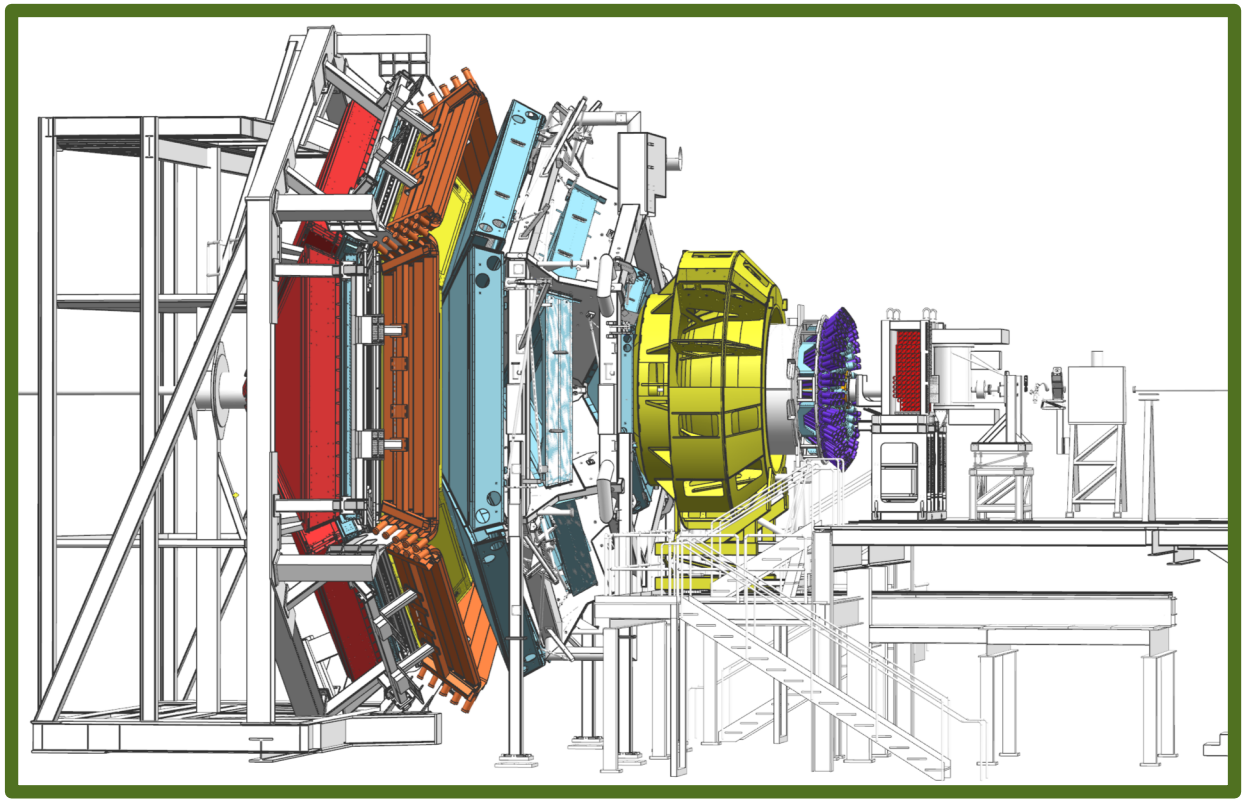
CLAS12 DETECTOR CALIBRATION STATUS



FOCUS ON WORK SINCE JUNE 2019 CLAS MEETING

DANIEL S. CARMAN, NOV. 2019

CLAS12 Run Periods

Run Group A

1) Feb. – May 2018
2) Sep. - Nov. 2018
3) Mar. – Apr. 2019

- 2.2, 6.4, 10.2, 10.6 GeV
- Torus +/- polarity; different settings
- FMT in/out
- LTCC 2/4 boxes (different gas levels)
- Different Central Detector geom.
- Different DC efficiencies (gas gain)

Run Group K

Nov. – Dec. 2018

- 6.5, 7.5 GeV
- FT on/off
- Different luminosities/backgrounds
- LTCC 2 boxes (different gas levels)

Run Group B

Feb. – Mar. 2019

- 10.2, 10.6 GeV
- LTCC 2 boxes
- LD_2 target – different backgrounds

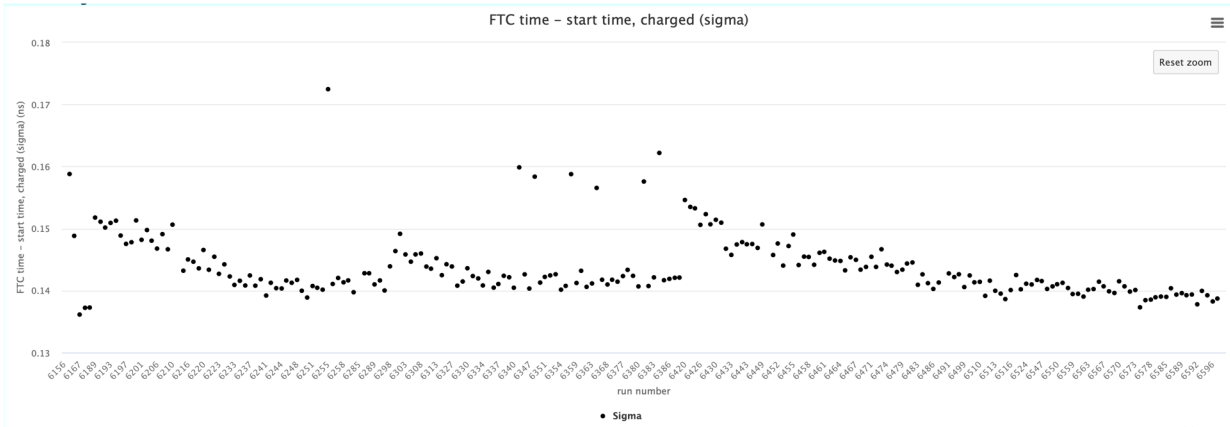
CLAS12 Reference Calibration Runs

#	Run	Run Group	Torus	Sol	<i> (nA)	E_b (GeV)	Tag	Date
1	3222	A (Spr 18)	+100%	-100%	25	10.6	5.7.4	2/15/18
2	3355	A (Spr 18)	-100%	-100%	35	10.6	5.7.4	2/20/18
3	4013	A (Spr 18)	-100%	-100%	50	10.6	5b.7.1	12/21/18
4	5038	A (Fall 18)	-100%	-100%	45	10.6	6b.3.0	7/30/19
5	5197	A (Fall 18)	-100%	-100%	45	10.6	6b.3.0	7/30/19
6	5424	A (Fall 18)	+100%	-100%	40	10.6	6.3.1	8/22/19
7	5700	K (Win 18)	+100%	-100%	30	7.5	6b.3.0	7/30/19
8	5893	K (Win 18)	+100%	-100%	60	6.5	6b.3.0	7/30/19
9	6164	B (Spr 19)	-100%	-100%	35	10.6	6.3.1	8/17/19
10	6233	B (Spr 19)	-100%	-100%	35	10.6	6.3.1	8/17/19
11	6489	B (Spr 19)	-100%	-100%	50	10.6	6.3.1	8/17/19
12	6715	A (Spr 19)	-100%	-100%	50	10.2	6.3.1	8/22/19

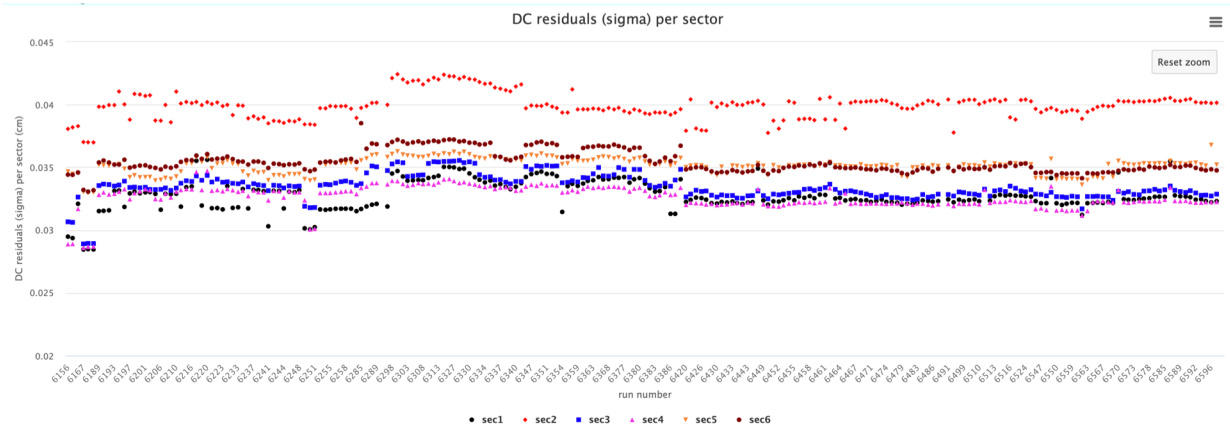
Pass-0 Monitoring

*See Andrey Kim's talk

FT-Cal Time Resolution (ns)



DC Residuals (cm)

