

# MuID for the PHENIX Experiment

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# Content

- Motivation
- MuID design for PHENIX
- MuID Readout and Trigger
- MuID Performance
- Summary

# Goals for the Phenix MuID

- Prime Goal is to detect deconfined state of nuclear matter - QGP and study its properties
- Search QGP via direct muons in final state
- Drell-Yann process
- Heavy quark production
- Z and W production

# Physics with the PHENIX Muon Arms

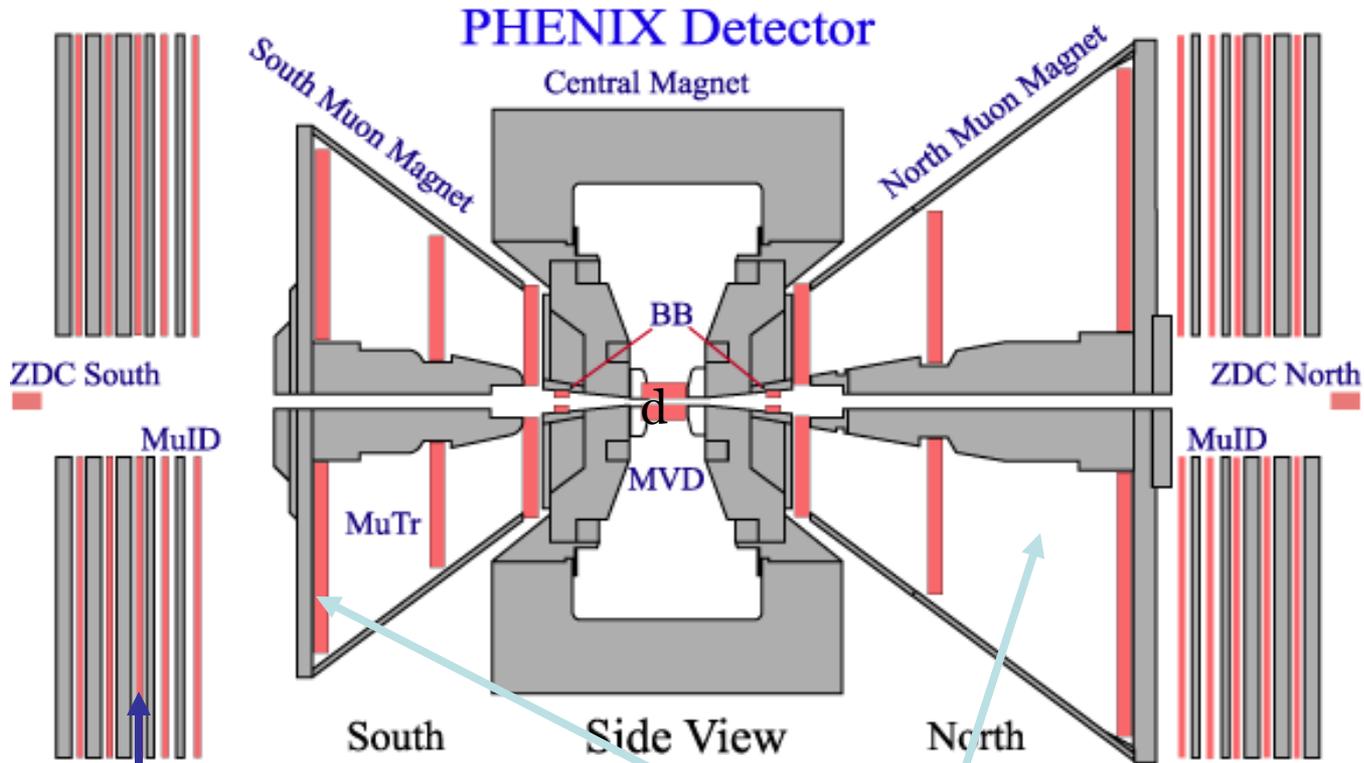
- QGP signals in Au+Au collisions
  - J/ψ suppression
  - Charm enhancement

) ← μμ  
← μ, eμ
- Proton spin structure with polarized p+p collisions
  - Double-longitudinal spin asymmetry for J/ψ and open heavy flavor production →  $\Delta G(x)$
  - Parity violating spin asymmetry for W boson production →  $\Delta q(x)$

# PHENIX MUON ARMS

North muon identifier (MuID)

Commisioned Summer 2002



South muon identifier (MuID)

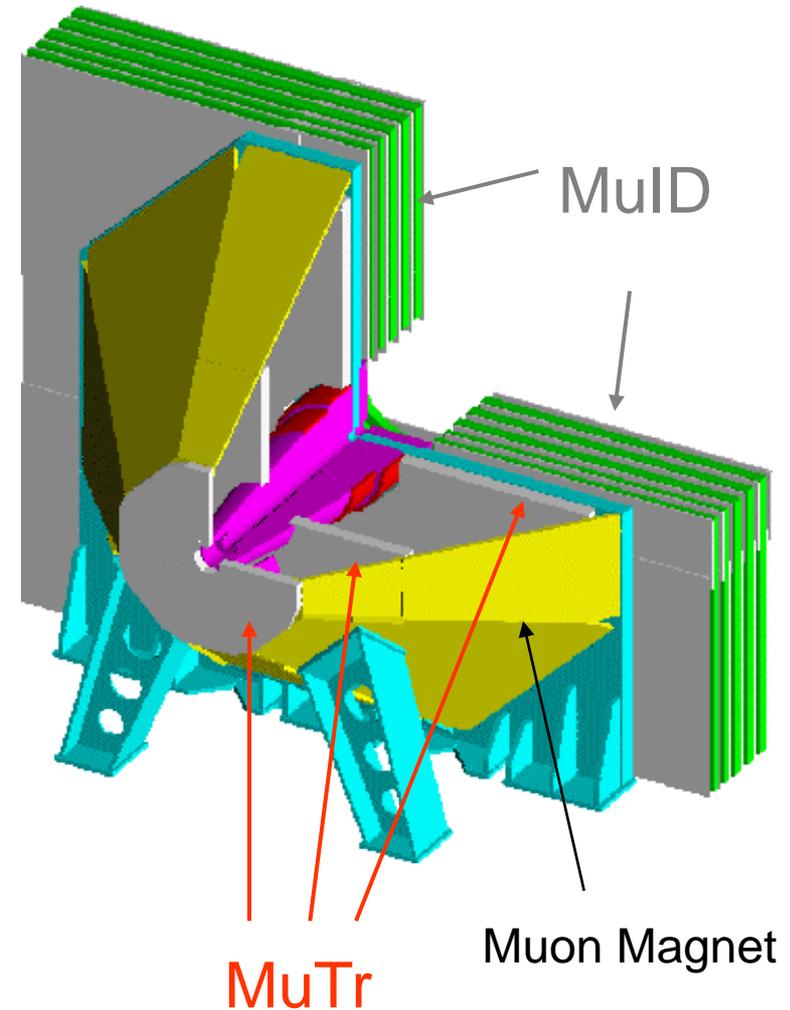
5 gaps per arm filled with planes of transversely oriented Iarocci tubes

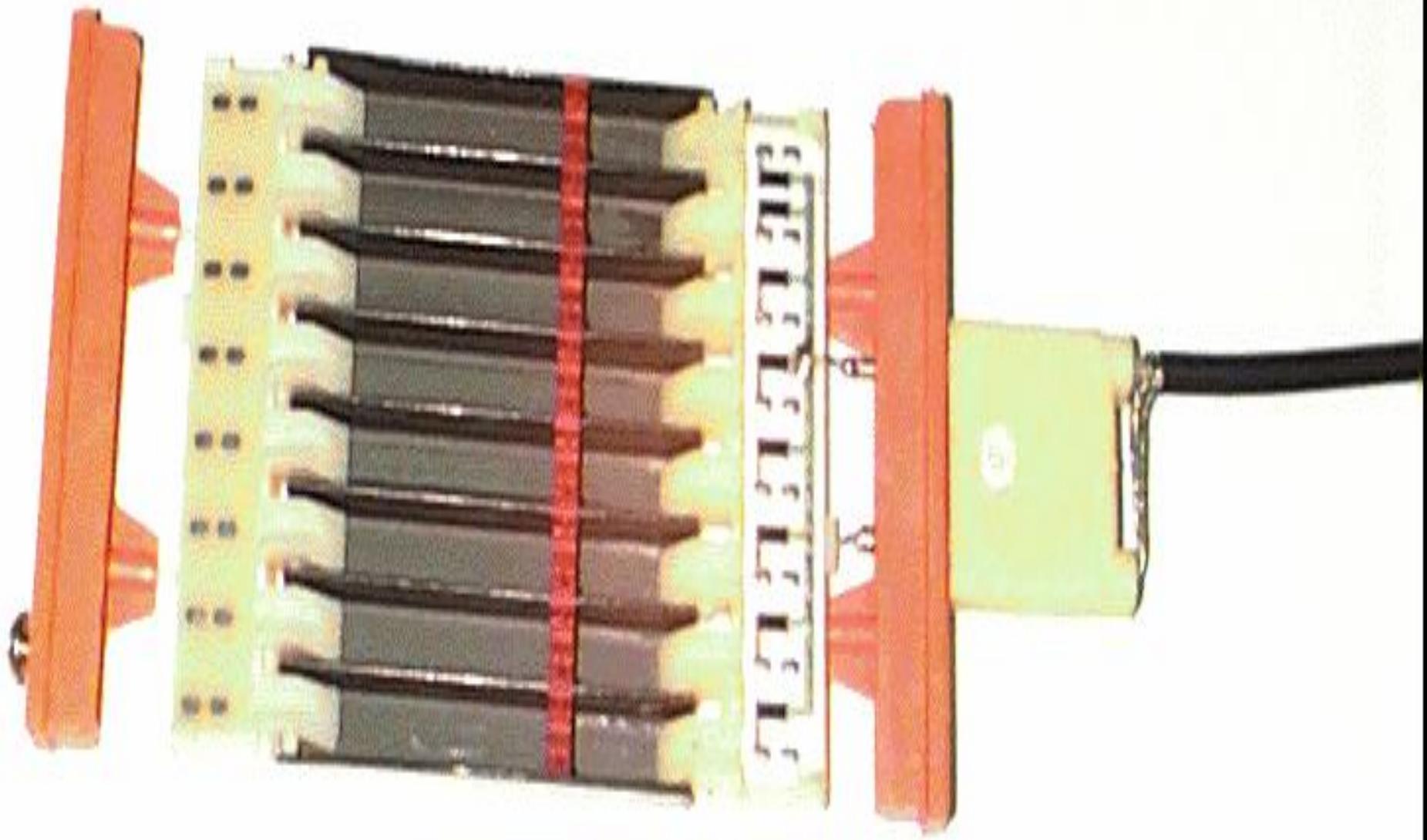
South/North muon trackers (MuTR)

3 octagonal stations of cathode strip chambers per arm

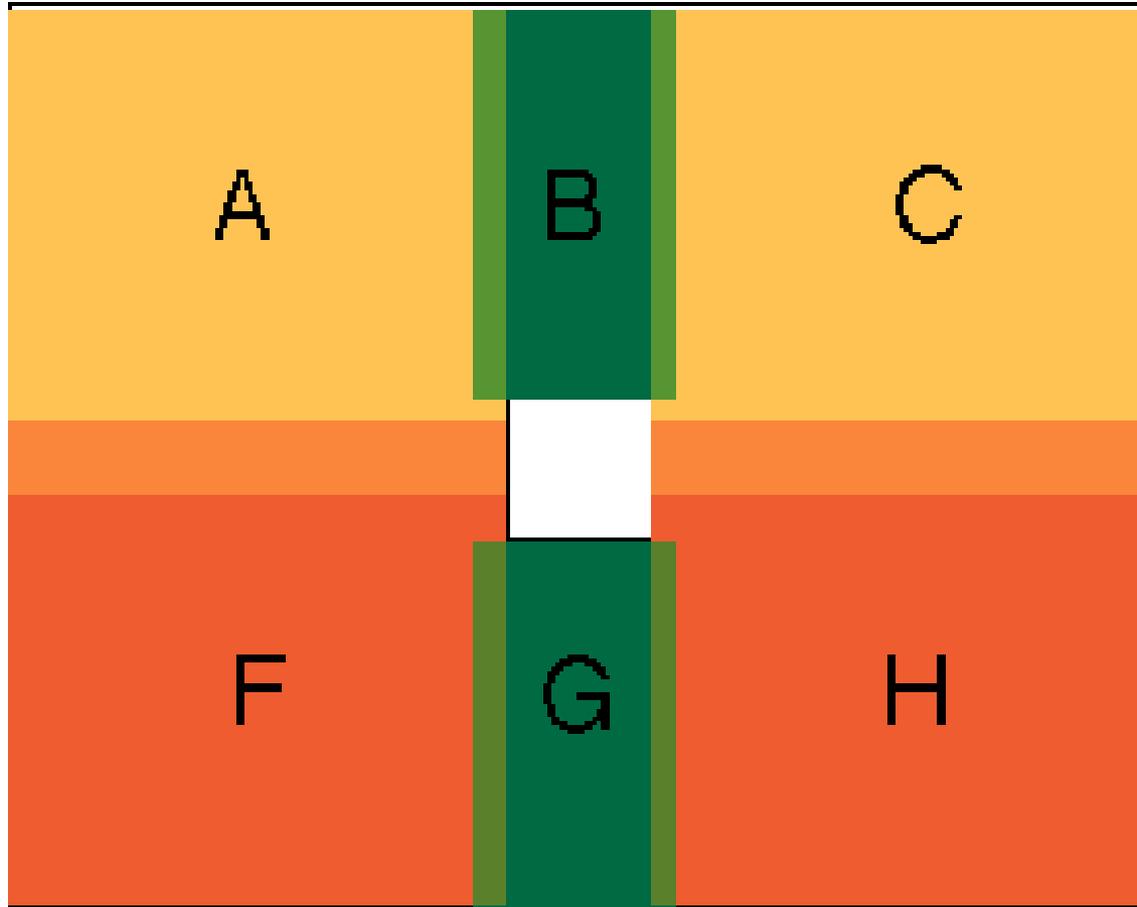
# PHENIX Muon Arm

- Detect muons with  $p_{tot} > 2\text{GeV}/c$ ,  
 $1.2 < \eta < 2.2$  (South Arm)  
 $1.2 < \eta < 2.4$  (North Arm)
- Pre-hadron-rejection with Central Magnet steel ( $\lambda_{int} \sim 5$ )
- **Muon Tracking Chamber (MuTr)**
  - Measure momentum of muons with cathode-readout strip chambers at 3 stations inside Muon Magnet
- Muon Identifier (MuID)
  - $\pi/\mu$  separation with 5-layer sandwich of chambers (larocci tubes) and steel
  - Trigger muons
- Successfully operated first time during Run-2

