

Simulation & Reconstruction

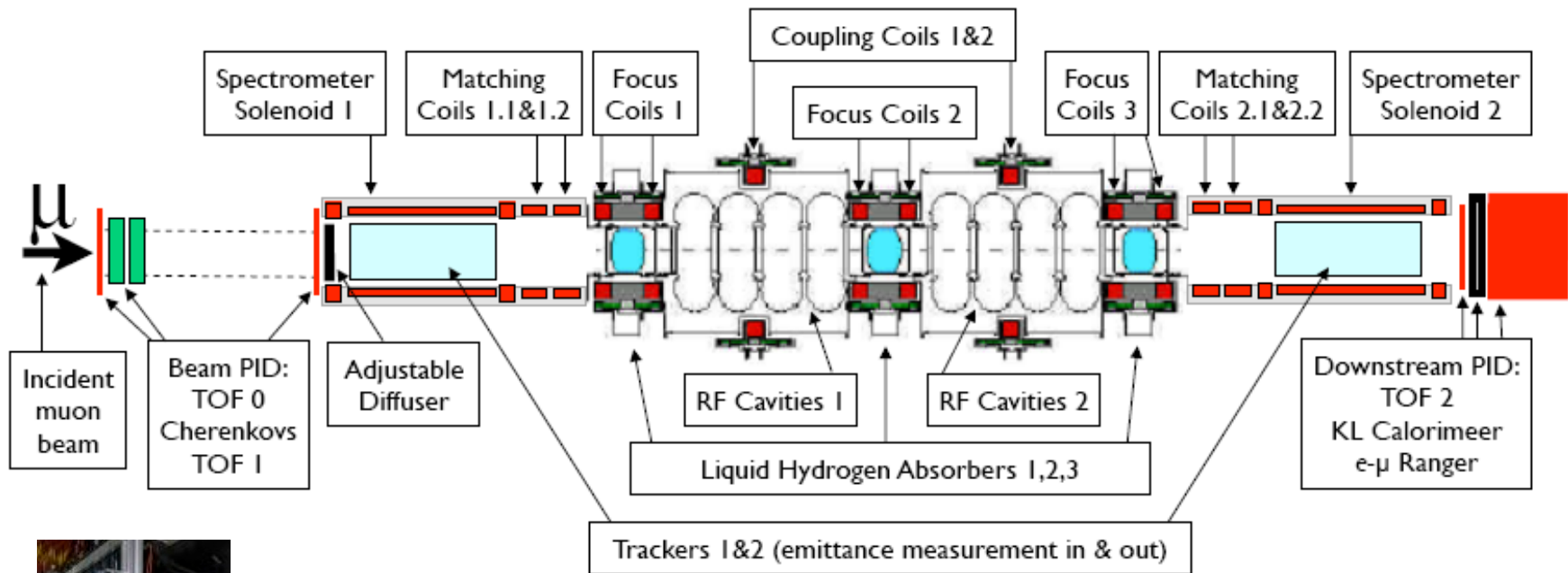
Durga Rajaram
IIT, Chicago

MICE Project Board
29 April 2014

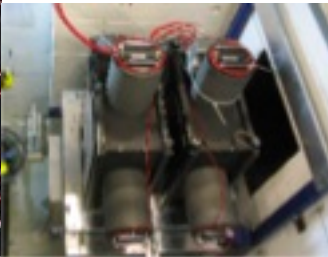
MPB-6 Recommendation

- Present a status report on the MICE simulation, online and offline analysis capabilities and show results of the end-to-end Monte Carlo simulations, including tracking and reconstruction, in support of the Step IV, V and VI physics goals at the next meeting.

