO_2 gas mixture (3%/8%/89%)



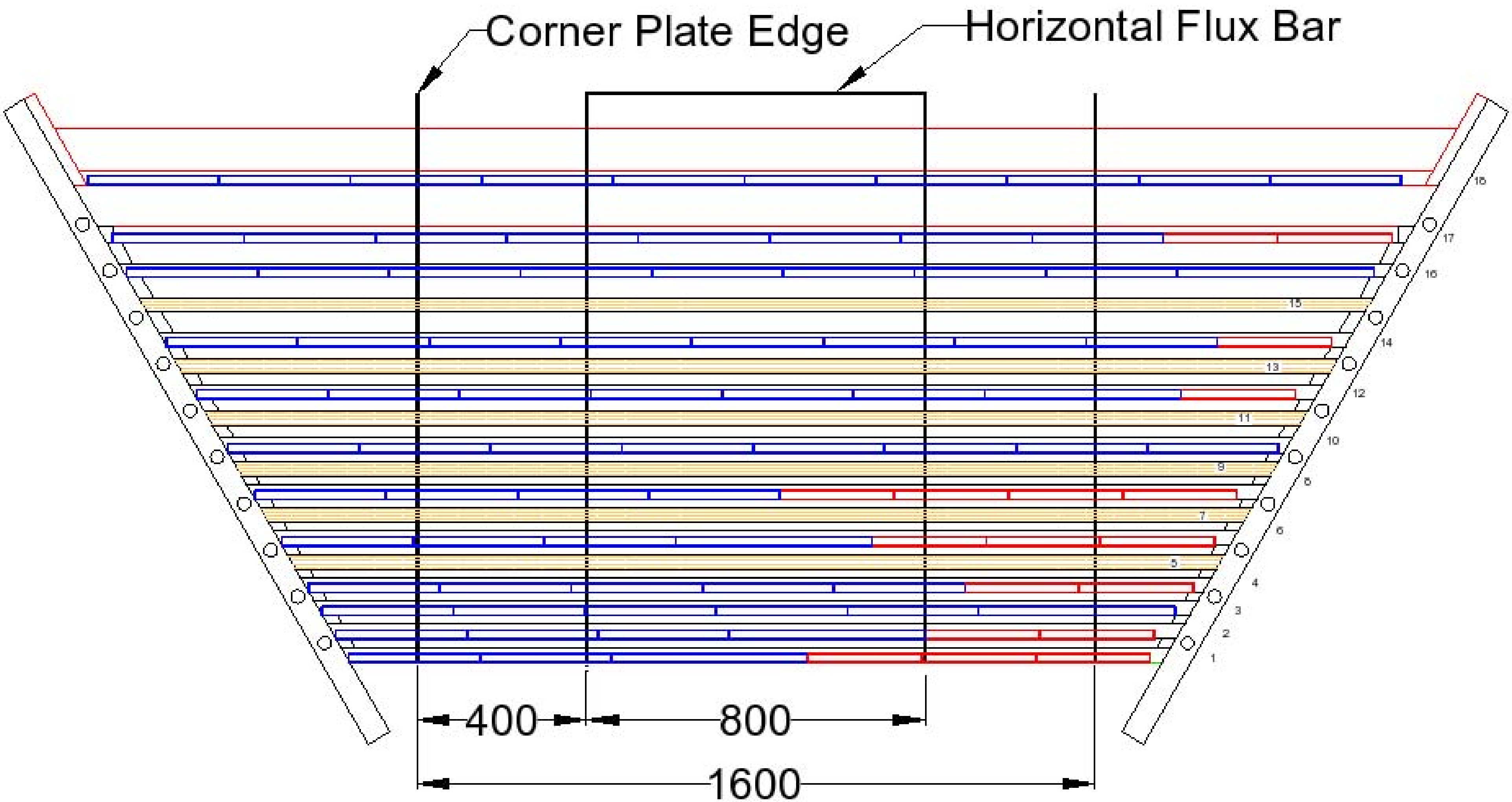
- Z-strips:
  - Vacuum laminated Cu-foil + Mylar
  - 96 strips (orthogonal to LST wires)
  - 35mm wide strips separated by 2mm gap
- LSTs were installed in summer 2004 in the IFR top and bottom sextants:
  - 12 active LST layers per sextant
  - 6 layers of brass per sextant

