OLD DOMINION UNIVERSITY

Calibration Status of BONuS12 Experiment Towards Pass1 Review

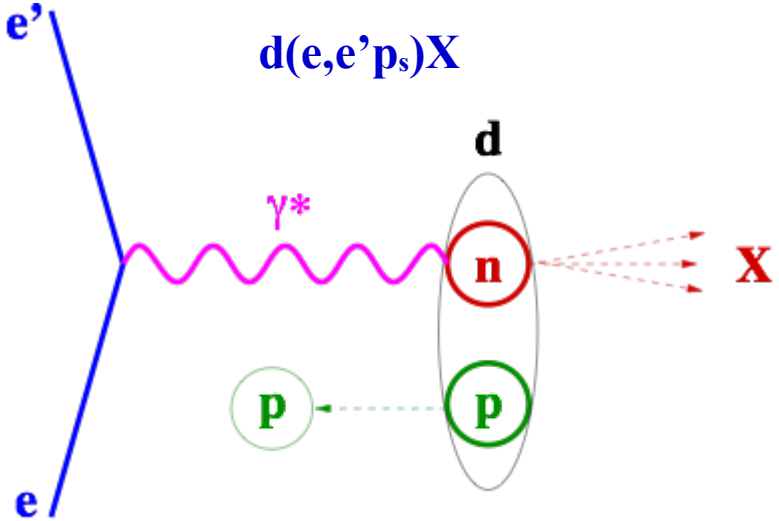
M. Hattawy

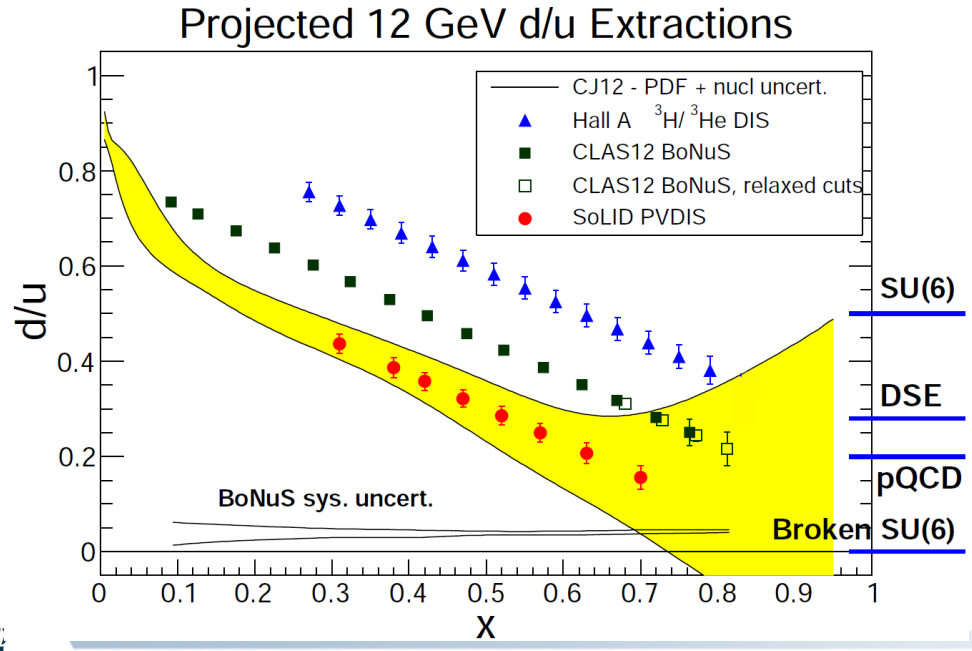
(On Behalf of CLAS Collaboration)

CLAS Collaboration Meeting, March 4th, 2021

BONuS12 Physics Motivations

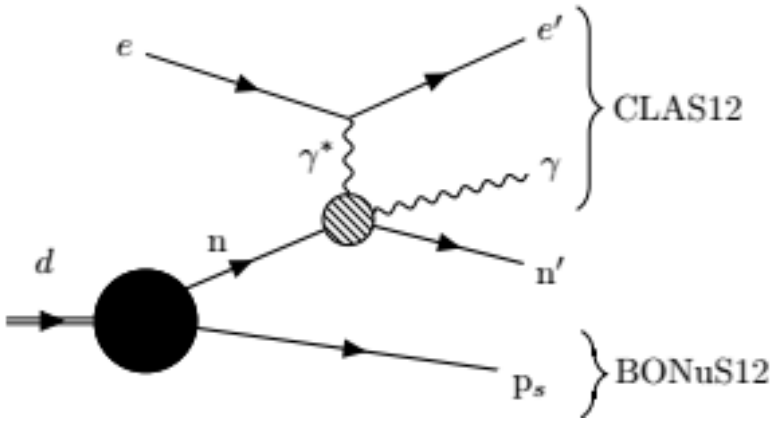
Parton Distribution Functions (PDFs)



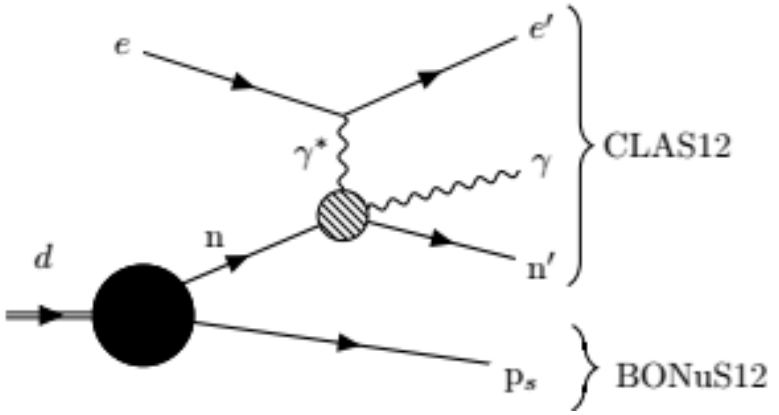


Generalized Parton Distribution Functions (GPDs)

