PHENIX Muon Tracker Electronics in Year-1

Ming X. Liu

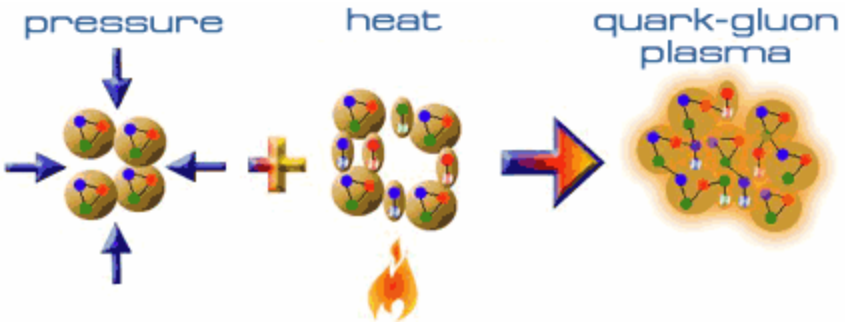
Los Alamos National Lab

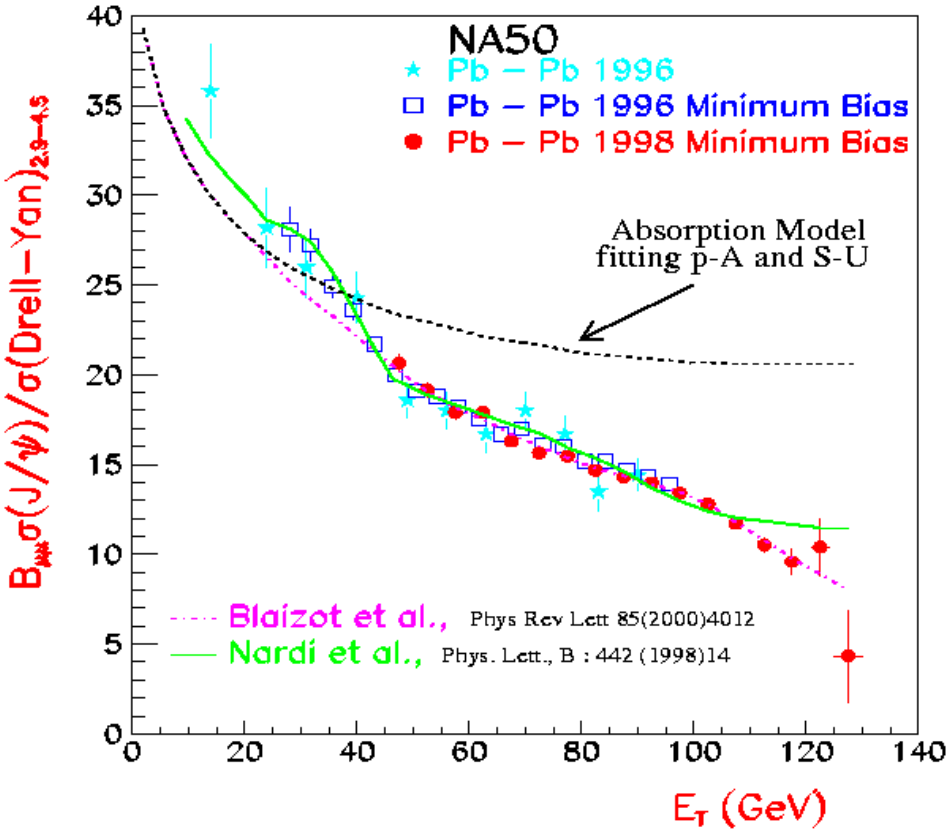
- Phenix Experiment
- Muon Tracking System Design Specs
- Analog and Digital Design
- Results from RHIC Run-II

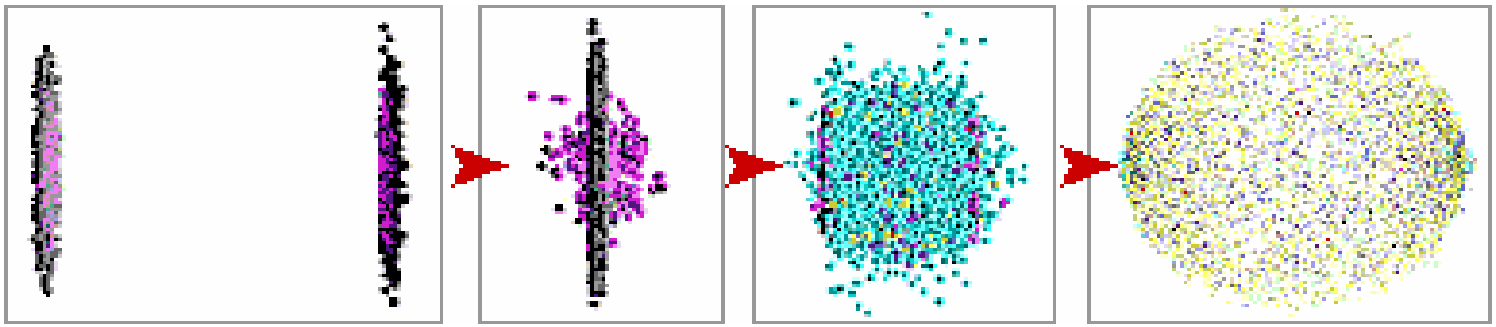
Physics - QGP?

$$J/\psi(c\bar{c}) \rightarrow \mu^+\mu^-$$

$$M_{J/\psi} = 3.1 GeV$$

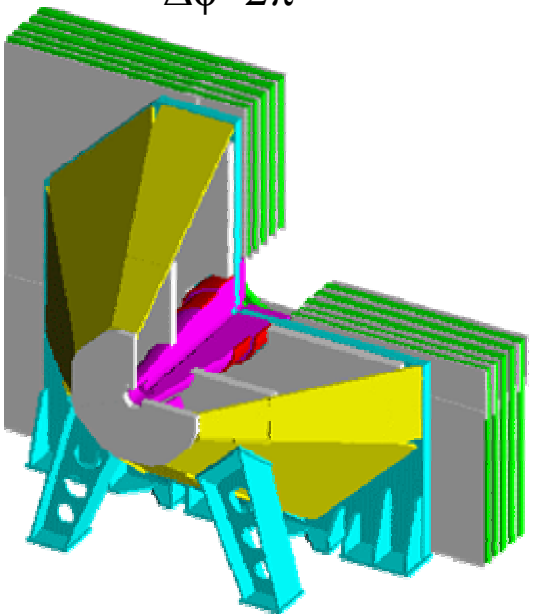


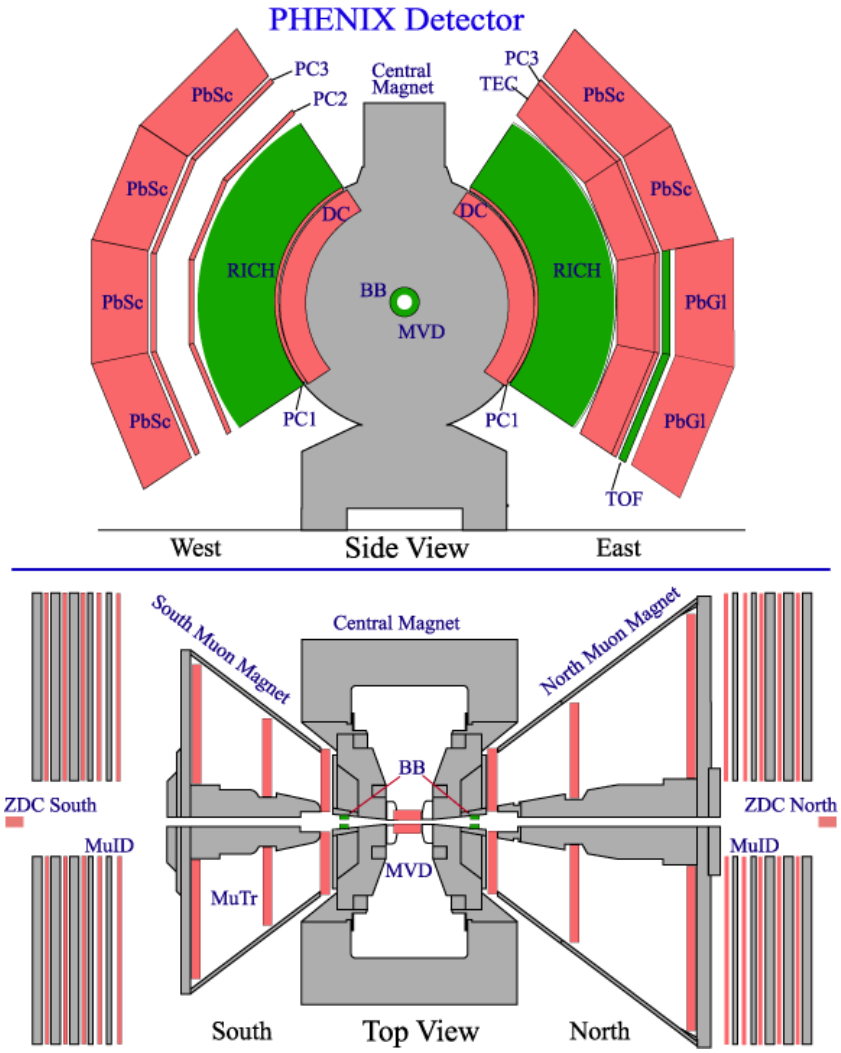




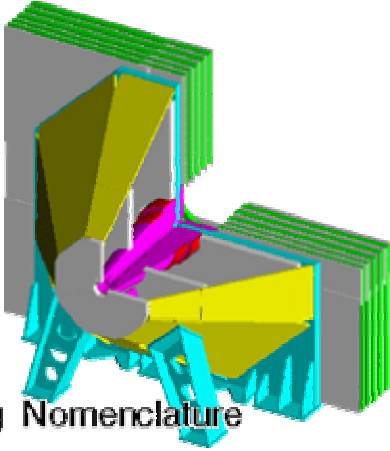
PHENIX Experiment

- Central Arms
  - Tracking,EMCal,PID
  - $|\eta| < 0.35$
- Muon Arms
  - Tracking+MuID
  - $1.2 < |\eta| < 2.4$
  - $\Delta\phi = 2\pi$