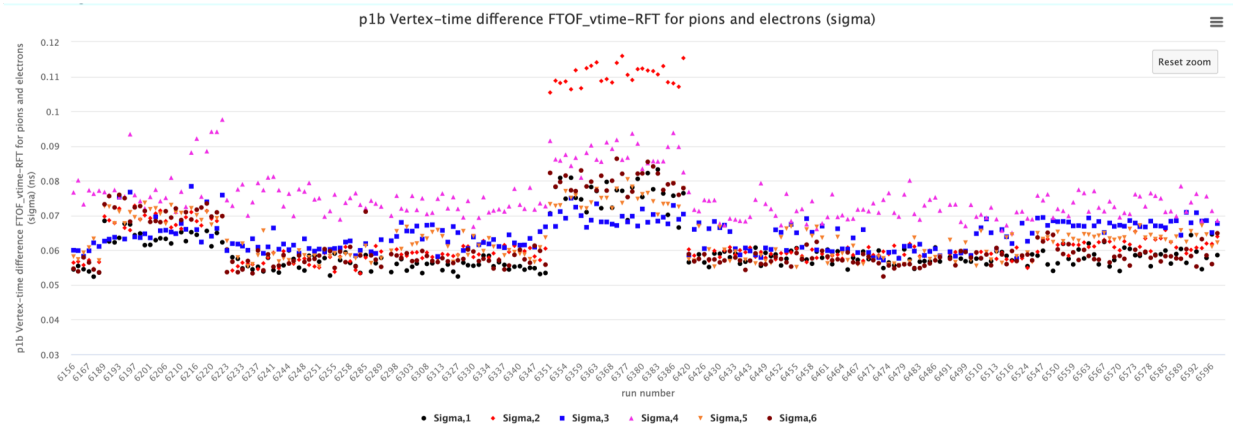


https://clas12mon.jlab.org/rgb/pass0/v15/tlsummary/

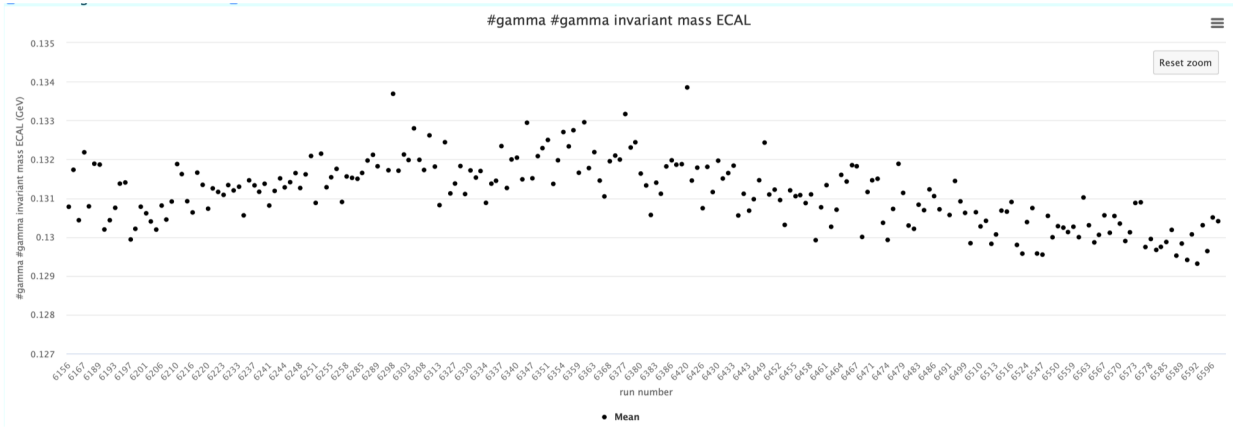
subsystem	variables	link
RF	• $n^{+/-}$ vertext time - RFtime1 per sector, FD • $n^{+/-}$ vertext time -RFtime1 CD • Electron vertext time - RFtime1 per sector, FD • Electron vertext time - RFtime1 per sector, FD • Proton vertext time - RFtime1 per sector, FD • Proton vertext time -RFtime1 CD • Average RFtime difference	timelines
TRIGGER	• Electrons/Protons per trigger per sector • Positives/Negatives/Neutrals per trigger per sector • Muons per trigger per sector • $n^{+/-}$ per trigger per sector • $K^{+/-}$ per trigger per sector	timelines
LTCC	• LTCC Number of Photoelectrons	timelines
HTCC	• Average Number of Photoelectrons per sector • HTCC Number of Photoelectrons	timelines
FT	• FTH MIPS time, neutral • FTH MIPS energy per layer (Mean) • FTC time - start time, neutrals/charged • FTC pi0 mass	timelines
FORWARD	• VZ (peak value) per sector, positives/negatives/electrons • Average Forward Reconstruction chi2, positives/negatives/electrons	timelines
EC	• $n^{+/-}$ time • $M_{\gamma\gamma}$ • sampling fraction	timelines
DC	• t max per sector per superlayer • t0 per sector per superlayer • DC resuduals (peak value) per sector per superlayer • DC residuals (peak value) per sector	timelines
CVT	• Average vz, positives/negatives • CVT Track Multiplicity • CVT positive/negative track multiplicity • CVT positive/negative track multiplicity per trigger • CVT ndf • CVT chi2/ndf • CVT momentum • CVT transverse momentum • CVT pathlength • Average CVT chi2, positives/negatives/electrons	timelines
FTOF	• Path-length Corrected Edep for negative tracks, p1a/p1b/p2 • Vertex-time difference FTOF_vtime-RFT for pions and electrons (mean/sigma), p1a/p1b/p2	timelines
CTOF	• Path-length corrected edep for negative tracks • Vertex-time difference CTOF_vtime-STT for negative tracks (mean/sigma)	timelines
PARTICLE_MASS_CTOF_AND_FTOF	• FTOF mass^2 at p1a/p1b for $n^{-/+}$/proton (mean/sigma) • CTOF mass^2 for $n^{-/+}$ (mean/sigma)	timelines
CND	• CVT z - CND z per layer • CND time per layer • MIPS dE/dz	timelines
CENTRAL	• Protons per trigger • $n^{+/-}$ per trigger • $K^{+/-}$ per trigger	timelines
BMTBST	• BST/BMT layers per track • BST/BMT Occupancy	timelines
BAND	• sector combination from adc, fadc, and tdc	timelines

Pass-0 Monitoring

FTOF Time Resolution (ns)



ECAL π^0 mean (GeV)



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BMTBST	• BST/BMT layers per track • BST/BMT Occupancy	timelines
BAND	• sector combination from adc, fadc, and tdc	timelines

Reconstruction Improvements

Reconstruction Code Updates Relevant for Calibrations*:

- DC: - improved swimming algorithm *(next release)*
  - fix wire sag/endplate distortions *(in progress)*
  - new t→d functional (polynomial)
  - improve modeling of DOCA uncertainty vs. d

*See Veronique Ziegler's talk

- CVT: - working to produce new code with alignment functionality *(in progress)*

*See Francesco Bossu's talk

- FT: - improve TW functional for FT-Cal timing
- EB: - implement vz correction to ST

*See Nathan Baltzell's talk

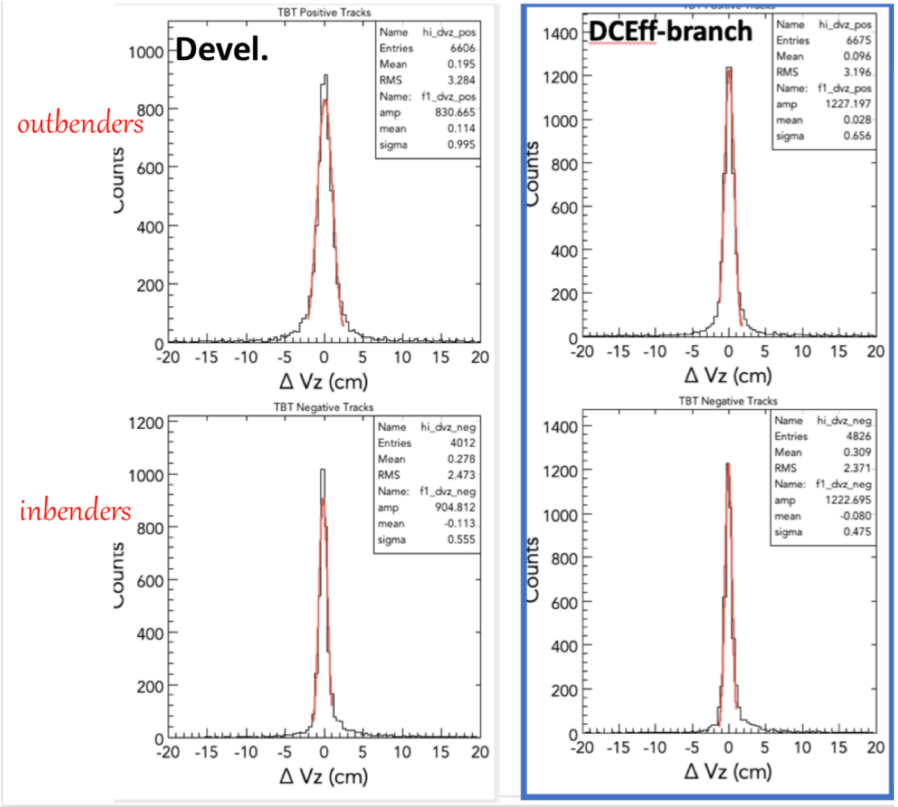
*Updates since 6/19 CLAS meeting

Note: recent reconstruction changes relevant for calibrations have been relatively modest:

- Focus on "frozen" version of code for DNP preparations
- Calibration procedures changing from development → production phase

Forward Tracking Improvements

Vertex Resolution Improvement



SIDIS MC

Improvement in vertex resolution leads to improved FTOF time resolution due to vertex correction

⇒ improved PID

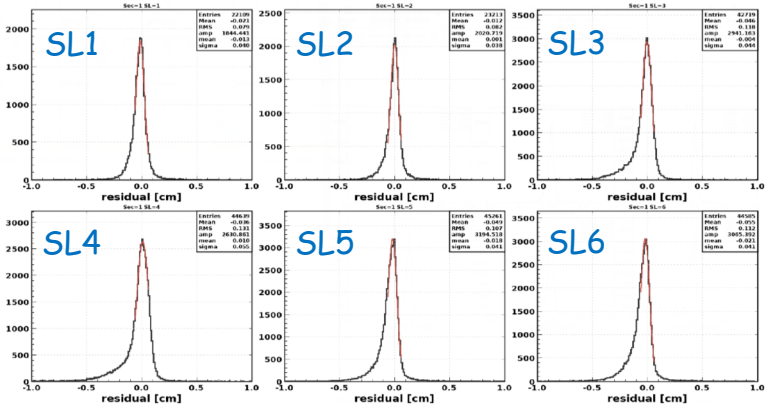
New tracking implementation currently in development branch being validated for next release

DC Calibration Status

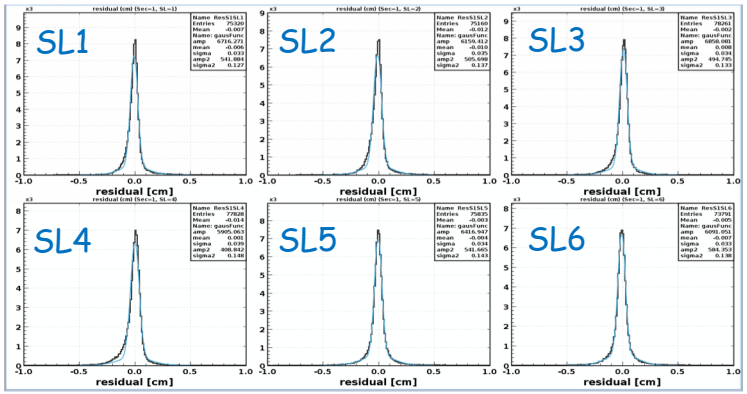
New time-to-distance functional implemented for calibration