$e^- D \rightarrow e^- p \gamma (n)$



$e^- D \rightarrow e^- n \gamma p$

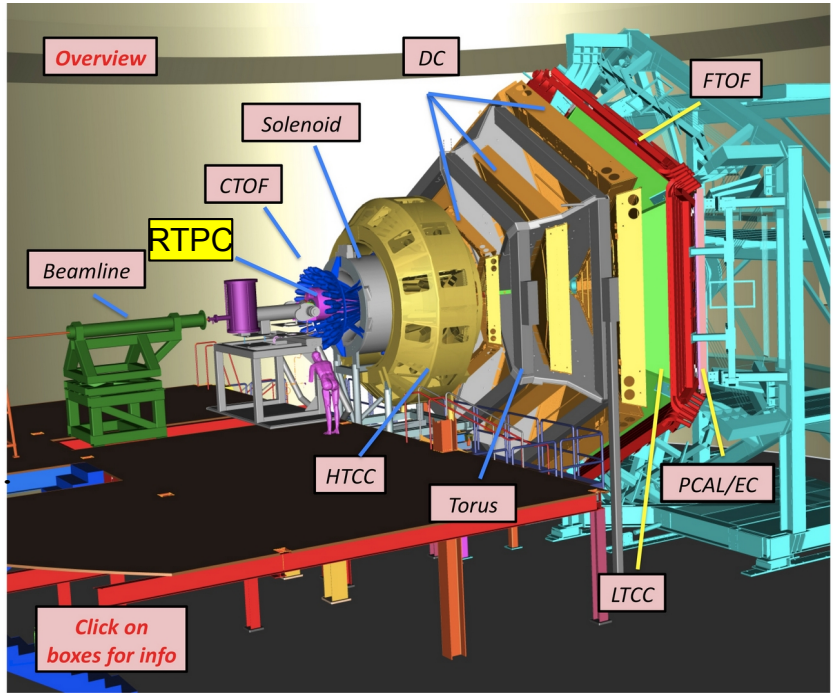


BONuS12 Experimental Setup

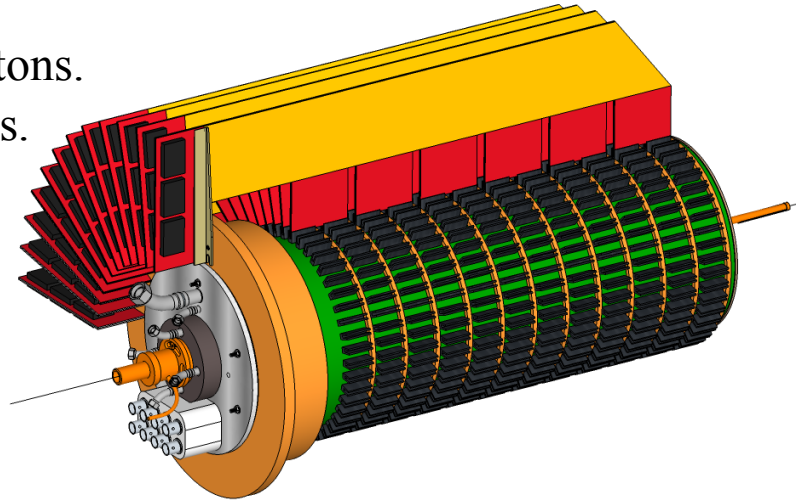
10.4 GeV

$e^- D \rightarrow e p \gamma (n)$

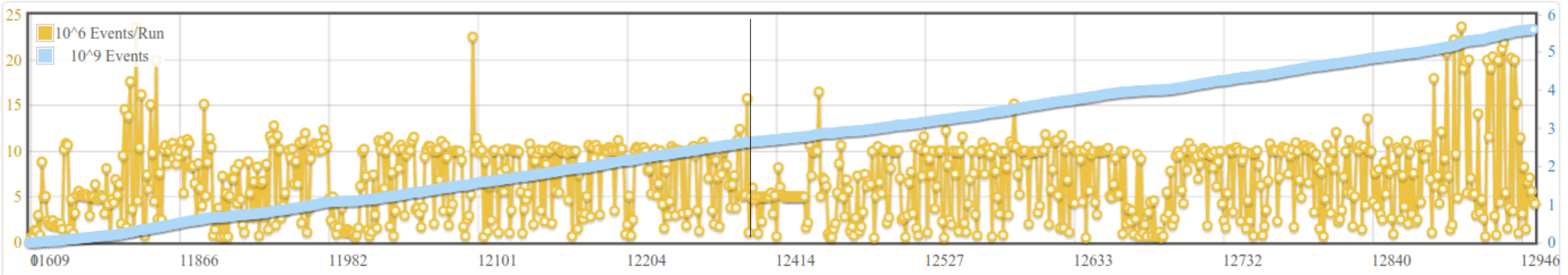
- **CLAS12 Forward Detector:**
  - → Superconducting Torus magnet.
  - → 6 independent sectors:
    - → HTCC: identifying e^- ($p < 5.0$ GeV/c).
    - → 3 regions of DCs: tracking charged particles.
    - → (LTCC and RICH): π^- identification ($p > 3.0$ GeV/c).
    - → FTOF Counters: identifying hadrons.
    - → PCAL and EC: detecting γ, e^- and n [5°,40°].



- **Central Detector:**
  - **Target:** D_2 gas @ 7.5 atm, 293 K
  - **BONuS12 RTPC:** Detects low energy spectator protons.
  - **Solenoid:** - Shields the detectors from Møller electrons.
    - Enables tracking in the RTPC.
  - **CTOF, CND, and FMT**



RG-F Data Summary



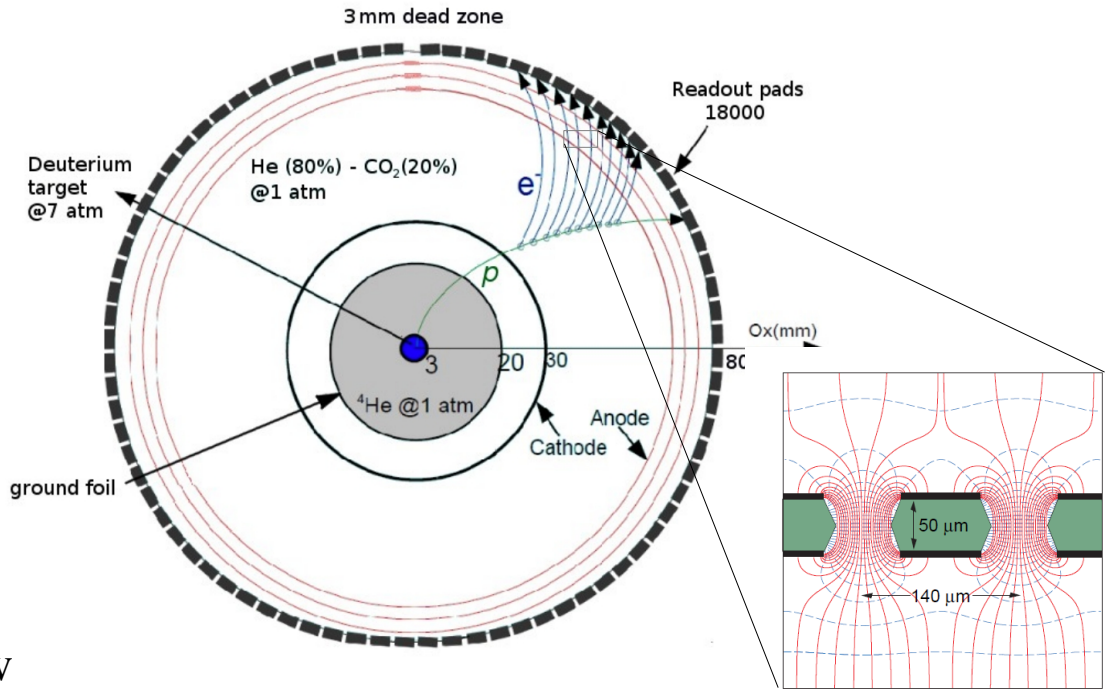
Showing runs: 11609 - 12955. 818 runs per page. Total runs: 818

Beam Energy	Target	Spring 2020	Summer 2020
1 Pass Data	H2	81M	185M
	D2	37M	45M
	4He	19M	44M
	Empty	1M	22M
	Total	138M	296M
5 Pass Data	H2	151M	266M
	D2	2275M	2355M
	4He	77M	51M
	Empty	21M	45M
	Total	2524M	2717M

BONuS12 RTPC

- Design:

- 100% azimuthal coverage.
- 400 mm long , 160 mm Ø.
- 60 mm diameter target with 50 μm Kapton wall.
- 30 mm radius of cathode foil (4 μm thick).
- 40 mm drift region with total drift voltage of 4.3 kV.
  $|\vec{B}|$ = 3.7-4 T
- 3 GEMs layers, gain of 100/layer
- 17280 readout elements (2.7 mm x 3.9 mm).



- Work principle:

Charged particle ionizes the gas atoms
→ Under EM field, released electrons follow their drift paths at a certain drift speed
→ Amplifications via the 3 GEM layers
→ Readout board → MVT FEU electronics → Signal height vs. Time bin

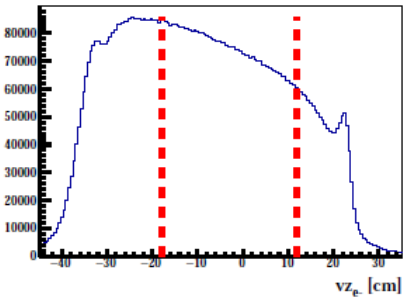
- Offline reconstruction:

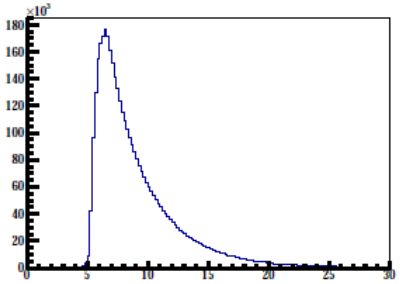
Signal height $\xrightarrow{\text{Pads' gains } (G_i)}$ $\left\langle \frac{dE}{dX} \right\rangle = \frac{\sum_i \frac{ADC_i}{Gi}}{vtl}$ → **PID**

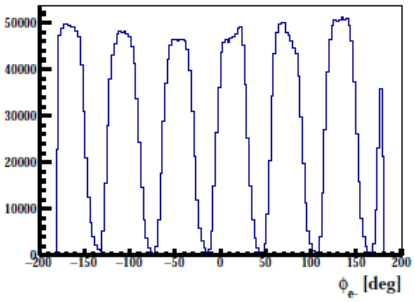
Time and Pad location → 3D reconstruction of track → vector p/q, vz, vertex time

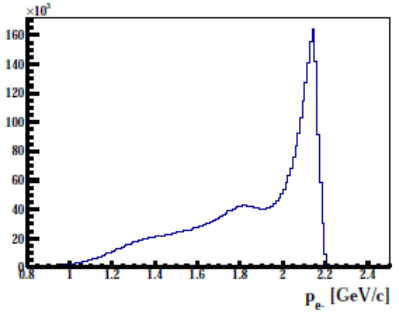
Preliminary Analysis – 1 Pass Data

Electron Selection : 2.14 GeV on H_2 target

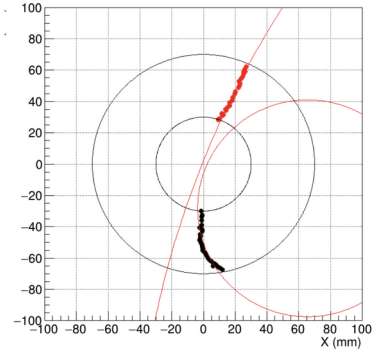


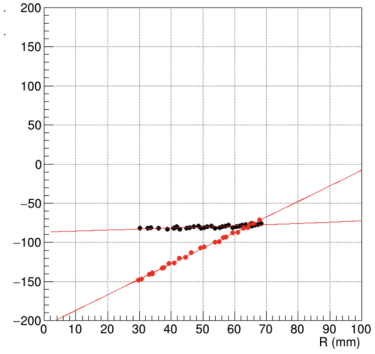


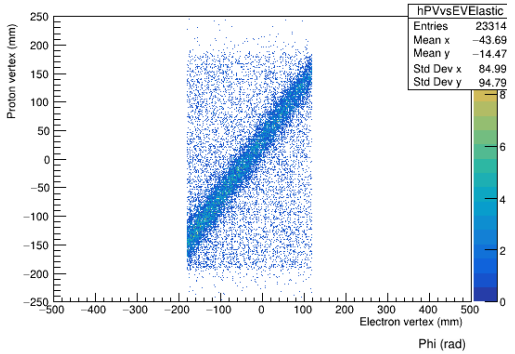


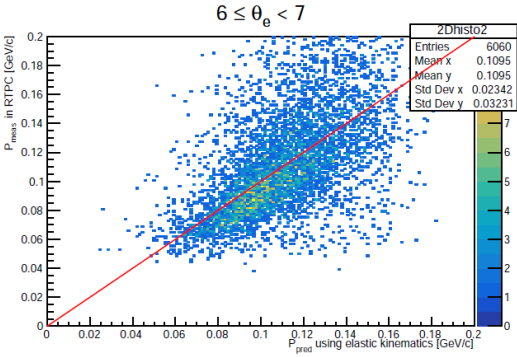


Radiative elastic e- in coincidence with good p tracks:

