CLAS12 DC Calibration Studies

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CLAS Collaboration Meeting
10th November 2020

Drift Chamber Team 2020-21

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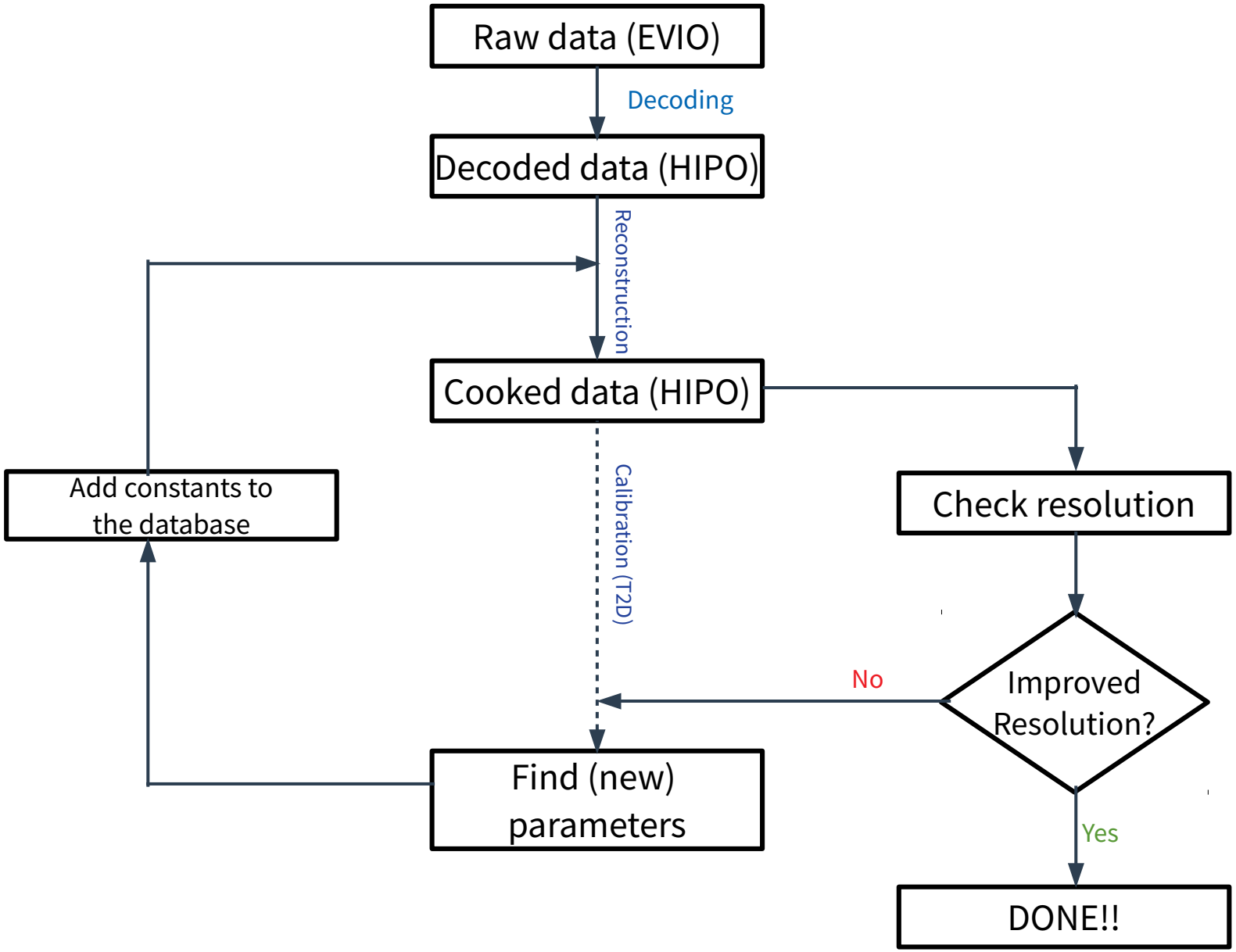
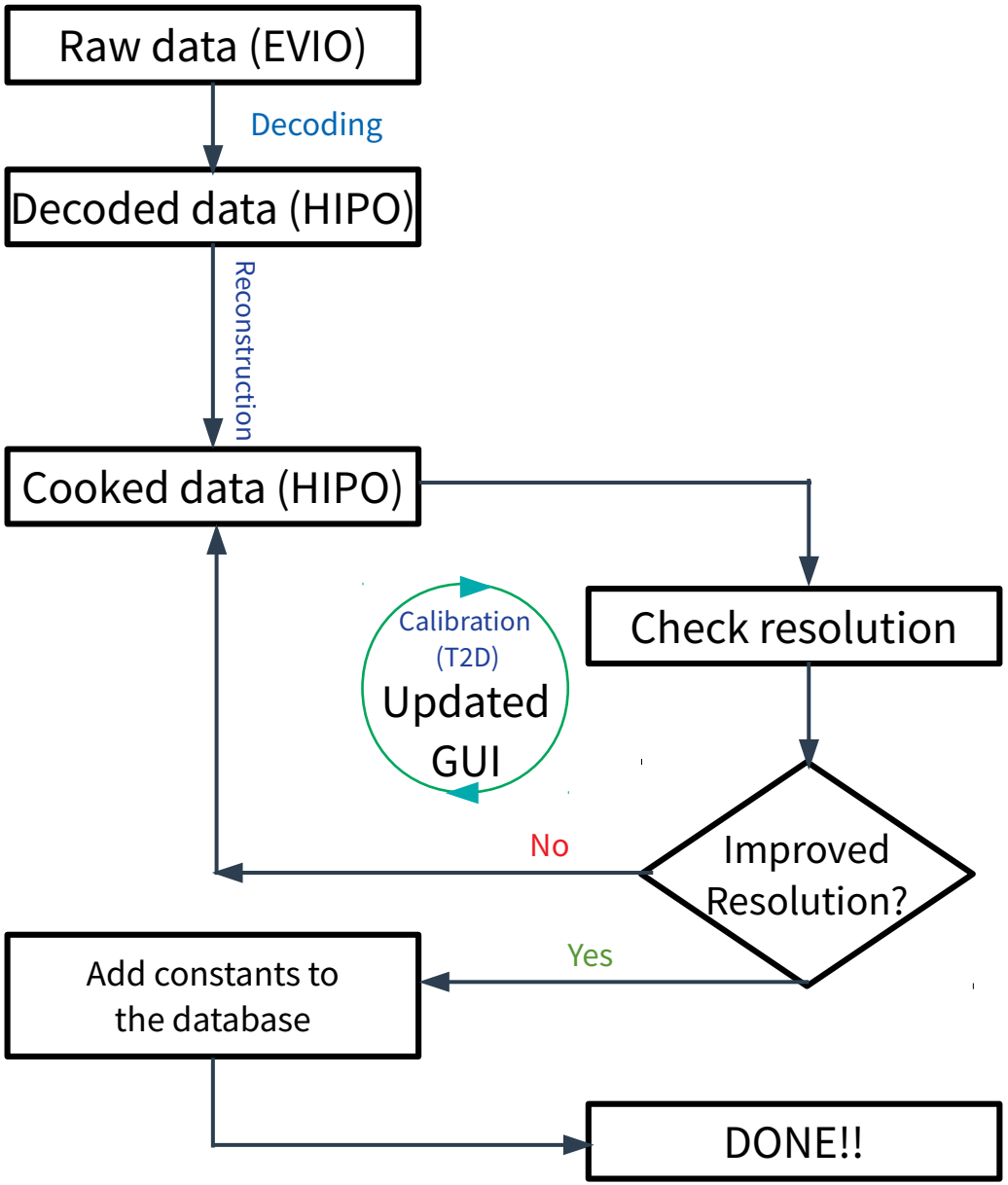
Drift Chamber Projects

- **Time to distance calibration:**
  - Check stability of calibrations and re-calibrate when necessary.
  - Develop/Update procedures to determine `t0` and `tmax` from time distributions.
  - Develop and validate semi-automatic procedures to correlate the distance to time parameters with atmospheric pressure.
  - Dependence of the calibrations on CLAS12 sectors.
- **Tracking simulations:**
  - Test and validate simulations of track efficiency and resolution
  - Adjust simulation parameters to match data and simulation.
- **Software**
  - Maintain/Update/Upgrade current calibration GUI, alignment and magnetic field modeling codes.
  - Check/validate track reconstruction when necessary.
- **Hardware/firmware:**
  - Cosmic studies to determine correlations of time and time-over-threshold to reject out-of time-time hits in firmware.