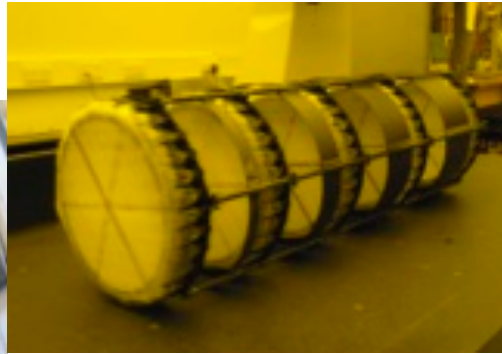
MICE Detectors



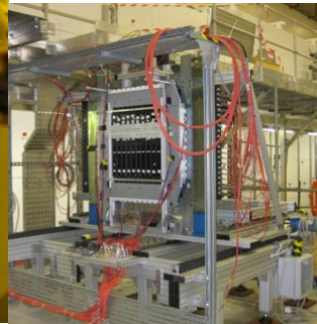
TOF



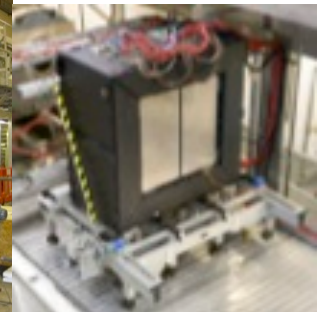
Ckov



Tracker

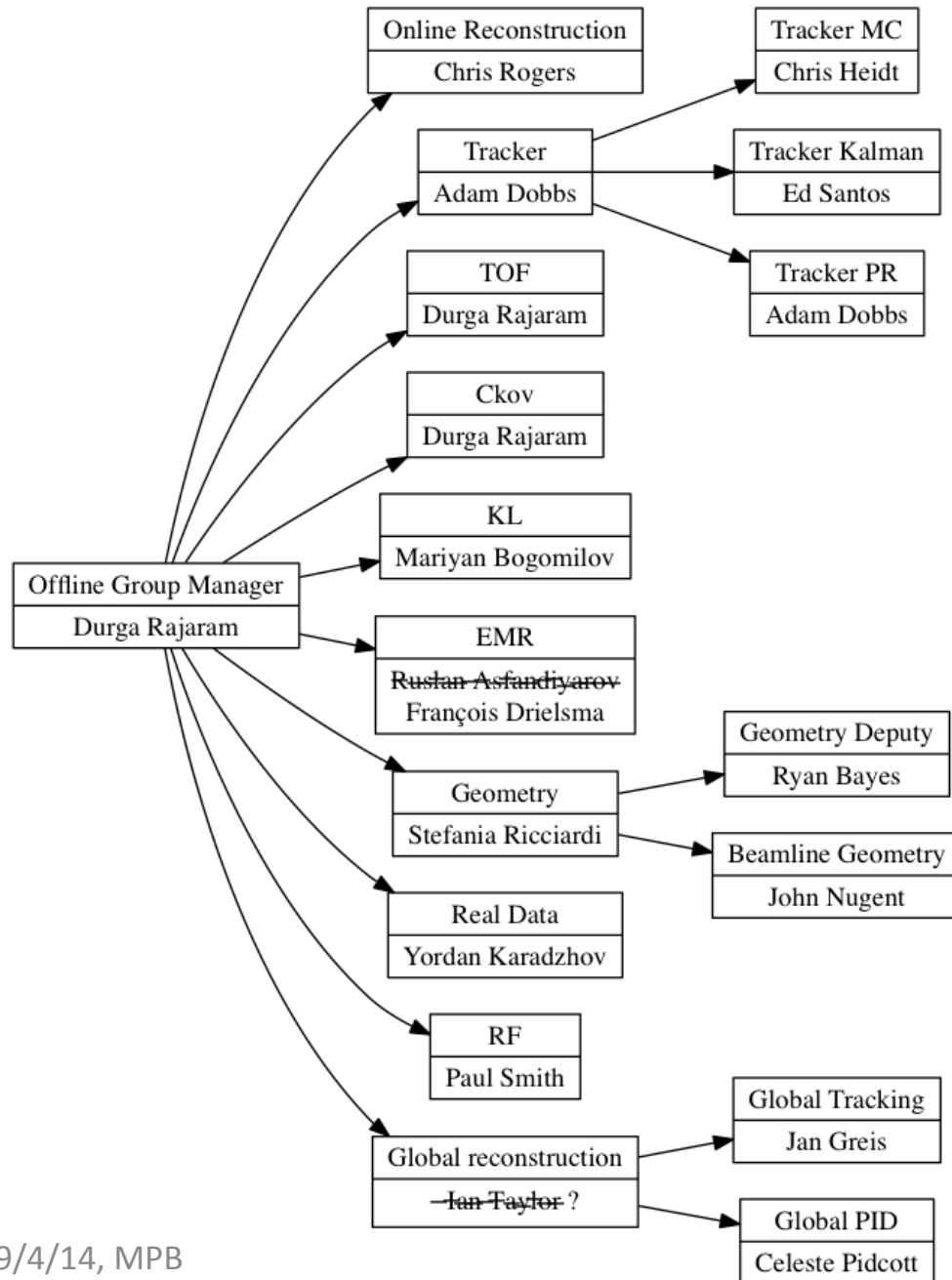


KL



EMR

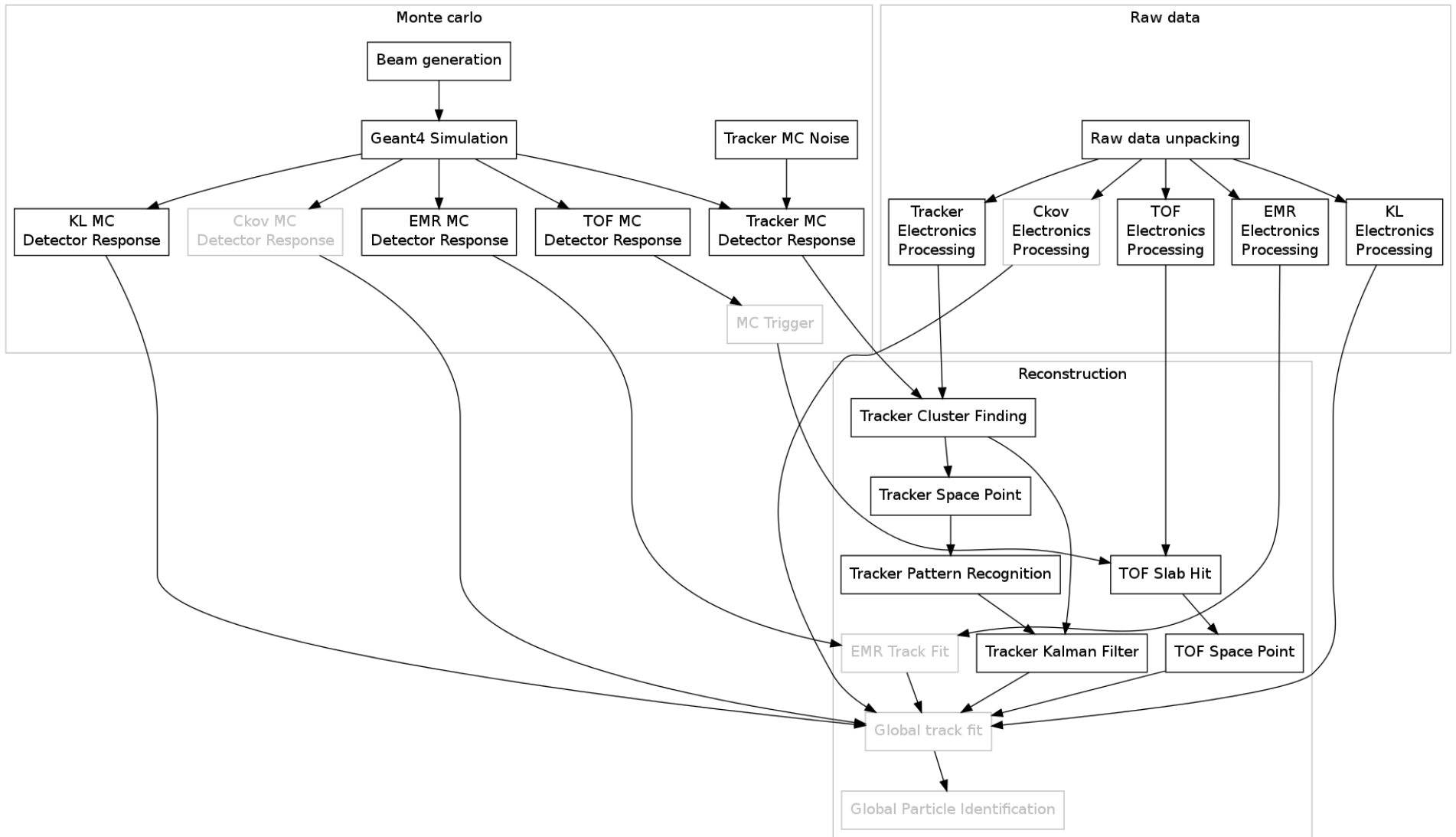
Organization



Changes:

- EMR
 - Student taking over from Asfandiyarov, some associated learning curve
- Ckov
 - New Undergraduate students supervised by DR
- Global
 - Jan Greis replaced Lane
 - Ian Taylor leaving. Need experienced hand to guide.
 - Critical item

Offline Flow

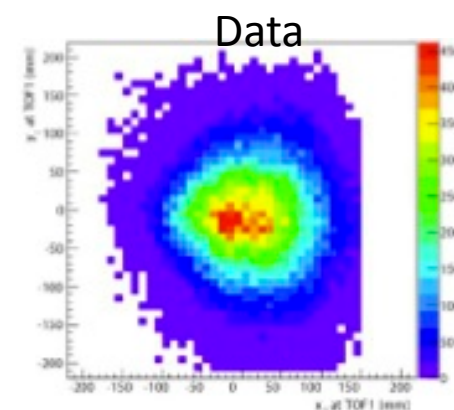
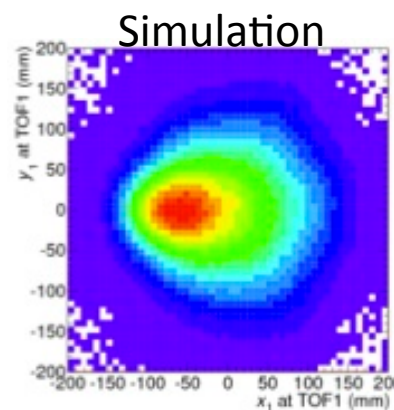
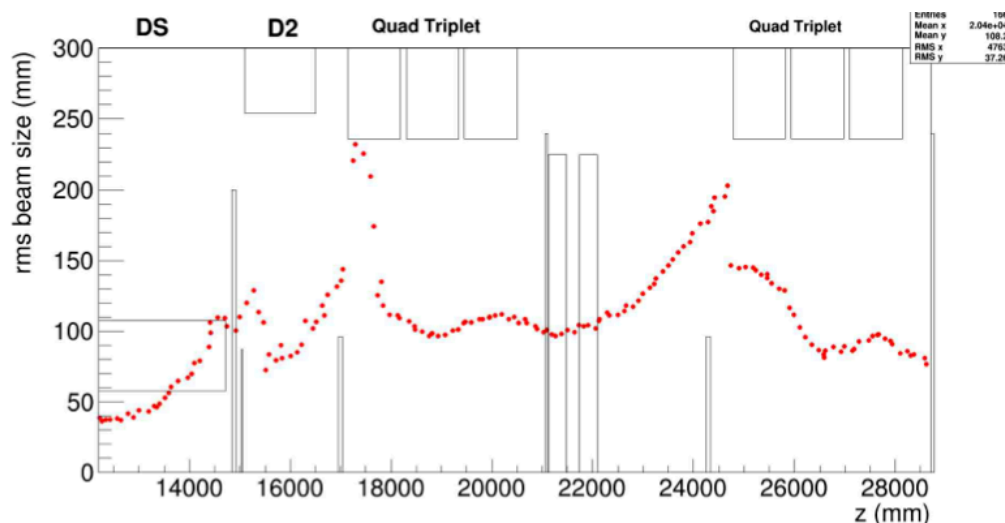


