Computing for the Muon Program at Fermilab

Tammy Walton

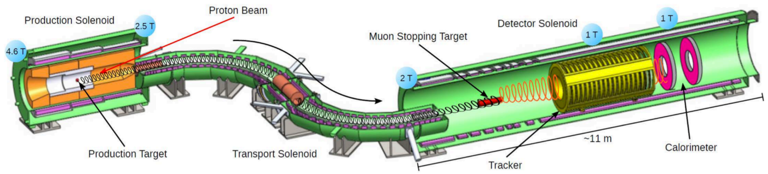
Muon Research Briefing

December 16, 2020

μ g-2

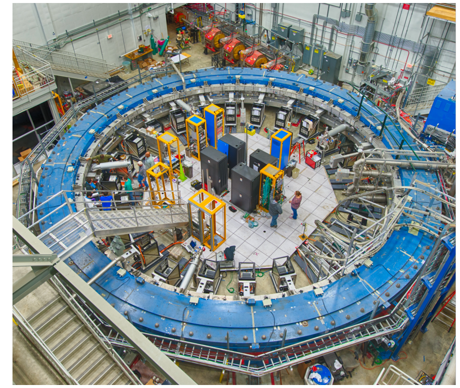
Mu2e

Muon Programs



Mu2e is aiming to reduce the branching ratio by a factor of 10,000, which requires 3 years of running

Project and Design by Karie Badgley



Muon g-2 requires about 20 X BNL data to reduce the statistical error by factor of 4

Computing

The current and near future muon precision measurements requires large amount of data on petabyte scales at a continuous and steady rate for many months.

Fermilab computing leadership and supported resources are essential in overseeing the conversion of large data collection into physics results.

Fermilab Supported Resources : Computing Ecosystem

FermiGrid

Access to Open Science Grid and High-Performance Computing Centers

Data Management, Submission and Monitoring Tools

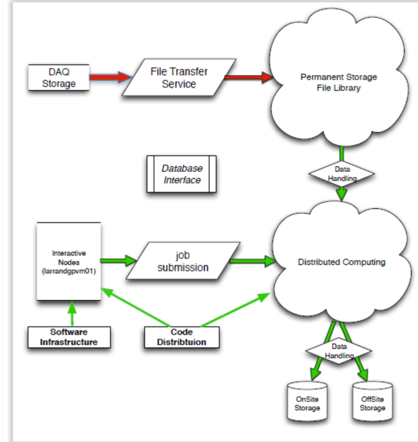
Interactive Computing Machines

Distribution and Build Systems

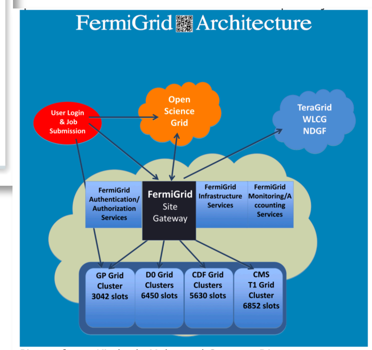
Source Code Version Control Systems and Repositories

Online and Offline Software Frameworks

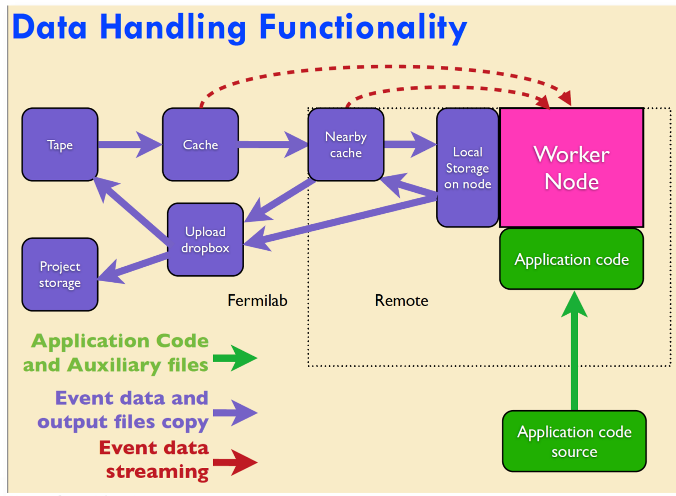
Interactive Analysis Tools



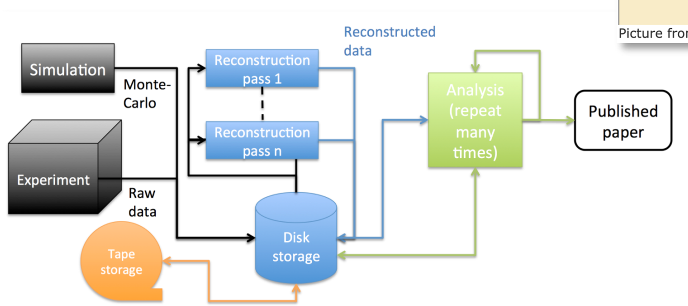
Picture from: Mike Kirby



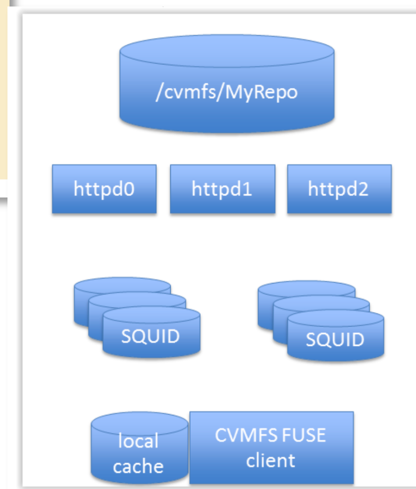
Picture from: Kimberly Myles and Canzone Diana



Picture from Adam Lyon



Picture from: Robert Illingworth



Picture from Dan Bradley

Experiment Supported Computing Tools

Data Production

Data Monitoring

Data Quality

Software Framework and Infrastructure

Simulation and Geometry

Calibration Algorithms

Reconstruction Algorithms

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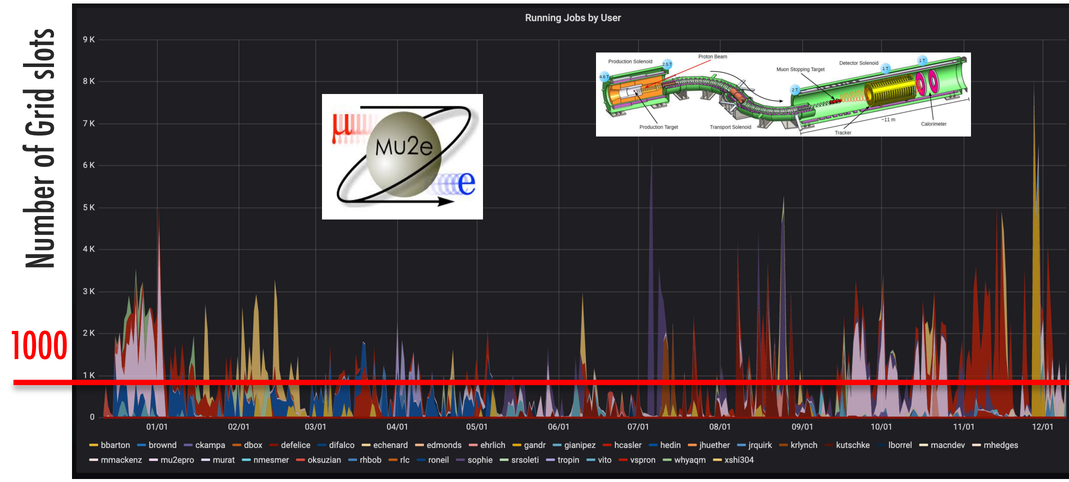

