GEM upgrades for 30 MeV

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GEM upgrades

- **Funding**
- **GEM Repairs**
- **Gas**
- **High Voltage**
- **Readout**
- **People of the Group**

  Dr. Ryan Richards – postdoc, joined Sep 2023
  Dr. Dulitha Jayakodige – postdoc, joined Jan 2025
  (Ryan+Dulitha = 0.5 FTE for DL, 0.5 FTE JLAB/SBS, 1.0 FTE MUSE)
  Manjukrishna Suresh – PhD student since Fall 2020, joined DL May 2023
  (Passed Qualifier in January 2025)

  Anne Flannery – PhD student on MUSE and former Jlab/VITA trainee
  Sarashowati Dhital – PhD student on SBS since Spring 2021, GEM experience
  Krystal Scott – PSI'23; MIT'24, now MS on Acc Sci, Jlab/VITA trainee 2025-27
  Tanvi Patel – PhD student on MUSE since Fall 2017, GEMs, graduated Su'25
  Angel Christopher – MS, MUSE, since Fall 2023, GEMs, graduated Sp'26
  Ezekiel Taylor, Alexa Livingstone – new PhD students, exploring Jlab Su'26

Funding situation

- DOE grant, ~270k/yr, EC 2010, renewals in 2015, 2017, 2020, 2023
- Expiration April 14, 2026
- Renewal request for 2026-2029 submitted in Fall 2025
- Conversation with Gulshan Rai before grant expiration in early April:
  No final decision yet. Partial reviews, so far looking good.
  However, most likely, no money will be available, even if reviews favorable.
  -18% cut for university research, plus "Gemini tax" = -30% overall cut
  Multi-year grants are frontloaded, FY26 renewals affected disproportionately

- No-cost extension until June 30, 2026. Recommended, not yet approved.
  HU allowed to extend postdoc contracts provisionally.
  Unobligated (carry-over) on June 30 estimated to be $139k
  $40k which had been de-obligated from year-2 might become available again
- The no-new-monies scenario will allow to support the group until April 2027.
  In that case, consider FY27 proposal, with FY27 awards no sooner than April.
  No travel, no release time, no equipment and supplies ☹
- Need additional funds to support DarkLight for a run in Fall 2026/Spring 2027
- Expect to get final news, hopefully better news, before end of June 2026

GEM repairs

- GEM repairs (shock treatments, bypassing RP) with mixed results so far
- Next step: sustain HV longer when bypassing protection resistor, as debris has tended to cause problems again with new shorts after closing GEM
- Keep HV divider on while supplying shock HV with Megger. Estimated that HV divider stays safe, and majority of power is directed to the short
- Portable NIM supply for cleanroom (need permission), slowctrl is possible but not readily available, to supply HV through divider while GEM is open. If short reappears, use Megger again. Only close GEM after stable ops are reached.
- Insulating screws near high potential points - is it clear that this was an issue only in some cases? Is covering screws with Kapton strip sufficient?
- Done it with “Michael” (sparked before, now ok, taking cosmics data), Ishara & Malinga (reappearing shorts), Bishoy (strange inexplicable short)
- Screw insulation to be done for GEMs at TRIUMF – When? Who?

Gas

- In December'25-January'26, observed sudden catastrophic GEM failures after months of stable operations – similar reports from MOLLER, CMS, …
- Considered low-temp related de-mixing? This would temporarily increase the gain due to CO2 fallout, which could explain the sparking under load, and then lower gains overall until the bottle runs empty due to higher CO2 fraction.
  If the high rates also caused lower gains, that temporary elevated gain might have been hard to observe
  → Should consider simulations how GEM gain is affected by gas quality
- A consideration of the current actually drawn, compared to the current expected to be drawn if all of the rate was due to amplification for MIP detection, showed that there has been excess load. This could point to much higher flux of ionizing particles than trigger rate (trigger deadtime).
  E.g. it could be due to X-rays creating a steady load of charge amplification, from RF, or form n-γ processes following γ-n
- No further failures were observed after (gently) raising the gas flow
- Do we require much more gas flow? Should we create a gas mixing system to control, or to be able to alter the gas mixing ratio? Additional quench comp.?
  → Should consider analysis of gain vs rates, efficiency vs rates, with help of slowctrl plugin; pursue Garfield simulations for gain vs gas

