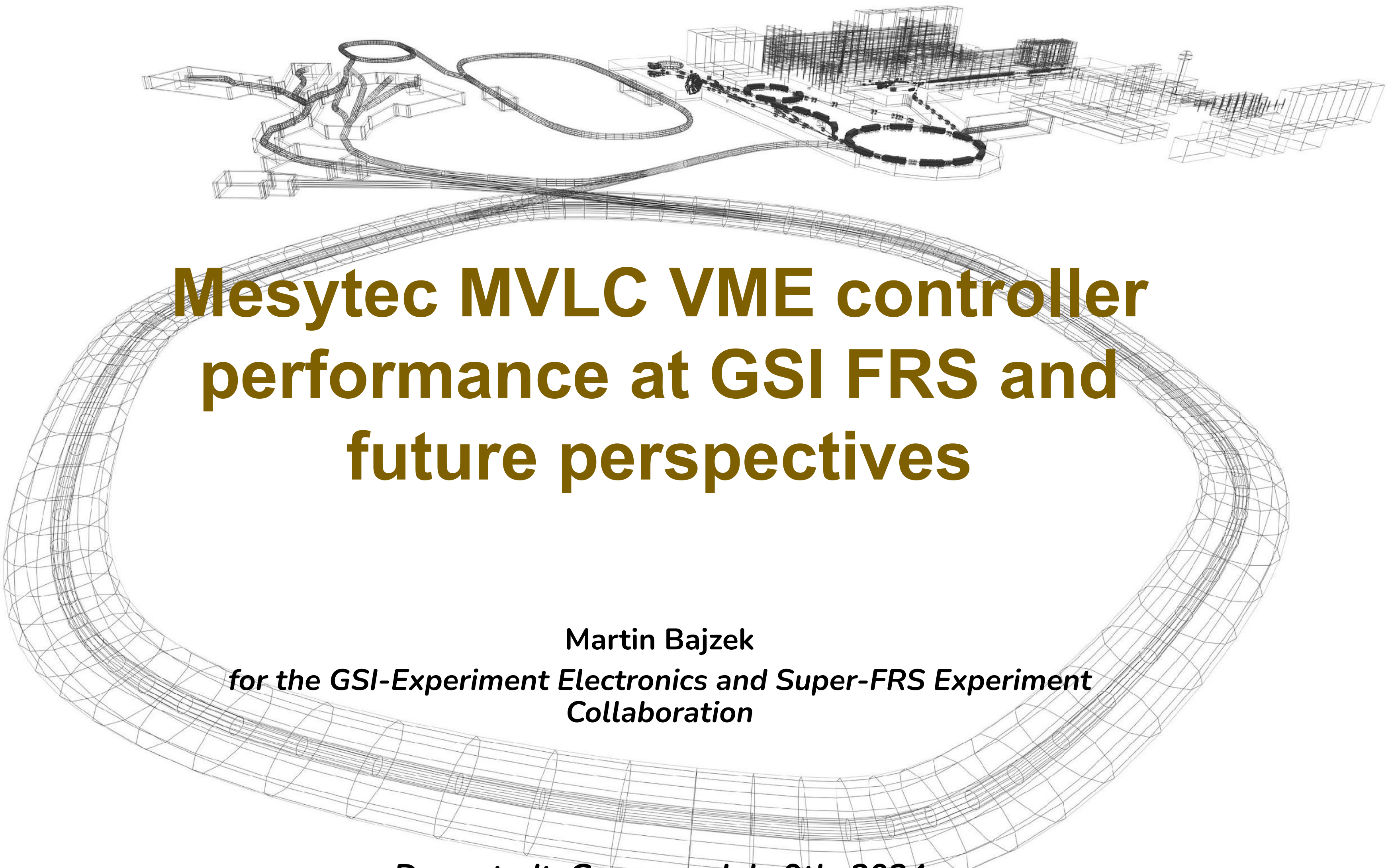

Mesytec MVLC VME controller performance at GSI FRS and future perspectives

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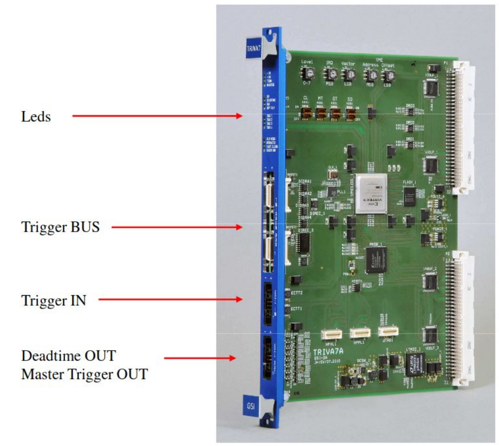
for the GSI-Experiment Electronics and Super-FRS Experiment Collaboration

