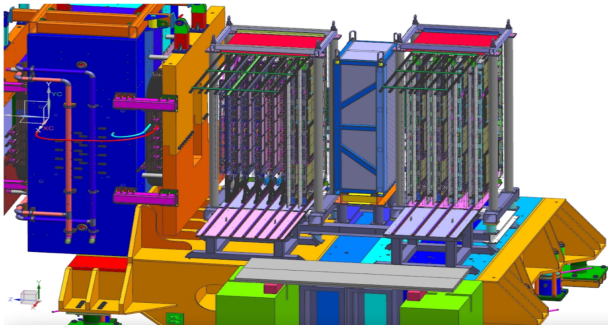


# SBS GEM Tracker Status

**Asar Ahmed**

*On behalf of the SBS GEM group*



# Outline

## 1 GEM based Tracker for GEP

- Introduction to GEM
- GEM for GEP V

## 2 Upgrade for GEP V

- GEM Repair and rearrangement
- Gas system and High Voltage upgrades

## 3 Installation and Tests

- Initial Installation
- Installation on Platform and Current Status

## 4 Summary

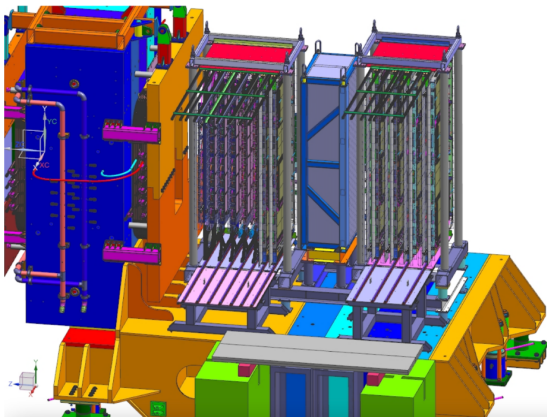


# **GEM based Tracker for GEp**

# GE<sub>p</sub> V GEM Tracker

## SBS

- ❑ Front Tracker(FT): 8 Layers
  - 2 XW, single module
  - 4 UV, single module
  - 2 XY, 4 modules each
- ❑ Rear Tracker (RT): 8 Layers
  - All XY, 4 modules each/layer



## Why GEMs

- ❑ SBS concept leads to need for high rate trackers with good position resolution.
  - GEMs: cost effective for high resolution tracking under high rates over large area.
  - Rate capability in MHz/cm<sup>2</sup>
  - High position resolution ( 75 $\mu$ m)
  - Low thickness (~0.5% radiation length)

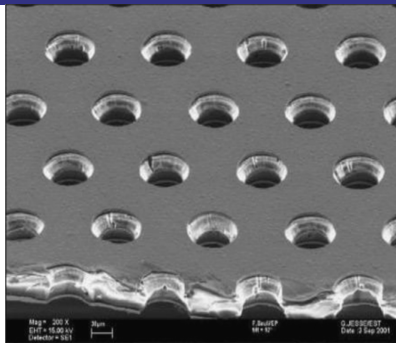


# Introduction to GEM

## GEM foil/hole design

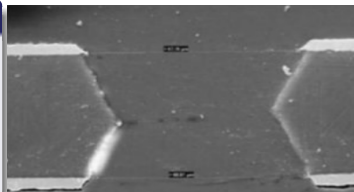
GEM foil consist of a  $50\ \mu\text{m}$  thin polyamide (Kapton/Apical) coated with a  $5\ \mu\text{m}$  thin layer of copper on both side

- Bi-conical holes:
  - inner diameter (polyamide):  $\sim 50\ \mu\text{m}$
  - outer diameter (copper):  $\sim 70\ \mu\text{m}$
  - pitch:  $\sim 140\ \mu\text{m}$  (holes density:  $6000/\text{cm}^2$ )
- Each hole under sufficient electric filed act as proportional counter.