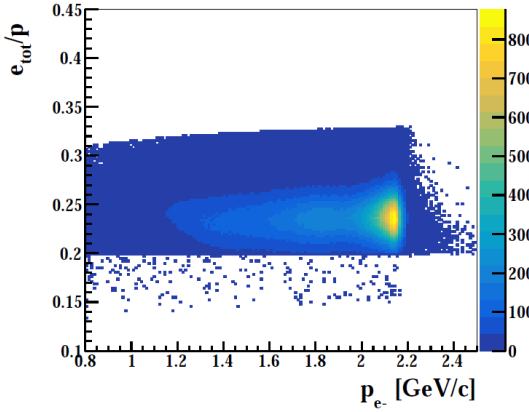


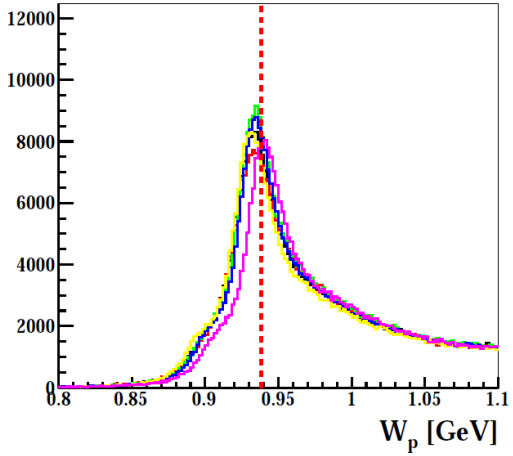


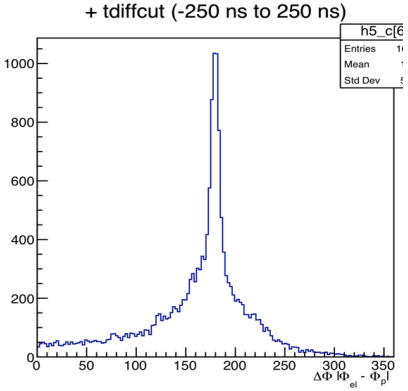


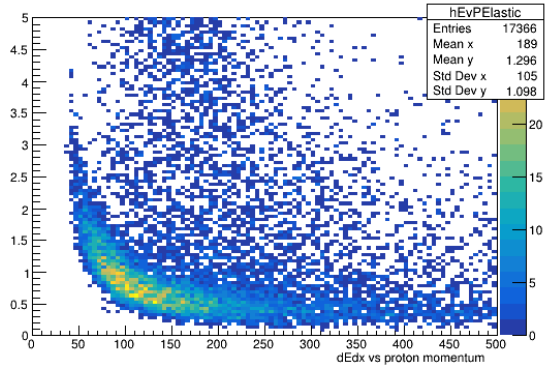


Phi (rad)









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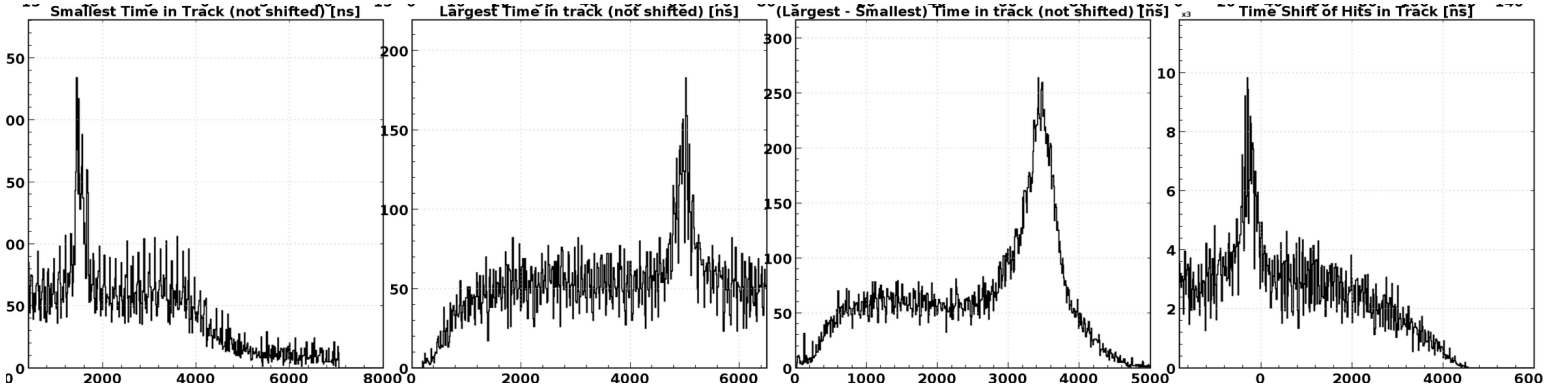
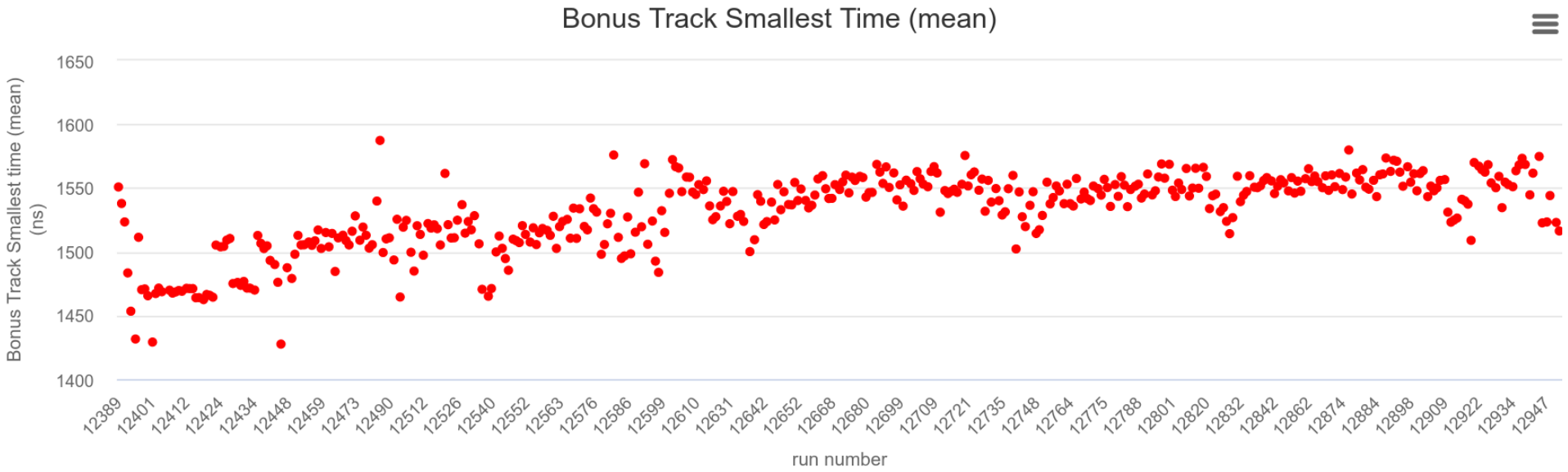
BONuS12 Timelines - Summer2020 (1/2)