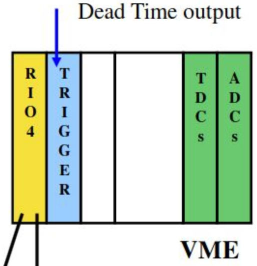
Darmstadt, Germany, July 9th, 2024

GSI DAQ - VMEbus before 2023

- VME controller CES RIO4 8070/8072 PowerPC
  - Commercially no longer available!
- Deadtime blocking with GSI TRIVA + GSI VULOM trigger modules



GSI Trigger Module:
15 Trigger Inputs, 14: start acq, 15 stop acq
Conversion Time setting
Dead Time output

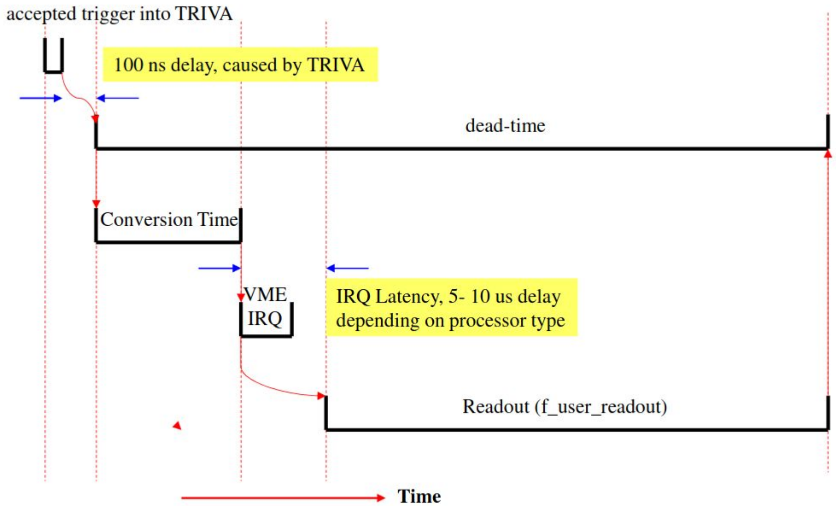


VME read Speed:

Single cycle:	7 MB/s
VME Block D32:	20 MB/s
VME Block D64:	40 MB/s
VME 2eSST:	150 MB/s

Data Monitoring: via TCP/IP sockets: GO4, ROOT, Custom Analysis Systems

Data Logging:
Tape Drives
Local Disks
NFS Disks
Remote Disks (RFIO, TCP/IP)
GSI Tape Robot (RFIO)



All images taken from: MBS (Multi Branch System), N.Kurz, EE, GSI, 2019 *https://www.gsi.de/fileadmin/EE/MBS/mbs_nov_2022.pdf*

GSI DAQ - VME in 2023+

- Adaptation of modern Mesytec MVLC, FPGA-based VME controller
- Low-latency, low-deadtime VME readout
- Trigger and I/O logic module
- Open-source driver & utility libraries in C/C++
- MVME software GUI package
  - DAQ and “analysis” software
  - Initialization and readout sequences
  - MVLC trigger I/O logic
- USB-3 connection to a Linux PC
- Original software (C++) incompatible with MBS integration
- Original MVLC gateware - no handle for:
  - GSI TRIVA trigger module
  - GSI VETAR timestamp module

Image taken from: https://www.mesytec.com/products/nuclear-physics/MVLC.html

MVLC/MVME integration into MBS

- MVLC catches TRIVA IRQ => dispatches readout action
- Adaptation of timestamp readout into MVLC sequences
- Initialization and readout sequences prepared for most VME modules used at GSI

- Firmware enhancements provided by Mesytec
- Converting MVLC USB data stream into GSI standard MBS LMD format
- MVME GUI loads MVLC sequences
- Custom command line tool ‘mec’ to read/write on the VMEbus
- All VME modules used at GSI proven to work
- Performance improvement compared to RIO4:
  - **Factor 3** for usual VME setup
  - Factor 5 for 2eSST readout of CAEN V1742 [WASA experiment]

- Changing from RIO4 to MVLC requires no additional HW changes!