## Properties of Kapton ( $50\ \mu\text{m}$ )

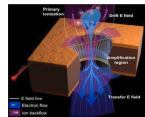
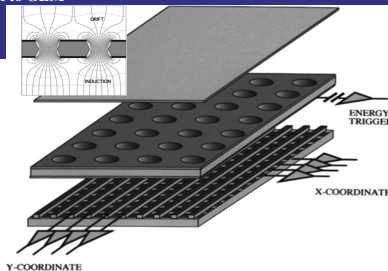
- High dielectric constant: 3.4
- Dielectric strength:  $2400\text{kV}/\text{cm}$
- Volume resistivity:  $1.5 \times 10^{17}\ \Omega\text{cm}$
- Stress to Produce 5% Elongation :  $90\ \text{MPa}$



# GEM operating principle

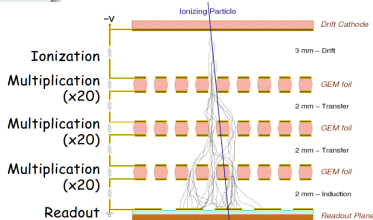
## Operation

- ❑ Incident charged particle or photon interact in the drift region and produces primary ionization in the counting gas
- ❑ Primary electrons then drift toward holes and ions toward drift electrode under low EF (**ionization region**)
- ❑ Due to enough high electric field inside holes, electrons acquire enough KE to produce secondary ionization in gas (**proportional region**)
- ❑ The avalanche created is then collected by readout for signal processing

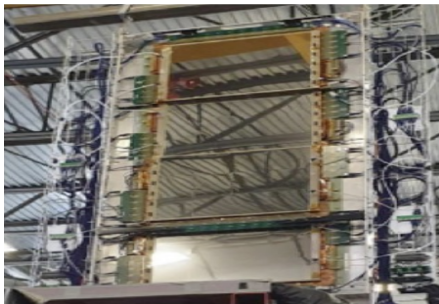


## Single foil issue

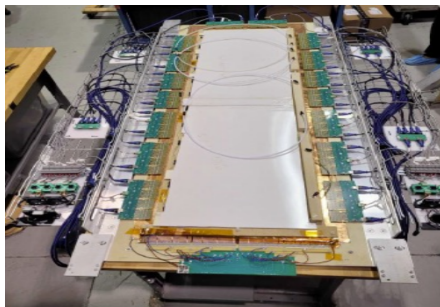
- ❑ Low gain
- ❑ Not enough charge to produce good signal
- ❑ High gain at high potential difference, but increase in discharge probability



# SBS GEMs Types



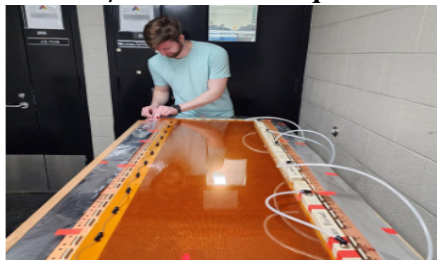
**XY: 60 x 50 sq. cm x 4**



**UV/XW: 40 x 150 sq. cm**

## Stock for GEP V

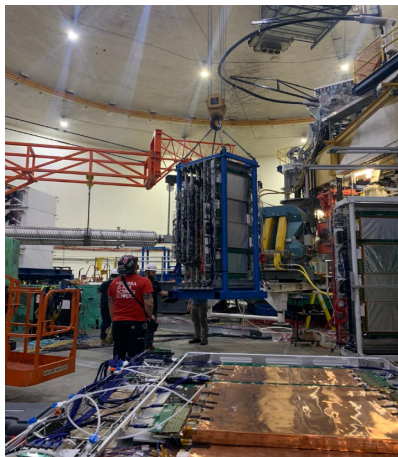
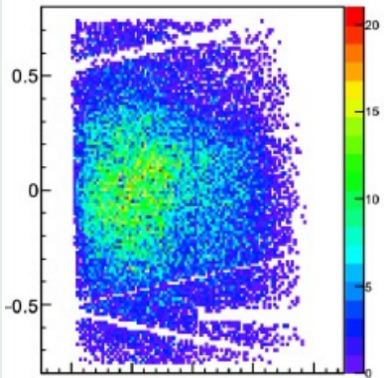
- ❑ Nilanga and Huong group at UVA has built:
  - 4×UV, 2×XW, 40×XY(+5 spares)
- ❑ Group has record of making largest area GEMs in the world
- ❑ All of these chambers have performed exceptionally well in beam



# Upgrade for GEp V

# Repair

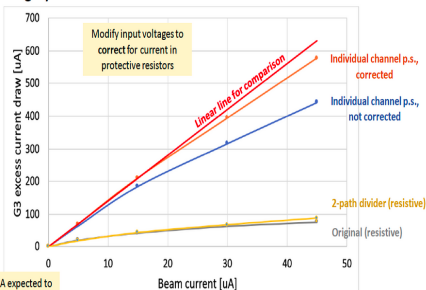
- ❑ Trackers removed from SBS and BB platform
- ❑ On GEMs
  - Isolated HV sectors for unstable chambers
  - HV upgrade on BB XY layer
  - Replaced 2 XY chambers
  - 13 faulty APVs and 2 backplanes replaced