Monte Carlo

- Beam
- Geometry
- Particle tracking
- Detector response

Beam generation

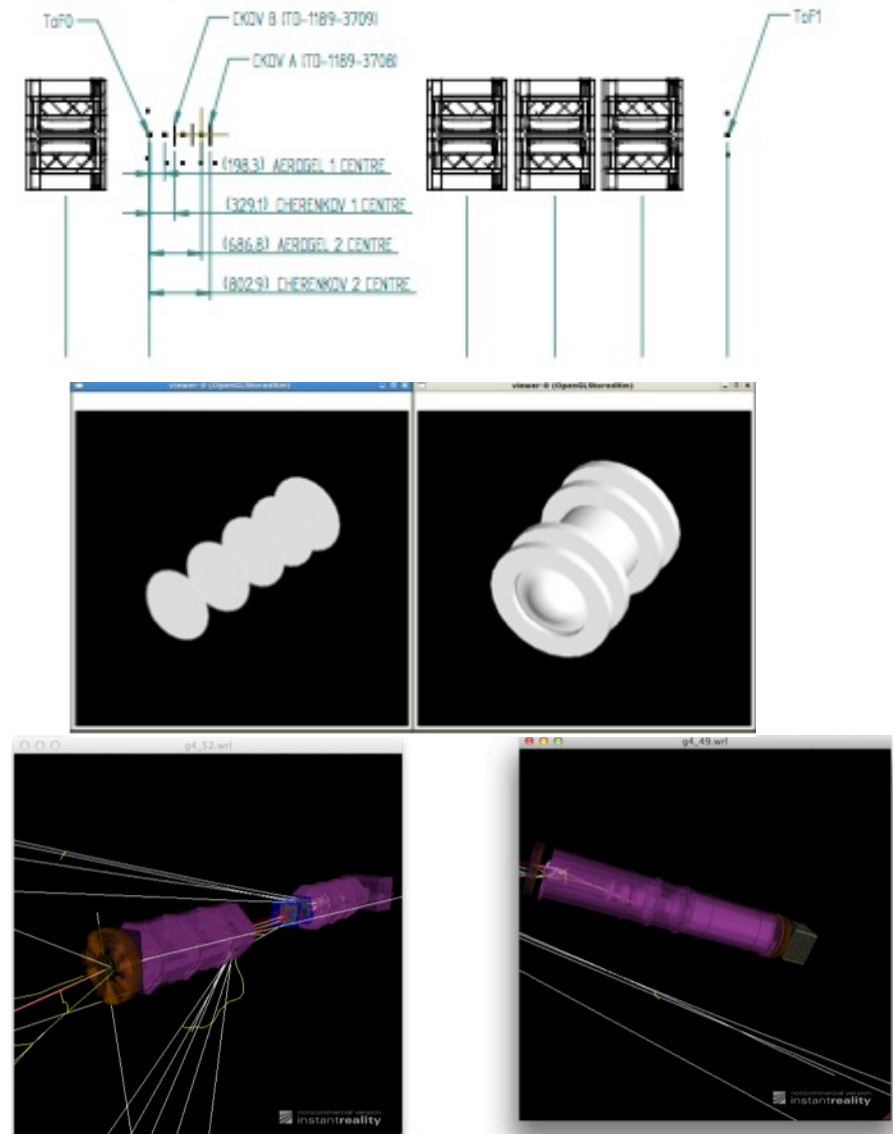
- Previously:
 - Generate pencil beam, or sample from a user-defined gaussian, or read in from a file
- Now added G4Beamline as a generator
 - Updated survey, geometries and currents
 - Generates beam upto D2
 - More realistic beam, better agreement with data (Step I)
 - *cf. Analysis presentation*
 - Ability to generate beam based on data-run currents



Geometry

Bayes/Ricciardi

- Default geometry description has been through flat text files
 - no surveying or versioning information
 - Prone to errors and outdatedness
- It was decided to have a CAD-based geometry description that is stored in the database
 - Significant progress
 - CAD models converted to GDML descriptions and stored in CDB
 - Realistic Step I & Idealistic Step IV geometries now available
 - *Except Ckov and EMR which are being finalized and integrated*
 - Requires validation and shakedown
 - Geometry loading time is an issue especially for user-testing, tuning, studies, etc
 - This is a new system, so there is risk associated with its deployment and usability
 - “Legacy” geometry continues to be supported and will be until the new geometry is proven

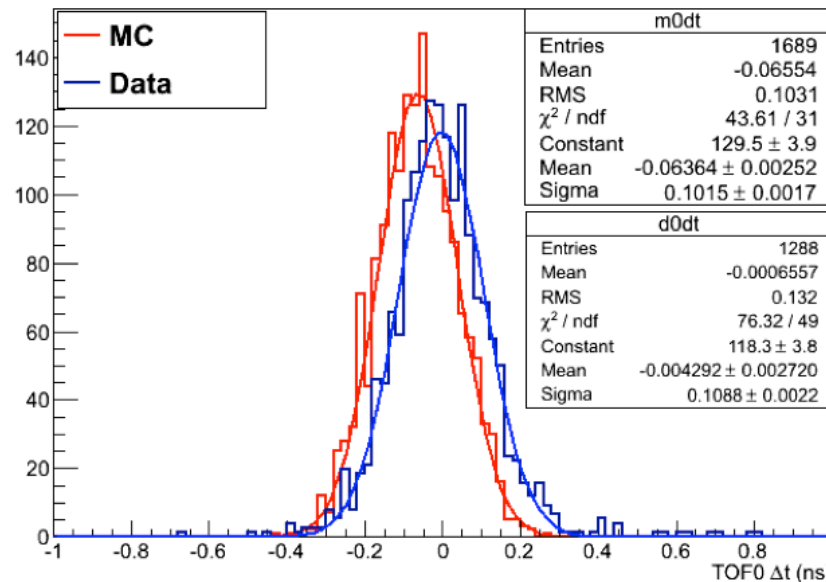


Simulation

- Particle tracking, energy loss, and scattering are done through GEANT
 - Upgraded to GEANT 4.9.6 – better handling of tessellated solids in geometry
- Custom field map models, or read in maps from file
- Two steps to simulating detector response
 1. Collect hits in each sensitive volume – volume ID, energy deposit, hit position, momentum, time...
 2. Electronics response aka digitization – mock DAQ readout – volume ID to cable map, energy to ADC...