Run 5038 - S1

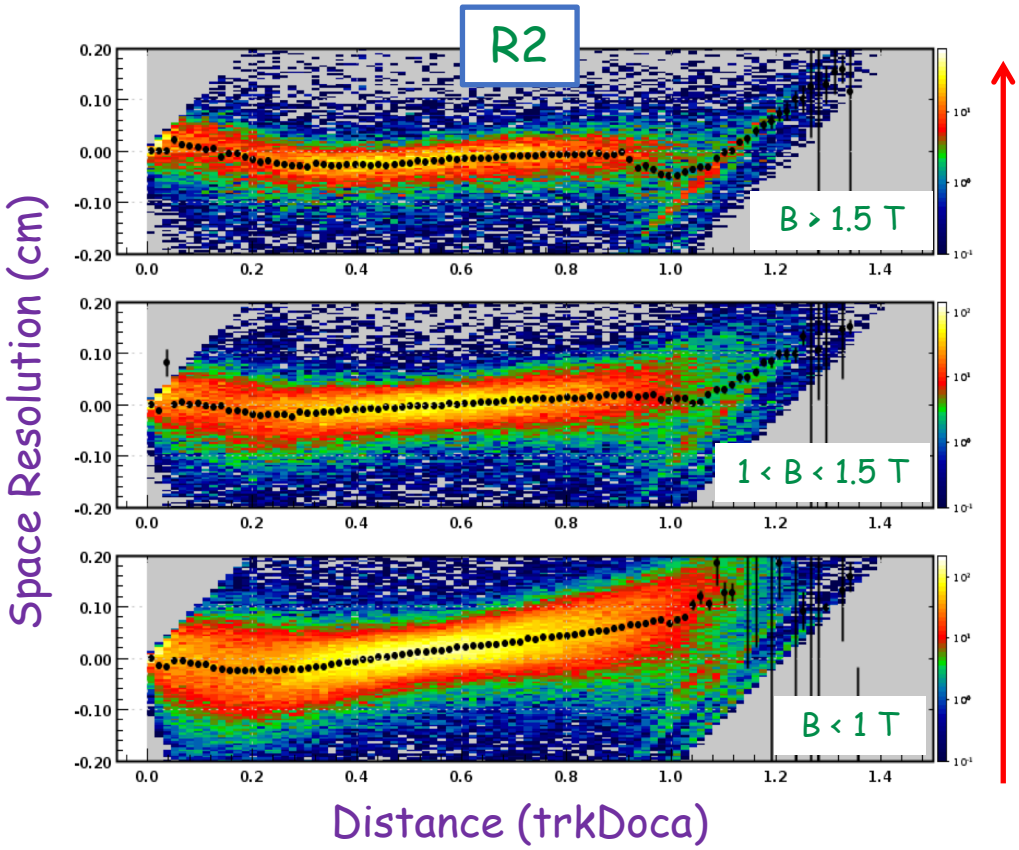
June



Current



Still working on B-field dependence

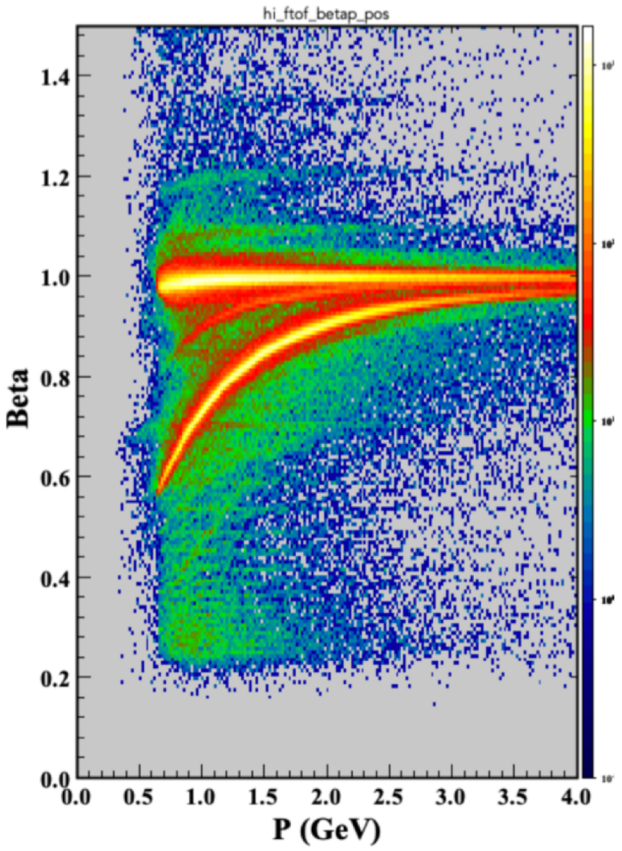


Fit function	Space Resolutions [μm]					
	SL1	SL2	SL3	SL4	SL5	SL6
EXP (5038)	400	380	440	550	410	410
POLY (5038)	330	350	340	390	340	330

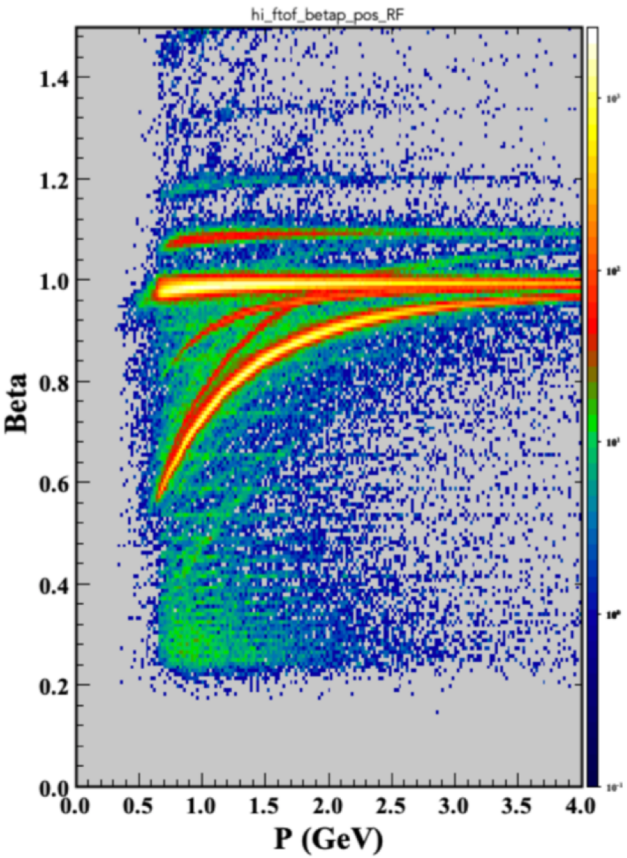
FTOF PID Status

Vertex correction to ST was implemented in 6b.3.0 (July 2019)

no correction



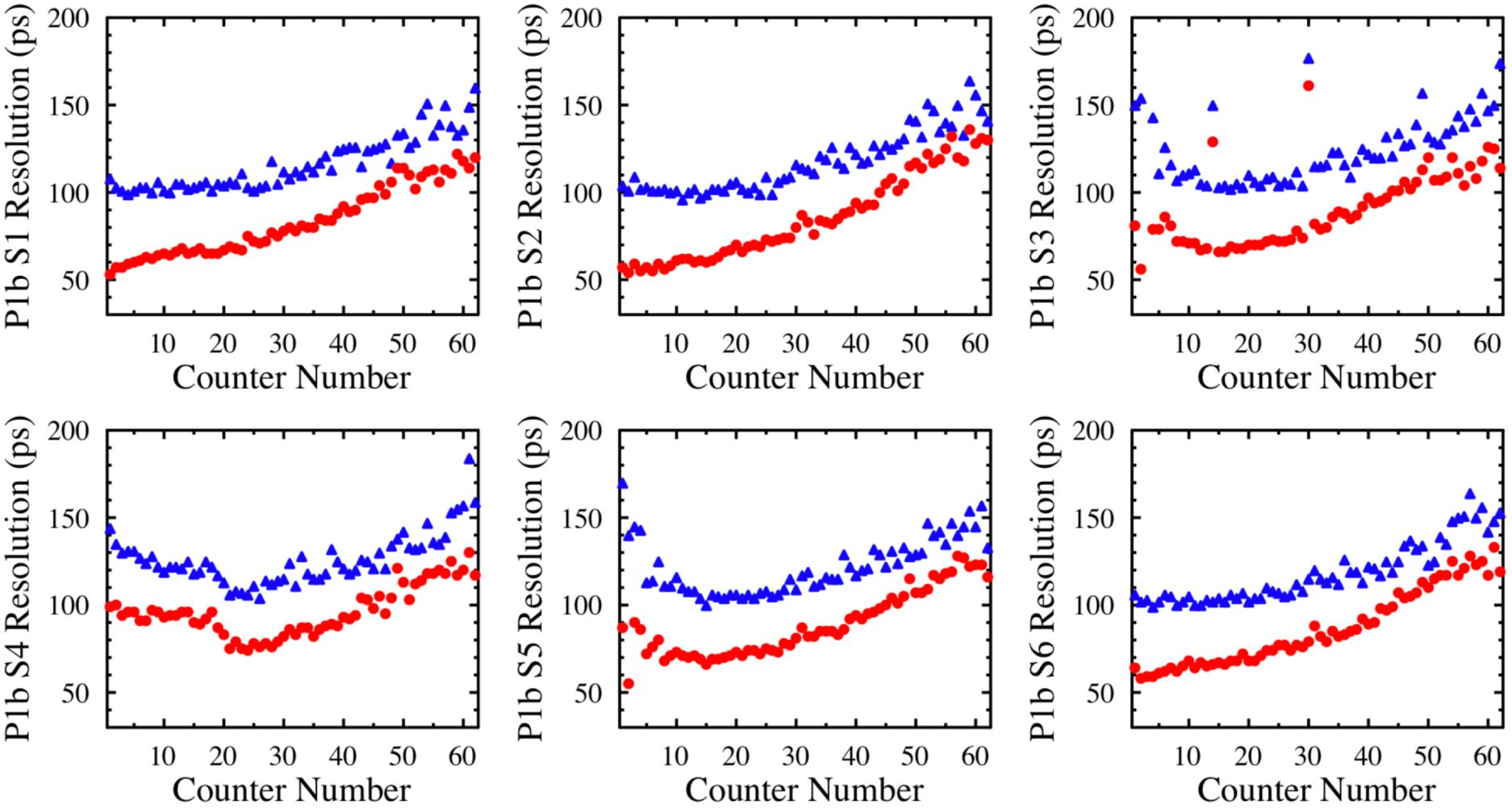
with correction



Recalibration of CLAS12 timing based on this correction has taken place for recent RG-A/K/B cooking