# HV multichannel upgrade

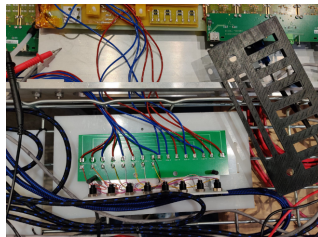
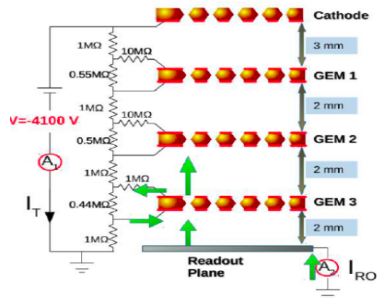
- ❑ Issue in high rate: gain drop due to low cost resistive high voltage divider
- ❑ Upgrades were done before in GEn-RP
  - The gain drop problem effectively gone
  - 2 more layers upgraded for GEp

Luminosity scan with different HV divider configurations during GEn (on optics target)



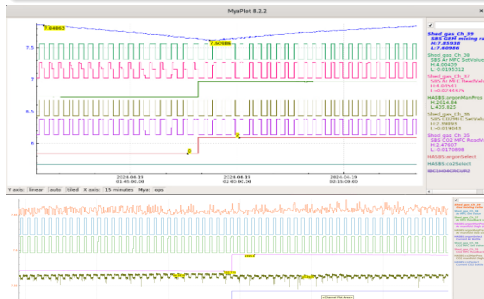
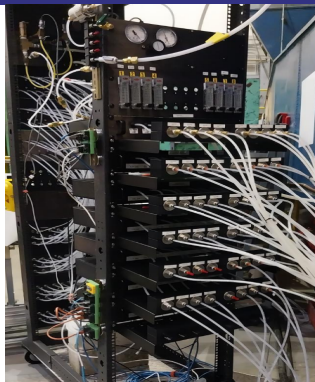
GEp at 50uA expected to increase rate shown here for 45uA by 2.7x

9



# Gas System Upgrades

- ❑ Gas System
  - New filter installed on gas distribution rack for dual protection (DSG)
  - Filters on SBS GEMs are also replaced
  - Replaced faulty regulator in the gas shed
    - ❖ Old: changeover pressure: 300psi
    - ❖ New: changeover pressure: 150 psi
- ❑ Binary Gas analyzer (BGA) calibrated to deliver  $\sim 73 : 27$  (Ar:CO<sub>2</sub>)
- ❑ Gas Flow monitoring is in place



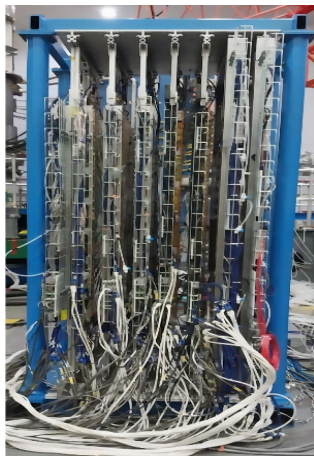
Hall A SBS GEM Flow Readout							
Regulator Input Pressure		Regulator Output Pressure		Reg. % of rms			
160.00 psi		170.00 psi		117.00 %			
H Flow D09	H Flow D10	S1 Flow D11	S1 Flow D12	S1 Flow D13	S1 Flow D14	S1 Flow D15	S1 Flow D16
108 acm	360 acm	227 acm	229 acm	224 acm	228 acm	221 acm	231 acm
Status: good	Status: good	Status: good	Status: good	Status: good	Status: good	Status: good	Status: good
S1 Flow D17	S1 Flow D18	S1 Flow D19	S1 Flow D20	S1 Flow D21	S1 Flow D22	S1 Flow D23	S1 Flow D24
222 acm	225 acm	211 acm	208 acm	211 acm	208 acm	214 acm	205 acm
Status: good	Status: good	Status: good	Status: good	Status: good	Status: good	Status: good	Status: good
S1 Flow D25	S1 Flow D26	S1 Flow D27	S1 Flow D28	S1 Flow D29	S1 Flow D30	S1 Flow D31	S1 Flow D32
229 acm	225 acm	220 acm	198 acm	194 acm	198 acm	214 acm	206 acm
Status: good	Status: good	Status: good	Status: good	Status: good	Status: good	Status: good	Status: good
S1 Flow D33	S1 Flow D34	S1 Flow D35	S1 Flow D36	S1 Flow D37	S1 Flow D38	S1 Flow D39	S1 Flow D40
228 acm	226 acm	222 acm	212 acm	196 acm	195 acm	0 acm	0 acm
Status: good	Status: good	Status: good	Status: good	Status: good	Status: good	Status: good	Status: good

