





Update on INFN GEMs for BigBite

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2/18/2021

SBS Collaboration Meeting

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Upcoming Experiments: GMn, GEn-RP, nTPE, and WAPP

2 INFN XY GEMs

GEMs used as tracking detectors, with high-resolution ~100 μm in high luminosity environment





INFN GEM room in Test Lab at Jlab, Feb. 2021

MPD Readout (VME mode) – JLab DAQ



Cosmic stand: scintillators for trigger on top and bottom, (top to bottom) chamber J4, J3, J0, J2.

All chambers on cosmic stand have metal cable trays, except chamber J3.



Chamber J1, stored on blue chest. Previously tested on cosmic stand.



Main Activities from Oct. 2020 to Feb. 2021

- 1. Replaced plastic cables to metal cable trays and reconnected all cables for chambers J0 and J2. Chamber J4 had metal cable trays before Oct. 2020. Chamber J3 still needs cable tray replacement.
- 2. Resolved DAQ/Electronics issues so that GEM readout is complete for all chambers, except shorted sectors. Took cosmic data and high voltage scan as verification.
- 3. DAQ upgraded from CODA 2 to CODA 3
- 4. While taking cosmic data and performing high voltage scan a sector on lowest module, M23, of chamber J4 shorts. Currently M23 of J4 inoperable.
- 5. Developed procedure for replacing short carbon fiber pieces of constructed GEM chambers. This is necessary because short carbon fiber pieces require machining to be installed on BigBite GEM frame.
- 6. Completed replacement of short carbon fiber pieces for chamber J0, resulted in multiple electronics disconnection. Was able to reconnect all electronics, but required more time. Used this as opportunity to refine procedure.
- 7. Constructed and tested BigBite GEM frame horizontally. Installed BigBite GEM frame in TEDF building vertically.
- 8. Horizontally tested insertion/removal of a realistic GEM chamber in BigBite GEM frame. Description of this process is being used to developed installation of GEM chambers vertically in TEDF.
- 9. Took cosmic data, as final check before moving chambers to TEDF. Found issues in cosmic data on chambers J4 and J3. Resolved Latency problem on chamber J2 due to 10-meter digital cables.
- 10. Current: Preparing TEDF for vertical testing of insertion/removal of a realistic GEM chamber. Installing 2 GEMs from INFN GEM room to BigBite frame in TEDF.
- 11. Current: Troubleshooting Electronics/DAQ to resolve readout issues on chambers J3 and J4.

XY Hit Map for cosmic run Nov. 2019



Electronics/ Cable Connection issues for MPD 18

Troubleshooting GEM readout electronics and DAQ



- Example for MPD 7 from Oct. 22 2020
- Checks configuration of APV cards, and analog response of APV cards.
- Does not check trigger response

2/18/2021

Reproducible patterns in both type of plot indicate which part of the GEM readout electronics needs manipulation



- Example for chamber J2 from Nov. 2 2020 run # 4643
- Checks configuration of APV cards, and analog response to a trigger
- Does not check proper latency setting

XY Hit Map for cosmic run Nov. 2019



Electronics/ Cable Connection issues for MPD 18

XY Hit Map (Cosmic run 147) Nov. 6 2020

(statistics: ~ 504000 events) AR/CO2 gas flow ~ ½ of "nominal" values HV = 4100V Includes pedestal subtraction For BigBite: chambers J0 and J2 For Recoil Polarimeter: chambers J3 and J4

- Plot generated by offline analysis (Andrew Puckett's code).
- Problems with readout electronics for MPD 7 were resolved by replacing APV cards and backplanes after troubleshooting with Low Level Histograms and Pedestal RMS plots
- Problems with readout electronics for MPD 18 were resolved by manipulating cable connections and electronic components.
- Soldered Resistor on upper module of J2 works at higher voltage

200

Y (mm)



Track-based Efficiency (Cosmic run 147) Nov. 6 2020

(statistics: ~ 504000 events) AR/CO2 gas flow ~ ½ of "nominal" values HV = 4100V Includes pedestal subtraction For BigBite: chambers J0 and J2 For Recoil Polarimeter: chambers J3 and J4

- Plot generated by offline analysis (Andrew Puckett's code).
- For chambers J4, J3, J0 efficiency is greater than 90%, except for known shorted sectors.
- Chamber J2 efficiency is
 lower in this plot due to
 incorrect latency, digital
 cables are 10-meters long
 instead of 20-meters long.
 Altered latency for J2 to
 proper value in Feb 2021.
 Verified with cosmic data.