- **No more f_user.c**

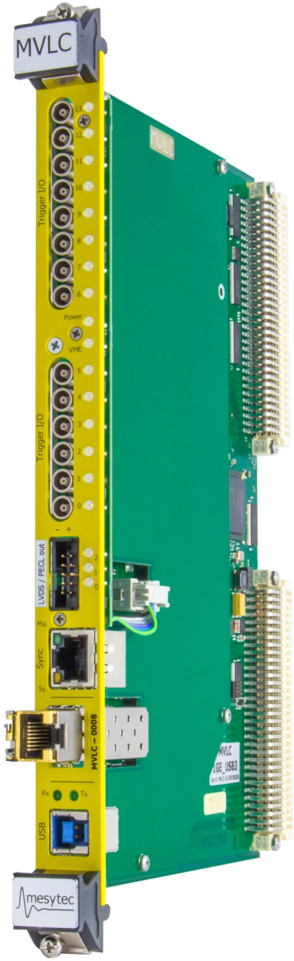
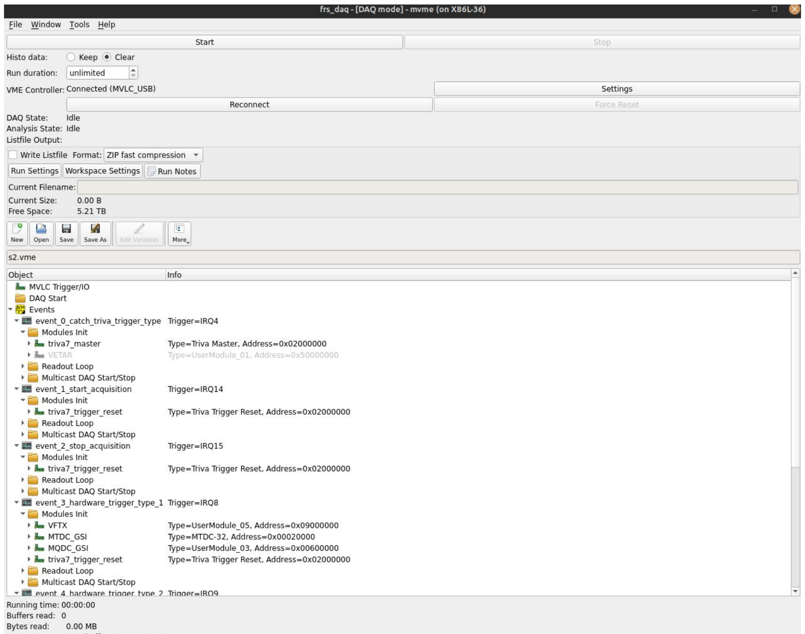
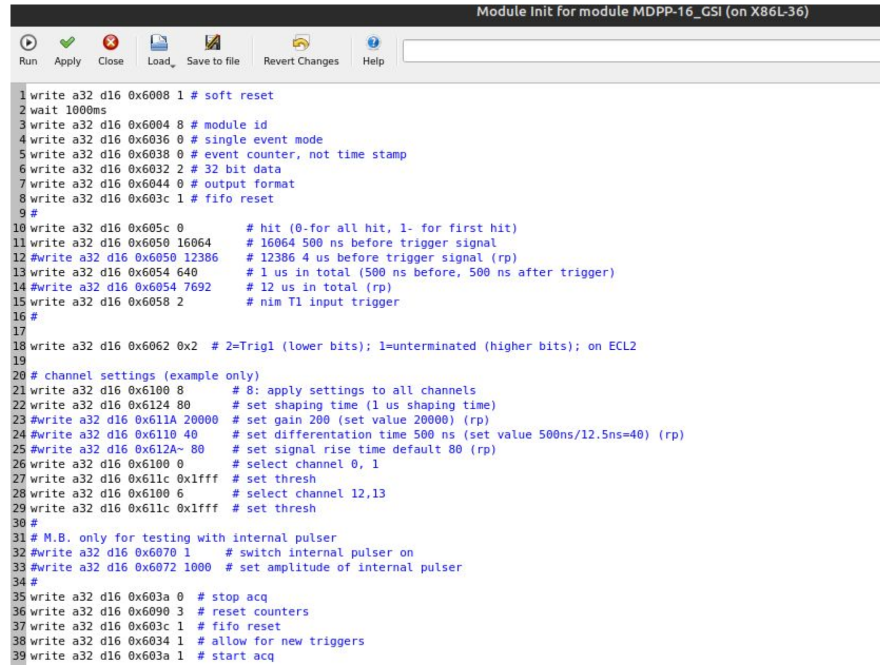