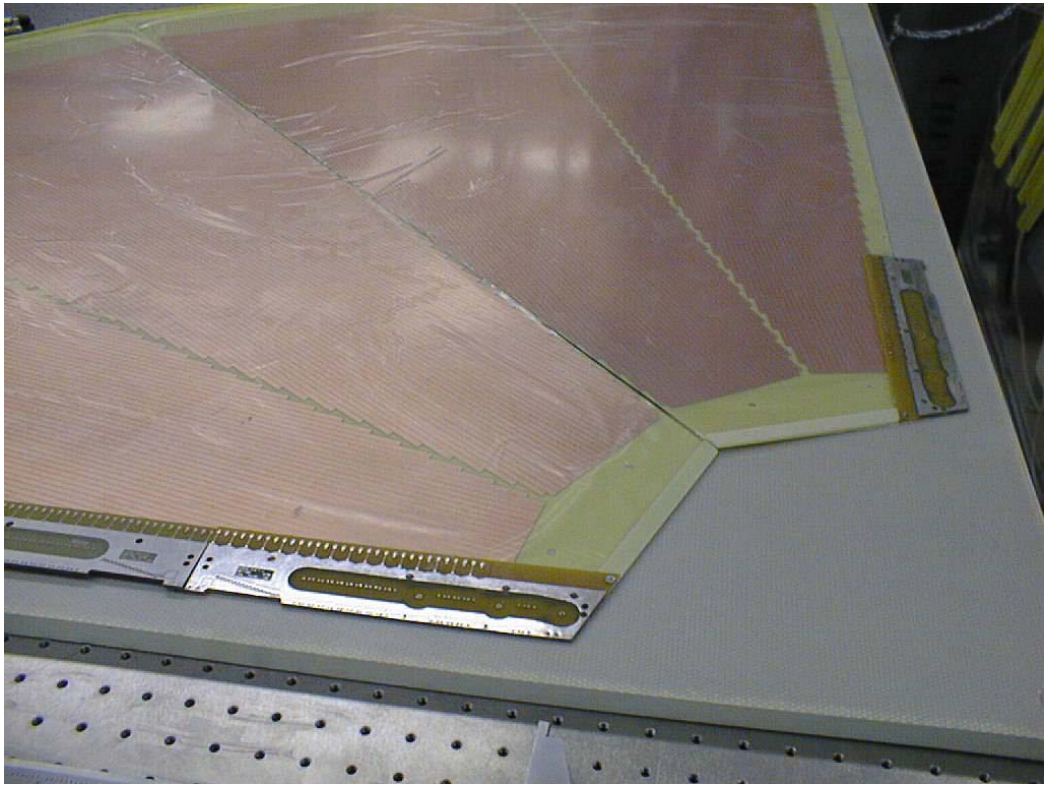


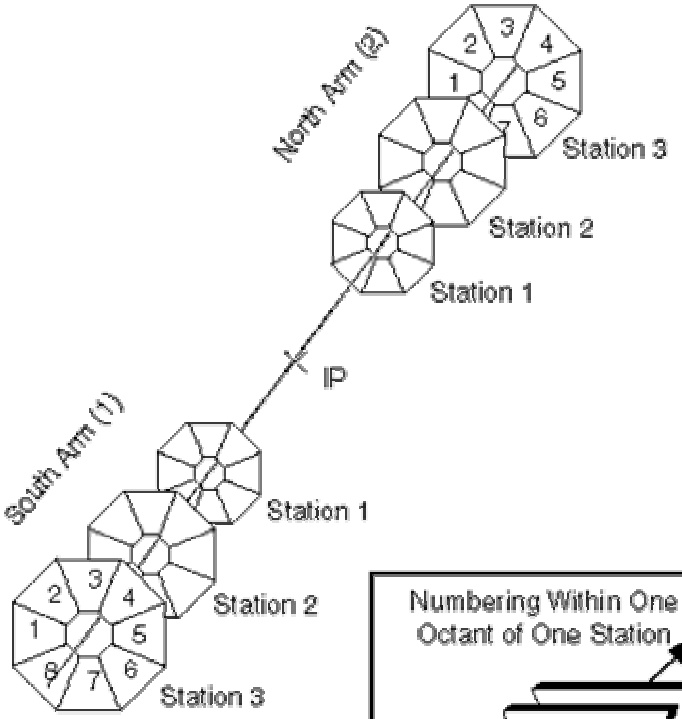
Muon Tracking Chamber

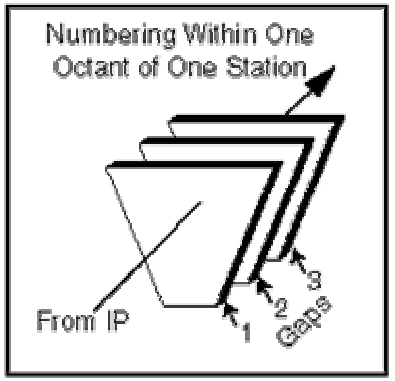


Muon Tracking Nomenclature

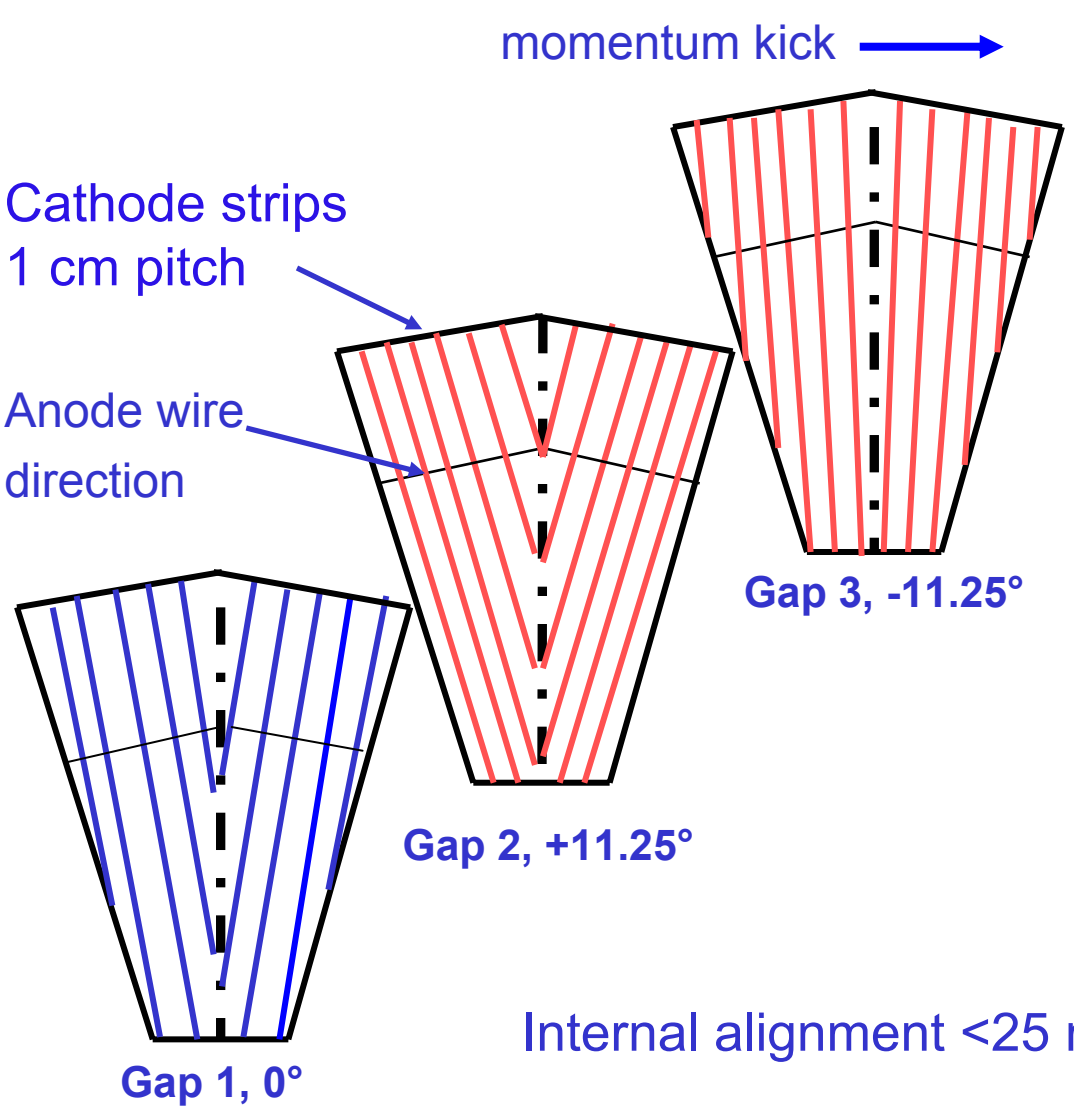
0.5 cm Cathode Strip Chamber

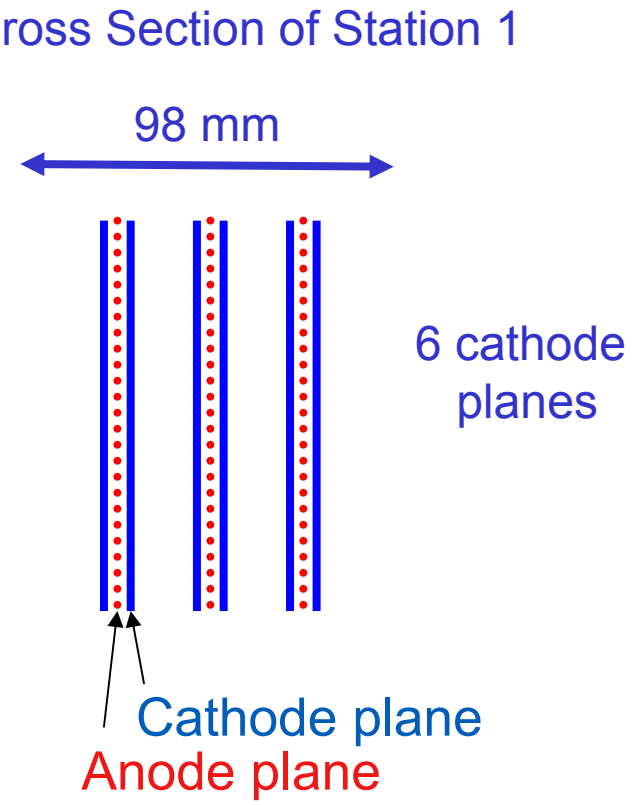






STRUCTURE OF A STATION





Internal alignment <25 microns

Muon FEE Design Specs

Good J/Psi mass resolution

- Low Noise
  - 100 μm resolution 1 cm cathode strip readout
  - input cap 10-150pF
- High Speed
  - sample new data on every beam crossing
  - 4 samples per pulse
  - hold 5 events
  - 25kHz LVL-1 [40uS]

- Serial Control and Monitor
  - FPGA,AMUADC,CPA
  - Temp, Voltage, Current
- Performance
  - 11 bits dynamic range[0-2047]
  - typical charge 80fC (0.4-800fC)
  - gain: 3.5mV/fC
  - noise requirement 1% or 0.8fC
  - pulse shape
    - rise time 0.7uS
    - decay time 10uS
  - optical link to outside world
  - reasonable power-up defaults;
  - calibration control

Muon FEE

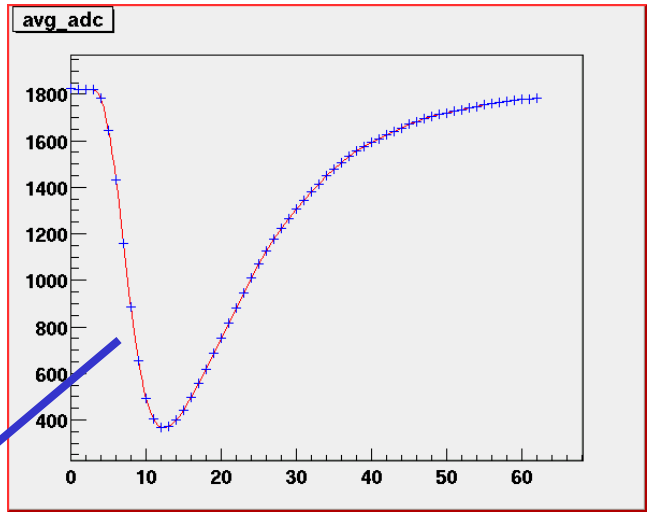
- Low noise high speed FEM

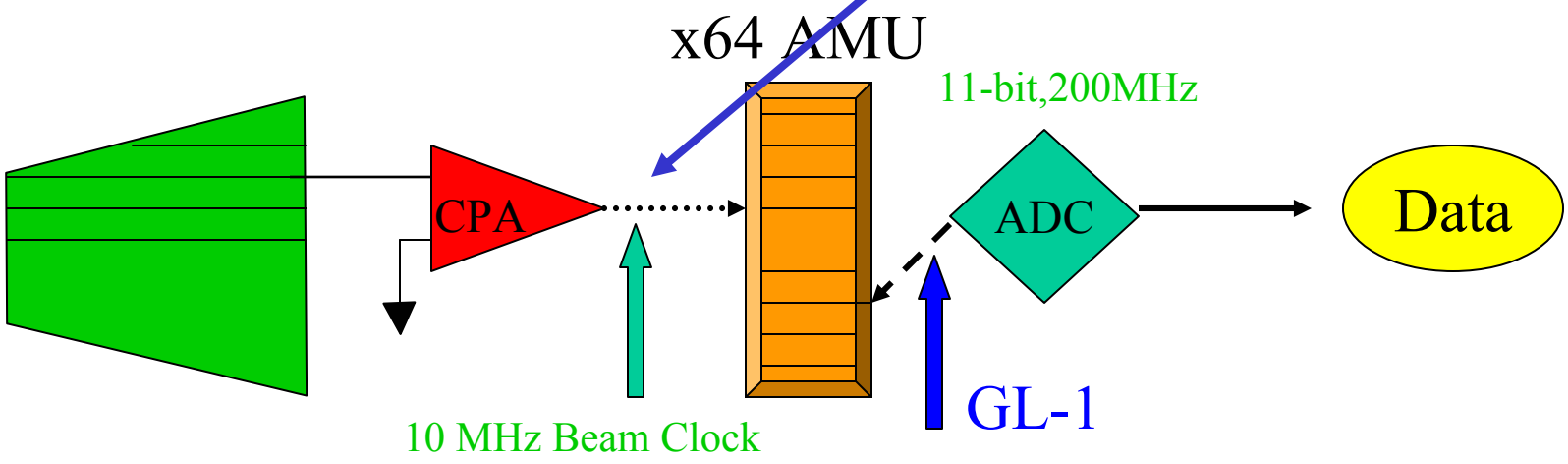
$$resolution: 100\mu m = x \cdot 1cm \Rightarrow x = 1\%$$

$$noise: Q' = 80\,fC \cdot 1\% = 0.8\,fC$$

$$Thermal\ noise:$$

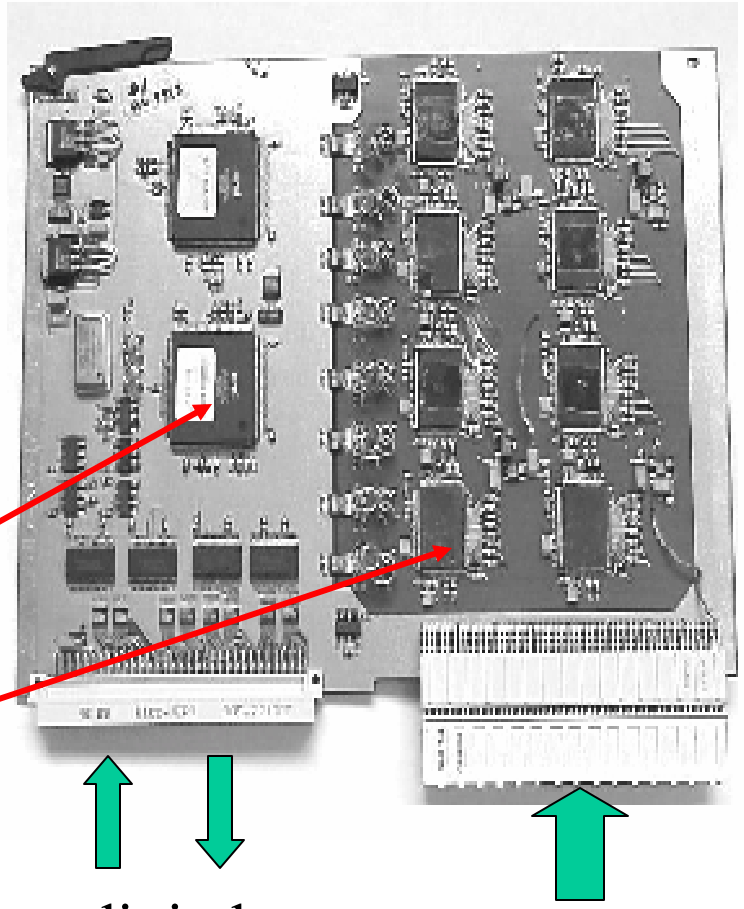
$$\frac{1}{2}\frac{Q_{thermal}^{\ 2}}{C_{\det}} = \frac{1}{2}kT \Rightarrow Q_{thermal} = 0.65\,fC$$





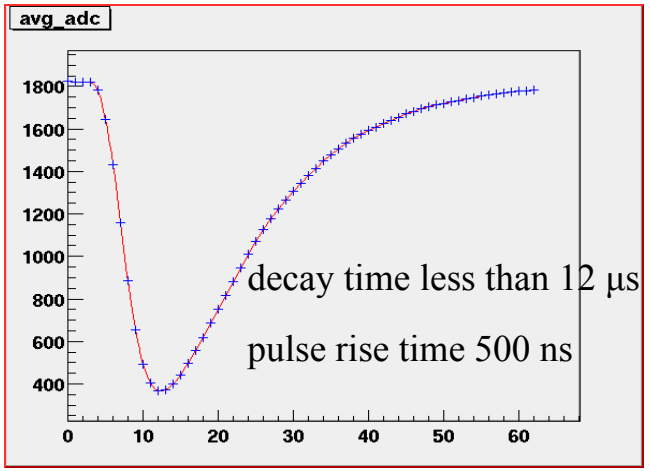
Cathodes Read-Out Card (CROC)

- Design Requirements
  - 64 Channel Readout per CROC
  - Less than 3125 electrons (RMS) noise for 10-150 pF of detector capacitance (including 24” cable) •
  - Less than 1% crosstalk between any channels on the board
  - gain: 3.5mV/fC
  - Digital/Analog isolation
- Main Components
  - AMU-ADC
  - CPA