Timing Calibration



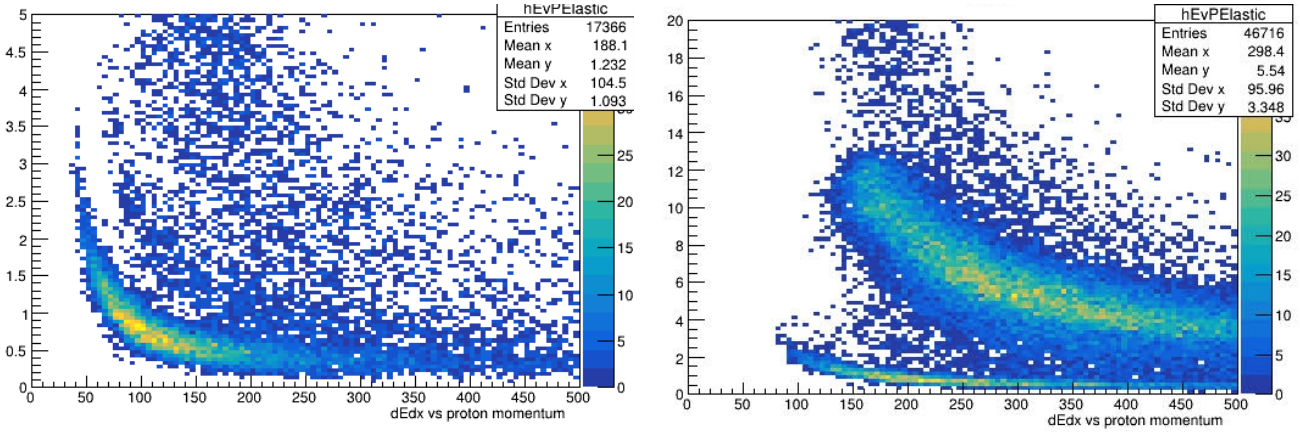


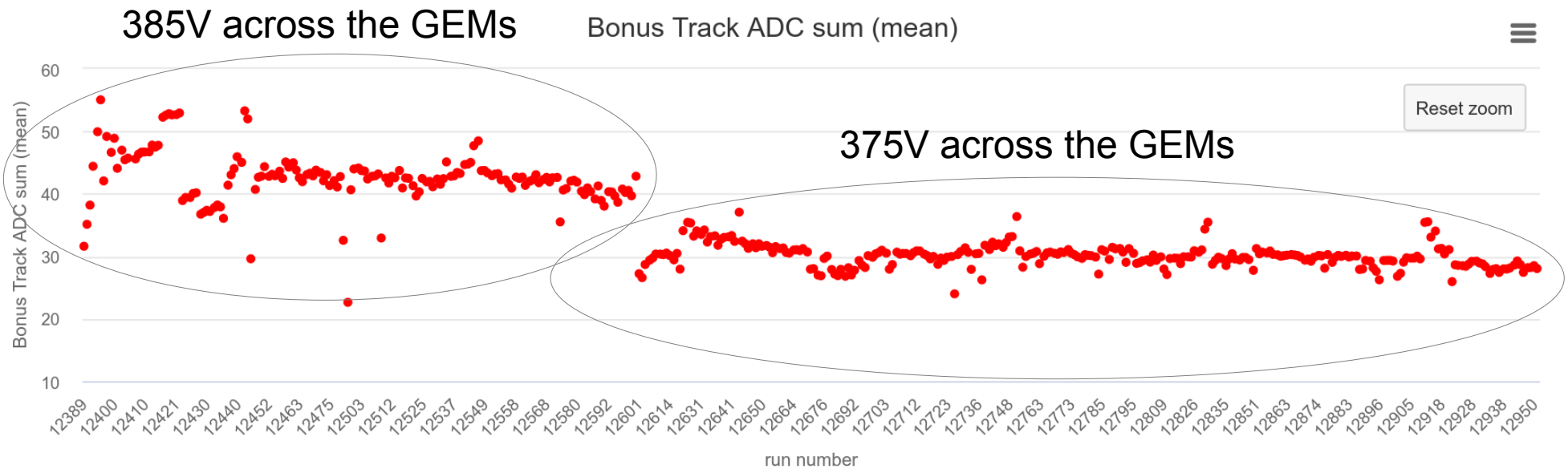
In progress: Regions have been defined, and a new calibration iteration will adapt for the variation in the observed timing quantities.

BONuS12 Timelines - Summer2020 (2/2)

Gain Calibration

H_2 vs. ^4He targets at the beginning of the summer 2020 Data



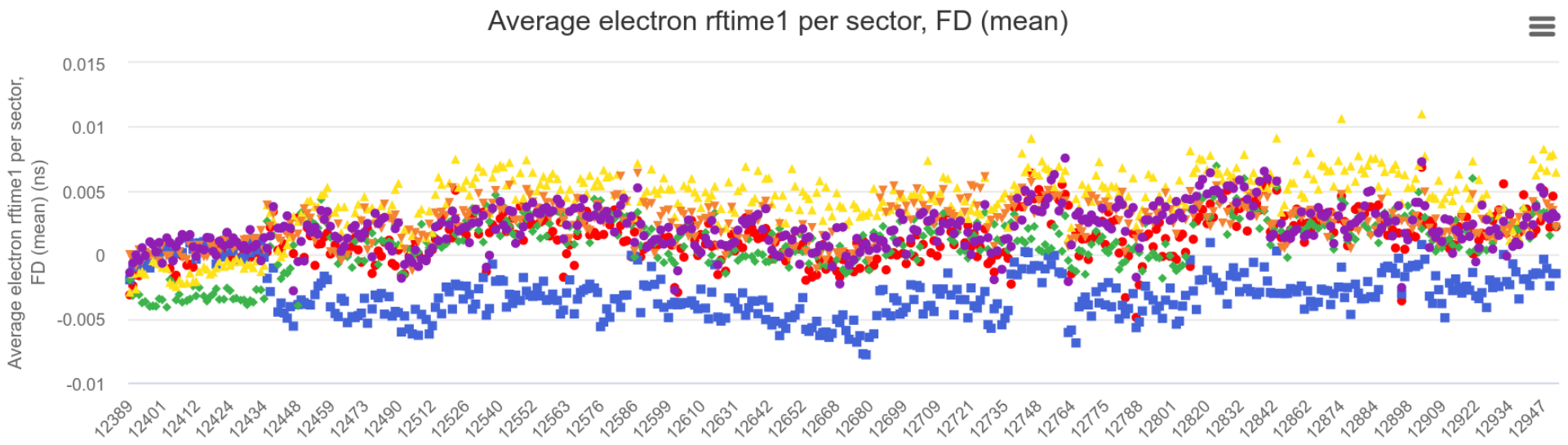


Ongoing: Two regions have been defined. Will adjust two Gain setting for the summer.