Detector Response (TOF)

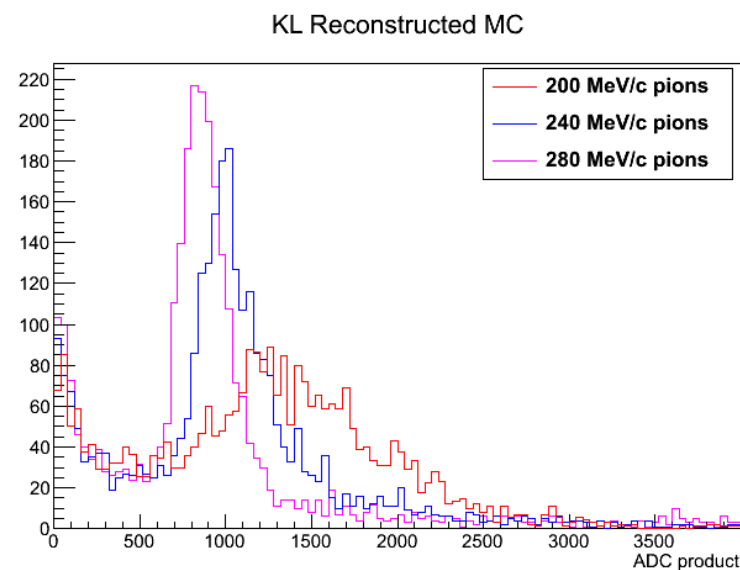
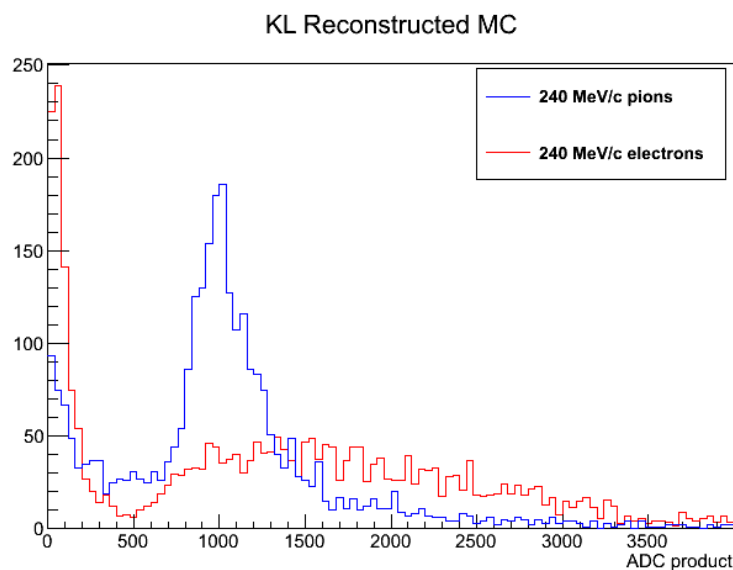
- Stable
 - Energy deposited is first converted to photoelectrons and then to an ADC count
 - Time of the hit is propagated to PMTs and converted to a TDC count
 - Calibration corrections are *added* in so that they can be taken out at reconstruction stage as is done with data



- Potential restructuring for trigger simulation (TOF is experiment's trigger)

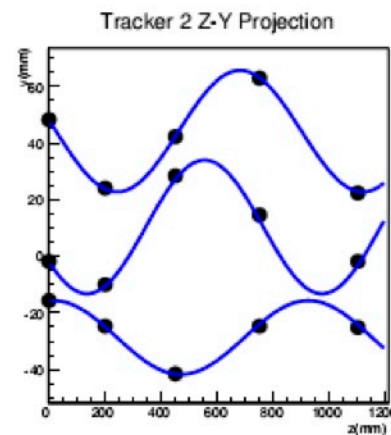
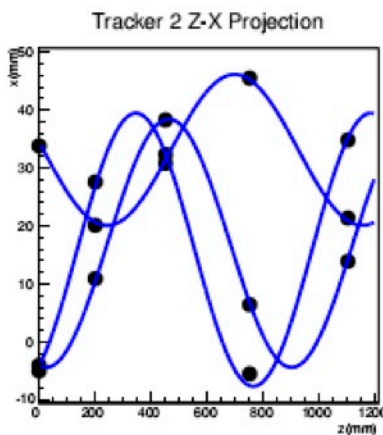
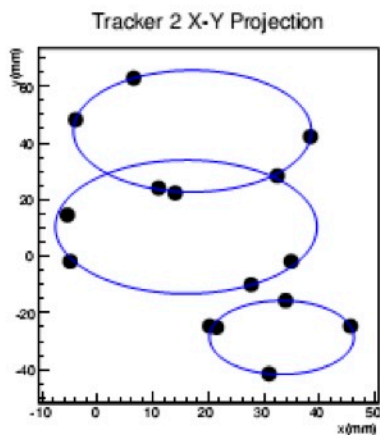
Detector Response (KL)

- **New:** Digitizer added along with updated geometry, and software to store hits in sensitive volumes
 - Outputs are ADC counts converted from energy deposits
 - Conversion factors are preliminary and likely require tuning
 - Needs validation against Step I data
 - Step I PID analysis can now use digitized and reconstructed KL



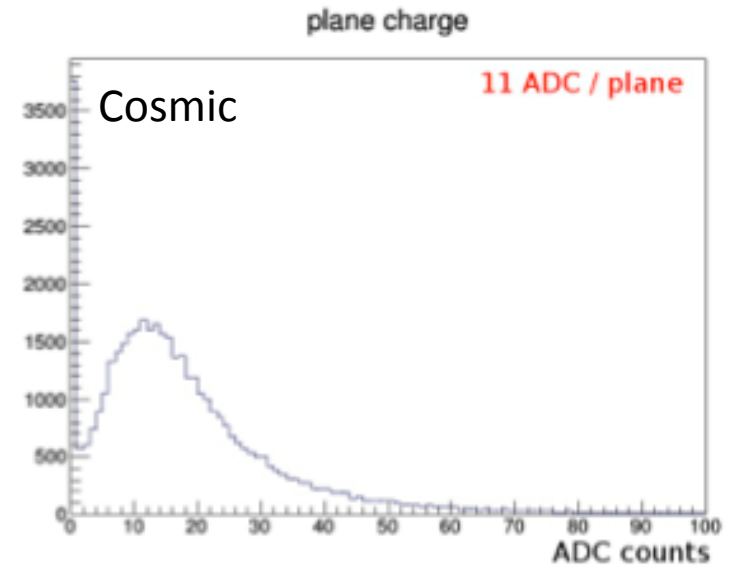
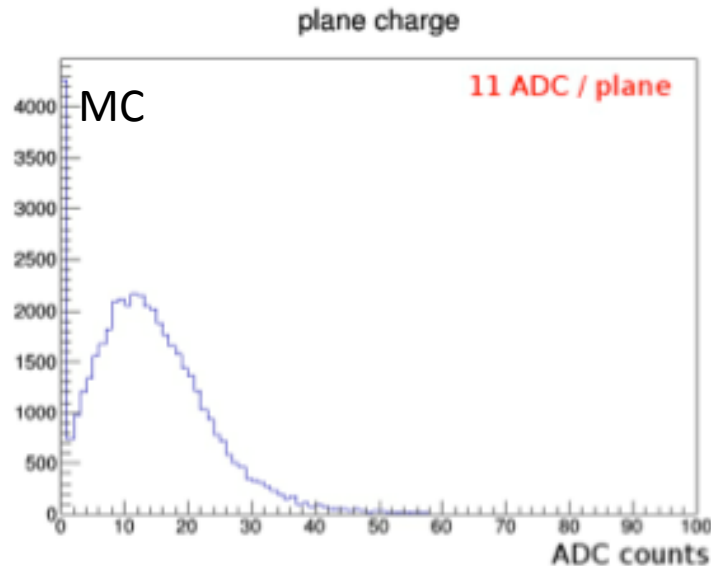
Detector Response (Tracker)

- Stable
 - Energy deposited is converted to photoelectrons, photoelectrons from a fiber channel are then summed and converted to an ADC
- New
 - Added Poisson noise to simulate VLPC dark current



Detector Response (in progress)