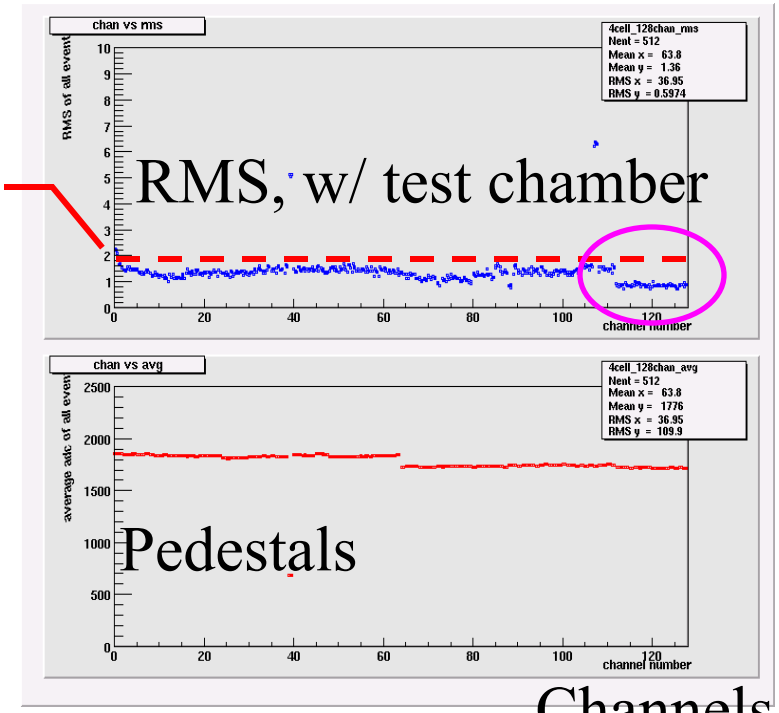


Muon FEE - CROC

- CPA(Charge Pre-Amp)
  - low noise (<3000 e's)
  - 8-channel preamp/shaper
  - 34-bit serial control
    - pedestals
    - pulse shape
- AMU-ADC
  - 32 channels
  - 64-cell AMU
  - serial control
    - V_ref, I_ref
    - 9-12 bits ADC conversion
  - 200MHz clock



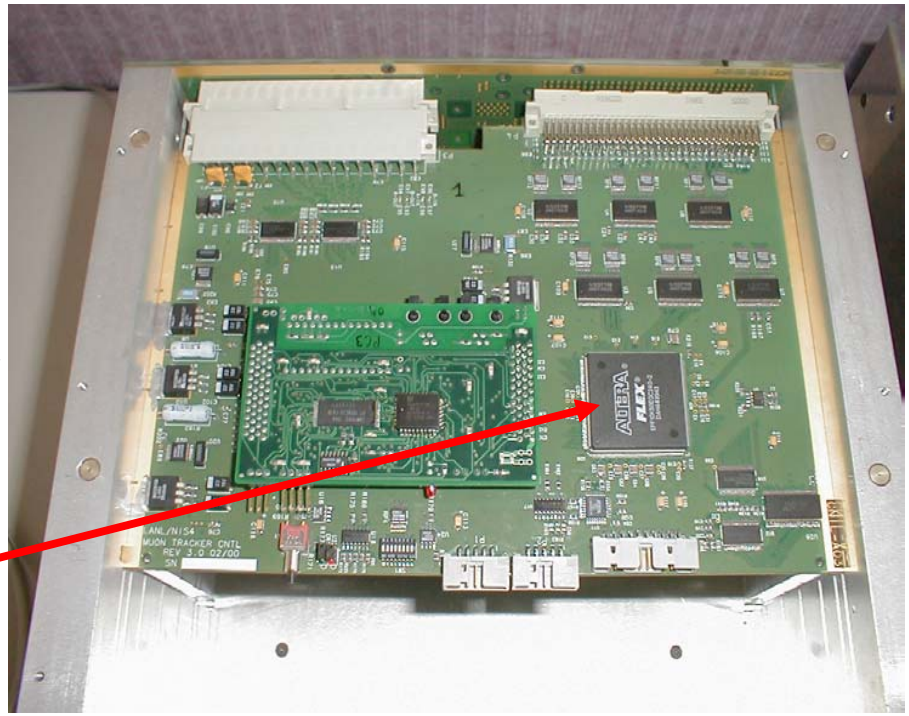
Noise Spec



Channels

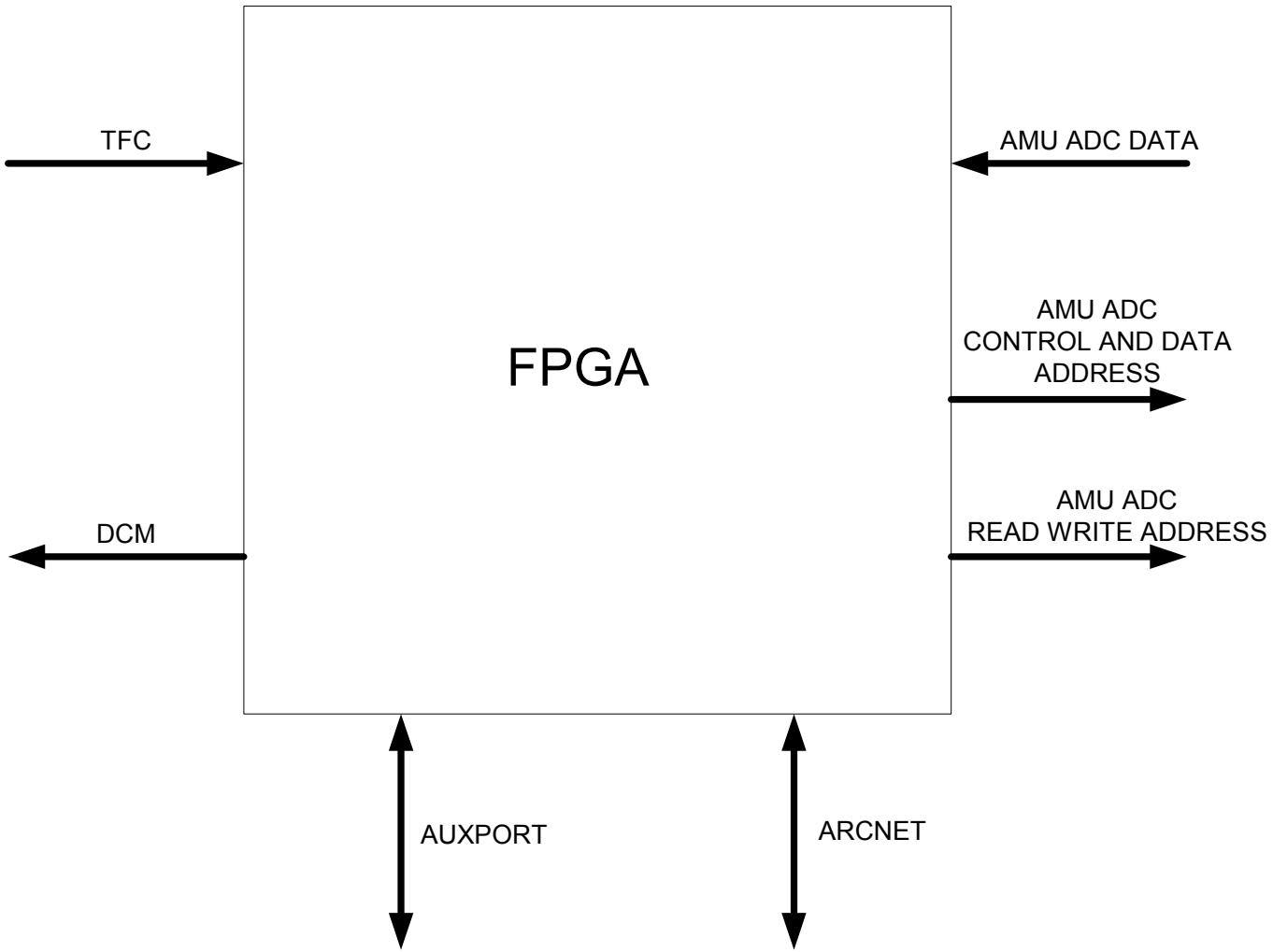
Controller Card (CNTL)

- Design Requirements
  - Control AMU/ADC data collection, conversion and read-out
  - Provide connection to 2 CROC boards
  - Provide connection to the outside world
  - Support the T&FC and DCM interface
  - Provide data relay from remote controller board to DCM
  - Support ARCnet connectivity to serial configuration bus
- FPGA - the brain
  - developed by Jack
  - work in progress



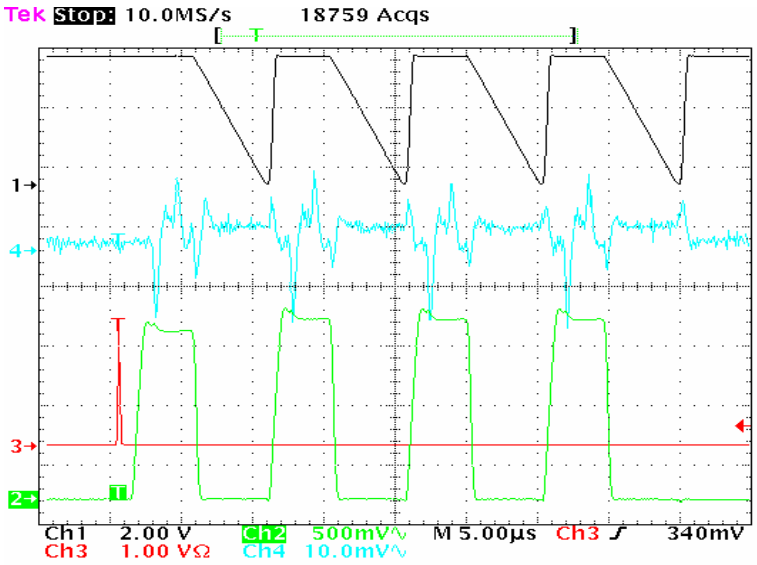
CNTL Card

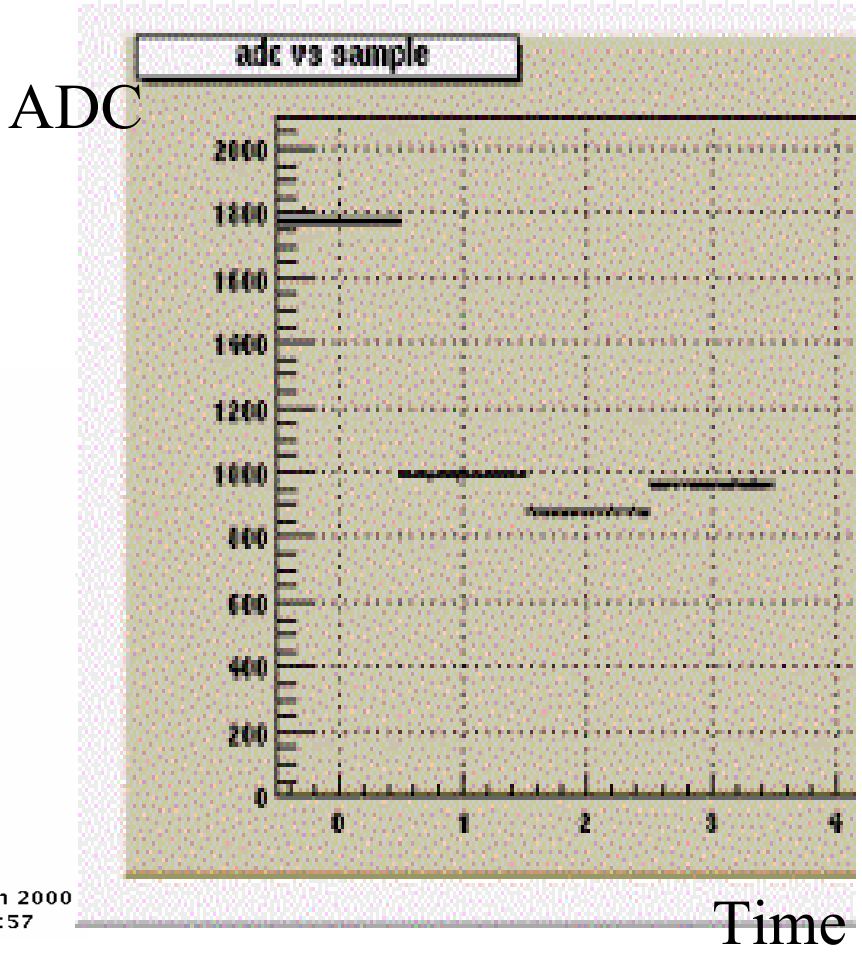
MUON TRACKER
CNTL FPGA



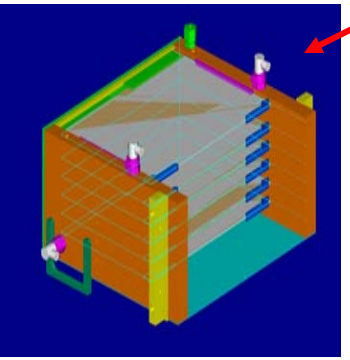
Muon FEE

- FPGA - current code
  - store every beam crossing
  - 4-sample per pulse
  - readout time 53uS
  - hold 4 events





Muon Tracking FEE Overview



LVDC Power Supplies

LVDC distribution cards

GTM

Signal from Counting House

Glink2Clink

ARCNet

Counting House

Cathode Plane

CROC

CROC

CONTROLLER

CROC

CROC

CONTROLLER

CRA manifold

Nitrogen manifold (Under Platform)

CRA manifold

H_2O manifold (UnderPlatform)

Clink2Glink

Patch Panel (platform)

DCM (counting house)

Slow Controls Monitors

VME Crate (platform)

HV Plane

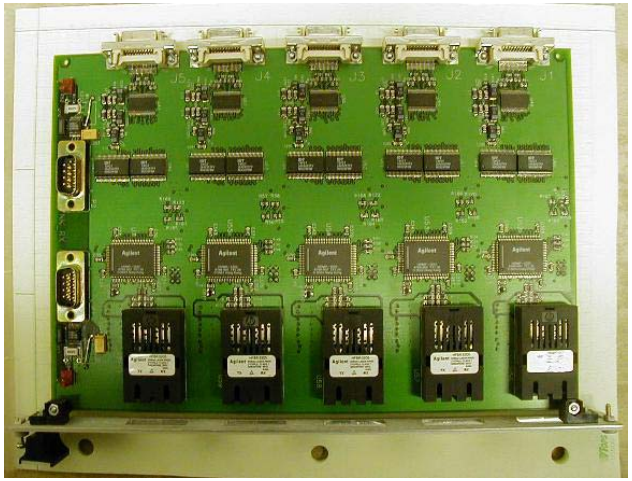
Pulser (platform)