# Rearrangement: GEM Layers

## ☐ New FT and RT

- Rearranged from Old SBS and BB
- New layer of 4 XY GEMs

Old to new mapping		
Front Tracker	New	Old
XW (b2b)	L0	XW L0
XW (b2b)	L1	XW L1
UV	L2	UV L0
UV	L3	UV L2
UV	L4	UV L1
UV	L5	UV L3
XY	L6	BB XY
XY	L7	L7
Back Tracker		
XY (b2b)	L8	L2
XY (b2b)	L9	L3
XY (b2b)	L10	L4
XY (b2b)	L11	L5
XY (b2b)	L12	L8 (or 14)
XY (b2b)	L13	L9 (or 13)
XY (b2b)	L14	L6
XY (b2b)	L15	EEL





# HV and LV System Updates

- Additional 12 LV breakouts installed on existing SBS LV distribution
- HV GUI for both FT and RT
- HV GUI for GEM expert

tk

Front Tracker HV:  
type, Layer, module

XW L0

XW L1

UV L2

UV L3

UV L4

UV L5

XY L8 M0

XY L6 M1

XY L8 M2

XY L7 M0

XY L7 M1

Back Tracker HV:  
type, Layer, module

XY L8 M2

XY L8M1 L8M3

XY L9 M0

XY L9M2 L8M0

XY L10 M1

XY L10M3 L11M1

XY L10M2 L11M0

XY L11 M2

XY L12 M0

XY L12 M2

XY L13 M1

XY L13 M2

XY L14 M0

XY L14 M2

XY L15 M0

XY L15 M2

Clear Front Tracker status

Clear Back Tracker status

Set trip limit? 0 to disable

Off  On

Trip buffer [uA]:

Iterate for V drop? 0 to disable

0

CS-Studio (Phoenix) (on adaqc.jlab.org)