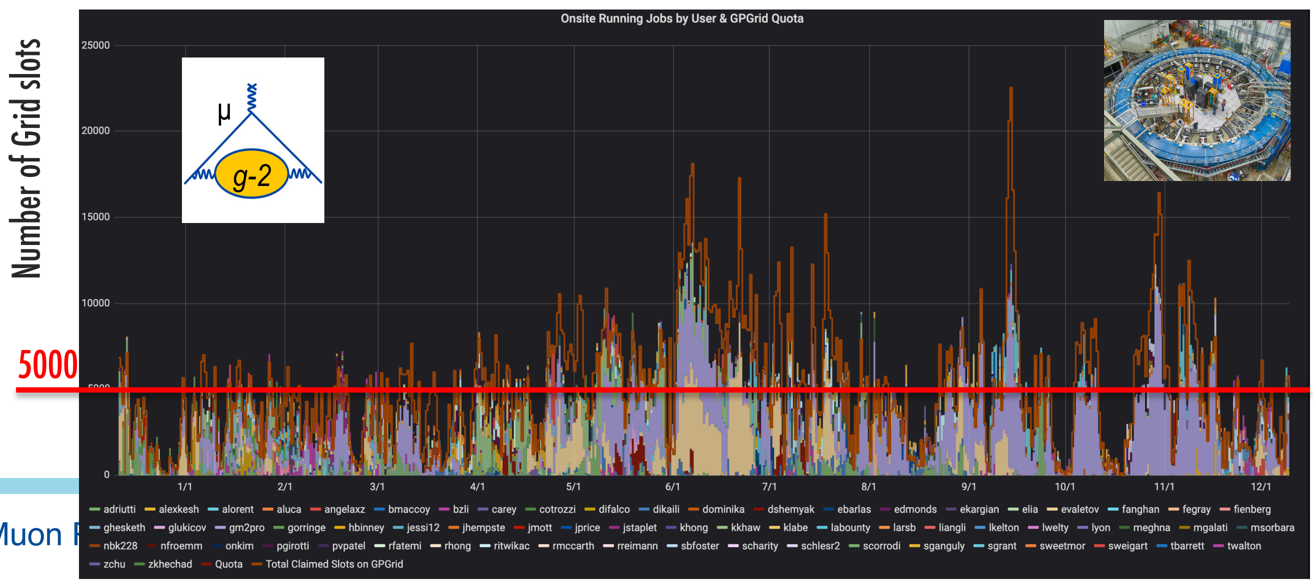

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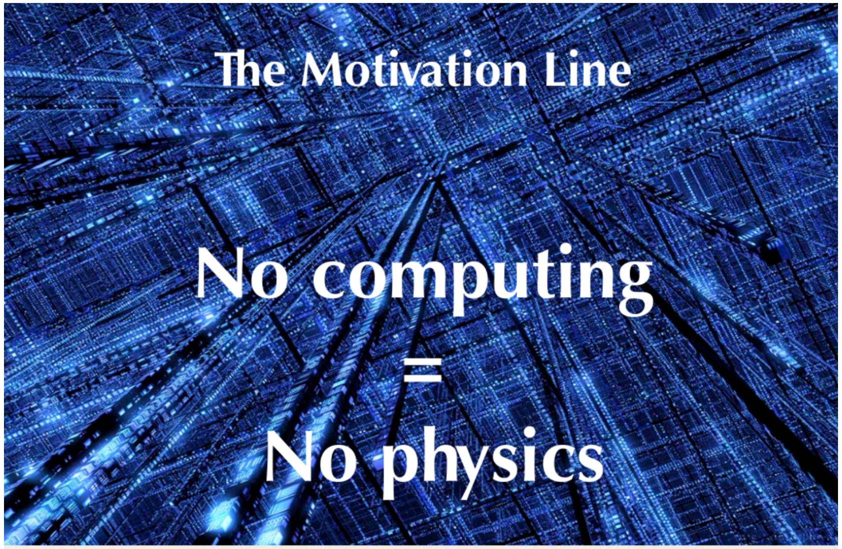
Calibration Algorithms

Reconstruction Algorithms

Needed for a successful physics program!



From Mayly Sanchez, Snowmass 2013

General Overview

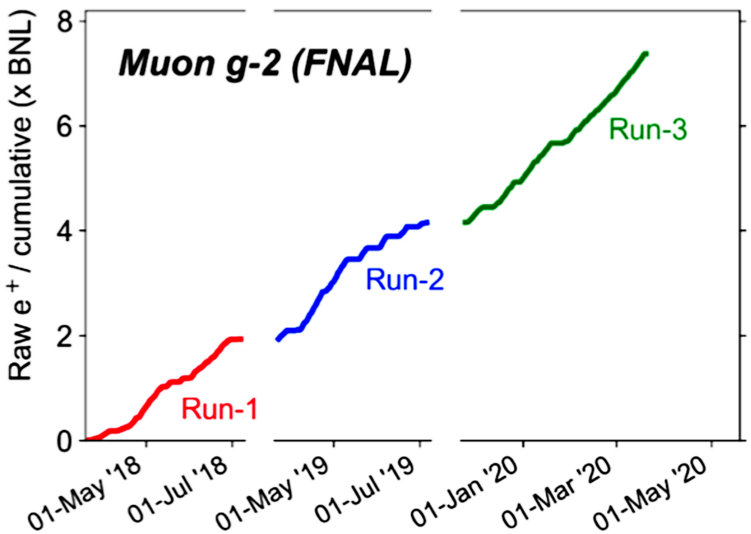
Mu2e General Overview : Project Phase

- Work plan
  - Preparing computing needs for pre-operations (2022) and operations (2024)
  - Defining the tasks, roles, and milestones
  - Identifying and training people
  - Developing software and physics analyses to coincide with data taking timeline
  - Using subsystem prototypes to improve the software

- Status snapshot
  - Mature simulations
    - Preparing to produce a large simulated dataset (2020 or early 2021)
    - Can run multi-threaded Geant4 simulation at HPC centers
  - Optimizing the current trigger and reconstruction algorithms
  - Preliminary design of data quality monitoring tools
  - Software code, build, release, and distribution systems are in placed

g-2 General Overview : Operations and Analysis Phases

- Run-1
  - 100% of data are processed
  - Implemented many of Fermilab supported resources
  - Robust software infrastructure and workflow
  - Mature simulations, reconstruction, and analysis codes
  - Running simulations at HPC center



- Run-2/3
  - 100% of Run2 data are processed
  - Using Fermilab supported Database for constants management
  - Investing in computing offline production shifts and training
  - Upgrading the offline data production workflow
  - Improving and optimizing simulation, reconstruction and analysis codes

Fermilab Scientific and Computing Staff

Ray Culbertson (Senior Scientist)

Mu2e Computing and Software Algorithm Developer and Co-Leader
Mu2e Software Workflow Developer

Jessica Esquivel (Research Associate)

g-2 Kicker Magnet Data Quality Manager
g-2 Kicker Magnet and Electrostatic Quadrupoles Simulation Developer

Lisa Goodenough (Applications Physicist)

Software Upgrader
g-2 Software Release Co-manager

Rob Kutschke (Senior Scientist)

Mu2e Computing and Software Co-Leader
Operations Mu2e L2 for Data Processing and Computing

Alessandra Luca (Research Associate)

g-2 Tracking Software Co-manager
g-2 Tracking Algorithm Developer

Adam Lyon (Senior Scientist)