Image taken from: https://www.mesytec.com/products/nuclear-physics/MVLC.html

Graphical User Interface (MVME)

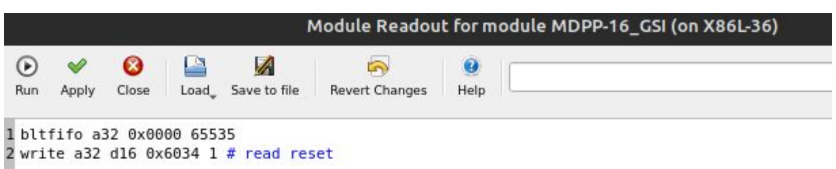


Main MVME gui window



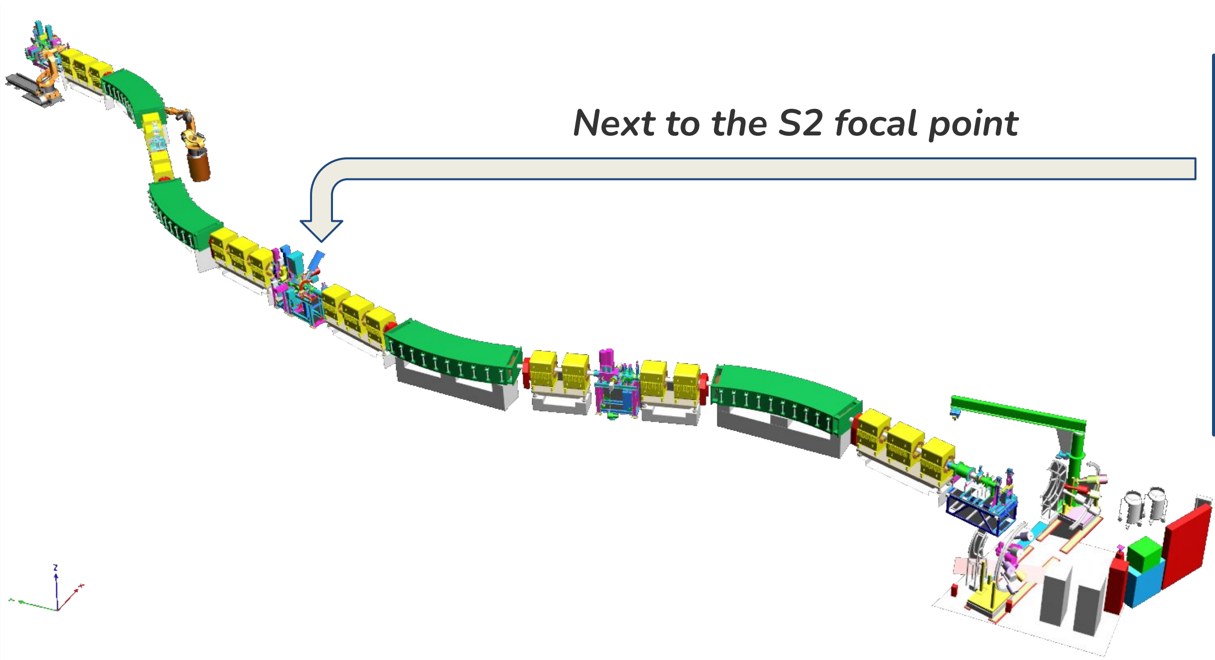
Module initialization

- NURDLIB unsupported
- Hand writing values into registers
- Replaces `f_user_init(...)` function

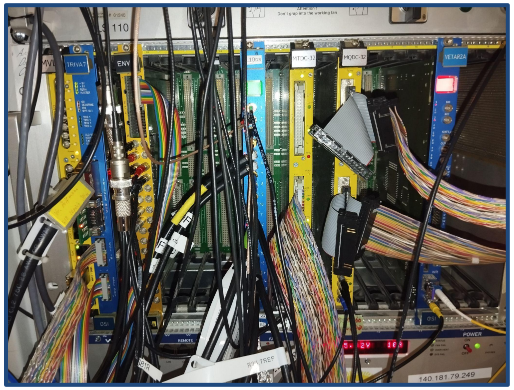


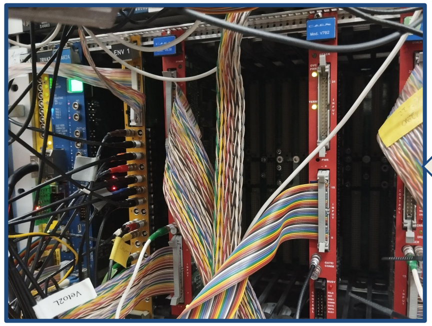
Readout loop - replaces `f_user_readout(...)`