Chambers

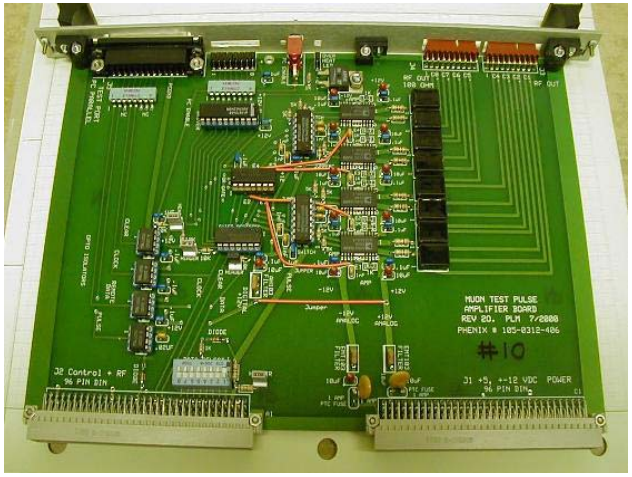
Gas system interface (platform)

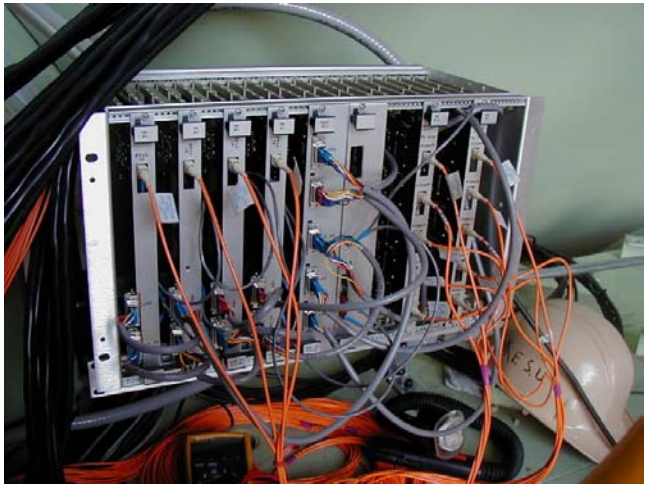
Supporting Muon Tracking Electronics

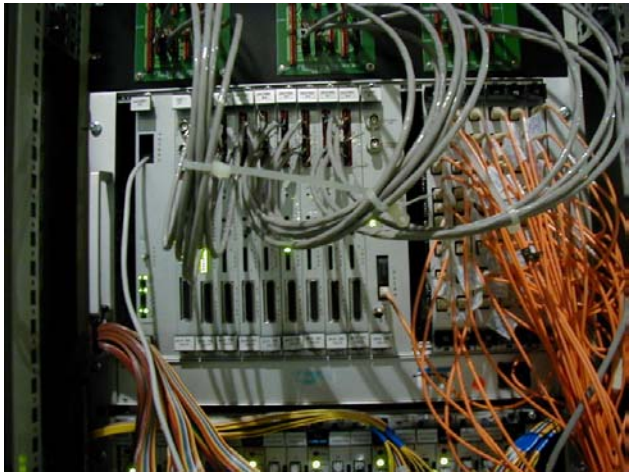
G/Clink cards



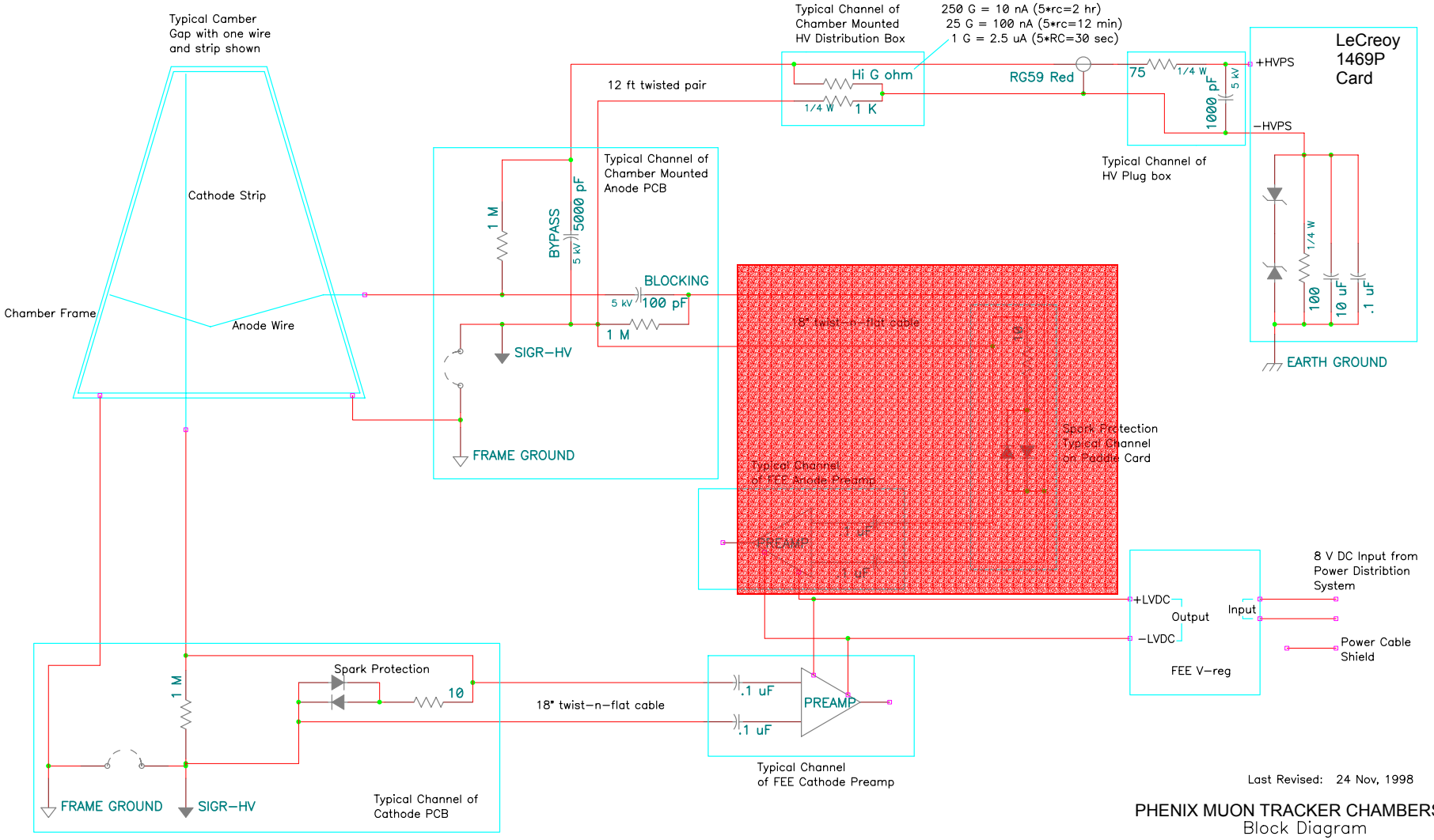
Calibration







System Diagram



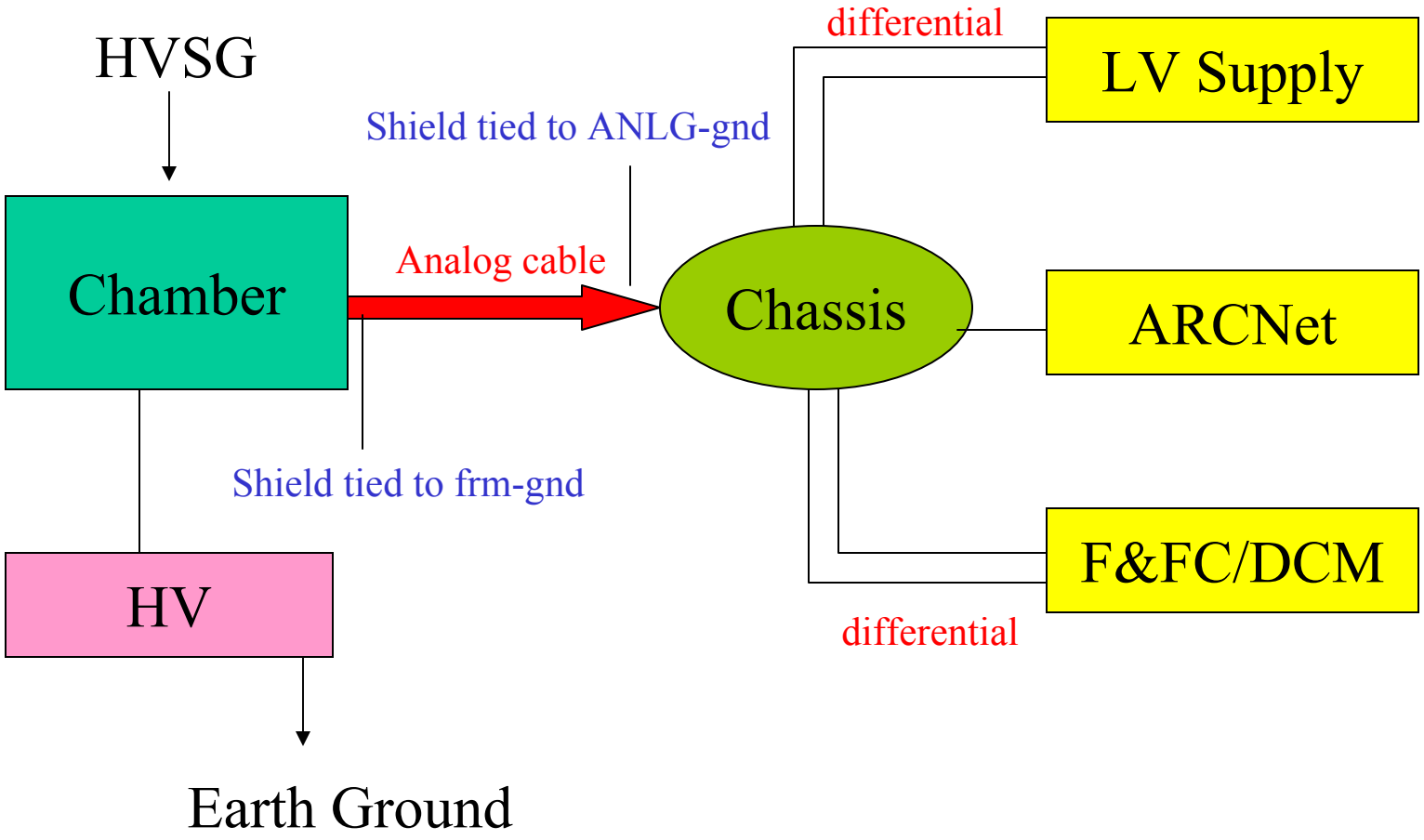
Last Revised: 24 Nov, 1998

PHENIX MUON TRACKER CHAMBERS
Block Diagram
−Electrical−

28 July, 1998
MuTr Block

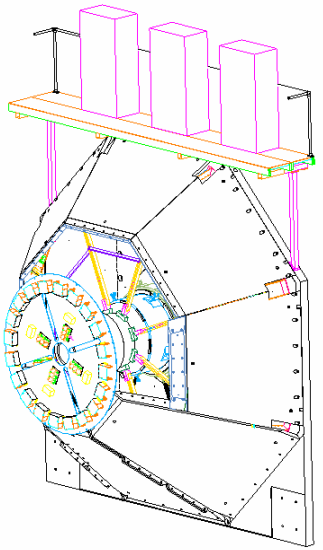
G Hart

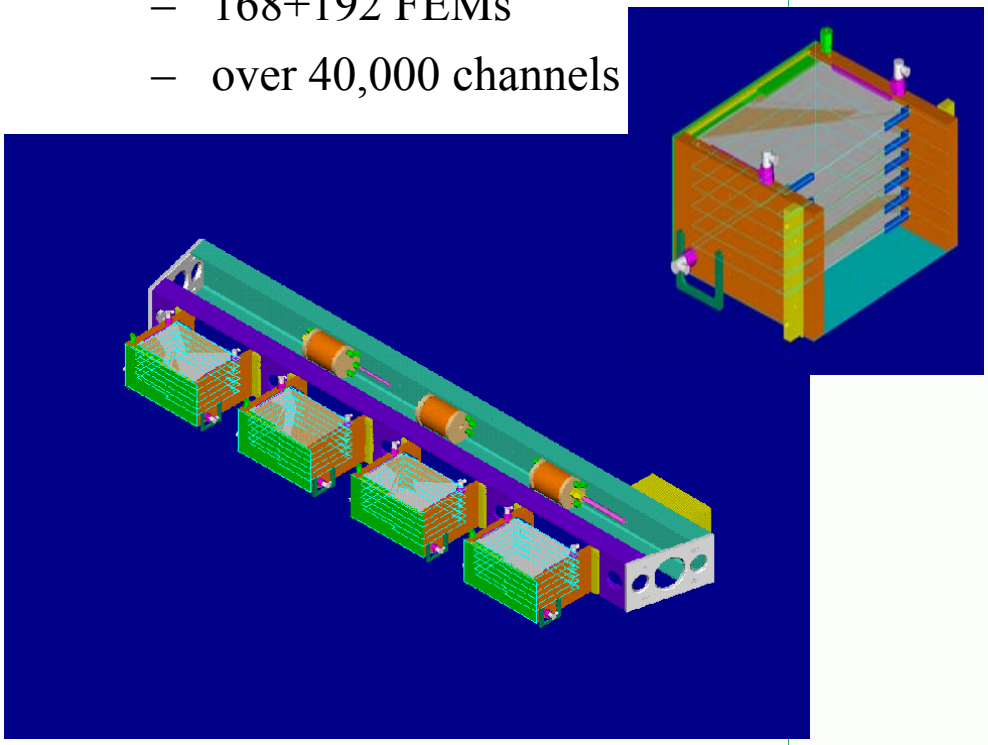
Grounding Configuration

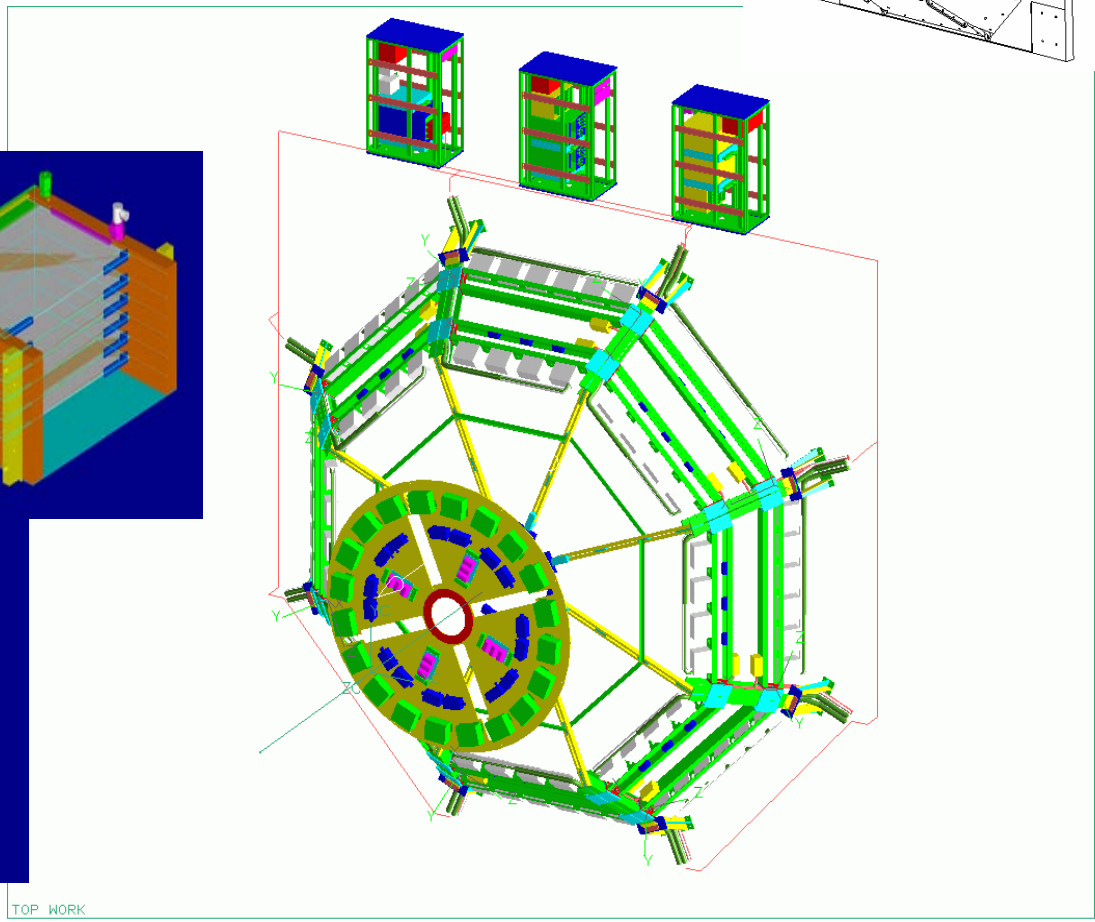


FEE Overview

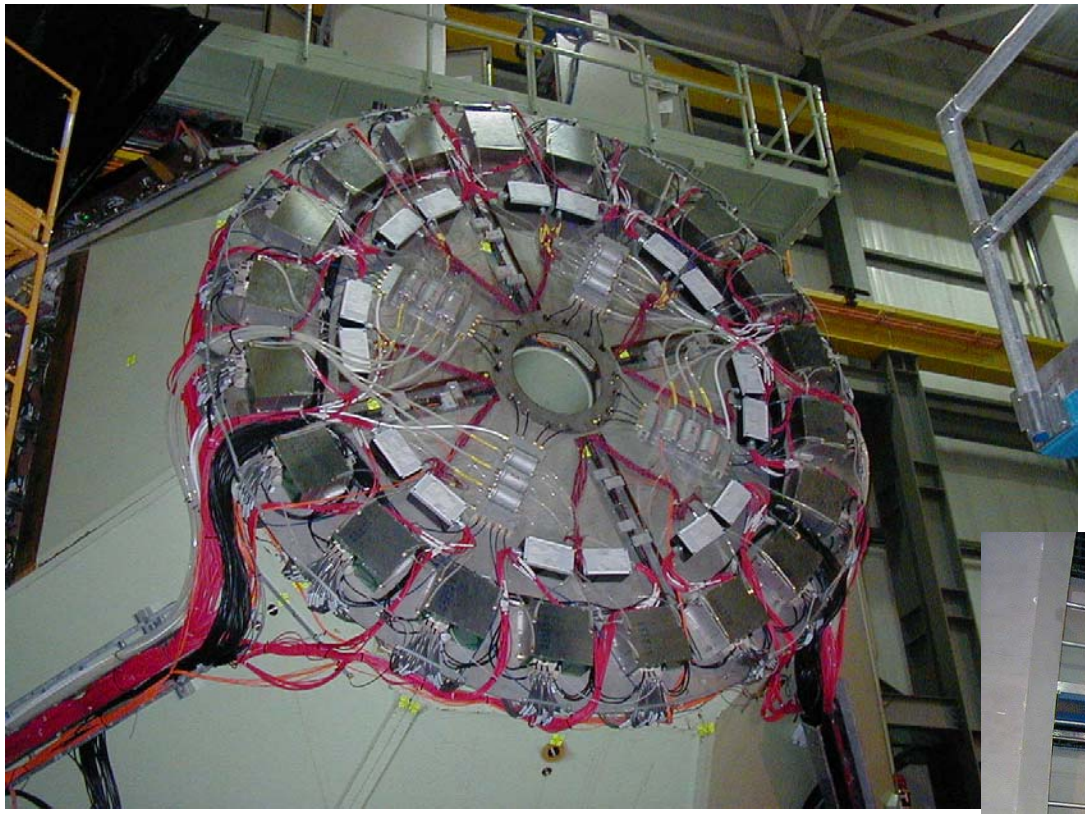
- Inside Magnet/no access
- Limited Space
- Power constrain
- Many Channels
  - 168+192 FEMs
  - over 40,000 channels