Granularity

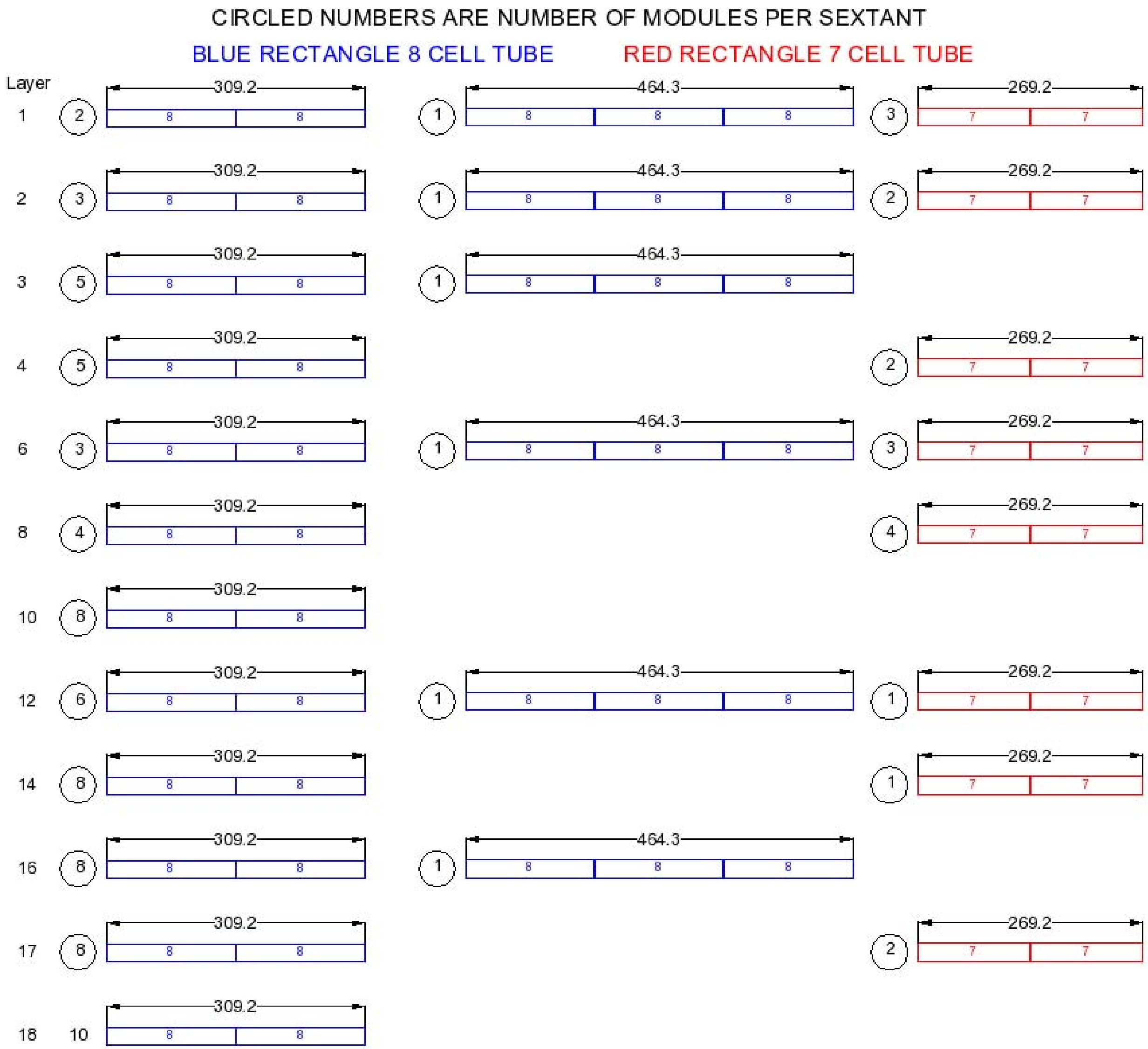
- Very high granularity:
  1164 tubes->4656 HV channels