The Calibration Process: (Original)

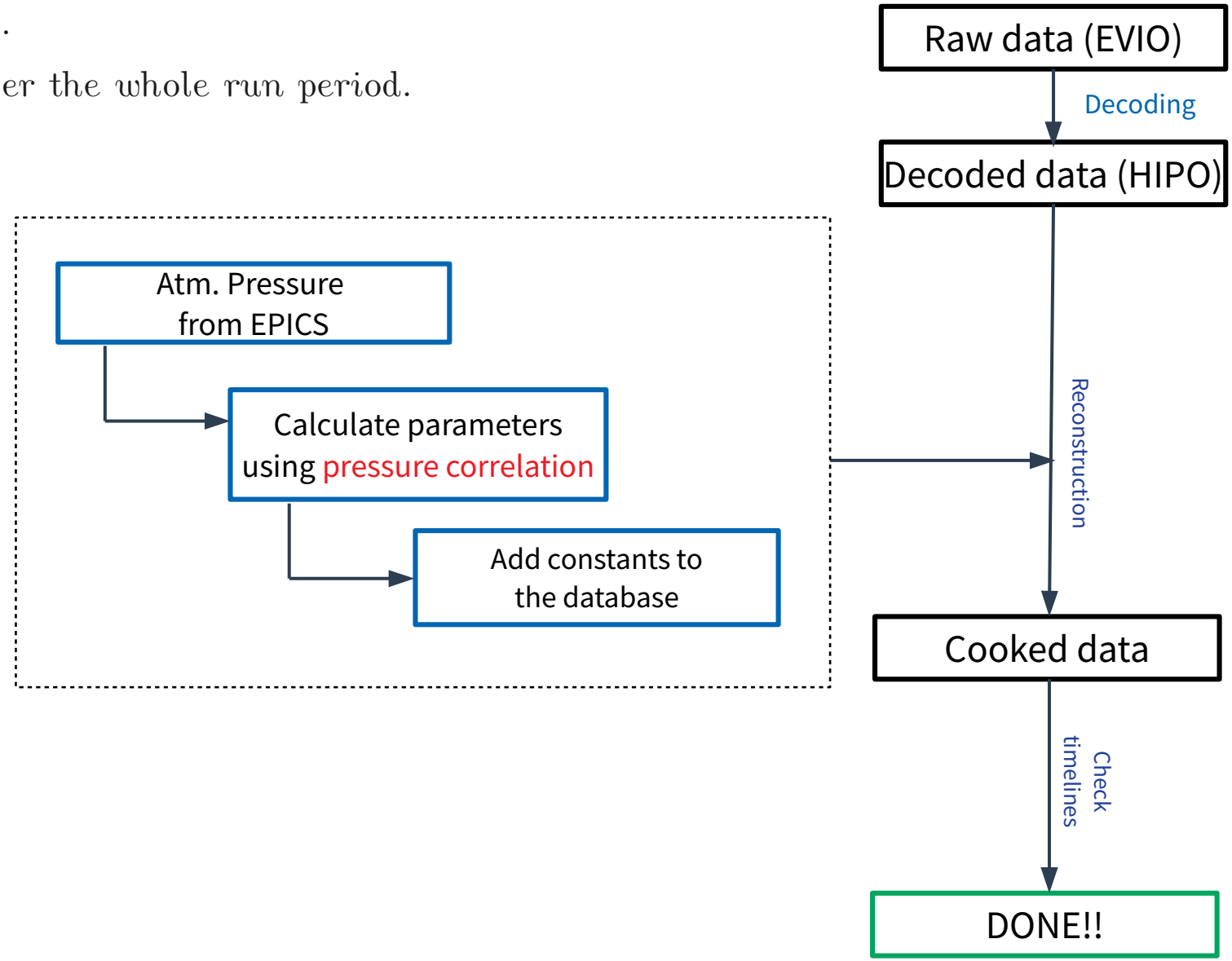


The Calibration Process (Current)



The Calibration Process: Semi-Automatic

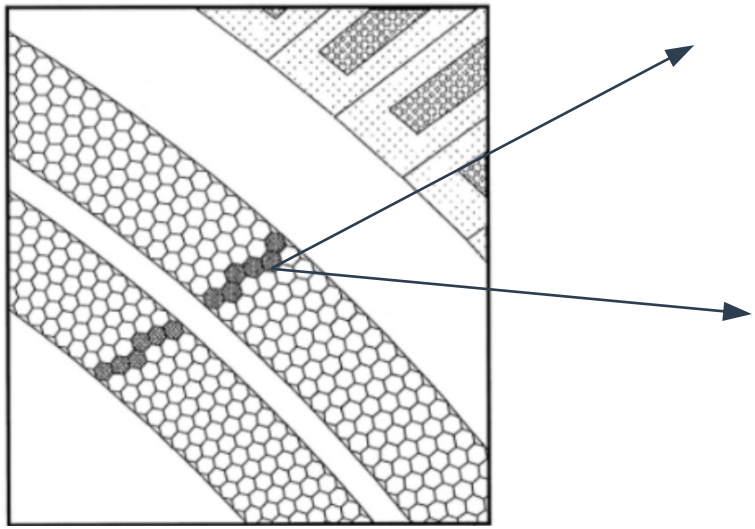
- Reduce the time and effort taken to calibrate a run/run period.
- Consistency over the whole run period.

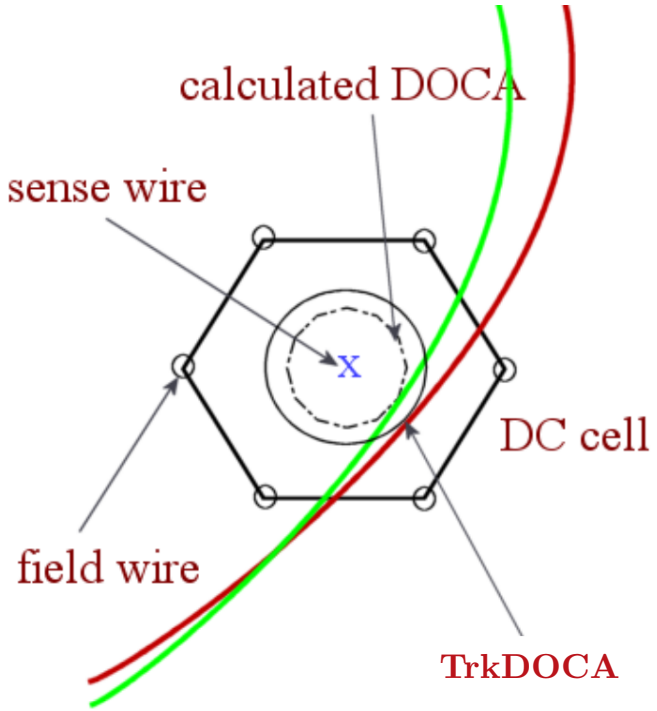


'Jargons' in DC Calibration:

- Use Time-Based-Tracking (TBT) along with the Hit-Based-Tracking (HBT).
- TBT $\rightarrow$ utilizes the time information.
- Calculate Distance of Closest Approach (DOCA) from TBT. This distance is known as the CalcDOCA.
- TrkDOCA$\rightarrow$ to calculate DOCA based on the hits, known as the Tracked DOCA.
- Time Residual = Difference of the two distances

Residual/Resolution = CalcDOCA – TrkDOCA

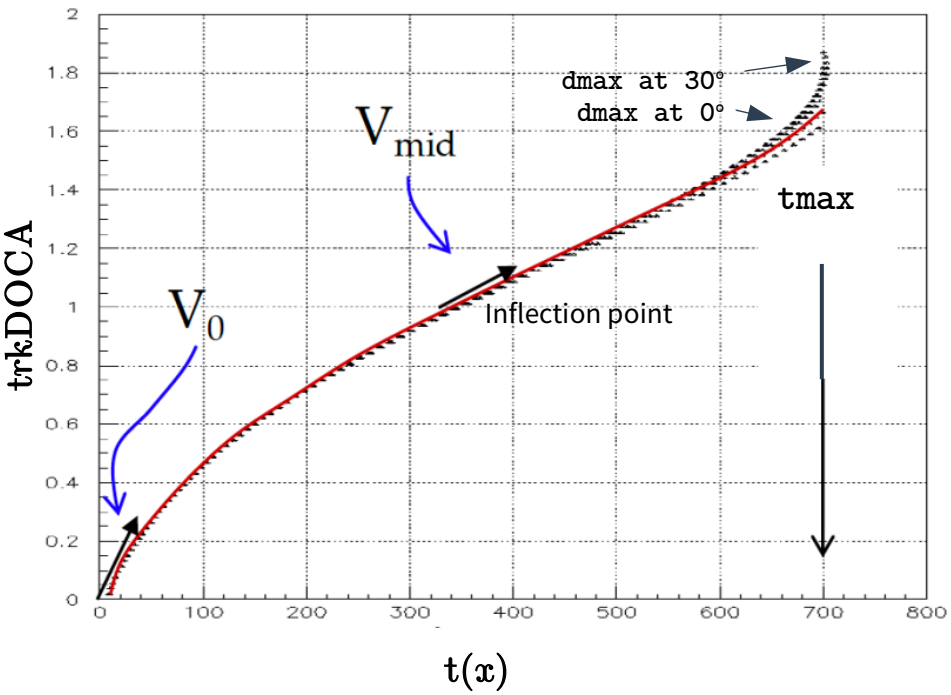




Understanding the Parameters

- Polynomial function:
  - $t(x) = ax + bx^2 + cx^3 + dx^4$

    where, x = trkDOCA
- The equation is solved using 4 constraints:
  - Velocity at $x = 0$ is the saturated drift velocity, **v0**; $v_0 = 1/d$
  - Inflection point at x=R is the parameter **R**. (maximum distance is referred as the dmax)
  - Velocity at the inflection point is the parameter **vmid**.
  - Time at dmax*cos(30-α) is **tmax**, where α is the local angle.