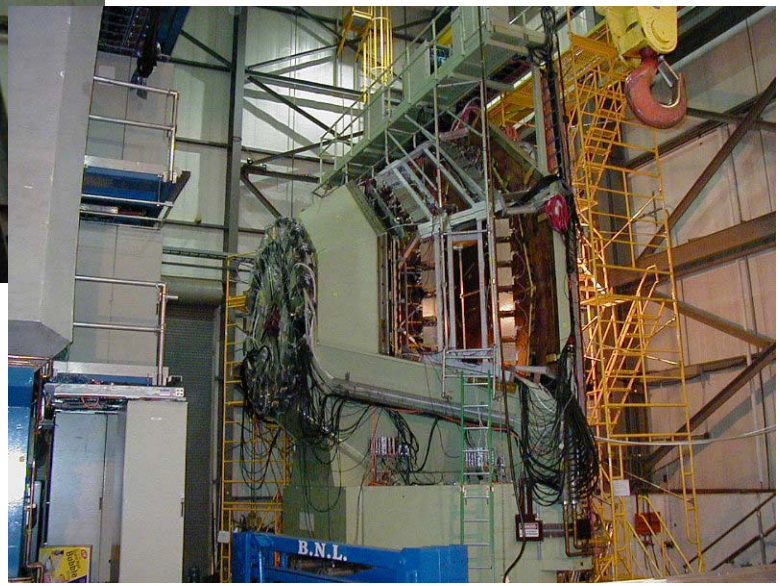






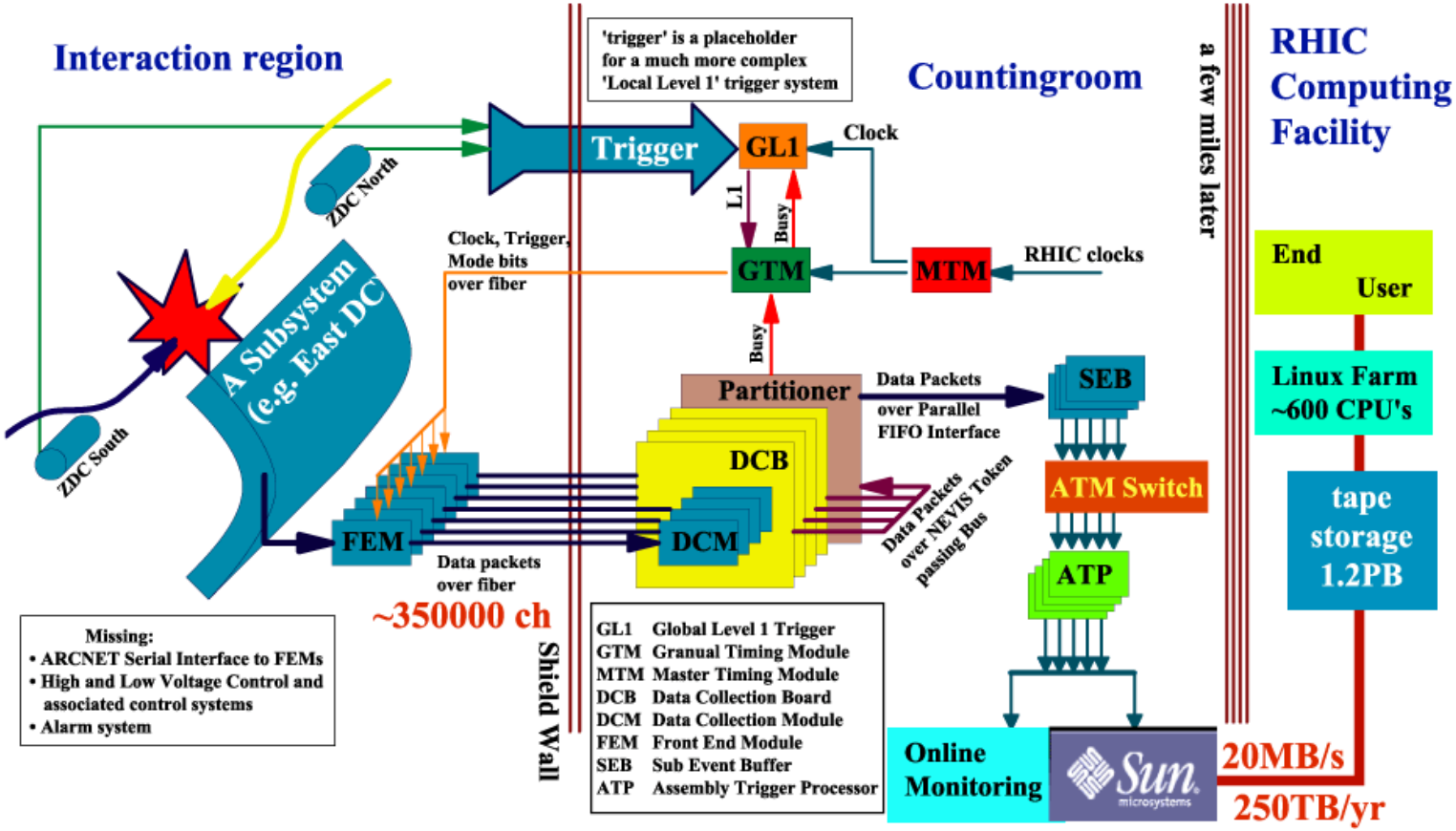
PHENIX South Muon Tracker





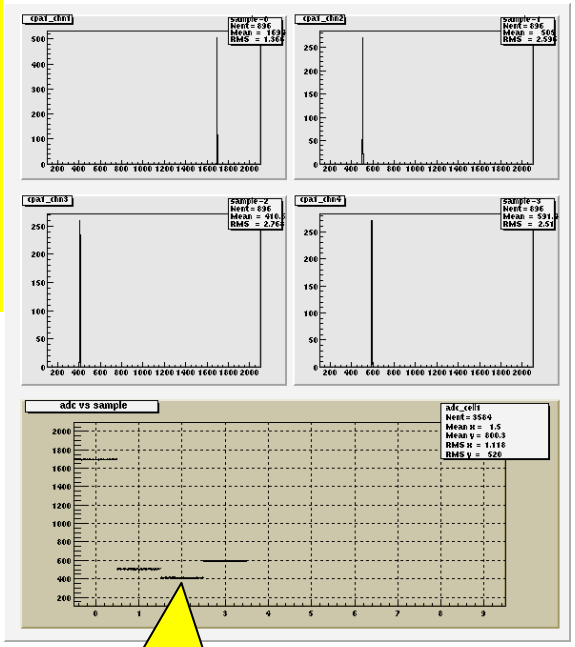
Interface to PHENIX DAQ

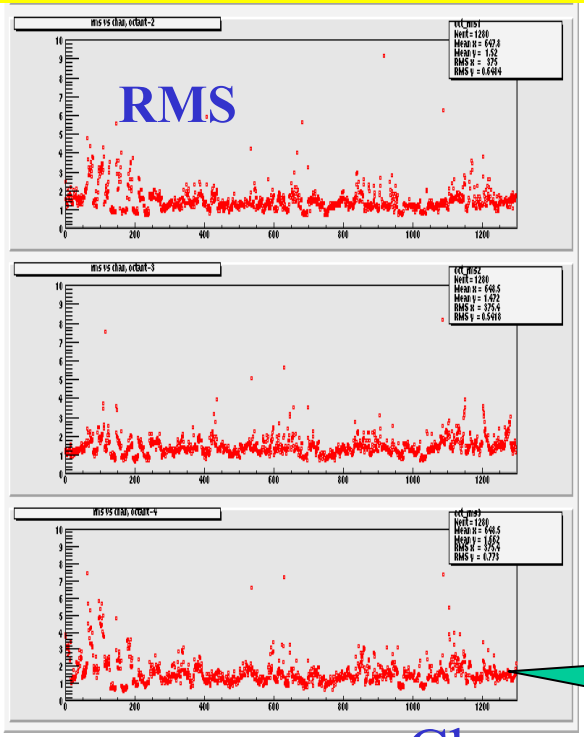
- Data readout and DAQ system



Detector Commissioning

- Electronics
- HV
- Noise Reduction
- Timing in Detector

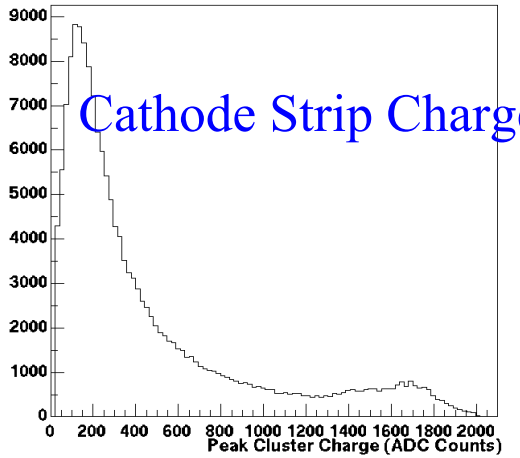




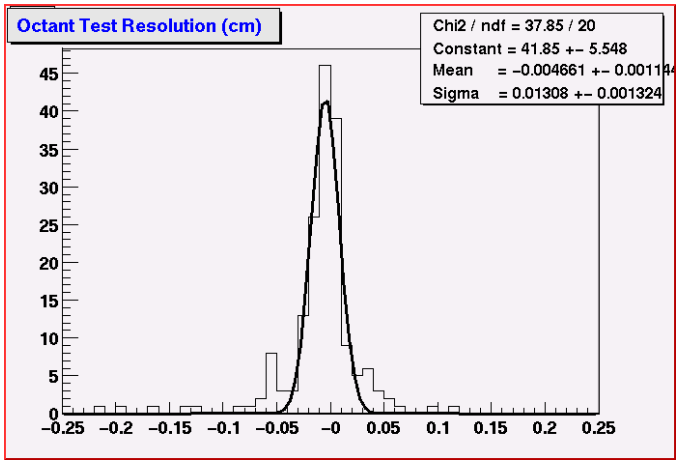
Channels

Good Timing

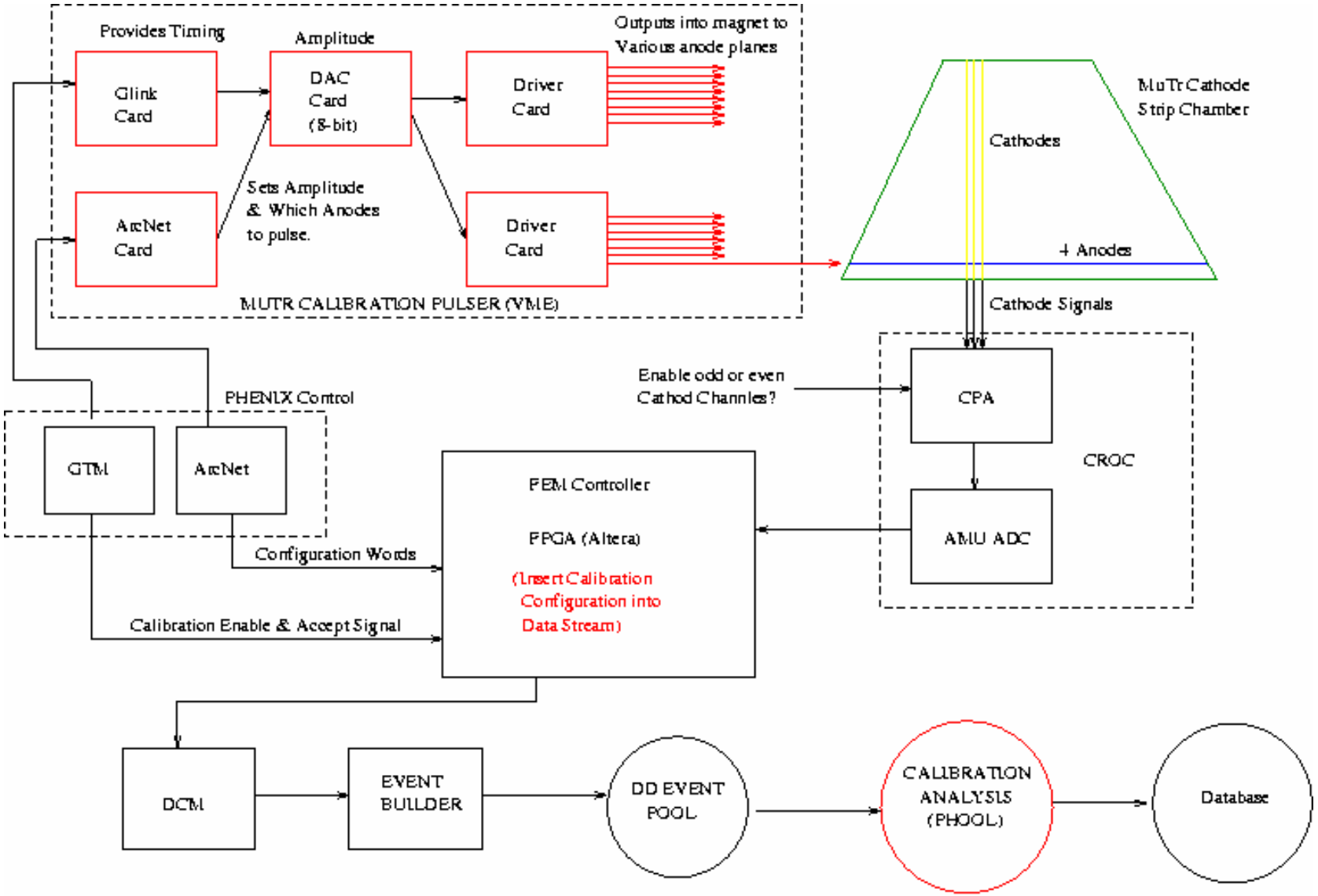
Low noise
rms ~ 2 ADCs