- The Ckov and EMR digitizations are not yet in the production release of MAUS
- Ckov:
 - digitization depends on finalizing geometry (Cremaldi and student), simulating optical photons and collecting hits and digitizing (Rajaram and students).
 - Possible refactoring, or rewrite
 - Risk: undergraduate students who are new to this and have to balance effort with coursework
- EMR:
 - The final geometry and hit collection are now complete and in MAUS
 - Digitization is getting started



Reconstruction

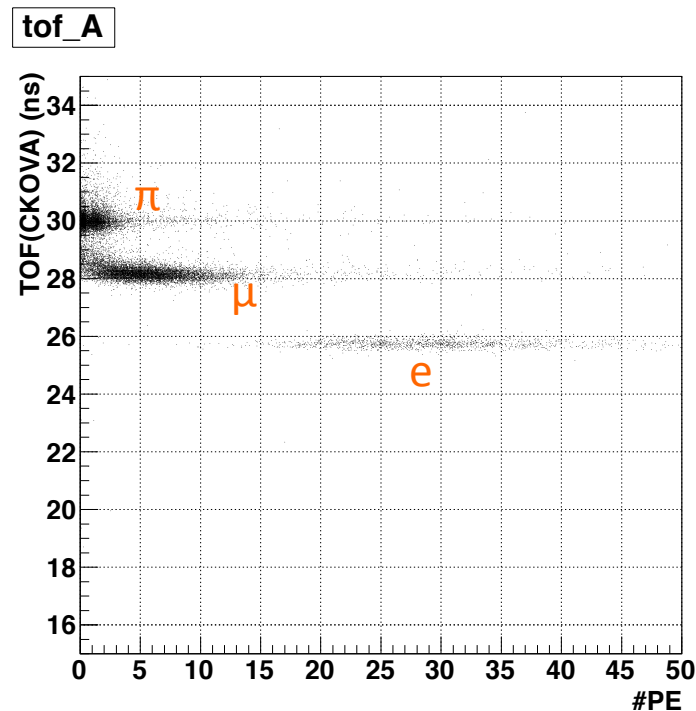
- For any given detector, the reconstruction algorithm is required to be agnostic about input – should not distinguish data from MC
- At the moment, MAUS can reconstruct every single Step IV detector
 - TOF, Ckov, KL, Tracker, EMR
 - Some are mature, some functional with optimizations and tuning in progress, some preliminary
- The final Global reconstruction (in progress) will take the individual detector reconstructions and provide a global track and an associated particle identification hypothesis

Reconstruction (TOF)

- Stable
 - Digits (MC or DAQ) are converted to slab hits.
 - x-y slab combinations are then used to form space-points
 - Space-point times are corrected for time-walk and trigger offsets based on calibrations stored in the DB
- **RFI**: Calibration algorithm needs some optimization to cover slabs/pixels with lower statistics
 - Reconstruction discards uncalibrated pixels resulting in a loss in acceptance

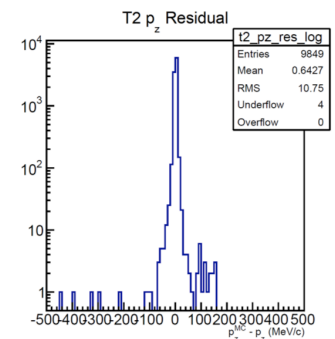
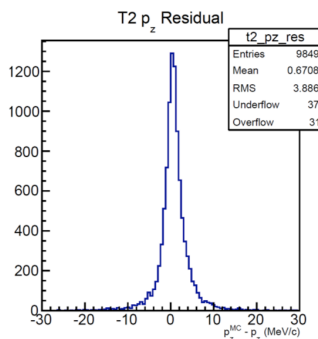
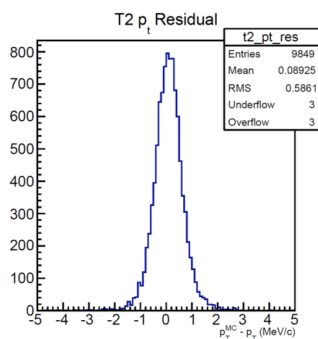
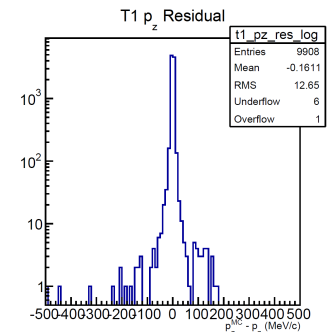
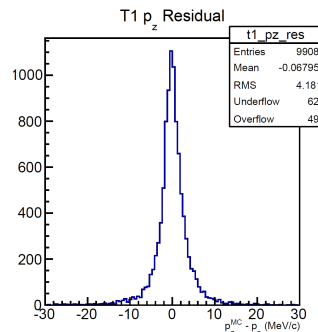
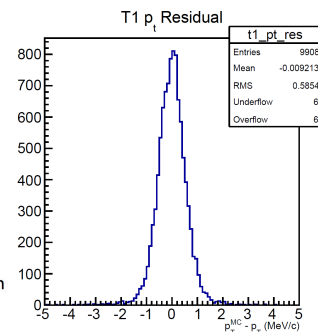
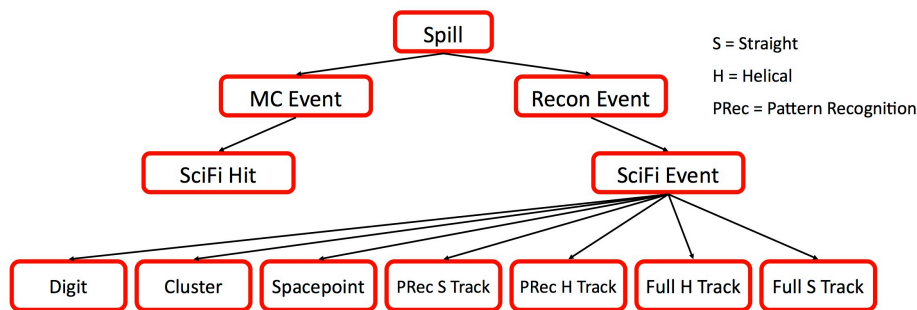
Reconstruction (Ckov)

- Functional
 - Flash ADC samples integrated and converted to number of photoelectrons
 - Conversion factor requires tuning based on single-photoelectron fits and should be stored in DB (hard-coded now)
 - Charge integration window may need to be optimized
 - Add multi-peak reconstruction