- The drift time is given by:

$$t = TDC - T_{start} - T_{flight} - T_{prop} - T_0 - T_{beta}$$

TDC time is corrected for trigger jitter and latency, flight time of the track, time of propagation of the signal along the wire to the readout, cable delay, and beta dependent time-walk correction

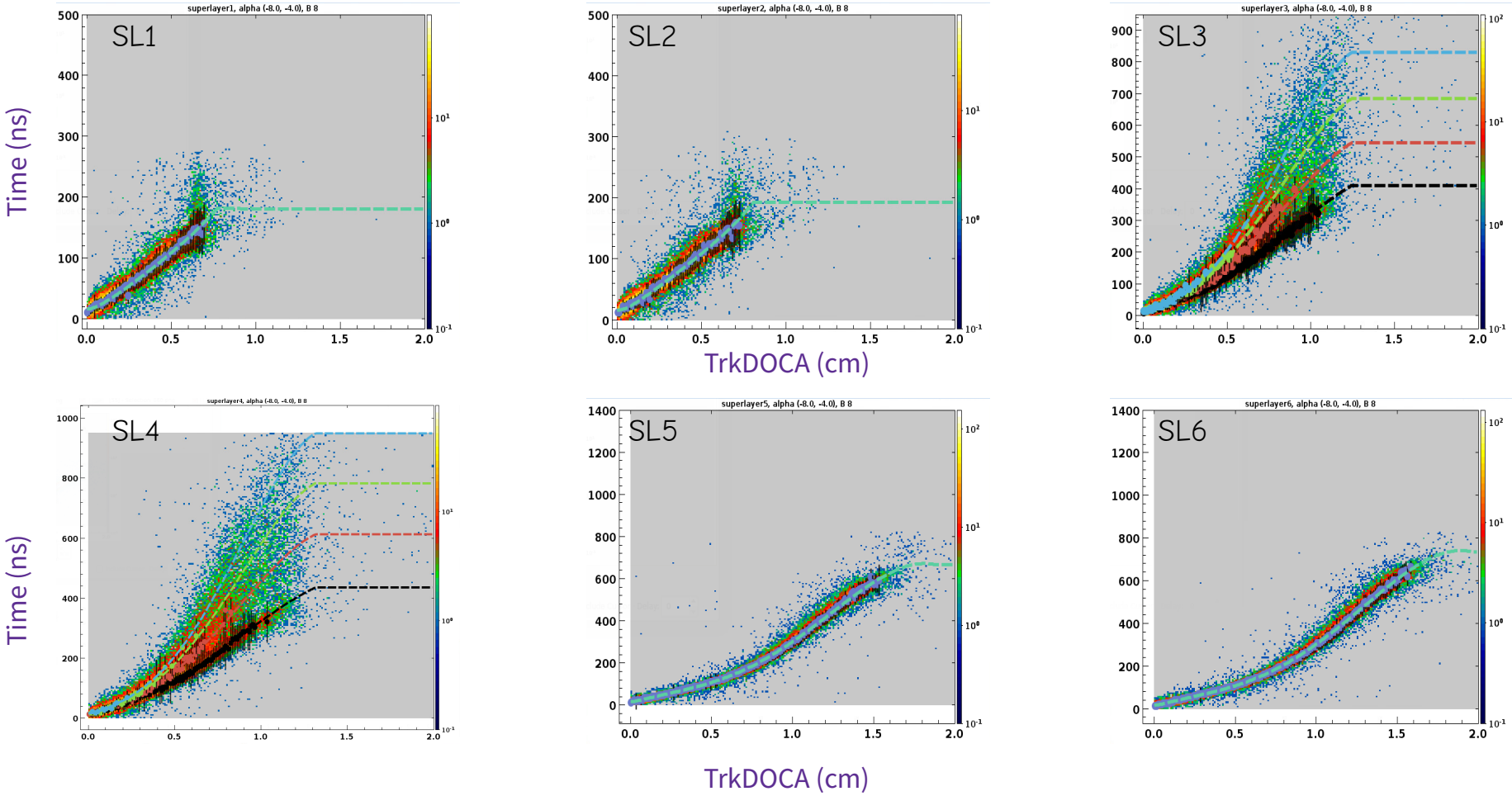
Calibration Protocols

- keep **R** fixed at a value of about 0.66 for all superlayers (SL).
- **DelBf** = 0 for Regions 1 and 3. **Varies for Region 2.**
- **b1-b4**: fixed at default/preloaded values.
- Fix **distbeta** = 0.08 for all SLs.
- **Vary v0, vmid and tmax. (Also vary deltaBf for R2 in steps)**
  - On the first pass, let only **v0**, **vmid** and **tmax** vary (for all superlayers).
  - On the second pass, let all three vary again for superlayers 1, 2, 5 and 6.
  - For superlayers 3 and 4, let **v0**, **vmid** and **deltaBf** vary and hold **tmax** fixed.
  - Do a third pass for superlayers 3 and 4 only; this time hold **deltaBf** and **tmax** fixed. Vary **v0** and **vmid**.

More info in the wikipage: CLAS12 DC Calibration

Time vs Distance (After 3rd Pass)

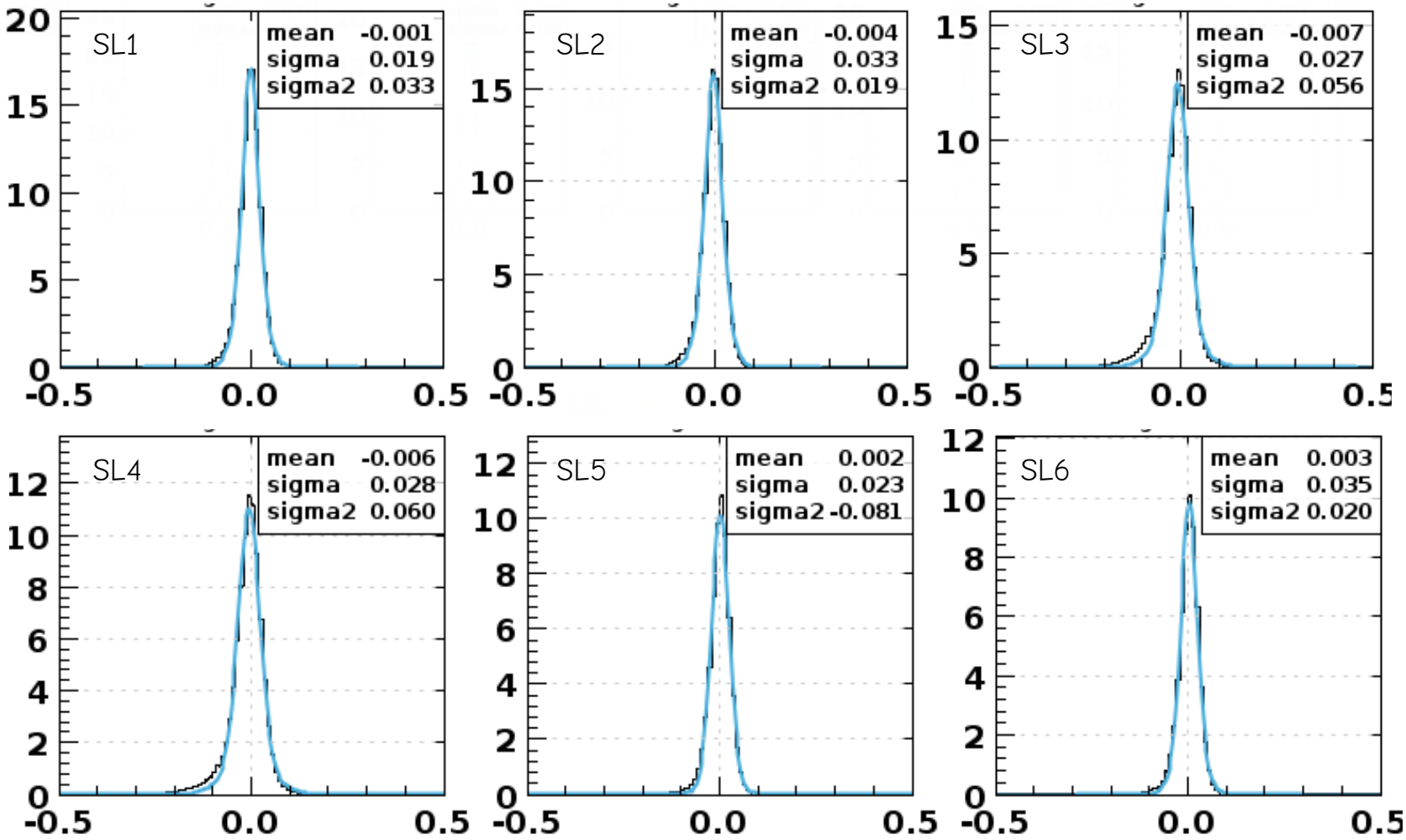
Run 6546



Time vs distance distributions for a local angle bin, $\alpha \in (-8, -4)$

Residual Distributions (After 3rd Pass)