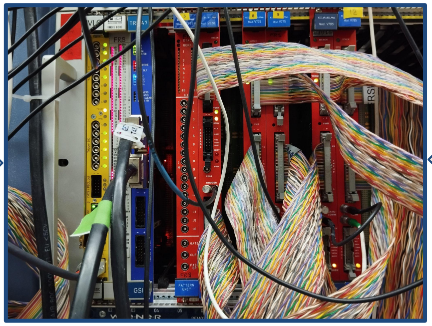
GSI FRagment Separator (FRS) DAQ

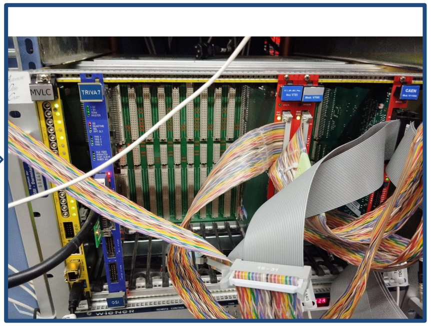


Next to the S2 focal point







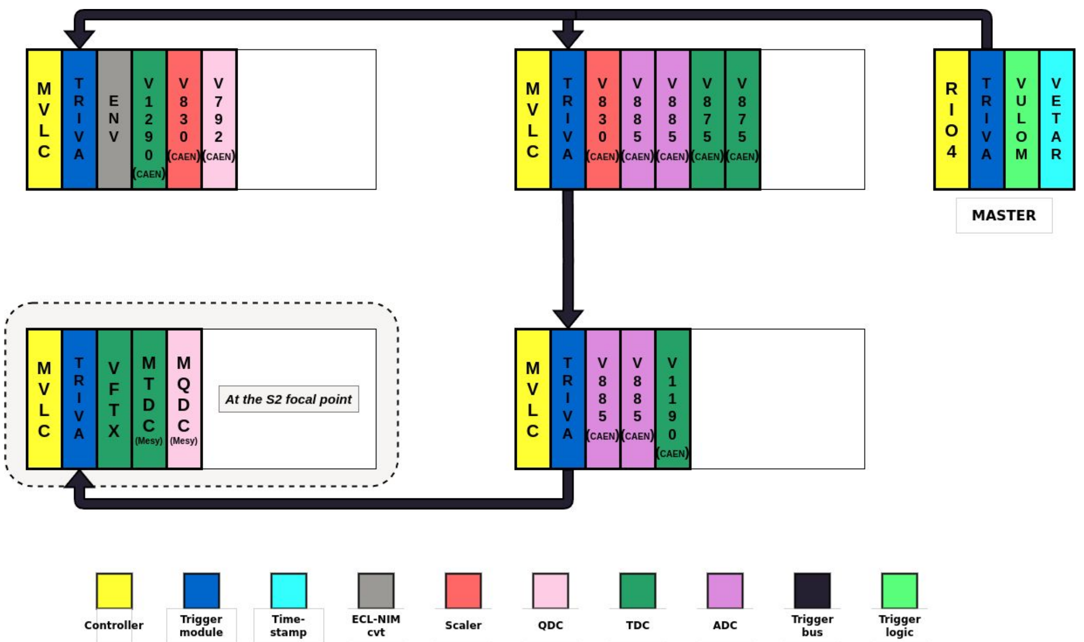


Located in the control room

MVLC in FRS DAQ

- Triggered readout mode
- 4 possible trigger types
    - Types 3,4 reserved for beginning-of-spill and end-of-spill ✅
- Synchronization of different systems with White Rabbit timestamp ✅
- RIO4 still used for VULOM
    - TRLO II isn't supported ❌
- **DAQ setup:**
- 4-5 VME crate system linked via trigger bus
- Four crates locally in the control room and one in an experimental cave at a focal point of the separator