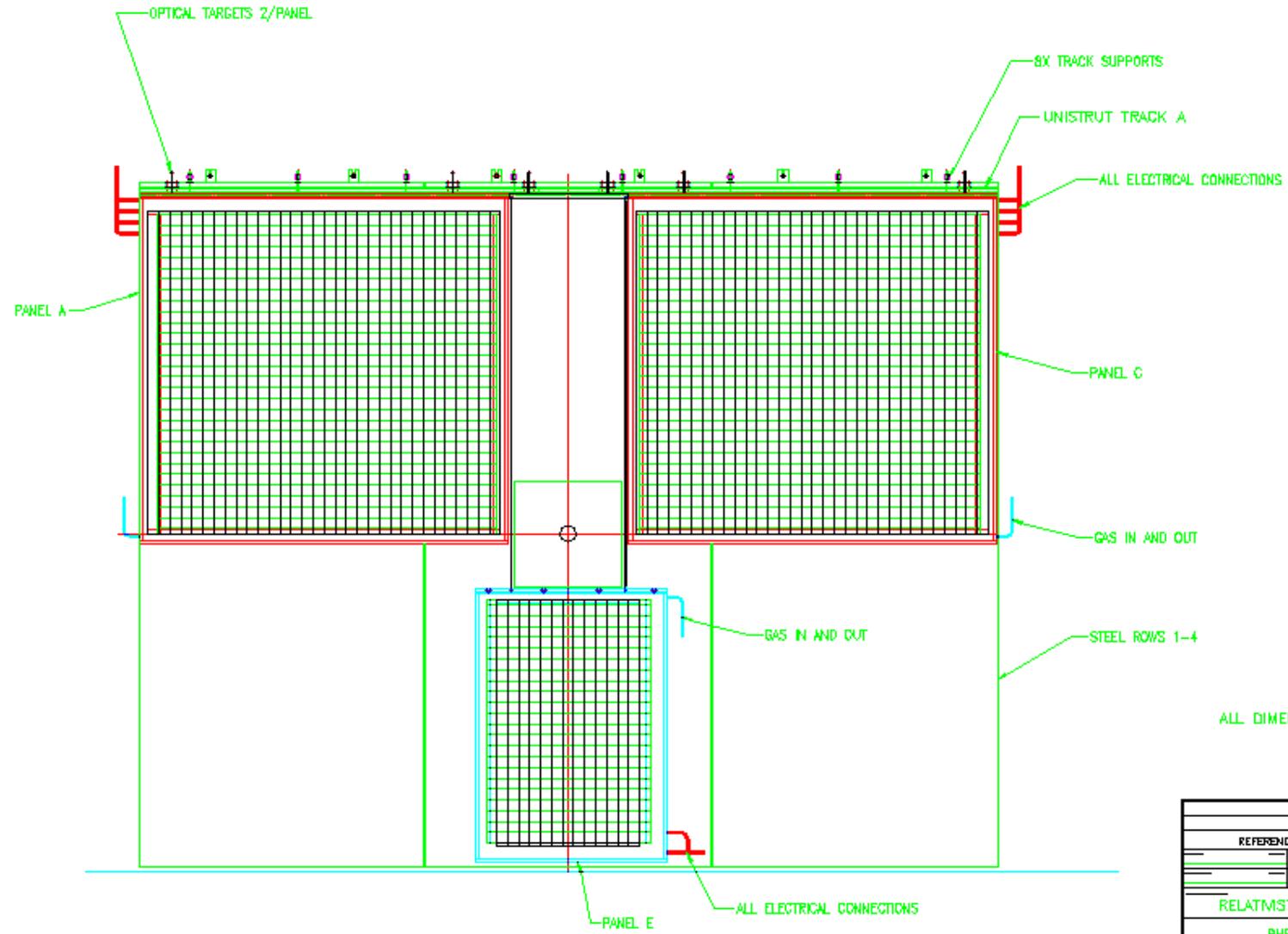




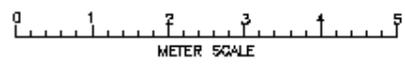
← 12500 mm →



↑ 9800 mm ↓



ALL DIMENSIONS MILLIMETERS



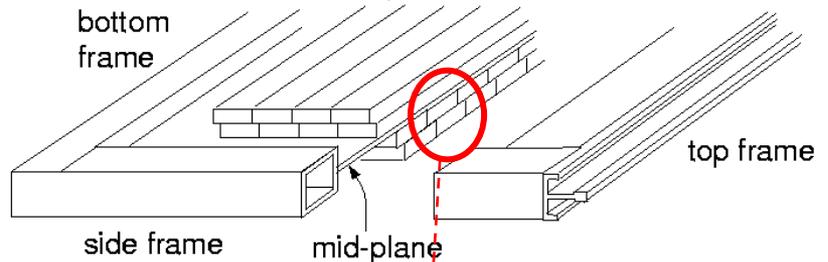
REFERENCE DRAWINGS		DWG NO.
RELATIVISTIC HEAVY ION COLLIDER		
PHENIX MUON IDENTIFIER		
TRACK A WITH PANELS A, C & E SOUTH ARM		
OAK RIDGE NATIONAL LABORATORY		
1 = 50	M-0212-0017	0

# MuID Structure

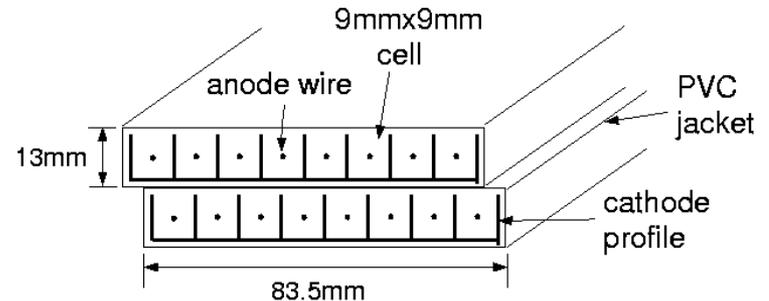
## Muon Identifier

5 gaps per arm filled with planes of transversely oriented plastic proportional (Iarocci) tubes

- 4 large panels and 2 small panels in one layer (gap)
- In a panel, Iarocci tubes with 2.5~5.6m length and 8.4cm width run both horizontally and vertically
- 6340 tubes ( 3170 channels ) / Arm



Cross section of the MuID panel

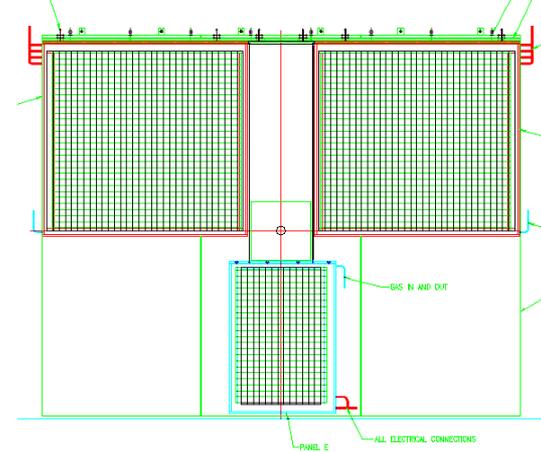


Cross section of the plastic tube(2-pack)

- One channel consists of two staggered tubes for better efficiency and faster drift time
- Those two layers are in different HV and gas chains to minimize dead channels