Run 6546

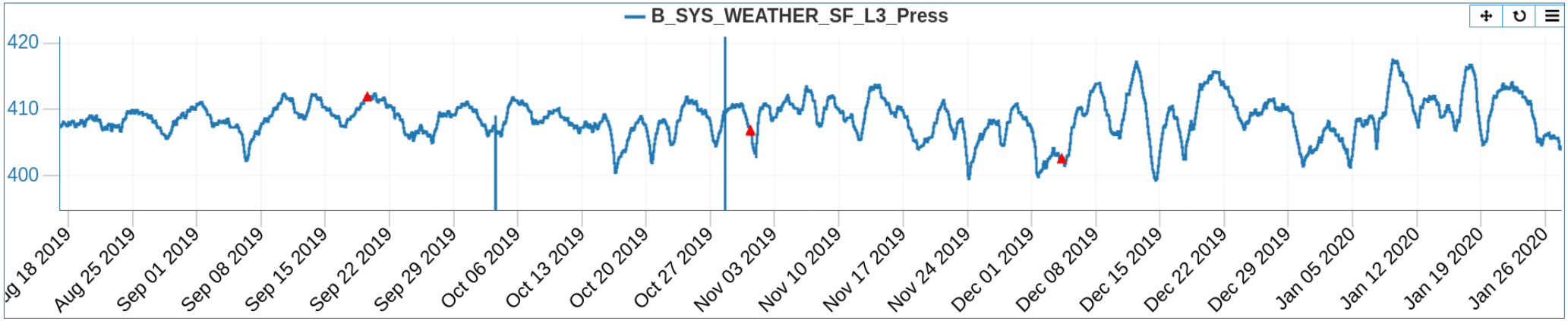


DC residuals:

- SL1: 190 μm
- SL2: 190 μm
- SL3: 270 μm
- SL4: 280 μm
- SL5: 230 μm
- SL6: 200 μm

Pressure Parametrization

- Pressure information is extracted from EPICS.

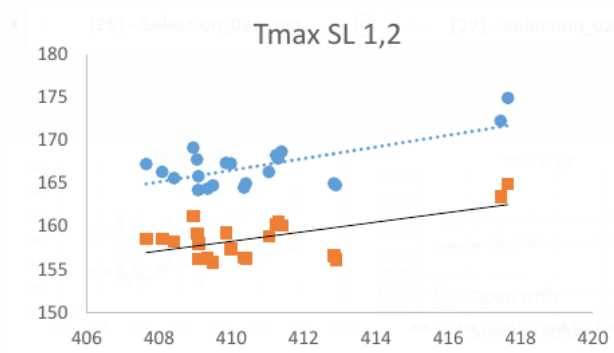


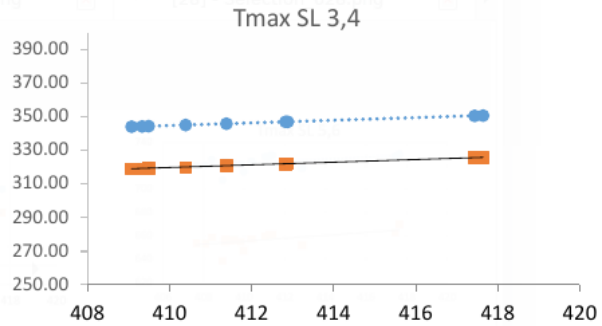
- Different low-luminosity runs considered:

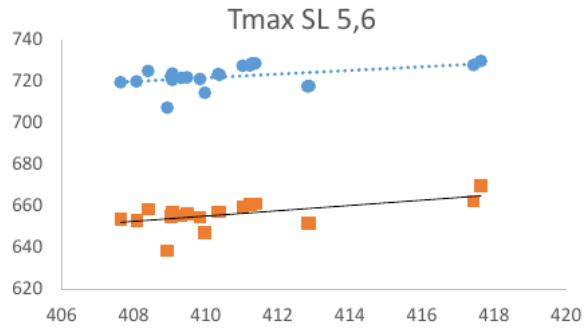
  5674, 5678, 5679, 5689, 5756, 5768, 5870, 5986, 5987, 5988, 5990, 6150, 6152, 6322, 6323, 6342, 6373, 6374, 6446, 6447, 6448

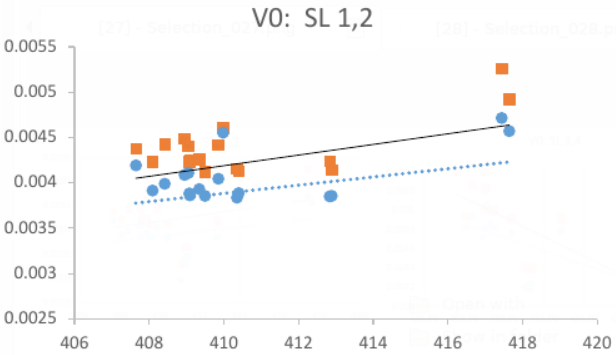
- Calibrate each run and extract the parameters following the calibration protocol.
- Study the variation of parameters such as `v0`, `vmid`, `tmax` and `delBf`. as a function of pressure for each run.

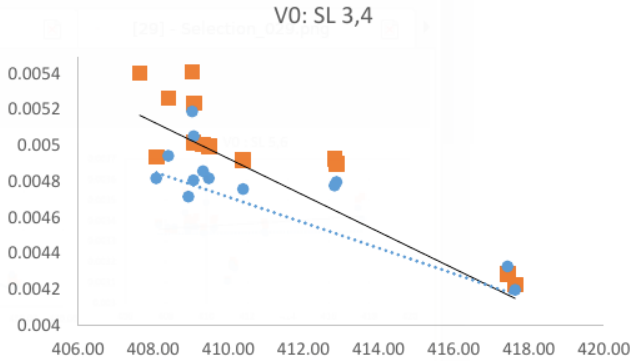
Pressure Parametrization

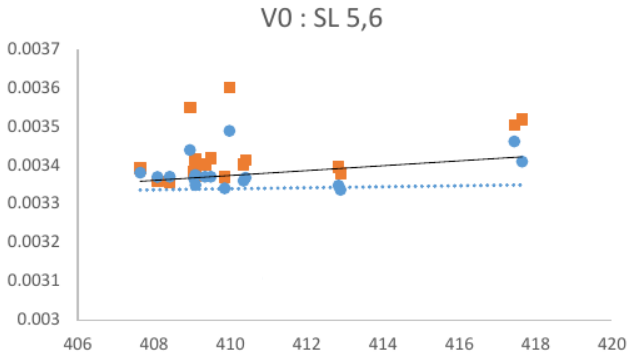


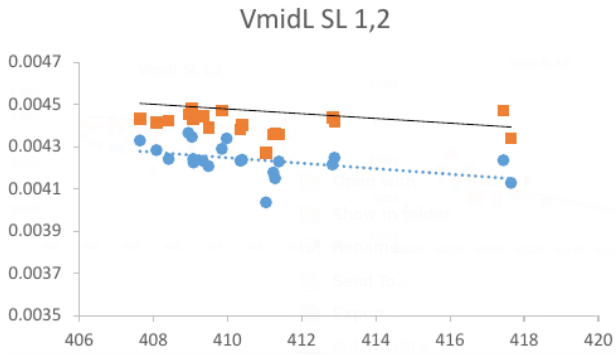


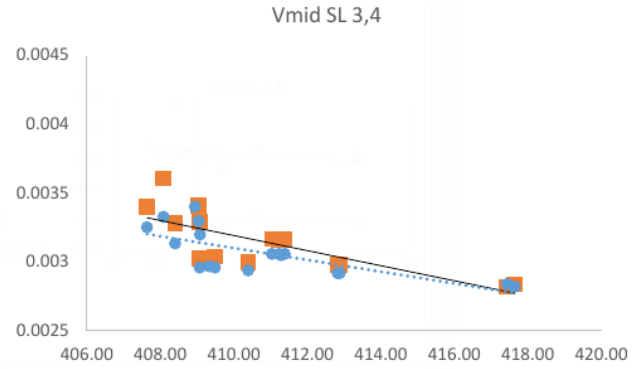


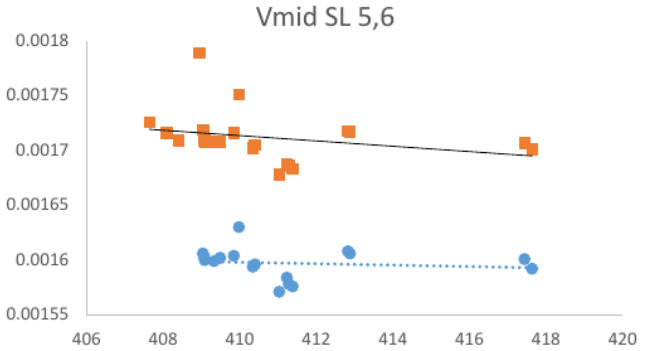








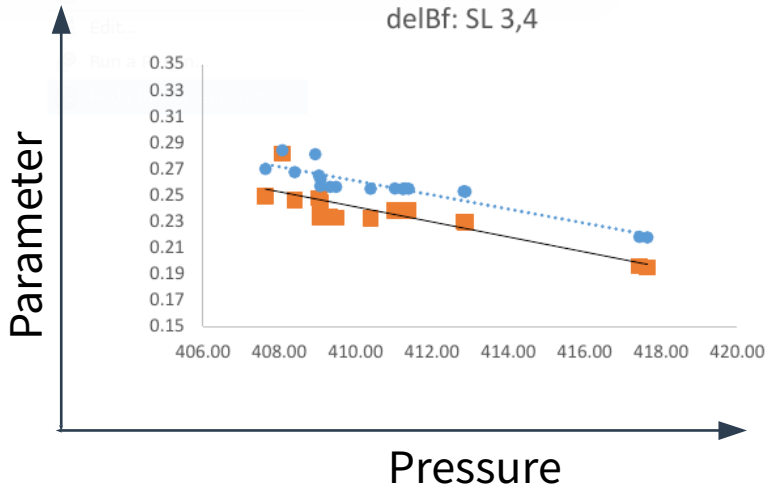




Parameters

Pressure

Pressure Parametrization



Linear dependence of the parameters on the atmospheric pressure

Superlayer	v0		vmid		tmax		delB	
	a	b	a	b	a	b	a	b
1	5.840E-05	-1.974E-02	-1.110E-05	9.040E-03	0.56	-7.100E+01		
2	5.840E-05	-1.991E-02	-1.110E-05	8.800E-03	0.56	-6.273E+01		
3	-1.062E-04	4.840E-02	-9.760E-05	4.350E-02	0.78	0.000E+00	-7.600E-03	3.370E+00
4	-1.062E-04	4.818E-02	-9.760E-05	4.327E-02	0.78	3.570E+01	-7.600E-03	3.379E+00
5	6.310E-06	7.870E-04	-2.430E-06	2.710E-03	1.27	1.328E+02		
6	6.310E-06	7.480E-04	-2.430E-06	2.598E-03	1.27	1.992E+02		