Scientific Computing Division Liaison
Organized the g-2 Computing Ecosystem
g-2 Simulation Developer and Leader
Database Algorithm Developer
g-2 Software Infrastructure Developer

James Stapleton (Research Associate)

g-2 Software Release Co-manager
Muon Spin Precession Algorithm Developer

Leah Welty-Rieger (Technical Aide)

g-2 Data Production Manager
g-2 Simulation Developer
Website Designer

Names	Title	Contribution
Saskia Charity	Research Associate	Field Production Manager Field Software and Algorithm Developer
Eric Flumerfelt	Computational Physics Developer	Data Acquisition Software Developer and Leader
Andrei Gaponenko	Scientist	Offline Software and Infrastructure Developer
Krzysztof Genser	Computational Physics Developer	Head of the Geant4 Support
Iris Johnson	Electrical Engineer Student	Firmware and Software Algorithm Developer
Manolis Kargiantoulakis	Research Associate	Muon Spin Precession Simulation Developer Quadrupole Algorithm Developer Machine Learning Group Leader
Kyle Knoepfel	Application Developer and System Analyst	Head of the Experiments Software Framework (art)
James Mott	Wilson Fellow	Former Tracking Software Co-manager Tracking Algorithm Developer Data Monitoring Algorithm Developer
Pasha Murat	Senior Scientist	Simulation Co-Leader
Ron Rechenmacher	Electrical Engineer	Data Acquisition Software Developer
Ryan Rivera	Electrical Engineer	L2 Manager for Data Acquisition System Data Acquisition Software Developer and Designer

Tammy Walton
(Associate Scientist)

Joined Muon g-2 as a Fermilab Research Associate in 2014

Developed the tracking software infrastructure and algorithms

Integrated and maintained the software code

Developed simulation and geometric tools

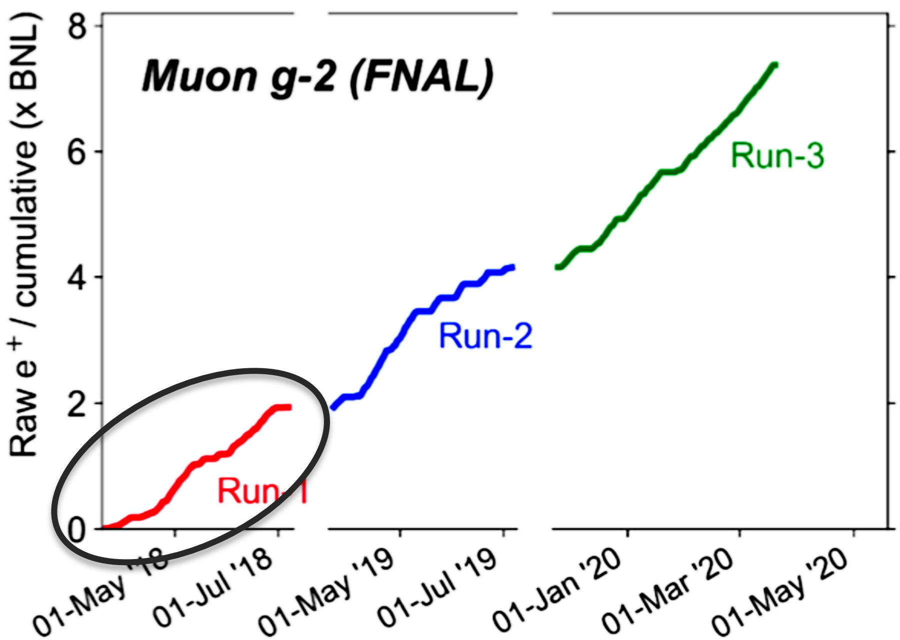
Prepared the data production tools and workflow for pre-operations

Implemented tools for accessing the database

Serving as co-coordinator for the offline team

Promoted to an Associate Scientist (Aug. 2020) in the Scientific Computing Division

Muon g-2 Computing



- Run – 1
  - Most of the offline team consists of graduate students and postdocs, where many people served multiple roles
  - The data were produced using various operation configurations
  - Many subsystems were used to determine the data quality
  - The calorimeter detectors required serval types of calibration constants
  - Managing all the various conditions, resulted in multiple processing of the data
  - The processing iterations for the offline data caused the physics analyses to be delayed

Serving (around October 2019) as co-coordinator for the offline team for Run 2 and beyond