LST layer arrangement



LST layer arrangement

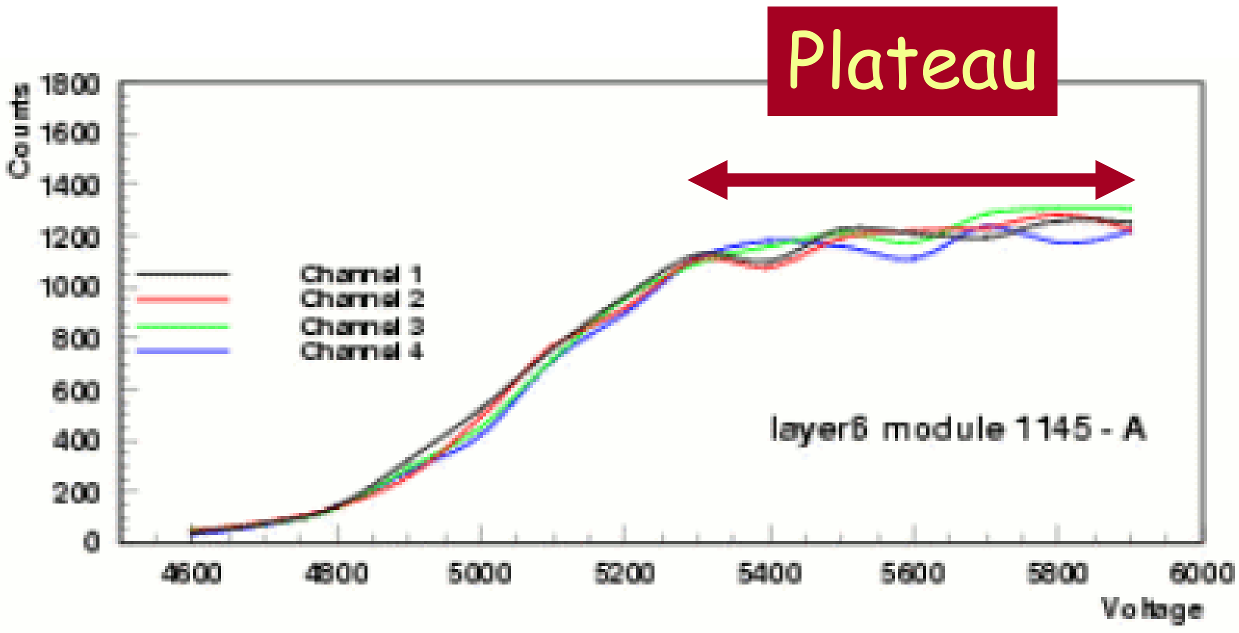


OSU HVPS features

- Variable output voltage 0-6kV
- 320 HV outputs
- Channels are grouped into 4 HV groups of 20 channels each
- Current measurement resolution 1 nA (0-12μA)
- Voltage measurement resolution 1V (1-6kV)
- Individual channel overcurrent protection
- Ramping and trip logic
- Ethernet and CANbus communication protocol