$$\text{Parameter} = a \times \text{Pressure} + b$$

Pressure Parametrization: Validation

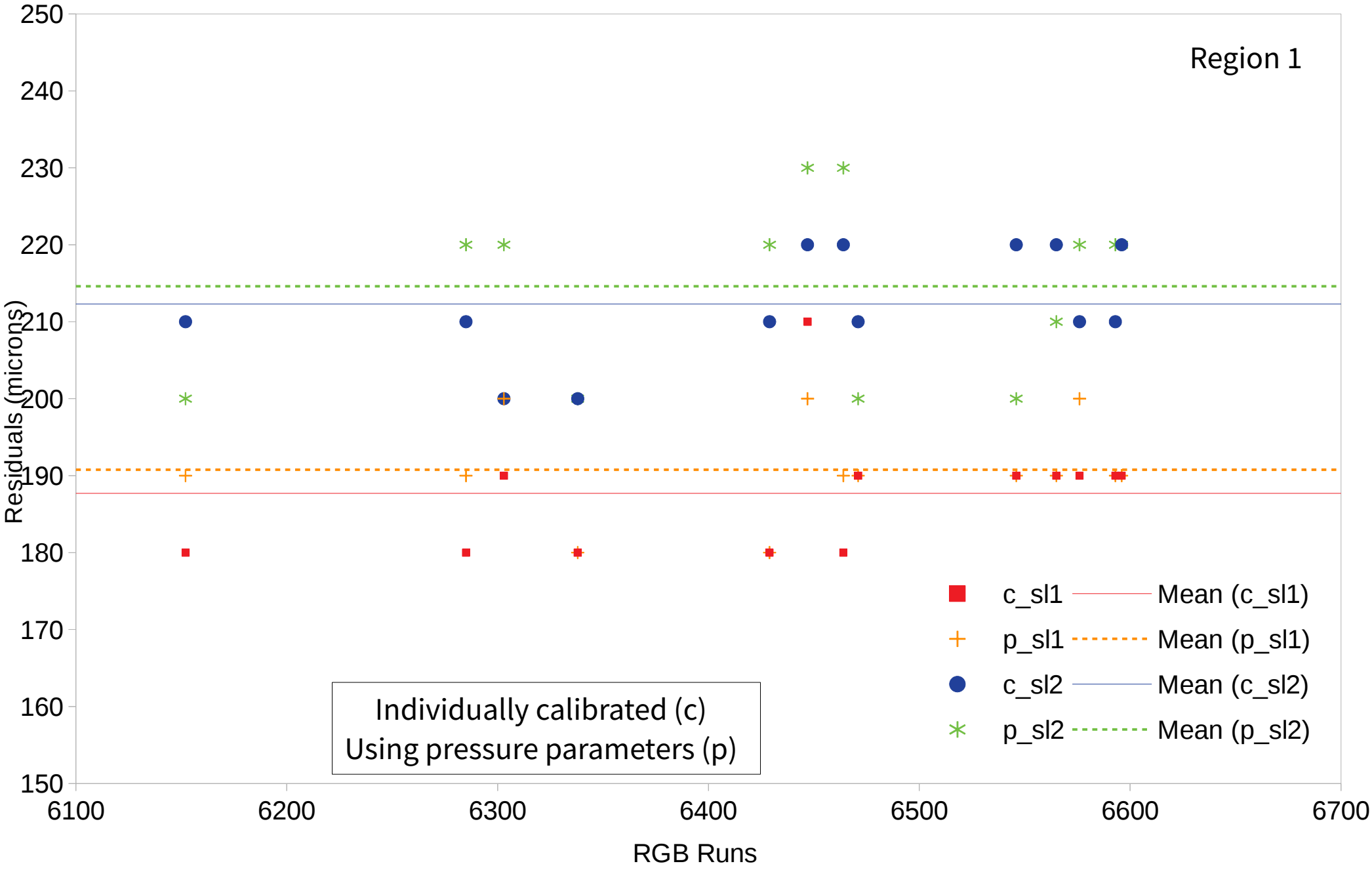
- 13 runs with different pressures are selected for the validation.
- Time to distance parameters are calculated based on pressure.

$$\textbf{Parameter} = \mathbf{a} \times \textbf{Pressure} + \mathbf{b}$$

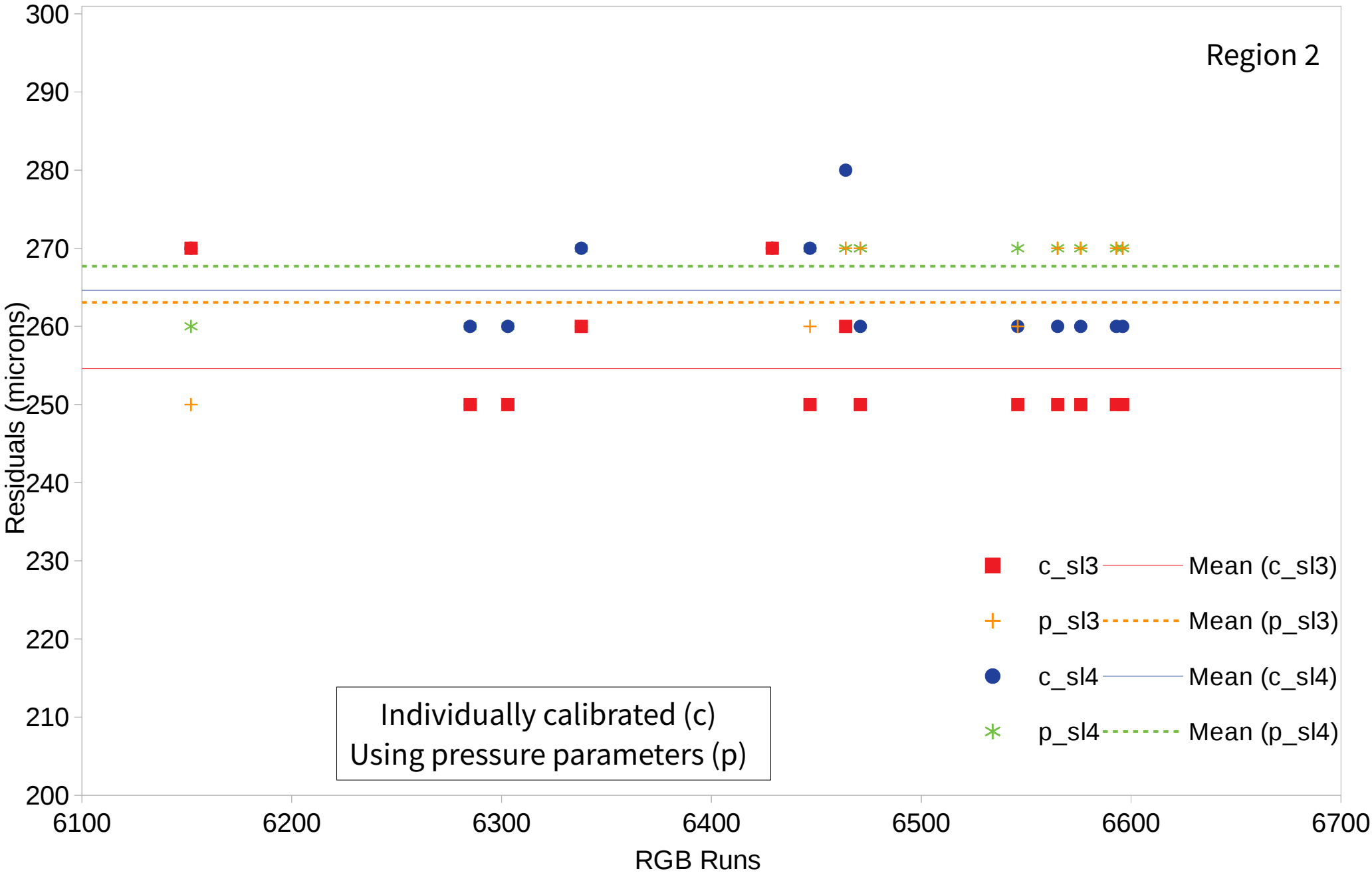
- Parameters are uploaded to CCDB for each run.
- Reconstructed with the uploaded parameters.
- Residuals are recorded for comparison.