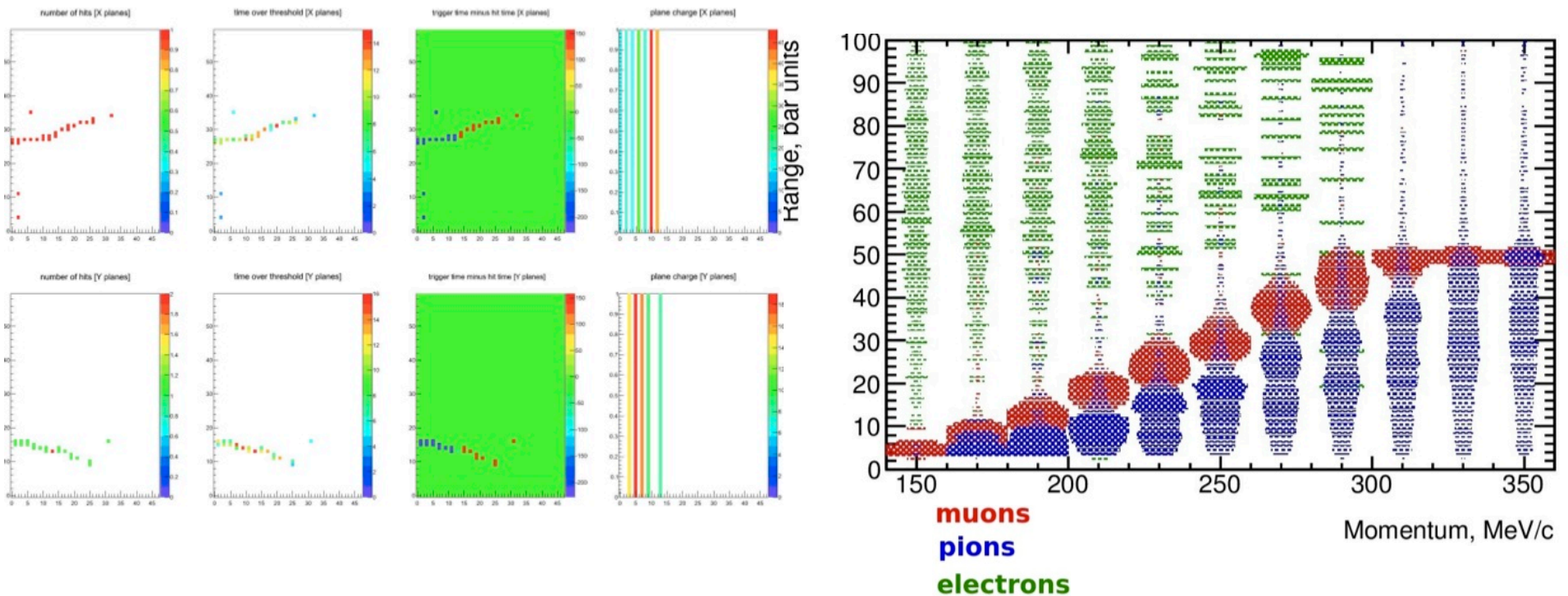
Reconstruction (Tracker)

- Functional
 - Space-point reconstruction, Pattern Recognition, Kalman tracking complete
 - Optimization underway
 - Efficiency studies in progress using MC
 - Calibration interface needs to be added
- Much improved documentation



Reconstruction (EMR)

- **New:** Reconstruction of plane hits complete
- Higher level reconstruction (tracks, charge ratios, range) are being developed – to be integrated
- Asfandiyarov is moving on, and Drielsma is taking over, so there is some learning curve
 - Risk if Drielsma has to move on to graduate/do other things

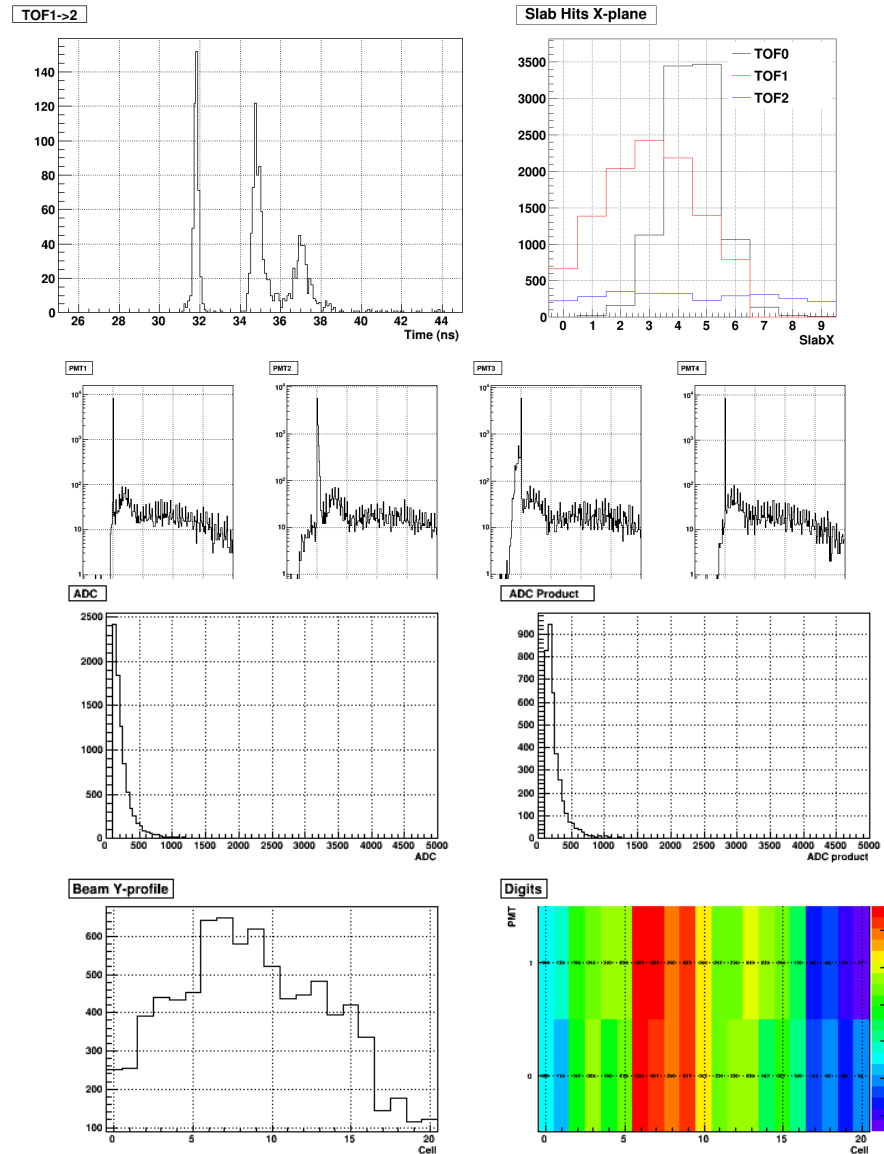


Reconstruction (Global)

- Global track fitting and particle ID are critical items
 - Tracking suffered from lack of experienced hand and grad student working on it has moved on.
 - A grad student (Jan Greis) has taken over and is getting up to speed
 - PID: framework developed & tested for TOF
 - In development: PID using TOF (time) + Tracker (momentum)
 - PID needs integration with the global tracking as that develops
- Ian Taylor, head of global reconstruction, is leaving → need someone experienced to guide the effort
- 9 months should be enough time, but requires fine breakdown to allow monitoring and catching risks early