FTOF Calibration Status

run 5038

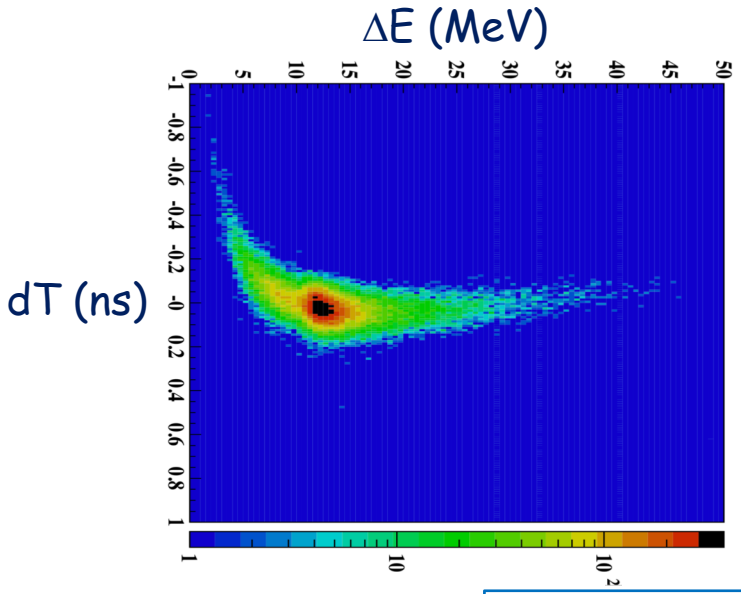


vertex correction

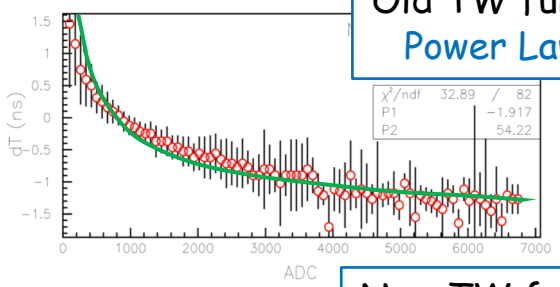
6b.2.0

6b.3.0

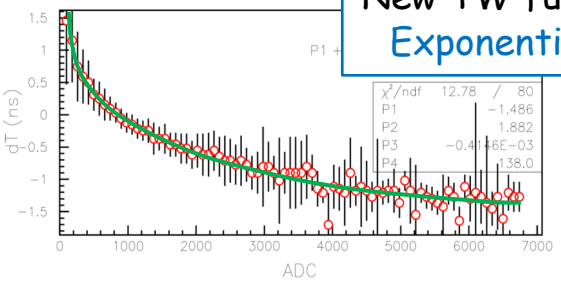
FTOF Calibration Improvements



Old TW func:
Power Law

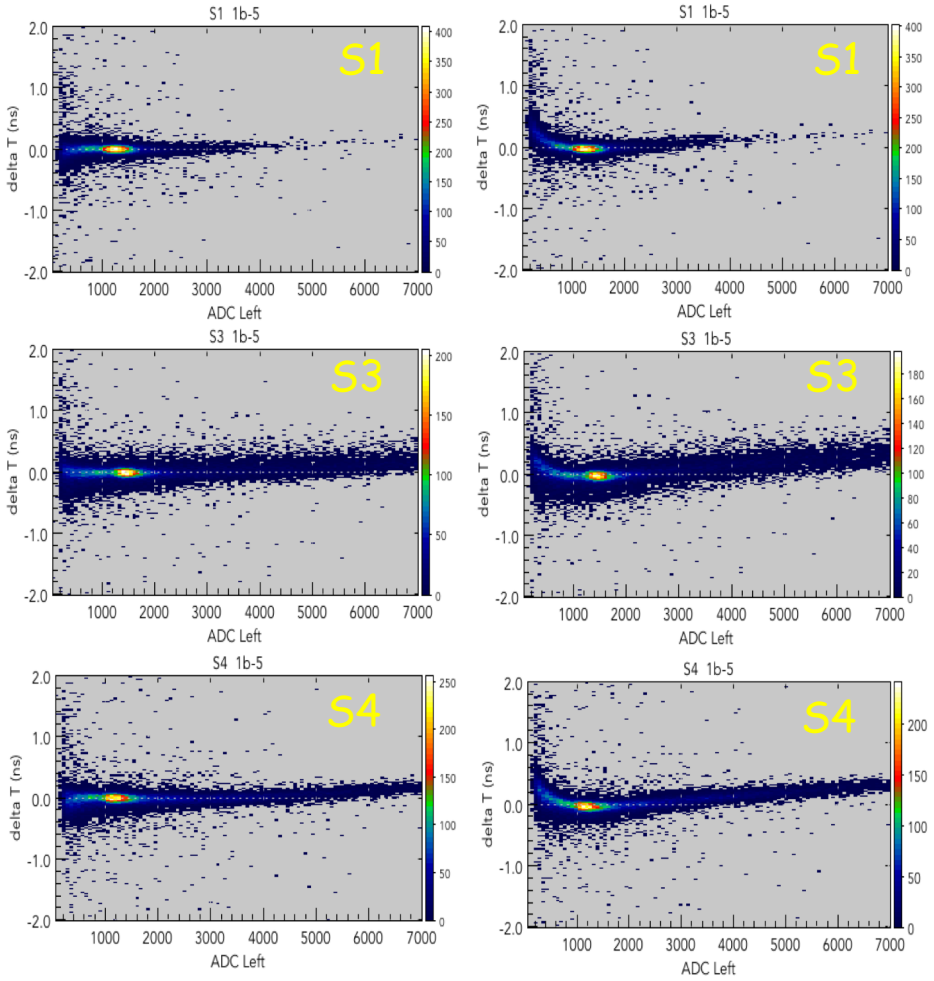


New TW func:
Exponential



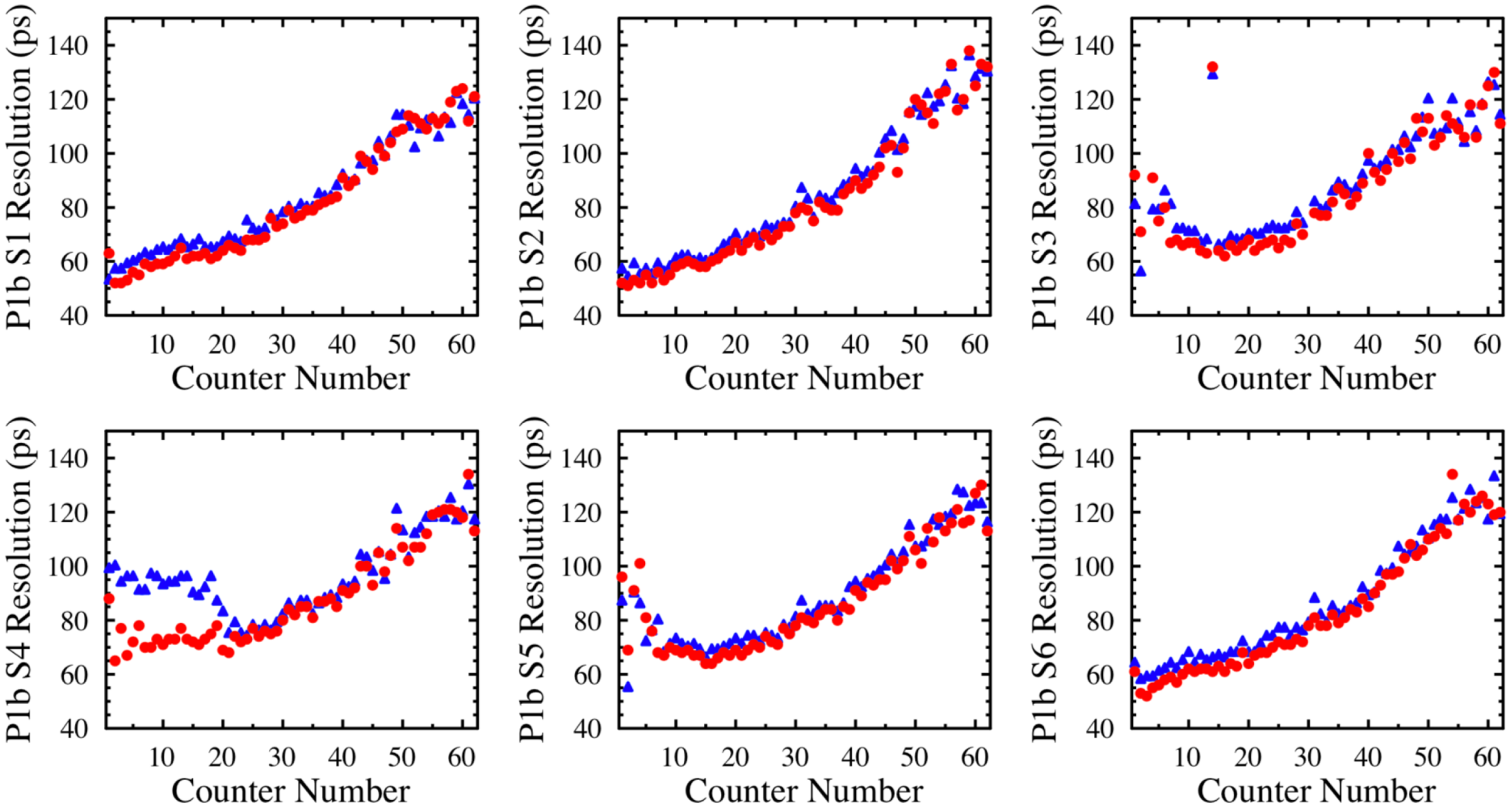
New TW

Old TW



FTOF Calibration Status

run 5038

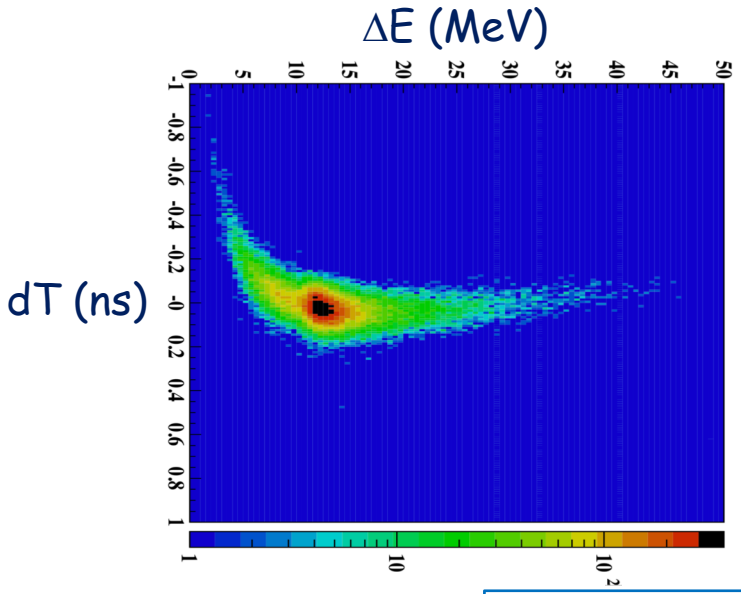


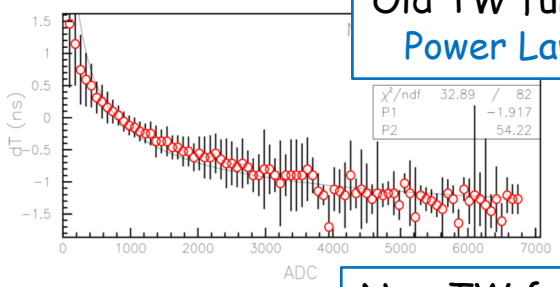
TW functional

6b.3.0 – Old TW

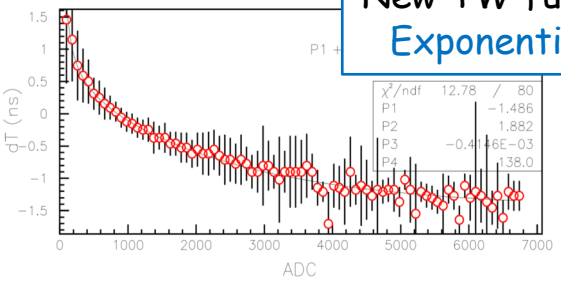
6b.3.0 – New TW

FTOF Calibration Improvements





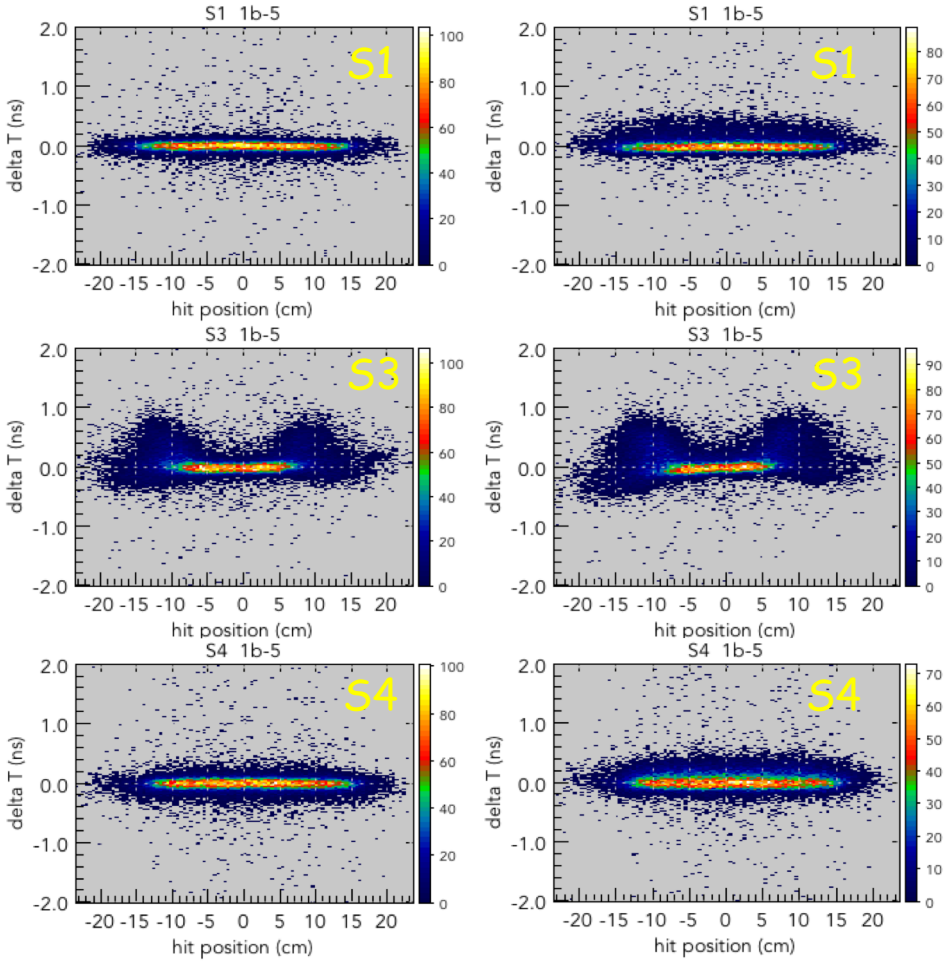
Old TW func:
Power Law



New TW func:
Exponential

New TW

Old TW

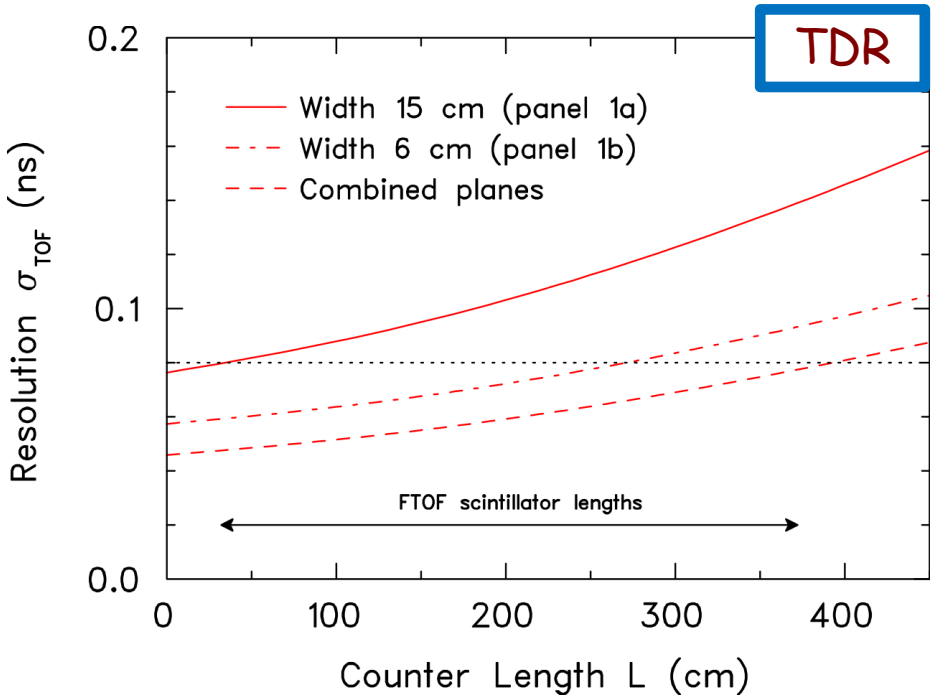


Material in front of FTOF smears response

Optimizing FTOF Time Resolution

Combine the measured times from the FTOF panel-1a and panel-1b to optimize the resolution

$$t_{corr} = \frac{\dfrac{t_{1b}^{cluster}}{\delta_{1b}} + \dfrac{(t_{1a}^{cluster} - \Delta r/\beta)}{\delta_{1a}}}{\left(\dfrac{1}{\delta_{1b}} + \dfrac{1}{\delta_{1a}}\right)}$$