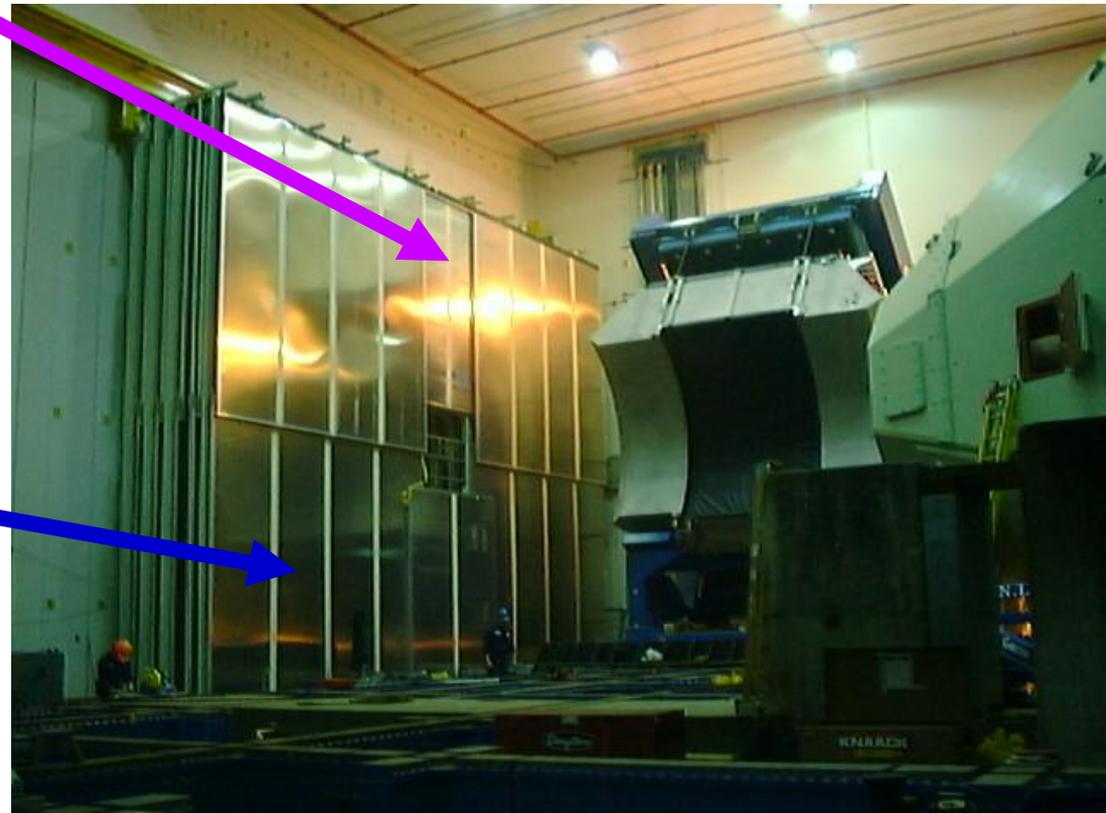
Small panel



## The South Muon Identifier



Large panel

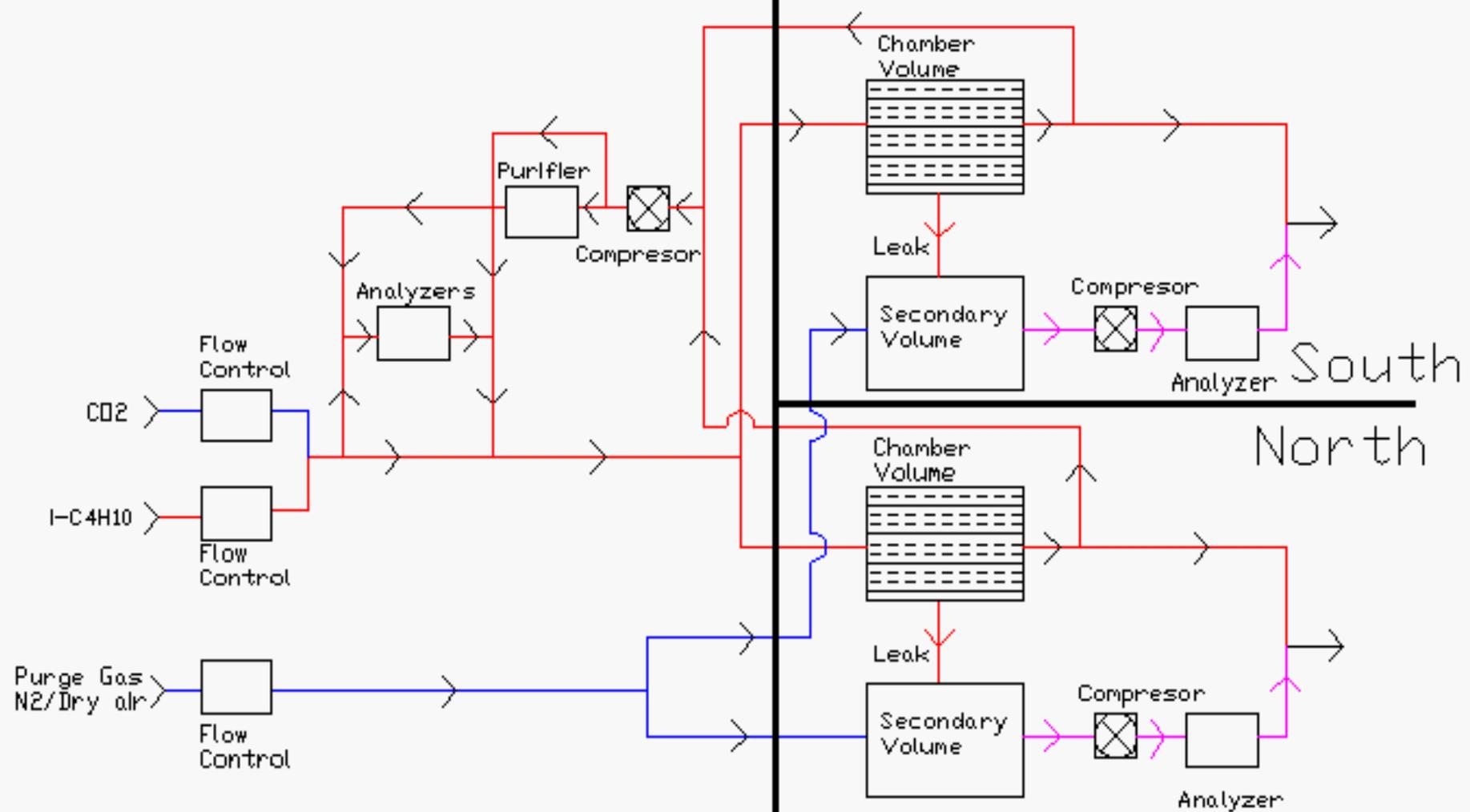


- Gas system

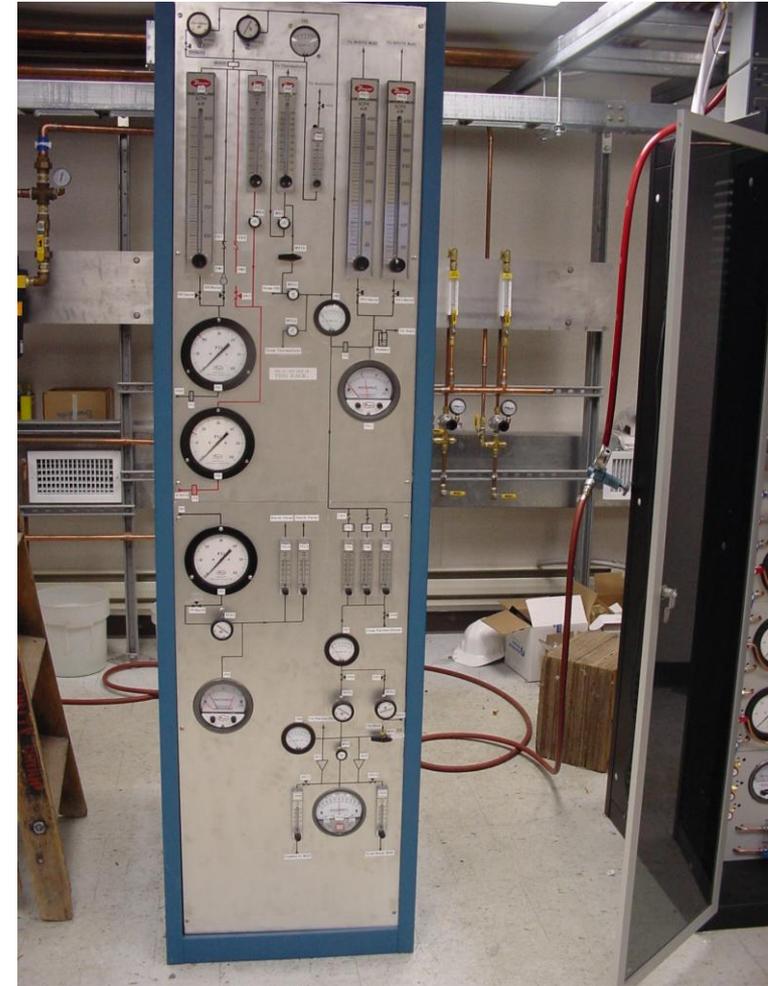
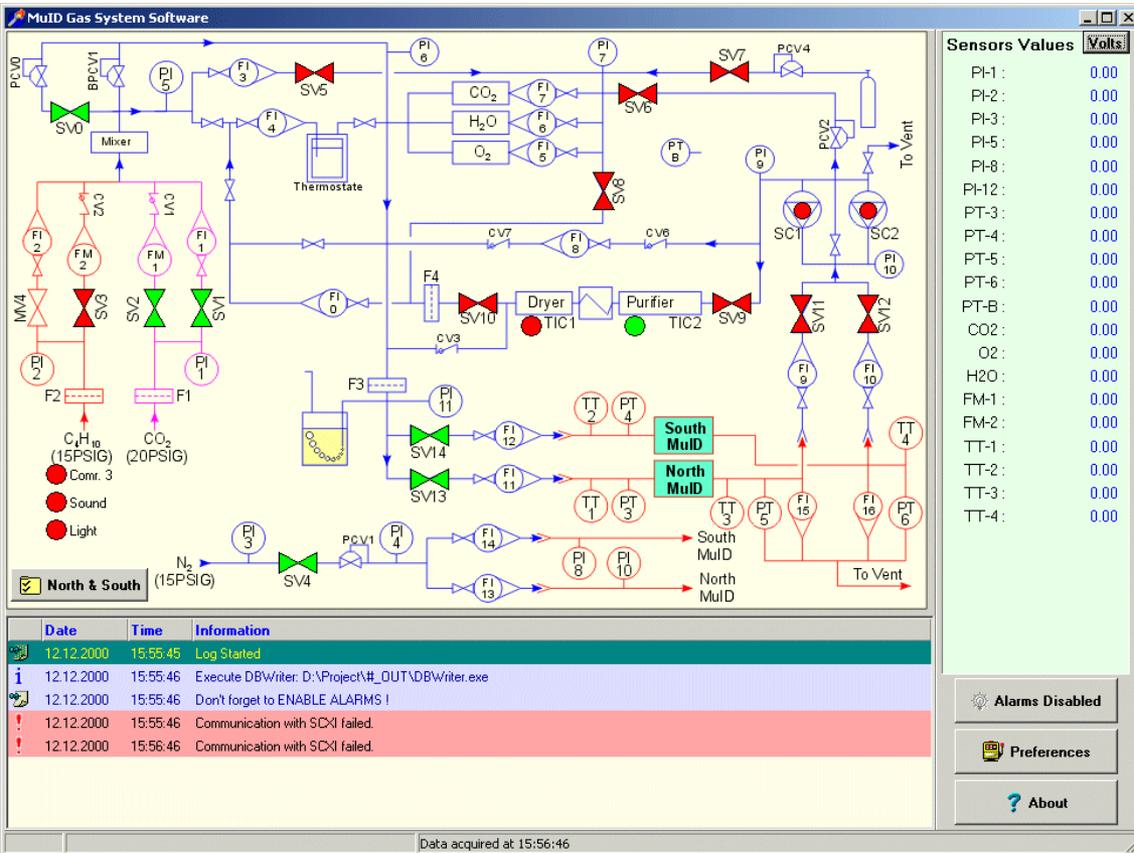
- Delivers and monitors one exchange (50 m<sup>3</sup>) per day of operational gas to tubes and nitrogen to the panel envelopes
- Non-flammable mixture of 92% CO<sub>2</sub> plus 8% Isobutane
- Uniform flow to all panels
- Very stable, trouble-free operation.  
Computer monitored with routine checks by shift crew.
- Isobutane transport in cold weather difficult a few nights. Now have heated sheds to hold bottles located closer.

Mixing House

Interaction Region



# GAS System



# MuID HV STATUS

- High Voltage System
  - Generally very good performance.
  - Serial communication now working.
  - All modules have repaired and installed.





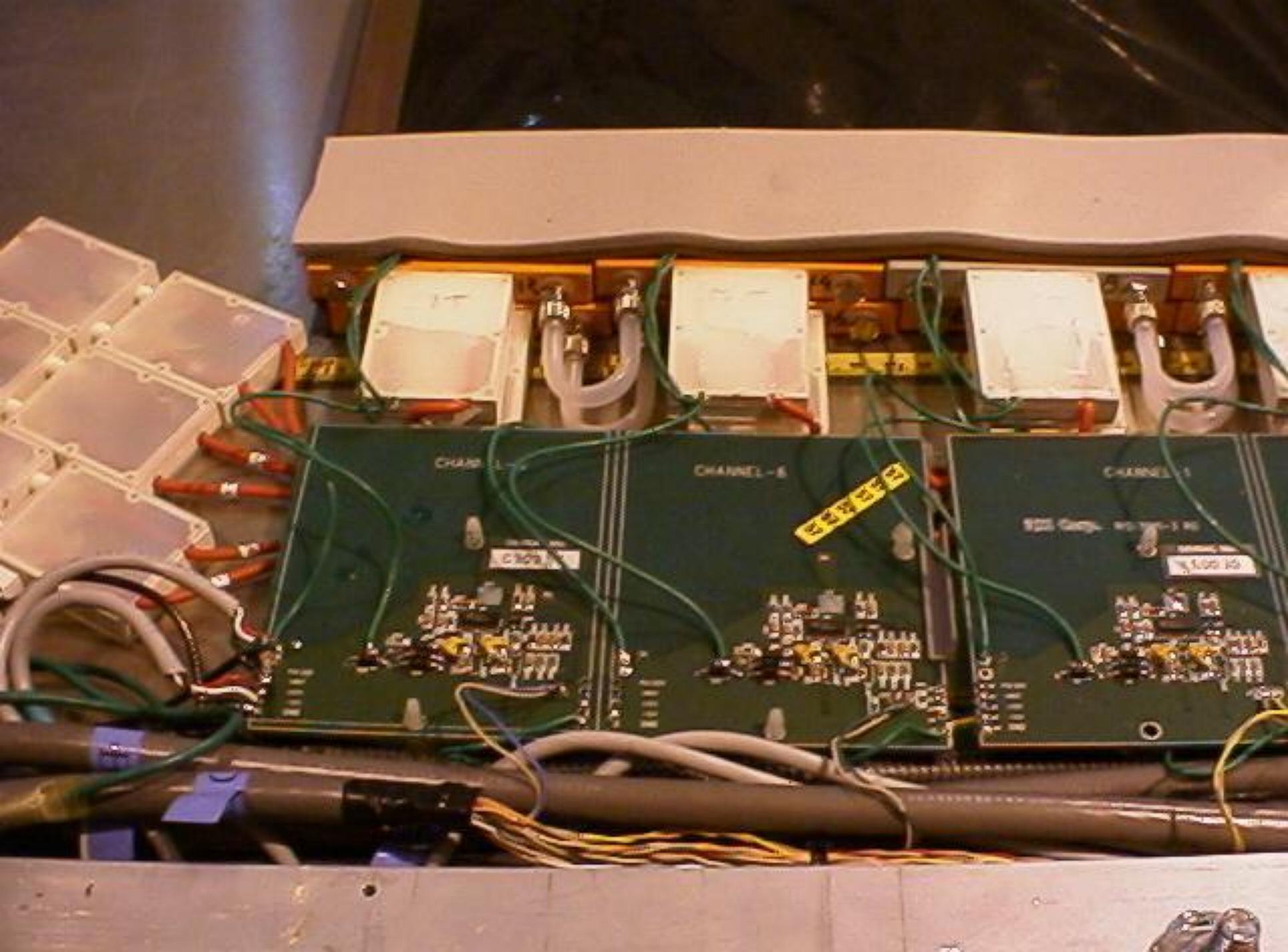
File Edit View Insert Format Tools Communicator

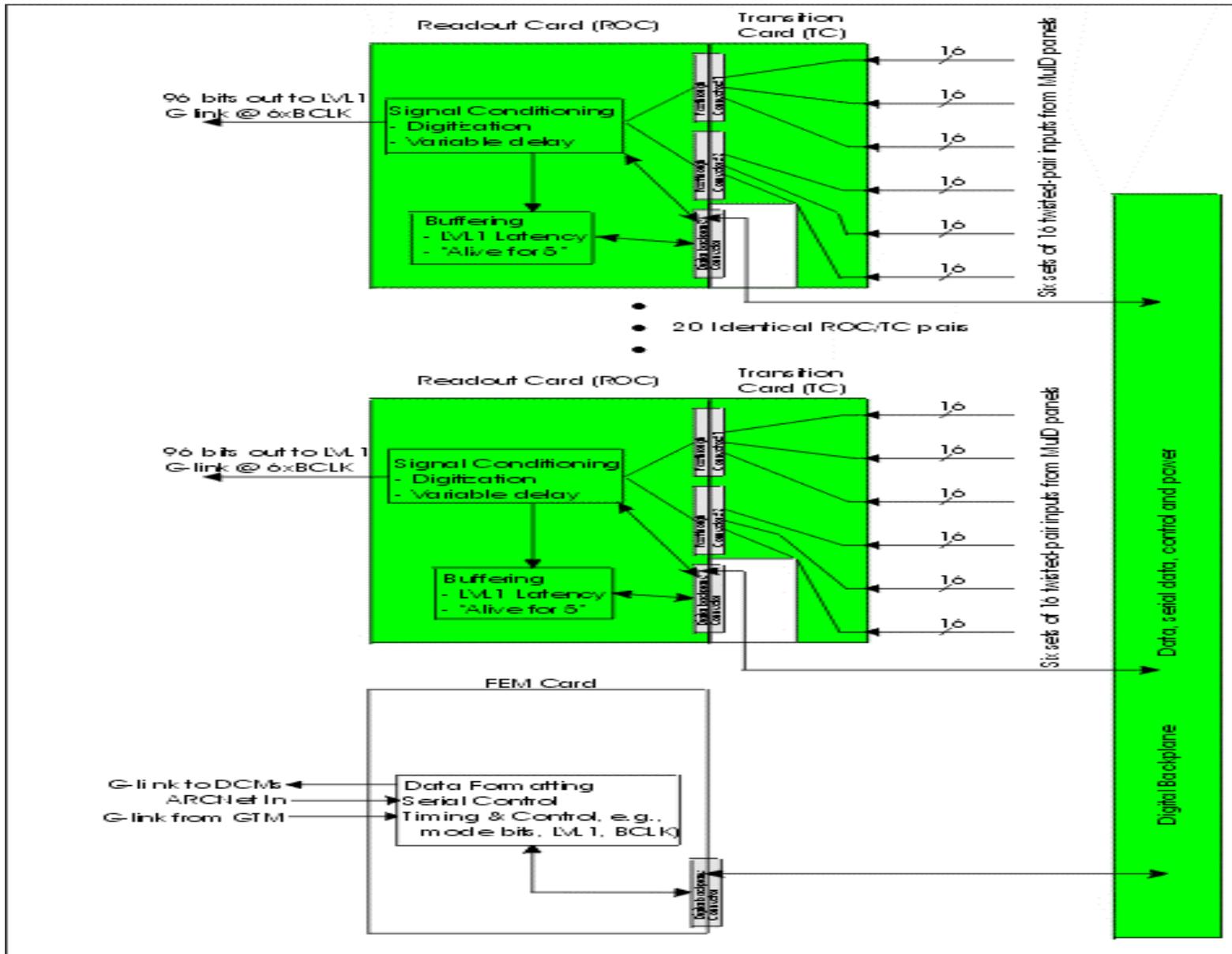
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Normal Variable Width +0

This and the previous entry (for the North) were taken just before MUID HV was shutdown down to the high currents (per Matthias). The DAQ was down anyway, so this didn't impact physics.