chamber resolution ~100um

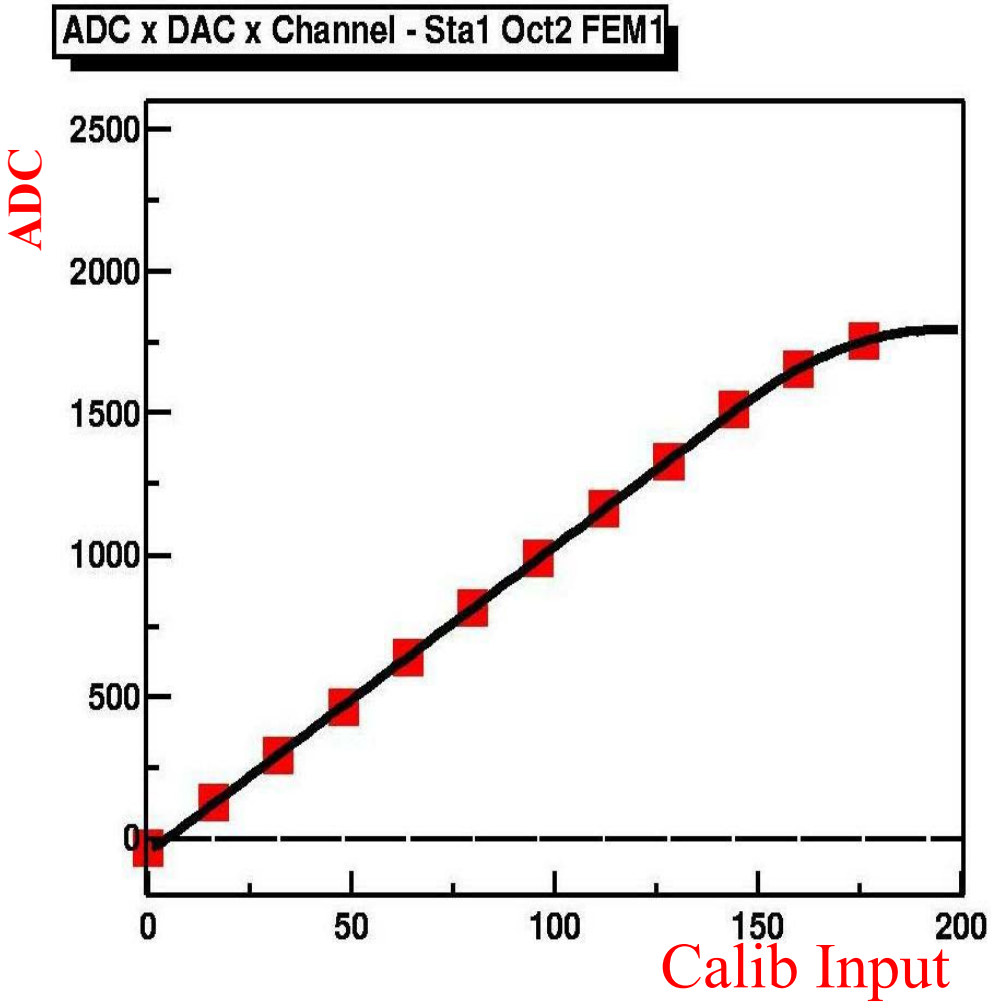


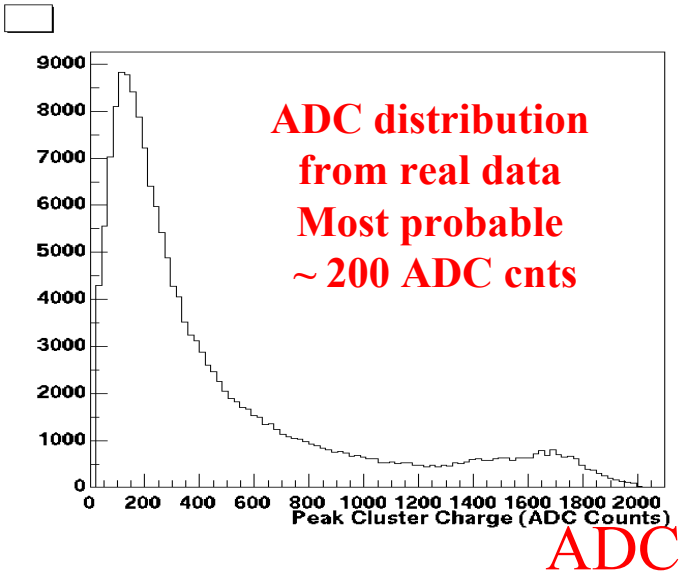
Muon Tracker Calibration System

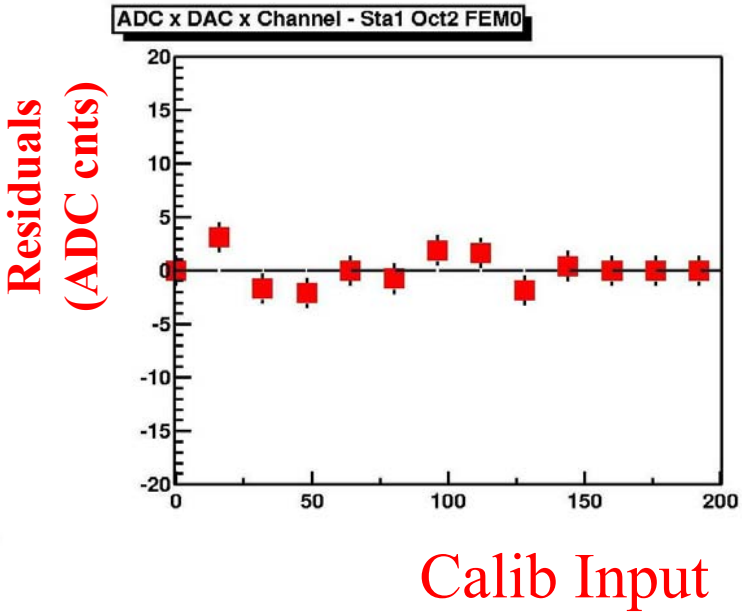


MuTr Calibration System - M. Leitch, P. McGaughey

Calibration



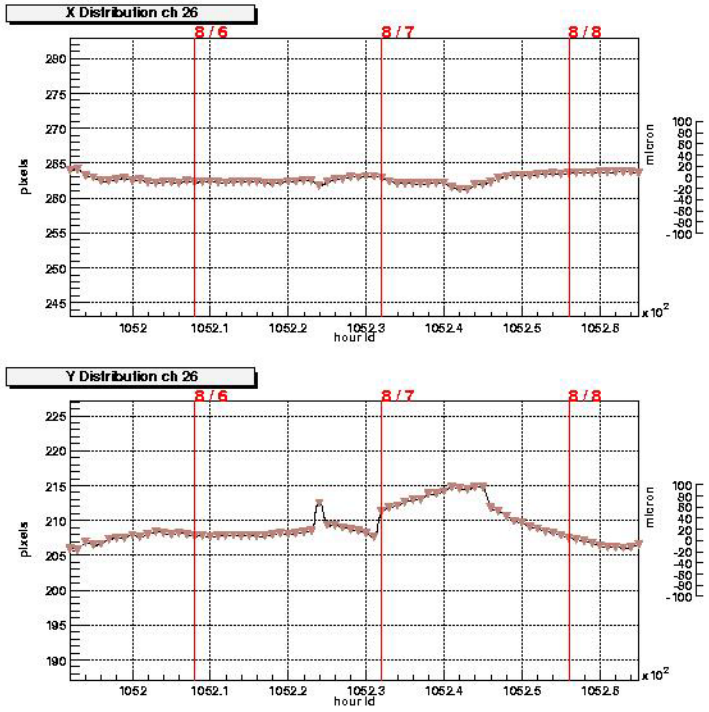


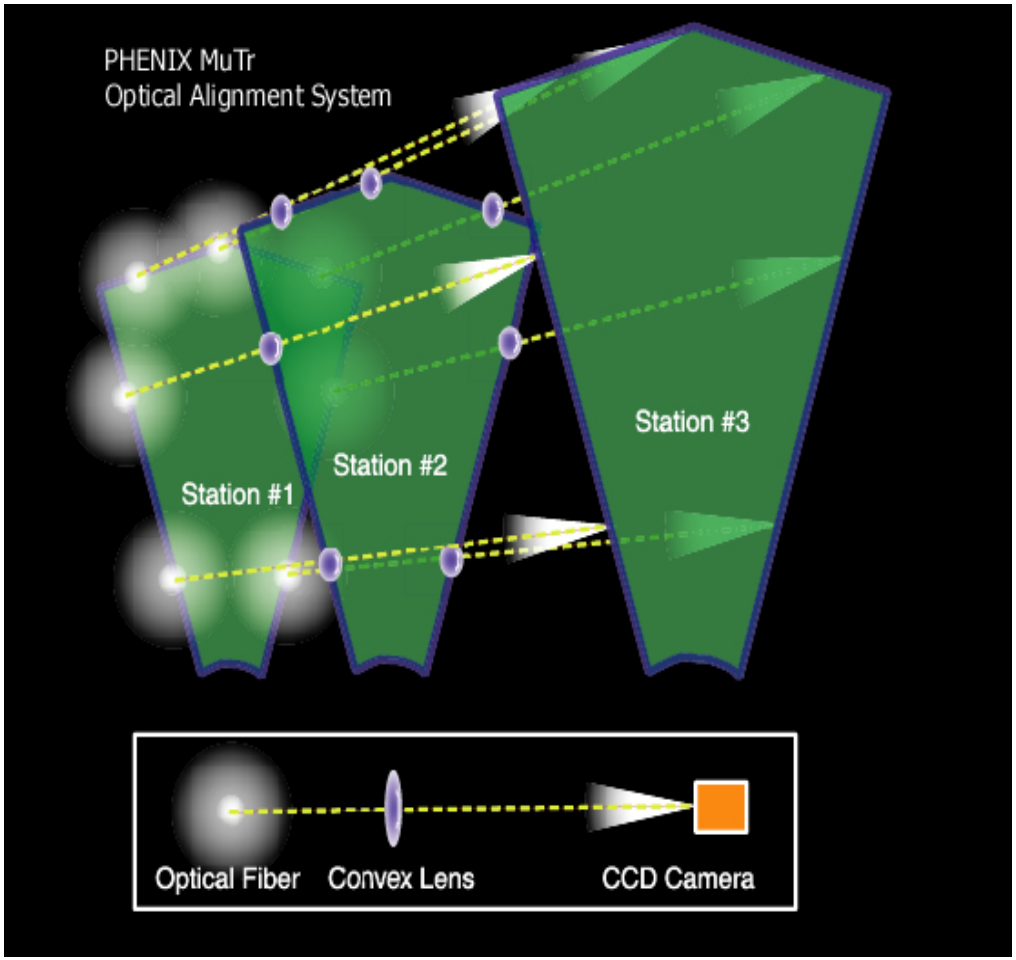


Chamber Alignment Monitoring

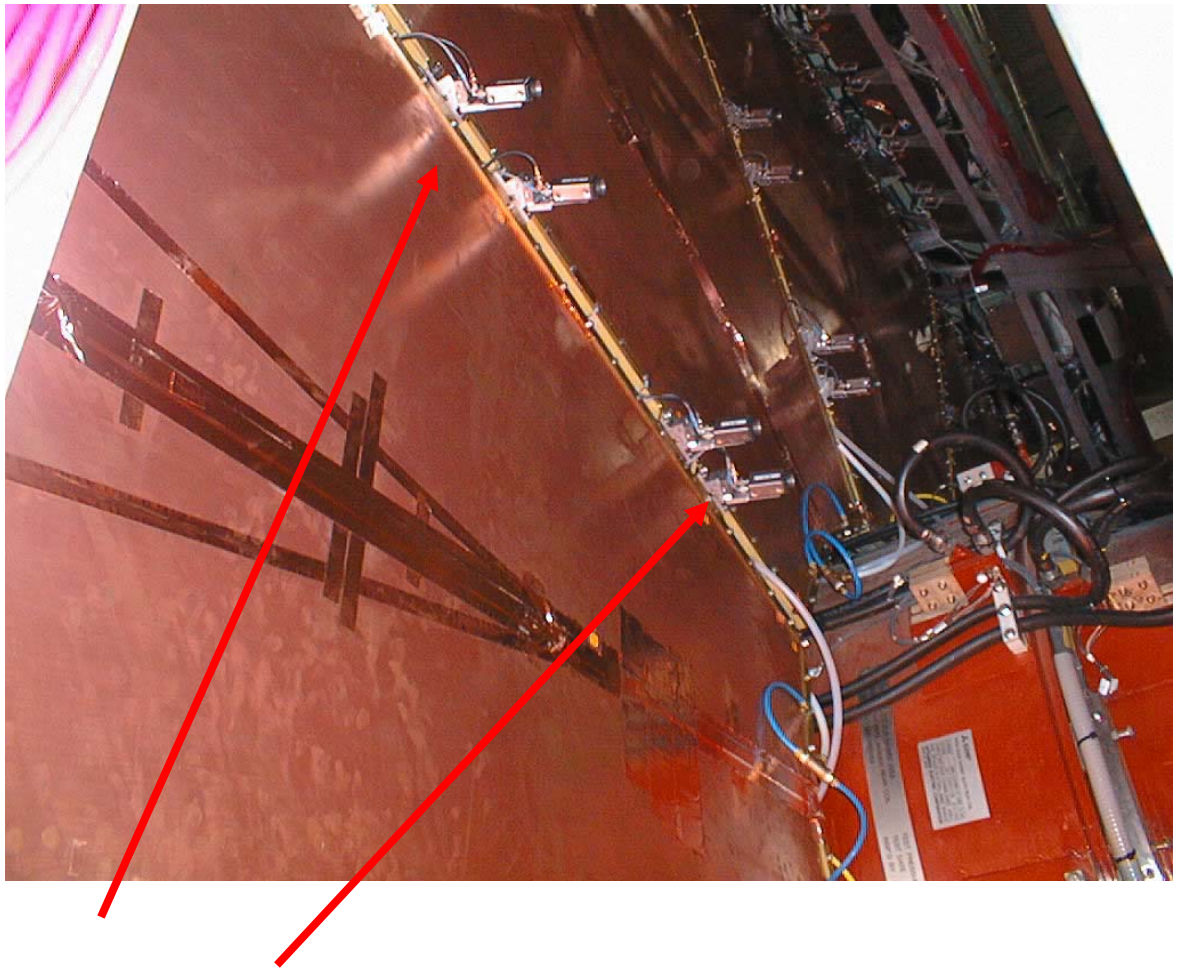
A good tracking resolution:

- low electronics noise
- stable gain
- geometry and alignment