Online Reconstruction

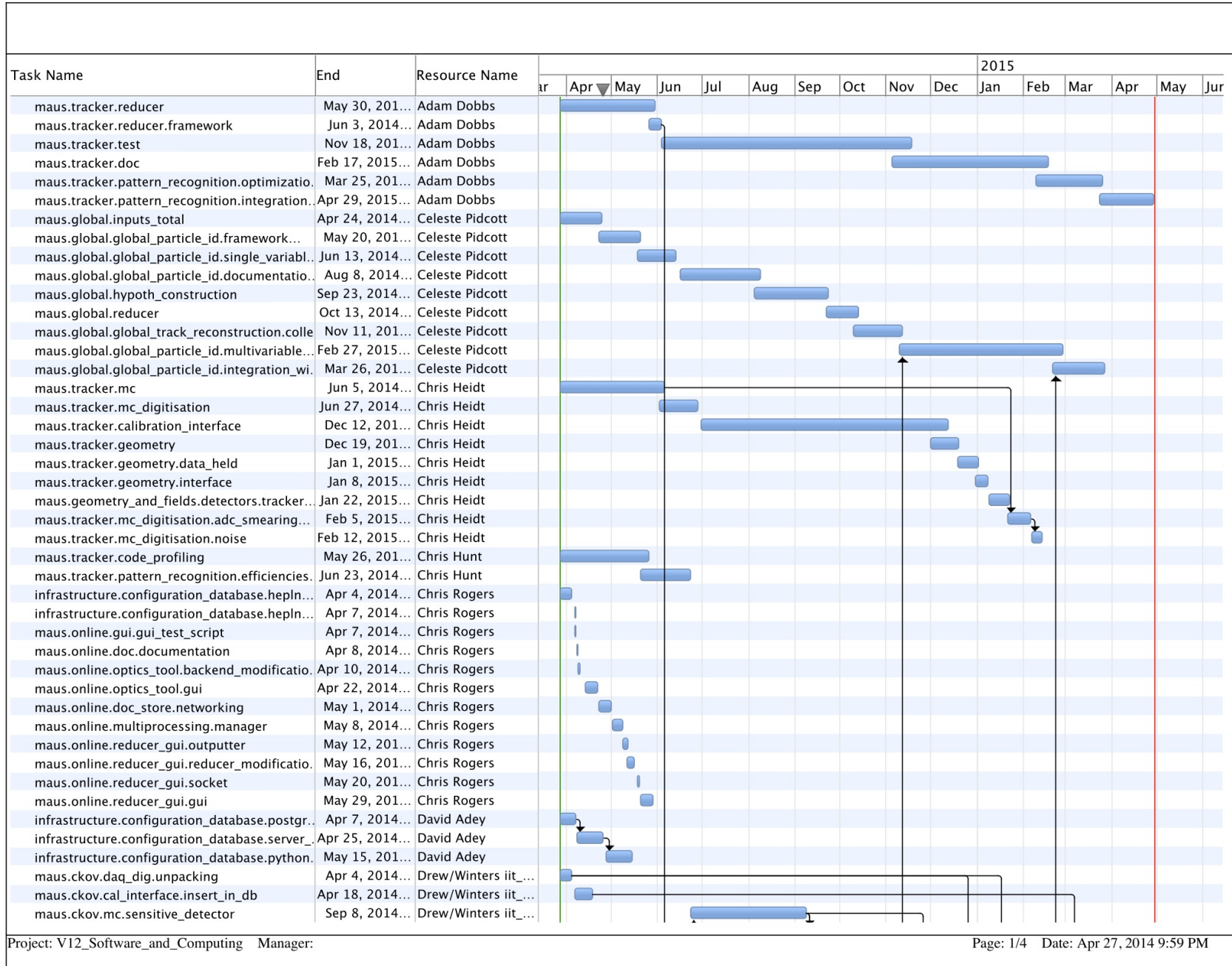
- Reconstruction software is same as for offline
- Distributed processing over worker nodes
- Summary and monitoring histograms visualized in MLCR as images via web interface
 - Plots intended to provide summary view of reconstruction quality
 - Lower level reconstruction plots serve to identify problems with detectors – e.g. inefficient tubes, dead channels...
 - Changes being made to visualization infrastructure (ROOT objects instead of raw images)
- Online reconstruction is available for TOF, Ckov, KL
 - Preliminary EMR display is available stand-alone, to be integrated with MAUS



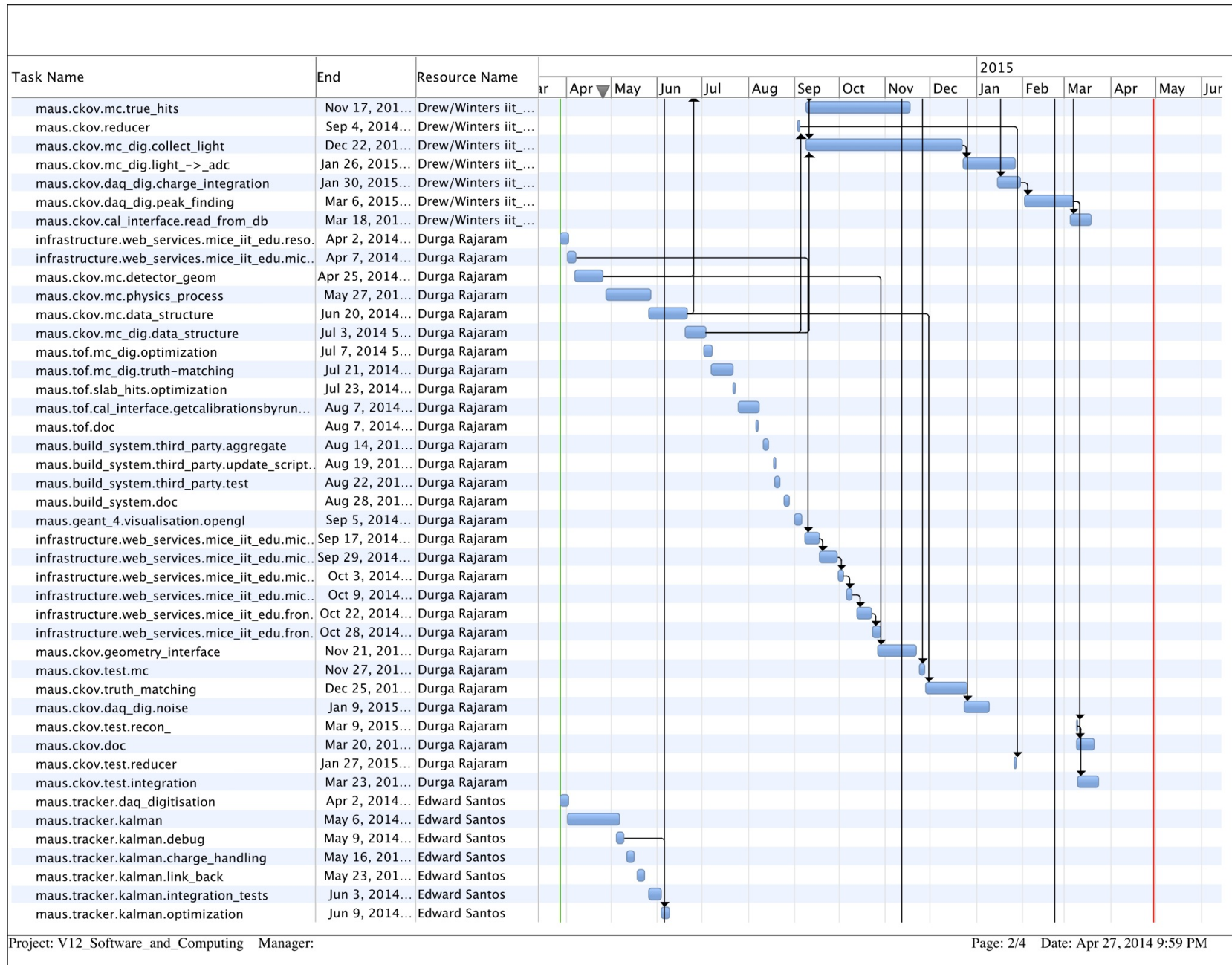
Software QA & Testing

- Software QA process
 - Style tests: does the code conform to style guidelines?
 - Unit tests: does the function do what's expected?
 - Currently, python coverage is ~68%, C++ coverage is ~78%
 - Integration tests: testing workflow – do all the pieces play nice together
 - Validation tests: does the simulation/reconstruction produce expected results?
- Continuous Integration test servers provide offline and online environments for developers to test their code before merging with the development branch
- Redmine issue tracker for bugs and features
- New release every ~2-4 weeks