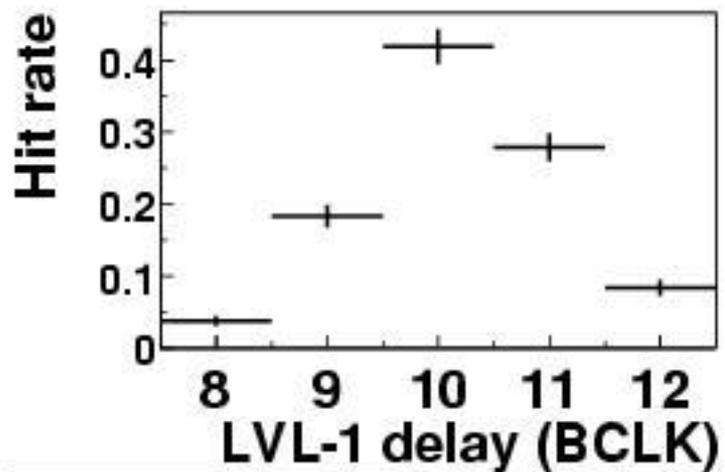
South MUID HV Monitor																										
ch1	ch2	Voltage/Current [uA]		Operational	High Current	Voltage Low/Off	Trip	Warning	Off	Disable	2/6	Main Frame Switch	96	97	98	Shift Mode										
ch3	ch4										0:32.11															
ch5	ch6															GP0_H	GP0_V	GP1_H	GP1_V	GP2_H	GP2_V	GP3_H	GP3_V	GP4_H	GP4_V	
PA0	4301	4302	4300	4301	4301	4300	4300	4301	4300	4300		4301	4301	4300	4302	4301	4300	4303	4300							
	0.70	2.18	0.41	0.39	0.56	5.40	0.19	0.18	0.68	0.59		0.14	1.14	1.18	0.26	0.14	2.33	2.21	0.32	0.24						
	4300	4301	4300	4300	4301	4001	4301	4300		4300	4301	4301	4301	4301	4301	4301	4301	4300	4301	4301	4301	4301	4301	4301	4301	4301
PA1	4300	4300	4301	4300	4300	4300	4300	4299	4301	4301	4301	4300	4302	4301	4300		4300	4302	4300	4300						
	0.38	0.38	0.87	0.76	0.22	0.21	0.71	16.07	0.21	0.27	0.75	0.74	0.38	0.33	1.52	1.34		0.67	4300	4300						
	0.54	0.55	0.66	0.53	0.18	0.05	0.53	0.53		0.52	0.59	0.55	0.99	5.09	1.05	1.03		2.29	2.21	2.12	10.18					
PA2	4301	4301	4301	4301	4301	4300	4301	4301	4300	4300	4301	4300	4300	4302	4301	4300	4302	4300	4302	4300	4300					
	0.66	0.50	0.80	0.67	0.51	0.55	0.69	0.61	0.60	0.59	0.41	0.69	1.02	1.00	1.20	1.14		1.83	1.88	2.39	2.27					
	4301	4302			4301	4300			4300	4301			4301	4303				4301	4300							
PA3	0.29	0.21			0.14	0.21			0.16	0.16			0.30	0.31				0.68	0.68							
	4300	4300	4300	4300	4299	4301	4300	4300	4301	4300	4299	4298	4301	4300	4300	4301	4302	4300	4300	4300	4299	4298	4301	4300	4300	4299
	0.59	0.53	0.37	0.35	0.38	0.36	0.20	0.17	0.37	0.56	0.18	0.18	0.61	0.62	0.25	0.29		1.33	1.38	0.52	0.50					
PA4	4302	4300	4302	4300	4301	4299	4301	4298	4302	4302	4302	4300	4301	4301	4301	4302	4302	4300	4300	4300	4302	4302	4300	4302	4300	4302
	0.47	0.49	0.53	0.54	0.38	0.34	0.37	0.35	0.45	0.40	0.35	0.34	0.68	0.65	0.69	0.69		0.03	0.04	0.32	0.30	0.03	0.04	0.32	0.30	
	4301	4299	4300	4302	4300	4300	4300	4300	4300	4300	4301	4301	4299	4300	4300	4302	4302	4300	4301	4301	4301	4299	4300	4300	4300	4301
PA5	0.39	0.33	0.77	0.67	0.19	0.18	0.55	0.50	0.21	0.21	0.58	0.52	0.33	0.28	0.90	0.91		1.01	3.16	2.56	1.87					
	4301	4300	4300	4301	4300	4301	4301	4301	4299	4301	4302	4301	4301	4301	4300	4301	4301	4301	4301	4299	4300	4301	4299	4300	4300	4299
	0.31	0.26	0.31	0.28	0.11	0.06	0.07	0.08	0.04	0.01	0.10	0.12	0.06	0.04	0.12	0.14		0.07	0.07	0.25	0.20					
PA6	4301	4301	4298	4301	4301	4301	4301	4300	4301	4300	4298	4300	4300	4301	4301	4301	4301	4301	4300	4300	4300	4300	4301	4301	4301	4300
	0.43	0.02	0.46	0.36	0.18	9.51	0.18	0.18	0.10	0.23	0.19	0.12	0.17	10.48	0.24	0.15		0.32	8.81	0.55	0.55					
	4299	4300	4300	4300	4300	4301	4300	4302	4300	4300	4300	4300	4301	4300	4300	4301	4301	4299	4300	4300	4300	4301	4300	4300	4300	4300
PA7	0.54	0.55	0.58	0.59	0.32	0.33	0.41	0.33	0.34	0.32	0.31	0.26	0.47	0.42	0.36	0.34		1.03	1.03	0.62	0.58					
	4301	4300	4301	4301	4301	4300	4100	4301	4300	4300	4300	4300	4301	4299	4300	4301	4301	4301	4300	4300	4301	4301	4301	4301	4301	4301
	0.53	0.46	0.65	0.56	0.08	0.13	0.21	0.31	0.32	0.24	0.24	0.29	0.03	0.04	0.32	0.30		0.47	0.45	0.40	0.39					
PA8	4301	4301			4301	4300			4302	4301			4299	4300				4300	4301							
	0.25	0.21			0.30	0.31			0.05	0.05			0.36	0.29				0.06	0.07							
	4302	4302	4301		4301	4301	4301	4301	4300	4302	4300	4300	4300	4299	4301			4300	4302	4300	4300					
PA9	0.32	0.29	0.38		0.10	0.09	0.11	0.12	0.10	0.04	0.14	0.11	0.01	0.06	0.14			0.10	0.10	0.25	0.26					
	4301	4300	4301	4300	4299	4300	4301	4300	4301	4300	4300	4300	4301	4302		4301	4301	4301	4301	4301	4302	4299				
	0.46	0.42	0.56	0.50	0.33	0.21	0.34	0.30	0.28	0.20	0.34	0.32	0.30	0.32		0.61		0.71	0.61	1.28	1.38					
PA10	4301	4300	4301	4301	4300	4300	4300	4300	4300	4300		4302	4299	4300	4300	4302	4301	4301	4301	4301	4301	4301	4301	4301	4301	
	0.76	0.64	0.78	0.66	0.94	0.51	0.50	0.46	0.55	0.56		0.43	0.82	0.70	1.15		1.68	1.69	1.22	1.13						