Tammy Walton

Spokespersons
C. Polly / G. Venanzoni

Scientific Computing Division Liaison
A. Lyon

Analysis Coordinator
D. Hertzog

Offline Computing and Simulations
L. Li / T. Walton

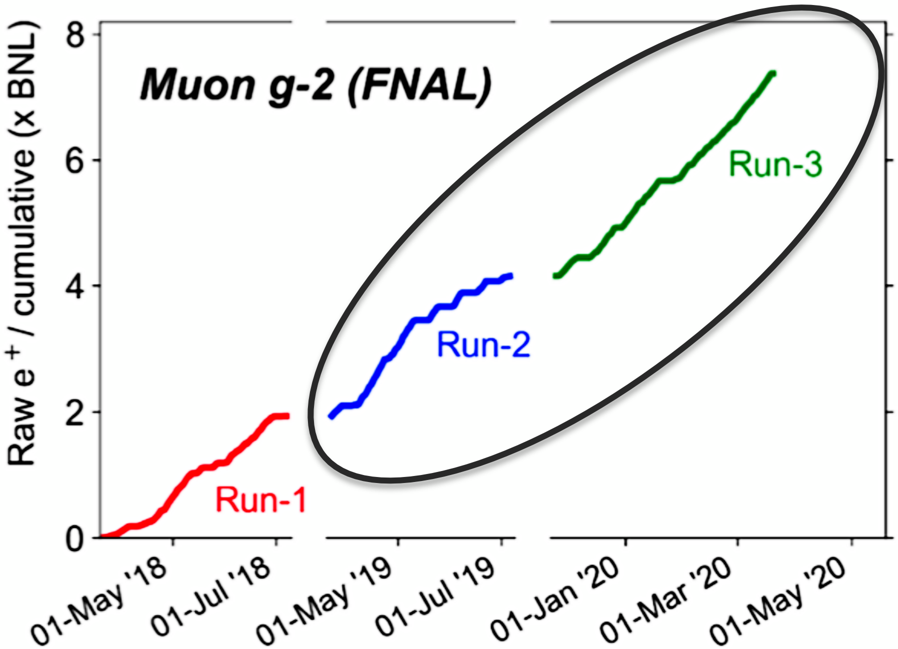
Release Manager
J. Stapleton

Simulation
R. Fatemi

Data Quality
F. Gray

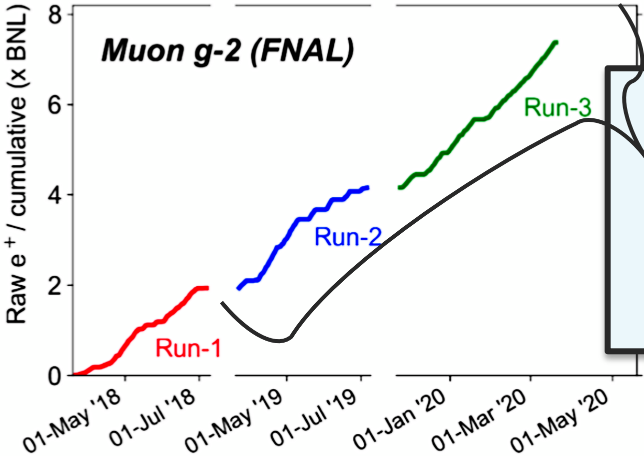
Nearline
J. LaBounty

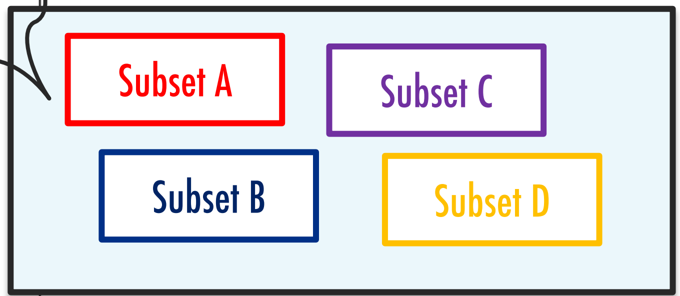
Production Manager
L. Welty-Reiger

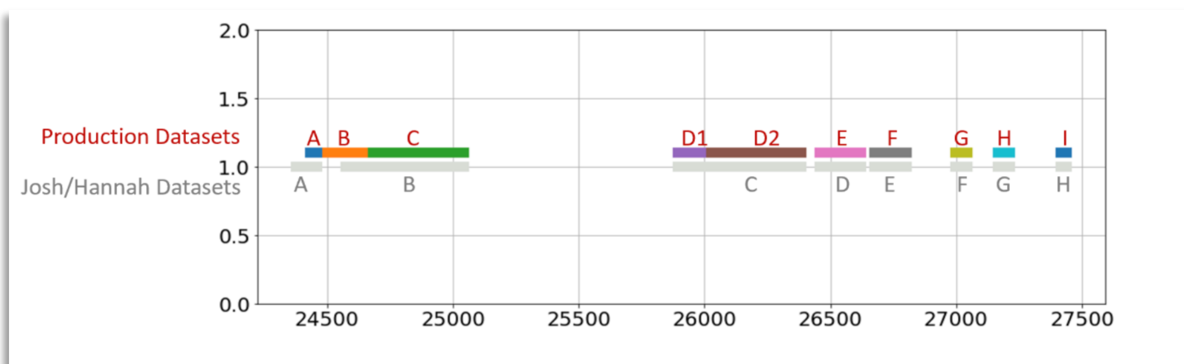


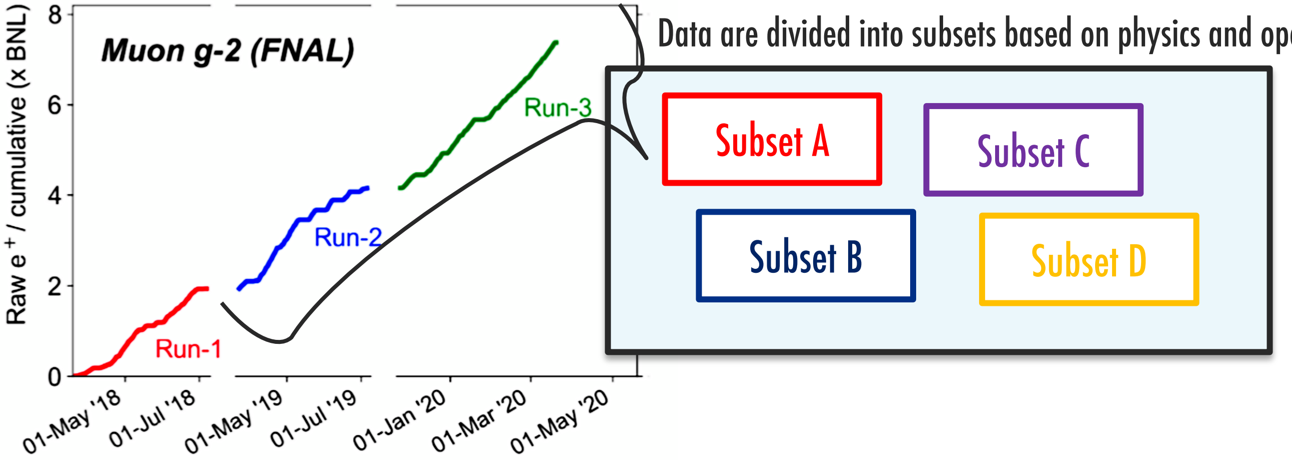
- Runs – 2 and 3
  - A robust system was developed to prevent similar production challenges
  - The raw data size for Run 2 and 3 are about 3 x larger than Run 1