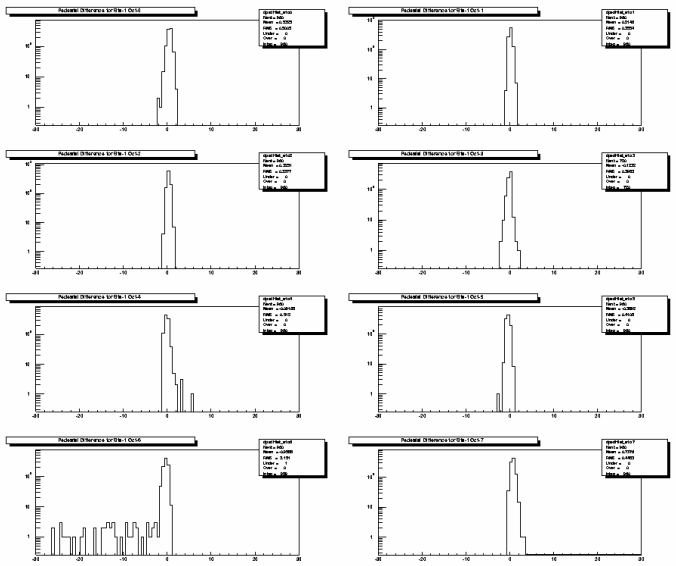
Optical Alignment System



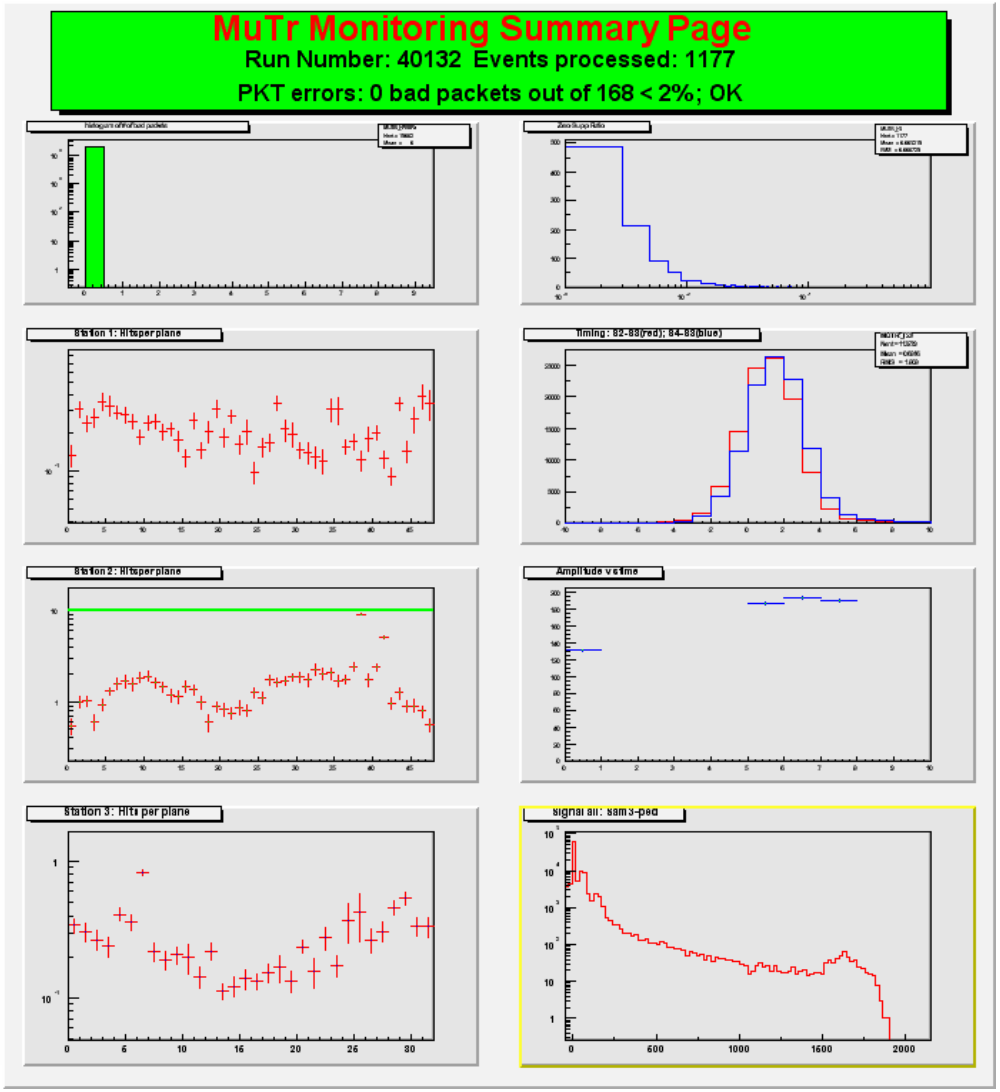
Cameras on station-3 chambers

Data QA: calib. & online monitor

- 4 Samples' relative timing
  - (1,6,7,8) beam-crossings
- DAQ Zero-Suppression (<5%)
  - (peak - pedestal)>3*rms
- Stable Pedestals and Gains
  - daily calibration



Pedestals from calibration data



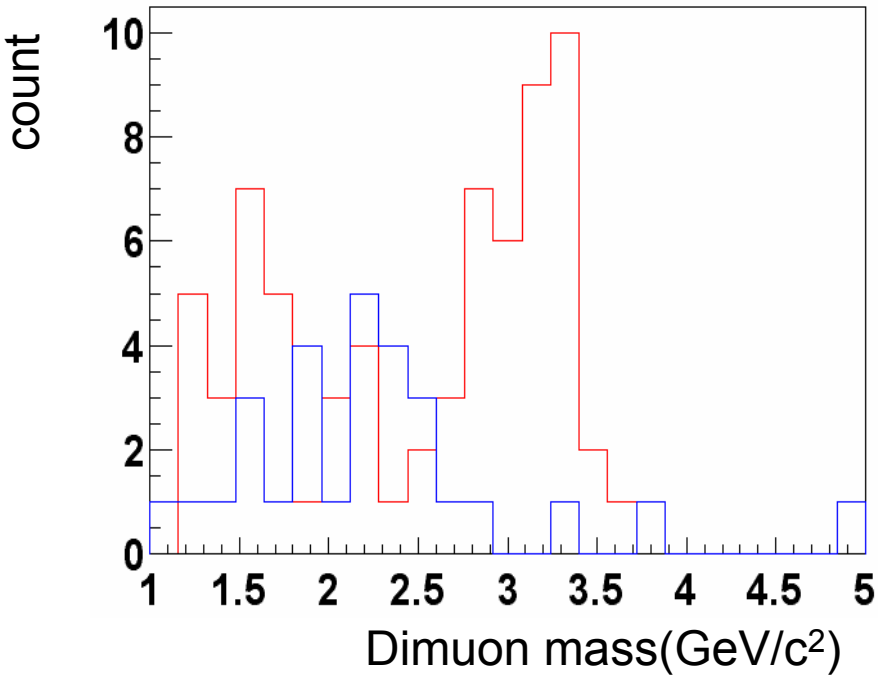
Dimuon Mass

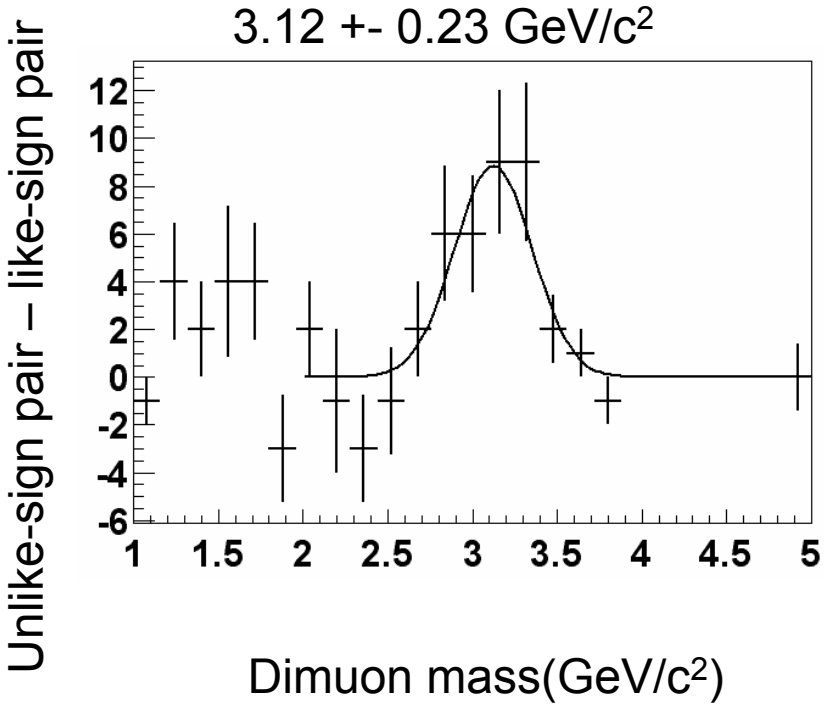
$$J/\psi(c\bar{c}) \rightarrow \mu^+\mu^-$$