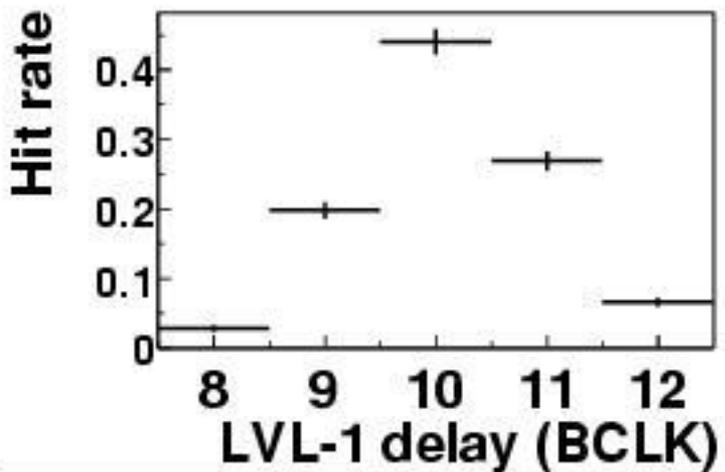




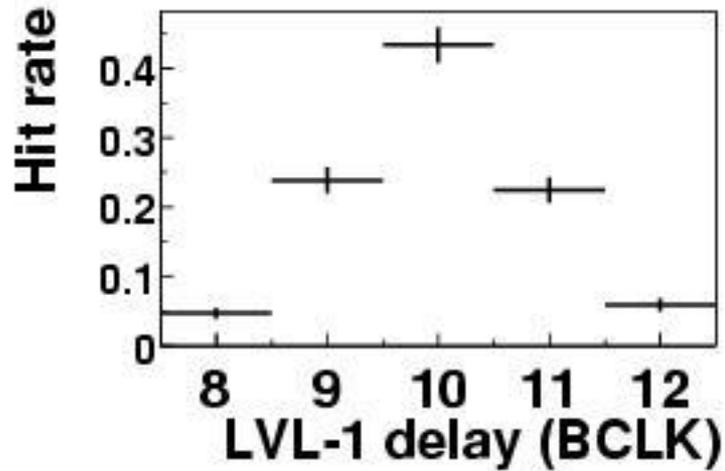
ROC0,Cable0,\_H



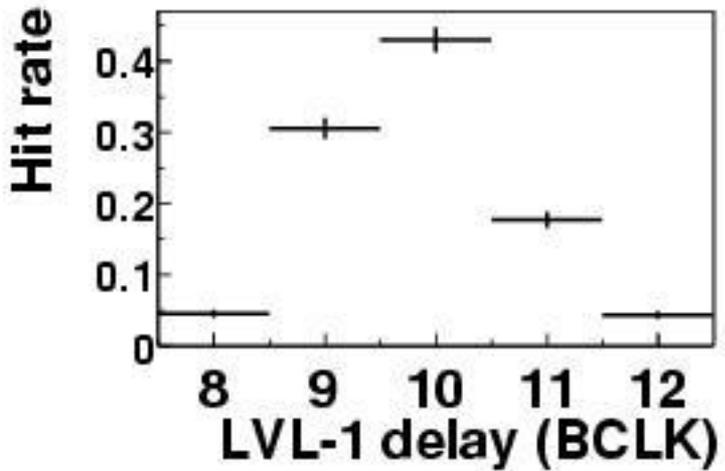
ROC0,Cable1,\_H



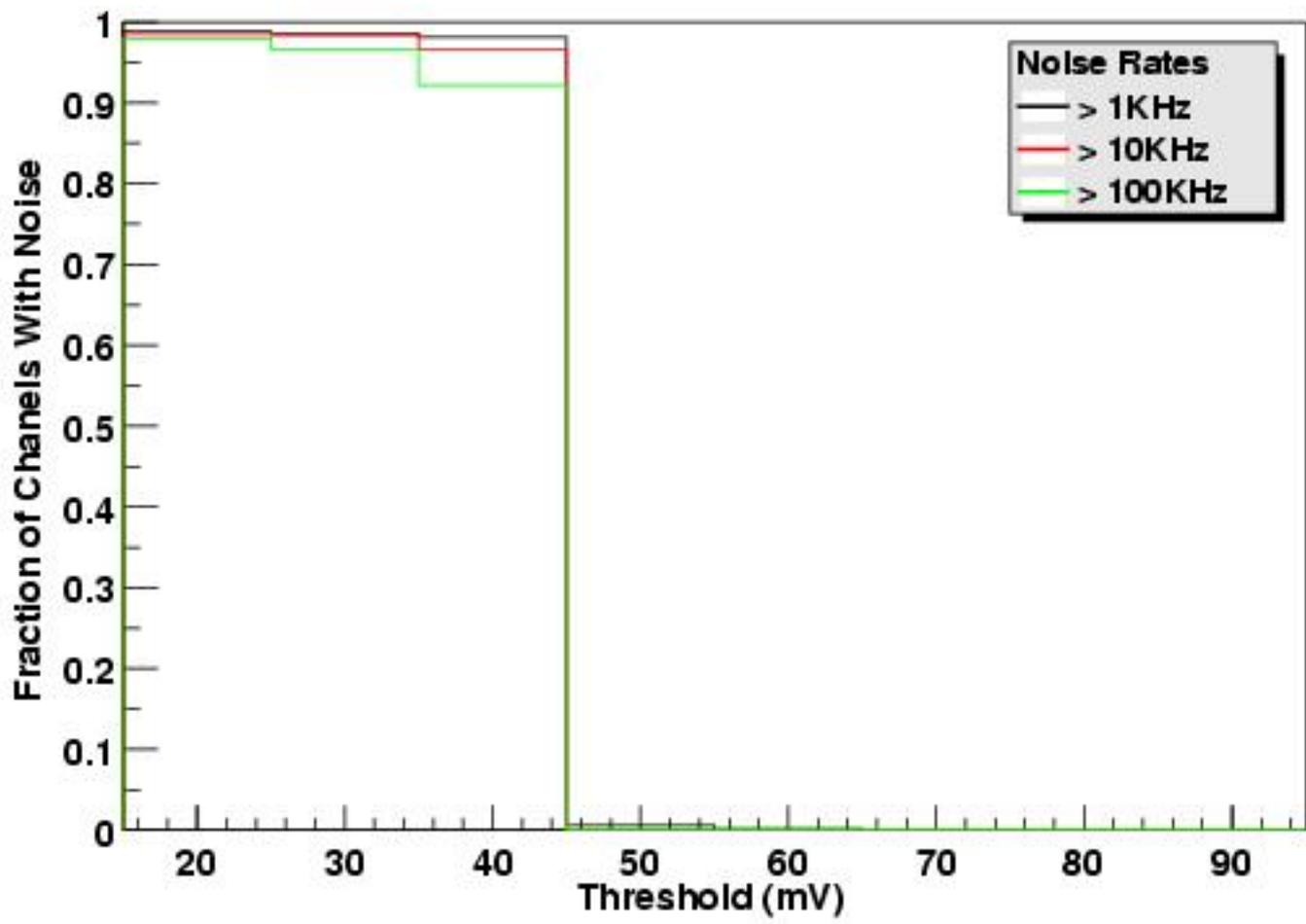
ROC0,Cable2,\_H



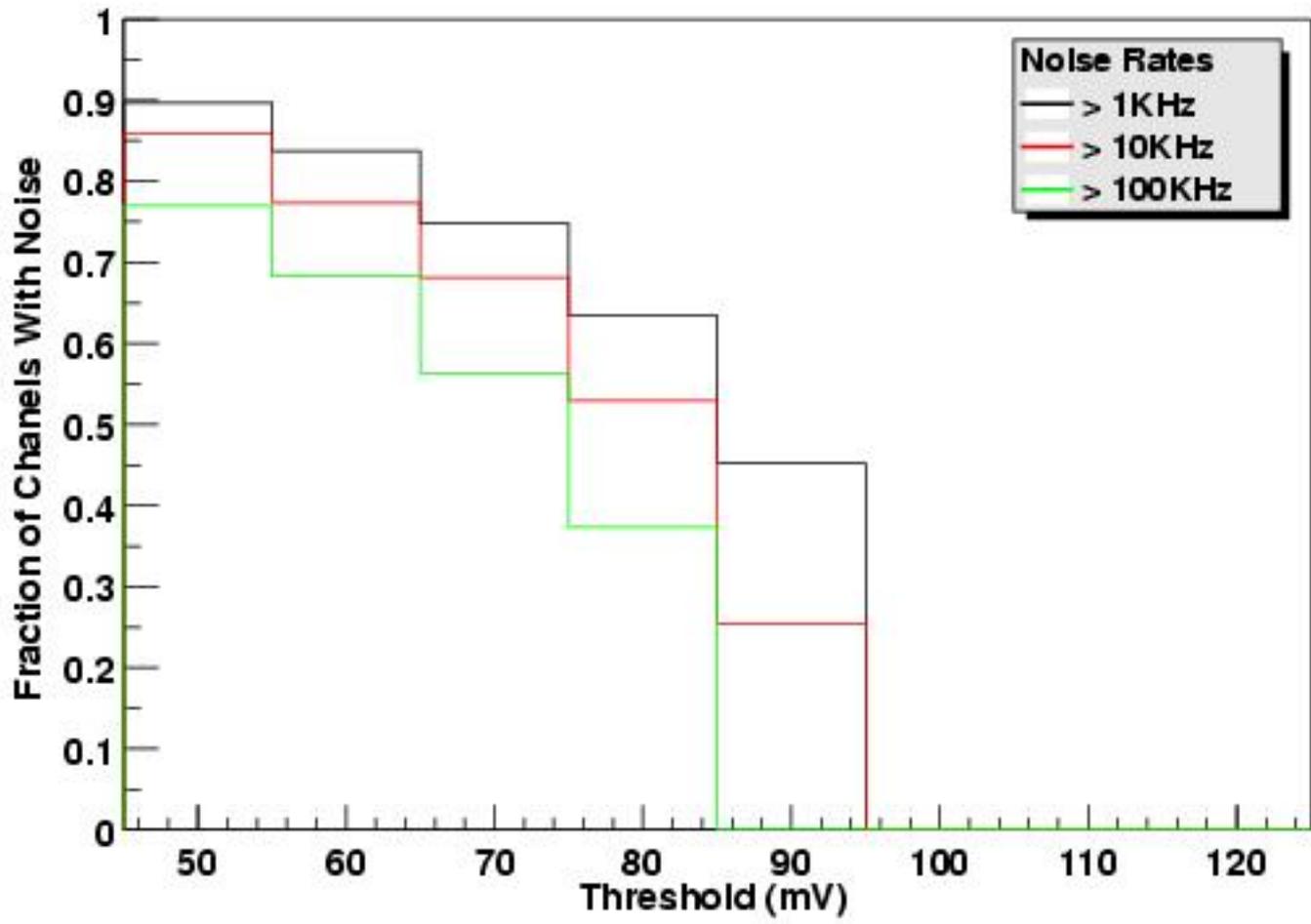
ROC0,Cable3,\_H

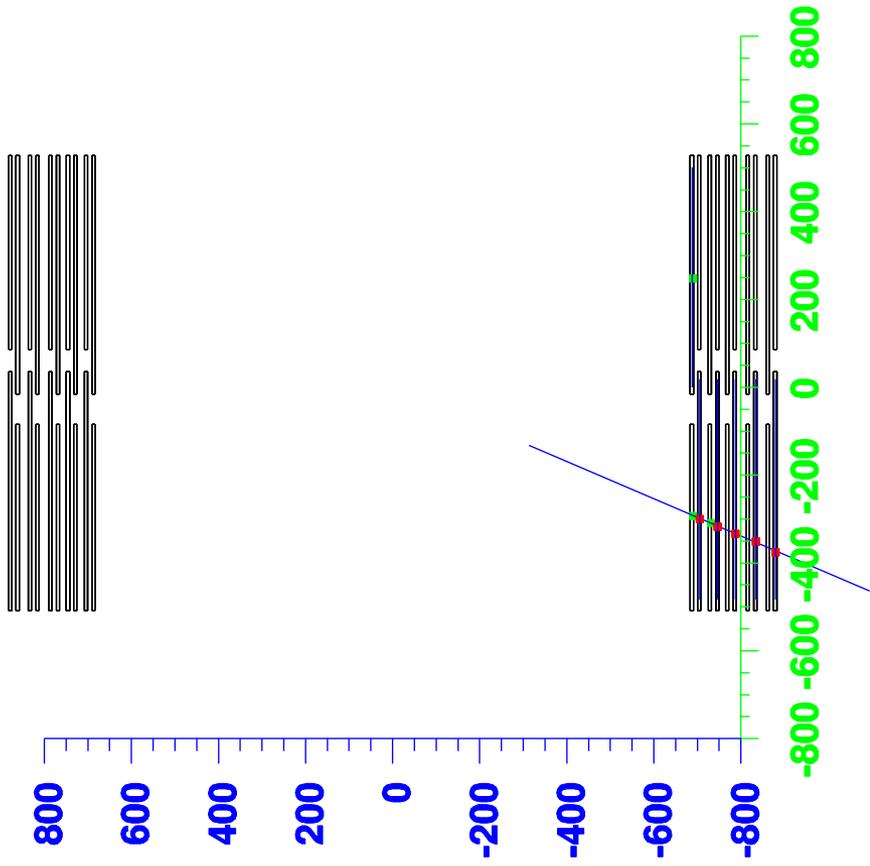


Noise Scan: North

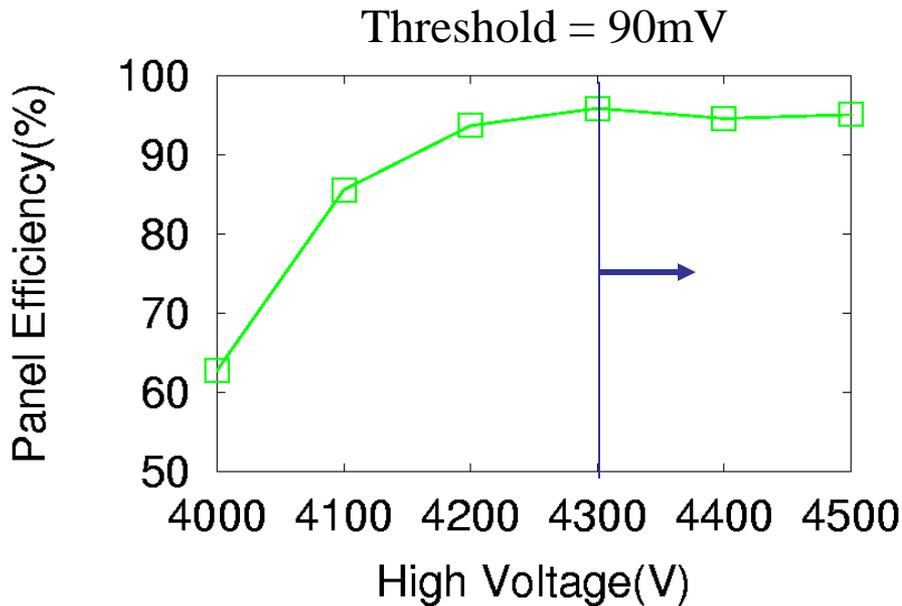


**Noise Scan South:**

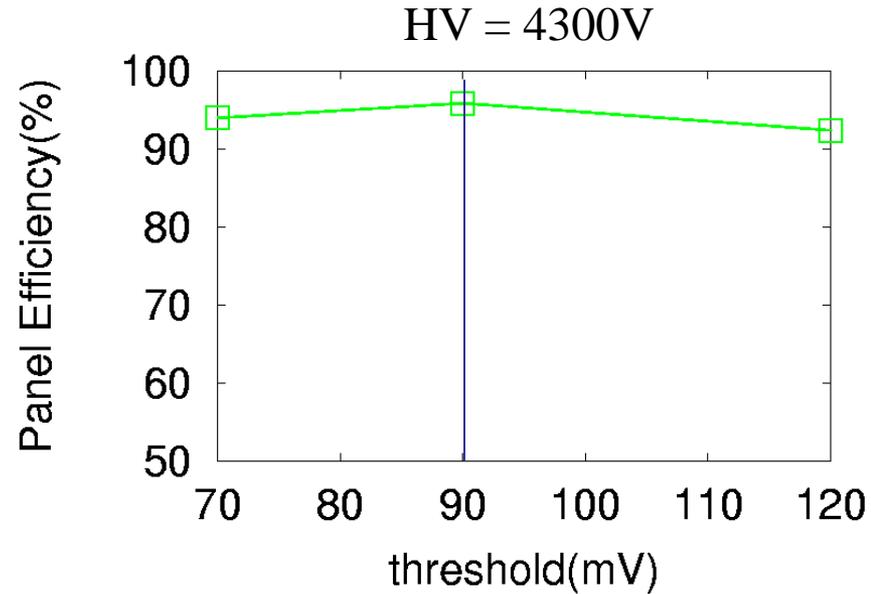




# HV/threshold Scan for Efficiency



Nice plateau for 4300~4500V  
→ Operation Voltage is set

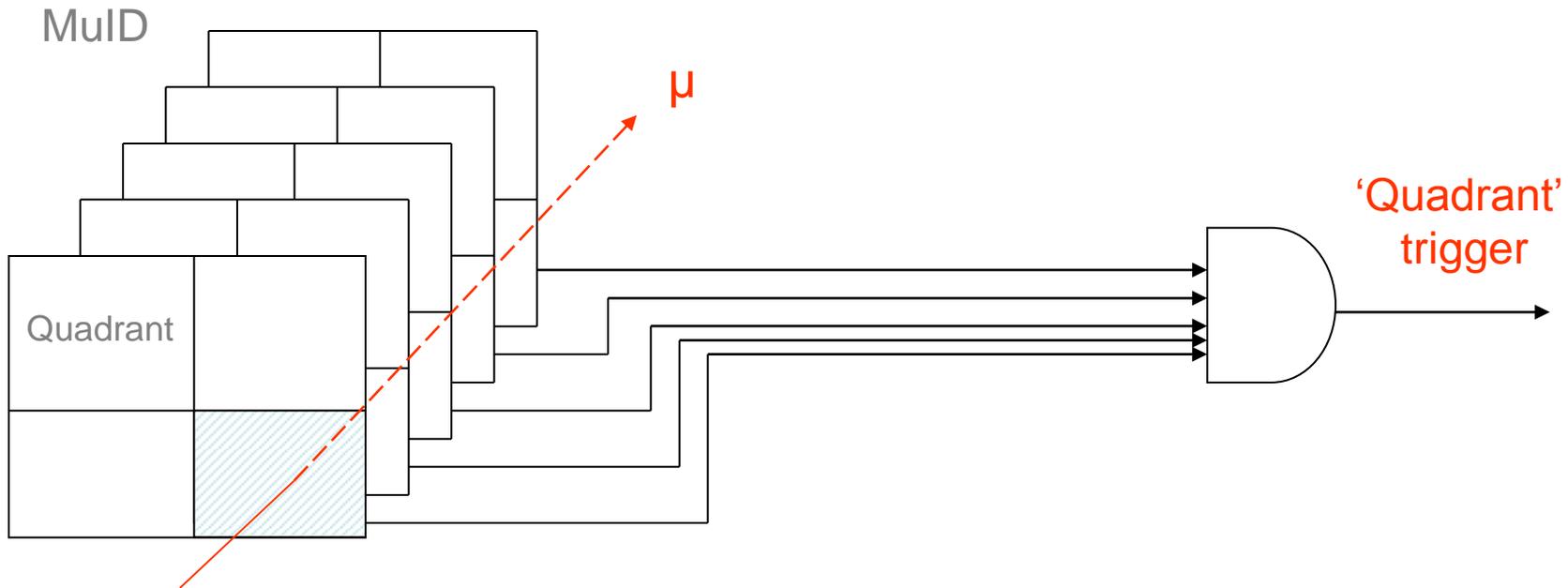


No threshold dependence  
→ set to 90mV  
Noise is serious < 60mV

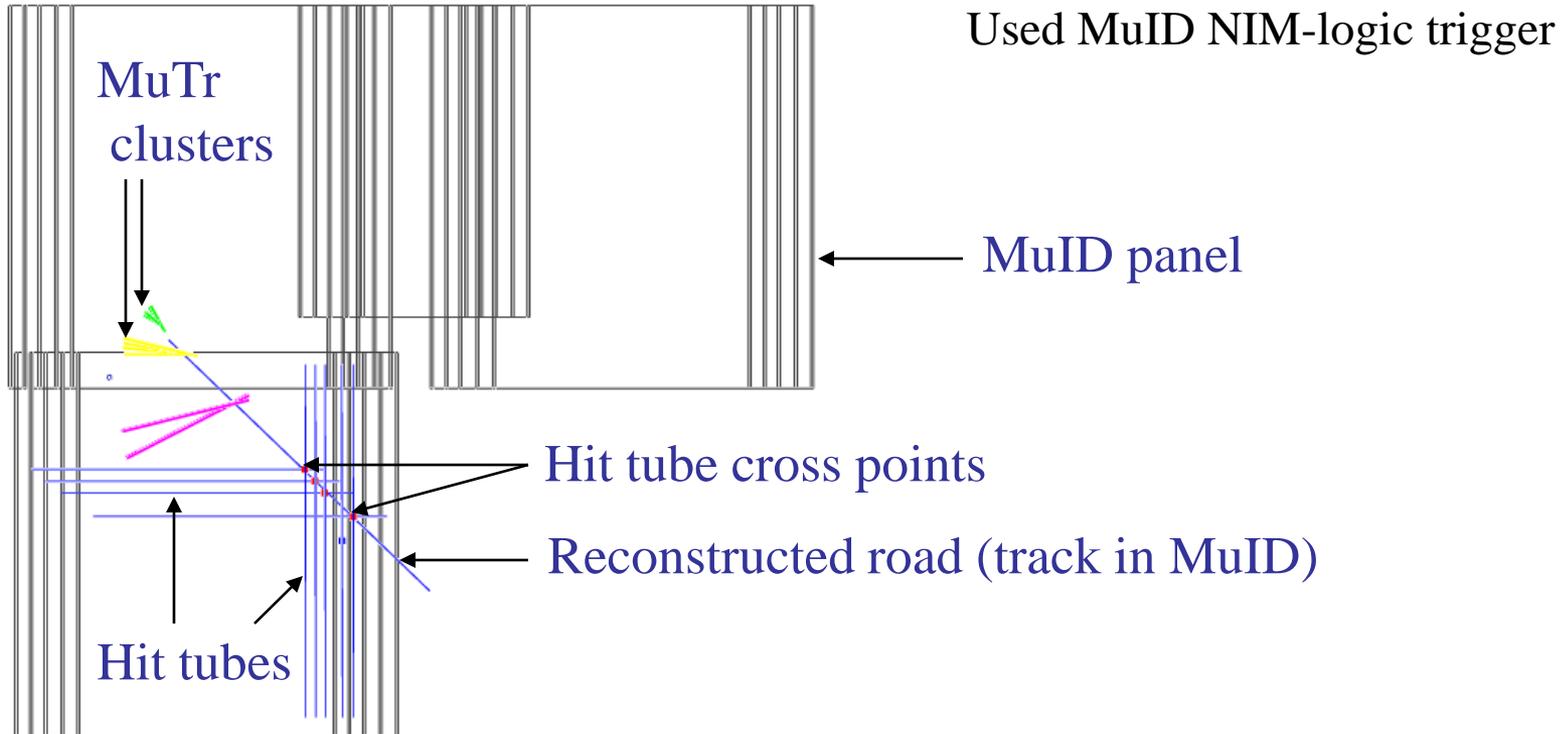
- ~95% tube efficiency is achieved

# Blue logic Trigger

- Coincidence of fired planes of each quadrant gives a “quadrant trigger”
- Minimum bias (BBC) AND one quadrant for the “single-muon trigger” and more than one quadrant for the “dimuon trigger”
- Inefficiencies from hardware dead time is 1~2%
- Trigger rate was dominated by non-collision beam related background → survived with Run-2 luminosity (~100 Hz for the single-muon trigger and ~10 Hz for the dimuon trigger)