- Optional 6th crate for MUSIC:
    - MVLC
    - TRIVA
    - MDPP16
    - VETAR



Initial results of MVLC integration

Pulser tests

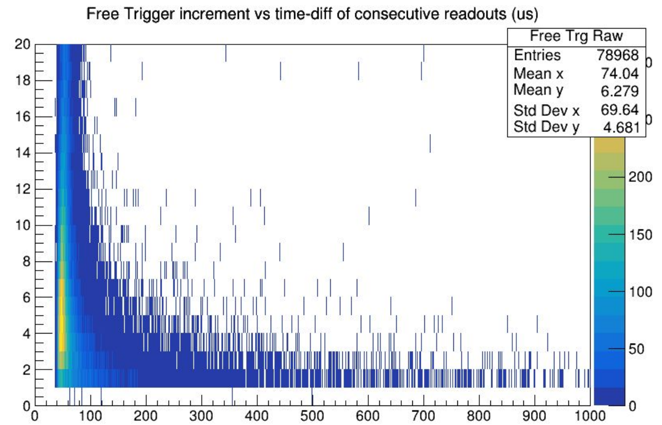
- RIO4 readout of single crate - 11-15 kHz (data rate 4 MB/s)
- MVLC readout of single crate - 33-40 kHz (data rate 12 MB/s)
  - Factor ~ 2.5 in readout speed, ~ 3 in data rate
- Tests performed with a 1 MHz input trigger (before deadtime)
- 4 crate system at ~ 30 kHz, depending on the signal load
  - Trigger rate goes down to 20-25 kHz, still a consistent factor 3 improvement compared to RIO4

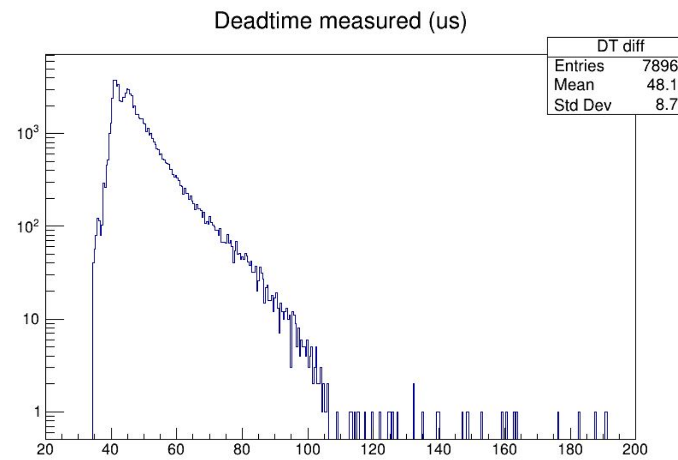
First beamtimes of 2024

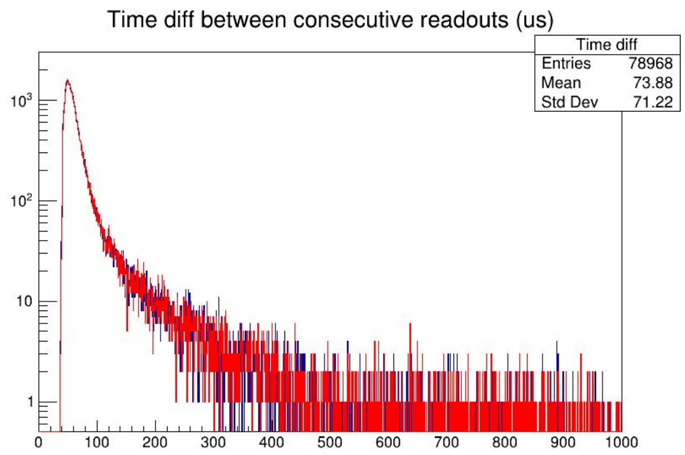
- MBS with MVLC used in approved experiments of 2024
- Conversion times adjusted to zero-latency of MVLC readout
  - For stability, kept higher than usual: **15us, 18us, 20us, 20us**
- Deadtime locking with GSI TRIVA+VULOM proven to work with multiple trigger types
- Readout actions in multi-hit TDC's adjusted compared to before
  - BLT terminated with BERR

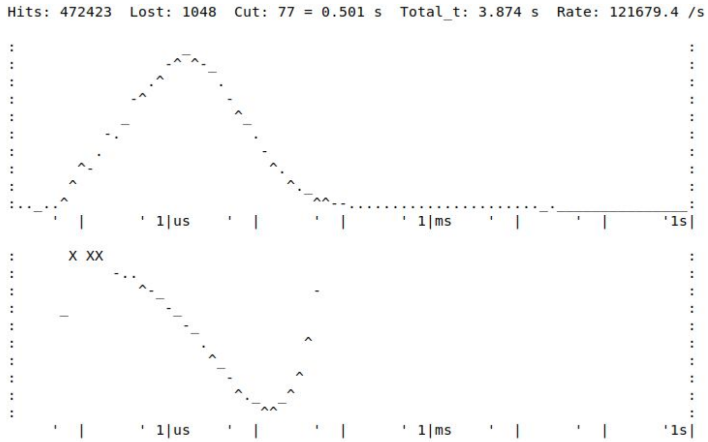
MVLC integration results

- ^{100}Mo particle rate: ~250k/spill, 2s spill duration, CVT's = **15, 18, 20 us**