X & Y Residuals (Cosmic run 147) Nov. 6 2020



High Voltage (HV) Trip, M23 of Chamber J4 Nov. 7-10 2020



Zoom-in HV Trip, M23 of Chamber J4 Nov. 7-10 2020



- HV for M23 of J4 corresponds to HV channel 5.
- M23 is a newer module, so maybe it was not fully tested at HV of 4150 V.
- HV power supply firmware internally has a trip time of 500 milliseconds. This value is configurable.
- M23 of chamber J4 does not recover HV.
- Will need to determine shorted sector on M23 of J4 with heat camera while applying about 100 V of HV. Shorted sector will then be disabled on M23.

Preliminary Avg. Efficiency vs HV from Nov. 2020 cosmic data



- Each module is portioned into 2D bins
- Average Efficiency is the mean of all the local efficiencies in for the 2D bins
- Error bars are the RMS of all the local efficiencies in the 2D bins. Represent the variation of the efficiency for the module.
- Currently these plots include dead sectors and spaces between modules.
- Chamber J2 has incorrect latency.
- Chamber J4 has flat plots, probably related to already in plateau or problem with calculation

Preliminary X/Y Residual vs HV from Nov. 2020 cosmic data



- Expect to see that residuals have no dependence on HV. Possibly slight improvement as HV increases.
- Expect about 0.01 mm variation in residual, so these are acceptable.
- X-Residuals being greater than Y-Residuals is most likely due geometry GEM module readout strips.

XY Hit Map (Cosmic run 421) Feb. 8-9 2021 Red on J4 is most

(statistics: ~ 503000 events) AR/CO2 gas flow ~ "nominal" values HV = 4000V



For BigBite: chambers JO and J2 For Recoil Polarimeter: chambers J3 and J4

- Red on J4 is most likely due to issues with readout electronics on MPD 7
- Green is the module M23 with a shorted sector.
- Blue on J3 is most likely due to issues with readout electronics on MPD 15
- For red and blue, curious part is Low Level Tests, Pedestals, and DAQ do not provide errors. Present nominal response.
- Troubleshooting ongoing.

BigBite GEM frame construction and install Deb 7. 2020 - Feb. 3 2021







Top Left: Fully Assembled BigBite GEM Frame Top Right: Misaligned track mount and angle bracket. Hall A Techs drilled larger holes on track mount Bottom left: Misaligned hole on the steel weldment, likely due to welding tolerance. Hall A Techs drilled larger holes on the angle bracket



Above Left: Test with spare UVa UV GEM frame and BigBite Frame

Above Right: Test with spare INFN GEM frame and BigBite Frame

BigBite GEM frame construction and install Deb 7. 2020 - Feb. 3 2021







Left: Completed frame leaving Test Lab on forkliftRight: Frame on BigBite Detector, Zeke left and Holly rightMiddle: Frame on crane in TEDF High Bay being moved into position

Horizontal Insertion/Removal of INFN GEM in BigBite Frame Jan. 26 2021



Left: INFN GEM (chamber J1) on transportation cart, next to BigBite Frame.

Middle: J1 in back most tracks of BigBite Frame. Orientation: Front is floor. (Left to Right): Sean, Sebastian, Zeke, and Holly as photographer.

Right: J1 in 2nd from front tracks of BigBite Frame and UV Frame above.

Comment: Mechanical clearance was close, but fine. Aligning GEM on tracks was straightforward. Useful for determining vertical installment procedure.

Lab (limited) activities in Italy

Ordered ultrasound bath to try clean rejected single foils and module with shorted sectors

Adapted a vacuum chamber for GEM dryer (after cleaning) with picoAmp resistivity monitor





Almost continuous N₂ gas flow (since Spring/2020) into 2 GEM modules and ~monthly check of foil resistances (no relevant changes registered so far)

Hoping to get a last module assembled once the clean room will be repaired (order submitted)

Ph.D. Thesis Outlook:

- Installation, commissioning, hardware, and analysis related to INFN GEMs for BigBite and Recoil Polarimeter. In general, developing knowledge about GEMs, GEM readout electronics, and DAQ.
- INFN GEMs will be used for GMn, GEN-RP, nTPE, and WAPP
- Tentative Thesis Topic: Analysis of nTPE
- Software Interest: GEM Cluster/ Tracking software
- Participate in data taking, curating data, and GEM hardware support for GMn, GEn-RP, nTPE, WAPP

Thanks for Listening! Questions?