High voltage

- Up to (neg.) 4,300V @ <1mA supplied to passive HV divider (5.5 MΩ) on GEM
- CAEN V6533N VME based (6 channels)
- 9W power limit → use only 2 channels per module;
  Using 2 CAEN modules for 4 GEMs
- SHV cables from VME to GEMs, 1 per GEM

High voltage

- **Excess current loads of several percent observed under high-rate load. At O(>1%) expect gain suppression of O(10%) in third GEM stage, as a feature of the passive HV divider in combination with 1 MΩ protection resistor.**
- **A shorted sector (e.g. in G3) changes the HV steps unfavorably; RP = 1 MΩ || R3 = 0.5 MΩ step reduces Rtot from 5.5 to 5.33 MΩ (-3%), i.e. an excess current of ~3% appears suddenly when a sector shorts. The short reduces R3 from 0.5 to 0.33 MΩ (-33%), or V3 from ~400V to ~270V. The remaining sectors will no longer amplify charge.**

- **Consider CAEN 8-channel floating supply A1515 + mainframe SY5527**
  https://www.caen.it/products/a1515b/
  https://www.caen.it/products/sy5527lc/
  Costs: $6-8k per card, $4-10k for mainframe, e.g. 2*8k+10k = $26,000 (can possibly operate 2 GEMs per card, i.e. one supply per arm)
- **This would avoid HV-divider related gain drop under load. GEM limit is far higher. JLAB SBS (GEp-V) relied on this.**
- **This would also allow to run the GEM even if a sector is shorted. All shorted sectors were edge sectors. Alternatively, "blow up" inaccessible protection resistor to disable the sector, however bearing the risk that it shorts**

High voltage

A1515

SY5527

Readout upgrades

- Jan and Ethan maxed out the DAQ speed and data throughput with the present VME based scheme
- Operating close to VME limit ~1 Gbps / 100 MB/s at T_{read} ~200 μs

- VXS/VTP scheme:
  → Use VME only to power MPD; read out optically;
  process MPD data with VTP or SSP on VXS crate, 10 Gbps
  can run 4 MPDs / 6 samples at few kHz w/o zero-suppression
  Event size: 13*6*128*(32/2)*4 = 640 kb → 5 kHz = 3.2 Gbps (factor ~3)
- VXS/VTP scheme (developed for Jlab's Coda DAQ framework, used in SBS) would require substantial integration work in order to be run under MIDAS

- Not the highest priority at this time

Action items: GEM hardware

- Complete shock treatments of Ishara and Malinga to reach stable operation
- Cosmic ray stand w/ 3 GEMs (Michael, Ishara, Malinga): 2-of-3 efficiency maps → compare with gains and efficiencies at TRIUMF, in particular for "Malinga" (fka RG1) – this should tell us if the gas played a role

- Exposure to higher particle flux: Hall D test beam (hard to get), parasitic setup in e.g. in Hall C (difficult to set up), strong source (not easily feasible), irradiation with X-ray bkg source (e.g. UVA) while triggering on cosmics (UVa);
- Use HUPCI (Hampton University Proton Cancer Institute) proton beam after hours, access to undeveloped treatment room. Can serve as pilot project to invigorate research coalition between Physics Department and HUPCI

Action items: GEM and simulation software

- **Analysis of slowctrl GEM current vs trigger rate (Dulitha started)**
- **Analysis of cluster charge (GEM current) vs trigger rate (combining GEM plugins and slowctrl), gain, efficiency (e.g. cut on elastics)**
  → this analysis can only show relative current vs rate
- **Garfield simulation of GEM performance, amplification, gain, charge per cluster, current vs rate; dependence of gas mixture, HV.**
  Use parametrized output for Geant4 digitization
  → this simulation can provide absolute GEM current drawn vs rate
- **DarkLight simulation of expected trigger rate, and particle flux into GEMs from scattering of beam on target, including cut on elastics**
  → this simulation can provide absolute trigger rate
- **Revisit FLUKA simulation of backgrounds originating from downstream beam pipe and beam dump for realistic beam parameters**

→ Can we understand the GEM excess current?
→ Can we understand the observed trigger rates?
→ What is the total flux into GEMs and scintillators?

THANK YOU! – QUESTIONS?