/daqg/home/asow/EPICS/HV/CS5/main-menu.bob SBS-GEM-Front HV SBS-GEM-Back

100%

SBS GEM Front HV Controls

Ch ID	Output	Status	Vmax	Vmin	Vset	Vmax	Vmin	Amplitude	ExpDev	Triptol
Front_wm_10_M0	set	1	615.92	-0.0130	615.8	6.960	700.0	10.0	10.0	1.000
Front_wm_10_M1	set	1	326.06	-0.0320	326.0	6.900	600.0	10.0	10.0	1.000
Front_wm_10_M2	set	1	616.10	0.1390	615.8	7.240	700.0	10.0	10.0	1.000
Front_wm_12_M0	set	1	362.20	0.0480	362.2	7.060	600.0	10.0	10.0	1.000
Front_wm_12_M1	set	1	615.96	0.0360	615.8	7.020	700.0	10.0	10.0	1.000
Front_wm_12_M2	set	1	398.48	0.2440	398.5	7.350	600.0	10.0	10.0	1.000
Front_wm_14_M0	set	1	615.96	-0.0050	615.8	6.960	700.0	10.0	10.0	1.000
Front_wm_14_M1	set	1	615.98	-0.0450	615.8	6.940	700.0	10.0	10.0	1.000
Front_wm_14_M2	set	1	326.02	0.4000	326.0	7.400	600.0	10.0	10.0	1.000
Front_wm_16_M0	set	1	615.90	0.1170	615.8	7.100	700.0	10.0	10.0	1.000
Front_wm_16_M1	set	1	362.20	0.3080	362.2	7.200	600.0	10.0	10.0	1.000
Front_wm_16_M2	set	1	615.98	-0.0250	615.8	6.960	700.0	10.0	10.0	1.000
Front_wm_18_M0	set	1	398.48	0.1240	398.5	7.200	600.0	10.0	10.0	1.000
Front_wm_18_M1	set	1	615.94	-0.0110	615.8	6.980	700.0	10.0	10.0	1.000
Front_wm_18_M2	set	1	616.14	-0.0140	615.8	6.940	700.0	10.0	10.0	0.500
Front_wm_12_M3	set	1	326.00	0.1000	326.0	7.000	450.0	10.0	10.0	0.500
Front_wm_12_M4	set	1	616.06	0.0130	615.8	6.960	700.0	10.0	10.0	0.500
Front_wm_12_M5	set	1	362.24	-0.0200	362.2	7.010	450.0	10.0	10.0	0.500
Front_wm_14_M3	set	1	615.96	0.0320	615.8	7.000	700.0	10.0	10.0	0.500
Front_wm_14_M4	set	1	398.46	0.1840	398.5	7.300	450.0	10.0	10.0	0.500
Front_wm_14_M5	set	1	616.06	0.1190	615.8	7.060	700.0	10.0	10.0	0.500
Front_wm_16_M3	set	1	615.82	0.0300	615.8	14.950	700.0	10.0	10.0	0.500
Front_wm_16_M4	set	1	326.00	0.2120	326.0	15.220	450.0	10.0	10.0	0.500
Front_wm_16_M5	set	1	616.06	0.0620	615.8	15.000	700.0	10.0	10.0	0.500
Front_wm_18_M3	set	1	362.20	0.0520	362.2	15.240	450.0	10.0	10.0	0.500
Front_wm_18_M4	set	1	615.82	0.0460	615.8	14.990	700.0	10.0	10.0	0.500
Front_wm_18_M5	set	1	398.52	0.1200	398.5	15.000	450.0	10.0	10.0	0.500
Front_wm_14_M6	set	1	616.22	0.0450	615.8	15.010	700.0	10.0	10.0	0.500
Front_wm_14_M7	set	3	464.82	1.2740	415.8	10.000	700.0	10.0	10.0	0.500
Front_wm_14_M8	set	1	325.98	1.4240	326.0	10.250	600.0	10.0	10.0	0.500
Front_wm_14_M9	set	3	461.70	1.0420	415.8	10.000	700.0	10.0	10.0	0.500
Front_wm_14_M10	set	1	362.20	1.1400	362.2	10.300	600.0	10.0	10.0	0.500
Front_wm_14_M11	set	3	462.66	0.8320	415.8	10.060	700.0	10.0	10.0	0.500
Front_wm_14_M12	set	1	398.48	1.3480	398.5	10.410	600.0	10.0	10.0	0.500
Front_wm_14_M13	set	3	461.60	0.5130	415.8	10.020	700.0	10.0	10.0	0.500
Front_wm_16_M6	set	1	616.00	-0.1110	615.8	7.100	700.0	10.0	10.0	0.500
Front_wm_16_M7	set	1	326.06	-0.2800	326.0	6.700	600.0	10.0	10.0	0.500
Front_wm_18_M6	set	1	616.04	-0.2130	615.8	6.940	700.0	10.0	10.0	0.500
Front_wm_18_M7	set	1	362.16	0.1900	362.2	7.150	600.0	10.0	10.0	0.500

- Simulation shows FT sees high background flux
- To balance data rate GEM layers are distributed on 4 vtp

Impact on GEM background rate (GEP-3,  $Q^2 = 12.04 \text{ GeV}^2$ ), Front Tracker  
SBS front tracker

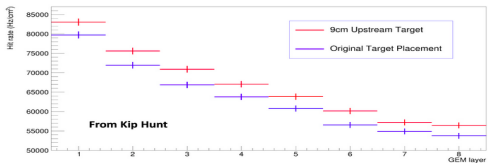


UCONN 9/3/24

SBS Software Working Group Meeting

9

Impact on GEM background rate (GEP-3,  $Q^2 = 12.04 \text{ GeV}^2$ ), Back Tracker  
SBS back tracker