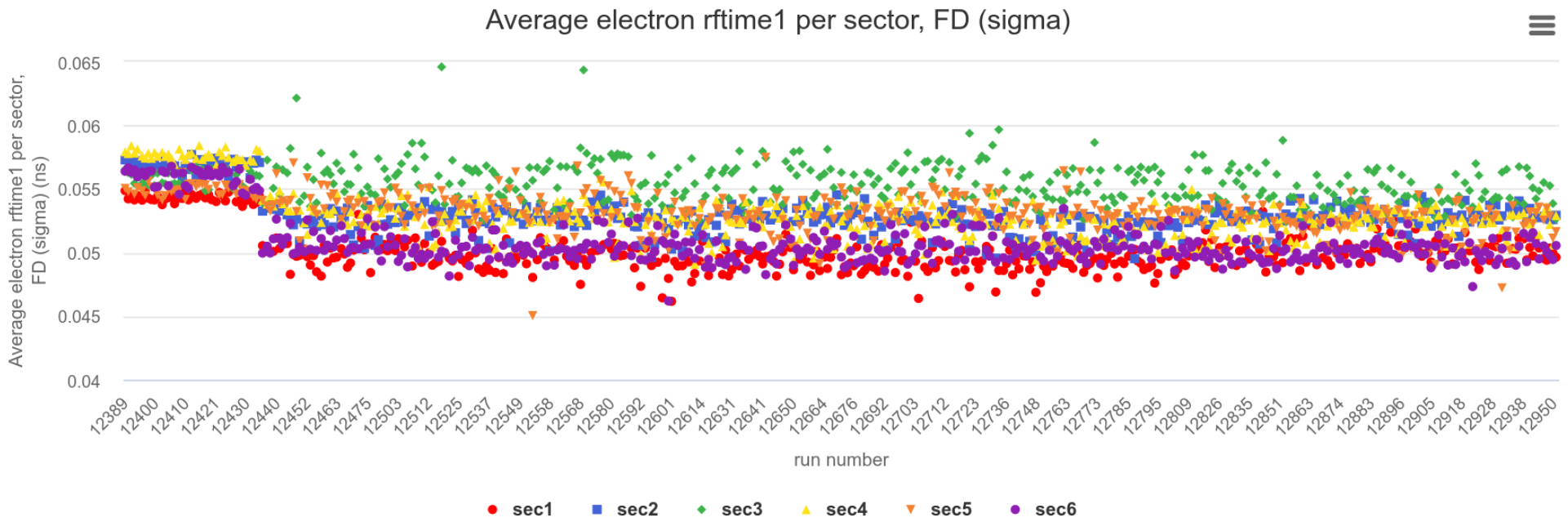
RF Calibration - Summer2020

Raffaella & Jose

RF time
$\mu < 7$ ps

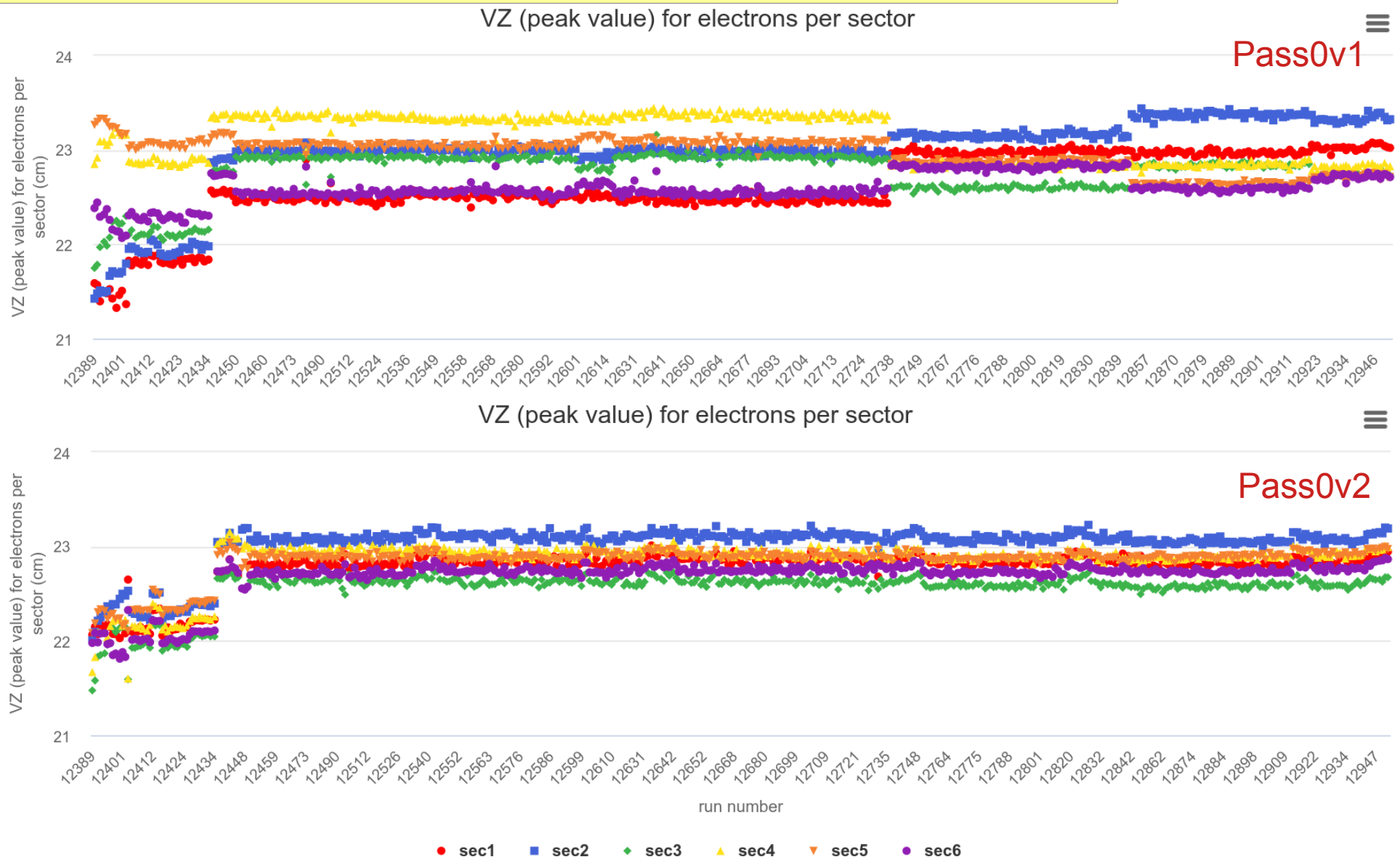


RF time
$\sigma < 60$ ps



Beam Offset Corrections - Summer2020

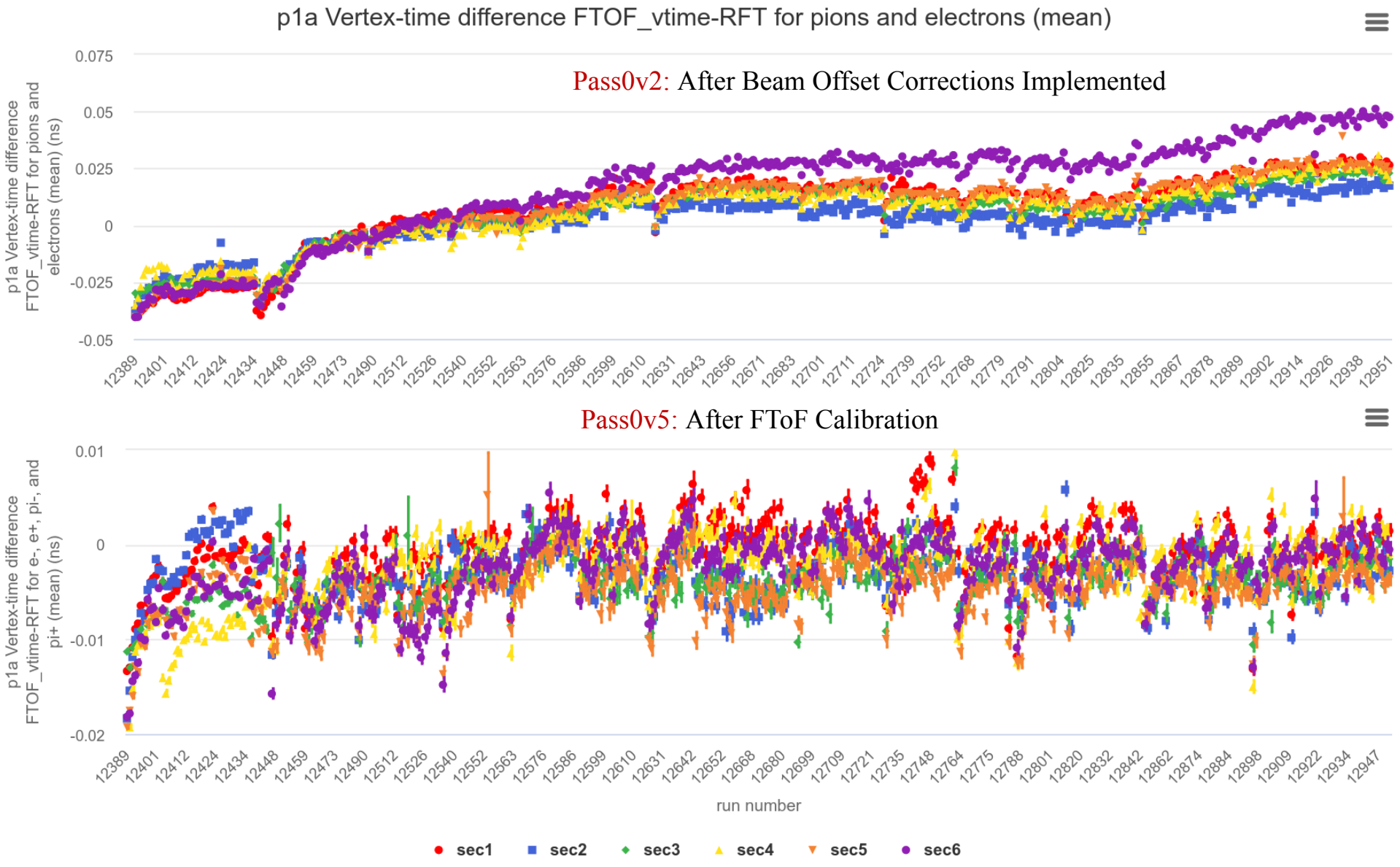
» Using the Downstream Al (30um) target window to correct for the beam position in XY plane.
» Azimuthal (sector) variation has been reduced from 1cm to less than 0.5 cm.



FToF Calibration - Summer2020

» p1a time means within10 ps for basically all runs and sectors (p1b ~ 5 ps, p2 ~5 ps).
» p1a time sigmas within 120 ps (p1b ~ 60ps, p2 ~350 ps).

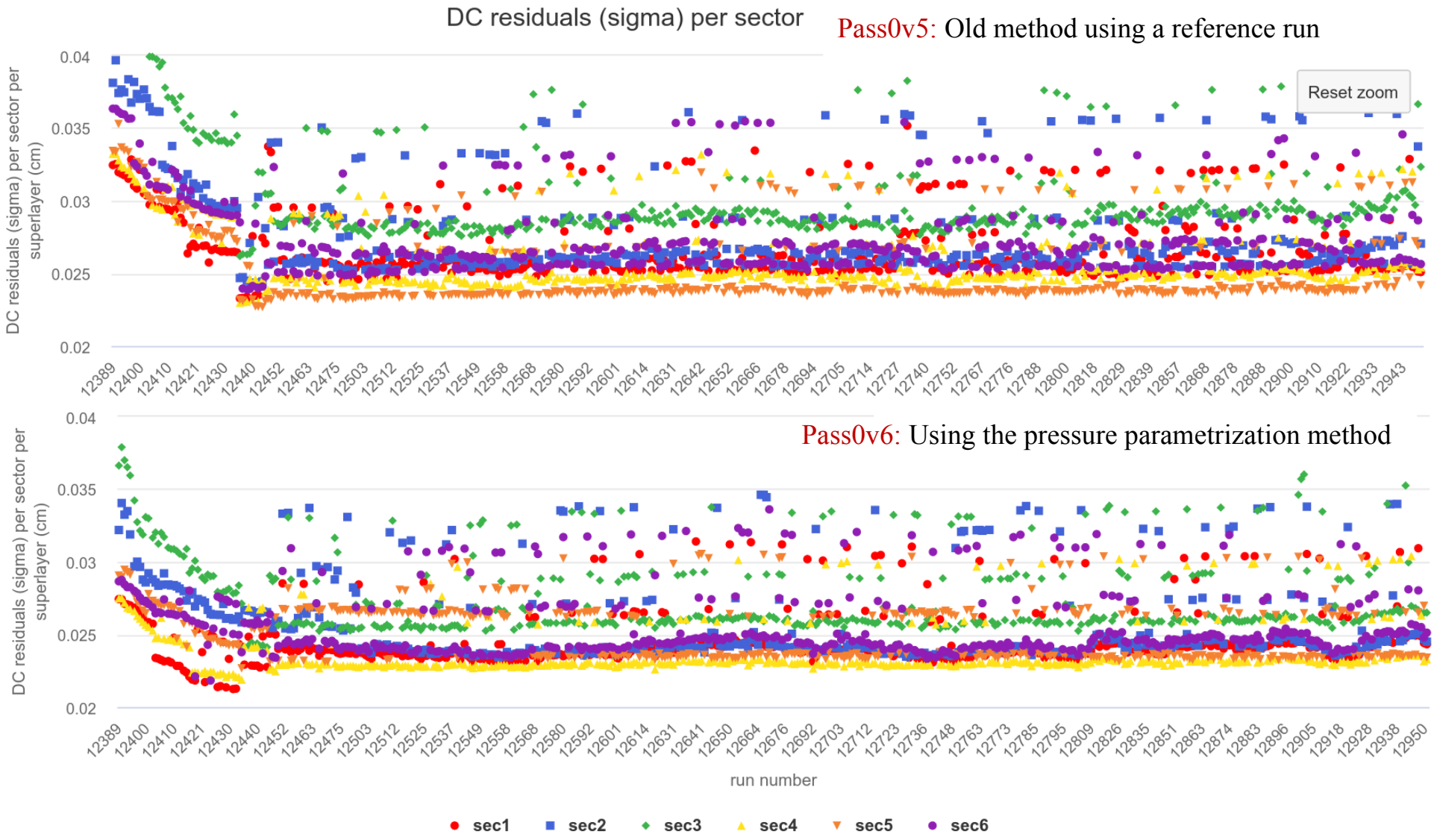
D. Carman



DC Calibration – Summer 2020

» Implemented the pressure paramterization method for DC reconstruction.
» Residuals < 350 um for all the runs and all the sectors.