Algorithms for cluster > 1:

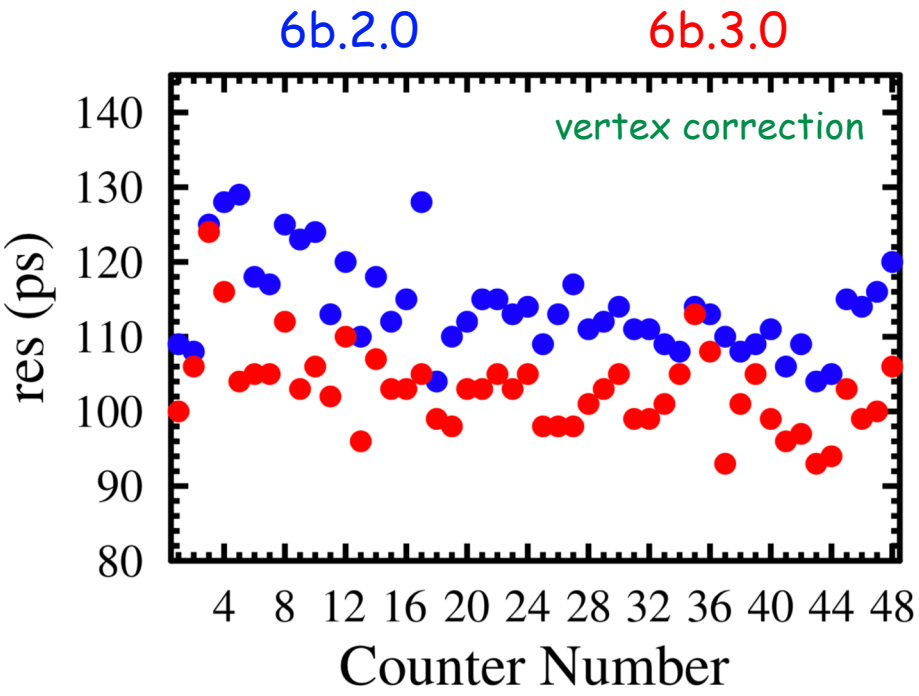
- *use hit with t_{min}*
- *use hit with E_{max}*
- *use weighted average*

Upgrade to future EB PID

GEMC Studies with cluster=1

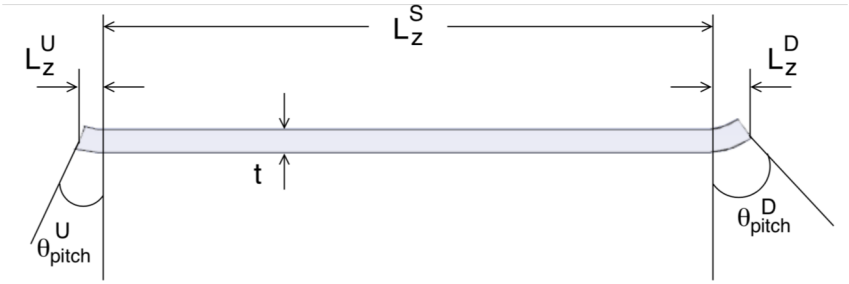
(20% gain)	e	p	π^+	π^-
FTOF 1a	152 ps	164 ps	160 ps	151 ps
FTOF 1b	62 ps	67 ps	65 ps	61 ps
FTOF 1a+1b	49 ps	54 ps	54 ps	51 ps

CTOF Calibration Status



Worsening resolution for N < 16 connected with CVT/Central Detector misalignment?

The timing resolution goal is 80 ps



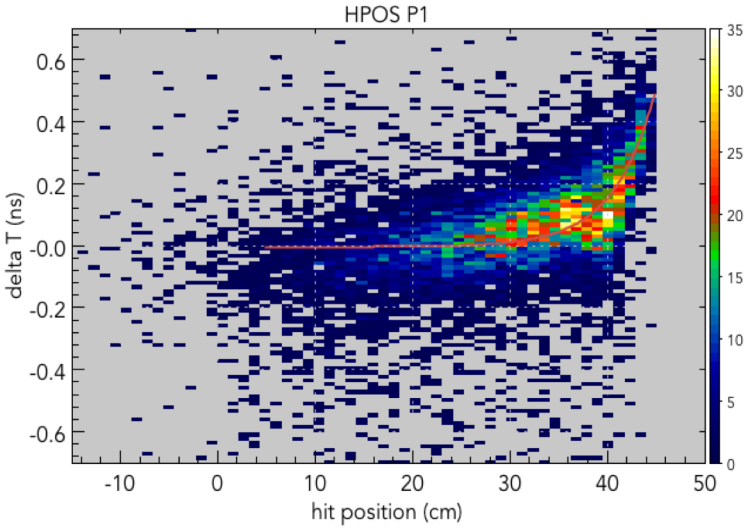
CTOF scintillation bar

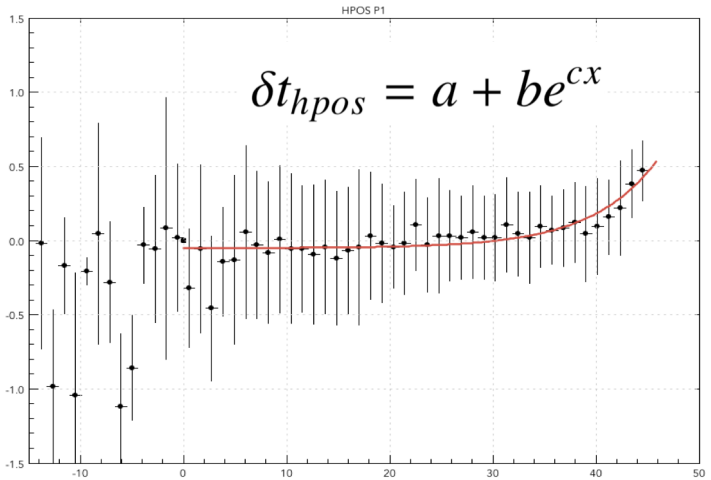
We are still battling with the curved ends of the bar

most of the tracks are incident on the downstream curved portion

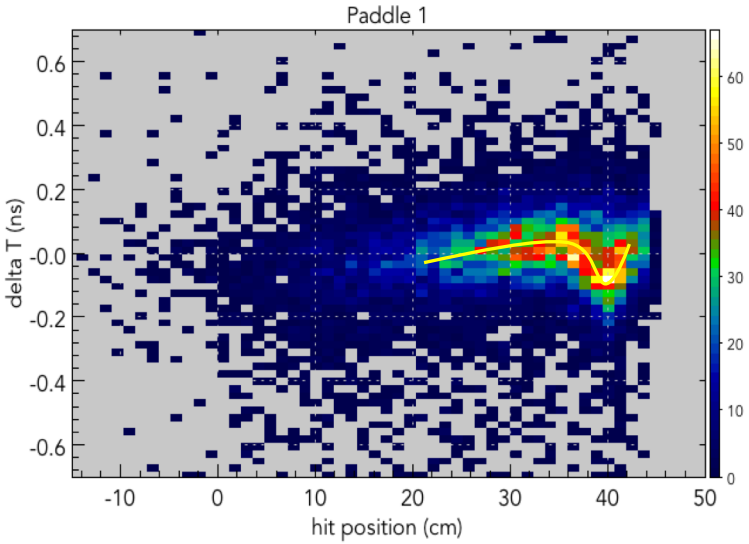
CTOF Calibration Status

before





after



- Issue with 1) properly computing path length and 2) Cherenkov light affects v_{eff}
- HPOS correction improves timing resolution, but a limiting remnant remains