RGB Runs	Pressure (mmHg)	Current
6546	402.17	50 nA
6338	402.78	50 nA
6565	405.79	50 nA
6303	408.53	50 nA
6471	408.88	50 nA
6429	409.70	50 nA
6596	409.73	50 nA
6447	409.97	5 nA
6593	410.03	50 nA
6576	410.23	50 nA
6464	411.91	50 nA
6285	413.14	35 nA
6152	417.64	5 nA

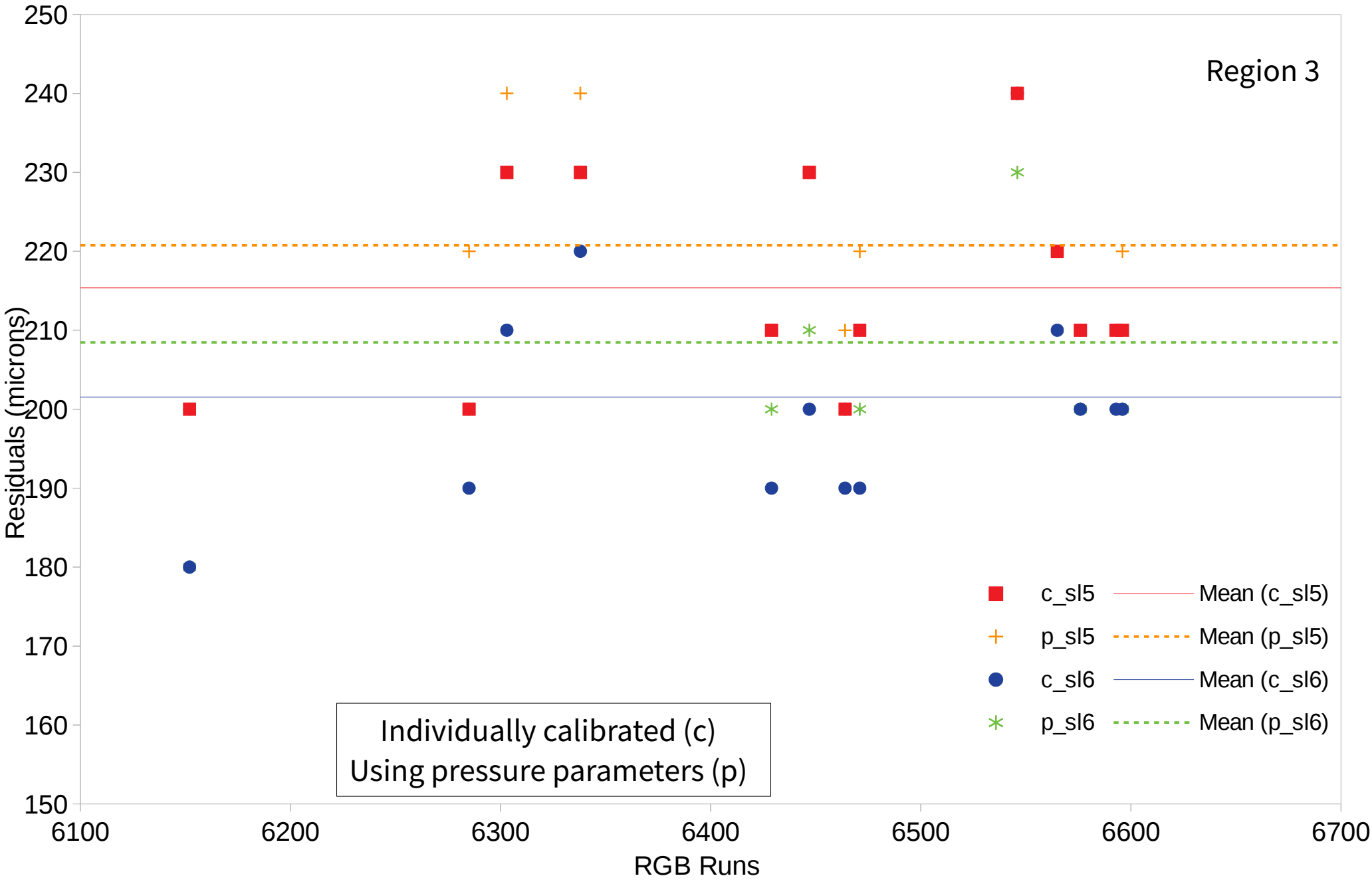
Pressure Parametrization: Validation



Pressure Parametrization: Validation



Pressure Parametrization: Validation



Summary

- We calibrated runs in two ways:
  - Individual calibrations using rigorous, well-defined protocols.

    Residuals are in the range 180-260 microns.
  - Time-to-distance parameters calculated as a function of atm. Pressure.

    Residuals measured to be within 190-270 microns.
- The two methods of calibration are consistent.
- This means that we now have a fast, practical and consistent method to calibrate every run in a run period very quickly.

Thank you for your attention!!

Extras

Poly 4: code snippet

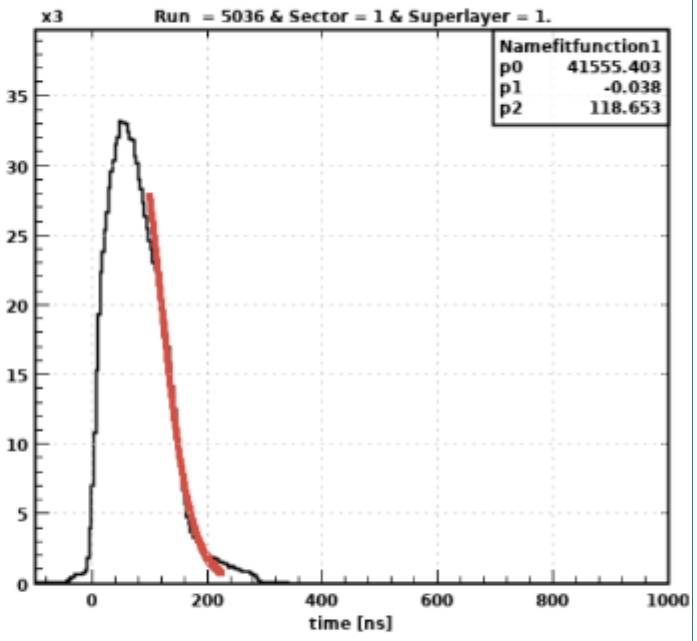
```
double cosA = DMAX * TMath::Cos((30.0-ang)*PI/180.0);

double dmaxalpha = DMAX*cosA;
double xhatalpha = (double)x[0]/dmaxalpha;

double denom = cosA * cosA * DMAX * DMAX * (3.0 * cosA * cosA - 8.0 * cosA * r + 6.0 * r * r) * v0 *vmid;

a = (cosA * cosA * cosA * DMAX * (v0-vmid))
        - 3.0 * cosA * DMAX * r * r * vmid
        + 3.0 * cosA * cosA * DMAX * r * (vmid - v0) / (DMAX * DMAX * r * r * denom);

b = (6.0 * cosA * cosA * DMAX * r * r * (v0 - vmid)
    + 8.0 * cosA * DMAX * r * r * r * vmid
    - 8.0 * r * r * r * tmax * v0 *vmid
    + cosA * cosA * cosA * cosA * DMAX * (vmid - v0))/(DMAX * r * r * denom);

c = (3.0 * cosA * cosA * cosA * cosA *DMAX * (v0 - vmid)
    - 6.0 * cosA * DMAX * r * r * r * vmid
    + 6.0 * r * r * r * tmax * v0 * vmid
    + 6.0 * cosA * cosA * cosA * DMAX * r * (vmid - v0))/(r * denom);

d = 1.0/v0;

double tt = a*x[0]*x[0]*x[0]*x[0] + b*x[0]*x[0]*x[0] + c*x[0]*x[0] + d*x[0];


double deltatime_bfield = delBf * pow(bfield,2) * tmax *
                        ( b1 * xhatalpha
                        + b2 * pow(xhatalpha, 2)
                        + b3 * pow(xhatalpha, 3)
                        + b4 * pow(xhatalpha, 4) );

tt += deltatime_bfield;
return tt * pow(10.0, -9);
```

← Go back

tmax *Calculation*

- Different approaches to calculate tmax :
  - **Fitting the trailing edge with a function (sigmoid).**