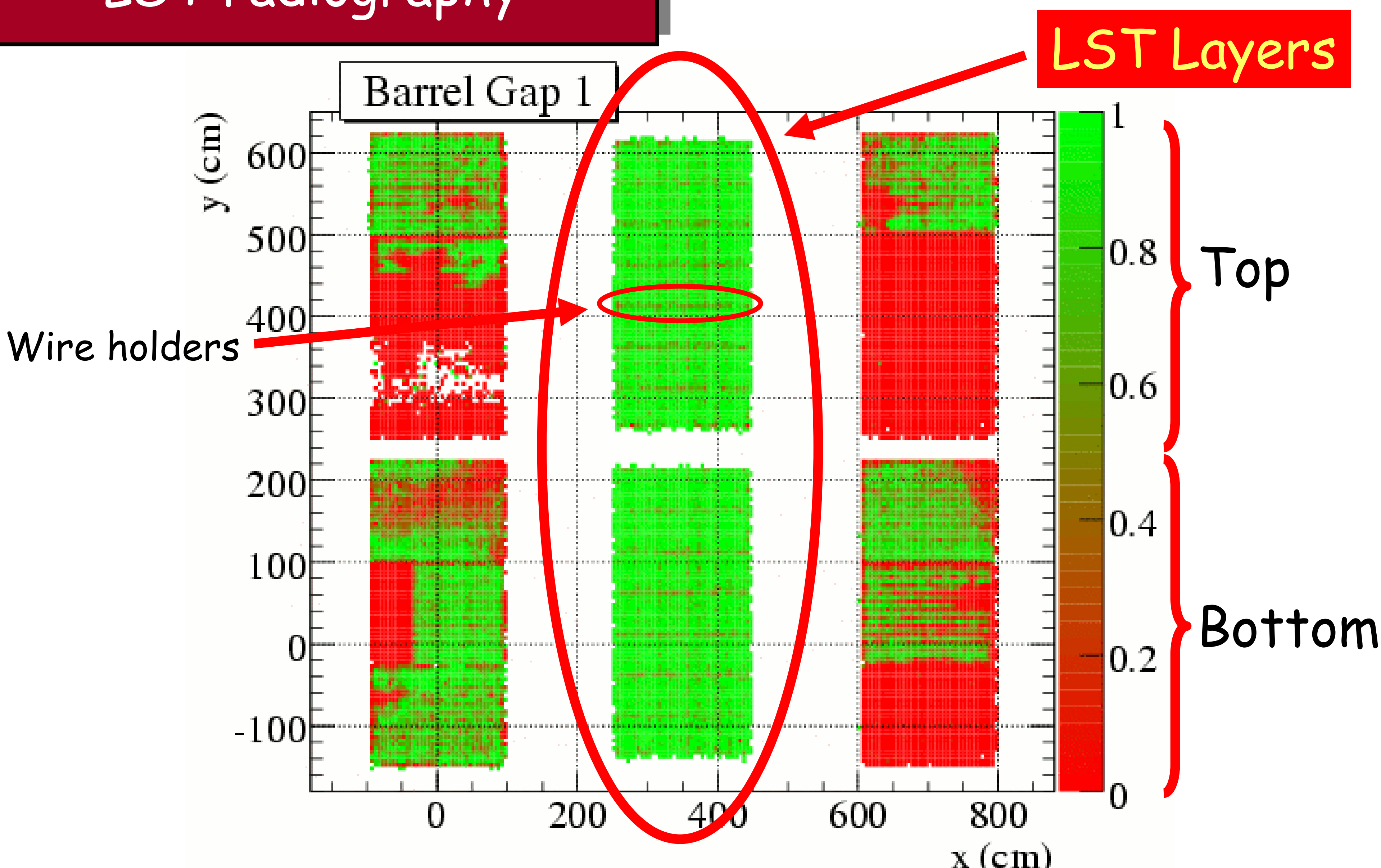
Single Rates

- Tubes are tested by scanning their counting rates at several HV points (single rate measurement):



