Experimental Parallel Summary

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August 8, 2025

Experimental Parallel Sessions

- **13 talks** and **2 discussions** covering performance, instrumentation, and computing.
- Many **new studies** and **new results** presented this year!
- Can't summarize everything, but recordings of all parallel sessions available on indico.

Parallels: Detector Performance — KPTC 106

Conveners: Lawrence Lee (University of Tennessee, Knoxville), Nadia Pastrone (INFN Torino (IT)), Sarah Demers (Yale University)

2:00 PM	Pandora Overview and Special Considerations for $\mu\mu$ Environment (15'+3'). Speakers: Gregory Penn (Yale University), Gregory Penn. PFlow_Penn_USMC...	18m
2:18 PM	Calibration Challenges in the MAIA Calorimeters (15'+3'). Speaker: Rose Powers (Princeton University). Powers_USMCC_de... Powers_USMCC_de...	18m
2:36 PM	ECal BIB Mitigation Studies (15'+3'). Speaker: John Dervan (Northeastern University). Dervan_USMCC_20...	18m
2:54 PM	Trigger and DAQ Rate Considerations (15'+3'). Speaker: Angira Rastogi (Lawrence Berkeley National Laboratory). ARastogi_USMCC_A...	18m
3:12 PM	Topical Discussion: Detector Considerations for Neutrinos at $\phi \approx \pi$ (3'+15'). Speakers: Matheus Hostert (Harvard University), Matheus Hostert (Harvard). neutrino_slice_disc...	18m

Parallels: Detectors and Instrumentation R&D — KPTC 106

Conveners: Jennifer Ott (University of Hawaii at Manoa), Maurice Garcia-Sciveres (Lawrence Berkeley National Laboratory), Simone Mazza (University of California, Santa Cruz)

11:00 AM	Introduction and 4D tracking. Speakers: Jennifer Ott (University of Hawaii at Manoa), Jennifer Ott. JOtt_muC_LGADs.pdf, JOtt_muC_LGADs.p...	18m
11:18 AM	Status of 4D tracking detectors and readout. Speaker: Artur Apreysan. 4D-trackers-Apresya...	18m
11:36 AM	Forward Muon Detection and Luminosity Measurement. Speaker: Darin Acosta. FwdMuonAndLumi...	18m
11:54 AM	Dual readout in homogenous inorganic scintillators for precision calorimetry. Speaker: Grace Cummings (Fermi National Accelerator Laboratory (US)). GECummings_USM...	18m
12:12 PM	Achieving Sub-Picosecond Clock Synchronization for Accelerators and Detectors. Speaker: Dr Rohith Saradhy (University of Minnesota). 2025_08_07_USMC...	18m

Parallels: Computing + AI/ML — KPTC 106

Conveners: Kevin Pedro (Fermilab), Mark Neubauer (University of Illinois at Urbana-Champaign), Walter Hopkins (Argonne National Laboratory), Walter Hopkins (Argonne National Laboratory)

2:00 PM	How to simulate a muon collider detector. Speaker: Benjamin Rosser (The University of Chicago). usmcc_simulation_...	15m
2:18 PM	Tracking software and ML tracking. Speaker: Rocky Bala Garg. USMCC_Tracking_R...	15m
2:36 PM	AI/ML opportunities. Speaker: Abhijith Gandrakota (Fermilab). AIML_MuC_Abhijith... AIML_MuC_Abhijith...	15m
2:54 PM	Computing resources and challenges. Speaker: Kevin Pedro (Fermilab). Computing Resourc... Computing Resourc...	15m
3:12 PM	Open discussion	18m

Performance Highlights

- Increasingly moving to **more realistic** modeling of our detector!
  - More precise modeling of low-energy BIB neutrons; more realistic tracker digitization.

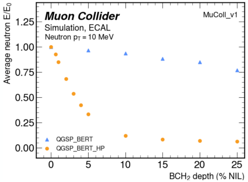
*The default **dd4HEP+GEANT4** configuration in MuCollSoft uses the **QGSP_BERT** physics list*

How does QGSP_BERT model neutron interactions?