UCONN 9/3/24

SBS Software Working Group Meeting

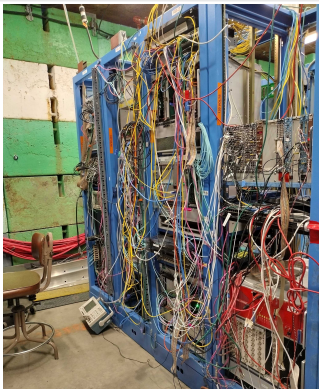
10

				2	0
				3	1
				4	2
	VTP Fiber		Front tracker XW L0	5	3
				6	4
				7	5
				8	6
	VTP Fiber		Front tracker XW L1	9	7
				10	8
				11	9
				12	10
	VTP Fiber		Front tracker UV L2	13	11
sbsvtp5				14	0
				15	1
	VTP Fiber		Front tracker UV L3	16	2
				17	3
				18	4
				19	5
	VTP Fiber	SBSVME32	Front tracker UV L4	20	6
				2	8
				3	9
sbsvtp3	VTP Fiber		Front tracker UV L5	4	10
				5	11
				6	0
				7	1
				8	2
	VTP Fiber			9	3
				10	4
				11	5
vtp4	VTP Fiber		Front tracker XY L6	12	6
				13	7
				14	0
				15	1
				16	2
	VTP Fiber			17	3
				18	4
vtp2	VTP Fiber	INTELBMPD2	Front tracker XY L7	19	5
				20	6

## DAQ..

 Full Setup

- APVs: 1620 ( 207,360 channels)
- MPDs: 94 (on 6 crates)
- payloads: 24
- vtp: 4

 CODA is configured for GEp (Alex, Ben)

# Installation and Tests

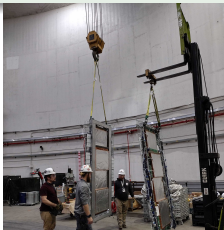
# Tests on the Floor

- ❑ All layers were flushed with nitrogen for weeks before any tests
- ❑ All chambers (**except L15**) tested at 3650V for HV stability for couple of days
  - For cosmics: chamber were flushed with ArCO<sub>2</sub> mixture
  - 2 days of data were taken for FT(Forced to clear the space on the ground)
  - Cosmic data helped us to find issue with APVs, backplanes and MPDs(replaced 4)



## Layer 15

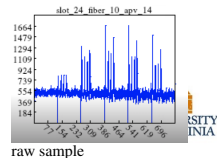
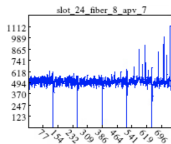
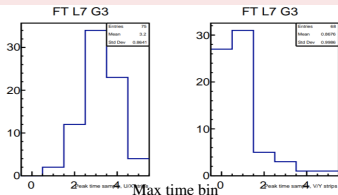
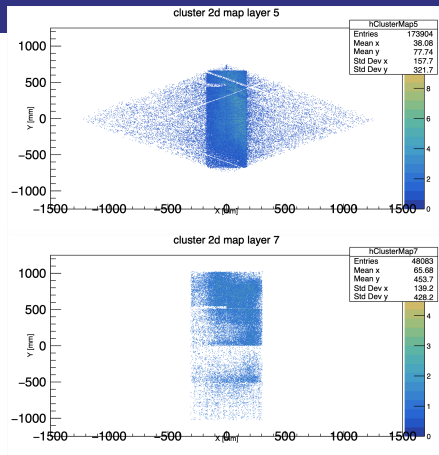
- ❑ 4 chambers tested in test lab
- ❑ Installation(chamber, backplanes, APVs, LV and fans) on frame done in EEL
- ❑ Coupled with L14 and inserted in RT



# Initial Cosmic Testing

## Key Points

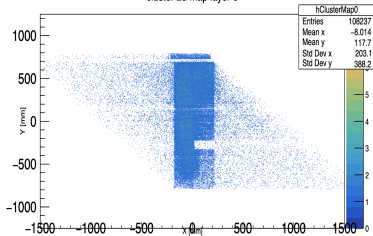
- ❑ Overall, data was good, and detectors were operating as expected
- ❑ Several problems were diagnosed and treated during our first round of cosmic testing
  - Mapping issues were corrected
  - Scintillator gain matching was problem
  - Global latency adjustments, but also individual MPD latency adjustments
  - The data helped us to establish configuration files for Xinzhan's data viewer and database for **replay** script



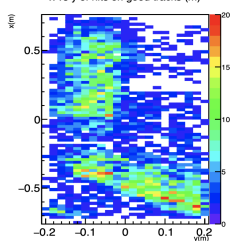
# Tracking

- ❑ All plots have less events to one side (same physical side for all)
- ❑ Detectors are efficient in that area still
- ❑ Suggest poor trigger
  - Most likely culprit is the new scintillator we got from ESB