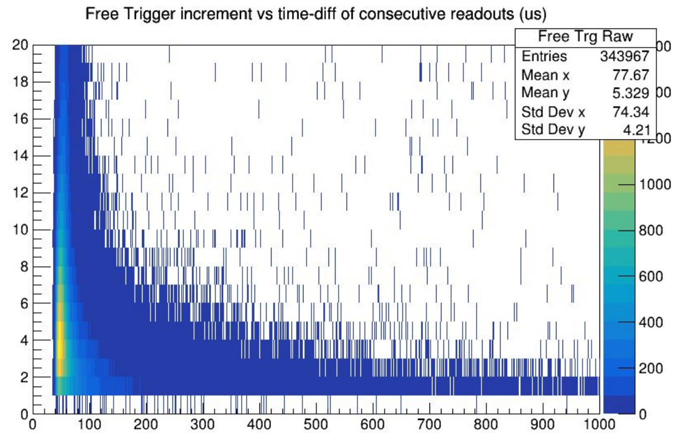


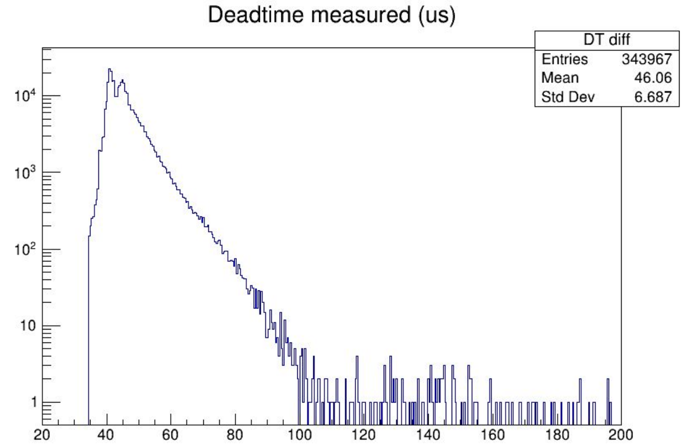


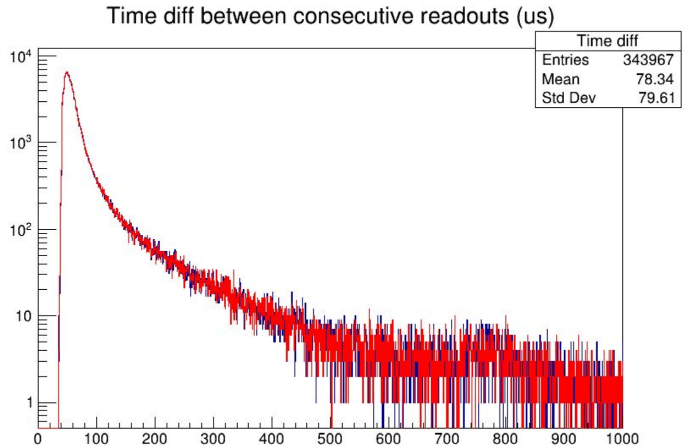


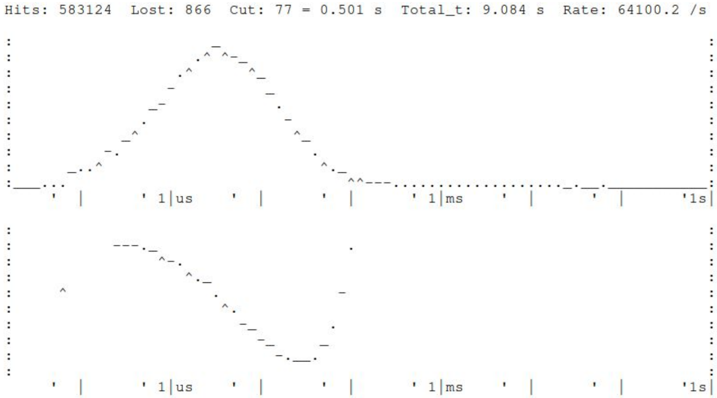
MVLC integration results

- ^{100}Mo particle rate: ~140k/spill, 2s spill duration, CVT's = **15, 18, 20 us**