Data are divided into subsets based on physics and operations







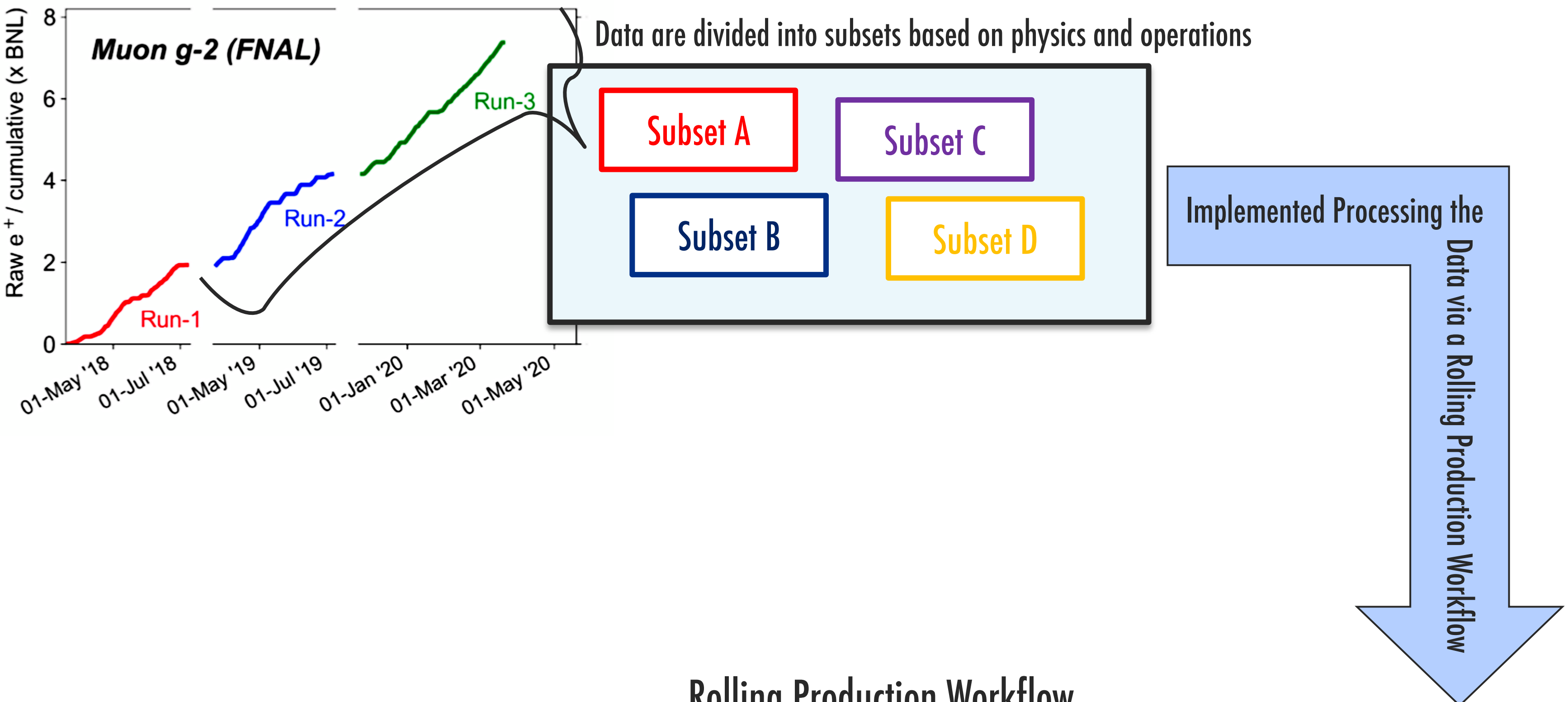


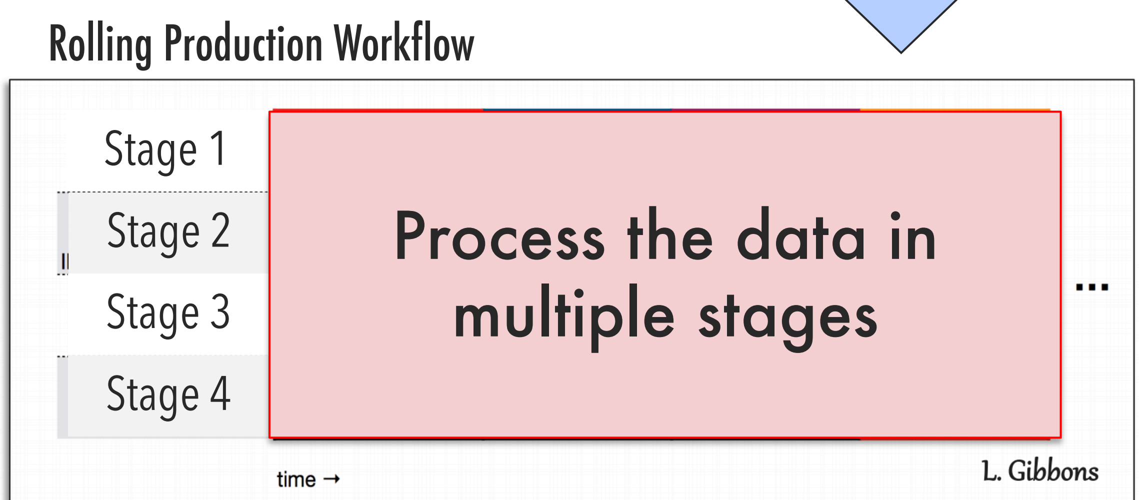
Applications to the raw data:

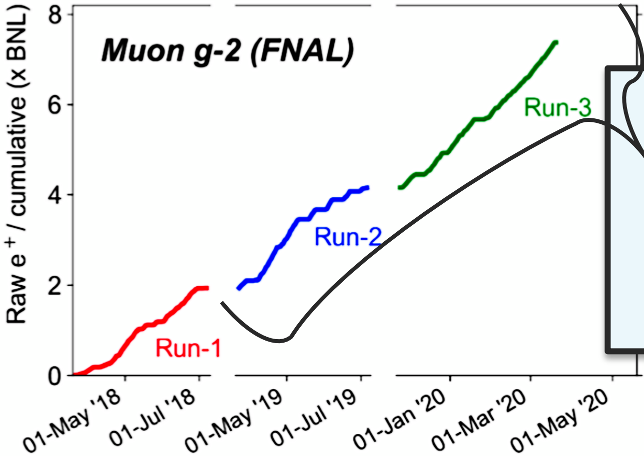
Apply calibration and alignment constants

Reconstruct the calorimeter and tracker data

Verify the integrity and quality of the data using subsystems such as the electrostatic quadrupoles, kicker magnets, T0 counter, the site location of the data, and much more


Muon g-2 (FNAL)
Raw e+ / cumulative (x BNL)
0
2
4
6
8
Run-1
Run-2
Run-3
01-May '18
01-Jul '18
01-May '19
01-Jul '19
01-Jan '20
01-Mar '20
01-May '20
Data are divided into subsets based on physics and operations
Subset A
Subset C
Subset B
Subset D
Implemented Processing the Data via a Rolling Production Workflow


Rolling Production Workflow
Stage 1
Stage 2
Stage 3
Stage 4
Process the data in multiple stages
...
time →
L. Gibbons



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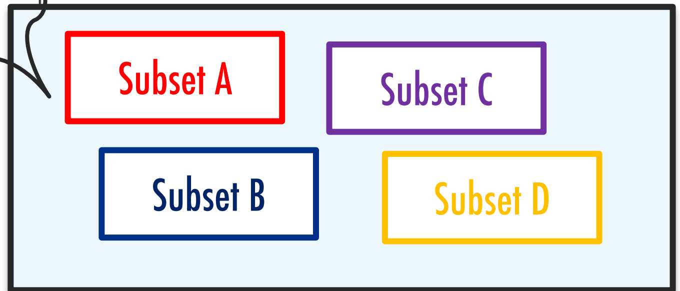


Implemented Processing the Data via a Rolling Production Workflow

Rolling Production Workflow

Stage 1	Subset A	Subset B	Subset C	Subset D	
Stage 2		Subset A	Subset B	Subset C	...
Stage 3			Subset A	Subset B	
Stage 4				Subset A	

time →

L. Gibbons

Mu2e

μ g-2

Stage 1	Subset A	Subset B	Subset C	Subset D
Stage 2		Subset A	Subset B	Subset C
Stage 3			Subset A	Subset B
Stage 4				Subset A

…

time →

L. Gibbons

Collaborative efforts between Fermilab and universities

上海交通大學
Shanghai Jiao Tong University

UNIVERSITY of WASHINGTON

Cornell University

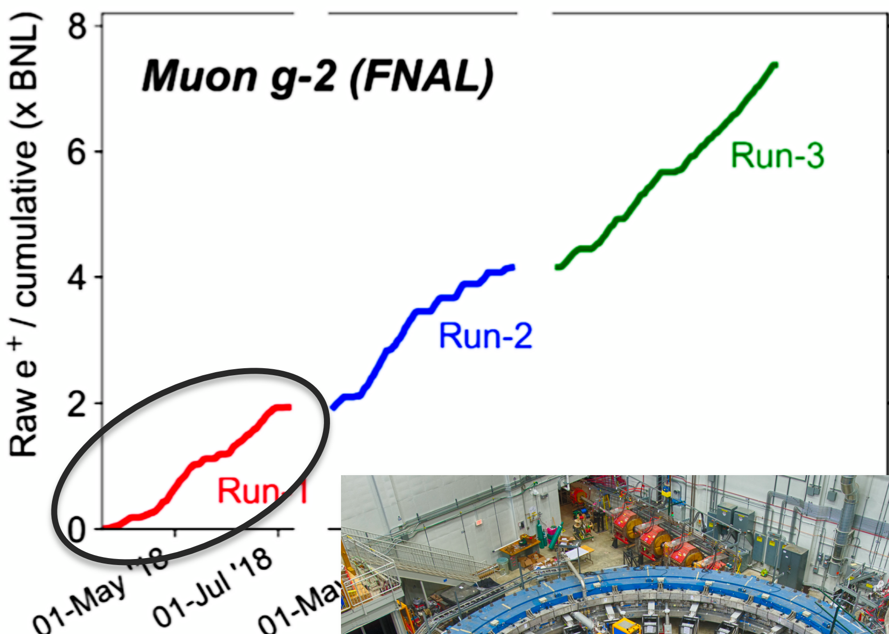
INFN
Istituto Nazionale di Fisica Nucleare
SEZIONE DI PISA