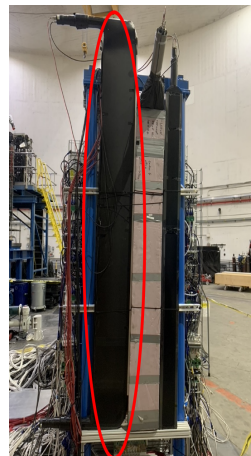
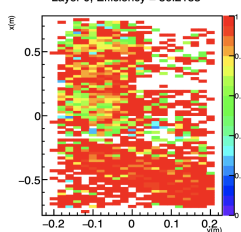
cluster 2d map layer 0



x vs y of hits on good tracks (m)

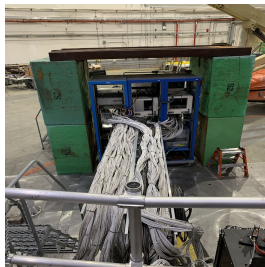
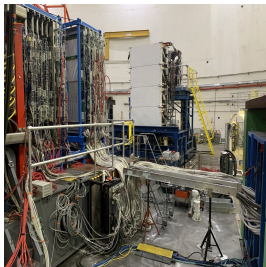


Layer 0, Efficiency = 86.2183



# Installation on platform

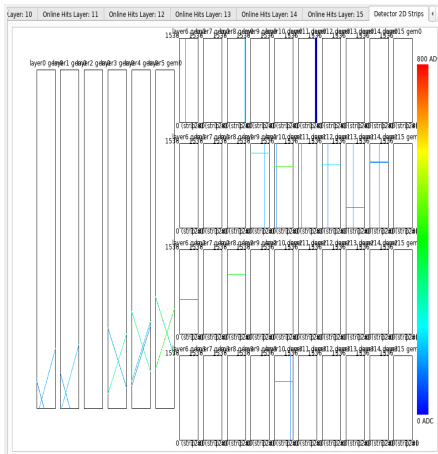
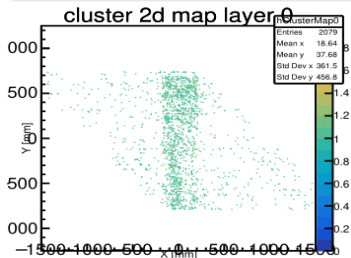
- ❑ Both FT and RT on platform (FT still need to move by  $\sim 6$ " towards target)
  - Gas lines connected to all chambers (tested prior)
  - Installed scintillators
  - LV and HV line connected
  - HDMI cables connected to MPD (slack near platform)



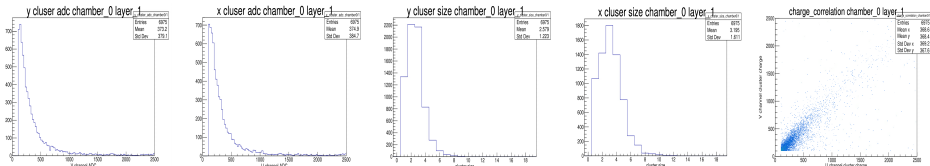
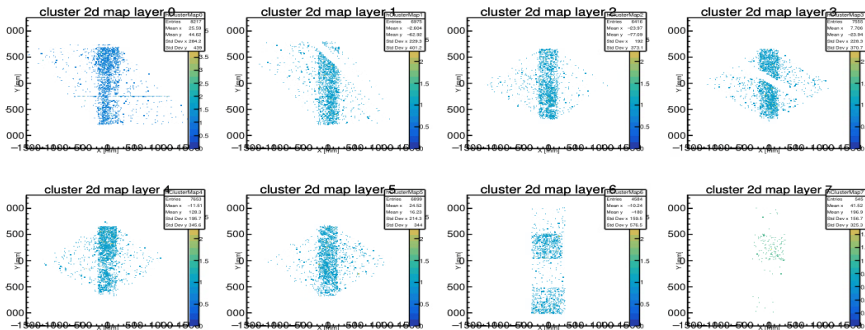


# Current Status

- ❑ Both FT and RT is configured to 4 vtp
- ❑ Low level test conducted, found expected behavior
- ❑ DAQ is configured for GEP
- ❑ Taking cosmic data(rate < 0.5 Hz)
- ❑ Latency adjustment is going on (low rate is delaying the process)