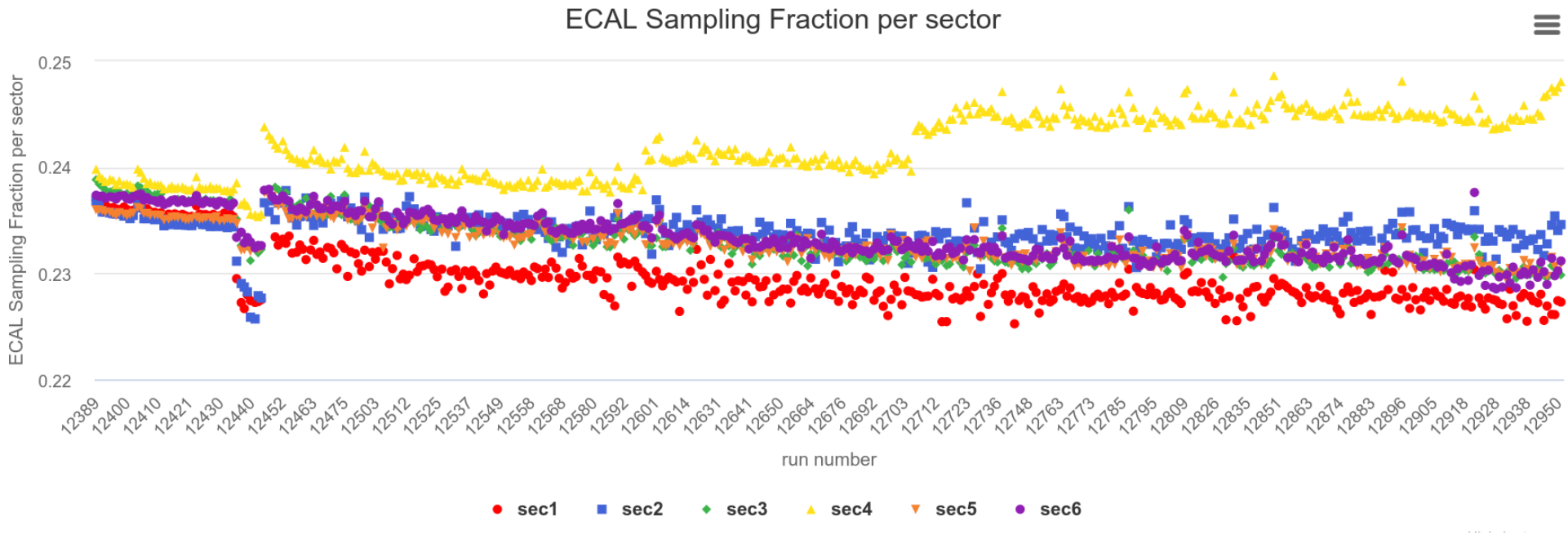
Mac, Taya, Bradley, DC team



EC Calibration – Summer 2020

C. Smith

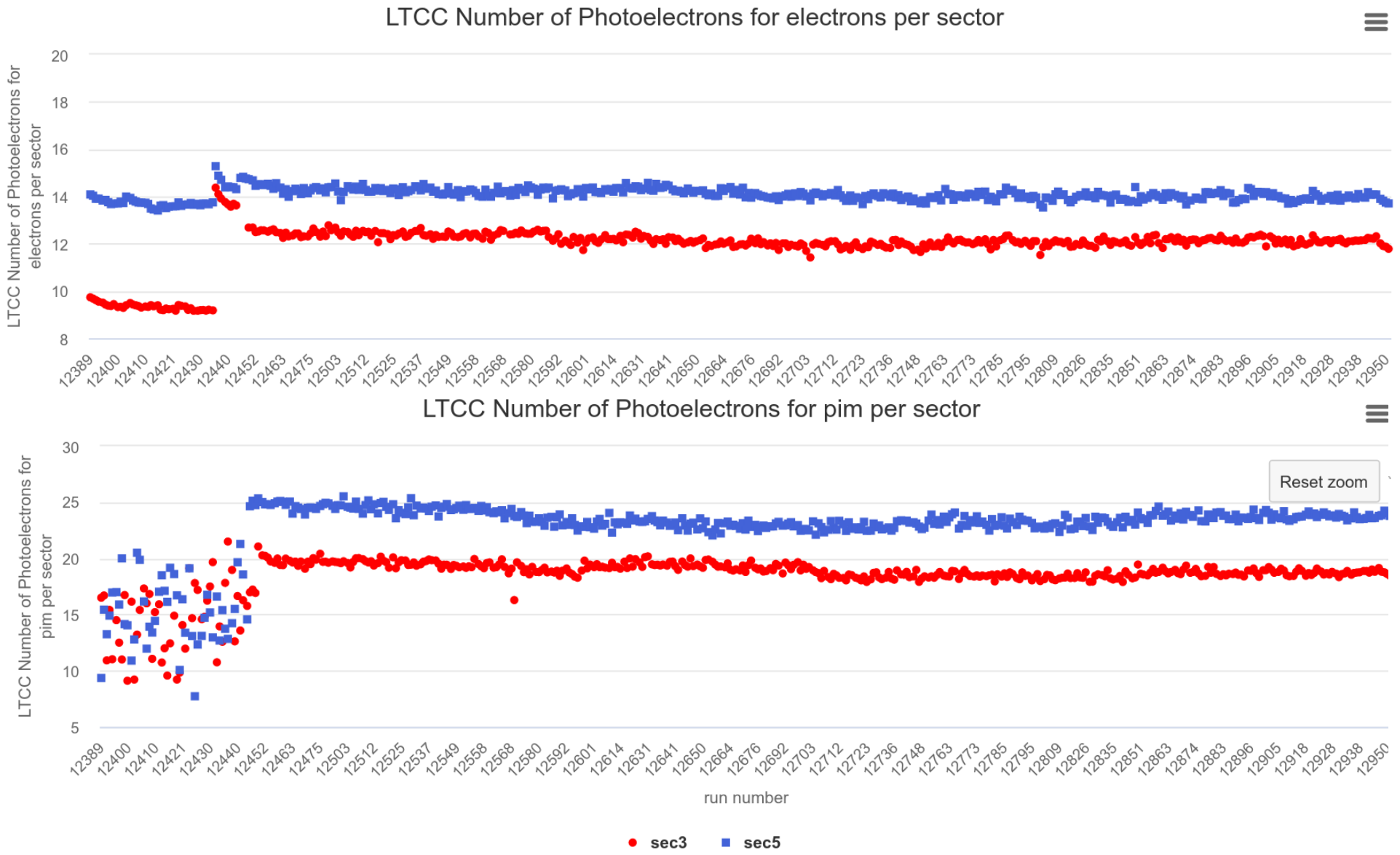
» All Sectors except S4 show ~ 2% drift in the Sampling Fraction over the whole Summer run.
» S4 shows stronger shifts due to gain instability, fixed by compensating for the SF shifts.
» Other sectors are very close to each other with slight shifts in SF.



LTCC Calibration - Summer2020

» S3 shows lower nphe for e- during the outbending 2 GeV runs, but calib-wise everything seems stable.
» Slight performance shift between the two sectors, but very stable during the production (10.4 GeV) data.

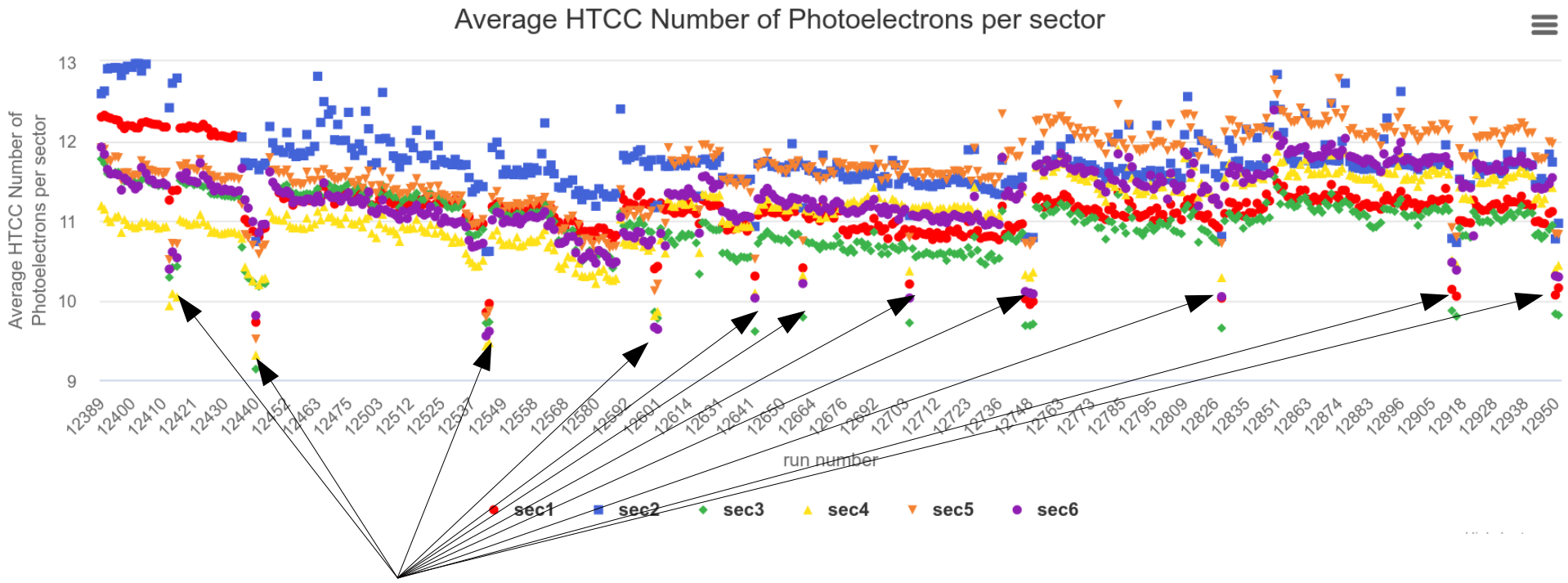
V. Mascagna



Ongoing HTCC Calibration - Summer2020

» Basically no big shifts, but there is a window for improvments.
» 9 Periods have been defined.
» Ongoing calibration that will be finalized by March 10th.