$$M_{J/\psi} = 3.1GeV$$

Red: unlike-sign pair

Blue: like-sign pair





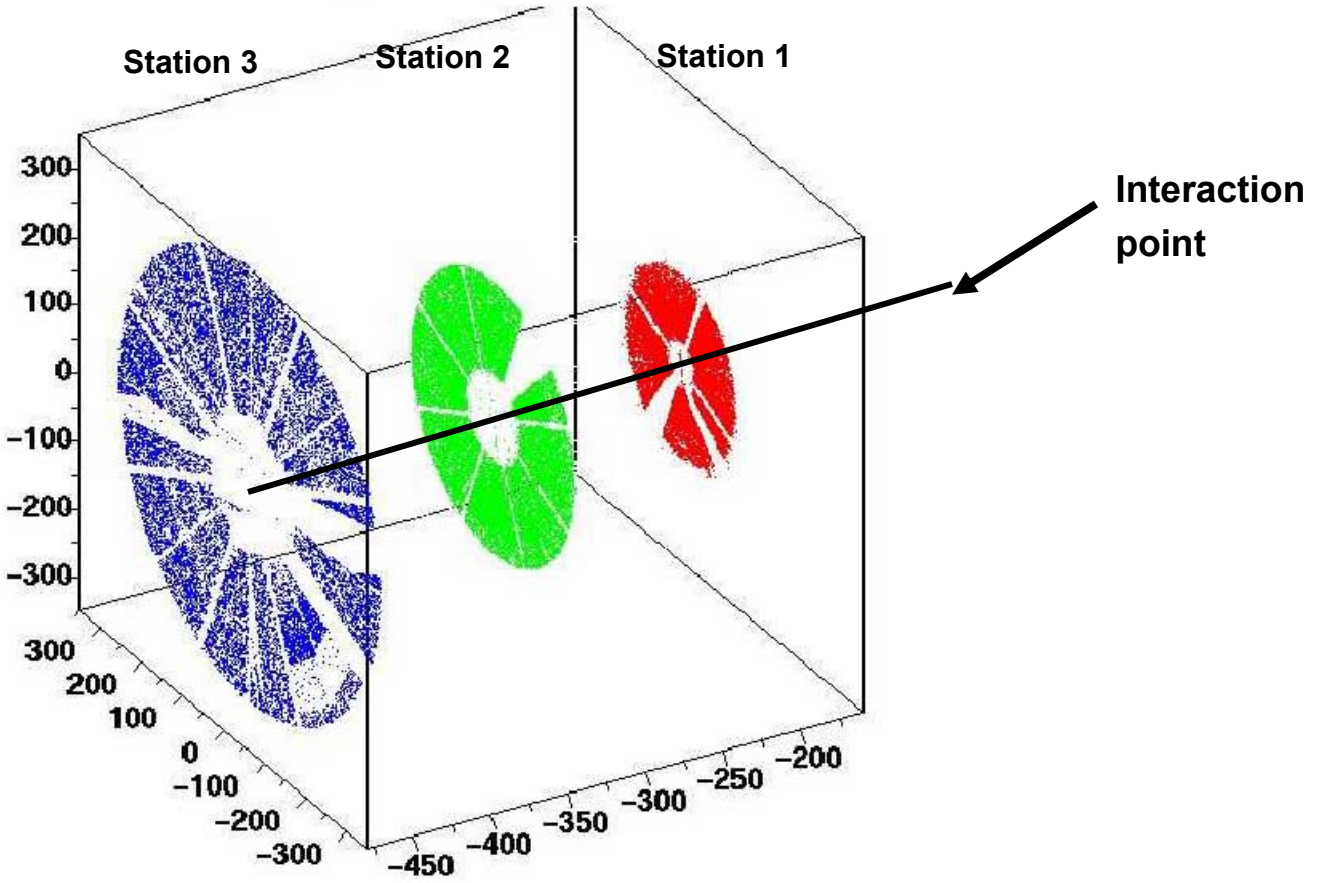
Significant enhancement of unlike-sign pair in the J/ψ mass region

- Peak (3123 +- 56 MeV/c²) is consistent with J/ψ mass
- Mass width (230 +- 40 MeV/c²) is consistent with expectation -> further improvement is expected

Current Status and Issues

- Worked as expected in Run-2
  - no major problems
  - luminosity was low
- G/Clink loss and readout problem
  - very sensitive to external disturbance --> replaced all bad cables
    - "dead" FEMs, ~5% -> loss acceptance
  - can't re-lock on the fly ->DAQ hung
- For higher luminosity (Run-4, 5, ...)
  - conversion time 53 uS is too long [40]
  - need to hold 5 events
  - new FPGA work in progress

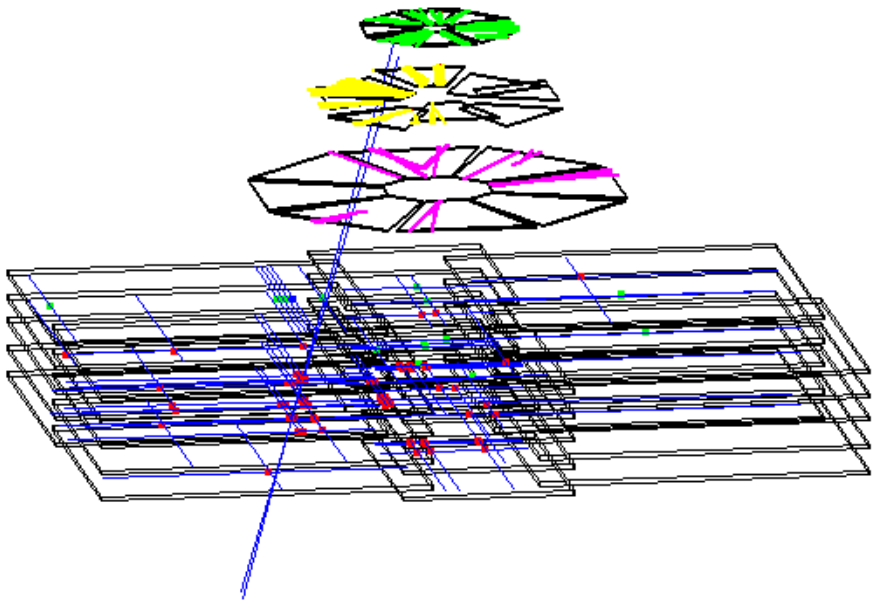
ACTIVE MUON TRACKER CHANNELS



Visualization of active regions of three tracking stations. Dead regions are due to problems with HV and front end modules during 2001-2 run. Majority of problems corrected for next run.

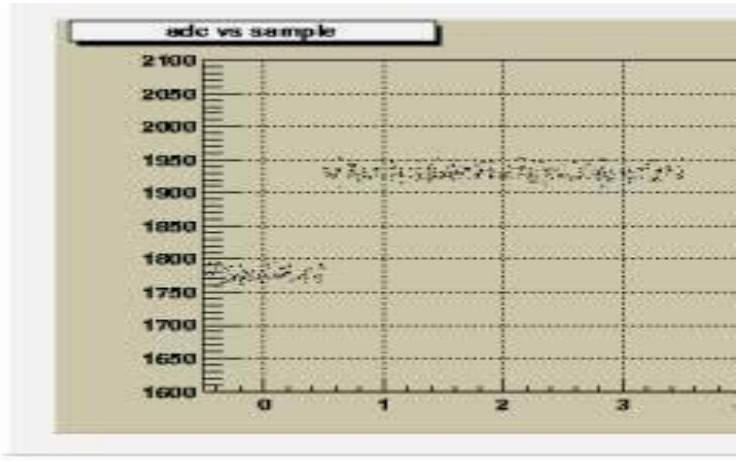
Summary and Outlook

First collision events were observed on 07/18/2001

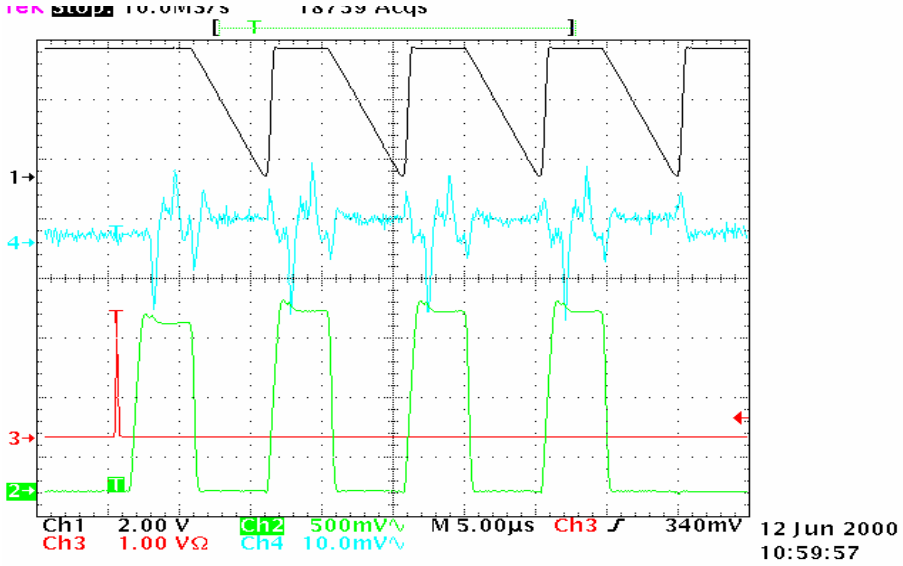


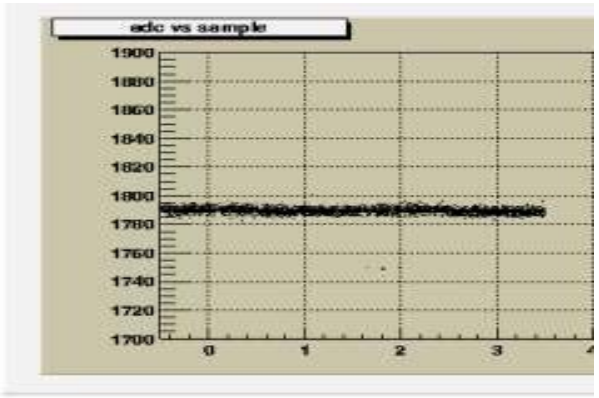
- Successfully installed and commissioned muon detector in the PHENIX
- **More work to improve FPGA code to handle:**
  - 5 events buffer(4)
  - 40uS conversion (53)

Conversion Time and Baseline Shift - AMUADC



- Problem is eliminated by adding 4 uS delay between conversion and data transfer (add 12+uS).
- Possible remedial actions
  - tune delay to minimize
  - use only three samples
  - relax requirement for five events





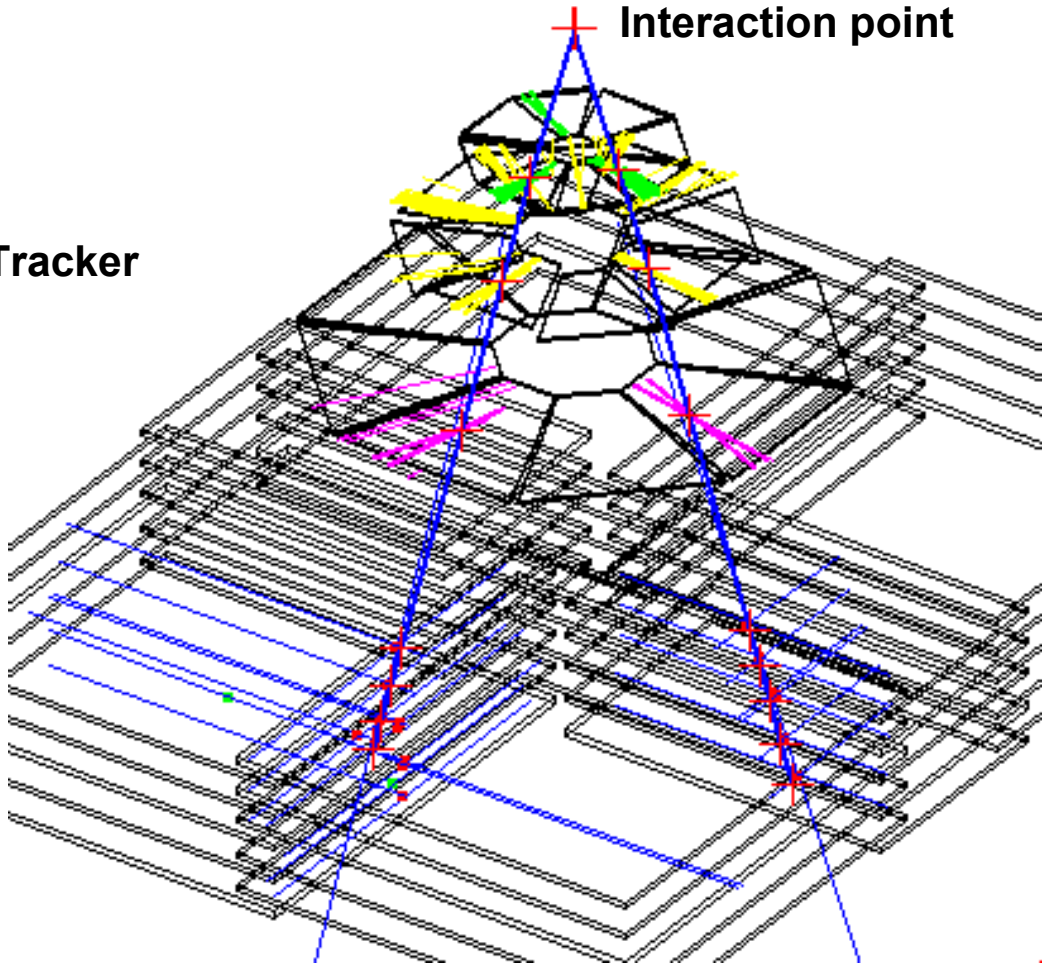
Disabled HV & FEMs

- HV
  - Station-1,2,3
    - 1825V:1850:1850
  - 72/304=23.7% disabled
- FEMs (total 168)
  - Sta-1: 4/40
  - Sta-2: 2/64
  - Sta-3: 2/64

  were disabled

  (loss ~15% acceptance)

DIMUON CANDIDATE



Dimuon candidate from p+p collision (rotated for clarity with beam line running vertically)