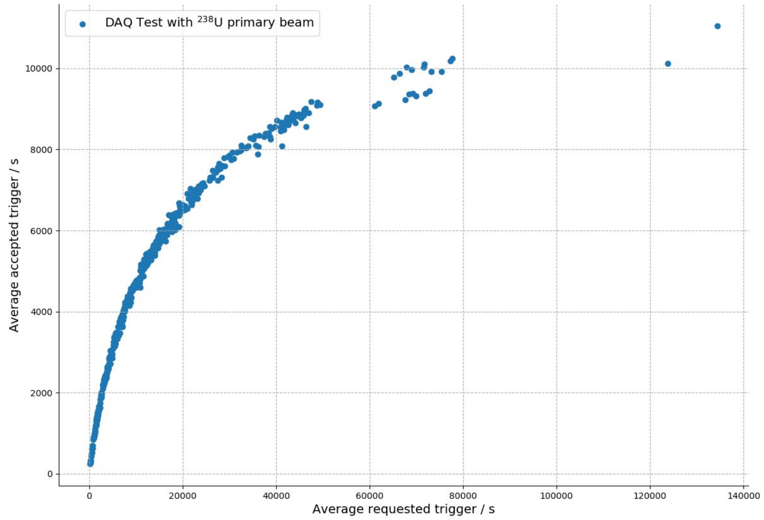




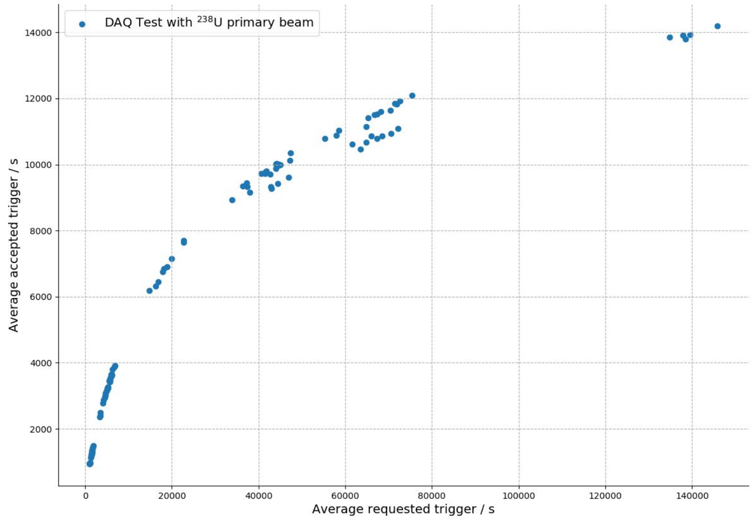


MVLC integration results (III)

- FRS DAQ test shift in May 2025 with ^{100}Mo beam @500 MeV/u
- Benchmarked performance of all three MVLC crates
- Accepted trig / requested trig (livetime ratio) unreliable
  - Microspill structure
- Deadtime: shows small dependance on particle rate (payload size)



Full system



“Main” crate

Conclusion

- MBS runs stably and reliably with the new MVLC VME controller
- Successful 14+ physics experiments @GSI FRS in 2024 with primary beams from ^{12}C to ^{238}U

Future plans

- **Bypassing MVME**
  - For module initialization and setting up readout sequences
  - Yaml parser of the initialization config file
  - NURDLIB-ish solution?
- **VULOM + TRLO II adaptation**
  - TRLO II - flexible FPGA trigger control software commonly used with RIO4 controller
    - Complex logic represented in custom language
    - Parses configuration file into VME writes
    - Use at R3B / FRS for configuring complex digital and trigger logic

- Optimizing CVT's

Thanks to all the GSI collaborators

Nikolaus Kurz , Jörn Adamczewski-Musch , Sergey Linev

GSI Experiment Electronics

Yoshiki Tanaka, Stephane Pietri, Emma Haettner, Christine Hornung, Jianwei Zhao,

Super-FRS Experiment Collaboration

Appendix: Why is readout speed important?

- More exotic phenomena = lower cross sections, more statistics required
- For any beam rate, ideally resolve every particle hit?
  - Multi-hit capable modules
  - Trace sampling systems
- Multihits = complicated analysis
- Fraction of all particles able to be recorded
  - Clever trigger selection -> increased efficiency of capturing exotic events
- Main goal - decrease DAQ dead-time