1 **hadElastic** = G4 elastic had. scattering process
- **Chiral invariant PS** elastic model (0eV → 100 TeV)
- Cross sections: **G4ElasticXS**

2 **neutronInelastic** = nuclear excitation + spallation interactions
- Interpolation between **BertiniCascade** neutron-nucleon + secondary production model (0→6GeV), **FTFP** (3GeV→25GeV), and **QGSP** (>12 GeV)
- Cross sections: **G4InelasticXS**

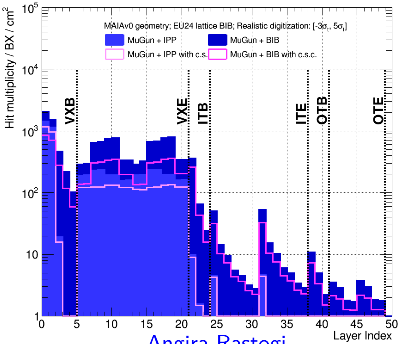
3 **nCapture** = discrete radiative neutron capture
- Nuclear recoil and γ release modeled by **nRadCapture** (G4NeutronRadCapture)
- Cross sections: **G4NeutronCaptureXS**



- But these rely on **parametrized** rather than **data-driven** cross-sections → fail at **low energies**
- Neutrons at ≤20 MeV need **QGSP_BERT_HP** to properly describe (in)elastic scattering, capture, fission, and radioactive decay

We need HP to fully describe low-energy neutron behavior!

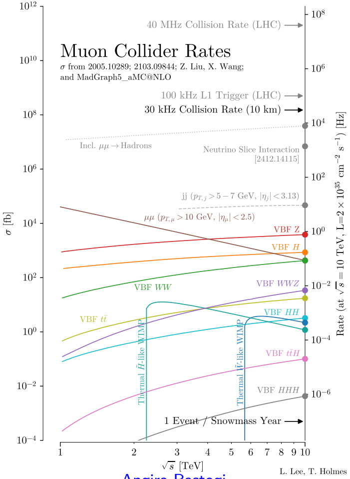
JP Dervan



Angira Rastogi

Discussion: Neutrinos and Data Rates

- Significant rate of **beam-induced neutrinos** (BINs): neutrino showers in detector!
  - Much **higher rates** than most processes: additional detector challenge (and opportunity?).



Angira Rastogi

Muon Collider
Building toy models of muon collider

More neutrinos than we have ever detected by >3 orders of magnitude.

To give sense of the rate @ MuC 10 TeV:

For every 2 bunch xs, you get 1 BIN$^{\dagger *}$.

(† there are infinitely many more BIBs/xs!)
(* this is also a statement on the # of bunch xs)

Collider	MuC 10 TeV	MuC 3 TeV	μTRISTAN
Beams	$\mu^+\mu^-$	$\mu^+\mu^-$	$\mu^+\mu^+$
Muons/bunch	1.8×10^{12}	1.8×10^{12}	1.4×10^{10}
bunches/cycle	1	1	40
$f_{\rm inj}$	5 Hz	5 Hz	50 Hz
C	8.7 km	4.3 km	4.3 km
BIN inclusive reactions			
ECal (0.15 kt)	0.9%	3.0%	3.0%
HCal (1.4 kt)	7%	15%	15%
Muon Sys (7.5 kt)	13%	33%	32%
Nozzles (0.14 kt)	79%	48%	48%
Total / bunch xs.	0.44	0.029	0.0053
Total / year	1.5×10^{11}	2.0×10^{10}	1.5×10^{11}

BIN exclusive reactions in HCAL and ECAL/year			
Total NC	1.5×10^{9}	4.6×10^{8}	3.4×10^{9}
Total ν_e CC	4.7×10^{9}	1.4×10^{9}	1.1×10^{10}
Total ν_μ CC	5.4×10^{9}	1.7×10^{9}	1.1×10^{10}

M. Hostert 5

Matheus Hostart

Instrumentation Highlights: Timing

- Lots of work on high-granularity timing detectors in HEP (Jennifer Ott, Artur Apresyan):

Summary

- **Considering the muon collider baselines, requirements, aspirations: neither spatial resolution nor timing resolution are overly strenuous**
  - 30-60 ps are being achieved with DC-LGADs developed for the HL-LHC, assuming high radiation levels!
- **Using precision timing to identify vertices and reconstruct tracks, separate collision data from beam backgrounds is tempting (required) – but keep in mind that this is being done in software, the detector itself will still experience the full hit rate**
  - E.g. resistive silicon detectors will not do well in a high-occupancy environment