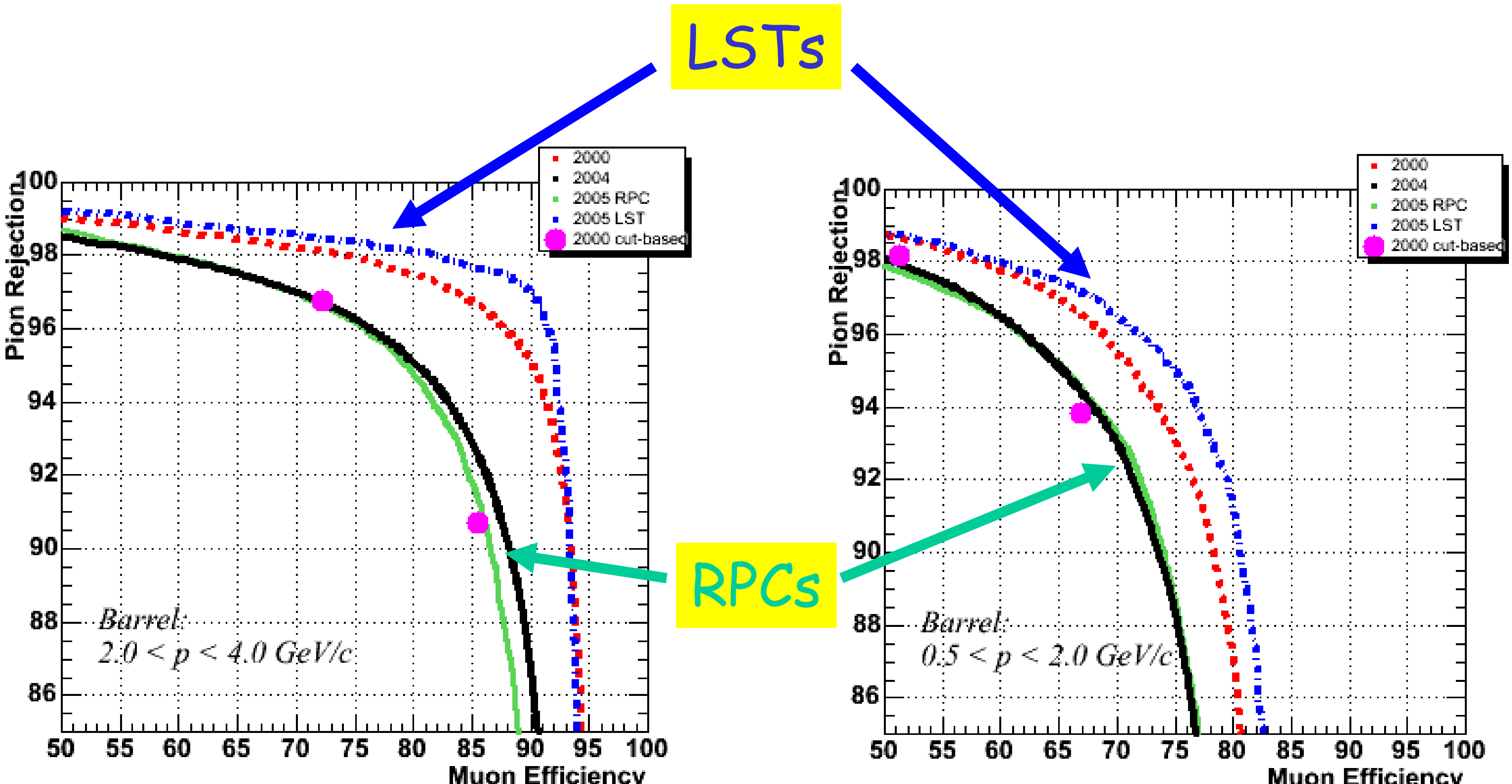
- Single rates measurements are done once a month
- All tubes show nice plateaus