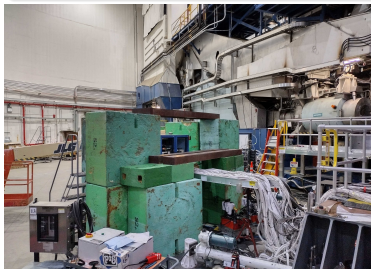
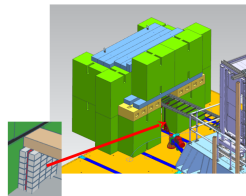


## Current Status..

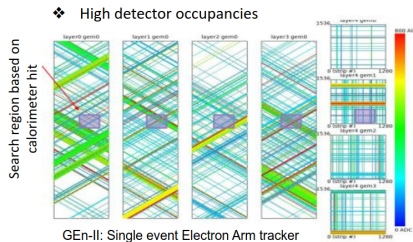


# Work in progress

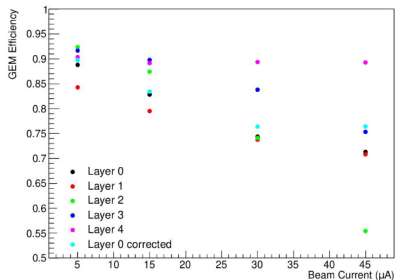
- Shielding Installation
- Latency adjustment
- official SBS-replay script
  - Currently, replay scripts are only configured for FT(up during our initial cosmic testing)
  - New Database mapping files have been made for both the FT and RT in the experimental(current cosmic) configuration
- Next steps are to implement full GEM setup to do tracking with cosmic data
- GEM document for shift takers in progress



# High Rate Challenge for Tracking



❖ Tracking efficiency drops as rate increases



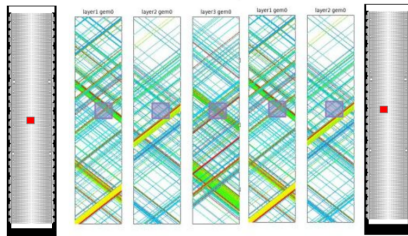
## High rate conditions lead to:

- Drop voltage on GEM protective resistor (solved by multichannel power inputs)
- Large number of 2D hit combinations
- large number of tracks
- Increase difficulty in track finding

# Pixel Chamber

## Improving track reconstruction by adding two Pixel GEM layers

- ❑ Pixel GEM layers
  - Triple-GEM amplification
  - Pixel readout:  $0.9 \times 0.9 \text{mm}^2$
  - Active area  $40 \times 40 \text{cm}^2$
- ❑ Applying coincidence condition between two pixel layers, resolve tracking ambiguities caused by uncorrelated bkg hits
- ❑ Narrow down the search area for hits in the subsequent 2D-strip-readout, Accelerate track-finding process under SBS condition



## Status

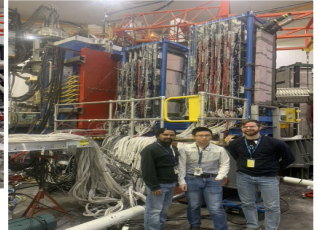
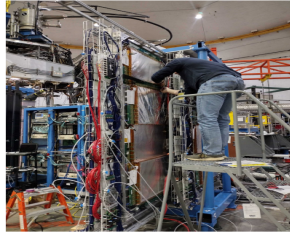
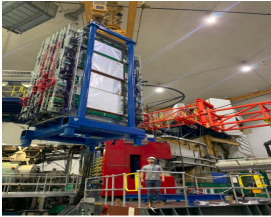
- ❑ Detector design at UVA is complete
- ❑ The procurement of components is underway

**It is planned to have the chambers ready by April, but the actual delivery time depends on when the components from CERN will arrive**

# Summary

- Chambers were repaired and HV stress test conducted for stability at 3650V
- Whole new layer is installed on RT
- Gas system is upgraded with new filters (dual protection) and new regulator installed in gas shed
- Faulty APVs, MPDs and backplanes were replaced
- GUIs for HV, Gas system and experts updated
- Latency adjustment is going on
- SBS-replay script has to update, configuratin for DB is setup
- We will take cosmics till FT need to move at its place.
- Pixel GEM is underway

Thank you and query please. . .



**Jacob McMurtry**  
**Ching Him Leung**  
**Asar Ahmed**  
**Ibrahim Albayrak**

**Anurudha Rathnayake** : apologies for not in the picture

### Special thanks to

- Vimukthi Gamage
- Holly Szumila-Vance
- Chandan Ghosh
- Xinzhan Bai