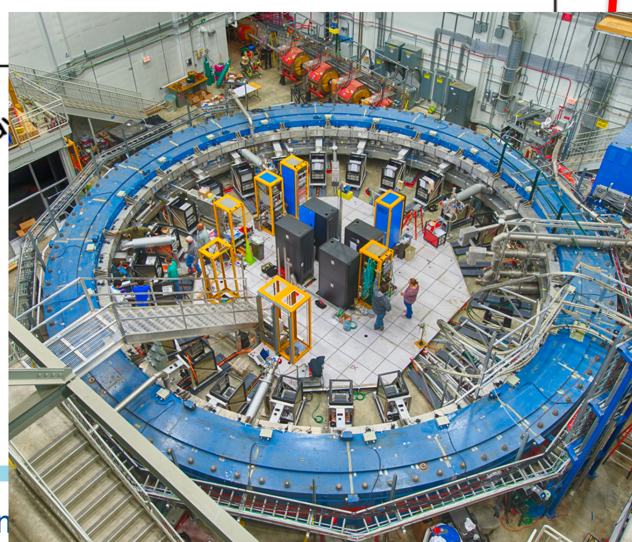
University of Kentucky

Argonne NATIONAL LABORATORY

REGIS UNIVERSITY

RECAP





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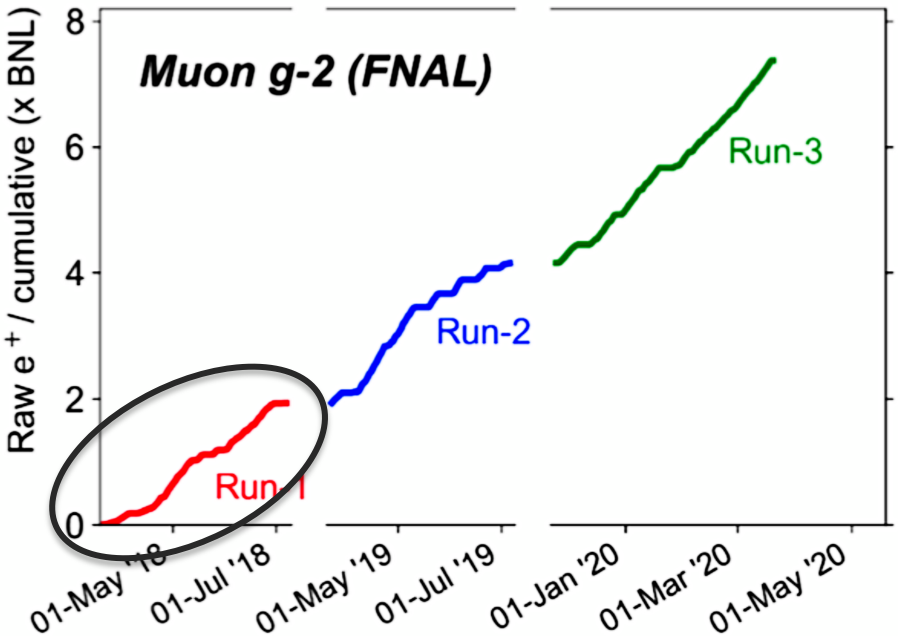
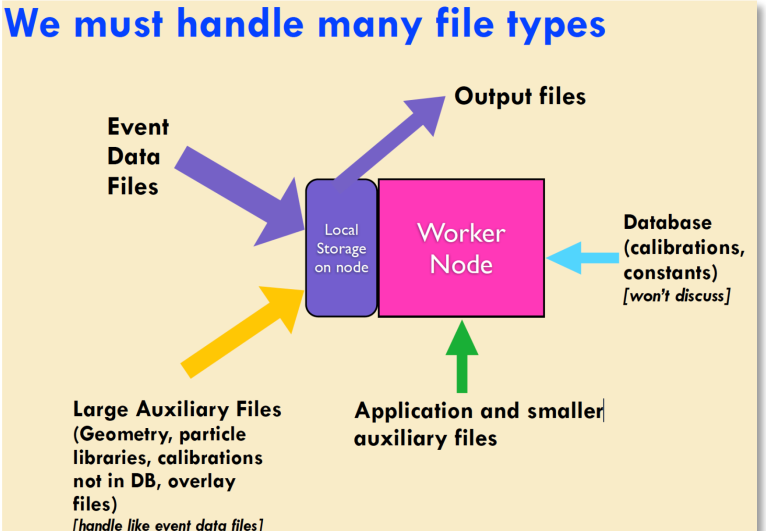
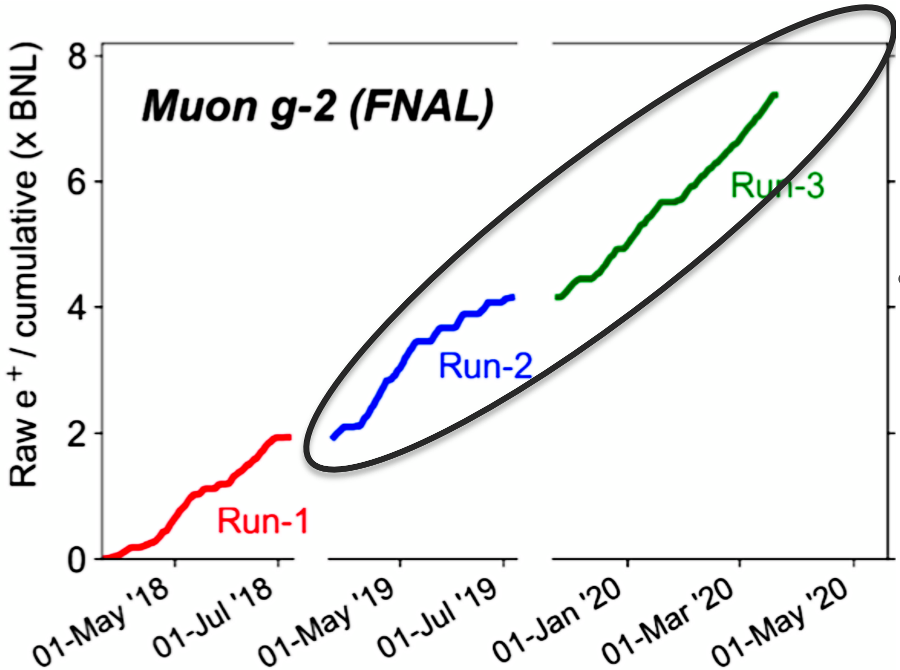
- Managing constants for Run 1
  - Used a file system for managing the many systems calibration and data quality constants
  - Created errors