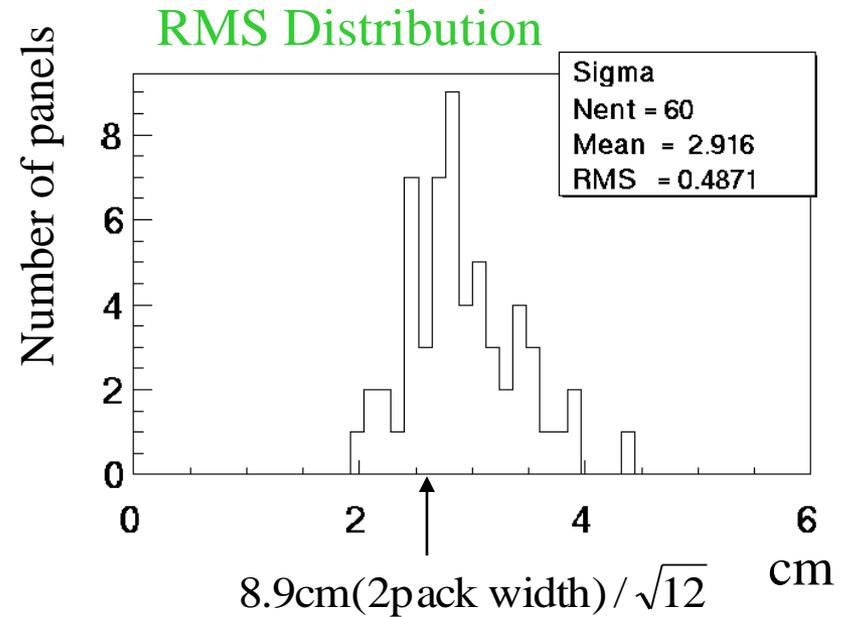
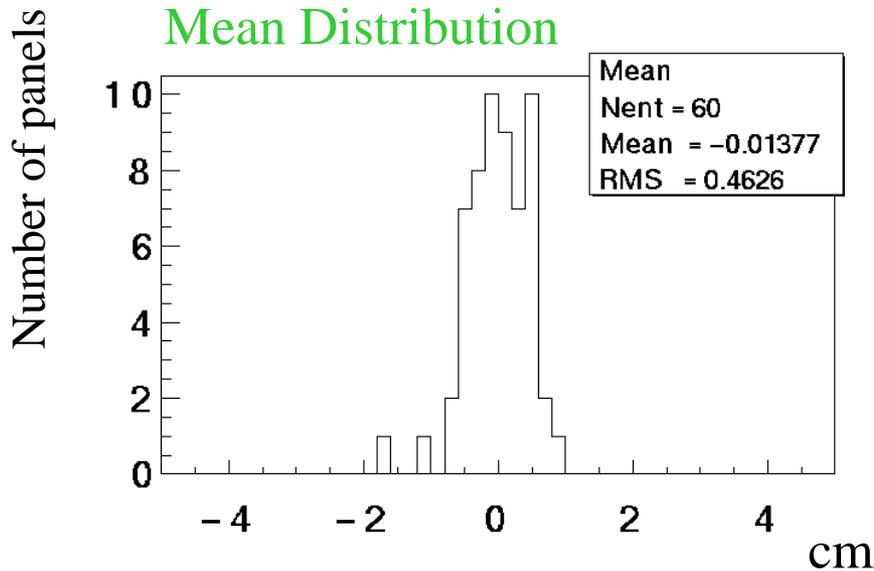
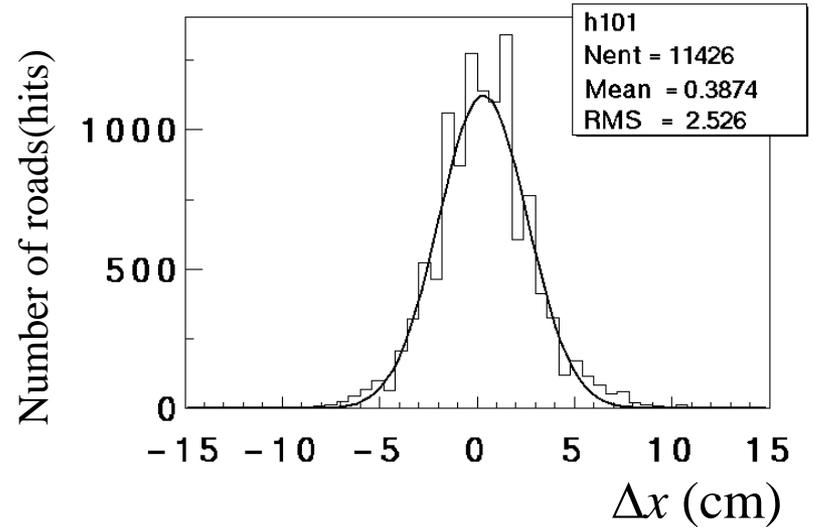
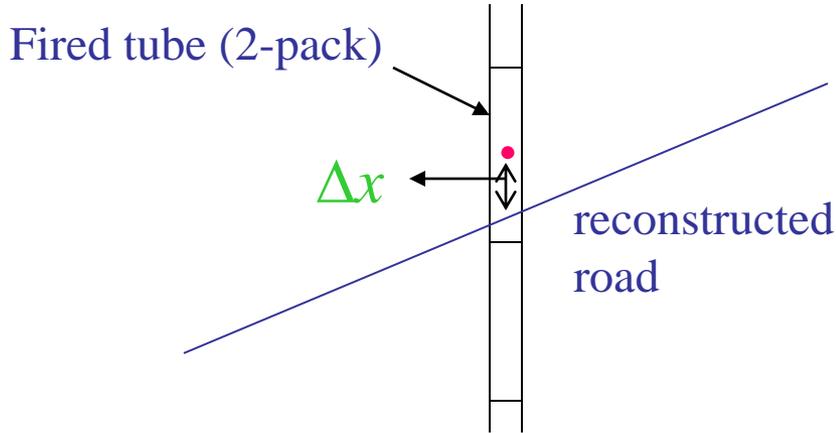


# Cosmic rays are found!



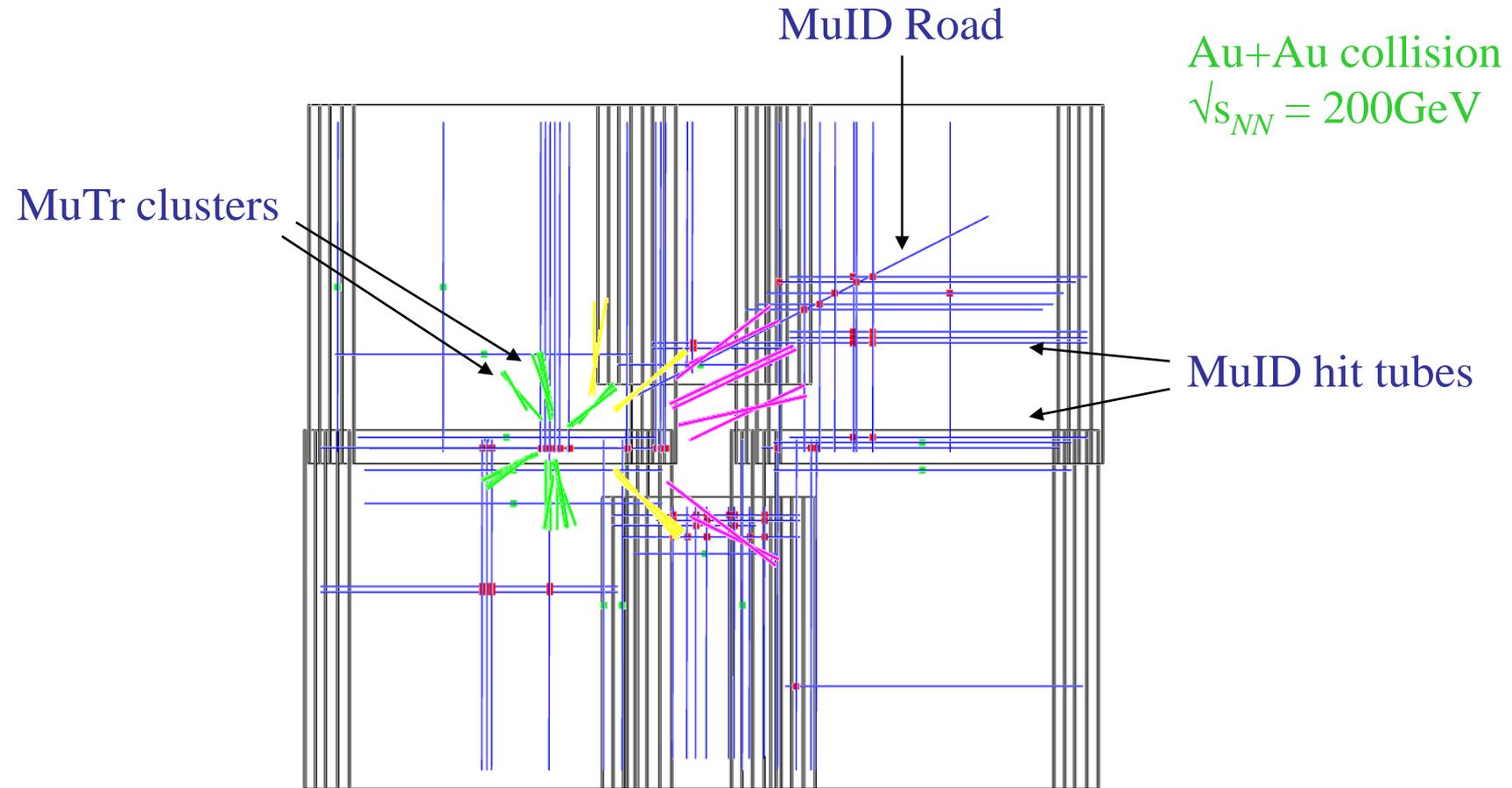
- Both hardware and software (road-finder, event display, ...) are confirmed to be working well.
- Roads matches clusters in MuTr.
- Useful for calibration of *both MuID and MuTr*.

# Geometry check



*Geometry is confirmed to be OK*

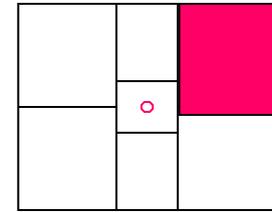
# Roads Found in Au+Au Collisions!



- The entire South MuID is being operated in Au+Au collisions at  $\sqrt{s_{NN}} = 200 \text{ GeV}$
- Road-finder is working well in Au+Au collision

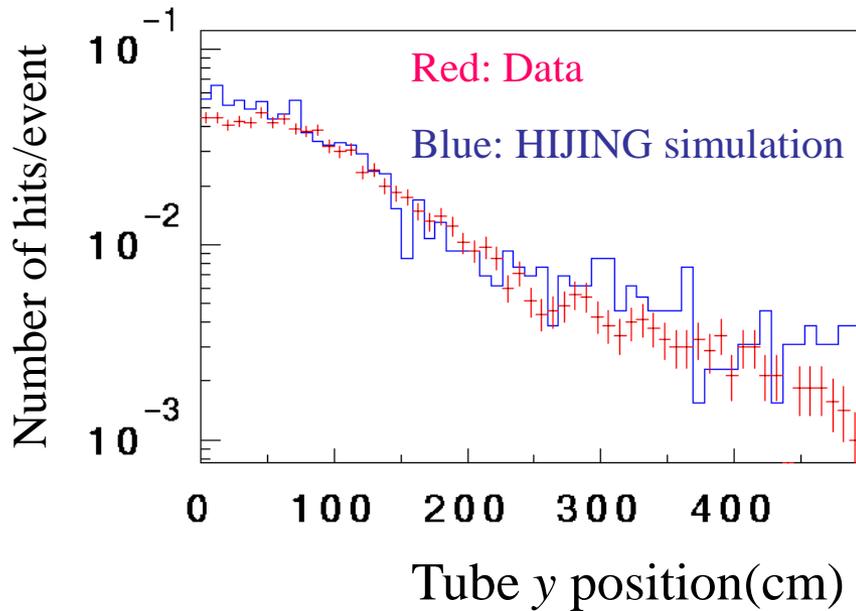
# Tube Hit Rates

Panel 0

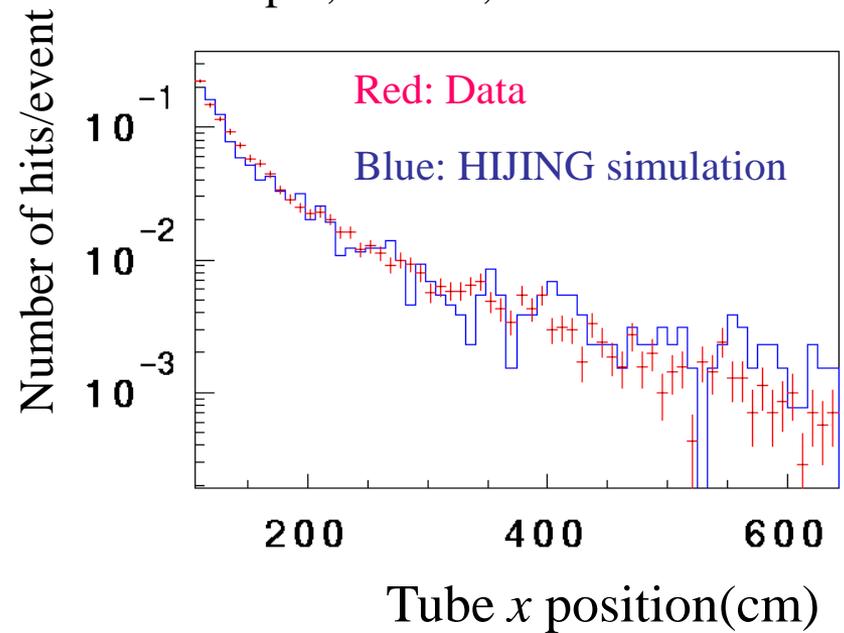


Viewed From IP

Gap3 (4<sup>th</sup> gap), Panel0, Horizontal

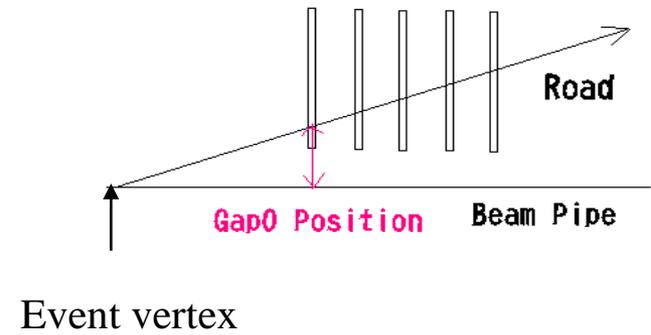
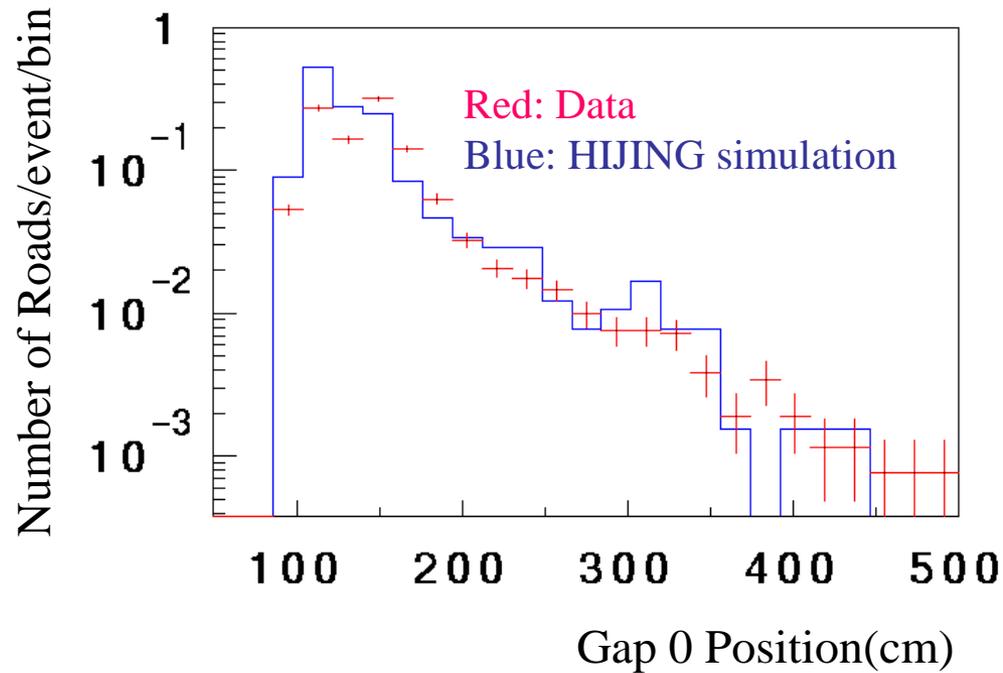