Working to find a way to eliminate this issue

FT Calibration Status

FTHodo:

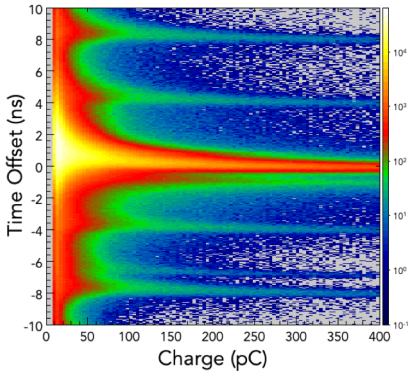
- Energy and timing calibration completed
- Timelines show very good stability

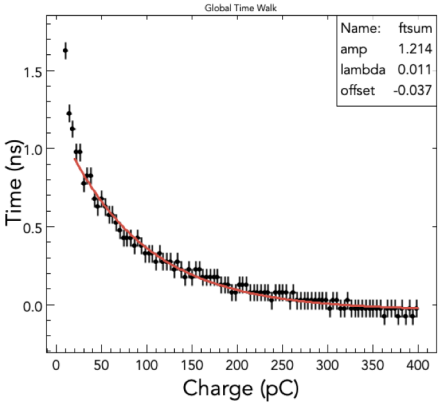
FTCal:

- Timing (TW and offsets) calibrations done
- Timelines show small but progressive drop of light yield due to radiation damage; recoverable with warmup at room temp
- Still to-do:
  - Redo leakage correction accounting for actual channel thresholds

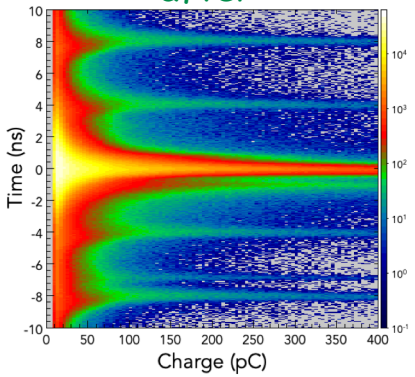
Example of time walk calibration

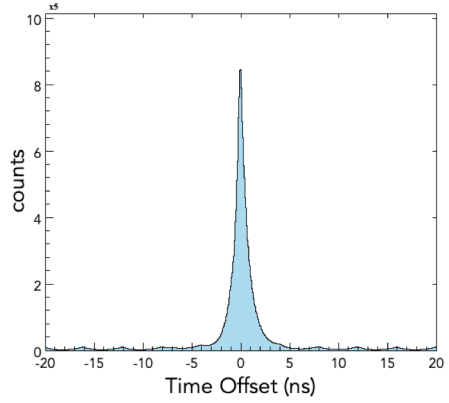
before





after



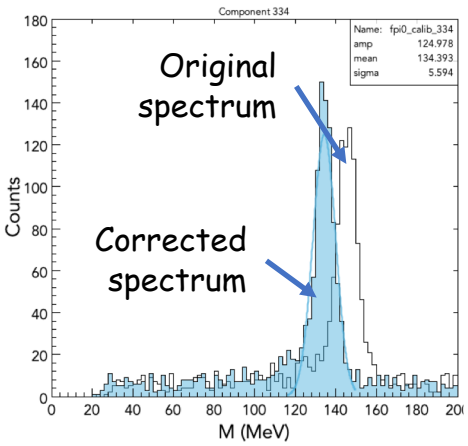


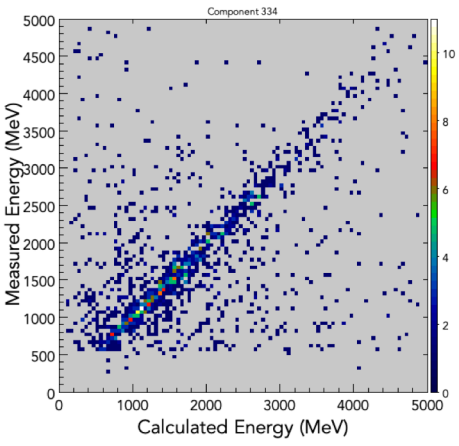
FT Calibration Status

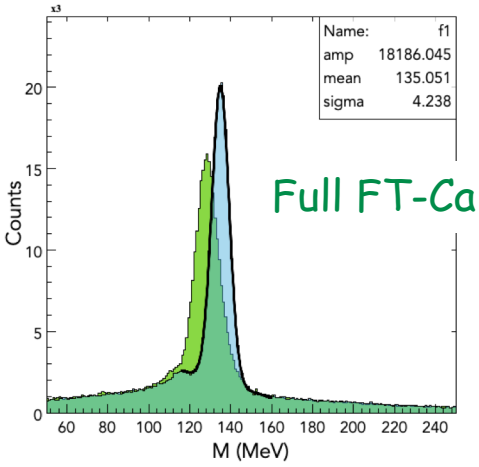
FT-Cal energy calibration based on π^0 mass:

- Use events with two neutral clusters in FT-Cal
- For each crystal, select the events in which the crystal is the seed of one of the clusters
- For the same events, calculate the ratio between the measured cluster energy for the given crystal and the energy calculated from the nominal π^0 mass and the other cluster energy
- Fill histogram with this correction factor and fit it
- Use this correction factor to recalculate the cluster energies
- Apply procedure iteratively, until the factors are less than 1%