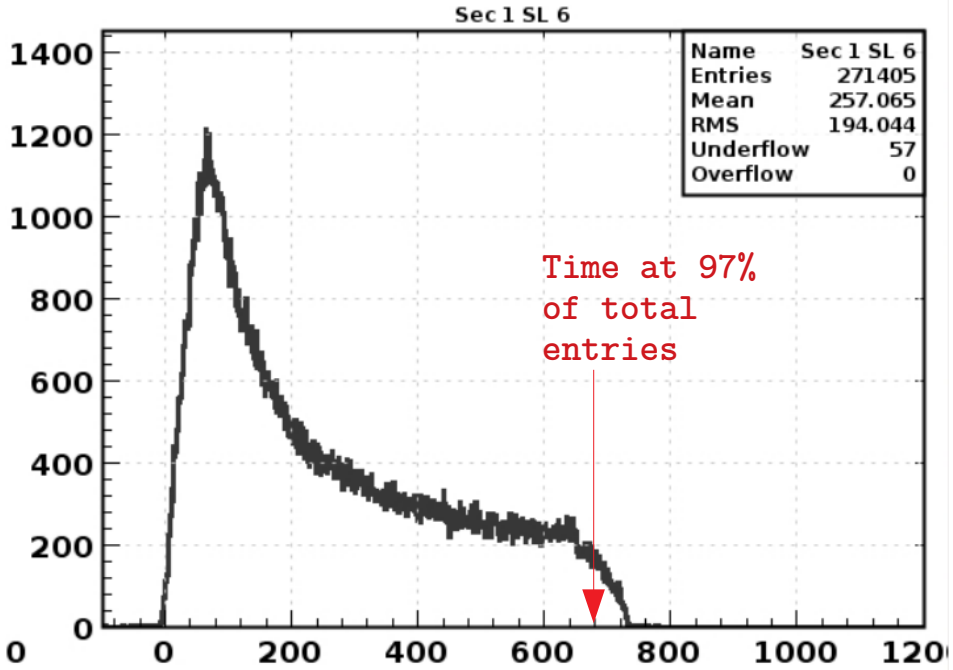
- $y(t) = \frac{p_0}{1+\exp^{-p_1(t-p_2)}}$
- Used the slope $(\frac{dy}{dt})_{t=p_2}$ and $y(t = p_2)$ to extrapolate a straight line
- The interception of that extrapolated straight line on time axis is the value of t_{max}
- Derived $t_{max} = p_2 - (\frac{2}{p_1})$
- An example, for run#5036, sector 1, and superlayer 1
  $t_{max} = 118.653 - (\frac{2}{-0.038}) = 171.28$ ns

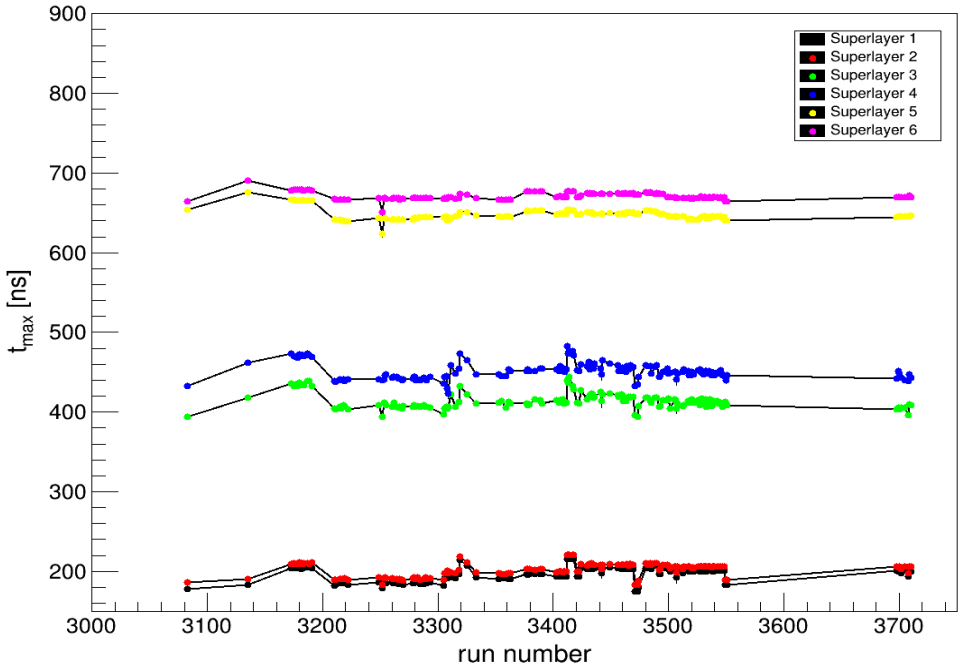


(courtesy: Shirsendu)

tmax *Calculation*

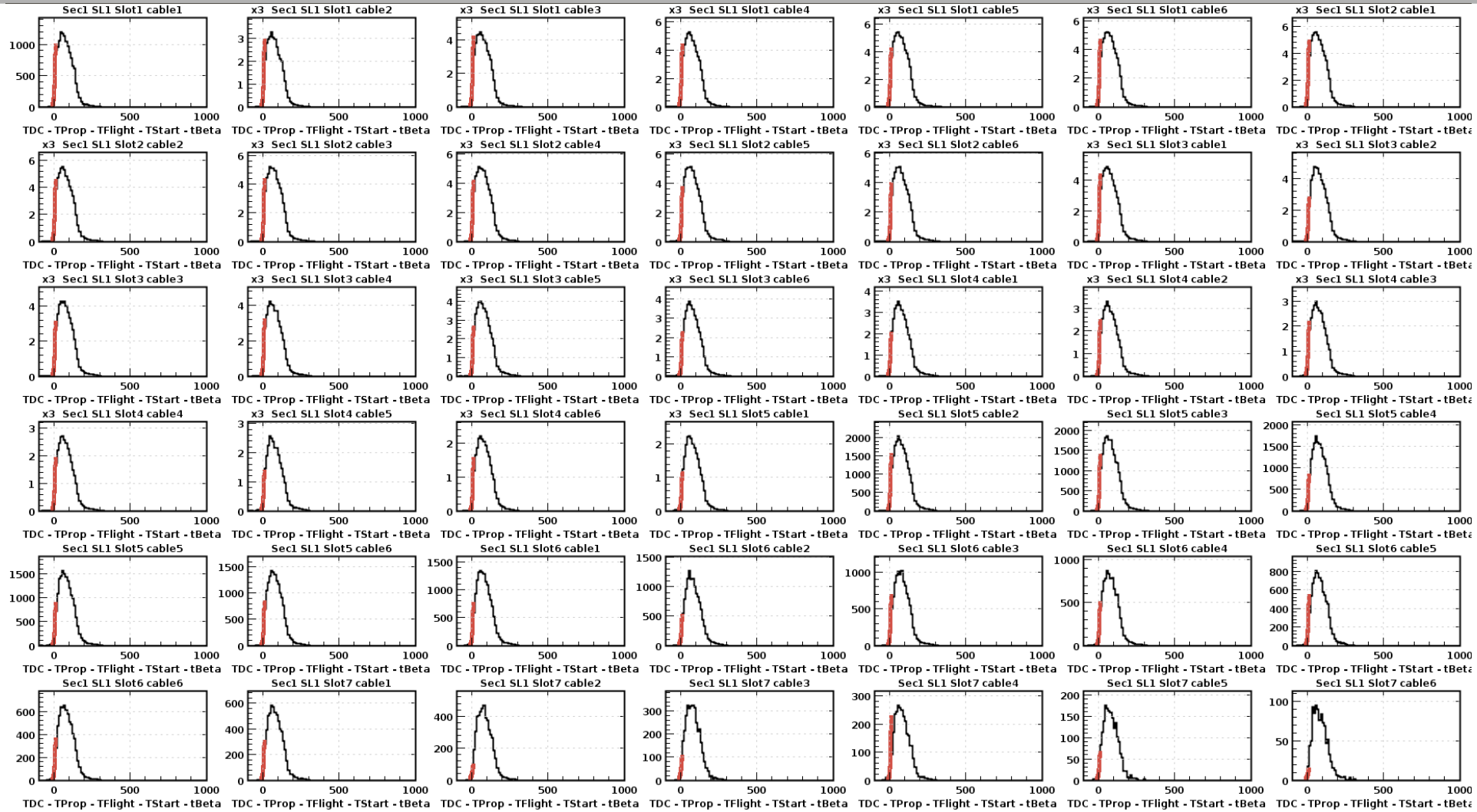
- Different approaches to calculate tmax :
  - **Fitting the trailing edge with a function (sigmoid).** $y(t) = \frac{p_0}{1+\exp^{-p_1(t-p_2)}}$
  - **97% of total entries**
    - The time distribution is integrated bin by bin.
  - When the integrated events reach 97% of the total entries, the bin corresponds to the tmax.
  - A tmax timeline can be utilized as a re-calibration criteria.