LST radiography



LST Muon ID Performance

- Pion rejection vs. Muon efficiency for high and low momentum muons



Rabbit/Xilinx/Boards/Interlocks

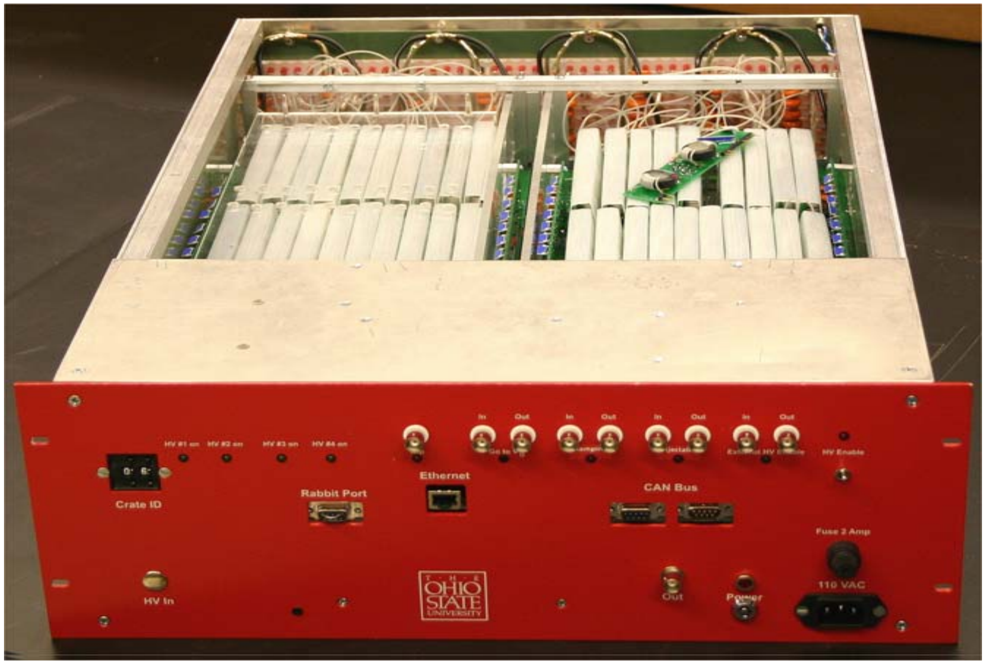
- Microcontroller Rabbit (Ethernet port) RCM-3200
- FPGA Xilinx Spartan XCS-30
- Dynamic C embedded software developed
- I/O:
  - Ethernet
  - CANbus controller Philips SJAXXXX
- Front panel interlocks:
  - HV external enable signal
  - HV enable switch
  - Injectable voltage
  - Trip
  - Ramping
  - Go to Injectable voltage
- LEDs:
  - HV on for each HV group
  - Ramping, trip, Injectable, etc

Detector controls Features

- Injectable/Runnable
- Alarm Handler
- Ambient DB and Archiver
- Save restore
- Trip reporting
- Automated Trip reset
- Single Rate
- Conditioning

The LST HV system

- OSU HVPS:
  - Run5: 6 HVPS + 1 hospital supply
  - HV output up to 6000V
  - 80 current monitoring channels
  - 4 HV output pins per channel (corresponding to a tube)
  - High granularity (320 outputs)
  - 4 HV groups of 20 channels (corresponding to a layer)



- Safe for detector:
  - Individual channel LST overcurrent protection
  - Sophisticated trip logic (spike, time over threshold, ramping, internal power supply)
  - HV control box to provide input to BaBar SIAM injection inhibit
- Safe for operations:
  - Removable key
  - External signal/front panel/software HV enables
  - Highest output current per channel 12 microAmps (startle hazard)
- Fully integrated (via CANbus) in BaBar ODC and state machine
- Easy access for maintenance
- Upgradeable firmware to implement new features