Single crystal

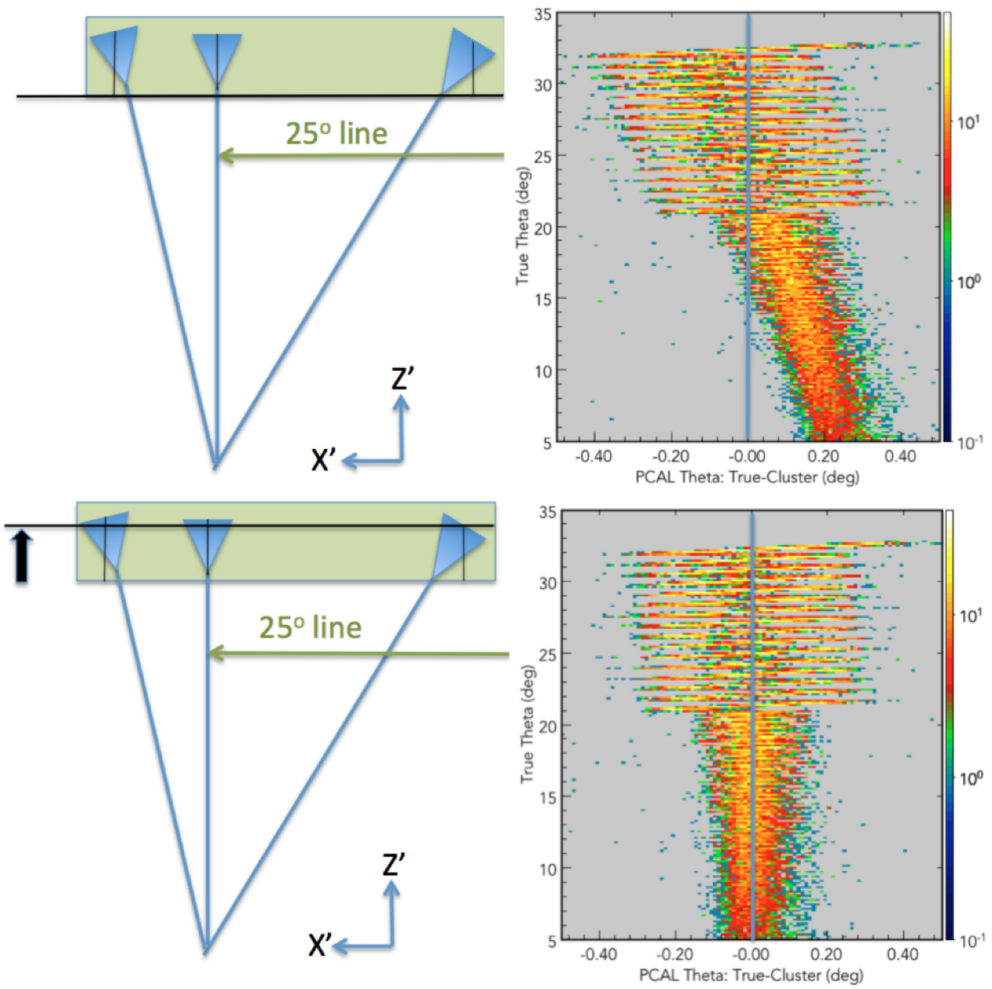






- Cluster energy range 1-5 GeV
- Allows check of linearity

ECAL Cluster Reconstruction

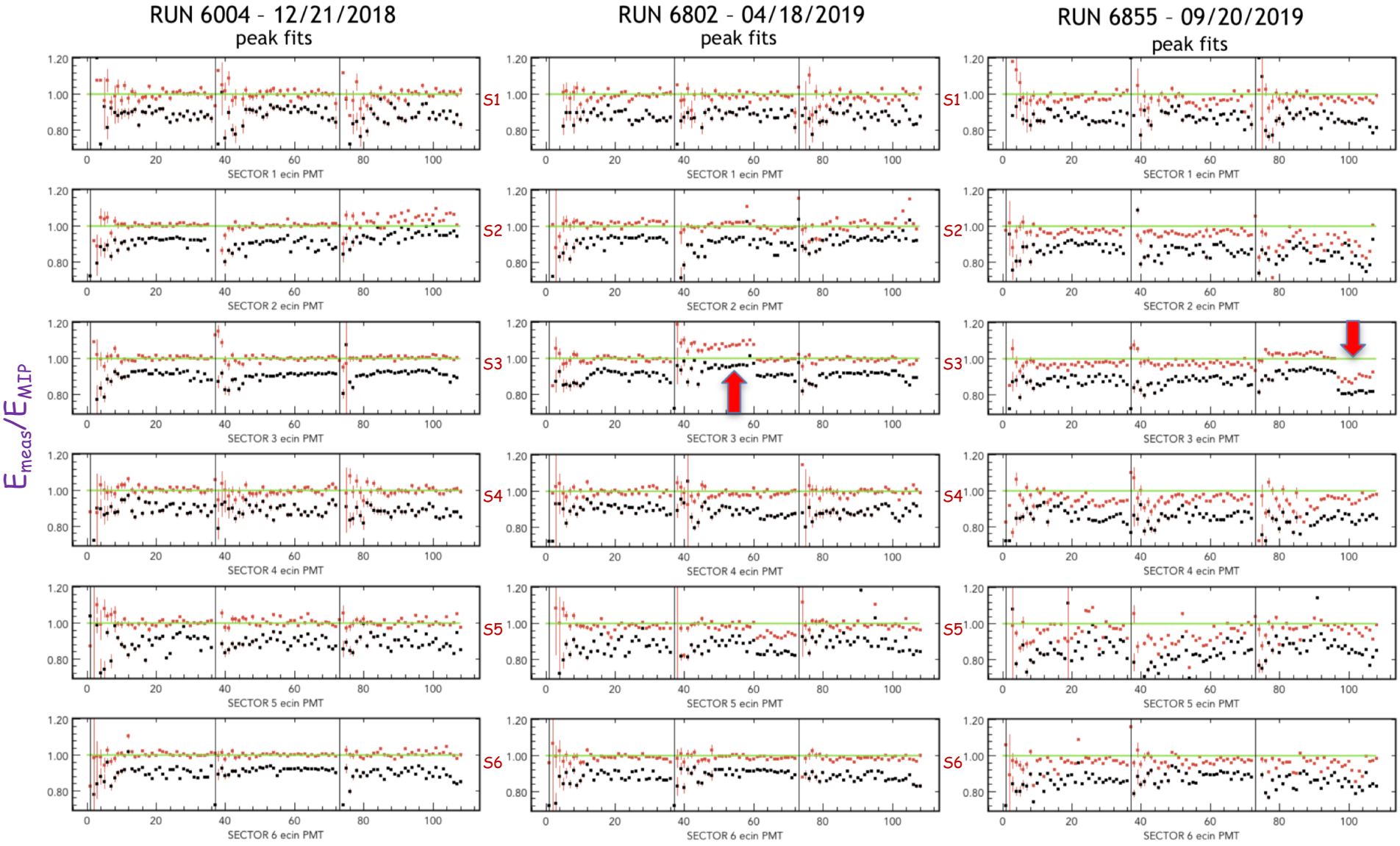


- Off-normal straight tracks introduce a parallax shift using the nominal cluster z reporting plane – results in position dependent error in cluster angle
- Empirically shifting the reporting plane deeper into stack removes the effect
- This fix will be in the next reconstruction release

GEMC:
2 GeV photons
θ: 5-35°, ϕ = ±5°
PCAL S1

ECAL Calibration Stability

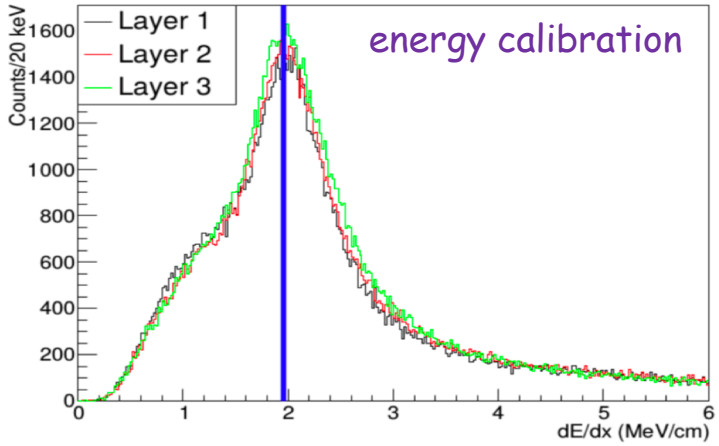
MIP Study

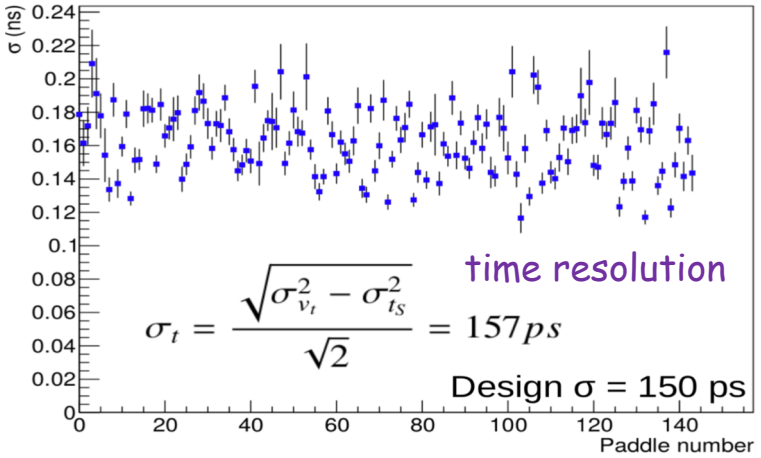


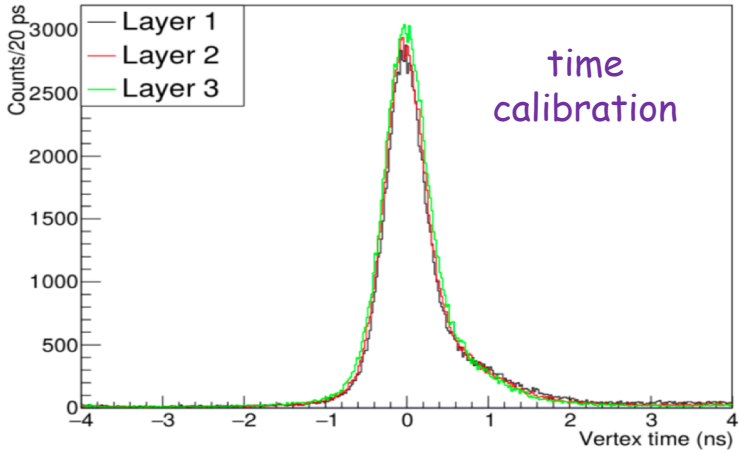
mean fit

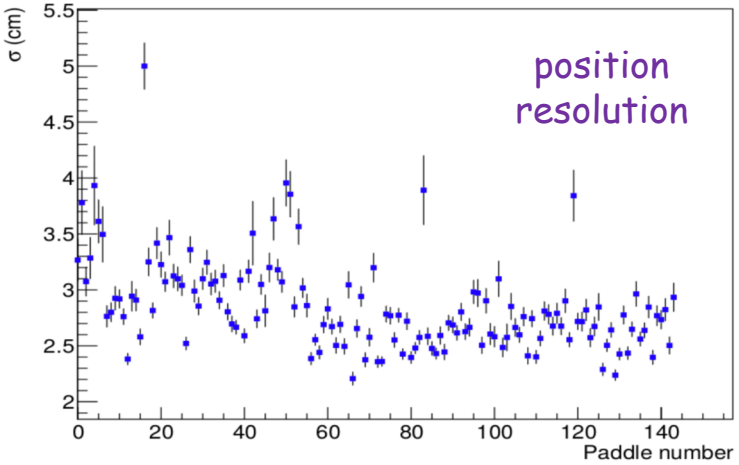
CND Calibration Status

Calibration code stable since June – calibration stability under study for RG-B



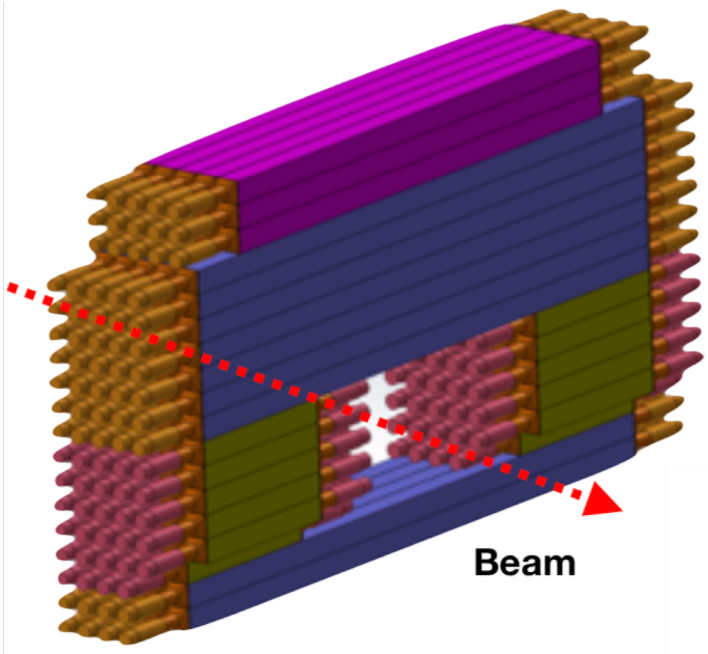




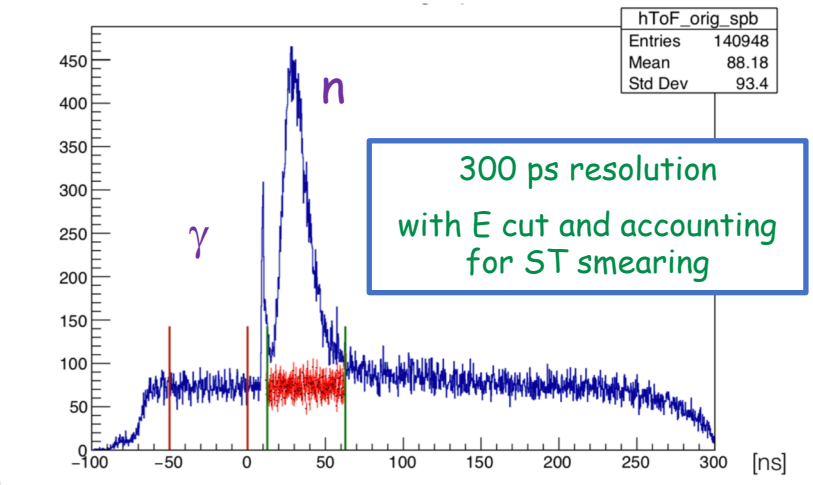


Focus now on developing effective charged particle veto

BAND Calibration Status



	Type of data used	Type of file used for analysis	Coding Language	Product usable by calibrator
HV-Gain response	Cosmic (stand-alone)	Decoder output	C++	50 —> 100 %
ADC to MeV	Source (stand-alone)	Decoder output	C++	0 —> 50 %
PMT time-walk	Scanned laser (stand-alone)	Decoder output	C++	100 %
L-R offsets, effective velocity,	Cosmic (stand-alone)	Decoder output	C++	100 %
Global alignment	Laser (stand-alone), Production data	Decoder output Cooked output	C++	100 %
Monitoring	Prod.	Decoder output	C++	25 —> 75 %