Gap 3, Panel0, Vertical



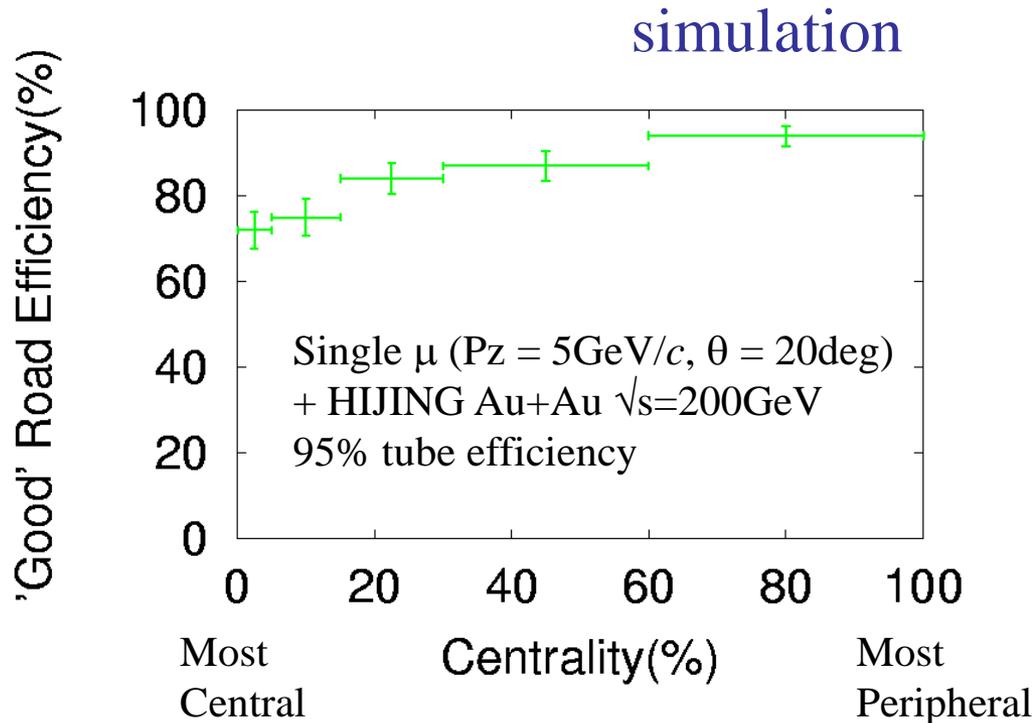
- Hit rates agree with simulation well

# Road Density



- Road position distribution agrees with simulation

# Road efficiency in Au+Au collisions



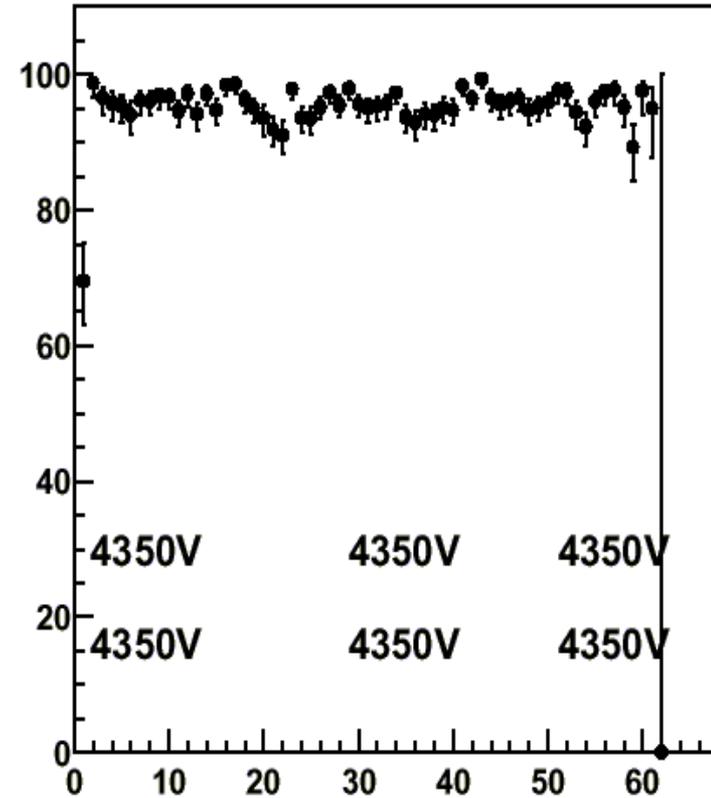
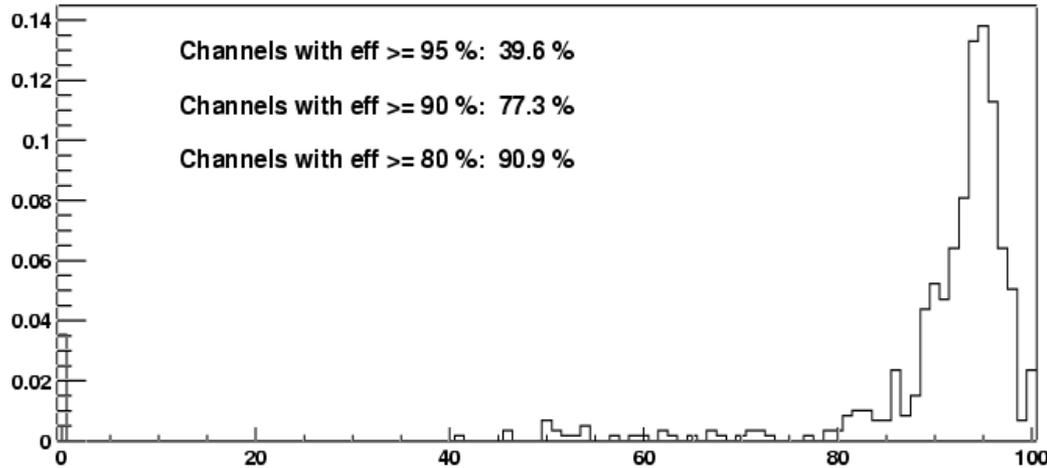
- Single muons (  $P_z = 5\text{GeV}/c$  and  $\theta = 20\text{deg}$ . ) mixed with HIJING events
- 'Good' road means 2/3 of hits of a road comes from the signal muon.
- ~70% of 'good' road efficiency will be achieved at most central events

# CHANNEL-BY-CHANNEL EFFICIENCIES

Eff: panel 5, orient 1

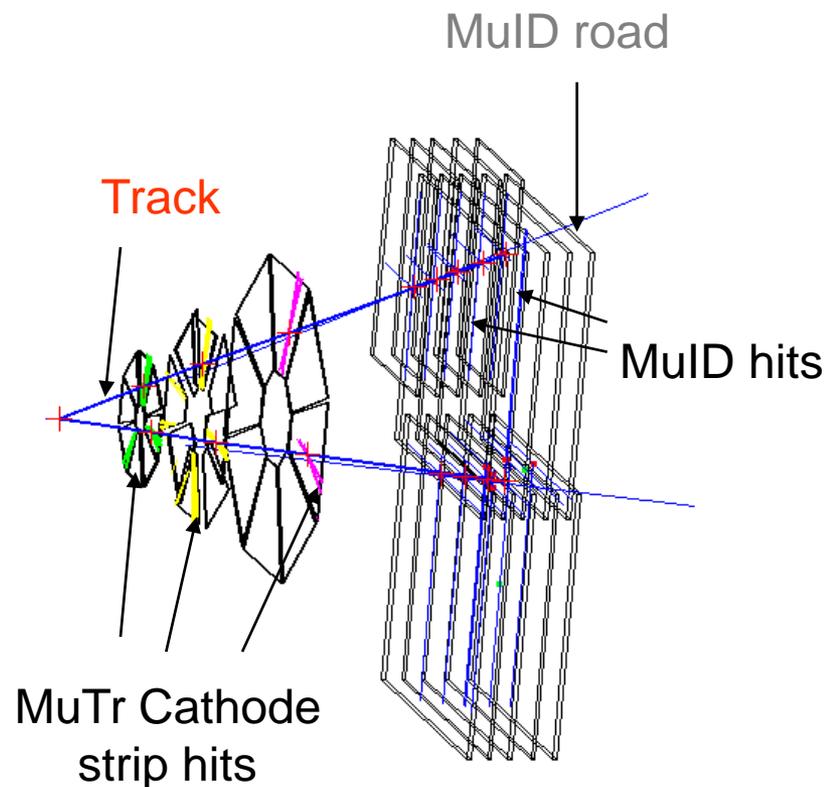
Average eff 95.18

Total Eff Dist



# Finding muon tracks

- Find roads (tracks in MuID)
- **Find tracks** in MuTr using roads as seeds
- **Fit tracks** including an event-vertex point

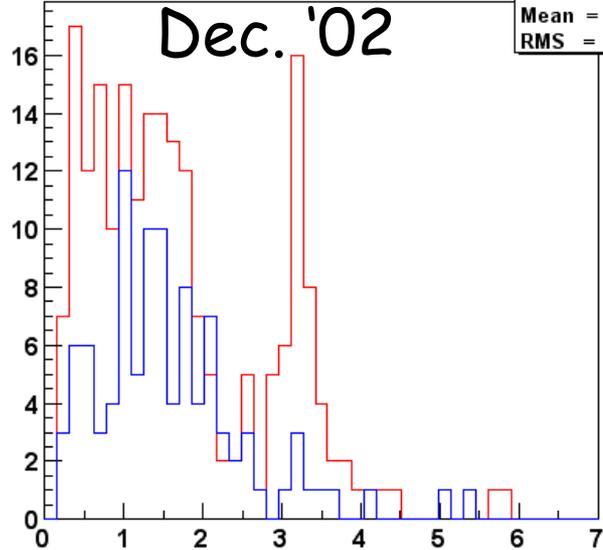


“ $J/\psi$  candidate” event

# Full Data Set run by Raphael/Frederic

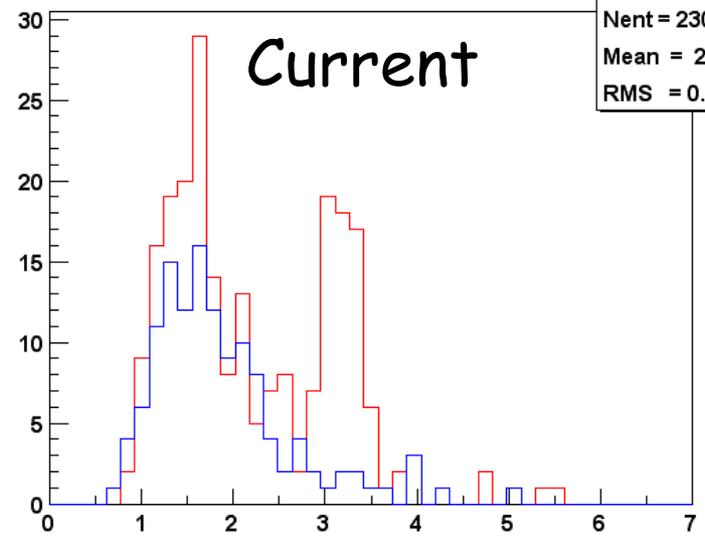
dimuon mass: RED=+-

h101  
Nent = 211  
Mean = 1.714  
RMS = 1.119



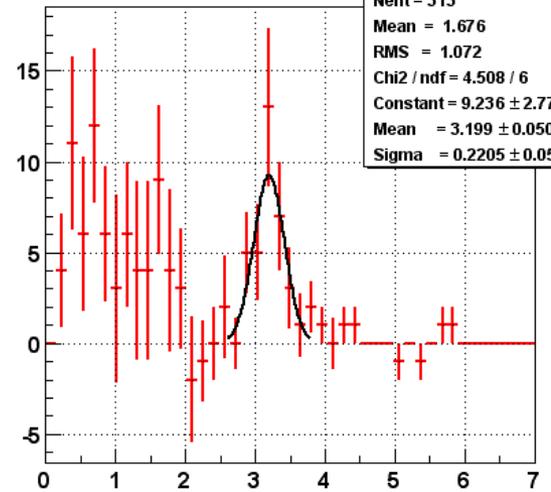
dimuon mass: RED=+-

h101  
Nent = 230  
Mean = 2.235  
RMS = 0.9211



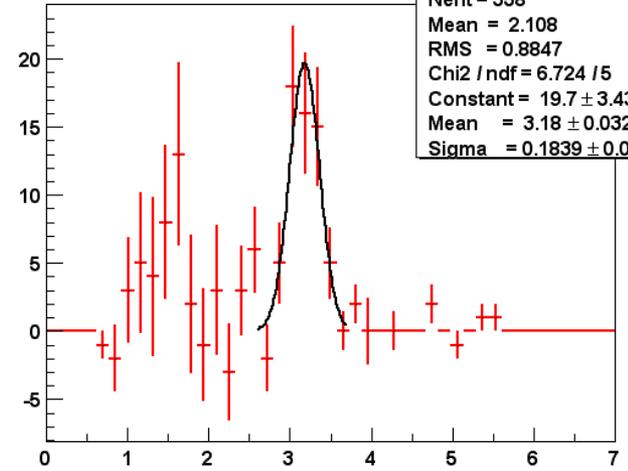
dimuon mass: RED=+/-

h103  
Nent = 313  
Mean = 1.676  
RMS = 1.072  
Chi2 / ndf = 4.508 / 6  
Constant = 9.236 ± 2.771  
Mean = 3.199 ± 0.05062  
Sigma = 0.2205 ± 0.05627



dimuon mass: RED=+/-

h103  
Nent = 358  
Mean = 2.108  
RMS = 0.8847  
Chi2 / ndf = 6.724 / 5  
Constant = 19.7 ± 3.435  
Mean = 3.18 ± 0.03239  
Sigma = 0.1839 ± 0.02287



~59 counts in peak  
resolution ~180 MeV

(QM: 36 counts in peak  
==>64% increase  
resolution ~257 MeV)