LST HV system

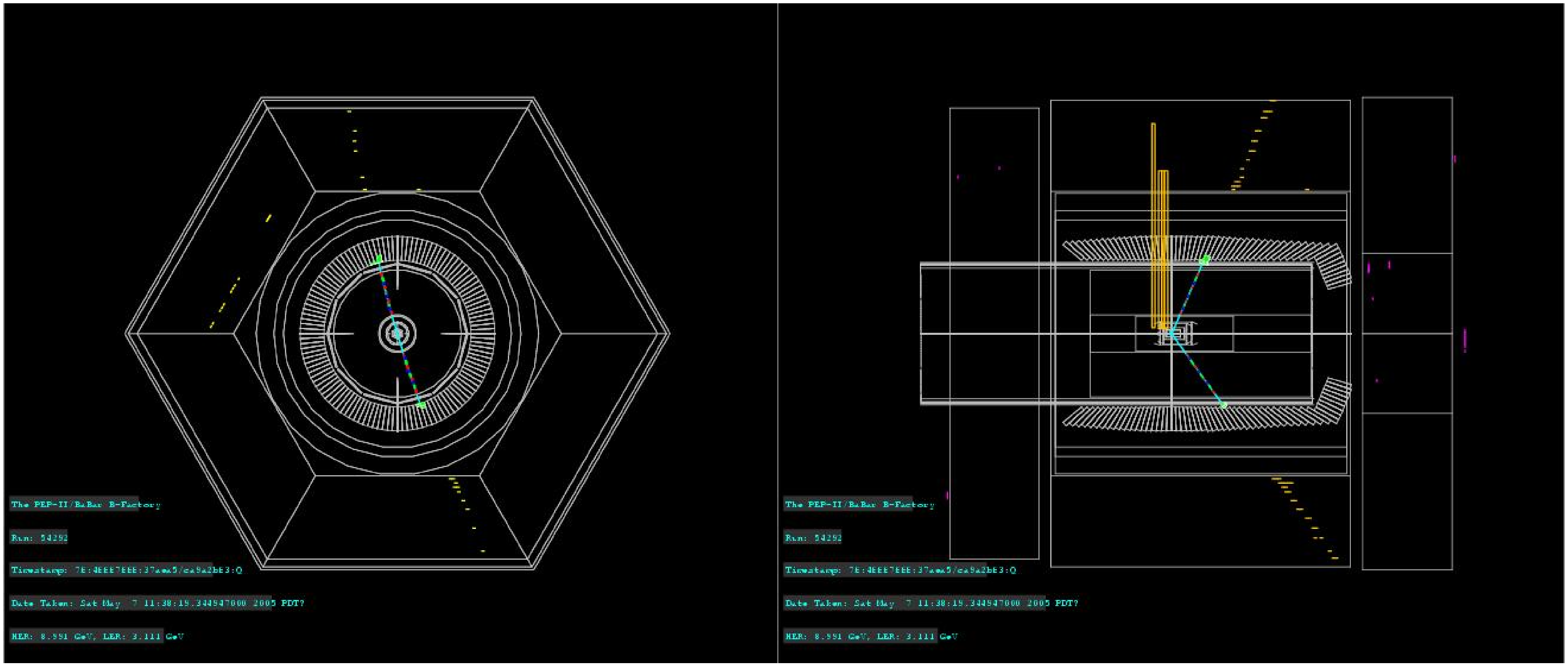
- Run5 LST HV system performance was fine
- Beam experience:
  - Some wire channels showed a repetitive trip behavior and the hospital HVPS helped recover some of these channels. Problematic channels are operated at lower voltage
  - Frequency of trips of LSTs due to self-sustained discharge at higher luminosity suggests the implementation of an automatic trip reset functionality
- A few problems:
  - 2 HVPS failed (with a known failure mode) in IR2 and they were replaced
  - LST SIAM injection inhibit signal glitch due to a firmware bug, it was solved with a firmware upgrade
- All 23 LST HVPS (21+2 spares needed for final configuration) are at SLAC and are working fine:
  - 7 HVPS in IR2 power top and bottom sextant (including hospital)
  - 1 extra spare ready in IR2
  - 13 HVPS powering tubes in CEH and gaining operational experience
  - 2 extra spares in CEH

The LST slow controls

- IOCs:
  - ifr-mon, ifr-hv, lst-hv
  - All running VxWorks and EPICS 3.14.7 (CBlow task patch is in)
  - Using lst-test in CEH (controlling 15 supplies and 1 GMB):
    - PPC IOC
    - RTEMS operating system
    - EPICS 3.14.7
  - Status:
    - *All IOCs running smoothly*
- ODC:
  - The first deployment of a PPC/RTEMS IOC in IR2 (in June) caused communication problems (and some down time, half of the time listed in Steve's wall of shame for LSTs)
  - After a quick revert to the MVME/VxWorks old solution, no LST IOC crashes experienced.
  - A few new features/utilities introduced for operations:
    - Configuration tools
    - Automatic trip logging/reporting/paging

LST Event Display

- Di-muon event in the LSTs



CEH status

- All LST modules, cables and HVPS are at SLAC:
  - All HVPSes, long- and short-haul cables working fine and being used
  - Finished QC on all LST modules (many man-years effort, thanks to the CEH shifters crew!)
  - QC data analysis in progress, already plenty of good modules for next installation
- Operations:
  - Keep all tubes under gas and HV
  - Opportunity of shift sign-up for next summer installation