(courtesy: Shirsendu)

t0 *fits*

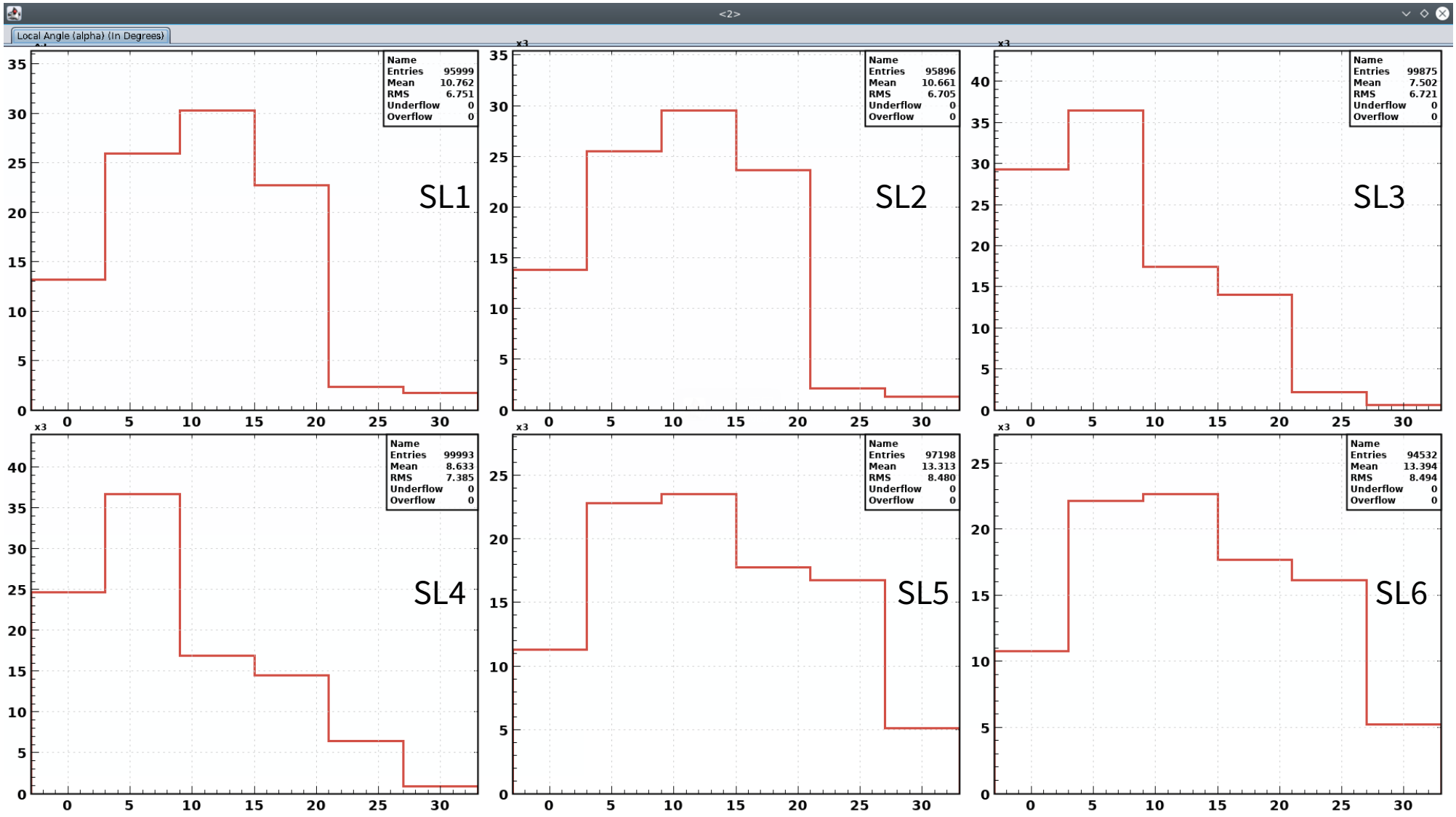


- X-axis, time = TDC - TProp - TFlight - TStart – tBeta
- (run 5300).
- The plot contains the 42 (7 slots * 6 cables) histograms for sector 1 and superlayer 1. Fits are using a sigmoid function

(courtesy: Shirsendu)

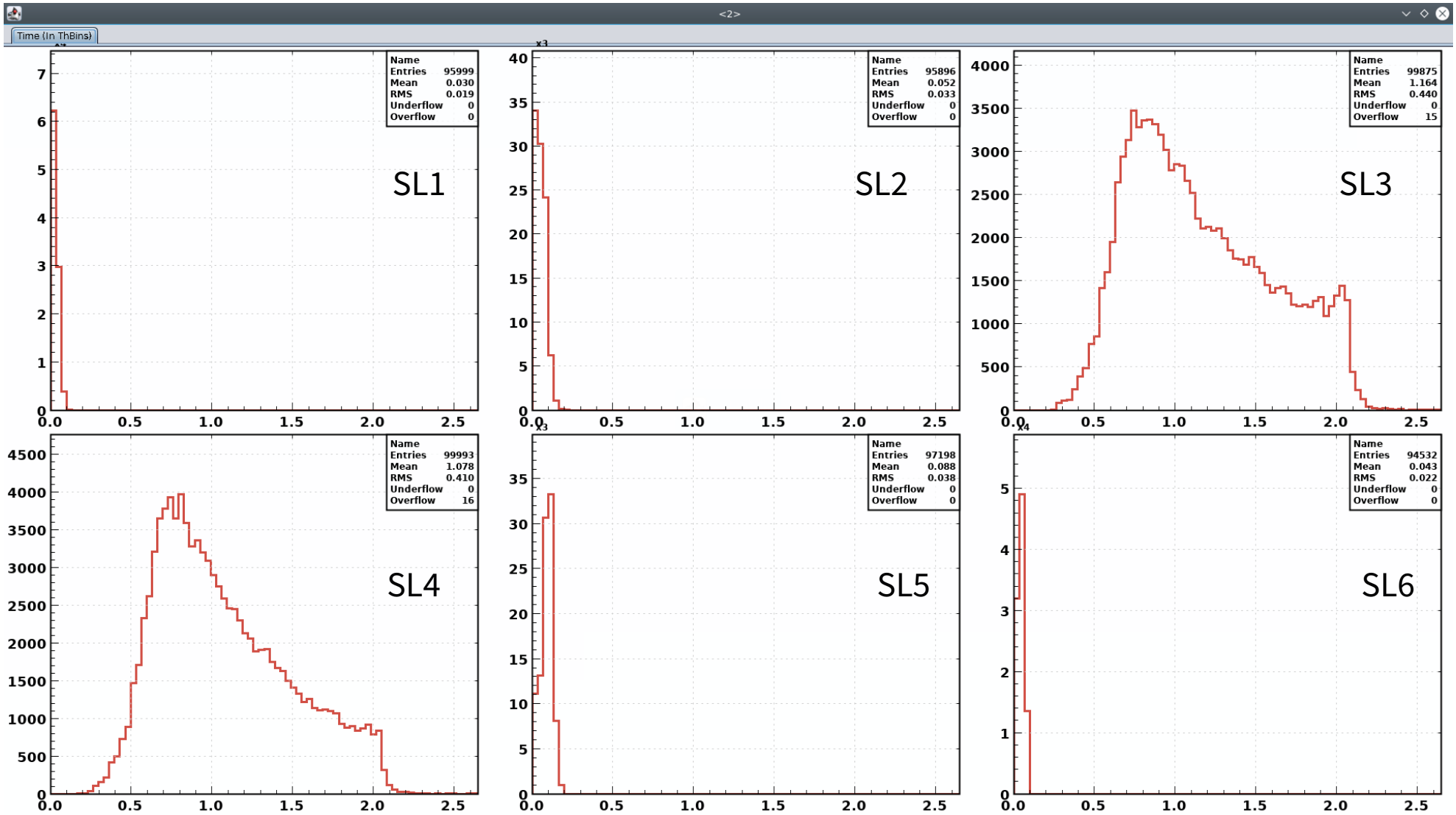
Local Angle (α)

Sector 1: Run 5038.00001



B-field (dB)

Sector 1: Run 5038.00001



hipo-utils -dump

HitBasedTrkg::HBClusters	20600	22	42	38076	2310
HitBasedTrkg::HBCrosses	20600	25	14	43103	812
HitBasedTrkg::HBHits	20600	21	279	23281	14787
HitBasedTrkg::HBSegments	20600	23	37	40394	2701
HitBasedTrkg::HBTracks	20600	26	2	43923	276
LTCC::adc	21600	11	2	6380	30
LTCC::clusters	21600	22	1	59422	44
LTCC::tdc	21600	12	1	16909	9
RAW::tdc	20000	12	48	17309	432
RAW::vtp	20000	14	945	17749	4725
REC::Calorimeter	300	32	5	71574	485
REC::Cherenkov	300	33	2	72228	88
REC::CovMat	300	38	2	73974	128
REC::Event	300	30	1	71524	42
REC::ForwardTagger	300	34	2	72324	100
REC::Particle	300	31	3	71399	117
REC::Scintillator	300	35	3	72067	153
REC::Track	300	36	2	72432	30
REC::Traj	300	40	44	72470	1496
RECHB::Calorimeter	300	12	5	59755	485
RECHB::Cherenkov	300	13	1	60409	44
RECHB::Event	300	10	1	59705	42
RECHB::ForwardTagger	300	14	2	60461	100
RECHB::Particle	300	11	3	59580	117
RECHB::Scintillator	300	15	3	60248	153
RECHB::Track	300	16	2	60569	30
RF::adc	21700	11	2	9881	30
RF::tdc	21700	12	24	17023	216
RICH::hits	22000	21	3	59474	78
RICH::tdc	21800	12	6	17247	54
RUN::config	10000	11	1	22482	38
RUN::rf	10000	12	2	59560	12
RUN::trigger	10000	13	3	22528	24
TimeBasedTrkg::TBClusters	20600	32	12	66447	660
TimeBasedTrkg::TBCovMat	20600	37	2	44207	204
TimeBasedTrkg::TBCrosses	20600	35	6	68095	348
TimeBasedTrkg::TBHits	20600	31	72	60607	5832
TimeBasedTrkg::TBSegments	20600	33	12	67115	972
TimeBasedTrkg::TBTracks	20600	36	2	68451	236
TimeBasedTrkg::Trajectory	20600	53	44	68695	1628