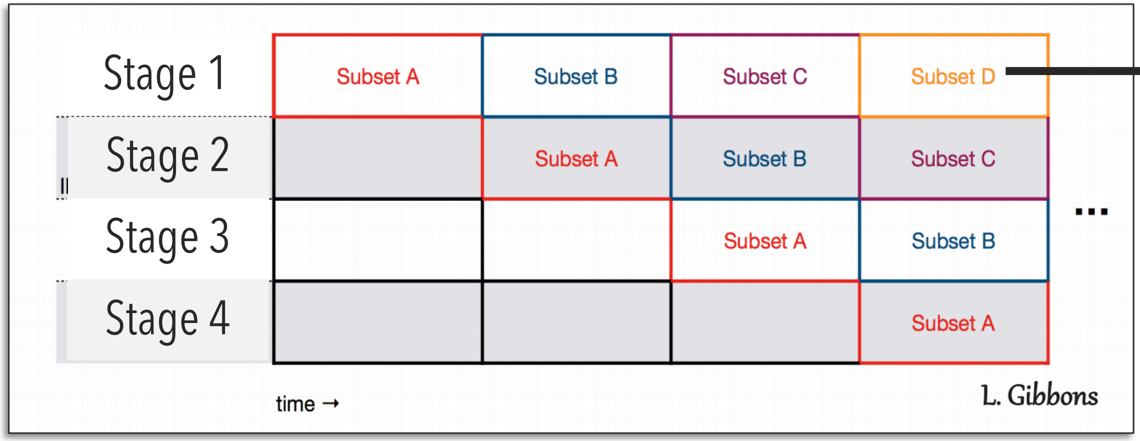




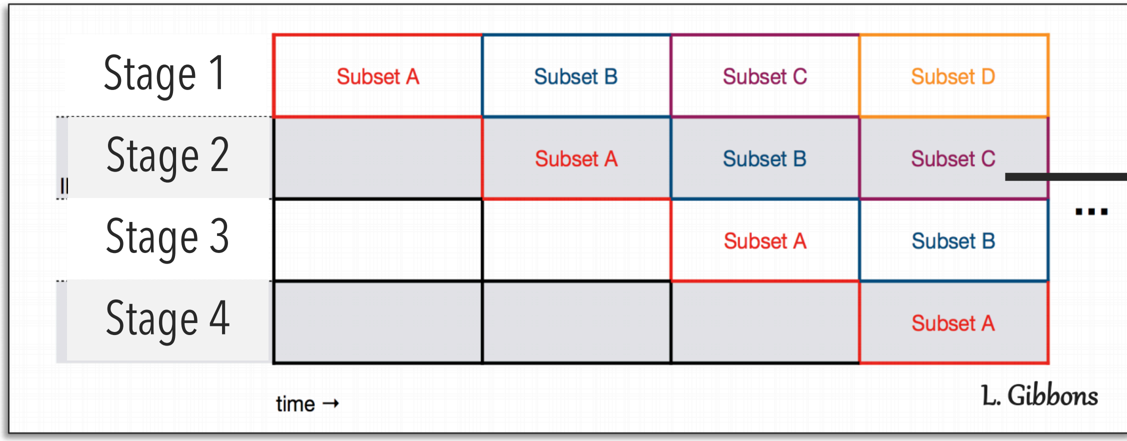
Picture from Adam Lyon



- Managing constants for Run 1
  - Used a file system for managing the many systems calibration and data quality constants
  - Created errors
- Solution for Run 2 and beyond
  - Decided to use Fermilab supported constants database for managing constants
  - Implemented the workflow



Perform the minimal reconstruction to extract files needed for constant analyses.

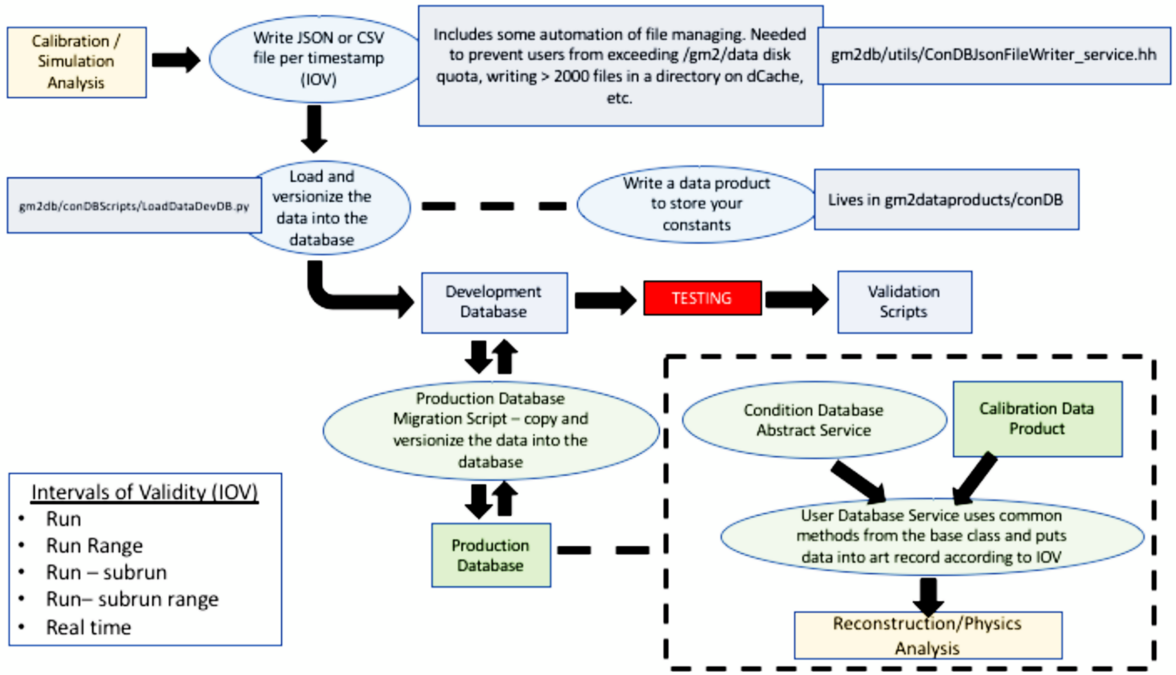


Calibration constants analysis and Database stage

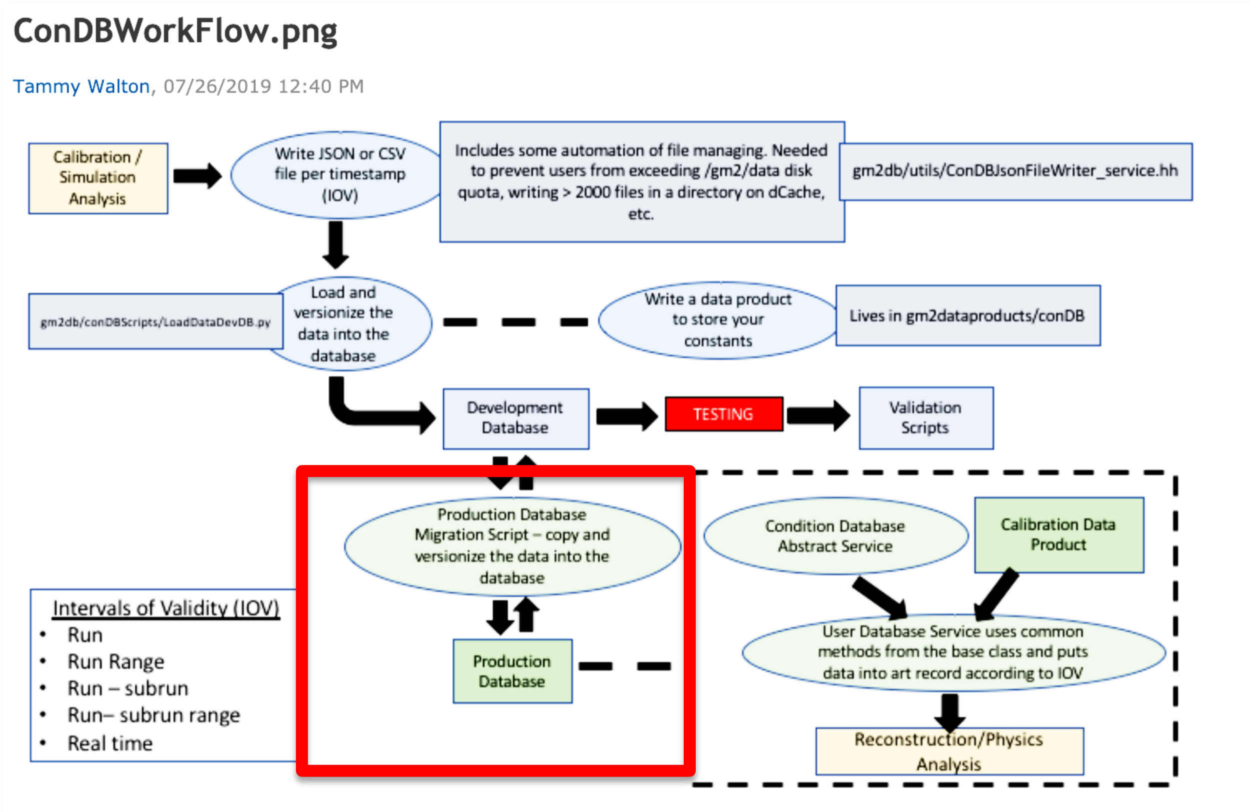
Calibration constants analysis and Database stage