XY Hit Map (Cosmic run 141) Nov. 4 2020

Chamber JO

(statistics: ~ 514000 events) AR/CO2 gas flow ~ ½ of "nominal" values HV = 4000V Includes pedestal subtraction

Chamber J4

For BigBite: chambers J0 and J2 For Recoil Polarimeter: chambers J3 and J4

Chamber J2

- Plot generated by offline analysis (Andrew Puckett's code).
- Soldered Resistor on upper module of J2 is not working properly



Chamber J3

Track-based Efficiency (Cosmic run 141) Nov. 4 2020

(statistics: ~ 514000 events) AR/CO2 gas flow ~ ½ of "nominal" values HV = 4000V Includes pedestal subtraction For BigBite: chambers J0 and J2 For Recoil Polarimeter: chambers J3 and J4

- Plot generated by offline analysis (Andrew Puckett's code).
- For chambers J4, J3, J0 efficiency is greater than 90%, except for known shorted sectors.
- Chamber J2 efficiency is lower in this plot due to incorrect latency, digital cables are 10-meters long instead of 20-meters long.



X & Y Residuals (Cosmic run 141) Nov. 4 2020



Pedestal RMS vs Channel #, Run 381 Feb 2 2021, HV=0 V, N2 gas • Plots for each APV card by MPD on Chamber JO.

 Blue is improved. Green is manipulated, but no improvement. Most likely due to impedance mismatch or noise inherent to the module.



Pedestal RMS vs Channel #, Run 381 Feb 2 2021, HV=0 V, N2 gas • Plots for each APV card by MPD on Chamber J4.

 Blue is improved. Green is manipulated, but no improvement. Most likely due to impedance mismatch or noise inherent to the module.



Pedestal RMS vs Channel #, Run 381 Feb 2 2021, HV=0 V, N2 gas

- Plots for each APV card by MPD on Chamber J2.
- Blue is improved. Green is manipulated, but no improvement. Most likely due to impedance mismatch or noise inherent to the module.



Pedestal RMS vs Channel #, Run 381 Feb 2 2021, HV=0 V, N2 gas

- Plots for each APV card by MPD on Chamber J3.
- Blue is improved. Green is manipulated, but no improvement. Most likely due to impedance mismatch or noise inherent to the module.



Swapping Short Carbons for Chamber J1 (Jan. 25 2021)





Left: Aluminum bar support with triangular constraining pieces to support long carbon fiber pieces. No interaction with GEM module window Right: Foam wedges to keep the carbon fiber pieces from interacting with the GEM module

In general no visible disconnects between Kapton Fingers and APV cards. Better understand this procedure and is optimized with 2 people.



Track-based Efficiency (Cosmic run 421) Feb. 8 2021

(statistics: ~ 503000 events) AR/CO2 gas flow ~ "nominal" values HV = 4000V Includes pedestal subtraction

Chamber J4 Chamber J3 Chamber JO Chamber J2 (mm) × 800 (mm) × ⁸⁰⁰ (m m m 0.9 0.9 × 600 600 600 60 0.8 0.8 0.8 400 40 400 400 0.7 0.7 200 200 20 200 0.6 0.6 0.5 0.5 0.4 -200 -200 0.3 0.3 0.3 -400 -400 -4000.2 0.2 -600 -600 -6000.1 -800--200 -100 0 -200 -100 0 100 200 -200 -100 0 100 200 100 200 -200 -100 0 100 200 Y (mm) Y (mm) Y (mm) Y (mm)

For BigBite: chambers JO and J2 For Recoil Polarimeter: chambers J3 and J4

- Plot generated by offline analysis (Andrew Puckett's code).
- For chambers J0, J2 efficiency is greater than 90%, except for known shorted sectors.
- Demonstrates efficiency
 resolved for J2 after
 adjusting latency.
- J4 and J3 have bad plots because of problem with readout electronics

Summary of Algorithm for GEM Track-based Efficiency and Residuals

• A track is a group of three or more layers with hits fitting a straight line with a reduced χ^2 below some user-defined maximum.

Algorithm Summary:

- 1. For the track with the best χ^2 firing the largest possible number of layers, this projects that track to each layer, and then fills two histograms "hshouldhit_layer" and "hshouldhit_module", regardless of whether there was a hit on that track in that module or not. These histograms form the denominator for the efficiency determination. For an almost unbiased determination with a four-layer setup, this would have to require that all OTHER layers fired.
- 2. For the same track, loop over all the hits on that track and then fill histograms "hdidhit_layer" and "hdidhit_module", which represent the numerator for the efficiency determination.
- 3. The local, "track-based efficiency" is simply the ratio of the "did hit" histogram over the "should hit" histogram by layer and module.

Residual Definitions:

- "Inclusive" residuals are the difference between the reconstructed position of the hit and projected position of the fitted track, where the fitted track includes the hit in question.
- "Exclusive" residuals are the differences between the reconstructed position of the hit and the projected position of the fitted track, where the track is fitted to all OTHER hits excluding the hit in question.

GEM Module Readout Strips



APV Dataframe and Low Level Test



- the dataframe baseline