N. Markov

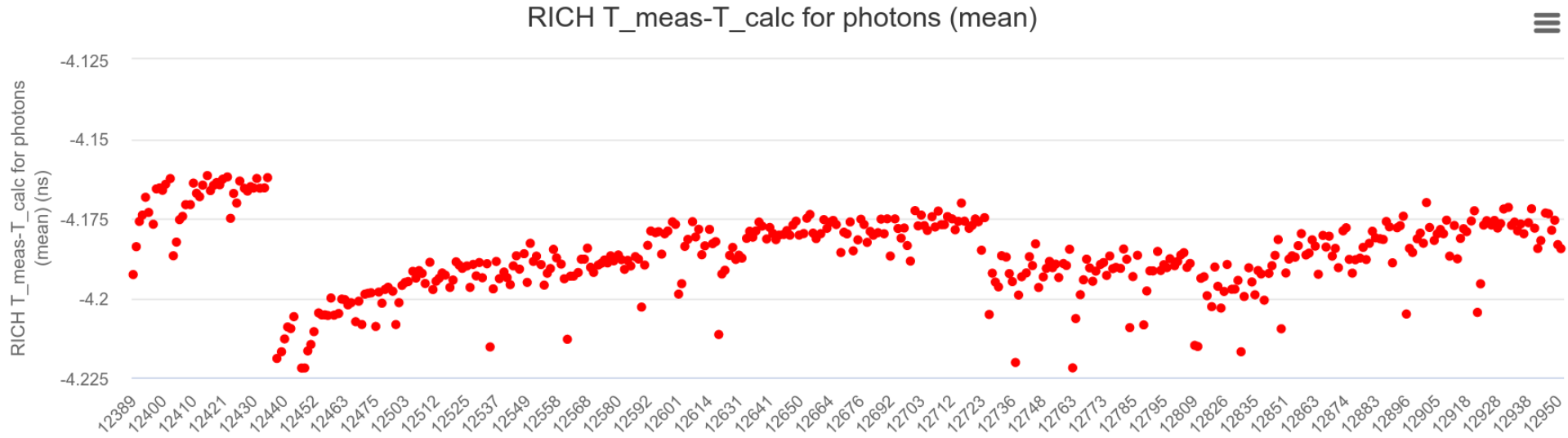


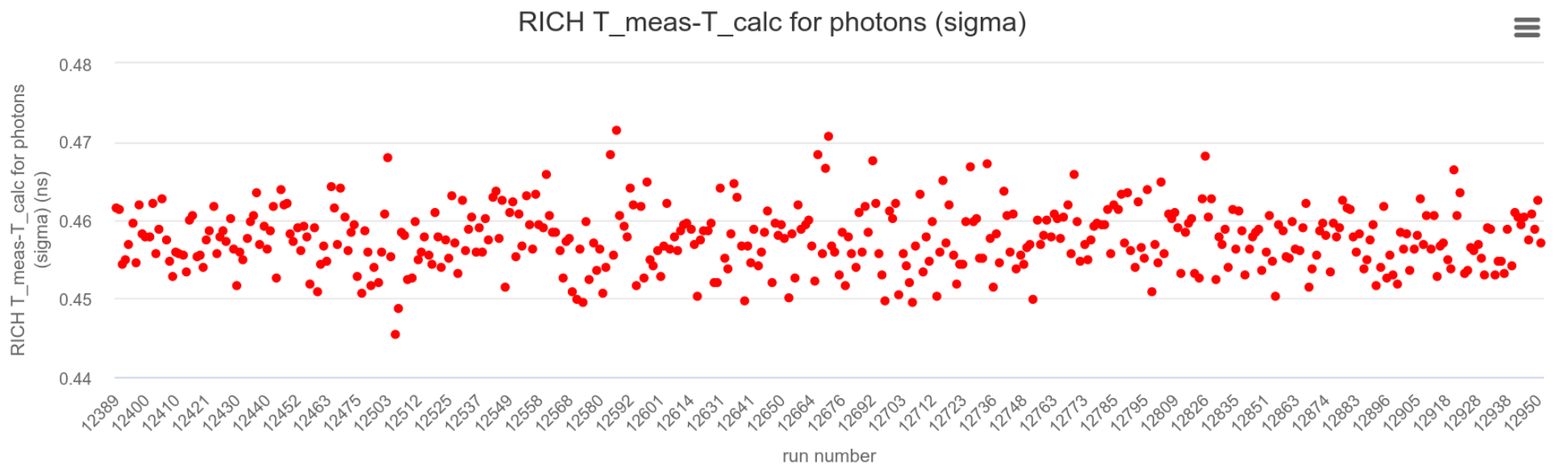
Empty target runs

Ongoing RICH Calibration - Summer2020

» Typical mean < 60 ps and Typical sigma <460 ps
» Pending for the expert to select calibration runs!

M. Mirazita





FMT Alignment - Summer2020

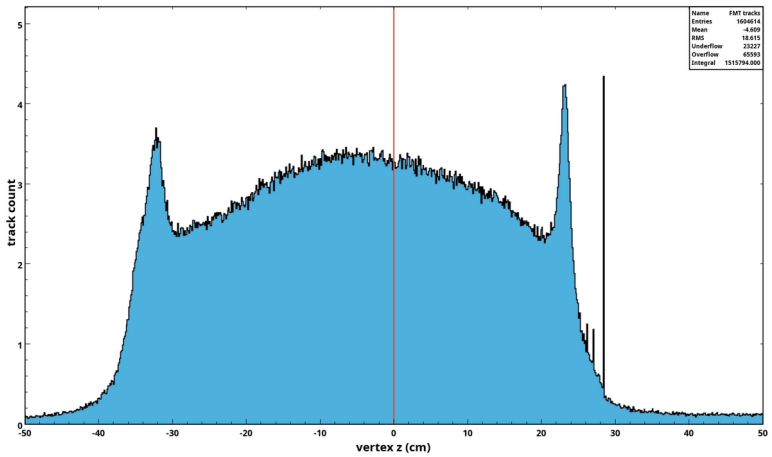
Raffaella & Burno

Alignment was performed by minimizing residuals between a DC track and a matching FMT cluster. Results are available in the CCDB under /geometry/fmt/alignment.

To validate results, changes have been applied to FVT reconstruction. Among these:
- We implemented the alignment shifts to FMT constants, coordinate transformations, and the DC trajectory surfaces.
- The swimming method SwimToBoundaryPlane had an error when checking the vertex and was fixed.
- Many more minor changes were done (and more are still in progress) to apply the shifts correctly and to improve FVT reconstruction in general.

With the changes applied we see more tracks obtained after alignment, but no major vertex resolution improvement has been seen so far.

For future work, we're looking into more issues in reconstruction and we're planning to perform FMT alignment without working from DC tracks.



Conclusions

◊ RG-F has received 87% of the Approved PAC days. Total of 5.68B triggers (83% on D_2 target)

→ Spring run (Feb 11th – March 24th , 2020) ~ (RTPC1 + RTPC3) 47% of the collected data.

→ Summer run (Aug 1st – Sep 21st , 2020) ~ (RTPC3) 53% of the collected data.

◊ The Summer run calibration is at an advanced stage:

RF, Beam Offsets, FToF, DC, and LTCC calibration are DONE.

HTCC and RICH calibrations are Ongoing.

RTPC: Ongoing & already in an advanced stage.

FMT, CToF, and CND: will need well calibrated FD and RTPC (after pass1).

→ Pass1 review is expected by end of March.

◊ The Spring run: RF, Beam Offsets, FToF are DONE.

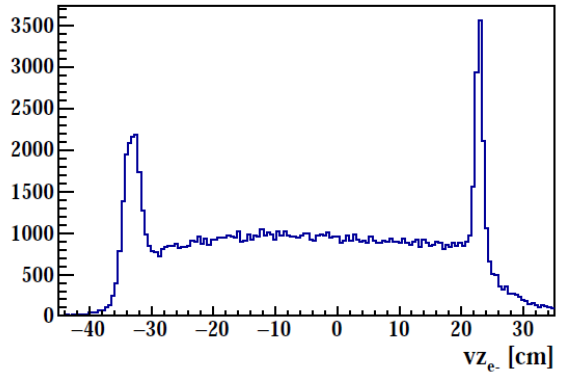
Pass0v4 is in the process to clear if we need additional FToF calibration.

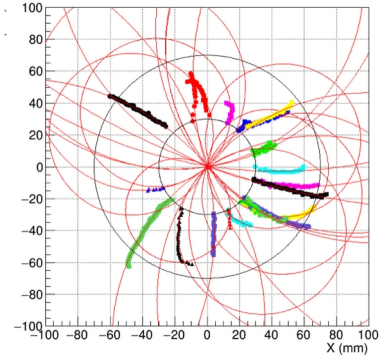
Backup Slides!