# Muon Identifier Shielding

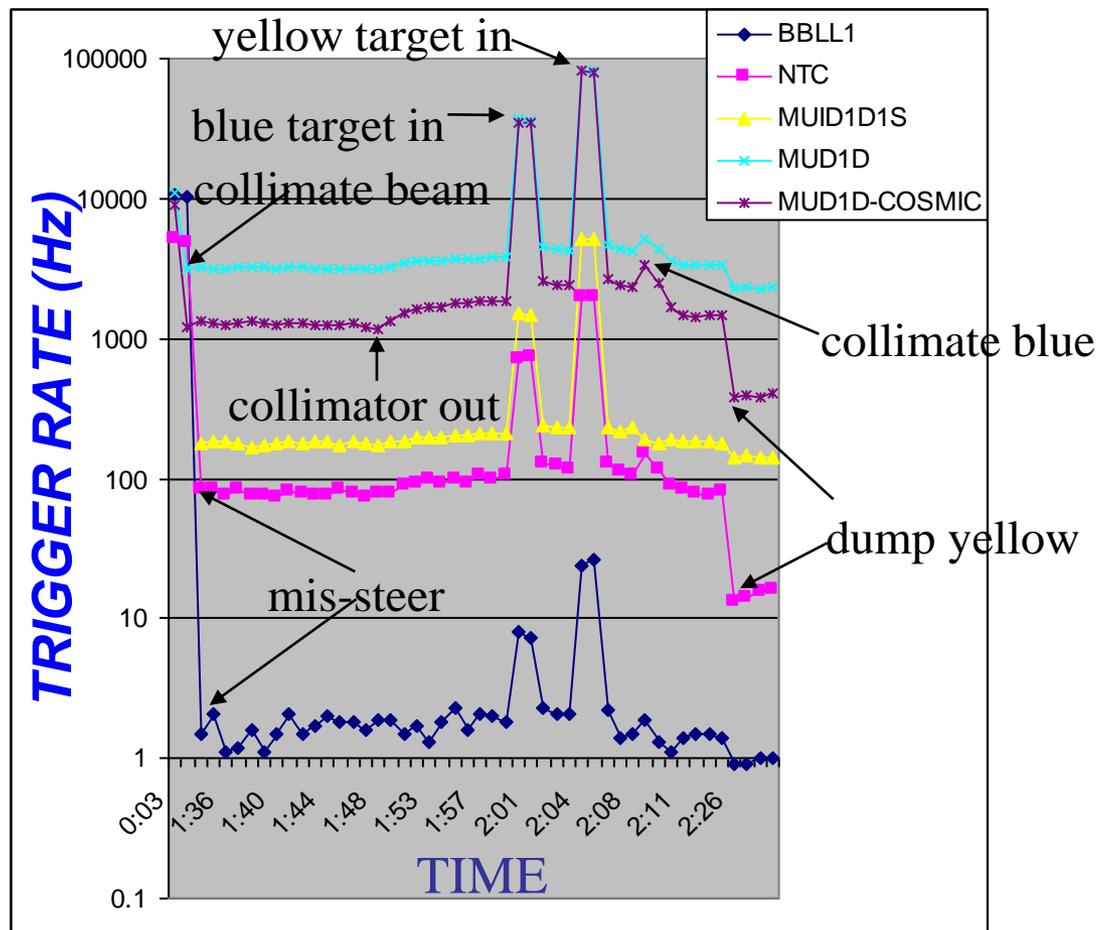


Initial approach to shielding:  
hand-stacked bars.



Ready for Run 3 now.  
Special thanks to  
Charlie Pearson and CAD.

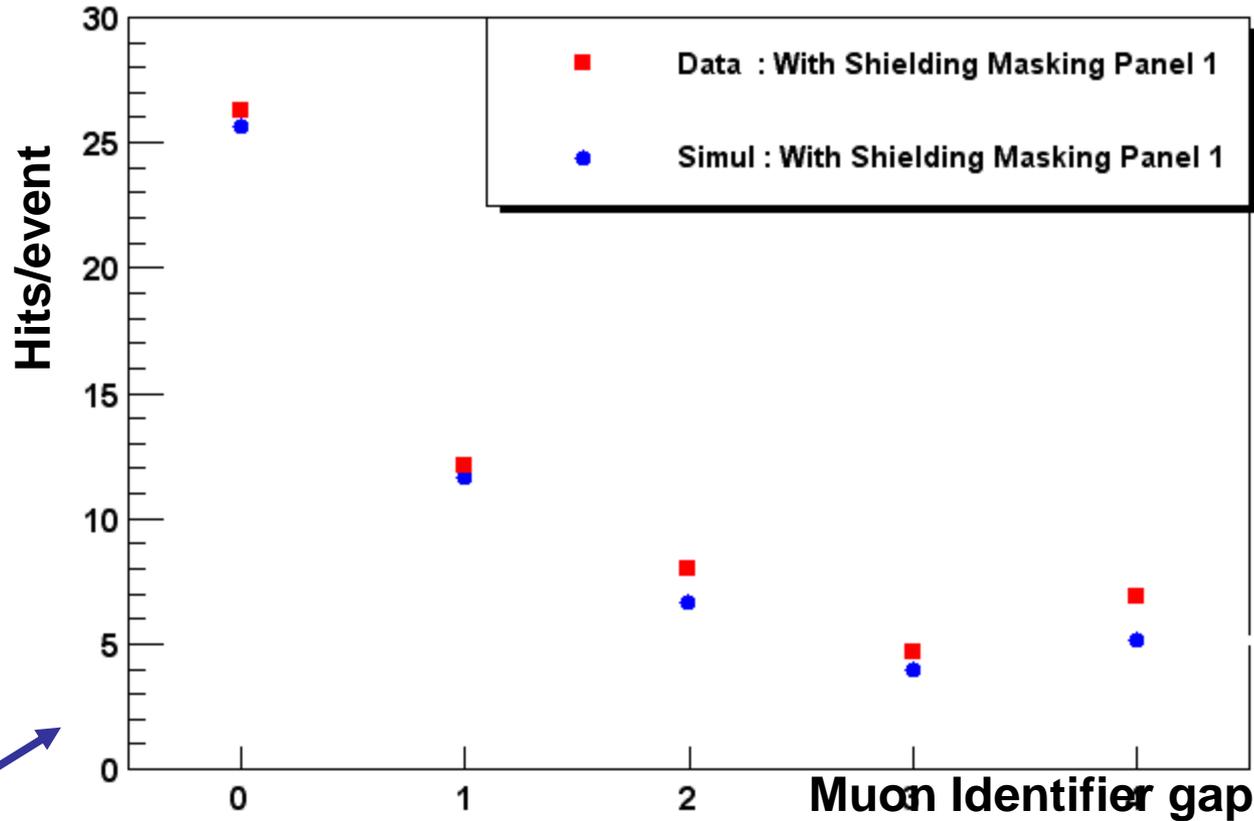
# BACKGROUND STUDIES



After  $\beta^* = 1$  m achieved, significant non-collision background observed. Studied problem with help from RHIC during p+p running by mis-steering beam and seeing panel currents remain high. Rates very sensitive to beam scrape. Collimation helps tremendously. RHIC expects to further investigate and improve this situation.

# OCCUPANCY

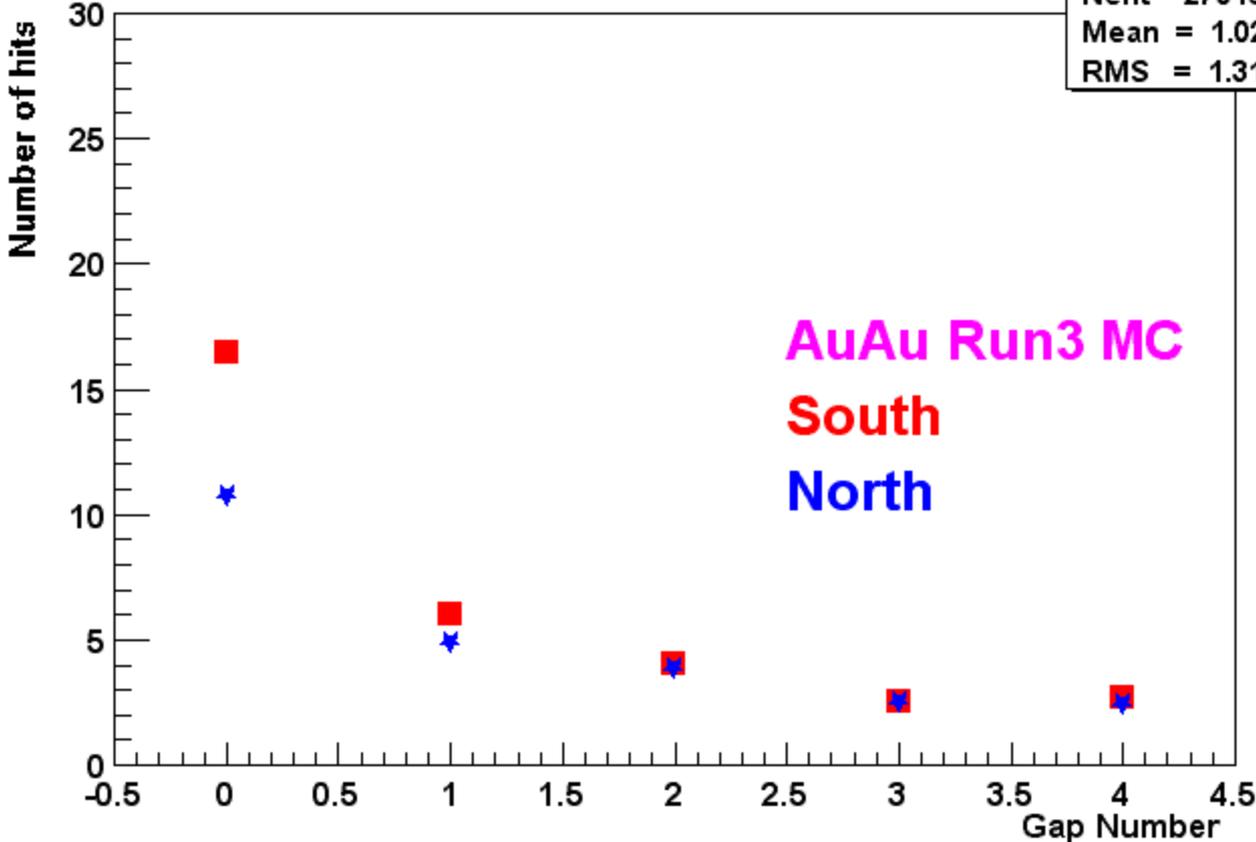
Occupancy as a function of depth in identifier



Occupancy observed in muon identifier for data agrees closely with expectations from simulation gap-by-gap. Occupancy generally decreases with depth in the identifier. The small increase for last gap is due to secondaries striking material in the square hole and is consistent with expectations from simulation.

**Hits per Gap: south**

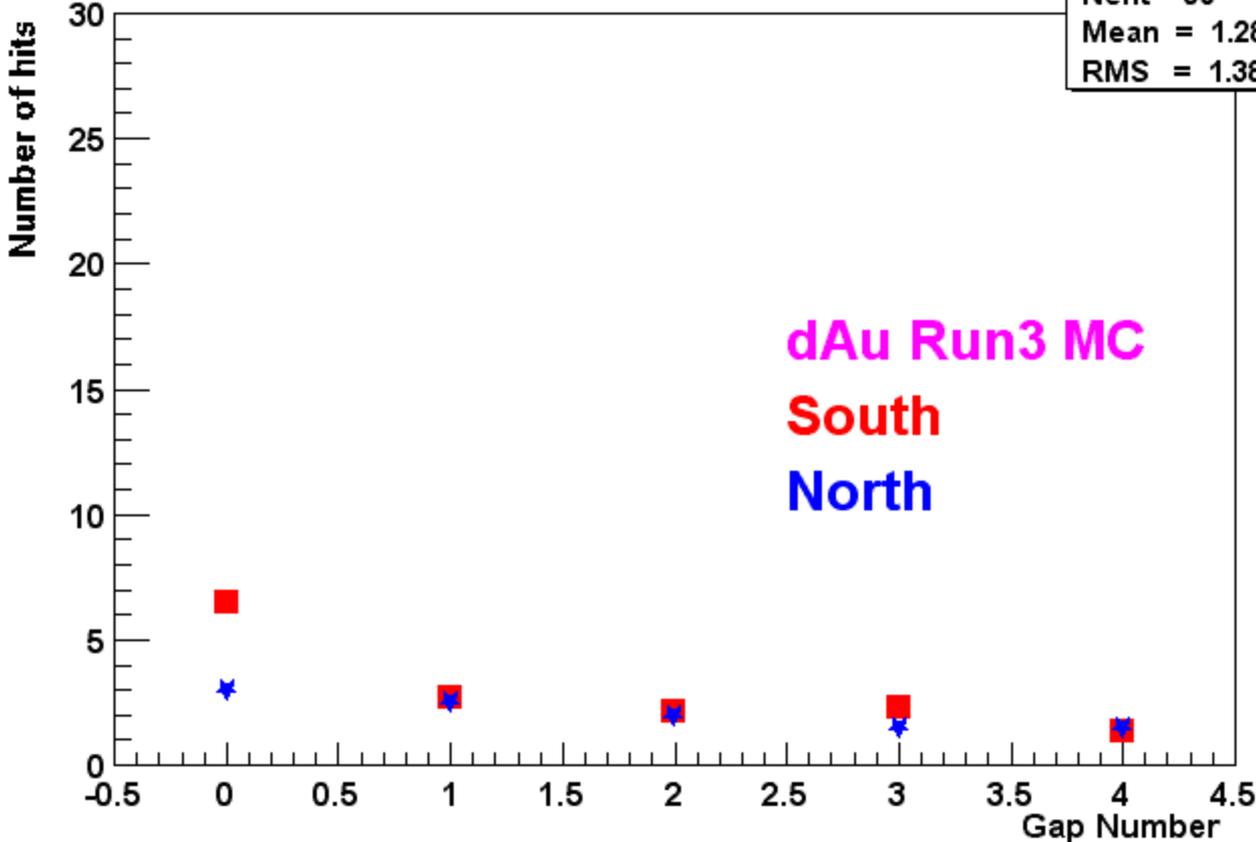
hSouthHitsPerGap  
Nent = 27016  
Mean = 1.027  
RMS = 1.316



AuAu Run3 MC  
South  
North

**Hits per Gap: south**

hSouthHitsPerGap  
Nent = 90  
Mean = 1.289  
RMS = 1.384



# MuID PERSONNEL

- 15 Institutions: BNL, CIAE, Columbia, Iowa State, KEK, Kyoto Univ., LANL, ORNL, RIKEN, RIKEN BNL Research Center, State Interphysica, SUNY Stony Brook, Tokyo Inst. Tech., Univ. Tennessee, Yonsei Univ.
- Detector Council Representative and MuID Mechanics Subsystem Manager: Ken Read
- MuID FEE Subsystem Manager: Vince Cianciolo
- Local BNL Coordinator and Gas System Expert: Atsushi Taketani
- Commissioning/operations: V. Dzhordzhadze, A. Glenn, D. Hornback, N.Kamihara, J. Newby, H.D.Sato

# Summary

- South MuID Arm was successfully operated in Run2.
- First results were obtained on  $J/\Psi \rightarrow \mu^+\mu^-$  in p+p collisions with South Muon system (MuID + MuTr).
- The Au+Au Muon data analysis from Run2 is in progress.
- Both Arms of the Phenix MuID system was successfully commissioned in November-December 2002.
- Currently both MuID Arms are operating and taking data in Run3.
- Many interesting results are expected with MUONS in Run3 and in the next coming runs.