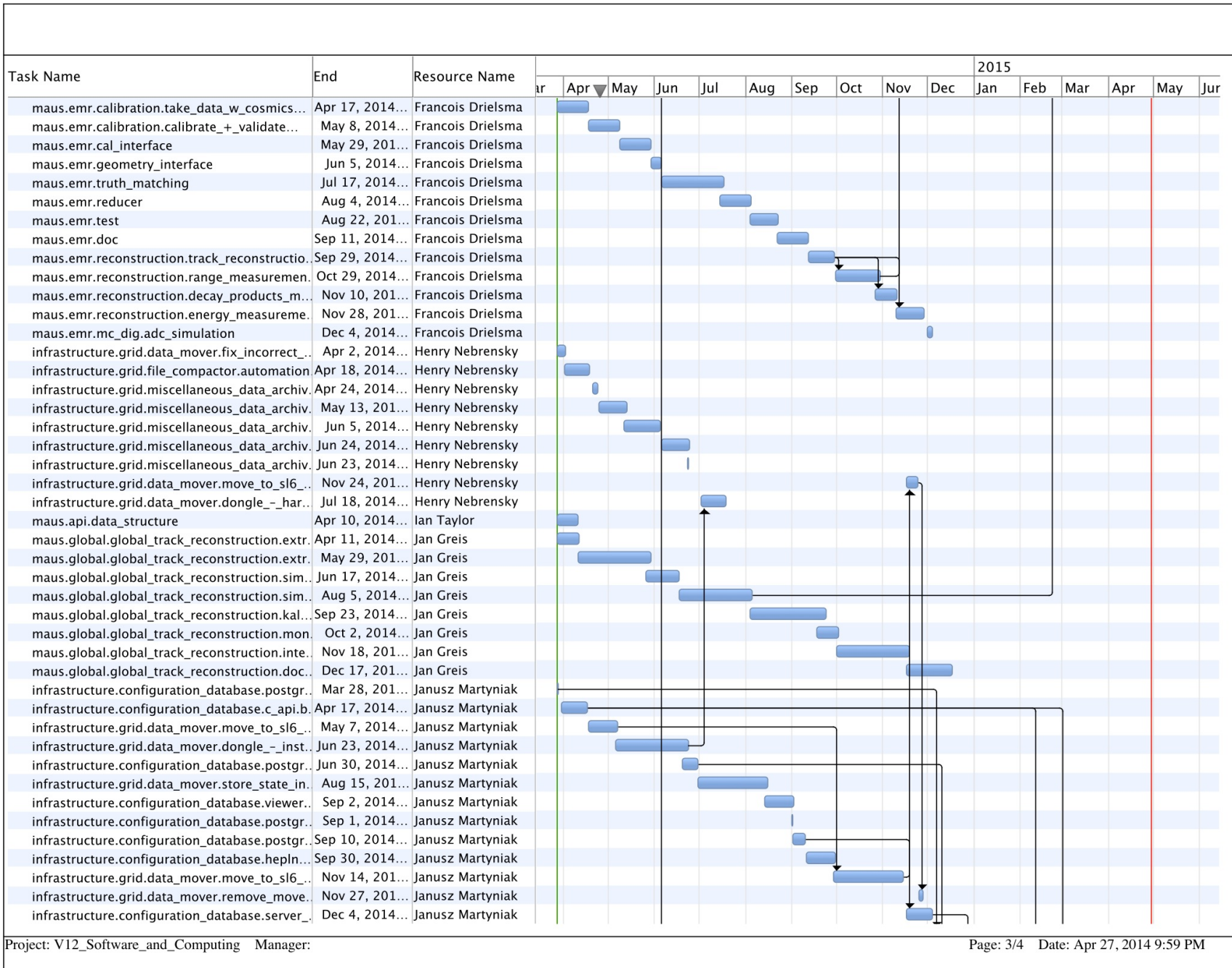
Schedule



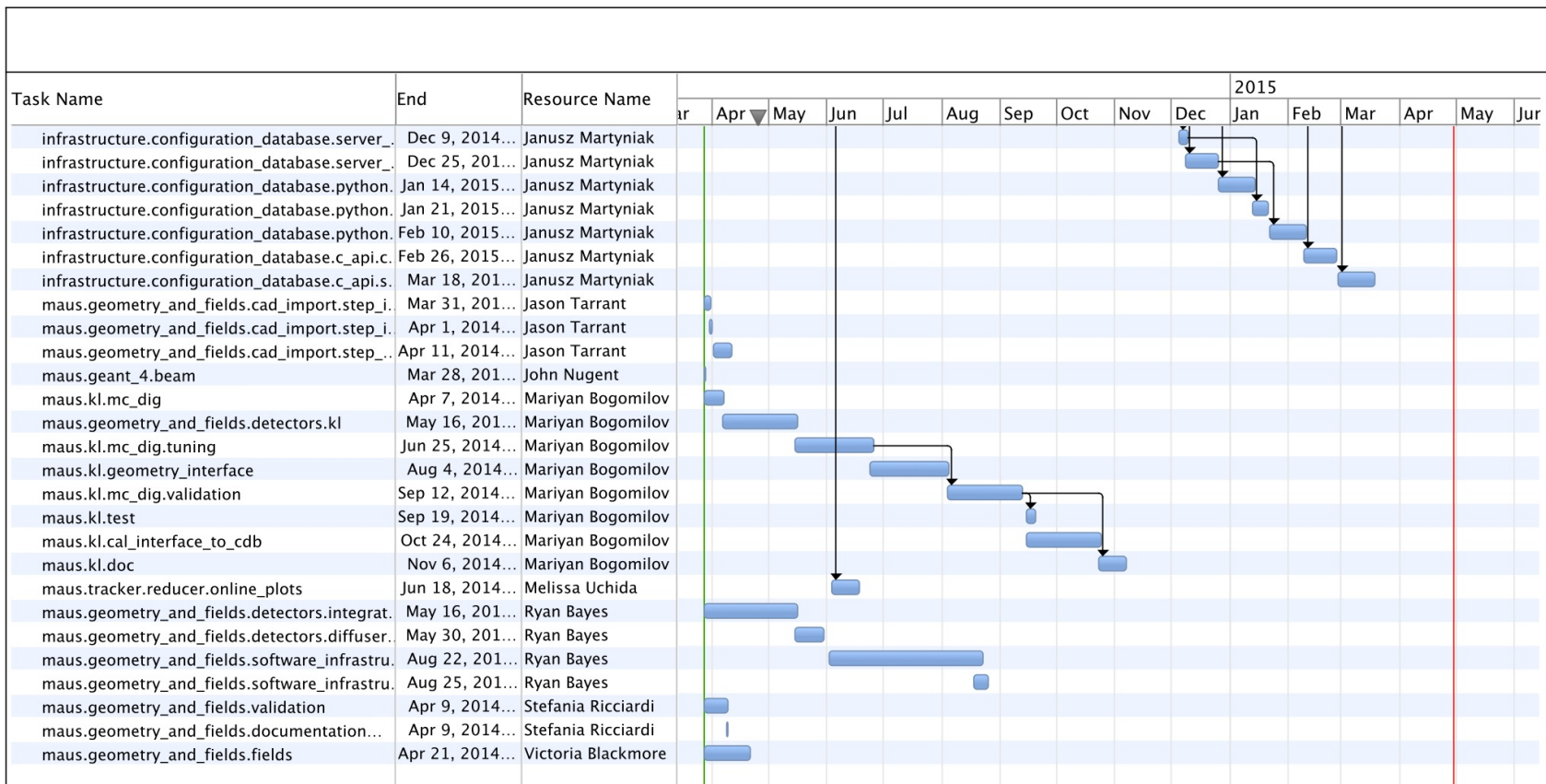
Schedule



Schedule



Schedule



Conclusions

- MAUS can reconstruct data from every Step IV detector
- Capable of simulating the TOF, KL, and Tracker
 - EMR and Ckov in development, to be integrated
- The big gap is global reconstruction
 - Need new manager, and frequent monitoring to catch risks early
- CAD-geometry implementation has progressed
 - Needs validation against full simulation
 - Usability and optimization issues to be evaluated
- Need to focus and make sure we have working simulation and reconstruction (beam + geometry + detectors + global) ready for Step IV