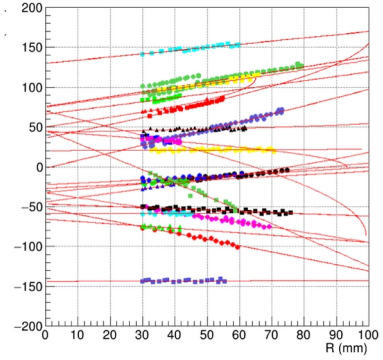
Preliminary Analysis – 5 Pass Data

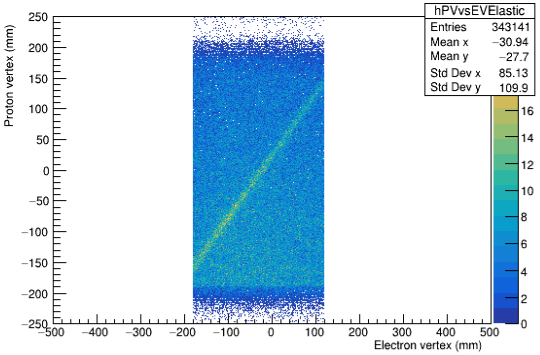
e- @10.4 GeV beam on D_2 target

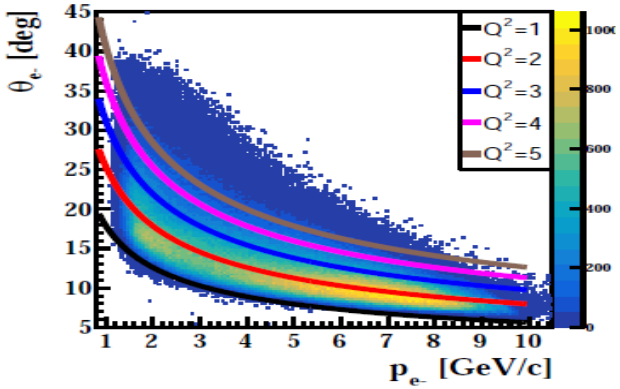
Proton Selection on D_2 target

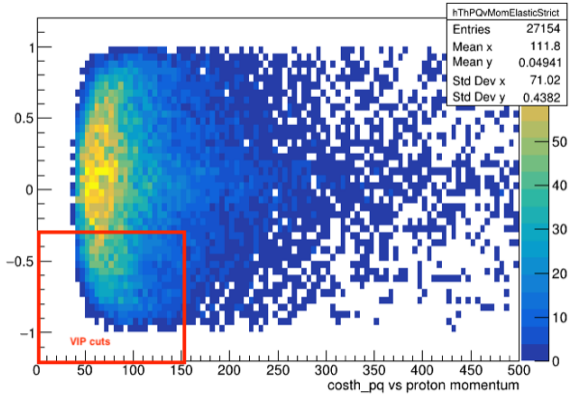


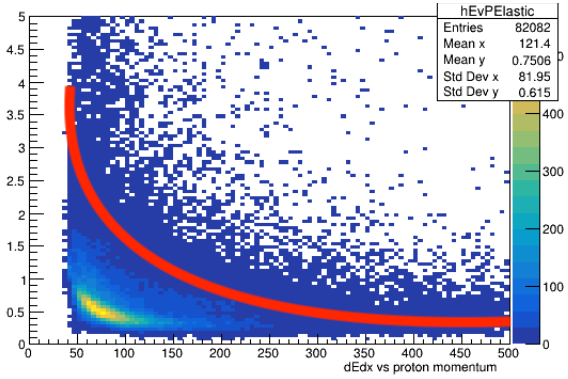


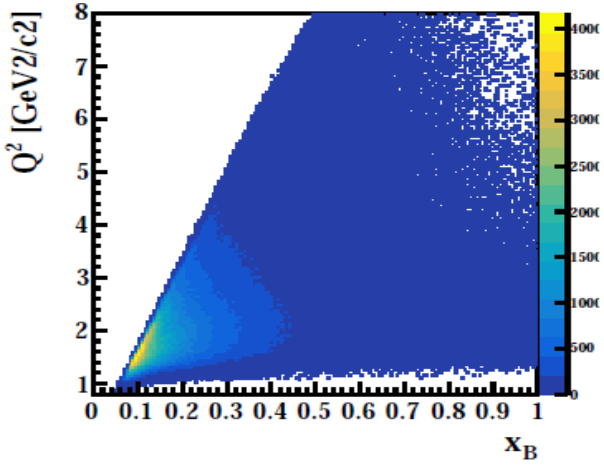


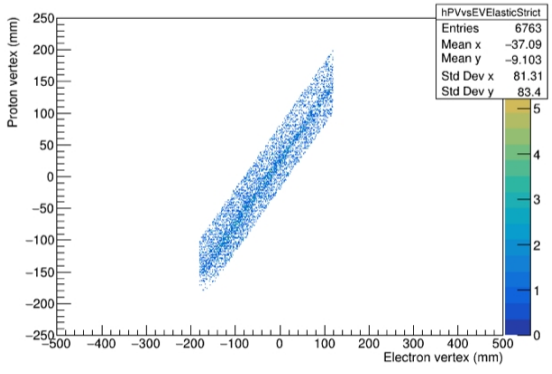


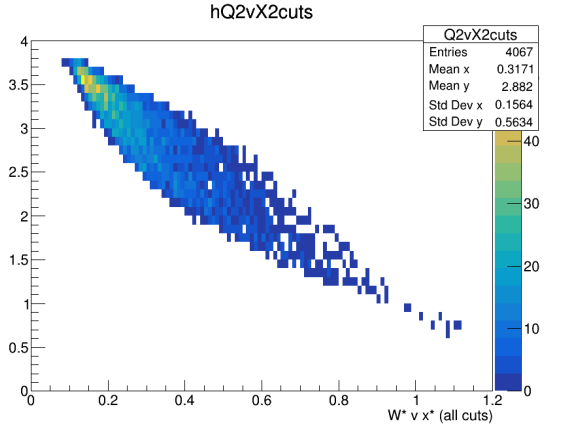












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RG-F Future Work & Manpower

Work Item	Volunteer	Volunteer	Volunteer
1. Garfield++ studies	Yu-Chun Hung	Aruni Nadeeshani	
2. Maintaining and updating BONuS12 GEMC simulation	Yu-Chun Hung	Krishna Adhikari	
3. Radiative losses from simulation for different final state particles	Madhusudhan Pokhrel	Krishna Adhikari	Eric Christy (inclusive)
4. Analysis of simulated data, i.e., elastic and other channels (n-DIS, n-DVCS, n-DVMP, ...)	Madhusudhan Pokhrel	Mohammad Hattawy	
5. Implementing Kalman filter for BONuS12	Mathieu Ouillon	Sebastian Kuhn	
6. Improving BONuS12 code for track finding, merging, and disentangling	Mathieu Ouillon	Sebastian Kuhn	
7. Extracting resolutions and corrections in vertex, momentum, theta, phi; effiency using the elastic data	Madhusudhan pokhrel	Mohammad Hattawy	
8. Improving the gain calibration and the calculated dEdx	Madhusudhan pokhrel	Sebastian Kuhn	Mohammad Hattawy
9. Checking the CLAS12 alignment using the zero-field run, then re-do DC calibration if needed (DC expert)	Mohammad Hattawy		
10. Checking the energy calibration of PCAL+ECAL for e- and extracting corrections (through etot/p vs. time)	Jiwan Poudel	Mohammad Hattawy	
11. Checking the energy calibration for final photons through pi0 final state particles and extract corrections	Jiwan Poudel	Mohammad Hattawy	
12. Extract acceptance ratios and detection effiency from simulation for different final state particles (e-, p, n, photon, D2)	Mohammad Hattawy		
13. Checking the calibration of the neutron detection in the central CND and CToF from experimental data	Mohammad Hattawy	Daniel Carman	Silvia Niccolai
14. Contributing in the FMT reconstruction implementation	Bruno Benkel (software)	Jorge Lopez (validation)	Raffaella De Vita (supervisor)
15. Continue supporting cooking the BONuS12 data	Bradley Yale	Mohammad Hattawy	
16. Analyzing the elastic data on the four different targets (H2, D2, 4He, empty)	Sebastian Kuhn	Krishna Adhikari	Eric Christy
17. DIS analysis on D2 using the 10GeV data	Sebastian Kuhn	Krishna Adhikari	Eric Christy
18. n-DVCS analysis on D2 using the 10 GeV data	Mathieu Ouillon	Mohammad Hattawy	
19. Maintaining the database	Aruni Nadeeshani	Mohammad Hattawy	
20. Target Purity studies	Narbe Kalantarians		

A Short History of RG-F

- 2/10-12: RTPC1/FMT installed in Hall, Cosmic Runs.
- 2/12-14: Accelerator startup and beam tuning
- 2/14-15: 2.1 GeV outbending run on all the target types (H_2, empty, D_2 and ^4He) (calibration).
- 2/16-3/9: 10.4 GeV inbending production running on all the targets
- 3/9-14: 10.4 GeV outbending production running on all thetargets
- 3/14-16: Brief return to 10.4 GeV inbending production running on D_2
- 3/16-20: Swap RTPC1 against RTPC3
- 3/20-24: 10.4 GeV inbending production running on all the targets.
- 3/24-06/08: Run halted (MEDCON-6).
- 06/08-07/17: Sealing RTPC3 (along the seam, first using Silicon on SL1, then DP-190 on SL0) and changing the target straw (15um → 30 um target windows).
- 07/17- 07/31: Cosmic data (maps in B field and HV).
- 08/02-08/06: 2.2 GeV outbending and inbending (half torus field) run on all the target types (calibration)
- 08/08-09/08: 10.4 GeV inbending (full torus field) run on all the target types.
- 09/08 – 09/10: Changed the beamline exit window (38 hours started on 09/08 @ 11:30 AM)
- 09/10-09/21: Back to 10.4 GeV inbending (full torus field) run on all the target types.
- 09/21 @ 7:00: Run is completed. We took another 4 hours of cosmic data.