ConDBWorkFlow.png

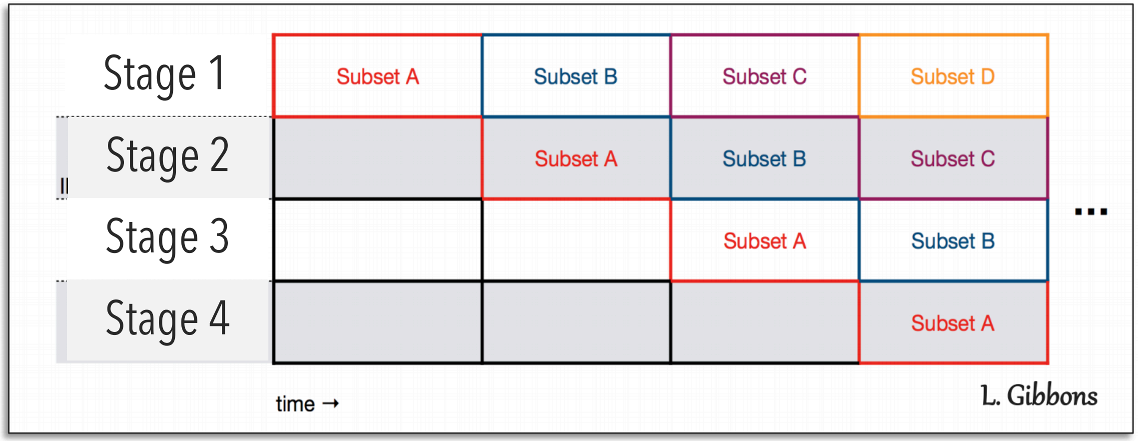
Tammy Walton, 07/26/2019 12:40 PM



Calibration constants analysis and Database stage



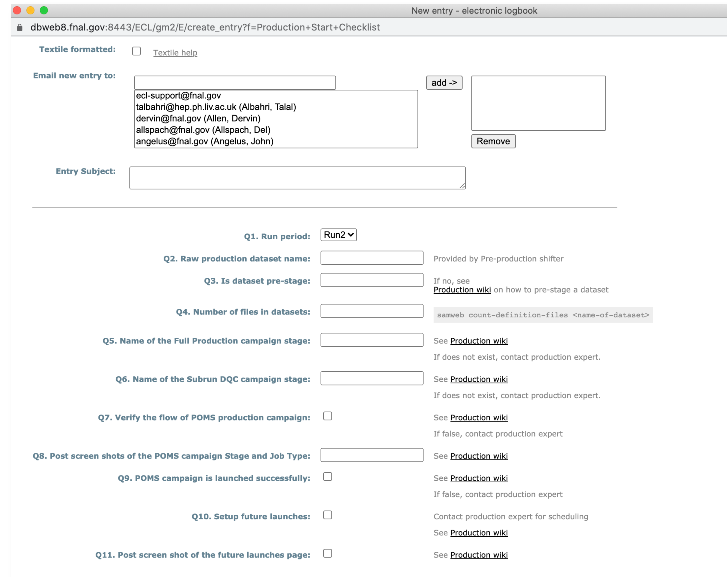
Does not require experts!

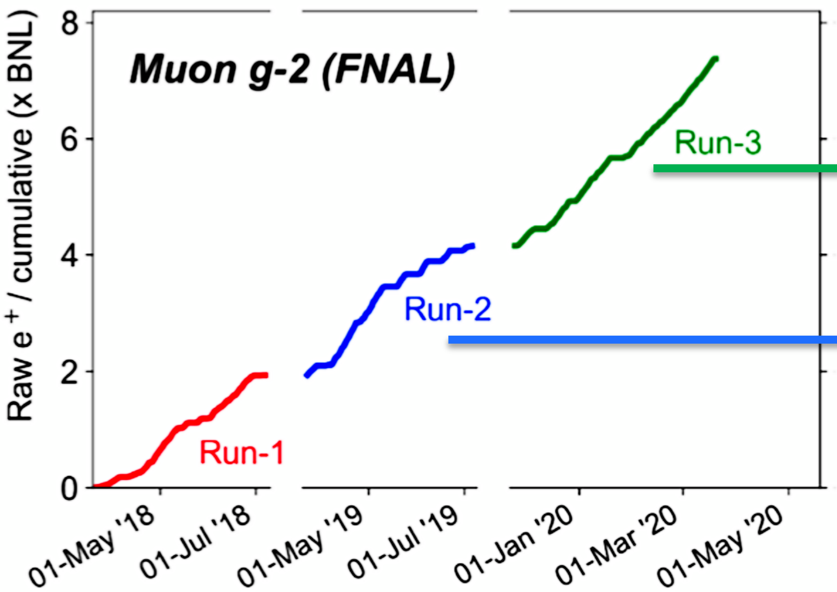


Steady and stable implementation of the rolling production includes many datasets that are processed at various time.

Instituted a system to include production shifters monitoring the data processing

Date	Stage Name	Shifter's Name	Dataset Name
2020/08/12-08/18	Pre-production	Leah (expert) + Jason, Elia (shadow)	gm2pro_daq_raw_run3_PreProd_N,O
2020/08/12-08/18	Database	Tammy (expert) + Laura, Maria (shadow)	gm2pro_daq_raw_run3_PreProd_N
2020/08/12-08/18	Full production	Liang (expert) + Lorenzo, Zhaolin (shadow)	gm2pro_daq_offline_run2E,F
2020/08/12-08/18	Subrun DQC	Fred (expert) + Josh, Paolo (shadow)	gm2pro_daq_offline_run2E,F





15% of the data are ready for analyzers

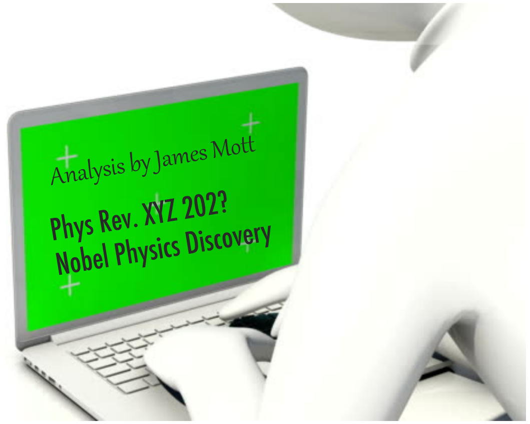
100% of the data are ready for analyzers

Preparing to include the in-progress Run-4 data!

Conclusions

- The muon programs at Fermilab are privileged to advance computing resources

- Fermilab scientists and computing professionals continue to lead the experiments in the development, integration, and production of data and software codes



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