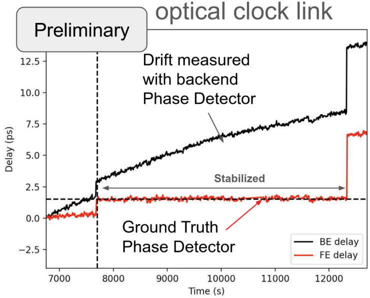
➢ ***Consider the big picture and operational constraints: availability of detector process lines, uniformity of large sensors, ...***

➢ ***Further specify (through simulations and modelling) critical performance parameters to select or develop the optimal semiconductor sensor technology***

J. Ott, LGAD R&D, US Muon collider workshop 2025

Jennifer Ott

Real-time compensated 1km optical clock link



Stabilization Characteristics:

Std.Dev ~ **120 fs**

Peak to Peak ~ **650 fs**

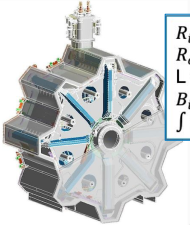
Avg. Over ~ **5s (0.2Hz)**

Rohith Saradhy

Instrumentation Highlights: Forward Muons

A Far Forward Muon Spectrometer Design Study

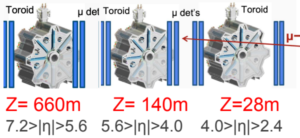
- To begin to address some of the feasibility questions, we initiated a GEANT-4 feasibility study of a downstream muon spectrometer
  - In contrast to instrumenting the nozzle (challenging with BIB!), and **to provide magnetic bending**
  - Also studied TeV muon scattering and energy loss in the tungsten shielding cone (covers |η|>2.4)
- Explored using an (ATLAS) endcap toroidal magnet design as a realistic strawman design
  - Largish opening to accommodate beam line components, and with less B field impact on beam
  - Study muon tagging and momentum measurements, and the impact on physics measurements



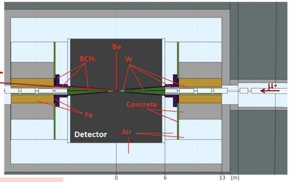
R_{in} = 1.05 m
R_{out} = 5.1 m
L = 4.5 m
B_{in} = 4.1 T
$\int B \cdot dl$ = 4–18 T · m

ATLAS-PHOTO-2022-007-6

ATLAS Endcap Toroids



Layout adapted from Collamati et al. on μ⁺μ⁻ collider: arXiv:2105.09116



Small angles require large distances from IP

Acosta Forward Muons and Lumi Measurem

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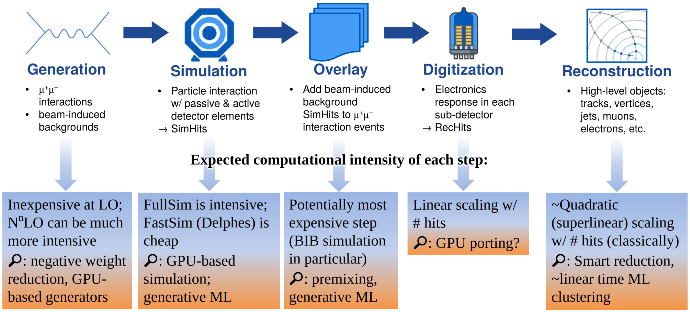
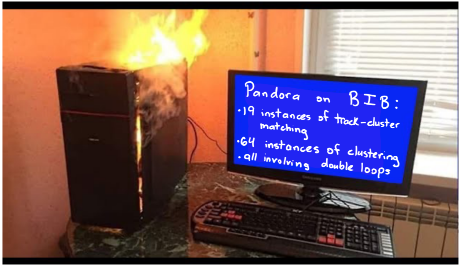
Darin Acosta

Computing Resources



Kevin Pedro



Gregory Penn

- Running full simulation+reconstruction with BIB very expensive! Lots to optimize:
  - Epecially **tracking**. Where can we **apply ML**? (Abhijith Gandrakota, Rocky Bala Garg).
  - Should explore generative ML approach to full BIB simulation!
  - Need to provide updated **fast simulation** infrastructure for 10 TeV detectors.
  - In many cases fastsim will be good enough; still need to be **able** to run full simulation.

Backup