$$\frac{1}{2}(t_L + t_R) - t_{vertex}$$

BAND was installed for use in RG-B

Also to be used in RG-F/BONUS12 experiment

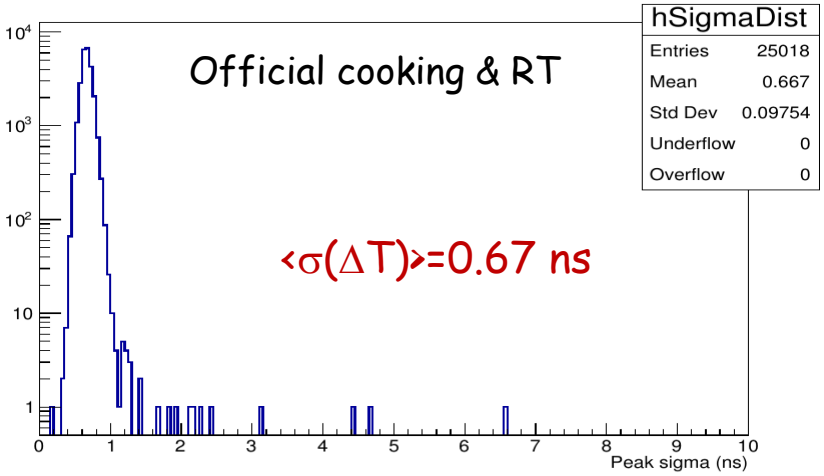
*See Efrain Segarra's talk

RICH Calibration Status

RICH reconstruction software integrated into official CLAS12 software in July

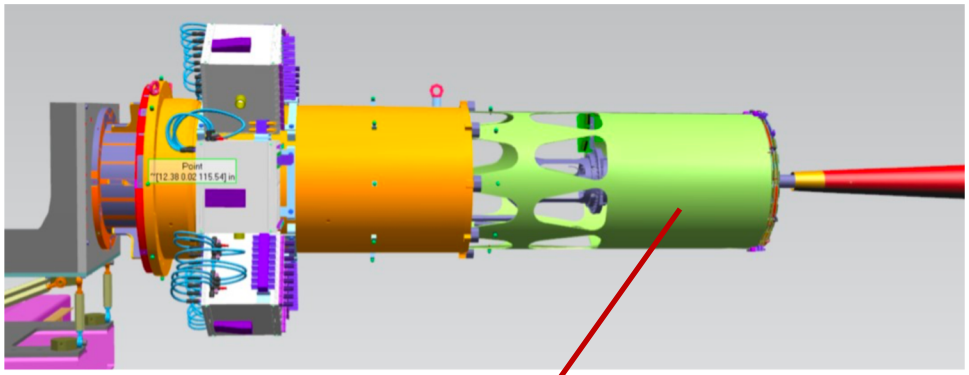
- Time calibration: now using hipo4 files
- Time calibrations very good; systematics of stability studied
  - Time walk parameters are quite stable → once per run period
  - Time offset parameters are also stable → few times per run period, often is just an overall constant
- Revision of the time calibration suite to use the farm
  - Much faster results

Run 5038



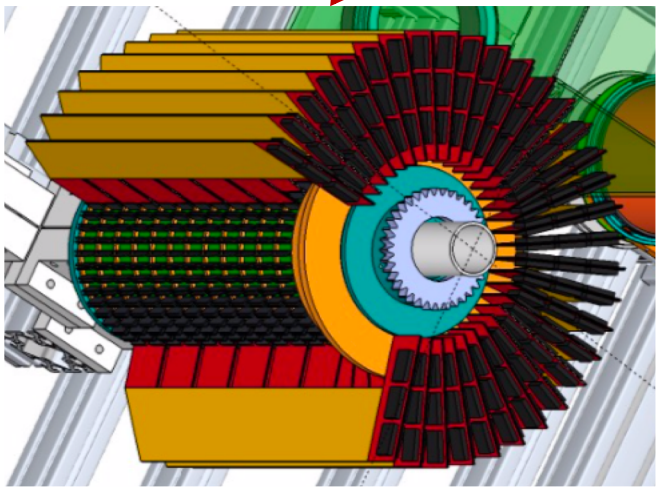
*See Marco Contalbrigo's talk

BONUS12 Calibration Status



Run Group F:
Feb. 12 – May 6, 2020

*See David Payette's talk



Recent discussion within CALCOM Group:

- Overview presentation given on Sep. 27, 2019 (Mohammad)
- Work on calibration software getting underway

https://clasweb.jlab.org/wiki/images/0/07/CALCOM_BONuS12_Sep27_2019.pdf

Remaining Calibration Work

- DC:
  - Finalize studies with new t → d function
  - Continue systematic studies of calibration response
- ECAL:
  - Complete studies of long-baseline calibration drifts
  - Develop PMT gain corrections to account for loss with time
  - Develop new timing calibration scheme and implement into calibrations
  - Understand systematics in timing vs. PID, path length, geom
- FTOF:
  - Finalize functional for TW correction
  - Understand systematics in MIP peak position (e.g. vs. torus polarity)
- CTOF:
  - Finalize HPOS correction
  - Fix counter hit point definition

Remaining Calibration Work

- FT:
  - CAL: Refine energy leakage correction over full ΔE range
  - TRK: Reconstruction code development
- CND:
  - Complete neutron detection efficiency studies
  - Finalize charged particle veto scheme
- BAND:
  - Complete neutron detection efficiency studies
- RICH:
  - Complete development of PID scheme and implement in Event Builder
  - Complete alignment work
- LTCC:
  - No timing calibration – need code development
- BONUS12:
  - Development of calibration algorithms/documentation/tools

*See Nick Markov's talk

Performance Status

System	Spec	Achieved	Spec	Achieved
BAND	$\langle eff_n \rangle$ = 35%	TBD	δt < 300 ps	300 ps
CND	$\langle eff_n \rangle$ = 10%	9%	δt = 150 ps	157 ps
CTOF	δt = 80 ps	100 ps		
DC	δx = 250 – 400 μm	300 – 400 μm		
ECAL	$\sigma_E/E = 10\%/\sqrt{E}$	$10\%/\sqrt{E}$	δt < 500 ps	< 600 ps
FT	$\sigma_E/E < 2\%/\sqrt{E} + 1\%$	$3.3\%/\sqrt{E}$	δt < 300 ps	< 150 ps
FTOF	60 – 110 ps (p1b)	60 – 110 ps (p1b)	90 – 180 ps (p1a)	90 – 250 ps (p1a)
HTCC	eff_π < 1%	< 1%	$\langle nphe \rangle$ = 16	16
LTCC	eff = 90%	TBD	δt = 1 ns	TBD
RICH	δt < 1 ns	0.7 ns	π/K rej > 500	TBD
SVT	S/N > 10	~14	δx = 50 – 65 μm	~55 μm

**Entries highlighted in red have not yet met spec's*

Concluding Remarks

- The calibration suites for all subsystems are well advanced
  - Nominal calibration procedures followed for RG-A/K/B cooking for DNP2019
  - Development work continues (optimization and fine-tuning in most cases)
  - Calibration teams trained for production calibrations with new software release
  - Service task: Calibrators assigned not by Run Group but by year
  - Effect on calibrations of TBD for:
    - new DC and CVT alignment
    - new torus field map
    - new forward and central tracking

*See Mac Mestayer's talk

- Development of timelines to monitor subsystem calibrations have proven essential for determining calibration shifts and issues:
  - Subsystems defined metrics that will be used to determine when to recalibrate
  - Timeline quantities for each subsystem still being refined and optimized
- Limitations of calibrations toward achieving design specs being investigated
  - Most issues understood and work plans to overcome them in progress
  - Working closely with Software Coordinator, Software Group, and the RG Analysis Coordinators

BACKUP SLIDES

CLAS12 Calibration Sequence

1) DC (+ FTOF Time Matching) Calibration:
   - time → distance calibration
     - relies on at least crude ST calibration from FTOF (few ns level)
     - calibrate offset between FTOF FADC and TDC time

2) FTOF (+ CTOF Time Matching) Calibration:
   - energy calibration
     - can be done before DC calibration using even crude DC calibration parameters for path length corrections
   - timing calibration
     - calibrate FTOF timing; employs PID from EB (requires initial FTOF calib)
     - defines event ST using electron in ECAL (1st option), positron in ECAL (2nd option), high momentum pion in DC/FTOF (3rd option)
     - calibrate offset between CTOF FADC and TDC time

3) CLAS12 Subsystem Calibration:
   - CND, CTOF, ECAL, FT (Hodo, Cal), HTCC, LTCC, RICH calibrations
     - timing calibration employs event ST from FTOF; employs PID from EB (requires initial CTOF calib)
     - energy calibration employs PID from EB

4) RF Calibration:
   - Capture overall RF timing shifts run-by-run

Subsystem Recalibration Criteria

Subsystem	Recalibration Criteria
CND	Timing: $\langle\Delta t\rangle$ > 165 ps
	Gains: <gain shift> > 10%
DC	T_{max} > ±5 ns / ±20 ns (partial /full)
ECAL	Timing: var(δt) > 300 ps
	Gain: <gain shift> > 5%, var(G) < 5%
FT	CAL energy: $\sigma(\pi^0$ mass) > 20% or 2-3 MeV shift
	CAL timing: <resolution> worsens by 10%
	HODO energy: MIP peak position shifts by > 0.2 MeV
	HODO timing: <resolution> worsens by 10%
TOF	Gains: <gain shift> > 10%
	Timing: $\langle\Delta t\rangle$ > 170 ps (p1a), > 90 ps (p1b), > 88 ps (CTOF)

IN PROGRESS

1) recalibrations required after readout or HV changes
2) RF calibrated run-by-run
3) HTCC, LTCC, RICH : TBD

Run Group A/K – Calibration Team

Subsystem	Group Leader	RG-A/K Calibrator(s)
BAND	Larry Weinstein	Florian Hauenstein, Efrain Segarra, Reynier Cruz Torres
CND	Silvia Niccolai	Pierre Chatagnon
CTOF	Daniel S. Carman	Chan Kim
DC	Mac Mestayer	Dilini Bulumulla, Taya Chetry, Shirsendu Nanda
ECAL	Cole Smith	Cole Smith/Joshua Artem Tan
FT	Raffaella De Vita	Raffaella De Vita, Nick Zachariou
FTOF	Daniel S. Carman	Christopher McLauchlin
HTCC	Youri Sharabian	Nick Markov, Will Phelps
LTCC	Maurizio Ungaro	Maurizio Ungaro
MVT	Maxime Defurne	Maxime Defurne, Guillaume Christiaens
RF	Raffaella De Vita	Jose Carvajal
RICH	Marco Contalbrigo	Marco Contalbrigo, Andrey Kim
SVT	Yuri Gotra	Yuri Gotra

Run Group B – Calibration Team

Subsystem	Group Leader	Calibrator(s)
BAND	Larry Weinstein	Florian Hauenstein, Efrain Segarra, Reynier Cruz Torres
CND	Silvia Niccolai	Paul Naidoo
CTOF	Daniel S. Carman	Achyut Khanal
DC	Mac Mestayer	Dilini Bulumulla, Taya Chetry, Shirsendu Nanda
ECAL	Cole Smith	Cole Smith, Susan Schadmand
FT	Raffaella De Vita	Raffaella De Vita, Nick Zachariou, Susan Schadmand, Alessandra Filippi
FTOF	Daniel S. Carman	Jose Carvajal
HTCC	Youri Sharabian	Isabella Illari
LTCC	Maurizio Ungaro	Maurizio Ungaro
MVT	Maxime Defurne	Maxime Defurne, Gerry Gilfoyle
RF	Raffaella De Vita	Jose Carvajal
RICH	Marco Contalbrigo	Hyon-Suk Jo
SVT	Yuri Gotra	Yuri Gotra